SDC-91-00064
August, 1991

Proceedings of the Solenoidal Detector Collaboration Meeting at LBL

August 5-10, 1991
Lawrence Berkeley Laboratory
Berkeley, CA 94720

Plenary Sessions

August 5 - Monday

SDC Status	G. Trilling(LBL)
Solenoid Status Report	A. Yamamoto(KEK)
Impact of Material in Tracking Volume - Task Force Report	J. Matthews(LANL/New Mexico)
Status Report on R&D Plan Scope Scenarios, Cost Targets and Goals of Meeting	M. Gilchriese(LBL)

August 6 - Tuesday

Tracking Detector Performance	M. Corden(Florida State)
Calorimetry Presentations	
Selected Calorimeter Simulation Results	D. Green(Fermilab)
Associated Higgs Production	K. Einsweiler(LBL)
ForwardCalorimetry Studies	M. Barnett(LBL)
Simulation for SDC Muon System	S. Kunori(Maryland)
SDC Level 1 Trigger	G. Sullivan(Chicago)

August 7 - Wednesday

Report on Scope Issues	
Tracking Scope and Costs	A. Seiden(UC Santa Cruz)
Muon Descoping Ideas	R. Thun(Michigan)
Front End Electronics Costs	B. Williams(Pennsylvania)
DAQ Costs	I. Gaines(Fermilab)
Trigger Costs	W. Smith(Wisconsin)
Calorimetry Presentations	
Physics Requirements	
e ID and CDF(PS/SM) - Segmentation	B. Wicklund(ANL)
QCD Rates	G. Sullivan(Chicago)
Calorimeter Physics Performance	J. Siegrist(SSCL)
Liquid Argon	
Engineering Design	W. Pope(LBL)
LAC Cost Estimate	G. Guenterberg(M. Marietta)
Critical Issues and Performance	Y. Unno(KEK)
Liquid Ar Performance: Speed, Noise, Pileup and Electron Uniformity	C. Hearty(LBL)
Scintillation Tiles	
Radiation Damage, Source	V. Hagopian(FSU)
Radiation Damage, Beam	K. Takikawa(KEK)
Tile-Fiber Optical System	J. Proudfoot(ANL)
SM Design Status	F. Rondeaux(CEN Saclay)
Cost/Performance	S. Gourlay(Fermilab)

August 9 - Friday

Calorimetry Summary	
Calorimetry	D. Green(Fermilab)
Shower Maximum	R. Hubbard(CEN Saclay)
Forward Calorimetry	W. Frisken(York)
Tracking Summary	
Baseline Designs and Costs	A. Seiden(UC Santa Cruz)
Tracking Steering Committee	J. Elias(Fermilab)
Straw Tube Placement	H. Sadrozinski(UC Santa Cruz)
Muon Group Report	G. Feldman(Harvard)
Electronics Summary	
Front-End Electronics	H. Williams(Pennsylvania)
DAQ	I. Gaines(Fermilab)
Trigger	W. Smith(Wisconsin)
Installation Scenario and Schedule	D. Bintinger(SSCL)

August 10 - Saturday

Report of Task Force on Field Uniformity	T. Kondo(KEK)
Comments on Tracking Volume and Detector Scope	G. Trilling(LBL)
Recommendation on Tracking Volume and Status of Descoping	M. Gilchriese(LBL)

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Tracking

August 6 - Tuesday

Possible Disadvantages of Non-Uniform Field for Tracking	J. Hylen(Fermilab)

August 8 - Thursday

Straw Tube R&D Plans at Duke	A. Goshaw(Duke)
Straw Module Status Report	G. Hanson(Indiana)
Pixel's Progress	D. Nygren(LBL) & S. Parker (Hawaii)
Gas Microstrip Work in the US - Update	A. Sill(Rochester)
Status of Intermediate Tracking	E. Gabathuler(Liverpool)
VLPC Update	P. Besser(Rockwell)
Fiber Tracking - Cosmic Ray Results	R. Ruchti(Notre Dame)

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Tracking and Physics and Detector Performance Joint Meeting

August 5 - Monday

Part 1: Performance

Momentum Resolution of SDC Tracking System and Effects of Field Uniformity	T. Kondo(KEK)
Minimum Number of Axial Layers	F. Abe(KEK)

Part 2: Technical Simulation Issues

Progress on Track Finding and Fitting	B. Hubbard(UC Santa Cruz)
Indiana University Simulation Status	F. Leuhring(Indiana)
Progress in Straw Tracking	A. Palounek(LBL)
Simulation of a Scifi Tracking Trigger for the SDC	D. Adams(Rice)
Pattern Recognition in a Scifi Tracking System for the SSC	D. Adams(Rice)
Hybrid Central Tracker - Track Finding	M. Corden(FSU)
Preliminary Look at Tracking Efficiency in Hybrid and Silicon	D. Coupal(SSCL)

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Superconducting Magnet

August 5 - Monday

SDC SC Magnet Progress	A. Yamamoto(KEK)

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Calorimeter

August 5 - Monday

Liquid Argon	
Engineering Design	W. Pope(LBL)
Critical Engineering Issues	Y. Unno(KEK)
LAC Cost Estimate	G. Guenterberg(M. Marietta)
Tile/Fiber	
Baseline Design	T. Kirk(ANL)
Baseline Engineering Design	V. Guarino(ANL)
Baseline Cost	D. Scherbarth(Westinghouse)
Pb EM, Fe Hadron Engineering Design	L. Bartoszek(Fermilab)
Pb EM, Fe Hadron Calorimeter Design	J. Freeman(Fermilab)
Fabrication and Cost	S. Gourlay(Fermilab)
"Iron" Detector Simulation	W. Foster(Fermilab)
Integration for LA, Tile/Fiber	D. Bintinger(SSCL)

August 6 - Tuesday

Absorber Configurations	T. Handler(Tennessee)
LA Critical Issues	
Critical Issues and Beam Test	Y. Unno(KEK)
Speed, Noise, Pileup and Electron Uniformity for Liquid Argon	C. Hearty(LBL)
Why Not Tile/Fiber for SDC Calorimetry	G. Abrams(LBL)
Radiation Damage Results	
Saclay Results, Sources and Beam	J. Ernwein(CEN Saclay)
Tsukuba Beam Test Results	K. Takikawa(Tsukuba)
Tsukuba Source Test Results	K. Yasuoka(Tsukuba)
FNAL Source Tests	A. Byon(Fermilab)
IHEP/Beiging Tests	D. Green(Fermilab)
FSU & LSU Results	A. Fazely(LSU)

August 8 - Thursday

Compensation and Energy Resolution	T. Gabriel(ORNL)
FNAL Optical Studies/Experience	J. Freeman(Fermilab)
Pb/Fe Options	D. Green(Fermilab)
New Approaches in Calorimetry	A. Ronzhin(IHEP Protvino)

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Calorimeter, Electronics and Physics and Detector Performance Joint Meeting

August 8 - Thursday

Shower Max Status

PS/SM Status	R. Hubbard(CEN Saclay)
PS/SM Test beam Status and Front Ends	P. Melese(Rockefeller)
SM Electronics and Trigger	P. Le Du(CEN Saclay)

Trigger and Electronics

Trigger - Physics Discussion	H. Frisch(Chicago)
Trigger Issues	K. Einsweiler(LBL)
Liquid Argon Trigger Issues	M. Levi(LBL)

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Muon System

<Simulation>

Simulation for SDC Muon System	S. Kunori(Maryland)
SDC Muon Simulation	M. Daoudi(Colorado)

<Muon Trigger>

Trigger Resolution Effects	R. Thun(Michigan)
Level 1 Muon Trigger	G. Feldman(Harvard)
L1 Muon Trigger Study	T. Zhao(Washington)
Trigger Resolution Study	S. Behrends(Brandeis)
Study of the Muon Trigger Efficiency	V. Molchanov(IHEP Protvino)

<Muon Resolution>

Momentum Resolution with/without BWC1 & Prompt Muon Rates - Review	H. Iwasaki(KEK)
Descoping Effects on Muon Resolution	J. Wiss(Illinois)

<System Designs and Testing>

Some Results of Simulation of the Effects Connected with e.m. Environment of High Energy Muons	Y. Gornushkin(JINR/SSCL)
Wisconsin Chambers	F. Feyzi(Wisconsin)
Muon Detector System	H. Lubatti(Washington)
Boston Group Chamber Update	G. Feldman(Harvard)
Supermodule Design & Analysis Review: Boston Chamber Concept	J. Gorman(CSDL)
Why a Jet Chamber?	S. Odaka(KEK)
Status of the Large Jet Chamber R&D for the SDC Muon Detector	S. Terada(KEK)
Japanese University Activities for SDC Muon System	A. Maki(KEK)
Resistive Plastic Drift Tubes	K. Heller(Minnesota)
University of Rochester Resistive Field Shaping & Low Mass, Lightweight Support Module Testing	A. Still(Rochester)
Cerenkov Beam Test - Preliminary Results	U. Nauenberg(Colorado)
Use of Gas Cerenkov Counters as Part of a Trigger System for Muons in SSC Detectors	A. Ronzhin(IHEP Protvino)
Scintillation Counters for Trigger System of SDC	V. Kubarovsky(IHEP Protvino)
Muon Factory Model	R. Loveless(Wisconsin)

<Costs>

SDC Muon System WBS	G. Guenterberg(M. Maricita)
WBS 3 Options and Cost Summary	F. Feyzi(Wisconsin)

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Muon Magnets

August 5- Monday

Coil Design Status	J. Cherwinka(Wisconsin)
Barrel Magnet and Support	J. Western(SSCL)
Forward Toroid & Installation Concept	L. Dittert(Kaiser)

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Electronics, Triggering and Data Acquisition Sessions

August 5 - Monday

Baseline Trigger	W. Smith(Wisconsin)
Baseline Control System	T. Moore(LBL)
SDC Baseline Data Acquisition System	I. Gaines(Fermilab)
DAQ & Controls Descoping Options	R. Partridge(Brown)

August 6 - Tuesday

Interfaces	
Calorimeter Electronics	W. Foster(Fermilab)
Calorimeter Electronics	M. Levi(LBL)
Shower Max Electronics	P. Le Du(CEN Saclay)
Fiber Tracker Electronics	A. Baumbaugh(Fermilab)
Conceptual Design of Straw-Tube Readout with TMC	Y. Watase(KEK)
Straw Tracker System-TVC Option	R. Van Berg(Pennsylvania)

August 8 - Thursday

Trigger Working Group	Smith: Organizer
Data Acquisition Working Group	Gaines, Partridge: Organizers
DAQ R&D at KEK	M. Nomachi(KEK)
DAQ Baseline Design Options	R. Partridge(Brown)
Surface Facilities for Electronics	C. Bebek(LBL)
Discussion of Pipeline Length	W. Smith(Wisconsin)

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Electronics and Fiber Tracking Joint Meeting

August 8- Thursday

VLPC Device and Packaging Development	E. Anderson(Rockwell)
Scintillating Fiber Tracking for the SSC Using VLPC	M. Atac(UCLA)

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Computing and DAQ Joint Meeting

August 8 - Thursday

Online Requirements and Architecture	A. Fry(SSCL)

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Integration

August 6 - Tuesday

Status Report on Underground, Surface and Facilities Systems	W. Harris(SSCL)
Cost and Schedules: Installation	D. Etherton(SSCL)
SEFUR Summary; Milestones	T. Thurston(SSCL)
Hall Parameters	J. Piles(SSCL)
Toroid Supports	J. Western(SSCL)
Electrical Systems	W. Kampmeier(SSCL)
Mechanical Systems	M. Hecht(SSCL)
Cryogenics	B. Richardson(SSCL)
Detector ES&H	B. Lavelle(SSCL)
Detector Construction Planning	J. Brown(Kaiser)
Report of the Task Force on Magnet/ Tracking Configuration	T. Ryan(LBL)
Integration for LA, Tile/Fiber	D. Bintinger(SSCL)
Update on Electronics Integration	
Straw Electronics	D. Van Berg (Pennsylvania)
Muon Supermodules	F. Feyzi(Wisconsin)
Electronics within Barrel, Status and Request for Feedback	A. Dubois(LBL)
Layout of Forward System	A. Dubois(LBL)
Preliminary Integrated SDC Schedule	W. Edwards(LBL)

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APPENDIX

LIST OF PARTICIPANTS

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Interim Management Plan

M. Gilchriese — Interim Project Manager

M. Harris
T. Thurston — Interim Chief Detector Engineers

Search Committee for Permanent Project Manager Set Up:
L. Price
G. Feldman
D. Green
T. Kendo

M. Breidenbach
S. Olsen
R. Briggs

PAC Presentations
(Santa Fe, July 8, 1991)

GEM Presentation (Barish/Sanders/Willis)

SDC Presentation (Gilchriese/Trilling)

ELMUD Presentation (Linn?)

Draft R&D/Engineering Plan submitted by SDC

SDC STATUS

G. TRILLING

Subgroup: Overall Date: Friday

Speaker: Trilling

Title: SDC Status

Comments:

CONCLUSIONS
(CONTINUED)

The SDC needs to understand in much more detail what in-kind contributions will be available from its non-U.S. members, to define more clearly the actual level of U.S. funds needed.
With a sound detector concept, it should be able to maximize the overall non-U.S. contribution level.

The SDC and its detector will, for many years, be a crucial link which allows the ambitious performance goals of the SSC to be translated into potential for dramatic discovery. This is why such a large group is working on this enterprise; and why, in spite of base program commitments, that group has built up so much momentum. It is the opinion of both the U.S. and non-U.S. members of the SDC that if indeed $600M are needed, the extra funding involved is sufficiently modest on the scale of the SSC enterprise that it will be found in the totality of countries involved.

Expressions of Interest

Number	Spokesperson	Name of EOI	Number of Institutions	Number of Collaborators
SSC-EOI0001	A. Krisch	Inclusive Spin-Spin Effects and Cross Sections Near 20 TeV	3	38
SSC-EOI0002	J. Orear	Low P_t Physics at the SSC	11	20
SSC-EOI0003	G. Trilling	Solenoidal Detector Collaboration (SDC)	74	500
SSC-EOI0004	H. Sobel	A Very Long Baseline Neutrino Oscillation Experiment	11	34
SSC-EOI0005	W. Willis	High Luminosity at the SSC	4	17
SSC-EOI0006	M. Marx	Electrons Muons Partons with Air Core Toriods (EMPACT)	44	222
SSC-EOI0007	R. Lander	10^{34}	1	3
SSC-EOI0008	N. Lockyer	Bottom Collider Detector (BCD)	32	85
SSC-EOI0009	H. Kagan D. Kania S. Schnetzer	A Compact Diamond-Based Detector for the SSC	5	19
SSC-EOI0010	S. Ting	L*	66	217
SSC-EOI0011	S. Reucroft L. Sulak R. Webb	A Calorimeter-Based High-Rate Detector for the SSC (TEXAS)	15	42
SSC-EOI0012	R. Kanofsky	(Proposals to be Submitted)		
SSC-EOI0013	J. Rosen	Internal Target Beauty Physics at the SSC	1	1
SSC-EOI0014	B. Cox	Super Fixed Target Beauty Facility	36	138
SSC-EOI0015	G. Giacomelli	Search for Magnetic Monopoles		
SSC-EOI0016	M. Atiya	A High Resolution Detector for $H^0 \rightarrow \gamma\gamma$	1	2
SSC-EOI0017	H. Bryant	Relativistic Atomic Physics at the SSC	11	23
SSC-EOI0018	S. Linn	Electromagnetic and Muon Detector for the SSC	5	6
SSC-EOI0019	J. D. Bjorken	A Full-Acceptance Detector for SSC Physics at Low and Intermediate Mass Scales	1	1
SSC-EOI0020	B. Barish B. Willis	To Construct A Major SSC Detector	52	310
		Total:	373	2388

IV. Solenoidal Detector Collaboration (SDC)

The Committee received a report from the SDC indicating considerable technical progress on many of the detector subsystems. In addition, the overall engineering and system integration efforts are making excellent progress and the currently used cost estimating procedures seem to be realistic. Included in the report was a plan to reduce the scale of the detector by a "thinning-down" of the configuration described in the Letter of Intent -- the new design has an estimated cost of $595M, based on the criteria established by the Theriot Panel. The Committee acknowledges a positive effort on the part of the SDC to reach a design with a realistic cost.

However, in light of the Committee's belief in the desirability of proceeding with two major detectors, it is unlikely that the funds available for the construction of the SDC detector will match their current cost estimates. At the present time, reasonable estimates of the amounts of Laboratory and foreign funds that can be used to construct the detector are less than $500M. As noted by the collaboration, some or all of this shortfall may be recovered by the development of more efficient manufacturing techniques and further optimization of subsystem designs. Nevertheless, in the realization that these efforts may be insufficient, the Committee examined scenarios in which costs were reduced to the $500M level by the elimination of some detector subsystems and the reduction of the coverage of others. The resulting detector appeared to be capable of addressing most of the major physics goals of the SDC, particularly those that are likely to be accessible during the initial years of the SSC program, albeit with somewhat reduced efficiencies in some areas. Thus, in spite of the stringent financial constraints, we expect that the SDC can produce a proposal for a powerful detector within a credible financial plan. The PAC reiterates the requirement that the cost of the detector must be within the funding the collaboration can reasonably anticipate.

CONCLUSIONS

The SDC has confidence that it can build a "thinned-down" version of the general purpose detector described in the EoI/LoI for about $600M. Details of this "thinning" need further study, but the conclusion is unlikely to change.

The SDC intends to study further those many areas for which, through more efficient manufacturing methods, there is a chance that costs could be reduced further toward the $500M level.

To satisfy its physics goals, the SDC feels that it must maintain
1) its present concept as a general purpose detector,
2) the full rapidity coverage defined in the LoI.
If the full rapidity coverage cannot be achieved at turnon, it should be available by the time that the SSC comes close to its design specifications.

About 700 physicists from a dozen countries, including about 400 from the U.S. have joined together in the SDC to develop the concept proposed in the LoI. Abandonment of 1) or 2) above would seriously jeopardize our large potential non-U.S. support, as well as the interest of our U.S. contingent.

Remarks on Scope Reduction

Two methods of scope reduction:

1) "Thinning down"
   This reduces cost while still maintaining geometrical coverage. It increases technical and scientific risks, and cannot be easily rectified as more funding becomes available.

2) Staging
   This reduces cost by reducing initial coverage, or ganging the electronics. If properly designed, this can be upgraded as more funding becomes available.

To achieve the required cost goals within our present detector concept, we need to combine *both* strategies. It is better to stage than to have a forever compromised detector through excessive "thinning".

The SDC detector will run for many years, and perhaps the whole life of the SSC.

The Committee recommends that the Laboratory support the R&D and engineering studies needed by the SDC for the preparation of a Technical Design Report. We note, however, that their request for 1992 significantly exceeds the amount of funds that are expected to be available. A substantial reduction in the level of required funds could be made if parallel R&D activities on the same detector component, particularly in the areas of tracking, muon detectors, and forward calorimetry, were discontinued, and engineering studies of noncritical-path items were slowed down.

We encourage the SDC to proceed with its plan to submit a Technical Design Report by April, 1992. In the meantime, we recommend that the collaboration make oral progress reports to members of the PAC in October of this year.

Principal Goals For This Meeting

Detailed review of central calorimetry.
(In preparation for a choice of technology to be made in the fall).

Definition of detector scope for proposal (cost ~ $500M).

This involves not only cost, but technical issues.
(Note report of TF on Material in Tracking Volume)

Tracking volume must be decided this week.
(thinning down form of scope reduction)

Subsystem cost targets will be given.

Staging options must be considered.

Note: Trying to meet subsystem cost targets will tend in the direction of deseeping by thinning down. Possibilities of greater savings through staging must be considered and discussed.

What Does This Mean For The SDC?

On April 1, 1992, we must propose a detector with the following cost structure:

* $275M +/- $50M in contributions from U.S. SSCL funds.
* Remaining costs credibly distributed among non-U.S. collaborators.

The precise definition of non-U.S. contributions will still take some time, but our present working estimate is $200M total in in-kind contributions and common funds.

The SDC must therefore, at this meeting, develop a plan for a detector of initial cost about $500M which can be gracefully upgraded as additional funding from U.S. and/or non-U.S. sources becomes available.

Another consequence of the PAC recommendations is that we must reduce our R&D/Engineering budget to about half of present request.

SOLENOID STATUS REPORT

A. YAMAMOTO

PROGRESS ON DESIGN STUDY OF THE SDC THIN SUPERCONDUCTING SOLENOID

A. Yamamoto, Y. Doi, Y. Makida, K. Tanaka, H. Yamaoka,
S. Terada and T. Kondo,

KEK, National Laboratory for High Energy Physics
Oho, 1-1, Tsukuba, Ibaraki, 305, Japan

R. Kephart, R Fast, B. Foster, D. Friends, J. Grimson, C. Grozis,
J. Krebs, A. Lee, R. Stanek, A.M. Stefanik and R. Wands,

Fermilab., National Accelerator Laboratory
Batavia, IL, 60501, U.S.A.

JULY 25, 1991

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*TO BE PRESENTED AT THE SDC COLLABORATION MEETING TO BE HELD AT LAWRENCE BERKELEY LABORATORY ON AUG. 5, 1991.

PROGRESS ON DESIGN STUDY OF THE SDC THIN SUPERCONDUCTING SOLENOID

A. Yamamoto, Y. Doi, Y. Makida, K. Tanaka, H. Yamaoka,
S. Terada and T. Kondo,

KEK, National Laboratory for High Energy Physics
Oho, 1-1, Tsukuba, Ibaraki, 305, Japan

R. Kephart, R Fast, B. Foster, D. Friends, J. Grimson, C. Grozis,
J. Krebs, A. Lee, R. Stanek, A.M. Stefanik and R. Wands,

Fermilab., National Accelerator Laboratory
Batavia, IL, 60501, U.S.A.

Design study of the SDC thin superconducting solenoid is being carried out in co-operative work between KEK and FNAL. This report describes progress of the design study and status of basic R&D. The solenoid is required to have a central magnetic field of 2 Tesla with a useful magnetic volume of 3.4 m in diameter and 8 m in length. The transparency of 1.2 radiation length (Xo) is considered to be achieved, based on some new design concepts and R&D progress as given this report.

The following industrial partners have been involved in this study:
Toshiba Co.Ltd, Tokyo, Japan,
The Furukawa Electric Ltd., Tokyo, Japan,
Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo, Japan,
PS Associates, California, U.S.A.

I. INTRODUCTION

The SDC thin superconducting solenoid has been designed to provide a magnetic field of 2 tesla with a tranparency of 1.2 Xo in the central region of the SDC detector as one of major detectors to be constructed in the Superconducting Supe Collider (SSC) in Texas, U.S.A. Figures 1-1 and 1-2 show cross sections of two options of the SDC detector configuration being discussed.

A schematic sketch of the SDC solenoid being considered is shown in Fig. 1-3. It is an important design requirement to provide the magnetic field of 2 tesla with keeping a transperency of around 1.2 radiation length to allow partilce passing though the magnet wall. According to the task force work in the SDC, the magnet is expected to be adapted in operation either with closed iron return yoke or with no iron yoke depending on calorimeter design in the SDC detector design.

This report describes progress of the design study of the SDC solenoid and status of R&D efforts.

2. CONCEPTUAL DESIGN

2.1. Basic Requirements

According to discussions in the Magnet Task Force in last summer, basic requirements on the SDC solenoid magnet design have been fixed as follows:

Magnet Size:	
Cryostat inner radius:	1.75 m
outer radius:	<2.10 m (2.05 m)
Cryostat half length:	4.0 m
Tracking Volume:	
Outer radius:	1.70 m
Axial half length:	4.0 m
Central magnetic field:	2 Tesla
Transperency (η=0):	<=1.2 Xo
Operational environment:	in return yoke or in air

A conceptual cross section of the axial end of the SDC solenoid is shown in Fig. 2-1. The size of the magnet has been fixed as a result of compromization with the physics/cost of the detector. The magnetic field of 2 tesla is being understood as the highest field to be achievable in presenttechnology level for thin solenoids.

The magnetic field design in the solenoid has not been yet fixed up due to continu-ing discussions on calorimeter design in the SDC detector. The magnet is required to be able to adapt to either magnetic design with iron return yoke or assentially in air core operation.

2.2. Design Approach

To make transperancy of the magnet as small as possible, we have introduced following new concepts into the SDC solenoid design

- E/M ratio to verify lightness and transparency.
- High strength Al stabilized superconductor.
- High speed quench propagation by introducing a concept of pure AL axial strip quench propagator.
- Honeycomb wall in cryostat.

We propose to take a higher E/M ratio of >7 kJ/kg in comparison with that of about 5 kJ/kg for existing ones as shown in Fig. 2-3. We intend to [illegible] material with a level of 30 % in comparison with present magnet and, therefore, it is very important to dump the stored energy more homogeneously in the coil than that of existing magnet. We have introduced the pure Al strip quench propagator to enhance transverse quench velocity resulting in more uniform energy dump.
This concept has been already evaluated in R&D program at KEK for a superconducting magnet in space use. It has worked fine.
We understand that the maximum coil temperature after quench is one of the most important issues to be concerned.
If we assumed uniform energy dump in the coil, the E/M ratio enable us to know an average temperature rise after quench according to the following relation:

$$R = E/M = H(T1) - H(T2)$$

where H = INTEGRAL Cp dT is the enthalpy as a function of the temperature. As shown in Fig. 2-2, the enghalpy of aluminum of 10 kJ/kg corresponds to T1 = 80 K and is acceptable to keep the thermal stress still negligible after a quench and full energy dump in the worst case. Figure 2-3 show E/M plots as a function of the stored energy in various magnets. Main parameters of the SDC solenoid based on the above design concpts are summarized as follows (Table 2-1):

Table 2-1. Main parameters of the SDC thin superconducting solenoid.

		In air	In iron
Dimensions:			
Cryostat	Inner Radius	1.75 m	
	Outer Radius	2.10 m	
	Half Length	4.0 m	
Coil	Effective Radius	1.85 m	
	Half Length	3.8 m	
	Coil + OSC	44 + 31mm	
Tracking	Aperture Radius	1.7 m	
	Half Length	4.0 m	
Transperancy	Radiation Thickness	1.2 Xo	
	Interaction Length	0.25 λo	
Electrical Parameters			
Central Field		2.0 T	2.1 (~2.2) T
Int. B.dl	(η=0)	3.4 T.m	3.6 T.m
	(η=1.0)	T.m	
	(η=1.5)	T.m	
Nominal Current		8,000 A	8,000 A
Inductance		4.2 H	4.6
Stored Energy		133 MJ	160 MJ
E/M		7.4 kJ/kg	8.9 kJ/kg
Mechanical Parameters			
Effective Cold Mass		18 tons	
Total Weight		23 tons	
Radial Magnetic Pressure (@z=0)		1.6 MN/m2	
Axial Total Compressive Force		18 MN	
Superconductor			
Nb.Ti/Cu/Al ratio		0.5/0.5/29	
Overall conductor size		4.37 x 4.4 mm2	
Load Line Ratio(@ 2.2T, 4.2K)		50 %	
RRR of pure Al (@ B=0T)		600	
Yield Strength of pure Al		65 MPa	

3. MAGNETIC FIELD

The field distribution in the thin solenoid has been evaluated with program code POISSON and ANSYS. Figure 3-1 shows the flux lines with the Poisson code in the SDC solenoid to be operated in air. The axial electromagnetic force is 1770 tonf with a central magnetic field of 2 T. Figure 3-2 shows various configurations of iron return yoke and compressive axial force in each case. In a typically simple configuration, the axial compressive force is 1120 tonnes and a half level in comparison with the solenoid operated in air. The magnetic impulse(i.e. bending power) in the solenoid is plotted as a function of psudorapidity in each typical air core or iron dominated solenoid ~ Fig 3.3

The peak field in the solenoid coil has been carefully evaluated in the case of the air core solenoid. A peak field of 2.8 Tesla is calculated at the axial coil end possibly due to the effect of large current operation in the solenoid and dut to the self field effect. Under this conduction, a load line ratio of the SDC superconductor is about 50 %. and the conductor still has a plenty safety margin.

4. TRANSPERENCY

Transparency of the solenoid wall has been calculated as summarized in Table 4-1. The radiation thickness of 1.2 Xo and interaction length of 0.25 λo has been calculated in the present configuration.

Table 4-1. Transperency of the SDC solenoid.

Element	thick. eq.	X_o	λ_o
Outer Vac. wall (Al-H/C.	8 mm	0.090	0.0009
Outer Rad. Shield	2	0.020	0.0001
Outer Support Cylinder	31	0.348	0.0787
Superconductor			
(Al stab.)	41.0	0.461	0.1044
(Nb.Ti/Cu)	2.8	0.175	0.0161
(CFRP)	1.0	0.005	0.0002
(Al Strip)	1.0	0.011	0.0008
Inner Rad. Shield	2.0	0.020	0.0001
Inner Vac. wall	6.0	0.067	0.0030
Super-insulation	2.0	0.007	0.0002
		1.206	0.2605

where:

	X_o	λ_o
Aluminum	89 mm	394 mm
Nb.Ti/Cu	16 mm	174 mm
CFRP	190 mm	530 mm
(CFRP)	(240 mm)	(550 mm)
Mylar(S/I)	287 mm	617 mm

5. MECHANICAL STABILITY

The SDC thin solenoid is required to have more reliable mchanical design than that of existing thin solenoids presently operated, because the magenet is to be operated up to 2 T full excitation in air. The following stress is especially important to be considered:

1) Combined hoop and axial stress in superconductor due to possible magnet operation in air. It creates the maximum shear stress ($2\tau = \sigma 1 - \sigma 2$), at the axial coil center, in conductor pure Al

2) Shearing stress (τ_a) at boundary between the coil and the outer support cylinder due to axial electromagnetic force, especially at the

coil end.

It is our basic consideration in the SDC mechanical design to make the design in elastic region, based on development of high strength aluminum stabilized superconductor, even though the nominal field is 2 Tesla in the solenoid. The development of high strength aluminum stabilized superconductor is really a key issue.

The followings are our design basis in mechanical stresses : We have defined allowable stress in the coil structure as follows:

Al Stabilizer	(Conductor)	:	< 66 MPa (100 % x Y.S.)
CFRP, GKG	(Insulation)	:	< 100 MPa(<100 % x Y.S.)
Al-5083	(Support cy.)	:	< 150 MPa(20% x Y.S.)

Table 5-1. Mechanical characteristics of the material.

Element			Conducto	Insulatio	Cylinder
Material Mechanical Process Heat Process			3%Sup-Al 10% Red. 130c(15h	GFRP(GKG)	Al-5083
Young's Modulus	(@RT)	[GPa]	70,000	34,500	70,000
	(@77K)	[GPa]	70,000	34,500	75,000
Ultimate Strength	(@RT)	[MPa]			
	(@77K)	[MPa]			
0.2% Yield Str.	(@RT))	[MPa]	49		
	(@77K)	[MPa]	66		141
Bonding Shear str.	(@RT)	[MPa]		>20	
	(77K)	[MPa]		>20	
RRR)			626		
Allow. stress	(@<77K	[MPa]	66	100	100

First, we consider approximate electromagnetic stress in the coil by using a simple analytical model. Radial magnetic pressure in a long solenoid is approximately given by:

$$pr = Bz2 / 2\mu o = 1.6 \text{ MPa} \ (= 16\text{atm} = 227 \text{ psi})$$

Therefore, hoop stress loaded in the coil and support cylinder is

$$\begin{aligned} \sigma\phi &= R / t \times pr \\ &= 1.85\text{m} / (0.044+0.031)\text{m} \times 1.6\text{MPa} \\ &= 39 \text{ MPa} \end{aligned}$$

On the other hand, a compressive force along the coil axis in the long solenoid is approximately,

$$\begin{aligned} Fz &= dE/dz \\ &= B2 / 2\mu o \ \times \ V / zcoil \\ &= B2 / 2\mu o \ \times \ Sap \\ &= 1.7 \text{ a } 10E7 \text{ N} \\ &= 1,700 \text{ tonf} \end{aligned}$$

where E is the stored energy, z is the effective coil length, V is the magnetic volume and Sap is the area of effective magnetic aperture. Therefore, the integrated axial stress in the coil and support cylinder is approximately given by:

$$\begin{aligned} \sigma z &= Fz / (2 \times Rt) \\ &= - 20 \text{ MPa} \end{aligned}$$

These two stress components will be combined and accumulated at the coil center and the maximum combined stress (the maximua shear stress: 2τ) in the conductor is given by :

$$\begin{aligned} 2\tau &= (\sigma 1 - \sigma 2) + (\sigma 2 - \sigma 3) + (\sigma 3 - \sigma 1) \\ &\approx (\sigma\phi - \sigma z) \\ &= 39 + 20 \text{ MPa} \\ &= 59 \text{ MPa} \end{aligned}$$

$$(< \sigma y = 66 \text{ MPa} \ldots \text{ Elastic limit})$$

Shear stress at epoxy bonding between the coil and support cylinder is another important issue to be well evaluated. We may estimate this shear stress by a simple model in the most pessimistic case as follows:

If the magnetic field at the coil end has only radial component with a field intensity of 2 Tesla, the electromagnetic Lorents force is given by

$$\begin{aligned} fz &= Br \times I \\ &= 2 \text{ Tesla} \times 8,000 \text{ A/m} \\ &= 16,000 \text{ N/m} \end{aligned}$$

We assume this axial force is supported by radial outer surface of the coil. Therefore, shear stress at the outer boundary of conductor is calculated by

$$\begin{aligned} \sigma(\text{shear}) &= fz / wz \\ &= 16,000 \text{ N/m} \ / \ 0.0045 \text{ m} \\ &= 3.6 \text{ MPa} \end{aligned}$$

$$(< \sigma(\text{shear-breakdown}) = 18 - 30 \text{ Mpa})$$

where wz is the axial width of the conductor. A practical shear stress should be smaller than above, because the end part is also axially supported by another part of the conductor continuously wound to the central part of the coil.

Finite element analysis has been carried out to verify stress more precisely. Figures 5-1 and 5-2 show structure configuration, mesh distribution, force on the coil and deformation with excitation. Figure 5-3 shows the stress level computed. The shear stress in conductor is 59 MPa and shear stress at epoxy bonding is 1 MPa or less. We have concluded the present SDC thin solenoid design is still in elastic region and stable enough. Summary of the stres s analysis is given by Table 5-2.

Table 5-2. Results of stress analysis.

		El. Limit	Anal. Ca..	FEA
Conductor	Pure Al. 1145	65 MPa	55 MPa	55 MPa
Insulation	GFRP/ KCERR	>.11 MPa	30	30
Cylinder	A-5083	169 MPa	59 MPa	55
Joint Bonding	Epoxy	[illegible]	[illegible]	[illegible]

6. QUENCH ANALYSIS

Quench analysis has been carried out by using the program QUENCH. Results are given in Figs. 6-1, 6-2 and 6-3 for R(dump resister) = 100, 50 and 1 m Ω, respectively. In these calculation, we assume pure Al strip quench pagagator with a thickness of 1 mm resulting $\varepsilon = kz/k\phi = 0.085$. The maximum temperature is less than 100 K even in the case of R=0; whole energy dumped into the coil. Figure 6-4 shows the effect of pure aluminum strip (ε) on the maximum temparature in the coil after quench. The present design with $\varepsilon = 0.085$ seems to be reasonable.

7. CRYOSTAT

1. General Design

Figure 7-1 and 7-2 show cross sections of the crostat at the coil end and various scheme of supporting structure. In the current design, we are assuming to have one fixed end and the other free along the coil axis. It is much simpler in design and fabrication.

Figures 7-6 and 7-7 show general views of the SDC thin solenoid installation into iron structure as tentative plans to be discussed. From the view point of the magnet installation, it is easier to put a chimney straight up to the top of the detector passing through iron structure. Figure 7-8 shows a cross section of the chemney in which a diameter of 30 cm is assumed for the chimney pipe.

It is very efficient to use honeycombs, or isogrid strucutre in the outer vacuum wall in order to save material with keeping stiffness against external pressure. The followings are comparisons of these two structure. Figure 7-3 shows schematic configuration of the isogrid vacuum vessel wall and Fig. 7-4 shows the effect of the isogrid structure on the radiation thickness of the magnet. Figure 7-5 shows characteristics of the honeycomb wall structure. The comparison of the characteristics between the isogrid an honeycomb configuration are given in Table 7-1.

Table 7-1. Comparison of Isogrid and Honeycomb configuration.

	Isogrid-2219T851	Honeycomb
Physical thickness	27.94 mm (1.1")	50 mm
Effective thckness	5.41 mm (0.21")	4.0 mm
Equiv. thick. in solid plate	26 mm	26 mm
Weight Reduction Ratio	4.8	6.5
Fabrication techinique	Machining/weld.	Weld/Epoxy Bonding
Leak tight Joint	Complete Welding	Welding inside wall
Reliability	better	modest
Uniformity	modest	better

*Design base:
Buckling external pressure: 2atm
Outer Radius : 2.05 m
Half Length : 3.8 m

Further trade off study will be necessary to fix the design. A similar design is also being considered for the innner vacuum wall to prevent buckling of the inner wall in case of abnormal positive pressure in the vacuum chamber.

8. COOLING AND CRYOGENICS

We are evaluating two options of (i) thermosiphone using gravitational pumping techinique and (ii) ordinal forced flow two phase helium to circulate liquid helium to cool down the magnet. A schematic diagram and technical comparisons are given as follows (Table 8-1):

Table 8-1. Comparison of thermosiphone with Force 2φ He.

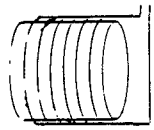
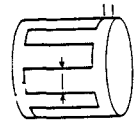
	Thermosiphone	Forced 2φ Flow
Diagram		
Cooling Pass	Short & Parallel	Long and Single Pass
Configuration	Complex Larger space	Simple Smaller space
Conductance	Very high	Small or modest
Cooling Perform. Pre-cooling Delta. T Time period Instability Steady Operation Stability	 smaller shorter possible Higher	 larger longer less Lower
Operation	Stable	Simple

Figure 8-1 shows schematic diagrams of the magnet cooling loop in each case of the thermosiphone and the forced two phase flow cooling.

To consider a refrigeration system to cool down the magnet and to maintain stable magnet operation at liquid helium temperature, the following boundary condition have been assumed.

Cold Mass	:	20 tons
Cool down time	:	10 days (- 12)
Quench Recovery Time:		4 hours (- 12)
Reliability		Reserve Capacity, Additional Liquid Storage, Consideration on Pumps in Liq. Storage, No operative equipment in the cryostat.

The following refrigeration power will be required in various cases as follows:

1. Cool-down: 366 l/h (12.5 g/s)
   Refrigeration---1,250 W
   Liquefaction ---12.5 g/s
   Cost Factor ---1.6

2. Charging Magnet: 500 W and 35 l/hr (1.2 g/s)
   Rerigeration ---620 W
   Liquefaction ---6.2 g/s
   Cost Factor ---1

3. 4 hour quench recovery: 1,756 l/hr (60g/s)
   Boundary condition:
   Stored Energy --- 130 MJ
   Cold Mass --- 20 tons
   Temperature --- 75 K equilibrium
   Option #1:
   Refrigeration --6000 W
   Liquefaction --60 g/s
   Cost Factor <5

Option #2:
Stored Liquid Helium -- 6,000 l
Helium gas recovery -- 60 g/s
Reliquefy in 10 hours with extra capacity of 1500 W Refrigeration

Figure 8-2 shows possible flow schematic of helium system and Fig. 8-3 shows an example for the magnet cool-down characteristics.

9. R & D WORKS

9-1. Development of Superconductor

The SDC solenoid is required to have the central field of 2 Tesla and, therefore, higher mechanical strengh in the conductor is required. According to the design study, the following parameters have been considered.

σ (0.2) > 6 kgf/mm2 = 60 MPa (@ < 77 K)
> 4.5 kgf/mm2 (@ < 300 K)
RRR > 500 (ρ 300K/ρ 4.2K)
size = 4.4 x 44 mm

The progress of the superconductor R&D is as following

σ (0.2) > (6.5 kgf/mm2 = 65 MPa) (@ < 77 K)
> 4.8 kgf/mm2 (@ < 300 K)
RRR > 626 (ρ 300K/ρ 4.2K)
size =
Composition: 5N-Al + impurity (200 ppa)
Process: Cold Work (10% reduction) and Heating (130°C, 15h)

The composition of 5N(99.999%) aluminum plus impurity is a key issue to optimize characteristics of high strength and residual resistivity ratio (RRR). The conductor cross section and the picture developed are shown in Fig. 9-1 and 9-2, respectively. Figure 9-3 shows RRR ratio and mechanical yield strength of the pure aluminum as a function of mechanical reduction by cold work. The cold work may enhance the mechanical strength effectively and decrease RRR as also shown in Fig. 9-4.

The Al stabilizer will be annealed during cure process after coil winding process. Including this effect, the cold work of 10 % reduction in thickness of aluminum stabilized superconductor has been decided. Figure 9-5 shows plots of RRR as a function of yield strength under various conditions for cold work and heat process. It is

interesting that the characteristics may roughly fit to the following relation:

RRR = - k . (YS - x(RT)) at room temperature

RRR = - k . (YS - x(LN2)) at 77 K

The mechanical strength is improved at lower temperature, then we could expect the characteristics of 6.5 kgf/mm2 in yield strength and 625 in RRR.

As a summary, the following process and characteristics of high strength pure aluminum is concluded.

			σ (0.2)	RRR
1.	5N-AL + X (200ppm)	...> 3N8up	2.0 kgf/mm2	758
2.	Cold Work (reduction)	...> 10 %	5.7	542
3.	winding and curing	...> 130°C, 15h	>4.8	626
4.	Cool-down to	...> <77 K	>6.5	626

Fabrication of large scale conductor with high aspect ratio in area has been successfully tested as shown in Fig. . Reduction of thickness in cold work has been also successfull without damage in Nb.Ti/Cu superconductor. Figure *** shows mehcanical bonding of superconductor to pure aluminum. Mechanical shear strength is *** kgf/mm2.

Measurement of the critical current of the superconductor has been made and results are shown in Fig. ***. The load line ratio in operation to the measured critical current is about 50 % and sufficiently stable enough.

9-2. R&D for coil winding

Research and Development of the coil winding machine has been carried out with the following parameters:

Coil dia.	...	3.85 m φ
Coil length	...	0.2 m
Coil thickness	...	44 mm + 31 mm
Conductor size	...	4.37 x 43.7 mm2
Y/S of conductor	...	4 kgf/mm2 (@ Room Temp.)
GNI insulation	...	GFRP with a thickness of 0.2 mm
Turn-to-turn Ins	...	GKEPP (2 x 100 um)

Figure 9-7 shows sketches of the R&D winding and Fig. 9-8 shows the coil winding R&D process. The cross section of the conductor wrapped with turn-to-turn insulation was observed as shown in Fig. 9-9 and insulation including ground insulation is shown in Fig. 9-10. Figures 9-11 to 9-14 show process of the shear strength between coil and support cylinder (without ground insulation). The result of > 21kgf/mm2 is sufficent enough for our requirement in the design study as follows:

- Requirment σ(sh) > 1.5 kgf/mm2
- Results σ(sh) > 2.0 kgf/mm2

10. PROTOTYPE COIL DEVELOPMENT

A prototype coil development with a full diameter and one quater in length is being started to study of:

- Coil Fabrication Technique
- High E/M ratio ... 7 - 10 kJ/kg
- Fast Quench Proparation with pure AL strip
- High Strength Al based superconductor to be loaded under 6 kgf/mm2 in the maximum shear stress (2τ)
- Equivalent axial force loaded by putting current 50 % higher than nominal cuurent in the main coil, then shear strength at boding between the coil and the outer support cylinder to be tested.
- Stability and Minimum quench energy to be measured to understand safety margins.
- Quench behaviour and the maximum temperature and thermal stress measurement

Figure 10-1 shows a schematic design sketch of the prototype coil winding machine with the outer support cylinder. The magnetic flux lines and contour lines of the prototype coil are shown in Figs. 10-2-(a) and (b). The axial magnetic force and the central field as a function of coil length are shown in Fig. 10-3. It is clear that the operation of the prototype coil at I = 11250 A is eulivalent in axial load in comparison with the main magnet operation at I = 8,000 A. Figure 10-4 shows a quench characteristics in the prototype coil.

The development program has been approved and procurement is being carried out to select the industrial partner to proceed the prototypecoil R&D. Main parameters of the promtype coil are as follows (Table 10-1).

Table 10-1. Main paramters of the prototpe coil.

Design prarameters		Main Coil	Prototype Coil
Dimensions:			
Cryostat	Inner Radius	1.75 m	1.75 m
	Outer Radius	2.10 m	2.05 m
	Half Length	4.0 m	1.2 m
Coil	Effective Radius	1.85 m	1.85 m
	Half Length	3.8 m	0.85 m
	Coil + OSC	44 + 31	44 + 31 mm
Tracking	Aperture Radius	1.7 m	1.7 m
	Half Length	4.0 m	1.2 m
Transperency	Radiation Thickness	1.2 Xo	1.2 Xo
	Interaction Length	0.25 λo	0.25 λo
Electrical Parameters			
Central Field		2.0 T	1.54
Int. B.dl (η=0)		3.4 T.m	
Nominal Current		8,000 A	11,250 A
Inductance		4.2 H	0.69 H
Stored Energy		133 MJ	48 MJ
E/M		7.1 kJ/kg	10 kJ/kg
Mechanical Parameters			
Effective Cold Mass		18 tons	4.5 tons
Total Weight		21 tons	9 tons
Radial Magnetic Pressure (@z=0)		1.67 MPa	1.73 Mpa
Axial Total Compressive Force		17.7 MN	16.7 MN
Maximum hoop stress		41 MPa	43 MPa
Maximum axial stress		-21 MPa	-19 Mpa
Maximum shear stress (2τ)		62 MPa	62 MPa
Max. shear stress on bonding		<10 MPa	
Peak field in coil		2.8 T	3.8 T
Load line Ratio		50 %	

Table 10-2. PROTOTYPE AND MAIN COIL DEVELOPMENT PLAN

YEAR	R&D ITEMS
JFY1990 (APR/90 -)	BASIC R&D - HIGH STRENGTH AL STABILIZED SUPERCONDUCTOR - INNER WINDING TECHNIQUE
JFY1991 (APR/91 -)	PROTOTYPE (1/4L) COIL DEVELOPMENT - SUPERCONDUCTOR (6 KM) FABRICATION - COIL INNER-WINDING MACHINE DEVELOPMENT
JFY1992	- COIL WINDING - CRYOSTAT ELEMENT
JFY1993	- ASSEMBLY OF COIL AND CRYOSTAT - COOLING AND EXCITATION TEST - EVALUATION AND ENGINEERING DESIGN REPPORT
JFY1994	MAIN MAGNET FABRICATION - SUPERCONDUCTOR (25 KM) - CRYOSTAT ELEMENT
JFY1995	- COIL WINDING - MAGNET ASSEMBLY
JFY1996	- COOL-DOWN AND EXCITATION TEST IN AIR - TRANSPORTATION TO SSCL - INSTALLATION INTO THE SDC DETECTOR IRON STRUCTURE
JFY1997	- COOL-DOWN AND EXCITATION TEST IN IRON - FIELD MEASUREMENT

11. SUMMARY

1. Design study of the SDC thin superconducting solenoid is being carried out in cooperative work between KEK and FNAL.

2. The SDC thin solenoid design is feasible with a central magnetic field of 2 T and a transparency of 1.2 Xo.

3. **The coil axial and radial force may be maintained within elastic limit in mechanical design.**

4. Shear stress between the coil and the outer support cylinder should be small enough. The epoxy bonding may sustain safely enough.

5. Present magnet design may be adapted to either (in air or in iron) option of calorimeter system.

6. A prototype (1/4 length) magnet is planned to be developed in these threee years. The same order of the combined mechanical stress (2τ) is to be loaded in the coil with higher current applied into the coil to verify the magnet design and to study of the characteristics of the high E/M thin superconducting solenoid for the SDC experiment.

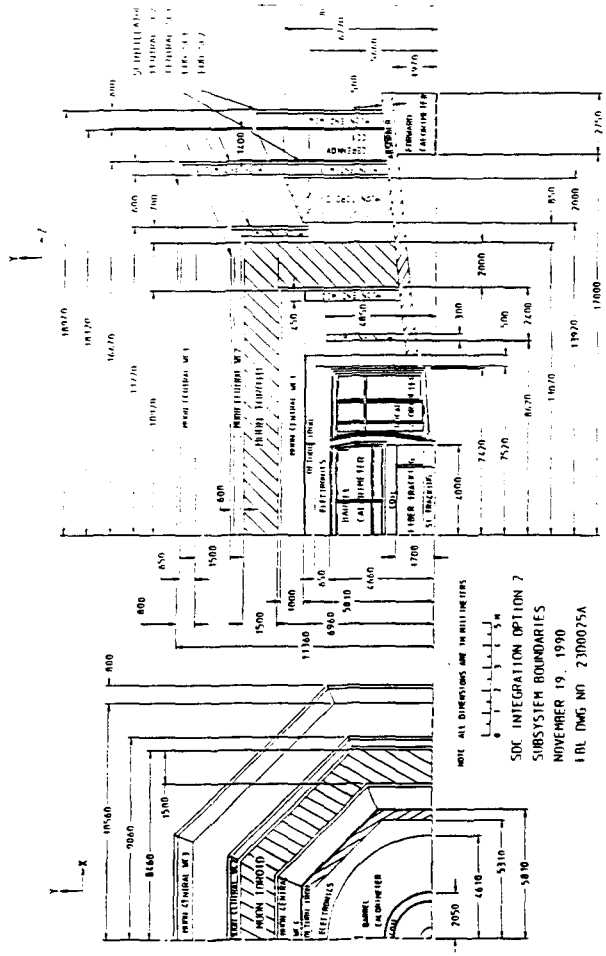


FIG. 1-1 Quadrant plan view of SDC detector with lead/liquid argon calorimeter option

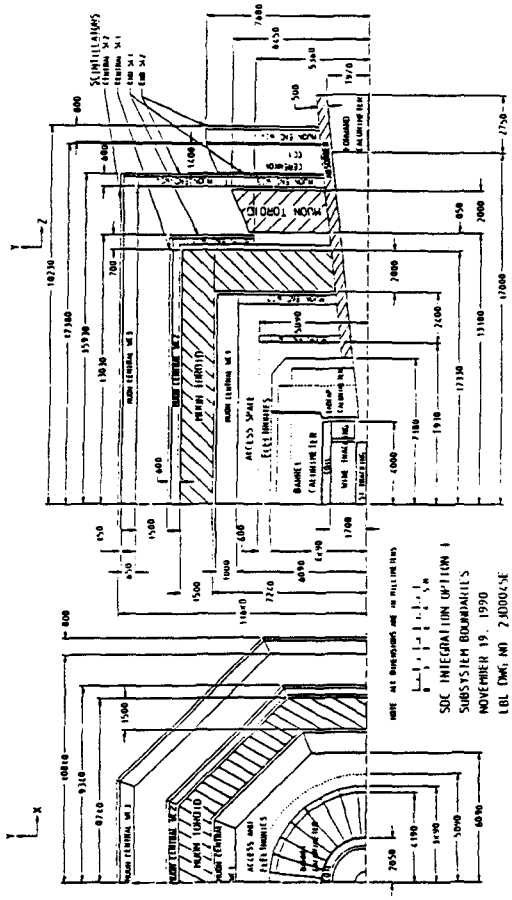


FIG. 1-2 Quadrant plan view of SDC detector with lead/scintillator calorimeter option.

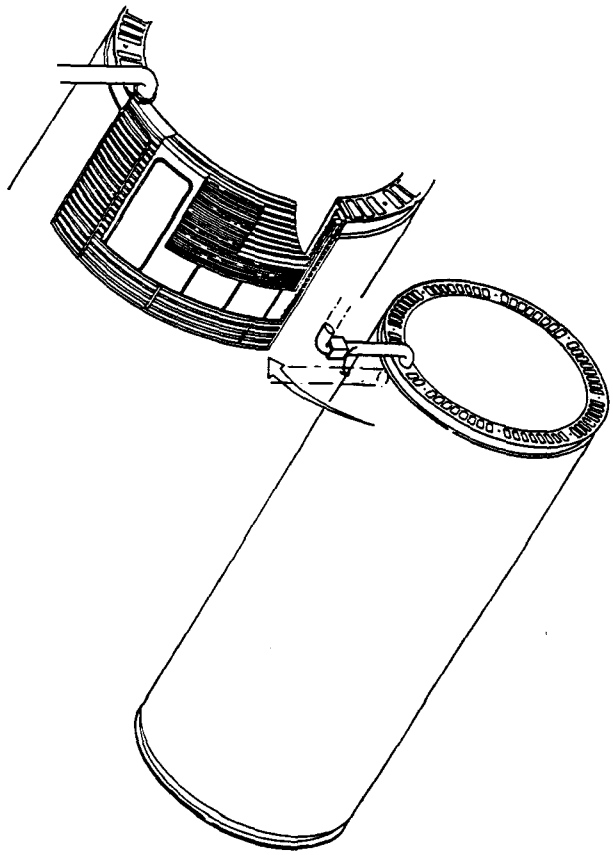
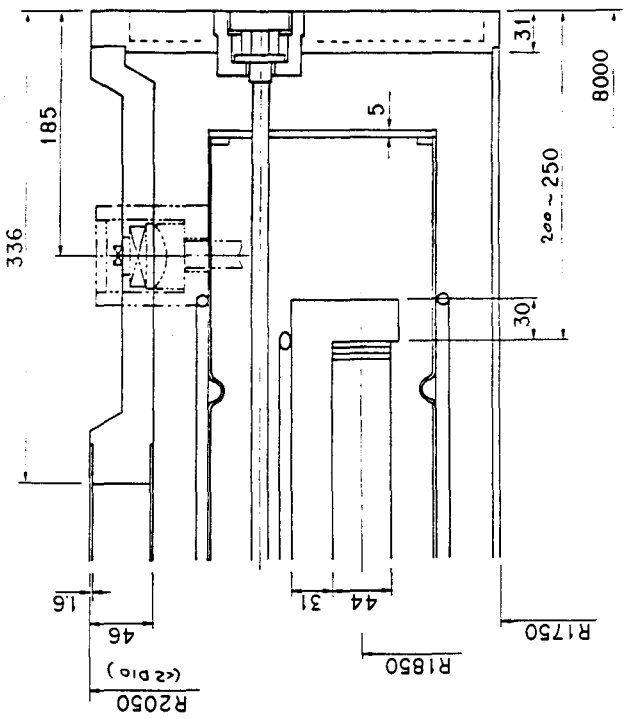


FIG. 1-3



CROSS SECTION OF THE END OF THE SDC SOLENOID

FIG. 2-1

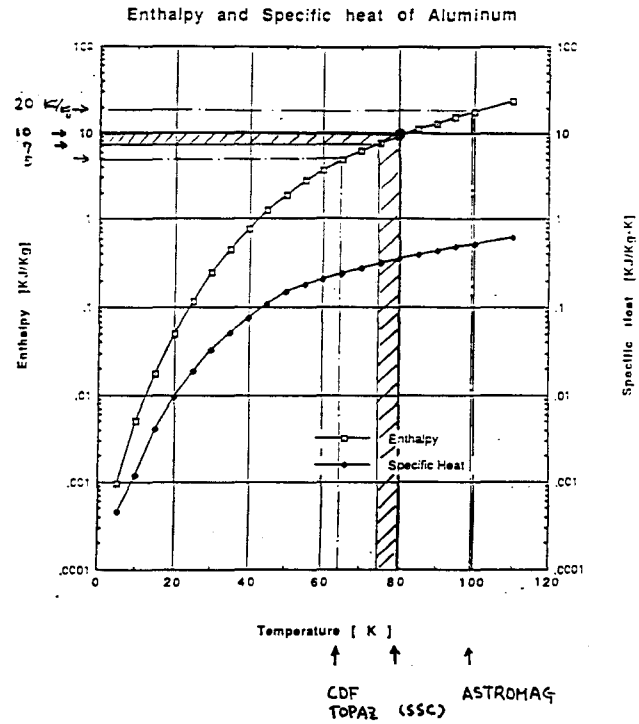


FIG. 2-2

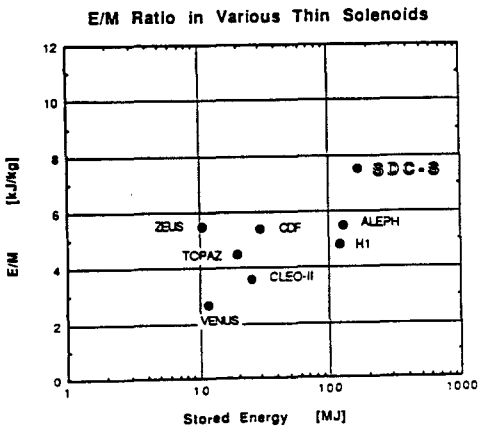


FIG. 2-3

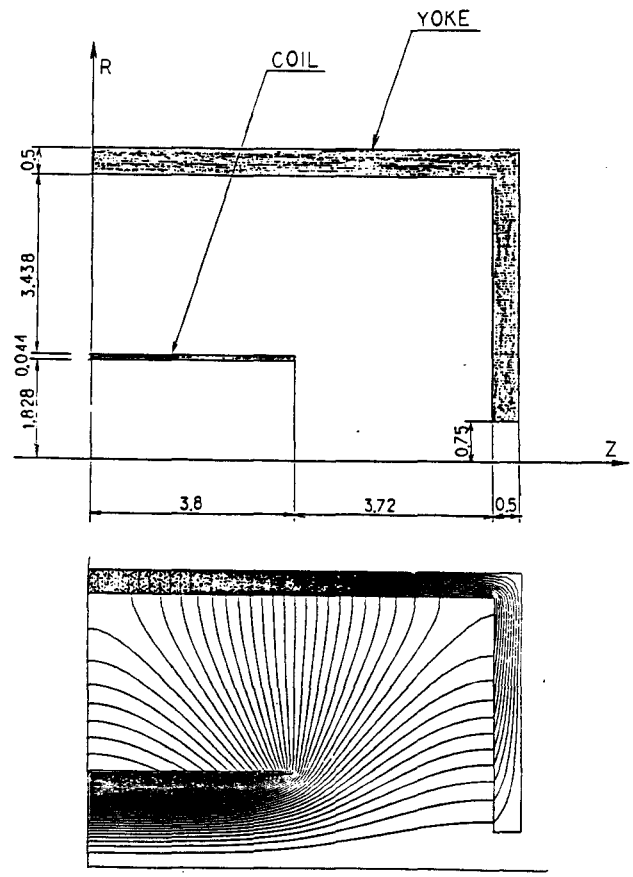
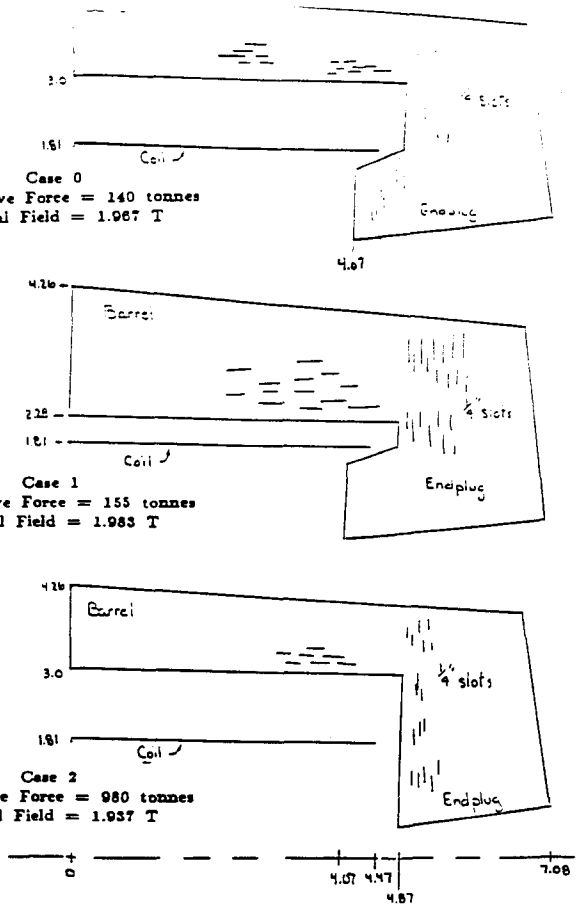


FIG. 3-1 COMPUTATION MODEL AND MAGNETIC FLUX LINE COMPUTED WITH POISSON

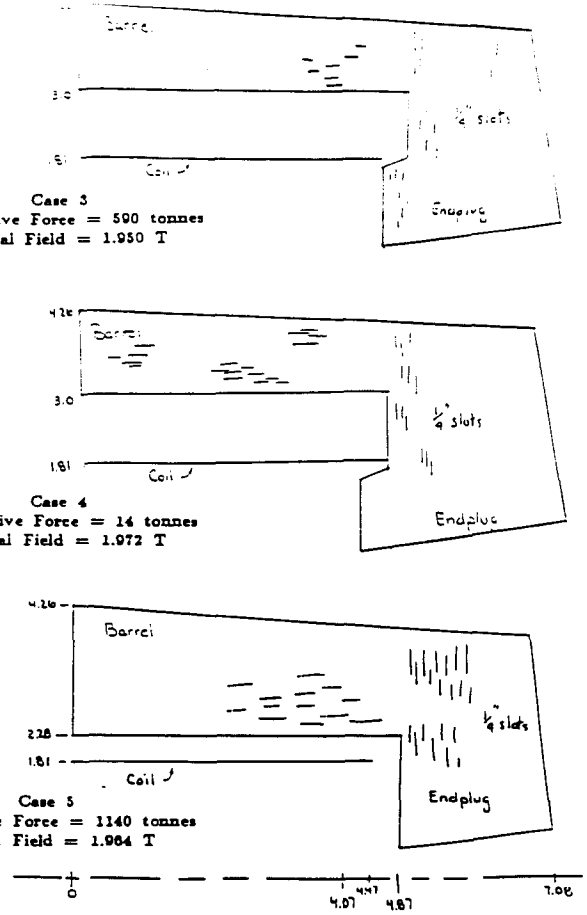


Case 0
Compressive Force = 140 tonnes
Central Field = 1.967 T

Case 1
Compressive Force = 155 tonnes
Central Field = 1.983 T

Case 2
Compressive Force = 980 tonnes
Central Field = 1.937 T

FIG. 3-2-(a) Axial Compressive Forces on Coil

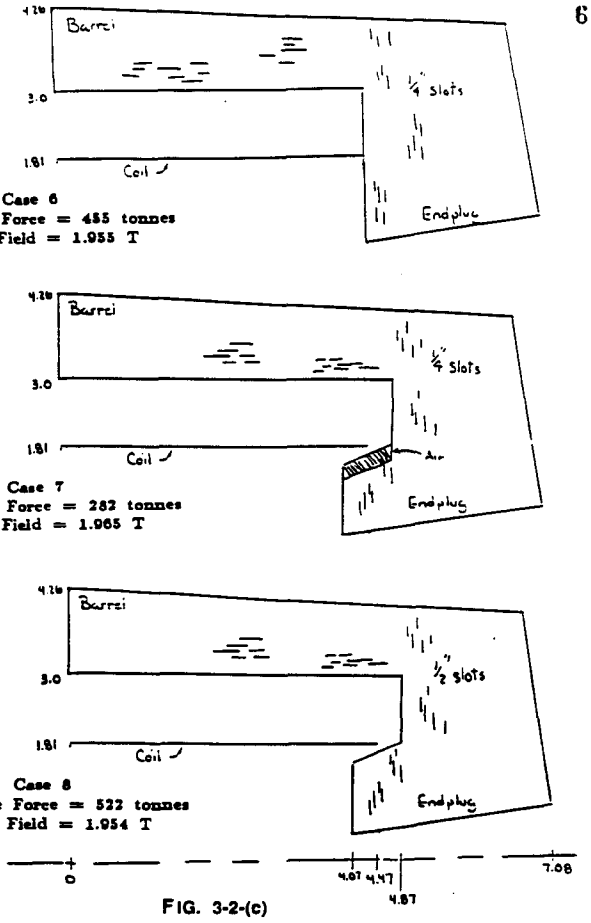


Case 3
Compressive Force = 590 tonnes
Central Field = 1.950 T

Case 4
Compressive Force = 14 tonnes
Central Field = 1.972 T

Case 5
Compressive Force = 1140 tonnes
Central Field = 1.964 T

FIG. 3-2-(b)



Case 6
Compressive Force = 455 tonnes
Central Field = 1.955 T

Case 7
Compressive Force = 282 tonnes
Central Field = 1.965 T

Case 8
Compressive Force = 522 tonnes
Central Field = 1.954 T

FIG. 3-2-(c)

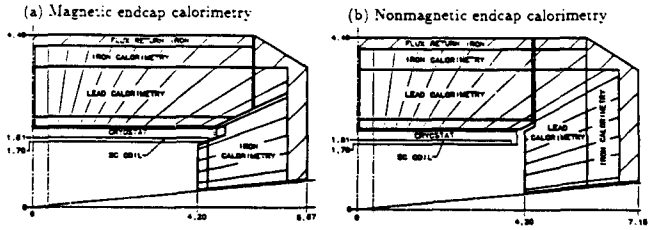


FIG. 8. Coil-iron-calorimeter geometries for Type-U solenoid with magnetic endcap calorimetry (a) and with nonmagnetic endcap calorimetry (b). The axial field at the origin is 2 T in either case. The stored energy with iron calorimetry is 147 MJ; with nonmagnetic calorimetry it is 122 MJ.

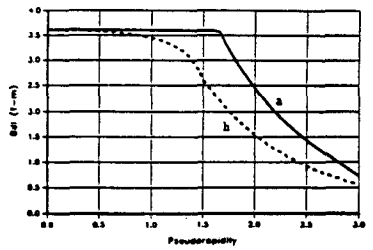


FIG. 9. Bending power versus pseudorapidity for a Type-U solenoid with (a) iron endcap calorimetry and (b) nonmagnetic endcap calorimetry.

FIG. 3-3

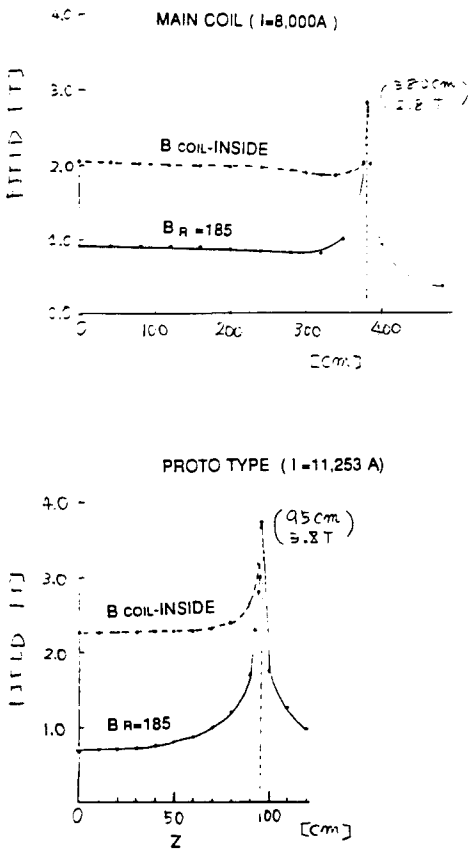
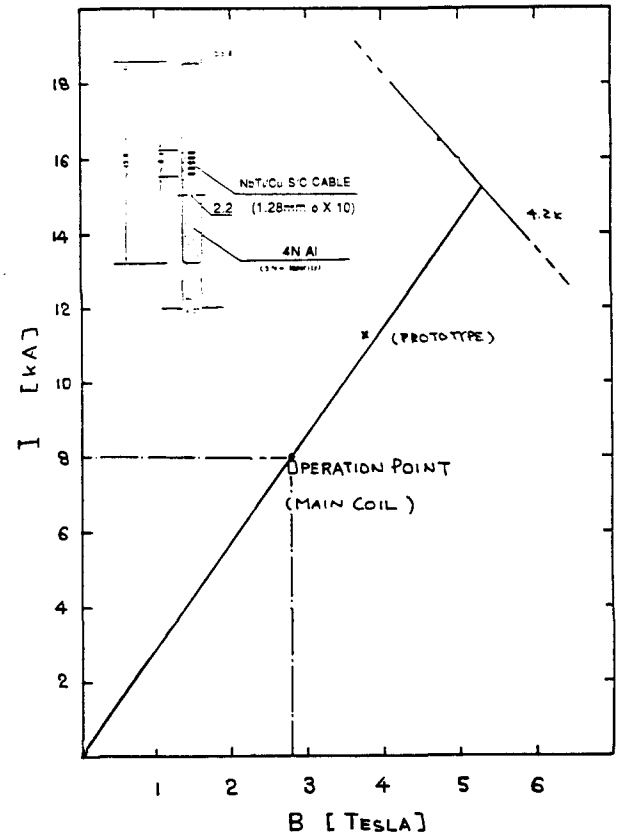
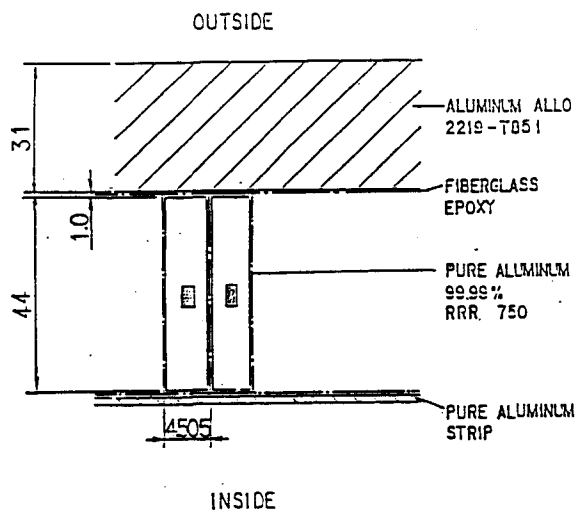


FIG. 3-4



I-B CHARACTERISTICS OF THE SDC SUPERCONDUCTOR

FIG. 3-5



No		E (kgf/mm²)			ν (P=1.55mm)
		R	θ	Z	
1	A2219	8300	8300	8300	0.34
2	GFRP	1220	3450	3450	0.33
3	PURE Al	7000	7000	8650	0.34
4	NbTi/Cu	–	–	–	–

FIG. 5-1 CROSS SECTION OF THE COIL AND PROPERTIES OF EACH ELEMENT

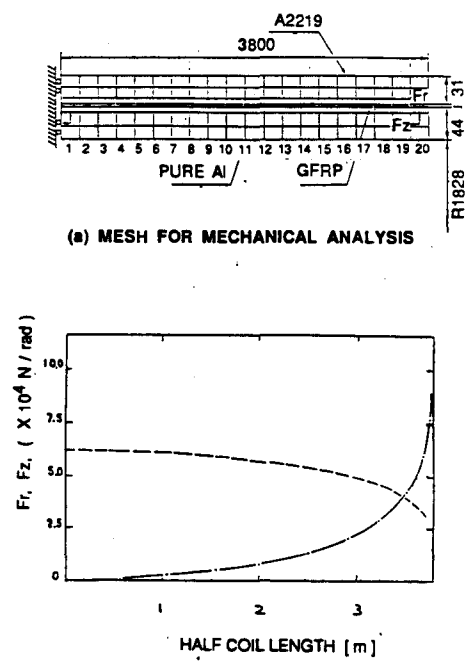


FIG. 5-2 MECHANICAL DEFORMATION OF THE SDC MAIN COIL DUE TO COMBINED HOOP AND AXIAL ELECTROMAGNETIC FORCE

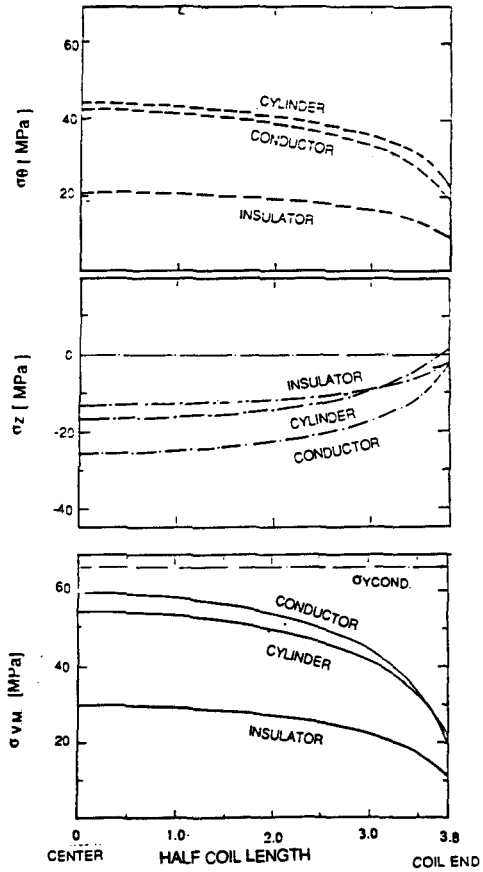


FIG. 5-3 MECHANICAL STRESS ALONG COIL AXIS

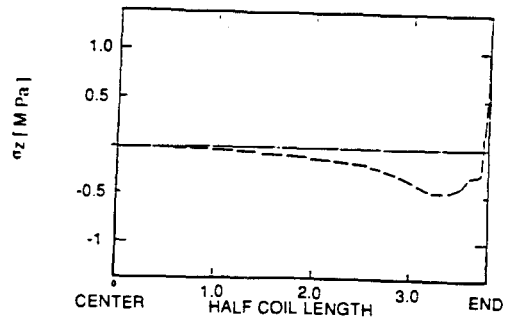
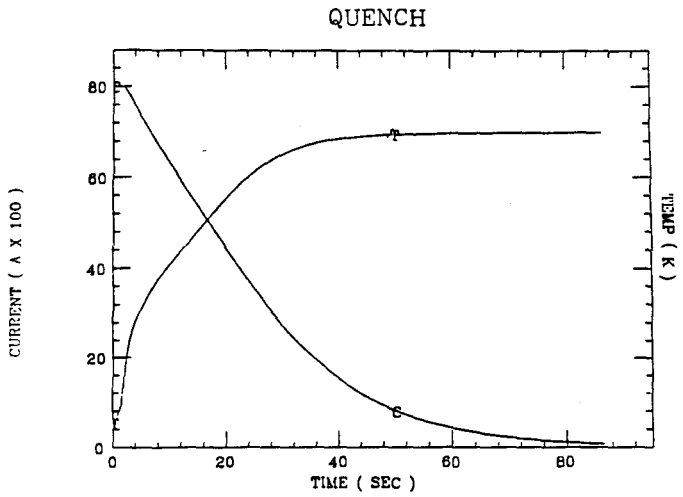


FIG. 5-3 (CONT.)

SHEAR STRESS AT BONDING B/W COIL AND SUPPORT CYLINDER

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FIELD=    20.0000   AR=      1.9769   THET=      4.5000
T=     0.5000   NT=       2000   DTIM=     2.0000   VDETE=  8000.0000
AL= 0.1000E+01   EPS= 0.8500E-01
XLIM=     4.5000   YLIM=   760.0000   ZLIM=  1162.0000
XO=     2.2500   YO=     0.0000   ZO=   581.0000
AMPO=  8000.0000   RPR=     0.1000   GAM=     0.0000   BSM= 99999.0000   KEN=     6.46

ALPHA =   1.00000     INIT. X VELOCITY=  252.1398

EPSILON=   0.08500     INIT. Y VELOCITY=   73.5107

    TOTAL INTERNAL ENERGY=  0.63E+08     TOTAL EXT. ENERGY  0.92E+08
FRACTION OF ENERGY DUMPED IN CRYOSTAT  0.316833
MAX TEMPERATURE RISE=     69.99
MAXIMUM INTERNAL VOLTAGE=    352.35
TIME CONSTANT= 20.500000
INTEGRAL CURRENT SQUARED DT =  5.101sE+10
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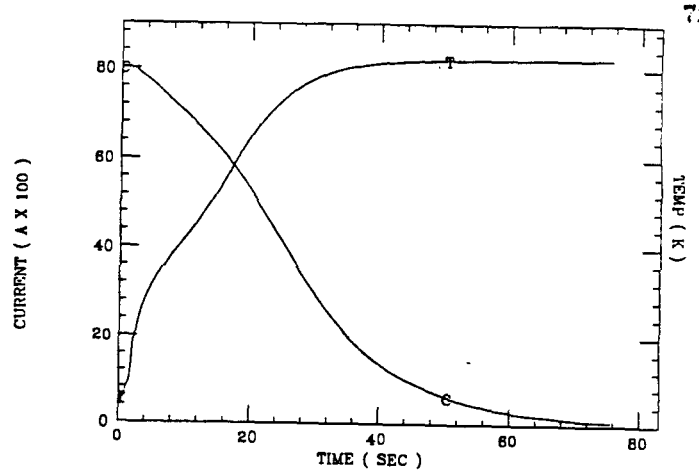
FIG. 6-1

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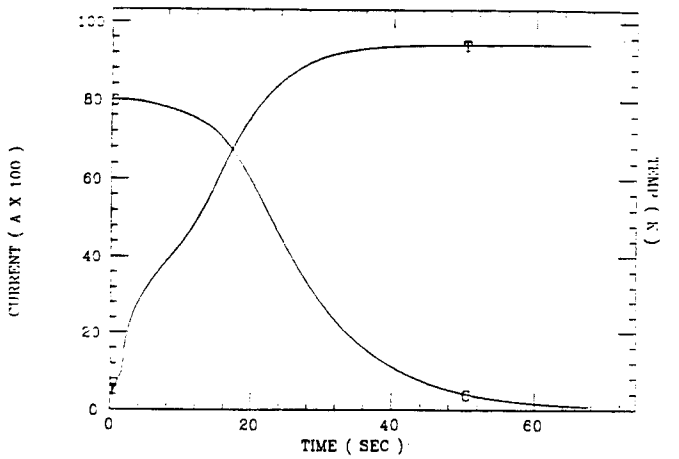
FIELD=    20.0000   AR=      1.9769   THET=      4.5000
T=     0.5000   NT=       2000   DTIM=     2.0000   VDETE=  8000.0000
AL= 0.1000E+01   EPS= 0.8500E-01
XLIM=     4.5000   YLIM=   760.0000   ZLIM=  1162.0000
XO=     2.2500   YO=     0.0000   ZO=   581.0000
AMPO=  8000.0000   RPR=     0.0600   GAM=     0.0000   BSM= 99999.0000   KEN=     0.1600

ALPHA =   1.00000     INIT. X VELOCITY=  252.1398

EPSILON=   0.08500     INIT. Y VELOCITY=   73.5107

    TOTAL INTERNAL ENERGY=  0.80E+08     TOTAL EXT. ENERGY  0.56E+08
FRACTION OF ENERGY DUMPED IN CRYOSTAT  0.596255
MAX TEMPERATURE RISE=     82.13
MAXIMUM INTERNAL VOLTAGE=    784.79
TIME CONSTANT= 29.500000
INTEGRAL CURRENT SQUARED DT =  0.1102E+10
```

FIG. 6-2




```
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TMAX=     9.6000   BMAX=     95.0000   TEMPG=     7.0000
FIELD=    20.0000   AR=      1.9769   THET=      4.5000
T=      0.5000   NT=      2000   DTIM=    200.0000   VDETE=  8000.0000
AL= 0.1000E+01   EPS= 0.8500E-01
XLIM=     4.5000   YLIM=    760.0000   ZLIM=  1162.0000
XO=     2.2500   YO=      0.0000   ZO=    581.0000
AMPO=  8000.0000   RPR=     R.0500   GAM=     0.000R   BSW= 99999.8000   HEN=     4.1620

ALPHA =   1.00000      INIT. X VELOCITY=  252.1398

EPSILON=   0.08500      INIT. T VELOCITY=   73.5107
```

FIG. 6-3

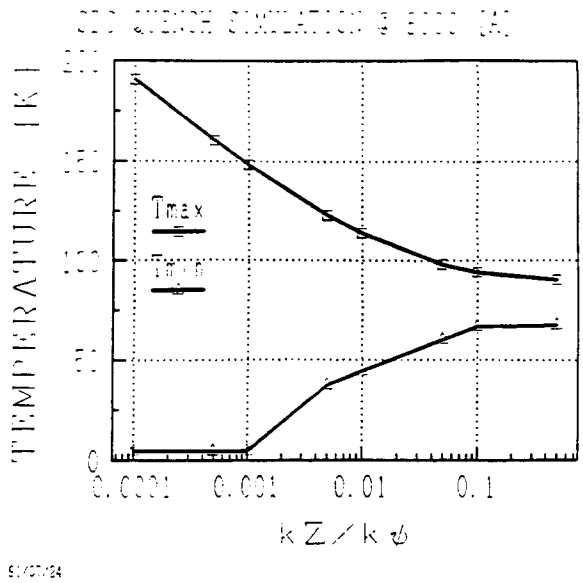
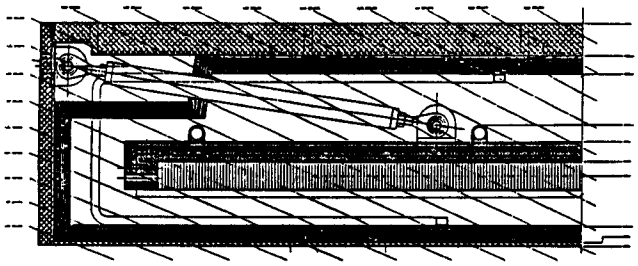


FIG. 6-4



WARREN TRUSS SUPPORT ON NEAR END PROVIDES AXIAL AND RADIAL STIFFNESS

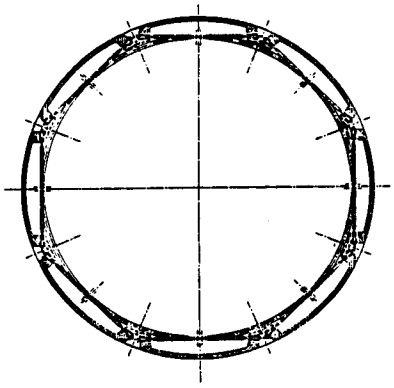
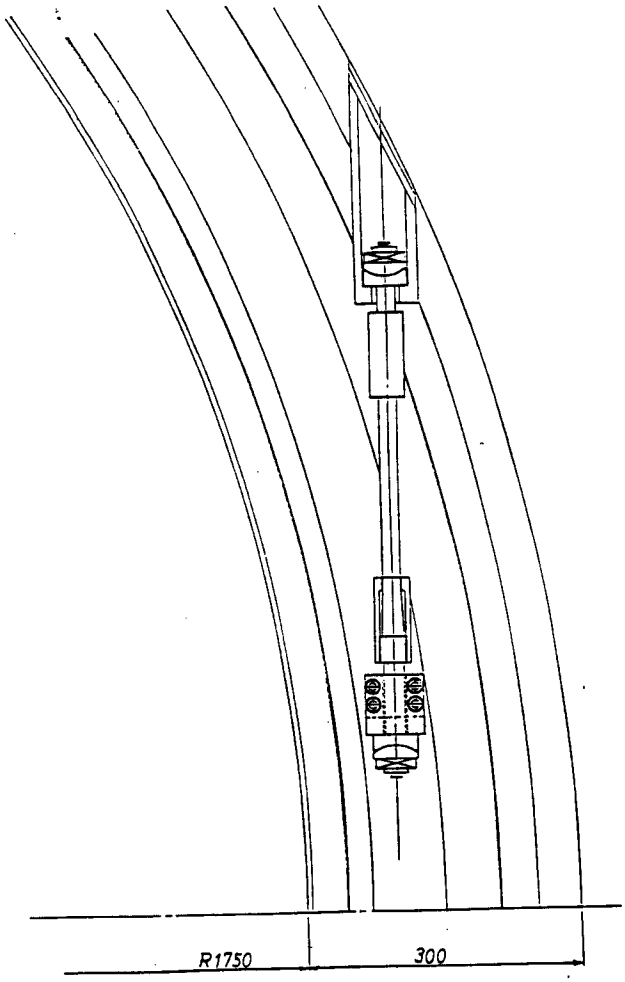
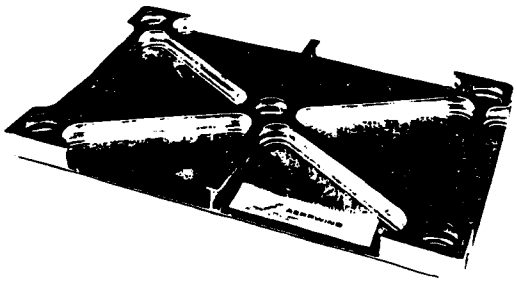


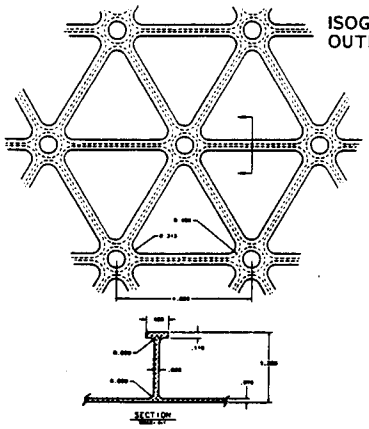
FIG. 7-1 SUPPORT SYSTEM ON FAR END PROVIDES RADIAL STIFFNESS ONLY



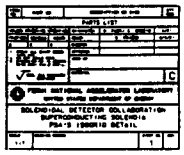
STRUCTURE IN A DIRECTION (ALTERNATE)

77

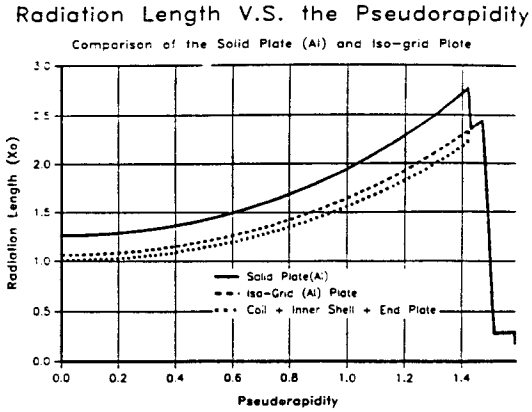




ISOGRID FOR
OUTER VACUUM SHELL



78



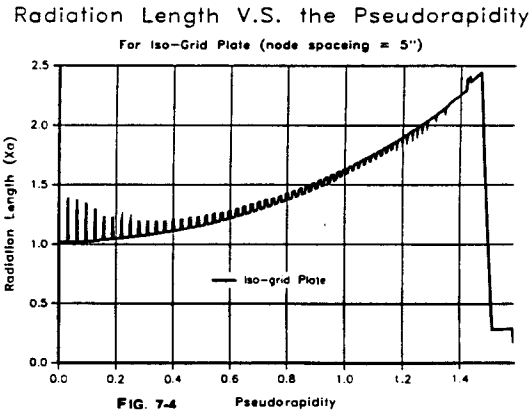
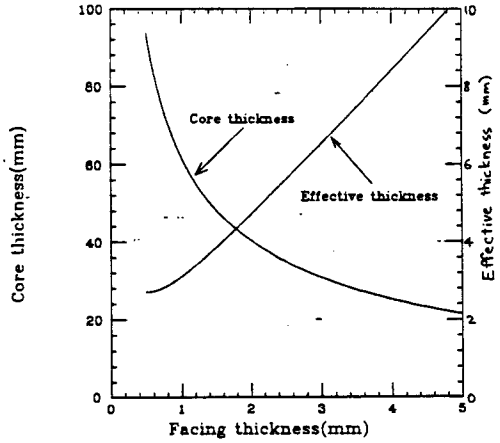


FIG. 7-4

79

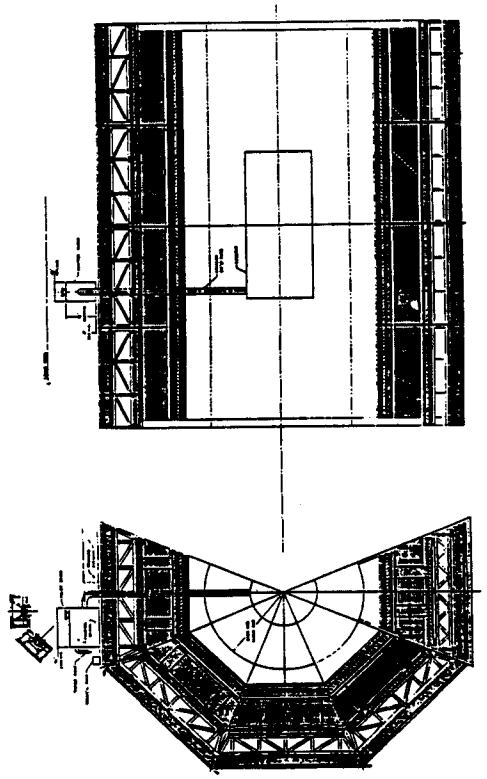


- CYLINDER SIZE : ϕ4.1m X 8m
- P COLLAPSE : 2 atm
- CORE : SIZE ○ 3/16 HEX, 1mil thick
  A5052
  DENSITY 0.05gr/cm³

CHARACTERISTICS OF AL HONEYCOMB OUTER VAC. WALL

FIG. 7-5

80



CRYO CHIMNEY THROUGH DETECTOR-
-ROUTE A

FIG. 7-4

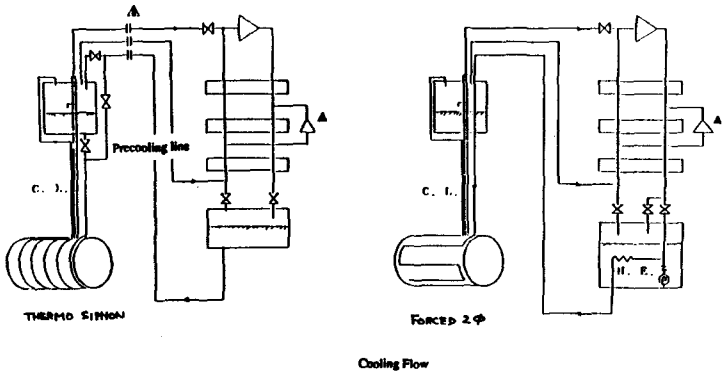


FIG. 8-1

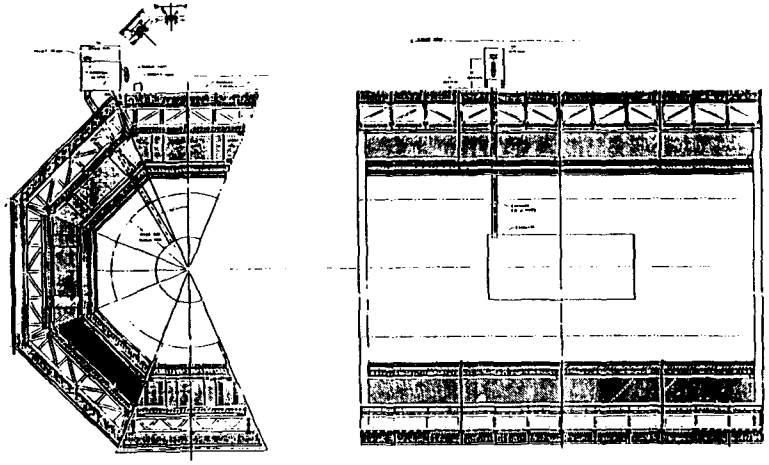


FIG. 7-7 CRYO CHIMNEY THROUGH DETECTOR--ROUTE B

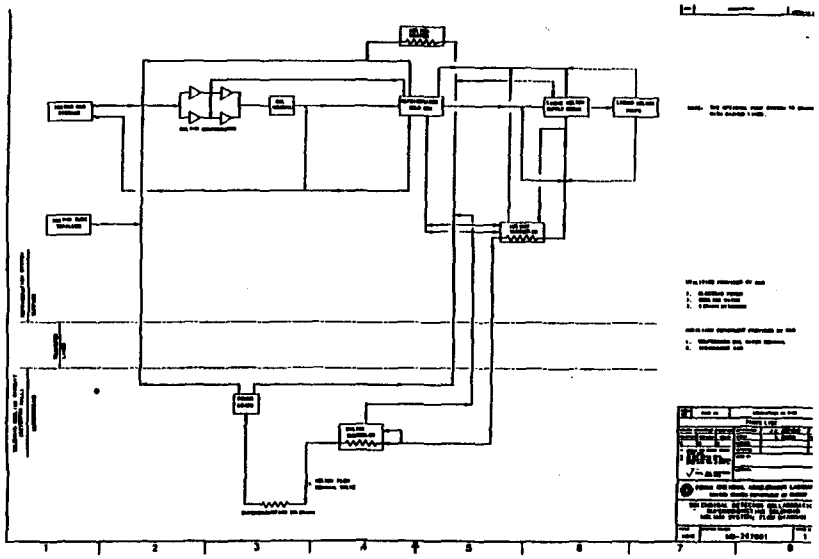


FIG. 8-2 POSSIBLE FLOW SCHEMATIC OF HELIUM SYSTEM

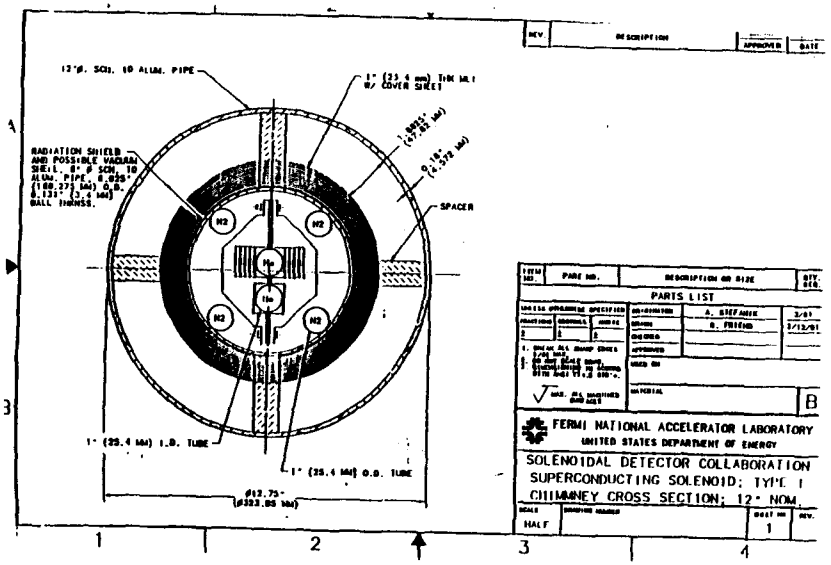


FIG. 7-8

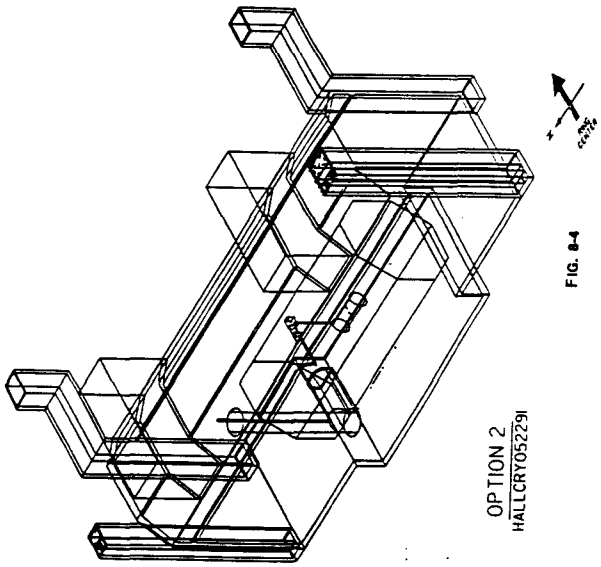


FIG. 8-4

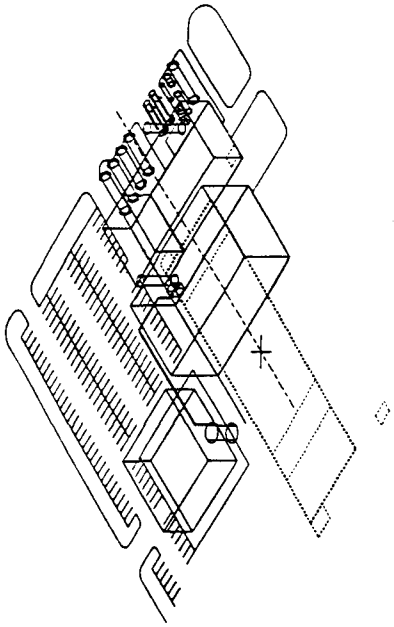


FIG. 8-5

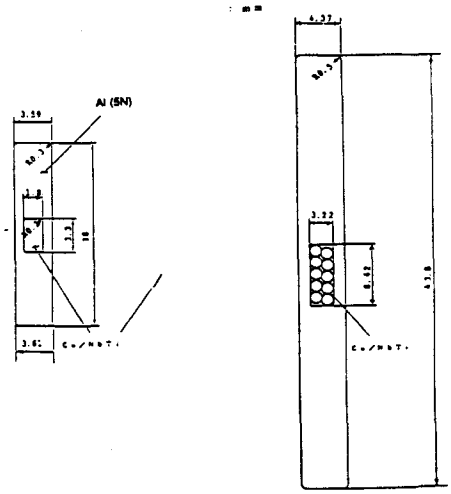
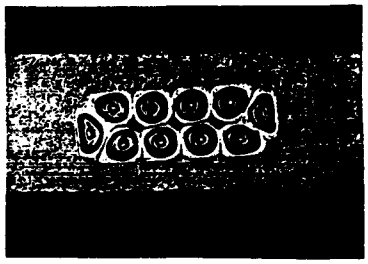


FIG. 9-1 CROSS SECTIONS OF (a) TOPAZ AND (b) SDC SUPERCONDUCTOR



CROSS SECTIONS OF THE SDC AL STABILIZED SUPERCONDUCTOR

FIG. 9-2

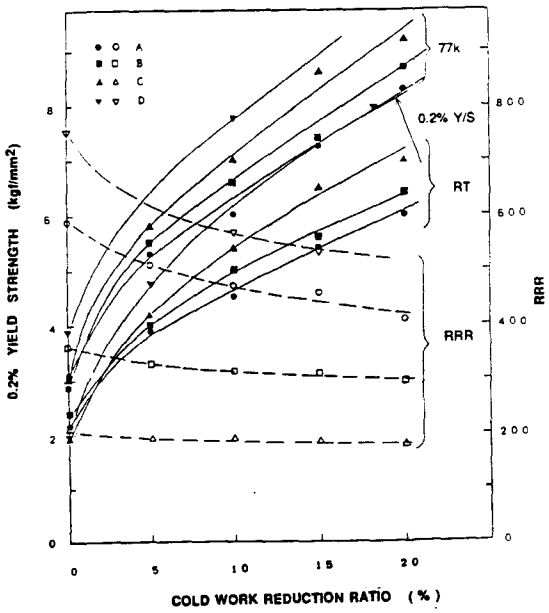
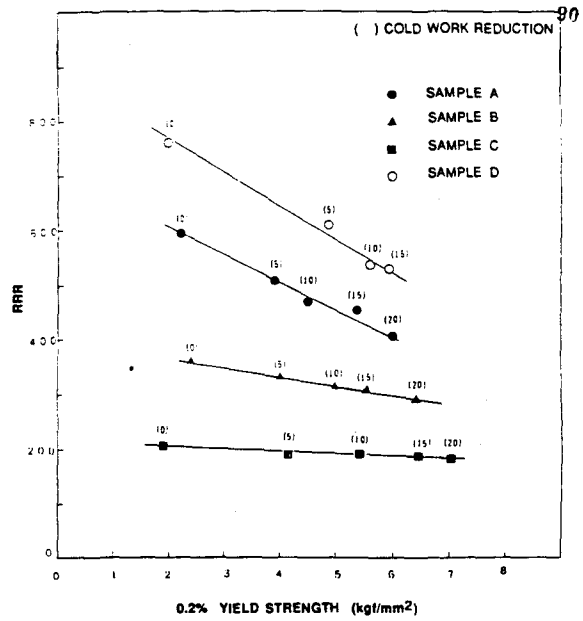
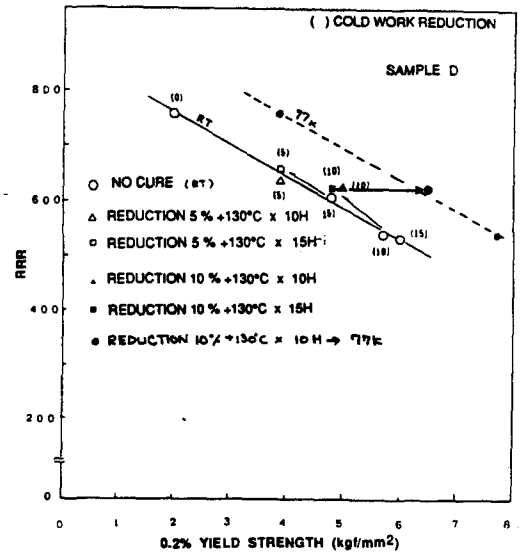


FIG. 9-3 YIELD STRENGTH & RRR v.s. REDUCTION



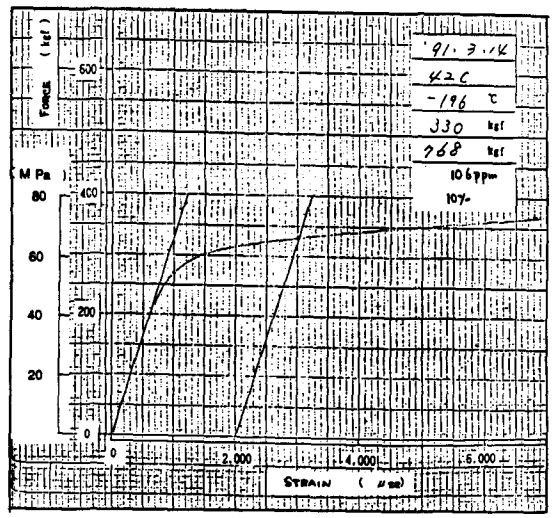
RRR v.s. 0.2% Y/S

FIG. 9-4



RRR v.s. Y/S in SAMPLE D

FIG. 9-5



A STRESS- STRAIN CURVE OF HIGH STRENGTH PURE Al (4N)

FIG. 9-6

93

KEK MODEL COIL WINDING IN PROGRESS AT TOSHIBA

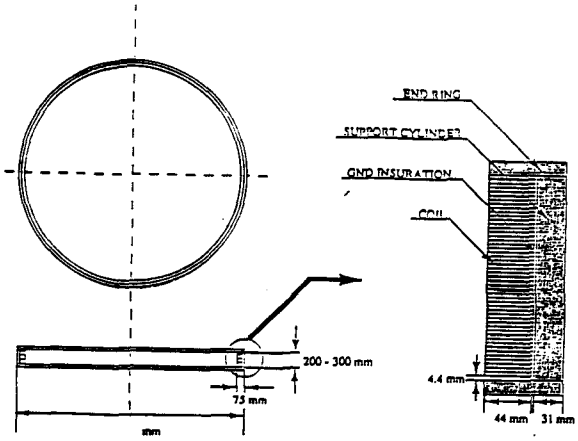
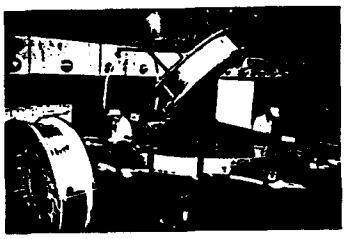


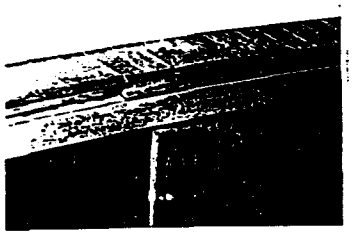
FIG. 9-7

94

1
SUPPORT CYLINDE



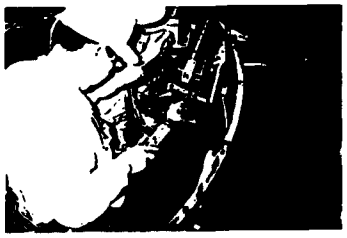
2
WINDING MACHINE



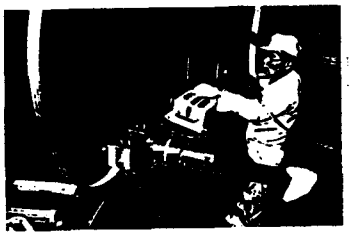
3
START FOR WINDING

FIG. 9-8 SDC COIL WINDING R&D (1)

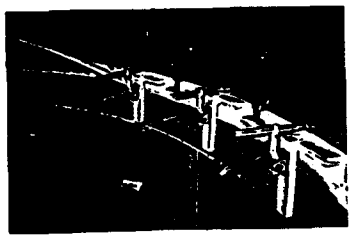
95



4
WRAPPING OF INSULATION TAPE (EGEPP)



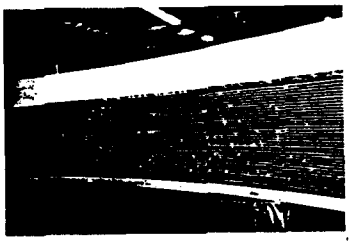
5
INNER COIL WINDING



6
TEMPORAL FIXTURE DURING WINDING

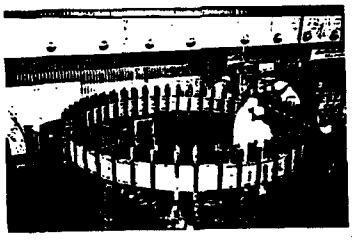
FIG. 9-8 (CONT.) SDC COIL WINDING R&D (2)

97



7
WELDED JOINT OF CONDUCTOR

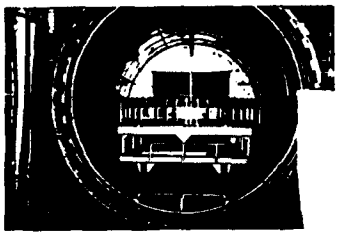
8
INSULATION AFTER JOINT WELDING



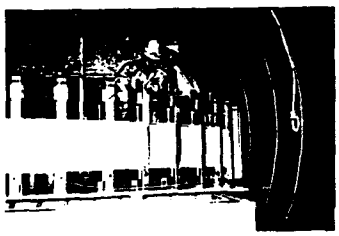
9
PRESSING FIXTURE DURING CURE

FIG. 9-8 (CONT.) SDC COIL WINDING R&D (3)

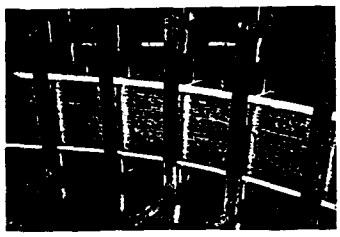
98



10
CURE IN
AUTO- CRAVE



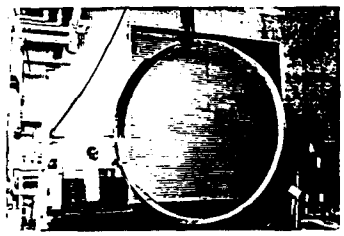
11
ADDITIONAL
PRESSING AT 60°C



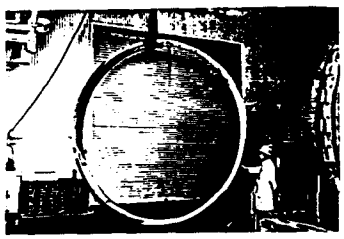
12
INSIDE VIEW

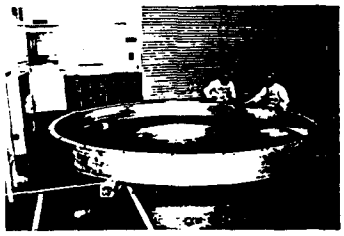
FIG. 9-8 (CONT.) SDC COIL WINDING R&D (4)

99



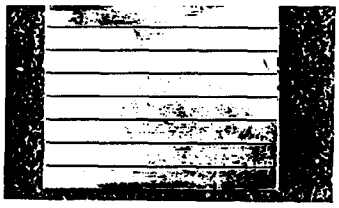
R&D COIL COMPLETED



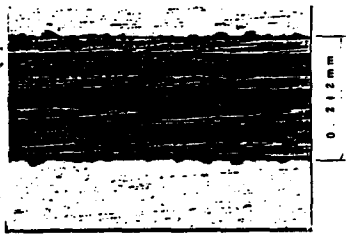


100

DUMMY CONDUCTOR WRAPPED WITH KGEPP INSULATOR



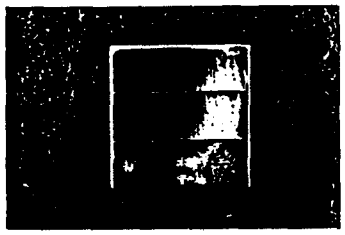
ENLARGED



4 LAYYER X (25 μm + 30 μm)=0.22mm
DUBLE-HALF WRAPPED

FIG. 9-9 CROSS SECTIONS OF TURN-TO-TURN INSULATION

101



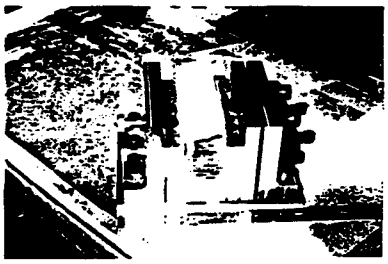
GND

TURN

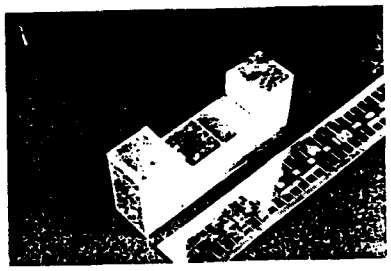
X 4 0

CROSS SECTIONS OF GND & TURN
INSULATIONS

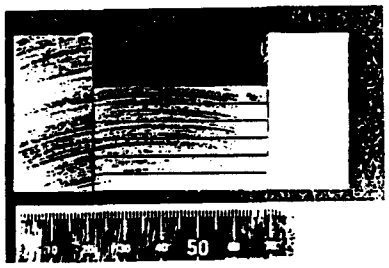
FIG. 9-10



FIXTURE FOR EPOXY CURING



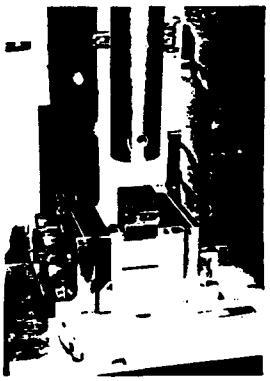
VIEW OF SHEAR TEST SAMPLE



CROSS SECTION

FIG. 9-11

A SAMPLE FOR SHEAR STRENGTH TEST ON TURN-TO-TURN EPOXY BONDING



FIXTURE FOR THE TEST

TEST IN LN_2

VIEWS OF SHEAR TEST OF TURN-TO-TURN INSULATION BONDING

FIG. 9-12

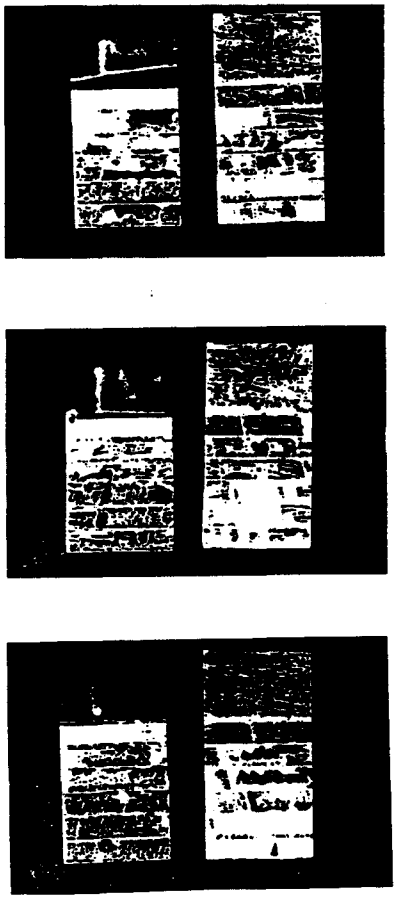
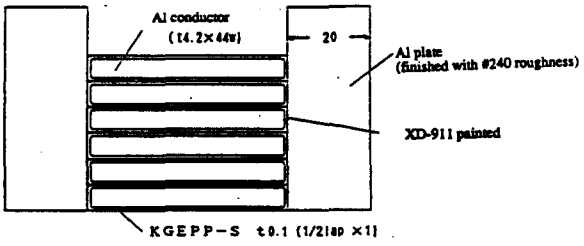


FIG. 9-13 VIEWS OF SAMPLES AFTER SHEAR TEST



* NO GND INSULATION

Result of Shear Strength Test

Temperature	No.	Shear Strength [Kg/mm2]	average	note
Room	1	2.16	2.36	one side
	2	2.58		one side
	3	2.35		one side
LN2	4	3.31	2.70	both side
	5	2.13		one side
	6	2.65		one side

FIG. 9-14 SHEAR STRENGTH TEST FOR EPOXY BONDING B/W CONDUCTOR AND OUTER SUPPORT SYLINDER

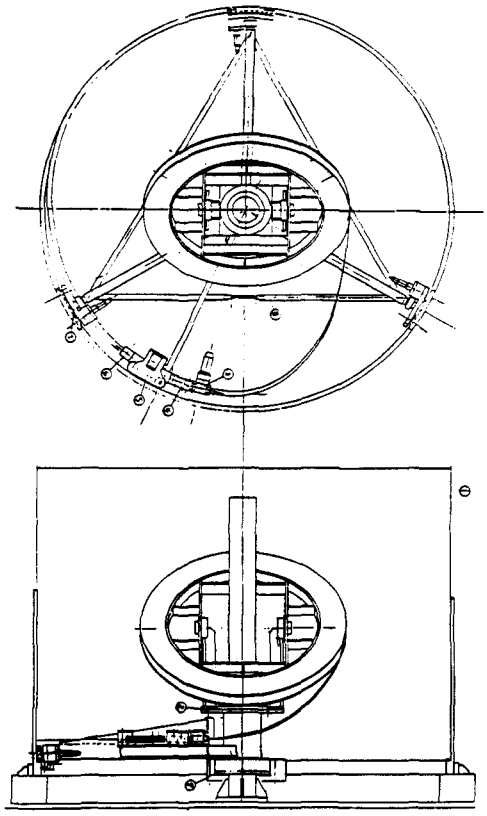


FIG.10-1 SCHEMATIC VIEW OF THE PROTOTYPE COIL WINDING MACHINE

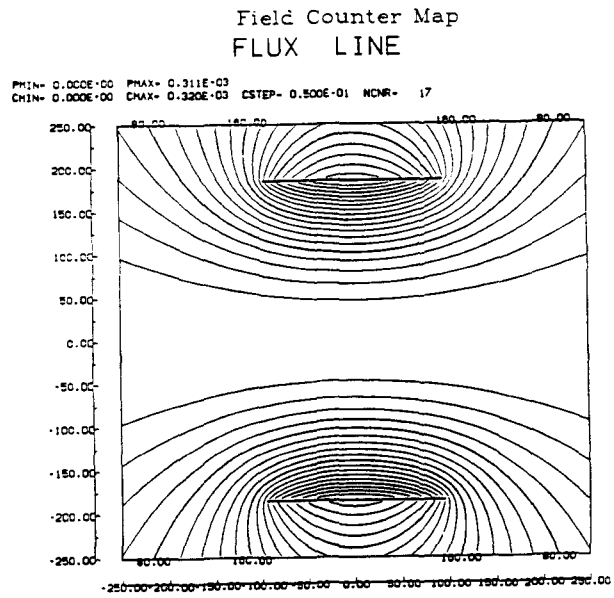


FIG.10-2(a) MAG FLUX IN THE PROTOTYPE

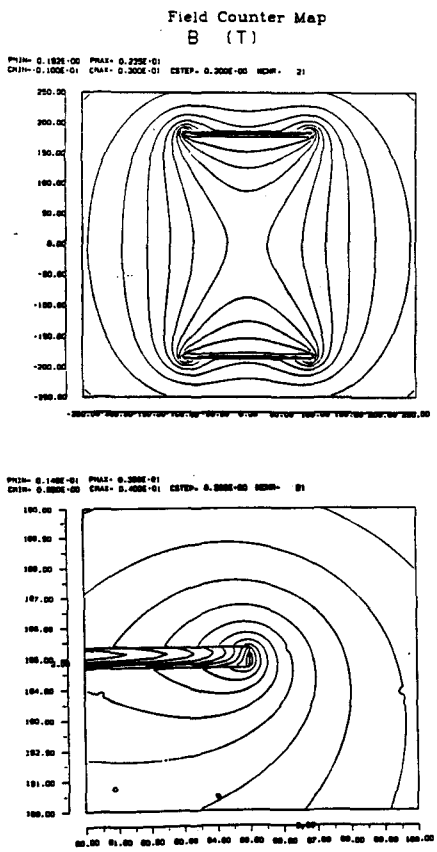


FIG.10-2(b) FIELD DISTRIBUTION IN THE PROTOTYPE

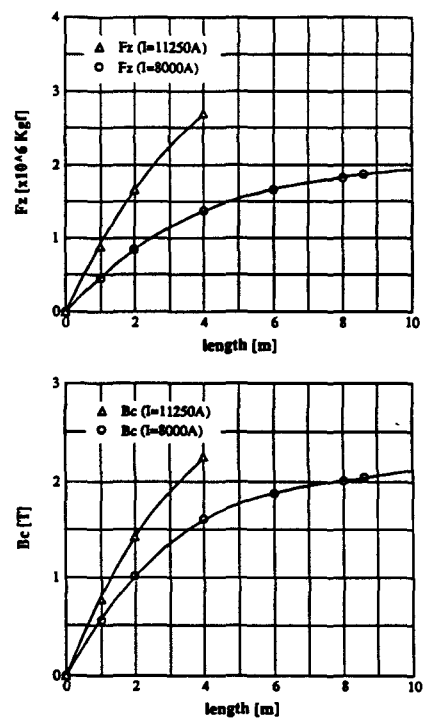
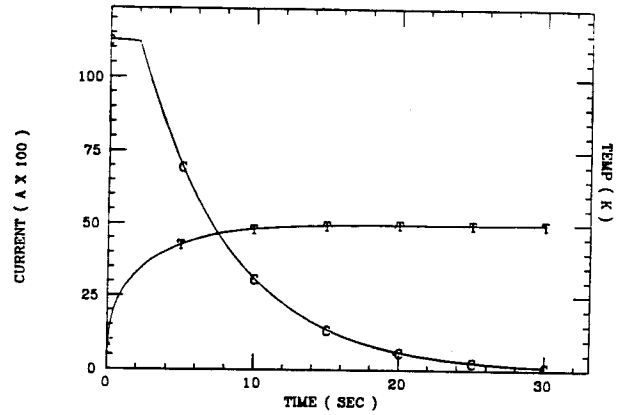


FIG.10-3 Fz & Bc v.s Coil Length

QUENCH




```
TOPI=  0
TMAX=     9.6000   BMAX=    95.0000   TEMPC=     7.0000
FIELD=   20.0000   AR=      1.9769   THET=      6.5000
T=       0.0500   BT=        2000   BTIN=      2.0000   VDETE=  0000.0000
AL= 0.1000E+01   EPS= 0.8500E-01
XLIN=     4.5000   YLIN=   190.0000   ZLIN=   1142.0000
XO=       2.2500   YO=       0.0000   ZO=     501.0000
AMPO= 11253.0000   RPO=      0.1000   GAS=      0.0000   RRN= 99999.0000   RRN=      0.6730

ALPHA =   1.00000      INIT. X VELOCITY=  354.6650

EPSILON=  0.00500      INIT. Y VELOCITY=  103.6819

    TOTAL INTERNAL ENERGY=  0.32E+07      TOTAL EXT. ENERGY  0.66E+00
FRACTION OF ENERGY DUMPED IN CRYOSTAT  0.074112
MAX TEMPERATURE RISE=      49.78
MAXIMUM INTERNAL VOLTAGE=      57.55
TIME CONSTANT=  0.249068
INTERNAL CURRENT DURARED BY =  0.6605E+09
```

FIG.10-4 QUENCH CHARACTERISTICS OF THE PROTOTYPE

IMPACT OF MATERIAL IN TRACKING VOLUME

TASK FORCE REPORT

JOHN MATTHEWS
AUG 5, 1991

- TRIGGERING.
- e ID EFFICIENCY ISSUES:
  - i) E/p CUT
  - ii) EM CALORIMETER ISOLATION
  - iii) TRACK – SHOWER MAX MATCH
- EM CALORIMETER CALIBRATION.
- e MOMENTUM RESOLUTION.
- TRACKING MATERIAL BUDGET: A MODEL.
- CONCLUSIONS/SUMMARY.

Task Force on Impact of Material in Tracking Volume

Task force members:
J. Matthews, D. Adams, J. Chapman, G. Hanson, C. Hearty, J. Haupman,
B. Hubbard, R. Hubbard, J. Hylen, R. Husack, Y. Unno, B. Wicklund

Discussion from G. Trilling:
There is increasing concern that our tracker seems to be a pre-EM-calorimeter, with some of the material quite far from the calorimeter where the affect is worst. We need to develop a clear understanding of the impact of this material on our ability to exploit our detector.

There are many dimensions to this problem. These involve not only tracking but also calorimetry, electron ID, ability to identify isolated electrons, calibration of the calorimeter etc.

Proposed charge:
Assess the impact of radiator in the tracking volume on the capabilities for:
1) Tracking including momentum resolution for electrons, effects of multiple scattering, pattern recognition problems due to increased occupancy.
2) Electron ID including degradation in E/p, and in shower localization in both calorimeter and pre-shower/shower-max system.
3) Triggering because of increased rates due to converted photons and degraded momentum measurement for electrons.
4) Determining isolation from calorimetric measurements on electrons.
5) Calibration of the EM calorimeter by Z-->e + e decay.
6) Other studies affected by the material in the tracking volume.

Quantify this impact as a function of the amount of radiator in the tracking volume and as a function of rapidity.

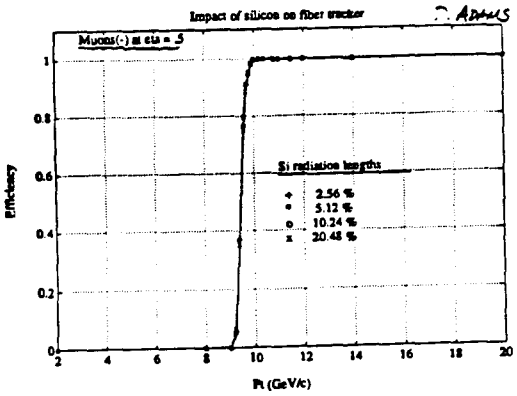
Due date of report: June 20.

PRELIMINARY REPORT JUNE 20, 1991

"FINAL" REPORT AUG 5, 1991

- TRIGGERING:
  - i) ESTIMATES FOR "ISOLATED e" TRIGGER RATES SUGGEST THIS IS NOT A SIGNIFICANT PROBLEM (WICKLUND, JUNE 4)
  - ii) SIMULATION OF A CHARGED PARTICLE TRIGGER USING 4 SCI. FI. (BARREL) SUPERLAYERS:
    - a) μ's: ESSENTIALLY NO DEGRADATION WITH TRACKING MATERIAL
    - b) e's: DECREASED EFFICIENCY WITH INCREASED TRACKING MATERIAL.
      Q. IS THIS CONSISTENT WITH SIMPLE BREMSSTRAHLUNG MODEL?

CONCLUSIONS:
1) MULTIPLE SCATTERING NOT AN ISSUE
2) e BREMSSTRAHLUNG WILL RESULT IN DECREASED CHARGED TRIGGER EFFICIENCY FOR $P_\perp \sim P_{\perp\,THRESHOLD}$.
(EFFIC > 90% @ $P_\perp > (P_{\perp\,THRESHOLD} \times 2)$
IF $\#X_0$ (INNER TRACKER) $\leq 10\%$)



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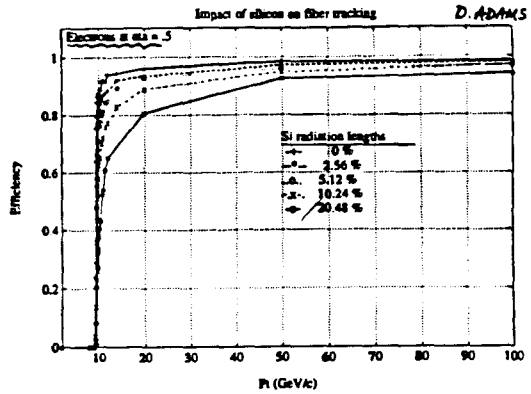

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Efficiency vs p_T for different amounts of material inside the outer tracker ($\eta = 0.5$).

- 3.6% X_0
- 6.5%
- 10.0%
- 14.4%
- 25.3%

Total material inside outer tracker

(Trigger uses layers at 70, 100, 130 & 160 cm)

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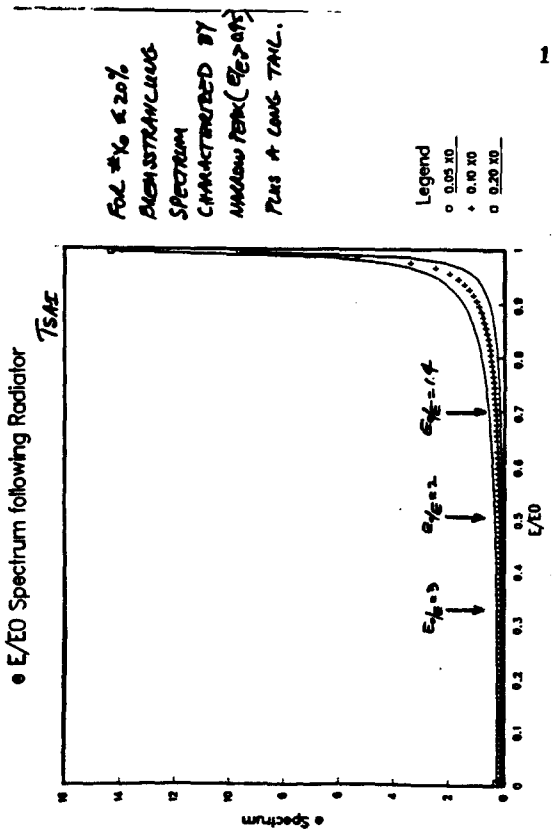

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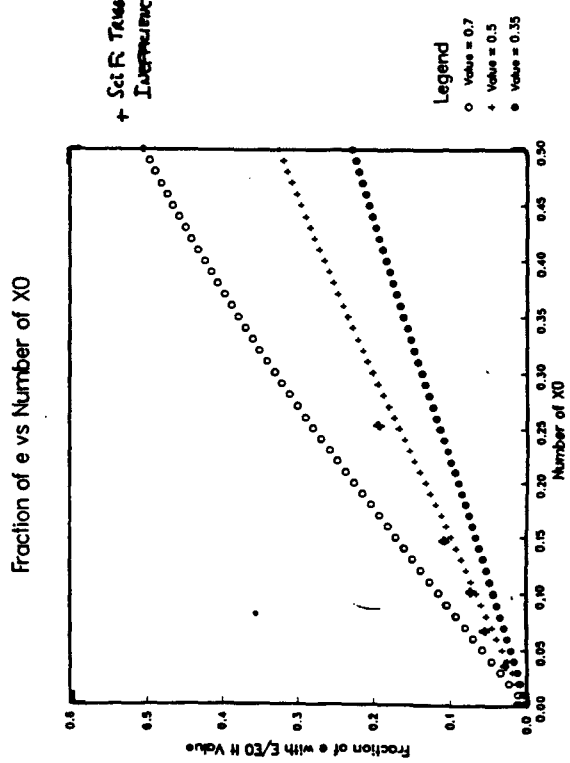


- e IDENTIFICATION ISSUES:

i) e ID TYPICALLY INVOLVES SEVERAL CUTS:

- HAD/EM SMALL
- ISOLATED EM CLUSTER
- TRANSVERSE SHOWER PROFILE
- TRACK – CALORIMETER (SHOWER MAX/PRESHOWER) MATCH
- $0.8 \le E/p \le 2$ ("NOMINAL", REALLY DONE WITH HADRON CUT) (AVOID $\pi^\pm \pi^0$ FAKING $e^\pm$)
- TRACK QUALITY

ALL INFLUENCED BY TRACKING MATERIAL

ii) GOALS/CONCERNS:

- MUST NOT COMPROMISE EM CALORIMETER ENERGY MEASUREMENT/CALIBRATION
- MUST HAVE HIGH e TRACK EFFICIENCY
  - SOME PHYSICS $H \to ZZ \to 4e^\pm$ HAS THE e(EFFICIENCY)^4
  - RELATES TO OVERALL SDC DESIGN/PHYSICS EMPHASIS (eg CALORIMETRY CRACKS < 3% CONTRIBUTION TO e INEFFICIENCY)

- E/p SELECTION $\equiv$ $0.8 \le E/p \le \begin{cases} 2 & \text{"LOOSE"} \\ 1.5 & \text{"TIGHT"} \end{cases}$

WHERE: $E \equiv$ (EM) CALORIMETER ENERGY

$p \equiv$ TRACKING VALUE OF MOMENTUM

IN GENERAL $E \approx E_{TRUE}$ (EVEN WITH BREMSSTRAHLUNG)

AND $p_{\text{ENTERING TRACKING}} \ge p_{\text{MEAS}}^{\dagger} \ge p_{\text{EXITING TRACKING}}$.

OBSERVATIONS: ① E/p EFFICIENCY DECREASES WITH INCREASING TRACKING MATERIAL

② INCREASED E/p EFFICIENCY IN TRACK FITS THAT (TEND TO) EXCLUDE POINTS AFTER A HARD BREM.

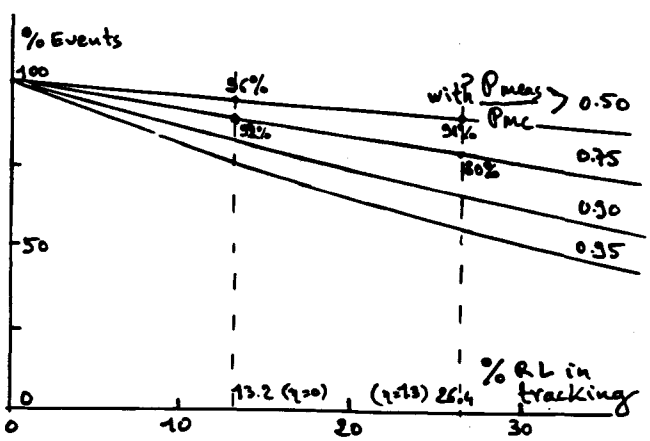
(SOME SIMILARITY TO PROBABILITY FOR ≥2 HARD BREM VS # OF X_0)

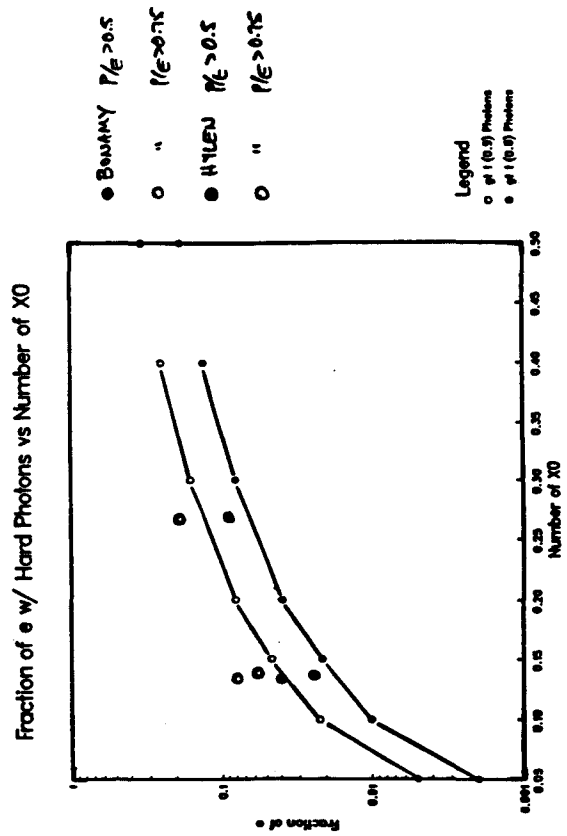
CONCLUSIONS: KEEP TRACKING MATERIAL ≤ 15-20% X_0 FOR E/p EFFICIENCIES > 90%.

† VARIOUS "MATERIAL TASK FORCE" STUDIES HAVE CHOSEN DIFFERENT ALGORITHMS TO OBTAIN p_{MEAS}.

P. BONAMY

'3 POINT MODEL'



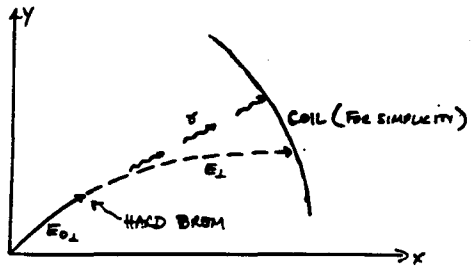


- DOES CALORIMETRY LIMIT THE AMOUNT OF TRACKING MATERIAL?

i) ISSUES INCLUDE:

* EM CLUSTER ISOLATION
- EM SHOWER TRANSVERSE PROFILE(S)
* TRACK – EM CALORIMETER (SHOWER MAX/PLESWALLER) MATCHING → ≈ E/p CUT EFFICIENCY
* E_{CALOR} VS E_0

ii) UNAVOIDABLE INTERNAL & BEAM PIPE BREMSSTRAHLUNG SETS A SCALE FOR TRACKING MATERIAL. FOR SIMPLICITY WE CONSIDER THE e-γ SEPARATION AT 1.8 m (~ COIL CENTER)



iii) THE e-γ SEPARATION DEPENDS ON THE e ENERGY FOLLOWING A HARD BREMSSTRAHLUNG (≡ E). THE FRACTION OF e'S DEPENDS ON:

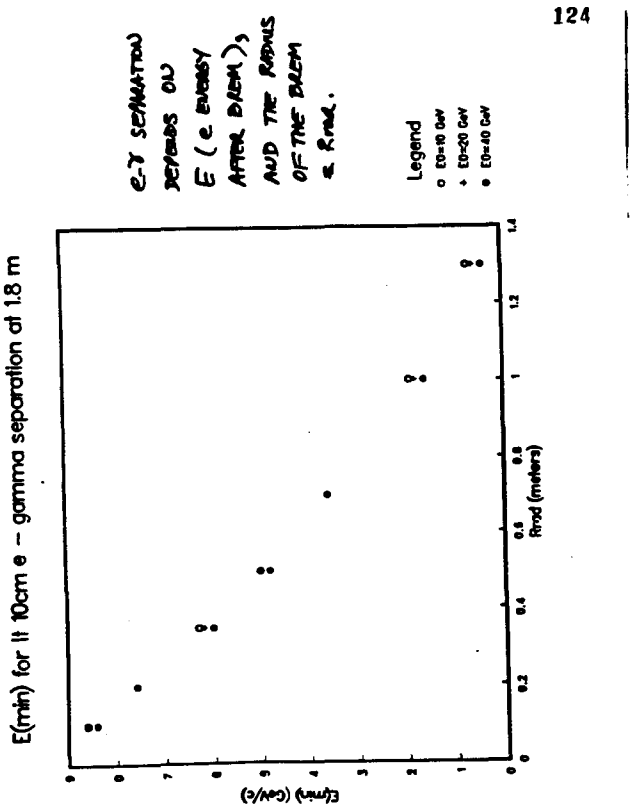
a) r_{rad} (RADIUS OF HARD BREM)

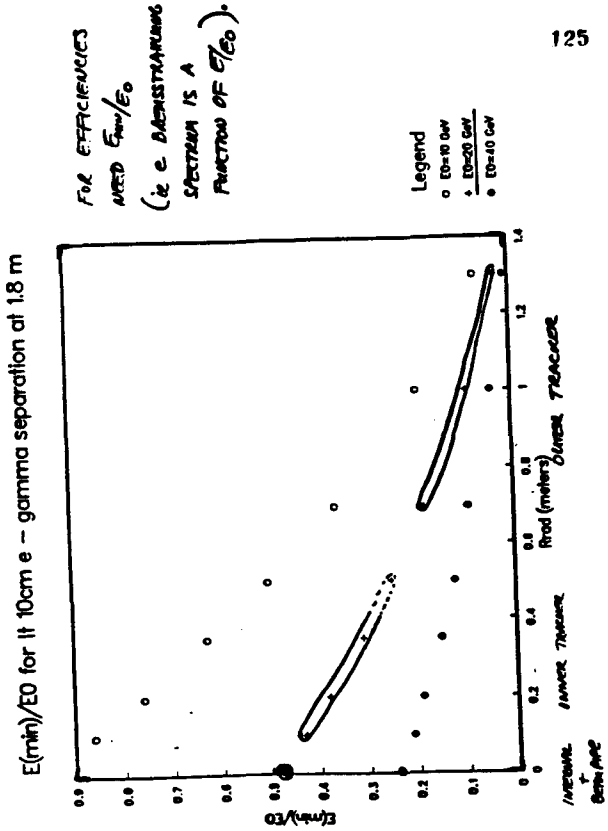
b) PROBABILITY THAT $(E/E_0)_\perp \geq (E_{min}/E_0)_\perp$

GIVEN BY e BREMSSTRAHLUNG SPECTRUM VS # X_0 IN RADIATOR

iv) USING THE # OF X_0 IN "INTERNAL RADIATOR" + BEAM PIPE (~3% X_0) TO SET THE SCALE, THEN THE MATERIAL IN THE INNER TRACKING SUBSYSTEM SHOULD NOT BE SIGNIFICANTLY GREATER THAN ~5% X_0.

(NOTE, FOR COMPARISON THE MATERIAL INSIDE CDF TRACKER ≈ $\underbrace{3\text{-}4\%\ X_0}_{\text{NO SVX}} \longrightarrow \underbrace{5\text{-}7\%}_{\text{WITH SVX}}$)





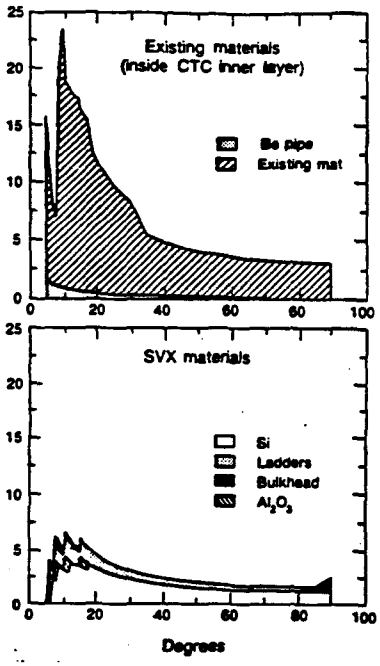


Figure 8a,b: Percent radiation lengths contained within the CTC inner layer without the SVX and the additional contribution of the SVX, versus the polar angle of a particle.

- TRACK - SHOWER MATCH

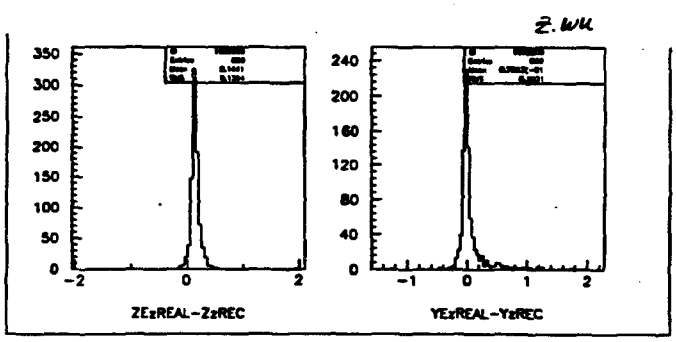
i) SHOWER MAX:
SCINTILLATOR STRIPS : 1.5cm × 12cm
Z STRIPS AT $5X_0$
$r\phi$ STRIPS AT $6X_0$

ii) e CANDIDATE TRACKS ARE EXTRAPOLATED TO THE LOCATION OF THE SHOWER MAX DETECTORS, AND THE TRACK POSITION COMPARED TO:
a) SHOWER CENTROID (ZHONG-KUN WU)
b) NEAREST "CLUSTER" (P. BONAMY)

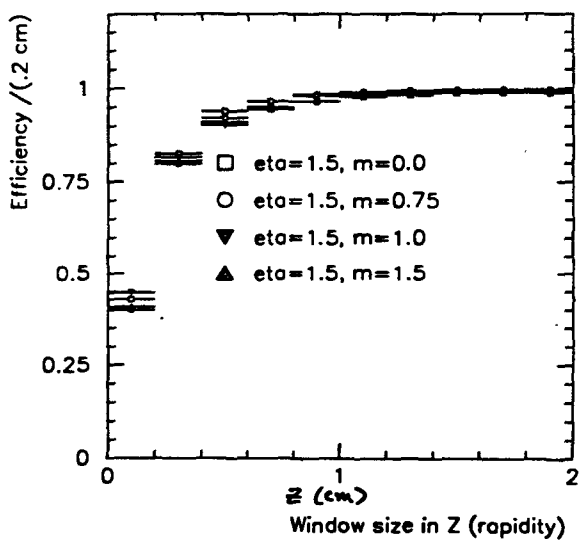
OBSERVATIONS : ① σ_z OF SHOWER MAX INSENSITIVE TO MATERIAL IN TRACKING VOLUME

$\sigma_{r\phi}$ INCREASES WITH INCREASING MATERIAL IN TRACKING VOLUME

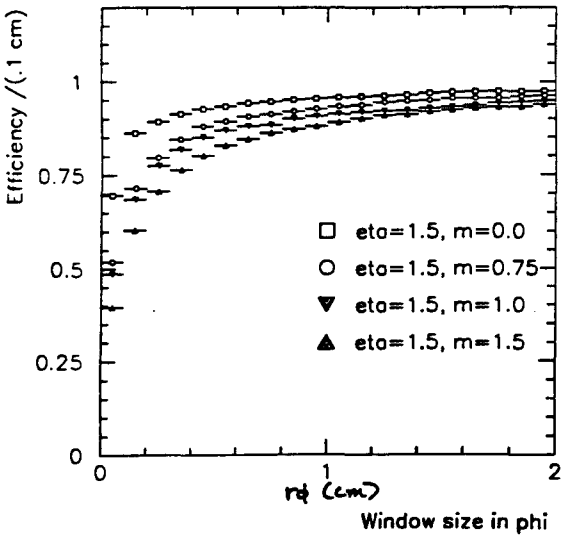
② WITH AN E/p CUT : $p/E \geq 0.75$,
THEN $(z_{TRACK} - z_{NEAREST\ CLUSTER})$
AND $(r\phi_{TRACK} - r\phi_{NEAREST\ CLUSTER})$
RMS VALUES HAVE ONLY A SMALL INCREASE WITH INCREASED MATERIAL



$\chi^2/DOF < 2$ $\chi^2/DOF < 2.$

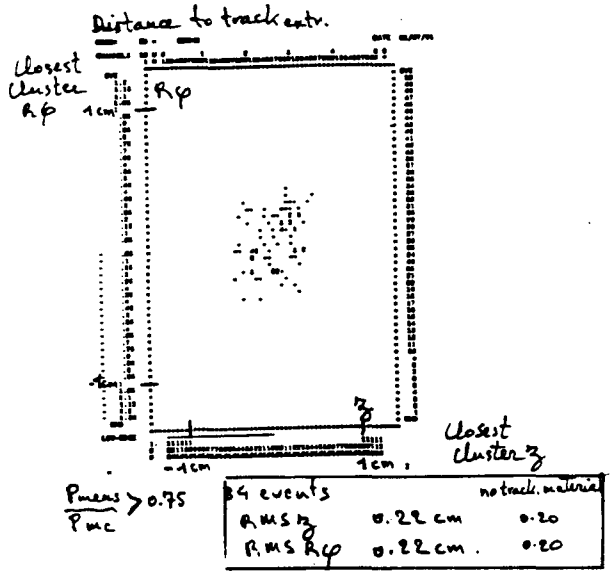


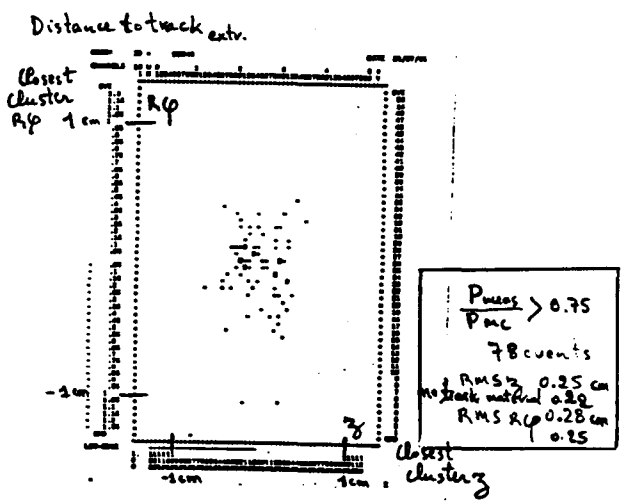
NON-BENDING PLANE



BENDING PLANE

P. BONAMY





- TRACK-SHOWER MATCH (cont):

OBSERVATIONS: ③ WITH THE E/p CUT: P/E ≥ 0.75 THEN REPRESENTATIVE TAGGING EFFICIENCIES INCLUDE:

	$t/X_0 = 13\%$	$t/X_0 = 26\%$ †
z	0.99	0.94
rφ	0.99	0.91

(SELECTIONS INCLUDE: >40 MeV CLUSTER ENERGY AND: W/, W/o (0.75cm, 1.0cm) SPACE MATCH IN (z, rφ))

† THE 26% X_0 RESULTS ARE FOR E_e = 20 GeV, THE 13% X_0 RESULTS ARE FOR E_e = 40 GeV.

CONCLUSIONS: ① THE SHOWER MAX SIMULATIONS ARE CONSISTENT WITH VERY HIGH e EFFICIENCIES FOR e's PASSING A TIGHT E/p CUT.

② SHOWER MAX EFFICIENCIES ARE REDUCED FOR LOW VALUES OF $P_\perp$ (~10 GeV/c)

P. BOHAMY PB 15

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SM Strips 12 × 1.5 × 0.25 cm³

B Case 0, η = 0, e⁻ = 40 Gev

Tracking 13.2% RL

e efficiency 100 events generated

P_{meas}/P_{mc}	—		> 0.50	> 0.75		Double Clusters	
	100 events		93 events	84 events			
Space cut / E cluster	—	< .75 cm	—	—	< .75 cm		
> 20 Mev	98	97	93	84	84	0	Z 5 RL
> 40 Mev	96	96	92	83	83	0	
> 60 Mev	92	92	88	80	80	0	
		< 1.0 cm			< 1.0 cm		
> 20 Mev	97	92	93	84	84	3	Rφ 6 RL
> 40 Mev	93	88	91	83	83	3	
> 60 Mev	91	86	89	81	81	2	

PB 21

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SM Strips 12 × 1.5 × 0.25 cm³

B Case 0, η = 1.3, e⁻ = 20 Gev

Tracking 13.2% × 2 RL

e. Efficiency 100 events generated

P_{meas}/P_{mc}	—		> 0.50	> 0.75		Double Clusters	
	100 events		84 events	78 events			
Space cut / E cluster	—	< 1.0 cm	—	—	< 1.0 cm		
> 20 Mev	82	80	81	77	77	0	Z 5 X₀
> 40 Mev	76	75	75	73	73	0	
> 60 Mev	54	54	54	54	54	0	
# events	100	100	84	78	78		
	—	< 1.5 cm		—	< 1.5 cm		
> 20 Mev	88	78	80	77	76	3	Rφ 6 X₀
> 40 Mev	77	70	71	71	70	0	
> 60 Mev	38	37	38	38	37	0	
# events	100	100	84	78	78		

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- EM CALORIMETER CALIBRATION

» EGS SIMULATION OF BASELINE SDC TRACKER (17% X₀ @ η=0), AND ½π* X₀ AND 2π* X₀ SYSTEMS FINDS SIGNIFICANT VARIATIONS IN M_Z (PEAK POSITION) AS MEASURED WITH CALORIMETER AND TRACKING SYSTEMS.

» ALTHOUGH THE 2π* X₀ CASE "LOOKS SIGNIFICANTLY WORSE" THAN THE OTHER SIMULATIONS, WHAT LIMIT THIS SETS ON THE TRACKING MATERIAL IS NOT CLEAR.

(NOTE, A STUDY OF EM CALORIMETER CALIBRATION IS IN PROGRESS)

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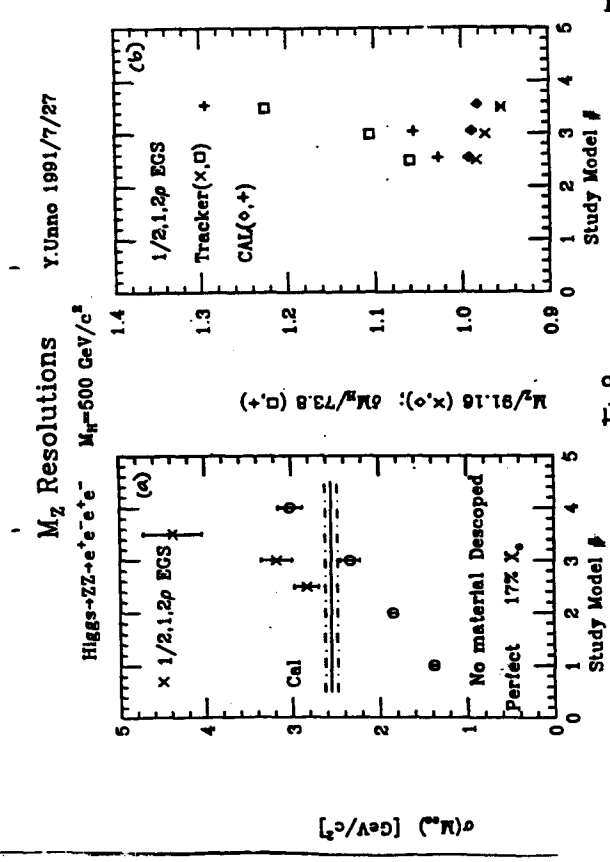


Fig. 9

- e MOMENTUM RESOLUTION:

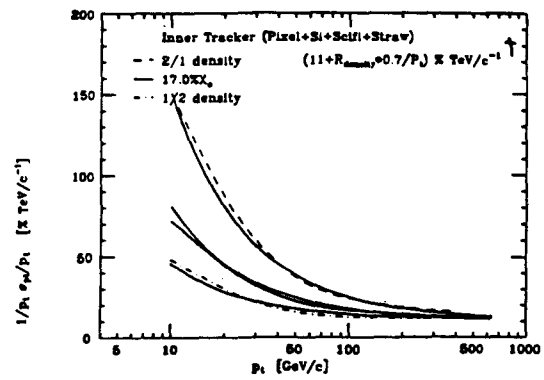
i) FITS TO THE PEAK OF THE e MOMENTUM DISTRIBUTION (IN EGS SIMULATIONS OF THE SDC TRACKER) ARE CONSISTENT WITH:

$$\left(\sigma_{p_\perp}/p_\perp^2\right)_e \doteq \left(\sigma_{p_\perp}/p_\perp^2\right)_\mu$$

THUS SOFT BREMSSTRAHLUNG(S) IS LESS IMPORTANT THAN MULTIPLE SCATTERING IN MODIFYING $\sigma_{p_\perp}/p_\perp^2$.

ii) NOTE; AS THE TRACKING MATERIAL IS REDUCED SO ALSO ARE THE NUMBER OF TRACKING MEASUREMENTS. THE NET RESULT IS APPROXIMATELY CONSTANT $\sigma_{p_\perp}/p_\perp^2$ FOR $p_\perp \lesssim 50$ GeV/c.

e⁺ Track Resolution and Efficiency (EGS4)

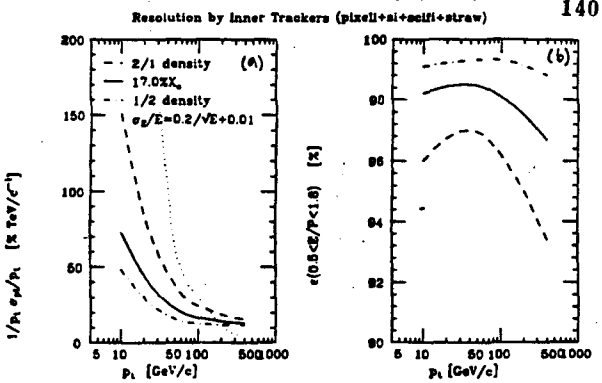


Y.Unno 1991/7/25 •RESRUN

† FOR DESCOPED TRACKER THE # OF TRACKING MEASUREMENTS DECREASE → 1ST TERM INCREASES, AND THE TRACKING MATERIAL DECREASES → 2ND TERM DECREASES. "INTERPLAY" OF 2 TERMS MAY RESULT IN ≈ SAME $\sigma_{p_\perp}/p_\perp^2$ FOR MODEST VALUES OF $p_\perp$ (ie ≪ 1TeV)

e⁺ Track Resolution and Efficiency (EGS4)

Resolution by Inner Trackers (pixel+si+scifi+straw)



e⁺ Track Resolution and Efficiency (EGS4)

Resolution by Inner Trackers (pixel+si+scifi+straw)

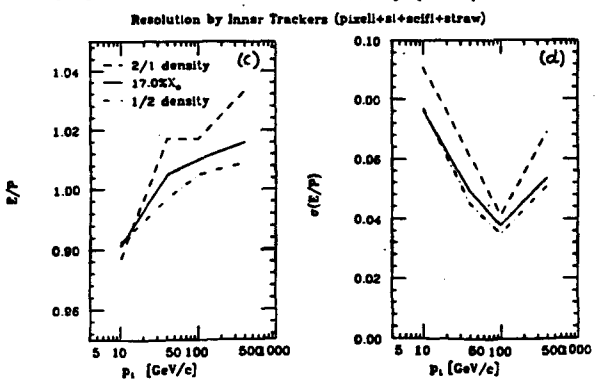
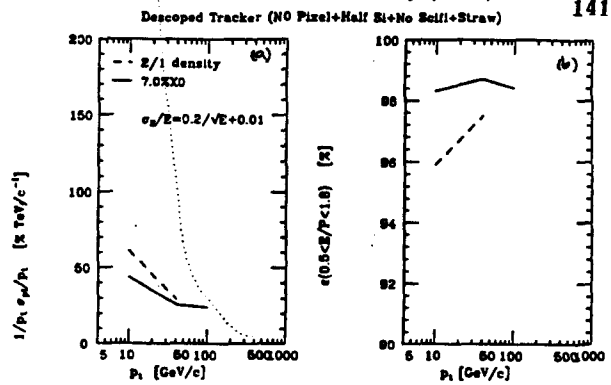


Fig. 5

Y.Unno 1991/7/23 •ETKRES

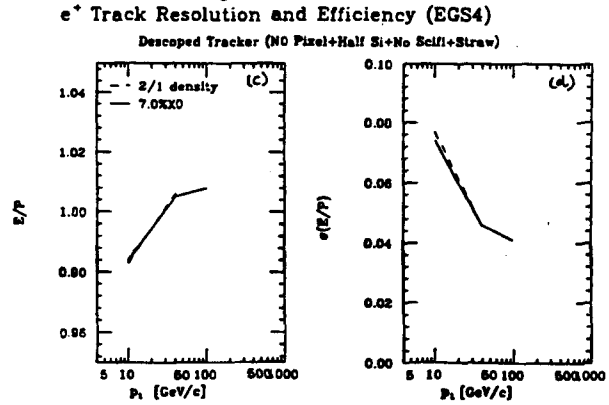
e⁺ Track Resolution and Efficiency (EGS4)

Descoped Tracker (NO Pixel+Half Si+No Scifi+Straw)



e⁺ Track Resolution and Efficiency (EGS4)

Descoped Tracker (NO Pixel+Half Si+No Scifi+Straw)



Y.Unno 1991/7/23 •ETKRES

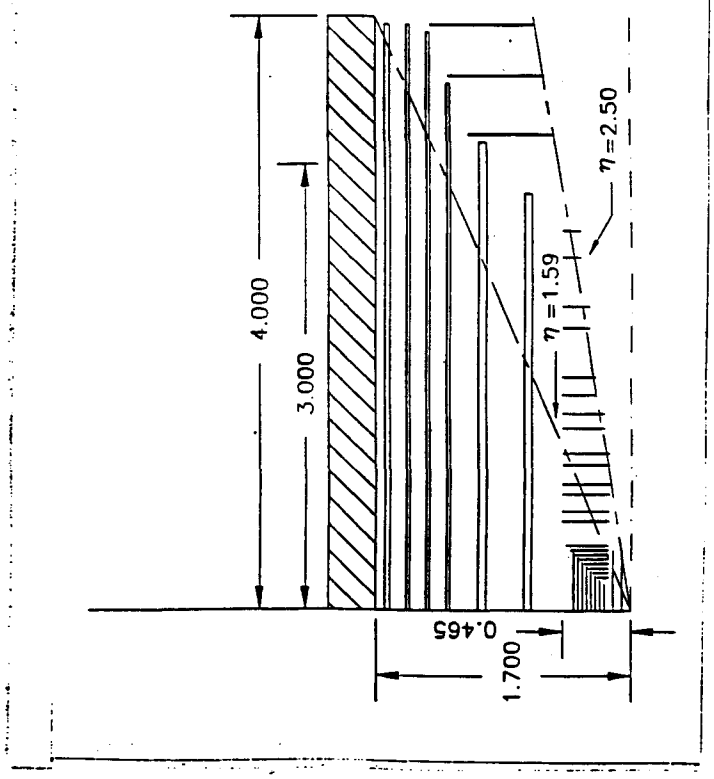
- SDC TRACKING MATERIAL:

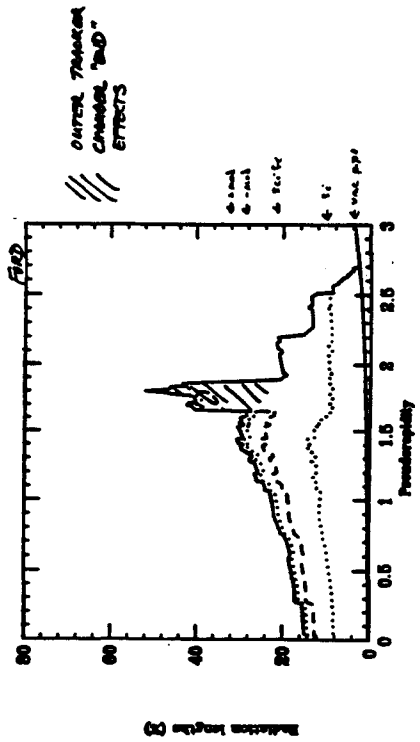
a) "BASELINE" DESIGN:

- NOT OPTIMIZED TO MINIMIZE # OF X_0 IN TRACKING SYSTEM
- SHOWED THAT THE # OF X_0 CAN BE LARGE.
- NEEDS "DESCOPING"
- CAN THE "SPIKE" AT $|\eta| \sim 1.75$ BE REDUCED/ELIMINATED?

b) Q. WHAT IS A POSSIBLE "DESCOPED" TRACKER MATERIAL BUDGET VS η?

- ONLY AXIAL OUTER TRACKER
  - REMOVES SPIKE AT $|\eta| = 1.75$
  - EMPHASIZES $1/\sin\theta$ PROBLEM FOR LONG TRACKING SYSTEMS
- SIGNIFICANTLY LESS MATERIAL WOULD PROBABLY RESULT IN DIFFERENT FUNCTIONALITY
- $\langle \# X_0 \rangle \sim 18\%$ (INCLUDING INTERNAL BREMSSTRAHLUNG)

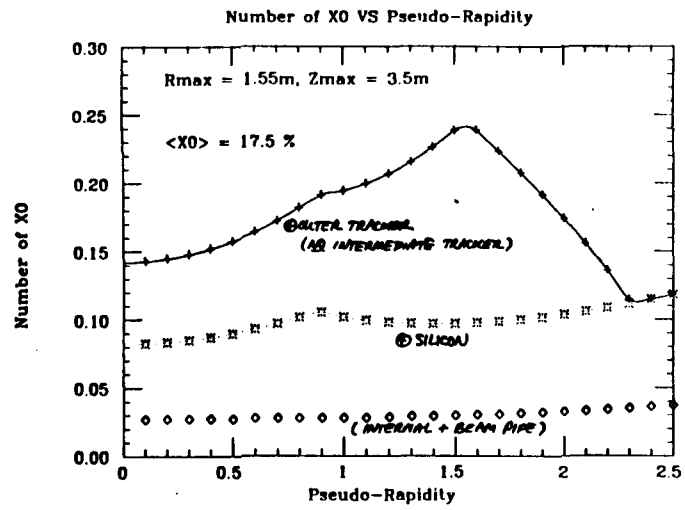


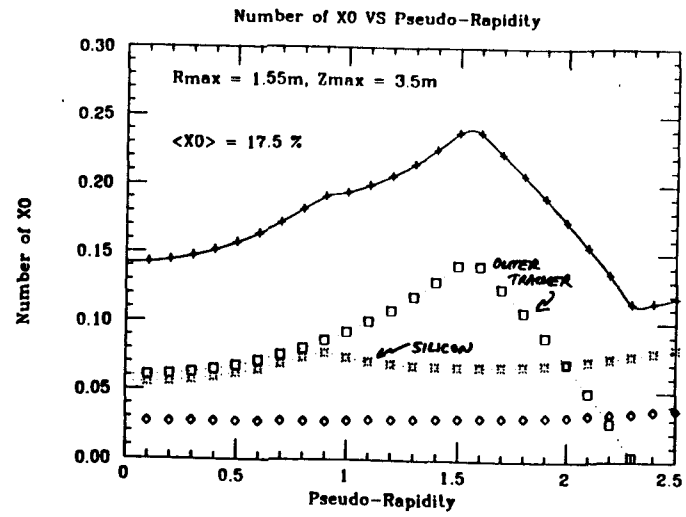


Task Force on Impact of Material in Tracking Volume

As the tracking system will descope from the "engineering baseline design", an estimate of the material in a possible "descoped" tracker is:

1) "internal bremsstrahlung"	r = 0 cm	all eta	$\#X_0$ = 2.5%
2) "beam pipe"	r = 5 cm	all eta	$\#X_0$ = 0.2%/sin(theta)
3) "silicon"	r = 10 - 45 cm	theta > pi/4 theta < pi/4	$\#X_0$ = 5.0%/sin(theta) $\#X_0$ = 5.0%/cos(theta)
"outer shell"	r = 60 cm	all eta	$\#X_0$ = 0.5%/sin(theta)
4) "outer tracker"	r = 70 - 155 cm	eta < 1.5 eta > 1.5	$\#X_0$ = 6.0%/sin(theta) $\#X_0$ = ?? (depends on existence of intermediate tracking)
5) "coil center"	r = 180 cm	(use B = 2 T to this radius)	
6) "EM Calor front"	r = 205 cm	(for e/gamma match at calorimeter)	





• SUMMARY/CONCLUSIONS:

① TRIGGERING:

a. BACKSTRAHLING REDUCES IN DECREASED TRACKING TRIGGER EFFICIENCIES FOR $P_T \sim P_{T\,THRESHOLD}$

FOR EFFIC > 90% AT $P_T > 2 \times P_{T\,THRESHOLD}$, THEN TRACKING MATERIAL BEFORE TRIGGER ≤ 10% X_0.

② † "E/p" EFFICIENCY:

FOR "E/p" EFFICIENCIES > 90% KEEP THE MATERIAL IN THE TRACKING SYSTEM ≤ 15-20% X_0.

③ † EM ISOLATION:

MATCHING THE CONTRIBUTION FROM INTERNAL + BEAM PIPE BACKSTRAHLING TO THAT IN THE INNER TRACKER SUGGESTS ~5% X_0 IN THE INNER TRACKER.

④ † IN GENERAL EFFICIENCIES FOR EM ISOLATION, TRACK-SHOWER MATCH, SHOWER MAX EFFICIENCIES ARE REDUCED AT $P_T \sim 10$ GeV AND IMPROVE WITH INCREASING P_T. SAME OF THESE EFFECTS ARE MADE WORSE BY MATERIAL IN THE TRACKING VOLUME.

† SAME CUTS ARE HIGHLY CORRELATED, ∴ THE E/p EFFICIENCY CAN PROVIDE A GOOD ESTIMATE FOR THE EM TAG EFFICIENCY.

Solenoidal Detector Collaboration Meeting
LBL
August 5, 1991

M. G. D. Gilchriese

- Milestones
- Brief update on SDC experimental facilities status
- 1992 R&D and Engineering Plan status and budget
- Technical Proposal production
- Descoping
  - Drawings and parameters
  - Requests
  - Budget target
- Meeting logistics

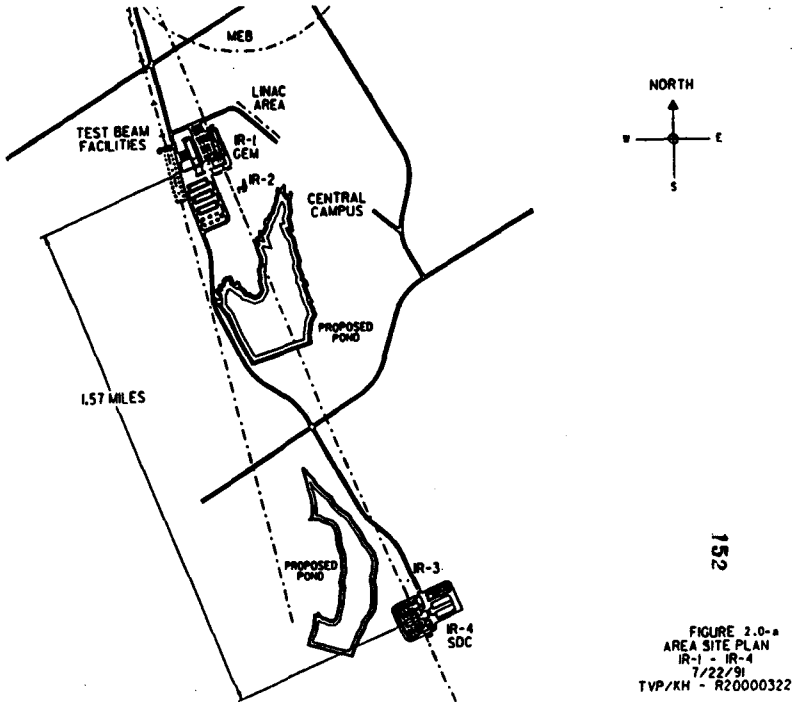


FIGURE 2.0-a
AREA SITE PLAN
IR-1 - IR-4
7/22/91
TVP/KH - R20000322

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SELECTED SDC MILESTONES FY91-92†

FY91 MILESTONES		FY92 MILESTONES	
Revised "baseline" design	Mar. 15	Final FY92 R&D plans	Oct. 1
IR location/hall construction type	Apr. 15	First draft of responsibility matrix	Oct. 1
Establish "baseline" for costing	May 15	SSCL/PAC meeting	Oct. 3?
Draft FY92 R&D plan	Jul. 1	Fix "baseline" for Tech. Proposal	Oct. 15
Draft R&D Management Plan	Jul. 1	Begin Title I for underground hall	Oct. 15?
Revised cost estimate	Jul. 1	Draft Management Plan	Nov. 1?
Draft construction schedule	Jul. 1	First draft of Tech. Proposal	Jan. 15
SSCL/PAC status review	Jul. 8	First draft of Cost&Schedule Book	Jan. 15
Forward cal. R&D directions	Aug. 10	Second draft of responsibility matrix	Jan. 15
Scope decision(new cost "baseline")	Aug. 10	Internal cost review	Jan. 20
Complete assignments for Tech. Proposal	Aug. 10	SSCL/PAC status review	Feb. 1?
Establish tracking "baseline"	Sep. 28	Revised Management Plan	Mar. 15?
Complete pre-Title I hall report	Sep. 30	Due date for Tech. Proposal	Apr. 1
Central calorimeter selection	Sep. 30	Due date for Cost&Schedule book	Apr. 1
		Final responsibility matrix	Apr. 1
		Begin Title II for underground hall	Apr. 15?
		SSCL/PAC review of Tech. Proposal	May 15?
		Final construction Management Plan	Jun. 1
		DOE review	Jul. 1?
		Draft agreements	Aug. 15?
		Construction start	Oct. 1

† Revised Aug. 1 1991

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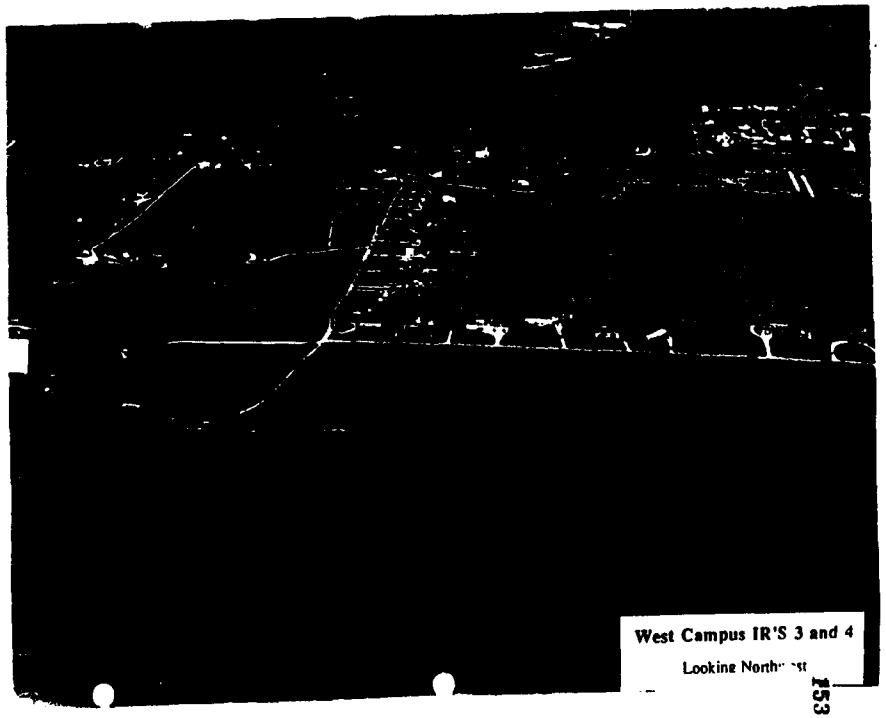

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Update on Experimental Facilities for SDC

- Location - IR4(see picture)
- Requirements to initiate Title I design of underground hall to be completed by September 1991 - see pictures
- Title I expected to start in October 1991
- Title II to start April 1992
- Hall complete January 1996 - see schedule
- Presentations tomorrow starting at 9 AM in Bldg. 2, Rm. 100 at Integration meeting

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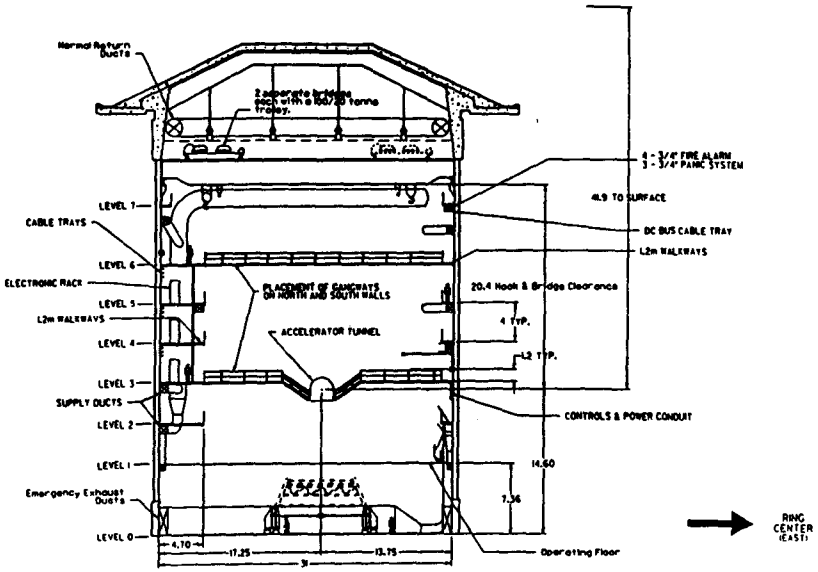
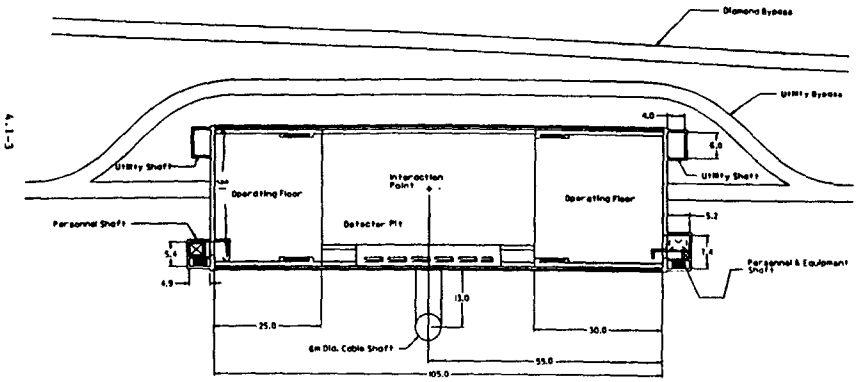


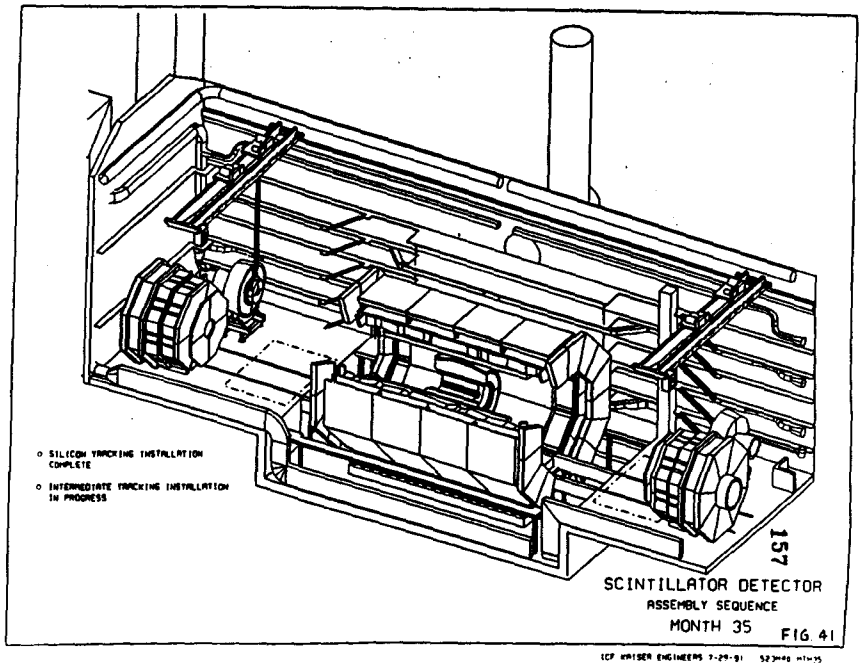
HALL GANGWAYS

FIGURE 4.1.2.4-a



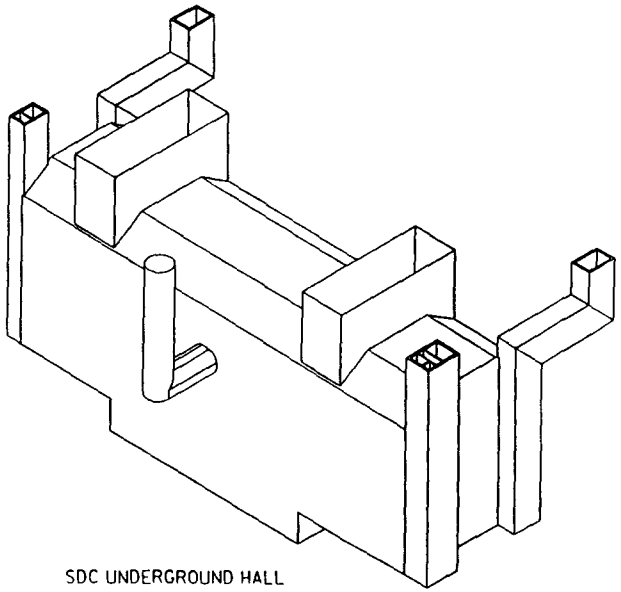
SDC UNDERGROUND PLAN VIEW

FIGURE 4.1.1-b



SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 35 FIG. 41

ICF KAISER ENGINEERS 7-29-91 523H46 H1H35



SDC UNDERGROUND HALL

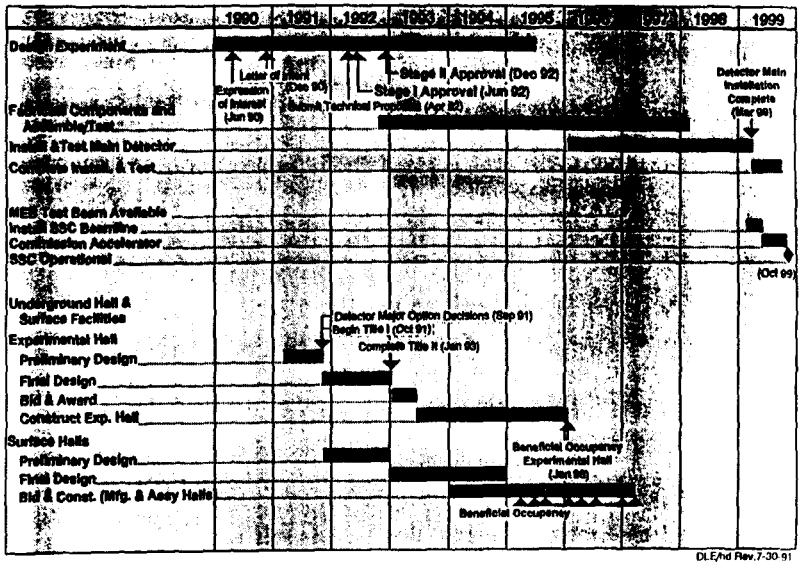
FIGURE 4.1.1-a

Technical Proposal Production

- Due date is April 1, 1992
- Start now!
- Propose to disburse technical production of sections. Overall coordination to be provided by Don Groom, Editor and his crew at LBL(B. Armstrong, P. Bautz and L. Robinson)
- Instructions available at desk
- Section editors to be identified by Technical Board
- Don, Pat and I will be in contact to organize

SSC INITIAL EXPERIMENTAL PROGRAM

PRELIMINARY SDC DETECTOR SCHEDULE



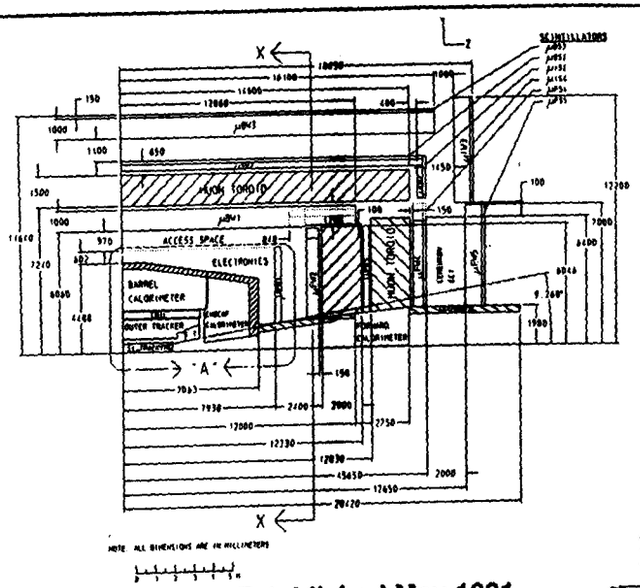
Technical Proposal Production

The SDC Technical Proposal - Coordinating Institutions(Tentative)

1. Introduction - LBL
2. Overview of the Detector - LBL
3. Physics Performance - LBL
4. Central Tracking System - LBL, ORNL
5. Superconducting Solenoid - KEK, FNAL
6. Calorimeter System - FNAL
7. Muon System - SSCL
8. Electronics, Data Acquisition,Trigger and Control Systems - LBL
9. On-line Computing - SSCL
10. Off-line Computing - ANL
11. Safety - SSCL
12. Experimental Facilities - SSCL
13. Installation and Commissioning - SSCL
14. Test Beam Program - SSCL
15. Cost and Schedule Summary - LBL, SSCL

1992 R&D and Engineering Plan and Budget

- Draft produced for July 8 PAC meeting
- Request was about US $26M(+0.9 for computing)
- Recent budget guidance from SSCL is about 1/2 the request
- Subsystem budget targets given to Technical Board and to be discussed at this meeting
- Detailed budget to be formulated over next few months via individual subsystem meetings as well as at collaboration meetings
- Revise draft in accordance with detailed budget by October. Budget agreements as appendices.



Costing Baseline - Established May 1991

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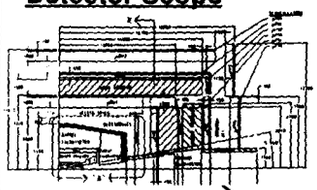
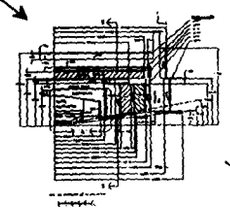
Detector Scope



Cost Baseline(May) - $800M



Descope I(Aug) - $600M

Tech. Proposal Baseline(Oct) - <$500M? ?????

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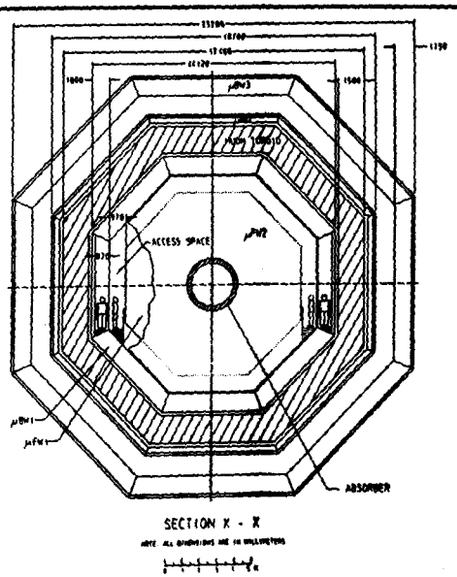

Costing Baseline - Established May 1991

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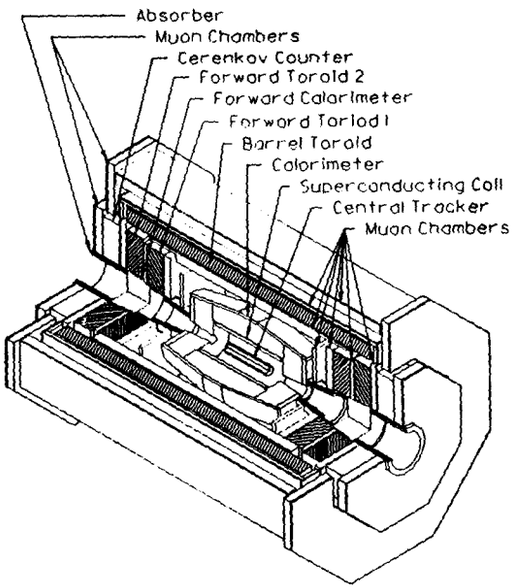

The SDC Detector

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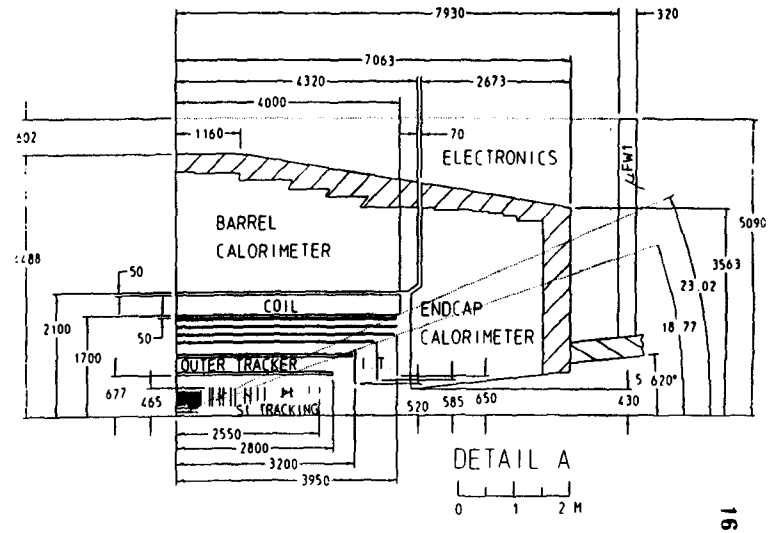
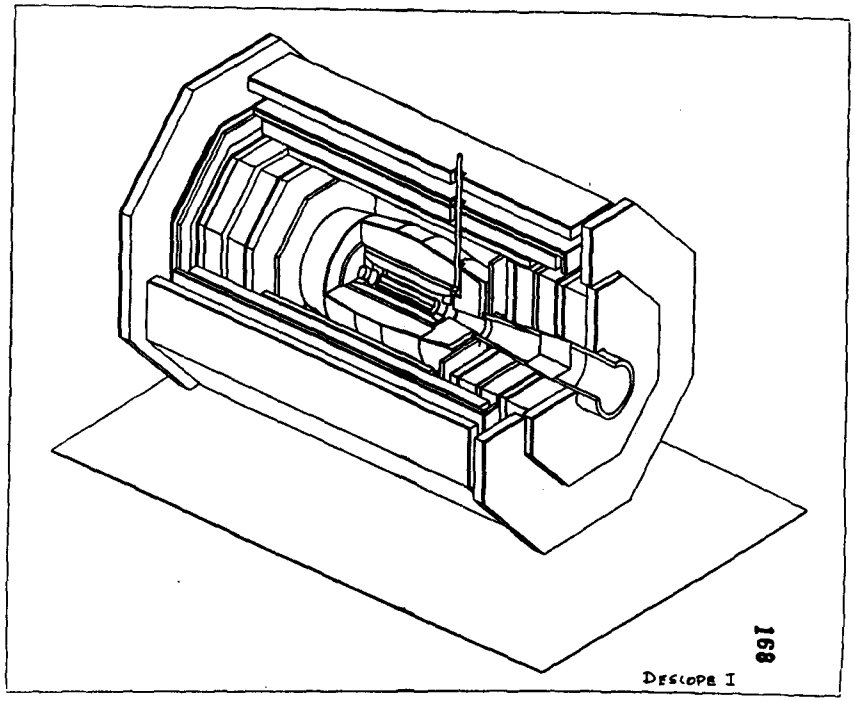


Costing Baseline - Established May 1991

Descoping

- Drawings and parameters for "Descope I" have been produced based upon information from June collaboration meeting. Limited number of copies of these are available at the desk.
- Total cost is ≈ $600M - see tables
- Nothing is finalized yet!
- Need much more input in detail from subsystem groups

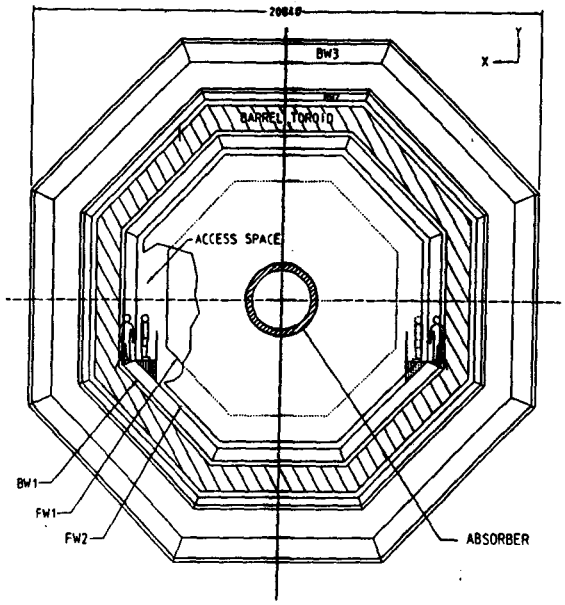


SDC Parameters List Comparison

Revised 10/29/91

	Preliminary Descope I	Lol
Tracking System		
Volume: Radius x half-length(m)	1.7 x 4.0	1.7 x 4.0
Silicon Tracker		
Number of pixel channels	777	
Number of strip channels	~ 5 x 10⁶	4 x 10⁷
Number layers - Barrel	~ 12	65 x 10⁶
Number layers - Forward	~ 12	16
Total rad lng of silicon(%)	16.3	~ 20
Barrel Tracker		~ 28
Number of straw planes	5 or 7	8
Number of straw channels	~ 1.4(7) x 10⁵	~ 1.9 x 10⁵
Impermeable Tracker		
Technology not decided, eg. fiber channels	~ 2 x 10⁵	—
Solenoid		
Central field(Tesla)	2.0	2.0
Stored energy(MJ)	122	122
Calorimeter System		
Central Calorimeter		
Technology	Solid Glass/Liquid	Solid Glass/Liquid
Weight(metric tons)	~ 6700	~ 3500
Number of cells, square-tower	3 (1 EM and 2 HAD)	4
Number of depth segments-endcap	4 (1 EM and 3 HAD)	4
EM resolution(dE x dη)	0.05 x 0.05	0.05 x 0.05
HACI resolution(dE x dη)	0.05 x 0.05	0.05 x 0.05
HACI resolution(dE x dη)	0.1 x 0.1	0.05 x 0.05
Number of barrel channels	~ 27,000	~ 40,000
Number of barrel EM+ det. channels	~ 41,000	~ 25,000
Forward Calorimetry		
Technology	To be determined	TBD
Weight(metric tons)(both ends)	~ 400	~ 750
Depth segmentation	2	2
Number of channels(both ends)	~ 2500	~ 7000
Muon System		
Central		
Barrel toroid thickness(m)	1.0	1.5
Barrel toroid weight(metric tons)	~ 11,600	15,400
Number of chamber layers	18	36
Number of chamber channels[1]	~ 70,000	~ 46,000
Number of scint. counter channels	2(1)	2
	~ 6,000	~ 12,000
Forward		
End toroid thickness(metric tons)(both ends)	3.0	4.0
End toroid weight(metric tons)(both ends)	~ 3500	~ 7,000
Number of chamber layers(each end)	28	36
Number of chamber channels(both ends)	~ 40,000	~ 42,000
Number of scint. counter layers	2(1)	2
Number of scint. counter channels	~ 2,000	~ 5,600
Number of Cerenkov ctr. channels(both ends)	~ 500	~ 500

[1] Depends strongly on type of muon chamber. Could be more or half the value shown.



SECTION X - X

NOTE ALL DIMENSIONS ARE IN MILLIMETERS

0 1 2 3 4 5 M

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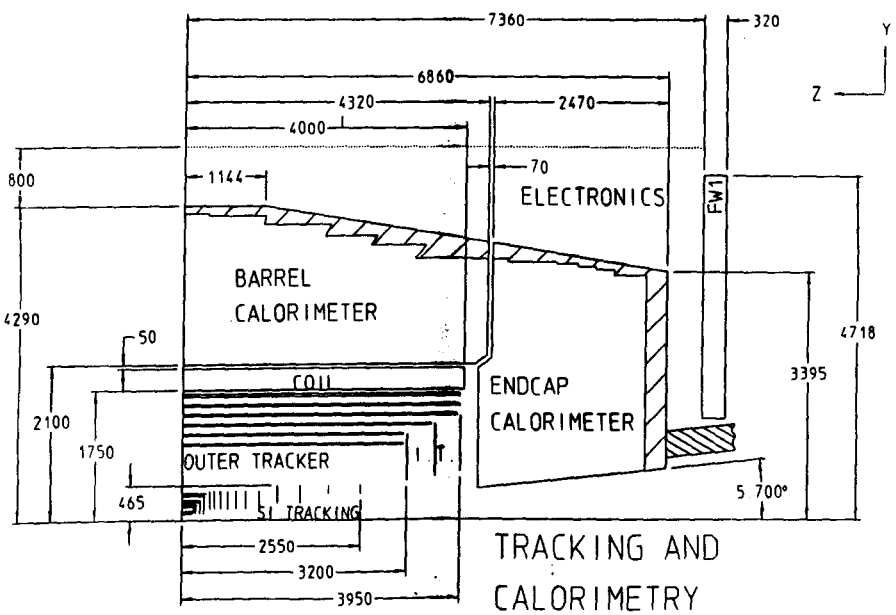
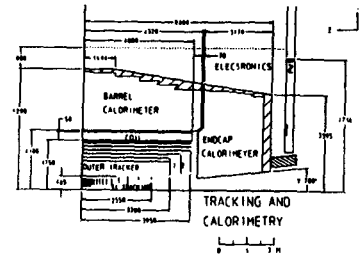


TRACKING AND CALORIMETRY

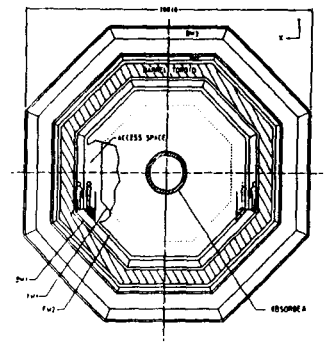
0 1 2 M

173

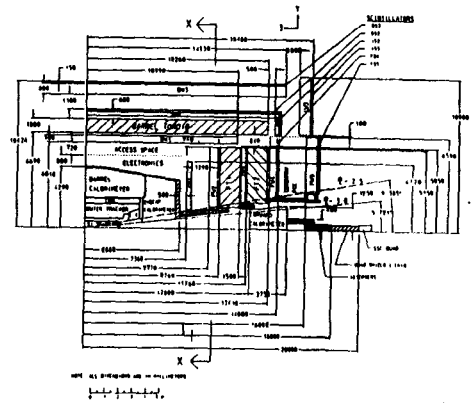


TRACKING AND CALORIMETRY

0 1 2 M



SECTION X - X



NOTE ALL DIMENSIONS ARE IN MILLIMETERS

0 1 2 3 4 5 M

SDC SCINTILLATOR CALORIMETER OPTION
DESCOPE OPTION 1
LBL DWG # 23D0145 8/3/91 Y MINAMIHARA

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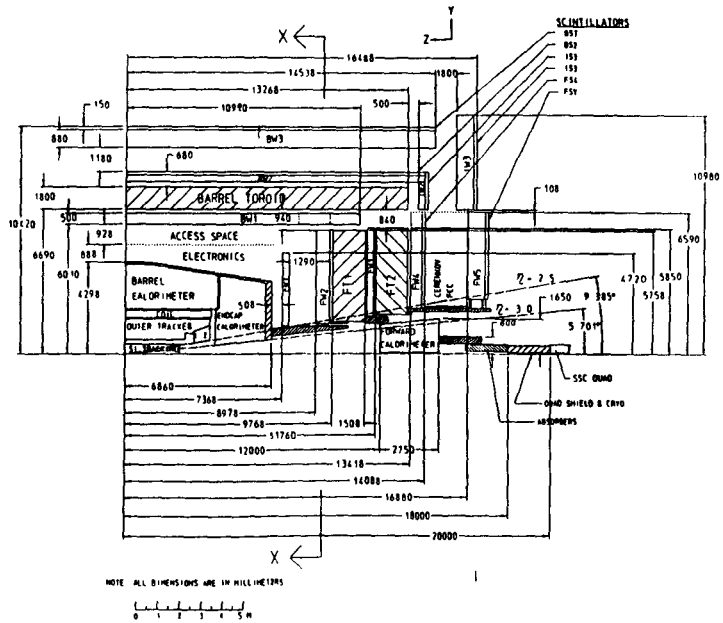
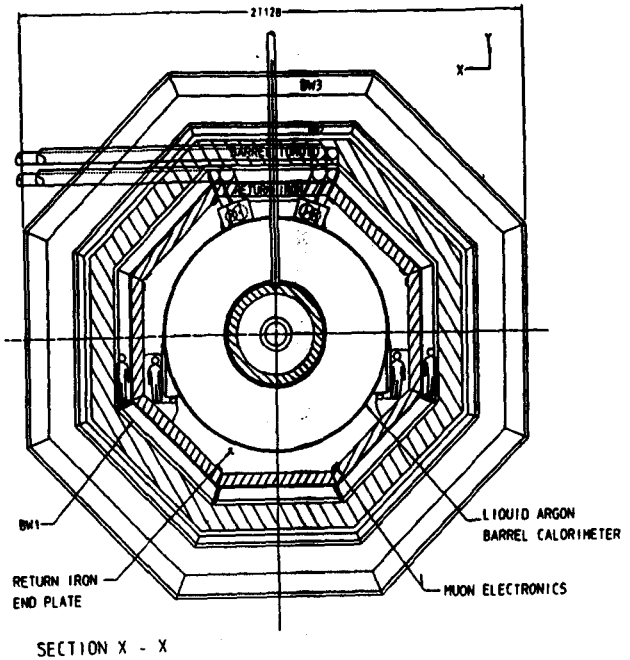


NOTE ALL DIMENSIONS ARE IN MILLIMETERS

0 1 2 3 4 5 M

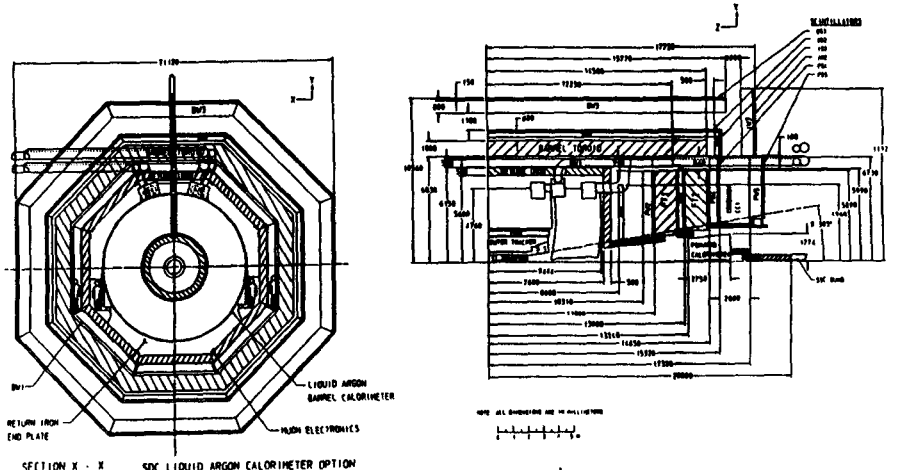
SDC SCINTILLATOR CALORIMETER OPTION
DESCOPE OPTION 1
LBL DWG # 23D0145 8/3/91 Y MINAMIHARA

171



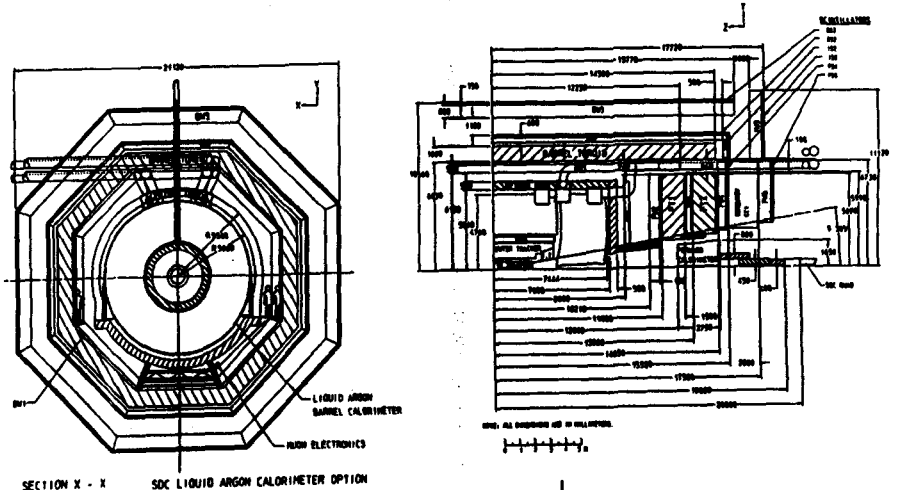
SECTION X - X

NOTE ALL DIMENSIONS ARE IN MILLIMETERS



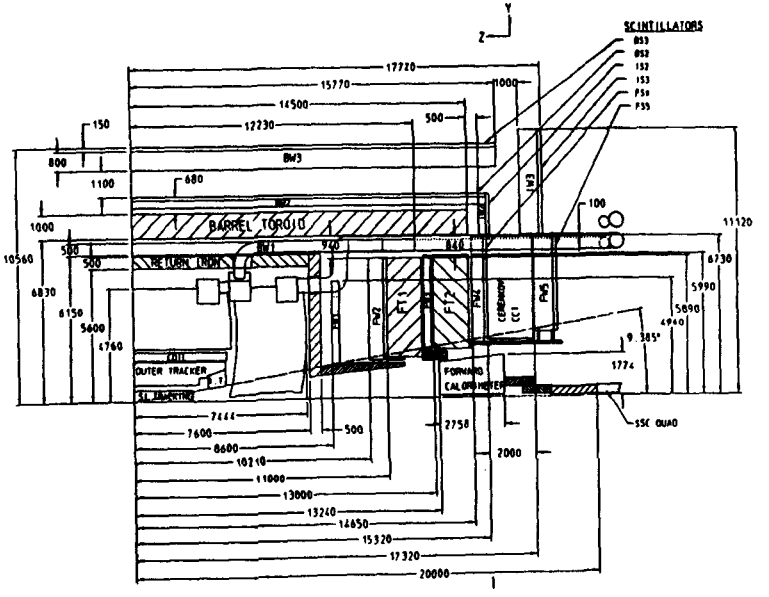
SECTION X - X

SDC LIQUID ARGON CALORIMETER OPTION
LAC DESCOPE OPTION 1
LBL DWG # 23D0175 6/3/91 Y MINAMIHARA



SECTION X - X

SDC LIQUID ARGON CALORIMETER OPTION
LAC DESCOPE OPTION 2 WITH CYL RET IRON
8/3/91 Y. MINAMIHARA

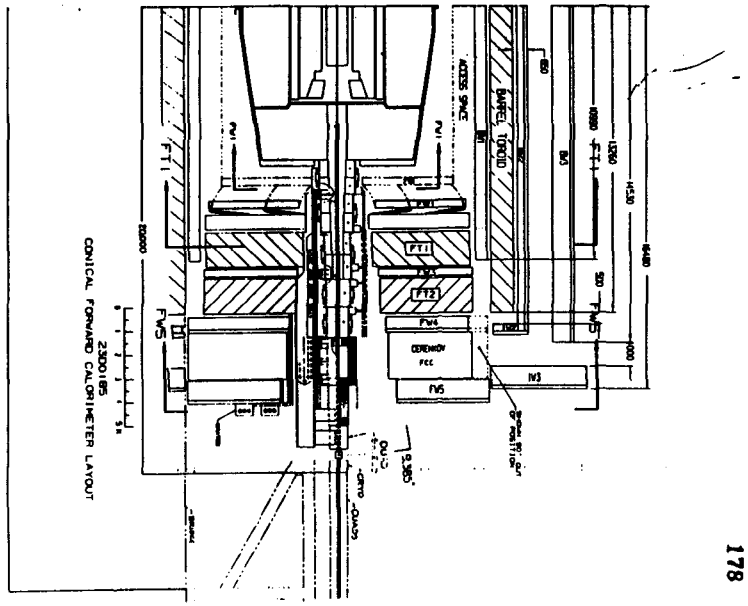


NOTE ALL DIMENSIONS ARE IN MILLIMETERS

SDC LIQUID ARGON CALORIMETER OPTION
LAC DESCOPE OPTION 1
LBL DWG # 23D0175 8/3/91 Y. MINAMIHARA

Descoping

- What is required to meet cost target of ≈$500M?
  - Further "thinning, in particular tracking volume?
  - Staging plan?
  - Combination?
- Need feedback from working groups on scope, cost, tracking volume and staging(and performance!)
  - Wednesday morning midcourse correction
  - Final presentations on Friday
  - Technical Board Friday night
  - Summary on Saturday
- Critical dimensions - must define by end of meeting
  - Tracking volume: compare(at least) 1.7x4m to 1.5x3m
  - Inner radius of barrel toroid



	MATL &MFG LABR	EDIA	% EDIA	SUB TOT	CONT	% CONT	TOTAL
1.0 TRACKING SYSTEMS							
1.1 SILICON TRACKING SYSTEM	21	11	34%	32	11	34%	43
1.2 BARREL TRACKER	20	9	31%	29	9	31%	38
1.3 INTERMEDIATE TRACKER	9	3	25%	12	5	42%	17
2.0 CALORIMETERS							
2.1 BARREL CALORIMETER	60	15	25%	75	24	32%	99
2.2 INTERMEDIATE CALORIMETER	18	5	28%	23	8	35%	31
2.3 FORWARD CALORIMETER	10	5	33%	15	6	40%	21
3.0 MUON SYSTEMS							
3.1 MAGNET SYSTEMS	30	9	23%	39	10	24%	49
3.2 MEASUREMENT SYSTEMS	35	13	27%	48	17	35%	65
4.0 SUPERCONDUCTING MAGNETS							
4.1 SC SOLENOID	23	1.1	5%	24.1	5	21%	29.1
4.2 SOLENOID CRYO SYSTEMS	5	1	17%	6	1.4	23%	7.4
5.0 DAQ SYSTEMS							
5.1 FRONT-END SYSTEMS	23	10	30%	33	9	27%	42
5.2 DATA ACQUISITION SYSTEMS	18	7	28%	25	7	28%	32
5.3 TRIGGER SYSTEMS	7	18	72%	25	9	36%	34
5.4 CONTROL SYSTEMS	2	3	60%	5	1	20%	6
5.5 POWER CONDITIONING SYSTEMS	2	2	50%	4	1	25%	5
6.0 COMPUTING							
6.1 ON-LINE COMPUTING	4	3	43%	7.5	2.5	33%	10
7.0 INFRASTRUCTURE							
7.1 MECHANICAL UTILITIES	0.3	0.1	25%	0.4	0.1	25%	0.5
7.2 ELECTRICAL UTILITIES	1	0.5	33%	1.5	0.5	33%	2
7.3 SAFETY SYSTEMS	1	1	50%	2	1	50%	3
7.4 STRUCTURAL SUPPORT SYSTEMS	2	1	33%	3	1	33%	4
8.0 TEST BEAM PROGRAM							
8.1 TEST BEAM PROGRAM	6	1.5	20%	7.5	2	27%	9.5
8.2 SUBSYSTEM INSTALL AND TEST	16	4	20%	20	6	30%	26
9.0 MANAGEMENT							
9.1 PROJECT PLANNING	0.4	1.3	74%	1.7	0.4	24%	2.1
9.2 PROJECT TRACKING	0.1	1.2	92%	1.3	0.3	23%	1.6
9.3 DOCUMENT DIST. AND CONTROL	0.4	1.3	76%	1.7	0.4	24%	2.1
9.4 QUALITY ASSURANCE	1	1.1	91%	1.1	0.3	27%	1.4
9.5 ES&H	0.1	1.9	95%	2	0.5	25%	2.5
9.6 DETECTOR INTEGRATION	0.5	8.3	94%	8.8	2.2	25%	11
TOTALS	315	138	31%	453	141	31%	594

8/3/91 3:00 PM

Cost Comparison without R&D

	TOTAL COSTS WITH CONTINGENCY					
	Lol Estimate ($M)	Lol Rev. Panel ($M)	Preliminary Cost Baseline ($M)	Preliminary Descope I ($M)	Preliminary Descope II ($M)	Target "500M" ($M)
1.0 TRACKING SYSTEMS						75
1.1 SILICON TRACKING SYSTEM	39.5	66.9	71.7	43	43	
1.2 BARREL TRACKER	23.1	26.9	53.5	38	35	
1.3 INTERMEDIATE TRACKER	11.3	19.5	16.6	17	17	
2.0 CALORIMETERS						125
2.1 BARREL CALORIMETER	77.3	98	128	89	88	
2.2 INTERMEDIATE CALORIMETER	36.5	44.2	66.2	31	28	
2.3 FORWARD CALORIMETER	20.7	21.5	24.2	21	21	
3.0 MUON SYSTEMS						75
3.1 MAGNET SYSTEMS	48.6	51.2	72.3	49	48	
3.2 MEASUREMENT SYSTEMS	48.7	74.4	82.8	65	53	
4.0 SUPERCONDUCTING MAGNETS						35
4.1 SC SOLENOID	29.8	30	29.1	29.1	22	
4.2 SOLENOID CRYO SYSTEMS	4.8	4.8	7.4	7.4	7.4	
5.0 DAQ SYSTEMS						100
5.1 FRONT-END SYSTEMS	27.7	34	54.5	42	40	
5.2 DATA ACQUISITION SYSTEMS	20.8	26.5	42.5	32	32	
5.3 TRIGGER SYSTEMS	48.9	48.8	47.8	34	34	
5.4 CONTROL SYSTEMS	5.7	5.7	7.1	6	6	
5.5 POWER CONDITIONING SYSTEMS	3	3	9.2	5	5	

8/3/91 3:31 PM

Meeting Logistics

- Overall agenda is available at registration desk
- Subgroup room assignments available at registration desk. Mollie Field is room coordinator
- Subgroup agenda received as of Aug. 2 are posted and subgroup leaders have copies
- We want copies of all presentations and notes presented. Subgroup leaders will receive envelopes and instructions at registration. Plan to publish "proceedings" with copies of transparencies.
- Any problems ask at desk outside

Cost Comparison without R&D

	TOTAL COSTS WITH CONTINGENCY					
	LoI Estimate ($M)	LoI Rev. Panel ($M)	Preliminary Cost Baseline	Preliminary Descope I ($M)	Preliminary Descope II ($M)	Target "500M" ($M)
6 COMPUTING						10
6.1 ON-LINE COMPUTING	11.9	13.8	10	10	10	
7 CONVENTIONAL FACILITIES						10
7.1 MECHANICAL UTILITIES	1	1	0.5	0.5	0.5	
7.2 ELECTRICAL UTILITIES	1	1	2	2	2	
7.3 SAFETY SYSTEMS	5	5	5.5	3	3	
7.4 STRUCTURAL SUPPORT SYSTEMS	3.1	3.1	5.8	4	4	
8 INSTALLATION AND TEST						35
8.1 TEST BEAM PROGRAM	9	15	10	9.5	9.5	
8.2 SUBSYSTEM INSTALL. AND TEST	19	40	26	26	26	
9 PROJECT MANAGEMENT			20%	20%	20%	20
9.1 PROJECT PLANNING			2.1	2.1	2.1	
9.2 PROJECT TRACKING			1.6	1.6	1.6	
9.3 DOCUMENT DIST. AND CONTROL			2.1	2.1	2.1	
9.4 QUALITY ASSURANCE			1.4	1.4	1.4	
9.5 ES&H			2.5	2.5	2.5	
9.6 DETECTOR INTEGRATION			11	11	11	
TOTALS	510	672	818	564	563	501
Tracking volume RXL	1.7x4.0	1.7x4.0	1.7x4.0	1.7x4.0	1.5x3.0	????

or 49

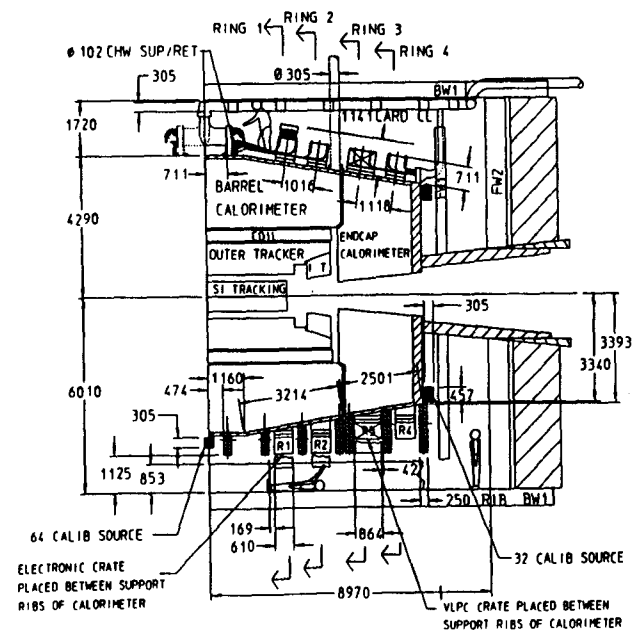
8/3/91 3:31 PM

SDC Meeting Rooms

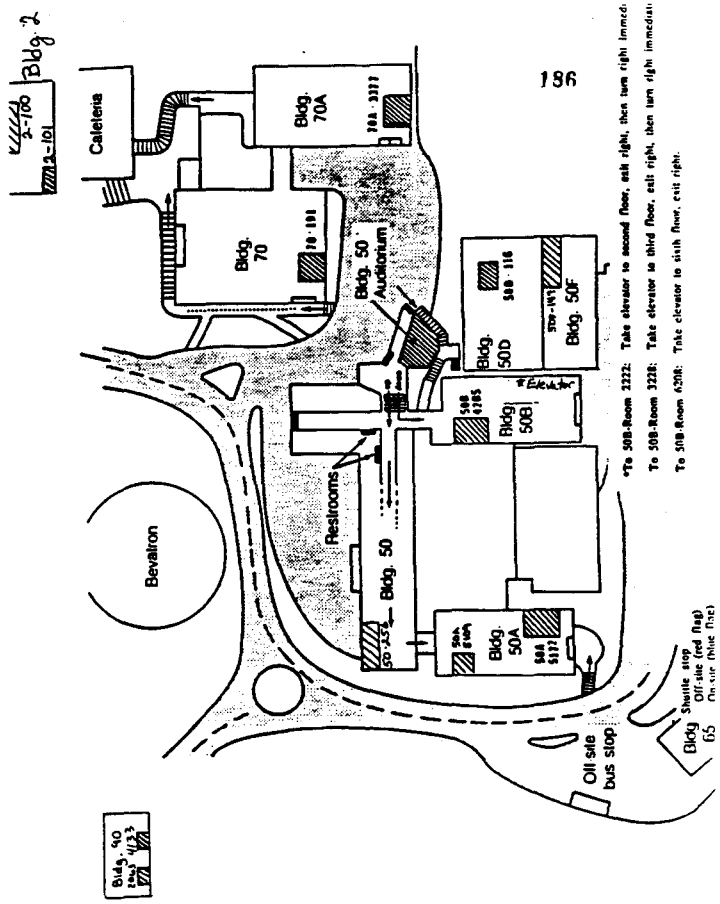
	Aug. 5	Aug. 6	Aug. 7	Aug. 8	Aug. 9
Tracking Group I(combined meetings)	Bldg. 2 Rm. 100	70A-3377	70A-3377	70A-3377	-------
Tracking Group II(silicon tracker)	50F-147	50F-147 (not 9-10:30)	50F-147	50F-147 (not 12:30-3)	-------
Tracking Group III(other)	50B-6208	50B-6208	50B-6208	50B-6208	-------
Solenoid	50-256	50-254	-------	-------	-------
Calorimetry I (combined meetings)	50 Aud.	50A-5132 (not 10-11:30)	50 Aud. (not 11:45-1)	50 Aud.	-------
Calorimetry II(other)	50B-2222	50B-2222 (not 9-10)	50B-2222	50B-2222	50B-2222
Calorimetry III(small meetings)	-------	--------	50A-5109 (not 10:30-11)	50A-5109	--------
Muon I	70-191	70-191	70-191	70-191	--------
Muon II(small meetings)	50B-3228	50B-3228 (not 9-11)	50-256	50-256	50-256
Electronics I	50B-4205	50B-4205	50B-4205	50B-4205	50B-4205
Electronics II	90-4133	90-4133	90-4133 (not 12-5)	90-4133	--------
Physics and Detector Performance	50A-5132	50 Aud.	Bldg. 2 (Rm. 100)	50A-5132	--------
Computing	50D-116	50D-116	50D-116 (not 2-3:30)	Bldg. 2 Rm. 101	--------
Integration/Cost/Schedule	90-2063	Bldg. 2 Rm. 100	90-2063	90-2063	90-2063

Other rooms:

SDC Library - 50A-2161
Terminals, Macs, etc - 50B-1232 and 50B-1237



UTILITY AND CRATE(192) LAYOUT
FOR DESCOPE OPTION 1 OF JUNE 29, 1991
LBL DWG 2300155 8/3/91 Y MINAMIHARA



TRACKING DETECTOR PERFORMANCE

M. CORDEN

Tracking Detector Performance

① Resolution

- non-uniform field — Kondo
- combined track fit — Corden
- which are the important parameters?

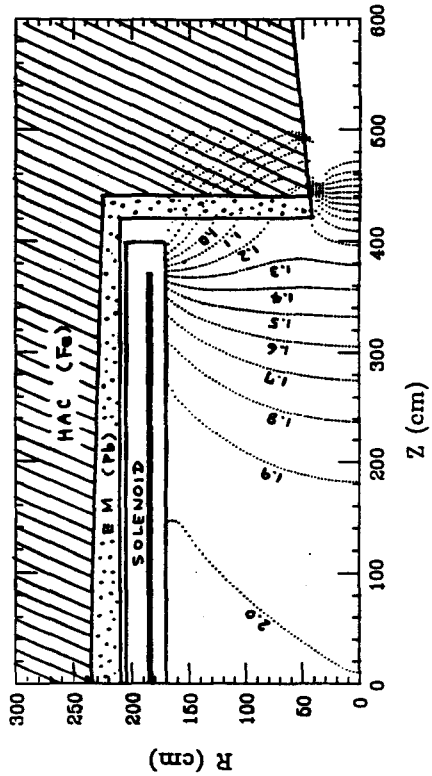
② Track Finding

- silicon — Hubbard
- fiber — Adams
- straw — Luehring, Palounek
- straw + silicon — Abe
- hybrid + silicon — Coupal
- consequences for descoping.

Kondo

(4) magnetic field contour of B_z

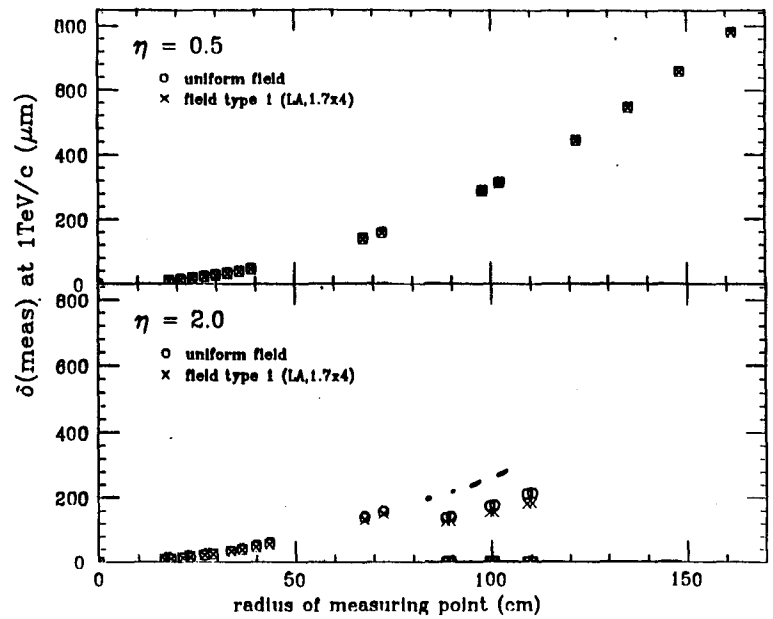
Type 4, (r,z/2)=(1.7m,4.0m). Tile-fiber, EM(Pb), Had(all Fe)



(bad case)

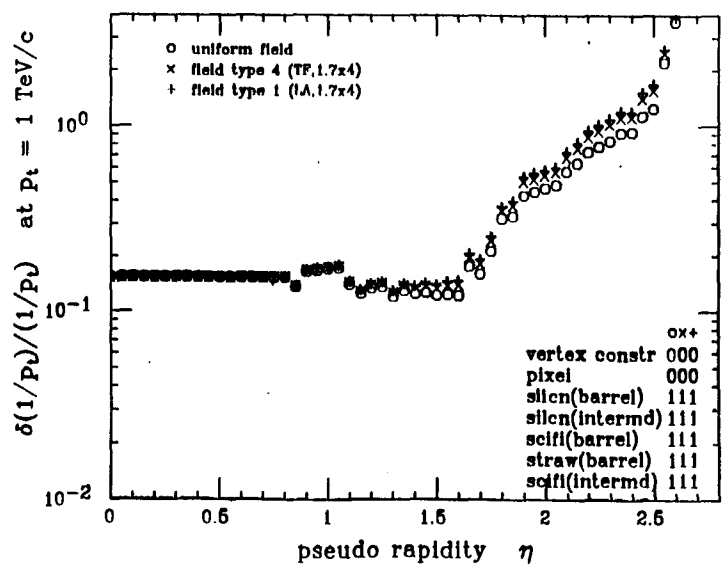
Kondo

deviation from the straight line



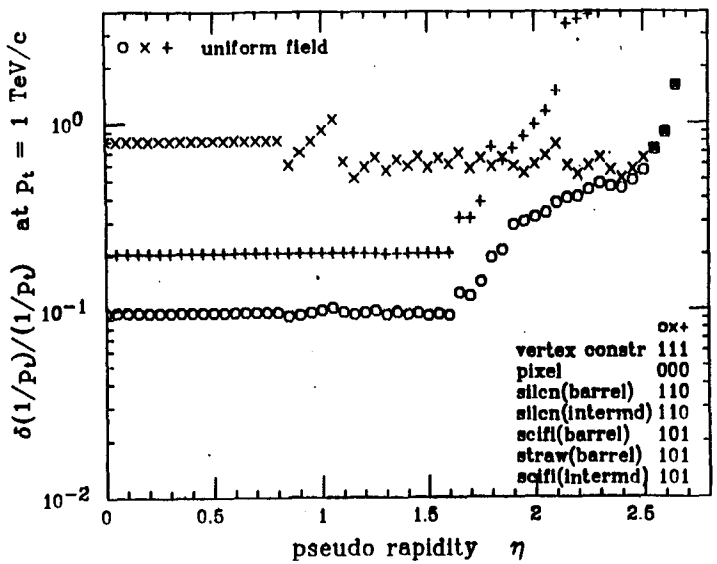
Kondo

field dependence for 1.7mx4m



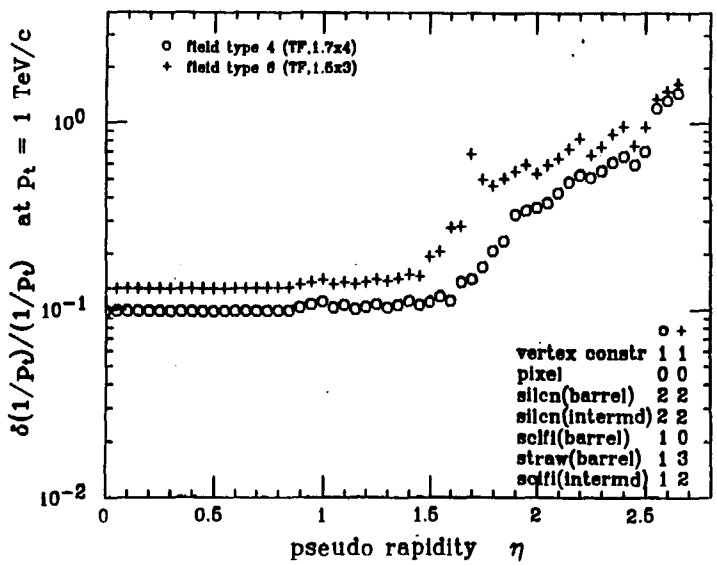
Kondo

(1) with and without silicon tracker



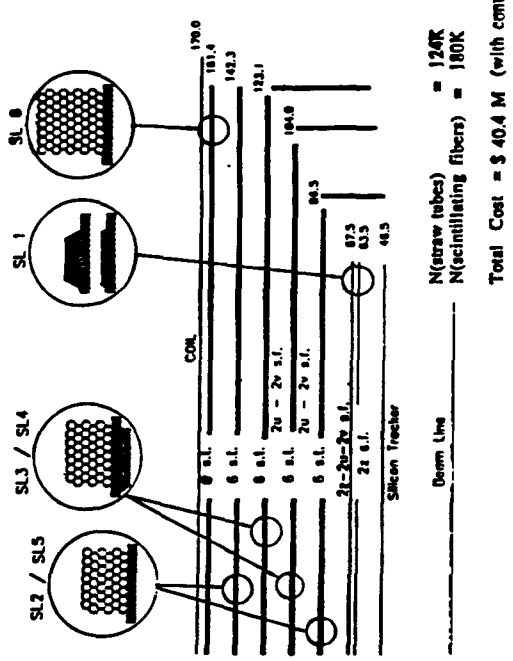
Kondo

1.7mx4m vs 1.5mx3m



July 24, 1991

Straw Tube - Scintillating Fiber Outer Tracker

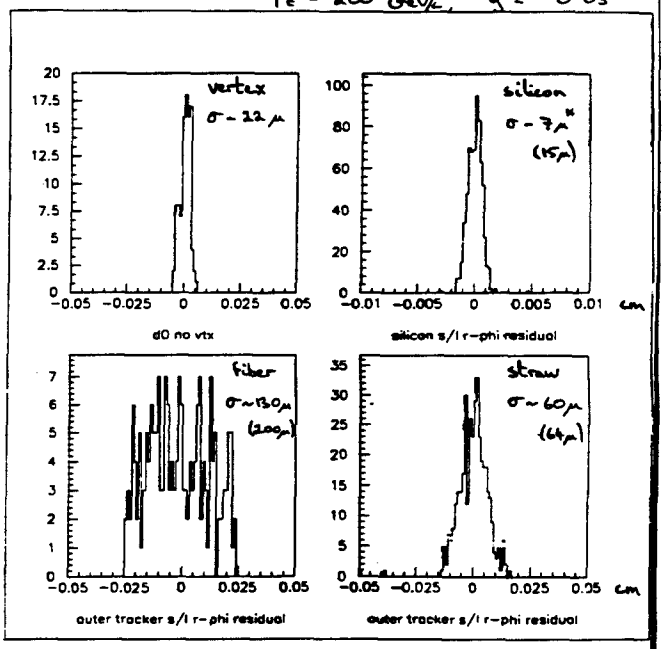


Corden

1-track events

r − φ track residuals per segment.

P_t = 200 GeV/c, y = −0.05

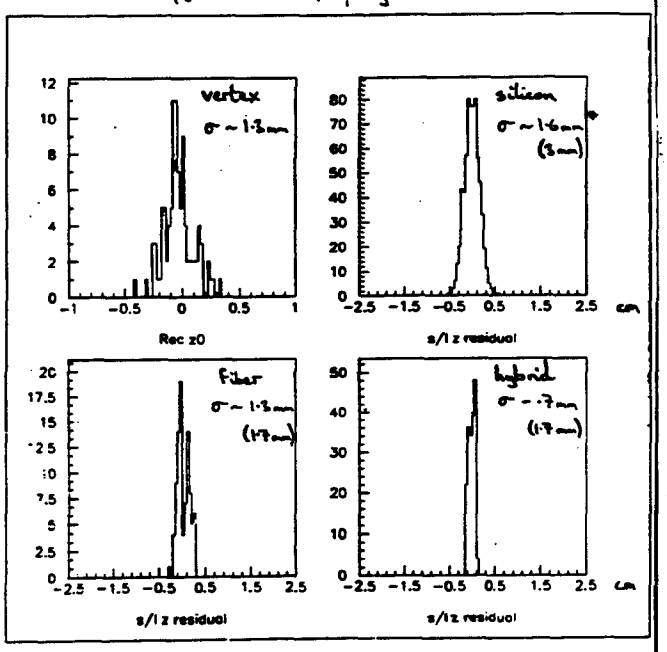


Note: vertex not used in fit
"silicon segments "double count" layers, ⇒ smoothing
"fibers" is for 2 layers of 1 mm fibers only.
"straws" is for 6 layers, except 9 in trigger layer, 180 μ for single layer.

Corden

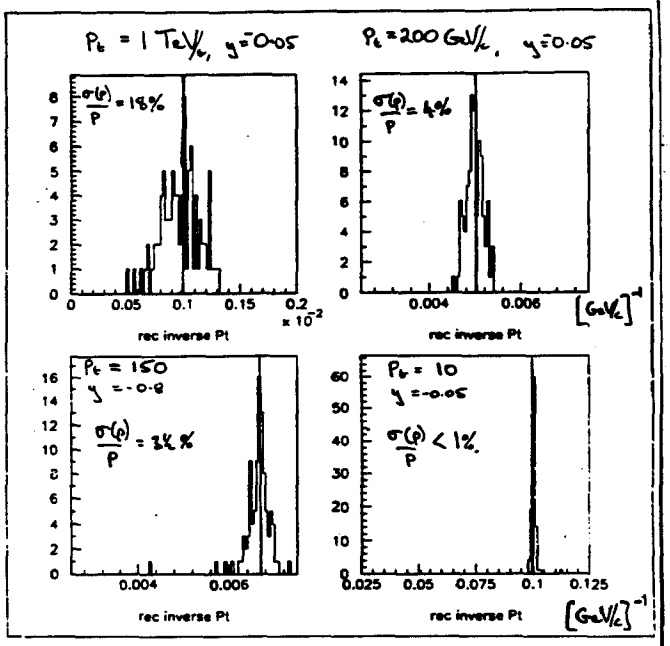
z single track residuals, per segment.

P_t = 200 GeV/c, y = −0.05



Corden

reconstructed $1/P_t$

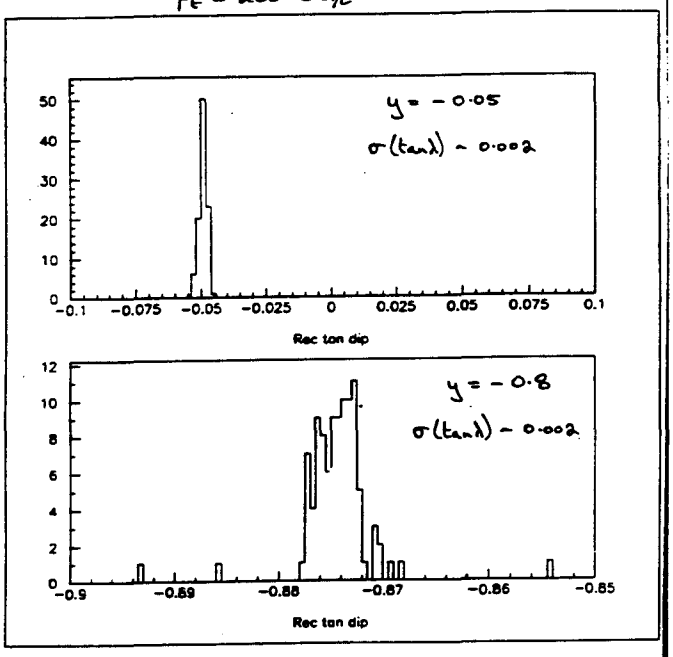


Roughly, $\frac{\sigma(p)}{p^2} \approx 20\%$ (central region).

Corden

198

$P_t = 200$ GeV/c



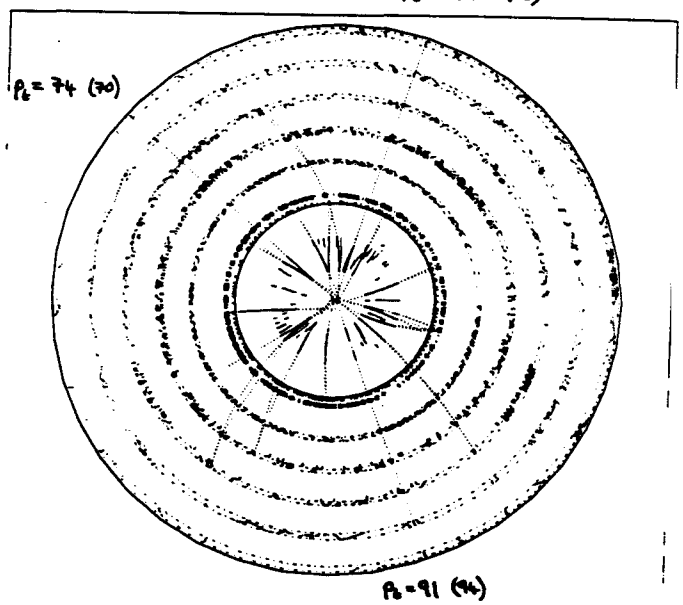
[redacted]

$h \to Z^0 Z^0 \to 4\mu$. (barrel) Corde

199

4th μ is at $y = 1.8$.

$P_t = 97$ (93)



Resolution Conclusions

200

Not important: field non-uniformities
vertex constraint (unless very precise)
resolution of individual layers (except outermost)
number of layers.

Only one important parameter: tracking volume.

reduce r_{max} from 1.7 to 1.5 m ⇒ increase $\frac{\Delta p}{p}$ by ~30% (lever arm)^2.

decrease $L/2$ from 4 to 3 m ⇒ lose ¼ unit rapidity of "good resolution" each end.

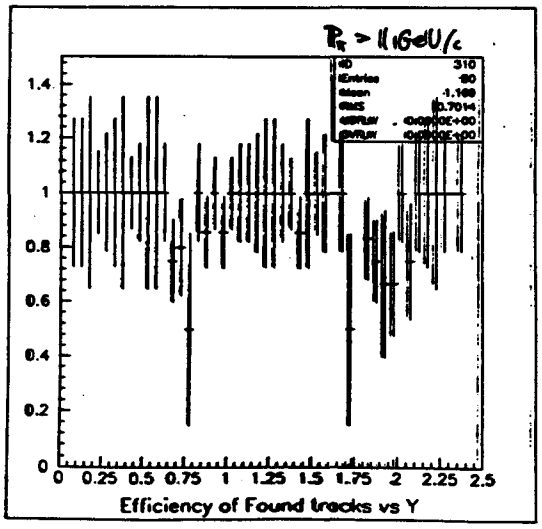
Hubbard

Inner tracker alone.

201

- Require 5 axial hits, $\frac{\#\text{ hits}}{\#\text{ possible}} \geq .5$

10 events only, Higgs → 4 ℓ

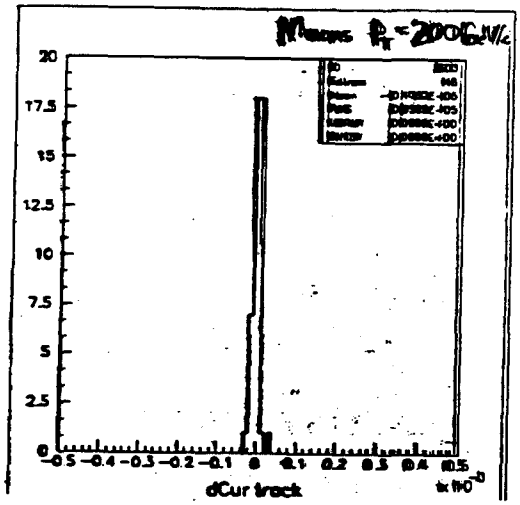


H Hubbard

Single tracks

202

Curvature Resolution



δP

$\rightarrow \frac{\delta P_T}{P_T} = \leq .0025 P_T$ Default tbe

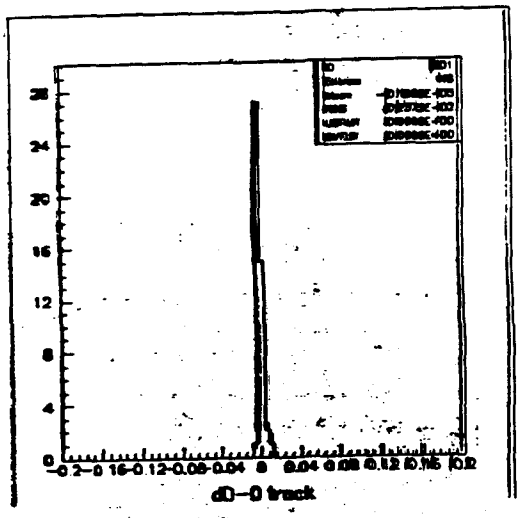
$\leq .003 P_T$ Default, no'bc

$= .0017 P_T$ Descope II, no'bc

H Hubbard

203

Transverse Impact Parameter resolution

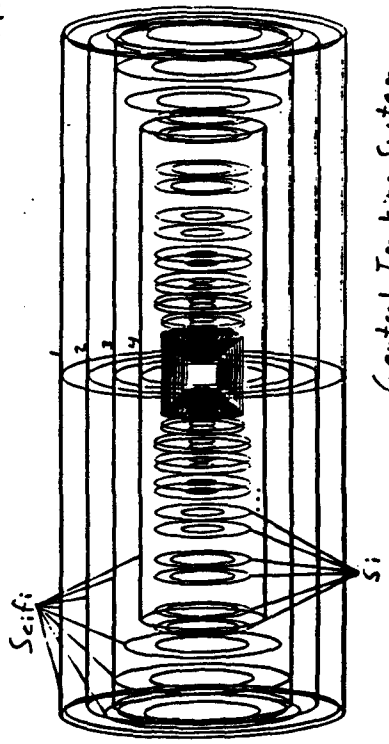


$\delta D_0 = \leq 66\ \mu$ Default

$23\ \mu$ Descope II

H Adams

204



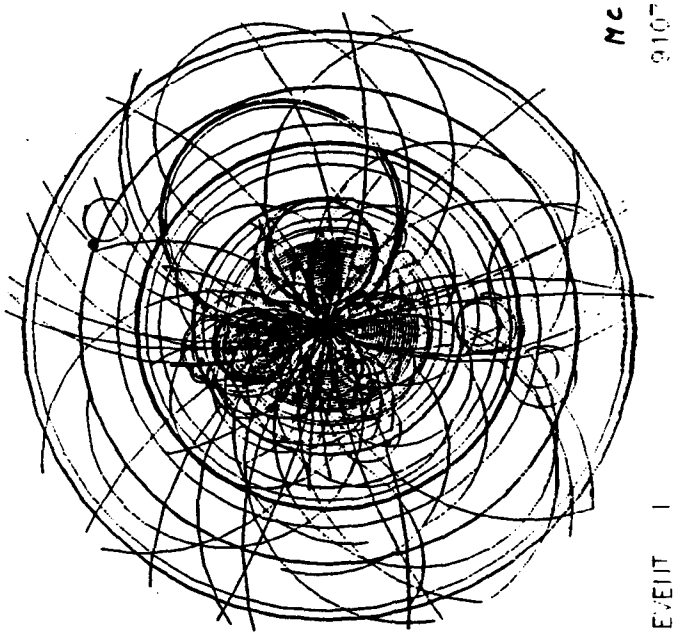
Central Tracking System

super layer	radius	z_{max}	η_{max}	occ/evt (multi-evt)
1	160	400	1.65	0.0001
2	130	390	1.87	0.0018
3	100	390	2.07	0.0035
4	70	290	2.13	0.0063

Here we only make use of the scifi barrels (superlayers 1-4)

H Adams

205



MC tracks

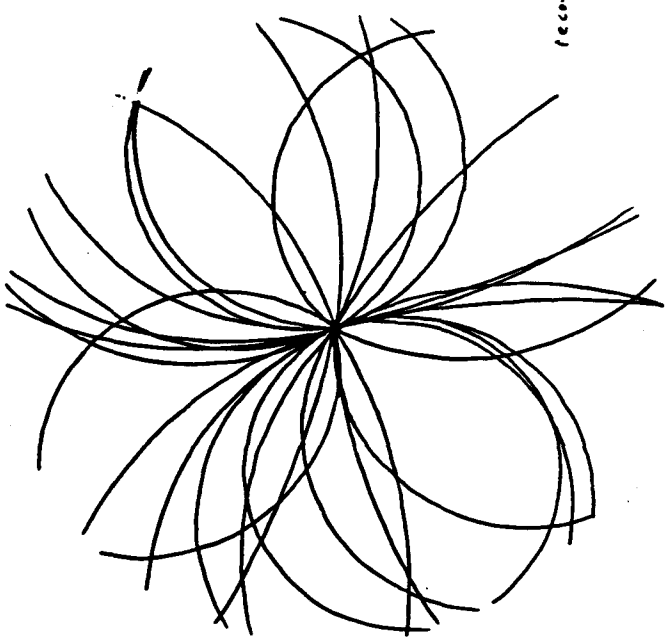
910730 111

EVEIT 1

Adams

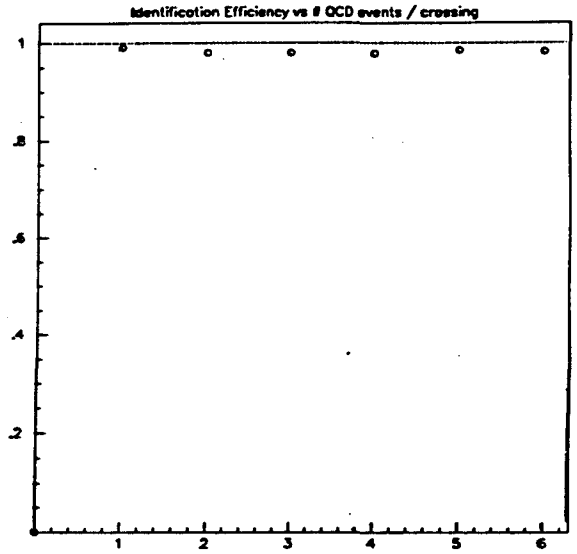
206

reconstructed



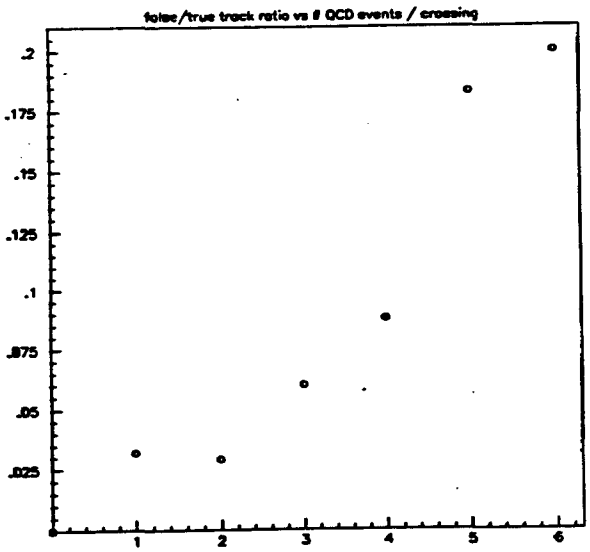
Adams

207



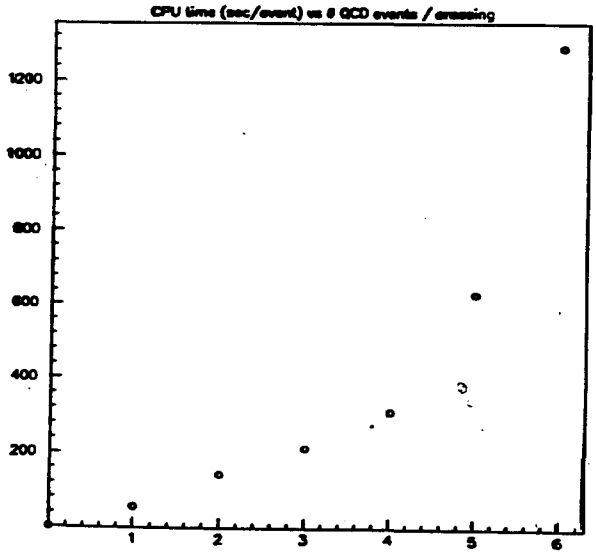
Adams

208



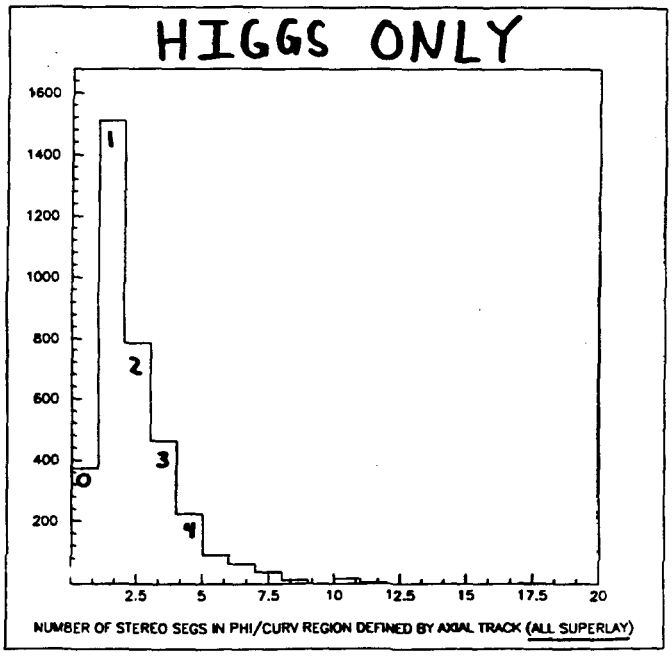
Adams

209



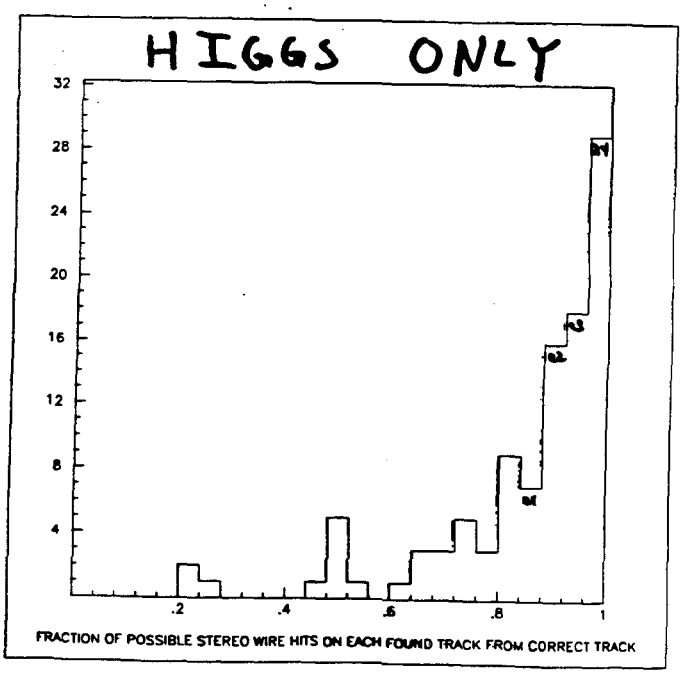
Luehring

210



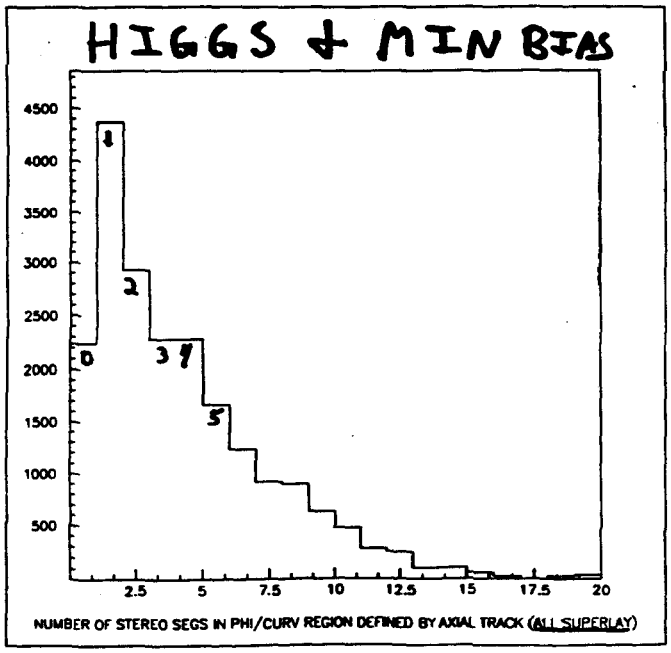
Luehring

211



Luehring.

212



213

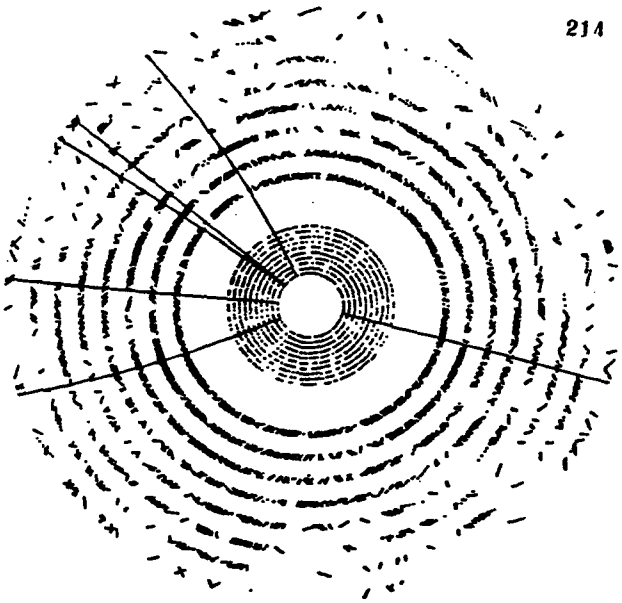
Minimum Number of Axial Layers

— Study for the Discoping —

FAbe
KEK

1. Review : Matrix approximation etc
2. Simulation update
3. Study for descoping
4. Summary

214



ISAJET

$H^0 \to Z^0 Z^0 \to 4\mu$

$M_H = 320$ GeV

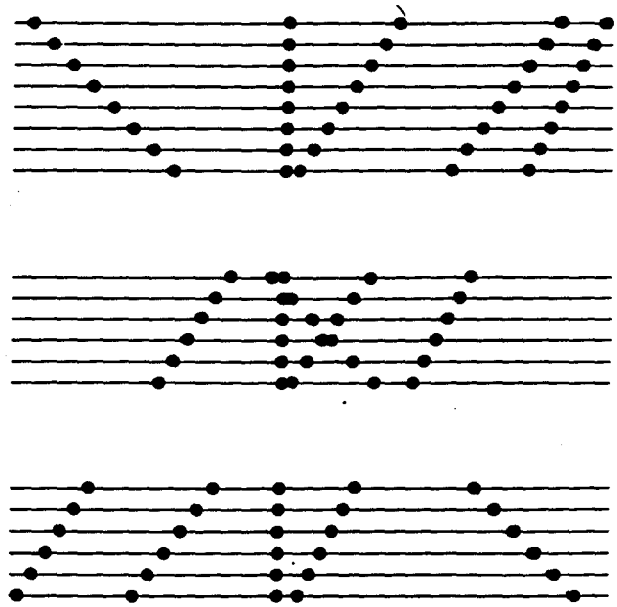
GEANT simulation

5 minimum bias event pileup without filtering

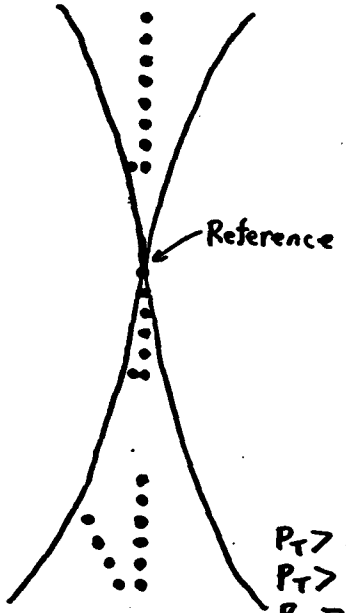
Reconstruction CPU time:

11 min by VS3100M38 (~3MIPS) → 28 steps/event

215



216

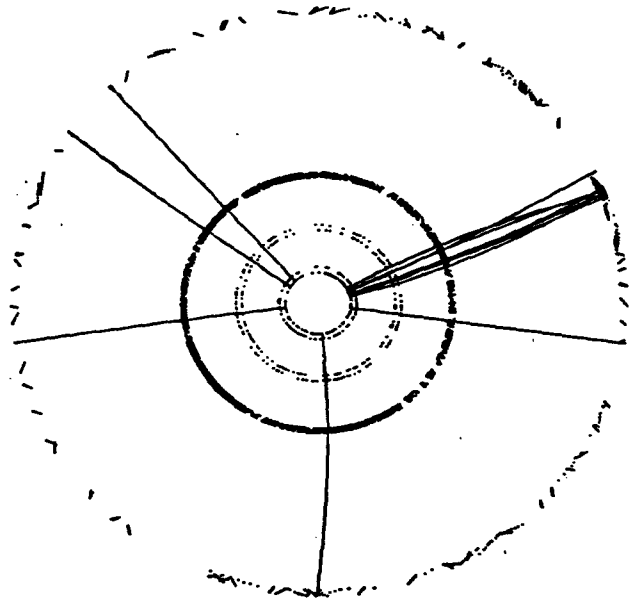


$P_T > 20$ GeV

$P_T > 5$ GeV

$P_T > 3$ GeV

217



18A

Si 4 layers

Straw 14 layers

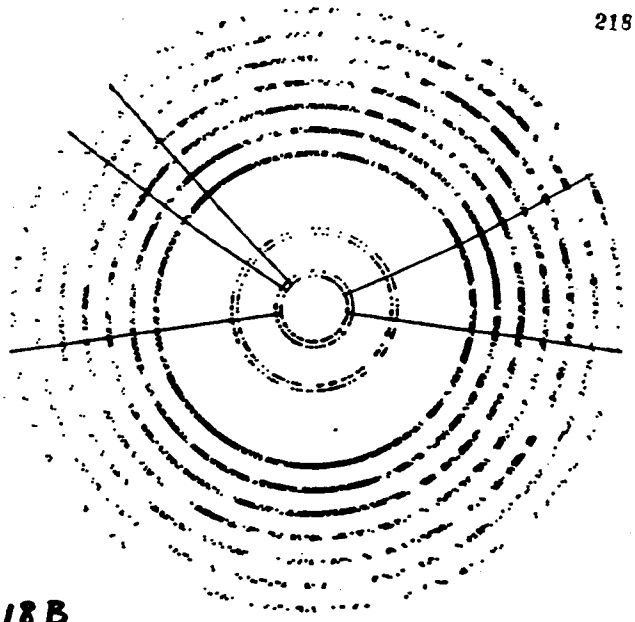
Hist ≥ 5 points

Fitting > 9 points

11

Abe

218

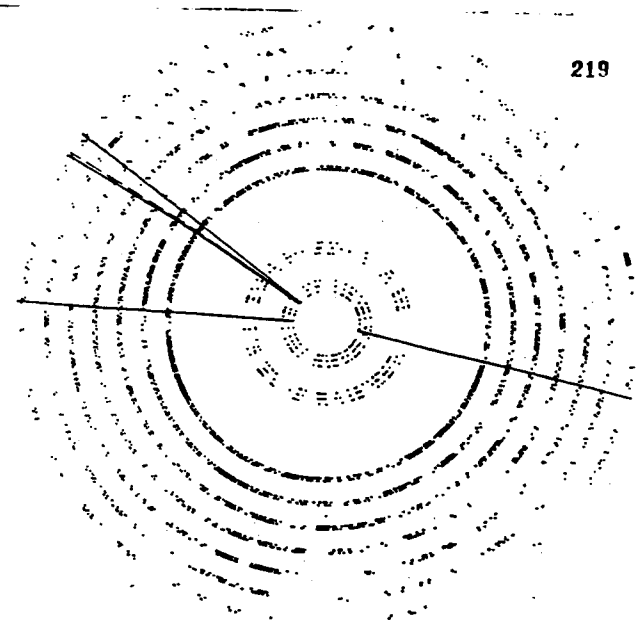


18 B
Si 4 layers
Straw 14 layers

Hist ≥ 5 points
Fitting > 10 points

11

219



~~18 B~~
Si 4 layers
Straw 14 layers

Hist ≥ 5 points
Fitting > 9 points

1

Abe.

220

# Si layers	# straw superlayers	straws per superlayer	tracks found	4-track events
10	8	6	40/44	8/11
4	2	7	36/47	3/11
4	7	2	36/47	6/11
6	7	2	43/47	8/11

$H \to ZZ \to 4\mu$, $L \sim 10^{33}$ background

Conclude need widely spaced points, global track-finding methods, when so have.

Unfortunately, that produces less savings in both $ and material budgets.

Tracking Efficiency

D. Cupal 8/87

Way Preliminary

221

Ingredients

- Silicon digitizations, segments (& tracks)
- Hybrid " "
- Segment-linking package
- SDC shell
- MC matching utilities*
- Missing: straw or fiber system segments (!)

Experiences

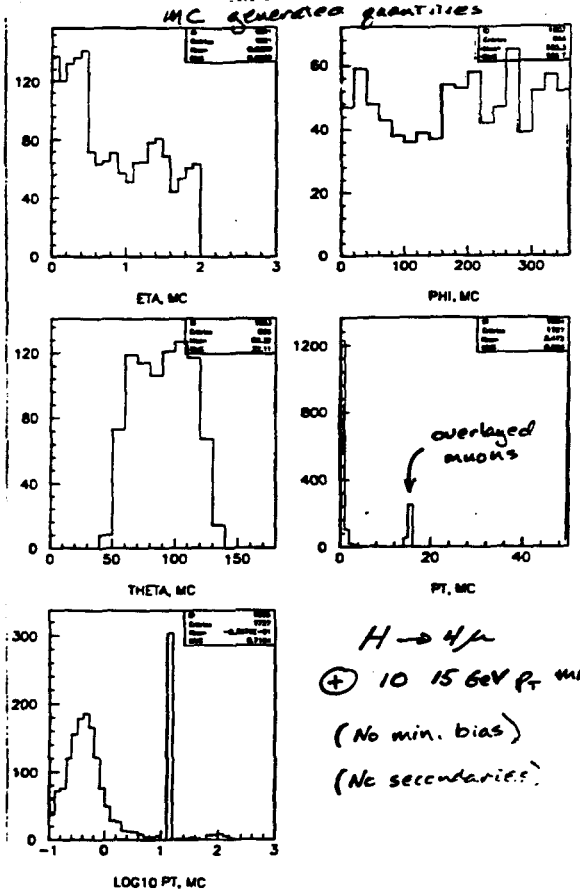
- Shell simulation - large & cumbersome but basically works
- ~15 minutes/event on SSC batch mach (need parallelization!)
- Difficult to debug

* MC track ⇔ recon. track if >60% of hits on recon. track come from MC track.

MC generated quantities

Coupal

222



$H \to 4\mu$

⊕ 10 15 GeV p_T muons on top

(No min. bias)

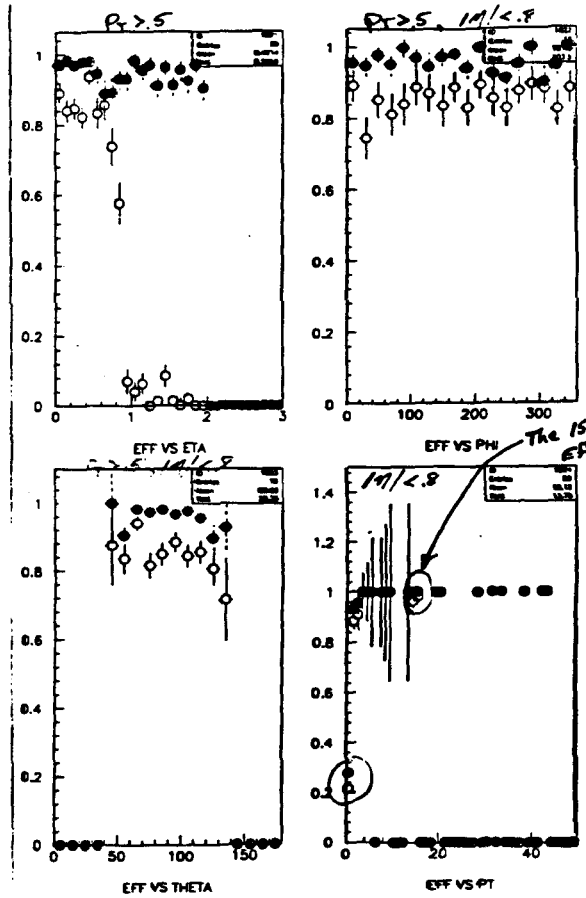
(No secondaries)

$p_T > .5$

$p_T > .5$, $|\eta| < .8$

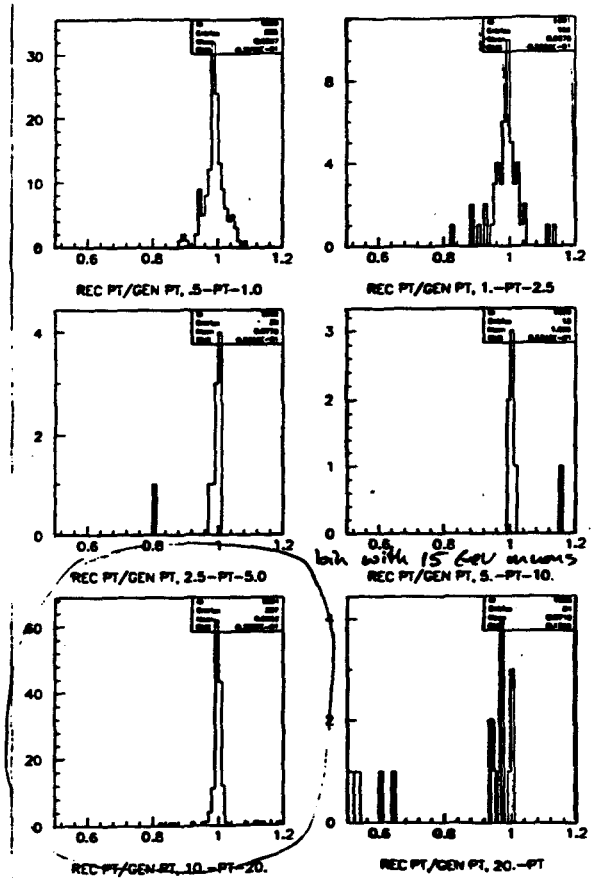
Coupal

223



Coupal

224

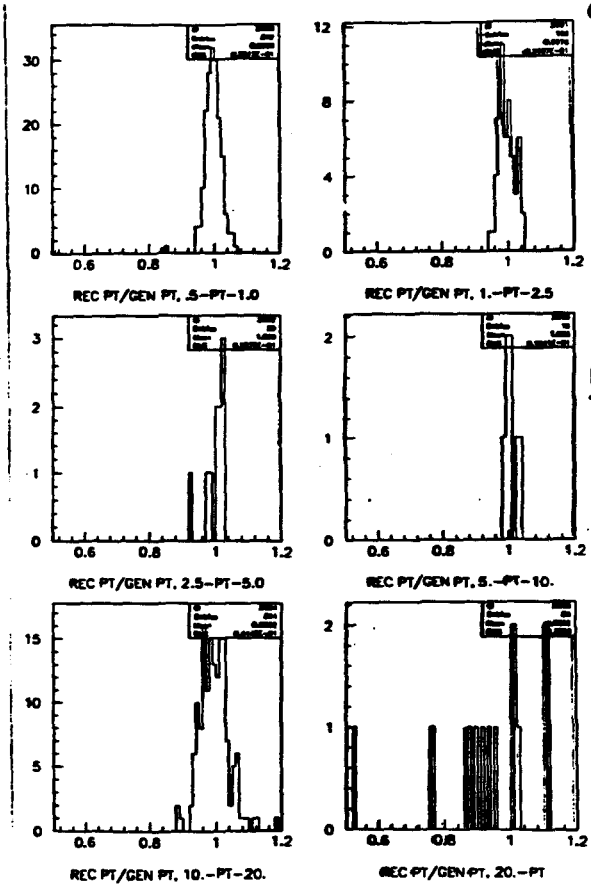


$P/E \in P_T$ bin

with 15 GeV muons

Coupal

225



P/E

Silicon Tracking

Remove Outer Two Layers

Coupal

226

... job still running.

Short-term future
- add min-bias, secondaries
- hybrid hybrid? (= fibers only)
  (= straws only)

Conclusions

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- We have seen examples of tracking detectors descoped beyond the point of viability

- As we go to less and less channels, it may be necessary to give up local track finding methods, (segments & linking), in favor of global methods (histogramming; brute force combinatorics).
  ⇒ penalties in computer time, redundancy/clarity, vertex assumptions,

- as always, need more work (and resources).

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SELECTED CALORIMETER SIMULATION RESULTS

D. GREEN

229

Subgroup: Plenary Physics + Det. Rep. Date: 8/6

Speaker: D. Green

Title: Selected Calorimeter Simulation Results

Comments:

2 copies
Return 1 copy to L. Price

CALORIMETER SIMULATION WORK

A POTPURRI

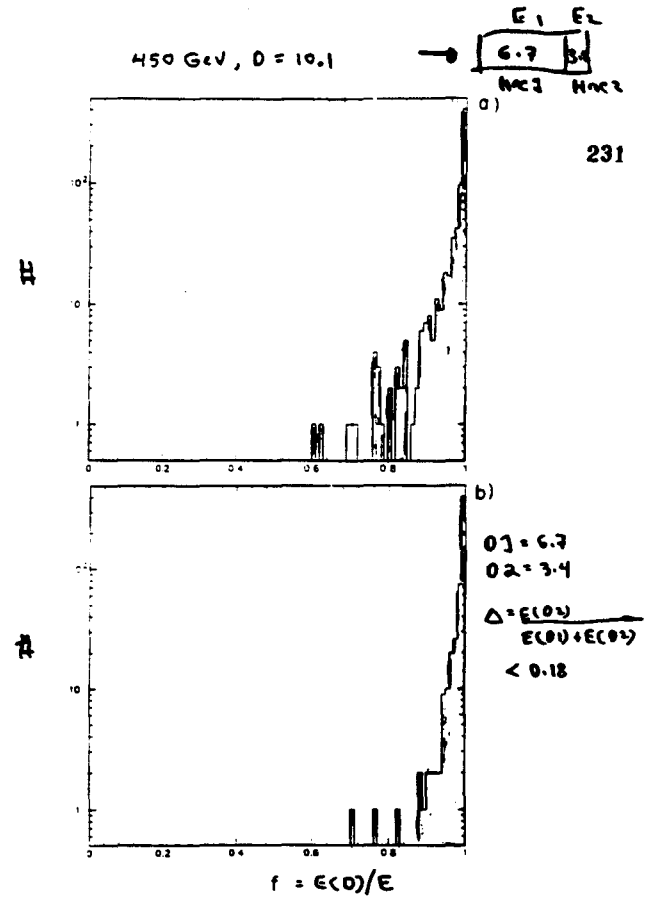
OF "DESCOPE" TOPICS

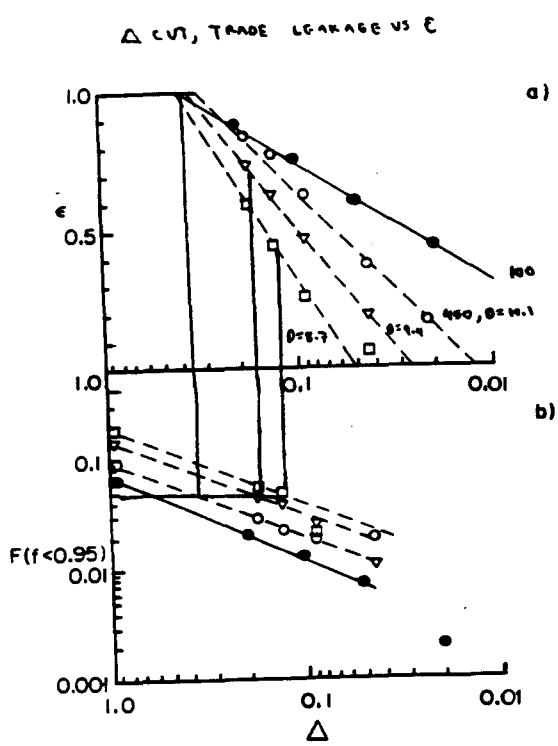
SINCE THE LAST SDC COLLABORATION MEETING
(APOLOGIES, FINAL ONLY)

I) DEPTH AND LONGITUDINAL SEGMENTS

"WEIGHTING"

II) e AND ISOLATION, STRIPS
AND THEIR WIDTH





L. JONES
WEIGHTING

N_i : MIP IN LAYER i
δx : THICKNESS EACH LAYER (COUNTER + ABS.)
K : NORMALIZATION CONSTANT

$$E_h = \sum_{i=1}^{\infty} \underbrace{K\left(\frac{dE}{dx}\right)}_{C} \delta x N_i.$$

If the calorimeter is broken at layer L

$$E_h = \underbrace{K\left(\frac{dE}{dx}\right)}_{C} \delta x \sum_{i=1}^{L-1} N_i + \Delta E_h,$$

where

$$\Delta E_h = \sum_{i=L}^{\infty} \underbrace{K\left(\frac{dE}{dx}\right)}_{C} \delta x N_i.$$

OR:

$$E_h = C \sum_{i=1}^{\infty} N_i$$

$$E_h = C \sum_{i=1}^{h-1} N_i + C \sum_{i=h}^{\infty} N_i$$

IF dE/dx BEYOND LAYER L FALLS AS $e^{-x/\lambda}$,

$$\Delta E_h = \underbrace{K\left(\frac{dE}{dx}\right)_L}_{C/\delta x} N_L \int_0^\infty e^{-x/\lambda} dx$$

or

$$\Delta E_h = K\left(\frac{dE}{dx}\right)\lambda N_L.$$

Hence the total energy is found from

$$E_h = \underbrace{K\left(\frac{dE}{dx}\right)\delta x}_{C}\left\{\sum_{i=1}^{L-1} N_i + \frac{\lambda}{\delta x} N_L\right\}.$$

OR: $E_\ell = C\left\{\sum_{i=1}^{\ell-1} N_i + A N_\ell\right\}$

WHERE $A = \frac{\lambda}{\delta x}$.

IN PRACTICE, VARY A TO OPTIMISE PERFORMANCE

WEIGHTING OF OUTER LAYERS (L. JONES)

450 GEV LABE DATA

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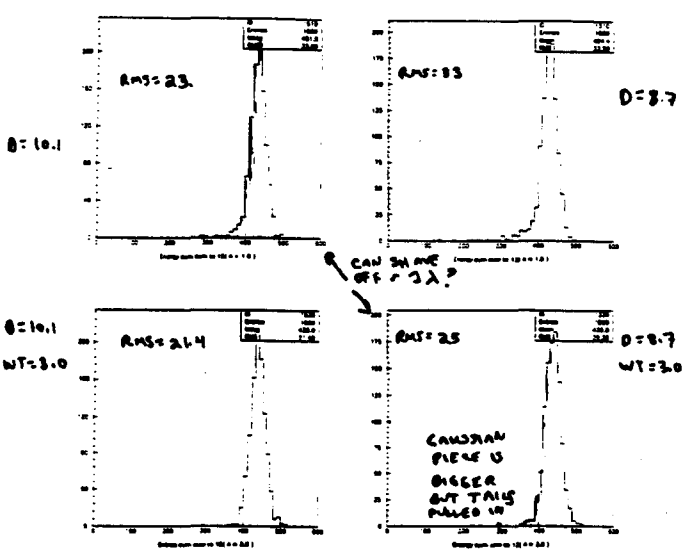
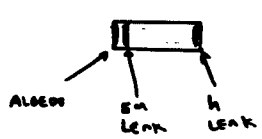


WHAT NEXT? (S. OLSEN)



HANGING FILE BEAM TESTS

MC ⊕ TESTS

450 GEV LABE DATA

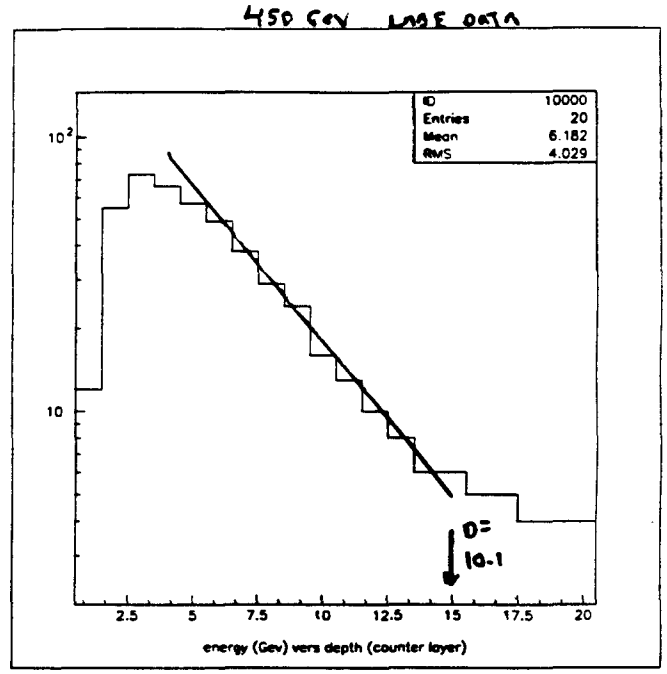


Figure 2. Same as Fig. 1; logarithmic energy scale.

WHAT IS THE INDUCED NONLINEARITY? (A. BERETVAS)

A ~ λ_{EFF} WHICH IS E DEPENDENT

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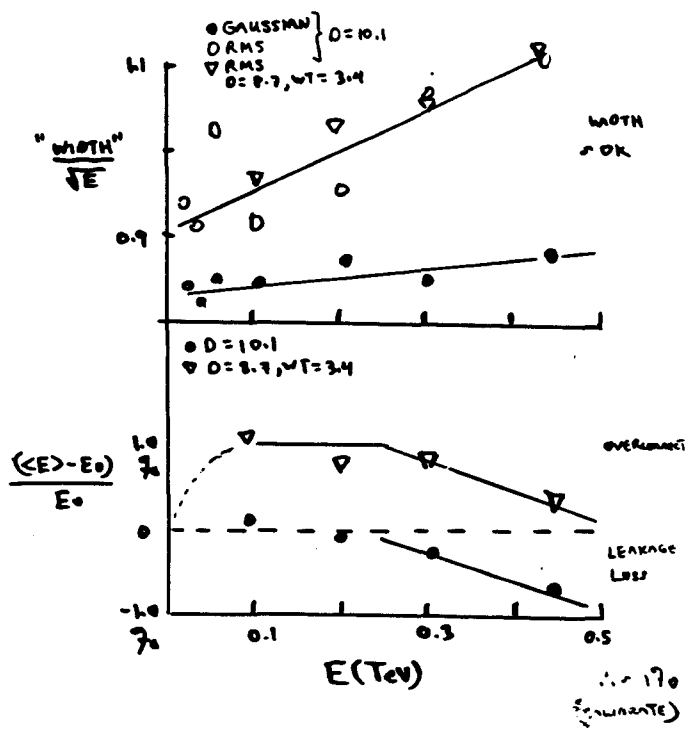


∴ ~ 17% (GUARANTEE)

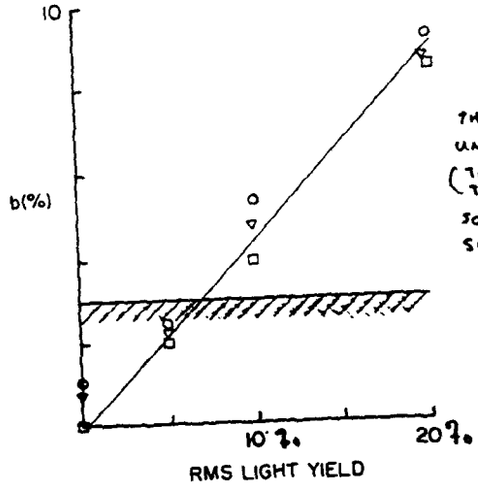
WORK ON ENGINEERING SPEC FOR SAMPLING CALORIMETER (GENERIC) THICKNESS VARIATIONS

b

LABE DATA, 100, 200, 450

NO INDUCED NON-LINEARITY

h DATA



THIS IS UNCALIBRATED (TOWER BY TOWER) SO 4% IS SAFE

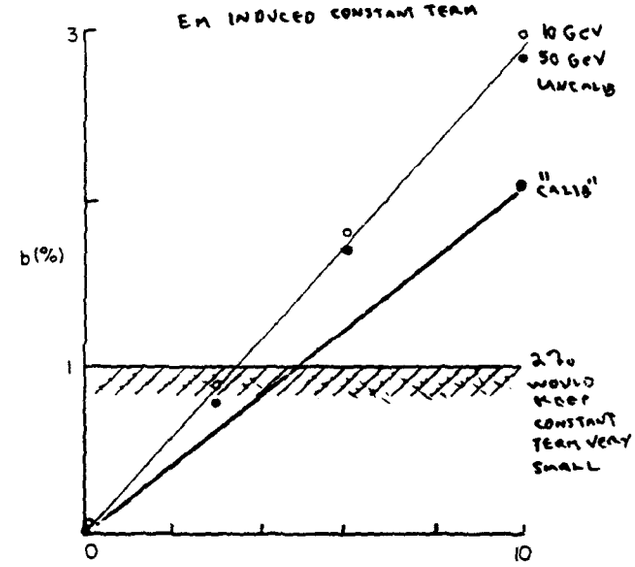
[CALIBRATION ALLOWS YOU TO MEASURE THE PLATE THICKNESS @ 0.5 TOWER]

e

(DEPENDS SOMEWHAT ON # OF SAMPLES ⇒ THIN PLATES)

EGS WORK (J. MARRAFINO)

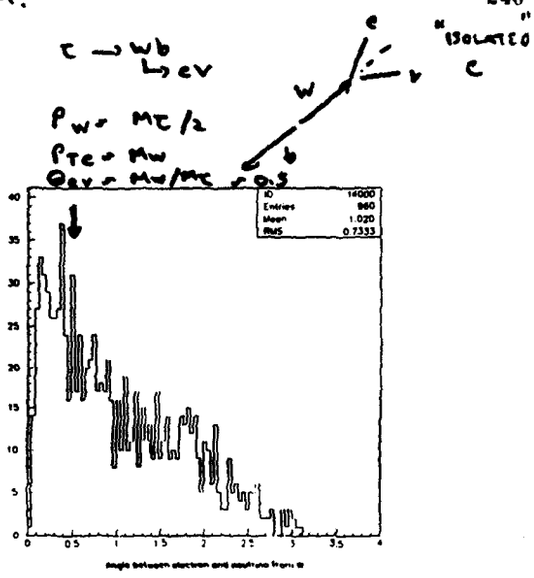
EM INDUCED CONSTANT TERM



II. WHAT ABOUT ⊥ SEGMENTATION FOR EM?

$\tau \to W\nu$
$\hookrightarrow e\nu$

$P_W = M_\tau/2$
$P_{T\tau} = M_W$
$Q_{ev} = M_W/M_\tau \sim 0.5$

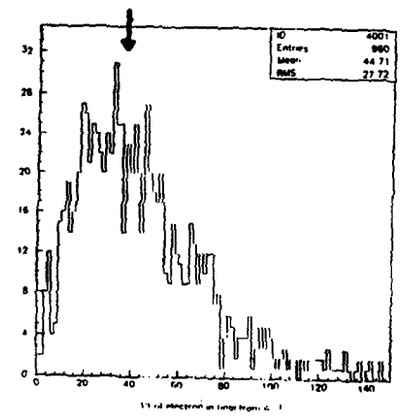


Qev

WHAT ABOUT ISOLATED e?

$P_{T\tau} \sim P_W/2 \sim M_\tau/4$

~ 37.5 GeV

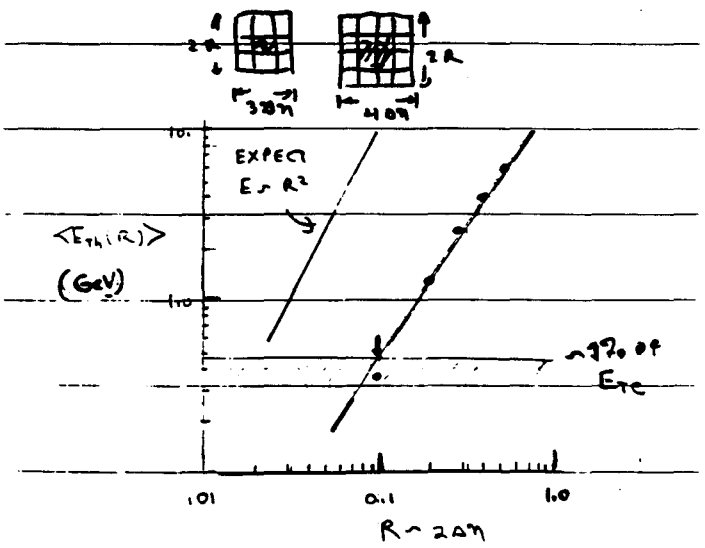


$(P_T)_e$

SCALE IS 1% PILEUP FOR $(0.05)^2$
CAN USE R^2 PILEUP, R FLUCTUATIONS

MONTE CARLO RESULTS

W → eν , e ISOLATION



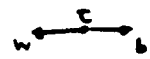
⇒ Δη ~ 0.05

TRANSVERSE SEGMENTATION
AND τ DECAYS

HOW ABOUT
NON-ISOLATED
DECAYS e

τ → Wb

$P_b \sim M_\tau/2$



b → c e ν

$(P_\perp)_e \sim M_b/3$

$(P_\parallel)_e \sim P_b/3$

$\theta_{ee} \sim 2M_b/P_b$

$\boxed{\theta_{ee} \sim M_b/M_\tau}$

ISOLATED e , $M_\tau \sim 150$ GeV

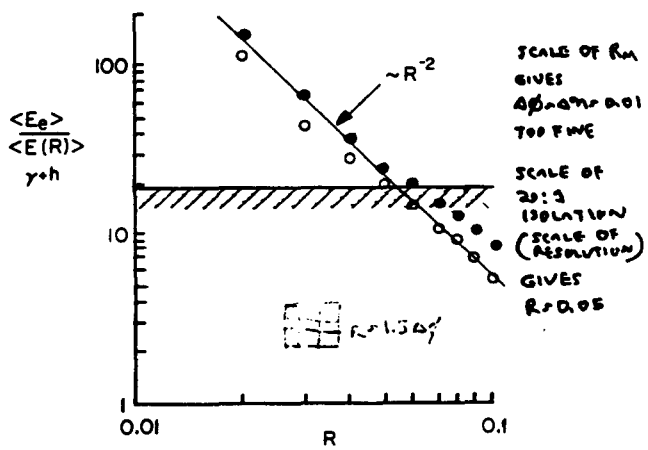
$\theta_{ee} \sim 0.03$

∴ COULD BE A DETERMINING FACTOR

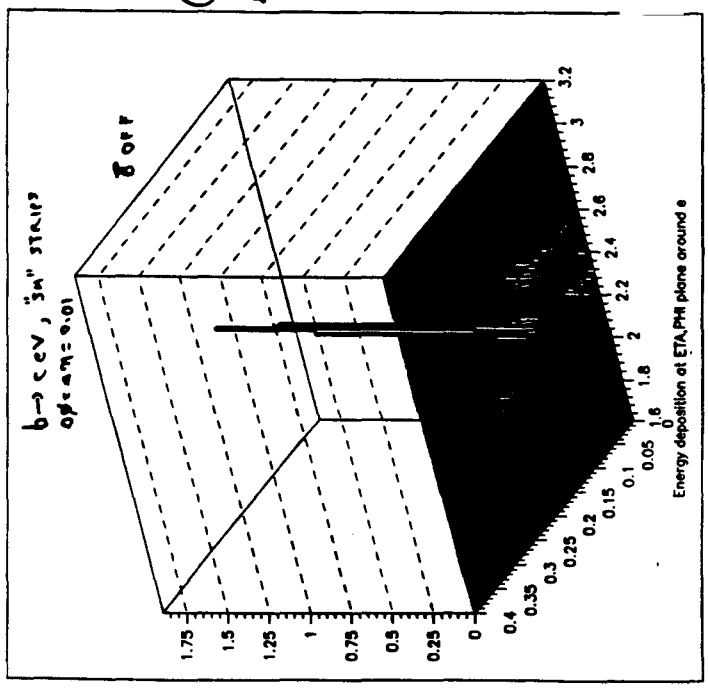
τ
↳ W b → c e ν
↳ e ν

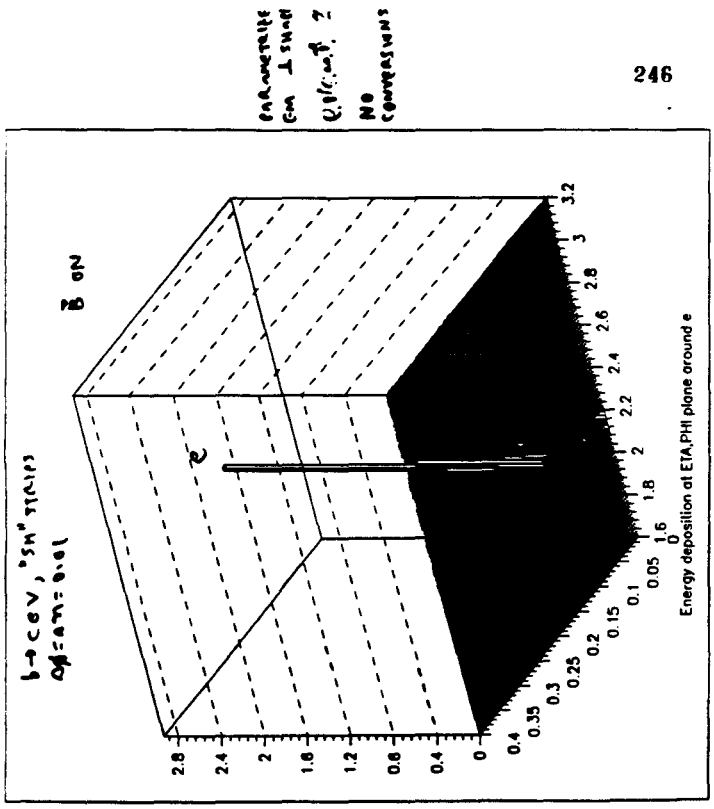
e FROM b
"ISOLATION"

PILEUP GOES AS ~ $1/R^2$
[• B OFF , ○ B ON]



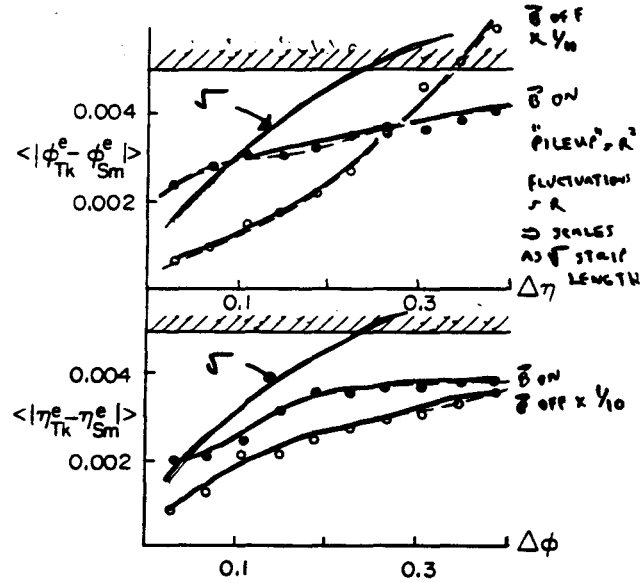
(W, WW)
Ρ^γ, γ, ?





"SM" STRIPS = 0.01

COMPARE e POSITION
FROM "TRACKING" ≡ EXACT
TO
CG. OF 3 STRIPS
AS A FUNCTION OF STRIP LENGTH



⇒ STRIP LENGTH UP TO
~0.5 IS NOT TOO BAD

EFF 8/6/91

ASSOCIATED HIGGS PRODUCTION

K. EINSWEILER

Associated Higgs Production

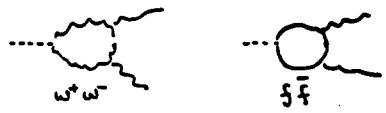
→ vital component of SDC strategy for intermediate mass Higgs

$W+H$, $t\bar{t}+H$ cover region $80 \lesssim m_H \lesssim 140$

Assume $H \to \gamma\gamma$ only

} other possibilities:
- W^+W^- · poor mass resolution
- $b\bar{b}$
- $\tau\tau$ · peak at $\sim m_Z$

$Br(H \to \gamma\gamma) \sim 5-20 \times 10^{-4}$ throughout this region



large, positive — small, negative

model dependence not yet well known

} Gunion & Haber }

→ Thanks to Ian Hinchliffe for recalculating processes and installing them in PAPAGENO

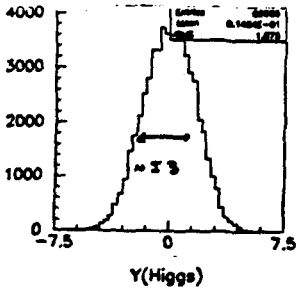
Detection : 1 lepton
2 photons

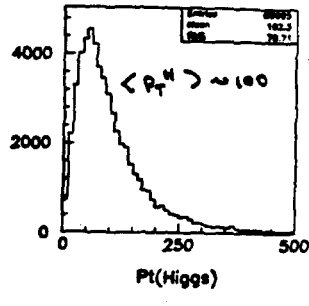
Kinematics for two processes are very different ...

1) $W+H$ for small m_H is a small $\hat{s}$ process
→ produced H has broad rapidity and narrow p_T distribution
→ poor acceptance

2) $t\bar{t}H$ much more central
→ good acceptance
(assume $m_t = 150$, results not strong function of this value)

~ 80 - 90 % of highest p_T leptons come from $t \to W$ not from b, c, ...
→ isolated

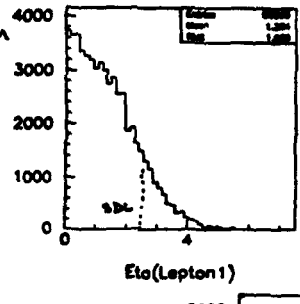


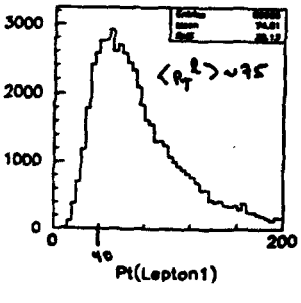


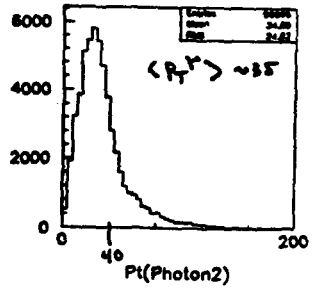
252

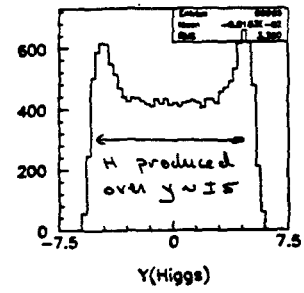
$t\bar{t}+H$ production

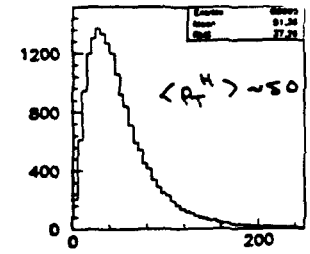
$m_H = 80$ GeV





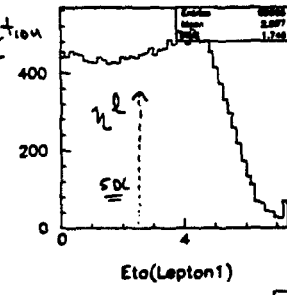




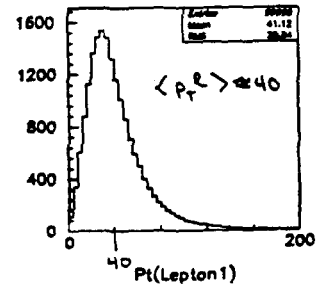


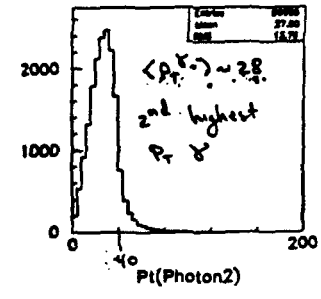
$W^+ + H$ production

$m_H = 80$ GeV



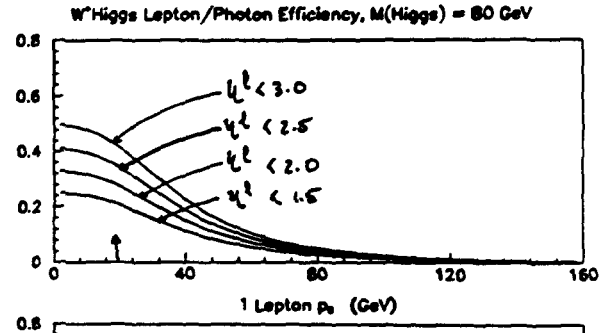
η^ℓ extends to beyond 5

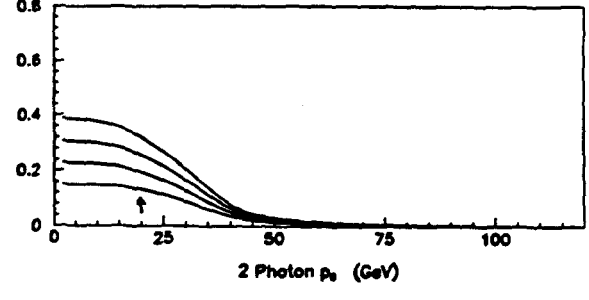




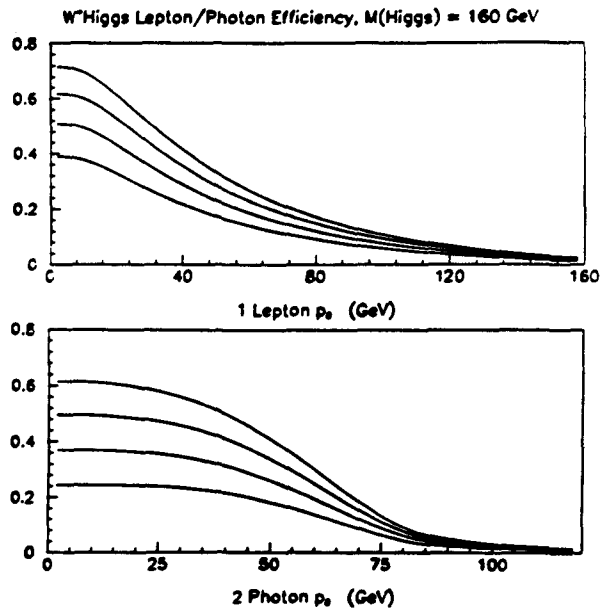
- Highest p_T lepton vs threshold
- 2nd highest p_T photon vs threshold

$p_T > 20$ is appropriate



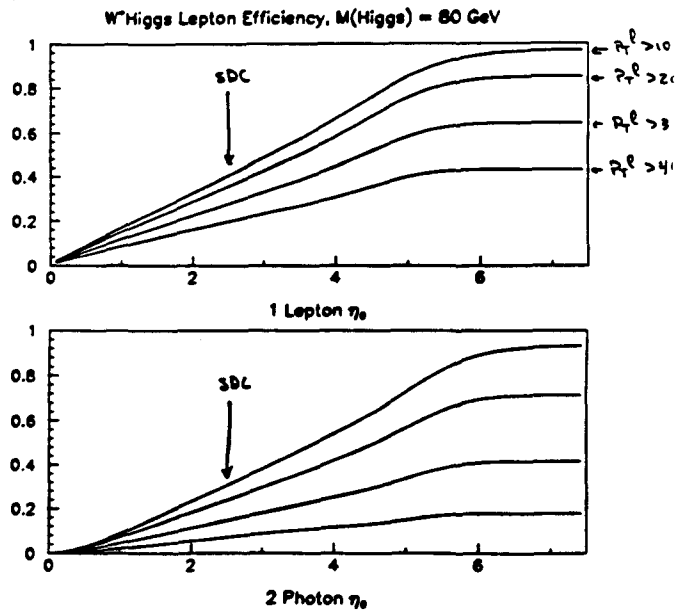


254

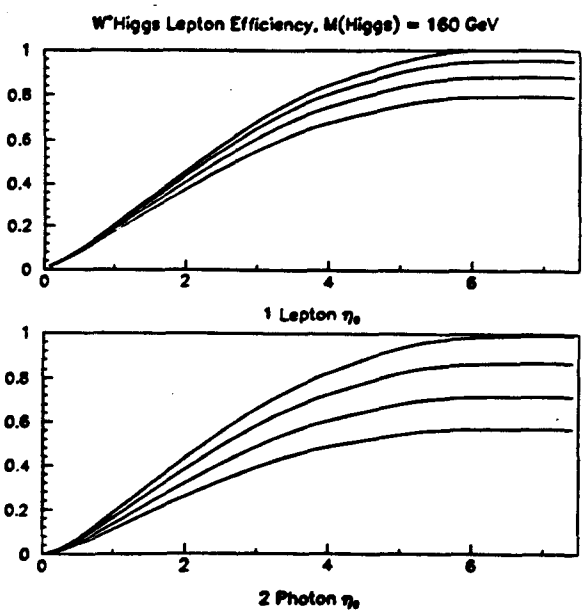


255

- smallest η lepton
- 2nd smallest η photon

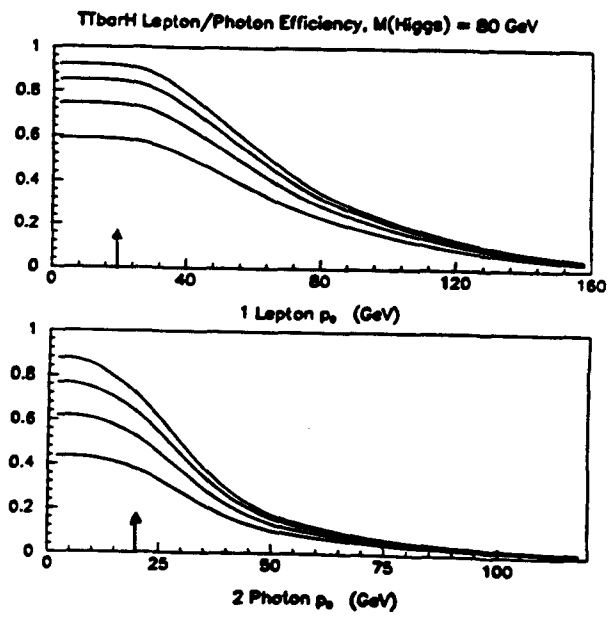


256

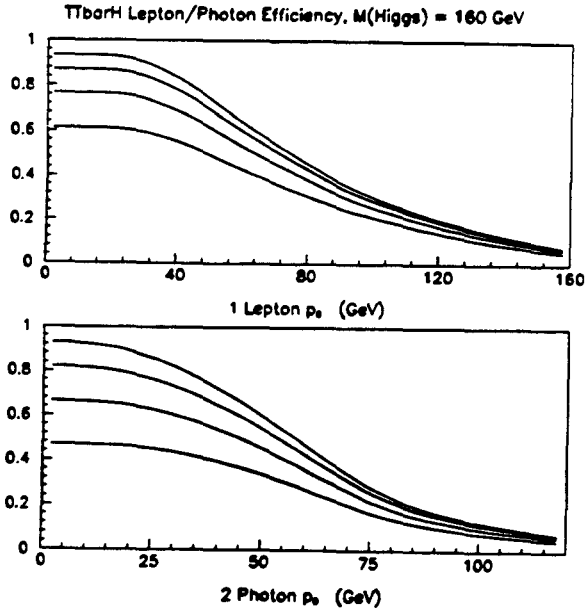


257

- Highest p_T lepton vs threshold
- 2nd highest p_T photon vs threshold

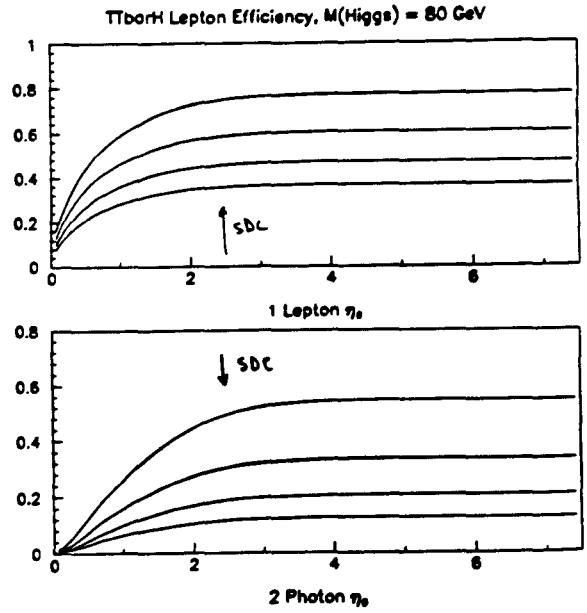


258

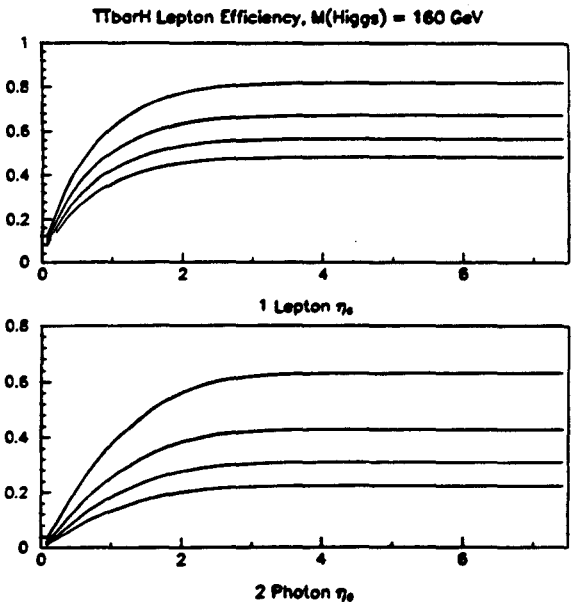


259

- smallest η lepton
- 2nd smallest η photon



260



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Acceptances

for $P_T^\ell, P_T^\tau > 20$ GeV, $|\eta| < 2.5$

$t\bar{t}H$	WH	m_H
~55%	~18%	80
~62%	~25%	100
~67%	~30%	120
~70%	~34%	140
~72%	~38%	160

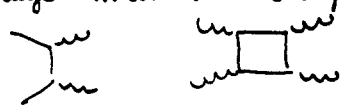
note: BR $(H \to \gamma\gamma)$ falls by ~ factor 4 from $m_H = 140$ to $m_H = 160$ due to opening of $H \to WW$ channel ...

EM Resolution Requirements

⇒ require evaluation of backgrounds to understand S/N

recall : $H \to \gamma\gamma$

· large irreducible background



QCD 2-γ

large reducible background

QCD 2-jet

Here : require 1 lepton, 2 γ, $P_T > 20$

ignore topology cut $\Delta R > 0.4$ between outgoing particles { · removes background singularities · isolates lepton, gammas

it is a "small" effect on the signal ($\lesssim$ 20%)

Backgrounds considered :

irreducible { $W\gamma\gamma$, $t\bar{t}\,\gamma\gamma$

reducible { $b\bar{b}\,\gamma$, $b\bar{b}\,\gamma\gamma$

- rely on recent calculation of $q\bar{q}\gamma\gamma$ from Kunszt & Stirling (code not yet available)

  ⇒ larger background than LoI ...

- apply .85 efficiency / lepton as in LoI

  { · calorimeter requirements document states "goal" of 90% global electron efficiency

  → inconsistent with yesterdays "materials" conclusions?

  ⇒ argue for "goal" of ~10% of X_0 at $\eta = 0$ including internal brem

Consider two different sampling calorimeter resolutions :

good : $\frac{10\%}{\sqrt{E}} \oplus .25\%$

poor : $\frac{30\%}{\sqrt{E}} \oplus 2\%$

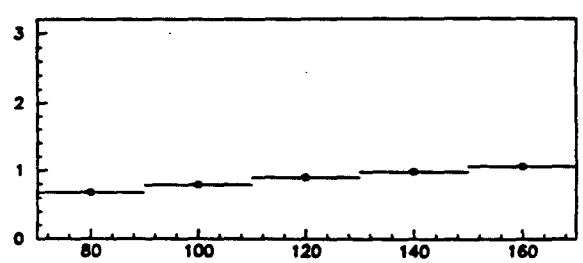
in intermediate Higgs region, both stochastic and constant terms are important

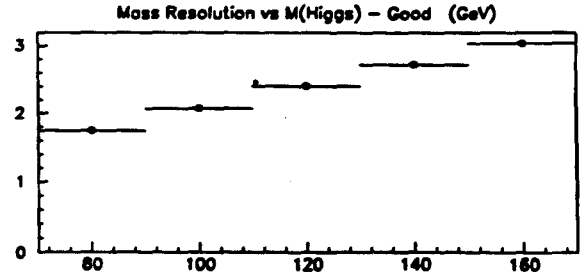
⇒ above calorimeters differ by ~ factor 3

Mass Resolution ($\sigma(m_{\gamma\gamma})$) for $t\bar{t}H$ final state for different values of m_H

$m_H = 80$ ~ .6 GeV
~ 1.8 GeV

(W+H results ~ identical ...)

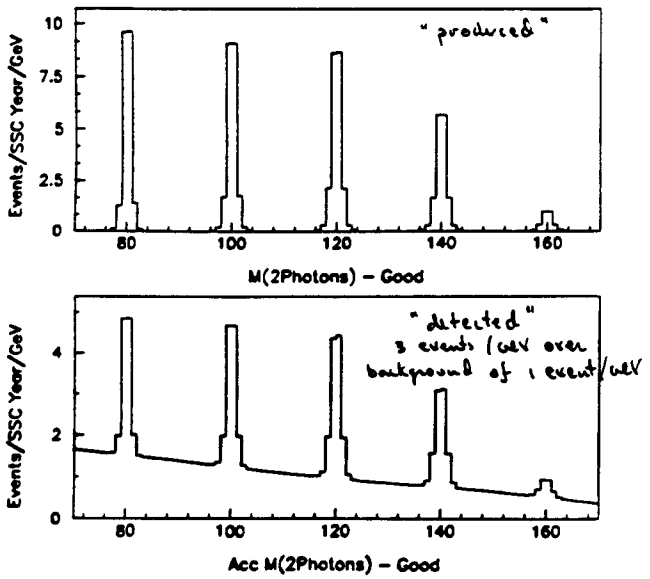




$t\bar{t}H$ process

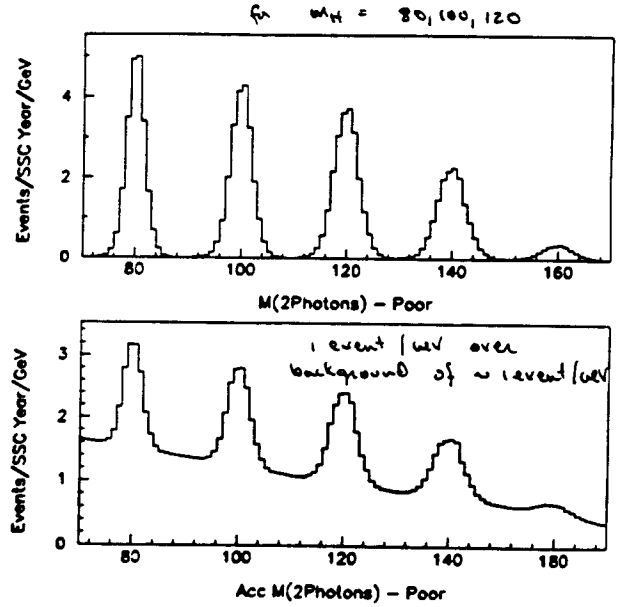
$m_H = 80 \sim 120$ ~ 20 events produced
~ 8 events detected

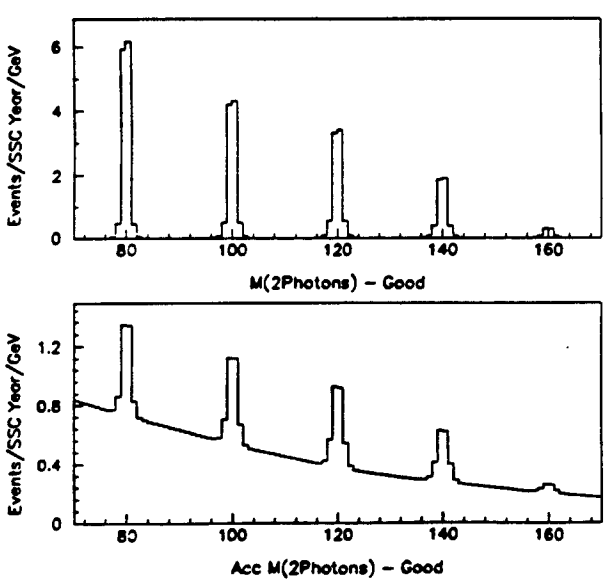
for ± 2 GeV window ($\gtrsim 2\sigma$)
background = 10, 8, 6 for m_H = 80, 100, 120

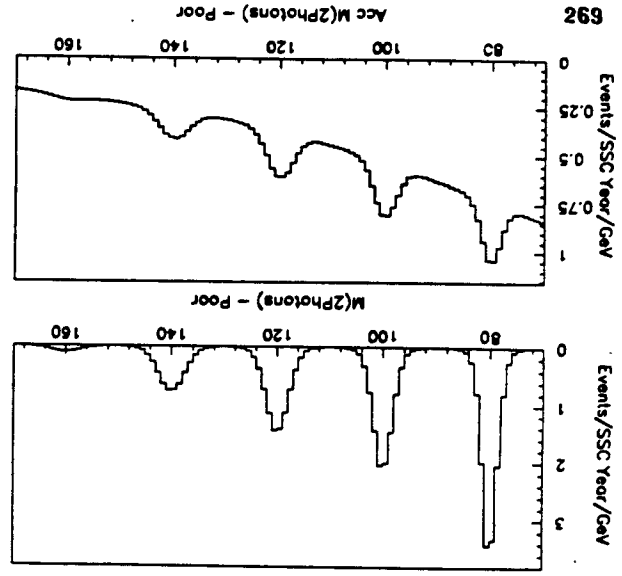


$t\bar{t}H$ process

for ± 4-5 GeV window ($\gtrsim 2\sigma$)
background = 20, 20, 16 events
for m_H = 80, 100, 120







Conclusions:

Quality EM calorimetry is vital for SDC to remain competitive on intermediate Higgs searches

- Associated Higgs mechanisms can be studied with a sampling calorimeter, but both constant and stochastic terms are important.

"factor 3" ~ S/N

- Efficiency for low P_T ($\lesssim 20$ GeV) leptons / photons is vital for intermediate mass Higgs physics

"factor 2" ~ S/N

{ ~ 10 events / SSC year over non-zero backgrounds }

- Full coverage for $\mu/e/\gamma$ also vital

"factor 2" ~ S/N

FORWARD CALORIMETRY STUDIES

M. BARNETT

What is the

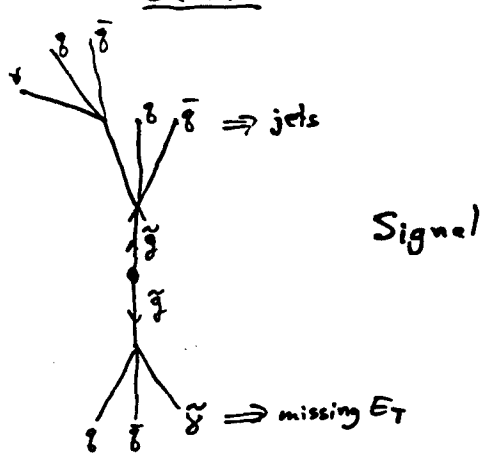
PHYSICS Impact

of Staging the

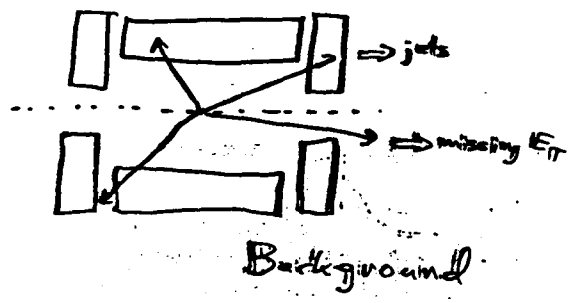
Forward Calorimeter

?

Gaino

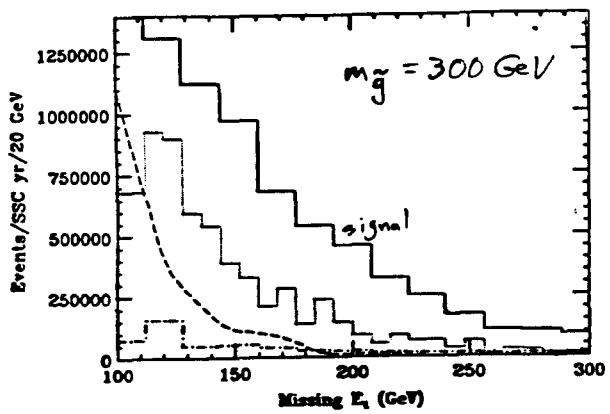


Signal

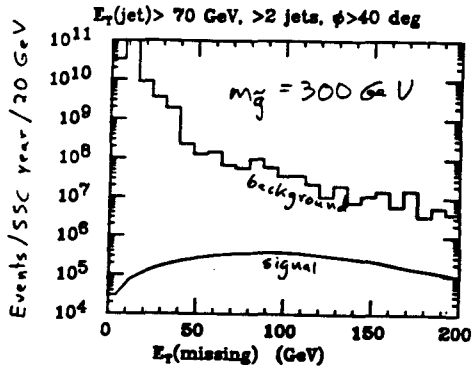


Background

With Forward Calorimeter



No Forward Calorimeter



Heavy [illegible]

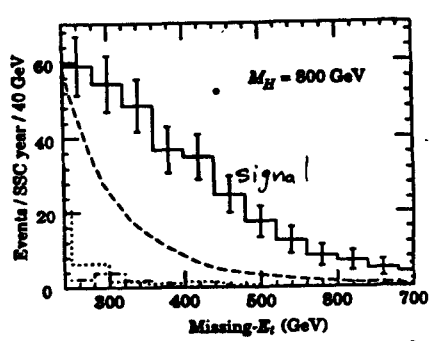
$(\tilde{\chi} \to \nu\bar{\nu}) = \gamma B(\tilde{\chi} \to \nu\bar{\nu})$ [illegible]

Signal

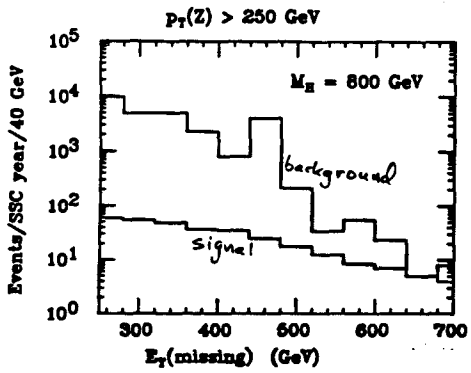
[illegible] missing E_T

Background

With Forward Calorimeter



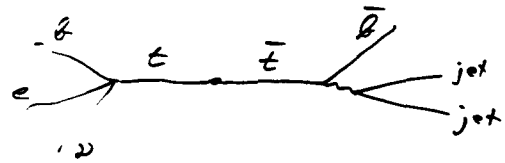
No Forward Calorimeter



4th Generation Top Quark

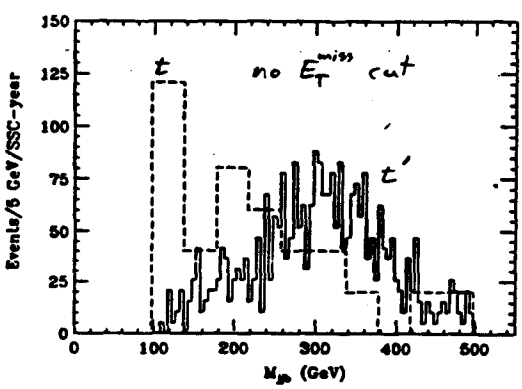
$m_t = 150$ GeV

$m_{t'} = 400$ GeV



$m(t) = 150$ GeV

$m(t') = 400$ GeV



with E_T^{miss} cut

t reduced by 20.

t' reduced by 1.4

Heavy Higgs Search ($m_H > 2M_Z$)

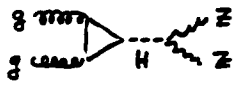
from Vernon Barger

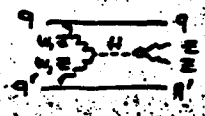
Branching fractions

$B(H \to ZZ \to 4\ell) \simeq 0.14\%$	small, but "gold plated"
$B(fH \to ZZ \to \ell\bar{\ell}, \nu\bar{\nu}) \simeq 0.8\%$	"silver plated"
$B(H \to W^+W^- \to \ell\bar{\nu}, \bar{\ell}\nu) \simeq 3.1\%$	only approx. reconstruction of m_H from m_T but still OK!
$B(H \to W^+W^- \to \ell\bar{\nu}, \bar{q}q) \simeq 20\%$	serious Wjj bkgd with $M_{jj} \approx M_W$ $(S/B \lesssim 1)$

Seymour
Freidemann
Kane-C.P. Yuan

Production:

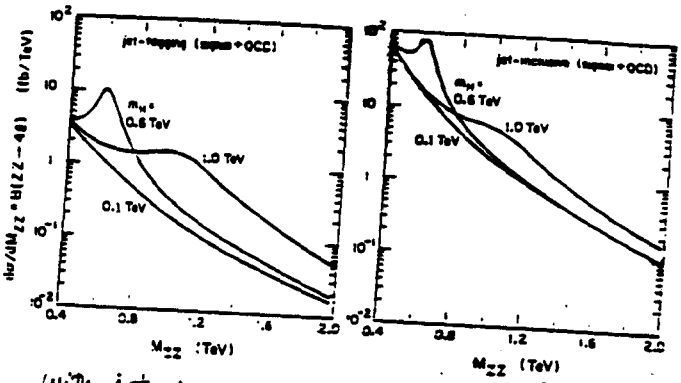




dominates jet inclusive for $m_H \lesssim 0.6$ TeV

forward jets can be tagged

Comparison of jet-tagging and jet-inclusive results. [Jet-inclusive includes full order α_s QCD corrections of Ohnemus-Owens]



with jet tagging, Higgs signal appears as a sharp resonance (m_H=0.6) or a flat plateau (m_H=1)

with jet inclusive, QCD bkd is appreciable fraction of m_H = 1 TeV signal, making definite identification questionable

SSC Events (M_{ZZ} > 0.5 TeV)

$pp \to H \to ZZ \to 4\ell$

Signal $\equiv N(m_H) - N(m_H = 0.1)$

m_H (TeV)	Higgs signal 0.6	0.8	1.0	QCD + electroweak background
jet-inclusive events/10 fb^{-1}	84	43	26	49
significance $S/\sqrt{B}$	12.0	6.1	3.7	
single jet-tag events/10 fb^{-1}	13	11	9	4.2
significance $S/\sqrt{B}$	6.3	5.4	4.4	

Assumes no uncertainty on bgkd normalization. Once bkg. normalization uncertainities are considered, jet tagging yields a much more significant M_H = 1 TeV signal than jet inclusive.

∴ Single jet tag is a powerful tool in heavy Higgs search, especially for upgraded $\mathcal{L}$. Same single jet tagging method can be applied to $H \to ZZ \to \ell\bar{\ell}\nu\bar{\nu}$.

If SDC does not have a forward calorimeter on the first day, it is possible that the discovery of new physics will be left to GEM or LHC experiments.

Simulation for SDC Muon System

6-Aug-91 S. Kunori

Physics (Input)
↓
Detector Simulation
↓
Event Reconstruction
↓
Analysis
↓
Physics (Output: reconstructed)

Functions

Barrel: Trigger
Muon ID
Momentum Measurement (combined / stand alone)

Forward: Momentum Meas. (stand alone / combined)
Muon ID
Trigger

Acceptance : S Errede

Δp/p : J. Wise

Triggers : R. Thun
T. Zhao
S. Behrends
H. Imagaki

Neutrons : K. Johns

SDC SIM : H. Paudi + U. Sloan

S. Errede
Univ. of Illinois
May 30, 1991

SDC Muon Physics Acceptance Impact if Delete Intermediate Muon System

The Isajet v6.24 Monte Carlo was used for muon acceptance studies for various muon benchmark physics processes summarized below.

Requirements on muons:

a.) All muons to be in central (barrel) region, |eta mu| < 1.5
b.) For W -> mu nu, muon with Pt > 20 GeV/c (~20% reduction)
c.) For Z0, Z' -> mu+mu-, at least one muon with Pt > 20 GeV/c
(~19%, ~4%, ~1.4% reduction for Z0, Z'(200) and Z'(500) respectively)
d.) For ZZ pairs, Higgs -> 4 mu, at least 2 muons with Pt > 20 GeV/c
(~0.7%, 0.4%, 1.1% reduction for ZZ pairs, H(400) and H(800) resp.)

[A] W+_ -> mu+_ nu

Sigma*B(W+_ -> mu+_ nu) = 34.7 nb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 80%; after Pt cut imposed, geometrical acceptance reduced from 58.0% (LoI) -> 35.5% (C-mu only)
=> 3.5 x 10**8 total events produced
=> 1.6 x 10**8 LoI (C-mu + I-mu) events
=> 8.9 x 10**7 C-mu only events) 1.6

[B] Z0 -> mu+mu-

Sigma*B(Z0 -> mu+mu-) = 3.3 nb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 81%; after Pt cut imposed, geometrical acceptance reduced from 47.0% (LoI) -> 22.8% (C-C only)
=> 3.3 x 10**7 total events produced
=> 1.3 x 10**7 LoI (C-C + C-I + I-I) events
=> 6.1 x 10**6 C-C only events) 2.1

[C] Z' -> mu+mu- (Mz' = 200 GeV/c2)

Sigma*B(Z' -> mu+mu-) = 144 pb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 96.1%; after Pt cut imposed, geometrical acceptance reduced from 48.0% (LoI) -> 21.8% (C-C only)
=> 1.4 x 10**6 total events produced
=> 6.6 x 10**6 LoI (C-C + C-I + I-I) events
=> 3.0 x 10**5 C-C only events) 2.2

[D] Z' -> mu+mu- (Mz' = 500 GeV/c2)

Sigma*B(Z' -> mu+mu-) = 0.7 pb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 98.6%; after Pt cut imposed, geometrical acceptance reduced from 61.0% (LoI) -> 29.9% (C-C only)
=> 7000 total events produced
=> 4210 LoI (C-C + C-I + I-I) events
=> 2064 C-C only events) 2.0

[E] ZZ pairs -> 4mu

Sigma*B(ZZ -> 4mu) = 25 fb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 99.3%; after Pt cut imposed, geometrical acceptance reduced from 32.2% (LoI) to 9.1% (C-C only)
=> 250.0 total events produced
=> 79.9 LoI events
=> 22.6 C-C C-C only events) 3.5

[F] Higgs-> ZZ -> 4mu (Mh=400 GeV/c2)

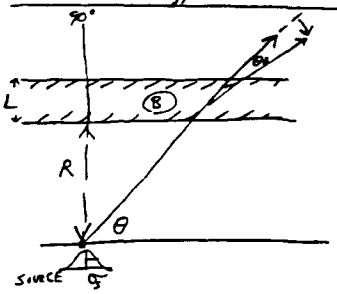
Sigma*B(Higgs -> ZZ -> 4mu) = 8.8 fb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 99.9%; after Pt cut imposed, geometrical acceptance reduced from 48.2% (LoI) to 17.7% (C-C only)
=> 88.0 total events produced
=> 43.1 LoI events
=> 15.5 C-C C-C only events) 2.8

[G] Higgs-> ZZ -> 4mu (Mh=800 GeV/c2)

Sigma*B(Higgs -> ZZ -> 4mu) = 1.5 fb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 98.9%, after Pt cut imposed, geometrical acceptance reduced from 66.3% (LoI) to 29.7% (C-C only)
=> 15.0 total events produced
=> 9.8 LoI events
=> 4.4 C-C C-C events) 2.2

Recalculate trigger resolution effects

R. Thun



$$\theta_B = \frac{0.3BL}{p\sin\theta}$$ 289

$$\delta\theta_s \approx \frac{\sigma_s \sin\theta}{(R+L)/\sin\theta} = \frac{\sigma_s \sin^2\theta}{(R+L)}$$

$$\delta\theta_{MS} = \frac{.015}{p}\sqrt{X_{em}+X_{lead}+X_{Fe}}$$

$$\cong \frac{.015}{p}\sqrt{30 + 90 + \frac{L/\sin\theta}{0.0176}}$$

(30 ← lead; 90 ← 9λ Fe + SCINT; $\frac{L/\sin\theta}{0.0176}$ ← Toroid)

$\delta\theta_I$ ← intrinsic depends on drift cl. characteristics

Particle momentum p

$P_\perp = p\sin\theta$

assume $R = 7.24$, $L = 1.5$, $B = 1.8$, $\sigma_s = .05$

so, for 1.5m TOROID

				$P_\perp$ at which $\delta\theta_s = \delta\theta_{MS}$
at 90°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0057$	$\delta\theta_{MS} = \frac{0.215}{P_\perp}$	38 GeV
at 45°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0029$	$\delta\theta_{MS} = \frac{0.164}{P_\perp}$	57 GeV
at 30°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0014$	$\delta\theta_{MS} = \frac{0.128}{P_\perp}$	91 GeV

for 60m TOROID →

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$P_\perp$ for $\delta\theta_s = \delta\theta_{MS}$
90°	$0.54/P_\perp$	.0061	$0.199/P_\perp$	32.6 GeV
45°	↓	.0030	$0.850/P_\perp$	50.0
30°		.0015	$0.115/P_\perp$	76.7

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SUMMARY

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1.5m toroid

$P_\perp = 20$ GeV/c — all angles in mr.

θ	BEND θ_B	SOURCE $\delta\theta_s$	MULT. SCATT $\delta\theta_{MS}$	CH. RES $\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	40.5	5.7	10.8	1.9	12.4	0.31	0.12
45°	40.5	2.9	8.2	1.3	8.8	0.22	0.12
30°	40.5	1.4	6.4	0.9	6.6	0.16	0.12

$P_\perp = 40$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	20.3	5.7	5.4	1.9	8.1	0.40	0.12
45°	20.3	2.9	4.1	1.3	5.2	0.26	0.12
30°	20.3	1.4	3.2	0.9	3.6	0.18	0.12

1.0m toroid

$P_\perp = 20$ GeV/c — all angles in mr

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	27.0	6.1	10.0	1.9	11.9	0.44	0.12
45°	27.0	3.0	7.5	1.3	8.2	0.30	0.12
30°	27.0	1.5	5.8	0.9	6.1	0.23	0.12

$P_\perp = 40$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	13.5	6.1	5.0	1.9	8.1	0.60	0.12
45°	13.5	3.0	3.8	1.3	5.0	0.37	0.12
30°	13.5	1.5	2.9	0.9	3.4	0.25	0.12

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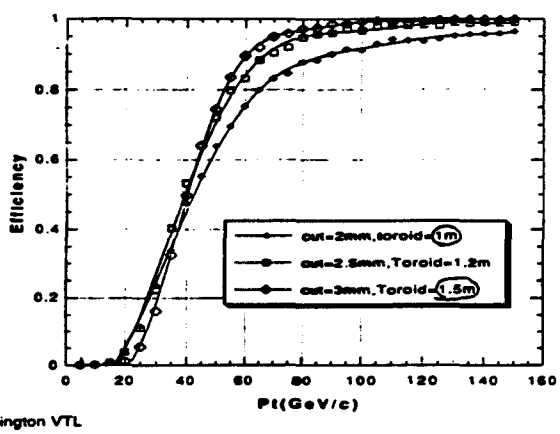
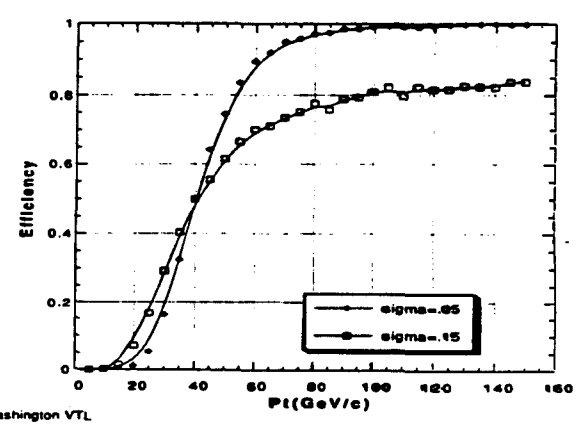
T. Zhao



J. Washington VTL

Fig. 3



U. Washington VTL

Fig. 4

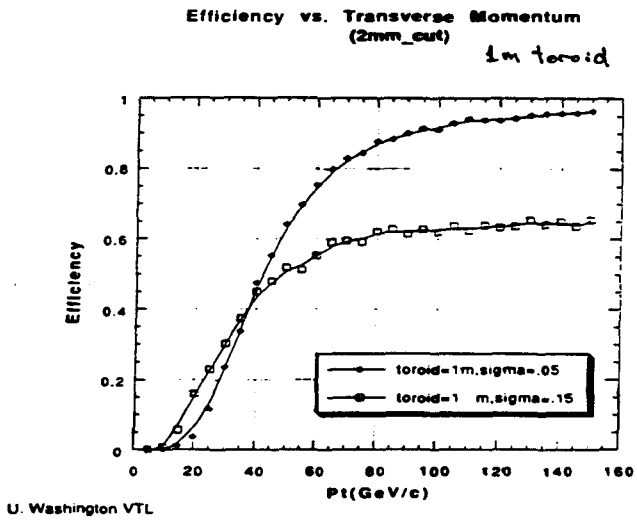


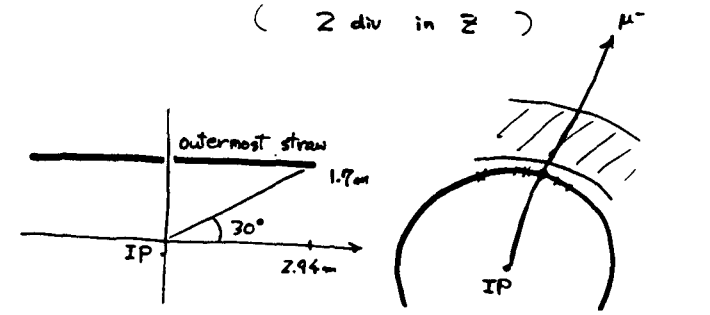
Fig. 5

IV. μ isolation in $t\bar{t}$ events

$t\bar{t}$
$\hookrightarrow b\,W^+$
$\hookrightarrow \mu^-\nu C$

Generator: PYTHIA 5.3
Top: $m_t = 150$ GeV/c
$B_0 = 2$ tesla
$\pi^\pm, K^\pm$ particles.

$\mu^\pm$: $P_t(\mu) > 10$ GeV/c
@ $r = 1.7$ m
$0 < z(\mu) < \frac{1.7\,m}{\tan 30^\circ}$ $(= 2.94\ m)$
or $-\frac{1.7\,m}{\tan 30^\circ} < z(\mu) < 0$
(2 div in z)

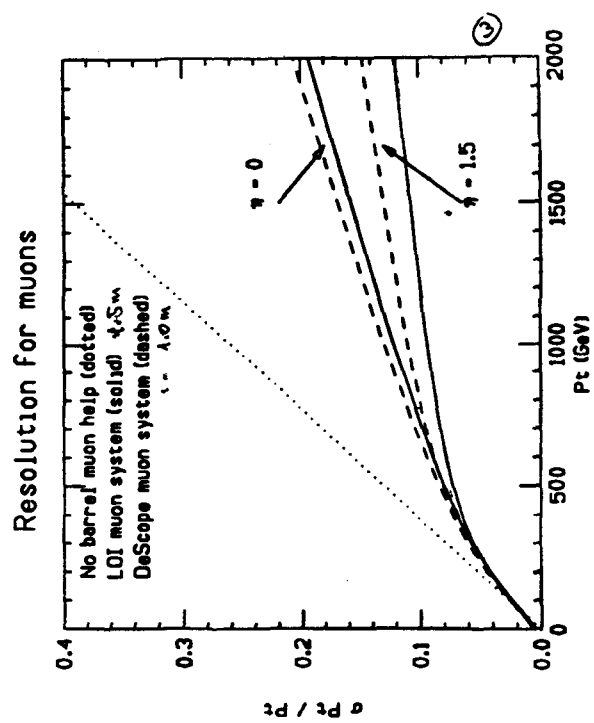


3. μ isolation in $t\bar{t}$ events

$t \to bW^+$
$\hookrightarrow \mu^-\nu C$

$P_t(\mu) > 10$ GeV/c
2 div. in z $\left(\begin{matrix} 0 < z < 3\,m \\ -3\,m < z < 0 \end{matrix}\right)$

- in $r\phi$ @ $r = 1.7$ m
  ($\sim$ 1 charged track/20 cm) per μ-track
  it is $\sim 2.7 \times$ (uniform distribution)
  but still very low density
- with P_t-information from toroid
  $\Delta(r\phi)\cdot P_t < 0.6$ m·GeV/c
  (~ 0.26 charged tracks)/μ



J. Wiss

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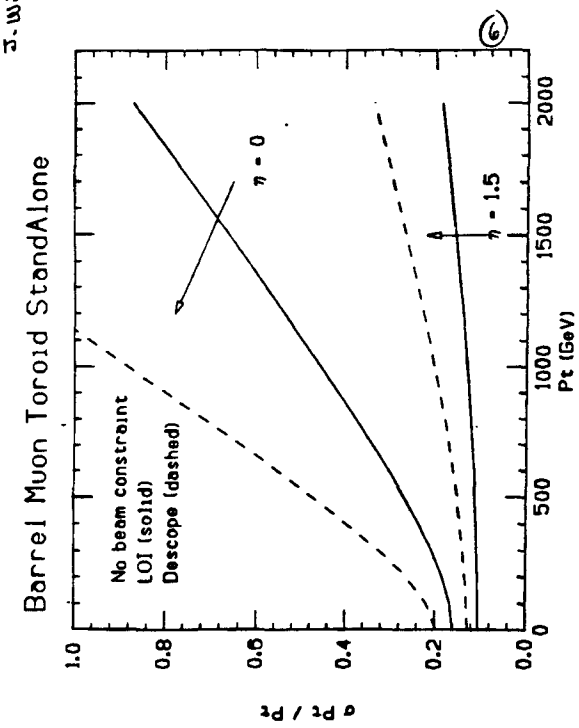
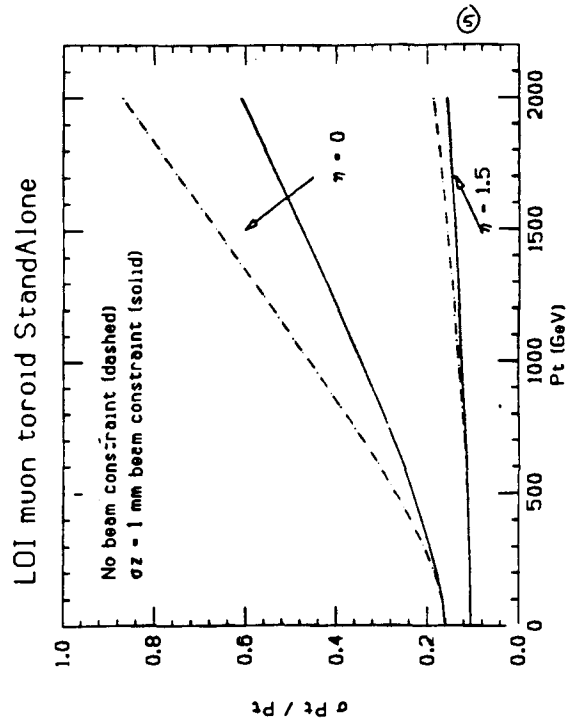
(6)



298

(5)



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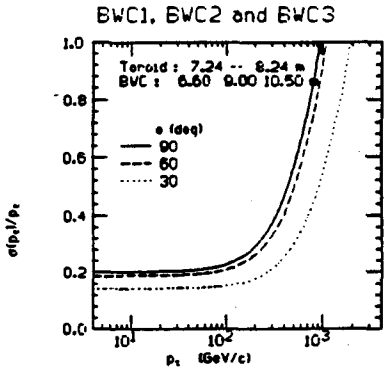


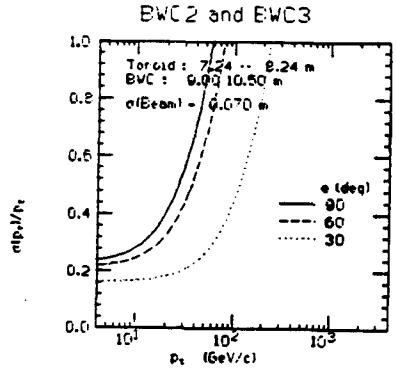
Toroid 7.24 - 8.24 m
$D_2 = 1$ m
BWC1 6.6 m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2 = 1.5$ m
$\sigma = 200\ \mu m$
(per supermodule)

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 1.044 \times 10^{-3} \right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2012 \right)^2 \right]^{1/2}$$

P_t (turn) = 193 GeV/c		@ $\theta = 90°$
207		60°
272		30°

θ \ P_t (GeV/c)	20	50	100	200
90°	0.202	0.208	0.227	0.290
60°	0.188	0.193	0.208	0.260
30°	0.143	0.145	0.152	0.176

300

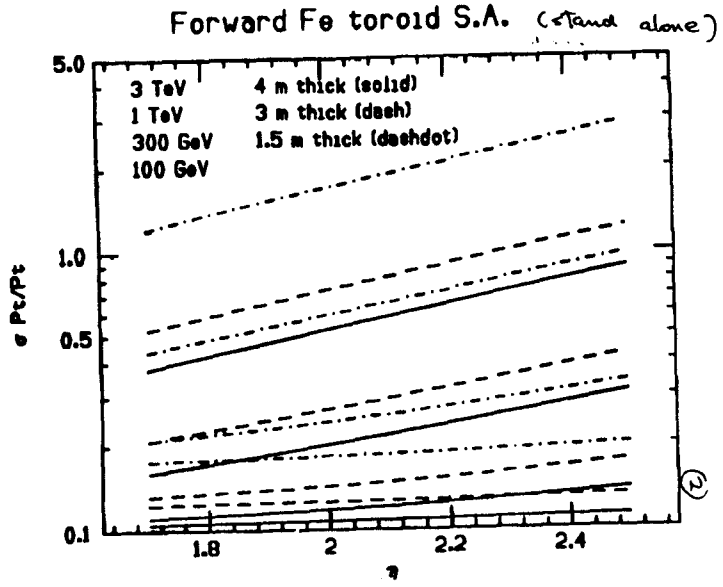


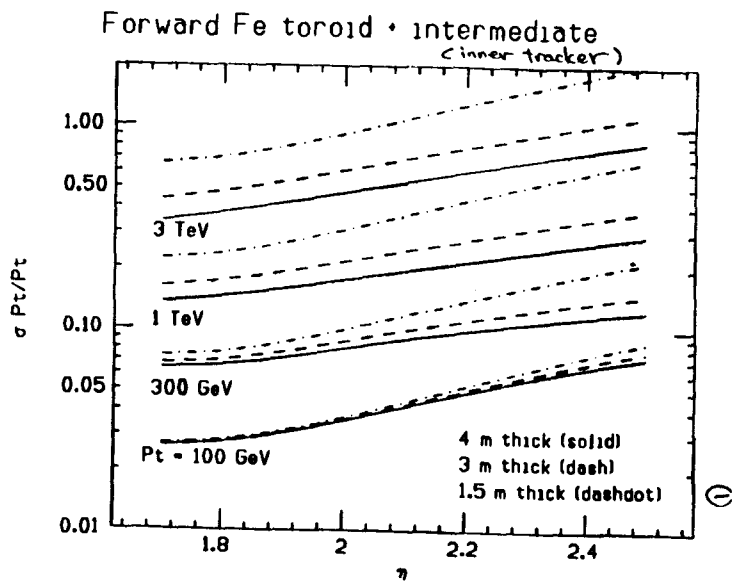
Toroid 7.24 - 8.24 m
$D_2 = 1$ m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2 = 1.5$ m
$\sigma = 200\ \mu m$
(per supermodule)
$\sigma_{beam} = 7$ cm

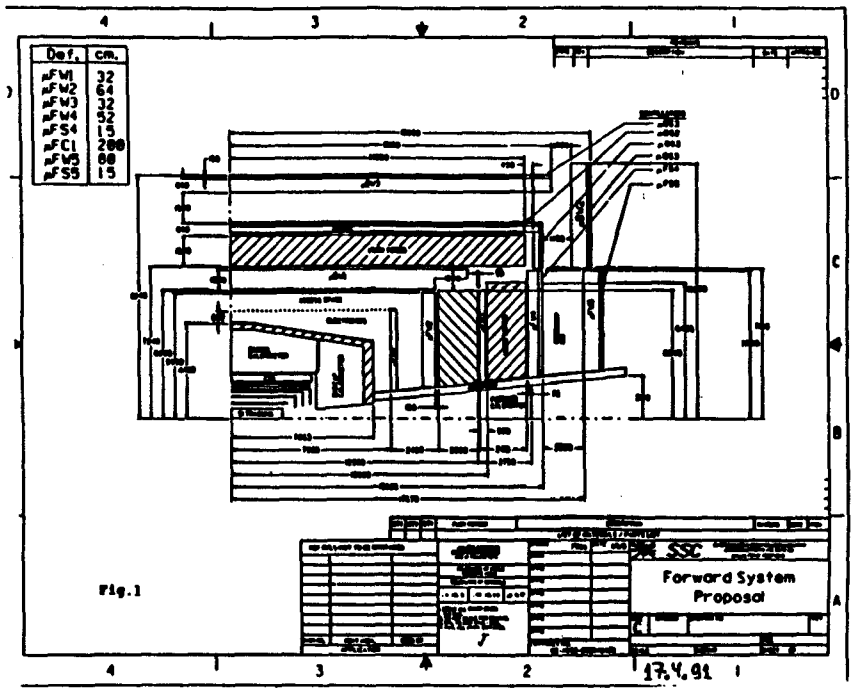
$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.415 \times 10^{-4} \right)^2 + \left(P_t \cdot \sin^2\theta \cdot 1.676 \times 10^{-2} \right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2296 \right)^2 \right]^{1/2}$$

P_t (turn) = 14 GeV/c		@ $\theta = 90°$
17		60°
39		30°

θ \ P_t (GeV/c)	10	20	50	100
90°	0.284	0.406	0.869	1.692
60°	0.248	0.330	0.664	1.276
30°	0.168	0.183	0.265	0.450







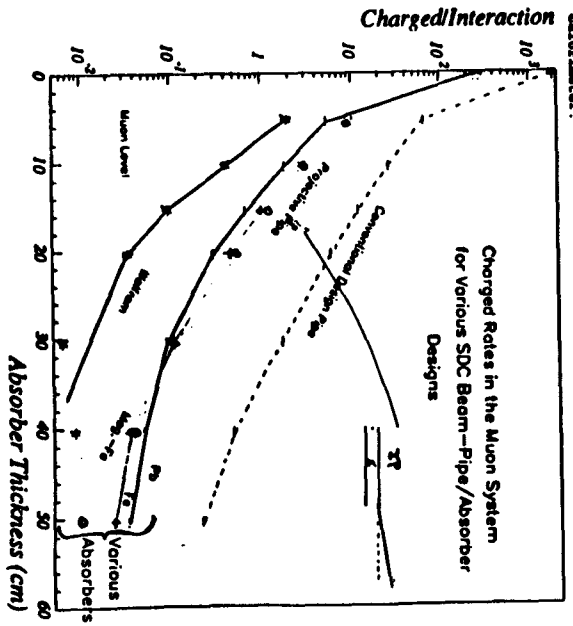


Fig.4. The integrated flux of the charged particles through the absorber vs absorber thickness for various designs. The uppermost curve corresponds to the conventional cylindrical pipe and the lead absorber. All other curves are for the projectile pipe design and different absorbers: lead, iron, aluminium and beryllium. All curves are normalized to one interaction in the IP. Thus, Level 1 charge rapidly the rate of charged particles (dominantly muons) coming through the endcap calorimeter.

A. Kulik
Y. Gornushkin

K. Johns

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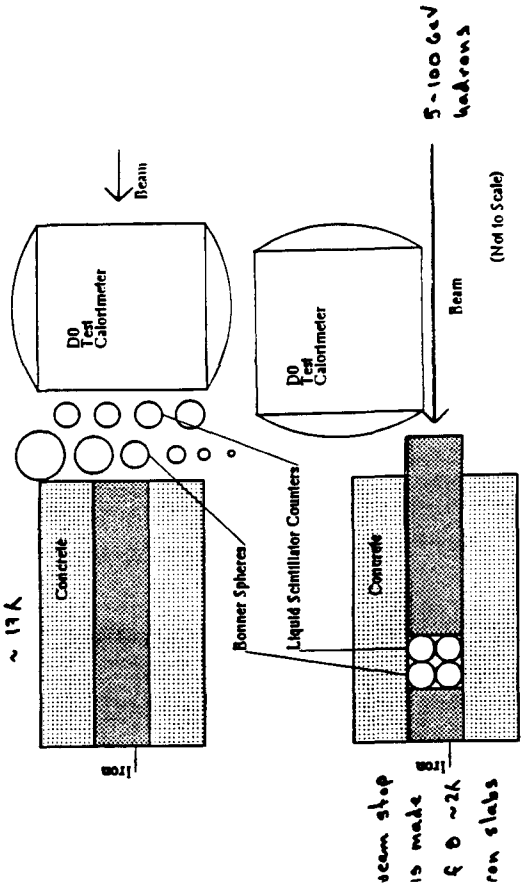

Plan Views of E821 Detector Configurations

Figure 1

R. Johns

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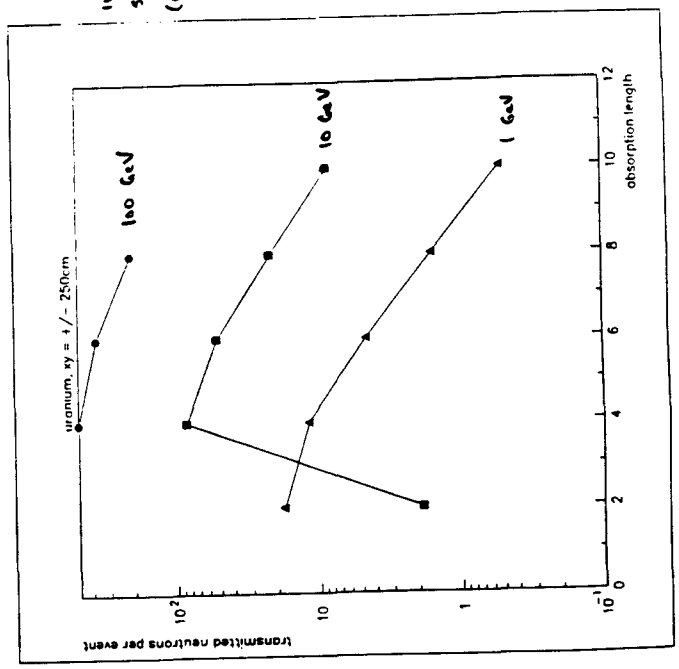
Incorrect scaling (weighting)



H. Daoudi
V. Sloanim

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Software:

- Detector Geometry (2 LoI designs)
- Wire chambers implemented (Barrel + Forward)
- Tracking info stored in data bank
- Option to include Inner detectors (WR, AN, ...)
- Smeared hits in wire chambers
- Option to vary Toroid thickness
- Option to remove forward absorber

Addition:

Track fitting

Missing:

Punch-through simulation

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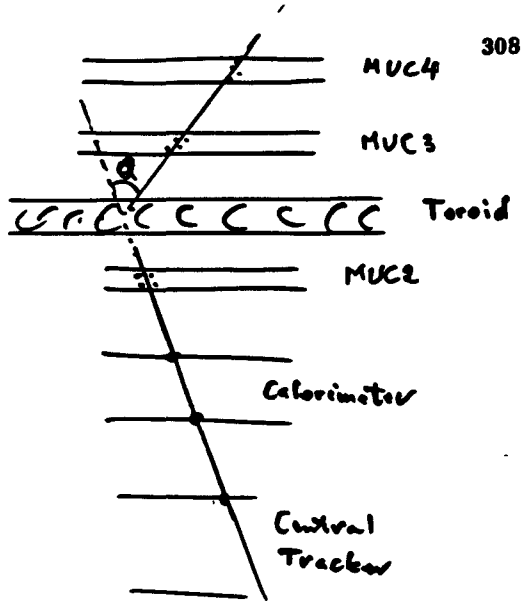
Resolution



Fit:

Orthogonal Reduction Algorithm

Fit a straight line before toroid
" " " " after "

Assume chamber resolution → 200 μm

Measure angular deflection

$\Rightarrow P \Rightarrow \frac{dP}{P}$

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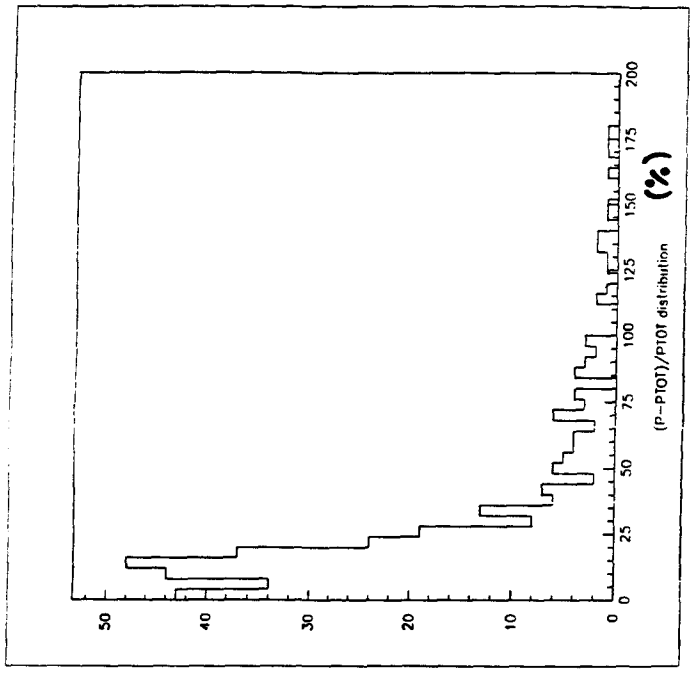

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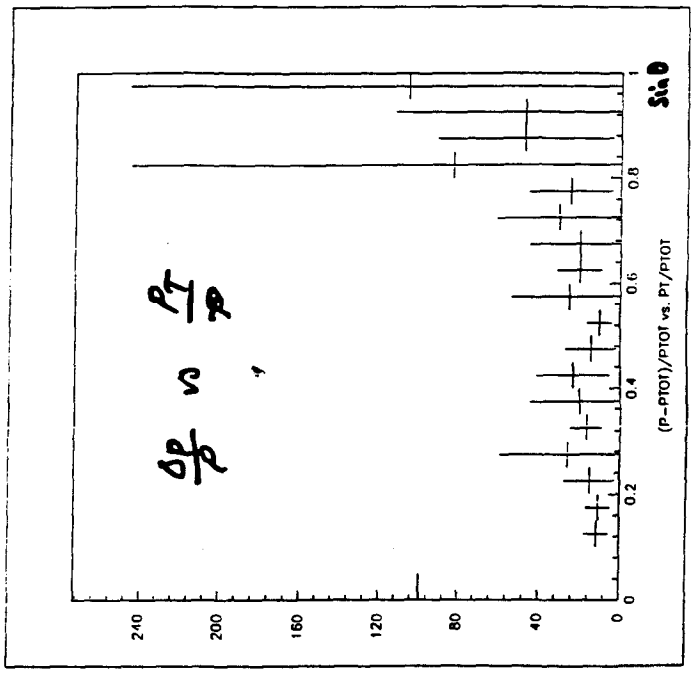

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Acceptance

LoI design 1 (Saint. cal.)

Pythia generator

Physics Processes:

$H^0 \to Z^0 Z^0 \to 2\mu^+ 2\mu^-$ 160, 400, 800 GeV

$W^+ W^-$ pairs

$W' \to \mu\nu$ 500, 1000, 2000 GeV

$Z' \to \mu^+\mu^-$ 1000, 4000 GeV

(1000 Events each)

Detectors turned on:

MU, AN, WR

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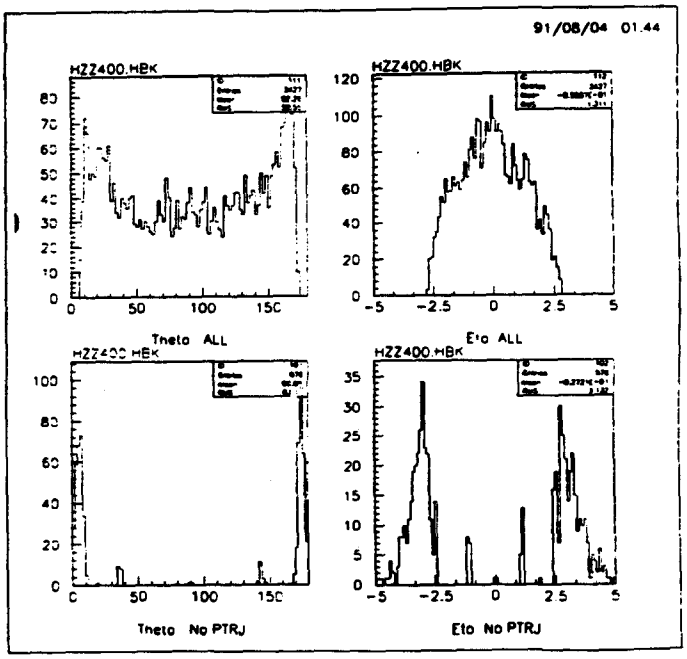
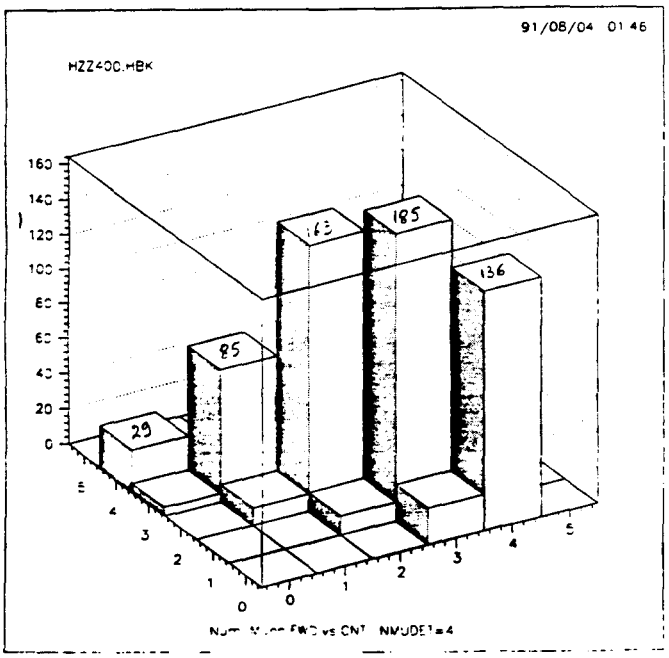




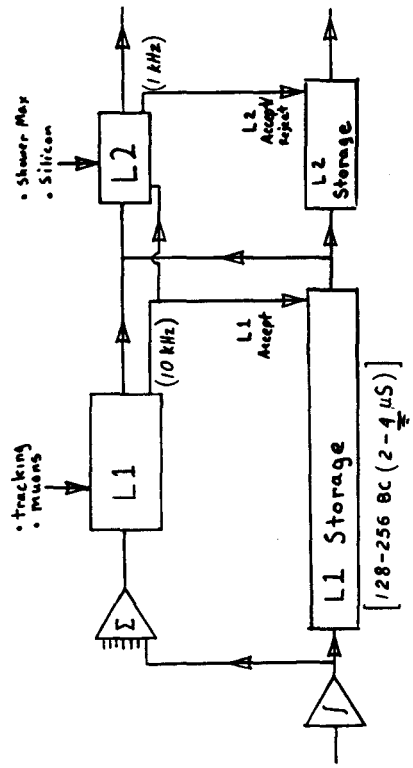
Greg Sullivan
Univ. of Chicago

Conclusion

1. Acceptance has been studied.
   with / w/o FWD muon system
   factor 2.8 loss for Higgs 400 GeV.
   to 4 μ's
2. Δp/p for toroid 1.5 m and 1 m were calculated.
3. Trigger efficiency (L1)
   Clear loss by reducing toroid thickness from 1.5m to 1.0m were seen.
4. BWL may be very important for L2 trigger and global pattern recognition.
5. SDCSIM started producing results.

SDC Level 1 Trigger

SDC Meeting
LBL
Aug. 5-10, 1991



L1/L2 Data Flow

Table 1. SDC DAQ Preliminary Design Parameters

Parameter	Design $\mathcal{L}$	High $\mathcal{L}$	Units
Maximum Luminosity	10^{33}	10^{34}	$cm^{-2}s^{-1}$
Beam Crossing Rate	63	63	MHz
Maximum Interaction Rate	10^8	10^9	Hz
Level 1 Trigger Rejection Factor	$10^3 - 10^4$	$10^4 - 10^5$	
Expected Level 1 Trigger Rate	10^4	10^4	Hz
Maximum Level 1 Trigger Rate	10^5	10^5	Hz
Level 2 Trigger Rejection Factor	$10^2 - 10^3$	$10^1 - 10^3$	
Expected Level 2 Trigger Rate	10^3	10^3	Hz
Maximum Level 2 Trigger Rate	10^4	10^4	Hz
Level 3 Trigger Rejection Factor	$10^1 - 10^2$	$10^1 - 10^2$	
Expected Level 3 Trigger Rate	10^1	10^1	Hz
Maximum Level 3 Trigger Rate	10^2	10^2	Hz
Deadtime at Maximum Trigger Rates	< 10	≈ 15	%
Deadtime From DAQ Errors and Downtime	< 5	< 5	%
Level 1 Trigger Latency	2 - 4	2 - 4	μs
Maximum Level 2 Latency	100	100	μs
Average Level 2 Processing Time	< 10	< 10	μs
Time to Process an Event in Level 3	100 – 1000	100 – 1000	MIPS-sec
Farm Processing Power	$10^6 - 10^8$	$10^6 - 10^8$	MIPS
Number of Processors in Farm	500 – 5000	500 – 5000	
Average Event Size for Full Event	0.25 – 1	0.25 – 1	MB

Local trigger

- Physics objects (i.e. e, γ, jets) are sent from front end crates.
- Reduced bandwith sent to global trigger.

  ex: electron bits

E_t	η	φ	iso	Shower max
8	4	1	1	?

  ~ 16 bits/electron + 11 bits (time stamp)

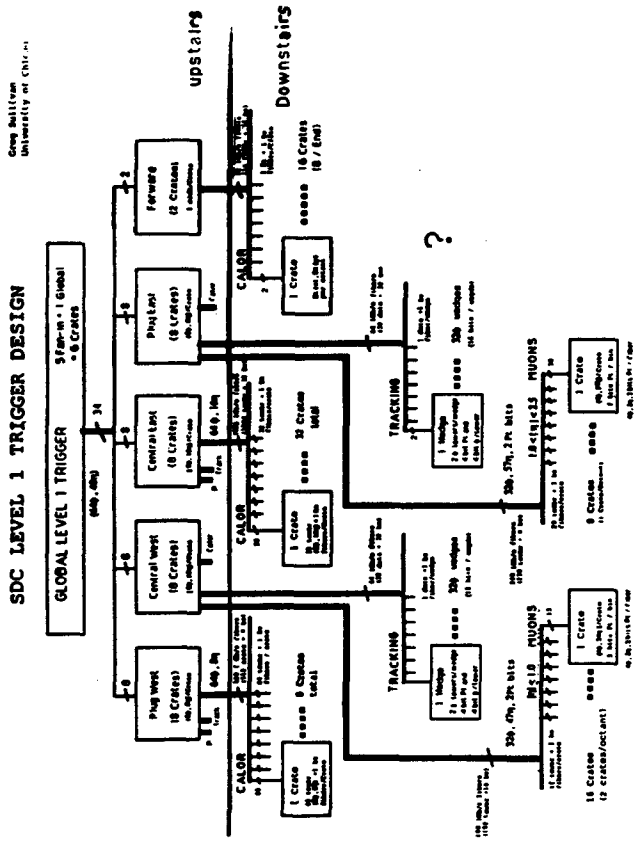
- Can be Synchronous or Asynchronous
  (~ 6 fiber/crate) (<1 fiber/crate)

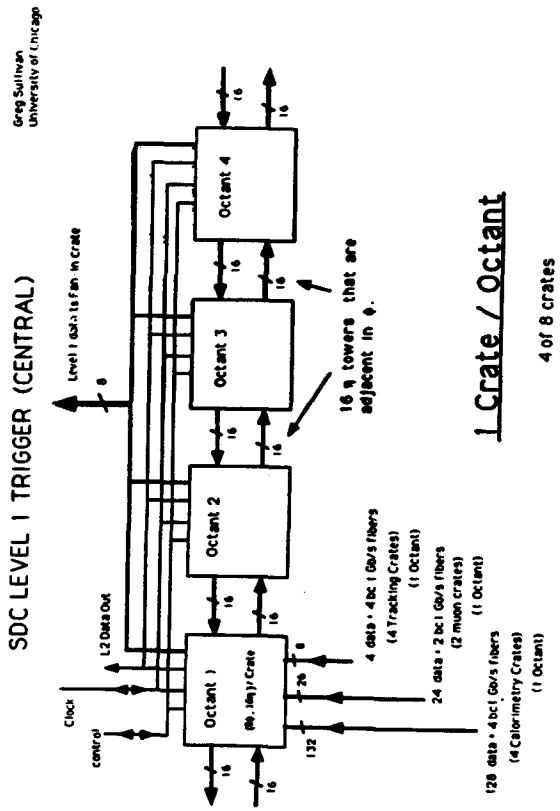
Central Trigger

- Digitize every beam crossing
- Transmit data over Fiber (LED)
- Synchronous data to trigger

  1 Gbit/sec per trigger tower

  (~ 32 fibers/crate)





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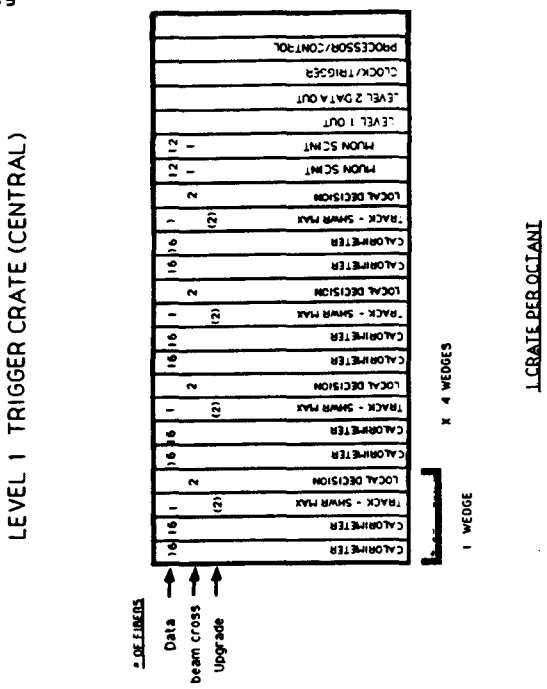
University of Chicago



Electrons.

- Information to Local Decision card
  1) 2 Threshold bits for every em tower These indicate if the tower is above one of three programmable thresholds
  2) 1 had/em bit for every em (32 total) tower Indicates that tower is either above or below programmable had/em cut
  3) 1 isolation bit for each em tower(32 total) Indicates the ratio of hadronic energy in 8 border towers to em tower energy is below a programmable value
  4) 1 track match bit for each em tower(32 total) Indicates a track above a programmable Pt threshold matches the em tower ϕ coordinate of a tower over either threshold Also has capability built in to match in ϕ at the shower max detector granularity

- Local decision card logic (i.e triggers)
  1) High Pt and Isolated and had/em and track
  2) two Low Pt , both had/em and isolated and track
  3) prescaled Single Low Pt
  4) prescaled High and low Pt with one criteria relaxed
  5) prescaled programmable criteria

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University of Chicago

Jets.

- Information to local decision card.
  1) 2 Threshold bits for each "jet" tower Indicate if tower is above any of three thresholds.

- Decision card logic.
  1) single jet trigger over high threshold
  2) di-jet trigger over low threshold
  3) prescaled single jet trigger over low threshold.

Missing Et.

- Et(x) and Et(y) from each crate sent to global trigger.

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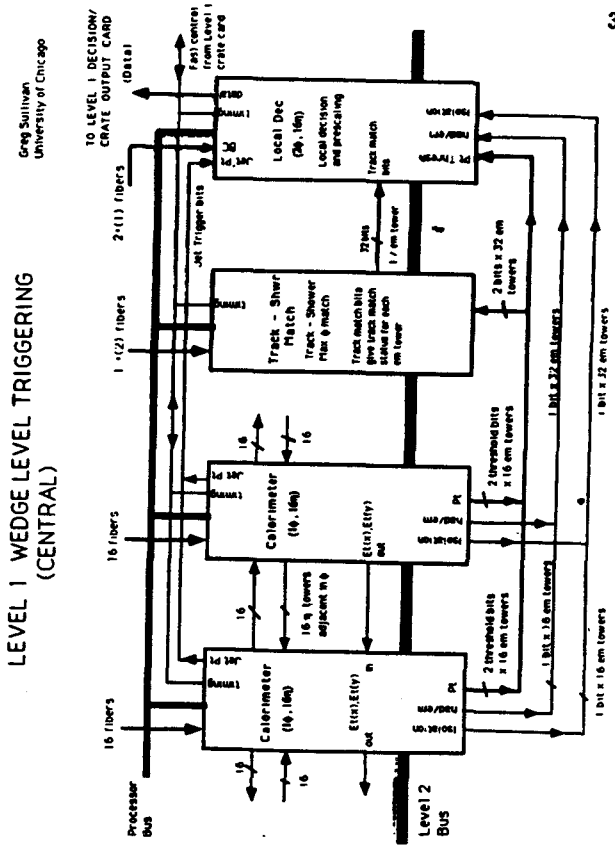
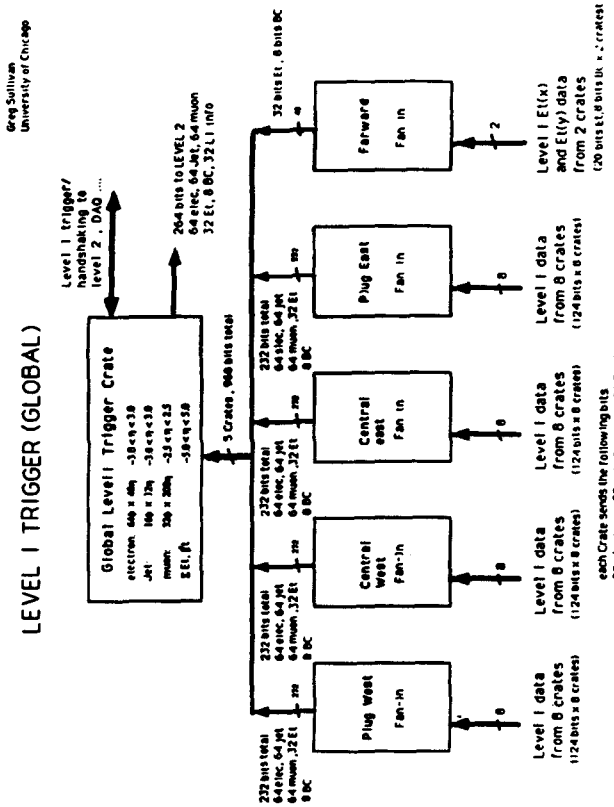
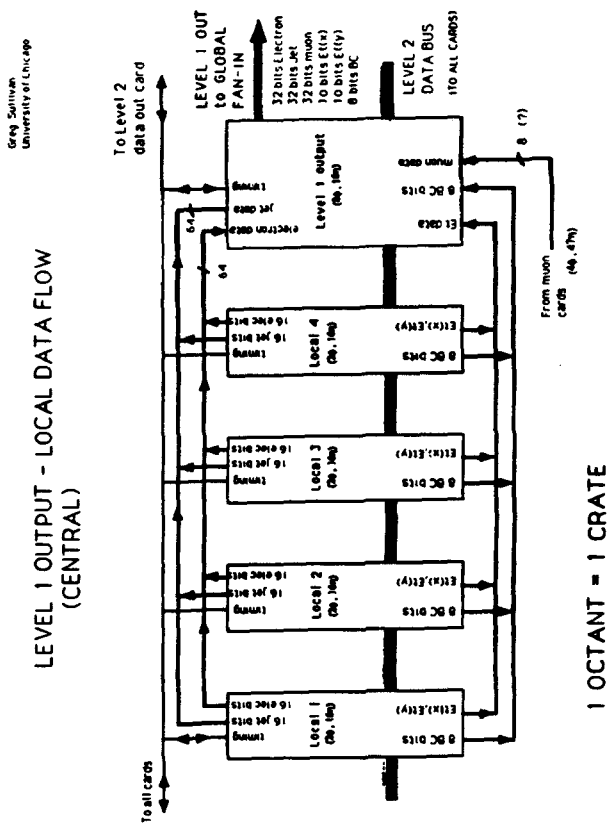


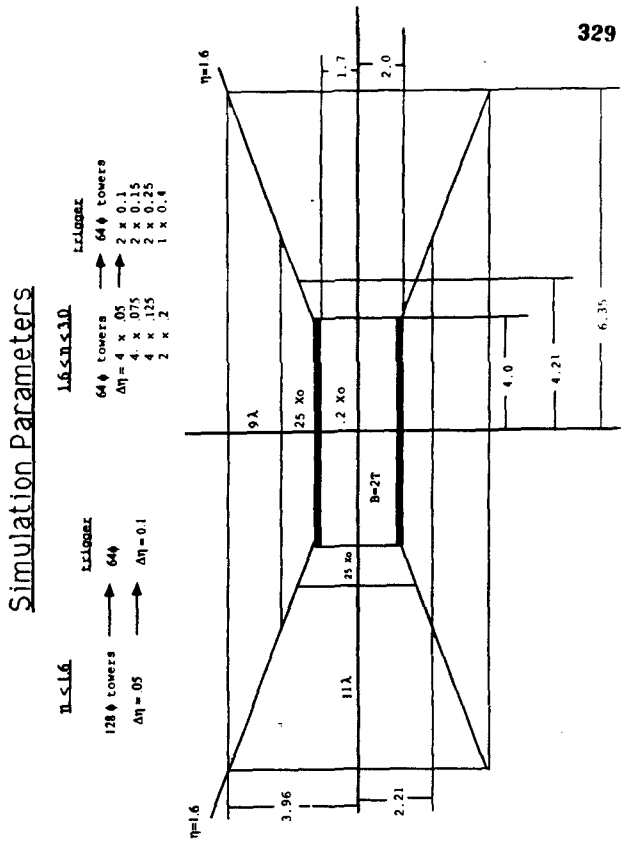




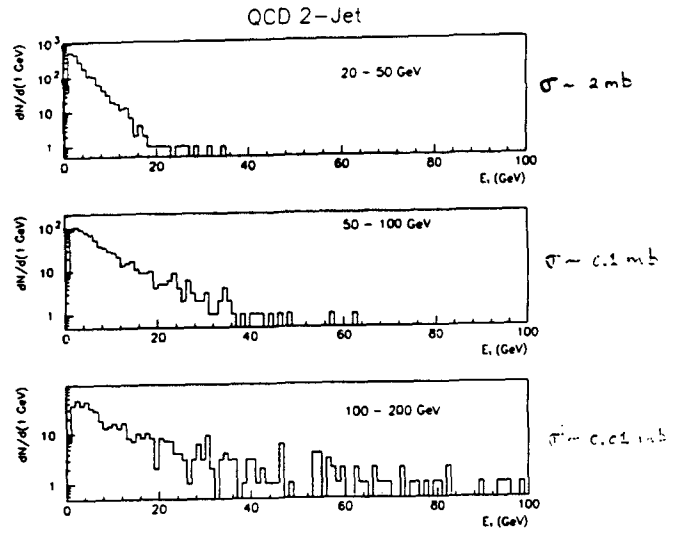
TRIGGER SIMULATION

Description of Simulation

- Generate Data Sets with Isajet
  minbias, 2-Jet, W, Z,
- Poisson distribution of minbias at every beam crossing.
- Smear Vertex position.
- Use shaping function/time history for energy in calorimeter towers.
- π, K decays in flight
- Conversions
  material in tracking volume put in on an average.
- Tracking resolution from EOI, eff = 1.0
  $\frac{\Delta P_T}{P_T^2} = 3.0\ \mathrm{Tev}^{-1}$
- Calorimeter longitudinal & lateral shower fluctuations.
- Shower max in ϕ bins



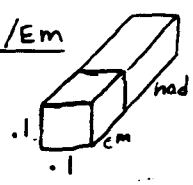
$|\eta| \leq 3.0$



highest em tower w/ had/Em < 0.2

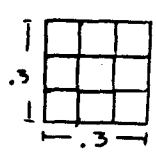
Cuts

Had/Em



had/em < 0.2, 0.1, 0.05

Isolation



$$Iso = \frac{\text{8 had border towers}}{\text{em tower}}$$

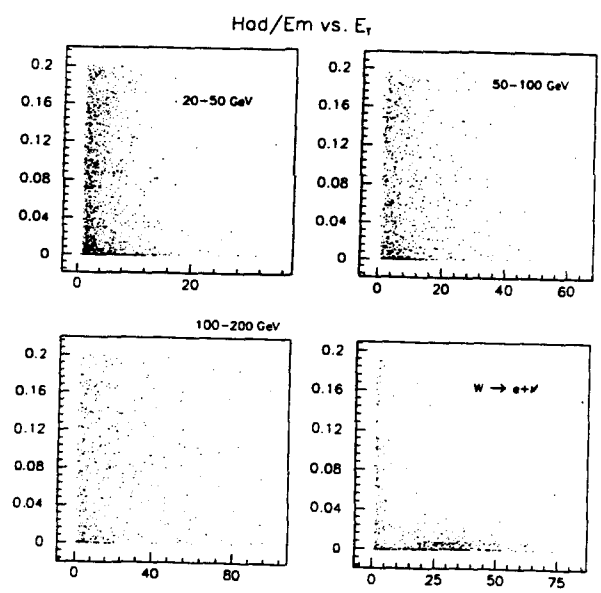
< 0.1 , 0.07

Track

$$\left[\text{abs}(\eta) \leq 1.6 \text{ .AND. } P_T > 5.0\right] \text{ .OR. } \left[1.6 < \text{abs}(\eta) < 3.0\right]$$

$(P_T > 10.0)$

Had/Em of highest em tower vs. E_T of tower



Isolation of highest em tower vs. E_T of tower

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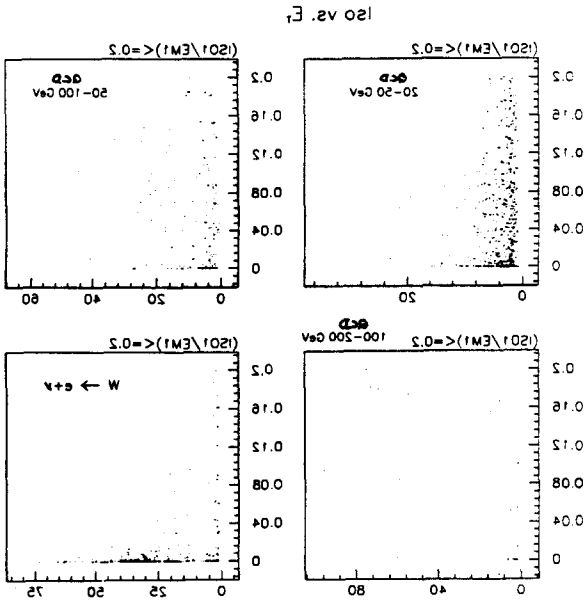
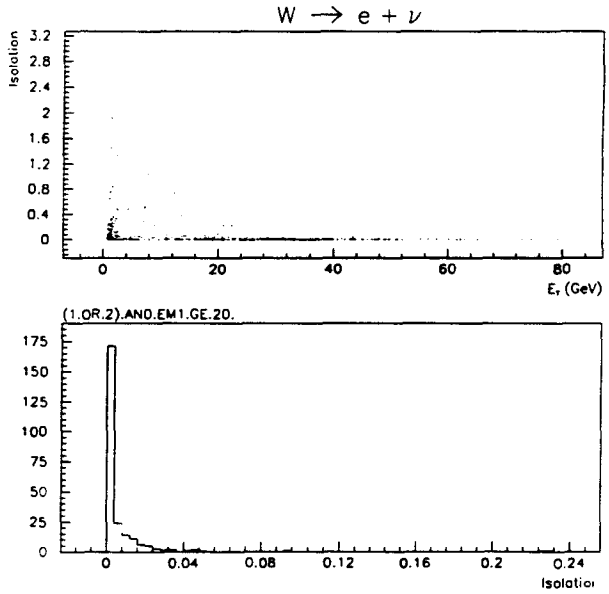


Isolation for $W \to e + \nu$

334



- $W \to e + \nu$ generated over allowed kinematic range.
- Trigger towers $|\eta| \leq 3.0$ → Acceptance ≈ .65

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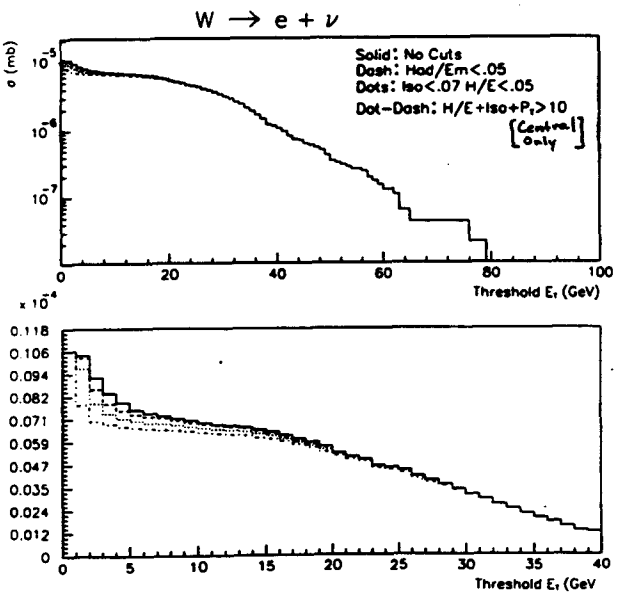
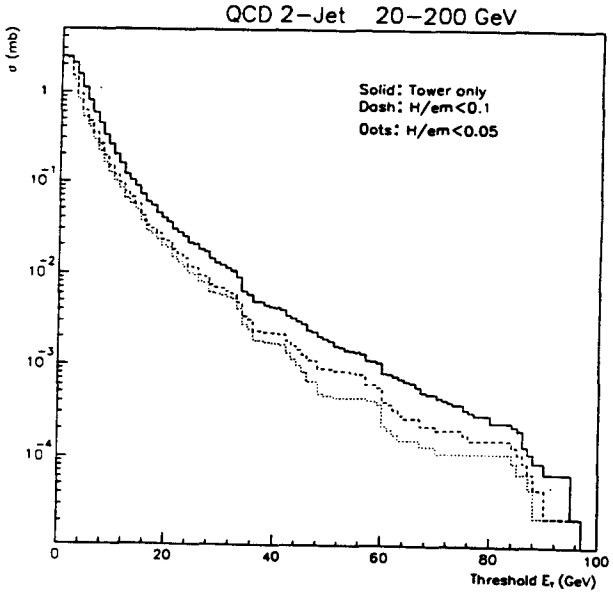


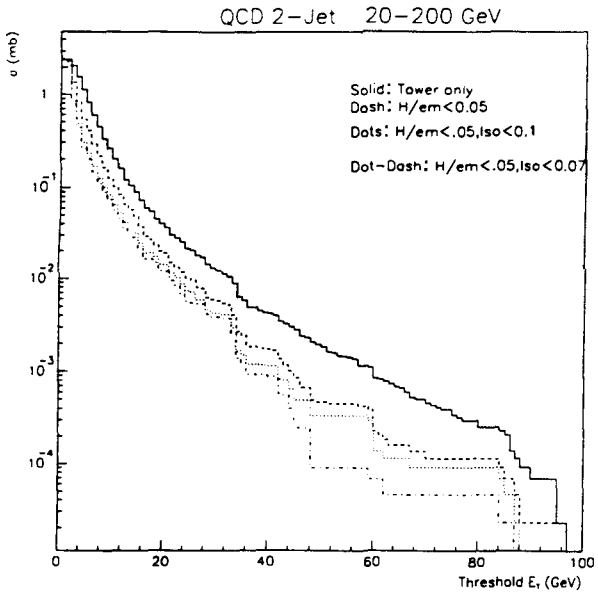
Background Rate vs. Had/Em ratio

336



Rate Vs. Isolation for Had/Em < 0.05

337



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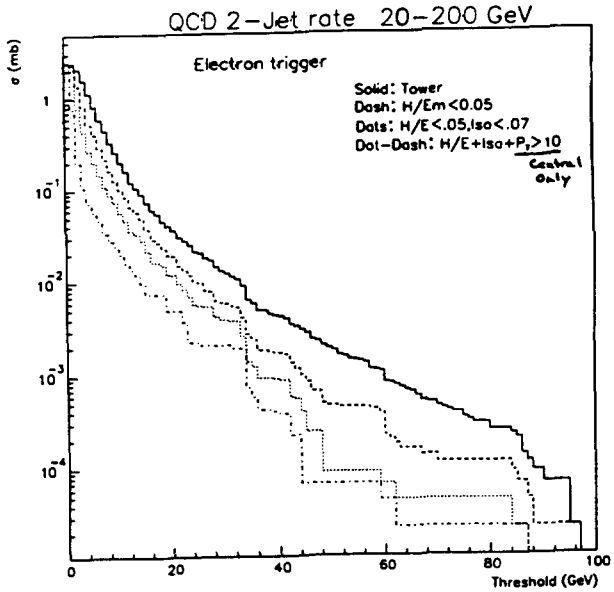

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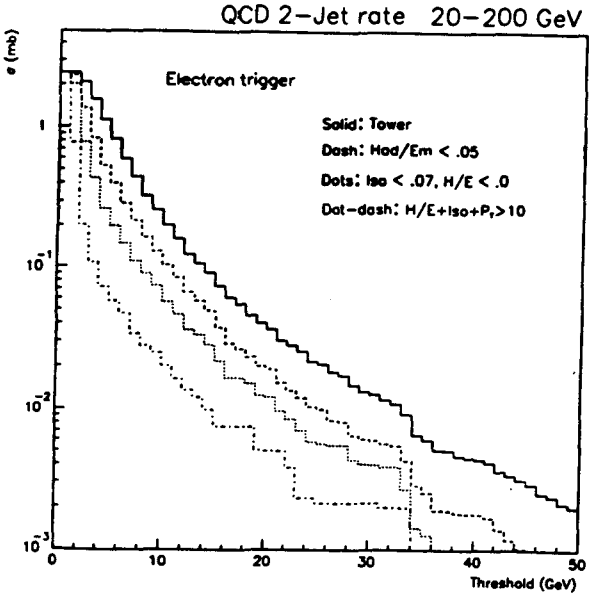

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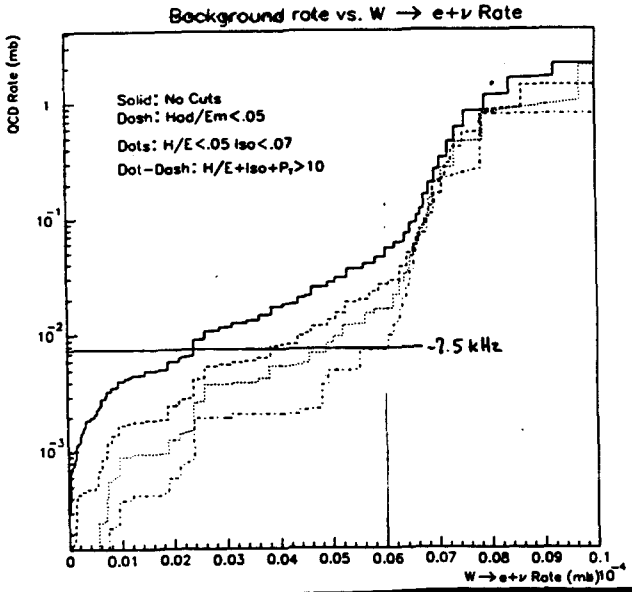

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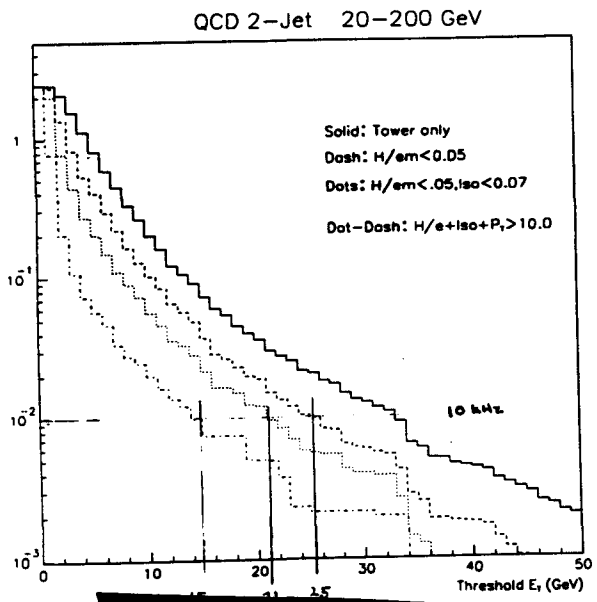

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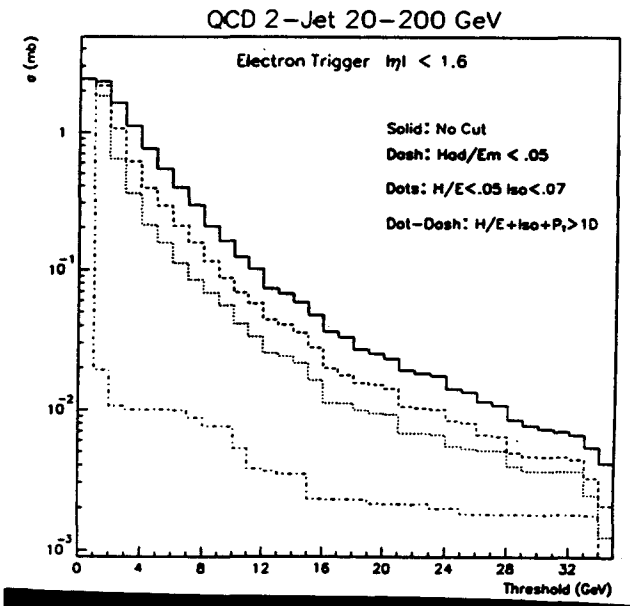
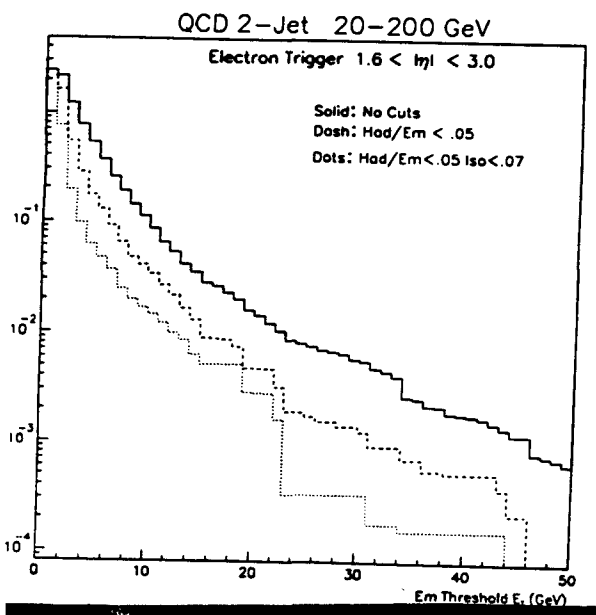


343



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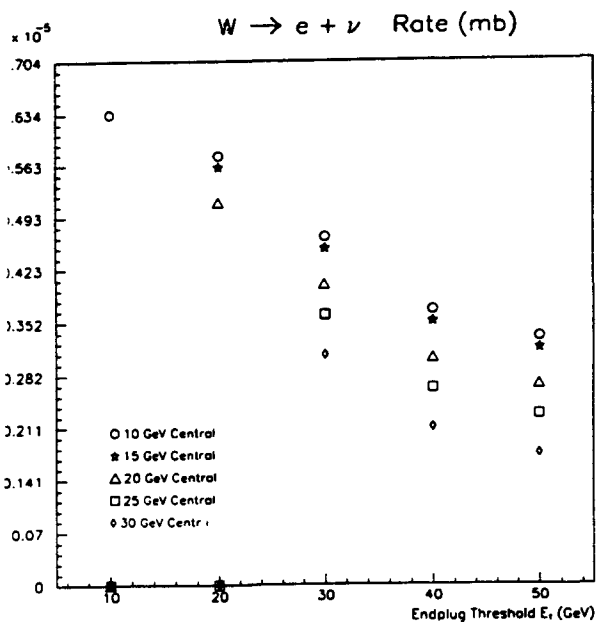
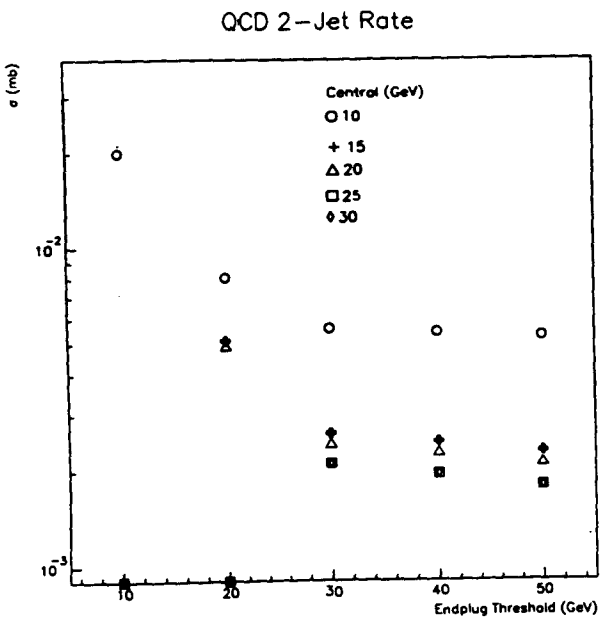


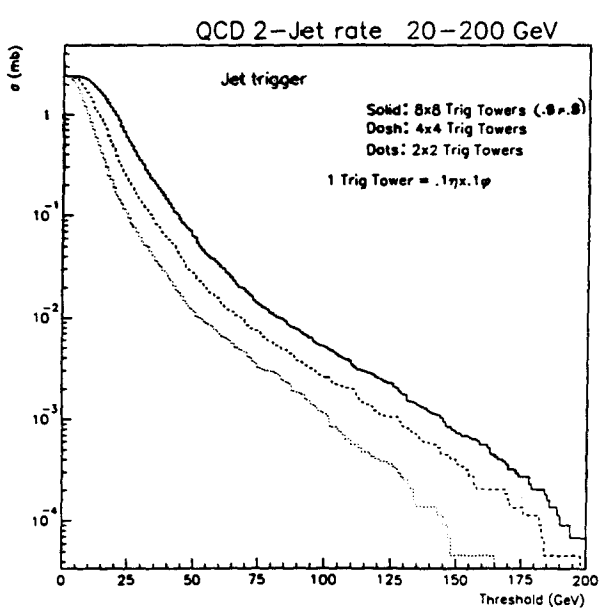


Level 1 Electron trigger rates.

Rate (kHz)		Endplug Threshold (GeV)				
		10	20	30	40	50
Central Threshold (GeV)	10	20	8.5	6.0	5.5	5.5
	15		5.0	2.7	2.4	2.2
	20		4.8	2.3	2.2	2.0
	25			2.0	1.8	1.7
	30			2.0	-	-

CUTS

$$Had/Em < 0.05$$
$$Isolation < 0.07$$
$$(|\eta| < 1.6 \; .and. \; P_T > 10.0) \; .or. \; |\eta| > 1.6$$



Level 1 Strawman Trigger Table

Trigger	E_T (GeV)	$\sim\sigma$ (μb)
electron	15. $\|\eta\|<1.6$ 30. $1.6<\|\eta\|<3.0$	3
Central photon	35 ?	1
muon	15	1 (?) EOI
Jet	150	1
2 electrons	10	1
2 muon	10	1
e/μ	10/10	1
$\not{E}_T$	140	1 (EOI)
ΣE_T	1000	1 (EOI)
ΣP_T	?	–

Minbias (pre-scaled)

electron	"	10
muon	"	10
Jet	"	100

Future Work

1) Put in FADC Resolution.
2) Put in tracking efficiency from tracking simulat.
3) Study track - Shower max match at Level 1
4) di-electron rates.
5) ΣE_T, $\not{E}_T$ trigger rates.
6) Examine segmentation issues (Descoping)
7) Check against CDF trigger rates.
8) Breakdown of QCD Background rates into prompt e, conversion, π^0, π^+ overlap

TRACKING SCOPE AND COSTS

A. SEIDEN

Tracking - Status Report

Goal has been:

(1) Reduce cost.

(2) Reduce material.

(3) Maintain performance.

System: Silicon at $r \leq 50$cm.
Fibers and/or Straws ≥ 70cm.

Intermediate Tracker: Gas Microstrips.

Performance, parametrically, depends most strongly on:

r^{si}_{inner}, r^{si}_{outer}, σ^{si}_{meas} and r^{last}_{outer}, σ^{outer}_{meas}

Keep Small — Keep large — Keep Small. — Keep Large.

Also need sufficient axial and stereo measurements for track finding and ~~stereo~~ dip measurement.

Silicon Descoping

Enclosed are two descoped silicon designs which we are looking at. The philosophy for both designs has been to retain as much as possible:

(1) Momentum resolution

(2) Vertexing for $|\eta| \lesssim 1.9$.

(3) Uniformity in performance, i.e., no gaps in acceptance or jumps in quantities like the momentum resolution as a function of rapidity.

(4) Nearly uniform material distribution as a function of rapidity i.e., no large material build up at large rapidity.

The design has:

(1) 7 or 8 hits (i.e., 14 or 16 measurements, ignoring dead channels) for the rapidities $\lesssim 2$.

(2) 6 hits for rapidities from about 2 to 2.5.

(3) About 36 m^2 of silicon, requiring about 6×10^6 electronics channels.

(4) Use of 12 cm long detector units nearly everywhere.

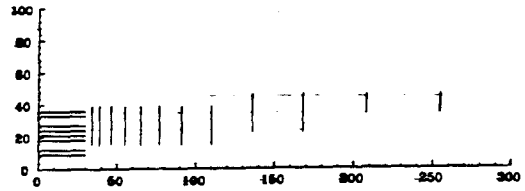
(5) The momentum resolution remains everywhere within 10% of the LOI design when combined with the LOI outer trackers.

(6) The inner two layers can be strips, pixels, or strips to be upgraded to pixels.

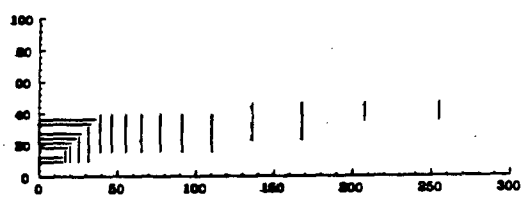
The pattern recognition capabilities of these designs have not yet been fully looked at, but the work in this direction has begun.

If the performance in the central region is adequate, then I would envision possible upgrades (other than replacement of inner layers) focusing on the forward region. The addition of one layer at $z = 3$ m covering 50 cm $\leq r \leq$ 74 cm would provide 7 hits for all forward rapidities up to $\eta = |2.5|$. The extra point would provide a vertex constrained transverse momentum resolution at 1 TeV, which varies smoothly from 20% at $\eta = 2.1$ to 46% at $\eta = 2.5$. The total additional

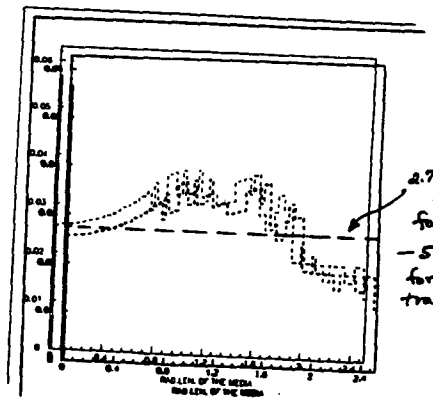
DESIGN #1



Design #2



Cost = $40 Million, including contingency – but without pixels.



Outer Trackers:

Units: 6 to 8 straws.

.85% X^0 including supports (normal incidence).

Arrange either Axial or Stereo.

or

2U, 4A, 2V fibers.

Need less layers since can mix Axial and Stereo Measurements.

1.8% X^0 including supports (normal incidence).

Likely minimal numbers to consider:

5 Straw Layers

4 fiber Layers

or

Mix.

DESCOPED ALL STRAW TRACKER

SL.	straws	r (m)	z(m)	Stereo	Modules	ΣX_0 before
1	6	0.704	2.80	0°	84	-
2	6	1.04	3.20	+3°	124	0.85%
3	8	1.34	3.90	0° T	160	1.70%
4	6	1.48	3.95	-3°	176	2.66%
5	8	1.61	3.95	0° T	192	3.51%

Cost = \$ 16.5 M + 1.7 M × # superlayers

+ 0.016 M × # Trig. Modules (352)

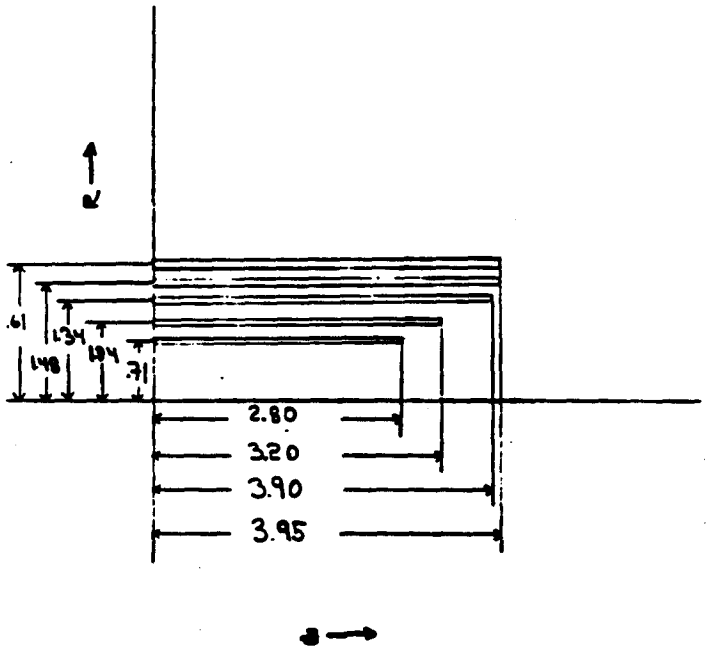
+ 0.011 M × # Nontrig. Modules (384)

= \$34.8 M (Baseline was \$ 31.7 M with 4 superlayers)

Total Straws = 7.35×10^5 (Baseline was 7.22×10^5)

G. Hanson
8-6-91

Descoped All Straw Tracker



FIBER TRACKING SCENARIOS

"BASELINE" 1.7m × 4m — \$35.6 M
2 VECTOR BARRELS (x,u,ux'), (x,x') — (FROM WBS)
362 K FIBERS — D. KOLTICK & D. VANDERSCHUFF

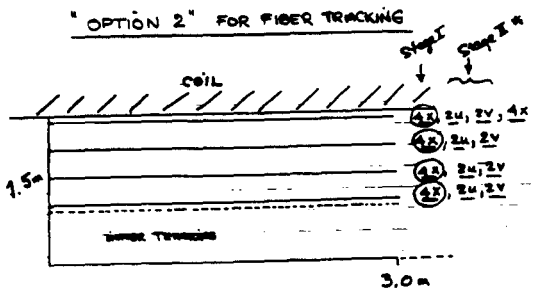
"D. ADAMS" SIMULATION 1.5m × 1/2 — ~\$45 M
4 BARRELS (x,u,v)
500 K FIBERS

"OPTION 1" 1.5m × 1/2 — ~\$36 M
2 BARRELS (x,u,v)
2 BARRELS (x only)
375 K FIBERS

"OPTION 2" STAGE READOUT OF D. ADAMS VERSION (OR VARIANTS) — ~\$35 M
(STAGE UV)
250K CHANNELS READ OUT
500 K CHANNELS/FIBERS IN PLACE
(SAVES \$10M)

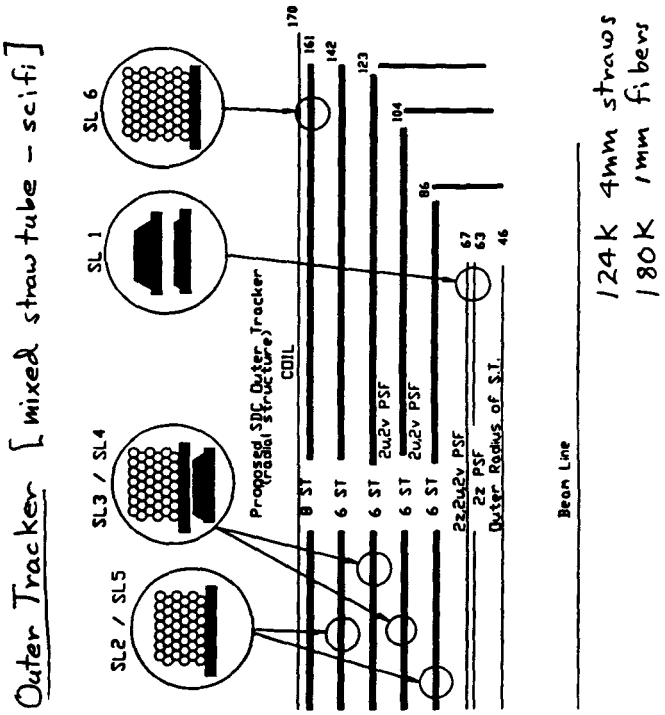
fiber

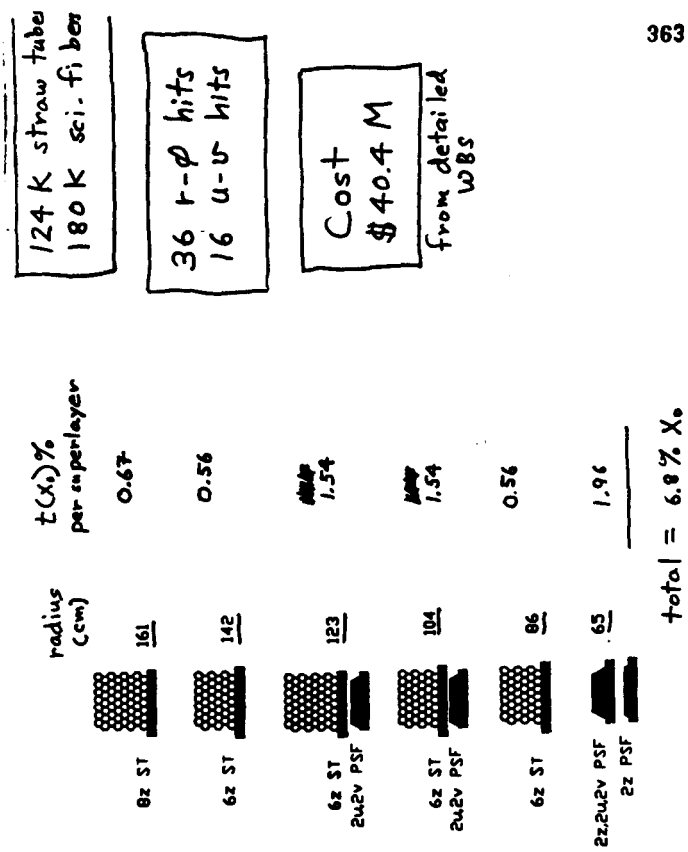
NO INTERMEDIATE TRACKING IN ANY OF THE ABOVE SCENARIOS



* CHOICE OF STEREO 2u, 2v (3-D SPACE POINT)
OR AXIAL 4x' (VECTOR OPTION)

TO BE DECIDED THROUGH SIMULATION





Intermediate Tracker - U.K. & Canada.

Consensus to pursue Gas Microstrips.

Made of Tiles 15cm × 15cm (wedge shaped, arranged into forward disks).

6 disks (2 measure ϕ versus z, 2u stereo, 2v stereo) form a measuring layer.

3 such layers spread out along z from 3m to 4m.

300μm anode spacing ⇒ ~8μm accuracy per measurement.

Goal: Measurement of $\frac{d\phi}{dz}$ in disks grouped in 4 η bands provide first-level tracking trigger! Should work up to very high $\mathcal{L}$.

Changes from LOI

Silicon:

$28\,m^2 \rightarrow 16\,m^2$ ratio = .57

Wires:

$1.9 \times 10^5 \rightarrow 1.35 \times 10^5$ ratio = .71

Fibers:

$1 \times 10^6 \rightarrow \begin{cases} 375k \text{ to} \\ 500\,k \end{cases}$ ratio = .375 to .500

Material	Normal Incidence (leave out outermost layer)
Silicon	5%
Wires	3.5%
Fibers	5.4%

11.5%

14.7%

Maximum – All 4 Layers have 8 fibers. Comparable material: 24 fibers or 34 straw layers.

Rapidity Averaged = 5.5% for silicon + 1.7 × Outer Value.

Costs for very slimmed down system: \$40m silicon

\$35m Outer (possibly + \$10m staged).

\$17m Intermediate Tracker.

How does the system perform:

Several programs beginning to use full system information, but pattern recognition not yet fully global.

Likely to take several months before results on a range of physics processes available. Critical to get such information as input to decisions.

MUON DESCOPING IDEAS

R. THUN

"DESCOPING" IDEAS

7 AUG 91
MUONS

1.) ELIMINATE ACCESS SPACE
- acceptable vis-a-vis muons
- → preamps on chambers, trigger outside
- → careful design of HV, gas systems

2.) TOROID THICKNESS
- barrel: 1.5 m → 1.0 m
  - OK — very risky
- forward: 4.0 m → 3.0 m → 2.0 m
  - probably OK — risky

3.) REMOVE BW1
- No!! → 2d level θ, ϕ triggers
- → track linking
- → 2d $p_\perp$ measurement

4.) REMOVE ϕ
- No!! → track matching
- → 2d level trigger

5.) REMOVE STEREO
- No! → link θ, ϕ
- → resolve ghosts

6.) LARGE CELLS (~16 cm)

NO.... → long drift
→ smeared trigger resolution
→ no one building prototype

7.) SCINT. COUNTERS

0 layer : No! need time info.
1 layer : time only, no redundancy
2 layer : time + $P_\perp$ cut

8.) MULTIPLEXING

9.) STAGE BARREL COMPONENTS

NO!

10.) STAGE FORWARD SYSTEM

stage both ends NO!
stage one end → maybe
stage one toroid + ch. both ends → maybe

COST STUDIES UNDER WAY

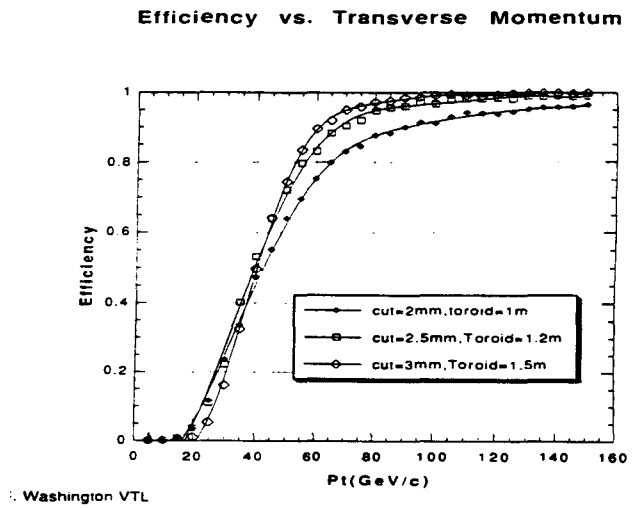


Fig. 3

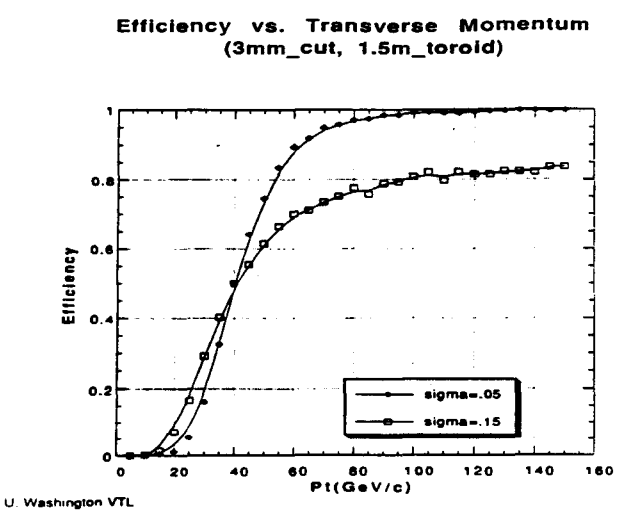


Fig. 4

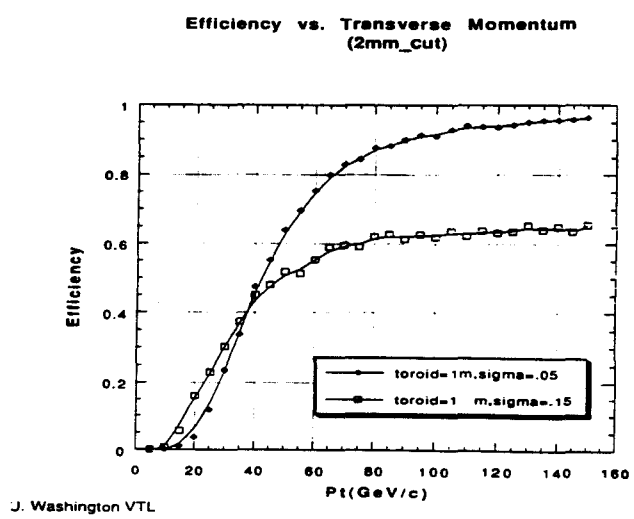


Fig. 5

SUMMARY

1.5 m toroid

round tube: 4
DRIFT VELOCITY
90-5-5
A-CO_2-CH_4

$P_\perp$ = 20 GeV/c

all angles in mr.

θ	BEND θ_B	SPACE $\delta\theta_S$	MULT. SCATT $\delta\theta_{MS}$	CH. RES $\delta\theta_I$	$\delta\theta$ $\sqrt{(\delta\theta_S)^2+(\delta\theta_{MS})^2+(\delta\theta_I)^2}$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	40.5	5.7	10.8	1.9	12.4	0.31	0.12
45°	40.5	2.9	8.2	1.3	8.8	0.22	0.12
30°	40.5	1.4	6.4	0.9	6.6	0.16	0.12

$P_\perp$ = 40 GeV/c

θ	θ_B	$\delta\theta_S$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	20.3	5.7	5.4	1.9	8.1	0.40	0.12
45°	20.3	2.9	4.1	1.3	5.2	0.26	0.12
30°	20.3	1.4	3.2	0.9	3.6	0.18	0.12

1.0 m toroid

$P_\perp$ = 20 GeV/c

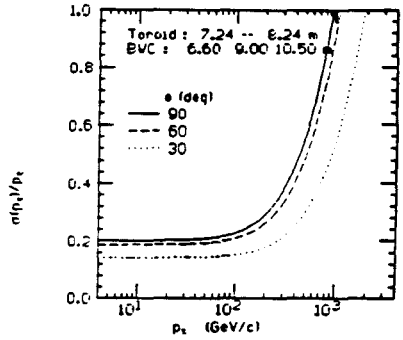
all angles in mr

θ	θ_B	$\delta\theta_S$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	27.0	6.1	10.0	1.9	11.9	0.44	0.12
45°	27.0	3.0	7.5	1.3	8.2	0.30	0.12
30°	27.0	1.5	5.8	0.9	6.1	0.23	0.12

$P_\perp$ = 40 GeV/c

θ	θ_B	$\delta\theta_S$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	13.5	6.1	5.0	1.9	8.1	0.60	0.12
45°	13.5	3.0	3.8	1.3	5.0	0.37	0.12
30°	13.5	1.5	2.9	0.9	3.4	0.25	0.12

BWC1, BWC2 and BWC3



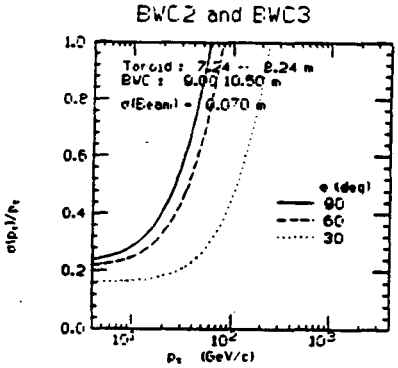
Toroid 7.24 – 8.24 m.
D_2 = 1 m
BWC1 6.6 m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2$ = 1.5 m
σ = 200 μm
(per supermodule

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 1.044 \times 10^{-3} \right)^2 + \left(\sqrt{\sin\theta} \;\; 0.2012 \right)^2 \right]^{1/2}$$

P_t(turn) = 193 GeV/c @ θ = 90°
207 60°
272 30°

θ \ P_t (GeV/c)	20	50	100	200
90°	0.202	0.208	0.227	0.290
60°	0.188	0.193	0.208	0.260
30°	0.143	0.145	0.152	0.176

BWC2 and BWC3



Toroid 7.24 – 8.24 m
D_2 = 1 m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2$ = 1.5 m
σ = 200 μm
(per supermodule)
σ_{Beam} = 7 cm

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.415 \times 10^{-4} \right)^2 + \left(P_t \cdot \sin^2\theta \cdot 1.676 \times 10^{-2} \right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2296 \right)^2 \right]^{1/2}$$

P_t(turn) = 14 GeV/c @ θ = 90°
17 60°
39 30°

θ \ P_t (GeV/c)	10	20	50	100
90°	0.284	0.406	0.869	1.692
60°	0.248	0.330	0.664	1.276
30°	0.168	0.183	0.265	0.450

[E] ZZ pairs -> 4mu
Sigma*B(ZZ -> 4mu) = 25 fb Ldt = 10*40 (1 Year LT)
Pt > 20 GeV/c acceptance = 99.3%; after Pt cut imposed, geometrical acceptance reduced from 32.2% (LoI) to 9.1% (C-C only)
=> 250.0 total events produced
=> 79.9 LoI events
=> 22.6 C-C C-C only events) 3.5

[F] Higgs-> ZZ -> 4mu (Mh=400 GeV/c2)
Sigma*B(Higgs -> ZZ -> 4mu) = 8.8 fb Ldt = 10*40 (1 Year LT)
Pt > 20 GeV/c acceptance = 99.6%; after Pt cut imposed, geometrical acceptance reduced from 48.2% (LoI) to 17.7% (C-C only)
=> 88.0 total events produced
=> 43.1 LoI events
=> 15.5 C-C C-C only events) 2.8

[G] Higgs-> ZZ -> 4mu (Mh=800 GeV/c2)
Sigma*B(Higgs -> ZZ -> 4mu) = 1.5 fb Ldt = 10*40 (1 Year LT)
Pt > 20 GeV/c acceptance = 98.9%; after Pt cut imposed, geometrical acceptance reduced from 66.3% (LoI) to 29.7% (C-C only)
=> 15.0 total events produced
=> 9.8 LoI events
=> 4.4 C-C C-C events) 2.2

377

FRONT END ELECTRONICS COSTS

B. WILLIAMS

378

Front End Electronics

	Fixed	Per ch	
Calorimeter	4.5	125	14.5
Shower Max	2.7	58	
Straws	3.8	53	10.3
Fibers	1.1	7	3.9
Muon Wires	1.9	95	11.4
Muon Counters	0.1	112	1.2
			$31-37

379

DAQ COSTS

I. GAINES

380

DAQ Descoping

Baseline Design:

$22M M&S
$12M labor
$8M contingency (24%)

$42M total

escoping Target:

$13M M&S
$7M labor
$5M contingency (25%)

$25M total

TECHNICAL RISKS/SCOPE REDUCTIONS ASSOCIATED WITH DAQ COST REDUCTION

1) Leave out a stage in module development (prototype/1st pre-production/2nd pre-production/production)

2) Combine functions to reduce number of processors in each crate (slow control/event readout/event flow control)

3) Reduce number of DAQ crates:
   a) downscope number of channels
   b) more multiplexing before DAQ system

4) Enforce standardization of DAQ components/front end interfaces to reduce engineering

5) Eliminate duplication

6) Carefully evaluate unit costs

DAQ Cost Reductions

$4.1M - Eliminate separate slow controls CPU

$3.7M - Simplify/standardize DAQ crate
Fewer channels
No diagnostic bus

$2.3M - No engineering on ESRN system: use SSCL "standard"

$1.6M - Reduced engineering for FE integration
eliminate step
standardize
duplicated with FE costs

$1.1M - Eliminate main event builder

$0.9M - Less project management (smaller, less complex)

$0.7M - Fewer development tools (fewer people)

$14.8 Total

TRIGGER COSTS

W. SMITH

SDC Baseline Trigger Design

(Input from Madison Trigger Meeting July 17-19)

Requirements: Trigger Efficiently on:

Electrons from inclusive W's } 50% of theoretically possible
Muons from inclusive W's

Jets at high P_T } overlap existing σ over 1-2 decades
High P_T Photons

Missing E_T (SUSY, $H \to ZZ \to \ell\ell\nu\nu$)

Multilepton low P_T Trigger (B physics)

Level 1 Trigger Baseline

Electron: Cal: Isolated e/h
Track: Match w/ Cal: ∅
Show Max: ∅ Match

Muon: Muon Track > P_T only

Jet: Energy in .4 x .4 Tower > Thresh

Photon: Electron w/o Track match

E_T, $\not{E}_T$: Global Cal. Energy Sum

Level 1 output: 10-100 kHz

Design Technique: ① Calculate basic trigger primitives on detector

② Transmit to Counting House on surface at 1.1 Gb/s on optical fibers (@300/hour ≈ 85% counting)

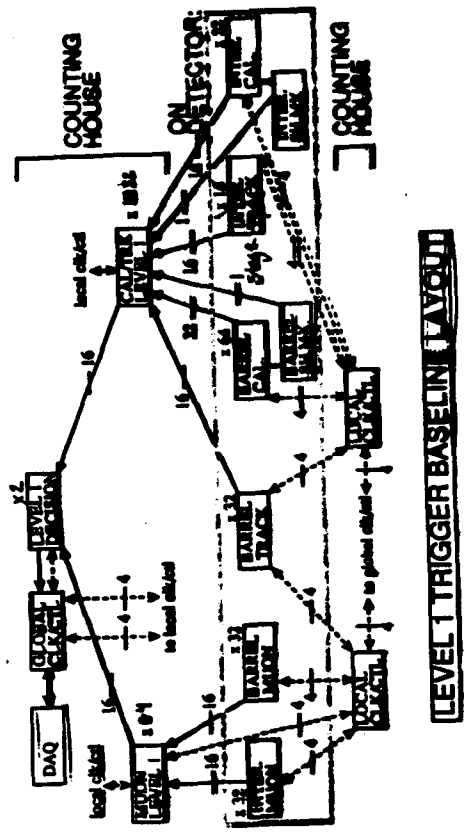
③ Do Trigger calculations in C.H. and transmit decision back to detector

Level 2 Baseline Trigger Options

1. Outer Tracking - Muon Match
   ⇒ Tighten P_T cut
2. Silicon - Outer Tracking Match
   ⇒ Eliminate Conversions
   ⇒ Intermediate Angle
3. Topological Cuts
   ⇒ Cut on # forward or # central jets + leptons
4. Full Shower Max Info:
   Isolation
   Track match (e only)
   ⇒ Tighten (Verify) Electron Cut
   Photon Cut
5. Track vs. Cal E/p
   ⇒ Tighten Cal-Trk Match

Which Options? Must Decide ⇒ Simulation

Conclusion: Must keep Level 2.
(Rates thru L1 + DAQ too uncertain)



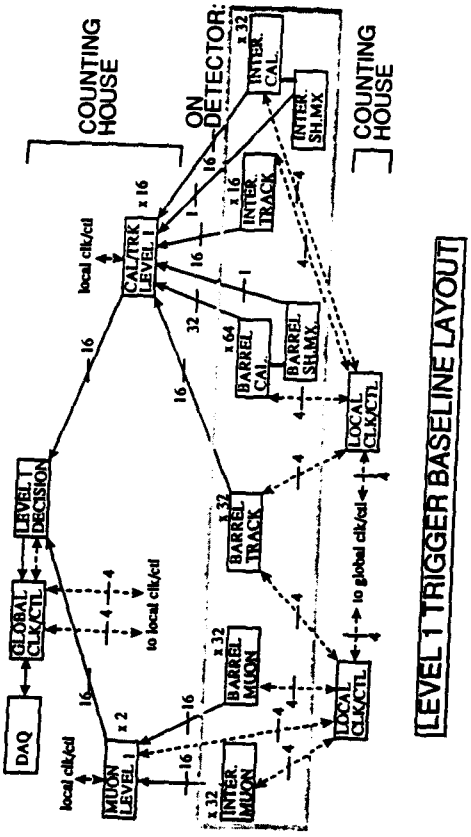
SIMULATION LEVEL 1 TRIGGER INFORMATION

Systems:	Stats.	$N_{obj,min}$	$N_{obj,max}$	η Bins	φ Bins	Info. Bits	Tot. Bits
Barrel Muon	2	0	1.6	47	32	4:P_T	12032
Inter. Muon	2	1.6	2.5	57	32	4:P_T	14592
Barrel Track	2	0	1.0	1	1024	4:P_T	8192
Stage → Inter. Track	2	1.0	2.5	1	1024	4:P_T	8192
Barrel Cal.	2	0	1.6	96	64	8:E_{em},8:E_h	32768
Inter. Cal.	2	1.6	3.0	7	64	8:E_{em},8:E_h	14336
Barrel S.Mx.	2	0	1.6	1	1024	1:hit	2048
Inter. S.Mx.	2	1.6	3.0	1	1024	1:hit	2048
Not in L1 → Silicon	1	0	2.5	10	1024	1:hit	10240

LEVEL 1 TRIGGER BASELINE DESIGN

Crate Type	Crts	Cds/Crt	Info./Cd:	Bts/Cd	Fb/Cd	Tot Fb
Barrel Muon	32	16	2 Trk x (2:η,1:φ,4:P_T)	14	1	512
Inter. Muon	32	16	2 Trk x (2:η,1:φ,4:P_T)	14	1	512
Barrel Track	32	16	2 Trk x (2:φ,4:P_T)	12	1	512
Stage → Inter. Track	16	16	2 Trk x (2:φ,4:P_T)	14	1	256
Barrel Cal.	64	16	2 Tow x ((8:E_{em},8:E_h)	32	2	2048
Inter. Cal.	32	16	2 Tow x ((8:E_{em},8:E_h)	32	2	1024
Barrel S.Mx.	64*	1	1 Hit x (1:Hit)	32	2	128
Inter. S.Mx.	32*	1	1 Hit x (1:Hit)	64	4	128

*Included in Calorimeter Crates



LEVEL 1 TRIGGER BASELINE LAYOUT

Snapshot of Trigger Costs

W. Smith
8/7/91

Comment	Item	Cost (k$)	Conting (k$)	Total (k$)
	LEVEL 1:	16,581	5,139	21,720
incl. sh. mx)	Calorimeter	3,756	1,164	4,920
incl. Link, Global)	Muon	4,393	1,361	5,754
incl. linking)	Track	2,882	893	3,775
Clk+Ctl only)	Silicon	260	81	341
incl. Clk+Ctl)	Global	5,240	1,640	6,930
	LEVEL 2:	5,706	1,770	7,476
incl. sh. mx.)	Calorimeter	674	209	883
	Track	264	82	346
	Muon	264	82	346
Effect + fitst to L2)	Silicon	2121	658	2,779
	Global	2383	739	3,122
	TOTAL (L1+L2):	22,287	6,909	29,196

Summary

Table 1: Electronics Systems Costs (incl. Conting.)

WBS	System	Preliminary Estimate ($M)	New Target ($M)	Nov
5	Electronics	157.9	97	
5.1	Front End	59.1	37	31-3
5.2	DAQ	42.3	25	26
5.3	Trigger	42.4	30	29
5.4	Controls	7.3	3	4
5.5	Power Conditioning	6.8	2	

Comments on Trigger Progress/costs

η-ϕ maps are important!

Processor costs → DAQ

Optical Links → Trigger

Where did Cost Savings Come from?

Reduction in algorithm complexity
(no longer muon-track correl. in L1)

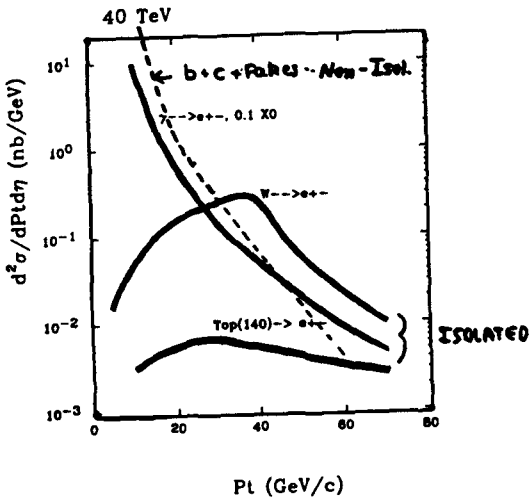
Standardization of clock/Control Interfaces to FE and DAQ

Standardization of L2 Processors and Interfaces
(get L2 Data from L1 where possible)

Reduction in module development + testing

Moving electronics to counting house in standard packaging (Crates, Racks, etc)

Remove Intermediate Tracking in L1.



(Fig. 5)

"Scales" e/γ, h±, Jet

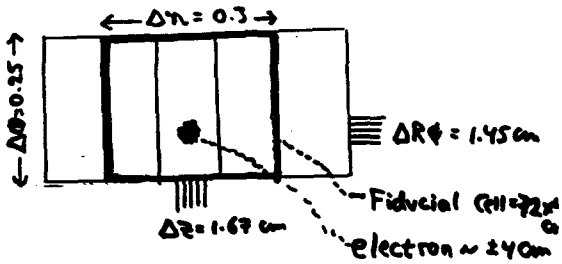
- Jet Size (R<0.7) .... ±140 cm → Global Isolati variables
- electron Fiducial Cell ... ± 40 cm
  (To get sensible HAD/EM)

† • e/γ Shower Size ..... ~ exp(−X/0.6 cm)

† • 50 GeV γγ Separation .... 1.0 cm (π°)
  4.0 cm (η)

- SDC Cell Size ... 10 x 10 cm

† These Scales Require Shower MAX Detector



- "Inside" 72x48 cm Cell
  - Sort out EM Shower Profiles
- "Outside" 72x48 cm Cell
  - "ISOLATION" (A2 Dente)

Shower Max. Implementation

(1) OUTSIDE electron Fiducial cell ...
"ISOLATION" (Add Pt, Et -- Anyone can figure this out!

(2) INSIDE electron Fiducial cell

- Fit (Large ~ 20 cm) Area in Rφ to electron profi
  (.07 x .07) z
  → x, z = 0 (±1.8 mm @ 50 GeV)
  → Pulse Height (σ ~ 25% 10-50 GeV)
  → Fit (SHAPE) χ^2 (e, γ Showers have Surgical profiles)
- Match Rφ, z Views (STEREO)
  (Pulse Height matching ± 5 % @ 50 GeV)

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- electron ID
  - Sh. MAX • Δx, $\Delta z \sin\theta$ < 2,3 cm (TRACK MATCH)
    - $\chi^2_{x,z}$ (Shower Profile)
    - HAD/EM < .04 (.1 in TRIGGER)
    - Pulse Height in Show. Max (Redundant with Had/EM)
    - Sharing between Calorimeter Cells

CUT on $1+3/1+2+3$

- Photon ID
  - $\chi^2_{x,z}$ (Stat. separation of γ, π^0)
  - Had/EM
- Miscellaneous Fun
  - $M_{\gamma\gamma} \to \pi^0, \eta$
  - $\chi \to \psi\gamma$ ...

402

electron ID

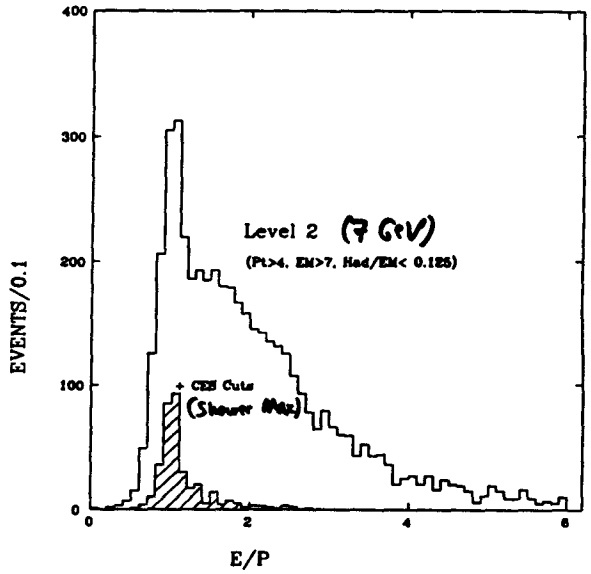


Figure (1)

403

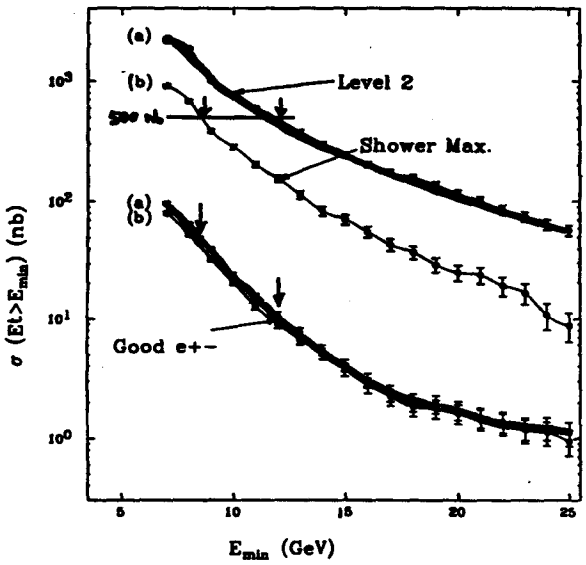
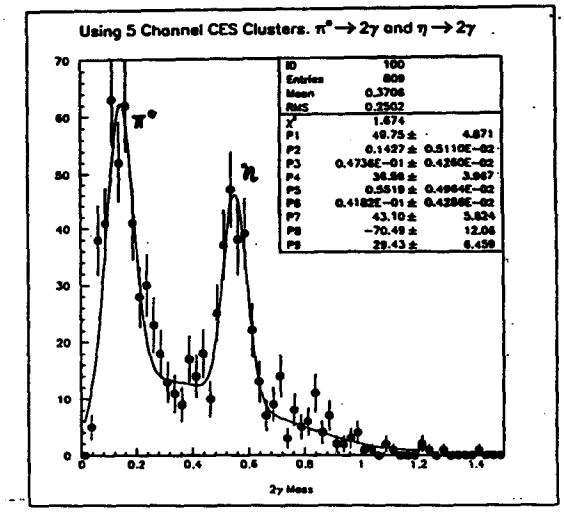


Figure (11)

404

$E_t > 10$ GeV
(Δx MIN = 5 cm)



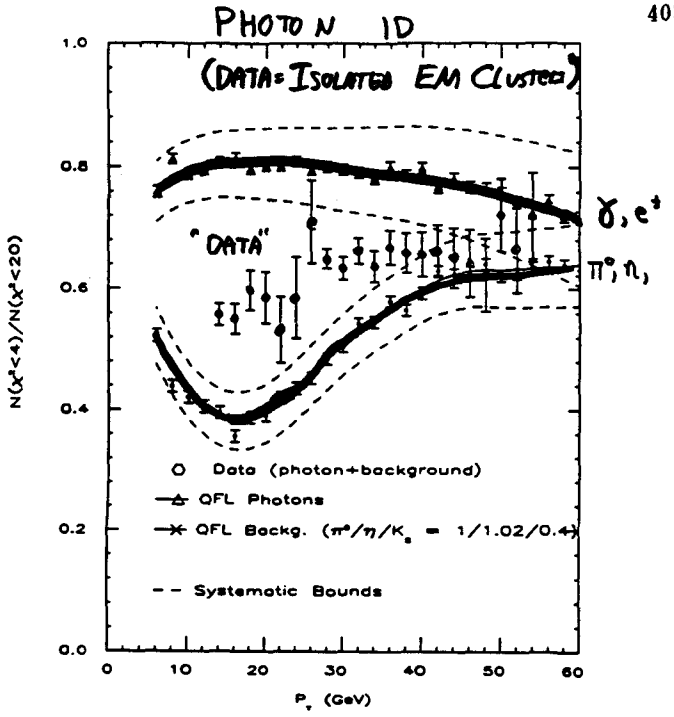
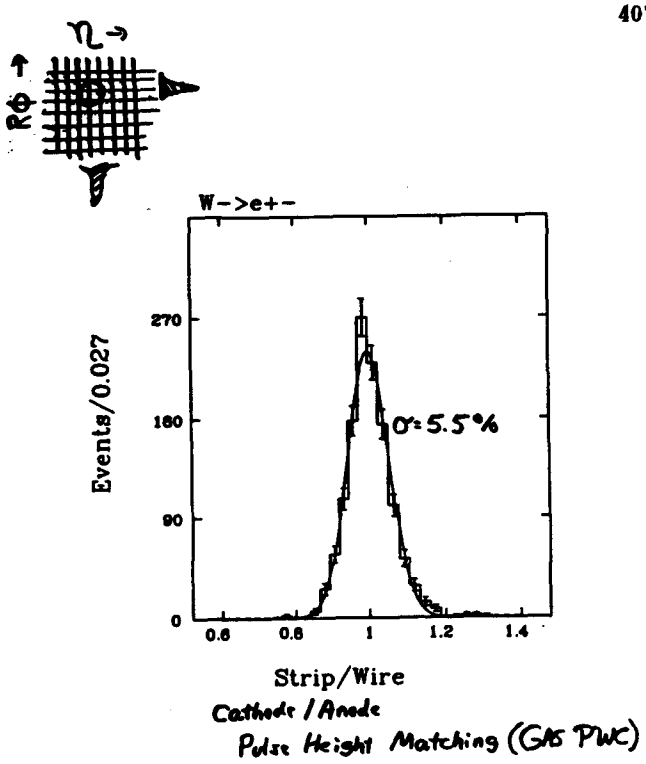


Figure 1: The efficiency to have $\chi^2 < 4$ out of $\chi^2 < 20$ is shown for the data (open circles), the photon simulation (triangles and solid curve), and the background simulation (asterisk and solid curve).

Details on

- $\Delta R\phi$, Δz Position Resolution
- χ^2 (Shower profile)
- Shower Max. Pulse Height ($6X_0$) + Preshower ($1.1X_0$)
- Stereo Matching



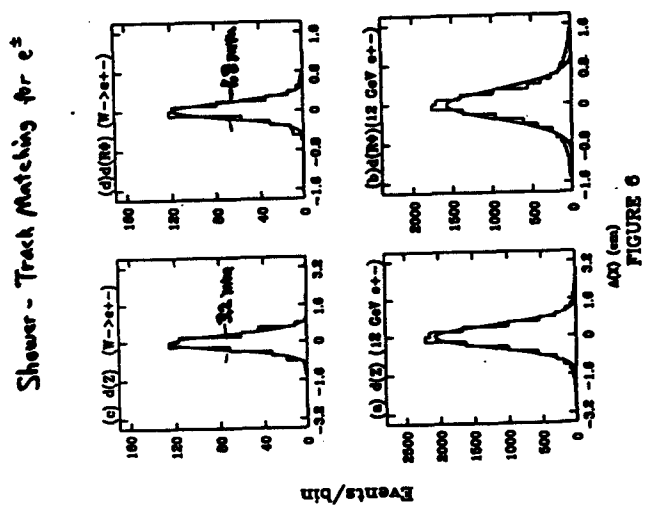
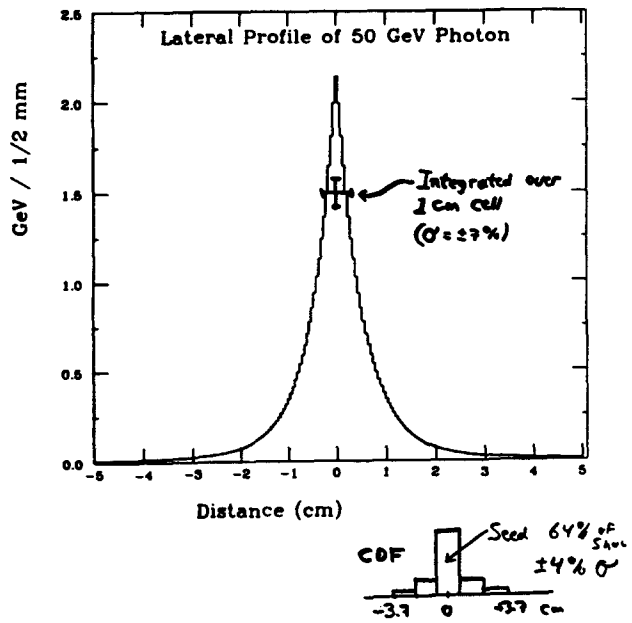
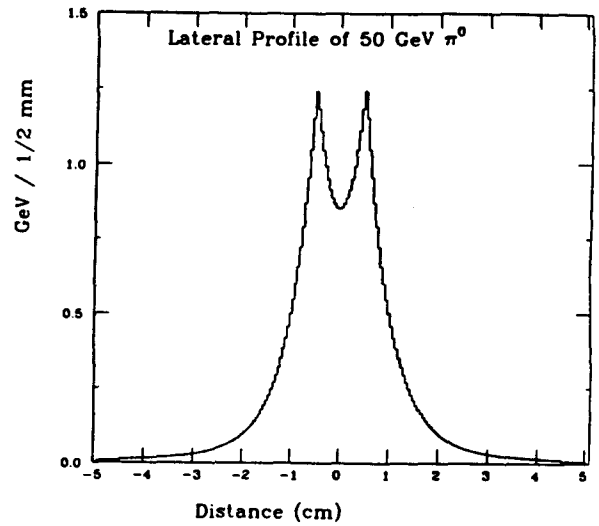
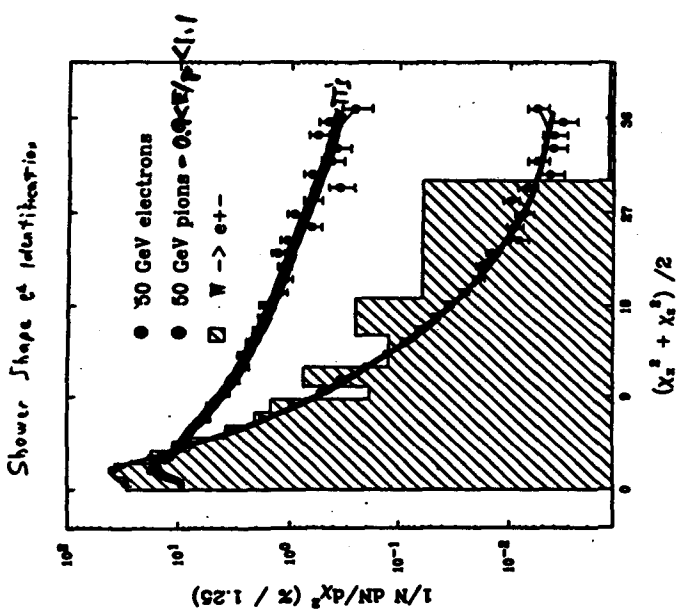


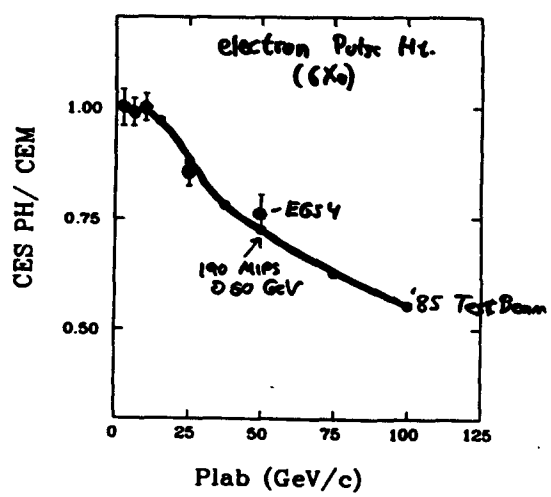
FIGURE 6

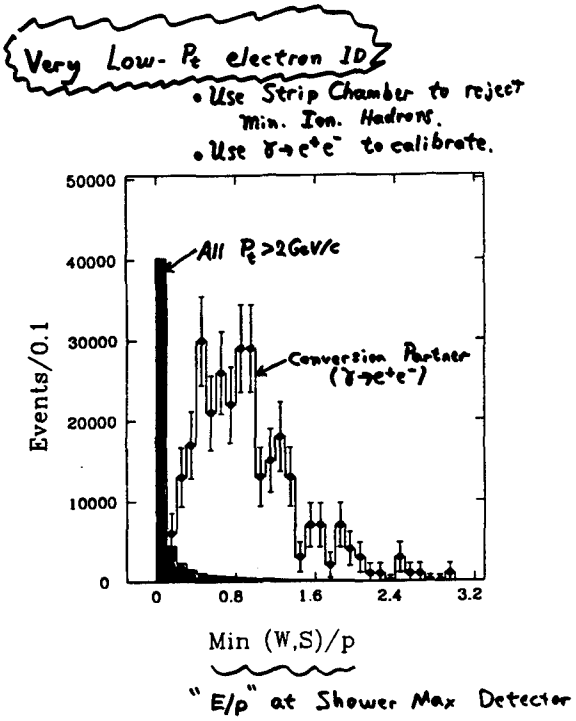
SHOWER SHAPES, SDC at 6 Xo










Very Low- P_t electron ID
• Use Strip Chamber to reject Min. Ion. Hadrons.
• Use $\gamma \to e^+e^-$ to calibrate.
All P_t >2GeV/c
Conversion Partner ($\gamma \to e^+e^-$)
Events/0.1
Min (W,S)/p
"E/p" at Shower Max Detector

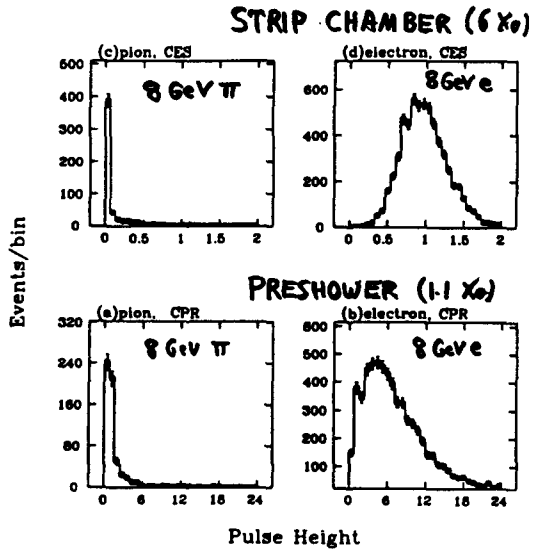
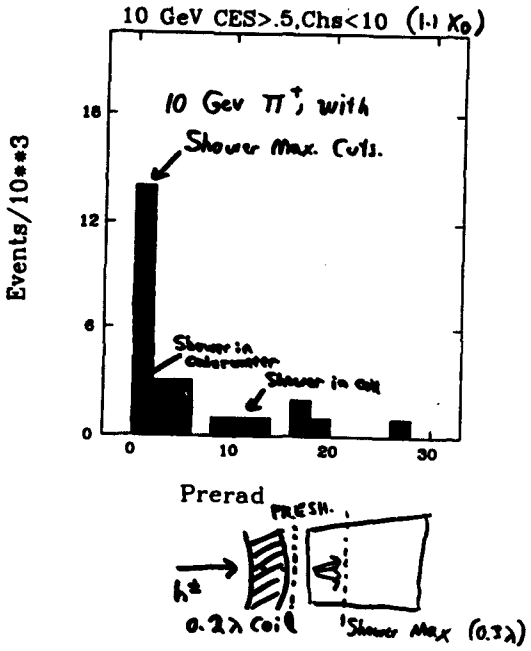
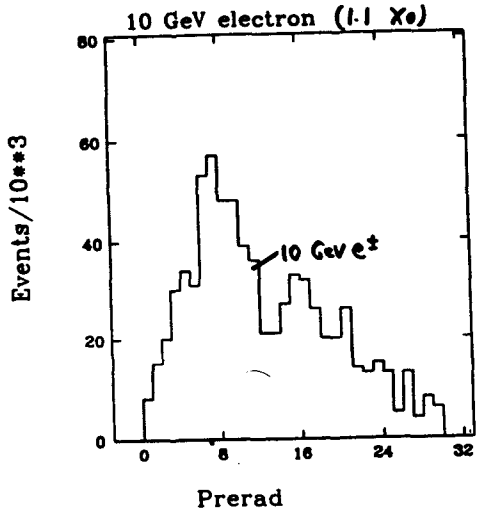

STRIP CHAMBER (6 X_0)
(c)pion, CES
8 GeV π
(d)electron, CES
8GeV e
PRESHOWER (1.1 X_0)
(e)pion, CPR
8 GeV π
(b)electron, CPR
8 GeV e
Events/bin
Pulse Height

Fig. 12

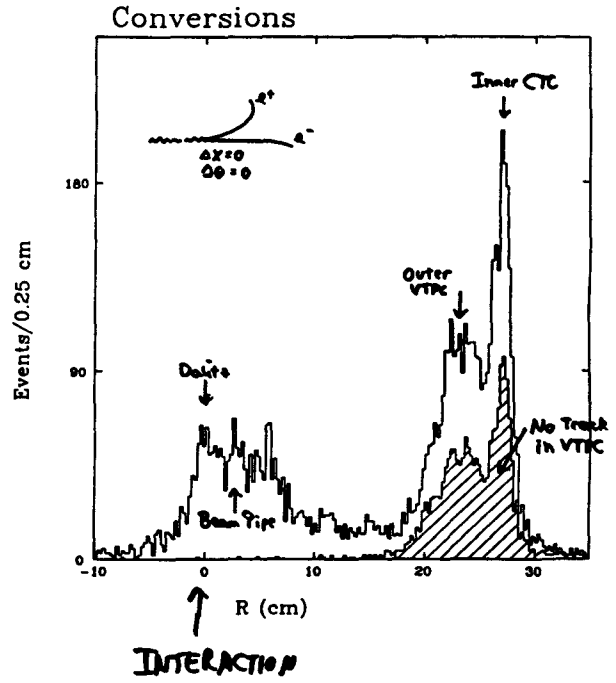

10 GeV CES>.5,Chs<10 (1.1 X_0)
10 Gev π^+, with Shower Max. Cuts.
Shower in Calorimeter
Shower in air
Events/10**3
Prerad
PRESH.
$h^\pm$
0.2λ Coil
Shower Max (0.3λ)

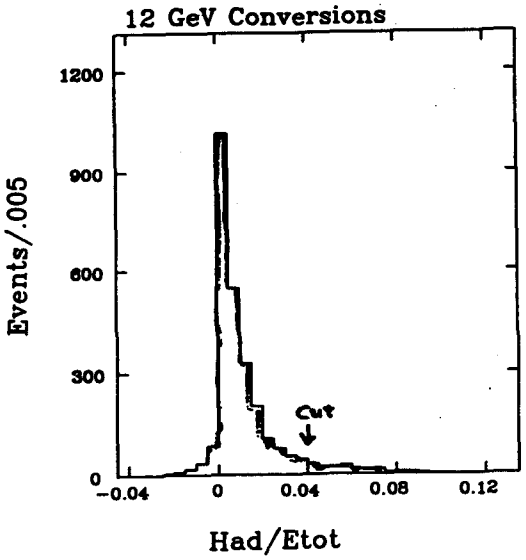

10 GeV electron (1.1 X_0)
10 Gev $e^\pm$
Events/10**3
Prerad

Backgrounds

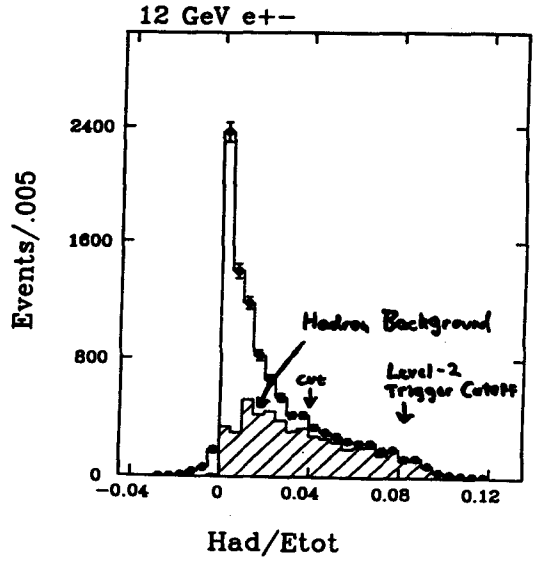
- "Small" in $W, Z \to e^{\pm}$ (See Rates, Given Mev, Mee)
- Low Et (b,c..) More Complicated . . .
  - Conversions - EASY (TRACKING + CALOR ⇒ Find other positron) ~70% efficiency
  - Fake Hadrons - HARD (early showering $h^{\pm}$ look like electrons)
  - CDF
    - b,c .. 50%
    - $h^{\pm}$ .. 14%
    - Seen Conv's .. 22%
    - UnSeen Conv's .. 14%

    } Appx Mix





(b) Calibration of Hadron Leakage Using $\gamma \to e^+e^-$ Conversions (12-30 GeV)

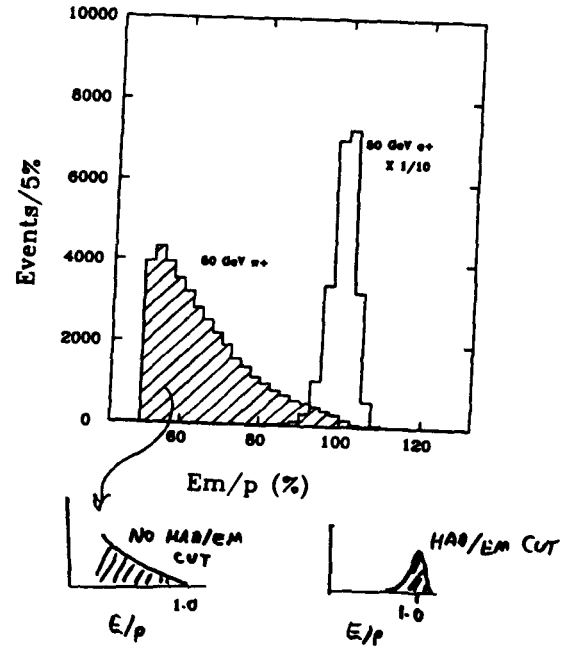


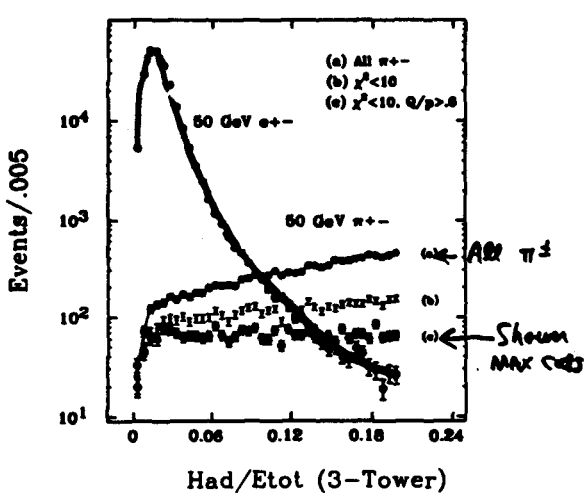
(c) Prompt electron sample (unseen $\gamma \to e^+e^-$ removed)

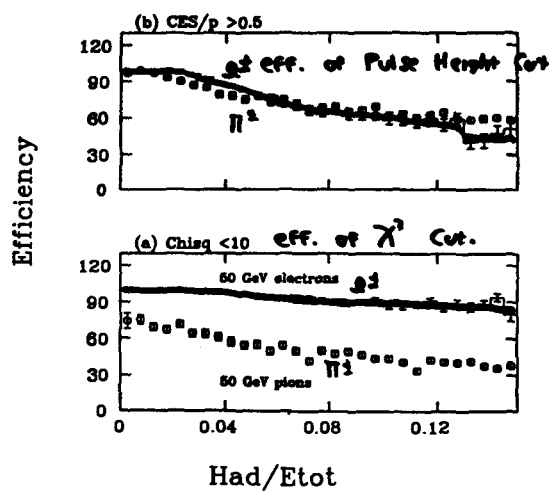
HADRON BG's (More)

(1) Interesting Correlations between Shower Max and HAD/EM

(2) Cell Size Needed for HAD/EM is Larger than needed for EM Shower ! (HADRON LATERAL PROFILE)







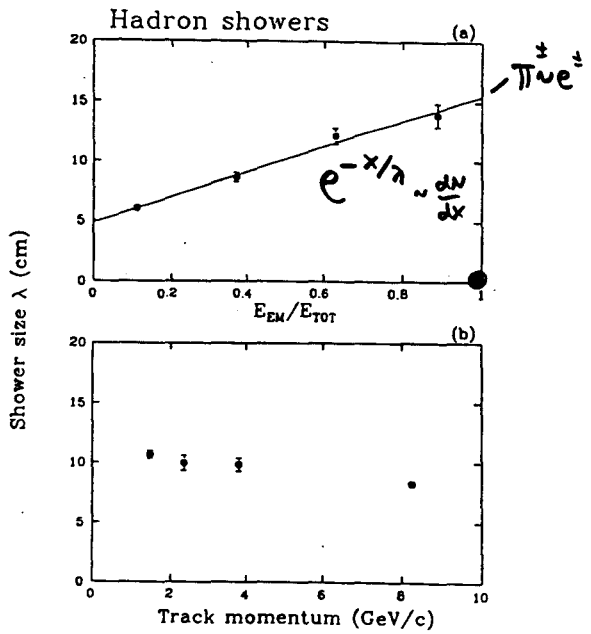
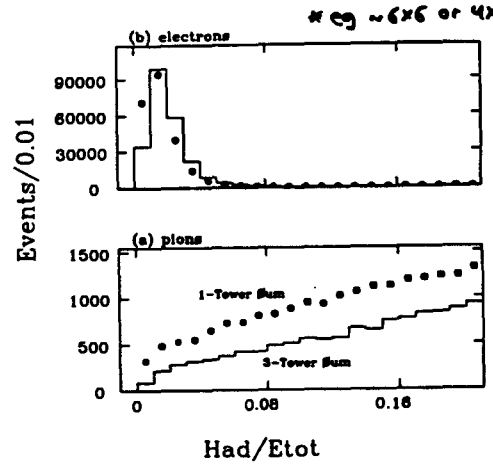


Fig. 8

Definition of "HAD" in HAD/EM
$\eta \times \phi$ = .3×.25 (3 Tower)*
= .1×.25 (1 Tower)
* eg ~6×6 or 4×4 in SDC



Food for Thought
(Non-Isolated $e^{\pm}$)

- Why use Had/EM at all
  - Requires large cell (.2×.2 $\eta\phi$)
  - Forces E/P=1 Peak (EM+HAD ≅ 1 !)
- Shower Max
  - Uses Small area
  - Gets ~5× Less Rejection
  - Does not force E/P=1 Peak.

Greg Sullivan
Univ. of Chicago

QCD Rates

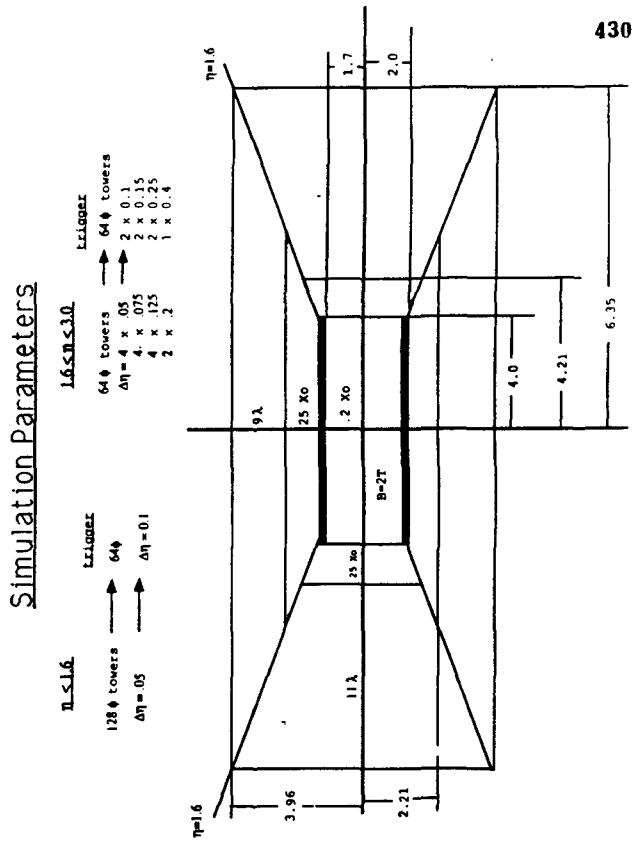
SDC Meeting
Aug. 5-10, 1991

Description of Simulation

429

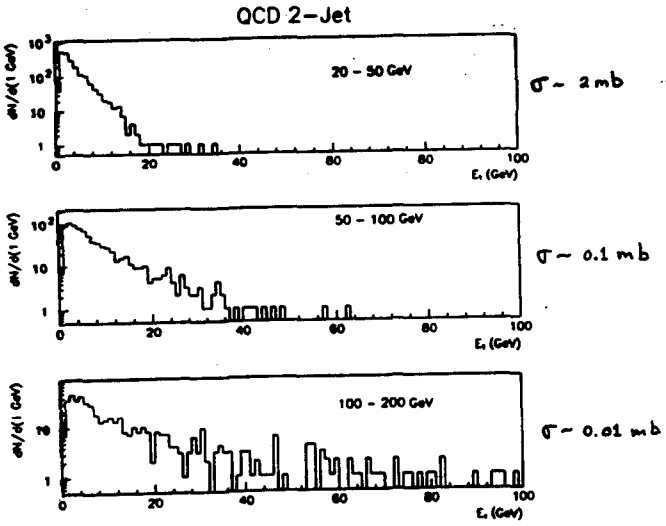
- Generate Data Sets with Isajet
  minbias, 2-Jet, W, Z, ···
- Poisson distribution of minbias at every beam crossing.
- Smear Vertex position.
- Use shaping function/time history for energy in calorimeter towers.
- π, K decays in flight
- Conversions
  material in tracking volume put in on an average.
- Tracking resolution from EOI, eff = 1.0
  $\frac{\Delta P_T}{P_T^2} = 3.0\ \mathrm{TeV}^{-1}$
- Calorimeter longitudinal & lateral shower fluctuations.
- Shower max in ϕ bins

430



431

$|\eta| \leq 3.0$

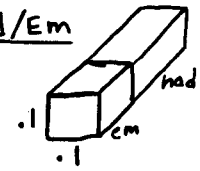


highest em tower w/ had/Em < 0.2

Cuts

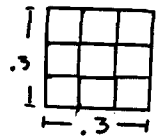
432

Had/Em



had/em < 0.2, 0.1, 0.05

Isolation



$$Iso = \frac{\text{E had border towers}}{\text{em tower}}$$

< 0.1, 0.07

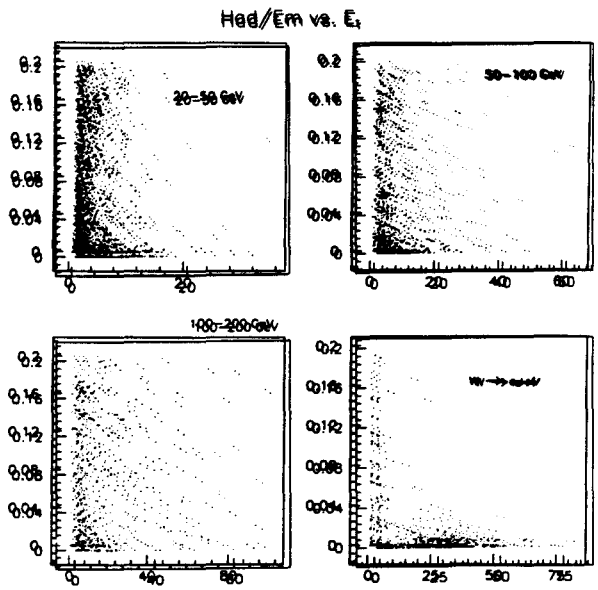
Track

$$\left[\mathrm{abs}(\eta) \leq 1.6 \text{ .AND. } P_T > 5.0\right] \text{ .OR. } \left[1.6 < \mathrm{abs}(\eta) < 3.0\right]$$

$(P_T > 10.0)$

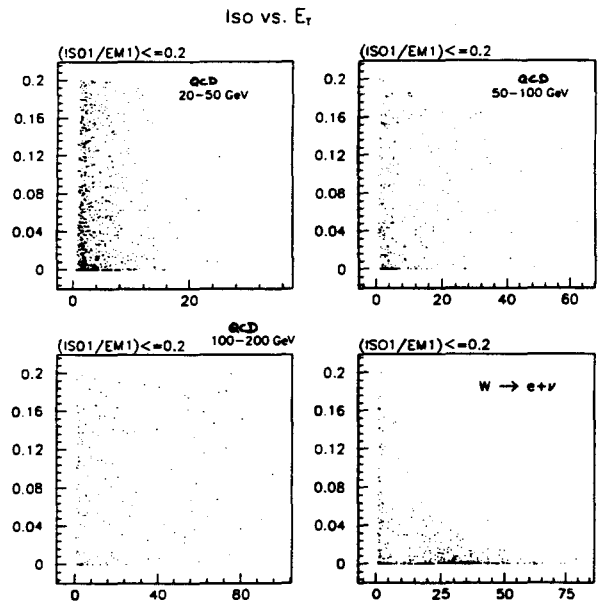
Had/Em of highest em tower vs. E_T of tower

433



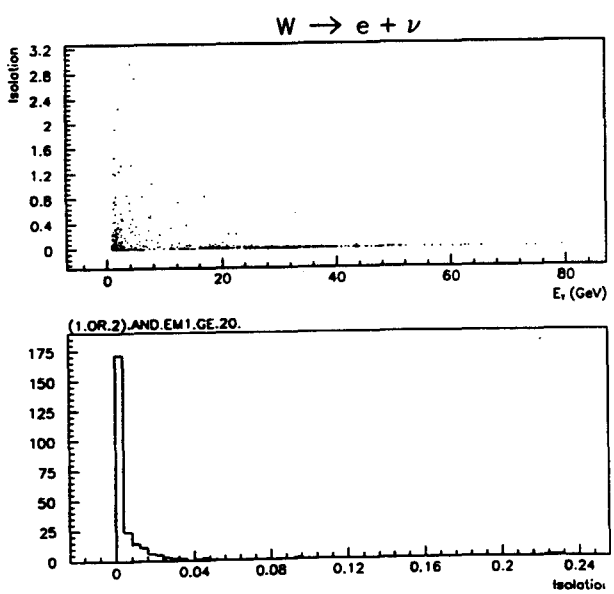
Isolation of highest em tower vs. E_T of tower

434

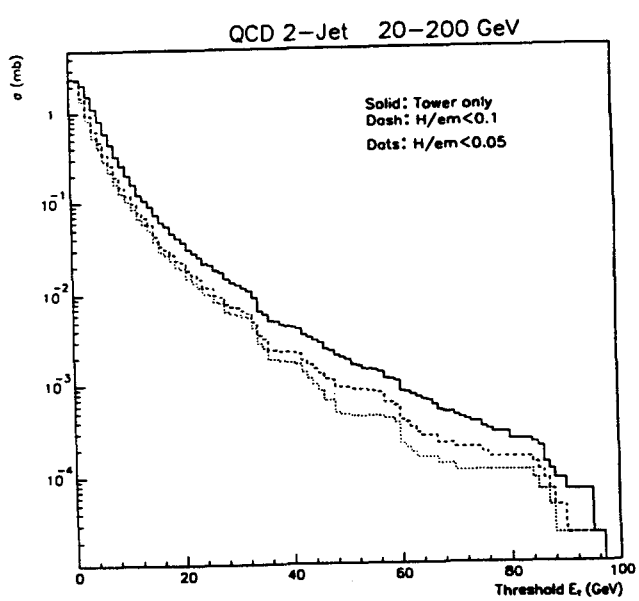


Isolation for $W \to e + \nu$

435

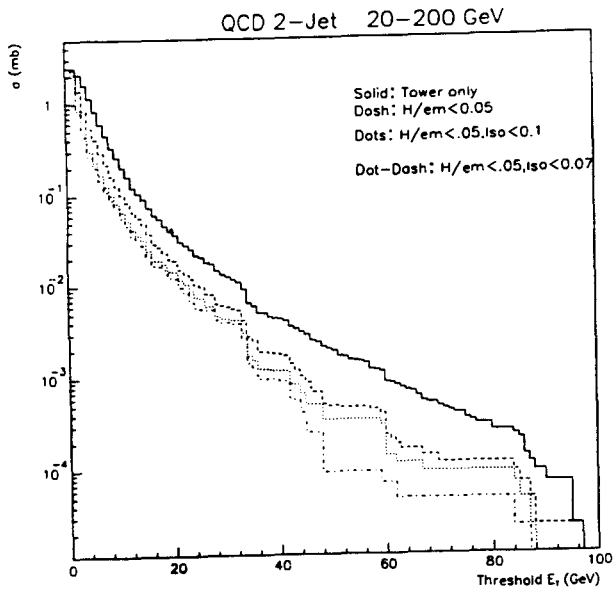


436



Rate Vs. Isolation for Had/Em < 0.05

437



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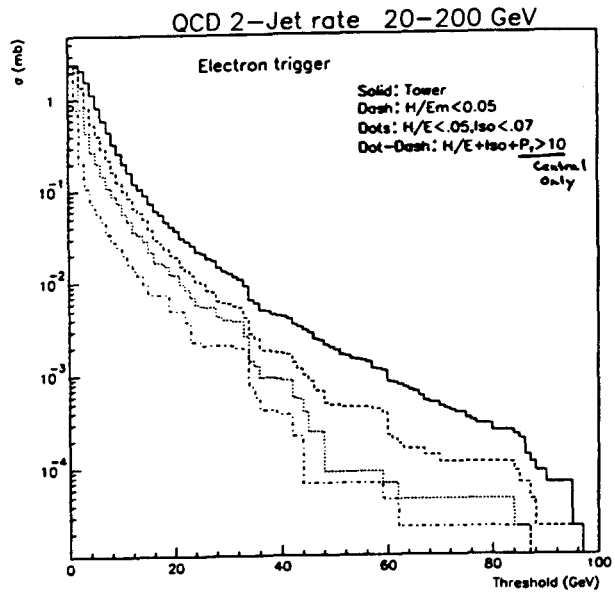
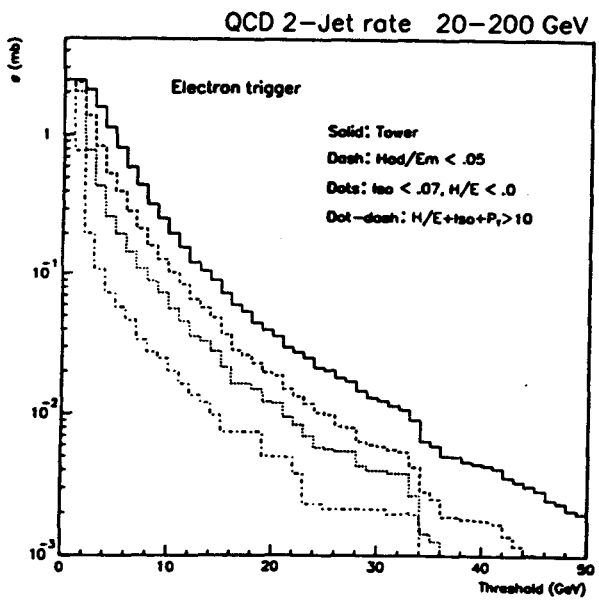


[redacted]

439



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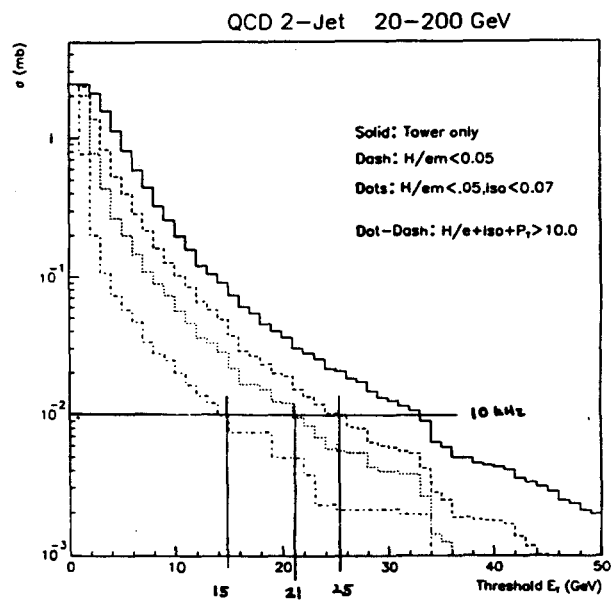
440



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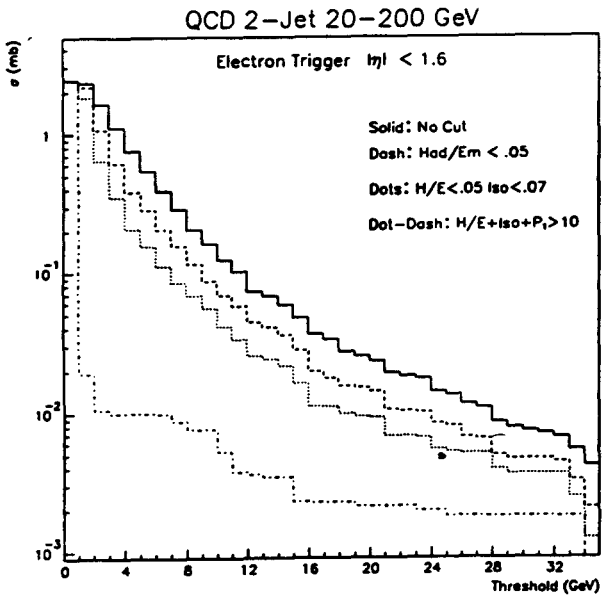
441



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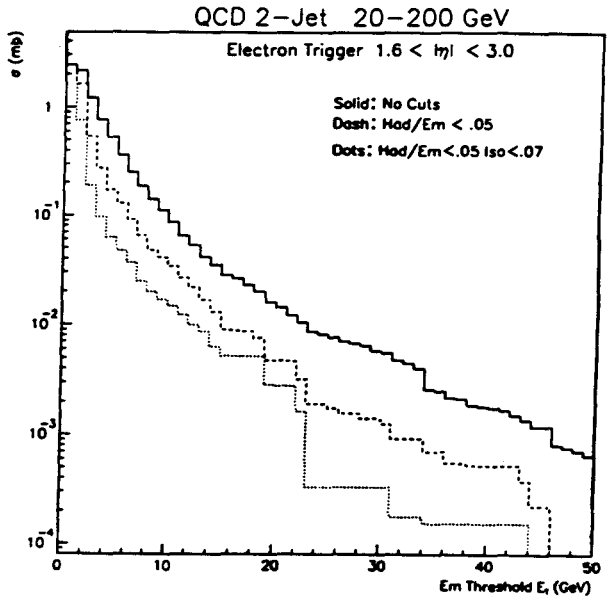

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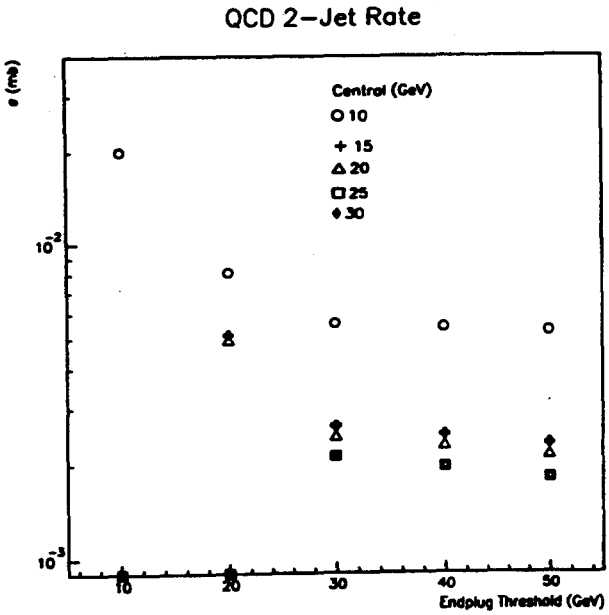

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Level 1 Electron trigger rates.

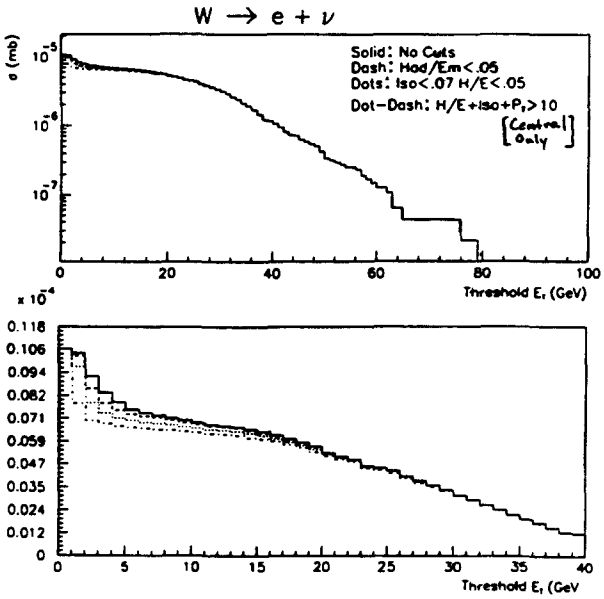
Rate (kHz)		Endplug Threshold (GeV)				
		10	20	30	40	50
Central Threshold (GeV)	10	20	8.5	6.0	5.5	5.5
	15		5.0	2.7	2.4	2.2
	20		4.8	2.3	2.2	2.0
	25			2.0	1.8	1.7
	30			2.0	-	-

CUTS

$$Had/Em < 0.05$$
$$Isolation < 0.07$$
$$(|\eta| < 1.6 \; and. \; P_T > 10.0) \; .or. \; |\eta| > 1.6$$

- $W \to e + \nu$ generated over allowed kinematic range.
- Trigger towers $|\eta| \leq 3.0$ → Acceptance ≈ .65

445



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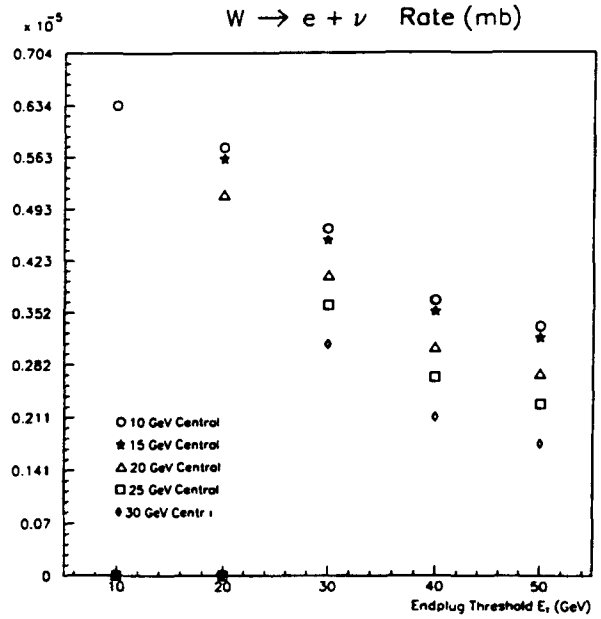

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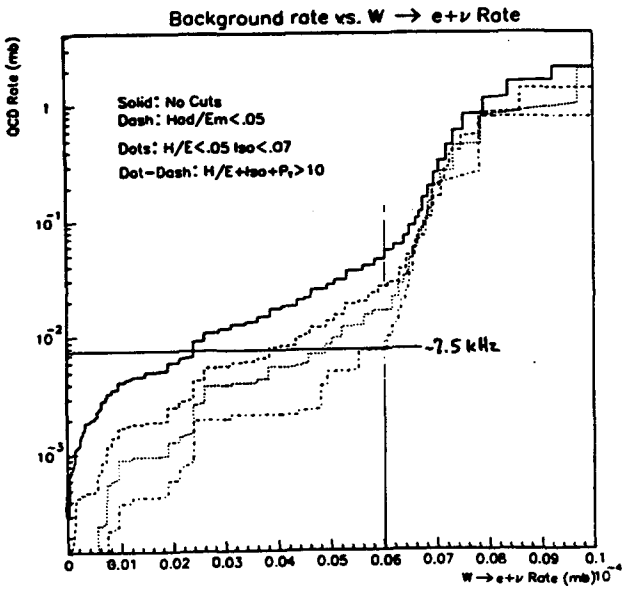

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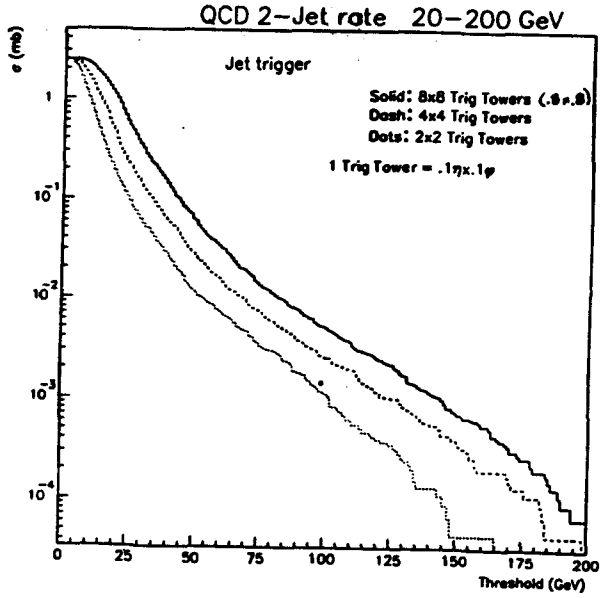

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Level 1 Strawman Trigger Table

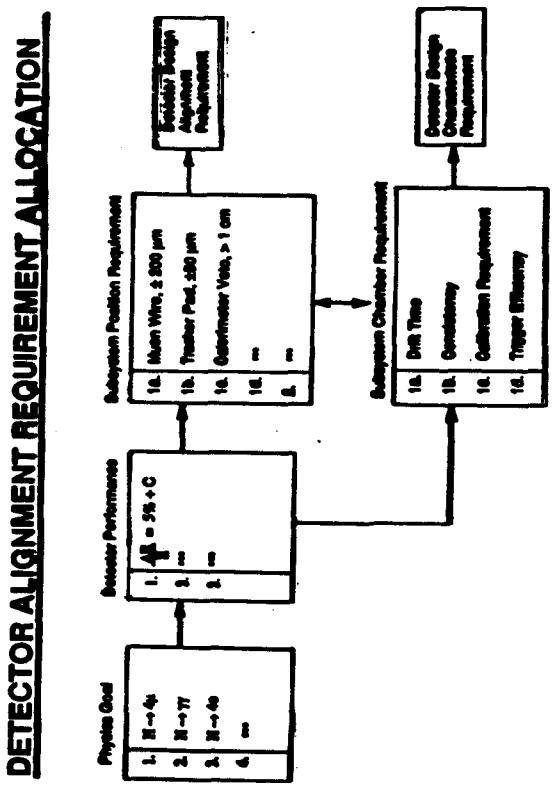
Trigger	E_T (GeV)	$\sim\sigma$ (μb)
electron	15. $\lvert\eta\rvert<1.6$	3
	30. $1.6<\lvert\eta\rvert<3.0$	
Central photon	35 ?	1
muon	15	1 (?) EOI
Jet	150	1
2 electrons	10	1
2 muon	10	1
e/μ	10/10	1
$\not{E}_T$	140	1 (EOI)
ΣE_T	1000	1 (EOI)
ΣP_T	?	–
Minbias (pre-Scaled)		
electron "	10	
muon "	10	
Jet "	100	

Future Work

1) Put in FADC Resolution.
2) Put in tracking efficiency from tracking simulations.
3) Study track - Shower max match at Level 1
4) di-electron rates.
5) ΣE_T, $\not{E}_T$ trigger rates.
6) Examine segmentation issues (Descoping)
7) check against CDF trigger rates.
8) Breakdown of QCD Background rates into prompt e, conversion, π^0, π^+ overlap

CALORIMETER PHYSICS PERFORMANCE

J. SIEGRIST



A Tentative Vote for Supersymmetry

Do new measurements offer indirect support for an elegant attempt to unify fundamental forces of nature?

THEORETICAL PHYSICISTS GOT QUITE A JOLT back in 1983, when CERN began to report to an elegant idea years of their researchers dared to hope. Actually, the discovery would have confirmed a weak prediction of a much-admired theory called supersymmetry (Science, 29 April 1983, p. 491), which looked to one of the grand unified theories (GUTs) that attempt to unite the three fundamental forces that govern particles and fields.

Although the discovery was confirmed, the 1983 measurements have since gotten shaky, and physicists walking down CERN's corridors are supersymmetry. The challenge—and the attractiveness of the idea—is that with the strengths of the three forces change as the energy of interaction increases, they become equal at an energy of about 10^{15} GeV, given or take a hundred billion times greater than anything realized in current accelerators. At that energy the strong, weak, and electromagnetic forces should merge into one. The prediction, however, is that when these physics is extrapolated to higher energies, the energy dependence of the coupling constants curves don't come close to converging (see graph, left).

One of several ways to make the calculations converge is to postulate a set of new particles that are "supersymmetric" to those already known. Such "superparticles" would contribute to the coupling strengths, and so forth that for zero, bringing the curves together. Their given, would differ by one-half in spin: 1/2 for fermions (a proton or electron, for example) and 0 "sfermions" (an electron, for example). Combining supersymmetry with GUTs would be a powerful idea indeed. Many physicists would be particularly pleased by the prospect of a single unification scheme, which would be a major step toward a theory of all the fundamental forces of nature.

Combining supersymmetry with GUTs produces a single unification scheme, although supersymmetry can do the job (right).

Arnold's remarks "unnerving," but complain that his analysis failed to take into account the "renormalization" effects that change any coupling constant. "The question is just financial," Pondrom says. Still, Arnold gets a cautious vote of confidence from William Marciano, a theorist from Brookhaven National Laboratory: "It should be encouraging for those who believe in supersymmetry," he says.

GUTs in general have fallen on hard times over the past decade, as none has made exclusive predictions that could be tested at running accelerators. By implying that supersymmetry might soon be testable, Arnold's work has brought new life to the idea. Although Arnold has borrowing now on his laurels, he expects to see many attempts to verify his discovery sooner or later. Indeed, CERN Director-General Carlo Rubbia hyped the findings in an interview last spring in Physics Today, saying that "the Large Hadron Collider, so far, though, there's no sign that SSC management is prepared to run this particular experiment.

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SCIENCE, VOL. 253

unification to an especially narrow range—between 100 GeV and 2 TeV. These figures represent energies that lie within reach of the next generation of particle accelerators. That alone is enough to get some experimentalists, such as Boston University physicist Larry Sulak, excited. These "spectacular" results, he says, imply that it will be possible to find superpartners, particles at the Superconducting Super Collider (SSC). But the results, he added this spring in Lawrence Berkeley Laboratory, gold "This is not very supports supersymmetry or anything else," he says. "The best case can say is that [GUT] models are consistent with these measurements." Other skeptics, such as Michael Peskin, a theorist at the Stanford Linear Accelerator Laboratory, find

CALORIMETER PERFORMANCE ISSUES

'REQUIREMENTS' DOCUMENT DESCRIBES PHYSICS AND TECHNICAL CONSIDERATIONS ON WHAT THE DESIGN PARAMETERS SHOULD BE

DETECTOR 'AS-BUILT' MAY NOT MEET REQUIREMENTS - NEED TO KEEP TRACK OF SHORTCOMINGS ALREADY SUFFERED AS WE MAKE BUDGET CUTS

HOPE FOR A 'FINAL' VERSION OF THE DOCUMENT IN JANUARY '92

- TRIGGER STUDIES → SEGMENTATION REQUIREMENTS
- LOOK AT MORE PROCESSES, ARGUE ABOUT THE VALIDITY OF THE ARGUMENTS

SIEGRIST WILL SERVE AS REFEREE; DOCUMENT YOUR COUNTER-ARGUMENTS VIA SDC NOTES AND BRING THEM TO MY ATTENTION

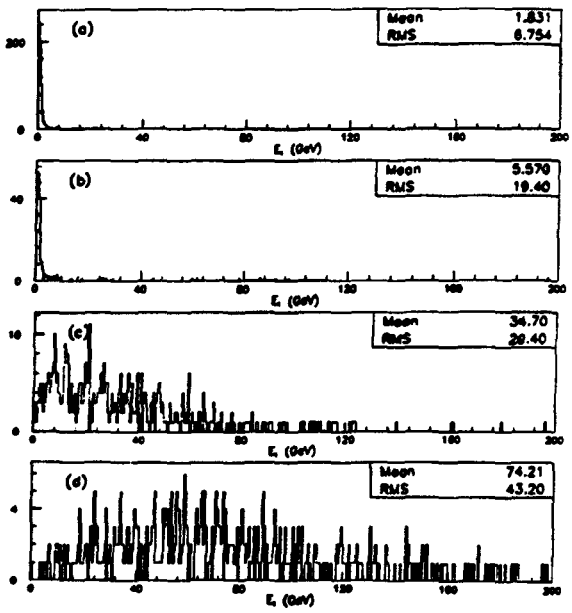
WHAT DID I LEARN FROM THIS EXERCISE (CON'TD)

- $t\bar{t}$ BACKGROUND LOOKS TOUGH. REQUIRE EFFICIENT REMOVAL of $t\bar{t}$

  (→ hi pt b's LOOK PARTICULARLY TOUGH)
- TRIGGER REQUIREMENTS - NEXT MAJOR AREA
- FORWARD PEOPLE WILL FILL THEIR SECTION.
  SHOWER MAX ARGUMENTS ALSO NEED FILLING.
  GENERAL CLEANUP COMMENTS SHOULD BE SENT TO ME
  τ SECTION?
  B PHYSICS SECTION?

WHAT DID I LEARN FROM THIS EXERCISE?

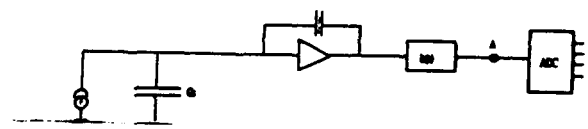
- H → 4 LEPTONS SETS MANY OF OUR REQUIREMENTS. WE NEED MORE WORK ON $\gamma\gamma$ MODES
- A SUMMARY OF HIGGS WORK IS NEEDED (EINSWEILER, IN PROGRESS)
- OTHER PHYSICS PROCESS? SUPERSYMMETRY



3.16b

Figure 4: The distribution of E_t in a cone of radius $R = 0.3$ for the same electron p_t range displayed in Fig. 3. The individual distributions also have the same significance as those in Fig. 3.

Figure 3.17



$$\langle E_{Tow} \rangle = \frac{\bar{E}\,\bar{n}_p\,\Delta\eta\,\Delta\phi\,\bar{n}_{ev}}{2\pi\,\Delta t} \int_0^{\infty} h(t)\,dt$$

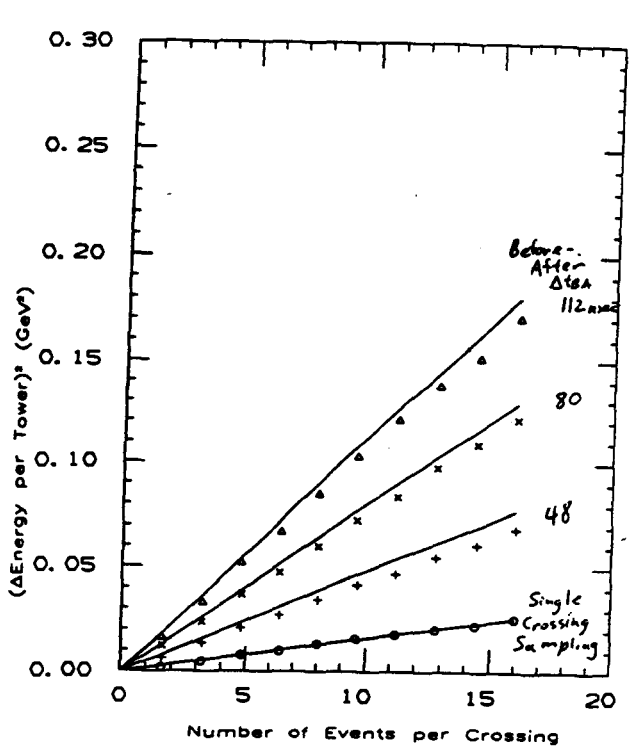


Fig. 8 3.18

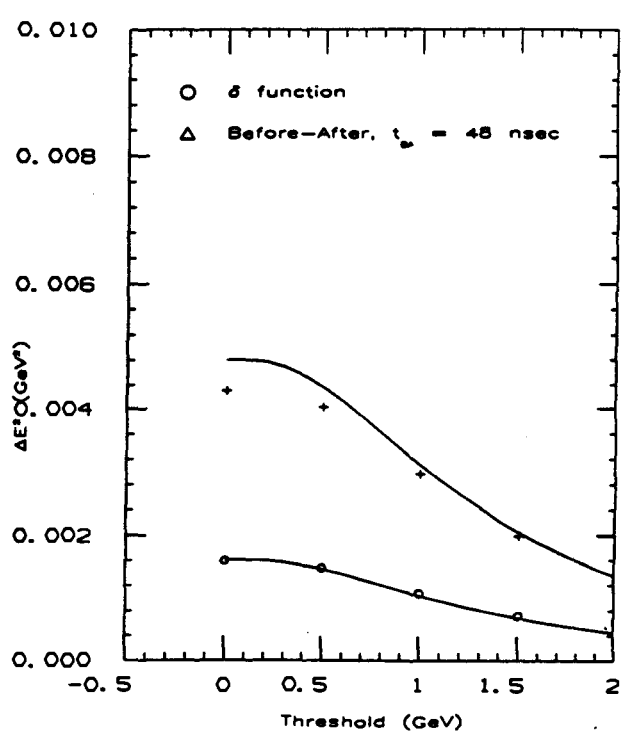
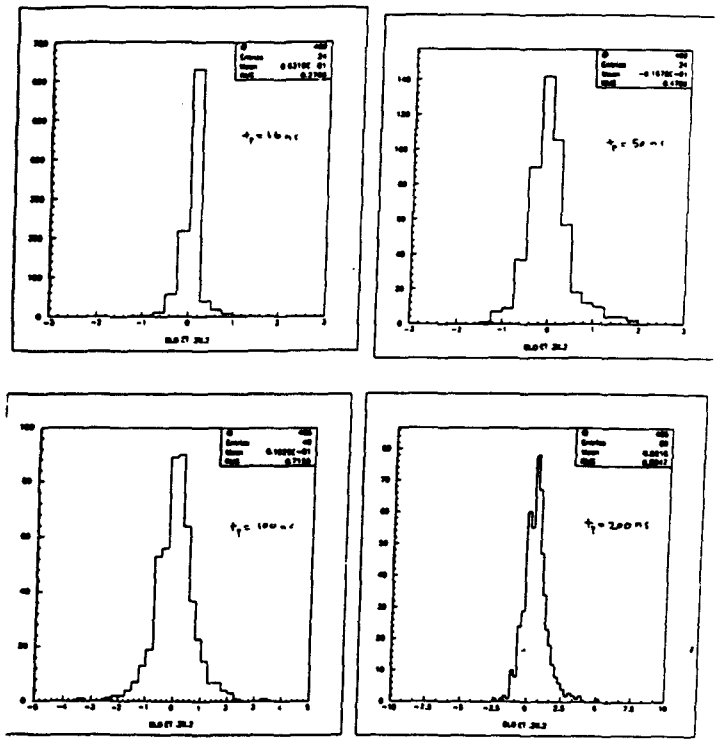


Fig. 4 3.19

Fig 3

E_T in .2x.2 cells



3.21

Figure 2.8

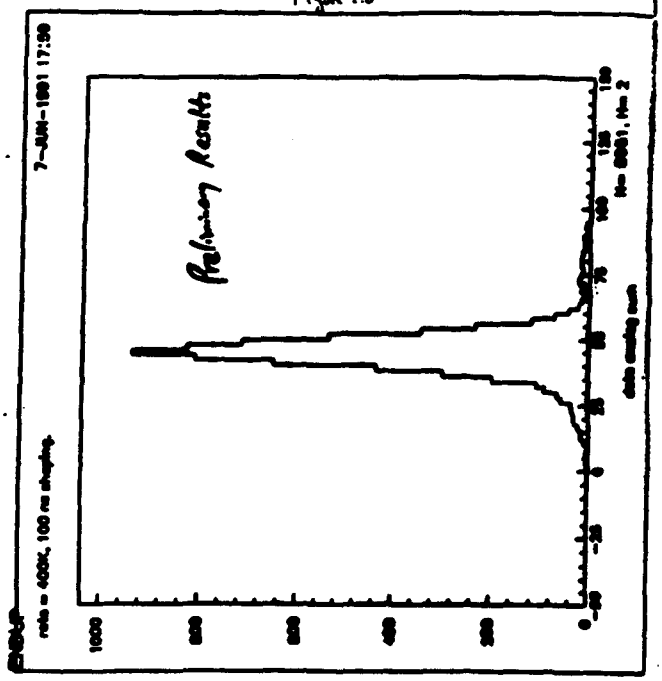


Figure 2.9

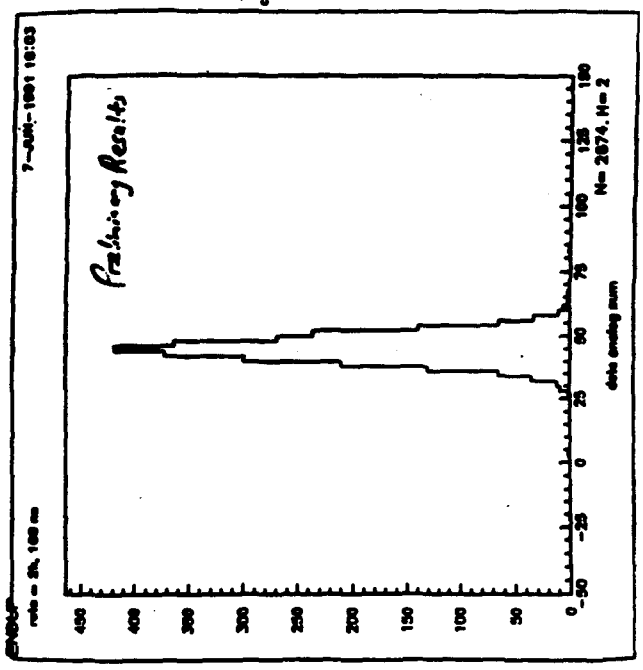
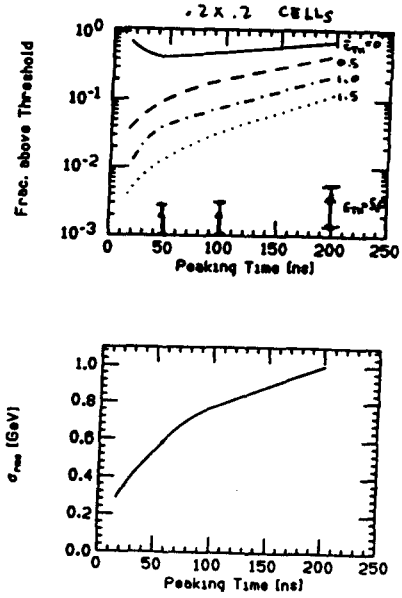


Fig 5

.2 X .2 CELLS



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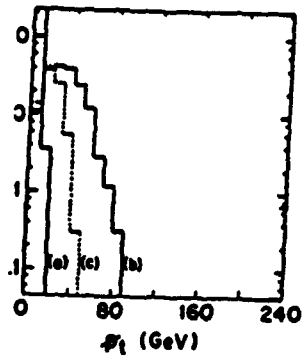
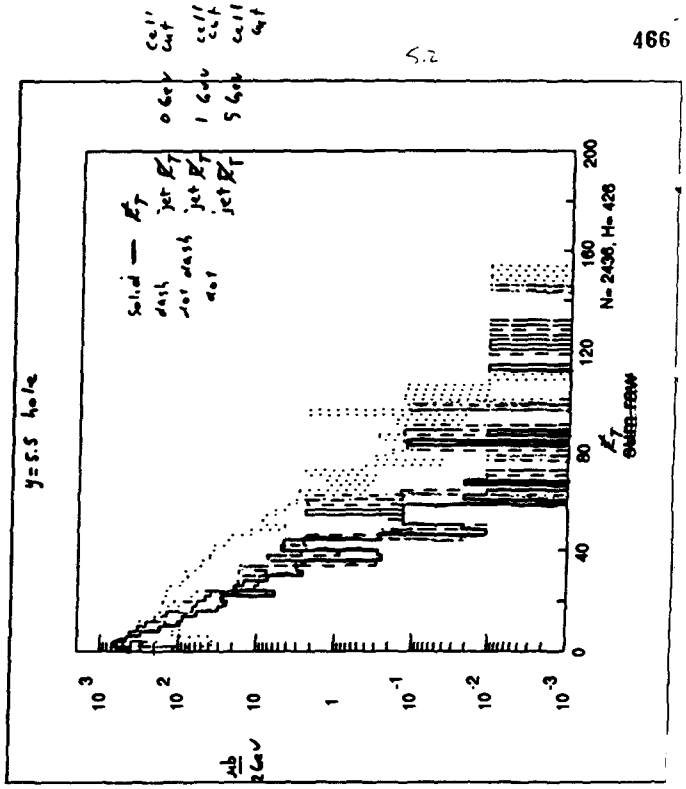
5.1



The momentum imbalance $\not{p}_t$ as measured in
eter for minimum bias and two jet events. (a):
): single sample noise and (c): optimally fil-
for $\mathcal{L} = 10^{30}$.

5.2



SOLENOIDAL DETECTOR COLLABORATION

LAWRENCE BERKELEY LABORATORY

CALORIMETRY SUBGROUP

August 8, 1988

ENGINEERING DESIGN OF THE LIQUID ARGON CALORIMETER

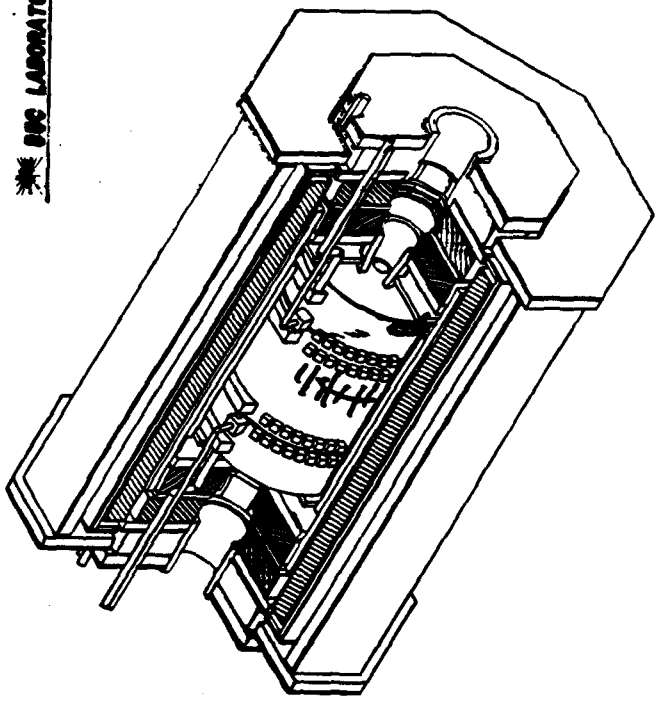
Information compiled by:

William L. Pope, LBL

for the

SDC/LAC GROUP

SDC LABORATORY



Calorimeter topics to be discussed:

1 CRYOSTAT DESIGN

a. Barrel LAC ROI (Nov. 1990) update
b. New endcap configurations

2 MODULE DESIGN

a. Barrel EM and Hadronic
b. New endcap "Big Wheel"

3 CRYOGENIC SYSTEM DESIGN

4 PREAMP COOLING

a. Rochester & KHI experiments
b. LLNL & KHI calculations

5 SIGNAL CABLE FEEDTHRU DESIGN

6 INTEGRATION

a. Cryogenic piping interface
b. Beam beam & its support

7 ACCESS

a. to Calorimeter & Tracker electronics
b. to Inner Muon chamber electronics

8 LAC SAFETY

CRYOSTAT DESIGN (see CDR, Section 4)

A. LAC ROI (Nov. 1990) *update*

1. Barrel– eta = 1.2

- inner cylinder/head flanges (moved away from corner)
- LAr head thinning in EM end region

2. *endcap*–the eta = 3 problem (discussed below)

B. Concurrent endcap configuration studies

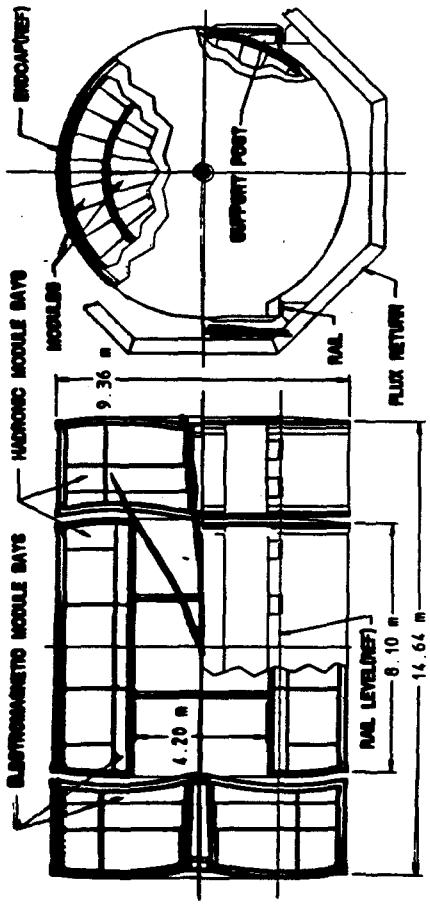
1. LBL conceptual design

- double conical LAr & vac heads
- EM penetrating stay (cylinder)
- *thin* inner cylinders–*no* axial load
- inner vacuum cylinder–*close* to the beam pipe

2. KEK/KHI designs

- existing LAr head shape
- EM penetrating stay (cylinder)
- *thin* inner LAr cylinder–with axial load
- front vacuum head shape investigations

C. Common Ground–The "KBL" endcap



ASAE CDRE DESIGN

4-4

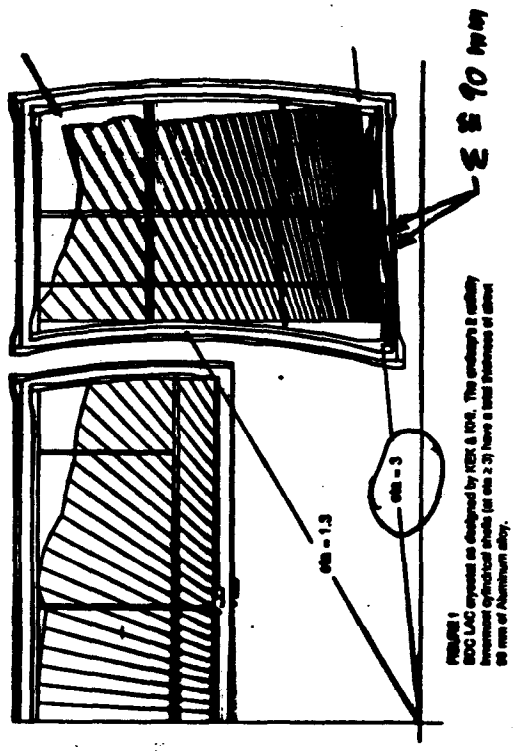


FIGURE 1
EDG LAC crystal as designed by KEK & KHI. The endcap is entirely transversal cylindrical shells (at eta ≥ 3) have a wall thickness of about 55 mm of Aluminum alloy.

Brief LBL Endcap Configuration Investigation
(See LBL SD-4 [illegible], WBS 2.2, July '91)

1. **Design Objective**—LBL's goal was to achieve a design capable of meeting applicable requirements of the ASME Boiler & Pressure Vessel Code such that it is;
   - no worse than the current KEK/KHI design for 0 ≤ eta ≈ 1.3,
   - *significantly better* than the LAC LOI design at eta ≥ 3,
   - *no worse* at eta ≈ 1.9 (the region of the EM penetrating stay) than the current design is at eta ≈ 1.3, where the barrel and endcap "overlap".
2. *LBL Conceptual Design;*
   - ≈ 55 mm thk. double conical, front LAr & vacuum heads (locally stiffened)
   - ≈ 12 mm thk. EM penetrating stay
   - ≈ 8 mm thk, ring stiffened inner LAr cylinder—with *no axial load* (SF ≥ 2)
   - ≈ 2 mm thk, ring stiffened inner vacuum cylinder—*close* to the beam pipe—with *no axial load* (SF ≥ 6)

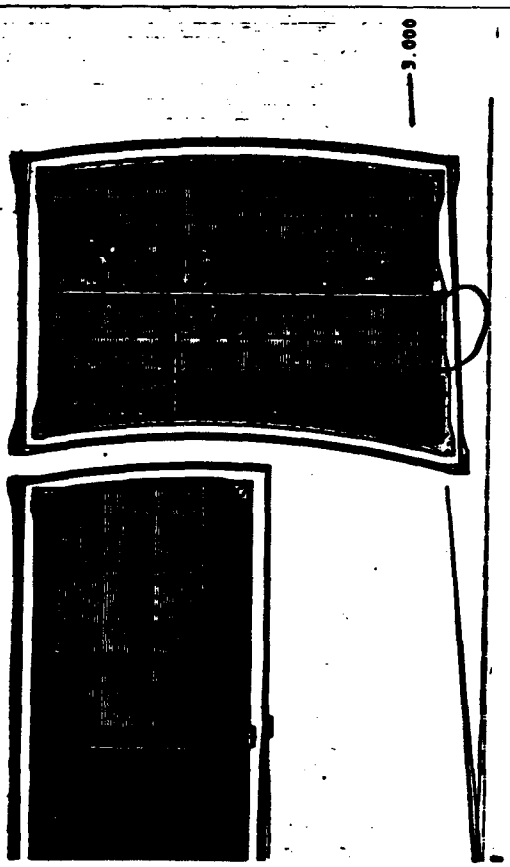
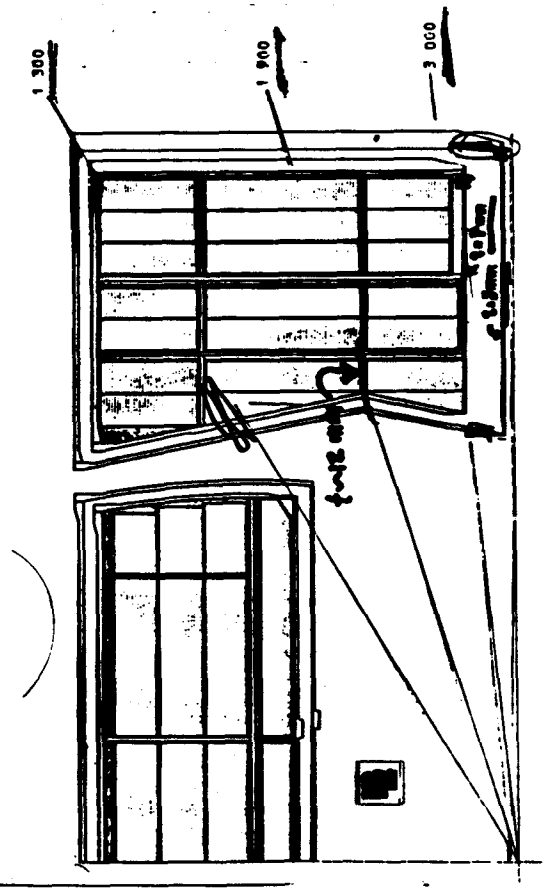
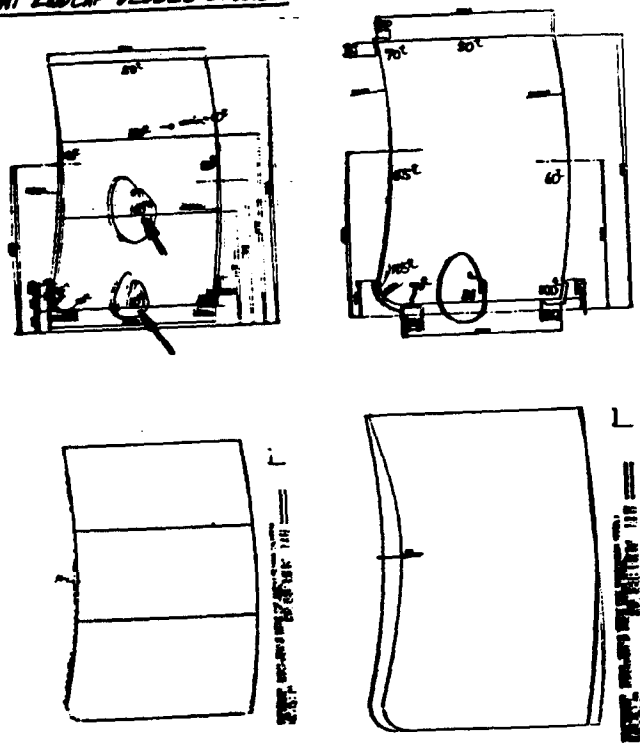


FIGURE 1
DATE: 7-23-91



NEW LBL ENDCAP CONCEPT
DATE: 8-2-91

BNI ENDCAP VESSEL STUDIES



MODULE DESIGN (See CDR, Section 5)

A. Barrel Modules

1. HADRONIC

a. Baseline construction using developed technology

b. alternate cast Pb concept

2. ELECTROMAGNETIC

a. Baseline construction

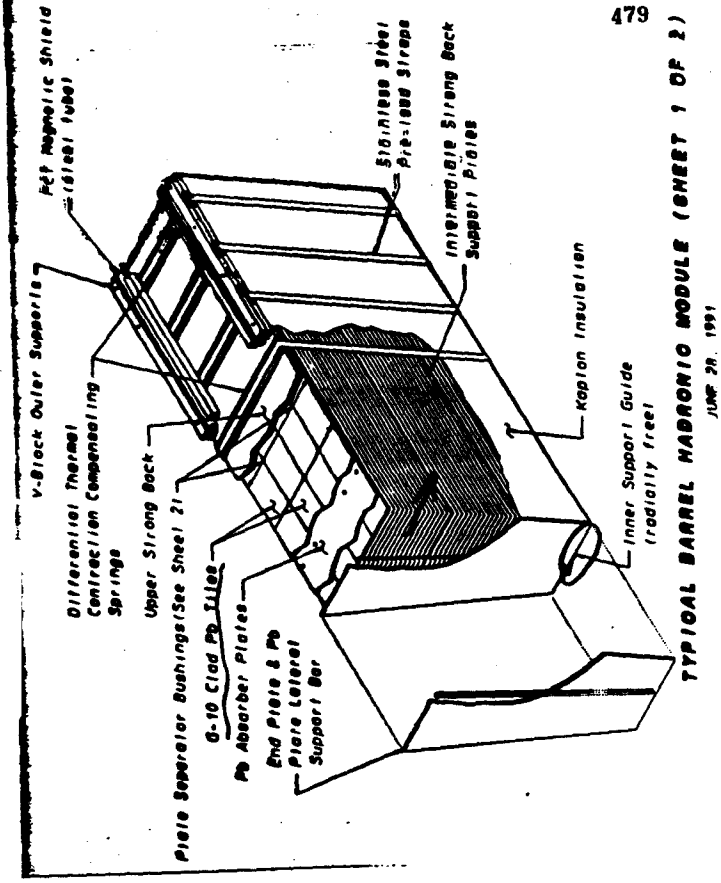
- BNL test configuration
- low dead area fraction (≈ 1.7 %)
- Pb creep mitigation

b. alternate construction option using developed technology

- can also have low dead area
- WE CAN CHOOSE IN A WEEK

B. NEW BASELINE endcap "Big Wheel" modules

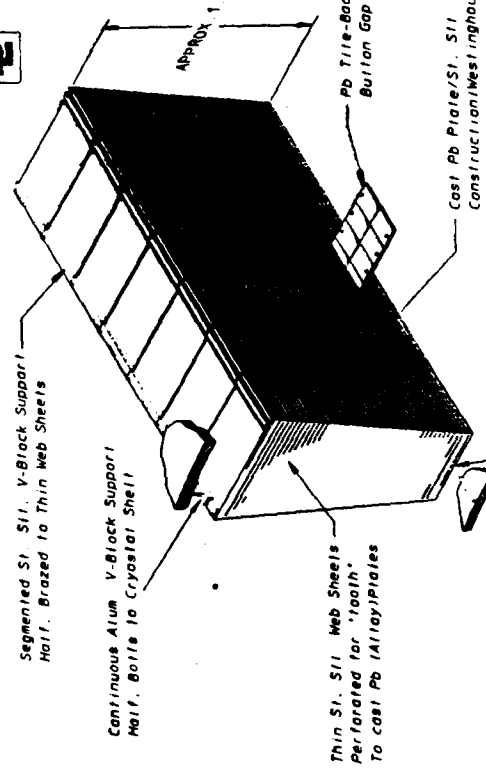
- simplifies vessel ass'y and close-out
- proven technology (BH & D-Zero)
- adaptable to vessel's sta = 3 solution
- no special provisions for prestop cooling required



TYPICAL BARREL HADRONIC MODULE (SHEET 1 OF 2)

JUNE 28, 1991

CAST Pb BARREL MODULE CONCEPT



June 27, 1991

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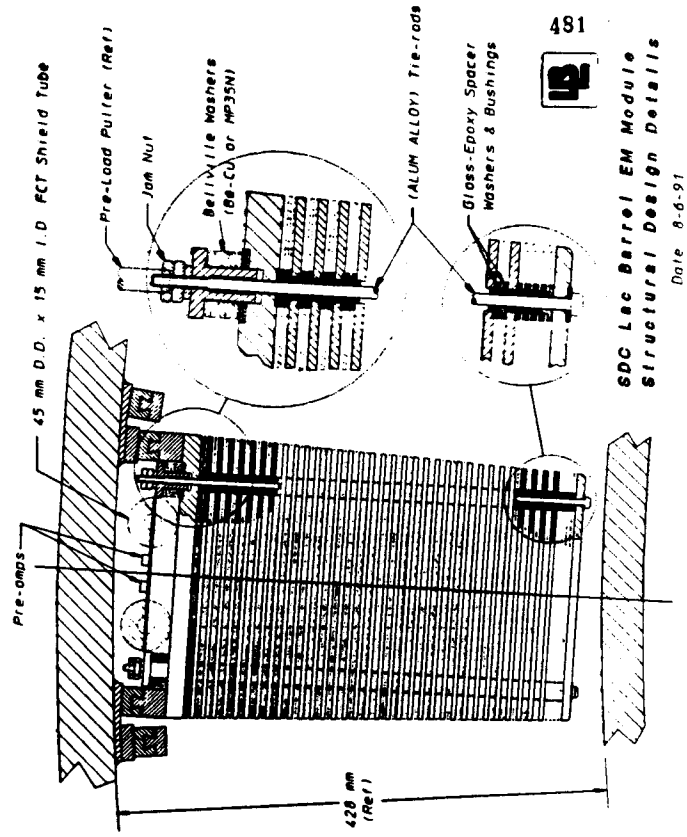

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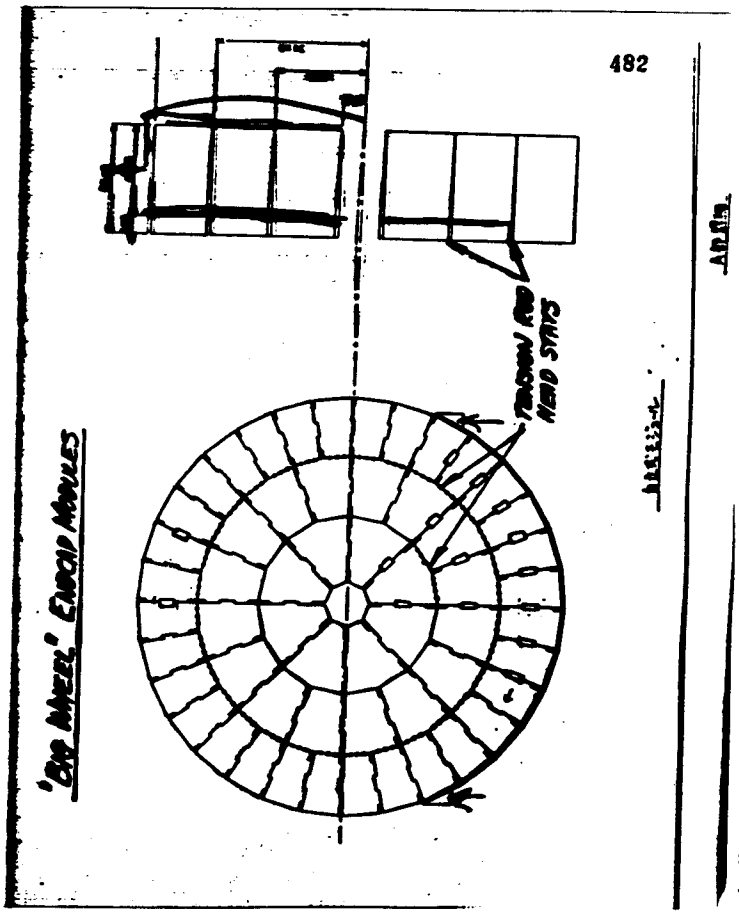

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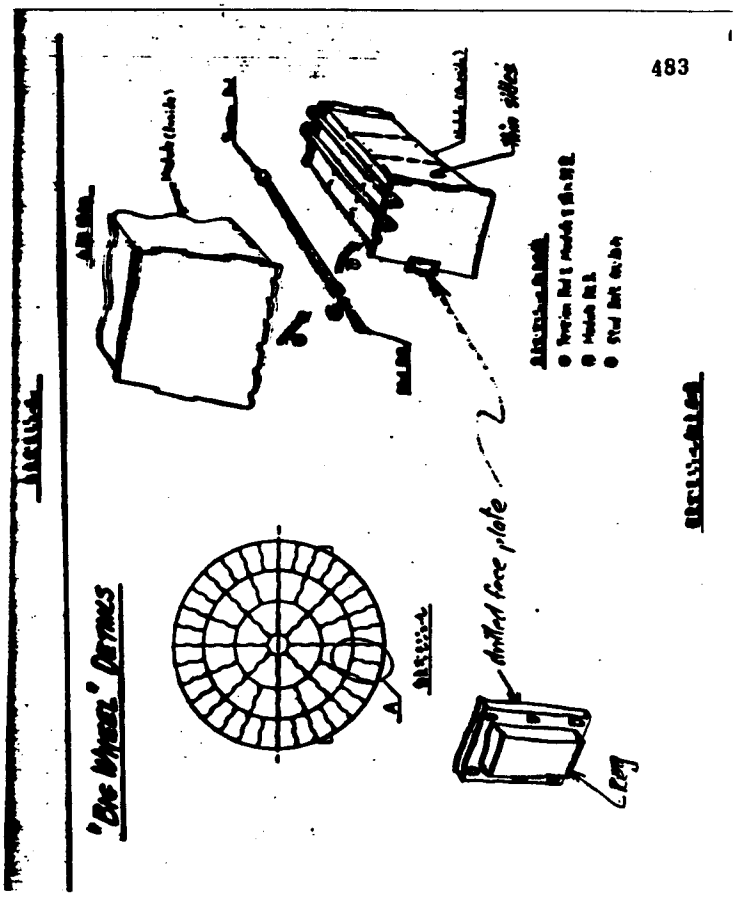

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CRYOGENIC SYSTEM DESIGN
(See CDR, Section 6)

A. ***Baseline Design*** **is the pulsed, 2 phase N_2 cooling system developed by Watt & Barrera (SLAC).**

B. **Proven Technology (MK II, Venus, SLD).**

C. **Main Transfer Lines (MTL).**

- **cryogenic fluid, vacuum, & vent provisions in large, robust, common conduits.**
- **Invar cryo lines eliminate bellows in MTL.**

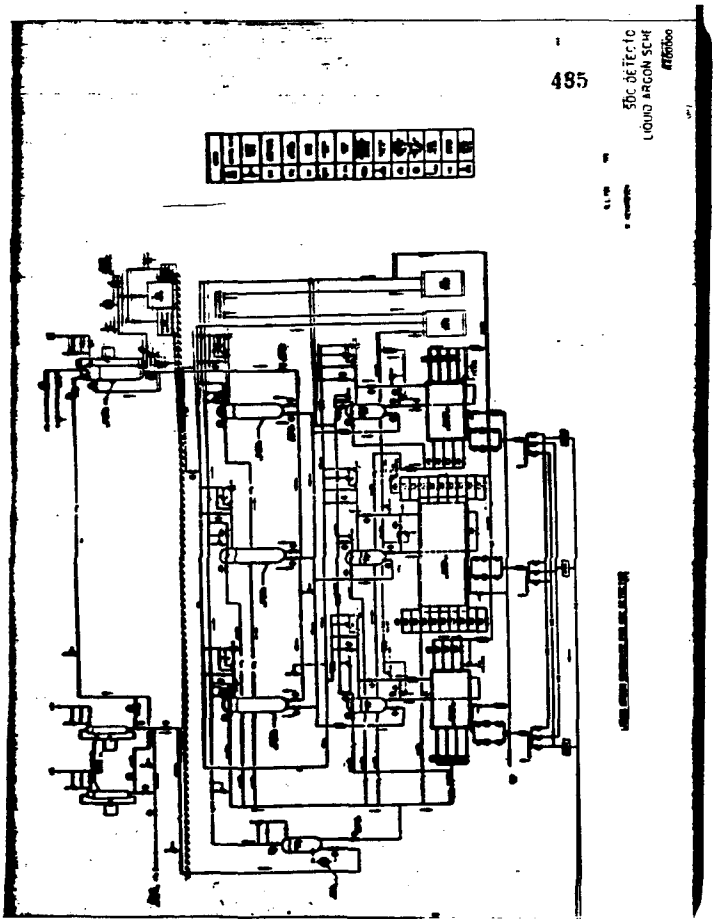
D. **Small stroke bellows in common cryostat vacuum annulus have been minimized and are of double walled stainless steel construction.**

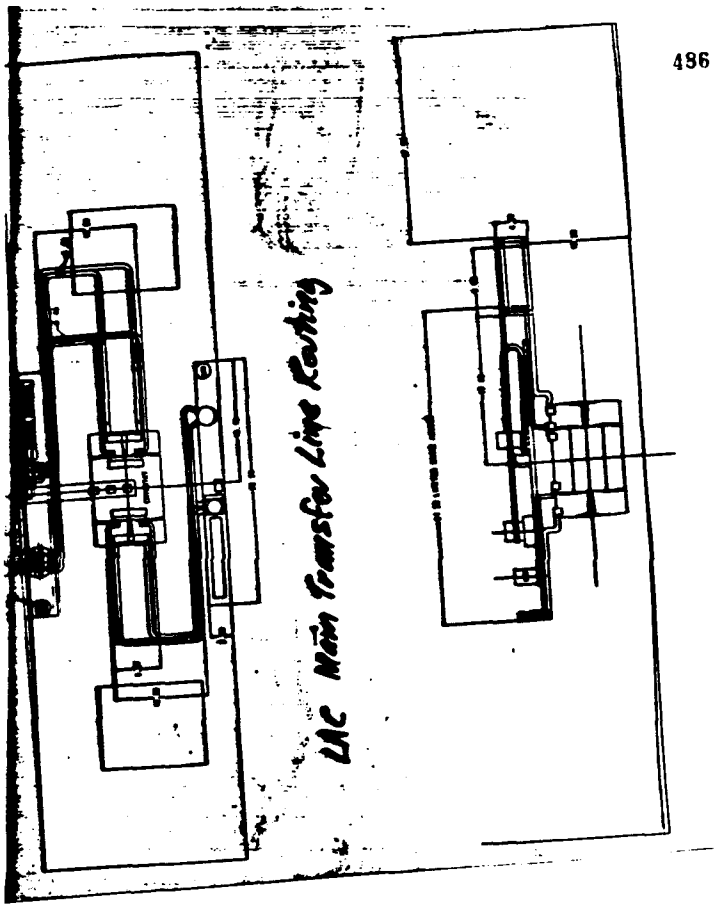
E. **Cryostat-to-MTL hoses in vacuum annulus are braided, stainless steel.**

F. **Gleason carriages allow endcap moves with *fully functional* cryo, vacuum, vent, and Safety Relief provisions.**

G. **Large LAr Storage dewars at Detector level.**

H. **This system has satisfied Preliminary Hazard Analyses by the SSCL review committee.**





PREAMP COOLING

The LAC's preamps reside at the back of the modules in LAr. See Section 7 of the CDR for a complete description of their properties and expected performance.

1. Heat & Analyses strongly suggest that boiling of LAr can be avoided in the *Baseline LAC*

2. Experimental Tests:

→ 2.1 University of Rochester

→ 2.2 KEK/KHI

3. Design Calculation Documentation:

→ 3.1 LLNL Analyses (Don Slack)

3.2 KHI Analyses

→ 4. Extension of the forgoing to Barrel modules:

4.1 Sensible heat gain to LAr at HAD preamps can be removed by Watt's *existing 2 phase N2 circuits* (in the vacuum annulus).

4.2 Sensible heat gain to LAr at EM preamps can be removed by additional 2 phase N_2 circuits attached to the LAr vessel's mid-shell wall (2 circuits minimum; 4 circuits with 100 % redundancy).

4.3 Local reduced density, single phase LAr is easily routed (at the back of barrel modules through slots in new T-shaped V-Block supports--R. Richardson, SSCL) adjacent E's cooled wall back to the condenser, without entering HV gaps.

5. Endcap modules of the Baseline "Big Wheel" configuration require no special preamp cooling provisions.

6. Baseline Preamp Cooling System;

The SDC LAC's Baseline Preamp Cooling System Design is described in 4 & 5 above (disregard reference to others in the CDR).

7. Detailed, single phase fluid, FEA Modeling can verify the expected performance.

8. Existence Proof of Barrel Module Preamp cooling;

A relatively simple test, of a full-scale mock-up (region between 3 adjacent modules' outer strongbacks and their nearby, 2 phase N_2 cooled wall) in an appropriate LAr test dewar can provide an existence proof for the Baseline Preamp Cooling Design.

After the SDC selects the LAC I

SIGNAL CABLE FEEDTHRUS

A. Previous Gas Cooled configuration

- vacuum isolation bellows (200 k pins)
- conduction intercept with N2 gas cooling
  --this was needed to achieve very low pin heat leak with the 0.1 Ohm maximum D.C. cable impedance of the *Electrostatic Transformer* readout option
- design review problems

B. New non-gas cooled *Baseline Configuration*

- Magnetic Transformer readout
- retains vacuum isolation bellows
- ≤ 50 Ohm D.C. cable impedance
  --this allows stainless steel cables of low A/L to achieve required low heat leak without gas cooling
- low heat leak & LAr subcooling preclude local boiling at receptacle pins
- LAr spill mitigation system added
- simpler, cheaper, more reliable design

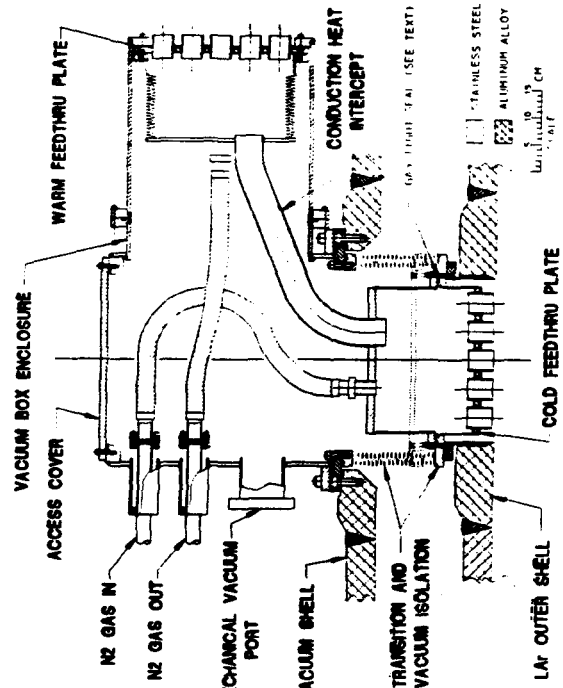


FIGURE 4. Cross-sectional details of the N2 gas cooled signal cable Feedthru assembly. The SCFT utilities high pin density hermetic connectors, stainless steel bellows, and cryogenic fittings all of commercial design.

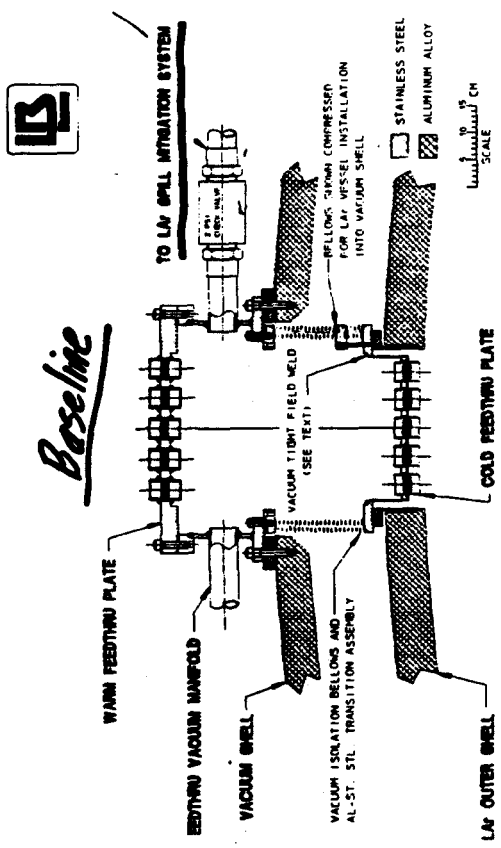
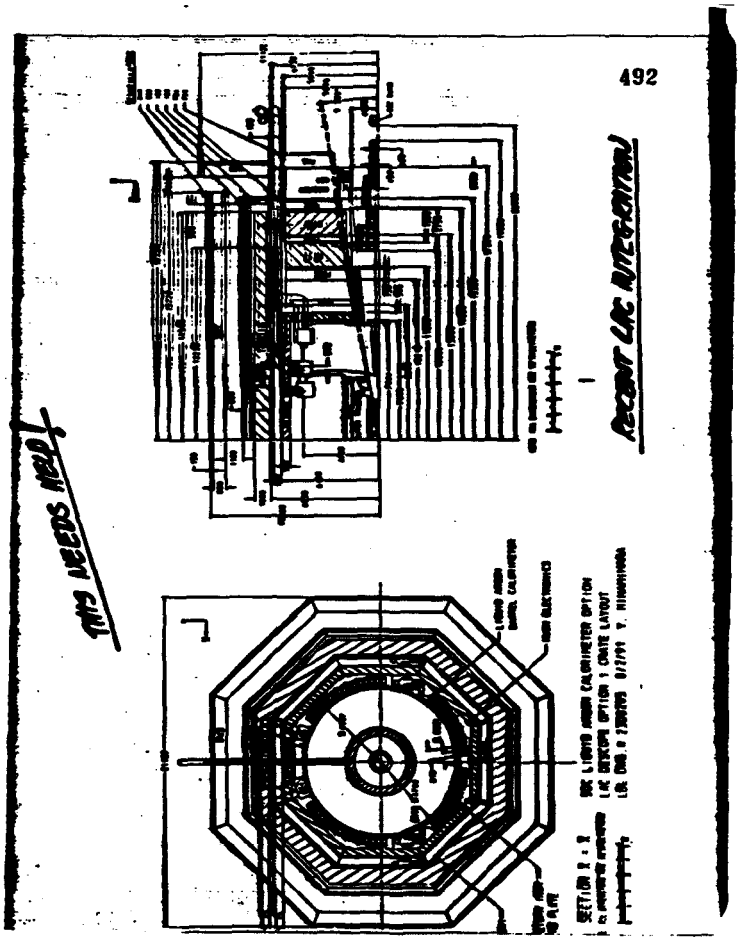
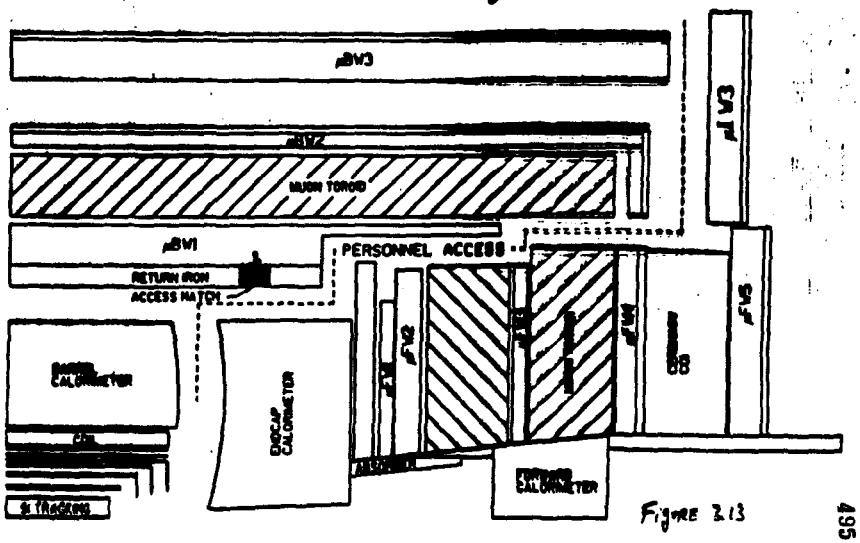
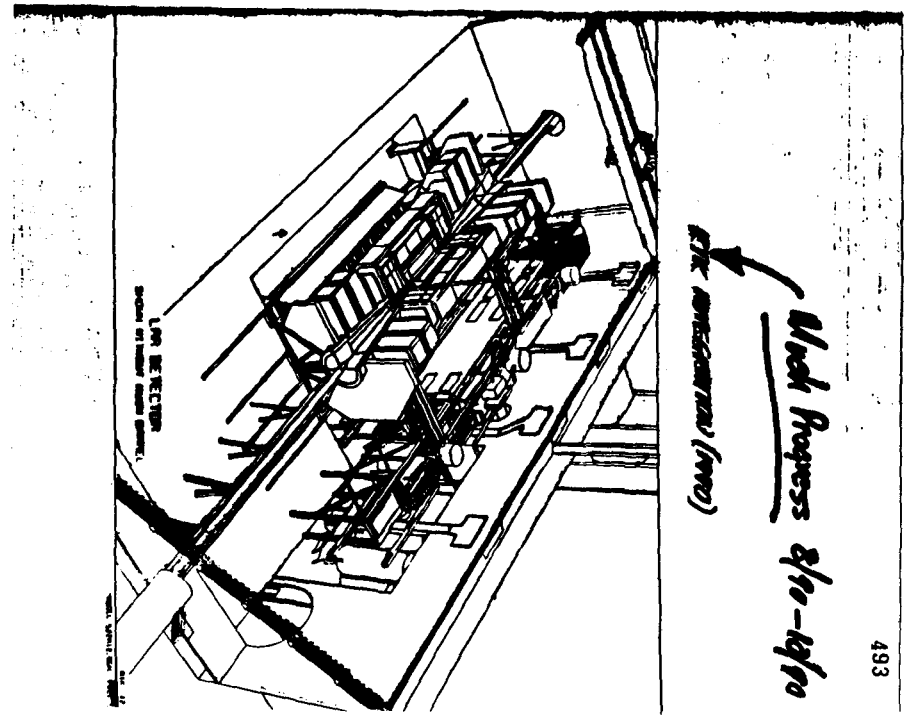
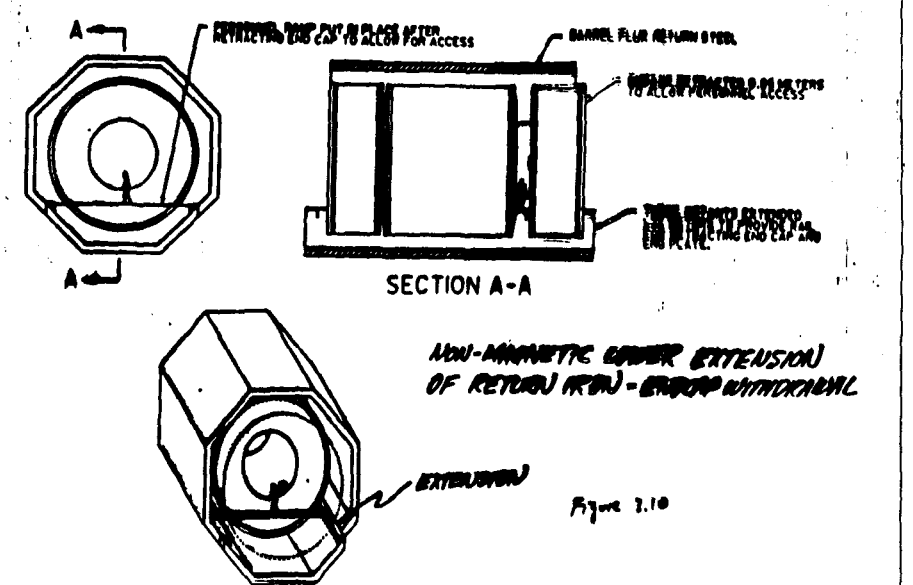


FIGURE 1. Cross-sectional details of the non-gas cooled signal cable Feedthru option. The SCFT utilities high pin density hermetic connectors, stainless steel bellows, and cryogenic fittings all of commercial design.









SSC Laboratory **Physics Research Division**

Liquid Argon Preliminary Hazard Analysis Results

- No "SHOW STOPPERS' uncovered
- Engineering concepts currently present in preliminary design must be carried forward into detailed design activities
  - LAr Storage dewars at same level at detector
  - Double bellows designs
  - Robust transfer line design and installation
  - Thorough situation awareness instrumentation of vacuum etc.
  - Effective ODH policies and procedures (inc. training)
- Endcaps moved "empty but cold" for major maintenance
- Comprehensive FMECA required during detailed engineering design

CONCLUSIONS

- We've adopted Proven Technology in sub-systems wherever possible
- $\eta \approx 3$... Mass reduced $\approx$ 5X
- Preamp Cooling — Tests & Analyses show Baseline Design is workable
- We're very cost competitive
- No LAC Safety problems
- We're ready to move into the next design phase — with the SDC Integration Team

SSC-91-Z-11115

SDC Liquid Argon Calorimeter (LAC) Cost Estimating Tasks

Prepared By:

I. Bolton, J. Bogue, G. Gustenberg, L. Mann, M. Montgomery, J. Polden, R. Vinnedge

9 August, 1991

SCIENCE SYSTEMS
MARTIN MARIETTA ASTRONAUTICS GROUP
DENVER, CO.

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SDC LAr Calorimeter Cost Summary ($K)

	Current Baseline
Modules	30,916
Cryostat	21,879
Feedthrus	5,010
Calorimeter Assembly	2,905
Fixtures	10,135
Test Equipment	1,729
Transportation	1,152
Cryogenic System	8,328
Facilities	2,108
Return Iron	4,934
EDIA	17,516
Total	106,612
Contingency (28.0%)	28,724
Total w/Contingency	135,336
Derived $/lb	11.74

SDC LAr Calorimeter Cost Summary ($M)

	Current Baseline	LOI
Modules	30.9	33.4
Cryostat	21.9	46.0
Feedthrus	5.0	4.3
Calorimeter Assembly	2.9	
Fixtures/Tooling	10.1	1.0
Test Equipment	1.7	
Transportation	1.2	5.7
Cryogenic System	8.3	7.9
Facilities	2.1	2.0
Return Iron	4.9	5.0
EDIA	17.5	14.0
Total	106.6	119.3
Contingency (28.0%)	26.7	
Total w/Contingency	135.3	
Derived $/lb	11.74	

Note: LOI number of $133.4 M included an additional $14.1 M for electronics and installation

LAC Cost Ground Rules and Assumptions

1. All costs are reported in 1990 thousands of dollars.

2. Estimates include engineering, design, inspection and quality assurance (EDIA), procurement, fabrication, and assembly.

3. Cost estimates include all labor and materials, except for physicists salaries, required to design, develop, and build the detector.

4. The following methods were used to develop the cost estimate:
   - bottoms-up estimates
   - industrial engineering and manufacturing analyses
   - parametrics and factors
   - historical detector costs
   - vendor quotes

5. Labor estimates were developed using industrial fabrication processes for the cryostat and laboratory processes for the modules (applying laboratory labor rates to the cryostat is not realistic without increasing the labor hour estimate due to the large industrial automation assumed for fabrication)

6. Contingency analysis follows the SDC approach developed

7. Estimates were developed bottoms-up by Design, Industrial, Manufacturing, and Cost Engineers

8. The following engineering functions have been included in EDIA. Engineering manhours have been estimated for each calorimeter component and are included in the engineering (EN) category of the cost spreadsheet.

LAC Cost Ground Rules and Assumptions

- Design Engineering
- Design Analysis
- Engineering Support
- Test Engineering
- Systems Engineering
- Logistics
- Engineering Labs
- Quality Engineering
- Safety

8. Inspection/quality assurance is the inspection "touch" effort. This is included under the fabrication (FB) column of the cost spreadsheet.

10. Administration includes effort to perform planning, contracts administration, procurement, finance, personnel, project management and administration. This is included under the administration (AD) and administration manufacturing (ADM) columns of the cost spreadsheet.

11. Manufacturing support is the factory and test effort (production control, inventory, material handling, supervision, facilities maintenance, etc.) which is non-fabrication labor. This effort is included under the manufacturing support (EMS) column of the cost spreadsheet.

12. The cost estimates are based on the baseline design configuration developed by KH and LBL and ASME/AWS code.

13. Labor estimates were developed largely from detailed manufacturing estimates. Manufacturing plans were used for outlining the tasks for fabrication and assembly of the cryostat and modules. Industrial engineers developed the machine and labor hours required for each task based on industrial standards.

LAC Cost Ground Rules and Assumptions

14. Aluminum sheets for the manufacturing of the cryostat were assumed to be obtained in optimum stock sizes available from Aluminum vendors to minimize cutting, machining, and welding.

15. The following labor rates were assumed for costing purposes.

- LBL labor rates were used for all module effort
- Industrial labor rates were used for all off-site assembly
- SDCL labor rates were used for on-site assembly

	Module Assy (LBL)	Cryostat Assy (Ind)	On-Site Assy (SDCL)
EN	$42.00	$41.67	$52.00
EMS	$13.00	$60.25	$44.00
	$13.00	$60.25	$100.00
	$13.00	$60.25	$100.00
	$100.00	$41.70	$50.00
	$50.00	$60.25	$50.00
ES	$100.00	$60.25	$100.00
FB	$100.00	$60.25	$100.00

16. The following labor category definitions have been assumed in accordance with the SDC Cost Ground Rules:

EN - engineering
EMS - manufacturing support
ES - included in EN
EAS - included in EN
FB - included in EN

SDC LAr Calorimeter Cost Summary

	Procurement ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Modules	19,141	14,778	4,852	38,568	8,537	44,105
Cryostat	4,949	18,930	4,800	28,679	9,677	33,869
Feedthrus	4,362	647	396	5,396	1,445	6,811
Calorimeter Assembly	0	2,808	2,808	5,571	1,448	7,019
Tooling/Fixtures	8,328	3,808	4,088	14,184	5,043	19,207
Test Equipment	1,640	0	80	1,720	596	2,316
Transportation	1,152	0	136	1,288	439	1,727
Cryogenic System	7,900	0	428	8,328	2,831	11,159
Facilities	2,000	0	108	2,108	717	2,825
Return Iron	4,881	0	503	4,384	1,678	6,012
Total	49,188	39,098	17,818	106,734	29,603	136,338

LAC Cost Ground Rules and Assumptions

DRM - Included in EN
AD - administration (i.e. contracts, finance, accounting, planning, personnel, administration, etc.)
ADM - administration during manufacturing
TE - technician (QA)
TEM - direct manufacturing touch labor
LA - Included in TE
LAM - Included in TEM

Appendix A - SDC LAr Calorimeter Cost Roll-Up

Module Specifications

Module #	Qty	# Pb Plates	Outer Radius	Inner Radius	Height	Outer Width	Inner Width	Avg Width	Length
1	64	33	2,888	2,332	356	[illegible]	[illegible]	246	2,880
2	128	33	2,888	2,332	356	[illegible]	[illegible]	246	2,880
3	32	67	4,388	2,818	1,467	841	[illegible]	697	2,830
4	64	67	4,388	2,818	1,467	841	[illegible]	697	1,740
5	64	67	4,388	2,818	1,467	841	[illegible]	697	739
6	32	33	3,088	461	2,604	1,304	181	692	369
7	64	42	3,088	608	2,687	608	100	361	729
8	64	63	3,088	593	2,478	608	116	359	1,078
9	64	21	4,360	3,155	1,189	864	619	737	363
10	64	42	4,360	3,155	1,189	864	619	737	729
11	64	63	4,360	3,155	1,189	864	619	737	1,078

SDC LAr Calorimeter Cost Summary

	Procurement ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Module 1	689	861	348	1,818	479	2,387
Module 2	1,347	1,490	432	3,269	808	4,078
Module 3	2,868	1,190	408	4,154	986	5,080
Module 4	3,415	2,159	840	6,114	1,387	7,501
Module 5	1,496	1,936	508	3,940	999	4,939
Module 6	270	254	261	785	183	968
Module 7	1,140	1,316	484	2,882	719	3,599
Module 8	1,679	1,707	477	3,860	944	4,804
Module 9	580	952	373	1,904	483	2,387
Module 10	1,189	1,270	417	2,855	703	3,559
Module 11	1,803	1,818	496	3,996	938	4,917
Total	19,141	14,778	4,852	38,568	8,537	44,105

$/Manday

	Modules Assy (LBL)	Cryostat (Industry)	On-Site Assy (SSCL)
EN	$436.00	$612.07	$404.32
ENM	$313.60	$[illegible].25	$404.32
DR	$313.60	$306.02	$193.43
AD	$182.40	$421.78	$259.06
TE	$292.00	$[illegible]	$259.06
LA	$120.00	$281.21	$193.43
EA	$313.60	$446.24	$193.43

EDIA Summary

	EN (mandays)	TE (mandays)	AD (mandays)	EDIA ($k)
Modules	5,682	6,532	1,466	4,[illegible]
Cryostat	5,137	3,460	1,024	4,[illegible]
Feedthrus	2,120	153	273	[illegible]
Calorimeter Assembly	5,557	[illegible]	769	[illegible]
Tooling/Fixtures	5,572	766	760	4,0[illegible]
Test Equipment	134	0	16	[illegible]
Transportation	206	0	25	13[illegible]
Cryogenic System	645	0	77	42[illegible]
Facilities	163	0	20	10[illegible]
Return Iron	362	0	46	[illegible]
Total	[illegible]	11,[illegible]	4,476	17,619

SDC LAr Calorimeter Cost Summary

	Material ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SDC LAr [illegible] (Entire Calorimeter)

LAr Baseline

	Material ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Modules	18,141	14,775	4,[illegible]	[illegible]	[illegible]	44,1[illegible]
Cryostat	4,[illegible]	16,930	4,[illegible]	[illegible]	[illegible]	[illegible]
Feedthrus	4,3[illegible]	947	[illegible]	[illegible]	1,44[illegible]	[illegible]
Calorimeter Assy	0	2,[illegible]	[illegible]	[illegible]	1,44[illegible]	7,01[illegible]
Tooling/Fixtures	[illegible]	2,[illegible]	4,0[illegible]	14,1[illegible]	[illegible]	1[illegible]
Test Equipment	1,[illegible]	0	[illegible]	1,72[illegible]	[illegible]	[illegible]
Transportation	1,1[illegible]	0	13[illegible]	1,[illegible]	43[illegible]	1,727
Cryogenic System	7,[illegible]	0	42[illegible]	[illegible]	[illegible]	11,1[illegible]
Facilities	[illegible]	0	1[illegible]	2,1[illegible]	717	[illegible]
Return Iron	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	17,619	105,72[illegible]	[illegible]	[illegible]

[illegible]

	Outside Rad. [illegible]	Inside Rad. [illegible]	Surface Area [illegible]	% of Baseline Volume	Total Cost [illegible]	
Baseline	[illegible]	[illegible]	[illegible]	100%	[illegible]	
Option 1	41[illegible]	[illegible]	[illegible]	97%	[illegible]	move LAC in [illegible] cm
Option 2	[illegible]	[illegible]	[illegible]	91%	[illegible]	move LAC in [illegible] cm
Option 3	[illegible]	173.1	[illegible]	[illegible]	117,[illegible]	move LAC in [illegible] cm

1. length of calorimeter stays constant
2. material costs [illegible] by volume
3. number of layers is constant (no impact to module assembly labor)
4. cryostat/calorimeter assembly scales by volume

[illegible]

	Outside Rad. [illegible]	Inside Rad. [illegible]	Surface Area [illegible]	% of Baseline Volume	Total Cost [illegible]	
Baseline	[illegible]	[illegible]	[illegible]	100%	[illegible]	
Option 1	[illegible]	[illegible]	[illegible]	10[illegible]%	[illegible]	move inside radius in [illegible]%
Option 2	[illegible]	[illegible]	[illegible]	114%	[illegible]	move inside radius in 20%
Option 3	[illegible]	[illegible]	[illegible]	1[illegible]%	[illegible]	move inside radius in 40%

1. length of calorimeter stays constant
2. material costs increase by volume
3. number of layers increases with depth (module assembly labor)
4. cryostat/calorimeter assembly scales by volume

Calorimeter Length Cost Sensitivity

	Outside Rad. (cm)	Inside Rad. (cm)	Length (cm)	Volume (m^3)	% of Baseline Volume	Total Cost ($k)	
Baseline	420.0	233.1	602.0	320	100%	138,330	
Option 1	420.0	233.1	702.0	300	90%	123,150	move ends in 0.5 m
Option 2	420.0	233.1	802.0	244	70%	110,003	move ends in 1 m
Option 3	420.0	233.1	402.0	193	50%	88,893	move ends in 2 m

1. radius of calorimeter stays constant
2. material costs decrease by volume
3. number of layers is constant (no impact to module assembly labor)
4. cryostat/calorimeter assembly scales by volume

Channel Count Sensitivity

	# of Feedthrus	# of Channels	Feedthru ($k)	Electronics ($k)	LAC Total ($k)	
Baseline	100	93,600	6,811	23,424	138,330	
Option 1	90	84,360	6,130	21,080	124,000	10% decrease in channels
Option 2	77	70,272	5,100	17,560	103,000	30% decrease in channels
Option 3	61	46,800	3,400	11,712	69,081	50% decrease in channels

1. feedthru costs scale by channel count
2. signal handling costs by channel count
3. assume $500/channel

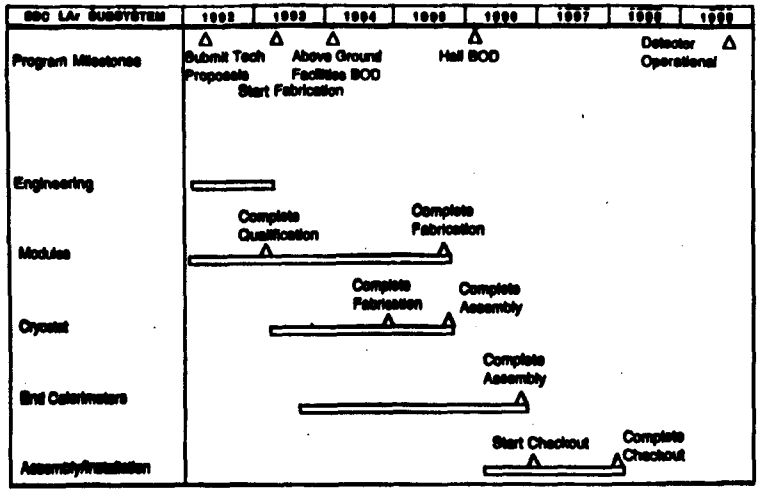
Pb Bar Modules

	Materials ($k)	Mfg Labor ($k)	EDIA ($k)	Base ($k)	WBS Total ($k)	Delta Cost ($k)
Baseline	19,141	14,770	4,[illegible]	36,[illegible]	44,100	0
Opt	21,[illegible]	5,[illegible]	3,[illegible]	30,[illegible]	41,607	-2,[illegible]

1. Pb bar changes from 95.77% (phenol) to 91.88% (hydrocal), 91.[illegible]% (mod) to 92.[illegible]% (Bd)
2. Pb stacking steps eliminated
4. Bridge eliminated
5. Module Assembly steps revised

SDC LAr SUBSYSTEM

- The Project Schedule Is Based On The KEK Design and MMAG IE Analysis
- The Project Critical Path Starts With The Completion Of The Engineering Thru The Module Qualification And Fabrication, To The Final Assembly and Checkout
- Currently There Is 12 Months Margin (Schedule Reserve) Available
- The Schedule Has Not Been Resource Loaded So Optimization Has Not Been Accomplished



Critical Issues Related to the Engineering

Y.Unno
KEK
and
The SDC LAC group

- Electron hermeticity
- η=3
- Depth
- Preamp reliability

Y.U 1991/6/18

Critical Issues for the LAC

517

Item	Status	Comment
Preamp (Rad.hard)		BNL hybrid: $>10^{13}$n/cm^2, >12Mrad
Speed		τ_{rise}<30ns
Noise		τ_p=100(EM), 200ns(HAD) σ_{E_t} (ΔR<0.15)
Pileup		3 meas., τ_p=50~200ns σ_{E_t}~0.5GeV
e/h meas.		Hadron module beam test
e hermeticity		97%accept.(σ_E<25%/$\sqrt{E}$)
Reliability		<0.2% failure(SLD) in 10^8s
P/a cooling		KEK/Rochester test results
Safety		SSCL Safety committee
η=3,E_t		KHI, LBL
Integration		LBL
Cost		MMA

1991/8/5

518

Solved

Solved

Solved

"Solved"

Solved

Solved

Solved

Solved

Solved

Solved

(cf. T/F $175M) $135M undescoped

• Introduction

519

• The objective of the LOI design was the overall configuration.

• In November, critical regions were identified:

(1) Wall thickness around η=1.2~1.3 for electron acceptance,

(2) Wall thickness around η=3 for hadron acceptance.

• Engineering efforts have been paid to propose solutions to the issues (see the talk by Bill Pope).

• The requirements for the calorimeter depth were
≥9 λ_I(Central) and ≥12 λ_I(Intermediate).
The LAC was designed to have
~9 λ_I(Central) and ~11 λ_I(Intermediate).
(Intermediate ~11λ_I was chosen because the required 12λ_I was not informed well.)

• A new requirement for 10 TeV di-jet mass resolution has put the depth requirement 10±1 λ_I. We propose a design if the 10 λ_I depth requirement is absolute necessity.

• Other issues were the reliability of preamp for a long term usage and for radiation damage.

520

• Electron hermeticity

Wall thickness around η=1.2~1.3 for electron acceptance

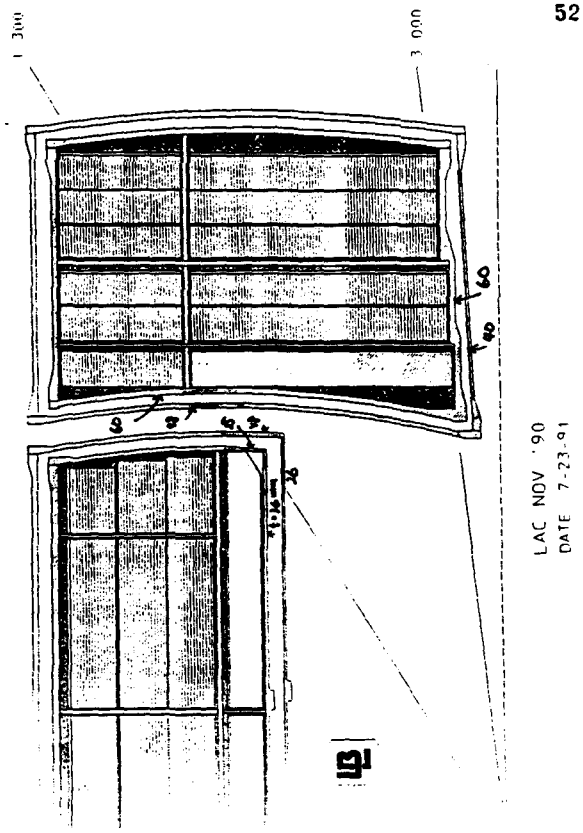
• Thining the Barrel walls→Cryostat cut-view

• Utilization of the extra Massless gap(MLG) for the η=1.2~1.3 region→EGS modeling

• Dead material in front of the EM calorimeter without the extra MLG

• EM resolution with the MLG correction

521



C. Hearty
522

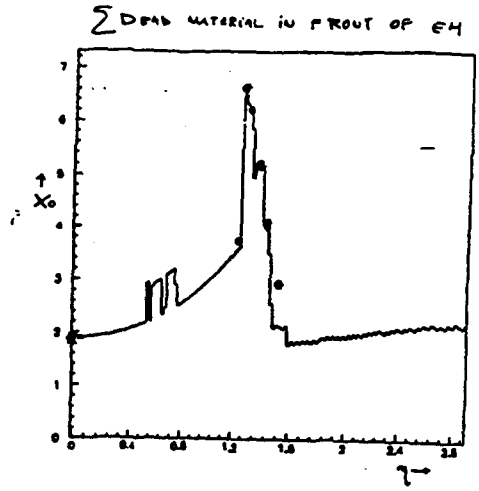


Figure 2

523

C. Hearty

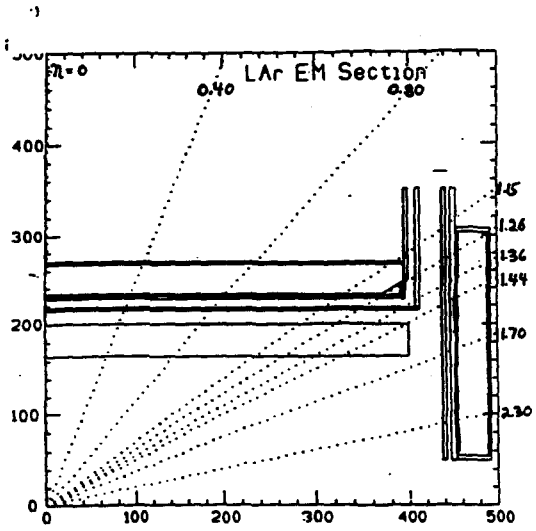


Figure 1

—Massless Gap

524

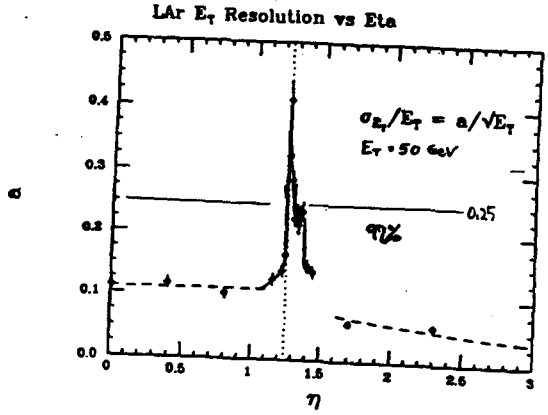


Figure 5b

525

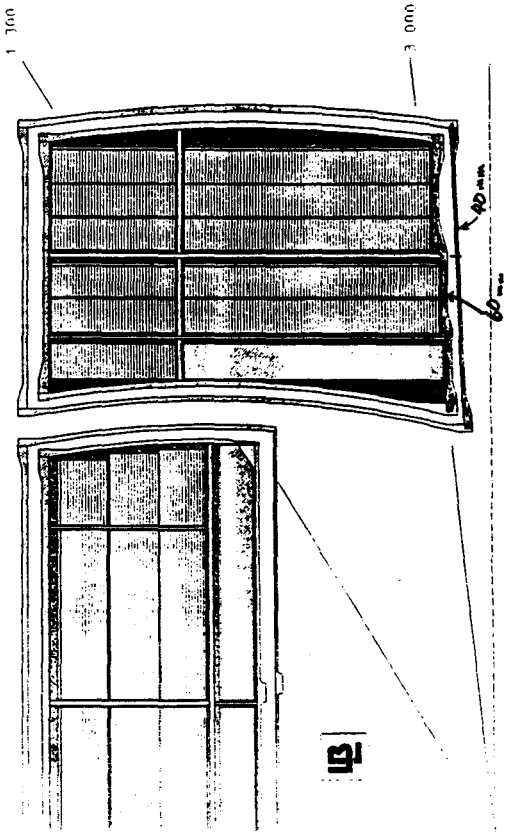
• η=3 issue

Wall thickness around η=3 for hadron acceptance

• The LOI design was not optimized for the issue. LBL worked out a design to thining the inner walls of the Endcap cryostat (LAr and Vacuum vessels). KEK/KHI also figured out a design for the LAr vessel.

• Dead masses in front of the calorimeter for the LOI and for the new LBL design

526



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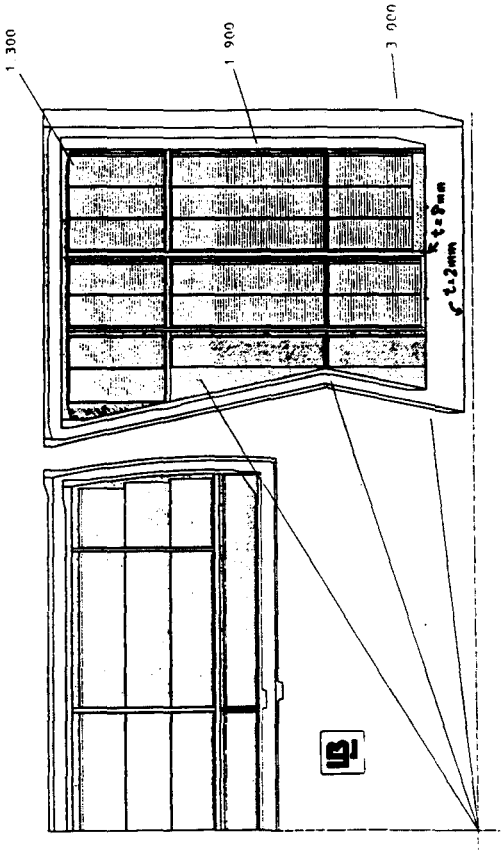
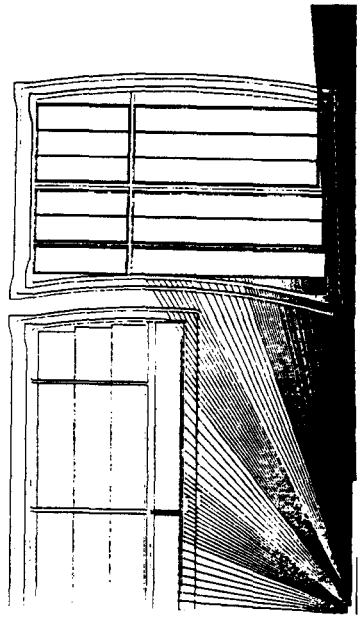
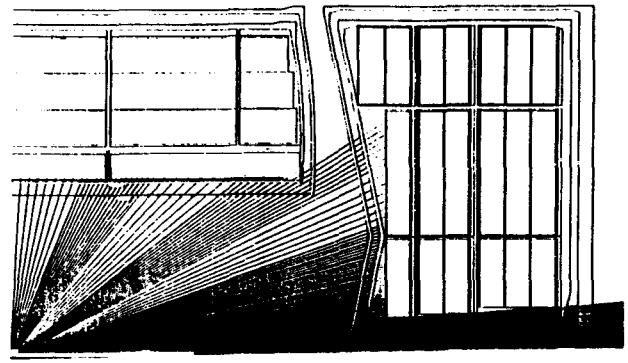


SDC LAC NOV 90

528 (12)



NEW LBL ENDCAP CONCEPT

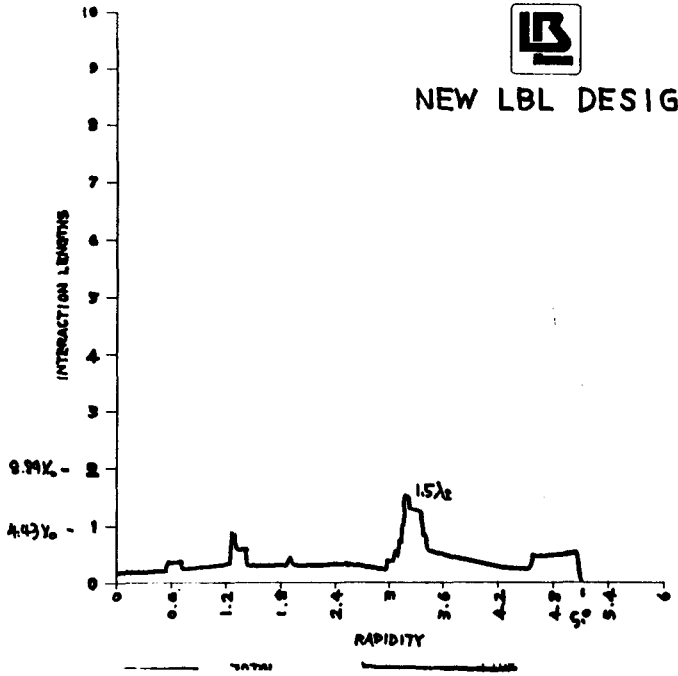


lor_wmrsly3 (Rich Weidenbach)
color (David P. O'Neill)
7-24-91

ideal foward calorimeter

529

NEW LBL DESIGN



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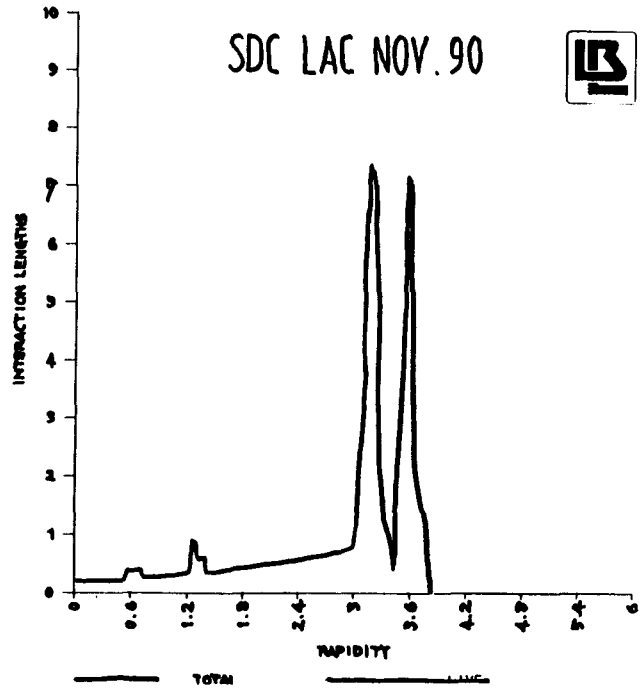
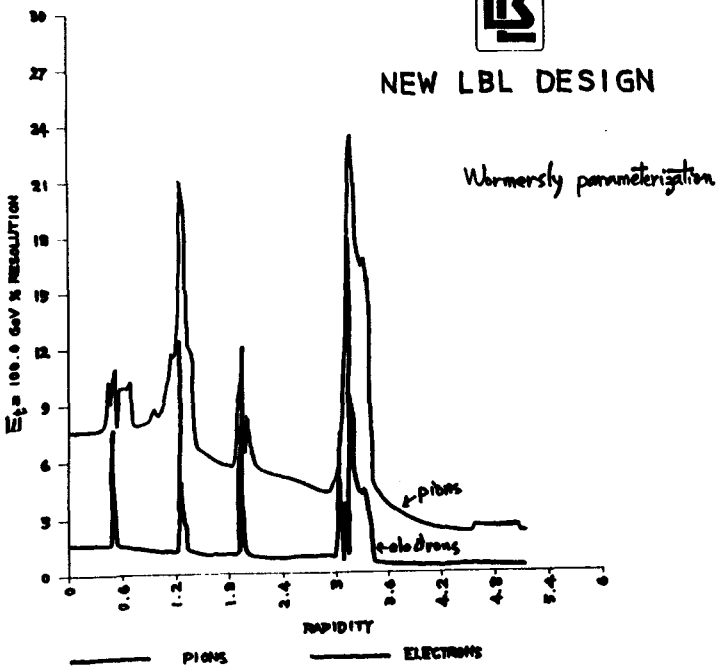
SDC LAC NOV. 90



530

NEW LBL DESIGN



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• Summary of the η=3 issue

• The material in front of the first active region of the new LBL design is

$\leq 1.5\ \lambda_I$.

• There is a common ground in the LBL and KHI design and a (to be developed) KBL design will have the mass $\leq 2\ \lambda_I$ in front of the active region for $\eta \leq 5$.

$\leq 8\ X_0$

• Depth

• What factor drives the depth requirement?

• Containment of hadronic showers

9~10 λ_I for 1 TeV jets (D.Bintinger[1])

10±1 λ_I for 10 TeV di-jet mass resolution (~2%) (D.Green[2])

• What is the requirement by physics processes?

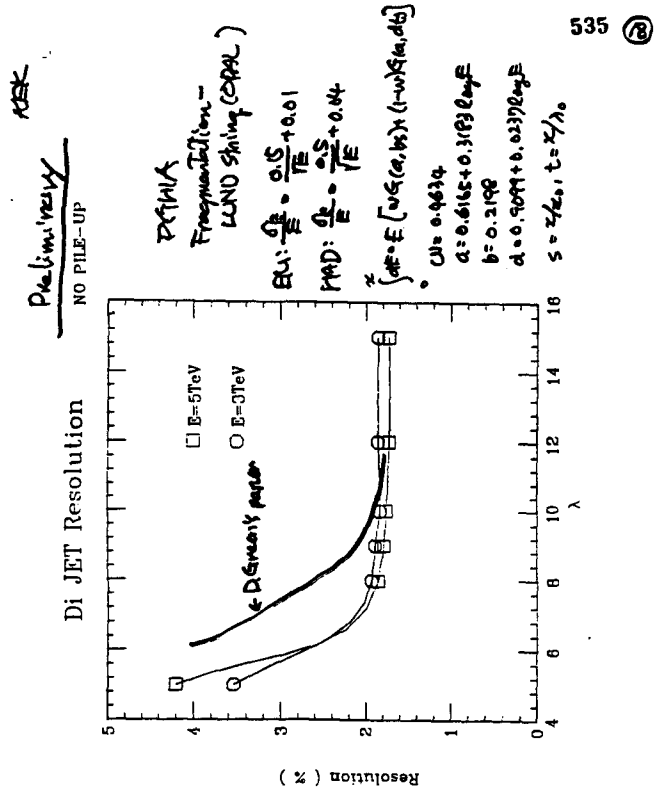
Missing E_t -- 7 λ_I[2]

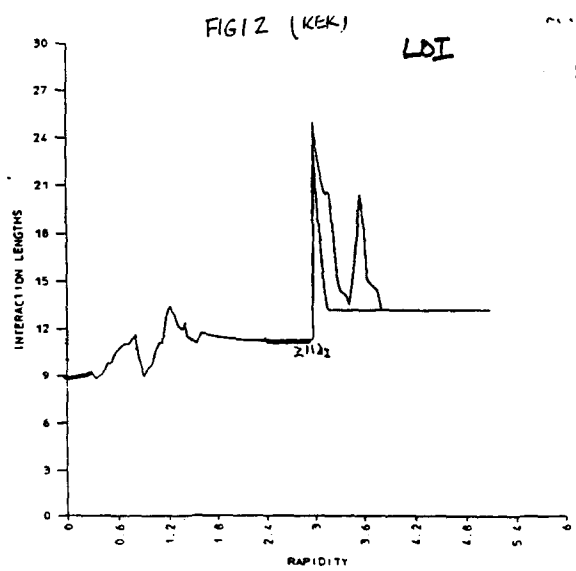
Intrinsic width of a new resonance into jet-jet:

Techni-ρ	Γ/M~20% (QCD coupling)
Excited Quark[3]	Γ/M~4% (QCD coupling)

Z'→jet+jet is undetectable[4] (EW coupling) (Note that only those with QCD coupling can be detectable over the large QCD jet-jet background)

[1] D.Bintinger, Proceedings of the Workshop on Calorimetry for the Supercollider, March 13-17, 1989, Tuscaloosa
[2] D.Green, Proceedings of the SDC Collaboration Meeting at KEK, May 13-16, 1991, SDC-91-00033
[3] U.Baur et al., Int. Jour. Mod. Phys. A2(1987)1285
[4] J.S.Whitaker et al., Experiments, Detectors, and Experimental areas for the Supercollider, Berkeley, CA., 1987





• If there is an absolute necessity to have a thick hadron calorimeter, we propose to change the thickness of the LAC by the following amounts:

(1) Barrel $9\lambda_I \rightarrow 10\lambda_I$: IR=2.1m→1.9m
(i.e. Tracker OR=1.7m→1.5m)

(2) Endcap $11\lambda_I \rightarrow 12\lambda_I$: Z_1=4.4m→4.2m

Obviously there are two ways to go: inward and outward. Outward step increases the radius of the calorimeter and drives the whole detector cost up, we prefer to go inward.

Reference:

Hadronic module density: 10.0 g/cm^3
Interaction length of Pb: 194 g/cm^2/λ_I
→ 19.4cm/λ_I

• Preamp reliability

• Failure modes

(1) Random failure
(2) DC power ON/OFF
(3) Cryogenic cycling
(4) Sparks
(5) Radiation damage

• How to verify that the preamp lives forever?

To establish at the 90% C.L. that the probability of an item failing in time t (or number of cycles, t) is ε, we must test N objects for time (or number of cycles) T with no failure, where

True failure rate $\leq 2.3/NT \leq \varepsilon/t$, i.e.

$$NT \geq 2.3t/\varepsilon.$$

• Tests to be conducted: we require ε=0.1%.

(1) Random failure in t=10^8s (10 operating years)
→10,000 preamps (in LAr or LN_2) for 267 days

This failure rate is 0.004%/1000hrs.
SLD experience is 0.028%/1000hrs at room temperature; seven times higher. But, orders of magnitude improvement at cryogenic temperature because the failure rate varies as exp(-ε/kT) (MIL-HDBK-217E).

Preamp Reliability

Goal is failure rate <0.004% / 1000 hours
==> 0.3% failures in 10 years of operation
(not calendar years - preamps off during down times).

Previous Experience

SLD: preamp failure rate is 84/34000 per year
= 0.028% / 1000 hours

• seven times larger than desired, but SLD preamps are at 40 deg. C; electronics failure rates are proportional to e**(-a/kT)
(a="activation energy", 0.2< a< 2.0 ev for IC's)

==> orders of magnitude improvement at 88K

Helios: 584 preamps operated at 88K for 3 years with no failures (1 infant mortality)

==> failure rate < 0.015%/1000 hours, 90% CL

(2) DC power ON/OFF in t=500 cycles (once per week for 10 years)
→100 preamps at 1 cycle/min for 8 days

(3) Cryogenic cycles in t=20 cycles (2 cycles/year and 10 years)
→100 preamps at 10 cycles/day and 46 days

(4) Sparks are unknown but, let's say, t=100 sparks
→100 preamps at 1 spark/10 sec and 7 hours

(5) Radiation damage: tests are underway

JFETs are exposed to

2x10^5 Gy (20Mrad) at 87K
10^{14} neutrons/cm^2(25% noise increase).

MESFETs are exposed to

10^{15} neutrons/cm^2.

At the nominal luminosity of 10^{33} cm^{-2}sec^{-1}, at η=3 and preamps after the 25X_0 or the back of hadronic module, the ionizing dose is <1/10x6kGy/yr and the neutron fluency is ~1/2x1.5x10^{13}neutrons/cm^2/yr. MESFET is already acceptable for 10 years of 10^{34} cm^{-2}sec^{-1}.

• Summary

(1) Electron hermeticity
97% at $\sigma_E/E<25\%/\sqrt{E}$
still sensitive and electrons will not be lost

(2) η=3 $<2\lambda_I$, $<8X_0$

(3) Depth $9\lambda_I$ in the Barrel
$11\lambda_I$ in the Endcap

• Request to clarify the requirement by physics, not by containment.

• If absolute necessity, we add thickness of 19.4 cm/λ_I .

(4) Preamp reliability

• Establishing random failure rate appears to be a major undertaking but feasible.

• Neutron fluency is the limiting factor. JFET is acceptable for 10 years of the nominal luminosity of 10^{33} cm^{-2}sec^{-1} and MESFET can live with 10 years of 10^{34} cm^{-2}sec^{-1}. Further radiation damage test for other JFET's should be continued.

Critical Issues and Beam Test

Y.Unno
KEK

and
The SDC LAC group

• List of remaining issues

• Beam test setup

• Results: resolutions, *e/h*

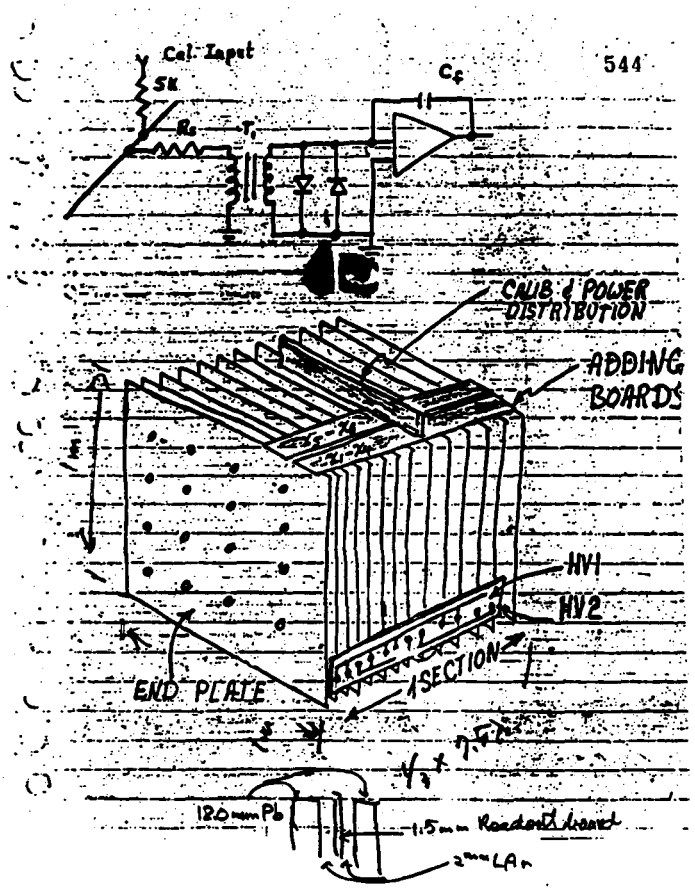
Objectives of the beam test

) Drift velocity of electrons in the Liquid Argon is said be slow. However, what we need is the signal, and st-readout can be achieved by fast charge transfer e and by shaping the signal for an appropriate aking time (detail will be discussed by C.Hearty).

The objective of the beam test is to test the fast-adout with bipolar shaping with the peaking times of), 100, and 200 ns, for HADRONIC and ECTROMAGNETIC calorimetry.

) e/π (e/h) measurement with Pb absorber in DRONIC calorimetry with the fast-readout.

) Uniformity of response across the module crack in ECTROMAGNETIC calorimetry of the SDC design.



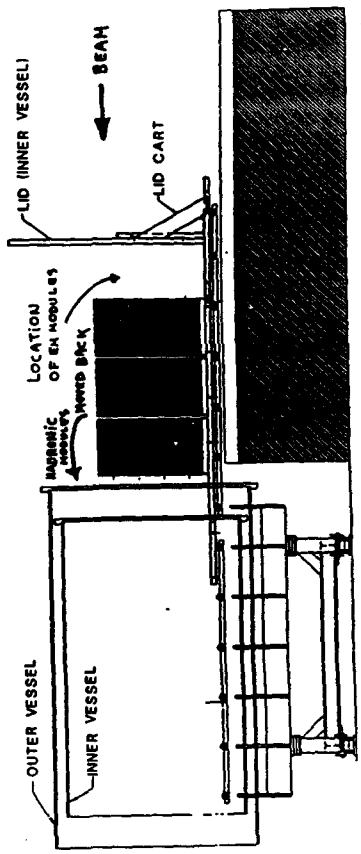


FIGURE 8·17

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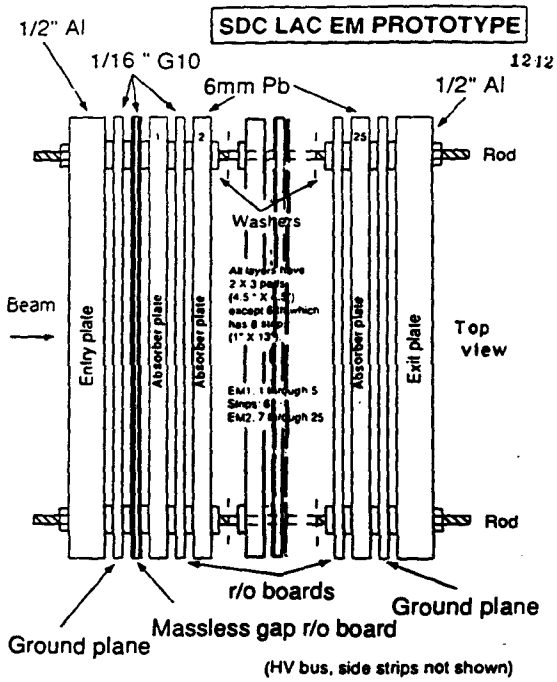

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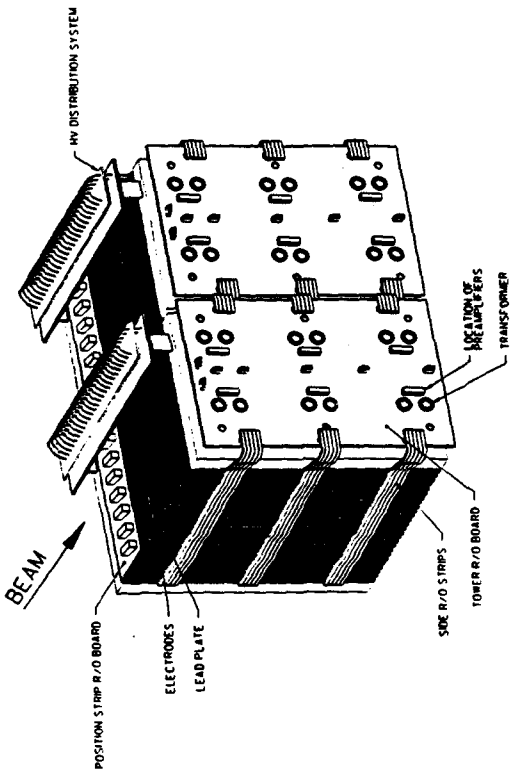
SSC LABORATORY



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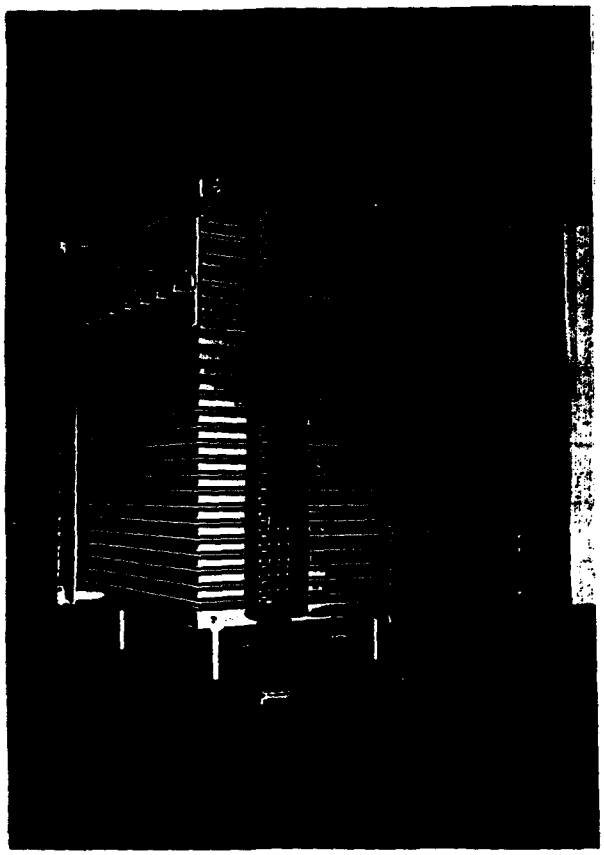

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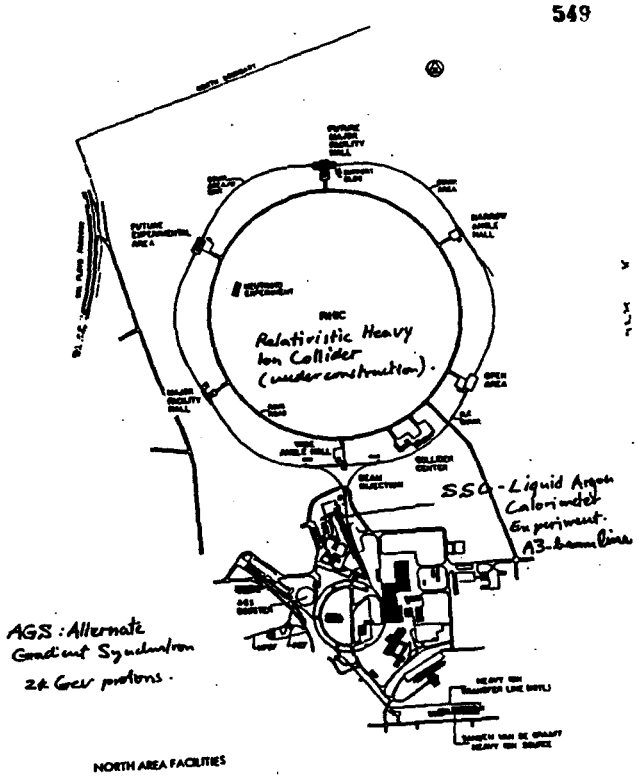


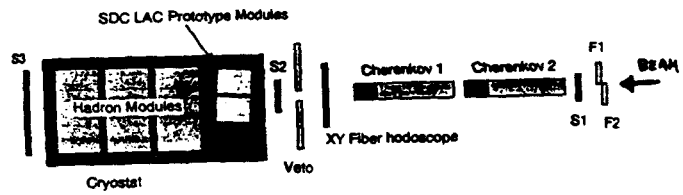


Figure 8.16

Schematic view of the BNL Spring '91 test

Summary of the BNL A3 beam line

- Triggers:

$S_1 \cdot S_2 \cdot \bar{V} \cdot C_1 \cdot C_2 \cdot \bar{S} \rightarrow e^-$

$S_1 \cdot S_2 \cdot \bar{V} \cdot \bar{C}_1 \cdot \bar{C}_2 \cdot \bar{S} \rightarrow \pi^-$

$S_1 \cdot S_2 \cdot \bar{V} \cdot \bar{C}_1 \cdot \bar{C}_2 \cdot S \rightarrow \mu^-$

F_1, F_2, and XY Fiber hodoscope were used to define better parallel beams and positions for the EM module.

- Momentum: 0.5~20 GeV/c
- Intensity: 10^3~10^6 particles/spill
- Extraction: ~0.8 sec
- Electron concentration: ~1% at 10 GeV/c

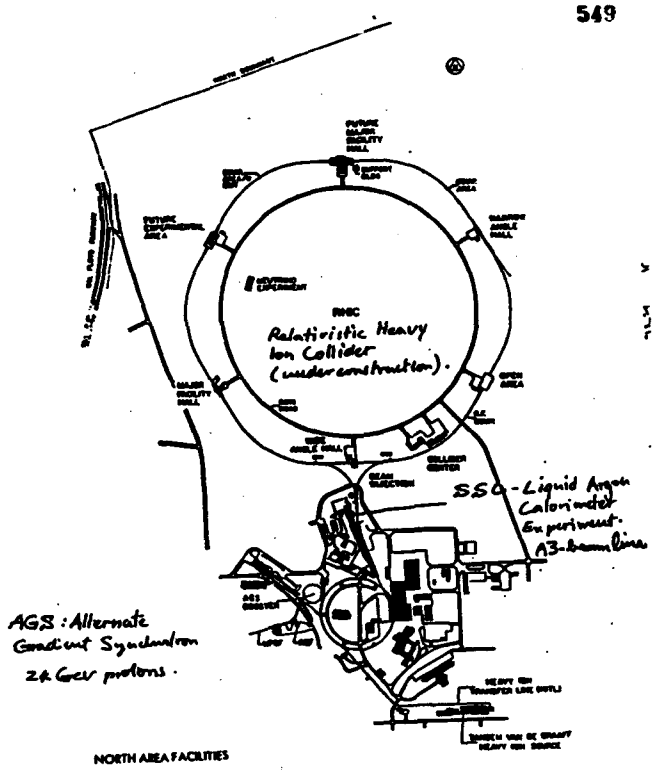
Readout Electronics chain

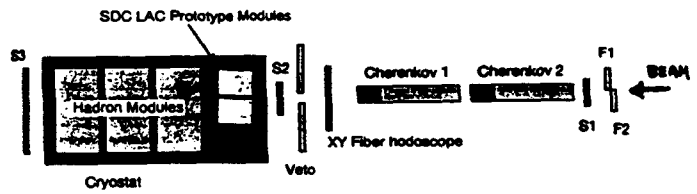
Very much like the proposed electronics chain of the SDC LAC option other than Analog memory (or more correctly, we follow the readout chain in the beam test laid by the Liquid Argon subsystem R&D).

- Preamp in the Liquid Argon
- Intermediate amp on the feedthru (outside)
- Variable Gain Amp in the counting hut:

  (1) t_p=100 ns Bipolar shaping to individual ADC's
  (2) Analog sum to a shaper with t_p=50, 100, 200 ns shaping, then to an ADC or a transient recorder

- Calibration chain





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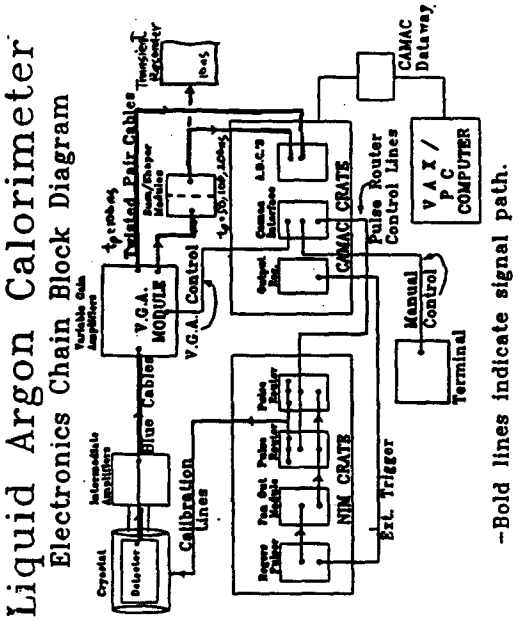


Results

The beam test data are under rigorous analysis among collaborators. The results being presented here are one of many and also should be taken as preliminary. More and better-understood results will be available by the time of the Corpus Christi Conference.

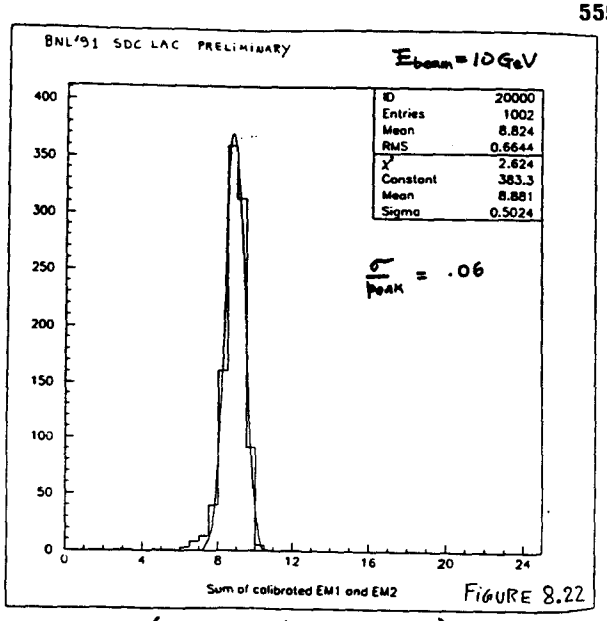
- EM module:

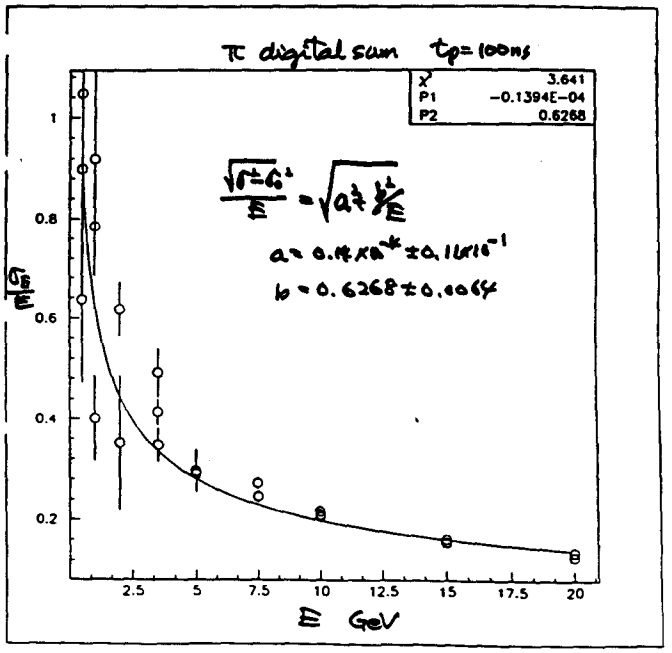
  Energy sum of EM1 and EM2

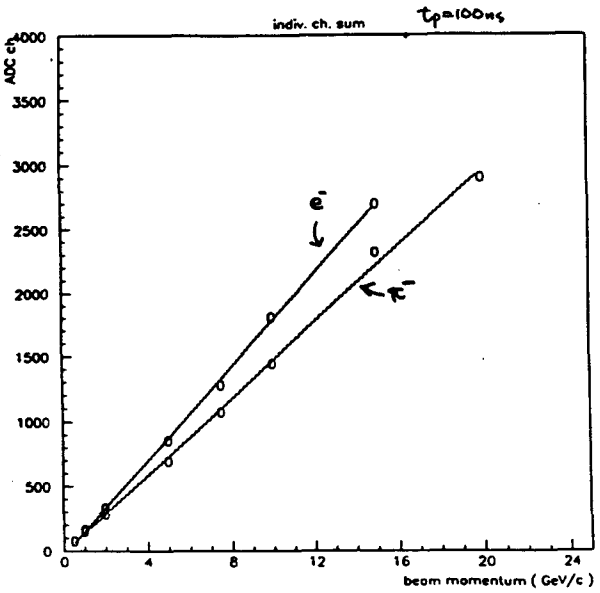
- Hadronic module:

  Hadron energy resolution at t_p=100 ns (individual digital channel sum)

  Responses of electrons and pions t_p=100 ns and e/π ratios







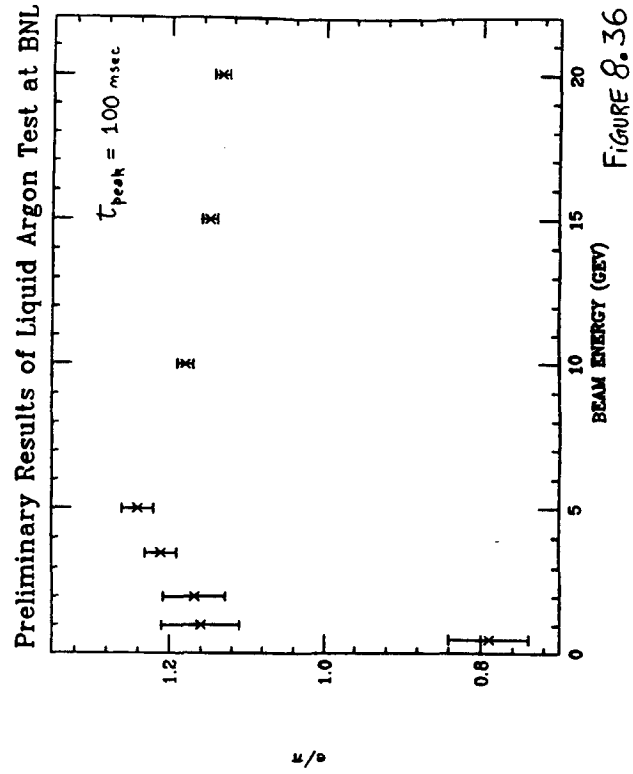


FIGURE 8.36

From the e/π to the e/h ratio

- The pion response(π) can be expressed by the electron response(e) and the hadron response(h) as

$$\pi = f\pi^{\circ} e + (1-f\pi^{\circ})h \qquad (1)$$

where the factor, $f\pi^{\circ}$, is the (average) π° fraction in the hadronic shower. Then the electron response over the pion response ratio is

$$e/\pi = e/(f\pi^{\circ} e + (1-f\pi^{\circ})h) \ . \qquad (2)$$

After some manipulation, we have the e/h ratio as

$$e/h = (1-f\pi^{\circ})/(1/(e/\pi) - f\pi^{\circ}) \ . \qquad (3)$$

- D.Groom's ansatz is

$$\pi/e = 1 - (1 - h/e)(E/E_0)^{-0.15} \qquad (4)$$

where E_0~1GeV.

- Non-unity e/h induces a constant term in the hadronic resolution, parametrized as

$$\sigma_E/E(const.\ by\ e/h) = 0.14 \times |1-e/h| \ . \qquad (5)$$

e/π=1.15 @E=20GeV, then e/h ?

- We have estimated the π° fraction by using GEANT/GHEISHA. We have

$$f\pi^{\circ} = 0.361 \text{ @20GeV.}$$

The data

$$e/\pi = 1.15$$

is transformed into

$$e/h = 1.26 \ .$$

- When we use the D.Groom's ansatz, we obtain

$$e/h = 1.25.$$

- The induced constant term will be

$$\sigma_E/E(const.\ by\ e/h) = 3.5\% \ .$$

Liquid Argon Performance: Speed, Noise, Pileup and Electron Uniformity

Christopher Hearty

August 7, 1991
SDC Collaboration Meeting at LBL

OUTLINE

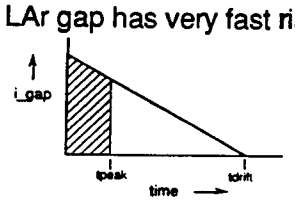
1. Introduction
2. Speed
   - speed of response
   - time resolution
3. Noise
   - pileup
   - electronic noise
   - summary/total
4. Missing Et
5. Electron Uniformity/Hermiticity

Introduction (and Summary)

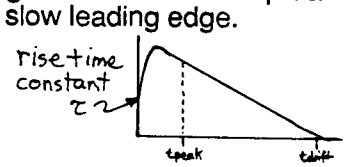
- Liquid argon has a fast risetime that is preserved by the SDC electrode structure.
- resolution and uniformity across phi crack are acceptable; very good elsewhere
- electronic noise and pileup sufficient for SDC physics program.
- <5 ns time resolution for >1 GeV in EM channel, 5--10 GeV in hadronic.
- The response of the detector in all of the above is understood and can be calculated, as has been verified by beam test data.

Speed of Response

Current in LAr gap has very fast rise time:



Charge transfer time and preamp response time slow leading edge.

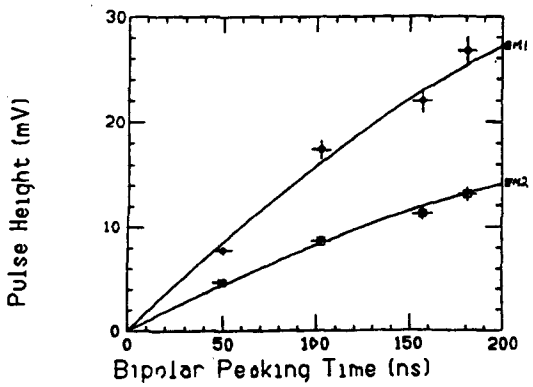


- $\tau \approx \sqrt{L \cdot C_0}$ ==> need to keep inductance low
- noticable signal loss for tau ≥ tpeak (signal loss <==> increase in noise)

Beam test results

(electrode structure same as SDC)

Collected signal vs tpeak for 10 GeV e-

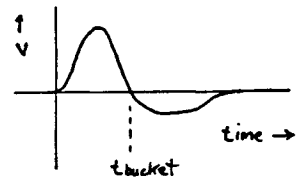


lines = expected variation with tpeak for tau << 50 ns
(arbitrary normalization)

Even for tpeak = 50 ns, no significant signal loss from finite rise time effects.

Time Resolution

- bucket tag using zero cross of bipolar shape



$$\sigma_t \approx t_{peak} \cdot \frac{N}{S}$$

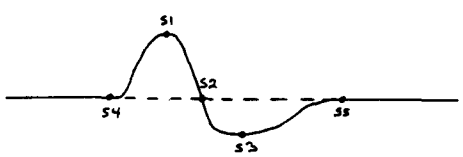
For 10 GeV e- into test beam module,
EM2: S = 5.1 GeV
N = 0.067 GeV
tpeak = 100 ns

==> sigma_t (expected) = 1.3 ns

Measured: sigma_t = 1.5 +/- 0.2 ns

Timing: Trigger

Use ~5 waveform samples to measure amplitude and zero cross, and to tag significant pileup.



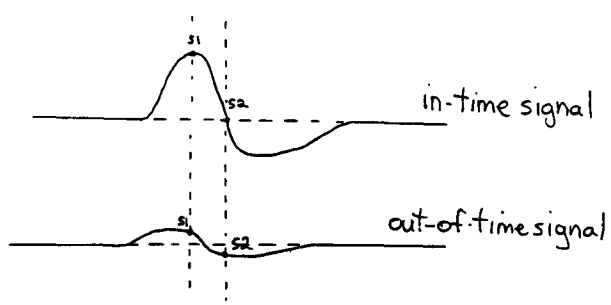
Level 1 may be simpler

Timing: Readout

Trigger determines the bucket of interest

For each channel, record waveform at expected location of peak and zero cross (s1,s2)

==> timing information is preserved



Maybe more (five?) samples for EM

Effect of Timing Resolution

Electron Isolation

Expect small signals, so do not apply bucket tag to isolation cone (just sum s1 for each channel)

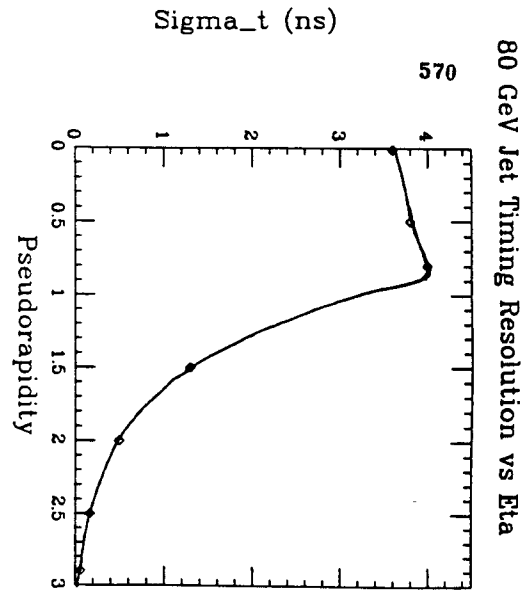
==> never create "isolated" electron by mistiming accompanying energy

Missing-Et/ Fake Signal

Probability of placing a ≥80 GeV Et jet in the adjacent bucket is 2E-5.

==> <1 Hz at 10**33

Level 1/2 trigger issue only; easy to spot at level 3 or offline



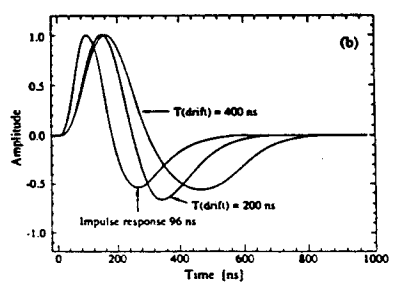
For SDC, at eta = 0,

Sigma_t < 5 ns for
- E > 1 GeV in EM channel
- E > 5 -- 10 GeV in hadronic channel

(See summary table later)

Pileup

Convolution of shaper and triangular input current:



Resulting shape has long, low amplitude negative tail and no net amplitude
==> average observed energy is zero

Observed pileup E_t in cell 0.2×0.2 @ 10^{33}

- $\langle E_t \rangle = 0$
- asymmetric tails from asymmetric bipolar shape

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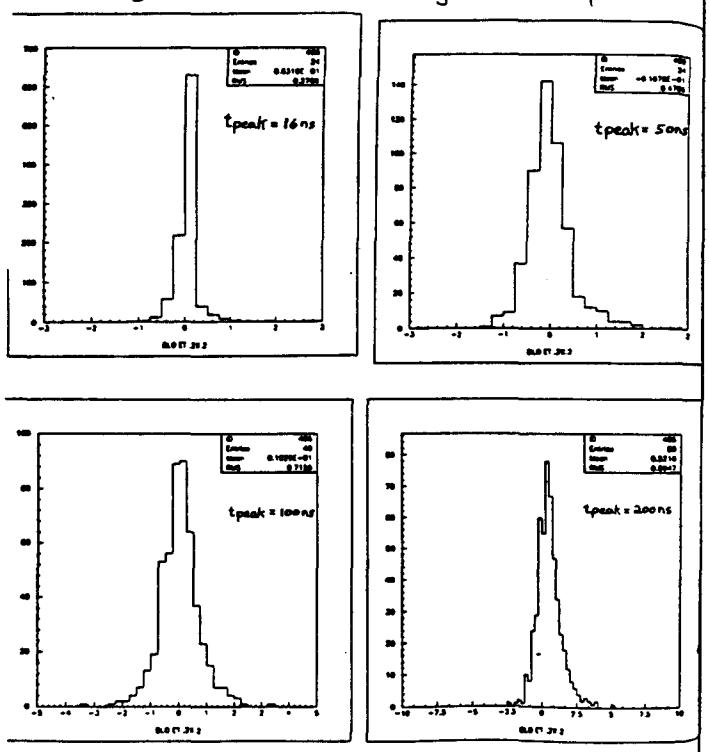

7.3.6

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Pileup "noise" from non-zero rms:

$$\sigma_p^2 = \sigma^2(E_t) \cdot W$$

$\sigma^2(E_t)$ = variance of Et deposited per crossing

W = effective duration in number of beam crossings of observed shaper output

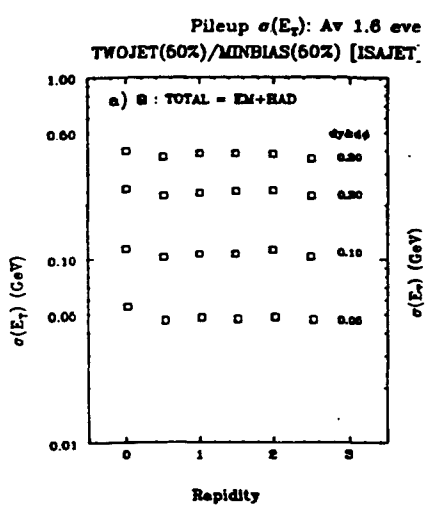
$$= \sum_{i=-\infty}^{\infty} h^2(t_i)$$

$\propto$ tpeak (approx)

$$\sigma_p \propto \sqrt{\mathcal{L} \cdot \Delta\Omega \cdot t_{peak}} \quad \text{(approx.)}$$

575

$\sigma(E_t)$ vs η, various cell sizes



7.3.4

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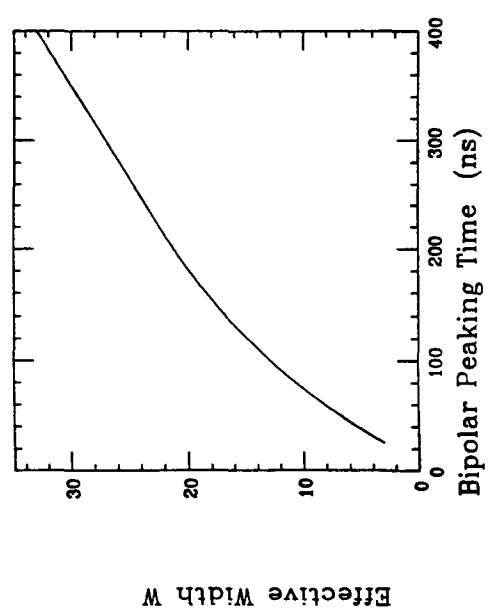
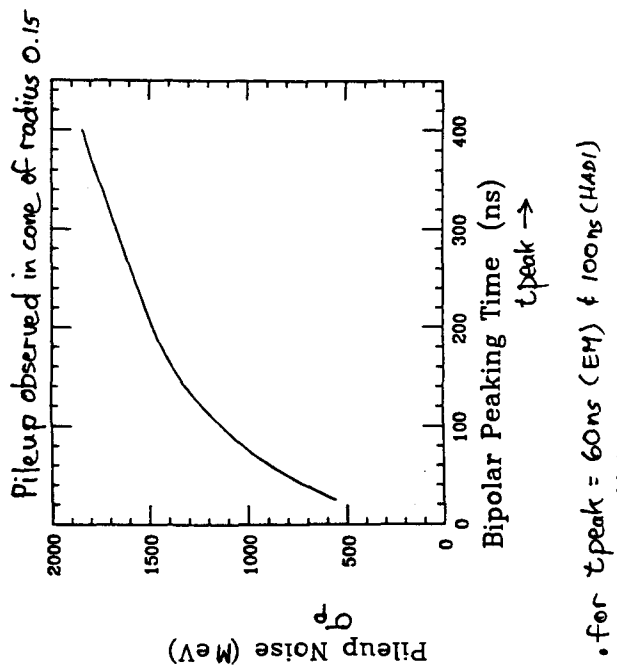


Figure 7.3.5

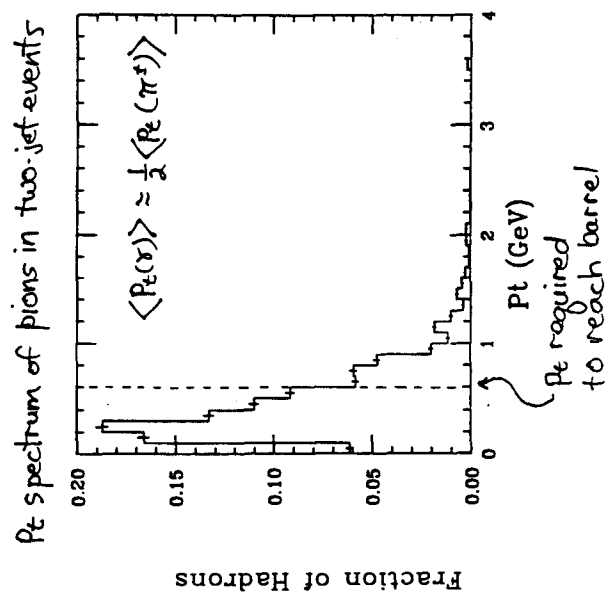


• for t_{peak} = 60ns (EM) & 100ns (HAD)
σ_p = 830 MeV

7.3.7

Several effects will improve this (not yet included)

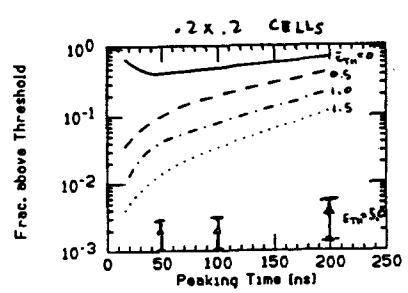
- pt spectrum is soft
  ==> many pions will not reach barrel
- pileup mostly matters in electron isolation cone
  ==> threshold on each channel will suppress much pileup energy
  (e.g., 200 MeV / EM channel)



7.3.8

Effect of Pileup on Electron Isolation

Fraction of crossings with observed Et above threshold



For tpeak=60 ns, observed Et in 0.2X0.2 cone is >1.5 GeV less than 2% of crossings at 10**33; 4% at 10**34

==> very small inefficiency for reasonable threshold

• probability of creating an isolated e- similarly small, but needs more study, including electronic noise

Beam Test Pileup Measurement

10 GeV pions incident on BNL hadronic module at rates up to 1 Mhz. (histograms for 2 and 400 kHz)

Increase in rms of 10 GeV peak in agreement with expected value.

SDC EM tower hit at rate of 800 kHz, but effect is very much less than BNL because pileup pt is much less than the 10 GeV of BNL test.

Figure 7.7

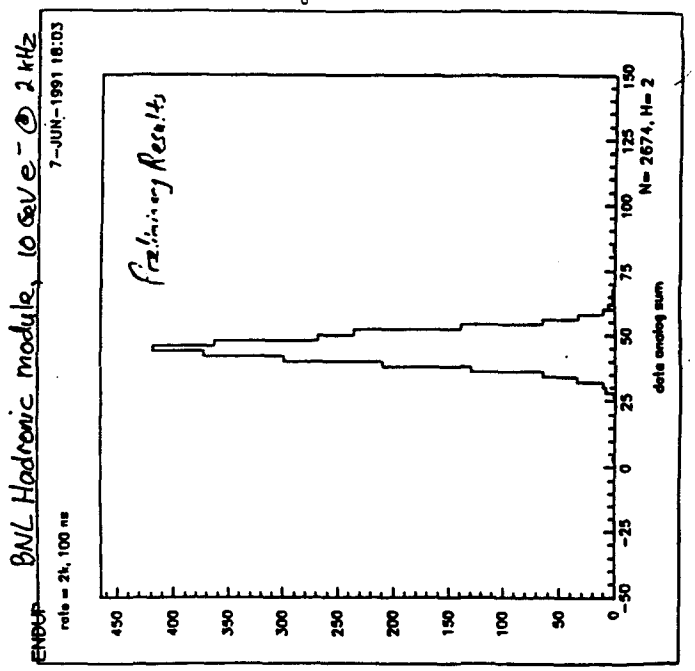
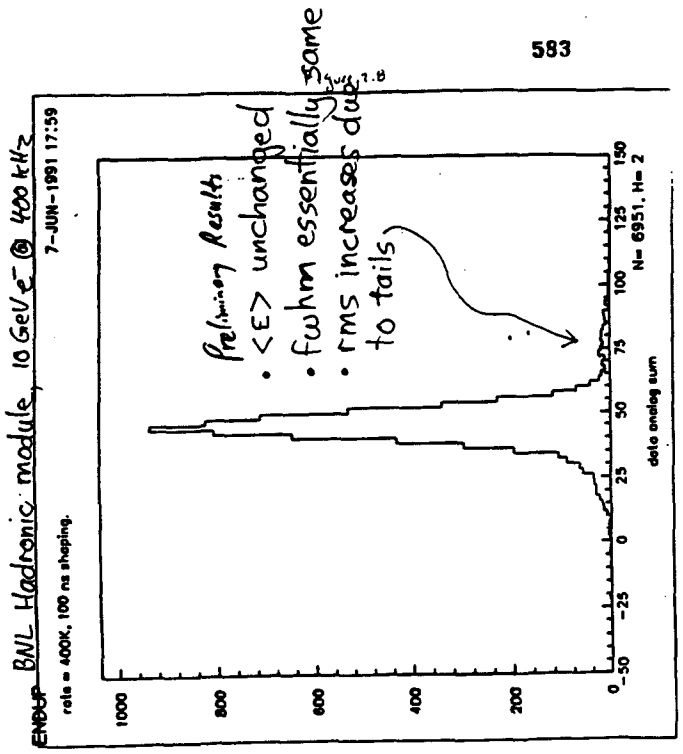


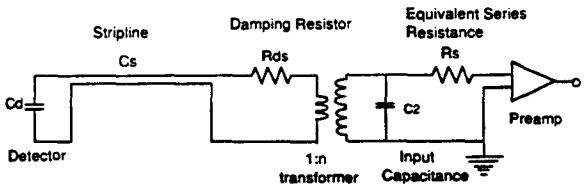
Figure 7.8



Electronic Noise

Equivalent Noise Charge

ENC is the impulse charge on the signal pads of the electrodes that gives the same response after the shaper as the electronic noise



Schematic diagram of front end for calculating noise. Rds and Rs are the two significant noise sources.

Only series noise is important for JFET:

$$ENC^2 = \frac{8k}{t_{peak}}\left[R_{ds}\cdot T_{ds}C_1^2 + R_s T_s\left(\frac{C_1}{n} + n\cdot C_2\right)^2\right]$$

Rds is damping resistor at temperature Tds
Rs is the equivalent series resistance of the JFET at temperature Ts
C1 = Cd + Cs is the total capacitance upstream of transformer
C2 = Cfet + Cstray is the total capacitance downstream

Transformer matches C1 to C2, so ENC depends linearly on C1 in 1st term and on sqrt(C1) in second term.

For SDC, Rds = 2 ohms, Tds = 88 K
Rs = 17 ohms, Ts = 300K (equiv)
Cfet = 40 pF, Cstray = 10 pF

Choose stripline so Cstrip = Cdet/3, but Zstrip ≥ 4 ohms

Equivalent Noise Energy

Relate energy deposited in the calorimeter to charge collected during the effective integration time (tpeak).

- Ballistic deficit:

$$\frac{Q}{Q_0} = \frac{2t_{peak}}{t_{drift}}\left(1 - \frac{1}{2}\frac{t_{peak}}{t_{drift}}\right) = \begin{cases} 0.28 & t_{peak} = 60\,ns \\ 0.44 & t_{peak} = 100\,ns \end{cases}$$

- Sampling fraction:
  fraction of energy in LAr from dE/dx.
  s = 0.13 EM
  = 0.023 hadronic

- p/mu: fraction of energy deposited in LAr by showers is less by
  e/mu = 0.66
  pi/mu = 0.53

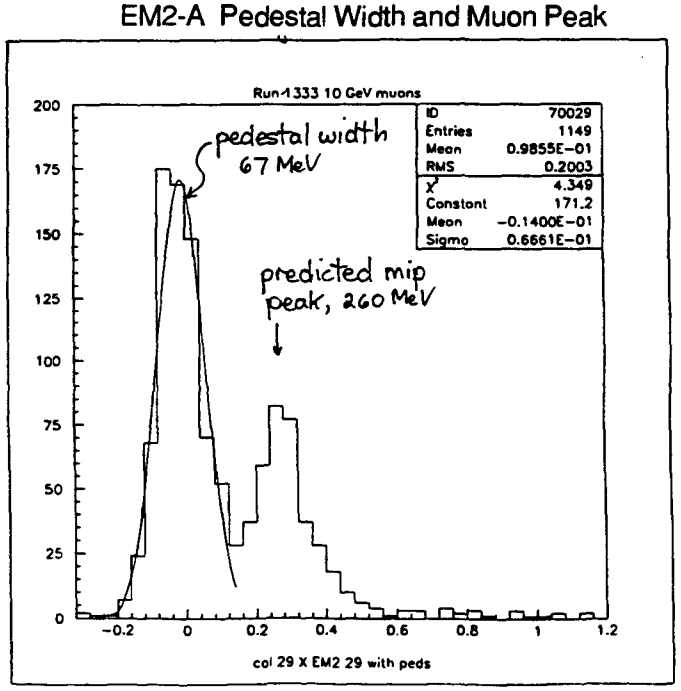
$$\frac{dQ}{dE} = 3.03 * S * \frac{Q}{Q_0} * \frac{P}{\mu} * B_{block} \quad \left[\frac{fc}{MeV}\right] \quad \frac{\text{charge on sig. pad}}{\text{energy in calor.}}$$

- 3.03 is LAr ionization
- Bblock = 0.9 for charge lost on blocking C

(finite rise time effects would decrease Q/Q0)

Electronic Noise: Test Beam Module

EM2-A Pedestal Width and Muon Peak



EM2-A Pedestal width

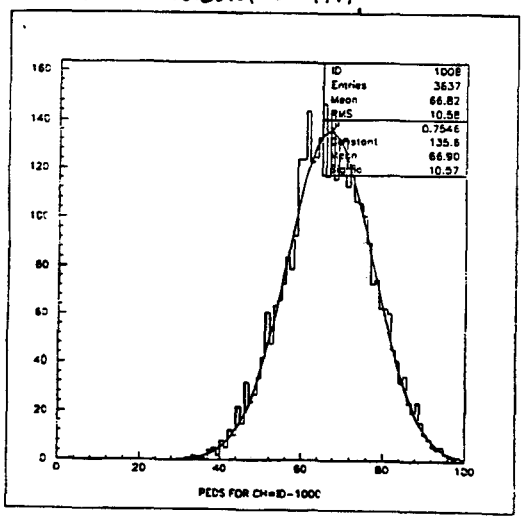


Figure 1. Pedestal width (ADC counts) for Channel 8 (EM2) VGA gain = 10.

Comparison between measured and predicted ENE (MeV), BNL test beam module:

Channel	Measured	Predicted
EM1-A	16 +/- 2	23 +/- 5
EM1-B	17 +/- 2	23 +/- 5
EM2-A	67 +/- 7	50 +/- 10
EM2-B	50 +/- 7	50 +/- 10

Measured values are consistent with expected thermal noise (not a surprise).

No significant pickup. (EM2 pedestal width corresponds to preamp output voltage of 150μV)

Summary of Noise per Channel

- eta = 0
- pileup for 10**33
- Mip = energy deposited by mip; mip S/N is signal-to-noise for mip
- sigma_t is timing resolution for 10 GeV in channel
- two preamps per hadronic section; sum before readout

		per Preamp									per Channel					
Section	N_{amp}	N_{pap}	$<r>$	C_D	C_s	C_{tot}	n	t_{peak}	ENC	ENE	ENE	Pileup	Total	Mip	Mip	σ_t
			cm	pF	pF	pF		ns	fC	MeV	MeV	MeV	MeV	MeV	S/N	ns
EM1	1	5	236	970	340	1310	5	60	1.7	27	27	30	40	32	0.8	< 1
EM2	1	26	255	5680	460	6140	11	60	4.9	75	75	54	92	161	1.7	< 1
HAD1	2	18	314	3100	1030	4130	9	100	2.8	194	274	44	278	662	6.3	2.8
								200	2.0	80	113	63	129		5.1	2.6
HAD2	2	27	387	7070	1530	8600	13	100	4.9	337	477	3	477	993	2.1	4.8
								200	3.5	139	197	4	197		5.0	3.9

- Total EM noise essentially constant for 60 ≤ tpeak ≤ 100 ns. 60 ns selected to minimize pileup at 10**34.
- EM noise increases 2.4X for 10**34 (proportional to Lum**0.38)
  EM+HAD1 noise increases 1.6X for 10**34
  (proportional to Lum**0.20)
- Noise insensitive to details of pileup calculation:
  +/- 30% in sigma(inelast) or Lum
  ==> +/- 5% in EM+HAD1 noise
- 200 ns tpeak for hadronic clearly closer to optimum than 100 ns. tpeak limited by pipeline and level 1 trigger time.
- separation between ENE and Mip
  ==> threshold per channel before sum (not used in results next section)

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- hadronic section electrode structure optimized for minimum radius. Other options:
  - 3 mm gaps
  - double gap structure
  - 7 mm lead

  all give HAD1 noise ~20% less. Latter option also gives substantially better hadronic energy resolution. Each requires 4 to 10 cm additional radial space.

Electrode Structure

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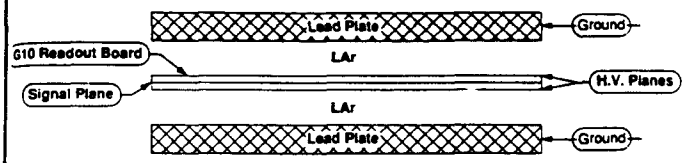
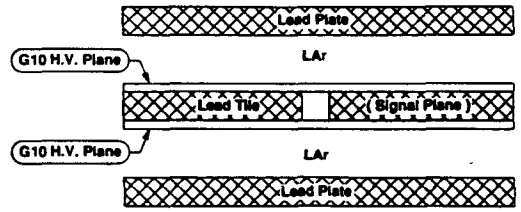
a) Double gap Electrode Structure



b) Single Gap Electrode Structure



7.2.1

J.B. Hunter & / C. Hearty
Original 7-24-91
Updated 7-24-91

595

Noise in Cones

tpeak (EM) = 60 ns
tpeak (had) = 100 or 200 ns

Cone Radius	Excluded Section	Electronic Noise (GeV) t_{peak} = 100 ns	200 ns	Pileup Noise (GeV) 100 ns	200 ns	Total Noise (GeV) 100 ns	200 ns
Single Tower	—	0.56	0.24	0.13	0.15	0.57	0.28
	HAD2	0.29	0.14	0.13	0.15	0.31	0.20
0.15	—	2.9	1.3	0.63	0.96	3.1	1.6
	HAD2	1.5	0.73	0.61	0.93	1.7	1.2

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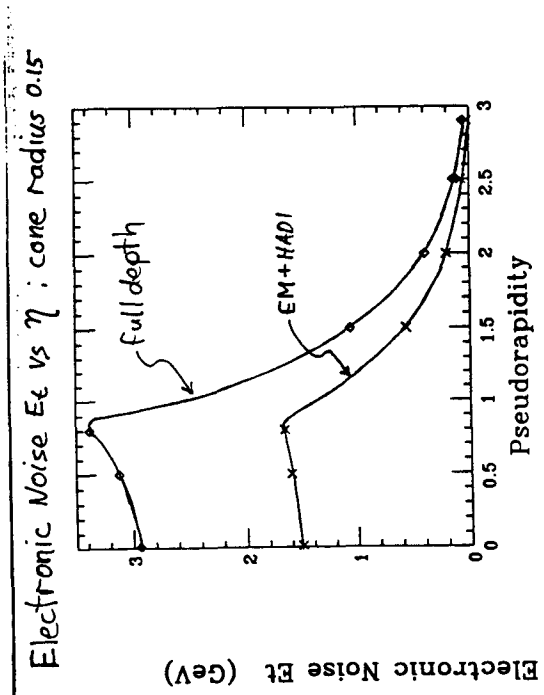

7.5.3

Electron Uniformity

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Three areas to check:

- cryostat walls near eta = 1.3 (Nobu's talk yesterday)
- tie rods
- phi crack

All three studied with EGS and/or Geant.
Phi crack studied in beam test.

Phi Crack

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3 mm non-projective cracks between modules (~1.5% of surface area)

Effects studied at BNL test beam
- preliminary results only

Order of presentation:

- Geant study of 10 GeV e- on test beam module
- preliminary beam test results
- Geant study of SDC

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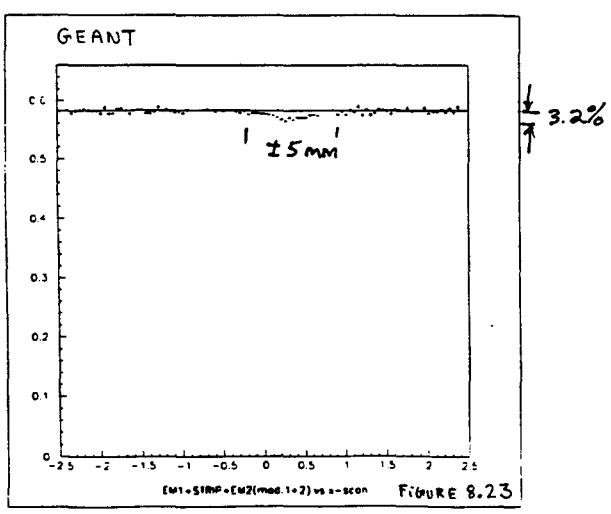


FIGURE 8.23

600

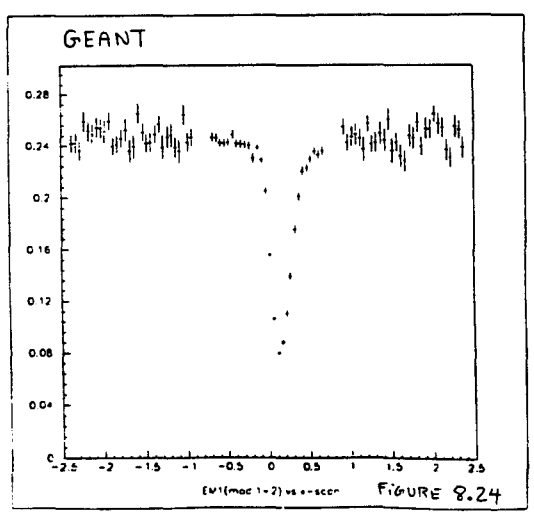


FIGURE 8.24

601

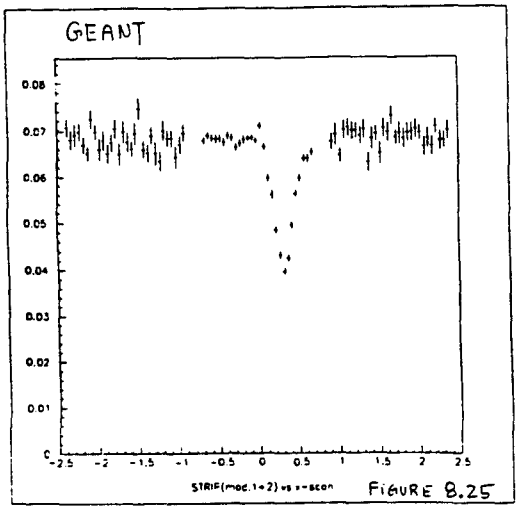


FIGURE 8.25

602

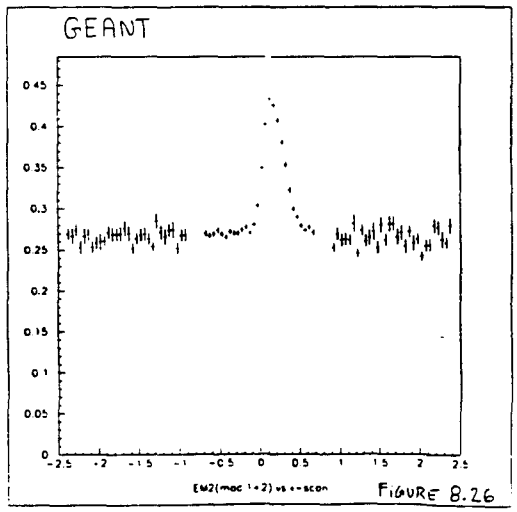


FIGURE 8.26

603

Geant response, EM1+EM2 only

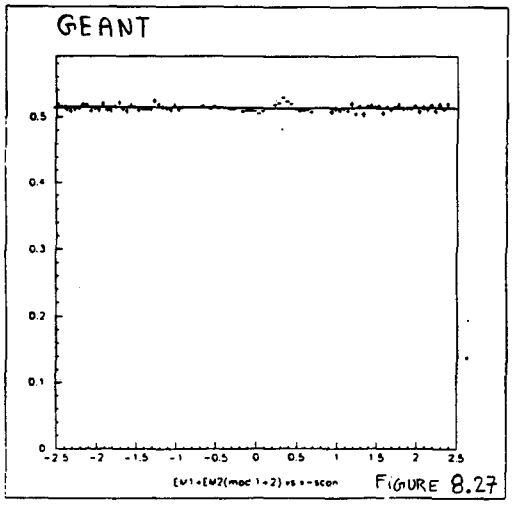


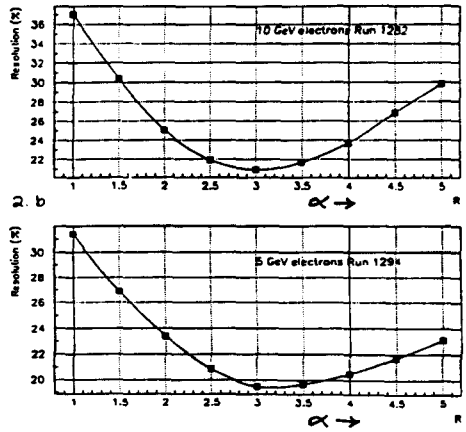
FIGURE 8.27

604

Calibration

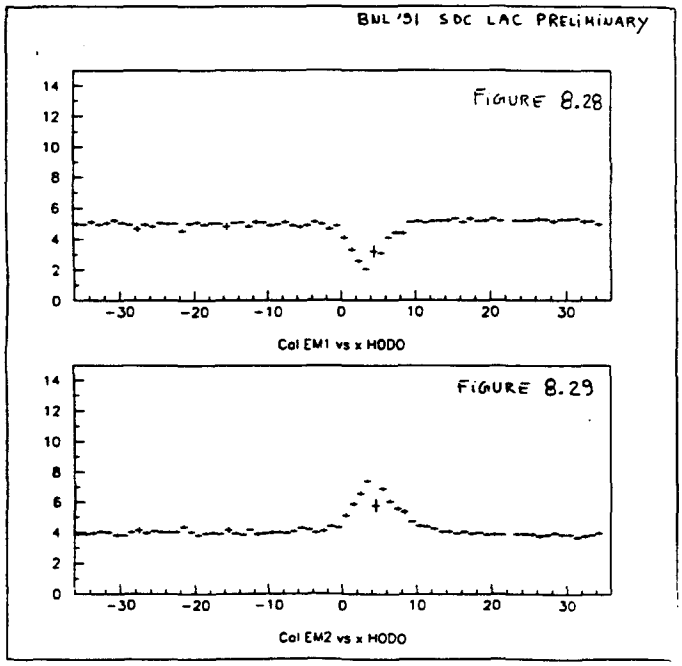
- optimize EM1 + EM2 resolution

Resolution of EM1 + α · EM2

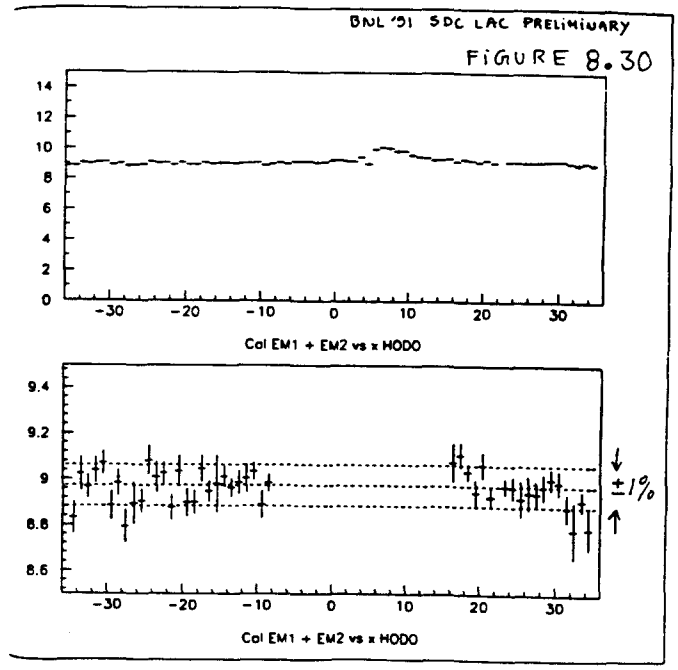


- errors in calibration will be reflected in non-uniformity near crack

605

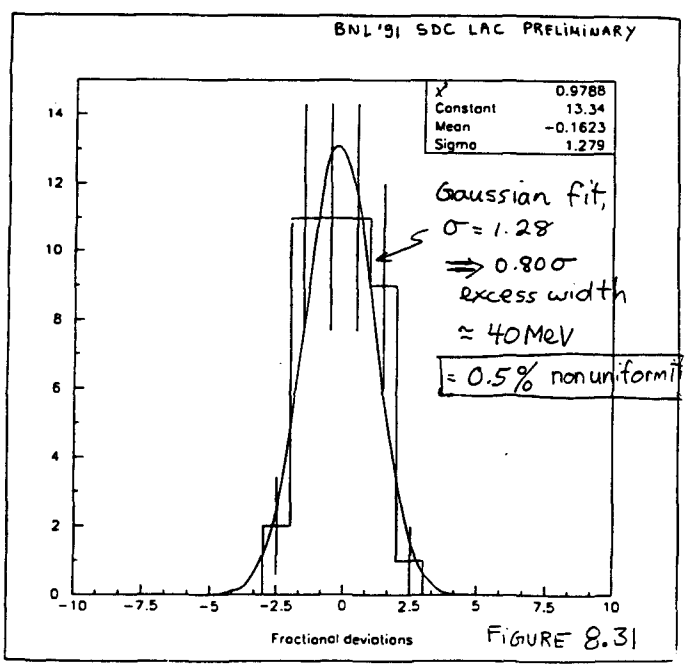


606



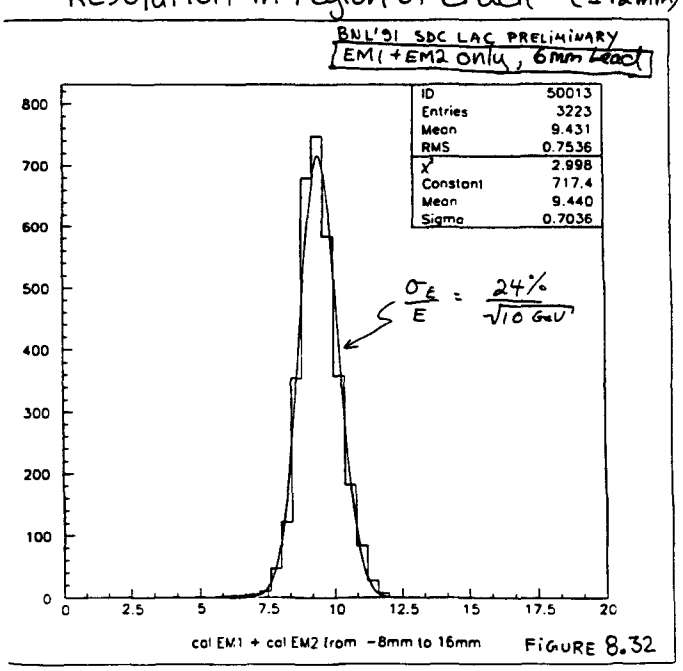
607

Histogram of $(r_i - \langle r \rangle)/\sigma_i$;
r_i = response at scan point i



608

Resolution in region of crack (±12mm)



Introduction (and Summary)

- Liquid argon has a fast risetime that is preserved by the SDC electrode structure.
- resolution and uniformity across phi crack are acceptable; very good elsewhere
- electronic noise and pileup sufficient for SDC physics program.
- <5 ns time resolution for >1 GeV in EM channel, 5--10 GeV in hadronic.
- The response of the detector in all of the above is understood and can be calculated, as has been verified by beam test data.

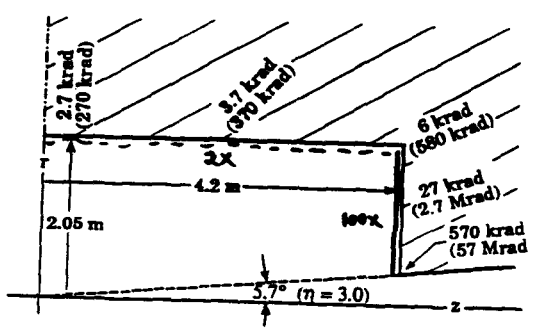
RADIATION DAMAGE, BEAM TEST 611

— K. TAKIKAWA —

K.T. summarizing the results presented by
J. Ernwein on SACLAY test
D. Green on BEIJING test
K. Takikawa on TSUKUBA test

RADIATION DOSE IS DUE TO "MINBIAS" EVENTS WITH $\langle p_T \rangle_{\pi^0} \sim 0.6$ GeV

The SDC detector (100 YEARS AT DESIGN $\mathcal{L}$)



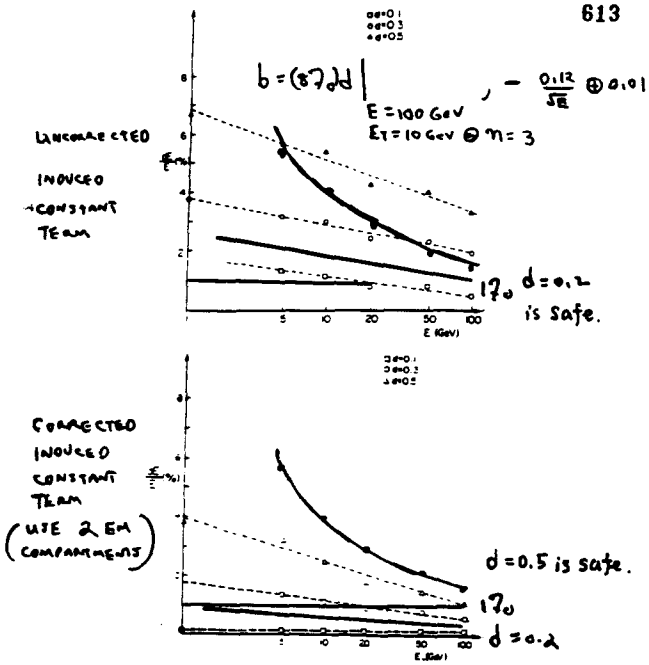
DOSE $\sim \left(\frac{1}{\sigma}\frac{d\sigma}{d\eta}\right)\frac{\langle p_T \rangle}{\theta^3}$

$1/\theta^3$ SCALING

→ DOSE IS VERY LIMITED IN ANGLE

WHAT HAPPENS TO THE DAMAGED AREA?
NONLINEARITY INDUCED BY NONUNIFORMITY
RADDAM - EGS (A. PMA)

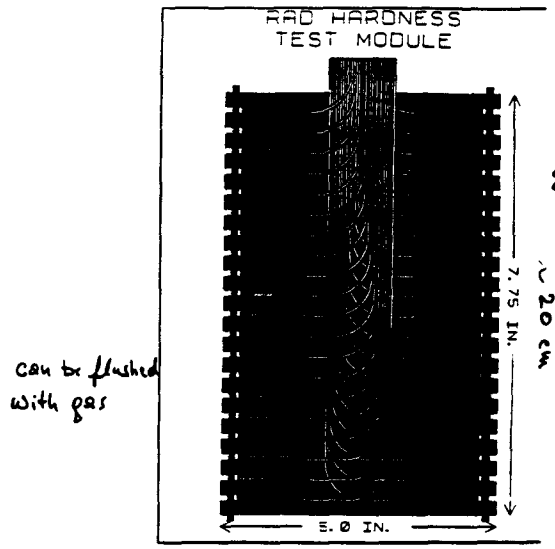
613



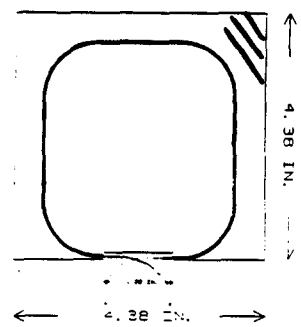
FERMILAB

2 Modules
7, 8

614



20 x 1.1 X_0
lead



SCSN-81
BCF-91A

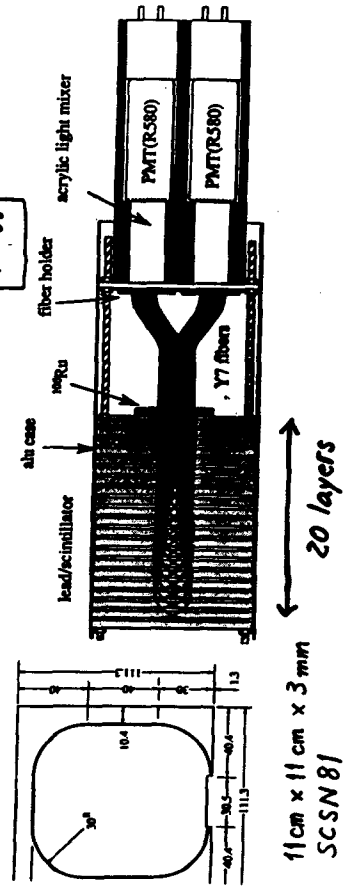
3

615

Schematic view of Test module

The basic design is due to Bill Foster (Nov. 1990).

$|\Delta G_{uv}| \lesssim 2\%$



- Ru source to monitor PMT gain
- Y7 spliced to a clear fiber
- Groove not polished
- Edge of Tile polished
- Tile wrapped with white paper

616

Summary

- Critical issues in engineering have been answered yesterday.
- Critical issues of the LAC with fast-readout have been investigated in the beam test at BNL. To understand the data fully will take more time, but...
- The (preliminary) results are:

EM: $\sigma_E/E = 18\%/\sqrt{E}$ (@t_{Pb}=6mm)
(without Shower max strip)
HAD: $\sigma_E/E = 63\%/\sqrt{E}$ (@t_{Pb}=12mm)

e/π (HAD)=1.15 @20GeV → e/h=1.25
σ_E/E(const. by e/h)=3.5%

These values are as expected by simulation programs.

- This leads us to expect for the Pb absorber thickness of the SDC LAC,

EM: $\sigma_E/E = 13\%/\sqrt{E}$ (@t_{Pb}=4mm)
HAD: $\sigma_E/E = 3.5\% + 68\%/\sqrt{E}$ (@t_{Pb}=14mm)

(e/h=1.25 should be slightly better for larger t_{Pb}/t_{Al})

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[redacted]

SOURCE MEASUREMENTS

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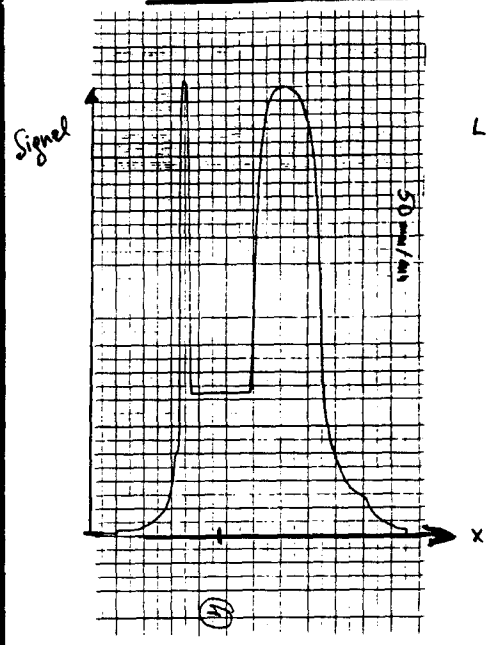
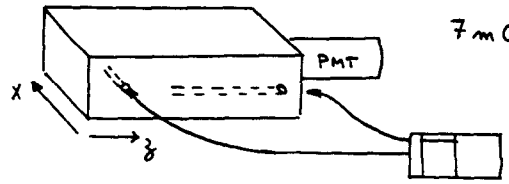




7 mCi ^{137}Cs (

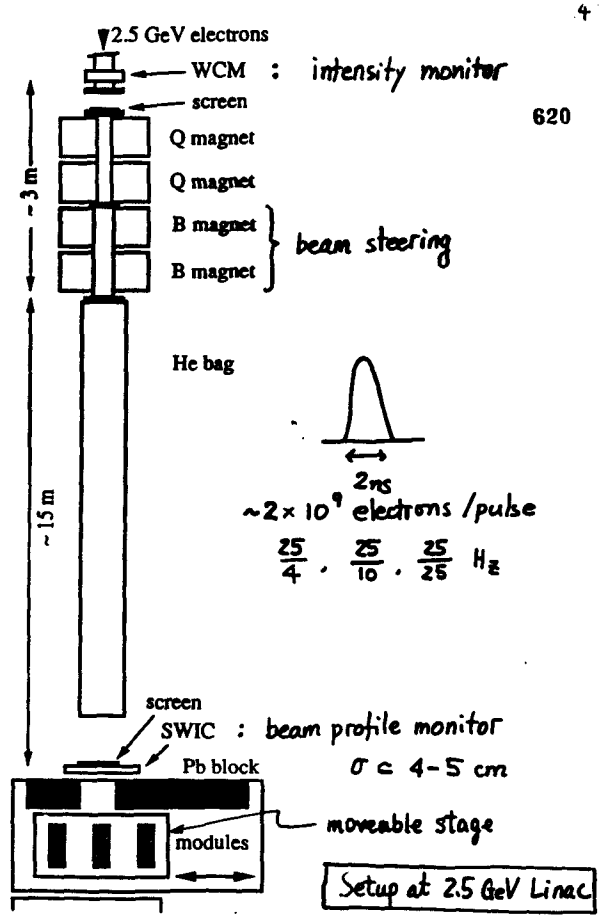
Source Driver

(V. Rome

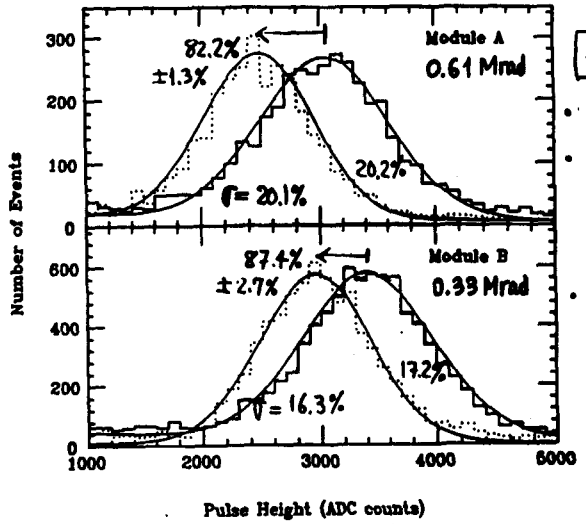
4

[redacted]

620



Pulse height distribution for 2 GeV electrons

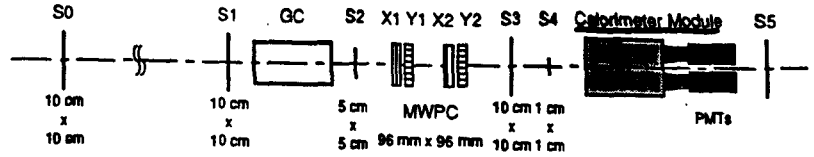


uncertainties:

- statistical (peak, pedestal)
- PMT gain (deviation from τ fluctuations)
- peak fitting (fitting region, background subtr.)

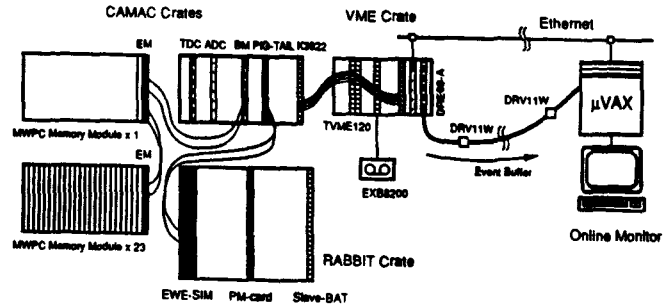
Gain shift after 0.61 Mrad is 18%.
" 0.33 Mrad " 13%.

Setup at KEK PS π2 test beam



0.5 ~ 3.0 GeV/c electrons

KEK π2 Beam Line Set-up for Tile-Fiber Calorimeter Beam Test

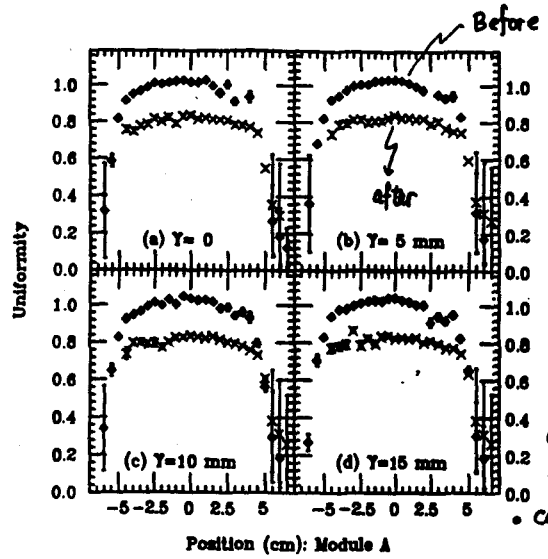


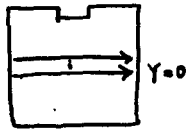
KEK π2 Beam Line Data Acquisition System

DOSES and DOSE RATES

	TSUKUBA	BEIJING	SACLAY	
$\dot{D}$ krad/h	16 – 140	100	120	2400
$\langle\dot{D}\rangle$ krad/h	~2 – 10	20	.75	12
D Mrad	.3 – 5	4	.25	2
			SLOW	FAST

SSC average dose rate $\langle\dot{D}\rangle$ is ~ 1 rad/h {at end of barrel, $\mathcal{L} = 10^{33}$}





Uniformity not degraded
↕
uniformity remains same even for non-uniformly irradiated sample

- confirmed from ^{60}Co exposure

RESPONSE UNIFORMITY MEASURED WITH 2-GeV electrons

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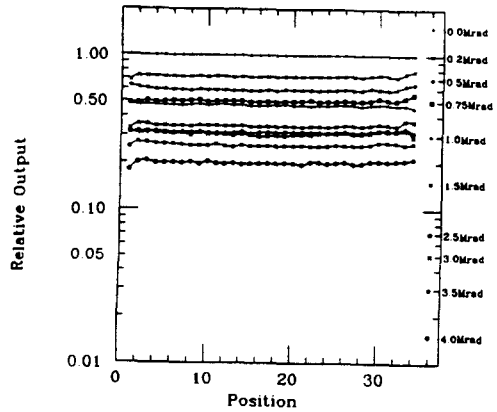
MEASURED WITH SOURCE SCAN

RELATIVE
T. TUBE SCAN



⇒ NO MAJOR NONLINEARITIES
UP TO 4 MRAD

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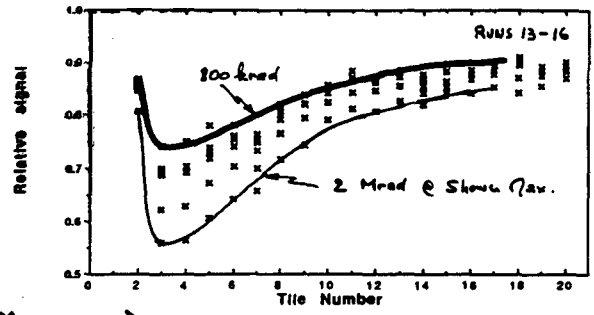
SACLAY

DAMAGE PROFILE FOR HIGH DOSES



BEAM →

PROFILE OF DAMAGE

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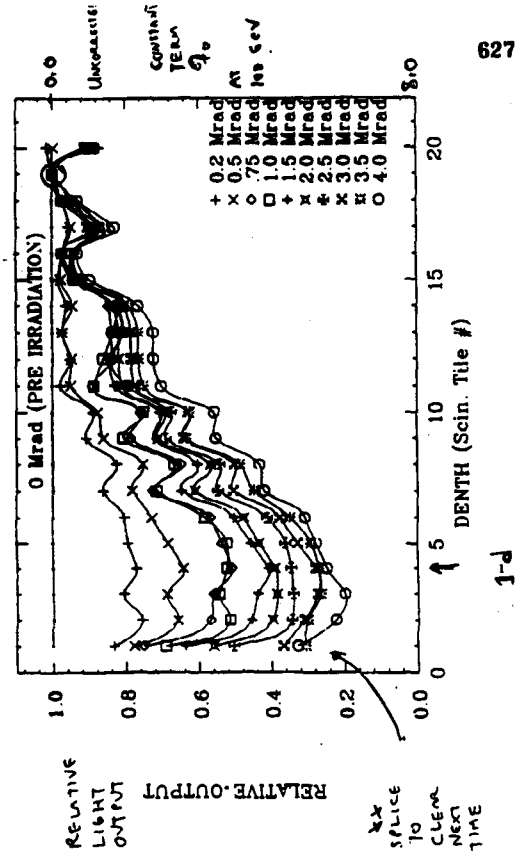
P1/5

BEIJING

IHEP DATA
NO ANNEAL

TILE MODULE #5 L2 AIR NO BLACK

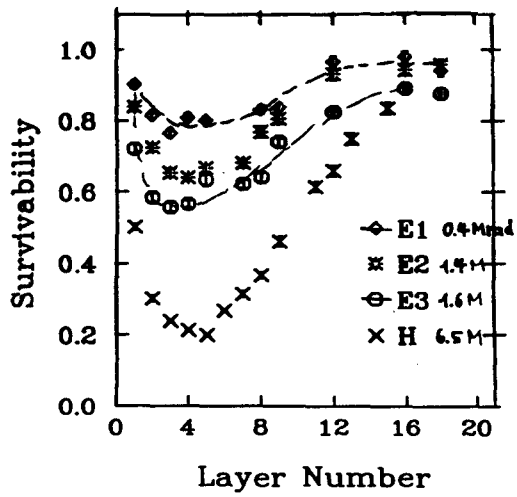


RELATIVE LIGHT OUTPUT

** SPLICE TO CLEAN NEXT TIME

628

TSUKUBA



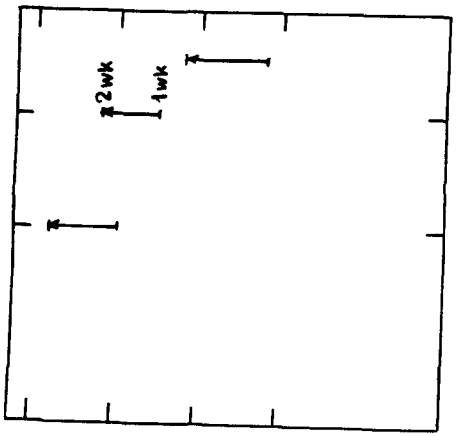
Damages of module C, E_1, E_2 measured with a Ru source.

Consistent with the electron test beam measurements on module A & B.

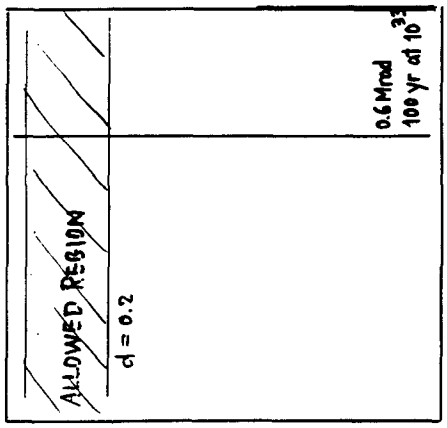
60Co induced damage agrees with electron shower induced damage.

633

SCSN-81/BCF-91
Long-term annealing



634



Ignoring long-term annealing, existing plastics are a candidate for precision calorimetry

P-T

635

BARREL IS OK.

FOR THE ENDCAP WE NEED TO DO BETTER.

- We will test Bicron new scintillator.
- Kuraray is also developing new plastics.
- Optimize grooving & fiber routing in tile.
- Green tile / Orange fiber

– We have three places set up to do beam test –

J. Proudfoot.
7/8/91.

636

Tile-Fiber Optical System.

1. Light yield.
2. Uniformity (within tile)
3. Uniformity (tile-to-tile)
4. Masking
5. Splice reproducibility.
6. Source calibration & response equalization

Table 2

Photocathode Efficiency
(all bi-alkalai), Green Light from BCF-91A Fiber

Tube	Stages	Typical N Photoelectrons
Amperex 2230	12	1.9
EMI 9839	12	3.0
Hammamatsu R580	10	3.4
Phillips 2081 Green Ext.	10	1.9
Phillips 2081 Green Ext.	10	2.9

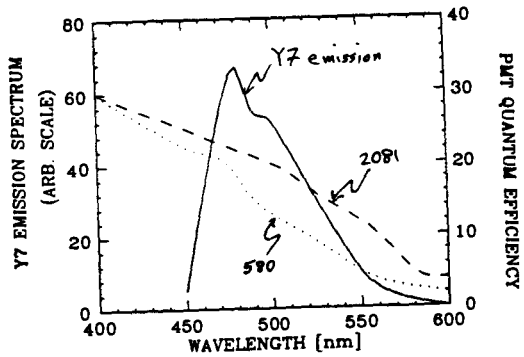
To be used in Test Modules.

FNAL MUCH Better. (9pe's/mip d 4mm tile

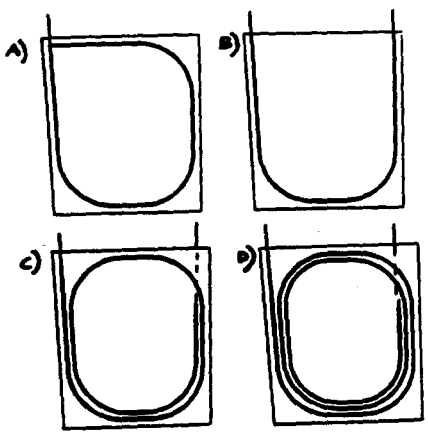
We have also looked at relative outputs of some scintillator materials.
(2.5mm Thickness)

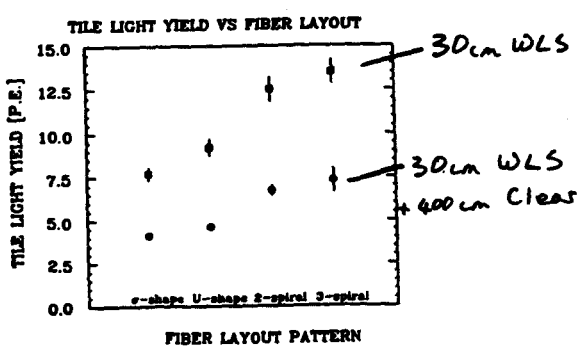
SCINT	SPLICE	CLEAR Fiber	GROOVE	MYLAR Side	COUNTS ADC	PE
RH1	ANL	2.8M	LSU	?	90	1.64
RH1	FNAL	2.5	LSU	?	98	1.78
RH4	ANL	2.8	LSU	?	119	2.16
Styrene	FNAL	2.5	FNAL-SP1	A	140	2.54
PVT	FNAL	2.5	FNAL-SPI	A	300	5.45
PVT	FNAL	2.5	FNAL-3D	B	240	4.36

The Bicron RH1 and RH4 were materials available in March 1991. Different versions have been developed recently.



3. Figure 3: A comparison of the emission spectrum [8] of BCF-91 green WLS fiber with Y7 dye (solid line) with the quantum efficiency [7] of a standard bialkali photocathode (dotted line) and the quantum efficiency of a "green-extended" bialkali photocathode (dashed line).





EGS Study, Assuming Coherent Dep/or Non-Uniformity (WORST CASE)

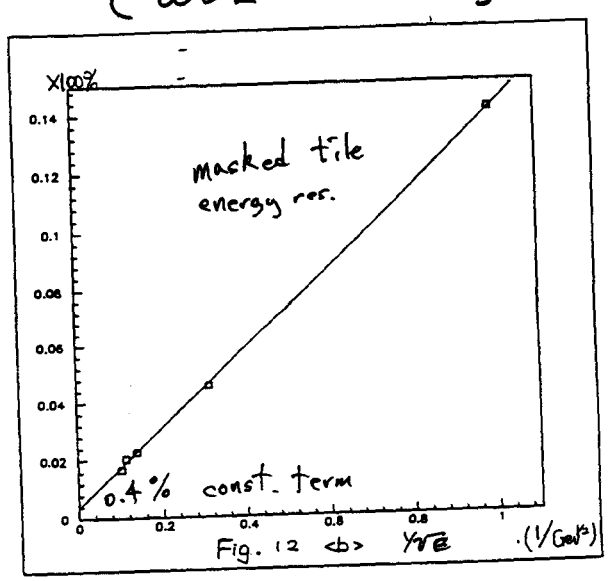


Fig. 12 <b> vs E

⇒ conclude transverse non-uniformity ≤ ~2% acceptable

$\delta_0 \simeq 0.1$ Corresponds to $\sigma \simeq 0.05$

641

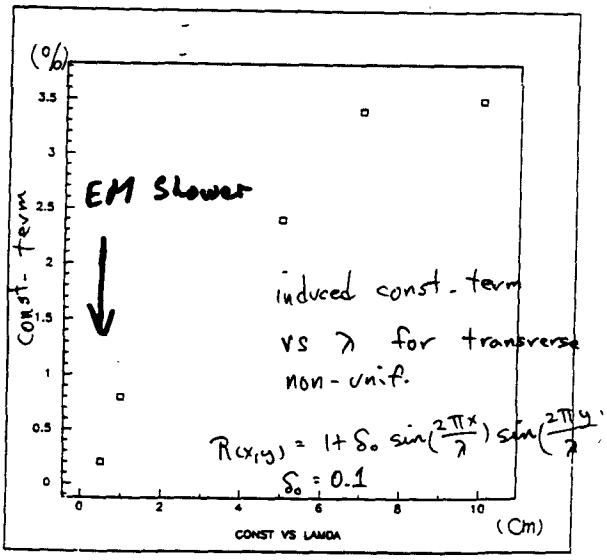
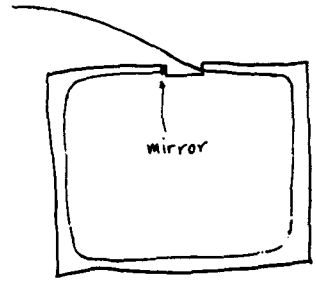


Fig. 10

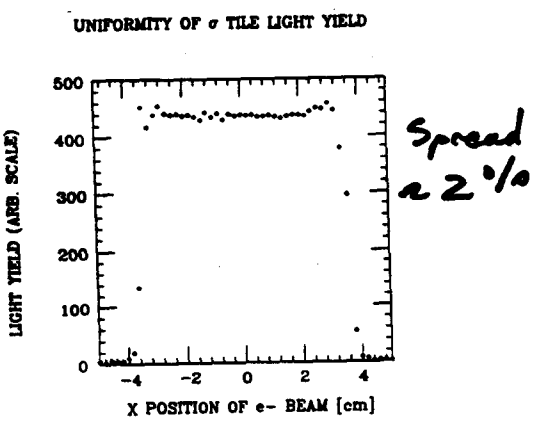
tile size = 10×10 cm

Sigma tile

642



643



10. Figure 10: Spatial uniformity of the light collection of unmasked 4mm thick PVT tile with σ pattern of fiber layout. A scan across the tile. The signal fall-off at x=± corresponds to the edges of the tile. The spread of the response is ≈ 2%.

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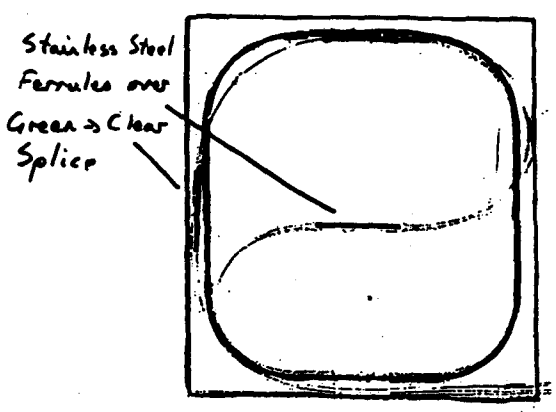
III) Scintillator Light Output

We have tried a number of combinations of tile and fiber:

Thickness	Configuration	Wrapping	Number Pe
2.5 mm	RH4, two straight fibers, mirrored ends	White Paper	1.0 to 1.1
2.5 mm	Styrene, 4 U fibers, bends outside	White Paper	1.65 to 2.0
5 mm	SCSN38, two straight fibers, mirrored ends	White Paper	1.7
2.5 mm	RH4, U fiber, 2.8 M clear spliced on	Aluminum Mylar	2.5
2.5 mm	RH4, U fiber, 2.8 M clear	White Paper	1.66
2.5 mm	RH4, U fiber, 2.8 M clear	Black Tedlar	0.9
2.5 mm	RH4, U fiber, 60 degree beveled edges,2.8 M alum. mylar	Aluminum Mylar	1.75
2.5 mm	RH4, 2 fibers with 4 ends to phototube,2.8M	Aluminum Mylar	2.0
2.5 mm	RH4, one loop fiber, 2.8 M clear	Aluminum Mylar	3.0



A tile from EM Tower 2, Layer 29. The loop fiber path in the tile is shown as well as the external fiber routing. The steel ferrules are used to reinforce the splices between wave shifter fiber and clear fiber.

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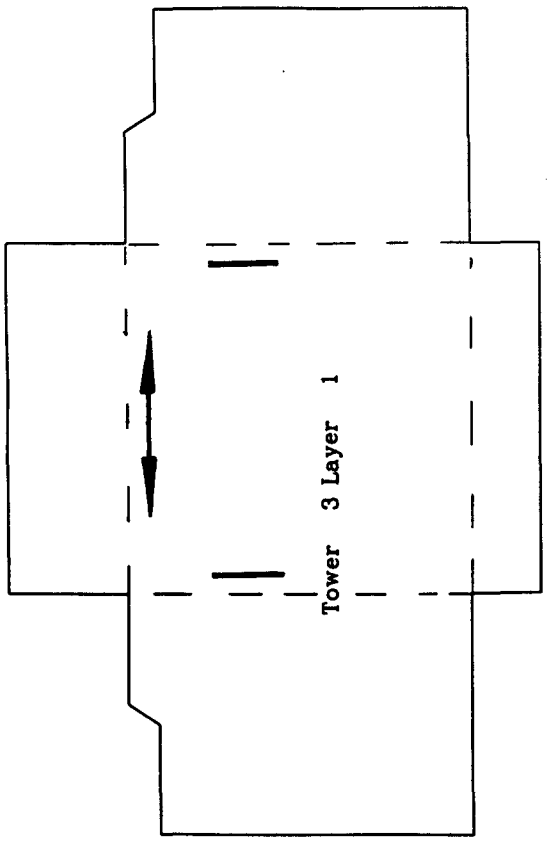
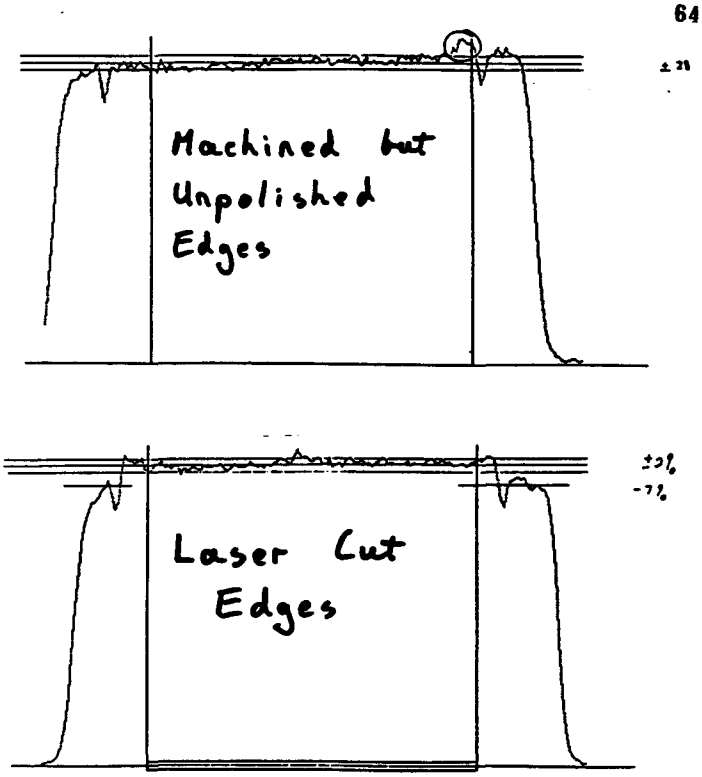
Candidate "Simple" Mask



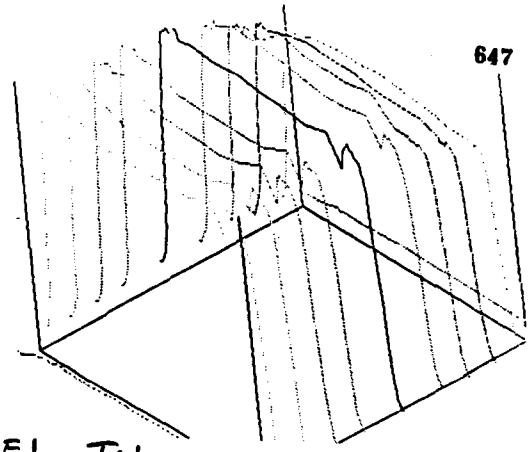
Diagonal Uniformity Scan
No Mask, Fibers Decoupled at Exit.

646



(DGU)

647

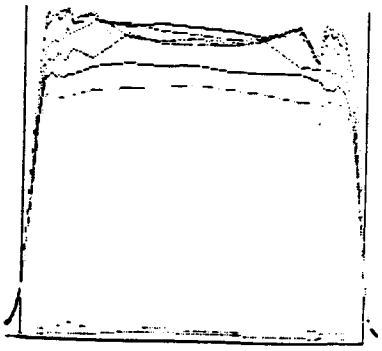


Bevelled Edge Tile

30°

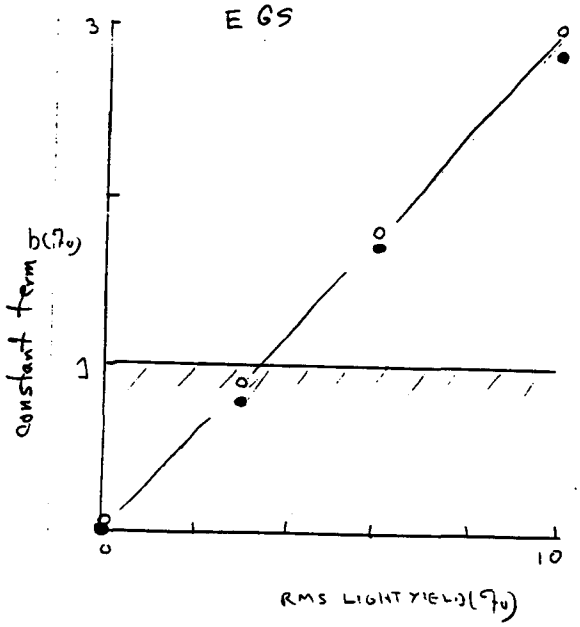
Light Output ~ 1.7 pe/mip @ Normal Inc.

U Groove.



EM tile required unif.
(tile-to-tile)
E GS

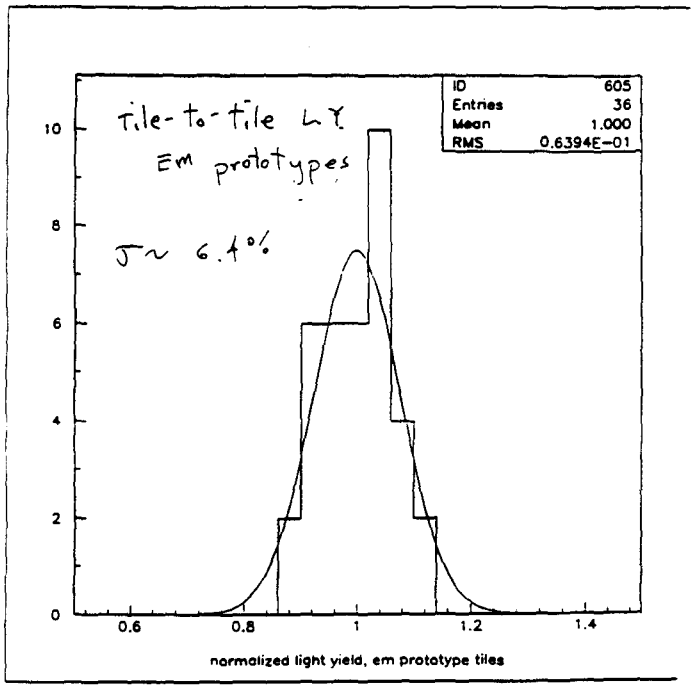
648



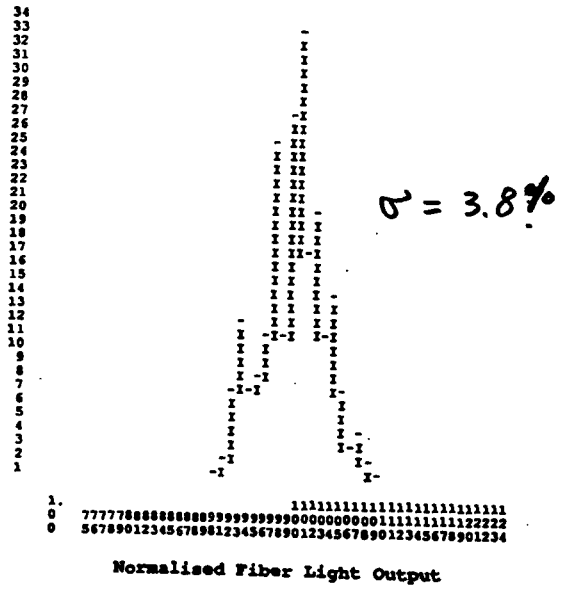
$\sigma_{LY} \leq 3\%$ for const. term < 1%
(global calibration)

$\sigma_{LY} \leq 7\%$ for const. term < 1%
(tower calibration)

CDF EM Prototype 649



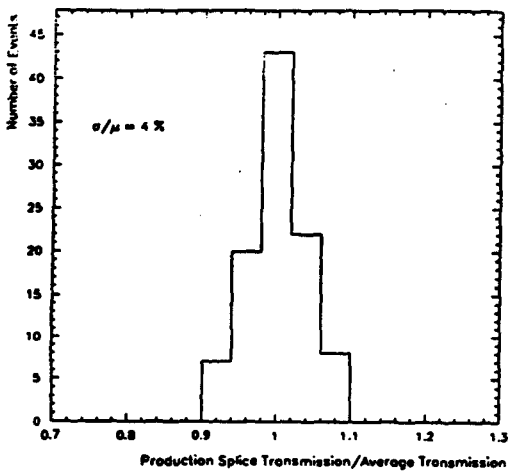
Fiber Quality Monitor 650



Light output from the fibers accepted for the prototype module. 90% of the fibers were acceptable at this stage. The RMS variation is 3.8 %.

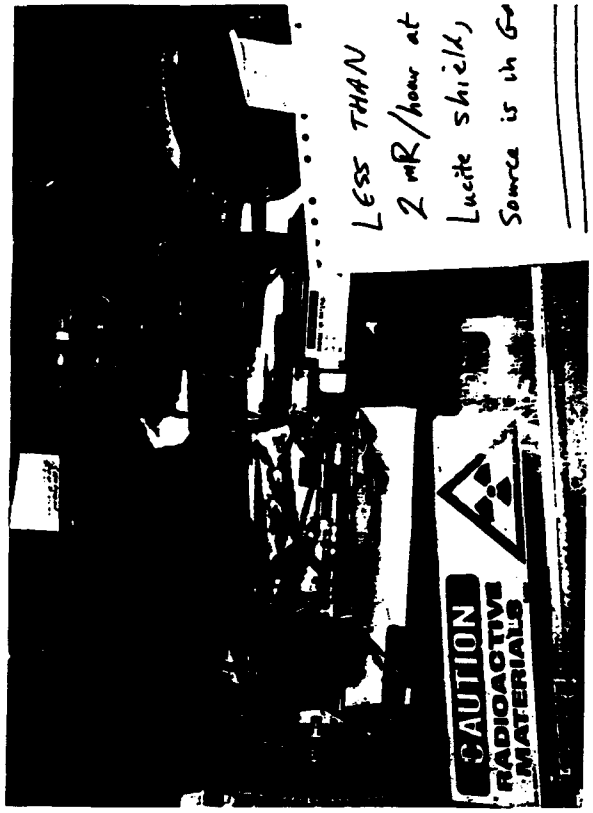
651

652



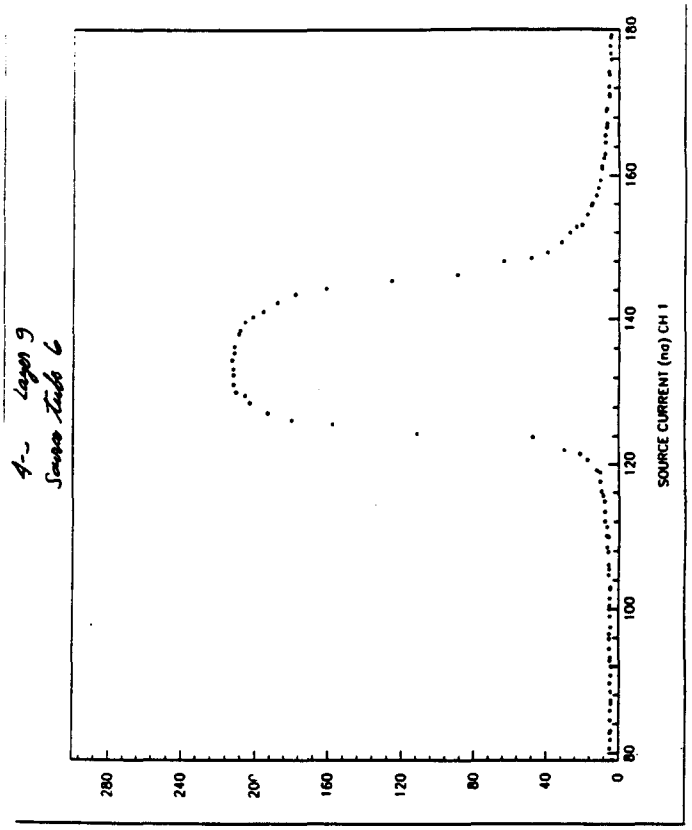
Conclude — variation in light output of test module fibers is consistent with being wholly associated with splice variation

653



LESS THAN
2 mR/hour at
Lucite shield,
Source is in G

654



4- Layer 9
Source Track 6

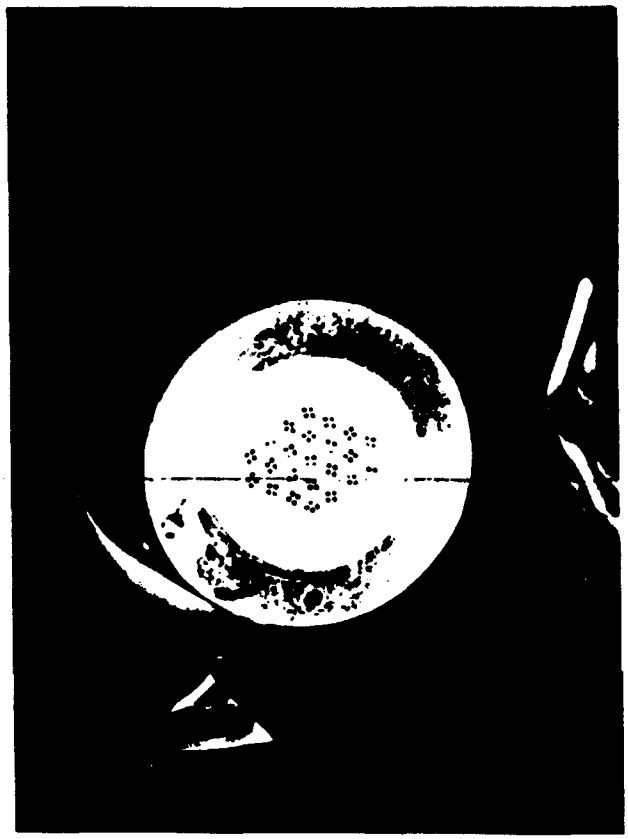
655

6/24/91 7:56am

CHANNEL	1	NMAX	4	PED	3.0686	
133						
357						
457						
680						
133	MAX	208.5414		FIT	208.0411	
357	MAX	207.5814		FIT	207.5077	0.25%
457	MAX	207.7314		FIT	207.0682	
680	MAX	207.7514		FIT	207.6616	
CHANNEL	2	NMAX	4	PED	3.4019	
163						
326						
487						
646						
163	MAX	186.7081		FIT	186.0090	
326	MAX	186.6481		FIT	186.6315	0.41%
487	MAX	186.8081		FIT	187.4520	
646	MAX	186.6081		FIT	186.6300	
CHANNEL	3	NMAX	4	PED	4.3100	
192						
289						
516						
616						
192	MAX	140.0281		FIT	139.0277	
289	MAX	139.4791		FIT	139.5041	0.33%
516	MAX	140.8791		FIT	140.7579	
616	MAX	140.3081		FIT	140.3771	
CHANNEL	4	NMAX	4	PED	4.5193	
221						
261						
544						
585						
221	MAX	174.0407		FIT	173.4518	
261	MAX	173.9807		FIT	173.9329	0.13%
544	MAX	173.5807		FIT	173.3372	
585	MAX	173.4807		FIT	173.4364	
CHANNEL	5	NMAX	0	PED	4.2267	
CHANNEL	6	NMAX	0	PED	9.3164	
CHANNEL	7	NMAX	0	PED	0.0656	

$\langle \sigma \rangle = 0.28\%$

656



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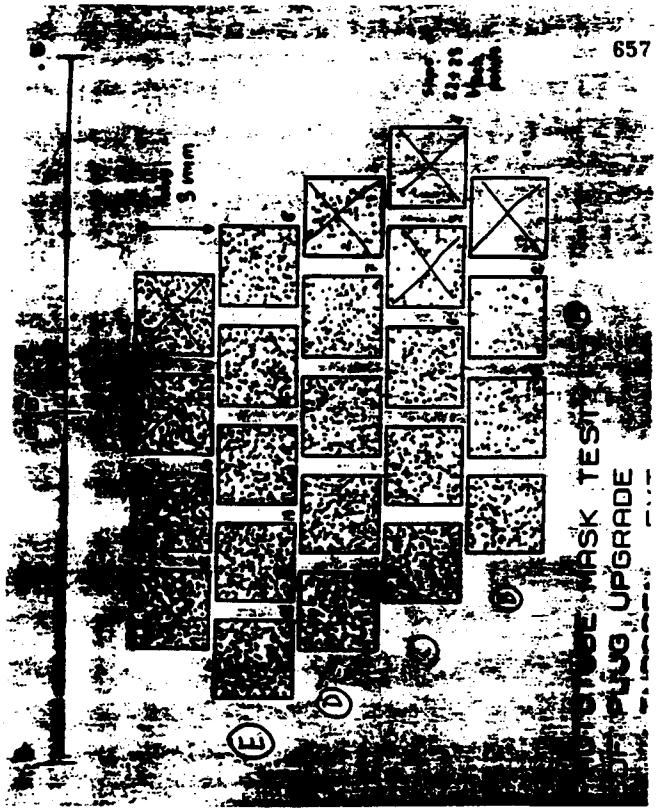

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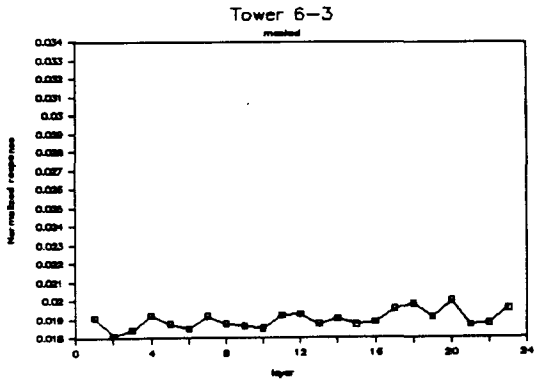
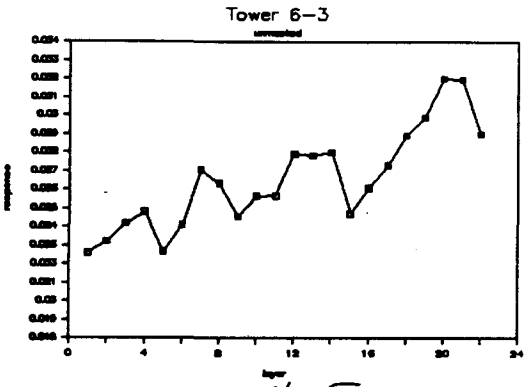


$\sigma = 2.6\%$

$\delta = 7\%$ (air gap)

659



11.5% σ

660

SM DESIGN STATUS

F. RONDEAUX

1 prototype

661

SDC Calorimeter
Tile/Fiber Fabrication and Cost

Prepared by the Fermilab Technical Support Section

Presented by S. Gourlay, Fermilab

August 5, 1991

662

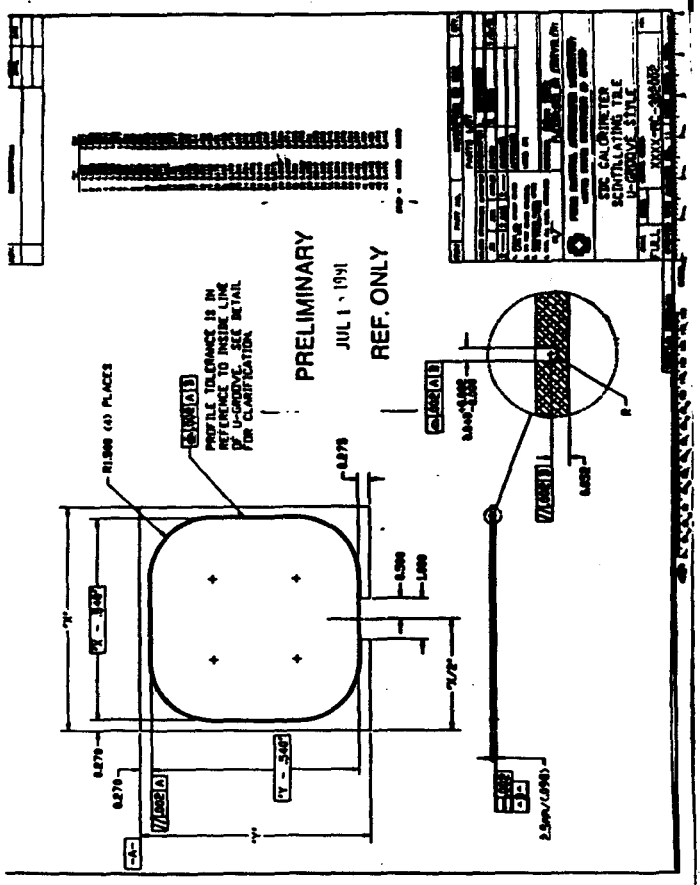


Figure 1. Drawing of Typical Tile Showing Dimensional Tolerances

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SDC Tile Size Summary

Section	Aspect Ratio	Size Range	Number of Sizes	Quantity Each	Total
EM Barrel	Rectangular	4 - 6"	76	Approx. 2800	101400
HAC 1	Rectangular	5 - 9"	128	128 - 1536	178240
HAC 1 Spec.	Rectangular	4 - 9"	60	128	7936
HAC 1 RB Spec.	Rectangular	9.6 - 6"	72	128	9216
HAC 2	Rectangular	12 - 19"	36	128 - 640	13696
HAC 2 Spec.	Rectangular	9.6 - 16"	15	128	1920
EM End Cap	Trapezoidal	3 - 6"	1060	64	67840
HAC 1 End Cap	Trapezoidal	3 - 7"	929	64	59456
HAC 2 End Cap	Trapezoidal	4 - 16"	162	64	10368
		Total	2538		532160
			Base Material	Polystyrene	
			Thickness	2.5mm +/- 0.1mm	

664

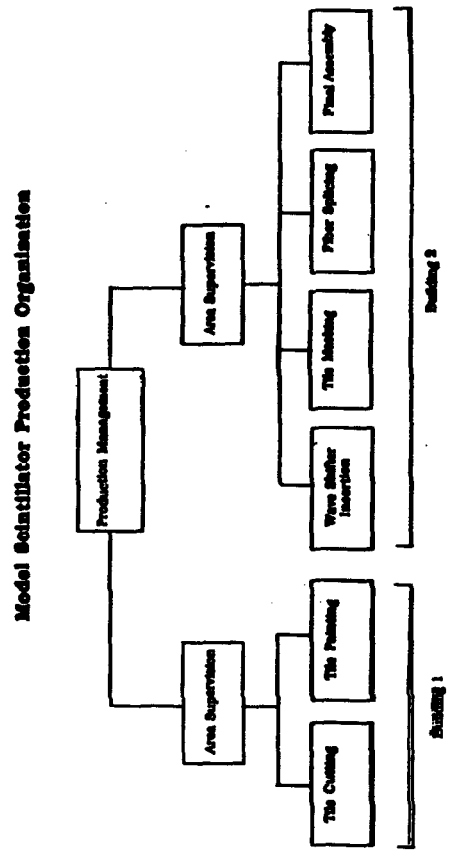
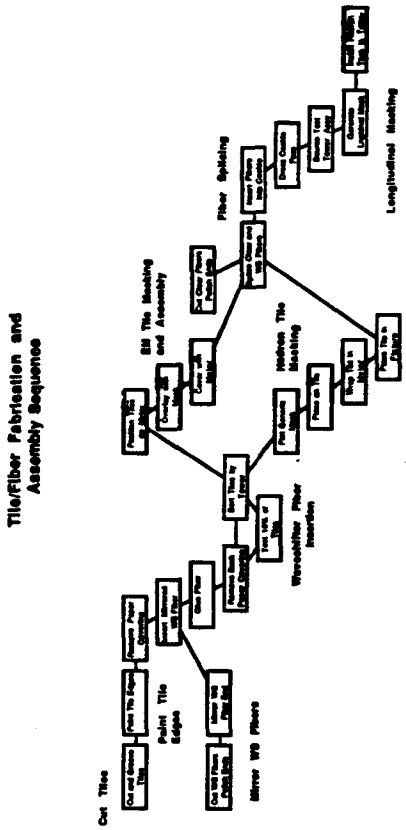


Figure 2. Tile Production Organization

665



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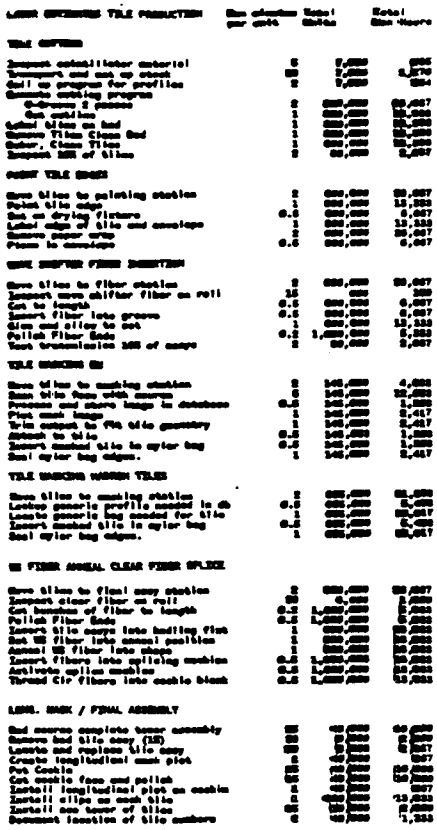


667

Tile/Fiber Cost Baseline Comparison

Compare June/Dallas Baseline With Current Baseline

Original Baseline -

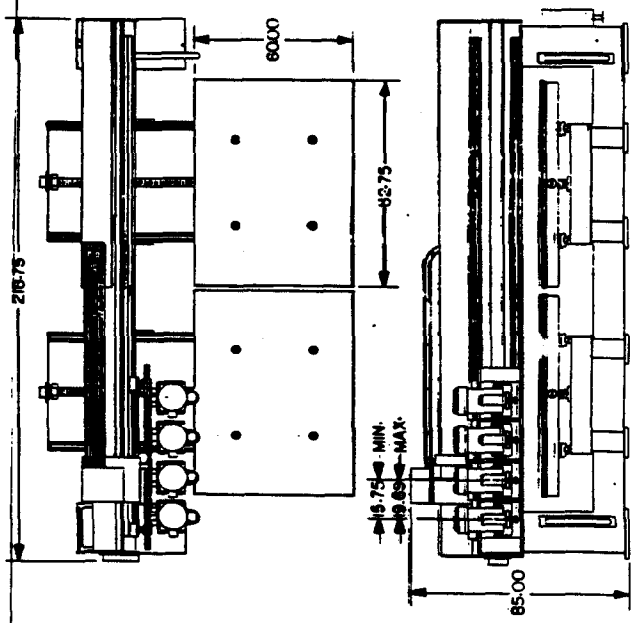
- Modeled after CDF prototype endplug fabrication techniques
- Assumed that all fabrication steps would be carried out using lab facilities

New Baseline -

- Methodology still based on CDF experience
- Modifications made to reduce costs
  - Subcontract for cost effectiveness
  - Obtain vendor quotes
  - Modify design (Based on SDC manufacturing studies)
  - Reduce hands-on labor and handling
  - Descope

Examples -------

668



Examples of Baseline Modifications

Tile Cutting

Original estimate based on prototype CDF tile production using a single-head computer controlled router

=> Thru-put of 100 tiles/shift

Investigate alternatives -

- Speed/feed tests
- Use of multi-head machines
- Vendor quotes (very common procedure)

=> Thru-put of 400 tiles/hour

=> cost reduction of 70 % based on vendor quotes

Other cutting methods to consider -

- Laser cutting
- Injection molding

Tentative quote from Kasari for barrel tiles approx. $2M

Edge Painting

Originally based on painting individual tile edges

- Devised a stack painting technique to eliminate handling individual tiles
- Batches of 100 - 200 tiles at a time
- Labeling done at tile cutting step

80 % Cost Reduction

Fiber Mirroring/No Annealing

- Reduce material handling by eliminating half of the fiber splices
- Eliminate fiber annealing

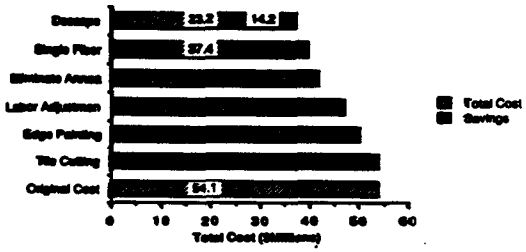
60 % Cost Reduction

Redistribute Labor Resources

- Reduces average labor rate from $30 - $25/hr

16 % Cost Reduction

Scintillator Cost Reduction Summary



We're not done yet .....

Many R&D issues to be attacked which drive costs

New assembly techniques

- **Edge painting/Bagging**
- **Fiber insertion/assembly techniques**
- **Source testing/longitudinal masking**
- **Tile cutting process**
- **Masking Hadron - maybe not necessary**

Esp. Hadron

CALORIMETRY SUMMARY

D. GREEN

SDC CALORIMETRY GROUP

8/91 WHERE ARE WE ?

WHERE ARE WE GOING?

1) SDC PHYSICS REQUIREMENTS

2) CDR LA

3) CDR T/F - SEPT 1

4) TB + SSCL SEPT 12-14

⋮

SDC Calorimeter Group August Agenda

**** FINAL DRAFT ****

Dear Colleagues,

Thanks for the many and varied suggestions. The number of potential speakers is a testament to the great amount of good work going on and the vitality of the Calorimeter Group. The downside is that the time is limited. We remind you that the main purpose of the meeting is a final critical comparison between the liquid argon and tile/fiber technologies. Contributions not weighing directly on this issue, e.g. FY 92 R&D, FCAL, SM, have been (regretfully) truncated. We beg your indulgence.

The Calorimeter Technical Board

August 5 Engineering Design, Cost Estimates, (current state of the baseline designs)

Liquid Argon	G. Abrams
1-2 Engineering Design	Pope
2-2:45 Critical Engineering Issues	Unno
2:45-3:15 LAC Cost Estimate	Montgomery
Tile/Fiber	
3:15-4:00 Tile/Fiber Baseline Eng. Design	Kirk, Guarino
4:00-4:30 Tile/Fiber Baseline Cost	Schorberth
4:30-5:00 Tile/Fiber Engineering Design- Fe	Bertoszek
5:00-5:30 Tile/Fiber Cost- Fe	Gourlay
Integration Issues	
5:30-6:00 Integration for LA, Tile/Fiber	Bintinger

August 6 Preview of the Plenary, Critical Issues

12:40-1 Absorber Configurations	T. Handler
LA Critical Issues	
1:00-1:45 LA, Critical Issues	Unno
1:45-2:45 Speed, Noise, Pileup- Test Beam	C. Hearty
Results	
2:45-3:00 Tile/Fiber as seen by LAC	G. Abrams
Radiation Damage Results	
3-3:40 Saclay Results, Source and Beam	J. Erwein
3:40-4:00 Tsukuba Beam Test Results	K. Takikawa
4:00-4:20 Tsukuba Source Test Results	K. Yasuoka
4:20-4:40 FNAL Source Tests	A. Byon
4:40-5:10 IHEP/Beijing Tests	D. Green
5:10-5:30 FSU & LSU Results	A. Fazely
Additional Issues	
5:30-6:00 CDF Optical Studies/Experience	J. Freeman
6:00-6:30 ANL&Rockefeller Opt. Syst. Studies	J. Proudfoot
6:30-7:00 Calibration Issues, LA and T/F	J. Siegrist
7:00-7:30 BNL Test Beam Results, LA	Unno
7:30-8:00 e/h, Resolution- LA, Pb, and Fe	Gabriel

**** Snacks brought in if necessary ****

August 7 Plenary Presentations (Physics Requirements/ Performance)

10:30-12:30 Physics Requirements	J. Siegrist
10:30-11:00 e ID and CDF (PS/SM)-Segmentation	B. Wicklund
11:00-12:00 QCD Studies	M. Miller
12:00-12:30 Physics Requirements	J. Siegrist
Performance of Present Baseline Designs	
2-4 Liquid Argon	G. Abrams
*** Abrams to organize ***	
4-6 Scintillation Tiles	J. Proudfoot
4:00-4:25 Radiation Damage, Source	V. Magapien
4:25-4:50 Radiation Damage, Beam	K. Takikawa
4:50-5:10 T/F Uniformity, Masking	J. Proudfoot
5:10-5:30 SM Design Status	F. Rondeaux
5:30-5:50 Depth,Hermiticity, Resolution	(J. Hauptman)
5:50-6:10 Cost/Performance	S. Gourlay

August 8 SDC Calorimeter Group

Issues & Decisions

8:30-9:00 Critical Issues ,LA	Hearty
9:00-9:30 Critical Issues, T/F	??
9:30-10:00 LA/Scin Choice Criteria	(Kondo)

K.E. REQUIREMENTS

677

3 10:00-10:30 Pb/Fe Choice Criteria (Green)
10:30-11:00 Reassess
Wisc Baseline (descoped?) Engineering ??
Design, Cost for Aug 9 Presentation

(joint meeting 11-4 with electronics and physics groups)

SM Engineering and Status D. Hubbard

11-11:30 PS/SM Status Hubbard
11:30-12 PS/SM Transducers Malone

Lunch

Trigger and Electronics - Update, Progress Reports

1:30-2:00 Physics Requirements for Trigger K. Eimscoiller
2:00-3:00 Electronics/Trigger (Wisc Baseline?) B. Foster, M. Levi
3-3:30 L2 Trigger P. Le Du

FCAL Status

3:30-4 FCAL Status- Critical Tests, R&D Plan B. Frisken

SM Options

4-4:30 SM for LA Hearty
4:30-5 PS/SM for Tile/Fiber Rondeaux, Hubbard

FY92 R&D Plan, Update

J 5:00-5:30 R&D FY92 Guidelines, Schedule D. Green

Discussion of Future Plans

6-7 Plan and Schedule for Decisions ??
LA vs Tile/Fiber, Pb vs Fe
Comparison of Performance ??
Comparison of Cost ??

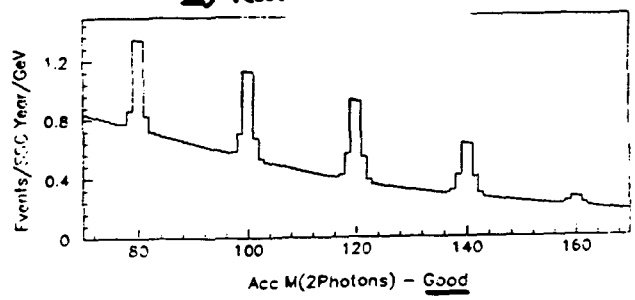
(Documentation for LA & Tile/Fiber)

Is any other documentation needed?

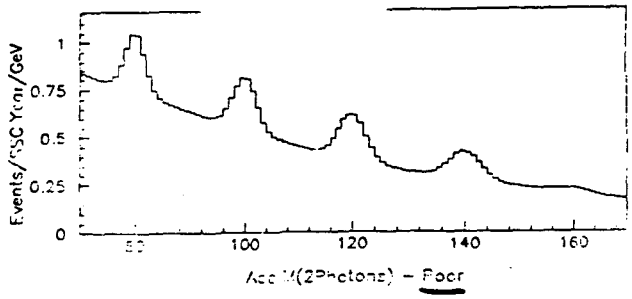
August 9 Plenary Presentaion to SDC of the Present Status of the Calorimeter Group

678

H→γγ RIDES ON
SERIOUS BACKGROUNDS
⇒ RESOLUTION IS CRUCIAL

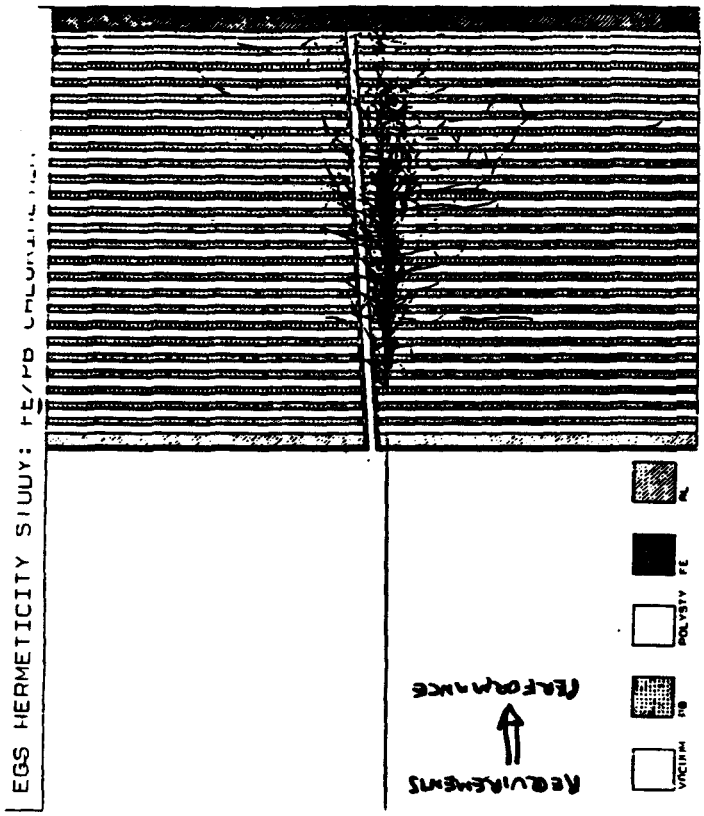


$M_{\gamma\gamma}$

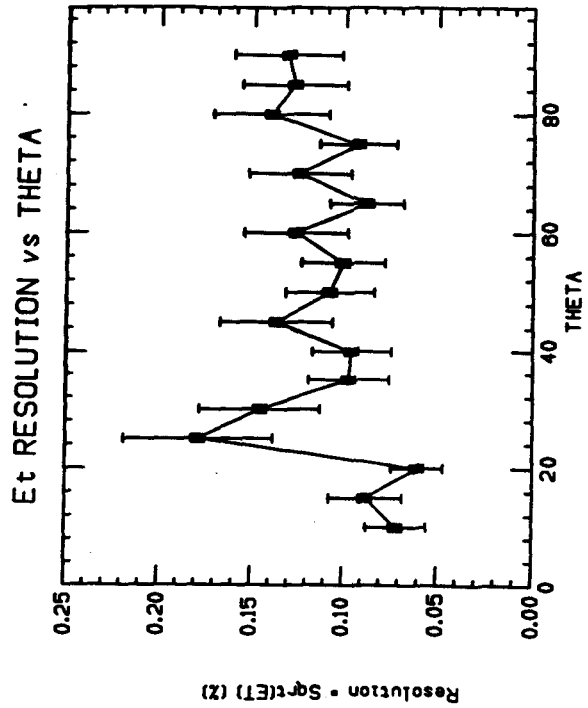


$M_{\gamma\gamma}$

679



680



LA CDR

SOLENOIDAL DETECTOR COLABORATION
LAWRENCE BERKELEY LABORATORY
CALORIMETRY SUBGROUP

August 5, 1991

ENGINEERING DESIGN OF THE LIQUID ARGON CALORIMETER

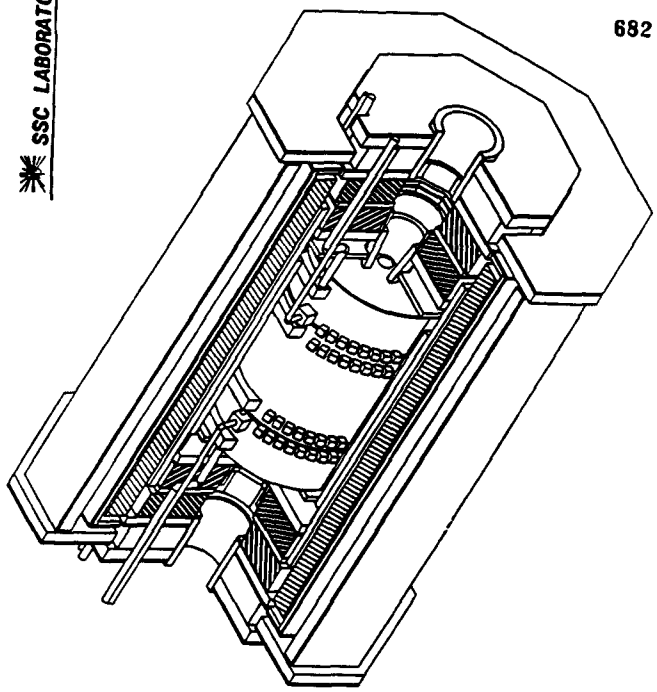
Information compiled by;

William L. Pope, LBL

for the

SDC LAC GROUP

SSC LABORATORY



SSC Laboratory Physics Research Division

Liquid Argon Preliminary Hazard Analysis Results

- No "SHOW STOPPERS" uncovered
- Engineering concepts currently present in preliminary design must be carried forward into detailed design activities
  - LAr Storage dewars at same level at detector
  - Double bellows designs
  - Robust transfer line design and installation
  - Thorough situation awareness instrumentation of vacuum etc.
  - Effective ODH policies and procedures (inc. training)
- Endcaps moved "empty but cold" for major maintenance
- Quantitative FMECA required during detailed engineering design

Environmental Safety and Health

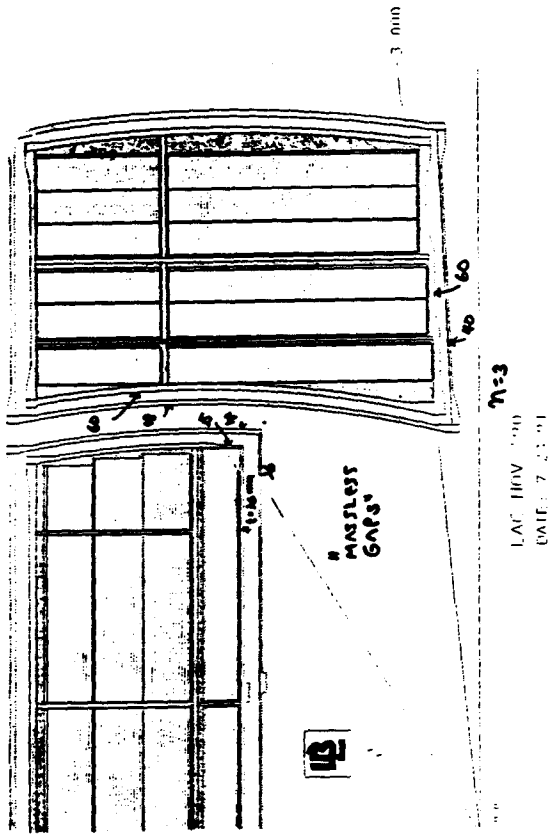
Y.Unno 1991/8/5

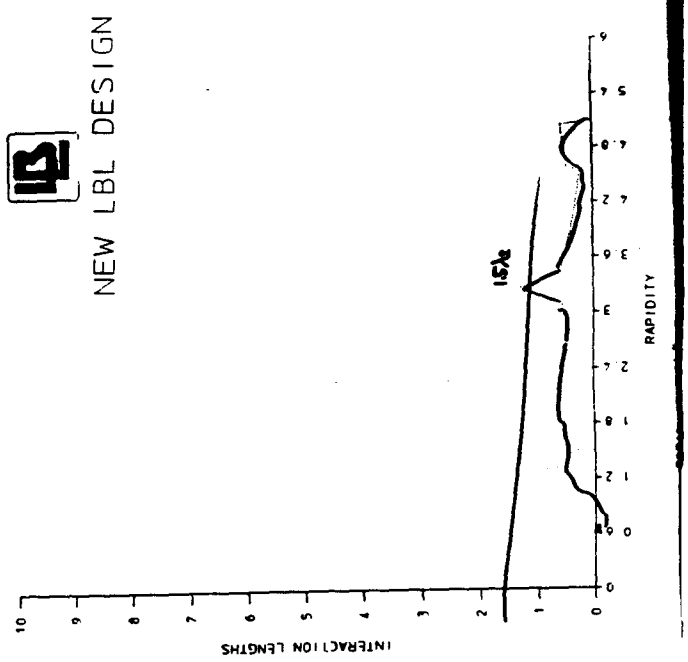
Critical Issues Related to the Engineering

Y.Unno
KEK

and
The SDC LAC group

- Electron hermeticity
- η=3
- Depth
- Preamp reliability





• Summary

(1) Electron hermeticity
97% at $\sigma_E/E<25\%/\sqrt{E}$
still sensitive and electrons will not be lost

(2) $\eta=3$ $<2\lambda_I$

(3) Depth $9\lambda_I$ in the Barrel
$11\lambda_I$ in the Endcap

• Request to clarify the requirement by physics, not by containment.

• If absolute necessity, we add thickness of 19.4 cm/λ_I .

(4) Preamp reliability

• Establishing random failure rate appears to be a major undertaking but feasible.

• Neutron fluency is the limiting factor. JFET is acceptable for 10 years of the nominal luminosity of 10^{33} cm^{-2}sec^{-1} and MESFET can live with 10 years of 10^{34} cm^{-2}sec^{-1}. Further radiation damage test for other JFET's should be continued.

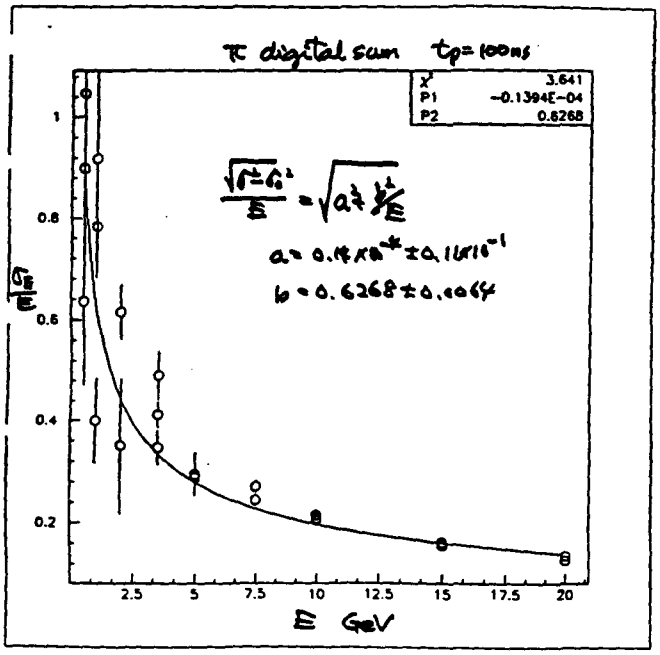
~ OK

Y.U 1991/6/18

Critical Issues for the LAC

Item	Status	Comment
Preamp (Rad.hard)		BNL hybrid: $>10^{13}$n/cm^2, >12Mrad
Speed		$\tau_{rise}\leq$30ns
Noise		τ_p=100(EM), 200ns(HAD) σ_{Et} (ΔR<0.15)
Pileup		3 meas., τ_p=50~200ns σ_{Et}~0.5GeV
e/h meas.		Hadron module beam test
e hermeticity		97%accept.($\sigma_E<25\%/\sqrt{E}$)
Reliability		<0.2% failure(SLD) in 10^8s
P/a cooling		KEK/Rochester test results
Safety		SSCL Safety committee
η=3,E_t		KHI , LBL
Integration		LBL
Cost		MMA

BNL TEST BEAM



Histogram of $(r_i - \langle r \rangle)/\sigma_i$;
r_i = response at scan point i

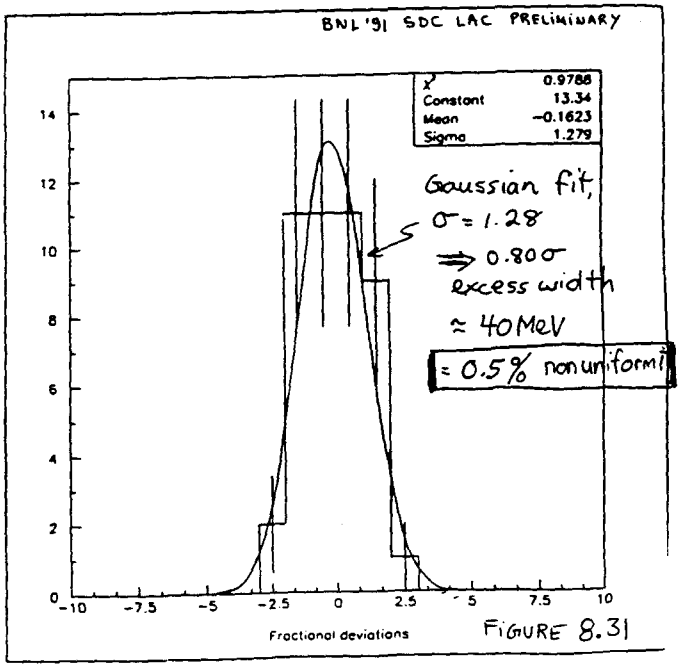


FIGURE 8.31

Resolution away from crack

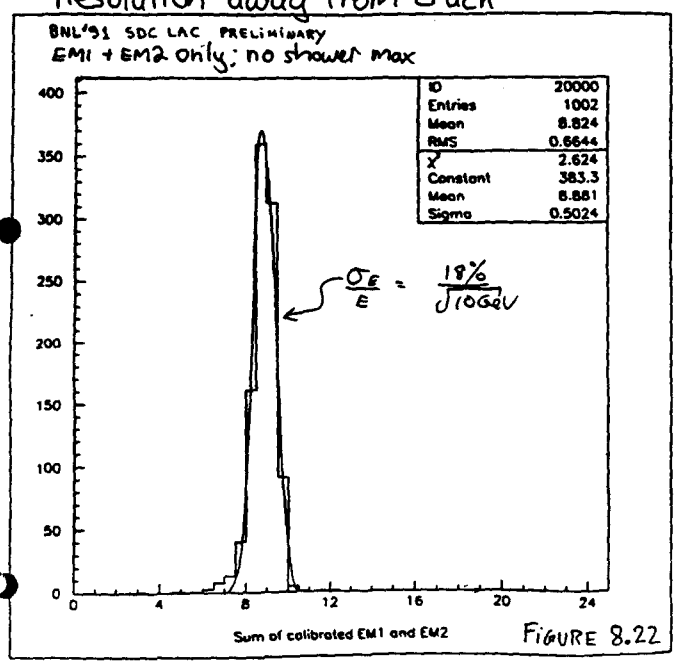


FIGURE 8.22

Why Not Tile/Fiber for SDC Calorimetry ?

Gerry Abrams
August 4, 1991

Liquid Argon case has been presented.

- **BNL Beam Test Performed** ✓
- **Conceptual Design Report** ✓
- **Martin Marietta Cost Estimate** ✓

We now have a LAr design that works

Is Tile/Fiber better ?

In some ways	Yes -
Faster -	pileup ↓ but LAr already OK pipeline shorter 4 μsec → 3.6-3.7 ?
Integrates better -	no plumbing uniform B μ access
Cost	Nov. '90 + $ 50M Aug. '91 ???

BUT

SDC LAr Calorimeter Cost Summary (M)

MM

	Current Baseline
Modules	30,916
Cryostat	21,879
Feedthrus	5,010
Calorimeter Assembly	2,905
Fixtures	10,135
Test Equipment	1,729
Transportation	1,152
Cryogenic System	8,328
Facilities	2,108
Return Iron	4,934
EDIA	17,516
Total	106,612
Contingency (28.0%)	28,724
Total w/Contingency	135,336
Derived $/lb	11.74

SDC LAr Calorimeter Cost Summary (M)

	Current Baseline	LOI
Modules	30.9	33.4
Cryostat	21.9	46.8
Feedthrus	5.0	4.2
Calorimeter Assembly	2.9	
Fixtures/Tooling	10.1	1.8
Test Equipment	1.7	
Transportation	1.2	5.7
Cryogenic System	8.3	7.8
Facilities	2.1	2.0
Return Iron	4.9	5.0
EDIA	17.5	14.8
Total	106.6	119.3
Contingency (28.0%)	28.7	
Total w/Contingency	135.3	
Derived $/lb	11.74	

Note: LOI number of $133.4 M included an additional $14.1 M for electronics and installation

SDC Central Calorimeter Tile/Fiber Baseline Design

Version: August 5, 1991

Presented by
Thomas B. W. Kirk
Argonne National Laboratory
HEP Division

at

SDC Full Group Meeting
Lawrence Berkeley Laboratory
Berkeley, California

August 5, 1991

Tile/Fiber Calorimeter Features

- **Energy Resolution**
  EM resolution is good enough to see the 80 - 140 GeV Higgs in the mode:
  $W + H^0$, $W \to l\nu$, $H^0 \to \gamma\gamma$

  LoI Fig 22

- **Speed**
  energy collection time well matched to SSC collision rate; upgrade potential to 10^{34} Luminosity x3 better than LAr

- **Hermiticity**
  tight barrel/endcap geometry and low structural mass yield good resolution on missing E_T

  Trost & Kirk (in progress)

- **Compensation**
  EM and hadron energy have equal response (e/h=1.0); helps the jet energy resolution due to fragmentation fluctuations

  Gabriel, et al.

- **Safety**
  safety hazards associated with the tile/fiber technology are small and manageable

- **Cost**
  the tile/fiber calorimeter is cheaper...

but...

Tile/Fiber Calorimeter Downscoping

Baseline Cost $175.5M Baseline

Two levels of downscoping were considered

~~747K~~ Tiles + 117K SMDs

Dollar reduction goals from June '91 SDC Meet. were:

- Level 1 downscope ↔ Descope 1, Descope 2 (~$150M)
- Level 2 downscope ↔ Descope 3 (~$120M)

• Descope 1 (est cost = 129 M) 368K Tiles 30K SMDs

- same geometrical size and absorbtion as Baseline
- x2 reduction in HAC1, HAC2 longitudinal sampling
- HAC2 has $\Delta\eta\Delta\phi = 0.1 \times 0.1$
- x2 reduction in SMD tile count
- one EM readout channel

• Descope 2 (est cost = 130 M) 282K Tiles 60K SMDs

- same geometrical size and absorbtion as Baseline
- x2 reduction in HAC2 longitudinal sampling
- HAC1, HAC2 have $\Delta\eta\Delta\phi = 0.1 \times 0.1$
- x2 reduction in SMD tile count

• Descope 3 (est cost = 127 M) 282K Tiles 60K SMDs

- same longitudinal & transverse granularity as Descope2
- same absorbtion thickness as Baseline
- R_{inner} = 1.9m (down from 2.1m)
- L_{inner} = 3.9m (down from 4.2m)

Comments:

Descope 2 has few serious performance compromises;
Descope 3 has not been well studied at this point in time

8/9/91

T/F Cost Est. K.J.K.

Changes

Baseline $194 M

- Labor Rates
- Scope Refinement
- Technical Refinement

Generates

August Baseline $175.4M

- Remove Outside Fe
- HAC1 Sampling halved
- HAC2 Sampling halved, $\Delta\eta\Delta\phi = .1 \times .1$
- SMD Descoped by tile count x 4
- ie tile & piece count reduction but constant engr. design

Generates

August Descope 1 $129.3M

- Technical Process Refinement
- Mgmt./Engr. Labor Rates

August Descope 1 Correction $121 M

Tile/Fiber Central Calorimeter
Descope Model Definitions
Version: August 5, 1991

Parameter	Baseline	Descope 1	Descope 2	Descope 3
Barrel I.R. (m)	2.1	2.1	2.1	1.9
Endcap Front (m)	4.2	4.2	4.2	3.7
Solid Outer Steel	Yes	No	No	No
Depth @ $\eta = 0$	10λ	10λ	10λ	10λ
Depth @ $\eta = 3$	12λ	12λ	12λ	12λ
EM				
Long. Chan./Tower	2	1	2	2
Long Gran. (cm)	1	1	1	1
Trans. Gran.	.05 x .05	.05 x .05	.05 x .05	.05 x .05
Shower Max.[a]				
Layer 1 $\Delta\phi$	.05	.05	.05	.05
Layer 1 $\Delta\eta$	.0125	.0125	.0125	.0125
Layer 2 $\Delta\phi$	.00625	N/A	.00625	.00625
Layer 2 $\Delta\eta$	.05	N/A	.05	.05
Tiles/Tower (Aver.)	12	4	6	6
HAC1				
Long Gran. (cm)	2	4	2	2
Trans. Gran. ($\Delta\eta\Delta\phi$)	.05 x .05	.05 x .05	.1 x .1	.1 x .1
HAC2				
Long Gran. (cm)	4	8	8	8
Trans. Gran. ($\Delta\eta\Delta\phi$)	.05 x .05	.1 x .1	.1 x .1	.1 x .1

Characteristics common to all models here:

EM and HAC1 absorber is cast lead with stainless steel reinforcement.
HAC2 absorber is bolted steel plates.

[a] [illegible]

MECHANICAL DESIGN OF LEAD AND STEEL PLATE CALORIMETER

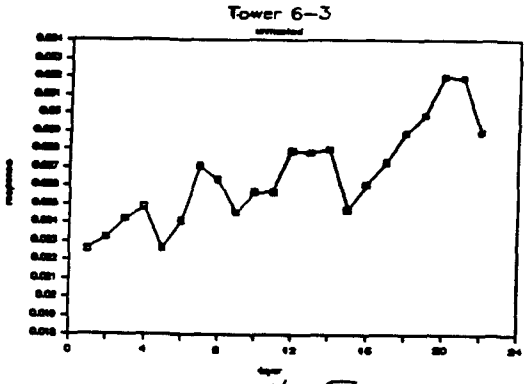
VICTOR GUARINO
ARGONNE NATIONAL LABORATORY
AUGUST 5, 1991

701

702

703

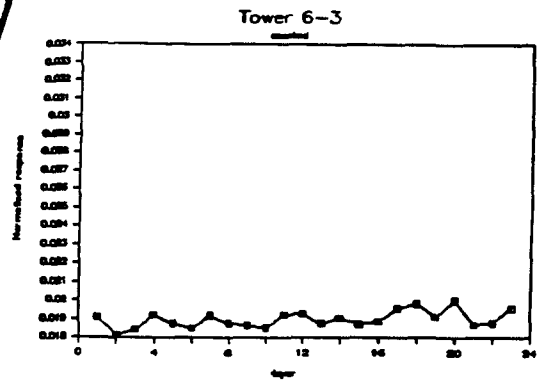
704



11.5% σ

NEW OPTICS FEATURES

SOURCE FOR "DYNAMIC MASKING"
AND
CALIBRATION



σ = 2.6%

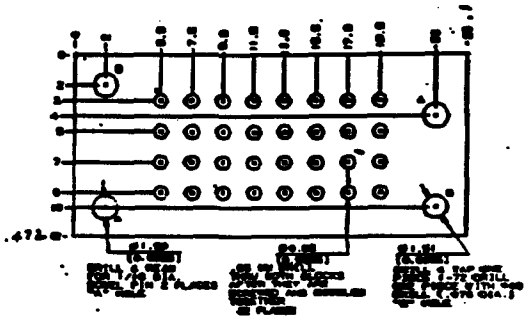
δ = 7% (air gap)

First Results from the Optical Connect/Disconnect

END CAP
EM
REPLACEMENT

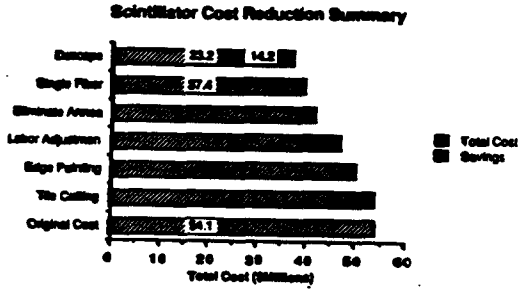
A. Burlon, M. Cobal, H. Grassman, S. Leone (INFN Padova and Pisa)

Design : M Atac (FNAL)



- 2 Prototypes built
- total of 8 fibers glued in
- no sophisicated surface treatment yet

=> reproducibility for each of the 8 fiber connections better than 1%

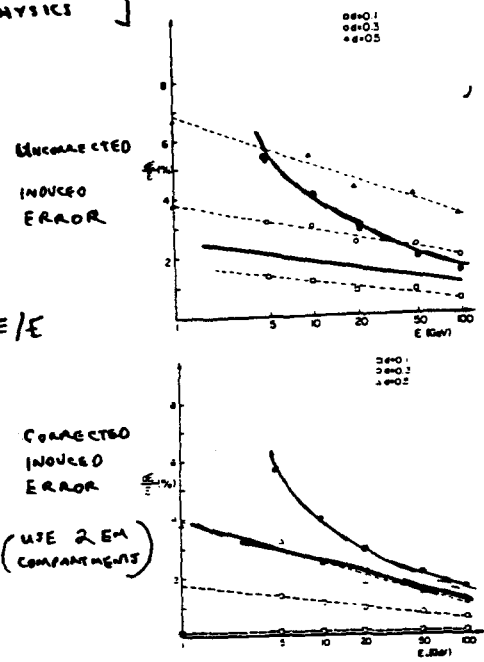


COST STUDIES ON TILES

THERE IS A MODEL TO RELATE DAMAGE TO PHYSICS

WHAT HAPPENS TO THE DAMAGED AREA?
NONLINEARITY INDUCED BY NONUNIFORMITY
RADDAM - EGS

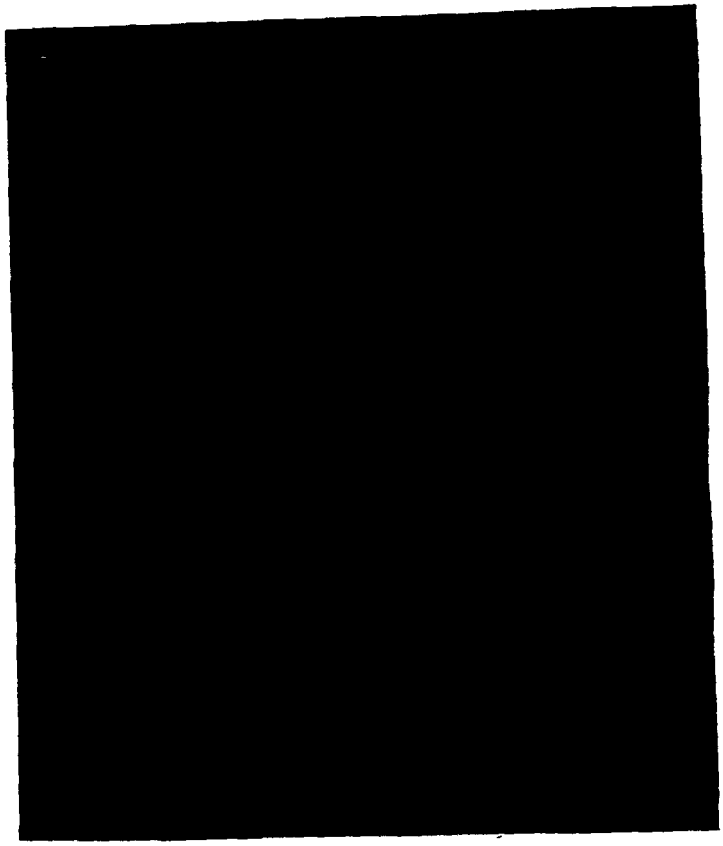
709



$\sigma = \frac{0.12}{\sqrt{E}} \oplus 0.01$

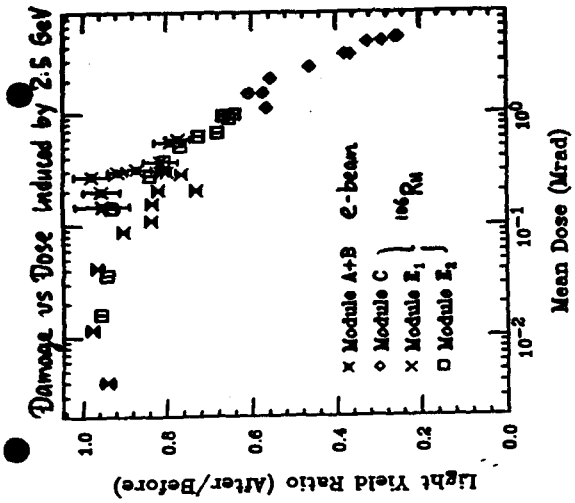
$d = 0.2$ is safe.

$d = 0.5$ is safe.



710

Damage vs Dose Induced by 2.5 GeV Electron Shower Tsukuba

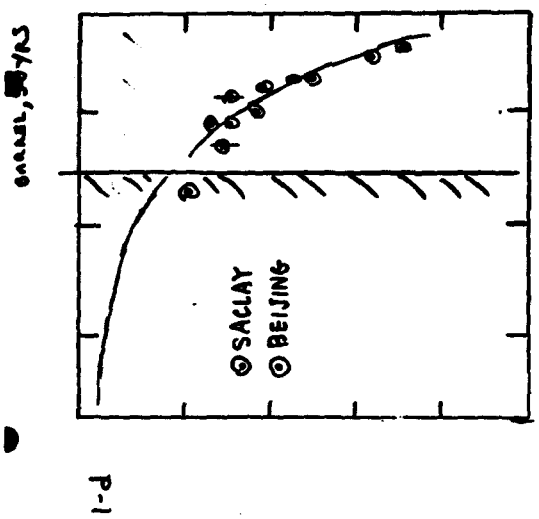


Damages of module C, E1, E2 measured with a Ru source.

Consistent with the electron test beam measurements on module A & B.

711

THERE ARE 3 DATA SETS RELATING DOSE D TO DAMAGE d



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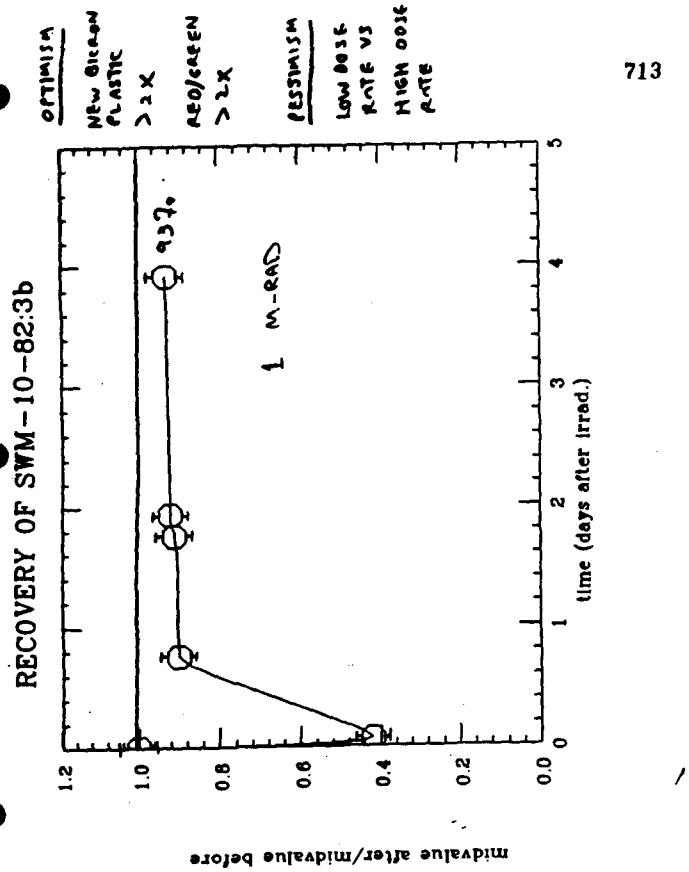

714

From: FNAL::DGREEN 28-MAY-1991 23:19:25.69
To: PLAVALLIE
CC: DGREEN
Subj: Pat, please send this out to the SDC_CALOR.DIS group ASAP. Thanks. Dan

SDC CALORIMETER GROUP

FY92 INSTITUTIONAL BUDGET REQUEST

Dear Colleagues,

We have already attempted to establish the tasks that are needed in FY92. However, it is necessary to identify which institutions desire to accomplish these tasks. In particular, understanding the non US efforts should allow duplication to be removed. It is also necessary to plan what your institution would do if various decisions are taken. To that end there are 6 branches— Liquid Argon, Scint RAD, Engineering Scint/Pb, Engineering Scint/Fe, SM/PS, and FCAL. I ask that you send these task lists to Siegrist, Green, Proudfoot, Foster, Hubbard, and Frisken respectively. It is expected that a given institution will make multiple submissions. A list of, and dates for, the deliverables is also required. Please extract this message, fill out the form below, and return it to the appropriate person. This message has been sent to the entire SDC_CALOR.DIS list, since it may be of general interest. Only 1 response (per option) per institution is needed. Please note in making requests that funds for FY92 do not allow a large ramp up of activities even if technological choices are assessed. Please note also that the Calorimeter Group needs a first pass at this by the June SDC meeting. This means that replies from you are needed almost immediately, since it is anticipated that some winnowing will be needed.

Thank you
Dan Green

FY91 FUNDING LEVEL _____ DOE, _____ TEXAS, _____ FOREIGN SOURCES

EXPECTED FY92 LEVEL _____ DOE, _____ TEXAS, _____ FOREIGN SOURCES

TASK	OP $		EQPT $
	SWF	MRS	
1.			
2.			
3.			
4.			
5.			
6.			

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SHORT TERM FUTURE

UPDATE PHYSICS REQUIREMENTS

IMPACT OF T/F – LA ON
OTHER SYSTEMS → DOCUMENTATION

T/F CDR – SEPT 1

CRITICAL PERFORMANCE
COMPARISON ....

COSTS

TB SEPT 12-13-14

* TEST BEAMS @ FNAL

716

Aug 5-10 Review, presentations

Sept. 4 Scint. Conceptual Design Report (CDR)
Update Liquid Argon CDR
Update Requirements Document

Sept. 12-14 SSCL – Tech. Bd meeting
12th Open. Critical presentations, summary
Impact on other systems, costs ....
13th TB meeting and report
14th TB meeting and recommendation
Draft recommendation and report

Sept. 26 ORNL
Presentation to collaboration
Presentation to Exec. Board for ~~decision~~ review

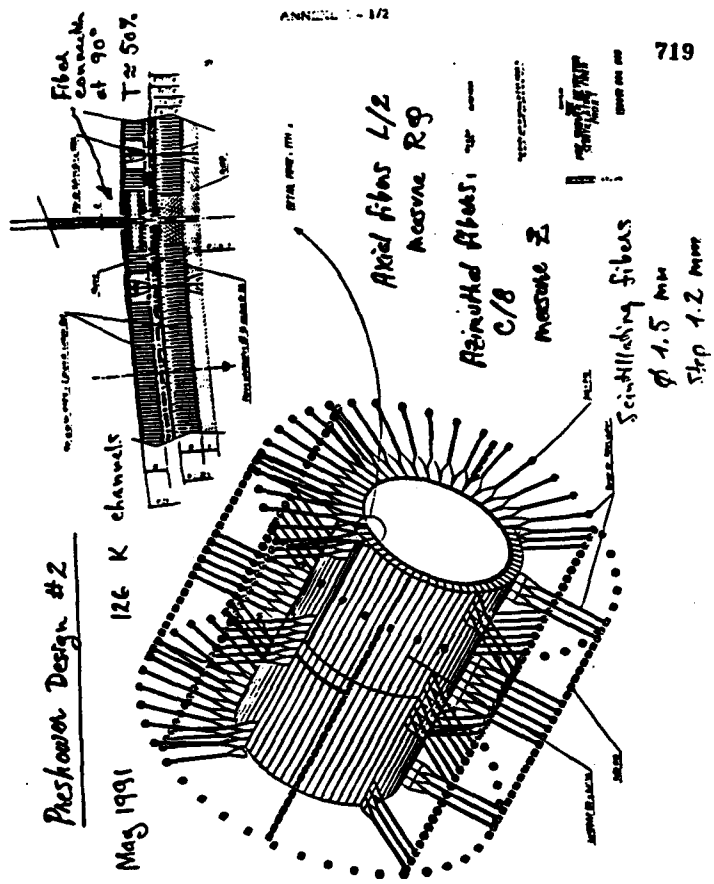
SHOWER MAXIMUM SUMMARY

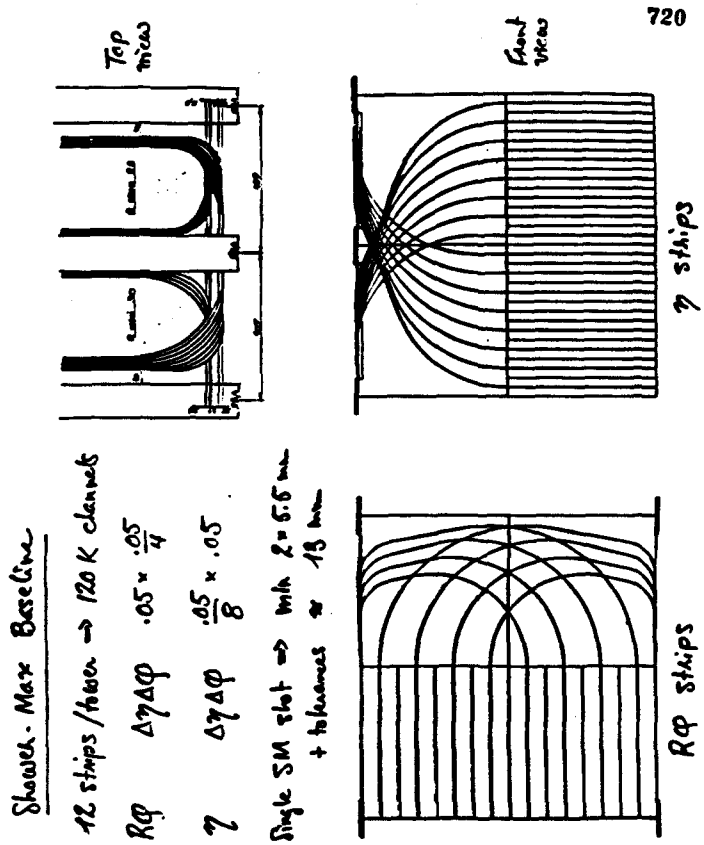
R. HUBBARD

PS/SM Review

PS/SM Baseline Designs	Rondeaux
Beam Test & Photodetectors	Melèse
Physics Evaluation	Wicklund Wu Bonamy
Descope & Upgrade	Hubbard
Electronics & Trigger	Le Dû Faisch.
Radiation Damage	Einwein
Liquid Argon Option	Heality

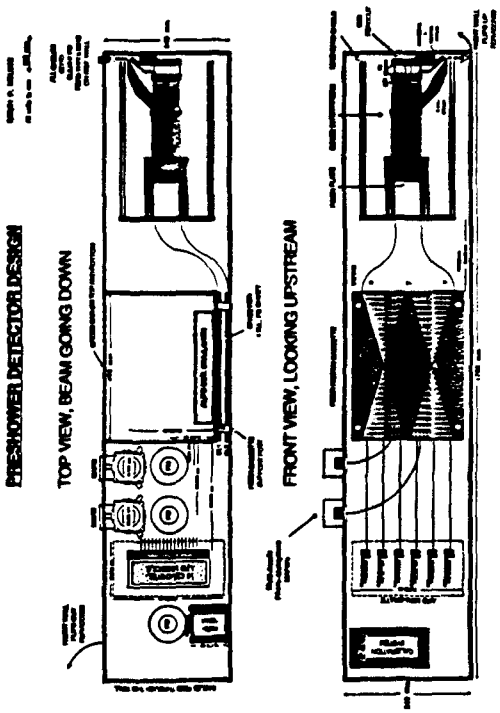
CHARGE : Recommendation PS Vs. SM
August 1991





Melese

721



PS Test Module (Rockefeller)

Readout : Image intensifiers
APD's
MCPMTs

Rockefeller
Northeastern, SSCL
Yale, UCLA

Melese

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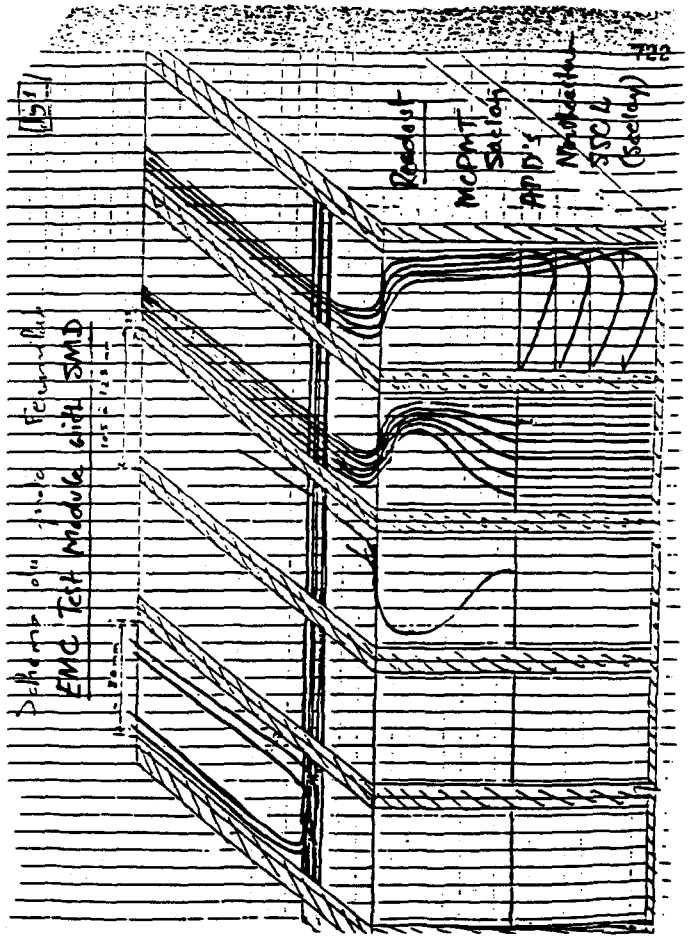
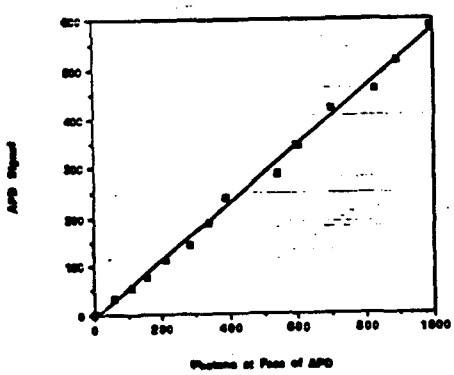


WIRKCOND

723

Linearity

SSC LABORATORY



APD in proportional mode
~5V below breakdown (150-200V)

Gain ~ 100

(QE_{green} ~ 60%

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electron ID at CDF

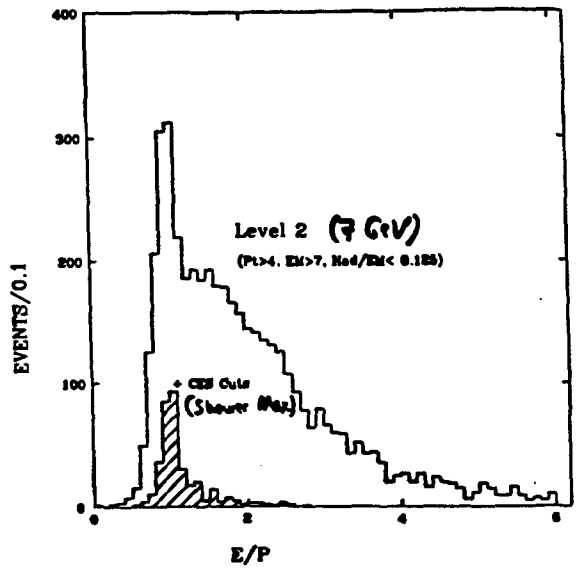


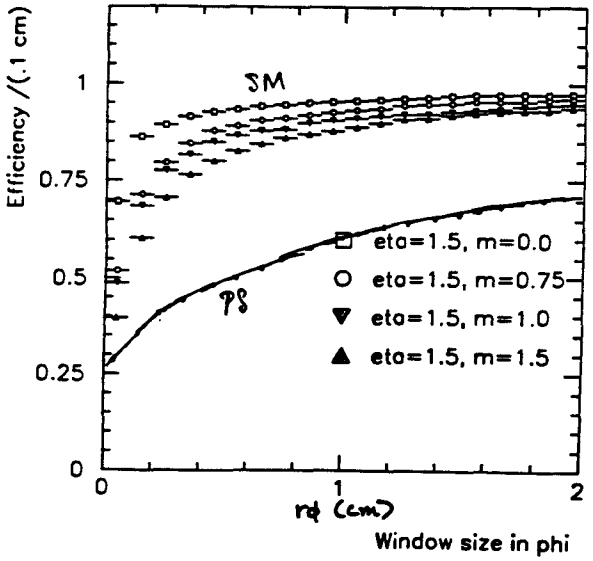
Figure (1)

Track-shower match
Lateral profile
Pulse-height match (2 projections)

Z. Wu
Rockefeller

725

Electron Efficiency Vs. Window Size



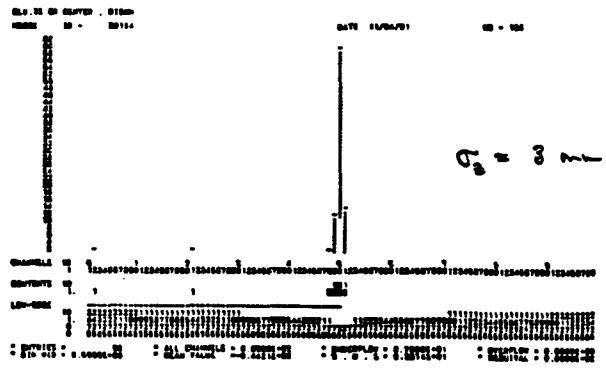
BENDING PLANE

Bonamy

e^- Clusters in SM

726

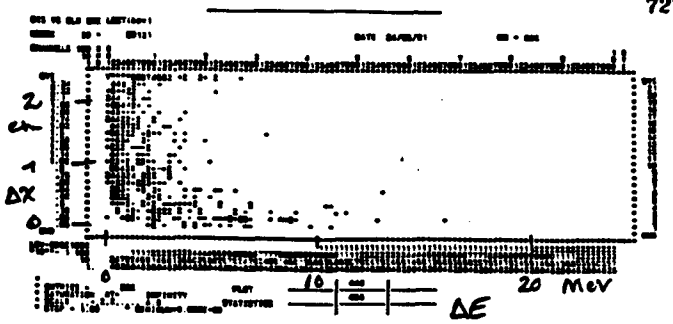
1 mip = 450 keV e gas
Expect 1 p.e./mip



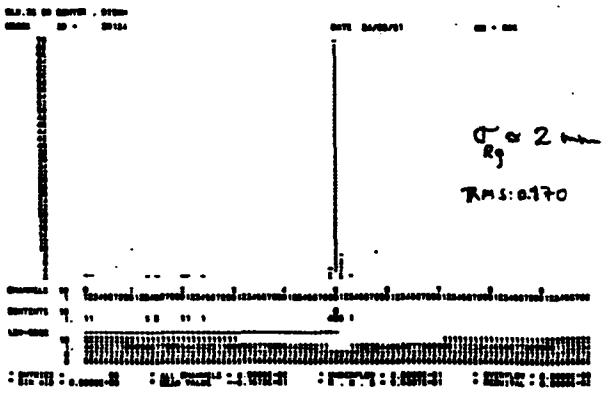
Bonamy

e^- Clusters in PS

727



1 mip = 160 keV e gas



PS Vs. SM

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PS advantages

- Finer track-shower match
- Higher energy γ's Vs. π^0's
- Reject late-interacting $\pi^\pm$
- lower radiation damage

SM advantages

- Bigger, cleaner signals
- Higher $e^\pm$ efficiency, comparable background
- Matched to trigger towers (after upgrade)
- Less space required
  - 18 mm in EMC for SM
  - 70 mm behind coil for PS
- Lower occupancy (less channels hit)

CHOOSE SHOWER MAX

and ...

Read-out Tile #1 !

Mass-less gap

Extra rejection isolated $e^{\pm}$ vs. $\pi^{\pm}$

Extra factor 8 for late $\pi^{\pm}$ interactions

Statistical separation γ/π^0 at high E_γ

Combine with SM count of multi-π^0's

Measure energy from coil

⇒ recover energy resolution.

Shower-max type electronics

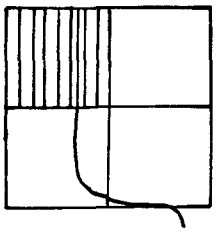
⇒ 25% increase in SM channel count

Packaging ⇒ some added cost

ADD TO BASELINE NOW ?

Mechanical Problems with Descope

Baseline

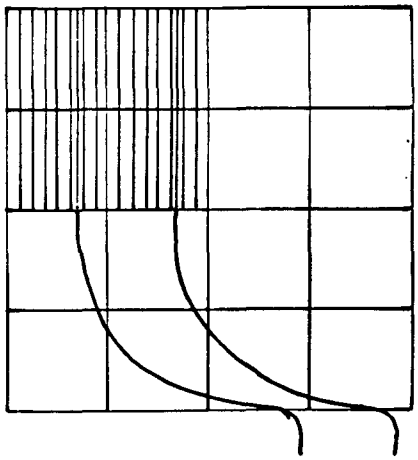


Fiber routing

2×2 towers

Single wedge

Descope



Fiber routing

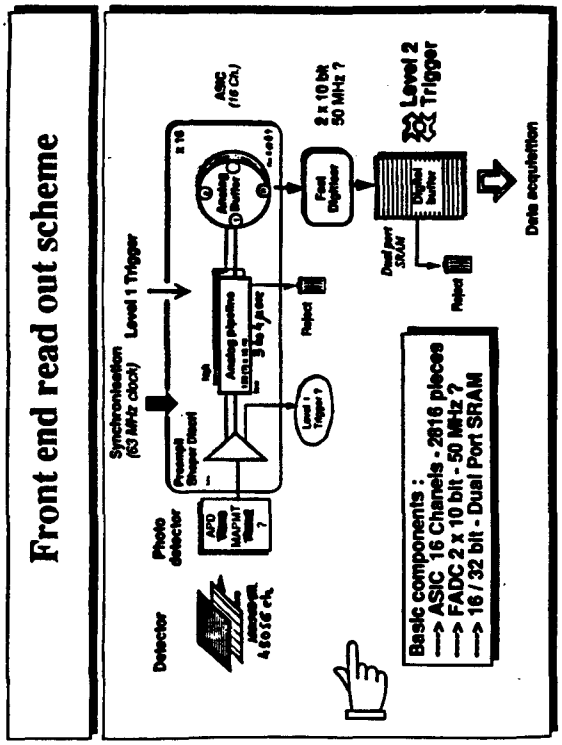
4×4 towers

Double wedge

Too heavy?

Special transport

Gang 2 fibers to same channel, then STAGE!



LeDu

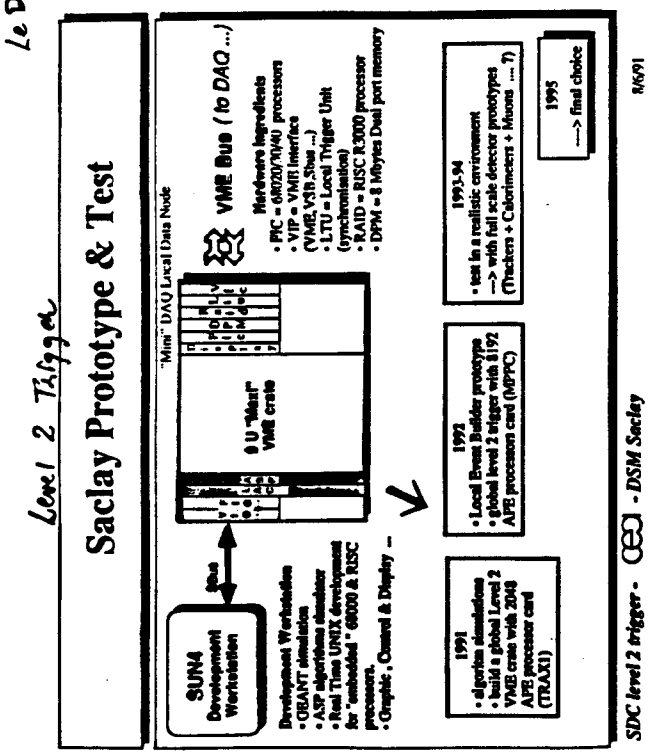
ELECTRON TRIGGER EXAMPLE (DON'T MISS THE POINT)

WHAT	CUTS	PHYSICS
1) LOW E_T PRESCALE	$E_T > T_1$ (7GeV) strip/track, had/em	IN SITU CALIB.
.) TIGHT e	$E_T > T_2$ (15?) E/p, strip/track, iso, had/em	W, Z, .. ?
) CENTRAL e	$E_T > T_3$ (20?) strip/track, had/em, E/p	W, Z, top, ...
) CENTRAL "γ"	$E_T > T_4$ (35?) had/em	W', Z', ...
) 2 TIGHT e	2 @ $E_T > T_5$ (7?) strip/track, iso, had/em, E/p	Drell-Yan at low ϵ
) 2 Central e	2 @ $E_T > T_6$ (10?) strip/track, had/em, E/p	Z, D-Y, Z', ...
) 2 "γ"	2 @ $E_T > T_7$ (15?)	Z, top, H, ...
) etc. (e.g. $e\mu$ PANOPLY, $e\gamma$, $e\not{E}_T$?? ....)		

Fitch

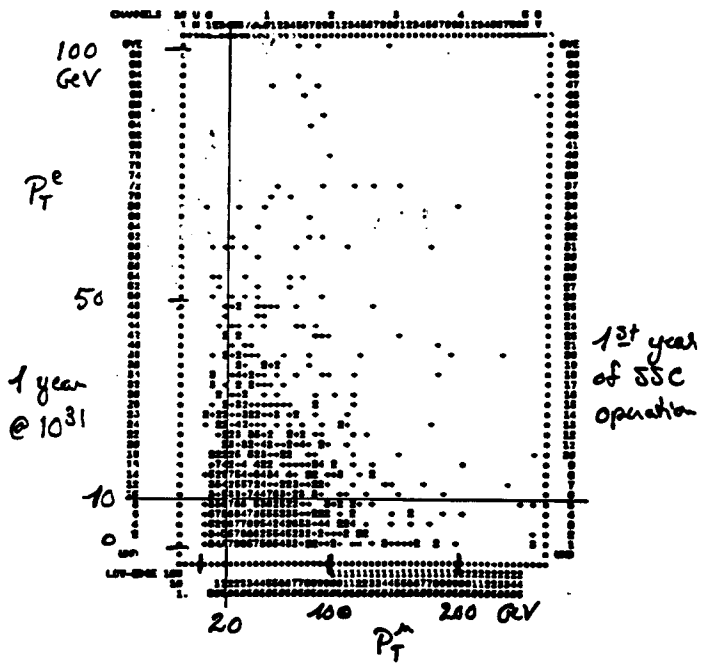
Le Dû

Level 2 Trigger



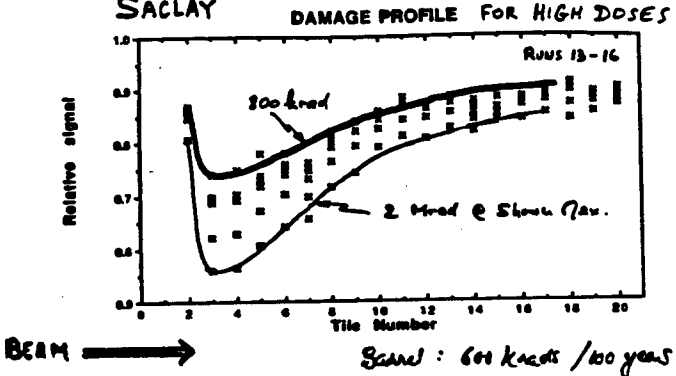
$t\bar{t} \to e^- \mu^+$

$M_t = 150$ GeV



P_T, $|\eta|$ cuts $\Rightarrow$ 250 events (25%)

Ehrenein



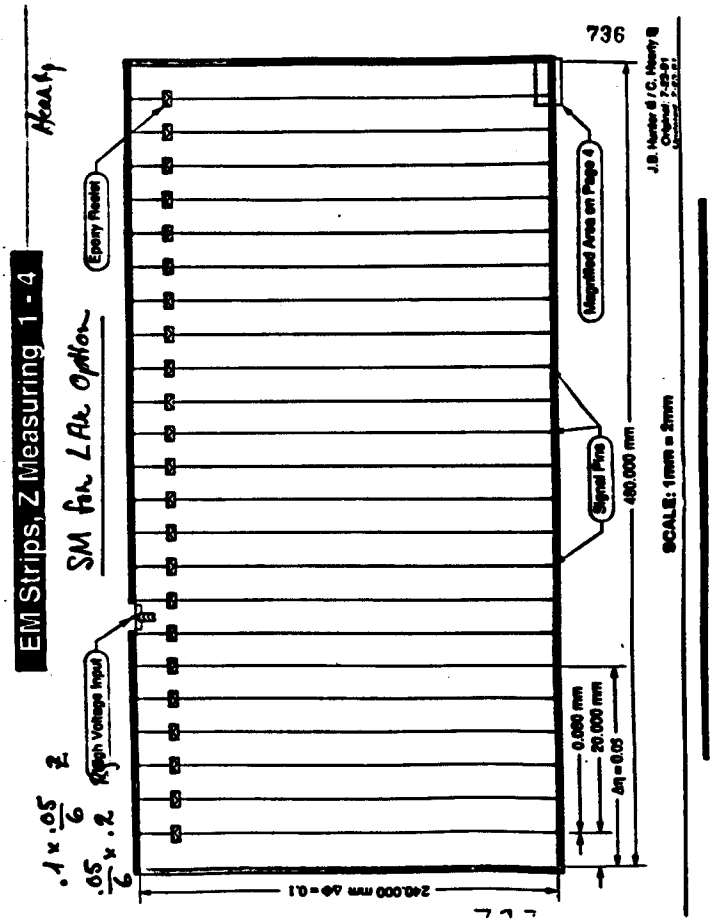
Barrel : 600 krads / 100 years
Ends : 1 Mrad/yr $\eta = 3$
$\mathcal{L} = 10^{33}$

PROFILE OF DAMAGE

Light yield at SM $\approx$ 1 p.e./mip
$E = 10$ GeV/c @ $\eta = 0$ $\Rightarrow$
$\geq$ 20 mips for $\epsilon_e = 90\%$

SM depth ? Baseline $6\ X_0$
Less dose at $10\ X_0$
Simulations !

Hearty



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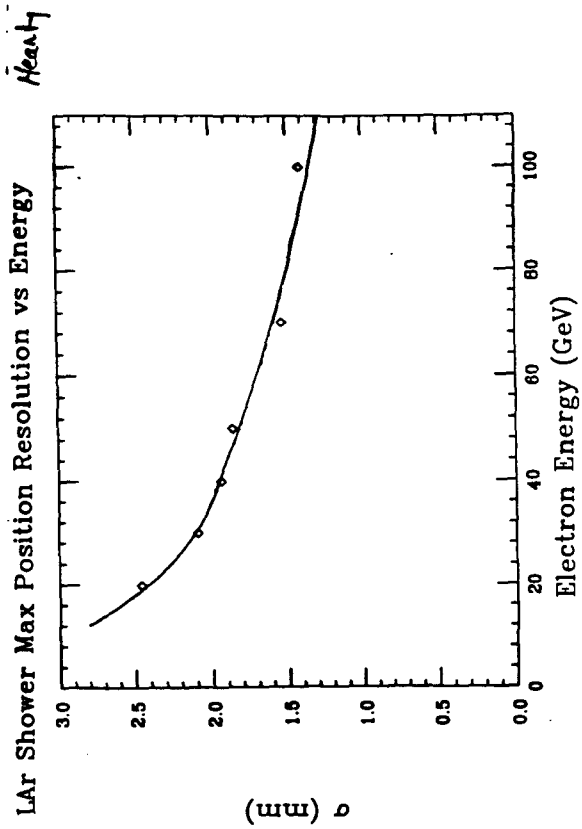

Bill Frisken, Aug 9/91

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FCal Update

1. Physics requirements.
2. Critical Issues / Decision Timetable.
3. Geometry
4. Integration aspects.

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FCal Meeting, Director's Conference Room, 50A/5132

Agenda for August 4/91:

9am Chair's remarks Bill Frisken

Physics requirements (eta range, resolution, part offtrigger?)
Mike Barnett et al

Integration issues: *the eta=3 problem
*mechanical interface w/SDC, SSC.

11am: Coffee

11:15am Choice of Geometry: backstop or inverse cone??
(We need a statement of preference soon)

*simulation results John Hauptman
*discussion, assignments.

12:15 Lunch

1:30pm Crucial issues for the competing technologies:

*remarks Bill Frisken
*discussion

2pm Status of the competing technologies (accomplishments, schedule/milestones for crucial r/d, testing and design issues)

*Warm Liquid Ionization M. Pripstein, W. Wenzel
*Cold Liquid Ionization TBA
*High Pressure Gas Ionization Nikos Giokaris
*Liquid Scintillator TAMU/FNAL James White
Toronto Bill Frisken

3:30 Coffee

3:45 The FY92 R/D Plan revisited.
*the present situation Bill Frisken
*discussion ——> recommendations to Calorimeter steering committee.

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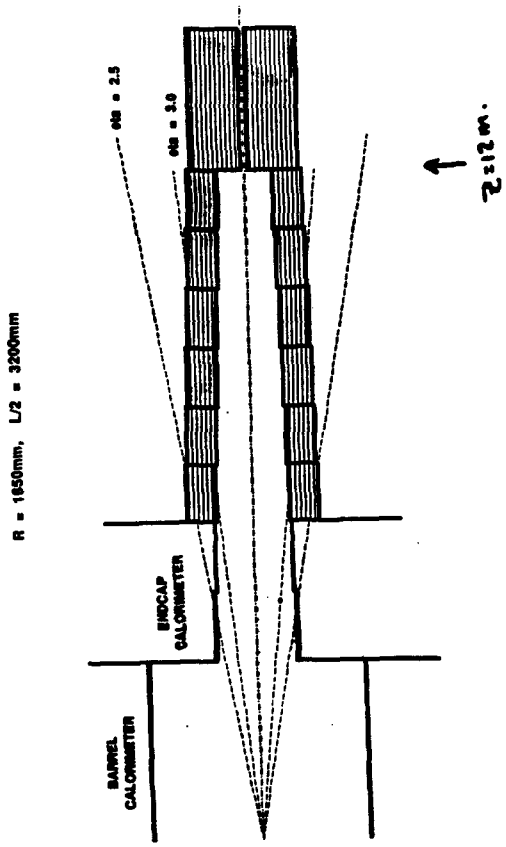

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Q. Wot, no Forward Calorimeter?

A. STAGING FCal saves us lots of bother....

.....the bother of publishing all the new physics —— M. Barnett.

This will be done for us by GEM & LHC.

FCal's contribution to the missing E_t measurement is crucial for.

1. Supersymmetry
2. Heavy Higgs
3. t' (4th gen.)

——→ Barnett Xpermain....

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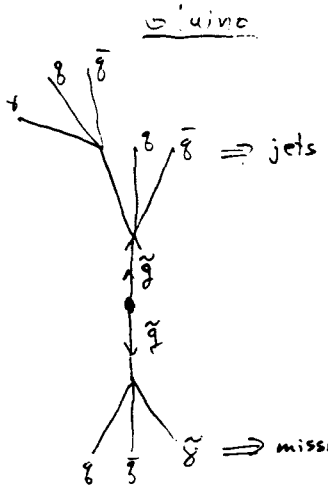
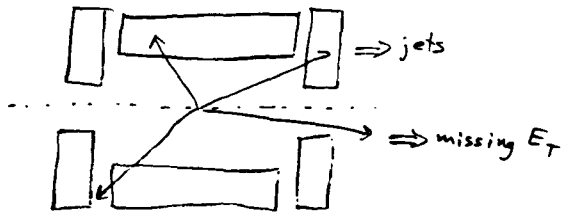


Signal



Background

With Forward Calorimeter

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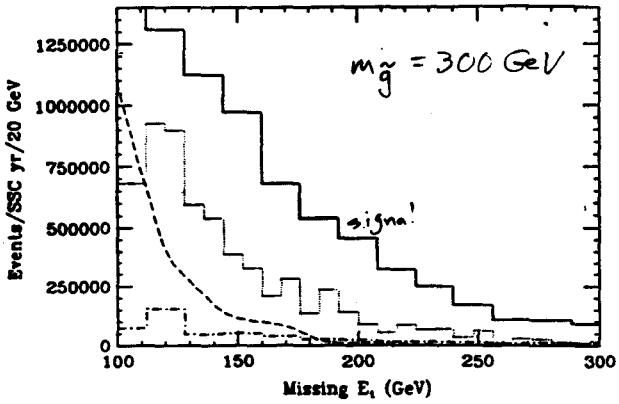

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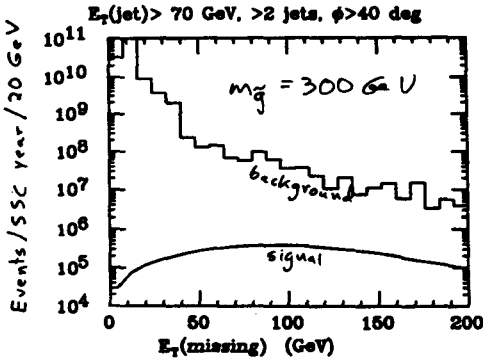
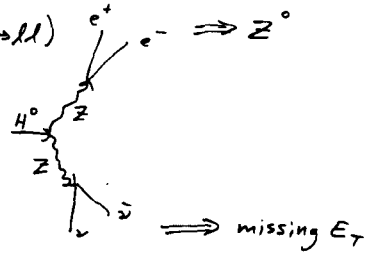
No Forward Calorimeter



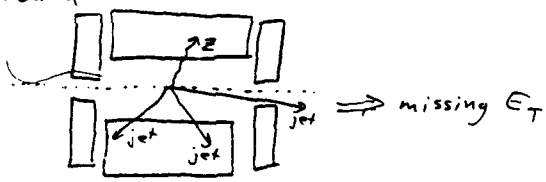
Heavy Higgs

$B(Z \to \nu\bar{\nu}) = 6\, B(Z \to \ell\ell)$

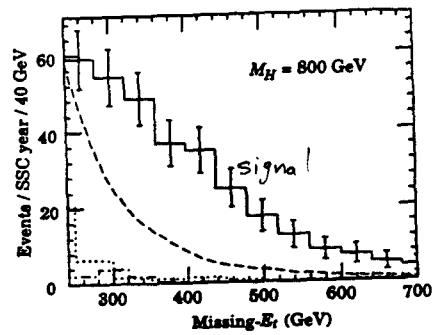
Signal



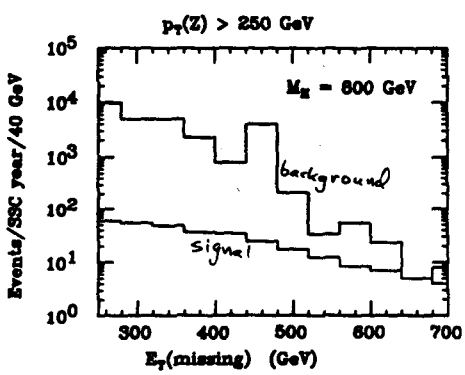
Background



with Forward Calorimeter



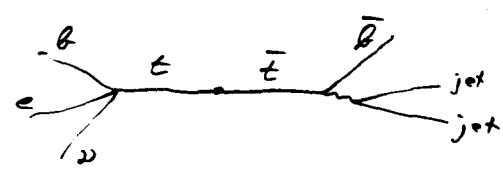
No Forward Calorimeter



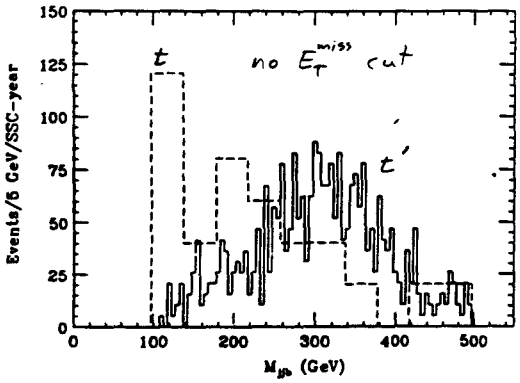
4th Generation Top Quark

now → m_t = 150 GeV

5 → $m_{t'}$ = 400 GeV



$m(t) = 150$ GeV
$m(t') = 400$ GeV



With E_T^{miss} cut
t reduced by 20.
t' reduced by 1.4

- $\sigma(\not{E}_T)$ should be good, but we haven't yet got the simulation strength to translate this into a granularity spec.
- Jet tagging still looks like an important feature, and would drive the granularity specification.

→ as fine as practicable
$\sim 10^3$ channels per end.

Competing Geometries

1. EOI/LOI — "Backstop"
   - conventional
   - heavy
   - ugly glitch E.C.Cal—FCal

2. Inverse Cone:
   - lighter
   - better access
   - smoother transition from E.C. Cal.

Shallow angle?
→ John Hauptman, Myungyun Pang .....

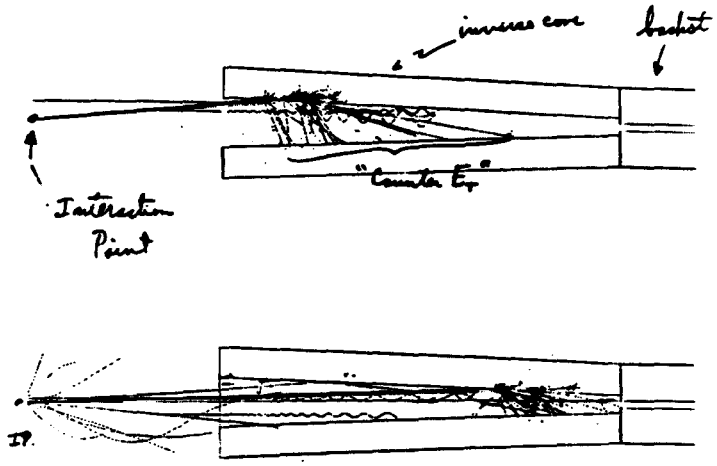


Figure 2. Pythia-GEANT jet in an inverse cone geometry, showing particle albedo from the inside surface, the "counter E_T" of particles reaching the opposite side of the cone, and the effects of a weak dipole magnetic field which tends to act as a magnetic mirror keeping low energy particles from reentering the tracking volume. (a) a 200 GeV quark jet at y=3.35 (θ=0.07). (b) a 200 GeV quark jet at y=5.0 (θ=0.0138).

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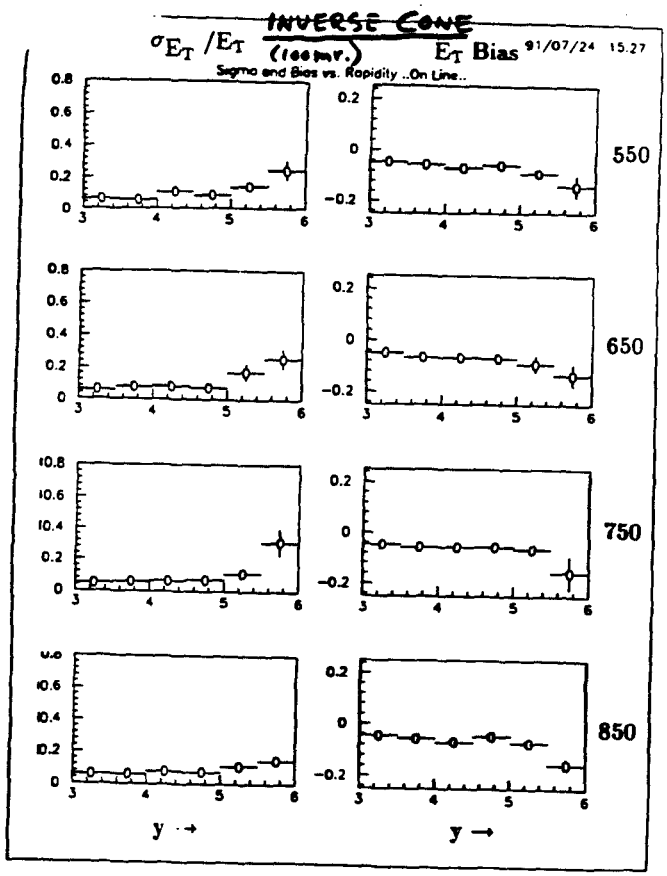

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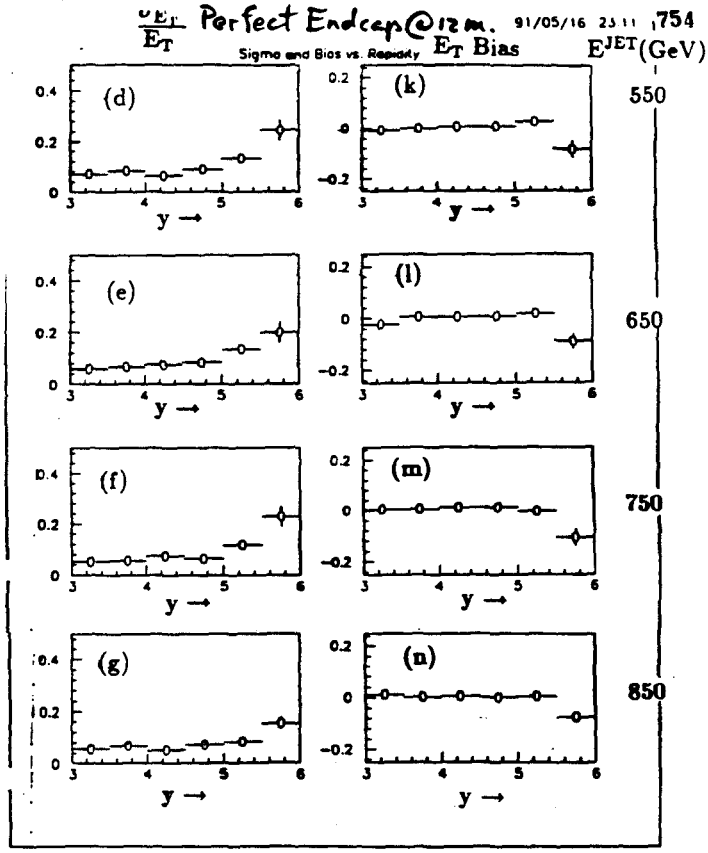

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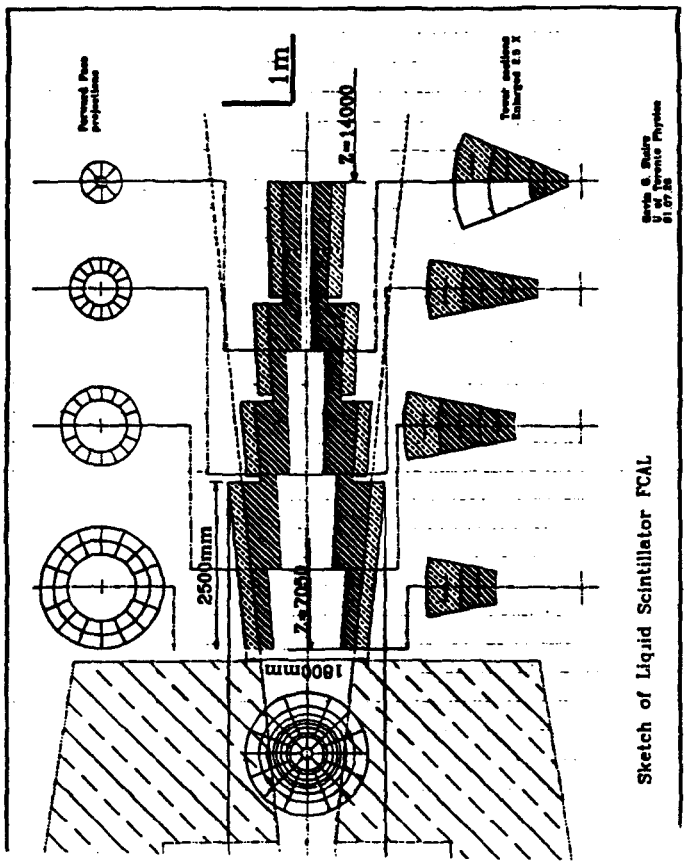

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4 Technologies

- Argon – high pressure gas.
- Argon – liquid.
- Warm liquid.
- Liquid scintillator.

FCal – Critical Issues:

Hostile Environment!

1. Radiation Damage (M – Co^{60}?)

2. Rate Problems.

(M, S) • Pileup — pulse shaping
→ asymmetries

(M – Y, S) • + ions → SPACE CHARGE!

3. Buildable system concept

↑

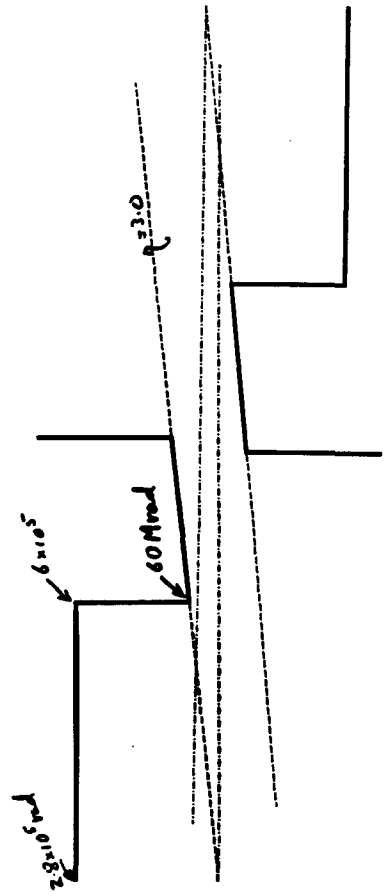
Choose technology Feb 29/92
(geometry in Nov. 91)

We are tuning FY92 R/D to these issues.

LOI SDC

$\mathcal{L} = 10^{34}$ fb/10ns.

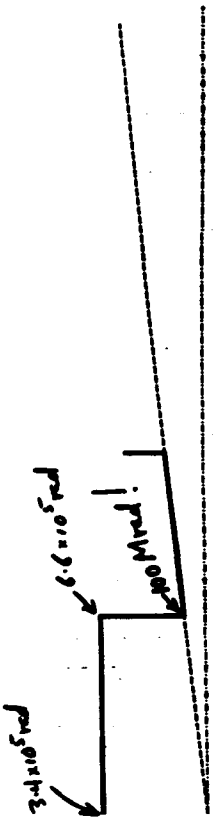
R = 2.05 m
Z = 4.20 m

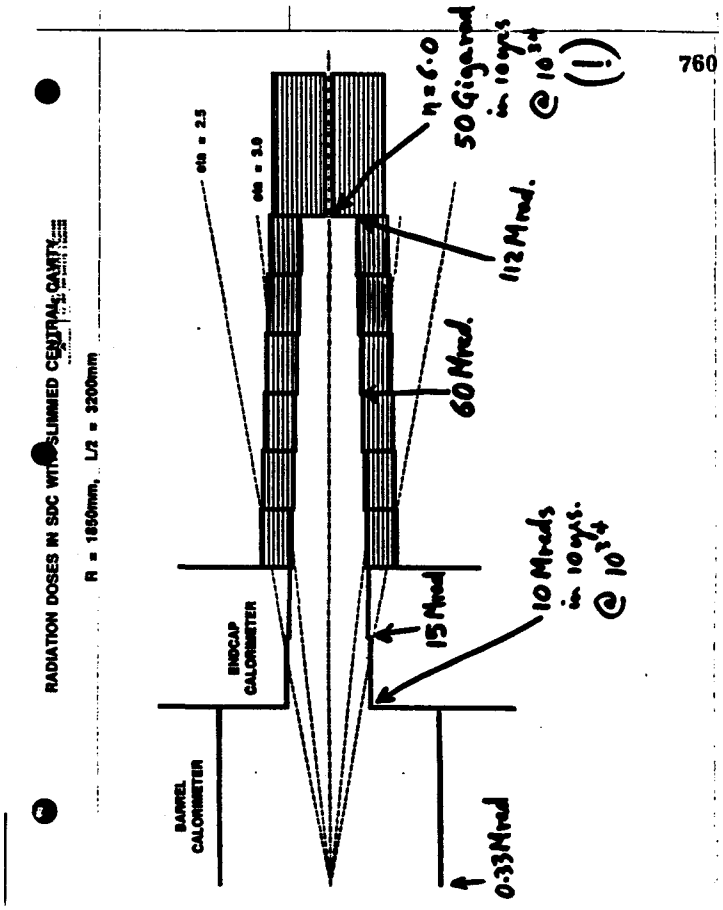


SLIMMED SDC

$\mathcal{L} = 10^{34}$ fb/10ns.

R = 1.85 m
Z = 3.20 m





"Space Charge" (Naive version)

W.L. 1mm gap @ 50kV/cm : $\mu^+ = \frac{.5\,cm^2}{kV\text{-}sec}$

$\hookrightarrow \tau = 4\,msec$

$1\,g_y = 1\,\frac{Joule}{kg.}$ $\quad 50\,\frac{Mrad}{gr.} = \frac{.6\times10^{19}\,eV}{gr.\,gap.\,cm^2}$

@ 50eV/pair $\longrightarrow \frac{10^{10}\,ions}{sec.\,gap.\,cm^2} = \frac{4\times10^{7}\,ions}{gap.\,cm^2.\,\tau}$

$\sigma = \frac{E}{\epsilon_0} = 3\times10^{10}\,\frac{electrons}{cm^2}$ (@ 50kV/cm)

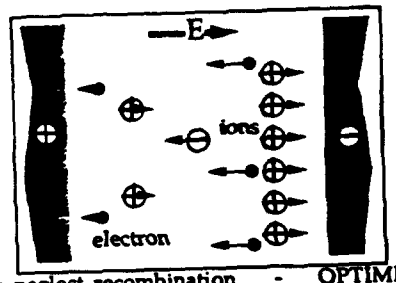
$\longrightarrow$ shutdown @ $1\,\frac{grad}{gr.}$ (W.L.? LAr? etc?)

$\longrightarrow$ gain fluctuations?

$\hookrightarrow$ needs more careful investigation.

1 WAW, 8/8/91

FIELD DISTORTION BY IONS - RADIATION LIMIT FOR IONIZATION CALORIMERTRY



We neglect recombination - OPTIMISTIC!
(see J. P. Rutherfoord for general approach. "Will a Liquid Argon Calorimeter Work at High Luminosity?". U of Arizona. unpublished.)

For $E_{anode} \geq 0$: $(E_{ion}/E_{cath})^2 \leq \approx 1$

$E_{ion}^2 = 4\pi I g^2/\mu$ SENSITIVE GAPS SHOULD BE NARROW WITH LARGE E_{cath}

I = specific ionization rate ∝ radiation level

g = gap width - μ = ion mobility

$\int E dx/g = \int E du = \langle E \rangle$ - independent of ions!

THIS NORMALIZATION MINIMIZES THE EFFECTS OF FIELD DISTORTION

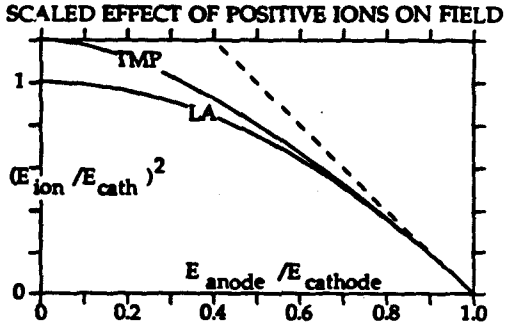
2 WAW, 8//9/91

Details: solve nonlinear equation:

$$d^2(E^2)/du^2 = 2E_{ion}^2\,[1 + \alpha\,(E/\langle E\rangle - 1)]$$

α measures slope of ionization vs field strength
α = 0 and 0.5 for LA and TMP, respectively.

SCALED EFFECT OF POSITIVE IONS ON FIELD

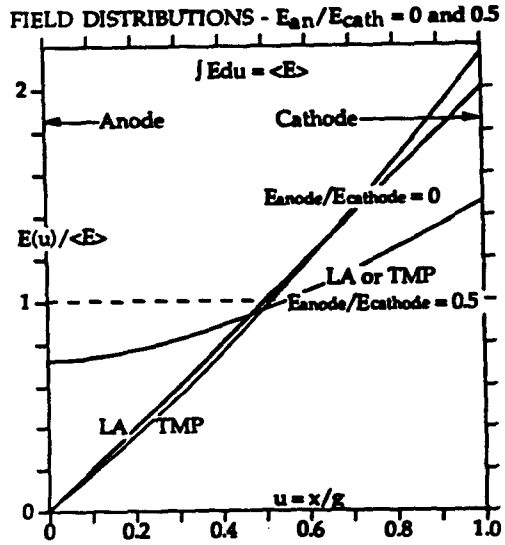


CONCLUDE

- Scaled distortions depend little on α.
- Between modest distortion and collapse of field there is little difference in ionization.
- Therefore, major distortions are irrelevant.

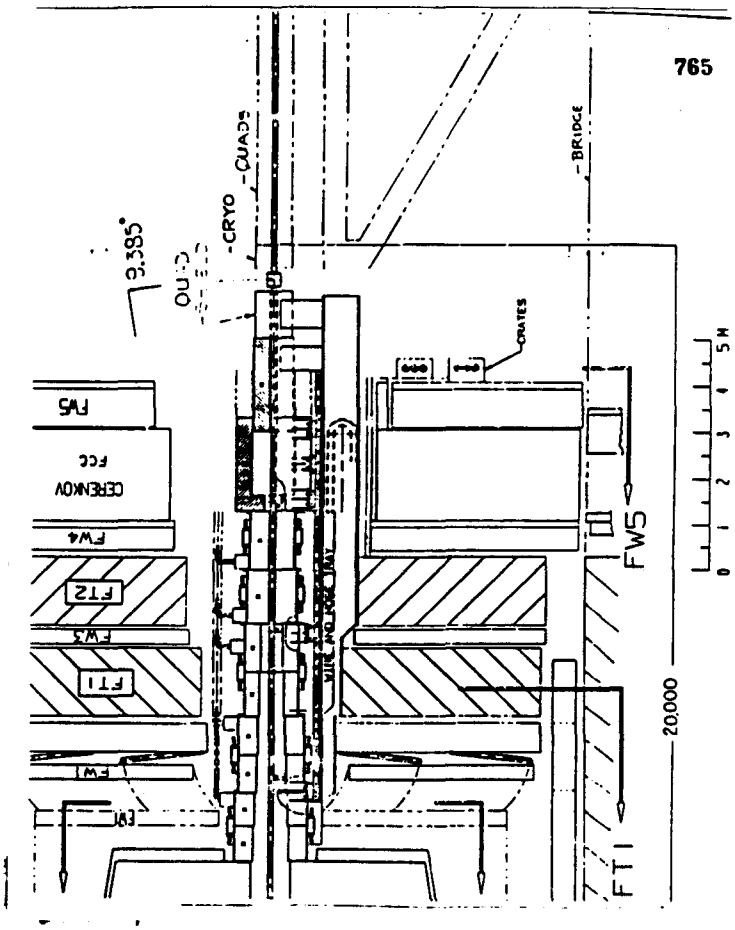
3 WAW, 8/9/91

FIELD DISTRIBUTIONS - E_{an}/E_{cath} = 0 and 0.5

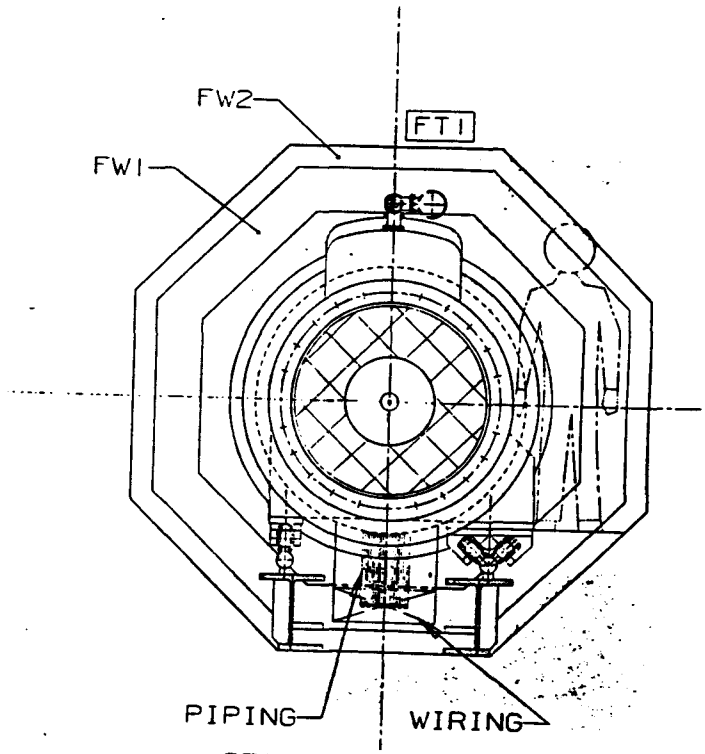


CONCLUDE

- For a given E_{ion} the scaled distributions are essentially independent of α.



A. [illegible]



SECTION FT1 - FT1

Tracking

Summary : Baseline Designs & Costs.

R&D : Silicon & Gas Microstrips.

Changes from LOI

Silicon:

$28\,m^2 \rightarrow 16\,m^2$ ratio = .57

Wires:

$1.9\times10^5 \rightarrow 1.35\times10^5$ ratio = [redacted] .71

Fibers:

$1\times10^6 \rightarrow \begin{cases} 375k \text{ to} \\ 500k \end{cases}$ ratio = .375 to .500

Material	Normal Incidence (leave out outer most layer)
Silicon	5%
Wires	3.5%
Fibers	5.4%

11.5%

14.7%

Maximum – All 4 Layers have 8 fibers. Comparable material: 24 fibers or 34 straw layers.

Rapidity Averaged = 5.5% for silicon + 1.7 × Outer Value.

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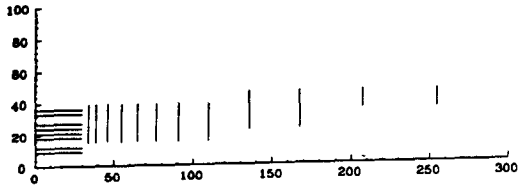
DESIGN #1



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Outer Trackers:

Units: 6 to 8 straws.

.85% X^0 including supports (normal incidence).

Arrange either Axial or Stereo.

or

2U, 4A, 2V fibers.

Need less layers since can mix Axial and Stereo Measurements.

1.8% X^0 including supports (normal incidence).

Likely minimal numbers to consider:

5 Straw Layers

4 fiber Layers

or

Mix.

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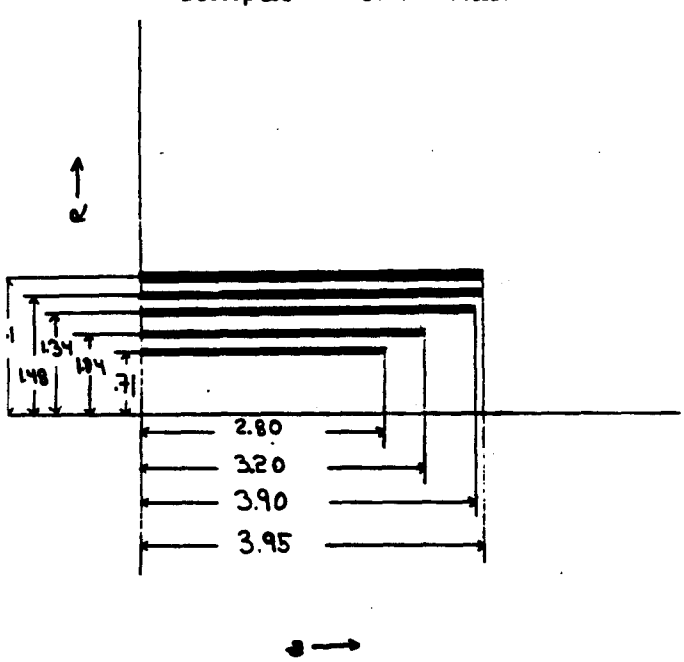
Descoped All Straw Tracker



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DESCOPE 7 (INCREASED TO 5 SUPERLAYERS AND DECREASED INSIDE DIAMETER OF TRACKER)

NEW SUPERLAYER DATA:

	#	DIAM(M)	Z(U)	STEREO	# MODULES	
	1	1.40E	2.80	0	84	84.06
	2	2.0E	3.20	3	124	123.62
	3	2.6E	3.90	0	160	
	4	2.96	3.96	-3	176	
	5	3.2E	3.96	0	192	

DATA		BEFORE	AFTER	FACTOR	COST(K$)
	(FIXED COSTS)	16524	16524	0	16523
	DIAMETER CHANGE	3.4	3.4	N/A	(BELOW)
	(EFFECTS LAYER & MOD COSTS)	-	-	-	-
	(# OF SUPER LAYERS)=	4	5	N/A	8400
LAYER#5	(# OF TRIGGER MODULES)=	192	192	0	3013
LAYER#4	(# OF STEREO MODULES)=	176	176	0	1996
LAYER#3	(# OF TRIGGER MODULES)=	160	160	0	2511
LAYER#2	(# OF STEREO MODULES)=	124	124	0	1406
LAYER#1	(# OF AXIAL MODULES)=	84	84	0	953
	(# OF METERS LONG)=	3	5	N/A	0
	TOTAL COST				34303

DESCOPED ALL STRAW TRACKER

773

SL.	#mods	r (m)	z(m)	Stereo	Modules	ΣX_0 before
1	6	0.704	2.80	0°	84	-
2	6	1.04	3.20	+3°	124	0.85%
3	8	1.34	3.90	0° T	160	1.70%
4	6	1.48	3.95	-3°	176	2.66%
5	8	1.61	3.95	0° T	192	3.51%

Cost = \$ 16.5 M + 1.7 M × # superlayers

+ 0.016 M × # Trig. Modules (352)

+ 0.011 M × # Nontrig. Modules (384)

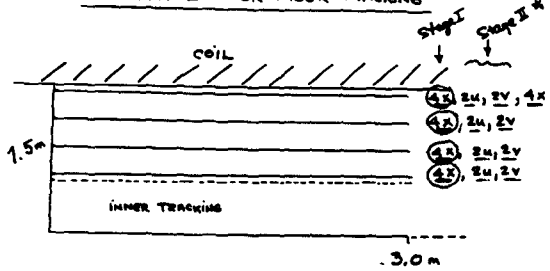
= \$34.8 M (Baseline was \$ 31.7 M with 4 superlayers)

Total Straws = 1.35 × 10^5 (Baseline was 1.22×10^5)

G. Hanson
8-6-91

"OPTION 2" FOR FIBER TRACKING

774



* CHOICE OF STEREO 2u, 2v (3-D SPACE POINT) OR AXIAL 4x' (VECTOR OPTION)

TO BE DECIDED THROUGH SIMULATION

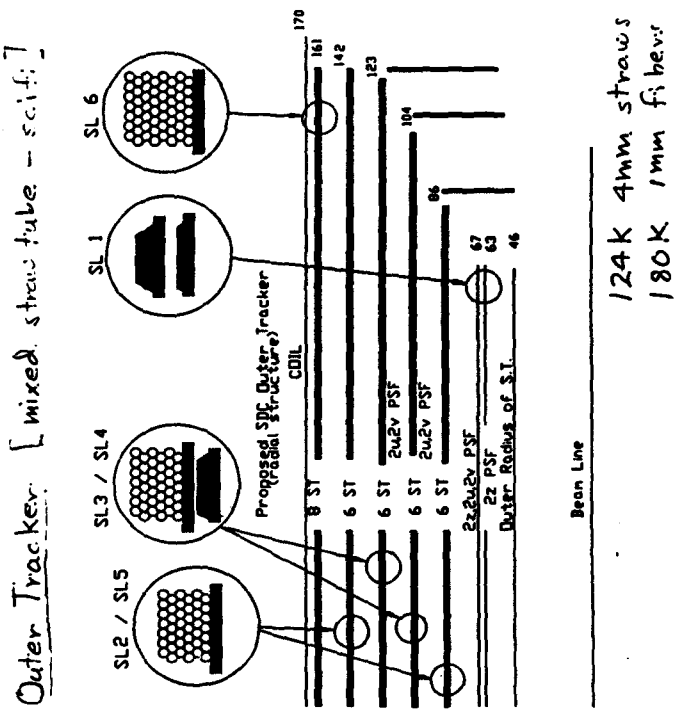
FIBER TRACKING SCENARIOS

775

"BASELINE"	1.7m × 4m 2 VECTOR BARRELS (x,u,u',x'), (x,x') 862K FIBERS	\$35.6 M (FROM WBS) D. KOLTICK & D. VANDERGRIFF
"D. ADAMS" SIMULATION	1.5m × 4/2 4 BARRELS (x,u,v) 500 K FIBERS	~ \$45M
"OPTION 1"	1.5m × 4/2 2 BARRELS (x,u,v) 2 BARRELS (x only) 375 K FIBERS	~ \$36M
"OPTION 2"	STAGE READOUT OF D. ADAMS VERSION (OR VARIANTS) (STAGE UV) 250K CHANNELS READOUT 500K CHANNELS/FIBERS IN PLACE (SAVES \$10M)	~ \$35M

NO INTERMEDIATE fiber TRACKING IN ANY OF THE ABOVE SCENARIOS

776



Costs for very slimmed down system: \$40M silicon
\$35M Outer (possibly + \$10M staged).
\$17M Intermediate Tracker.

How does the system perform:

Several programs beginning to use full system information, but pattern recognition not yet fully global.

Likely to take several months before results on a range of physics processes available. Critical to get such information as input to decisions.

Intermediate Tracker – U.K. & Canada.

Consensus to pursue Gas Microstrips.

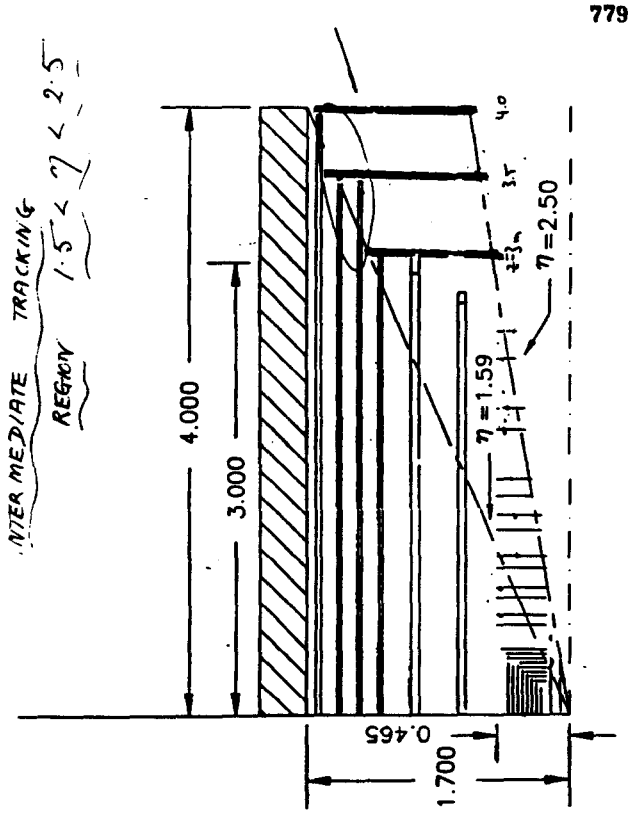
Made of Tiles 15cm × 15cm (wedge shaped, arranged into forward disks).

6 disks (2 measure ϕ versus z, 2u stereo, 2V stereo) form a measuring layer.

3 such layers spread out along z from 3m to 4m.

300μm anode spacing ⇒ ~8μm accuracy per measurement.

Goal: Measurement of $\frac{d\phi}{dz}$ in disks grouped in 4 η bands provide first-level tracking trigger. [illegible] up to very high $\mathcal{L}$.



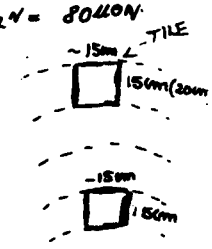
PROPOSAL FOR INT. TRACKING SYSTEM

THREE SUPER-LAYERS

2R, 2U, 2V × 3

ANODE PITCH = 300μm.

RESOLN = 80μm



COSTS BASED ON SILICON

LABOUR / MANAG	= 4M
TILES	4½M
ELECTRONICS	= 1.2M (3M ANODES)
READ-OUT	= 0.6M
SUPPORT STRUCT.	= 7.2M
TOTAL	= 16.5M

TOTAL TILES = 8000

OCC/TILE = 30%

NO OF ANODES/TILE = 450

Momentum Resolution at Large Rapidities:

$$\frac{\sigma_{P_\perp}}{P_\perp^2} = 59\% \, (\mathrm{TeV}^{-1}) - \text{Si Alone.}$$

$$\frac{\sigma_{P_\perp}}{P_\perp^2} = 44\% \, (\mathrm{TeV}^{-1}) - \text{Si + Gas Microstrips.}$$

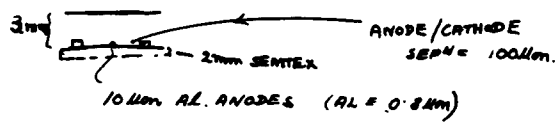
For $P_\perp = \frac{M_Z}{2} = 50\,\mathrm{GeV}$

this gives, for second case above; $\frac{\sigma_{P_\perp}}{P_\perp} = 2.2\%$. This is a very good measurement!

PRESENT SITUATION

LIVERPOOL / R.AL [BREMAN ET AL]

- TILES OF 6cm × 1cm SEMTEX GLASS WORKING RELIABLY SEVERAL MONTHS



- OPERATING IN CF_4 / ISOBUTANE 80/20 MIX

BEAUTIFUL PULSES 50 NANOSECOND

GAIN $10^3 - 10^4$

- ELECTRICAL CONNECTIONS HAVE BEEN ACHIEVED
- OTHER WORK → IN PROGRESS [UK]

  SET UP PLATE WITH INDIVIDUAL ANODES + MICROSTRIP ELECTRONICS (SILICON)
- 2mm → 500μm → 200μ (GLASS)

  DIFFERENT MATERIALS — SILICON (BULK)
- MAKE TILE — 'A4' SIZE = 20cm × 15cm.
- MEASURE EFFICY (HIGH 90's) — PRECISELY IN TEST BEAM.
-

R&D - Focus on Substrates.

Liverpool / R.A.L. - Semtex Glass

Texas A&M / Rochester - Plastic Substrate

Canada (Carleton) - Lithography on Plasti

Both of the Above - Glass/Ceramics/Silico

PIXEL'S PROGRESS

I. PROTOTYPES (HUGHES & LBL):

A. 32 × 64 ARRAY 50 × 150 μm² PIXELS SMART, TIMESTAMPING, GHOST ELIMINATION "PROOF-OF-PRINCIPLE" DEVICE, PERIPHERY TIMP

B. "RADIATION-HARD" PIXEL CELL - HUGHES SOI

C. "ADVANCED" PIXEL CELL - CR-RC SHAPING, DC SERVOS, AUTONOMOUS OPERATION

II. PROTOTYPE STATUS:

A. 32 × 64 SECOND GENERATION DEVICE DUE BACK FROM FOUNDRY 8-9-91. FIRST DEVICE WORKED, WITH SOME PROBLEMS - < 200 e⁻ NOISE, SPARSE DATA WORKS.....

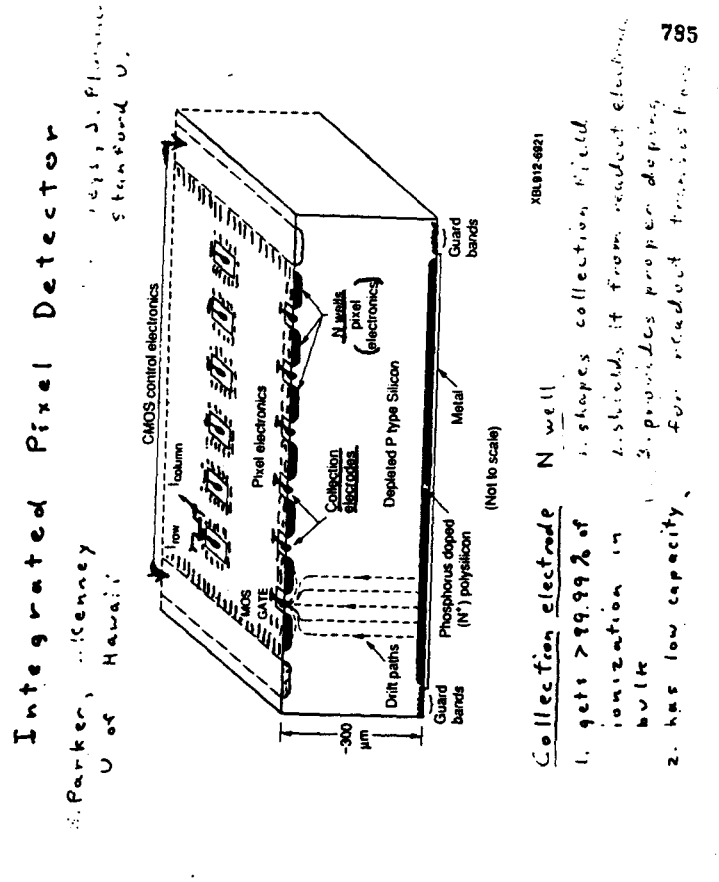
B. "RADIATION HARD" PIXEL CELL FABBED - AWAITING TE.

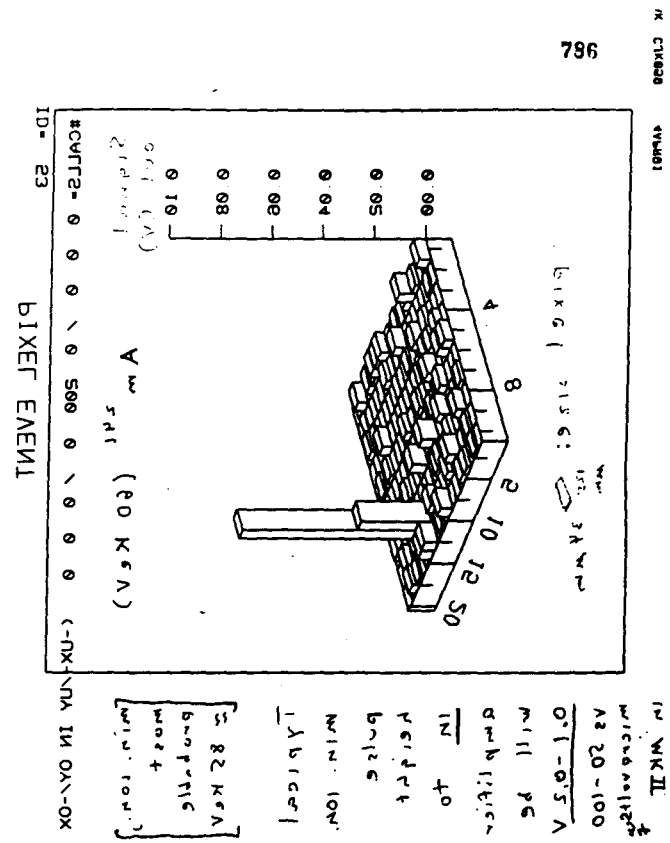
C. ADVANCED PIXEL CELL IS WORKING WELL < 200 e⁻ NOISE, REASONABLE TIME WALK. PROBLEM: UNEXPECTEDLY LARGE THRESHOLD VARIATION CAN BE SOLVED WITH NEW DESIGN CONCEPT.

III. ARCHITECTURE:

NEW TIME-OVER-THRESHOLD CONCEPT OFFERS PROSPECT FOR GOOD CHARGE & TIME RESOLUTION IN A PURELY DIGITAL SYSTEM.

IV. BEAM TESTS PLANNED AT FNAL IN FALL





R&D Strip System

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(1) Completed measurements on radiation behavior of biased detectors which indicate a dosage lifetime of about 10^{14} particles/cm^2 (1 MeV neutrons or 800 MeV protons). These are room temperature measurements. Have taken similar data this summer at 0°C to check temperature dependence of the damage.

(2) Data of a year ago indicate good performance of advanced bipolar and rad hard CMOS up to the 3 megarad lifetime limit of the detectors.

(3) We now have two test amplifier-discriminator 16 channel chips from Orbit (inexpensive) with approximately the correct rise-time and less than 1 milliwatt/channel power. Expect by end of year to have 64 channel chip from Tektronix (expensive) which is close to our design goals.

(4) We have a test wick which demonstrates passive (ie, no pumps) heat removal. Studying details of heat conductivity and temperature profiles to work on optimizing the design

(5) Have made finite element mechanical models of:

Individual wafer module (24 cm long unit).
Cylinder of detectors
Forward disk array,

indicating adequate mechanical performance — want 5 μm stability in bend direction, 80 μm in orthogonal direction.

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Tracking Steering Committee

789

LBL
Aug 9, 1991
J. Elias

- Technology choice decision paths
- ORNL Agenda Sept '91
- FY92 Engineering and R+D planning

Tracking Steering Committee

LBL 8-8-91

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8:30 Short technology/update reports
Straw G. Hanson Fiber R. Ruchti
& Strip E. Galatthe Straw A. Grebenik
Pixel D. Nygren

9:30 Technology choice decision path(s)

Update on silicon strip length and strip-pixel situation

Decision prerequisites, requirements

Decision scope

Decision process & schedule

10:30 Break

11:00 Technology choice discussion cont'd.

ORNL agenda

R&D/Engineering budget process & schedule

12:30 Lunch

1:30 resume

further discussions re above

tracking scope/cost/performance/volume

proposal editor(s)

Outer (Barrel) Tracker

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Designs:

Scintillating Fibers ⟷ Mixed ⟷ Straw Tubes

Issues:

① Baseline design for the Technical Proposal

② FY92 $ plan for Engineering and R+D

Challenge:

Provide, along with inner and intermediate systems, "full" tracking and triggering capability for conditions where

Radius ~ CDF
Length ~ 2½ × CDF
Field ~ 30% > CDF
< particle density > ~ 10 × CDF
frequency is 60 MHz versus 0.3 MHz

and we have de-scoped by ~ ×2 in channels

Outer Tracker Selection Criteria

LBL 8-8-91

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At ANL in Nov '89 we said

0) it "works" as R, R, R for phys. & trigger
1) proof of principal prototype does tracks
2) prototype electronics works
3) X_0 and λ_0 at 90° ok
4) Performance
   σ_p
   triggering
   hermiticity
   vertexing
   reconst. efficiency
   } versus occupancy ($\mathcal{L}$)
5) Cost
6) Mechanical
   Engineering alignment, heat, ..
   Assembly
7) Risk
   Reliability (MTBF)
   Redundancy
   Repairability
   Radiation damage
8) High luminosity upgrade

(Silicon / Straw / Fiber): R&D has not yet met these criteria
Simulation of performance .... do the descoped designs work

LDL 8/9/91

Near Term Expectations

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Sept 25 — ORNL meeting
Expect early full simulation results & fiber cosmic ray results for a superlayer

Oct 15 — Expect results from straws operated at actual HV with "real" electronics

Nov 15 — SSCL meeting
Expect VLPC "costing" answer
Expect incisive simulation results on capabilities of the designs.

Dec 15 — Possibility of fiber test beam results from full size superlayers
Possibility of straw cosmic ray & source results from a superlayer operated at SSC parameter values.

Results on systems aspects, ~1000 channel prototype, are 1 to 1.5 years away.

⇒ There is an unavoidable and significant risk dimension in resolving the baseline design and budget $ issues this fall.

LDL 8/9/91

After extensive and extended discussion:

Review Panel Proposal

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Schedule

Sept 25 ORNL — First meeting
Presentations of req'd material (see agenda)
Executive session, set Oct goals

Oct ?? ? — Second meeting
Similar activities

Nov 15 SSCL — Third meeting
Similar activities

Dec 2 — Recommendations due.

Membership requests
All from SDC
7 members
3 interested parties from tracking grp
1 comm not from tracking grp
1 silicon group (global view)
2 T.B.D.

LDL 8/9/91

ORNL Sept '91

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Wed. day — Cost + Scheduling working meeting

Wed. eve — FY92 budget group working meeting.

Thu → Sat tracking parallel session time — Review panel presentation meeting

Review panel executive session

Tracking group + Review panel plan next (Oct?) step in the process.

8/9/91

Cost & Schedule Agenda

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- Prepare schedule summary information for use by the budget group in assessing the impact of different scenarios
- Prepare single page roll-ups and scaling formulae for the costs of the de-scoped designs
  1.) All straw
  2.) All fiber
  3.) Mixed system
- Identify and resolve or explain the present $ discrepancies between 1.) 2.) and 3.) when one uses 1.) and 2.) to check 3.)
- Prepare material in the tracking volume report which has all three designs on a common basis (including silicon).

MEMBERS of the SDC COMMITTEE on STRAW PLACEMENT

Morris Binkley (FNAL)	BINKLEY@FNAL	(708) 840 3112
Richard Boyce (SLAC)	RFB@SLACVM	(415) 926 2932
Richard Kadel (LBL)	KADEL@LBL	(415) 486 7360
Hartmut Sadrozinski (UCSC)	HFWS2@SLACVM	(408) 459 4670 (Chair)
Roger Stone (LBL)	RSTONE@LBL	(415) 486 7360

APPENDIX B

CRITERIA to DECIDE between DIFFERENT STRAW PLACEMENT SOLUTIONS

1) Structural integrity
2) Ease of assembly, alignment and servicing
3) Amount of material (expressed in radiation length)
4) Cost
5) Ease of manufacturing
6) Compatibility with stereo layers
7) Ease of interfacing with electronics (grounds) and cooling

APPENDIX C

AGENDA for the SDC STRAW REVIEW
MAY 20, 1991, SSC Lab

8:30 Executive Session
9:00 Discussion of Scope and Ground Rules of Review
9:10 Presentation by Physicists & Engineers
Al Goshaw (Duke): Introduction
9:20 Straw Modules
Harold Ogren (Indiana U.)
Roger Swensrud (WSTC)
John Mayhall (ORNL)
11:00 Single Straws
Seog Oh (DUKE U.)
David Vandergriff (ORNL)
13:00 Working Lunch with Speakers
13:50 Executive Session
14:15 Al Goshaw (Duke): R&D Plan
14:30 Recall Engineers and Physicists for Open Floor Questions
(Oh, Ogren, Goshaw)
15:30 Executive Session - Write Report
17:00 Adjourn

APPENDIX D

STRAW TUBE PROPONENTS ATTENDING the REVIEW MEETING

Institution	Person	Technical Background
Colorado	Bill Ford	physicist
Duke	Al Goshaw	physicist COORDINATOR
	Seog Oh	physicist
	Joe Simpkins	mechanical engineer
Indiana	Gail Hanson	physicist
	Harold Ogren	physicist
	David Rust	physicist
	Randy Foster	programmer/designer
ORNL	Tony Gabriel	physicist
	John Mayhall	mechanical engineer
	Ted Ryan	mechanical engineer
	John Shaffer	mechanical engineer
	David Vandergriff	mechanical engineer
WSTC	Roger Swensrud	mechanical engineer

EXECUTIVE SUMMARY

Aside from small variants, the proponents proposed basically two alternative designs for the straw tube placement onto the support structure:

a) "single straw" approach where single straw tubes are assembled and placed one by one on the support structure,

b) "modular" approach where about 200 straws are placed in rigid shells forming modules which are then placed onto the support structure.

It is important to note that there are many R&D issues common to the two solutions. One of them is the support structure design which is envisioned to be a stable base composite cylinder.

The Committee determined that several tasks must be completed to allow a choice to be made based on sound engineering results. It seems unlikely that the envisioned milestones can be met before January, 1992. These milestones are:

a) for the single straw concept: an 8m straw must be constructed and tested with sense wires and mid terminations in place. A straw placement device of appropriate length (~3m) has to be constructed for proof of principle to demonstrate quick and efficient glueing with low mass.

b) for the module design: it is necessary to demonstrate that a 4m shell can be fabricated with the required 50 micron straightness after loading with straws. Time and funds must be made available for possibly two attempts.

For both concepts, the consequences of the differential expansion and swelling of the tubes relative to their constraints (cylinders or shells) have to be evaluated.

The above tasks should carry the highest priority even to the extent of displacing present planned FY91 activities. Should additional funding be required to complete the above specific tasks, a request should be made immediately.

If a 4m shell can be constructed with the required tolerances, it is further recommended that this configuration be selected as the central tracker straw baseline design. Within the time and funding available, the single straw activities should continue until the module design proves workable. If the module design proves unworkable within a finite amount of time (e.g., 6 months) then the single straw configuration should be adopted.

We do not recommend construction of a full-size stable base support cylinder at this time. Instead we recommend that a vigorous program in Finite Element Analysis (FEA) should be undertaken to assess the effects of stresses, temperature and humidity on the complete structure of straw tubes/modules, supports and cylinders. Special attention should be given to the end flanges and the supports.

The committee is concerned about the very sketchy costing.

Areas of concern

- Effect of CTE differences of support cylinder and other components
- High risk of "thin" walled support cylinder both for fabrication and vulnerability to radial loading
- Accessibility at end of support cylinders for module maintenance and replacement
- Sufficient time not allowed in the schedule for the procurement process

Additional R&D

Committee members with experience in building large tracking devices pointed out the following areas which need attention soon:

A. Mechanical testing of all materials and assemblies

B. Radiation testing of all materials and assemblies

C. Quality control of all materials and processes

D. Assembly and test procedures (or how they will be determined)

E. Costing that is determined by the actual procedures proposed

F. Some indication that this is being treated as a manufacturing problem (100k straws) and not a lab project

COMPARISON OF STRAW POSITIONING TECHNOLOGIES

	MODULES	SINGLE STRAW
PHYSICS		
GAPS	≈	≈
RADIATION LENGTH (1)	−	+
STEREO	+	
FLAMBES	(+)	(−)
STRAWS		
TECHNOLOGY	≈	≈
LENGTH	4m	8m
GAS TIGHTNESS	+	−
MAINTENANCE / FABRICATION		
SENSITIVITY OF GAS	+	−
PLACEMENT (2)	++	−
REPAIRS	++	−
ASSEMBLY	++	−
DISTORTIONS OF CYLINDER (3)	−	N.A.
STRAIGHT/NONLINEAR SHELL (4)		
COST	− ?	+ ?

(1) MODULES ADD 0.2% PER SUPERLAYER (≈+50%)
(2) SINGLE STRAWS NEED 8m PLACEMENT MACHINE → 3m PROTOTYPE HAS TO WORK
(3) FEA OF FULL LOADING OF CYLINDER
(4) RIGID, STRAIGHT PROPERTIES OF 4m HAS TO BE CONSTRUCTED

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Table 1.1. Straw Section of Engineering Baseline Design.

Superlayer	Radius (m)	Number of Straws/Layer	Number of Layers/Superlayer	z_{min} (m)	z_{max} (m)	Stereo Angle (°)
3	1.21722	1912	6	0.03	3.550	-3
4	1.34963	2120	6	0.03	3.900	0
5	1.48205	2328	6	0.03	3.950	+3
6	1.61447	2536	9	0.03	3.950	0

Total number of straws (both ends): 121,968.

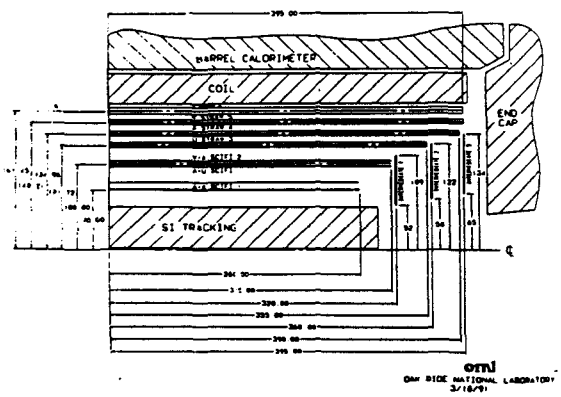

Fig. 1.1. A section through one quadrant of the tracking system of the baseline design

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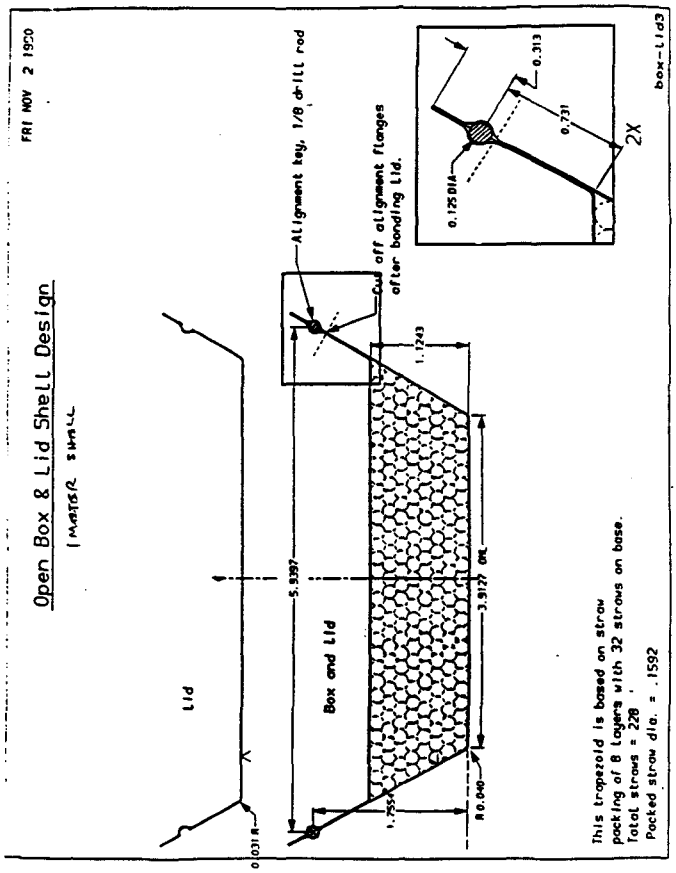

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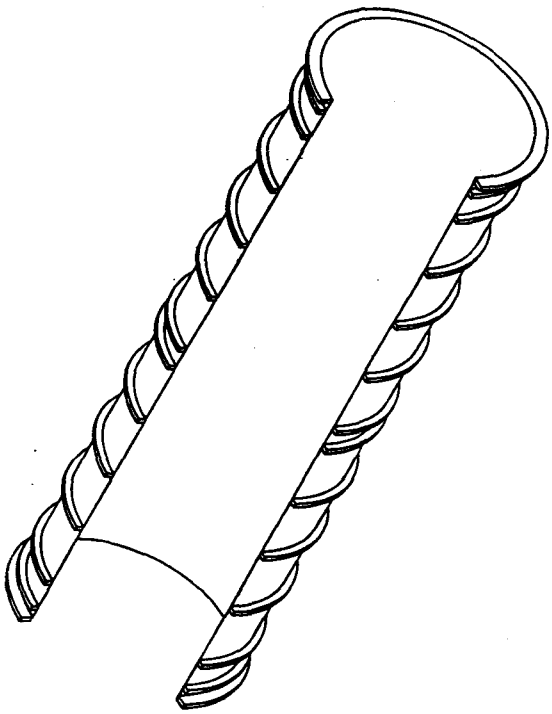

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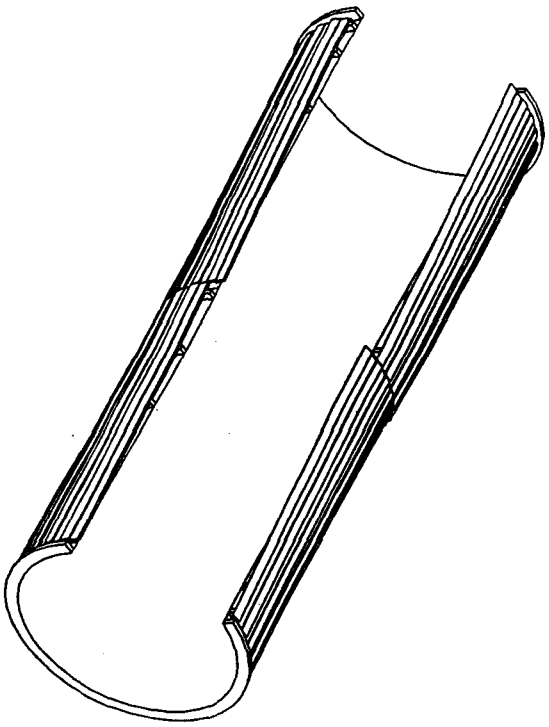


Fig. 3.5. A cut-away view of the stereo module superlayer.

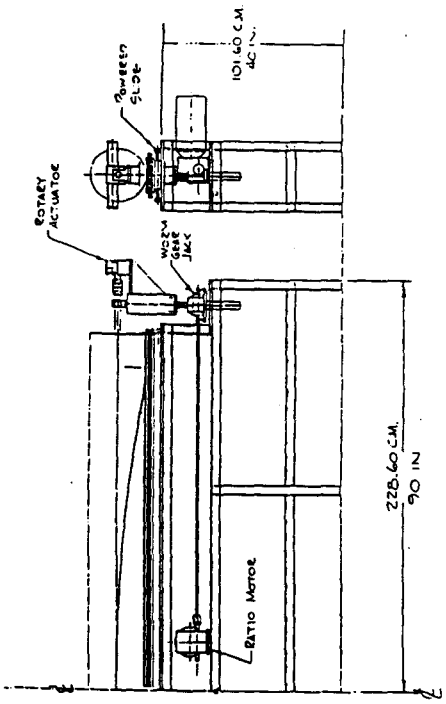
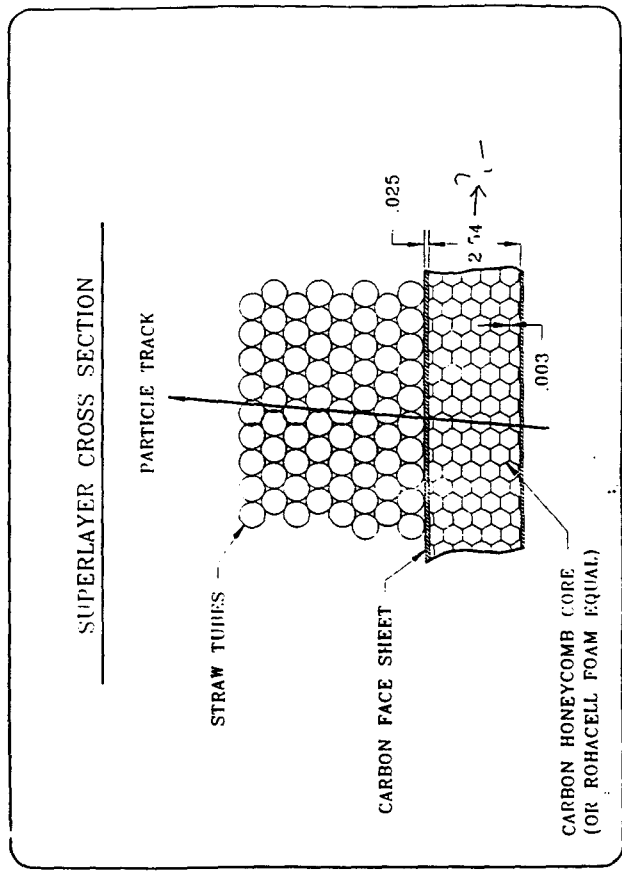


Fig. 3.11. Prototype straw tube placement machine.



STRAW TUBE PLACEMENT

H. SADROZINSKI

Sadrozinski
Plenary
8/9

M. G. D. Gilchriese
50A-2160
Lawrence Berkeley Laboratory
Berkeley CA 94720
415-486-6790
Fax# 415-486-5101

To: Straw Tube Tracker Designers

I'm quite late but I have enclosed the report of the
Among the many tasks for you at the August collaboration meeting, I am requesting that you address some of the concerns of the review committee. In particular

1) what is a realistic date to make a selection between the "single straw" approach and the "modular" approach?

2) when will an 8m straw be fabricated and tested?

3) when will a 4m module be built and tested?

4) what is your response to the recommendations of the committee contained in the summary?

Regards,

M. Gilchriese

cc: G. Trilling

REPORT of the REVIEW COMMITTEE on STRAW TUBE PLACEMENT in the SDC

June 1991

INTRODUCTION

The SDC Technical Coordinator had charged the Committee to review the technical options of straw tube placement in the SDC tracking system. Appendix A lists the members of the committee. The committee submitted to the proponents of the SDC straw tracking system a list of criteria by which to decide on a preferred technical solution (Appendix B). A report describing the options and proposed mile stones and R&D plans was assembled by the proponents of the straw tube tracking system and a draft was submitted to the committee on May 16, 1991. The final report (Appendix E) was distributed to the committee on May 28-29 1991. In the report the proponents do not select a preferred solution but describe the alternatives and propose a date of October 1991 for a decision between two basically different approaches to the straw tube placement onto the support structure.

The Committee met on May 29, 1991 at the SSC Lab and listened to presentations of physicists and engineers as outlined in the agenda appended as Appendix C. After discussions with the proponents present (Appendix D), the committee decided to forward the following recommendations.

MEMBERS of the SDC COMMITTEE on STRAW PLACEMENT

Morris Binkley (FNAL)	BINKLEY@FNAL	(708) 840 3112
Richard Boyce (SLAC)	RFB@SLACVM	(415) 926 2932
Richard Kadel (LBL)	KADEL@LBL	(415) 486 7360
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APPENDIX B

CRITERIA to DECIDE between DIFFERENT STRAW PLACEMENT SOLUTIONS

1) Structural integrity
2) Ease of assembly, alignment and servicing
3) Amount of material (expressed in radiation length)
4) Cost
5) Ease of manufacturing
6) Compatibility with stereo layers
7) Ease of interfacing with electronics (grounds) and cooling

APPENDIX C

AGENDA for the SDC STRAW REVIEW MAY 29, 1991, SSC Lab

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9:00	Discussion of Scope and Ground Rules of Review
9:10	Presentation by Physicists & Engineers
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	John Mayhall (ORNL)
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Colorado	Bill Ford	physicist
Duke	Al Goshaw	physicist COORDINATOR
	Seog Oh	physicist
	Joe Simpkins	mechanical engineer
Indiana	Gail Hanson	physicist
	Harold Ogren	physicist
	David Rust	physicist
	Randy Foster	programmer/designer
ORNL	Tony Gabriel	physicist
	John Mayhall	mechanical engineer
	Ted Ryan	mechanical engineer
	John Shaffer	mechanical engineer
	David Vandergriff	mechanical engineer
WSTC	Roger Swensrud	mechanical engineer

EXECUTIVE SUMMARY

Aside from small variants, the proponents proposed basically two alternative designs for the straw tube placement onto the support structure:

a) "single straw" approach where single straw tubes are assembled and placed one by one on the support structure,

b) "modular" approach where about 200 straws are placed in rigid shells forming modules which are then placed onto the support structure.

It is important to note that there are many R&D issues common to the two solutions. One of them is the support structure design which is envisioned to be a stable base composite cylinder.

The Committee determined that several tasks must be completed to allow a choice to be made based on sound engineering results. It seems unlikely that the envisioned milestones can be met before January, 1992. These milestones are:

a) for the single straw concept: an 8m straw must be constructed and tested with sense wires and mid terminations in place. A straw placement device of appropriate length (~3m) has to be constructed for proof of principle to demonstrate quick and efficient glueing with low mass.

b) for the module design: it is necessary to demonstrate that a 4m shell can be fabricated with the required 50 micron straightness after loading with straws. Time and funds must be made available for possibly two attempts.

For both concepts, the consequences of the differential expansion and swelling of the tubes relative to their constraints (cylinders or shells) have to be evaluated.

The above tasks should carry the highest priority even to the extent of displacing present planned FY91 activities. Should additional funding be required to complete the above specific tasks, a request should be made immediately.

If a 4m shell can be constructed with the required tolerances, it is further recommended that this configuration be selected as the central tracker straw baseline design. Within the time and funding available, the single straw activities should continue until the module design proves workable. If the module design proves unworkable within a finite amount of time (e.g., 6 months) then the single straw configuration should be adopted.

We do not recommend construction of a full-size stable base support cylinder at this time. Instead we recommend that a vigorous program in Finite Element Analysis (FEA) should be undertaken to assess the effects of stresses, temperature and humidity on the complete structure of straw tubes/modules, supports and cylinders. Special attention should be given to the end flanges and the supports.

The committee is concerned about the very sketchy costing.

Areas of concern

- **Effect of CTE differences of support cylinder and other components**
- **High risk of "thin" walled support cylinder both for fabrication and vulnerability to radial loading**
- **Accessibility at end of support cylinders for module maintenance and replacement**
- **Sufficient time not allowed in the schedule for the procurement process**

dditional R&D

Committee members with experience in building large tracking devices pointed ut the following areas which need attention soon:

A. Mechanical testing of all materials and assemblies

B. Radiation testing of all materials and assemblies

C. Quality control of all materials and processes

D. Assembly and test procedures (or how they will be determined)

E. Costing that is determined by the actual procedures proposed

F. Some indication that this is being treated as a manufacturing problem (100k straws) and not a lab project

COMPARISON OF STRAW POSITIONING TECHNOLOGIES

	MODULES	SINGLE STRAWS
PHYSICS		
GAPS	≈	≈
RADIATION LENGTH (1)	−	+
STEREO	+	−
FLANGES	(+)	(−)
STRAWS		
TECHNOLOGY	≈	≈
LENGTH	4m	8m
GAS TIGHTNESS	+	−
MAINTENANCE / FABRICATION		
SCHEDULING OF FAB	+	−
PLACEMENT (2)	+	−
REPAIRS	+	−
ASSEMBLY	+	−
DISTORTIONS OF CYLINDER (3)	+	−
STRAIGHT MODULAR SHELL (4)	−	n.a.
COST	− ?	+ ?

(1) MODULES ADD 0.24 % PER SUPERLAYER (≈ +50 %)
(2) SINGLE STRAWS NEED 8m PLACEMENT MACHINE
→ 3m PROTOTYPE HAS TO WORK
(3) FEA of FULL LOADING OF CYLINDER
(4) RIGID, STRAIGHT MODULES OF 4m HAS TO BE CONSTRUCTED

Table 1.1. Straw Section of Engineering Baseline Design.

Superlayer	Radius (m)	Number of Straws/Layer	Number of Layers/Superlayer	ϵ_{min} (m)	ϵ_{max} (m)	Stereo Angle (°)
3	1.21722	1912	6	0.03	3.550	-3
4	1.34963	2120	6	0.03	3.900	0
5	1.46205	2328	6	0.03	3.950	+3
6	1.61447	2536	9	0.03	3.950	0

Total number of straws (both ends): 121,968.

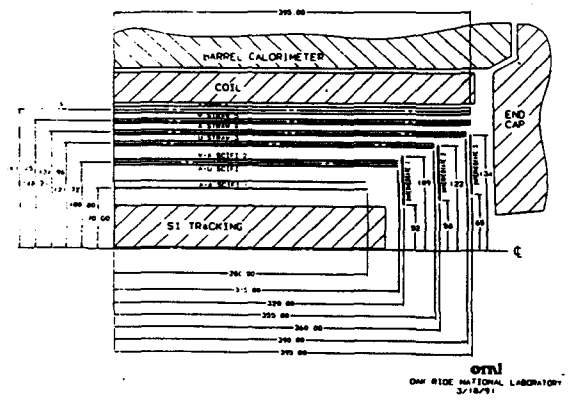
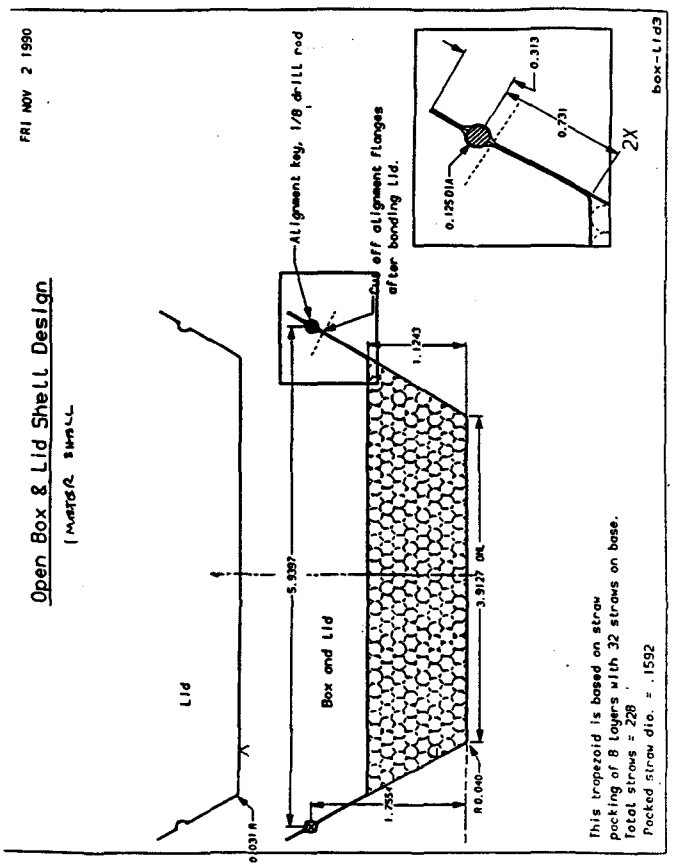
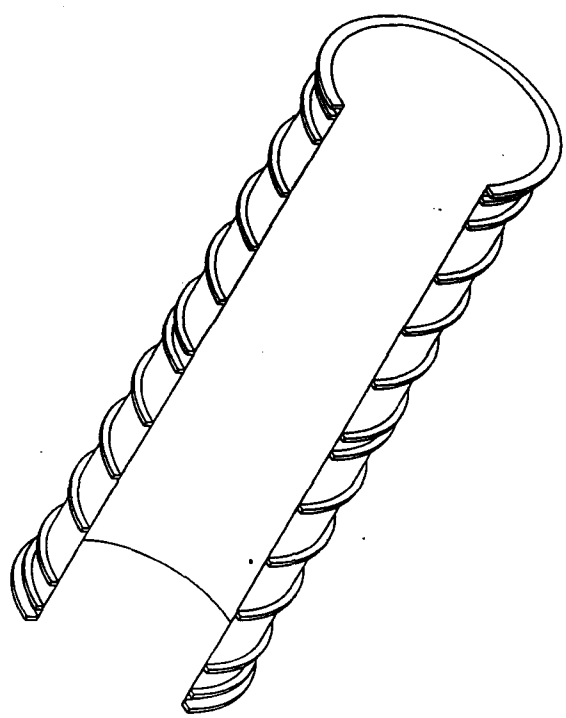


Fig. 1.1. A section through one quadrant of the tracking system of the baseline design





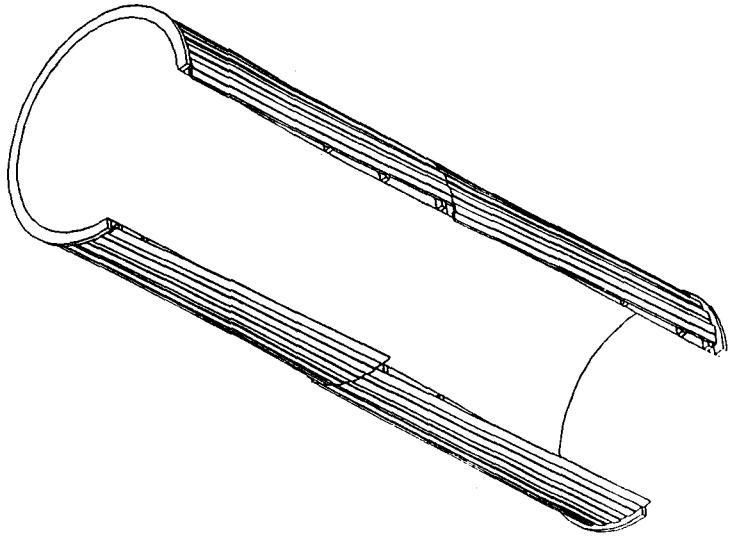
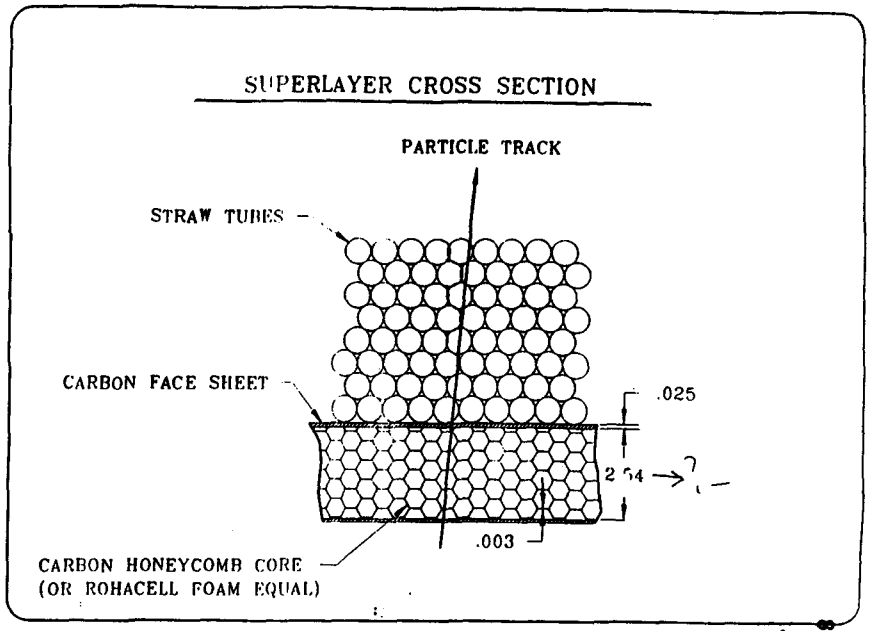


Fig. 3.5. A cut-away view of the stereo module superlayer.



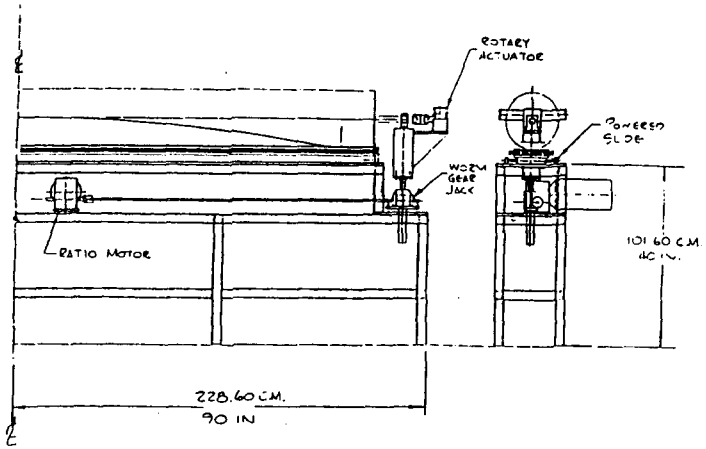


Fig. 3.11. Prototype straw tube placement machine.

Muon Group Report

G. Feldman
9 Aug 1991

1. Chamber Design
2. Descoping Decisions

Chamber Design

We are presently prototyping four designs for the muon system chambers.

We will make a decision on design(s) in January and have all agreed to work on the common design(s). The decision will be made, probably with the help of SDC members outside the muon group, on the basis of performance and cost.

There are a few key problems which different groups have solved in different ways:

Wires have to stretch over up to 9 meters.

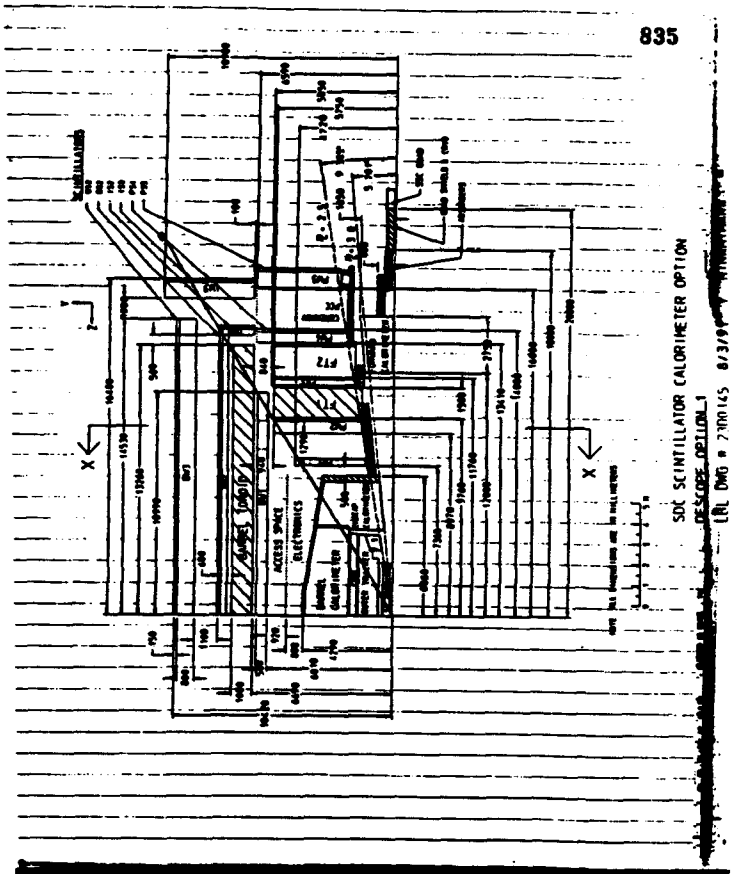
1. Supported them only from their ends and let them sag about 1 mm in the center.

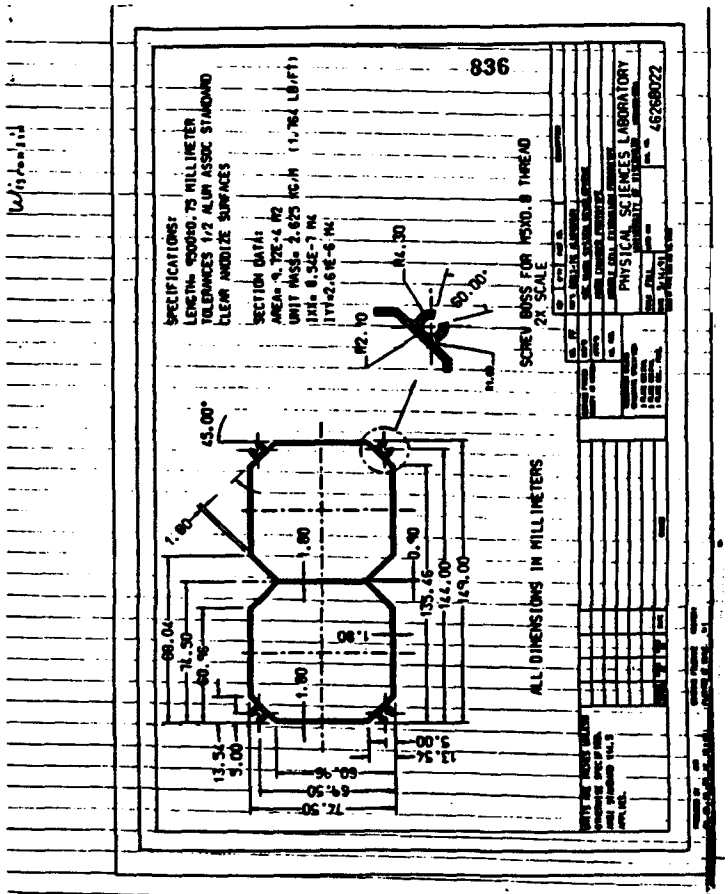
2. Support them in one or two places and worry about the precise positioning of the supports.

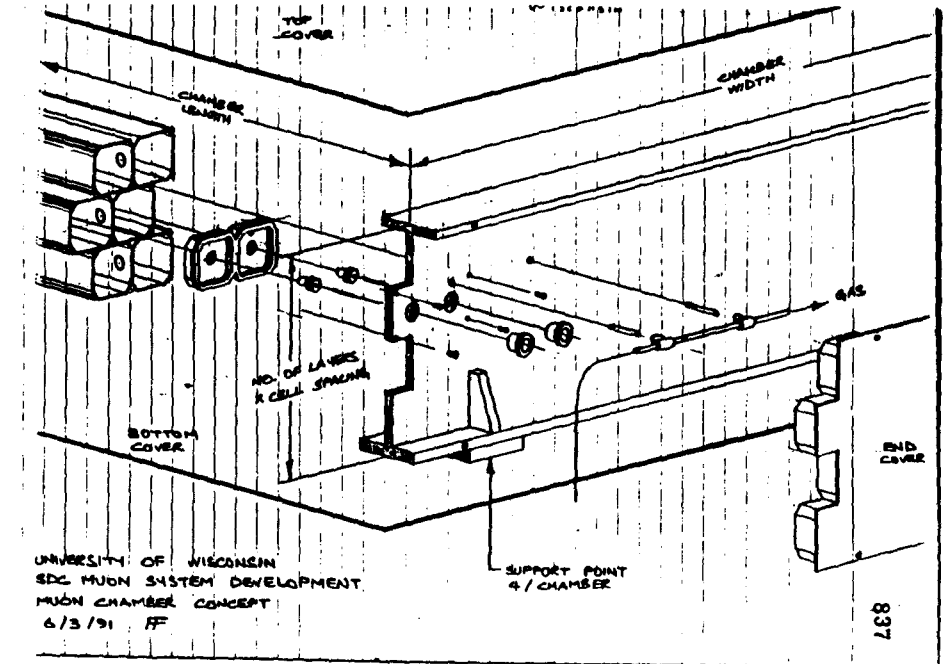
The barrel theta chambers accept particles from 0° to 56° to the normal.

1. Use (approximate) cylindrical geometry, so that all angles are equivalent.

2. Use shaped fields and orient them so that particles cross approximately normal to the field lines.







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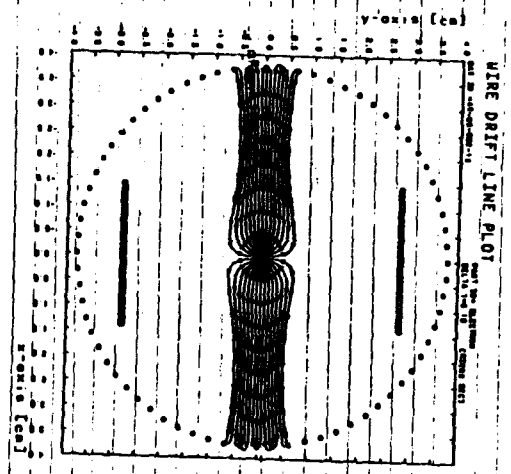
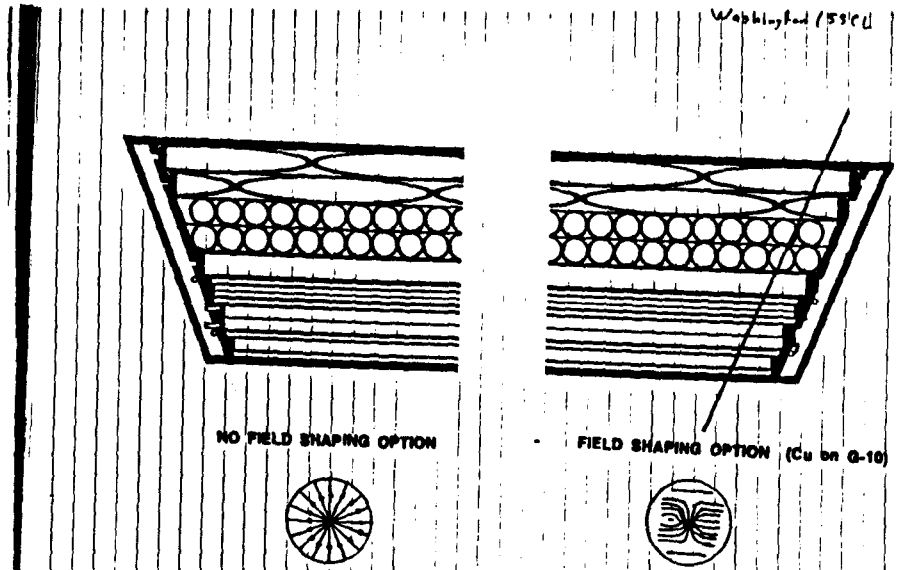


$V_{sense} = V_{drift} - 4800$ Volts

50 μm sense wire

839



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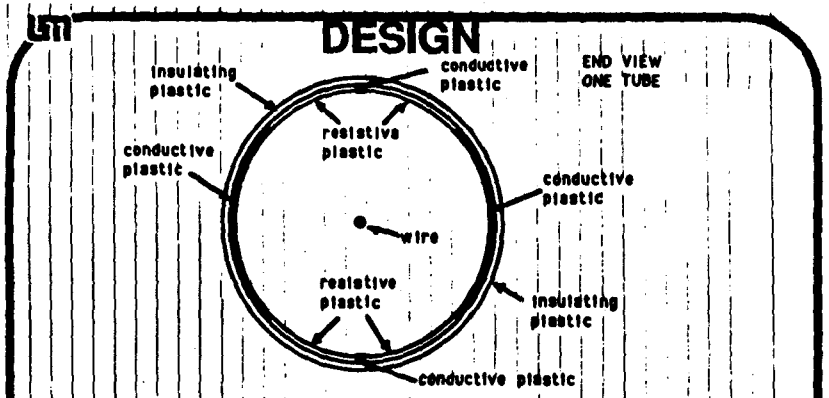


Tri-extrusion of 3 polyester plastics

Insulating shell – 0.07" Eastman PETG

Resistive electrode – 0.02" DuPont Hytrel # 5544

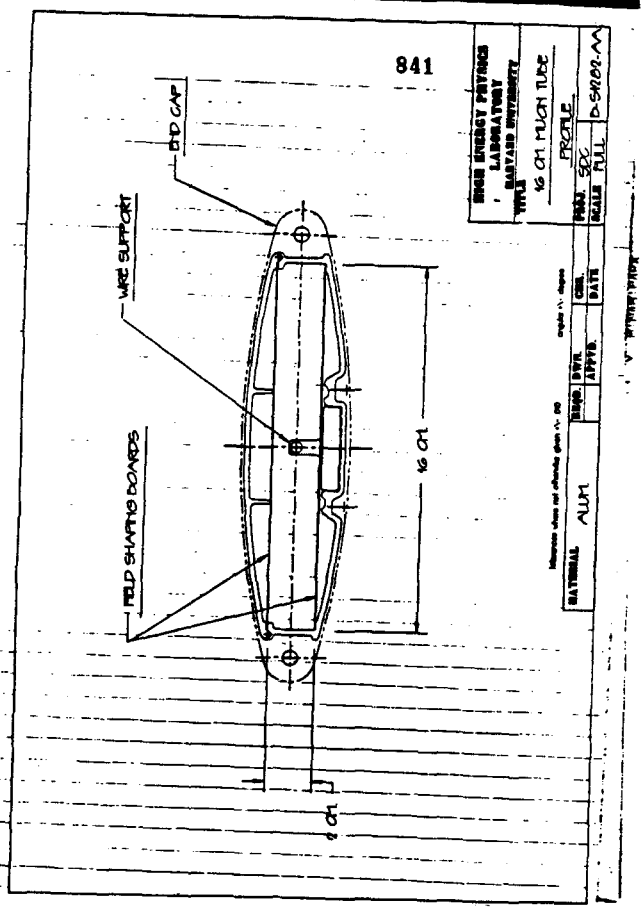
10^{12} Ω / square

Conductive electrode – 0.02" Hitech conductive polyester

0.6 Ω cm

840

841



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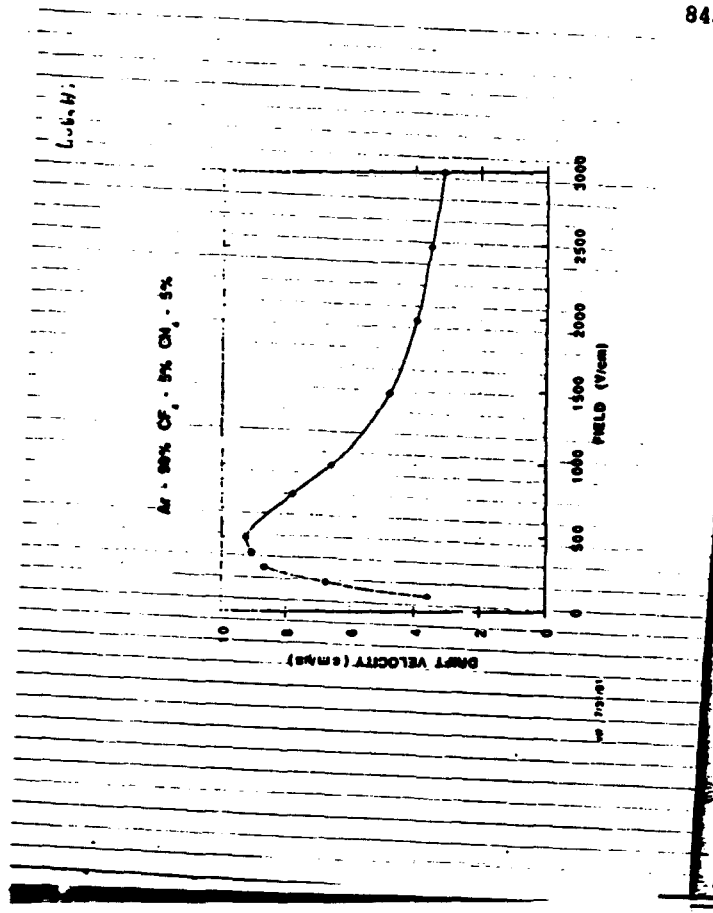

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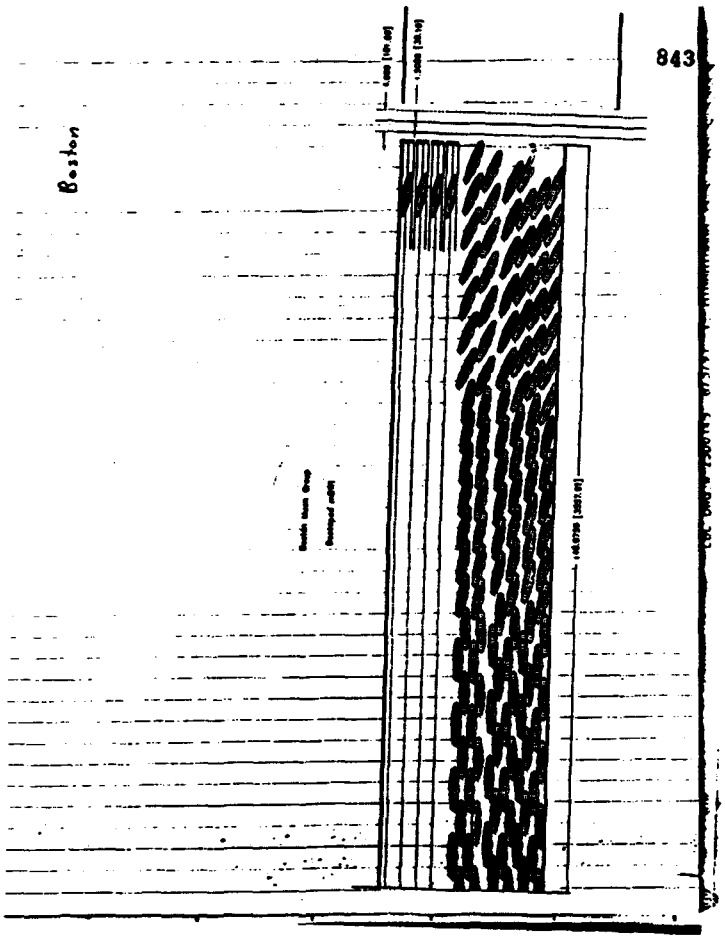

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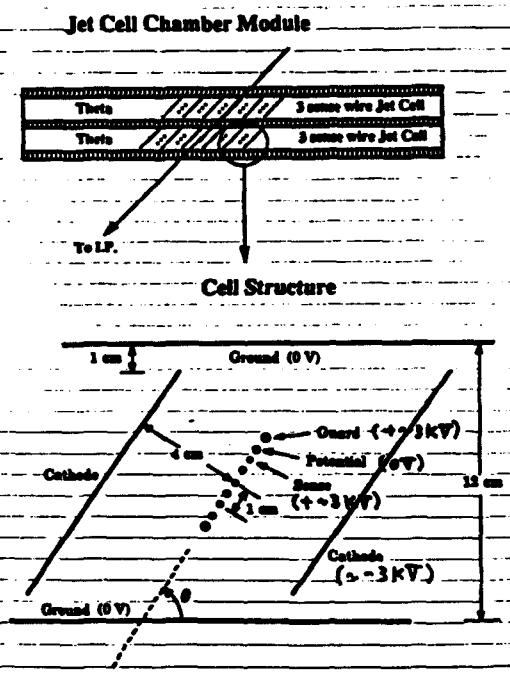
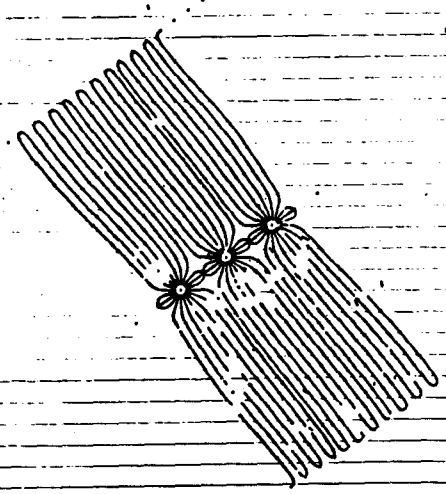
Slanted Jet cell partitioned with stiff cathode plates placed in a rigid box frame



Equal Drift-Time Contours

3 Sense Wires

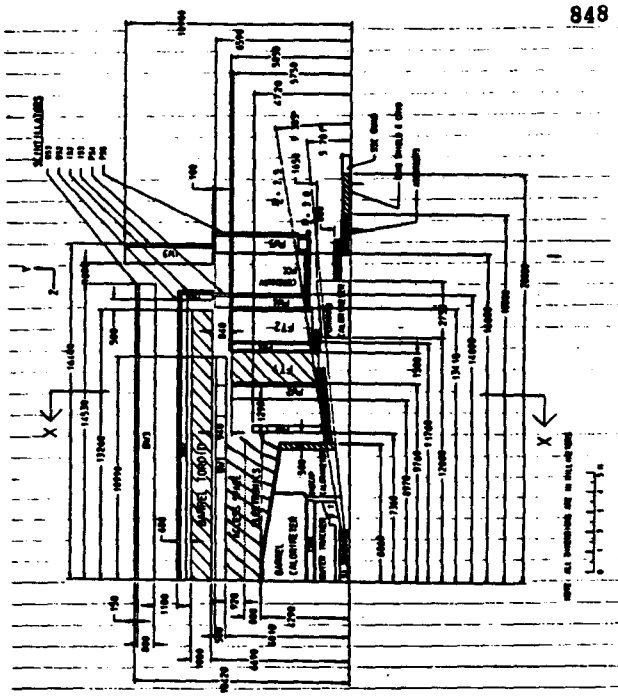


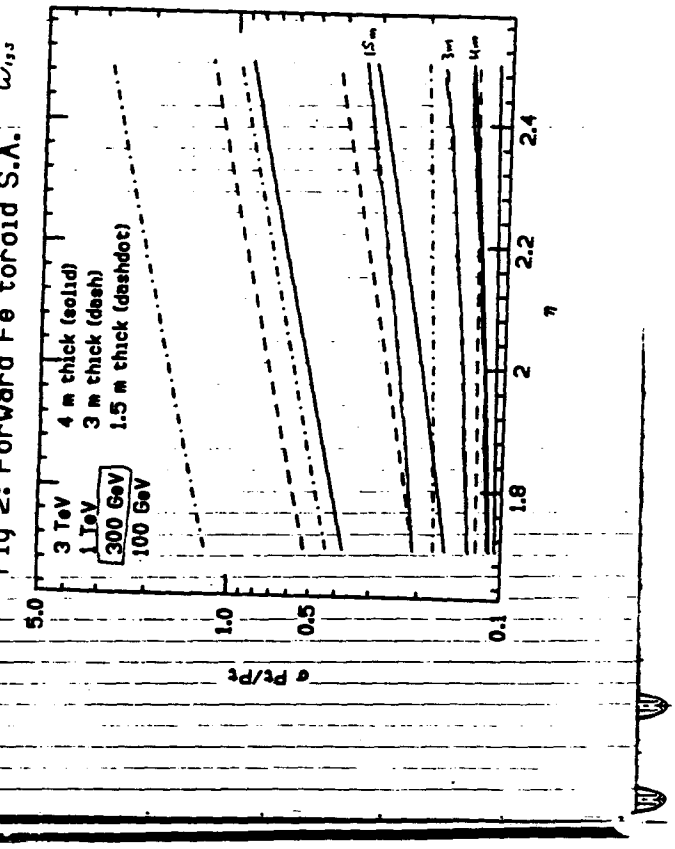
Summary of chamber styles

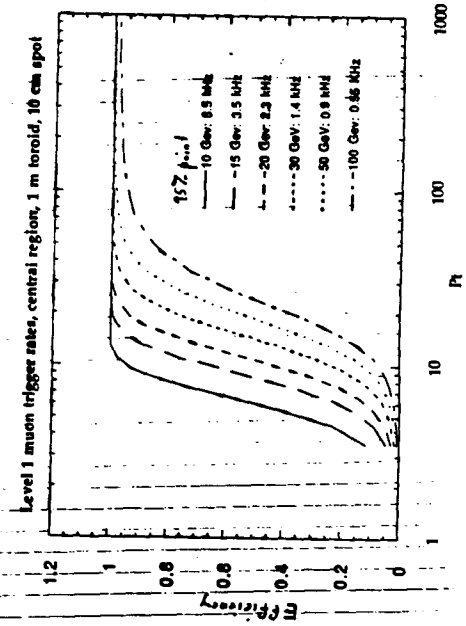
Item/Group	Wisc/ Md	Wash/ SSCL	Boston	Japan
Cylindrical(C) or Shaped (S) Field	C	C /S	S	S
Supported (S) or Unsupported (U) Wires	U	U	S	S
Drift (cm)	4	4	8	4
Individual Tubes (I) or Chambers (C)	I/C	I	I	C
Trigger	Δt	Δt	Δt	Δt + Σt

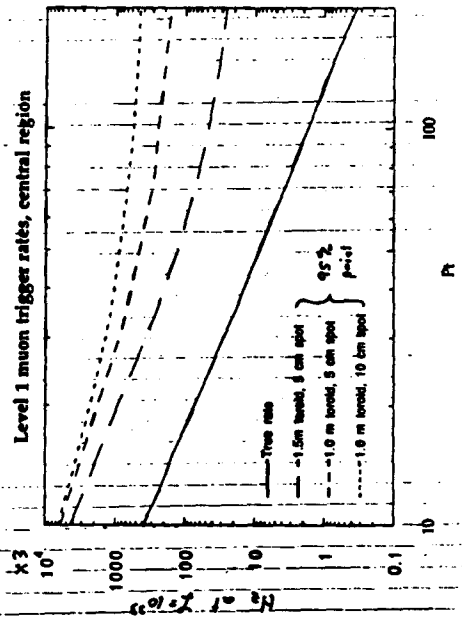
Descoping Decisions

- Access/electronics space is very expensive, 15 M$/(radial m). How much of it do we need?
- Barrel toroid steel is even more expensive, 26 M$/(radial m), but it appears too risky to the first level trigger to go below 1.5 m.
- Forward toroidal steel is worth 6.5 M$/m. For reasonable amounts of iron, this is a resolution issue. We think going from 4 m to 3 m is reasonable, but going to 2 m gives up too much resolution. (We presently have more muon resolution in the forward direction than GEM.)









• We have argued about the justification of every chamber in the system and have come to the following minimal configuration for the barrel:

	LOI	Descoped
BW1	6θ 4φ 2s	4θ
BW2	4θ	4θ
BW3	6θ 4φ 2s	4θ 4φ 2s
Total	28	14 ~~18~~

• Emphasis is on θ layers, because that is the direction of the the 1st level trigger and the redundant momentum measurement. However, the φ direction is equally important, because it is essential for the 2nd level trigger. We have reduced it to the bare minimum and moved it to the outside to save money and get to a region of lower occupancy. This still needs further review.

- We retain all 28 layers of chambers in the forward direction, as they are needed for a reliable momentum measurement.

- The scintillator counters have been descoped to a single photomultiplier per counter.

Bottom line:

Revised LOI cost:	148 M$
Descoped cost:	115 M$ - 15 M$/m of radial space saving.

FRONT END ELECTRONICS SUMMARY

H. WILLIAMS

Overview of Calorimeter Readout

- Shower max. readout can use same electronics as "analog calorim readout"
- With present trigger baseline, "digital" and analog calorim readout have very similar overall architecture.
  - same crates, readout controller, control signals, L1-L2 storage
- Digital Readout
  - 18 PMt / card
  - 13 cards / crate
- Analog Readout
  - 64-128 ch/card

"BASELINE" DESIGN IMPLEMENTATION for DIGITAL PMT READOUT SYSTEM

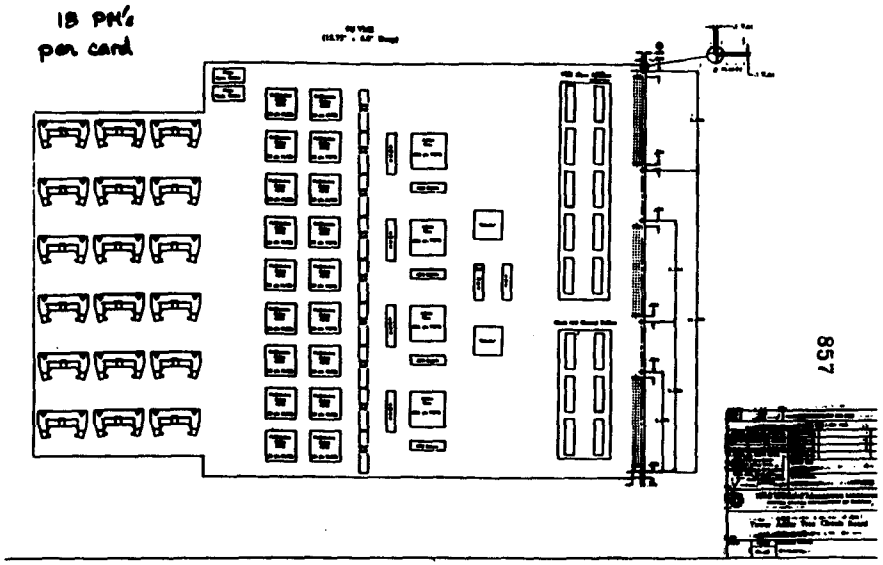
BILL FOSTER AUG '91

TWO COMPONENTS:

1. PMT BASE/DIG.
2. DIGITAL READOUT & TRIGGER CARD (VME SLAVE)

- GATED INTEGRATOR
- FADC
- COCKROFT-WALTON HV SUPPLY + MONITOR
- ~16 events local digit storage

Standard Card, Crate.



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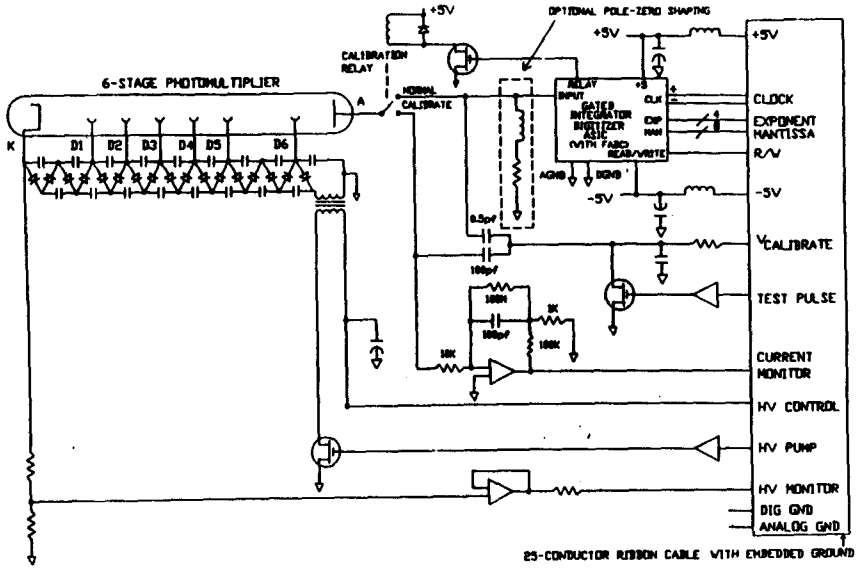
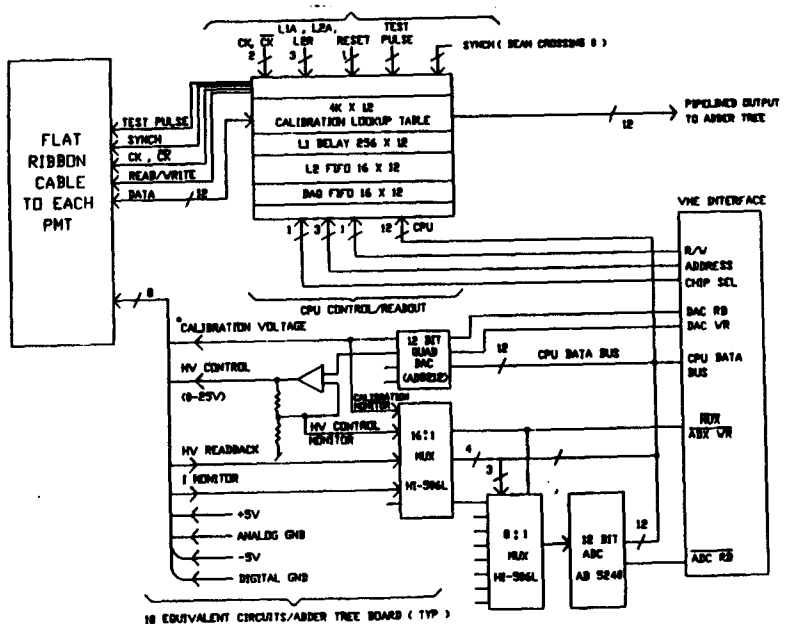


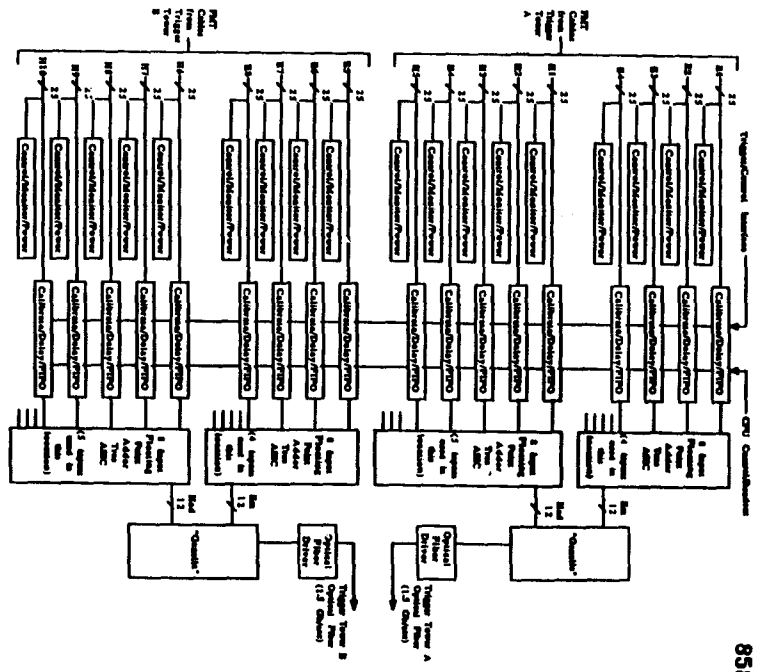
SDC SCINTILLATING TILE
PHOTOMULTIPLIER TUBE CIRCUIT SCHEMATIC

859



TOWER ADDER TREE CIRCUIT BOARD
PMT INPUT CIRCUITRY

860



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SCA CARD

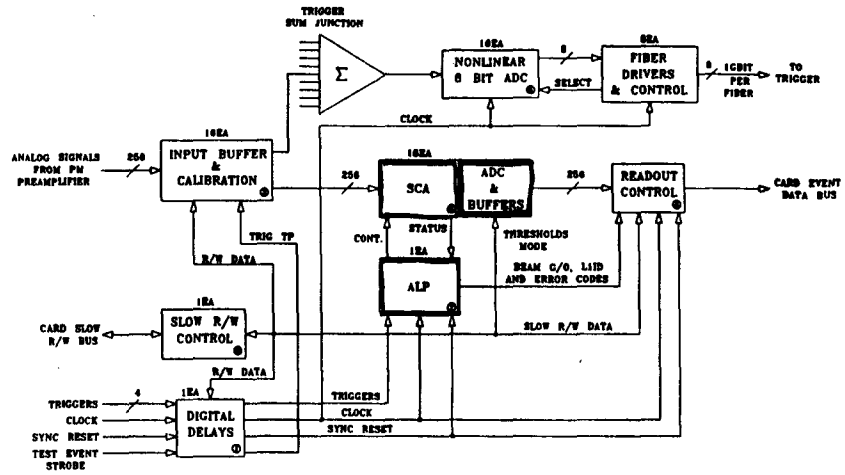
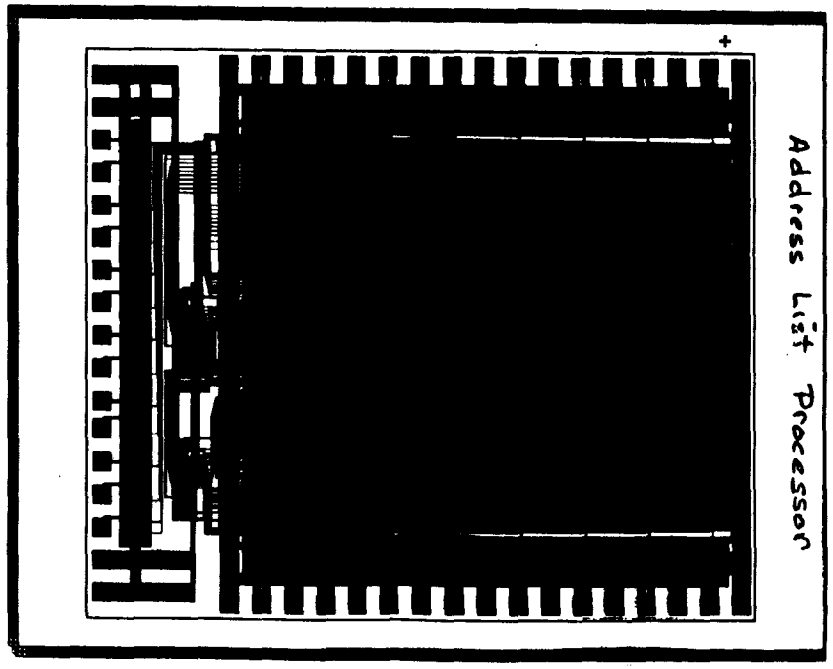
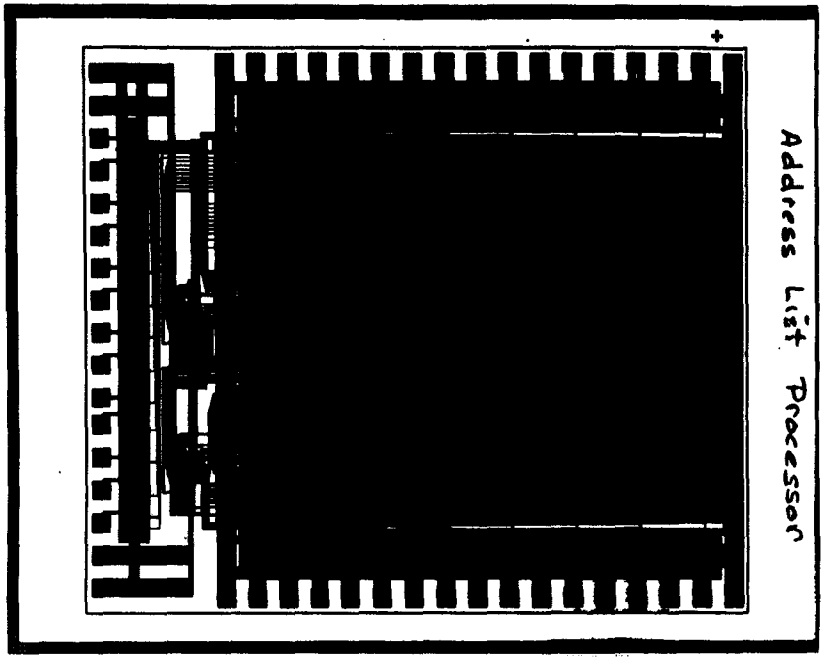
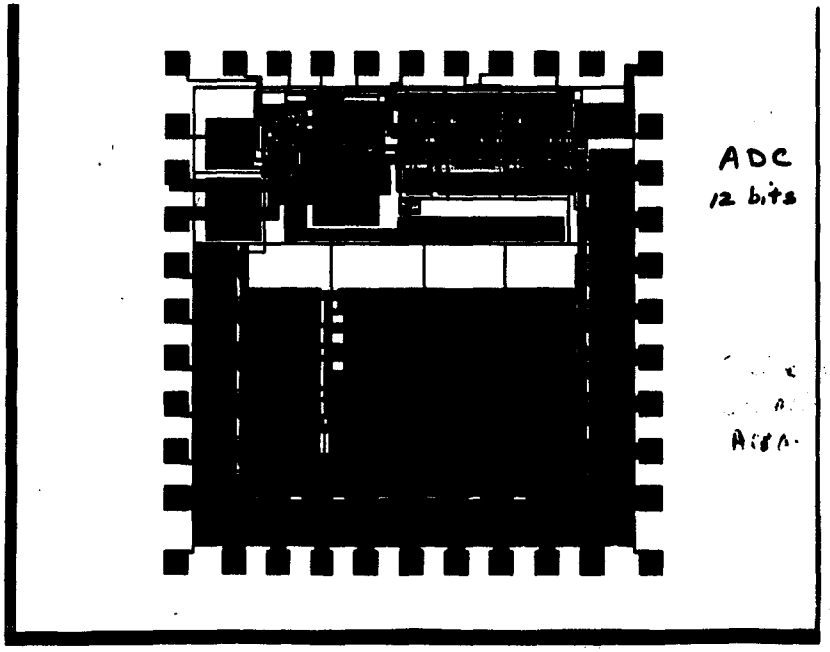


Figure 4.6







Chip Parameters:

865

SCA Parameters	Achieved Performance
No. channels/chip	16
No. of elements/channel	256
Power/channel	10 mW
Non-linearity	+/- 0.1% (½% of reading)
Pedestal variation	0.5 mV rms
Charging time constant	1.5 ns
Channel dynamic range	5000
Maximum sample rate	90 MHz
Maximum readout rate	200 KHz
Noise floor	0.7 mV rms
Input voltage range	0.2-4.8 Volts
Capacitor droop rate	0.1 mV/msec
Output Settling Time	1.2 µsec (to 0.02%)

Current Status:

Work continuing on maintaining large dynamic range.

Learning how to reduce effects of digital noise.

ADC being integrated with SCA.

Design Work in Progress:

1) Design an Analog Store with 5 volt Differential Inputs
2) Address Generation & Pointer Manipulation
3) High Speed Preamp & Shaper

866

Implications on Front End Elec / Trigger of Liq. Argon / Scintillator

Readout / Trigger path nearly identical.

Readout

samples (readout) / event
3 scintillator, 3-5 Liq Argon

For Liq Argon, read negative as well as posit

- Sparsification should be OK for Liq Argon
- DSP on SCA board to do signal processi optional
- Readout without sparsification prob. OK

Triggering

Same basic scheme for Liq Ar / scintillator

Liq. Argon would have:
- amplitude + time bit or (better)
- extra chip + 5 pipeline steps on trigger board to derive time
  possibly improve amplitude

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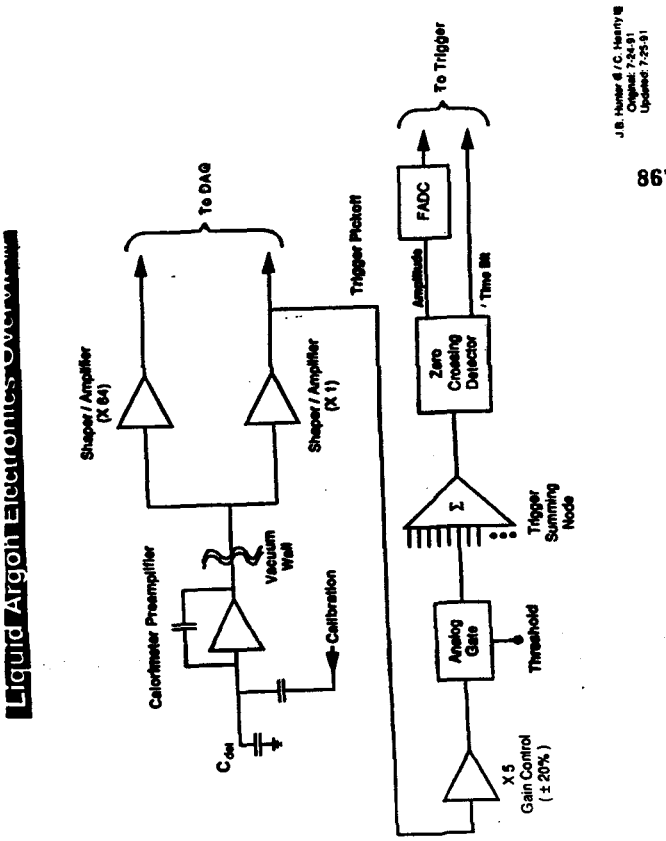

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Preliminary conclusion:

The choice of calorimeter technology does not have significant impact on electronics, DAQ, or triggering.

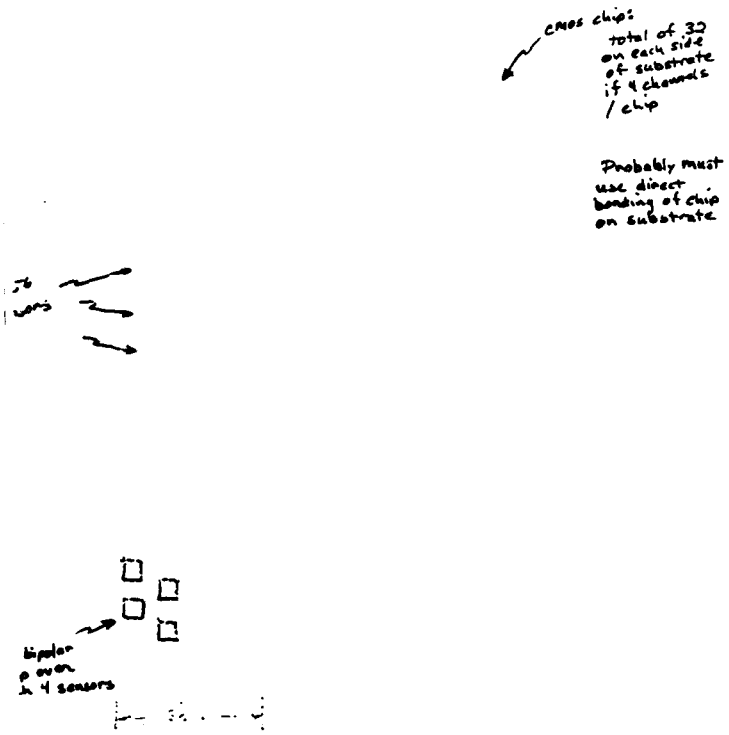
Straw Tube Readout

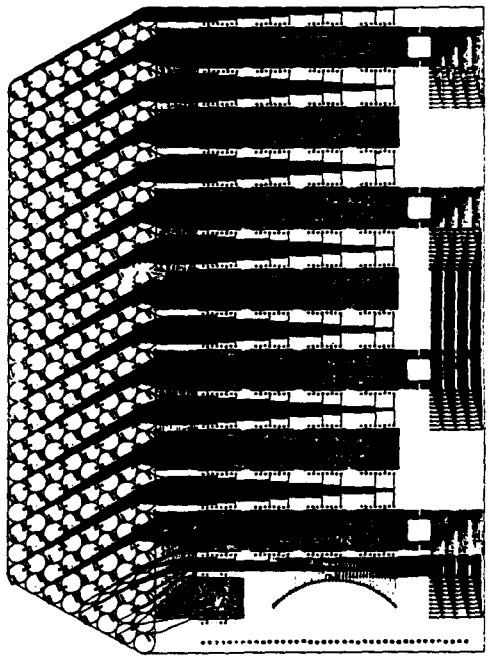
Effort in Japan

- TMC has demonstrated performance & Level 1 storage.
- Can be redesigned to allow 4 μsec storage.
- Radiation-hardness promising
- Material & Cost needs better evaluation
- Pursue packaging in hybrids

Effort in US

- Progress on TVC/AMU — all pieces simulate at 60 process looks good to 2-Mrad
- Preamp/shaper good to > 2 MRads
- Pursue chip-on-substrate mounting lower cost & mass?
- Preamp/shaper/disc about to be fabricat





Scintillating Fiber Readout

* Nothing new on logic after discriminator (i.e. logic after receipt of signals from Rockwell)
* Reasonably straight forward
* Independent Cost estimate desired (as for all systems)

Muon Readout

* Nothing really new; will mostly follow straw design. Refined cost estimate desirable.

Trigger Pipeline Length

SCA "uncomfortable" at 4 μsec

Digital Calor. & scintillating fiber "don't care"

Charge readout of silicon strips appears to have significant problem for ≳ 3 μsec

strongly suggest trigger group design for ≈ 3 μsec. (implications for muon drift)

877

DAQ review (by DAQ group) Sept 5 (am)

Review of Front End Systems Sept 9-11 (?)
1st of two steps; second in December

878

DAQ SUMMARY

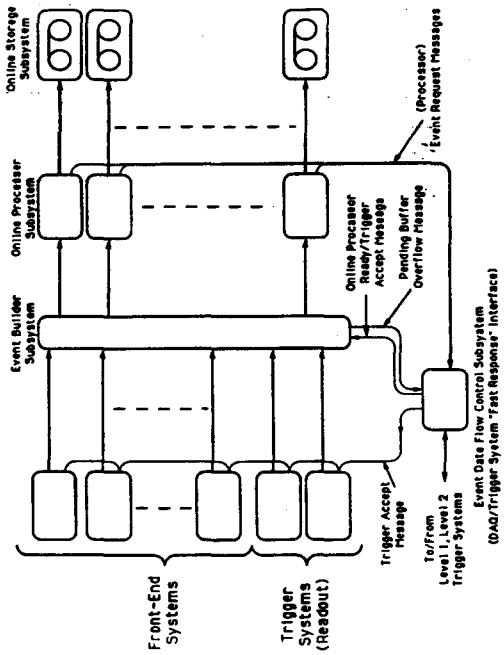
I. GAINES

Data Acquisition Topics

879

1) Revised baseline design
2) Conceptual design review
   FNAL Sept 5
3) M. Nomachi - DAQ R&D at KEK
4) R. Partridge - Baseline options
5) Meetings w on-line
   slow controls

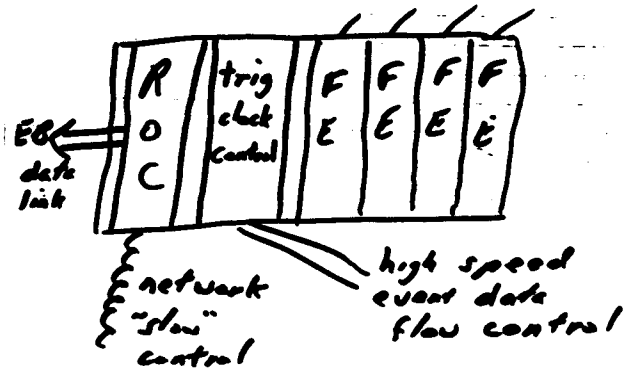
880



Simplified Block Diagram
Of Costed Data Acquisition System Architecture

Standard DAQ crate

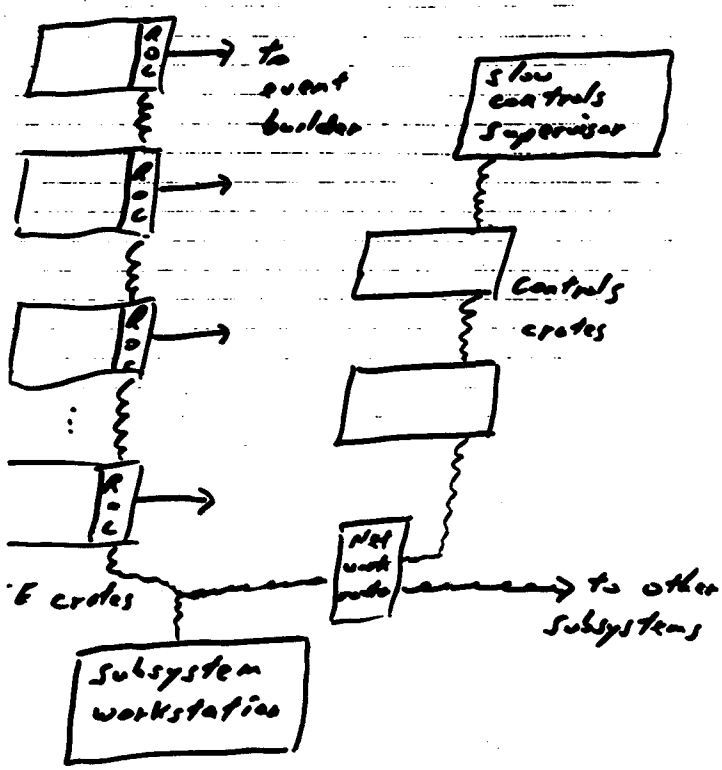
881



Standard (commercial) crate and backplane (augmented with SDC specific signals)

For each subsystem:

882



DAQ Conceptual Design Review

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FNAL Thurs, Sept 5

1) Review DAQ requirements

2) Discussion of baseline design and options

3) Organization for technical proposal preparation

4) Schedule / Milestones
   - Identification of critical path items
   - When do we need to make technology choices

5) FY92 R&D and Engineering Budget

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OPTICAL TRANCEIVER

development at KEK

6U VME module

8 MB/sec max with TAXI (120Mbps)

is made for SDC test module

will be used at KEK B-factory

SDC Meeting at LBL

August, 1991

Masaharu NOMACHI

KEK online group

LBL 1-a
M. Nomachi
29-July-1991
@final

R & D on 1Gbps switching

- optical switch
- ECL (FUJITSU) switch

SDC Meeting at LBL

August, 1991

Osamu SASAKI

KEK electronics group

Masaharu NOMACHI

KEK online group

LBL 1-b
M. Nomachi
29-July-1991
@final

Large scale barrel shifter using high speed ECL chip

- ECL (FUJITSU) switch
- 512 x 512 barrel shifter
- Addressable FIFO

SDC Meeting at LBL

August, 1991

Masaharu NOMACHI

KEK online group

LBL 1-c
M. Nomachi
29-July-1991
@final

SUBSYSTEM CRATE

CPU	DAQ CONTROL	LOCAL TRIG	UNUSED	UNUSED	UNUSED	UNUSED	UNUSED	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT	DATA COLLECT

FARM CRATE

DPM EB	REMSERV EDU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU	FARM CPU

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Meetings with on-line & slow controls groups

On-line (Alan Fry)
- Requirements
- Conceptual design

On-line + controls (Tom Moore)

"Partitioning" of SW jobs:

- controls & on-line provide tools/templates/building blocks
- DAQ writes application code
  - alarms/error logger
  - "slow" DAQ
  - system start-up
- Users write specific applications
  - subsystem monitoring/calib.

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TRIGGER SUMMARY

W. SMITH

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Trigger Systems

Recent + Future Activities

Simulation Efforts

Trigger Baseline

Trigger L1 Pipeline Length

Trigger Standardization (+Costs)

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Trigger Meetings:

Madison, Jul 17-19
- Review of Trigger Designs for L1 + L2
- Determination of Trigger Strategy.
- Proposal for Level 1 Trigger Baseline
- Discussion of Level 2 Baseline.
- Proposal for Level 1 Pipeline Length
- Development of Interfaces to FE + DAQ
- Review of Trigger Simulation

SSCL, Sep. 11:
- Review of Trigger R+D Program

October:
- Review of Trigger Conceptual Design

December:
- First Pass at Trigger Design Choices (Upstairs vs. Downstairs)

Trigger Simulation Effort

⇒ Fast Parameterized MC for Trigger Studies

Overall Organization – G. Sullivan, U. Chicago

Silicon Tracking – B. Foster, U. Bristol

Fiber Tracking – R. Lewis, Penn State

Straw Tracking – J. Chapman, U. Mich

Calorimetry – G. Sullivan, U. Chicago
W. Temple, U. Wisconsin

Muons – J. Chapman, U. Mich
K. Johns, U. Arizona

Status: Running on VMS at U. Chicago, U. Wisconsin
on UNIX at SSCL PDSF.

Goal: Update (and include) detector elements by end of August,

Add New Generators, check against CDF

Make High statistics samples

SDC Baseline Trigger Design

(Input from Madison Trigger Meeting July 17-19)

Requirements: Trigger Efficiently on:

Electrons from inclusive W's } 50% of theoretically possible
Muons from inclusive W's

Jets at high P_T } overlap existing σ over 1-2 decades
High P_T Photons

Missing E_T (SUSY, $H \to ZZ \to \ell\ell\nu\nu$)

Multilepton low P_T Trigger (B physics)

Trigger Baseline

Input to Level 1 Trigger

Calorimeter: 8 bits E_e, E_h in .1 x .1 towers

Shower Max: Hits in .025 ϕ bins

Central Track: 4 bits P_T in .025 ϕ bins

Central/Inter Muons: 4 bits P_T in .05 η x .4 ϕ bins

Input to Level 2 Trigger

Central/Inter. Silicon Tracking

Full shower Max Information

Full Muon Coordinate Information

Level 1 Trigger Baseline

Electron: Cal: Isolated e/h
Track: Match w/ Cal: ϕ
Show Max: ϕ Match

Muon: Muon Track > P_T only

Jet: Energy in .4 x .4 Tower > Thresh

Photon: Electron w/o Track match

E_T, $\not{E}_T$: Global Cal. Energy Sum

Level 1 output: 10-100 kHz

Design Technique: ① Calculate basic trigger primitives on detector.

② Transmit to Counting House on surface at 1 Gb/s on optical fibers (#300/link ≈ 35% counting)

③ Do Trigger calculations in C.H. and transmit decision back to detector

Level 2 Trigger Baseline

Outer Tracking - Muon Match
⇒ Tighten P_T cut

Silicon - Outer Tracking Match
⇒ Intermediate Angle
⇒ Eliminate Conversions

Shower Max Isolation + Track Match (e only)
⇒ Tighten Electron + Photon Cuts (E/p)

Output Rate: 1 kHz

Design Technique:

If subsystem sends data to L1, store and use for L2 calculations
(send enough info. to L1 for L2 needs)

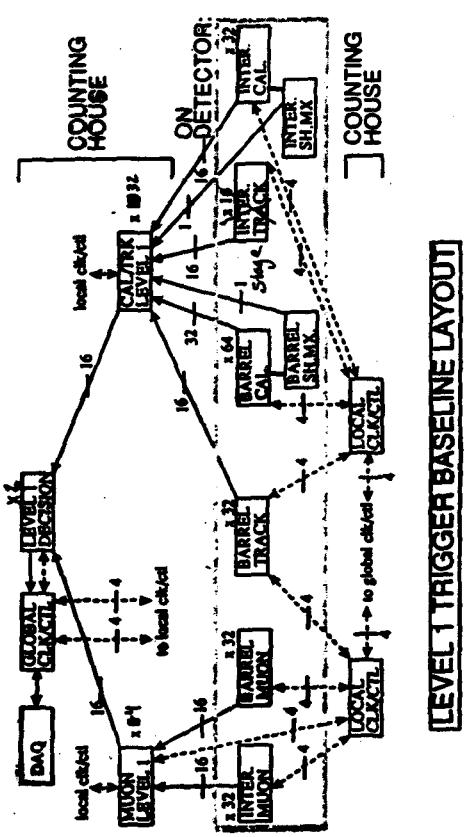
If subsystem does not send data to L1 use DAQ path if possible. otherwise send heavily muxed data up on fibers.

(Elimination of data path: cost savings)

Baseline Level 1 Trigger Table

(compiled by G. Sullivan, U. Chicago)

Trigger	E_T (GeV)	η	σ (μb)
Electron	15.	$\lvert\eta\rvert < 1.6$	3
(no track match)	30.	$1.6 < \lvert\eta\rvert < 3.0$	
Photon	35	$\lvert\eta\rvert < 1.6$	1
Muon	15		1
Jet	150		1
2 Electrons	10	for both	1
2 Muons	10	for both	1
e/μ	10	for both	1
$\not{E}_T$	140		1
ΣE_T	1000		1
Prescaled Electron	10		
Prescaled Muon	10		
Prescaled Jet	100		



LEVEL 1 TRIGGER CRATES

1. Calorimeter-Track (32) or $1.6 < \eta < 3.0$
   (covers $0 < \eta < 3/2$, $\Delta\phi = 0.8$)
   - 8 Calorimeter Logic Boards
     - Receive Data from Cal Crates for ($\Delta\eta = .4, \Delta\phi = .8$)
     - Sum E_T, E_x, E_y in (.4 x .4) Regions
     - Find Cal. Iso. em deposits
   - 2 Track Logic Boards
     - Collect Tracks from Barrel or Inter. ($\Delta\phi = .8$)
   - 2 Cal/Trk/Shmx Match Boards
     - Receive Sh. Mx. Hits for ($\Delta\eta = 1.6, \Delta\phi = .8$)
     - Match Trk + Cal. Iso. em + Sh.Mx.
     - Sort Resulting e's.
   - 1 Regional Logic Board
     - Sort Electrons
     - Collect .4 x .4 Regions > thresh.
     - Sum E_T, E_x, E_y
     - Transmit Results to Level 1
   - 1 Clock/Control Board
   - 1 Crate Processor (DAQ Interface)

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2. Muon Crate (4)

(covers $0<\eta<3$, $\Delta\phi=4\pi$)

16 Muon Logic Boards

Receive Muon Tracks from 3 Muon Crates ($\Delta\phi=\pi$)

Sort & Test against thresholds

1 Regional Logic Board

Collect Muon Tracks from Receivers

Transmit Muon Tracks to Level 1

1 Clock/Control Board

1 Crate Processor (DAQ Interface)

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3. Decision Crate (1)

8 Cal/Trk Result Boards

Receive Results from 4 Cal/Trk Crates

1 Muon Result Board

Receive Results from 4 Muon Crates

1 Electron Subtrigger Board

1 Muon Subtrigger Board

1 Jet Subtrigger Board

1 E_T Subtrigger Board

1 E_{miss} Subtrigger Board

1 Final Trigger Decision Board

1 Control Interface

Communicates with Global Clock/Control

1 Clock/Control Board

1 Crate Processor (DAQ Interface)

4. Local Clock/Control Interface Crate (4)

16 Clock/Control Interface Boards

Communicate with 4 Front End or Trigger Crates

1 Clock/Control Master

Communicates with Global Clock/Control

1 Crate Processor (DAQ Interface)

Detailed Protocol on 4 Fibers

1: Subsys → Trigger: L1 Subsys. Control
2. Trigger → Subsys: L1 clock, cross Test
3. " ": L1 Control (Accept, Reject, [redacted])
4. " ": L1 Number (L1 ID, Bunch phase)

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5. Global Clock/Control Crate (1)

1 Interface to Machine Clock

1 Interface to Final Decision Module

1 Beam Pickup Interface

1 Deadtime Monitor Module

1 Clock/Control Interface

Communicates with 2 Local Clock/Control Crates

1 Crate Processor (DAQ Interface)

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TRANSMIT TRIGGER SIGNAL TO COMPONENT PIPELINE

Cause of Delay	Time (crossings)	
Global First Level Trigger Box		
1. GFLTB -> pipeline controller (nearby)	1	
2. Pipeline setup & synchronization	2	
3. Pipeline Controller -> Pipeline Fanout (far)	50	Possible → 42 i.e. (cryo tower) (clock m. ch.)
4. Local Fanout to Pipeline	10	
5. Phase between pipeline and sample	+/- 0.5	
Only for Some pipelines → 6. Loss of sample where pipeline stops	1	
7. Particle interaction -> pipeline front	-5	
8. Presamples	6	
9. Signal shaping for sample of rise	-1	
Total	**64**	(-9)

A total offset of 64 crossings requires the GFLT accept to be issued at a time 64 crossings less than the pipeline length.

TRIGGER DECISION TIME

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Cause of Time Delay	Time (in Crossings)
Calorimeter through Global:	
1. Propagation to Detector	6
speed 2. Digitization (incl. synch.)	4
÷2 3. Local Pattern Logic	21 (→ 16)
4. Regional Pattern Logic	12
5. Regional Correlations btw. Components	6
6. Transmission to Component Global Logic	14
7. Component Global Logic	15
8. Transmission to GFLT	50 (→ 42?)
9. GFLT Calculation	20
Total	**148** (→ 132 - 8)
Muon through Global:	
1. Propagation to Chamber	2
2. Drift in Chamber	50-100
3. Propagation along Wire	2
4. Segment Finder	2
5. Segment Linker	6
6. Transmission to GFLT	50 (→ 42?)
7. GFLT Calculation	20
Total	**132-182** (-8)

TOTAL PIPELINE LENGTH

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Cause of Time Delay	Time (in Crossings)
Calculation of Trigger Decision	
Reduce Calorimeter thru Global = 148* → < 132	
→ Muon through Global = 132 - 182	
	132 ~~148~~ - 182 (-8?)
→ Propagation of Trigger to Pipeline	64 (-9?)
→ **Total**	196 ~~212~~ - 246 (→ 17)
	= ~~3.4~~ 3.1 - 3.9 µsec (-.3µS)

*Note: Additional speedup in calorimeter trigger calculations can reduce 148 crossings below 132, reducing the minimum total pipeline length to 196 crossings or 3.1 µsec.

Trigger Design Goal = 3µS (µ Drift = 800nS

Safe Maximum for FE's = 4µS

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Standardization of Trigger Control/Cloc

Trigger Module in Every FE Crate:

Normal Operation: Pass Through

Send over bus/cable to FE Crate. distribution network ⟺ [Trigger Clk/ctl Module] ⟺ (optical fiber) Trigger Clock/Control Signals from/to Counting House (L1 Accept, etc)

Standalone Operation:

Identical

Communicate over bus/cable with FE Crate. distribution network ⟺ [Trigger Clk/ctl Module] ⟷ Communication with local Crate Processor + Trigger Electronics

Trigger clock/control Signals generated internally

⇒ Generate Test Pulse sequences.
Operates in Test Beams
Takes system offline for installation/Test
Single interface point for Trigger Integration

Summary

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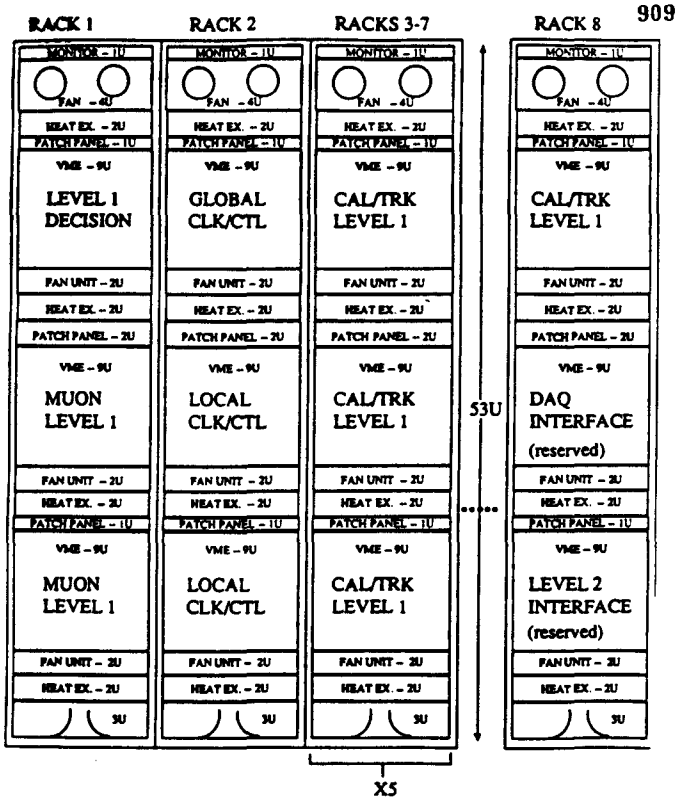
Table 1: Electronics Systems Costs (incl. Conting.)

WBS	System	Preliminary Estimate June ($M)	New Target Aug ($M)	Nov
5	Electronics	157.9	97	100
5.1	Front End	59.1	37	31-3
5.2	DAQ	42.3	25	26
5.3	Trigger	42.4	30	29
5.4	Controls	7.3	3	6
5.5	Power Conditioning	6.8	2	4

Total: 96-102



LEVEL 1 TRIGGER RACK LAYOUT

INSTALLATION SCENARIO AND SCHEDULE

D. BINTINGER

SDC

INTEGRATION MEETINGS

AUGUST 1991

DETECTOR CONSTRUCTION PLANNING

Bintinger
8/9 Installation Scenario - Schedule
Plenary
Integration

PREPARED BY:

ICF KAISER ENGINEERS INC.

August 6, 1991

SDC SCINTILLATOR CALORIMETER DETECTOR

CONSTRUCTION PLANNING AND SCHEDULING

The following represents construction planning and scheduling of the solenoidal detector inside the hall.

Three dimensional modeling in the workstation is being used to develop conceptual tools and fixtures and simulation of assembly status situations at different stages of construction to better visualize problems of access and space requirements.

The drawings that follow are in a state of development and do not represent final concepts as the design of the detector itself has not been finalized.

CONSTRUCTION SEQUENCE: Figures 2 through 43 show the construction sequence through month 41. There are two types of drawings shown. The monthly assembly sequence drawings which are coordinated with the schedule. Interleaved with the monthly assembly sequence drawings are sequences that show construction methods for some of the operations. These drawings are not yet coordinated with each other so that there are discrepancies that will be corrected as the job progresses. These discrepancies ocurr due to the trial and error method utilized in the design as well as the changes in the data received periodically from the different participants in the collaboration.

The monthly sequence drawings attempt to show the construction situation for the particular month shown. These drawings will include in the future, items such as scaffolding, temporary storage of jigs and fixtures, temporary shops, miscellaneous fork lifts and cherry pickers, all of which take space in the construction floor.

SCHEDULE: Figure 1 shows the latest version of the construction schedule of the detector for the underground portion only. This schedule is being coordinated with the construction sequence drawings that follow and it is being revised as the construction sequence methods are developed.

MONTH 0: This drawing (fig 2) shows the hall at beneficial occupancy. It includes the air conditioning of the hall as well as the two construction cranes.

Figure 3 shows the muon steel barrel supports with the hydraulic aligning system. This system is being revised at present and will include horizontal tie bars or beams between the supports.

MONTH 6: This drawing (fig 4) is self explanatory.

Figure 5 shows the barrel bottom layer of plates already installed and plates for octants 4 and 6 in the process of being installed. In the background, the assembly frame, utilized as a form for the rest of the octant plates, is being

assembly frame, utilized as a form for the rest of the octant plates, is being assembled.

Figure 6 shows the assembly frame already in place and plates for octants 3 and 7 being installed. Previously, the crossover bridges had been installed.

Figure 7 shows plates for octants 2 and 8 being installed. The walkways shown are bolted temporarily to the barrel plates and will be used for fastening the toe bolts that hold the plates together.

Figure 8 shows the octant 1 plates being installed.

MONTH 9 (figure 9) shows the status of the barrel steel assembly on month 9.

Figure 10 shows forward toroid number 2 being assembled. The bottom plates are placed on temporary cribbing and also on the Hillman rollers supports. After assembly, the hydraulic jacks placed on the Hillman rollers will lift the toroid and the temporary cribbing will be removed.

Figure 11 shows the forward toroid number 2 complete.

Drawings 12 and 13 show the forward toroid number 1 support and roller system. This support system was developed at a later date and differs from what is shown in other drawings. Each toroid weighs in the neighborhood of 2000 metric tons, so it requires four 600 ton capacity Hillman rollers to be able to move it.

Figure 14 shows the forward toroid steel assembly almost complete.

Figure 15 shows the steel for the forward toroids completed and muon chamber uFW3 being installed. Forward toroids number one and two are constructed separated by enough distance as to be able to have access to bolting and for assembly of the interleaving muon chamber. Later the toroids are moved to their proper seperation and bolted together as a unit.

MONTH 12 (figure 16) shows the muon barrel completed and the start of the installation of the muon chamber guides and of the barrel steel coils.

Figure 17 shows a coil segment being lowered to the hall floor. The picture illustrates the large size of this component and the problem of handling it through the construction shaft. The method of handlig these coils on the surface and through the construction shaft has not been adressed by this collaboration member at this time.

Figure 19 shows the installation of muon chamber guides inside the muon steel barrel. The tool used for this purpose is very conceptual and needs further development. The concept attempts to show the problem of operating heavy objects inside the muon steel where there is no crane access. This tool is to be used in the installation of muon chamber guides that may weigh several hundred pounds, barrel steel coil segments that weigh in the order of 8000 pounds, plus conduit, cable and gas lines for the muon chambers.

This tool has to be provided with walkways for installation workers and be flexible to reach most of the octants in the barrel.

Figures 19 and 19, show the method used to install muon barrel coil segments on the outside of the barrel steel.

The concept here is that the coil segment (which has to be fabricated and shipped in one piece) is attached to a hollow shipping frame large enough to avoid excessive coil deflection and which will allow a worker to crawl inside it to bolt the coil in place and to later free the coil from the support frame. Two cranes are needed simultaneously for this operation.

The inner coil segments are installed by the installation frame described above. Figure 20 shows the support beam with the coil being attached to the installation frame. The installation frame is later rolled into the barrel steel for the coil installation (see figure21). The tool is provided with rotation capabilities and with hydraulic cylinders that allow the tool operator to position the coil segment in its final location.

Figure 22 shows the installation tool rotated 45 degrees to enable it to install a coil segment in octant 2. The figure also shows the crane holding a walkway for bolting to the barrel steel. This walkway will be later used for the installation of muon chamber truss guides as shown in figure 23, plus elctrical conduits and gas lines.

MONTH 15: This drawing (figure 24) is self explanatory.

MONTH 19: This drawing (Fig 25) shows the muon chambers installed in octant 9, otherwise the picture is self explanatory.

Figure 26 shows a muon chamber panel being installed on octant 4. The tool used for this purpose includes guides that match with the barrel guides. One end of this tool is bolted to the barrel steel temporarily until the muon chamber is rolled onto the barrel steel. Two trolleys are used to pick up the tool and rotate it into position.

Figure 27 shows the method of pick-up of the tool and chambers when vertical panels are to be installed. The crane in this case utilizes the main hook and an auxiliary hook to control rotation.

Figure 28 shows the tool as it is used to install a panel on octant 2.

MONTH 19 (fig 29) shows the central calorimeter being lowered to the hall floor, while progress is being made in the assembly of the and toroids.

The central calorimeter weighs in the order of 4000 metric tons. In order to lower the calorimeter to the hall floor, a system was designed to make this operation as inexpensive as possible. The system consists of a frame on top of which the calorimeter is rolled. This frame is held by four hollow hydraulic jacks that operate on a bundle of cables (see fig 30). The frame is then lowered to the hall floor by slow reciprocating motions of the jacks (see fig 31).

The calorimeter and its supporting frame are detached from the jacking system and rolled over to the steel barrel (see fig 32). The frame is designed to match the height and rail system of the permanent calorimeter supporting frame.

Figure 33 shows progress up to MONTH 21.

Figures 34 through 36 show the method of installation of the rear absorber, muon chambers and the Cerenkov counter on the and toroids. We have been informed that the design of both the muon chambers and the forward calorimeter/obsorber system is being redesigned, so no more work is planned on this system until the revised design is received.

MONTH 24 through month 41 are shown on figures 37 through 42, and are self explanatory.

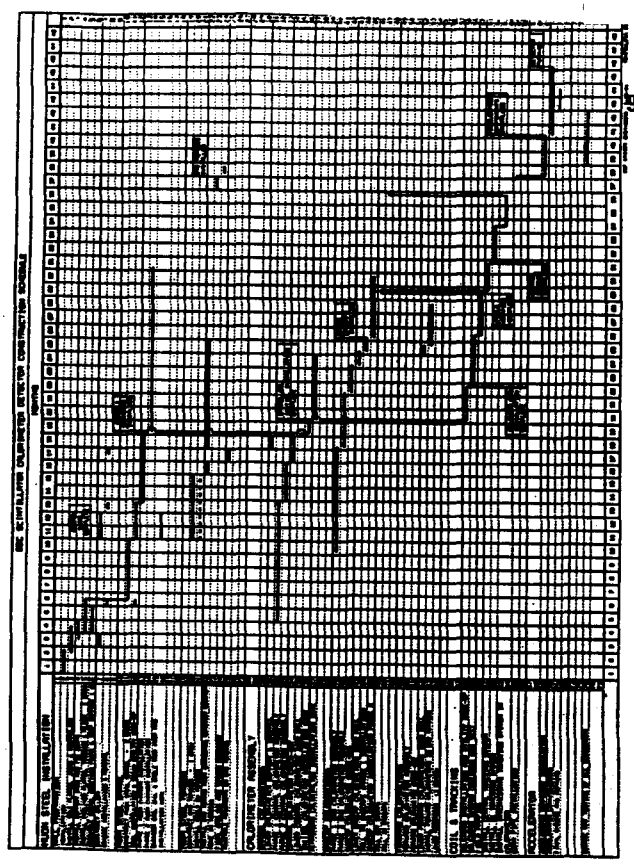
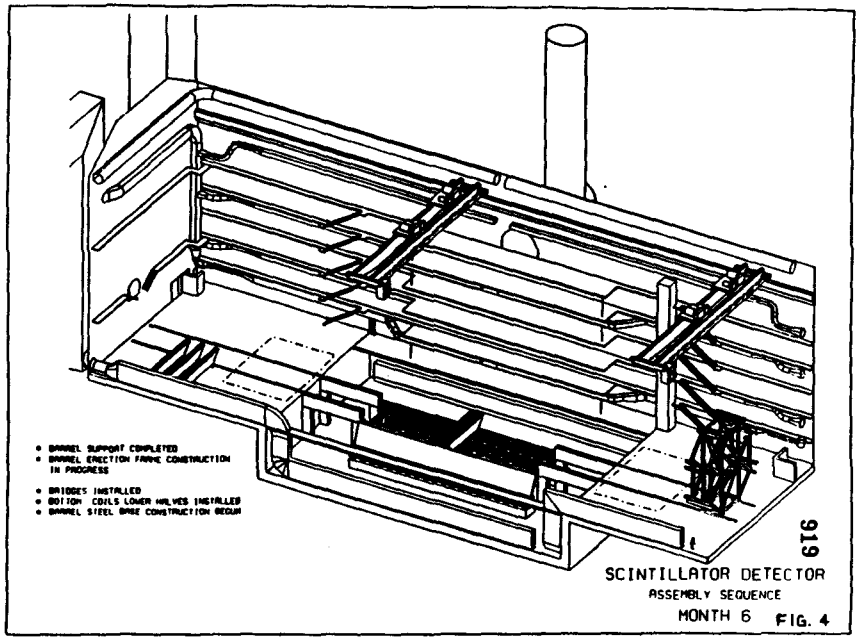
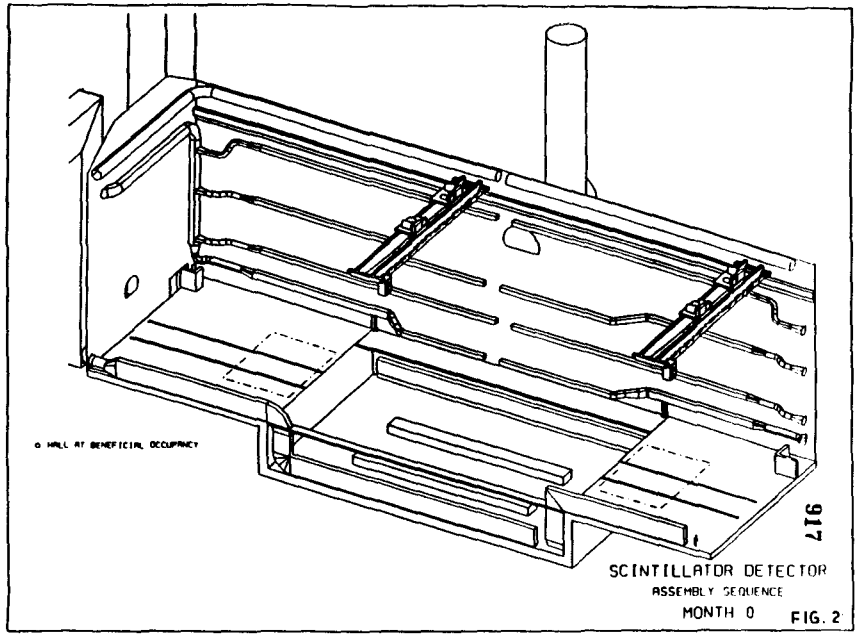
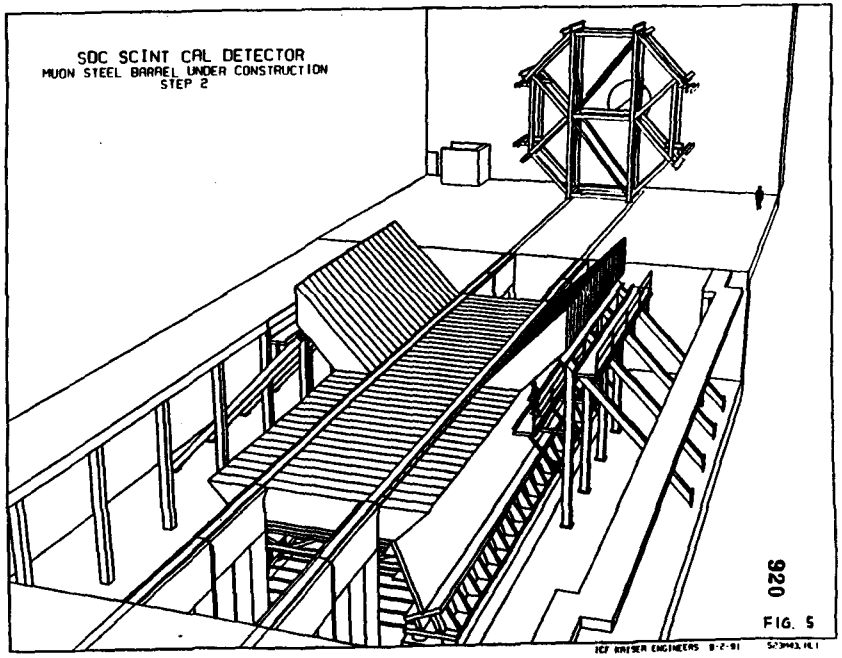
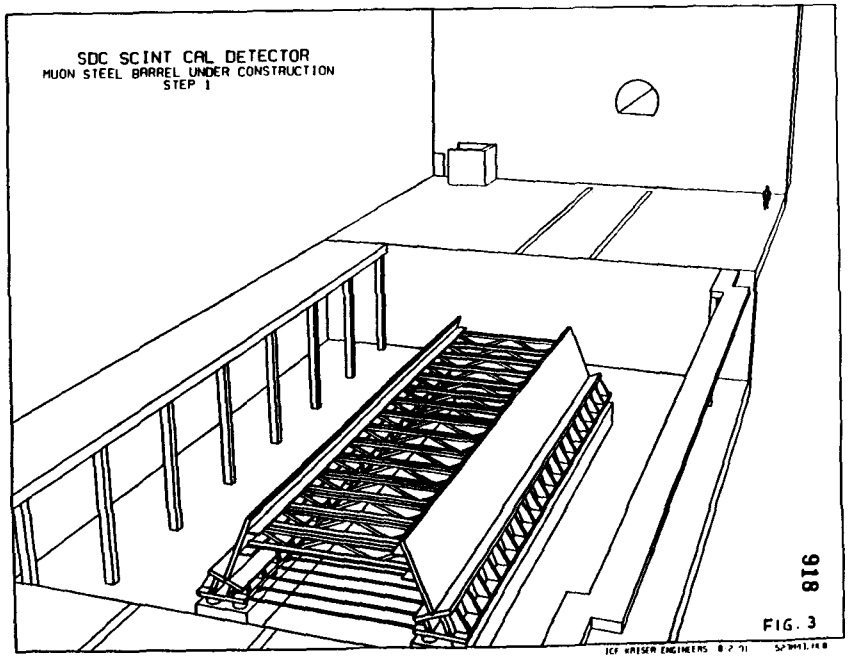


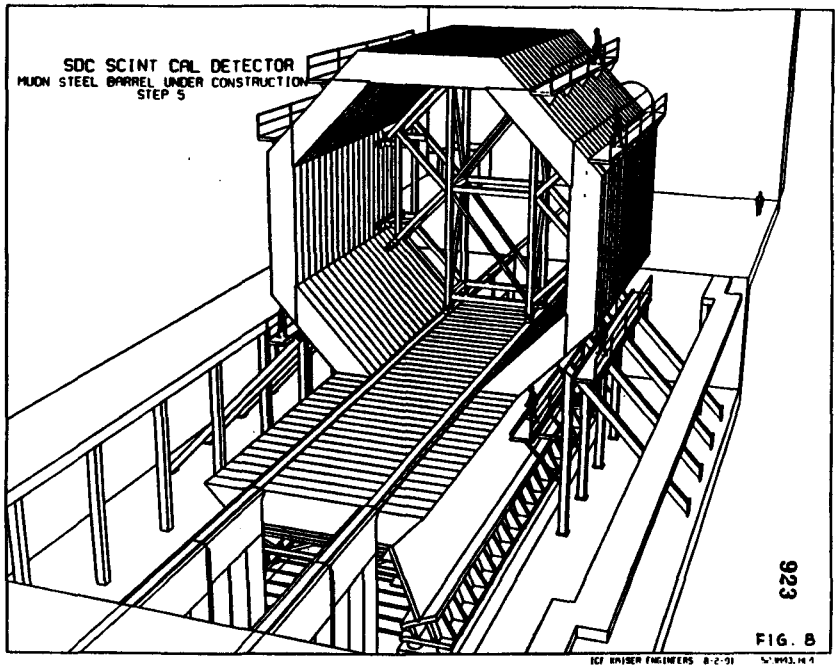
FIG. 1


• BARREL SUPPORT COMPLETED
• BARREL ERECTION FRAME CONSTRUCTION IN PROGRESS
• BRIDGES INSTALLED
• BOTTOM COILS LOWER HALVES INSTALLED
• BARREL STEEL BASE CONSTRUCTION BEGUN
919
SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 6
FIG. 4


• HALL AT BENEFICIAL OCCUPANCY
917
SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 0
FIG. 2


SDC SCINT CAL DETECTOR
MUON STEEL BARREL UNDER CONSTRUCTION
STEP 2
920
FIG. 5


SDC SCINT CAL DETECTOR
MUON STEEL BARREL UNDER CONSTRUCTION
STEP 1
918
FIG. 3


SDC SCINT CAL DETECTOR
MUON STEEL BARREL UNDER CONSTRUCTION
STEP 5
923
FIG. 8
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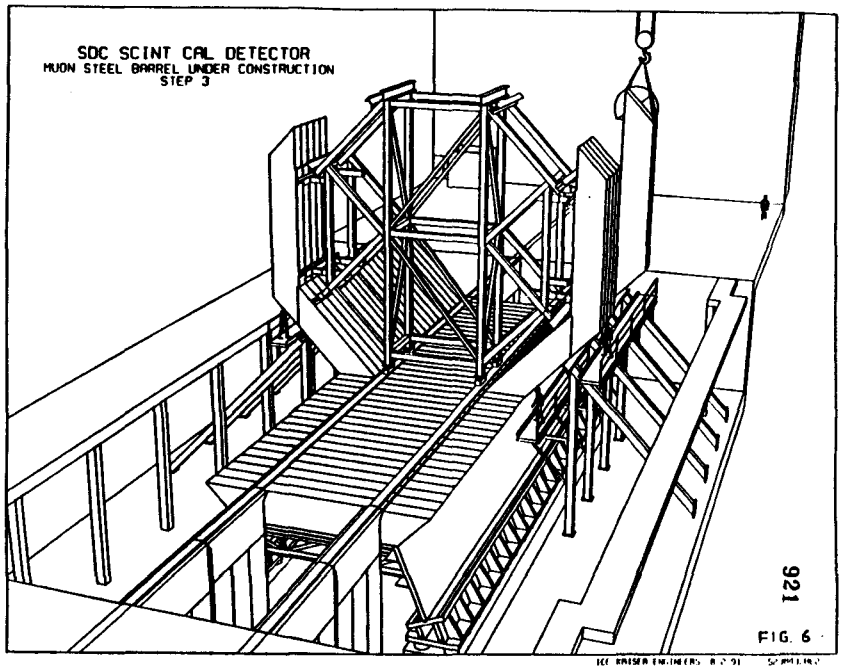
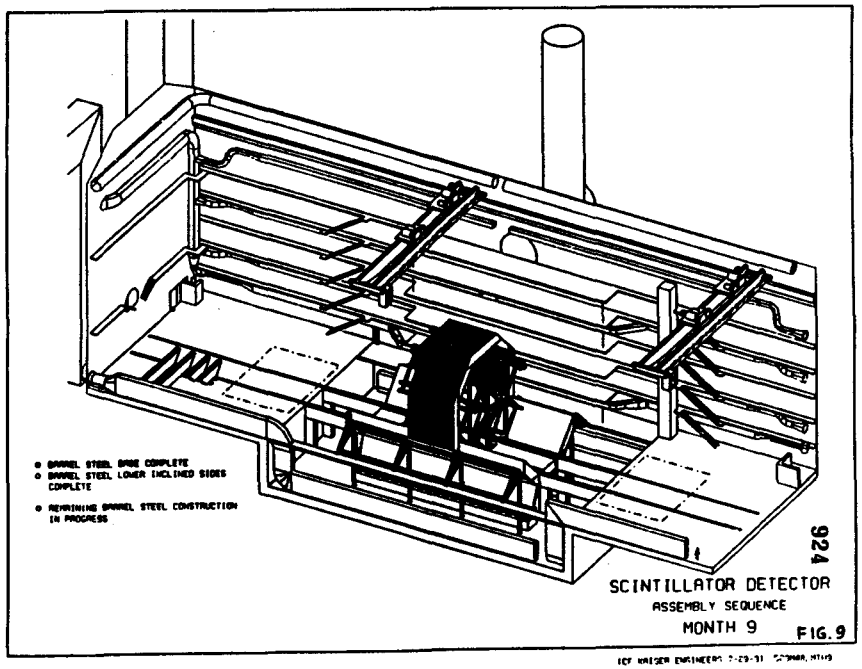
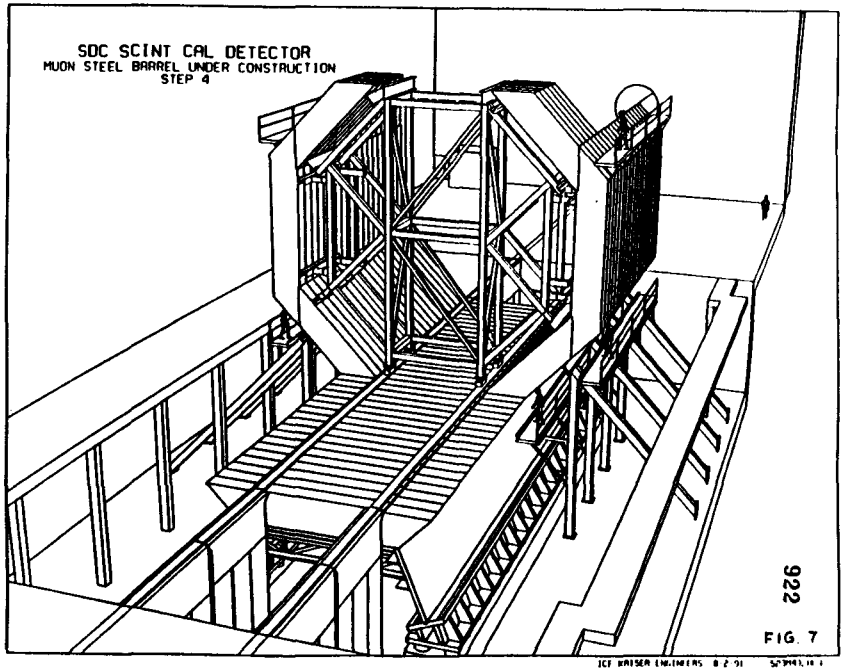
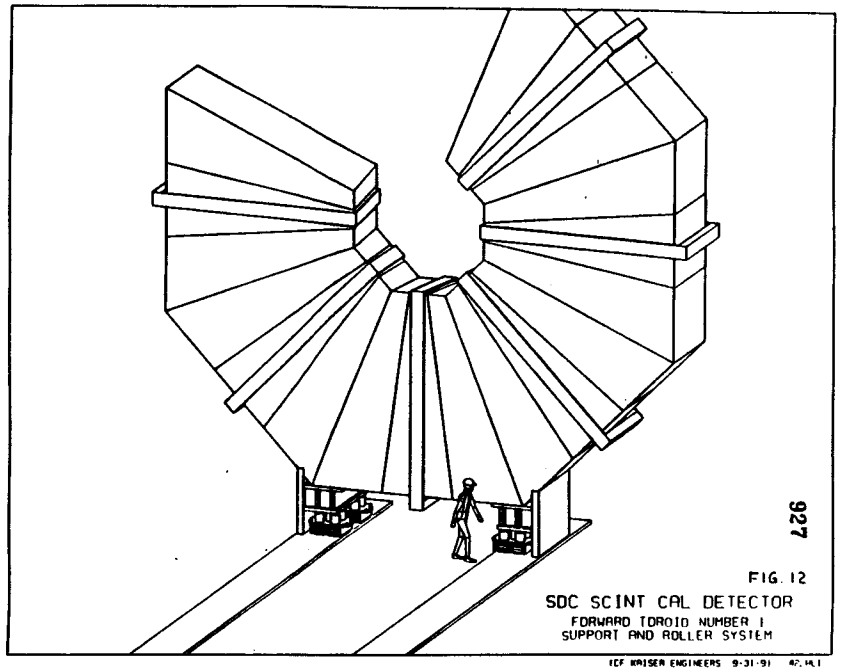
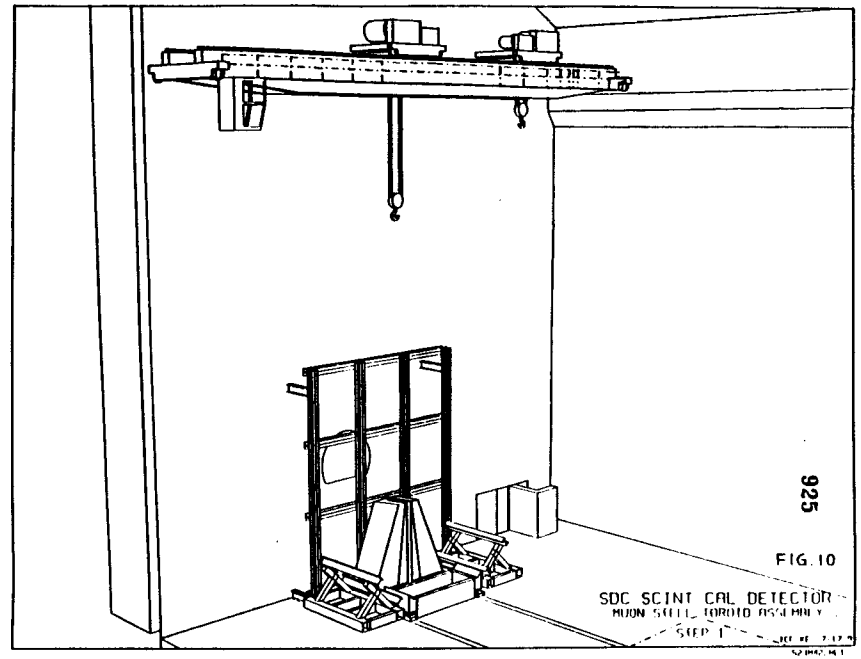
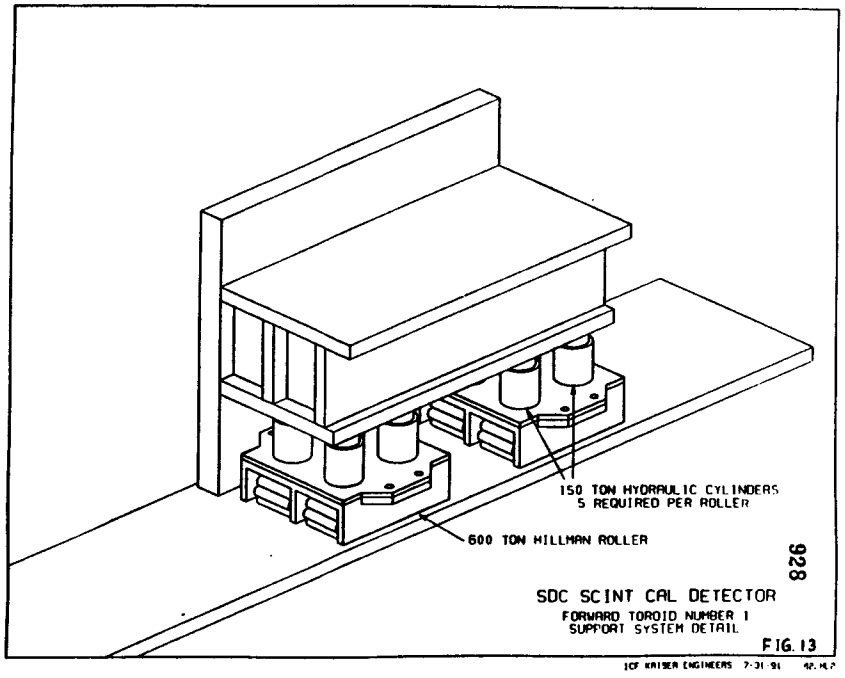

SDC SCINT CAL DETECTOR
MUON STEEL BARREL UNDER CONSTRUCTION
STEP 3
921
FIG. 6

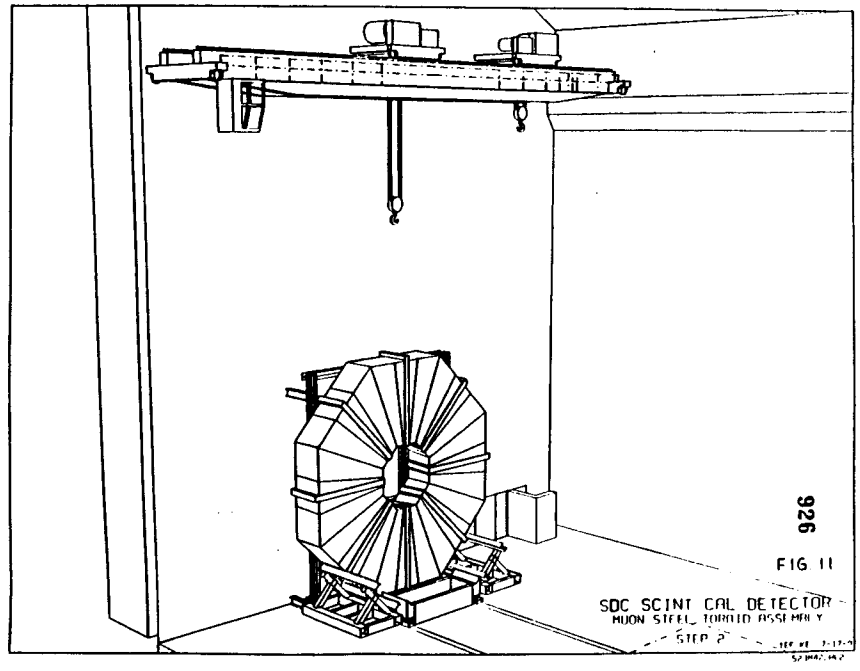

• BARREL STEEL BASE COMPLETE
• BARREL STEEL LOWER INCLINED SIDES COMPLETE
• REMAINING BARREL STEEL CONSTRUCTION IN PROGRESS
924
SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 9
FIG.9

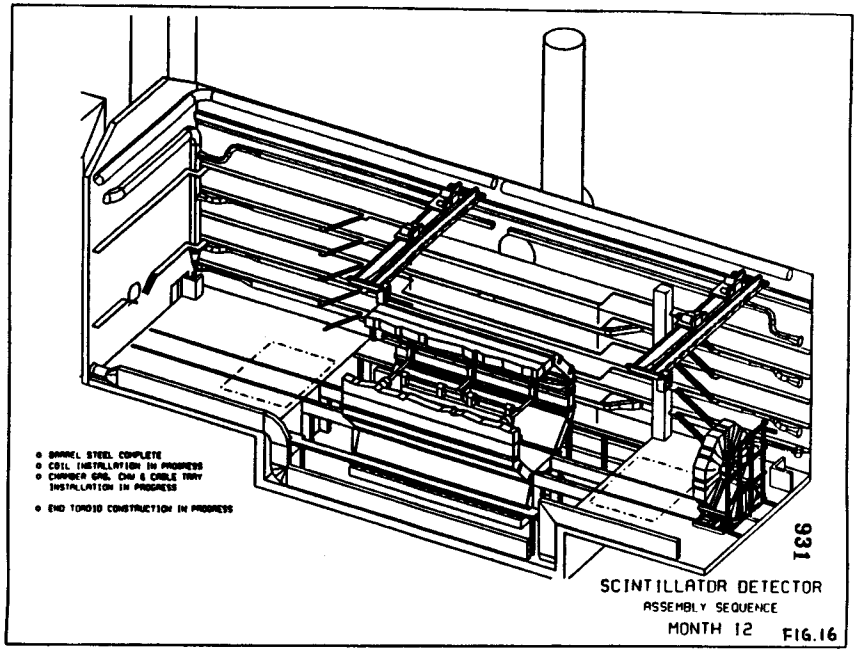

SDC SCINT CAL DETECTOR
MUON STEEL BARREL UNDER CONSTRUCTION
STEP 4
922
FIG. 7
ICF KAISER ENGINEERS 8-2-91


927
FIG. 12
SDC SCINT CAL DETECTOR
FORWARD TOROID NUMBER 1
SUPPORT AND ROLLER SYSTEM
ICF KAISER ENGINEERS 9-31-91


925
FIG. 10
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 1


150 TON HYDRAULIC CYLINDERS
5 REQUIRED PER ROLLER
600 TON HILLMAN ROLLER
928
SDC SCINT CAL DETECTOR
FORWARD TOROID NUMBER 1
SUPPORT SYSTEM DETAIL
FIG. 13
ICF KAISER ENGINEERS 7-31-91


926
FIG. 11
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 2



SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 12 FIG.16

ICF PRISER ENGINEERS 7-29-91

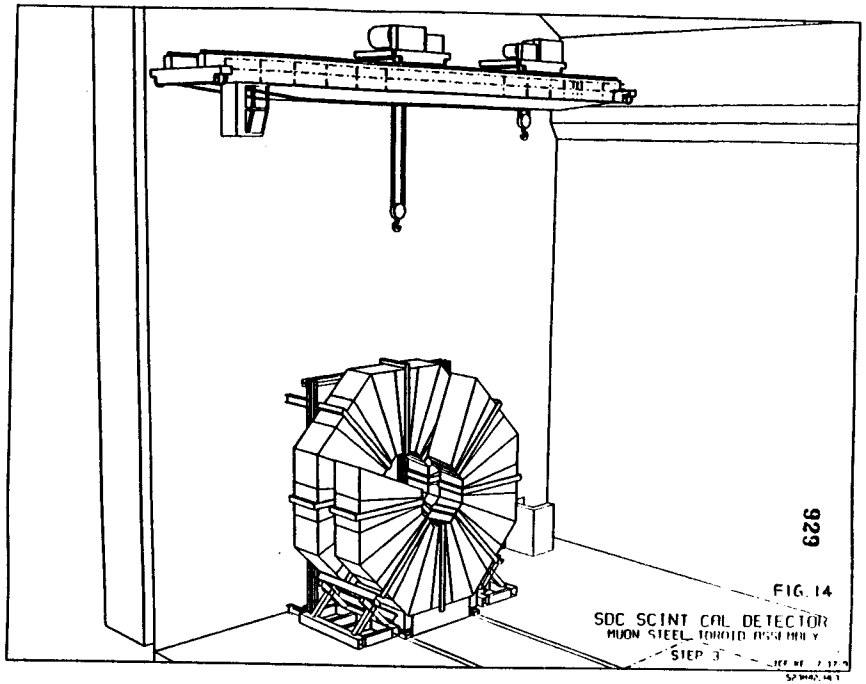


FIG. 14
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 3

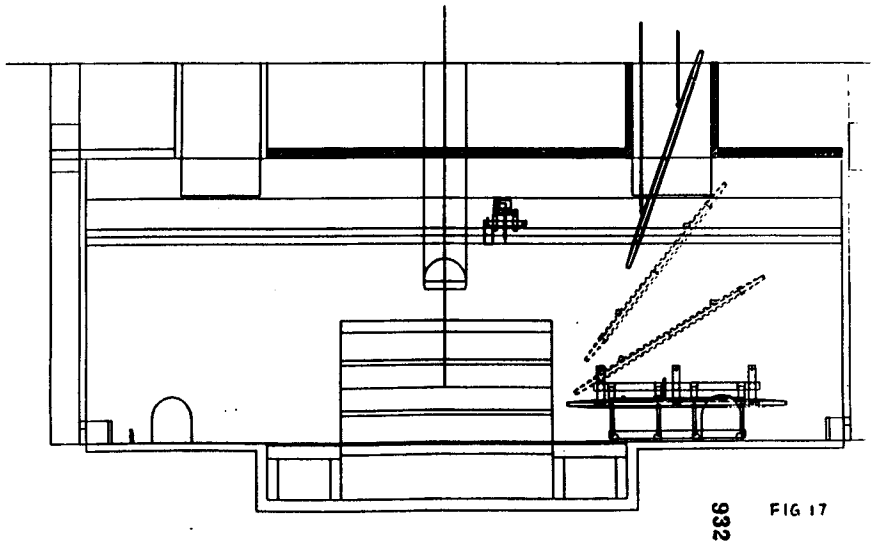


FIG 17

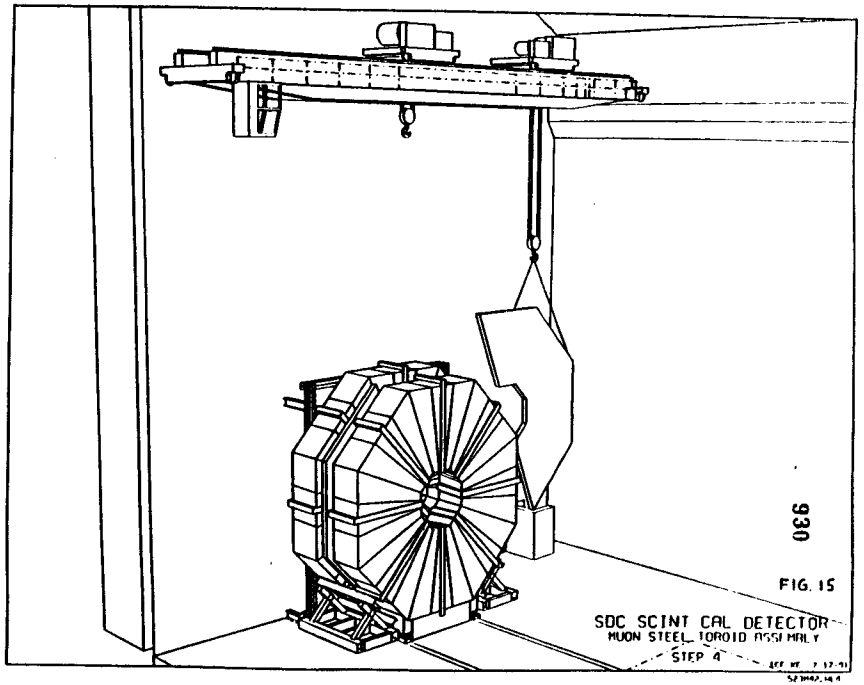


FIG. 15
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 4

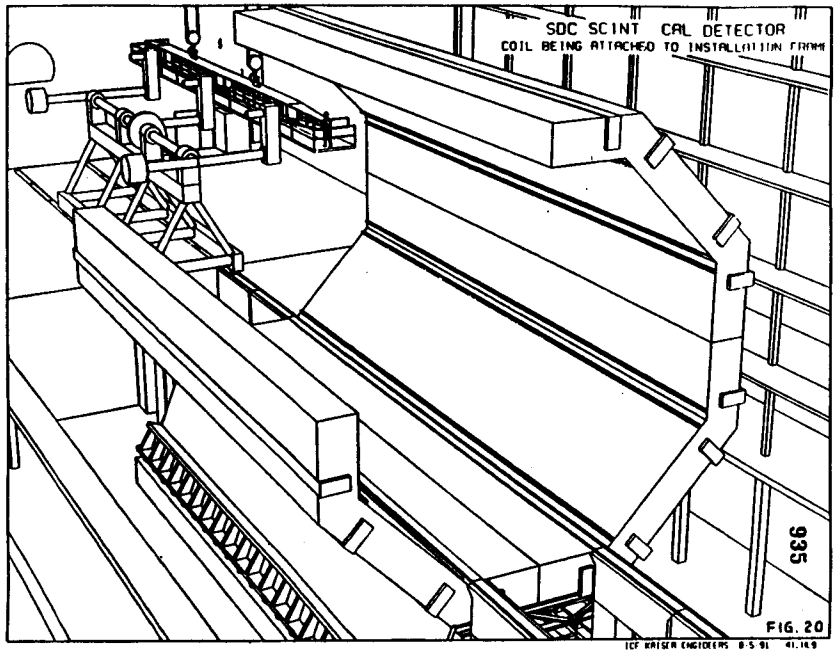


FIG. 20

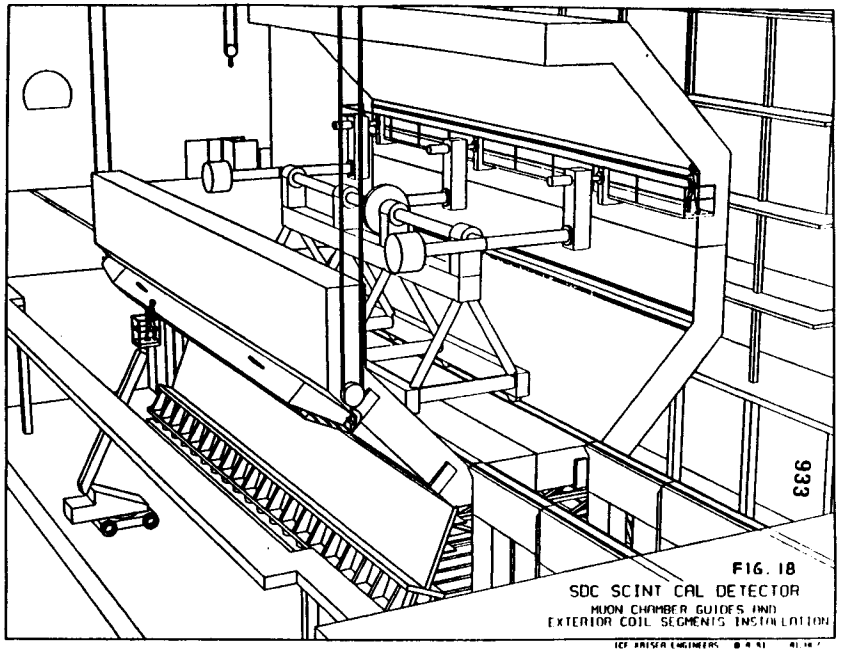


FIG. 18

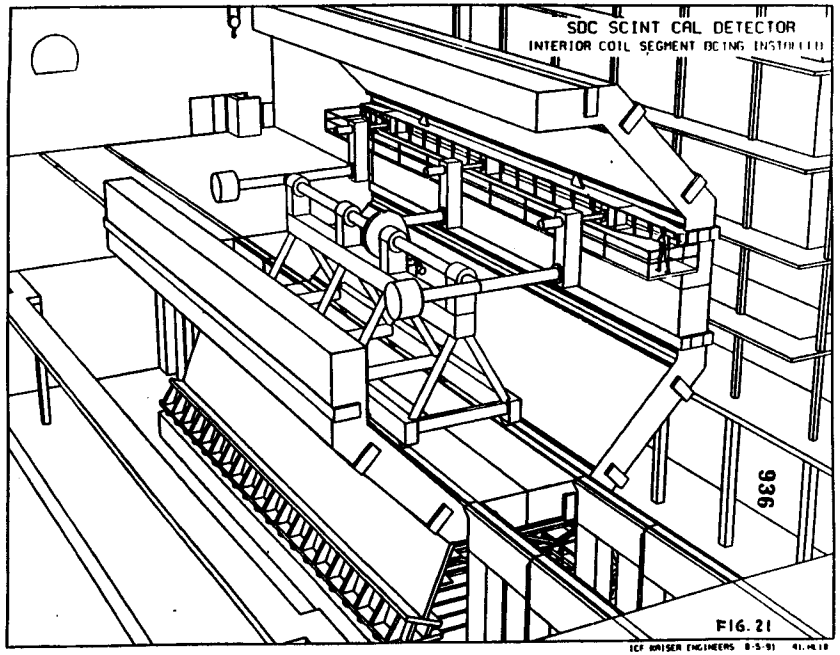


FIG. 21

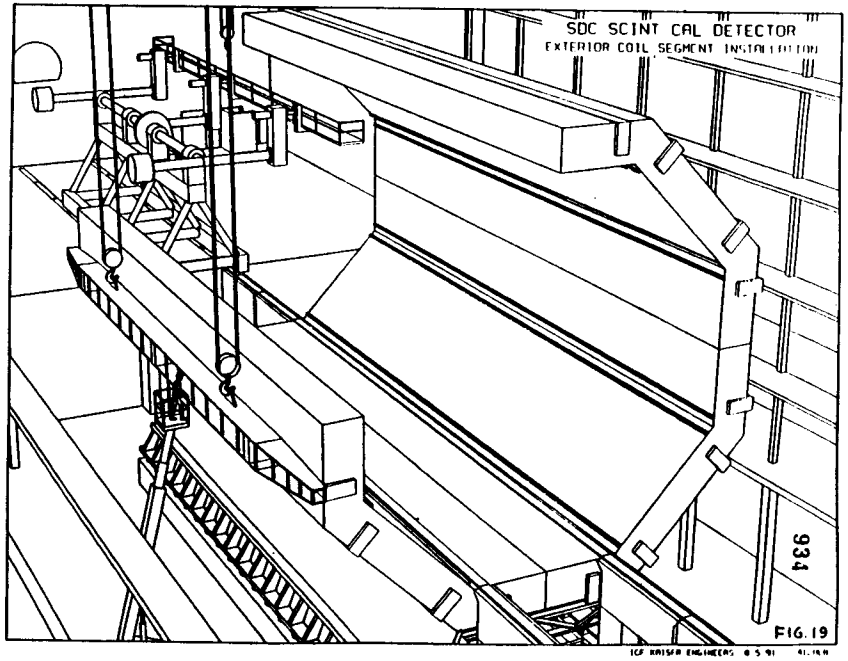
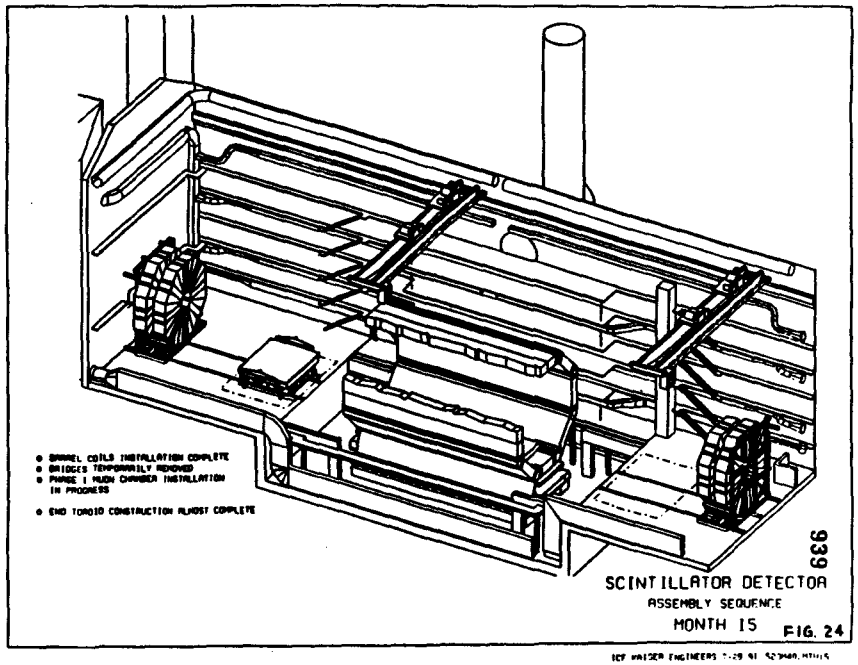
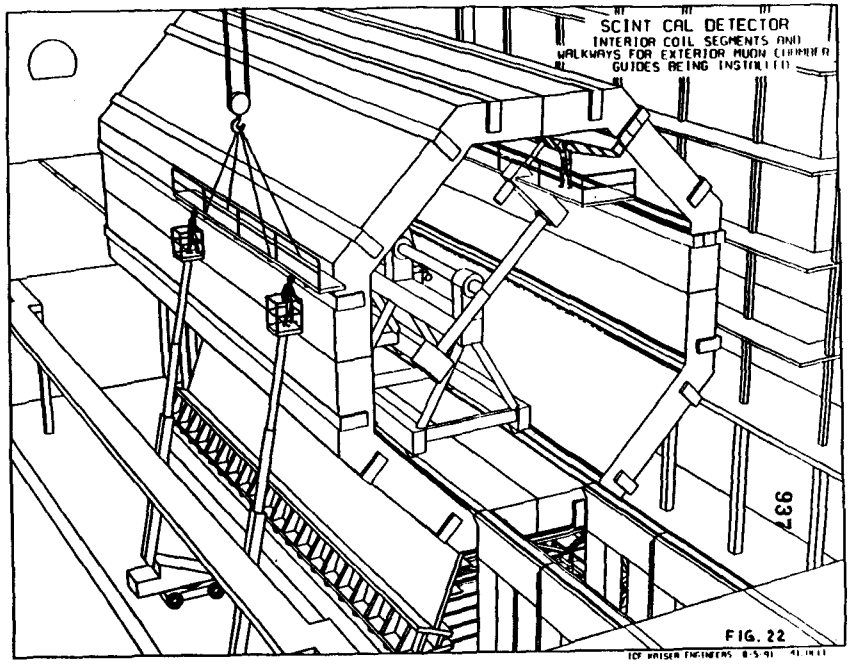


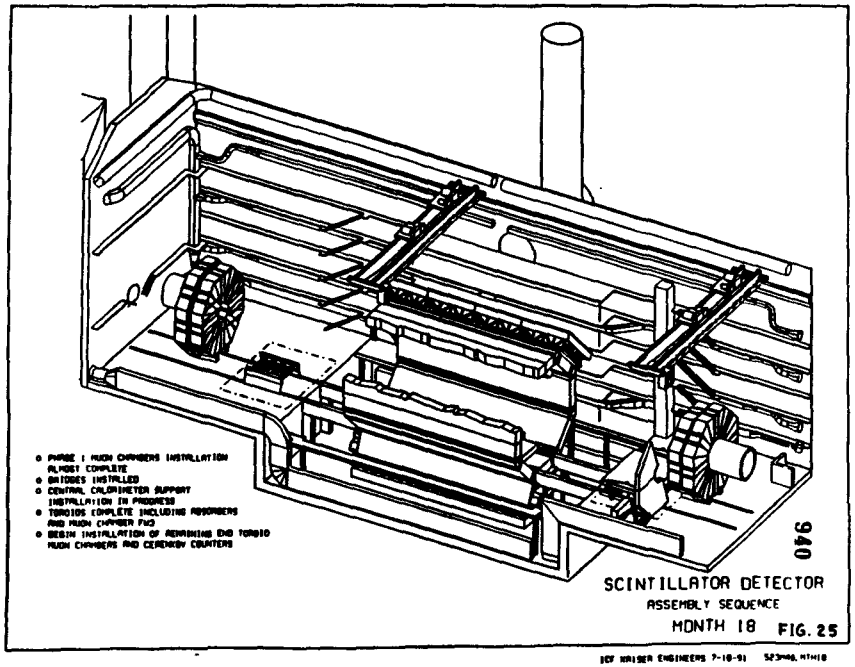
FIG. 19



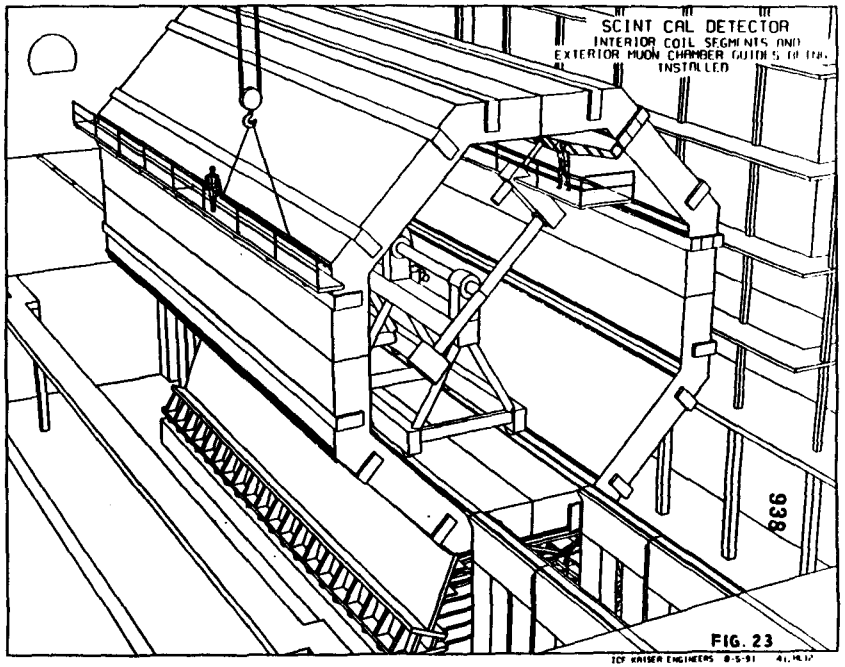
ICF KAISER ENGINEERS 7-29-91



ICF KAISER ENGINEERS 8-5-91



ICF KAISER ENGINEERS 7-18-91



ICF KAISER ENGINEERS 8-5-91

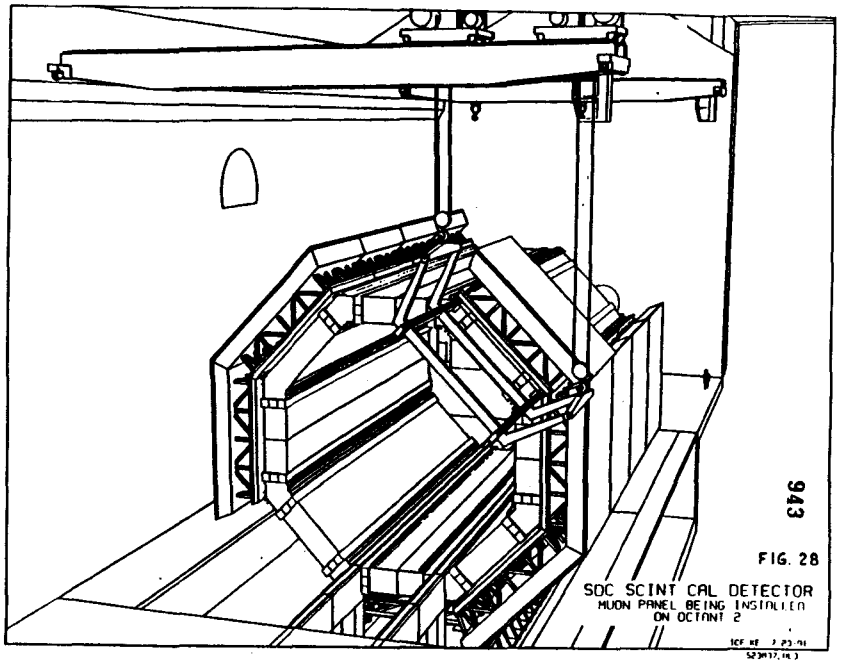


FIG. 28

SDC SCINT CAL DETECTOR
MUON PANEL BEING INSTALLED
ON OCTANT 2

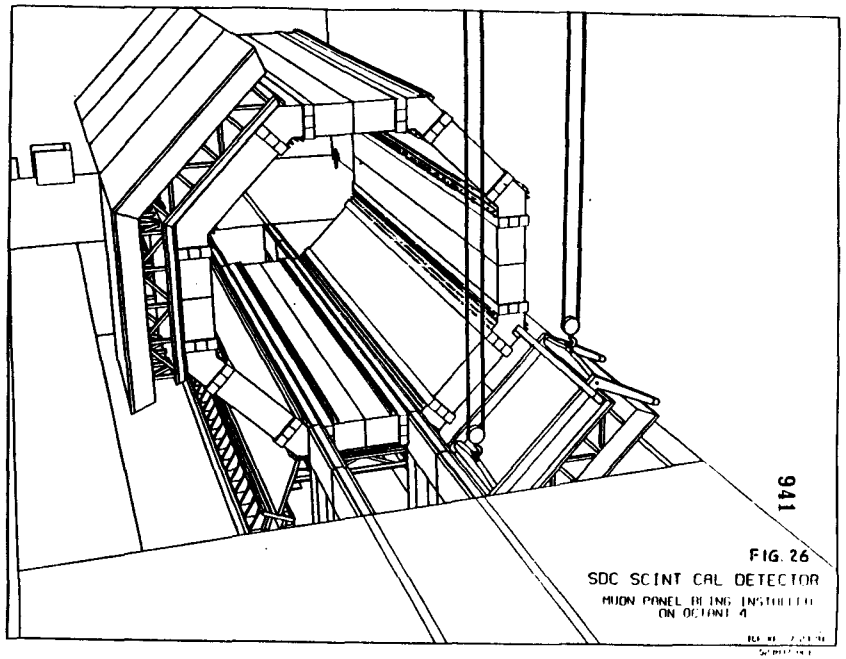
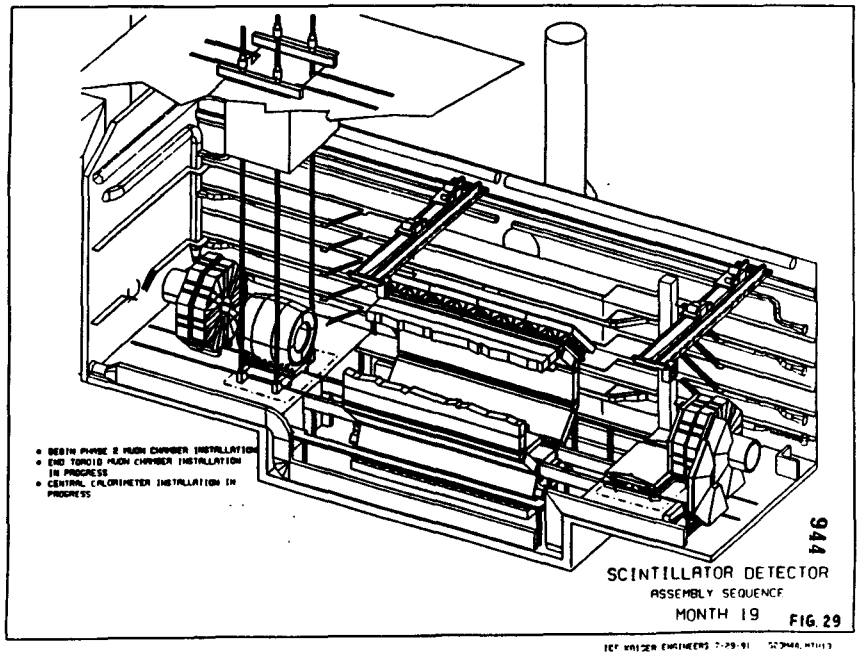


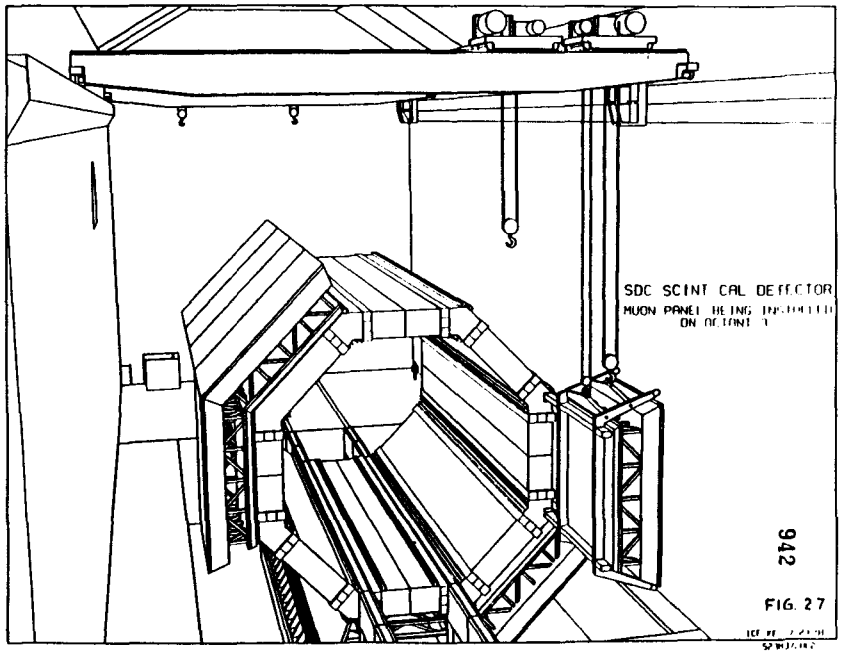
FIG. 26

SDC SCINT CAL DETECTOR
MUON PANEL BEING INSTALLED
ON OCTANT 4



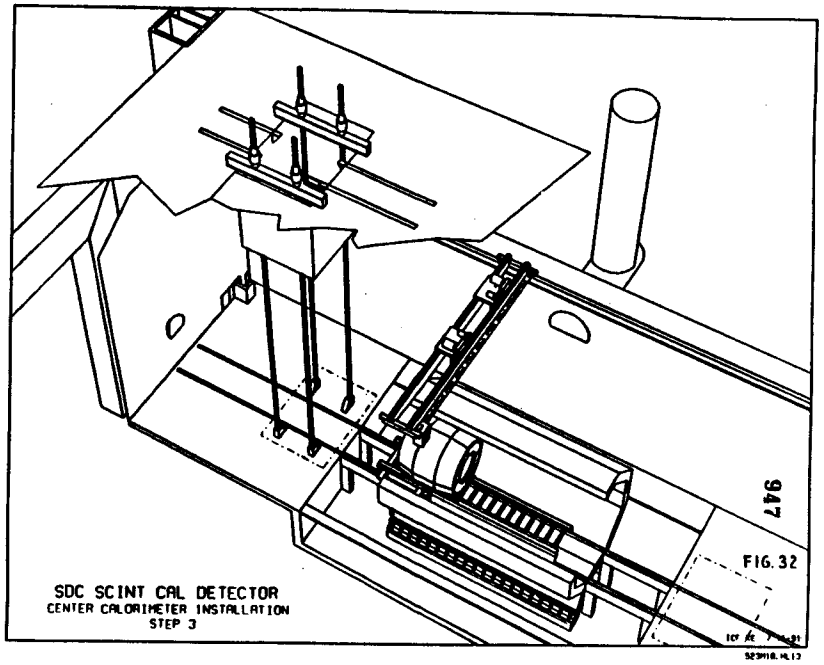
SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 19

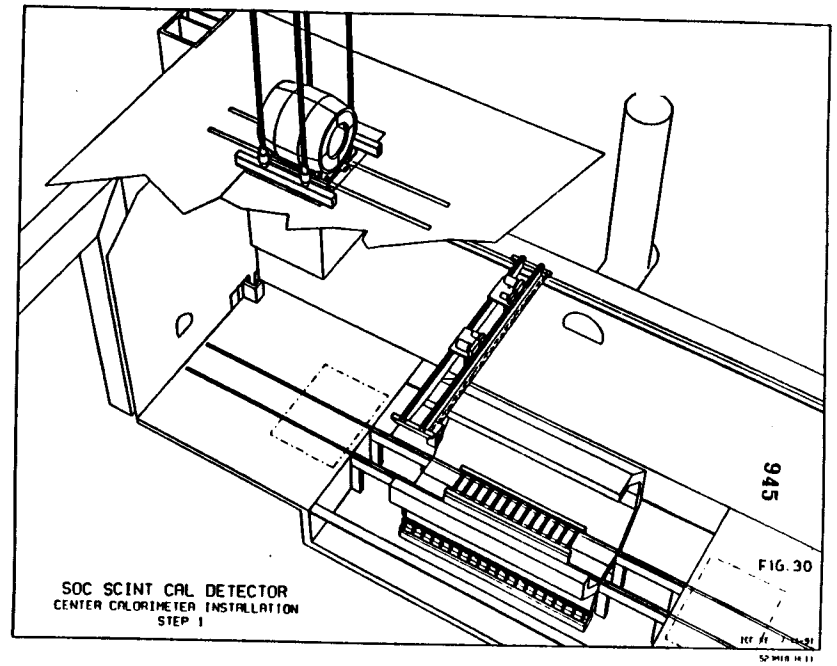
FIG. 29

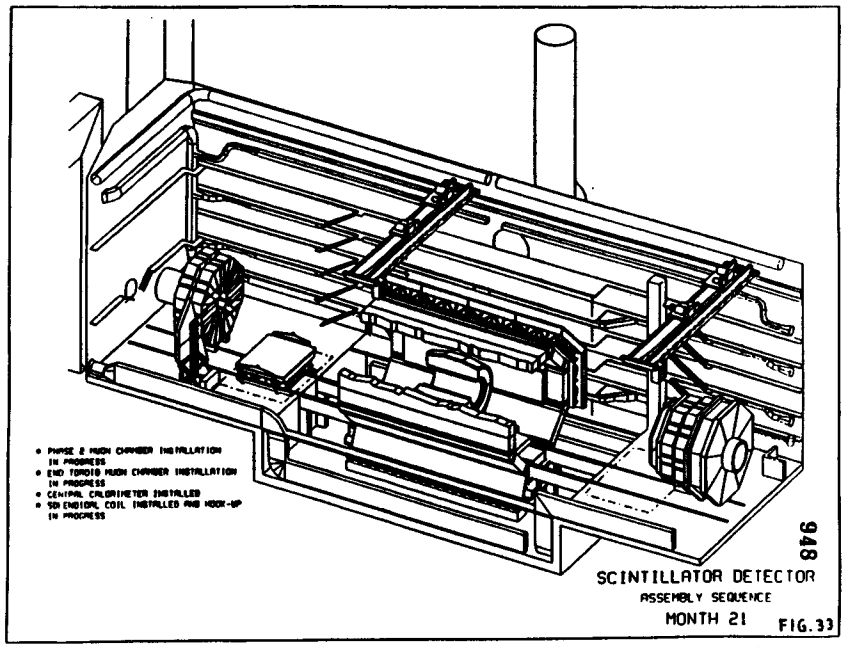


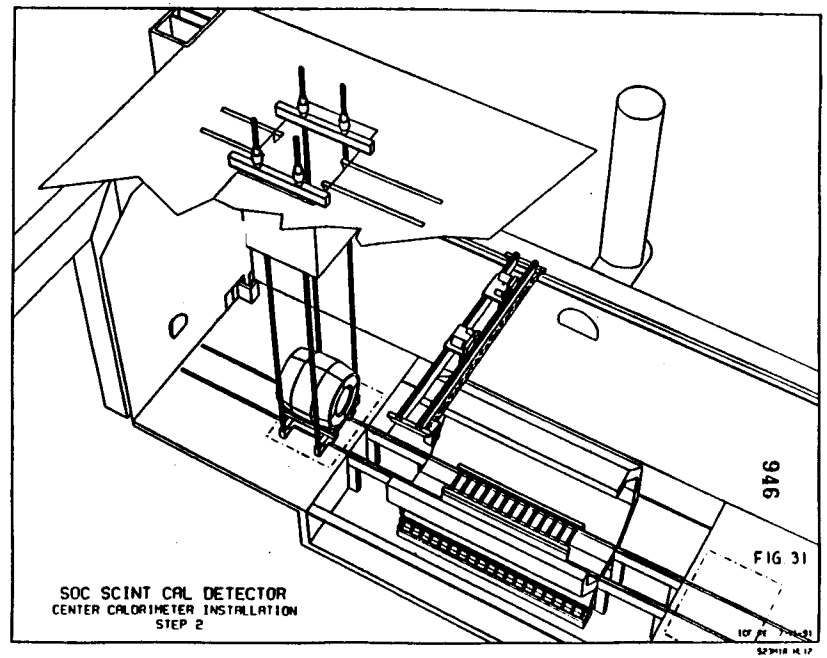
SDC SCINT CAL DETECTOR
MUON PANEL BEING INSTALLED
ON OCTANT 3

FIG. 27


947
FIG. 32
SDC SCINT CAL DETECTOR
CENTER CALORIMETER INSTALLATION
STEP 3


945
FIG. 30
SOC SCINT CAL DETECTOR
CENTER CALORIMETER INSTALLATION
STEP 1


• PHASE 2 MUON CHAMBER INSTALLATION IN PROGRESS
• END TOROID MUON CHAMBER INSTALLATION IN PROGRESS
• CENTRAL CALORIMETER INSTALLED
• SOLENOIDAL COIL INSTALLED AND HOOK-UP IN PROGRESS
948
SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 21
FIG. 33


946
FIG 31
SOC SCINT CAL DETECTOR
CENTER CALORIMETER INSTALLATION
STEP 2

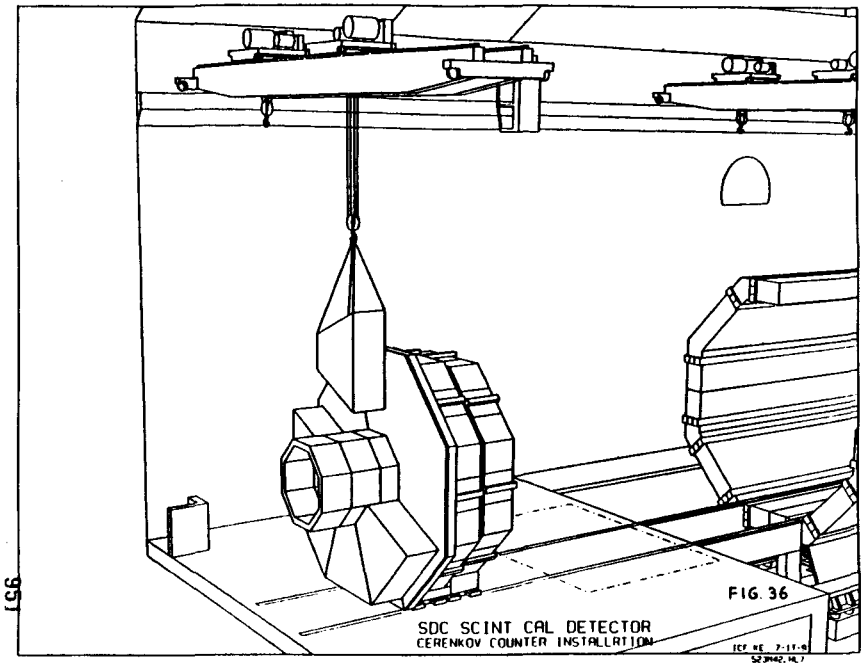


FIG. 36

SDC SCINT CAL DETECTOR
CERENKOV COUNTER INSTALLATION

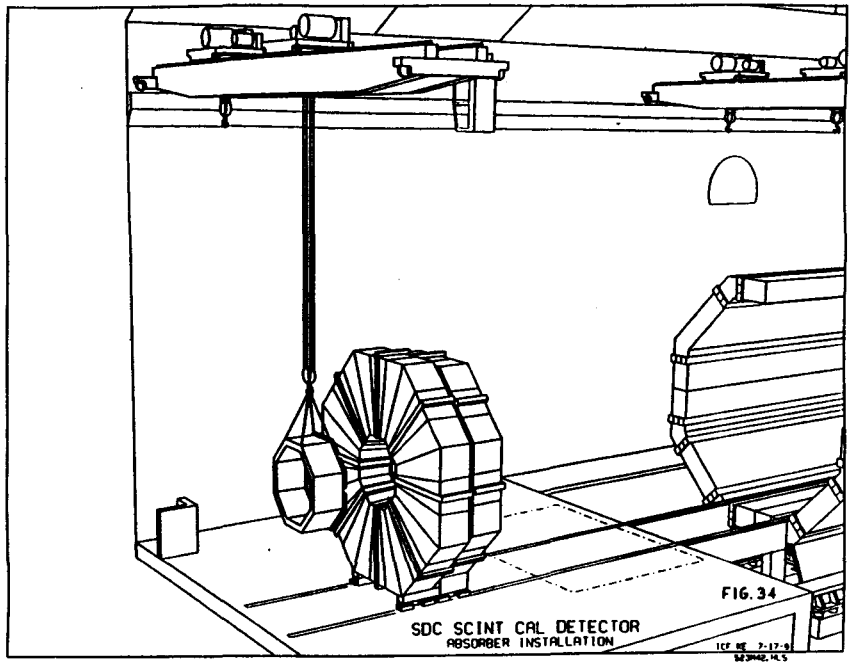
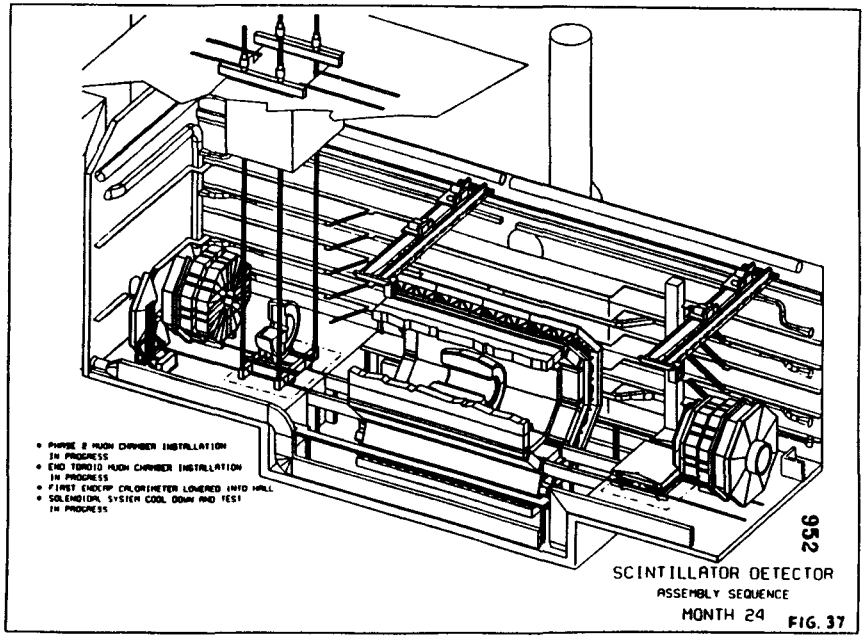


FIG. 34

SDC SCINT CAL DETECTOR
ABSORBER INSTALLATION



SCINTILLATOR DETECTOR
ASSEMBLY SEQUENCE
MONTH 24

FIG. 37

ICF KAISER ENGINEERS 7-29-91

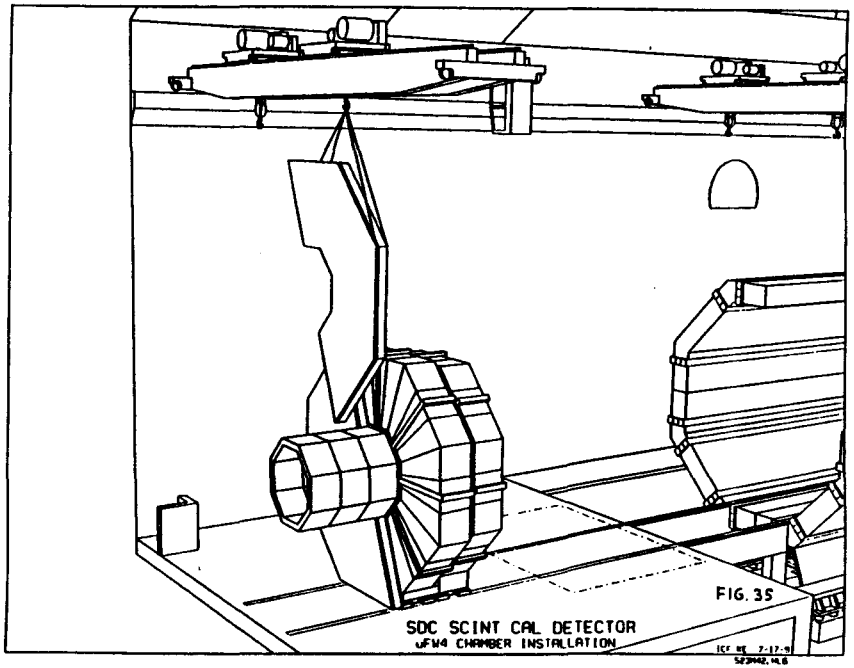


FIG. 35

SDC SCINT CAL DETECTOR
μFW4 CHAMBER INSTALLATION

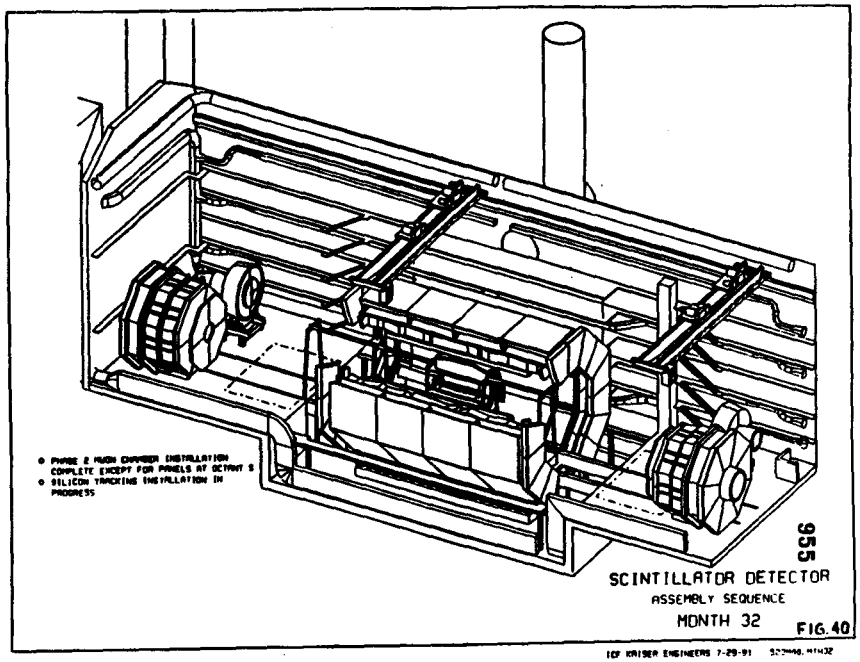


FIG. 40

ICF KAISER ENGINEERS 7-29-91 523M40.MTH32

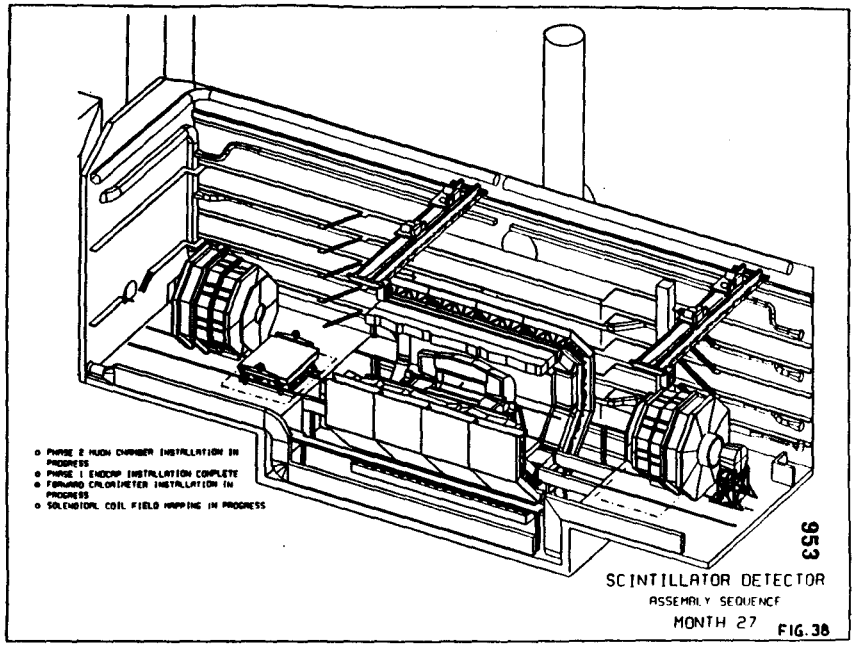


FIG. 38

ICF KAISER ENGINEERS 7-29-91 523M40.MTH27

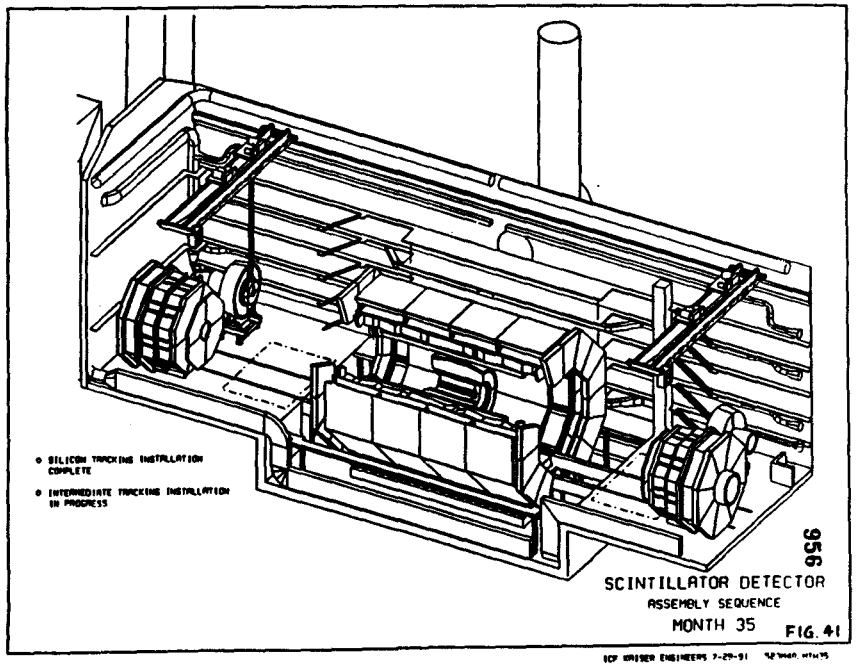


FIG. 41

ICF KAISER ENGINEERS 7-29-91 523M40.MTH35

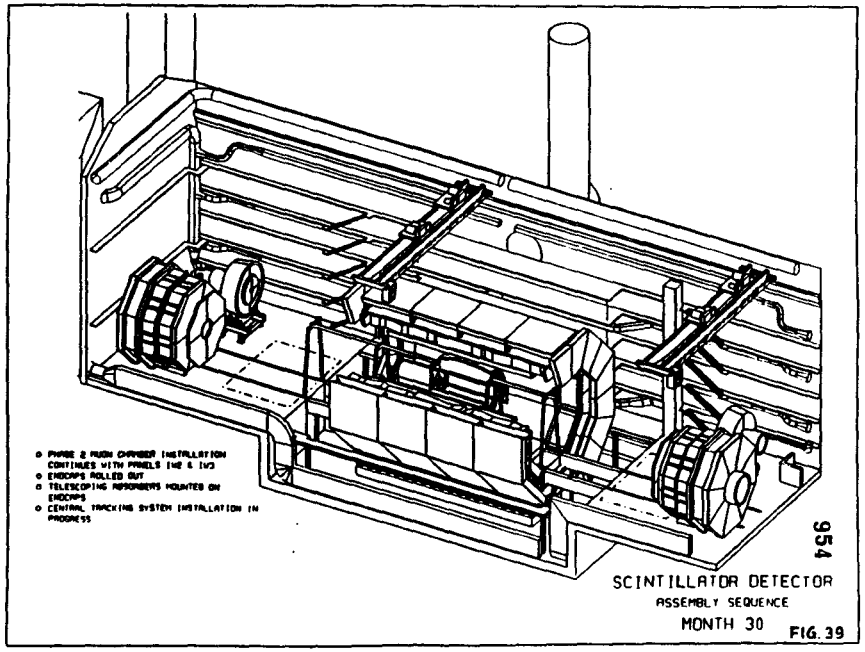
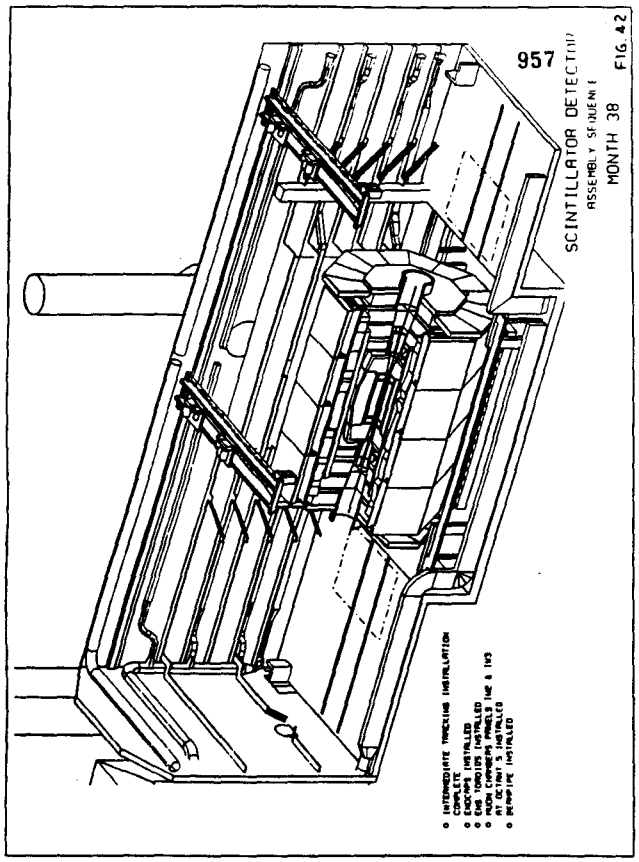
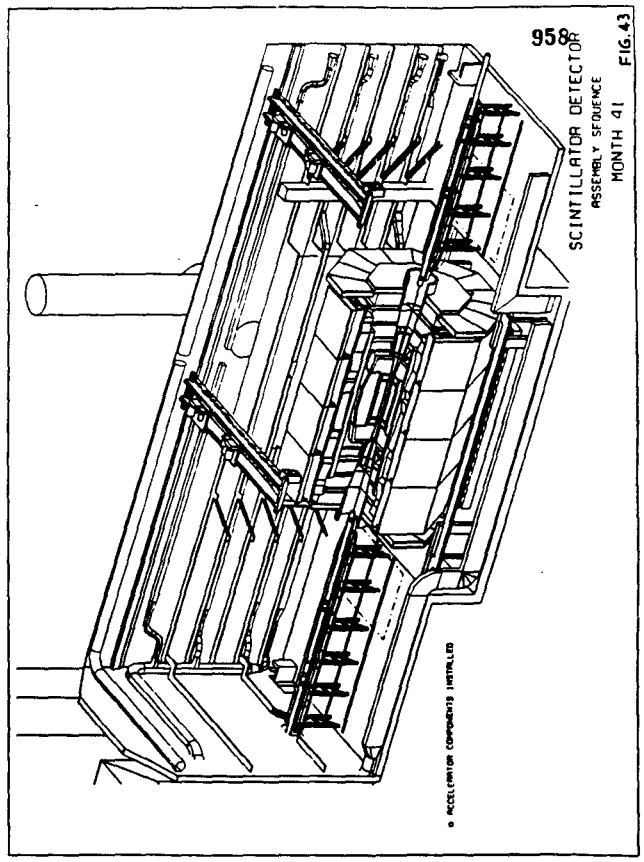


FIG. 39

ICF KAISER ENGINEERS 7-29-91 523M40.MTH30





959

T. Kondo
8/10/91

REPORT OF TASK FORCE ON FIELD UNIFORMITY

Plenary
8/10 AM
Complete

960

TASK FORCE ON MAGNET FIELD UNIFORMITY

Task Force

chairman : T. Kondo

members : B. Barnett
J. Dainton or Brian Foster
R. Lewis
M. Corden
A. Weinstein
H. Ogren
J. Chapman
J. Hylen
D. Adams

Charges Assemble information relevant to compare tracking system performance in the two field configurations

- relatively uniform field
- non-uniform field

report due at the August 5-10 SDC meeting

961

SDC-90-00066	J.Matthews	Effects of Non-uniform magnetic fields on SDC central tracking
SDC-90-00074	S.Odaka	Momentum resolution for muons using the full tracking system
SDC-90-00095	T.Kirk	Report of the SDC magnet task Force
SDC-90-00097	H.Iwasaki	Momentum resolution in a nonuniform magnetic field
SDC-90-00102	A.Yamamoto etal	Design Study of an Air core thin solenoid for SDC detector
SDC-90-00103	Y.Takaiwa	Short solenoid vs long solenoid - effects on tracking
ANL meeting	J.Hylen	Effect of field non-uniformity on inner tracking for some sample field
LBL meeting	T.Kondo	
LBL meeting	J.Hylen	

962

Things to be considered

* $\Delta p/p$
* Triggering
* Pattern Recognition
* Others (E×B, field measurement, ..., ...)

963

FACT #1 $\int B\,dl$ is wrong
$\int \vec{B}\times d\vec{l}$ is right

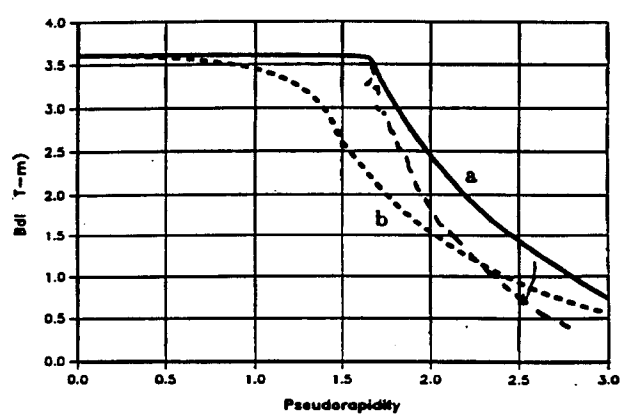
FACT #2 $\frac{\Delta p_T}{p_T} \propto \int dl \int \vec{B}\times d\vec{l} \sim BL^2$
not BL

FACT #3 Detector locations and their position resolutions are important
↓
BL^2 is wrong for non-uniform tracking system

FACT #4 Vertex constraint is very important

964

LoI Fig. 9



Jim Hylen
FNAL
SDC workshop 9/6/91

Possible Disadvantages of Non-Uniform Field for Tracking

Degraded Momentum Resolution (minimal)

Pattern Recognition

Triggering

CPU requirements

Drift Angle in wire chambers?

Path of loopers? (+/- ?)

Measurement of detector alignment

Field measurement

In non-uniform field: (Need simulation!)

Global pattern recognition, such as histogramming method presented yesterday, probably wont work ☹

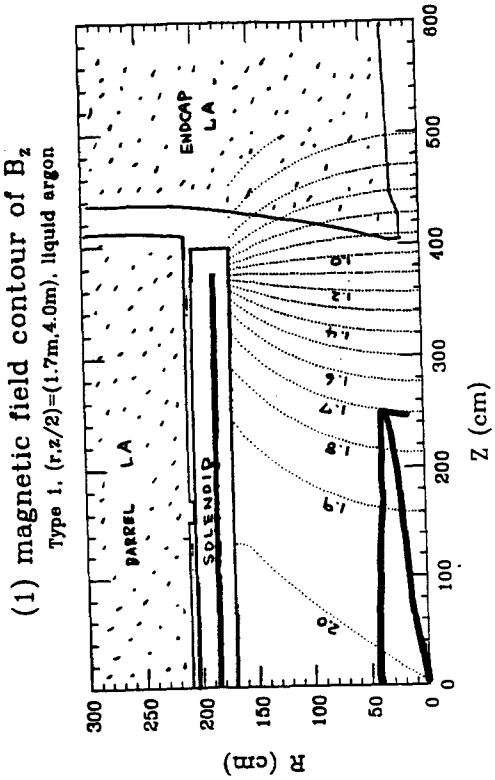
Must do pattern recognition in r, ϕ, z, λ simultaneously

Intuition: Strong fiber system → local space points, local vectors → probably OK ☺

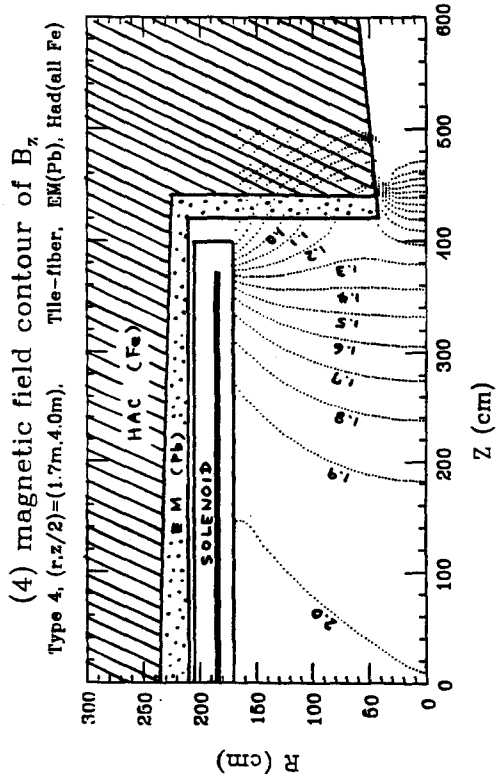
Thinned out outter system need proof that it would work ☹?

8 layer silicon strip system → still work, could then swim to outter system & pick up hits ☺

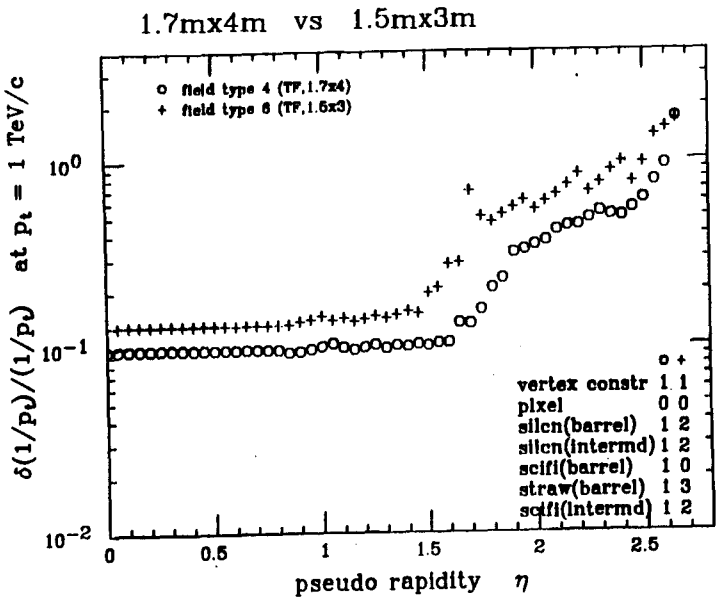
Pattern Recognition in tracking will probably be largest SDC CPU load — we could really use some estimate of whether non-uniform field will cost $1 million, $10 million, $100 million in CPU $.



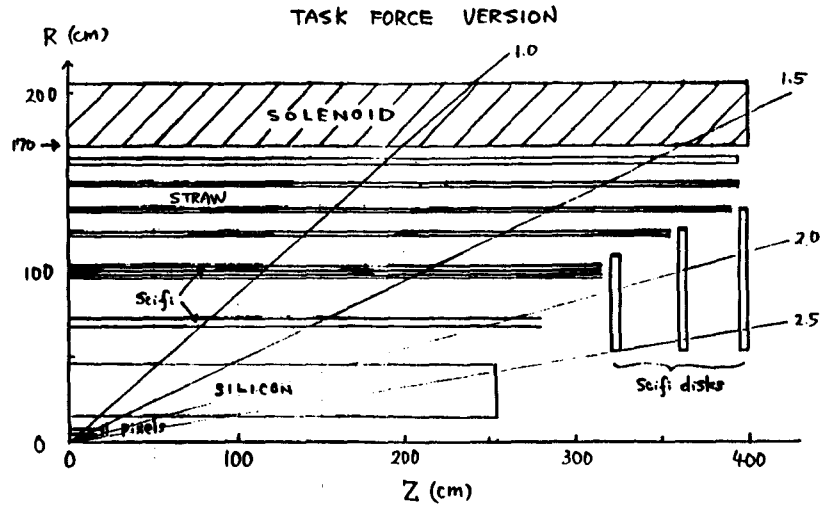
Kondo



(bad case)

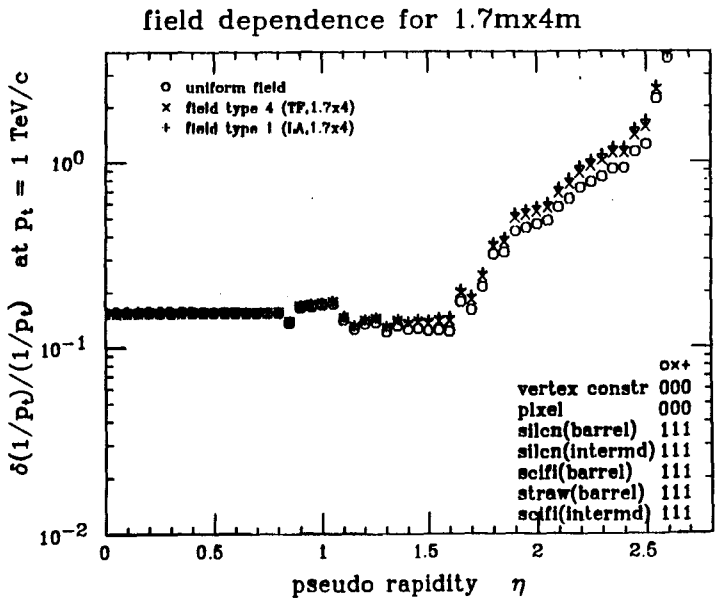


971

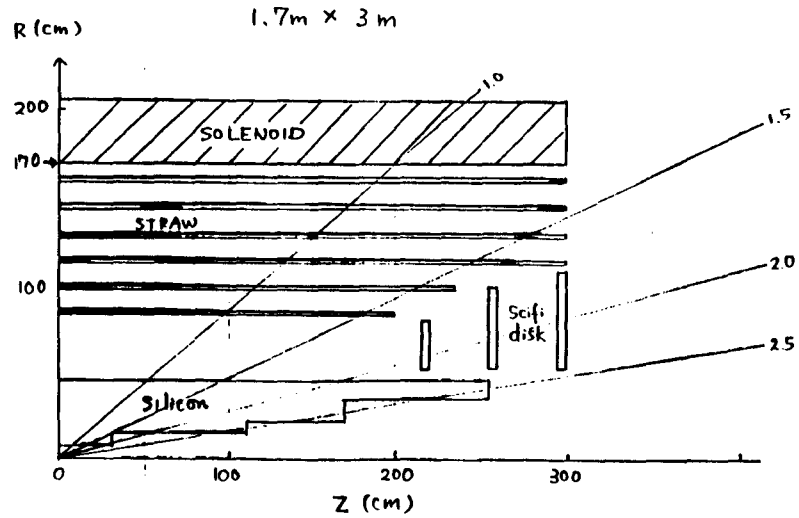


969

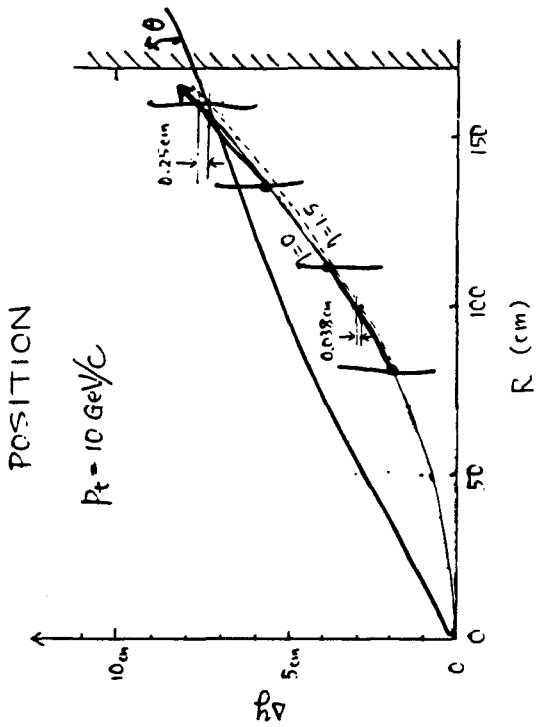
Kondo

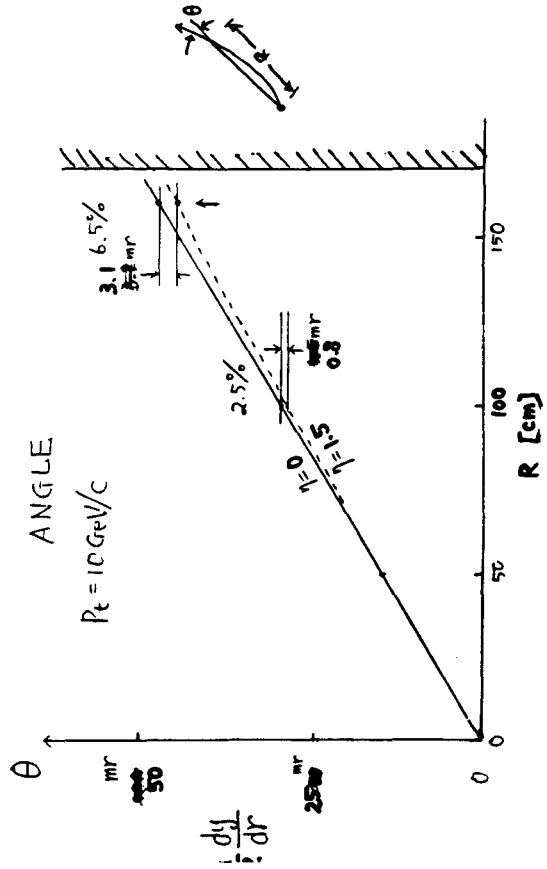


972



970





Effects on Track Trigger

975

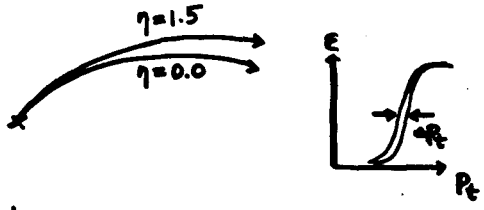
Level 1 (Level 2) will be done in r-φ projection

↓

no information on z coordinate

↓

non-uniform field makes difference in trajectory

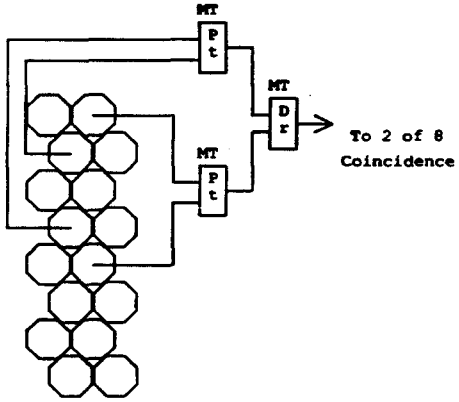


P_t Trigger by

1. angle $\Delta\phi$: $\Delta P_t = 0.65$ GeV/c
2. angle difference $\Delta\phi_1 - \Delta\phi_2$: $\Delta P_t = 1.1$ GeV/c
3.

976

One of Eight Patterns



DETECTOR SCOPE

There will be requests for some reductions in subsystem costs from those already proposed in yesterday's presentations, with some suggestions as to how to meet them.

These are not final, and will be reconsidered at the Oak Ridge SDC meeting. The burden of proof will be on the subsystem groups to demonstrate important damage to physics goals as a requirement for any increase of the cost targets.

Any further cost reductions necessitated by insufficient funds next April will probably have to be met by staging scenarios.

TRACKING VOLUME

The total cost saving involved for radius reduction of 0.2 m keeping aspect ratio the same is about $15M for the scintillator calorimetry option, and somewhat larger for the LA option.

If the decision is not to change the tracking volume, the equivalent saving needs to be found elsewhere within the subsystems. Hence a decision of "no change" implies a judgment that the saving is better made elsewhere in the detector.

The tracking volume decision made at this meeting will stand as the basis of the design proposal.

FUNDING ISSUES

On April 1, 1992, we must propose a detector with the following cost structure:

- $275M +/- $50M in contributions from U.S. SSCL funds.
- Remaining costs credibly distributed among non-U.S. collaborators.

The precise definition of non-U.S. contributions will still take some time, but our present working estimate is $200M total in in-kind contributions and common funds.

The SDC must therefore, at this meeting, develop a plan for a detector of initial cost about $500M which can be gracefully upgraded as additional funding from U.S. and/or non-U.S. sources becomes available.

What determines where we sit in the +/- $50M range?
I believe that in order to be on the positive side of that range:
We must have a stronger US representation than GEM,
We must make a clear case that we are not requesting unnecessary frills
We must look very ready to start construction limited only by funding approvals.

RECOMMENDATION ON TRACKING VOLUME AND STATUS OF DESCOPING

M. GILCHRIESE

Tracking Volume Recommendation

Keep radius at present value of 1.7m.

Length requires some additional study. Factors to consider include
- attenuation lengths in fibers and straws
- best aspect ratio
- space requirements for intermediate tracker
- "snout" on endcap calorimeter ?
- coil length and good field region
- space for polyethylene absorber on endcap

Evaluation by ORNL meeting. Likely answer in range 3.5-4m

Bob Kephart
A. Yamamoto
Aug. 7 1991

Impact of Changing the SDC Coil Radius

Can we change the coil radius ? Yes of course technically there is no problem, BUT the impact of such a change will rapidly grow with time.

What if we change coil radius NOW ?

A) Conductor has been sized and R&D is in progress in Japan for a 44 mm conductor optimized for a coil of 1.7 M radius and 4 M half length.

Options :

1) Keep the present 44 mm conductor => nonoptimal, but no delay. Impact = about 4 mm of extra aluminum in the conductor.

2) Change the conductor size to the optimal => 6 month delay

B) Engineering calculations must be redone at KEK/FNAL/Toshiba for the correct dimensions and documentation updated. This is clearly less work than generating them initially, but we estimate a few months of lost effort. (analytic calculations, Finite element magnetostatic calculations, Finite element stress analysis, quench calculations, etc.) Impact => lost effort = wasted R&D money.

C) Impact = cost savings on coil construction & the rest of detector at the expense of physics performance.

Estimated savings is :

1) $ 25.7 M —> about $ 18 M for coil construction (L/2 = 3 m)
2) small savings < 10 % on the cost of refrigerator & utilities = < $ 0.5 M

Maximum savings = about $ 8 M (principle savings are presumably elsewhere in the detector)

What if we change the coil radius LATER (eg in 1 year) ?

A) all of the above. plus

B) Winding machine will be complete at Toshiba for fixed radius => we would have to modify this machine and all related fixtures.

C) Outer support cylinder and outer HC/Isogrid vacuum shell will have been fabricated at the wrong radius.

D) Engineering drawings etc for prototype will be nearly complete.

Options:

1) build and test prototype of the wrong diameter. (violates the idea that we are verifying the final design , winding fixtures, etc)

2) redo all of the above . Impact = 6-9 month delay and wasted effort of R&D team at KEK/FNAL, inefficient use of an expensive industrial vendor = increased R&D costs.

If radius is fixed now, what if we change the coil length LATER (eg in 1 year) ?

A) Cost savings : If the change were made before the final coil contract was bid, then changing the length from L/2 = 4 m to L/2 = 3 m at a radius of 1.7 m would reduce the cost from $ 25.7 M to 21.2 M. Again the cost savings for the cryoplant and utilities would be small.

B) Such a change would make the field less uniform and remove about 0.25 units of rapidity in which the tracks pass through the full coil radius and thus feel its full bending power.

C) L/2 = 3 m requires an increase in the operating current of about 6 % to maintain the central field at 2 T for non iron dominated cases. If the conductor were not changed, this represents a loss in operating safety margin.

HOW TO ESTIMATE

CHANGE OF THE COST FOR THE SDC THIN SOLENOID

WE ASSUME:

C (cost) => $\propto$ (2/3)

TRACK. VOL.	1.7 X 4	1.7 X 3	1.5 X 3	1.5 X 3	1.5 x 3
R	1.7	1.7	1.5	1.5	1.5
COND. SIZE	44.X4.4	44X4.4	44X4.4	40X4.4	62x4.4
E/M [KJ/KG]	7.5	7.5	7.5	7.5	7.5
Bc [Tesla]	2	2	2.1	2	2.5
X [Xo]	1.2	1.2	1.2	1.1	1.5
E [MJ]	133	100	86	78	190
Inpar.[kA]	8,000	8,500	8,400	8,000	9,600
d.(Iop/Ic) [%]	50	56	50	50	70(?)
Cost [$M]	25.7	21.2(+2)	19(+2)	18(+2)	33(?)
dp/p [%]	---	loss +/- 0.25 q	-18	-22	0
notes		less uniform B		new cond. develop.	keep same p resol.

$3M. The chamber and counter costs are much harder to estimate. A guess is a savings of about $3M, mostly from reducing the length of the barrel.

7.5 Summary

The cost reductions resulting from shrinking the tracking volume from 1.7x4m to 1.5x3m are summarized below. All savings are relative to the cost-baseline detector.

System	Savings($M)	Passive Sent	LAC
Silicon Tracker	0	0	0
Outer Tracker(Straws)(includes elecs.)	3	~~3~~ 4	4
Solenoid	7(?)	7	
Barrel Calorimeter	11	>~5?	
Endcap Calorimeter	3		
Muon Steel	3	>~5	
Muon Chambers and Counters	3		
TOTAL	30	~26	

8.0 Impact on Physics

In this section two effects are considered: the degradation in momentum resolution resulting from shrinking the volume and the possibility of increased difficulty in forming an inner tracking trigger in the intermediate region.

The momentum resolution would be degraded by about 30% if the tracking volume is reduced. **** Need more discussion here and some plots. Compare for H->ZZ*, 200 GeV H->ZZ at a minimum***

*** I believe the conclusion will be ****. A 30% degradation in the momentum resolution will not have a significant impact on our ability to observe the Higgs particle in any of the modes we can detect. The impact on other processes has not been quantified, but is also believed to not be serious. In summary, degradation of the momentum resolution by about 30% should not be a factor in selecting the size of the tracking volume.

The tracking-trigger requirements in the intermediate region are not well understood. If the intermediate tracker is to be a critical element in the electron trigger, then spacing between measurements must be a concern. In the smaller volume there is less room for the intermediate tracker, unless the silicon is reduced in scope. However, the silicon is the critical element in track finding and momentum resolution. The balance between these

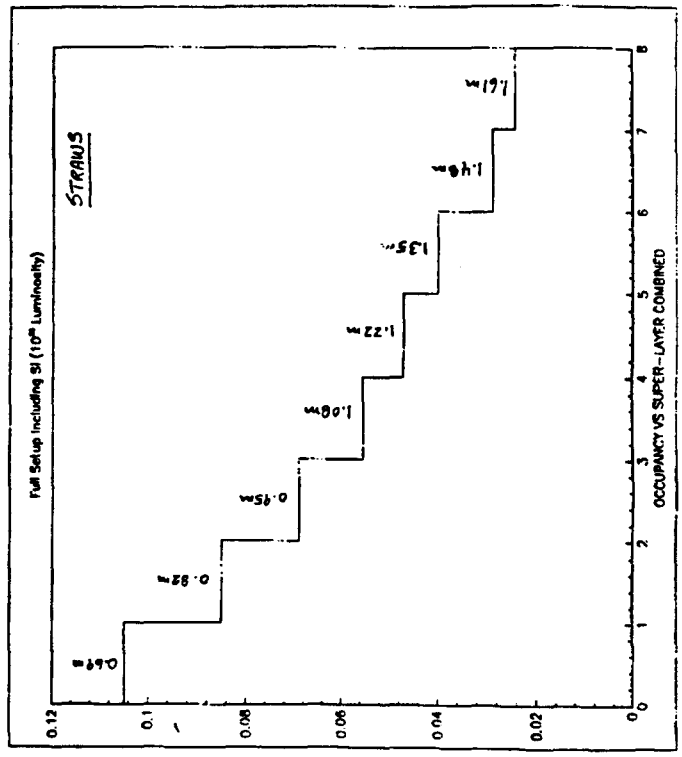


Fig. 2.4

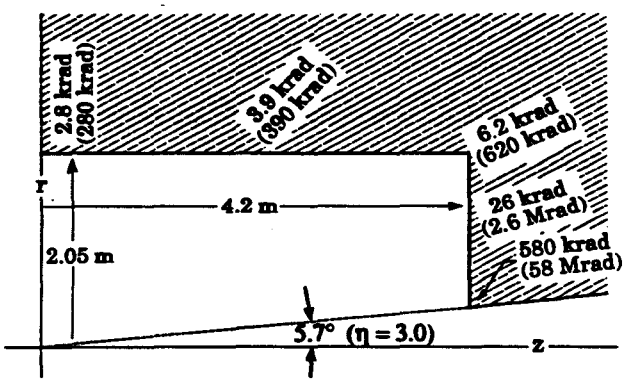


Fig. 4.1

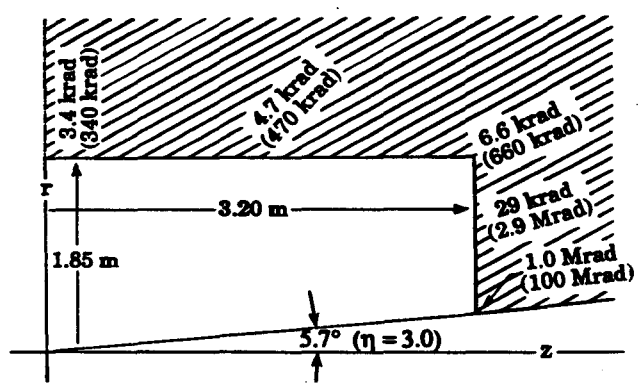
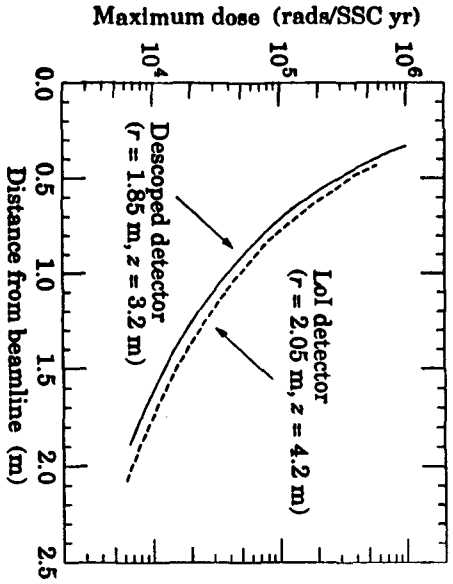


Fig. 4.2



993

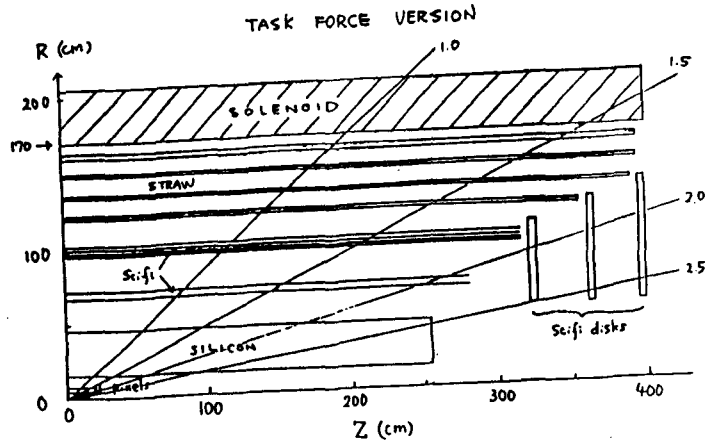


Fig. 4.3

994

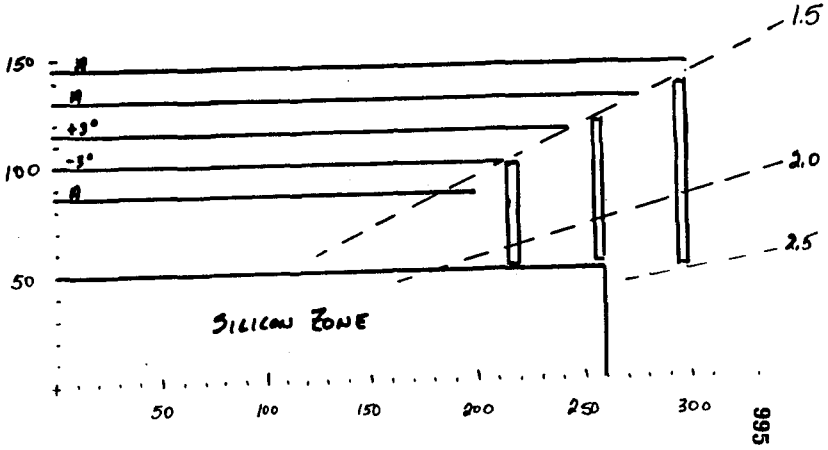


Fig. 4.3

995

Status of Descoping

- You heard yesterday from the subgroups on their efforts to reduce cost => "Descope II"
- Cost of Descope II is ≈ $560M
- Further reductions are necessary to move towards the $500M target.
- Suggestions follow.
- Evaluate by collaboration meeting at ORNL(Sept. 26-28)

996

Cost Comparison without R&D

	TOTAL COSTS WITH CONTINGENCY					
	LoI Estimate ($M)	LoI Rev. Panel ($M)	Preliminary Cost Baseline ($M)	Preliminary Descope I ($M)	Preliminary Descope II ($M)	Target "600M" ($M)
1.1 SILICON TRACKING SYSTEM	39.5	66.9	71.7	43	40	
1.2 BARREL TRACKER	23.1	20.9	33.6	38	36	
1.3 INTERMEDIATE TRACKER	11.3	16.8	16.6	17	17	
2.1 BARREL CALORIMETER	77.3	98	120	89	82	
2.2 INTERMEDIATE CALORIMETER	36.8	44.2	65.2	31	30	
2.3 FORWARD CALORIMETER	20.7	21.8	24.2	21	20	
3.1 MAGNET SYSTEMS	49.6	61.2	72.3	49	62	
3.2 MEASUREMENT SYSTEMS	48.7	74.4	82.8	68	63	
4.1 SC SOLENOID	29.8	30	29.1	29.1	29	
4.2 SOLENOID CRYO SYSTEMS	4.8	4.8	7.4	7.4	7	
5.1 FRONT-END SYSTEMS	27.7	34	54.5	42	36	
5.2 DATA ACQUISITION SYSTEMS	20.9	20.8	42.8	32	25	
5.3 TRIGGER SYSTEMS	49.3	49.8	47.6	34	38	
5.4 CONTROL SYSTEMS	6.7	6.7	7.1	6	6	
5.5 POWER CONDITIONING SYSTEMS	3	3	6.2	6	4	

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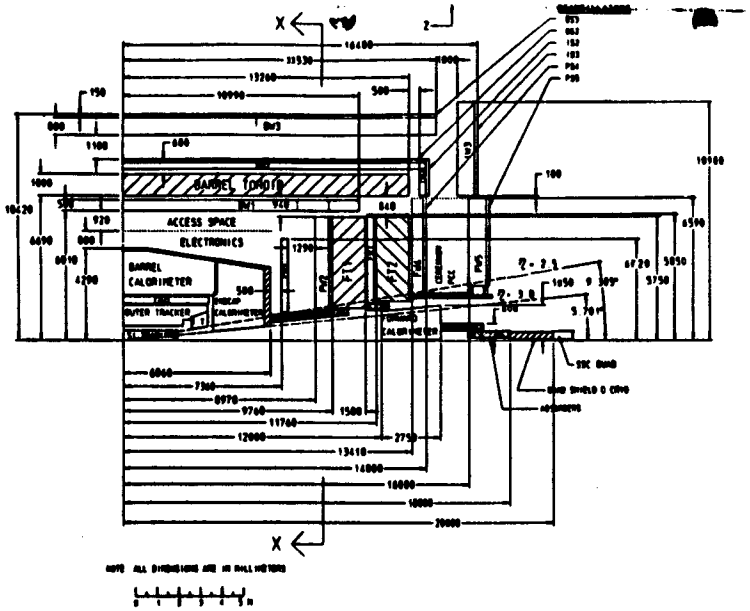
999



SDC SCINTILLATOR CALORIMETER OPTION
DESCOPE OPTION 1
LBL DWG # 23D0145 8/3/91 Y MINAMIHARA

997

Descoping Homework and Targets

Tracking System

Present total: $92M **Target:$85M**

Possible reductions

I) Silicon-straw-gas microstrip combination
Further reduction in silicon layers(material)?
Reduce straw superlayers to 4(2 axial, 2 stereo)
Fix intermediate tracker cost at $15M - what can be done?

II) Silicon-fiber-gas microstrip combination
Reduce silicon?
What is functionality of fibers at cost of $30M?

1000

Cost Comparison without R&D

	TOTAL COSTS WITH CONTINGENCY					
	LoI Estimate ($M)	LoI Rev. Panel ($M)	Preliminary Cost Baseline ($M)	Preliminary Descope I ($M)	Preliminary Descope II ($M)	Target "600M" ($M)
6.1 ON-LINE COMPUTING	11.0	13.9	10	10	10	10
7.1 MECHANICAL UTILITIES	1	1	0.8	0.8	0.5	
7.2 ELECTRICAL UTILITIES	1	1	2	2	2	
7.3 SAFETY SYSTEMS	6	6	5.6	3	3	
7.4 STRUCTURAL SUPPORT SYSTEMS	3.1	3.1	5.6	4	4	
8.1 TEST BEAM PROGRAM	8	10	10	8.8	9.5	
8.2 SUBSYSTEM INSTALL. AND TEST	19	48	26	26	26	
9.1 PROJECT PLANNING			2.1	2.1	2.1	
9.2 PROJECT TRACKING			1.6	1.6	1.6	
9.3 DOCUMENT DIST. AND CONTROL			2.1	2.1	2.1	
9.4 QUALITY ASSURANCE			1.4	1.4	1.4	
9.5 ES&H			2.5	2.8	2.8	
9.6 DETECTOR INTEGRATION			11	11	11	
TOTALS	810	872	818	884	861	820
Tracking volume R,XL	1.7x4.8	1.7x4.8	1.7x4.8	1.7x4.8	1.7x4.8	1.7x????

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998

Descoping Homework and Targets

Calorimetry

Present total:$142M Target:$135M

For scintillator central calorimetry

Reduce to 9λ at η=0 and scale appropriately-what is physics impact?
Continue to explore transverse and longitudinal sampling - can further reductions be made and what is physics impact?

For forward calorimetry

Cost savings from inverted cone?
Does rad hard=> simple=> cheap?

1001

Descoping Homework and Targets

Muon System

Present total:$115M Target:$95M

Possible reductions

Reduce access space to back of calorimeter($15M per meter). If calorimeter goes to 9λ? Look very hard at access needs.

Single scintillator layer?

Forward system trigger redundancy?

1002

Descoping Homework and Targets

Electronics System

Present total:$100M Target:$100M

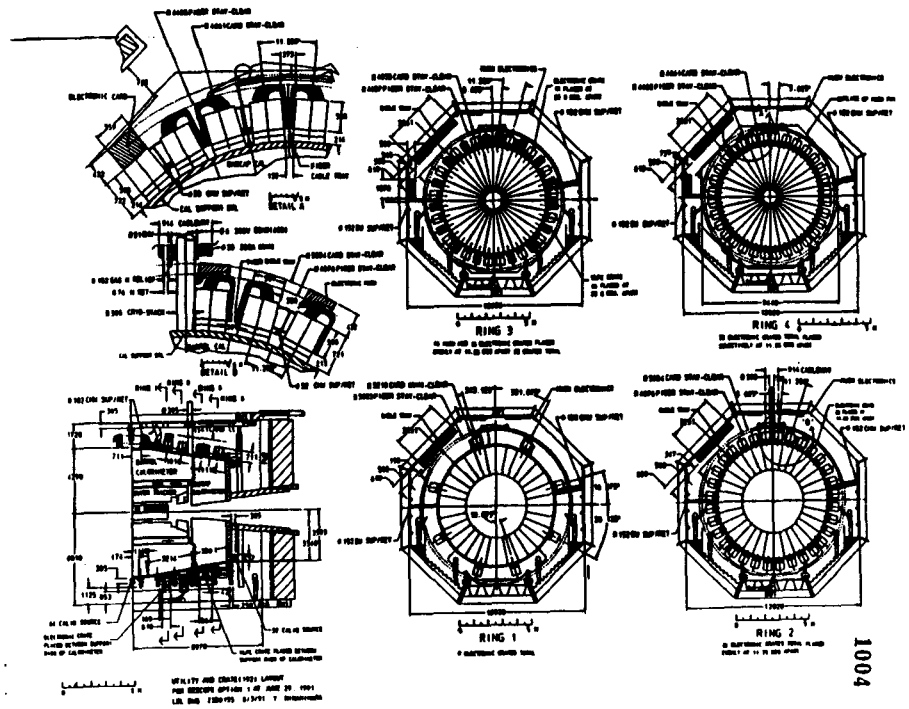
Looks OK but need rapid feedback on layout of electronics on back of calorimeter and feasibility of reduced access.

Remainder of Detector

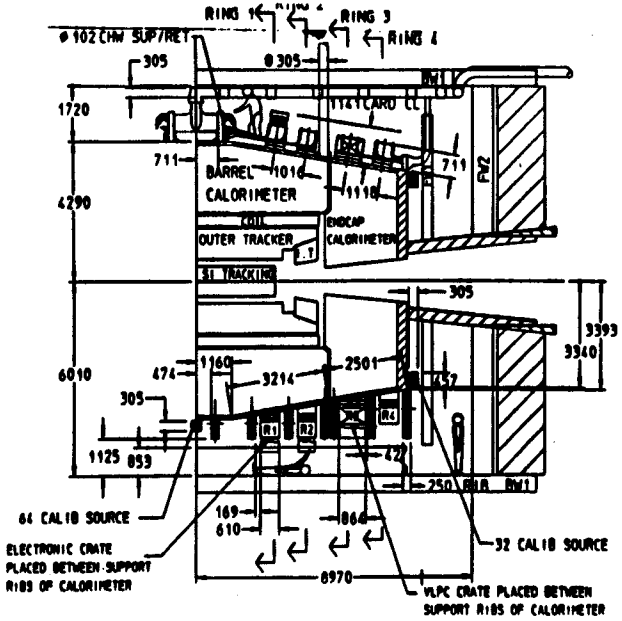
Cost of installation is a soft estimate. Look harder.

Accounting?

1003

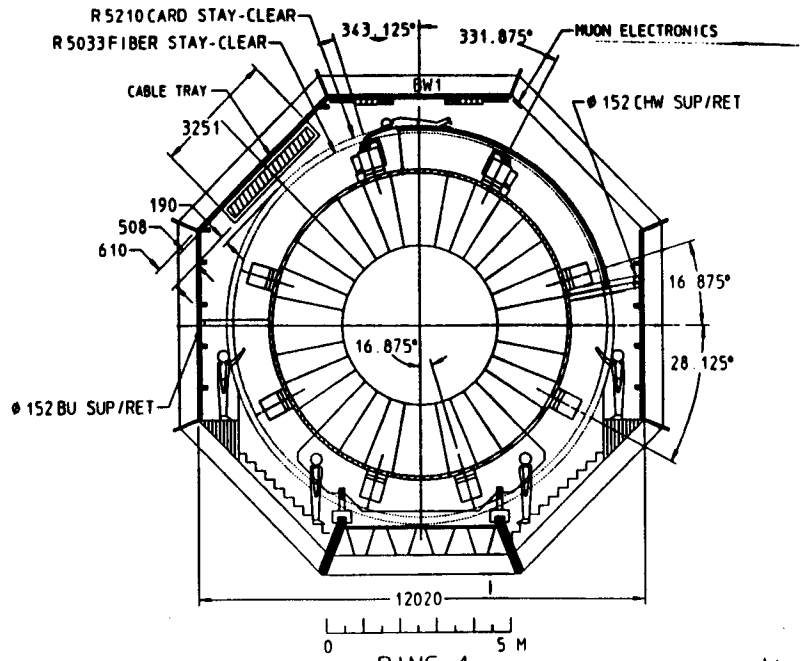


1004



UTILITY AND CRATE(1992) LAYOUT
FOR DESCOPE OPTION 1 OF JUNE 29, 1991
LBL DWG. 23D0155 8/3/91 Y. MINAMIHARA

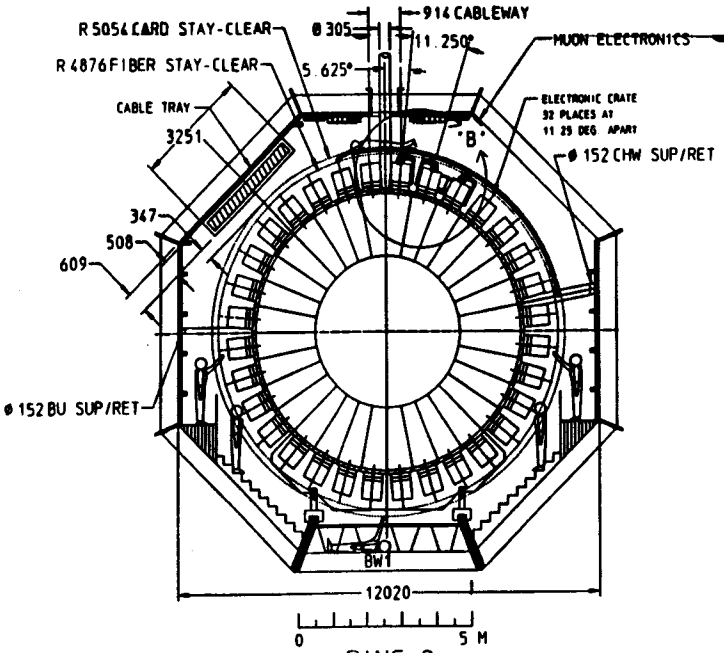
1007



RING 1

8 ELECTRONIC CRATES TOTAL

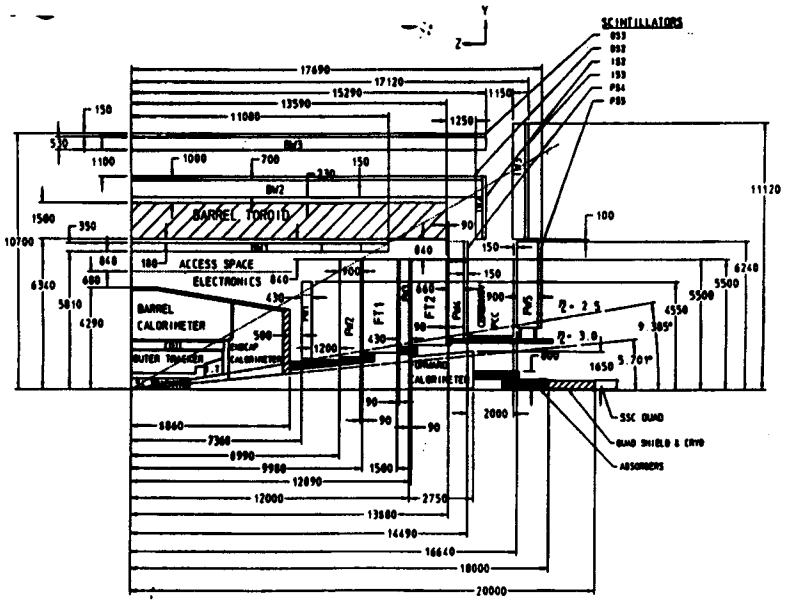
1005



RING 2

32 ELECTRONIC CRATES TOTAL PLACED
EVENLY AT 11.25 DEG APART

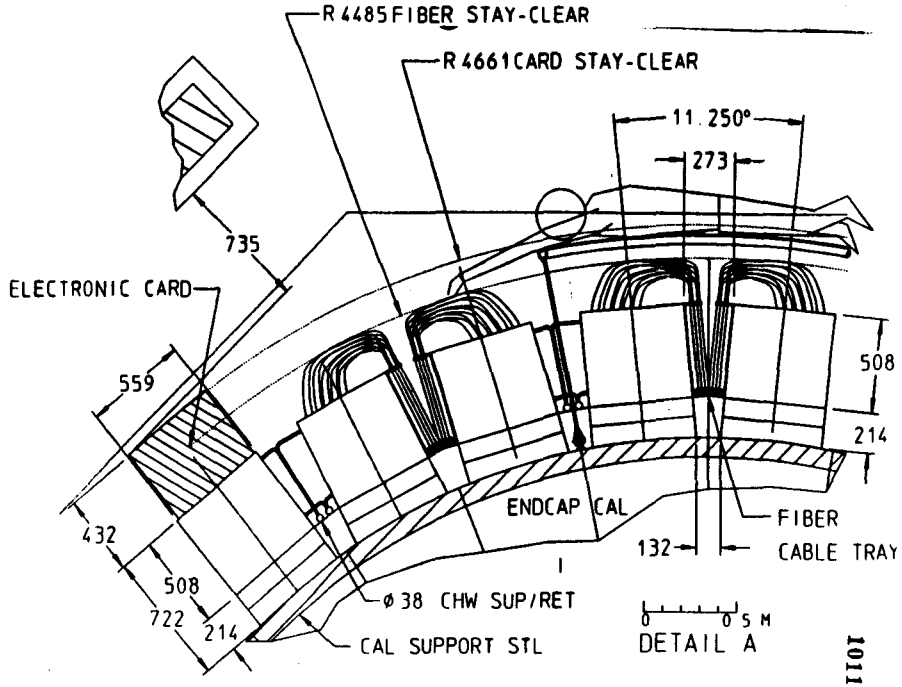
1008



NOTE: ALL DIMENSIONS ARE IN MILLIMETERS.

SDC SCINTILLATOR CALORIMETER OPTION
DESCOPE OPTION 2 STUDY A
8/9/91 Y. MINAMIHARA

1006



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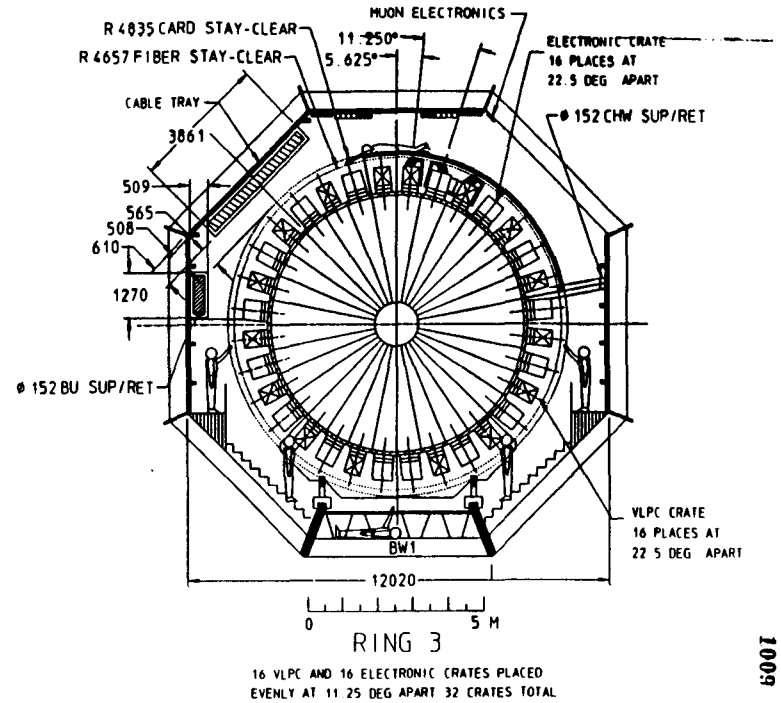

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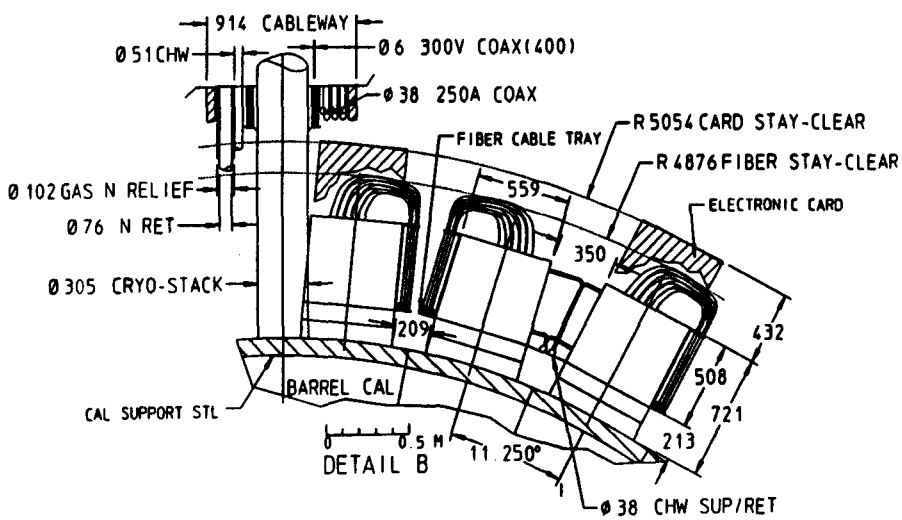

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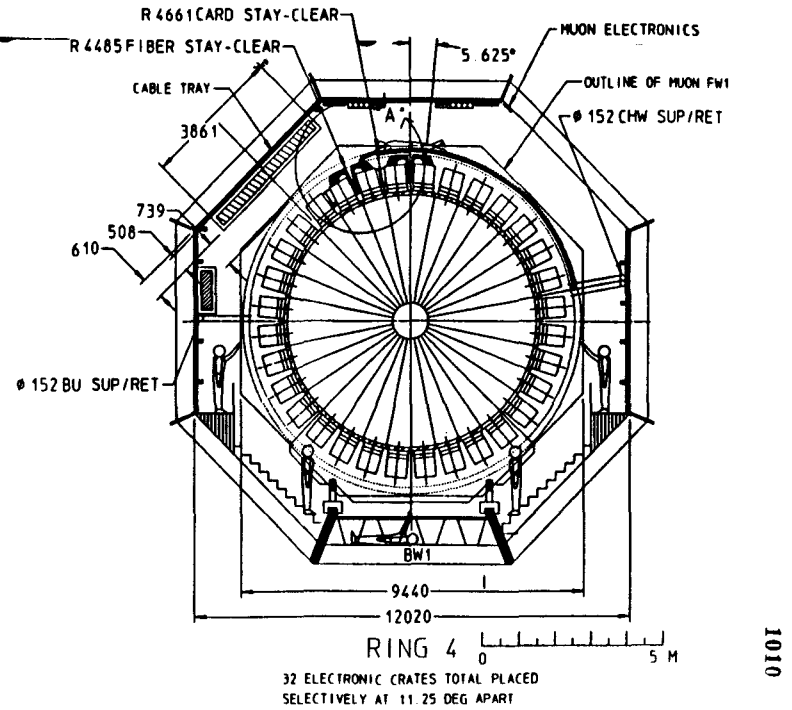


1010

Plan and Request

- Respond to suggestions by ORNL meeting
- Reports and discussions
- Physics impact
- Additional staging?

Tracking

August 6 - Tuesday

Possible Disadvantages of Non-Uniform Field for Tracking	J. Hylen(Fermilab)

August 8 - Thursday

Straw Tube R&D Plans at Duke	A. Goshaw(Duke)
Straw Module Status Report	G. Hanson(Indiana)
Pixel's Progress	D. Nygren(LBL) & S. Parker (Hawaii)
Gas Microstrip Work in the US - Update	A. Sill(Rochester)
Status of Intermediate Tracking	E. Gabathuler(Liverpool)
VLPC Update	P. Besser(Rockwell)
Fiber Tracking - Cosmic Ray Results	R. Ruchti(Notre Dame)

LPBautz:8/27/91

Jim Hylen
FNAL
SDC workshop 8/6/91

1015

Possible Disadvantages of Non-Uniform Field for Tracking

Degraded Momentum Resolution (Minimal)

Pattern Recognition

Triggering

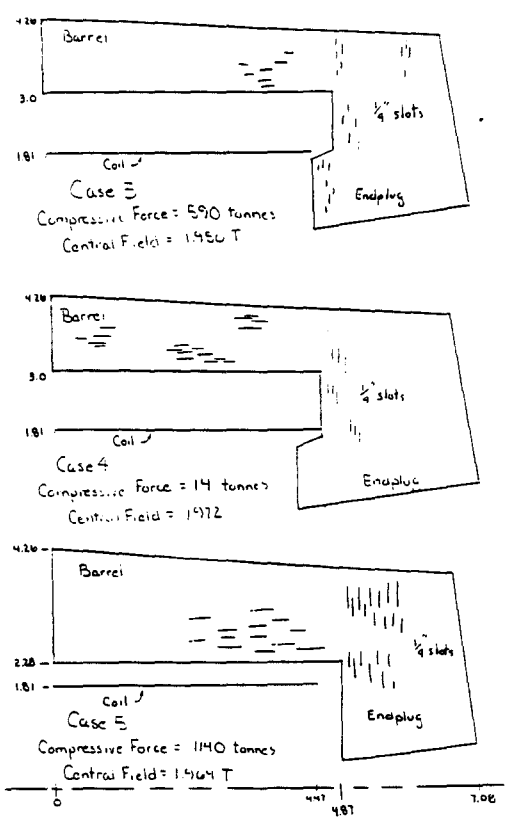
CPU requirements

Drift Angle in wire chambers?

Path of loopers? (+/- ?)

Measurement of detector alignment

1016

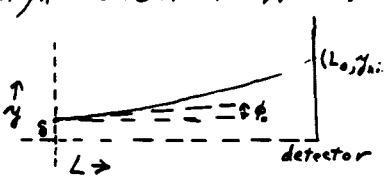


1017

Relation of track hit position to field (high momentum approx.)

UNIFORM FIELD

$$y_{hit} \simeq \delta + \phi_0 L_0 + \frac{qBL_0^2}{2P}$$

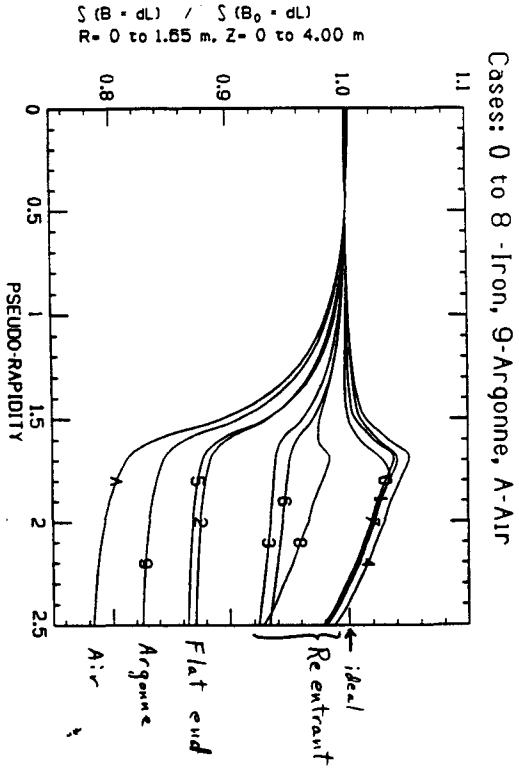


NON-UNIFORM FIELD $\quad \frac{d\vec{P}}{dt} = q\,\vec{v} \times \vec{B}$

"P_T Kick" $\quad \Delta p = q \int_0^{L_0} d\vec{L} \times \vec{B}$

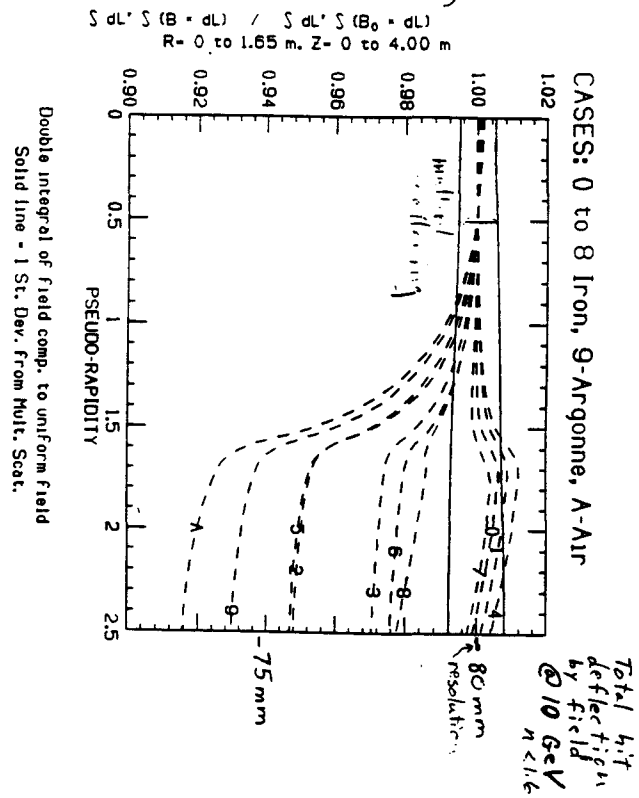
angular deflection $\quad \Delta\phi = \frac{\Delta p}{p} = \frac{q}{p} \int_0^{L_0} d\vec{L} \times \vec{B}$

$$y_{hit} = (\text{const.}) + \frac{q}{p} \int_0^{L_0} dL \int_0^{L} d\vec{L} \times \vec{B}$$



"Kick" or angular deflection compared to uniform field

Hit deflection (non-uniform) / Hit deflection (uniform)



Total hit deflection by field @ 10 GeV $\eta < 1.6$

To design detector with pattern recognition in mind
"reduce number of possible combinations at an early stage by
→ associating coordinates to space points
→ reducing dimensionality by operating in projections"
Regler & Frühwirth

In uniform fied, with axial detector
$r\ \phi$ (→ curvature, ϕ_0)
are decoupled from z_0, dip

(in radial detectors, similar decoupling occurs)

In baseline system with uniform field:

→ projections work
→ super layer produces local vector "space points"

⇒ powerful, rugged system to deal with high occupancy SSC events

In non-uniform field: (Need simulation!)

Global pattern recognition, such as histogramming method presented yesterday, probably wont work ☹

Must do pattern recognition in r, ϕ, z, λ simultaneously

Intuition: Strong fiber system → local space points, local vectors → probably OK ☺

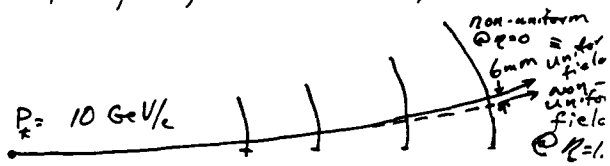
Thinned out outter system need proof that it would work (??)

8 layer silicon strip system → still work, could then swim to outter system & pick up hits ☺

Pattern Recognition in tracking will probably be largest SDC CPU load — we could really use some estimate of whether non-uniform field will cost \$1 million, \$10 million, \$100 million in CPU \$.

TRIGGER: Take Fiber system presented to tracking group yesterday (D. Adams).

4 "superlayers", 4 axial fiber layers each



Algorithm used 1mm fiber bins → factor of 6 degredation in trigger rejection capability due to non-uniform field smearing hit position

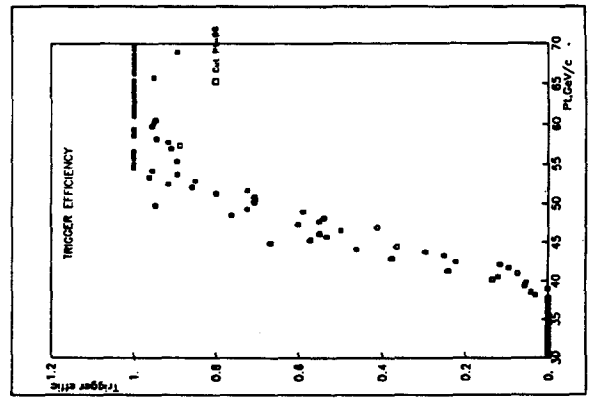
Alternatively:
match slope (to local perpendicular)

Uniform Field
@10 GeV/c $\theta_{80cm} \sim 25$ mr $\theta_{160cm} \sim 50$ mr

Non-Uniform Field
@10 GeV/c $\eta=0$ $\theta_{80cm} \sim 25$ mr $\theta_{160cm} \sim 50$ mr
$\eta=1.5$ $\theta_{80cm} \sim 25$ mr $\theta_{160cm} \sim 40$ mr

With resolution of 1 to 2 mr, factor of 5 degradation in trigger rejection capability

Ray Lewis



Straw tube R+D Plans at Duke (next 3-4 months)

A. Goshaw

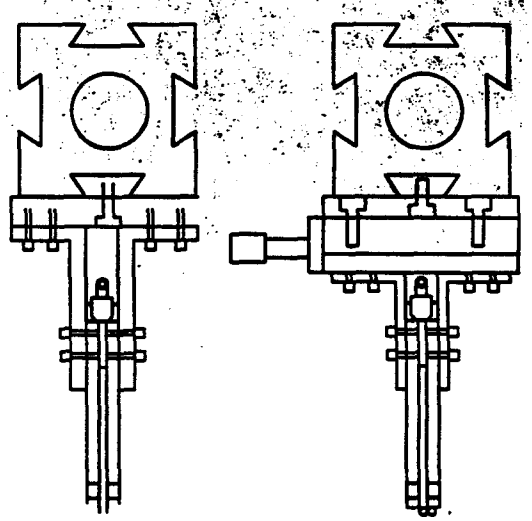
construction and test of straws of length 7-8 m ⇒ wire supports, mid-tube terminator, readout at both ends (straws with 1000 Å Cu cathode)

use 2.7 m straw tube superlayer to test Penn front-end electronics as it becomes available (Colorado and ORNL); test will be made at low and high occupancies using 5 10-millicurie Sr^{90} sources

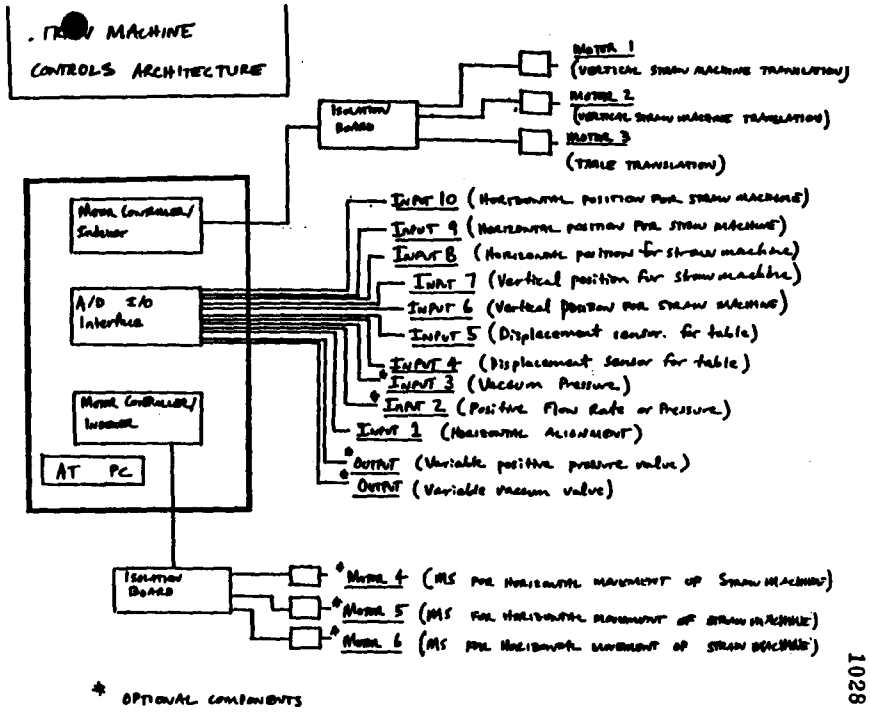
construct 3 meter straw placement machine ⇒ semiautomatic laying and gluing of 3 m straw tube superlayer (with ORNL)

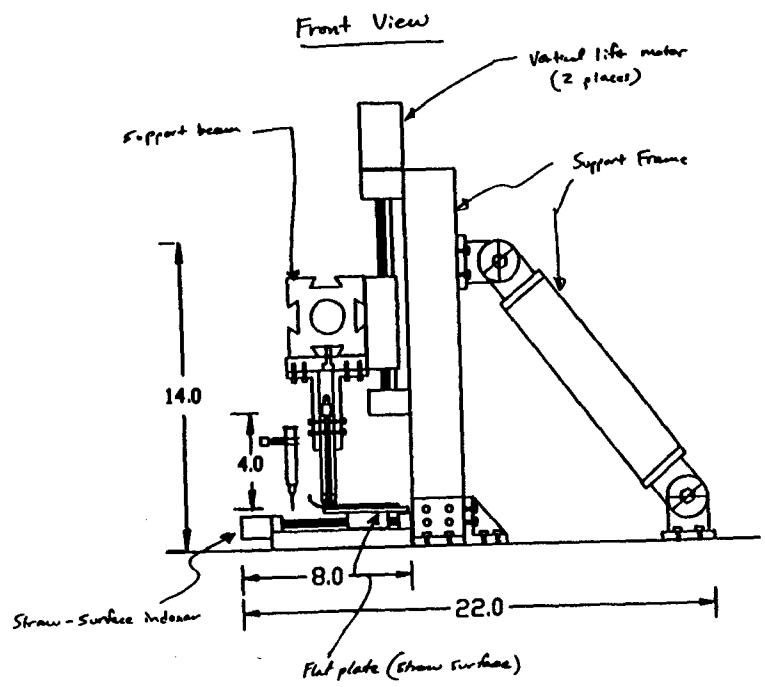
in conjunction with TRIUMF and QRS, continue radiation hardness studies

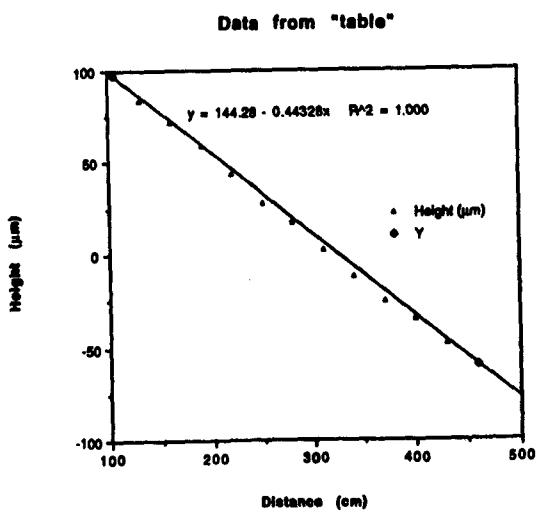
test survey techniques for straw tubes and wires

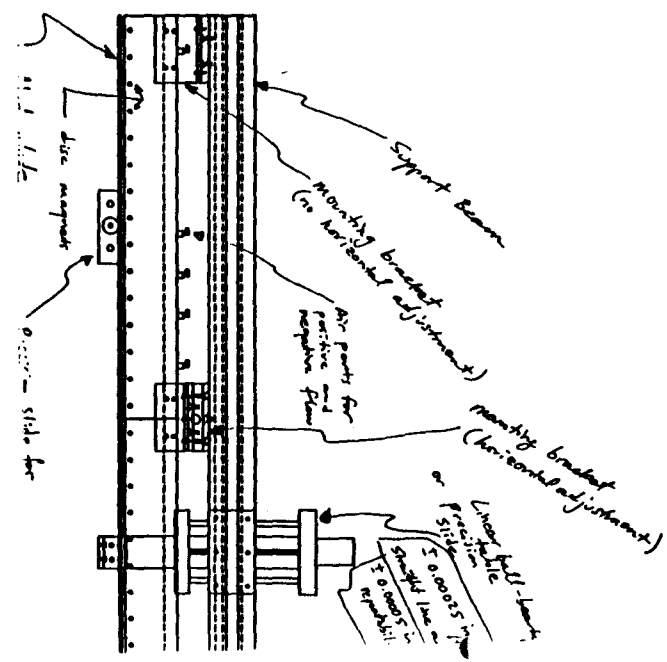


"Fixed" bracket "Adjustable" bracket

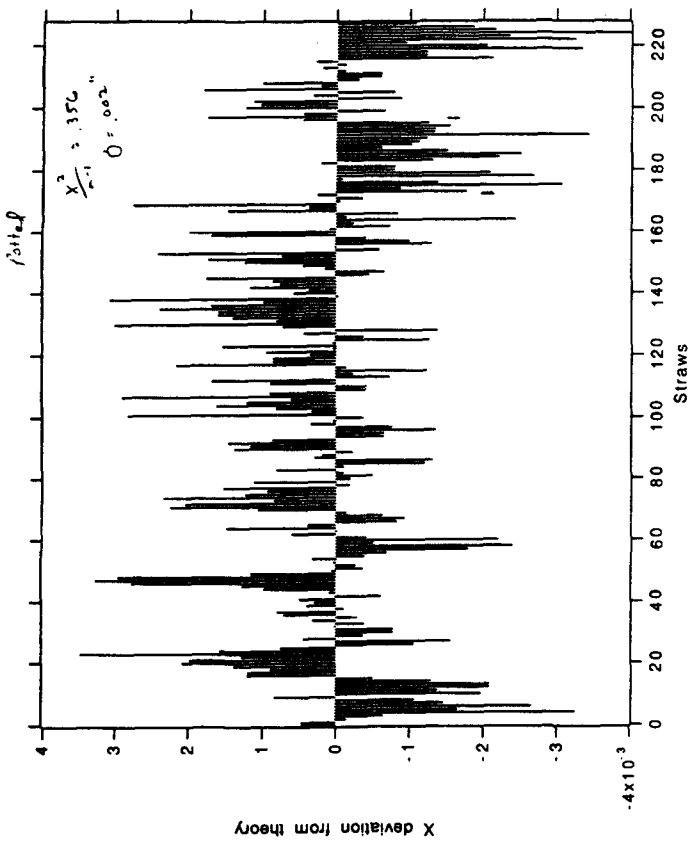

STRAW MACHINE
CONTROLS ARCHITECTURE
Motor Controller/ Indexer
A/D I/O Interface
Motor Controller/ Indexer
AT PC
Isolation Board
Motor 1 (Vertical straw machine translation)
Motor 2 (Vertical straw machine translation)
Motor 3 (Table translation)
Input 10 (Horizontal position for straw machine)
Input 9 (Horizontal position for straw machine)
Input 8 (Horizontal position for straw machine)
Input 7 (Vertical position for straw machine)
Input 6 (Vertical position for straw machine)
Input 5 (Displacement sensor for table)
Input 4 (Displacement sensor for table)
Input 3 (Vacuum Pressure)
Input 2 (Positive Flow Rate or Pressure)
Input 1 (Horizontal Alignment)
Output (Variable positive pressure valve)
Output (Variable vacuum valve)
Isolation Board
Motor 4 (MS for horizontal movement of straw machine)
Motor 5 (MS for horizontal movement of straw machine)
Motor 6 (MS for horizontal movement of straw machine)
* Optional components


Front View
Vertical lift motor (2 places)
Support beam
Support Frame
14.0
4.0
8.0
22.0
Straw-surface indexer
Flat plate (Straw surface)

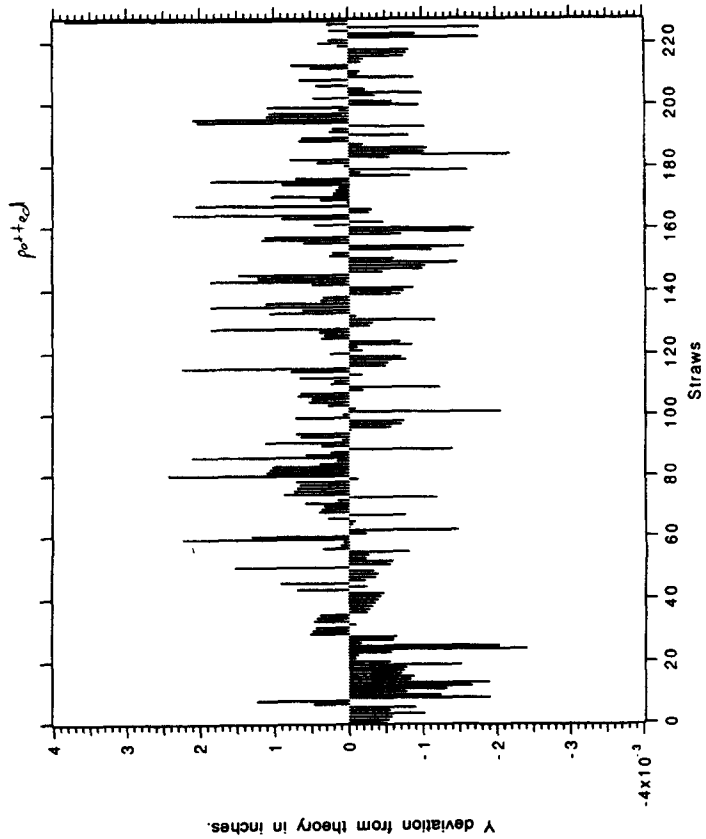

Data from "table"
y = 144.28 - 0.44328x R^2 = 1.000
Height (µm)
Y
Height (µm)
Distance (cm)
100
50
0
-50
-100
100
200
300
400
500


Support Beam
Mounting bracket (no horizontal adjustment)
Air ports for positive and negative flow
Mounting bracket (horizontal adjustment)
Linear ball-bearing or Precision Slides
Disc magnet
Origin-slide bar

1034



1035



1036

Based on the Experience with this First 1-meter Shell, which did not quite meet some of the Specifications, We Are Negotiating With Composites Horizons for Another 1-m Shell and a 4-m Shell

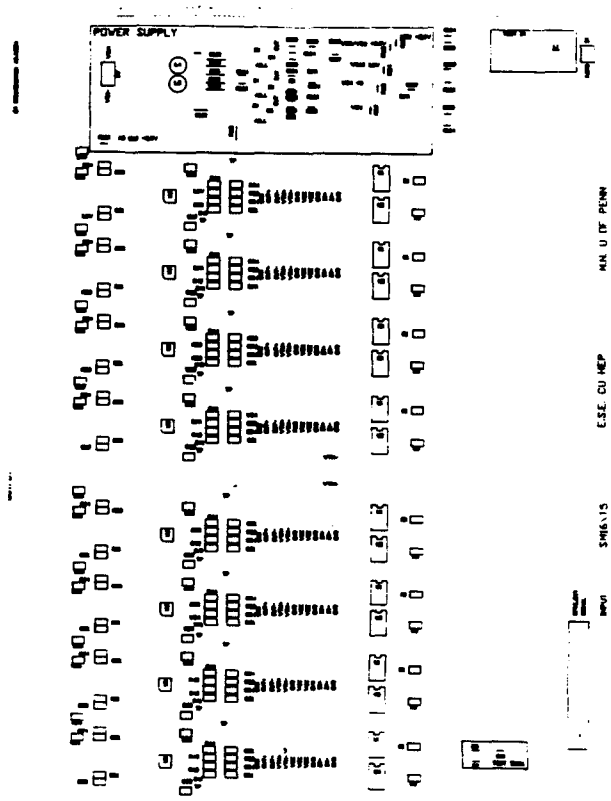
Specifications: Indiana, ORNL, WSTC
Engineering Consulting: ORNL
Acceptance Measurements: ORNL

We are studying the operating characteristics of the modules with existing electronics

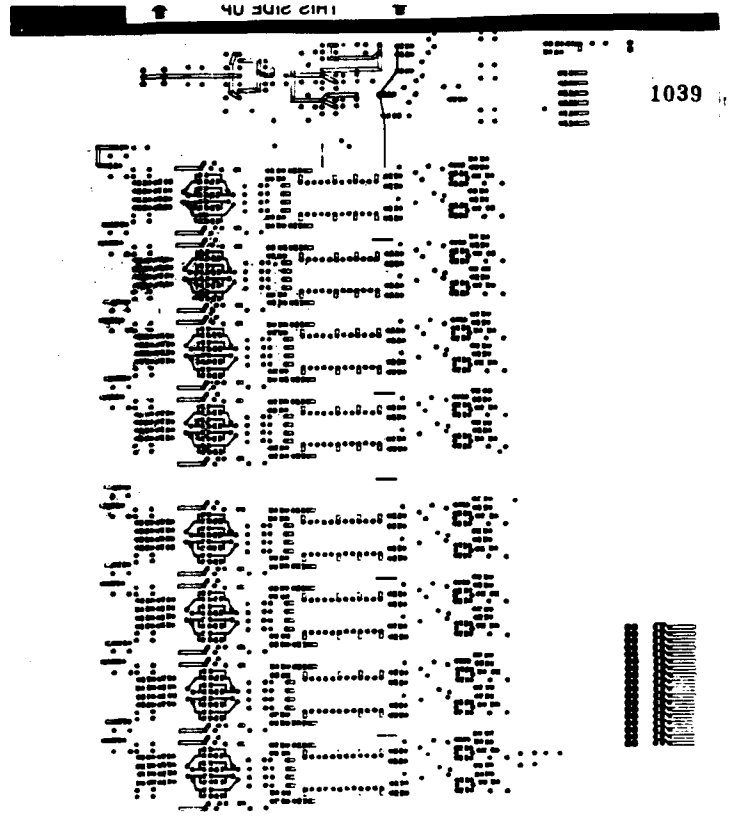
We will soon test them with Penn electronics using hybrid board from Colorado

We are evaluating straw materials & coatings, improving design for wire supports, working on designs for wire terminations and better connections to wires.

1037



1038



1039

1040

WSTC Is Working on Support Structure,
Module Attachment, Costing, Integration

1041

PIXEL'S PROGRESS

I. PROTOTYPES (HUGHES & LBL):

A. 32 x 64 ARRAY - 50 x 150 μm PIXELS
SMART, TIMESTAMPING, GHOST ELIMINATION
"PROOF-OF-PRINCIPLE" DEVICE, PERIPHERY SIMPLE

B. "RADIATION-HARD" PIXEL CELL - HUGHES SOS

C. "ADVANCED" PIXEL CELL - CR-RC SHAPING
DC SERVOS, AUTONOMOUS OPERATION

II. PROTOTYPE STATUS:

A. 32 x 64 SECOND GENERATION DEVICE
DUE BACK FROM FOUNDRY 8-9-91. FIRST
DEVICE WORKED, WITH SOME PROBLEMS -
< 200 e⁻ NOISE, SPARSE DATA WORKS....

B. "RADIATION HARD" PIXEL CELL FABBED - AWAITING TEST

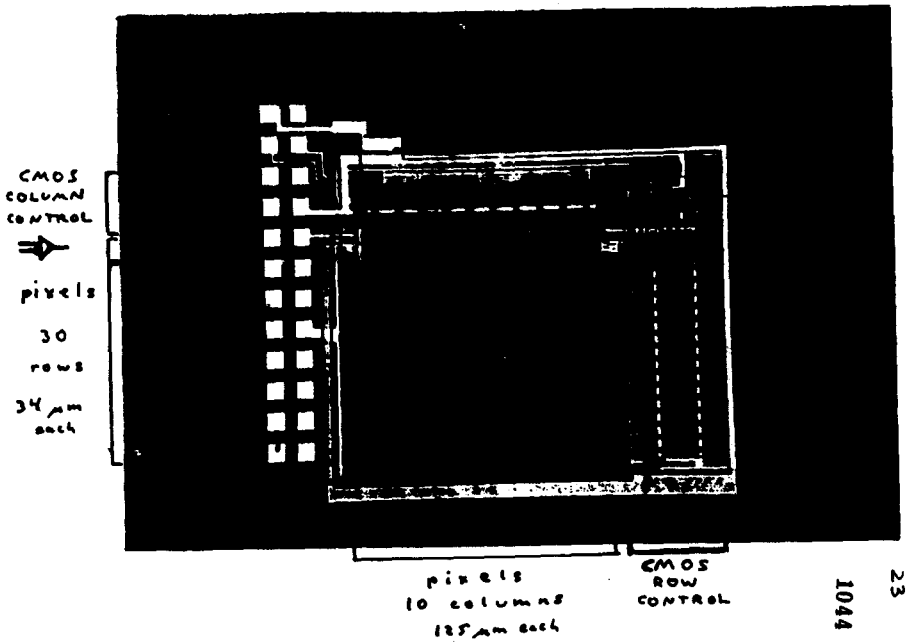
C. ADVANCED PIXEL CELL IS WORKING WELL
< 200 e⁻ NOISE, REASONABLE TIME WALK.
Problem: UNEXPECTEDLY LARGE THRESHOLD VARIATIONS -
CAN BE SOLVED WITH NEW DESIGN CONCEPT.

III. ARCHITECTURE:

NEW TIME-OVER-THRESHOLD CONCEPT OFFERS
PROSPECT FOR GOOD CHARGE & TIME RESOLUTION
IN A PURELY DIGITAL SYSTEM.

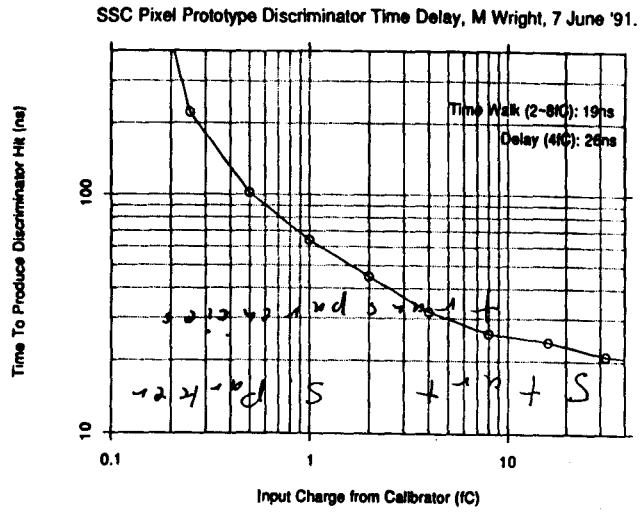
IV. BEAM TESTS PLANNED AT FNAL IN FALL

Integrated Pixel Detector

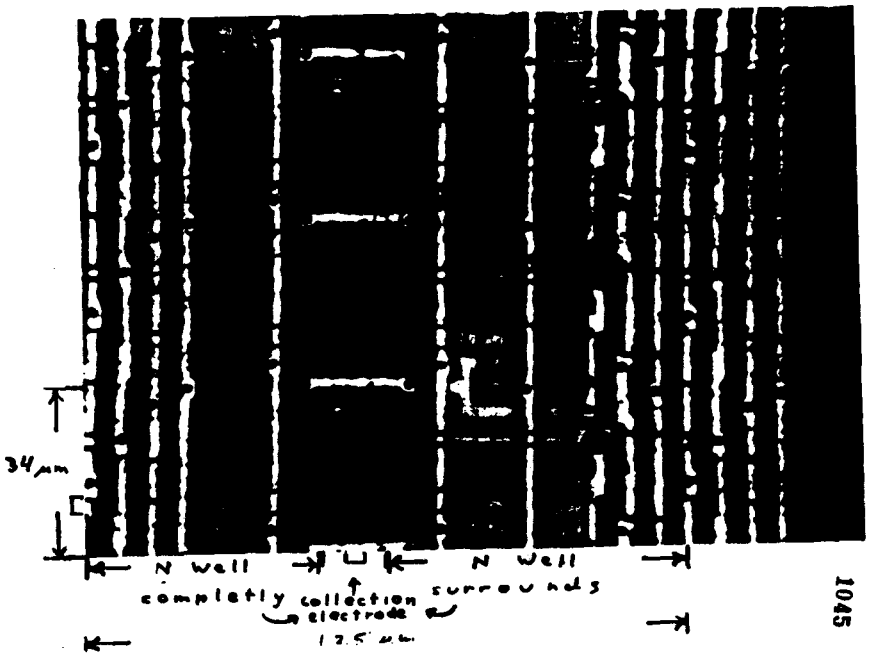


1044

23



1042

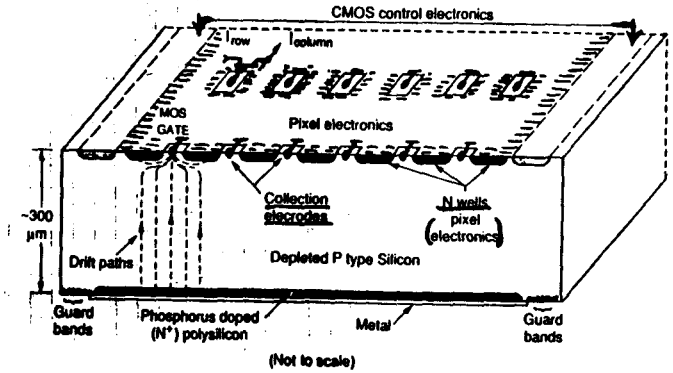


1045

Integrated Pixel Detector

S. Parker, C. Kenney
U of Hawaii

W. Snoeys, J. Plummer
Stanford U.



1043

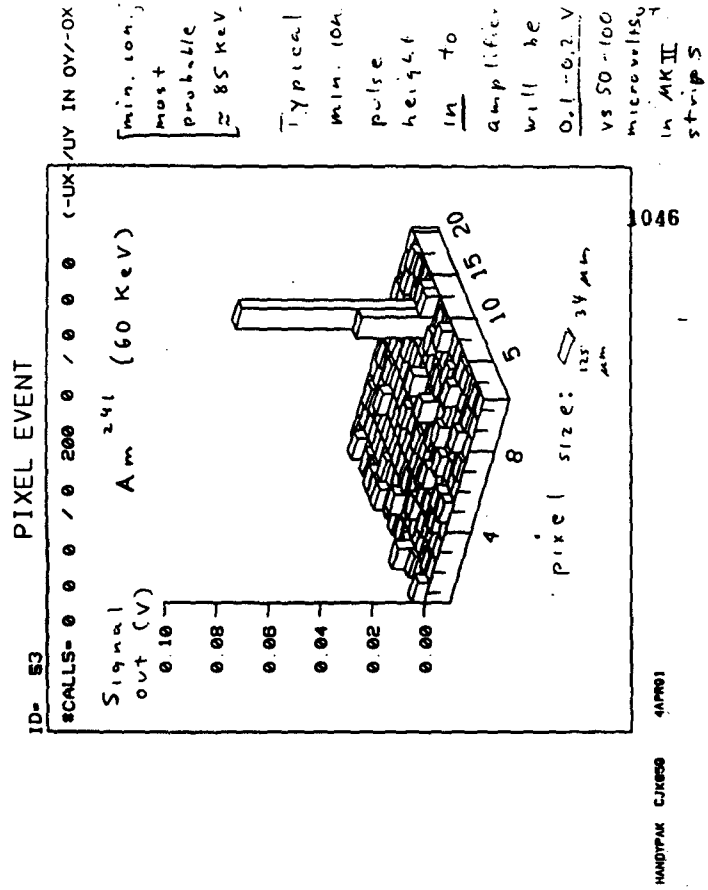
Collection electrode

1. gets >99.99% of ionization in bulk
2. has low capacity (including mos gate)

N well

1. shapes collection field
2. shields it from readout electronics
3. provides proper doping for readout transistors

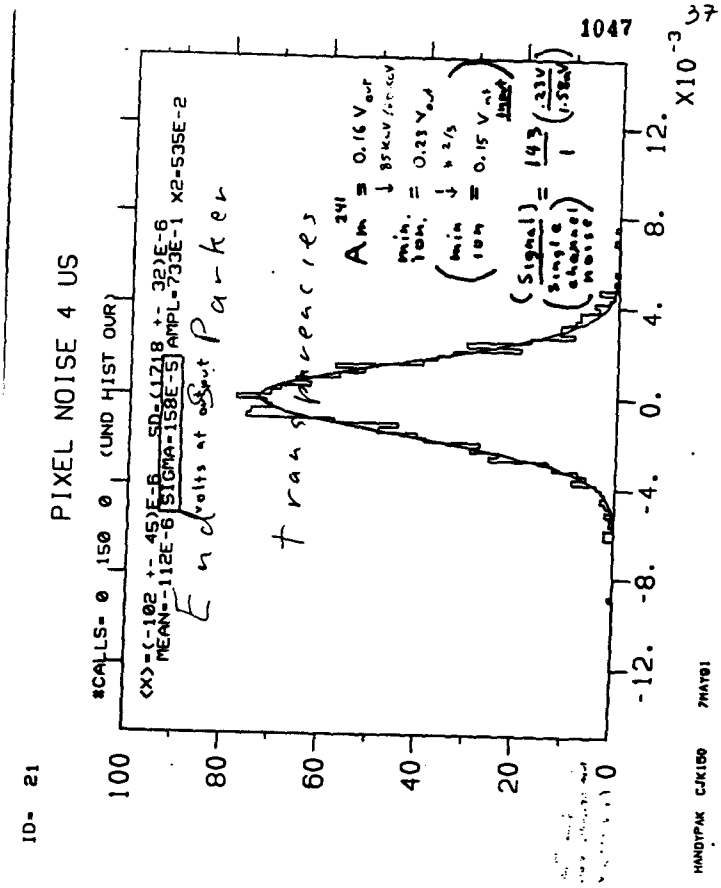
1046



min. ion. most probable ≈ 85 keV

Typical min. ion. pulse height in to amplifier will be 0.1 - 0.2 V vs 50 - 100 microvolts in MK II strips

1047



Energy deposits at output Parker transducers

Am^{241} = 0.16 V_{out} ↓ 85 keV/min. ion

min. ion = 0.23 V_{out} → ≈ 2/3

min ion = 0.15 V_{out} input

$\left(\frac{signal}{single\ channel\ noise}\right) = \frac{143}{1}\left(\frac{.33V}{.5 keV}\right)$

1048

Intermediate Tracker - Microstrip work in the US.

by ALAN SILL. (ROCHESTER)

Rochester -

Plastic substrates - testing of resistance properties to find candidate materials as a backing to glass, Si technology. Identified 2 (Hytrel & radiation cured coating on polyester or PETG or polystyrene), working with Texas A&M which has identified 2-3 others.

Resistivity being measured in a controlled setup - Faraday cage, detecting air gun, picoammeter in direct line, etc.

Modeling - electrostatic field shaping calculations using ANSYS finite element model (using thermal analog) from Detlef Mathern @ CERN.

Texas A&M

Plastic & other substrates - tested several plastics, identified 2 new ones (Texin elastomer & polypropylene special processed material), also rejected several others. Also testing glass & will try amorphous Silicon too.

1049

Texas A&M cont'd

Simulation - Gene Baronsch has developed a GEANT/SDC shell model for Texas A&M proposal, will be installed soon as an option into the official SDC shell card files.

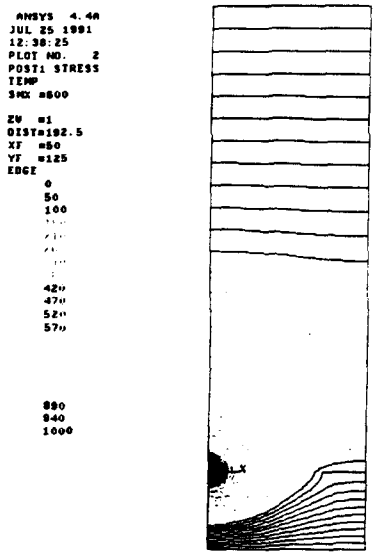
Can be generalized soon to other approaches

Purdue. -

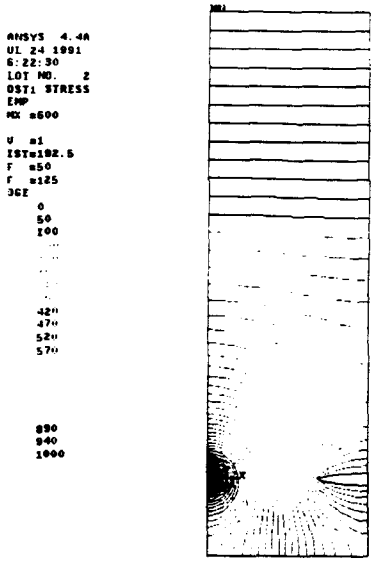
Inquiries received from Ian Shipsey re. participation in plastic research & more general SDC simulation. Hope to begin soon.

Duke -

Inquiries received & meeting attendance from one person.



Microstrip Detector #4 (2 Dim. Simul.) From DETLEF@CERNVM.CERN.CH



Microstrip Detector #4 (2 Dim. Simul.) From DETLEF@CERNVM.CERN.CH

STATUS OF

INTERMEDIATE TRACKING

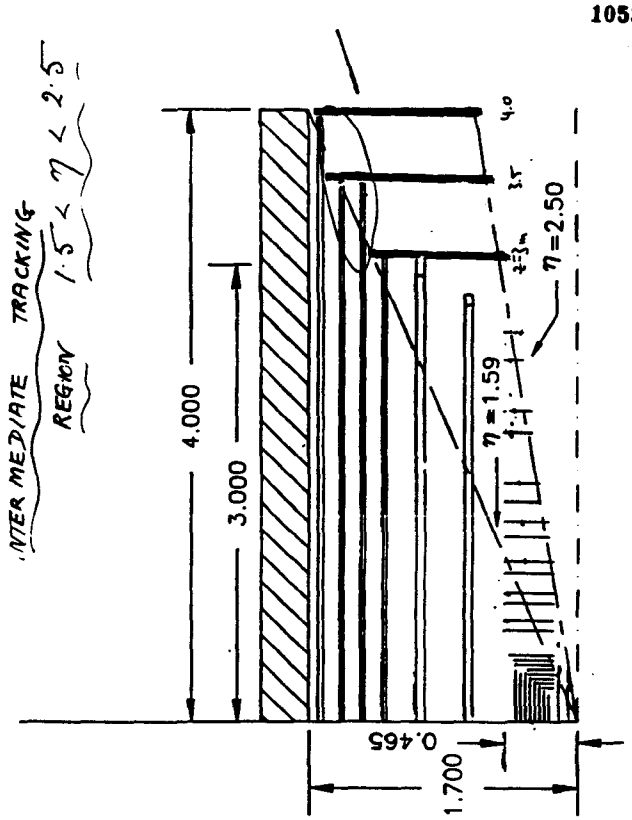
by

ERWIN GABATHULER

LIVERPOOL UNIVERSITY

INCLUDES WORK IN

OTHER U.K + U.S LABS



INTERMEDIATE TRACKING

1054

REMINDER $1.5 < \eta < 2.5$

$|\eta| = 1.$

LARGE - PHYSICS GAP FOR ALL PROCESSES e.g. γ W, Z, H → LEPTONS CONTRIBUTES → NEW PHYSICS

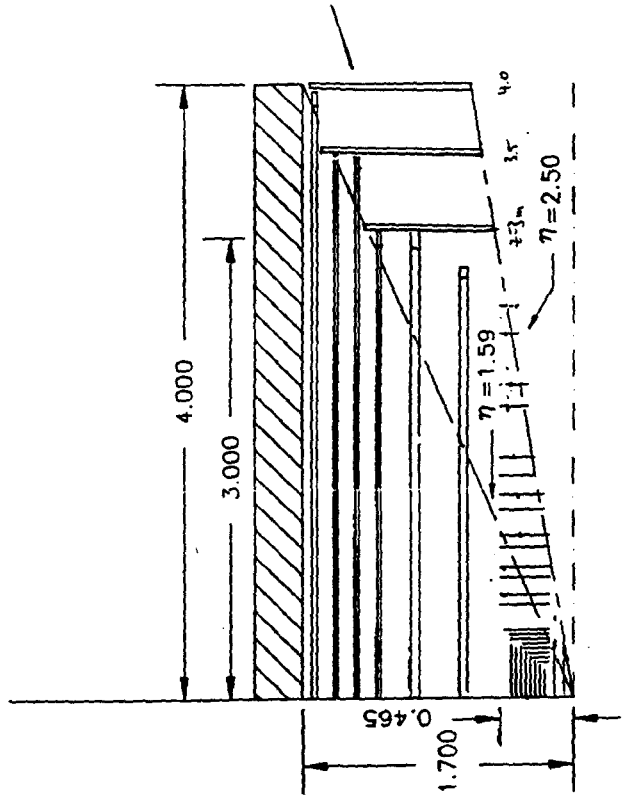
II OCCUPANCY IS HIGH - ALL DETECTORS (WIRES, STRAWS, FIBRES - PROBLEMS IN THIS REGION - NO RADIATION PROBLEM.

III PROJECTIVE GEOMETRY - FINE ϕ SEGMENTATION FOR TRIGGERING IN THIS REGION.

IV PROVIDE ADDITION PATTERN RECOGNITION CAPABILITY

V ANSWER - WE HAVE NOW MADE GAS-FIBRE STRIPS WHICH WORK RELIABLY -

1055

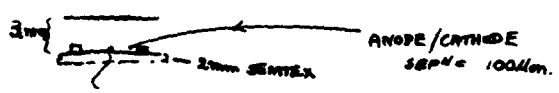


PRESENT SITUATION

1056

LIVERPOOL / R.A.L [BRENNAN ET AL]

- TILES OF 60cm × 1cm SEMTEX GLASS WORKING RELIABLY SEVERAL MONTHS



10μm AL. ANODES (AL = 0.8μm)

- OPERATING IN CF_4 / ISOBUTANE 80/20 MIX

BEAUTIFUL PULSES 30 NANOSECOND GAIN 10^3-10^4

- ELECTRICAL CONNECTIONS HAVE BEEN ACHIEVED

- OTHER WORK → IN PROGRESS [UK] SET UP PLATE WITH INDIVIDUAL ANODES + MICROSTRIP ELECTRONICS (SILICON)

- 2mm → 500μm → 200μ (GLASS) DIFFERENT MATERIALS - SILICON (BULK)

- MAKE TILE - "A4" SIZE = 200cm × 150cm.

- MEASURE EFFICY (HIGH 90's) - PRECISELY IN TEST BEAM.

-

[illegible] (IN OTHER LABS)

1057

SIMULATION - CARLETON / TEXAS A+M / U.K

PLASTIC SUBSTRATES - TEXAS A+M / ROCHESTER

GLASS / CERAMICS / SILICON - LIVERPOOL / RAL TEXAS A/M.

FRONT-END ELECTRONICS - TEXAS (A+M)

WORK @ TEXAS A+M

① LARGE AREA PLANAR MICROSTRIP 300μm PITCH

② KNIFE EDGE CHAMBERS (ANODE SEPN = 50μm / 75μm) - FABRIN GOOD MORE WORK ON GEOMETRY / FIELD CHANGE ETC

③ READ-OUT ELECTRONICS - ASSOCN WITH SSC LAB / E-CAD DESIGN.

CANADA (CARLETON)

- DEVELOPMENT OF ACCURATE LITHOGRAPHIC PROCESSES - ON PLASTIC WITH INDUSTRY (WHITE TEDLAR) TITANIUM OXIDE BASE
- RESISTIVE SUBSTRATES ON SILICON
- SOFTWARE ANALYSIS - USING "SHELL"

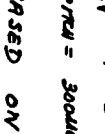
PROPOSAL FOR INT. TRACKING SYSTEM

THREE SUPER-LAYERS

2R, 2U, 2V × 3

ANODE PITCH = 300μm.

RESOL^N = 80μm



COSTS BASED ON SILICON

LABOUR/MANAG = 4M

TILES 4½M

ELECTRONICS - 1·2M (3M ANODES)

READ-OUT = 0·6M.

SUPPORT } = 7·2M.
STRUCT. }

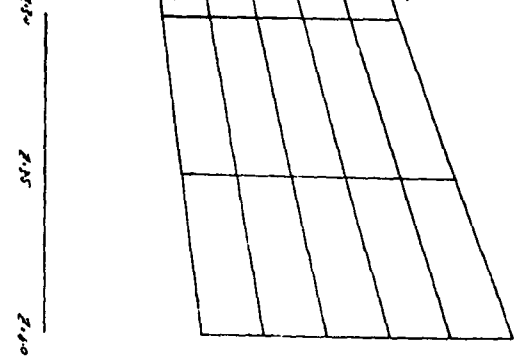
TOTAL = 16·5M.

TOTAL TILES = 8000

OCC/TILE = 30%

NO OF ANODES/TILE = 450

1056



R	θ	φ
1·50	0·357	1·297
1·30	0·244	1·843
1·10	0·263	2·004
0·90	0·221	2·189
0·70	0·172	2·405
0·50	0·124	2·729

1059

GAS MICROSTRIP ITD VERSION 30/7/91

SOME NUMBERS

Z	RADIUS INNER	RADIUS OUTER	CIRCUMFERENCE INNER	CIRCUMFERENCE OUTER	No. OF PLATES	ANODES/PLATE	ANODES/RING	ANODE PITCH INNER	ANODE PITCH OUTER	PLATE SIZE INNER	PLATE SIZE OUTER	PLATE SIZE RADIAL
3.0	0.375	0.525	2.356	3.299	24	448	10752	219.140	306.796	0.098	0.137	0.150
	0.525	0.675	3.299	4.241	30	420	12600	261.799	337.539	0.110	0.141	0.150
	0.675	0.825	4.241	5.184	36	504	18144	288.769	385.694	0.118	0.143	0.150
	0.825	0.975	5.134	6.126	42	448	18816	336.490	325.580	0.122	0.146	0.150
	0.975	1.125	6.126	7.069	48	448	21504	336.882	299.491	0.127	0.147	0.150
3.5	0.4375	0.6125	2.749	3.848	28	384	10752	255.443	357.929	0.098	0.137	0.175
	0.6125	0.7875	3.848	4.948	35	360	12600	305.432	392.699	0.110	0.141	0.175
	0.7875	0.9625	4.948	6.048	42	432	18144	352.708	333.309	0.118	0.144	0.175
	0.9625	1.1375	6.048	7.147	48	392	18816	321.605	379.863	0.126	0.149	0.175
	1.1375	1.3125	7.147	8.247	56	384	21504	332.363	383.695	0.128	0.147	0.175
4.0	0.500	0.700	3.142	4.398	32	336	10752	293.187	409.062	0.098	0.137	0.200
	0.700	0.900	4.398	5.655	40	315	12600	349.066	448.799	0.110	0.141	0.200
	0.900	1.100	5.655	6.912	48	378	18144	377.666	480.925	0.118	0.144	0.200
	1.100	1.300	6.912	8.168	56	336	18816	357.321	436.106	0.123	0.146	0.200
	1.300	1.500	8.168	9.425	64	336	21504	389.363	438.280	0.128	0.147	0.200

No OF PLATES/END/LAYER/SUPERLAYER = 629

No OF ANODES/END/LAYER/SUPERLAYER = 245448

∴ FOR 2 ENDS AND 4 LAYERS/SUPERLAYER 5032 PLATES AND 1,963,584 ANODES

FOR 2 ENDS AND 6 " " 7548 " " 2,945,376 "

PAUL BLESSER

1060

HISTORY OF VLPC DEVELOPMENT

AUGUST 1987	-	APPLIED PHYSICS LETTER ON SSPM
SEPTEMBER 1987	-	CONTACT BY M. ATAC, FERMILAB
APRIL 1988	-	EXPERIMENTS BY PETROFF AND ATAC USING FIBERS AND WITH SSPM
NOVEMBER 1988	-	PRESENTATIONS BY PETROFF (IEEE) AND ATAC (SSC WORKSHOP) OF EXPERIMENT RESULTS
JANUARY 1989	-	HISTE PROPOSAL SUBMITTED (SSPM)
SUMMER 1989	-	VLPC DIFFERENTIATED FROM SSPM (PETROFF)
JULY 1990	-	PURCHASE ORDER FROM UCLA TO RI FOR HISTE
APRIL 1991	-	VLPC CONCEPT DEMONSTRATED

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HISTE

PERIOD OF PERFORMANCE: JULY 30, 1990 - DECEMBER 31, 1991

VALUE: $435K

GOALS:

- PROVIDE DETECTORS FOR FIBER TRACKING EXPERIMENTS (SSPM/VLPC)
- DEMONSTRATE VLPC OPERATION
- IMPROVE VLPC PERFORMANCE

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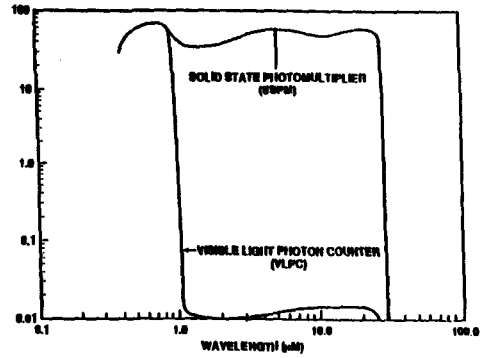
VISIBLE LIGHT PHOTON COUNTER (VLPC)

CALCULATED SPECTRAL QUANTUM EFFICIENCY



- IMPURITY BAND CONDUCTION DEVICE
- ULTRA-SENSITIVE PHOTON DETECTOR IN VISIBLE SPECTRUM
- PRACTICALLY BLIND IN INFRARED SPECTRUM (> 1.1 μm)
- APPLICABLE TO

  ASTRONOMY
  HIGH ENERGY PHYSICS
  MEDICINE

OPENS DOOR TO IBC DETECTOR APPLICATIONS TO HIGH ENERGY PHYSICS.

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HISTE STATUS

- FIRST VLPC MATERIAL GROWN AND PROCESSED ON IR&D, WITH IR&D MASK SET
- DEVICES TESTED ON CONTRACT
  - OPERATE AS EXPECTED FROM MODEL
  - PERFORMANCE NOT ADEQUATE FOR FIBER TRACKING
- DESIGNED AND FABRICATED HISTE MASK SET
  - SSPM MATERIAL
  - FABRICATED AND TESTED ON CONTRACT
- SECOND LOT OF VLPC MATERIAL GROWN
- FABRICATED AND TESTED DEVICES
  - VLPC CONCEPT DEMONSTRATED
  - FURTHER IR SUPPRESSION REQUIRED
- THIRD LOT OF VLPC MATERIAL GROWN
  - DEVICES IN FABRICATION
  - COMPLETION BY LATE AUGUST
- DEVICE CHARACTERIZATION
  - SEPTEMBER, OCTOBER
  - VERIFY VISIBLE PERFORMANCE, IR SUPPRESSION
  - EXPECT UNRESTRICTED DEVICES
- DEVICE DELIVERIES
  - PROVIDE DEVICES FOR FIBER TRACKING EXPERIMENTS
  - LATE OCTOBER, NOVEMBER

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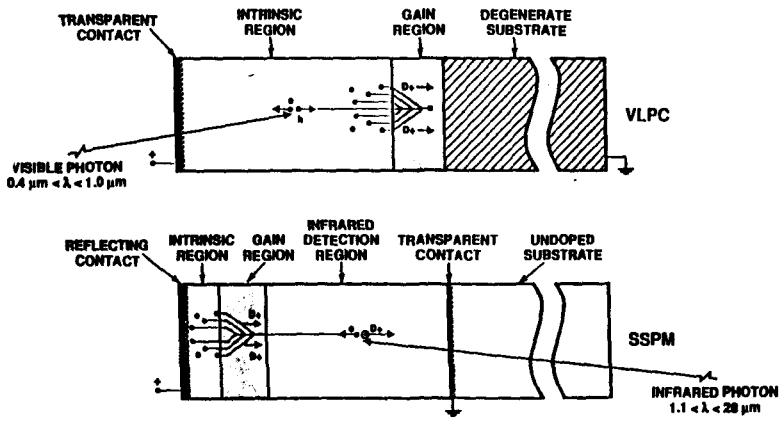
SCHEMATIC CROSS-SECTIONS OF VISIBLE LIGHT PHOTON COUNTER (VLPC) AND SOLID STATE PHOTOMULTIPLIER (SSPM)



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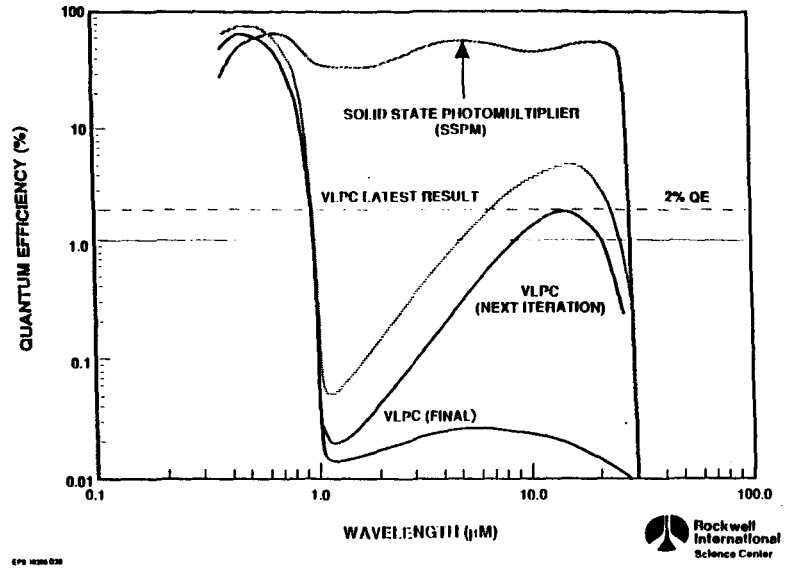
VLPC SPECTRAL QUANTUM EFFICIENCY



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VLPC DEVELOPMENT – FY'92 PLANS

- DESIGN AND FABRICATE NEW MASK SET
  - CASSETTE APPROACH
- HIGHER IMPLANT DOSE FOR TRANSPARENT CONTACT
  - REDUCED CONTACT RESISTANCE
  - LWIR FILTER
- IMPROVED AR COATING
  - INCREASE QE
- MAXIMIZE RESPONSE AT FIBER SCINTILLATION WAVELENGTH
- FABRICATE REFINED VLPC LOT
- CHARACTERIZATION/TESTING
- SCREENING, PACKAGING, DELIVERY OF 1024 DEVICES
- TECHNICAL SUPPORT
- CHARACTERIZE EFFECTS OF NEUTRON AND GAMMA RADIATION

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Review of Recent Fiber Tracking R&D Results.

R. Ruchti
Notre Dame
For Fiber Tracking Group
3-8-91, LBL

FTT 18: UCLA
PERKINS
UC-CHICAGO
IOWA
PURDUE
NOTRE DAME
IOWA STATE
FOCS
PURDUE
BNL
MICHIGAN
ROCHESTER
ROCKWELL
ECO-4
BICRON

SINGLE FIBER STUDIES → ARRAY OF FIBER RIBBONS

EXPERIMENTAL ARRANGEMENT

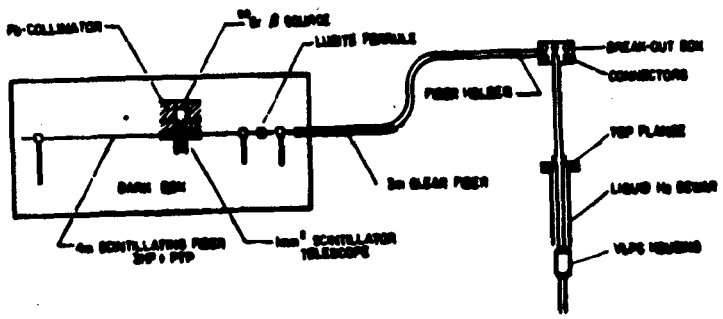
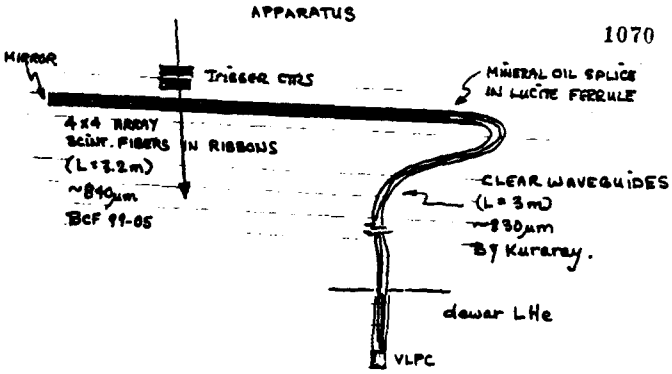


Fig. 6 - Experimental arrangement for measuring detected photon by a VLPC using a 4 meter length of scintillating fiber of 0.6 mm core (3HF+ PTP in polystyrene). The scintillating fiber is spliced to a 3 meter long optical clear fiber that carries the photons to the VLPC.

1070



16 SCIFI
16 CLEAR WAVEGUIDES

16 VLPCs - operated at 6.3V or 6.5V bias
T = 6.5K

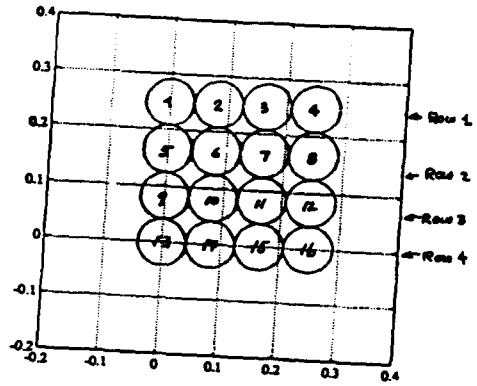
16 TIA's

LRS 1882 Fast Bus ADC - 170pC

COSMIC RAY STUDIES
^{60}Co source for calibration.

TRIGGER COUNTERS LOCATED 3m FROM SPLICE, SO CONFIGURATION IS:
3m SCIFI + 3m Clear Waveguide

1071



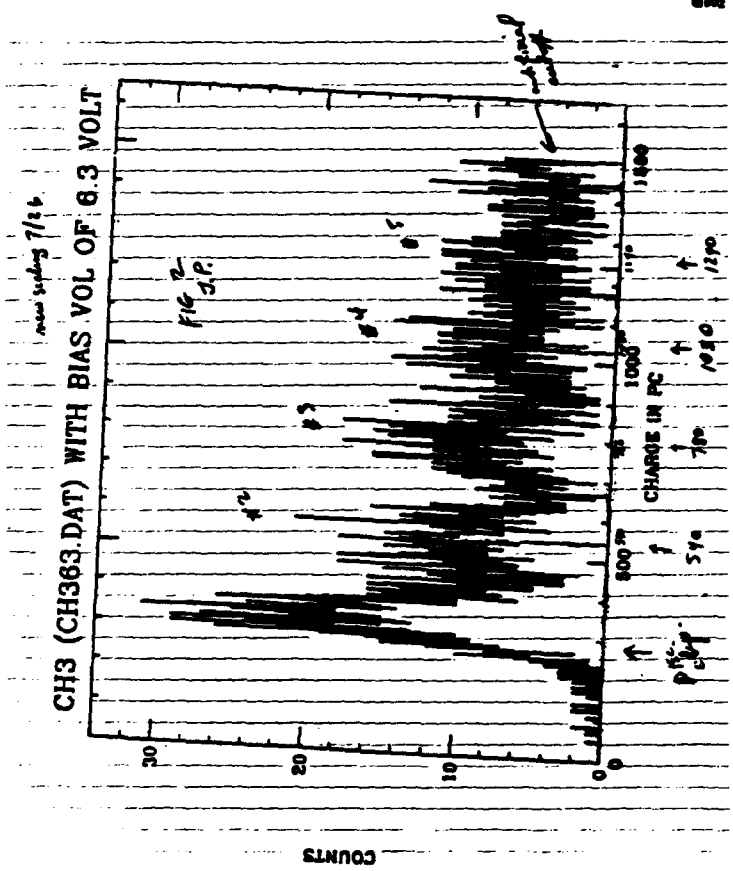
FIBER RIBBON SCHEMATIC

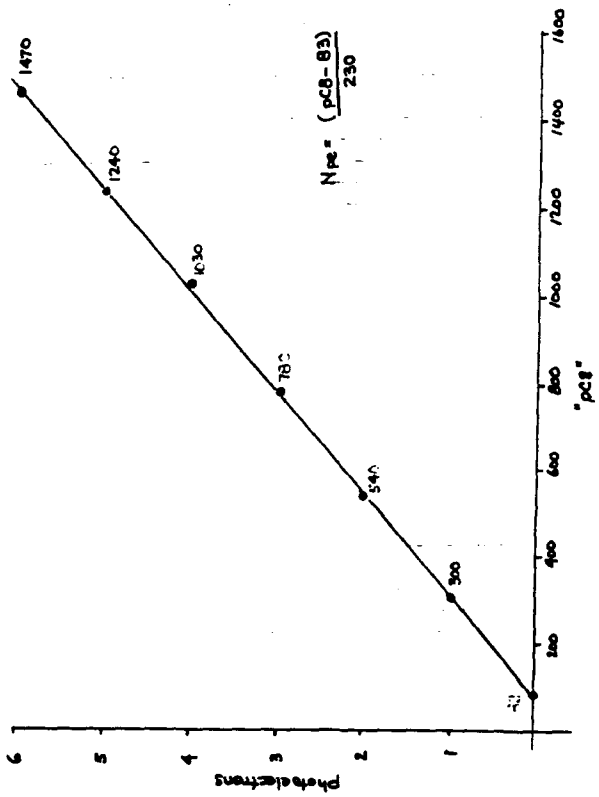
1072

PROCEDURE

1. ESTABLISH PHOTOELECTRON CALIBRATION
   a. PEDESTAL
   b. ^{60}Co SPECTRUM
   c. NUMBER OF pC/PHOTOELECTRON
2. EXAMINE EVENT CHARACTERISTICS
   a. Fiber Position
   b. Features: δ-rays, cross talk
   c. Incident Cosmic Ray Direction
3. Establish Layer Efficiency.

1073





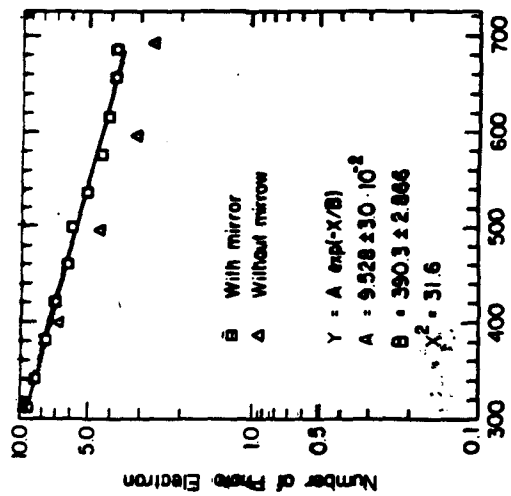


Fig. 7 - Detected number of photons as a function of source positions from the VLPC are indicated with and without a mirror at the end of the scintillating fiber.

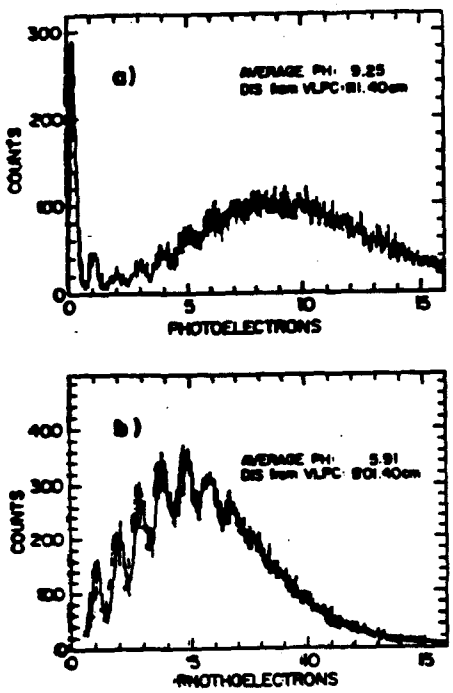


Fig. 6 - Four examples of pulse height spectra obtained at the indicated source positions. The weighted average number of detected photons are given on the figures.

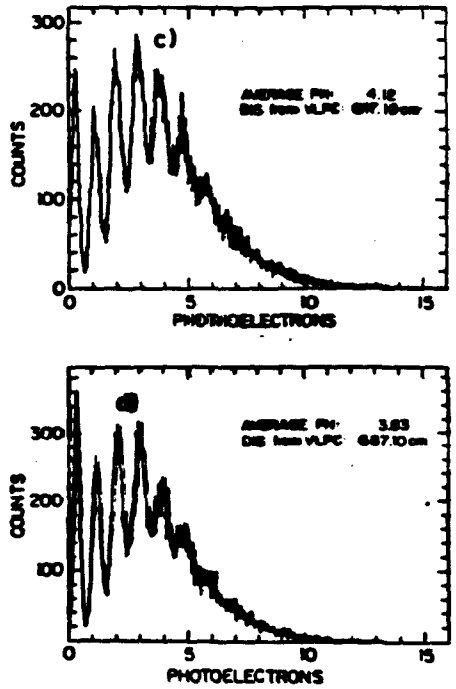
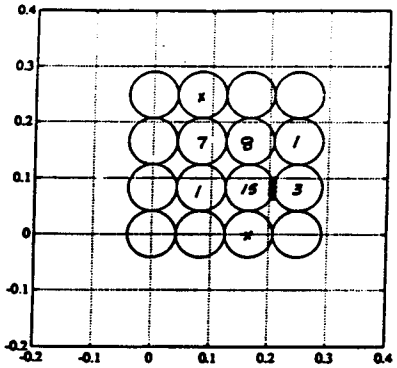


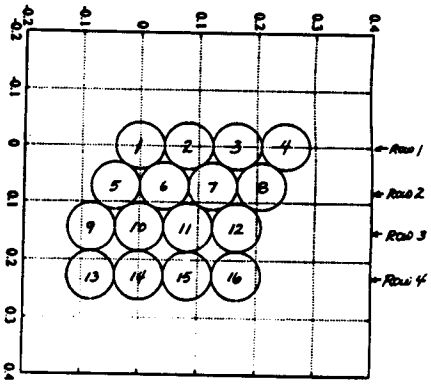
Fig. 6 - Four examples of pulse height spectra obtained at the indicated source positions. The weighted average number of detected photons are given on the figures.

1078



TRIGGER 2-15
≥ 1 p.e.

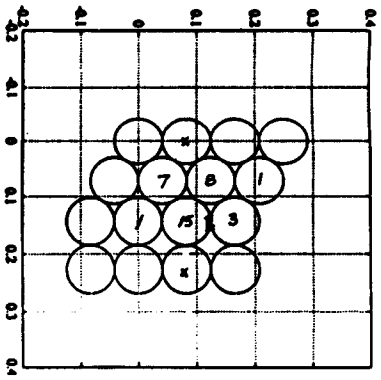
1079



"FIRST-PASS" GEOMETRY CORRECTION

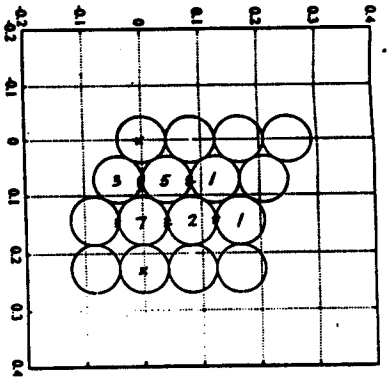
(ROW 4 SHOULD BE MOVED TO THE RIGHT A LITTLE BIT)

1080



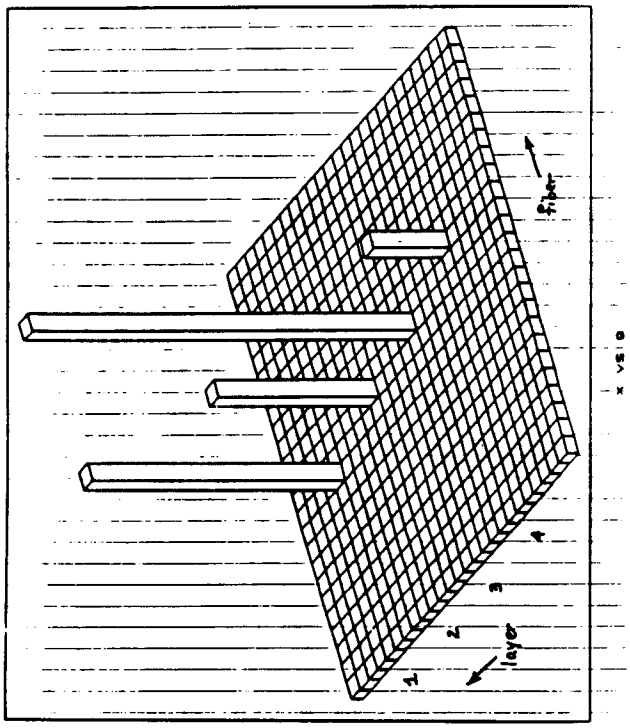
TRIGGER 2-15
≥ 1 p.e.
geometry corrected

1081



TRIGGER 1-14
≥ 1 p.e.

1082



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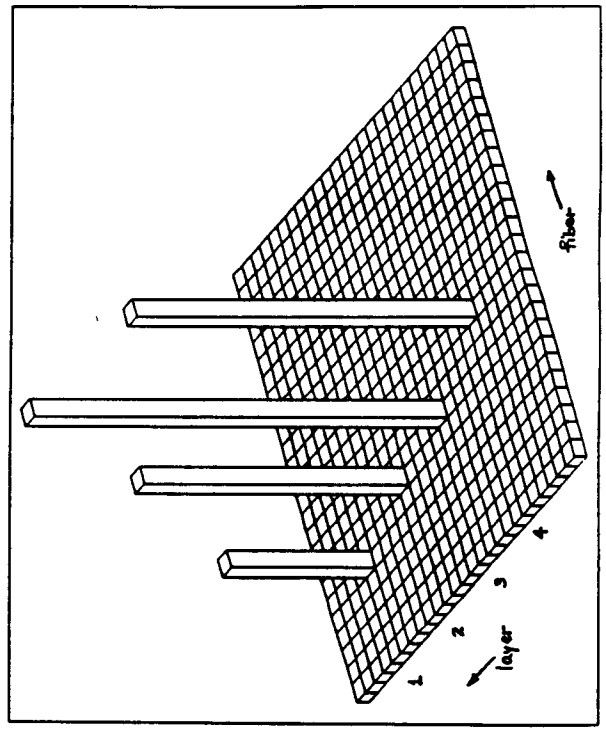

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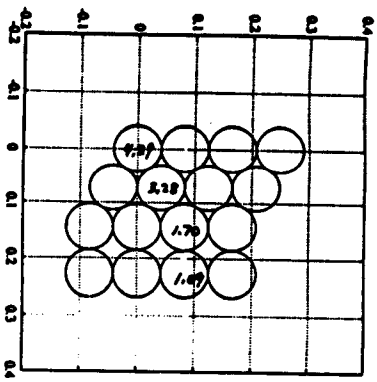

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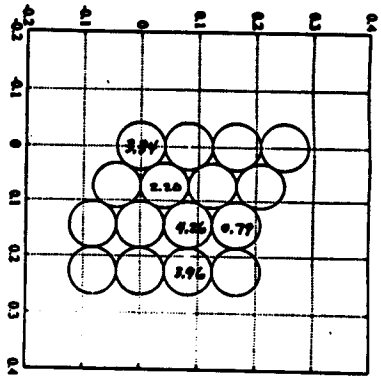
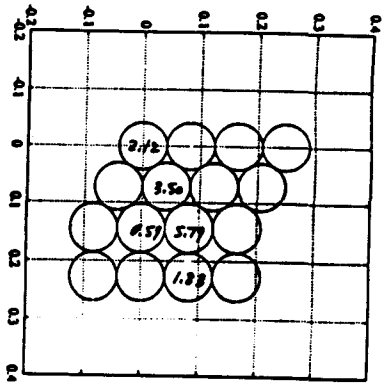


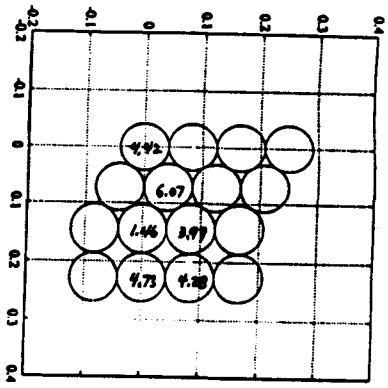
1086

ef. 201
trg 1-15



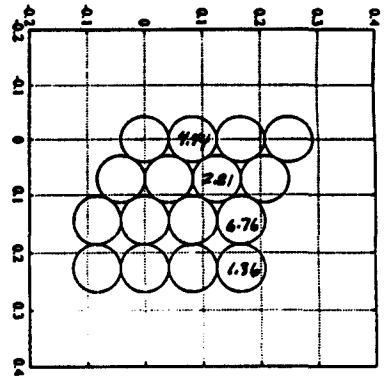
1087

392
1-15



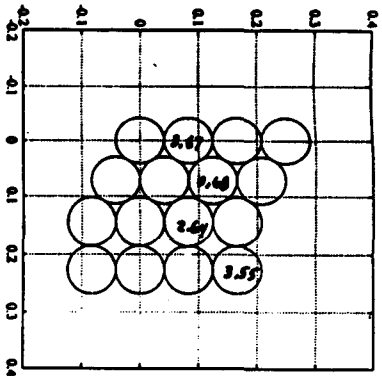
1088

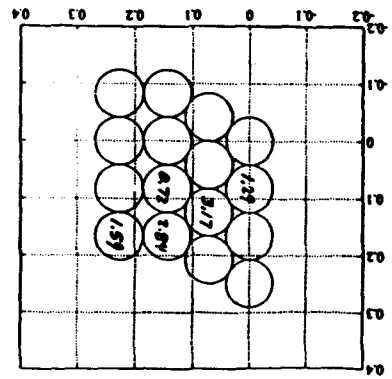
138
2-16



1089

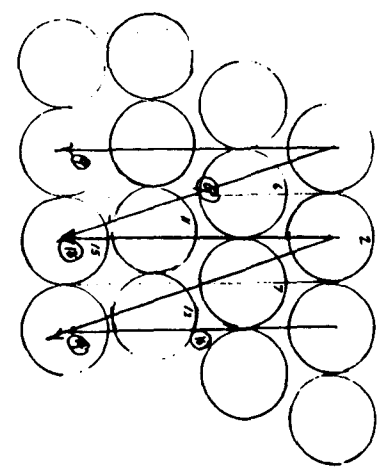
782
2-16





185
2-16

"BEAM" DIRECTION STUDY RELATIVE TO THE RIBBON STACK



Proposed stacking arrangement — consistent with data.

TYPICAL COSMIC RAY
PHOTOELECTRON SPECTRUM
LAYERS 2+3

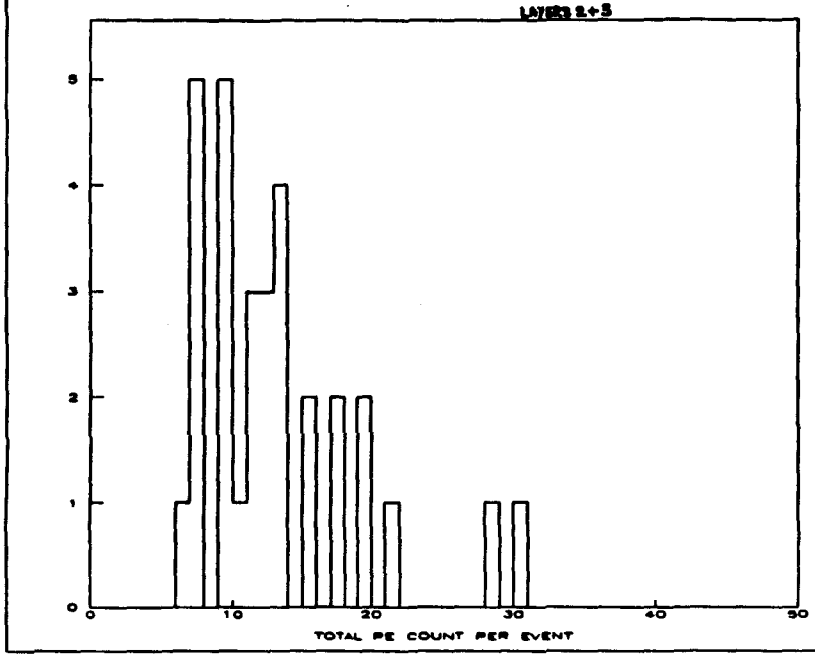


TABLE : PHOTOSTATISTICS & EFFICIENCY FOR LAYERS. TRIGGER 2-15

PE cut in 2 & 15	# events	⟨PE⟩ in event	⟨PE⟩ in layer 2+3	⟨PE⟩ layer 2	⟨PE⟩ layer 3	# zeros layers 2+3	# zeros layer 2	# zeros layer 3	inefficiency layer 2	inefficiency layer 3
≥0.3	90	11.9	6.1	2.6	3.5	2	12	6	0.13	0.07
≥0.5	75	12.5	6.3	2.8	3.6	—	9	3	0.12	0.04
≥0.8	56	13.3	6.4	2.6	3.9	—	7	1	0.13	0.02
≥1.0	53	13.6	6.6	2.7	4.0	—	7	—	0.13	—
≥1.5	35	14.6	6.8	2.7	4.3	—	4	—	0.11	—
≥2.0	25	15.0	6.7	2.5	4.4	—	2	—	0.08	—
≥2.5	10	16.0	6.4	2.9	3.7	—	1	—	0.10	—

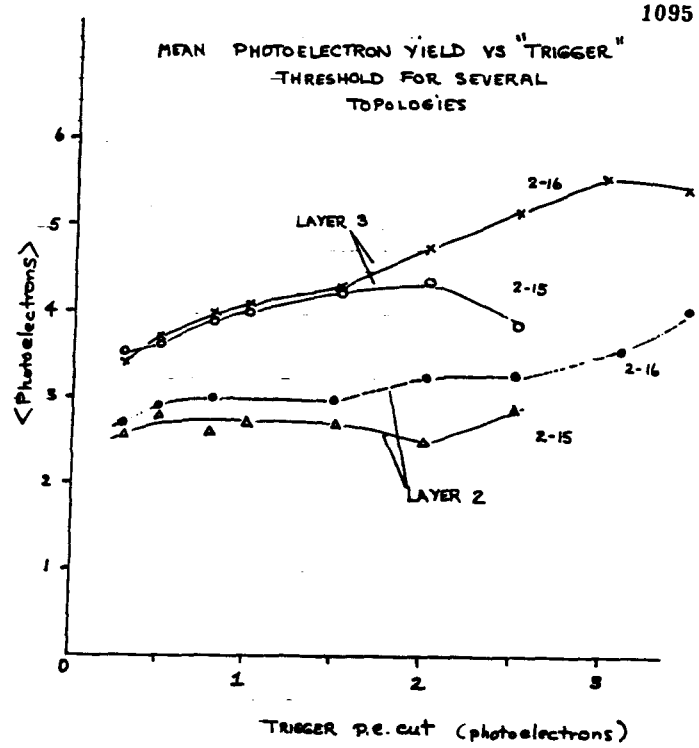
FIBER DIAMETER ≃ 840μm
FIBER SPACING ≃ 850μm
CLADDING WALL ≃ 25μm

1094

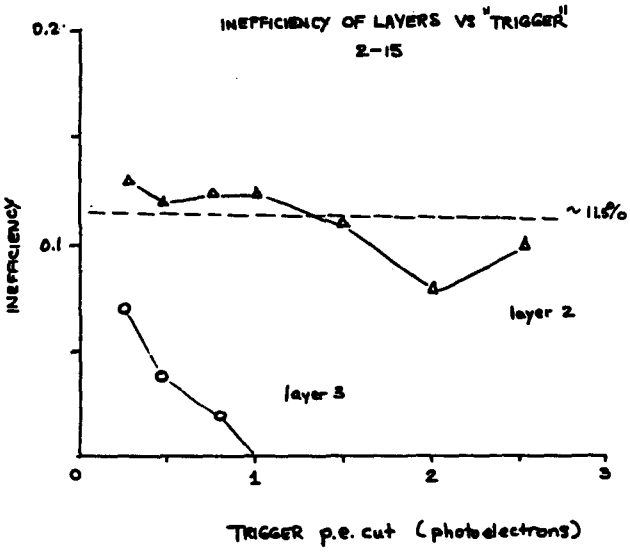
TABLE: PHOTOSTATISTICS & EFFICIENCY FOR LAYERS — TRIGGER 2-16

PE cut in ± %	# events	<PE> in event	<PE> in layer 2+3	<PE> in layer 2	<PE> in layer 3	# zeros layer 2+3	# zeros layer 2	# zeros layer 3	inefficiency layer 2	inefficiency layer 3
≥0.3	98	12.3	6.8	2.7	3.4	3	6	5	0.06	0.05
≥0.5	86	13.1	6.7	2.9	3.7	—	1	2	0.01	0.02
≥0.8	72	14.0	7.0	3.0	4.0	—	—	1	—	0.01
≥1.0	58	14.7	7.3	3.0	4.1	—	—	1	—	0.02
≥1.5	48	15.5	7.5	3.0	4.8	—	—	1	—	0.02
≥2.0	36	17.1	8.3	3.3	4.8	—	—	—	—	—
≥2.5	30	17.7	8.6	3.3	5.2	—	—	—	—	—
≥3.0	23	18.7	9.2	3.6	5.6	—	—	—	—	—
≥3.5	15	19.9	9.8	4.1	5.5	—	—	—	—	—

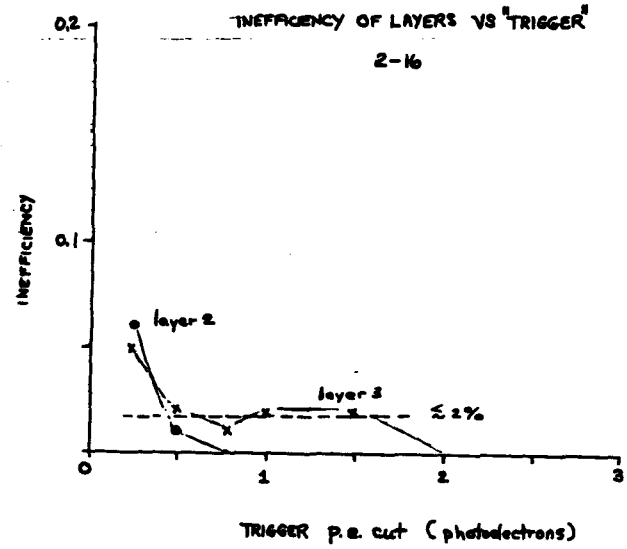
1095



1096



1097



CONCLUSIONS FROM DATA

1. We see clear cosmic rays !

2. Photo-electron yield is excellent:

   2.7 – 4.0

3. Single layer inefficiency is $\lesssim$ 12% for worst case example.

   (~7% GEOMETRY, ~5% PHOTOSTATISTICS)

4. Double layer efficiency ~100% even for this photostatistics.

5. Fiber layers have "self-alignment" feature, as do others, which is being used to study performance.

COMMENTS:

VLPC - CONTINUE DEVELOPMENT OF IR BLIND DEVICES AT ROCKWELL

PUSH CONTRACT PROCESS TO GET CERN-CASSETTES CONCEPTUAL DESIGN INITIATED.

FIBERS - BCF99-05
BCF98

UNIFORMITY / RIBBONS / SCHIT TESTS

TESTS -

16 CHANNEL TEST – VLPC/SCIFI COSMIC RAYS	JULY 1991 SEPT 1991
32 CHANNEL TEST – VLPC/SCIFI COSMIC RAYS	SEPT-OCT 1991
SCIFI/MA-PMT FERMILAB BEAM	SUMMER/FALL 1991
SCIFI/APD FERMILAB BEAM	SUMMER/FALL 1991

ENGINEERING INPUT ESSENTIAL

Tracking and Physics and Detector Performance Joint Meeting

August 5 - Monday

Part 1: Performance

Momentum Resolution of SDC Tracking System and Effects of Field Uniformity	T. Kondo(KEK)
Minimum Number of Axial Layers	F. Abe(KEK)

Part 2: Technical Simulation Issues

Progress on Track Finding and Fitting	B. Hubbard(UC Santa Cruz)
Indiana University Simulation Status	F. Leuhring(Indiana)
Progress in Straw Tracking	A. Palounek(LBL)
Simulation of a Scifi Tracking Trigger for the SDC	D. Adams(Rice)
Pattern Recognition in a Scifi Tracking System for the SSC	D. Adams(Rice)
Hybrid Central Tracker - Track Finding	M. Corden(FSU)
Preliminary Look at Tracking Efficiency in Hybrid and Silicon	D. Coupal(SSCL)

LPBautz:8/26/91

MOMENTUM RESOLUTION

OF

SDC TRACKING SYSTEM

&

EFFECTS OF FIELD UNIFORMITY

T. KONDO (KEK)

AUG 5, 1991 LBL

DRAFT

Momentum Resolution of the SDC Tracking System

August 2, 1991

T.Kondo, S.Odaka, Y.Takaiwa and S.Terada

KEK, National Laboratory of High Energy Physics
1-1, Oho, Tsukubashi, 305, Japan

The aim of this note is to provide plots of the rapidity dependence of the momentum resolution of the SDC tracking system for various magnet as well as various tracking device configurations so far proposed. The program developed for this aim is flexible enough to evaluate variety of combinations of tracking devices. The program includes the contribution of not only axial stripe/fibers/wires but also slant ones as well as silicon disks and spiral fibers. Comparisons are made to evaluate the differences in momentum resolution for uniform field as well as for realistic field based on the proposed calorimeter configurations.

Goals

1. $\delta p/p$ of various configurations
   tracking devices
   magnetic fields

2. effects of non-uniformity

Method

a_μ ϕ, θ, d, 5 par

$$\sigma(a_\mu) = \sqrt{E_{\mu\mu}}$$

where $E = G^{-1}$

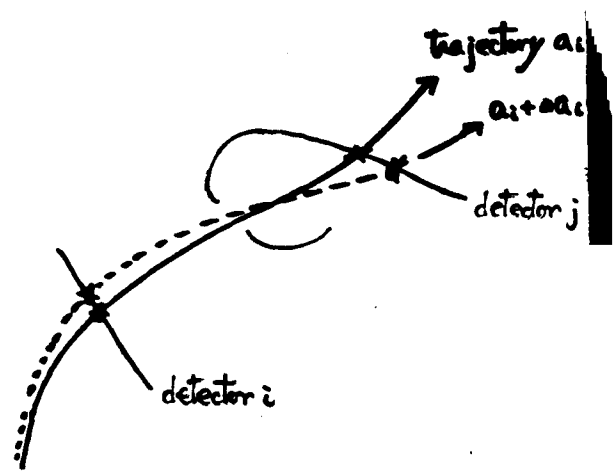
$$G_{\mu\nu} = \frac{1}{2}\frac{\partial^2\chi^2}{\partial a_\mu \partial a_\nu}$$

$$\chi^2 = \sum_i \frac{1}{\sigma_i^2}\left[f(x_i,\vec{a}) - y_i\right]^2$$

i = measurement

see S. Odaka SDC-90-00074

$G_{\mu\nu}$ evaluated by the finite-difference method.

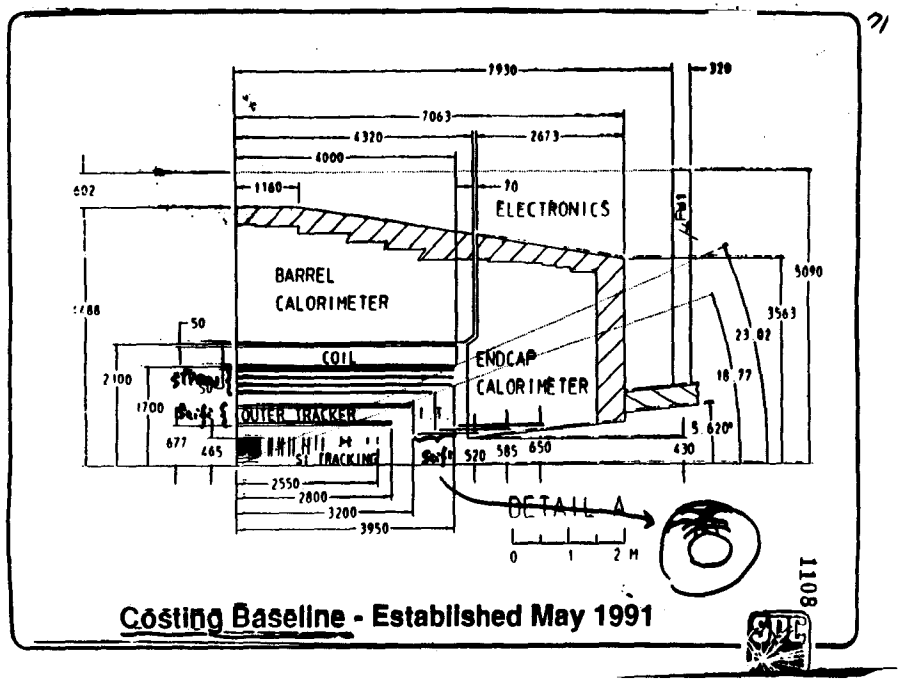


Magnetic Field Configurations

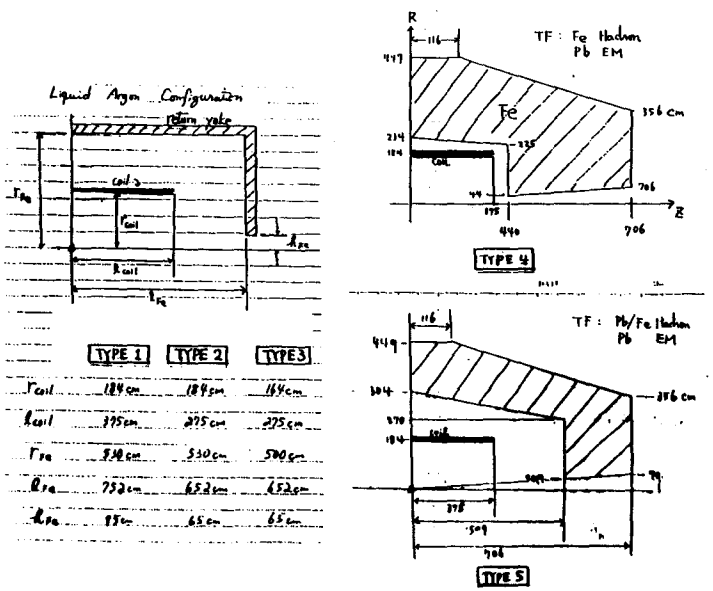
Type	T_{coil}	Z_{coil}^{max}	return yoke etc
0	184 cm	375 cm	uniform field (ideal case)
1	184	375	behind LAC
2	184	275	"
1.5x3 3	164	275	"
4	184	375	tile-fiber (EM: Pb, HAC: Fe)
5	184	375	" (EM, HAC1: Pb, HAC2: Fe)
1.5x3 6			HAC Fe

(Type 2 for tracking volume of 1.7m x 3m, Type 3 for tracking volume of 1.5m x 3m)

see figures

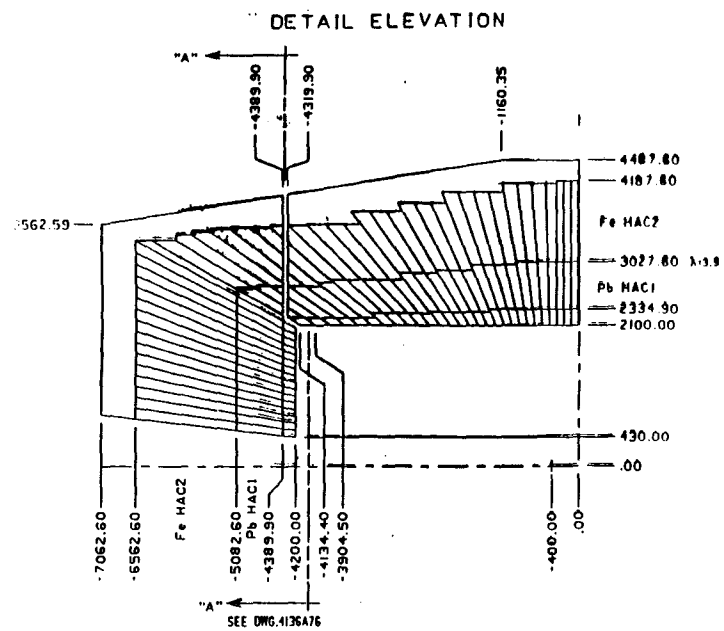


Costing Baseline - Established May 1991



	TYPE 1	TYPE 2	TYPE 3
r_{coil}	184 cm	184 cm	164 cm
h_{coil}	375 cm	275 cm	275 cm
r_{Fe}	530 cm	530 cm	530 cm
l_{Fe}	752 cm	652 cm	652 cm
h_{Fe}	85 cm	65 cm	65 cm

Fig.1 Locations of coils and return yokes for types 1 to 5. The numbers shown in the pictures are in cm.



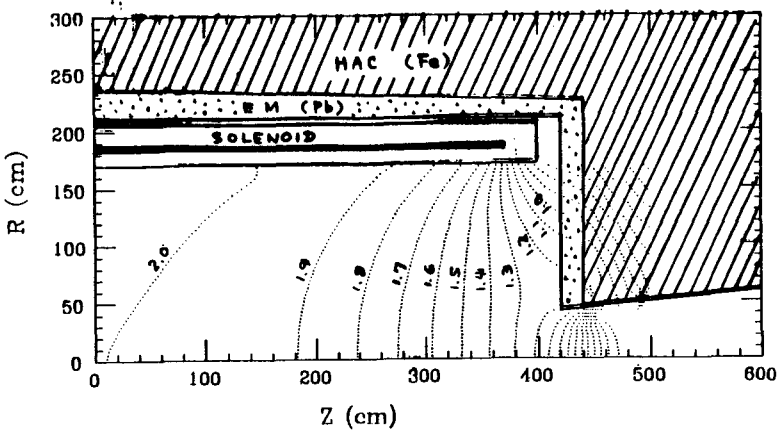
CALORIMETER VOLUME = 673 CUBIC METERS
CALORIMETER WEIGHT = 5837 SHORT TONS
5295 METRIC TONS
INFO. FROM DWG. 4136A21.R6

0.389.4136A73.R3
DIM.IN MILLIMETER
SCALE .02:1.00
KEPES 3-21-91

Kondo

(4) magnetic field contour of B_z

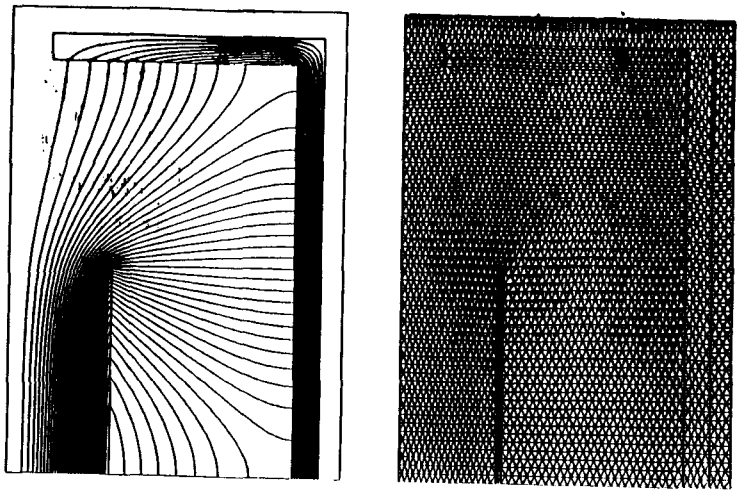
Type 4, (r,z/2)=(1.7m,4.0m), Tile-fiber, EM(Pb), Had(all Fe)



(best case)

1112

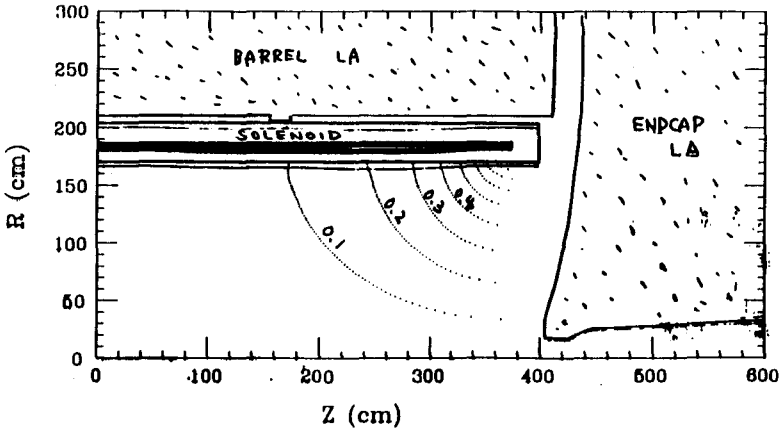
TYPE 1



1110

(1) magnetic field contour of B_r

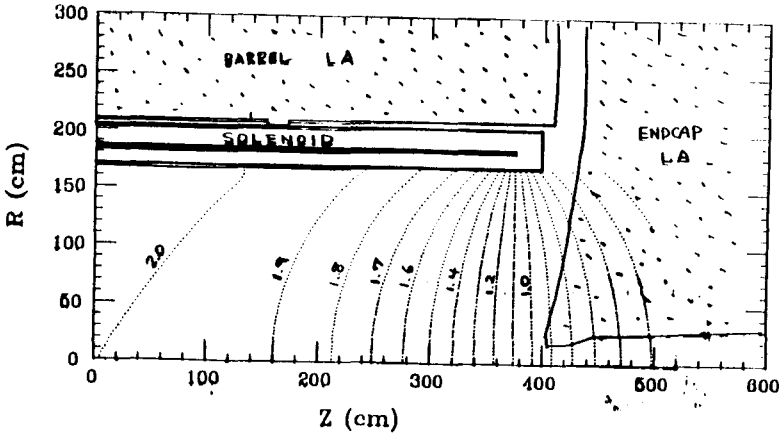
Type 1, (r,z/2)=(1.7m,4.0m), liquid argon



1113

(1) magnetic field contour of B_z

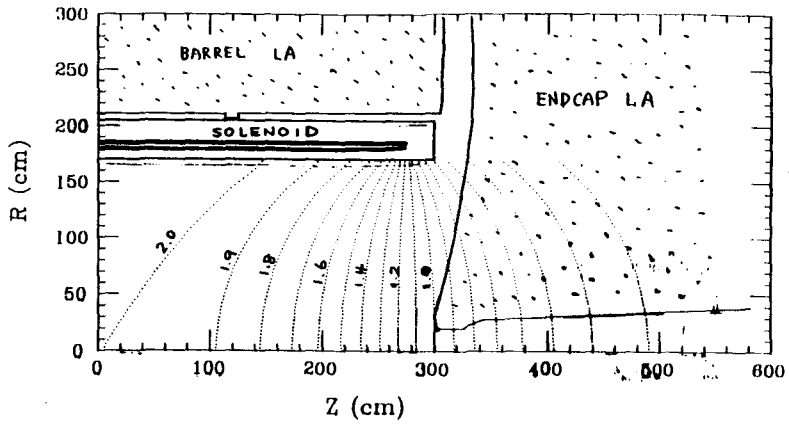
Type 1, (r,z/2)=(1.7m,4.0m), liquid argon



1111

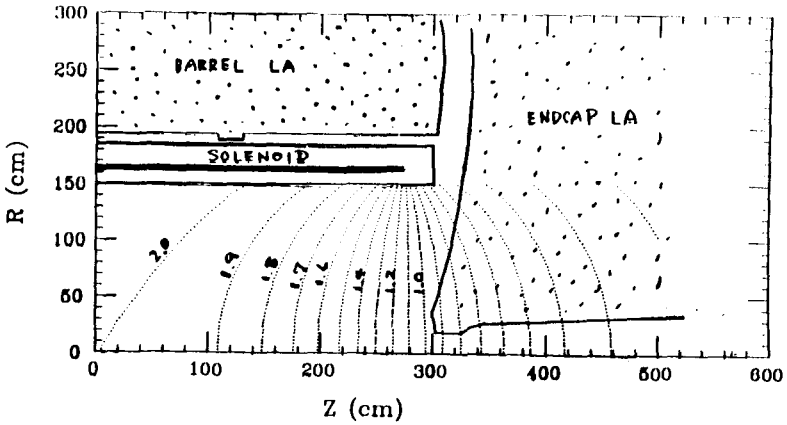
(2) magnetic field contour of B_z

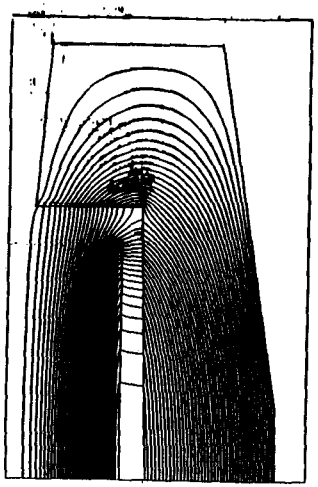
Type 2, (r,z/2)=(1.7m,3.0m), liquid argon

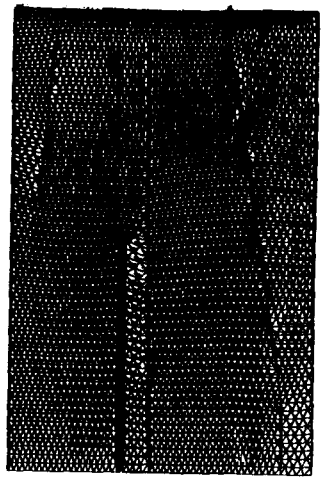


(3) magnetic field contour of B_z

Type 3, (r,z/2)=(1.5m,3.0m), liquid argon

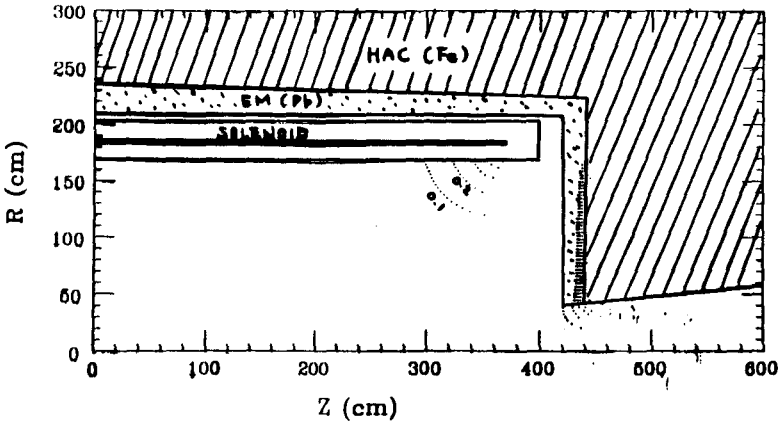


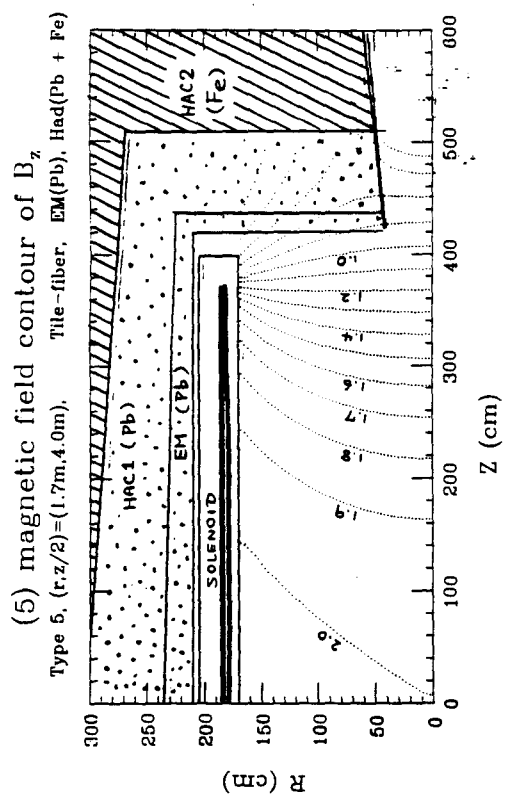




(4) magnetic field contour of B_r

Type 4, (r,z/2)=(1.7m,4.0m), Tile-fiber, EM(Pb), Had(all Fe)





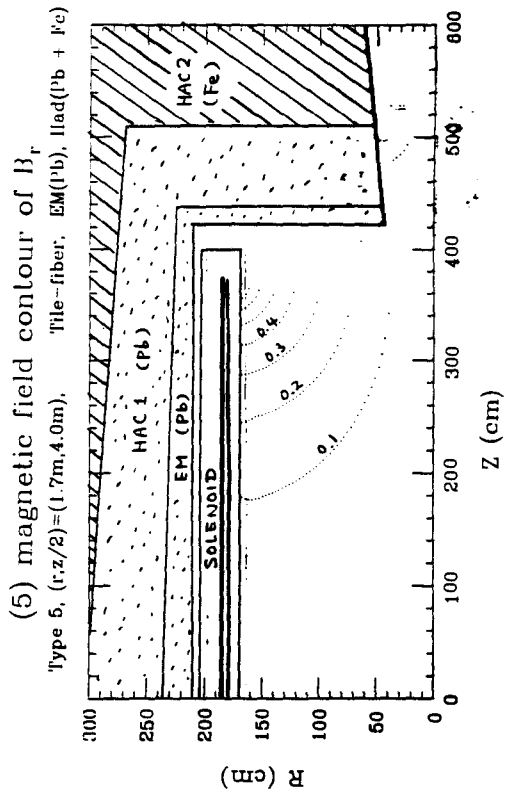


Table 1 : Silicon Tracker

	option 1 r	option 2 z	option 2 r	option 2 z (cm)
barrel	18	18	9	15
	21	21	12	15
	24	24	18	18
	27	27	21	21
	30	30	24	24
	33	33	27	27
	36	36	33	33
	39	39	36	36
disk	15 – 22.5	22.5	9 – 16.5	16.5
	15 – 25.5	25.5	9 – 19.5	19.5
	15 – 28.5	28.5	9 – 25.5	25.5
	15 – 31.5	31.5	9 – 31.5	31.5
	15 – 34.5	34.5	9 – 31.5	31.5
	15 – 37.5	37.5	15 – 39	39
	15 – 40.5	40.5	"	46
	15 – 46.5	43.5	"	55
	"	60	"	65
	"	66	"	77
	"	77	"	91
	"	84	"	110
	"	97	"	136
	"	105	22.5 – 46.5	168
	18 – 46.5	122	"	208
	"	132	34.5 – 46.5	255
	24 – 46.5	145		
	"	157		
	29 – 46.5	190		
	"	203		
	35 – 46.5	246		
	"	254		

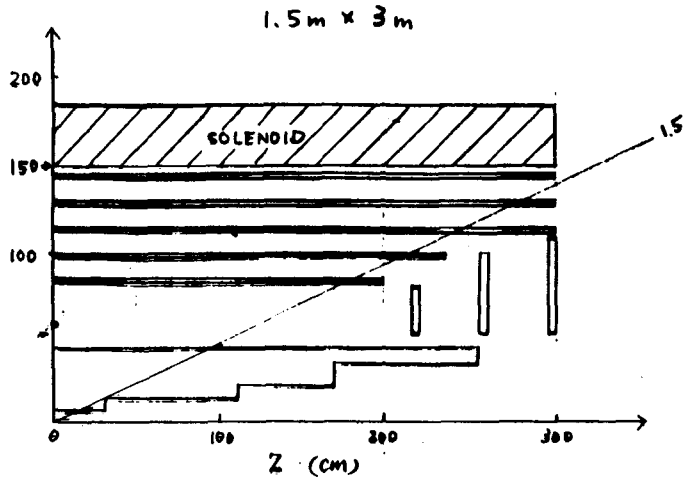
resolution 15 μm
double sided , stereo angle 5 mr

Table 2 : outer Tracker superlayers

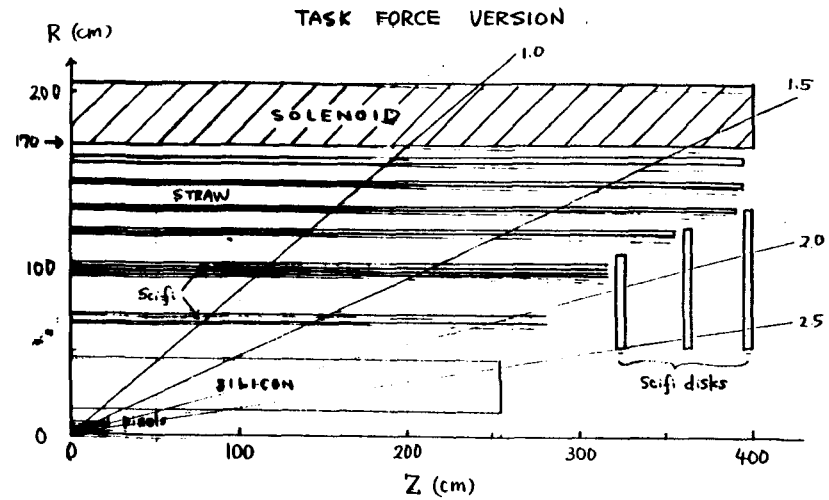
	option 1 r (cm)	option 1 Zmax (cm)	option 1 θ (°)	option 1 σ (μm)	option 2 (3) r (cm)	option 2 (3) Zmax (cm)	option 2 (3) θ (°)	option 2 (3) σ (μm)
Scifi	67.6	280	0	60				
	92.4	280	0	"				
	97.7	315	0	"				
	98.0	315	-4.5	"				
	102.1	315	3	"				
	102.3	315	0	"				
Silicon	121.7	355	-3	61	85	200	0	61
	105.0	390	0	"	100	235	3.0	"
	148.2	395	3	"	115	300	0	"
	161.4	395	0	50	130	300	-3.0	"
					145	300	0	"
					(160	300	0	")

Scifi-disk

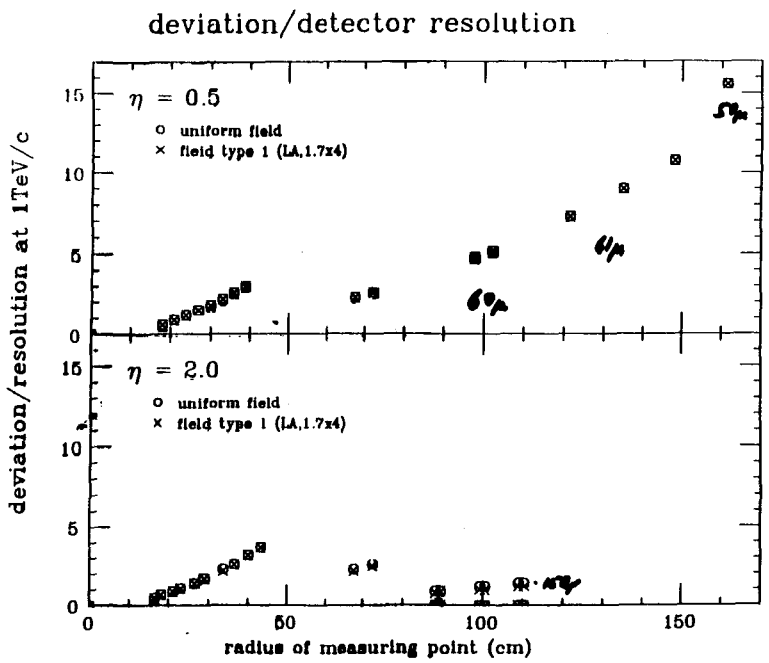
r (cm)	Z (cm)	θ	σ (μm)	r (cm)	Z (cm)	θ	σ (μm)
52-109	320	+	150	52-80	215	+	150
"	"	–	150	"	"	–	"
"	"	R	100	"	"	R	150
"	325	+	150	"	220	+	150
"	"	–	150	"	"	–	"
"	"	R	100	"	"	R	100
58-122	360	+	150	52-100	255	+	150
"	"	–	"	"	"	–	"
"	"	R	100	"	"	R	100
"	365	+	150	"	260	+	150
"	"	–	"	"	"	–	"
"	"	R	100	"	"	R	100
65-134	395	+	150	52-110	295	+	150
"	"	–	"	"	"	–	"
"	"	R	100	"	"	R	100
"	400	+	150	"	300	+	150
"	"	–	"	"	"	–	"
"	"	R	100	"	"	R	100



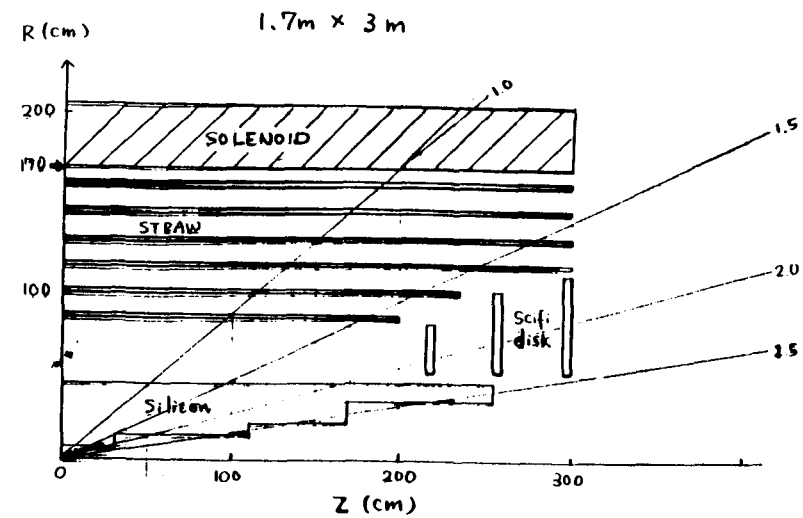
1124



1122



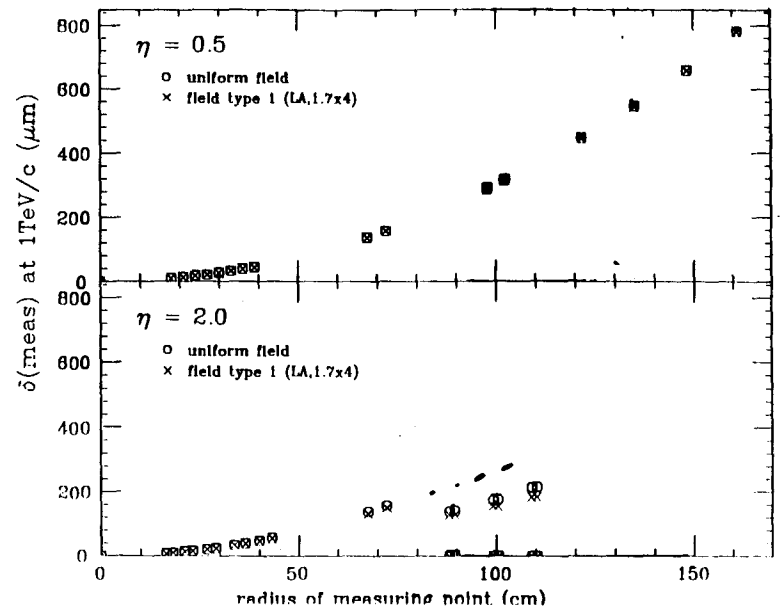
1125



1123

Kondo

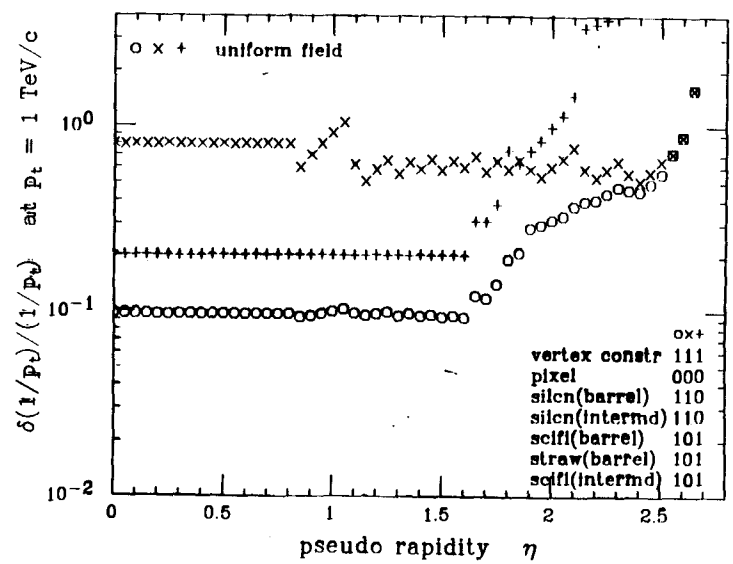
deviation from the straight line



1126

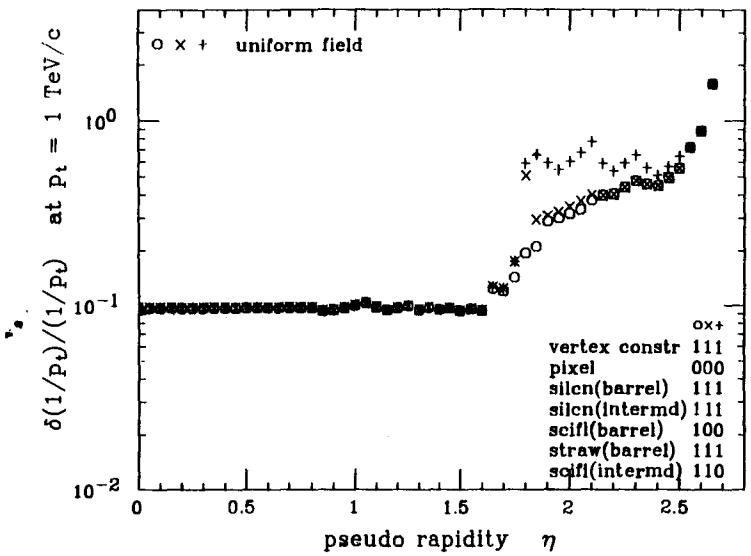
Kondo

(1) with and without silicon tracker



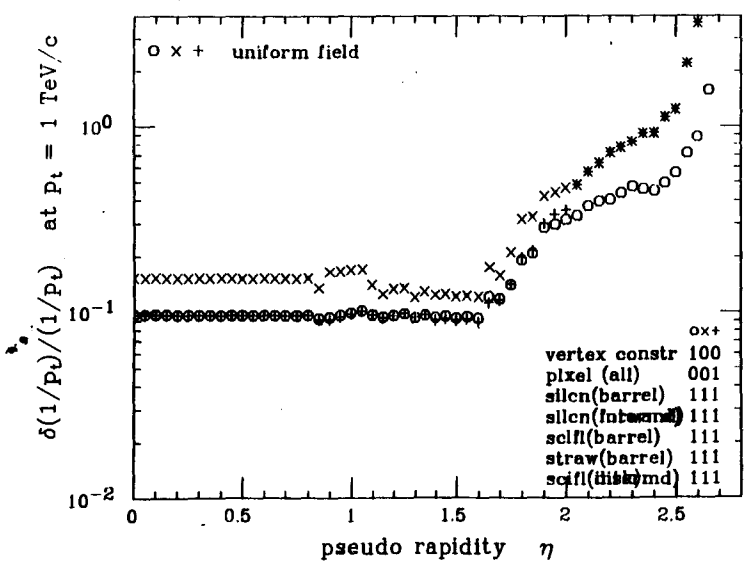
1127

(2) with and without scifi tracker



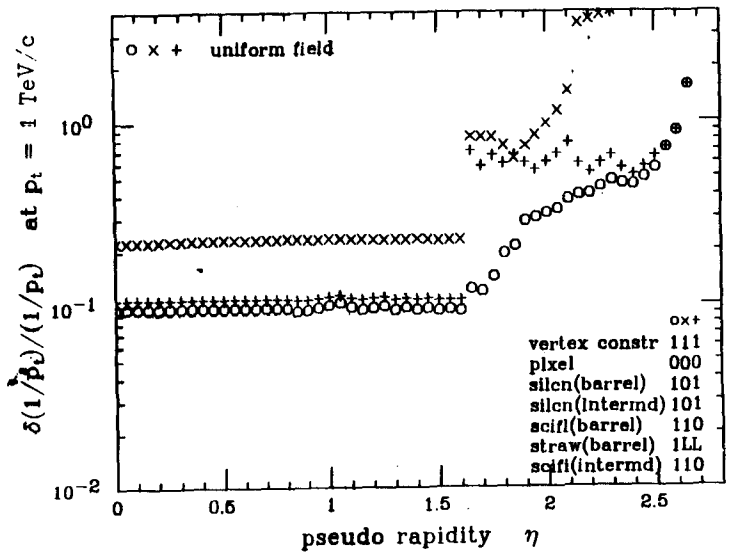
1128

(3) vertex constraint vs pixels

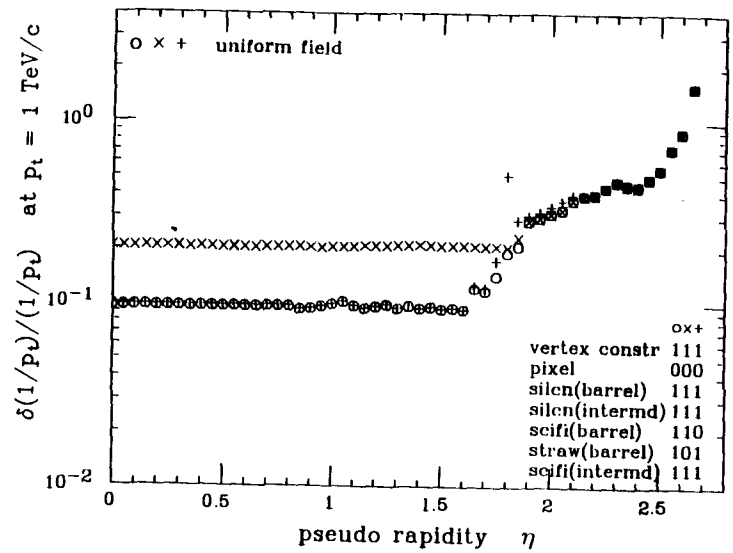


1129

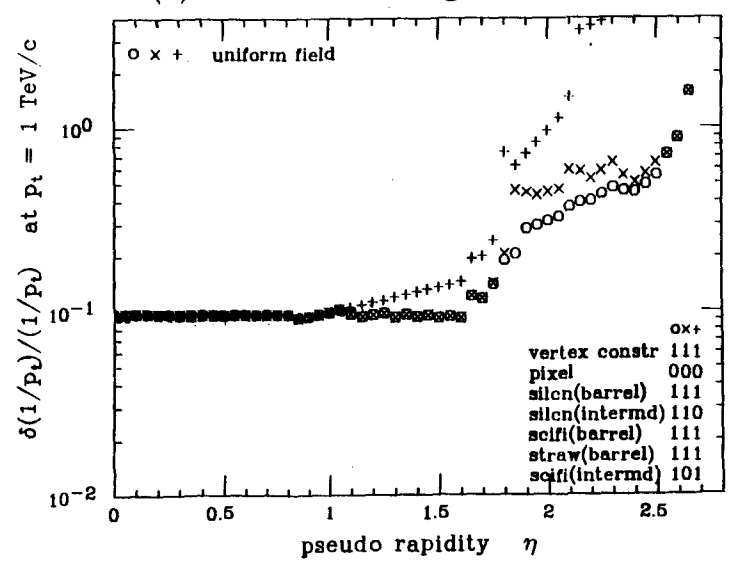
(6) with only last straw super layer



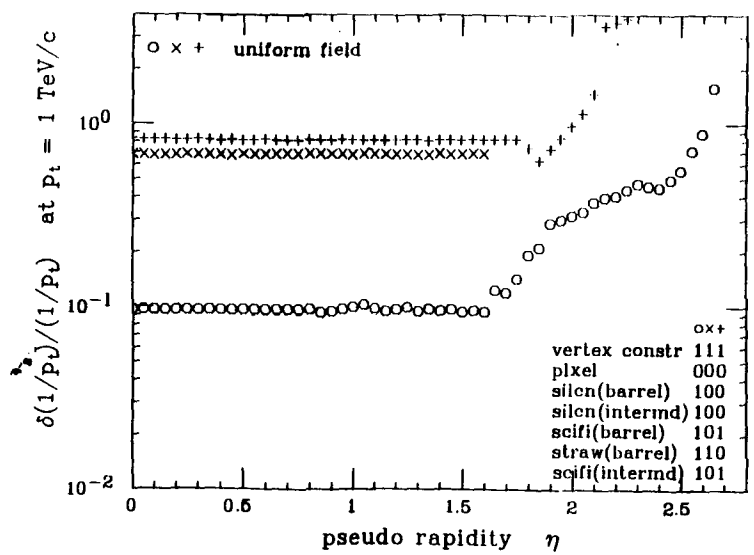
(4) barrel straws and barrel scifi



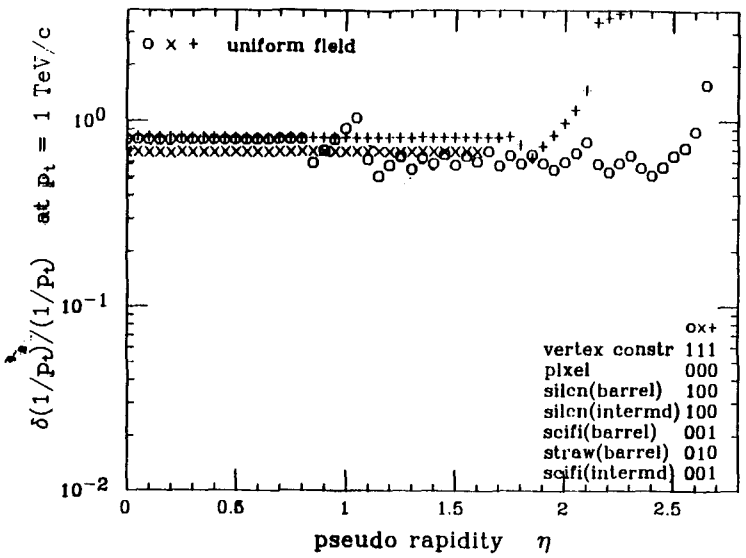
(7) intermediate-angle silicon and scifi



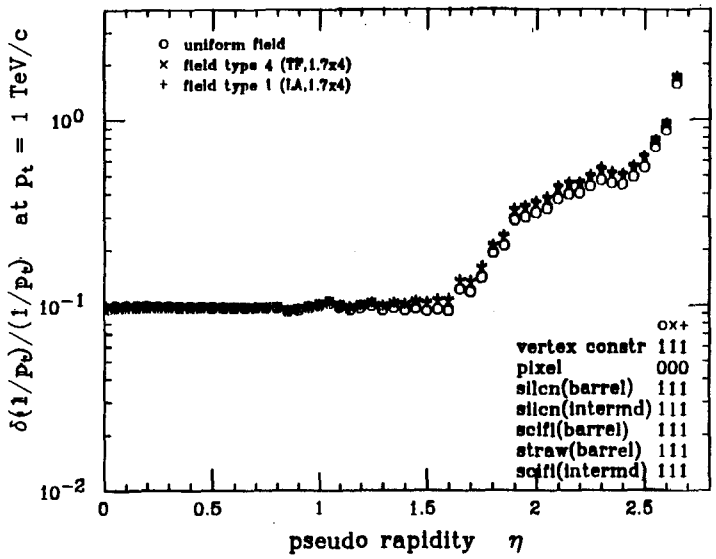
(5) straw only and scifi only



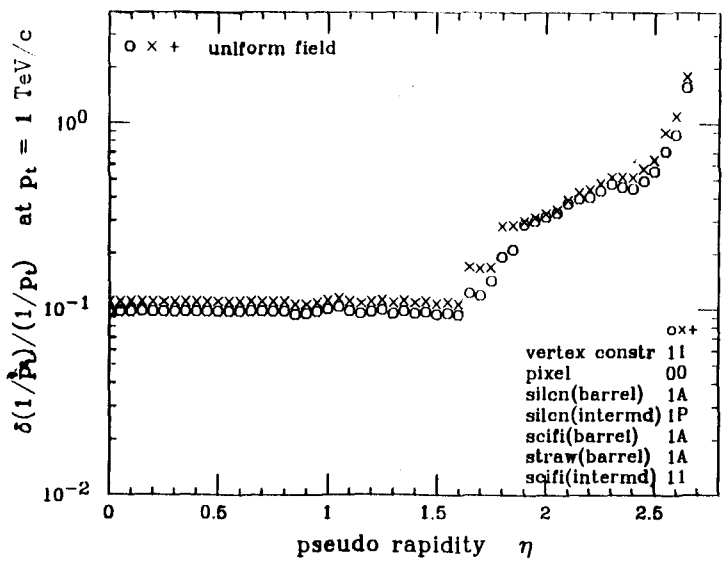
(8) silicon only, straw only, scifi only



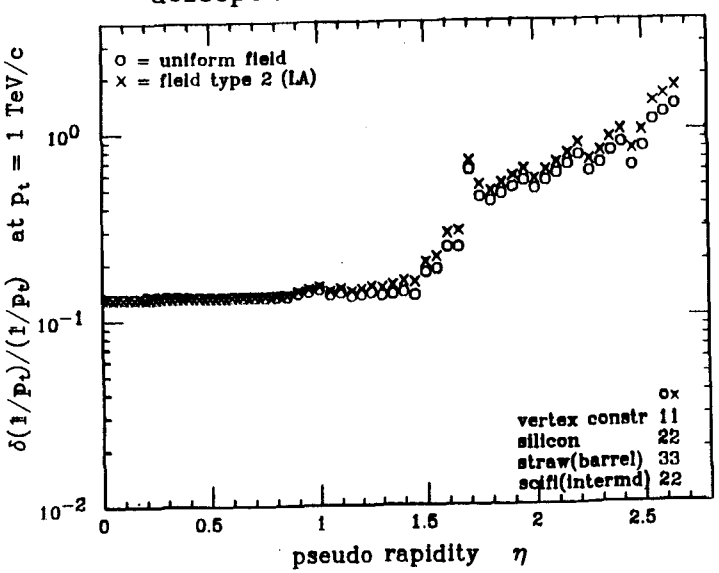
field dependence for 1.7mx4m



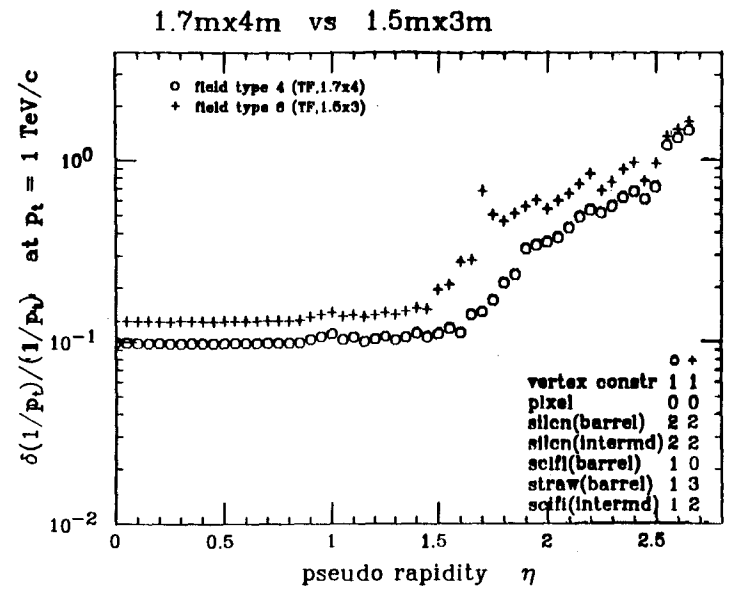
(9) effects of slant layers



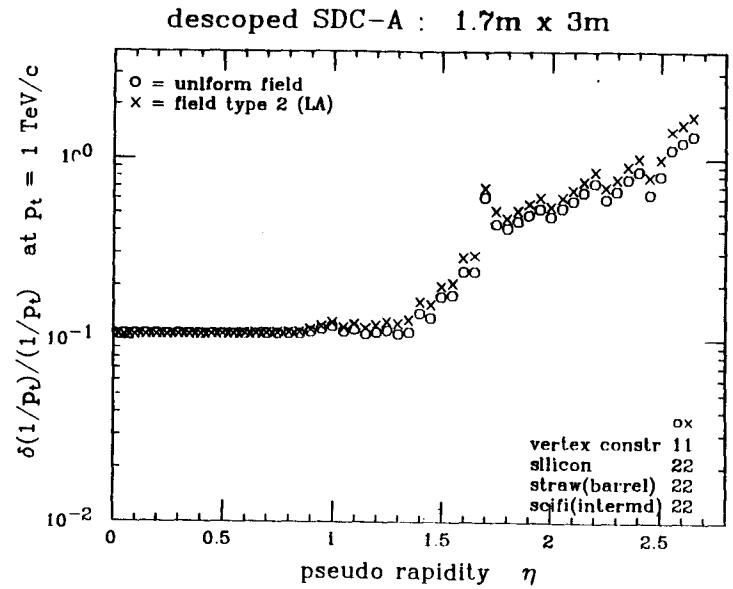
descoped SDC-B : 1.5m x 3m



Kodo

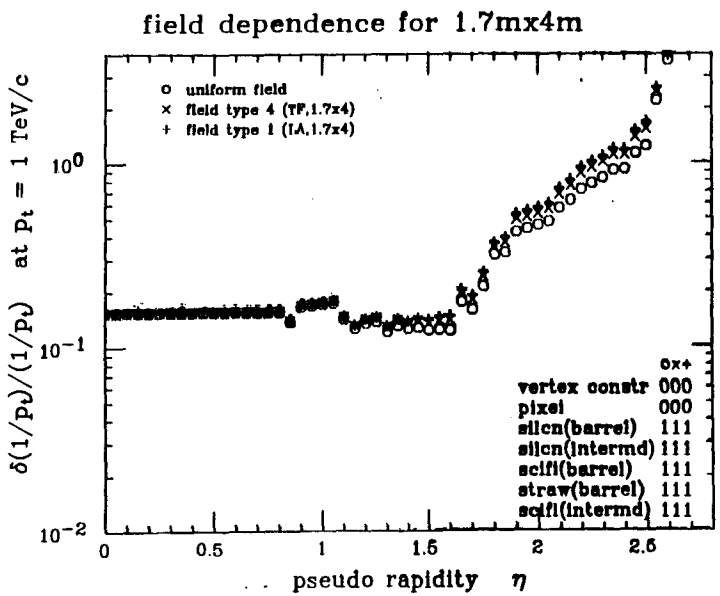


1140

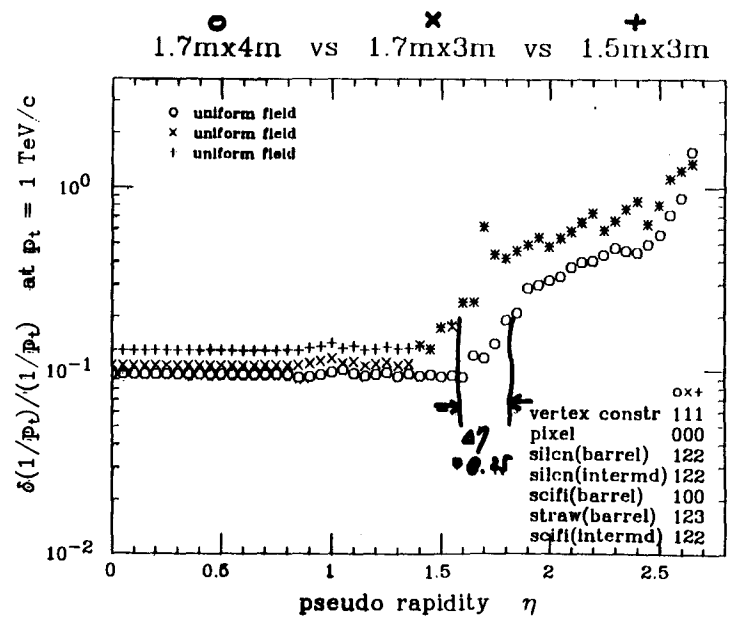


1138

Kodo

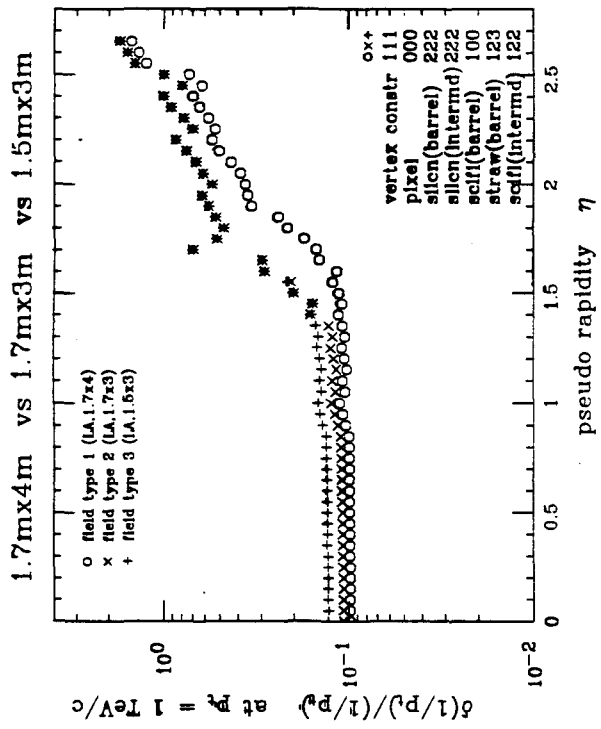


1141

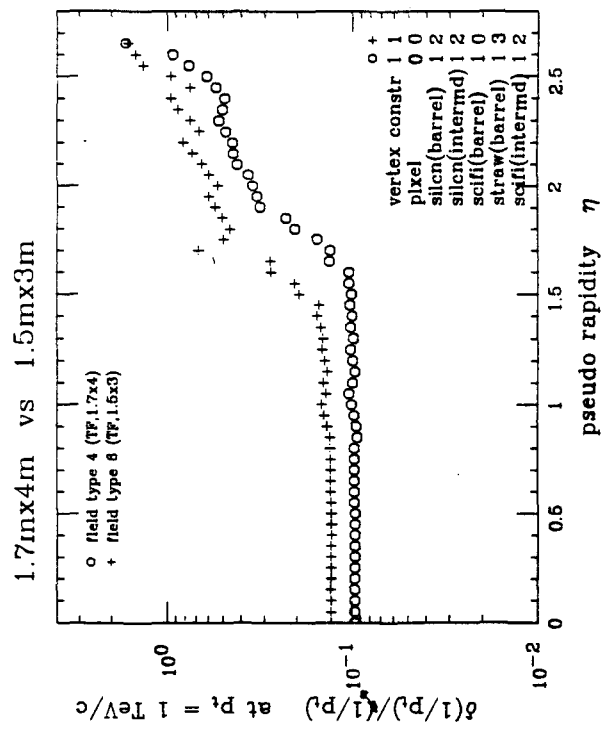


1139

1142



1143



1144

Tentative Conclusions

1. There are some non-uniformity for all designs.

2. Silicon, Scifi, Straw } individually $\frac{\Delta p}{p_t} \sim 0.8 \sim 1.0 P_t$ [TeV] (with vertex constraint)

3. with Si $\sim 0.2 P_t$
   without Si $\sim 0.4 P_t$

4. with Silicon & Straw, sci-fi does not contribute to $\Delta p/p$.

5. vertex constraint as pixel

1145

6. $\frac{\Delta p}{p} \sim 0.6 P_t$ for $\eta > 2.0$ is due to silicon mainly.

7. $\Delta p/p$ improve ~30% by including shaft

8. $\frac{\Delta p}{p}$ does not degrade so much in (non-unif. field) if Silicon works

9. 4m → 3m $\eta = 1.75 \rightarrow 1.50$

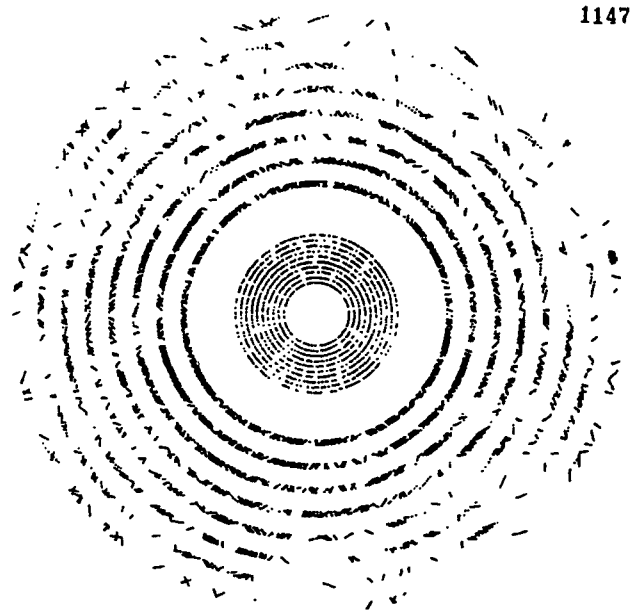
10. $r = 1.7m \rightarrow 1.5m$ $\frac{\Delta p}{p} \uparrow 30\%$

Minimum Number of Axial Layers

— Study for the Discoping —

FAbe
KEK

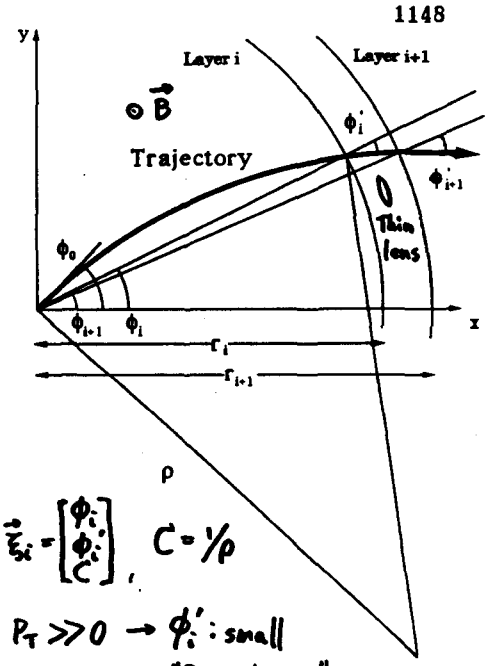
1. Review : Matrix approximation etc
2. Simulation update
3. Study for descoping
4. Summary



ISAJET
$H^0 \to Z^0 Z^0 \to 4\mu$
$M_H = 320$ GeV

(To scale)

GEANT
5 minimum bias event pileup without filtering



$\vec{\xi}_i = \begin{bmatrix} \phi_i \\ \phi_i' \\ C_i \end{bmatrix}$, $C = 1/\rho$

$P_T \gg 0 \to \phi_i' :$ small

--> "Paraxial ray"

$\vec{\xi}_{i+1} = \underbrace{b_i}_{\text{Transfer matrix}} \vec{\xi}_i$ ---- linear transformation

Matrix approximation

Using paraxial-ray hypothesis, the transformation of the track parameter $\bar{\xi}_i$ can be written as,

$$\bar{\xi}_{i+1} = b_i \bar{\xi}_i \tag{1}$$

where b_i is the transfer matrix,

$$b_i = \begin{bmatrix} 1 & (r_{i+1}-r_i)/r_{i+1} & (r_{i+1}-r_i)^2/2r_{i+1} \\ 0 & 1-(r_{i+1}-r_i)/r_{i+1} & r_{i+1}-r_i-(r_{i+1}-r_i)^2/2r_{i+1} \\ 0 & 0 & 1 \end{bmatrix} \tag{2}$$

Using Eq. (1), the following relation can be obtained.

$$\bar{\xi}_i = B_i \bar{\xi}_1 \tag{3}$$

where,

$$B_i = \prod_{j=1}^{i} b_j \tag{4}$$

Thus the track can be traced using Eq. (3) if the track parameter at innermost layer $\bar{\xi}_1$ is given.

1150

Vertex constraint

The transfer matrix from center to a layer i is obtained by assuming $r_i = 0$ in Eq. (2).

$$\vec{\xi}_i = \begin{bmatrix} 1 & r_i/2 \\ 0 & r_i/2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \phi_0 \\ C \end{bmatrix}$$

Using this transformation, the parameters ϕ_0 and C are obtained from ϕ's at any combinations of the layers i and j as,

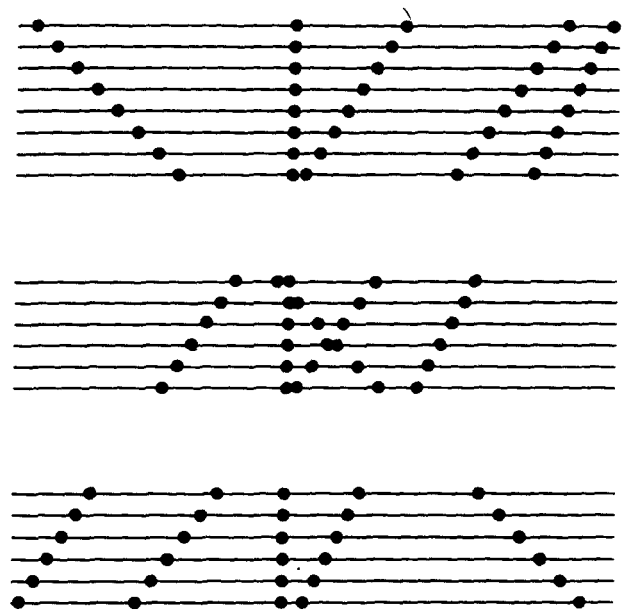
$$\begin{bmatrix} \phi_0 \\ C \end{bmatrix} = \frac{1}{D} \begin{bmatrix} r_j/2 & -r_i/2 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} \phi_i \\ \phi_j \end{bmatrix}$$

where,

$$D = (r_j - r_i)/2$$

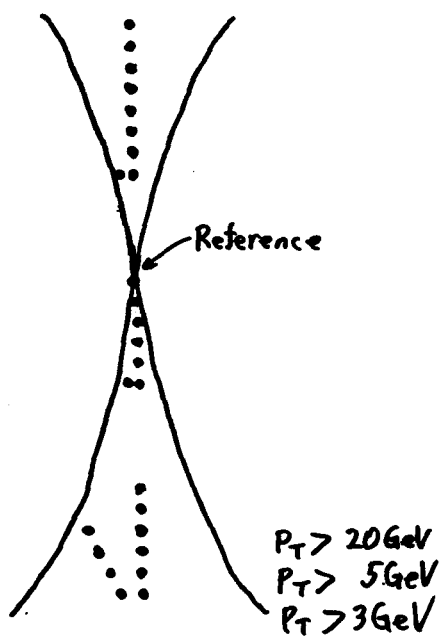
To obtain better track separation, precise determination of the track parameters ϕ_0 and C is necessary. For precise determination of ϕ_0 and C, the distance between the layers i and j shall be large enough.

1151



~~Also~~

1152

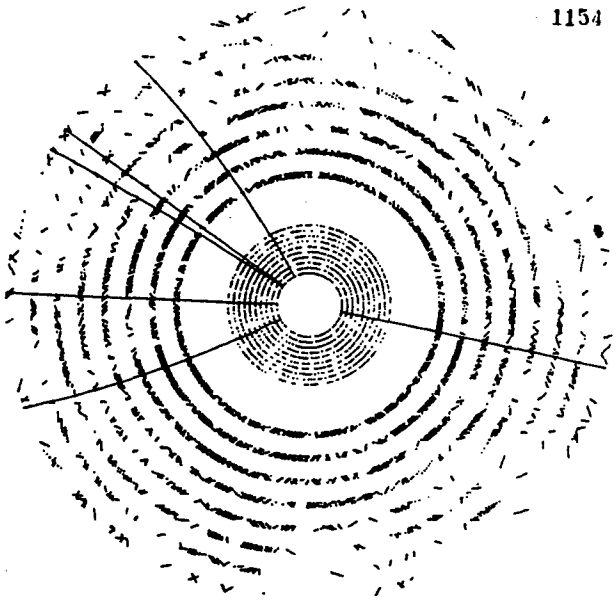


1153

12 $H^0 \to Z^0 Z^0 \to 4\mu$ events with 5 minimum bias events pileup. has been studied. 11 events had all 4 muons in $|\eta| < 1.5$ and $P_T > 3$ GeV/c.

All 4 muons	reconstructed	8	events
3 muons	"	2	"
2 muons	"	1	"

$$\varepsilon = \frac{8}{11} = 72.7 \pm 13.4\ \%$$



ISAJET

$H^0 \to Z^0 Z^0 \to 4\mu$

$M_H = 320$ GeV

GEANT simulation

5 minimum bias event pileup without filtering

Reconstruction CPU time:

11 min by VS3100M38 (~3MIPS) → 2B steps/event

Simulation Study

ISAJET (version 6.21)

$H^0 \to Z^0 Z^0 \to 4\mu$ $\quad M_H = 320$ GeV

Minimum bias (two jets $p_T > 2$ GeV)

GEANT simulation (version 3.13)

Traced through LOI version SDC central tracking system $|\eta| < 1.5$

dE/dx, multiple scattering, Compton, γ-conversion etc.

Chamber resolutions

Silicon	50 μm (pad width)
Straw	~~150~~ 200 μm σ

Chamber efficiencies

Silicon	99 %
Straw	95 %

Left-right ambiguity of the straw chamber

Propagation delay

TOF

TRIAL RECONSTRUCTION RESULT:

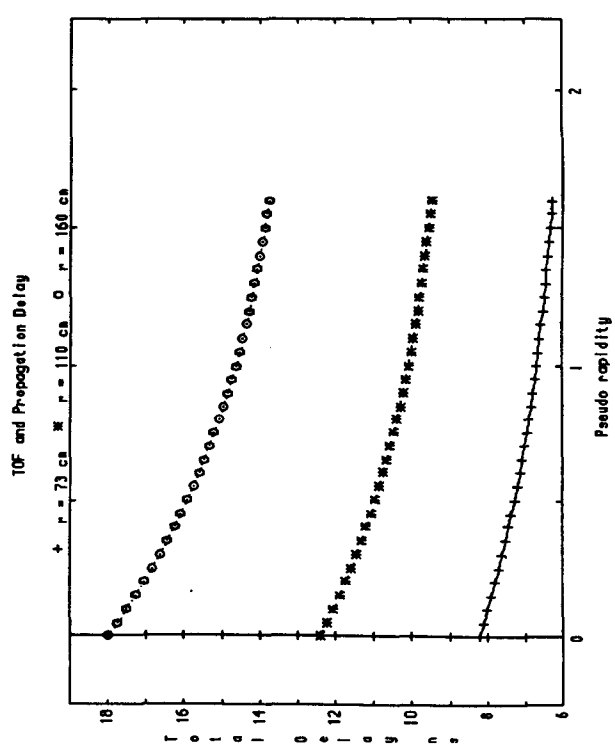
PHI-RHO_INVERSE DISTRIBUTION

287:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
288:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
289:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
290:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0
291:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
292:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
293:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4	0	0	0	0	0	0
294:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
295:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
296:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
297:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
298:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
299:	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
300:	0	0	0	0	0	0	0	0	0	0	0	0	29	16	0	0	0	0	0	0	0	0	0	0
301:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
302:	0	8	0	0	0	0	0	0	0	0	0	0	33	45	0	0	0	0	0	0	0	0	0	0
303:	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0
304:	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
305:	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0
306:	0	0	0	0	0	0	0	0	0	0	16	8	0	0	0	0	0	0	0	0	0	0	0	0
307:	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
308:	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
309:	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
310:	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
311:	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
312:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
313:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
314:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
315:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
316:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ϕ^0 ↑ → C

Reconstructed track parameters

DMAX = 0.24000E+02
NPHIO = 97 NRHOIO = 301
PHIO = 3.5724018 RHOIO = 0.18673E-02
Points selected: NPNT= 57 PHIREF= 3.7295799
ITER= 0 NCHPL= 0 CHSQ=0.737750168E+02 NPNT= 51
nlrev = 0 PHIREF= 3.7295799
Peak Found: DMAX= 12.000 PHIREF= 1.7477905



1158

Event pileup update

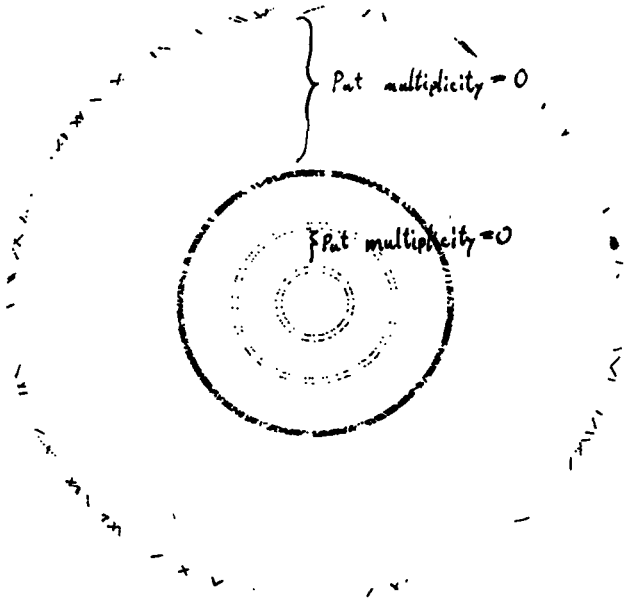
- Silicon tracker

  2 minimum bias events are folded.

- Straw tracker

  - 2 minimum bias events are folded in timing.
  - 3 minimum bias events are folded out of timing (± 16ns).

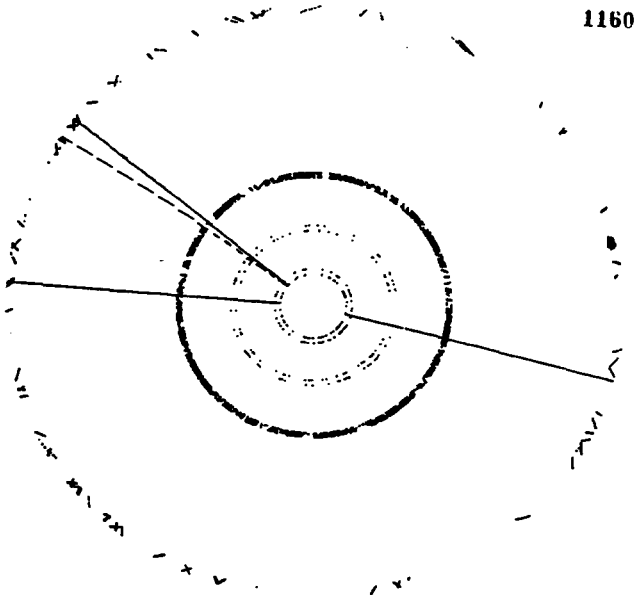
1159



Descope config 18A

Si 4 layers
Straw 14 layers

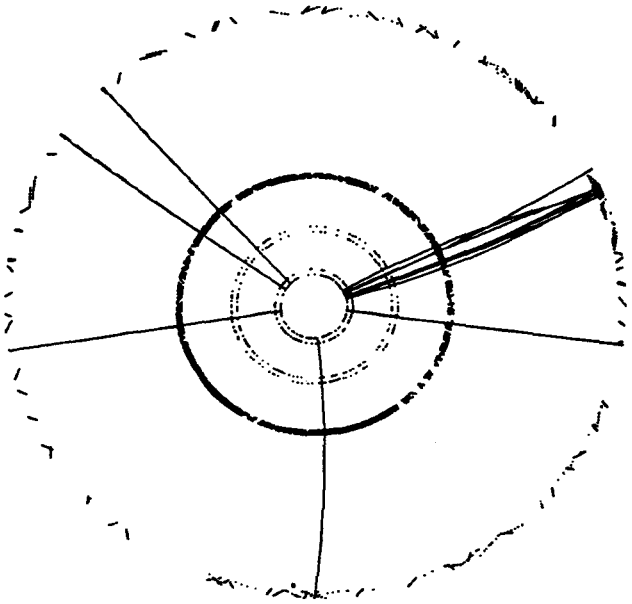
1160



18A
Si 4 layers
Straw 14 layers

Hist ≥ 5 points
Fitting [redacted] 9 points

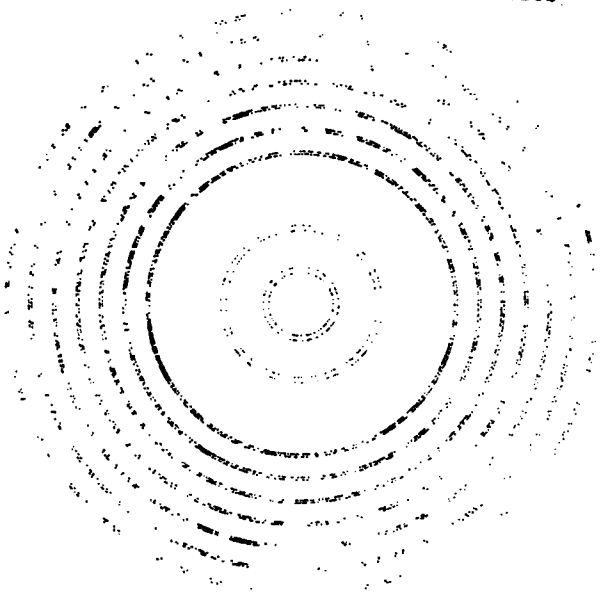
1161



18A
Si 4 layers
Straw 14 layers

Hist ≥ [redacted] 5 points
Fitting [redacted] 9 points

1162

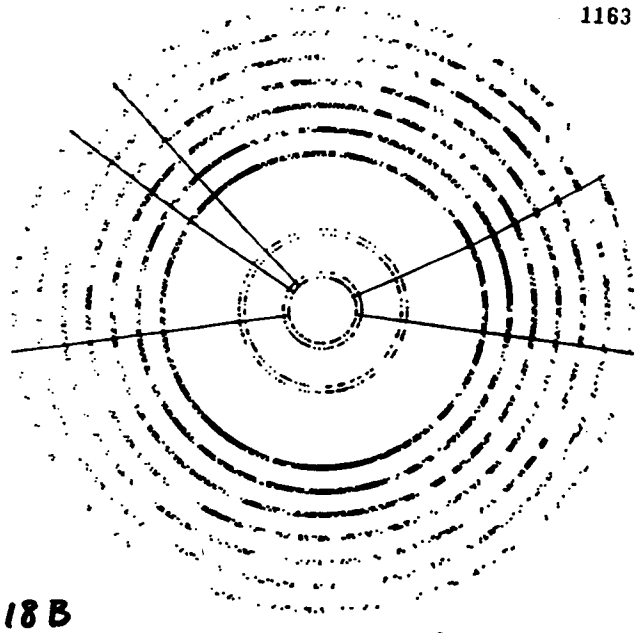


Descope config 18B

Si 4 laye
Straw 14 lay

Hbe

1163

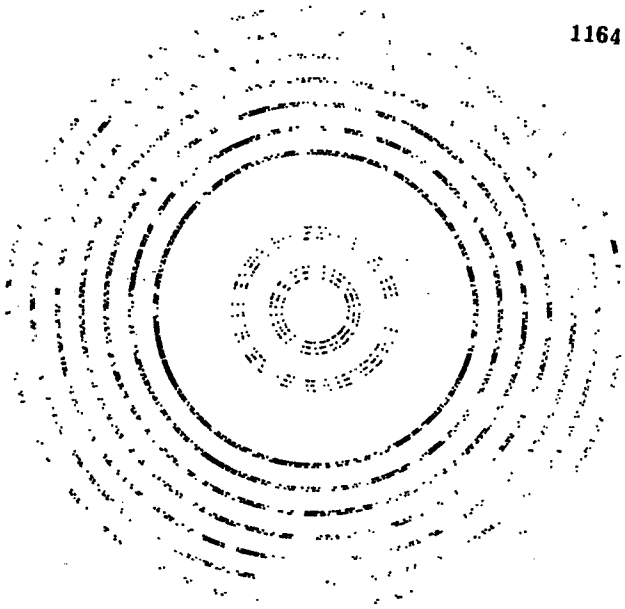


18B
Si 4layers
Straw 14 layers

Hist ≥ 5points
Fitting > 10points

11

1164

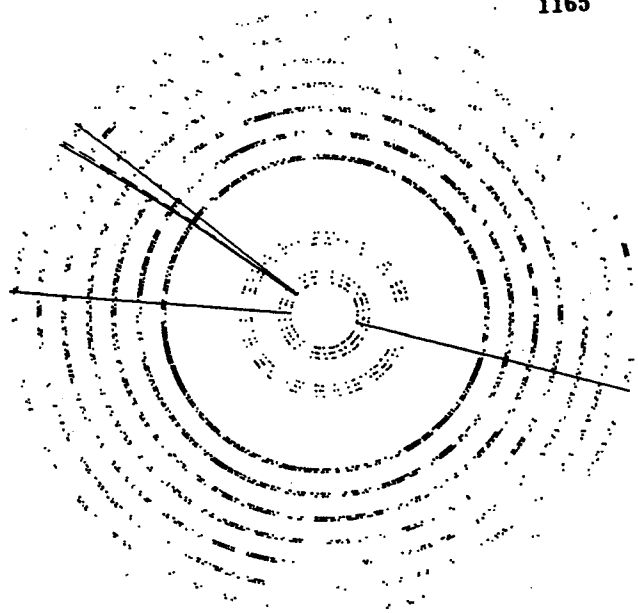


Descope config 20B

Si 6 layers
Straw 14 layers

Hbe

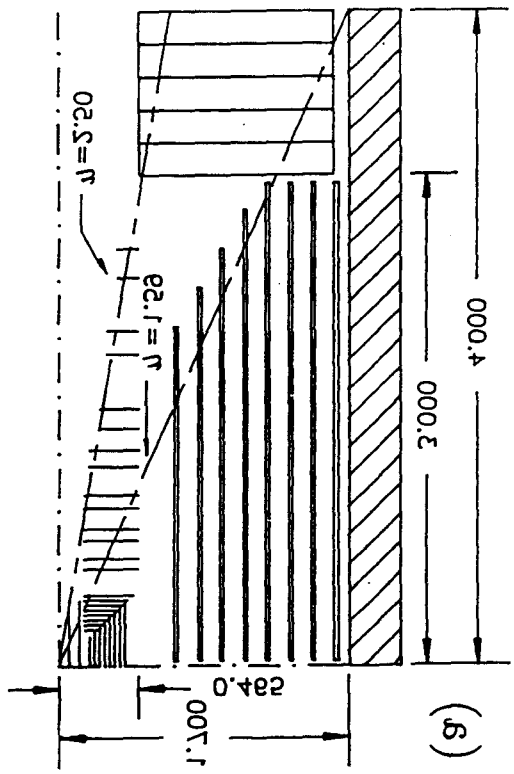
1165



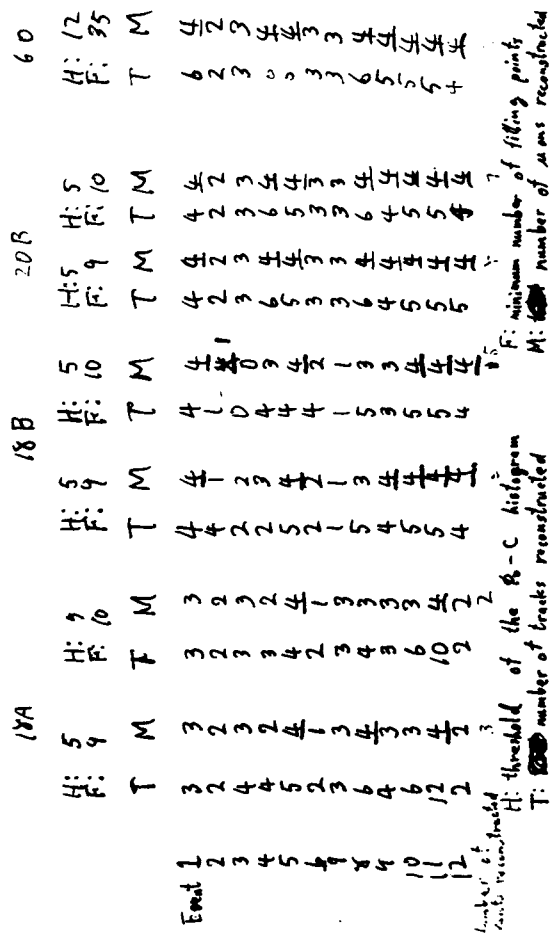
~~18B~~
Si ~~4~~ 6 layers
Straw 14 layers

Hist ≥ 5 points
Fitting > 9 points

1166



1167



1168

Summary

Study on the minimum number of axial layers has been made using GEANT simulator and the matrix approximation/histgramming algorithm. The results can be summarized below:

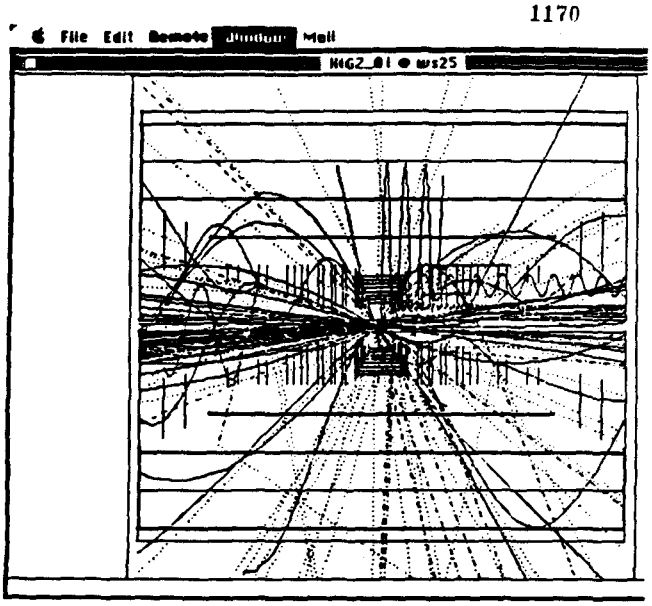
1. Using this algorithm, we need at least 6 axial layers of silicon chamber and 14 axial layers of straw chamber.
2. Almost equal distance configuration of layers looks better than 2 dense superlayers, but it's need further study in higher statistics to get solid answere.

1169

B. Hubbard
8/5/91
& KO, WSL

Progress on track finding & fitting (global & local)

- descoping work
- track fitting in Silicon
- global track finding + fitting progress
- what we need to do to finish



MacX Clipboard Page 1 Mon, Jul 29, 1991

Geometry

At the moment, we have 3 different geometries that are set up in the code

(1) "standard"

Not really LOI, old version of layout. ~ $30 m^2$

$r_{inner} = 18$ cm, $r_{outer} = 45$ cm

8 layers barrel, 22 layers forward

(2) "Hans"

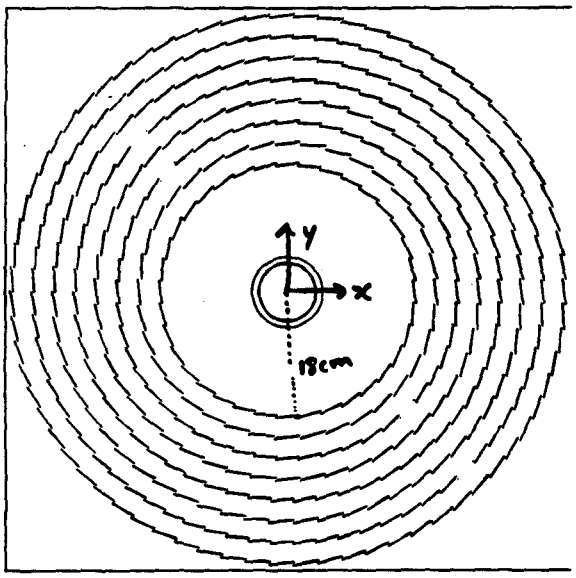
more realistic portrayal of (1)

shingling in forward

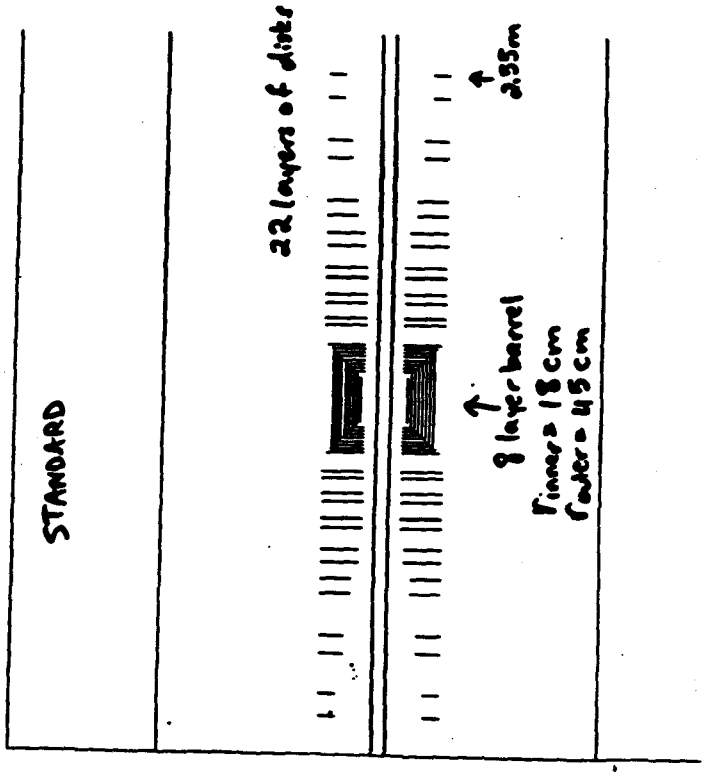
(3) "descope1" based on Nobu's design

~ $16 m^2$ $r_{inner} = 9$ cm $r_{outer} = 36$ cm

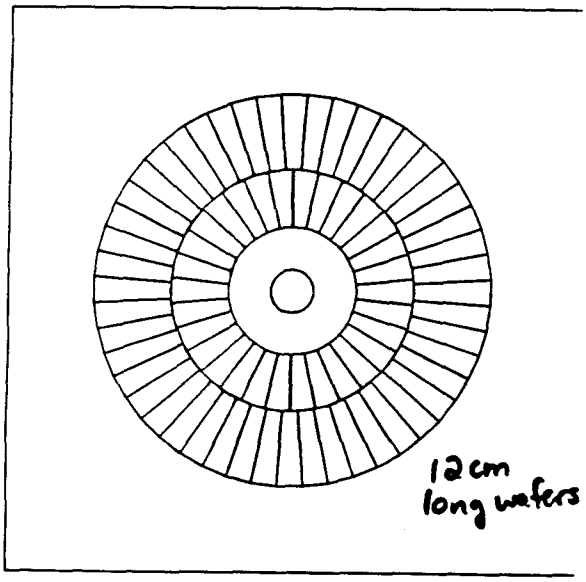
8 layers barrel, 12 layers forward



cut at z = 0
standard

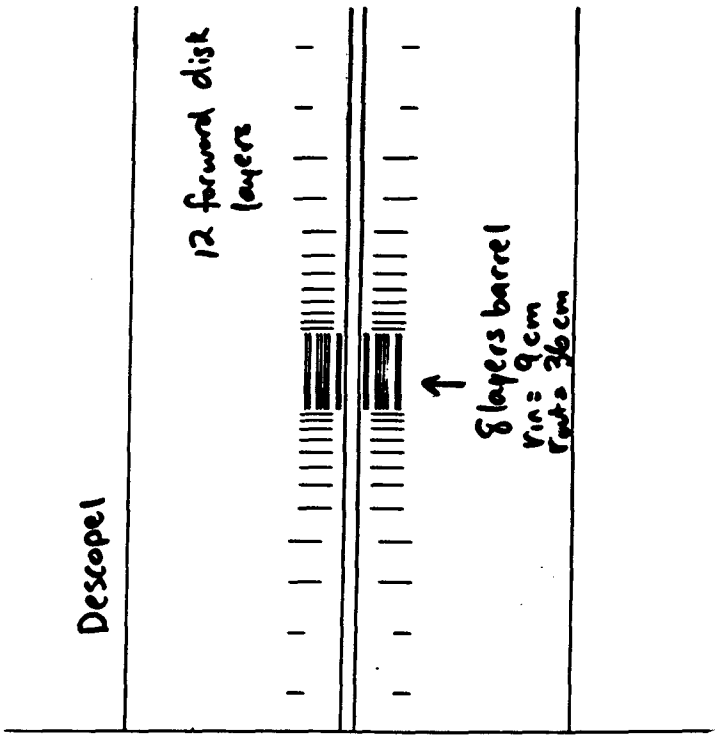


1174

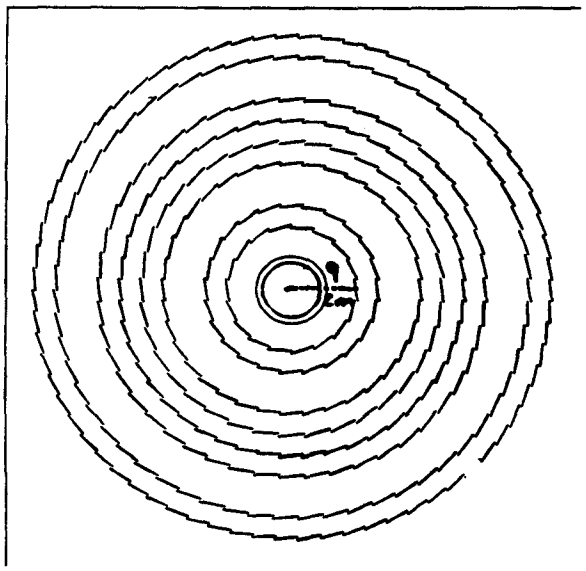


standard

1175



1176



descope 1

1177

```
GEONBANS HUNAC    A1    Dated 07/31/91 22:25:45   From disk SHP194    Page

*message "STGEON_BANS.HUNAC: Bans's latest: 7/15/91, with bonded wafers"
*
* Setup silicon system geometry
*
* Module parameters specified on ST/GEON/MODULE command:
*
* Module number
* Number of Layers
* Detector type (unused, always 1)
* Material # of support structure (6 for carbon)
* Thickness of silicon wafers (cm)
* Dead region at ends of wafers (cm)
* Dead region at sides of wafers (cm)
* Density factor for silicon (normally 1.0)
* Tilt angle (compensates for Lorentz angle) (radians, barrel only)
*
* Layer parameters specified on ST/GEON/LAYER command:
*
* Layer number
* Number of z wafers (barrel) or rings (forward)
* Position (r:barrel, z:forward, cm)
* Minimum extent (z:barrel, r:forward, cm)
* Maximum extent (z:barrel, r:forward, cm)
* Layer thickness (cm, including support material)
* Strip pitch (cm)
* Stereo angle (radians)
* Radiation lengths of support material
* Energy threshold for digitization (GeV)
*
* Wafer parameters specified on ST/GEON/WAFER command:
*
* Wafer number
* Minimum extent (in Z for barrel, r for forward) (cm)
* Maximum extent (in Z for barrel, r for forward) (cm)
* Number of phi wafers
* Phi offset of phi wafer 1 (radians)
* Wafer width (cm for barrel, radians for forward)
* Wafer type (see document) 1:readout at low Z or r,
*                            -1:readout at high Z or r
*                            2:bonded at low Z or r and to type 1
*                            -2:bonded at high Z or r and to type -1)
* Position offset of odd phi wafers (r for barrel, Z for forward) (cm)
* Position offset of even phi wafers (r for barrel, Z for forward) (cm)
*
* Barrel module parameters (module 1):
*
*
ST/GEON/MODULE 1 8 1 6 .03 .05 .05 1. .1309
*
ST/GEON/LAYER 1 6 18. -36.  36.   1.  .005  .005  .0025 .000025
*
ST/GEON/WAFER 1  -18. -12. 36  0.   3.3  -2 0. 0.
ST/GEON/WAFER 2  -12.  -6. 36  0.   3.3  -1 0. 0.
ST/GEON/WAFER 3   -6.   0. 36  0.   3.3   1 0. 0.
ST/GEON/WAFER 4    0.   6. 36  0.   3.3   2 0. 0.
ST/GEON/WAFER 5    6.  12. 36  0.   3.3  -2 0. 0.
ST/GEON/WAFER 6   12.  18. 36  0.   3.3  -1 0. 0.
```

stereo angle

wafer type

Track finding ("TS algorithm")

→ Not changed recently except to allow use of segments with missing stereo information

Method (review)

- Associate pairs of hits in adjacent Si layers to form 'vector segments', with parameters defined at DCA0 and errors which take multiple scattering into account
- cluster segments to make tracks based on χ^2 for both axial + stereo variables (within a single module)

TS fitting: improved version of Hylen's SILFIT

- Iterative helix fit with full multiple scattering correction
- Four passes:

A) • Fit originally assigned points. Require at least 8
  • Start with parameters from clustering
  • Iterate up to 4 times, or until χ^2 ceases to improve

B) • If χ^2 large (>50), drop points with large residuals
  • Drop one hit, iterate as above, repeat up to 8 hits

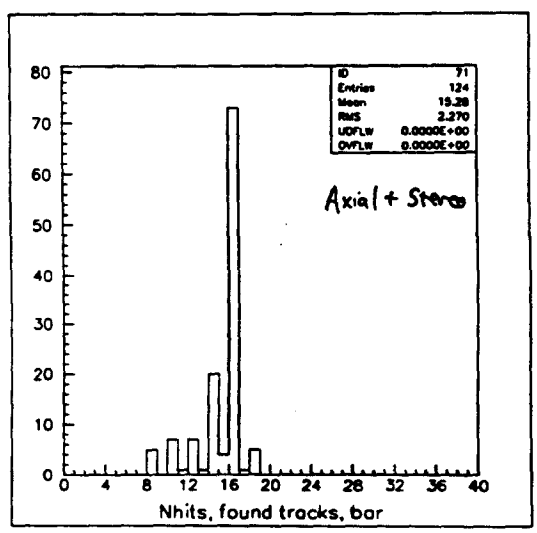
C) • Add points, if available.
  • For each wafer which a particle crosses, compare hit positions with trajectory.
  • Add hits within 5 strips, if not already assigned

D) • For primary track candidates, with $|d_0/\sigma| < 2$, add vertex constraint.

Still Silicon strips only.

Progress:
- improved iteration scheme
- hit adding uses 'hits' rather than 'vectors'
- bug fixes in forward m.s. calculation

Working on understand track resolutions for inner tracking system alone.



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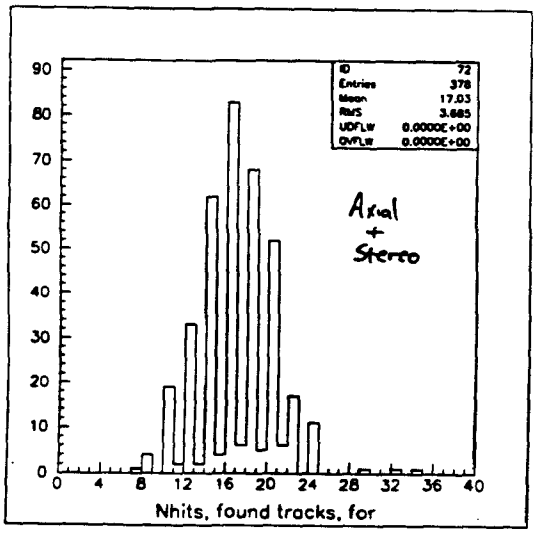

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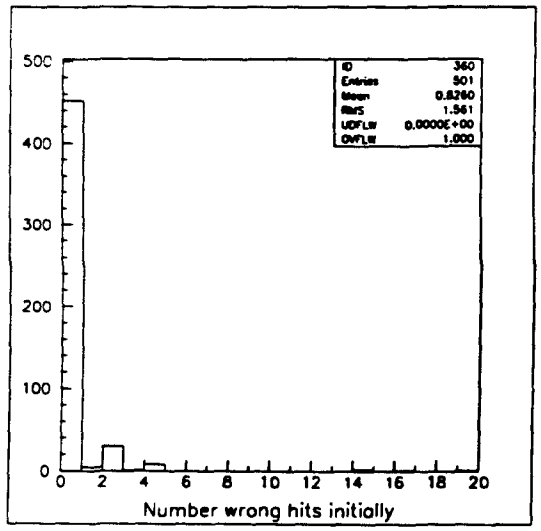


1184

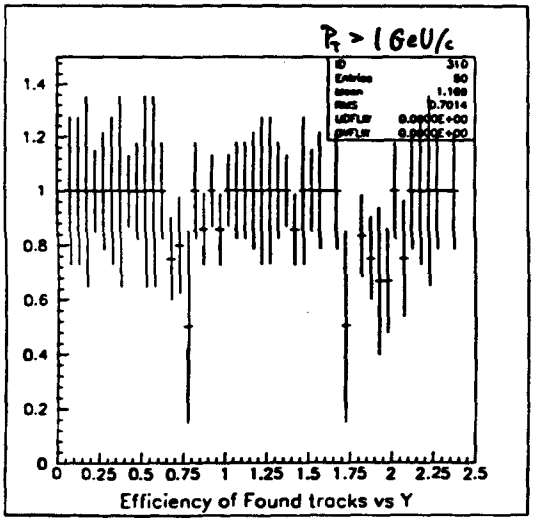
Hubbard

Inner tracker alone.

Require 5 axial hits,

$\frac{N \text{ hits}}{N \text{ possible}} \geq .5$

10 events only, Higgs → 4 ℓ

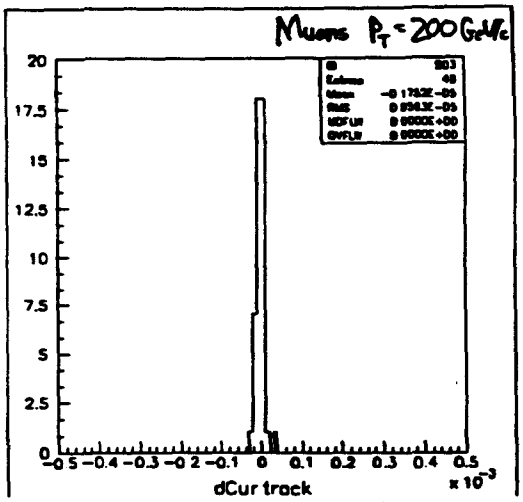


Hubbard

Single tracks

1185

Curvature Resolution



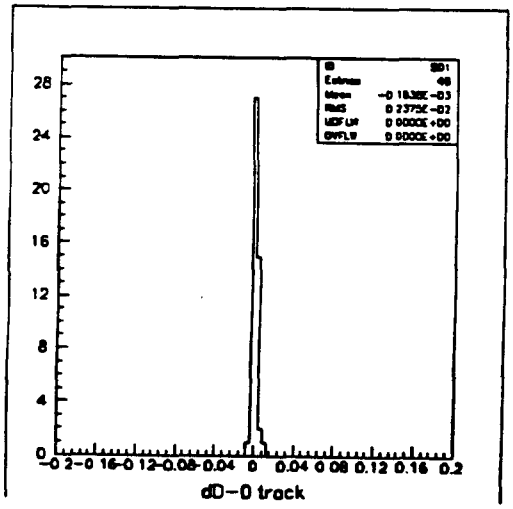
δP

$\rightarrow \frac{\delta P_T}{P_T} = \begin{cases} \leq .00025\, P_T & \text{Default be} \\ \leq .0003\, P_T & \text{Default, no be} \\ = .00017\, P_T & \text{Descope 1, no be} \end{cases}$

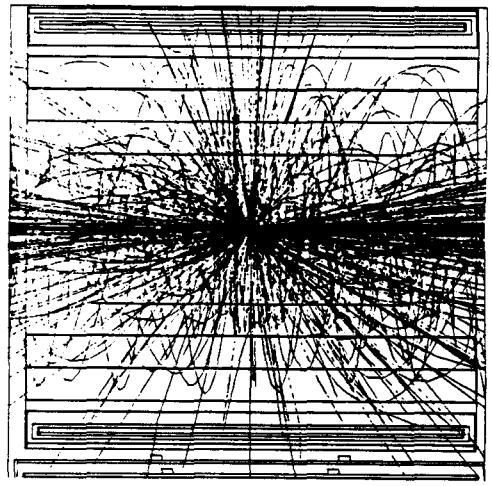
Hubbard

1186

Transverse Impact Parameter resolution



1187

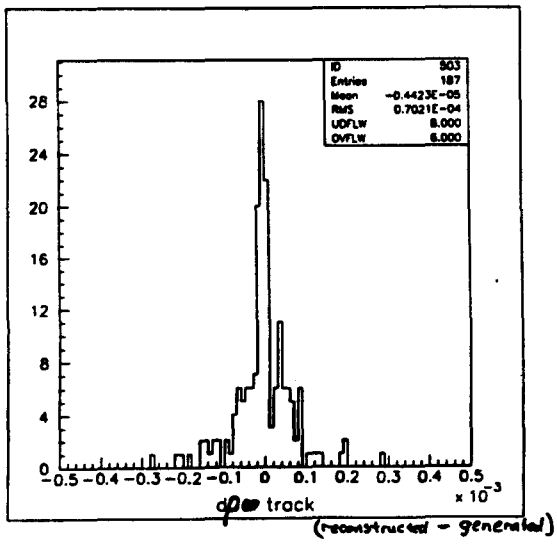


$\delta D_0 =$ ≅ 66 μ Default

23 μ Descope 1

1188

$\rho = \frac{-q \cdot .0063 \cdot B}{P_T}$



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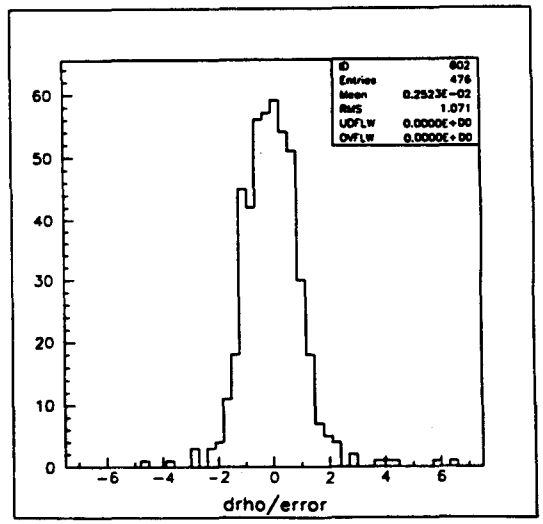

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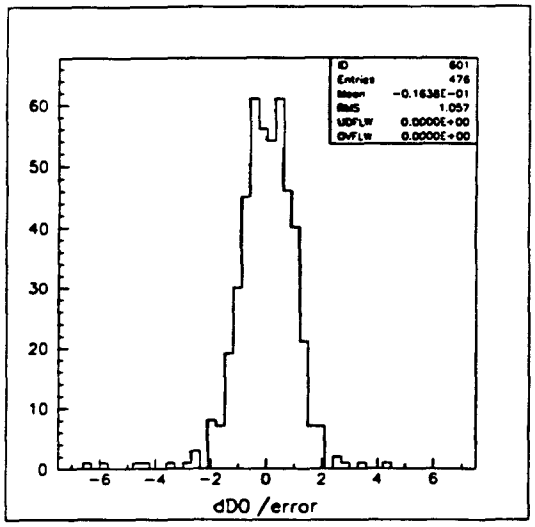

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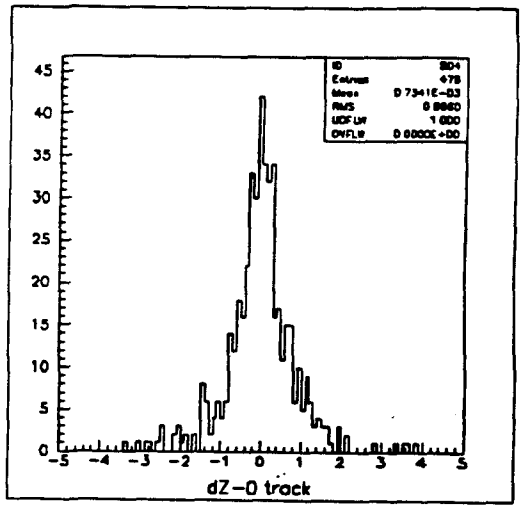
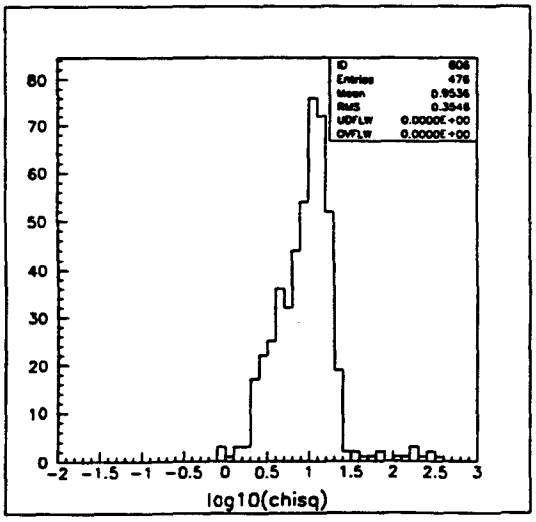


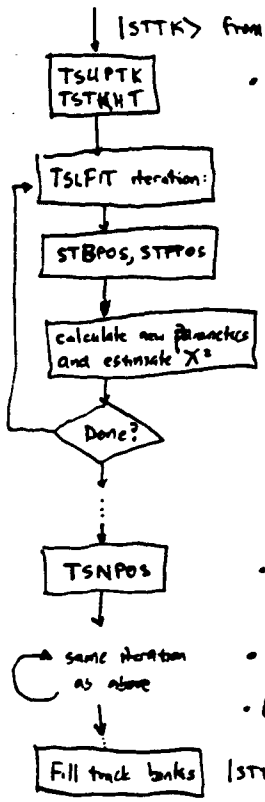
Default geometry

1192



1193

TS fitting: present code (s.hdem only)



- unpack track and hit data
- for each hit, calculate predicted position of trajectory in that element
- include multiple scattering error as accumulated to each layer
- for adding hits, determine which elements should have been hit.
- beam constraint, add axial point at 0,0,0, error ~ 10 μ

Next: include other detectors.

What do we need:

(A.) Segments from other detectors.
[or coordinates]

clustering

(B.) Conversion of segment parameters for TS clustering (done, not tested)

(C.) Clustering, ~~[illegible]~~
Calculate χ^2 for vector matching
investigate cuts,

(E) pack/unpack data from TRCT bank

fitting

(F.) calculate predicted position of trajectory in other systems (add like STBPOS)

(G.) calculate multiple scattering from beampipe, support structures, superlayers

(H.) determine which layers should have been hit, calculate χ^2 to track trajectory for adding segments. (like STNPOS)

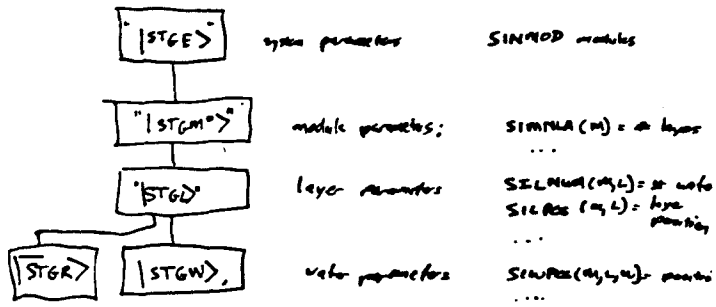
Geometry!

(I.) investigate cuts, ~~[illegible]~~ not on station.

Geometry:

Need more consistent storage/access of geometry parameters.

For ST, we use a bank structure accessed by statement functions:



These aren't actually in Zebra banks, but this would be simple to do with a few SEFILL calls.

INDIANA UNIVERSITY SIMULATION STATUS

F. Luehring
Indiana University

INTRODUCTION

- **Use of the SHELL**
- **Linking to Silicon Segments**
- **Stereo Pattern Recognition (Work of Xiao Yang Luo)**
- **Conclusions / Future Plans**

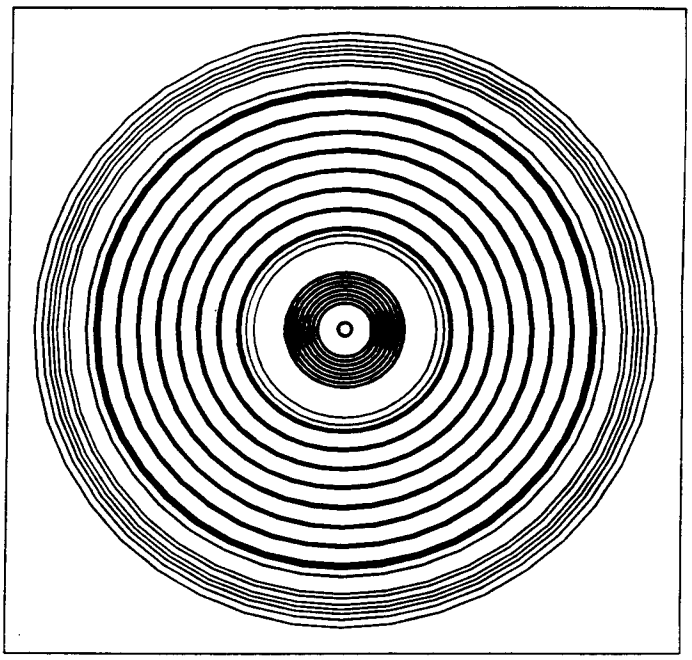
LINKING TO SILICON

- Simple algorithm used (just to get started):
  1) Reconstruct tracks using only straw tube tracker.
  2) Extrapolate to a track through the silicon.
  3) Use a loose phi/curvature cut to select possible silicon matches.
  4) Choose the segment closest in phi.
- Test cases used:
  1) Five stiff tracks including two closely spaced tracks.
  2) Higgs particle event. (Not fully investigated).
  3) Higgs with a full -20 to +4 bunch crossing minimum bias background. (Need time cut in silicon.)

GOAL:

CREATE AN ALGORITHM THAT DOES PATTERN RECOGNITION USING BOTH SILICON AND STRAW SIMULTANEOUSLY

1199



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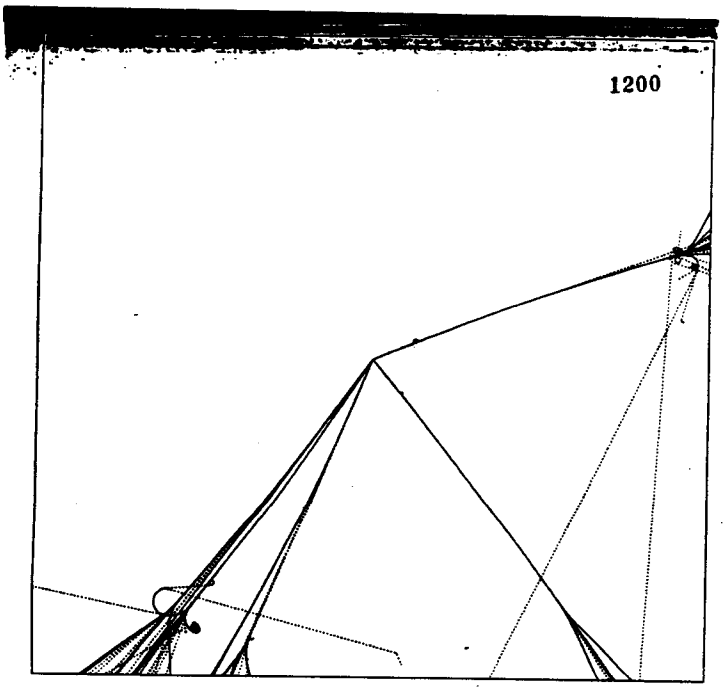

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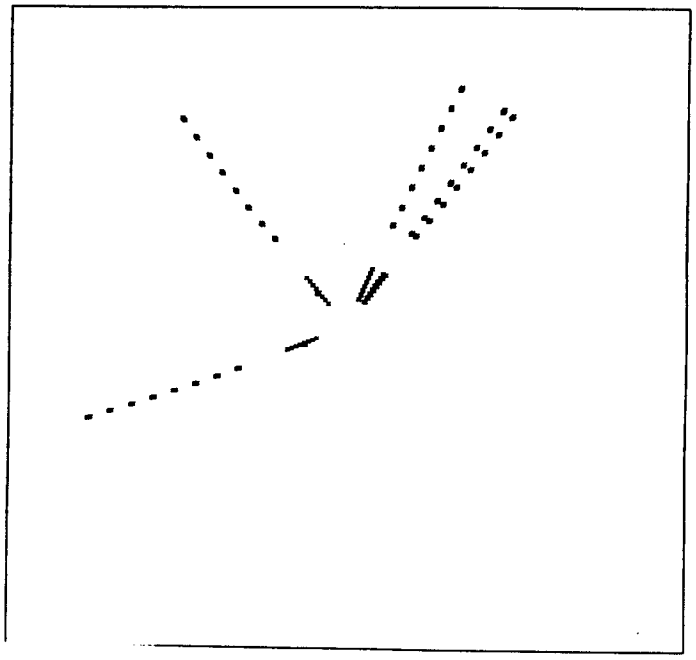
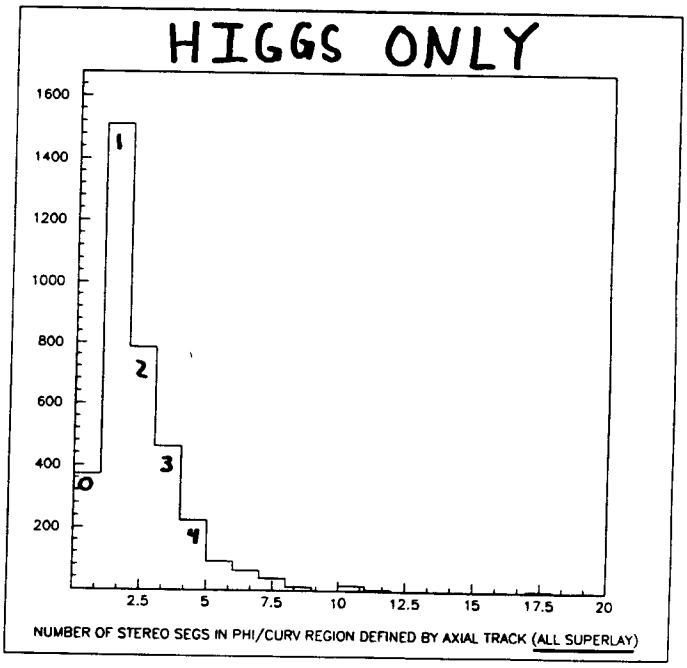
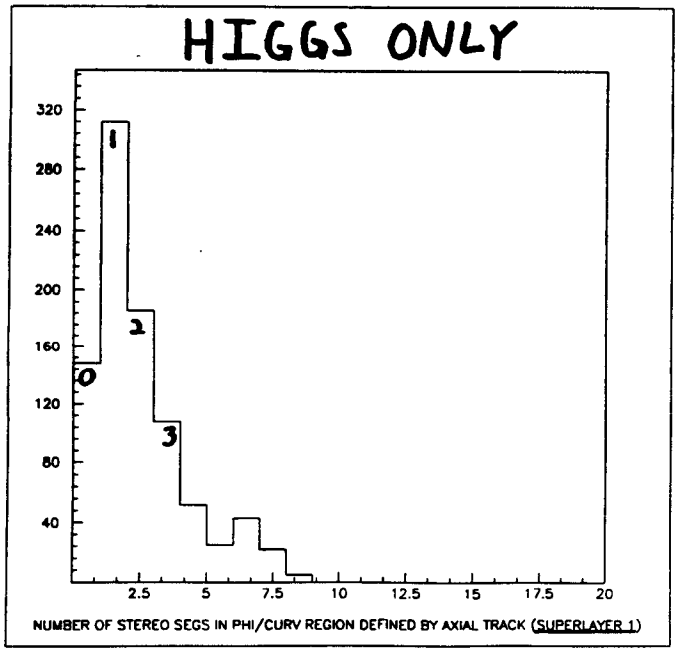


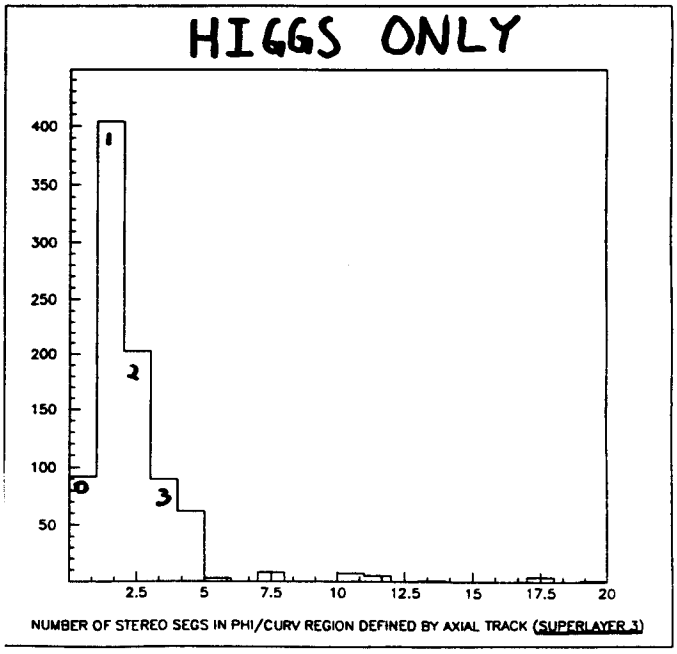
Higgs

USE OF THE SHELL

		0	1	2	3	μ	σ
1000	• Straw Tube Detector / Reconstruction in SHELL	3604	373	1510	785	462	2.4 / 1.7
1001	• Two Halves, Eight Super Layers, Stereo	901	148	312	186	108	2.5 / 1.8
1002	• Carbon Support Cylinders	901	92	404	203	90	2.3 / 2.0
1003	• No Endcaps or Electronics Assemblies	906	24	300	155	10	2.8 / 1.7
1004	• Full Straw Tube Segment Finding Algorithm (Except Segment Banks Not Filled Yet)	901	127	445	108	2	2.0 / 1.1
	• Straw Tube Segment Linking and Pattern Recognition					μ	σ
1400	• Use of other packages						
1400	• Shell Event Generator (Higgs + Minimum Bias)	104	1	11	23	67	24 / .8
1401	• Beam Pipe / Coil	104	7	16	18	29	28 / 4.2
1402	• Silicon Tracker (Including Segment Banks) • No Pixels	104	2	17	10	7	3.3 / 3.9
1403							
1404							







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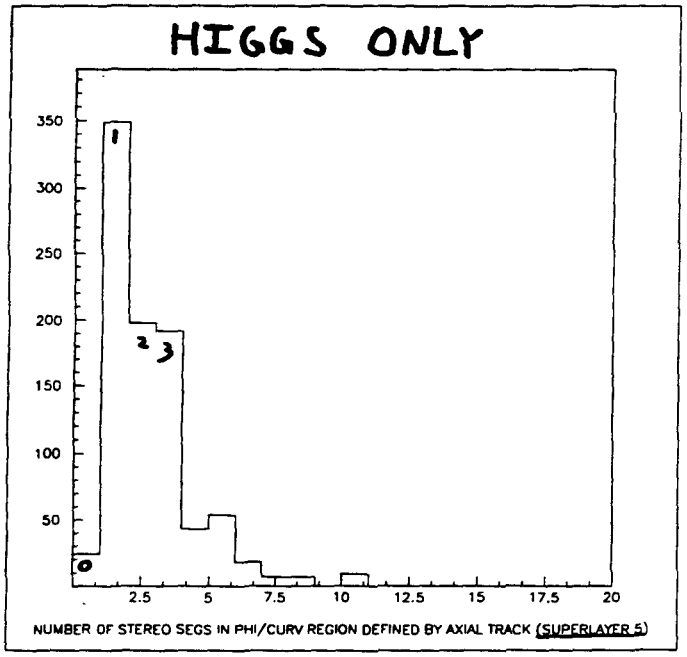

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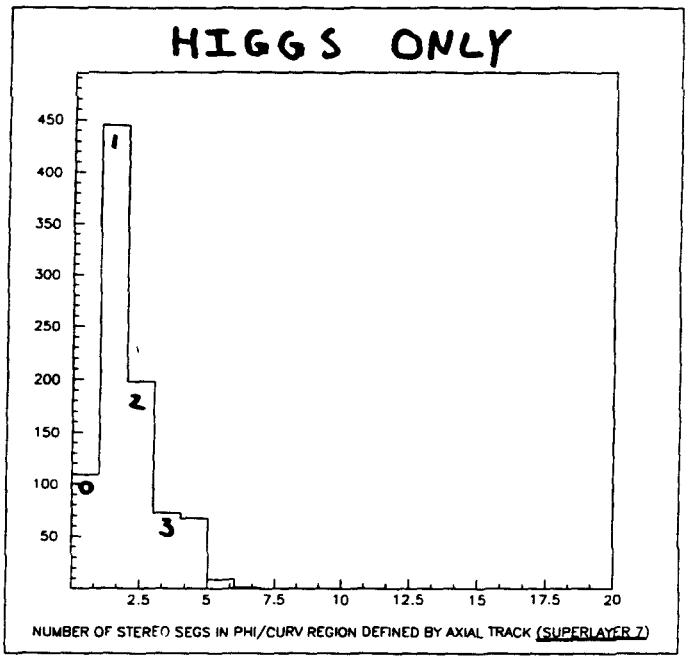

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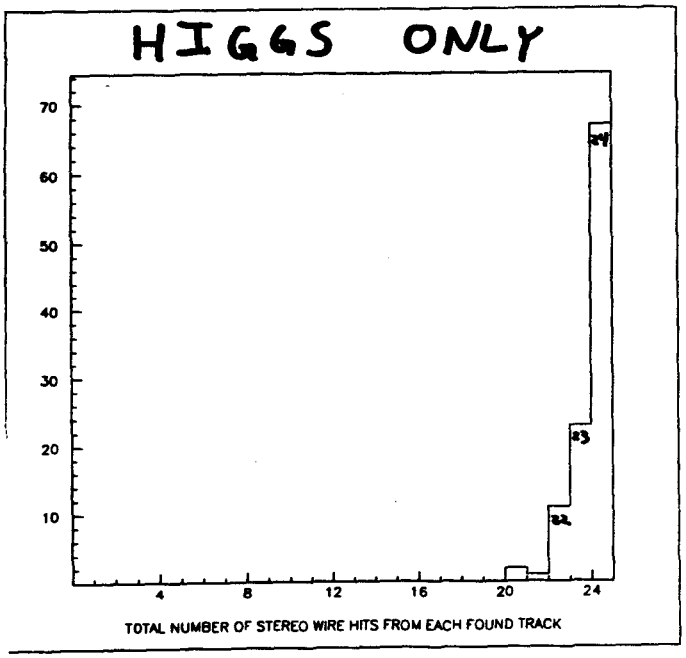
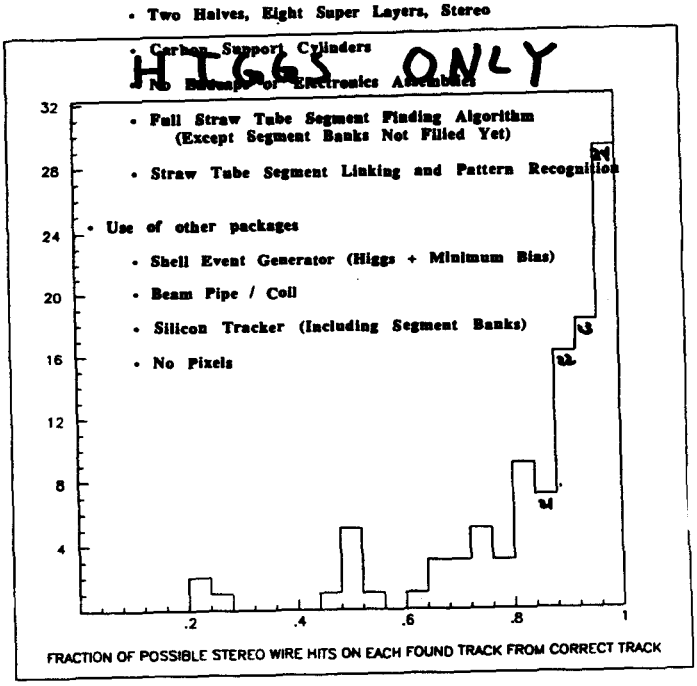


Luehring

1209

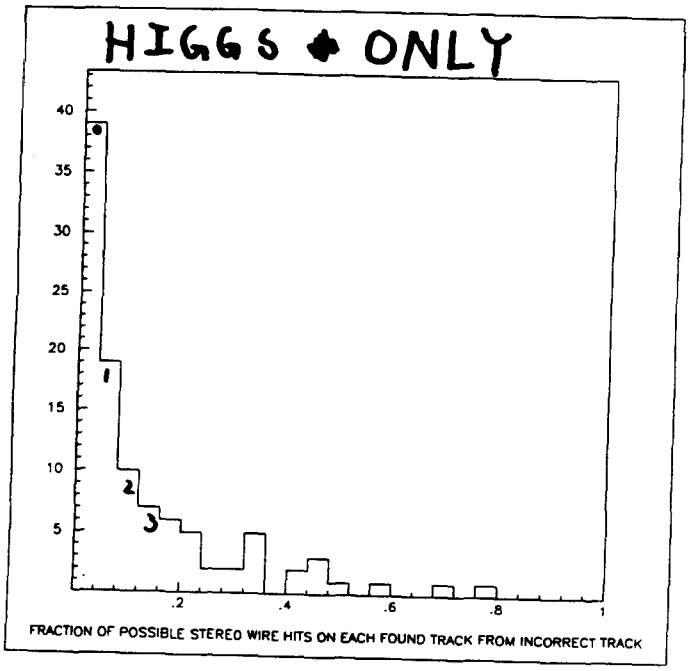
USE OF THE SHELL

- Straw Tube Detector / Reconstruction in SHELL
  - Two Halves, Eight Super Layers, Stereo
  - Carbon Support Cylinders
  - No Backup of Electronics Assemblies
  - Full Straw Tube Segment Finding Algorithm (Except Segment Banks Not Filled Yet)
  - Straw Tube Segment Linking and Pattern Recognition
- Use of other packages
  - Shell Event Generator (Higgs + Minimum Bias)
  - Beam Pipe / Coil
  - Silicon Tracker (Including Segment Banks)
  - No Pixels



Luehring.

1210



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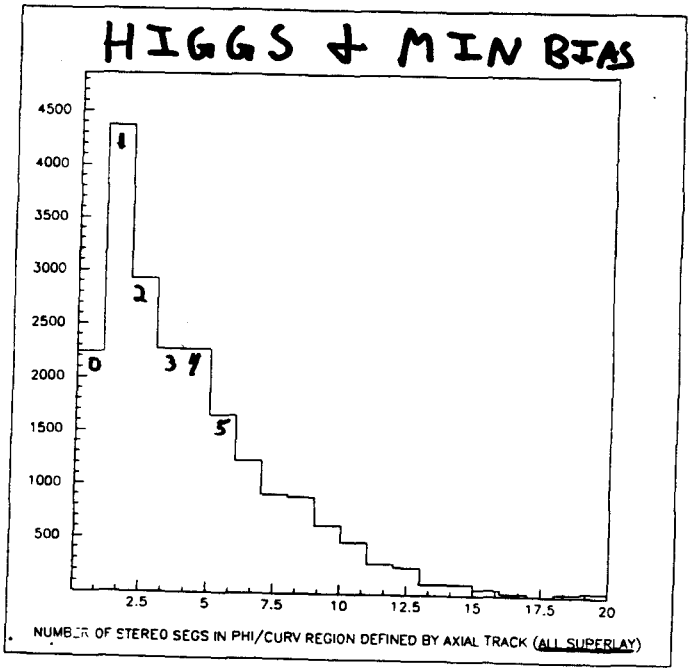

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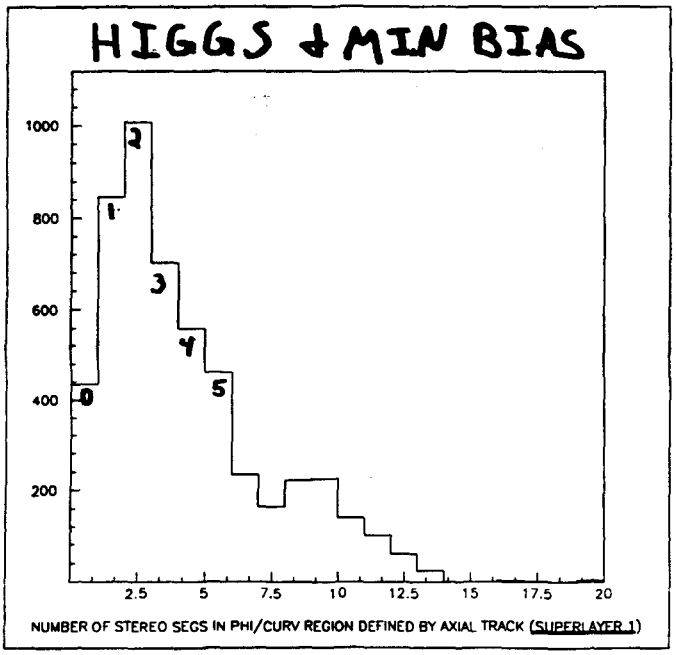

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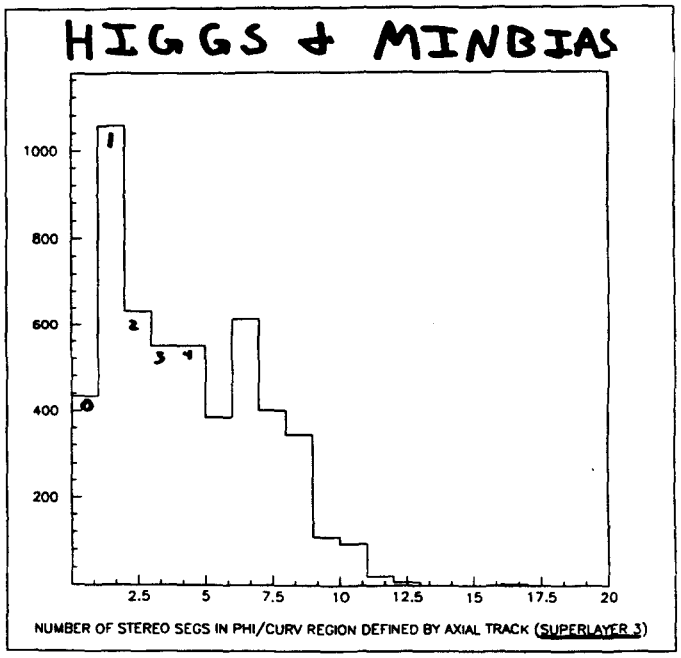
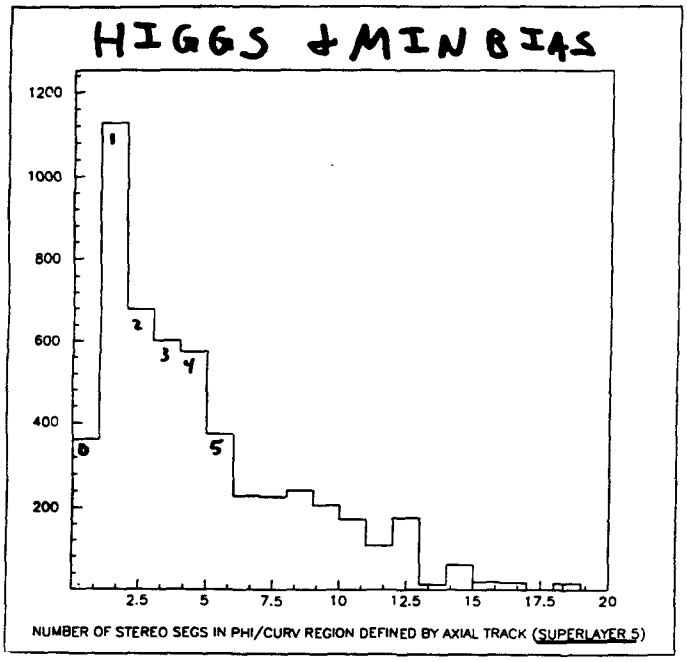
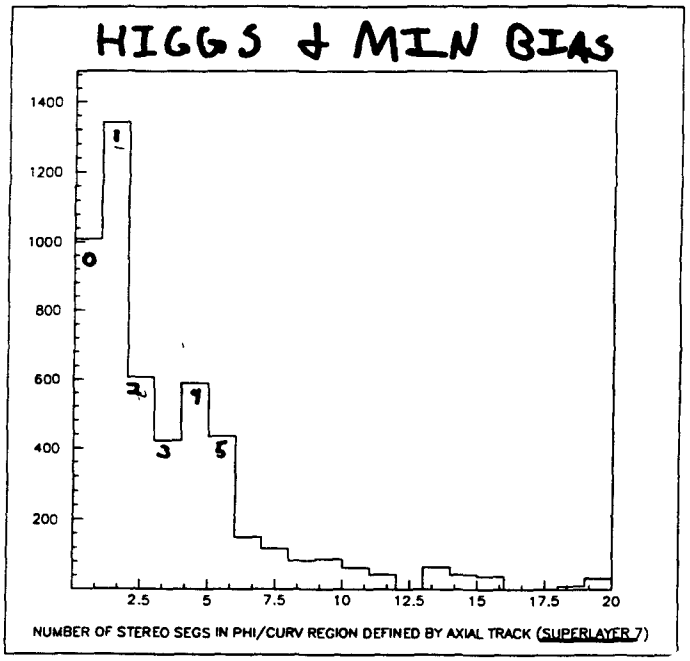


1214

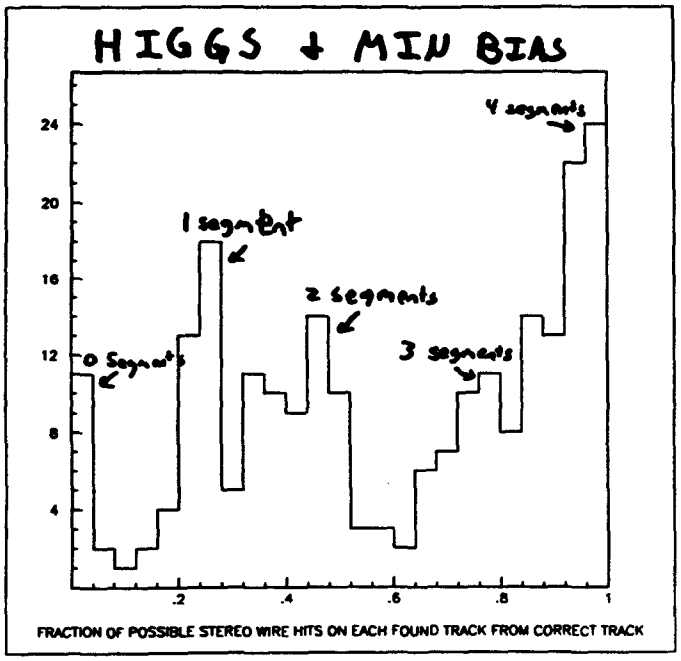


1215

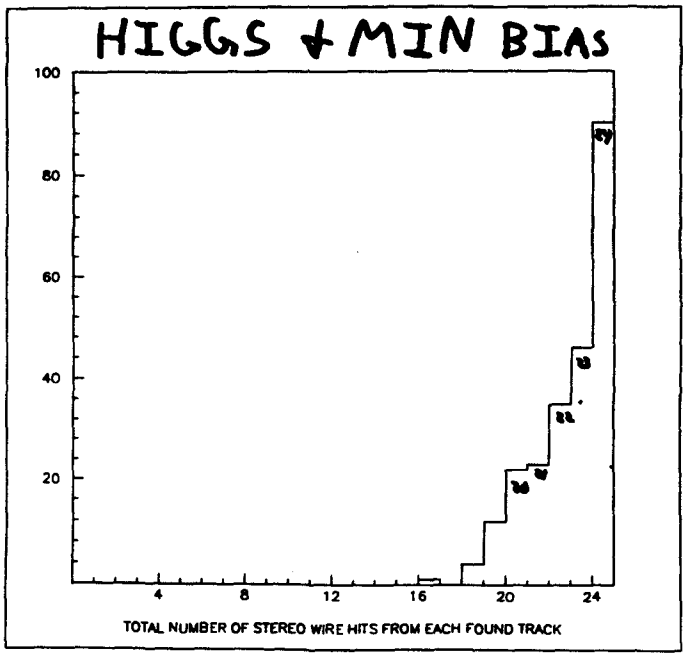


Looking

1216

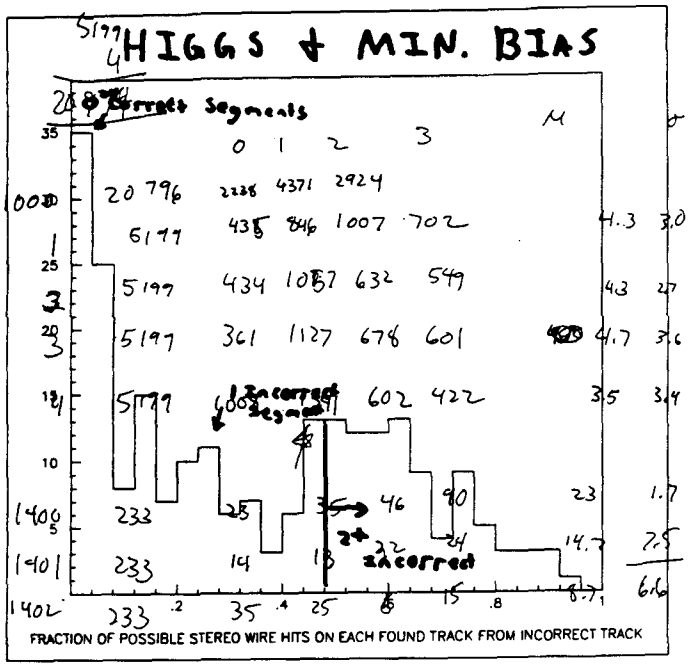


1217



Higgs + M.B.

No Cut on axial # of segs

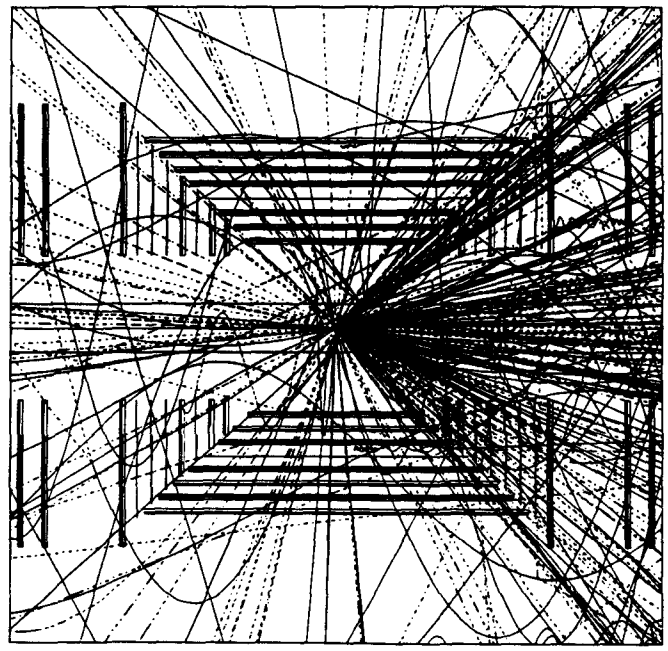


CONCLUSIONS / FUTURE PLANS

- Silicon / Straw Segment Linking:
  - It is possible to link to the silicon.
  - Work remains to create a global inner/outer pattern recognition algorithm.
  - The Z resolution of the combined system will be investigated.
- Stereo Straws:
  - The segment finding algorithm finds at least one possible stereo about 90% of the time.
  - In the Higgs case, the segment linking algorithm normally finds at least 80% of the right hits on a track.
  - Further optimization of the algorithm is required for Higgs with a minimum bias background.
- Further work needed
  - Optimizing the CPU/event.
  - Putting the straw (RW) segments into the segment banks.
  - Proper use of SHELL temporary storage banks.
  - Need to read back vertex info in order to check the goodness of momentum reconstruction.
  - Write a read back program that starts at the reconstruction phase of the shell.
  - Create larger data sets on tape under a variety of conditions (i.e. more statistics).

PROGRESS IN STRAW TRACKING

A. PALOUNEK



WR package

- geometry definition interactively (or in file)
  - # superlayers
  - # layers in each SL
  - length, # sense wires, straw ϕ
  - stereo angle
  - support cylinder, mylar thickness
  - material calculated automatically
- level of calculation interactively (file)
  - material only (calor, ...)
  - no digis
  - no reconstruction
- some bug fixes
- much general clean-up

AR package

- finds track segments in WR superlayers (from W. Ford)
- tied to WR geometry
  - private common blocks - no SHELL
  - xxGE data structure yet ★
- stereo as if in center
  - not quite right ★
- some GEANT-isms ★

AR package

- finds track segments in WR superlayers (from W. Ford)
- tied to WR geometry
  - private common blocks - no SHELL
  - xxGE data structure yet ★
- stereo as if in center
  - not quite right ★
- some GEANT-isms ★

AT package

- modified to use WR/AR data
- not fully debugged
- question of stereo

outstanding problems

~~stereo~~

noise (random, correlated)
connection to μ, calor ⇒ new bugs
intermediate angle, interface
dead material
geometry data structure
program flow
"too many steps"
temporary space
NTUPLES
sequences only (PATCHY/CMZ)
GEANT parameters (AUTO calculation)

AIM FOR GLOBAL TRACK FIT ASAP

segment linking + track fitting

What do we need from this meeting?

AT package modified to use WK/AR data

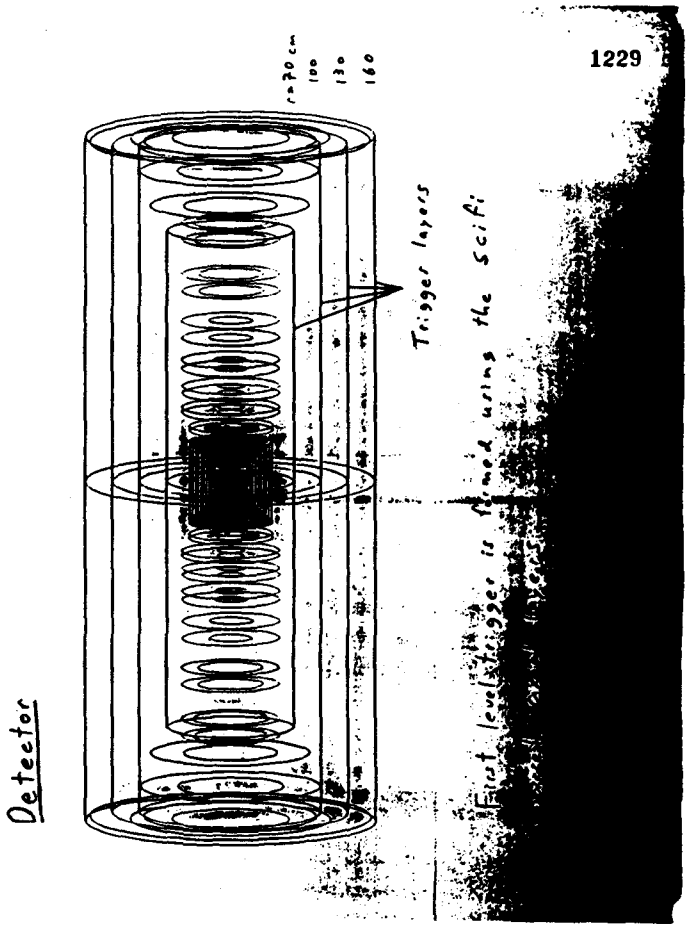
more discussion to divide tasks
(continue cooperation) – not quite right
where versions caveat emptor?
geometry data structures / treatment
physics studies + processes
what are limits on
p_T resolu
position
impact parameter
pattern recognition
many technical discussions
tracking only; SHELL as a whole
bring in other simulations
pixels
intermediate angle trackers
μ
→ link them
trigger
readout

Simulation of a Scifi
Tracking Trigger
for the SDC

D. Adams
Aug 91

1. Detector
2. Simulation
3. Algorithm
4. Efficiency vs. p_T + material

Work done by B. Lowery @ UTD



Simulation

> - Single tracks with definite p_T and η and random φ are used to study efficiency.
  - So far, overlapped "minimum bias" events have been used to look at false trigger rates. We use Pythia subprocess 95 (QCD inelastic).
  - Would be nice to have a sample of events which provide a false trigger in the calorimeter to study the rejection power of the tracking trigger.
> - Events are tracked in the SDC shell using GEANT w/ standard defaults.
  - The response of the fibers is simulated using SFTSIM (SDC package SF).
  - Si + beam pipe are included as inactive material.
  - Field is 2 Tesla.

Efficiency

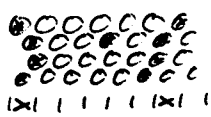
- The following figures show the trigger efficiency as a function of p_T for a threshold of 9.5 GeV/c. First curve is μ, second is e. Both $\eta = 0.5$
- Material
  - 3 mm Be beam pipe ⇒ 3.6 % X_0 at $\eta = 0$
  - 4 × 6 mm scifi ⇒ 6.4 %
  - Varying amounts of Si distributed in 4 layers

2.4 mm	⇒ 2.9 %
4.8	5.4
9.6	10.8
19.2	21.7

Trigger Algorithm

1. Clustering

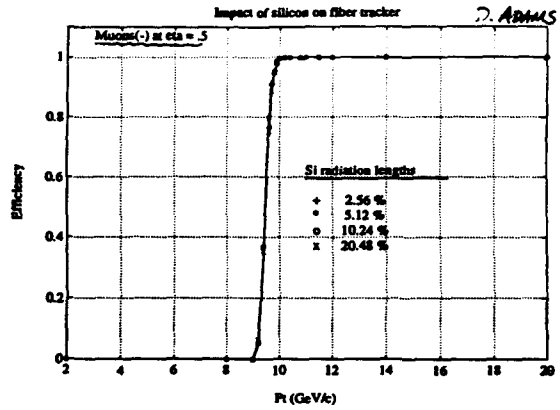
Each superlayer (4 axial layers) is divided into bins which are populated according to the hit fiber distribution.

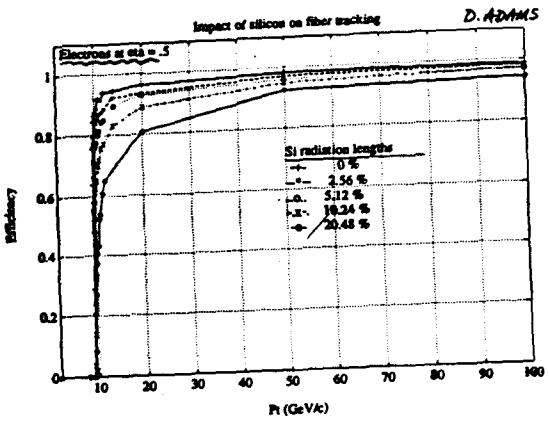


2. Linking

Tracks are found by linking hit bins from the different superlayers

- Each superlayer contributes a hit bin
- The hits lie along a circular trajectory which includes the beam line corresponding to $p_T > p_{T\,min}$. E.g. $p_{T\,min} = 10$ GeV/c





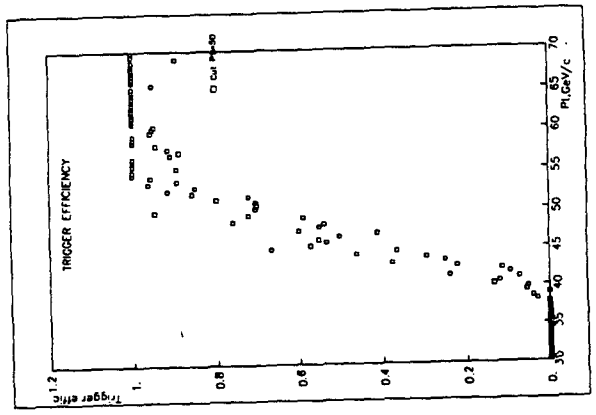
Efficiency vs p_T for different amounts of material inside the outer tracker ($\eta = 0.5$).

- 3.6% Si
- 5.5%
- 10.0%
- 14.4%
- 25.3%

Total material inside outer tracker

(Trigger uses layers at 70, 100, 130 & 160 cm)

From R. Lewis

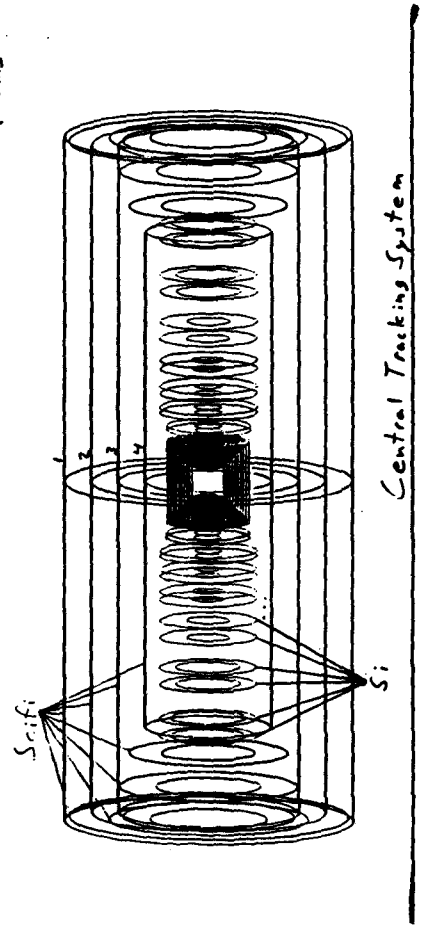


Pattern Recognition in a Scifi Tracking System for the SSC

D. Adams
Aug 1991

1. Detector
2. Simulation
3. Reconstruction
4. Evaluation
5. Results
6. Future

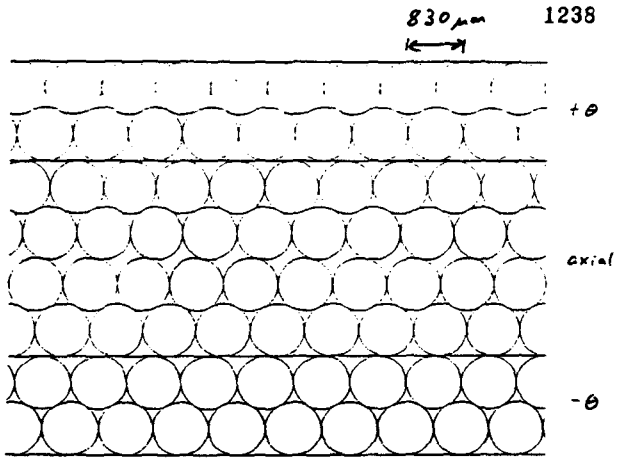
D Adams



Here we only make use of the scifi layers (superlayers 1-4)

Super layer	radius	z_{max}	η_{max}	occupancy (fraction)
1	160	400	1.65	0.0009
2	130	390	1.82	0.0018
3	100	390	2.07	0.0035
4	70	290	2.13	0.0063

1238



→ superlayer Structure

- 2 stereo +θ
- 4 axial
- 2 stereo -θ

Each superlayer is made up of three "orientation" layers

1239

Simulation

- Events are generated using Pythia. We generate 1, 2, 3, ... events/crossing using Pythia subprocess 95 (QCD inelastics).
- Events are tracked using GEANT with all relevant processes (dE/dx, mult. scat, brem, ...) turned on. Material of the full SDC Si + scifi tracking systems are included. Particles are tracked until they exit the tracking volume ($r = 170$ cm, $|z| = 400$ cm).
- The detector response for the scifi system is simulated using SFTSIM. Parameters are set so that the fibers have a high detection efficiency.
- Framework for the simulation is an old version of ANLSIM with modifications. Work is in progress to move the reconstruction (TRF) into the SDC framework. (SFTSIM is already included)
- A constant field of 2T inside the tracking volume is used. Note that $p_T > 0.48$ GeV/c can reach outer layer at 160 cm.

1240

Reconstruction (Pattern Recognition)

- Tracks are reconstructed using the Rice package TRF.
- Approach is simple and CPU-intensive. All likely combinations are fit and accepted if they satisfy a χ^2 criterion. Details follow →.
- Multiple scattering, dE/dx, brem are not accounted for in the reconstruction.

1241

Clustering

- Nearby hit fibers within a layer are combined into clusters.
- Nearby clusters within an orientation layer are combined to form orientation clusters.
- Consistent triplets including one orientation cluster from each orientation are used to define superclusters.

In the last step, we require all three orientations to contribute to reduce the number of ghosts.

Linking

- Pairs including one supercluster from each of the outer two superlayers are used to start tracks. All pairs consistent with a track coming from r=0 are selected.

- Each track is extended to each supercluster in the next superlayer. Tracks are fit with the three superclusters and are kept if they satisfy a χ^2 criterion. Note that tracks may die or may branch out into additional tracks in this step.

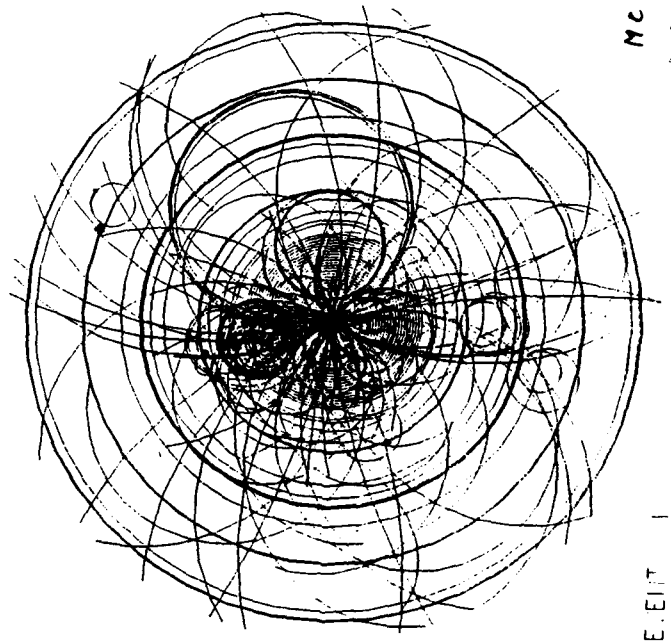
- The above step is repeated for the next superlayer and so on...

1242

1243

Adams

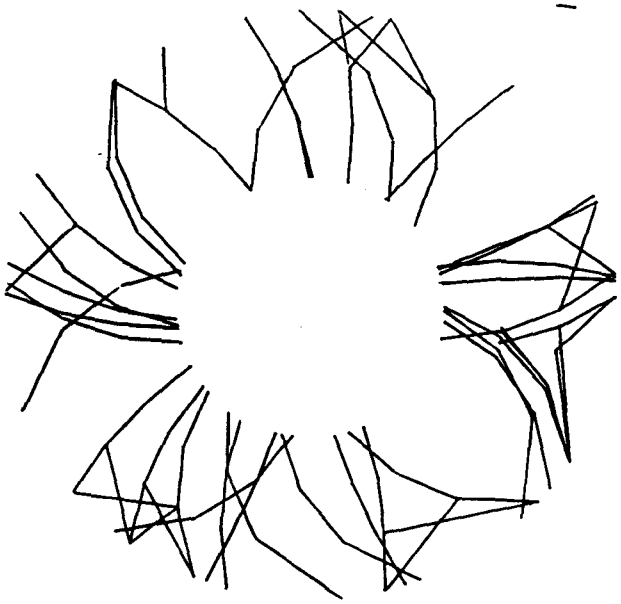
MC tracks



1244

Adams

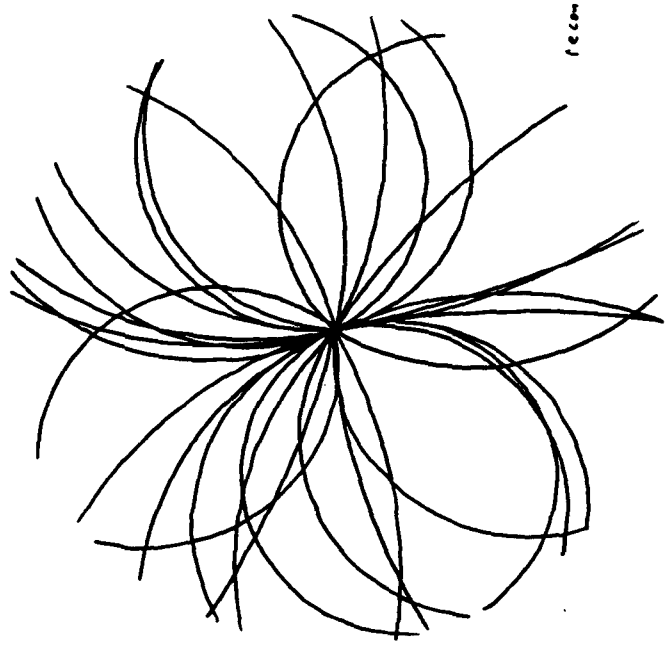
links



1245

Adams

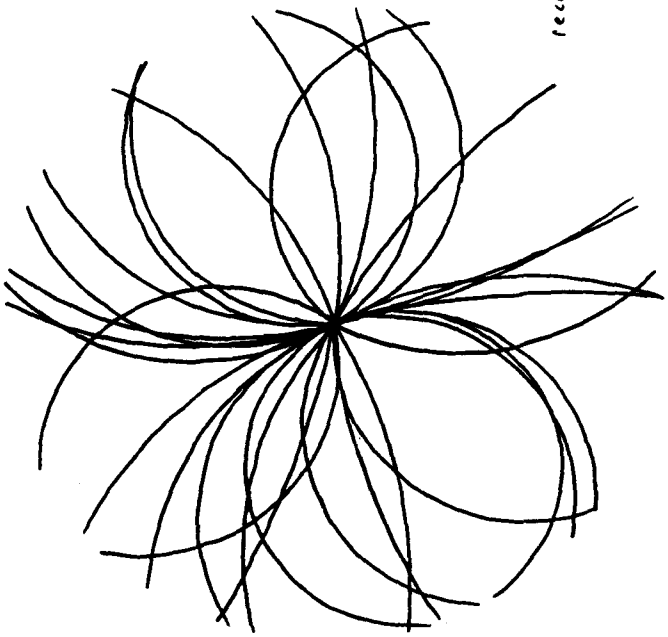
reconstructed



Adams

1246

reconstructed



1247

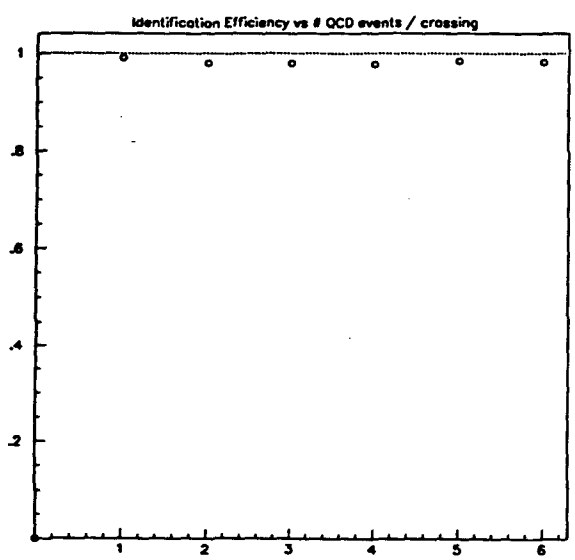
Evaluation

- Each reconstructed track is matched to the Monte Carlo track responsible for the majority of its superclusters.
- A subset of the M.C. tracks are used to define efficiency:
  - $r_{vtx} < 0.1$ cm (track from beam line)
  - $r_{exit} > 169$ cm (track exits through side of tracking volume ⇒ all four silicon superlayers are crossed)
  - $-0.01 < \frac{p_{T_{vtx}} - p_{T_{exit}}}{p_{T_{vtx}}} < 0.05$
  - $\left|\sin(\alpha_{exit}) - \frac{0.51}{p_T}\right| < 3.03$

    (The last two are loose cuts to eliminate tracks have significant change in direction or energy.)
  - $p_{T_{vtx}} > p_{T_{min}} \approx 0.5$ GeV/c
- Efficiency is defined to be the fraction of tracks in this subset that have been matched to a reconstructed track.
- Any reconstructed track which is not matched to a MC track is said to be a false track.

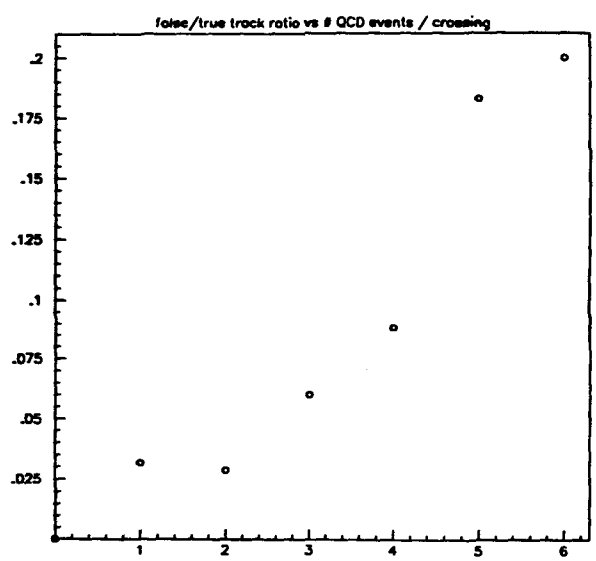
Adams

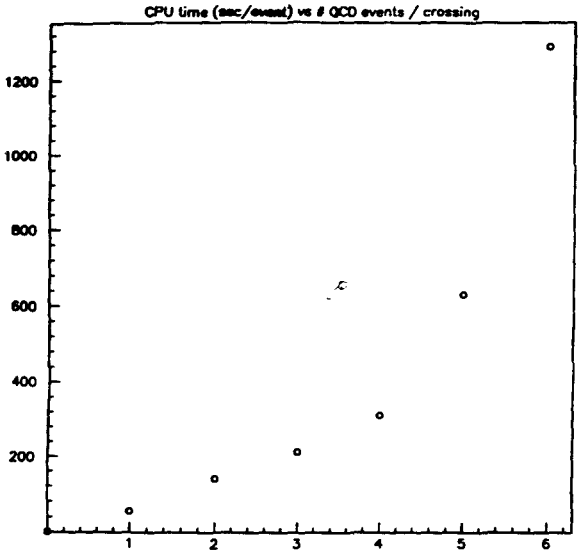
1248



Adams

1249





Results

- Efficiencies are high (98-99 %) for 1, 2, ..., 6 inelastic events / crossing
- False track rates are significant but not excessive (20% for 6 inel./xing)
  ⇒ need additional layer(s) (e.g. silicon)

Future

- Move TRF to SOCSIM.
- Include Si detectors.
- Vary the number of superlayers.
- Vary the stereo angles.

Hybrid Central Tracking Chamber

Track Finding.

M. Corden
M. Mermikides
D. Xiao

1/ Straw segment finding (r-φ)

Look for adjacent or next-adjacent hit straws.
Give preference to radial direction. [No drift time]
Require 4/6 hits (forms to information).

Fit drift times of candidate to determine t_ϕ, (z), left-right ambiguities.

Refit after t_ϕ correction, with smaller errors, to determine position & direction.

2/ Fiber segment finding.

Essentially, simple clustering, for both axial & stereo fibers for 2-fiber superlayers; like straws for 4-fiber s/l.

3/ Stereo matching.

Performed locally, per superlayer. Axial segments are extrapolated to the stereo fiber layers. Look for matching pair of u & v clusters, $x = u + v$ within u/v window & tolerance. Update axial segment with z.

4/ <u>segment linking</u> (in r-ϕ)

Start from outer superlayer, <u>(for now)</u>, in ϕ window.
Segment direction permits consistency test for initial linking segments. No vertex constraint. Continue inward.
After a chain found, define a road, go back and look for missed segments.

(<u>Beware</u> approximations as superlayers get farther apart)

Includes straw, fiber & silicon segments
(Latter have to be converted & un-extrapolated).

Future: consider starting from Silicon?

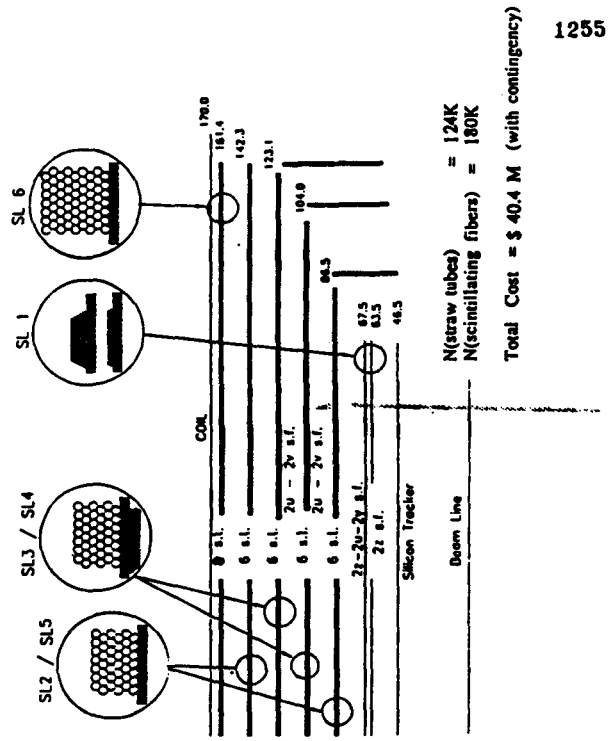
5/ <u>Fitting</u>

3D helix fit assuming uniform field, optional inclusion of vertex.

Should eventually fit silicon coordinates, not segments.

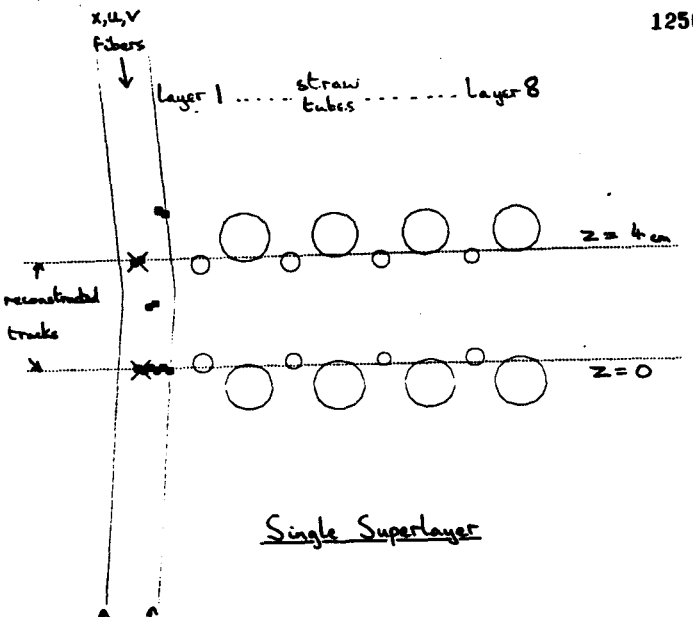
July 24, 1991

Straw Tube - Scintillating Fiber Outer Tracker



N(straw tubes) = 124K
N(scintillating fibers) = 180K

Total Cost = $ 40.4 M (with contingency)



<u>Single Superlayer</u>

Track segments are found from straw numbers only, then refit using drift times.

<u>Shell comments</u>

Runs under shell in conjunction with ST package.
Geometry read from file.

GEANT/HIGZ - based graphics.

Can re-draw or re-reconstruct an event for diagnostic purposes.

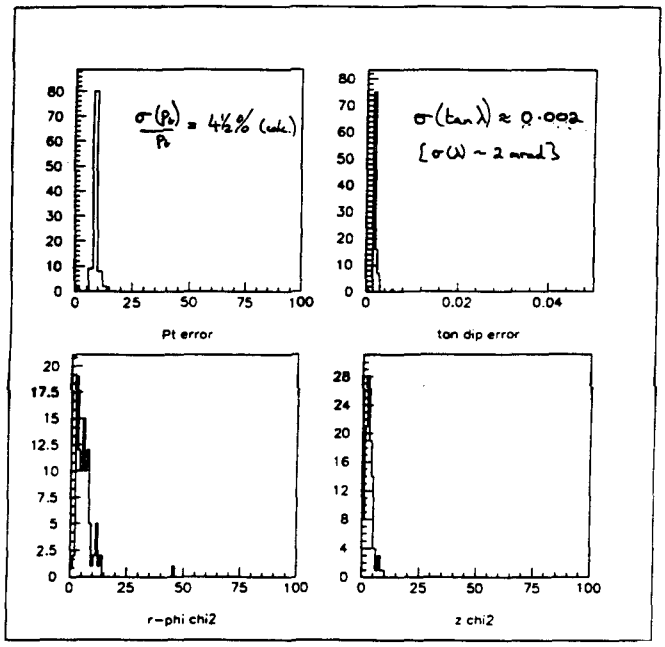
Can write out event, & read back for analysis only.
Slow!

A need: standard generator files, especially "minimum bias".

Also, descoped geometry files.

1258

$P_t = 200$ GeV/c, $y = 0.05$

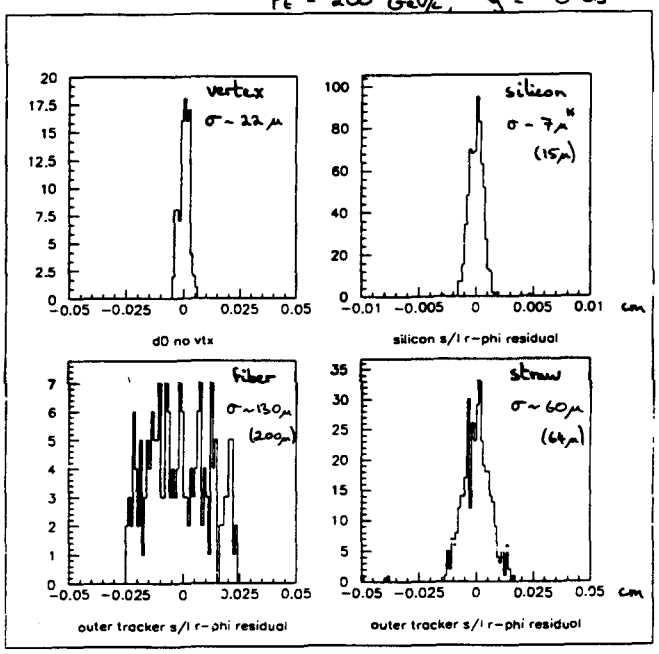


Corden

1259

$r-\phi$ track residuals per segment.

$P_t = 200$ GeV/c, $y = -0.05$



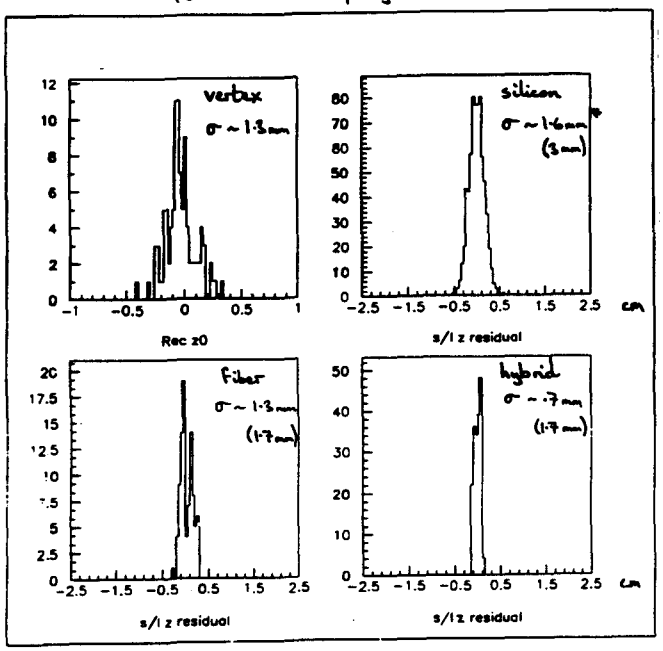
Note: vertex not used in fit
"silicon segments "double count" layers, ⇒ smoothing
"fibers" is for 2 layers of 1 mm fibers only.
"straws" is for 6 layers, except 9 in trigger layer, 150μ for single layer.

Corden

1260

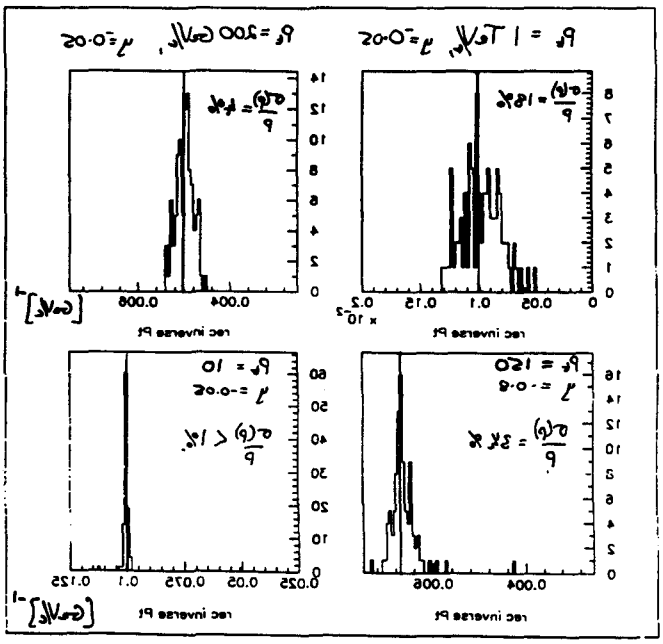
z single track residuals, per segment.

$P_t = 200$ GeV/c, $y = -0.05$



1261

reconstructed $1/P_t$

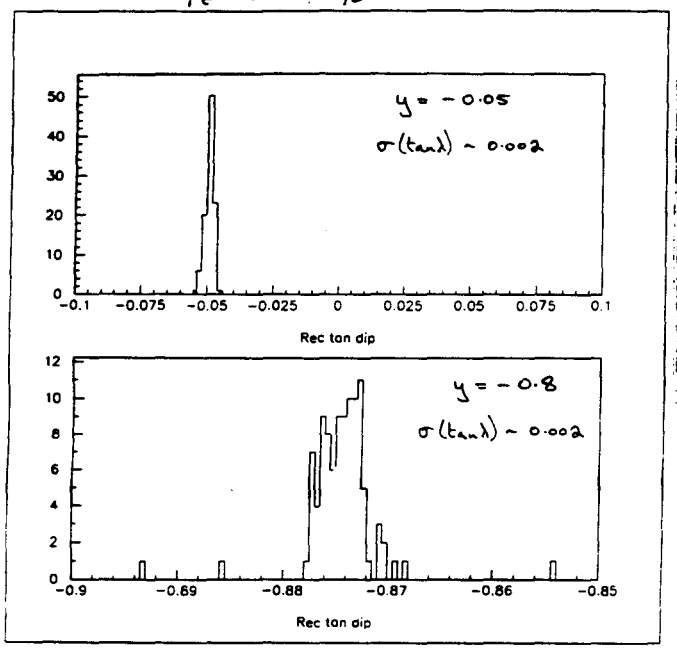


Roughly, $\frac{\sigma(p)}{p_t} \approx 50\%$ (central region).

Corden

1262

P_t = 200 GeV/c

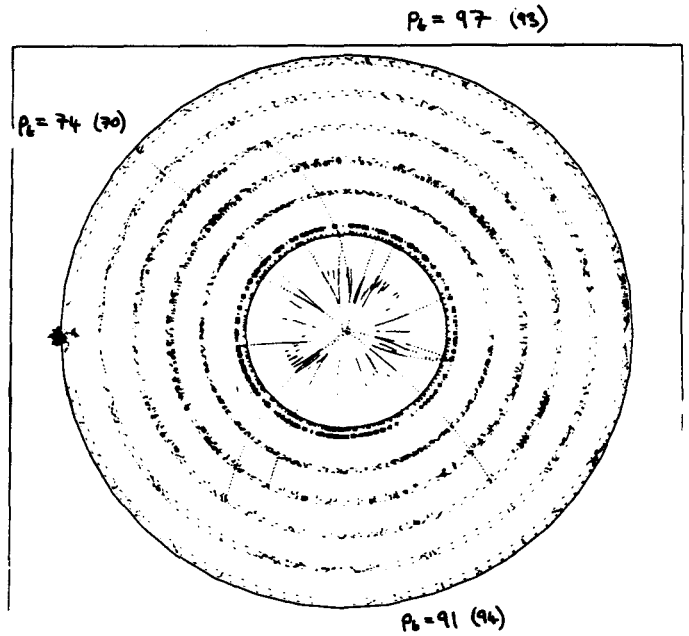


Corden

1263

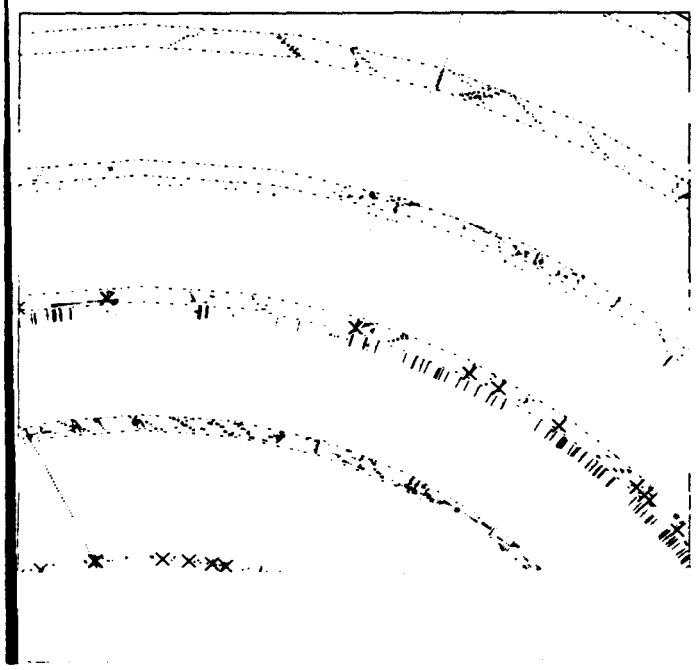
$h \to 2^\circ 2^\circ \to 4\mu$. (barrel)

4th μ is at $y = 1.8$.



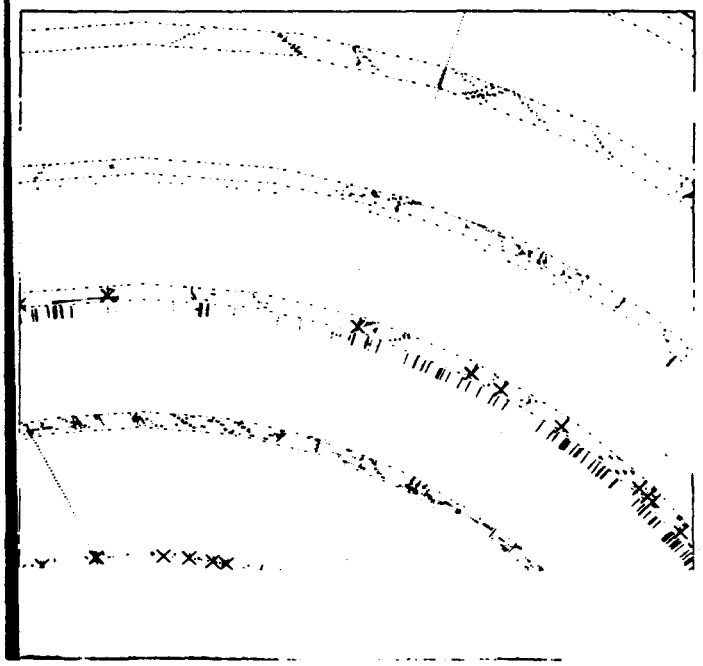
Corden

1264



Corden

1265



Tracking Efficiency

D. Coupal 8/5/91

1270

Very Preliminary

Ingredients

- Silicon digitizations, segments (& tracks)
- Hybrid " "
- Segment - linking package
- SDC Shell
- MC matching utilities*
- Missing: Straw or fiber system segments (!)

Experiences

- Shell Simulation - large & cumbersome but basically works
- ~15 minutes/event on SSC batch mach (need parallelization!)
- Difficult to debug

* MC track ⇔ recon. track if >60% of hits on recon. track come from MC track.

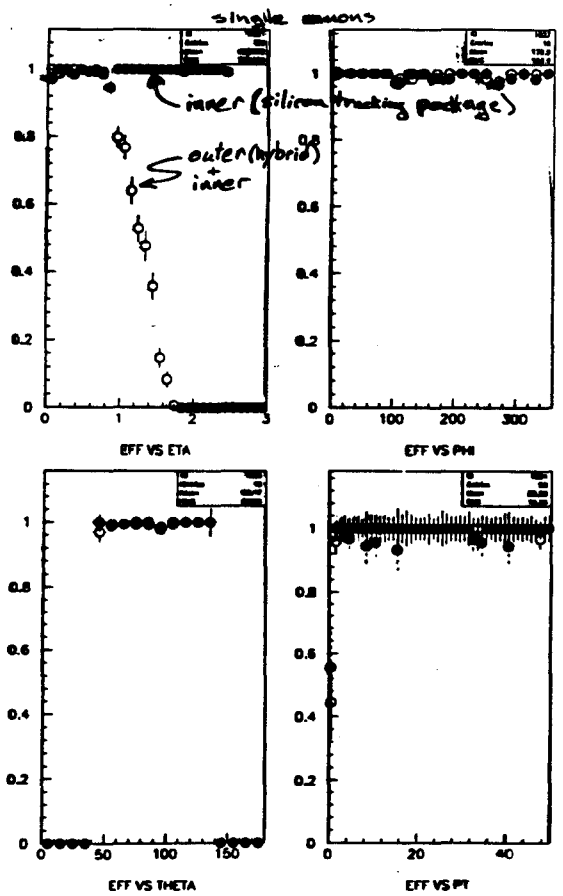
1271

USERS:[COUPAL.SDC.SHELL.NEW]UT.CAR

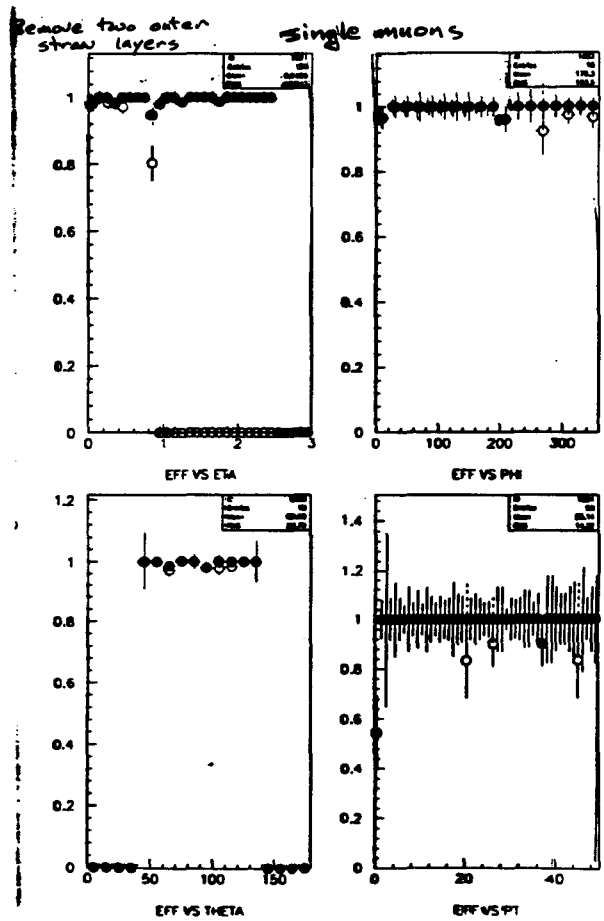
```
      SUBROUTINE UTMTAC(CMPATH,IGRUNB,UTMIT,UTMATC,NMATCH)
CA)-----------------------------------------------(begin of short description)
C  Match reconstructed tracks with Monte Carlo events
CB)-----------------------------------------------(begin of long description)
C
C     Purpose and methods : This routine loops through the reconstructed
C                 tracks in track bank CMPATH and matches them with MC
C                 tracks using the digitizations and/or a chisquare match
C                 of the parameters
C
C     Called by: (Utility routine)
C
C     Input arguments :
C        CMPATH    C     path to track bank (for example
C                                  /RECO/UTRK/UTRK/UTTK)
C        IGRUNB    I     array of bank numbers for the banks in the path
C                        up to the track bank.
C        UTCUT     R     fraction of hits required for a positive match.
C                        0.0 => no mat made
C        CHIQUT    R     maximum chisquare for track parameter match
C                        0.0 => no mat made
C        IWRIT     I     - 1 then write bank matched track to track bank
C                        - 0 don't write it
C
C
C     Output arguments:
C        UTNMT     I     number of tracks found in bank
C        NMATCH    I     number of tracks with MC match
C
```

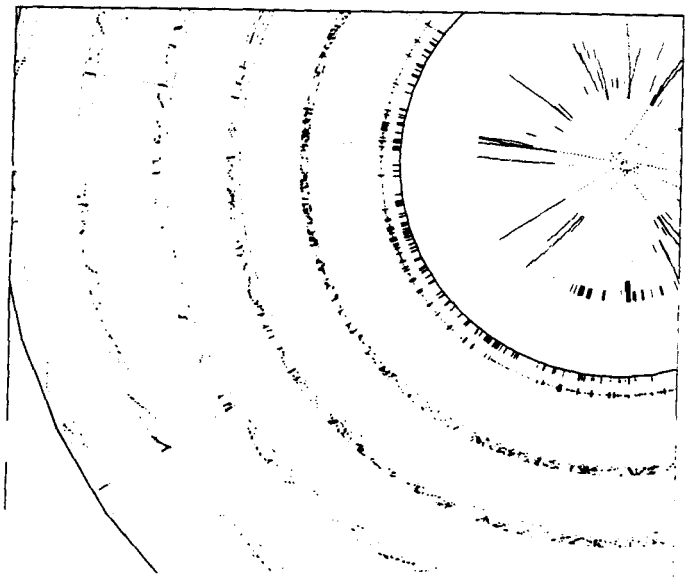
```
      SUBROUTINE UTMATC(CMPATH,IGRUNB,UTMIT,UTMATC,ITMATC,NHMATC,CHMATC)
CA)-----------------------------------------------(begin of short description)
C  Find best match of reconstructed track with Monte Carlo tracks
CB)-----------------------------------------------(begin of long description)
C
C     Purpose and methods :
C
C     Called by: (Utility routine)
C
C     Input arguments :
C        CMPATH    C     path to track bank (for example
C                                  /RECO/UTRK/UTRK/UTTK)
C        IGRUNB    I     array of bank numbers for the banks in the path
C                        up to the track bank
C
C
C     Input/Output arguments : (none)
C
C     Output arguments:
C
C        UTMIT     I     number of hits on track
C        UTMATC    I     number of tracks that matched with reco. track.
C        ITMATC(J) I     Jth MC track number that matched
C        NHMATC(J) I     number of matched hits for Jth MC track
C        CHMATC(J) R     chi**2 of match for Jth MC track
C
```

1272



1273





Nos. of superlayers, resolution

[illegible] no.	Silicon		Fiber		Straw		outer radius	$\frac{\sigma(p)}{p^2}$ (TeV)
no effect	8	15μ	2	75μ	5	61μ, 50μ	165 cm	27%
100μ	4	"	"	"	3	" "	"	32%
"	"	50μ	"	"	"	" "	"	34%
"	"	"	"	"	"	" "	125 cm	61%
"	"	15μ	"	"	"	" "	"	60%
10μ	"	50μ	"	"	"	" "	"	40%
100μ	"	15μ	0	-	0	-	40 cm	400%
0μ	"	"	"	"	"	"	"	100%
∞	1	15μ	0	-	3	50μ	165 cm	31%

acknowledgements to Steve

Analytic calculations of measurement error: summary
(Steve Linn)

- Dominant effect is outer radius of tracker.
- number of layers has very little effect.
- vertex has no effect unless resolution is at least as good as Silicon
- varying silicon resolution has no effect; (10-50) varying straw resolution does.

Effectively, the Si tracker provides a (exact) fixed point, but has insufficient lever arm for a stand-alone momentum measurement.

Occupancy Recap
(old prog.)

	inner radius	length	10^{33} all hits	10^{33} digs	approx. 10^{34} all hits	approx. 10^{34} digs
straw	65 cm	200	18%	16%	131%	43%
	97	250	9%	8%	61%	35%
	130	300	5.2%	5%	37%	25%
	163	300	2.4%	2.2%	16%	13%
fiber	134 cm	300		.7%		2.7%

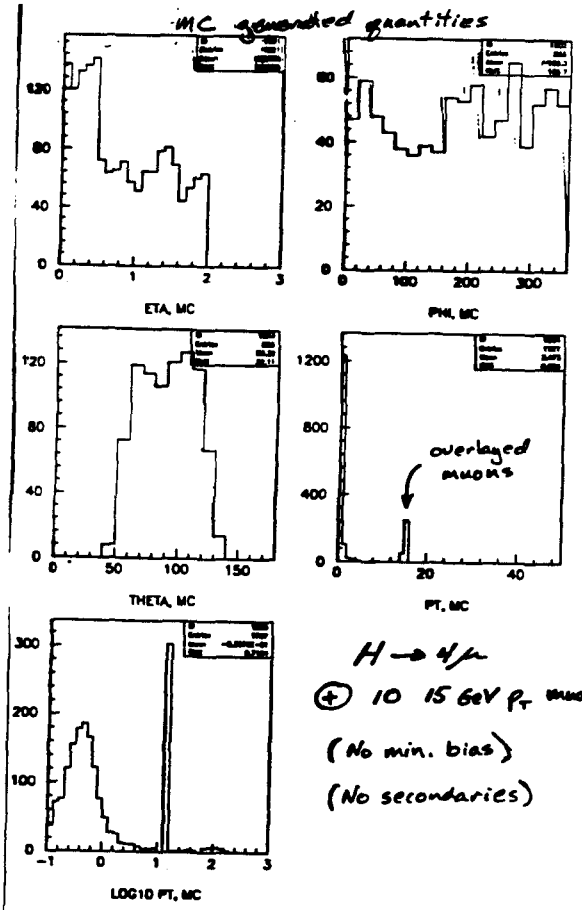
Here, 1 high p_t trigger event (μ+4cm) + minimum bias background assumed.

"Conservative" dead time assumptions, i.e. as $L \to \infty$, Occupancy $\to 0$ and all hits are lost.

MC generated quantities

Coupal

1274



$H \to 4\mu$

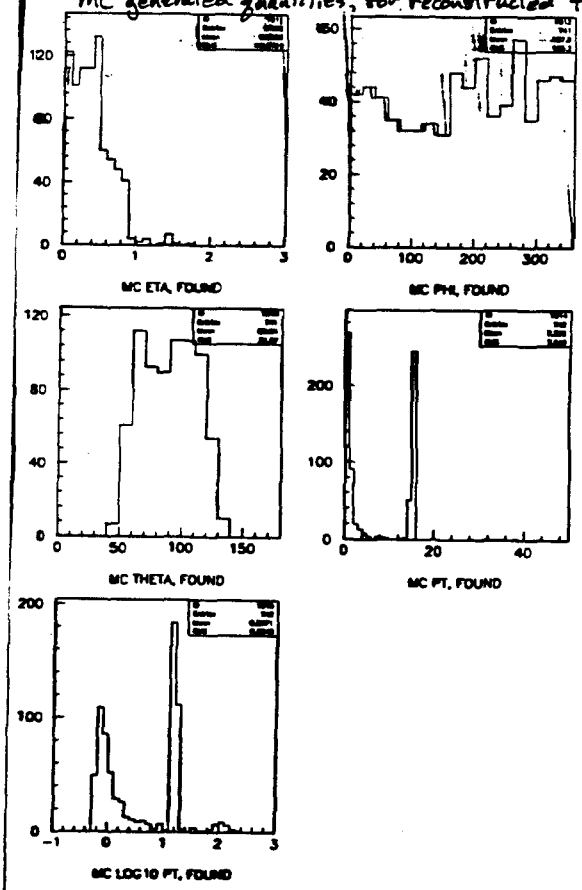
⊕ 10 15 GeV p_T muons on top

(No min. bias)

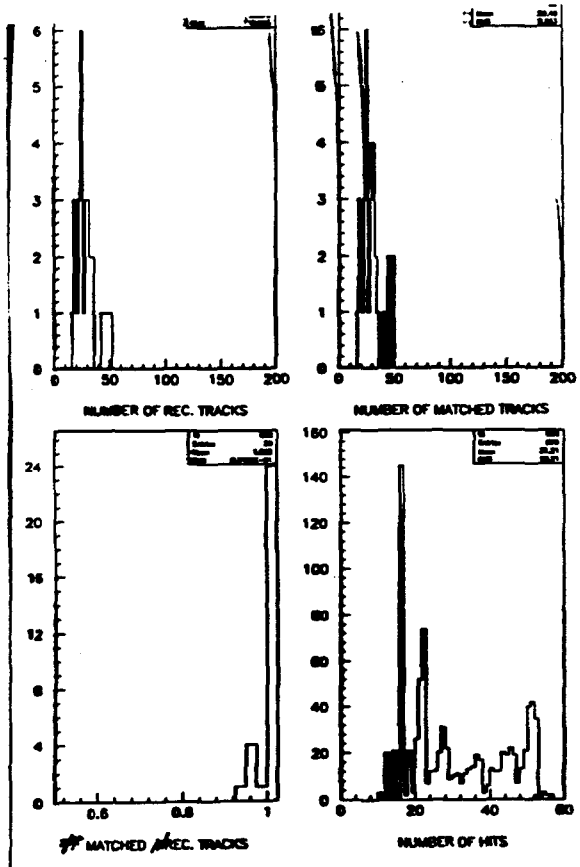
(No secondaries)

MC generated quantities, for reconstructed tracks

1275



1276



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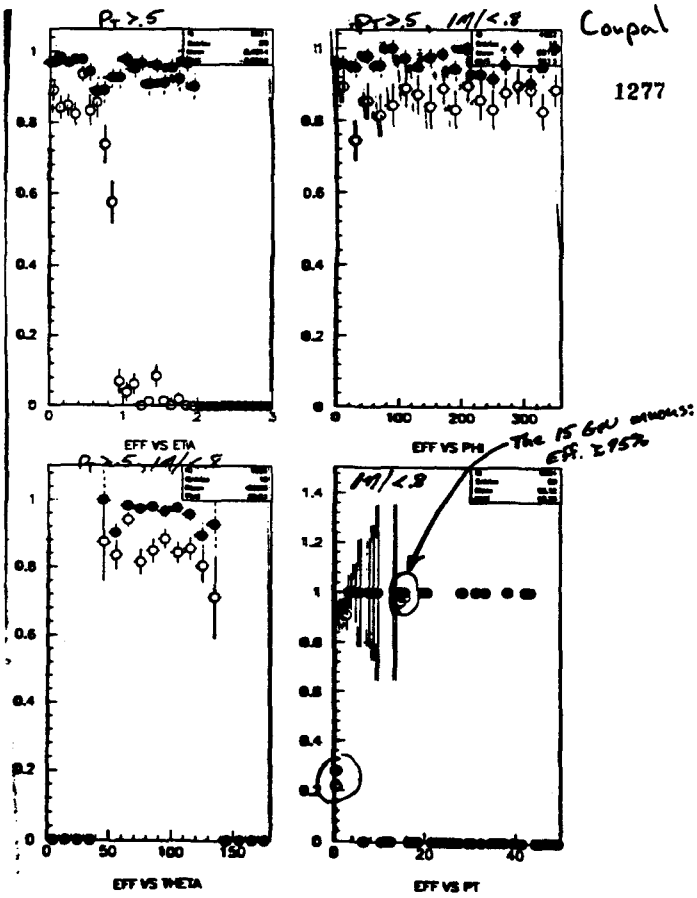
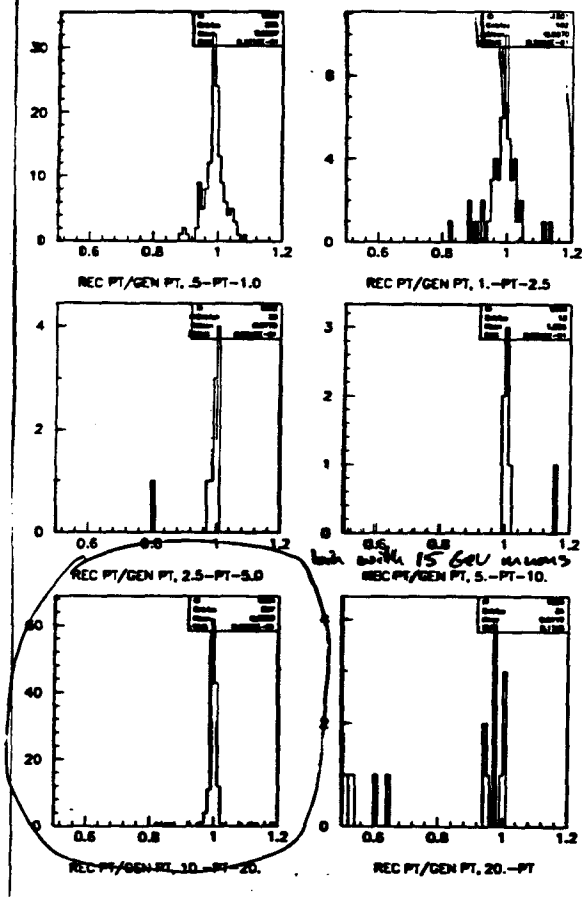
1277



Coupal

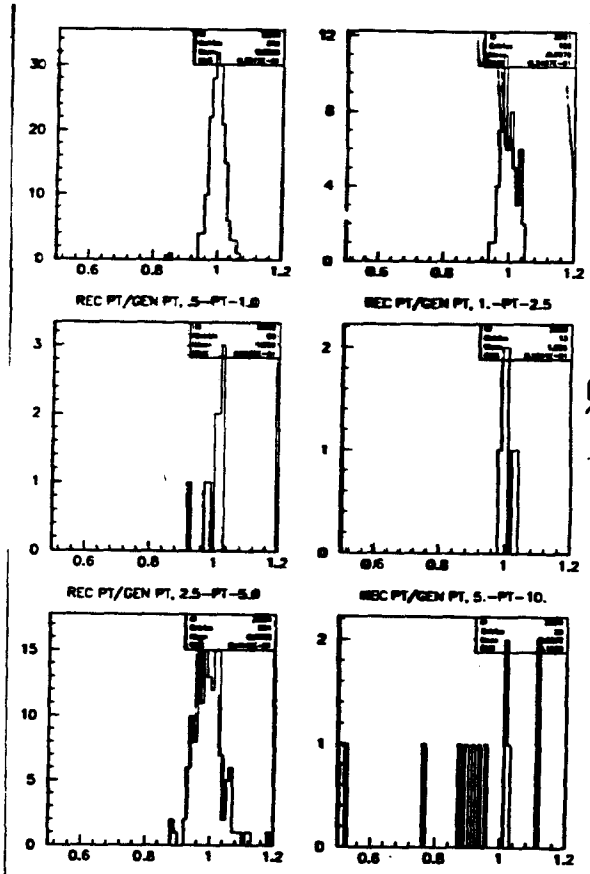
1278



P/E ($\equiv P_T$ Gen

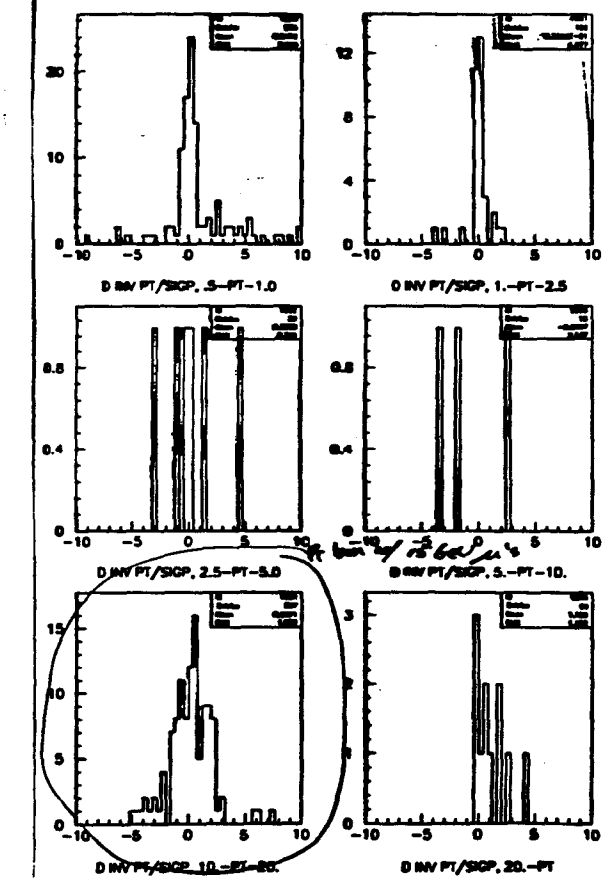
Coupal

1279



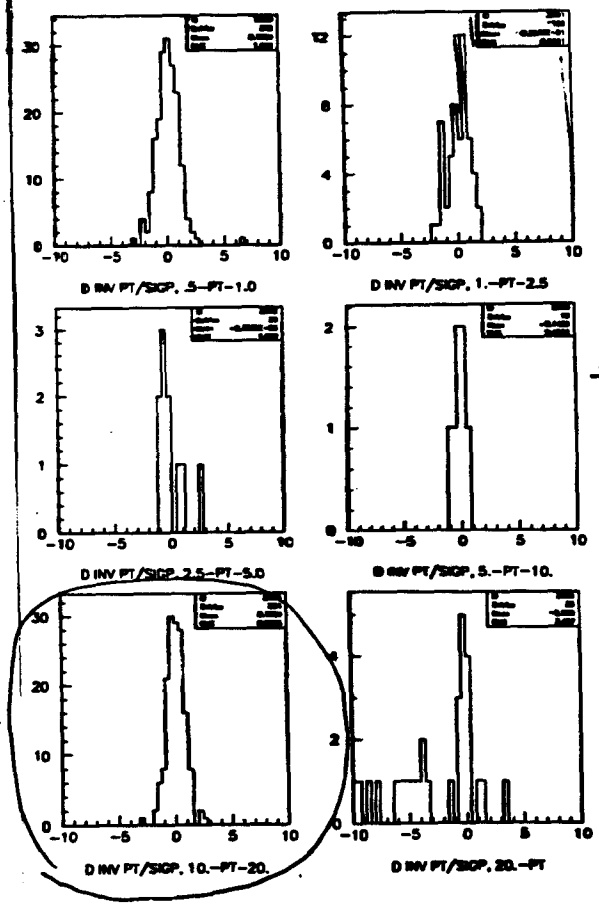
P/E / Silicon Tracking

1280



$\frac{\Delta(1/P_e)}{\sigma_{1/P_e}}$

1281



$\frac{\Delta(1/P_e)}{\sigma_{1/P_e}}$ / Silicon Track

Remove Outer Two Layers

Coupal

1282

... job still running.

Short-term future

- add min-bias, secondaries
- hybrid hybrid? (= fibers only)
  (= straws only)

Superconducting Magnet

August 5 - Monday

SDC SC Magnet Progress A. Yamamoto(KEK)

LPBautz:8/26/91

SDC SC MAGNET PROGRESS

A. YAMAMOTO

Subgroup: SC MAGNET Date: Aug 5

Speaker: A YAMAMOTO

Title: SK SC MAGNET PROGRESS

Comments: 2 copies please (1 → R Kephart)

SC MAGNET

PROGRESS ON DESIGN STUDY OF THE SDC THIN SUPERCONDUCTING SOLENOID

A. Yamamoto, Y. Doi, Y. Makida, K. Tanaka, H. Yamaoka, S. Terada and T. Kondo.

KEK, National Laboratory for High Energy Physics
Oho, 1-1, Tsukuba, Ibaraki, 305, Japan

R. Kephart, R Fast, B. Foster, D. Friends, J. Grimson, C. Grozis, J. Krebs, A. Lee, R. Stanek, A.M. Stefanik and R. Wands.

Fermilab., National Accelerator Laboratory
Batavia, IL. 60501, U.S.A.

JULY 25, 1991

*TO BE PRESENTED AT THE SDC COLLABORATION MEETING TO BE HELD AT LAWRENCE BERKELEY LABORATORY ON AUG. 5, 1991.

A PROPOSAL TO SHARE R&D WORKS FOR SOLENOID

	COIL	CRYOSTAT & EXT. SYS
	KEK	FNAL
PHASE 1	• STRONG Al STAB. COND. • COIL WINDING TECH. • BONDING AGAINST Fe	• HONEYCOMB VAC. WALL • SUPPORT FOR EM FORCE • CONSIDERATIONS ON CRYOGENICS, P/S, ···
PHASE 2	• PROTOTYPE COIL • ASSEMBLE OF COIL & CRYOSTAT	PROTOTYPE HC WALL (SUPPORT)
	TEST & DESIGN REPORT FOR RFP	

SDC SOLENOID MAGNET WORKING GROUP MEETING

August 1?, 1991

The Fermilab and KEK groups will discuss their R&D work in a series of presentations. These include:

1. Refrigerator and coil cooling scheme—Andy Stefanik
   cooldown and quench recovery, pressure drop, transfer line route, surface facilities layout
2. Chimney and control dewar—Andy Stefanik
   penetration through detector, installation, field joint
3. Materials for outer vacuum shell—Ron Fast
   SDC DR-SR,
4. Status of design of hospital vacuum shell—Ron Fast
5. Cold-mass support scheme—Jim Krebs
   Warren truss with composite members
6. Attachment of cryostat to calorimeter—Jim Krebs, Chuck Grozis
7. Electrical equipment—Ron Fast
8. Magnetization and coil protect—Bob Wands, Ang Lee
9. Safety and Quality Assurance—Bob Wands
   effect of the "new scheme", SSCL standards and requirements
10. Cost and schedule—Rich Stanek
    impact of a failure
11. Presentation for collaboration meeting—Shiro Yamamoto
12. Review of R&D work at KEK—Shiro Yamamoto
    quench calculations, placement and size of cooling tubes
13. Prototype magnet—all
    To what extent does prototype model the full-size magnet?
    Who does what? Dimensions? Interfaces? Schedule?
    Coil-cold mass
    Supports
    EM shields
    Vacuum vessel
    Chimney
    Control dewar
    Power supply, etc
    Assembly scheme
14. SDC proposal to SSCL—Shiro Yamamoto, Bob Kephart
    Who makes what?
15. Design report—Shiro Yamamoto, Bob Kephart
    Who makes what sections?
    Does SSCL contribute?

SDC THIN SOLENOID

- REQUIREMENTS

  $B \doteq 2$ TESLA

  $R_B \doteq 1.85$ m ($R_{TRACK} = 1.7$ m)

  $X \doteq 1.2\ X_0$ (AS THIN AS POSSIBLE)

- WHAT'S ARE NECESSARY NEW

  E/M : 5 kJ/kg → 7 kJ/kg

  VAC WALL : SOLID PLATE → HONEYCOMB

	ORDINAL DES.	ADV. DESIGN
E/M	5 kJ/kg	7.5 kJ/kg
VAC WALL	SOLID	HONEYCOMB
X (RAD. THICK.)	1.9	1.2
λ	0.4	0.25
REQUIRED: HIGH STR. PURE AL	$\sigma_{y,0.2} = 20$ MPa	65 MPa
HIGH kg → FAST QUENCH	$k_g/k_p < 10^{-3}$	$\lesssim 10^{-1}$
HONEYCOMB WALL	$t \approx 30$ mm	< 8 mm

Magnet Size:	
Crostat innar radius:	1.75 m
outar radius:	<2.10 m (2.05 m)
Cryostat half length:	4.0 m
Tracking Volume:	
Outer radius:	1.70 m
Axial half length:	4.0 m
Central magnetic field:	2 Tela
Transparency (η=0):	<=1.2 Xo
Operational environment:	in raturn yoke or in air

We introduced following new concepts into the SDC solenoid design.

- E/M ratio to verify lightness and transparency,
- High strength Al stabilized superconductor,
- High speed quench propagation by intoducing a concept of pure AL axicial strip quench propagator,
- Honeycomb wall in cryostat.

30	0.338	0.076	
46.5	0.522	0.118	
61.5	0.692	0.156	
	1.86	0.4	0.4

Table 4-1. Transparency of the SDC solenoid.

Element	thick. eq.	Xo	λ o
Outer Vac. Wall (Al-H/C)	8 mm	0.090	0.0203
Outer Rad. Shield	2	0.022	0.0051
Outer Support Cylinder	31	0.348	0.0787
Superconductor			
(AL stab)	41.0	0.461	0.1041
(Nb.Ti/Cu)	2.8	0.175	0.0161
(CFRP)	1.0	0.005	0.0002
(Al Strip)	1.0	0.011	0.0025
Inner Rad. Shield	2.0	0.022	0.0051
Inner Vac. Wall	6.0	0.067	0.0152
Super-insulation	2.0	0.007	0.0032
		1.208	0.2505

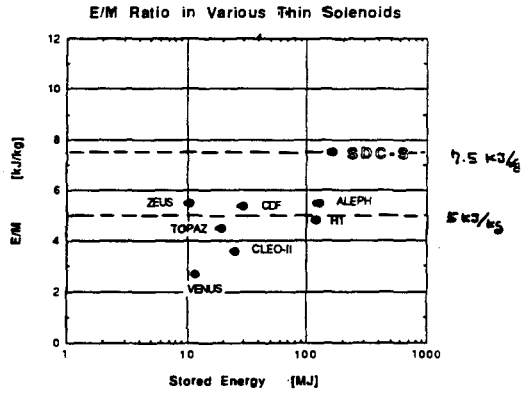


FIG. 2-3

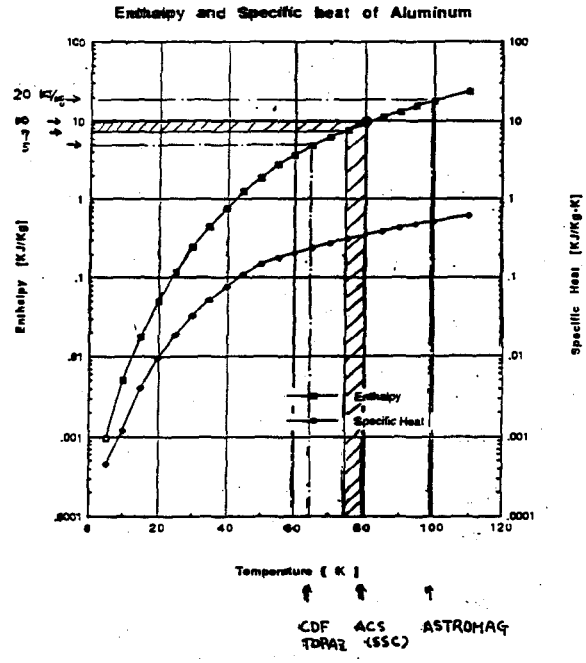


FIG. 2-2

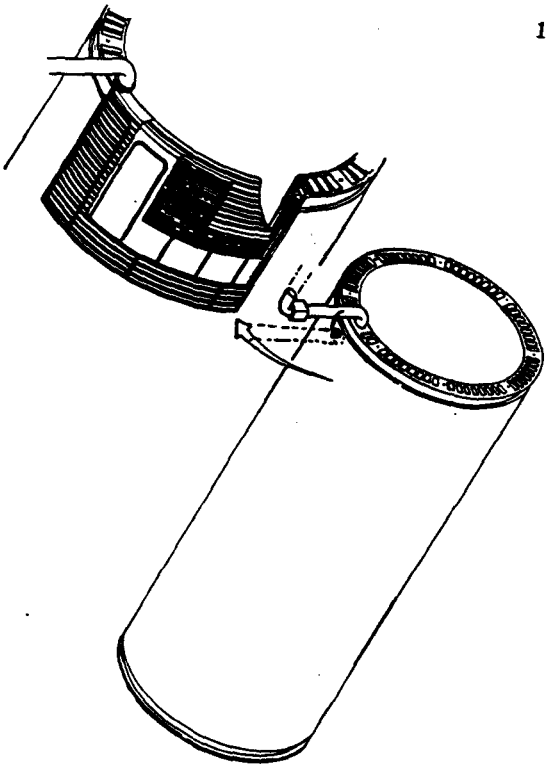
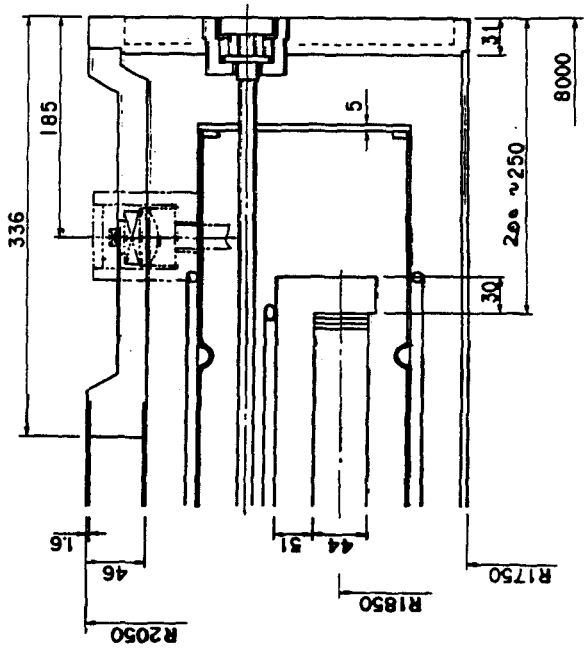


FIG. 1-3



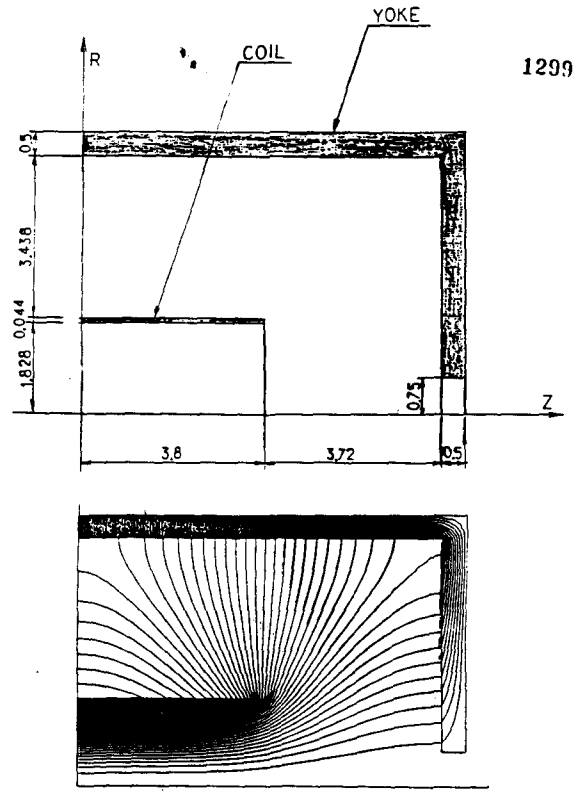
CROSS-SECTION OF THE END OF THE SDC SOLENOID

FIG. 2-1

Table 2-1. Main parameters of the SDC thin superconducting solenoid.

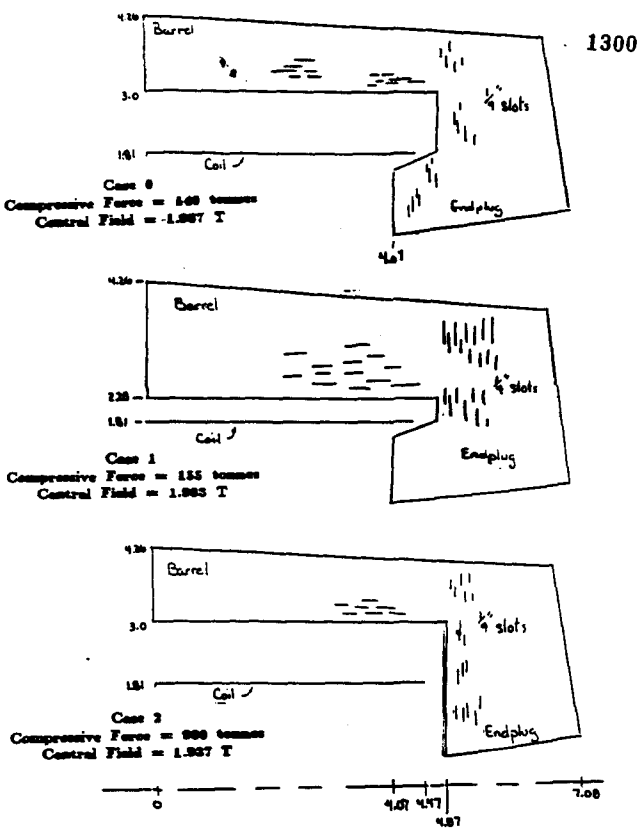
		in air	in iron
Dimensions:			
Cryostat	Inner Radius	1.75 m	
	Outer Radius	2.10 m	
	Half Length	**4.0 m**	
Coil	Effective Radius	1.85 m	
	Half Length	3.8 m	
	Coil + OSC	44 + 31mm	
Tracking	Aperture Radius	1.7 m	
	Half Length	4.0 m	
Transperency	Radiation Thickness	1.2 Xo	
	Interaction Length	0.25 λo	
Electrical Parameters			
Central Field		2.0 T	(2.1 (-2.2) T)
Int. B.dl	(η=0)	3.4 T.m	3.6 T.m
	(η=1.0)	T.m	
	(η=1.5)	T.m	
Nominal Current		8,000 A	8,000 A
Inductance		4.2 H	4.6
Stored Energy		133 MJ	160 MJ
E/M		7.4 kJ/kg	8.9 kJ/kg
Mechanical Parameters			
Effective Cold Mass		18 tons	
Total Weight		23 tons	
Radial Magnetic Pressure (@z=0)		1.6 MN/m2	
Axial Total Compressive Force		18 MN	
Superconductor			
Nb.Ti/Cu/Al ratio		0.5/0.5/29	
Overall conductor size		4.37 x 4.4 mm2	
Load Line Ratio (@ 2.2T, 4.2K)		50 %	
RRR of pure Al (@ B=0T)		600	
Yield Strength of pure Al		65 MPa	

1298



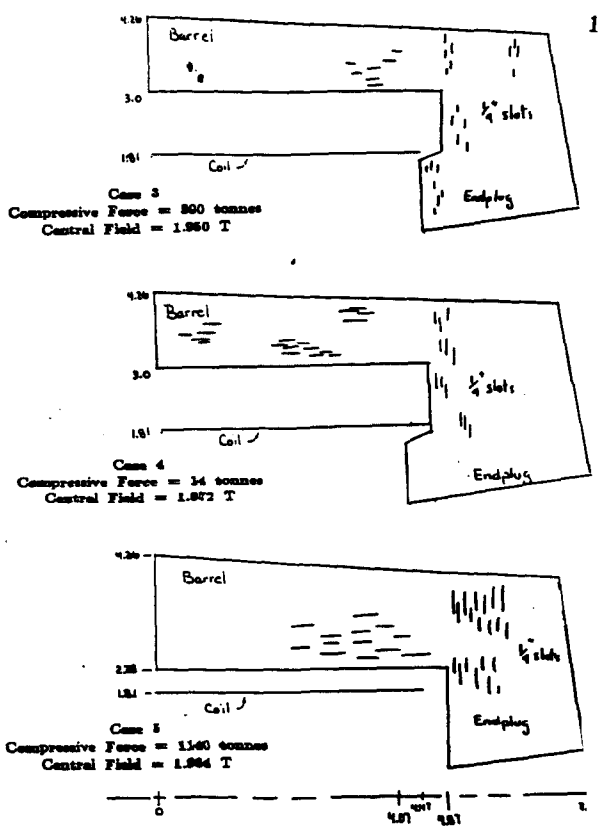
1299

FIG. 3-1 COMPUTATION MODEL AND MAGNETIC FLUX LINE COMPUTED WITH POISSON



1300

FIG. 3-2-(a) Axial Compressive Forces on Coil



1301

FIG. 3-2-(b)

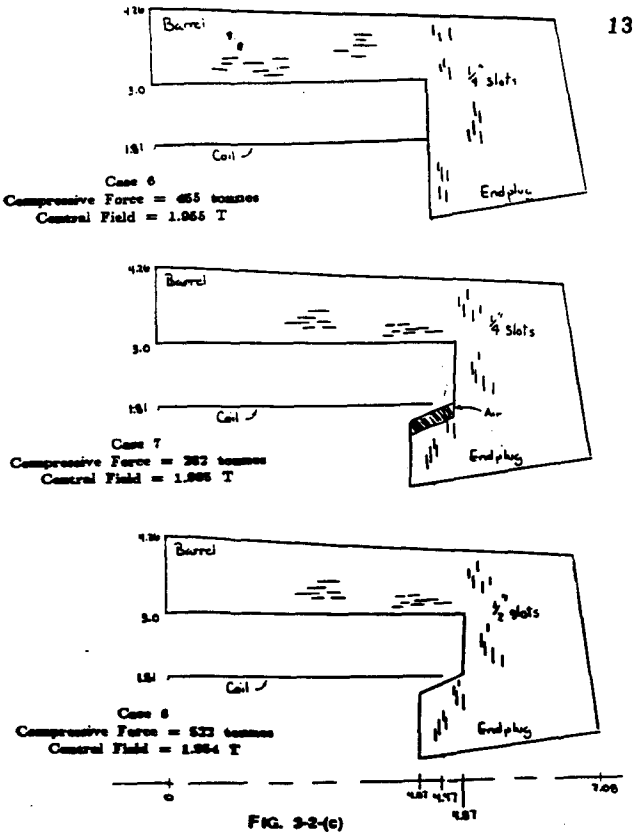


FIG. 3-2-(c)

	IN AIR	IN IRON (CASE 2)
B	2.0	2.0
F_R	16 atm	16 atm
F_Z	1770 tons	~ 1000 tons
$\Delta F_R / R$	~0	~0
$\Delta F_Z / Z$	≲ 5	~ 20 ton/
CONFIGURATION		EM (Pb) + HC (Pb)*
		* EXAMPLE

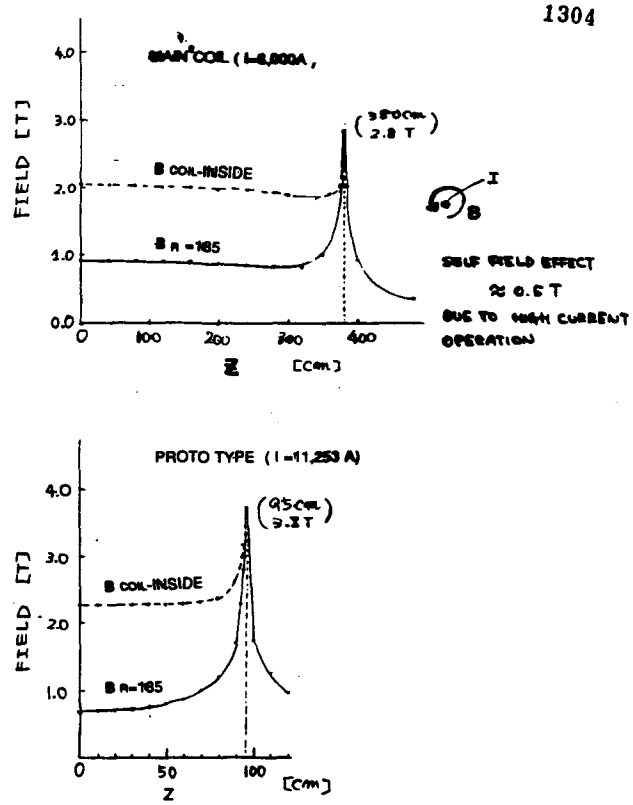
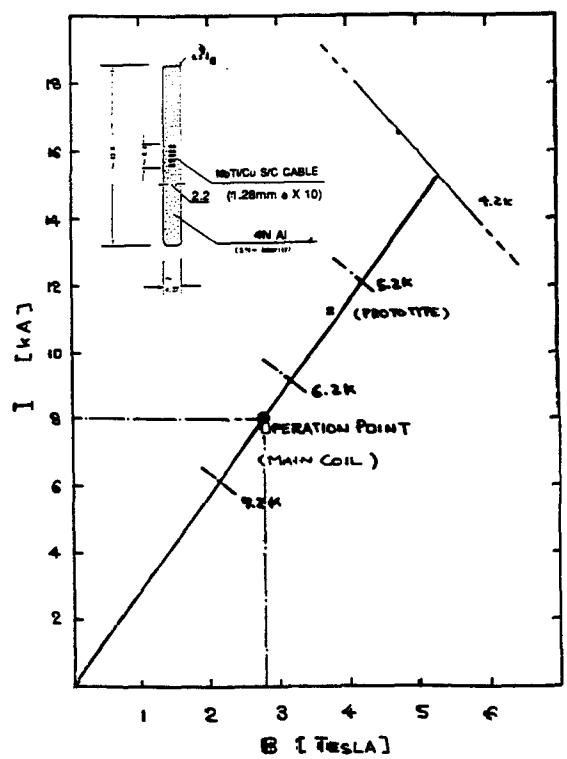


FIG. 3-4



I-B CHARACTERISTICS OF THE SDC SUPERCONDUCTOR

FIG. 3-5

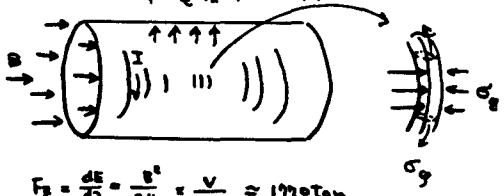
MECHANICAL STABILITY

- DESIGN CONCEPT
  - ELASTIC DESIGN ($\sigma < 6.5\ kgf/mm^2$)
  - STRAIN LESS THAN 0.1%
- IMPORTANT ITEMS TO BE CONSIDERED
  - COMBINED STRESS OF F_R AND F_z

$$\sigma_{y_{0.2}} > 2\tau = (\underset{\text{TENSION}}{\sigma_\varphi} + \underset{\text{COMPRESSION}}{\sigma_z}) \simeq 40\,MPa + 20\,MPa = 60\,MPa$$

$$P_R = \frac{B^2}{2\mu_0} = 16\ atm$$

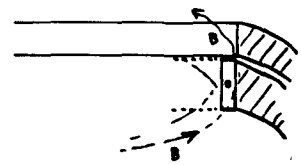
$$\sigma_\varphi = \frac{R}{t} P_R \simeq 40\ MPa$$



$$F_z = \frac{dE}{dz} = \frac{B^2}{2\mu_0} \times \frac{V}{z_{coil}} \simeq 1770\ ton$$

$$\sigma_z = \frac{F_z}{2\pi R t} \simeq 20\ MPa$$

- SHEAR STRESS AT BOUNDARY B/W COIL AND OUTER SUPPORT CYLINDER



$$f_z = B_r \times I \qquad [N/m]$$

$$\leq 2\tau \times 8000A$$

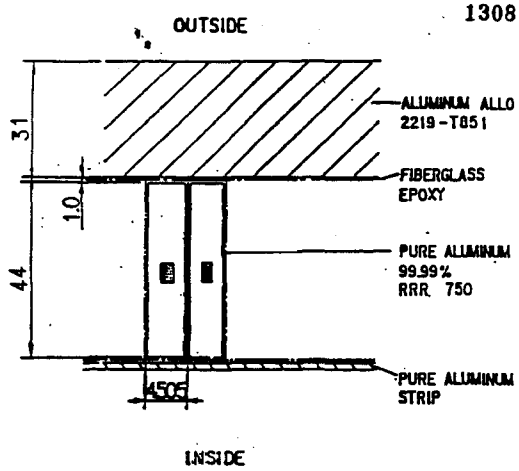
$$= 16{,}000\ N/m$$

$$\sigma_{SH} \leq f_z / w_z$$

$$\leq \frac{16000\ N}{0.0045\ m}\ A$$

$$\leq 3.6\ MPa \Leftarrow \ll 18\ MPa$$

(measured)



No.		σ (kgf/mm²) R	θ	Z	ν (GPa/GPa)
1	Al2219	8800	8300	8300	0.34
2	GFRP	3220	3650	3450	0.33
3	PURE Al	7000	8000	8000	0.34
4	NbTi/Cu	–	–	–	–

FIG. 5-1 CROSS SECTION OF THE COIL AND PROPERTIES OF EACH ELEMENT

Mechanical characteristics of the material.

Element		Conducto	Insulatio	Cylinder
Material		3N8up-Al	GFRP(GKG)	Al-5083
Mechanical Process		10% Red.		
Heat Process		130c(15h		
Young's Modulus (@RT)	[GPa]	70,000	34,500	70,000
(@77K)	[GPa]	70,000	34,500	75,000
Ultimate Strength (@RT)	[MPa]			
(@77K)	[MPa]			
0.2% Yield Str. (@RT)	[MPa]	49		141
(@77K)	[MPa]	65		
Bonding Shear str. (@RT)	[MPa]		>20	
(77K)	[MPa]		>20	
RRR)		626		
Allow. stress (@<77K	[MPa]	66	100	100

Plans to consider [illegible] stress in the coil

1310

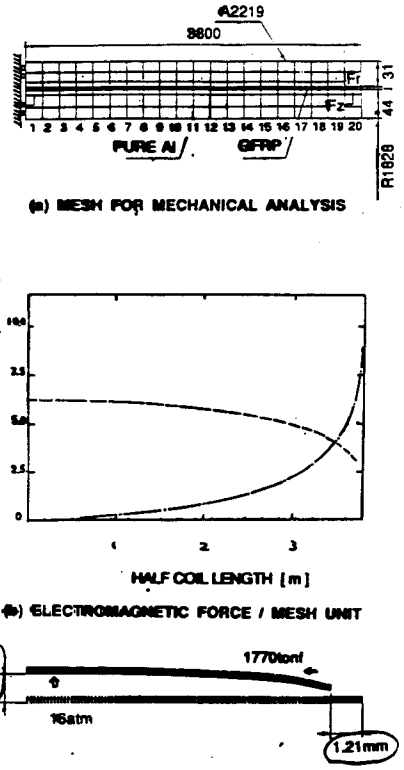
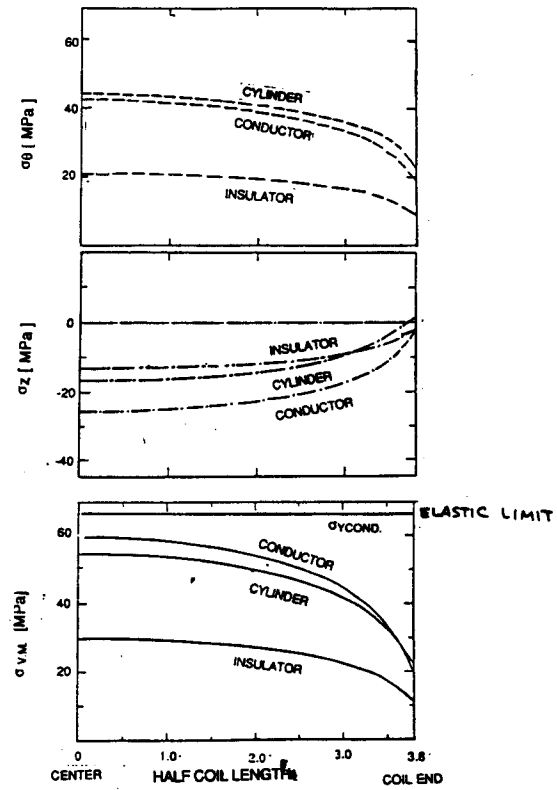
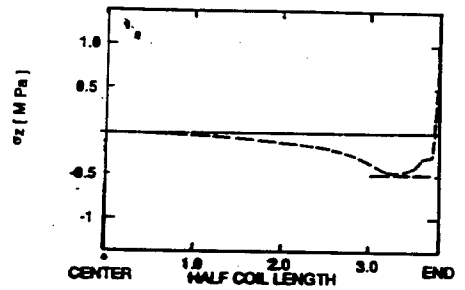


FIG. 5-2 MECHANICAL DEFORMATION OF THE SDC MAIN COIL DUE TO COMBINED HOOP AND AXIAL ELECTROMAGNETIC FORCE

1311

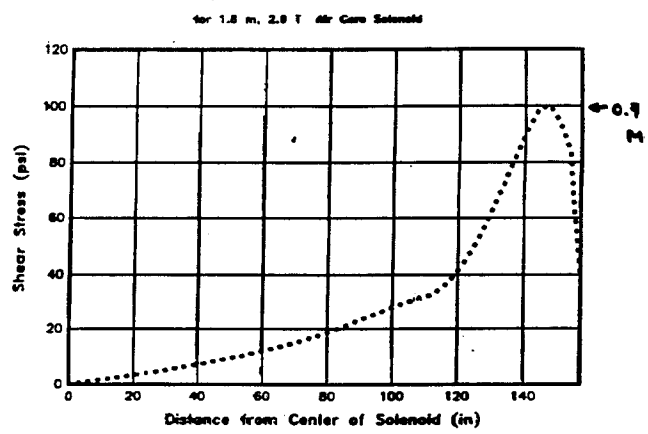


1312



$\sigma_z \ll 18$ MPa
(0.5 MPa)

1313



COMPUTED BY B. WANDS (FNAL)

FIG. 5-3 (C...., SHEAR STRESS AT BONDING B/W COIL AND SUPPORT CYLINDER

Shear Stress between Conductor and Support Cylinder

FIG. 5-4

1314

Table 5-2. Results of stress analysis.

		El. Limit ($\sigma_{0.2}$)	Anal. Cal.	FEA
Conductor	pure Al (3N8)	66 MPa	59 MPa	59 MPa
Insulation	GFRP/ KGEPP	>100 MPa	30	30
Cylinder	A-5083	169 MPa	59 MPa	55
Cyl. Bondin	Epoxy	(18 x 1/3)	< 4	< 1

1315

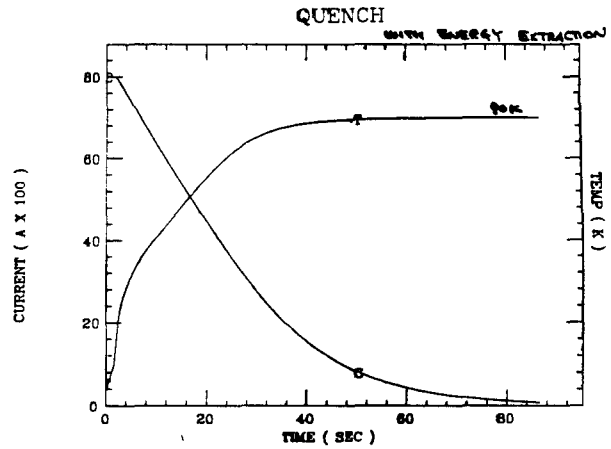


FIG. 6-1

1316

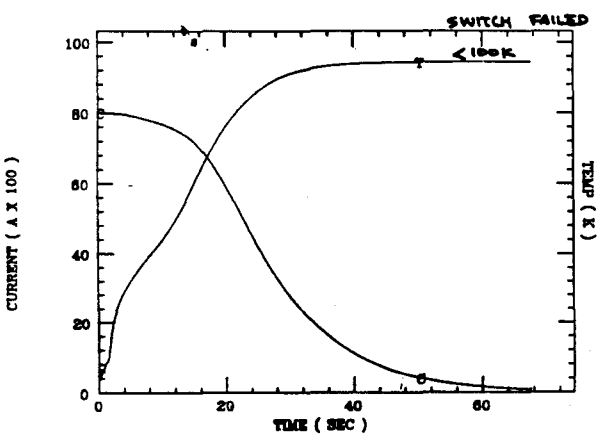


FIG. 6-3

1317

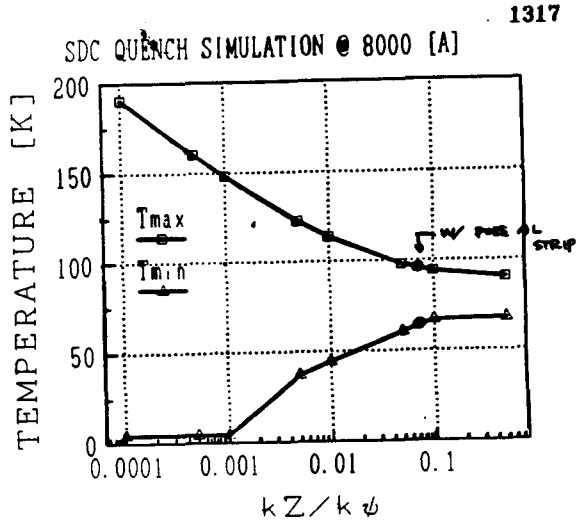
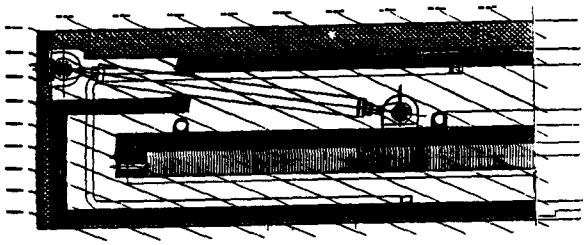


FIG. 6-4

1318



WARREN TRUSS SUPPORT ON NEAR END PROVIDES AXIAL AND RADIAL STIFFNESS

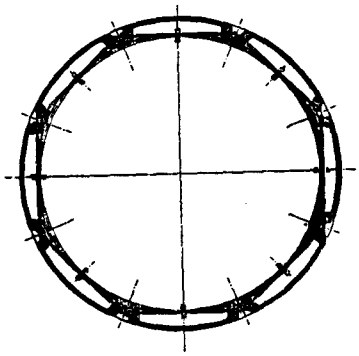


FIG. 7-1 SUPPORT SYSTEM ON FAR END PROVIDES RADIAL STIFFNESS ONLY

1319

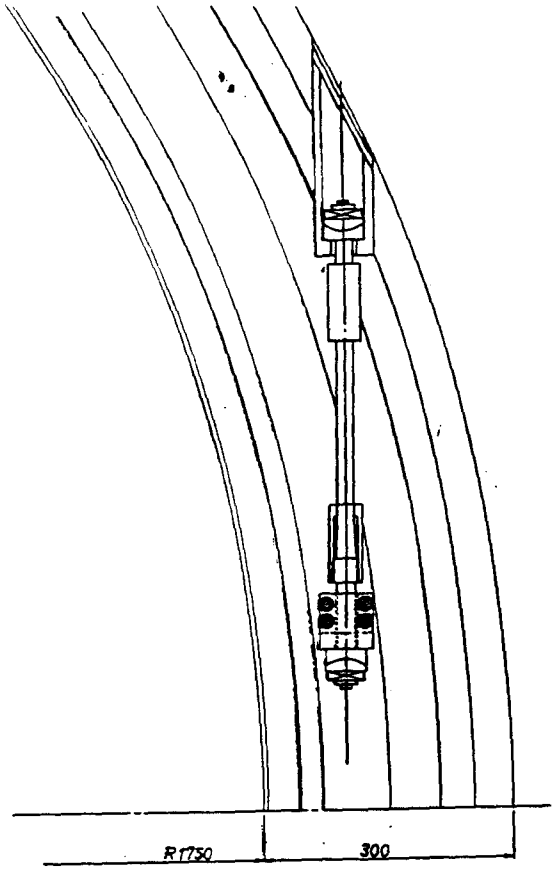
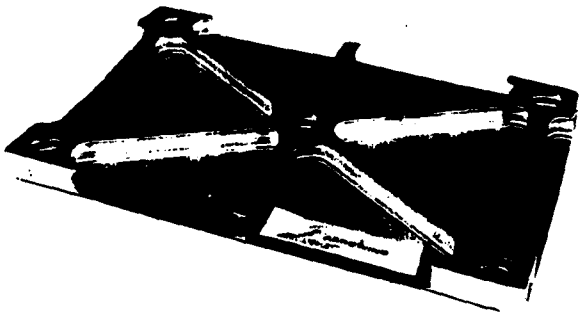
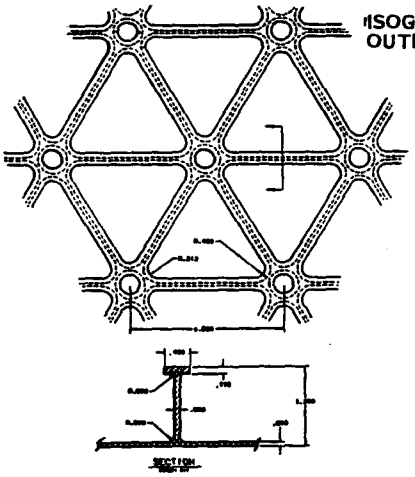


FIG. 7-2 A COIL SUPPORT STRUCTURE IN ϕ DIRECTION

1320

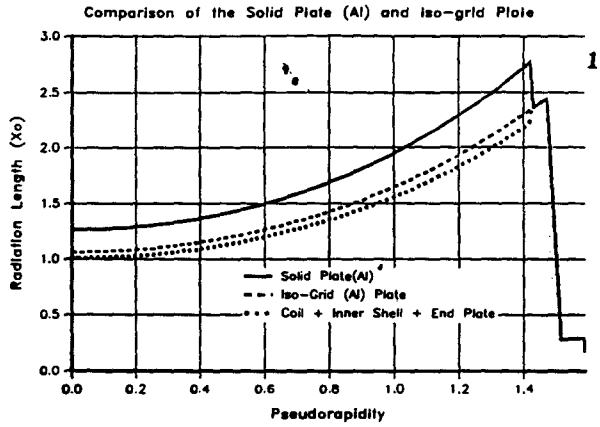




ISOGRID FOR OUTER VACUUM SHELL

FIG. 7-3

1321



Radiation Length V.S. the Pseudorapidity

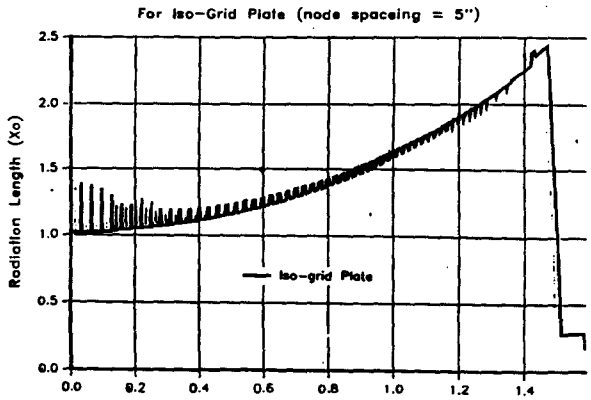
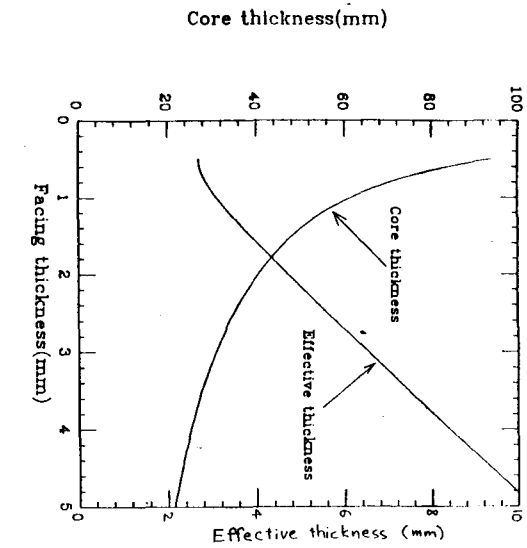


FIG. 7-4



- CYLINDER SIZE : φ4.1m X 8m
- P COLLAPSE : 2 atm
- CORE : SIZE ⬡ S/16 HEX. 1mil thick
  A5052
  DENSITY 0.05gr/cm³

CHARACTERISTICS OF AL-HONEYCOMB-OUTER VAC. WALL

FIG. 7-5

Table 7-1. Comparison of Isogrid and Honeycomb configuration.

	Isogrid-2219T851	Honeycomb
Physical thickness	27.94 mm (1.1")	50 mm
Effective thckness	5.41 mm (0.21")	4.0 mm
Equiv. thick. in solid plate	26 mm	26 mm
Weight Reduction Ratio	4.8	6.5
Fabrication techinique	Machining/weld.	Weld/Epoxy Bonding
Leak tight Joint	Complete Welding	Welding inside wall
Reliability	better	modest
Uniformity	modest	better

*Design base:

Buckling external pressure: 2atm
Outer Radius : 2.05 m
Half Length : 3.8 m

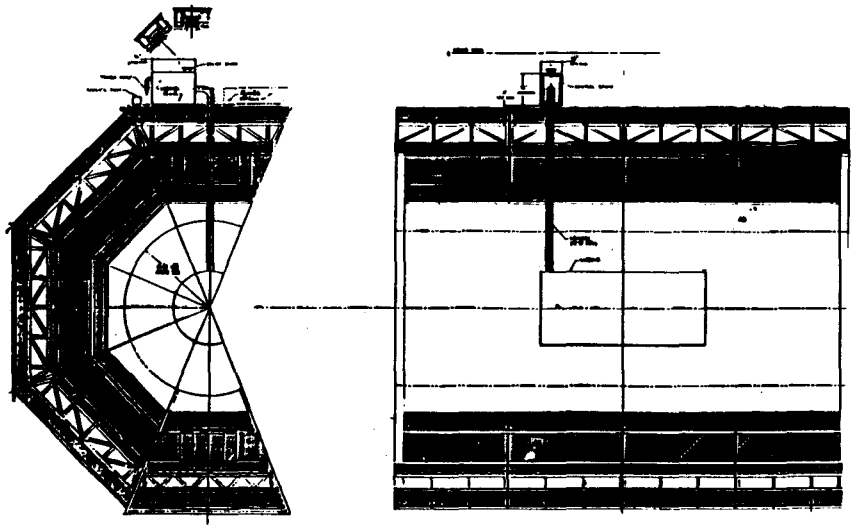


FIG. 7-6 CRYO CHIMNEY THROUGH DETECTOR--ROUTE A

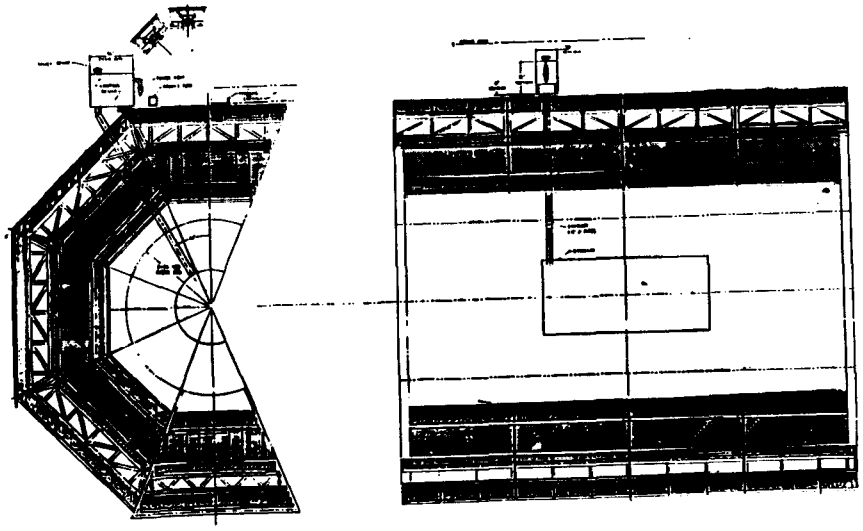
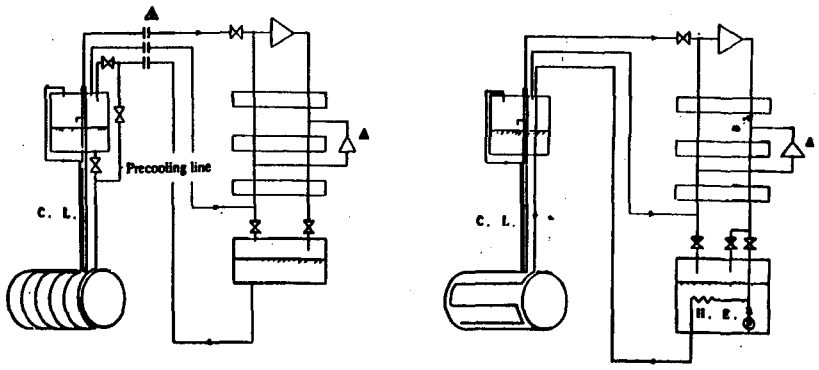


FIG. 7-7 CRYO CHIMNEY THROUGH DETECTOR--ROUTE B



ACS Cooling Flow

FIG. 8-1

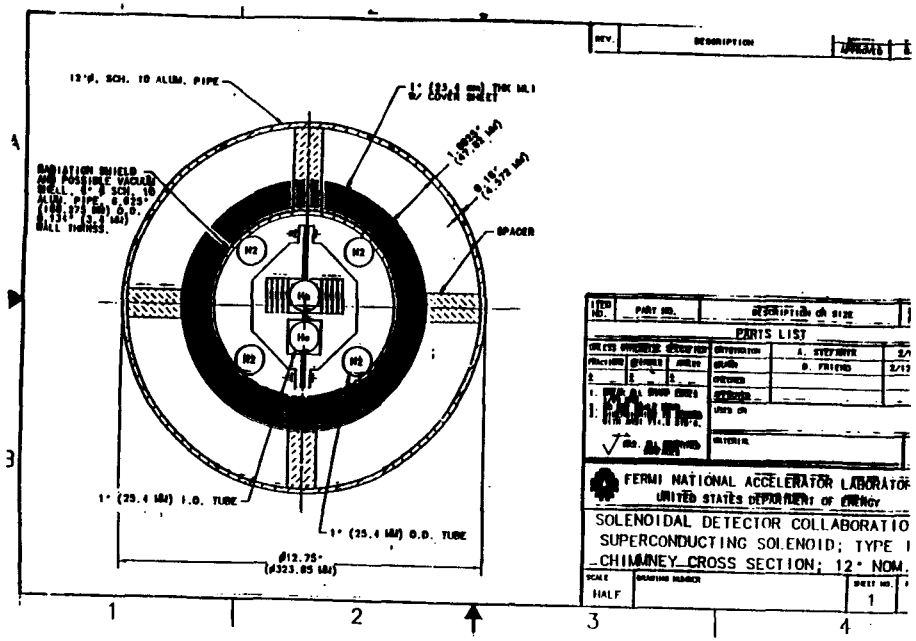


FIG. 7-8

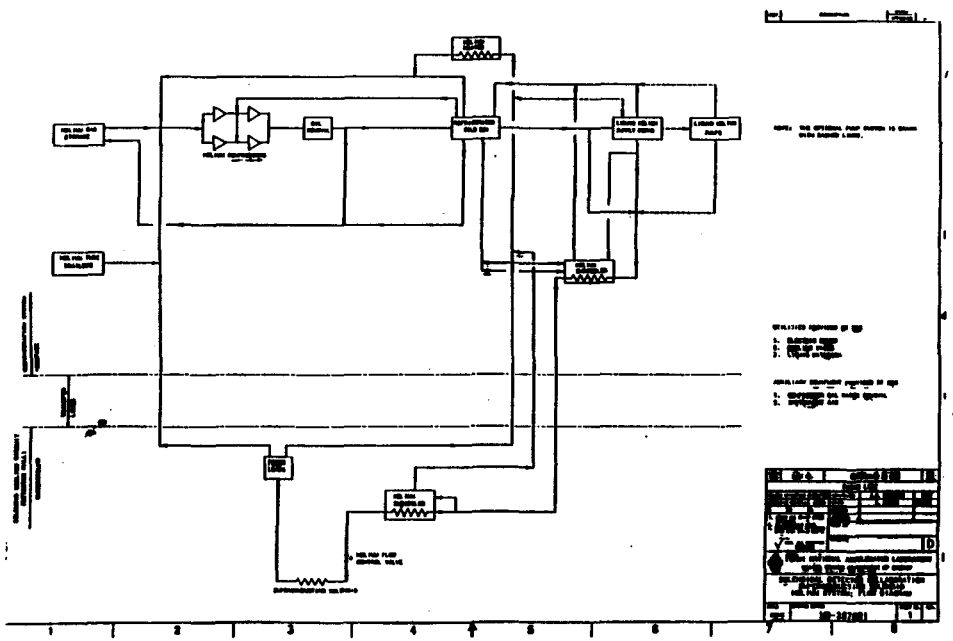
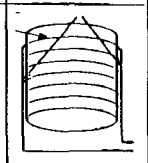
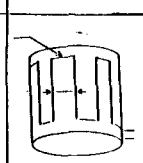


FIG. 8-2 POSSIBLE FLOW SCHEMATIC OF HELIUM SYSTEM

8. COOLING AND CRYOGENICS

We are evaluating two options of a thermosiphon using gravitational pumping technique and (ii) original forced flow two phase helium to circulate liquid helium to cool down the magnet. A schematic diagram and technical comparisons are given as follows (Table 8-1):

Table 8-1. Comparison of thermosiphone with Force 2φ He.

	Thermosiphone	Forced 2φ Flow
Diagram		
Cooling Pass	Short & Parallel	Long and Single Pass
Configuration	Complex Larger space	Simple Smaller space
Conductance	Very high	Small or modest
Cooling Perform. Pre-cooling Delta. T Time period Instability	smaller shorter possible	larger longer less
Steady Operation Stability	Higher	Lower
Operation	Stable	Simple

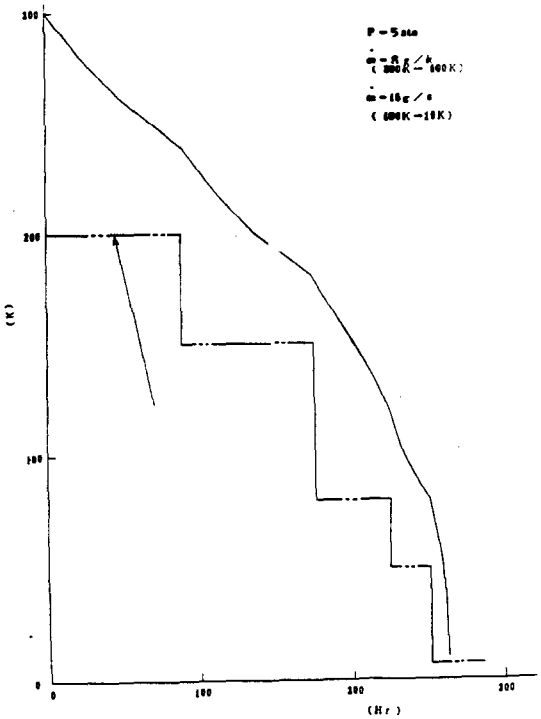


FIG. 8-3

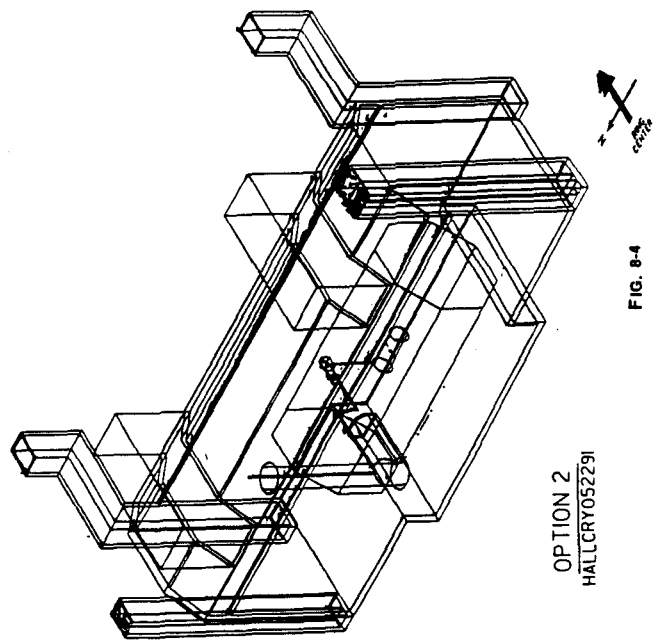


FIG. 8-4

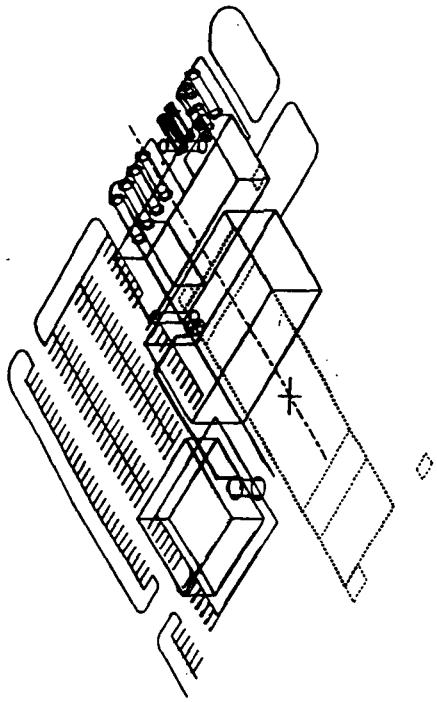


FIG. 8-5

TECHNICAL PLAN FOR THE

SDC SOLENOID R&D

- REQUIREMENTS
  - B_c 2 TESLA
  - SIZE 3.9$^{\phi}$ x 7.6$^{L}_{M}$ (3.4$^{\phi}$ x 9.0^{L} FOR TRACK)
  - TRANSPERENCY ≤ 1.2 X_0
  - FEATURES
    - HIGH FIELD
    - POSSIBLE OPERATION IN AIR (LARGE F_E)

- R & D
  - PHASE 1 (~1 year)
    - ENGINEERING DESIGN
    - BASIC R&D
  - PHASE 2 (1 ~ 2 years)
    - PROTOTYPE MAGNET

      FULL ϕ_{IA} x 1/4 LENGTH (PREFERED)

      (3.9 m$^{\phi}$ x 1.9 m^{L})

1. DEVELOPMENT OF SUPERCONDUCTOR

· REQUIREMENTS FOR PURE Al

$\sigma_{0.2} \geq 6$ kgf/mm² (77K), ≥ 4.5 kgf/mm² (300K)

RRR ≥ 500 ($\rho_{300K}/\rho_{4.2K}$)

SIZE $\approx 4.4 \times 44$ mm²

· PROGRESS

$\sigma_{0.2} = (6.5$ kgf/mm²$)$, 4.8 kgf/mm²
[77K] [300K]

RRR = 626

after heat treatment of
130°C × 15h

PURITY 5N Al + 200 ppm · X

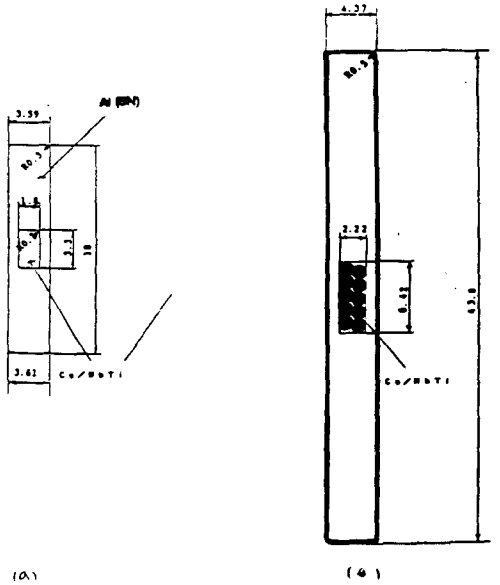


FIG. 9-1 CROSS SECTIONS OF (a) TOPAZ AND (b) SDC SUPERCONDUCTOR

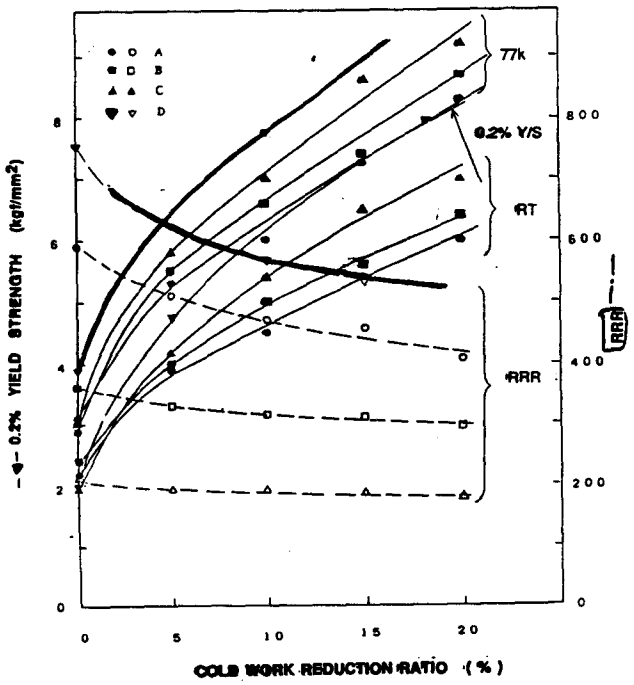


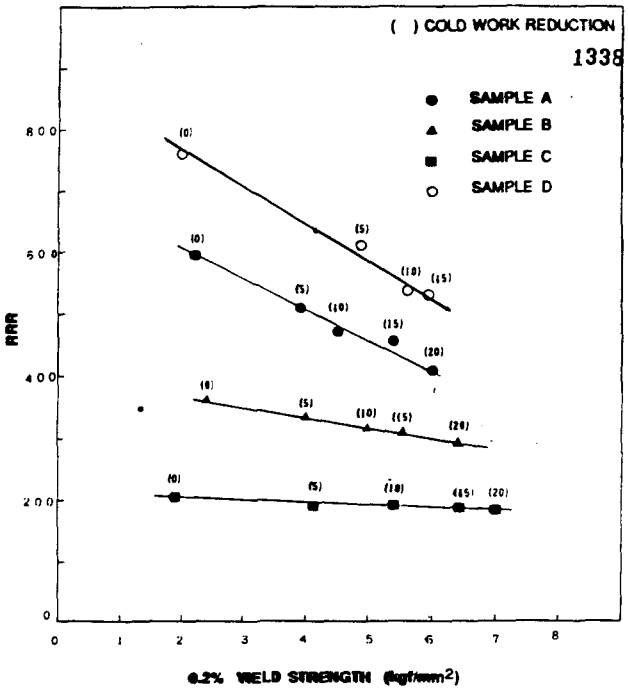
FIG. 9-3 YIELD STRENGTH & RRR v.s. REDUCTION

図1.12 SDC用アルミ安定化銅伝導線断面

CROSS SECTION OF THE SDC SUPERCONDUCTOR

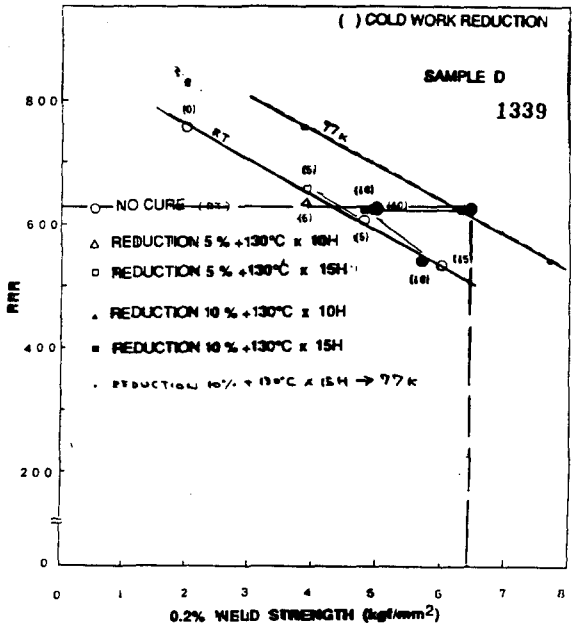
図1.13 SDC用アルミ安定化銅伝導線断面拡大

ENLARGED NbTi/Cu CABLE



RRR v.s. 0.2% Y/S

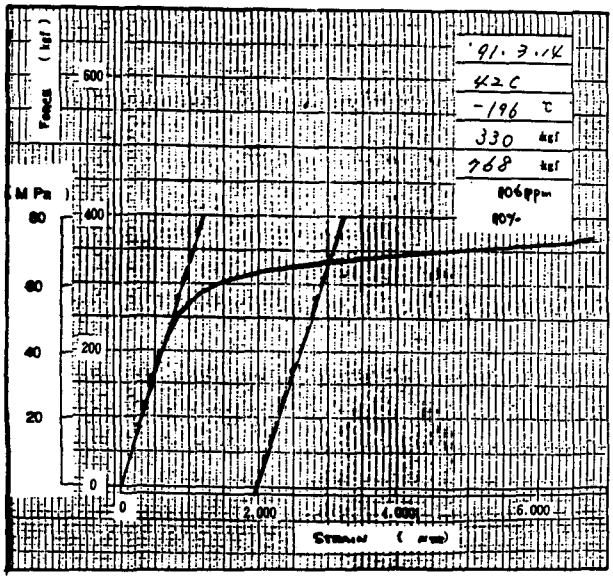
FIG. 9-4



RRR v.s. Y/S in SAMPLE D

FIG. 9-5

1340



A STRESS- STRAIN CURVE OF HIGH STRENGTH PURE Al (4N)

FIG. 9-6

1341

SUMMARY OF HIGH STRENGTH AL STABILIZER

	σ (0.2)	RRR
1. 5N-AL + X (200ppm) ...> 3N8up	2.0 kgf/mm2	758
2. Cold Work (reduction)...> 10 %	5.7	542
3. winding and curing ...> 130°C, 15h	4.8	626
4. Cool-down to ...> <77 K	6.5	626

1342

2. COIL WINDING R&D

1) DEVELOPMENT OF INNER WINDING MACHINE.

- TEST WINDING IN PROGRESS

COIL DIA. ···	3.85 m$^{\phi}$
COIL LENGTH ··	0.2 m.
CONDUCTOR SIZE ···	4.4 x 44 mm^2

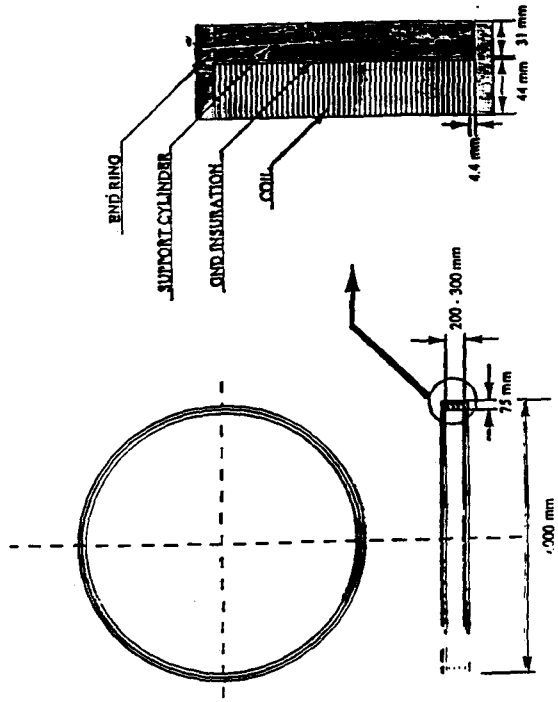
2) BONDING TEST W/ FULL SIZE DUMMY CONDUCTOR

REQUIREMENT ···	$\sigma'_{SH} \geq 1.5$ kgf/mm^2
PROGRESS ···	$\sigma_{SH} \geq 1.8$ kgf/mm^2

· ELECTRICAL TEST OF TURN-TO-TURN INS (KGSM)

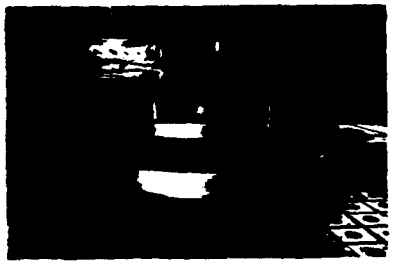
⇒ 13 kV (B.D)

1343



MODEL COIL WINDING IN PROGRESS

1344



3 サポートシリンダ

SUPPORT CYLINDER

3 巻線機

WINDING MACHINE

3 巻線機

WINDING MACHINE

1345

4 絶縁チューピング

TURN-TO-TURN INSULATION

5 巻線

WINDING

4 仮止治具

TEMPORAL FIXTURE

1346

7
導体溶接部

CONDUCTOR
WELDING · JOINT

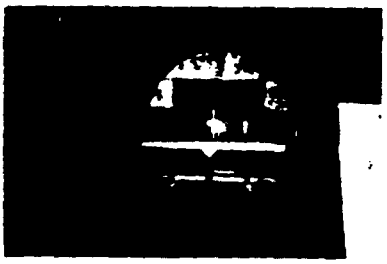
8
溶接上テーピング

INSULATION AFTER
WELDING JOINT

9
プレス治具

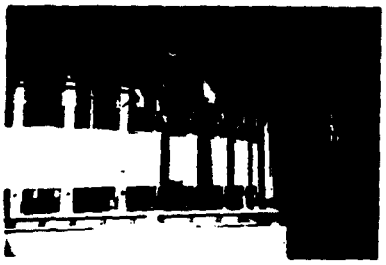
CURE · FIXTURE

1347



10
ボートクレーブで
プレスキュア

CURE IN
AUTO CRAVE



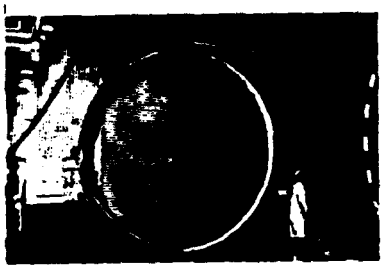
11
巻し線の

ADDITIONAL
PRESSING AT
60 K

12
界上内部

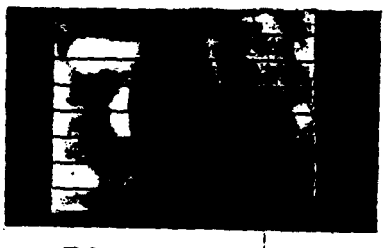
LOOK INSIDE

1348



WINDING & CURING COMPLETED

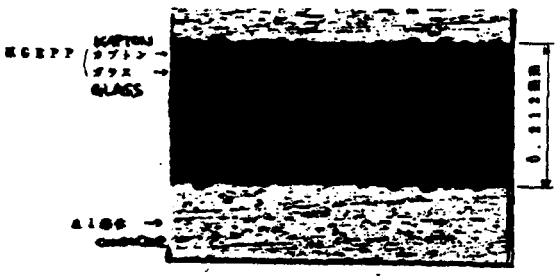
1349

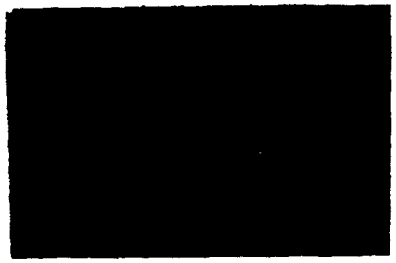


TURN TO TURN INSULATION

拡大

ENLARGED





対絶＋層間
(試料B)

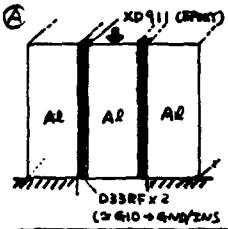
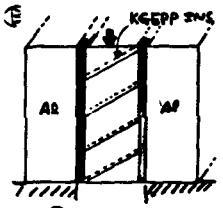
1350

GND & TURN-TO-TURN INSULATION

TURN-TO-TURN & GND INSULATION

1351

BONDING STRENGTH AT 77 K

SET - UP	BROKEN PART	σ SHEAR (N=3)
Ⓐ 	B/W D33RF ⇔ Al (B STAGE EPOXY) ⇓ SUP. CYL ⇔ GND/INS	3.44 kgf/mm² 3.81 3.57 $\bar{\Sigma}$ = 3.61
Ⓑ 	B/W KGEPP ⇔ Al (B STAGE EPOXY) ⇓ CONDUCTOR ⇔ KGEPP MOST PESSIMISTIC TEST (T∞)	1.80 1.98 1.88 $\bar{\Sigma}$ = 1.82
★ PRACTICAL SITUATION SHOULD BE B/W Ⓐ & Ⓑ		

KGEPP
BOND. STR. ENHANSED

写真 1

1352

プレス硬化治具

PRESS FIXTURE

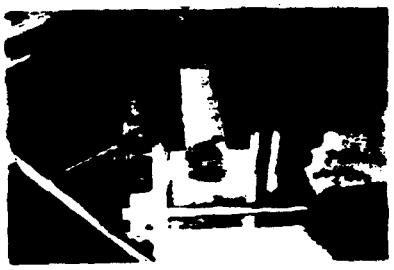


写真 2

剪断せん断試験用

SPECIMEN FOR SHEAR TEST

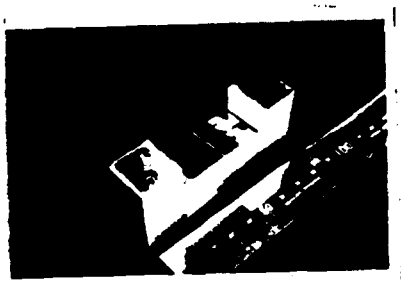
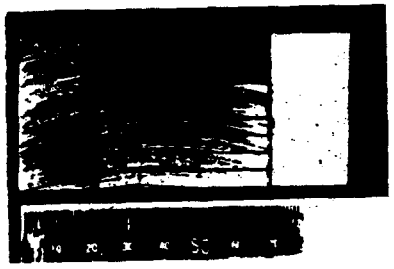


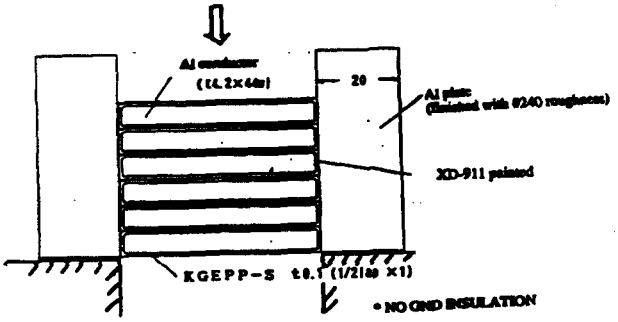
写真 3

剪断せん断試験用
の断面

CROSS SECTION



1353



Result of Shear Strength Test

Temperature	No.	Shear Strength [Kg/mm2] average		state
Room	1	2.16	2.36	one side
	2	2.58		one side
	3	2.34		one side
LN2	4	3.31	2.70	both side
	5	2.13		one side
	6	2.65		one side

FIG. 9-14 SHEAR STRENGTH TEST FOR EPOXY BONDING B/W CONDUCTOR AND OUTER SUPPORT SYLINDER

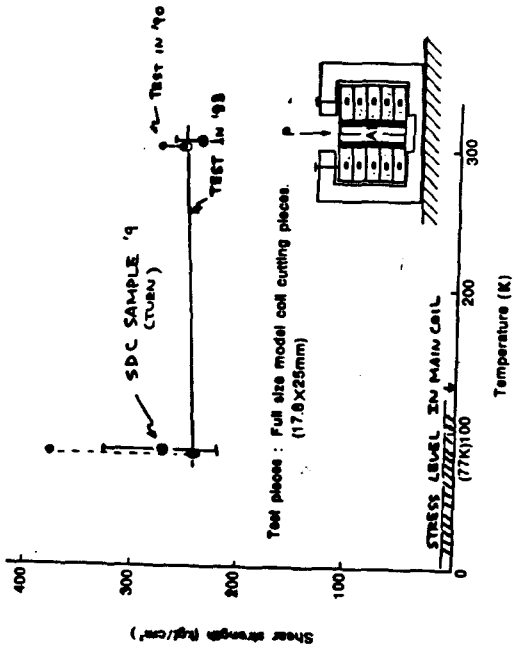
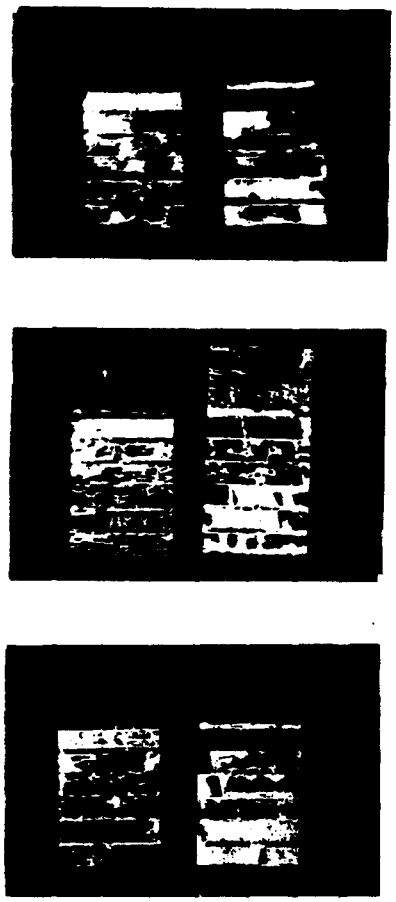


Fig.8 Bonding strength between superconductor and ground insulation meterial. (For TOPAZ MODEL COIL)



写真

試料1の破断面

試料2の破断面

試料3の破断面

SAMPLES AFTER TEST

PHASE II R & D

- **PROTOTYPE MAGNET**
  - FULL DIA × 1/4 LENGTH
  - 1.5 × I_{NOM}
    - ⇒ { EQUIV. Fz
    - { 3/4 B_c
- **SUBJECT TO BE STUDIED**
  - DEMONSTRATION OF
    - PRACTICAL WINDING TECHNIQUE
    - E/M = 9 ~ 7.5 kJ/kg
  - EVALUATION OF
    - Fz ≃ 2000 Ton
    - T_{max} ≲ 100 K
      FAST V_z , QUENCH BACK.
    - MQE ≳ 0.2 J

⇒ OVERALL STABILITY & SAFETY

WHAT SHALL BE EVALUATED IN THE SDC SOLENOID PROTOTYPE

E/M = 7.5 kJ/kg
X = 1.2 X_0

MECHANICAL STABILITY	QUENCH SAFETY
$\sigma_{EZ\cdot COIL} \simeq 60$ MPa	$T_{MAX} \lesssim 100$K
$\sigma_{SH\ CONCRETE} \lesssim 5$ MPa	$E_{MQE} \gtrsim 0.2$ J
(PHASE I & II)	(PHASE II)

- COIL WINDING TECHNIQUE
- CRYOSTAT (HONEYCOMB WALL)

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- Coil Fabrication Technique
- High E/M raito ... 7 - 10 kJ/kg
- Fast Quench Proparation with pure AL strip
- High Strength Al based superconductor to be loaded under 6 kgf/mm2 in the maximum shear stress (2τ)
- Equivalent axial force loaded by putting current 50 % higher than nominal cuurent in the main coil, then shear strength at boding between the coil and the outer support cylinder to be tested.
- Stability and Minimum quench energy to be measured to understand safety margins.
- Quench behaviour and the maximum temperature and thermal stress measurement

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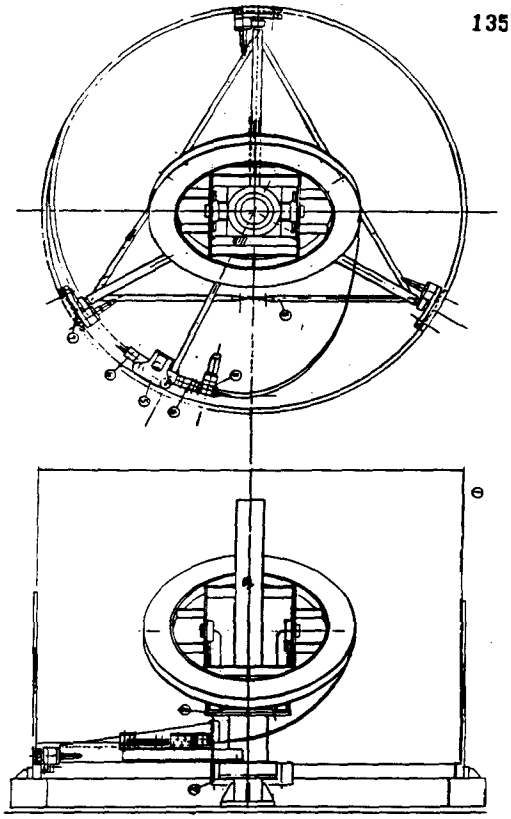

FIG.10-1 SCHEMATIC VIEW OF THE PROTOTYPE COIL WINDING MACHINE

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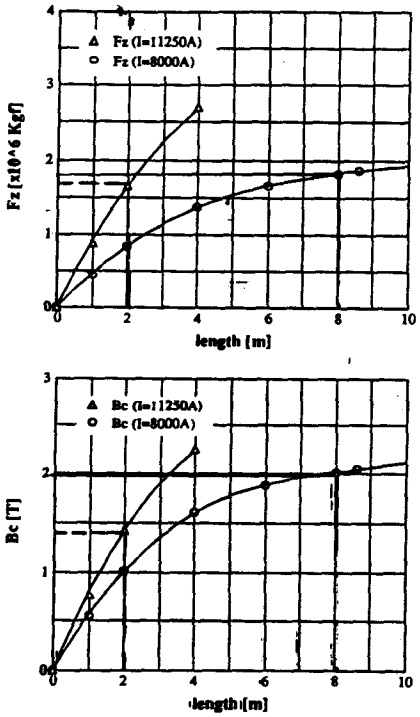

FIG. 10-3 Fz & Bc v.s Coil Length

1361

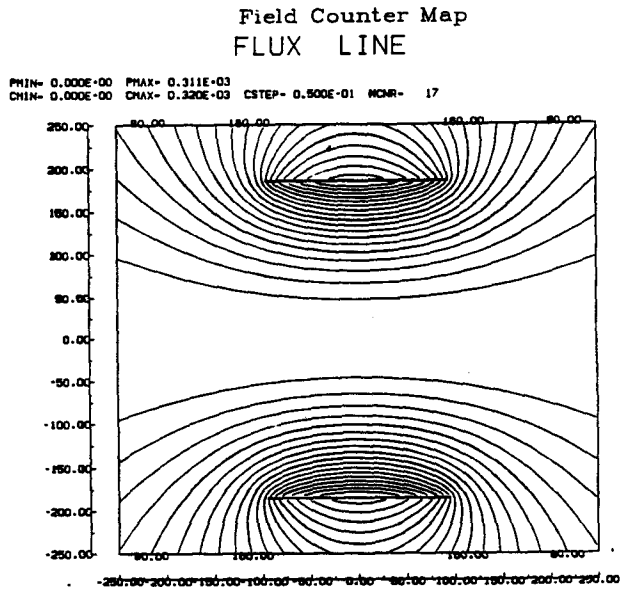

FIG.10-2(a) MAG FLUX IN THE PROTOTYPE

FIG.10-3(b) FIELD DISTRIBUTION IN THE PROTOTYPE

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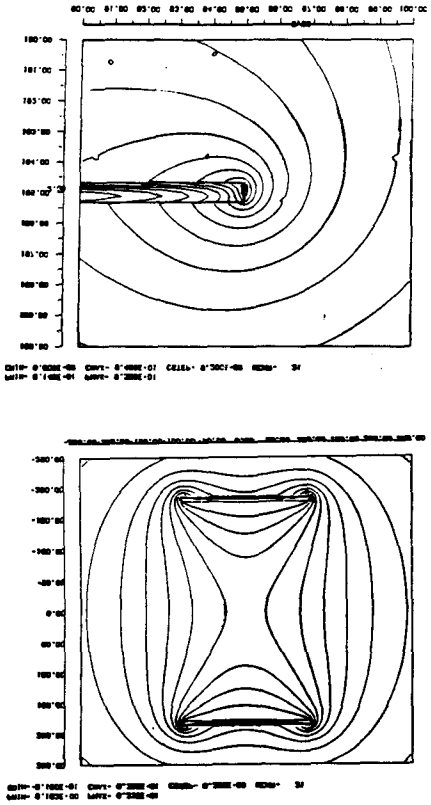

Field contour map

B (T)

1363

QUENCH

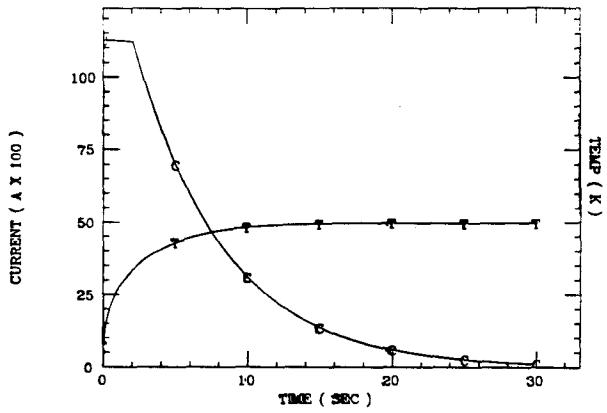

FIG.10-4 QUENCH CHARACTERISTICS OF THE PROTOTYPE

1364

DIVISION OF R&D EFFORTS

	KEK	BOTH	FNAL
BASIC R&D	CONDUCTOR COIL DESIGN COIL WINDING	MAGNETICS MECH. ANALYSIS QUENCH ANALYSIS	HONEYCOMB VAC. WALL CHIMNEY SUPPORT CRYOGENICS POWER SUPPLY
PROTOTYPE	(COLD PART) COIL LN2 SHIELD CHIMNEY ASSEMBLY	(CRYOSTAT) (SUPPORT) TEST REPORT	(WARM PART) HONEYCOMB VAC. WALL END FLANGE (CONTROL DEWAR IF NECESSARY)

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Table 10-2. PROTOTYPE AND MAIN COIL DEVELOPMENT PLAN

YEAR	R&D ITEMS
JFY1990 (APR/90 -)	BASIC R&D - HIGH STRENGTH AL STABILIZED SUPERCONDUCTOR - INNER WINDING TECHNIQUE
JFY1991 (APR/91 -)	PROTOTYPE (1/4L) COIL DEVELOPMENT - SUPERCONDUCTOR (6 KM) FABRICATION - COIL INNER-WINDING MACHINE DEVELOPMENT
JFY1992	- COIL WINDING - CRYOSTAT ELEMENT
JFY1993	- ASSEMBLY OF COIL AND CRYOSTAT - COOLING AND EXCITATION TEST - EVALUATION AND ENGINEERING DESIGN REPPORT
JFY1994	MAIN MAGNET FABRICATION - SUPERCONDUCTOR (25 KM) - CRYOSTAT ELEMENT
JFY1995	- COIL WINDING - MAGNET ASSEMBLY
JFY1996	- COOL-DOWN AND EXCITATION TEST IN AIR - TRANSPORTATION TO SSCL - INSTALLATION INTO THE SDC DETECTOR IRON STRUCTURE
JFY1997	- COOL-DOWN AND EXCITATION TEST IN IRON - FIELD MEASUREMENT

Table 10-1. Main parameters of the prototpe coil.

Design prarameters		Main Coil	Prototype Coil
Dimensions:			
Cryostat	Inner Radius	1.75 m	1.75 m
	Outer Radius	2.10 m	2.05 m
	Half Length	4.0 m	1.2 m
Coil	Effective Radius	1.85 m	1.85 m
	Half Length	3.8 m	1.9 m
	Coil + OSC	44 + 31	44 + 31 mm
Tracking	Aperture Radius	1.7 m	1.7 m
	Half Length	4.0 m	1.2 m
Transperency	Radiation Thickness	1.2 Xo	1.2 Xo
	Interaction Length	0.25 λn	0.25 λo
Electrical Parameters			
Central Field		2.0 T	1.54
Int. B.dl (η=0)		3.4 T.m	
Nominal Current		8,000 A	11,250 A
Inductance		4.2 H	0.68 H
Stored Energy		133 MJ	48 MJ
E/M		7.1 kJ/kg	10 kJ/kg
Mechanical Parameters			
Effective Cold Mass		18 tons	4.5 tons
Total Weight		21 tons	8 tons
Radial Magnetic Pressure (Bz=0)		1.67 MPa	1.73 Mpa
Axial Total Compressive Force		17.7 MN	16.7 MN
Maximum hoop stress		44 MPa	43 MPa
Maximum axial stress		-21 MPa	-19 Mpa
Maximum shear stress (2τ)		62 MPa	62 MPa
Max. shear stress on bonding		<10 MPa	
Peak field in coil		2.8 T	3.8 T
Load line Ratio		50 %	~76%

11. SUMMARY

1. Design study of the SDC thin superconducting solenoid is being carried out in cooperative work bewteen KEK and FNAL.

2. The SDC thin solennid design is feasible with a central magnetic field of 2 T and a transparency of 1.2 Xo.

3. The coil axial and radial force may be maintained within elastic limit in mechanical design.

4. Shear stress between the coil and the outer support cylinder should be small enough. The epoxy bonding may sustain safely enough.

5. Present magnet design may be adapted to either (in air or in iron) option of calorimeter system/

6. A prototype (1/4 length) magnet is planned to be developed in these threee years. The same order of the combined mechanical stress (2τ) is to be loaded in the coil with higher current applied into the coil to verify the magnet design and to study of the characteristics of the high E/M thin superconducting solenoid for the SDC experiment.

7. WE NEED TO FIX THE COIL RADIUS TO START THE PROTOTIPE COIL DEVELOPMENT, THIS SUMMER.

Calorimeter

August 5 - Monday

Liquid Argon	
Engineering Design	W. Pope(LBL)
Critical Engineering Issues	Y. Unno(KEK)
LAC Cost Estimate	G. Guenterberg(M. Marietta)
Tile/Fiber	
Baseline Design	T. Kirk(ANL)
Baseline Engineering Design	V. Guarino(ANL)
Baseline Cost	D. Scherbarth(Westinghouse)
Pb EM, Fe Hadron Engineering Design	L. Bartoszek(Fermilab)
Pb EM, Fe Hadron Calorimeter Design	J. Freeman(Fermilab)
Fabrication and Cost	S. Gourlay(Fermilab)
"Iron" Detector Simulation	W. Foster(Fermilab)
Integration for LA, Tile/Fiber	D. Bintinger(SSCL)

August 6 - Tuesday

Absorber Configurations	T. Handler(Tennessee)
LA Critical Issues	
Critical Issues and Beam Test	Y. Unno(KEK)
Speed, Noise, Pileup and Electron Uniformity for Liquid Argon	C. Hearty(LBL)
Why Not Tile/Fiber for SDC Calorimetry	G. Abrams(LBL)
Radiation Damage Results	
Saclay Results, Sources and Beam	J. Ernwein(CEN Saclay)
Tsukuba Beam Test Results	K. Takikawa(Tsukuba)
Tsukuba Source Test Results	K. Yasuoka(Tsukuba)
FNAL Source Tests	A. Byon(Fermilab)
IHEP/Beijing Tests	D. Green(Fermilab)
FSU & LSU Results	A. Fazely(LSU)

August 8 - Thursday

Compensation and Energy Resolution	T. Gabriel(ORNL)
FNAL Optical Studies/Experience	J. Freeman(Fermilab)
Pb/Fe Options	D. Green(Fermilab)
New Approaches in Calorimetry	A. Ronzhin(IHEP Protvino)

LPBautz:8/26/91

SOLENOIDAL DETECTOR COLABORATION

LAWRENCE BERKELEY LABORATORY

CALORIMETRY SUBGROUP

August 5, 1991

ENGINEERING DESIGN OF THE LIQUID ARGON CALORIMETER

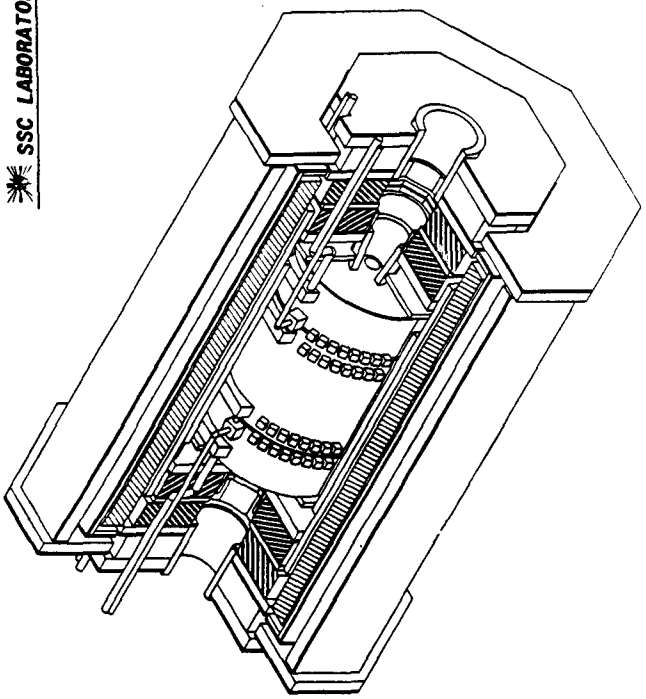
Information compiled by;

William L. Pope, LBL

for the

SDC LAC GROUP

SSC LABORATORY



Calorimeter topics to be discussed:

1 CRYOSTAT DESIGN

a. Barrel LAC LOI (Nov. 1990) update
b. New endcap configurations

2 MODULE DESIGN

a. Barrel EM and Hadronic
b. New endcap "Big Wheel"

3 CRYOGENIC SYSTEM DESIGN

4 PREAMP COOLING

a. Rochester & KHI experiments
b. LLNL & KHI calculations

5 SIGNAL CABLE FEEDTHRU DESIGN

6 INTEGRATION

a. Cryogenic piping interface
b. Return Iron & its support

7 ACCESS

a. to Calorimeter & Tracker electronics
b. to inner Muon chamber electronics

8 LAC SAFETY

CRYOSTAT DESIGN (see CDR, Section 4)

A. LAC LOI (Nov. 1990) *update*

1. *barrel*-- eta ≈ 1.2

* inner cylinder/head flanges (moved away from corner)

* LAr head thinning in EM end region

2. *endcap*--the eta ≈ 3 problem (discussed below)

B. Concurrent endcap configuration studies

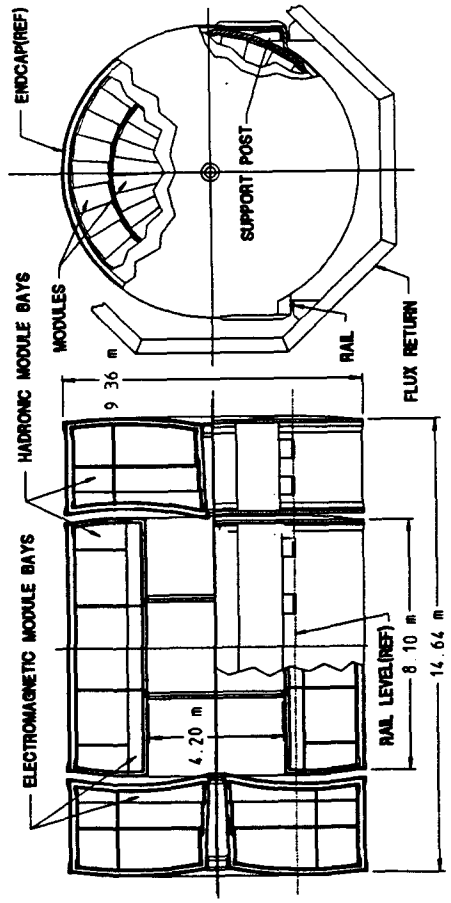
1. LBL conceptual design

* double conical LAr & vac heads
* EM penetrating stay (cylinder)
* *thin* inner cylinders--*no* axial load
* inner vacuum cylinder--*close* to the beam pipe

2. KEK/KHI designs

* existing LAr head shape
* EM penetrating stay (rods)
* *thin* inner LAr cylinder--*with* axial load
* front vacuum head shape investigations

C. Common Ground--The "KBL" endcap



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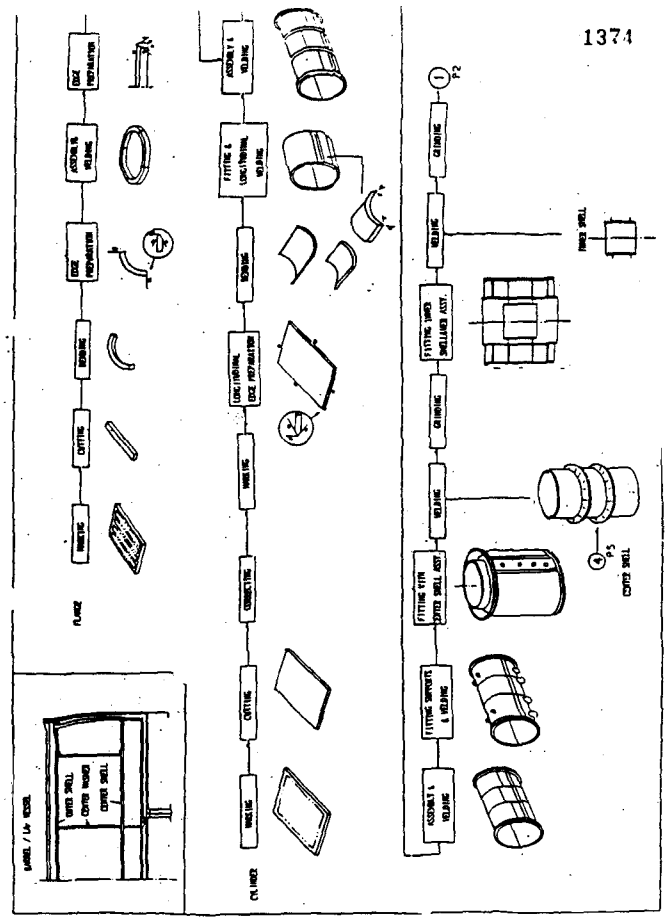

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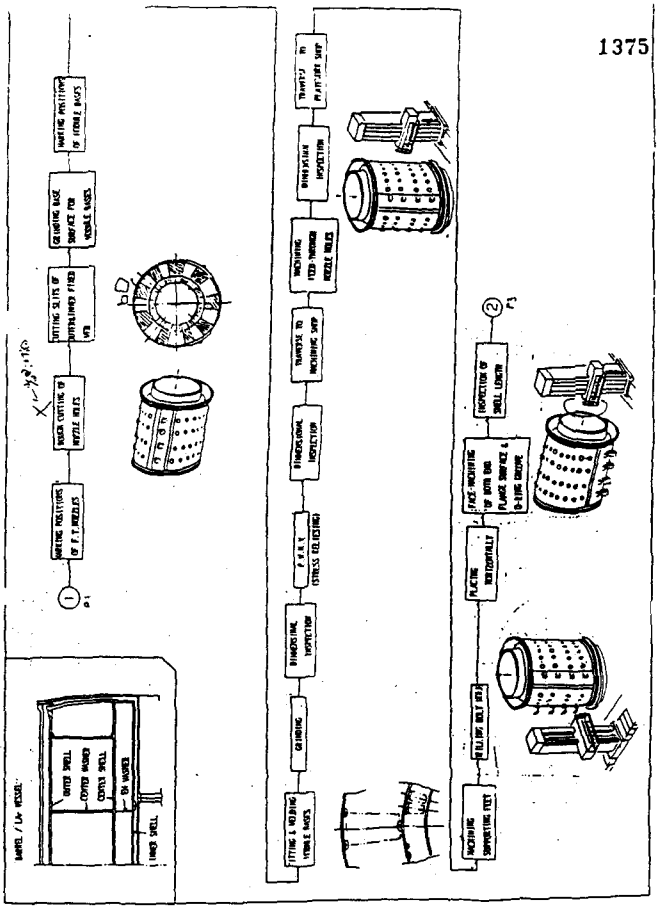

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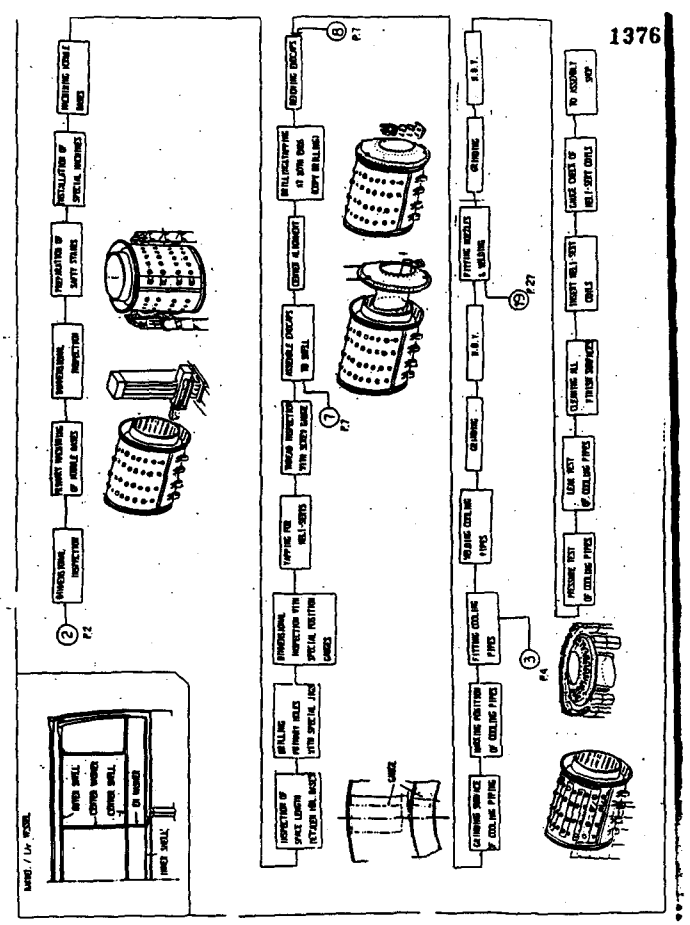

ASME CODE DESIGN

4-4

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(2) 応力評価

応力評価は、ASMEより以下の2式を満たすものとする。

一次応力　一般膜応力　$P_m < S_m$

二次応力　膜＋曲げ応力　$P_L + P_b + Q < 3S_m$

(参考資料)　ASME B&PV Sec.Ⅷ　Div.2 Appendix 4-130 より

4-131　APPENDIX 4

応力区分	一次応力			二次応力	ピーク応力
	一般膜応力	局部膜応力	曲げ応力	膜応力＋曲げ応力	
代表的な例を表4-120に示す。	内圧容器を構成する円筒・鏡板・フランジ・管板などの応力の大部分は応力分布が均一に近く、機械的荷重によってもたらされる。	内圧容器を構成するマウントパッドなどの応力分布は均一でなく、機械的荷重によってもたらされる。	内圧容器内にある中間板の取付部などの応力は、機械的荷重によって生じる。	構成する部品の応力分布は均一でなく、機械的荷重によって生じる。	(i) 応力集中によって一次又は二次応力を超過する場合 (ii)(a) 疲労を考慮する必要のない場合 (b) 疲労を考慮する必要のある場合
記号[1]	P_m	P_L	P_b	Q[2]	F[3]
応力区分の組合せ及び応力強さの評価基準	P_m → $1.5S_m$[4]	P_L → $\frac{1.5}{1.5}S_m$	$P_L + P_b + Q$ → $\frac{3}{1.5}S_m$[5]		
	設計荷重使用	$P_m + P_b$ → $\frac{1.5}{1.5}S_m$	$P_L + P_b + Q + F$ → S_m[6]		
	非設計荷重使用				

注 1) 上の表記は、応力強さの全応力成分間の差分である。S_m の値は、温度サイクルの中の最高温度の最高温度に対する。P_m の値は、P_L 以上である。P_L は一定である二次応力成分と温度サイクルとの比較によって、P_L の値は、温度サイクルの中の最高温度の温度サイクルの中で定まる温度のみならず、温度の変動は、温度の大小について生じる温度のみならず、S_m の値は温度サイクル及びサイクルの中間の中で定まって定まる。したがって、温度サイクル及びサイクルの間の中で用いて、$\sigma = 1.5S_m$ の値を用いている場合の中では、S_m の値を定めていることを忘れないようにする。

2) 外部からの応力は、温度と圧力の組合せ荷重で生じるとする応力の中間から同じ温度の一定応力を用いることもできる。しかし、温度の変化による応力はしばしば（一定応力＋二次応力）を生じさせることがある。その場合は、Q だけでなく（P_L（及び P_b）＋P_L ＋ Q の合計応力を考慮。同様に外部力の応力分布の中による中間の場合は、P 成分＋P_L による応力及び中間の応力である。例えば、温度が2倍の P_L 及び応力値中間の場合は中間の応力を考慮する場合は、$P_m = 2$、$P_b = 0$、$Q = 0$、$F = P_L$（$\sigma - 1$）となり、ピーク応力は $P_m + P_b$（$2 - 1$）＝P_m となる。

3) S_m は許容応力値（1－100 L 100 L）及び 100 L から 出されるものとしたがって、温度依存値に対する許容応力は S_m である。

4) 記号 P_m、P_L、P_b、Q 及び F は一応力値を表わすのではなく、それぞれ八つの応力成分 σ_x、σ_y、σ_z、τ_{xy}、τ_{yz}、τ_{zx} 及び σ_{xy} の中間を示すものとなる応力値を表す。

5) 本図は図 D－100 に示す。

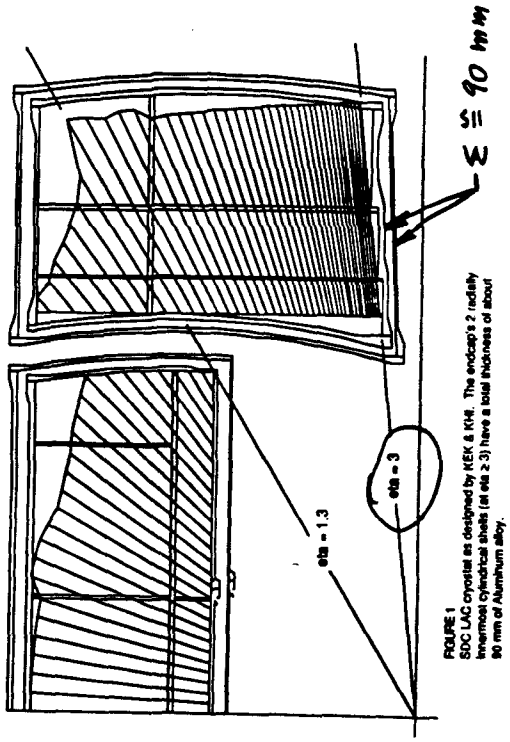


FIGURE 1
SDC LAC cryostat as designed by KEK & KHI. The endcap's 2 radially innermost cylindrical shells (at eta ≥ 3) have a total thickness of about 90 mm of Aluminum alloy.

Brief LBL Endcap Configuration Investigation

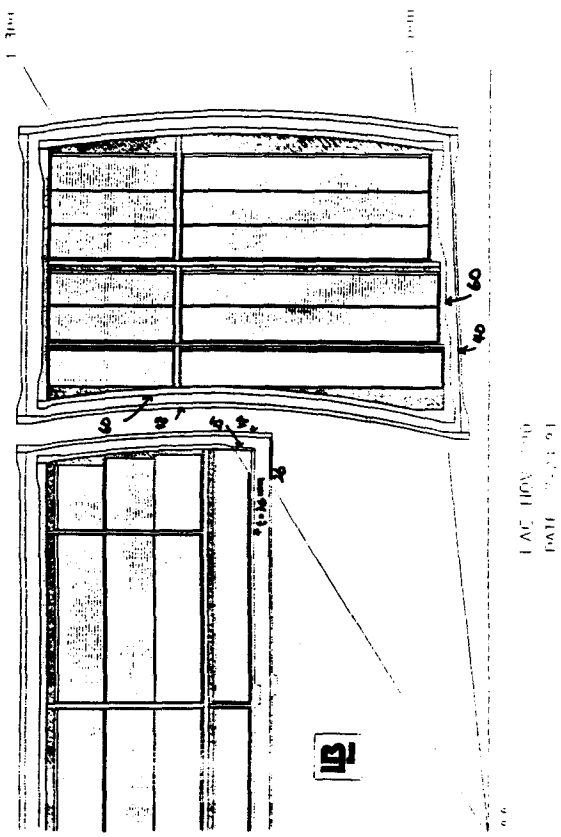
(See LBL SD # 0041, WBS 2.2, July '91)

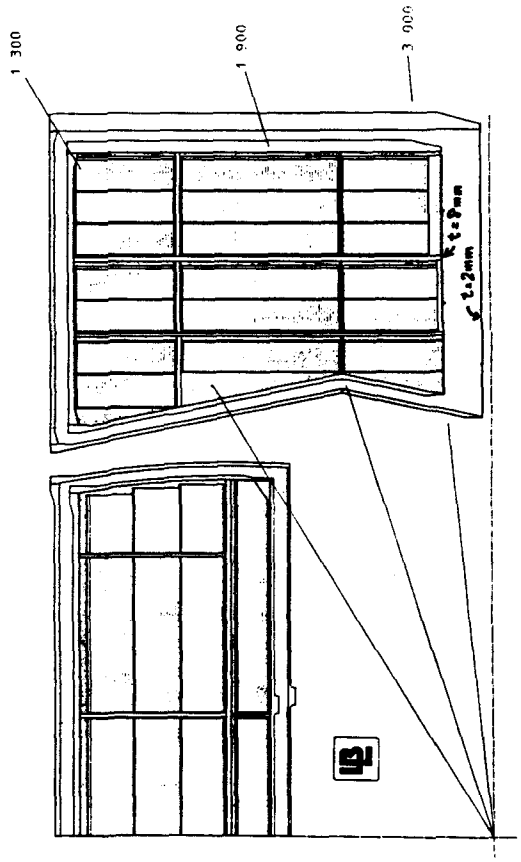
1. Design Objective--LBL's goal was to achieve a design capable of meeting applicable requirements of the ASME Boiler & Pressure Vessel Code *such that it is;*

   - *no worse* than the current KEK/KHI design for 0 ≤ eta ≈ 1.3,
   - *significantly better* than the LAC LOI design at eta ≥ 3,
   - *no worse* at eta ≈ 1.9 (the region of the EM penetrating stay) than the current design is at eta ≈ 1.3, where the barrel and endcap "overlap".

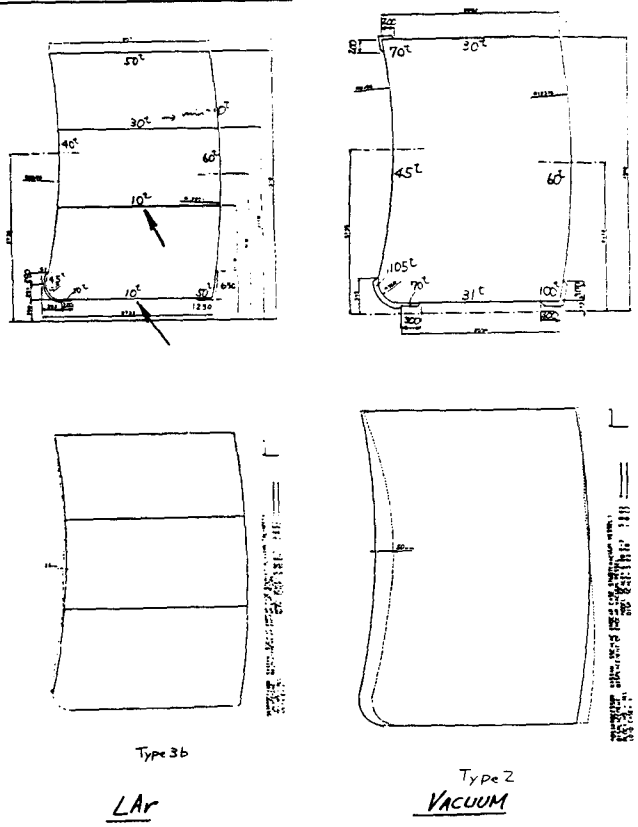
2. *LBL Conceptual Design;*

   - ≈ 55 mm thk. double conical, front LAr & vacuum heads (locally stiffened)
   - ≈ 12 mm thk. EM penetrating stay
   - ≈ 8 mm thk, ring stiffened inner LAr cylinder--with *no axial load* (SF ≥ 2)
   - ≈ 2 mm thk, ring stiffened inner vacuum cylinder--*close* to the beam pipe--with *no axial load* (SF ≥ 6)





NEW LBL ENDCAP CONCEPT
DATE 8-2-91



MODULE DESIGN (See CDR, Section 5)

A. Barrel Modules

1. HADRONIC

a. *Baseline* construction using developed technology

b. alternate cast Pb *concept*

2. ELECTROMAGNETIC

a. *Baseline* construction

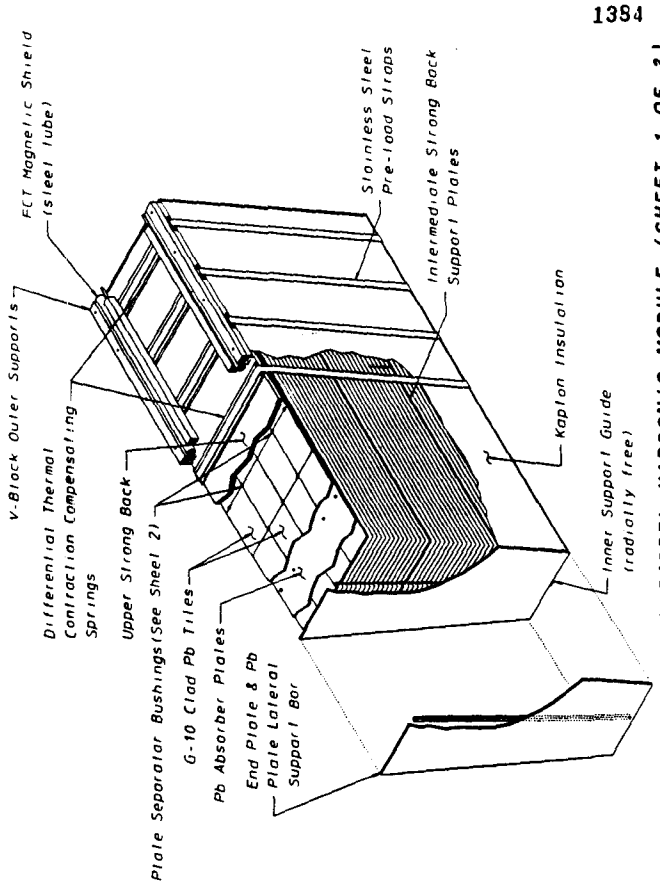
* *BNL test configuration*
* low dead area fraction (≈ 1.7 %)
* Pb creep mitigation

b. alternate construction *option* using developed technology

* can *also* have low dead area
* *WE CAN CHOOSE IN A WEEK*

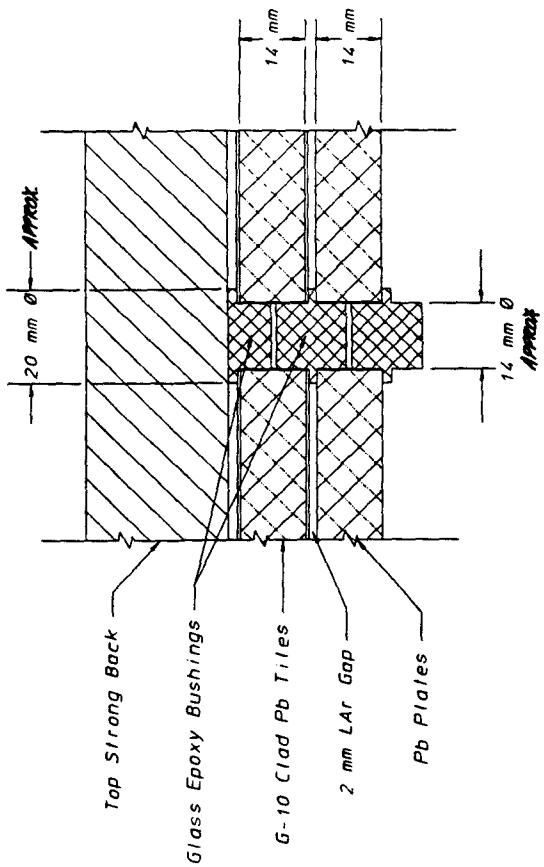
B. *NEW BASELINE* endcap "Big Wheel" modules

* simplifies vessel ass'y and close-out
* proven technology (H1 & D-Zero)
* adaptable to vessel's eta = 3 solution
* no special provisions for preamp cooling required



TYPICAL BARREL HADRONIC MODULE (SHEET 1 OF 2)

JUNE 28, 1991



BARREL HAD MODULE (SHEET 2 OF 2)

(Typical Plate Separator Bushing Detail)

JUNE 28, 1991

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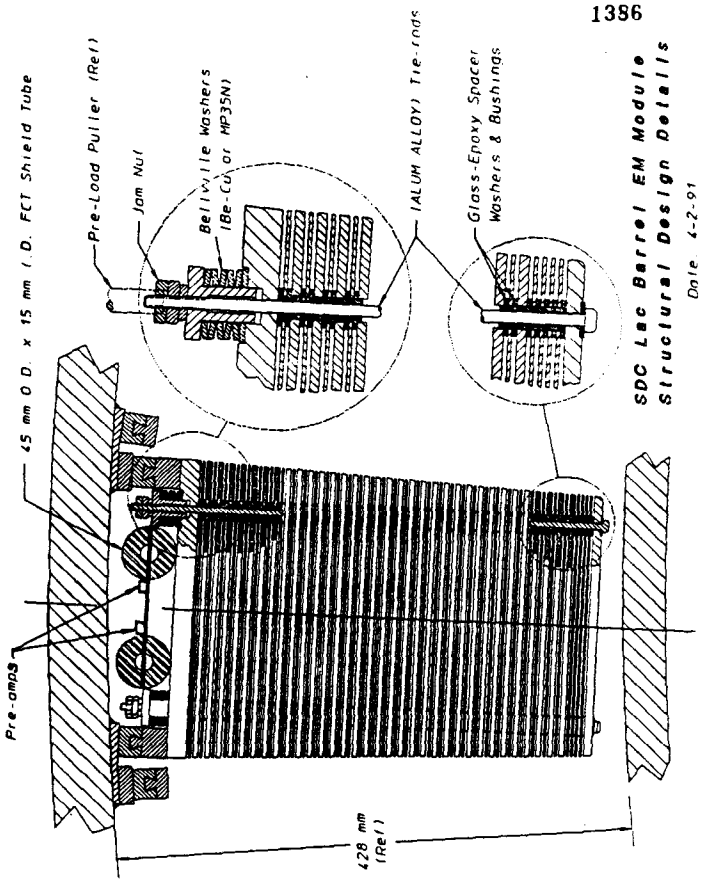

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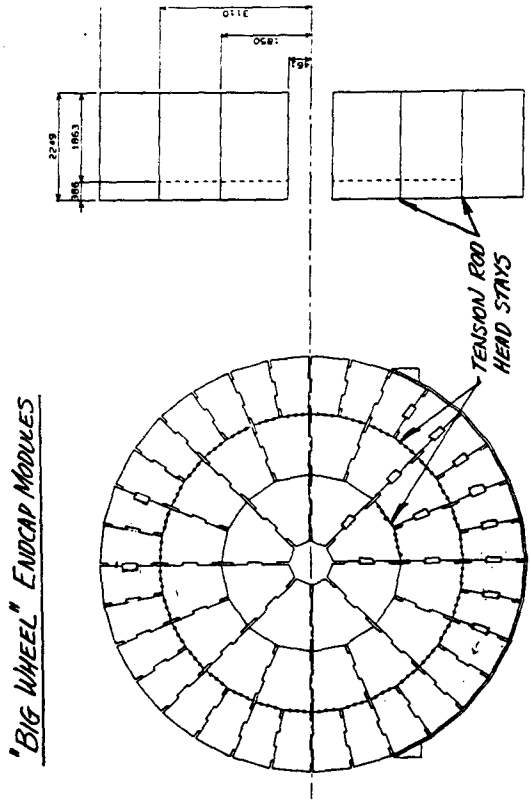

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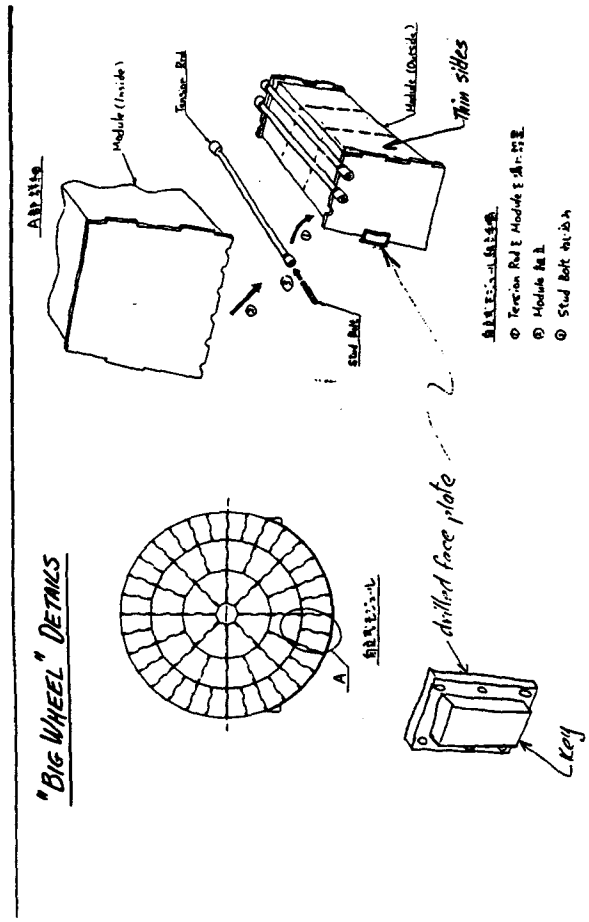

1389

CRYOGENIC SYSTEM DESIGN
(See CDR, Section 6)

A. *Baseline Design* is the pulsed, 2 phase N2 cooling system developed by Watt & Barrera (SLAC).

B. Proven Technology (MK II, Venus, SLD).

C. Main Transfer Lines (MTL).

- cryogenic fluid, vacuum, & vent provisions in large, robust, common conduits.
- Invar cryo lines eliminate bellows in MTL.

D. Small stroke bellows in common cryostat vacuum annulus have been minimized and are of double walled stainless steel construction.

E. Cryostat-to-MTL hoses in vacuum annulus are braided, stainless steel.

F. Gleason carriages allow endcap moves with *fully functional* cryo, vacuum, vent, and Safety Relief provisions.

G. Large LAr Storage dewars at Detector level.

H. This system has satisfied Preliminary Hazard Analyses by the SSCL review committee.

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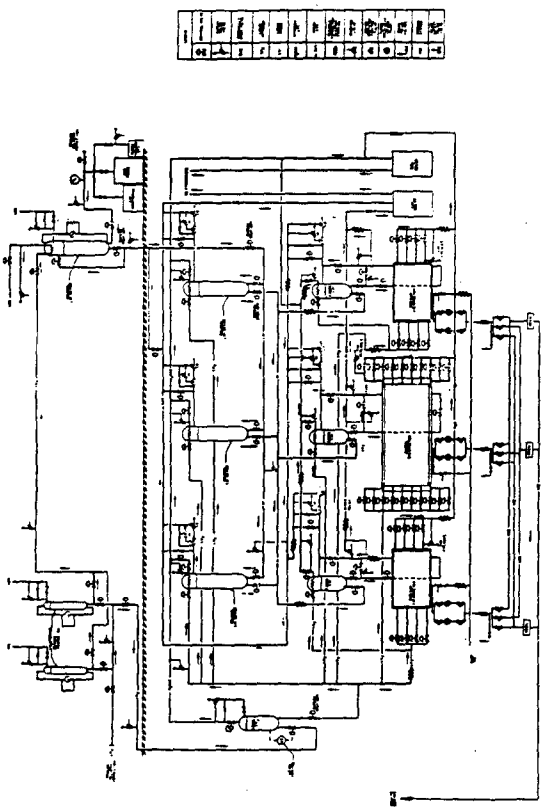

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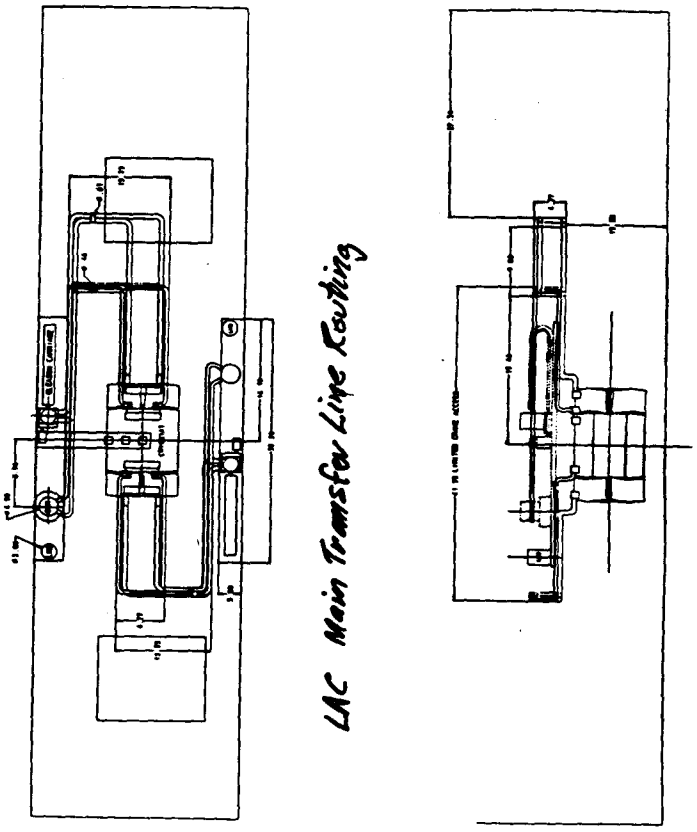

LAC Main Transfer Line Routing

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PREAMP COOLING

The LAC's preamps reside at the back of the modules in LAr. See Section 7 of the CDR for a complete description of their properties and expected performance.

1. Test & Analyses *strongly suggest* that boiling of LAr can be avoided in the *Baseline LAC*

2. Experimental Tests:

   2.1 University of Rochester

   2.2 KEK/KHI

3. Design Calculation Documentation:

   3.1 LLNL Analyses (Don Slack)

   3.2 KHI Analyses

4. Extension of the forgoing to Barrel modules:

   4.1 Sensible heat gain to LAr at HAD preamps can be removed by Watt's *existing 2 phase N_2 circuits* (in the vacuum annulus).

   4.2 Sensible heat gain to LAr at EM preamps can be removed by additional 2 phase N_2 circuits attached to the LAr vessel's mid-shell wall (2 circuits minimum; 4 circuits with 100 % redundancy).

1393

   4.3 Local reduced density, single phase LAr is easily routed (at the back of barrel modules through slots in new T-shaped V-block supports--R. Richardson, SSCL) adjacent it's cooled wall back to the condenser, without entering HV gaps.

5. Endcap modules of the Baseline "Big Wheel" configuration *require no special preamp cooling provisions.*

6. Baseline Preamp Cooling System;

   The SDC LAC's Baseline Preamp Cooling System Design is described in 4 & 5 above (disregard reference to others in the CDR).

7. Detailed, single phase fluid, FEA Modeling can verify the expected performance.

8. Existence Proof of Barrel Module Preamp cooling;

   A relatively simple test, of a full-scale mock-up (region between 3 adjacent modules' outer strongbacks and their nearby, 2 phase N_2 cooled wall) in an appropriate LAr test dewar can provide an existence proof for the Baseline Preamp Cooling Design--

   After the SDC selects the LAC !

SIGNAL CABLE FEEDTHRUS

A. Previous Gas Cooled configuration

* vacuum isolation bellows (200 k pins)
* conduction intercept with N2 gas cooling
  --this was needed to achieve very low pin heat leak with the 0.1 Ohm maximum D.C. cable impedance of the *Electrostatic Transformer* readout option
* design review problems

B. New non-gas cooled *Baseline Configuration*

* Magnetic Transformer readout
* retains vacuum isolation bellows
* ≤ 50 Ohm D.C. cable impedance
  --this allows stainless steel cables of low A/L to achieve required low heat leak without gas cooling
* low heat leak & LAr subcooling preclude local boiling at receptacle pins
* LAr spill mitigation system added
* simpler, cheaper, more reliable design

HIGHLIGHTS OF PREAMPLIFIER COOLING

1. TESTING & ANALYSIS PROVE LOCAL BOILING OF LAr CAN BE MITIGATED

2. TESTING WAS AS FOLLOWS:

   2.1 COOLING BY DIRECT COUPLING TO LN_2

   2.2 COOLING BY INDIRECT COUPLING TO LN_2

   2.3 COOLING BY CONVECTION IN LAr

   2.4 CONCLUSION: NO LOCAL BOILING OCCURRED AT OPERATING POWER LEVELS IN ANY TEST

3. CALCULATIONS: PRELIMINARY CALCULATIONS INDICATE THAT IN THE LAC THE LAr IS SUBCOOLED AND DOES NOT BOIL

FIGURE 4. Cross-sectional details of the N2 gas cooled signal cable Feedthru assembly. The SCFT utilities high pin density hermetic connectors,stainless steel bellows, and cryogenic fittings all of commercial design

FIGURE 1. Cross-sectional details of the non-gas cooled signal cable Feedthru option. The SCFT utilities high pin density hermetic connectors, stainless steel bellows, and cryogenic fittings all of commercial design.

ACCESS TO CALORIMETER, TRACKER, & MUON CHAMBER ELECTRONIC.

INTEGRATION HELP NEEDED!

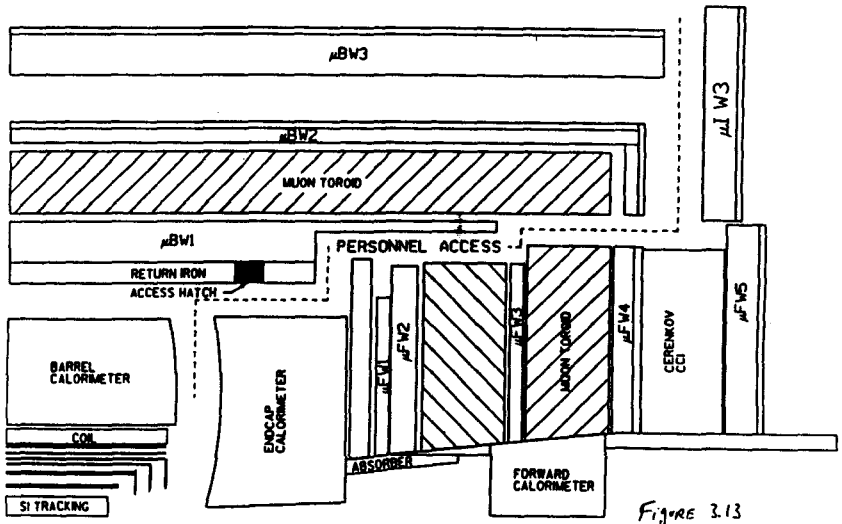
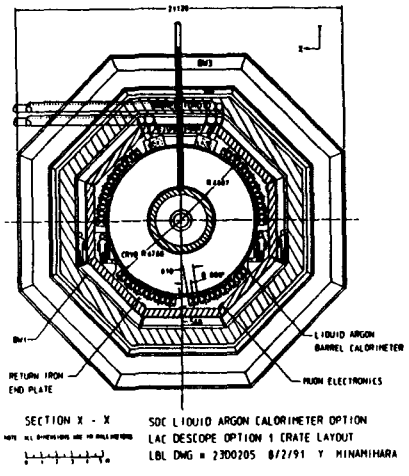
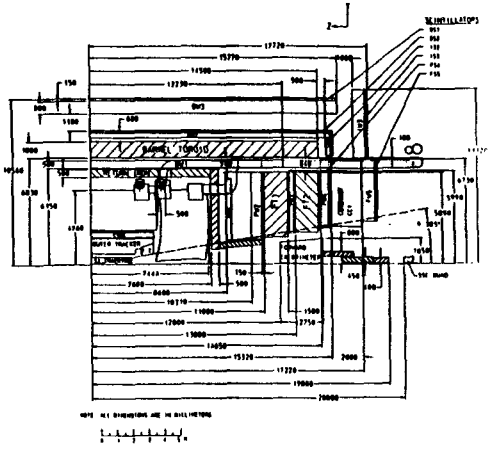


Figure 3.13

THIS NEEDS HELP!



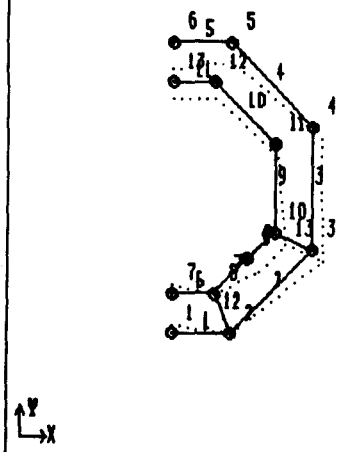


RECENT LAC INTEGRATION

Module C-5: General Two-Dimensional Frames

```
** R E S U L T S **
Deflections:
 Xmax  = 2.909398E-02 Joint = 9
 Ymax  =-6.544202E-02 Joint = 6
Bending Moment:
 Mmax  =-4.083525E+05
 Member= 2   Joint = 3
Shear Force:
 Vmax  = 4.611899E+03
 Member=12
Axial Force:
 Amax  =-9.029194E+03
 Member= 7
Reactions:
 Rxmax = 2.003666E+03 Joint = 7
 Rymax = 1.100002E+04 Joint = 2
 Rmzmax= 3.593750E-01 Joint = 2
```

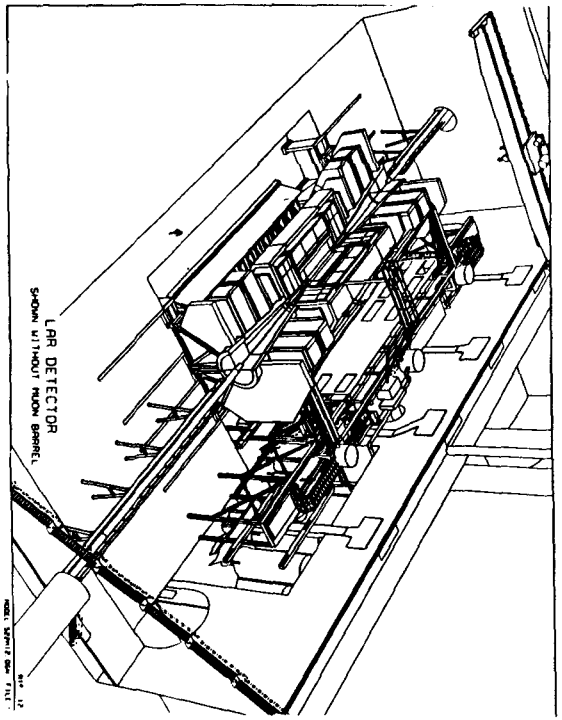
DEFLECTION



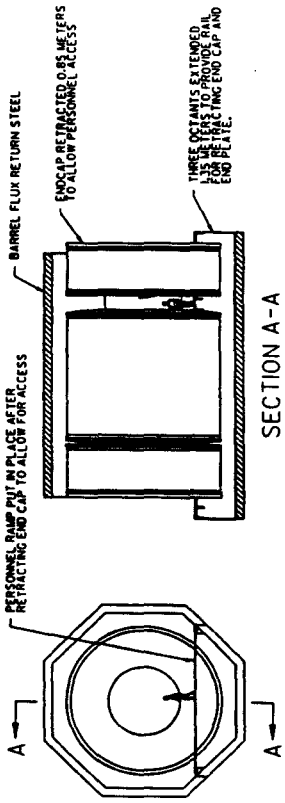
Jeff Western 6/20/91

ENTER F6 FOR MOMENT DIAGRAM OR
F7 FOR LOAD SELECTION MENU

F2PRINT F3DISP F6NEXT F7MENU F8REDO F9SAVE F10TOP



RTK INTEGRATION (1990)



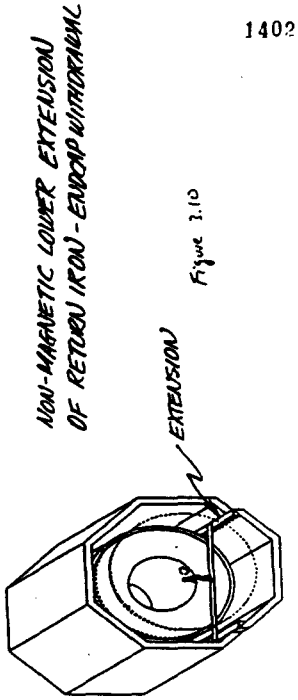


Figure 3.10

SSC Laboratory Physics Research Division

Liquid Argon Preliminary Hazard Analysis Results

- No "SHOW STOPPERS" uncovered
- Engineering concepts currently present in preliminary design must be carried forward into detailed design activities
  - LAr Storage dewars at same level at detector
  - Double bellows designs
  - Robust transfer line design and installation
  - Thorough situation awareness instrumentation of vacuum etc.
  - Effective ODH policies and procedures (inc. training)
- Endcaps moved "empty but cold" for major maintenance
- Quantitative FMECA required during detailed engineering design

Environmental Safety and Health

Critical Issues Related to the Engineering

Y.Unno
KEK

and
The SDC LAC group

- Electron hermeticity
- η=3
- Depth
- Preamp reliability

• Introduction

- The objective of the LOI design was the overall configuration.
- In November, critical regions were identified:

  (1) Wall thickness around η=1.2−1.3 for electron acceptance,

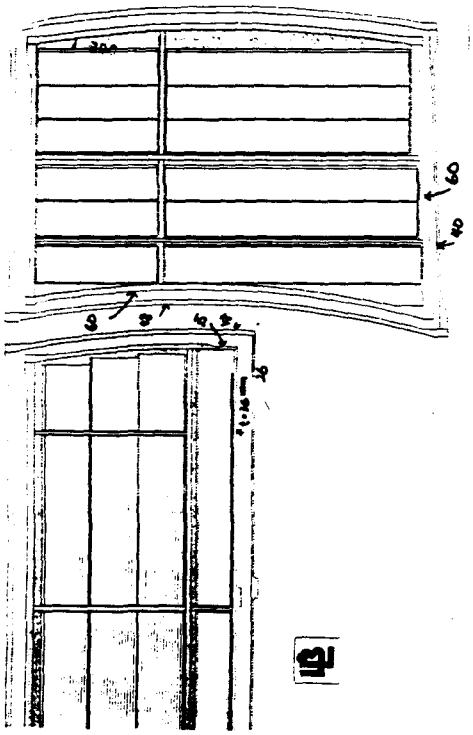
  (2) Wall thickness around η=3 for hadron acceptance.

- Engineering efforts have been paid to propose solutions to the issues (see the talk by Bill Pope).
- The requirements for the calorimeter depth were
  ≥9 λ_I(Central) and ≥12 λ_I(Intermediate).

The LAC was designed to have
  ~9 λ_I(Central) and ~11 λ_I(Intermediate).

(Intermediate ~11λ_I was chosen because the required 12λ_I was not informed well.)

- A new requirement for 10 TeV di-jet mass resolution has put the depth requirement 10±1 λ_I. We propose a design if the 10 λ_I depth requirement is absolute necessity.
- Other issues were the reliability of preamp for a long term usage and for radiation damage.



• Electron hermeticity

Wall thickness around η=1.2~1.3 for electron acceptance

- Thining the Barrel walls→Cryostat cut-view
- Utilization of the extra Massless gap(MLG) for the η=1.2~1.3 region→EGS modeling
- Dead material in front of the EM calorimeter without the extra MLG
- EM resolution with the MLG correction

C. Hearty

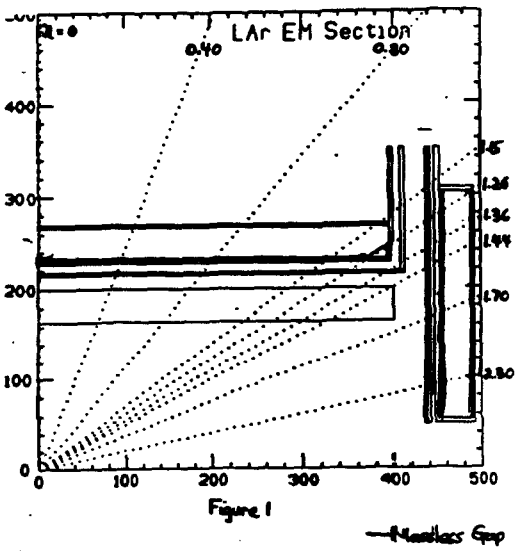


Figure 1

—Massless Gap

C. Hearty

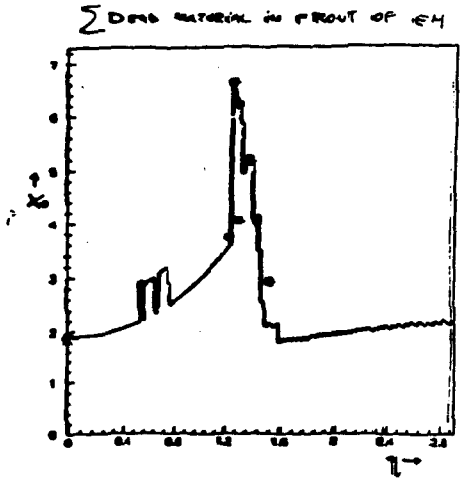


Figure 2

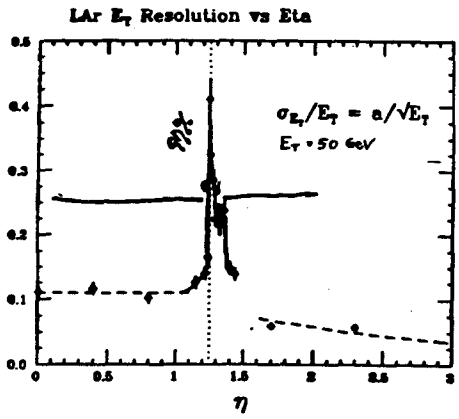


Figure 5b

• Summary of the Electron hermeticity

• 97% acceptance at $\sigma_E/E<25\%/\sqrt{E}$

• Calorimeter is sensitive in the $\sigma_E/E>25\%/\sqrt{E}$ and electrons will not be lost.

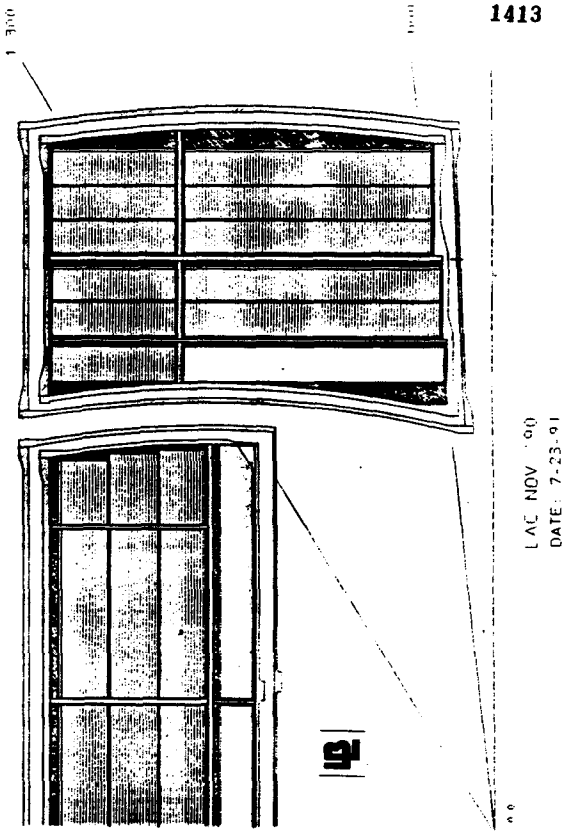
(The ϕ module boundary will be disoussed by C.Hearty)

• η=3 issue

Wall thickness around η=3 for hadron acceptance

• The LOI design was not optimized for the issue. LBL worked out a design to thining the inner walls of the Endcap cryostat (LAr and Vacuum vessels). KEK/KHI also figured out a design for the LAr vessel.

• Dead masses in front of the calorimeter for the LOI and for the new LBL design



1414

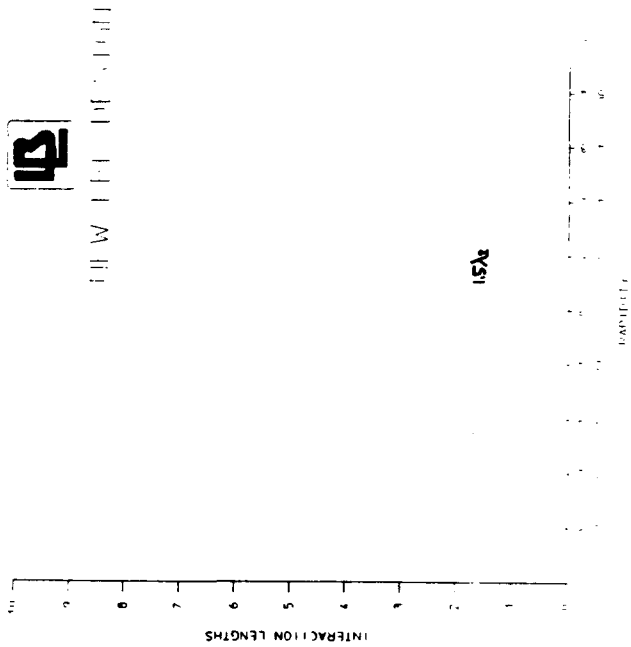
kek_wmrsly3 (Rich Weidenbach)
color (David P. O'Neill)
7-24-91

ideal forward calorimeter

1415

1416

1417



• Summary of the η=3 issue

• The material in front of the first active region of the new LBL design is

$\leq 1.5\ \lambda_I$.

• There is a common ground in the LBL and KHI design and a (to be developed) KBL design will have the mass $\leq 2\ \lambda_I$ in front of the active region for $\eta \leq 5$.

• Depth

• What factor drives the depth requirement?

  • Containment of hadronic showers

  9~10 λ_I for 1 TeV jets (D.Bintinger[1])

  10±1 λ_I for 10 TeV di-jet mass resolution (~2%) (D.Green[2])

• What is the requirement by physics processes?

  Missing E_t – 7 λ_I[2] —

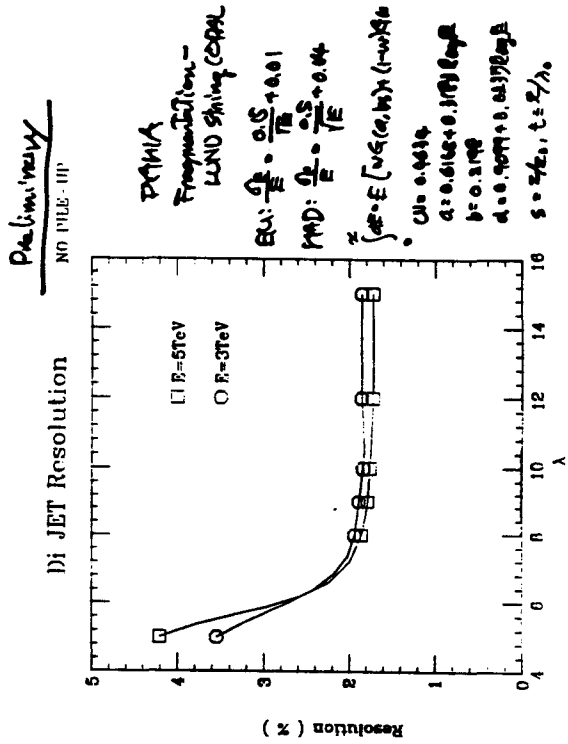
  Intrinsic width of a new resonance into jet-jet:

  Techni-ρ Γ/M~20% (QCD coupling)

  Excited Quark[3] Γ/M~4% (QCD coupling)

  Z'→jet+jet is undetectable[4] (EW coupling) (Note that only those with QCD coupling can be detectable over the large QCD jet-jet background)

[1] D.Bintinger, Proceedings of the Workshop on Calorimetry for the Supercollider, March 13-17, 1989, Tuscaloosa
[2] D.Green, Proceedings of the SDC Collaboration Meeting at KEK, May 13-16, 1991, SDC-91-00033
[3] U.Baur et al., Int. Jour. Mod. Phys. A2(1987)1285
[4] J.S.Whitaker et al., Experiments, Detectors, and Experimental areas for the Supercollider, Berkeley, CA, 1987



(19)

1422

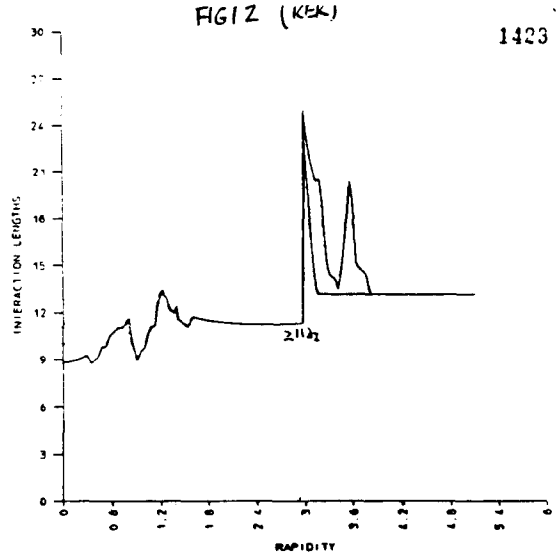
- I urge the Physics Assessment Group define clearly the required mass resolution, since the thickness of the calorimeter is one of the very costly items (if you ask, at least for the LAC option) and should be optimized to reduce the cost of the whole detector.

- Ray tracing for the calorimeter thickness for the LOI and for the new LBL Endcap design.

(20)

FIG 12 (KEK)

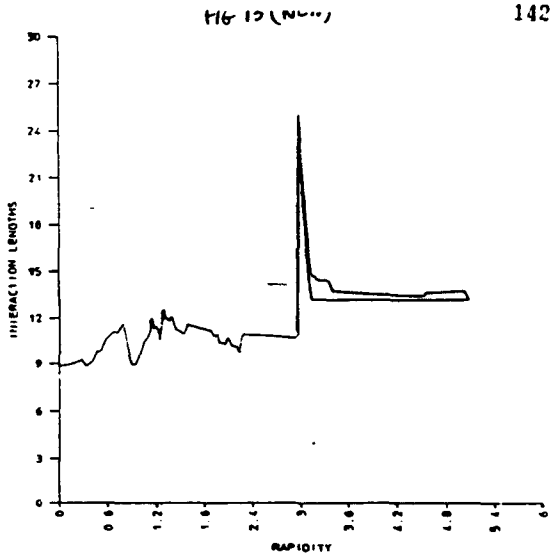
1423



(21)

FIG 13 (NCHU)

1424



1425 (22)

- If there is an absolute necessity to have a thick hadron calorimeter, we propose to change the thickness of the LAC by the following amounts:

(1) Barrel $9\lambda_I \rightarrow 10\lambda_I$: IR=2.1m→1.9m
(i.e. Tracker OR=1.7m→1.5m)

(2) Endcap $11\lambda_I \rightarrow 12\lambda_I$: Z_1=4.4m→4.2m

Obviously there are two ways to go: inward and outward. Outward step increases the radius of the calorimeter and drives the whole detector cost up, we prefer to go inward.

Reference:

Hadronic module density: 10.0 g/cm^3
Interaction length of Pb: 194 g/cm^2/λ_I
→ 19.4cm/λ_I

• Preamp reliability

- Failure modes

  (1) Random failure
  (2) DC power ON/OFF
  (3) Cryogenic cycling
  (4) Sparks
  (5) Radiation damage

- How to verify that the preamp lives forever?

  To establish at the 90% C.L. that the probability of an item failing in time t (or number of cycles, t) is ε, we must test N objects for time (or number of cycles) T with no failure, where

  True failure rate $\leq 2.3/NT \leq \varepsilon/t$, i.e.

  $$NT \geq 2.3t/\varepsilon.$$

- Tests to be conducted: we require ε=0.1%.

  (1) Random failure in $t=10^8 s$ (10 operating years) →10,000 preamps (in LAr or LN_2) for 267 days

  This failure rate is 0.004%/1000hrs.
  SLD experience is 0.028%/1000hrs at room temperature; seven times higher. But, orders of magnitude improvement at cryogenic temperature because the failure rate varies as $\exp(-\varepsilon/kT)$ (MIL-HDBK-217E).

Preamp Reliability

Goal is failure rate <0.004% / 1000 hours
==> 0.3% failures in 10 years of operation
(not calendar years - preamps off during down times).

Previous Experience

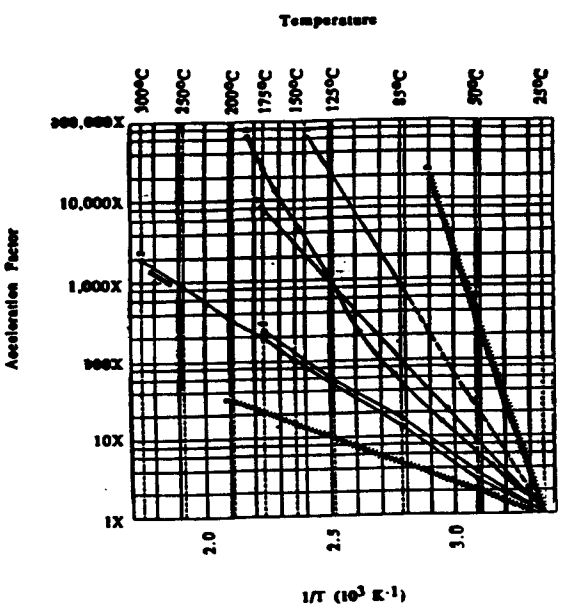
SLD: preamp failure rate is 84/34000 per year
= 0.028% / 1000 hours

- seven times larger than desired, but SLD preamps are at 40 deg. C; electronics failure rates are proportional to e**(-a/kT)
  (a="activation energy", 0.2< a< 2.0 ev for IC's)

==> orders of magnitude improvement at 88K

Helios: 584 preamps operated at 88K for 3 years with no failures (1 infant mortality)

==> failure rate < 0.015%/1000 hours, 90% CL



9.2 Variation of the failure rate of hybrid circuits with temperature [Ref. 9.12]. The cross hatched lines delimit all devices considered. Curve 3 corresponds to all MOS, all linear, and bipolar ECL devices in the normal mode of operation. Curve 5 follows the rule of thumb that failure rates (hence acceleration factors) double for every ΔT=+10°C.

Testing

Extensive testing needed:

- operate all preamps through infant mortality before installation or subsequent testing
- cryo cycling: 100 preamps cycled 50 times daily for 10 days with no failures
  ==> <0.05% (90% CL) will fail in 10 cryo cycles
- dc power cycling: 100 preamps cycled every 30 seconds for 16 days (@88K) with no failures
  ==> <0.05% (90% CL) will fail in 1000 cycles
- sparking: verify transformers and/or protection diodes at input protect against sparking
- random failures: test at elevated temperatures (otherwise impossible to see)

Results of testing ==> redesign

HV Reliability

SLD experience: ~200 shorts in 20000 m**2 of lead surface ==> 0.010/m**2 (stable)

SDC will have 38000 m**2 of exposed lead (tiles covered with G10)
==> 380 shorts (70% in hadronic section)

- at least 5 HV circuits/channel; no channels will be killed by HV shorts
- correct response of affected channel by *in situ* calibration

(2) DC power ON/OFF in t=500 cycles (once per week for 10 years)
→100 preamps at 1 cycle/min for 8 days

(3) Cryogenic cycles in t=20 cycles (2 cycles/year and 10 years)
→100 preamps at 10 cycles/day and 46 days

(4) Sparks are unknown but, let's say, t=100 sparks
→100 preamps at 1 spark/10 sec and 7 hours

(5) Radiation damage: tests are underway

JFETs are exposed to

2×10^{8} Gy (20 Mrad) at 87K
10^{14} neutrons/cm^2 (25% noise increase).

MESFETs are exposed to

10^{15} neutrons/cm^2.

At the nominal luminosity of 10^{33} cm^{-2}sec^{-1}, at η=3 and preamps after the 25X_0 or the back of hadronic module, the ionizing dose is <1/10x6kGy/yr and the neutron fluency is ~1/2x1.5x10^{13}neutrons/cm^2/yr. MESFET is already acceptable for 10 years of 10^{34} cm^{-2}sec^{-1}.

• Summary

(1) Electron hermeticity
97% at σ_E/E<25%/$\sqrt{E}$
still sensitive and electrons will not be lost

(2) η=3 <2λ_I

(3) Depth 9λ_I in the Barrel
11λ_I in the Endcap

- Request to clarify the requirement by physics, not by containment.
- If absolute necessity, we add thickness of 19.4 cm/λ_I .

(4) Preamp reliability

- Establishing random failure rate appears to be a major undertaking but feasible.
- Neutron fluency is the limiting factor. JFET is acceptable for 10 years of the nominal luminosity of 10^{33} cm^{-2}sec^{-1} and MESFET can live with 10 years of 10^{34} cm^{-2}sec^{-1}. Further radiation damage test for other JFET's should be continued.

SSC-91-Z-11115

SDC Liquid Argon Calorimeter (LAC) Cost Estimating Tasks

Prepared By:

J. Belden, J. Burgan, G. Gunnerberg, L. Moore, M. Montgomery, J. Polden, R. Vanadigo

9 August, 1991

SCIENCE SYSTEMS
MARTIN MARIETTA ASTRONAUTICS GROUP
DENVER, CO.

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5.0 CONTINGENCY ANALYSIS

6.0 DOWNSIZING OPTIONS

7.0 SCHEDULE ANALYSIS

APPENDICES

A - SDC LAC Cost-Roll-Up
B - Engineering (EN) Labor Estimates
C - Module Materials/Labor Estimates
D - Cryostat Materials/Labor Estimates
E - Schedule Analysis
F - Conceptual Design Document
G - Additional Design Information
H - Contingency Analysis

SDC LAr Calorimeter Cost Summary (B$k)

	Current Baseline
Modules	30,916
Cryostat	21,879
Feedthrus	5,010
Calorimeter Assembly	2,905
Fixtures	10,135
Test Equipment	1,729
Transportation	1,152
Cryogenic System	8,328
Facilities	2,108
Return Iron	4,934
EDIA	17,516
Total	106,612
Contingency (28.0%)	28,724
Total w/Contingency	135,336
Derived $/lb	11.74

SDC LAr Calorimeter Cost Summary (B$M)

	Current Baseline	LOI
Modules	30.9	33.4
Cryostat	21.9	46.0
Feedthrus	5.0	4.3
Calorimeter Assembly	2.9	
Fixtures/Tooling	10.1	1.0
Test Equipment	1.7	
Transportation	1.2	5.7
Cryogenic System	8.3	7.9
Facilities	2.1	2.0
Return Iron	4.8	5.0
EDIA	17.5	14.0
Total	106.6	119.3
Contingency (28.0%)	28.7	
Total w/Contingency	135.3	
Derived $/lb	11.74	

Note: LOI number of $133.4 M included an additional $14.1 M for electronics and installation

LAC Cost Ground Rules and Assumptions

1. All costs are reported in 1990 thousands of dollars.

2. Estimates include engineering, design, inspection and quality assurance (EDIA), procurement, fabrication, and assembly.

3. Cost estimates include all labor and materials, except for physicists salaries, required to design, develop, and build the detector.

4. The following methods were used to develop the cost estimates:
   - bottoms-up estimates
   - industrial engineering and manufacturing analyses
   - parametrics and factors
   - historical detector costs
   - vendor quotes

5. Labor estimates were developed using industrial fabrication processes for the cryostat and laboratory processes for the modules (applying laboratory labor rates to the cryostat is not realistic without increasing the labor hour estimates due to the large industrial automation assumed for fabrication)

6. Contingency analysis follows the SDC approach developed

7. Estimates were developed bottoms-up by Design, Industrial, Manufacturing, and Cost Engineers

8. The following engineering functions have been included in EDIA. Engineering manhours have been estimated for each calorimeter component and are included in the engineering (EN) category of the CSR spreadsheet.

LAC Cost Ground Rules and Assumptions

DRM - included in EN
AD - administration (i.e. contracts, finance, accounting, planning, personnel, administration, etc.)
ADM - administration during manufacturing
TE - technician (QA)
TEM - direct manufacturing touch labor
LA - included in TE
LAM - included in TEM

SDC LAr Calorimeter Cost Summary

	Procurement ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Module 1	689	881	348	1,918	479	2,397
Module 2	1,347	1,490	432	3,269	806	4,075
Module 3	2,658	1,190	406	4,154	996	5,060
Module 4	3,415	2,159	840	6,114	1,387	7,501
Module 5	1,496	1,936	509	3,940	998	4,938
Module 6	270	254	261	785	183	968
Module 7	1,140	1,318	424	2,882	718	3,599
Module 8	1,876	1,707	477	3,860	944	4,804
Module 9	580	952	373	1,904	493	2,397
Module 10	1,169	1,270	417	2,855	703	3,558
Module 11	1,903	1,818	466	3,886	932	4,817
Total	16,141	14,775	4,952	35,668	8,537	44,105

LAC Cost Ground Rules and Assumptions

- Design Engineering
- Design Analysis
- Engineering Support
- Test Engineering
- Systems Engineering
- Logistics
- Engineering Labs
- Quality Engineering
- Safety

9. Inspection/quality assurance is the inspection "touch" effort. This is included under the technician (TE) column of the cost spreadsheet.

10. Administration includes effort to perform planning, contracts administration, procurement, finance, personnel, project management and administration. This is included under the administration (AD) and administration manufacturing (ADM) columns of the cost spreadsheet.

11. Manufacturing support is the factory and test effort (production control, inventory, material handling, supervision, facilities maintenance, etc.) which is non-touch labor. This effort is included under the manufacturing support (ENM) column of the cost spreadsheet.

12. The cost estimates are based on the baseline design configuration developed by RHI and LBL and ASME/AWS codes.

13. Labor estimates were developed largely from detailed manufacturing estimates. Manufacturing plans were used for outlining the tasks for fabrication and assembly of the cryostat and modules. Industrial engineers developed the machine and labor hours required for each task based on industrial standards.

LAC Cost Ground Rules and Assumptions

14. Aluminum sheets for the manufacturing of the cryostat were assumed to be obtained in optimum stock sizes available from Aluminum vendors to minimize cutting, machining, and welding.

15. The following labor rates were assumed for costing purposes.

- LBL labor rates were used for all module effort
- Industrial labor rates were used for all off-site assembly
- SSCL labor rates were used for on-site assembly

	Module Assy (LBL)	Cryostat (Industry)	On-Site Assy (SSCL)
EN	$436.00	$418.07	$404.38
ENM	$313.00	$669.85	$404.38
DR	$313.00	$300.92	$193.48
AD	$182.40	$481.75	$259.06
TE	$[illegible]	$300.92	$259.06
LA	$180.00	$481.81	$193.48
EA	$313.00	$446.84	$193.48

16. The following labor category definitions have been assumed in accordance with the SDC Cost Ground Rules:

EN - engineering
ENM - manufacturing support
EA - included in EN
EAM - included in EN
DR - included in EN

SDC LAr Calorimeter Cost Summary

	Procurement ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Modules	18,141	14,778	4,682	35,566	8,537	44,106
Cryostat	4,948	16,930	4,800	26,679	9,977	33,556
Feedthrus	4,362	647	356	5,366	1,445	6,811
Calorimeter Assembly	0	2,906	2,666	5,571	1,448	7,019
Tooling/Fixtures	8,326	3,809	4,028	14,164	5,043	19,207
Test Equipment	1,640	0	88	1,729	588	2,316
Transportation	1,152	0	136	1,288	438	1,727
Cryogenic System	7,800	0	428	8,328	2,831	11,159
Facilities	2,600	0	108	2,108	717	2,825
Return Iron	4,681	0	253	4,934	1,678	6,612
Total	49,152	39,068	17,818	106,734	29,602	136,336

Appendix A - SDC LAr Calorimeter Cost Roll-Up

Module Specifications

Module #	Qty	# Pb Plates	Outer Radius	Inner Radius	Height	Outer Width	Inner Width	Avg Width	Length
1	64	33	2,888	2,332	356	264	228	246	2,880
2	128	33	2,888	2,332	356	264	228	246	2,880
3	32	67	4,288	2,818	1,467	841	553	697	2,830
4	64	67	4,288	2,818	1,467	841	553	697	1,740
5	64	67	4,288	2,518	1,467	841	553	697	733
6	32	33	3,088	461	2,604	1,204	181	692	356
7	64	42	3,088	506	2,567	802	100	351	728
8	64	63	3,088	593	2,472	802	118	359	1,078
9	64	21	4,380	3,155	1,196	864	610	737	363
10	64	42	4,380	3,155	1,196	864	610	737	728
11	64	63	4,380	3,155	1,196	864	610	737	1,078

1 - 7/31/91 - 7:35 AM

Appendix A - SDC LAr Calorimeter Cost Roll-Up

$/Manday	Modules Assy (LBL)	Cryostat (Industry)	On-Site Assy (SSCL)
EN	$436.00	$612.07	$404.32
ENM	$313.60	$869.25	$404.32
DR	$313.60	$308.02	$193.43
AD	$182.40	$421.79	$259.05
TE	$292.00	$388.62	$259.05
LA	$120.00	$281.21	$193.43
EA	$313.60	$448.24	$193.43

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Appendix A - SDC LAr Calorimeter Cost Roll-Up

EDIA Summary	EN (mandays)	TE (mandays)	AD (mandays)	EDIA ($k)
Modules	5,682	6,532	1,468	4,682
Cryostat	5,137	3,460	1,024	4,800
Feedthrus	2,120	153	273	356
Calorimeter Assembly	5,557	846	769	2,666
Tooling/Fixtures	5,572	766	760	4,028
Test Equipment	134	0	16	88
Transportation	208	0	26	136
Cryogenic System	645	0	77	428
Facilities	163	0	20	108
Return Iron	382	0	46	253
Total	19,999	11,697	4,476	17,818

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	Materials ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Barrel						
Argon Vessel	4,548	14,330	4,768	26,677	6,679	33,356
Feedthru Interface	22	0	0	22	6	28
Cooling-Coils	24	0	0	24	6	30
Pressure Cooling Circuits	24	0	0	24	6	30
Beer Shield Stage	220	2,450	0	2,670	668	3,337
Argon Vessel Assembly	24	0	0	24	6	30
Vacuum Vessel	82	0	0	82	21	103
Gas Cooling-Circuits	82	0	0	82	21	103
Beer Shield Stage	18	0	0	18	5	23
Vacuum Vessel Assembly	82	0	0	82	21	103
Cryostat-Outer Beam (Radiation)	72	768	807	1,646	412	2,057
Junction Beam	8	0	0	8	2	10
Cold Mass Supports	24	0	0	24	6	30
Vessel Rail Supports	24	0	0	24	6	30
Ends						
Argon Vessel	24	0	0	24	6	30
Feedthru Interface	24	0	0	24	6	30
Cooling Coils	24	0	0	24	6	30
Pressure Cooling Circuits	24	0	0	24	6	30
Beer Shield Stage	18	2,450	0	2,468	617	3,085
Argon Vessel Assembly	24	0	0	24	6	30
Vacuum Vessel	82	0	0	82	21	103
Gas Cooling Circuits	82	0	0	82	21	103
Beer Shield Stage	18	0	0	18	5	23
Vacuum Vessel Assembly	82	0	0	82	21	103
Cryostat-Outer Beam (Radiation)	72	768	807	1,646	412	2,057
Junction Beam	8	0	0	8	2	10
Cold Mass Supports	24	0	0	24	6	30
Vessel Rail Supports	24	0	0	24	6	30
Total	4,848	20,768	6,382	32,000	8,000	40,000

SDC LAr SUBSYSTEM

- The Project Schedule Is Based On The KEK Design and MMAG IE Analysis
- The Project Critical Path Starts With The Completion Of The Engineering Thru The Module Qualification And Fabrication, To The Final Assembly and Checkout
- Currently There Is 12 Months Margin (Schedule Reserve) Available
- The Schedule Has Not Been Resource Loaded So Optimization Has Not Been Accomplished

SDC LAr Downsizing (Entire Calorimeter)

LAr Baseline

	Material ($k)	Mfg Labor ($k)	EDIA ($k)	WBS Base ($k)	Cont. ($k)	WBS Total ($k)
Modules	16,141	14,775	4,652	35,568	8,537	44,105
Cryostat	4,849	18,230	4,600	26,679	6,677	33,356
Feedthrus	4,362	847	386	5,595	1,445	8,811
Calorimeter Assy	0	2,908	2,666	5,571	1,448	7,019
Tooling/Fixtures	8,329	3,809	4,026	14,164	5,043	19,207
Test Equipment	1,840	0	89	1,729	590	2,319
Transportation	1,182	0	136	1,299	436	1,737
Cryogenic System	7,900	0	428	8,328	2,831	11,159
Facilities	2,000	0	100	2,100	717	2,828
Return Iron	4,881	0	853	4,934	1,678	6,612
Total	49,184	39,069	17,818	106,734	29,602	136,336

Calorimeter Location Sensitivity

	Outside Rad. (cm)	Inside Rad. (cm)	Surface Area (m^2)	% of Baseline Volume	Total Cost ($k)	
Baseline	426.5	233.1	408,135	100%	136,336	
Option 1	416.5	223.1	393,667	97%	132,382	move LAC in 10 cm
Option 2	396.5	203.1	369,303	91%	126,472	move LAC in 30 cm
Option 3	386.5	173.1	338,478	82%	117,609	move LAC in 40 cm

1. length of calorimeter stays constant
2. material costs decrease by volume
3. number of layers is constant (no impact to module assembly labor)
4. cryostat/calorimeter assembly scales by volume

Calorimeter Inside Radius Cost Sensitivity

	Outside Rad. (cm)	Inside Rad. (cm)	Surface Area (m^2)	% of Baseline Volume	Total Cost ($k)	
Baseline	426.5	233.1	408,135	100%	136,336	
Option 1	426.5	209.6	438,980	108%	144,619	move inside radius in 15%
Option 2	426.5	186.8	464,636	114%	150,941	move inside radius in 20%
Option 3	426.5	169.9	488,118	120%	156,082	move inside radius in 40%

1. length of calorimeter stays constant
2. material costs increase by volume
3. number of layers increases with depth (module assembly labor)
4. cryostat/calorimeter assembly scales by volume

SDC LAr Downsizing (Entire Calorimeter)

Calorimeter Length Cost Sensitivity

	Outside Rad. (cm)	Inside Rad. (cm)	Length (cm)	Volume (m^3)	% of Baseline Volume	Total Cost ($k)	
Baseline	426.5	233.1	602.0	390	100%	136,336	
Option 1	426.5	233.1	702.0	300	90%	123,188	move ends in 5.5 m
Option 2	426.5	233.1	802.0	344	79%	110,983	move ends in 1 m
Option 3	426.5	233.1	402.0	163	59%	89,888	move ends in 2 m

1. radius of calorimeter stays constant
2. material costs decrease by volume
3. number of layers is constant (no impact to module assembly labor)
4. cryostat/calorimeter assembly scales by volume

Channel Count Sensitivity

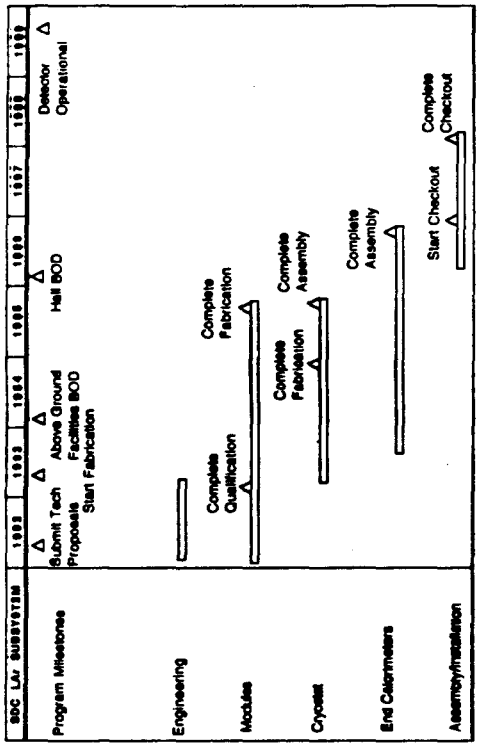
	# of Feedthrus	# of Channels	Feedthru ($k)	Electronics ($k)	LAr Total ($k)	
Baseline	100	93,600	8,811	23,424	136,336	
Option 1	90	84,360	8,130	21,600	124,000	10% decrease in channels
Option 2	77	70,272	8,100	17,900	100,000	20% decrease in channels
Option 3	61	46,800	8,000	11,718	81,561	50% decrease in channels

1. feedthru costs scale by channel count
2. signal handling costs by channel count
3. assume $200/channel

Pb Cost Statistics

	Materials ($k)	Mfg Labor ($k)	EDIA ($k)	Base ($k)	WBS Total ($k)	Delta Cost ($k)
Baseline	16,141	14,775	4,652	35,568	44,105	0
Clad	21,888	8,875	3,738	33,500	41,887	-2,218

1. Pb brick changes from $0.77/lb (sheets) to $1.00/lb (Hubbell), $1.35/lb (Rio) to $2.53/lb (Ell)
2. Pb stacking steps eliminated
4. Straps eliminated
5. Module Assembly steps revised



SDC Central Calorimeter
Tile/Fiber Baseline Design
Version: August 5, 1991

Presented by
Thomas B. W. Kirk
Argonne National Laboratory
HEP Division

at

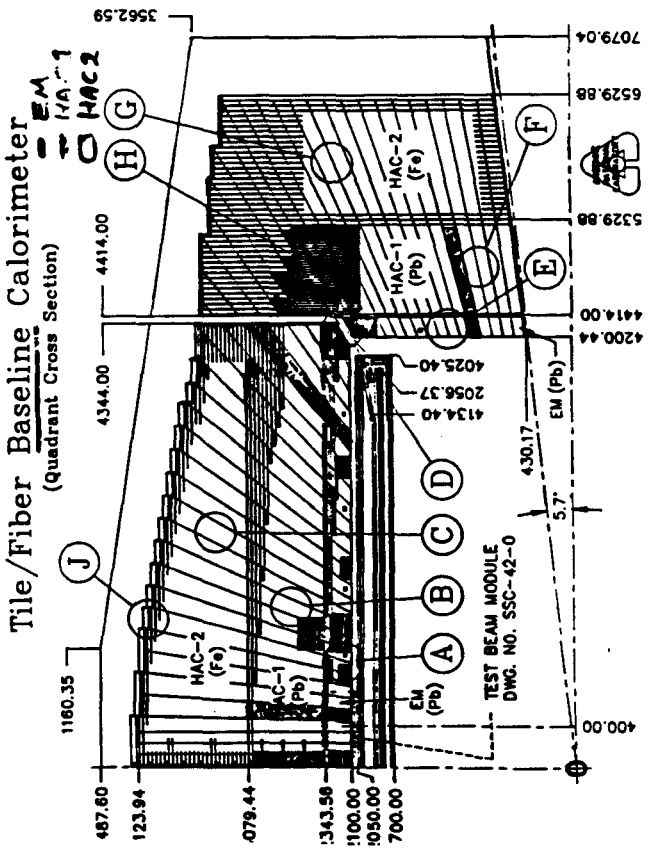
SDC Full Group Meeting
Lawrence Berkeley Laboratory
Berkeley, California

August 5, 1991

SDC Central Calorimeter
Tile/Fiber Baseline Design
Version: August 5, 1991

Key Specifications:

$\Delta\eta\Delta\phi$	0.05 x 0.05 (all sections)	LoI
$\Delta E/E$	$0.18/\sqrt{E(GeV)} \oplus 0.003$ (EM)	Handbr, Jab, Proceedings
	$0.52/\sqrt{E(GeV)} \oplus 0.024$ (HAC)	SDC Note
X_{0total}	$[22X_0, \eta=0.0] \rightarrow [25X_0, \eta\geq1.4]$	Kirk & Wickland - SDC Note
λ_{total}	$[10\lambda_0, \eta=0.0] \rightarrow [12\lambda_0, \eta\geq1.4]$	Green, Lehr, et al - SDC Note
R_{inner}	2.10m	
R_{outer}	4.49m (exclusive of PMTs, electronics, etc.)	
L_{inner}	4.20m	
L_{outer}	7.08m (exclusive of PMTs, electronics, etc.)	
Weight	2683 Tons, barrel 962 Tons each	
Passive absorber	steel-reinforced cast Pb, EM & HAC1 bolted steel plates, HAC2	ANL WSTC
Active absorber	2.5mm radhard scin. plastic	
Shower Max. Det.	8 scin. strips/tower in $\Delta\eta$ 4 scin. strips/tower in $\Delta\phi$ 12 strips/tower, 4.5 mm thick	CEN Saclay slightly different
Hermiticity	calorimeter closed down to η=2.97 barrel/endcap vert. crack = 7.0 cm	
Speed	charge collection time = 16 ns	



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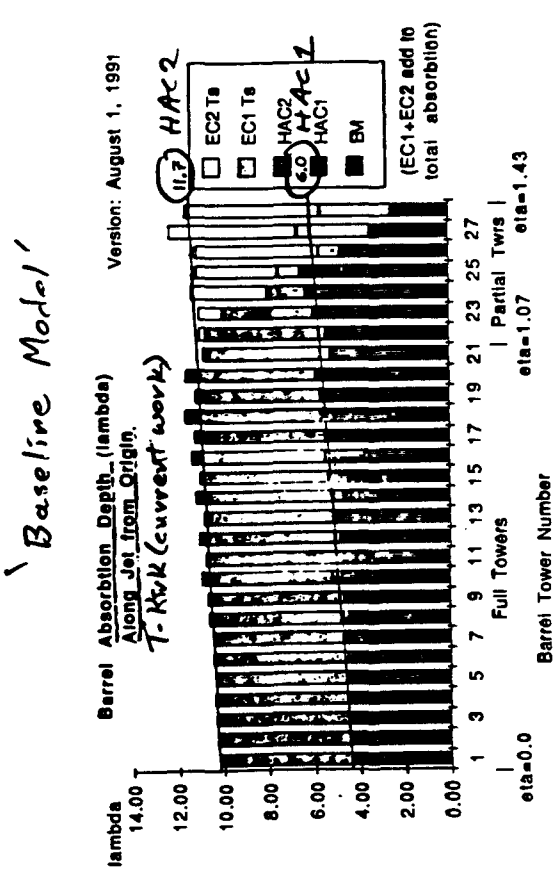

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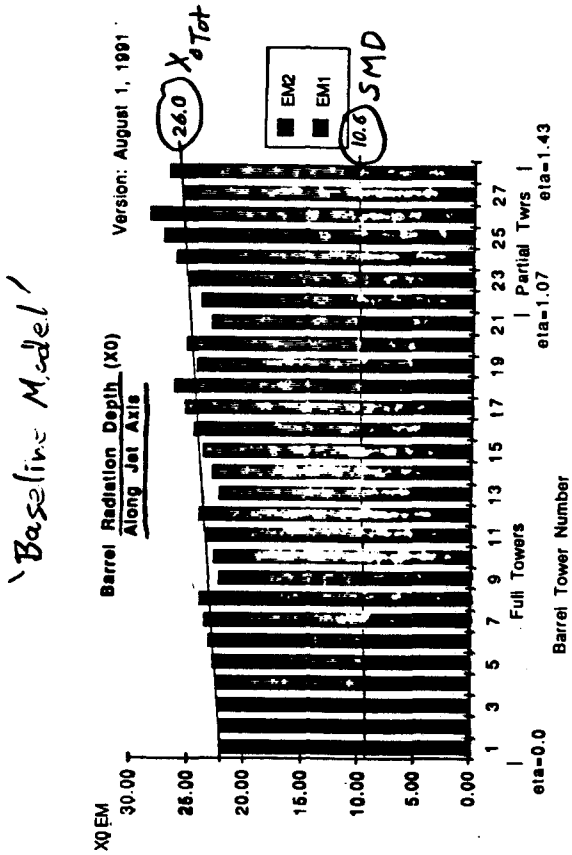

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Tile/Fiber Calorimeter Features

- **Energy Resolution**
  EM resolution is good enough to see the 80 - 140 GeV Higgs in the mode:
  $W + H^0$, $W \to l\nu$, $H^0 \to \gamma\gamma$
  LoI Fig 22.
- **Speed**
  energy collection time well matched to SSC collision rate; upgrade potential to 10^{34} luminosity x3 better than LAr
- **Hermiticity**
  tight barrel/endcap geometry and low structural mass yield good resolution on missing E_T
  Trost & Kirk (in progress)
- **Compensation**
  EM and hadron energy have equal response (e/h=1.0); helps the jet energy resolution due to fragmentation fluctuations
  Gabriel, et al.
- **Safety**
  safety hazards associated with the tile/fiber technology are small and manageable
- **Cost**
  the tile/fiber calorimeter is cheaper...

but...

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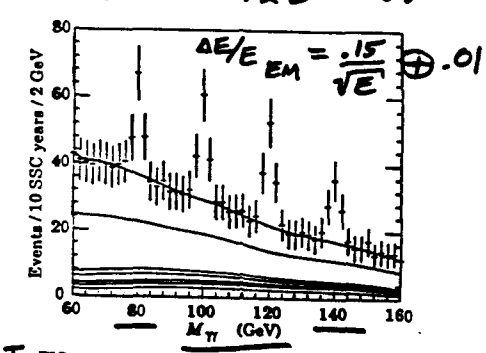
Physics capabilities

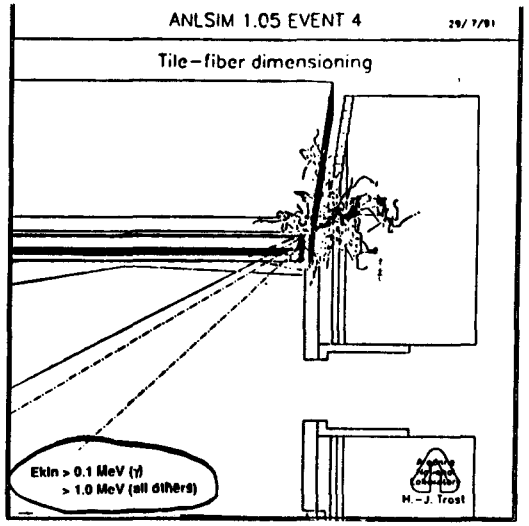
WH^0, $H^0 \to \gamma\gamma$, $W \to l\nu$



LoI FIG. 22. The $\gamma\gamma$ invariant mass distribution for the process $W + H \to l\nu\gamma\gamma$, including all backgrounds. The signal contains peaks from $M_H = 80, 100, 120, 140$ GeV. The lepton and photons were all required to satisfy $p_t > 20$ GeV/c, and to be separated in η-ϕ space by a distance of 0.4. A jet misidentification probability of 5×10^{-4} was assumed in plotting the QCD backgrounds. An isolation cut reduces the b backgrounds by a factor 10. The background curves are cumulative, and are (from lowest to highest): 3-*jet*, 2-*jet* + γ, *jet* + $\gamma\gamma$ combined, then $b + \gamma\gamma$, $b + \gamma$ + *jet*, $b\bar{b} + \gamma$, followed by W + *jets*, $W + \gamma$ + *jet* and $W + \gamma\gamma$.

Tough Challenge!

10GeV π



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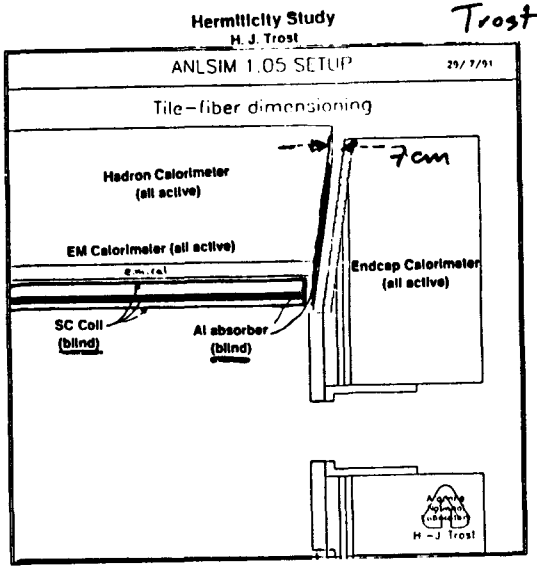
Hermiticity Test
Trost & Kirk
(in progress)



Green:
LoI Tile/Fib.
Geom.

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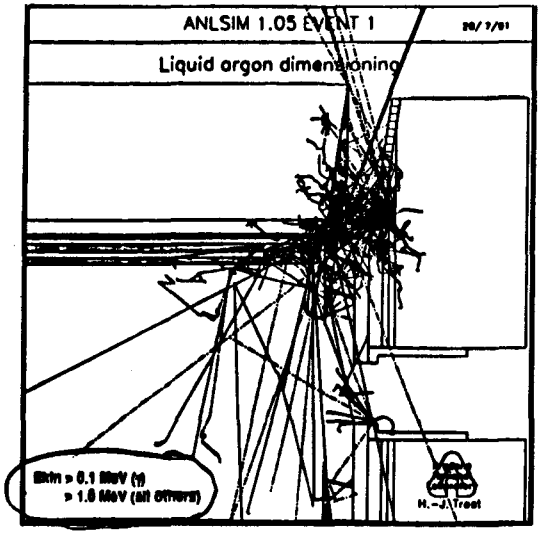
10 GeV π



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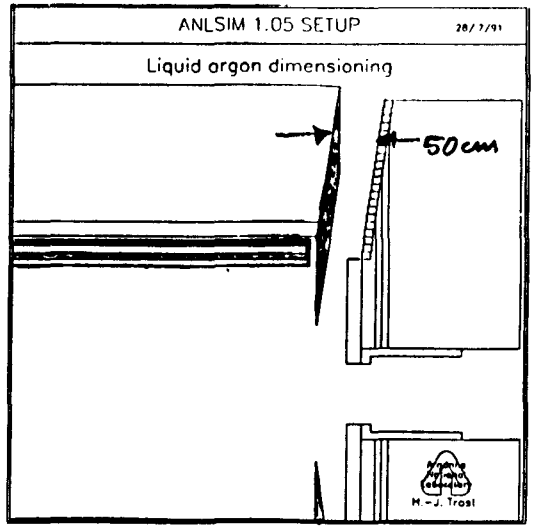

Red:
LoI LAr
Geom.

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Energy Resolution in Active Calorim
@ 10 GeV π

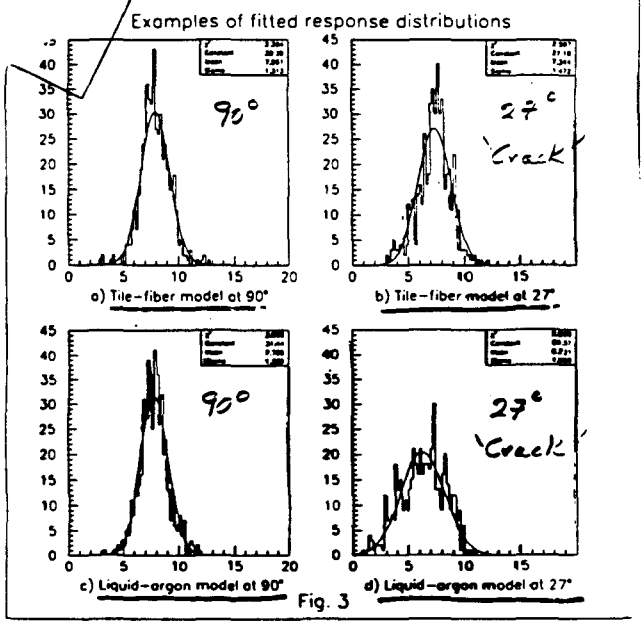


Fig. 3

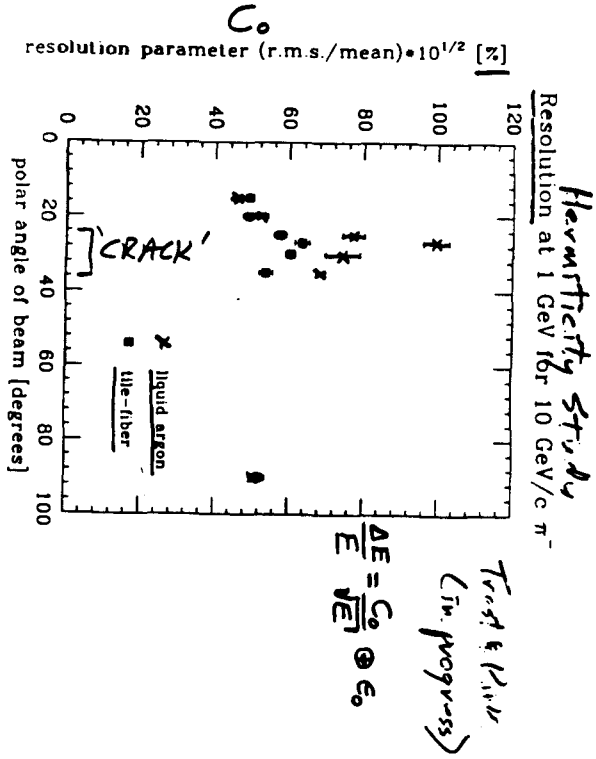


Fig. 6

Tile/Fiber Calorimeter Questions

- **Will it survive the radiation damage? How about 10 years @ 10^{34}??**

  (*lots* of talks here on this subject!)

- **Will the light yield and tile uniformity allow the intrinsic energy resolution to be achieved?**

  (Jim Freeman & Jim Proudfoot's talks)

- **Will the Pb calorimeter stand up? For 10 years??**

  (Vic Guarino's talk)

- **Is the cost estimate reliable?**

  (Dave Scherbarth's talk)

Tile/Fiber Calorimeter Downscoping

Baseline Cost: $132.5M
Baseline
747K Tiles
+ 117K SMDs

Two levels of downscoping were considered

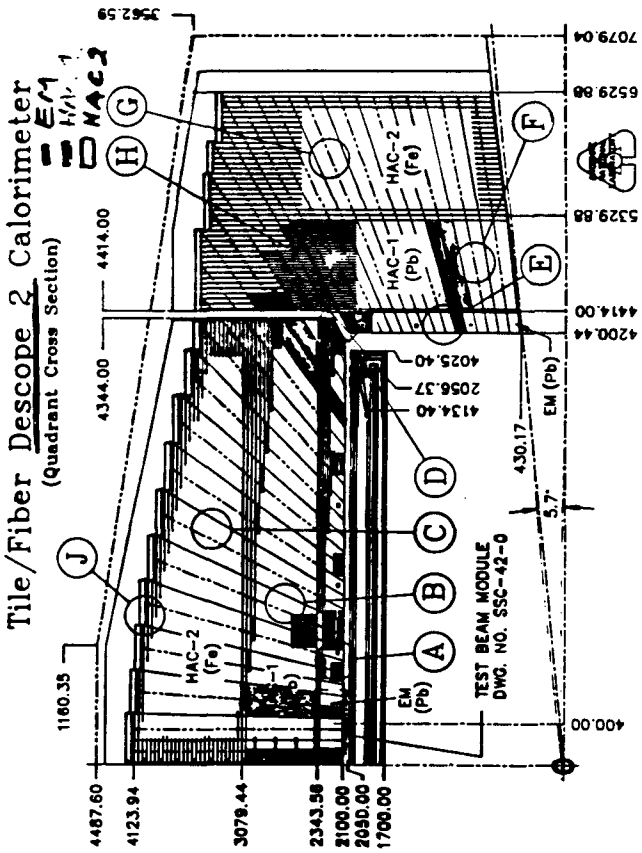
Dollar reduction goals from June '91 SDC Meet. were:
- Level 1 downscope ↔ Descope 1, Descope 2 (~$150M)
- Level 2 downscope ↔ Descope 3 (~$120M)

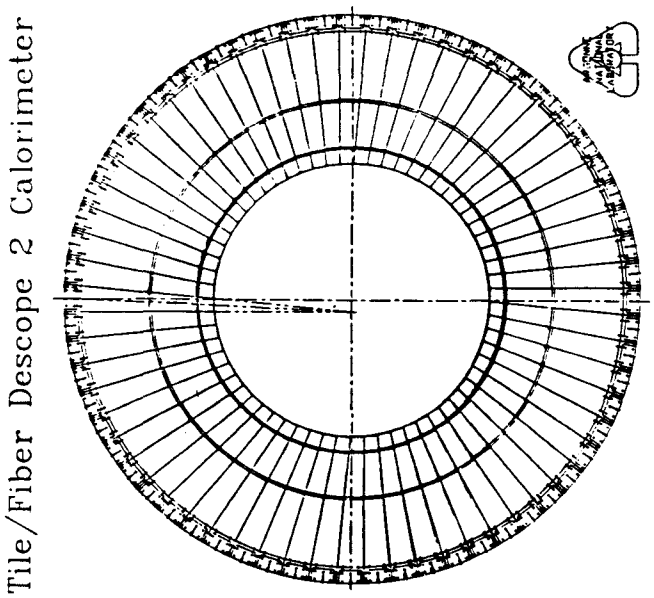
- **Descope 1** (est cost = 129 M) 368K Tiles 30K SMDs
  - same geometrical size and absorbtion as Baseline
  - x2 reduction in HAC1, HAC2 longitudinal sampling
  - HAC2 has $\Delta\eta\Delta\phi = 0.1 \times 0.1$
  - x2 reduction in SMD tile count
  - one EM readout channel

- **Descope 2** (est cost = 130 M) 282K Tiles 60K SMDs
  - same geometrical size and absorbtion as Baseline
  - x2 reduction in HAC2 longitudinal sampling
  - HAC1, HAC2 have $\Delta\eta\Delta\phi = 0.1 \times 0.1$
  - x2 reduction in SMD tile count

- **Descope 3** (est cost = 127 M) 282K Tiles 60K SMDs
  - same longitudinal & transverse granularity as Desoope2
  - same absorbtion thickness as Baseline
  - R_{inner} = 1.9m (down from 2.1m)
  - L_{inner} = 3.9m (down from 4.2m)

Comments:
Descope 2 has few serious performance compromises;
Descope 3 has not been well studied at this point in time





Tile/Fiber Central Calorimeter
Descope Model Definitions
Version: August 5, 1991

Parameter	Baseline	Descope 1	Descope 2	Descope 3
Barrel I.R. (m)	2.1	2.1	2.1	1.9
Endcap Front (m)	4.2	4.2	4.2	3.7
Solid Outer Steel	Yes	No	No	No
Depth @ $\eta = 0$	10λ	10λ	10λ	10λ
Depth @ $\eta = 3$	12λ	12λ	12λ	12λ
EM				
Long. Chan./Tower	2	1	2	2
Long. Gran. (cm)	1	1	1	1
Trans. Gran.	.05 x .05	.05 x .05	.05 x .05	.05 x .05
Shower Max [a]				
Layer 1 $\Delta\phi$	.05	.05	.05	.05
Layer 1 $\Delta\eta$	.0125	.0125	.0125	.0125
Layer 2 $\Delta\phi$	.00625	N/A	.00625	.00625
Layer 2 $\Delta\eta$	.05	N/A	.05	.05
Tiles/Tower (Aver.)	12	4	6	6
HAC1				
Long Gran. (cm)	2	4	2	2
Trans. Gran. ($\Delta\eta\Delta\phi$)	.05 x .05	.05 x .05	.1 x .1	.1 x .1
HAC2				
Long Gran. (cm)	4	8	8	8
Trans. Gran. ($\Delta\eta\Delta\phi$)	.05 x .05	.1 x .1	.1 x .1	.1 x .1

Characteristics common to all models here:

EM and HAC1 absorber is cast lead with stainless steel reinforcement.
HAC2 absorber is bolted steel plates.

[a] CEN Saclay has a slightly different model & tile count ...

Tile/Fiber Calorimeter
Options

- **Pb/Fe Boundary in HAC Section**
  - pure Fe option may fail the LoI hadron energy-resolution performance criterion
  - thinner Pb HAC1, thicker Fe HAC2 moves away from the performance optimum
  - thicker Pb HAC1, thinner Fe HAC2 raises cost, suffers B-flux return problem and gives small resolution gains
  - more Fe, less Pb may result in somewhat lower cost (not yet comparatively studied)

- **Finer Sampling in EM Calorimeter**
  - below $1.0X_0$ plate thickness, cast lead must yield to lead plates with Al or steel skins for mechanical strength (CDF approach)
  - $0.5\ X_0$ EM plates will yield a 30% improvement in the stochastic energy resolution term ($0.18/\sqrt{E} \rightarrow 0.13/\sqrt{E}$)
  - no clear physics case demands this resolution
  - the cost will be higher than the Baseline EM design
  - but better is better...

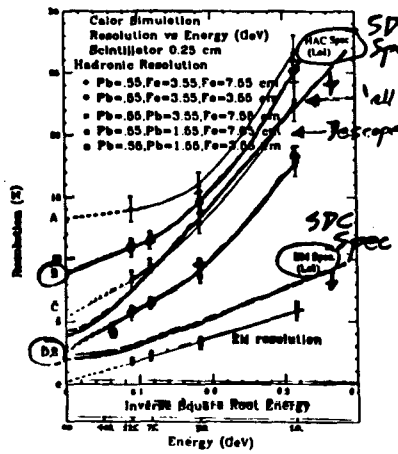
Comment:
The options within the Tile/Fiber regime will require a bit more study to arrive at an optimum solution.

MECHANICAL DESIGN OF LEAD AND STEEL PLATE CALORIMETER

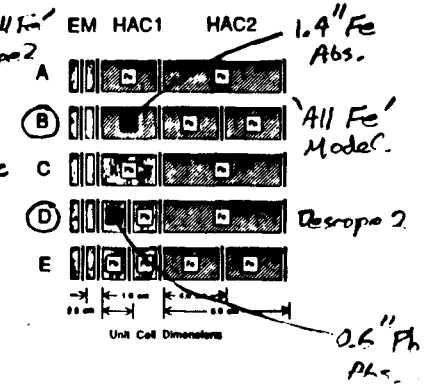
VICTOR GUARINO
ARGONNE NATIONAL LABORATORY
AUGUST 5, 1991

"Which Passive Absorber?"

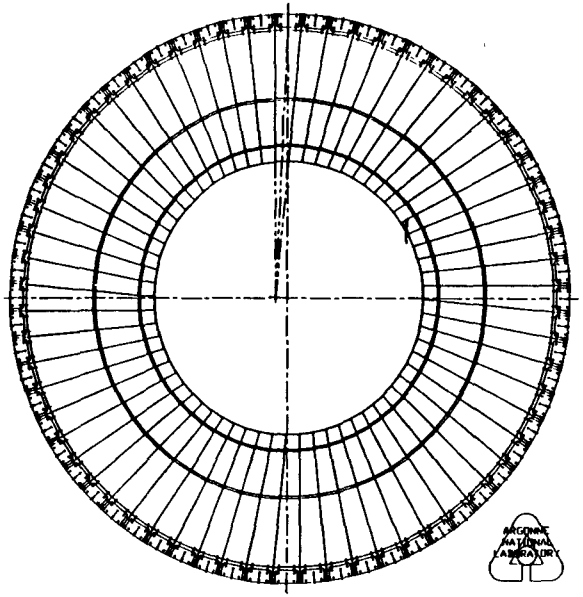
Handler, Tal, et al.
(Current Work)



Tile/Fiber Calorimeter
Energy Resolution Simulations
Pb and Fe Absorbers

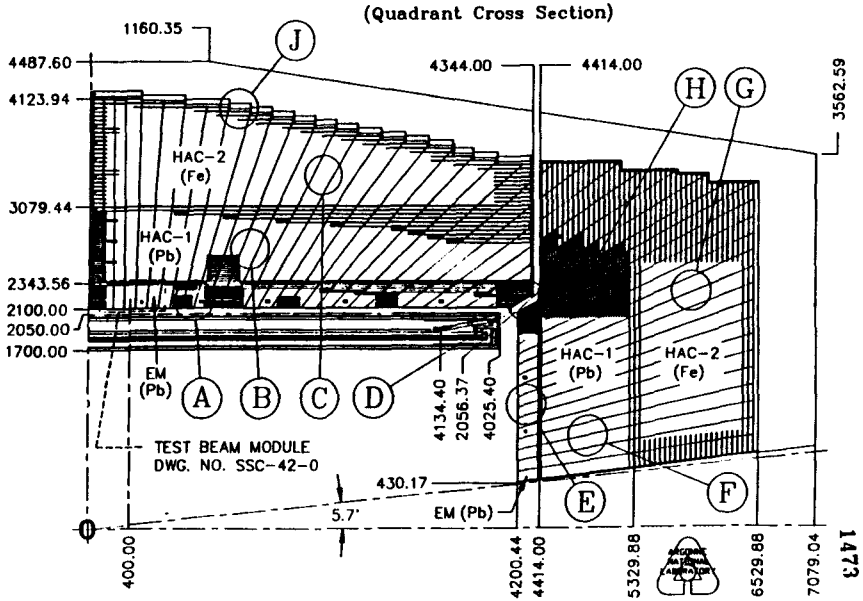


Tile/Fiber Descope 2 Calorimeter



Tile/Fiber Baseline Calorimeter

(Quadrant Cross Section)



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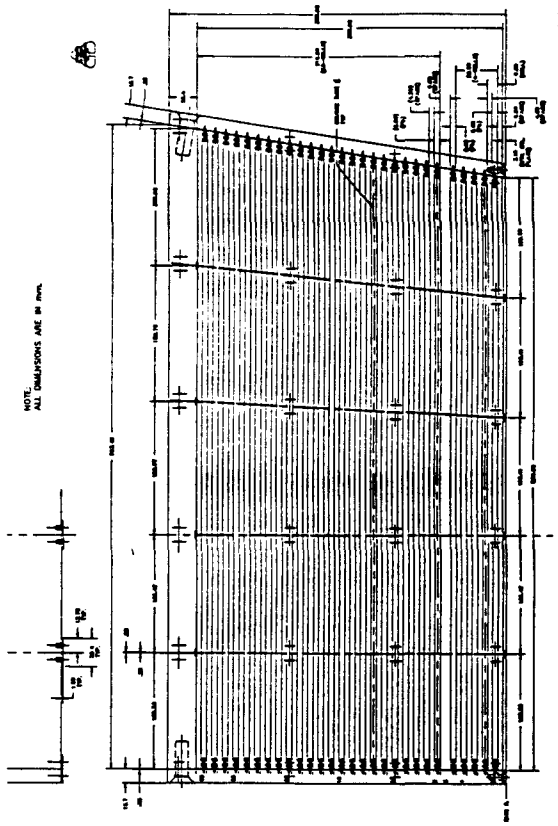
LEAD AND STEEL PLATE CALORIMETER DETAILS

A - Barrel EM structure
B - Barrel HAC1 structure
C - Barrel HAC2 structure
D - Barrel/end cap transition
E - End cap EM structure
F - End cap HAC1 structure
G - End cap HAC2 structure
H - End cap magnetic/coil forces geometry
J - Support channel - module

1475



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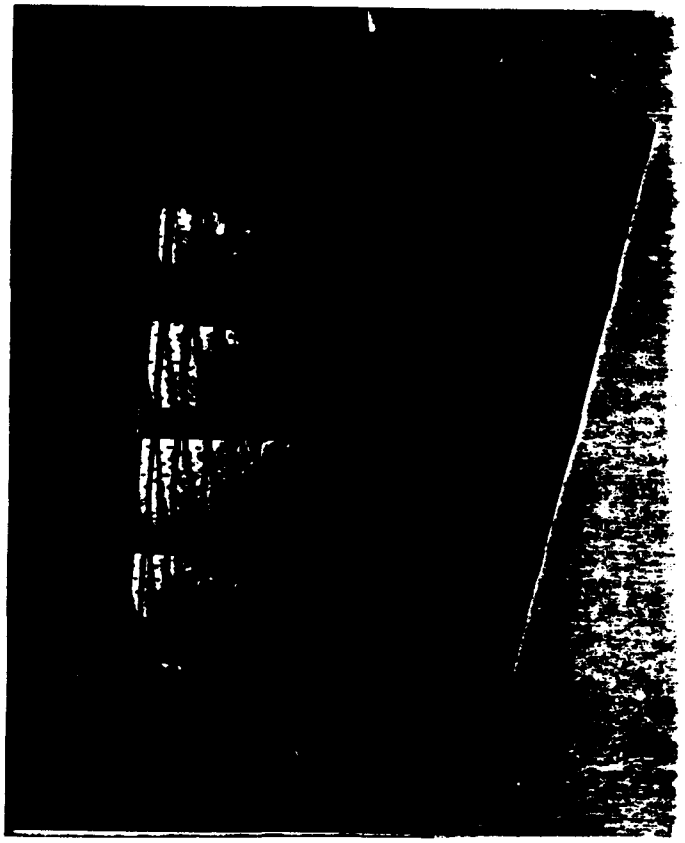

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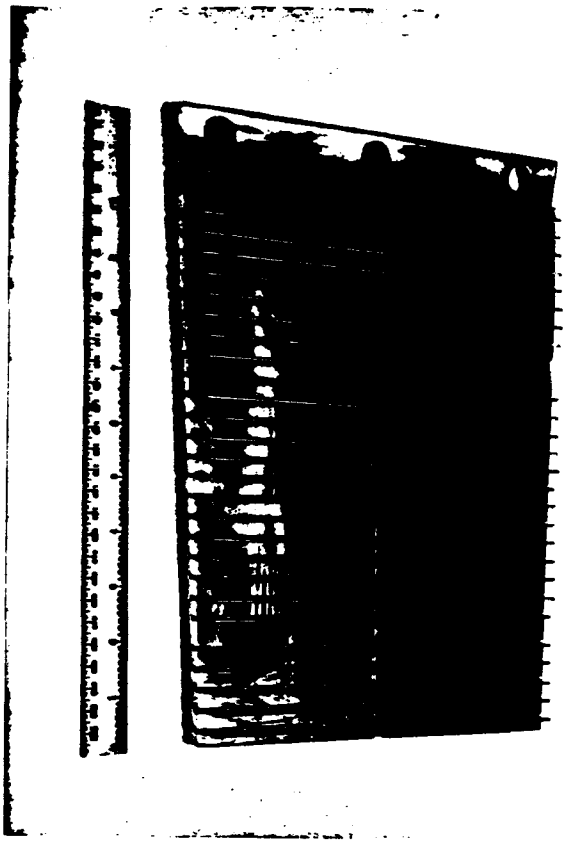
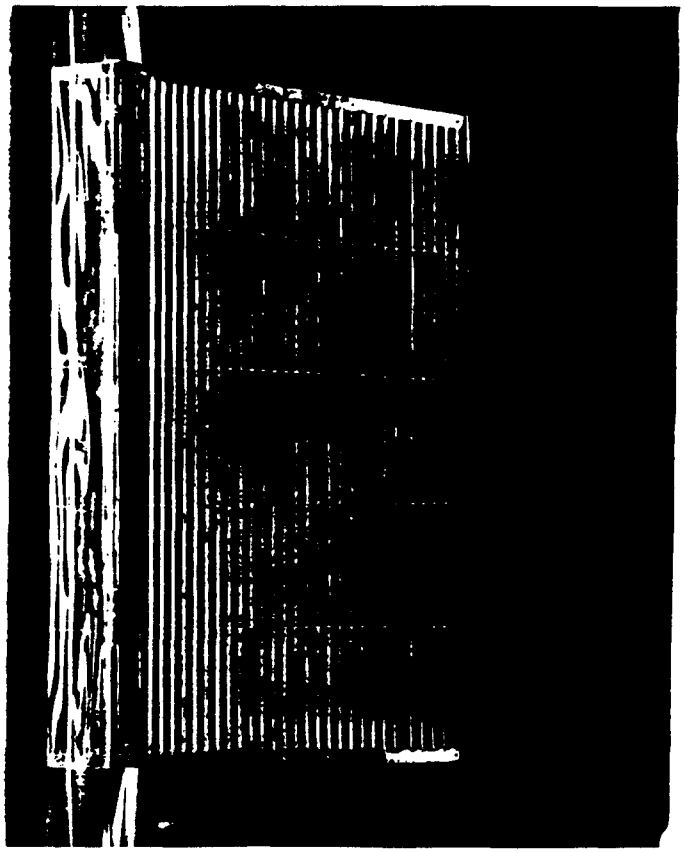


1478

1479



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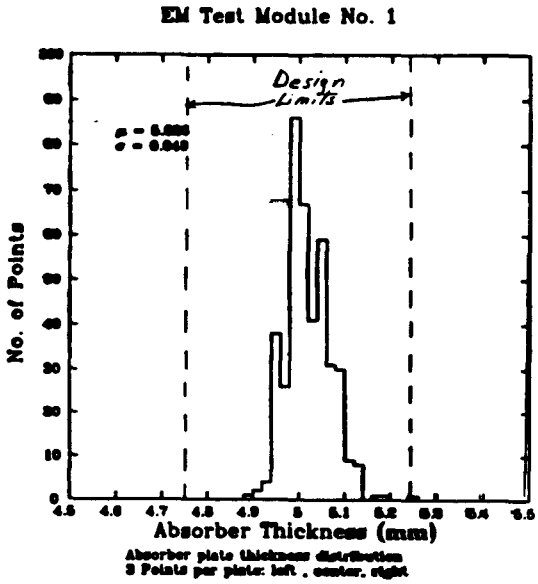

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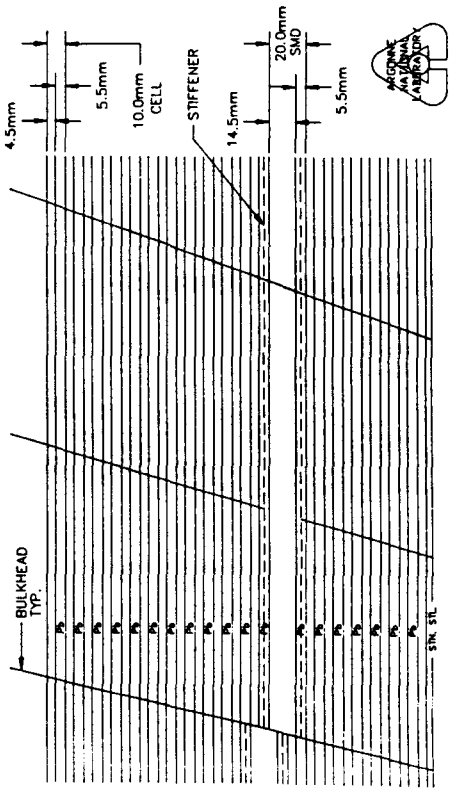


Ⓐ Barrel EM Structure

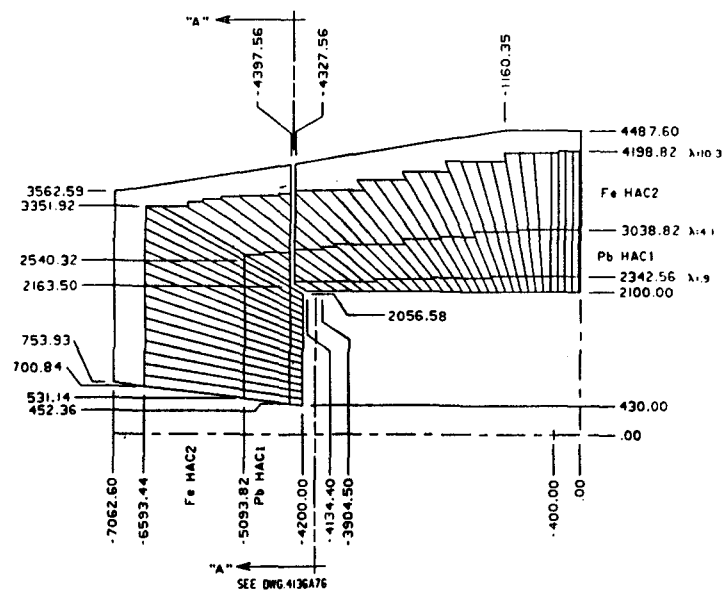
SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
SCINTILLATOR TILE QUANTITY

	TILE QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	128,512	34,560	163,072
SMD	86,016	34,560	120,576
HAC1	196,608	121,472	318,080
HAC2	140,288	163,136	303,424
TDTAL	551,424	353,728	905,152

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
PHOTOMULTIPLIER TUBE (PMT) QUANTITY

	PMT QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	14,336	5,740	20,096
SMD	1,344	540	1,884
HAC1	7,168	3,904	11,072
HAC2	6,400	4,928	11,328
TOTAL	29,248	15,132	44,380

LEAD IRON CALORIMETER
DETAIL ELEVATION



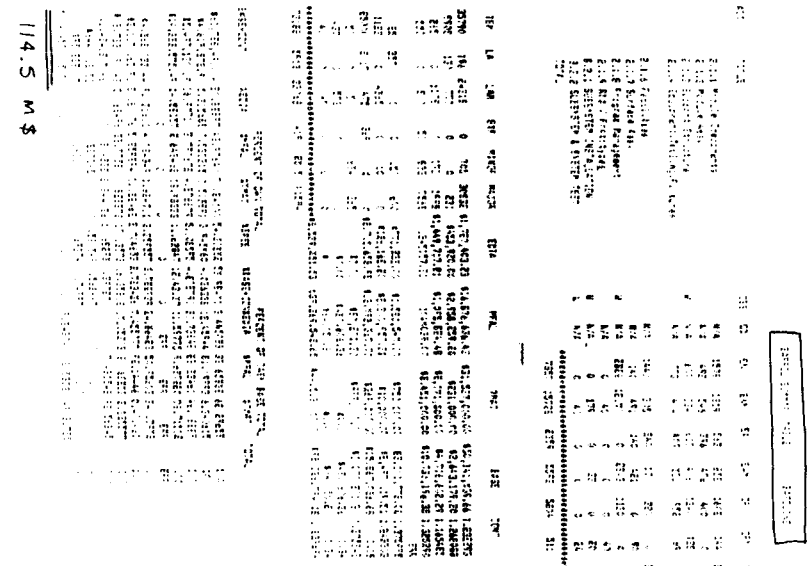
D.389.4136A73.R5
DIM. IN MILLIMETERS
SCALE .02:1.00
KEPES 5-10-91

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
BARREL (WBS NO. 2.1) COMPONENT MATERIALS

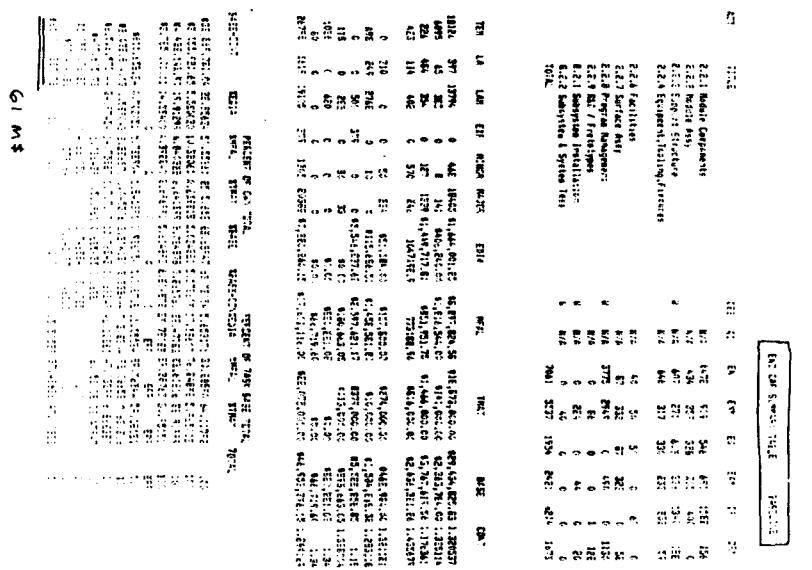
MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	165.4831	88.560384	254.043
Mass (kg)	0	0	0	1,299,042	695,199	1,994,241
Stainless Steel						
Volume (m^3)	2.6675	0	6.338	0	0	9.0055
Mass (kg)	20,940	0	49,753	0	0	70,693
Scintillator						
Volume (m^3)	4.9487	0.4498	9.8109	11.6537	0	26.8631
Mass (kg)	5,206	473	10,321	12,260	0	28,260
Lead						
Volume (m^3)	10.3922	0	60.8277	0	0	71.2199
Mass (kg)	117,941	0	690,334	0	0	808,275
Void & Wrap						
Volume (m^3)	3.9589	0.36	7.8487	9.323	0	21.4905
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	21.9673	0.8098	84.8253	186.4598	88.560384	382.6227
Mass (kg)	144,087	473	750,408	1,311,302	695,199	2,901,469
Mass (tons)						3,192
Mass (tonnes)						2,901

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
END CAP (BOTH ENDS, WBS 2.2) COMPONENT MATERIALS

MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	114.638	72.47098	187.109
Mass (kg)	0	0	0	899,909	568,897	1,468,806
Stainless Steel						
Volume (m^3)	0.671711	0	2.647	0	0	3.3187
Mass (kg)	5,273	0	20,779	0	0	26,052
Scintillator						
Volume (m^3)	0.775542	0.12926	3.64306	8.0731	0	12.62096
Mass (kg)	815.87	135.98	3,832	8,493	0	13276.9
Lead						
Volume (m^3)	2.985837	0	21.354	0	0	24.3398
Mass (kg)	33,886	0	242,346	0	0	276,232
Void & Wrap						
Volume (m^3)	0.620434	0.10341	2.914448	6.458481	0	10.09677
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	5.053524	0.23267	30.559	129.17	72.47098	237.486
Mass (kg)	39,975	135.98	266,957	908,402	568,897	1,784,367
Mass (tons)						1,963
Mass (tonnes)						1,784



114.5 M$



61 M$

CALORIMETER COST SUMMARY

ITEM		COST ($) (BASE + CONTINGENCY)
EMC		23,068,404
HAC1		24,358,919
HAC2		35,730,060
SH. MAX.		9,841,568
OUTER STEEL		10,795,565
SCINT. TOOLING		8,372,000
PMT TOOLING		290,586
MODULE ASSY, TEST, SHIP		10,861,798
CALORIMETER SUPPORT		9,929,273
FACILITY CONSTRUCTION		4,879,691
SURFACE ASSY & INST.		10,197,018
FACILITY MNG.		13,675,135
SCINT.	$11,431,819	
MODULE ASSY.	$1,170,088	
LEAD CASTING	$1,073,228	
PROGRAM MNG.		11,564,925
PROTOTYPE		1,892,423
TOTAL		$ 175,457,365

CALORIMETER COST SUMMARY

ITEM	COST ($) BASE + CONTINGENCY
SCINTILLATORS	52,784,813
MODULE ABSORBER STRUCTURE	40,991,488
PHOTOMULTIPLIER TUBES	24,217,106
OUTER STEEL	10,795,565
MODULE ASSY, SHIP, + AUXILARY COMPONENTS	13,084,754
CALORIMETER SUPPORT	9,929,273
SURFACE ASSY. AND INST.	10,197,018
PROGRAM MNG.	11,564,925
PROTOTYPE.	1,892,453
TOTAL	$ 175,457,395

LEAD/IRON SCINTILLATING CALORIMETER

SCINTILLATOR COST SUMMARY

CONSTRUCT. SCINTILLATOR ASSYS.	
EMC	4,440,981
SMD	2,342,134
H1	7,977,861
H2	9,059,359
INSERT SCINTILLATORS INTO MODULE	
EMC	1,682,504
SMD	981,895
H1	1,498,344
H2	1,791,094
TOOLING	8,372,000
FACILITY CONSTRUCTION	3,206,823
FACILITY MANAGEMENT	11,431,819
TOTAL	52,784,813

Scaling procedure for converting barrel calorimeter cost estimates to end cap calorimeter cost estimates:

In scaling barrel cost estimates to the end cap, the quantities of engineering, engineering assistant, and drafting manpower were left unchanged. Technician and laborer manpower, as well as material expenditures, were scaled per a scaling factors calculated for the various wbs elements. Scaling factors are typically based on such material quantities as weight, tile quantity, module quantity, etc. The attached table has a detailed breakdown of all scaling factors used. All technician, laborer, and material expenditures were scaled except those that were relatively small. Resource blocks containing 10 man-days or less, or 10 k$ or less, were not scaled downward, but instead were left unchanged.

July 3, 1991

7-3-91
DWS
3 OF 4

WBS #	TITLE	SCALING PARAMETER	END CAP QTY	BRL. QTY.	SCALE FACTOR EC/BRL
2 * 26	NITRO. PURGE ASSY	MODULE QTY	64	128	.5
2 * 27	CALIBRATION TST. & ASSY.	MODULE QTY	64	128	.5
2 * 28	SHIP CONTAIN ASSY	MODULE QTY	64	128	.5
2 * 3	CALORIMETER SUPPORT	NUMBER OF SUPPORT PTS.	12	18	.67
2 * 41	MODULE STRUC. TOOLING	CALORIMETER MASS	3,858,118 lbs	6,321,054 lbs	.61
2 * 44	MODULE ASSY TOOLING	CALORIMETER MASS	3,858,118 lbs	6,321,059 lbs	.61
2 * 45	ERECTION TOOLING	"	"	"	"
2 * 62	MODULE ASSY FACILITY	"	"	"	"
2 * 7	SURFACE ASSY	"	"	"	"
2 * 81	PPGM MNG. DESIGN REV.				1
2 * 82	SCHED. REV.				1
2 * 83	REPORTS				1
2 * 84	COORDINATION				1

* 1 FOR BARREL, 2 FOR END CAP

7-3-91
DWS
1 OF 4

WBS #	TITLE	SCALING PARAMETER	END CAP QTY	BRL. QTY.	SCALE FACTOR EC/BRL
2 * 111	EM MODULE STRUCTURE	MASS	86,150 lbs.	305,538 lbs	.28
2 * 112	HAC1 MODULE STRUCTURE	MASS	540,595 lbs	1,628,191 lbs.	.33
2 * 113	HAC2 MODULE STRUCTURE	MASS	1,979,800 lbs	2,857,892 lbs	.69
2 * 114	OUTER SUPPORT STEEL	MASS	1,251,573 lbs	1,529,437 lbs	.82
2 * 11153	ASSEMBLE FULL MODULE STRUCT.	MASS	3,858,118 lbs.	6,321,059 lbs	.61
2 * 121	EM SCINT ASSYS.	TILE QTY.	34,560	127,512	.27
2 * 122	SPD SCINT ASSYS.	TILE QTY.	34,560	86,016	.40
2 * 123	HAC1 SCINT. ASSYS.	TILE QTY.	121,472	196,608	.62
2 * 124	HAC2 SCINT. ASSYS.	TILE QTY	163,136	140,288	1.16
2 * 13	PHOTOTUBE ASSYS (ALL)	PMT QTY	15,132	29,248	.52
2 * 131	EM SECTION PMT ASSYS.	PMT QTY	5760	14,336	.40 (.52 USED IN 7-1-91 COST)

* = 1 FOR BARREL, 2 FOR END CAP

7-3-91
DWS
4 OF 4

WBS #	TITLE	SCALING PARAMETER	END CAP QTY	BRL. QTY.	SCALE FACTOR EC/BRL
2 * 25	SYSTEMS INTEG.				1
2 * 261	SCINT FAC. MNG.				0
2 * 262	MODULE FAC. MNG.	CALORIMETER MASS			.62
2 * 263	LEAD CASTING FAC. MNG.	CALOR. MASS			.62
2 * 87	QA	CALOR. MASS			.62
2 * 88	SAFETY	CALOR. MASS			.62

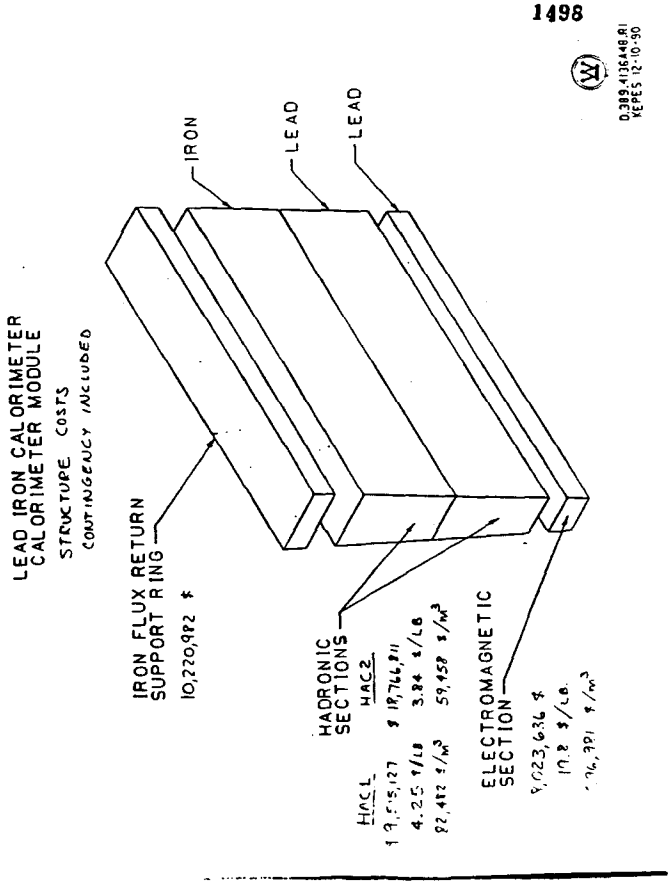
* = 1 FOR BARREL, 2 FOR END CAP.

7-3-91
DWS
2 OF 4

WBS #	TITLE	SCALING PARAMETER	END CAP QTY	BRL. QTY.	SCALE FACTOR EC/BRL
2 * 132	SPD SECTION PMT ASSYS	PMT QTY	540	1344	.40 (.52 USED 7-1-91)
2 * 133	HAC1 PMT ASSYS.	PMT QTY	3904	7168	.54 (.52 USED 7-1-91)
2 * 134	HAC2 PMT ASSYS.	PMT QTY.	4928	6400	.77 (.52 USED 7-1-91)
2 * 14	NITROGEN PURGE	NUMBER OF MODULES	64	128	.5
2 * 15	CALIBRATION & TEST	NUMBER OF MODULES	64	128	.5
2 * 1A	ELECTRONIC CRATE BRACKET	NUMBER OF MODULES	64	128	.5
2 * 211	EM SCINT. INSERTION	NUMBER OF CHANNELS	5760	14,336	.40
2 * 212	SPD SCINT INSERTION	NUMBER OF CHANNELS	540	1344	.40
2 * 213	HAC1 SCINT INSERTION	TILE QTY.	121,472	196,608	.62
2 * 214	HAC2 SCINT INSERTION	TILE QTY.	163,136	140,288	1.16
2 * 25	MODULE DIMEN. TEST	MODULE QTY	64	128	.50

* = 1 FOR BARREL, 2 FOR END CAP

1498



1499

DESCOPE DEFINITIONS
FOR CENTRAL CALORIMETRY

PARAMETER	BASELINE	DESCOPE 1	DESCOPE 2	DESCOPE 3
BARREL I.R. (m)	2.1	2.1	2.1	1.9
END CAP FRONT (m)	4.2	4.2	4.2	3.7
SOLID OUTER STEEL	YES	NO	NO	NO
DEPTH @ $\eta = 0$	10λ	10λ	10λ	10λ
DEPTH @ $\eta = 3$	12λ	12λ	12λ	12λ
EMC				
LONG. CHAN./TOWER	2	1	2	2
LONG. GRAN. (cm)	1	1	1	1
TRANS. GRAN.	.05 x .05	.05 x .05	.05 x .05	.05 x .05
SHOWER MAX				
LAYER 1 $\Delta\phi$	.05	.05	.1	.1
LAYER 1 $\Delta\eta$	.0125	.0125	.0125	.0125
LAYER 2 $\Delta\phi$	.00625	N/A	.00625	.00625
LAYER 2 $\Delta\eta$	.05	N/A	.1	.1
TILES/TOWER	12	4	6	6
HAC1				
LONG. GRAN. (cm.)	2	4	2	2
TRANS. GRAN. (η x ϕ)	.05 x .05	.05 x .05	.1 x .1	.1 x .1
HAC2				
LONG. GRN. (cm.)	4	8	8	8
TRANS. GRAN.	.05 x .05	.1 x .1	.1 x .1	.1 x .1

1500

CENTRAL CALORIMETER COST (M$)

	BASELINE DESIGN	DESCOPE 1	DESCOPE 2	DESCOPE 3
BARREL				
BASE COST	92.3	68.3	68.6	66.9
CONTINGENCY	1.24	1.25	1.25	1.25
BASE + CONT.	114.5	85.1	85.4	83.7
END CAP				
BASE COST	47.0	34.1	34.6	33.6
CONTINGENCY	1.30	1.29	1.30	1.30
BASE + CONT.	61.0	44.2	44.6	43.7
TOTAL				
BASE COST	139.3	102.4	103.2	100.5
CONTINGENCY	1.26	1.26	1.26	1.27
BASE + CONT.	175.6	129.3	130.0	127.4

1501

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
SCINTILLATOR TILE QUANTITY
DESCOPE 1

COMPONENT	TILE QUANTITY		
	BARREL	END CAP	TOTAL
EMC	128,512	34,560	163,072
SMD	28,672	11,520	40,192
HAC1	98,304	60,736	159,040
HAC2	17,536	20,392	37,928
TOTAL	273,024	127,208	400,232

SDC SCINTILLATOR PLATE CALORIMETER - DESCOPE 1
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
END CAP (BOTH ENDS, WBS 2.2) COMPONENT MATERIALS

MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	114.638	0	114.638
Mass (kg)	0	0	0	899,909	0	899,909
Stainless Steel						
Volume (m^3)	0.671711	0	2.647	0	0	3.3187
Mass (kg)	5,273	0	20,779	0	0	26,052
Scintillator						
Volume (m^3)	0.775542	0.0646	1.822	4.037	0	6.699
Mass (kg)	815.87	67.99	1,916	4,247	0	7,047
Lead						
Volume (m^3)	2.985837	0	21.354	0	0	24.3398
Mass (kg)	33,886	0	242,346	0	0	276,232
Void & Wrap						
Volume (m^3)	0.620434	0.168	4.736	10.495	0	16.019
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	5.053524	0.23267	30.559	129.17	0	165.015
Mass (kg)	39,975	67.99	265,041	904,156	0	1,209,240
Mass (tons)						1,330
Mass (tonnes)						1,209

1504

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
SCINTILLATOR TILE QUANTITY
DESCOPE 2

	TILE QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	128,512	34,560	163,072
SMD	43,008	17,280	60,288
HAC1	49,152	30,368	79,520
HAC2	17,536	20,392	37,928
TOTAL	238,208	102,600	340,808

1505

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
PHOTOMULTIPLIER TUBE (PMT) QUANTITY
DESCOPE 1

	PMT QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC	7,168	2,880	10,048
SMD	448	180	628
HAC1	7,168	3,904	11,072
HAC2	1,600	1,232	2,832
TOTAL	16,384	8,196	24,580

1502

SDC SCINTILLATOR PLATE CALORIMETER - DESCOPE 1
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
BARREL (WBS NO. 2.1) COMPONENT MATERIALS

MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	165.4831	0	165.4831
Mass (kg)	0	0	0	1,299,042	0	1,299,042
Stainless Steel						
Volume (m^3)	2.6675	0	6.338	0	0	9.0055
Mass (kg)	20,940	0	49,753	0	0	70,693
Scintillator						
Volume (m^3)	4.9487	0.2249	4.905	5.827	0	15.9056
Mass (kg)	5,206	237	5,160	6,130	0	16,733
Lead						
Volume (m^3)	10.3922	0	60.8277	0	0	71.2199
Mass (kg)	117,941	0	690,334	0	0	808,275
Void & Wrap						
Volume (m^3)	3.9589	0.5849	12.7546	15.1497	0	32.4481
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	21.9673	0.8098	84.8253	186.4598	0	294.0622
Mass (kg)	144,087	237	745,247	1,305,172	0	2,194,743
Mass (tons)						2,414
Mass (tonnes)						2,195

1503

SDC SCINTILLATOR PLATE CALORIMETER - DESCOPE 2
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
END CAP (BOTH ENDS, WBS 2.2) COMPONENT MATERIALS

MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	114.638	0	114.638
Mass (kg)	0	0	0	899,909	0	899,909
Stainless Steel						
Volume (m^3)	0.671711	0	2.647	0	0	3.319
Mass (kg)	5,273	0	20,779	0	0	26,052
Scintillator						
Volume (m^3)	0.775542	0.12926	3.64306	4.037	0	8.585
Mass (kg)	815.87	135.98	3,832	4,247	0	9,031
Lead						
Volume (m^3)	2.985837	0	21.354	0	0	24.3398
Mass (kg)	33,886	0	242,346	0	0	276,232
Void & Wrap						
Volume (m^3)	0.620434	0.10341	2.914448	10.495	0	14.133
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	5.053524	0.23267	30.559	129.17	0	165.015
Mass (kg)	39,975	135.98	266,957	904,156	0	1,211,224
Mass (tons)						1,332
Mass (tonnes)						1,211

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
PHOTOMULTIPLIER TUBE (PMT) QUANTITY
DESCOPE 2

	PMT QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	14,336	5,760	20,096
SMD	672	270	942
HAC1	1,792	976	2,768
HAC2	1,600	1,232	2,832
TOTAL	18,400	8,238	26,638

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
SCINTILLATOR TILE QUANTITY
DESCOPE 3

	TILE QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	128,512	34,560	163,072
SMD	43,008	17,280	60,288
HAC1	49,152	30,368	79,520
HAC2	17,536	20,392	37,928
TOTAL	238,208	102,600	340,808

SDC SCINTILLATOR PLATE CALORIMETER - DESCOPE 2
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
BARREL (WBS NO. 2.1) COMPONENT MATERIALS

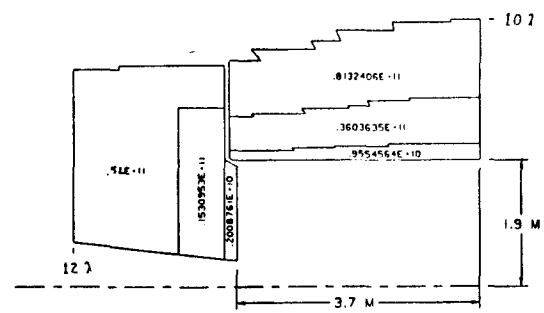
MATERIAL	EMC	SMD	HAC1	HAC2	O.S.S.	TOTAL
Carbon Steel						
Volume (m^3)	0	0	0	165.4831	0	165.48
Mass (kg)	0	0	0	1,299,042	0	1,299,042
Stainless Steel						
Volume (m^3)	2.6675	0	6.338	0	0	9.0055
Mass (kg)	20,940	0	49,753	0	0	70,693
Scintillator						
Volume (m^3)	4.9487	0.4498	9.8109	5.827	0	21.0364
Mass (kg)	5,206	473	10,321	6,130	0	22,130
Lead						
Volume (m^3)	10.3922	0	60.8277	0	0	71.2199
Mass (kg)	117,941	0	690,334	0	0	808,275
Void & Wrap						
Volume (m^3)	3.9589	0.36	7.8487	15.1497	0	27.3173
Mass (kg)	0	0	0	0	0	0
Total						
Volume (m^3)	21.9873	0.8098	84.8253	186.4598	0	294.06
Mass (kg)	144,087	473	750,408	1,305,172	0	2,200,140
Mass (tons)						2,420
Mass (tonnes)						2,200

SDC SCINTILLATOR PLATE CALORIMETER
LEAD/IRON ABSORBER
REF: WESTINGHOUSE DWG. D.389.4136A73.R5
PHOTOMULTIPLIER TUBE (PMT) QUANTITY
DESCOPE 3

	PMT QUANTITY		
COMPONENT	BARREL	END CAP	TOTAL
EMC (1&2)	14,336	5,760	20,096
SMD	672	270	942
HAC1	1,792	976	2,768
HAC2	1,600	1,232	2,832
TOTAL	18,400	8,238	26,638

LEAD IRON CALORIMETER
DETAIL ELEVATION
DESCOPE 3

15% VOLUME REDUCTION FROM DESCOPE 2



ROTATED VOLUME IN CUBIC MILLIMETERS

D.412 4136492.R1
DIM. IN MILLIMETERS
SCALE .02 1.0%
LAYERS 50-62
REPLS 11-2-91

SCALABLE RAW MATERIAL
IN DESCOPE 2

ITEM	QTY	UNIT $	TOTAL $
CARBON STEEL	4.8 x10⁶ LB.	.3 $/LB.	1,440,000
STAINLESS STEEL	212,839 LB.	1.65 $/LB	351,184
SCINTILLATING TILE	11,848 m²	200 $/m²	2,369,600
LEAD	2.39 x10⁶ LB.	.43 $/LB	1,026,000
TOTAL			5,187,000

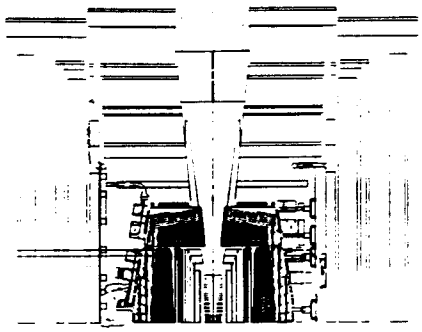
COST REDUCTION IN DESCOPE 3, RELATIVE TO DESCOPE 2, RAW MATL. ONLY;

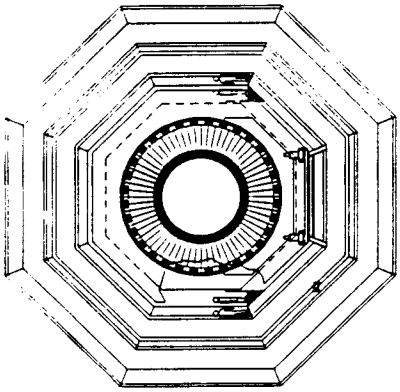
$\Delta S = (5,187,000)(.15) = \$778,000$

PB EM, FE HADRON ENGINEERING DESIGN

L. BARTOSZEK

1514





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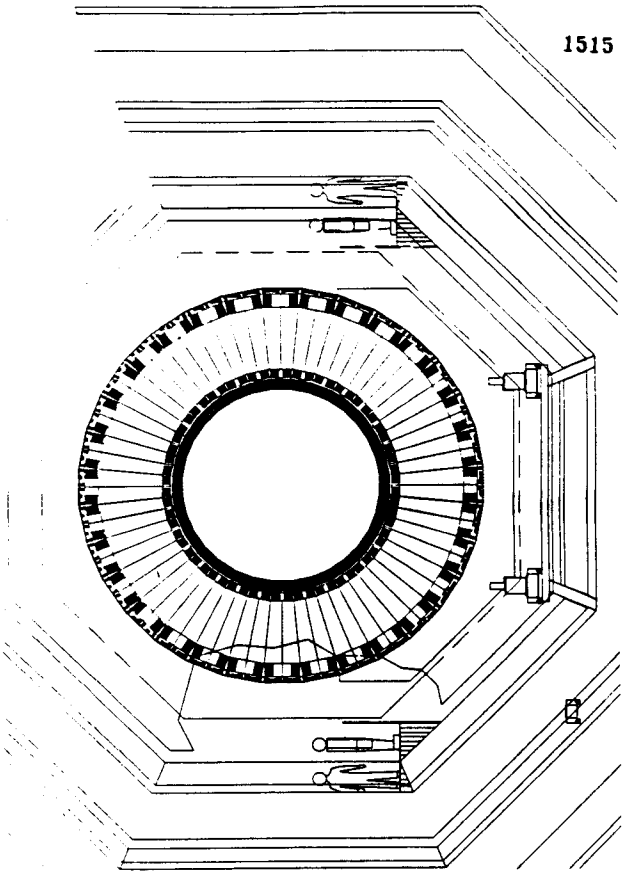

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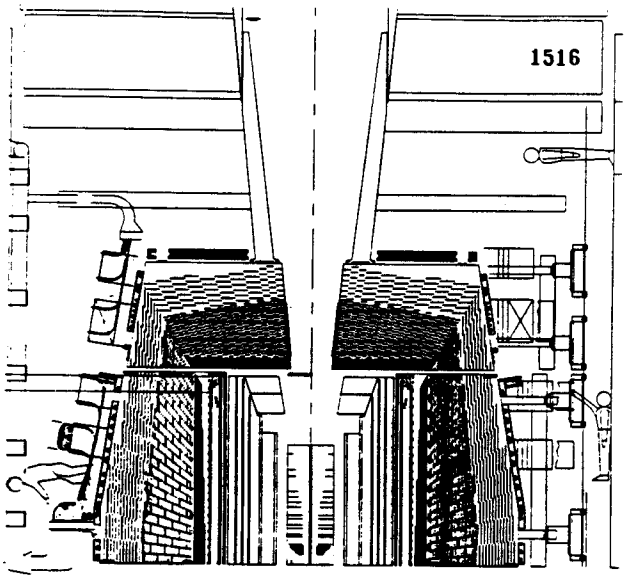

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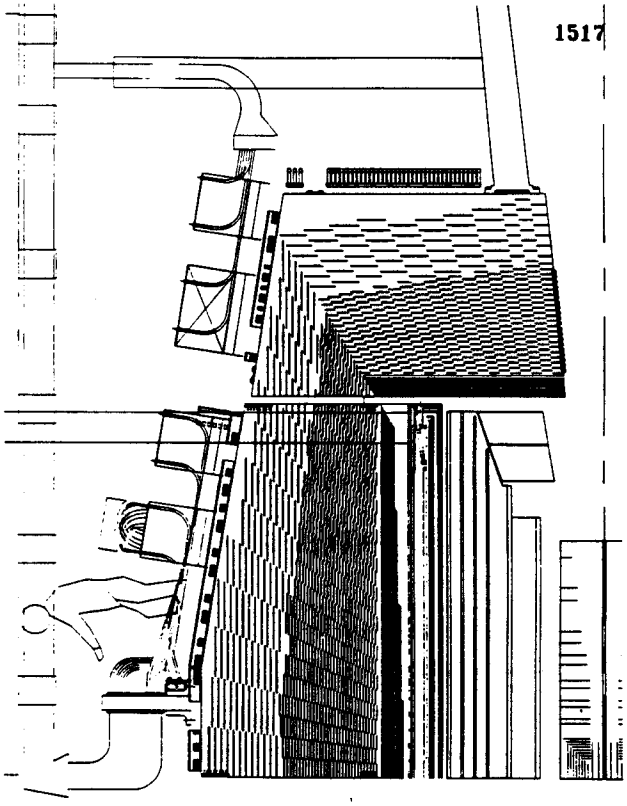

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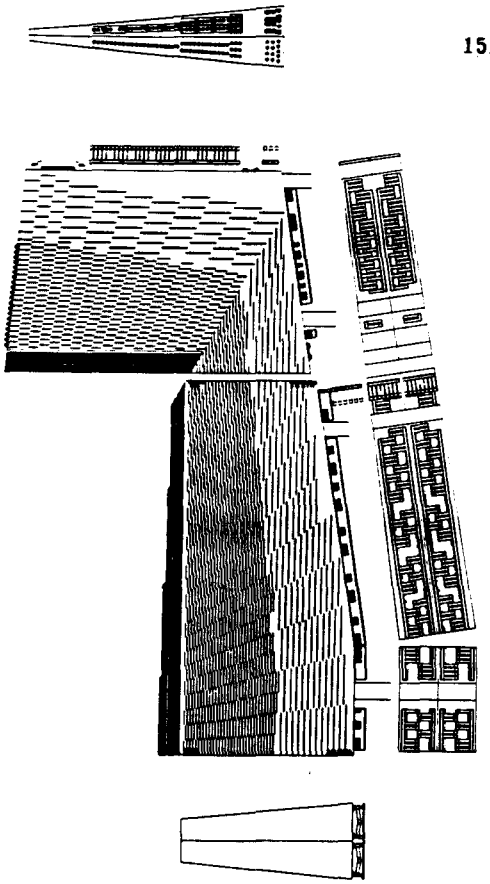

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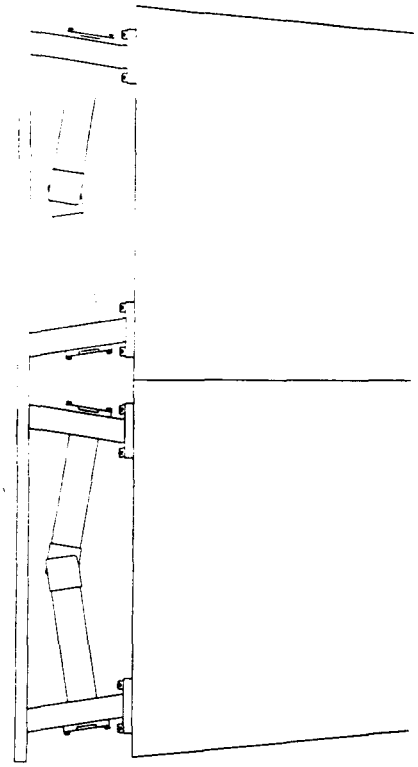

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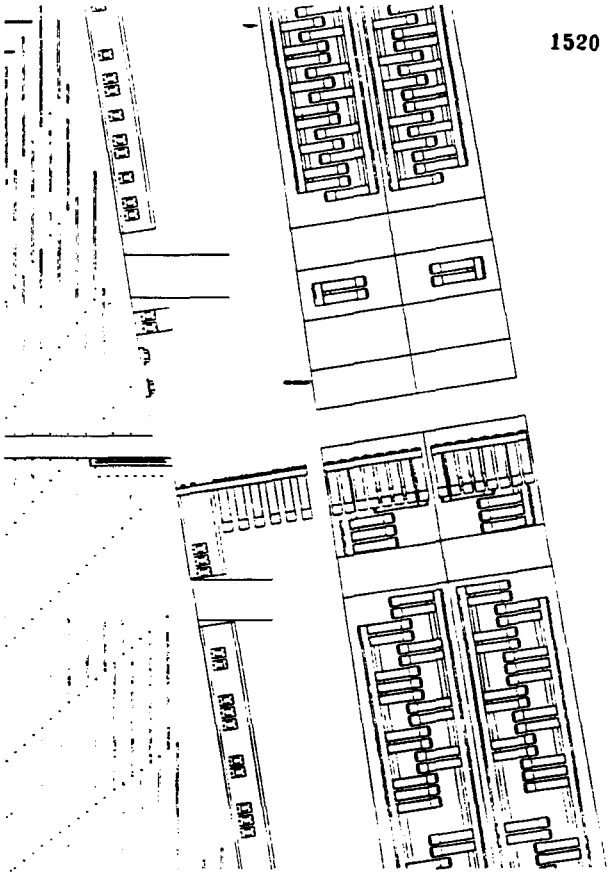

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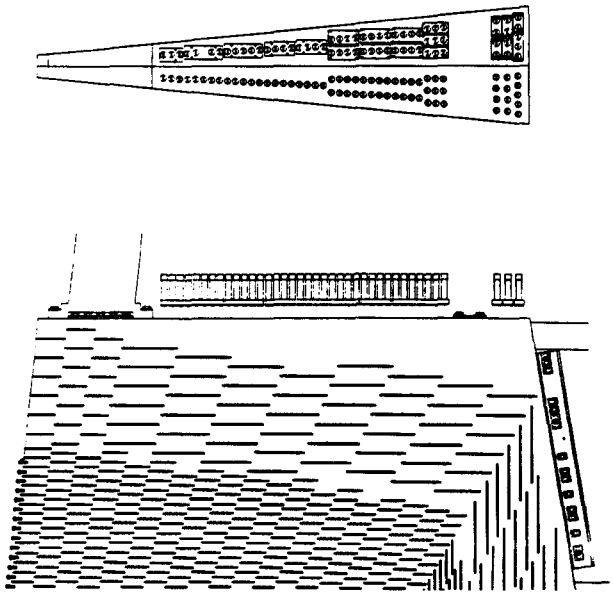

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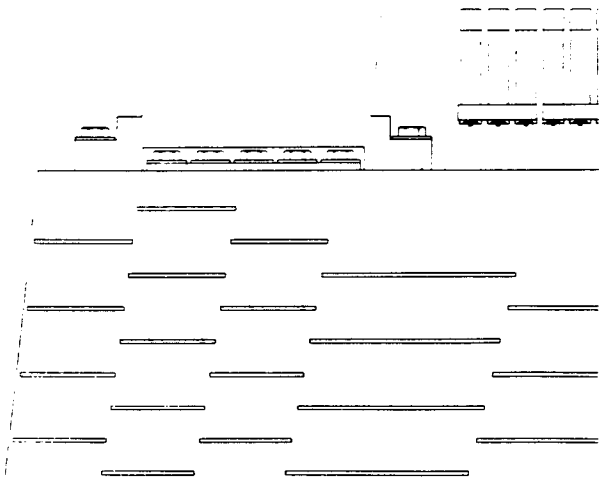

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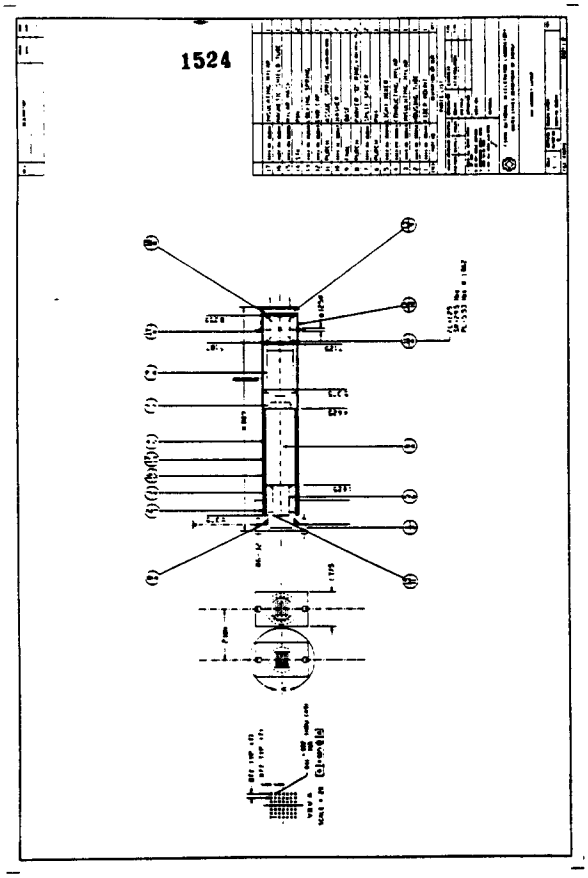

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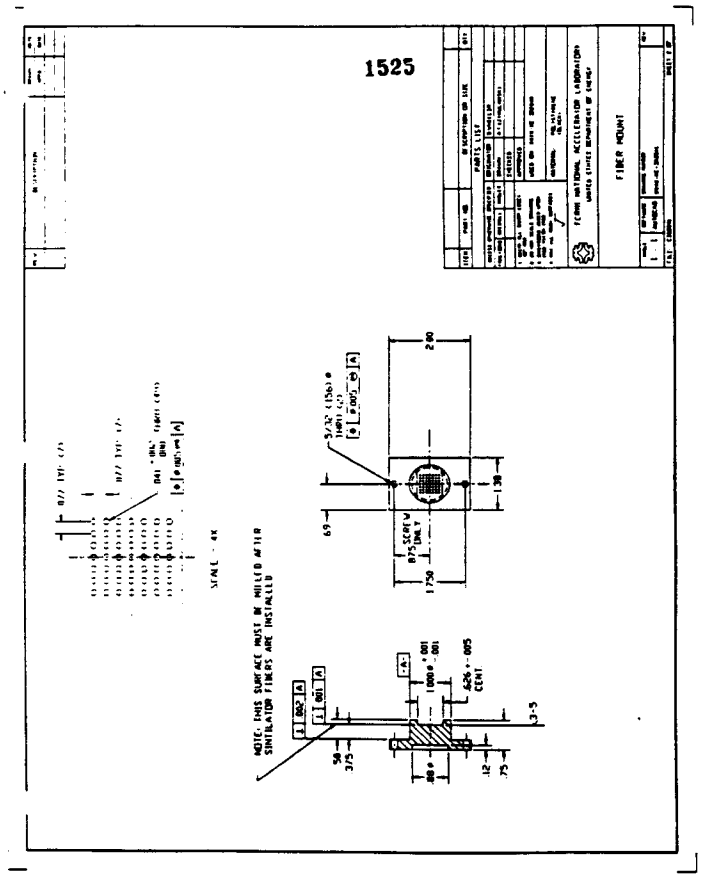

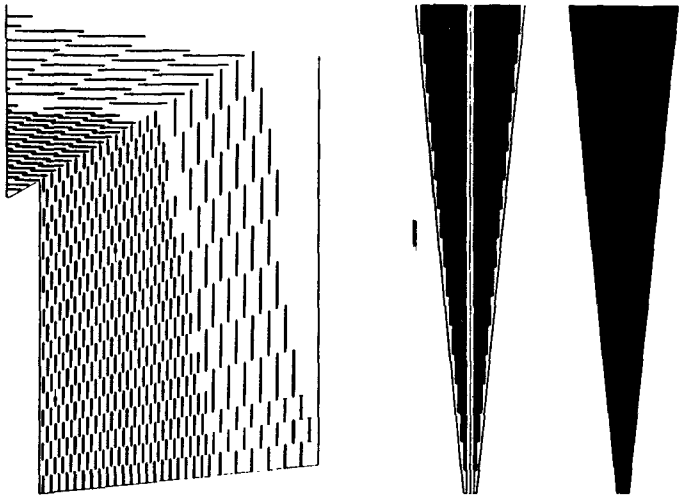

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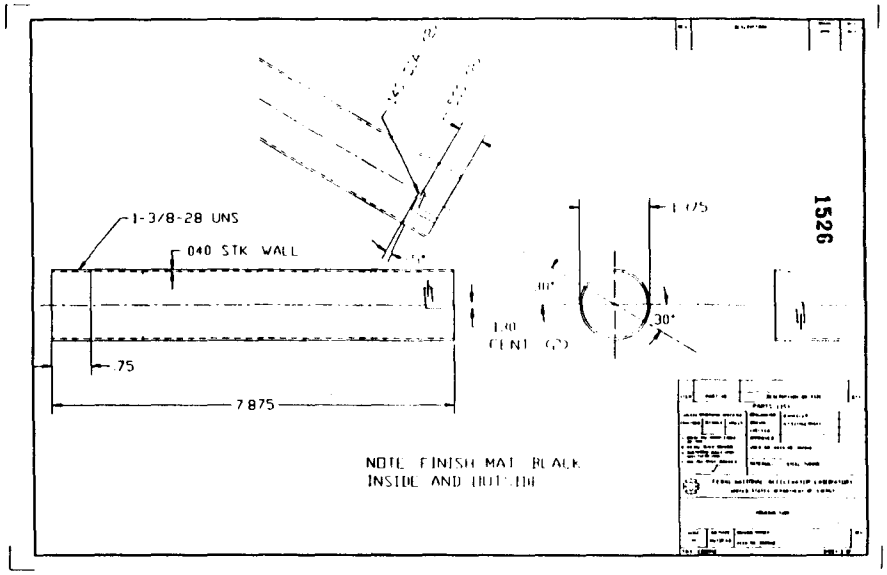

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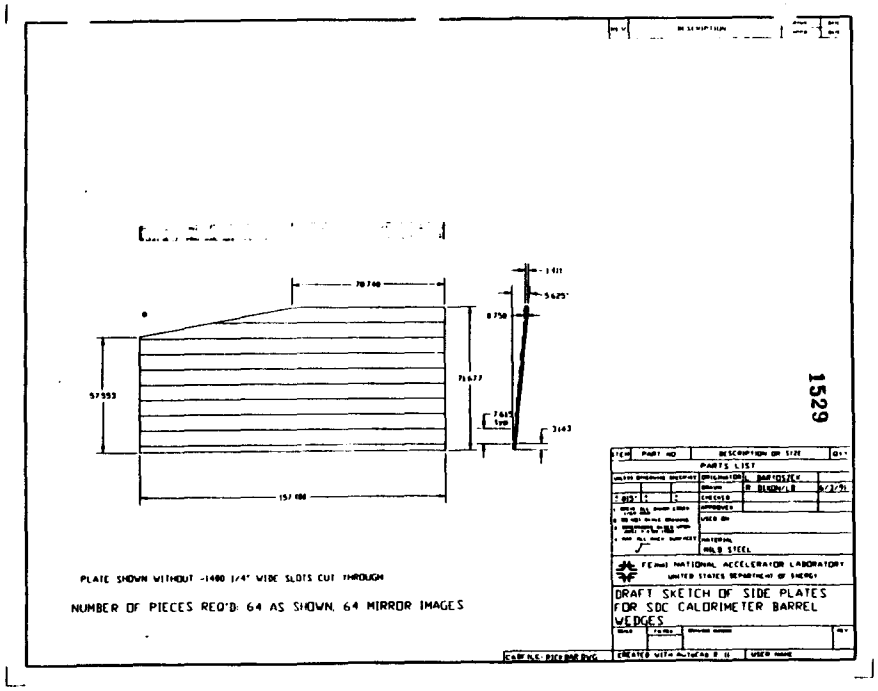

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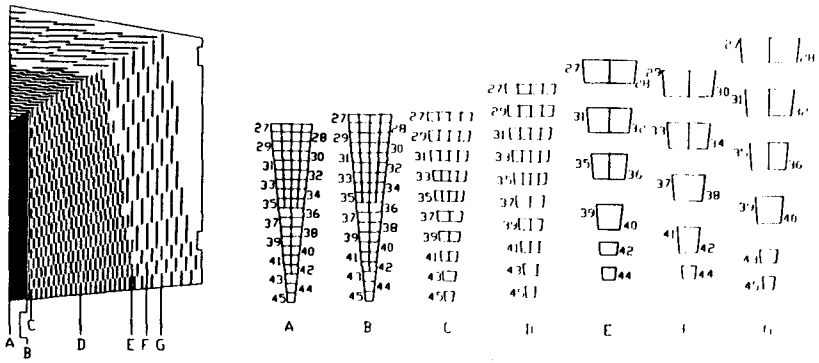
CROSS SECTIONS THROUGH THE END CAP SHOWING TILE SHAPES



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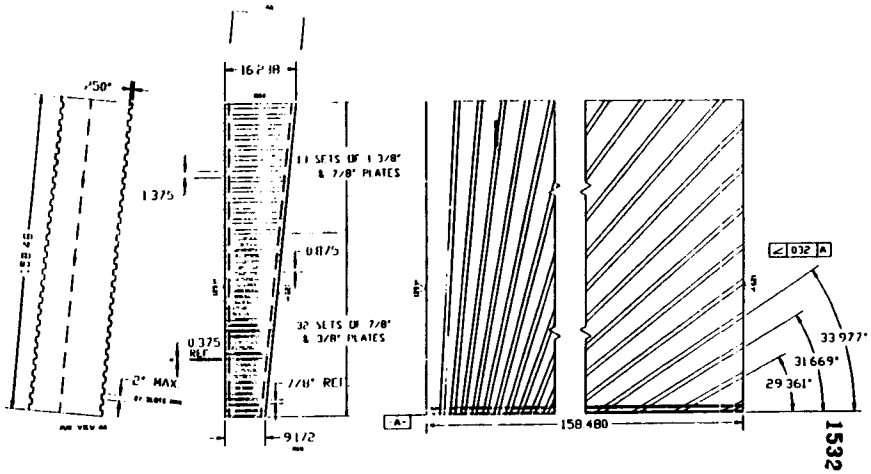

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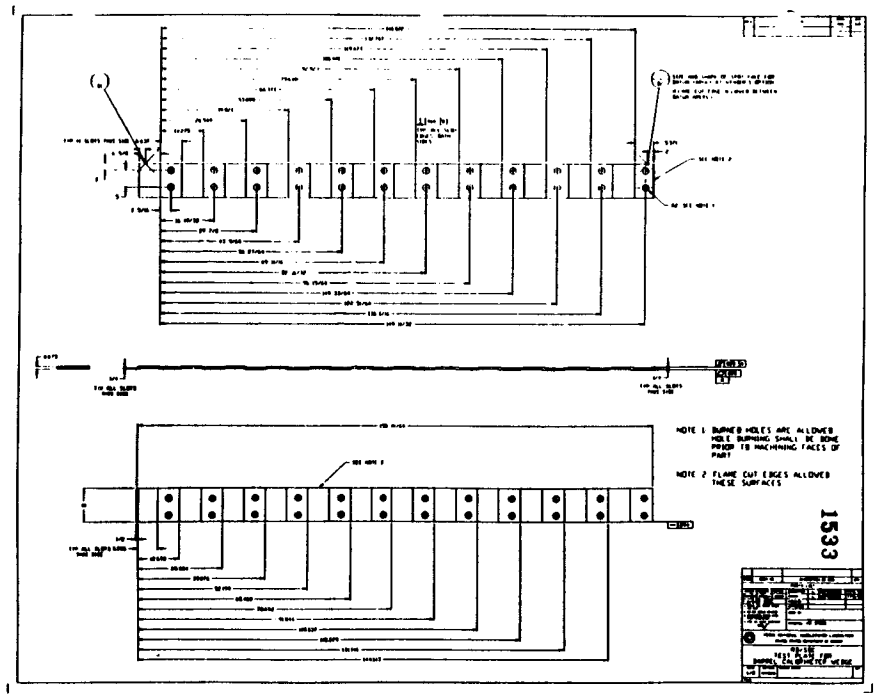

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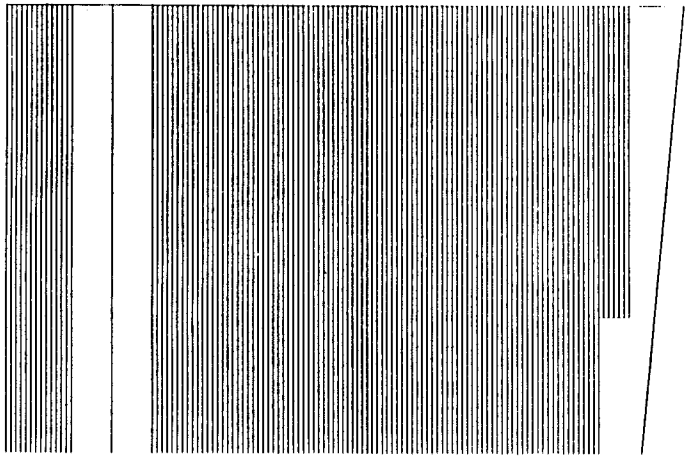

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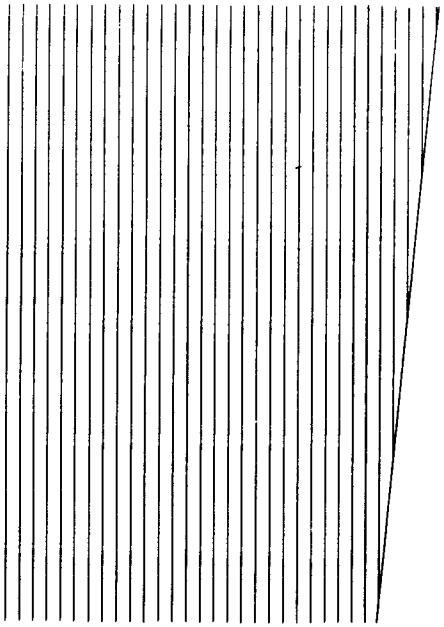

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1534

HORIZONTAL (THICKPLATE) 1/2 WEDGE ASSEMBLY
COST BREAK DOWN

UNASSEMBLED — Ave. cost $2.65/lb.

OPERATIONS REQUIRED:

1.) Punch holes
2.) Grind plates flat and parallel
3.) Mill slots
4.) Deliver to FNAL unassembled

ASSEMBLED — Ave. cost $3.11/lb.

OPERATIONS REQUIRED:

1.) Punch holes
2.) Grind plates flat and parallel
3.) Mill slots
4.) Stacking fixture
5.) Stack plates
6.) Plug weld
7.) Mill welded assembly faces and fiber slots
8.) Deliver to FNAL

REFERENCES:

1.) Ryerson Steel
2558 West 16th St. Chicago, IL 60608
Attn. Chuck Brown

2.) Ideal Tool
5615 So. Claremount Chicago, IL 60636
Attn. Fred Dion

3.) Chicago Bridge and Iron Inc.
St. George Rd. Bourbonnais, IL 60914
Attn. Allen Wright

4.) Youngberg Industries, Inc.
P.O. Box 217 Cherry Valley, IL 61016
Attn. W.H. Mortenson

QUOTATION 1535

IDEAL TOOL & MANUFACTURING COMPANY
5615 SO CLAREMONT AVENUE • CHICAGO, ILLINOIS 60636
PHONE 312/476-1080
FAX 312/476-5268

Fermi
National Accelerator Laboratory
P.O. Box 500
Mail Stop 221
Batavia, Illinois 60510
Attn: Mr. Brian Wheeler

ATTENTION:

DATE July 16, 1991
YOUR INQUIRY
DATED
REQUEST OF Brian Wheeler

QUANTITY	DESCRIPTION	PRICE
	Please accept this quotation of price and delivery date as follows:	
	Barrel Calorimeter Wedge Consisting of approx 90 plates.	
	Ideal Tool to machine each plate with approx 24 slots and 12 2" Ø holes using A-36 HRS as received from Steel Warehouse. No finishing top or bottom of plate quoted.	Approx. $1,500.00 each plate
	NOTE: Plates only quoted - the assembly is too heavy for our equipment and cranes.	
	If finish on top and bottom of plates is required (Clean up only.)	$80.00/130.0 each plate
	Quote is approximate only and price may change when requoted.	

THE PROVISIONS ON THE REVERSE SIDE HEREOF SHALL CONSTITUTE A PART OF THIS QUOTATION

DELIVERY negotiable
TERMS - NET 30 DAYS - F.O.B. ~~XXXXXXXX~~ delivered

WE THANK YOU FOR THE OPPORTUNITY OF QUOTING AND WILL APPRECIATE RECEIVING THIS ORDER.

COMPANY INCORPORATED STATE OF ILLINOIS MAY 16 1990

57390

BY Frederick L. Dion
Sales Engineer

TOOLS DIES JIGS FIXTURES GAUGES SPECIAL MACHINERY EXPERIMENTAL WORK METAL STAMPINGS AND PRODUCTION WORK DESIGNING AND ENGINEERING PRECISION DIE AND PLATE GRINDING SLITTING SHEET AND SHEAR BLADE GRINDING CYLINDRICAL GRINDING INTERNAL AND EXTERNAL

JUL 17 '91 10:48AM FAX SALES — TEL: 415-377-0721 — JUL 15 '91 15:27 No. 004 P. 01

1536

Ryerson
a subsidiary of
Inland Steel Industries Inc

PLANT: CHICAGO — PHONE: 312-763-2421
ADDRESS: XL038
PAGE 1

7-22-91

FERMI NATIONAL ACCELERATOR LAB.
PELDOTT RD.
BATAVIA, ILL. 60510

ATTN MR. BRIAN WHEELER

DEAR MR. WHEELER

THANK YOU FOR YOUR RECENT INQUIRY WHICH I AM PLEASED TO QUOTE THE FOLLOWING PRICES. THESE ARE TENTATIVE PRICES BASED ON THE PRELIMINARY DRAWINGS SUBMITTED JULY 10TH + JULY 12TH, 1991.

128 HALF WEDGE ASSEMBLIES - HR MILD STEEL .33 MAX. CARBON. EACH ASSEMBLY TO CONSIST OF THE FOLLOWING: — APPROX. 41,000 LBS/ASSEMBLY

32 PLATES, 3/4" x VARIOUS (9.17"-12.76") x 158 31/64" PLATES WILL BE GROUND TOP + BOTTOM, AND TWO LARGE EDGES. ALSO MILL BOTH ENDS. LENGTH, WIDTH, + THICKNESS TOLS., ± .005 — 14,281 ea/ASSEMBLY

45 PLATES, 7/8" x VARIOUS (9.17"-16.24") x 158 31/64" GRIND PLATES - SAME AS ABOVE - EXCEPT ALSO MACHINE 23 NOTCHES — 48,234 ea/ASSEMBLY

13 PLATES 1 3/8" x VARIOUS (12.76"-16.24") x 158 31/64" GRIND SAME AS ABOVE, + ALSO MACHINE 23 NOTCHES. — 17,498 ea/ASSEMBLY

Terms of payment subject to the approval of the Credit Department

A service charge will be added to accounts not paid within the prescribed time limit, and shall be effective. See reverse side for special terms of sale

By: _____
Date: _____

Joseph T Ryerson & Son, Inc

1537

CBI — CBI Services, Inc.
St. George Road
Bourbonnais, Illinois 60914-9749
815 933-2200

TELECOPY

DATE: 7-15-91
TO: BRIAN WHEELER
FERMILAB
FAX (708) 840-4343

FROM: ALLAN WRIGHT
CBI SERVICES

WE ARE TRANSMITTING 1 LETTER SIZE PAGES INCLUDING THIS COVER SHEET.

IF ANY PROBLEMS ARISE, PLEASE CALL (815) 933-2200.

WE ARE TRANSMITTING ON AN ADLER ROYAL FX 945 GROUP 3 MACHINE.

OUR TELECOPY NUMBER IS (815) 933-6722, TELECOPY OPERATOR SHARON HOWARD

RE: BARREL CALORIMETER WEDGE

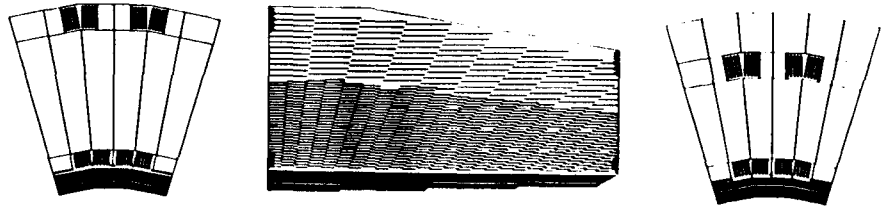
ADDITIONAL COMMENTS:

MR WHEELER: CONFIRMING TODAY'S TELEPHONE CONVERSATION:
CBI'S ROUGH BUDGET PRICE TO PROVIDE FABRICATED MATL'S FOR 128 ASSY'S AS FOLLOWS:
(A) SHIP FAB. PLATES UNASSEMBLED - $ 12,500,000
(B) SHIP PLATES ASSEMBLED - $ 18,000,000

BUDGET PRICES ABOVE BASED ON PRESENT DAY COSTS.

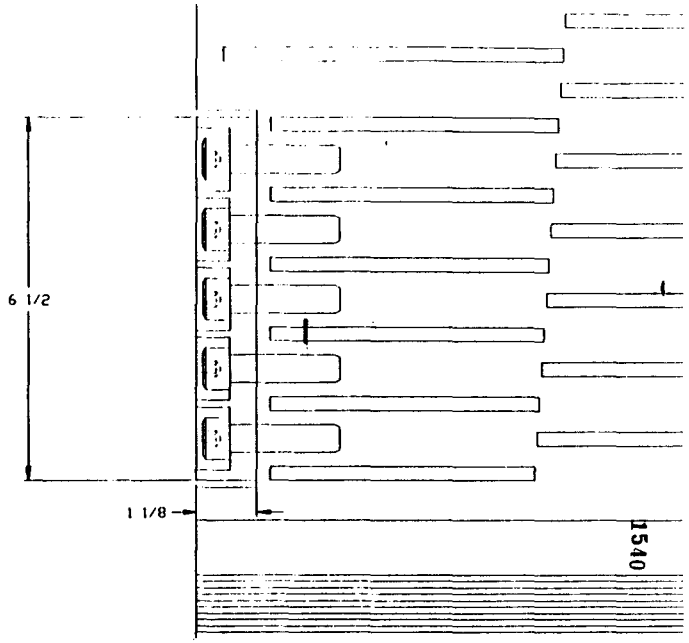
Allan Wright

DRAWING OF BRACKETS ATTACHING BARREL WEDGES TO EACH OTHER



BEAM_AXIS

1538



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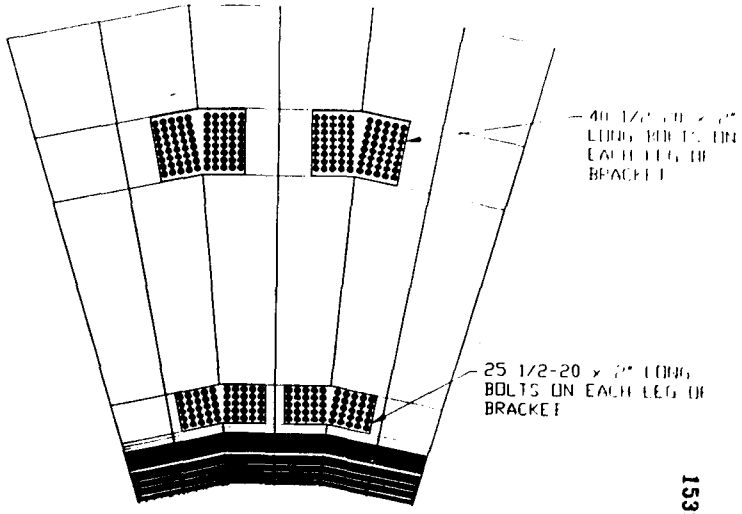

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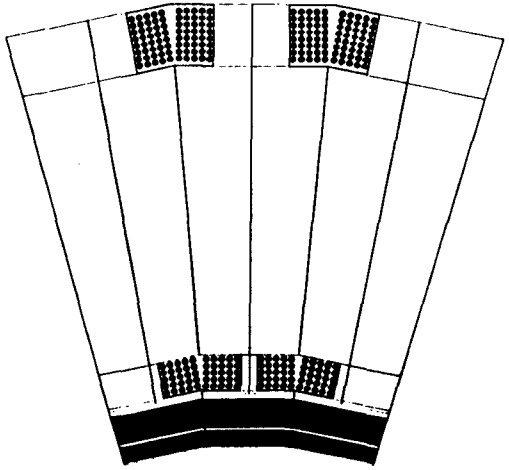

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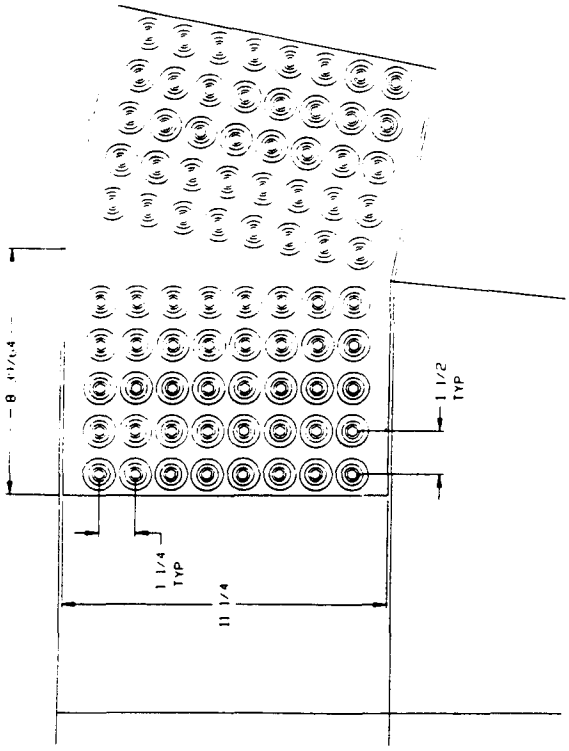

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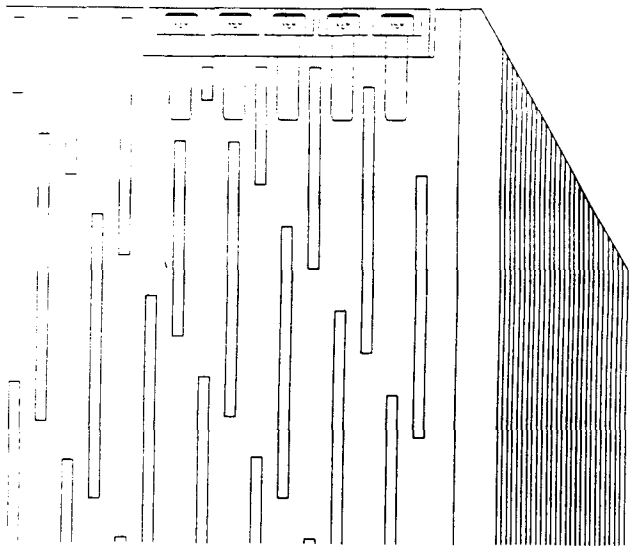

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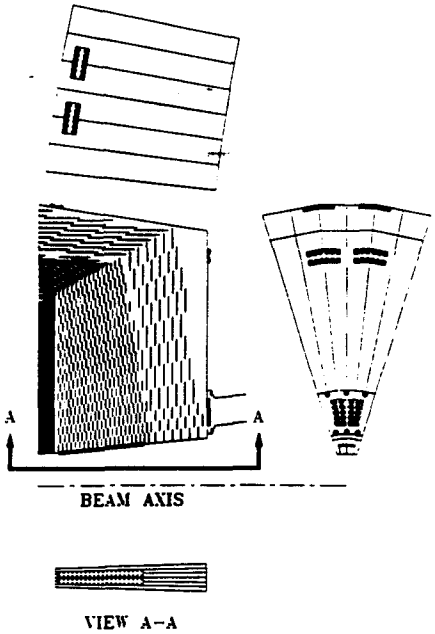
DRAWING OF BRACKETS ATTACHING END CAP WEDGES TO EACH OTHER

DEVELOPED TRUE VIEW OF TOP SURFACE



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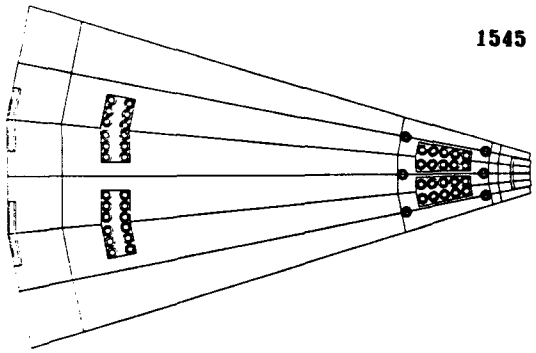

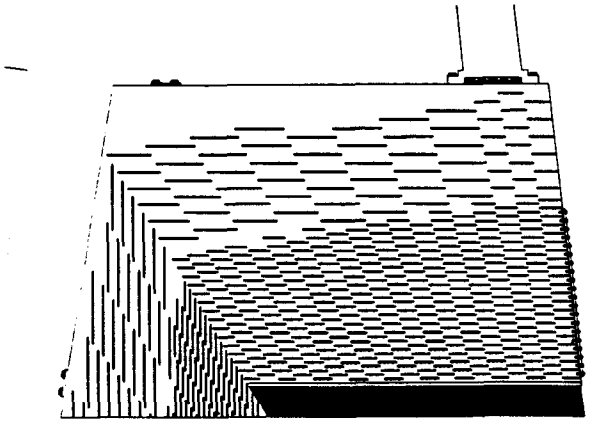

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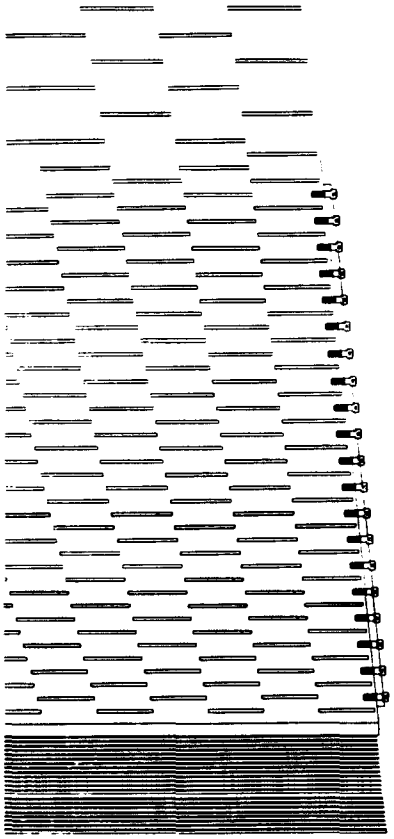

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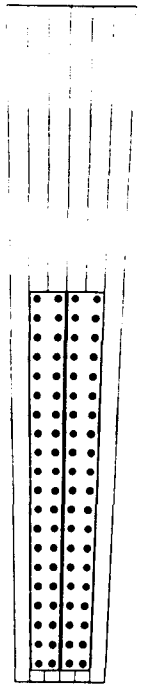

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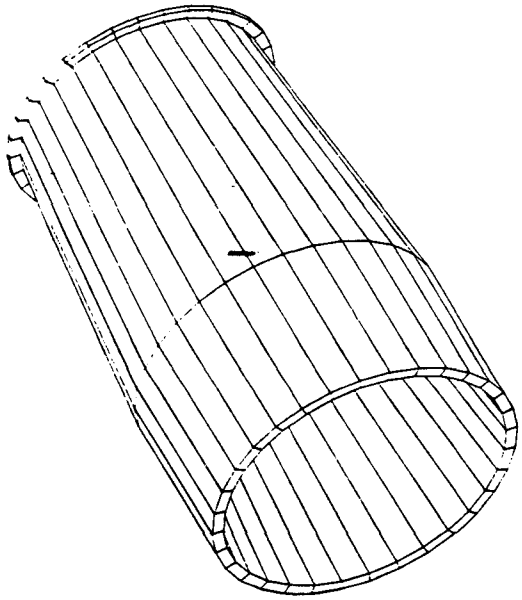

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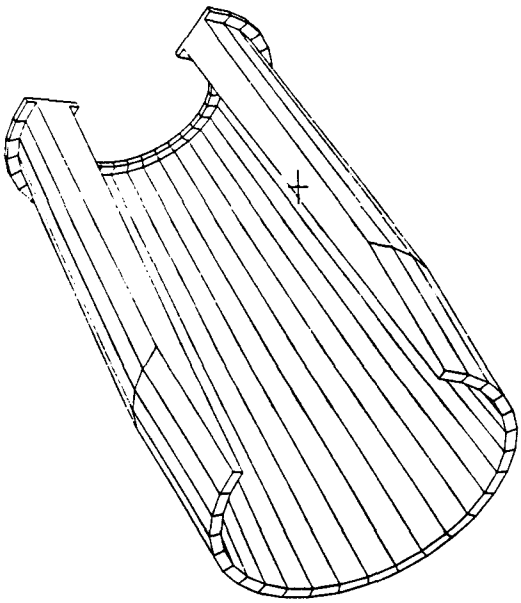

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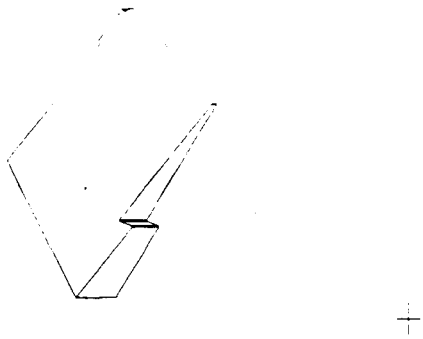

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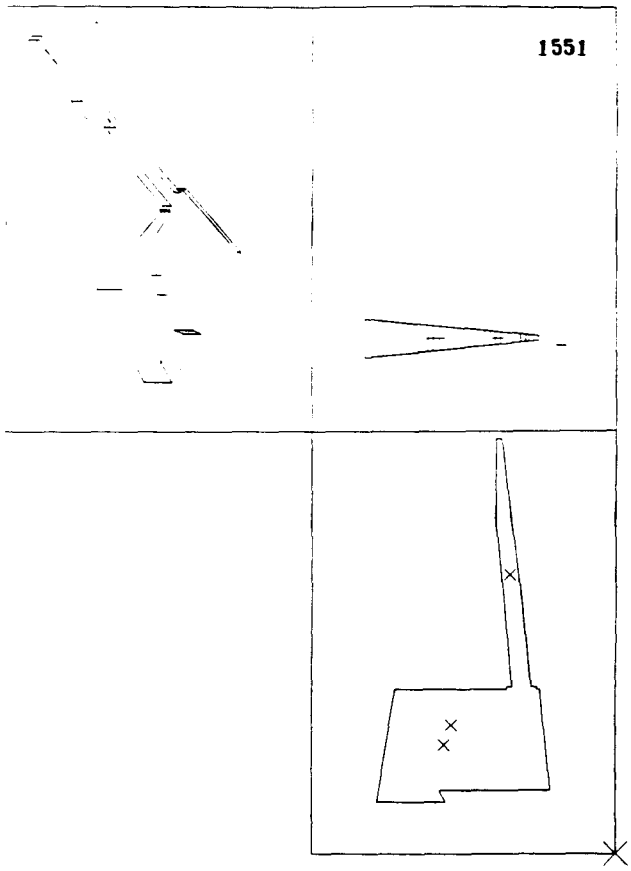

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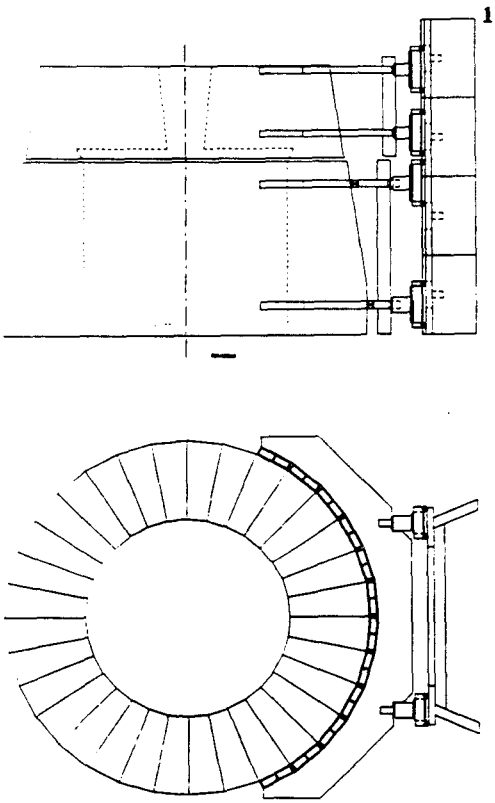

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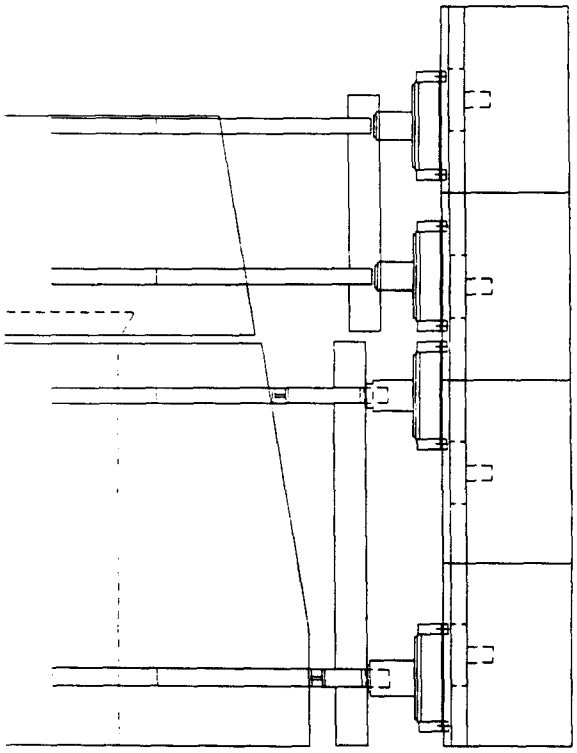

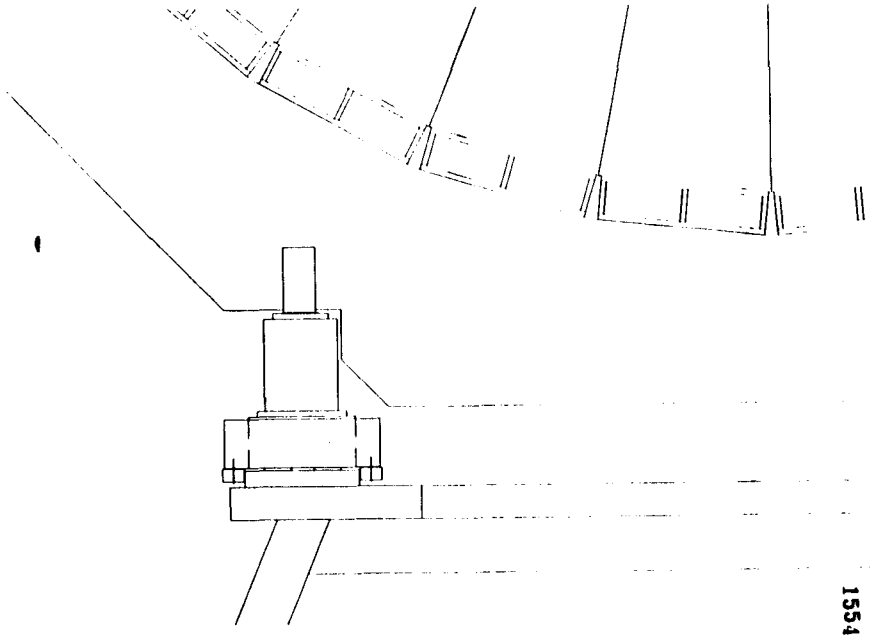

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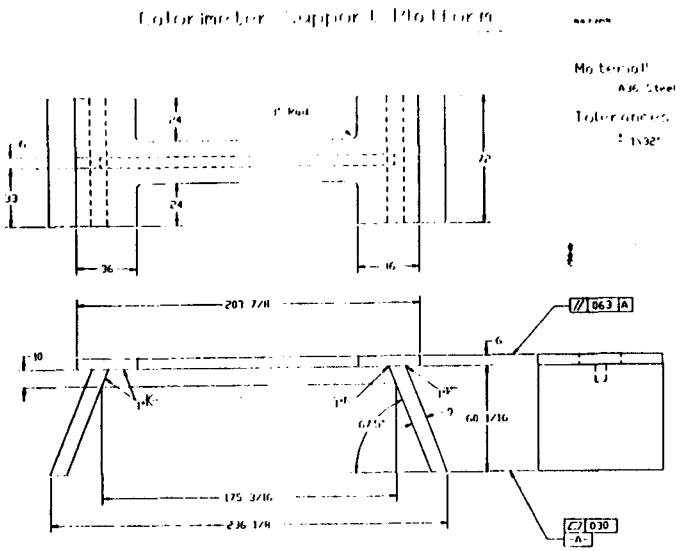

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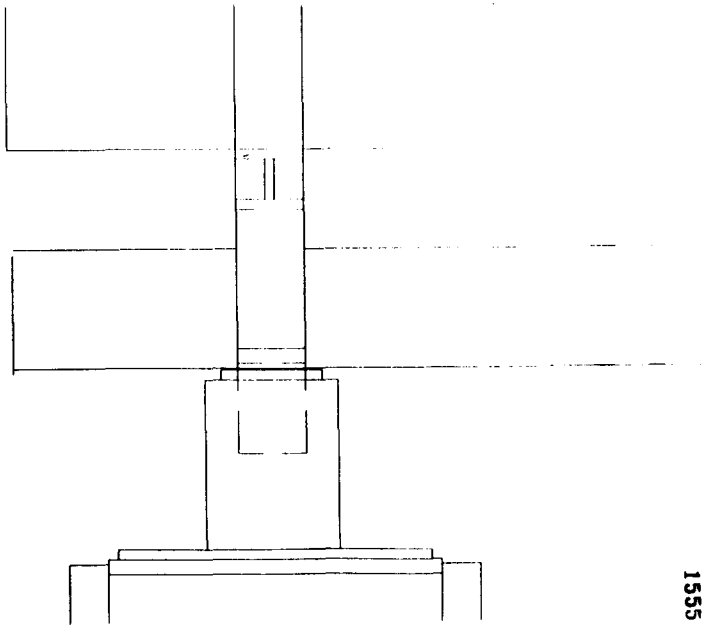

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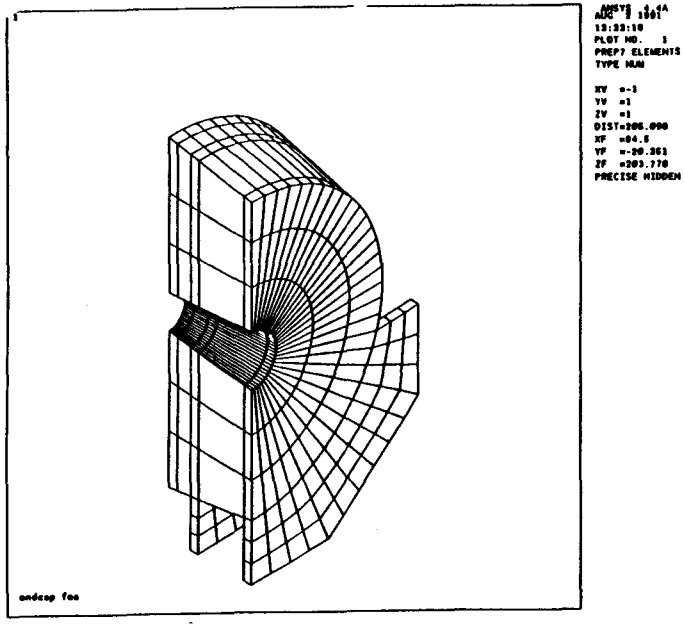

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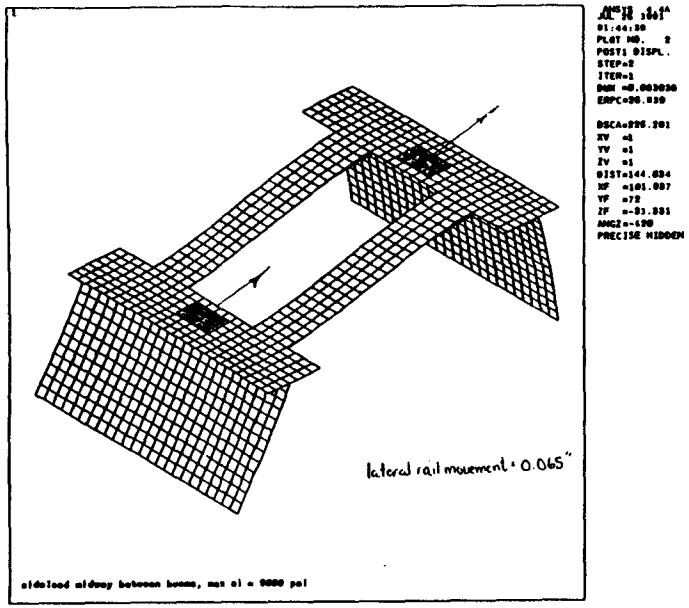

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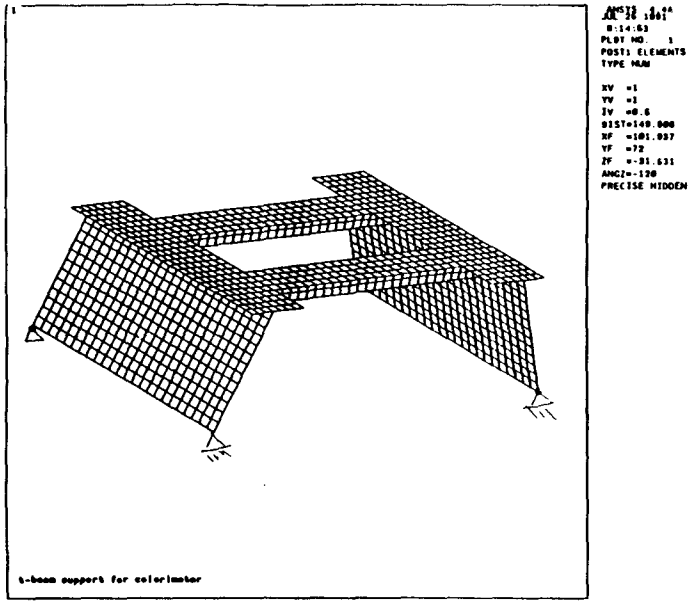

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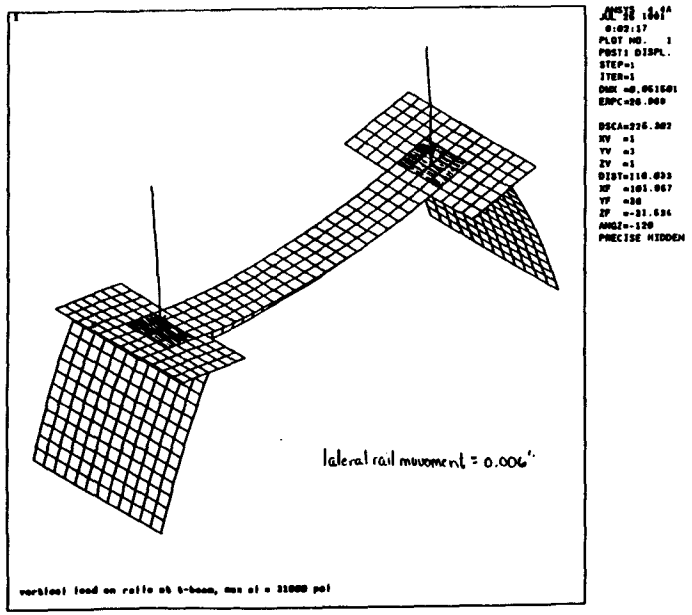

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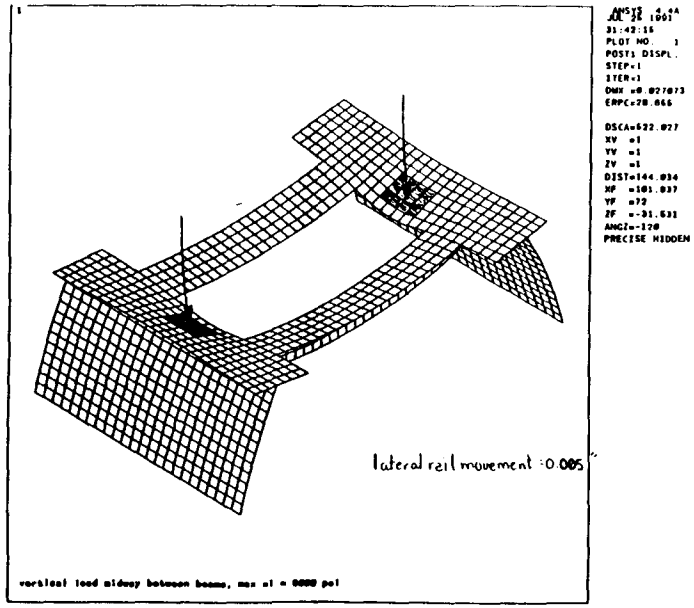

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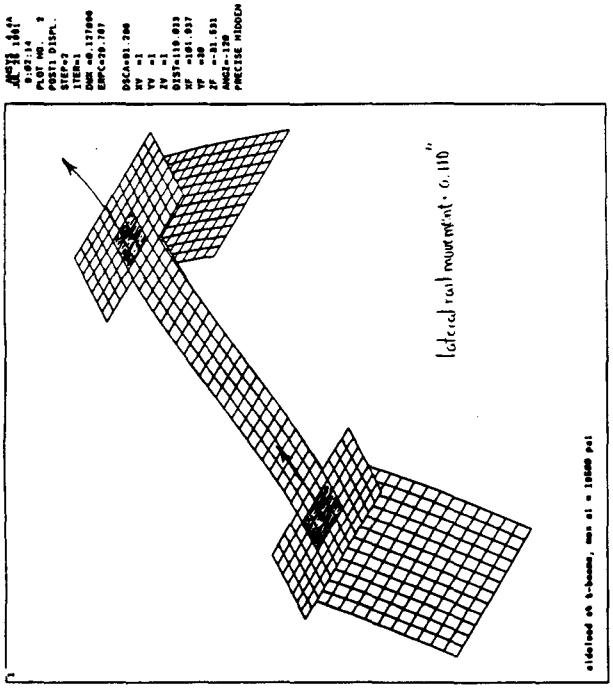

Pb EM / Fe Had

Calorimeter Design

J. FREEMAN

Features:

- conventional mechanical design
- iron allows conventional (safe) solenoid, uniform $\vec{B}$
- mech. strength, 1.5 Kton weight saving → easier support
- hermiticity: no cracks between tiles, no cryostat
- emphasize EM → ~½ tiles in EM

Pb EM / Fe Had

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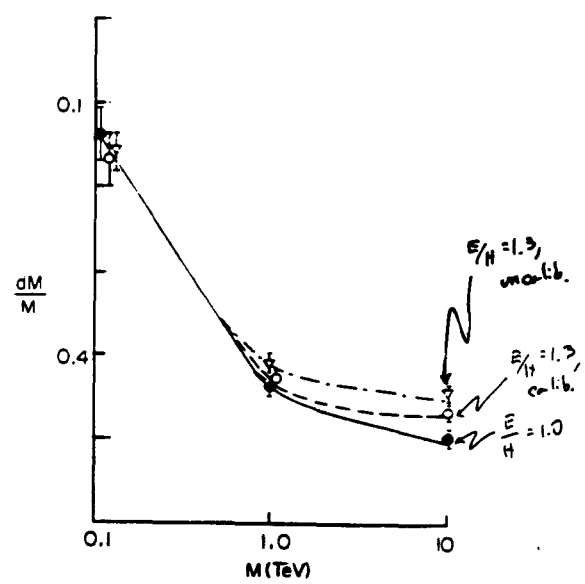

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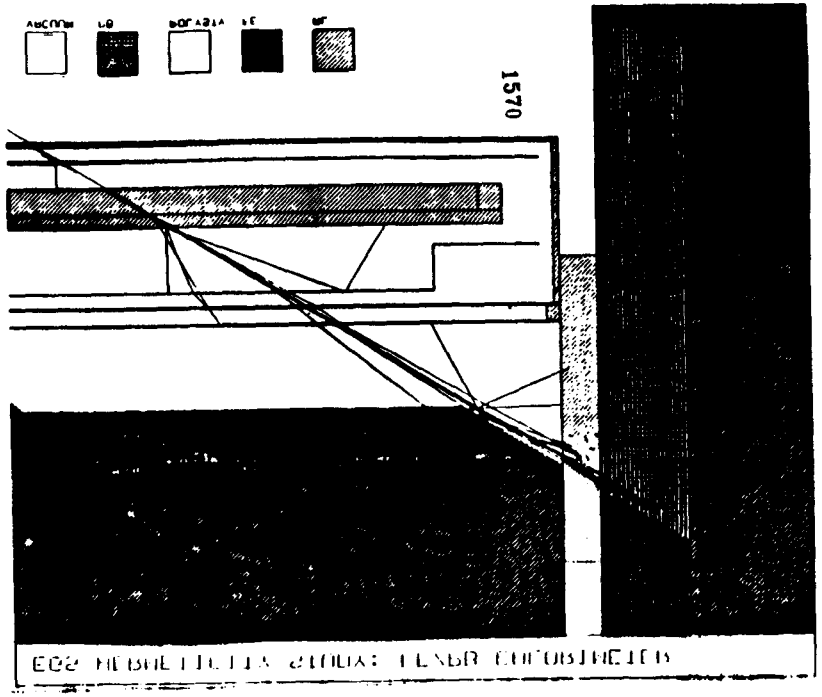
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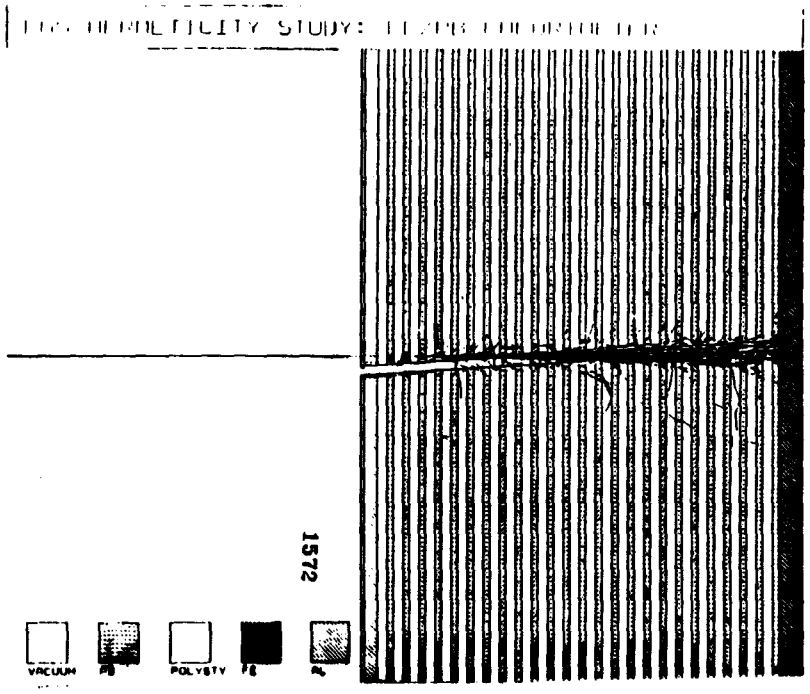
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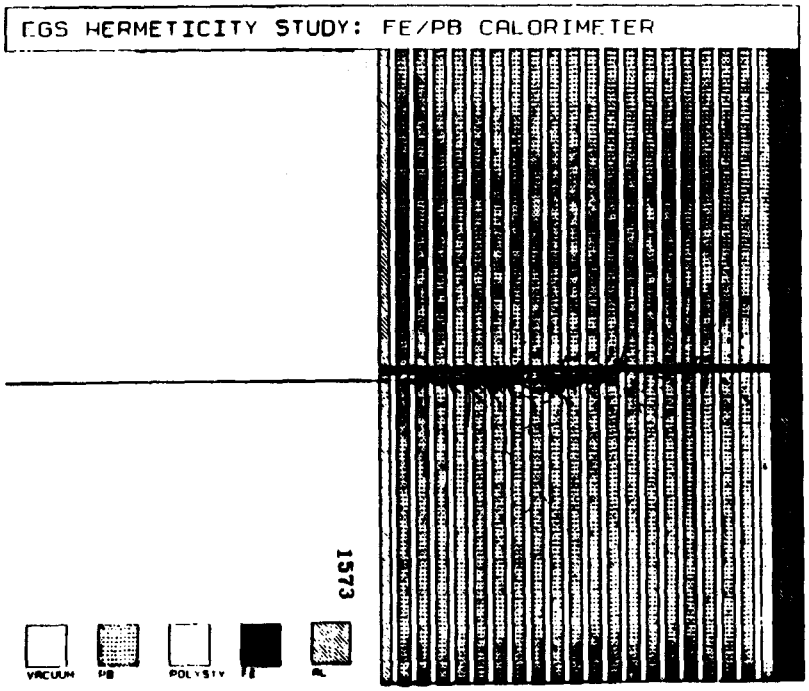
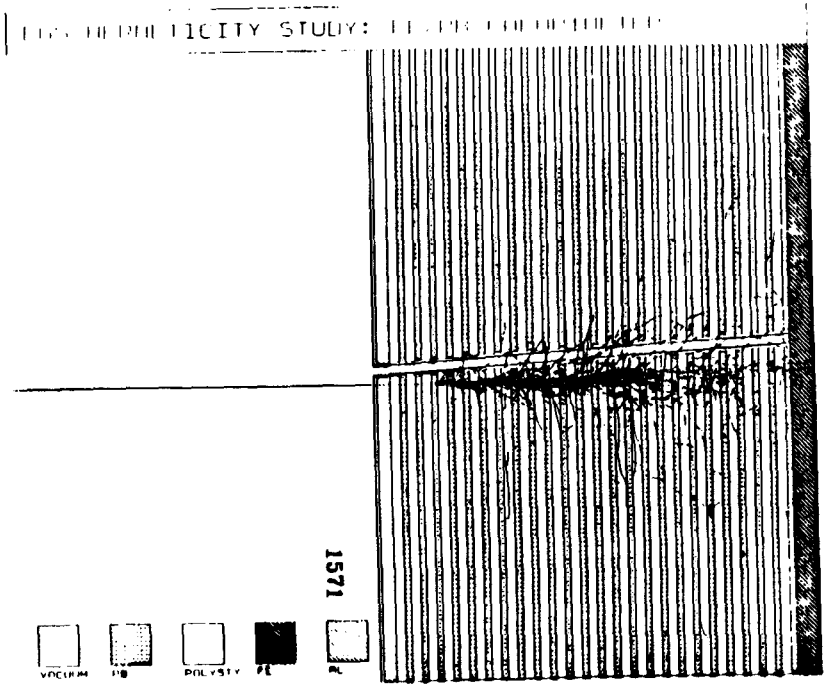
VACUUM
POLYSTY


EGS HERMETICITY STUDY: FE/PB CALORIMETER
1573
VACUUM
POLYSTY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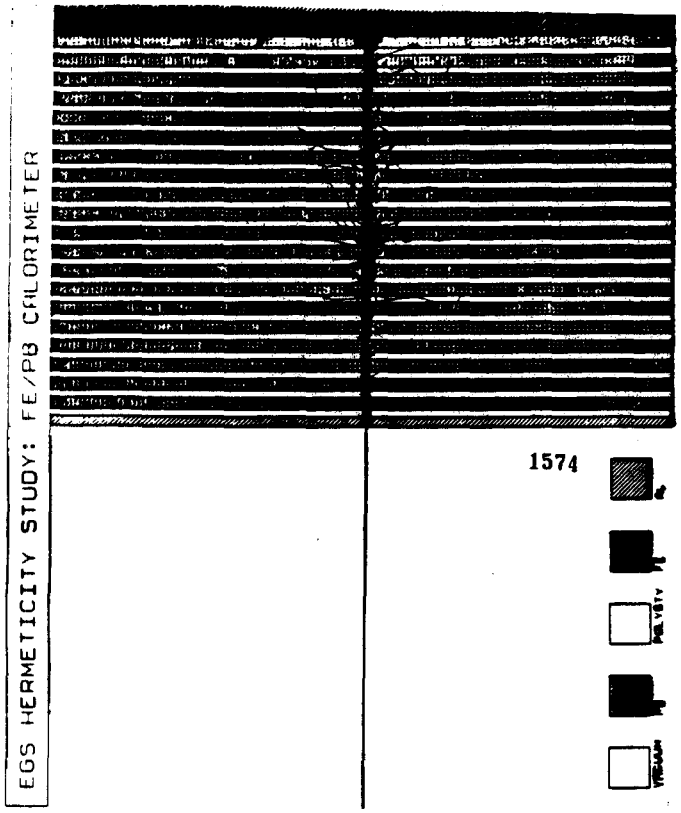
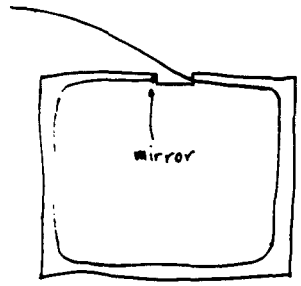
VACUUM
POLYSTY



1575

Sigma tile



1576

Hadron Optical Assembly

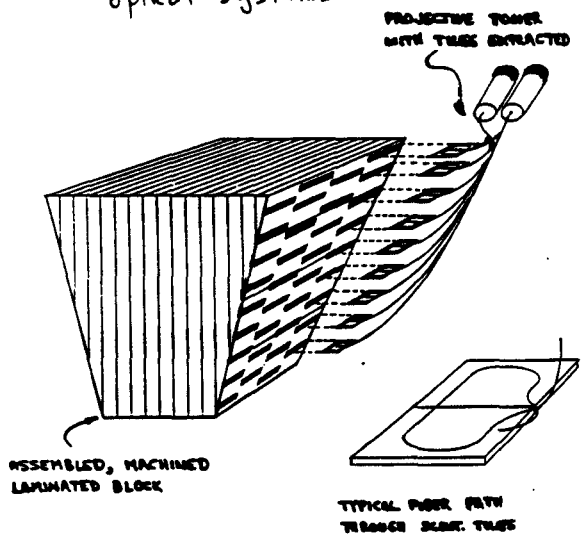
(~ same as CDF prototype)

- tiles cut on mill
- edges painted
- green fibers glued in place
- wrapped —
- clear fiber spliced on
- installed into optical package
- installed in Fe
- tested/trimmed in place

1577

HAC assembly strategy

install complete pretested optical systems



SCHEMATIC COMPENSATING FE/SCINT. TILES
SOLENOIDAL CALORIMETER MODULE

1578

EM optical assembly

- tiles cut
- painted
- "dealed" into pb/scint stack
- piano wires tensioned
- EM module installed on HAC
- WLS fibers mirrored
- WLS fibers spliced to clear
- fiber assembly tested
- fiber assembly threaded into tiles
- fibers dressed to cookie
- test /trim

1579

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1581

1586

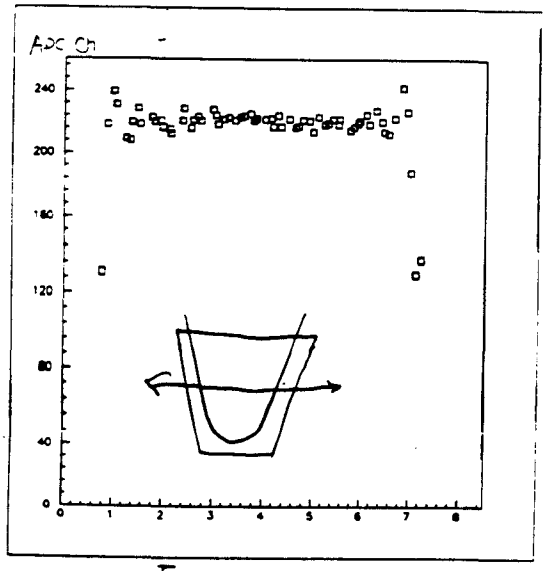


Fig. 11 <b>

masked tile uniformity

$\sigma \leq 2\%$ after masking

1587

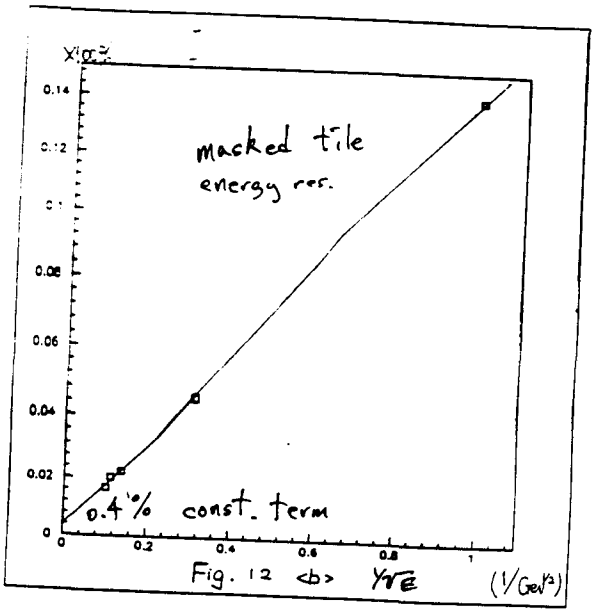
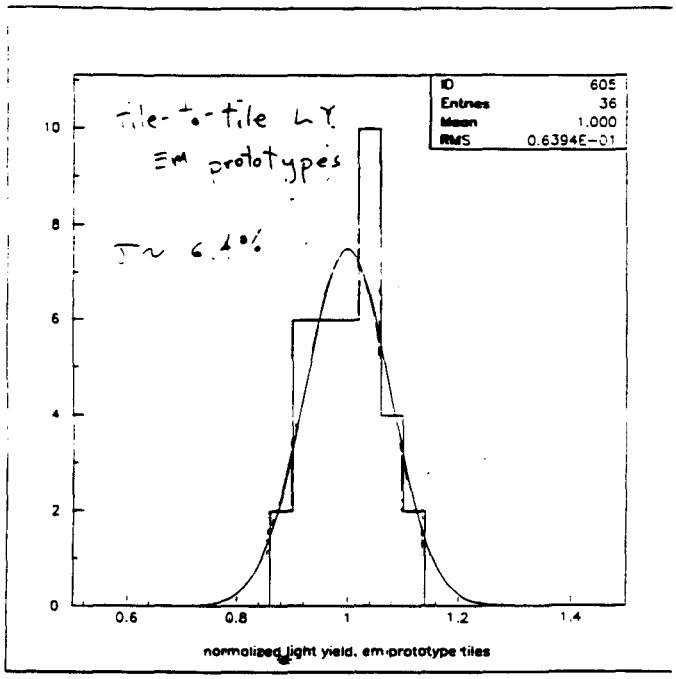


Fig. 12 <b> $\sigma/\sqrt{E}$

$\Rightarrow$ conclude transverse non-uniformity $\lesssim \sim 2\%$ acceptable

1590



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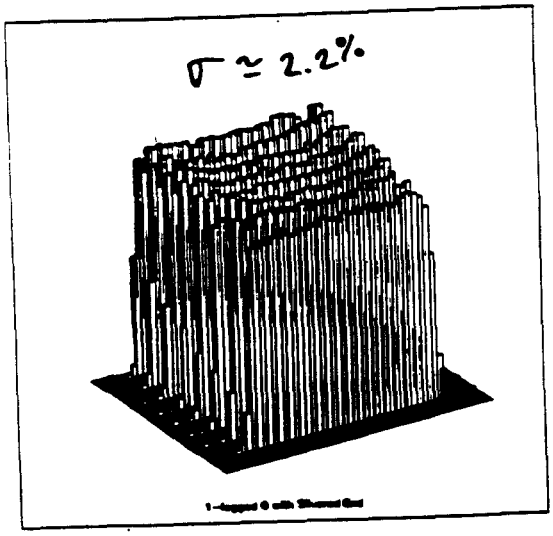

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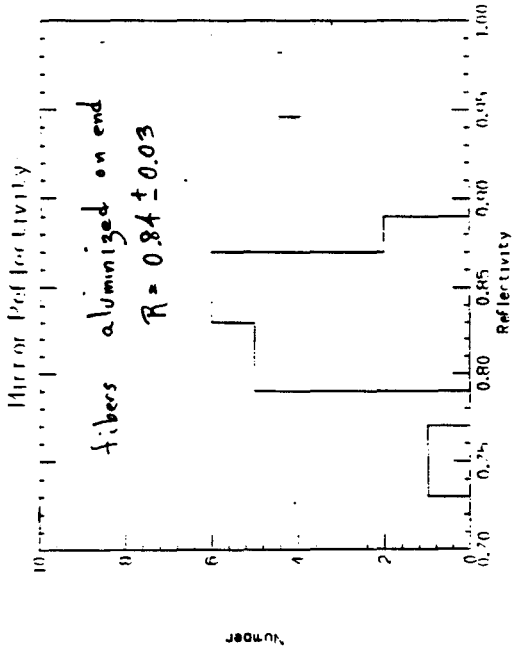

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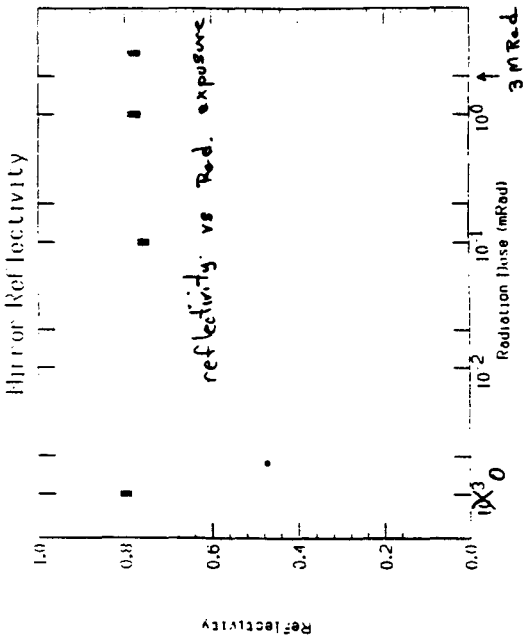


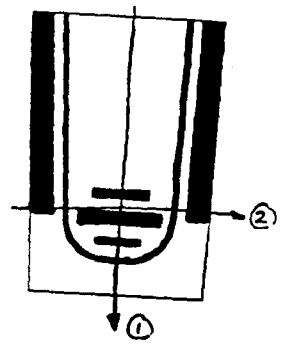
1594

Generic Masking

CDF endplug group studied generic masking vs individual masking. Conclusion: generic masking controlled transv. non-unif to within ±2%. Use photographic expansions of mask pattern front-to-back. Recall major function of individual masking was to adjust tile absolute light yield.

1595

EM tile mask (generic)



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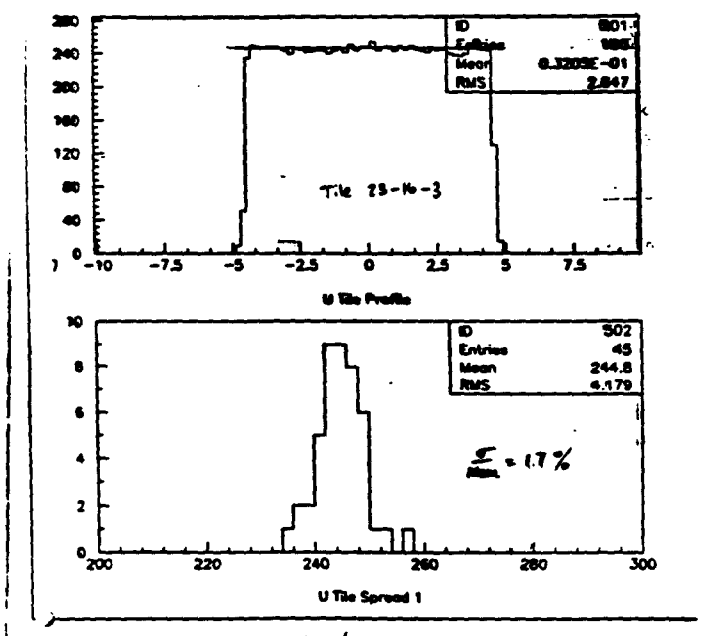
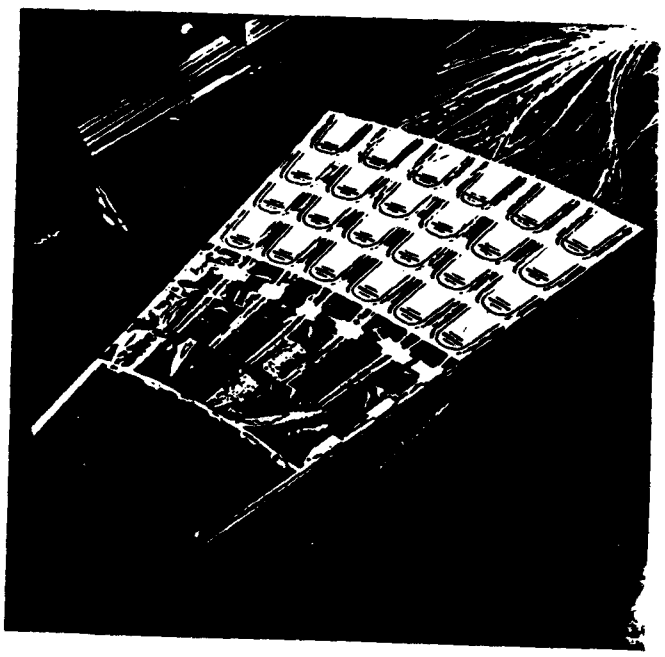


Masked EM tile

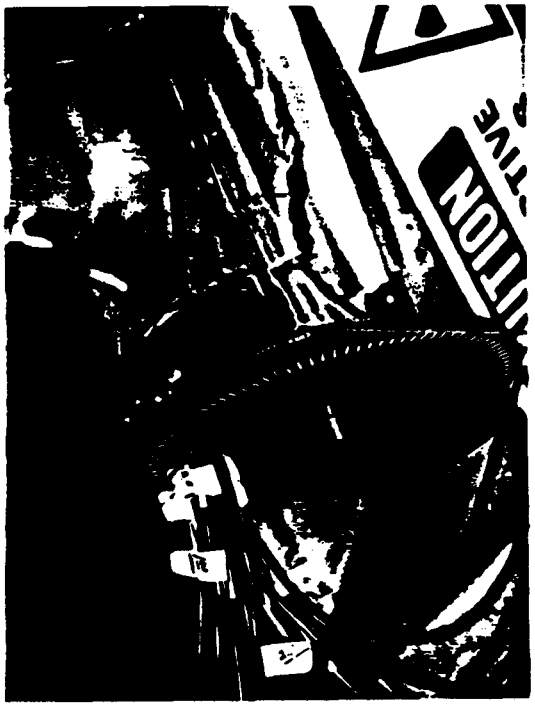
1597



1598

1599

1600



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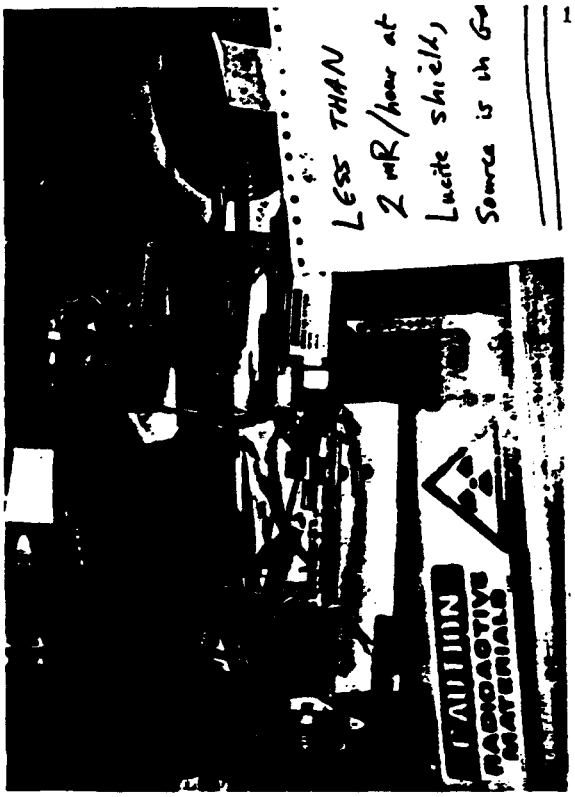
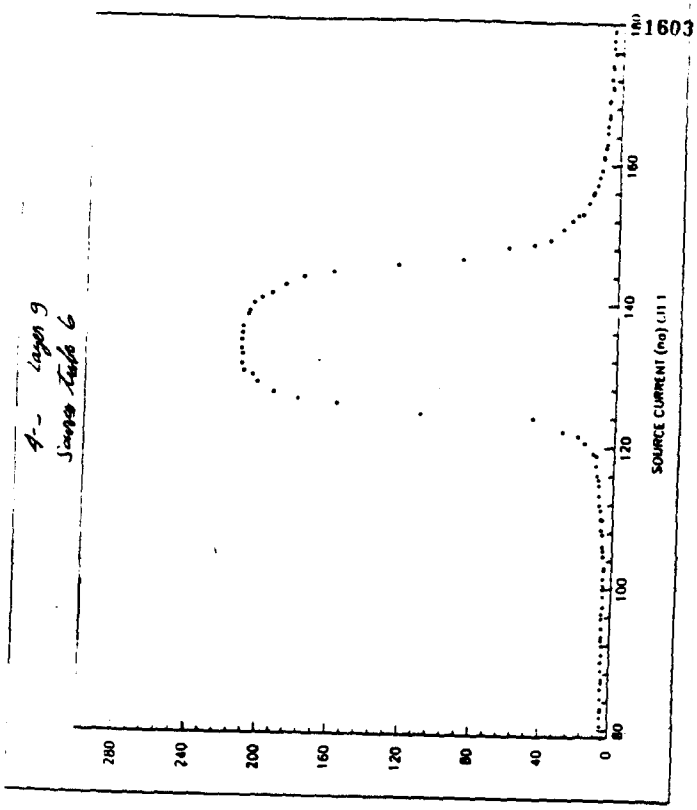


1602

1603



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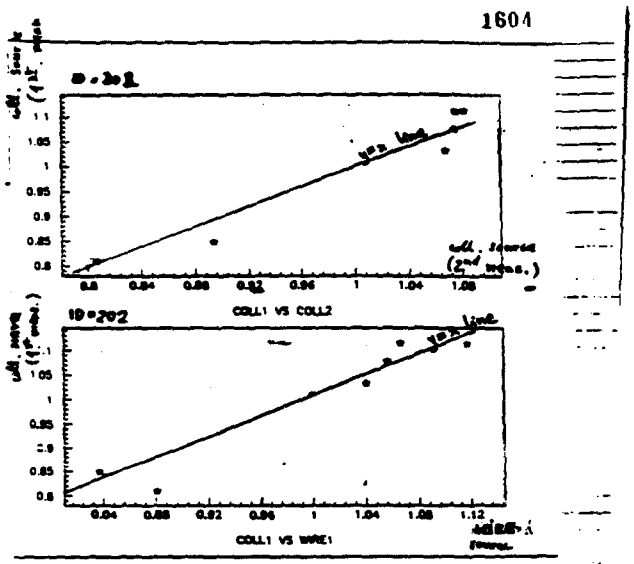


note: ① wire source data included signal from other (neighboring) tiles.

② all 2 set of measurements normalized internally ($\langle coll1 \rangle = 1$, $\langle coll2 \rangle = 1$, ...)

1605

6/24/92 7:[illegible]

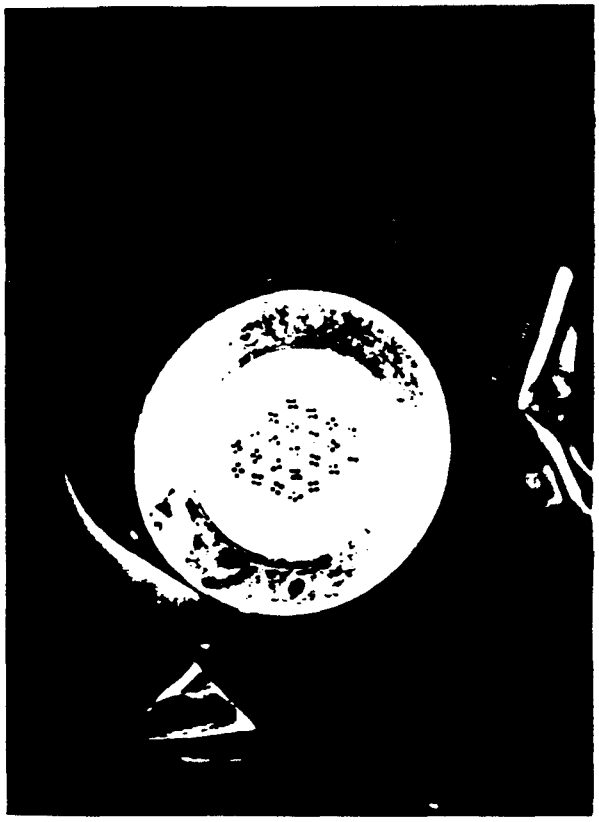
CHANNEL	1	MMAX	4	PED	3.[illegible]
135					
357					
457					
680					
138					
357	MMX	208.5414	FIT	208.9411	
457	MMX	207.5014	FIT	207.5077	
680	MMX	207.7314	FIT	207.9582	
	MMX	207.7814	FIT	207.6616	
CHANNEL	2	MMAX	4	PED	3.4919
363					
326					
457					
646					
363	MMX	185.7881	FIT	185.8099	
326	MMX	185.6481	FIT	185.6315	
457	MMX	185.6381	FIT	187.452[illegible]	
646	MMX	185.6881	FIT	185.5300	
CHANNEL	3	MMAX	4	PED	4.3100
362					
203					
536					
636					
362	MMX	140.8881	FIT	139.9277	
203	MMX	139.4781	FIT	139.8941	
536	MMX	140.8981	FIT	140.7576	
636	MMX	140.3881	FIT	140.3771	
CHANNEL	4	MMAX	4	PED	4.5193
221					
261					
544					
585					
221	MAX	174.0407	FIT	173.4538	
261	MAX	173.9907	FIT	173.9328	
544	MAX	173.5807	FIT	173.3372	
585	MAX	173.4807	FIT	173.4364	
CHANNEL	5	MMAX	0	PED	4.2387
CHANNEL	6	MMAX	0	PED	9.1164
CHANNEL	7	MMAX	0	PED	0.0086

1606

Hadron Tower light yields

Tower	Yield/3.3 pe/mip	sigma/mean
7-1	0.84	11.9(%)
7-2	0.84	12.1(%)
7-3	0.89	12.5(%)
7-4	0.87	11.2(%)
7-5	0.85	9.2(%)
7-6	0.87	10.8(%)
6-1	0.99	11.5(%)
6-2	0.97	9.5(%)
6-3	0.98	11.5(%)
6-4	0.99	10.2(%)
6-5	0.97	9.2(%)
6-6	1.0	8.9(%)
5-1	0.73	10.7(%)
5-2	0.78	11.9(%)
5-3	0.79	9.5(%)
4-1	0.81	11.6(%)
4-2	0.85	9.5(%)
4-3	0.84	9.1(%)

1607



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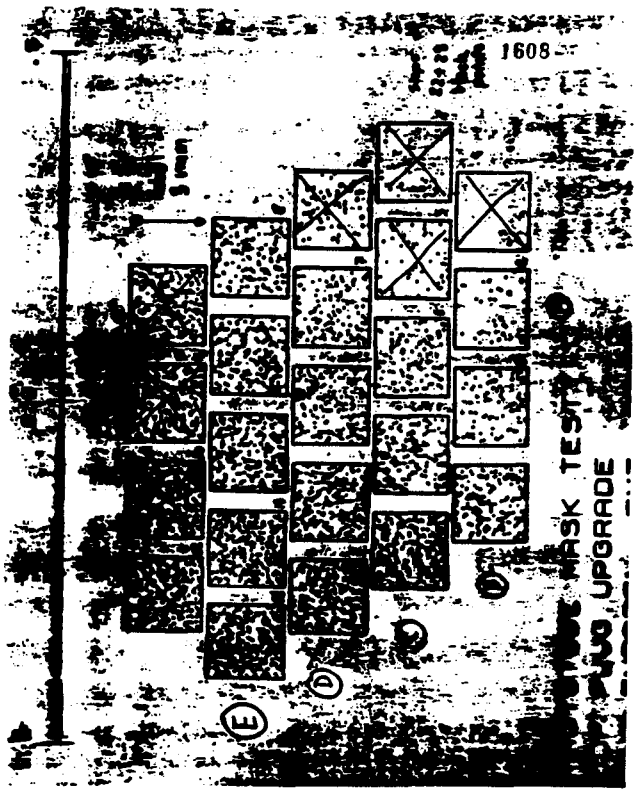

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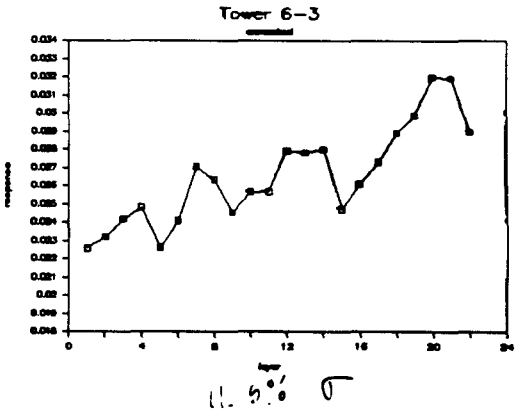
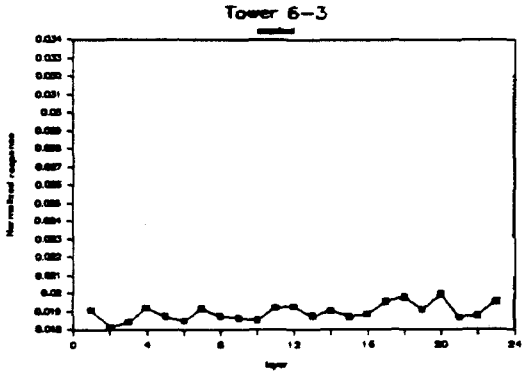


11.5% σ

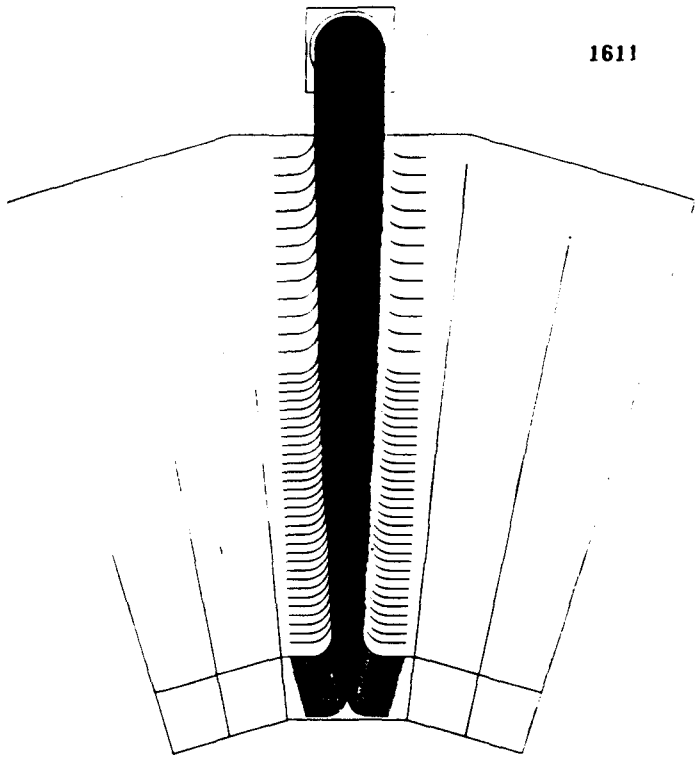
1610



$\sigma = 2.6\%$

$\delta = 7\%$ (air gap)

1611



1612

Annealing / preforming fiber bend

made coils of fibers with different diameters

1" ø, 9.5 turns

2" ø, 4.5 turns

- studied various techniques for preforming:

  none, hot water, hot air, various cool-down schemes.
- studied BCF91, Y7 fibers
- studied light transmission thru coil vs time

  immediately, 5 days, 10 days, 30 days, ...

⇒ conclude: with 2" ø, very little aging for no annealing (unmeasureable)

⇒ no annealing aged better than other schemes

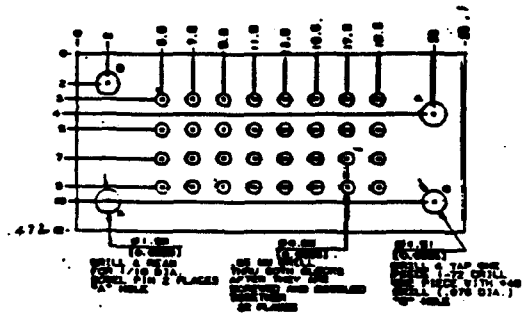
⇒ abandon annealing

1613

First Results from the Optical Connect/Disconnect

A. Burlon, M. Cobal, H. Grassman, S. Leone (INFN Padova and Pisa)

Design : M Atac (FNAL)



- 2 Prototypes built
- total of 8 fibers glued in
- no sophisicated surface treatment yet

=> reproducibility for each of the 8 fiber connections better than 1%

1614

SDC Calorimeter
Tile/Fiber Fabrication and Cost

Prepared by the Fermilab Technical Support Section

Presented by S. Gourlay, Fermilab

August 5, 1991

1615

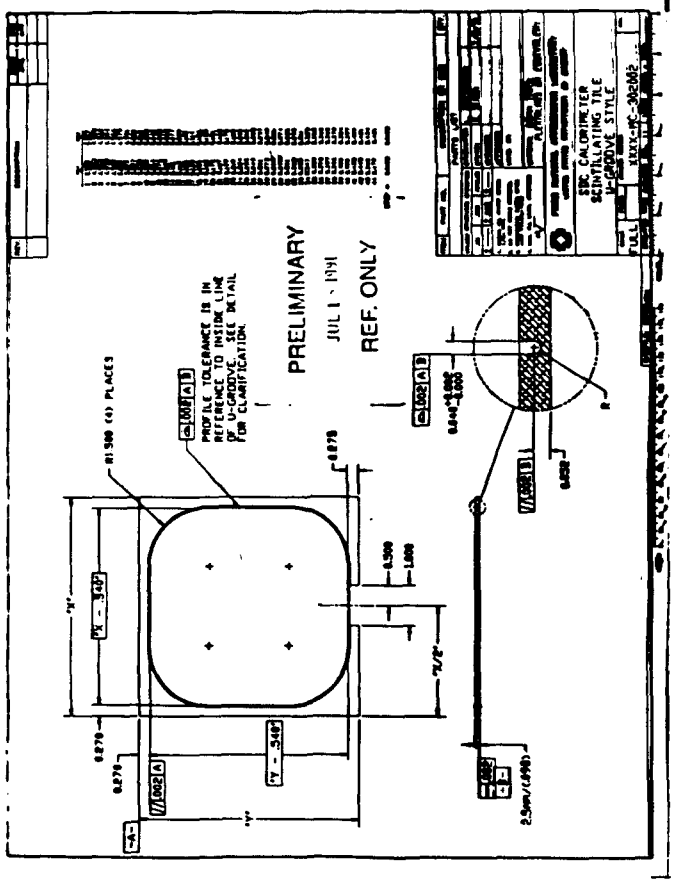


Figure 1. Drawing of Typical Tile Showing Dimensional Tolerances

1616

SDC Tile Size Summary

Section	Aspect Ratio	Size Range	Number of Sizes	Quantity Each	Total
EM Barrel	Rectangular	4 - 6"	78	Approx. 2500	191488
HAC 1	Rectangular	5 - 9"	128	128 - 1536	170240
HAC 1 Spec.	Rectangular	4 - 9"	60	128	7936
HAC 1 RD Spec.	Rectangular	9.6 - 9"	72	128	9216
HAC 2	Rectangular	12 - 19"	35	128 - 640	13696
HAC 2 Spec.	Rectangular	9.6 - 16"	15	128	1920
EM End Cap	Trapezoidal	3 - 5"	1060	64	67840
HAC 1 End Cap	Trapezoidal	3 - 7"	929	64	59456
HAC 2 End Cap	Trapezoidal	4 - 16"	162	64	10368
		Total	2538		532160
			Base Material	Polystyrene	
			Thickness	2.5mm +/- 0.1mm	

1617

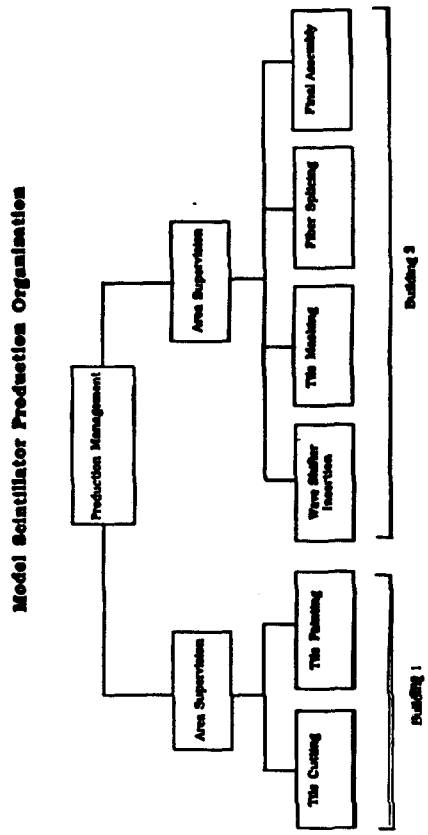
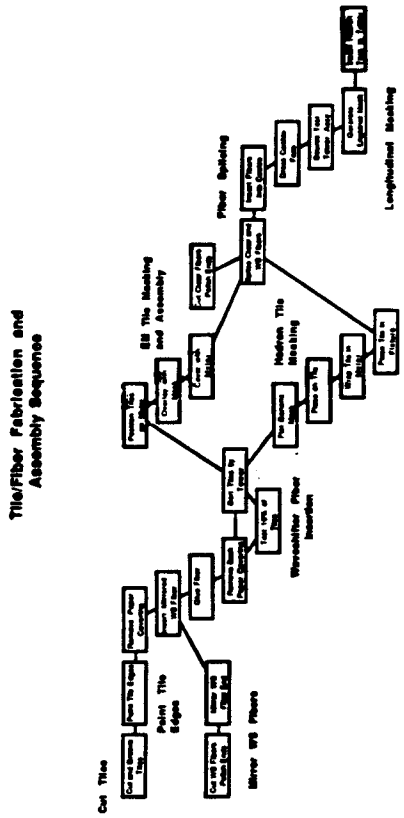


Figure 2. Tile Production Organization

1618



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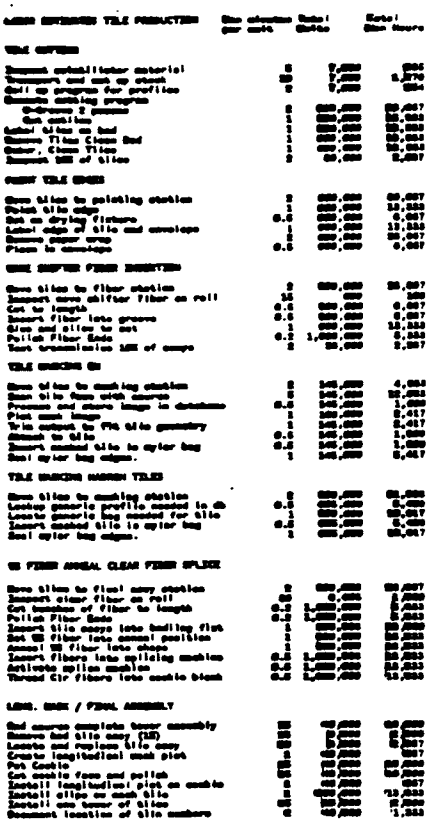


1620

Tile/Fiber Cost Baseline Comparison

Compare June/Dallas Baseline With Current Baseline

Original Baseline -

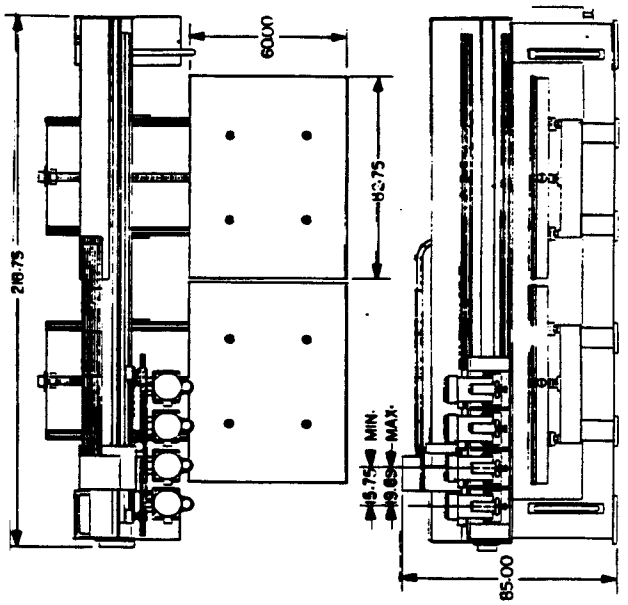
- Modeled after CDF prototype endplug fabrication techniques
- Assumed that all fabrication steps would be carried out using lab facilities

New Baseline -

- Methodology still based on CDF experience
- Modifications made to reduce costs
  - Subcontract for cost effectiveness
  - Obtain vendor quotes
  - Modify design (Based on SDC manufacturing studies)
  - Reduce hands-on labor and handling
  - Descope

Examples -------

1621



Examples of Baseline Modifications

Tile Cutting

Original estimate based on prototype CDF tile production using a single-head computer controlled router

=> Thru-put of 100 tiles/shift

Investigate alternatives -

- Speed/feed tests
- Use of multi-head machines
- Vendor quotes (very common procedure)

=> Thru-put of 400 tiles/hour

=> cost reduction of 70 % based on vendor quotes

Other cutting methods to consider -

- Laser cutting
- Injection molding

Tentative quote from Kerari for barrel tiles approx. $2M

Edge Painting

Originally based on painting individual tile edges

- Derived a stack painting technique to eliminate handling individual tiles
- Batches of 100 - 200 tiles at a time
- Labeling done at tile cutting step

80 % Cost Reduction

Fiber Mirroring/No Annealing

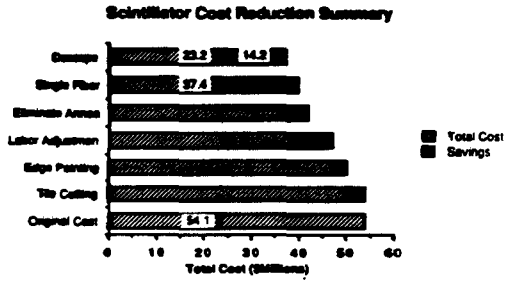
- Reduce material handling by eliminating half of the fiber splices
- Eliminate fiber annealing

60 % Cost Reduction

Redistribute Labor Resources

- Reduces average labor rate from $30 - $25/hr

16 % Cost Reduction



We're not done yet .....

Many R&D issues to be attacked which drive costs

New assembly techniques

- Edge painting/Bagging
- Fiber insertion/assembly techniques
- Source testing/longitudinal masking
- Tile cutting process
- Masking Hadron - maybe not necessary

Esp. Hadron

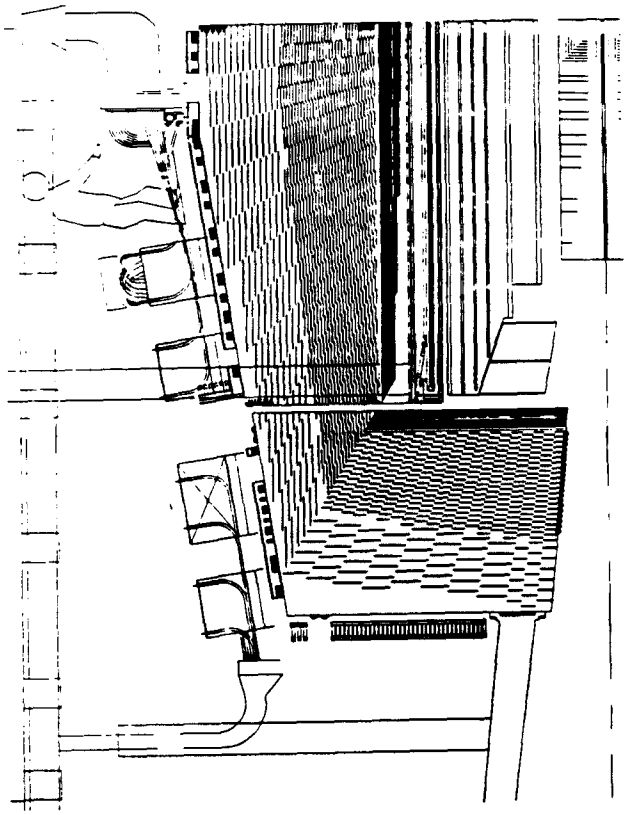
"Iron" Detector Simulation

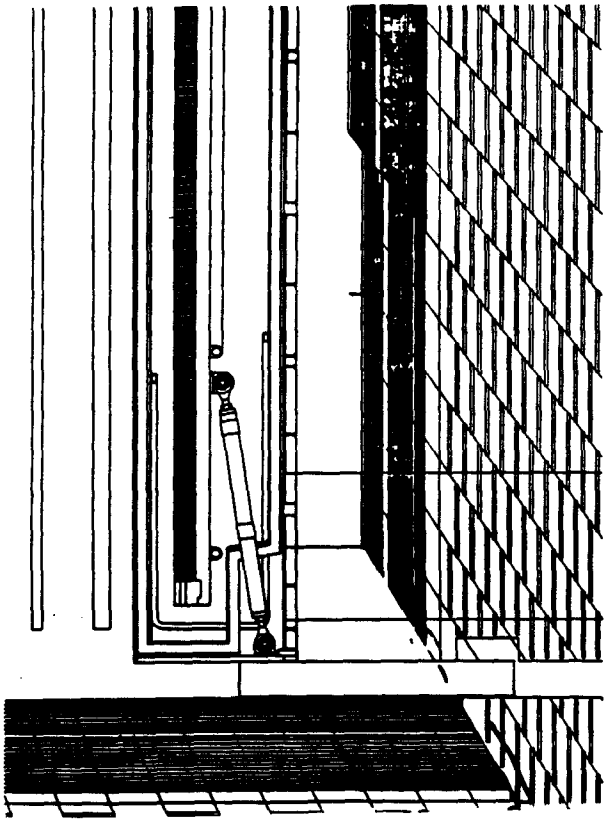
GW Foster Aug '91

COIL MODEL - Dimensions Taken from
June '91 Engineering Drwg.
FNAL Solenoid Subsys

Includes:
- inner vacuum shell
- inner N2 intercept
- Conductor
- Bobbin
- outer N2 intercept
- outer "isogrid" vacuum Shell (approximated by 2 cylinders)
- End Ring Attach fixturing (approximated by Alum. Block)

Ignores:
- Chimney
- Warren Girder Cold-mass support
- other junk near the end of solenoid

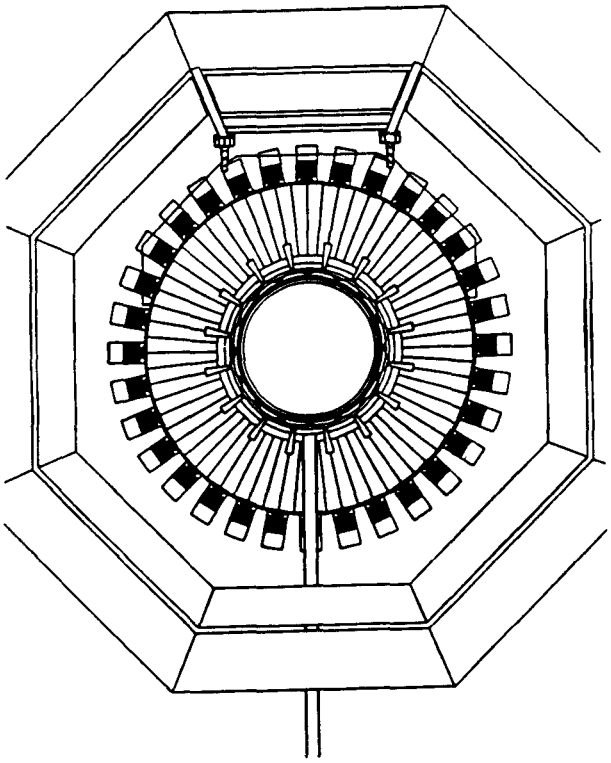




SOLENOID SUPPORT ARMS IN EGS SIMULATION

- dimensions taken from engineering calculations from J. Krebs SDC Solenoid Subsys note sized for forces in iron-endwall design.
- design note assumes Aluminum, current plan is for composite (==>less X0)
- simulations assume support arms cover full circumference of readout crack
==> this is actually the worst case<==

1630



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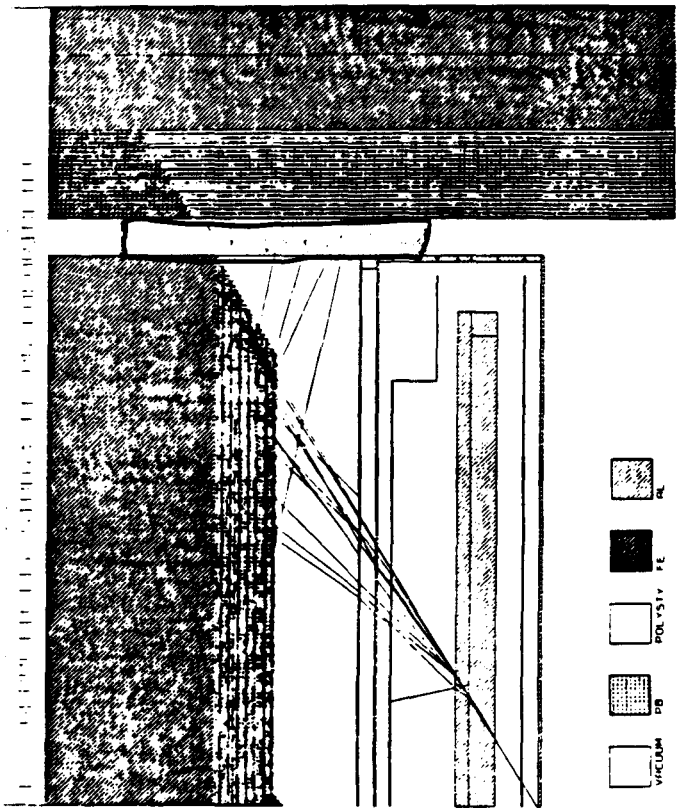


1632

CALORIMETER EGS SIMULATION

Includes:

- Dimensions and Tile counts taken from L. Bartoszek CAD files for Iron/Pb Calor
- 1/8" Pb sampling in Barrel
- 1/4" Pb Sampling in Endwall
- 2.5mm Scint thickness
- Aluminum Cover Plate for Stack Compression
- 0.020" cover skin

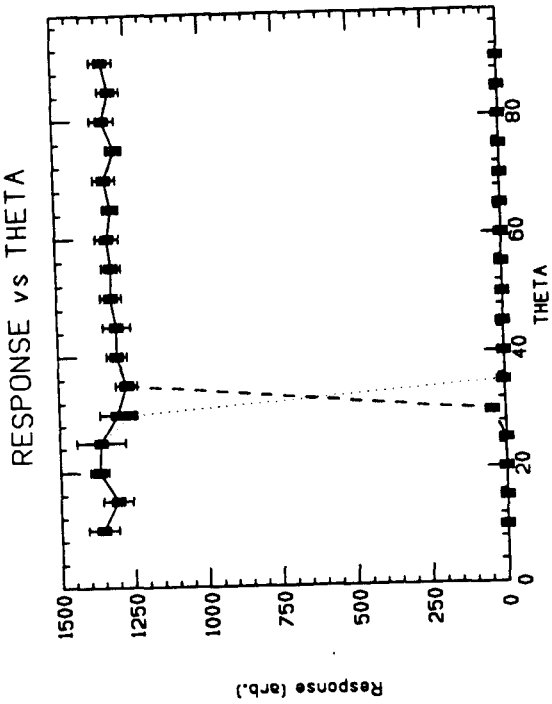
Not Included:

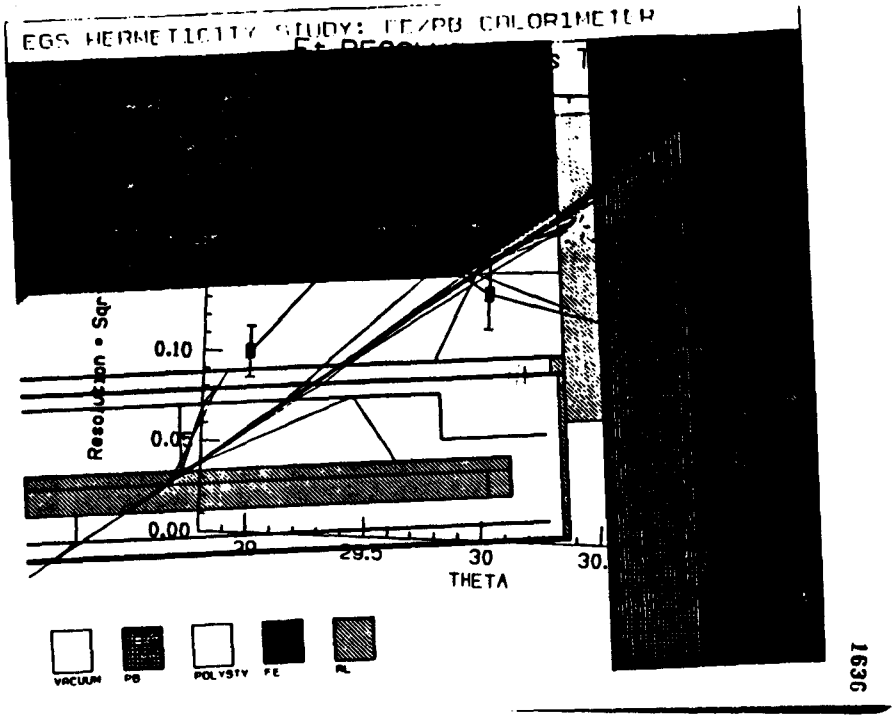
- Photostatistics
- Piano wires for stack compression (These are Non-Projective)

****
NO "MASSLESS GAPS" OR OTHER CORRECTIONS
****

...these will improve the response downstream of the coil...

1633





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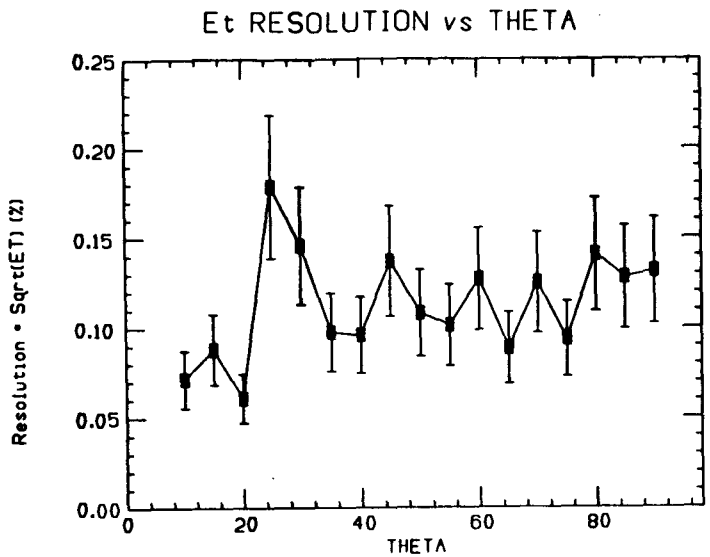

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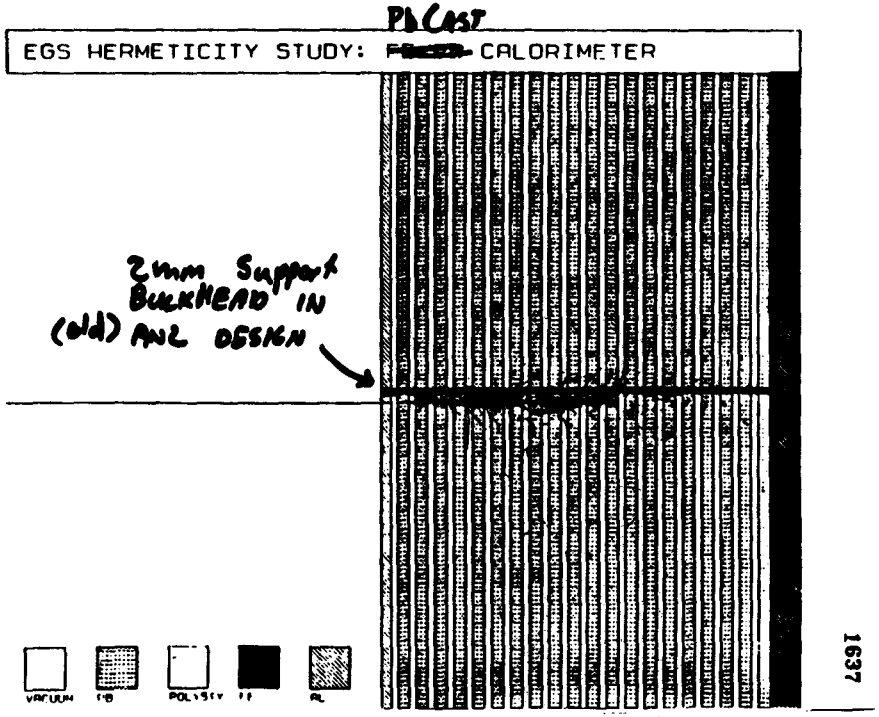

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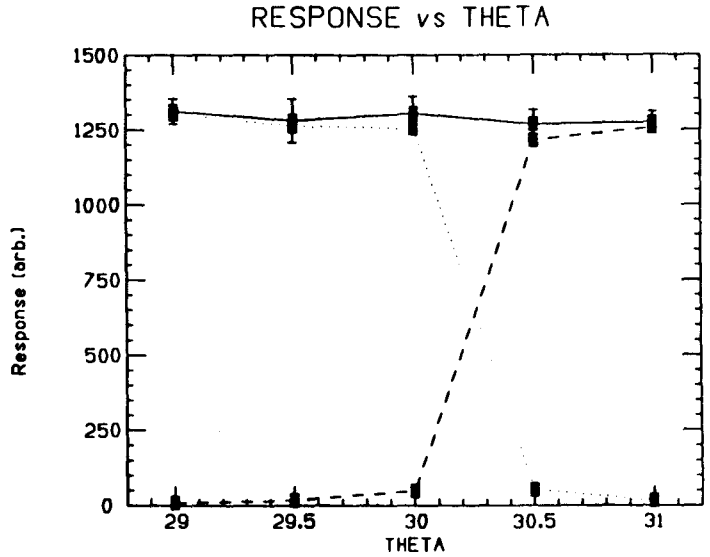

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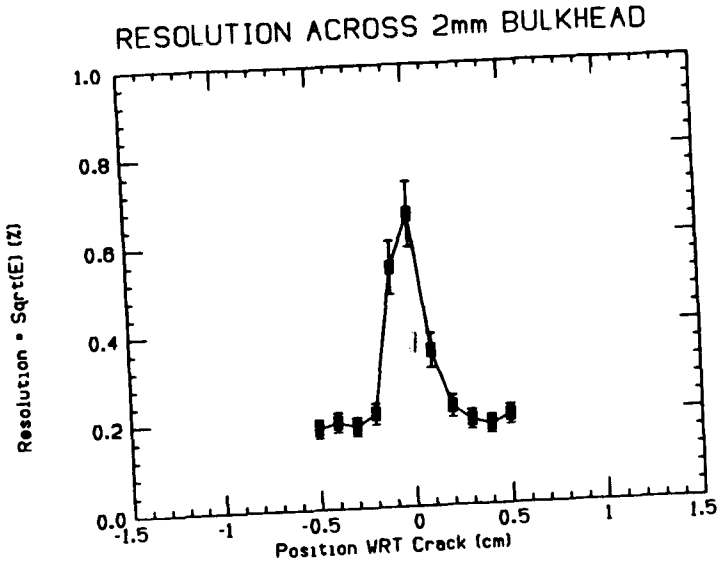
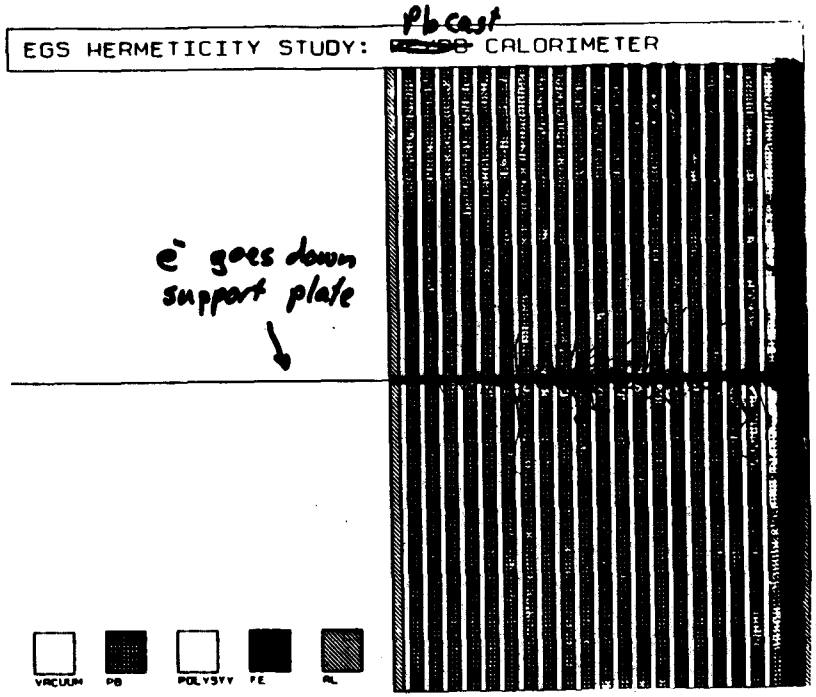
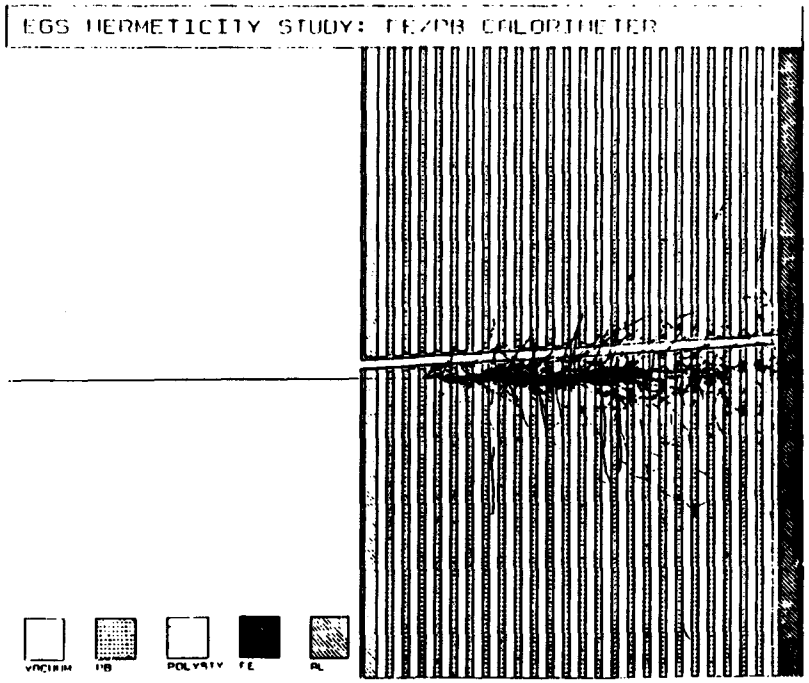
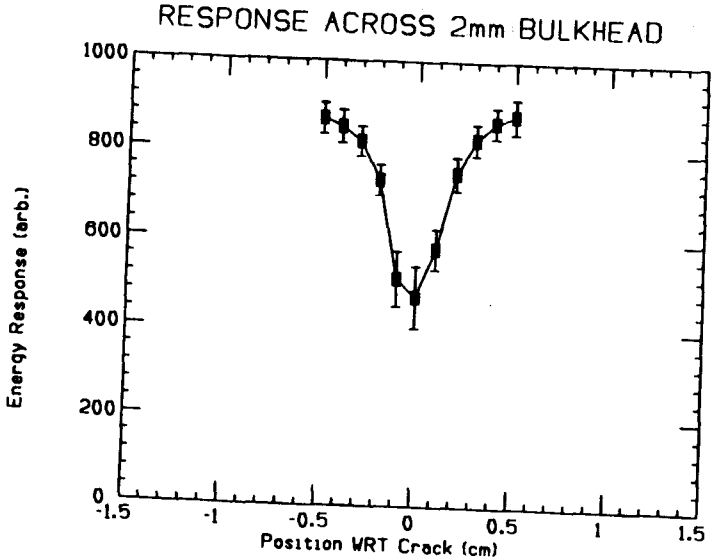
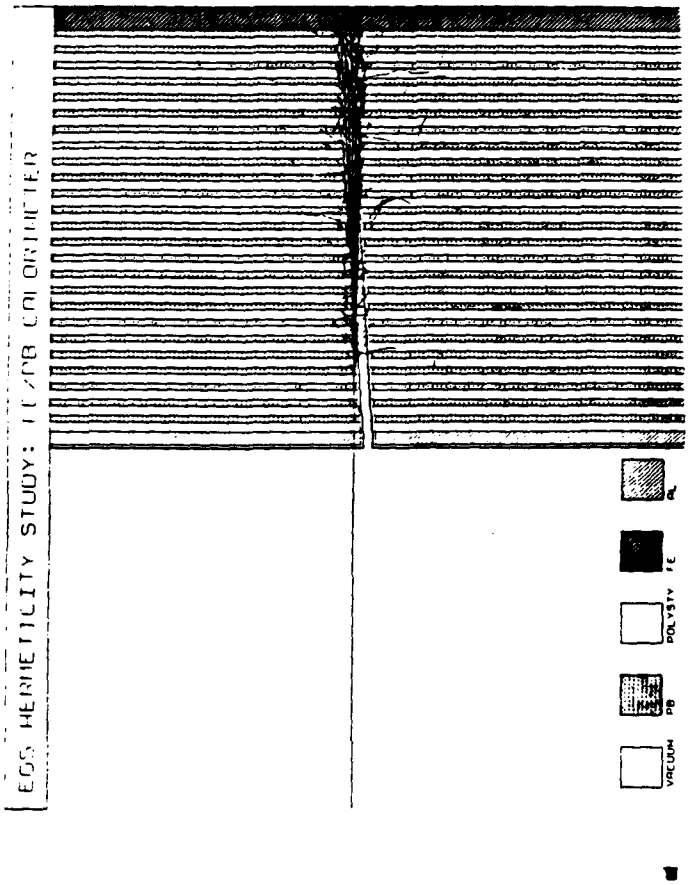

RESOLUTION ACROSS 2mm BULKHEAD
Resolution • Sqrt(E) (%)
Position WRT Crack (cm)


EGS HERMETICITY STUDY: Pb cast CALORIMETER
e⁻ goes down support plate
VACUUM
PB
POLYSTY
FE
AL


EGS HERMETICITY STUDY: FE/PB CALORIMETER
VACUUM
PB
POLYSTY
FE
AL


RESPONSE ACROSS 2mm BULKHEAD
Energy Response (arb.)
Position WRT Crack (cm)

1642



1643

INTEGRATION FOR LA, TILE/FIBER

D. BINTINGER

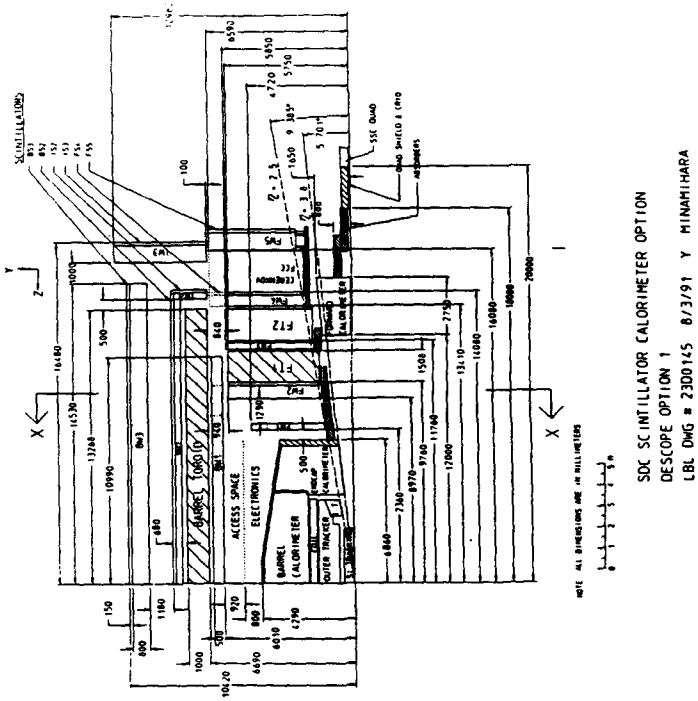
LAC - Scint. Cal. Integration

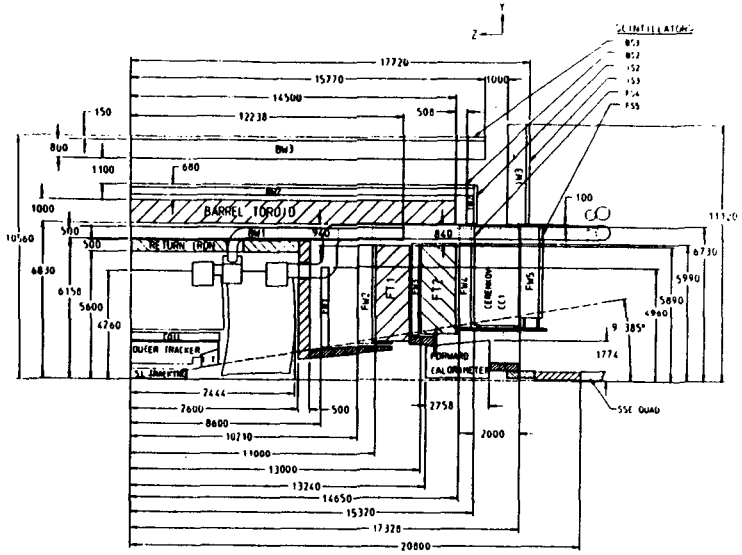
1644

Radius LAC	10.56 m	S.C. 10.42 m
Length (b)	18.27 m	17.03 m
Access Movement	~1 m	~1 m perhaps 3-4 m
BW1 Access	Difficult	OK
Installation	Phase 1 Muon Chm. Install. ~ 1 yr	Phase 1 Muon Chm. Install. ~ 6 mos.
BW1 Acceptance	Cryo. Piping	

Bintinger

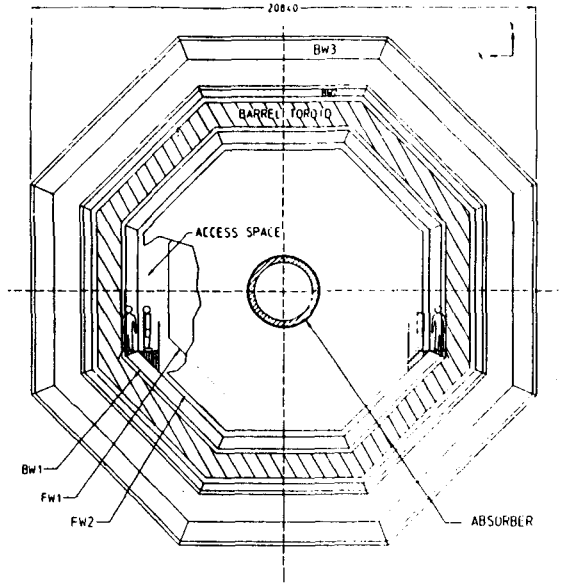
1645





SDC LIQUID ARGON CALORIMETER OPTION
LAC DESCOPE OPTION 1
LBL DWG # 23D0175 8/3/91 Y MINAMIHARA

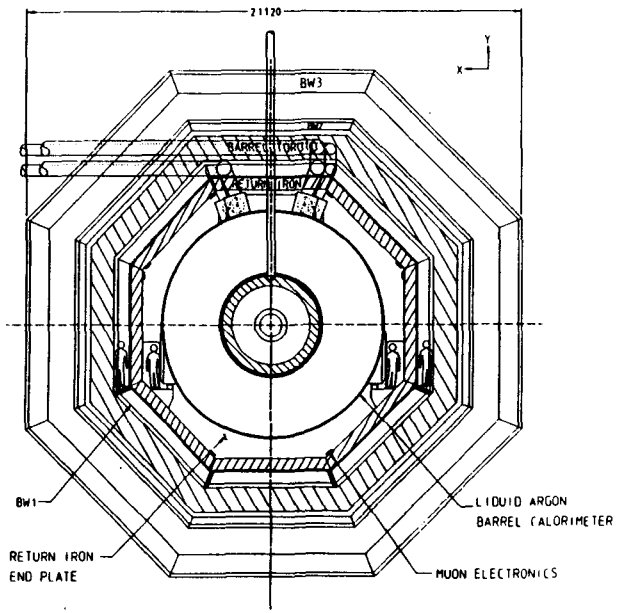
1648



SECTION X - X

NOTE ALL DIMENSIONS ARE IN MILLIMETERS

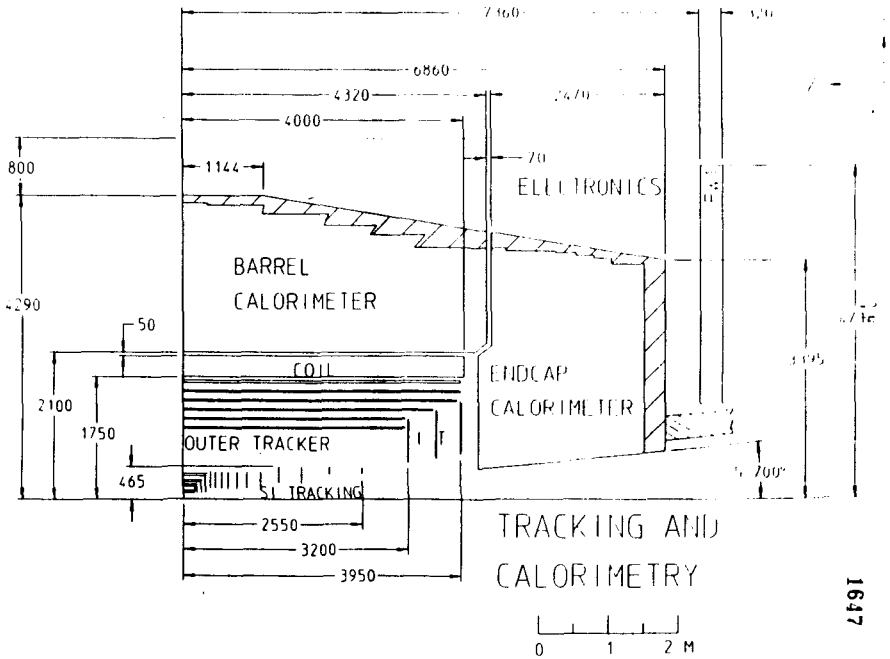
1646



SECTION X - X

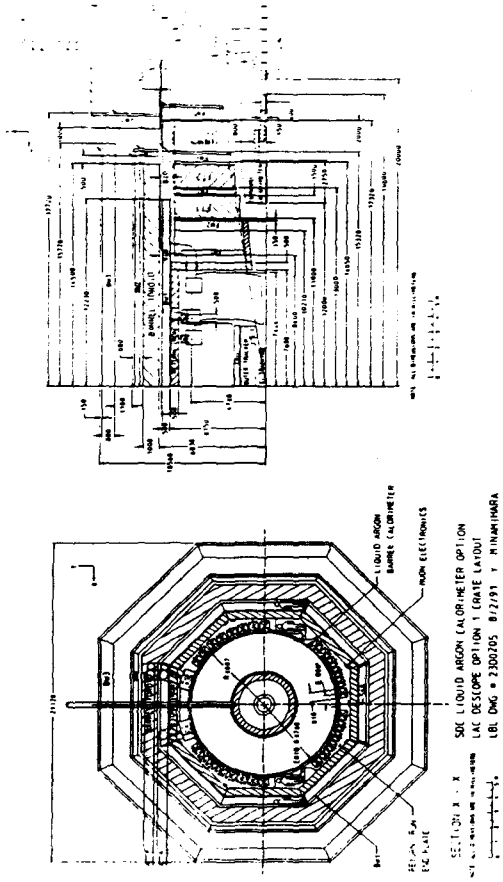
NOTE ALL DIMENSIONS ARE IN MILLIMETERS

1649



1647

1650



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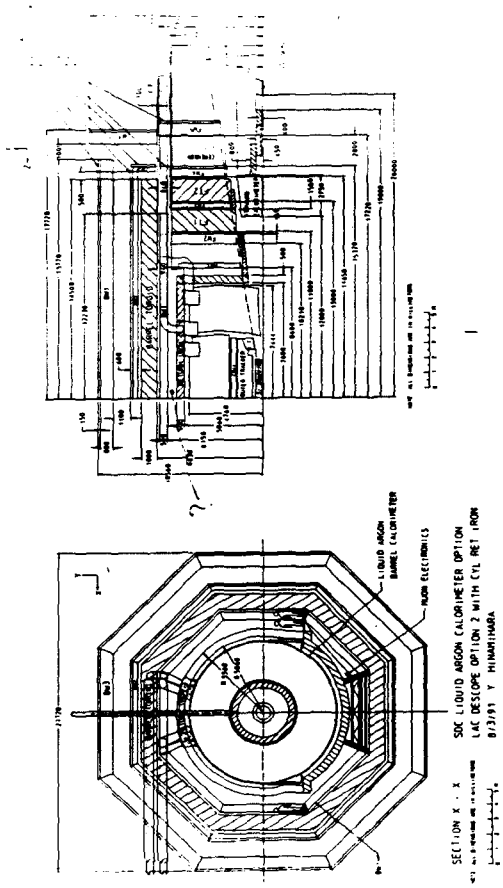

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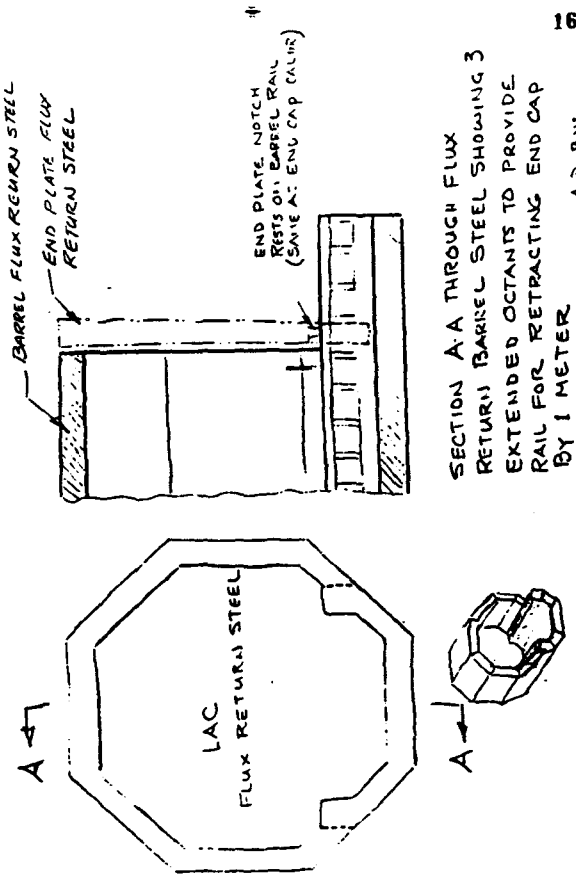
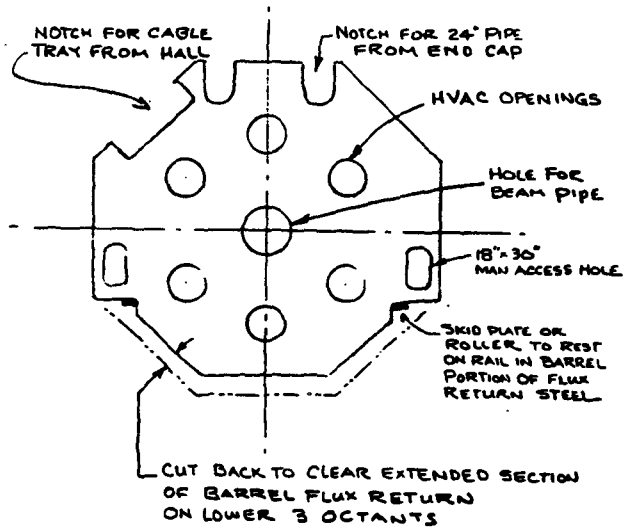


SECTION A-A THROUGH FLUX RETURN BARREL STEEL SHOWING 3 EXTENDED OCTANTS TO PROVIDE RAIL FOR RETRACTING END CAP BY 1 METER

A. DuBois 7-19-91

1653



SCHEMATIC ELEV. VIEW OF END PLATE OF FLUX RETURN STEEL

NOT TO SCALE

A. DuBois 7-19-91

Simulation Studies of 3 Segment Calorimeters

Tom Handler
Univ of Tennessee

P.K. Job
Argonne National Lab

T. A. Gabriel
Oak Ridge National Lab

Configurations Simulated

	EM	HAC1	HAC2
AUG01			
	Pb/Scint	Pb/Scint	Fe/Scint
Thicknesses	0.55/0.25	1.55/0.25	3.55/0.25
# cells	20	34	27
AUG02			
	Pb/Scint	Pb/Scint	Fe/Scint
Thicknesses	0.55/0.25	3.55/0.25	7.55/0.25
# cells	20	15	13
AUG03			
	Pb/Scint	Fe/Scint	Fe/Scint
Thicknesses	0.55/0.25	3.55/0.25	3.55/0.25
# cells	20	15	27
AUG04			
	Pb/Scint	Fe/Scint	Fe/Scint
Thicknesses	0.55/0.25	3.55/0.25	7.55/0.25
# cells	20	15	13
AUG05			
	Pb/Scint	Pb/Scint	Fe/Scint
Thicknesses	0.55/0.25	1.55/0.25	7.55/0.25
# cells	20	34	13

Interaction Lengths

	EM	HAC1	HAC2	TOTAL
Aug01	0.644	3.083	5.719	9.446
Aug02	0.644	3.115	5.856	9.615
Aug03	0.644	3.177	5.719	9.540
Aug04	0.644	3.177	5.856	9.677
Aug05	0.644	3.083	5.856	9.583

Depth of Calorimeter

1	179.80
2	174.40
3	175.60
4	174.40
5	178.60

2m x 2m transverse

Numbers of particles run at the various energies

	10 GeV	30 GeV	75 GeV	125 GeV	250 GeV
# hadrons	500	300	300	200	200
# electrons	200	200	200	200	200

Note that at 250 GeV only configuration AUG05 was run

No Photo statistics or light efficiency incorporated into simulations

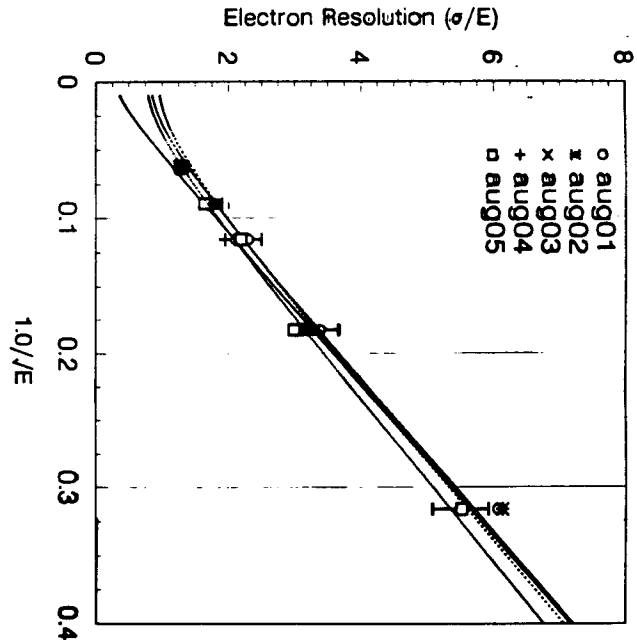
48 ns integration time on neutrons

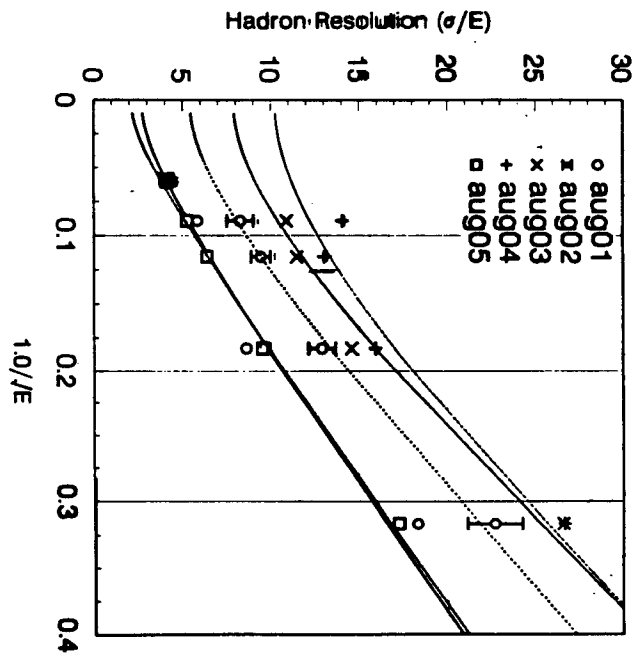
Weighting Factor

$$\text{weight} = \frac{\sum\left(\frac{dE}{dx}\right)_i \rho_i(\Delta x)_i}{\left(\frac{dE}{dx}\right)_{scint} \rho_{scint}(\Delta x)_{scint}}$$

Resolution Function

$$\left(\frac{\sigma}{E}\right)^2 = \frac{a^2}{E} + b^2$$





Electromagnetic Resolution Results

	a	b
AUG01	0.1786 +/- 0.0068	0.0027 +/- 0.0095
AUG02	0.1747 +/- 0.0120	0.0086 +/- 0.0023
AUG03	0.1788 +/- 0.0094	0.0083 +/- 0.0024
AUG04	0.1786+/- 0.0071	0.0084 +/- 0.0045
AUG05	0.1676 +/- 0.0114	0.0076 +/- 0.0026

Hadronic Resolution Results

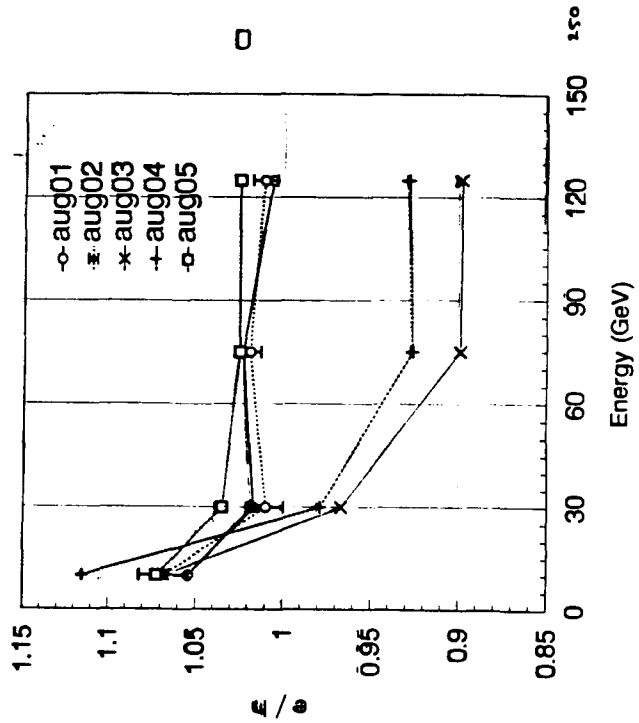
	a	b
AUG01	0.5164 +/- 0.0244	0.0271 +/- 0.0078
AUG02	0.6685 +/- 0.0449	0.0542 +/- 0.0098
AUG03	0.7569 +/- 0.0434	0.0788 +/- 0.0084
AUG04	0.7443 +/- 0.0514	0.1023 +/- 0.0094
AUG05	0.5262 +/- 0.0234	0.0211 +/- 0.0086

Pb

Fe

e/h Values

	10 GeV	30 GeV	75 GeV	125 Gev	250 GeV
AUG01	1.054 +/- 0.011	1.017 +/- 0.006	1.023 +/- 0.005	1.005 +/- 0.005	
AUG02	1.068 +/- 0.014	1.010 +/- 0.010	1.019 +/- 0.006	1.011 +/- 0.007	
AUG03	1.068 +/- 0.016	0.967 +/- 0.010	0.899 +/- 0.007	0.898 +/- 0.008	
AUG04	1.115 +/- 0.016	0.979 +/- 0.011	0.926 +/- 0.008	0.928 +/- 0.012	
AUG05	1.072 +/- 0.010	1.035 +/- 0.006	1.025 +/- 0.005	1.025 +/- 0.004	1.026 +/- 0.003



Y.Unno 1991/8/6

Critical Issues and Beam Test

Y.Unno
KEK

and
The SDC LAC group

- List of remaining issues
  - Beam test setup
- Results: resolutions, *e/h*

Y.U 1991/6/18

Critical Issues for the LAC

Item	Status	Comment
Preamp (Rad.hard)		BNL hybrid: $>10^{13}$n/cm^2, >12Mrad
Speed		τ_{rise}≤30ns
Noise		τ_p=100(EM), 200ns(HAD) σ_{Et} (ΔR<0.15)
Pileup		3 meas., τ_p=50~200ns σ_{Et}~0.5GeV
e/h meas.		Hadron module beam test
e hermeticity		97%accept.(σ_E<25%/$\sqrt{E}$)
Reliability		<0.2% failure(SLD) in 10^8s
P/a cooling		KEK/Rochester test results
Safety		SSCL Safety committee
η=3,E_t		KHI, LBL
Integration		LBL
Cost		MMA

Objectives of the beam test

(1) Drift velocity of electrons in the Liquid Argon is said to be slow. However, what we need is the signal, and fast-readout can be achieved by fast charge transfer time and by shaping the signal for an appropriate peaking time (detail will be discussed by C.Hearty).

The objective of the beam test is to test the fast-readout with bipolar shaping with the peaking times of 50, 100, and 200 ns, for HADRONIC and ELECTROMAGNETIC calorimetry.

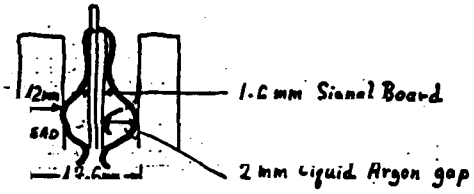
(2) e/π (e/h) measurement with Pb absorber in HADRONIC calorimetry with the fast-readout.

(3) Uniformity of response across the module crack in ELECTROMAGNETIC calorimetry of the SDC design.

Don Akkowicki (BNL)

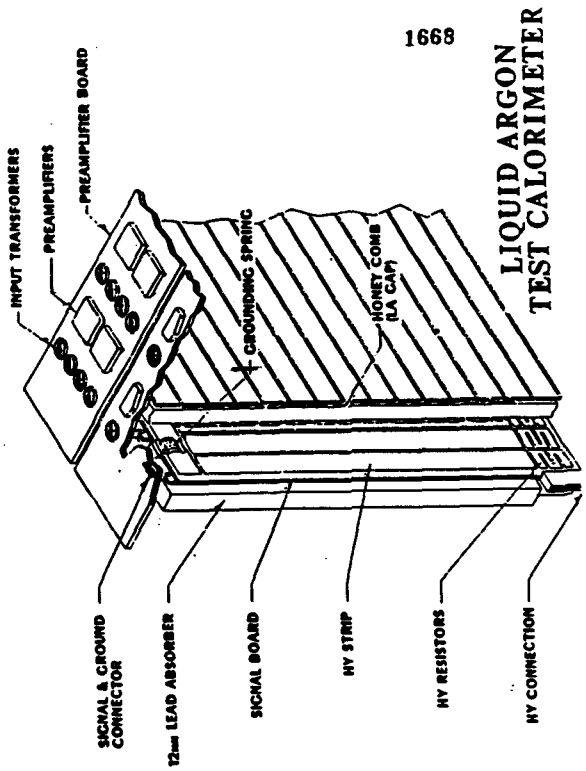
STACK

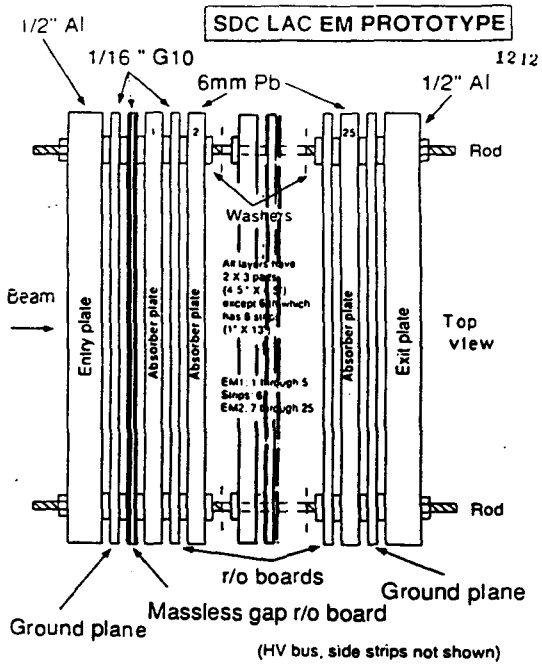
- SIZE 100 cm X 100 cm
- DEPTH 170 cm (7.5 λ)
- SEGMENTATION 3 Longitudinal Sections
- ABSORBER 12 mm Lead (.01% calcium, 1.3% Tin)
- WEIGHT 5 Tons per section
- Section contains 16x and 16y cells



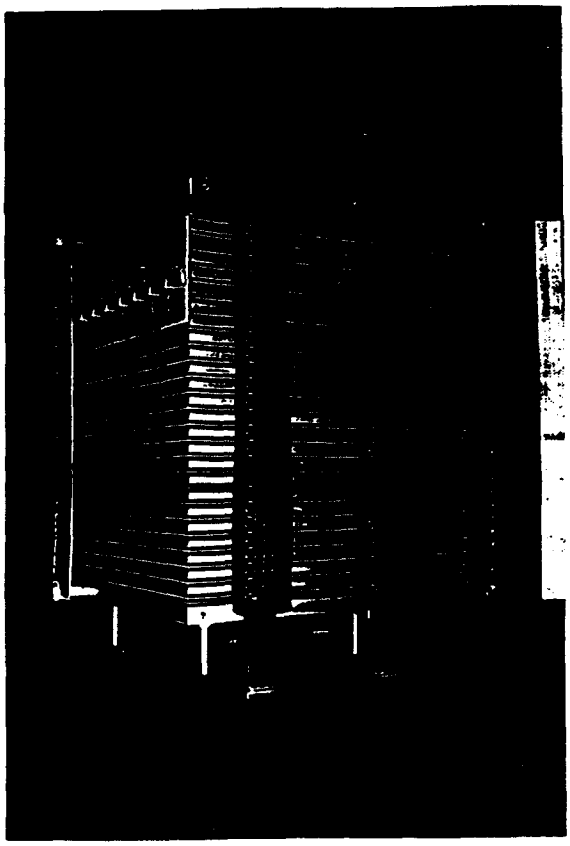
- SIGNAL BOARD has 40 2.5cm strips
- STRIPS alternate in x and y
- TOTAL NR. CHANNELS (40x + 40y) 3 Sect = 240CH

Connection scheme and coupling transformers will follow closely the HELIOS method of acheiving low inductance charge transfer to the preamps.





1670



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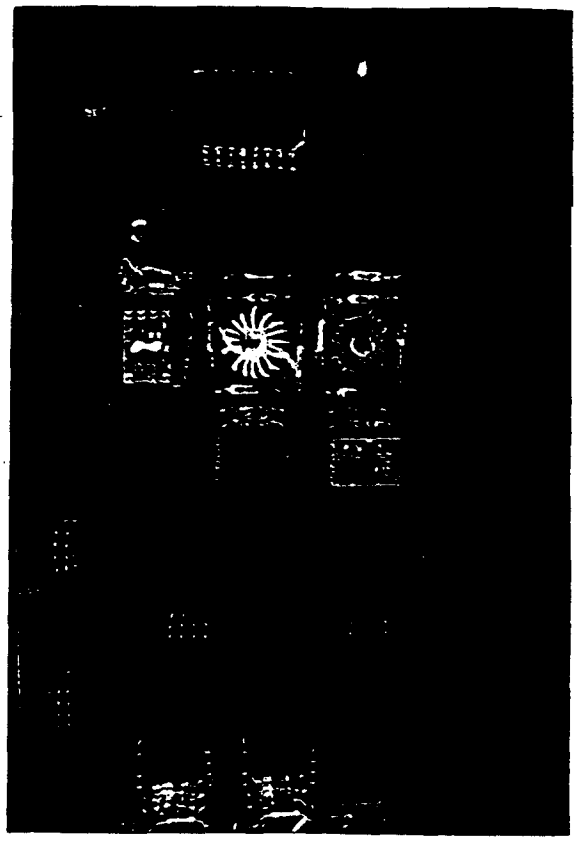
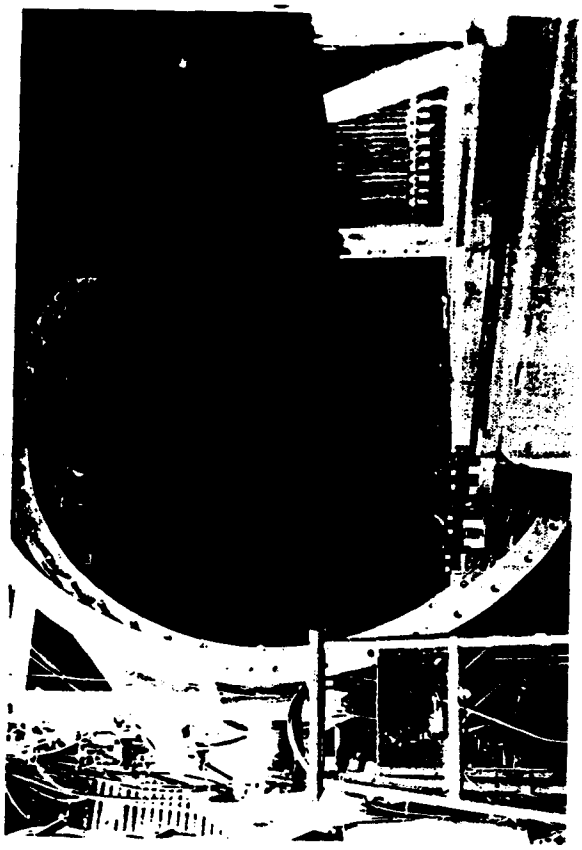


1672



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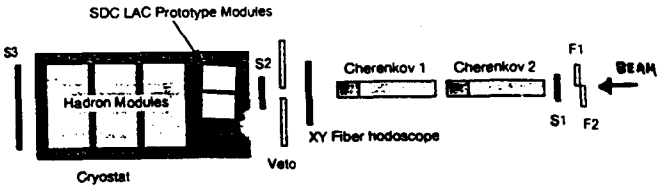


Figure 8.16

Schematic view of the BNL Spring '91 test

Readout Electronics chain

Very much like the proposed electronics chain of the SDC LAC option other than Analog memory (or more correctly, we follow the readout chain in the beam test laid by the Liquid Argon subsystem R&D).

- Preamp in the Liquid Argon
- Intermediate amp on the feedthru (outside)
- Variable Gain Amp in the counting hut:

  (1) t_p=100 ns Bipolar shaping to individual ADC's
  (2) Analog sum to a shaper with t_p=50, 100, 200 ns shaping, then to an ADC or a transient recorder

- Calibration chain

Results

The beam test data are under rigorous analysis among collaborators. The results being presented here are one of many and also should be taken as preliminary. More and better-understood results will be available by the time of the Corpus Christi Conference.

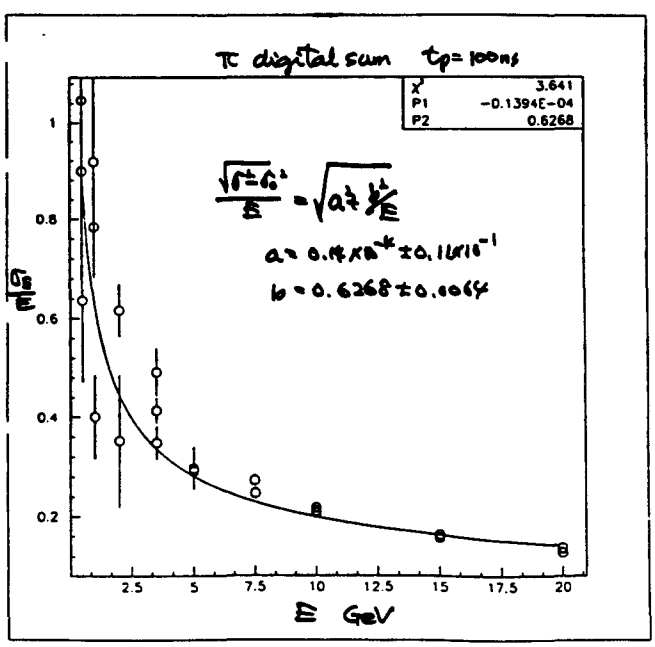
- EM module:

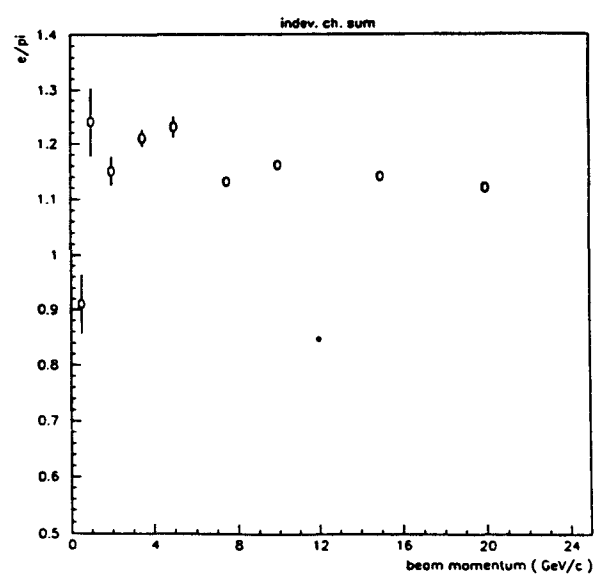
  Energy sum of EM1 and EM2

- Hadronic module:

  Hadron energy resolution at t_p=100 ns (individual digital channel sum)

  Responses of electrons and pions t_p=100 ns and e/π ratios





e/π=1.15 @E=20GeV, then e/h ?

- We have estimated the π° fraction by using GEANT/GHEISHA. We have

  $f\pi^\circ$ = 0.361 @20GeV.

The data

  e/π=1.15

is transformed into

  e/h = 1.26 .

- When we use the D.Groom's ansatz, we obtain

  e/h=1.25.

- The induced constant term will be

  σ_E/E(const. by e/h) = 3.5% .

Speed, Noise, Pileup and Electron Uniformity for Liquid Argon

Test Beam Results and Analysis for SDC

Christopher Hearty

August 6, 1991
SDC Collaboration Meeting at LBL

OUTLINE

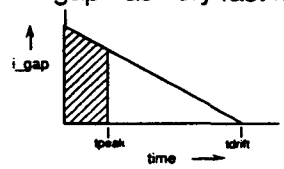
1. Introduction
2. Speed of Response
3. Noise
   - pileup
   - electronic noise
   - timing resolution
   - summary/total
4. Missing Et
5. Electron Uniformity/Hermiticity

Introduction (and Summary)

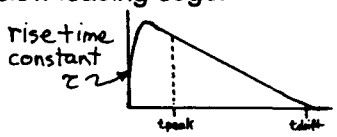
- Liquid argon has a fast risetime that is preserved by the SDC electrode structure.
- resolution and uniformity across phi crack are acceptable; very good elsewhere
- electronic noise and pileup sufficient for SDC physics program.
- <5 ns time resolution for >1 GeV in EM channel, 5--10 GeV in hadronic.
- The response of the detector in all of the above is understood and can be calculated, as has been verified by beam test data.

Speed of Response

Current in LAr gap has very fast rise time:



Charge transfer time and preamp response time slow leading edge.

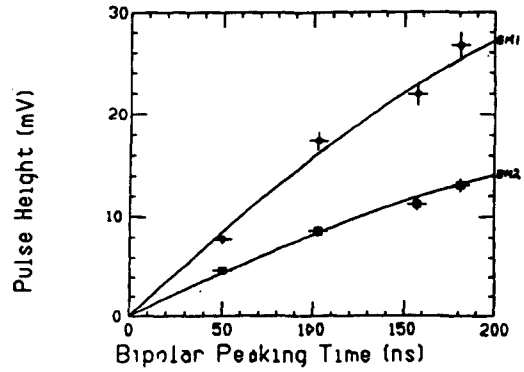


- $\tau \approx \sqrt{L \cdot C_0}$ ==> need to keep inductance low
- noticable signal loss for tau ≥ tpeak (signal loss <==> increase in noise)

Beam test results

(electrode structure same as SDC)

Collected signal vs tpeak for 10 GeV e-

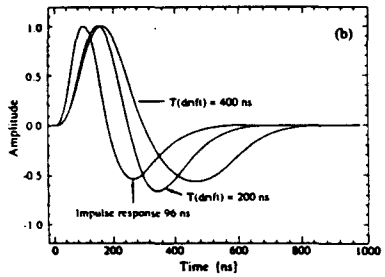


lines = expected variation with tpeak for tau << 50 ns (arbitrary normalization)

Even for tpeak = 50 ns, no significant signal loss from finite rise time effects.

Pileup

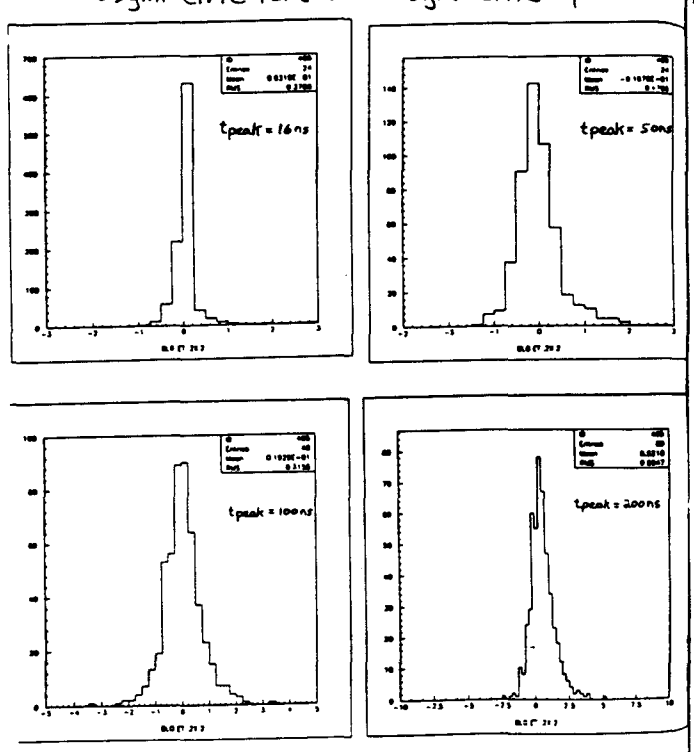
Convolution of shaper and triangular input current:



Resulting shape has long, low amplitude negative tail and no net amplitude
==> average observed energy is zero

Observed pileup E_t in cell 0.2×0.2 @ 10^{33}

- $\langle E_t \rangle = 0$
- asymmetric tails from asymmetric bipolar shape



Pileup "noise" from non-zero rms:

$$\sigma_p^2 = \sigma^2(E_t) \cdot W$$

$\sigma^2(Et)$ = variance of Et deposited per crossing

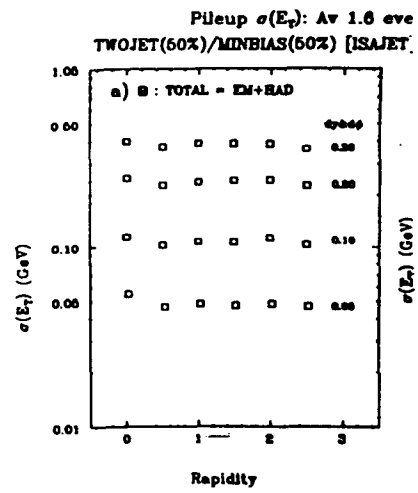
W = effective duration in number of beam crossings of observed shaper output

$$= \sum_{i=0}^{M_0} h^2(t_i)$$

$\propto$ tpeak (approx)

$$\sigma_p \propto \sqrt{\mathcal{L} \cdot \Delta\Omega \cdot t_{peak}} \quad \text{(approx.)}$$

$\sigma(E_t)$ vs η, various cell sizes



7.3.4

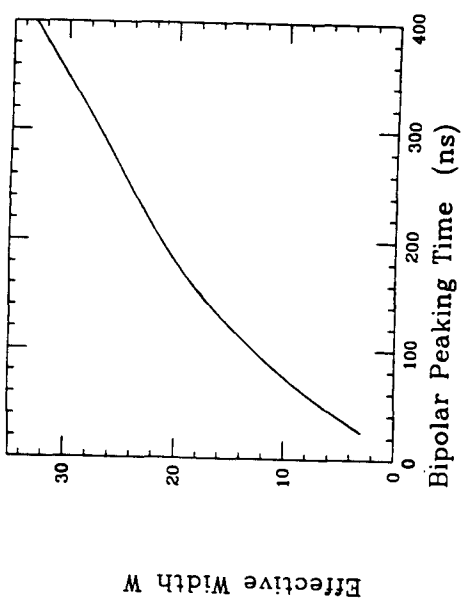
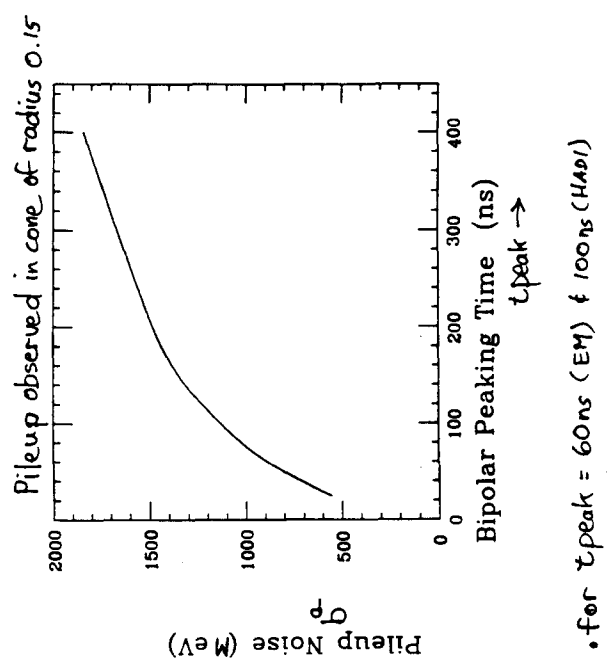
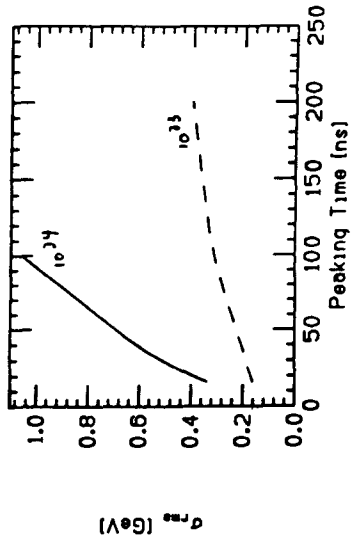


Figure 7.3.5



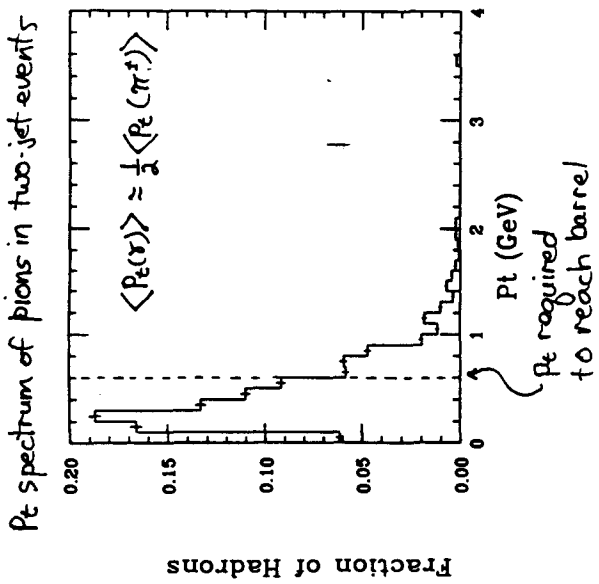
• for tpeak = 60ns (EM) & 100ns (HAD)
σ_p = 830 MeV

7.3.7



Several effects will improve this (not yet included)

- pt spectrum is soft
  ==> many pions will not reach barrel
- pileup mostly matters in electron isolation cone
  ==> threshold on each channel will suppress much pileup energy (e.g., 200 MeV / EM channel)



Beam Test Pileup Measurement

10 GeV pions incident on BNL hadronic module at rates up to 1 Mhz. (histograms for 2 and 400 kHz)

Increase in rms of 10 GeV peak in agreement with expected value.

SDC EM tower hit at rate of 800 kHz, but effect is very much less than BNL because pileup pt is much less than the 10 GeV of BNL test.

Figure 2.7

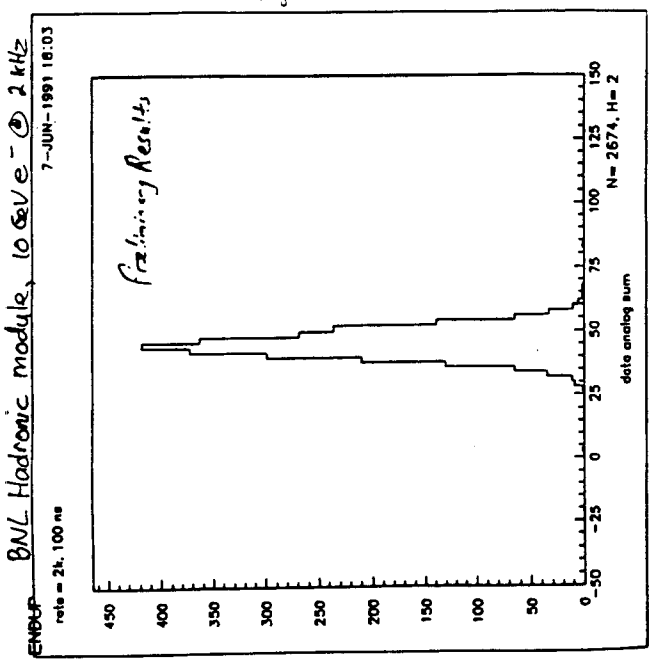
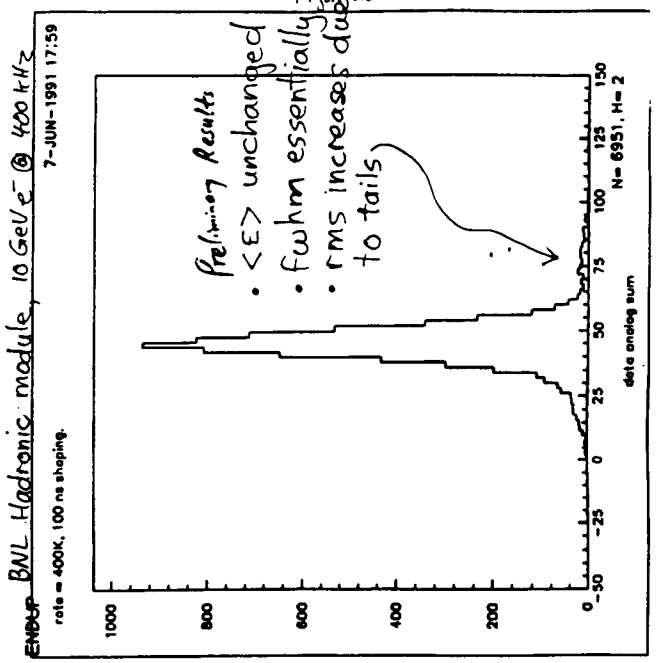


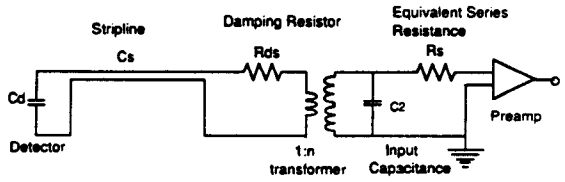
Figure 2.8



Electronic Noise

Equivalent Noise ~~Energy~~ Charge

ENC is the impulse charge on the signal pads of the electrodes that gives the same response after the shaper as the electronic noise —



Schematic diagram of front end for calculating noise. Rds and Rs are the two significant noise sources.

Only series noise is important for JFET:

$$ENC^2 = \frac{8k}{t_{peak}}\left[R_{ds}\cdot T_{ds}C_1^2 + R_s T_s\left(\frac{C_1}{n} + n\cdot C_2\right)^2\right]$$

Rds is damping resistor at temperature Tds
Rs is the equivalent series resistance of the JFET at temperature Ts
C1 = Cd + Cs is the total capacitance upstream of transformer
C2 = Cfet + Cstray is the total capacitance downstream

Transformer matches C1 to C2, so ENC depends linearly on C1 in 1st term and on sqrt(C1) in second term.

For SDC, Rds = 2 ohms, Tds = 88 K
Rs = 17 ohms, Ts = 300K (equiv)
Cfet = 40 pF, Cstray = 10 pF

Choose stripline so Cstrip = Cdet/3, but Zstrip ≥ 4 ohms

Equivalent Noise Energy

Relate energy deposited in the calorimeter to charge collected during the effective integration time (tpeak).

- Ballistic deficit:

$$\frac{Q}{Q_0} = \frac{2\,t_{peak}}{t_{drift}}\left(1 - \frac{1}{2}\frac{t_{peak}}{t_{drift}}\right) = \begin{cases} 0.28 & t_{peak} = 60\,ns \\ 0.44 & t_{peak} = 100\,ns \end{cases}$$

- Sampling fraction:
  fraction of energy in LAr from dE/dx.
  s = 0.13 EM
  = 0.023 hadronic

- p/mu: fraction of energy deposited in LAr by showers is less by
  e/mu = 0.66
  pi/mu = 0.53

$$\frac{dQ}{dE} = 3.03 * S * \frac{Q}{Q_0} * \frac{P}{\mu} * B_{block} \quad \left[\frac{fc}{MeV}\right] \quad \frac{\text{charge on sig. pac}}{\text{energy in calor.}}$$

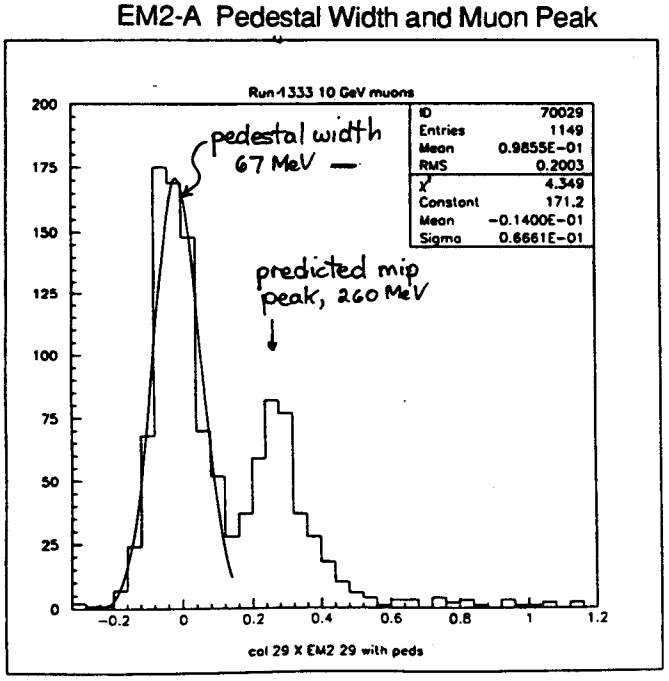
- 3.03 is LAr ionization

- Bblock = 0.9 for charge lost on blocking C

(finite rise time effects would decrease Q/Q0)

Electronic Noise: Test Beam Module

EM2-A Pedestal Width and Muon Peak



EM2-A Pedestal width

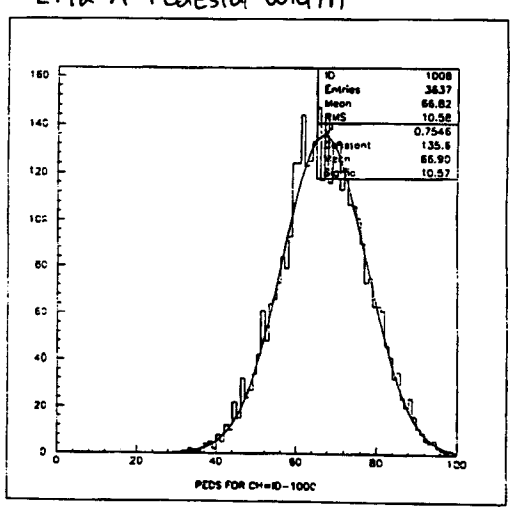


Figure 1. Pedestal width (ADC counts) for Channel 5 (EM2) VGA gain = 10.

1702

Comparison between measured and predicted ENE (MeV), BNL test beam module:

Channel	Measured	Predicted
EM1-A	16 +/- 2	23 +/- 5
EM1-B	17 +/- 2	23 +/- 5
EM2-A	67 +/- 7	50 +/- 10
EM2-B	50 +/- 7	50 +/- 10

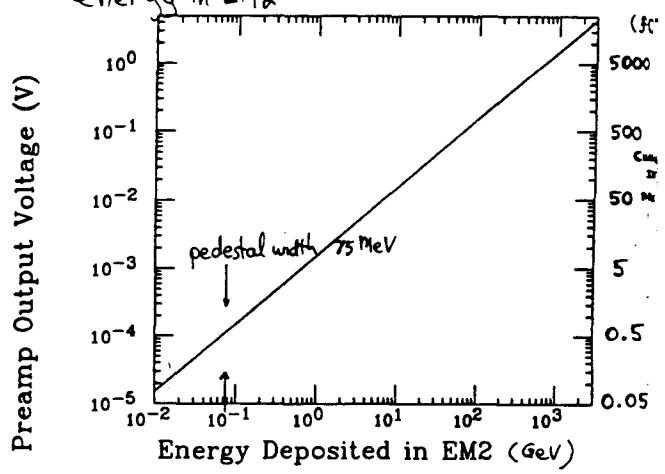
Measured values are consistent with expected thermal noise (not a surprise).

No significant pickup. (EM2 pedestal width corresponds to preamp output voltage of 150μV)

1703

SDC conceptual design

Preamp output voltage vs deposited energy in EM2

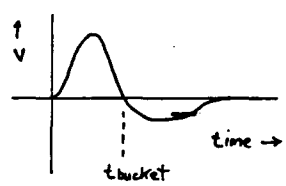


7.1.6

1704

Time Resolution

- bucket tag using zero cross of bipolar shape



$$\sigma_t \approx t_{peak} \cdot \frac{N}{S}$$

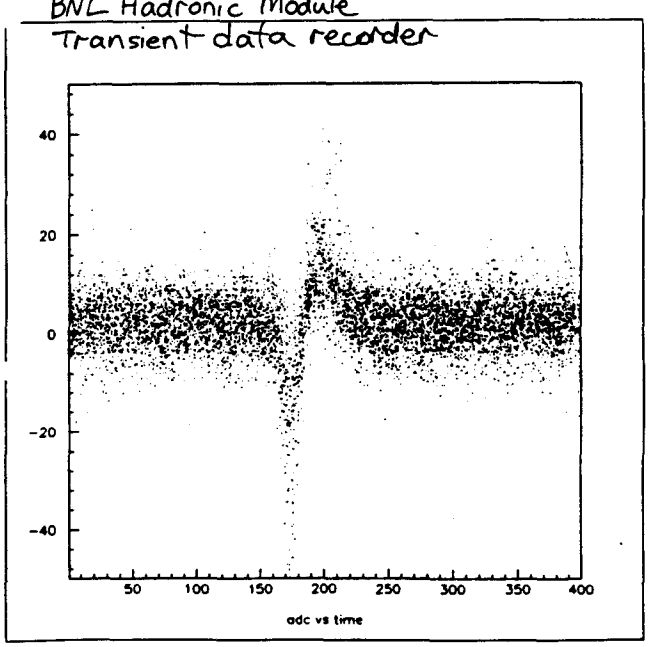
For 10 GeV e- into test beam module,
EM2: S = 5.1 GeV
N = 0.067 GeV
tpeak = 100 ns

==> sigma_t (expected) = 1.3 ns

Measured: sigma_t = 1.5 +/- 0.2 ns

1705

BNL Hadronic Module
Transient data recorder



For SDC, at eta = 0,

Sigma_t < 5 ns for
- E > 1 GeV in EM channel
- E > 5 -- 10 GeV in hadronic channel

(See summary table later)

Summary of Noise per Channel

- eta = 0
- pileup for 10**33
- Mip = energy deposited by mip; mip S/N is signal-to-noise for mip
- sigma_t is timing resolution for 10 GeV in channel
- two preamps per hadronic section; sum before readout

		per Preamp									per Channel					
Section	N_{amp}	N_{gap}	$<r>$	C_D	C_s	C_{tot}	n	t_{peak}	ENC	ENE	ENE	Pileup	Total	Mip	Mip	σ_t
			cm	pF	pF	pF		ns	fC	MeV	MeV	MeV	MeV	MeV	S/N	ns
EM1	1	5	236	970	340	1310	5	60	1.7	27	27	30	40	32	0.8	< 1
EM2	1	26	255	5680	460	6140	11	60	4.9	75	75	54	92	161	1.7	< 1
HAD1	2	18	314	3100	1030	4130	9	100	2.8	194	274	44	278	662	6.3	2.8
								200	2.0	80	113	63	129		5.1	2.6
HAD2	2	27	387	7070	1530	8600	13	100	4.9	337	477	3	477	993	2.1	4.8
								200	3.5	139	197	4	197		5.0	3.9

- Total EM noise essentially constant for 60 ≤ tpeak ≤ 100 ns. 60 ns selected to minimize pileup at 10**34.
- EM noise increases 2.4X for 10**34 (proportional to Lum**0.38)
  EM+HAD1 noise increases 1.6X for 10**34
  (proportional to Lum**0.20)
- Noise insensitive to details of pileup calculation:
  +/- 30% in sigma(inelast) or Lum
  ==> +/- 5% in EM+HAD1 noise
- 200 ns tpeak for hadronic clearly closer to optimum than 100 ns. tpeak limited by pipeline and level 1 trigger time.
- separation between ENE and Mip
  ==> threshold per channel before sum
  (not used in results next section)

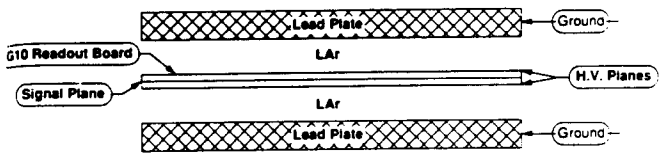
- hadronic section electrode structure optimized for minimum radius. Other options:
  - 3 mm gaps
  - double gap structure
  - 7 mm lead

  all give HAD1 noise ~20% less. Latter option also gives substantially better hadronic energy resolution. Each requires 4 to 10 cm additional radial space.

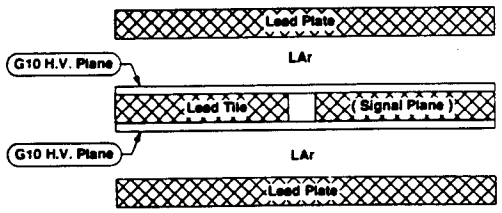
Electrode Structure

1710

a) Double gap Electrode Structure



b) Single Gap Electrode Structure



7.2.1

J B Hunter ⊕ / C Hearfy ⊕
Original 7-24-91
Updated 7-24-91

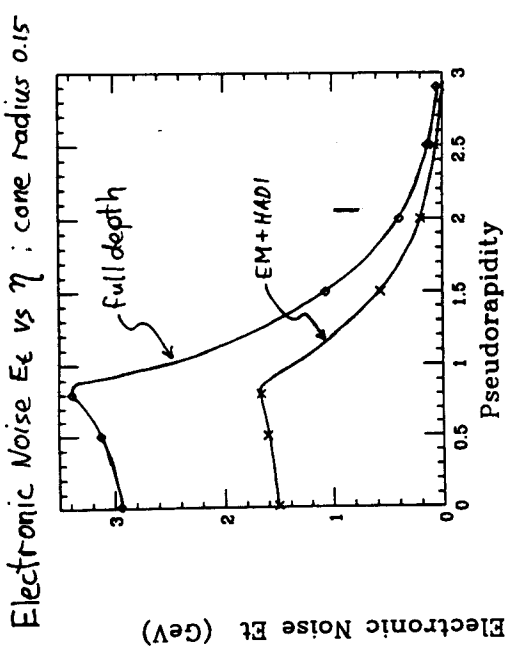
1711

Noise in Cones

tpeak (EM) = 60 ns
tpeak (had) = 100 or 200 ns

Cone Radius	Excluded Section	Electronic Noise (GeV) t_{peak} = 100 ns	Electronic Noise (GeV) 200 ns	Pileup Noise (GeV) 100 ns	Pileup Noise (GeV) 200 ns	Total Noise (GeV) 100 ns	Total Noise (GeV) 200 ns
Single Tower	—	0.56	0.24	0.13	0.15	0.57	0.28
	HAD2	0.29	0.14	0.13	0.15	0.31	0.20
0.15	—	2.9	1.3	0.83	0.96	3.1	1.6
	HAD2	1.5	0.73	0.81	0.93	1.7	1.2

1712



7.5.3

1713

Missing Transverse Energy

Reduced thickness of endcap eta=3 cryostat boundary has substantially reduced problems.

Study using clusters to measure Et and missing-Et, rather than channel sum. Advantages:

- reduce effect of dead material (apply correction to jet cones containing dead material).
- reduce effect of pileup and electronic noise.

1714

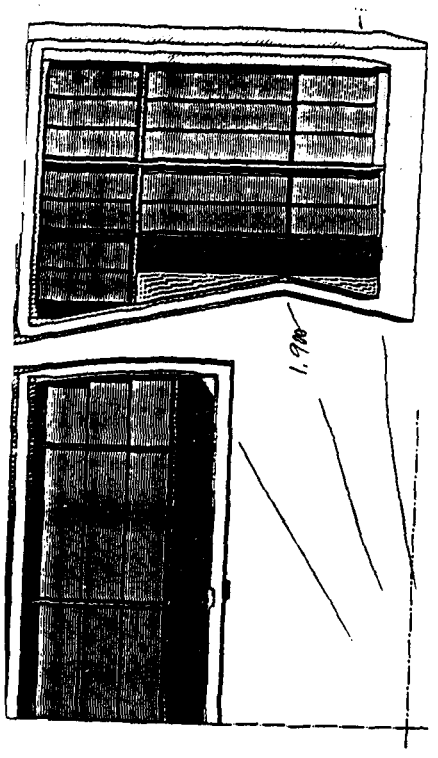
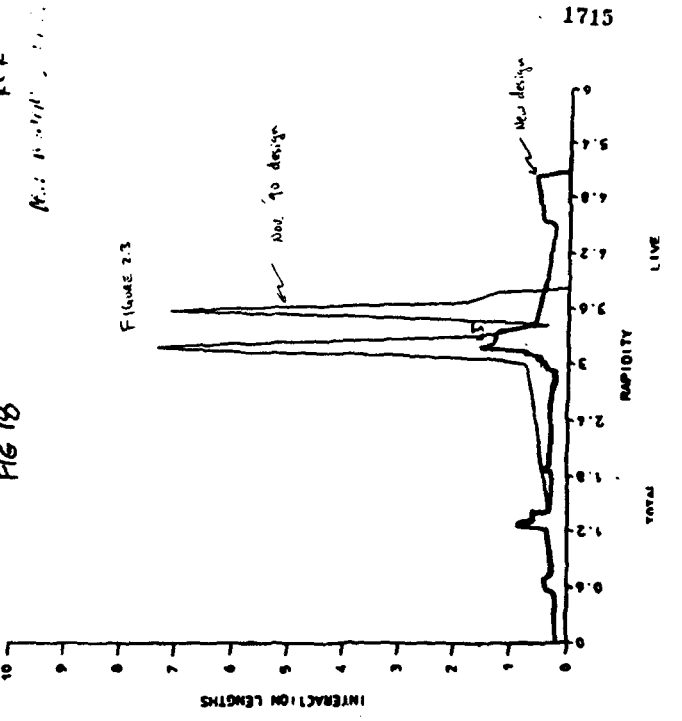


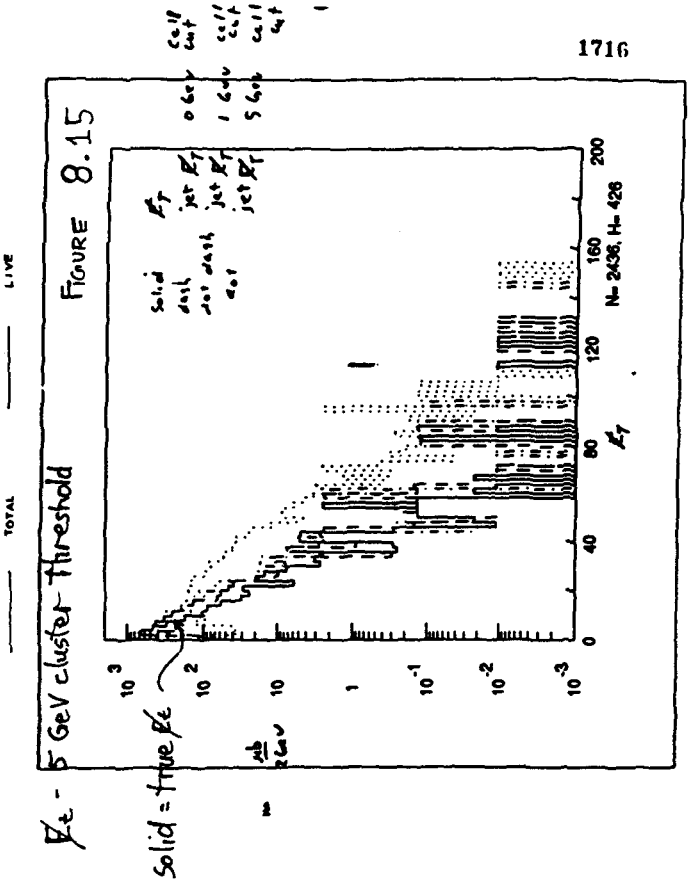
FIGURE 2.2

New LBL cryostat boundary at $\eta = 3$; KEK similar

1715



1716



1717

Electron Uniformity

Three areas to check:

- cryostat walls near eta = 1.3 (Nobu's talk yesterday)
- tie rods
- phi crack

All three studied with EGS and/or Geant.
Phi crack studied in beam test.

FIGURE 2.1

1718

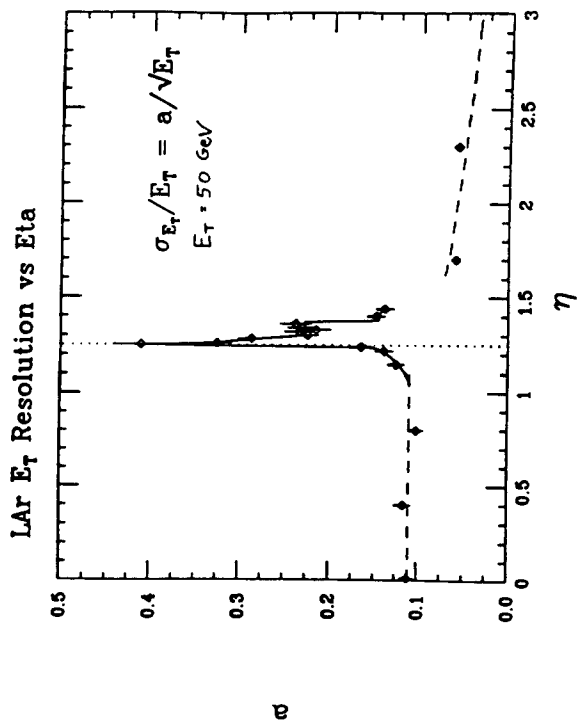


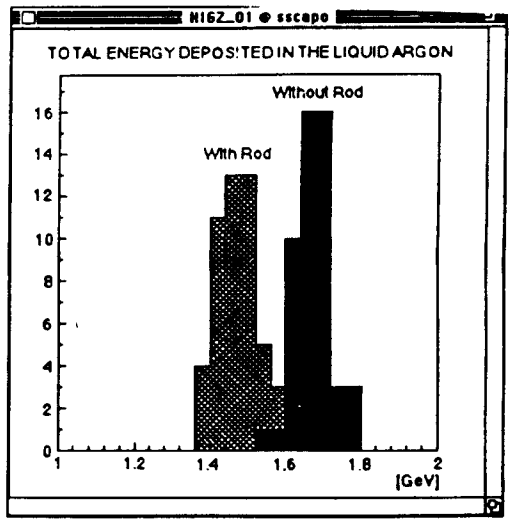
Figure 5b

1719

Tie Rods

Cover less than 2% of solid angle

Non-projective ==> no loss of signal



Effect is vastly mitigated by the fact that the rods constitute less than 1% of the total area. If the shower is carefully aimed at the rod, the effect is 4% in stochastic term and 12% in response.

1720

Phi Crack

3 mm non-projective cracks between modules (~1.5% of surface area)

Effects studied at BNL test beam
- preliminary results only

Order of presentation:

- Geant study of 10 GeV e- on test beam module
- preliminary beam test results
- Geant study of SDC

1721

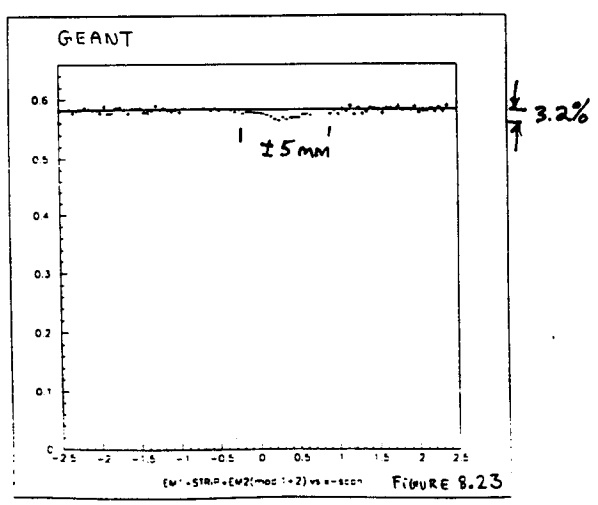


FIGURE 8.23

1722

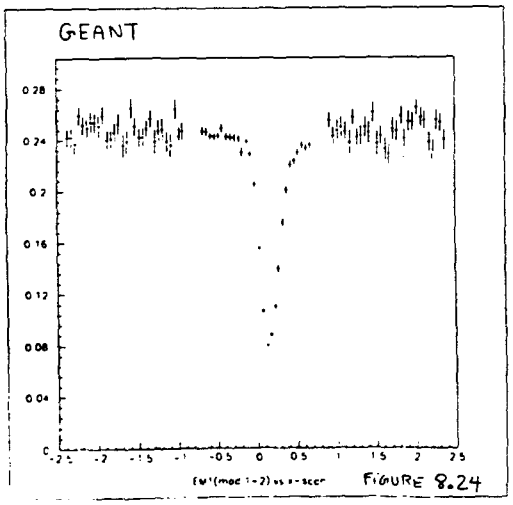


FIGURE 8.24

1723

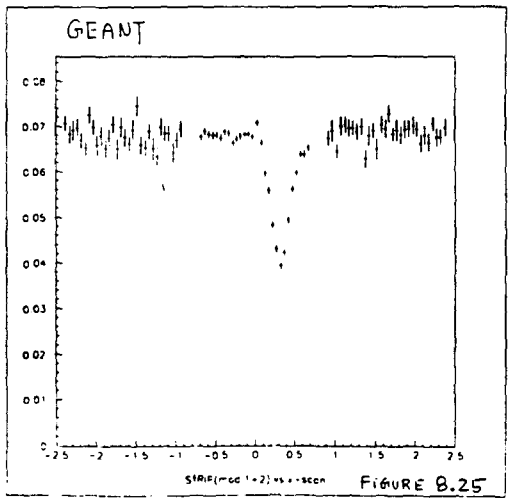


FIGURE 8.25

1724

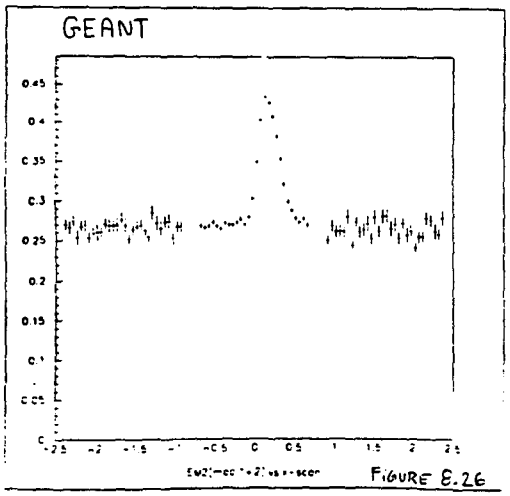


FIGURE 8.26

1725

Geant response, EM1+EM2 only

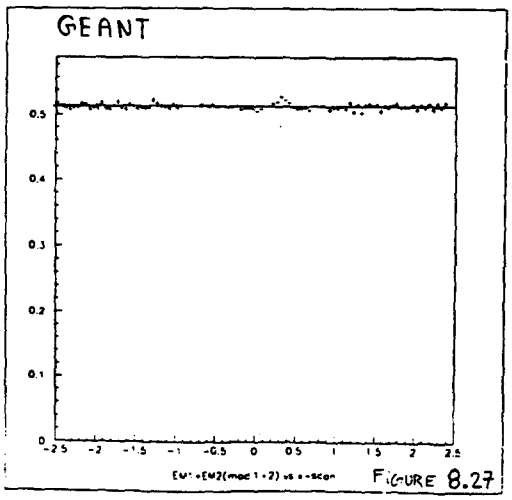
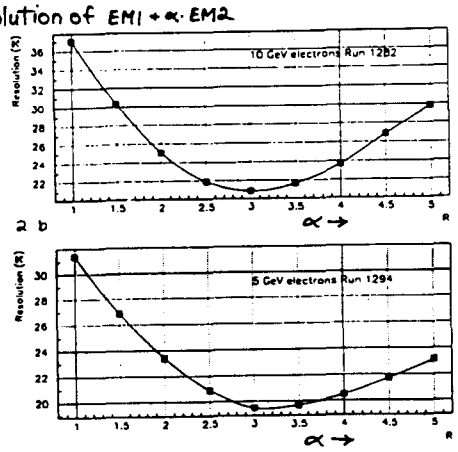


FIGURE 8.27

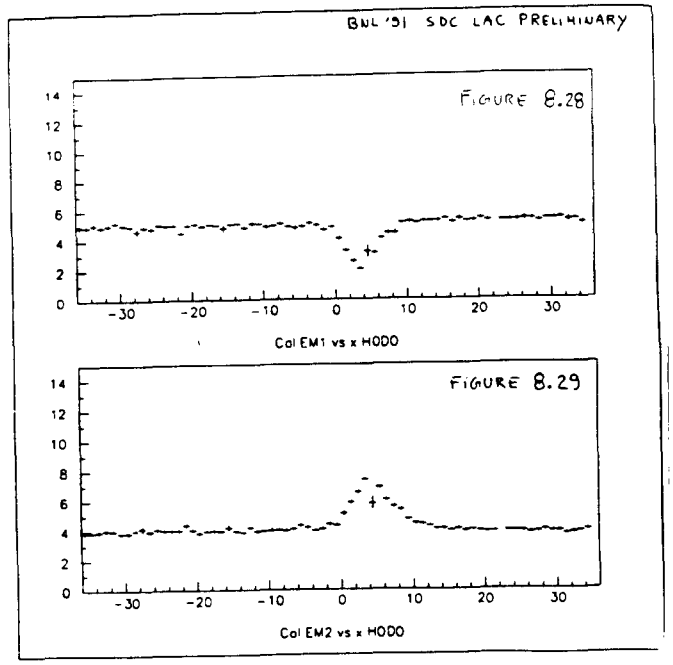
Calibration

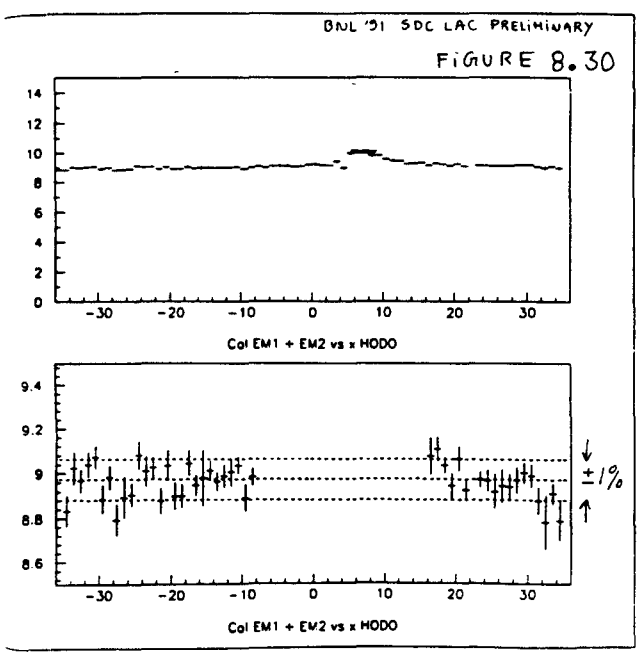
- optimize EM1 + EM2 resolution

Resolution of EM1 + α · EM2

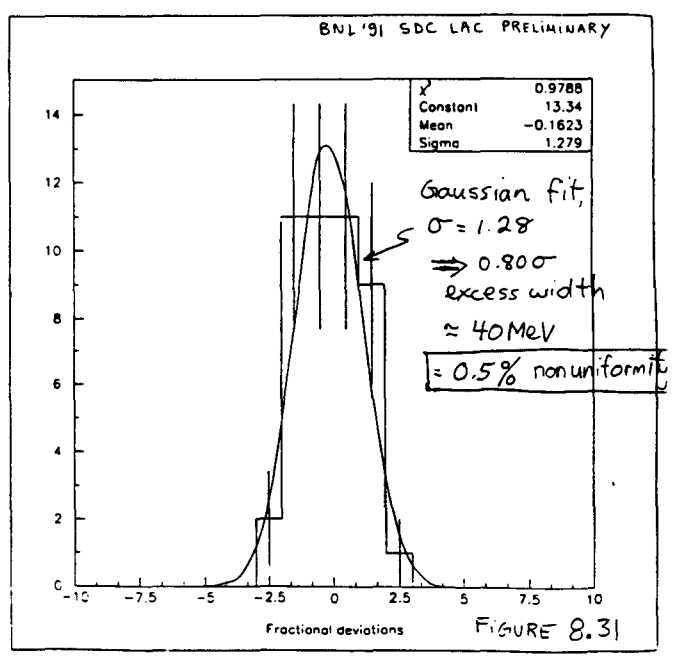


- errors in calibration will be reflected in non-uniformity near crack





Histogram of $(r_i - \langle r \rangle)/\sigma_i$;
r_i = response at scan point i



Resolution in region of crack (±12mm)

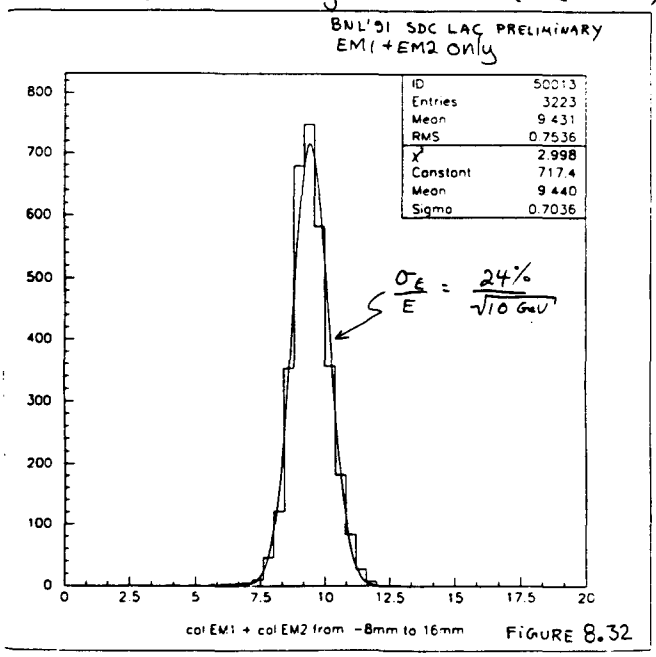


FIGURE 8.32

Resolution away from crack

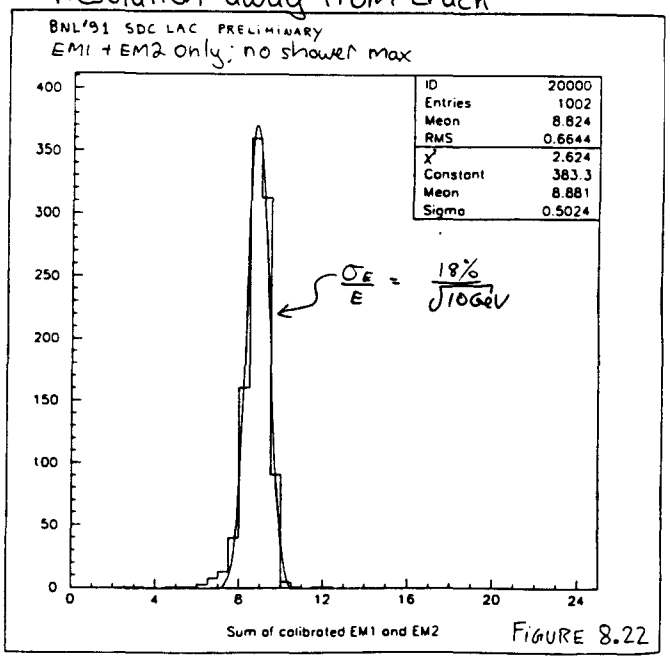


FIGURE 8.22

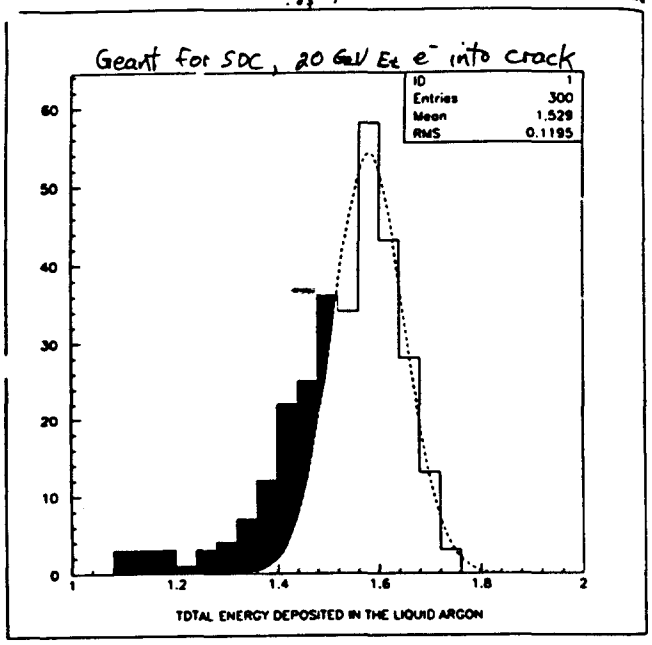


FIGURE 8.3

SDC / SSCL Physics Research Division

Resolution across a crack

Geant for SDC

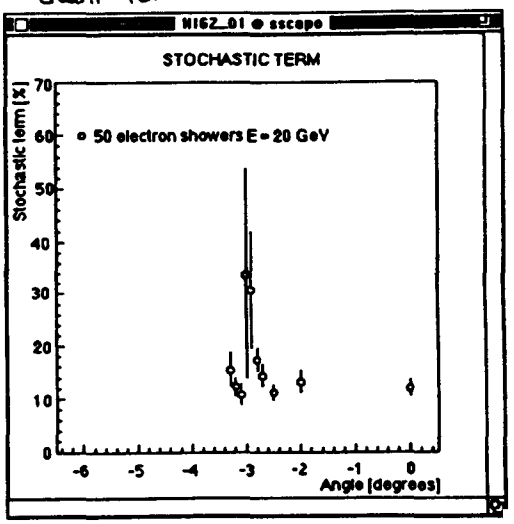


FIGURE 8.2

Introduction (and Summary)

- Liquid argon has a fast risetime that is preserved by the SDC electrode structure.
- resolution and uniformity across phi crack are acceptable; very good elsewhere
- electronic noise and pileup sufficient for SDC physics program.
- <5 ns time resolution for >1 GeV in EM channel, 5--10 GeV in hadronic.
- The response of the detector in all of the above is understood and can be calculated, as has been verified by beam test data.

Why Not Tile/Fiber for SDC Calorimetry ?

Gerry Abrams
August 4, 1991

Liquid Argon case has been presented.

BNL Beam Test Performed

Conceptual Design Report

Martin Marietta Cost Estimate

We now have a LAr design that works

Is Tile/Fiber better ?

In some ways	Yes -
Faster -	pileup ⇓ but LAr already OK pipeline shorter 4 μsec → 3.6-3.7 ?
Integrates better -	no plumbing uniform B μ access
Cost	Nov. '90 + $ 50M Aug. '91 ???

BUT . . .

FROM:ABCDEFGHIJKLMNOPQRSTUVWX TO:92147886174 JUL 25- 1991 8:57AM P.8

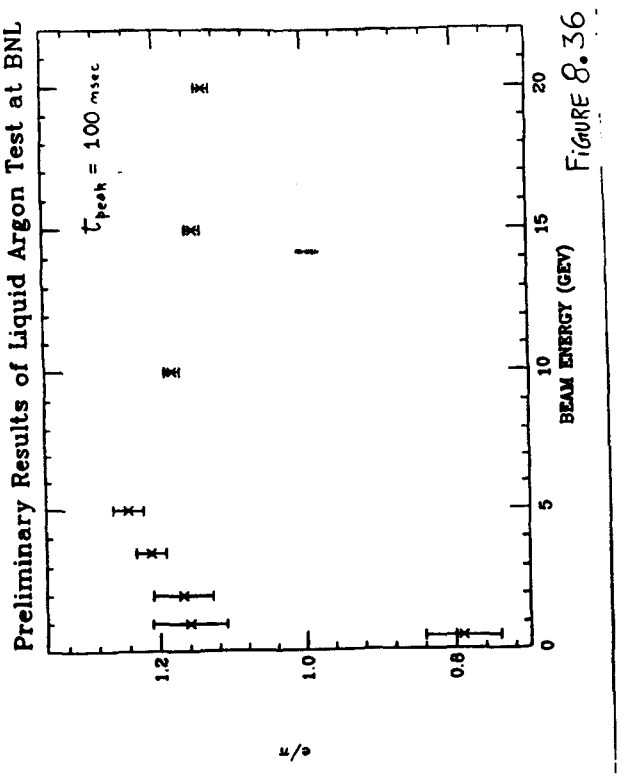


FIGURE 8.36

SDC LAr Calorimeter Cost Summary

Modules	30,916
Cryostat	21,879
Feedthrus	5,010
Calorimeter Assembly	2,905
Fixtures	10,135
Test Equipment	1,640
Transportation	1,152
Cryogenic System	7,900
Facilities	2,000
Return Iron	4,681
EDIA	17,516
Total	105,734
Contingency (28.0%)	29,602
Total w/Contingency	135,336
Derived $/lb	11.74

7/31/91

Liquid Argon still outperforms with -

1738

Intrinsic stability, uniformity

Impervious to radiation damage

High quality EM calorimetry (0.5% constant term)

AND . . .

The book on T/F is not yet closed !

1739

1) No conceptual design report

Don't know what T/F design looks like
Moving target
Ill-defined

How can you select something if you don't what it is ?

The case for Tile/Fiber has not yet been presented

2) Changes (could be called Improvements)

a) requirements
b) design/engineering
c) R&D

Want to decouple the engineers from the physicists

However we want R&D to continue -

rad hard plastic
automated production
prototype development
response uniformity
. . .

We need to know that physicists and engineers can work on their own side of the interface, and not interfere with the other.

In a LAr design, we can calculate the effect of changes.

In T/F ?

1740

3) Radiation damage -

a) There is more to calorimetry than just the barrel

$$H \rightarrow ZZ \rightarrow e^+e^-e^+e^-$$

$\eta = 1.5$ is not enough

(and note Kevin's talk on $t\bar{t}\,H$)

b) Development of rad hard plastic

We need a schedule

recent track record
radiation chemistry
optical changes

c) Analysis of radiation damage in a T/F calorimeter

damage effects

accidental beam loss
neutrons
ageing

how well can we correct
plug design
disentangle light ouput, transmission

We must not let the calorimeter limit the tolerable luminosity

1741

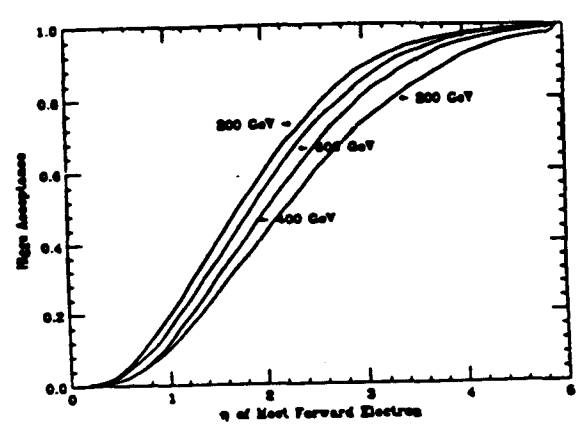


Figure 1: Acceptance of Higgs particles (M_H = 200, 400, 600 and 8
in the decay mode $H \rightarrow ZZ \rightarrow 4\,e$ where all four electrons have η l

4) Calibration

a) Uniformity

b) Linearity

c) Resolution

d) Prototype and Beam Tests

e) Radioactive sources

f) *in situ* calibration

What does a T/F calibration system look like ?

1742

Documents Required

1743

- Tile/Fiber Conceptual Design Report
- Interface Between Engineering and Physics for Tile/Fiber
- Schedule for Development of Rad Hard Plastic
- Radiation Damage in a Tile/Fiber Calorimeter
- Calibration for a Tile/Fiber Calorimeter

J. Erwein
Aug. 6, 1991 (LBL)

SACLAY RADIATION DAMAGE TESTS ON SCINTILLATOR EMC MODULES

1744

P. Bonamy, G. Dubost, J. Erwein, G. Villet, D. Hubbard, P. Le Dû, F. Roudeaux

Thanks to: V. Barnes, K. Johnson, A. Para

I. Test scintillators and fibers irradiated with ^{60}Co source. [SDC 91-00011]

II. Irradiate EMC modules in 1 GeV electron beam and measure drop of tile response. "LOW" dose rate

GOALS FOR THE AUGUST 1991 SDC MEETING

3) What is the [redacted] and [redacted] limit of [redacted] that can be bought in large quantities [redacted] with existing, mass produced scintillator? Define your procedure for establishing the limit.

5) What data and theory exist to extrapolate from the current radiation damage tests to [redacted]? Summarize the situation.

DOSES

All doses refer to Shower Max

1745

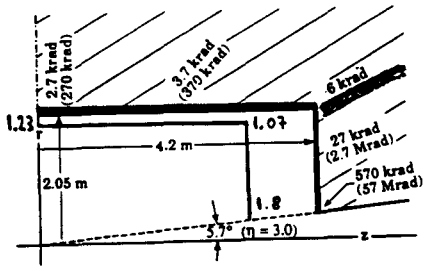


FIG. 4. Maximum ionizing dose in the SDC calorimeter, for standard conditions (10^{33} cm^{-2}s^{-1}, 1 year) and (in parenthesis) for [redacted] The maximum dose occurs at electromagnetic shower maximum. Values have been corrected from those given in the EoI.

LoI

Descope

Barrel will not suffer much from descoping

End cap ($\eta = 3$): Dose ~ 2

Testing if "barrels see forever" means: 600 krads at very low $\dot{D}$.

How low a dose rate ? 7 rad/h @ 10^{34}

→ Barrel cannot be tested outside SSC

DOSES (continued)

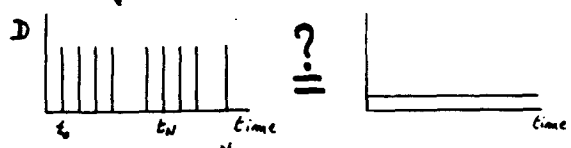
Testing end caps at 10^{33} for 1 year means:

~ 1 Mrad @ 120 rad/h

Must compromise: DOSE RATES

Saclay Raddam tests:		BARREL 10^{34} 7 rad/h	END CAP 10^{33} 120 rad/h
^{60}Co on Scintillator & Fibers	9 krad/h	~1300	~ 100
Electron Beam (1 GeV)			
"LOW" Dose	750 rad/h	100	6
"HIGH" Dose	12 krad/h	1700	100

"Average Dose Rate"



$$\langle \dot{D} \rangle = \frac{\sum_i^N D_i}{\ }$$

Light yield

SDC Note 91-11

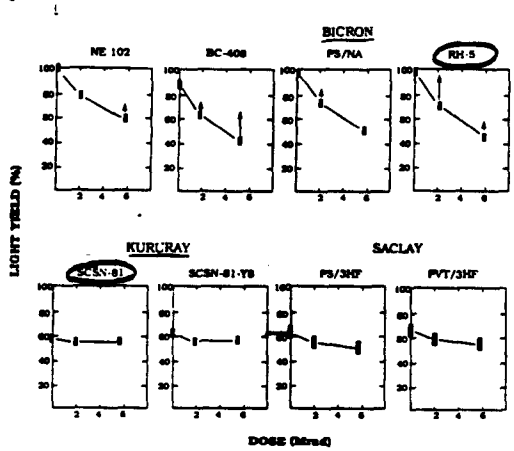


Figure 4.

Relative light yield as a function of absorbed radiation dose for 8 types of scintillator plates. Light yields are normalised to NE 102 = 100 %

A before irradiation
C 2 Mrad at 9 krad/h
C' 2 Mrad + 3 days of annealing in air
D 5.7 Mrad at 9 krad/h
D' 5.7 Mrad + 29 days of annealing in air

I

^{60}Co Source Tests

SDC-91-0001

Light yield and attenuation length of components: Scint. and Fibers

SDC Note 91-11

Attenuation in Scintillator

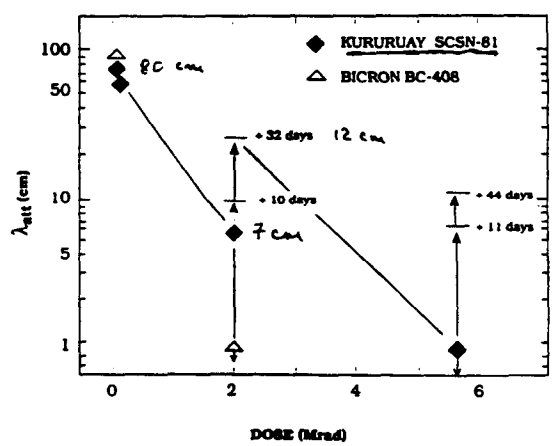


Figure 8.

Attenuation length (λ_{att}) of two types of scintillator calculated from the measurement of light transmission along the axis of 25 cm long scintillator bars. The graph shows the variation with absorbed dose and after annealing in air.

1750

PERIPHERAL CLEAR ZONE 1751

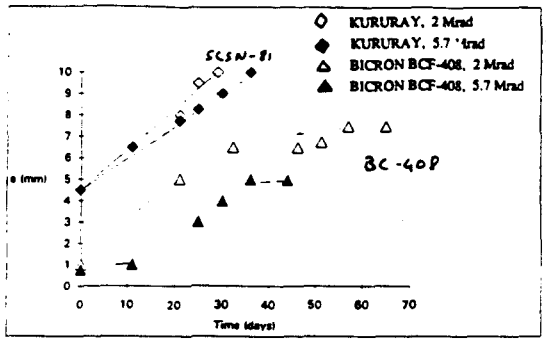


Figure 10.
Variation of the thickness of the visible peripheral annealed zone as a function of time after irradiation. The full area of the bar corresponds to e=10 mm for KURURAY and e=12.5 mm for BICRON.

SDC Note 91-1

1752

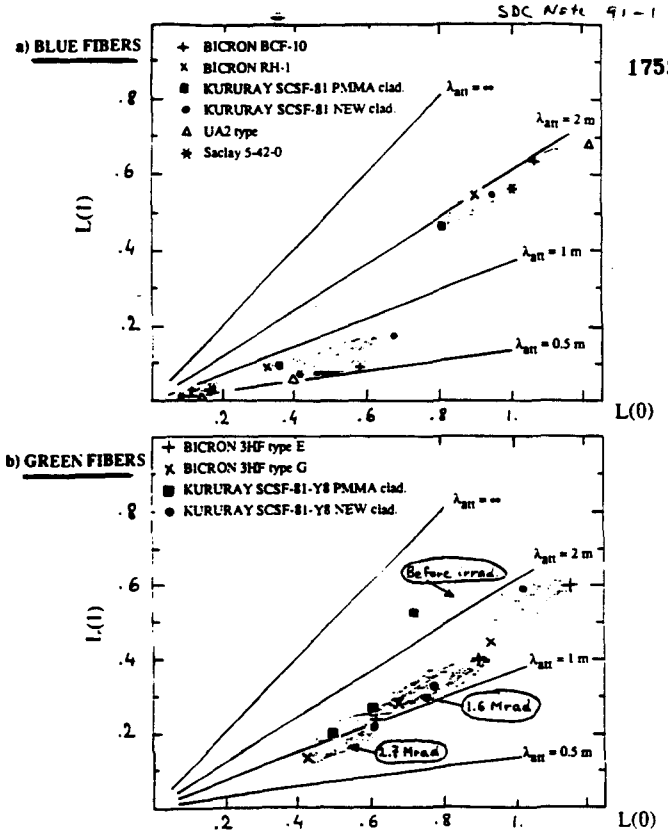


Figure 12.
Relative light yield [L(d)] and attenuation length [λ_{att}] of fibers after various doses of irradiation.
a) Blue fibers. L=1 corresponds to an absolute value of 7.7 photoelectrons.

II

1753

BEAM TEST

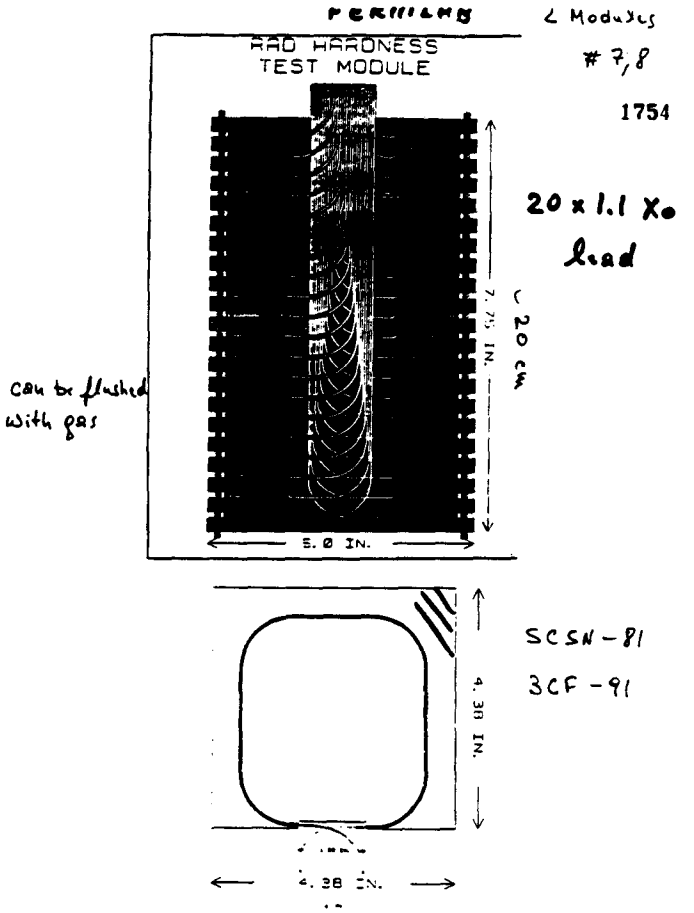
IRRADIATE MODULES with 1 GeV ELECTRONS (Orsay LINAC)

Measure Tile response to moving radioactive source (PMT current)

Sequence: 4-5 IRRADIATIONS/WEEK (10' duration)
Measure before, after, later....

DATA: 10 – 31 July

RESULTS ARE PRELIMINARY



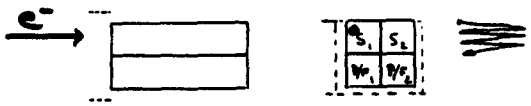
IRRADIATION

1755

Orsay LINAC 1 GeV electrons

Pulse width : 30 ns
Rep. rate : 12.5 , 25 , 50 Hz
Beam size : ϕ 1 cm

10 minute daily irradiation



Modules are on a "moving table" (Fermilab)

DOSIMETRY

1757

1. ALANINE PLASTICS 10 krad – 5 Mrad
2. Radio-chromic film FWT 0.1 – 5 Mrad
3. Fuji CTA film 0.5 – 30 Mrad
   K. TAKEBUCHI, H. YAMAMOTO

We used Arrays of all 3 dosimeters placed in front of modules and at S.M.

Leave dosimeters in place for several irradiations and use beam current to calculate dose for each run.

More than 160 dosimeters have been measured

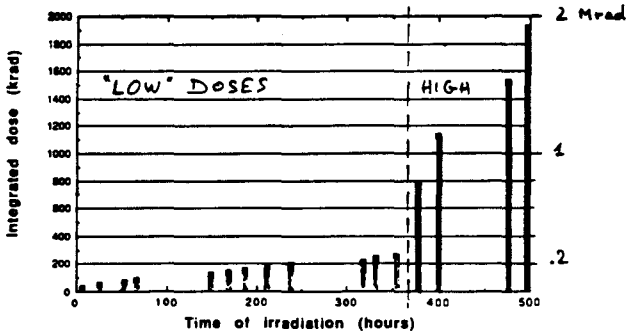
Consistent results:

1. Dose / unit beam monitor — $\sigma \sim 5\%$
   16.8 krad Alanines
   16.3 FWT film
   17.6 Fuji "
2. $\frac{SM}{Fmont}$ = 8.2 Alanines, 9.3 FWT films (OK for 1 GeV e^-)

IRRADIATION SCHEDULE 10-31 July 91

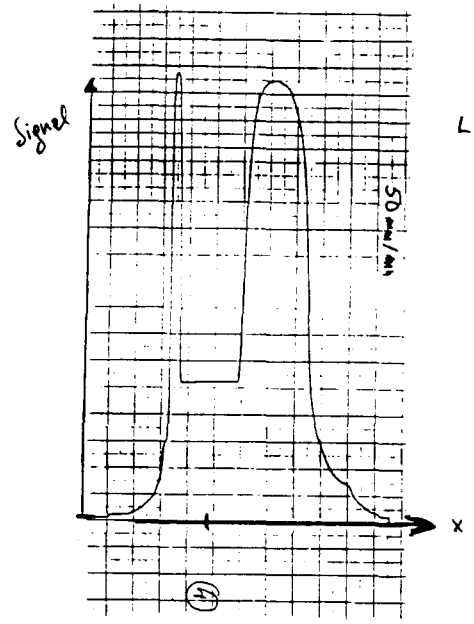
1758

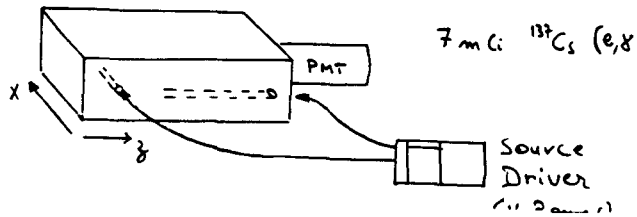
IRRAD.	Date	Hour	Monitor 1	Monitor 2	Frequency	DOSE(KRAD)	Cumul. DOSE	
1	10-Jul	4:48	60	30	12.5	29.4	29	LOW DOSE
2	11-Jul	0:29	40	30	12.5	19.6	49	
3	12-Jul	4:16	40	30	12.5	19.6	69	
4	12-Jul	16:56	40	30	12.5	19.6	88	
5	16-Jul	4:07	60	30	12.5	29.4	118	
6	17-Jul	0:35	40	30	12.5	19.6	137	
7	17-Jul	18:00	40	30	12.5	19.6	157	
8	18-Jul	19:06	38	30	12.5	18.6	175	
9	19-Jul	20:27	42	30	12.5	20.6	196	
10	23-Jul	4:30	40	30	12.5	19.6	216	
11	23-Jul	18:53	45	30	12.5	22.0	238	
12	24-Jul	16:30	40	30	50	19.6	257	
13	25-Jul	16:00	210	38	50	521	778	HIGH
14	26-Jul	14:20	180	30	50	353	1131	
15	29-Jul	18:00	200	30	50	392	1523	
16	30-Jul	15:49	200	30	50	392	1915	



SOURCE MEASUREMENTS

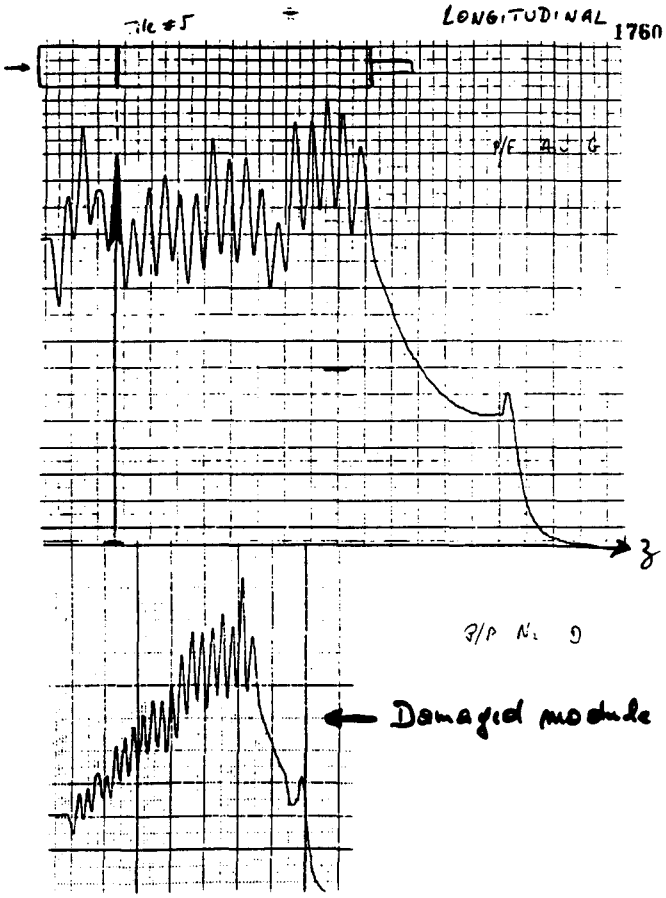
1759





7 mCi ^{137}Cs (e,γ

1760



RESULTS (PRELIMINARY)

1761

Parameters: DOSE

AVERAGE DOSE RATE

AIR vs Nitrogen

"Low" DOSE RATE (750 rad/h) ± 24 hour recovery

D=250 krad: SM tile looses 10% in air 25% in N_2

High DOSE RATE (12 krad/h)

D≈ 1.65 Mrad on top.

SM tile looses 40% in air, 90% in N_2

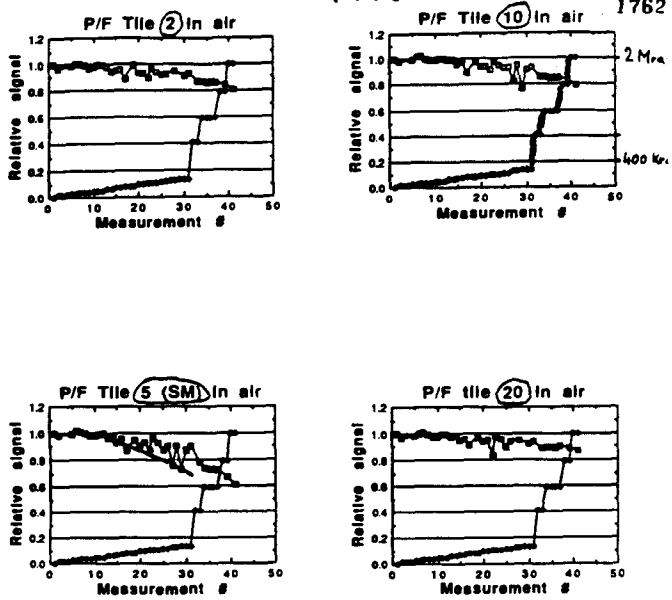
no recovery after 3 days

DOSE RATE EFFECT ?

"low" dose rate seems to have relatively worse effect than high dose rate.

Fermilab Modules **AIR**

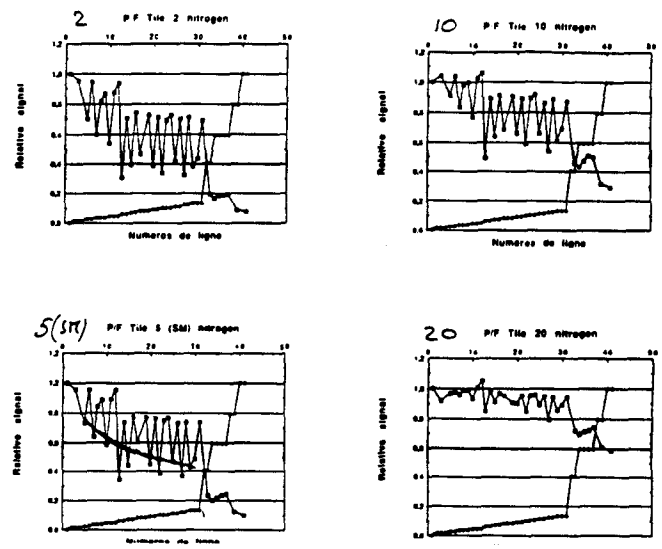
1762



After Irradiation
~ 1 day recovery

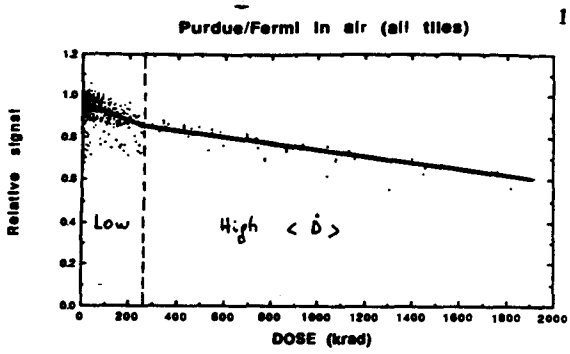
Fermilab module **Nitrogen**

1763



just after irradiation
~ 1 day recovery

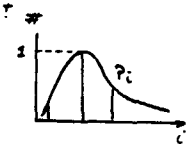
1764



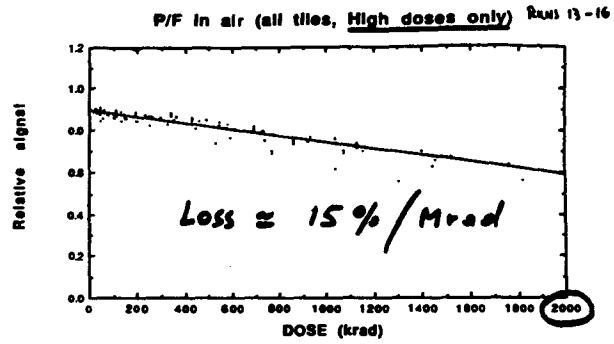
CONSIDER All 20 tiles
All 40 measurements } 800 data points

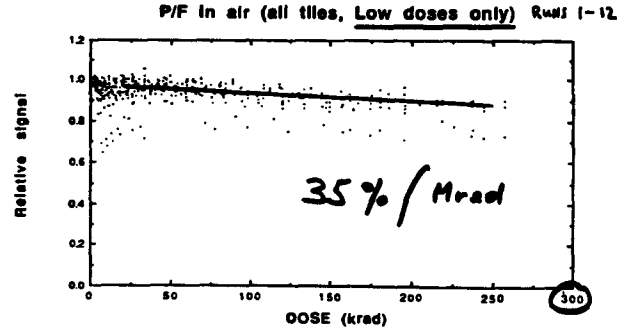
Signal : S_{ij} i = Tile #
j = Meas^T #

Dose : $D_{ij} = D_{SM(j)} \cdot P_i$



1765





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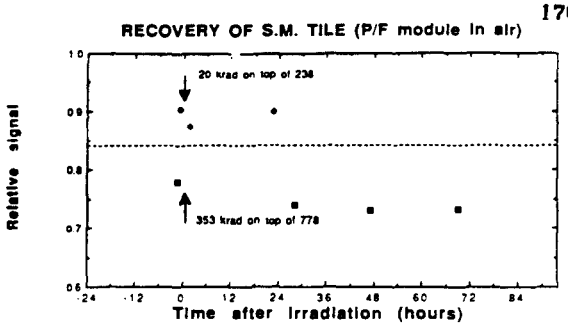

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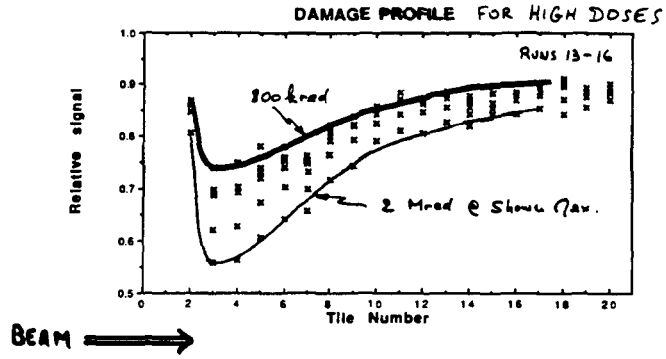


PROFILE OF DAMAGE

CONCLUSIONS (preliminary)

J.E Aug 6, 1991

Saclay Radiation Tests

1768

I. Light Yield + λ_{att} in tiles and fibers (^{60}Co) SDC 91-000

II. Beam Test: (July 1991)

Irradiate EMC modules with 1 GeV electrons

12 × 20 krad in 10' at 24 hr. intervals (≈ 250 krad)

4 × 400 krad – – – (≈ 1.9 Mrad)

Measure Tile response with source

Take $\frac{\Delta I}{I} = 35\% / \text{Mrad}$

BARREL

FOR EVER ≡ $\eta = 1.3$ 10 yrs @ 10^{34} ⇒ 600 krad (7 rad/

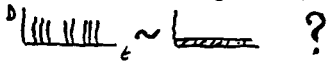
→ $\frac{\Delta I}{I} \simeq 20\%$

Barrel will survive if 20% loss of signal at SM is acceptable.

CAUTION ⚠ Because dose rate during test is still ≫ SDC dose rate (×100) $\frac{\Delta I}{I}$ may be larger than 35%

With high dose rate ($\frac{\Delta I}{I} = 15\%/\text{Mrad}$) one gets a better result: only 10% = $\frac{\Delta I}{I}$ must be tolerated!

⚠ Also, "AVERAGE" dose rate ....



?

Aging not induced by radiation?

CONCLUSIONS (suite)

J.E Aug. 6, 91

1769

END CAP

If $\frac{\Delta I}{I} = 35\%$ is a tolerable loss at SM,

then one can reach ~ 1 Mrad

i.e. $\eta = 3$ 1 yr @ 10^{33}

$\eta = 2$ 3 yrs @ 10^{34}

Same caveat about DOSE RATE

AIR vs Nitrogen

keeping Module in N_2 atmosphere is **bad**

RADIATION HARDNESS TEST OF SCINTILLATING TILE/FIBER CALORIMETRY (I)

University of Tsukuba

S. Funaki, K. Hara, T. Inuma, T. Kaneko, S. Kim, K. Kondo, Y. Miyamoto, S. Miyashita, Y. Morita, I. Nakano, M. Okabe, J. Suzuki, H. Takahashi, E. Takikawa, N. Uemura, K. Yasuoka

KEK

F. Abe, A. Asami, A. Enomoto, K. Furukawa, N. Kamikubota, T. Kamitani, H. Kobayashi, M. Mishima, S. Ohsawa, Y. Yoshimura

Goal:

Irradiate real EM test modules with high energy electrons and investigate systematic effects of the radiation-induced damage on the calorimeter performance.

We used:

KEK 2.5-GeV electron linac to irradiate the test modules, and electron test beam at the pi-2 test beam line of KEK 12-GeV proton synchrotron to measure the damage.

8 Tile/Fiber modules were irradiated by 2.5-GeV KEK Linac.

Modules A, B : Response was measured before and after irradiation with pi-2 electron test beam.

* Module A will be sent to Fermilab test beam.

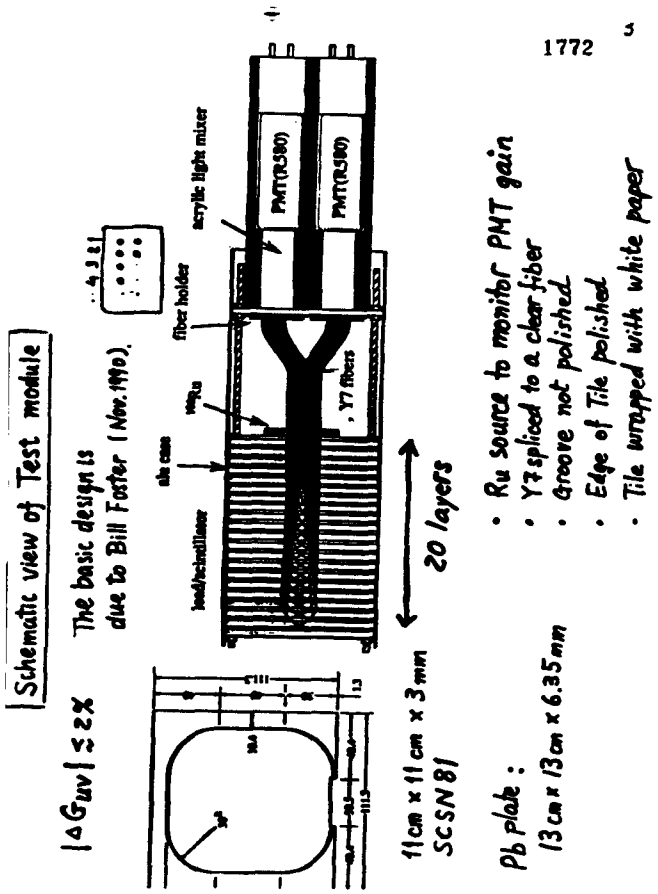
Module C : Before-response was measured with the electron beam and after-response with ^{106}Ru source.

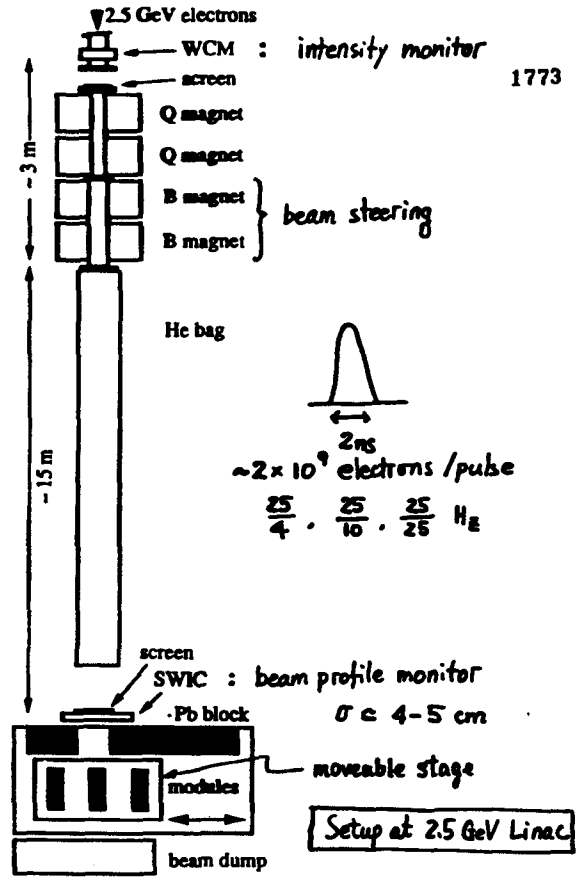
"Module" E1
"Module" E2 : ^{106}Ru induced current was measured before
"Module" E3 and after irradiation to compare with data taken from ^{60}Co exposure.

Module F1, F2 : Fermilab/Purdue modules shipped back to Fermilab.

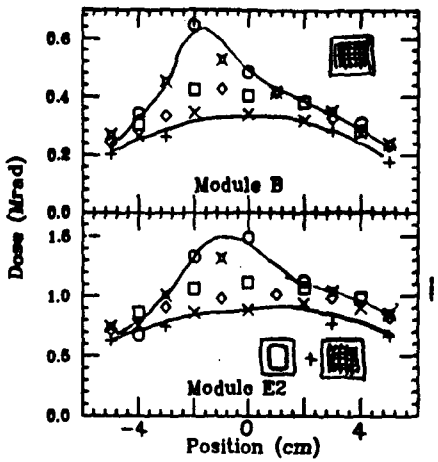
Contents

- Irradiation of Modules at Linac
- Dose Measurement
- Response to Electrons
  pulse height peak, resolution,
  uniformity, pulse heights of typical individual layers
- Measurement with a ^{106}Ru Source
- Monte-Carlo simulation on radiation-induced degradation of the calorimeter performance
- Conclusions

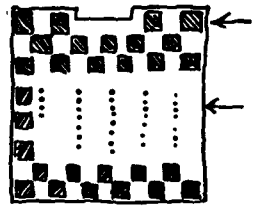




Lateral dose distribution



RCD Dosimeter
(1cm x 1cm)

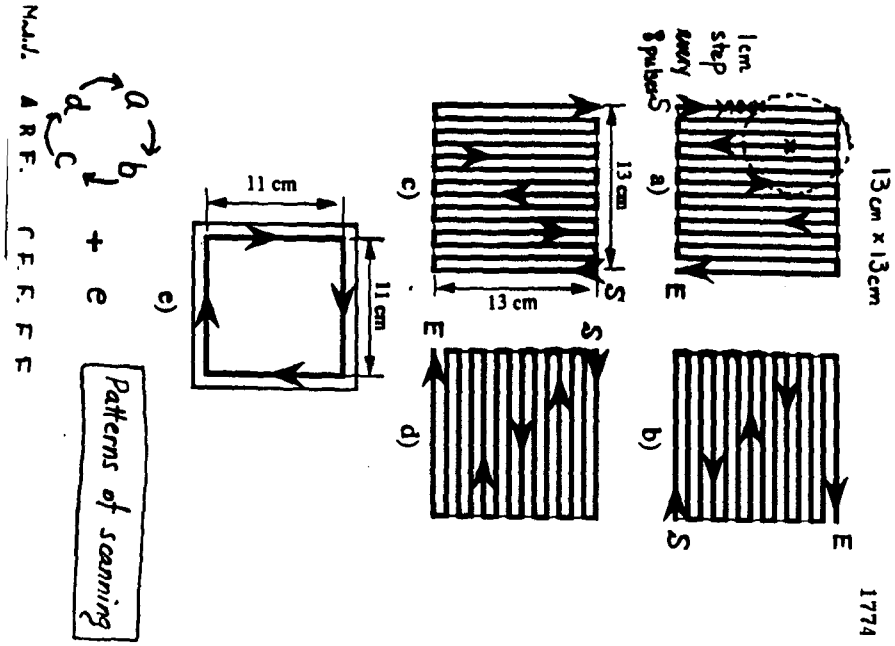


$\Delta D \simeq 10\%$

Dose (edge) = .5~.7 Dose (center)

⇨ take Dose (mean)

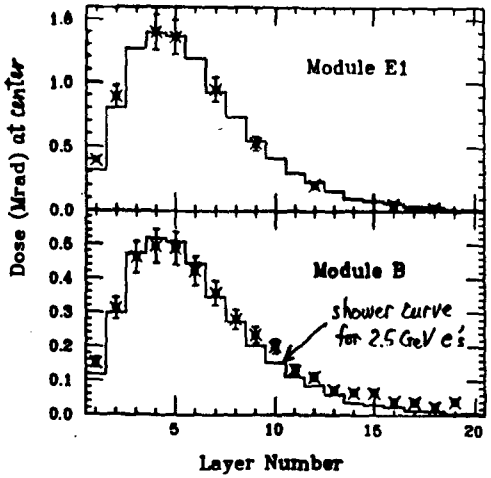
1776 7



Patterns of scanning

1774

Dose measurement with RCD film



Dose distribution in layers

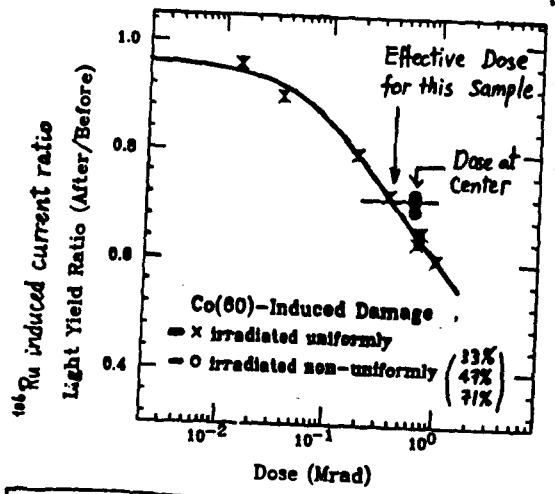
⇩

agree with simulation (area normalized)

⇩

Dose measurement is reliable

1775



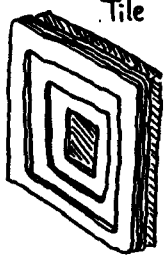
Effect of non-uniform irradiation

Sample	33%	47%	71%
D(center)	0.62	0.62	0.62
D(edge)	0.20	0.29	0.44
D(mean)	0.34	0.41	0.51
D(effective)	0.34	0.37	0.44

agree within ~15%

Fe absorber

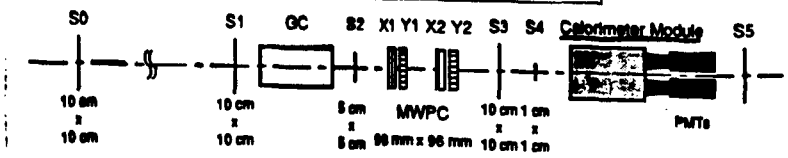
Tile



^{60}Co

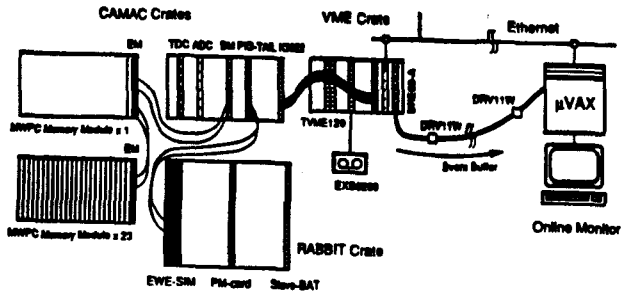
1777 8

Setup at KEK PS π2 test beam



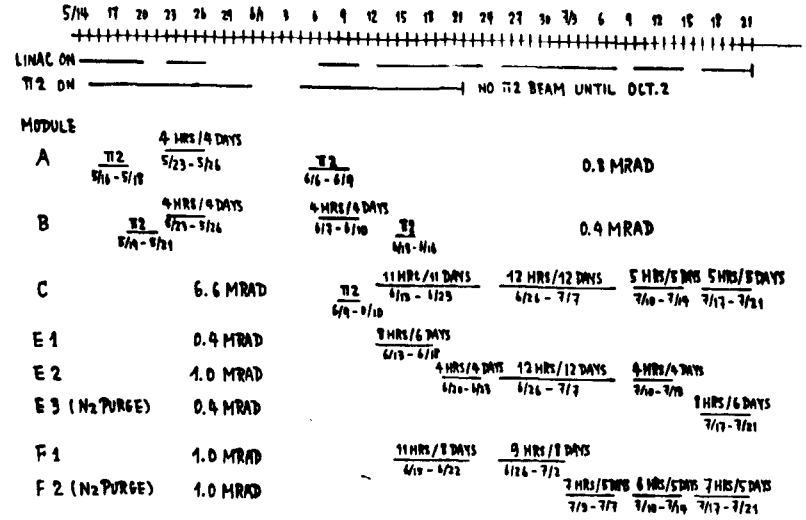
0.5 ~ 3.0 GeV/c electrons

KEK x2 Beam Line Set-up for Tile-Fiber Calorimeter Beam Test



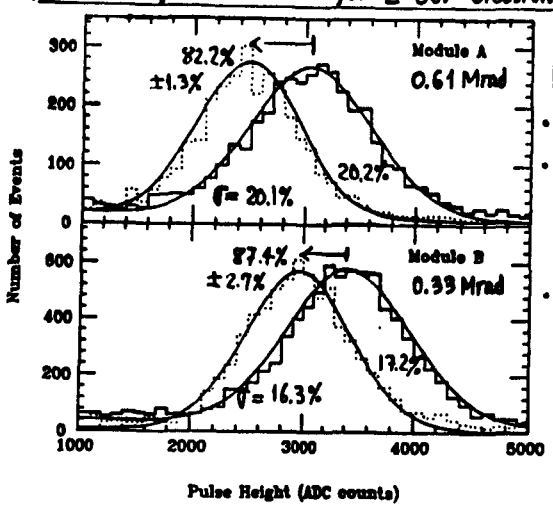
KEK x2 Beam Line Data Acquisition System

BEAM SCHEDULE as of June 18



MODULE E IS NOT A COMPLETE MODULE BUT ~10 TILE/FIBER'S AT TYPICAL DEPTHS.
MODULE F IS THE FNAL/PURDUE MODULE.

Pulse height distribution for 2 GeV electrons



uncertainties:

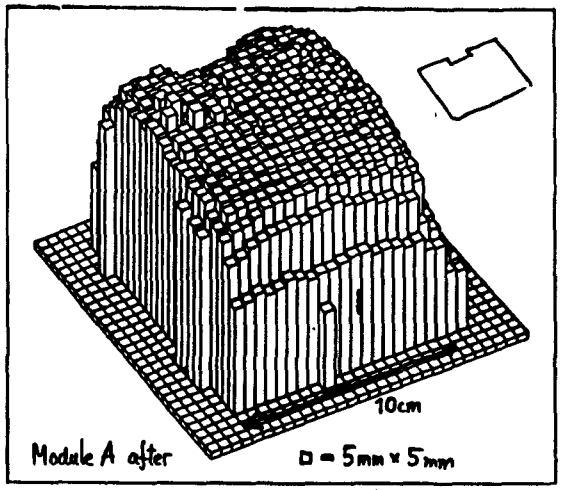
- statistical (peak, pedestal)
- PMT gain (deviation from τ fluctuations)
- peak fitting (fitting region, background subtr.)

Gain shift after 0.61 Mrad is 18%.
" 0.33 Mrad " 13%.

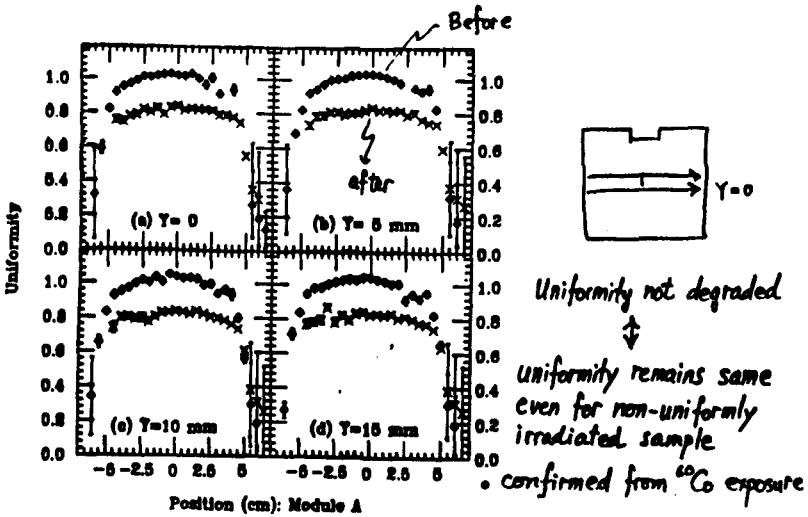
Table I. Irradiation conditions for Modules A to F. Tile/fiber assemblies of Module E were replaced three times. The uncertainty of the dose measured using dosimeters is about 10%. The numbers with a star are estimated from dosimeter data of a module irradiated in similar conditions and the measured beam intensity.

Module	Dose (center)	Dose (edge)	Dose (mean)	Dose Rate	(# days)	air/N_2	Measured with
Module A	0.84*Mrad	0.44*Mrad	0.61*Mrad	110*krad/h	(3 days)	air	e-beam
Module B	0.48 Mrad	0.24 Mrad	0.33 Mrad	16 krad/h	(8 days)	air	e-beam/Ru
Module C	8.1 Mrad	4.2 Mrad	4.8 Mrad	140 krad/h	(24 days)	air	Ru
Module D						Reference	
Module E_1	0.42*Mrad	0.22*Mrad	0.31*Mrad	38*krad/h	(5 days)	air	Ru
Module E_2	1.3 Mrad	0.77 Mrad	0.96 Mrad	49 krad/h	(14 days)	air	Ru
Module E_3	1.5 Mrad	1.0 Mrad	1.2 Mrad	48 krad/h	(5 days)	(N_2)	Ru
Module F_1	1.4*Mrad	0.88*Mrad	1.1*Mrad	83*krad/h	(14 days)	air	back to FNAL
Module F_2	1.5*Mrad	1.0*Mrad	1.2*Mrad	48*krad/h	(5 days)	(N_2)	back to FNAL

- Mean Dose : ~0.3 Mrad ~ 5 Mrad
- Dose Rate : 16 krad/h ~ 140 krad/h [Instantaneou $\dot{D}$]
- Exposure : 1 ~ 2 h / module/day Average $\dot{D} = \frac{\text{Dose}}{\#\text{days}}$ ~ 2 - 10 krad/h
- air / N_2

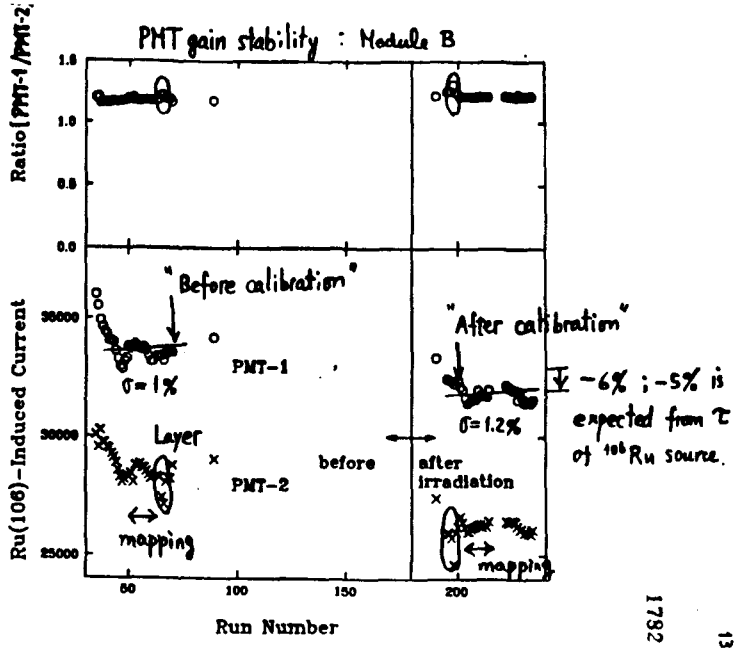


Respose Mapping with 2-GeV electrons



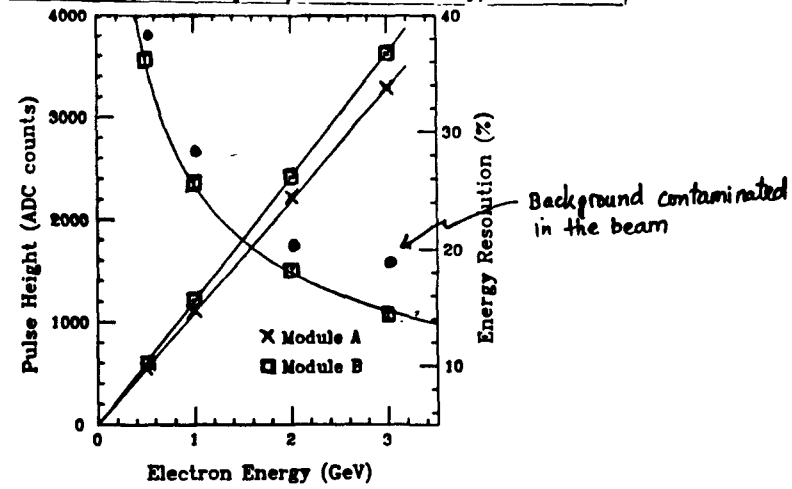
Uniformity not degraded
↕
uniformity remains same even for non-uniformly irradiated sample
• confirmed from ^{60}Co exposure

RESPONSE UNIFORMITY
MEASURED WITH 2-GeV electrons



−6% ; −5% is expected from τ of ^{106}Ru source.

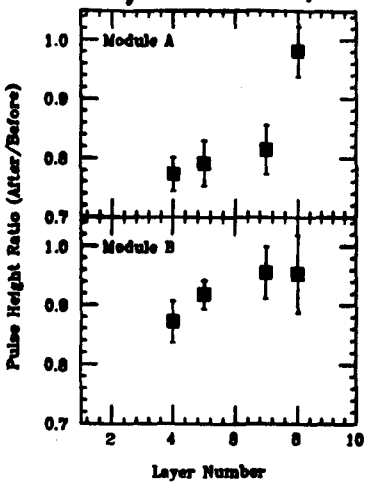
Measured pulse height peaks and energy resolutions



Data after irradiation

The response is linear in the limited range of this measurement.

Pulse height reduction of individual layers

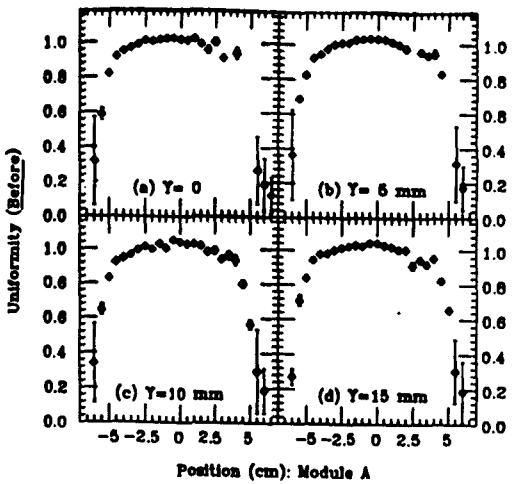


measured for layer 4, 5, 7, 8. .

$$\left[\frac{PMT_2(i)}{PMT_1 / \langle PMT_1 \rangle}\right]_{AFTER} / \left[\quad\right]_{BEFOR}$$

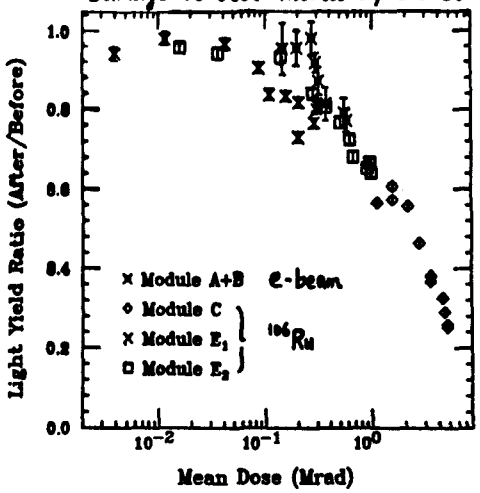
The errors are statistical only.
Fitting errors of ~5% are not show

1788



1786

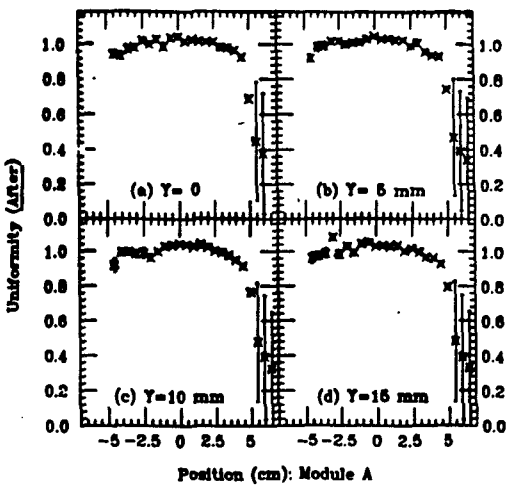
Damage vs Dose induced by 2.5 GeV Electron Shower



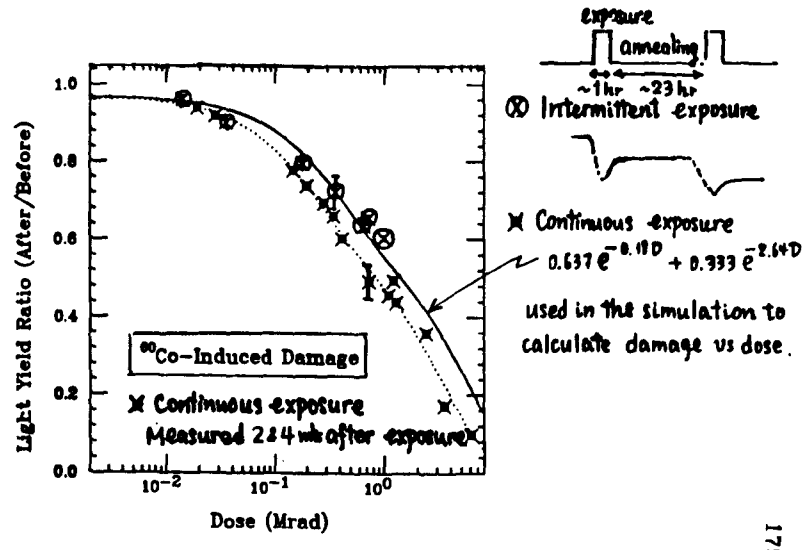
Damages of module C, E_1, E_2 measured with a Ru source.

Consistent with the electron test beam measurements on module A & B.

1789

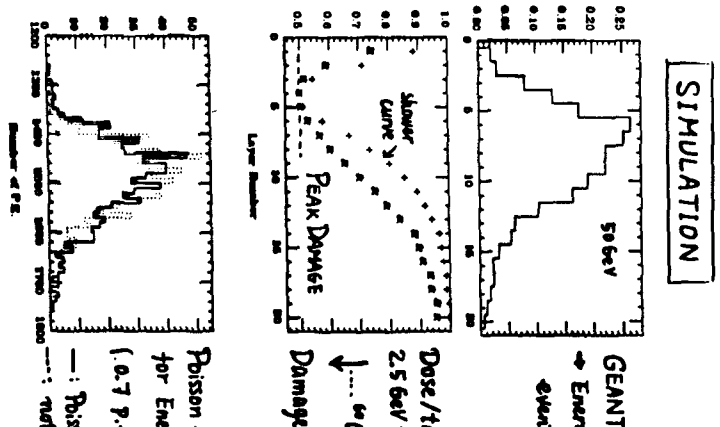


1787



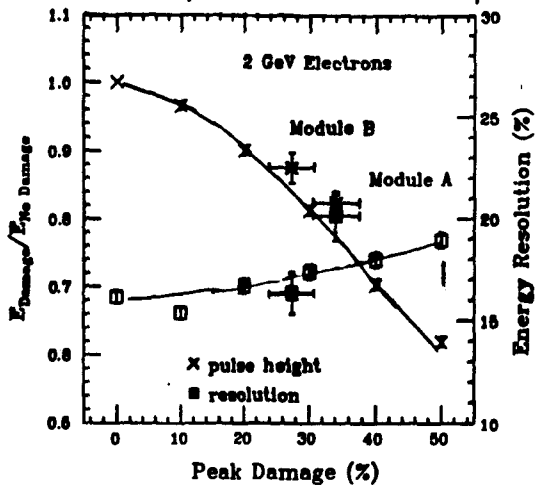
^{60}Co induced damage agrees with electron shower induced damage.

1790



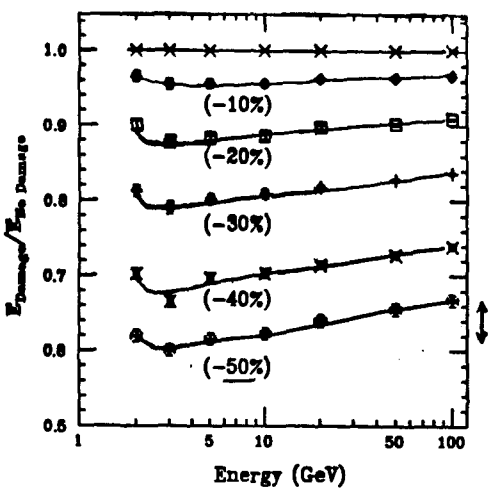
1791

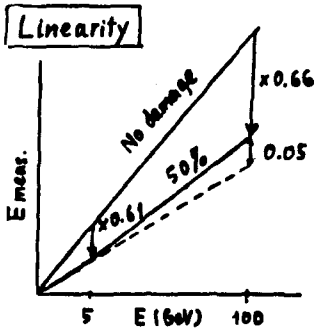
The simulation for 2 GeV electrons in comparison with the experiment



The simulation reproduces the measured pulse height reduction & energy resolution.

1792



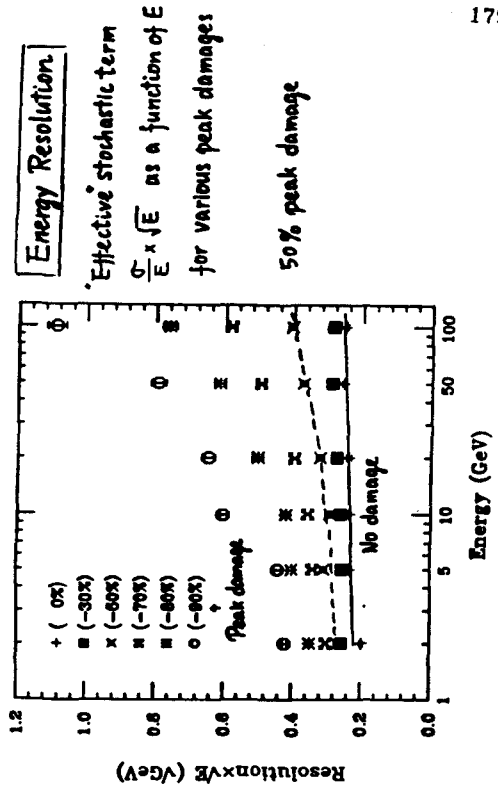


Non-linearity of ~5% in energy range 5 – 100 GeV

Seems not so difficult to correct for this non-linearity.

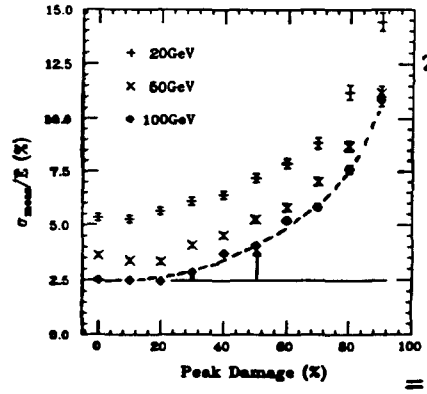
1793

1791 23



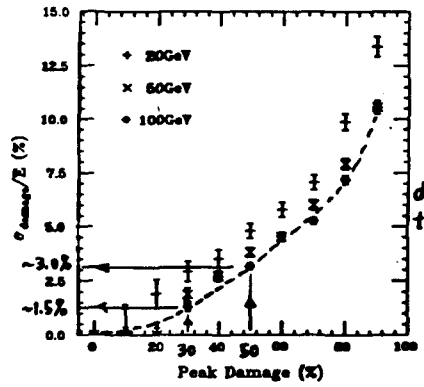
Resolution as a function of the peak damage for 20-, 50-, 100-GeV electrons

1795



$\boxed{\frac{\sigma_{meas.}}{E}}$

$\sigma^2_{meas} = \sigma^2_{No\,damage} + \sigma^2_{damage}$



$\boxed{\frac{\sigma_{damage}}{E}}$

damage induced contribution to energy resolution

1796 25

- The first evaluation of σ_{damage} by Green, Para, and Hauptman (FN565, May 1991) assumes:

  Damage Profile ∝ 1-GeV electron shower curve.

- We did simulations using the measured damage curve for the dose distribution induced by 1-GeV or 10-GeV electrons.

⇨ The results are essentially the same.

The behavior of σ_{damage}/E vs Peak damage is insensitive to the detail of damage profile (dose distribution & damage curve vs dose).

1797 26

Conclusions

1. Eight calorimeter modules were irradiated by 2.5-GeV electrons to a dose between 0.42 Mrad and 6.1 Mrad (dose at tile center). The dose at the edge was between 53% to 69%.

2. The 0.61 Mrad (mean dose) module showed 17.8% gain decrease. The 0.33 Mrad (mean dose) sample showed 12.6% gain decrease.

3. Response after irradiation of 0.61 Mrad (mean dose) was linear and the energy resolution was not degraded in the energy range 0.5 - 3 GeV of this experiment. At higher energies, non-linearity and resolution degradation are expected by simulation (see 6).

4. Uniformity of the response map was not degraded.

5. Measurement of the damage profile with 2-GeV electron test beam has a rather large error but is consistent with the ^{106}Ru source measurement. The 2.5-GeV electron shower induced damage as a function of dose agrees with the ^{60}Co induced damage.

6. Using the Geant code, radiation-induced degradation of the performance of the calorimeter with a single phototube readout was simulated for electron energy below 100 GeV. The dose was assumed to be induced by 2.5-GeV electron showers. The damage profile was calculated from the measured curve of ^{60}Co-induced damage vs dose.

- The simulation for 2-GeV electrons reproduces the pulse height reduction and energy resolution observed in this experiment.

- Non-linearity of the response is about 5% in an energy range between 5 to 100 GeV for a peak damage of 50%. This non-linearity seems to be correctable by a simple function.

- The degradation of energy resolution increases with peak damage. The radiation damage induced contribution to energy resolution, σ_{damage}/E, becomes 1.5% (3.0%) at a peak damage of 30% (50%), corresponding to 0.5 Mrad (2.0 Mrad).

7. Measurements on modules F1, F2, and A at Fermilab test beam are eagerly waited for to confirm the simulation results for higher energies.

THE SDC WORKSHOP AT LBL

Radiation Hardness of Scintillating Tile with Waveshifting Fiber

S. Funaki, K. Ikura, T. Iizuma, T. Kaneko, S. Kim, Y. Miyamoto, Y. Morita, I. Nakano, M. Otabe, J. Suzuki, H. Takahashi, K. Takikawa, N. Uemura, K. Yasuoka

Institute of Physics, University of Tsukuba
Tsukuba, Ibaraki 305, Japan

REPORTED BY
K. YASUOKA

^{60}Co-INDUCED – VS 2.5-GeV e$^-$-INDUCED

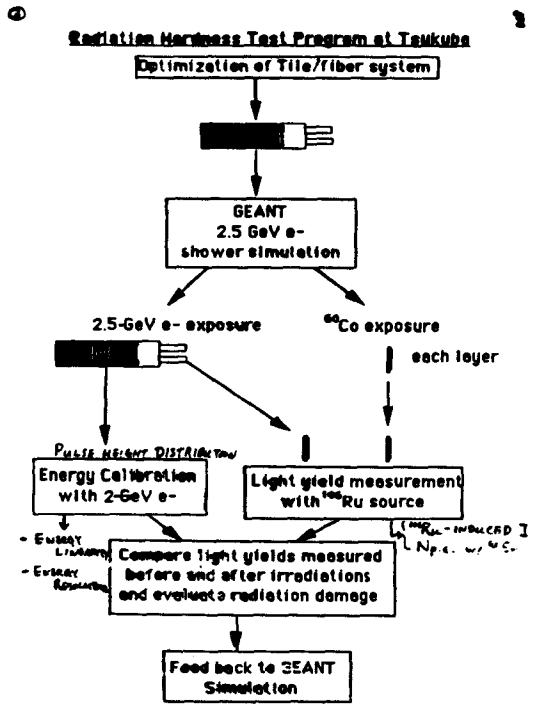
IN THE LAST MANY YEARS, MANY GROUPS HAVE BEEN STUDYING RADIATION DAMAGES OF SCINTILLATORS WITH RELATIVELY LOWER ENERGY ELECTRONS AND ^{60}Co γ-RAYS.

- IS THE ^{60}Co-INDUCED DAMAGE EFFECTIVELY THE SAME AS THE 2.5-GeV ELECTRON-INDUCED DAMAGE?
  1) ^{60}Co-INDUCED
  2) 2.5-GeV e$^-$-INDUCED

- IS THE DAMAGE INDEPENDENT ON THE METHOD HOW TO EVALUATE IT?
  1) ^{106}Ru-INDUCED CURRENT
  2) $N_{p.e.}$ MEASURED WITH a ^{90}Sr β-SOURCE
  3) PULSE HEIGHT DISTRIBUTION OF 2.0-GeV e$^-$'s

IF THE DAMAGE IS MADE ON ONLY THE SCINTILLATOR SURFACE, IT MIGHT DEPEND ON HOW TO EVALUATE IT.

COMPARISON OF EFFECTS OF THESE DAMAGES WOULD BE VERY USEFUL IN THE FUTURE RAD HARD TEST PROGRAM, SINCE IT IS VERY EASY TO MAKE ^{60}Co-INDUCED DAMAGES TO SCINTILLATORS THAN SEVERAL-GeV ELECTRON-INDUCED DAMAGES.



④ SCINTILLATING TILE w/ GROOVE

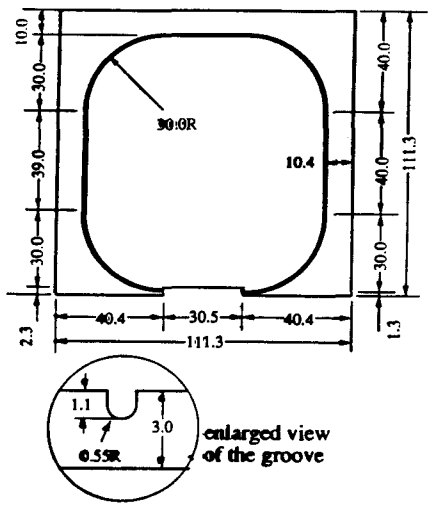


Figure 1: A scintillating tile with a wavesshifting fiber.

⑤ LIST OF SAMPLES USED IN THIS RADHARD TEST.

	Group	Sample	Exposure	Environment (air./atm.)	Dose (Mrad)	Evaluation: Dosimeter	Evaluation: Light Yield
[illegible]	1	A1~A8	^{60}Co γ	air/air	1.2	RCD	^{106}Ru-/
	2	A9~A16	^{60}Co γ	air/air	9.3	RCD	^{106}Ru-/
[illegible]	3	B1	^{60}Co γ	air/air	1.1	RCD	^{106}Ru-/
	4	B2	^{60}Co γ	air/air	0.025	RCD	^{106}Ru-/
[illegible]	5	C1~C3	^{60}Co γ	air/air	0.07	RCD	^{106}Ru-/
	6	C4~C8	^{60}Co γ	air/air	0.07	RCD	^{90}Sr-$N_{p.e.}$
[illegible]	7	D1~D2	^{60}Co γ	air/air	0.43	RCD	^{106}Ru-/
	8	D3~D4	^{60}Co γ	air/air	1.1	RCD	^{106}Ru-/
GAS	9 (E_0)	E_0-1~E_0-11	2.5-GeV e$^-$	air/air	0.5	RCD	^{106}Ru-/
	10 (E_0)	E_0-1~E_0-11	2.5-GeV e$^-$	air/air	[illegible]	RCD	^{106}Ru-/, ^{90}Sr-$N_{p.e.}$
	11 (E_0)	E_0-1~E_0-11	2.5-GeV e$^-$	nitrogen/air	[illegible]	RCD	^{106}Ru-/
CALORIMETER	12 (F)	——	2.5-GeV e$^-$	air/air	0.8	RCD/CTA	2.5-GeV e$^-$
	13 (G)	G1~G9	2.5-GeV e$^-$	air/air	0.4	RCD/CTA	2.5-GeV e$^-$, ^{106}Ru-/
	14 (H)	H1~H9	2.5-GeV e$^-$	air/air	0.8	RCD/CTA	2.5-GeV e$^-$, ^{106}Ru-/

Notes::
^{106}Ru-/ : ^{106}Ru-induced currents.
^{90}Sr-$N_{p.e.}$: Number of photoelectrons measured with ^{90}Sr.
(air./atm.) : (gas environment in irradiation / in annealing).

Table 2: List of samples used in this radiation hardness test.

⑥ IRRADIATION CONDITIONS FOR THE CONTINUOUSLY IRRADIATED SAMPLE "A"

Table 2: Irradiation condition A.

Sample#	Layer#	Distance (cm)	Dose Rate1 (krad/h)	Dose Rate2 (krad/h)	Dose (krad)	Exposure Time (hour)	Source (kCi)
A1	4	37.5	360	360	1000	2.77	110
A2	2,5	38.5	340	340	941	2.77	110
A3	2,7	48	227	227	628	2.77	110
A4	9	65	123	123	340	2.77	110
A5	1	17.5	82	82	227	2.77	5.9
A6	11	24	46	46	127	2.77	5.9
A7	16	50	12	12	33.2	2.77	5.9
A8	18	70	6	6	16.6	2.77	5.9
A9	4	37.5	360	360	10000	27.7	110
A10	2,5	38.5	340	340	9440	27.7	110
A11	2,7	48	227	227	6300	27.7	110
A13	9	65	123	123	3420	27.7	110
A13	1	17.5	82	82	2280	27.7	5.9
A14	12	24	46	46	1280	27.7	5.9
A15	16	50	12	12	333	27.7	5.9
A16	18	70	6	6	167	27.7	5.9

Notes:
These samples were exposed in air.
Dose Rate1 denotes an instantaneous dose rate.
Dose Rate2 denotes an effective dose rate.

THESE SAMPLES WERE EXPOSED AT THE SIMILAR IRRADIATION CONDITIONS AS EXPECTED AT EACH LAYER OF AN E-M CALORIMETER WHEN IT IS EXPOSED WITH A 2.5-GeV e$^-$ BEAM AT THE KEK LINAC.

⑦

^{60}Co EXPOSURE FACILITY
SAMPLE "A", "C", "D"

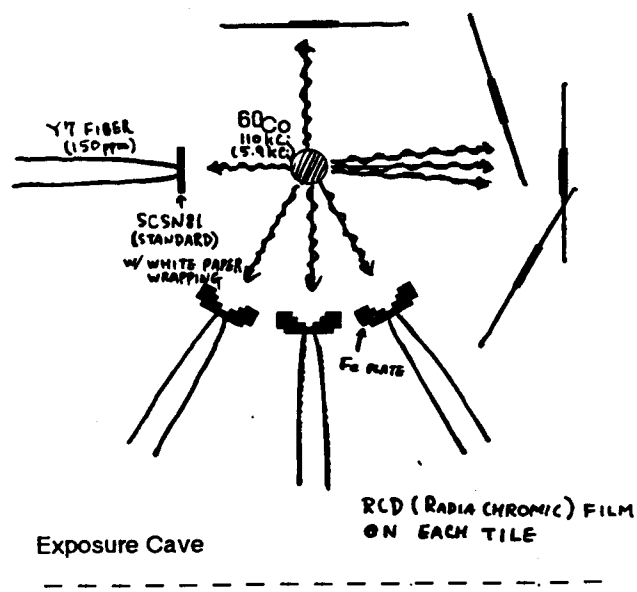


Figure 2: A schematic view of setup of scintillating tiles with waveshifting fibers in ^{60}Co exposures.

Annealing and Permanent Damages

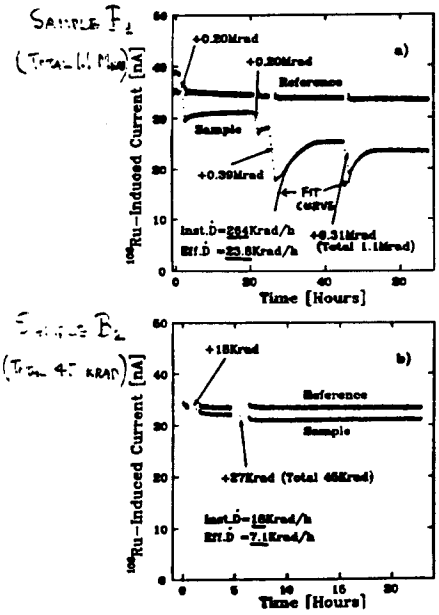


Figure 5: A history of radiation damages of the scintillating tiles with fibers and the annealing of damages after each irradiation.

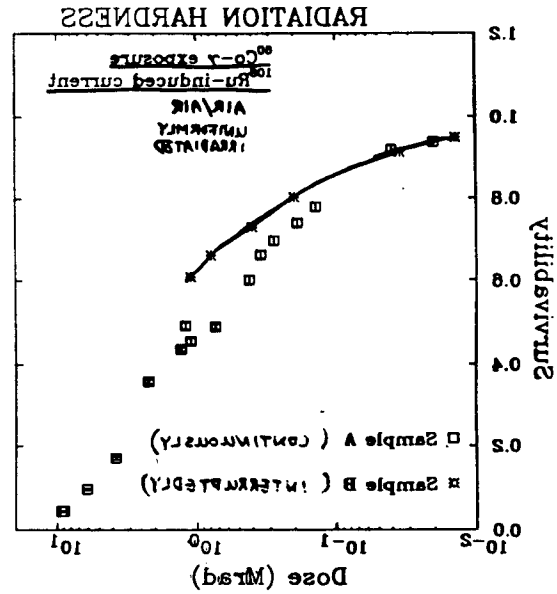


Figure 7: Survivability of the sample A irradiated continuously and the sample B irradiated intermittently.

	$\dot{D}_{inst}$ (Krad/h)	$\dot{D}_{rlt}$ (Krad/h)
A	7~440	7~440
B	264	24
B2	18	7

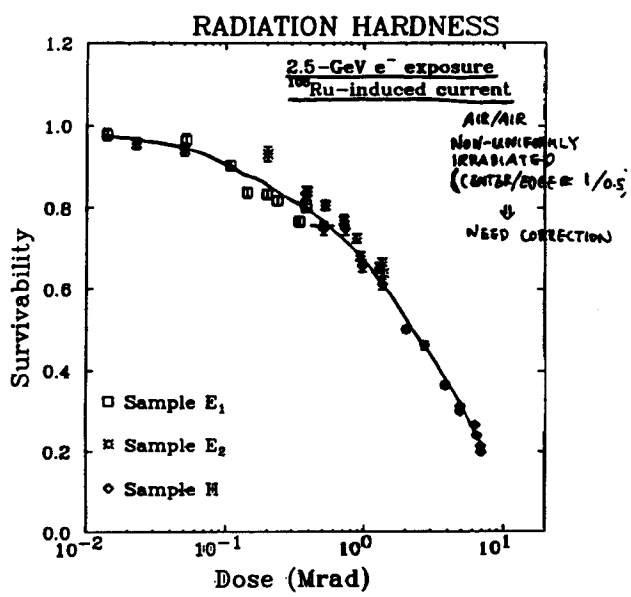


Figure 9: Survivability of the samples E_1, E_2, and H.

⑮ Comparison of Radiation Damages of the Samples Exposed in Air & N_2

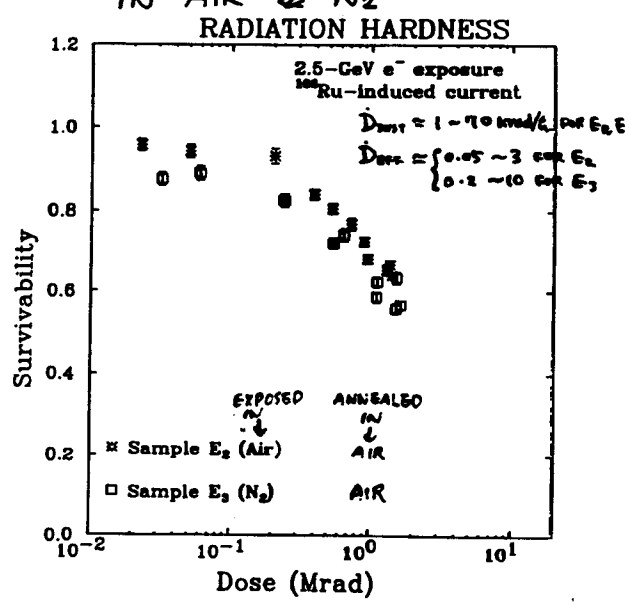


Figure 9: Effects of gas environment on radiation hardness of scintillating tiles with waveshifting fibers. The samples E_2 and E_3 were irradiated in air and nitrogen gases, respectively.

→ No better results were observed from the samples irradiated in N_2 gas and annealed in air.

(16) TOTAL DOSE & DAMAGE PROFILE IN CALORIMETER

1814

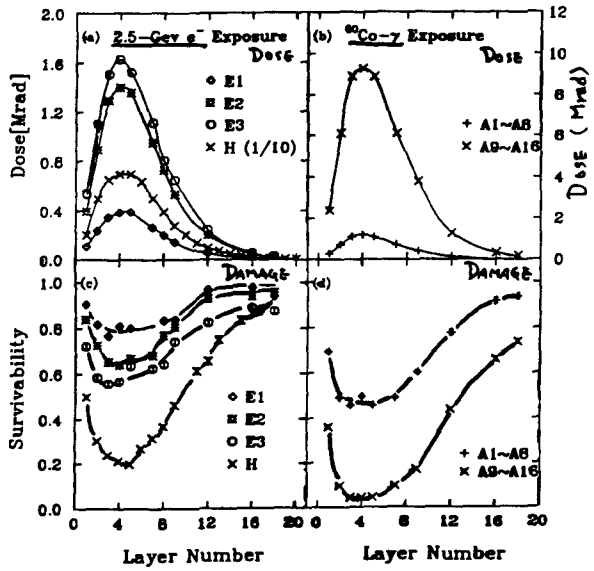


Figure 11: Dose and radiation damage profiles for the samples of E_1, E_2, E_3, and H exposed with 2.5-GeV electrons and for the samples of A's exposed with ^{60}Co γ-rays.

(17) DOSE RATE DEPENDENCE OF RADIATION DAMAGES

1815

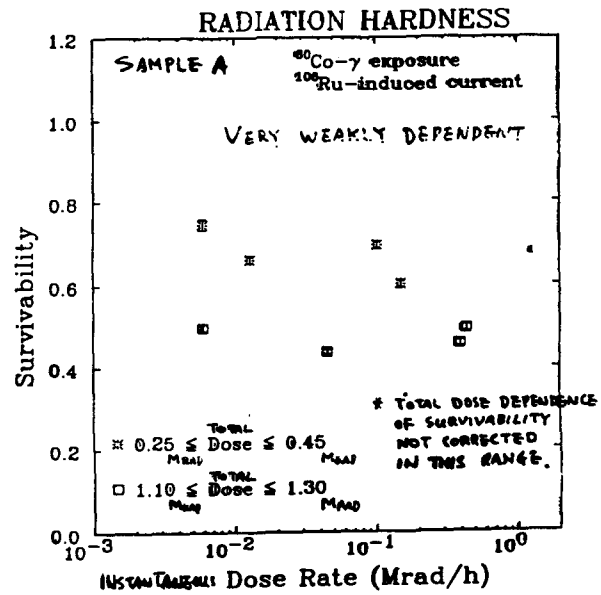


Figure 10: Dose rate dependence of radiation damages for scintillating tiles with waveshifting fibers. These samples were exposed with ^{60}Co γ-rays.

(18) EVALUATION OF RADIATION DAMAGES WITH 2-GeV e⁻ & ¹⁰⁶Ru-INDUCED I

1816

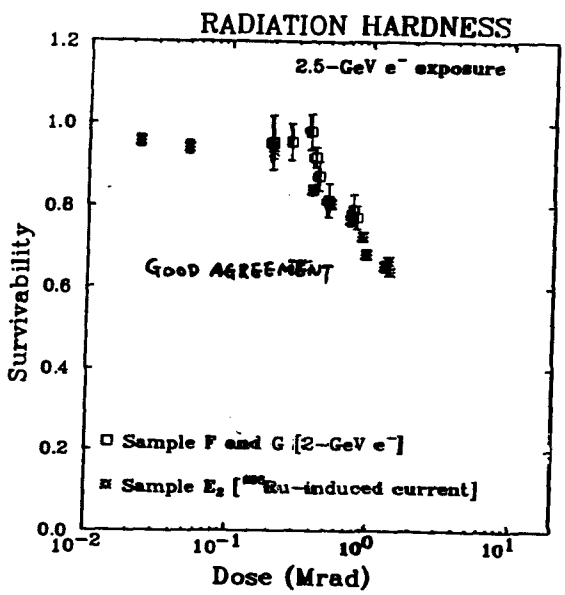


Figure 13: Comparison of radiation damages for the samples F, G, and E_2. The samples were irradiated with 2.5-GeV electrons. The damages of the F and G samples were evaluated by measuring the pulse height distribution with 2.5-GeV electron beams at KEK. On the other hand, the damages of the E_2 samples were evaluated by measuring ^{106}Ru-induced currents.

(19) COMPARISON OF RADIATION DAMAGES WITH 2.5-GeV e⁻'s & ⁶⁰Co γ-RAYS.

1817

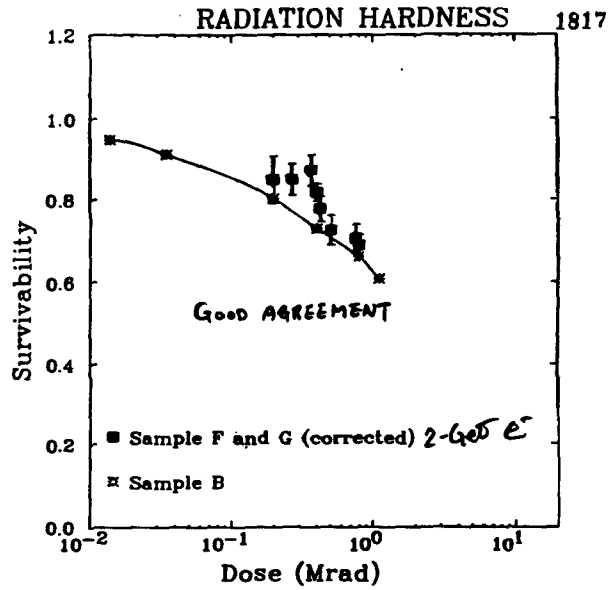


Figure 12: Comparison of radiation damages for the samples F, G, and B. The F and G samples were irradiated with 2.5-GeV electrons and their damages were evaluated by measuring the pulse height distribution with 2.5-GeV electron beams at KEK. Since the samples F and G were non-uniformly irradiated, the correction factor 0.89 was multiplied. On the other hand, the B samples were irradiated with ^{60}Co γ-rays and their damages were evaluated by measuring ^{106}Ru-induced currents.

UNIFORM/NON-UNIFORM IRRADIATION CORRECTION ⇒ C4(UNIFORM) / C2(NON-UNIFORM) = 0.89 / [illegible]

1818

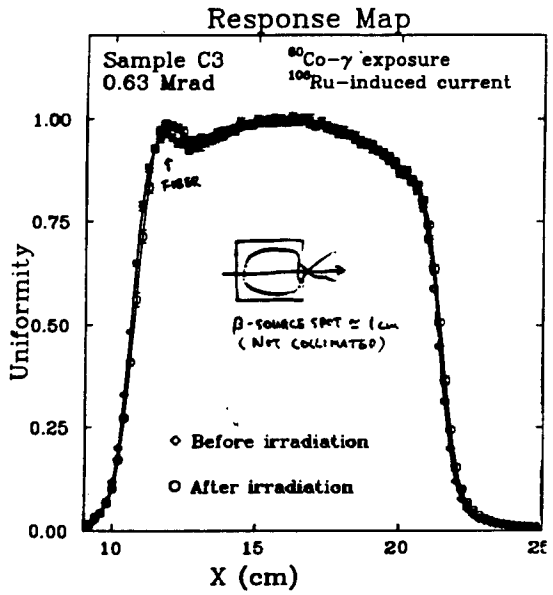


Figure 17: The sample C3 was mapped by measuring ^{106}Ru-induced currents before and after ^{60}Co exposures and uniformities were compared each other. No significant differences were observed at least upto 1.1-Mrad.

(21) EVALUATION OF RADIATION DAMAGES BY Np.e. MEASUREMENTS

$$F(x) = a \cdot \sum_{n=1}^{5} \frac{\mu^n e^{-\mu}}{n!} \cdot \frac{e^{-\frac{(x-n)^2}{2\sigma^2 n}}}{\sqrt{2\pi\sigma^2 n}}$$

1819

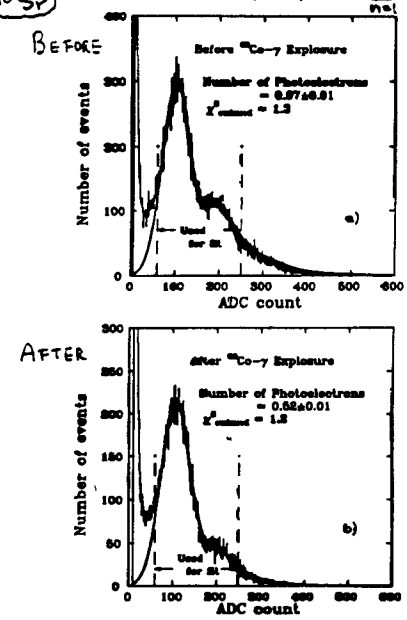
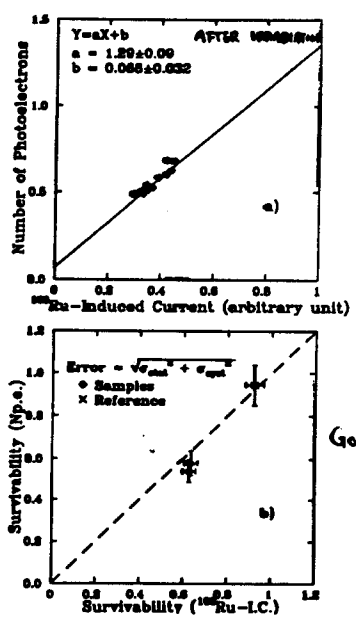


Figure 15: Pulse height distributions measured (a) before and (b) after ^{60}Co irradiations for the sample C4. The number of photoelectrons were measured by fitting the pulse height distribution to the convoluted Poisson and Gaussian functions.

(22) COMPARISON OF RADIATION DAMAGES EVALUATED WITH Np.e. & ^{106}Ru-INDUCED I

1820



GOOD AGREEMENT

Figure 15: (a) Correlation between ^{106}Ru-induced currents and the number of photoelectrons measured with ^{90}Sr. (b) Comparison of radiation damages evaluated by measuring the number of photoelectrons with minimum ionizing electrons decayed from ^{90}Sr and by measuring the ^{106}Ru-induced currents.

(23)

1821

Conclusions

1. ^{60}Co-induced radiation damages and 2.5-GeV e⁻-induced damages were evaluated by measuring :
   (1) ^{106}Ru-induced currents,
   (2) pulse height distributions of 2.0-GeV e⁻'s,
   and
   (3) number of photoelectrons with ^{90}Sr β sources.

   The damages were consistent with each other.

2. Dose rate dependence of radiation damages was very weak.

3. No differences were observed between response maps measured before and after irradiations upto at least 1.0 Mrad.

4. No better results from the samples purged in N^2 gases during irradiations.

WE MAY EVALUATE THE RADIATION DAMAGES OF THE E-M CALORIMETER BY EXPOSING ^{60}Co γ-RAY AND MEASURING ^{106}Ru-INDUCED CURRENTS AND/OR NUMBER OF PHOTOELECTRONS.

^{60}Co → OK ^{106}Ru-INDUCED CURRENT → OK

FNAL Source Tests

A. Byon-Wagner, G. Foster, J. Freeman,
D .Green, A. Para, Y. Zhou :

Fermi National Accelerator Laboratory

V. Hagopian, K. Johnson : Florida State University

R. Gustafson, M. Shappirio : University of Michigan

V. Barnes : Purdue University

&

CDF Plug Calorimeter Upgrade Group

Presented by Aesook Byon-Wagner

Aug 6, 1991

Outline

- Radiation Hardness Test Modules assembled at FNAL for Beam Tests
- Source Tests and Comparisons with Other Measurements
- On-going Programs

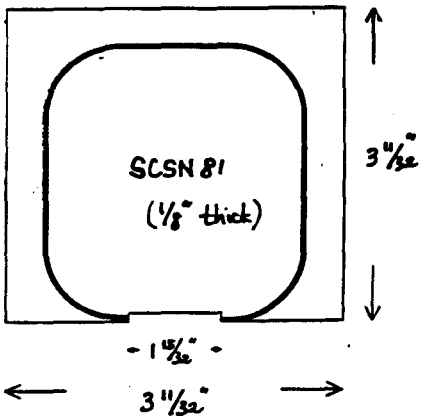
Radiation Hardness Test Modules

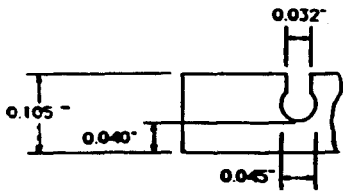
Beam test at	# of modules sent
IHEP	5
KEK	2
Saclay	2

(1) Tiles
- SCSN 81 1/8" thick
- ball groove at FNAL (2300 RPM, 1"/sec)
- edges painted with BC620 Reflective coating
- surfaces wrapped with Al foil and marvel guard
  ∵ white paper or Al mylar changes colors by radiation (> a couple of Mrad)

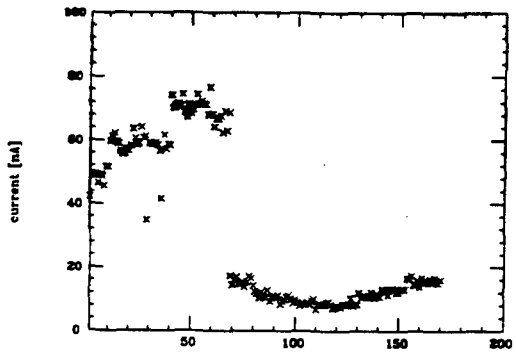
(2) Fibers
- BCF91, BCF91A 1 mm diameter
- test : transmission light yield of 60" fiber measured using UV light source (before and after fed thru groove)
- black painted : "To KILL" cladding lights

Latex flat finish decorator black paint





transmission light yield from one spool



↑ begining of spool ↑ end of spool

(5) Tile + Fiber
for module # > 6

- light yield measured with 5 mCi Cs^{137} source
- sorted by output signal to compensate variation in fiber length (40" → 22")
- absolute light yield measured using cosmic muons

PMT	QE at Green	Rad Hard tile	CDF EM II
R329	(~57%)	~11.5 PE/MIP	~3.3 PE/MIP
XP2018	(~12%)	~3.0 PE/MIP	>6 PE/MIP

1827

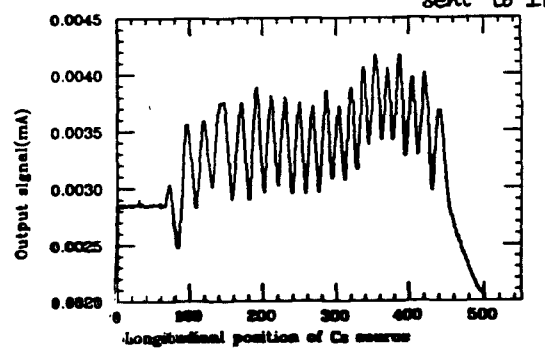
(4) module

- fibers glue to cookie (5 mm epoxy), faced off with diamond cutter
- air joint between cookie & PMT
- all modules were scanned before shipped out.

(5) dosimiter

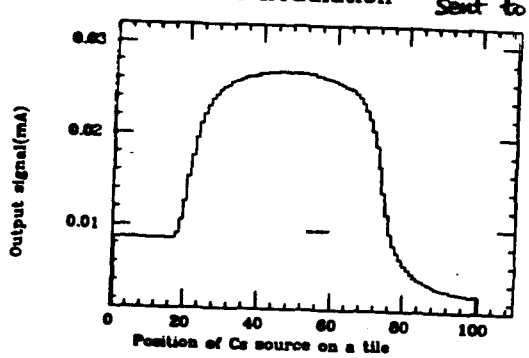
- radiochromic films (from FSU) in each module
- Alanine tube plastic imbedded in some modules

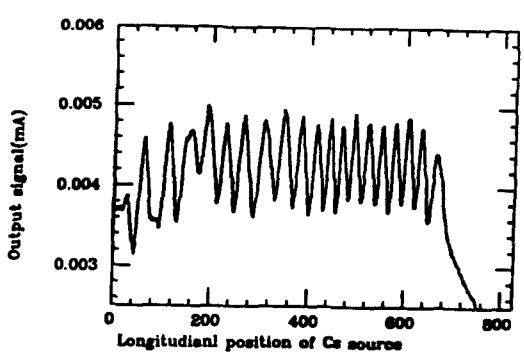
Before irradiation — sent to IHEP



1828

Before irradiation — sent to KEK

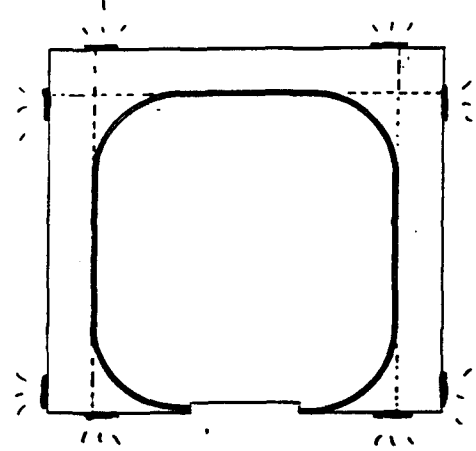




1829

(6) glue

- light yield with air joint = 65% * (with glue joint)
- tried EPOTEK 305 → loss of light yield
  fiber transmission light yield ≈ 0
  → drop this test

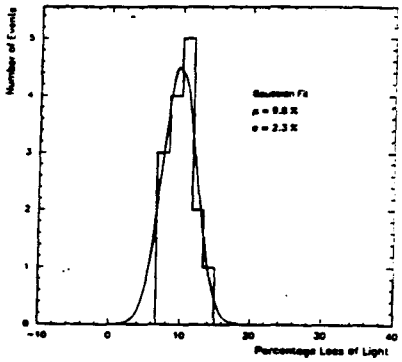


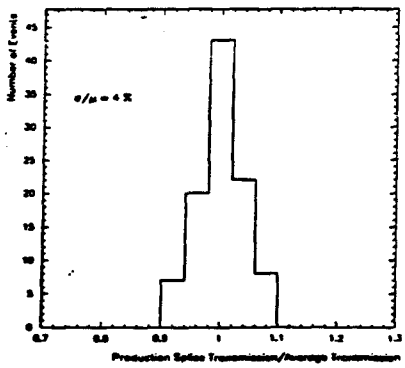
(7) splicing green to clear

- at the early stage of splicing technique
  → 20% failed and wide spread of light loss

1830

Apollinari et. al.





183

(8) Other blue scintillating tile than SCSN 81

a) PVT, RH2, Polysiloxane

- from bench test, SCSN 81 shown to be radiation hard.

→ we can try others next round.

(9) Red wavelength region

- assembled green tile (SCSN 81 + Y7 (60PPM)) + red fiber (3HF + R3) module
- lightoutput only can be detectable with R669 (NA3024)

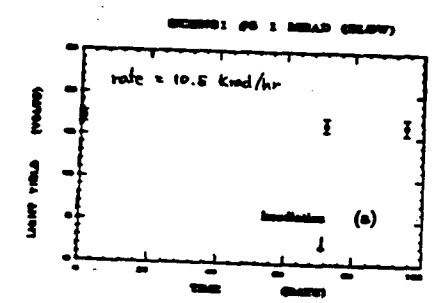
2. High Rate ^{60}Co Tests

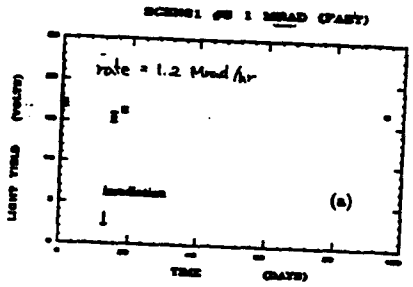
(1) SCSN 81 + BCF91

exposed at the Phoenix Lab of Univ. of Michigan

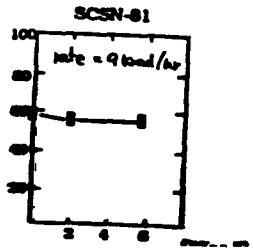
- ball groove, no glue
- rate ≈ 1 Mrad / hour
- in air
- light yield measured by Hamamatsu R329 using ^{137}Cs (1 mCi) source

183





Gickens et. al.



SDC-91-00011
Sahay

A. Bross et. al.

1833

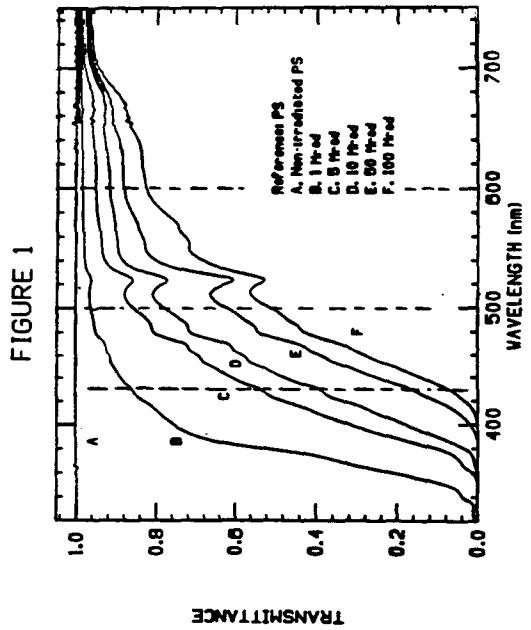


FIGURE 1

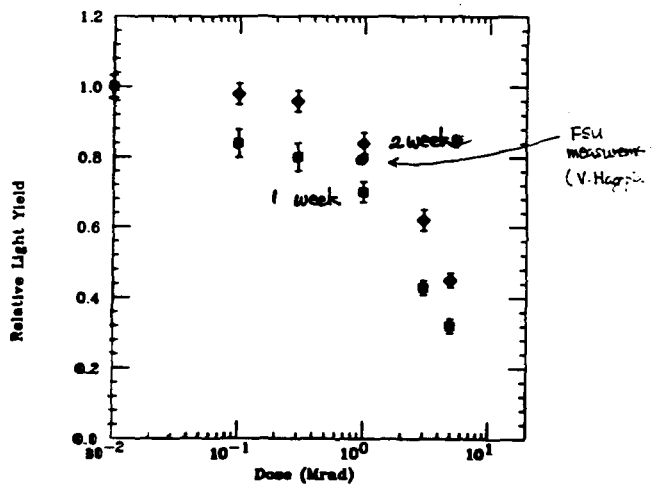
QE spectrum for R669

1834

QE(600 mm) ~ 15 %

1835

SCSN81 + BCF91 wrapped with Al foil



measured with R329

1836

1). BCF 91, BCF91A, Red, Orange fibers

1837

Green tile = SCSN 81 + Y7 (60 PPM)

Red fiber = 3HF + R3

Orange fiber = 3HF + O2 (SCSF - 3HFO2)

* 10 of each

SCSN 81 + BCF 91

SCSN 81 + BCF 91A

Green tile + orange fiber

Green tile + Red fiber

* light output measured by

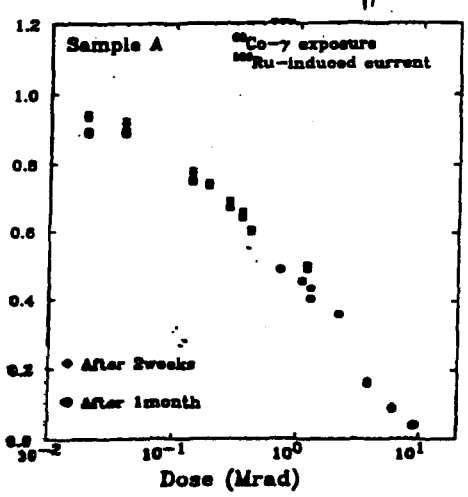
	QE at green	QE at red
XP2081B	12%	4%
R669	17%	15%

* light yield per tile

	BCF91A	BCF91	Orange	Red	(PE/M
XP2081B	3	2	0.9	0.4	
R669	4	3	2	1	

*irradiated by ^{60}Co at Michigan to 3 Mrad in air, ~1 Mrad/hr

SCSN81 + Y7 (150 PPM) wrapped with white pap



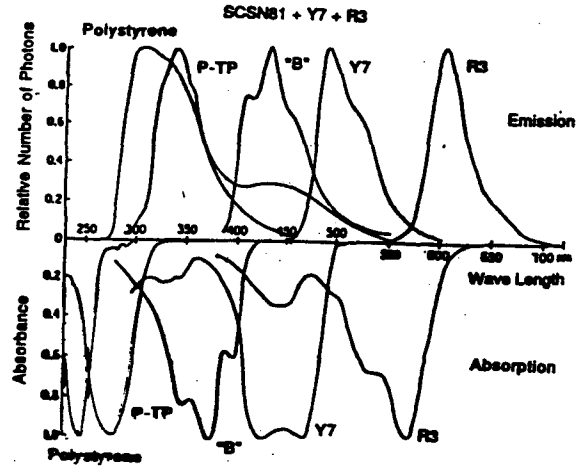
Preliminary results

1838

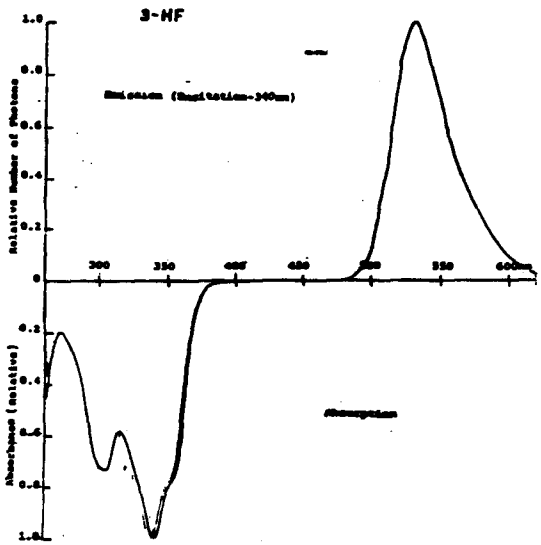
# days recovery	relative light yield (%) BCF91 (Nov. 90)	BCF91A (May 91)	
1	33	27	measured with XP2020
2	44	43	
3	49	48	

	Green	Orange	Red	Red
1	27	28	29	[redacted]
2	43	44	54	43
2½				65
3	48	54	67	76
		XP2081B		R669

1839



1840



1841

J. Future Tests

* IF have enough light and damage occurs uniformly
  ⇒ Correctable

∴ Would like to have
  Less damage and More light

* Break down
  - Tile
  - Wavelength Shifting Fiber
  - Clear Fiber
  - PMT

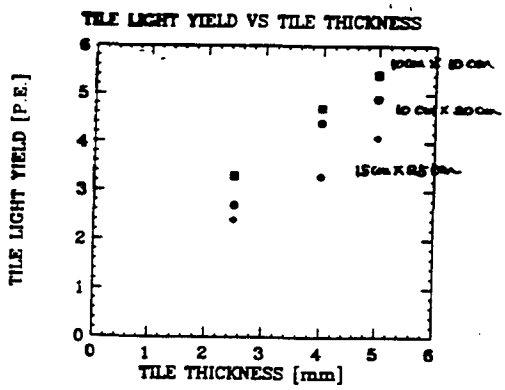
lot of radiation damage studies done on light yield (LY), attenuation length (AL)

1. Tile : LY important AL according (short path)

(1) thickness : thicker → more light
  test with different thickness

de Barbaro et al.

1842

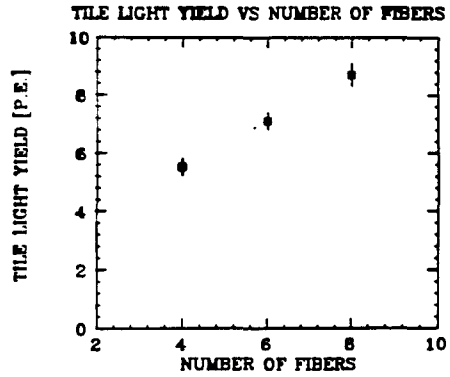


(2) absorption and emission coefficients
→ try SCSN81 + 3HF
SCSNP1 + YT (higher density)
Polysiloxane

(3) low rate, long term exposer (N. Giokaris et al)
by Co^{60} at Univ of Michigan
rate = 150 rad/hour → 1 Mrad/year
will have results at 0.3 Mrad by Sep '91
1 Mrad by May '92

de Barbaro et al.

1843



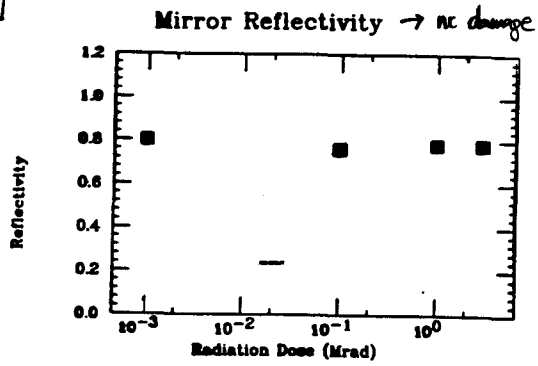
Wavelength Shifting Fiber
still short path → A.L is secondary effect

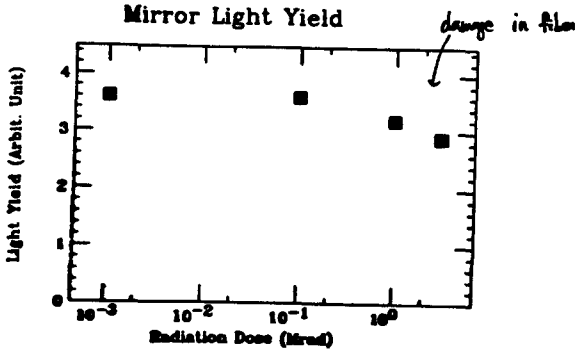
1) absorption, emission coefficients
→ try better match to tile emission spectra
→ try better match PMT to fiber emission light.

2) higher fiber density → more light
Aluminized fiber mirroring (developed to improve hermiticity of calorimeter)
↳ can increase fiber density without increasing dead space for read-out fibers

Jim Freeman

1844





1845

3. Clear fiber & Splicing

(1) Change in transmission → no damage seen upto 1 Mrad

(2) Attenuation length
possibility of using 3M silica optical fibers
200 – 2400 nm transmission
rad hard (after 4 Mrad exposer of 3m length, < few % loss)

4. PMT

	QE at green	light yield of rad hard module/tile
R329	~5%	~1.5 P.E/MIP
XP2081B	~12%	~3.0 P.E/MIP

one of module from KEK with 1 Mrad exposer in air now back at FNAL

→ try to mask out (equalize output from each tile) put in test beam

IHEP/BEIGING TESTS

D. GREEN

FSU & LSU RESULTS

A. FAZELY

Cal. 8/6
GABRIEL
Calk, Resolution

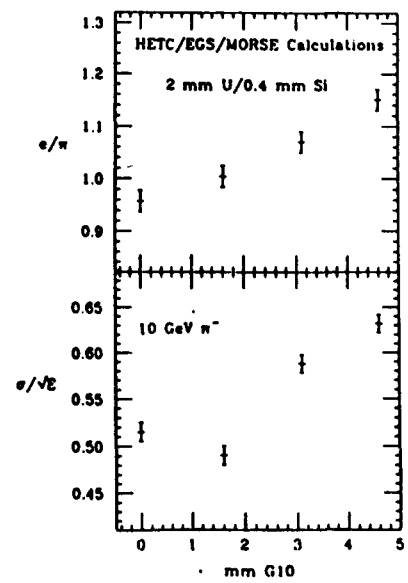
COMPENSATION AND ENERGY RESOLUTION

T. A. Gabriel, Director
Oak Ridge Detector Center
Oak Ridge National Laboratory

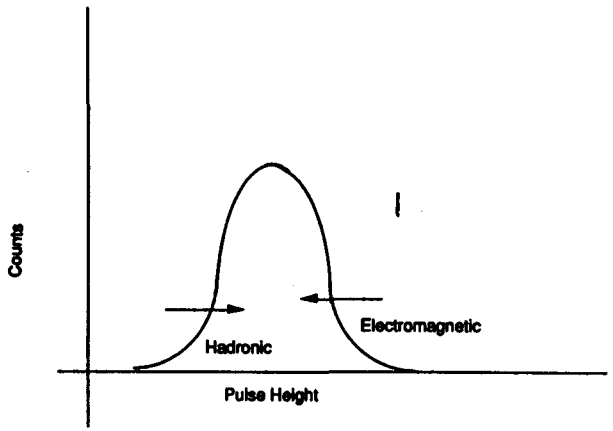
As I was putting this talk together, it become even clearer to me that the physics of compensating calorimetry is indeed very complicated. As I will use it here, a calorimeter is said to be compensating if on the average the signal from electrons and hadrons of the same energy produce the same signal. During this presentation I would like to briefly mention some of the reasons for achieving compensation and to present the factors effecting compensation and resolution since both are closely related.

There are several important reasons for achieving compensation

- Energy resolution is at a minimum
- No constant term $\frac{A}{\sqrt{E}} + B^{\prime\prime 0}$
- Linearity of response



Minimization of energy resolution due to compensation



There is no such thing as a compensating calorimeter. "Tricks" are applied to yield

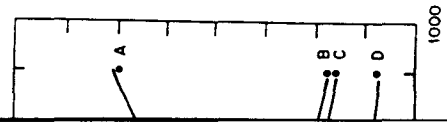
$$\frac{e}{\pi} \sim 1$$

However, it is still better to apply these tricks and produce a quasi-compensating calorimeter than a non compensating calorimeter.

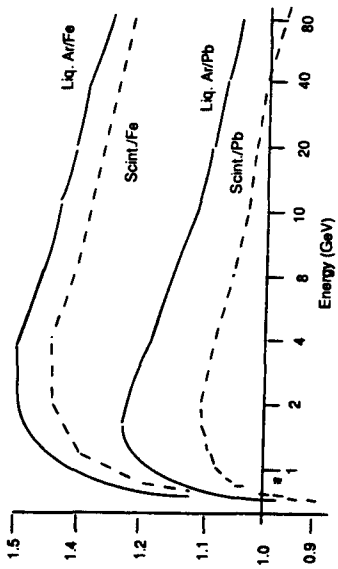
pensation

meter

mpensation.



Compensation can never absolutely be obtained at all energies because of the nature of the hadronic and electromagnetic cascades and because of active and passive media responses.



~ 0 - 1 GeV — hadrons act like muons
~ 1 - 5 GeV — Nuclear interactions start occurring

- binding energy losses
- neutron production

~ 5 - ∞ — Fraction of energy into electromagnetic channel is increasing

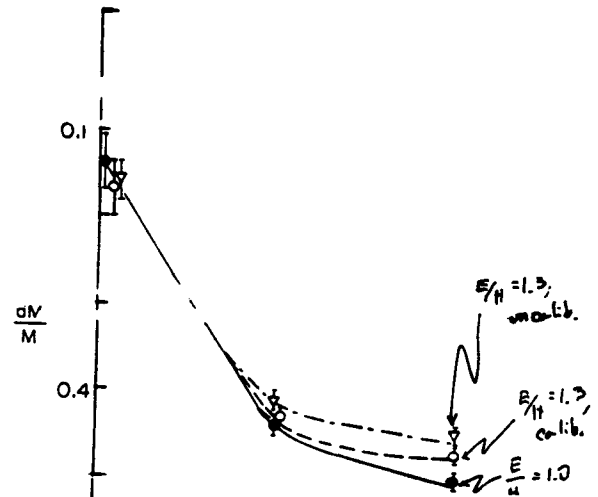
FNAL OPTICAL STUDIES

J. FREEMAN

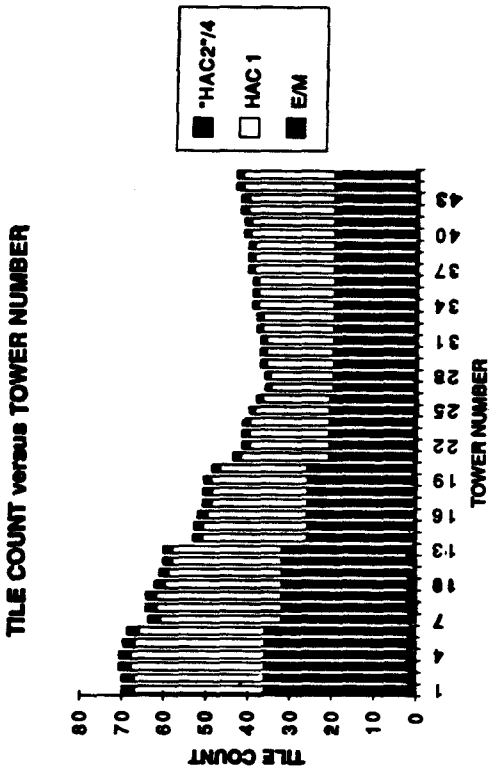
Pb EM / Fe Had Calorimeter Design

Features.

- Conventional mechanical design
- iron allows conventional (safe) solenoid, uniform $\vec{B}$
- mech. strength, 1.5 Kton weight saving → easier support
- hermiticity: no cracks between tiles, no cryostat
- emphasize EM → ~½ tiles in EM



1866



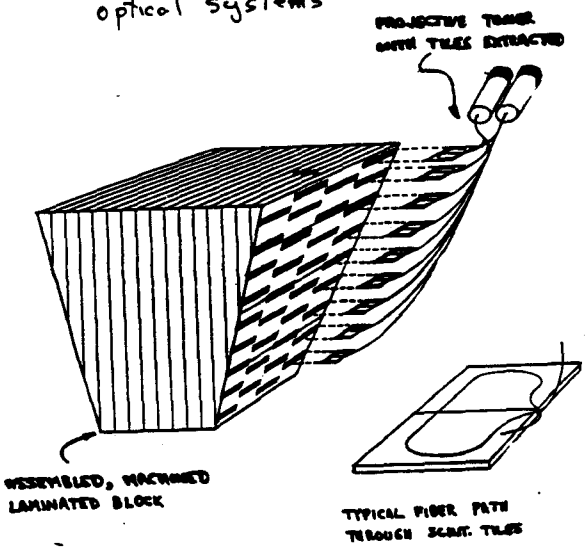
1867

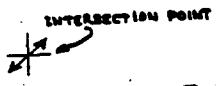
Hadron Optical Assembly
(~ same as CDF prototype)

- tiles cut on mill
- edges painted
- green fibers glued in place
- wrapped
- clear fiber spliced on
- installed into optical package
- installed in Fe
- tested/trimmed in place

1868

HAC assembly strategy
install complete pretested
optical systems





Schematic Compensating Fe/Scint. Tiles
Solenoidal Calorimeter Module

1869

EM optical assembly

- tiles cut
- painted
- "dealed" into pb/scint stack
- piano wires tensioned
- EM module installed on HAC
- WLS fibers mirrored
- WLS fibers spliced to clear
- fiber assembly tested
- fiber assembly threaded into tiles
- fibers dressed to cookie
- test/trim

1870

1871

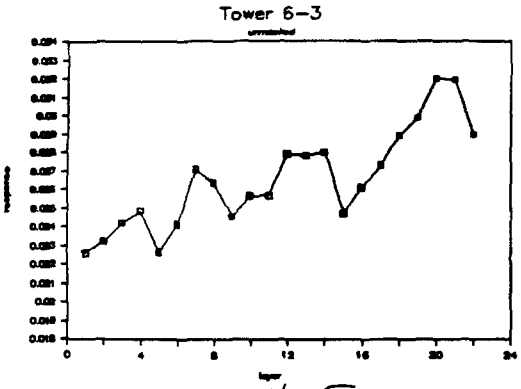
1872

1873

Rest of Talk

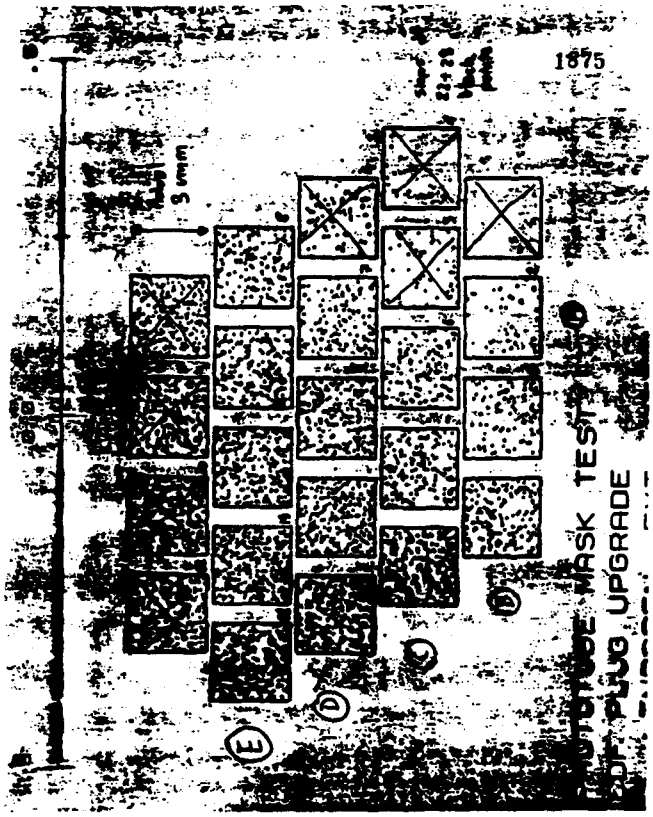
- spec's for optical system
- sigma tiles : light yield, uniformity
- mirroring
- generic masking
- longitudinal masking / sources
- annealing / preforming fibers
- optical connect / disconnect (for shower-max det.)

1874

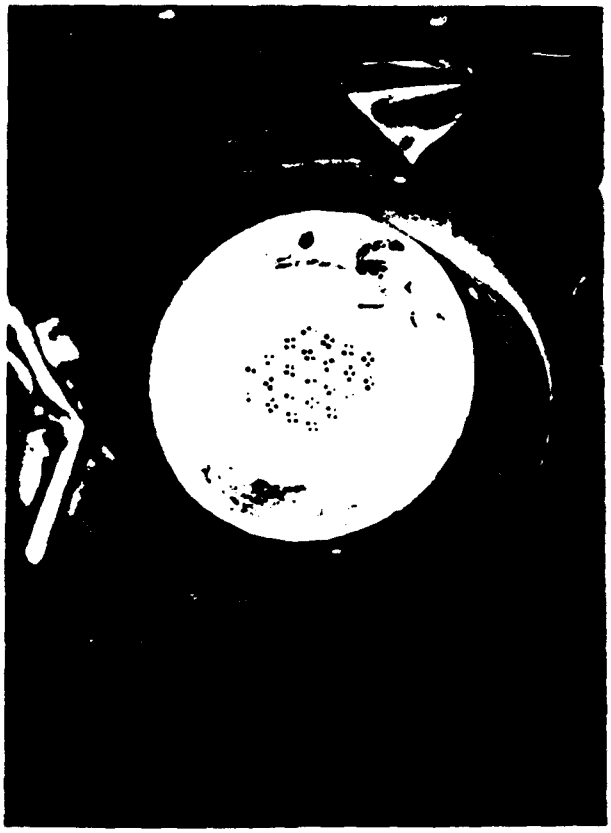


1.5% σ

1875



1876



1877

6/24/91 7:56am

CHANNEL	1	MAX	4	PED	3.8886	
133						
357						
457						
680						
133	MAX	208.5414	FIT	208.9411		
357	MAX	207.5914	FIT	207.5077		0.25%
457	MAX	207.7814	FIT	207.8682		
680	MAX	207.7814	FIT	207.8616		
CHANNEL	2	MAX	4	PED	3.4010	
163						
326						
487						
648						
163	MAX	185.7881	FIT	185.8999		
326	MAX	185.6481	FIT	185.6315		0.41%
487	MAX	186.8381	FIT	187.4826		
648	MAX	185.6881	FIT	185.8886		
CHANNEL	3	MAX	4	PED	4.3109	
192						
293						
515						
616						
192	MAX	140.6891	FIT	139.9277		
293	MAX	139.4791	FIT	139.5041		0.33%
515	MAX	140.5791	FIT	140.7579		
616	MAX	140.3891	FIT	140.5771		
CHANNEL	4	MAX	4	PED	4.5193	
221						
281						
544						
585						
221	MAX	174.6697	FIT	173.4519		
281	MAX	173.8897	FIT	173.8928		0.13%
544	MAX	173.8897	FIT	173.3372		
585	MAX	173.4897	FIT	173.4364		
CHANNEL	5	MAX	0	PED	4.2357	
CHANNEL	6	MAX	0	PED	0.1164	
CHANNEL	7	MAX	0	PED	0.0656	

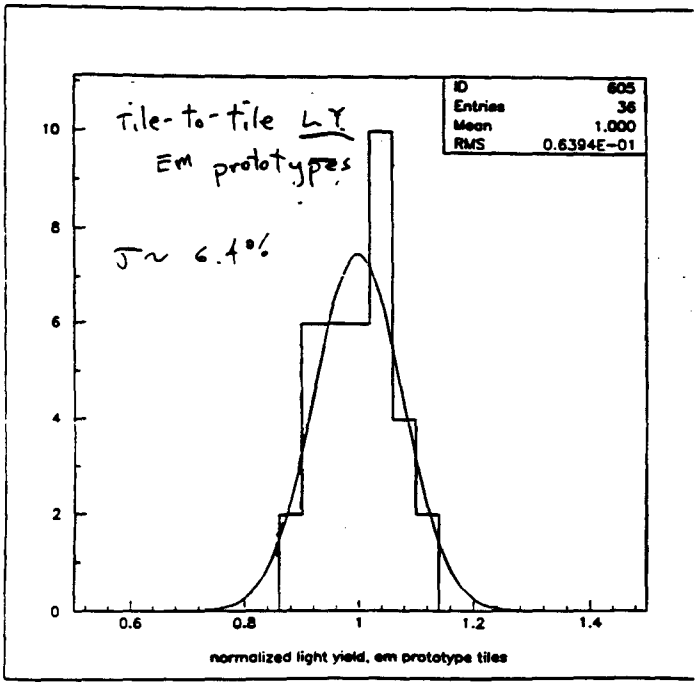
$\langle \sigma \rangle = 0.28\%$

1878

1879

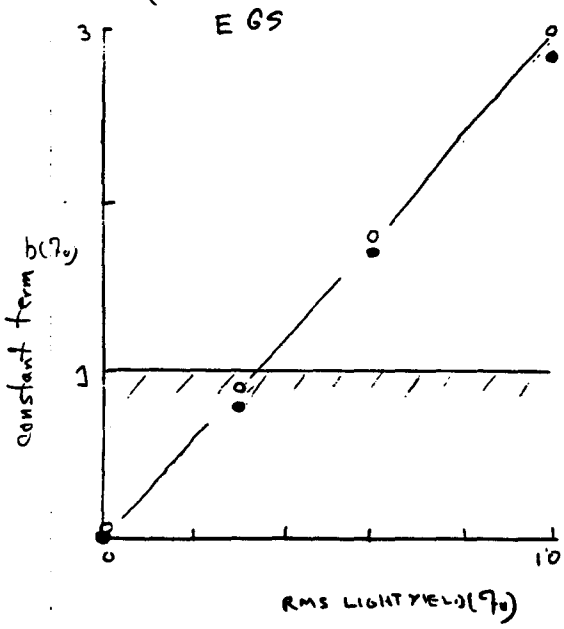
1880

CDF EM Prototype



1881

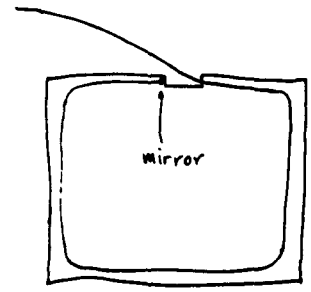
EM tile required unif.
(tile-to-tile)
EGS

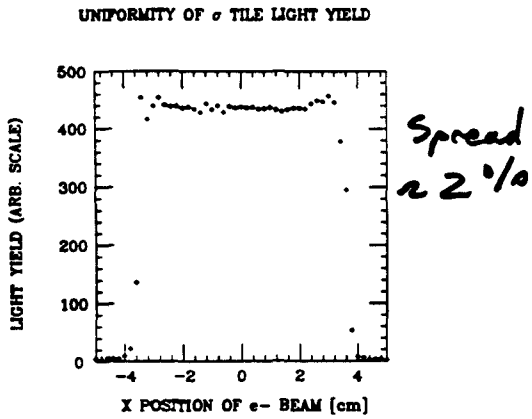


$\sigma_{LY} \leq 3\%$ for const. term $< 1\%$
(global calibration)

$\sigma_{LY} \leq 7\%$ for const. term $< 1\%$
(tower calibration)

Sigma tile





10. Figure 10: Spatial uniformity of the light collection of unmasked 4mm thick PVT tile with σ pattern of fiber layout. A scan across the tile. The signal fall-off at x=± corresponds to the edges of the tile. The spread of the response is ≈ 2%.

$\delta_0 \simeq 0.1$ Corresponds to $\sigma \simeq 0.05$

1884

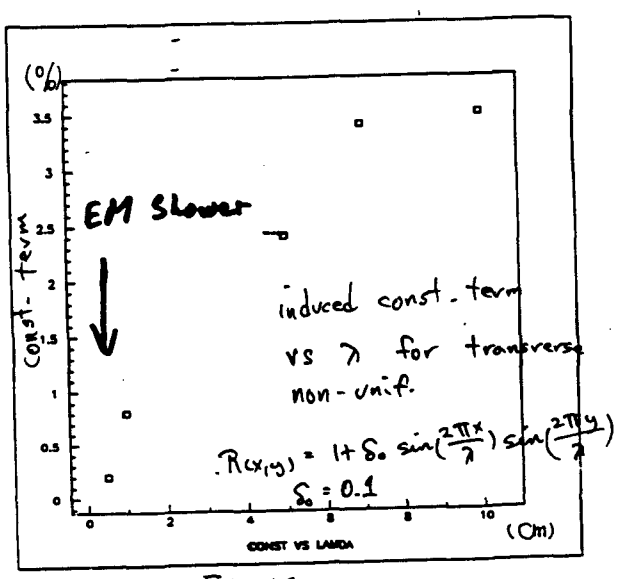
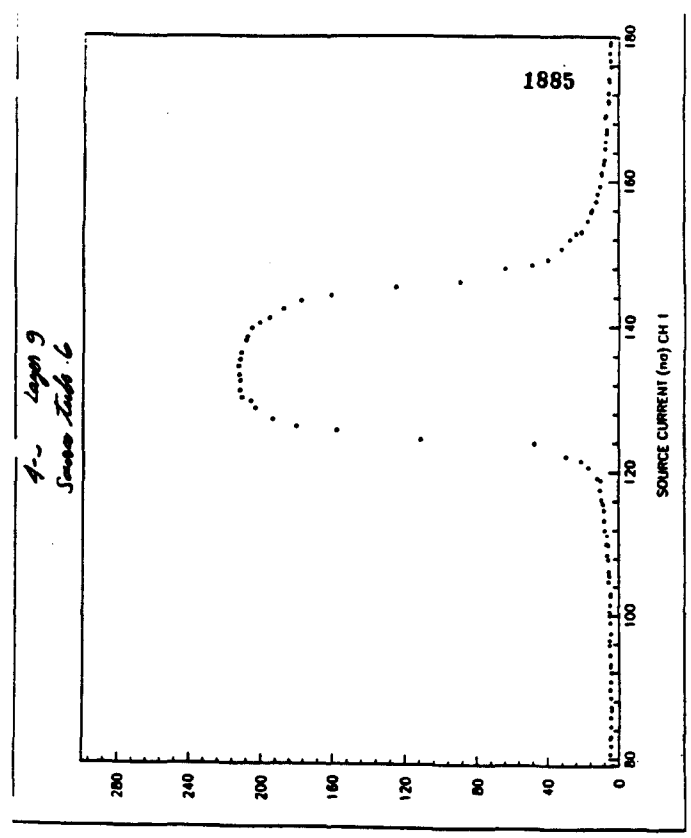


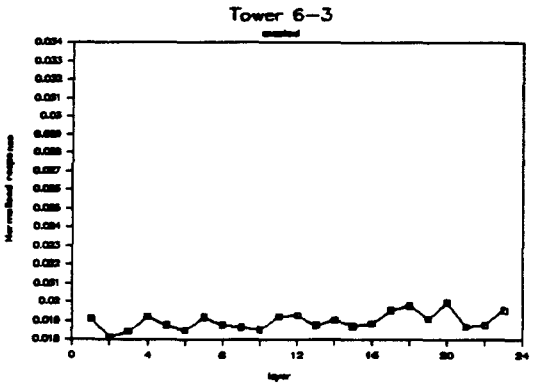
Fig. 10

tile size = 10×10 cm

1885



1886

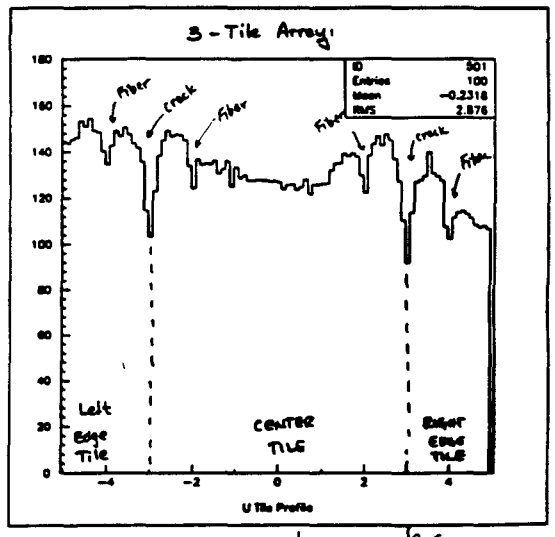


$\sigma = 2.6\%$

$\delta = 7\%$ (air gap)

1887

scan with all three tiles to PMT.

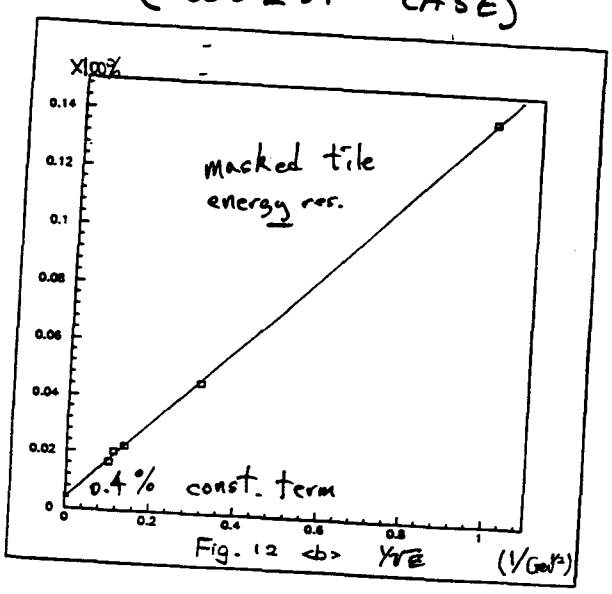


response to cracks

0.5 mm crack

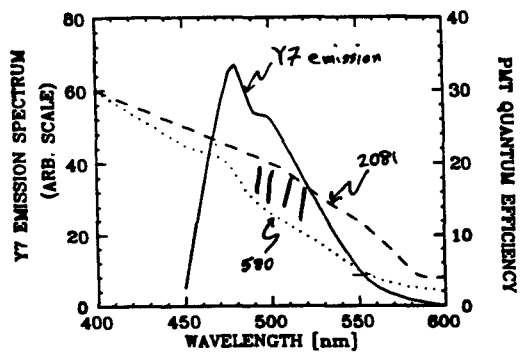
1888

EGS Study, Assuming Coherent Depth Non-Uniformity (WORST CASE)

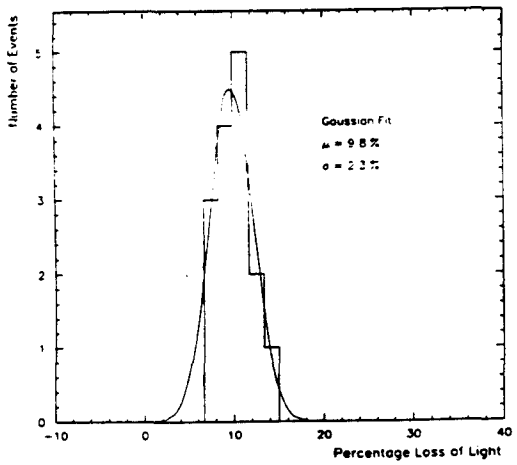


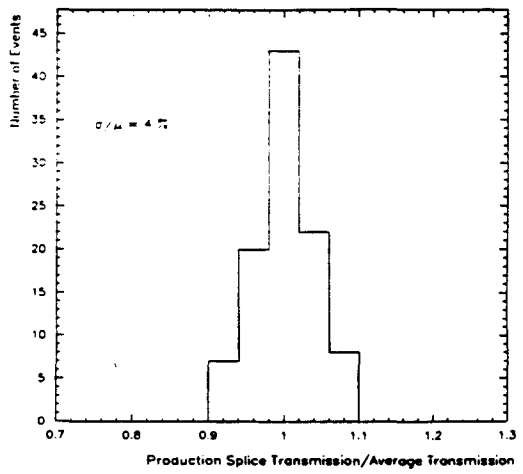
⇒ conclude transverse non-uniformity $\lesssim \sim 2\%$ acceptable

1889



3. Figure 3: A comparison of the emission spectrum [8] of BCF-91 green WLS fiber with Y7 dye (solid line) with the quantum efficiency [7] of a standard bialkali photocathode (dotted line) and the quantum efficiency of a "green-extended" bialkali photocathode (dashed line).

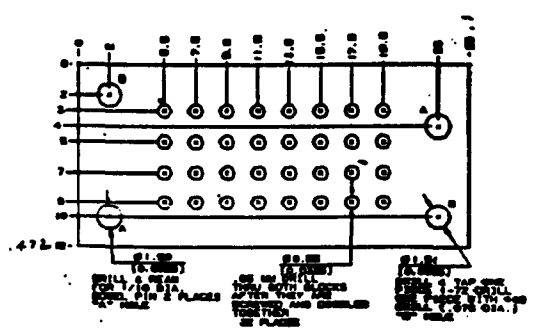




First Results from the Optical Connect/Disconnect

A. Burlon, M. Cobal, H. Grassman, S. Leone (INFN Padova and Pisa)

Design : M Atac (FNAL)



- 2 Prototypes built
- total of 8 fibers glued in
- no sophisicated surface treatment yet

=> reproducibility for each of the 8 fiber connections better than 1%

1894

Annealing / preforming fiber bend

made coils of fibers with different diameters

1" ø, 9.5 turns

2" ø, 1.5 turns

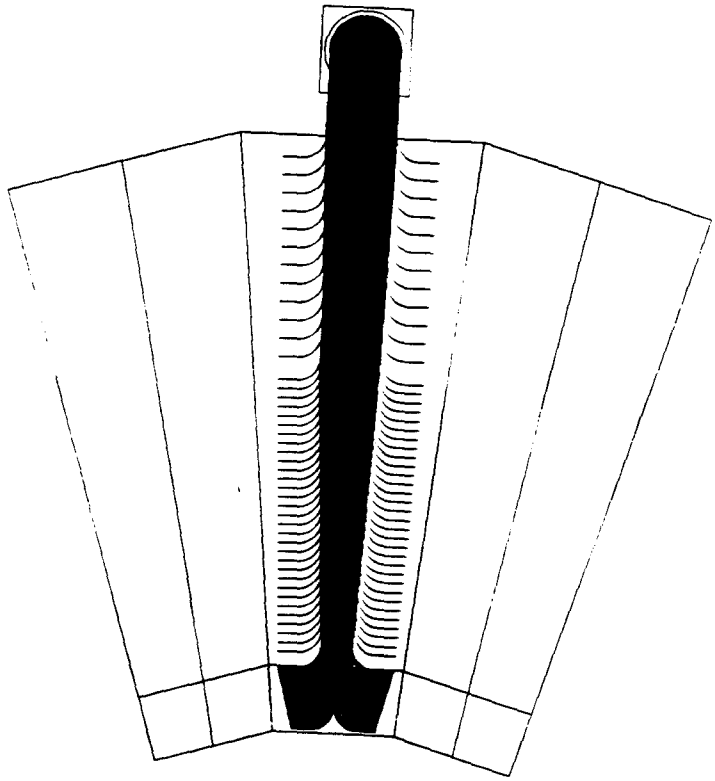
- studied various techniques for preforming: none, hot water, hot air, various cool-down schemes.
- studied BCF91, Y7 fibers
- studied light transmission thru coil vs time immediately, 5 days, 10 days, 30 days, ...

⇒ conclude: with 2" ø, very little aging for no annealing (unmeasureable)

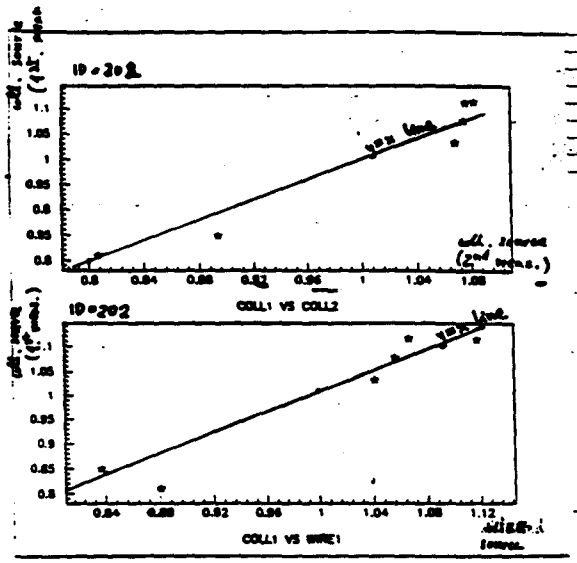
⇒ no annealing aged better than other schemes

⇒ a hard-- annealing

1895



1896



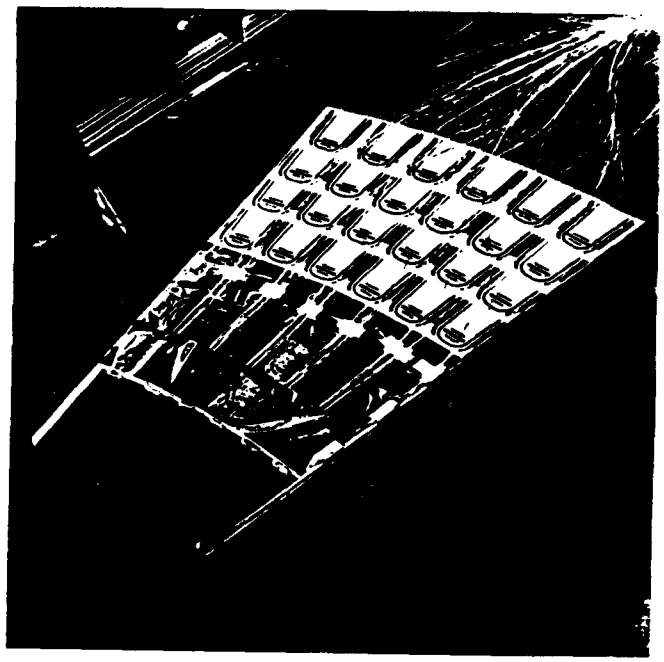
note: ① wire source data included signal from other (neighboring) tiles.

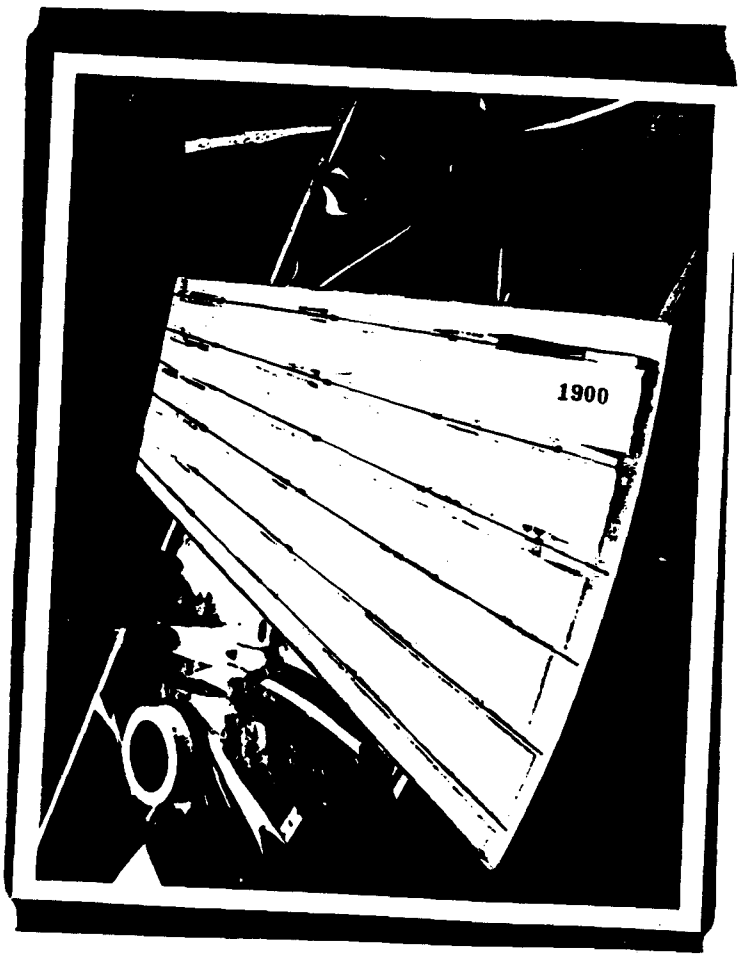
② all 3 set of measurements normalized internally (⟨coll 1⟩=1, ⟨coll 2⟩=1, ⟨wire 1⟩=1

1897

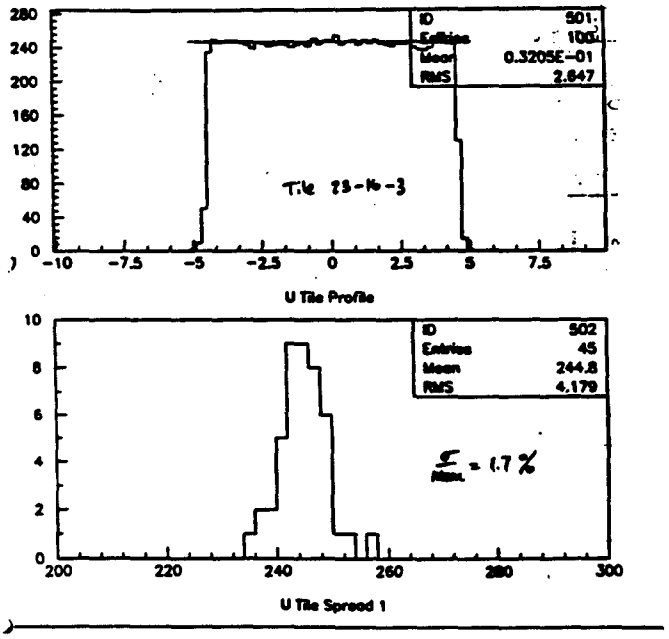
1898

1899



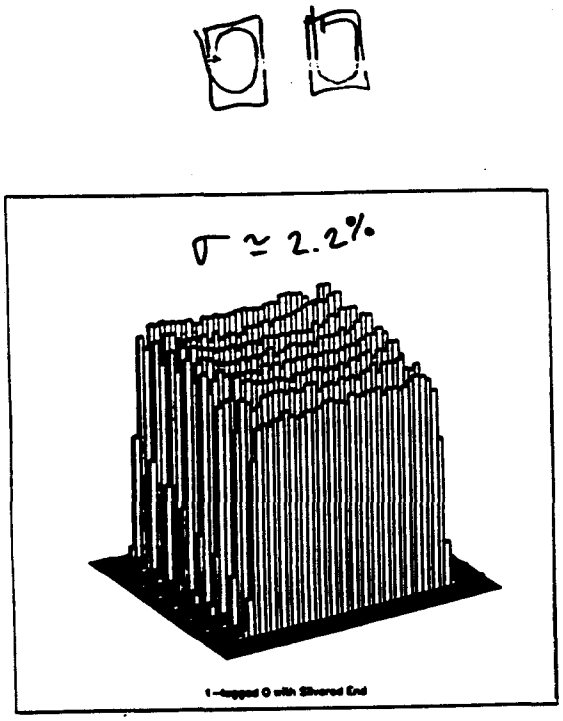


1901

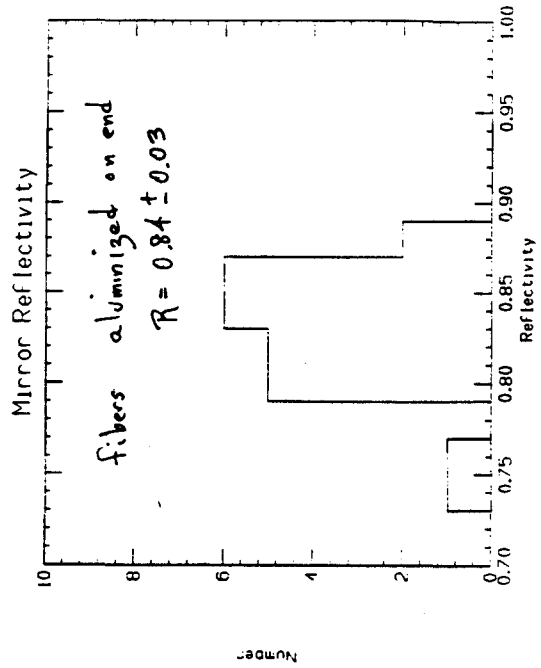


masked EM tile

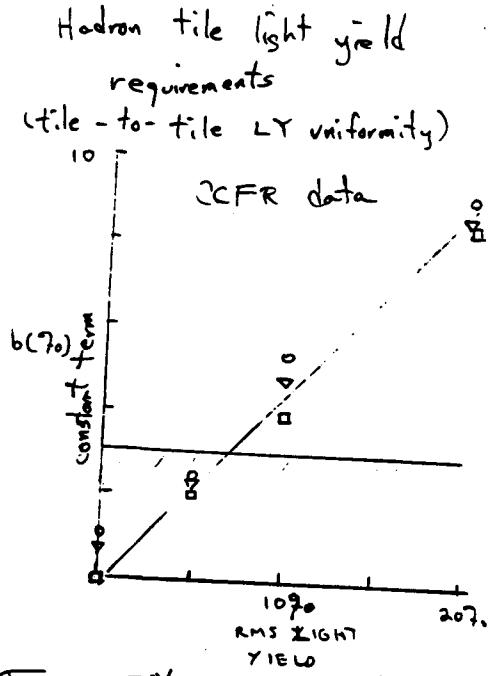
1902



1903



1904



$\sigma_{LY} \leq 7\%$ for const. term < 3%

(assuming global calibration)

1905

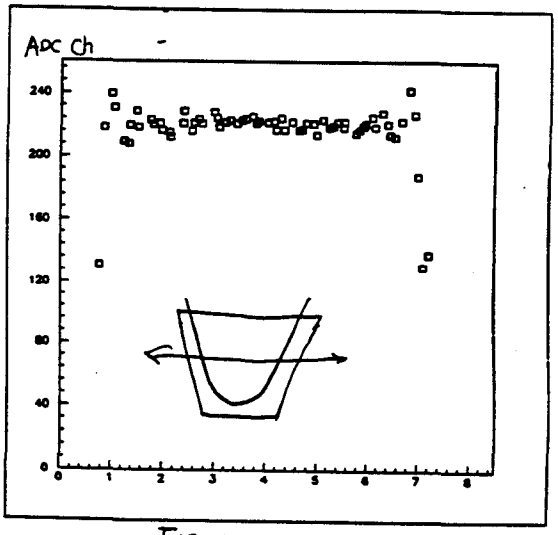


Fig. 11 <b>

masked tile uniformity

$\sigma \leq 2\%$ after masking

1906

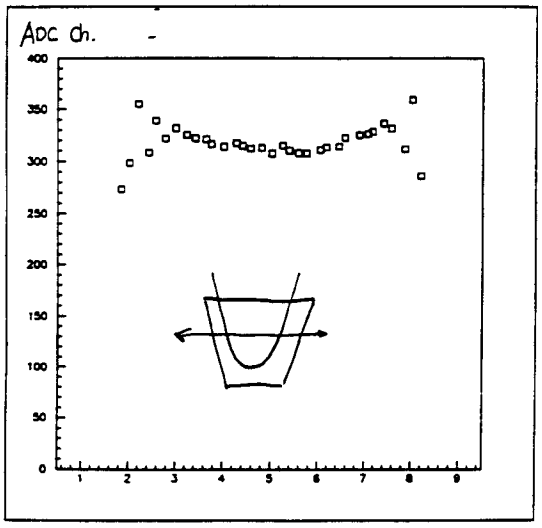


Fig. 11 <a>
unmasked tile uniformity

1907

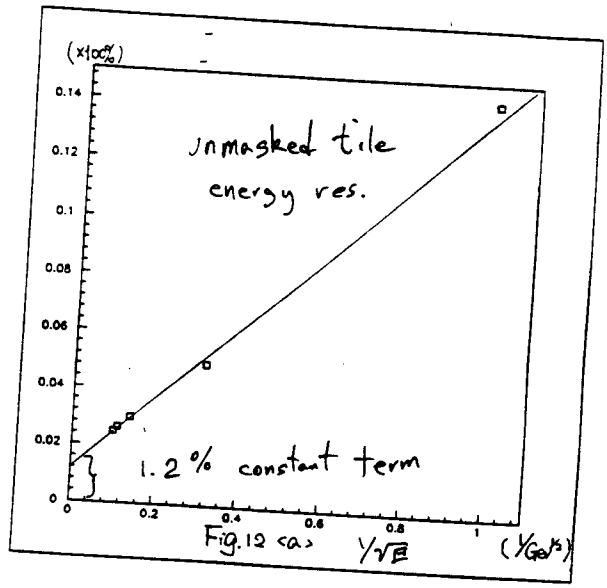
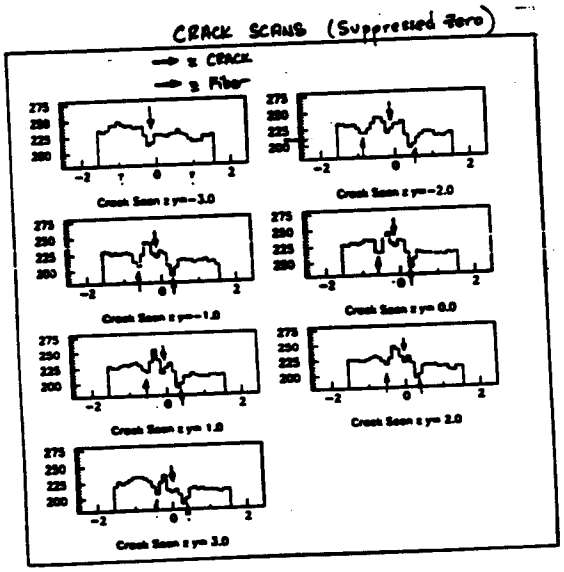
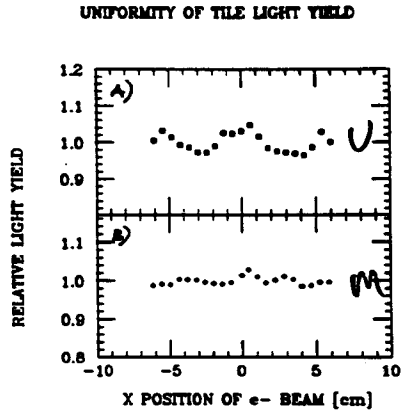


Fig. 12 <a>

1908

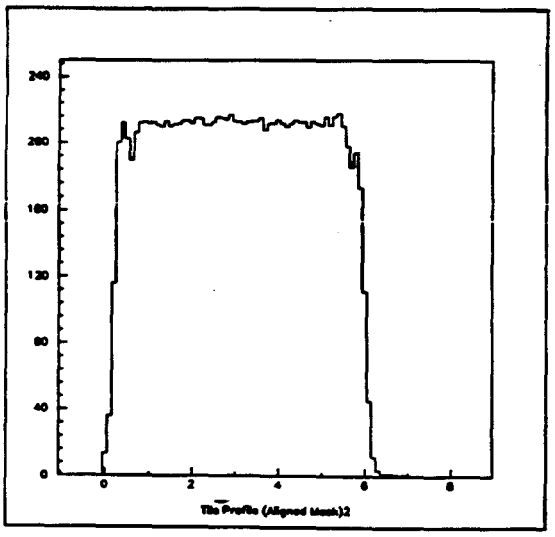


1909

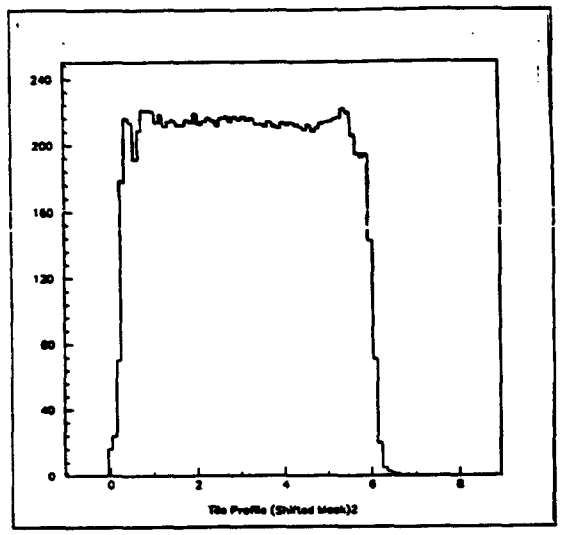


9. Figure 9: The spatial uniformity of light collection for 4 mm thick PVT tiles with U-shaped fiber layout pattern a) a scan across two unmasked tiles, and b) a scan across two tiles, selectively masked tile, resulting in the spatial uniformity of ≈ 2%.

1910

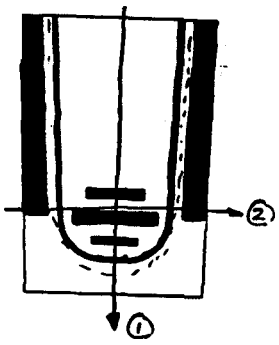


1911



1912

EM tile mask
(generic)

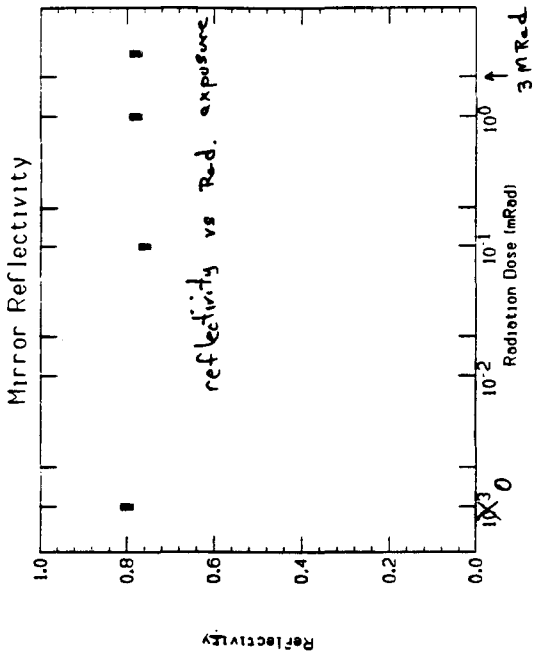


1913

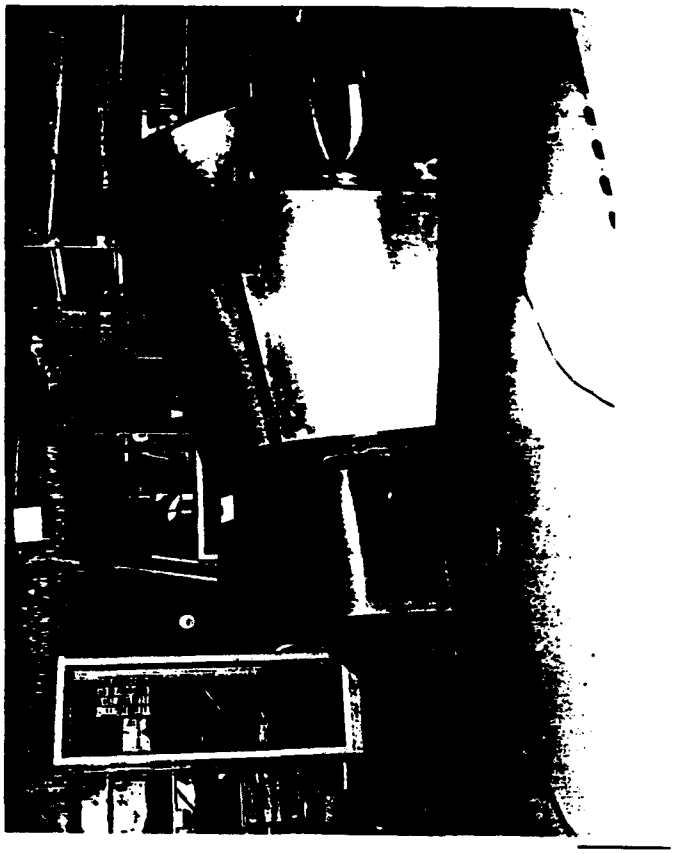
Generic Masking

CDF endplug group studied generic masking vs individual masking. Conclusion: generic masking controlled transv. non-unif to within ±2%. Use photographic expansions of mask pattern front-to-back. Recall major function of individual masking was to adjust tile absolute light yield.

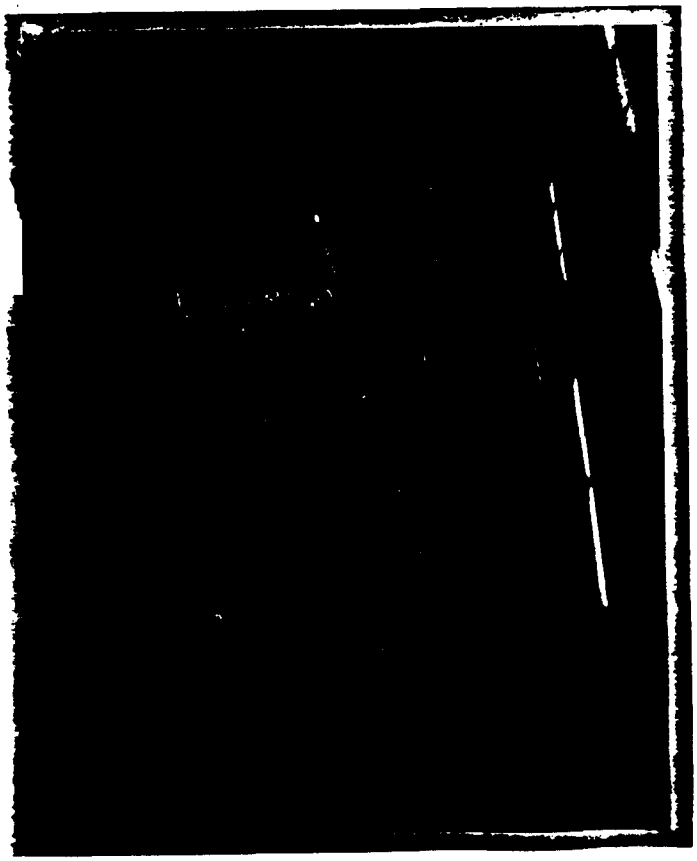
1914



1915



1917



PB/FE OPTIONS

D. GREEN

ORG
8/91

1918

Pb – Fe IN HAC 1

ACTUALLY INDEPENDENT OF LA – T/F

DESIGN TO COST

⇒ FIXED COST FOR CALOR

⇢ "MAXIMUM PHYSICS / $ "

HOW DO WE GET THERE

INTRO

Pb/Fe IN HAC

1919

(J. STEGEMAN ET AL.)

STANDARD MODEL COMPONENTS

q	$\binom{u}{d}$	$\binom{c}{s}$	$\binom{t}{b}$	"MATTER"
ℓ	$\binom{e}{\nu}$	$\binom{\mu}{\nu}$	$\binom{\tau}{\nu}$	
GAUGE BOSONS	γ, g, W+, Z^0, H			ENERGY

Detector Subsys. Contributions

SYSTEM	STANDARD MODEL COMPONENT					
	u,d,s, g = Jet	c,τ,b g = Jet vertex, lepton tag	ν	γ	e	μ
Track	✓-	✓			✓	✓
CAL	✓	✓	✓	✓	✓	✓-
Mu		✓				✓

q → J , ℓ, γ → EM SINGLE PARTICLE

ν → J

∴ FOR CALORIMETER ISSUE IS JETS AND EM SINGLE PARTICLE MEASUREMENTS

SDC CALORIMETER DESIGN

1920

PARAMETER	PROCESS	ALLOWED RANGE
HERMITICITY	JJ	J MISIDENTIFICATION $<10^{-3}$
CALIBRATION	Z	$(P_t)_e$ ≥20GeV TRIGGER
UPSTREAM(COIL) MATERIAL(TRACK)	Z, Γ_Z ISOLATED e TRIGGER	≤1 X_0 FOR COIL ≤0.1 X_0 FOR TRACKING
SPEED	Z→JJ Z→ee, PILEUP	≤1 BUNCH CROSSING
ANGULAR COVERAGE	ZZ → νν̄	|η|<3, e_e |η|<5, Z+J
TRIGGER COVERAGE	ZZ	$(P_t)_e$ ≥20GeV
TOTAL DEPTH	M_{JJ}=10TeV	D ≥ 10
LONGITUDINAL h SEGMENTATION	P_T IN JJ	D1,D2 FOR h
LONGITUDINAL EM SEGMENTATION	Z→ee	RADIATION DAMAGE 2 DEPTH SEGMENTS FOR EM AT LARGE|η|
EM RESOLUTION	H→γγ, Z→ee, Γ_Z/M_Z	0.2/√E⊕.01 OR BETTER
HADRON RESOLUTION	$(\sigma_W/\pi=0.01)$ M_{JJ}	0.7/√E⊕.03 OR BETTER
COMPENSATION	M_{JJ}	|e/h−1|<0.3
TRANSVERSE h SEGMENTATION	H→ZZ →JJ; t→Wb →eν	$\Delta\eta_h$<0.05; $\Delta\eta_h$<0.05, EM/HAD ISOLATION
TRANSVERSE EM SEGMENTATION	H→ZZ →JJ; t→Wb →eν	$\Delta\eta_e$<0.05 J REJECTION e EFFICENCY

1921

Table 2.2

Requirements on the Measurement of the Magnitude of the Energy

Parameter	Particle Type	Requirement	Physics or Technical Basis	Ref. Section
Energy Resolution EM stochastic term	e,γ	15-25%/ √E_t	low mass Z'→ee width, H→γγ	3
EM constant term	e,γ	<1.2%	high mass Z' width	3
HAD stochastic term	π	50-75% /√E_t	Jet resolution	4
HAD constant term	π	<4%	Jet resolution	4
Time stability of response	e,π	<1% after correction	Small EM constant term	3
e/h response	π	<1.5	Jet resolution	4
EM linearity	e	<4%, >10 GeV uncorrected <1% after correction	Good linearity correct w/ massless gap	3
HAD linearity	π	<2%	Compositeness	4
Non-gaussian tails EM HAD	e π	<5% loss*	e acceptance missing E_t tails?	3 4
Spatial uniformity EM HAD	e π	<5% loss*	e acceptance	3
Dynamic range EM HAD	e π	20 Mev-2 TeV 50 μV-5V	4 TeV Z' 10 TeV jets	3 4

*total electron [illegible] η [illegible] for all losses.

⇒ EM AND HAC RESOLUTION REQUIREMENTS ARE MUCH DIFFERENT

PRELIMINARY LoI STUDIES

$\frac{\sigma M_Z}{M_Z}$

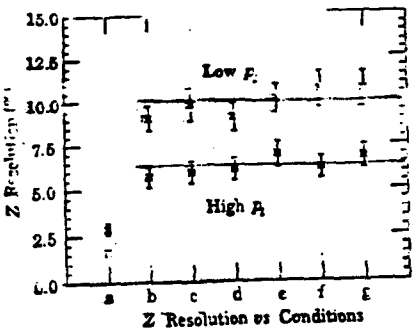


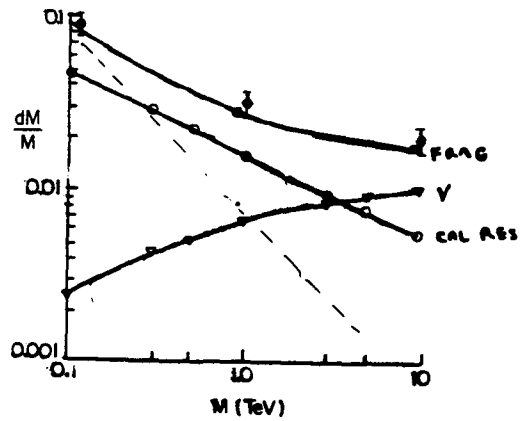
FIG. 33. Summary of mass resolution calculations for reconstructed Z's for the two p_t ranges described in the text. The first two points show the effect of detector-independent contributions to the resolution. The following points show the effect of variations in detector performance. The values plotted represent the sigma from the fits described in the text. The error bars correspond to the statistical error on the sigma. See the text for explanations of each entry.

a) NO UNDERLYING
b) CLUSTERING + UNDERLYING
c) "GOOD" ENERGY RESOLUTION
⋮
f) "POOR" ENERGY RESOLUTION
g) e/h = 1.8

$0.7/\sqrt{E} \oplus 0.03$ - HN

JJ MASS RESOLUTION

- CALOR $\sigma/E \oplus 0.03$
- FRAG (SOFT)
- V



$\left(\frac{dM}{M}\right)_V \sim \frac{3}{\sqrt{2}}\left(\frac{\alpha_s}{\pi}\right)^2 \ln\left[\frac{2m_Q}{p}\right] 2.8$

D = 8.0

CALOR89 STUDY OF h RESOLUTION

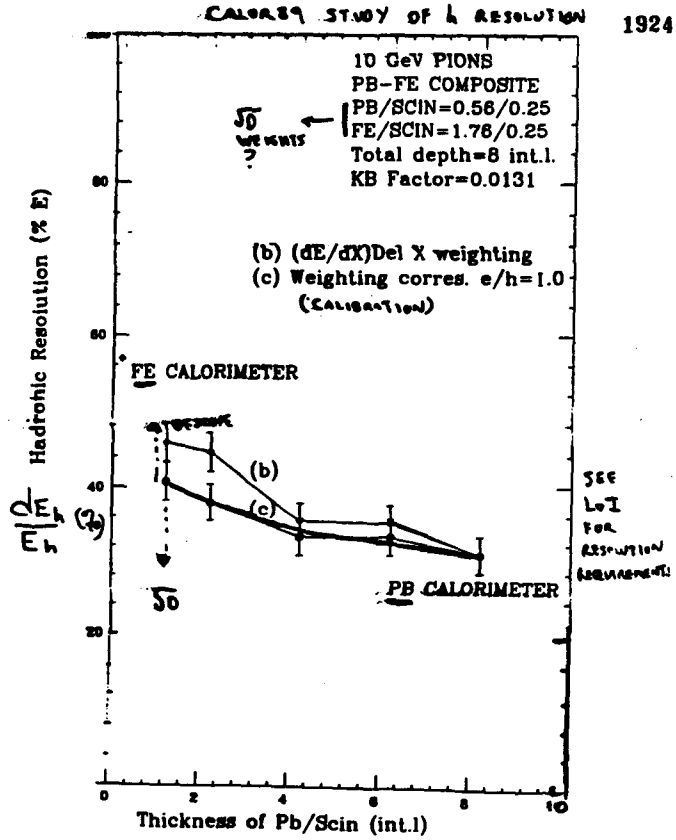


Figure.1

DESCOPE IS 1" IN HC 2 ⇒ STOCHASTIC HAS IS OK

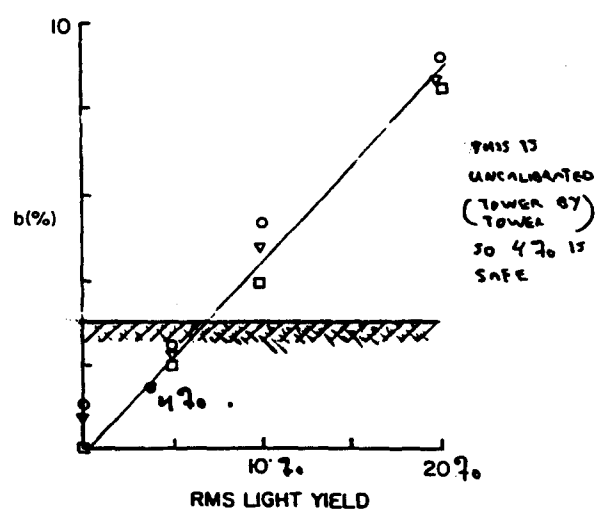
WORK ON ENGINEERING SPEC FOR SAMPLING CALORIMETER (GENERIC) THICKNESS VARIATIONS

h

LABE DATA, 100, 200, 450

AND INDUCED NON-LINEARITY

h DATA



[CALIBRATION ALLOWS YOU TO MEASURE THE PLATE THICKNESS @ 0<3 TOWER]

CALOR 89

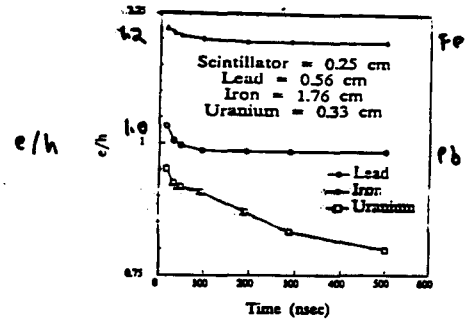


Figure 5. e/h for lead, iron and uranium calorimeters with nominal compensating geometries as a function of signal integration time.

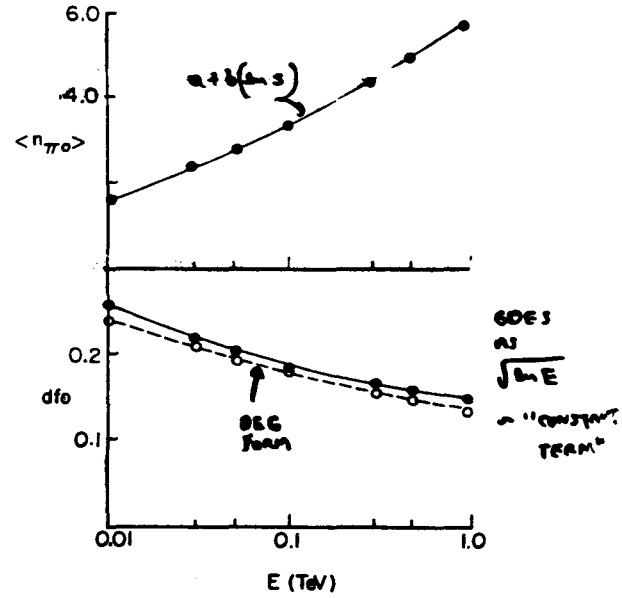
EXPECT $e/h \approx 1.2$ WITHOUT "INSERTS" FOR Fe ⇒ WITHIN SDC SPEC

CONSTANT TERM: SET BY PLATE, TILE TOLERANCES
- SET 2% SPEC

$b(e/h)$:

$E_e = E f_0$, $E_h = E(1-f_0)$ } SHOWER OF A SINGLE PARTICLE

$df_0 = f_0/\sqrt{\langle n_{\pi^0}\rangle}$

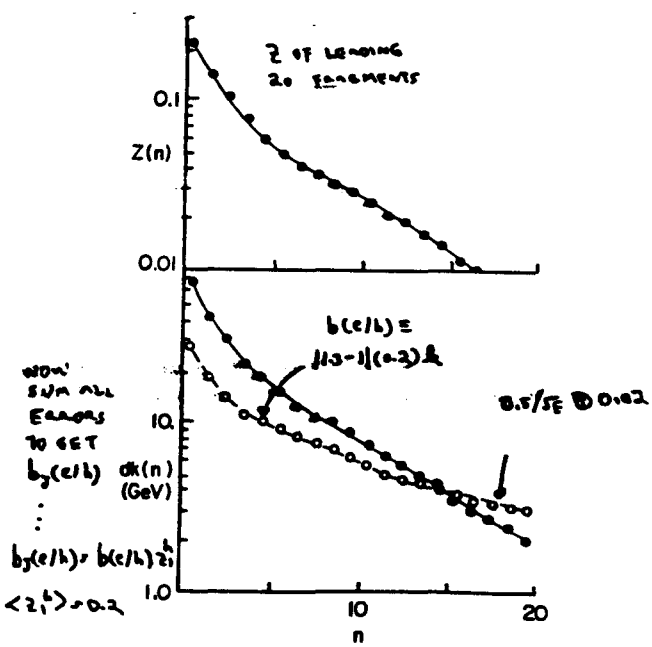


$dE/E = |e/h - 1|\, df_0$

WHAT ABOUT THE NON-COMPENSATION

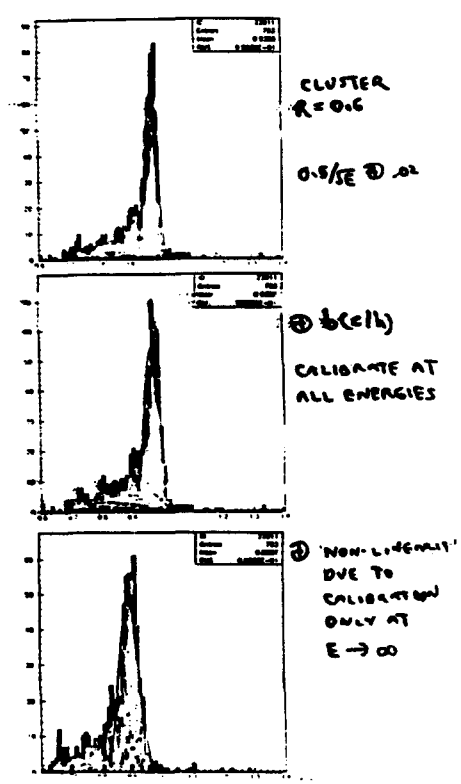
5 TeV JET – ROLE OF HAC IS TO MEASURE JETS

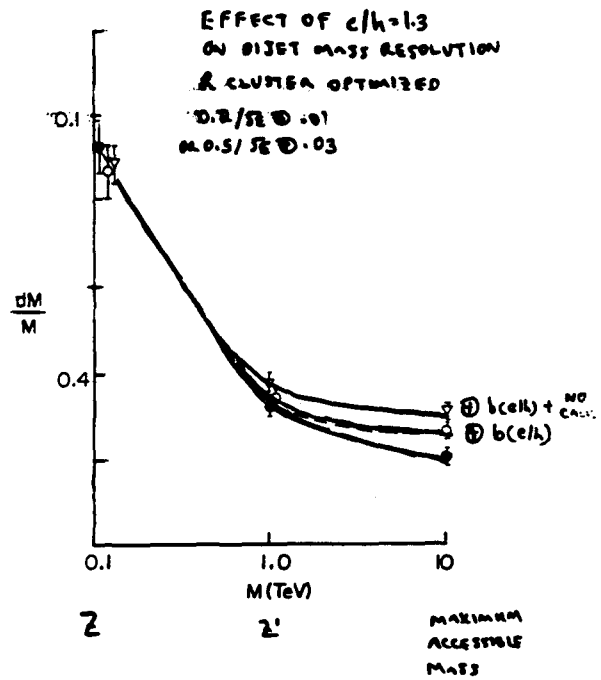
$O(z) \approx (1-z)^n/z$



EXTENSION OF 1D1 STUDIES

10 TeV DIJET





PHILOSOPHY FOR SDC CALORIMETRY

PUT ∅ IN CAL WHERE IT HELPS

e/h=1.2, 0.6/√E ⊕ 0.03 DOES NOT EFFECT ANY PHYSICS OF INTEREST (JETS) IN HAC ⇒ SAVE ON HAC WITH Fe

PUT YOUR ∅ IN EM WHERE PRECISION CALORIMETRY IS CRUCIAL:

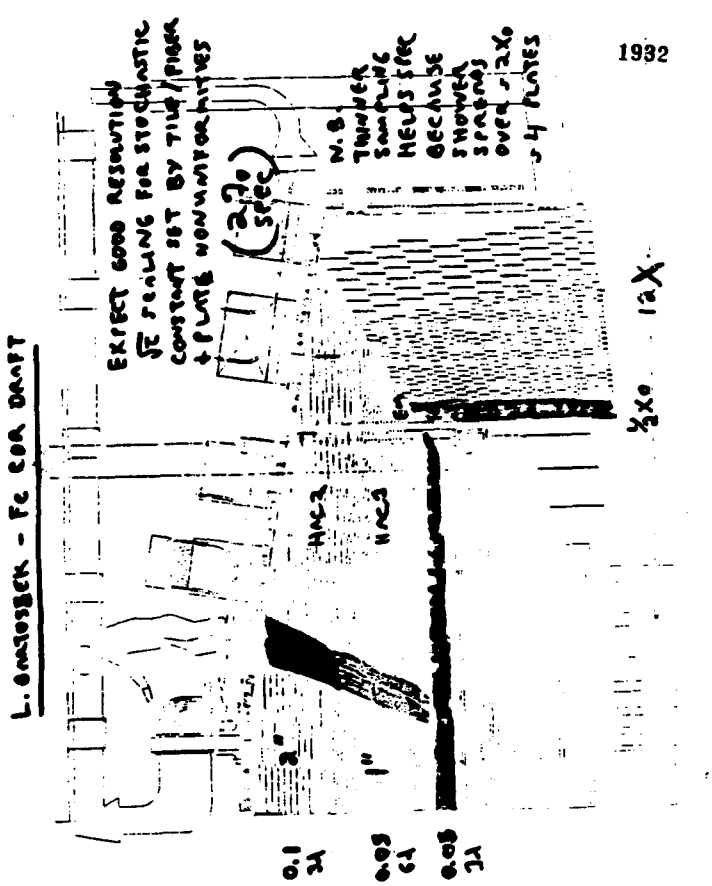
$\Gamma_Z/M_Z \sim \alpha_W \sim 0.03$

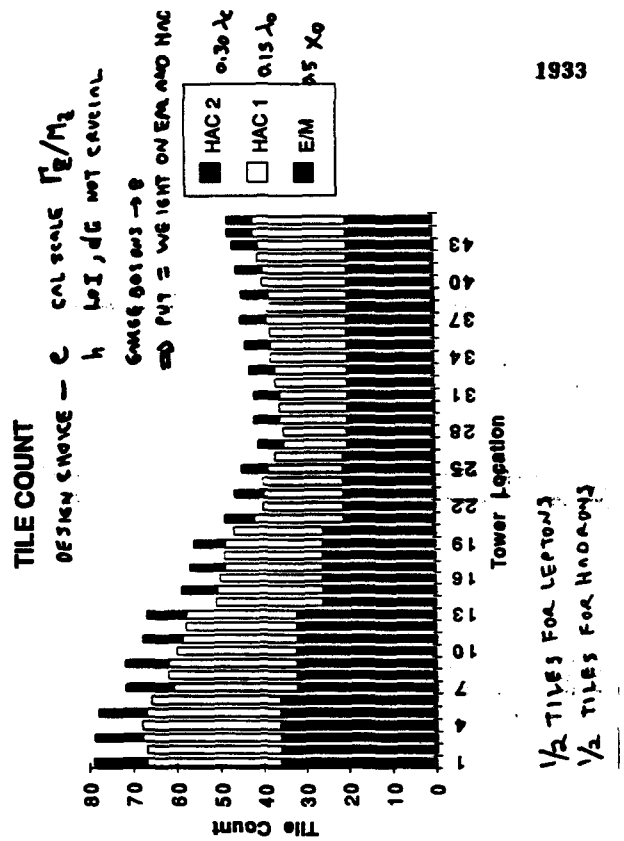
$\Gamma_H/M_H \sim \alpha_W \left(\frac{M_H}{M_W}\right)^2$ – CRUCIAL FOR LOW MASS HIGGS $H \to \gamma\gamma$

(L*, GEM, CRYSTALS..)

SUBSIDIARY CONDITIONS:

TRACKING SUPPORTS
SOLENOID SUPPORTS
MAGNETIC FIELD UNIFORMITY
REDUCED WEIGHT – SUPPORTS – CANTES





1934

KEVIN EMMERLER

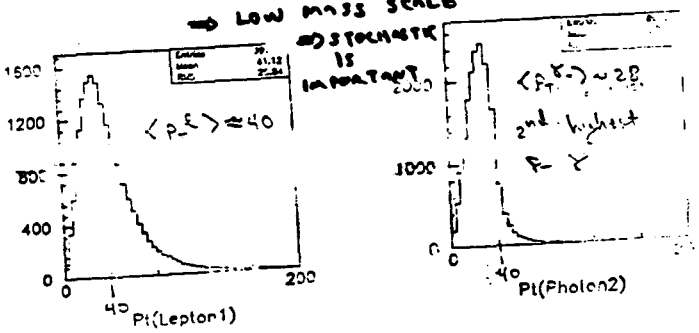
$H \to \gamma\gamma$

(MODE FOR $M_H \sim M_W$ TO $\sim 2M_W$)

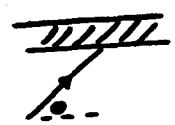
$E_T^\gamma \sim M_H/2$

⇒ LOW MASS SCALE

⇒ STOCHASTIC IS IMPORTANT



RESOLUTION SCALES W E_T



$\left(\frac{\delta E}{E}\right)_{RMS} = a/\sqrt{E} \oplus b$

$a = a_0 \sqrt{E}$

$= a_0 \sqrt{E_0/\sin\theta}$

∴ STOCHASTIC TERM $= \frac{a_0\sqrt{E_0}}{\sqrt{E_T}} \to \frac{b_0\sqrt{E_0}}{\sqrt{M_H}}$

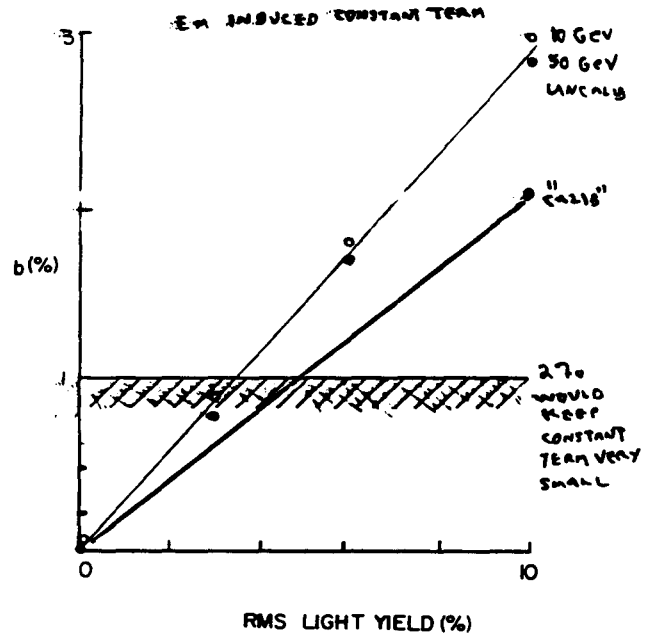
1935

e

(DEPENDS SOMEWHAT ON # OF SAMPLES ⇒ THIN PLATES)

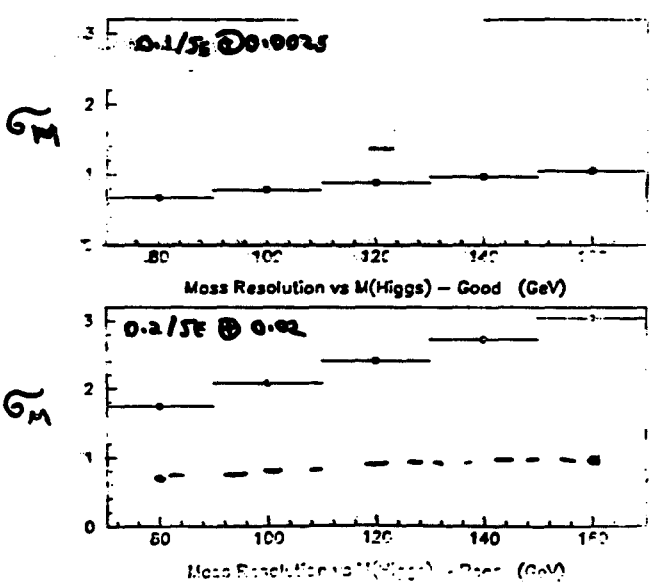
EGS WORK (J. MARAFINO)

EM INDUCED CONSTANT TERM



1936

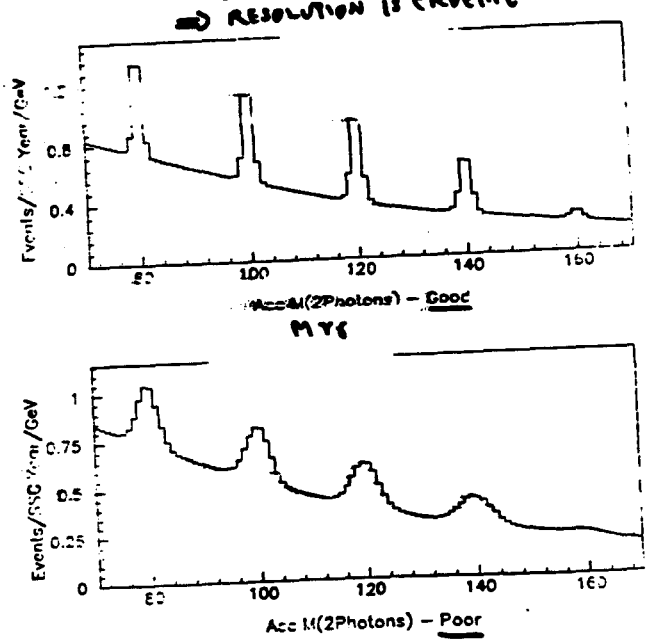
$H \to \gamma\gamma$



1937

$H \to \gamma\gamma$ RIDES ON SERIOUS BACKGROUNDS

⇒ RESOLUTION IS CRUCIAL



SUMMARY

DESIGN TO COST MEANS IMPROVING EM
MUST DEGRADE HAD

HAD MUST DO JETS WELL BUT FRAGMENTATION
FACTORS MEAN THAT POOR RESOLUTION
FOR SINGLE PARTICLES IS ACCEPTABLE

L* GOT A LOT OF MILAGE ATTACKING
THE PRECISION EM FRONT

→ WHY NOT IMPROVE SOL CALORIMETRY

$(dE/E)_{EM} \sim 0.12/\sqrt{E} \oplus 0.005$ IS ACHIEVABLE
WITH 1/2 X_0 SAMPLING, AND $\Delta \sim 1\%$
SPEC ON THICKNESSES

CHOICE IS TO MAXIMIZE PHYSICS
WITHIN A FIXED COST
IS IT A CORRECT CHOICE?

NEW APPROACHES IN CALORIMETRY

A. RONZHIN

Ronzhin A. IHEP, Protvino.

New approach in calorimetry.

Contemporary requirement to apparatus for collider experiments - to operate at counting rate $\geq 10^{8}$ p/cm² sec - are austere challenge to experimenters. We present several ways to solve the task. Some of this attempts are rather technological approaches - - improvment of scintillation calorimeters with fibers. But it is not looked possible to improve drastically the major limitation - its radiation hardness, wich is lower than 1 Mrad. The most radiatowally vulnerable part of sandwich calorimeters is scintillator, gas, liquid - medium which transforms shower particle energy into detectable signal - - light, ionization electrons and so on.

So we propose to do without the intermediate medium and directly detect low energy shower particles by secondary electron multipliers in vacuum for sandwich type calorimeter. This approach may be useful for forward calorimetry.

1. Calorimeters with fibers.

So far the scintillation calorimeters of sandwich type remain the fastest ones. Such calorimeters with wavelength shifters found a wide use. Nevertheless, several limitations of this type of detectors - such as hot zones, difficulties to make longitudinal segmentation, stability in magnetique field, etc. - forced to continue the search for ideal calorimeter.
A way to avoid these difficulties was proposed in Protvino and CERN.

In our work (Kryshkin and Ronzhin, NIM, 1986, A247, p. 583) was described a method for collecting light from calorimeters by means of an optical fiber connected to a fiber with WLS, covering an edge of a scintillator plate. The optical fiber passes between the continuous metallic plates (absorbers) and guides the light from scint. to a photodetector. For EM part of CAL. we used plate of scint. with dimensions 5 × 5 × 4 mm³. 9 plates of scint. were tightly packed in plate structure with full dimensions 15 × 15 × 4 mm³.

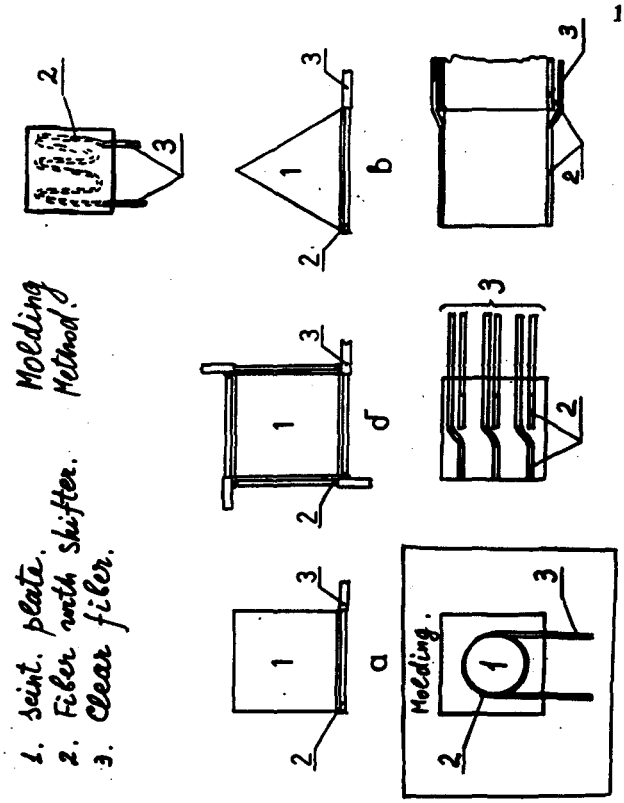
These plates were layered by plates of lead with sizes 15×15×3 mm³ (40 layers, 20 X₀). 1942 3.

The light from all scint. plates was connected by fibers to one ph.mult. The calorimeter was exposed to 26 GeV electron beam. The parameters of calorim. were the same ones that for calorimeter in modular structure but with plates of wavelength shifter. Nonuniformity of energy resolution and amplitude of signal along surface of calorimeter with fiber was only ≃±5% (lower by factor of 3 by comparing with CAL with WLS-plate), but curiously very big enough.

Later we have studied other type of light connection between scint. plate and fiber to understand this phenomenum. The reason of nonuniformity was mainly related with the mentioned condition. It is possible to improve situation by several ways, but preferable ones must be the simplest.

One of these is preparing of scint. plates with grooves of required shape by MOLDING

1943



4.

Some advantages of molding preparation.

1. Best uniformity (≤ 1%.) 1944
2. Fast production.
3. Low cost.
4. Radiative resistance. (Factor 3÷7 by comparing with used technology.) (*).

Fibers.

Requirements:

1. (2, 3, 4).
2. Number of ph.el. must be ≥3. (mip).
3. Good optical and mechanical properties.

We produce now the fiber with required parameters. Diameter of fiber can be vary from 2 mm to 0,3 mm. Transperancy ≃ 10 meter (1mm Ø). Material of fiber is plex (preferable to polyster.). We use coumarin and pirazoline as WLS in fiber.

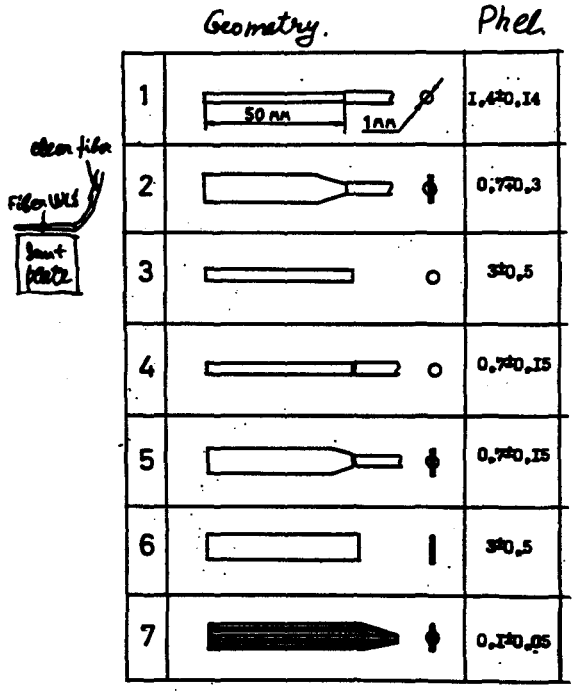
Scintillation plates.

We can produce scint. plate (made of polyst.) by molding with the size from 200×200×(2÷5) to 50×50×(2÷5) mm³.

In the end of 1991 we must finish CAL (2×2m²) with cells (0,2×0,2m²) and test it at beam.

6.

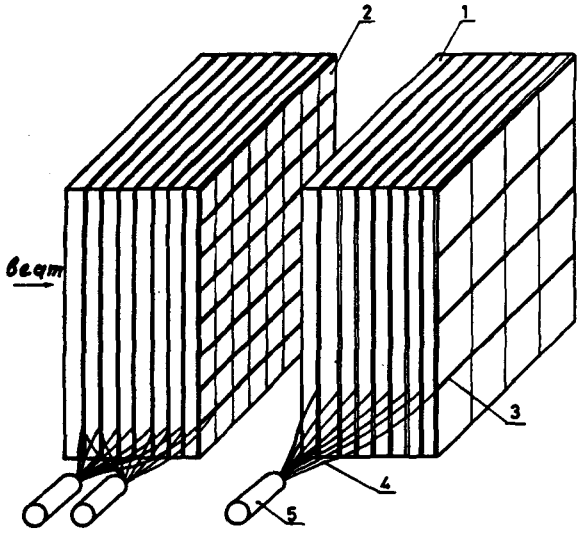
1945



Now number of photoelectrons is enough for EM and HAD. calorimeters.

Calorimeters with fibers.

1946



1. Absorber. 2. scint. plate. 3. fiber with shift.
4. Clear fiber. 5. Photomult.

Advantages of the approach are:

1. Absense of "hot zones", cracks, etc.
2. High uniformity.
3. Fast production.
4. Low cost.
5. Magn. field nonsenciti
6. Simple trigger.
7. Simple colliders conf

Calorimeter, Electronics and Physics and Detector Performance Joint Meeting

1947

August 8 - Thursday

Shower Max Status

PS/SM Status	R. Hubbard(CEN Saclay)
PS/SM Test beam Status and Front Ends	P. Melese(Rockefeller)
SM Electronics and Trigger	P. Le Du(CEN Saclay)

Trigger and Electronics

Trigger - Physics Discussion	H. Frisch(Chicago)
Trigger Issues	K. Einsweiler(LBL)
Liquid Argon Trigger Issues	M. Levi(LBL)

LPBautz:8/26/91

PS/SM STATUS

R. HUBBARD

(C1)

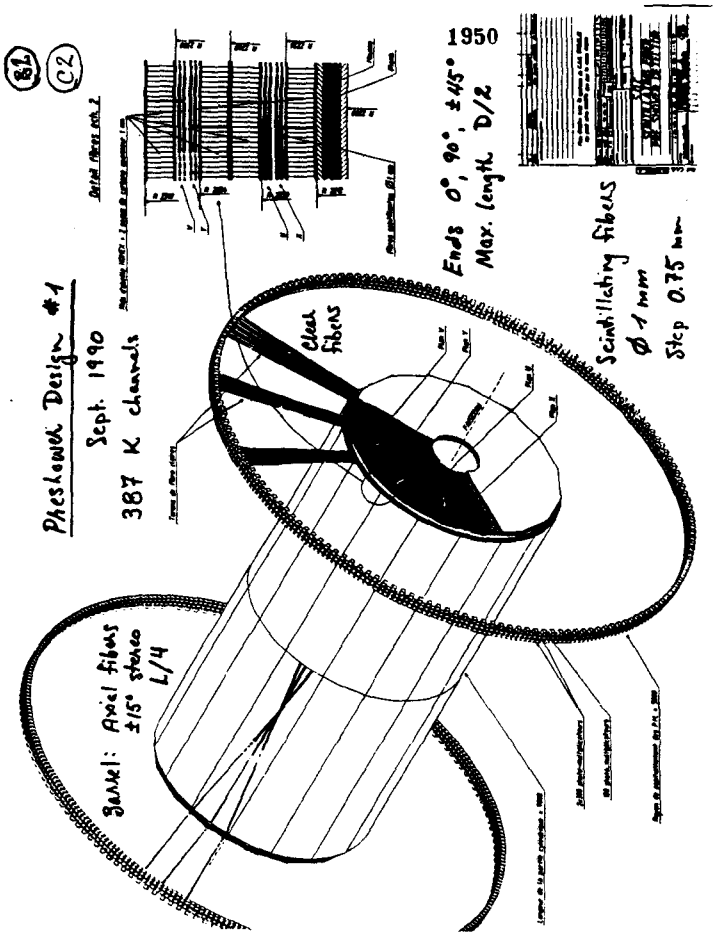
1949

PS/SM Design Report

Design & construction	Saclay	Rondeaux
Photodetectors & preamps & beam test	US groups	Rusack
APD's	Northeastern	Leadom/Reva
VLPC's	SSCL &	Bihel
MCPMT's	Rockefeller	Rusack
	UCLA	Amisaka
	Yale	Cushman
Pipeline and DAQ	Saclay	Beuville
Level 2 trigger	Saclay	Le Dû
Radiation damage	Saclay	Einwein

This talk: Mechanical design PS/SM
Descope Scenario
Cost

(S1) (C2)



Shower-Max Baseline

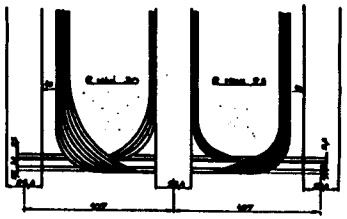
(58) (C5)

12 strips/tower ⇒ 120 K channels

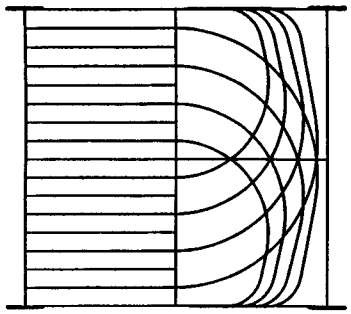
$R\varphi$ $\Delta\eta\Delta\varphi$ $.05 \times \frac{.05}{4}$

η $\Delta\eta\Delta\varphi$ $\frac{.05}{8} \times .05$

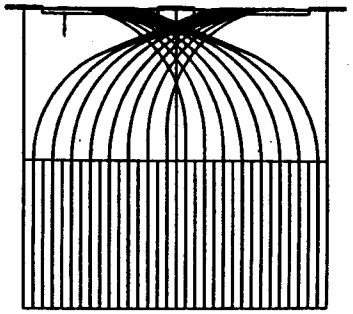
Single SM slot ⇒ min 2×5.5 mm + tolerances ≈ 13 mm



Top view



$R\varphi$ strips



η strips

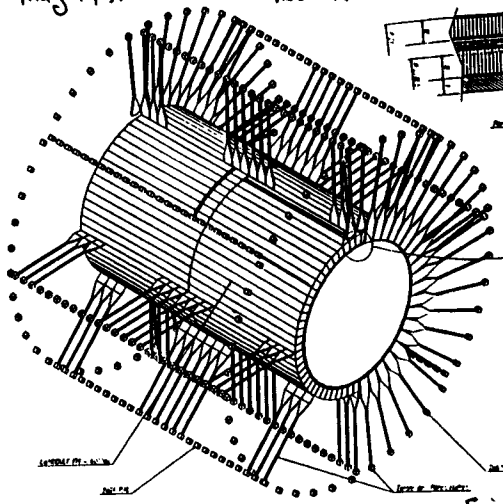
Front view

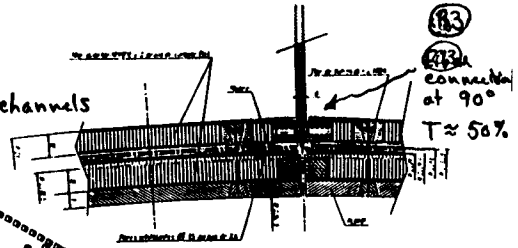
1953

Preshower Design #2

(R3) (R3)

May 1991 126 K channels





connection at 90°
T ≈ 50%

Axial fibers L/2
measure $R\varphi$

Azimuthal fibers: C/8
measure η

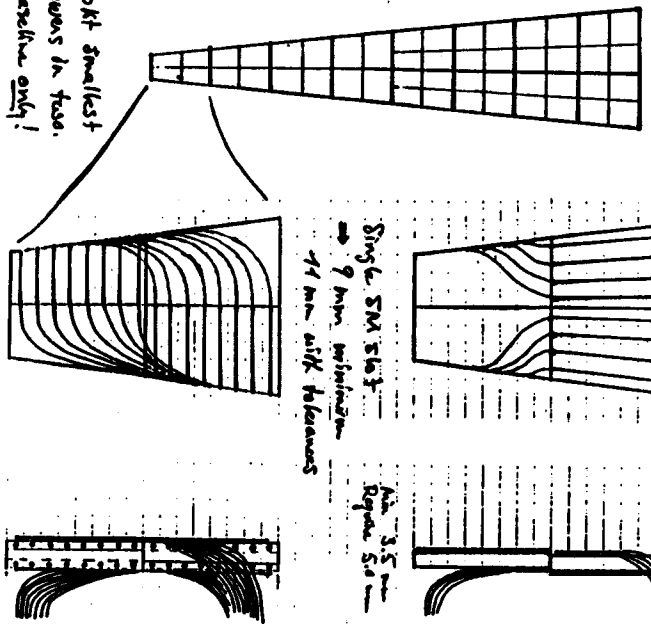
Scintillating fibers
ϕ 1.5 mm
Step 1.2 mm

1951

SM Baseline : Ends

(59) (C6)

Split smallest towers in base. Baseline only!



Single SM slot ⇒ 9 mm minimum 11 mm with tolerances

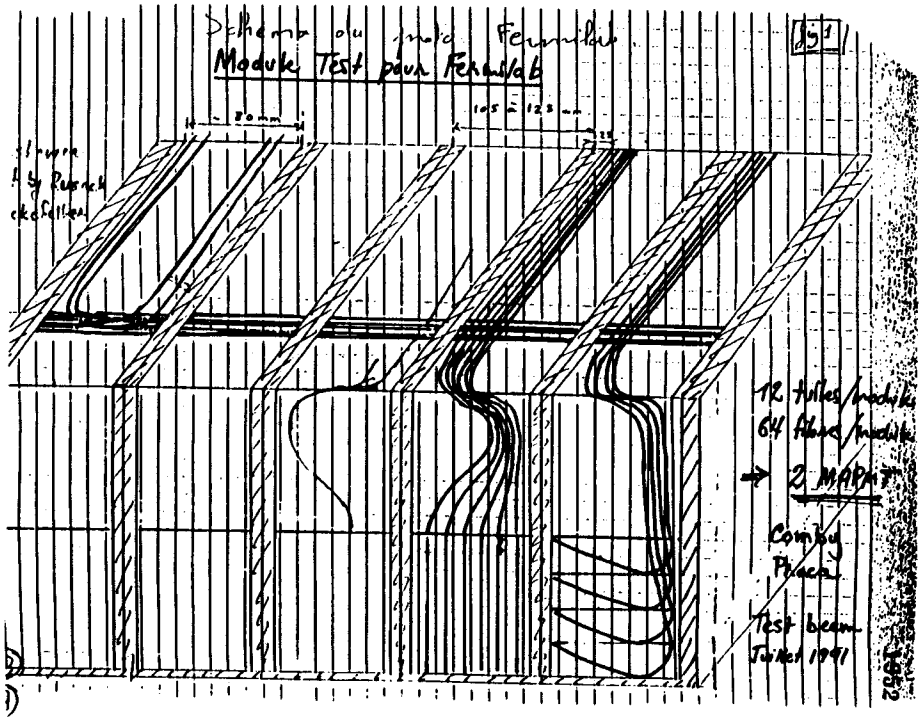
Min 5.5 mm Region 7.0 mm

Min 3.5 mm Region 5.0 mm

1954

Schema du module Fermilab
Module Test pour Fermilab

(J1)



12 tuiles/module
64 fibres/module
⇒ 2 MAPMT
Combu Placen
Test beam Juillet 1991

1952

SM Descope

8 $R\varphi$ strips / 2 towers } 80 K
8 η strips / 2 towers } physical channels

Gang fibers 2-by-2 → 40 K electronic channels

$R\varphi$ strips	$\Delta\eta\,\Delta\varphi$	$.20 \times \frac{.05}{8}$
η strips	$\Delta\eta\,\Delta\varphi$	$\frac{.05}{8} \times .20$

Stage electronics ⇒ 80 K channels

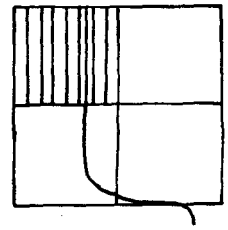
Features of descope strategy

$R_M \approx \Delta < 2 R_M$ — $R_M = 1.1$ cm
Electronics packaging — 8 strips / tower
"Recommended" descope — 40 K channels
Crossed channels ⇒ { Occupation × 2, Pixels × 1/16

Descope good match to Saclay funds
Staged version matches trigger towers

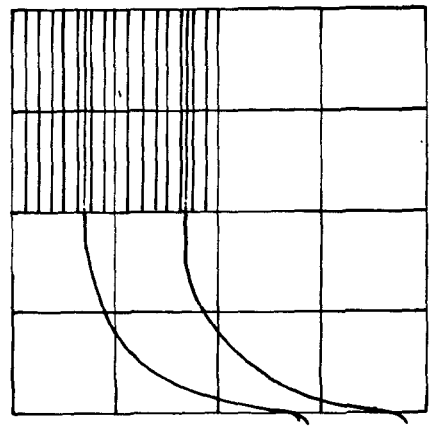
Mechanical Problems with Descope

Baseline



Fiber routing
2×2 towers
Single wedge

Descope



Fiber routing
4×4 towers
Double wedge

Too heavy?
Special transport

PS/SM Costing	PS #1	PS #2	SM base	SM descope
Physical channels	387 K	126 K	(160 K)	80 K
Electronic channels	387 K	126 K	120 K	40 K
Mechanics F — material	16500 kF	9950 kF	4205 kF	2575 kF
tools	2000 kF	2750 kF	4095 kF	3400 kF
R&D	2000 kF	2000 kF	2000 kF	1000 kF
man-power	65 MY	65 MY	80 MY	65 MY
Photodetectors U.S. — material	$20124 k	$6552 k	$6240 k	$2070 k
$52/ch. R&D	$2000 k	$1000 k	$1000 k	$600 k
man-power	-	-	-	-
Electronics F — material	35000 kF	16000 kF	15000 kF	6000 kF
R&D	3000 kF	2000 kF	2000 kF	1000 kF
man-power	35 MY	25 MY	25 MY	20 MY
Total — material	$28707 k	$11335 k	$10123 k	$4076 k
R&D	$2833 k	$1666 k	$1666 k	$833 k
man-power	100 MY	90 MY	105 MY	85 MY

Descope mainly photodetectors

$\Delta = \$6.88M + 20MY$

PS Vs. SM

Isolated $e^\pm$ Vs. $\pi^\pm$

PS	η	e/π	≈ 20	$\epsilon_e = 90\%$, $\eta = 0$, $E = 40$ GeV
SM	η	e/π	$\gtrsim 20$	

SM signals bigger and cleaner

Isolated γ Vs. π^0

PS $E_{max} \approx 90$ GeV in barrel
SM $E_{max} \approx 20$ GeV " "

PS $\gamma/\pi^0 \approx 2/1$ at $\epsilon_\gamma = 75\%$

Partially-isolated $e^\pm$ Vs. $\pi^\pm\pi^0$ $(b \to ce\nu)$

PS	η, φ	$e/\pi^\pm\pi^0 \approx 70$	$\epsilon_e \approx 70\%$
SM	η, φ	$e/\pi^\pm\pi^0 \approx 60$	$\epsilon_e \approx 92\%$
PS	η	$e/\pi^\pm\pi^0 \approx 25$	$\epsilon_e \approx 84\%$
SM	η	$e/\pi^\pm\pi^0 \approx 9$	$\epsilon_e \approx 92\%$

$\eta = 0$, $E = 40$ GeV

Integration

PS requires 5-10 cm behind coil

DESCOPE BASELINE SM with crossed strips
80 K physical strips $\frac{.05}{8} \times .10$

(C11)

1959

Read-out Tile #1 !

Extra rejection isolated $e^{\pm}$ vs. $\pi^{\pm}$
Extra factor 3 for late $\pi^{\pm}$ interactions

Statistical separation γ/π^{0} at high E_{γ}
Combine with SM count of multi-π^{0}'s

Measure energy from coil
⇒ recover energy resolution.

Shower-max type electronics
⇒ 25% increase in SM channel count

Packaging ⇒ some added cost

ADD TO BASELINE NOW ?

1960

~~PRESHOWER~~ SHOWERMAX TEST BEAM STATUS and FRONT ENDS

Phil Melese (RU)
8-8-91

Northeastern
Rockefeller
Saclay
SSC
UCLA
Yale

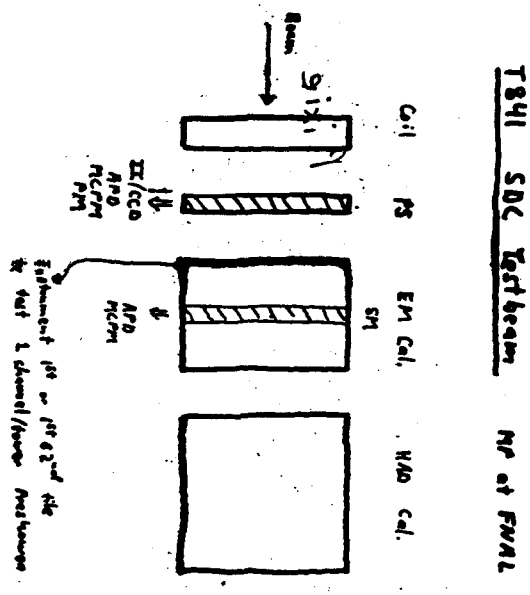
+ South Carolina

Optical readouts:

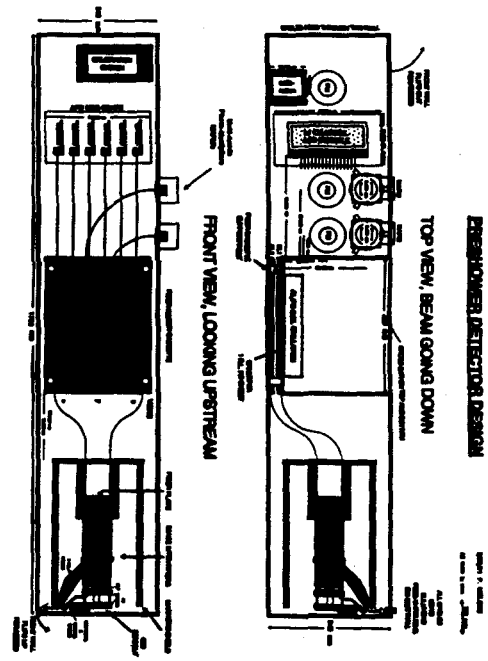
1) APD.
2) MCPMT.
3) SIT Pixel Tubes.
4) VLPCS.

Front End Readout Architecture

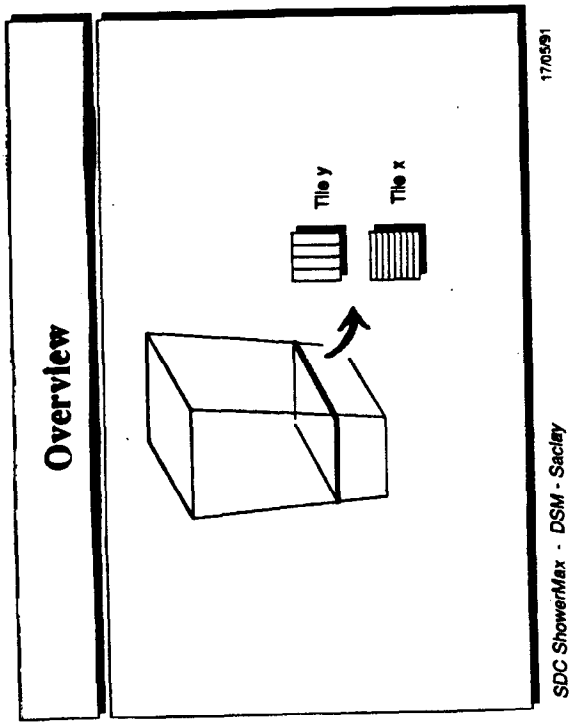
1961



1962

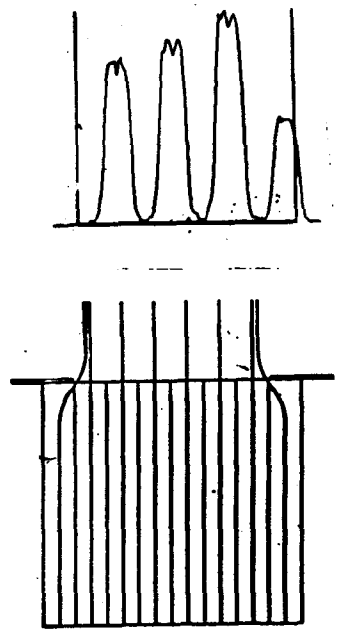


1963



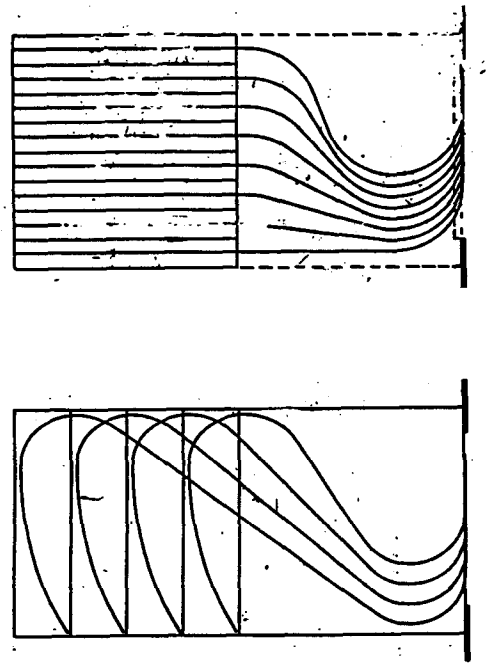
1964

SM Prototype tiles



1965

SM Prototype tiles



1966

PS/SM Test beam Status

PS Prototype Installed

- II/CCD Readout working
- 49 APD channels ready (96 in 2 weeks)
- MCPM in progress

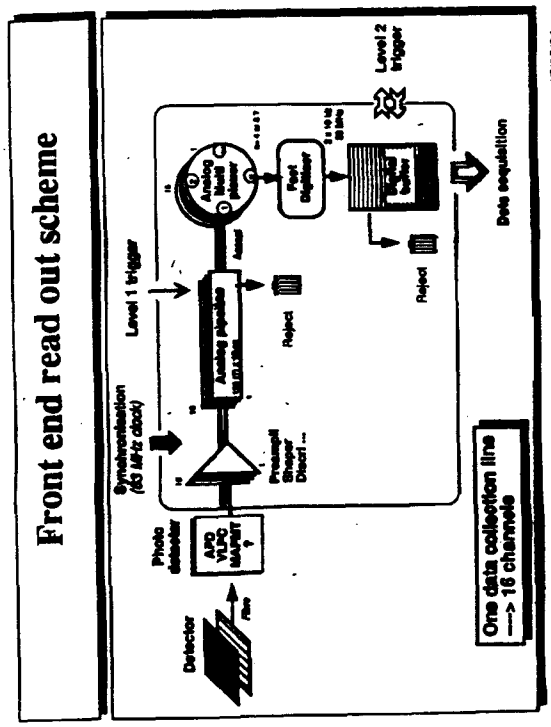
SM Tiles ready to install in EM

- MCPM's tested and ready
- (will use same APD's as PS)

Beam being tuned

- 1st beam Aug 5

EM Calorimeter is coming...



OPTICAL READOUT FOR THE SHOWER MAXIMUM DETECTOR

REQUIREMENTS:

The fundamental problem is one of cost. The requirements of the device are fairly clear at this stage. The system has 120K channels and we don't have $40M to readout the detector. Our goal is to design a system at $20/channel for the optical detector and $20/channel for the electronics. This requires the use of integration techniques (parallel channels, minimize interconnects etc.).

ok? and falling

Our test-beam measurement will tell us much about the readout requirements. The following readout requirements are assumed in our current designs:

1) Dynamic range $1:2^{12}$ due to 10-400 GeV range, shower fluctuations, and centroid finding
2) Resolution 8 bits.
3) Summed outputs for trigger level 1 and full signal at level 2.
4) Minimum signal corresponds to 350 photons from a tile.

Dynamic Range

This is given by the following argument. We want to optimise for 10 Gev to 400 GeV showers. In a shower 2 sigma fluctuations are a factor of 10 and we want to find the centroid requiring that we measure the neighbouring signals to 10% of that shower. This gives a maximum required dynamic range of 4,000.

CURRENT WORK 1991

We are testing different readout options in our forthcoming test beam run at Fermilab this summer. In that test beam we will test APD's and MCPMT's. These will be compared against a known image-intensifier CCD system which will be used as a reference.

APD's

The APD's are conventional 500 μ devices from EG&G. We will have 96 which will be used to readout both the preshower and the shower maximum detector.

1) Ball lens to match the light collection to the APD.
2) Temperature stabilised.
3) Gain order 100.
4) Quantum efficiency about 60%, better in the green than in the blue.

Work being done by SSC lab and Northeastern.

MCPMT'S

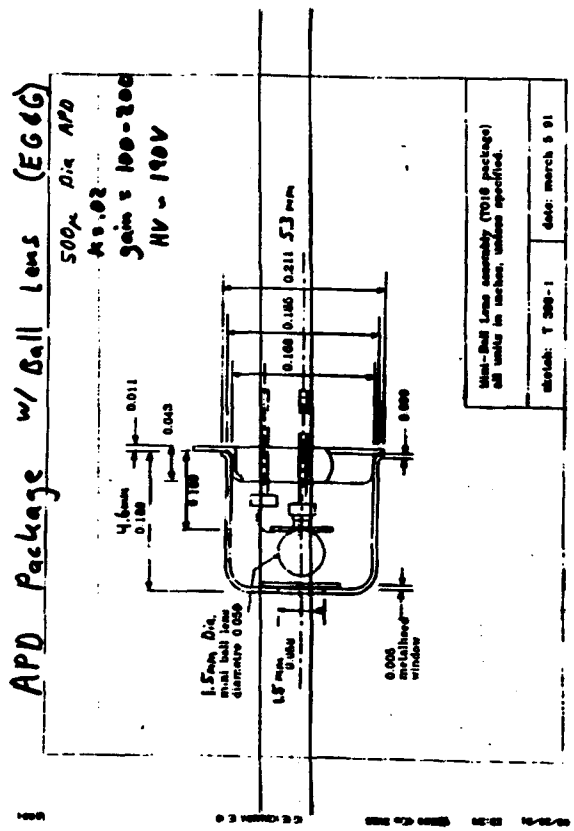
Phillips 64 channel photomultiplier tubes will be tested for both the Preshower and the shower maximum. Conventional photocathode, fiber optic window and maximum gain is 10^6.

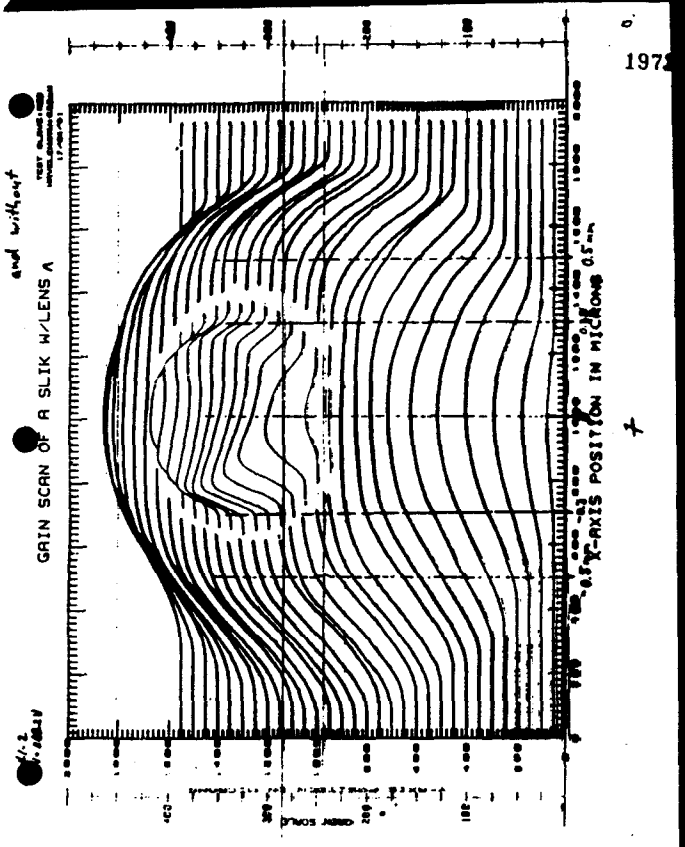
Yale - Preshower.
Saclay - Shower Maximum.

PIXEL TUBES:

This will not be in preshower/shower maximum test. Purchasing from Hughes Aircraft bump bonded pixel arrays devices to test inside an image tube. Expect first results from these tests November.

Rockefeller, Yale and South Carolina.

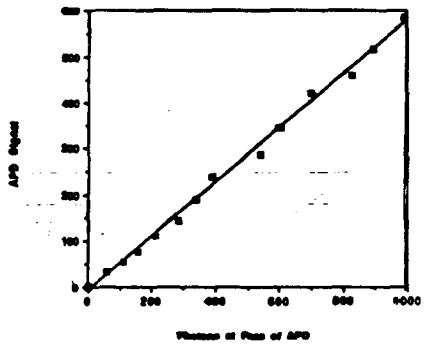




Xerox Telecopier 7021 : 9- 2-91 : 14:58 :

Linearity

SSC LABORATORY



APD in proportional mode
~5V below breakdown (150-200V)
Gain ~ 100
QE_{green} ~ 60%

FUTURE R&D WORK

APDS:

Overlapping interest with the tracking group, but tracker is a digital device and operates in Geiger mode, while we need a linear device.

R&D issues.

1) Gain is around 100. There is the expectation that stable gain around 200 or more can be achieved in linear mode with SLIK (super low k) devices.

2) Need to design package with an APD array and fast low-noise preamplifier on the same chip or hybrid.. Expect 16 - 24 APD's per package.

3) Temperature Stability.

[illegible]:

Sometimes known as 'Hybrid' tubes or Silicon Intensified Target (SIT) tube This is a version of a multi-anode PM tube where the anode of the tube is a silicon target. Amplification is provided by stepping the accelerated photo-electron in the silicon, expect gains of order 2000. FY91 we are exploring with Hughes Aircraft the possibility of making a tube with a hybrid target. Where a pixel array is bump-bonded to the readout device and placed inside the image tube, this is the same technology that is being used for the pixel detector in the tracker.

In FY91 test operation of bump-bonded device inside vacuum. FY91 design preamplifier and readout chip for SDC application.

MAPMT

Commercial devices exist from several companies. Need to investigate ways of reducing the cost per channel of these devices. Hamamatsu has 256 anode tube with <1% X talk for ~ $40/channel

VLPCS

Visible light photon counters. Operate at 6.6 K. They are a manufactured by Rockwell. Trackers say that they will cost $20 per channel with a digital readout. We will investigate these devices for our choice of readout.

Problems are:

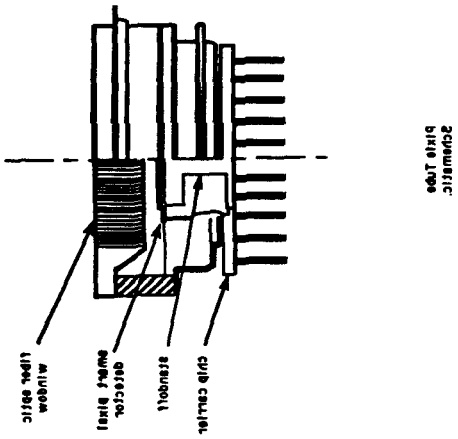
1) Low temperature operation of a fast preamplifier, difficult enough in digital mode, more so in analog mode.

2) Dynamic range.

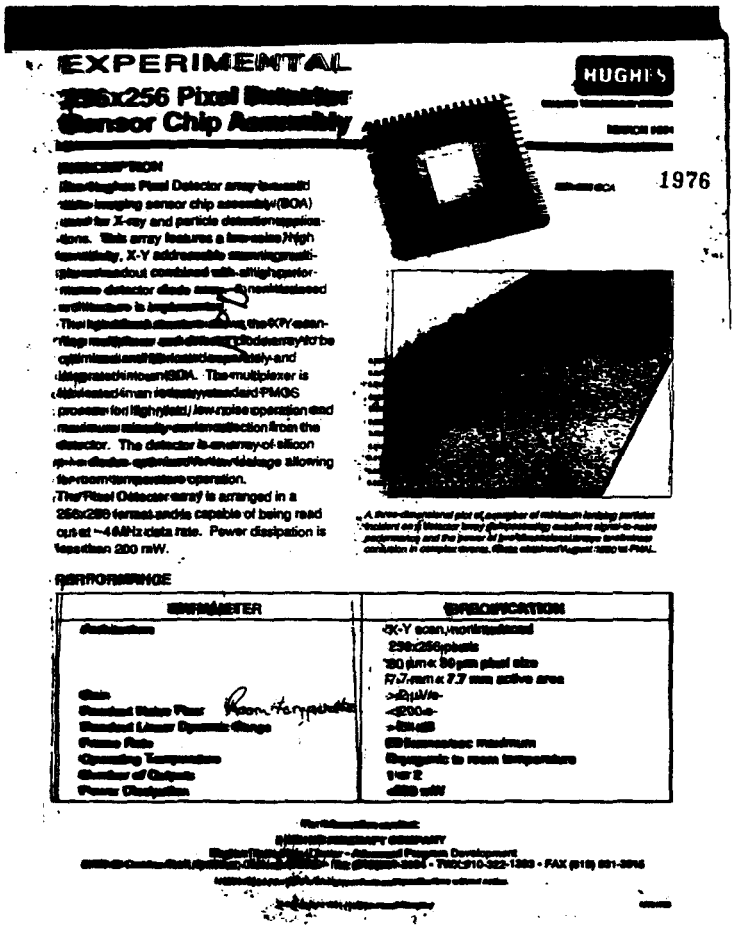
3) Cost per channel.

Northeastern & SSCL will investigate

1975



1976



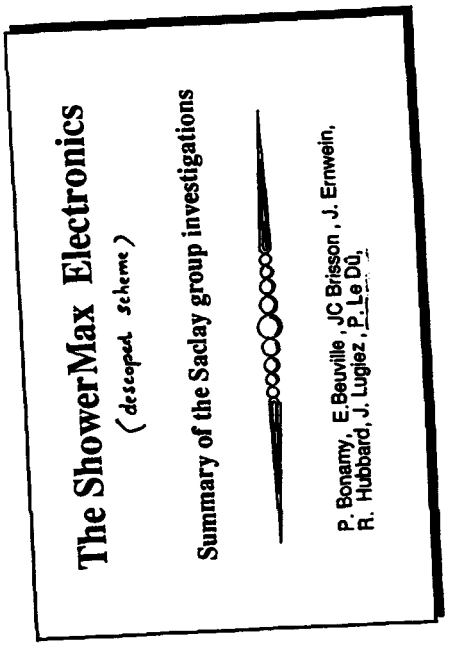
1977

Conclusion

"Realistic" SDC Prototypes of PS and SM will be tested with EM & HAD Calorimeters.

Optical Readout Tests of APD's and MCPM's.

1978



The ShowerMax ... an overview

Multipurpose device ---->

- electron trigger (L1 ? & L2)

--> increase the calorimeter granularity (isolation criteria ..)

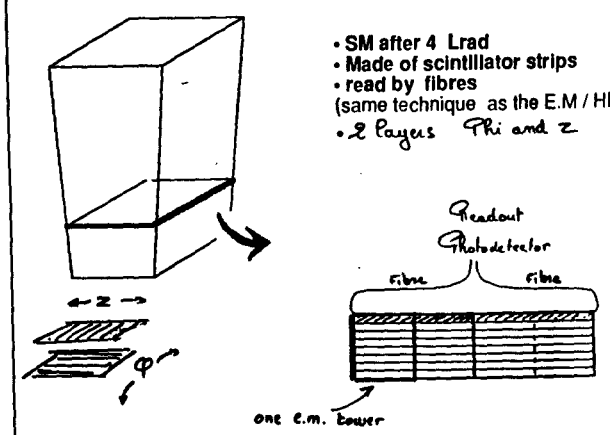
---> track match

Mechanical Design

- SM after 4 Lrad
- Made of scintillator strips
- read by fibres

(same technique as the E.M / HD calorimeter)

- 2 Layers Phi and z



Physical segmentation & channel count

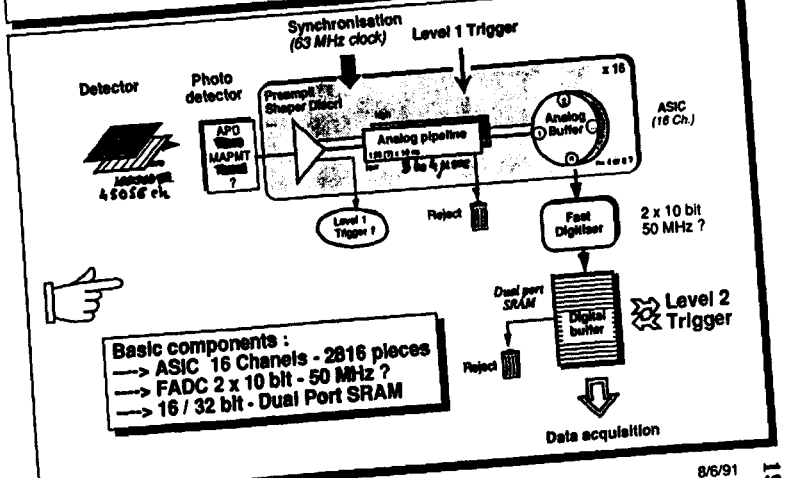
Compatibility with EM/hadron scintillating tile calorimeter

Barrel	End cap
• 8 wedges	• 32 sectors x 2 end caps
• 128 phi x 64 eta	• 48 pads / sector
• 8192 "towers"	• 1536"pads" x 2
---> 8 ch / 4 towers "Phi"	---> 16 ch. / 4 pads
---> 8 ch / 4 towers "z"	= 12288 channels
= 32768 channels	

1024 "phi" segmentation

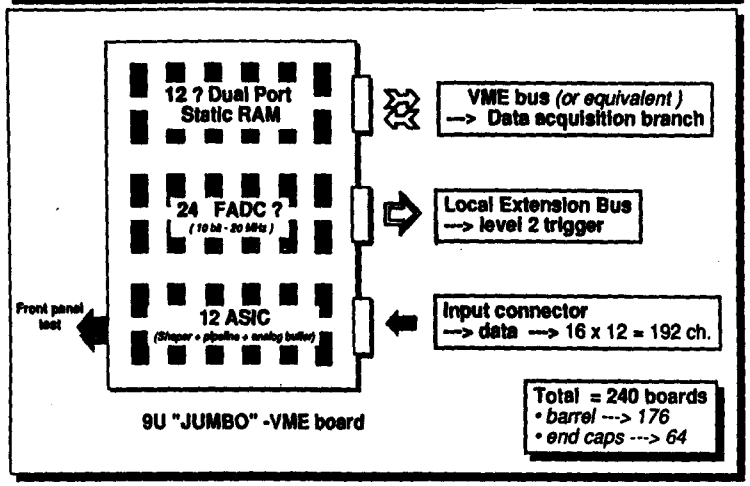
• Total = 45056 Channels

Front end read out scheme



Basic components :
---> ASIC 16 Chanels - 2816 pieces
---> FADC 2 x 10 bit - 50 MHz ?
---> 16 / 32 bit - Dual Port SRAM

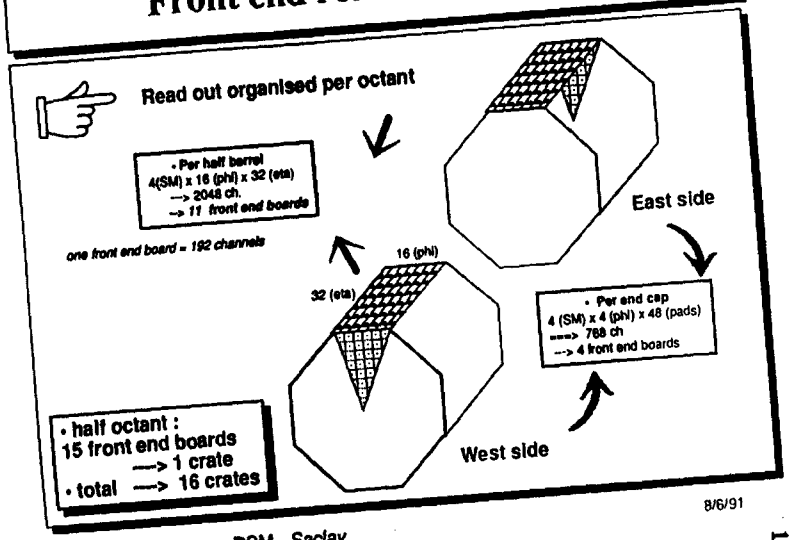
Front end board layout (A)



SDC ShowerMax - DSM - Saclay 8/6/91 8

1985

Front end read out partition

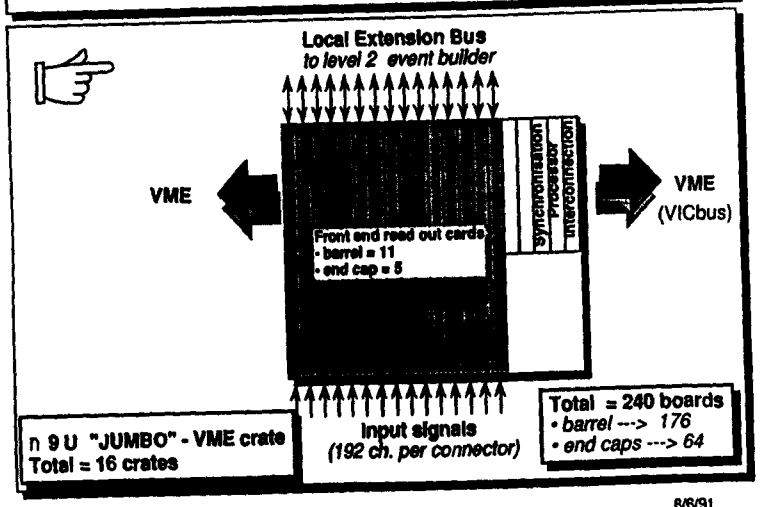


8/6/91

SDC ShowerMax - DSM - Saclay

1983

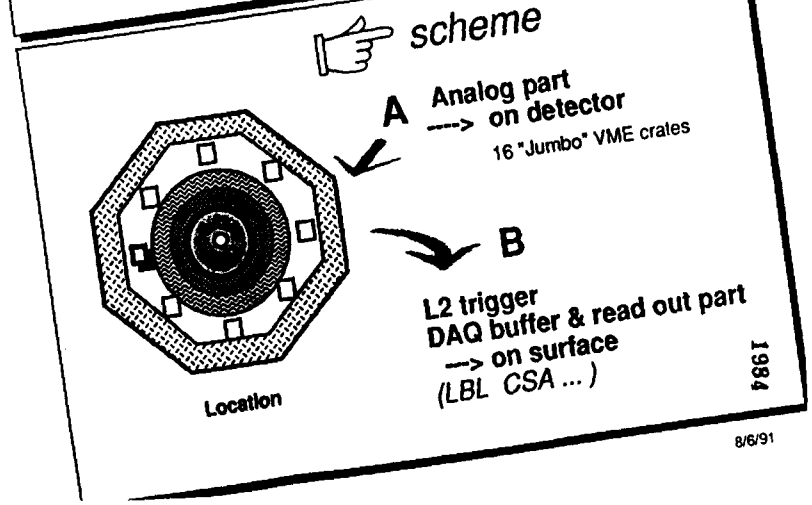
Front end Crate (A)



SDC ShowerMax - DSM - Saclay 8/6/91 9

1986

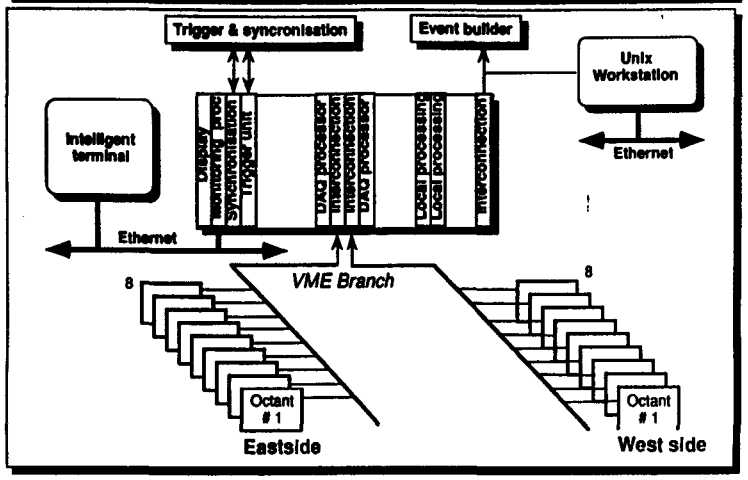
Electronics : topological layout



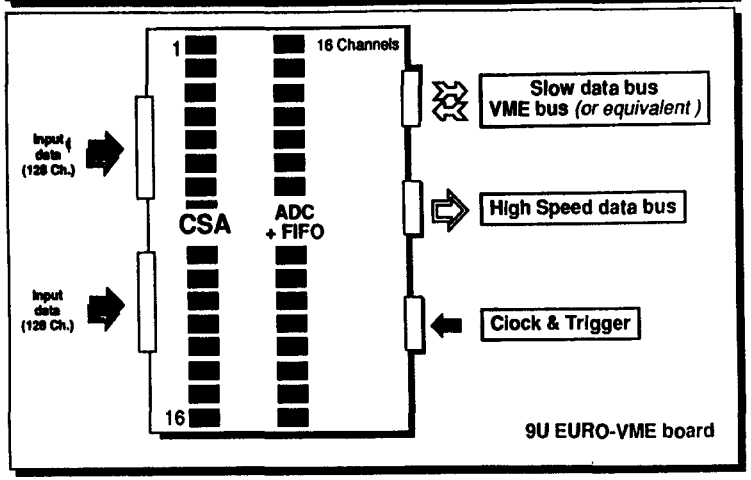
8/6/91

1984

Data acquisition



Front end board layout (B)



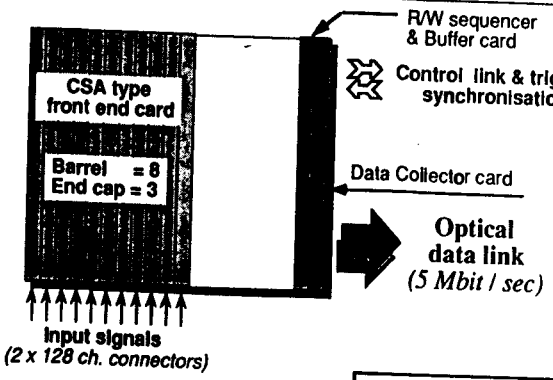
Front end board cost

➢ **The principal ingredient is the front end board**

	Component		Nb	FF	$	Total (FF)	Total ($)
	PC board	6 layers type (classe 4)	1	1500	250	1500	250
	Connectors	VME type	2	60	10	120	20
	Connector	data 196 pins	1	500	83.3	500	
?	ASIC	shaper +pipeline+analog buffer	12	300	50	3600	600
??	FADC	10 bit - 20 MHz	24	300	50	7200	1200
?	Static RAM	50 ns - 16 bit x 1024	12	100	16.7	1200	200
	Control logic	VME + clock ...	1	1000	167	1000	167
	Cabling & test		1	2000	333	2000	333
	Cost per board					17120	2770
	Cost per channel					89	14
	EM cost /ch	(Fermilab Flash encoder)					155

? = Upper limit

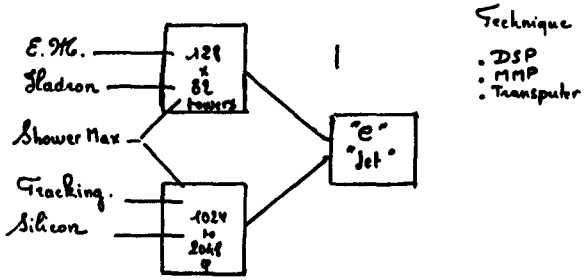
Front end Crate (B)



- 9 U EURO - VME crate
Total = 16 crates

The Showermax at the level 2 trigger

use the 2 layers (phi & Z) digitized data to refine the level 1 calorimeter trigger
---> isolated electron
---> electron cluster
---> topological cut
---> fine tracking merge



Technique
. DSP
. MMP
. Transputer

Summary & Cost

Compenents	Description or type	Number	cost/ unit KFF	cost/ unit K$	Total MFF	Total M$
Photodetector & Cables	APD, VLPC	45056	0.12	0.02	5.407	0.901
Front end						
Front end card	192 ch. digitiser	240	17	2.833	4.080	0.680
Crate	9U Euro-VME	16	18	3	0.288	0.048
Processor (Acquisition)	FIC	16	18	3	0.288	0.048
Synchro & trigger	LTU	16	9	1.5	0.144	0.024
Processor (Monitoring)	FIC	2	18	3	0.036	0.006
Crate Interconnection	VIC	16	15	2.5	0.240	0.040
DAQ						
Crate	VME	1	18	3	0.018	0.003
Processors	FIC & RAID	5	30	5	0.150	0.025
Crate Interconnection	VIC	3	15	2.5	0.045	0.008
Cables	optical fibres...				0.300	0.050
Workstation & Periph.	SUN4...				0.500	0.083
TOTAL					11.496	1.916
add 10% (protos,spares)					12.645	2.107

240 FF or 40 $ per channel
(Photodetector + Front end + DAQ)

The Showermax at the Level 1 trigger

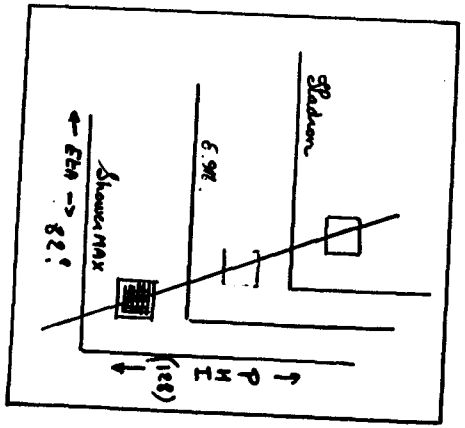
Efficient & cost effective solution to increase the selectivity of "isolated" electrons and reduce the background rate as soon as possible

- Extract one bit per "phi" bin at the front end ASIC level
---> 1024 x 4 = 4096 bit (2 barrel + 2 end cap)
---> merge with EM local or global
---> merge with "tracking" ???

The calorimetric L2 trigger

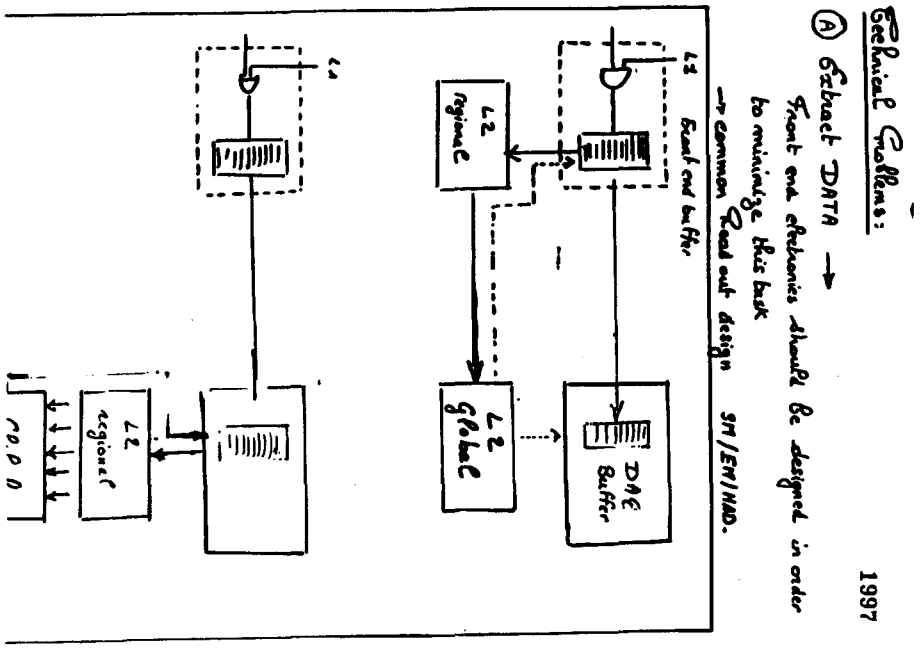
- Goal → combine EM + HAD + Showermax
- Segmentation → E.M. tower → 10K cells

Concept



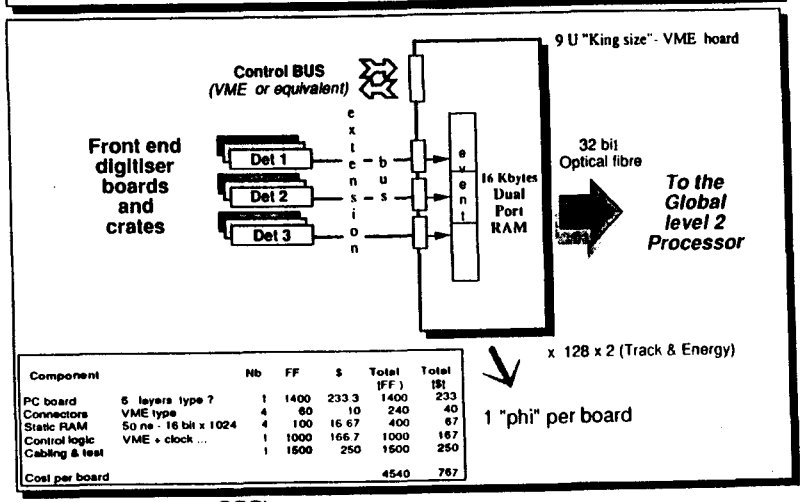
→ Programmable algorithms
→ "Fast" ~ 10-16 μsec

HAD | EM | em



1997

Local Event Builder Board



Component		Nb	FF	$	Total (FF)	Total ($)
PC board	6 layers type ?	1	1400	233.3	1400	233
Connectors	VME type	4	60	10	240	40
Static RAM	50 ns - 16 bit x 1024	4	100	16.67	400	67
Control logic	VME + clock ...	1	1000	166.7	1000	167
Cabling & test		1	1500	250	1500	250
Cost per board					4540	767

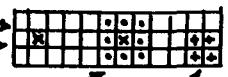
SDC level 2 trigger - CEA *- DSM Saclay* 5/06/91

1995

Algorithm simulation

- Multiplication = 5 µsec
- Threshold comparison over 8 bit = 1 µsec

Operation	Time
• E.M. cluster*	~ 2 µsec
• Hadron jet*	~ 2 µsec
• "isolated" electron*	≤ 7 µsec
• Et sum* Σ e.sinθ.	≤ 20 µsec
• "Overlap"* ΣE over 4 cells	~ 2 µsec

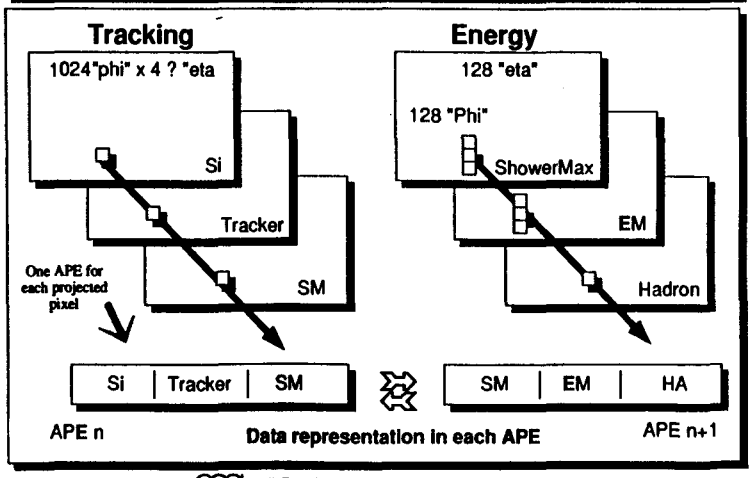


* assuming 5% of cell hits

JC Brisson, P. Le Dû and B. Thoris - DSM Saclay 17

1998

Global Level 2 Processor Principle



SDC level 2 trigger - CEA *- DSM Saclay* 8/6/91

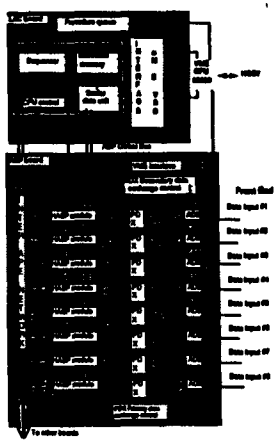
20

1996

ASP General Purpose Machine

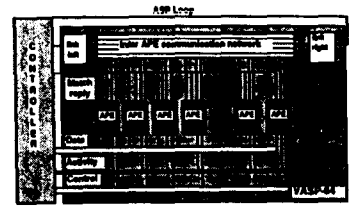
Controller card (LAC)
- Execute ASP applications
- High speed sequencer
- Microprogram memory

ASP card
- 9U "MAXI" VME board
- 8 HASP modules ---> 8192 APE
- I/O ---> 5Gbit/sec
- 100 Watts

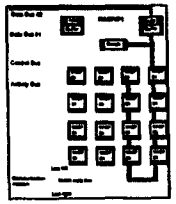


2001

ASP Elements



Exist ---> VASP-64 / E1 (Aspex)
- String of 64 APE
- Clock frequency 20 MHz
- 64 bit data register
- Time slot 40 ns
- CMOS 2 µm technology
- 5 $ per element



Hybrid (HASP)
(024 processors
(Polycon-Phoenix)

New (June 91) ---> VASP-64 / H1 (Aspex + Hugues)
- Clock frequency ≥ 40 MHz
- Time slot ≤ 25 ns
- SOS : rad hard Silicon On Saphire
- 0.8 µm technology

Future (94?)--> *ASP improvment*
- ≥ 64 bit data register possible (128 ?)
- Vector Data Buffer ? ---> very fast I/O
- 1 dollar per element ?

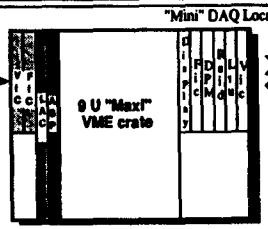
1999

Saclay Prototype & Test

SUN4 Development Workstation

SBus

"Mini" DAQ Local Data Node



VME Bus *(to DAQ ...)*

Hardware ingredients
- FIC = 68020/30/40 processors
- VIP = VME interface (VME,VSB,Sbus ...)
- LTU = Local Trigger Unit (synchronisation)
- RAID = RISC R3000 processor
- DPM = 8 Mbytes Dual port memory

Development Workstation
- GEANT simulation
- ASP algorithms simulator
- Real Time UNIX development for "embedded " 68000 & RISC processors.
- Graphic , Control & Display ...

1991
- algorithm simulations
- build a global Level 2 VME crate with 2048 APE processor card (TRAX1)

1992
- Local Event Builder prototype
- global level 2 trigger with 8192 APE processors card (MPPC)

1993-94
- test in a realistic environment ---> with full scale detector prototypes (Trackers + Calorimeters + Muons .... ?)

1995
---> final choice

2002

ASP : Associative String Processor

A short introduction ...

Basic idea

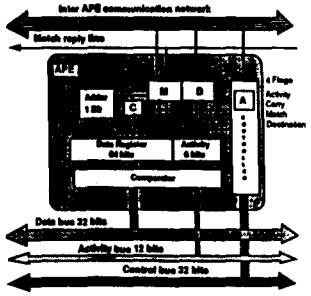
(independant of the technique)

- **Suppress memory access**
  ---> *one processor for each data word*
- **Suppress addressing mode**
  ----> *Content addressable memory*
  ----> *associative access to multiple data*

Basic component :

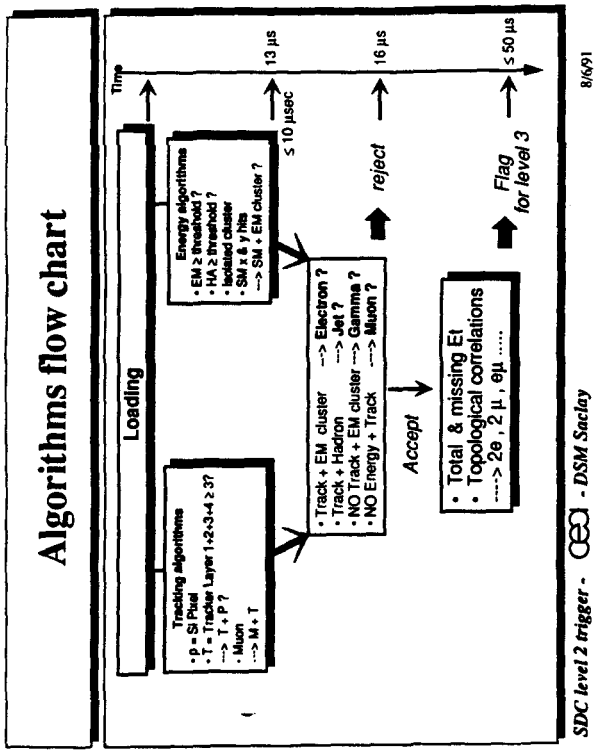
APE -->

Associative Processor Element

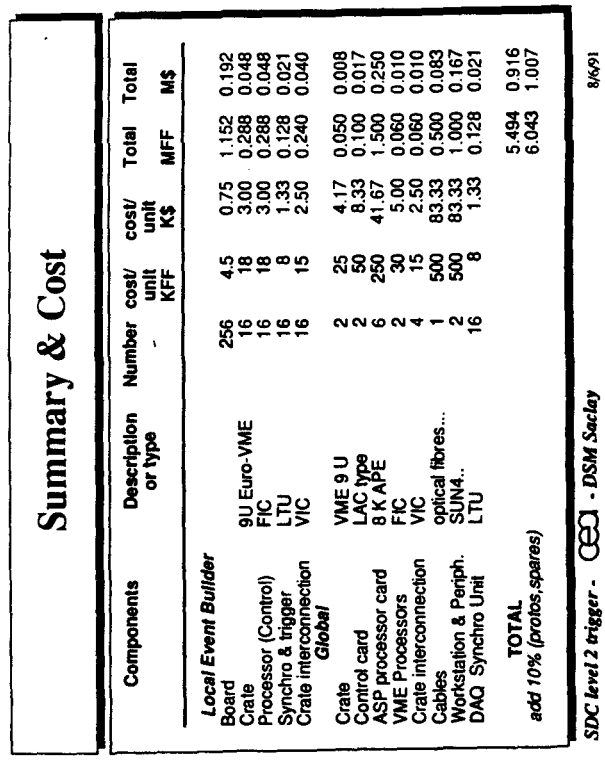


2000

2003



2004



Summary & Cost

Components	Description or type	Number	cost/ unit KFF	cost/ unit K$	Total MFF	Total M$
Local Event Builder						
Board		256	4.5	0.75	1.152	0.192
Crate	9U Euro-VME	16	18	3.00	0.288	0.048
Processor (Control)	FIC	16	18	3.00	0.288	0.048
Synchro & trigger	LTU	16	8	1.33	0.128	0.021
Crate interconnection	VIC	16	15	2.50	0.240	0.040
Global						
Crate	VME 9 U	2	25	4.17	0.050	0.008
Control card	LAC type	2	50	8.33	0.100	0.017
ASP processor card	8 K APE	6	250	41.67	1.500	0.250
VME Processors	FIC	2	30	5.00	0.060	0.010
Crate interconnection	VIC	4	15	2.50	0.060	0.010
Cables	optical fibres...	1	500	83.33	0.500	0.083
Workstation & Periph.	SUN4..	2	500	83.33	1.000	0.167
DAQ Synchro Unit	LTU	16	8	1.33	0.128	0.021
TOTAL					5.494	0.916
add 10% (protos,spares)					6.043	1.007

SDC level 2 trigger - DSM Saclay 8/6/91

2005

HJF 8/8/91

TRIGGER-PHYSICS DISCUSSION

4. FLASH

I. CRUCIAL QUESTIONS

1) IS THERE PHYSICS THAT WE CANNOT DO WITH OUR PROPOSED TRIGGER?

2) WILL IT WORK?
(ENOUGH FLEXIBILITY + REDUNDANCY?)

II. STRAWMAN L1 TRIGGER TABLE (VERY PRELIM)

III SOME OTHER GENERAL CONSIDERATIONS FROM THE TRIGGER POINT-OF-VIEW

2006

COMMON TRIGGER MISCONCEPTIONS

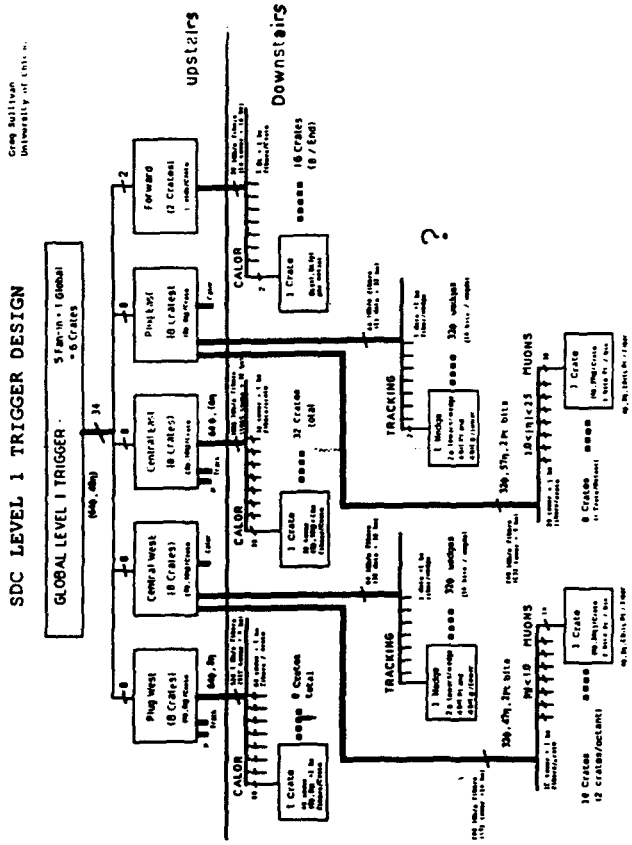
1. OVER EMPHASIS ON ALGORITHMS
   - INSTEAD FIND CORRECT MEASURABLES
   - PHYSICS SHOULD BE INDEP. OF ALGORITHMS

2. ANALYSIS IS INDEPENDENT OF TRIGGER
   - 1ST FACTOR OF 10^5-10^8 REJ. THERE(!)
   - MORE MIPS THERE
   - GET TO LOOK AT DATA AS YOU TAKE IT.

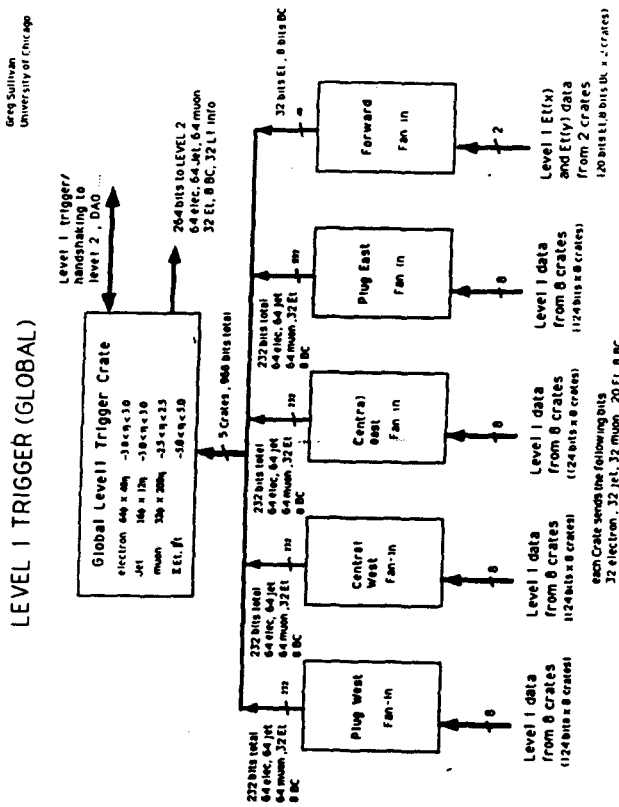
3. FOCUS ON HIGH P_T
   - NO RATE THERE
   - TRIGGER SEES + REJECTS 10^8 EV/SEC
     HAVE TO GET THIS RIGHT AT PARTS/MILLION
   - TERTIARY PARTICLES $t \to b \to c \to \mu$ ...

4. NOT PAYING ENOUGH ATTENTION TO YOUR TRIGG
   - YOU GET NO EVENTS...

2007



2008



Level 1 Strawman Trigger Table

2009

Trigger	E_T (GeV)	$\sim\sigma$ (Mb)
electron	15. $\lvert\eta\rvert<1.6$	
	30. $1.6<\lvert\eta\rvert<3.0$	3
Central photon	35 ?	1
muon	15	1 (?) EOI
Jet	150	1
2 electrons	10	1
2 muon	10	1
e/μ	10/10	1
$\not{E}_T$	140	1 (EOI)
ΣE_T	1000	1 (EOI)
ΣP_T	?	—

Minbias (pre-scaled)

electron	"	10
muon	"	10
Jet	"	100

ELECTRON TRIGGER EXAMPLE (DON'T MISS THE POINT)

2010

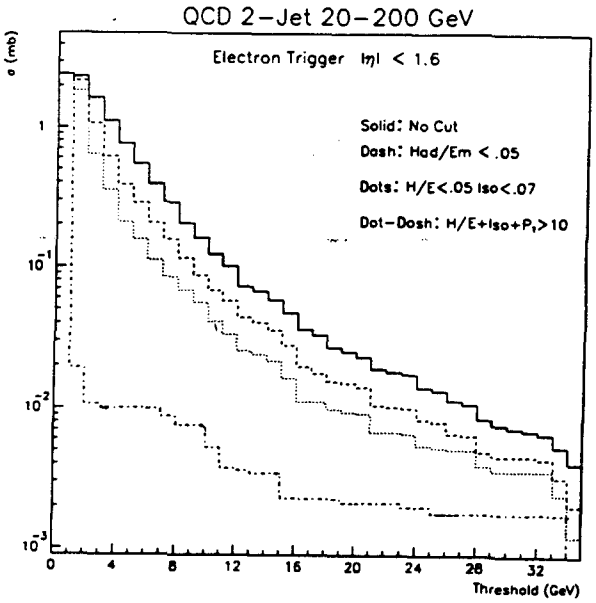
WHAT	CUTS	PHYSICS
1) LOW E_T PRESCALE	$E_T > T_1$ (7 GeV) strip/track, had/em	IN SITU CALIB.
2) TIGHT e.	$E_T > T_2$ (15?) E/p, strip/track, iso, had/em	W, Z, ...
3) CENTRAL e.	$E_T > T_3$ (20?) strip/track, had/em, E/p	W, Z, top, ...
4) CENTRAL "γ"	$E_T > T_4$ (20?) had/em	W, Z, ...
5) 2 TIGHT e.	2 e. [illegible] strip/track, had/em, E/p	[illegible]
6) 2 Central e.	2 e. [illegible] strip/track, had/em, E/p	[illegible]
7) 2 "γ"	2 γ [illegible]	Z, top, H, ...
8) [illegible]		

III. TRIGGER POINT-OF-VIEW (HAS NON-TRIVIAL CONSEQUENCES)

- LIKE A FIXED-TARGET EXPT. - ONLY SEE WHAT YOU TRIGGER ON.
- AT 10^8 REAL INTERACTIONS/SEC YOU WILL GET EVENTS SATISFYING ANY SINGLE CRITERION YOU PUT UP
  ⇒ REDUNDANT INFO. FROM MULTIPLE SUBDET. [illegible]
  NOTE: μ MUCH MORE VULNERABLE THAN e AT PRESENT.
- TRIGGER EFFIC. FOR HIGH E_T (SMALL σ) PHYSICS MUST BE ≈ 1.0
- TRIGGER IS THE FILTER THAT SELECTS DATA SETS AT HIGH PURITY
- LOCAL TRIGGERS (INGREDIENTS)
- SIMPLE TRIGGERS - WORK ON FUNDAMENTAL PHYSICS SIGNATURES (DON'T 2ND GUESS PHYSICS)
- BANDWIDTH TO "TAPE" IS BYTES/SEC, NOT EVENTS/SEC
- ONLY PARAMETER OBVIOUSLY IN CONFLICT BETWEEN LOW σ + HIGH σ PHYICS IS DEADTIME (A KNOB)

2011

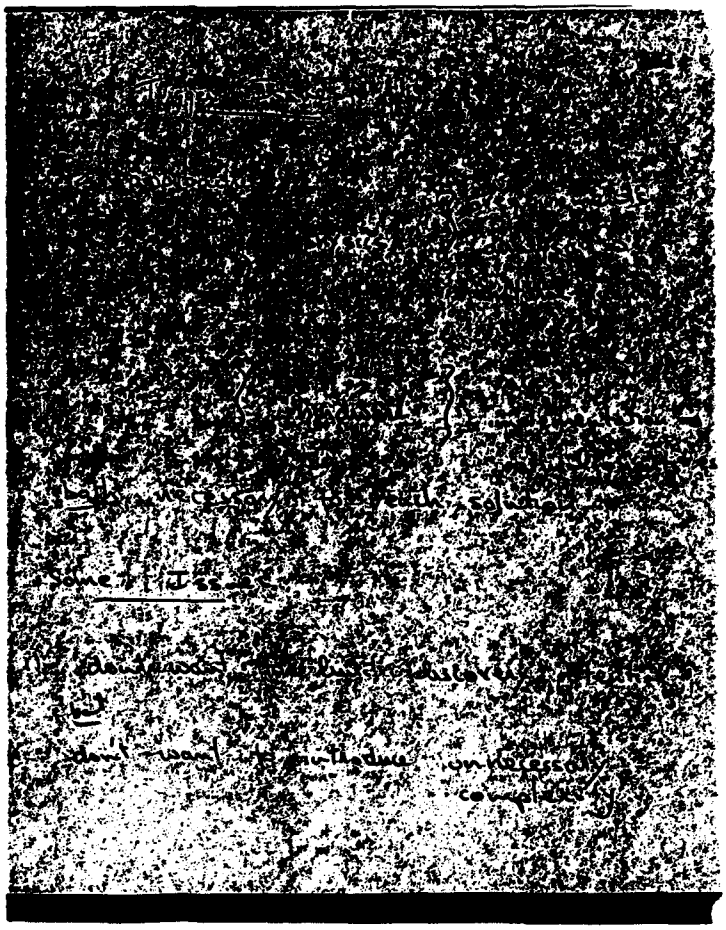
2012

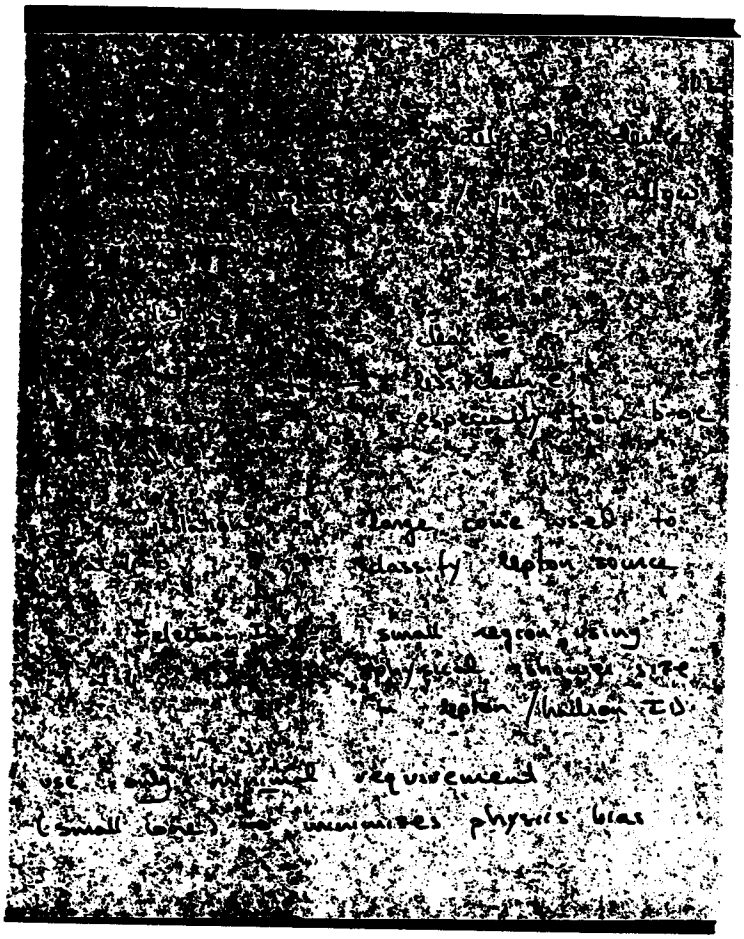


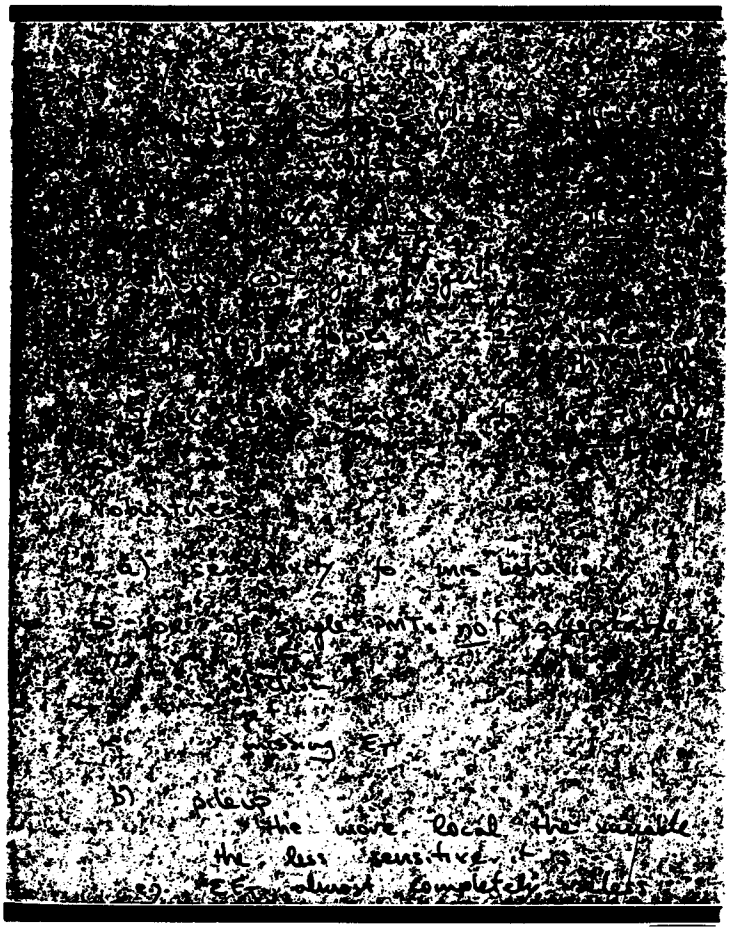
2013

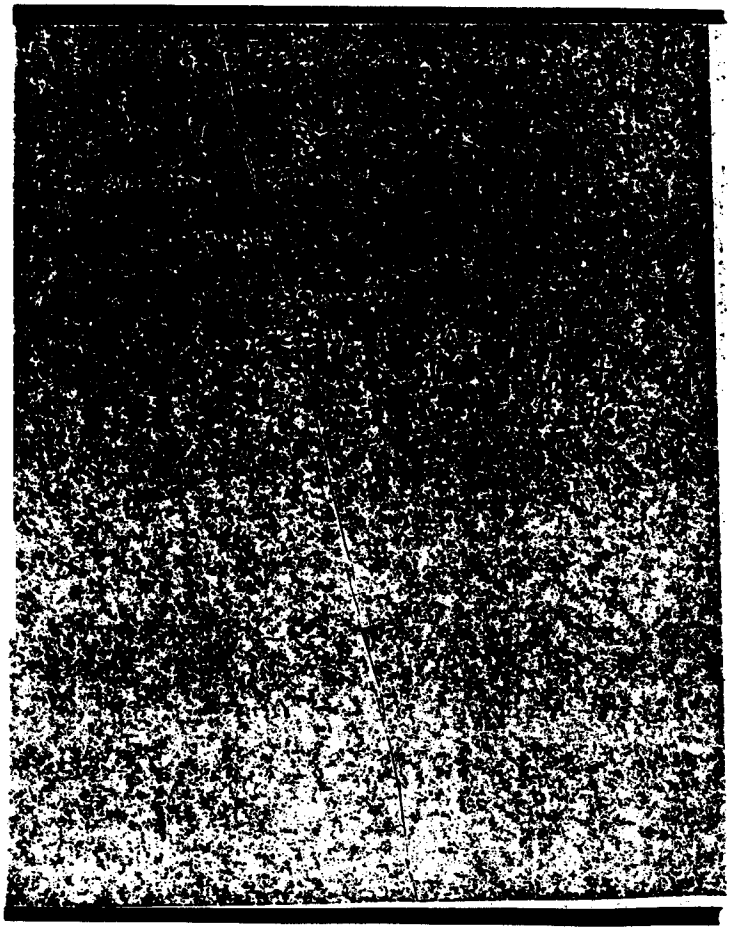
TRIGGER ISSUES

K. EINSWEILER





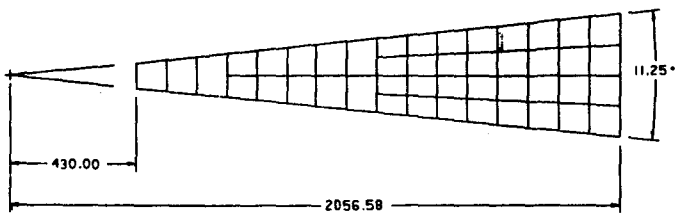




LIQUID ARGON TRIGGER ISSUES

M. LEVI

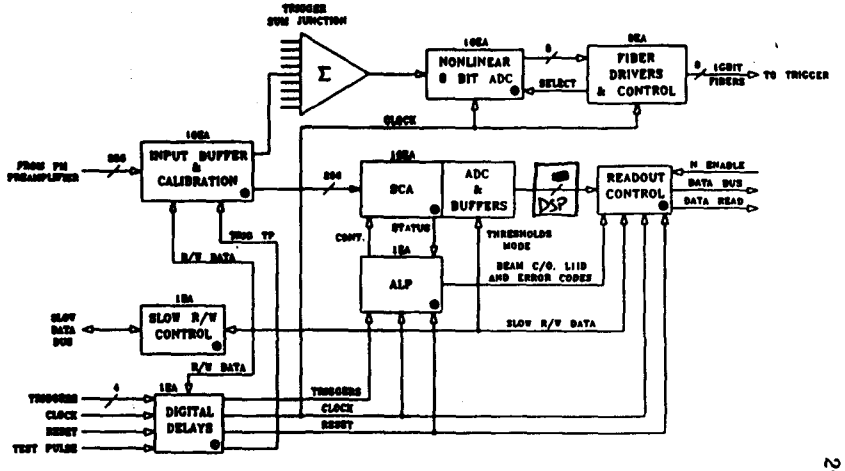
LEAD IRON CALORIMETER
CALORIMETER END CAP
A SINGLE MODULE INSIDE BEAMLINE VIEW



D.389.4136A03.R3
DIM. IN MILLIMETERS
SCALE: .09=1.00
KEPES 4-4-91

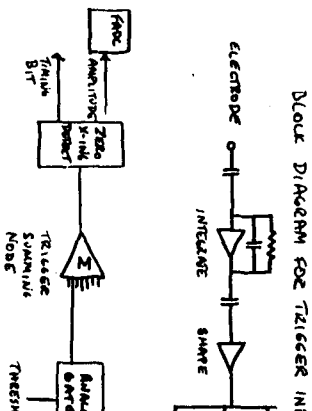
Fig. 2-28 Details of endcap calorimeter segmentation.

SCA READOUT, CALIBRATION & ZERO SUPPRESSION



LAr

BLOCK DIAGRAM FOR TRIGGER INPUTS



BIPOLAR SHAPE CANCELS RATE DEPENDENT PEDESTAL SHIFTS

(DRIFT [illegible] TO BE [illegible])

PEDESTAL [illegible], SHAPE, GAIN CONTROL, THRESHOLD, ETC.

THRESHOLDS: > [illegible] MeV IN EM, > [illegible] MeV IN HADRONIC ($\times 2\sigma$)

TIMING ACCURACY OF ZERO CROSSING

$$\delta T = t_{peak} \cdot [S/N]^{-1}$$

FOR EM COMPARTMENT TIMING UNIQUE FOR $E_T^{em} > 1.5$ GeV

HADRONIC " " " " $E_T^{had} > 12$ GeV

Muon System

<Simulation>

Simulation for SDC Muon System	S. Kunori(Maryland)
SDC Muon Simulation	M. Daoudi(Colorado)

<Muon Trigger>

Trigger Resolution Effects	R. Thun(Michigan)
Level 1 Muon Trigger	G. Feldman(Harvard)
L1 Muon Trigger Study	T. Zhao(Washington)
Trigger Resolution Study	S. Behrends(Brandeis)
Study of the Muon Trigger Efficiency	V. Molchanov(IHEP Protvino)

<Muon Resolution>

Momentum Resolution with/without BWC1 & Prompt Muon Rates - Review	H. Iwasaki(KEK)
Descoping Effects on Muon Resolution	J. Wiss(Illinois)

<System Designs and Testing>

Some Results of Simulation of the Effects Connected with e.m. Environment of High Energy Muons	Y. Gornushkin(JINR/SSCL)
Wisconsin Chambers	F. Feyzi(Wisconsin)
Muon Detector System	H. Lubatti(Washington)
Boston Group Chamber Update	G. Feldman(Harvard)
Supermodule Design & Analysis Review: Boston Chamber Concept	J. Gorman(CSDL)
Why a Jet Chamber?	S. Odaka(KEK)
Status of the Large Jet Chamber R&D for the SDC Muon Detector	S. Terada(KEK)
Japanese University Activities for SDC Muon System	A. Maki(KEK)
Resistive Plastic Drift Tubes	K. Heller(Minnesota)
University of Rochester Resistive Field Shaping & Low Mass, Lightweight Support Module Testing	A. Sill(Rochester)
Cerenkov Beam Test - Preliminary Results	U. Nauenberg(Colorado)
Use of Gas Cerenkov Counters as Part of a Trigger System for Muons in SSC Detectors	A. Ronzhin(IHEP Protvino)
Scintillation Counters for Trigger System of SDC	V. Kubarovsky(IHEP Protvino)
Muon Factory Model	R. Loveless(Wisconsin)

<Costs>

SDC Muon System WBS	G. Guenterberg(M. Marietta)
WBS 3 Options and Cost Summary	F. Feyzi(Wisconsin)

LPBautz:8/20/91

Simulation for SDC Muon System

6-Aug-91 S. Kuori

Physics (Input)
↓
Detector Simulation
↓
Event Reconstruction
↓
Analysis
↓
Physics (output: reconstructed)

Functions

Barrel: Trigger
Muon ID
Momentum Measurement
(combined
stand alone)

Forward: Momentum Meas. (stand alone
Muon ID combined)
Trigger

#1

Acceptance : S Errede
$\Delta P/P$: J. Wiss
Triggers : R. Thun
T. Zhao
S. Behrends
H. Iwasaki
Neutrons : K. Johns
SDCSIM : N. Dawdi + V. Slomin

S. Errede
Univ. of Illinois
May 30, 1991

SDC Muon Physics Acceptance Impact if Delete Intermediate Muon System

The Isajet v6.24 Monte Carlo was used for muon acceptance studies for various muon benchmark physics processes summarized below.

Requirements on muons:

a.) All muons to be in central (barrel) region, |eta mu| < 1.5
b.) For W -> mu nu, muon with Pt > 20 GeV/c (~20% reduction)
c.) For Z0, Z' -> mu+mu-, at least one muon with Pt > 20 GeV/c (~19%,~4%,~1.4% reduction for Z0, Z'(200) and Z'(500) respectively)
d.) For ZZ pairs, Higgs -> 4 mu, at least 2 muons with Pt > 20 GeV/c (~0.7%, 0.4%, 1.1% reduction for ZZ pairs, H(400) and H(600) resp.)

[A] W+_ -> mu+_ nu

Sigma*B(W+_ -> mu+_ nu) = 34.7 nb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 80%; after Pt cut imposed, geometrical acceptance reduced from 58.0% (LoI) -> 38.5% (C-mu only)
=> 3.5 x 10**8 total events produced
=> 1.8 x 10**8 LoI (C-mu + I-mu) events
=> 9.8 x 10**7 C-mu only events) 1.6

[B] Z0 -> mu+mu-

Sigma*B(Z0 -> mu+mu-) = 3.3 nb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 81%; after Pt cut imposed, geometrical acceptance reduced from 47.0% (LoI) -> 22.8% (C-C only)
=> 3.3 x 10**7 total events produced
=> 1.3 x 10**7 LoI (C-C + C-I + I-I) events
=> 6.1 x 10**8 C-C only events) 2.1

[C] Z' -> mu+mu- (Mz' = 200 GeV/c2)

Sigma*B(Z' -> mu+mu-) = 144 pb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 96.1%; after Pt cut imposed, geometrical acceptance reduced from 48.0% (LoI) -> 21.8% (C-C only)
=> 1.4 x 10**6 total events produced
=> 6.6 x 10**5 LoI (C-C + C-I + I-I) events
=> 3.0 x 10**5 C-C only events) 2.2

[D] Z' -> mu+mu- (Mz' = 500 GeV/c2)

Sigma*B(Z' -> mu+mu-) = 0.7 pb Ldt = 10**40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 98.6%; after Pt cut imposed, geometrical acceptance reduced from 61.0% (LoI) -> 29.9% (C-C only)
=> 7000 total events produced
=> 4210 LoI (C-C + C-I + I-I) events
=> 2064 C-C only events) 2.0

[E]

ZZ pairs -> 4mu

Sigma=B(ZZ -> 4mu) = 25 fb Ldt = 10x40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 99.3%; after Pt cut imposed, geometrical
acceptance reduced from 32.2% (LoI) to 9.1% (C-C only)
=> 250.0 total events produced
=> 79.9 LoI events
=> 22.6 C-C C-C only events ≥ 3.5

[F]

Higgs-> ZZ -> 4mu (Mh=400 GeV/c2)

Sigma=B(Higgs -> ZZ -> 4mu) = 8.8 fb Ldt = 10x40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 99.6%; after Pt cut imposed, geometrical
acceptance reduced from 49.2% (LoI) to 17.7% (C-C only)
=> 88.0 total events produced
=> 43.1 LoI events
=> 15.5 C-C C-C only events ≥ 2.8

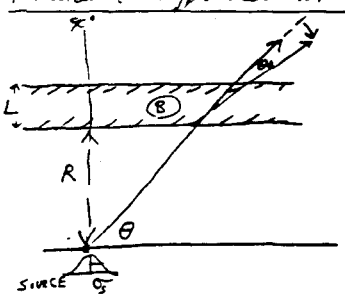
[G]

Higgs-> ZZ -> 4mu (Mh=600 GeV/c2)

Sigma=B(Higgs -> ZZ -> 4mu) = 1.5 fb Ldt = 10x40 (1 Year LT)
Pt > 20 GeV/c acceptance ~ 98.9%, after Pt cut imposed, geometrical
acceptance reduced from 66.3% (LoI) to 29.7% (C-C only)
=> 15.0 total events produced
=> 9.8 LoI events
=> 4.4 C-C C-C events ≥ 2.2

Recalculate trigger resolution effects

R. Thun



$$\theta_B = \frac{0.3BL}{p\sin\theta}$$

$$\delta\theta_s \approx \frac{\sigma_s \sin\theta}{(R+L)/\sin\theta} = \frac{\sigma_s \sin^2\theta}{(R+L)}$$

$$\delta\theta_{MS} = \frac{.015}{p}\sqrt{X_{em}+X_{lead}+X_{Fe}}$$

$$\cong \frac{.015}{p}\sqrt{30 + 90 + \frac{L/\sin\theta}{0.0176}}$$

lead; 9λ Fe + SCINT; Toroid

$\delta\theta_I$ ← intrinsic depends on drift el. characteristic

Particle momentum p

$P_\perp = p\sin\theta$

assume $R = 7.24$, $L = 1.5$, $B = 1.8$, $\sigma_s = .05$

so, for 1.5m TOROID

				$P_\perp$ at which $\delta\theta_s = \delta\theta_{MS}$
at 90°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0057$	$\delta\theta_{MS} = \frac{0.215}{P_\perp}$	38 GeV
at 45°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0029$	$\delta\theta_{MS} = \frac{0.164}{P_\perp}$	57 GeV
at 30°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0014$	$\delta\theta_{MS} = \frac{0.128}{P_\perp}$	91 GeV

for 40m TOROID →

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$P_\perp$ for $\delta\theta_s = \delta\theta_{MS}$
90°	$0.54/P_\perp$	.0061	$0.199/P_\perp$	32.6 GeV
45°	↓	.0030	$0.850/P_\perp$	50.0
30°		.0015	$0.115/P_\perp$	76.7

SUMMARY

1.5m toroid

all angles in mr.

DRIFT TUBE: 4 DRIFT VELOCITY 90-5-5 A-CO_2-CH_4

$P_\perp = 20$ GeV/c

θ	BEND θ_B	SCATTER $\delta\theta_s$	MULT. SCATT. $\delta\theta_{MS}$	CH. RES. $\delta\theta_I$	$\delta\theta$ $\sqrt{\delta\theta_s^2+\delta\theta_{MS}^2+\delta\theta_I^2}$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	40.5	5.7	10.8	1.9	12.4	0.31	0.12
45°	40.5	2.9	8.2	1.3	8.8	0.22	0.12
30°	40.5	1.4	6.4	0.9	6.6	0.16	0.12

$P_\perp = 40$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	20.3	5.7	5.4	1.9	8.1	0.40	0.12
45°	20.3	2.9	4.1	1.3	5.2	0.26	0.12
30°	20.3	1.4	3.2	0.9	3.6	0.18	0.12

1.0m toroid

all angles in mr

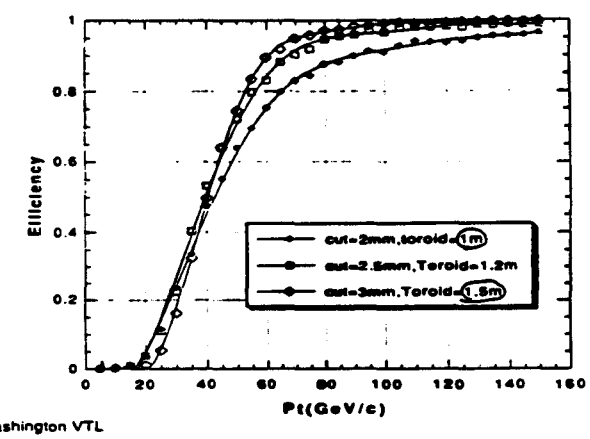
$P_\perp = 20$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	27.0	6.1	10.0	1.9	11.9	0.44	0.12
45°	27.0	3.0	7.5	1.3	8.2	0.30	0.12
30°	27.0	1.5	5.8	0.9	6.1	0.23	0.12

$P_\perp = 40$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	13.5	6.1	5.0	1.9	8.1	0.60	0.12
45°	13.5	3.0	3.8	1.3	5.0	0.37	0.12
30°	13.5	1.5	2.9	0.9	3.4	0.25	0.12

T. Thao



U. Washington VTL

Fig. 3

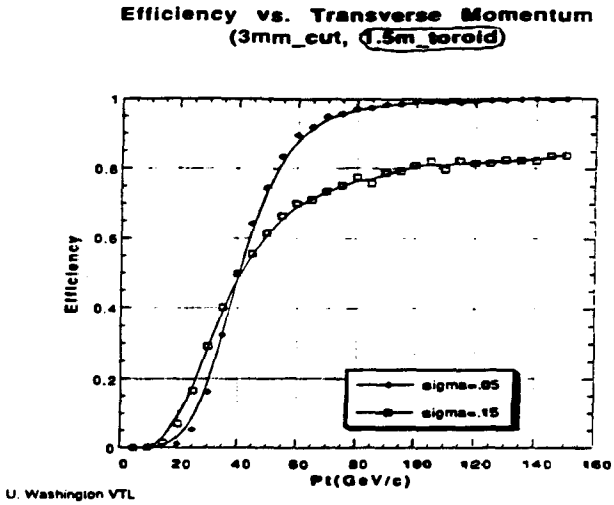


Fig. 4

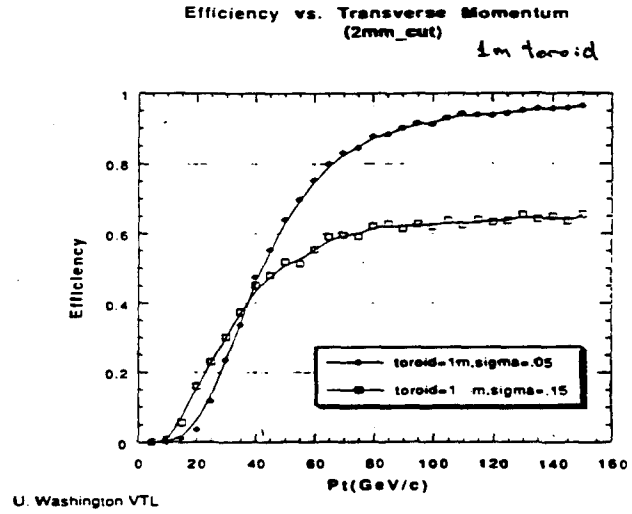


Fig. 5

H. Iwasaki

IV. μ isolation in $t\bar{t}$ events

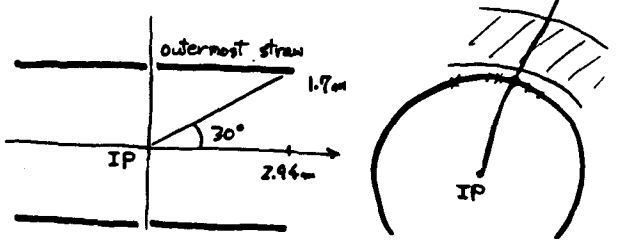
$t\bar{t}$
$\hookrightarrow b W^+$
$\hookrightarrow \mu^- \nu c$

Generator: PYTHIA 5.3
Top: $m_t = 150$ GeV/c
$B_0 = 2$ tesla
$\pi^\pm, K^\pm$ particles.

$\mu^\pm$: $P_t(\mu) > T_0$ GeV/c
@ $r = 1.7$ m

$$\begin{cases} 0 < z(\mu) < \frac{1.7\,m}{\tan 30^\circ} \; (= 2.94\,m) \\ \text{or } -\frac{1.7\,m}{\tan 30^\circ} < z(\mu) < 0 \end{cases}$$

(2 div in z)



H. Iwasaki

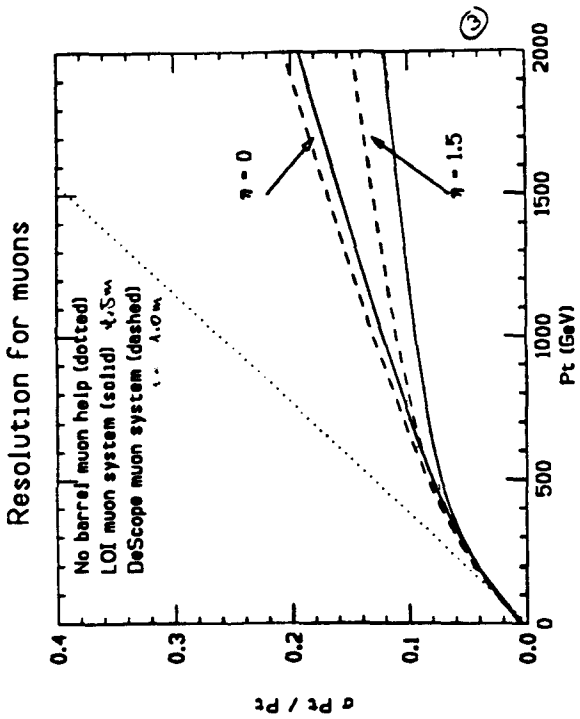
3. μ isolation in $t\bar{t}$ events

$t \to bW^+$
$\hookrightarrow \mu^- \nu c$

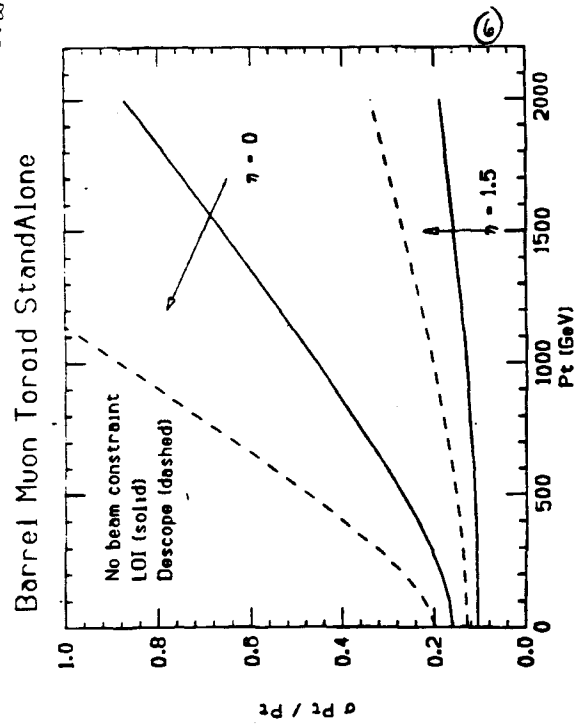
$P_t(\mu) > 10$ GeV/c
2 div. in z $\left(\begin{matrix} 0 < z < 3\,m \\ -3\,m < z < 0 \end{matrix} \right)$

- in $r\phi$ @ $r = 1.7$ m
  ($\sim$ 1 charged track / 20 cm) per μ-track
  it is $\sim 2.7 \times$ (uniform distribution)
  but still very low density
- with P_t-information from toroid
  $\Delta(r\phi) \cdot P_t < 0.6$ m·GeV/c
  (~ 0.26 charged tracks)/μ

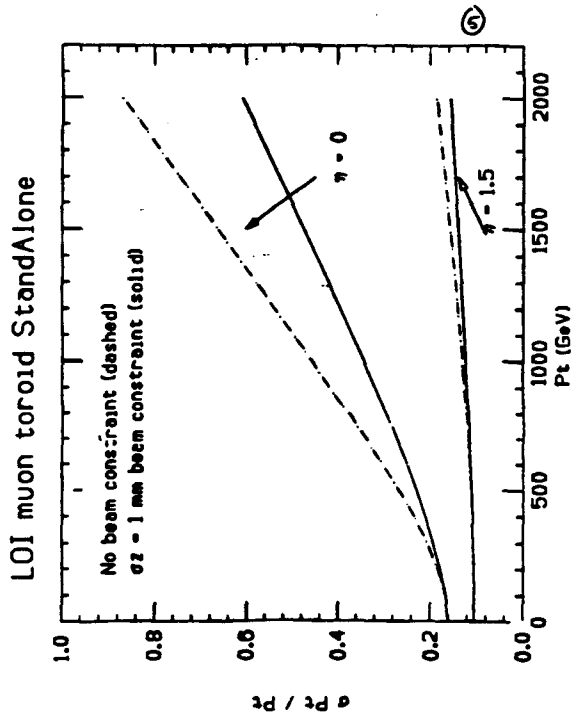
2035



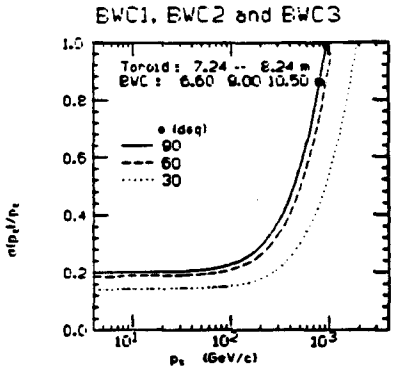
2036



2037



2038



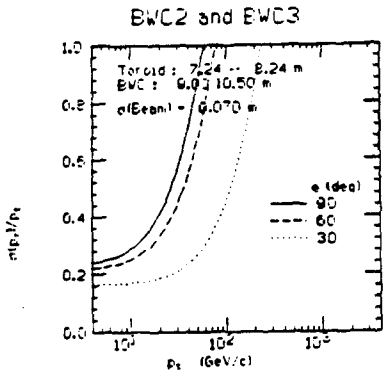
Toroid 7.24 - 8.24 m
$D_2 = 1$ m
BWC1 6.6 m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2 = 1.5$ m
$\sigma = 200\ \mu m$
(per supermodule

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 1.044 \times 10^{-3} \right)^2 + \left(\sqrt{\sin\theta}\ 0.2012 \right)^2 \right]^{1/2}$$

P_t (Tevron) = 19.3 GeV/c @ $\theta = 90°$
20.7 60°
27.2 30°

θ \ P_t (GeV/c)	20	50	100	200
90°	0.202	0.208	0.227	0.290
60°	0.188	0.193	0.208	0.260
30°	0.143	0.145	0.152	0.176

2039



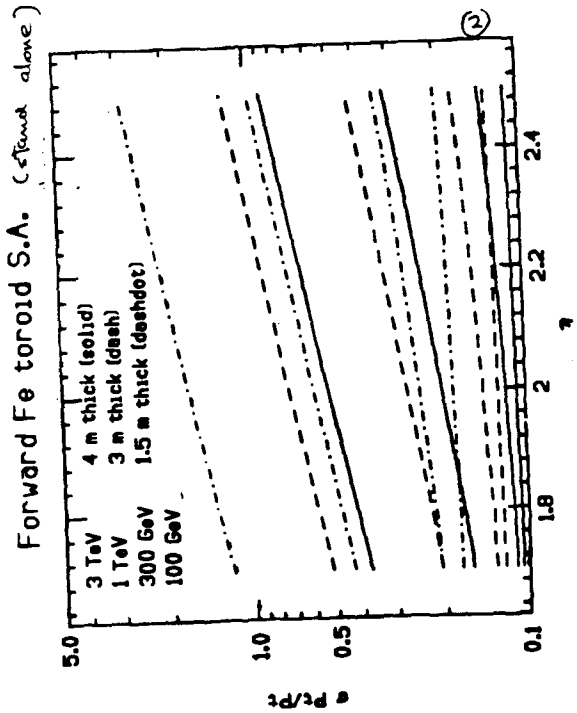
Toroid 7.24 – 8.24 m
$D_2 = 1$ m
BWC2 9.0 m
BWC3 10.5 m
$x_3 - x_2 = 1.5$ m
$\sigma = 200\ \mu m$
(per supermodule)
$\sigma_{Beam} = 7$ cm

$$\frac{\sigma_p}{p_t} = \left[\left(p_t \cdot \sin\theta \cdot 4.415\times10^{-4}\right)^2 + \left(p_t \cdot \sin^2\theta \cdot 1.676\times10^{-2}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2296\right)^2 \right]^{1/2}$$

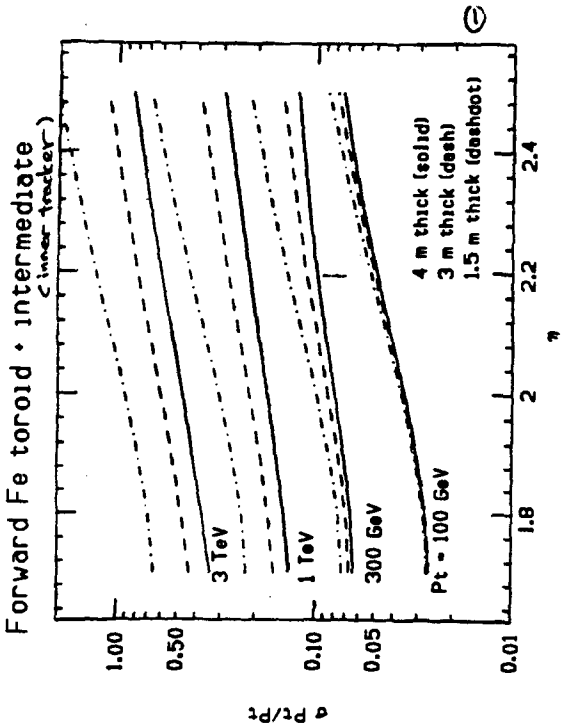
P_t (turn) = 14 GeV/c @ $\theta = 90°$
17 60°
39 30°

θ \ P_t (GeV/c)	10	20	50	100
90°	0.284	0.406	0.869	1.692
60°	0.248	0.330	0.664	1.276
30°	0.168	0.183	0.265	0.458

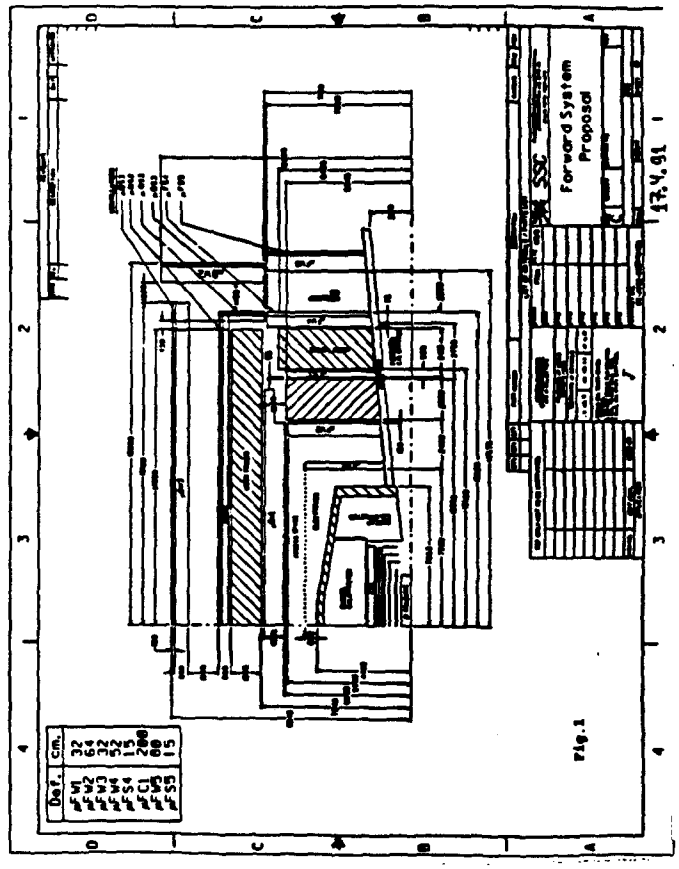
2040



2041



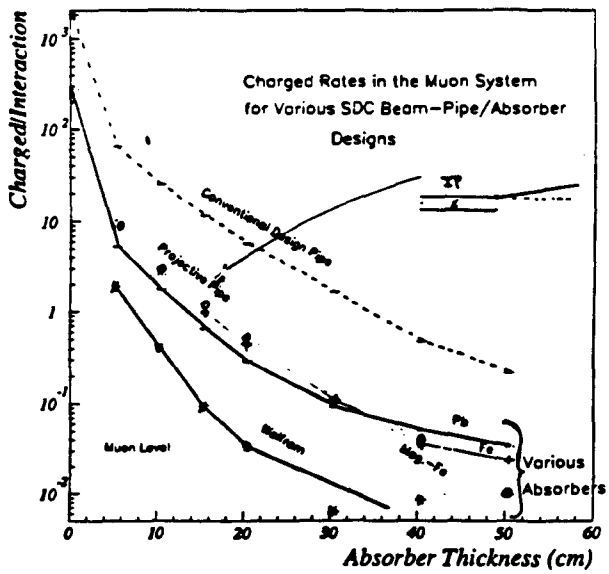
2042



A. Kulik
Y. Gornushki

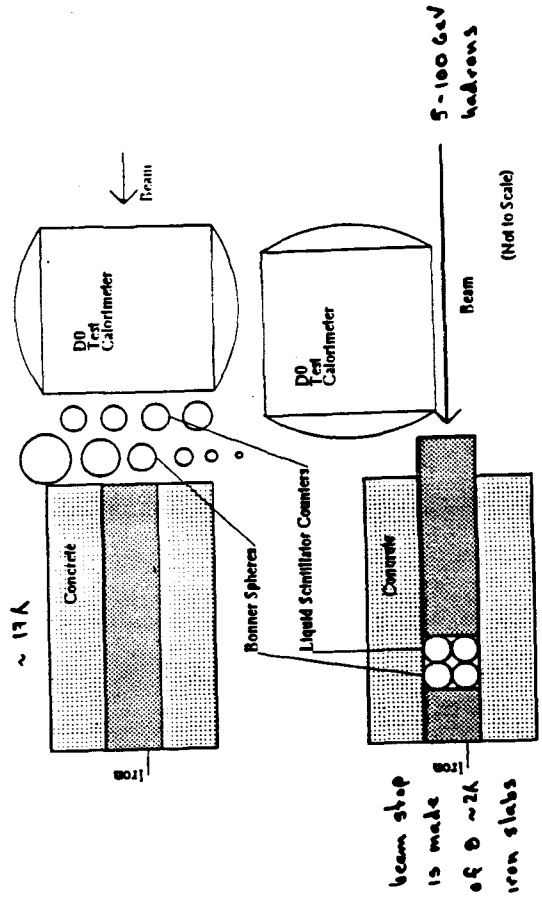
2043

Fig.4. The integrated flux of the charged particles through the absorber vs absorber thickness for various designs. The uppermost curve corresponds to the conventional cylindrical pipe and the lead absorber. All other curves are for the projective pipe design and different absorbers: lead, iron, magnetized iron and tungsten. All curves are normalized to one interaction in the IP. "Muon Level" shows roughly the rate of charged particles (dominantly muons) coming through the endcap calorimeter.



K. Jakubs

2044



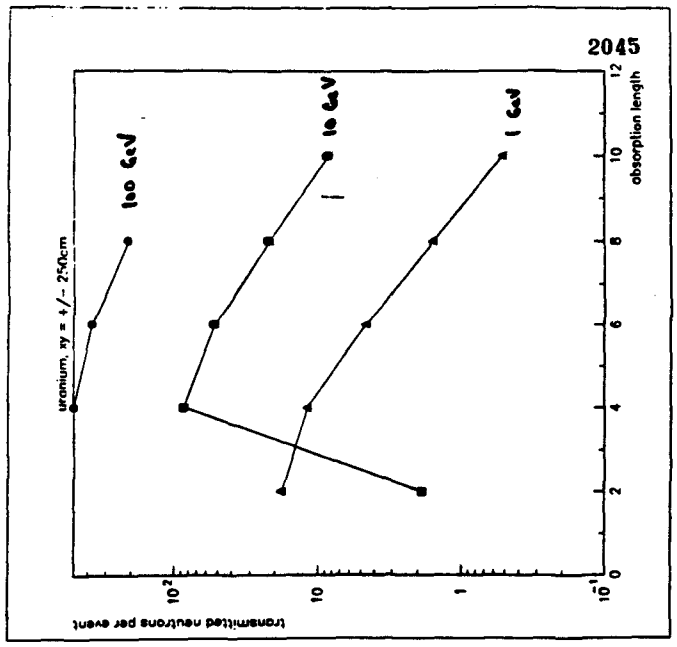
Plan Views of E821 Detector Configurations

Figure 1

R. Jakubs

Incorrect
Scoring
(weighting)

2045



H. Daoudi
V. Sloaim

2046

Software:

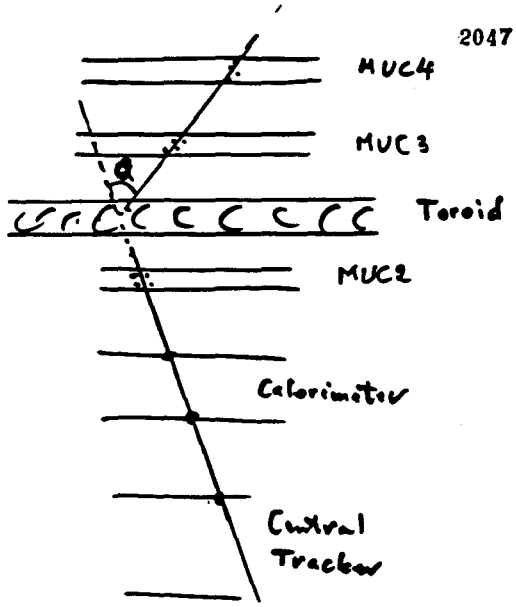
- Detector Geometry
  (2 LoI designs)
- Wire chambers implemented
  (Barrel + Forward)
- Tracking info stored in data bank
- Option to include Inner detectors
  (WP, AN, ...)
- Smeared hits in wire chambers
- Option to vary Toroid thickness
- Option to remove forward absorber

Addition:
Track fitting

Missing:
Punch-through simulation

Resolution

2047



Fit:
Orthogonal Reduction Algorithm

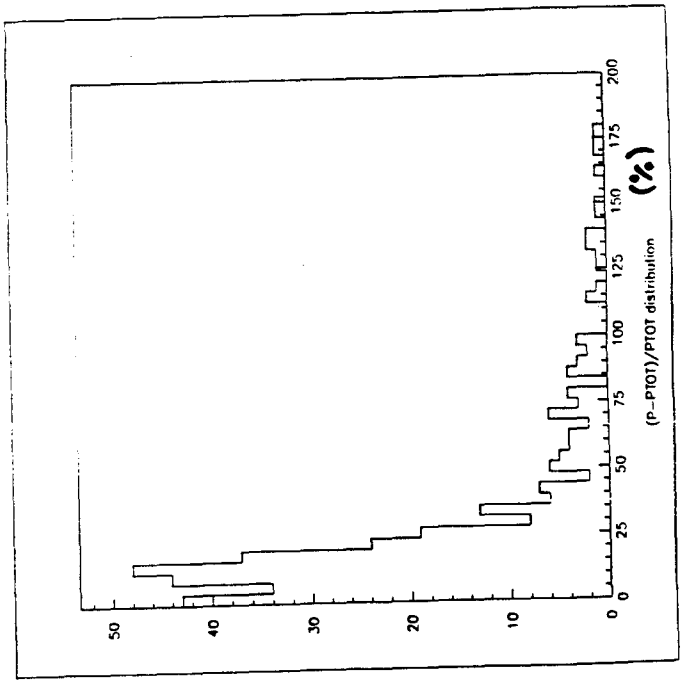
Fit a straight line before toroid
" " " " after "

Assume chamber resolution → 200 μm

Measure angular deflection

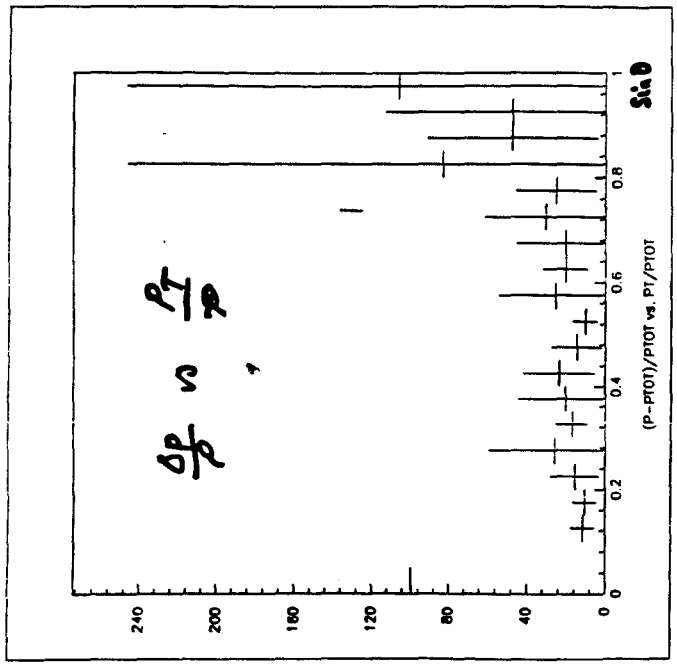
$\Rightarrow P \Rightarrow \frac{dP}{P}$

2048



N=35%

2049



Acceptance

2050

LoI design 1 (Saint. cal.)

Pythia generator

Physics Processes:

$H^0 \to Z^0 Z^0 \to 2\mu^+ 2\mu^-$ 150, 400, 800 GeV

$W^+ W^-$ pairs

$W' \to \mu\nu$ 500, 1000, 2000 GeV

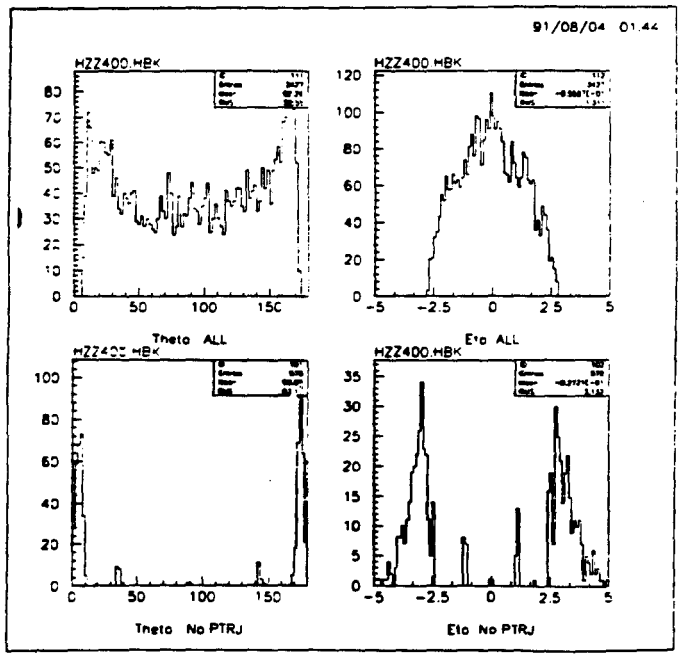
$Z' \to \mu^+\mu^-$ 1000, 4000 GeV

(1000 Events each)

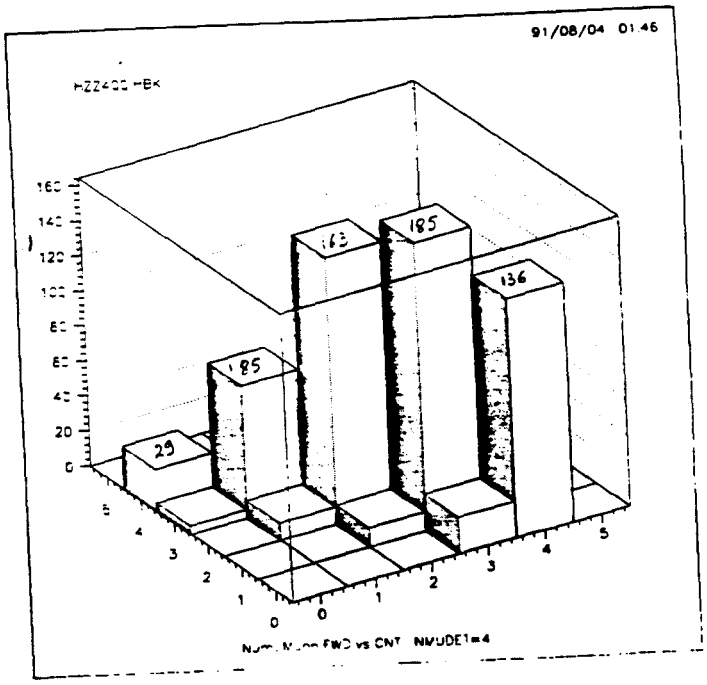
Detectors turned on:

MU, AN, WR

2051



2052



2053

Conclusion

1. Acceptance has been studied.
   with / w/o FWD muon system
   factor 2.8 loss for Higgs 400 GeV.
   to 4 μ's

2. Δp/p for toroid 1.5m and 1m were calculated.

3. Trigger efficiency (L1)
   Clear loss by reducing toroid thickness from 1.5m to 1.0m were seen.

4. BWL may be very important for L2 trigger and pattern recognition.
   global

5. SDCSIM started producing results.

#2

M. Daoudi
8-5-91 LBL

2054

SDC Muon Simulation

U. Nauenberg
V. Slonim
S. Kunori
MD.

Software Status
Resolution Studies (VS)
Acceptance Studies (MD)
Conclusions

M. Daoudi
V. Sloniri

2055

Software :

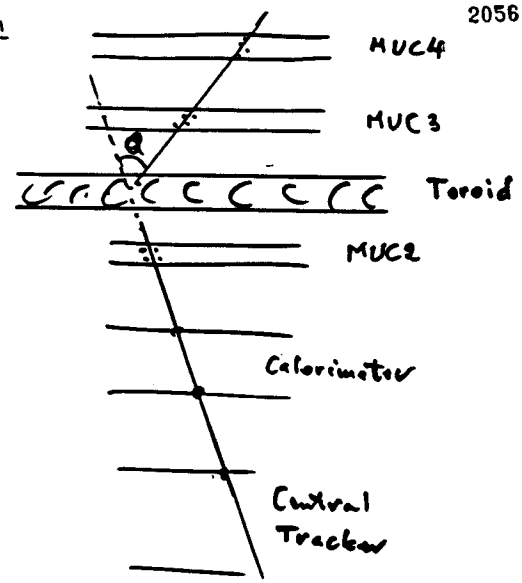
- Detector Geometry
  (2 LoI designs)
- Wire chambers implemented
  (Barrel + Forward)
- Tracking info stored in data bank
- Option to include Inner detectors
  (WR, AN, ...)
- Smeared hits in wire chambers
- Option to vary Toroid thickness
- Option to remove forward absorber

Addition :
Track fitting

Missing :
Punch-through simulation

2056

Resolution



Fit :
Orthogonal
Reduction
Algorithm

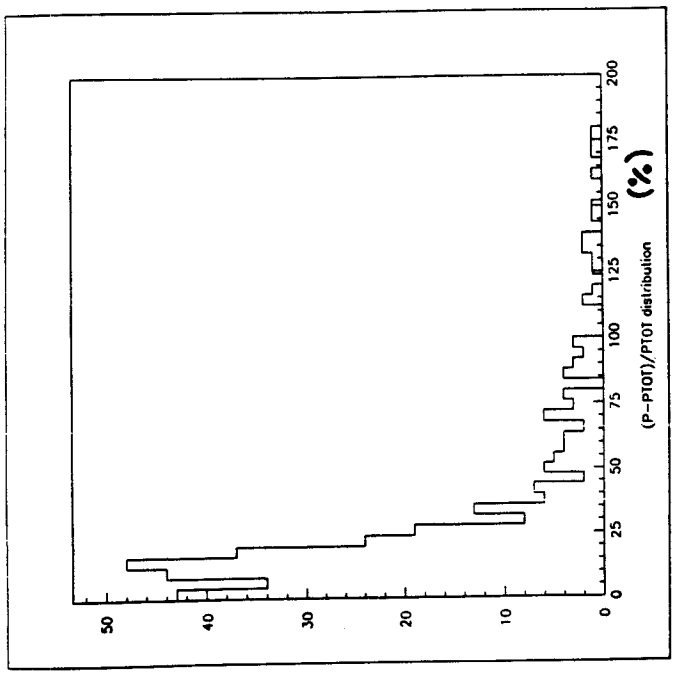
Fit a straight line before toroid
" " " " after "

Assume chamber resolution → 200 μm

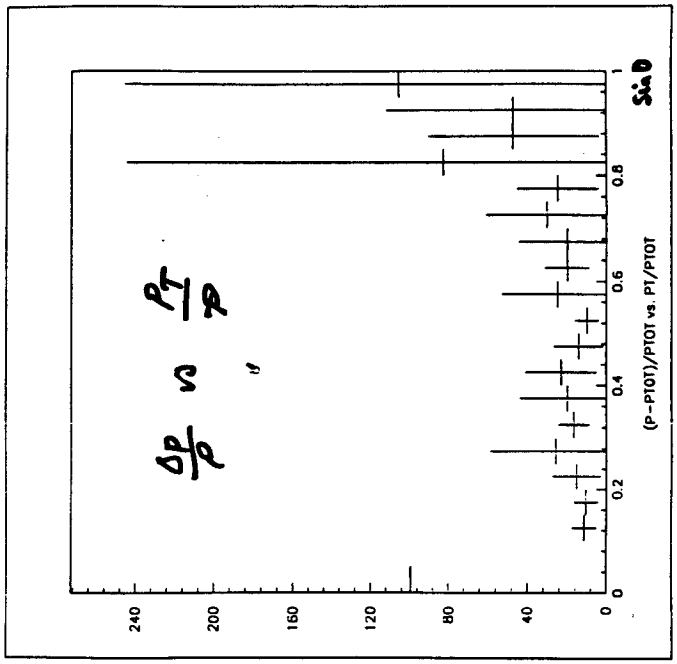
Measure angular deflection

$\Rightarrow P \rightarrow \frac{dP}{P}$

2057



2058



(%) σ_P/P

2059

Acceptance

LoI design 1 (Scint. cal.)

Pythia generator

Physics Processes:

$H^0 \to Z^0 Z^0 \to 2\mu^+ 2\mu^-$ 150, 400, 800 GeV

$W^+ W^-$ pairs

$W' \to \mu\nu$ 500, 1000, 2000 GeV

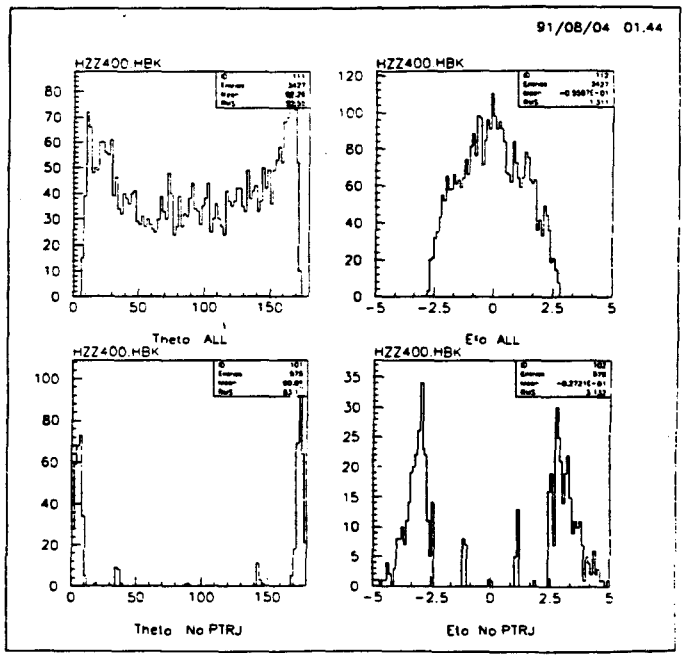
$Z' \to \mu^+\mu^-$ 1000, 4000 GeV

(1000 Events each)

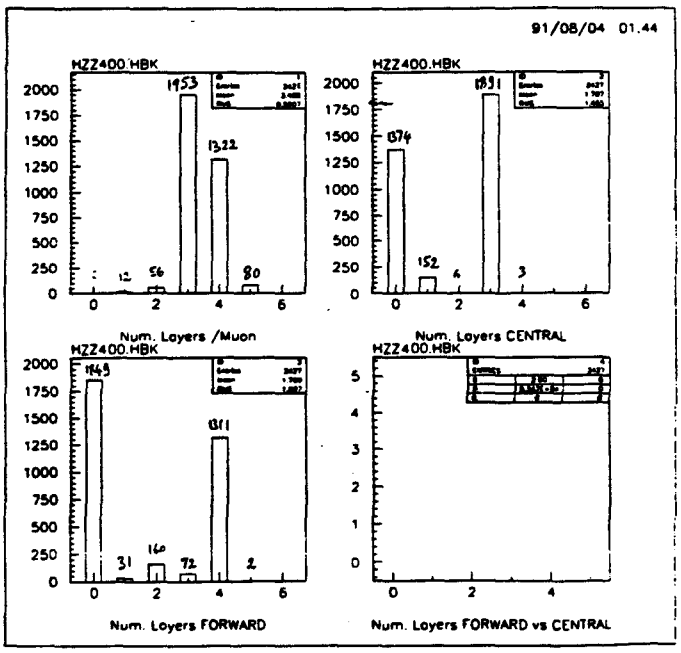
Detectors turned on:

MU, AN, WR

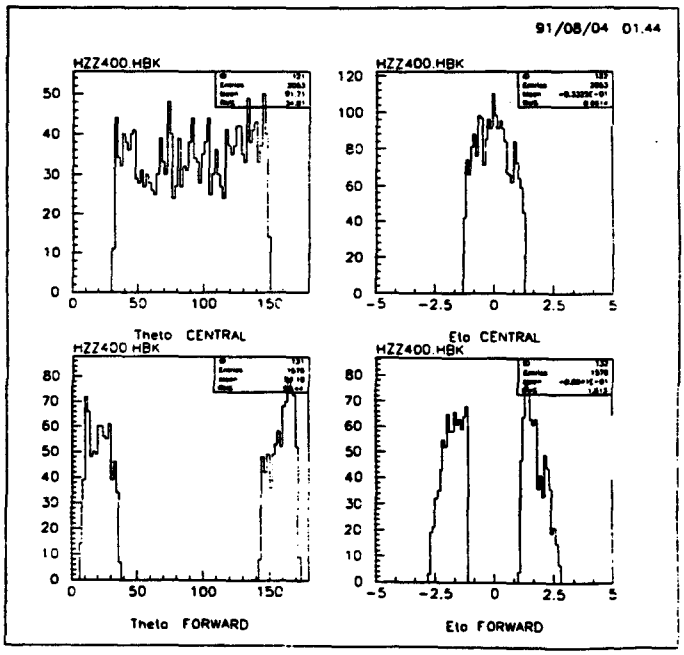
2060



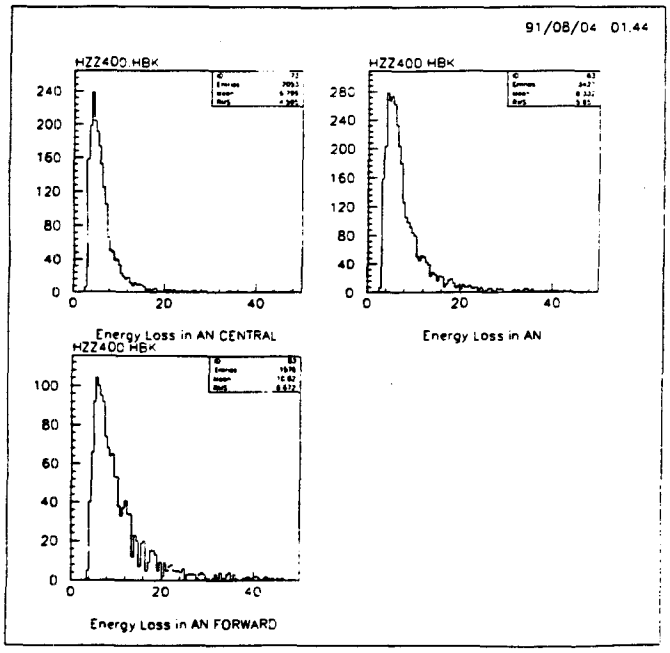
2061



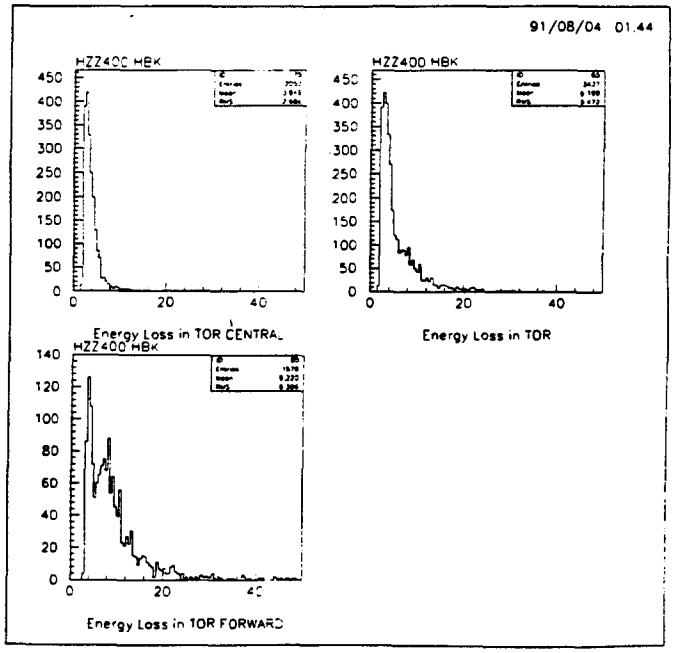
2062



2063



2064



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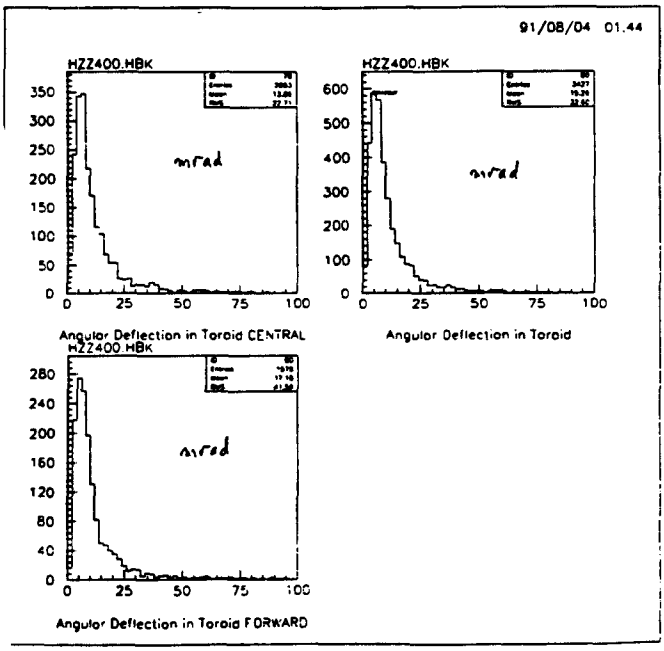
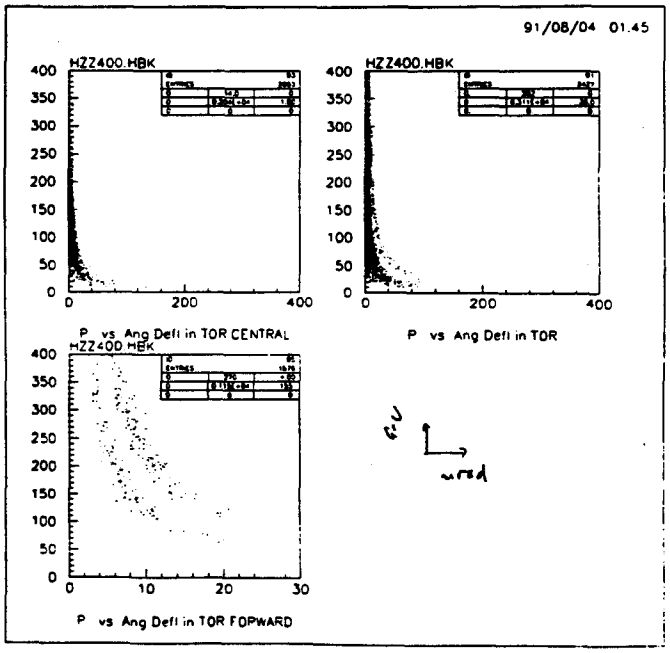
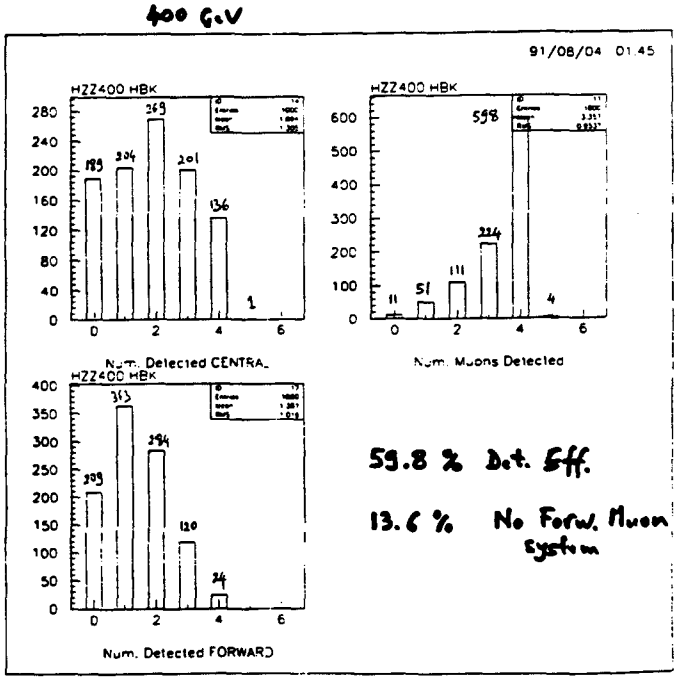
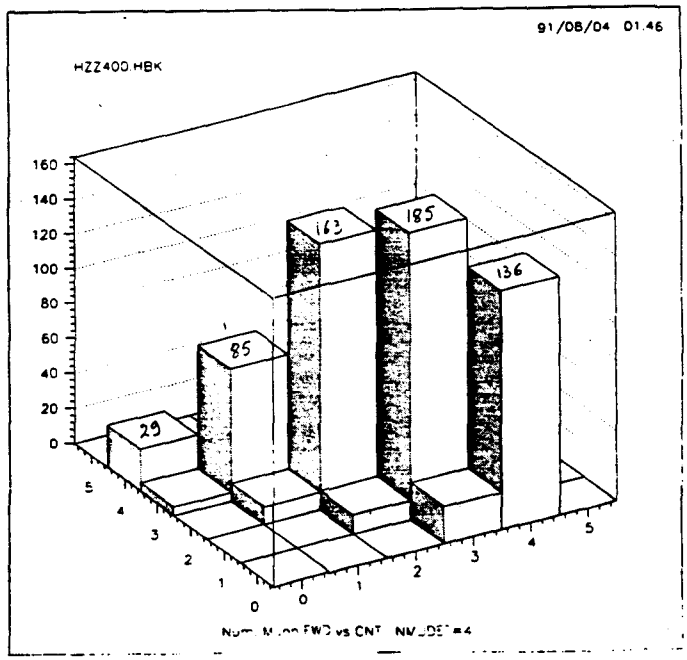


2066



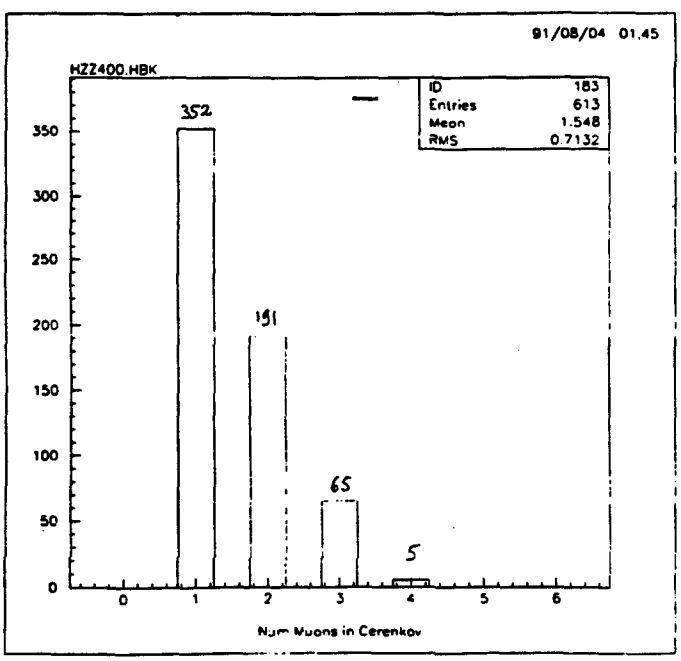
$H^0 \to Z^0 Z^0 \to 2\mu^+ 2\mu^-$
400 GeV





Cerenkov: $H \to ZZ \to 4\mu$

≥ 1 Muon	→	61.3%	= 35.2 + 19.1 + 6.5 + 0.5
≥ 2	→	26.1 %	= 19.1 + 6.5 + 0.5
≥ 3	→	7.0%	= 6.5 + 0.5
= 4	→	0.5%	



Summary and Conclusions

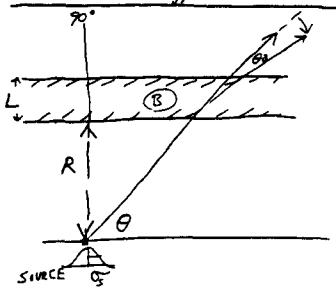
- Muon software in "good shape" for simulation studies
  Punch-through needed to implement
- Momentum resolution
  $\frac{\Delta P}{P} \approx 20\ \%$ for 200 μm chamber resolution
- Acceptance
  No forward muon detector is a bad idea (Higgs, Z')
  Čerenkov can be quite useful
- Need your input (and others) for more simulation

3

R. THUN
1 AUG 91

Recalculate trigger resolution effects

2071



$$\theta_B = \frac{0.3BL}{p\sin\theta}$$

$$\delta\theta_s \approx \frac{\sigma_s \sin\theta}{(R+L)/\sin\theta} = \frac{\sigma_s \sin^2\theta}{(R+L)}$$

$$\delta\theta_{MS} = \frac{.015}{p}\sqrt{X_{em}+X_{had}+X_{Fe}}$$

$$\cong \frac{.015}{p}\sqrt{\underset{\text{lead}}{30} + \underset{9\lambda\ Fe + \text{SCINT}}{90} + \underset{\text{TOROID}}{\frac{L/\sin\theta}{0.0176}}}$$

Particle momentum p

$P_\perp = p\sin\theta$

$\delta\theta_I \leftarrow$ intrinsic depends on drift ch. characteristics

assume $R = 7.24$
$L = 1.5$ $B = 1.8$
$\sigma_s = .05$

so, for 1.5 m TOROID

				$P_\perp$ at which $\delta\theta_s = \delta\theta_{MS}$
at 90°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0057$	$\delta\theta_{MS} = \frac{0.215}{P_\perp}$	38 GeV
at 45°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0029$	$\delta\theta_{MS} = \frac{0.164}{P_\perp}$	57 GeV
at 30°	$\theta_B = \frac{0.81}{P_\perp}$	$\delta\theta_s = 0.0014$	$\delta\theta_{MS} = \frac{0.128}{P_\perp}$	91 GeV

for 60m TOROID →

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$P_\perp$ for $\delta\theta_s = \delta\theta_{MS}$
90°	$0.54/P_\perp$	.0061	$0.199/P_\perp$	32.6 GeV
45°	↓	.0030	$0.250/P_\perp$	50.0
30°		.0015	$0.115/P_\perp$	76.7

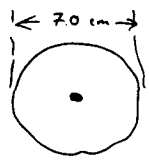
b) Cont.) 7 cm ID CELL
100 μm sense wire

90-10 A-CO_2

2073

3

X (cm)	V (cm/μsec)	V^2
0.5	4.5	20.25
1.0	4.6	21.16
1.5	4.4	19.36
2.0	3.6	12.96
2.5	2.6	6.76
3.0	2.2	4.84
3.5	1.8	3.24
sum	23.7	88.57



$$\frac{\delta V}{\langle V\rangle} = \frac{\sqrt{\langle V^2\rangle - \langle V\rangle^2}}{\langle V\rangle} = \frac{\sqrt{12.65 - 11.46}}{3.39} = \frac{1.10}{3.39} = 0.33$$

for 7 cm ID cell
100 μm wire

90-5-5 Ar-CO_2-CH_4

X (cm)	V (cm/μsec)	V^2
0.5	4.4	19.36
1.0	4.7	22.09
1.5	5.1	26.01
2.0	5.1	26.01
2.5	4.5	20.25
3.0	4.0	16.00
3.5	3.4	11.56
	31.2	141.28

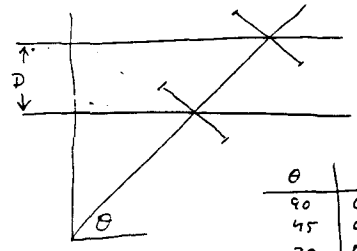
$$\frac{\delta V}{\langle V\rangle} = \frac{\sqrt{20.18 - 19.87}}{4.46} = \frac{0.56}{4.46} = 0.12$$

INTRINSIC TRIGGER RESOLUTION FROM CELLS

2

2072

a.) UNIFORM DRIFT VELOCITY (oriented, projective cells)



$$\delta\theta_I = \frac{\sqrt{2}\,\sigma}{D/\sin\theta}$$

for $\sigma = 0.3 \times 10^{-3}$ m
$D = 0.16$

θ	$\delta\theta_I$	$\delta\theta_I/\delta\theta_s$ (reduce as $\frac{1}{\sin\theta}$)
90	0.0019	0.33
45	0.0013	0.47
30	0.0009	0.66

b) For non-uniform velocities, Δt requirement introduces spread in θ measurement.

$$V = \frac{\Delta x}{\Delta t} \qquad \theta_M = \frac{\Delta x}{D/\sin\theta} = \frac{\langle V\rangle}{D/\sin\theta}\Delta t$$

average velocity over interval

$$\delta\theta_M = \frac{\delta V}{D/\sin\theta}\Delta t \qquad (\Delta t \text{ fixed})$$

$$\frac{\delta\theta_M}{\theta_M} \approx \frac{\delta V}{\langle V\rangle}$$

must take into account $V(x)$ dependence → non-Gaussian shape

$$\delta V \approx \sqrt{\frac{\int_0^d V^2 dx}{d} - \left(\frac{\int_0^d V dx}{d}\right)^2}$$

d = half-cell width

SUMMARY

2074

4

round tube: DRIFT VELOC 90-5-5 A-CO_2-CH_4

1.5 m toroid

$P_\perp = 20$ GeV/c — all angles in mr.

θ	BEND θ_B	SOURCE $\delta\theta_s$	MULT. SCATT $\delta\theta_{MS}$	CH. RES $\delta\theta_I$	$\delta\theta$ $\sqrt{(\delta\theta_s)^2+(\delta\theta_{MS})^2+(\delta\theta_I)^2}$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	40.5	5.7	10.8	1.9	12.4	0.31	0.12
45°	40.5	2.9	8.2	1.3	8.8	0.22	0.12
30°	40.5	1.4	6.4	0.9	6.6	0.16	0.12

$P_\perp = 40$ GeV/c

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	20.3	5.7	5.4	1.9	8.1	0.40	0.12
45°	20.3	2.9	4.1	1.3	5.2	0.26	0.12
30°	20.3	1.4	3.2	0.9	3.6	0.18	0.12

1.0 m toroid

$P_\perp = 20$ GeV/c — all angles in mr

θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	27.0	6.1	10.0	1.9	11.9	0.44	0.12
45°	27.0	3.0	7.5	1.3	8.2	0.30	0.12
30°	27.0	1.5	5.8	0.9	6.1	0.23	0.12

$P_\perp = 40$ GeV/c

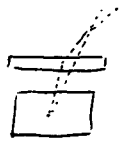
θ	θ_B	$\delta\theta_s$	$\delta\theta_{MS}$	$\delta\theta_I$	$\delta\theta$	$\frac{\delta\theta}{\theta_B}$	$\frac{\delta V}{V}$
90°	13.5	6.1	5.0	1.9	8.1	0.60	0.12
45°	13.5	3.0	3.8	1.3	5.0	0.37	0.12
30°	13.5	1.5	2.9	0.9	3.4	0.25	0.12

#4

G. Feldman

2075

Level 1 μ trigger



The polar angle difference between an infinite momentum track and the actual track is measured locally by the time difference on projective wires.

4 sets of pairs of projective wires.

Resolution: 1m-thick toroid $\frac{530\,mr}{P_t}$

1) Multiple scattering in calorimeter and toroid $\sim \frac{180\,mr}{P_t}$

2) Beam spot length 5 mr (10 mr ?)

3) Finite size of chambers 2-4 mr

4) Tracks crossing on wrong side of wires

Eliminated by coincidence of pairs

5) Chamber resolution 1-2 mr

2076

Toy model:

Gaussian errors due to scattering and beam size.

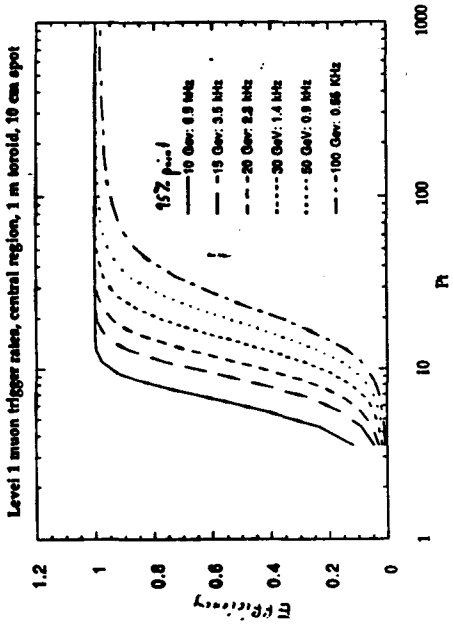
Rates taken as 100x Hoelin and Green, Fermilab 90/18 + NIM

rough agreement with Paige, Berkeley Trigger Workshop

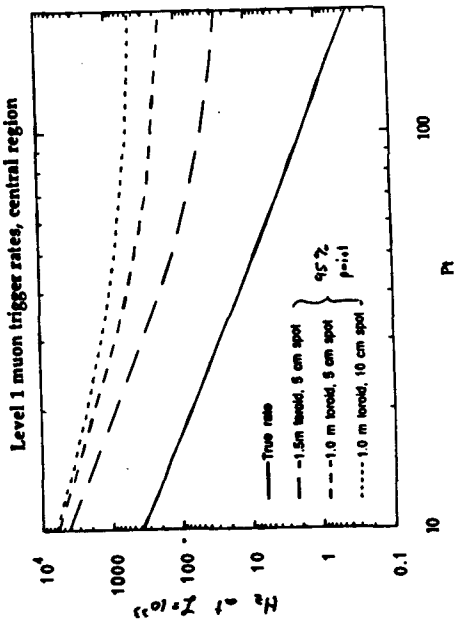
and Della Negra et al, CERN/DRDC/90-36

Processes: cab decay, light quark decay

2077



2078



5

L1 Muon Trigger Study *

Tianchi Zhao

Univ. of Washington

8-5-91

- Trigger Logic
- Toriod Thickness
- Size of Interaction Region
- Non-linear x-t

* Simulation based on R. Thun & A. Simon's earlier study

L1 Muon Trigger Simulation

Tianchi Zhao and Zhong Jin
University of Washington
August 4, 1991

The performance of the level-1 muon trigger using drift chambers is studied. We use the work done by R. Thun and A. Simon [SDC-91-00020] as our base model. Effects such as the size of the interaction region, the iron toroid thickness, non-linear x-t relations and different trigger requirements are investigated. The multiple scattering and toroid deflection are parameterized and calculated in 5 cm steps. We plan to also include the drift chamber resolution and trigger electronics resolution in future studies.

Drift tubes are arranged in 8 cm × 8 cm matrices. The maximum barrel length is 16 meters. The first section of calorimeter (0.7 meters) is assumed to be lead instead of iron. Other parameters are very similar to that used by Thun and Simon. We define the beam direction as z-coordinate in our study. For 1.5 meter toroid thickness, δz cuts of 3mm, 5mm and 10mm correspond to nominal P_t thresholds of 40, 25 and 12 GeV/c.

The P_t trigger threshold depends on θ for a fixed δz cut. We can consider three cases:

- As assumed by Thun/Simon, the distance between chamber layers is fixed and the drift direction in drift tubes is the beam direction. In this case

$$Pt_{threshold} \propto \delta z \times sin^2\theta$$

  Fig. 1 shows the comparison between a fixed cut of δz = 3mm and a variable δz cut of 3mm/$\sin^2\theta$. The softening of the trigger threshold due to the $1/\sin^2\theta$ dependence is obvious.

- If the drift field is tilted as most the drift chamber options under consideration, we have

$$Pt_{threshold} \propto \delta z \times sin\theta$$

  Fig. 2 shows the comparison between a fixed cut of δz = 3mm and a variable δz cut of 3mm/$\sin\theta$.

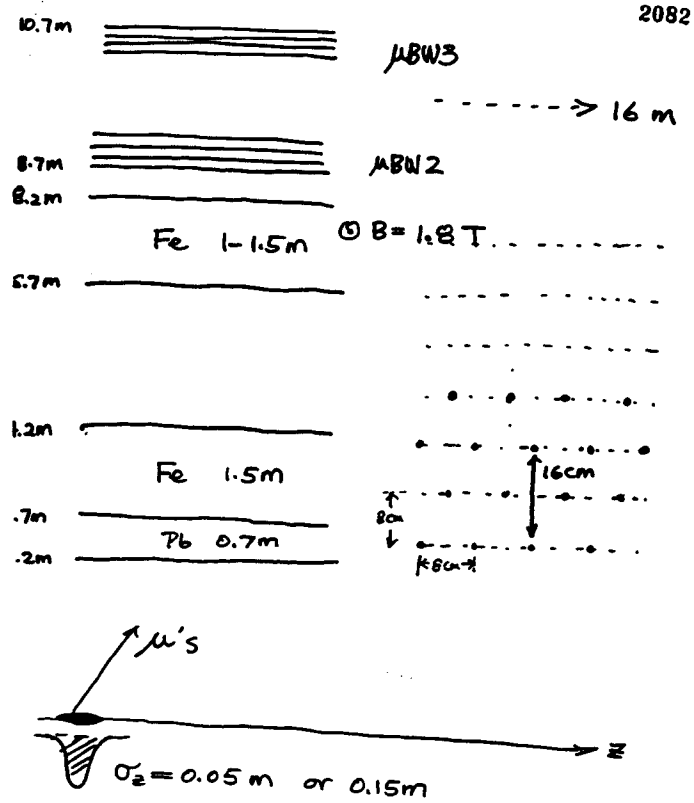
- If the drift field is tilted and also the distance between wire pairs for making trigger decisions is fixed, we then do not have such an angular dependence.

It is possible to design trigger electronics to accommodate this θ dependence using the Xilinx FPAG.

In fig. 3, trigger efficiency curves are given for three different toroid thicknesses, 1.5, 1.2 and 1.0 meters. The δz cut (Pt thresholds) have been adjusted to approximately 40 GeV/c for all three cases. The difference between 1.2m and 1.5m toroids is small. The 1m thick toroid performs much worse.

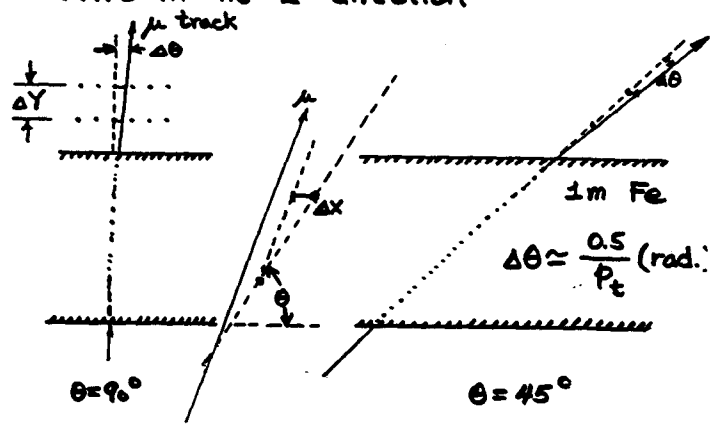
Effects of the size of the interaction region is shown in fig. 4 and 5. One of the two curve in each plot is produced by assuming that σ_z = 5 cm and the other curve is σ_z = 15cm. In fig. 4, the toroid thickness is 1.5 m and it is 1 m in fig. 5. Again, the δz cut is adjusted to 40 GeV/c. The consequence for 1m thick toroid if the interaction region is grown to σ_z = 15cm is disastrous.

Non-linear drift velocity is introduced in fig. 6. Cylindrical drift tube (without field shaping) and Ar-CO2-CH4 90-5-5 gas mixture are assumed. For comparison, fig. 7 shows the trigger efficiency curves without the non-linear drift velocity assumption. As expected, the non-linear drift speed slows down the rise of efficiency curves but not in a significant fashion.



Case 1:

- Tubes arranged as equally spaced layers
- Drift in the z-direction



$$\Delta\theta \simeq \frac{0.5}{P_t}\ (\text{rad.})$$

$$\Delta x = \Delta\theta\left(\frac{\Delta Y}{\sin\theta}\right)\cdot\frac{1}{\sin\theta} \cong \frac{\Delta Y}{P_t}\cdot\frac{1}{\sin^2\theta}$$

For the chamber systems under consideration in muon group,

$$\Delta Y \sim 20\text{cm}$$

$$\Delta x \simeq \frac{10}{P_t}\,\frac{1}{\sin^2\theta} \qquad (P_t \text{ in GeV/c})$$

Δx (cm) \ θ / P_t GeV	90°	75°	60°	45°	30°	Rate
10	1.00 (200ns)	1.07	1.33	2	4 (800ns)	<10kHz ?
50	0.2	0.21	0.27	0.4	0.8	<100Hz ?

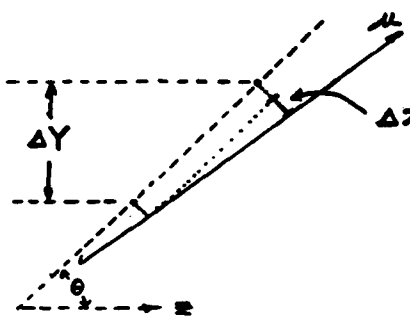
Trigger electronics measure: $\Delta T = \dfrac{\Delta x}{v_{drift}}$

For fixed P_t threshold: $\Delta T \propto \dfrac{1}{\sin^2\theta}$

ΔT trigger threshold has to be different at different θ

Case 2:

- Tubes arranged as equally spaced layers
- But drift in θ-direction



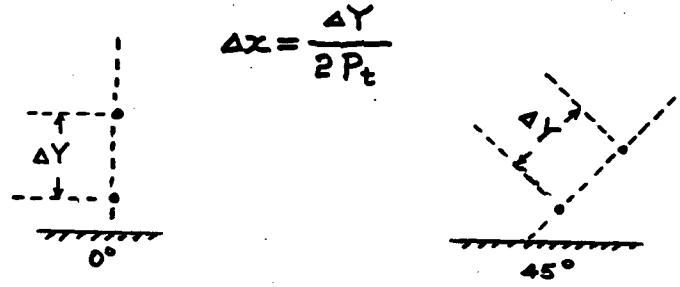
$$\Delta x = \Delta\theta\,\frac{\Delta Y}{\sin\theta} = \frac{\Delta Y}{2P_t}\cdot\frac{1}{\sin\theta}$$

Δx (cm) \ θ / P_t (GeV)	90°	75°	60°	45°	30°
10	1. (200ns)	1.04	1.15	1.41	2. (400ns)
50	0.2	0.21	0.23	0.28	0.4

Case 3: ("Boston Scheme")?

- Distance between trigger pair $= \Delta Y \cdot \sin\theta$
- Drift in θ-direction

$$\Delta x = \frac{\Delta Y}{2P_t}$$



Δx (cm) \ θ / P_t (GeV)	90°	75°	60°	45°	30°
10	1 (200ns)	1	1	1	1
50	0.2 (40ns)	0.2	0.2	0.2	0.2

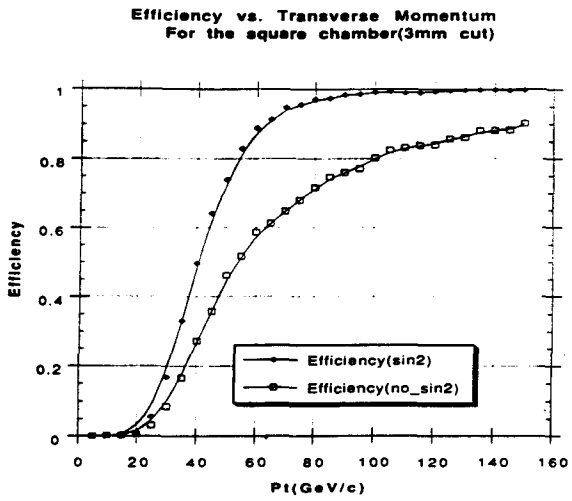


Fig. 1

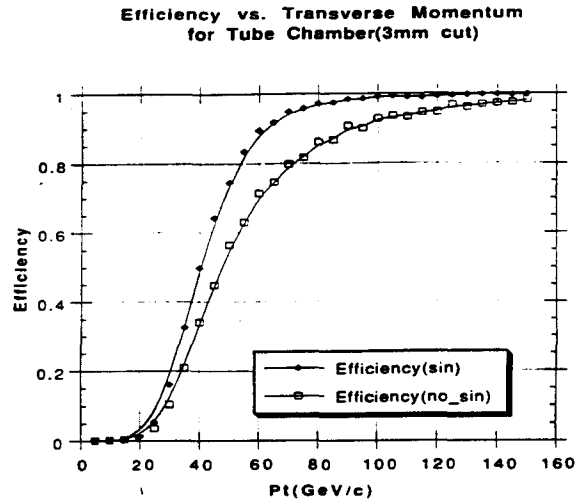


Fig. 2

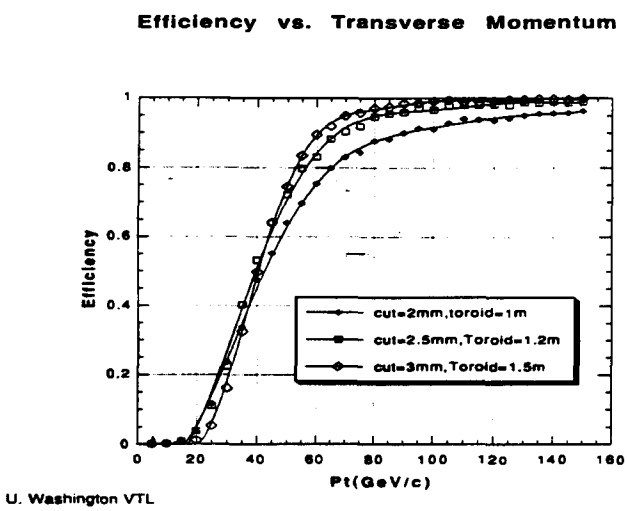


Fig. 3

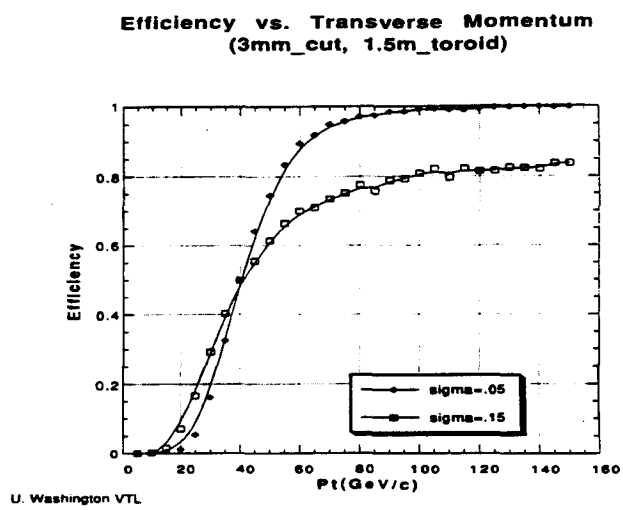


Fig. 4

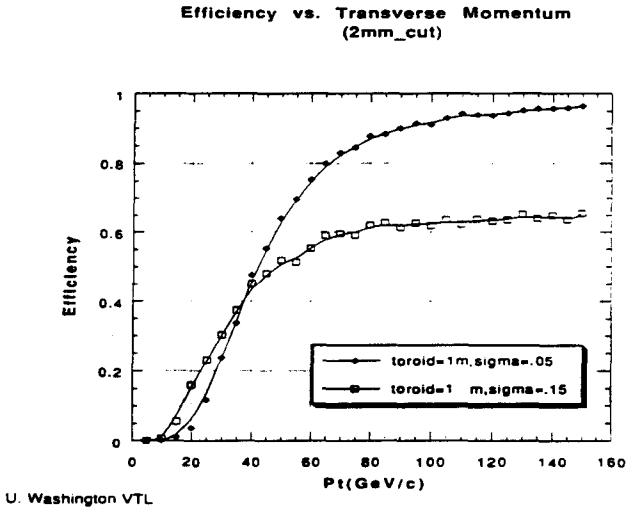


Fig. 5

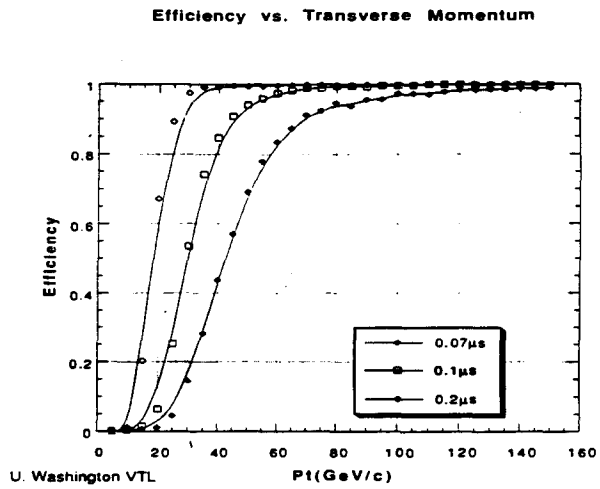


Fig. 6

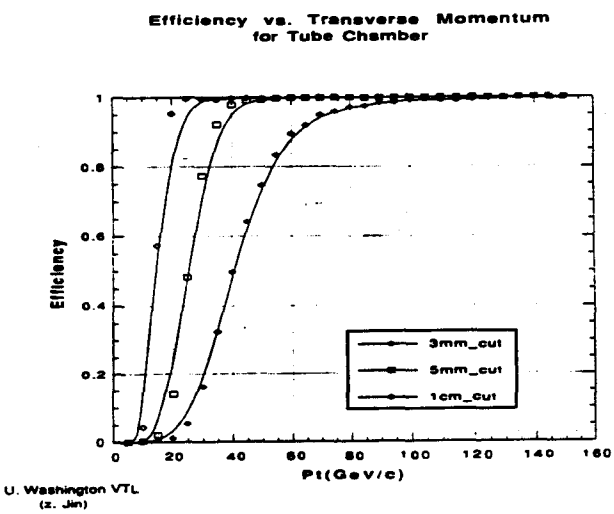


Fig. 7

#6 S. BEHREND:

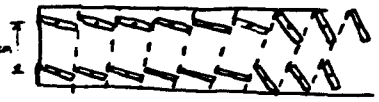
TRIGGER RES'N STUDY — THETA WIRES

- EXAMINE "LOCAL" (WITHIN 1 SUPERMODULE) ... + "GLOBAL" (2 SUPERMODULES; BEFORE + AFTER TOROID) TRIGGERS.
- USE ISAJET ($H \to \gamma\gamma$) + BOSSIM (HOME-BREW SIM'N)

INCLUDE: M. SCATT.
BEND IN COIL, CAL., TOROID
M-CHAMBER HITS
CHAMBER RES'N
WIRE PLACEMENT ERROR + SAG

LOCAL TRIGGER:

TRIGGER IN SUPERMODULE:



TRIGGER P_T: $P_T = \frac{0.3 \cdot B_{TOR} \cdot T_{TRG}}{\delta\theta}$

$\delta\theta = \frac{|drift(1) - drift(2)|}{26\,cm}$; $\sin\theta_{TRG}$

GLOBAL TRIGGER:

TO ABOVE IN BW1 + BW2

THE [illegible] ...NOT SO SIMPLE: TWO SOLUTIONS. PUNT AT PRESENT!)

2095

LOCAL TRIGGER

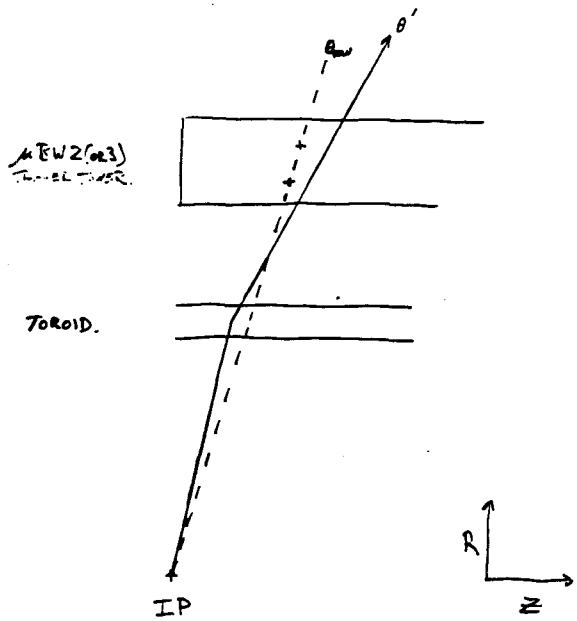
LOCAL ANGLE : $\delta\theta = \theta' - \theta_{TOW}$ (AFTER TOROID)

→ ASSUMES PRE-BEND μ HAD $\theta = \theta_{TOW}$

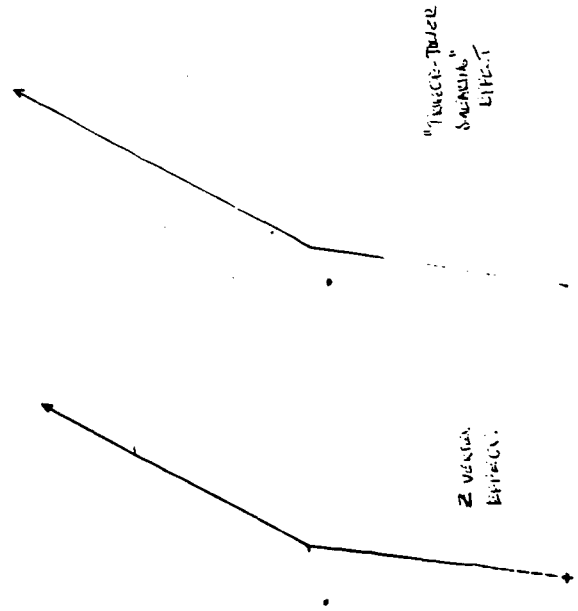
THIS HAS TWO CONSEQUENCES:

→ COUPLES TO Z VERTEX

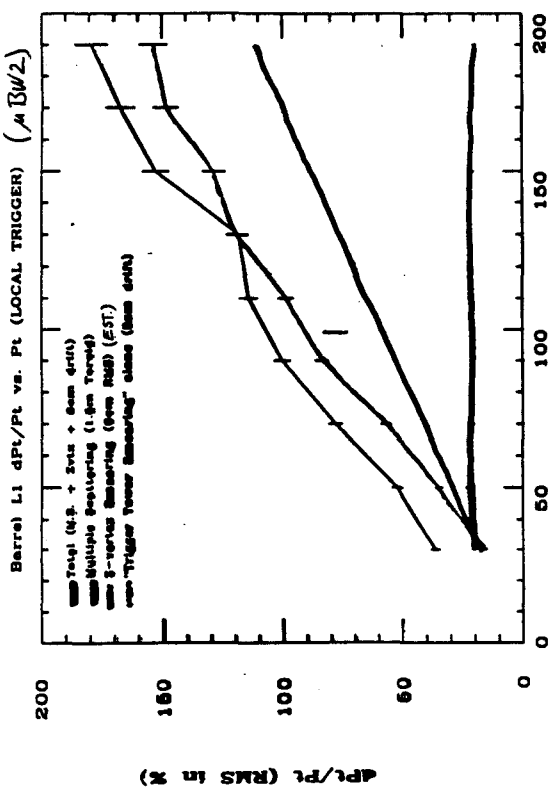
→ "TRIGGER TOWER SMEARING" (FINITE TOWER SIZE)



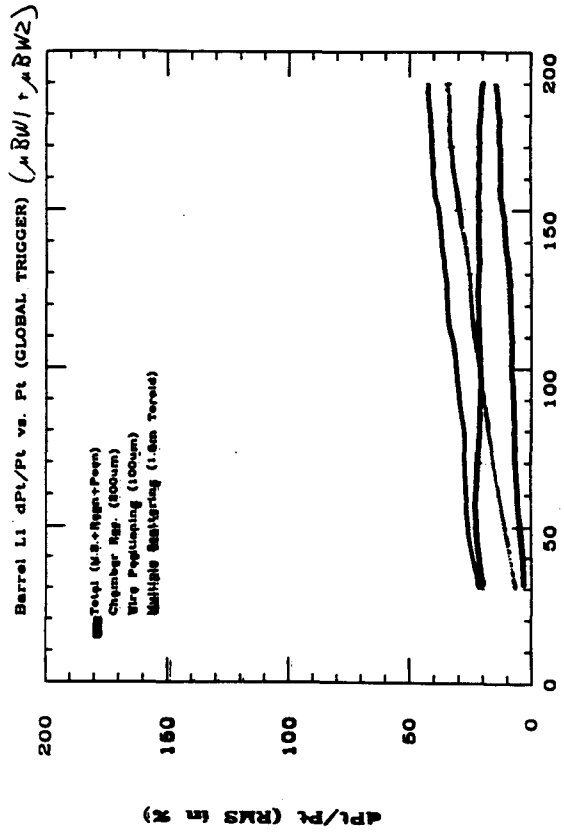
2096

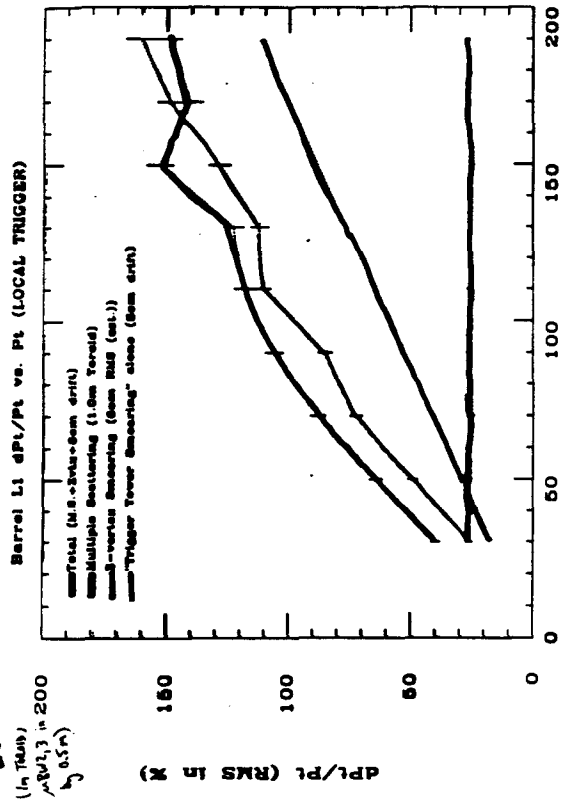


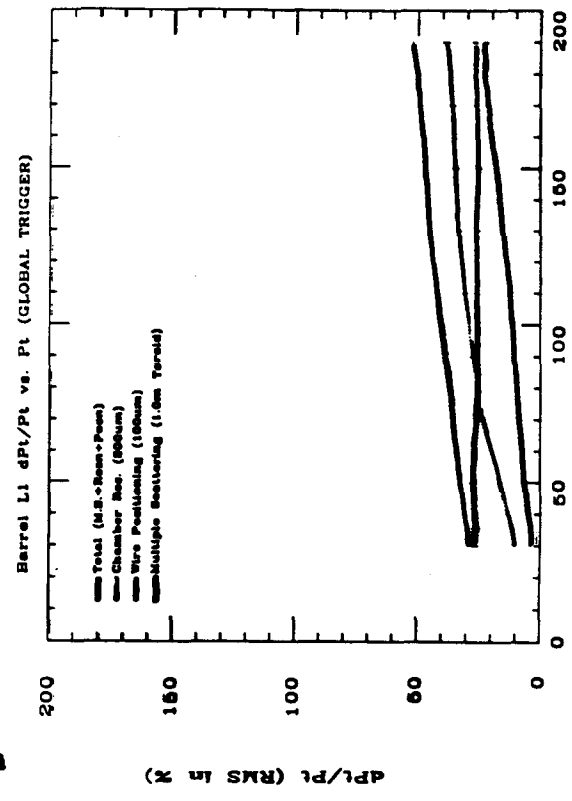
2097



2098

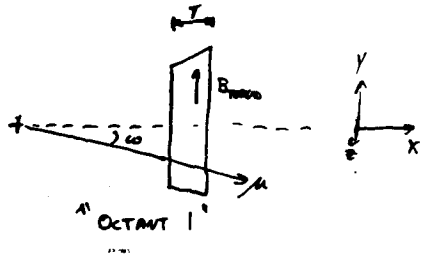






BENDING IN THE TOROIDS

COORDINATE SYSTEM:



BEFORE TOROID

$$\vec{P} = P\,(\sin\theta\cos\omega,\ \sin\theta\sin\omega,\ \cos\theta)$$

$$\equiv (P_x, P_y, P_z)$$

AFTER TOROID

$$\vec{P}' = (P_x\cos\delta - P_z\sin\delta,\ P_y,\ P_x\sin\delta + P_z\cos\delta)$$

δ: BEND-ANGLE IN (x,z) PLANE

$$\delta \cong \frac{0.3BT}{P_T\cos\omega}$$

7

V. Molchanov
IHEP, Protvino

Study of the muon trigger efficiency

Study of the muon trigger efficiency for Higgs, Z' and t-quark production has been carried out. ISAJET was used for simulation of the Higgs and t-quark generation, PYTHIA was used for simulation of Z' and associate Higgs generation.

First geometrical efficiency was determined. It was required that all muons should be in pseudorapidity range $|\eta_\mu| < 2.5$ and all electrons should be in pseudorapidity range $|\eta_e| < 3$. Events which passed specified conditions are called reconstructible, and trigger efficiency was determined with respect to these reconstructible events. For the trigger to take place it was necessary for at least one muon with P_T more than threshold value to be in the predefined pseudorapidity range ($|\eta_\mu| < 1.0, 1.5, 2.0, 2.5$).

Results for the 400 and 800 GeV Higgs boson are shown in Fig. 1, for 150 GeV Higgs — in Fig. 2. When analysing geometrical efficiency for associate Higgs production only muon from $W \to \mu\nu$ decay was taken into account. Results for Z' and t-quark are shown in Fig. 3. When analysing t-quark production only the muon from $t \to b\mu\nu$ decay was taken into account. Subset of efficiencies for these processes with $|\eta| = 1.5, 2.5$ and $P_T = 15, 20$ GeV is presented in Table 1.

Some further study has been done in connection with Z' asymmetry measurement. P_T threshold does not play any role here, so question only in η range. Distribution of events over $\eta_{\mu^-} - \eta_{\mu^+}$ for 1 TeV Z' is shown in Fig. 4. Events which lie in a large square ($|\eta_\mu| < 2.5$) are reconstructible. Events which lie in four small squares ($1.5 < |\eta_\mu| < 2.5$) represent trigger inefficiency. In the same figure events which also passed additional requirements $|\eta_{Z'}| > 2$ and $|\cos\theta^*| > 2/3$ (θ^* is an angle between directions of motion of μ^- and Z' in Z' rest system) are shown. Both these conditions strengthen the degree of asymmetry, but don't affect significantly trigger efficiency (see Table 2).

Distributions over $\cos\theta^*$ for 1 TeV Z' with different selection criteria are shown in Fig. 5. It is clear from the last two pictures that trigger inefficiency does not change measured asymmetry value (possible change is no more than $\simeq 0.2\%$). Results for 4 TeV Z' are similar and may be found in Fig. 6-7.

Comparing trigger efficiencies in the Table 1 we can see that either reduction trigger range from $|\eta| = 2.5$ to $|\eta| = 1.5$ or increase of P_T threshold from 15 to 30 GeV has substantial effect on following processes: $H(150) \to 2\mu 2e$, associate Higgs and t-quark production, and relatively small effect on other processes. That leaves some questions which require further investigations:

- electron trigger efficiency for $H(150) \to 2\mu 2e$ process
- other possibilities for the trigger on associate Higgs production
- possible effects on the detailed determination of t-quark properties

Also it is interesting to point that while forward muon system plays a crucial role in Z' asymmetry measurement forward muon trigger makes no essential improvement.

Physical Process	Geom. Eff	$p_t > 15GeV$		$p_t > 30GeV$	
		$\lvert\eta\rvert < 1.5$	$\lvert\eta\rvert < 2.5$	$\lvert\eta\rvert < 1.5$	$\lvert\eta\rvert < 2.5$
$H(400) \to 4\mu$	0.621	0.980	1.000	0.974	1.000
$H(400) \to 2\mu 2e$	0.676	0.888	1.000	0.877	1.000
$H(800) \to 4\mu$	0.757	0.969	1.000	0.969	1.000
$H(800) \to 2\mu 2e$	0.813	0.864	1.000	0.861	1.000
$H(150) \to 4\mu$	0.500	0.948	1.000	0.862	1.000
$H(150) \to 2\mu 2e$	0.548	0.828	0.986	0.574	0.721
$H(150)(W \to \mu\nu)$	0.739	0.607	0.946	0.495	0.774
$Z'(1000) \to 2\mu$	0.710	0.894	1.000	0.894	1.000
$Z'(4000) \to 2\mu$	0.896	0.966	1.000	0.966	1.000
$t(150) \to b\mu\nu$	0.819	0.648	0.941	0.519	0.750
$t(250) \to b\mu\nu$	0.672	0.661	0.930	0.570	0.801

Table 1: Muon trigger efficiency (review)

Restrictions	Geom Eff.	$\lvert\eta\rvert < 1.5$
$M_{Z'} = 1TeV$	0.710	0.894
$\lvert\eta_{Z'}\rvert > 3$	0.407	0.847
$\lvert\cos\theta\rvert > 2/3$	0.210	0.943
$\lvert\eta_{Z'}\rvert > 3$ $\lvert\cos\theta\rvert > 2/3$	0.099	0.974
$M_{Z'} = 4TeV$	0.896	0.966
$\lvert\eta_{Z'}\rvert > 3$	0.613	0.978
$\lvert\cos\theta\rvert > 2/3$	0.318	0.939
$\lvert\eta_{Z'}\rvert > 3$ $\lvert\cos\theta\rvert > 2/3$	0.209	0.963

Table 2: Muon trigger efficiency to Z'

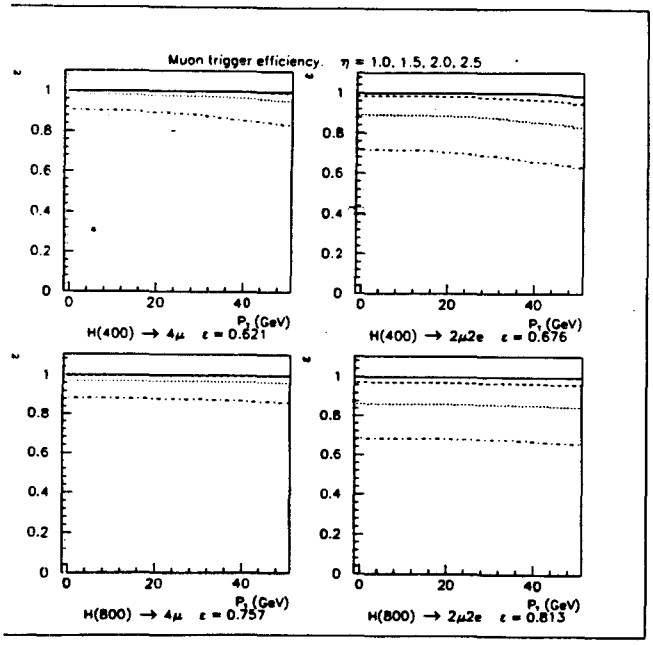


Fig. 1.

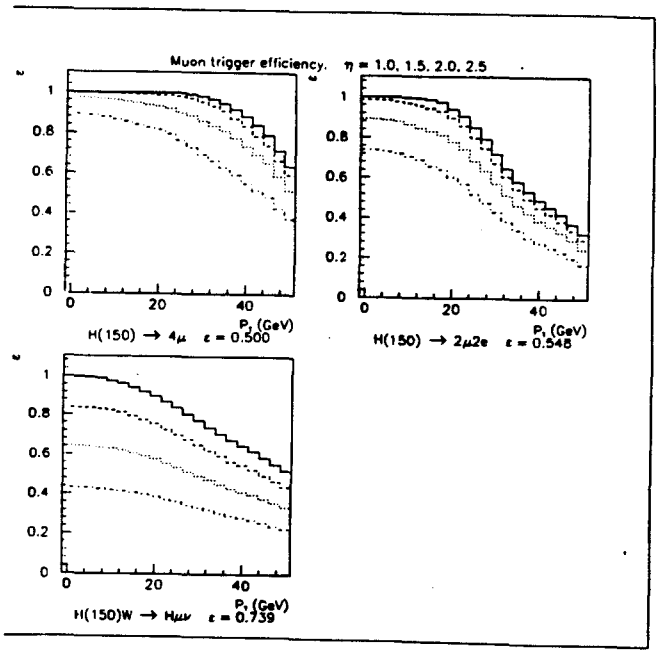


Fig. 2

2107

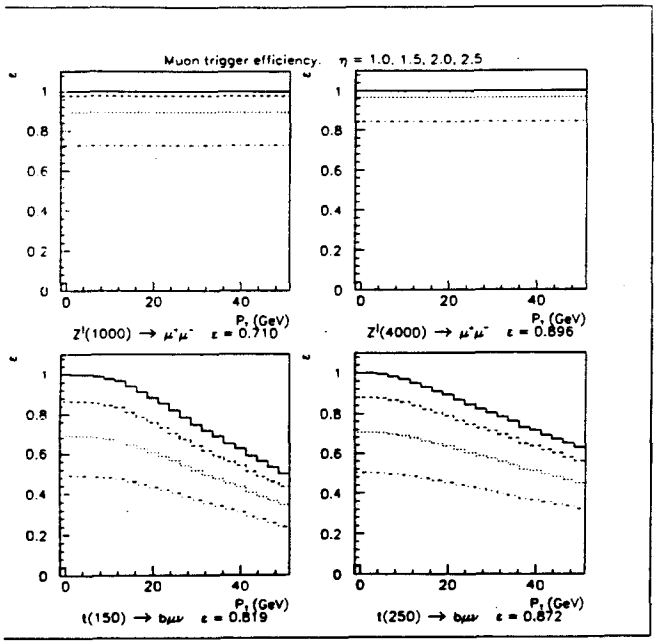


Fig. 3

2108

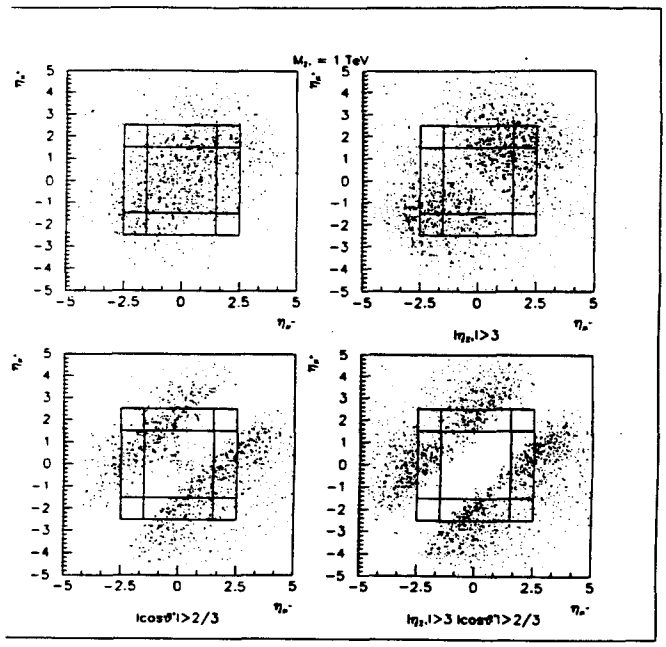


Fig. 4

2109

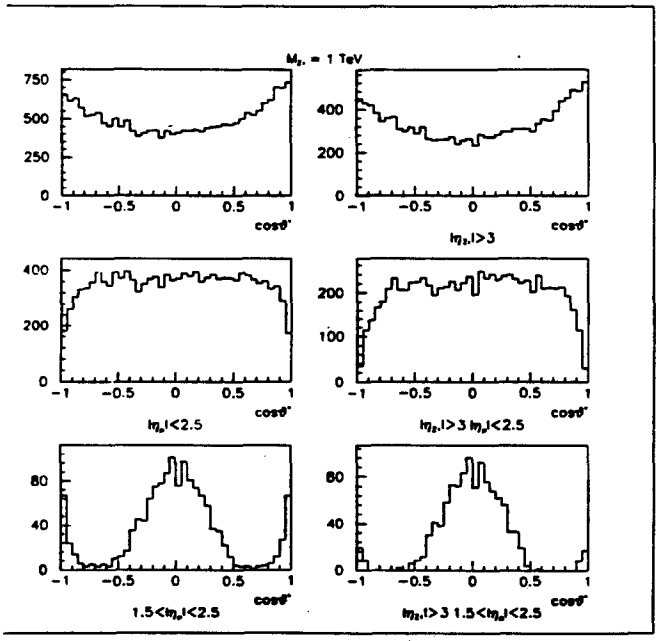


Fig. 5.

2110

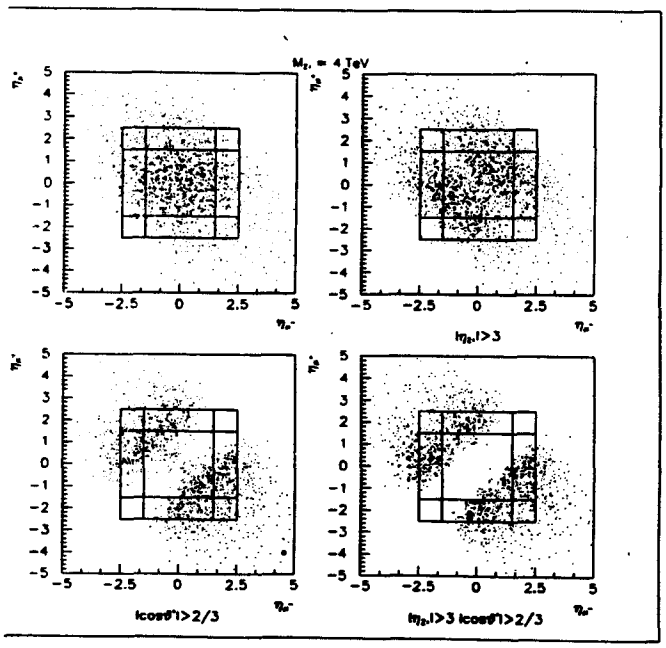


Fig. 6.

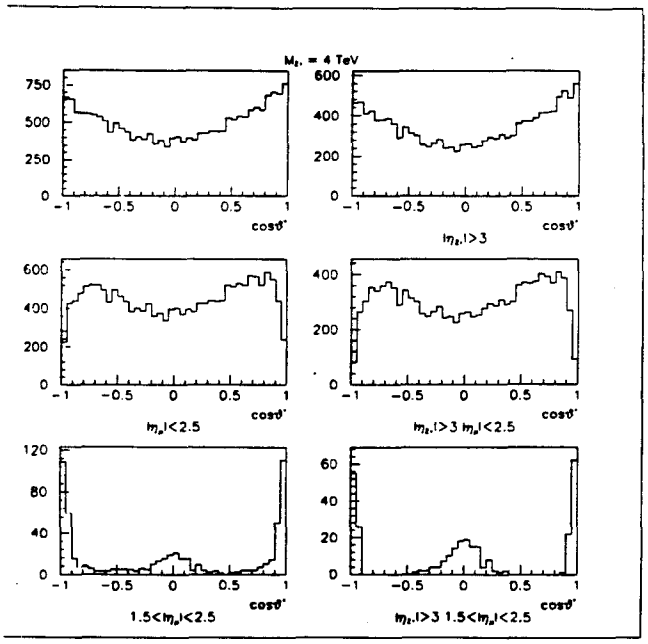


Fig. 7.

8

Muon Trigger & Electronics

Aug. 1991, Yasuo Arai (KEK)

I. μ Level 1 Trigger
Deflection Angle, Trigger Electronics, Efficiency

II. μ Level 2 Trigger
BWC1 - BWC2 Matching, Isolated μ
Electronics, Cabling

Muon Trigger Signature (Barrel)

- Timing + Pt : Scintilator Trigger
- Bending Angle : Slope of Track (Cell Trig., Layer Trig., Layer/Layer Trig.)
- Pt : Measure Bending Angle in Toroid
- φ matching : μ Track matching with CTC.
- Isolation: μ Track and Calorimeter Matching

Bending Power

•Toroid (1.8T,1m): $\beta = \frac{540\ (\text{mrad})}{Pt\ (\text{GeV/c})}$

$= \frac{810\ (\text{mrad})}{Pt\ (\text{GeV/c})}$ (for 1.5m)

•Solenoid (2T, 1.8m) : $\frac{\beta}{2} = \frac{540\ (\text{mrad})}{Pt\ (\text{GeV/c})}$

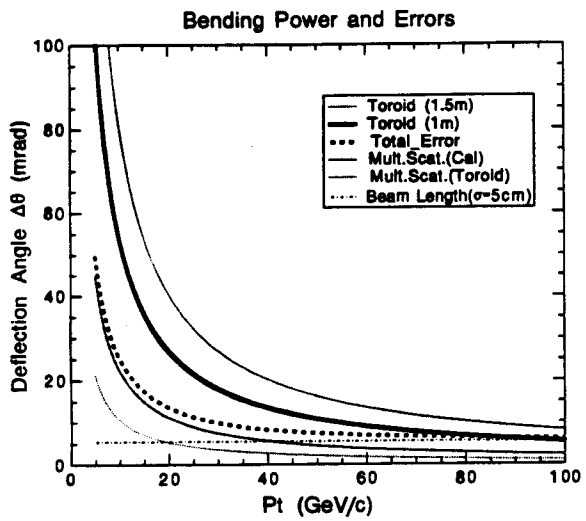
Source of Error

•Beam Length (±5cm) : 5.5 $\sin^2\theta$ (mrad)

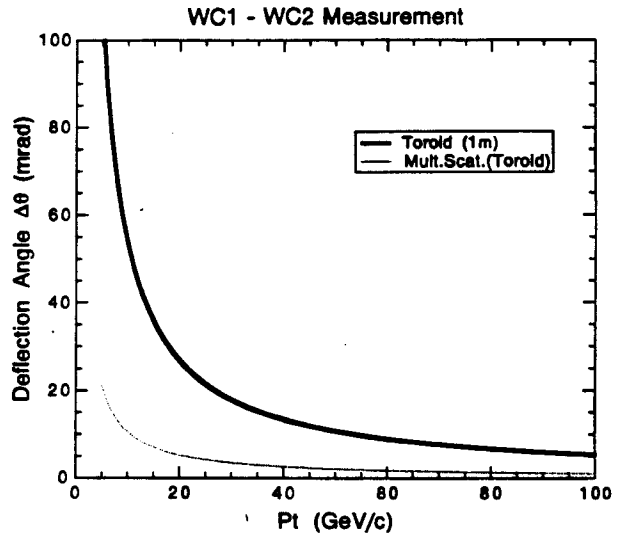
•Multi. Scatt. (256X_0 Cal) : 224 (mrad) / Pt (GeV/c)

•Multi. Scatt. (57X_0 Toroid) : 106 (mrad) /Pt (GeV/c)

2115



2116



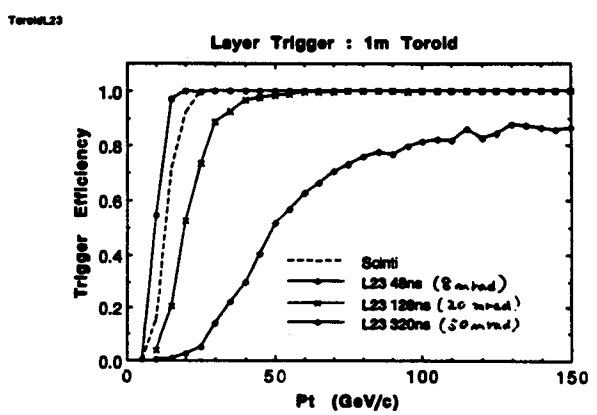
2117

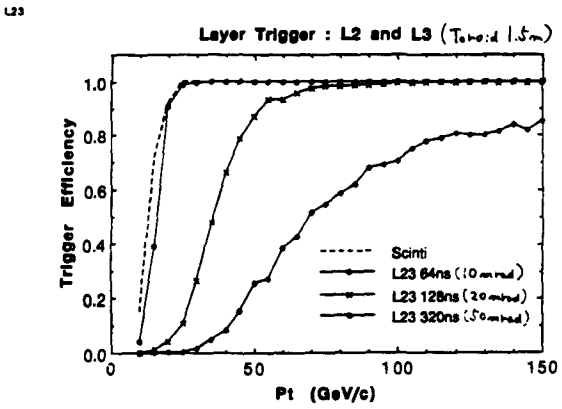
<u>Trigger Sensitivity</u>

- Scinti Trig. : $\frac{15\text{ cm}}{2\text{ m}} = 75$ (mrad)
- Cell Trig. : $\frac{0.5\text{ mm}}{1\text{ cm}} = 50$ (mrad)
- Layer Trig. : $\frac{1\text{ mm} \times \sin\theta}{16\text{ cm}} = 6 \sin\theta$ (mrad)
- WC2/WC3 Trig. : $\frac{1\text{ mm} \times \sin\theta}{1.5\text{ m}} = 1 \sin\theta$(mrad)
- WC1/WC2 Trig. : $\frac{1\text{ mm} \times \sin\theta}{1.5\text{ m}} = 1 \sin\theta$(mrad)
- ϕ Trig. : 1 CTC Layer $= \frac{250\ \mu\text{m}}{8\text{ mm}} = 31$ (mrad)

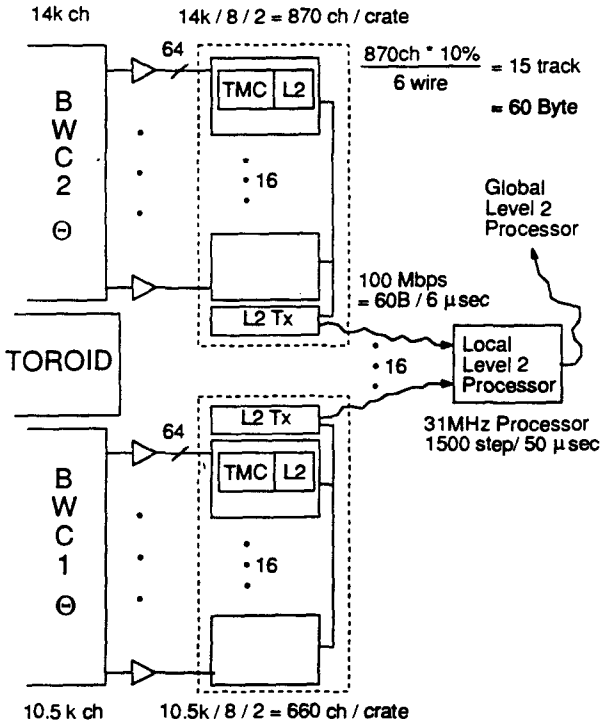
  2 CTC Layer $= \frac{1\text{ mm}}{15\text{ cm}} = 7$ (mrad)

21

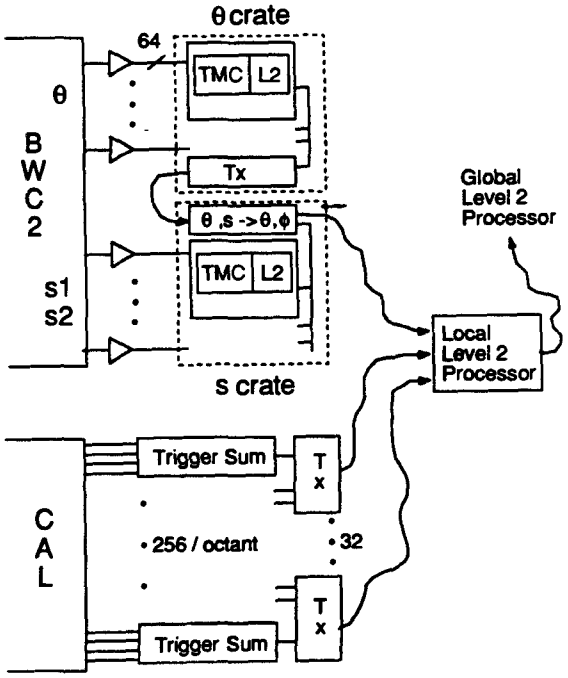




L2 : BWC1 - BWC2 Track Matching



L2 : BWC2 θ,s - Calorimeter Matching



•Isolation :

WC1 Layer Trig (r=7m, $\Delta\theta = 6 \sin\theta$ mrad)

--> r=2m interpolation

$$\Delta x = 6 \sin\theta \text{ mrad} \times \frac{5 \text{ m}}{\sin\theta} = 3 \text{ cm}$$

for Trigger Tower ($\Delta\eta \times \Delta\phi = 0.1 \times 0.1$)

$\Delta r \sim 20$ cm

Hiro Iwasaki (KEK)
SDC Collab @ LBL
5-10 / Aug / 91

I. Momentum Resolution with/without BWC1

I-1. σ_{P_t}/P_t with BWC1, BWC2 and BWC3

I-2. σ_{P_t}/P_t without BWC1

I-3. Summary of the momentum resolution

II. Prompt μ rates — Review —

II-1. Motivation

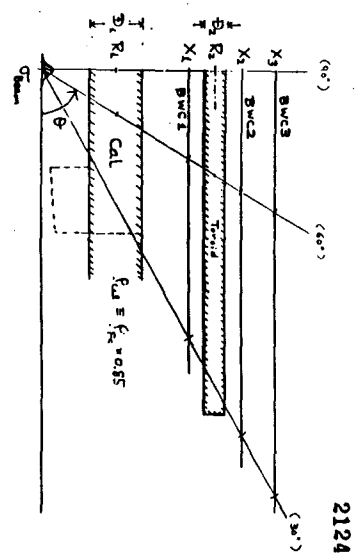
II-2. Compilation

① F. Paige, Trigger Workshop, Fermilab, 1985
② Y. Sakai, Solenoidal Detector Workshop, KEK, 1990
③ D. Green, D. Hedin, NIM A297 (1990) 111.
④ A. Nisati, LHC Workshop, Aachen, 1990
⑤ J.R. Cudell et al, LHC Workshop, Aachen, 1990

II-3. Summary of the prompt μ rates

I. Momentum Resolution with/without BWC1

Definition of parameters



BWC1, BWC2 and BWC3 ...

Chambers : "projective geometry"
dE/dx : not considered
B_z in the tracking/calorimeter region : not considered.

$$\boxed{\frac{\sigma_{P_t}}{P_t} = \frac{P_t}{\mathfrak{L}B_z}\left[\Delta u^2 \Theta \frac{R_1}{\Delta\Delta(\sigma)} + \theta_s^2\left(1+\frac{\Theta_s^2}{12}\left(\frac{R_2}{\Delta\Delta(\sigma)}\right)^2\right)\right]^{1/2}}$$

$$\theta_s = \frac{0.014}{P}\sqrt{\frac{d_s/\Delta u\Theta}{X_0}}$$

$$P_t\theta_s = \sqrt{\Delta u\Theta}\cdot 0.014\sqrt{\frac{\Theta_s}{X_0}} \propto \sqrt{\Delta u\Theta}$$

$$\Delta\Delta(\sigma) = [1]_{F+B}[x^2]_F[x^2]_B - [x]_F^2[x^2]_B - [x^2]_F[x]_B^2$$
$$R_1 = [1]_{F+B}[x^2]_{F+B} - [x]_{F+B}^2$$
$$R_2 = [1]_F[x^2]_F[x]_B + [1]_B[x]_F[x^2]_B - [x]_{F+B}[x]_F[x]_B$$

$$[f]_F \equiv \sum_{i=1}^{m}\frac{1}{\sigma_i^2}f(x_i)$$

$$[f]_B \equiv \sum_{i=m+1}^{N}\frac{1}{\sigma_i^2}f(x_i)$$

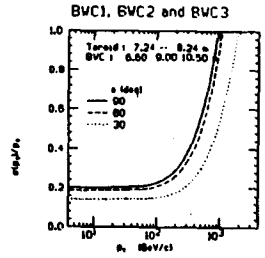
$$[f]_{F+B} \equiv [f]_F + [f]_B = \sum_{i=1}^{N}\frac{1}{\sigma_i^2}f(x_i)$$

σ_i : rms position resolution at x_i (perpendicular to the track)

$B_z = 1.8$ tesla

$\mathfrak{L}B_z = 0.54$ (m^{-1} · GeV/c)

Note: The origin of the x-coordinate is the center of the main toroid.



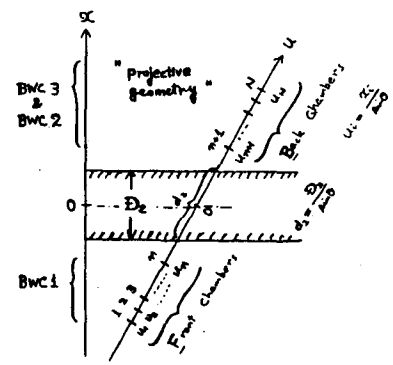
Toroid 7.24 - 8.24, $D_z = 1$ m
BWC1 6.6 m
BWC2 9.0 m
BWC3 10.5 m
$X_3 - X_2 = 1.5$ m
$\sigma = 200\ \mu m$ (per superwire)

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t\cdot\Delta u\Theta\cdot 1.044\times10^{-3}\right)^2 + \left(\sqrt{\Delta u\Theta}\ \ 0.2012\right)^2\right]^{1/2}$$

P_t (GeV/c)		
193	90°	
207	60°	
272	30°	

$\theta \backslash P_t$ (GeV/c)	20	50	100	200
90°	0.203	0.209	0.227	0.290
60°	0.188	0.193	0.208	0.260
30°	0.143	0.145	0.152	0.176

I-1. σ_{P_t}/P_t with BWC1, BWC2 & BWC3

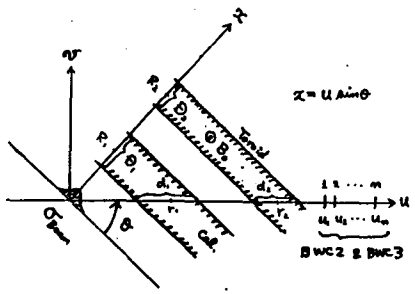


$\frac{\sigma_P}{P}$ = (function of u_i's)

$x_i = u_i\ \Delta u\Theta$

$\frac{\sigma_{P_t}}{P_t}$ = (function of x_i's)

I-2. σ_{P_t}/P_t without BWC1



Behind the Toroid : at $u = u_i$

$$v_i = \sigma_{Beam}\Delta u\Theta\cdot z_1 + \frac{d_1\theta_1}{\sqrt{12}}z_2 + (u_i - r_1)\theta_1 z_3 + \frac{d_2\theta_2}{\sqrt{12}}z_4 + (u_i - r_2)\theta_2 z_5 - \frac{\mathfrak{L}B_z d_3}{P}(u_i - r_3) + \sigma_i z_{(i)}$$

z_j ($j = 1 \sim 5$), $z_{(i)}$:
Gaussian random variable with mean zero and variance one.
$(\langle z_j\rangle = 0,\ \sigma_{z_j}^2 = 1\ ;\ \langle z_{(i)}\rangle = 0,\ \sigma_{z_{(i)}}^2 = 1)$

$$\theta_1 = \frac{0.014}{P}\sqrt{\frac{d_1}{X_0}},\quad \theta_2 = \frac{0.014}{P}\sqrt{\frac{d_2}{X_0}}$$

σ_i : position resolution at $u = u_i$

to fit these points with

$$v = \phi' u - \frac{\mathfrak{L}B_z d_3}{P}(u - r_3)$$

$\frac{\sigma_P}{P}$ = (function of u_i's)

$x_i = u_i\ \Delta u\Theta$

$\frac{\sigma_{P_t}}{P_t}$ = (function of x_i's)

$$\boxed{\frac{\sigma_{P_t}}{P_t} = \frac{P_t}{\mathfrak{L}B_z}\left[\Delta u^2\Theta\frac{R_1}{\Delta\Delta(\sigma)} + \left(\Delta u^2\Theta\frac{\sigma_{Beam}}{R_3}\right)^2 + \theta_s^2\left(\left(\frac{R_2}{R_3}\right)^2 + \frac{1}{12}\left(\frac{R_2}{R_3}\right)^2\right) + \theta_s^2\left(1 + \frac{1}{12}\left(\frac{R_2}{R_3}\right)^2\right)\right]^{1/2}}$$

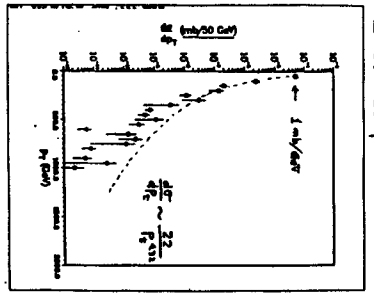
$$\Delta\Delta(\sigma) = R_1^2([1][x^2] - [x]^2)$$
$$R_3 = [x^2]$$

$$[f] \equiv \sum_{i=1}^{m}\frac{1}{\sigma_i^2}f(x_i)$$

Note: The origin of the x-coordinate is the interaction point.

- dE/dx is not considered.
- B_z in the tracking and the cal. regions are not considered.

II-2. Compilation



① **Frank Paige**

Ref. Trigger Workshop, Fermilab, 1985

Generator ISAJET 5.02

$\sqrt{s} = 40$ TeV, pp

η coverage all (?)

$\frac{d\sigma}{dp_T}$

~ 1 mb/GeV @ $P_t = 50$ GeV/c

$\frac{d\sigma}{dp_T} \sim \frac{22}{p_T^{4.33}}$ (mb/GeV)

Power-law form (P_t in GeV)

(50 GeV < P_t < 300 GeV)

$\frac{d\sigma}{dp_T} \sim 50$ mb/GeV @ $P_t = 20$ GeV

$\sigma(P_t > \text{threshold}) \sim \frac{66}{P_{t,min}^{3.33}}$ (mb)

$\sigma \sim 310$ mb for $P_t > 20$ GeV

II. Prompt muon rates — Review —

II-1. Motivation

@ $\mathcal{L} = 10^{33}$ $\quad 10^9$ H_3 events

L1 (3 μs latency, 16 ms decision) ↓ $\sim 10^4$ H_3 total ($\sim 10^{12}$: μ)

L2 (~50 μs latency, ~10 μs decision) ↓ $\sim 10^3$ H_3 ($\sim 10^{12}$: μ)

L3 ↓ $\lesssim 10$ H_3

L1 for μ

P_t-cut $\quad P_t \gtrsim 10$ GeV/c

with Scintillation counters (and BWC2, BWC3)

L2 is not clear yet, but μ-rates should be clarified for the strategy

- "prompt" ← this review
- "punchthrough"
- "decay"

1st term in [ ]

$$\sin^2\theta \frac{\theta_s}{d\ell(\sigma)} = \sin^2\theta \cdot \left(\frac{\sigma}{L}\right)^2 \left(\left(\frac{X_3}{R_3}\right)^2 + \left(\frac{X_2}{R_2}\right)^2\right)$$

$$\simeq \frac{2\sigma^{-1}}{(L/\sin\theta)} \quad \text{— angular resolution}$$

$$L \equiv X_3 - X_2$$

$$\frac{X_3}{R_3} \simeq 1, \quad \frac{X_2}{R_2} \simeq 1$$

2nd term in [ ]

$$\left(\sin^2\theta \frac{\sigma_{Beam}}{R_2}\right)^2$$

$$\cot\theta = \frac{z}{x}$$

$$-\frac{1}{\sin^2\theta}\Delta\theta = \frac{dz}{x}$$

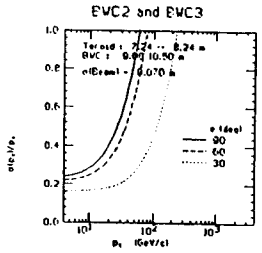
$$\therefore \sigma_\theta^2 = \left(\frac{\sin^2\theta}{x}\right)^2 \sigma_{Beam}^2$$

3rd/4th term in [ ]

$$\theta_1^2\left(\left(\frac{P_t}{P_t}\right)^2 + \frac{1}{12}\left(\frac{\theta_1}{P_t}\right)^2\right) \approx \theta_1^2\left(\frac{P_t}{P_t}\right)^2$$

$$\gg$$

$$\theta_1 = \frac{0.04}{P}\sqrt{\frac{\theta_1/\sin\theta}{X_0}} = \sqrt{\sin\theta}\,\frac{0.04}{P_t}\sqrt{\frac{\theta_1}{X_0}} \propto \frac{\sqrt{\sin\theta}}{P_t}$$



Toroid 7.24 – 8.24 m

$D_1 = 1$ m

BWC2 9.0 m

BWC3 10.5 m

$X_3 - X_2 = 1.5$ m

$\sigma = 200$ μm (per supermodule)

$\sigma_{Beam} = 7$ cm

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.415\times10^{-4}\right)^2 + \left(P_t \cdot \sin^2\theta \cdot 1.676\times10^{-3}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2296\right)^2\right]^{1/2}$$

P_t(turn) = 14 GeV/c @ $\theta = 90°$

17 $\quad 60°$

39 $\quad 30°$

θ \ P_t (GeV/c)	10	20	50	100
90°	0.294	0.406	0.969	1.692
60°	0.298	0.334	0.664	1.276
30°	0.168	0.183	0.265	0.659

I-3. Summary of σ_{P_t}/P_t

1. If we have BWC1, BWC2, and BWC3

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \sin\theta \cdot 1.044\times10^{-3}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2012\right)^2\right]^{1/2}$$

Two terms are equal at $P_t = 193$ GeV/c for $\theta = 90°$.

2. If we loose BWC1 and shrink the muon system by 1 m, σ_{P_t}/P_t becomes too poor.

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.553\times10^{-4}\right)^2 + \left(P_t \cdot \sin^2\theta \cdot 1.925\times10^{-3}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2395\right)^2\right]^{1/2}$$

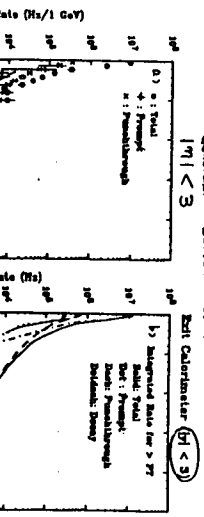
$\sigma_{P_t}/P_t = 1$ at $P_t = 50$ GeV/c for $\theta = 90°$.

3. BWC1 is essential to achieve the momentum resolution below ~30 % up to $P_t \approx 200$ GeV/c.

② **Y. Sakai**, Solenoidal Detector Workshop, KEK, 1990

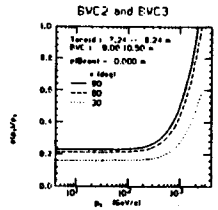
Generator ISAJET 6.21

Full Calorimeter ($|\eta| < 3$)



$\frac{d\sigma}{dp_T} \sim 30$ mb/GeV @ $P_t = 20$ GeV

$\sigma(P_t > 20\ \text{GeV}/c) \sim 150$ mb



$\sigma(\text{Beam}) = 0$

Toroid 7.24 – 8.24 m

$D_1 = 1$ m

BWC2 9 m

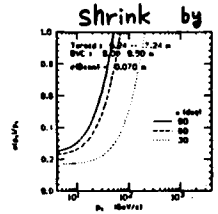
BWC3 10.5 m

$X_3 - X_2 = 1.5$ m

$\sigma = 200$ μm (per supermodule)

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.415\times10^{-4}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2296\right)^2\right]^{1/2}$$

Shrink by 1 m



Toroid 6.24 – 7.24 m

$D_1 = 1$ m

BWC2 8.0 m

BWC3 9.5 m

$X_3 - X_2 = 1.5$ m

$\sigma = 200$ μm (per supermodule)

$\sigma_{Beam} = 7$ cm

$$\frac{\sigma_{P_t}}{P_t} = \left[\left(P_t \cdot \sin\theta \cdot 4.553\times10^{-4}\right)^2 + \left(P_t \cdot \sin^2\theta \cdot 1.925\times10^{-3}\right)^2 + \left(\sqrt{\sin\theta} \cdot 0.2395\right)^2\right]^{1/2}$$

θ \ P_t (GeV/c)	10	20	50	100	P_t(turn)
90°	0.307	0.453	0.992	1.96	12 GeV/c

③ **D. Green, D. Hedin**

NIM A297 (1990) 111.

ISAJET-based model

(Fig. 7)

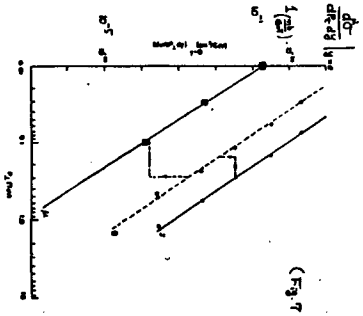


Fig. 7. Differential cross section inclusive for μ±, heavy flavors, and prompt muons (upper, heavy flavor decay; at $\sqrt{s} = 40$ TeV)

$\frac{d\sigma}{dp_T}$

$\frac{d\sigma}{dp_T}\Big|_{\eta=0} \sim \frac{338}{P_t^{3.33}}$ (mb/GeV)

power-law form (P_t in GeV)

@ $P_t = 20$ GeV $\frac{d\sigma}{dp_T}\Big|_{\eta=0} \sim 0.02$ mb/GeV

$\Delta\eta = 6 \rightarrow \frac{d\sigma}{dP_t} \sim 0.13$ mb/GeV

$\left\{\begin{array}{l} ? \\ ? \end{array}\right.$ Too small $\mathcal{O}(10^{-2})$

$\propto P_t^{-3.2}$

$\frac{d\sigma}{dp_T}\Big|_{\eta=0}(P_t > P_t(\text{min})) \sim \frac{152}{P_{t,min}^{2.33}}$ (mb)

$\Delta\eta = 6$

$\sigma(P_t > 5$ GeV$) \sim 25$ mb

$\sigma(P_t > 20$ GeV$) \sim 1.2$ mb

2-order smaller

D. Green, D. Hedin, NIM A297 (1990) 111.

(Table 1) ISAJET 5.20

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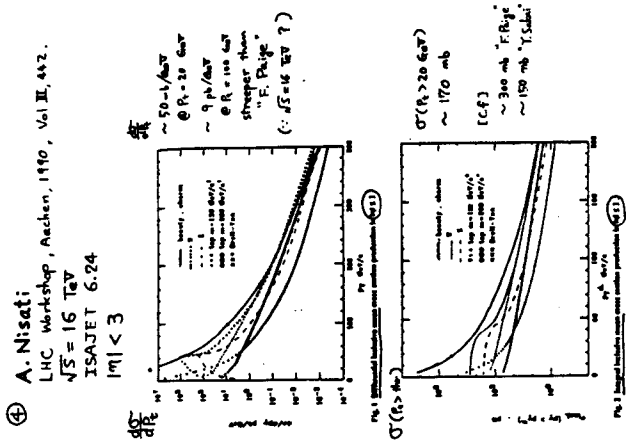
Table 1
Muon rates [a] versus absorber thickness

Thickness	Source	0 < |η| < 1	0 < |η| < 1	1 < |η| < 2	2 < |η| < 3
$9\lambda_0$	All	28 000	400	4100	23 000
	punchthrough	4900	70	420	4400
	prompt	450	16	120	250
$12\lambda_0$	All	16 000	150	2700	13 000
	punchthrough	430	1	30	400
	prompt	400	16	120	250
$15\lambda_0$	All	11 000	130	1500	9600
	punchthrough	40	0.4	1	40
	prompt	240	12	120	250
$18\lambda_0$	All	6800	80	700	6000
	punchthrough	5	-	0.4	1
	prompt	170	12	70	190
$21\lambda_0$	All	4400	50	460	3900
	punchthrough	0.7	-	-	0.7
	prompt	170	10	70	190
$24\lambda_0$	All	2700	30	270	2400
	punchthrough	-	-	-	-
	prompt	170	10	70	190
$35\lambda_0$	All	900	12	70	800
	punchthrough	-	-	-	-
	prompt	120	7	10	135
$45\lambda_0$	All	400	2	24	340
	punchthrough	-	-	-	-
	prompt	140	6.4	7	130

[a] Rates with $|\eta| < 3$ summed over p_T.



I-3. Summary of the momentum resolution

1. There is no large (< O(10)) discrepancy among "F. Paige", "Y. Sakai", "A. Nisati", and "J. R. Cudell et al.".
   - $\frac{d\sigma}{dp_t} \sim 50$ nb/GeV, $|\eta|<3$ @ $P_t = 20$ GeV
   - $\sigma(P_t > 20\ \mathrm{GeV}) \sim 200$ nb, $|\eta|<3$
2. $\frac{d\sigma}{dp_t}$ in "D. Green, D. Hedin (Fig 7)" is about 2 order smaller than others.
3. We should reexamine the muon rates with higher statistics for our geometry.

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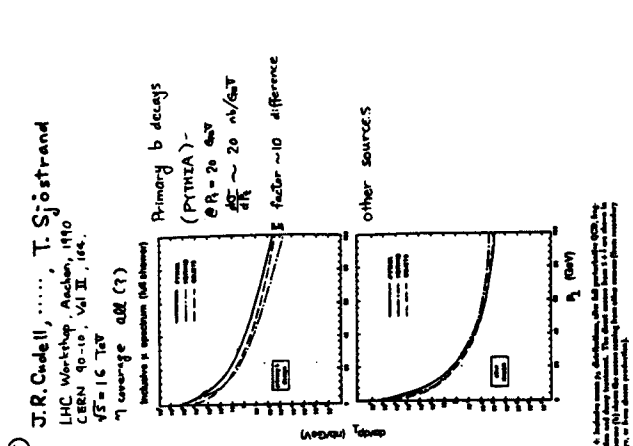

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#10

Jim Wiss
Univ Ill
Aug. 1,1991

2133

Here are some studies on the effects of descoping options for the muon system. These are partial responses to some M. Gilchriese questions, and some studies suggested by Gary Feldman. Here are Gilcriese's questions:

1) What determines the thickness of the barrel steel toroid?

2) What is the justification for BW1? What radial space should be allocated for BW1 if it exists?

3) What is the momentum resolution as a function of Pt he region covered by the forward toroids for total iron thickness of 1.5m? of 3m? of 4m? Do this for LoI inner tracker and then for descoped system. Assume either only silicon for the intermediate angle central tracker or silicon plus outer intermediate tracker. We need a good simulation which combines central and muon tracking systems, which takes full account of multiple scattering.

We begin with some results on the thickness of the forward toroid

(1) Figure 1 shows the effects of full offline momentum resolution for muons in the forward region for various choices of forward iron toroid thickness. These resolutions are slightly better than the LOI figure on page 23 because the LOI has an intermediate chamber 1/2 through toroid and a bigger downstream lever arm to accommodate Cerenkov counter. At high rapidity and large Pt where the iron toroid is really supplying the bulk of the momentum information (rather than the intermediate tracker) the effects of reducing forward toroid thickness are evident.

The resolution from the intermediate tracker was obtained from the LOI and is of the form:

```
A = .0053*eta
B = .00026+.0011*(abs(eta)-1.7)**2
Sigma Pt/Pt =sqrt(A**2+(B*P_t)**2)
```

The reciprocal variance from the intermediate tracker is added to the reciprocal variance obtained from the forward iron toroid as a stand alone to estimate the reciprocal variance of the combined system.
If a simple detector model of the intermediate tracker could he obtained a better estimate of combined resolutions could he made.

(2) Figure 2 shows the effective momentum resolution for various toroid thicknesses for the case of no help from the intermediate tracker. Here the effects of reducing the forward toroid are dramatic.

We next discuss the effects of descoping the barrel muon system (ie reducing the thickness of the barrel toroid and the radial extent of BW1).

(3) Figure 3 shows the effects of descoping the barrel toroid from the LOI 1.5 meter toroid to the 1 meter descope toroid. I also have included the effects of shrinking BW1 from its original 1 meter radial extent to the 0.5 meter radial extent in the descoped drawings. This plot includes all central tracking including a model of silicon. The dashed curve is the canonical central tracker resolution of 2% at 1 TeV. Clearly the muon system dramatically improves resolution at high momentum and the effects of descoping in a complete system are not that crucial. We have modeled each muon detector with a Z and Rphi resolution of 250 microns.

(4) Figure 4 shows the effects of descoping (as described above in point 3) for the hi luminosity option where we assume that good quality information exists for the silicon and the muon system but not for any other central tracking. A significant degradation in resolution is observed at large rapidity and and hi Pt due to descoping.

(5) Figure 5 examines the performance of the barrel muon detector as a complete stand alone system (solid curve) and with a 1 mm beam constraint for the central and eta = 0 rapidity. This is for the original LOI proposal. The (optimistic?) beam constraint helps somewhat at eta = 0.

(6) Figure 6 compares the performance of the LoI and Descoped barrel muon toroid in stand alone mode (no beam constraint). The Descoping has created a significant degradation in performance at eta = 0.

(7) Figure 7 investigates the effects of reducing the thickness of BW1. We plot the LOI muon toroid at eta = 0 as a complete standalone system with no beam constraint. The lower solid, dashed, and dotted curves give the resolution for the case where the R-Z measuring planes of BW1 are radially separated by 1 meter, 0.5 meter, and .25 meter. Some degradation in performance is noted.

The upper solid, dashed, and dotted curves give the performance for 1 meter, 0.5 meter, and .25 meter Delta R BW1, where we have assumed that inner planes are randomly aligned in Z by 1 mm (RMS) relative to BW2 and BW3 (which we assume are perfectly aligned). If one has difficulty in maintaining alignment (owing to the presence of the toroid) at this level, one seriously degrades the muon toroid stand alone performance if one gives up the concept of a thick BW1. I think this is the argument which sets the thickness of BW1 and was first suggested to me by Duncan Carlsmith.

(8) Figure 8 is a study suggested by Gary Feldman. It shows the momentum resolution obtainable by comparing the phi angle measured by the muon system and the angle measured by the outermost CTD layer. For these calculations, the bending power is provided by the magnetic flux returning through 2 meters of calorimetry with an assumed field strength of 0.523 Tesla. I assume that the CTD stub provides an angular resolution of 2 mrad. Furthermore I have turned off the solenoidal magnetic field in the CTD region which will tend to cancel a non-negligible fraction of the flux return bending power.

Calculations are presented for the phi angle as measured by BW1 alone (with an assumed angular resolution of 0.7 mrad), and the full barrel muon system consisting of BW1 --> BW3.
The dashed curves use full MCS weighting of all space points, and are probably inappropriate at the trigger level.
The solid curves use just the measured phi angle difference between the muon system and CTD stub and have no MCS weighting.

Clearly under all scenario's, the calorimetric flux return alone provides poor momentum resolution for a second level trigger compared to the resolutions obtainable in Figure 7 where R-Z information from BW1-3 is used to measure momentum using the bending power of the muon toroid.

(9) Figure 9 gives some resolutions for the case where a 100 micron
beam constraint (BC) is combined with information from the outer CTD layer
and the stub (dashed curve) or BC with information from the outer CTD
for the case (dashdot curve) where the BC + CTD stub + BMI information
is weighted in accordance with multiple coulomb scattering (MCS).
Again this is probably unsuitable for a 2nd level trigger.
If no MCS weighting is used, one obtains the the nearly momentum independent
solid curve. If only the beam constraint and outer CTD stub layer is
used without any use of BMI, one gets the solid curve where
resolution is roughly proportional to momentum.

Fig 2: Forward Fe toroid S.A.

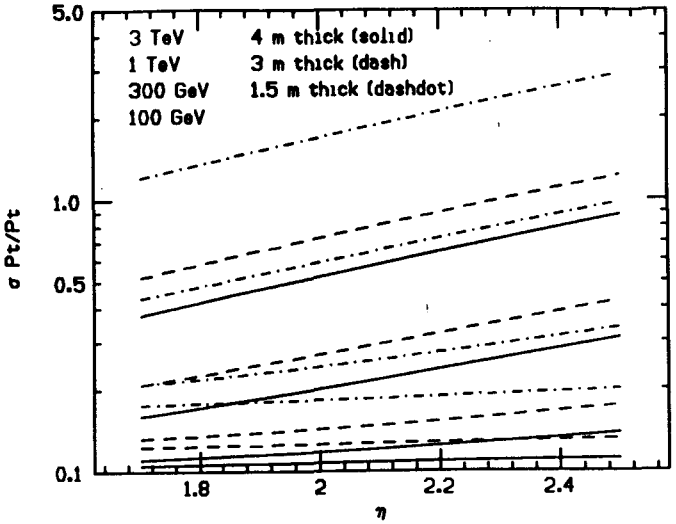


Fig.1: Forward Fe toroid + intermed

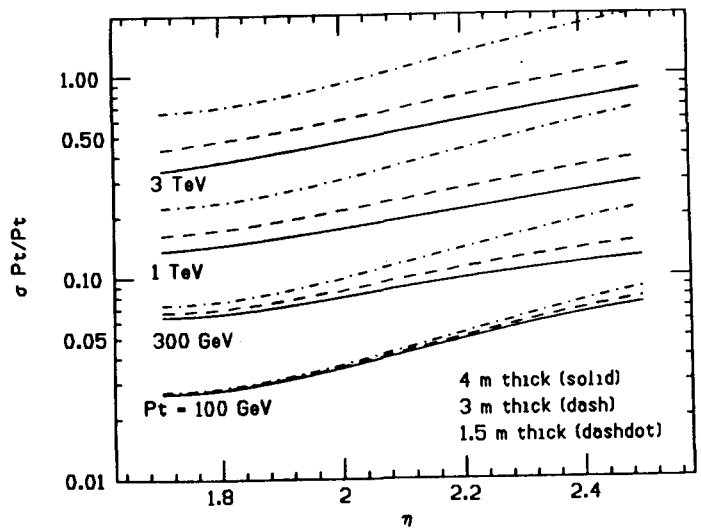


Fig 3:Resolution for muons

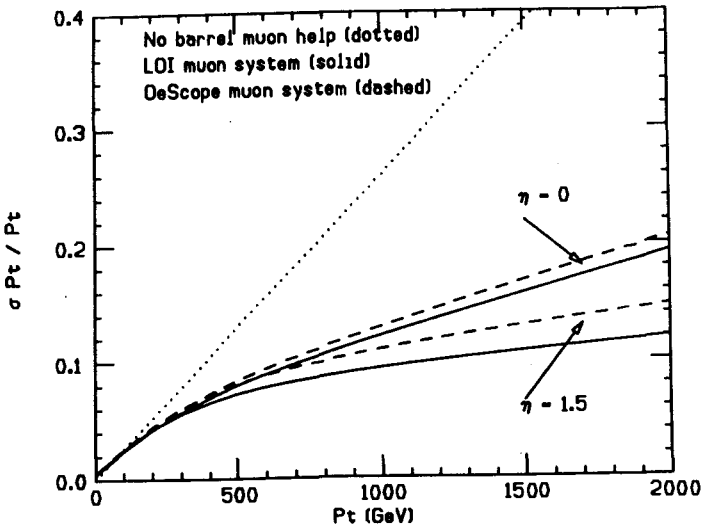


Fig 4: H1 Lum Option

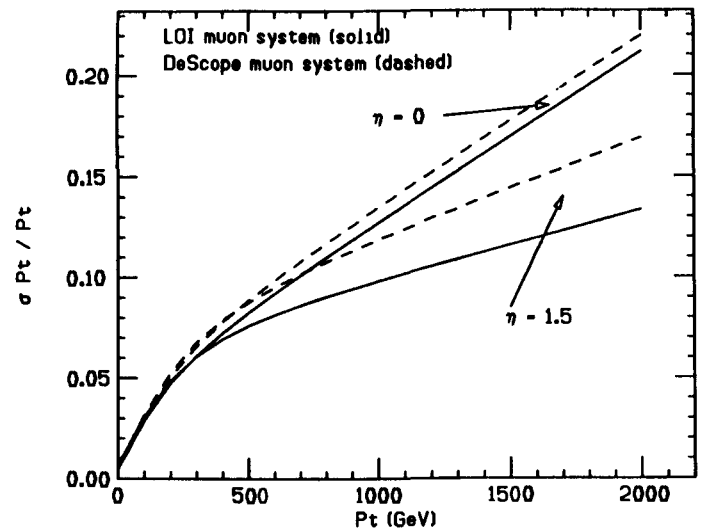


Fig 5: LOI barrel muon toroid StandAlone

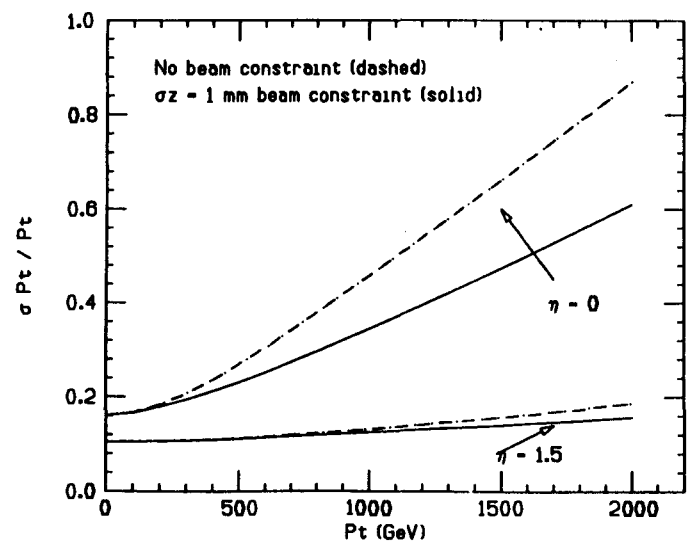


Fig 6: Barrel Muon Toroid StandAlone

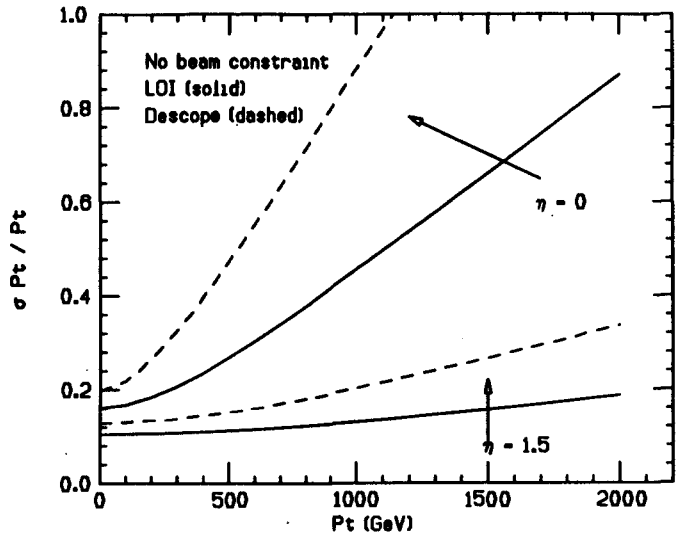
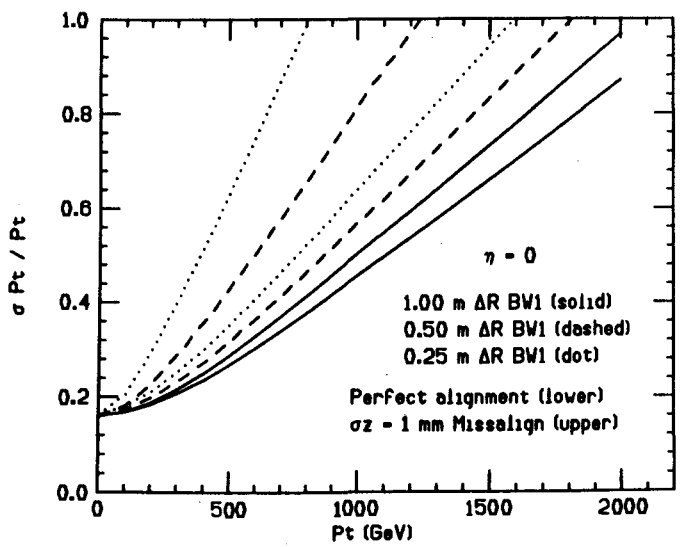
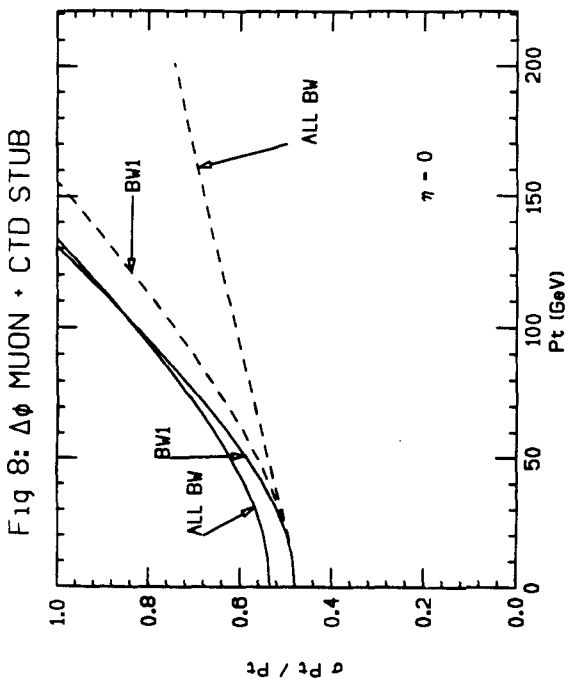
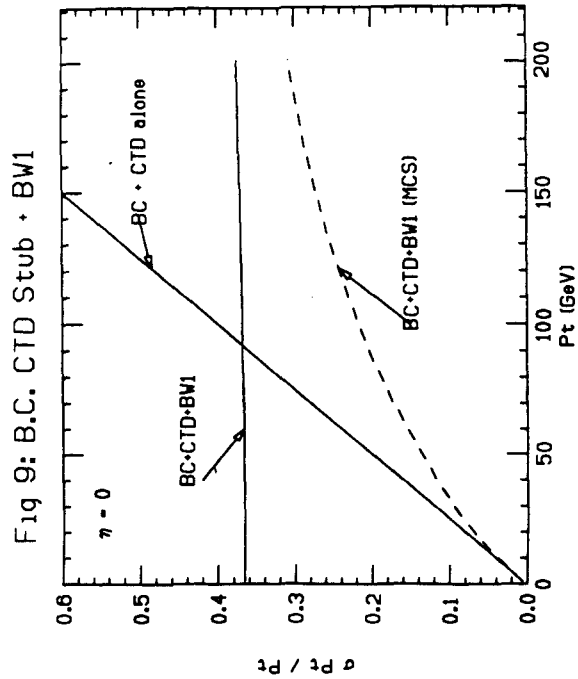


Fig 7: 1.5 m thick Muon Toroid StandAlone







11

Some results of simulation of the effects connected with e.m. enviroment of high energy muons.

Yu. Gornushkin (JINR/SSCL)
(GORNUSHKIN@SSCVX)

When high energy muon goes trough e stuff of material (calorimetrs, Fe toroids etc.) it losses energy by collision, leading to ionization of atoms in the material that is traversed, and by radiation. This radiation (e bremastrahlung and e direct pair production) finally transforms into electromagnetic accompainment of muon which can severely compromise the determination of muon position in muon system.

At present e beam test of MIT muon drift tubes (L.Osborne group) is going on, to study these effects experimentally.

The available relevant calculations are not in e complete agreement. There are some doubts about the reliability of GEANT simulation due to low energy thresholds in GEANT program also.
So the possibility to study the effects connected with electromagnetic accompainment of e muon both experimentally and by simulation makes some advantage both for simulation and for study of muon chambers operation. Checking the simulation results at least at one point (500 GeV) experimentally we can trust more to simulation results at higher energies of muons.

The following is a result of simulation of muon tubes beam test at FNAL, June 91.

The simulation code was based on GEANT 3.14.
The configuration of the set up is presented on Fig.1.
It is assumed to have a block made of 4 layers of muon tubes (walls - 2 mm of copper, cell cross section 2.32 x 20.8 mm) putted into e box with thickness of e wall (a stuff of lead (iron) before. The distance between stuff of lead and the chambers is 10 cm. It is rather close to the real situation (SDC muon chambers have 4 layers of tets chambers with about 9 cm distance from iron toroid).

On Fig.1 also an event with a muon accompained by the products of an interaction in material before chambers is shown.
On Fig.2 the result of e simulation for different thickness of lead-0., 2.5, 5.0, 10., 20.0 cm are presented.

One can see that a much track will be completely compromised by electrons (if one hit electronics used) after a thick enough stuff of material with a probability about 6%.
In a case of about 6% of events there will be 2 or 3 cells with electrons too. So for muon tubes after toroids a 500 GeV muon track can be measured with proper precision of muon chambers only in about 88% of events. This value will be equal to an efficiency of track reconstruction if the high space resolution of chambers will be assumed . The probability to have a compromised track in all four layers is even higher than to have electrons only in 3 layers. It is so because in the first case the electrons of higher energy comes right from a stuff of a material while in the last case, when only some layers have electrons, they are mostly produced in the walls of muon tubes (by photons of e.m.shower in material before chambers).

Fig.3 presents a dependence of a probability to have a several number of layers where muon track is compromised by electrons on the energy of a muon.

There is an opinion that the possible way to reduce a such background is to put before muon chambers a stuff of material with high critical energy. (The critical energy is that for which the electron range as determined by collisions of energy E such that E < Ecrit, the electron will likely come to the end of its range without emmiting a high energy photon that will convert to an electron-positron pair.

So such electron will not generate or propagate showers). The carbon or aluminum were suggested to be putted after toroids just to clear the muon track.
The proper GEANT simulation resulted in that it does not help for muons with energy of a few hundred GeV. The number of new tracks that muon produces in carbon is even more than the number of which it absorbs. Fig.4 presents these results. So it will be interesting to check experimentally this point too.

Also the dependence on the drift tube cell cross section was investigated. One possible way to decrease the number of channels of a muon system is to enlarge the muon tubes cell cross section. In SDC detector the drift tube assumed to be used in trigger design. The possible size of drift length in accordance with LCI is 4-5 cm. It can be difficult to build a good trigger with one hit TDC electronics for high energy muon within an electron-positron enviroment in a case of large drift lenght. The Fig.5 presents the dependence of a probability to have a clean muon track in tubes with different drift lenght for an energy of e muon 1 and 2 TeV.

The beam test will run with tubes made of copper (there is a special methodical goal for it). Table 1 presents a comparison of a probability to have a electromagnetic background in a chambers made of different material.

The probability to have several number of cells where background electron
(For different material of walls of muon chambers).

# of tube, where muon hided by	0	1	2	3	e
Lead 10 cm Walls Cu 1 mm	0.749 +/-0.008	0.108 +/-0.004	0.062 +/-0.003	0.0304 +/-0.003	0.053 +/-0.003
Walls Al 1 mm	0.784	0.082	0.054	0.022	0.058
Walls PVC 1 mm	0.813	0.068	0.044	0.017	0.058

When experimental data will be available the proper comparison with our simulations will be done.

2147

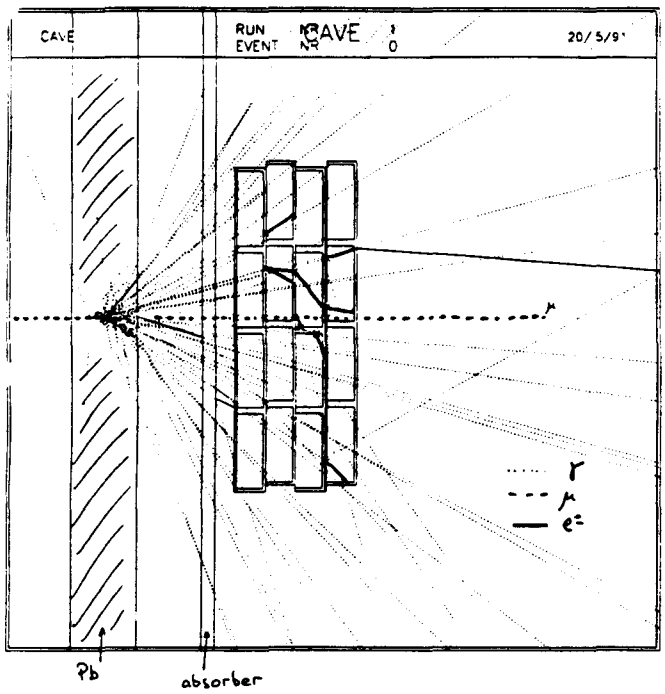
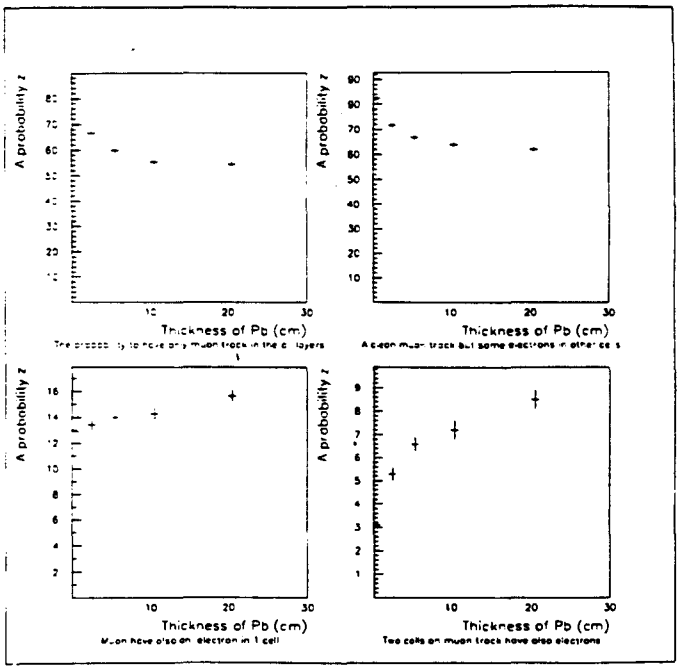


Fig. 1

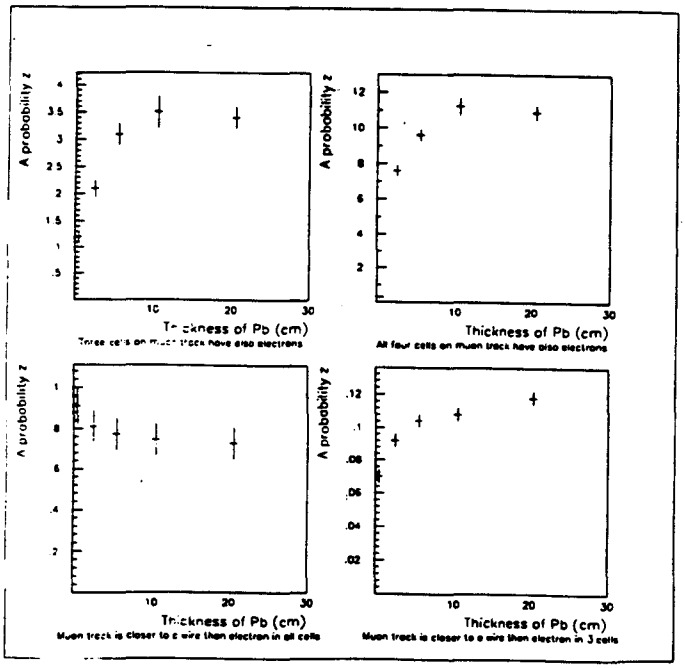
2148

Fig. 2 a



2149

Fig. 2 b



2150

Fig. 2 c

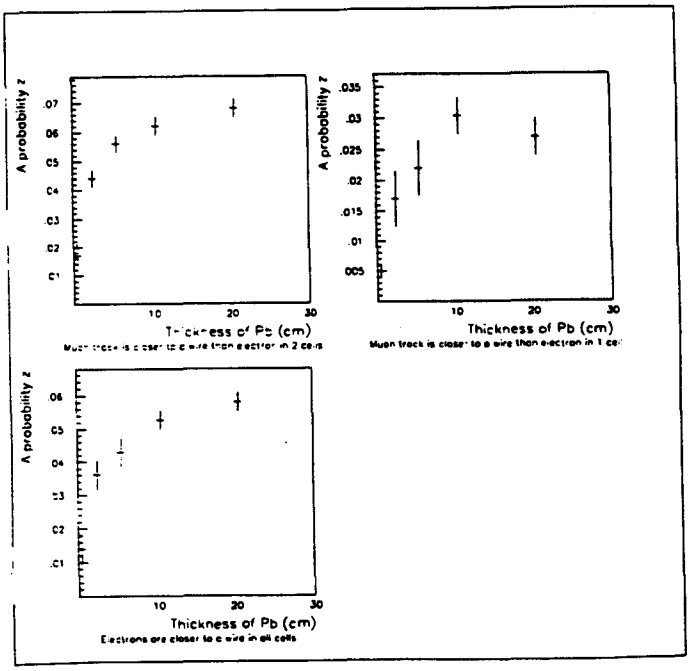


Fig. 3

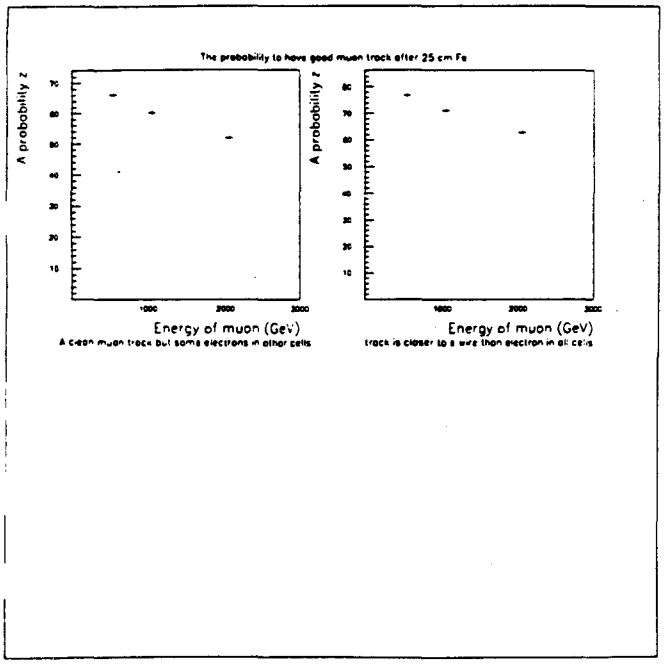


Fig. 4a

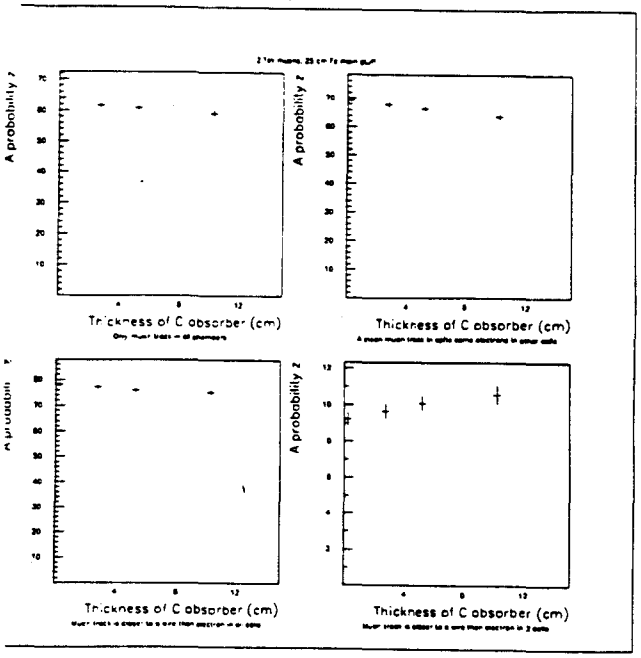


Fig. 4b

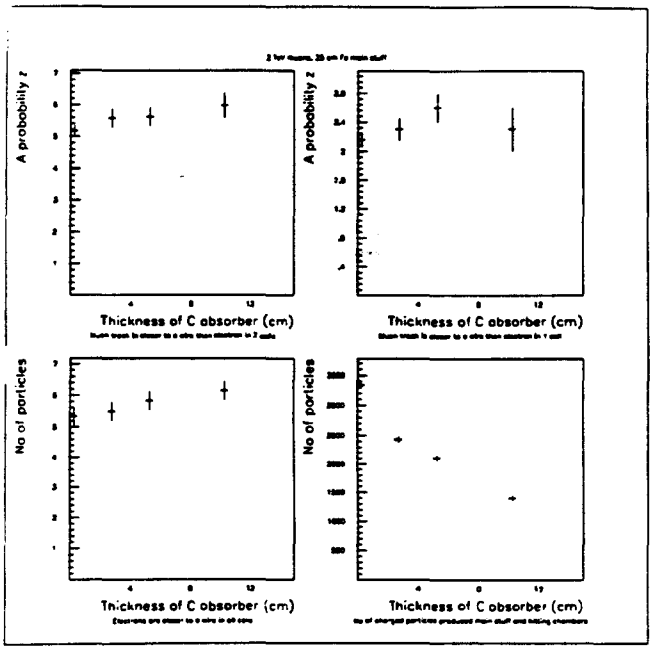
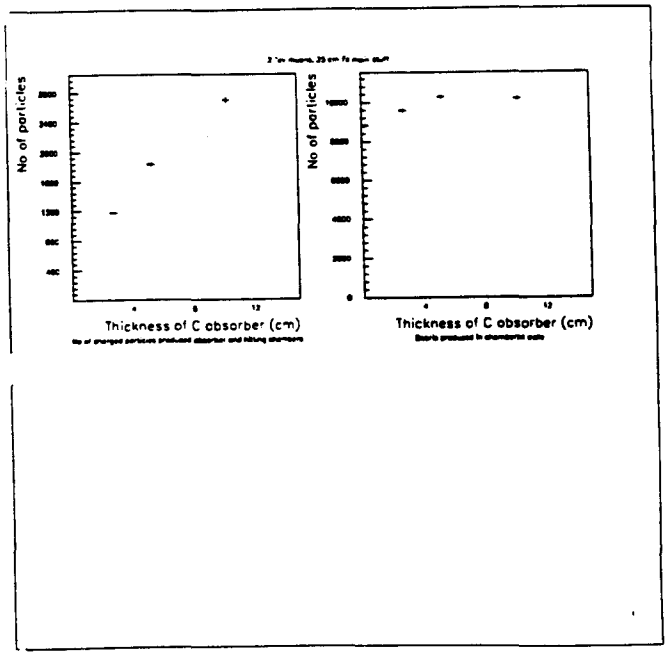
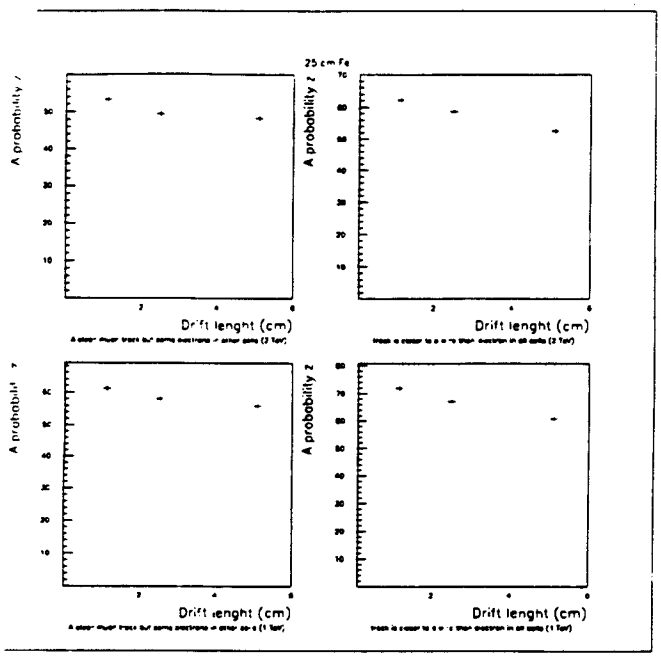


Fig 4c



2155

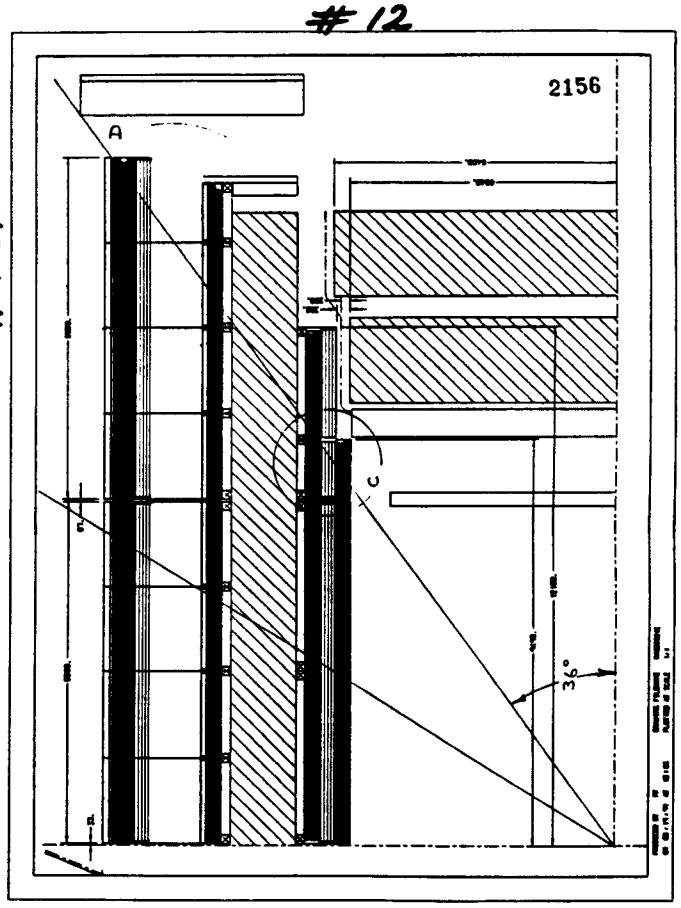
Fig. 5



12

F. FEYZI

2156



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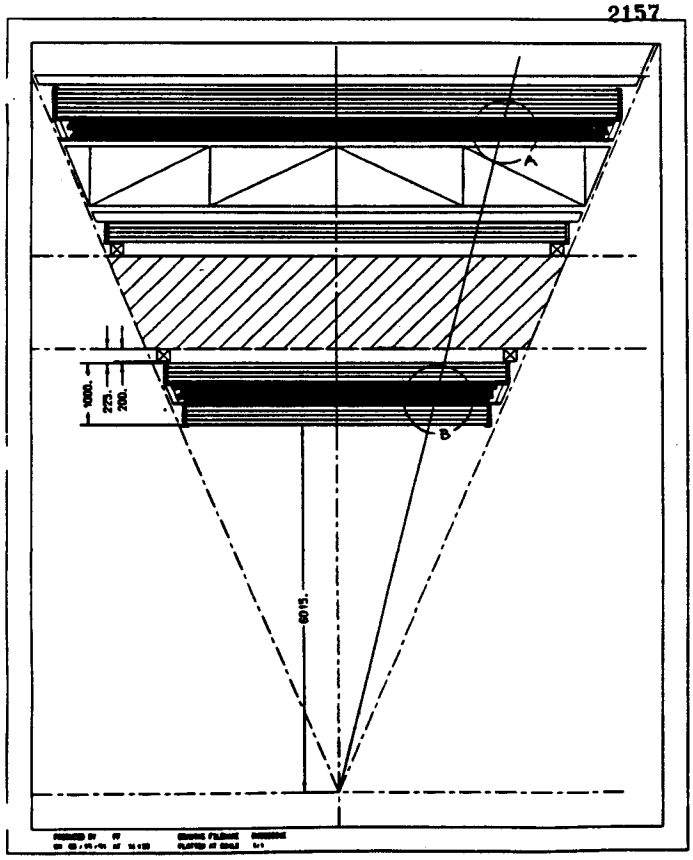

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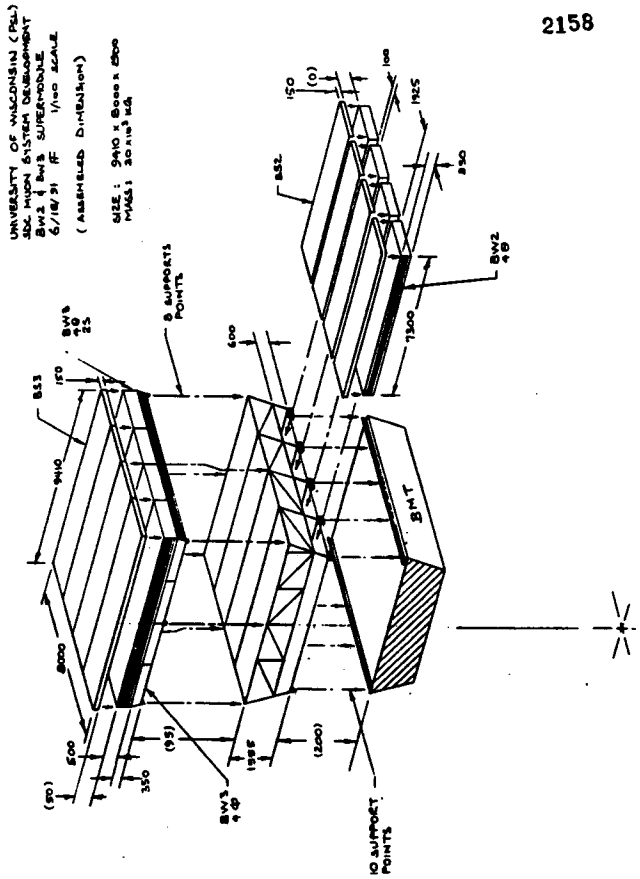
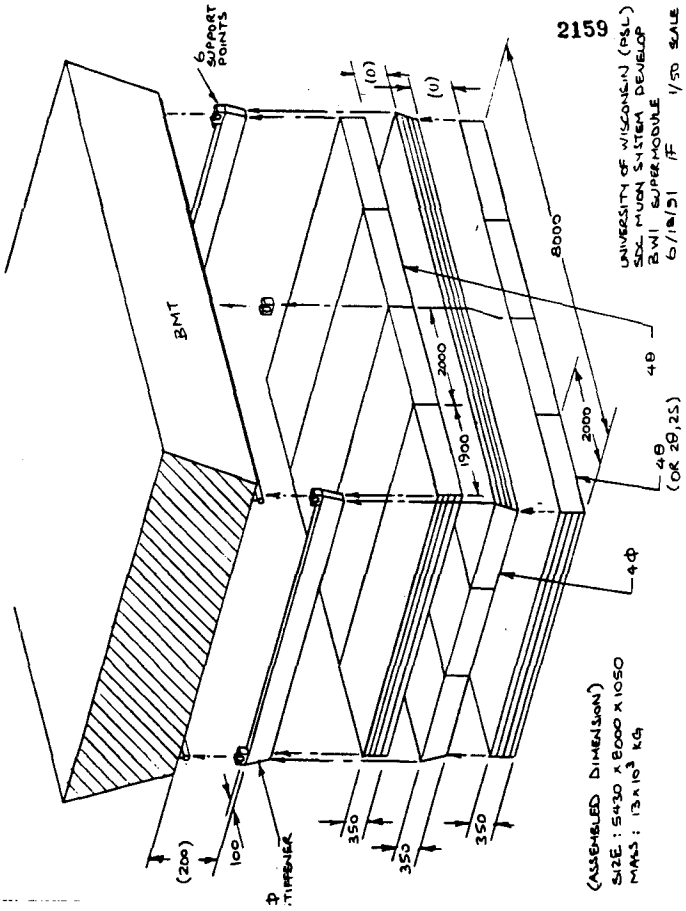
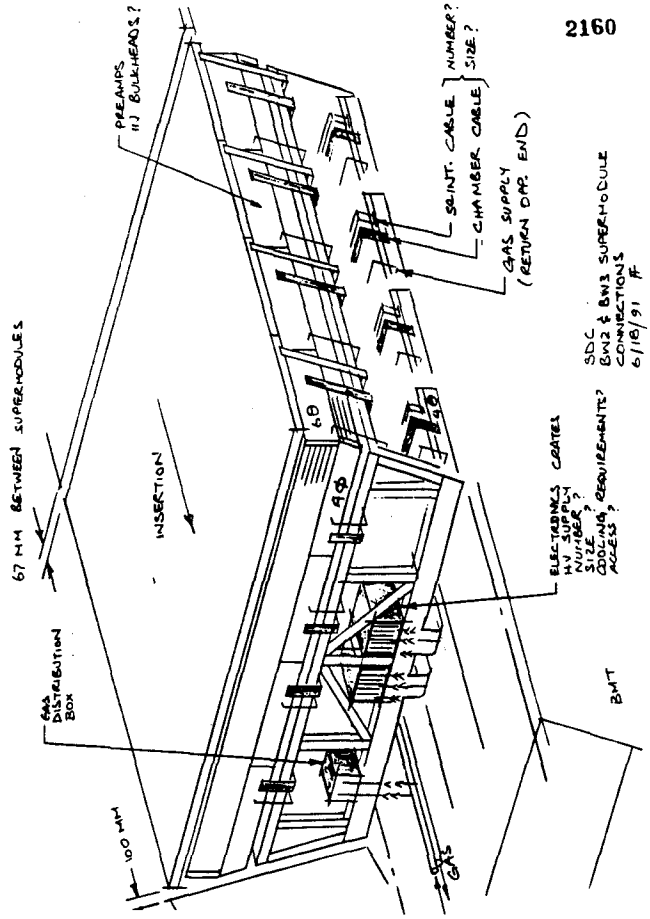
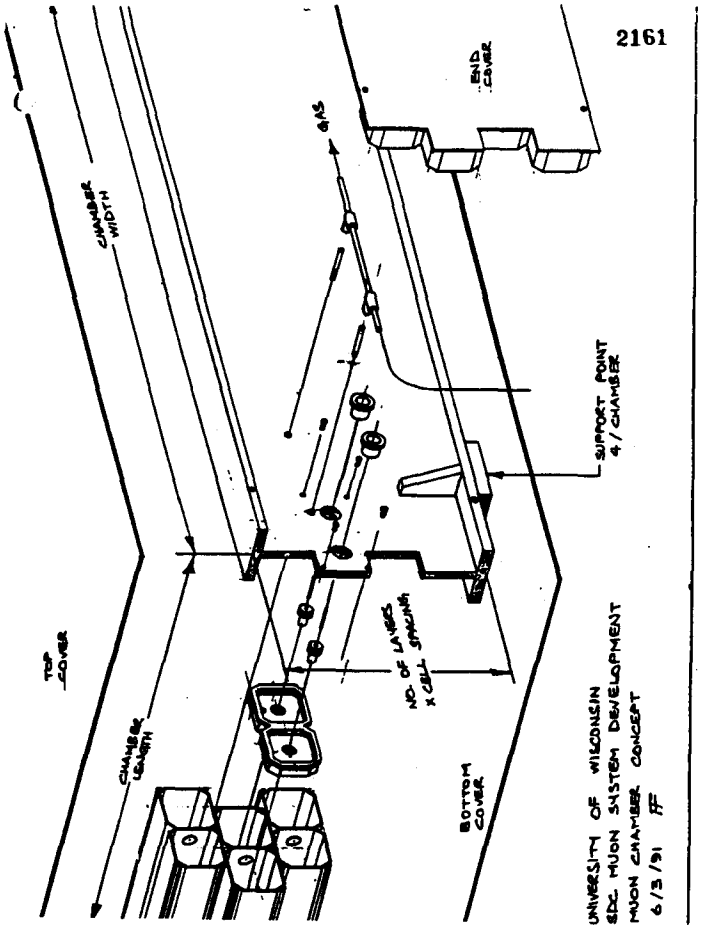






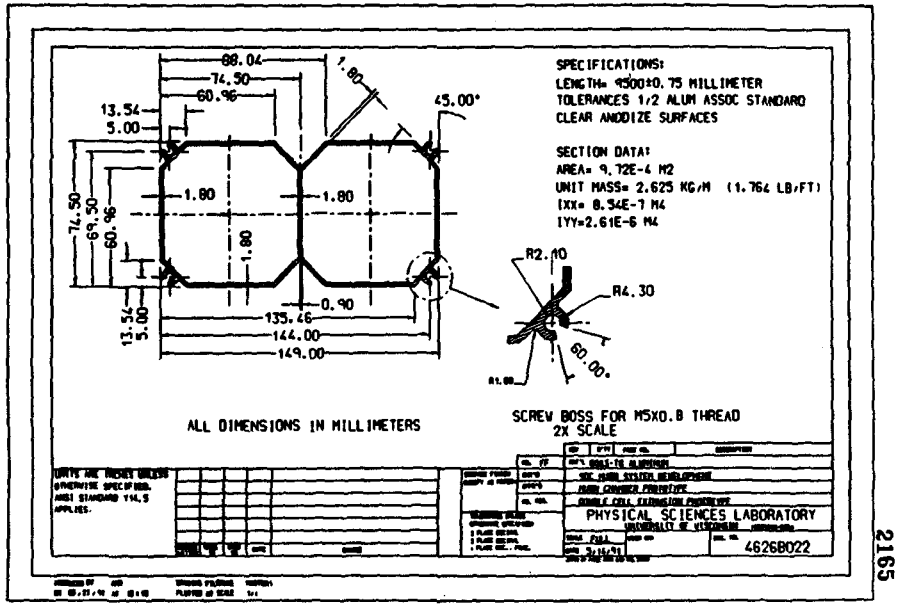


2162

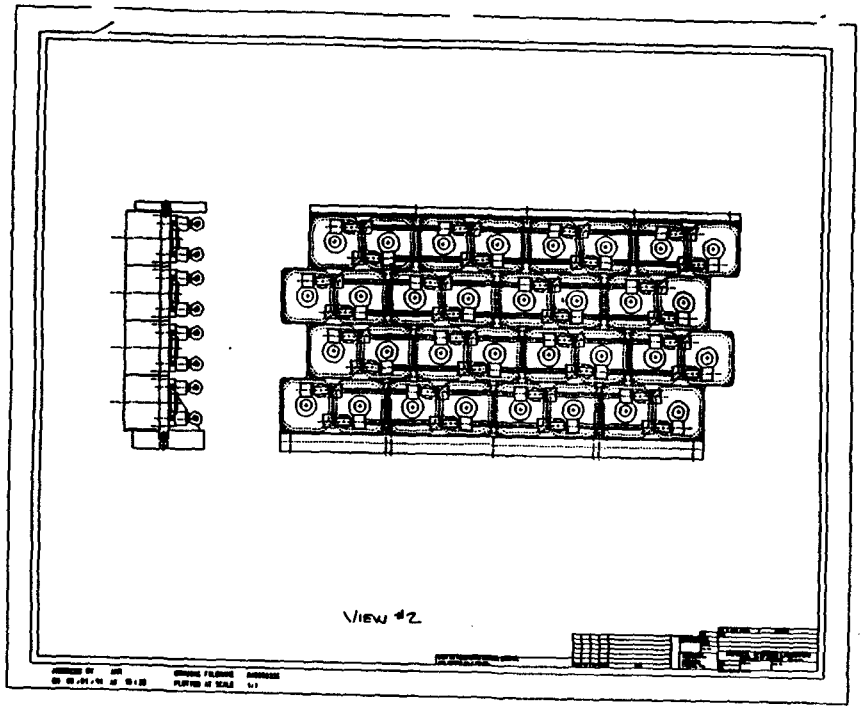
SDC Muon Barrel Chambers
Status of Wisconsin Prototype Chamber

Farshid Feyzi
UW-Madison, PSL
July 30, 1991

- Parts drawings complete
- Extrusions on order, final delivery expected by August 30, 1991
- Assembly station is set up
- Sample extrusions have been received, checked and approved
- First 1 meter double cell tube will be finished by August 16, 1991
- First 9.5 meter double cell tube should be finished by September 20, 1991
- 32 cell prototype should be finished and ready for testing by October 11, 1991



2165



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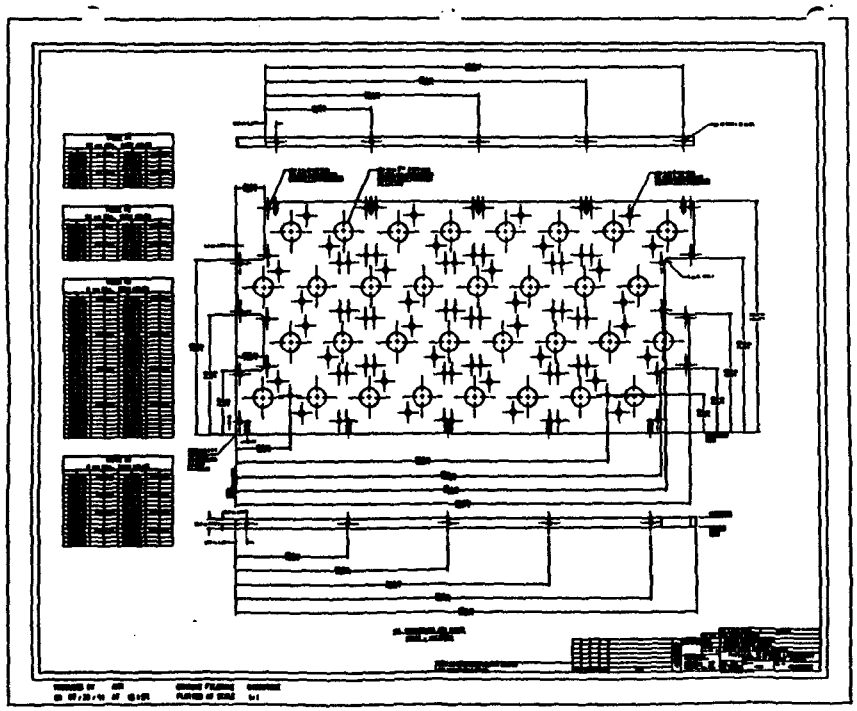

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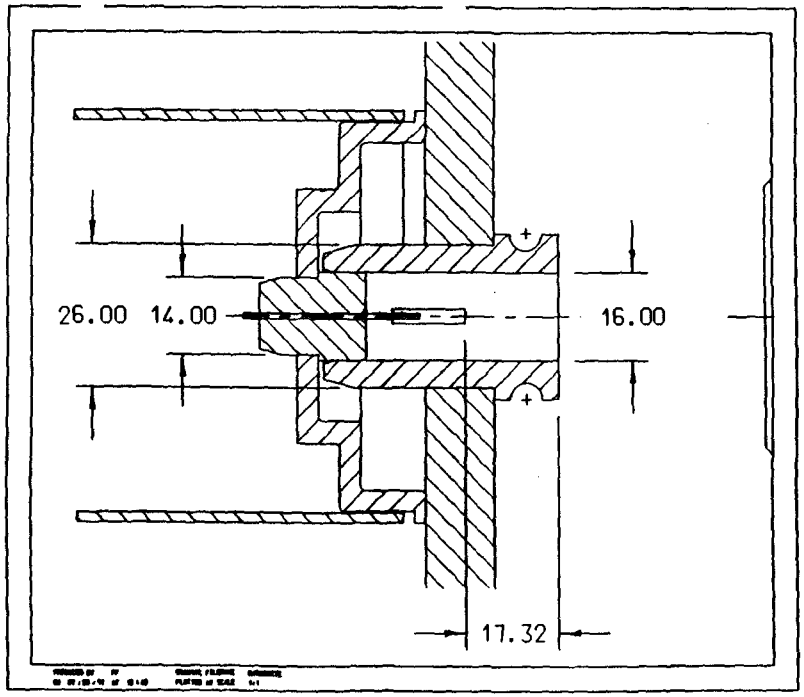

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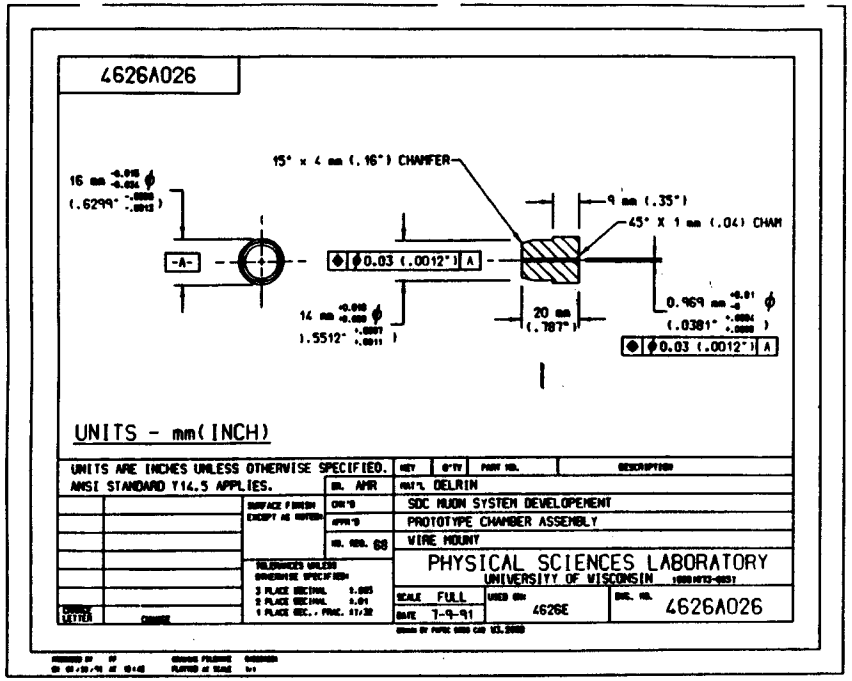

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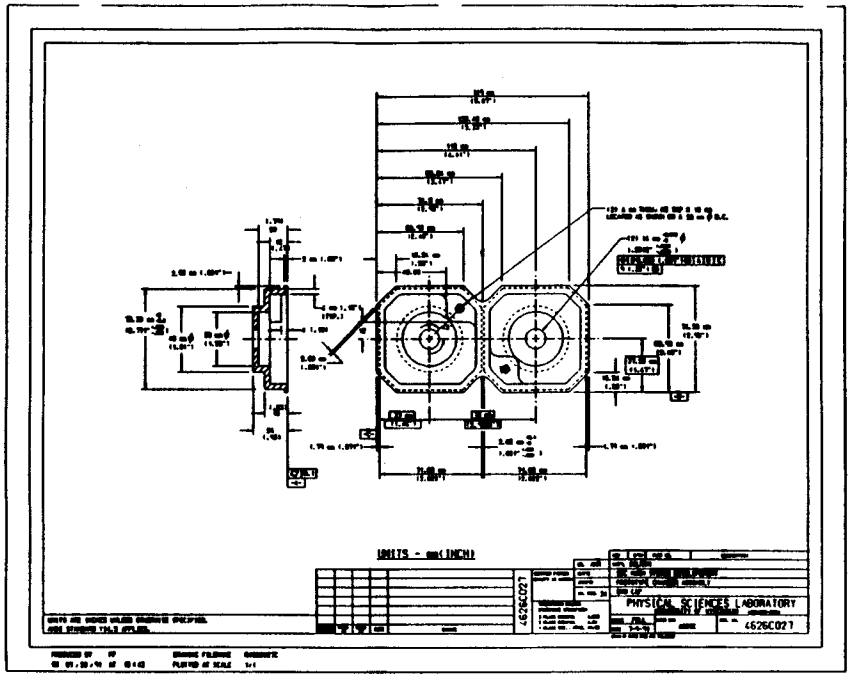

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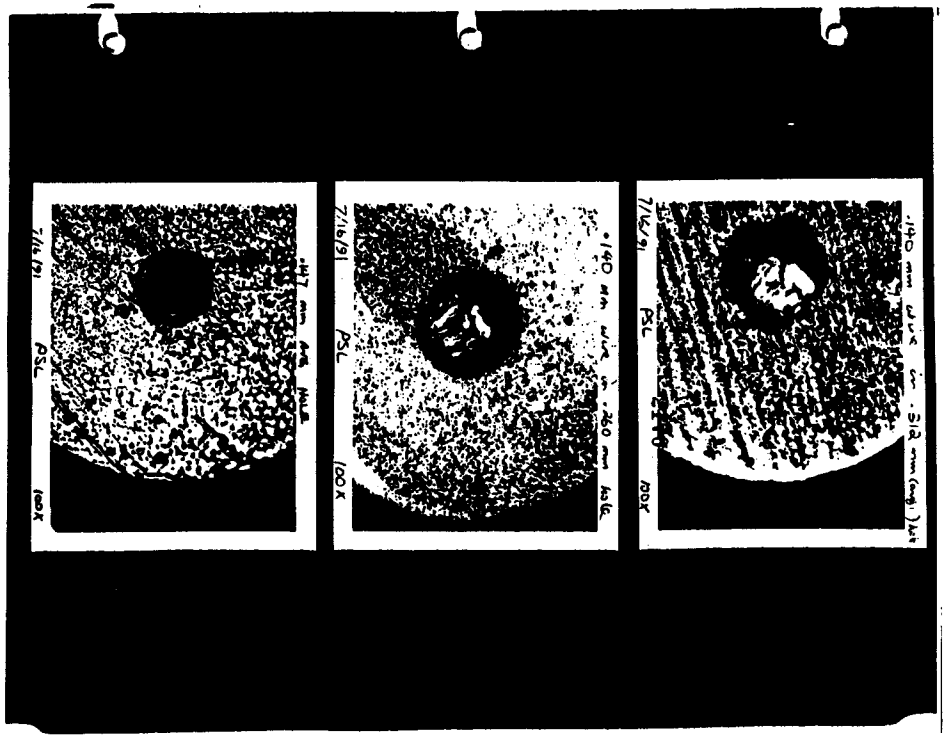

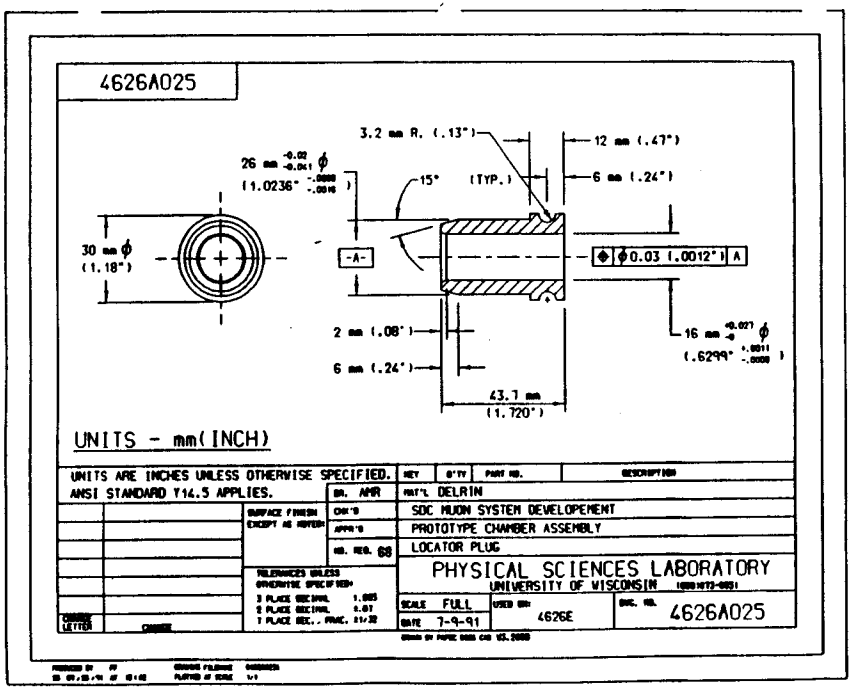

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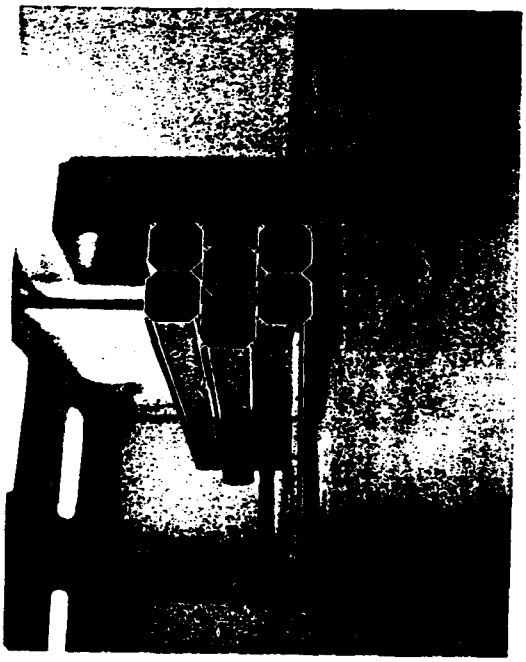
2171



2172

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2173

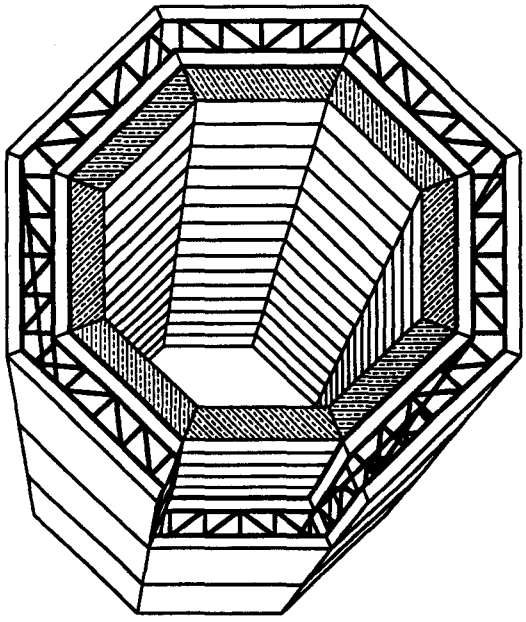
SDC LBL MEETING
AUGUST 5, 1991
HENRY LUBATTI

MUON DETECTOR SYSTEM

SSC-WASHINGTON APPROACH
(ROUND TUBES)

- SEPARATE THE FUNCTIONALITY OF DRIFT CELLS FROM CONSTRUCTION OF DETECTOR MODULES
- EACH DRIFT CELL IS FULLY FUNCTIONAL AND IS CONSTRUCTED AT SEVERAL DIFFERENT LABORATORIES AND UNIVERSITIES
- DRIFT TUBES ARE USED AS STRUCTURAL ELEMENTS OF THE DETECTOR MODULES
- ALIGNMENT AND ORIENTATION OF DRIFT CELLS WITHIN A MODULE IS FIXED BY DRIFT TUBE END CAPS AND MODULE END PLATES
- MODULES ARE ASSEMBLED AT THE SSC

2174



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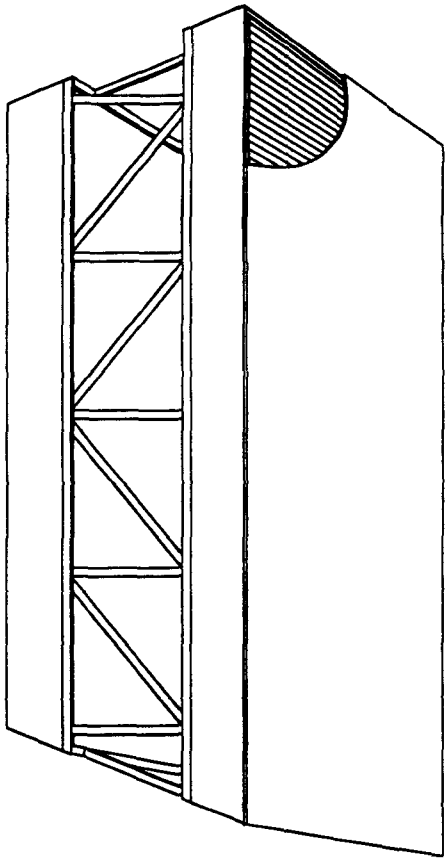
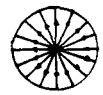


2176

DRIFT CELLS

- EACH CELL IS A GAS-TIGHT, WORKING DRIFT TUBE
- WE USE CIRCULAR, EXTRUDED 3 in. DIAMETER ALUMINIUM TUBES WITH 1/16 in. WALL THICKNESS

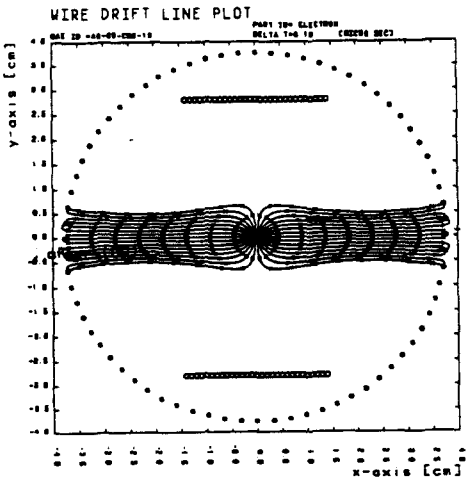
NO FIELD SHAPING OPTION



FIELD SHAPING OPTION (Cu on G-10)

- CIRCULAR GEOMETRY ALLOWS FOR EASY ORIENTATION OF TUBES WITH SIMPLE LOCATING SYSTEM, eg. PINS

2177



$V_{sense} = V_{drift} = 4800$ VOLTS
50 μm sense wire

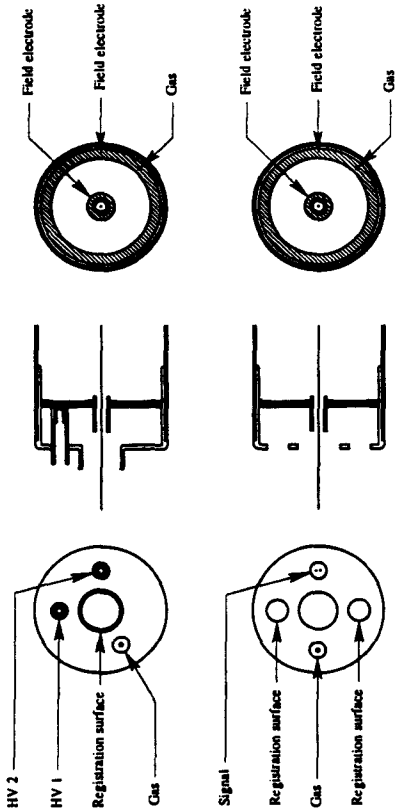
2178

DRIFT TUBE END CAPS

THREE GENERAL FUNCTIONS

- GAS SEAL AND PROVIDES GAS I/O
- MECHANICAL
  - REFERENCE SURFACE FOR PRECISION MOUNTING TO END PLATES
  - CENTERS THE ANODE WIRE
  - TENSIONS AND FIXES WIRE
- ELECTRICAL
  - CONTROLS ELECTRICAL END EFFECTS (STATIC FIELDS)
  - PROVIDES FOR SMOOTH E-M COUPLING TO OUTSIDE WORLD
  - SEPARATES SIGNAL AND HIGH VOLTAGE

2179



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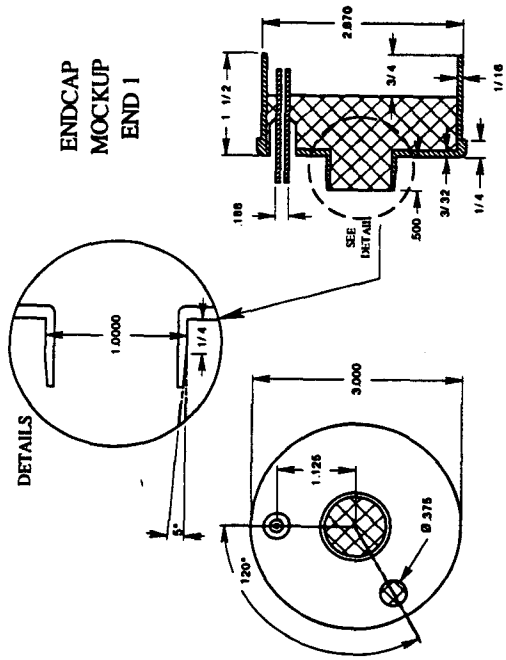

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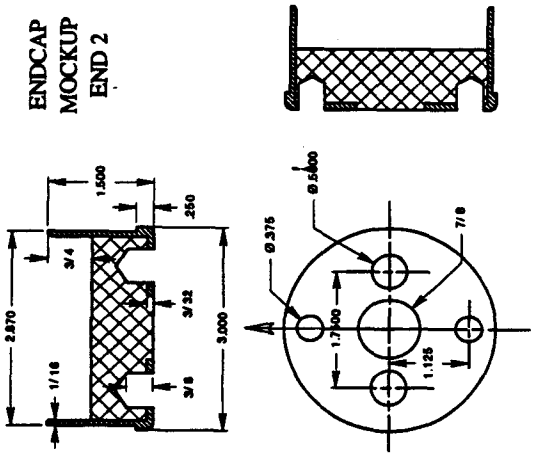


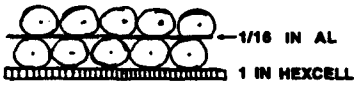
2182

MODULES

- APPROXIMATELY 9m x9m (largest)
- ASSEMBLY AT SSC

ASSEMBLY JIG
(LARGE FLAT SURFACE)

- BASE PLATE-HEXCELL
- Al END PLATES WITH MACHINED REFERENCE SURFACES
- TUBES PLACED ON SURFACE AND GLUED BOSS END FIRST, THEN FLAT END WHICH IS PINNED FOR FIXING ORIENTATION



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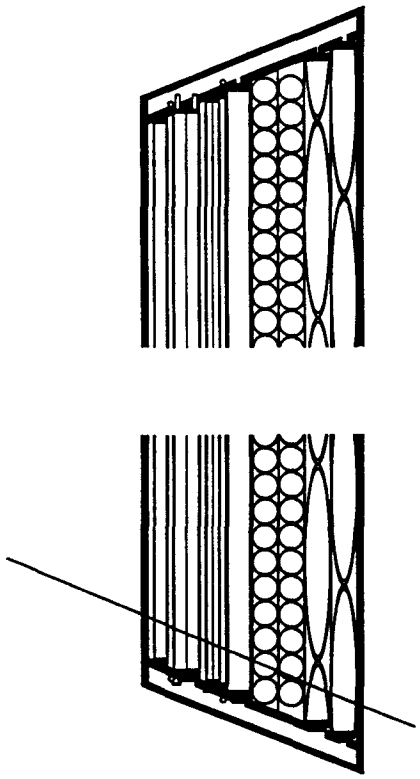

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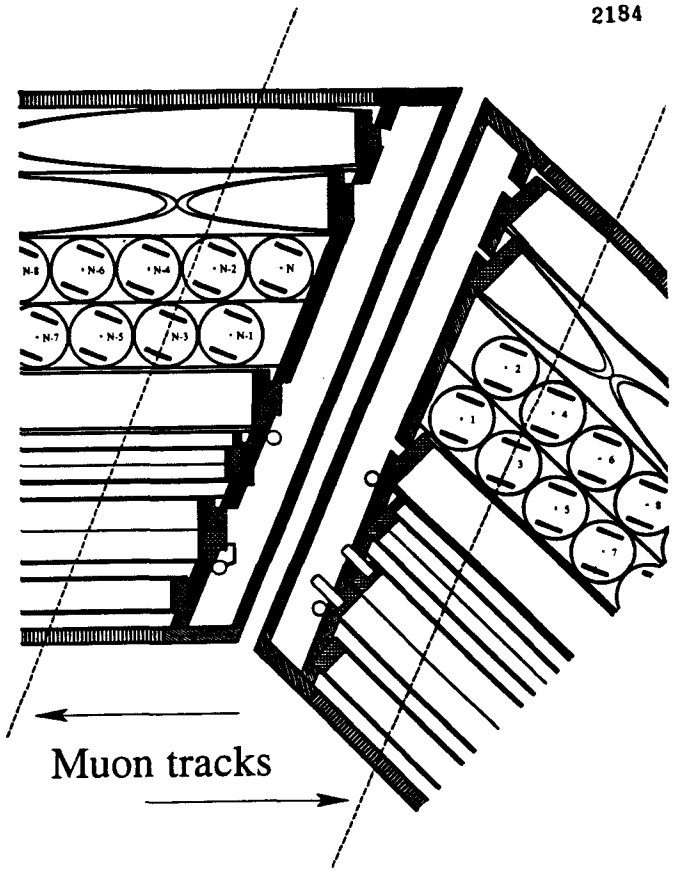
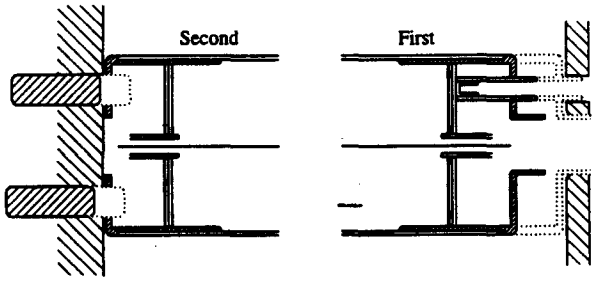
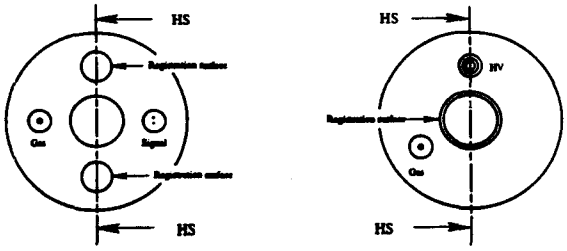


2185

Assembly sequence

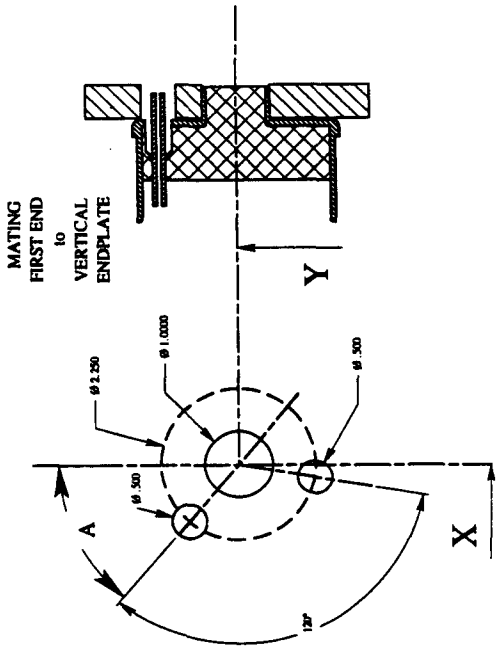


Horizontal Section



End views

2186



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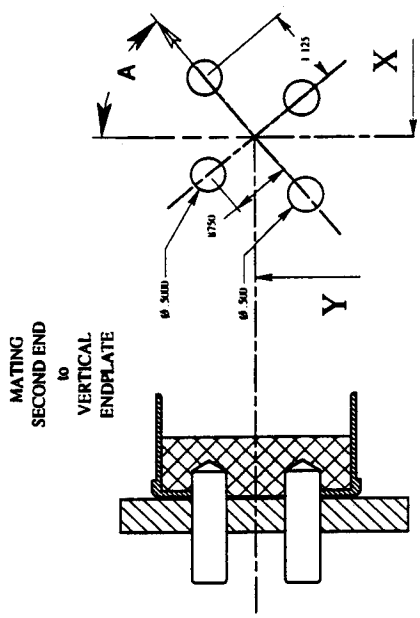

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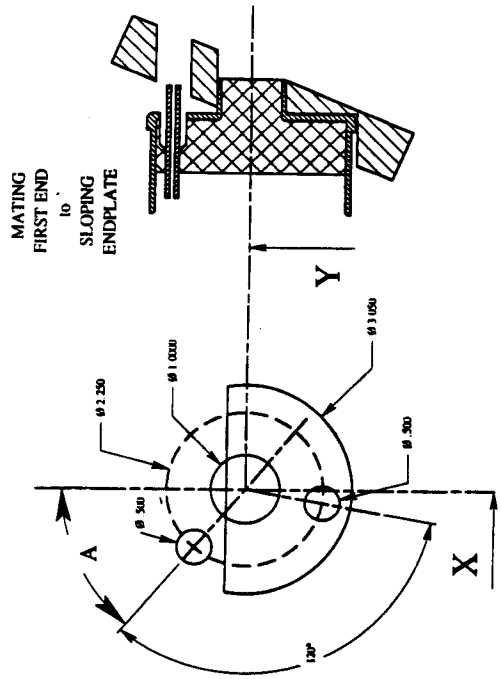

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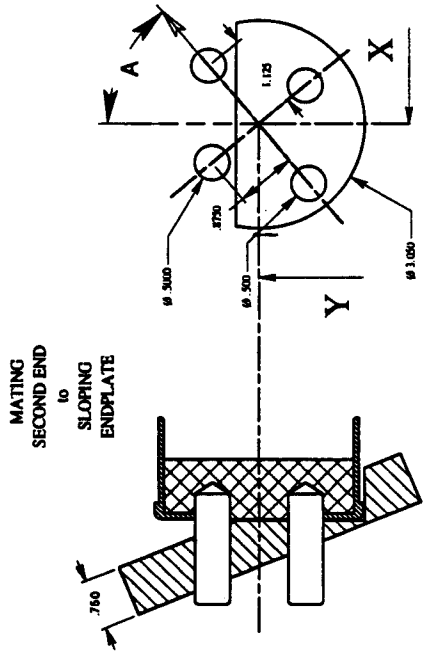


2190

WORK IN PROGRESS

END CAP DESIGN

- H. V. END
  1) H.V. INPUT
  2) GAS I/O
  3) TERMINATE IN TUBE IMPEDENCE
  4) GUARD RING may not need (FIELD AT END OF TUBE)
- SIGNAL END
  1) DECOUPLING CAPACITOR
  2) TRANSFORMERS-impedence matching
  3) GAS I/O

STUDY OF DRIFT VELOCITY

- IDENTIFY APROPRIATE GASES (non flammable gas mixtures)
- MAKE MEASURMENTS
  1. NO FIELD SHAPING
  2. FIELD SHAPING

2191

DRIFT VELOCITY MEASUREMENTS (PRELIMINARY)

[NOT FINAL DATA]

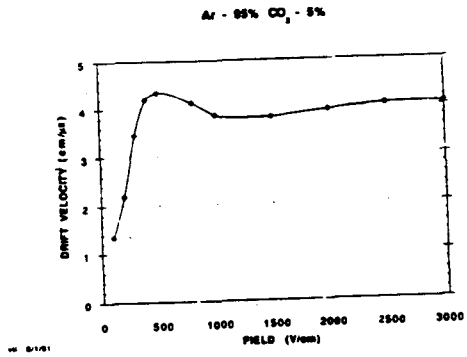
THREE COMPONENT MIXTURES

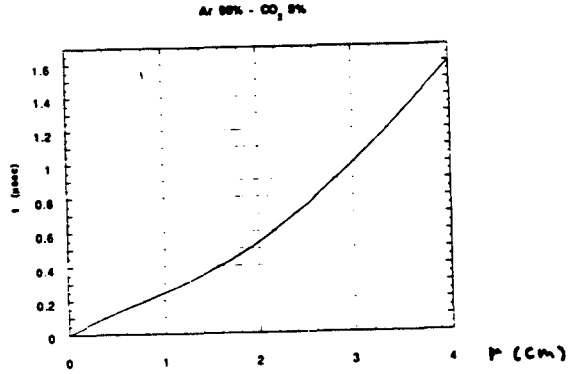
- Ar-CO2-C2H6, Ar-CO2-CH4, Ar-CO2-CF4
  Ar-CF4-CH4, Ar-CF4-C2H6

IMPLICATIONS FOR NO FIELD SHAPING
(ROUND TUBES)

- CALCULATE R vs. t FROM MEASURED DRIFT VELOCITY AND E = F(R)
- NONLINEAR BEHAVIOR IN ALL CASES
  - ACCEPTABLE FOR TRIGGER
  - WILL NEED OFF-LINE CORRECTION

2192





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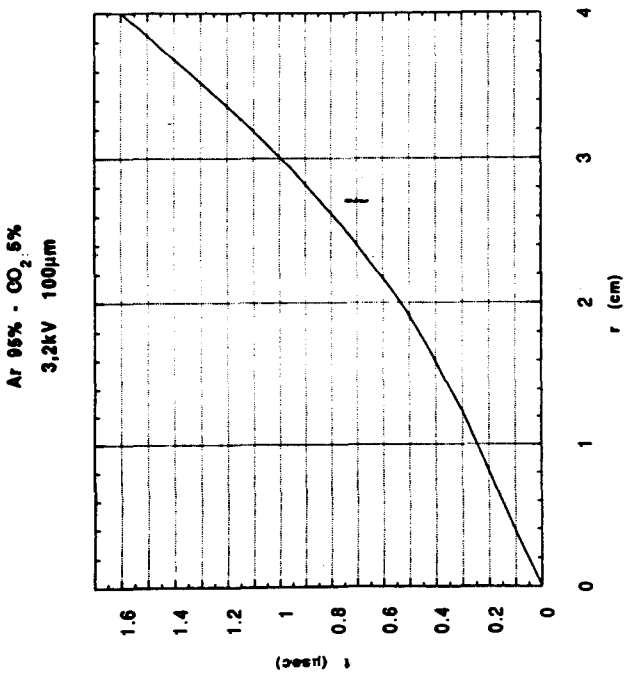

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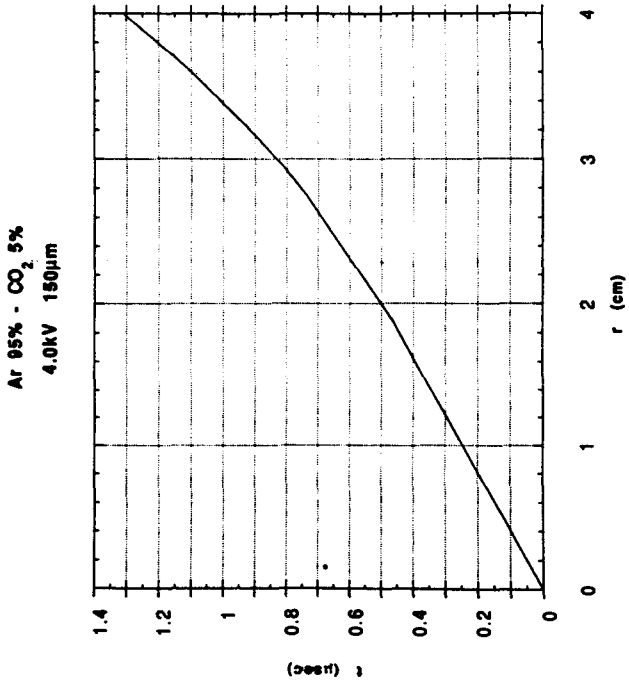

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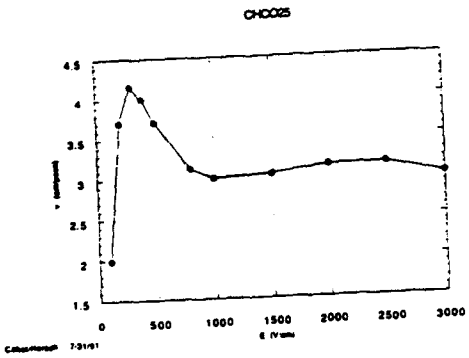

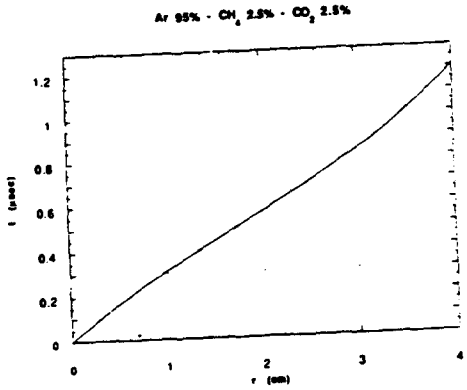

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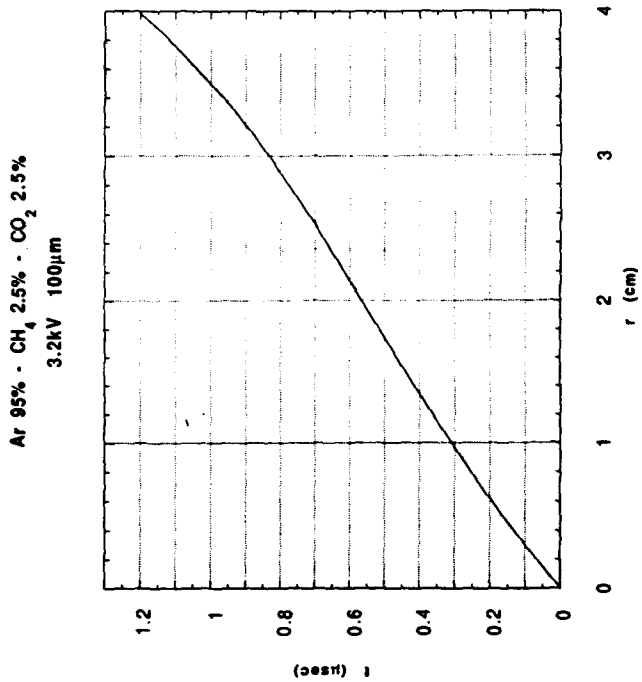

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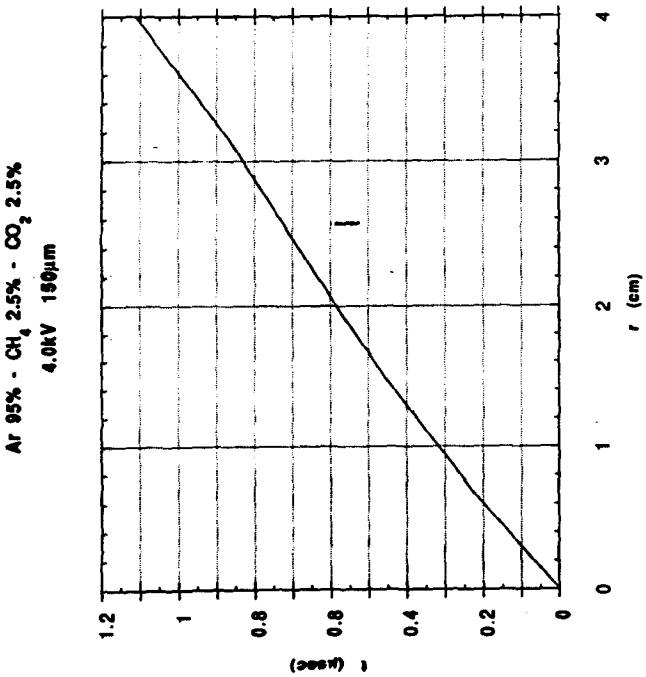

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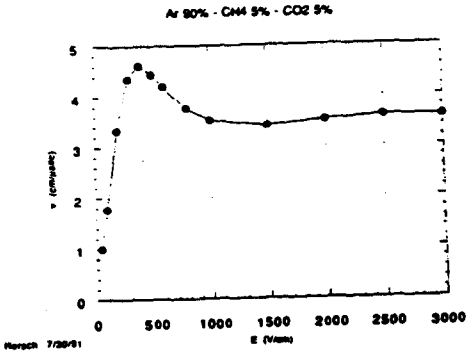

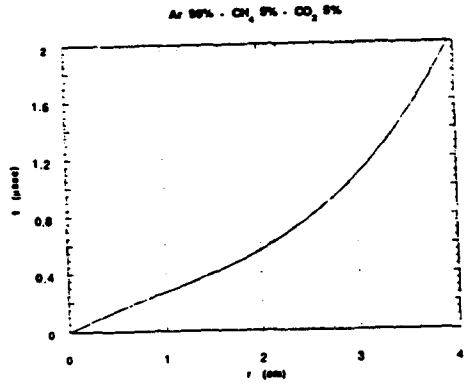

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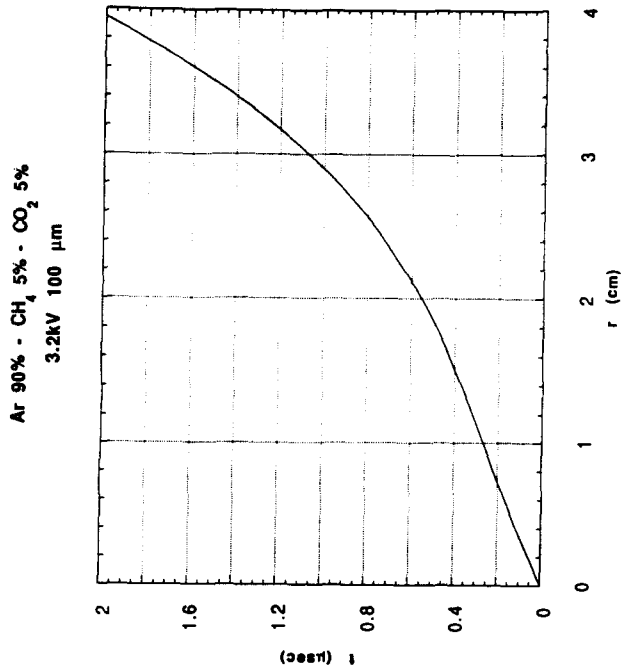

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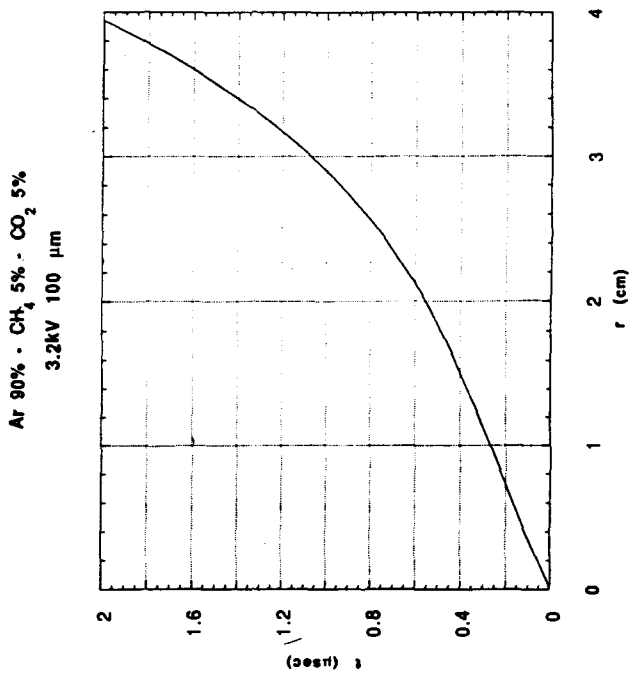

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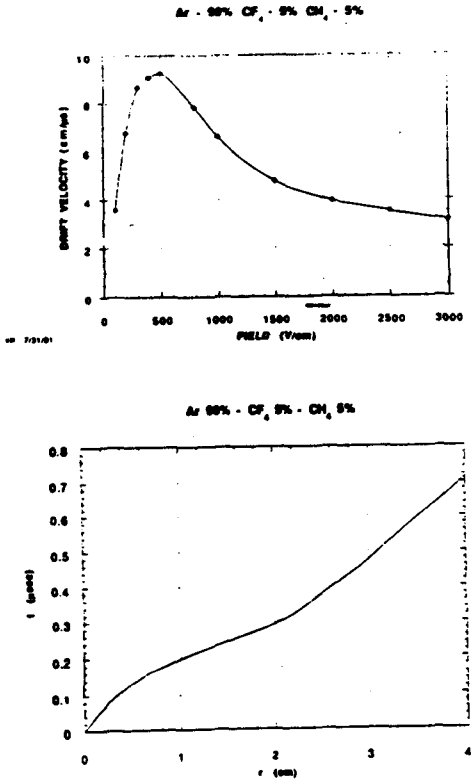

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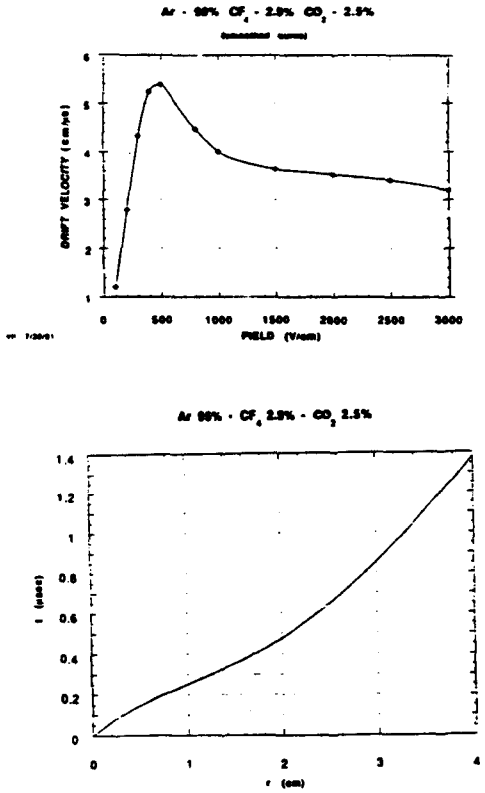

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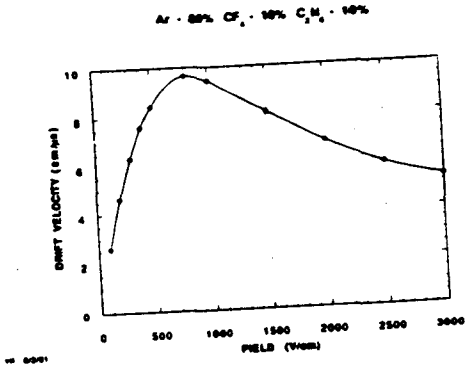
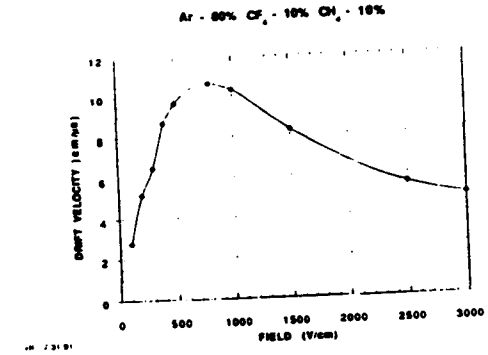




2204

- **EFFICIENCY STUDIES**
  (T. ZHAO THIS MEETING)
  - NO FIELD SHAPING
  - FIELD SHAPING
- **PROTOTYPE TEST CELLS**
  - 3 in. TUBES
    1. NO FIELD SHAPING
    2. FIELD SHAPING
    3. .050, .100 and .150 mm dia. for a few tubes
  - MEASURMENTS IN T816 TEST BEAM
- **BUILD PROTOTYPE MODULE**
  - SMALL -6 ft x 6 ft- IN SEATTLE (mechanical problems first order)
  - THETA, PHI AND STEREO VIEWS
- **FULL SCALE MODULE- 9 m**
  (AT SSCLAB)

2205

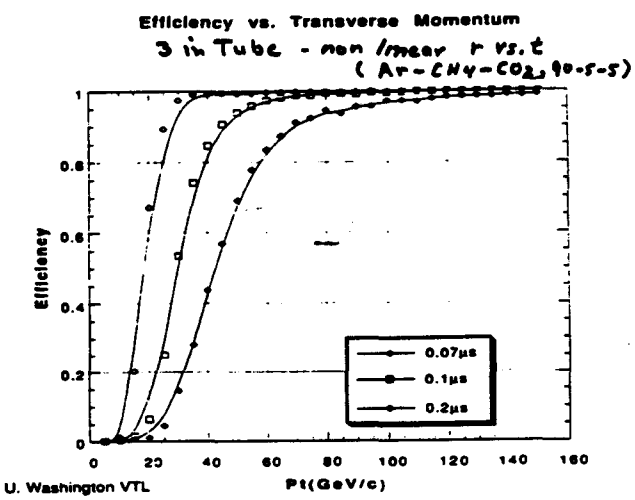


Fig. 6

2206

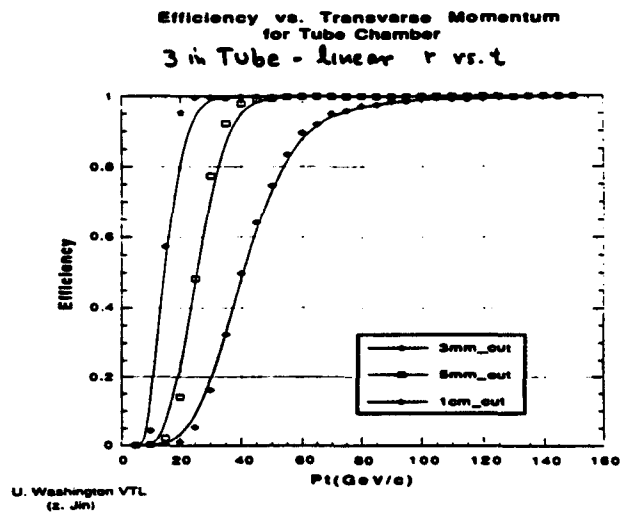
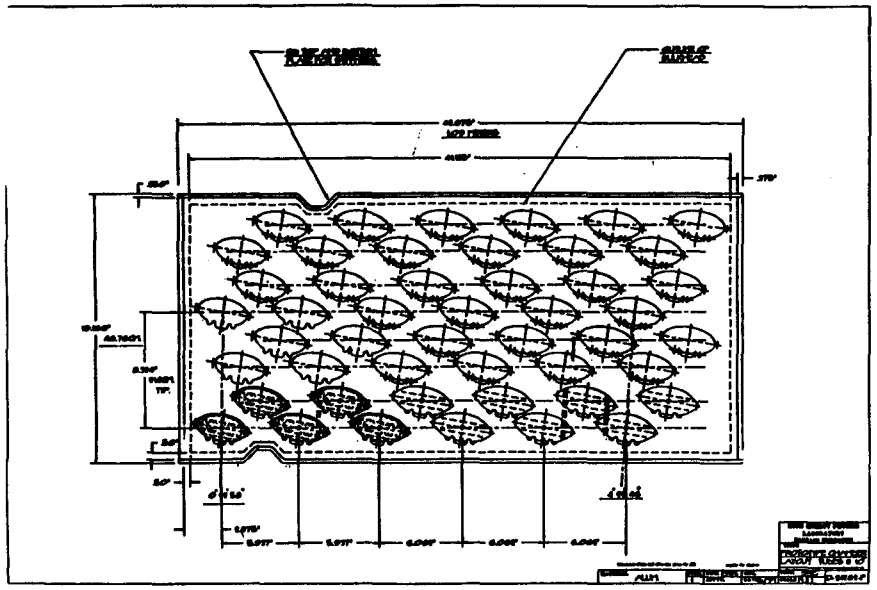
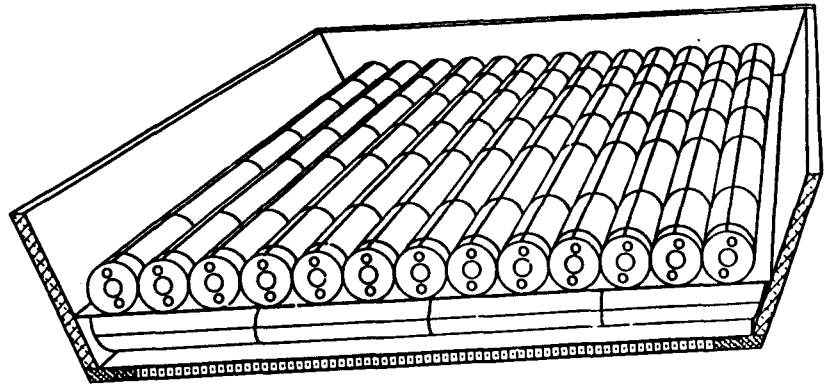


Fig. 7



2209

Prototype to test mechanical issues



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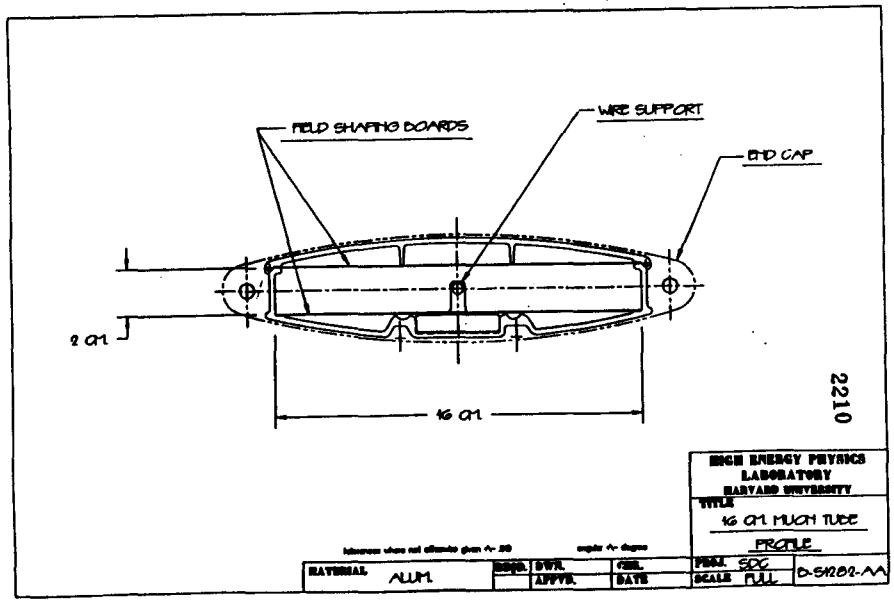


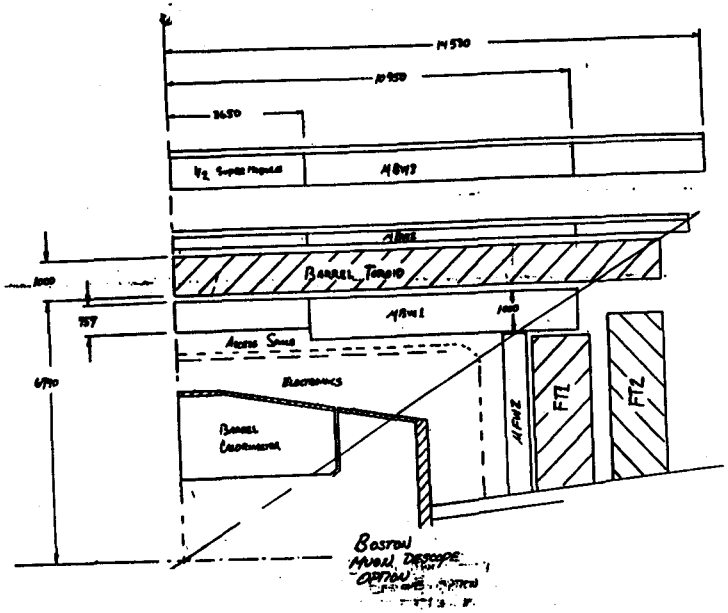
2210

14

G. Feldman

Boston Group Chamber Update

2208



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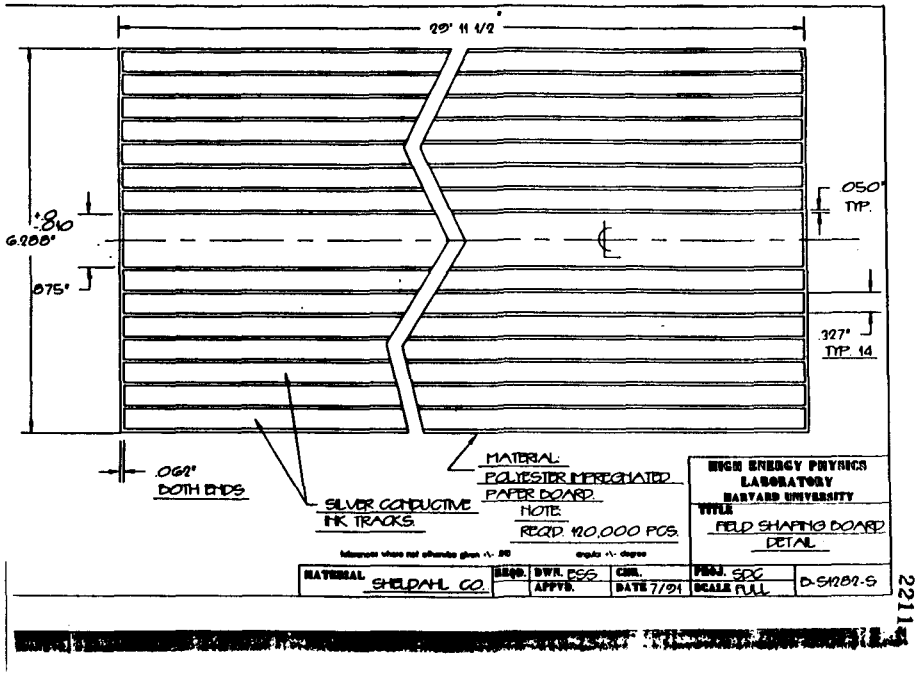

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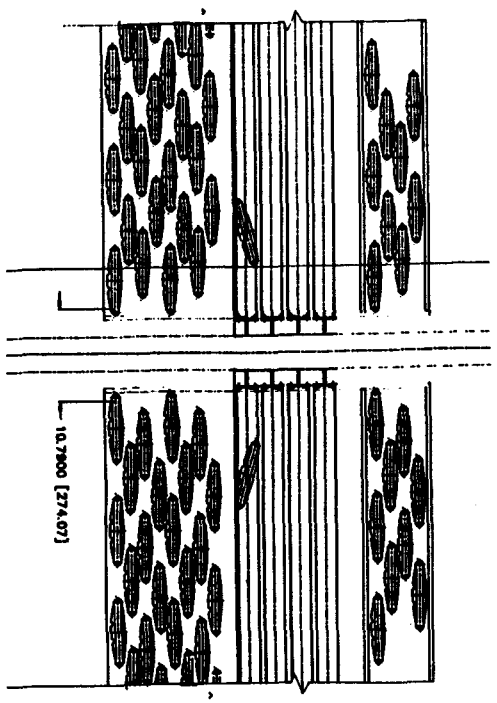
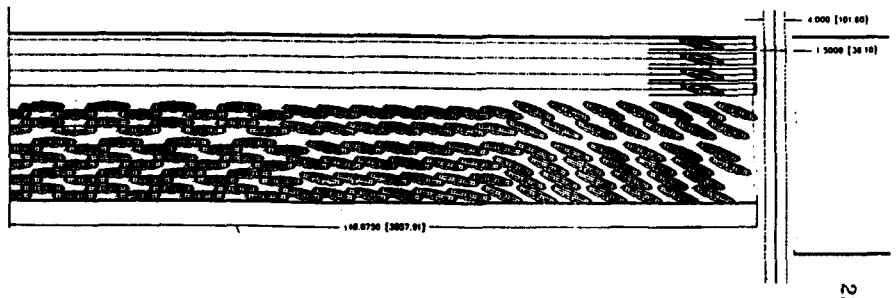


Boston Muon Group
Before Descope
Electronics Access @ theta = 0

2214

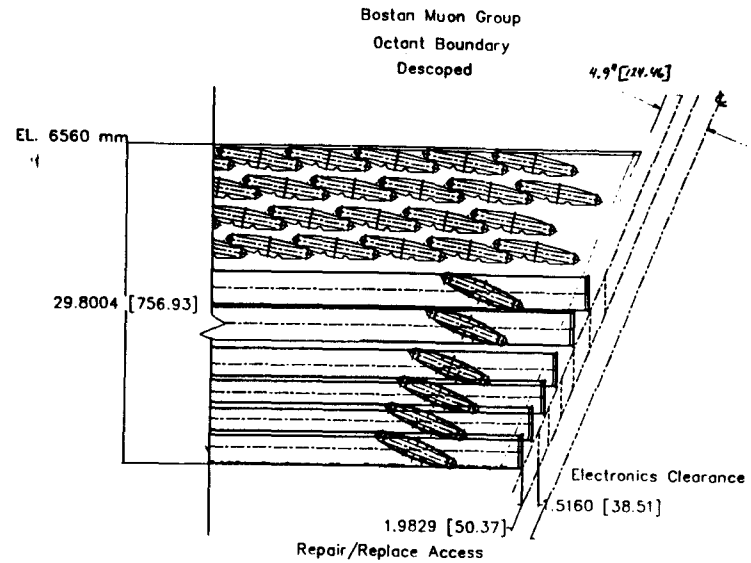


2212

SUPERMODULE DESIGN SUMMARY
BOSTON CHAMBER CONCEPT

- μBW1, μBW2, & μBW3 SUPERMODULES ARE TRAPEZOIDAL SECTION, STIFFENED THIN-PANEL BOX STRUCTURES
  - μBW1: 4Θ & 4 ϕ IN TWO LAYERS
  - μBW2: 4Θ IN ONE LAYER
  - μBW3: 4Θ, 4ϕ & 2S IN THREE LAYERS (LATER TWO)
- MODULE LAYOUTS UTILIZE 16 X 2 cm. DRIFT TUBE, WITH TUBES COMPRISING ~ 60% OF TOTAL MODULE WEIGHT
- BOX STRUCTURES PROVIDE APPROX. 1 mm OR LESS CENTER SPAN DEFLECTION
  - HORIZONTAL PANELS 3/8" (TOP/BOTTOM), 1/4" (INTERIOR)
  - BULKHEADS AND EXTERIOR VERTICALS 1/2"
  - SHEAR WEBS 1/8"
- BOX IS OF WELDED ALUMINUM CONSTRUCTION, WITH REMOVABLE ACCESS PANELS AS REQUIRED

2217

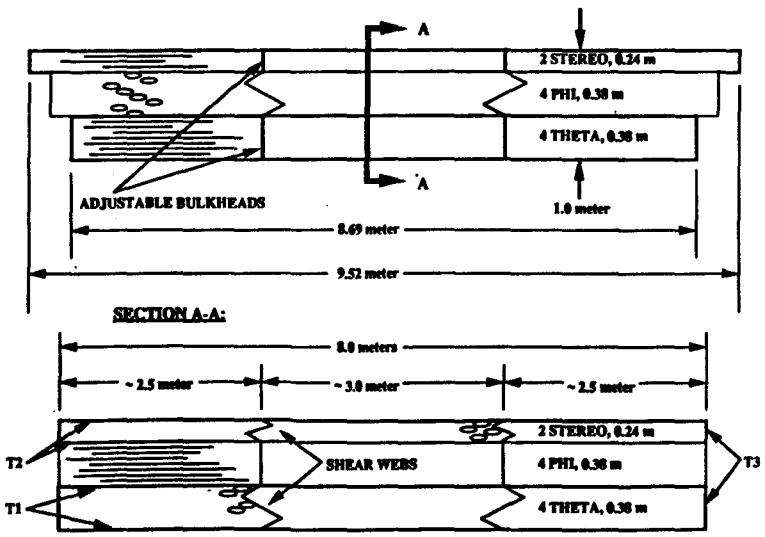


2215

J. GORMAN

SDC "BOSTON" MUON SUPERMODULE SCHEMATIC

BW3 DIMENSIONS SHOWN, SIMILAR THICKNESS DISTRIBUTION IN BW1



2218

SUPERMODULE DESIGN & ANALYSIS REVIEW
BOSTON CHAMBER CONCEPT

- SUPERMODULE DESIGN SUMMARY
- GRAVITY LOADING ON QUARTER SUPERMODULE
- POINT LOAD RESPONSE OF FULL SUPERMODULE
- DESIGN & ANALYSIS OF μBW3/μBW2 TRUSS CONCEPT
- SUPERMODULE COST DRIVERS AND DESIGN RATIONALE
- PRELIMINARY ASSEMBLY SEQUENCE AND BOX COSTING
- CONCLUSIONS

J.J.G./CSDL/7 AUGUST '91

15

2216

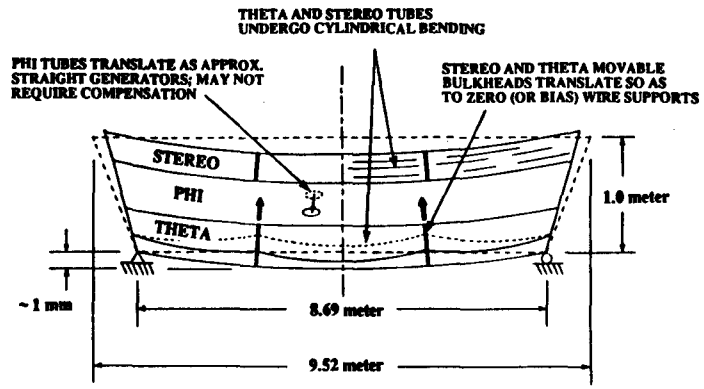
WEIGHT AND CENTER SPAN DEFLECTION ESTIMATES FOR "BOSTON" SUPERTOWER

DESCRIPTION		COMP. WT. (METRIC TONS)	TOTAL WT. (METRIC TONS)	DEFLECTION (MICRONS)
μBW1	TUBES	6.0	10.2	120
	BOX STRUCT.	4.2		
μBW2	TUBES	4.0	7.1	1160
	BOX STRUCT.	3.1		
TRUSS			3.0	
μBW3	TUBES	13.7	24.0	630
	BOX STRUCT.	10.3		

NOTE: CURRENT WEIGHTS REFLECT REVISED TUBE CROSS SECTION AND CONTAIN 12% MARGIN FOR MISC. ATTACHMENTS AND FITTINGS. DEFLECTIONS INCLUDE SHEAR BUT NOT FINITE JOINT FLEXIBILITY

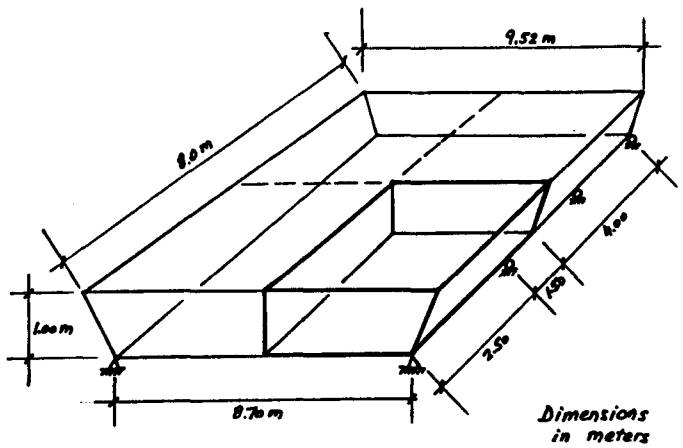
2221

SUPERMODULE COMPENSATION CONCEPT



BW3 GEOMETRY

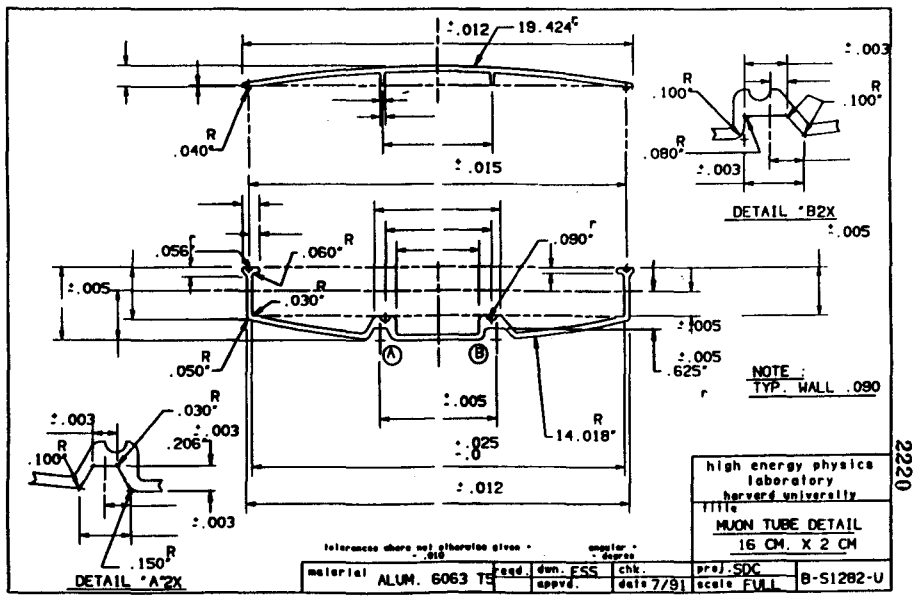
2219



SUPERMODULE CONFIGURATION

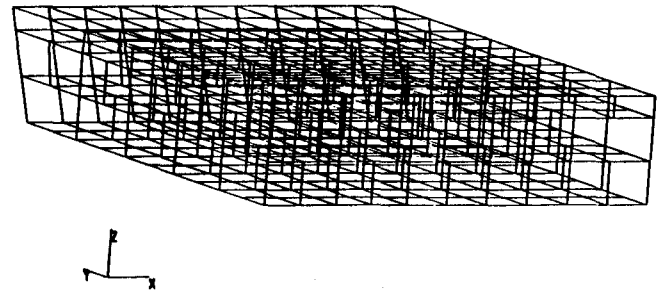
- Model and analysis of 1/4 supermodule (symmetry!)
- Supermodule weight estimated at 24 TONS (July 20/91)

2222



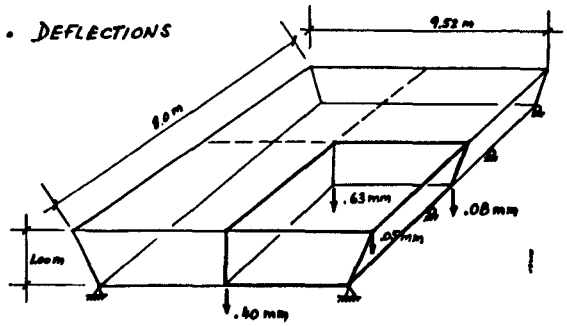
2220

M-72, IN JULY, 94



SUMMARY of RESULTS

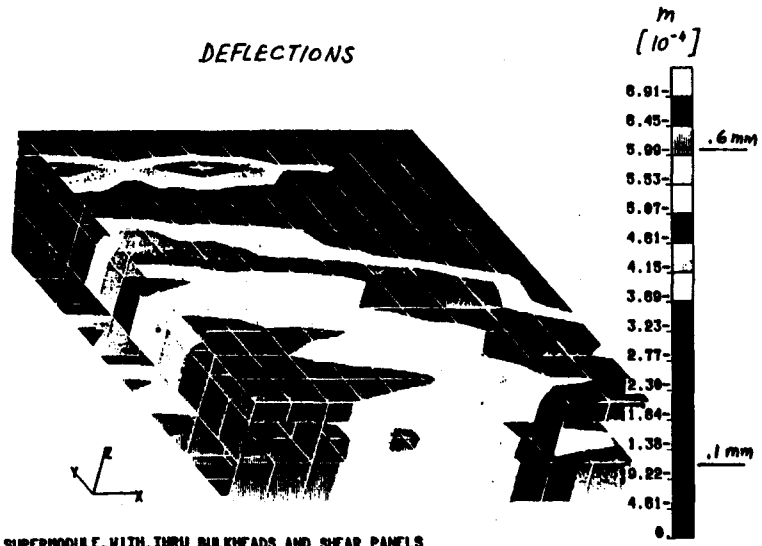
- DEFLECTIONS



- WEIGHT – 1/4 MODULE TUBES 3454 kg, STRUCT. 2564 kg } ≈ 6000 kg
  - Entire module 24 TONS
- STRESSES Very low since design is deflection limited
  Van Mises $\sigma_{max} < 5 \times 10^6\ N/m^2$
  $\approx 730\ psi$

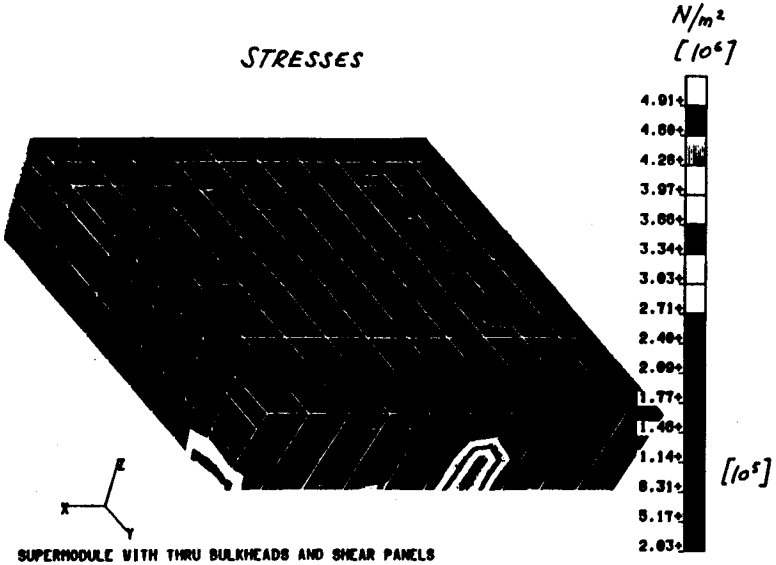
[$1\ psi = 6.895 \cdot 10^3\ N/m^2$]

DEFLECTIONS



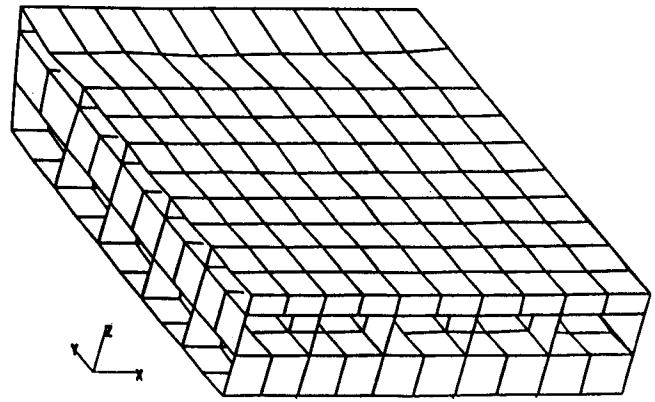
SUPERMODULE WITH THRU BULKHEADS AND SHEAR PANELS
TIME [0] FREQUENCY [0.00000
STEP [1] - ITERATION [1]

STRESSES



SUPERMODULE WITH THRU BULKHEADS AND SHEAR PANELS
SUBCASE 1 - ITERATION 1

DEFLECTED SHAPE

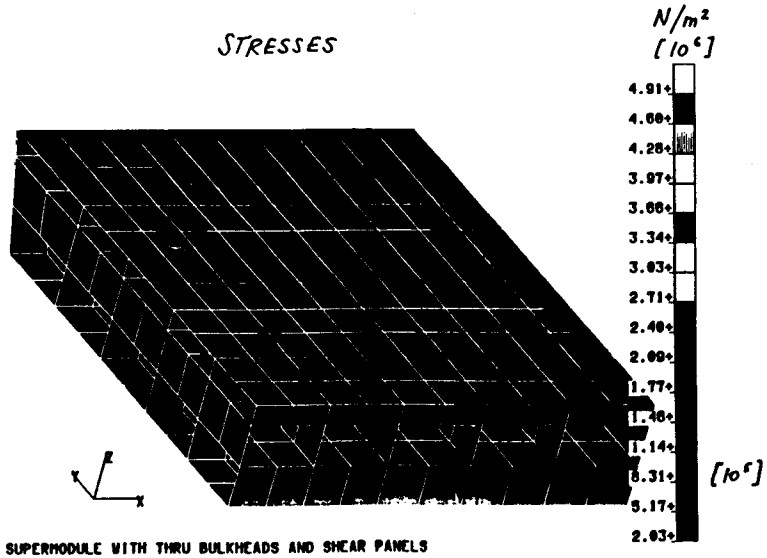


SUPERMODULE WITH THRU BULKHEADS AND SHEAR PANELS
SUBCASE 1 - ITERATION 1

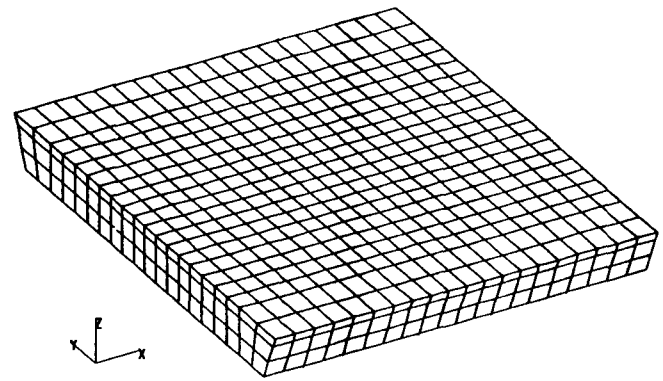
FULL SUPERMODULE ANALYSIS

- Evaluation of Concentrated Load Influence Coefficients
  - 1000 Newton Load @ Bulkhead Intersection
  - Consistent With ΔF Upon Adjustment
  - Compare Deflections at Other Locations
- Additional Deflections Very Small
  - Under Load : 12.3 microns
  - Adjacent Bulkhead Intersections
    - Same X 7.5 microns
    - Same y 7.5
    - Diagonal 6.0
    - Free Edges 1-4
    - Restrained Edges 0.1
- No Control System Evaluation Yet, But Δy^3 only 1% of Gravity Loading Should Not be a Problem

STRESSES



SUPERMODULE WITH THRU BULKHEADS AND SHEAR PANELS
SUBCASE 1 - ITERATION 1



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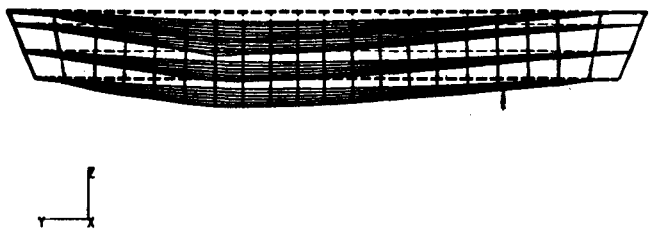
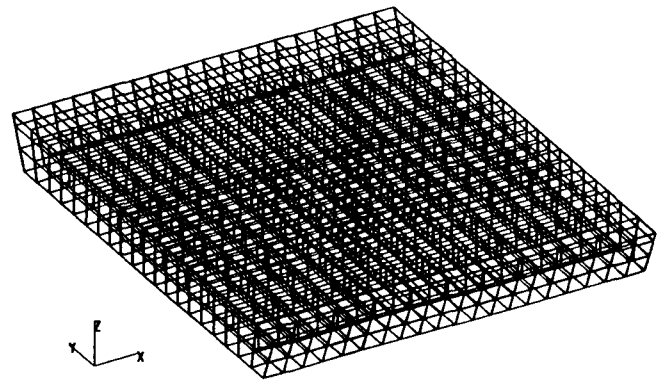


FULL SUPERPROFILE 1000 N LOAD ON NODE 541
TYPE [CR FREQUENCY] = 0.000
STEP = 1 - ITERATION = 1

2233



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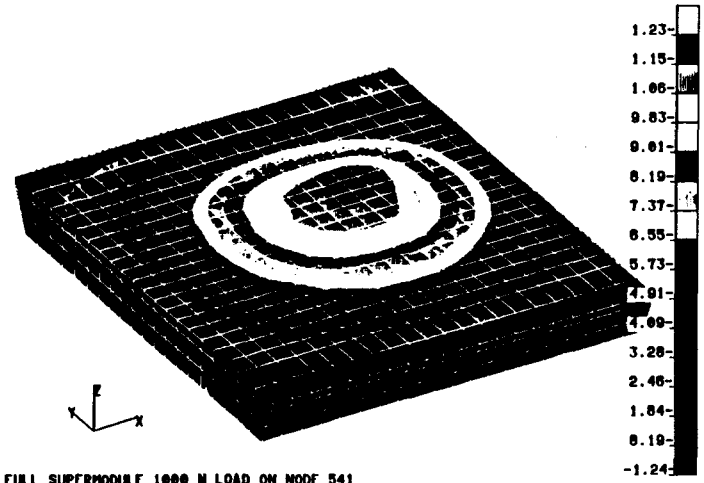

FULL SUPERPROFILE 1000 N LOAD ON NODE 541
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STEP = 1 - ITERATION = 1

2234

- SDC DETECTOR
- MUON CHAMBER SUPPORT

28 July 91
FA
CADL

PRELIMINARY TRUSS CONCEPT
TO CARRY BW3 (24 TONS) and BW2 (10 TONS)

- Both BW3 and BW2 are monolithic chambers thus optimizing tube # & physics
- BW2 Box needs small cut outs to allow for insertion of small diagonals required for side gravity loading.
- Preliminary design of truss uses
  1½" ϕ steel tubes — X-strong for trusses, standard weight for bracing

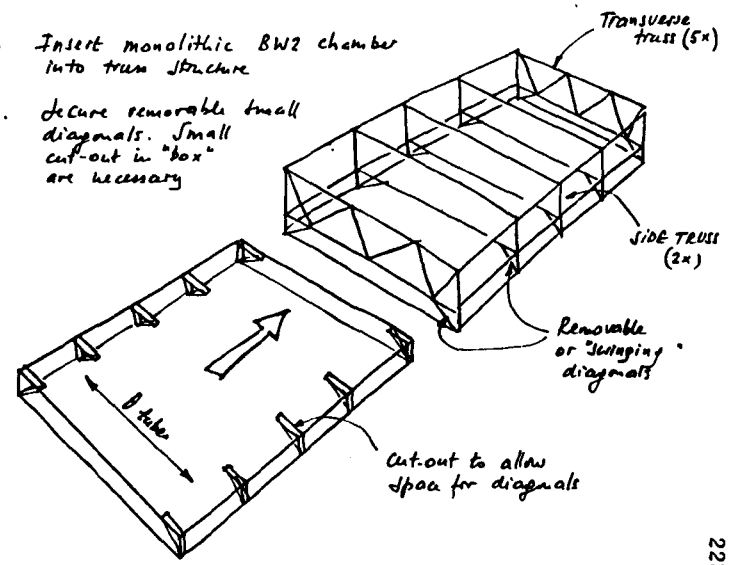
  Truss weight < 3 TONS
- Finite element analysis (simple) is needed to identify distortions and stresses under 5 gravity vectors. Reinforcements may be necessary.
- TOTAL WEIGHT 24 + 10 + 3 = 37 TONS (PSL has 30 TONS)

2235

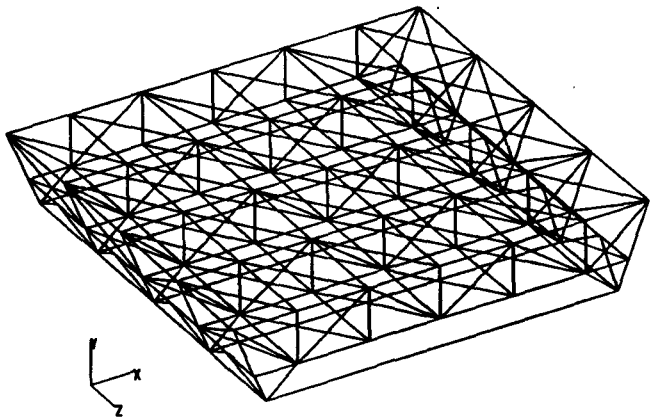
24 July 91
FA

TRUSS - BW2 ASSEMBLY CONCEPT

1. Insert monolithic BW2 chamber into truss structure
2. Secure removable small diagonals. Small cut-out in "box" are necessary

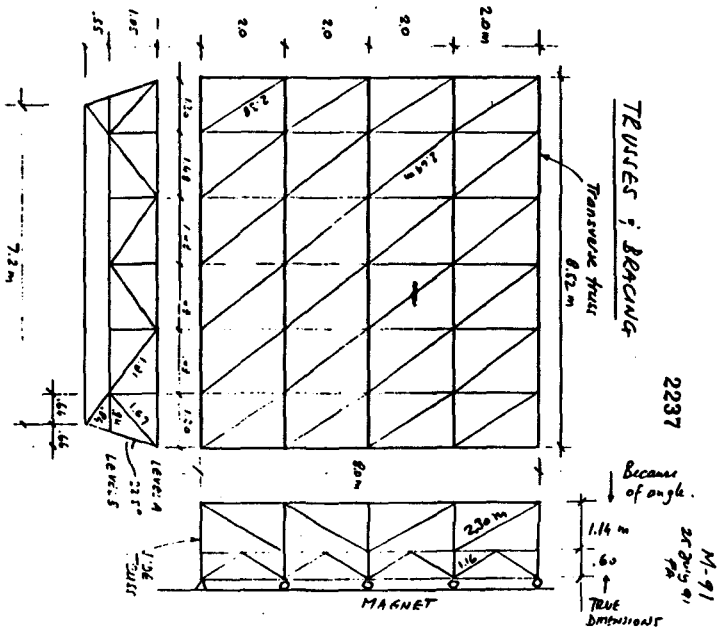


2236



2238

TRUSSES & BRACING



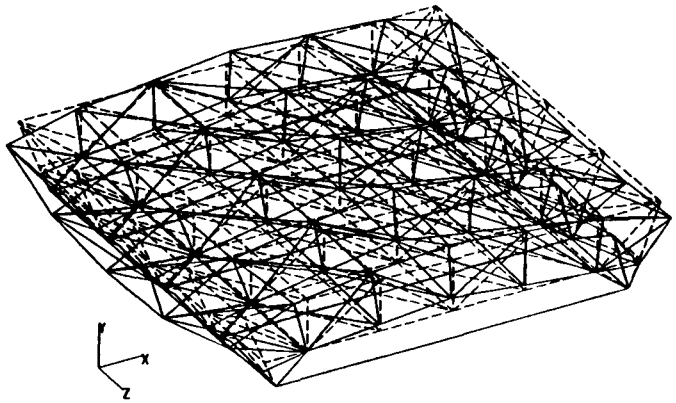
- USE JAMES PATTERN ON LEVEL B for bracing OR ANGLE DIFFERENCE FROM LEVEL A

PRELIMINARY
- FOR 5 transverse trusses & 2 side trusses
  USE 1½" ϕ X-strong steel tubes (1.9" OD)
  for Bracing in Levels A & B
  USE 1½" ϕ standard steel tubes (1.9" OD)

2237

M-91
25 July 91
FA

M-96



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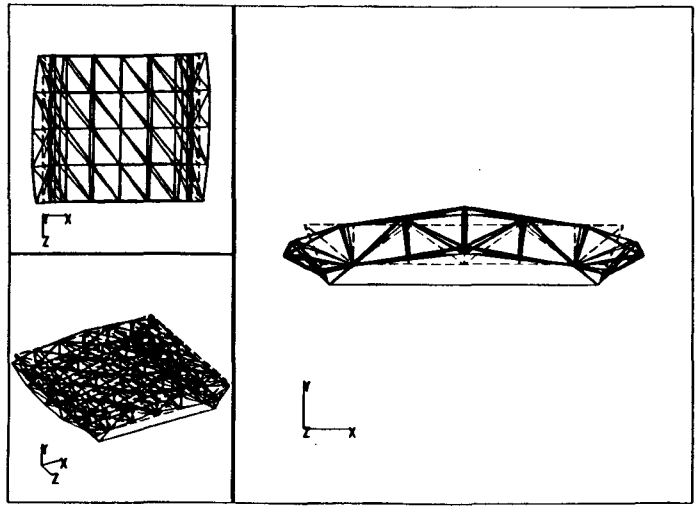
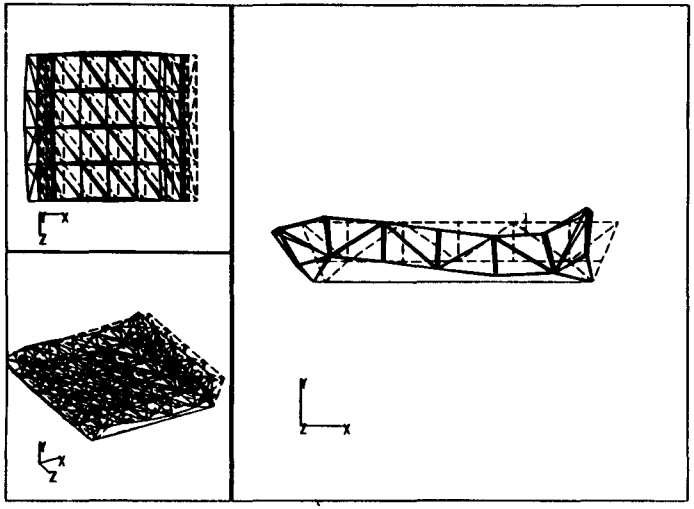


2240



2241

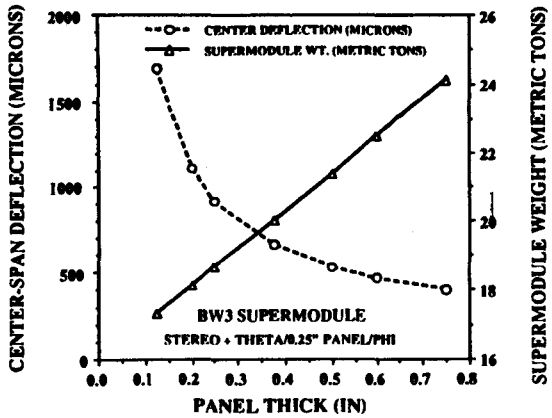
SUPERMODULE COST DRIVERS AND DESIGN RATIONALE

- TYPE AND WEIGHT OF STRUCTURE
- DISTRIBUTION OF TUBE ORIENTATIONS
- PRECISION BULKHEAD CONFIGURATION
- DISCRETENESS (#s) OF ALIGNMENT/COMPENSATION
- ALIGNMENT AND ACTUATION HARDWARE COMPLEXITY
- SUPERMODULE ASSEMBLY CONCEPT
- IN SITU CALIBRATION REQUIREMENTS/PROCEDURES

J.J.G. - 7/29/91

2242

REVISED SUPERMODULE DEFLECTION TRADES THETA AND STEREO COMBINED



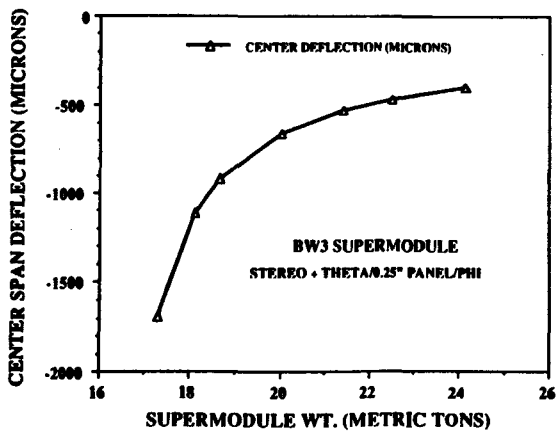
2245

DISTRIBUTION OF TUBE ORIENTATIONS

- REQUIREMENTS
  - PHYSICS PERFORMANCE
  - LAYOUT CONSTRAINTS
- CONFIGURATION OR PROCEDURE OPTIONS
  - STEREO SEPARATED FROM THETA
  - STEREO INTEGRATED WITH THETA
- DESIGN AND PERFORMANCE ISSUES
  - STEREO 1 DEGREE DEVIATION FROM THETA IS NEGLIGIBLE
  - MAY USE SAME BULKHEADS FOR SAVINGS IN ALIGNMENT SYSTEM
  - INTEGRATING STEREO WITH THETA SAVES A 0.25" PANEL (2800 LB)
- RECOMMENDATIONS
  - INTEGRATE THETA AND STEREO IN μBW3 SUPERMODULE

2243

SUPERMODULE WEIGHT VERSUS DEFLECTION



2246

TYPE AND WEIGHT OF STRUCTURE

- REQUIREMENTS
  - MINIMUM PRACTICAL DEFLECTION UNDER DIVERSE GRAVITY LOADINGS
  - MINIMUM WEIGHT CONSISTENT WITH DEFLECTION CONSTRAINTS
  - STRAIGHTFORWARD (INEXPENSIVE) CONSTRUCTION
- CONFIGURATION OR PROCEDURE OPTIONS
  - NUMEROUS COMBINATIONS OF PANELS AND BULKHEADS/STIFFENERS
  - STIFF, PASSIVE DESIGN TO DEFLECTION CONSTRAINTS
  - FLEXIBLE, COMPENSATED DESIGN
- DESIGN AND PERFORMANCE ISSUES
  - MAGNET MOTIONS A WILD CARD AND SUGGEST MAXIMIZING CAPABILITY
  - FABRICATION AND HANDLING ISSUES WILL ADD COMPENSATION REQTS.
  - SUPERMODULE WEIGHT VS. DEFLECTION SHOWS A PRONOUNCED "KNEE"
  - AVAILABLE PLATING THICKNESSES ARE <u>NOT</u> INFINITELY VARIABLE
- RECOMMENDATIONS
  - DESIGN SUPERMODULE TO "KNEE" IN DEFECTION CURVE
  - CORRESPONDS TO ABOUT 3/8" PANEL THICKNESSES FOR μBW3

2244

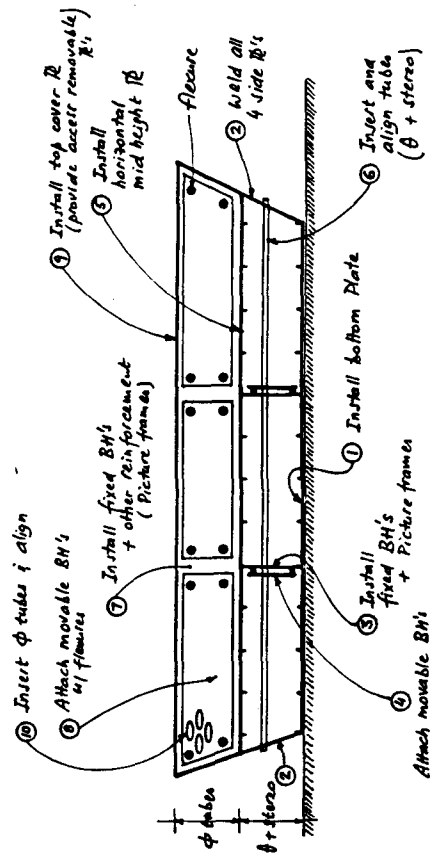
DISCRETENESS OF ALIGNMENT/COMPENSATION

- **REQUIREMENTS**
  - MINIMIZE OR COMPENSATE SUPERMODULE DEFLECTIONS AND GEOMETRY DISTURBANCES FROM OTHER SOURCES
  - REASONABLE ACQUISITION, ASSEMBLY, AND UTILIZATION COST
- **CONFIGURATION OR PROCEDURE OPTIONS**
  - SINGLE MOVABLE BULKHEAD SPAN VICE SEGMENTATION
  - PERHAPS NO COMPENSATION FOR PHI TUBES
- **DESIGN AND PERFORMANCE ISSUES**
  - BULKHEADS FOR PHI TUBES MUST BE SPLIT (I.E. 3 PER SPAN) TO ACCOMODATE SUPERMODULE PRIMARY BENDING.
  - BULKHEADS FOR THETA TUBES PROBABLY NEED BE SPLIT; ANTICLASTIC BENDING AND MAGNET DEFORMATION RESPONSE.
- **RECOMMENDATIONS**
  - BASELINE SIX (2x3) ADJUSTABLE SEGMENTS PER PHI OR THETA LAYER
  - MORE WORK TO JUSTIFY CONFIGURATION

Aug 2/91 FA Draper

SUGGESTED SUPERMODULE BW3 FABRICATION

Components assembly sequence



F. Ayer
2 August 1991
Draper

SUPERMODULE BW3

PRELIMINARY COST ESTIMATE

Material

- Tubes 351θ
  131φ — Costed Elsewhere
  175 stereo
  Total 657 all 8m long
- Aluminum Box $2/#, ~10 Tons — 44,000
- Movable BH's & End Precise Plates 24 @ $800 (NC mach.) — 19,200
- Alignment Hardware 6 @ $1200 — 7,200
- Flexures 12 BH @ $800 Each — 9,600

TOTAL MATERIAL — 80,000

Labor

- Box Fabrication, Estimate — 25,000
- Insertion of Tubes 657 @ $20/Tube — 13,140
- Alignment
  - before — 6,000
  - after — 6,000
- Miscellaneous — 10,000

60,140

TOTAL MAT & LABOR — 140,140

F. Ayer
2 August 1991
Draper

Miscellaneous

- Handling Equipment — 40K
- Fixturing, Tooling, Etc. — 30K

TOTAL — 70K

This cost is not repeated for each chamber

- With 2 chambers being built at the same time

Equipment & fixturing = 2 x 70K = 140K

Summary

Construction of BW3 → 32 Boxes

Total Cost — 140K x 32 = 4,480K
Equipment = 140K
4,620K

Gross Estimate 4.62 Mio
for 32 - BW3 Modules

CONCLUSIONS

- Efficient Supermodule Box Structures Can be Designed at About 20-24 Metric Tons for μ BW3
- Deflections OF the Order 1 mm Under Gravity Seems to be a Sensible Design Point, with Some Margin for Contingencies.
- Incremental Deflections Due To Bulkhead Adjustment are Only ~ 1% of Gravity Values.
- A Truss Concept Minimizing μ BW2 Cracks has been Formulated and Evaluated with Promising Results.
- Preliminary Assessment of Supermodule Assembly and Box Costing Has Been Made.

16

S. Odaka (KEK)
Muon subgroup
SDC Collab. Meeting, LBL, August 4 - 10, 1991

Why a jet chamber ?

The muon system of SDC is required to have a capability of

stand-alone momentum measurement
→ relatively good spatial resolution
~ 250 μm/station (superlayer)
→ good alignment (~ 100 μm) required
→ large modules (several m × 10 m)
and common endplates
→ no reason to avoid *large chamber* designs

and triggering.
→ *projective geometry*

⇒ Jet chamber is a *natural* solution.

What is more,
constant drift velocity → covenient for *triggering*.

Difficulties of tube designs

Square tubes

Effective drift field ~ 200 V/cm
→ P10 is the only choice for the drift gas.
No choice in fast gasses.
i.e. No freedom in the cell design.

Common endplate / projective geometry
→ gas-sealing problem
⇒ The structure will *not* be very simple.
The construction will *not* be very easy.

Tubes with field-shaping electrodes

E_{drift} ~ 1 kV/cm is possible,
but an incident-angle dependence of the resolution.
→ a rotated arrangement
⇒ A very *complicated* and/or
very *space-consuming* structure

Short spacing between the anode and the shaping electrodes
⇒ A better tube alignment is required.

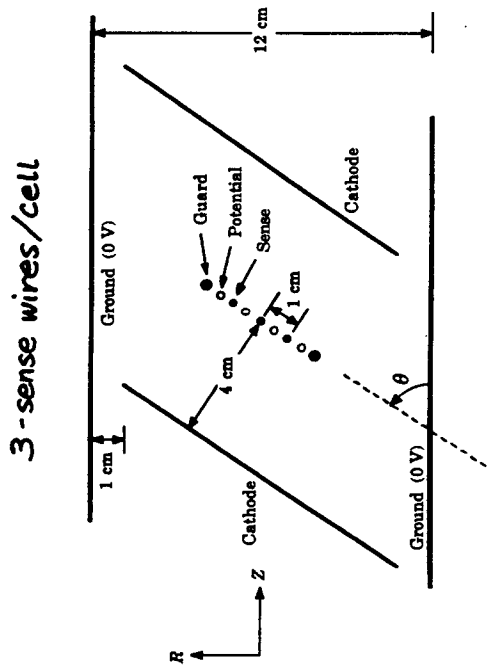
KEK Design

A uniform drift field formed with
very small number of electrodes:
sense wires
potential wires
guard wires
cathode planes
(*no field-shaping electrodes !*)

A perfect *projective-cell* arrangement with
identical cell parameters
(cell width, HV values, wire spacing, etc.)
for all cells.

Note: for *projective-cell* arrangements,
the number of cells ~ 3/4 of *projective-wire* arrangements in the barrel region.

$$\frac{n_{PC}}{n_{PW}} \cong \frac{\ln(x+\sqrt{1+x^2})}{x}\ ;\ x = \cot\theta_{min}$$



How to determine the cell parameters

Assumption of an ideal jet cell → *charge densities* on the cathode plane and the sense/potential wires

$$\sigma_c = -\varepsilon_0 E_{drift}$$
$$\lambda_s = -2w_{cell}\sigma_c/(1 + R_{s/p})$$
$$\lambda_p = R_{s/p}\lambda_s$$

$w_{cell} = 1$ cm,
and we chose $E_{drift} = 1$ kV/cm and $R_{s/p} = -1/3$.

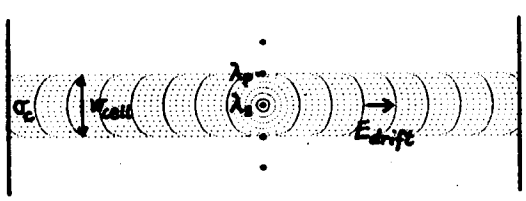
Give the wire diameters ⇒ *voltages* to be applied

Calculation based on the exact geometry
→ optimization of the guard-wire voltage

	diameter (μm)	voltage (kV)
sense	50	+ 2.87
potential	200	0
cathode	plane	− 3.23
guard	200	+ 2.87

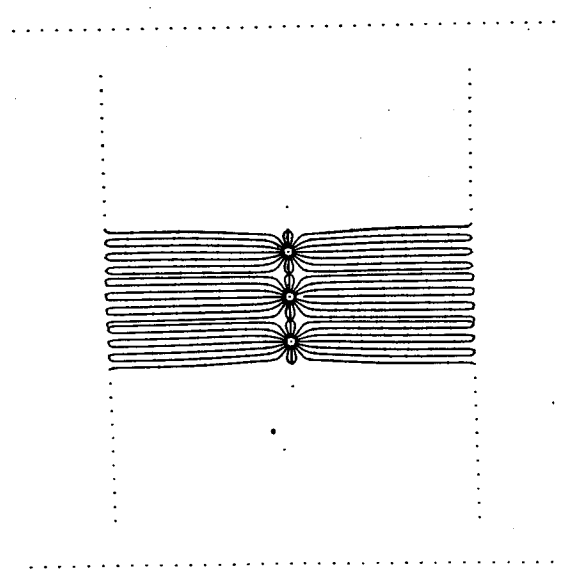
The *wire diameters* are still **tentative** and are to be optimized by the considerations on
gas gain
and mechanical/electrical stability.

Ideal Jet Cell

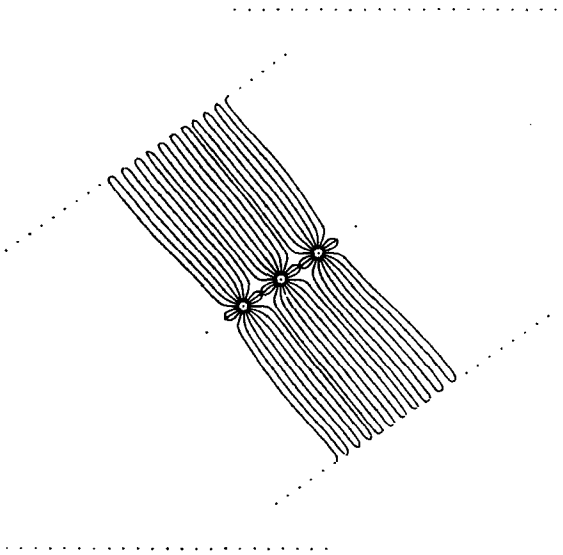


$$\lambda_s + \lambda_p + 2\,w_{cell}\,\sigma_c = 0$$
$$R_{P/S} \equiv \frac{\lambda_P}{\lambda_S}$$

$\theta \cong 90°$



$\theta \cong 35°$



Chamber Gas

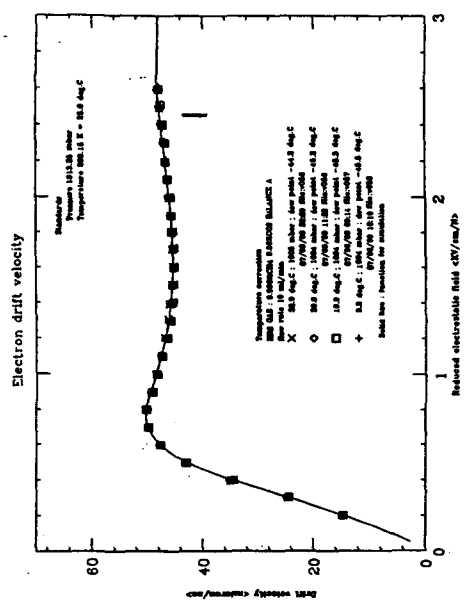
First candidate: HRS-gas; Ar/CO_2/Methane (90/9/1)

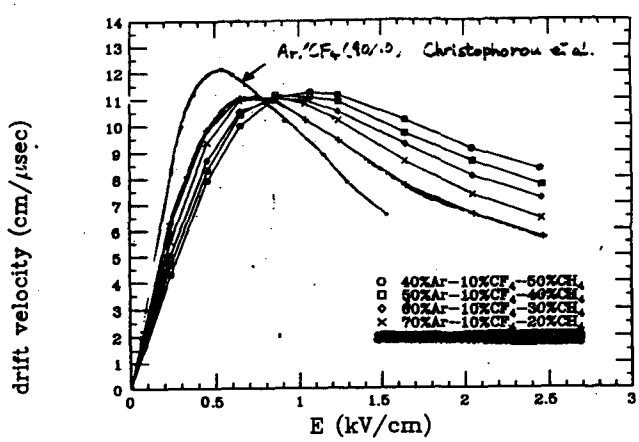
- well established (HRS, VENUS, AMY etc.)
- nearly saturating v_{drift} @ $E_{drift} \gtrsim 800$ V/cm
- nonflamable
- ⇒ The operation point has to be optimized.

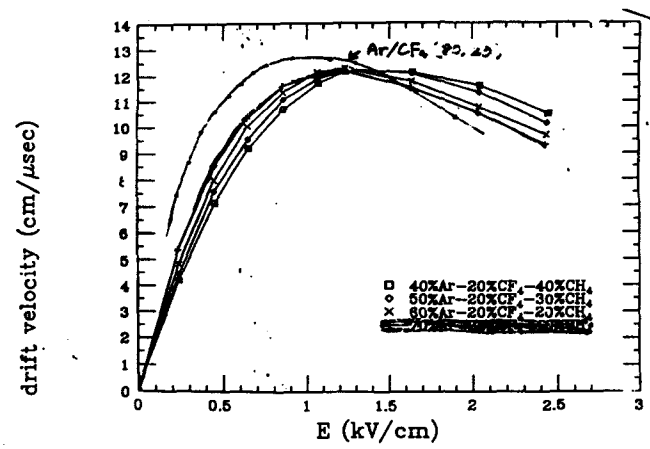
Option: Ar + 10~20% CF_4

- nonflamable
- *fast gas*
  - $v_{drift} > 10$ cm/μsec @ $E_{drift} \cong 1$ kV/cm
- may have a problem in *HV stability*
- → add some organic gas, *e.g.* a few % Methane
  - ⇒ need studies

HRS-gas: Ar + CO_2(9.5%) + CH_4(0.996%)







R&D at KEK

(1) Large chamber → Terada's talk

(2) Short chambers
50 cm long, *one cell* in each chamber

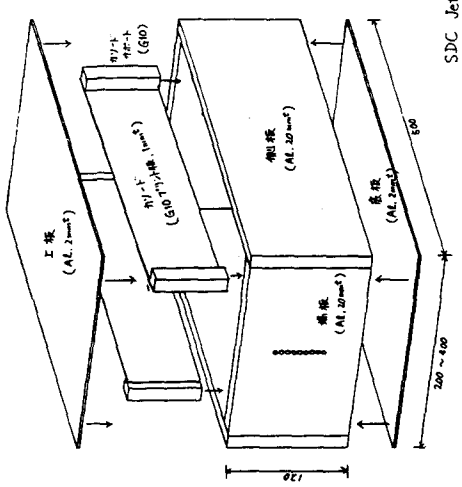
For a **proof** of the calculation results

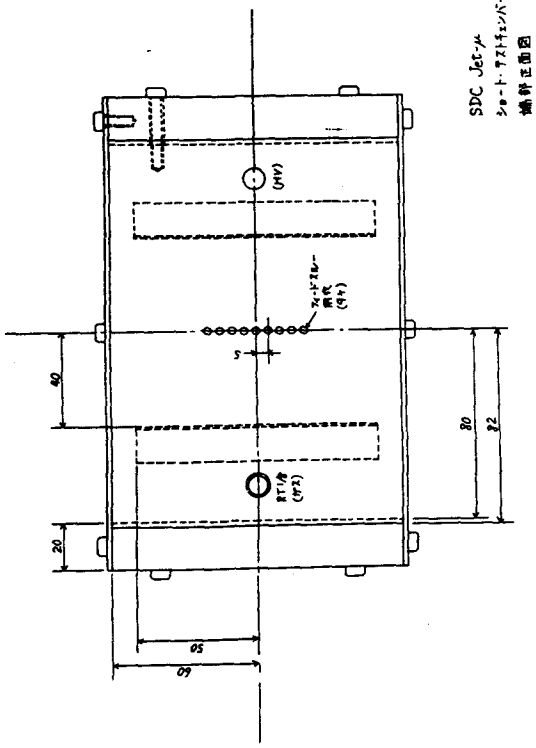
⇒ 2 chambers corresponding to $\theta = 90°$ and $30°$, respectively, *have been ordered.*
The first one ($\theta = 90°$) will be built by the end of August.

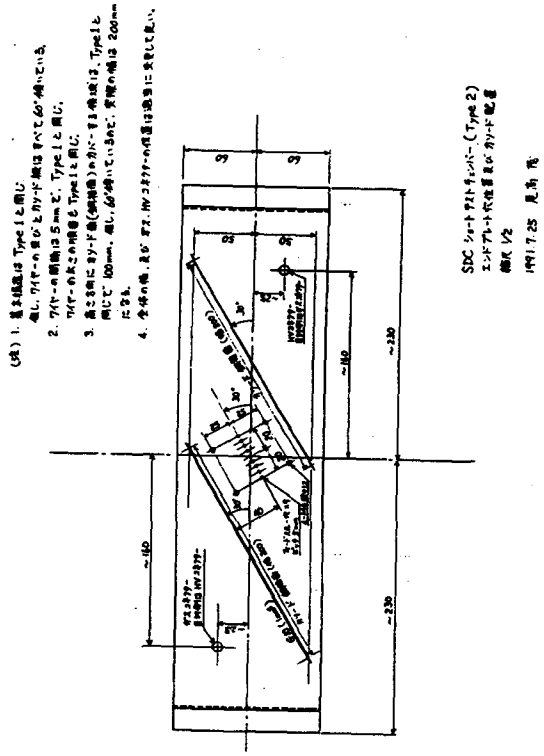
(3) Thin-tube chambers
an array of 8 × 15.5 mm diameter tubes (20 cm long)

Studies of **chamber gasses**

present: *gas gain* of the HRS-gas
A measurement has been done for a 30 μm$^{\phi}$ wire.
→ thicker wires
next: feasibility of *fast gasses* (Ar/CF_4-base)







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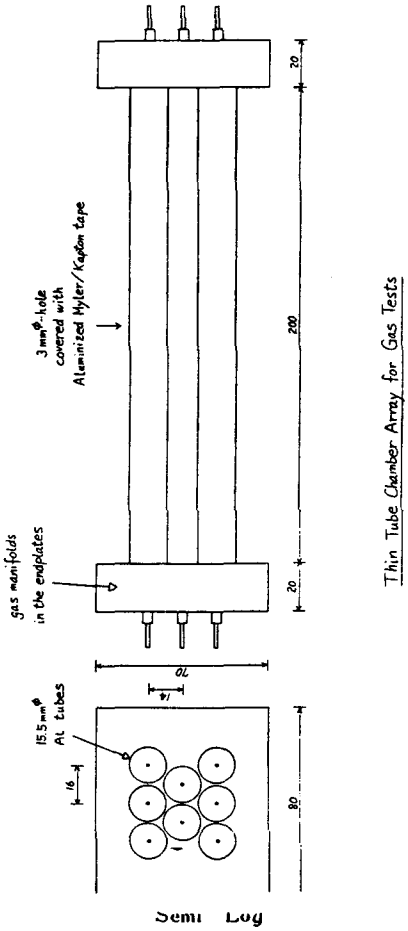
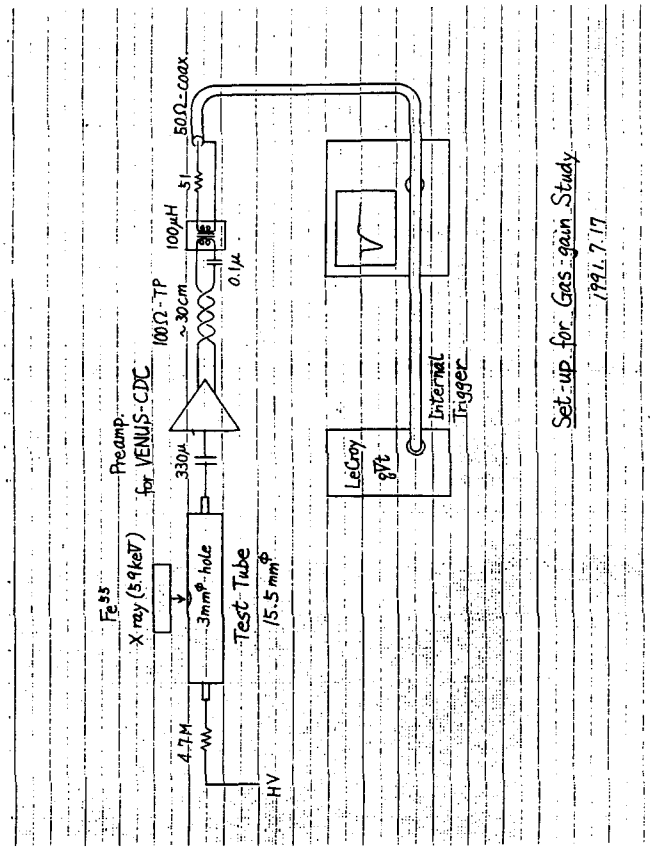


Thin Tube Chamber Array for Gas Tests

2268



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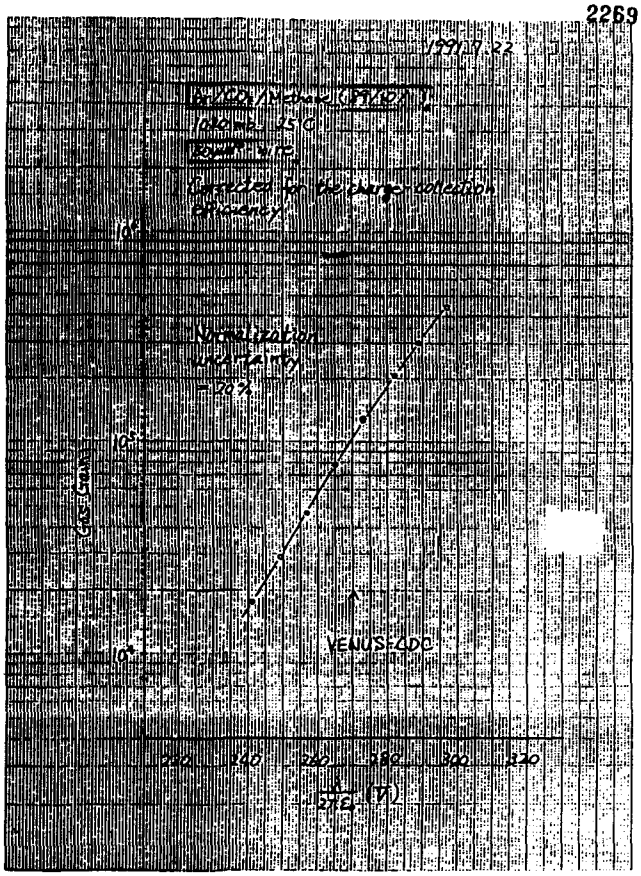

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91.07.27

2270

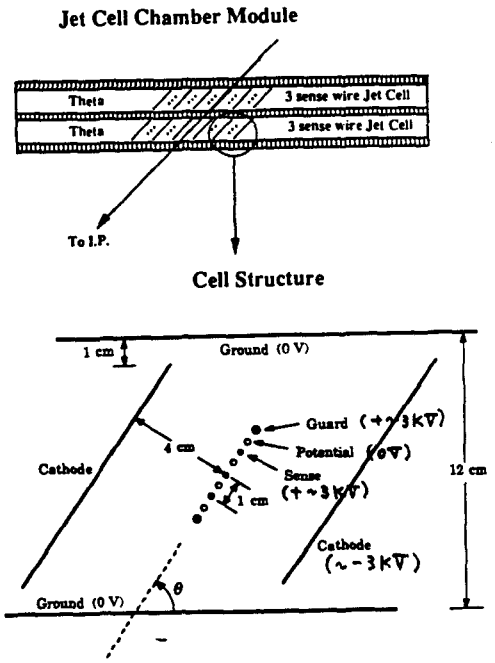
Status of the Large Jet Chamber R&D for the SDC Muon Detector

KEK Muon Chamber Group

Y. Funahashi, Y. Higashi, H. Iwasaki, T. Kondo, A. Maki, S. Odaka, T. Shinkawa, and S. Terada

1. Idea of the Jet cell chamber for the SDC muon detector:

Slanted Jet cell partitioned with stiff cathode plates placed in a rigid box frame 2271



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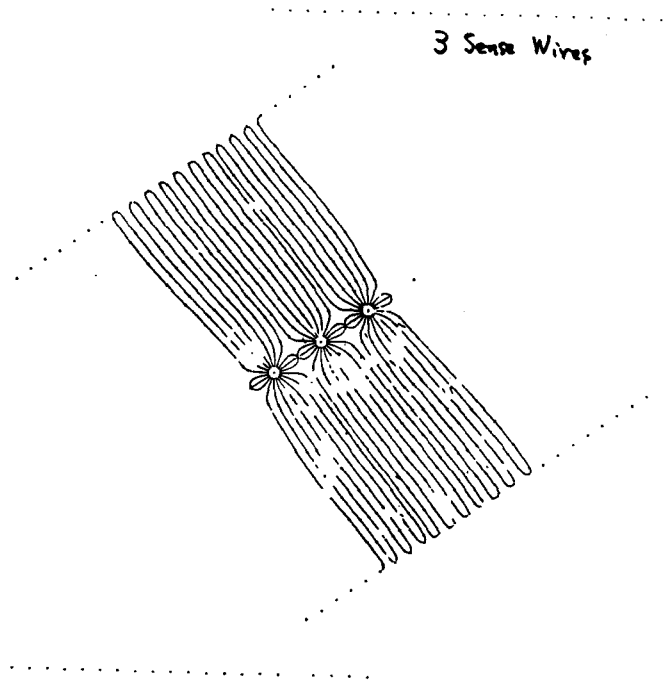
Equal Drift-time Contours



2. Principal items to be studied: 2273

i) Mechanical rigidity of the chamber module
ii) Performance of the chamber
iii) Mass production capability

—

3. Design of the R&D prototype chamber:

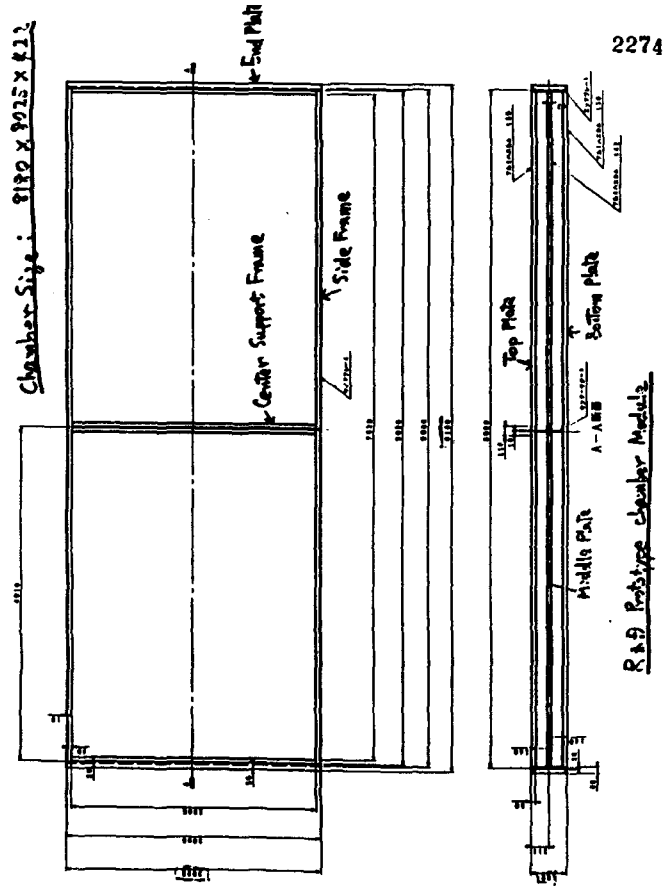
i) Outline of the R&D module:

- Frame size: 3 m x 8 m x 0.4 m;

- Layer type: Staggered two theta layers in one box frame

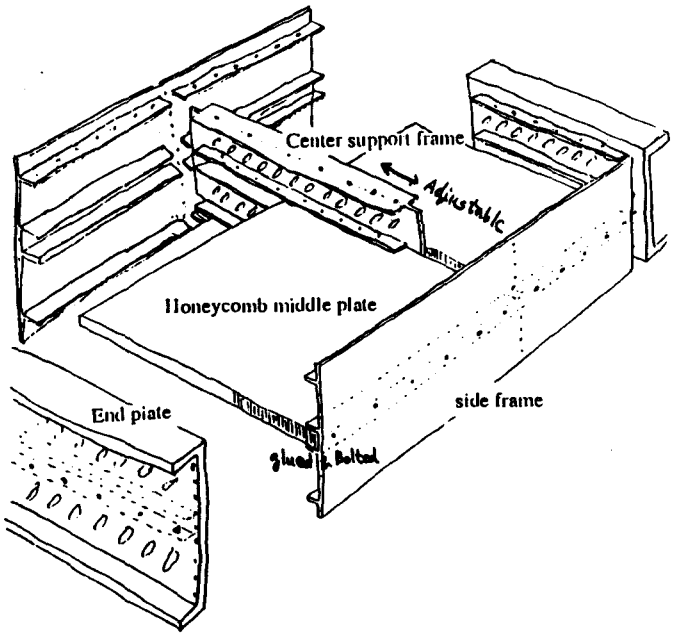
- Cell structure: Three sense wires in a cell of 4 cm drift, 0, 30 and 60 degrees slanted cells

2274



ii) Frame structure and assembly procedure:

2275



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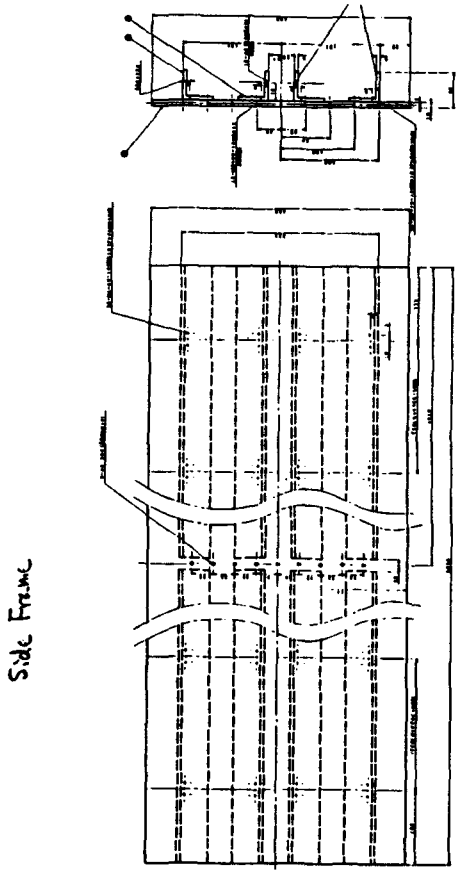

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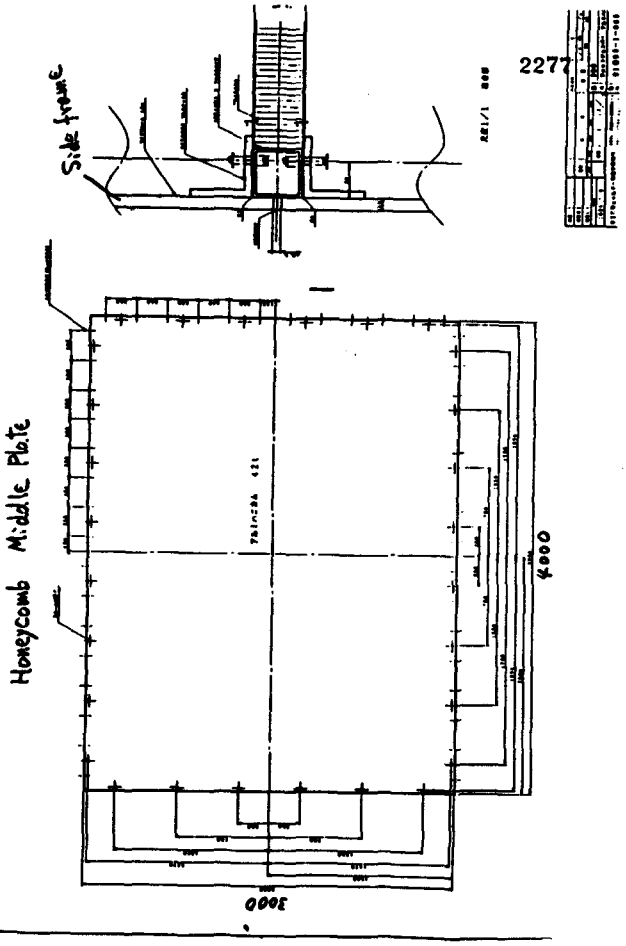

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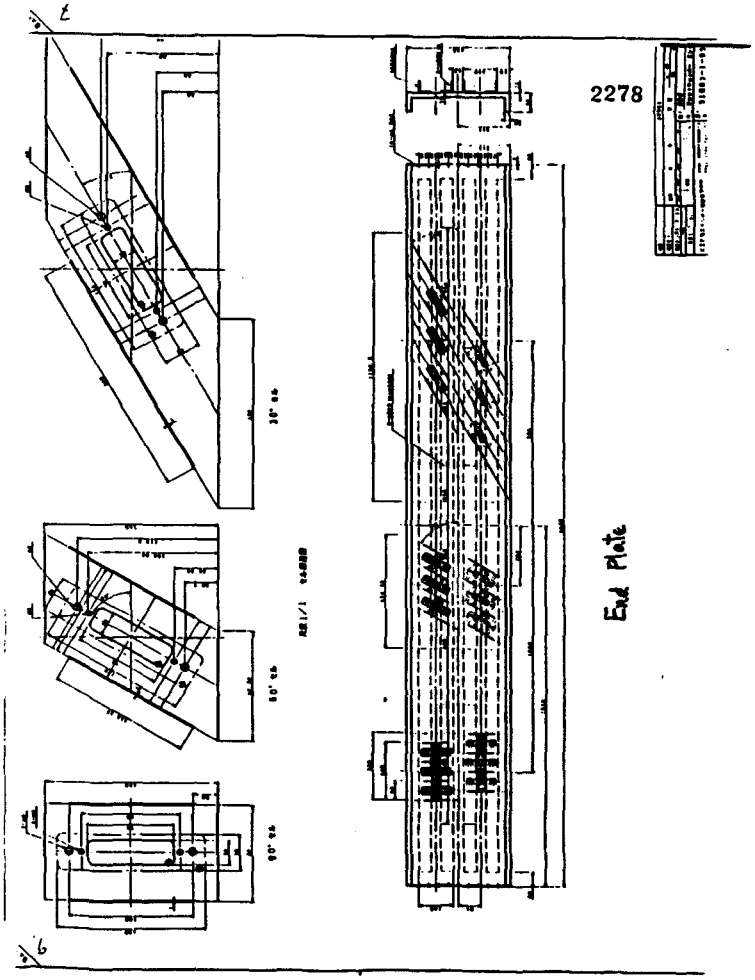

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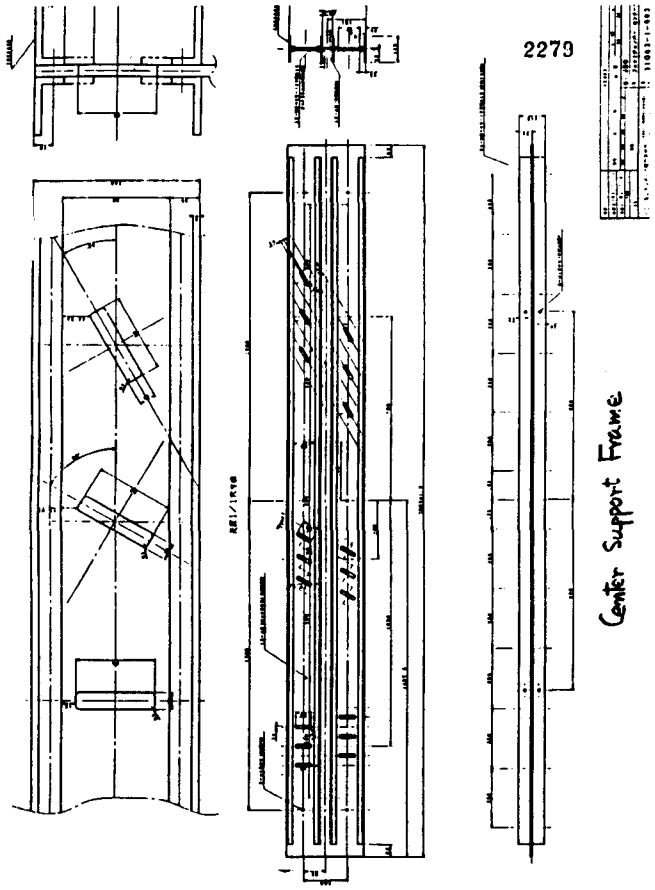

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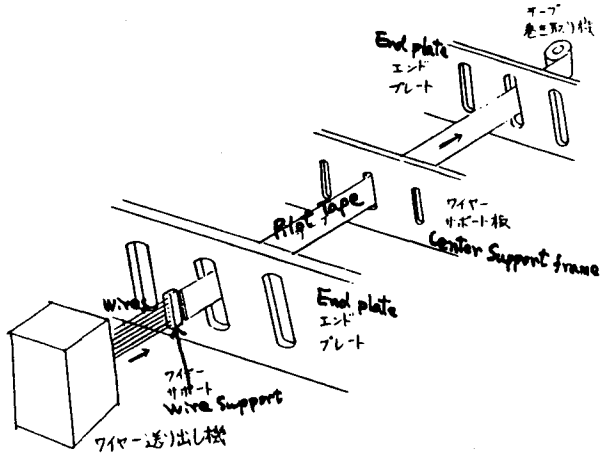
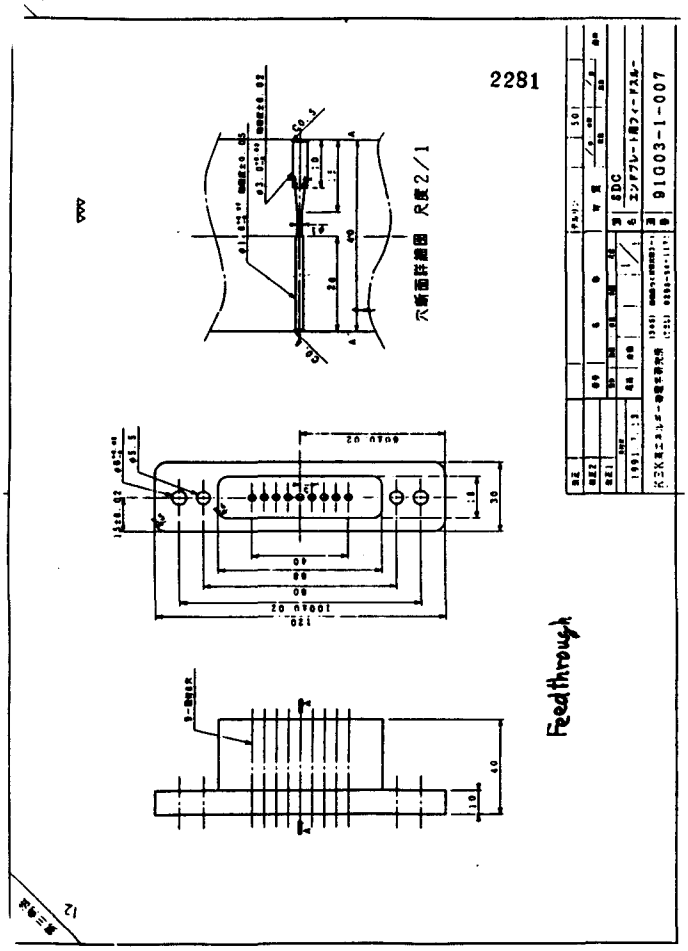


ワイヤー張り概念図 1991.5.9 尾高(S.Odaka)
(CDF-CTC方式)

2281



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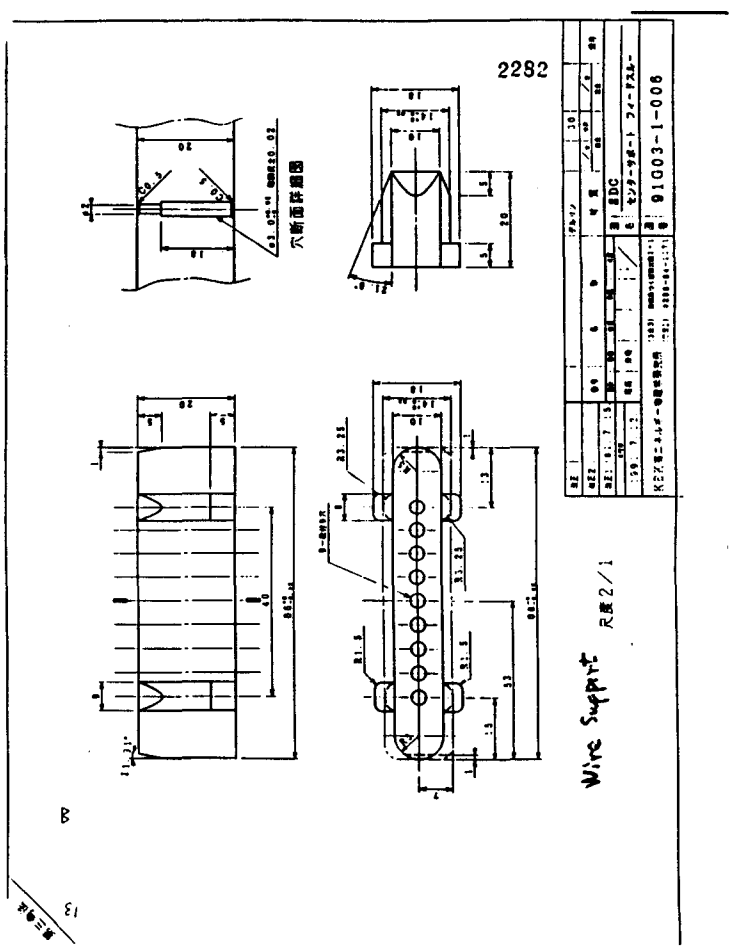

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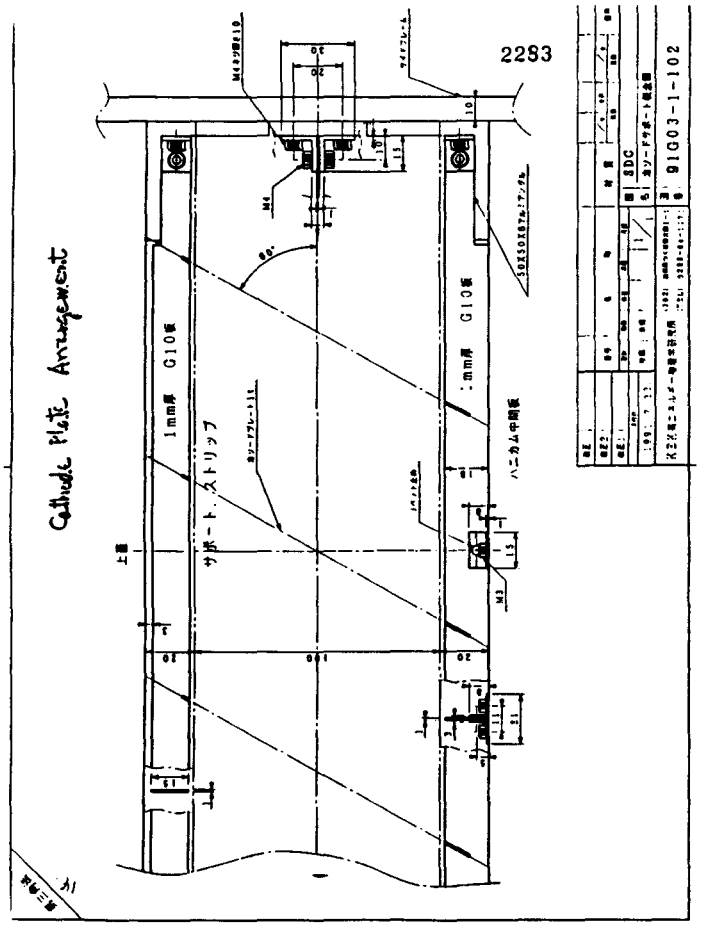

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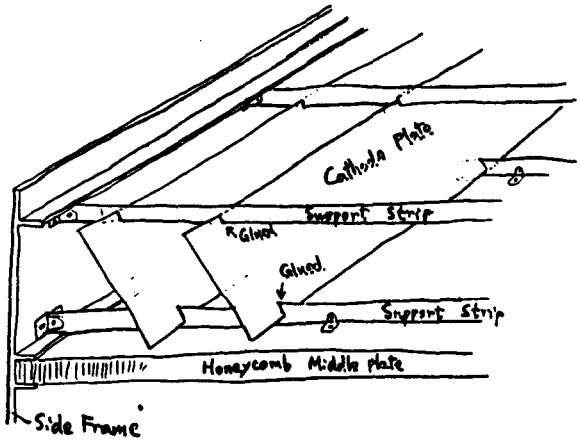
2284

Cathode Plate Arrangement

(Perspective view)

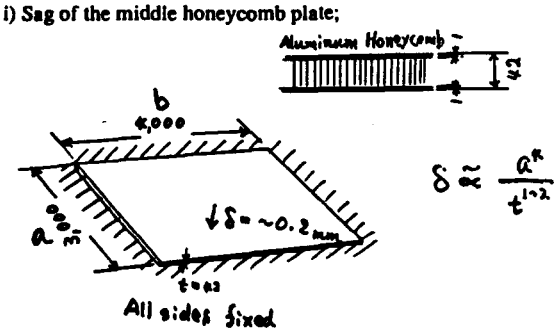


16

Rigidity of the Chamber Frame (R&D Prototype Module)

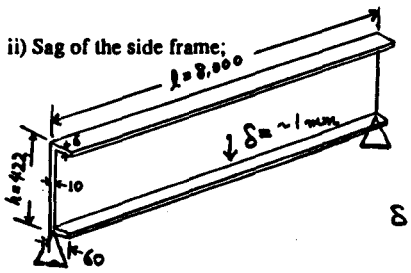
2285

i) Sag of the middle honeycomb plate;



$$\delta \propto \frac{a^4}{t^{1/2}}$$

ii) Sag of the side frame;



$$\delta \propto \sim \frac{l^4}{h^2}$$

91.08.03

1991 Large Jet Chamber R&D Schedule 2286

JUN	Meeting at SSCL (Mechanical/Assembly)	Frame Design	Preparing Frames & Material
JUL		End plate & Wire Support Design Cathode Design	
AUG	Meeting at LBL (Engineering)	Frame Pre assembly out Factory	← Honeycomb completion
SEP	Meeting at Oak Ridge (Initial chamber Review)	End plate & Wire Support NC Machining at KEK Chamber	
OCT		Assembly at KEK	
NOV	Meeting at SSCL (Second Chamber Review)	Wiring	
DEC		Chamber Test	
1992 JAN	Meeting at KEK? (Third chamber Review)		
FEB	Chamber decision ??		

#18

2287

Japanese University Activities for SDC Muon

Aki Maki (KEK)
SDC Meeting at LBL
August 1991

- University of Tsukuba
  - Simple Tube
  - CFTD
- Osaka City University
  - Projective Box
  - SCIFER

2288

Activities at Tsukuba Univ.

Simple Tube Design
"Magic Combination"
8 cm x 8 cm tube
3.5 kV on 100 μm wire
P10 Gas

CFTD

Deviations from Linear R-T Relation

2289

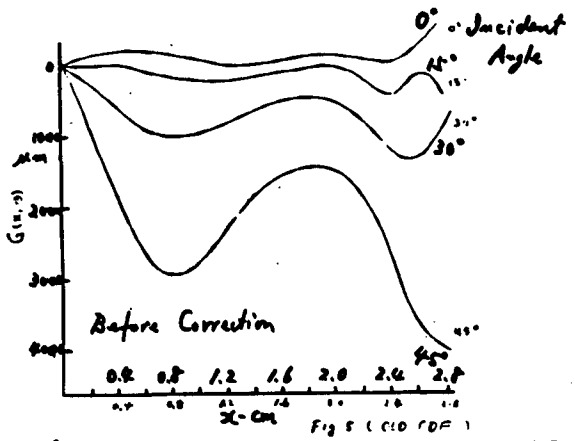


Fig 5 (OLD CDF)

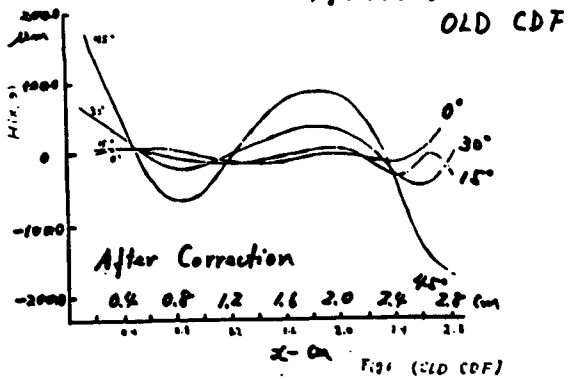


Fig 6 (OLD CDF)

2290

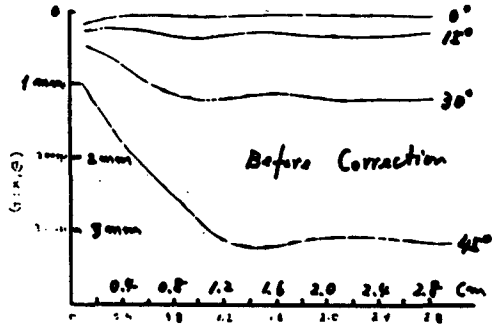


Fig 3 (DØ field)

DØ Field

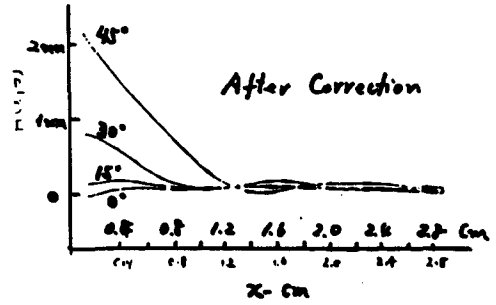


Fig 4 (DØ field)

2291

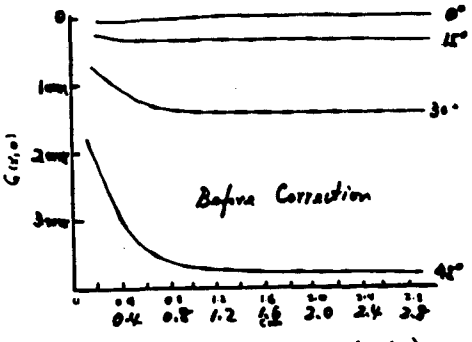


Fig 7 (jet chamber)

Jet Chamber

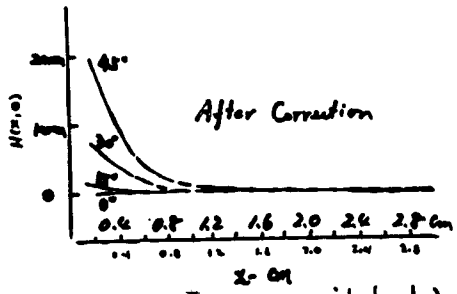
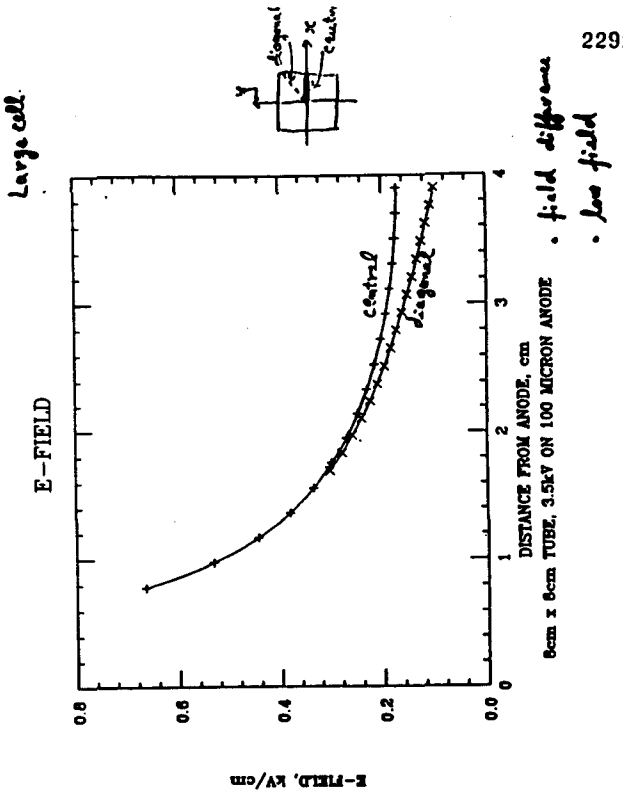


Fig 8 (jet chamber)

2292



2293

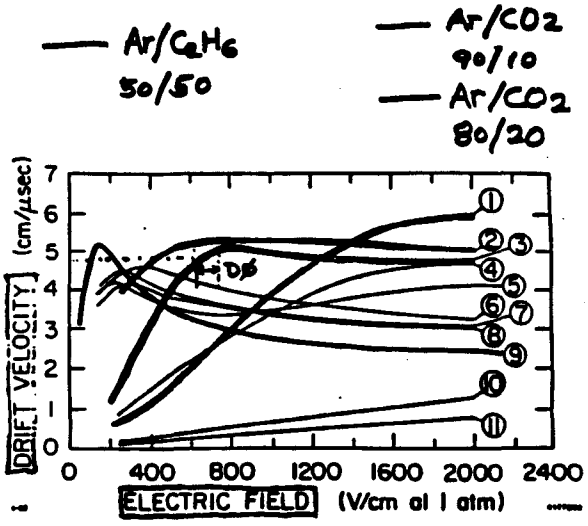
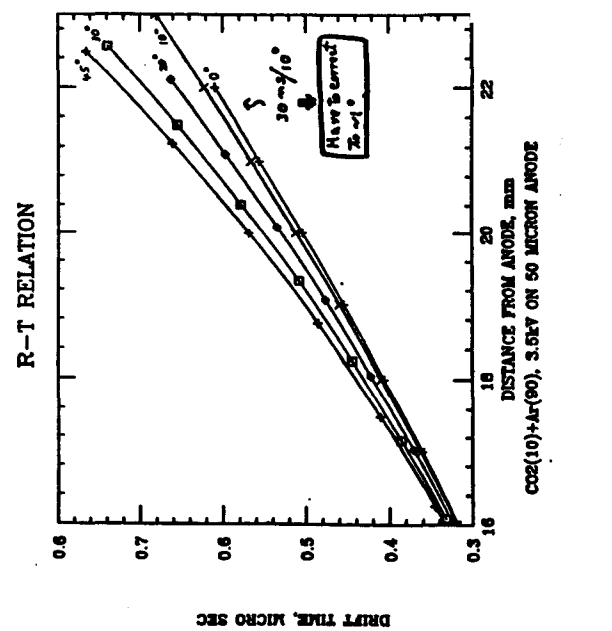


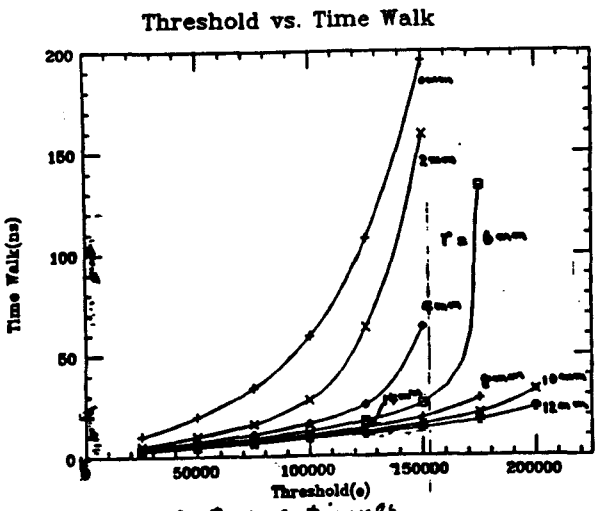
Fig. 1 Drift velocity versus the electric field for various gases. Gases are: (1) 80/20, Ar/CO_2; (2) 50/50, Ar/C_2H_6; (3) 90/10, Ar/CO_2; (4) $i\text{-}C_4H_{10}$; (5) 90/10, Ar/C_2H_4; (6) 90/10, $Ar/i\text{-}C_4H_{10}$; (7) 90/10, Ar/C_2H_6; (8) 90/10, Ar/C_3H_8; (9) 90/10, Ar/CH_4; (10) CO_2; (11) Ar.

"SLD Design study" 1982

page 163

2294

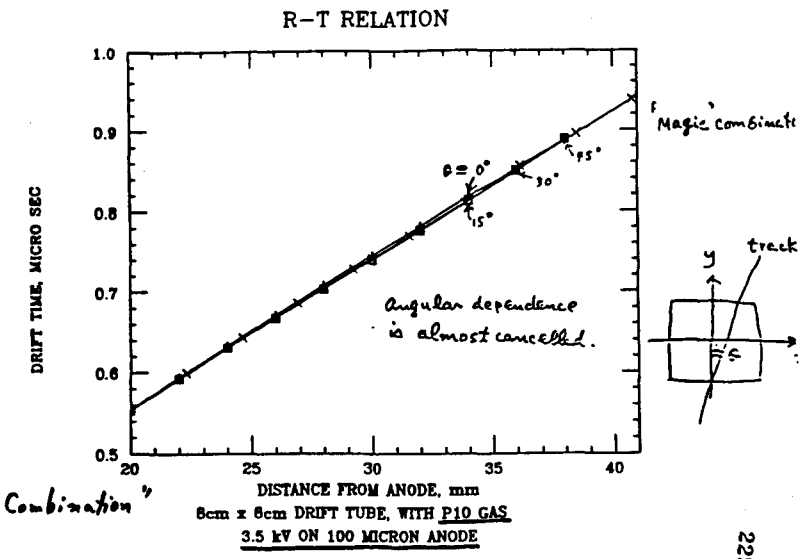




a few to 10 ns time walk.

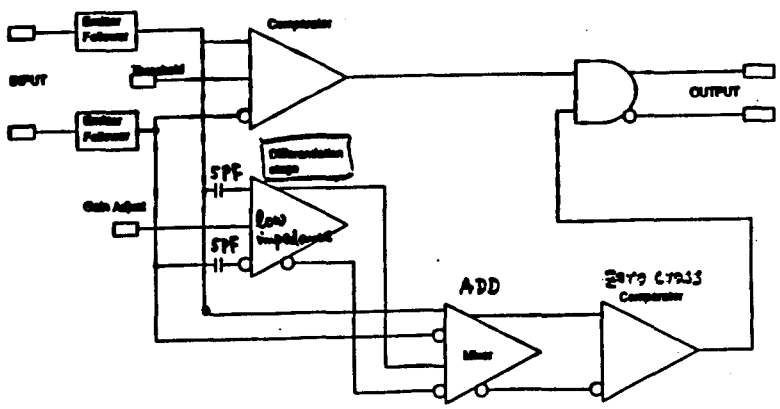
S. Itoh

2297



"Magic Combination"

2295



H. Ikeda, M. Tanaka et al.

2298

Pulse Shape

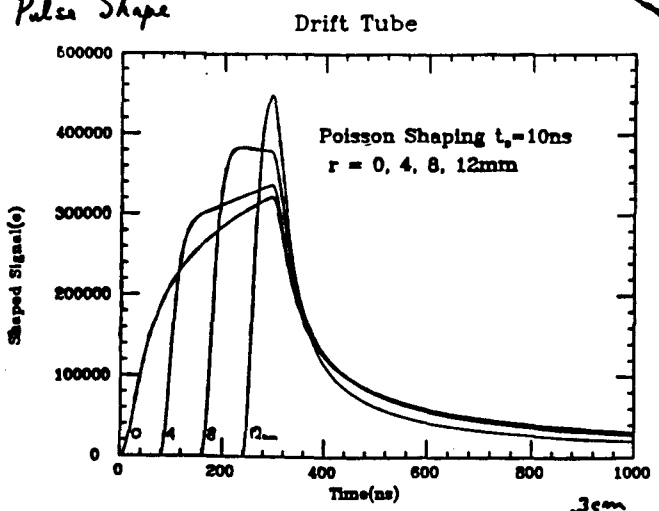


Fig. 2

3cm

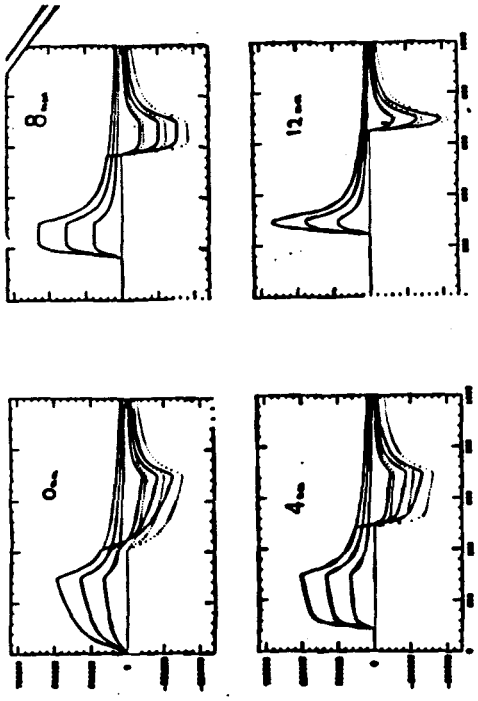
10μ

P10gas

S. Itoh

2296

2299



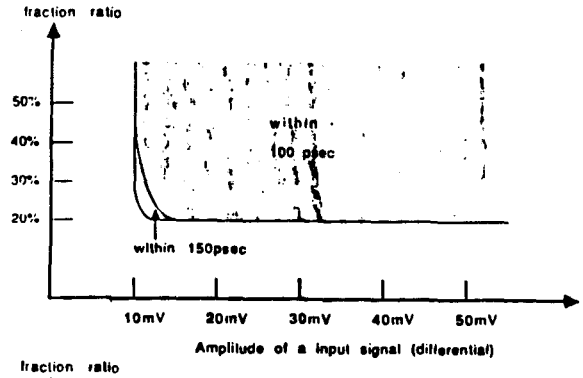
S. Ishi

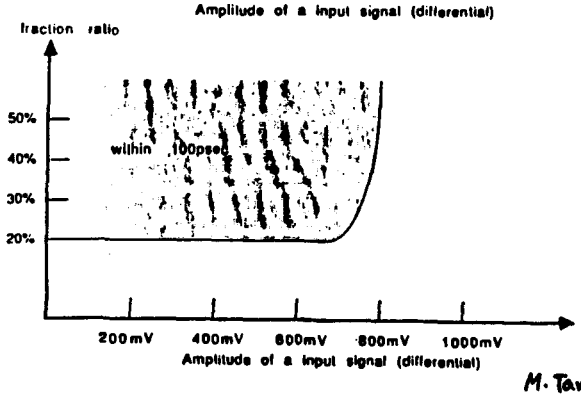
CFTD is very desirable

Fig.8

2300

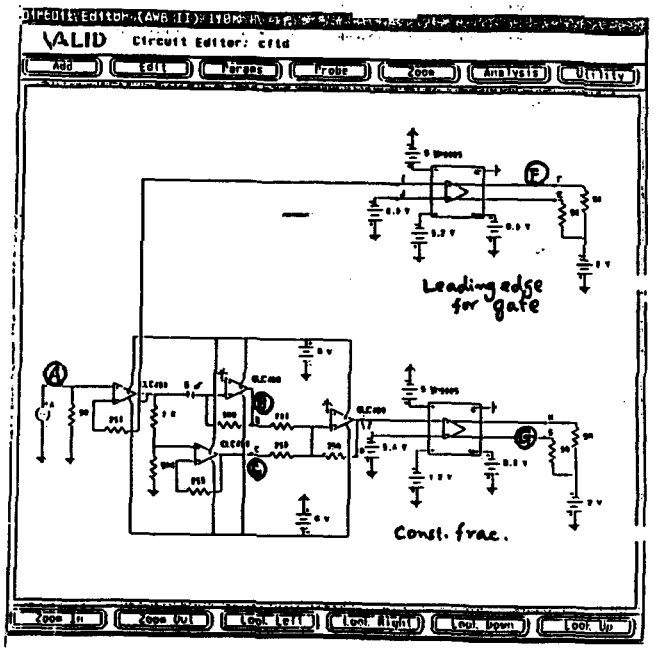
Constant fraction discriminator characteristics



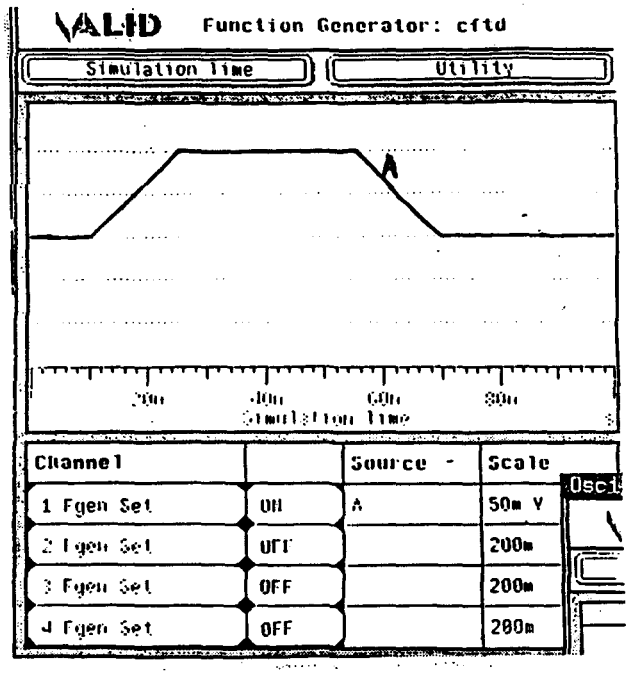


M. Tanaka

2301



2302



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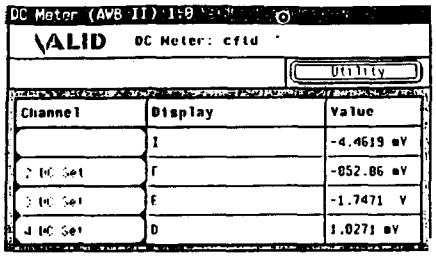
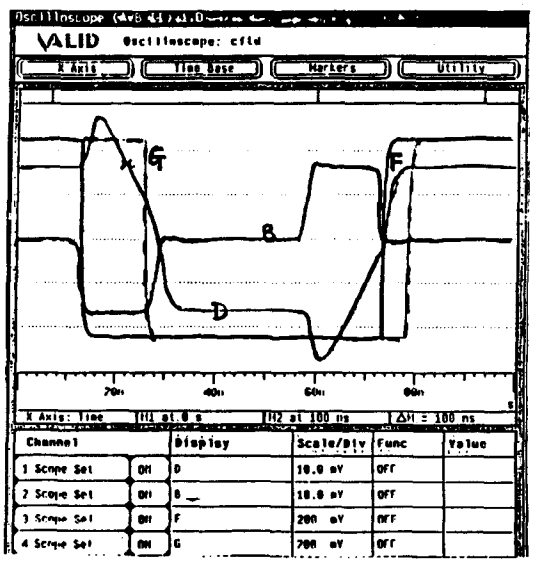




2304

Status of CFTD

1. IC — Need modification of bias circuit
   Will be completed within FY 91
   Working on simulation

2. Hand-made Circuit with fast OP amps (~10ns)
   - Check of each functions — done
     - buffering
     - differentiation
     - adding
     - zero crossing
   - Drawing — in progress
   - Parts collection — almost done
   - Simulation — almost done
   - Assembly & Test — End of August

2305

Schedule

Tsukuba Univ.

July 6	Support, Preamp, HV
13	Gas system
	TMC software
20	
	Prelim. Test — CFTD evaluation
	HV curve
27	
Aug.	Cosmic Ray Test
	Analysis
	CFTD Test
Sept.	

2306

Activities at OCU

Projective Box

3 Sense Wires in One Box

- Square / rectangular / circle
- DØ Field
- CDF upgrade
- Multi-anode
- Jet chamber

SCIFER wire

Long Test Chambers

attenuation, dispersion, resolution

SCIFER (Kobe Steel Ltd.)

- Low carbon steel

  Fe - C (0.15%) - Mn (1.5%) - Si (0.8%)

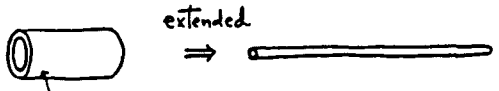
  Ferrite + Martensite → ferro-magnetic

- Fine microstructure

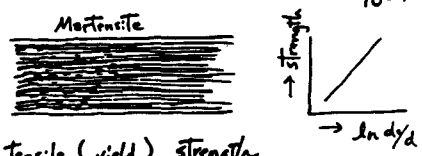
  Size of microstructure (~20A)

  $\sim \frac{1}{5000}$ of ordinary steel

- Large elongation



reduction in area $\sim \frac{1}{10^{\#4}}$



- Large tensile (yield) strength

  ~ 1.33 W

  ~ 1.5% Stainless

- Flexible → Fishing string
- Durable → Probe for ICs

Comparison of 50 μm Wires

	SCIFER	Tungsten	Stainless (AISI304)
Density(g/cm³)	7.8	19.4	7.8
Yield Point(g)	500 ~ 650	~ 430	
Tensile Strength(kg/mm²)	425	320	270
Young's Modulus(kg/mm²)	~ 20000	40500	18000
Specific Resistance(10^{-8}Ωm)*	30	5.5	75
Resistance(Ω/m)	150**	28	380**
λ(m)***	5.4	29	2.3
$R/\omega L$****	0.36	0.067	0.90
Resistance with 1μm Au	70	24**	100
λ(m)***	11	33	8.0
$R/\omega L$****	0.17	0.057	0.24

(*) @ 25°C
(**) Measured value
(***) L = 1.34 μH/m, C = 8.32 pF/m (4 cm dinmeter tube)
(****) @ f = 50MHz
Gold-plated stainless wires may not exist.

	Specific Resistance(ρ)	Resistance of 1μm plating/clad
Au	2.3 x 10^{-8} Ωm	140 Ω/m
Ni	7.2 x 10^{-8} Ωm	440 Ω/m

Attenuation (8m) $\sim e^{-8/5.4}$ = 0.23 (SCIFER)

" " $\sim e^{-8/11}$ = 0.48 (Au SCIFER)

$\bar{\rho}$ (Au SCIFER) = 8.7 g/cm³ (+ 12%)

Fig. 3 Stretch - strain curve

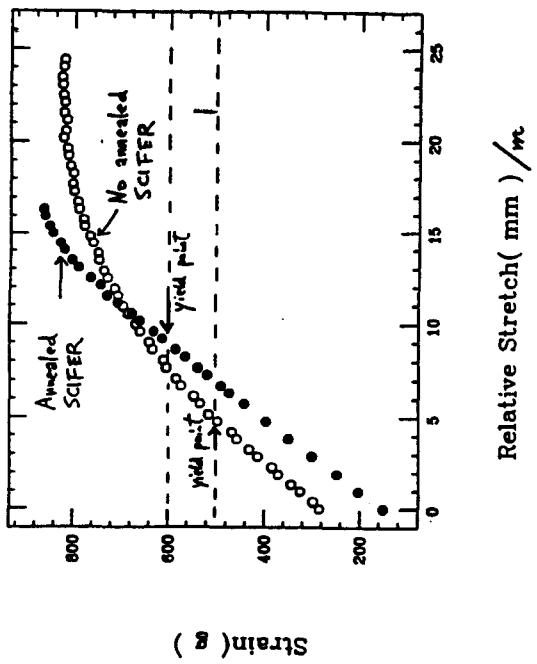
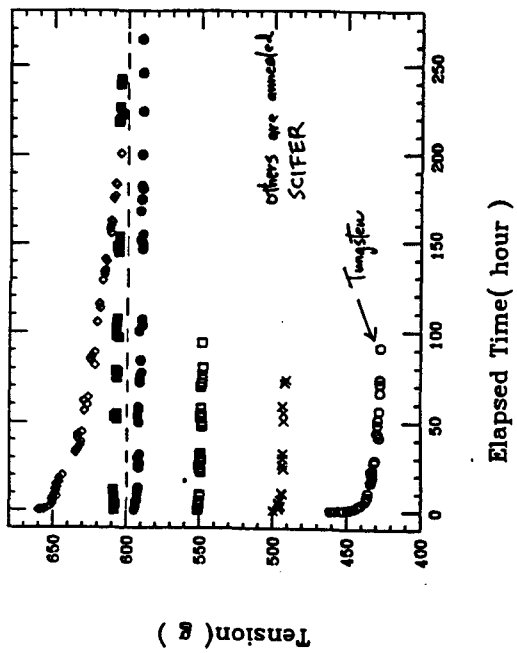
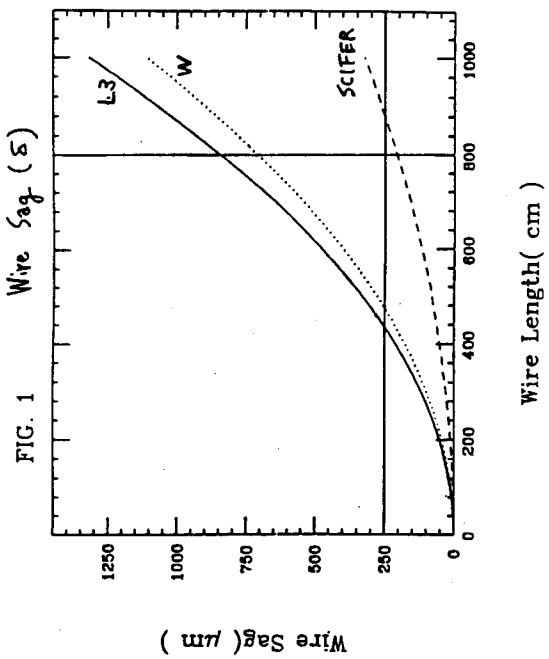


FIG. 4 Relaxation of tension



2311

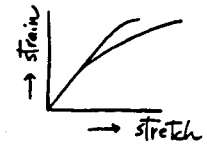
FIG. 1



2312

SCIFER characteristics

- Various kinds

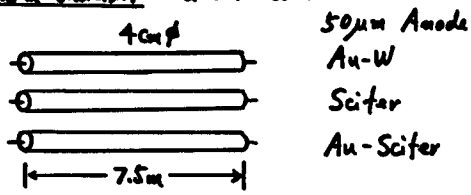


- Annealing yield point ≈ 10~20% increase
- Stretched - annealing + ~10% increase
- Soldering O.K.
- Crimping hard
- Ni clad (0.47μm)
  - → corrosion resistive (~AISI 304)
  - → smooth surface
- Sample by Sample variations ?
- ~~Cost~~ Price ~ 30¢/m ??
- Stretch Test.
- Relaxation Test
- Chamber Test

2313

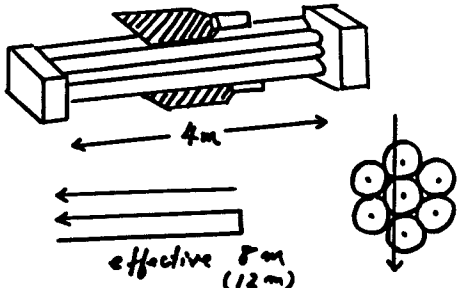
Plans for SCIFER Test

- 7.5m chamber under construction



Attenuation, Dispersion

- 4m chamber bundle (W + Scifer)
  ↳ completed



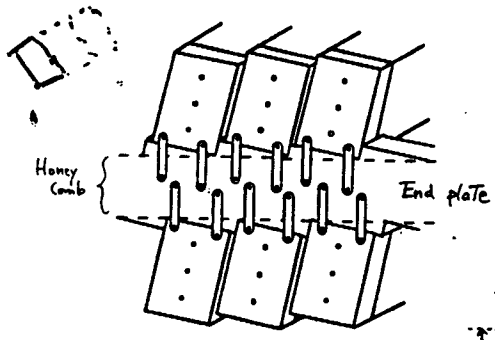
Resolution ⟷ length
Attenuation

2314

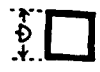
Projective Box Design

An example of barrel μ chambers

- Adapted Boston Group's wine rack mount
- No wire support



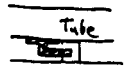
- Tube's deflection $\delta X \propto \ell^4 \cdot \frac{\rho}{E} \cdot \frac{1}{D^2}$



$\ell^4 \sim 16$

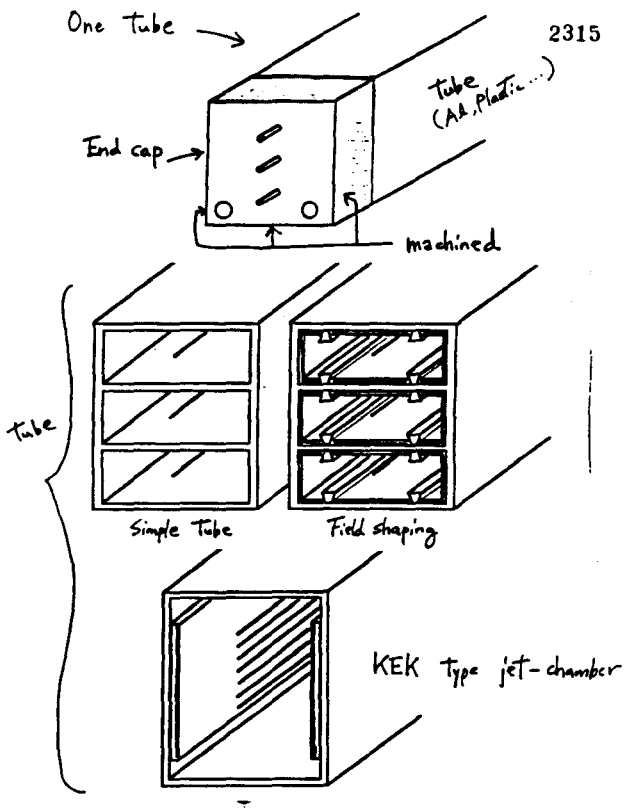
$\Delta X(3 \text{ in } 1) \sim \frac{1}{9} \cdot \Delta X(1 \text{ in } 1)$ ↖ individual tube

- All Tubes are identical
- Wire alignment
  wire in one plate



#17 #13

2315

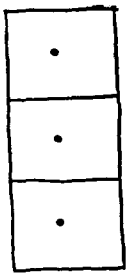


#18

Possibilities

3 in 1 8m Tube

2316

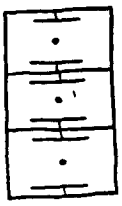


Square/rectangular/circle

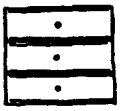
{ 100μm wire → P-10/P-8
{ 300μm wire → other gas.

Simple, resolution?

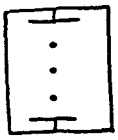
Narrow Operational Voltage



DØ

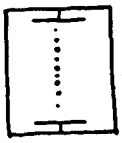


CDF upgrade, field shaping



Multi-anode

X-Talk?



Jet-chamber

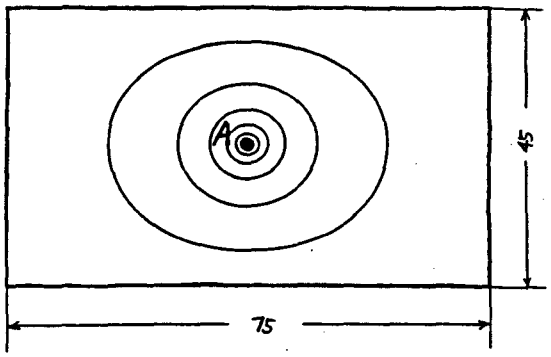
many wires

#19 Rectangular Tube (100μm Anode) 7/26/91

2317

Tube size 8cm x 5cm

	H.V.	wire	Tension
anode	3.2kV	100μ	800g



	100μm from φ	near wall	
Region	φ~3.100μ	~0.1cm	6/a
E	50.6 kV/cm	0.13kV/cm	100kV/cm

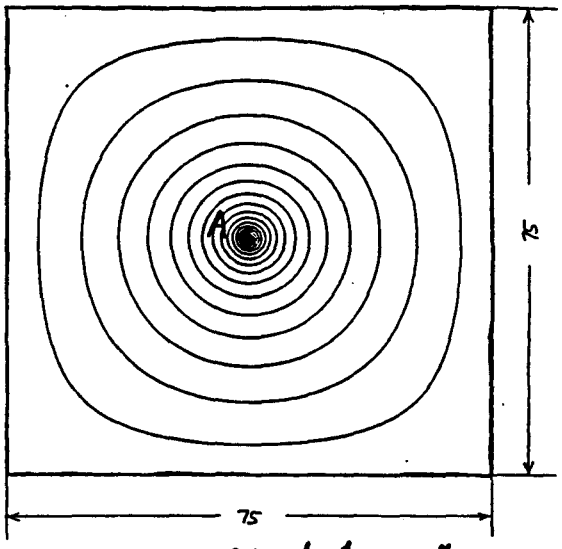
P-10 V_{peak} E ≈ 0.15 ~ 0.2kV/cm

#3 Square Tube 7/26/91

2318

Tube size 8cm x 8cm

	H.V.	wire	Tension
anode	4.5kV	300μ	8kg



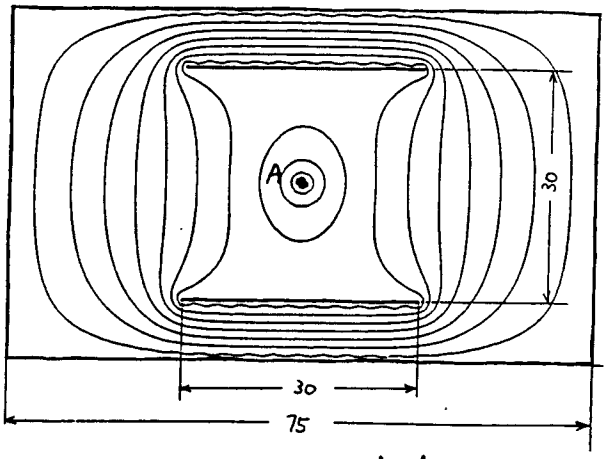
	200μm from φ	near wall	
	φ~3.200μ	~0.1cm	6/a
E	58kV/cm	0.5kV/cm	77kV/cm

Dφ Type

7/26/91

Tube size 8cm x 5cm 2319

	H.V.	wire	Tension
anode	4.5kV	50μ	350g
elec.Tr.	2.2kV		



100μm from φ

	ドリフト100μ	drift space	G/a
E	40kV/cm	0.78kV/cm	160kV/cm

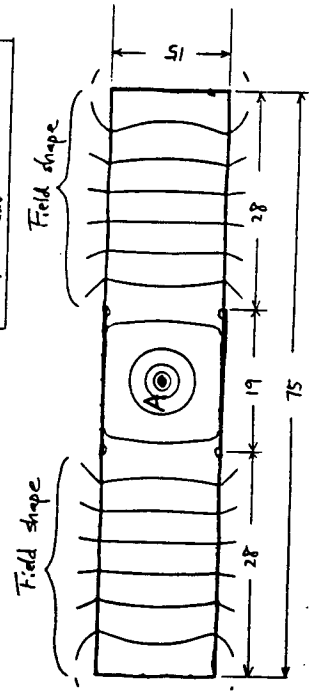
CDF upgrade μ Type

#25 7/26/91

2320

Tube size 8cm x 2cm

	H.V.	wire	Tension
anode	4.6kV	50μ	350g
elec.Tr.	0~2kV		



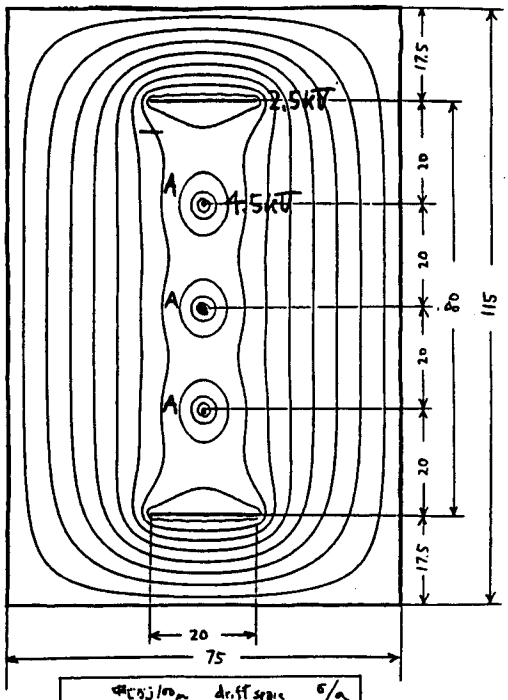
	ドリフト100μ	drift space	G/a
E	45kV/cm	0.76kV/cm	180kV/cm

Multi.-anode (MWPC) Type

#27 7/26/91

Tube size 8cm x 12cm 2321

	H.V.	wire	Tension
anode	4.5kV	50μ	350g
elec.Tr.	2.5kV		



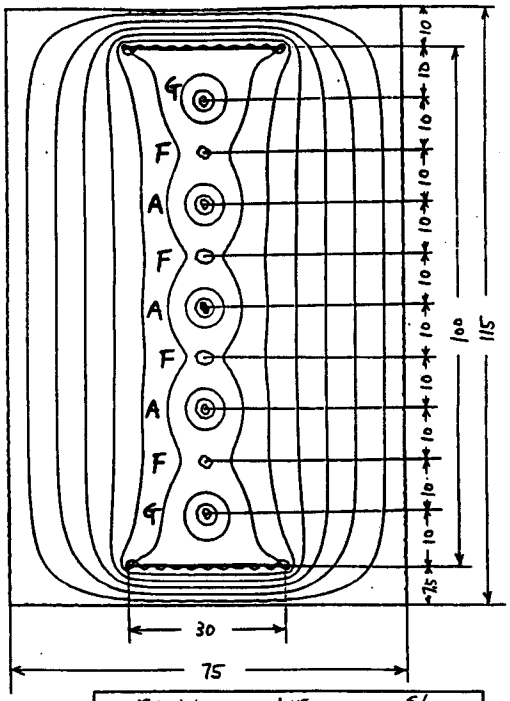
	ドリフト100μ	drift space	G/a
E	42kV/cm	0.54kV/cm	170kV/cm

Jet chamber Type

7/26/91

Tube size 8cm x 12cm 2322

	H.V.	wire	Tension
anode	4.0kV	50μ	350g
field	1.5kV	100μ	800g
guard	3.5kV	150μ	1500g
elec.Tr.	1.8kV		



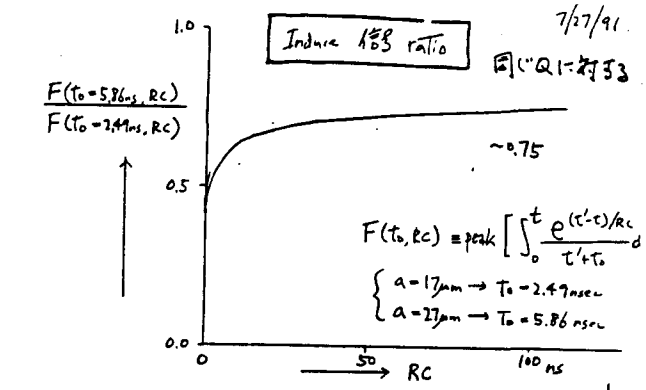
E_{field} = -12~13kV/cm

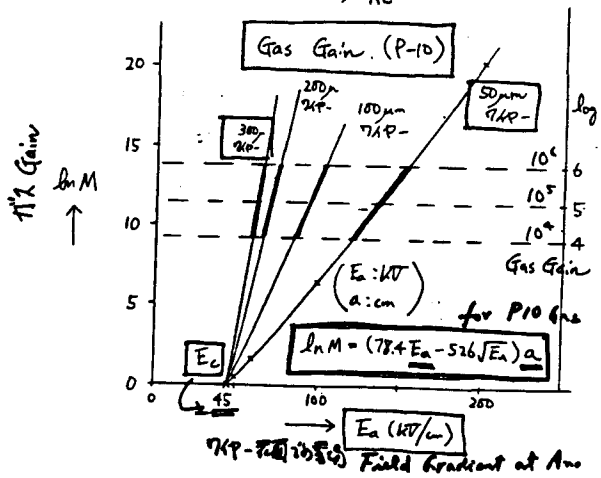
	ドリフト100μ	drift space	G/a
E	40kV/cm	0.54kV/cm	160kV/cm

#14

2323

7/27/91





#26

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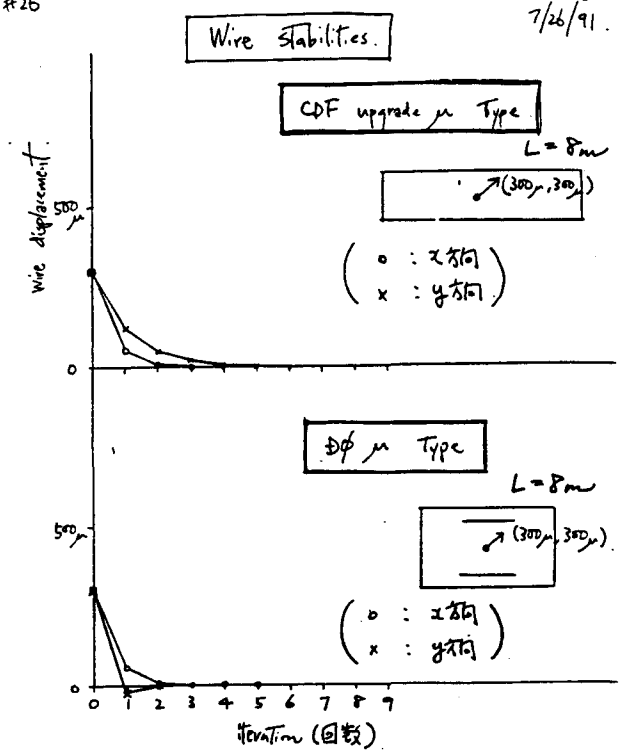
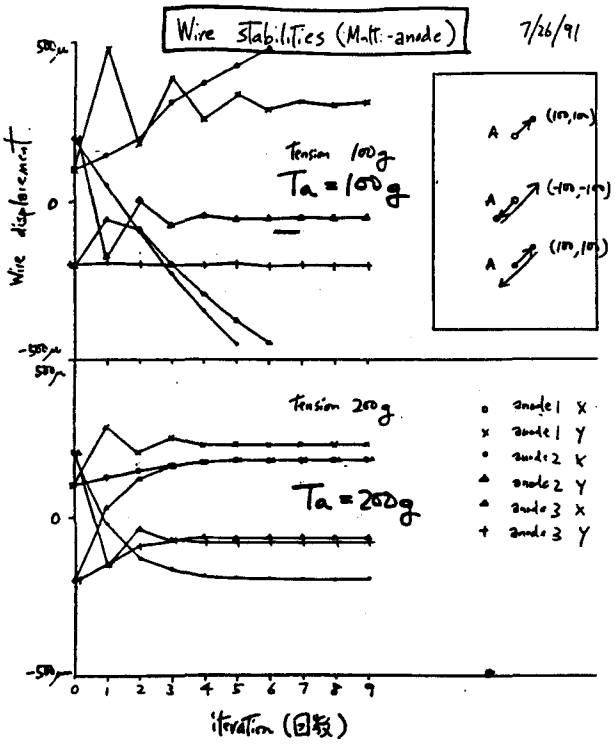
7/26/91



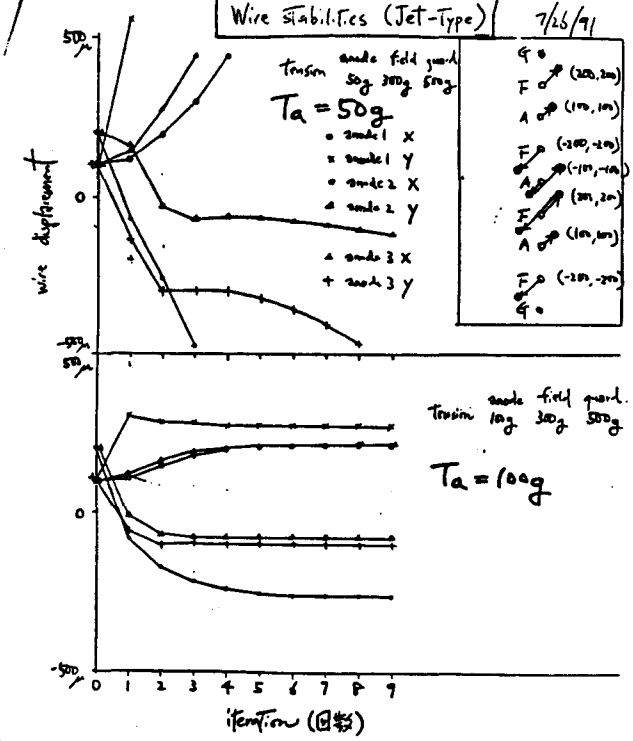
2325

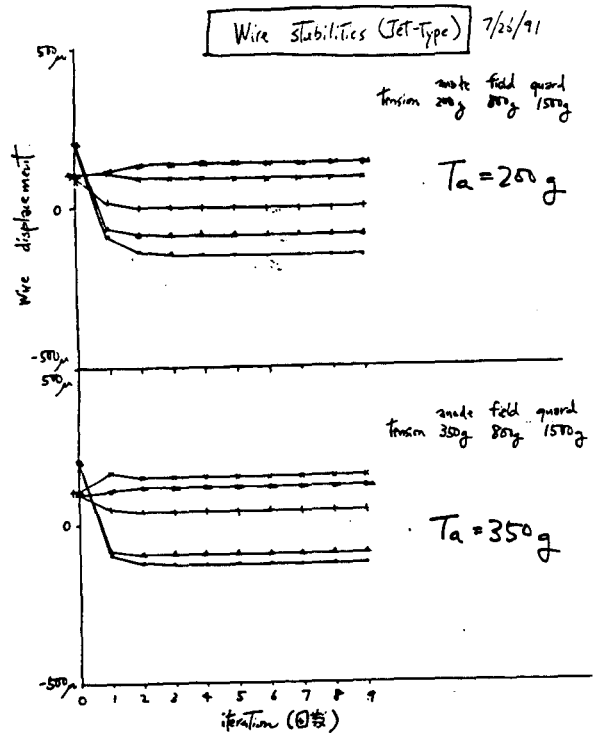
7/26/91



2326

7/26/91





Summary

- Wire supports → not necessary, may hurt
- SCIFER
  - Yield Strength ~ 600g for 50μm wires
  - Sag ~ 250μm for 8~9m chambers
  - Resistivity = 150Ω/m (70Ω/m with 1μm Au)
    → Attenuation length 5.4m (11m)
  - Magnetic → no problem(?) preparing long test chambers
- Projective Box Design
  - All Tubes → identical
  - (3, in 1) Tubes → mechanically strong
  - Accommodates various cell designs

preparing
- * Square tubes
  → 100μm wires with P-8/P-10 → resolution
  300μm wires → narrow operational H.V
- * DØ
  → may be the best ? 8cm ok, 16cm Hard
- * CDF upgrade μ
  → also good ?
- * Multi-anode
  → X-Talks ? , small E-field poor gas gain control
- * Jet-chambers
  → Many wires in one cell

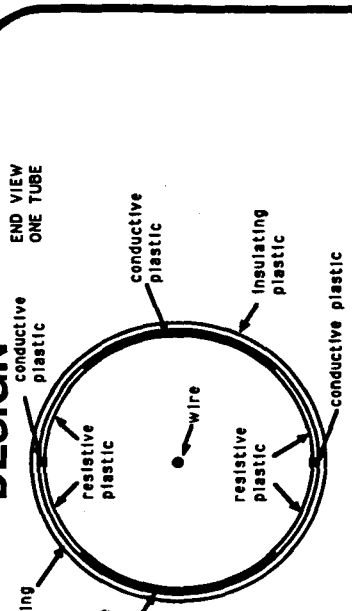
#19

RESISTIVE PLASTIC DRIFT TUBES

P. Border, K. Heller, A. Jones, J. Lin, D. Maxam, K. Ruddick
University of Minnesota

Progress so far.
- Design of tube to be co-extruded
- Extrusion die designed
- Contract for prototype with manufacturer (Inplex)
- Die being constructed
- First tube delivery "end of September"
- Cosmic ray test stand under construction
- 2 small proportional chambers
- 2 small counters
- Data acquisition system (CAMAC + IBM PC)

DESIGN



Tri-extrusion of 3 polyester plastics
- Insulating shell – 0.07" Eastman PETG
- Resistive electrode – 0.02" DuPont Hytrel # 5544
  10^{12} Ω / square
- Conductive electrode – 0.02" Hitech conductive polyester
  0.6 Ω cm

Kodar PETG copolyester 6763

Based on Poly (ethylene terephthalate)

	PETG	Polyethylene	Al
Specific gravity	1.27	0.96	2.7
Modulus of elasticity x 10^5 psi	2.9	2.0	100
$\frac{\rho}{E}$	0.44	0.48	0.027

$$\Delta y = k \frac{\rho g L^4}{E R^2}$$

PETG is slightly better than polyethylene but still has 16 times more sag than aluminum needs supports at half the distance

A. Sill

University of Rochester Resistive Field Shaping & Low-Mass, Lightweight Support Module Testing

- Foam Support, Aluminum Stress-skin panel design & manufacture, Summer '91
- Resistive plastic CDF-style field shaping insert card progress

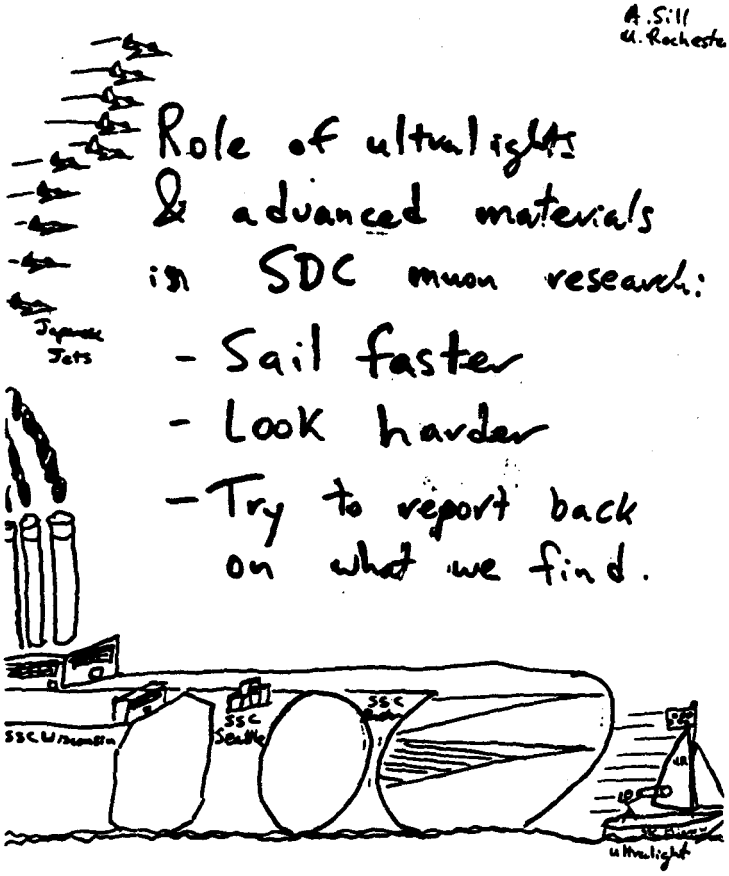
SDC meeting
5-10 Aug 91

A. Sill

A. Sill
U. Rochester

Role of ultralights & advanced materials in SDC muon research:

- Sail faster
- Look harder
- Try to report back on what we find.



Rochester foam support work since 6/91:

1) Made 1-layer x 4-tube model w/ 3" diameter tubes, 1.8 m long

   Removable tubes - learned to dispense & control foam, different types and schemes for filling tested

   - Pure injection (pressurized foam)
   - Mix & pour (pour-type foam)
   - Layered controlled dispensing (pressurized foam)

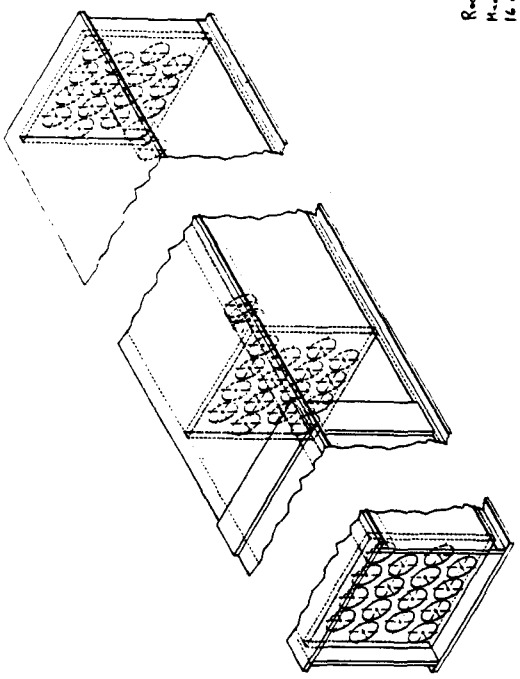
   3rd method above works best

   Also measured density & adhesion properties

2) Developed methods for priming & adhesion to aluminum

3) Initiated construction & design of a 9-meter x 16 cell prototype. (details follow)

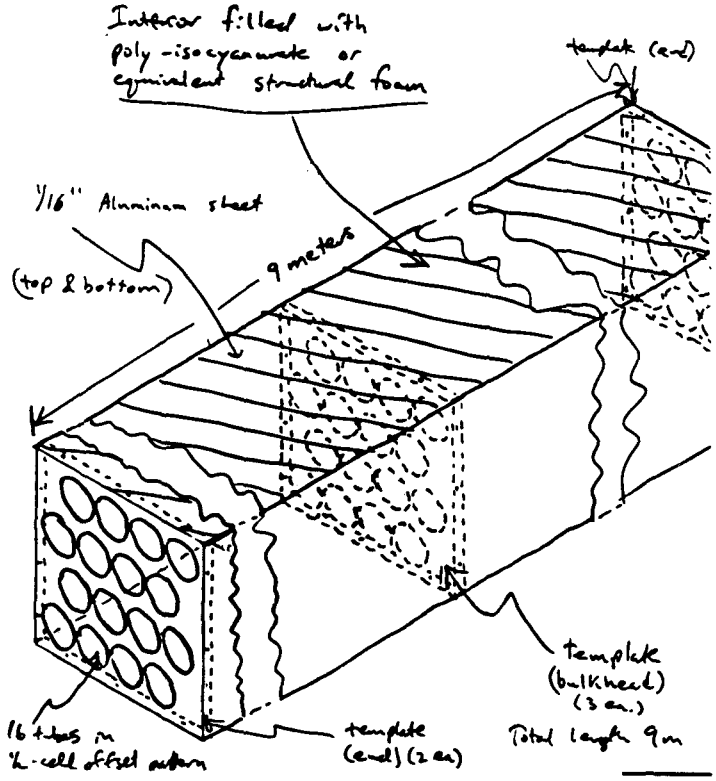
2335



Rockwell/SDC
Hom. Foam Prototype
16 cell x 9 meter
Aug 1991

2336

9 meter x 16 channel prototype for structural measurements:



2337

Goals for 9 meter lightweight support module:

✓ 1) Demonstration proof for foam support idea for plastic or light weight Aluminum (low mass) drift tubes

(essential for non-rigid extruded plastic tube approach, useful or interesting from the point of view of other designs)

★ In PROGRESS... 2) Measure sag for 9 m span x 4 layers of tubes

Compare w/ other designs — #s not ideas.

✓ 3) Gain experience with dispensing, handling & curing of foam in a large-scale structure.

Could be useful in scaling up to full size or other large scale structure

2338

Progress Towards Goals:

- Have built 1 foot long (30 cm) 16 channel scale model prototype using direct injection, 1 inch tubes
- Have also built 3 each 4-layer x 4 tube arrays 1.8 m long using 3 methods (see previous transparency)
- Studied adhesion of foam to PVC plastic, aluminum, mylar, & polyethylene using different approaches involving surface preparation (e.g. solvent cleaning & abrasion), priming, cure time, etc.
- Measured density of foam for different filling techniques & procedures.
- more on the way

Also:

- Initiated 3-D and 2-D finite element models for simple incarnations of foam & aluminum models using ANSYS for simple bars, stress-skin panels, etc. (Tubes to come later).

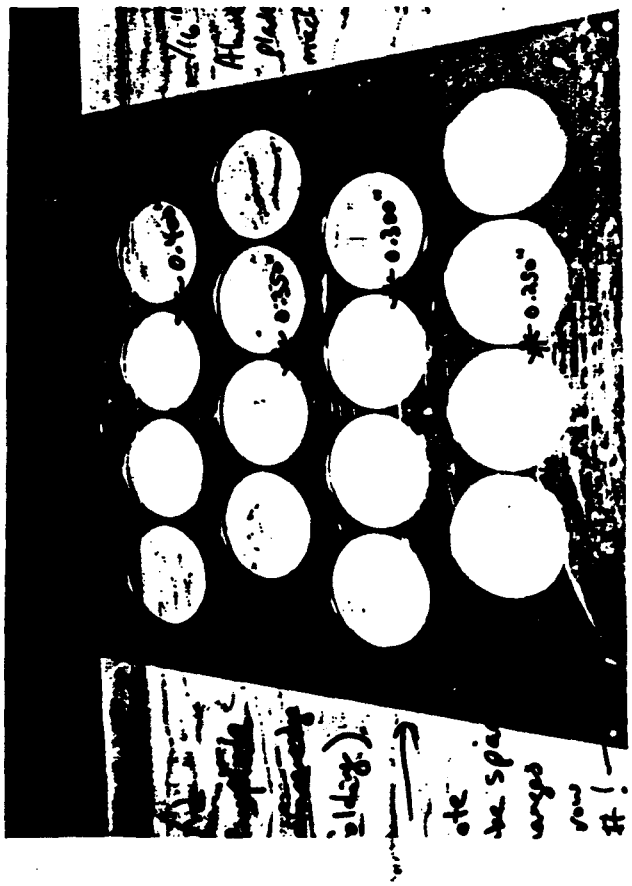
2339

Further details
(see photos):

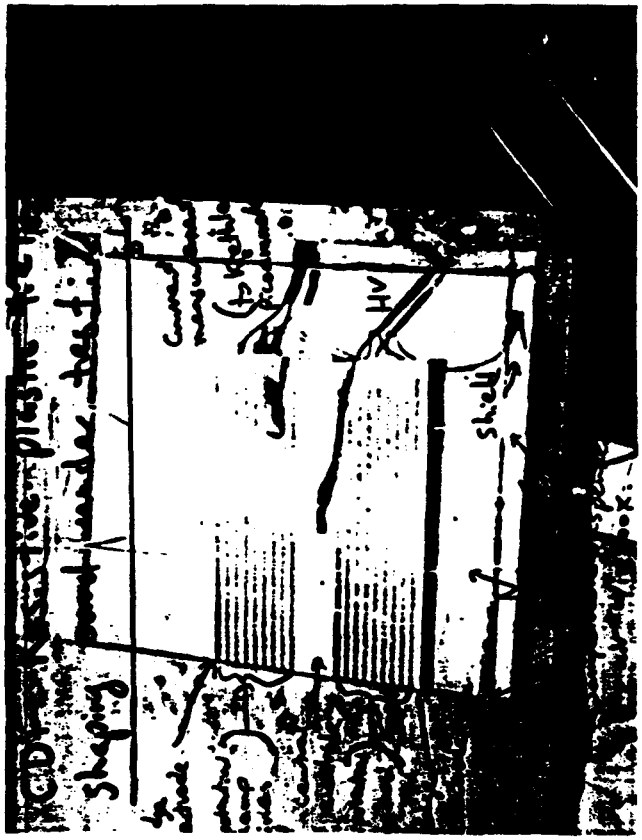
- Mold (in progress)
- Method of filling to produce least possible pressure on tubes while foam is rising & curing
- PVC pipe used in place of resistive plastic &/or aluminum tubes for mechanical model (conservative)
- Riveting to achieve bond for template (intermediate stiffener/locating guide) to aluminum sheet for top & bottom surface
- Strength both longitudinal & transverse.
- Field shaping test setup (last 2 photos)

2340

2341



2342



Conclusion:

We have built 1-layer × 4 tube, 1.8m drift tube supports out of low mass iso-cyanurate foam. In the process, we have learned how to handle larger modules & have in progress a 16 tube, 4 layer × 9 meter long array; will measure sag & performance of this method of support in the upcoming month to 6 weeks.

★ → It will be up to those who have proposed other methods of construction to prove that these other designs can do just as well as this one, or better (if possible).*

This method should prove to be a benchmark by which other ideas can be measured – as quickly as possible so that decisions can be made for FY 1992 and beyond.

Resistive plastic inserts for field shaping prepared & ready to be tested also.

– AFS

*(in terms of sag, ease of construction, etc.)

CERENKOV BEAM TEST

PRELIMINARY RESULTS

M. Christof, M. Daoudi, E. Erdos, U. Nauenberg
G. Schultz, J. Smathers, V. Slonim

U. of Colorado

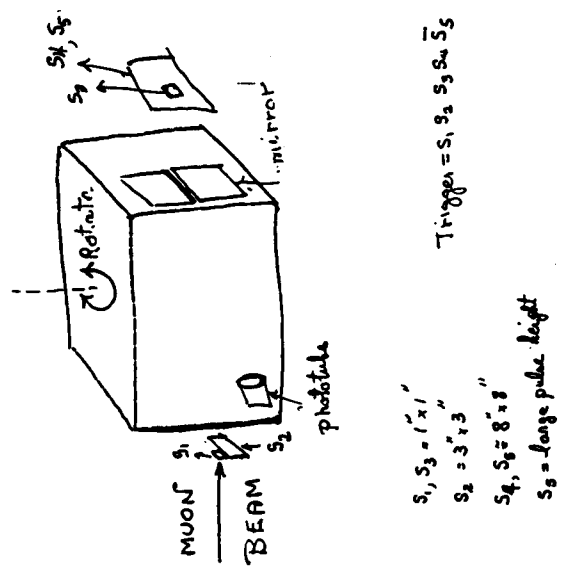
K. McFarland, C. Guss, J. Belz

Temple U.

K. Johns

U. of Arizona

FERMILAB TEST



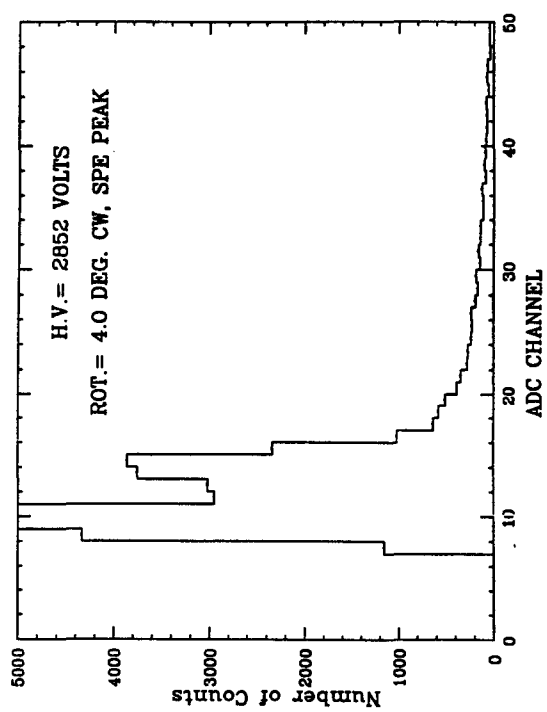


FIG. 1

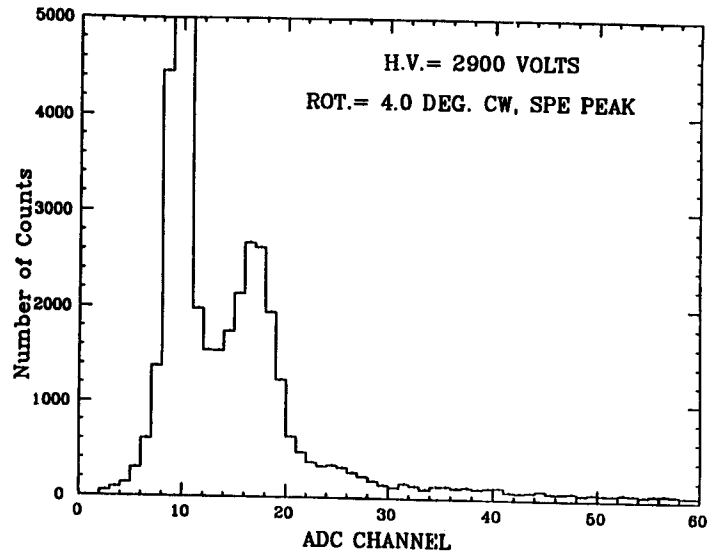


FIG. 2

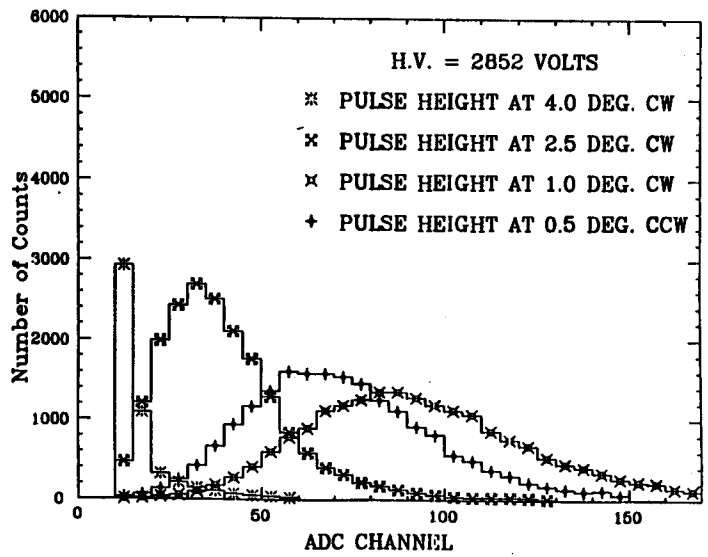
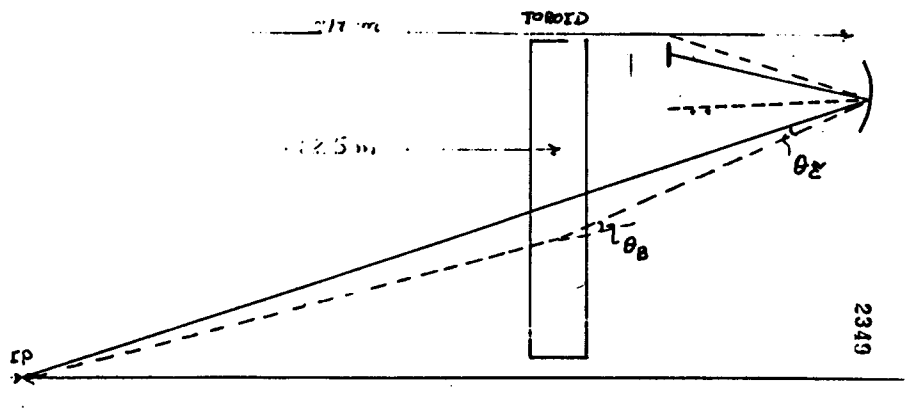


FIG. 2

$\theta_\chi \cong 0.73\,\theta_B$ from "sines law" $\sim \frac{\sin\theta_B}{17} \approx \frac{\sin\theta_\chi}{12.5}$

$\theta_{MS} \cong \frac{1}{8}\,\theta_B$

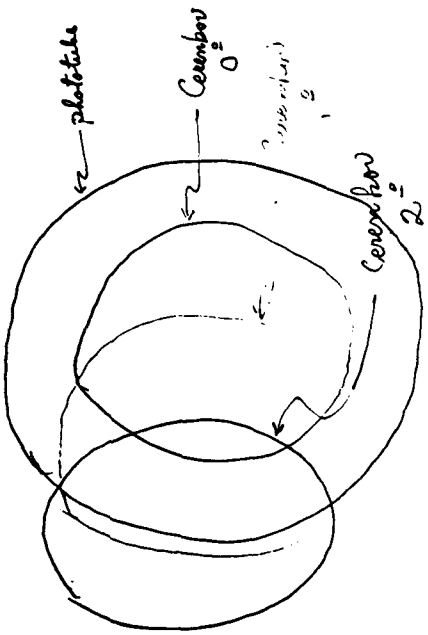


$B = 1.3\ T \qquad L = 4\ m$

$$P = \frac{0.3BL}{\theta_B} = \frac{2.16}{\theta_B}$$

θ_χ	$\theta_B = \theta_\chi/.73$	P (GeV/c)
1°	1.37°	90.3
2°	2.74°	45.2
3°	4.11°	30.1
4°	5.42°	22.6

2351



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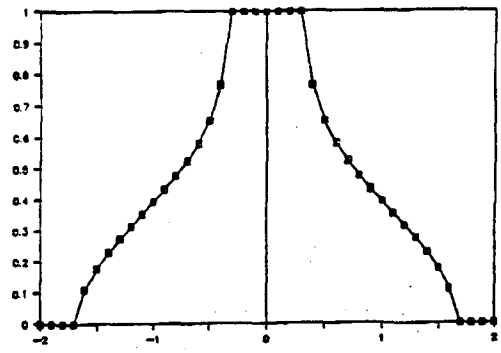
2352



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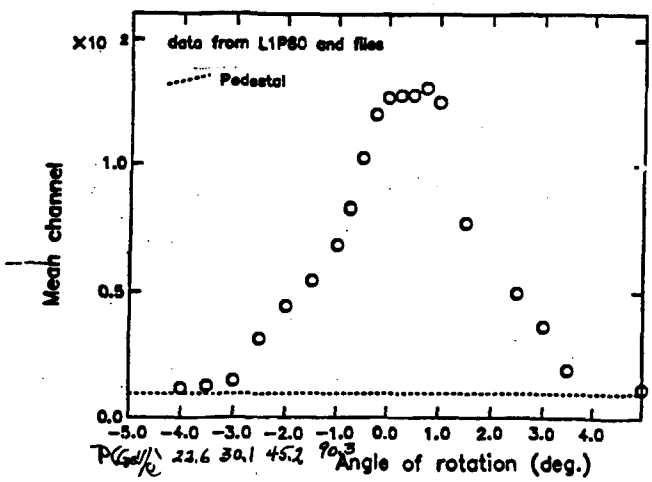
2353



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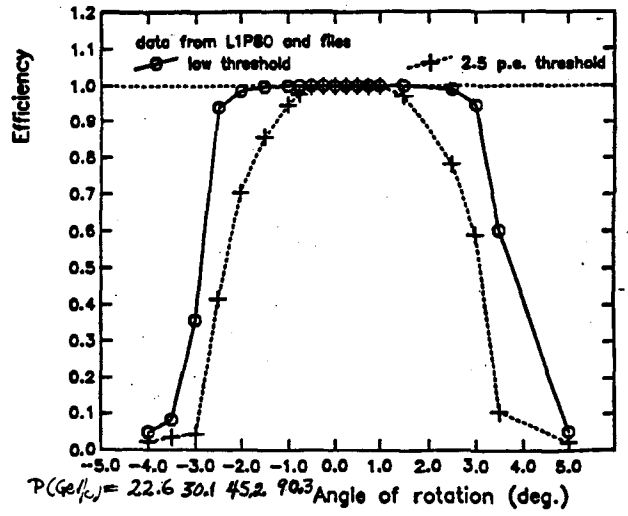
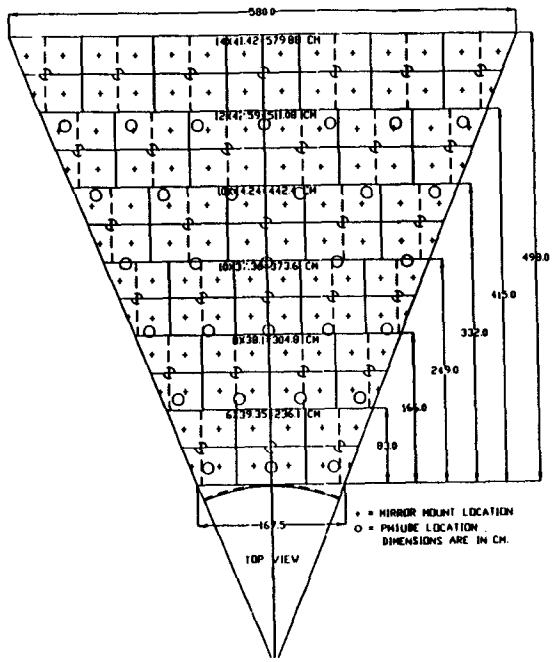
2354



John Smathers



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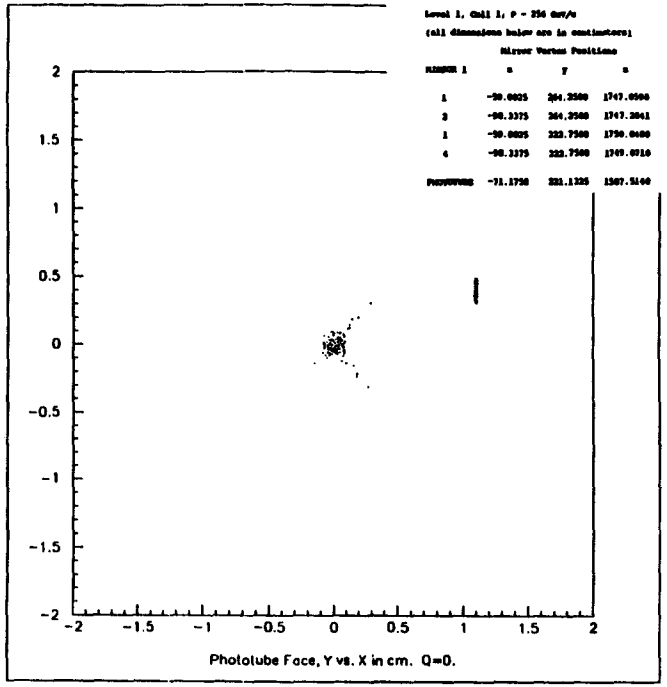

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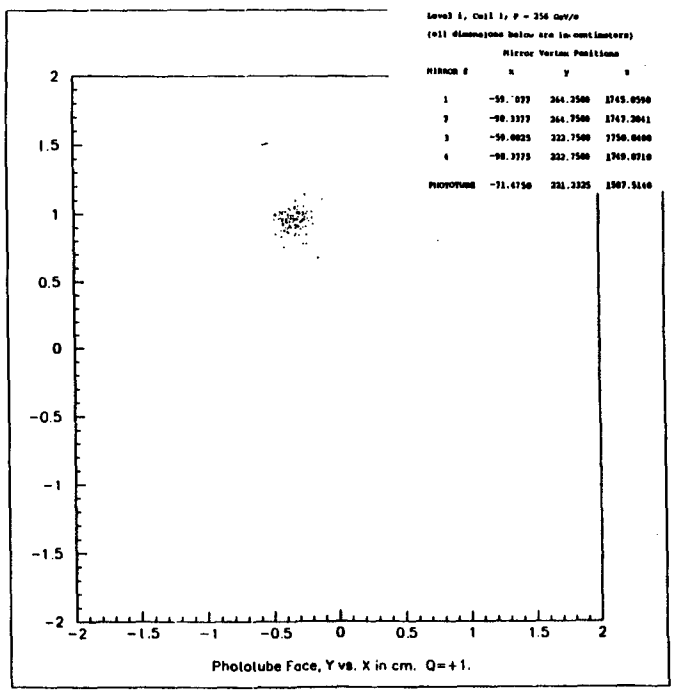

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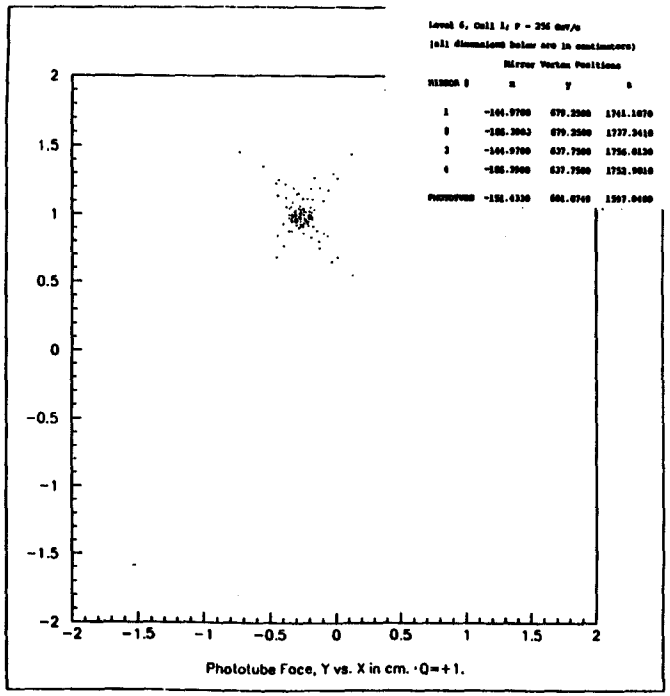


2358

22

IHEP, PROTVINO

A.I. Ronzhin in addition to: 1.

2359

The use of gas Cherenkov counters as part of a trigger system for muons in SSC detectors.
(Uriel Nauenberg, SDC-90-00092, October 1990.).

Our industry produce corresponding photomultipliers.

1. Photomultiplier „Cascade"

Data and general characteristics.

- Useful diameter of the photocathode – 120 mm.
- Quantum efficiency at 400 nm = 25%
- Gain ≈ $3 \cdot 10^4$
- Single electrons time distribution 1,5 nsec.
- Pulse duration 15 nsec.

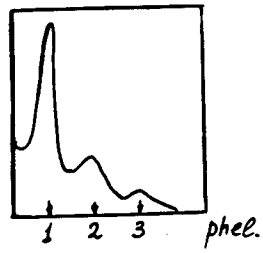
...

Photocathode SbKCs
1 dynode GaP ($\sigma_1 > 10$).
Number of dynodes 1 + 11 = 12.

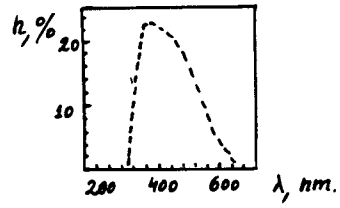
2.

2360

- Single electron spectrum.



- Spectral sensitivity characteristic.



- Nonuniformity of photocathode < 7% at Ø 100 mm.

These photomultipliers give us $N_0 > 100$.
N_0 is the „figure of merit" for Cherenkov count. from the expression: $N_{ph} = N_0 \cdot L \cdot \sin^2\theta$.
N_{ph} – number of photoelectrons, L – radiators lenght, θ – Ch. ang.

3.

2361

Our industry produces photomultiplier FEU-143 with parameters of „Cascade", but the diameter of photocathode equal 45 mm.

This photomultiplier may be used in Cherenkov counters with Winston cone.

...

Mirrors.

For NEPTUN experiment (IHEP, UNK, SZ) we produce spherical mirrors.

Mirrors parameters:

Diameter	600 mm
Focal distance	20000 (10000) mm
Full thickness	3 mm of glass.
Reflectivity (in visible range)	≈ 90%.

Our technology allows to produce mirrors with focal distance = 1500 mm. This value corresponds to SDC Cherenkov counters requirements.

23

1

2362

Scintillation Counters for Trigger System of SDC

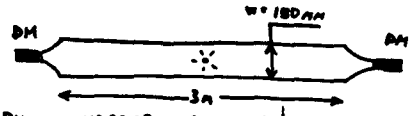
V. Ryakelin, V. Kuzmovsky
IHED, Protvino

I. Polymer Scintillator:

Base – Polystyrene
Dye – PTP + POPOP (420 nm)
Density – 1.05
Ref. Index – 1.59
Sheets size – lenght – up to 6 m; width – ~ 200 mm; thickness – ≤ 20 mm (desirable 10 mm)
Light Output: % Antracene – 52%; % NE 110 – 80-90%
Rise Time ≤ 1 ns
Decay time 3 ns
Light attenuation λ ≈ 200 cm
Production rate ~ 3 T/year

II. Muon Scintillator counters.

preliminary

1) 

PM - XP2262 (Soviet PM ФЭУ143, gain ~ 10^3)

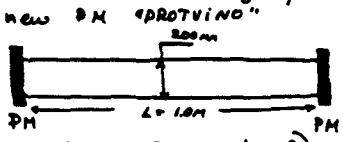
Number of Photoelectrons from the outer ~ 60

Attenuation Lenght l_0 ~ 150 cm

2) The same construction, but L = 1,0 m, w = 200 mm

Npe = 60

3) Counter without lightguide with new PM "PROTVINO"

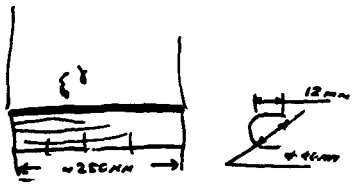


Size of sheet as in 2)

PM - "PROTVINO"

Npe = 65

PM - "PROTVINO"



24

R. Loveless
8 AUG 91

Questions.

1. Magnetic field near PM ?
2. Drawings of muon system for the design of the counters.
3. Reduction of the width from 15 → 10 (or 5) Is it necessary? It is possible to design multianode PM "PROTVINO".
4. The cost of 1 channel of electronics for μ-counter ?
5. The cost of one μ-counter ?
6. Who are going to design and test the μ-counters else ?

Muon Factory Model

- major parts manufactured at distributed facilities
- major parts shipped to SSC during 2-3 year period
- assembled into Towers in surface building in 2-3 year period
- towers installed on SSC in 3 month period

⇒ implies large fraction must be stored

⇒ requires ~ 6500-7000 m^2 building

but current plans have ~ 3000 m^2 area

⇒ factory model must be adjusted
- increase area of building
- descope size of system
- lengthen installation period

one possibility: install parasitically over longer period using ~20% of each track

Muon System Volume

barrel chem.	3300 m^3
int. chem.	600
forward chem.	600
barrel trusses	4000
int. trusses	1500
forward trusses	800
scin. counters	300
γ counters	400
	12000 m^3

- store this in 3000 m^2 area building
  ⇒ 4 m high assuming 100% packing fraction

- compare volumes of other components:

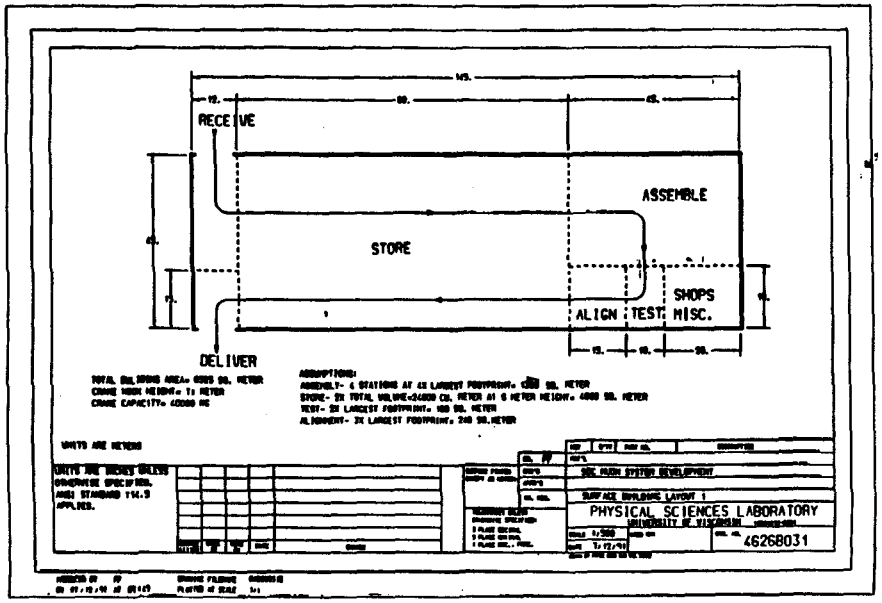
calorimeter	1300 m^3
steel	3300 m^3
other	400 m^3

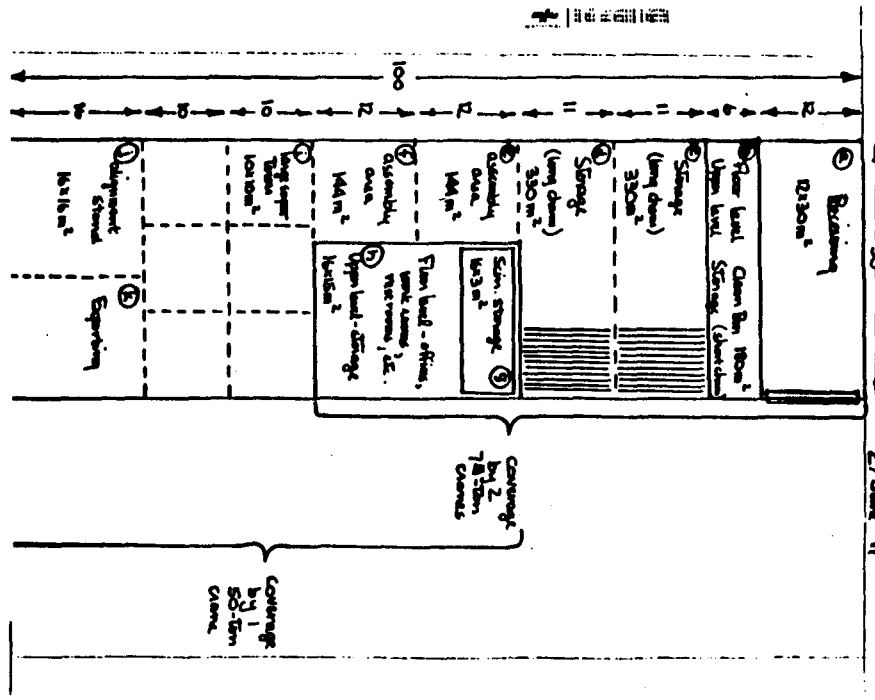
UW-MADISON
PSL
7/12/91

SDC SURFACE FACILITIES ALLOCATION

SYSTEM	VOLUME (CUBIC METER)	ALLOCATION (SQUARE METER)
Muon Measurement	12000	3000
Calorimeter	1300	3000
Muon Magnets	3300	5000 (Uncovered)
Other	400	
TOTAL SDC	17000	

FF:mk:C:\WP:surface.SDC





Bldg. cost

~ $1200 per m² ($100/sq.ft.)

3000 m² bldg. = 3.6 M$

5000 m² bldg. = 6.0 M$

options: store bldg. with mezz steel & coils
use commercial open for chambers & pin.
bldg. commercial open for chambers & pin.
→ extra handling & transportation
build higher stacks
→ ~ 120M$ per 10,000 m² space
different assembly scheme

Muon Chamber Cost Comparisons

Chamber Option	Number of Sense Wires	Material Costs	Mfg Labor ($k)	Total Cost ($k)	$/wire	$/super-module *
Wisconsin	75,863	4,916	10,811	15,727	209	655,278
Boston	28,512	7,614	13,951	21,565	756	898,539
KEK	58,909	14,240	9,768	24,008	408	1,000,334

* assumes 24 supermodules

Chamber Option	Cell Material ($k)	Chamber Material ($k)	Total Material ($k)	Cell Labor ($k)	Chamber Labor ($k)	Total Labor ($k)	Total Cost ($k)
Wisconsin	3,339	1,577	4,916	4,209	6,602	10,811	15,727
Boston	3,649	3,969	7,917	10,076	3,875	13,951	21,568
KEK	N/A	N/A	14,240	N/A	N/A	9,768	24,008

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SDC Muon System WBS

WBS #		Total ($k)	Contingency %	Total with Contingency ($k)
	Magnet System			
3.1.1	Barrel Toroid	39,108	21.8%	47,537
3.1.2	Forward Toroids	16,560	32.7%	21,981
3.1.3	Utilities	993	20.0%	1,191
3.1.4	Forward Absorber	1,390	24.0%	1,723
	Total Magnet System	56,051	24.6%	72,433
	Muon Measurement System			
3.2.1	Tracking Chambers	28,278	23.2%	34,834
3.2.2	Support Structure	2,142	22.2%	2,617
3.2.3	Alignment System	1,362	24.0%	1,688
3.2.4	Handling Fixtures	346	20.0%	415
3.2.5	Local Utilities	320	20.0%	384
3.2.6	Trigger Counters	15,278	25.7%	19,204
3.2.7	Super-Module Assembly	6,189	39.0%	8,603
3.2.8	Global Utilities	2,302	24.0%	2,854
3.2.9	Transportation	1,301	13.0%	1,471
3.2.10	Spares	1,728	24.0%	2,142
3.2.11	Prototype	1,538	24.0%	1,907
	Total Muon Measurement System	60,784	25.2%	76,119
	Total Muon System	118,835	25.0%	148,552

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Muon Chamber Cost Comparisons

Cell $ and Labor Summary

Chamber Option	Cell Material $/Cell	Chamber Material $/Cell	Total Material $/Cell	Cell Assembly Hours/Cell	Chamber Assembly Hours/Cell	Total Labor Hours/Cell
Wisconsin	70.7	33.4	104.2	1.6	1.6	2.8
Boston	135.8	146.9	281.8	6.5	2.5	9.0
KEK	N/A	N/A	242.0	N/A	N/A	3.0

Note: assumes 6 m long cell

Hours/Cell Estimating Method Comparison

	Current Estimates	Manufacturing Standards
Wisconsin	1.6	2.4
Boston	6.5	11.8
KEK	N/A	3.0

SDC Muon System WBS

WBS #		Procurement ($k)	Mfg Labor ($k)	EDIA ($k)	Total ($k)	Cont. ($k)	Total with Cont. ($k)
	Magnet System						
3.1.1	Barrel Toroid	28,087	5,064	5,958	39,108	8,428	47,537
3.1.2	Forward Toroids	13,426	689	2,445	16,560	5,421	21,981
3.1.3	Utilities	850	0	143	993	199	1,191
3.1.4	Forward Absorber	1,323	0	67	1,390	334	1,723
	Total Magnet System	43,686	5,753	8,612	56,051	14,382	72,433
	Muon Measurement System						
3.2.1	Tracking Chambers	10,556	11,447	6,275	28,278	6,556	34,834
3.2.2	Support Structure	1,849	0	293	2,142	475	2,617
3.2.3	Alignment System	1,124	0	238	1,362	327	1,688
3.2.4	Handling Fixtures	313	0	33	346	69	415
3.2.5	Local Utilities	264	0	56	320	64	384
3.2.6	Trigger Counters	11,915	331	3,032	15,278	3,926	19,204
3.2.7	Super-Module Assembly	0	3,410	2,780	6,189	2,414	8,603
3.2.8	Global Utilities	1,900	0	402	2,302	552	2,854
3.2.9	Transportation	1,177	0	124	1,301	169	1,471
3.2.10	Spares	1,124	525	79	1,728	415	2,142
3.2.11	Prototype	1,050	424	64	1,538	369	1,907
	Total Muon Measurement Syste	31,271	16,136	13,376	60,784	15,336	76,119
	Total Muon System	74,957	21,889	21,988	118,835	29,717	148,552

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Octagonal (Wisconsin) Chamber Design

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Octagonal Chamber Unit Costs

	units	$/unit	Cell Length (m) 1	6	10
Cell Material Costs					
Extrusions					
Aluminum (1.8mm)	meters	3.61	$3.61	$21.68	$36.14
Cutting	cell	0.32	$0.32	$0.32	$0.32
Notching	cell	0.25	$0.25	$0.25	$0.25
End Plates	cell	0.78	$0.78	$0.78	$0.78
Wires	meters	0.97	$0.97	$5.84	$9.74
Feedthrus/End Caps	cell	10.00	$10.00	$10.00	$10.00
Anodizing/Cleaning	meters	1.01	$1.01	$5.18	$8.52
Screws, Adhesive, Misc.	cell	5.00	$5.00	$5.00	$5.00
Chamber Material Costs					
Top/Bottom Chamber Skin	meters	3.34	$3.34	$20.05	$33.41
Labor Estimates					
Cell Assembly					
FTC Holes	min/cell	5.00	5.00	5.00	5.00
Gas and Screw Holes	min/cell	5.00	5.00	5.00	5.00
Machining of End Plate	min/cell	5.00	5.00	5.00	5.00
Cell Assembly	min/cell	38.40	38.40	38.40	38.40
Sense Wire Installation	min/cell	8.00	8.00	8.00	8.00
Chamber Assembly	min/cell				
Skin Placement	min/cell				
Chamber Mechanical	min/cell	57.60	57.60	57.60	57.60
Chamber Electrical	min/cell	38.40	38.40	38.40	38.40
Cell Material $/Cell			21.95	49.05	70.74
Chamber Material $/Cell			3.34	20.05	33.41
Total Material $/Cell			25.29	69.10	104.15
Cell Assy Hours/Cell			1.02	1.02	1.02
Chamber Assy Hours/Cell			1.60	1.60	1.60
Labor Hours/Cell			2.62	2.62	2.62

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Octagonal Chamber Design

	Qty	Layers/ Chamber	Length (m)	Width (m)	Area (m^2)	No. of Cells	Total Cells	Total Cell Length (m)	Chamber Mass (kg)	Total Mass (kg)	Material ($/ chamber)	Total Material ($)	Labor (hrs/ chamber)	Total Touch Hours
Main Measurement System														
Intermediate Tracking Chambers														
WC1 Chambers	341	16	5.60	2.00	11.2	53	26,968	150,903	3,962	241,391	21,552	1,411	1,047	88,377
First Layer Thick Chambers	64	5	6.60	8.00	10	80	5,120	33,734	644	35,736	4,004	336	210	17,829
Second Layer Thick Chambers	82	5	5.84	2.00	11	80	7,240	41,810	743	60,313	4,330	388	219	19,308
Pit Chambers (long)	45	4	8.00	1.74	14	85	4,185	33,480	1,175	52,877	6,309	284	244	10,079
Pit Chambers (short)	36	4	4.00	1.74	7	85	3,348	13,392	601	21,653	3,116	141	134	5,783
Base Chambers	34	2	8.50	2.00	11	53	4,482	24,486	518	42,206	2,989	251	136	11,879
WC2 Chambers	168	4	7.41	2.00	15	107	13,896	101,487	1,255	160,590	6,852	677	311	35,920
Thick Chambers	168	4			15	54	13,896	101,487	1,255	160,590	6,852	677	311	35,920
WC3 Chambers	168	10			15	107	35,792	261,202	3,674	585,711	20,231	8,607	724	25,924
Thick Chambers	168	4	6.86	2.00	18	107	13,872	122,264	1,544	193,447	7,394	1,018	304	40,108
Pit Chambers	126	4	6.00	2.18	17	119	15,120	90,720	1,657	189,700	4,479	570	136	17,797
Base Chambers	168	2	8.37	2.00	18	53	8,904	83,548	1,657	141,977	14,026	812	164	37,818
Intermediate Tracking Chambers	240	12			29		14,416	89,243	2,457	589,743	18,367	1,689	236	56,616
WC1 Chambers	18	4			11	11	1,458	6,756	967	15,476	5,413	97	236	3,820
Thick Chambers	18	4	6.75	1.70	11	61	1,458	6,756	967	15,476	5,413	97	236	3,820
WC2 Chambers	18	4			17		12,960	76,464	1,479	120,446	8,812	727	425	33,996
Thick Chambers	252	4			17	27	4,320	33,610	332	53,118	1,760	207	71	11,333
WC3 Chambers	180	4	7.75	0.51	19	135	8,640	45,878	1,146	73,331	6,821	497	364	22,646
Thick Chambers	54	4	5.31	2.53	13	63	2,160	11,472	1,146	49,304	306,556	29,565	197,907	2,895
Base Chambers	54	2			29	63	2,160	11,472	1,146	49,304	306,556	29,565	197,907	2,895
Forward Tracking Chambers	18	8	5.08	1.36	7	374	5,984	30,408	3,047	48,756	18,367	294	881	15,698
WC1 Chambers	18	4	5.08	1.61	10	677	14,652	84,052	7,964	127,424	65,950	735	2,301	36,811
Thick Chambers	18	4	5.08	2.08	10	397	8,352	38,463	3,829	61,257	21,875	382	1,041	18,643
WC2 Chambers	18	4	7.00	2.43	17	457	7,312	51,184	5,070	81,115	28,081	449	1,199	19,182
Thick Chambers	18	4	7.00	2.43	17	814	14,652	102,368	9,653	154,452	53,450	855	2,396	38,364
WC3 Chambers	18	8	7.00	2.43	17	814	14,652	102,368	9,653	154,452	53,450	855	2,396	38,364
Total	1,177				214		139,272	952,941		1,513,524		8,411		362,736

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Octagonal Chamber Unit Costs

	units	$/unit	Cell Length (m) 1	6	10	Comments
Cell Material Costs						
Extrusions						
Aluminum (1.8mm)	meters	3.61	$3.61	$21.68	$36.14	[illegible]
Cutting	cell	0.32	$0.32	$0.32	$0.32	[illegible]
Notching	cell	0.25	$0.25	$0.25	$0.25	[illegible]
End Plates	cell	0.78	$0.78	$0.78	$0.78	[illegible]
Wires	meters	0.97	$0.97	$5.84	$9.74	[illegible]
Feedthrus/End Caps	cell	10.00	$10.00	$10.00	$10.00	[illegible]
Anodizing/Cleaning	meters	1.01	$1.01	$5.18	$8.52	[illegible]
Screws, Adhesive, Misc.	cell	5.00	$5.00	$5.00	$5.00	[illegible]
Chamber Material Costs						
Top/Bottom Chamber Skin	meters	3.34	$3.34	$20.05	$33.41	Based on $0.50/kg previous purchase, 6.61 kg/m, 1 layer
Labor Estimates						
Cell Assembly						
FTC Holes	min/cell	5.00	5.00	5.00	5.00	
Gas and Screw Holes	min/cell	5.00	5.00	5.00	5.00	
Machining of End Plate	min/cell	5.00	5.00	5.00	5.00	
Cell Assembly	min/cell	38.40	38.40	38.40	38.40	
Sense Wire Installation	min/cell	8.00	8.00	8.00	8.00	
Chamber Assembly	min/cell					
Skin Placement	min/cell					
Chamber Mechanical	min/cell	57.60	57.60	57.60	57.60	
Chamber Electrical	min/cell	38.40	38.40	38.40	38.40	
Cell Material $/Cell			21.95	49.05	70.74	
Chamber Material $/Cell			3.34	20.05	33.41	
Total Material $/Cell			25.29	69.10	104.15	
Cell Assy Hours/Cell			1.02	1.02	1.02	
Chamber Assy Hours/Cell			1.60	1.60	1.60	
Labor Hours/Cell			2.62	2.62	2.62	

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Oval Chamber Design

	Qty	Length (m)	Module Volume (m^3)	Total Cells	Total Cell Length (m)	Total Material ($k)	Total Touch Hours
Main Measurement System							
Intermediate Tracking Chambers							
Intermediate Tracking Chambers	16	5.60	7.50	6,648	38,349	0	0
WC2 Chambers	16	4.30					
WC3 Chambers	16	6.90					
Forward Tracking Chambers	16	3.60		17,600	63,300	0	0
WC1 Chambers	16	3.00					
WC2 Chambers	16	3.30					
WC3 Chambers	16	3.30					
WC4 Chambers	16	4.20					
WC5 Chambers	16	4.20					
Total				52,960	306,995	7,614	255,774

Oval (Boston) Chamber Design

Oval Chamber Unit Costs

	units	$/unit	Cell Length (m) 1	6	10
Cell Material Costs					
Tube Base	meters	5.68	$5.68	$35.02	$56.76
Tube Cap	meters	3.08	$3.08	$18.01	$30.81
Field Shaping Board	meters	2.30	$2.30	$14.17	$22.97
Tube End Caps	cell	9.30	$9.30	$9.30	$9.30
Wire	meters	0.29	$0.29	$1.78	$2.89
Feedthrus	cell	3.24	$3.24	$3.24	$3.24
Wire Supports	cell	3.24	$3.24	$3.24	$3.24
Gas Fittings	cell	0.30	$0.30	$0.30	$0.30
Epoxy	cell	2.57	$2.57	$2.57	$2.57
Be/Cu Contacts	cell	2.70	$2.70	$2.70	$2.70
Tube Retention Spring	cell	0.20	$0.20	$0.20	$0.20
Chamber Material Costs		1,014	Prototype $/cell (8 m)		
Aluminum	$/m^3	541	$62.71		
Bulkheads	$/m^3	252	$29.22		
Fixtures	$/m^3	95	$10.96		
Alignment Hardware	$/m^3	126	$14.61		
Labor Estimates					
Tube Preparation					
Unpack, Cut to Size, Deburr	min/cell	60.00	60.00	60.00	60.00
Machine End Cap/Wire Support Slots	min/cell	60.00	60.00	60.00	60.00
Remove, Deburr, Clean and Store	min/cell	30.00	30.00	30.00	30.00
Cell Assembly					
Place & Secure Tube	min/cell	20.00	20.00	20.00	20.00
Mount & Epoxy Ends & Wire Supports	min/cell	60.00	60.00	60.00	60.00
Place & Epoxy Bottom Shaping Board	min/cell	30.00	30.00	30.00	30.00
String Wire, Tension, Check, Crimp, Solder	min/cell	60.00	60.00	60.00	60.00
Place & Epoxy Top Shaping Board	min/cell	60.00	60.00	60.00	60.00
Gas and Electrical Check	min/cell	20.00	20.00	20.00	20.00
Chamber Assembly					
Box Fabrication	min/cell	45.66	45.66	45.66	45.66
Insertion of Tubes	min/cell	24.00	24.00	24.00	24.00
Alignment	min/cell	21.92	21.92	21.92	21.92
Misc.	min/cell	18.26	18.26	18.26	18.26
Chamber Electrical	min/cell	38.40	38.40	38.40	38.40
Cell Material $/Cell			32.9	91.5	135.0
Chamber Material $/Cell			14.7	99.6	146.9
Total Material $/Cell			47.6	192.2	281.9
Cell Assembly Labor Hours/Cell			6.5	6.5	6.5
Chamber Assembly Labor Hours/Cell			2.5	2.5	2.5
Total Hours/Cell			9.0	9.0	9.0

KEK Chamber Design

KEK Chambers

	units	$/unit	# units WC1 theta	WC1 phi	WC2 theta	WC2 stereo	WC3 theta	Cost ($k) WC1 theta	WC1 phi	WC2 theta	WC2 stereo	WC3 theta	Total Cost ($k)
Material Estimates													
Side Frame Extrusions	m	24.16	450	773	999		729	11	19	14		18	61
Top Plate (50 mm)	m^2	399	1,447	1,447	1,885		2,339	517	517	674		836	2,545
Middle Plate (40 mm)	m^2	329	1,447	1,447	1,885		2,339	476	476	620		769	2,342
Bottom Plate (50 mm)	m^2	399	1,447	1,447	1,885		2,339	517	517	674		836	2,545
Middle Support Frame	m	28.91	259	135	259		259	7	4	7		7	24
Wire and Cell Wall Support	m	20.08	1,545	629	1,545		1,545	31	13	31		31	106
End Frame	m	60.04	515	180	515		515	31	11	31		31	104
Cathode Plate	m	17.93	19,670	21,460	34,160		49,032	353	385	613		879	2,230
Sense Wires (3/cell)	m	0.26	59,010	64,380	102,480		147,096	15	17	27		38	98
Potential/Guard Wires ($/cell)	m	0.89	118,020	128,760	204,960		294,192	104	114	181		260	660
Feedthrus	cell	3.24	3,500	2,000	4,667		5,400	11	6	15		17	50
Screws, Adhesive, Other Misc.	cell	5.00	3,500	2,000	4,667		5,400	18	10	23		27	78
Cathode Plate Supports	m	4.79	19,670	21,460	34,160		49,032	94	103	164		235	595
Stereo Tube Lengths	cell	230				12,200					2,803		2,803
Labor Estimates (per mfg site.)													
End Plate Detail	hrs/chamber	212.9											
Side Frame Detail	hrs/chamber	147.4											
Center Frame Detail	hrs/chamber	115.5											
Honeycomb Plate	hrs/chamber	2.7											
End Wire Guide	hrs/chamber	588.1											
Center Wire Guide	hrs/chamber	93.4											
Cathode Plate	hrs/chamber	624.7											
Cathode Plate Guide	hrs/chamber	672.9											
Cell, Wire Assembly	hrs/chamber	4.7											
Chamber Assembly	hrs/chamber	201.2											
Total (272 cells, 816 sense wires)	hrs/chamber	2663.5											
Total Material $k								2,169	2,192	3,074	2,803	3,985	14,240
Total Material $/Sense Wire								208	385	220	230	246	242
Total Labor Hours/Sense Wire		3.0											

Note: Labor estimate based on one module with 816 sense wire (272 cells, 3 sense wires/cell)
This is equivalent to 58,900 channels divided by 72 modules, 3 modules/octant for WC1, WC2, and WC3

Oval (Boston) Chamber Design

Oval Chamber Unit Costs

	units	$/unit	Cell Length (m) 1	6	10	Comments
Cell Material Costs						
Tube Base	meters	5.68	$5.68	$30.02	$56.76	vendor quote of $1.73/ft, 1.154 lbs/ft
Tube Cap	meters	3.08	$3.08	$19.01	$30.81	quoted at $0.939/foot, 0.626 lbs/ft
Field Shaping Board	meters	2.30	$2.30	$14.17	$22.97	verbal quote at $0.70/ft
Tube End Caps	cell	9.30	$9.30	$9.30	$9.30	quoted at $4.65 each, 2/cell
Wire	meters	0.29	$0.29	$1.78	$2.89	$0.175/m + 50% waste
Feedthrus	cell	3.24	$3.24	$3.24	$3.24	quoted at $1.62 each, 2/cell
Wire Supports	cell	3.24	$3.24	$3.24	$3.24	quoted at $1.62 each, 2/cell
Gas Fittings	cell	0.30	$0.30	$0.30	$0.30	quoted at $0.15 each, 2/cell
Epoxy	cell	2.57	$2.57	$2.57	$2.57	
Be/Cu Contacts	cell	2.70	$2.70	$2.70	$2.70	quote at $0.09 ea., 30/tube
Tube Retention Spring	cell	0.20	$0.20	$0.20	$0.20	quote at $0.066 each, 2/cell
Chamber Material Costs		1,014	Prototype $/cell (8 m)			SW3 Prototype (657 cells) is 6.0m x 8.8m x 1.0m ($94.0k)
Aluminum	$/m^3	541	$62.71			$2.00/lb, 10.3 tons/supermodule ($41.2k)
Bulkheads	$/m^3	252	$29.22			quote at $900/bulkhead, 24 per SW3 supermodule ($19.2k)
Fixtures	$/m^3	95	$10.96			12 @ $600 ea. ($7.2k)
Alignment Hardware	$/m^3	126	$14.61			6 @ $1,200 ea. ($8.0k)
Labor Estimates						
Tube Preparation						
Unpack, Cut to Size, Deburr	min/cell	60.00	60.00	60.00	60.00	
Machine End Cap/Wire Support Slots	min/cell	60.00	60.00	60.00	60.00	
Remove, Deburr, Clean and Store	min/cell	30.00	30.00	30.00	30.00	
Cell Assembly						
Place & Secure Tube	min/cell	20.00	20.00	20.00	20.00	
Mount & Epoxy Ends & Wire Supports	min/cell	60.00	60.00	60.00	60.00	
Place & Epoxy Bottom Shaping Board	min/cell	30.00	30.00	30.00	30.00	
String Wire, Tension, Check, Crimp, Solder	min/cell	60.00	60.00	60.00	60.00	
Place & Epoxy Top Shaping Board	min/cell	60.00	60.00	60.00	60.00	
Gas and Electrical Check	min/cell	30.00	20.00	20.00	20.00	
Chamber Assembly						
Box Fabrication	min/cell	45.66	45.66	45.66	45.66	$22k for SW3 (657 cells, $50/hr)
Insertion of Tubes	min/cell	24.00	24.00	24.00	24.00	$20/cell (657 cells, $50/hr)
Alignment	min/cell	21.92	21.92	21.92	21.92	$12k for SW3 (657 cells, $50/hr)
Misc.	min/cell	18.26	18.26	18.26	18.26	$10k for SW3 (657 cells, $50/hr)
Chamber Electrical	min/cell	38.40	38.40	38.40	38.40	
Cell Material $/Cell			32.9	91.5	135.0	
Chamber Material $/Cell			14.7	99.6	146.9	
Total Material $/Cell			47.6	192.2	281.9	
Cell Assembly Labor Hours/Cell			6.5	6.5	6.5	
Chamber Assembly Labor Hours/Cell			2.5	2.5	2.5	
Total Hours/Cell			9.0	9.0	9.0	

KEK Chamber Design

KEK Chamber Design

	Chambers	Length (m)	Width (m)	Area (m^2)	Total Sense Wires	Total Material ($k)	Total Hours
Muon Measurement System							
Barrel Tracking Chambers				129	58,900	14,240	179,095
WC1 Chambers				50	19,600	3,969	50,169
Theta Chambers (3 wires)	72	5.62	3.59	20	19,600	2,539	31,925
Phi Chambers (3 wires)	72	10.73	2.81	30	6,000	1,461	18,243
WC2 Chambers				49	29,200	6,334	79,861
Theta Chambers (3 wires)	72	7.32	3.59	28	14,000	3,365	42,567
Stereo Chambers (1 wire)	72	5.62	3.59	20	12,200	2,950	37,094
WC3 Chambers	72			33	16,200	3,917	49,256
Theta Chambers (3 wires)	72	9.08	3.59	33	16,200	3,917	49,256
Intermediate Tracking Chambers							
WC2 Chambers							
Theta Chambers							
WC3 Chambers							
Theta Chambers							
Stereo Chambers							
Forward Tracking Chambers							
WC1 Chambers							
WC2 Chambers							
WC3 Chambers							
WC4 Chambers							
WC5 Chambers							
Total					58,900	14,240	179,095

Summary

Option	Magnet ($k)	Measure ($k)	EDIA ($k)	Total Cost ($k)	Savings ($k)
Baseline	63,819	68,636	22,805	155,260	0
1	51,702	67,315	22,805	141,822	13,438
2	58,577	66,047	22,805	145,429	9,831
3	63,819	62,921	22,805	149,545	5,715
4	63,819	61,473	22,805	148,097	7,163
TOTAL					36,147

Downsize Options

Option 1 - Barrel thickness goes to 1 m (from 1.5 m) with no change in the inner radius. The outer and radius and all the chambers are smalle

Option 2 - Forward toroids go to thickness of 1.5 m and barrel shortens by 1 m at each end (29.6 m to 27.6 m)

Option 3 - Barrel chambers BW1 (4 theta, 2 phi), BW2 (4 theset, 2 phi, 2 stereo)

Option 4 - Eliminate the outer barrel scintillator counter layer (BS3) with each BS2 layer having 2 PMTs and light pipes

Muon Chamber Costs

Chambers	Baseline Length (m)	Baseline # Cells	Baseline Cost ($k)	Option 1 Revised Length (m)	Option 1 Revised # Cells	Option 1 Revised Cost ($k)	Option 2 Revised Length (m)	Option 2 Revised # Cells	Option 2 Revised Cost ($k)
BW1									
theta	N/A	14,000	2,800	no change	no change	2,800	no change	12,012	2,400
stereo	N/A	4,462	891	no change	no change	891	no change	4,462	616
phi (long)	8.00	4,160	840	no change	no change	840	7.34	no change	666
phi (short)	4.00	3,340	668	no change	no change	668	3.67	no change	582
BW2									
theta	7.41	13,000	2,651	6.96	no change	2,593	no change	12,040	2,467
BW3									
theta	8.00	13,000	2,623	8.36	no change	2,738	no change	12,040	2,540
stereo	9.37	8,784	1,894	8.00	no change	1,540	no change	6,362	866
phi	8.00	15,312	3,017	no change	14,296	2,838	7.50	no change	2,930
BW2									
theta	N/A	1,400	276	no change	1,030	196	no change	no change	276
BW3									
theta	N/A	4,320	1,000	no change	3,864	946	no change	no change	1,000
stereo	N/A	8,640	1,800	no change	7,700	1,353	no change	no change	1,500
TOTAL			17,004			17,097			16,400

1. muon chamber costs driven by cell lengths and quantities
2. cell lengths impact material costs, cell quantities impact material and labor

Chambers	Baseline Length (m)	Baseline # Cells	Baseline Cost ($k)	Option 3 Revised Length (m)	Option 3 Revised # Cells	Option 3 Revised Cost ($k)
BW1						
theta	N/A	14,000	2,800	no change	9,433	1,738
stereo	N/A	4,462	891	no change	no change	891
phi (long)	8.00	4,160	840	no change	2,083	421
phi (short)	4.00	3,340	668	no change	1,674	283
BW2						
theta	7.41	13,000	2,651	no change	no change	2,651
BW3						
theta	8.00	13,000	2,623	no change	no change	2,623
stereo	9.37	8,784	1,894	no change	no change	1,894
phi	8.00	15,312	3,017	no change	7,656	1,508
BW2						
theta	N/A	1,400	276	no change	no change	276
BW3						
theta	N/A	4,320	1,000	no change	no change	1,000
stereo	N/A	8,640	1,800	no change	no change	1,800
TOTAL			17,004			14,738

Magnet Systems

Option	Barrel Iron ($k)	Barrel Coils ($k)	Barrel Supt. ($k)	Fwd Iron ($k)	Fwd Coils ($k)	Fwd Supt ($k)	Utilities ($k)	Fwd Absorb. ($k)	EDIA ($k)	Total ($k)	Savings ($k)
Baseline	29,636	5,350	6,980	14,418	2,931	2,187	1,048	1,656	8,612	72,431	0
1	20,181	6,264	6,980	12,472	2,538	2,187	844	1,656	8,612	60,314	12,117
2	27,644	5,014	6,159	10,814	2,725	1,640	926	1,656	8,612	65,189	7,242
3	29,636	5,350	6,980	14,418	2,931	2,187	1,048	1,656	8,612	72,431	0
4	29,636	5,350	6,980	14,418	2,931	2,187	1,048	1,656	8,612	72,431	0

Muon Measurement Systems

Option	Chambers ($k)	Tooling ($k)	Support Sys. ($k)	Alignment ($k)	Fixtures ($k)	Utilities ($k)	Counters ($k)	Super-Mod. ($k)	Global Utilities ($k)	Transport ($k)	Spares ($k)	EDIA ($k)	Total ($k)	Savings ($k)
Baseline	27,504	2,537	3,229	1,860	465	432	20,601	5,823	2,452	1,347	2,386	14,193	82,829	0
1	26,717	2,464	3,137	1,860	452	420	20,601	5,656	2,382	1,308	2,318	14,193	81,508	1,321
2	25,962	2,395	3,048	1,860	439	408	20,601	5,497	2,315	1,271	2,252	14,193	80,240	2,589
3	24,100	2,223	2,829	1,860	407	379	20,601	5,102	2,149	1,180	2,091	14,193	77,114	5,715
4	27,504	2,537	3,229	1,860	465	432	13,438	5,823	2,452	1,347	2,386	14,193	75,666	7,163

Summary

Option	Magnet ($k)	Measure ($k)	EDIA ($k)	Total Cost ($k)	Savings ($k)
Baseline	63,819	68,636	22,805	155,260	0
1	51,702	67,315	22,805	141,822	13,438
2	58,577	66,047	22,805	145,429	9,831
3	63,819	62,921	22,805	149,545	5,715
4	63,819	61,473	22,805	148,097	7,163
TOTAL					36,147

Downsize Options

Option 1 - Barrel thickness goes to 1 m (from 1.5 m) with no change in the inner radius. The outer and radius and all the chambers are smaller.

Option 2 - Forward toroids go to thickness of 1.5 m and barrel shortens by 1 m at each end (29.6 m to 27.6 m)

Option 3 - Barrel chambers BW1 (4 theta, 2 phi), BW2 (4 theset, 2 phi, 2 stereo)

Option 4 - Eliminate the outer barrel scintillator counter layer (BS3) with each BS2 layer having 2 PMTs and light pipes

SDC Muon System WBS

WBS #		Exp ($k)	Minor ($k)	Major ($k)	WBS MD	WBS Materials ($k)	WBS Base ($k)	Cont. %	Cont. ($k)	WBS Total ($k)	EDIA ($k)	Mfg Labor ($k)	Labor ($k)	EDIA %
3	Muon System	0	901	74,356	166,336	74,957	118,835	25	29,717	148,552	21,898	21,898	43,877	15
3.1	Magnet System	0	69	43,617	51,068	43,686	58,081	25	14,352	72,433	8,612	5,753	14,365	12
3.1.1	Barrel Toroid	0	69	28,016	41,218	28,087	39,105	22	8,428	47,537	5,988	5,984	11,922	13
3.1.1.1	Magnet Iron	0	7	15,612	28,258	15,619	22,207	21	4,631	26,838	3,047	3,341	6,388	11
3.1.1.1.1	Short Thick Blocks	0	0	4,867	8,023	4,867	6,469	20	1,329	7,824	888	1,044	1,931	11
3.1.1.1.1.1	Plates		0	4,276	2,546	4,276	5,210	22	1,146	6,356	776	88	832	12
3.1.1.1.1.2	Block Bolts		0	54	26	54	64	14	9	73	10	0	10	13
3.1.1.1.1.3	Pins		0	138	88	138	158	14	22	181	24	0	24	13
3.1.1.1.1.4	Assembly		0	0	5,380	0	1,065	14	149	1,214	78	987	1,065	6
3.1.1.1.2	Long Blocks	0	0	9,860	13,796	9,860	12,346	21	2,560	14,906	1,709	1,688	3,394	11
3.1.1.1.2.1	Plates		0	8,747	4,997	8,747	10,390	22	2,286	12,676	1,546	97	1,643	12
3.1.1.1.2.2	Block Bolts		0	112	87	112	132	14	18	150	20	0	20	13
3.1.1.1.2.3	Pins		0	92	47	92	109	14	15	124	16	0	16	13
3.1.1.1.2.4	Assembly		0	0	6,666	0	1,716	14	240	1,956	126	1,589	1,715	6
3.1.1.1.3	Short Thin Blocks	0	7	81	64	88	88	21	18	106	12	8	20	11
3.1.1.1.3.1	Plates		0	81	32	81	72	22	16	88	11	0	11	12
3.1.1.1.3.2	Block Bolts		3	0	0	3	3	14	0	3	0	0	0	13
3.1.1.1.3.3	Pins		4	0	0	4	4	14	1	4	0	0	0	10
3.1.1.1.3.4	Assembly		0	0	32	0	9	14	1	10	1	8	9	10
3.1.1.1.4	Corner Bolts		0	124	63	124	146	14	20	167	22	0	22	13
3.1.1.1.5	Ring Pre-Assembly		0	0	317	0	65	20	13	78	5	60	65	6
3.1.1.1.6	Fixtures/Tooling		0	944	3,285	944	1,343	26	349	1,692	198	542	699	9
3.1.1.1.7	Transport to Port of Origin		0	1,464	747	1,464	1,722	20	344	2,066	258	0	258	12
3.1.1.2	Transportation to Site	0	0	4,786	2,449	4,786	5,627	17	977	6,604	842	0	842	13
3.1.1.2.1	Transport to Port of Entry		0	2,847	1,452	2,847	3,349	20	670	4,018	501	0	501	13
3.1.1.2.2	Storage		0	81	41	81	95	25	24	119	14	0	14	13
3.1.1.2.3	Rail to SSCL		0	1,464	747	1,464	1,722	13	224	1,946	258	0	258	13
3.1.1.2.4	Heavy Hauling to Hall Shaft		0	393	201	393	463	13	60	523	69	0	69	13
3.1.1.3	Z-Connectors	0	18	54	27	72	81	14	11	92	9	0	9	10
3.1.1.3.1	Block Bolts		18	0	0	18	18	14	3	21	0	0	0	0
3.1.1.3.2	Cables		0	54	27	54	63	14	9	72	9	0	9	13
3.1.1.4	Coils		0	3,730	2,994	3,730	4,763	34	1,619	6,383	1,033	0	1,033	16
3.1.1.4.1	Insulated Copper Coils					0		0	0			0		0
3.1.1.4.1.1	Copper					0		0	0			0		0
3.1.1.4.1.2	Insulation					0		0	0			0		0
3.1.1.4.1.3	Half-Turn Assembly					0		0	0			0		0
3.1.1.4.1.4	Joint Plates End Hardware					0		0	0			0		0
3.1.1.4.1.5	Coil Assembly and Test					0		0	0			0		0
3.1.1.4.1.6	Fabrication Tooling					0		0	0			0		0
3.1.1.4.1.7	Fittings and Hoses					0		0	0			0		0
3.1.1.4.1.8	Magnetic Shielding					0		0	0			0		0

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SDC Muon System WBS

WBS #		Exp ($k)	Minor ($k)	Major ($k)	WBS MD	WBS Materials ($k)	WBS Base ($k)	Cont. %	Cont. ($k)	WBS Total ($k)	EDIA ($k)	Mfg Labor ($k)	Labor ($k)	EDIA %
3.1.1.4.2	Supports					0		0	0			0		0
3.1.1.4.3	Interconnects					0		0	0			0		0
3.1.1.4.3.1	Electrical Coil-to-Coil					0		0	0			0		0
3.1.1.4.3.2	Electrical Supply and Return					0		0	0			0		0
3.1.1.4.3.3	Water Manifold					0		0	0			0		0
3.1.1.4.3.4	Water Supply and Return					0		0	0			0		0
3.1.1.5	Magnet Barrel Support System	0	44	3,636	9,897	3,681	6,430	18	1,189	7,619	1,026	1,723	2,749	13
3.1.1.5.1	Inboard Plates		0	427	718	427	650	14	91	741	124	99	223	17
3.1.1.5.2	T and S Bearing		34	0	539	34	191	14	27	218	72	83	157	33
3.1.1.5.3	Girders		0	481	1,249	481	844	14	118	962	161	232	393	17
3.1.1.5.4	Floor Plates		0	70	63	70	92	14	13	105	6	17	22	6
3.1.1.5.5	Pre-Assembly		0	0	760	0	205	14	29	234	44	161	205	19
3.1.1.5.6	Cables		0	192	363	192	291	20	58	349	32	67	99	9
3.1.1.5.7	800 MT Horizontal Jacks		0	768	1,932	768	1,212	20	242	1,454	176	268	444	12
3.1.1.5.8	800 MT Vertical Jacks		0	1,260	3,472	1,260	1,967	20	397	2,364	261	446	707	11
3.1.1.5.9	Load Cells		0	128	230	128	194	20	39	233	21	45	66	9
3.1.1.5.10	Hydraulic Control System		0	70	223	70	137	24	33	166	25	42	67	15
3.1.1.5.11	Alignment System		0	180	633	180	406	24	98	506	60	167	226	12
3.1.1.5.12	Electrical/Mechanical System		0	70	223	70	137	24	33	169	25	42	67	15
3.1.1.5.13	Lifting and Placement Fixtures		10	0	265	10	82	14	12	95	21	52	73	22
3.1.2	Intermediate Toroid	0	0	13,420	9,736	13,420	16,860	33	5,421	21,881	2,446	688	3,134	11
3.1.2.1	Magnet Iron		0	10,388	4,283	10,388	11,855	34	4,031	15,885	1,467	0	1,467	9
3.1.2.2	Coils		0	2,043	1,644	2,043	2,611	34	888	3,498	567	0	567	16
3.1.2.2.1	Insulated Copper Coils					0		0	0			0		0
3.1.2.2.1.1	Copper					0		0	0			0		0
3.1.2.2.1.2	Insulation					0		0	0			0		0
3.1.2.2.1.3	Half-Turn Assembly					0		0	0			0		0
3.1.2.2.1.4	Coil Test					0		0	0			0		0
3.1.2.2.1.5	Fabrication Tooling					0		0	0			0		0
3.1.2.2.1.6	Fittings and Hoses					0		0	0			0		0
3.1.2.2.1.7	Magnetic Shielding					0		0	0			0		0
3.1.2.2.2	Supports					0		0	0			0		0
3.1.2.2.3	Interconnects					0		0	0			0		0
3.1.2.2.3.1	Electrical Coil-to-Coil					0		0	0			0		0
3.1.2.2.3.2	Electrical Supply and Return					0		0	0			0		0
3.1.2.2.3.3	Water Manifold					0		0	0			0		0
3.1.2.2.3.4	Water Supply and Return					0		0	0			0		0
3.1.2.3	Support Structure		0	995	3,808	995	2,088	24	500	2,588	411	689	1,100	16
3.1.3	Utilities	0	0	850	412	850	993	20	198	1,191	143	0	143	12
3.1.3.1	Power Supply System	0	0	650	316	650	759	20	152	911	109	0	109	12
3.1.3.1.1	Power Supplies	0	0	400	194	400	467	20	93	561	67	0	67	12

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SDC Muon System WBS

WBS #		Exp ($k)	Minor ($k)	Major ($k)	WBS MD	WBS Materials ($k)	WBS Base ($k)	Cont. %	Cont. ($k)	WBS Total ($k)	EDIA ($k)	Mfg Labor ($k)	Labor ($k)	EDIA %
3.1.3.1.1.1	Barrel South End		0	100	49	100	117	20	23	140	17	0	17	12
3.1.3.1.1.2	Barrel North End		0	100	49	100	117	20	23	140	17	0	17	12
3.1.3.1.1.3	South Forward		0	100	49	100	117	20	23	140	17	0	17	12
3.1.3.1.1.4	North Forward		0	100	49	100	117	20	23	140	17	0	17	12
3.1.3.1.2	Power Buses	0	0	250	122	250	292	20	58	350	42	0	42	12
3.1.3.1.2.1	Barrel South End		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.1.2.2	Barrel North End		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.1.2.3	South Forward		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.1.2.4	North Forward		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.1.2.5	DC Breaker to Power Supply		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.2	Monitoring and Control System	0	0	200	97	200	234	20	47	280	34	0	34	12
3.1.3.2.1	Hardwired Control and Interlock Panel		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.2.2	Temperature Monitoring Instrument		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.2.3	Pressure and Flow Monitoring Instr.		0	50	24	50	58	20	12	70	8	0	8	12
3.1.3.2.4	Electrical and Magnetic Monitoring Instr.		0	50	24	50	58	20	12	70	8	0	8	12
3.1.4	Forward Absorber		0	1,282	194	1,282	1,388	24	334	1,722	87	0	87	4
3.2	Muon Measurement System	0	832	30,739	114,604	31,271	60,704	26	15,355	76,119	13,378	15,135	28,512	16
3.2.1	Tracking Chambers	0	48	19,511	77,940	19,558	30,279	25	6,555	36,834	6,275	11,447	17,722	16
3.2.1.1	Barrel	0	0	4,916	46,171	4,916	16,368	24	3,668	19,041	4,068	6,374	10,440	21
3.2.1.1.1	WC1 Chambers	0	0	1,411	16,366	1,411	5,225	24	1,254	6,480	1,590	2,224	3,816	30
3.2.1.1.1.1	First Layer Theta Chambers		0	326	4,134	326	1,301	24	312	1,614	394	571	966	30
3.2.1.1.1.2	Second Layer Theta Chambers		0	300	4,535	300	1,400	24	346	1,866	431	626	1,057	30
3.2.1.1.1.3	Phi Chambers (long)		0	204	2,409	204	851	24	204	1,055	215	352	567	25
3.2.1.1.1.4	Phi Chambers (short)		0	141	1,972	141	604	24	145	737	172	281	453	28
3.2.1.1.1.5	Stereo Chambers		0	351	3,196	351	1,082	24	260	1,356	376	394	773	35
3.2.1.1.2	WC2 Chambers	0	0	977	7,778	977	2,641	24	634	3,276	624	1,140	1,764	19
3.2.1.1.2.1	Theta Chambers		0	977	7,778	977	2,641	24	634	3,276	624	1,140	1,764	19
3.2.1.1.3	WC3 Chambers	0	0	2,527	21,128	2,527	7,466	24	1,797	9,265	1,652	3,010	4,661	20
3.2.1.1.3.1	Theta Chambers		0	1,016	7,778	1,016	2,780	24	667	3,447	624	1,140	1,764	18
3.2.1.1.3.2	Phi Chambers		0	1,038	8,530	1,038	2,936	24	716	3,656	852	1,288	1,920	18
3.2.1.1.3.3	Stereo Chambers		0	573	4,821	573	1,750	24	420	2,170	576	601	1,177	27
3.2.1.2	Intermediate	0	0	810	9,769	810	3,161	24	759	3,920	1,082	1,299	2,361	30
3.2.1.2.1	WC2 Chambers	0	0	87	663	87	295	24	69	364	76	123	198	22
3.2.1.2.1.1	Theta Chambers		0	87	663	87	295	24	69	364	76	123	198	22
3.2.1.2.2	WC3 Chambers	0	0	723	8,906	723	2,876	24	690	3,566	1,016	1,137	2,152	30
3.2.1.2.2.1	Theta Chambers		0	287	4,240	287	1,405	24	337	1,742	682	427	1,110	40
3.2.1.2.2.2	Stereo Chambers		0	437	4,666	437	1,471	24	353	1,824	324	710	1,034	18
3.2.1.3	Forward	0	0	2,865	21,987	2,865	7,192	24	1,719	8,881	664	3,812	4,477	7
3.2.1.3.1	WC1 Chambers		0	294	2,306	294	877	24	211	1,088	107	476	583	10
3.2.1.3.2	WC2 Chambers		0	736	6,244	736	2,062	24	495	2,462	183	1,104	1,287	7
3.2.1.3.3	WC3 Chambers		2	352	2,969	352	906	24	222	1,199	110	805	915	9

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SDC Muon System WBS

WBS #		Exp ($k)	Minor ($k)	Major ($k)	WBS MD	WBS Materials ($k)	WBS Base ($k)	Cont. %	Cont. ($k)	WBS Total ($k)	EDIA ($k)	Mfg Labor ($k)	Labor ($k)	EDIA %
3.2.1.3.4	WC4 Chambers		0	449	3,250	449	1,145	24	275	1,420	117	579	696	8
3.2.1.3.5	WC5 Chambers		0	955	6,487	955	2,172	24	521	2,693	167	1,150	1,317	6
3.2.1.4	Tooling	0	40	2,100	1,843	2,140	2,598	15	393	2,991	494	0	494	19
3.2.1.4.1	Extrusion Die		40	0	22	40	55	14	8	63	10	0	10	19
3.2.1.4.2	Winding Machines		0	600	263	600	727	18	131	858	127	0	127	18
3.2.1.4.3	Assembly Stations		0	600	263	600	727	14	102	829	127	0	127	18
3.2.1.4.4	Transport Fixtures		0	600	263	600	727	14	102	829	127	0	127	18
3.2.1.4.5	Production/Final QC Facility		0	300	146	300	363	14	51	414	63	0	63	18
3.2.2	Support Structure	0	104	1,669	874	1,849	2,142	22	475	2,617	293	0	293	11
3.2.2.1	Barrel System	0	126	1,373	547	1,499	1,737	22	379	2,116	236	0	236	11
3.2.2.1.1	Barrel Frames	0	0	828	306	828	960	22	216	1,176	131	0	131	11
3.2.2.1.1.1	Outer Truss Frames		0	384	144	384	466	24	108	566	63	0	63	11
3.2.2.1.1.2	End Truss Frames		0	120	47	120	140	24	36	186	20	0	20	11
3.2.2.1.1.3	Walkways, Ladders, etc.		0	300	112	300	356	20	71	426	48	0	48	11
3.2.2.1.2	Inner Chamber Supports	0	40	72	41	112	130	24	31	161	18	0	18	11
3.2.2.1.2.1	Support Frames		0	72	30	72	84	24	20	104	11	0	11	11
3.2.2.1.2.2	Extension Frame		40	0	10	40	46	24	11	57	6	0	6	11
3.2.2.1.3	Bottom Drawer Assembly	0	16	0	6	16	18	24	4	22	3	0	3	11
3.2.2.1.3.1	L2 Support Frames		7	0	3	7	8	24	2	10	1	0	1	11
3.2.2.1.3.2	L3 Support Frames		9	0	3	9	10	24	2	12	1	0	1	11
3.2.2.1.4	Barrel Truss Mounts	0	71	472	199	543	629	20	126	755	86	0	86	11
3.2.2.1.4.1	Rails		0	200	78	200	233	20	47	280	32	0	32	11
3.2.2.1.4.2	Rail Supports		0	160	68	160	186	20	37	223	25	0	25	11
3.2.2.1.4.3	Rail Alignment Fixture		10	0	4	10	12	20	2	14	2	0	2	11
3.2.2.1.4.4	Shims		16	0	6	16	18	20	4	22	3	0	3	11
3.2.2.1.4.5	End Alignment Bars		16	0	6	16	18	20	4	22	3	0	3	11
3.2.2.1.4.6	Module Mounts		0	110	40	110	128	20	26	153	18	0	18	11
3.2.2.1.4.7	End Inside Mounts		28	0	11	28	33	20	7	40	5	0	5	11
3.2.2.2	Forward System	0	28	312	127	340	405	24	97	502	65	0	65	11
3.2.2.2.1	ICW1/ICW2 Truss		0	64	22	64	74	24	18	92	10	0	10	11
3.2.2.2.2	ICW3 Frames		28	0	9	28	30	24	7	37	4	0	4	11
3.2.2.2.3	IW4 Crossbar Truss		0	94	34	94	109	24	26	135	15	0	15	11
3.2.2.2.4	IW4 Access Frame		0	6	2	6	7	24	2	8	1	0	1	11
3.2.2.2.5	Truss/Frame Mounts		0	91	35	91	106	24	25	131	14	0	14	11
3.2.2.2.6	ICW1/ICW2 Access Frame		0	6	2	6	7	24	2	8	1	0	1	11
3.2.2.2.7	Module Mounts		0	62	23	62	72	24	17	89	10	0	10	11
3.2.3	Alignment System	0	50	1,074	546	1,124	1,282	24	307	1,589	236	0	236	14
3.2.3.1	Barrel	0	10	632	312	642	776	24	187	964	138	0	138	14
3.2.3.1.1	1.1/Rad Truss Align System		0	280	136	280	339	24	81	421	60	0	60	14
3.2.3.1.2	1.1/End Truss Alignment System		0	192	96	192	233	24	56	289	41	0	41	14
3.2.3.1.3	Bottom Drawer Alignment System		0	60	29	60	73	24	17	90	13	0	13	14

2390 20

SDC Muon System WBS

SDC Muon System WBS

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F. FEYZI

WBS 3 OPTIONS AND COST SUMMARY

	OPTION			
	LOI	I	II	III
MBT Inside R (M)	7.24	7.24	6.74	6.74
MBT Length (M)	29.6	29.6	29.6	27.6
MBT Thickness (M)	1.5	1.5	1.5	1.5
MFT Inside Z (M)	10.33	10.33	10.33	10.33
MFT Outside R (M)	6.4	6.4	5.9	5.9
MFT Thickness (M)	4	4	4	3
BWI Thickness (M)	1	1	.5	.5
BWI Cell Size (MM)	75	75	38	38
BW2,BW3 Cell Size(MM)	75	75	75	75
LAYOUT:				
BW1	6Θ,4φ,2S	4Θ,4φ,4Θ	4Θ,4φ,4Θ	4Θ,4φ,4Θ
BW2	4Θ	4Θ	4Θ	4Θ
BW3	6Θ,4φ,2S	4Θ	4Θ	4Θ
IW2	4Θ	4Θ	4Θ	4Θ
IW3	4Θ,4φ	4Θ	4Θ	4Θ
FW1	4Θ	4Θ	4Θ	4Θ
FW2	4Θ,4S	4Θ,4S	4Θ,2S	4Θ,2S
FW3	4Θ	-	-	-
FW4	4Θ	4Θ	4Θ	4Θ
FW5	6Θ,4S	6Θ,4S	6Θ,4S	6Θ,4S
CHANNEL COUNT	138	102	121	118
TOTAL COST ($M)	151.6	129.6	126.9	119

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WBS 3.2 COST SUMMARY
COSTS ARE IN $M UNITS, INCLUDE EDIA AND CONTINGENCY

WBS NO.	ITEM	LOI	I	II	III
3.2.2.1	Barrel Chambers	20	13.2	17.6	17
3.2.1.2	Inter. Chambers	3.9	2.1	2.1	2.1
3.2.1.3	Forward Chambers	8.4	7.3	6.3	6.3
3.2.1.4	Tooling	3	2.2	2.6	2.6
3.2.2.1	Barrel Support	2.1	1.4	1.3	1.3
3.2.2.2	Inter. Support	.5	.3	.3	.3
3.2.2.3	Forward Support	1	.8	.7	.7
3.2.3.1	Barrel Align.	1	1	1	1
3.2.3.2	Inter. Align.	.7	.7	.7	.7
3.2.3.3	Forward Align.	.5	.5	.5	.5
3.2.4	Fixtures	.5	.5	.5	.5
3.2.5	Utilities	.5	.5	.5	.5
3.2.6	Trigger Counters	24	19	18	17
3.2.7.1	Barrel Assembly	4.9	2.9	2.9	2.9
3.2.7.2	Inter. Assembly	.8	.6	.6	.6
3.2.7.3	Forward Assembly	2.9	2.3	2.3	2.3
3.2.8	Global Utilities	2.9	2.1	2.5	2.5
3.2.9	Transportation	1.5	.9	.9	.9
3.2.10	Spares	2.5	1.6	1.6	1.6
TOTAL		82	60	63	61

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WBS 3.1 COST SUMMARY
COSTS ARE IN $M UNITS, INCLUDE EDIA AND CONTINGENCY

WBS NO.	ITEM	LOI	I	II	III
3.1.1	Barrel Toroid	45.5	45.5	42.8	39.9
3.1.2	Forward Toroid	21.2	21.2	18.2	15.2
3.1.3	Utilities	1.2	1.2	1.2	1.2
3.1.4	Forward Absorber	1.7	1.7	1.7	1.7
TOTAL		69.6	69.6	63.9	58

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Muon Magnets

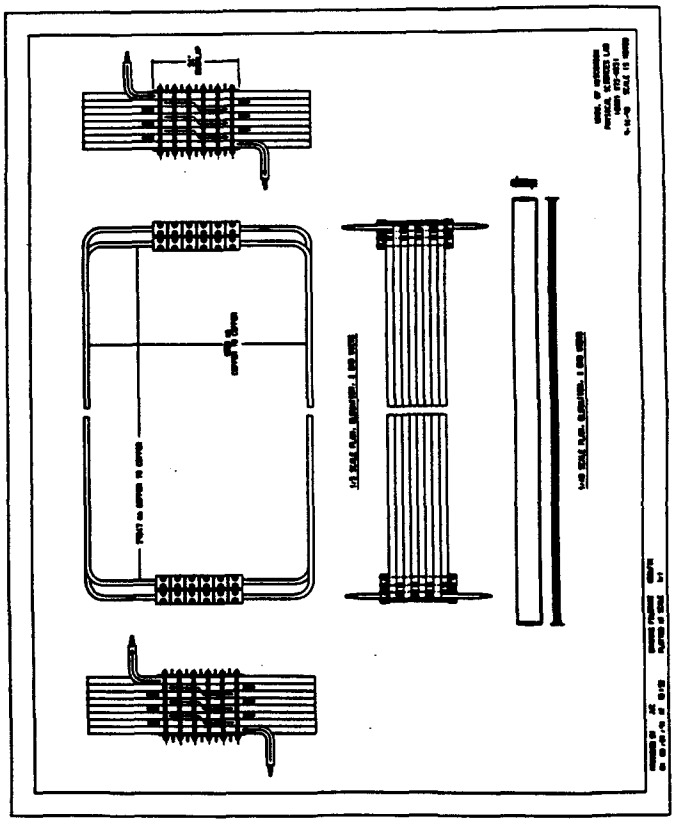
August 5- Monday

Coil Design Status	J. Cherwinka(Wisconsin)
Barrel Magnet and Support	J. Western(SSCL)
Forward Toroid & Installation Concept	L. Dittert(Kaiser)

LPBautz:8/21/91

COIL DESIGN STATUS

J. CHERWINKA



Muon Magnets

August 5- Monday

Coil Design Status	J. Cherwinka(Wisconsin)
Barrel Magnet and Support	J. Western(SSCL)
Forward Toroid & Installation Concept	L. Dittert(Kaiser)

LPBautz:8/21/91

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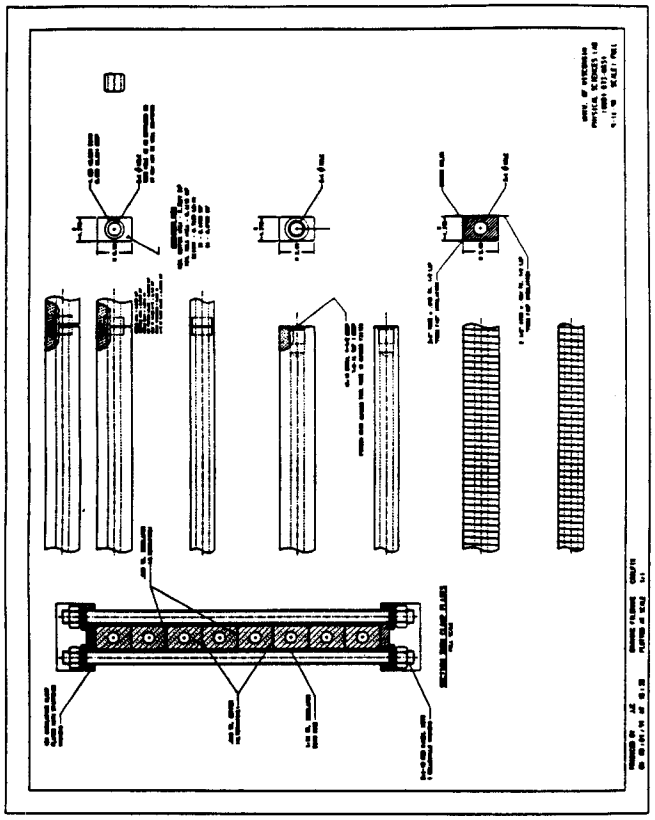

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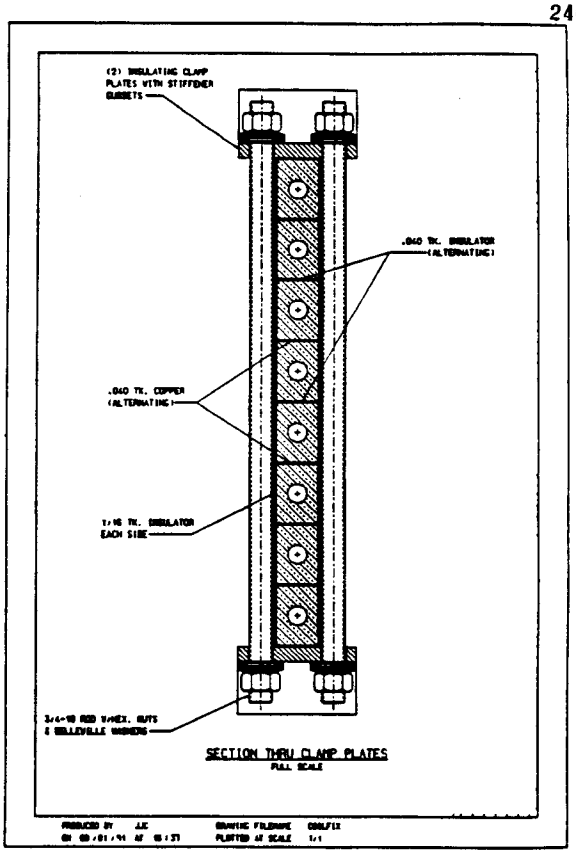

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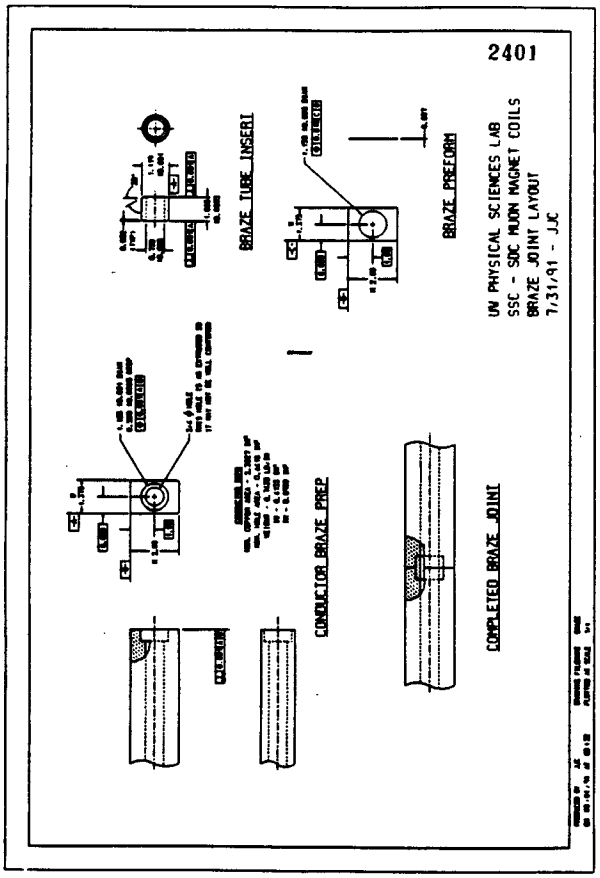

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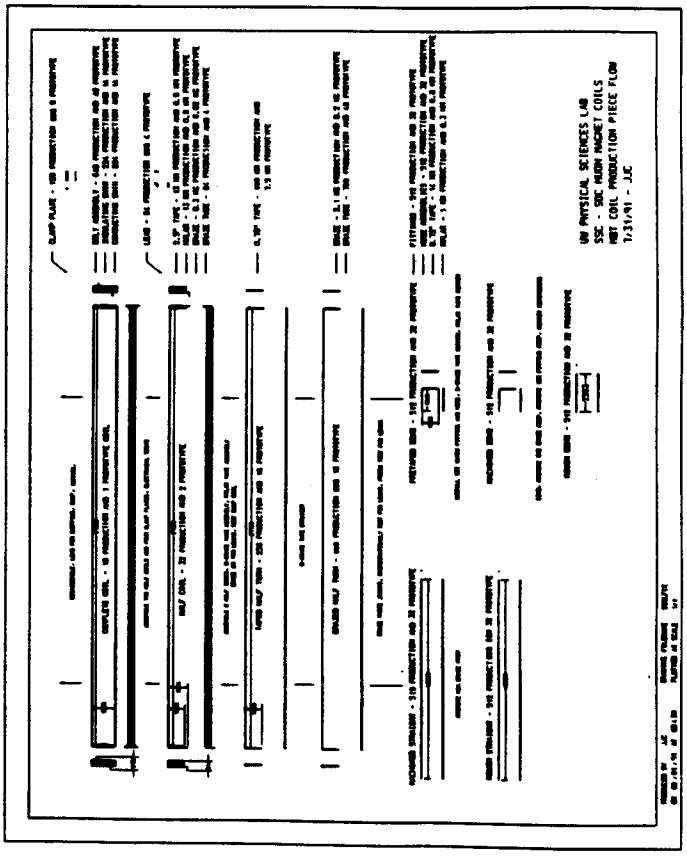
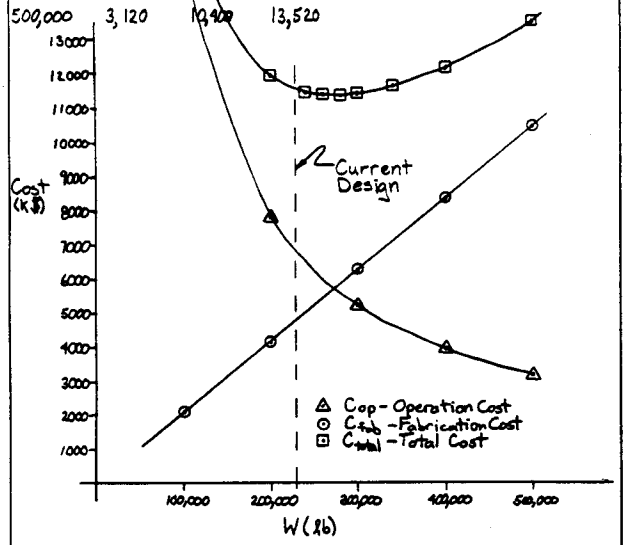


SSC/SDC | JJC | 7/8/91

2403

W lb	C_{op} k$ 1.56E12/W	C_{fab} k$ 20.8W	C_{total} k$ $C_{op}+C_{fab}$
229,320	6,803	4,770	11,573
100,000	15,600	2,080	17,680
200,000	7,800	4,160	11,960
300,000	5,200	6,240	11,440
400,000	3,900	8,320	12,220
500,000	3,120	10,400	13,520



2404

COILCOPY.XLS

	A	B	C	D	E	F	G
1	MAGNETIC AND ELECTRICAL INFORMATION						
2	B	1.8	Magnetic flux density	Tesla			
3	L-all	82.9931	Length of steel path	meter			
4	L-air	0.0074	Length of air path	meter			
5	Mu-st	1.26	Relative permeability of steel	unit less			
6	F	660236.4233	Magnetomotive force	Amp-turn			
7	N-coils	16	Number of coils	#			
8	N-turns	4579.836923	Number of turns per coil	Amp			
9	I	1.7992E-05	Current	Ohm meter			
10	R-copper	0.00056561	Resistivity of copper	Ohm			
11	R-coil	26.54774464	Resistance of the coil	Volt			
12	V-coil	118.1853002	Voltage for unit of the coil	Watt			
13	P-coil		Power used by the coil				
14	DIMENSIONAL INFORMATION						
15	H-cond	0.0508	Height of the conductor	meter			
16	W-cond	0.034925	Width of the conductor	meter			
17	D-hole	0.01905	Diameter of the conductor water hole	meter			
18	L-coil	29.88	Length of the inside of the coil	meter			
19	Wi-coil	1.95	Width of the inside of the coil	meter			
20	R-cornbond	0.10858375	Radius of the corner bends	meter			
21	Ov-coil	0.7186	Overlap of coil	meter			
22	MECHANICAL INFORMATION						
23	A-cond	0.001980197	Area of the conductor cross section	meter^2			
24	A-hole	0.00028507	Area of corner hole cross section	meter^2			
25	H-coil	9.750611E-07	Moment of inertia of coil height	meter^4			
26	W-coil	1.7297E-07	Moment of inertia of conductor width	meter^4			
27	H-coil	0.00019538	Approximate Moment of inertia of coil	meter^4			
28	W-coil	1.391E-05	Moment of inertia of coil width direction	meter^4			
29	HW-coil	11.58436364	Ratio of coil height to width	unitless			
30	L-cond	613.4177276	Length of conductor	meter			
31	W-copper	8940	Mass density of copper	kg per meter^3			
32	W-reinforced	13.33318236	Mass of conductor per meter	kg per meter			
33	W-coil	8835.20005	Mass of the coil	kilogram			
34	Wingspacend	0.01800	Width of tape for half leg conductor	meter			
35	Wingcoil	0.0635	Width of tape for holding coil together	meter			
36	Wfilmcoil	0.0635	Width of film for holding coil together	meter			
37	L-tapecoil	8811.380577	Length of conductor tape required	meter			
38	L-tapend	1863.946421	Length of coil tape required	meter			
39	L-filmcoil	1863.946421	Length of coil film required	meter			
40	DEFLECTION AND STRESS TABLE						
41	Sum	W Deflection	W Normal Stress	W Shear Stress H Deflect	H Normal	H Shear Stress	
42	(meter)	(mm)	(MPa)	(MPa)	(mm)	(MPa)	(MPa)

2405

COILCOPY.XLS

	A	B	C	D	E	F	G
1	COILING INFORMATION						
2	Dof-T-path	11.11111	Temperature differential for water	#			
3	N-path	4	Number of cooling paths per coil	Degree C			
4	Q-path	0.000827206	Water flow per path	meter^3 per sec			
5	Di-hole	0.018875	Diameter of hole inside	meter			
6	Do-hole	120.3442564	Length of conductor per cooling path	meter			
7	L-equivalent	0.4	Length of hose equivalent (pres. 80 psi)	unitless			
8	Di-tube	0.012826	Diameter of tubing inside	meter			
9	Do-tube	13	Number of tubings per path	unitless			
10	Re-tube	64198.18149	Reynolds number for water flow	unitless			
11	Nu-D-cond	7.975602	Nusselt number, roughness	unitless			
12	Prandtl-cond	5.1905	Prandtl number for conductor (from Handy Ch	unitless			
13	Kw-D-cond	0.376	Heat conductivity for conductor	unitless			
14	Kcor-D-cond	0.370	Heat conductivity for corner due to bends	unitless			
15	Re-hole	53963.03377	Reynolds number for water flow	unitless			
16	Nu-D-hole	7.974602	Nusselt number, roughness	unitless			
17	Prandtl-hole	5.1905	Prandtl number for water flow (from Handy Ch	unitless			
18	Kw-D-hole	0.1019	Heat conductivity for water	unitless			
19	R-cornbond	0.4	Radius of hose bends	meter			
20	R-D-cornbond	0.21	Bend coefficient for hose	unitless			
21	H-cornbond	0.6457362639	Pressure differential for water due to bends				
22	Dof-P-hose	0.3603841276	Hot expansion correction coefficient for hose	unitless			
23	Whose-filling	0.02629702	Hot expansion correction coefficient for filling	unitless			
24	Hcord-filling	0.0088437772	Pressure differential for water due to bends	kPa			
25	Dof-P-filling	0.0000000006	Pressure differential for water filling	kPa			
26	Dof-P-total	40	Number of conductor bars per coil	#			
27	COST INFORMATION	32	Number of brass jumps per coil	#			
28	N-bars	32	Number of ends with flange per coil	#			
29	N-brass						
30	N-ends						

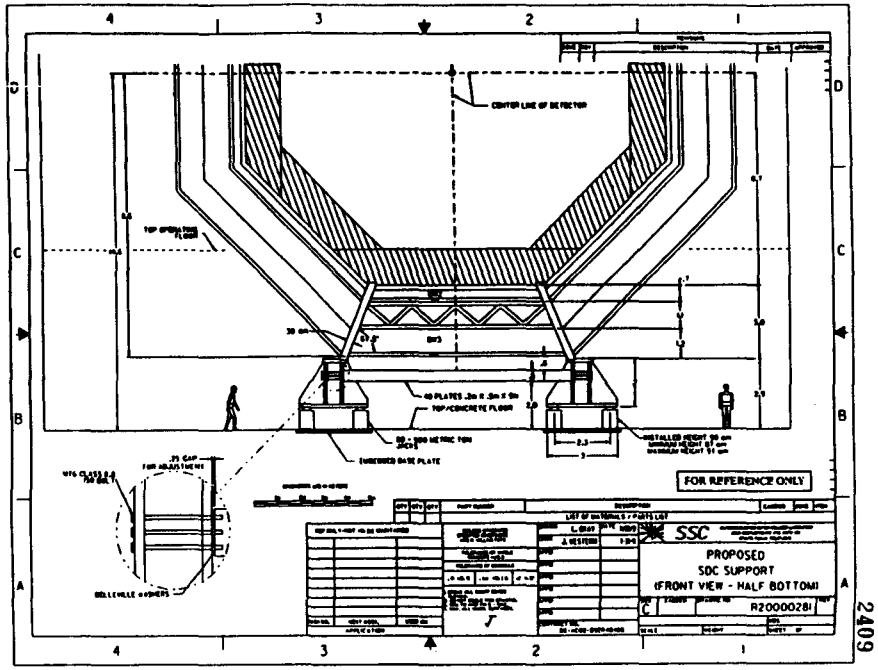
Page 3

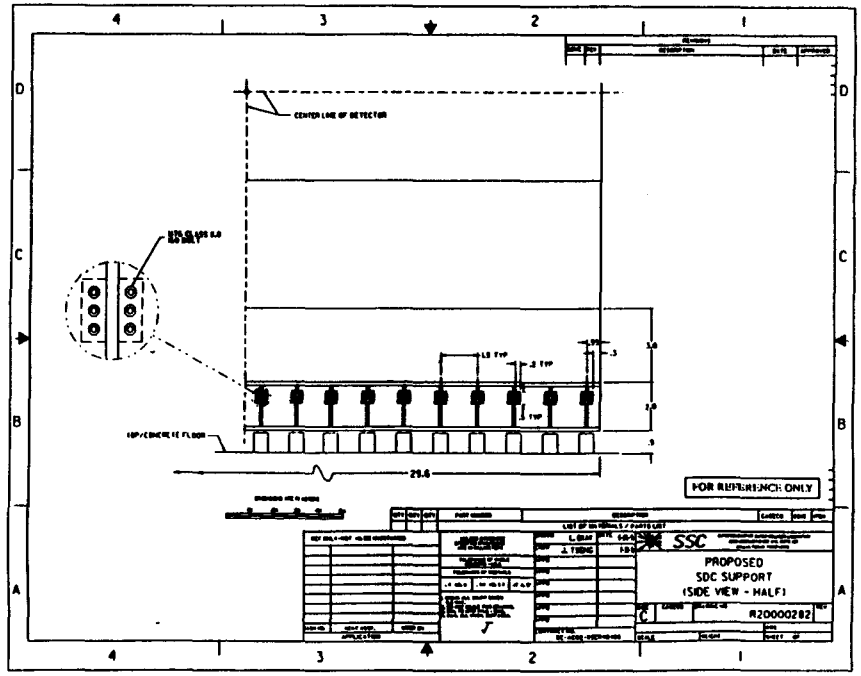
2406

COILCOPY.XLS

	A	B	C	D	E	F	G
31	N-clamp	4	Number of clamp plates per coil	#			
32	N-bands	32	Number of bands per coil	#			
33	N-bolts	688.5908376	Length to tape per coil	#			
34	C-tape		Cost to tape coil	$			
35	C-coil		Cost of coil fabrication	$			
36	C-fab		Cost of coil engineering	$			
37	C-tool		Cost to transport coils	$			
38	C-eng		Cost to install coils	$			
39	C-install		Total cost for the coil part	$			
40	C-total						
41	F-all	6600236.4233	Total Amp turns	Amp-turn			
42	F	4579.836923	Current	Amp			
43	R-all	26.54774464	Resistance of coil	Volt			
44	P-all	0.6973481153	Voltage for coil	Ohm			
45	Q-all	1.9E-05	Water flow for coil	meter^3 per sec			
46	Dof-T	1.11111	Temperature differential	Degree C			
47	Cp-P	0.00000000	Pressure differential	kPa			
48	C-pump		Cost for the pump	$			
49							
50	COMMENTS						
51	Pr	3.141592654		unitless			
52	Kw-D-cold	0.1024	Conversion from inches to meter	meter per inch			
53	Wdac	0.00000008	Water density at 70F (297 K)	mass^2 per sec			
54	Wdensity	997	Water density at 70F (297 K)	kg per meter^3			
55	Wspecheat	4185	Water specific heat at 70F (297 K)	kJ per kg C			
56	Wkcondu	0.000615	Water conductivity	watt per meter C			
57	Rough-copper	0.000015	Surface roughness	meter			
58	Rough-water	0.000015	Surface roughness	meter			
59	Kw-copper	1.17E-01	Heat conductivity for copper	Pa			
60	Kw-D-H	0.0007	Conversion constant for kilogram to m Newton per kilogram				

Page 3





SDC - Support Milestones

- Approved Conceptual Design & Scope of Work ... October 1991
  (Internal Review ... September 1991)

  Note: In order to complete the Conceptual Design and Scope of work by October 1991 we need to:
  1) Fix the torold steel thickness and size by August 9, 1991.
  2) Finalize the support concept by September 2, 1991.

- Selection of Engineering Design Firm ... January 1992
- Technical Review ... March 1992
- Technical Proposal Complete ... April 1992
- Detail Design Complete (15 months) ... April 1993
- Support Fabrication Complete ... February 1995
- Pre-assembly Complete ... November 1995
- Installation Complete ... March 1996

J. L. WESTERN 8/1/91

SDC DETECTOR SUPPORT MAXIMUM LOADING DIAGRAM

Jeffrey L. Western
July 31, 1991

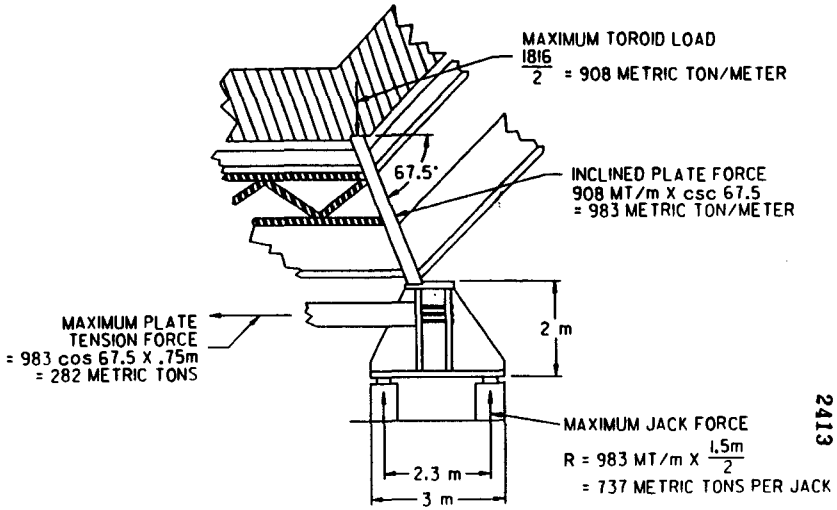
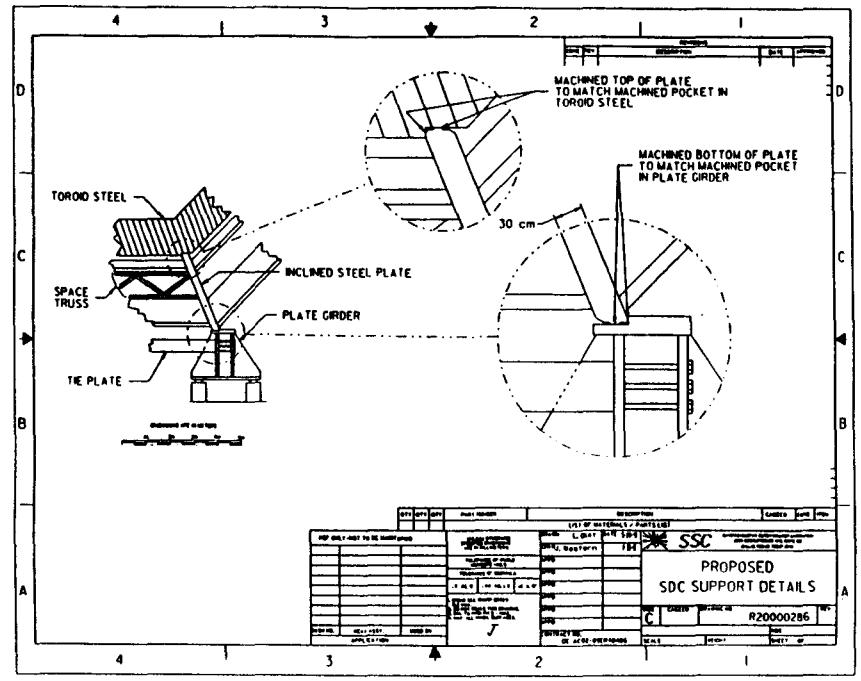


FIGURE 4.1.6-b

2413



2411

SDC - DETECTOR DEFORMATION LIMITS

MAXIMUM DEFORMATION: CANTILEVERED DEFLECTION CAN NOT EXCEED 10 mm OVER A 5 METERS SECTION OF THE DETECTOR

MAXIMUM RIGID BODY DEFLECTION: +30 mm / -70 mm OVER THE ENTIRE DETECTOR LENGTH

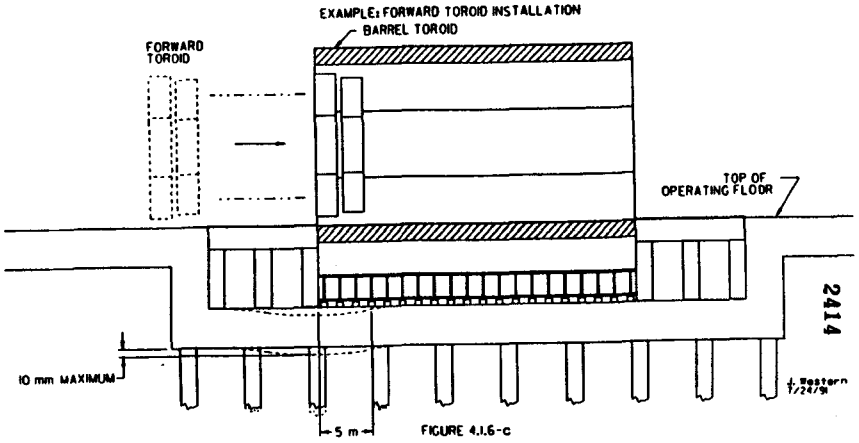
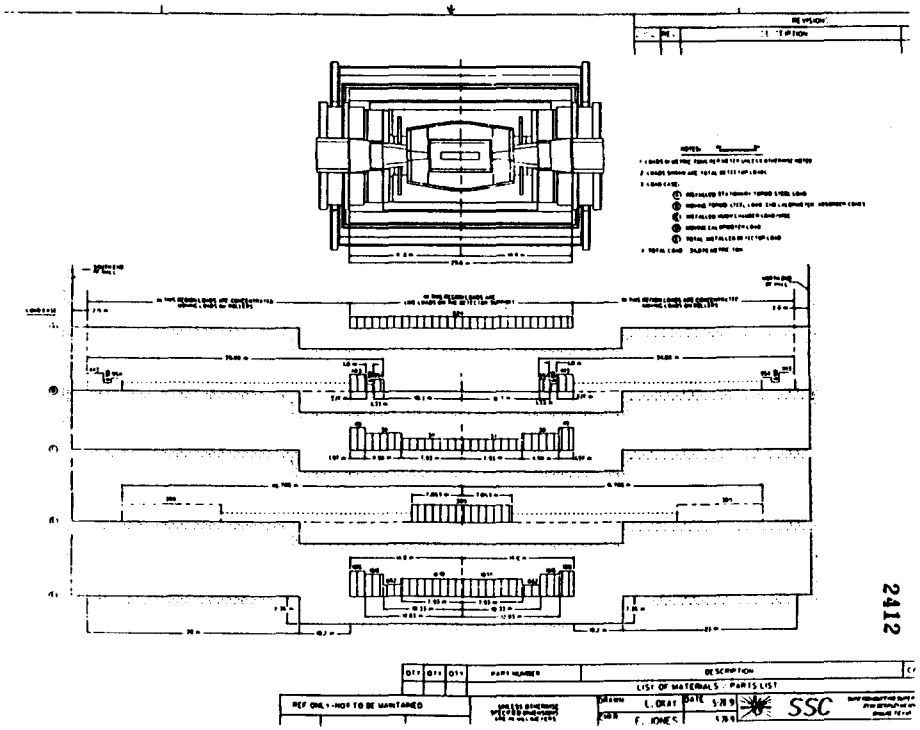


FIGURE 4.1.6-c

2414



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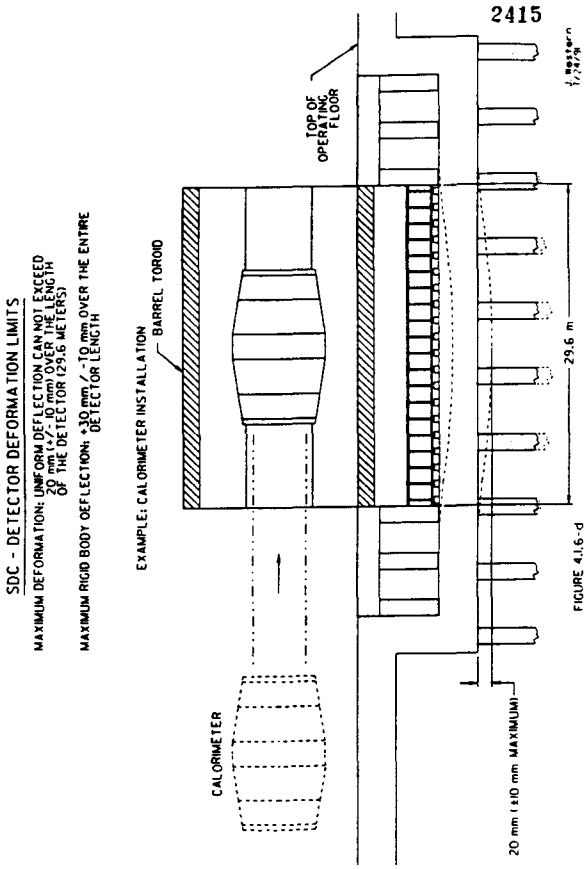


4.1.6 SDC Detector Floor Loading Conditions

The following loading conditions represent the combinations of loads as described on drawing R20000357 "SDC Detector Floor Loads" (Figure 4.1.6-a)

4.1.6.1 Operating condition

This is represented by Load Case E.

4.1.6.2 Installation Condition

This is represented by the worst combination of Load Case A, B, C, and D.

4.1.6.3 Maintenance condition

This is represented by either:

a) The worst combination of Load Case A, B, C, and D.

b) Leveling of the detector (load Case E) and there is a failure of a number jacks. The maximum jack loading is 737 metric ton per jack. See the "SDC Detector Support Maximum Loading Diagram". An estimate is that the individual jack loading would increase 20% (120% x 737 metric ton = 884 metric ton maximum) if there was a local jack failure. Design of the floor should include this local 20% increase of Load Case E (Example: one jack fails...load get spread over 5 surrounding jacks, two jacks fail...load gets spread over 10 surrounding jacks).

4.1.6.4 Future Condition

This condition would be best satisfied by assuming a possible 5% increase of any of the loading components as identified in Load Case A, B, C, or D.

4.1.6.5 Deflection Condition

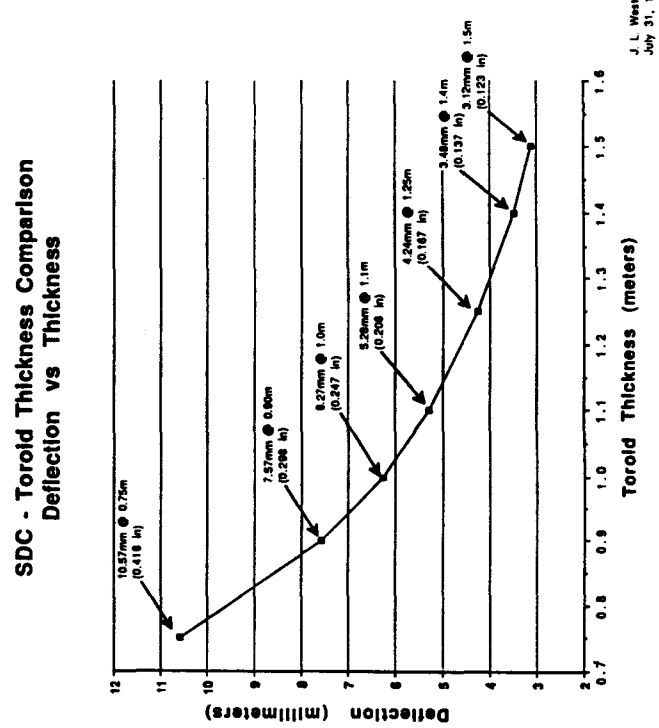
The SDC detector has a tolerance limit of +/- 3 mm over its entire length of which the majority of the tolerance compliance is achieved through the hydraulic jacking system. To assure operational performance of the detector and its support system, the concrete foundation must provide support for the detector such that no differential settlement of more than +/- 10 mm occurs across the jacking plane (plate bending of the jacking plane) throughout the life of the system. Global system (rigid body) settlement of the entire foundation (both displacement and rotation) is an order of magnitude less critical and has a tolerance range of +3 cm (rise of the foundation) / -7 cm (settlement of the foundation).

Summary of Data

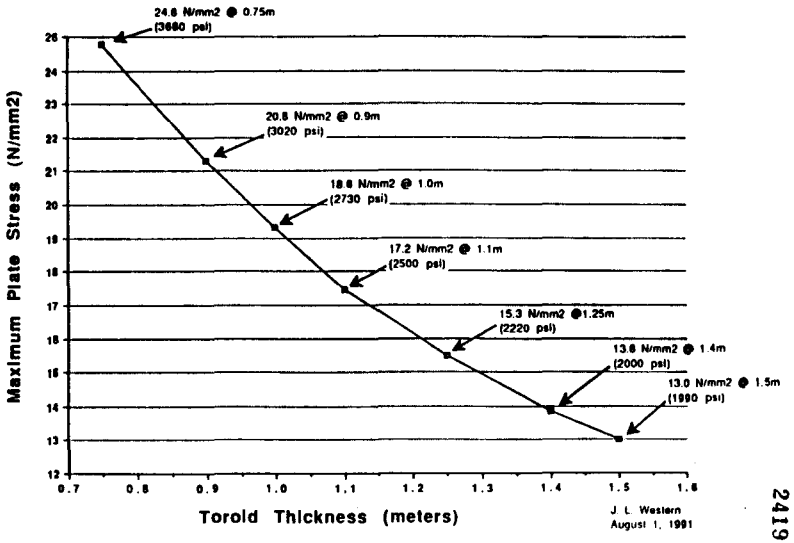
Toroid Thickness	Maximum Deflection	Maximum (1) Plate Stress	Maximum (2) Bolt Stress
1.5 Meter	3.12 mm (0.123 inch)	13.0 N/mm² (1,880 PSI)	206 N/mm² (29,800 PSI)
1.4 Meter	3.48 mm (0.137 inch)	13.8 N/mm² (2,000 PSI)	210 N/mm² (30,400 PSI)
1.25 Meter	4.24 mm (0.167 inch)	15.3 N/mm² (2,220 PSI)	219 N/mm² (31,770 PSI)
1.1 Meter	5.28 mm (0.208 inch)	17.2 N/mm² (2,500 PSI)	232 N/mm² (33,700 PSI)
1.0 Meter	6.27 mm (0.247 inch)	18.8 N/mm² (2,730 PSI)	246 N/mm² (35,720 PSI)
0.9 Meter	7.57 mm (0.298 inch)	20.8 N/mm² (3,020 PSI)	264 N/mm² (38,300 PSI)
0.75 Meter	10.57 mm (0.416 inch)	24.8 N/mm² (3,600 PSI)	316N/mm² (45,770 PSI)

1. Allowable Plate Stress = 0.6 Fy (AISC Allowable)
   (1010 Carbon Steel) = 0.6 x 210 N/mm² (30,000 PSI)
   = 125 N/mm² (18,000 PSI)

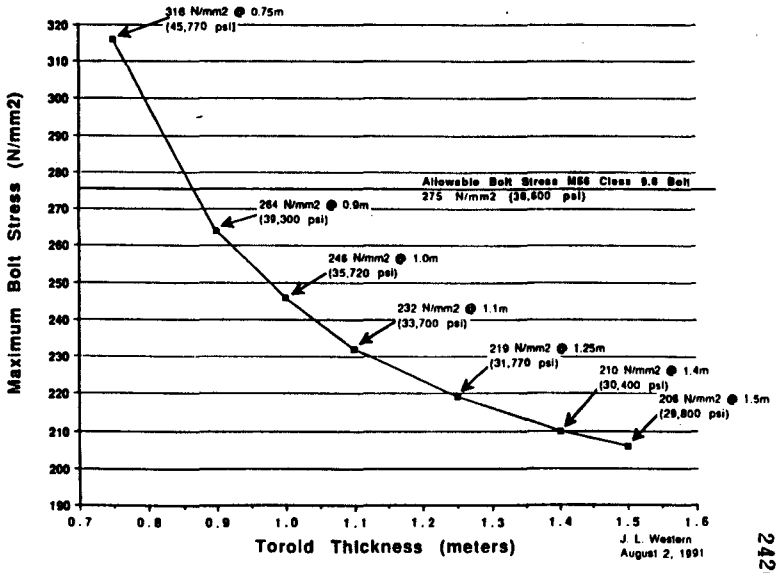
2. Allowable Bolt Stress = 0.33 Fu (AISC Allowable)
   (M56 Class 8.8 Bolt) = 0.33 x 830 N/mm² (120,000 PSI)
   = 275 N/mm² (39,600 PSI)



SDC - Toroid Thickness Comparison
Plate Bending Stress vs Thickness



SDC - Toroid Thickness Comparison
Bolt Tension Stress vs Thickness



FORWARD TOROID & INSTALLATION CONCEPT

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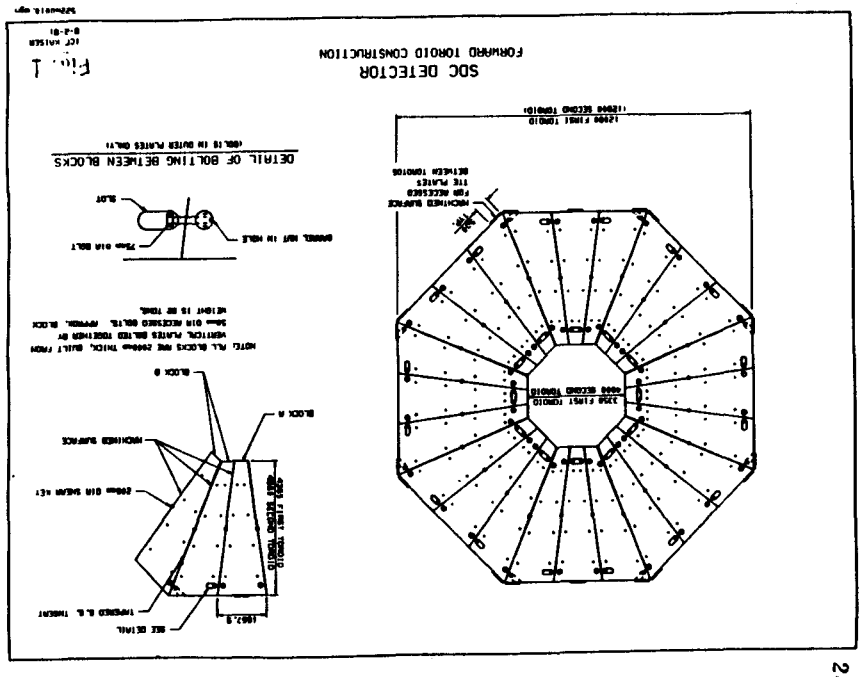

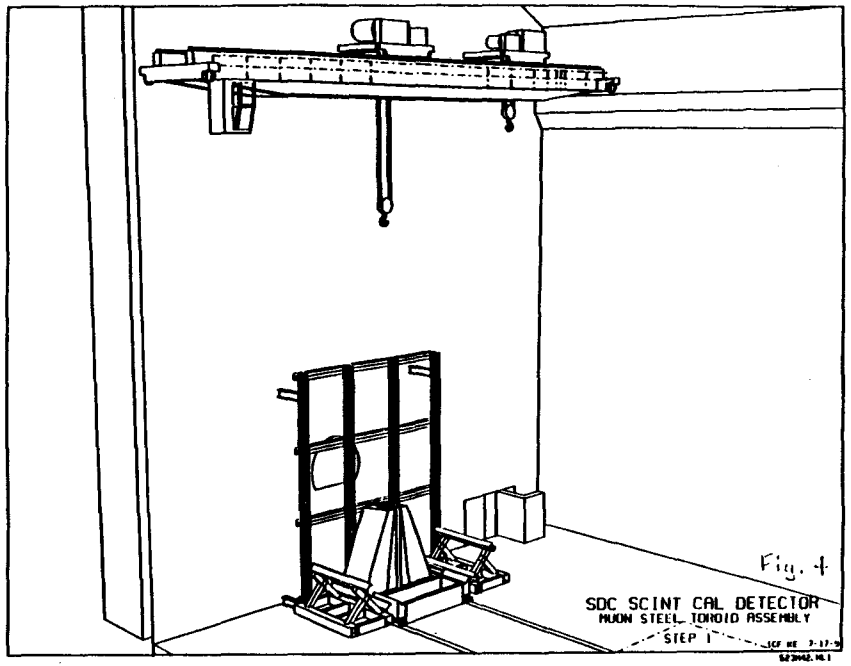

Fig. 4
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 1

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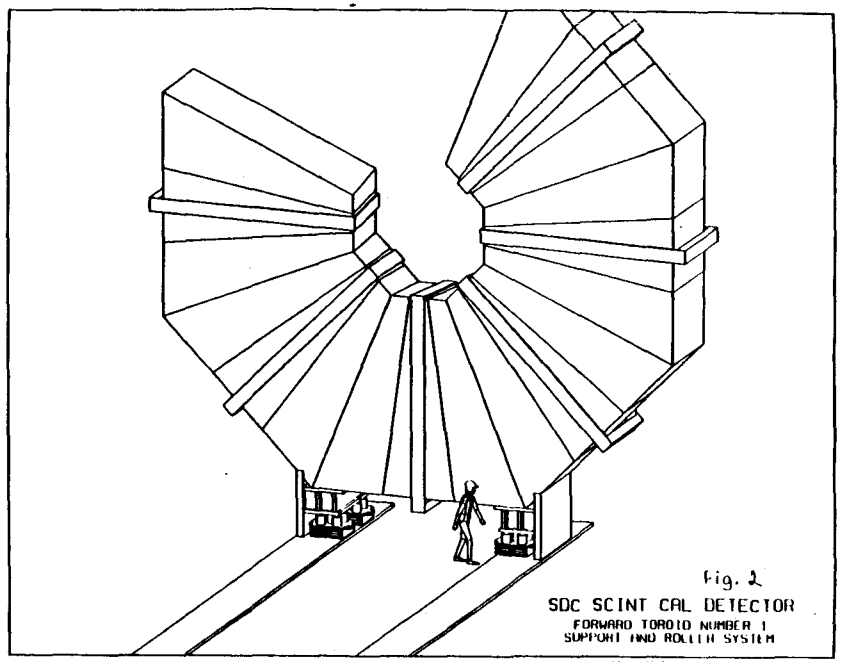

Fig. 2
SDC SCINT CAL DETECTOR
FORWARD TOROID NUMBER 1
SUPPORT AND ROLLER SYSTEM

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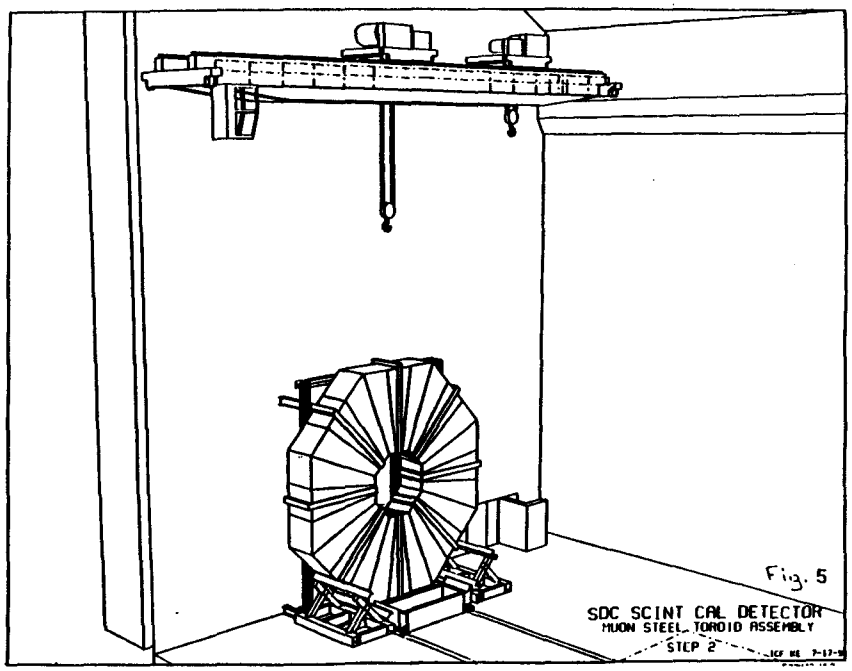

Fig. 5
SDC SCINT CAL DETECTOR
MUON STEEL TOROID ASSEMBLY
STEP 2

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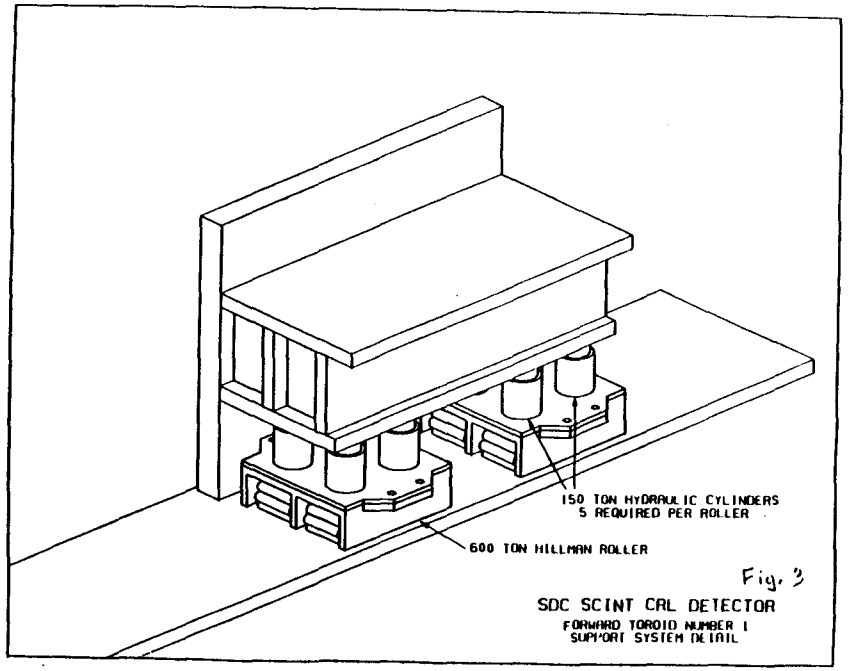

Fig. 3
SDC SCINT CAL DETECTOR
FORWARD TOROID NUMBER 1
SUPPORT SYSTEM DETAIL

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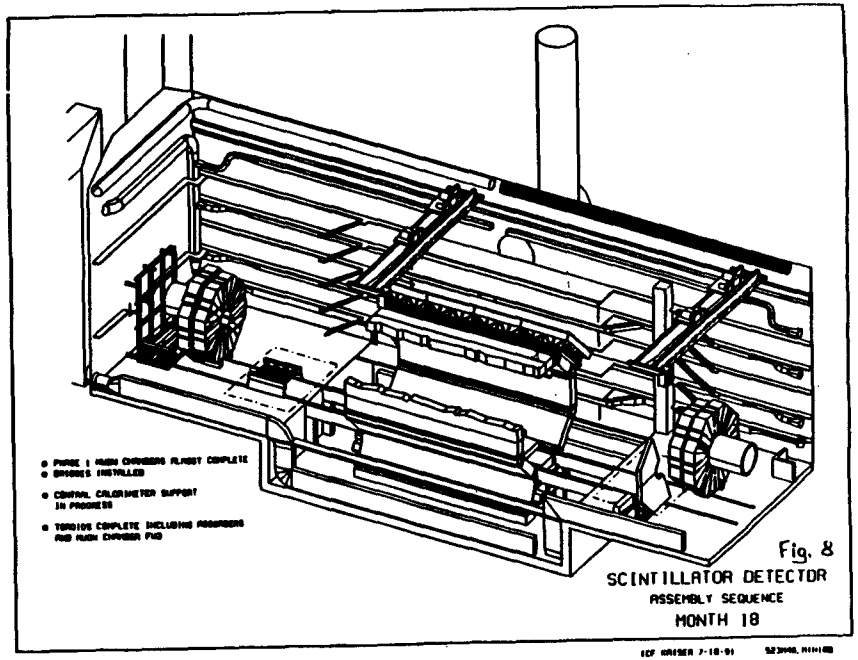

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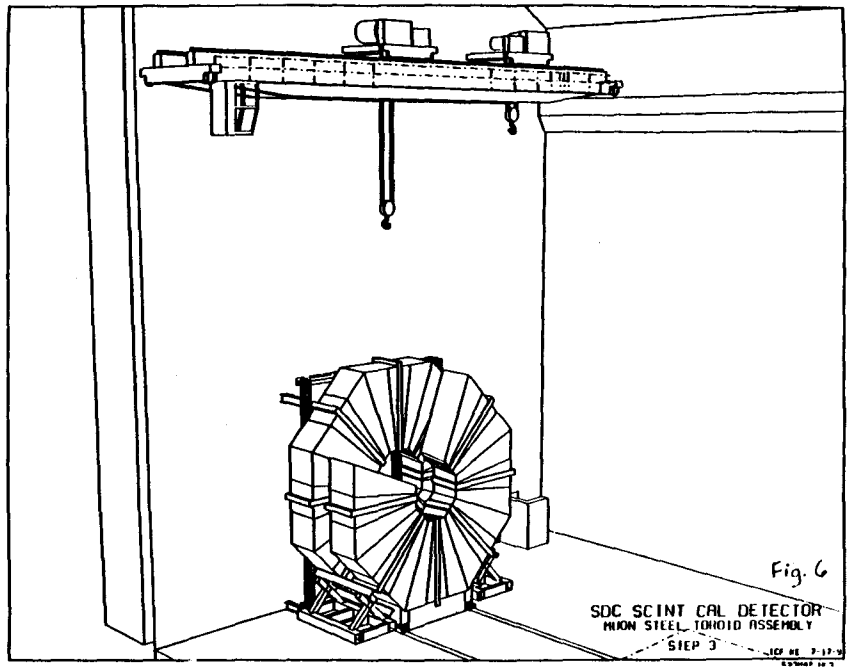

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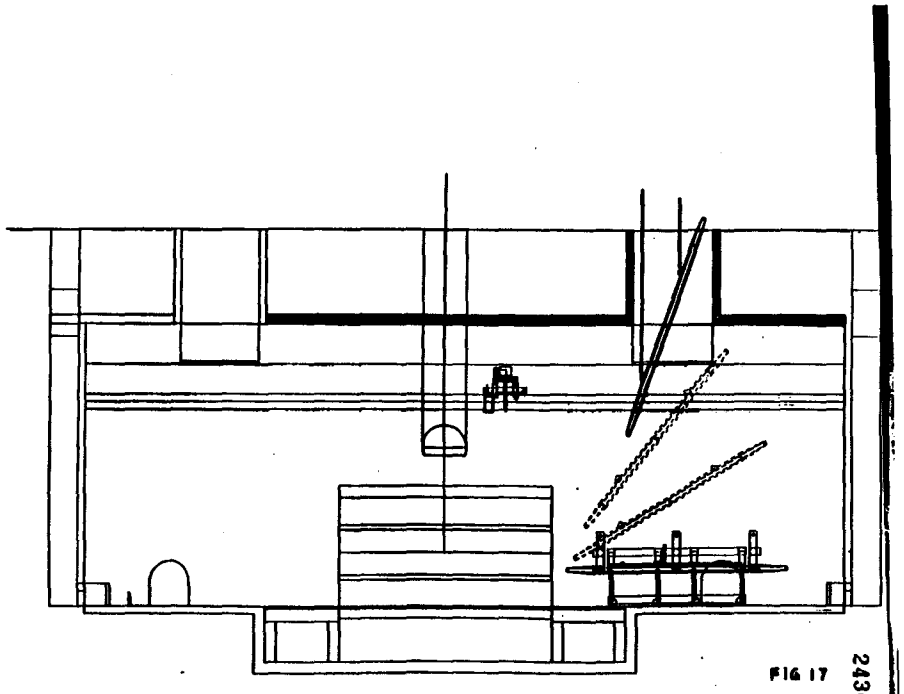

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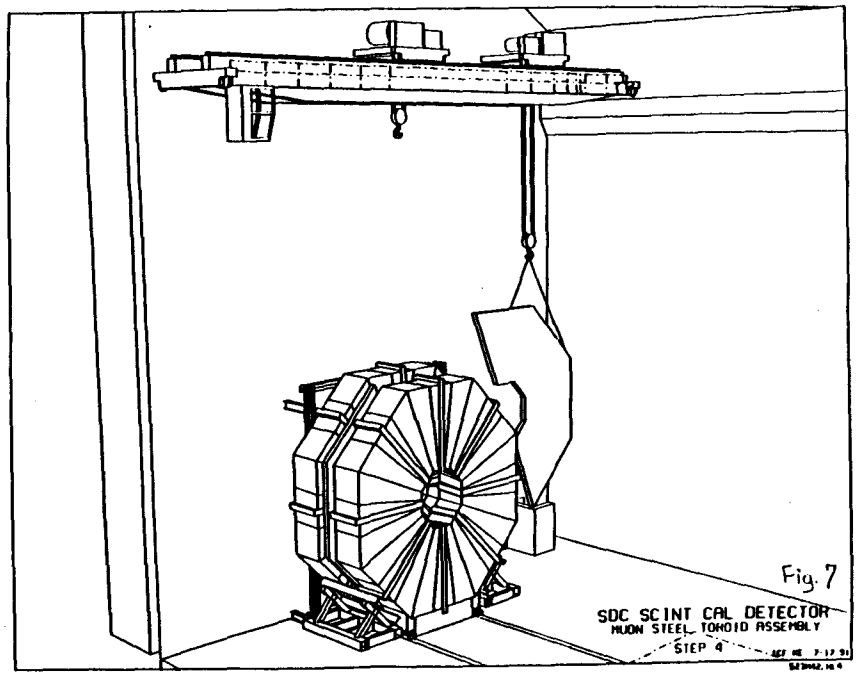

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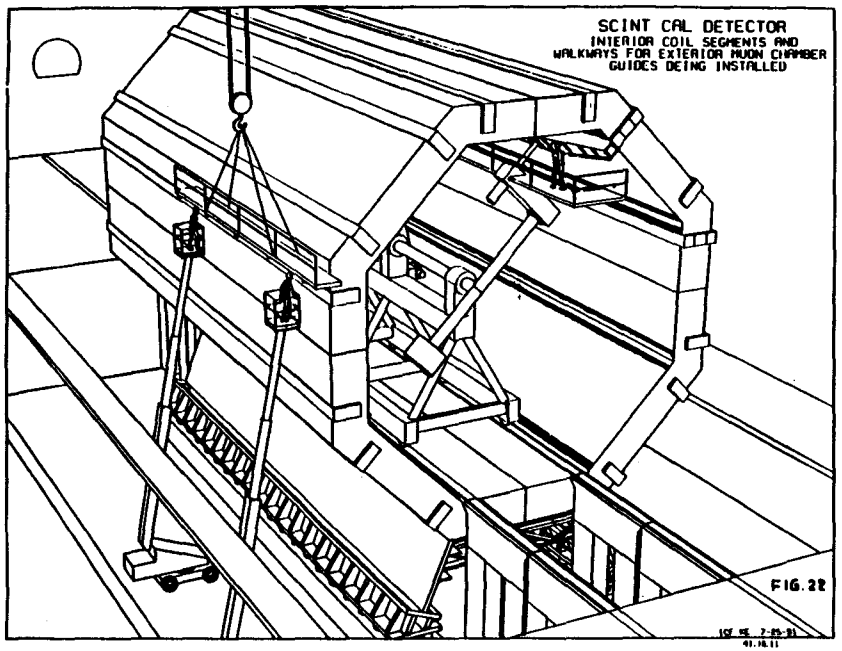

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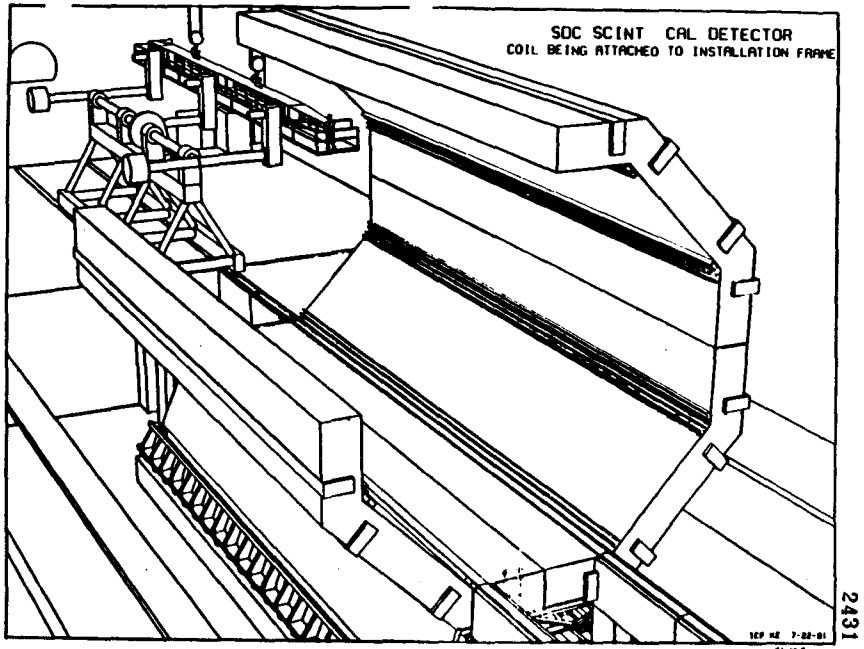

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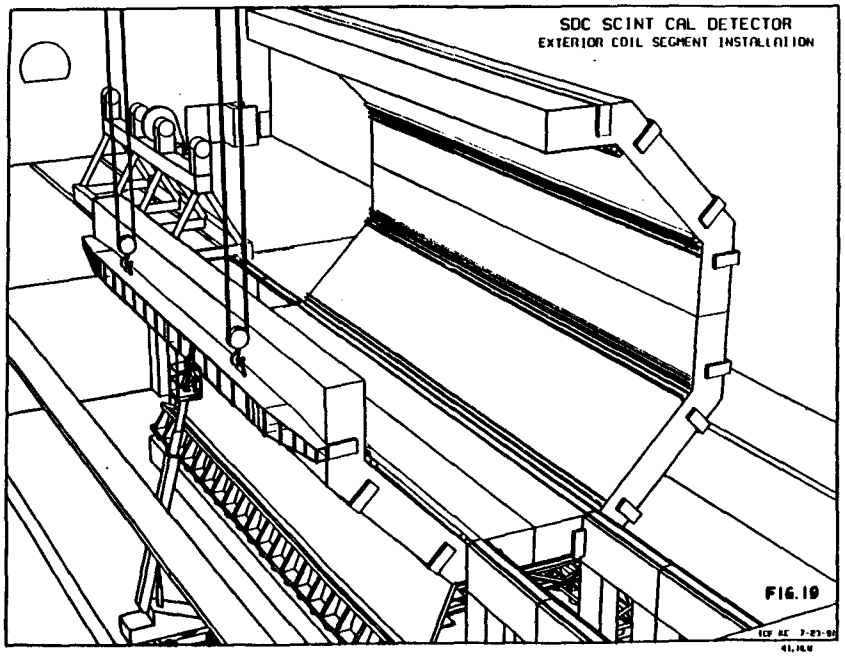

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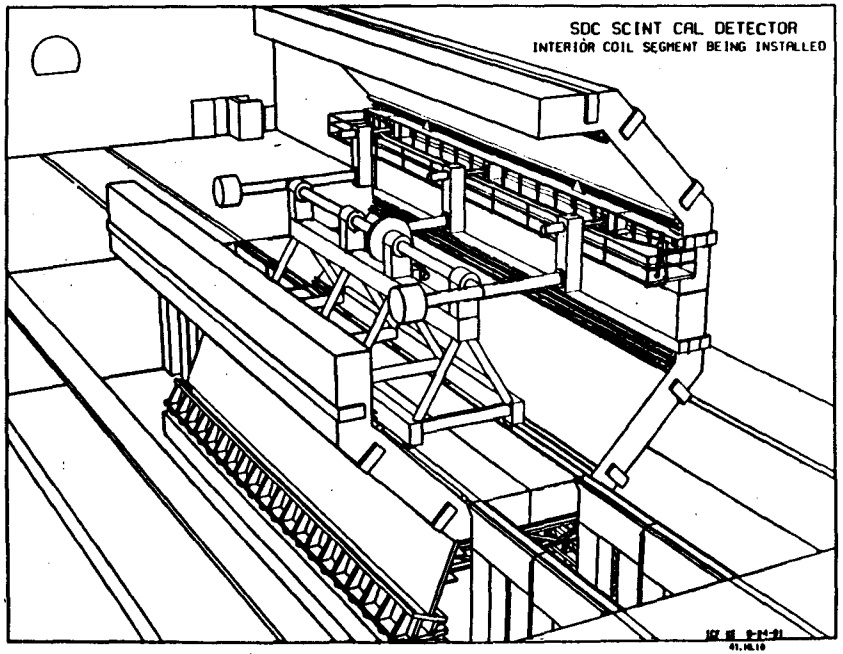

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Electronics, Triggering and Data Acquisition Sessions

August 5 - Monday

Baseline Trigger	W. Smith(Wisconsin)
Baseline Control System	T. Moore(LBL)
SDC Baseline Data Acquisition System	I. Gaines(Fermilab)
DAQ & Controls Descoping Options	R. Partridge(Brown)

August 6 - Tuesday

Interfaces	
Calorimeter Electronics	W. Foster(Fermilab)
Calorimeter Electronics	M. Levi(LBL)
Shower Max Electronics	P. Le Du(CEN Saclay)
Fiber Tracker Electronics	A. Baumbaugh(Fermilab)
Conceptual Design of Straw-Tube Readout with TMC	Y. Watase(KEK)
Straw Tracker System-TVC Option	R. Van Berg(Pennsylvania)

August 8 - Thursday

Trigger Working Group	Smith: Organizer
Data Acquisition Working Group	Gaines, Partridge: Organizers
DAQ R&D at KEK	M. Nomachi(KEK)
DAQ Baseline Design Options	R. Partridge(Brown)
Surface Facilities for Electronics	C. Bebek(LBL)
Discussion of Pipeline Length	W. Smith(Wisconsin)

LPBautz:8/23/91

W. Smith 8/5/91

SDC Baseline Trigger Design

(Input from Madison Trigger Meeting July 17-19)

Requirements: Trigger Efficiently on:

Electrons from inclusive W's } 50% of theoretically possible
Muons from inclusive W's

Jets at high P_T } overlap existing σ over 1-2 decades
High P_T Photons

Missing E_T (SUSY, $H \to ZZ \to \ell\ell\nu\nu$)

Multilepton low P_T Trigger (B physics)

Level 1 Trigger Baseline

Electron: Cal: Isolated e/h
Track: Match w/ Cal: Ø
Show Max: Ø Match

Muon: Muon Track > P_T only

Jet: Energy in .4 x .4 Tower > Thresh

Photon: Electron w/o Track match

E_T, $\not{E}_T$: Global Cal. Energy Sum

Level 1 output: 10-100 kHz

Design Technique: ① Calculate basic trigger primitives on detector

② Transmit to Counting House on Surface at 1 Gb/s on optical fibers (@300/link ≈ 25% coating)

③ Do Trigger calculations in C.H. and transmit decision back to detector

Level 2 Baseline Trigger Options

1. Outer Tracking - Muon Match
   ⇒ Tighten P_T cut
2. Silicon - Outer Tracking Match
   ⇒ Eliminate Conversions
   ⇒ Intermediate Angle
3. Topological Cuts
   ⇒ Cut on # forward or # Central Jets + leptons
4. Full Shower Max Info:
   Isolation
   Track match (e only)
   ⇒ Tighten (Verify) Electron Cut
   " " Photon Cut
5. Track vs. Cal E/P
   ⇒ Tighten Cal-Trk Match

Which Options? Must Decide ⇒ Simulation

Conclusion: Must keep Level 2.
(Rates thru L1 + DAQ too uncertain)

TRANSMIT TRIGGER SIGNAL TO COMPONENT PIPELINE

	Cause of Delay	Time (crossings)
1.	GFLTB -> pipeline controller (nearby)	1
2.	Pipeline setup & synchronization	2
3.	Pipeline Controller -> Pipeline Fanout (far)	50
4.	Local Fanout to Pipeline	10
5.	Phase between pipeline and sample	+/- 0.5
6.	Loss of sample where pipeline stops	1
7.	Particle interaction -> pipeline front	-5
8.	Presamples	6
9.	Signal shaping for sample of rise	-1
	Total	**64**

A total offset of 64 crossings requires the GFLT accept to be issued at a time 64 crossings less than the pipeline length.

TRIGGER DECISION TIME

	Cause of Time Delay	Time (in Crossings)
	Calorimeter through Global:	
1.	Propagation to Detector	6
2.	Digitization (incl. synch.)	4
3.	Local Pattern Logic	21
4.	Regional Pattern Logic	12
5.	Regional Correlations btw. Components	6
6.	Transmission to Component Global Logic	14
7.	Component Global Logic	15
8.	Transmission to GFLT	50
9.	GFLT Calculation	20
	Total	**148**
	Muon through Global:	
1.	Propagation to Chamber	2
2.	Drift in Chamber	50-100
3.	Propagation along Wire	2
4.	Segment Finder	2
5.	Segment Linker	6
6.	Transmission to GFLT	50
7.	GFLT Calculation	20
	Total	**132-182**

TOTAL PIPELINE LENGTH

Cause of Time Delay	Time (in Crossings)
Calculation of Trigger Decision	
Calorimeter thru Global = 148*	
Muon through Global = 132 - 182	
	148* - 182
Propagation of Trigger to Pipeline	64
Total	**212* - 246**
	= 3.4* - 3.9 μsec

*Note: Additional speedup in calorimeter trigger calculations can reduce 148 crossings below 132, reducing the minimum total pipeline length to 196 crossings or 3.1 μsec.

AVAILABLE LEVEL 1 TRIGGER INFORMATION

System:	Scts.	$\lvert\eta\rvert_{min}$	$\lvert\eta\rvert_{max}$	η Bns	φ Bns	Info. Bts	Tot. Bts
Barrel Muon	2	0	1.6	47	32	4:P_T	12032
Inter. Muon	2	1.6	2.5	57	32	4:P_T	14592
Barrel Track	2	0	1.0	1	1024	4:P_T	8192
stage → Inter. Track	2	1.0	2.5	1	1024	4:P_T	8192
Barrel Cal.	2	0	1.6	18	64	8:E_e,8:E_h	32768
Inter. Cal.	2	1.6	3.0	7	64	8:E_e,8:E_h	14336
Barrel S.Mx.	2	0	1.6	1	1024	1:hit	2048
Inter. S.Mx.	2	1.6	3.0	1	1024	1:hit	2048
Not in L1 → Silicon	1	0	2.5	10	1024	1:hit	10240

LEVEL 1 TRIGGER BASELINE DESIGN

Crate Type	Crts	Cds/Crt	Info./Cd:	Bts/Cd	Fb/Cd	Tot Fb
Barrel Muon	32	16	2 Trk x (2:η,1:φ,4:P_T)	14	1	512
Inter. Muon	32	16	2 Trk x (2:η,1:φ,4:P_T)	14	1	512
Barrel Track	32	16	2 Trk x (2:φ,4:P_T)	12	1	512
stage → Inter. Track	16	16	2 Trk x (3:φ,4:P_T)	14	1	256
Barrel Cal.	64	16	2 Tow x (8:E_h,8:E_e)	32	2	2048
Inter. Cal.	32	18	2 Tow x (8:E_h,8:E_e)	32	2	1024
Barrel S.Mx.	64*	1	1 hit x 32φ	32	2	128
Inter. S.Mx.	32*	1	1 hit x 64φ	64	4	128

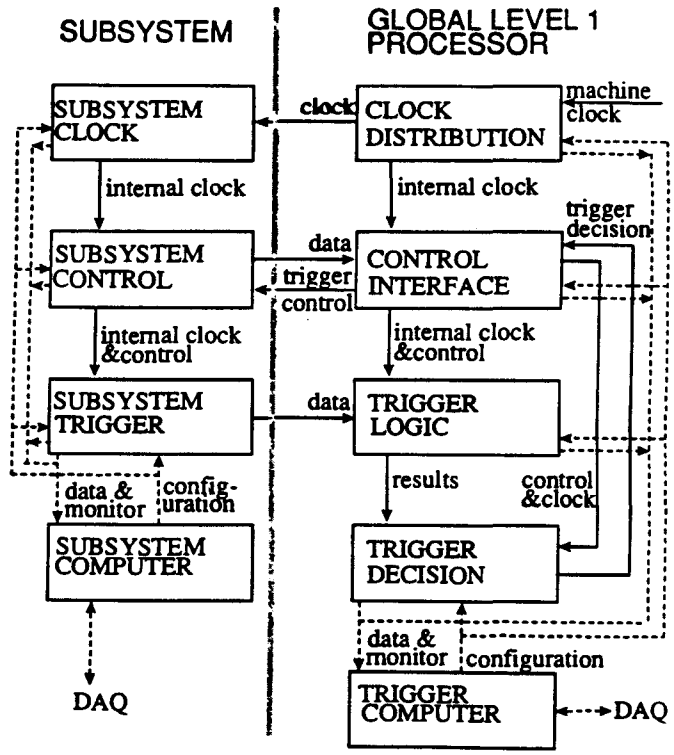
*Included in Calorimeter Crates

η - φ Bin Size Per Fiber

System:	η Bin	φ Bin
Barrel Muon	.034	.4
Inter. Muon	.016	.4
Barrel Track	1.0	.025
Inter. Track	1.5	.025
Barrel Cal.	.1	.1
Inter. Cal.	.1	.1
Barrel S.Mx.	1.6	.1
Inter. S.Mx.	1.4	.1

η - φ Bins Per Crate

System:	Δφ/Crt	$\lvert\eta\rvert_{mn}$	$\lvert\eta\rvert_{mx}$	η Bns	φ Bns
Barrel Muon	0.4	0	1.6	47	2
Inter. Muon	0.4	1.6	2.5	57	2
Barrel Track	0.4	0	1.0	1	64
Inter. Track	0.8	1.0	2.5	1	128
Barrel Cal.	0.2	0	1.6	16	2
Inter. Cal.	0.4	1.6	3.0	7	4
Barrel S.Mx.	0.2	0	1.6	1	32
Inter. S.Mx.	0.4	1.6	3.0	1	64



CLOCK/CONTROL CABLES: SUBSYSTEM TO L1 TRIGGER

1. Level 1 Subsystem Control: *LISC*

Bits	Data
1	Subsystem Trigger Busy
2	Subsystem Data Busy
3	Subsystem Trigger Error
4-8	Ambiguous Crossing
9-16	Subsystem Crossing Number

CLOCK/CONTROL CABLES: L1 TRIGGER TO SUBSYSTEM

2. Level 1 Clock: *LICL*

Bits	Data
1	62.5 MHz clock
2	Bunch Crossing Φ
3	Empty Bunch Indicator
4-16	Spare

3. Level 1 Control: *LICT*

Bits	Data
1	Test Enable
2-4	Test Trigger Type
5-6	Trigger Type
7-9	Readout Type
10-12	Crossing Ambiguity
13	Level 1 Reset
14	Level 1 Accept
15	Level 1 Reject
16	Data Valid

4. Level 1 Number: *LINO*

Bits	Data
1-8	Level 1 ID
9-16	Bunch Phase

FIBER OPTIC TRANSMISSION at 1 Gb/s

1. Send data in 18 bit quantities at 1.125 Gbaud with each 16 bits of data followed by 2 marker bits a,b.

2. Perform phase detection on the bits a,b to select the info from a tapped delay line 2 ns long.

3. A comparator generates a + pulse if transition ahead of expectation, - pulse if behind expectation, 0 pulse if no transition or transition when expected and charges or discharges a capacitor for that signal. A sampling ADC checks each capacitor each 1 millisecond and adjusts the delay line tap.

4. Each 16 words (each 256 ns), change the 2 a,b bits to give a clear word delineation. (The bits a,b could be from a 64 or 256 deep ROM so that they constitute a repeating pattern which has 2^{128} or 2^{512} possibilities). The sending and receiving units use the same pattern with several lines sharing the same actual ROM IC.

5. The word delineation selects the data from a tapped shift register with 24 bits to cover the ±10 ns variation. The word delineation is operated from a counter with very slow correction (see next)

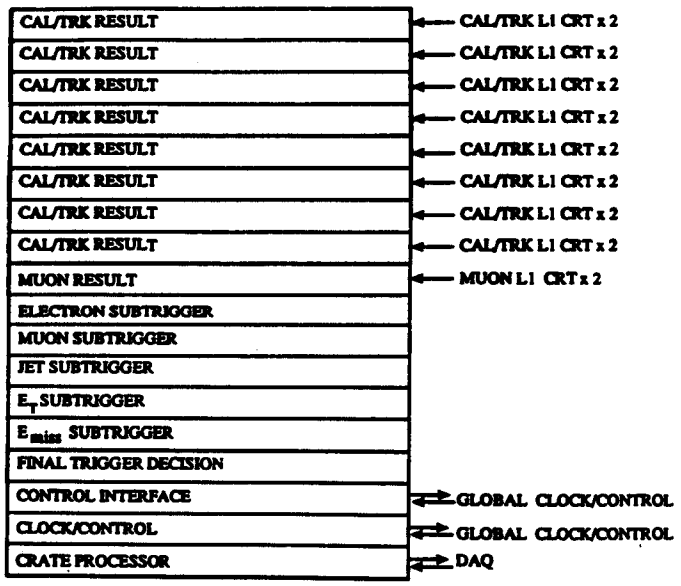
6. Each signal has a binary comparator to compare the 2 bits a,b with those expected 1 bit ahead and 1 bit behind which charge or discharge another capacitor as above. If an error persists, the shift register selection is advanced if voltage rises or retarded if voltage falls. This can be quite slow with 1 second decisions to allow for recovery from unusual changes within a few seconds.

3. **Decision Crate (1)**
   - 8 Cal/Trk Result Boards
     - Receive Results from 2 Cal/Trk Crates
   - 1 Muon Result Board
     - Receive Results from 2 Muon Crates
   - 1 Electron Subtrigger Board
   - 1 Muon Subtrigger Board
   - 1 Jet Subtrigger Board
   - 1 E_T Subtrigger Board
   - 1 E_{miss} Subtrigger Board
   - 1 Final Trigger Decision Board
   - 1 Control Interface
     - Communicates with Global Clock/Control
   - 1 Clock/Control Board
   - 1 Crate Processor (DAQ Interface)

4. **Local Clock/Control Interface Crate (2)**
   - 16 Clock/Control Interface Boards
     - Communicate with 8 Front End or Trigger Crates
   - 1 Clock/Control Master
     - Communicates with Global Clock/Control
   - 1 Crate Processor (DAQ Interface)

5. **Global Clock/Control Crate (1)**
   - 1 Interface to Machine Clock
   - 1 Interface to Final Decision Module
   - 1 Beam Pickup Interface
   - 1 Deadtime Monitor Module
   - 1 Clock/Control Interface
     - Communicates with 2 Local Clock/Control Crates
   - 1 Crate Processor (DAQ Interface)

GLOBAL LEVEL 1 TRIGGER DECISION CRATE



1 OF 16 CAL-TRACK LEVEL 1 TRIGGER CRATES
(covers $0<\eta<3.0$ and $\Delta\phi = 0.8$)

CALORIMETER LOGIC	← CAL x 32	$(0<\eta<0.4)$
CALORIMETER LOGIC	← CAL x 32	$(0.4<\eta<0.8)$
CALORIMETER LOGIC	← CAL x 16	$(0.8<\eta<1.0)$
TRACK LOGIC	← TRK x 32	$(0<\eta<1.0)$
CAL/TRK/SHMX MATCH	← SHMX x 8	$(0<\eta<1.6)$
CALORIMETER LOGIC	← CAL x 32	$(1.0<\eta<1.4)$
CALORIMETER LOGIC	← CAL x 32	$(1.4<\eta<1.8)$
CALORIMETER LOGIC	← CAL x 32	$(1.8<\eta<2.2)$
CALORIMETER LOGIC	← CAL x 32	$(2.2<\eta<2.6)$
CALORIMETER LOGIC	← CAL x 32	$(2.6<\eta<3.0)$
TRACK LOGIC	← TRK x 32	$(1.0<\eta<2.5)$
CAL/TRK/SHMX MATCH	← SHMX x 8	$(1.6<\eta<3.0)$
REGIONAL LOGIC	→ GLOBAL TRIGGER	
CLOCK/CONTROL	⇄ GLOBAL TRIGGER	
CRATE PROCESSOR	⇄ DAQ	

LEVEL 1 TRIGGER CRATES

1. **Calorimeter-Track** (16)
   (covers $0<\eta<3$, $\Delta\phi=0.8$)
   - 8 Calorimeter Logic Boards
     - Receive Data from Cal Crates for ($\Delta\eta=.4, \Delta\phi=.8$)
     - Sum E_T, E_x, E_y in 2 (.4 x .4) Regions
     - Find Cal. Iso. em deposits
   - 2 Track Logic Boards
     - Collect Tracks from Barrel or Inter.($\Delta\phi=.8$)
   - 2 Cal/Trk/Shmx Match Boards
     - Receive Sh. Mx. Hits for ($\Delta\eta=1.6, \Delta\phi=.8$)
     - Match Trk + Cal. Iso. em + Sh.Mx.
     - Sort Resulting e's.
   - 1 Regional Logic Board
     - Sort Electrons
     - Collect .4 x .4 Regions > thresh.
     - Sum E_T, E_x, E_y
     - Transmit Results to Level 1
   - 1 Clock/Control Board
   - 1 Crate Processor (DAQ Interface)

2. **Muon Crate** (2)
   (covers $0<\eta<3$, $\Delta\phi=4\pi$)
   - 16 Muon Logic Boards
     - Receive Muon Tracks from 2 Muon Crates ($\Delta\phi=.8$)
     - Sort & Test against thresholds
   - 1 Regional Logic Board
     - Collect Muon Tracks from Receivers
     - Transmit Muon Tracks to Level 1
   - 1 Clock/Control Board
   - 1 Crate Processor (DAQ Interface)

1 OF 2 MUON LEVEL 1 TRIGGER CRATES
(covers $0<\eta<3.0$ and $\Delta\phi = 2\Pi$)

MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← BARREL MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
MUON LOGIC	← INTER. MUON x 32
REGIONAL LOGIC	→ GLOBAL TRIGGER
CLOCK/CONTROL	⇄ GLOBAL TRIGGER
CRATE PROCESSOR	⇄ DAQ

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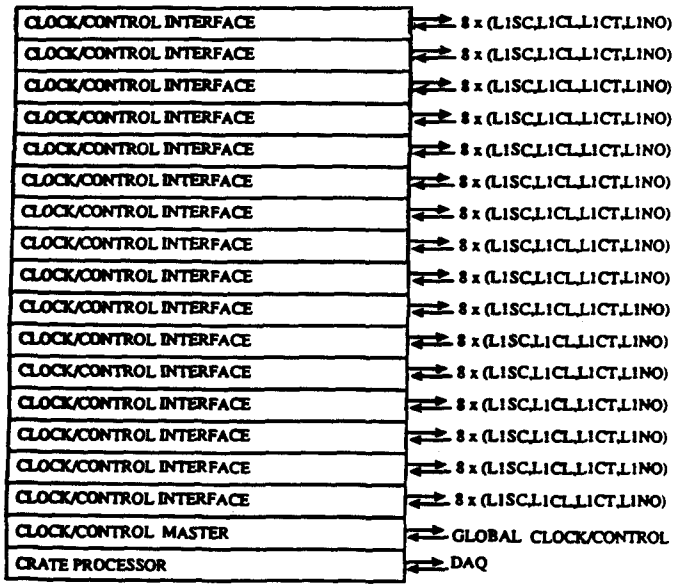
CLOCK/CONTROL INTERFACE CRATE
(operates 128 Subsystem or Trigger Crates)



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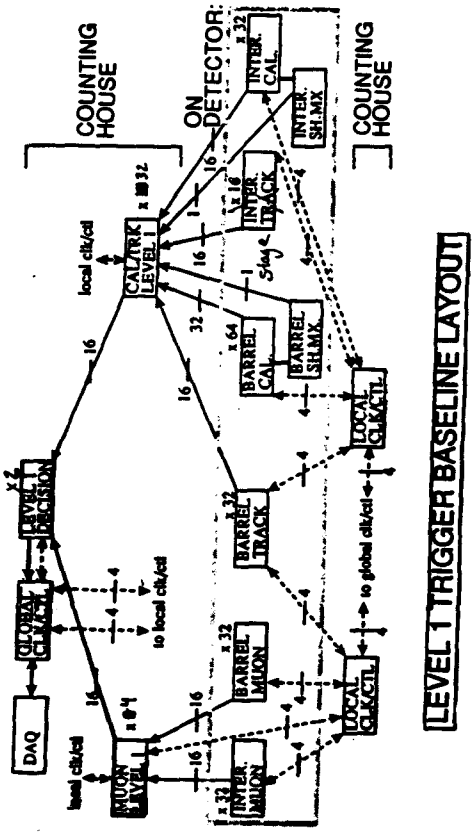

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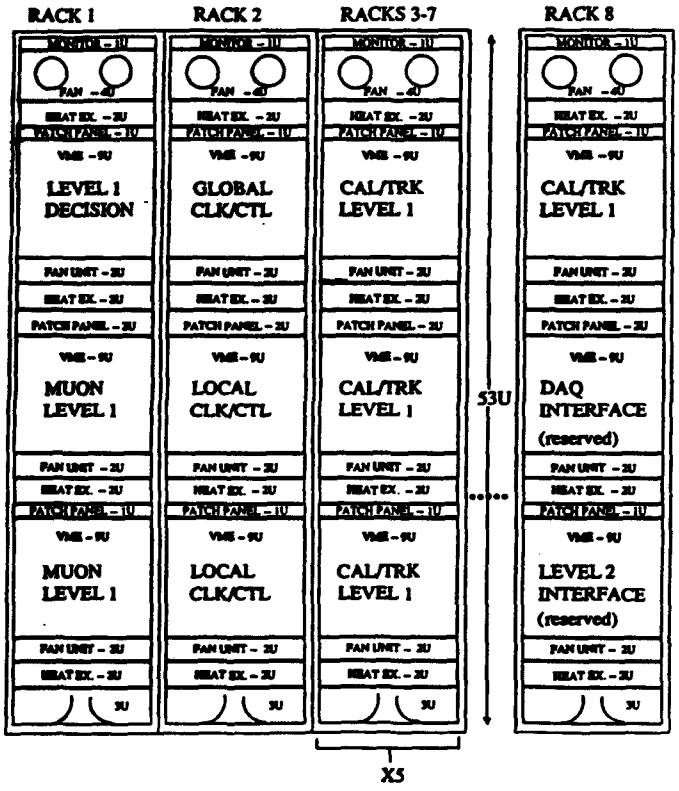

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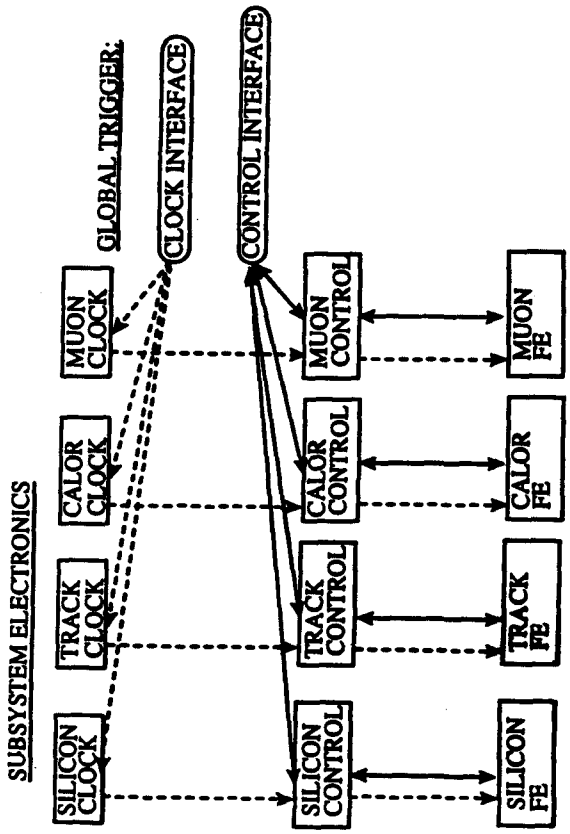


Specific Requirements

Supervisory System-

a. Provides 4 consoles through which the slow control functions can be manipulated or displayed
b. Provides an access path to the controlled/monitored systems for external systems, ie. SSCL
c. Provides coordination and high level interface for the DAQ and On-Line comp systems

Developmental System-

a. Provides a platform where controls systems algorithms can be assembled and tested
b. Provides the resources for control panel development
c. Provides a platform for custom control software development and testing

SDC Slow Controls and Safety Monitoring Subsystem

Thomas L. Moore

Baseline Assumptions

General-

- Slow Controls address facility monitoring and ancilliary equipment control of the detector.
- Provides monitoring of specific aspects of subsystem status and performance.
- Provides a gateway for external systems to access information about the detector and for selected external systems to affect parameter changes within the detector.
- Provides a framework in which interlocks report to interested subsystems for permissive equations calculation and fault reporting.
- Core controls software cloned from Accelerator suite, greatly reducing developmental costs.

Specific Requirements

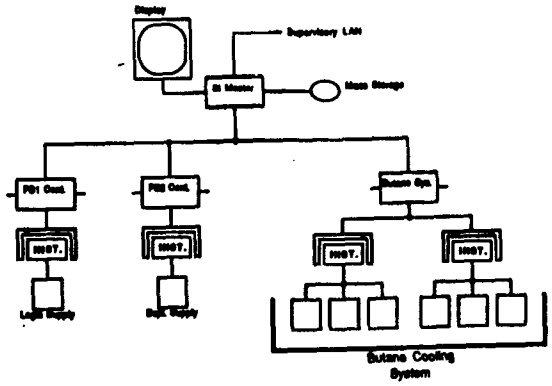
Si Tracker-

1. **Logic Supply**
   a. Evaluate interlocks for operation and safety
   b. Maintain selected Voltage
   c. Monitor Voltage and Current
   d. Coordinate with other Detector Subsystems

2. **Depletion Supply**
   a. Evaluate interlocks for operation and safety
   b. Maintain selected Voltage
   c. Monitor Voltage and Current
   d. Coordinate with other Detector Subsystems

3. **Butane Cooling System**
   a. Evaluate interlock conditions and take appropriate action if permissives are violated.
   b. Provide for manual/automatic valve manipulation
   c. Monitor pressures and temperatures
   d. Report status to other subsystems and supervisory control

4. Provide local and remote control capability



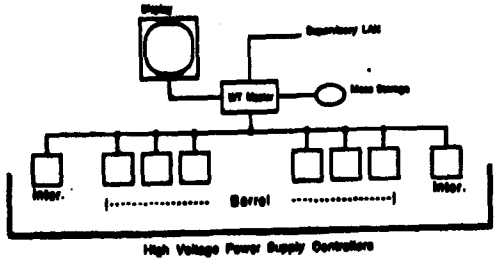
Specific Requirements

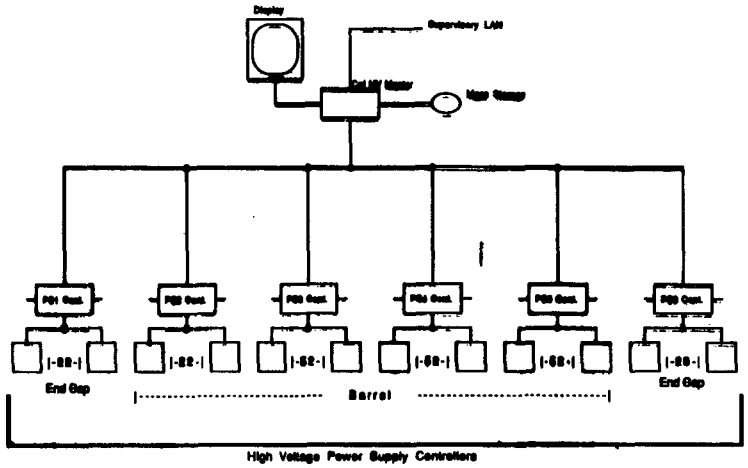
Wire Tracker-

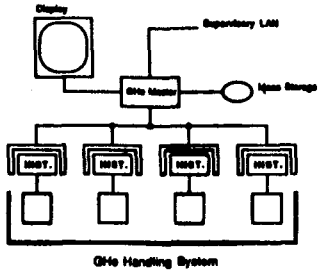
Provide local and remote control of 48 HV Power Supplies
   a. Maintain selected voltage
   b. Monitor Voltage and Current of each supply
   c. Evaluate interlocks and take appropriate action

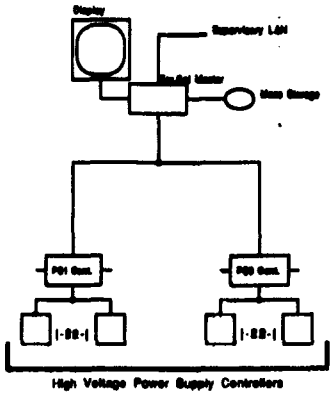
Fiber Tracker-

Provide local and remote control of the GHe/LHe cooling system for the VLPC's
   a. Maintain proper temperatures in the VLPC cryostats
   b. Evaluate interlocks and take appropriate action
   c. Coordinate with the Central Cryo system









Specific Requirements

Calorimeter-

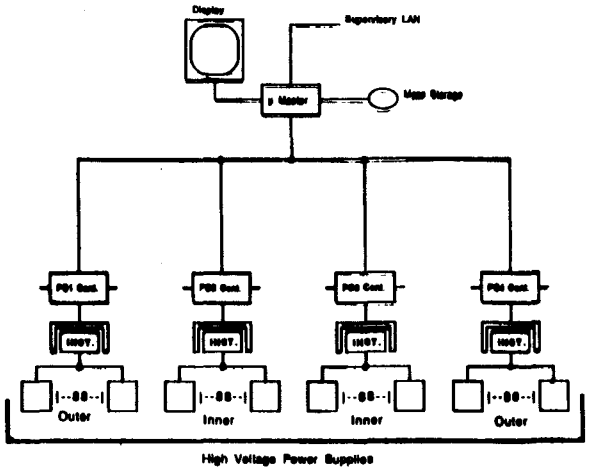
Provide local and remote control for 41000 channels of PMT HV
- **a. Maintain selected voltage on 41000 HV channels**
- **b. Monitor voltage and current on all supplies**
- **c. Evaluate interlocks and take appropriate action**
- **d. Detect HV faults and report to On-Line comp. system**

Forward Cal-

Provide local and remote control for 2500 channels of PMT HV
- **a. Maintain selected voltage on 2500 HV channels**
- **b. Monitor voltage and current on all supplies**
- **c. Evaluate interlocks and take appropriate action**
- **d. Detect HV faults and report to On-Line comp. system**

Muon Wire Chambers-

Provide local and remote control for ~3200 HV supplies
- **a. Maintain selected voltage on ~3200 HV channels**
- **b. Monitor voltage and current on all supplies**
- **c. Evaluate interlocks and take appropriate action**
- **d. Detect HV faults and report to On-Line comp. system**



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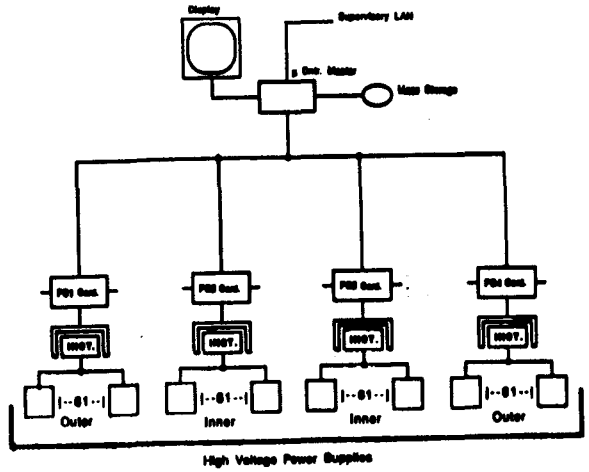
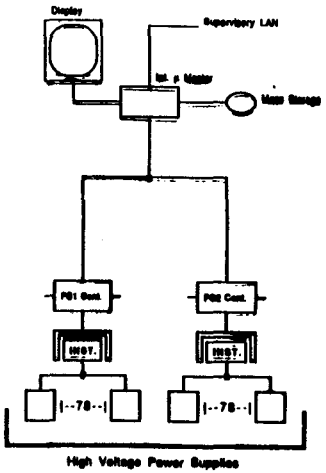


2473

μ Counter Slow Controls



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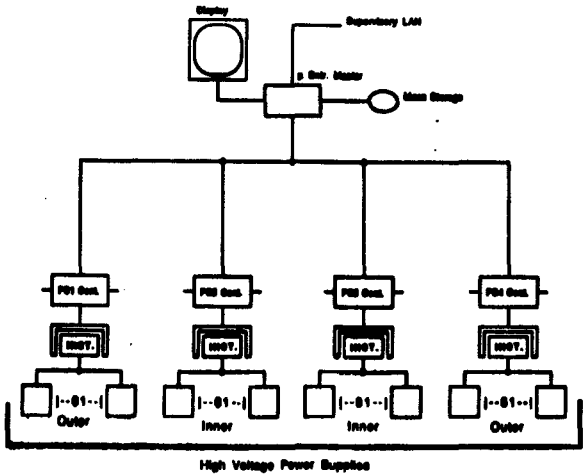


2474

μ Counter Slow Controls

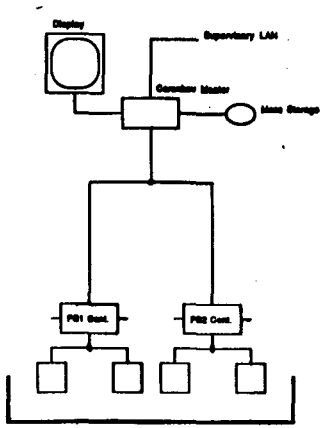
Specific Requirements

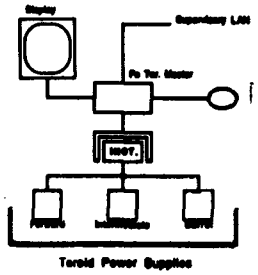
Cerenkov Counters-

Provide local and remote control for 500 PMT HV channels
- **a. Maintain selected voltage on 500 HV channels**
- **b. Monitor voltage and current on all supplies**
- **c. Evaluate interlocks and take appropriate action**
- **d. Detect HV faults and report to On-Line comp. system**

Iron Toroids-

Provide local and remote control for 3 high power magnet supplies
- **a. Evaluate interlocks for operation and safety**
- **b. Maintain selected Current**
- **c. Monitor Voltage and Current**
- **d. Coordinate with other Detector Subsystems**

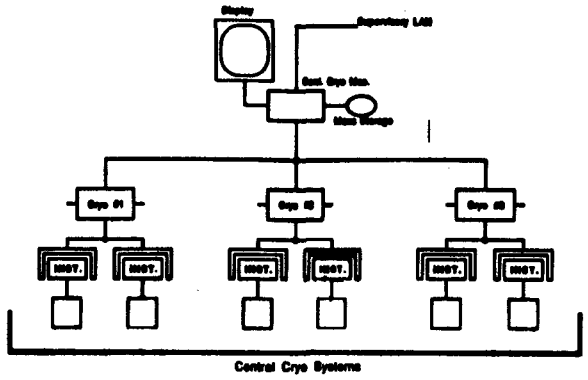




Specific Requirements

Superconducting Solenoid-

1. **Provide local and remote control of the S.C. power supply system**
   - **a. Power supply-**
     1. **Maintain selected Current**
     2. **Evaluate interlocks and take appropriate action**
     3. **Monitor Voltage and Current**
     4. **Perform control functions in accordance with prescribed algorithms**
   - **b. Quench System**
     1. **Monitor performance of quench detection algorithms**
     2. **Provide set-point control of trip levels within quench equation**
     3. **Evaluate interlocks and take appropriate action**
2. **Provide local and remote control of the S.C. cryo cooling system**
   - **a. Operate and maintain proper temperature profiles within the LHe system**
   - **b. Evaluate interlocks and take appropriate action**
   - **c. Provide automatic/manual control of cool-down cycles**
   - **d. Coordinate with central cryo system**



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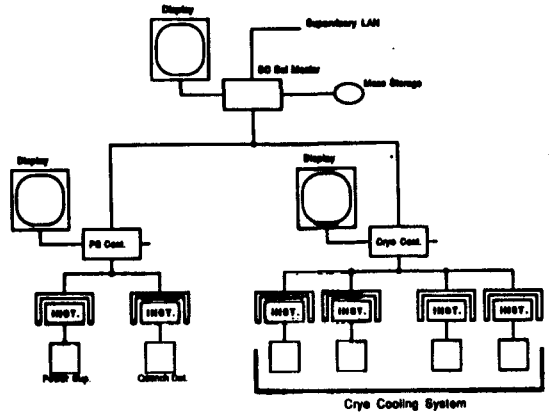

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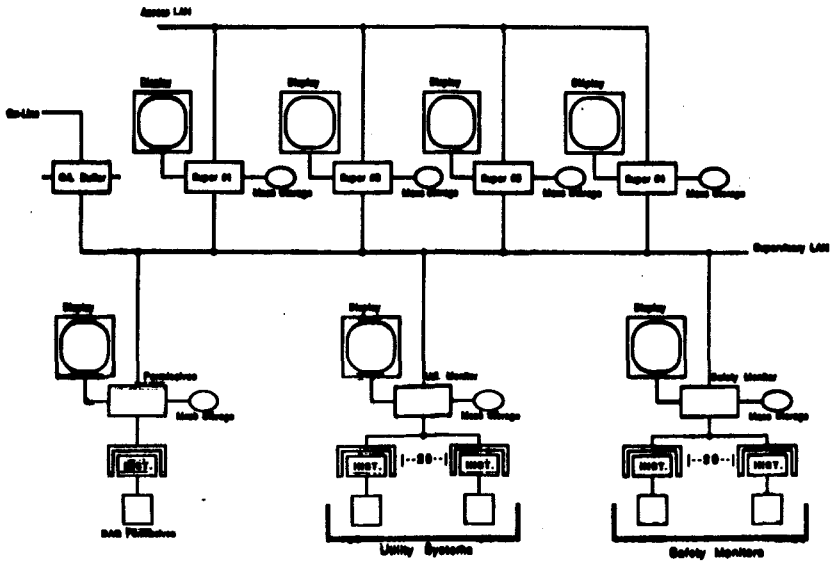


2482

Specific Requirements

Central Cryo System-

Provide local and remote control of the central cryo system

a. Monitor pressures and temperatures
b. Provide for manual/automatic valve manipulation
c. Evaluate interlock conditions and take appropriate action if permissives are violated.
d. Report status to other subsystems and supervisory control
e. Provide automatic/manual cool-down functions
f. Coordinate with S.C. Solenoid, LAr, VLPC LHe systems

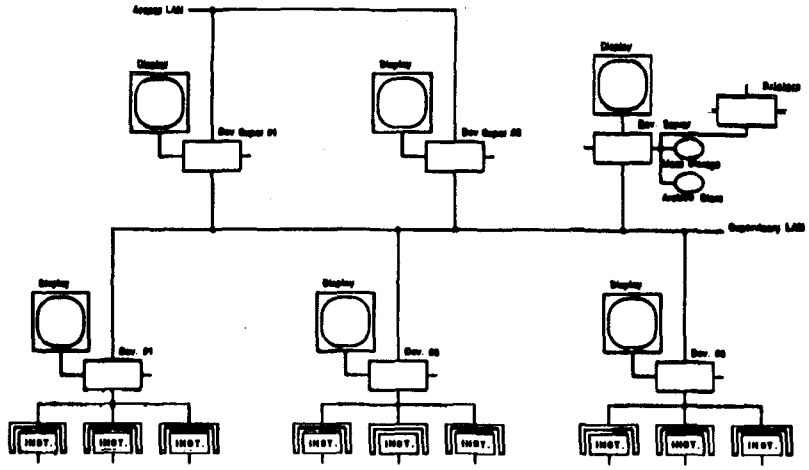
DAQ permissives-

a. Provide fast evaluation of interlocks and permissives to DAQ
b. Provide fast evaluation of DAQ signals, providing permissives to subsystems
c. Provides interlock monitoring and status displays

Utility and Safety Monitor-

Provides monitoring of selected interlocks and facility/utility parameters for display and transmission to relevant subsystems

2480



2483

Cost Summary

Subsystem	Controls Element	MEDIA	Base	%Cont.	Total
8.4.1.1	Si Tracker	95%	$398K	30%	$618K
8.4.1.2	Wire Tracker	65%	$117K	21%	$141K
8.4.1.3	Fiber Tracker	80%	$117K	14%	$134K
8.4.1.4	Calorimeter	64%	$150K	19%	$199K
8.4.1.5	Forward Cal	69%	$111K	17%	$131K
8.4.1.6	Barrel Muon	80%	$161K	16%	$186K
8.4.1.7	Barrel Muon Calr	80%	$181K	16%	$159K
8.4.1.8	Inter. Muon	85%	$144K	17%	$167K
8.4.1.9	Cerenkov	73%	$138K	17%	$162K
8.4.1.10	Iron Toroid	60%	$100K	18%	$118K
8.4.1.11	S.C. Solenoid	70%	$413K	18%	$488K
8.4.1.12	Central Cryo	87%	$166K	16%	$193K
8.4.1.13	Supervisor	48%	$194K	14%	$221K
8.4.2	Utilities Monitor	30%	$157K	12%	$255K
8.4.2	Safety Monitor	35%	$187K	12%	$209K
8.4.4	Dev. System	80%	$1920K	19%	$2286K
8.4.5	Project Mgmt	83%	$1020K	21%	$1231K
8.4.6	Crate Contract	160%	$56K	25%	$67K
8.4.7	Coop. Eq. Contract	100%	$63K	20%	$76K
8.4.8	Fiber Cable Contracts	100%	$44K	20%	$52K
8.4.9	LAN Cable Contract	100%	$56K	20%	$67K
8.2.1.8.4	Installation	82%	$557K	25%	$754K
8.8.2.8.4	Testing	72%	$468K	20%	$560K
Total**		77%	$7105K	19%	$8420K

**~10 FTE/Yr for 5 Yr plus cable installation.

2484

Cost Drivers and Descope Options

77% of element is labor, Hardware is not a driver

Much of the installation cost is in cable pulling, redefined scope will reduce installation burden.

Several of the presently costed elements will be greatly reduced

1. S.C. Magnet cryo-
   Cryo controls will be reduced to perform only interface functions with pre-packaged system supplied with cryogenics manufacturer.
2. Central Cryo-
   Will probably go away altogether.
3. HV power supply control will be based on completely different architecture than currently costed.

3-4 M$ reduction tied up in above comments. Further definition and negotiation among subsystems will be required before another full pass can be done.

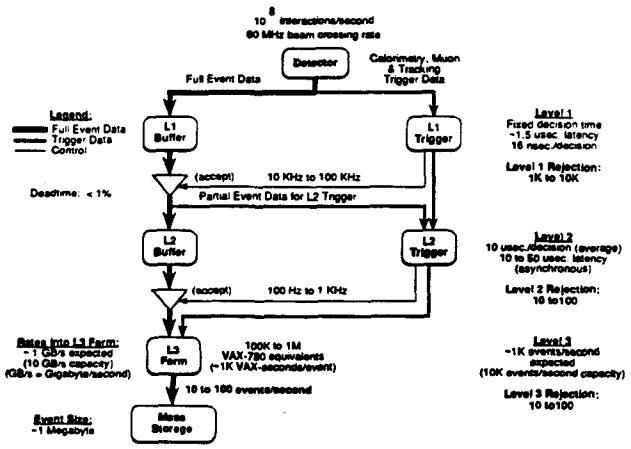
2485

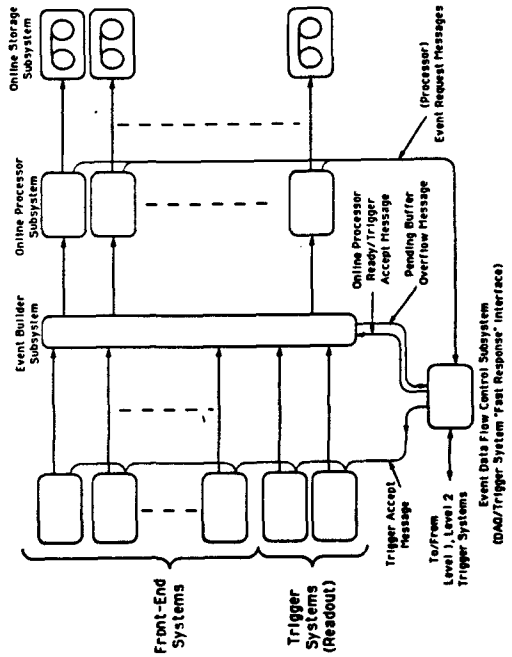
SDC Baseline DAQ

- Non-descoped
- $42M System
- Not what we will build (or even put in technical proposal)

Irwin Gaines
Aug. 6, 1991

2486





Simplified Block Diagram
Of Costed Data Acquisition System Architecture

SDC DAQ: Major Components

- Development Tools (5.2.1)
- Slow Controls Interface (5.2.2)
- Read-out Subsystem (5.2.3 and 5.2.4)
  Readout network for 10**6 front-end channels
- Front End and Trigger System Interfaces (5.2.5 and 5.2.6)
- Event Builder Subsystem (5.2.7)
  Switching network with 256 inputs, 256 outputs, aggregate bandwidth of 1 Gigabyte/sec
- Timing & Clock Distribution Subsystem
  High-speed dedicated links for 60Mhz clock and trigger distribution
- Data Flow Control Subsystem (5.2.8)
  Dedicated point-to-point message links to control event data flow, with message distributed to >620 destinations
- Online Processor Subsystem (5.2.9)
  Processing System with computing power of >10**5 MIPS
- Online Storage Subsystem (5.2.10)
  Mass Storage System with 100 MBytes/sec capacity
- ES&H Subsystem (5.2.11)
- DAQ Control Software (5.2.12)
  Software for control, monitoring, downloading and user interface with the DAQ system
- Offline Analysis Interface (5.2.13)
  High Performance network link (1 Gigabit/sec or greater) to offline computing system
- System Integration and Project Management (5.2.14 and 5.2.15)

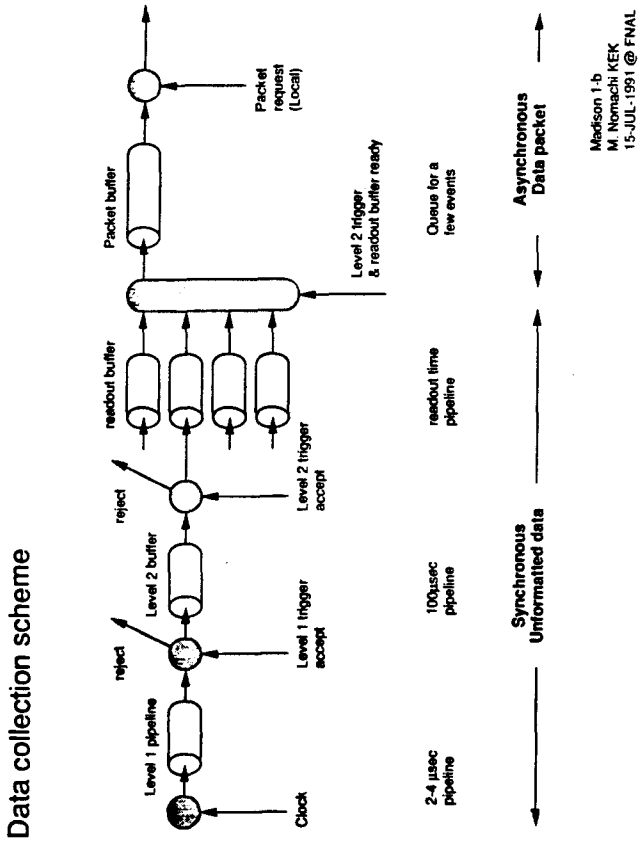
DAQ & Front-End/Trigger Interface Goals For Both Event Data Readout & Slow Controls

"SDC Standard" Event Data Readout Interface Goals:
- Industry-supplied hardware & software whenever possible
- Identical readout protocols, signal levels, connectors, cable, etc. across all Front-End & Trigger Systems
  (cases of "very little" data and several crates may justify an intermediate (hopefully commercial) stage of data "collection" before the "standard" readout interface)
- Single Readout Controller (or adjunct another "standard DAQ device")
  (has to fit in everybody's crate)
- Options for redundancy (e.g., two Readout Controllers per crate, etc.)

"SDC Standard" Slow Controls Interface Goals:
(for downloading, monitoring, diagnostics, etc.)
- Industry-supplied hardware & software whenever possible.
- Identical slow controls protocols, signal levels, connectors, cable, etc. across all Front-End & Trigger Systems
- Single Slow Controls CPU per Crate
  (has to fit in everybody's crate)
- Industry-standard Slow Controls serial link to on-detector (non-crate-housed) PC boards
- Options for redundancy (e.g., two Slow Controls CPUs per crate, etc.)

"SDC Standard" DAQ Interface Crate Goals:
- Used wherever possible
  (e.g., not used in Flash ADC Calorimetry crates (too special) but could possibly be used in several other Front-End systems or the Trigger systems)
- Industry-supplied hardware
- SDC-standardized method for conventional power into the crates
- Non-redundant (single bus) & redundant (two identical busses) options
- Industry-supported bus standard

2491



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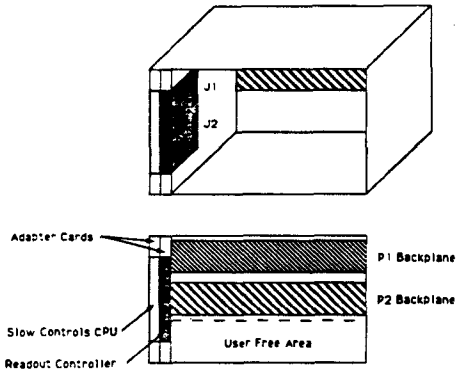
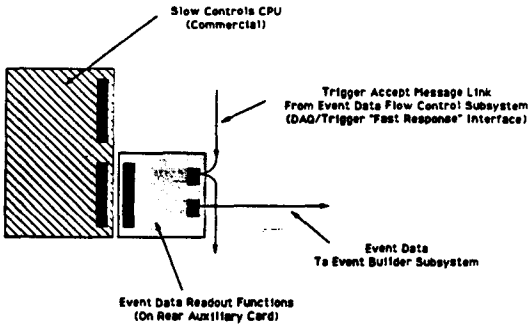


Slow Controls CPU & Readout Controller Implementation
VMEbus Example
9U x 400 Crate
One SC CPU & One ROC Per Crate

(Passive Adapter Card)

2493

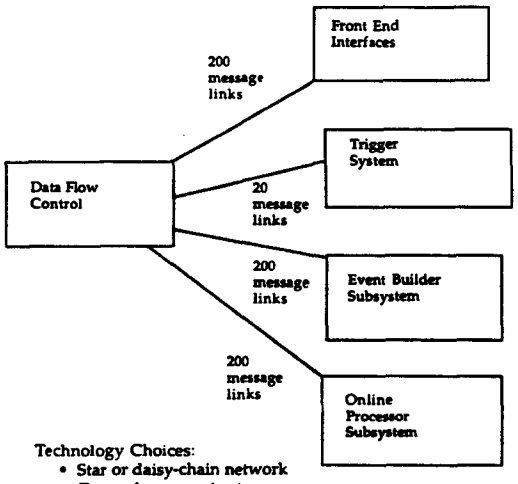


Slow Controls CPU & Readout Controller Implementation
VMEbus Example
CPU Functions As Both Slow Controls CPU & Readout Controller

(SDC Standard Readout Interface On Rear Auxiliary Card)

2494

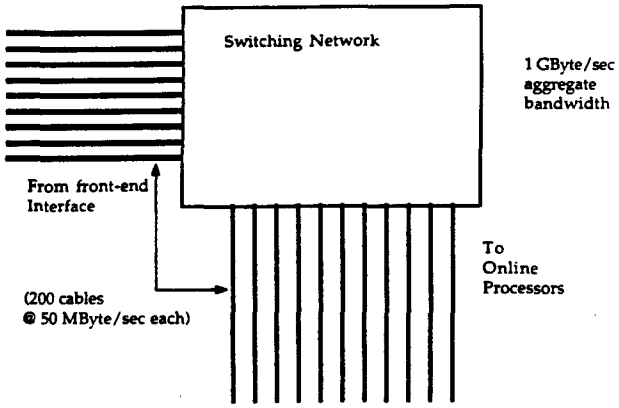
Event Data Flow Control Subsystem



Technology Choices:
- Star or daisy-chain network
- Type of communication

Costs
- 620 links @$500/link
- Total $300K

Event Builder Subsystem



Technology Choices:
- Speed of cables
- Number of cables
- Type of switching network (crossbar/dual-port memory/etc)

DAQ Software

5.2.12 **Online Data Acquisition Control Computer Subsystem Interface**
(Includes network interface and links to DAQ components and all system applications software but does not include any computer system (databases, operating systems, etc.) software)
- Write interface requirements document then write interface specifications document
- Procure & develop (hardware & software) infrastructure

5.2.12.3 **Network Interface & Links To DAQ Components**

5.2.12.4 **Runtime User Interface**
(Applications software only)

5.2.12.5 **Control, Monitoring & Downloading User Interface**
(Applications software only)

1 **Applications Software For Supporting The Use Of Memories & Intelligent Processors**
2 **Applications Software For Supporting "Slow" (Non-Event) Data Acquisition**
3 **Applications Software For Supporting Unusual Occurrences**
4 **Applications Software For Supporting The Control & Monitoring Of Adjustable Devices**

SDC DAQ

Manpower Costing **Total $13 M**

• Development Tools (5.2.1)	$0.4M
• Slow Controls Interface (5.2.2)	$0.6M
• Read-out Subsystem (5.2.3 and 5.2.4)	$1.8M
• Front End and Trigger System Interfaces (5.2.5 and 5.2.6)	$2.4M
• Event Builder Subsystem (5.2.7)	$1.1M
• Timing & Clock Distribution Subsystem	
• Data Flow Control Subsystem (5.2.8)	$0.9M
• Online Processor Subsystem (5.2.9)	$0.3M
• Online Storage Subsystem (5.2.10)	$0.3M
• ES&H Subsystem (5.2.11)	$1.0M
• DAQ Control Software (5.2.12)	$2.4M
• Offline Analysis Interface (5.2.13)	$0.1M
• System Integration and Project Management (5.2.14 and 5.2.15)	$1.9M

SDC DAQ

Cost Drivers

- 360 data sources, each provided with:
  - Slow controls interface $7K
  - Event data flow control link $0.3K
  - Event builder link $2.2K
- 210 of these are "standard" DAQ crates, each with:
  - Readout controller $5K
  - Diagnostic bus (boundary scan) interface $3.2K
  - Rack protection interface $3.3K
  - 1/3 of rack protection system ($20K) $7K

  Note that the other 150 non-standard crates must provide this functionality from their budgets
- 18 crates (SI detector subsystems) costed here
  - Crate, backplane and power supply $14K

  Note that other subsystems must cost crates in front-end budgets

DAQ Descoping

Baseline Design:	$22M M&S $12M labor $8M contingency (24%) --- $42M total
Descoping Target:	$13M M&S $7M labor $5M contingency (25%) --- $25M total

Richard Partridge
LBL SDC Workshop
August 5, 1991

DAQ & CONTROLS DESCOPING OPTIONS

June meeting mandated substantial cost reductions in DAQ and Controls. To meet these cost reduction goals we must:

- Carefully evaluate cost/performance tradeoffs
- Establish realistic requirements and specifications
- Find cost effective solutions that meet the requirements
- Consider staging options where appropriate
- "Improve" costing methodology

Editorial: Minimizing the DAQ/Controls cost is important since unnecessary spending on DAQ/Controls will reduce the physics capability of the whole detector. However, we must also keep in mind that an inadequate DAQ will reduce the physics capability of the detector in a very direct and drastic manner.

COST/PERFORMANCE TRADEOFFS

Current DAQ/Trigger design is probably over-designed, providing full function Level 2 and Level 3 triggers

Option A: Eliminate Level 2 Trigger

- Build single level hardware trigger
- Eliminate data paths to Level 2 trigger
- Eliminate Level 2 buffering and control logic from FEE
- Provide fast DAQ readout (50-100 kHz @ 200 kB/event)
- Stage Level 2 trigger if needed for running at full luminosity
  - Staged Level 2 would use DAQ readout for data path
  - Events would be buffered following readout from the FEE until the Level 2 trigger decision
- Current Level 3 farm provides 1-2 Vax seconds/event; is this sufficient?

Option B: Eliminate Level 3 Farm

- Provide robust Level 2 trigger to reduce trigger rate to ≈ 1 kHz
- Eliminate Level 3 farm, write 1 kHz to tape using high capacity tape drives being developed for HDTV (Sony?)
- SSC budget has 87 M$ set aside for computing; lets use some of that computing for final event selection
- Some processing of events still needed for monitoring, calibration, etc; this becomes part of the online computing facility

COST EFFECTIVE SOLUTIONS

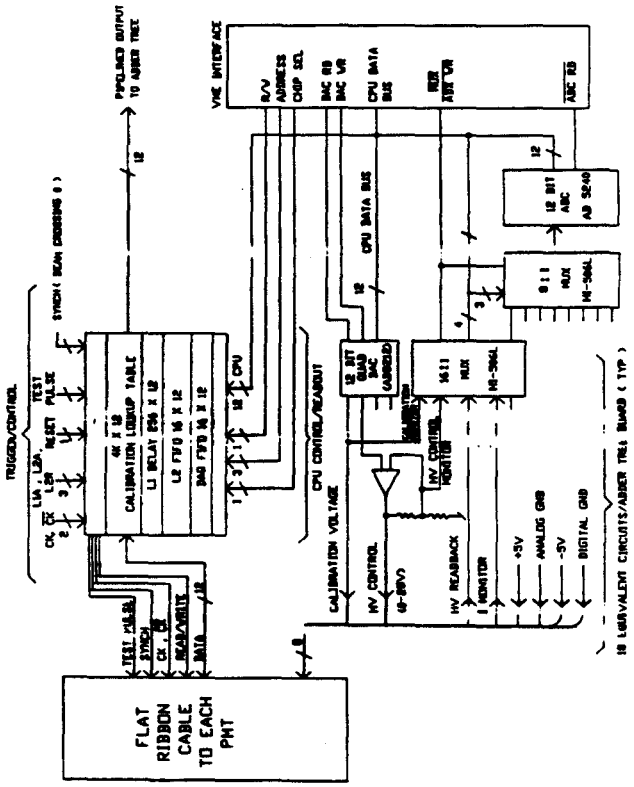
- Minimize number of different DAQ/Controls modules by combining functionality where appropriate
- Standardize DAQ (and trigger) interface to FEE
- Use commercial solutions where cost effective
- Dedicated single direction data paths are very cost effective, especially for large bandwidth systems
- Integrate DAQ slow-control and Controls
  - Controls should use same network as DAQ slow-control
  - Provide rack protection/monitoring data to existing crate processors using serial link
  - Integrate controls into standard online hardware/software environment
- Integrate PMT HV, current monitoring into FEE crates

"IMPROVE" COST ESTIMATE

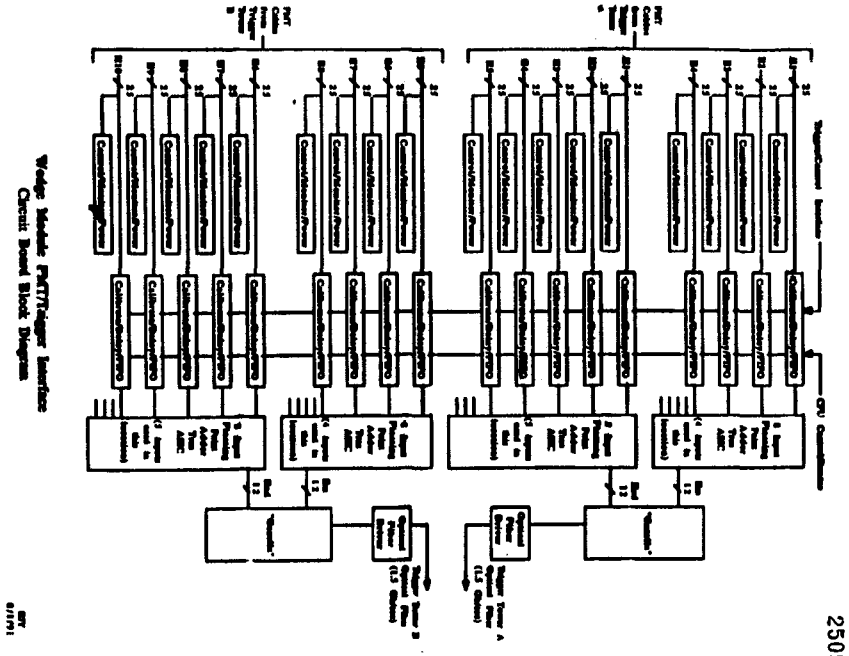
- Is $50/MIP too high?
  - HP workstation is ≈$200/MIP
  - DØ experience: CPU cost/performance changed by factor of ≈ 15 between design and acquisition
- Combine functionality, eliminate double counting
- Assume some engineering and software development will come out of the base program
- Reduce number of preproduction design stages
- Compare costs of alternative approaches

CALORIMETER ELECTRONICS INTERFACES

W. FOSTER



TOWER ADDER TREE CIRCUIT BOARD
PMT INPUT CIRCUITRY



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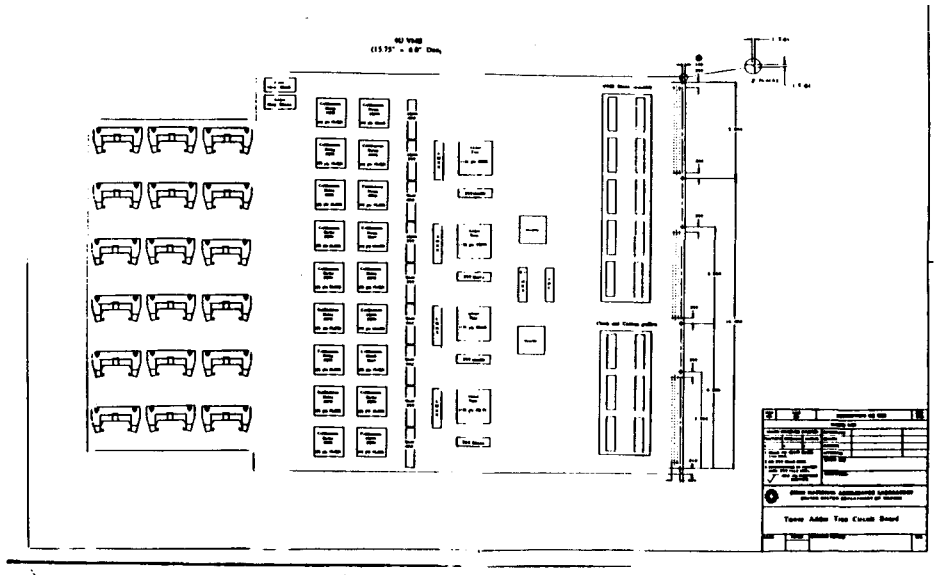

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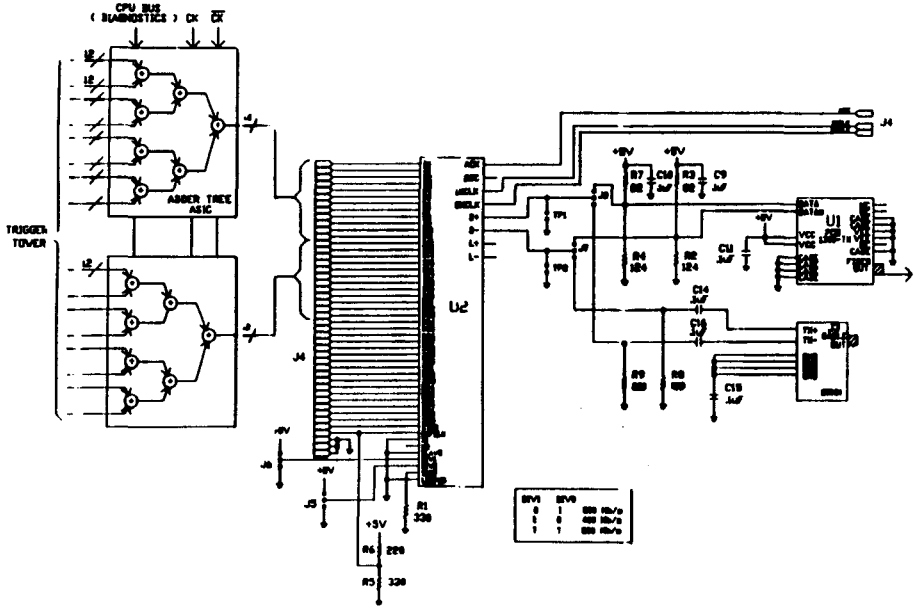
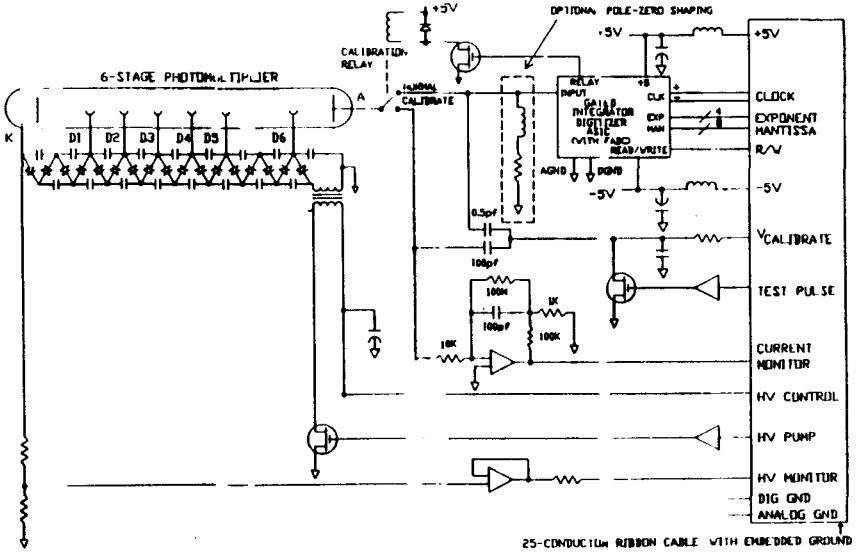


TOWER ADDER TREE CIRCUIT BOARD
ADDER AND OUTPUT FIBER DRIVER

2510

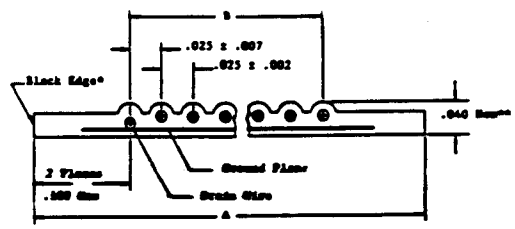


SDC SCINTILLATING TILE
PHOTOMULTIPLIER TUBE CIRCUIT SCHEMATIC

2508

PRODUCT SPECIFICATION
SPECTRA-STRIP CABLE OPERATIONS
HAMDEN, CT

.025" CENTER GROUND PLANE CABLE	November 17, 1987
PART NUMBER 133-3012-[illegible]	
PRELIMINARY PRODUCT SPECIFICATION	Page 2 of 2



Product shown above is with a drain wire.
* End edge for product without a drain wire.
** .043 mm for Quik Strip.

3.0 Order Information

PART NUMBER	NO. CONDUCTORS	SPAN "A" INCHES	SPAN "B" INCHES
133-3012-[illegible]	[illegible]	.675	.675 ± .005
133-3012-036	36	.825	.825 ± .005
133-3012-034	34	1.025	.825 ± .005
133-3012-040	40	1.175	.975 ± .006
133-3012-050	50	1.425	1.225 ± .006
133-3012-060	60	1.675	1.475 ± .006

Above Table — Series 133-3012-[illegible]: Product with a drain wire as shown above.
Series 133-3011-[illegible]: Product without a drain wire.
Quik Strip — Series 133-3014-[illegible]: Product with a drain wire.
Quik Strip — Series 133-3013-[illegible]: Product without a drain wire.

01D61

CALORIMETER ELECTRONICS INTERFACES

M. LEVI

Descope and Upgrade Scintillator Calorimeter Channel Count LBL readout scheme

Assumptions and comments
1. Kirk-Wicklund design - SDC-91-00018
2. Proudfoot descope - SDC SSCL meeting 6/22/91
4. 64 phi wedges in barrel and endcap (2 barrel halves and 2 endcaps).
5. One em compartment 0.05x0.05 in barrel.
6. Two em compartments 0.05x0.05 in endcap.
7. Hac1 compartment 0.05x0.05.
8. Hac2 compartment 0.1x0.1
9. Shower max contains is configured with four readouts per em.
10. All readout is via LBL scheme and each PMT requires two electronic channels and shower max requires one per PMT.
11. Split towers across the vertical crack have their electronics duplicated on either side of the crack.
12. 128 electronic channels per SCA frontend card.
13. 256 HV control and monitor channels per service card.
14. The word PMT is used to describe the detector device for the shower max detector even though this may be some other technology.

Descope per-wedge PMT counts (actual number of real phototubes)

Barrel

em	28x4	sm	28x4x4
hac1	28x4		
hac2	25x1		
totals	249		448

Split

em	1x8	sm	1x4x4
hac1	4x4		
hac2	8x1		
totals	28		16

Endcap

em1	45	sm	45x4
em2	45		
hac1	45		
hac2	12		
totals	147		180

The total number of non-sm PMTs is 27136 and of sm PMTs is 41216.

Descope per-wedge electronics count (includes crack/edge effects)

	PMT channels		SCA channels		SCA boards		Service boards	
	non-sm	sm	non-sm	sm	non-sm	sm	non-sm	sm
barrel	252	448	504	448	4	4	1	2
split	72	16	144	16	2	0	1	0
endcap	156	180	312	180	3	2	1	1

Descope per-wedge card count

Barrel crate - 14 slots
- 3 interface cards
- 8 SCA cards
- 3 PMT monitor and calibration cards

Endcap crate - 13 slots
- 3 interface
- 7 SCA cards
- 3 PMT monitor and calibration cards

Upgrade per-wedge PMT counts (actual number of phototubes)

Barrel

em1	28x4	sm	28x4x4
em2	28x4		
hac1	28x4		
hac2	25x1		
totals	361		896

Split

em1	1x4	sm	1x4x8
em2	1x4		
hac1	4x4		
hac2	8x1		
totals	32		32

Endcap

em1	45	sm	45x8
em2	45		
hac1	45		
hac2	12		
totals	147		360

The total number of non-sm PMTs is 34560 and of sm PMTs is 82432.

Upgrade per-wedge electronics count (includes crack/edge effects)

	PMT channels		SCA channels		SCA boards		Service boards	
	non-sm	sm	non-sm	sm	non-sm	sm	non-sm	sm
barrel	364	896	728	896	6	7	2	4
split	104	32	208	32	2	0	1	0
endcap	156	360	312	360	3	4	1	2

Upgrade per-wedge card count

Barrel crate - 20 slots
- 3 interface cards
- 13 SCA cards
- 4 PMT monitor and calibration cards

Endcap crate - 16 slots
- 3 interface
- 9 SCA cards
- 4 PMT monitor and calibration cards

SCINTILLATING TILE BARREL AND ENDCAP CALORIMETER ELECTRONIC COST ESTIMATE

Robert Ely, Jack Franck, Richard C. Jared, Issy Kipnis,
Frederick Kirsten, Stuart Kleinfelder
Michael Levi, Thomas Merrick, Oren Milgrome,
Robert Minor, Leverett Pope, Paul Salz,
Edward Theil and Jack Zelver

REVISION HISTORY

SCINTILLATING TILE BARREL AND ENDCAP CALORIMETER ELECTRONIC COST ESTIMATE

Document created Month	Day	Year	Comment
6	20	1991	Added missing section 5.3.F of the cost estimate, unit cost to section G, contingency analyses to section G, updated schedule and rate information to section G.

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SCINTILLATING TILE BARREL AND ENDCAP CALORIMETER ELECTRONIC COST ESTIMATE

1.0 PURPOSE OF DOCUMENT

The purpose of this document is to provide a estimate of cost, space requirements, power utilization and schedule for the electronics of the SDC barrel and end cap calorimeter.

2.0 METHODOLOGY

A strawman was first designed that provided a concept that could be cost effective and reviewed. This concept was presented to members of the collaboration, updated and corrected to provide a functional concept for cost estimating. The strawman is not an optimizing of cost and performance (some cost and performance trade-offs were considered in its generation), but a functional model that has the necessary components to process the calorimeter signals. The strawman was then used to perform a cost estimate. Estimating of cost was performed by the authors (R. Jared chairperson). Four of the authors have experience costing and building multi-million dollar projects. After the costing exercise schedule, space and power estimates were made.

3.0 REQUIREMENT/CONSTRAINTS

The requirements section is separated into two categories. The first section contains constraints related to the expected physics. The second section contains the function requirements that the system would be designed from. The second section contain the physics constraints in engineering terms, good engineering practices and practical considerations.

3.1 Physics constraints

The constraints as derived from the physics are listed below. It is assumed that the electromagnetic section has 15 layers and hadron 130. Electromagnetic and hadron sections have towers of 0.05 radians by 0.05 units of rapidity. The electromagnetic and hadron towers are separated into two depth sections each.

3.1.1 Calorimeter background occupancy

At a luminosity of 10^{33} there are 1.6 minimum bias events per cross over. These events have approximately 8 particles of 0.6 GeV mean within 1 unit of rapidity. The resulting average tower occupancy is 0.3% per cross over (assuming point depostition).

3.1.2 Event rates

The jet cross section for Sets between 4-10 GeV is approximately equal to the minimum bias cross section. The dependency as a function of energy is proportional to 10^{-4} Average particle transverse energy for minimum bias events is assumed to be 0.6 GeV. This translates into approximately the following table:

Energy Range(P_T)	Jet rate/crossover	particle energy	particles/tower/crossover
4-10 GeV	1.6	0.6 GeV	0.005
10-100 GeV	0.5	3.3 GeV	6.8×10^{-3}
100- 1000 GeV	2×10^{4}	5 GeV	1.3×10^{-2}
1-10 TeV	2×10^{-8}	20 GeV	2.3×10^{-2}

3.1.3 Maximum occupancy

High energy jets in interesting events may cause full occupancy in a cone of one radian/unit of rapidity. This data must be read out.

3.1.4 Dynamic range of electromagnetic and hadron sections

3.1.4.1 Hadron dynamic range

The largest jet of interest is defined as 1/2 the beam energy, 10 TeV. The average leading particle is assumed to have 25% of the momentum and the maximum energy of the leading particle is twice that amount or 5 TeV. This 5 TeV particle will have a transverse shower width of 18.6 cm FWHM or one tower can contain about 45% of the energy. Maximum signal of any electronic channel is set at 2 TeV (assuming equal sharing of energy between the (70%) front and (38%) back sections).

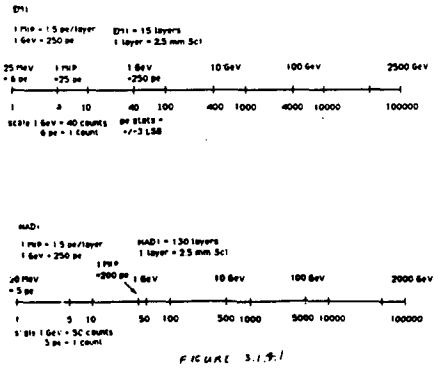


FIGURE 3.1.4.1

The minimum signal of interest in an electronic channel is determined from electron isolation and muon detection. The minimum signas is defined as 20 MeV.

Dynamic range is defined as 10^{-5} (2 TeV/20 MeV). Figure 3.1.4.1 shows this scale with minimum ionizing particles indicated.

3.1.4.2 Electromagnetic dynamic range

The largest jet of interest is defined as 1/2 the beam energy, 10 TeV. The average leading particle is assumed to have 25% of the momentum and the maximum energy of the leading particle is twice that amount or 5 TeV. This 5 TeV particle will have a transverse shower width of TBU (2 cm FWHM) or one tower can contain about 100% of the energy. Maximum signal of any electronic channel is set at 2.5 TeV (with equal sharing of energy between the front and back sections).

The minimum signal of interest in an electronic channel is determined from electron isolation and muon detection. The minimum signas is defined as 25 MeV.

Dynamic range is defined as 10^{5} (2.5 TeV/ 25 MeV). Figure 3.1.4.1 shows this scale with minimum ionizing particles indicated.

3.1.5 Trigger rates

The detector will have a 3 trigger levels. Level 1 and 2 triggers are generated by hardware systems. Level 3 three triggers are generated by software calculation that result in either saving on mass storage or rejecting the event. The following table gives there rates, timing and calorimeter action to be taken.

Trigger	Time after crossover	Rate/second	Calorimeter action
Level 1 accept	TBD 3 microseconds	10^{5}	Save event for readout
level 2 accept	TBD 200 microseconds	10^{4}	Readout event
level 2 reject	TBD 200 microseconds	10^{5}	Delete event
level 3	TBD 0.1 to 60 second	TBD 5 to 100	Nothing

3.1.6 Signal shaping time constraints

In a cone with a radius of 0.2 units of rapidity around a electron there will be no more than 1 GeV of pile up energy from minimum bias events. (Note a integration time of less than 100 nsec meets this requirement).

3.1.7 Electronic accuracy

The electronic errors will be less than 50% of the expected calorimeter resolution. The calorimeter resolution is expected to be 15% in the electromagnetic section and 40% in the hadron section divided by the square root of E in GeV added in quadrature with 1%.

3.2.0 Functional requirements

The functional requirements are derived from the physics constrains and practical considerations. By their nature there are implementation dependent specification contained in this section. These functional requirements were used/generated in developing the strawman.

3.2.1 Number of channels

There are 27,904 primary channels in the barrel calorimeter and 11,264 primary channels in the endcap calorimeter. Redundant channels should be added to help identify photomultiplier noise, HV breakdown and Cerenkov radiation in the fibers and tube glass. The number of redundant channels is TBD.

3.2.2 Calorimeter minimum bias occupancy

The occupancy in any electronic channel is 0.3% per beam cross over. The particals that generate these signals will have and average energy of 0.6 GeV per tower.

3.2.3 Event size

The average two jet event will occupy approximately 10% of the calorimeter channels. Local readout regions of the calorimeter will have 100% occupancy for high energy events. The readout sytsem must be capable of reading out 100% of the channels in localized area.

3.2.4 Signal integration time

The shaping time is less than 100 nsec. The shaping amplifier will recover to within 10% of the peak amplitude in 30 nanoseconds and 0.1% in 60 nanosecond.

3.2.5 Maximum and minimum signal

Minimum signal for a primary channel is 20 MeV (5 photo electrons) in the hadron section and 25 MeV in the electromagnetic section (6 photo electrons).
Maximum signal for a primary channel is 2 TeV in the hadron section and 2.5 TeV in the electromagnetic section.

3.2.6 Dynamic Range

The dynamic range is 10^{5} in the hardonic sections.
The dynamic range is 10^{5} in the electromagnetic sections.

3.2.7 Maximum and minimum signal for redundant channels

Minimum and maximum signal for redundant channel are TBD. (Note these signal will be readout over the same electronic chain as the primary channels).

3.2.8 Single channel dead time

A single electronic channel will have a probability of less than 10^{-8} of being bad due to preamplifier saturation or other similar effects.

The number of randomly located channels that are dead due to defects or inability to calibrate shall be less than 10^{3}.

3.2.9 Stand alone capabilities of system

The electronics will be subdivided into stand alone systems. The division will be determined by the mechanical module size that is beam tested and then installed. These subsystems will provide the primary means of checkout, calibration and defect location. In addition the subsystem will be able to trap events in a passive way for diagnostic purposes during normal data acquisition.

3.2.10 Electronic calibration

The electronic calibration accuracy will be 0.5% and provide patterns to test the trigger circuitry. Current of the photomultipliers with and without radioactive sources will be measured to 0.5% (note a radioactive source will cause a current of at least 5 nanoampers with a photomultiplier gain of 10^{5}). In addition signals will be supplied for lasers triggers that will cause a pulse of photons to the front end photomultipliers. The amplitude control will be used to measure the electronic linearity to better than 0.5%.

3.2.11 Signal sent to the trigger

The trigger system will be provided with super tower (0.1 radians by 0.1 units of rapidity) energy for each cross over. Tower energy will be transmitted along with a crossover number for both electromagnetic and hadron super towers. The energy will be digitized by a 8 bit nonlinear ADC with a 12 bit dynamic range. As the trigger is better modeled and studied it is expected that the some of the trigger primitives will be derived in the front end electronics. This will reduce the bandwidth required to transmit trigger data. Exact specifications are TBD.

3.2.12 Signals received from the trigger

The trigger system will provide six signals level 1 accept, level 1 reject, level 2 accept, level 2 reject, clock and reset. There will be either a level 1 accept or level 1 reject on each crossover. Level 1 accept rates will be less than 10^{5} per second. The accepts will be at TBU 3.0 microseconds after the crossover that caused the event. For each level 1 except there will be either a level 2 accept of level 2 reject. Level 2 accept rates will be less than 10^{4} per second. The clock signals are used for saving the energy/electronic signal on each crossover. The reset signal will place the front end electronics is a known state TBD. Exact specifications are TBD.

3.2.13 Radiation environment

There is approximately 10^{4} rads/year at the face of the calorimeter (polar angle 25 degrees). The electronic front end bins are located at this angle on the back side of the calorimeter. The radiation level at this location is TBD. The electronics must survive 10 years of radiation without degradation that effects the requirements or planned replacement must be defined.

3.2.14 Interface to the Data Acquisition System

The calorimeter will provide less than 100 labeled data streams to the Data Acquisition System. The format and structure of the data records are TBD.

4.0 STRAWMAN DESCRIPTION

In this section, the functions of the electronic system for the scintillation calorimetry are described. Although the physical placement of particular functions may change as the design progresses, for the purposes of the strawman each major functional block is situated in one of three physical areas--1) On Detector, 2) at Ground Level I, a shielded room close to the detector, and 3) at Ground Level II some distance from the detector.
Also for the purposes of the strawman, the electronics in areas 1) and 2) are considered part of the calorimeter electronic system; that in 3) as part of the data acquisition system for the SDC. This partitioning is also subject to change as the design progresses. Thus, the blocks labeled Event Collector, Trigger and Global Trigger are blocks that are intimate with the calorimeter electronics system, but are not considered part of it in this discussion.

4.1 Major Functional Blocks

The major functional blocks involved in the flow of data from the calorimeter to the processor farm are shown in Figure 4.1. These major blocks are individually described in this subsection.

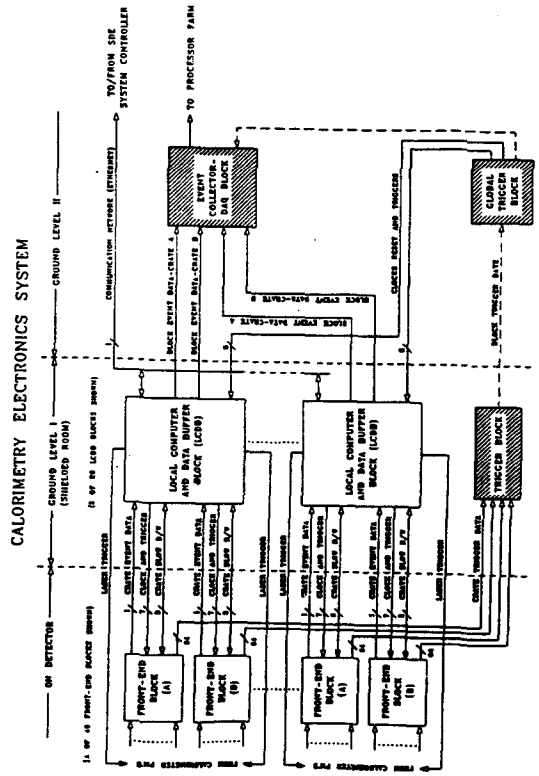


Figure 4.1

4.1.1 Front End Blocks

The Front End System is composed of approximately 40 identical Front-End blocks, 20 on each end of the detector. Each block processes signals from approximately 1000 calorimetry channels. The Front-End blocks are located completely on the detector. Their accessibility is thereby limited to beam-off conditions; adequate capability for remote monitoring and control must be built into the system. For example, facilities for the calibration of individual channels are provided.

Each block will be physically housed in a crate (patterned after a VMI crate) and preamplifier cards mounted on the calorimeter.

Following are the basic functions performed by each Front-End block:

- Each block accepts the raw signals from approximately one thousand channels of the calorimeter system.
- It also accepts timing, trigger and control signals from the Local Computer and Data Buffer block.
- It develops digital data for events selected by the trigger signals and passes these data to the Local Computer and Data Buffer block. The digital data are properly tagged with channel of origin and event identification.
- It also outputs Trigger Data signals to the Trigger block.

The Front End System operates in strict accord with the accepted protocols for triggering and data formatting. A document describing these protocols is under preparation by another group.

4.1.2 Local Computer and Data Buffer Block

Each Local Computer and Data Buffer Block (LCDB) supports a 'domain' consisting of two Front-End blocks. Each LCDB block has four main functions.

- It acquires the digital data output of the two Front-End blocks that it supports, buffers the data and forwards them in a continuous stream to the Event Collector blocks.
- It acts as a buffer between the Front-end blocks and the rest of the SDC electronics system. The LCDB block receives fast trigger and timing signals from the Global Trigger system and fans them out the Front-end blocks. It stores and forwards signals associated with the control and operational monitoring of Front-end blocks.
- It acts as a port on the bi-directional global communication network--also known as the Slow R/W network. It intercepts control messages addressed to its domain and forwards them to its two Front-End blocks. It receives data generated by its Front-End blocks in response to control messages and transmits them on the communication network.
- It can also operate its local domain as a stand-alone system for testing, calibration, debugging and monitoring of the Front-end system operation. Its local computer can be controlled via the communications network during this phase.

4.1.3 Event Collector Block

The event data buffered in each LCDB block are transmitted to the Event Collector Block. This block is not part of the Calorimetry electronics system, but must be designed for compatibility with the LCDB blocks. As shown in Figure 4.1, a single Event Collector (or perhaps two--one for each end) will service the entire calorimeter. It is envisaged that the primary function of this block is to collect data generated by the calorimetry system, format them as required, and forward them to the processor farm. The question of whether it forwards packets of data consisting of complete events or whether it forwards packets containing partial events in an arbitrary sequence is beyond the scope of this discussion.

4.1.4 Trigger Block

The Trigger Block receives from the front-end blocks whatever data (Crate Trigger Data) are required to make real-time decisions regarding Level 1 and Level 2 triggers. It must receive a complete set of trigger data each beam crossing (every 16 nsec). It pre-processes the trigger data as appropriate and forwards them to the Global Trigger as Block Trigger data.

4.1.5 Global Trigger; Fast Signal Set

The Global Trigger receives pre-processed trigger data (Trigger Data II) from the Trigger block associated with the calorimetry system as well as Trigger Blocks associated with other detectors that are parts of the SDC. It processes all these data to make a decision, every 16 nsec, whether to issue a Level 1 Trigger or a Level 1 Reject. It also makes decisions, on a longer time scale, when to issue Level 2 Triggers and Level 2 Rejects.

In this scheme, it is assumed that the Global Trigger is the source of all fast timing signals used by the calorimetry (and other) electronic systems on the SDC. These fast signals, which constitute the Fast Signal set include:

- Level 1 Accept trigger
- Level 1 Reject trigger
- Level 2 Accept trigger
- Level 2 Reject trigger
- Test Event strobe
- The 62 Mhz beam crossing clock
- Reset Synchronization Strobe (to synchronize event number counters on SCA cards)

All these fast signals are generated with a high degree of timing precision, i.e., of the order of one nanosecond.

4.2 Communications Paths

The system shown in Figure 4.1 includes a number of important inter-block communications paths spanning the physical distances between the detector and Ground Level I and between Ground Levels I and II. These paths have various requirements in terms of speed and timing precision. Except as noted in the list below, these communications paths will be implemented using fiber optics. It is expected that all data on these paths will be in digital form.

4.2.1 Paths Between Detector and Ground Level 1

The communications paths between the detector and Ground Level 1 are:

- **Crate Event Data Path** - Packets of digitized data from the calorimeter elements flow from Front-end blocks to the LCDB blocks on the Crate Event Data paths. The packets include tags to identify the channel of origin, and the event or trigger number with which the data in the packet are associated.

  Each optical fiber will service one Front-end block (crate), each of which has a capacity of 1024 scintillator channels. (At some points in the system, each scintillator channel is split into a high-range and a low-range analog channel.) The complete Crate Event Data path consists of a total of 40 fibers.

- **Clock and Trigger Path** - All fast timing and synchronization signals needed by the Front-End blocks are forwarded from the LCDB blocks. These are basically the seven signals listed above in 4.1.5. Each of these signals is carried to each crate on its own fiber--a total of 280 fibers.

  (A future project will be to explore possible means of transporting all seven signals on a single fiber to each crate, thereby reducing the total number of fibers for this purpose to 40).

- **Crate Slow R/W Path** - All 'slow' command and monitoring information flowing between the Front-end blocks and the LCDB blocks are carried on this path. This information will include threshold and mode control commands going to the Front-end blocks, and status information coming from the Front-end blocks. In full-scale operation this information will originate in, and be destined for, the global system controller at Ground Level II. In debugging situations, the local computer in the LCDB block can command and monitor its two Front-end blocks in a stand-alone mode.

  This is a bi-directional path, requiring two fibers per Front-end block; 80 fibers for the system.

- **Crate Trigger Data Path** - Pre-processed data required by the trigger processor to generate Level 1 and 2 triggers and rejects flow over a number of very high speed parallel links from the front-end blocks to the trigger block. The pre-processing will consist of the summing and digitizing, to 8-bit precision, of energies deposited in towers. A complete set of trigger data is required every 16 nsec.

  The scale of the summing will be a compromise between number of individual links required and the required bandwidth of the links. Present plans are that, for purposes of generating inputs to the trigger processor that are adequate for both Level 1 and Level 2 triggers, these towers will subtend an area of 0.1 radians x 0.1 in rapidity. This will require eight links from each SCA card to the trigger processor--a total of 8 per card x 8 cards per crate x 40 crates = 2560 links.

  Present plans are to implement each link as a single optical fiber. This is based on the expectation that 1000 Mb/s fiber optic links will be available at reasonable cost within 2-3 years. An less-desirable alternative could be to implement each link in multi-circuit twisted-pair cable. To achieve the required speed, each link would consist of 16 or more twisted pairs.

- **Laser Trigger Path** - Under control of the SDC system controller or the LCDB, test or calibration light pulses can be injected into every scintillator channel. The means for injecting light pulses into scintillators has not yet been selected.

  (Test pulses can also be injected into the front-end system at two other points of every channel. These are: 1) an electronic charge deposited into the input of every preamp; and 2) an analog signal injected into each input buffer function (on the SCA cards). The control of these two injection mechanisms is via the Clocks, Resets and Triggers path and the Communications Network paths described below.)

4.2.2 Paths Between Ground Levels I and II

- **Block Event Data Path** - 'Large' packets of event data are forwarded from the buffering function of the LCDB block to the Event Collectors (Section 4.6.3.1). These packets are formed from a large number of the smaller packets originated by the Front-end blocks and include additional higher-level location-identification fields.

  One optical fiber is required from each LCDB block to the Event Collector--a total of 40 fibers.

- **Clocks, Resets and Triggers Path** - All fast (nanosecond precision) timing and synchronization signals needed by the calorimetry system are forwarded from the Global trigger system to the LDCB blocks on this path. These signals include the signals in the Fast Signal set, listed in section 4.1.5.

  Each of the approximately eight fast signals is transmitted on a separate fiber; separate fibers are needed for each of the 20 LCDB blocks - a total of about 160 fibers.

- **Communication Network Path** - All command and control information from the SDC system controller is forwarded to the LCDB blocks on this path. Status information is sent back in the other direction. The data format is basically that of the Write and Read packets (section 4.5.1) augmented with synchronization and redundancy bits.

  This will probably be implemented as an Ethernet-type link, using coaxial cable.

4.2.3 Event Data Word Format

Event data are initially created in the 40 Front-End blocks. The 40 event-data streams eventually merge into a single data stream as the event data wends its way through the LCDB blocks and the Event Collector(s) on its way to the processor farm. In all these streams, the event data have a uniform format. In general, words already in the stream are not modified as they travel through the system; however, additional words are added at various points as the stream progresses toward its final destination. The additional words are typically higher-level address (physical origin of data) identifiers.

All Event Data are uniformly formatted as 16-bit words. Each word has two fields: a 4-bit Code field, and a 12-bit Value field.

Code	Value
4 bits	12-bits

The various codes and the value ranges expected for each code are listed in Appendix A.

4.3 Front-end Block

The front-end block Figure 4.3 of the preamplifiers and photomultipliers located on the outside of the calorimeter and the front-end crate that contains the cards necessary to store and readout data. Data from the detector is modified by the photomultipliers and preamplifiers then transmitted to the SCA card over coaxial cables. Storage of the data is performed on the SCA card until the trigger determines that data should be read out. Read out data passes through the data collector card to the LCDB. The R/W Seq. & Buffer Card is used to buffer clock signals and provide a means to read and write control/structure data to the cards in the front-end crate. PM current monitor cards are used primarily to measure photomultiplier current and provide control levels for the PM high voltage.

FRONT END BLOCKS FOR CALORIMETER
(1 OF 40 CRATES SHOWN)

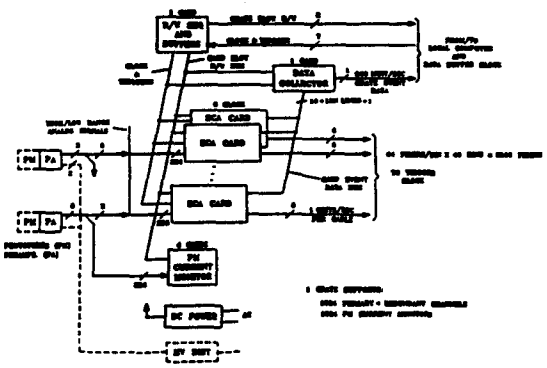


Figure 4.3

Each Front-end crate is patterned after a VMI crate. The crate has a capacity of 21 cards. Typically, only 14 of the 21 card slots will be filled. The total front-end system is housed in 40 crates, 20 at each end.

As shown in Figure 4.3, the functions of the front-end block are distributed on the various cards and the crate is connected to the rest of the system via cables and optical fibers.

- **Crate Logistics** -

  The crates are built according to the VMI specification. They fit into a standard rack, are 320 mm deep and 9U high. (One 'U' unit is 1 3/4 inches.) The cards are roughly 12 inches high by 15 inches deep.

  DC low-voltage power will be supplied from external power supplies.

  Each crate will dissipate power in the range of 1-2 kW. Each crate will have a water-cooled heat exchanger to remove heat from the crate's local forced air system. The circulating air will have temperatures in the range 10-20 °C.

  Crates will have 'walk-in' accessibility during beam off periods.

- **Communications to/from Crate** -

  Multi-channel coax cables are used to carry the high- and low-range signals from each preamplifier to the crate. These cables are connected directly to the SCA cards by means of connectors on the front of each card. A typical distance from preamplifier to crate is 10 feet. For the redundant channels (section 3.1), only the High-range signal is used.

  3M flat ribbon cables will run from each preamplifier card to its associated PM Current Monitor card in the crate. They carry the anode dc signal currents to the PM Current Monitor card; the phototube high voltage control signals to the preamplifier card; and the charge injection pulse amplitude along with a strobe level to the preamplifier card.

  Optical fibers are used to transport the following signals to and/or from the crate (see 4.2.1):

  - Crate Event Data - A single 500 Mb/s fiber carries all digitized event data from the crate. This fiber is directly connected to an optical driver on the Data Collector card.
  - Clock & Trigger - Separate fibers to each crate are used for each of the seven signals in this group (a total of 40 x 7 = 280 fibers). The fiber(s) are directly connected to optical receiver(s) on the R/W Seq and Buffer card.
  - Crate Slow R/W - Two 100 Mb/s fibers, one for each direction, are used to carry the bi-directional Slow R/W signals to and from the crate. The two fibers are directly connected respectively to an optical transmitter and an optical receiver on the R/W Seq and Buffer card. Standard TAXI chips are used for data formatting.
  - Crate Trigger Data signals (a total of 40 x 8 x 8 = 2560 fibers) are carried from the crate to the Trigger processor. These cables are directly connected to optical transmitters on the SCA cards.

  Multi-conductor copper-wire cables carry DC power to the crate.

- **Intra-crate Communications.**

Within each crate, the following sets of signals are carried to/from the individual cards via backplane wiring:

- **Clock and Triggers** (7 signals) - These are distributed from the R/W Seq and Buffer card to the SCA cards. Nanosecond precision is preserved. These signals include the Fast Signal set defined in section 4.1.5.
- **Card Slow R/W Bus** (32 lines) - The Slow R/W data are distributed from the R/W Seq and Buffer card to the individual SCA cards over a parallel 32-line data bus.
- **Card Event Data Bus** (29 lines) - The event data prepared by each SCA card are transmitted to the Data Collector card via a 29-line high-speed data bus. In this context, 'high-speed' means a cycle time of 32 nsec. The 29 lines include 16 data lines, 12 card select lines and a 'finish' signal line.

- **SCA Cards** (8) - The prime function of the SCA card is to process the event data from the scintillator elements of the calorimeter. Each SCA card channel accepts analog signals from a preamp, stores and selects them in response to the Level 1 and 2 trigger signals, and digitizes the event data so selected. The digitized data are output to the Data Collector via the crate backplane.

  Each crate contains up to 8 SCA cards, each of which can accept 256 channels of analog input signals. Since each preamp outputs two analog signals (high and low ranges), an SCA card can process the signals from 128 primary (tower segment) scintillators or 256 redundant scintillators (high range only)--up to 1024 scintillators per crate.

- **R/W Seq & Buffer Card** - The R/W Seq & Buffer card receives the fast Clock & Trigger signals from the Local Computer and Data Buffer and distributes them to the users in the crate.

  It also acts as the crate's port on the Slow R/W communication network. It receives/transmits the Slow R/W data off the crate in bit-serial mode over two optical fibers (one for each direction). It receives/transmits the Slow R/W data within the crate in bit-parallel mode via the backplane.

  Each crate has one R/W Seq & Buffer card.

- **Data Collector Card** - The Data Collector Card acquires digital event data from the SCA Cards via a crate backplane bus--the Card Event Data bus. It outputs these data via an optical fiber to the LCDB card.

  Each crate has one Data Collector Card.

- **PM Current Monitor Cards** (4) - Each crate has four PM Current Monitor Cards. Each PM Current Monitor Card executes several functions in support of 256 photomultipliers and preamplifiers calibration:• Measures the anode signal current in each of the 256 phototubes;
  - Generates analog signals to control the amplitude of the charge signal injected into each group of eight preamplifier inputs (32 control signals for 32 groups of eight);

  - Enables or disables the injection of charge into the groups of eight preamplifier inputs (32 enable/disable controls);
  - Adjusts the timing of the Injection strobe that causes the injection of charge into the groups of eight preamplifier inputs (32 timing controls);
  - Generates analog signals to control the dc high voltage supplied to each phototube (256 control signals).

4.4 Signal Sources; Phototubes and Preamps

The light signals developed in each scintillator are detected by a photomultiplier tube. The phototube anode electrical signals are amplified by preamplifiers Figure 4.4 that are physically close to the phototubes. Each preamplifier develops a high-range and a low-range output, which are conducted by multichannel cables to the crate.

PHOTOMULTIPLIER AND PREAMPLIFIER CARD

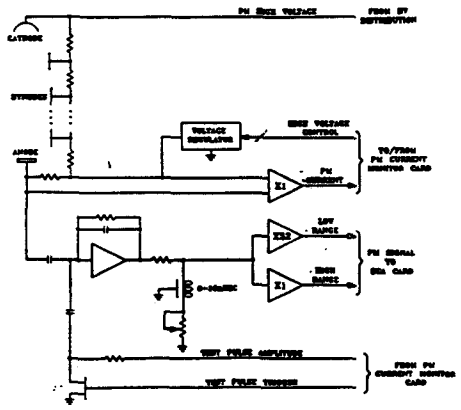


Figure 4.4

4.4.1 Phototube Logistics

The system will contain approximately 41,000 photomultiplier tubes. Each supports one scintillator channel. Groups of phototubes will be plugged into, and physically supported by, card assemblies that also have the wiring and components for the phototube voltage divider, voltage regulator and preamplifier. The magnetic shield for the tube is also physically supported by this assembly. Present plans are that the number of tubes in a group is eight; this number should change as the design progresses. The HV and phototubes are not included in the cost estimate.

The gain of each tube is remotely controlled. A tentative scheme for accomplishing this is shown in Figure 4.4. A common value of high voltage is supplied to the divider/regulator string for each tube in the group. Each tube then has a distribution scheme in which most of the high voltage appears across the tube's divider string, the remainder across the voltage regulator. By means of a dc control signal from the associated PM Current Monitor card, the value of voltage absorbed across the regulator can be varied, thereby varying the fraction of the high voltage available to the phototube, and thereby controlling its gain.

The fast (scintillator) signal at the anode of the phototube is capacitively coupled to the input of the preamp for that scintillator channel.

The slow, dc component, of the anode current is measured by a differential input amplifier that senses the voltage across the anode resistor. The dc gain of the phototube/scintillator combination is determined by measuring this voltage while a source of known strength is exposed to the scintillator.

4.4.2 Preamplifiers

Groups of preamplifiers are built directly on the cards that support the phototubes.

Because of the wide dynamic range (10^5) of the scintillator light signals, each preamp has two analog outputs--a high-range output and a low-range output, as shown in Figure 4.4. These overlapping ranges are separated by a factor of 25 in amplitude. The high-range signal covers the entire design amplitude range, which corresponds to an energy range of 0 to 2 TeV. The low range will saturate for the higher amplitude signals (above an energy of about 65 GeV).

The preamplifier has a delay-line shaping network. The signals from both the high and low ranges are shaped by this network.

For calibration, a charge signal of controllable amplitude can be injected into the input of each preamplifier. The amplitude of injected pulse is controllable in groups. The size of these groups is tentatively set at 128, but is subject to change.. The amplitudes applied to the groups are controlled via DACs in the PM Current Monitor cards in the crates (see Section 4.7). The DACs are controlled by the system controller. Timing of the injected pulse is determined by the Injection Strobe, which can be applied simultaneously (to within 2 nsec) to all 41,000 preamplifiers in the calorimeter.

4.4.3 High Voltage Distribution

The cabling and source of high voltage for the photomultipliers is outside the scope of this document at this time.

4.5 The Card Slow R/W Data Bus

The Card Slow R/W Data bus is the means by which individual components of the crate system are controlled and monitored

The R/W Seq and Buffer card in each crate acts as a buffer between the Card Slow R/W bus and the external Crate Slow R/W bus over which it receives/transmits Slow R/W data from/to the LCDB block dedicated to that crate. The transmission is over two bit-serial optical fibers, one for each direction. Only data traffic associated with the particular crate flows on these two fibers; the R/W Seq and Buffer card thus does no crate-address decoding on received command data. Slow R/W data travel in both directions on the crate's Card Slow R/W bus as 32-bit packets (words). Every packet has a 5-bit card address field and a 1-bit Response field. The remainder of the bits are assigned according to the particular use. The card address refers to the physical position of the card in the crate. (A crate address is not necessary at this level, since the fibers are dedicated to a particular crate.) The packets flow in bit-serial mode on the fiber and in bit-parallel mode on the backplane. The basic transfer speed for either mode is approximately 500 nsec per packet.

A compilation of the coding of packets is in Appendix B. Details of the Card Slow R/W bus timing and control and protocol will be in a future Appendix C.

4.5.1 Definition of Read and Write packets

Packets that are originated outside the crate by either the LCDB or the calorimetry system control are called (Slow R/W) Write packets, since they are 'written' to the card within the crate to which they are addressed. Some Write packets carry commands to be executed by the receiver and need no response; others carry requests for information from the receiver. A bit in each Write packet--the Response bit--signifies whether the addressed card is to respond with a Read packet. The (Slow R/W) Read packet typically carries information (data) on some feature within the card that will be useful to the LCDB or system controller in monitoring the operation of the addressed card.

If a Write packet contains an asserted ('1' state) Response bit, then the next packet transmitted via the Card slow R/W bus will be the associated Read packet. No further Write packets will be placed on the bus until the Read packet transaction has been accomplished, except in the case of a Response Time out

4.5.2 Card Address

Each Read and Write packet contains a field for a Card Address. This address is the physical location of the card within the crate. The card locations are numbered 0 to 20 from left to right as the crate is viewed from the front.

4.5.3 Slow R/W Write packets

Slow R/W Write packets are those received by the R/W Seq and Buffer card from the LCDB block. These packets typically contain a command addressed to a particular function within the crate. For a received data packet, the R/W Seq and Buffer card does a serial-parallel conversion and places the contents of the received packet on the 32-bit Card slow R/W Data bus.

The general format of Write packets is:

Card Address - Physical address of card in the crate. Cards are numbered 0 through 20 according to their position in the crate.

Response bit - '0' typically indicates that no Read packet response is expected after execution of the command in this Write packet.

'1' always indicates that the addressee is to transmit a Read packet in response to this Write packet.

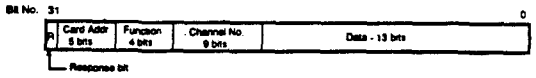
Function - Indicates the type of operation to be executed by the addressee.

0 - Generic function; e.g., the addressee can execute only one function.

1 - I.D. Request. Always sent with Response bit = '1'. Addressee must respond with its identification data. This may include type of card, serial number, etc. (see 4.5.7).

Others - Other function codes are listed in Appendix B.

Write packets addressed to SCA cards carry a channel address in a standard location when the function field contains a code pertaining to channel-related operations:



Channel No. - 0-255 used to address on of the 256 channels on an SCA card.

256-511 address other functions on an SCA card.

4.5.4 Read Packets

Read packets are generated by an addressee in response to a Write packet it has just received. An addressee is required to generate its Read packet as soon as possible after receiving the Write packet--in any case, within 10 microseconds.

If, for some reason, the addressee cannot assemble valid information to insert in the Read packet within 10 microseconds, it must send an Unable to Respond Read packet.

If the LCDB does not receive the response Read packet in a reasonable time, it can declare a Time out condition, send an abort command to the addressee, and start another transaction.

The format for a generic Read packet is:

Card Address - This is the physical address of the Read packet originator. The physical address is the position (slot) of the card in the crate in which it resides.

Data field - In the case of addressees on SCA cards, this will include the channel number and other data as necessary to identify the originator.

4.5.5 Card slow R/W bus Protocol Control Signals

The Card slow R/W bus is under the control of the Local Bus Sequencer function on the R/W Sequencer card (section 4.9). Specifications for the timing of operations and bus control signals will be developed during the course of the design work.

4.5.6 Card R/W Control function

Each card in the crate has a Card R/W Control function. This function interacts with the Card slow R/W bus control signals. It recognizes and accepts Write packets addressed to the card on which it resides. It prepares and outputs Read packets.

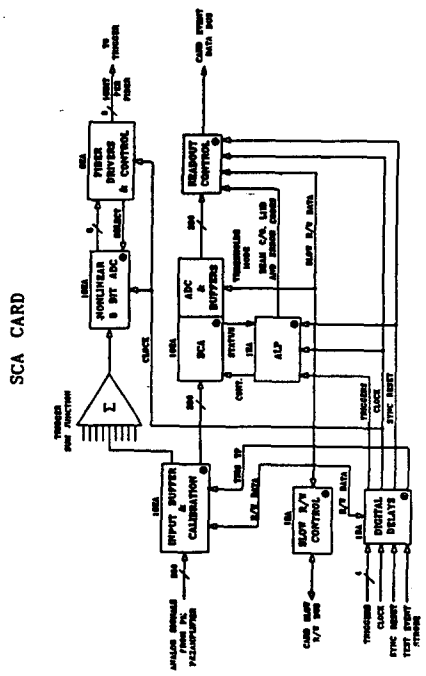
Each card has an internal bus structure appropriate to its particular needs with regard to Slow R/W interaction.

4.5.7 Card ID mechanism

Each card in the crate has a Card Identification, which can be read over the Slow R/W bus. The Card Identification consists of two fields, a Card Type code, and a Card Serial Number. Each unique card type has its own Card Type code; cards within that type have a unique serial number. By means of this mechanism, a remote system controller can 'map' the crate contents.

4.6 SCA Cards - Functional Description

A functional block diagram of the SCA card is shown in Figure 4.6. The prime function of the SCA card is to receive, process and digitize the signals from 256 analog signal channels. The functions of the individual blocks on the card are described in this section.



4.6.1 Digital Delay Function

Via crate backplane wiring, the digital delay block receives the Fast Signal set (section 4.1.5) from the R/W Seq and Buffer card. The timing of these signals is stable to about ± 0.5 nsec with respect to the beam crossing. However, because the propagation delays from the source of these signals to the particular SCA card may differ from card-to-card, a local means of correcting the propagation delay is provided.

This correction is done by the Digital Delay function, which can adjust, independently, the delay for each of the [seven] fast signals as appropriate for that particular card. The set points for each delay are received in Slow R/W Write packets. The commands containing the set points may originate either in the crate's LCDB card (particularly when the crate is running in a stand-alone mode) or from the calorimetry system controller.

The delay of each signal passing through the digital delay function is independently adjustable. The range of adjustment is 16 nsec; the precision of adjustment is 1 nsec.

The signals that have adjustable delays are:

- Level 1 Accept
- Level 1 Reject
- Level 2 Accept
- Level 2 Reject
- Clock (62 Mhz)
- Test Event Strobe
- Synchronization Strobe

4.6.2 Slow R/W Control Function

Details of the internal bus structure on the SCA card necessary to implement all the Slow R/W features will be developed as part of the design process.

4.6.3 Input Buffer and Calibration Function

The Input Buffer and Calibration function receives 256 channels of analog signals from the Photomultiplier Preamps. For Primary (see 3.1) scintillator channels, these will be both high- and low-level signals from 128 scintillators; for Redundant scintillator channels, these will be only high-level signals from 256 scintillators.

The Input Buffer and Calibration function can insert amplitude-programmed test pulse signals on selected channels. It passes the analog signals to the SCA functions. It also forms eight trigger sum signals each representing the analog addition of a group of 8 high-level preamp signals

The analog signals are received as single-ended analog signals with single delay-line shaping. These signals travel from preamp to Input Buffer card on a coaxial cable transmission line having a characteristic impedance of 50 ohms. This point will require more study.

The channels are numbered 0 to 255. For Primary scintillator channels, even-numbered channels are assigned to low-level signals from the photomultiplier preamps; odd-numbered to the high-level.

4.6.3.1 Buffering Function

The Buffering function receives the analog signals from the preamplifiers and electrically terminates the cables over which the signals arrive. It transmits copies of the signals to the SCA function, and copies of the high-range signals to the Trigger Summing function. It also provides for the injection of test event signals into the analog signal channels.

4.6.3.2 Trigger Summing Function

The Input Buffer card forms eight sum signals which are forwarded to the Trigger Sum Junction. Each signal is the sum of a group of 16 high-level analog signals from the primary scintillator channels; redundant channels are not used. Each such group typically represents a scintillator tower subtending 0.1 radians x 0.1 rapidity units. The summing preserves the timing and shape of the input signals to allow association of the trigger information with a particular beam crossing.

4.6.3.3 Calibration Function

The Input Buffer and Calibration card can insert calibration pulses of pre-programmed charge amplitude on any selected group of signal channels. The programming of charge amplitude and group selection is done by the system controller via Slow R/W data. The generation of calibration pulses is timed by the Test Trigger. The precision of time-of-arrival of the Test Trigger is adequate to generate calibration pulses that emulate any selected beam crossing.

Typically, the system controller programs the amplitude and selects the group of channels with up to 16 Hit Pattern packets, then issues a Test Trigger pulse. A calibration pulse of the programmed amplitude is then inserted into each selected channel.

4.6.4 SCA Function

The Switched Capacitor Array (SCA) function is physically composed of 16 SCA integrated circuits (ICs). Each SCA IC has 16 input and output channels; the SCA function on an SCA card thereby accommodates 256 channels.

A brief description of the functional operation of the SCA IC follows.

The SCA IC is an externally addressed (steered) analog memory. It contains 4096 sample and hold analog memory cells subdivided into 16 channels of 256 cells each. By means of steering addresses, externally generated by the ALP function, each cell can be assigned to one of four states: Idle, Level 1 Pending, Level 2 Pending, and Output Pending. The ALP function applies

the identical steering addresses to all 256 channels. All 256 channels are therefore operating in precisely the same manner.

The SCA IC can sample and store the level of analog inputs at a 62 Mhz rate. It can simultaneously store and retrieve analog samples from two different cells. It is therefore capable of storing and selecting samples of signals from the scintillation calorimeters in accordance with the Level 1/2 Trigger Protocol.

The SCA function has as its inputs the 256 analog signals from the Input Buffer & Calibration function. These signals are sampled and stored, at a 62 MHz rate, in the Level 1 Pending lists. In response to Level 1 and Level 2 triggers, some of the stored samples are converted to the Output Pending state (these are the samples relevant to accepted events). All 'bookkeeping' necessary to accomplish this is performed by the ALP function. Analog samples stored in the Output Pending list are output to the ADC & Buffers function under control of the ALP function.

4.6.5 ADC and Buffers Function

The ADC & Buffers function is physically composed of 16 ADC integrated circuits. Each IC contains 16 12-bit analog-to-digital converters, plus 16 digital FIFO buffers that can store the results of the last four analog to digital conversions. The ADC & Buffers function on an SCA card thereby accommodates 256 channels. A conversion takes 32 μsec. The result of each conversion is a 12-bit number, which is placed in the four-word FIFO buffer for that channel.

The operation of the ADC & Buffers function is controlled by the ALP function. Under control of the ALP, each channel of the ADC & Buffers function receives an analog level from the SCA function. The ADC & Buffers function may operate in either of two modes: a sparse mode; or a non-sparse mode.

In the non-sparse mode, each ADC channel performs an analog-to-digital conversion on the analog level presented to it by the SCA function. All 256 channels perform the conversion simultaneously. All 256 channels of FIFO buffer memory simultaneously receive the 12-bit results of the conversion. Digital words that reach the bottom of a FIFO are available to be transferred to the Readout Control function. The transfer is via a local (card-level) 12-bit event data bus, with appropriate control signals (see later section for details).

4.6.6 Selection of Event Data Mode

The system controller, via the Slow R/W bus, may command the ADC and Buffers function to use on of three criteria for selecting the event data that it transfers to the Readout Control function. The three resulting modes of operation are:

- **All data mode** - The results of all 256 ADC conversions are transferred in monotonic order;
- **High/Low mode** - Analog signals from primary scintillators (section 4.1) are divided into low- and high-ranges. Each range is separately digitized. In this mode, only the the low-range digitized value is transferred (even-numbered channel) is transferred, unless this value is at the upper end of its range (4095). If so, only the high-range digitized value is transferred (odd-numbered channel). This decision is individually made on each channel for each event data transfer.

In this mode, all scintillator channels are represented in the output stream, however only 128 SCA channels appear in the output stream--some will be even, and some will be odd. The SCA channels that do appear are in monotonic order;

- **Sparse mode** - This is a special case of High/Low mode, in which only those channels whose digitized value is above a programmed threshold are output. The FIFOs are read out in monotonic order; however, those channels whose analog sample level was below threshold are skipped.

The selection of one of the three modes is commanded via the Slow R/W data bus.

4.6.7 Readout Control Function

Each SCA card has a Readout Control function. Its purpose is to control the flow and format of event data from the 16 ADC & Buffer functions on each card onto the Card Data Event bus toward the crate's R/W Seq & Buffers block.

On the SCA card side, it interfaces to, and controls, the local (card-level) 12-bit event data bus. After a Level 2 Accept trigger, and after time for the analog-digital conversion and FIFO queuing, it requests event data from each channel in turn--starting with channel 0 and ending with channel 255.

The sequential transfer of event data from each channel is accomplished with four simple control signals:

- Data Request - Generated by the Readout Control Function. This is a token-passing (daisy-chain) request mechanism that is threaded through the ADC & Buffer functions of all 256 channels.
- Data Ready - Generated by the currently addressed ADC & Buffer function. This indicates that a channel now 'owns' the token, and is outputting an event data word or a channel id word as dictated by the state of the ID/Data signal. (In the non-sparse mode, this signal permits the transfer of event data to be self-timed, not dependent of the number of skipped channels.)
- ID/Data - Generated by the Readout Control Function. A '1' requests the ADC & Buffer function that 'owns' the token to output a channel ID number; a '0' requests it to output the event data word for that channel.
- Read Transfer clock - Generated by the Readout Control Function. A pulse on this signal line causes the token to pass from channel to channel.

A brief description of the steps in the readout of an event in non-sparse mode are as follows: First, the Data Request token is passed to channel 0's ADC & Buffer function. The Data Ready signal is asserted. The ID/Data signal is put in the '1' state. The Channel ID for channel 0 is placed on the local bus. The ID/Data signal is put in the '0' state. The event data word is placed on the local bus.. When the Readout Control function has accepted the word, it pulses the Read Transfer clock line, causing the Data Ready signal to be de-asserted and the token to be passed to the next channel. This process continues until the Readout Control function gets the token from the last channel, which signals the end of the readout for that event.

NOTE: Optionally, for a non-sparse mode, the time to readout an event may be cut in half if the Readout Control function keeps its ID/Data line in the '0' state, and pulses the Read Transfer clock after every word is transferred. In this fashion, only event data words are moved on the local bus; the event id numbers are inserted into the Card-Event block (see below) by the Readout Control function.

The process is similar for the sparse mode, except that channels without an event data word for that event simply pass the token on to the next channel without pause, and without asserting Data Ready.

Details of timing, signal levels, etc., for the local event data bus will be developed in the course of the design work and will appear in Appendix C.

The Readout Control function gathers and formats the data for an entire event before forwarding them in a Card-Event block via the Crate Event Data bus.

The event data formatting performed by the Readout Control function includes:

- Expand each data word received on the local data bus from 12 bits to 16 bits by adding a 4-bit Code field, with appropriate code as shown in the block format below.
- As a preamble for the Card-Event block, add three 16-bit words--Board Number, Event Error Code, and Level 1 Trigger Number.

The format of a Card-Event block on the crate's Event Data Bus is:

CODE	VALUE	COMMENTS
2	Board Number	
1	Error Number	
6	Level 1 Number	
3	Channel No. *(1st)*	
4	Event Data Value from *(1st)* channel	
3	Channel No. *(2nd)*	
4	Event Data Value from *(2nd)* channel	
	etc.	} Repeat Channel no.
	etc.	} and event data fields
3	Channel No. *(last)*	
4	Event Data Value from *(last)* channel	

A description of the Crate Event Data Bus is given in section 4.8.1.

4.6.8 Address List Processor Function

As mentioned in section 4.6.4, each analog memory cell in the SCA is assigned one of four cell states: Idle, Level 1 Pending, Level 2 Pending, and Output Pending. The Address List Processor (ALP) performs the bookkeeping involved in assigning and memorizing the state of each cell.

Internally, the ALP maintains four lists of cell addresses; the four lists corresponding to the four cell states. In a reset (power up) condition, the addresses of all cells are assigned to the Idle list; the other three lists are empty. After reset, as each analog sample for each beam crossing is stored by the SCA, the address of the cell holding that sample is placed in the Level 1 pending list. A Level 1 Accept Trigger causes the address of the cell holding the cell from the appropriate beam crossing to be placed in the Level 2 Pending list. A Level 2 Accept causes the appropriate cell address from that list to be placed in the Output Pending list. The contents of cells whose addresses are in the Output Pending list are sequentially transferred to the ADC for digitization. Addresses of cells 'hit' by Level 1 or 2 Rejects or whose contents have been digitized are returned to the Idle list.

All cell address communication between the ALP and the SCA is via two steering address buses. One carries the address of the next cell to receive an incoming analog sample; the other carries the address of the next cell to be digitized. The ADC & Buffer Function commences the digitization of a sample upon receiving a Digitize command from the ALP.

The ALP list processing is identical for both sparse and non-sparse modes.

The ALP list processing is stimulated--i.e., controlled--by the four trigger signals: Level 1 Accept; Level 1 Reject; Level 2 Accept and Level 2 Reject. The processing is timed by the 62 MHz clock. Upon receiving a Card Reset, The ALP puts all cell addresses in the Idle list. When Card Reset is removed, the list processing begins at once.

The number of cell addresses available to the ALP is equal to the number of capacitive storage elements per channel of the SCA. This number is frozen into the design of the SCA, and must likewise be frozen into the design of the ALP.

Certain operational 'errors' may occur in the operation of the ALP. For example, an insufficiently high rates of Level 2 Accept/Reject triggers could result in all storage locations in the SCAs being in the Level 2 Pending list. There would therefore be no more locations available in the Idle list in which to store incoming data, which would thereby be lost. Means of detecting and reporting these errors will be developed in the design process, and an assessment of the effect on event data reliability will be made.

4.6.9 Trigger Sum Function

The Trigger Sum function consists of 16 Trigger Sum Junctions. Each junction performs a continuous analog sum of the analog signals in the high-level range of eight scintillator channels. This grouping effectively defines towers of 0.1 radians x 0.1 in rapidity.

4.6.10 Nonlinear ADC Function

The Nonlinear ADC function consists of 16 Nonlinear 8-bit ADCs. Each digitizes the analog output of one of the 16 Trigger Sum Junctions at a 62 Mhz rate. The purpose is to contribute towards the system trigger decision which is made every cycle of the 62 MHz beam crossing clock.

The span of the analog input signal is equivalent to an energy range of 300 Mev to approximately 5 Tev in the scintillator tower. The digital output is an 8-bit number.

The non-linear relation between the value of the digital output and the analog input will be specified during the design process.

4.6.11 Fiber Drivers and Control Function

The Fiber Drivers and Control function acquires the digital trigger data from the Non-linear ADCs and forwards them off the detector via optical fibers. On each SCA card, the Fiber Drivers and Control Function consists of eight Fiber Driver and Control sections.

Each section acquires the eight-bit data words from two Non-linear ADCs every 16 nsec (each tick of the 62 MHz beam clock). It assembles the two eight-bit words into a 16-bit Trigger Tick' packet. The packet is over-encoded into an 18- or 20-bit word (to maintain 1/0 equality), bit-serialized and output onto an optical fiber. One or two synchronization words are inserted into the data stream periodically to ensure word synchronization at the receiving end.

The bit-serial transmission speed on the fiber is approximately:

$$18 \text{ bits/packet} \times 62 \times 10^6 \text{ packets/sec} = 1.12 \text{ Gbit/sec.}$$

Each SCA card therefore outputs eight continuous streams of Trigger Tick packets on eight fibers. Since each fiber is a dedicated point-to-point medium, the identification of the origin of the data is implicit in the physical fiber. [We may later decide to include an additional identification scheme for positively identifying individual fibers in the large bundle that comes to the trigger processor. This could be as simple as a mechanism for turning the stream on and off via Slow R/W control, which is addressed to a particular driver on a particular card.]

It is essential that the trigger processor know the correlation between beam crossover number and Trigger Tick packets--i.e., which of the stream of incoming packets corresponds to a particular clock tick. An initial correlation can be made via the calibration facility--i.e., by injecting accurately timed light pulses into the scintillators. Controllable delay functions on either the sending or receiving ends of the fiber links may be required to equalize the crossover-to-packet-arrival delays at the trigger processor. During data-taking, correlation is maintained (or re-established) by the synchronization words.

4.6.12 SCA Card Error Reporting

Surges in trigger rates or glitches of various sorts may cause the SCA card functions to malfunction. Errors in operation that degrade the event data must be reported to the event processors. This reporting is via the SCA Error Code word which is inserted in each SCA-Event data block. Appendix A lists the presently assigned error codes. More codes will undoubtedly be assigned as the design of the system progresses. (See comments on ALP errors in section 4.6.7.)

4.7 PM Current Monitor Card

A block diagram for the PM Current Monitor Card is in Figure 4.7. Each card performs the following functions for the 256 photomultiplier tubes and preamplifiers that it supports:

- On command, it can measure the average dc anode current of any one of the 256 photomultipliers. The measurement datum is read out over the Card Slow R/W Data bus under control of either the LCDB or the calorimetry system controller.
- It controls the amplitude of the calibration charge pulse injected into each group of eight preamplifiers for calibration. This control is via 32 DACs, each of which is loaded via the Card Slow R/W Data bus.
- It enables/disables the injection of the charge pulse into each group of eight preamplifiers. This control is via a 32-bit latch, loaded via the Card Slow R/W Data bus.
- It controls the timing of the injected charge pulse over a range of 16 nsec. This control is via 32 digitally controlled time delays, each of which is controlled via the Card Slow R/W Data bus.
- It controls the dc voltage applied to each phototube. This control is via 256 DACs, each of which is controlled via the Card Slow R/W Data bus.
- It supplies dc power to the preamplifier cards.

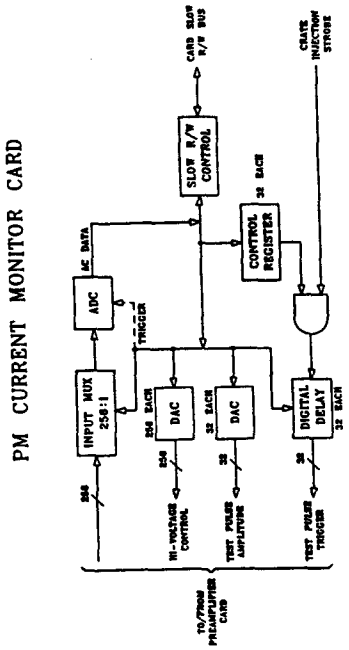


Figure 4.7

All the above signals are conveyed via sets of cables between the PM Current Monitor cards and the preamplifier cards (which are physically closely coupled to the phototubes). These cable runs are approximately 10 feet in length.
The cable between each single preamplifier card and the PM Current Monitor card includes the following signal paths plus an appropriate number of ground returns:

- 8 wire pairs carrying anode signal-current signals to the PM Current Monitor card;
- 8 wires carrying phototube high-voltage control signals to the preamplifier card;
- 1 wire (pair) carrying the injection amplitude control signal;
- 1 wire (pair) carrying the injection strobe signal (nanosecond timing).

Of the above signals, all but the last are (slow) dc analog signals, appropriately filtered for noise suppression. The injection strobe signal must be conveyed with timing precision and stability to the nanosecond level.
On the PM Current Monitor card, one of the 256 anode signal-current signals is selected by the input MUX and fed to an ADC (which need not be a fast ADC).
The anode signal-current signal selection is controlled via the Slow R/W bus. Reception of a Slow R/W Write packet that performs a selection will also cause the ADC to be triggered after a delay appropriate to the speed of the input MUX. The ADC's digital data are read out onto the Slow R/W bus as the Read packet that is the response to the preceding Write packet. (There should be no intervening traffic on the crate's Slow R/W bus.
The dc control signal for controlling a phototube's high voltage originates in one of 256 DACs on the PM Current Monitor card. These DACs are loaded via the Slow R/W bus .
The dc control signals for setting the amplitude of charge signals injected into preamplifier inputs are controlled by 32 12-bit DACs on the PM Current Monitor card, one DAC for each group of eight preamplifiers. These DACs are also loaded via the Slow R/W bus.
The timing of the charge signals injected into the eight preamplifier inputs on a preamplifier card are controlled by a 32 digital delay units on the PM Current Monitor card. Each unit controls the delay of the injection strobe supplied to a preamplifier card. These delays are controlled via the Slow R/W bus. The individual injection strobes can also be enabled or disabled via the Slow R/W bus.

4.8 Data Collector Card

The function of the Data Collector Card is to gather the event data from all SCA cards in a crate and to forward them, via an optical fiber, to the LCDB block. A crate may contain up to 12 SCA cards. A block diagram is in Figure 4.8.

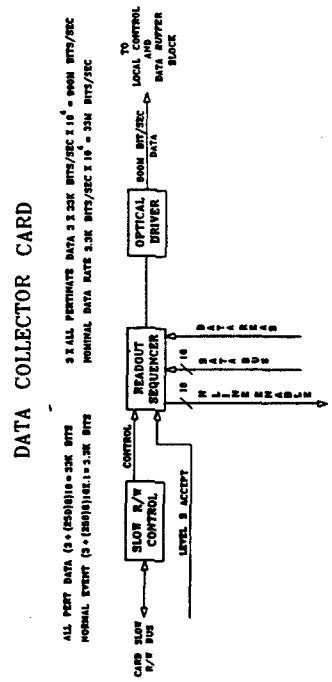


Figure 4.8

Typically, a readout operation is begun when the Data Collector card receives a Level 2 Accept trigger. It then commences to acquire the card-event block (section 4.6.6) from each SCA card that pertains to the 'current' event. (The 'current' event is the event associated with the last Level 2 Accept.) As data are received, they are immediately output onto a 500 Mbit/s optical fiber link to the LCDB block. The set of SCA-event blocks for the current event constitutes a Crate-Event block, which contains the complete event data set acquired by the crate for the current event.

In an typical readout operation, the Data Collector card acquires SCA-event blocks from SCA cards as they become available. It forwards these blocks over the optical fiber link in the sequence in which it acquired them. Event data blocks from several events may be intermixed in the stream of SCA-event blocks output by the Data Collector card. Each, however, is tagged with an Event ID, which enables a downstream entity to steer the blocks into files containing, eventually, complete sets of data from the entire calorimeter for particular events. This feature may be required in an SSC upgrade to a luminosity of 10^{34} It is not expected to be used in initial operation.

4.8.1 Card Event Data Bus

The event data flow from SCA cards to Data Collector card is via a high-speed backplane bus. In this context, high-speed implies a 16-bit word transfer cycle of 32 nsec. The bus consists of 16 data lines, 12 dedicated slot pointers (N lines), and a set of readout control lines.

Details of the Backplane Event Data Bus are given in Appendix A. As work progresses, the appendix will include signal line definitions and timing of transfers of the event data words.

4.8.2 Transfer of SCA-event Blocks

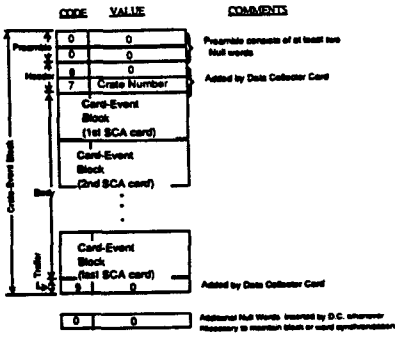
The Data Collector card enables the readout of a particular SCA card by asserting the dedicated N line for the slot in which the SCA card resides. The SCA card then places on the data lines, word-by-word, the Card-Event block it has accumulated for a complete event. (The format of these data is shown in 4.6.6.) The timing of the word-by-word transfer is controlled by the Data Collector card via the readout control lines. Via one of the readout control lines, the SCA signals the Data Collector card when the last word of the current Card-Event block is on the data lines. The Data Collector card then activates the N line for the next SCA card.

When all SCA cards have transferred the Card-event block for the current event, the Data Collector card then processes subsequent Level 2 Accept triggers.

4.8.3 Crate-Event Block

In the typical data flow sequence, the Data Collector card gathers and outputs the complete data set generated within the crate for the current event. This data set is formatted as a Crate-Event block.

A Crate-Event block basically consists of the card-event blocks from each SCA card resident in the crate, ordered by slot number of the SCA card, together with two header words, and followed by a trailer word. The format of a Crate-Event block is:



4.8.4 Fiber Format and Synchronization

A 16-bit data word is launched upon the fiber every 32 nsec (two clicks of the beam clock). Since there will not always be a data word ready to send, the Data Collector card inserts Null Words to occupy 32 nsec periods where no data word is available. This occurs, for example, between event blocks when the Level 2 Accept rate is low. A Null word consists of all zero--i.e., both the Code and Value are zero. Null words may be inserted anywhere within or without a Crate-Event block, and are to be discarded by the receiver.

The mechanisms for establishing and maintaining block and word synchronization will be further developed during the course of the design work.

4.9 R/W Sequencer Card

A block diagram of the R/W Sequencer card is in Figure 4.9. It is the crate's port for the Clock and Trigger signal path and the Crate slow R/W path, both of which lead to the LCDB block. It receives clock and trigger signals from the Clock and Trigger path and repeats them on the backplane of the crate, by which the signals are distributed to the other cards. It acts as a bi-directional repeater between the Card slow R/W backplane bus and the Crate slow R/W path for transactions involving its crate.

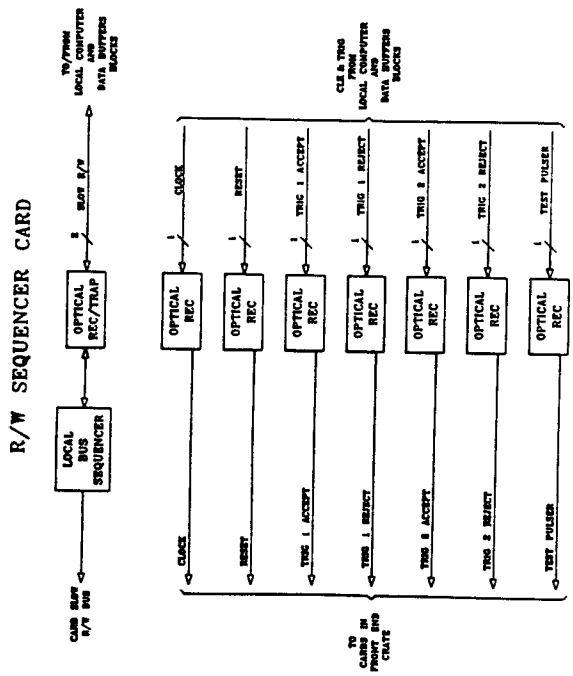


Figure 4.9

As shown in Fig. 4.9, each of the seven fast signals on the Clock and Trigger path is received via an optical fiber. An optical receiver for each signal is on the card. The received signals are repeated onto the crate backplane. The Crate slow R/W path that connects the R/W Sequencer card to the LCDB block consists of two fibers, one for each direction of communication. An optical receiver and an optical transmitter to interface to these two fibers are on the card.

4.9.1 Local Bus Sequencer function

Signals received over the Crate slow R/W path are transferred verbatim to the Local Bus Sequencer function. These received signals will be in the form of 32-bit Write packets (section 4.5) together with synchronization and redundancy bits. All packets received by the card will be intended for this crate; the LCDB block is responsible for selecting and forwarding only those Write packets that are relevant to this crate.

The Local Bus Sequencer function receives the incoming continuous bit-serial stream originated by the LCDB. A large part of this stream will carry null words, whose purpose is to maintain word and bit synchronization at the receiver. The function performs a serial-parallel conversion on incoming words and extracts those conveying Write packets; null words are discarded. It also performs a redundancy check on the word conveying the Write packet. If the redundancy check is OK, the Write packet is placed on the Card slow R/W bus, together with the necessary control signals. If the Response bit in the Write packet is '1', the Local Bus Sequencer acquires the associated Read packet from the Card slow R/W bus, performs a parallel-serial conversion, adds synchronization and redundancy bits, and transmits via the Crate slow R/W path to the LCDB block. When no Read packets are waiting to be transmitted, it places null words on the outgoing Crate slow R/W fiber.

The control of the transactions on the Card slow R/W bus is described in Section 4.5.5.

Received Write packets containing errors as detected by the redundancy check are not forwarded to the Card slow R/W bus. The Local Bus Sequencer function prepares and transmits a psuedo-Read packet informing the LCDB of the error.

4.9.2 Slow R/W Control function

The Slow R/W Control function on an R/W Sequencer card has identical functions to those on other cards, such as SCA cards (section 4.6.2). Although it is on the same card as the Local Bus Sequencer, it behaves as if communicated via the Card slow R/W bus. Its functions are to detect Write packets addressed to the slot in which the R/W sequencer card resides, and to apply the packet contents appropriately to the Optical Receiver functions.

4.9.3 Optical Receiver function

The optical receivers convert the optical signals received on the fibers to electrical signals, which are transmitted to the other cards on the crate backplane.

4.10 The Local Computer and Data Buffers (LCDB) Block

The Local Computer and Data Buffers (LCDB) block, situated at Ground Level I, acts as the interface between two Front-end blocks (crates) and the part of the calorimetry system located at Ground Level II. A tentative block diagram is in Figure 4.10a. This figure depicts the main functionalities of the LCDB block; however, the precise way in which the functions are partioned

within the block will be a subject of intensive study and development. This present description should be considered primarily a cataloging of the operations carried out in the LCDB block.

As shown in Figure 4.10a, the LCDB block has four main functions--the Buffer Memory function; the Clock Distribution function; the Slow Communication function; a local computer (CPU) function; and a Communication Port. All but the CPU and Communication Port functions are duplicated--i.e., there is a separate functional block for each of the two crates that the LCDB services.

4.10.1 Buffer Memory Function

The basic operating mode of the buffer memory function (see Figure 4.10b) is to act as a store-and-forward node for the event data from a crate, receiving event data via the Crate Event Data path, and forwarding them to the Event Collector block, which is located at Ground Level II.

The Buffer Memory function has other modes of operation including: the trapping, for local analysis, of an event; storing data (and not forwarding them) in memory for later use; forwarding toward the Event Collector a synthesized set of event data for diagnostic purposes.

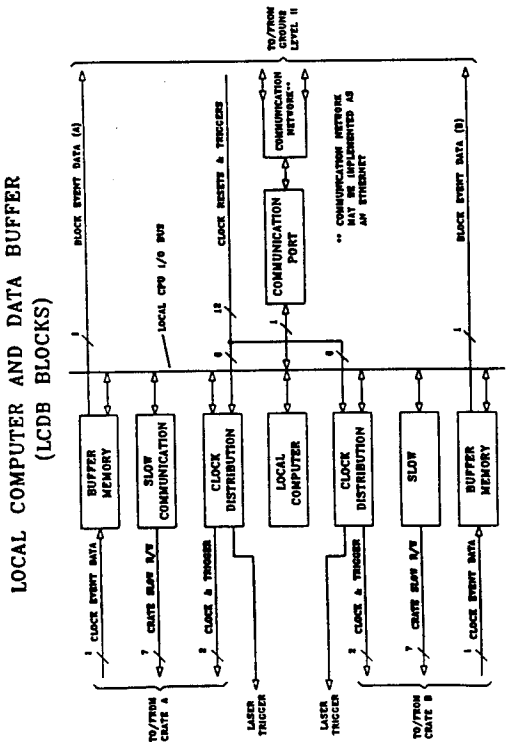


Figure 4.10a

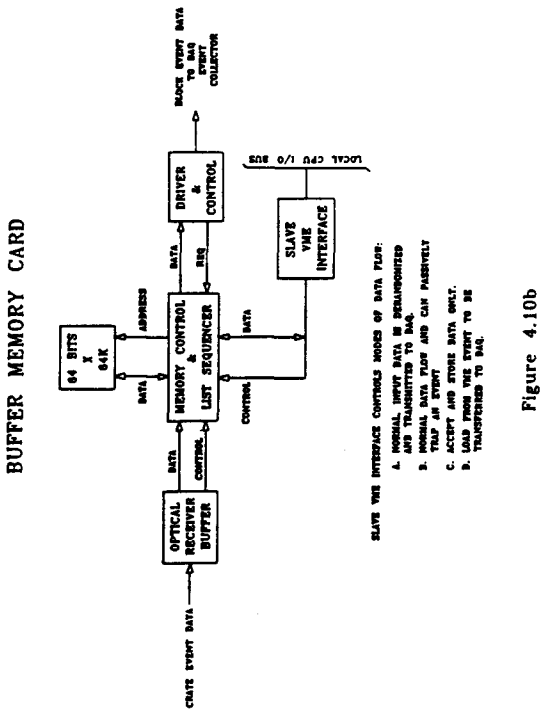


Figure 4.10b

4.10.2 Clock Distribution Function

This function (see Figure 4.10c) is responsible for supplying the Fast Signal set of Clock and Trigger signals to a crate via the Clock and Trigger path. The set of signals may have originated in either of two places. During normal event-taking operation, it will originate in the calorimetry system's Global Trigger processor. Alternatively, for testing or diagnostics, it may be locally generated within the Clock Distribution function under control of the CPU function. In the local mode, arbitrary patterns of Level 1 and Level 2 triggers, reset and test pulses can be programmed under the control of the local CPU function.

Selection of one or the other source of the Fast Signal set is via the MUX, which in turn is controlled by the CPU function.

The propagation delay of each of the Fast Signal set through the function is under control of the CPU function.

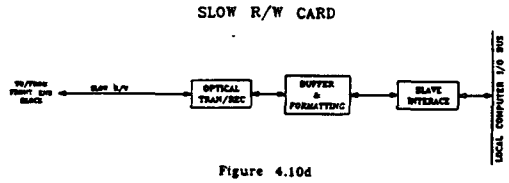


Figure 4.10d

4.10.3 Slow Communications Function

This function (see figure 4.10d) sends and receives Write and Read packets to or from a crate via the Crate Slow R/W path. Both sending and receiving is under control of the CPU function.

CLOCK DISTRIBUTION
AND LOCAL CONTROL FOR TESTING CARD

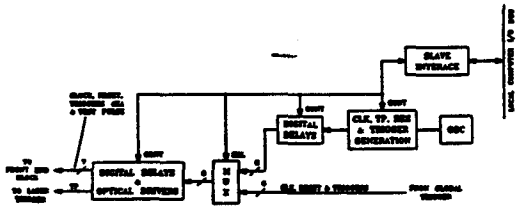


Figure 4.10c

4.10.4 Communication Port Function

The Communication Port Function is a node on the Ethernet-like Communication Network. Via this node, it sends/receives bit-serial communications from Ground Level II (calorimetry system controller). It transfers these communications to/from the CPU function via the bit-parallel Local CPU I/O bus performing serial-parallel and parallel-serial conversions and reformatting as necessary.

Some communications will be replicas of Write and Read packets appropriate to the Slow R/W paths. Other communications will be in the form of software downloads or other block transfers to/from the CPU function.

4.10.5 CPU Function

The core of the CPU function is a microcomputer located within the LCDB package. The microcomputer will be based on a fast, 32-bit word-size, microprocessor (such as the 68040). It will be supported by a small ROM containing a simple operating system, and several megabytes of RAM. On power-up the CPU will initialize itself and install the operating system from ROM. This operating system will include the ability to communicate (for example by remote procedure calls) with the calorimetry system's controller via the Communication Network. Typically, the calorimetry controller will download one or more application programs and appropriate data into the CPU function's RAM via the Communication Network, and command the CPU to begin execution of a downloaded program.

The CPU will be able to execute a number of tasks. Among these are:

- **Oversight of Slow R/W communication** - The CPU acts as the local port on the Communications Network. From the traffic on this network, the CPU separates the Slow R/W communications (commands) from the calorimetry system's controller addressed to either of the LCDB's crates. It forwards these to the appropriate one of the two Slow R/W functions, which in turn transmits it to its crate as a Write packet. Any Read packets resulting from the Write packet are received by the Slow R/W function and passed on the the CPU. If appropriate, the CPU forwards the information to the system controller.

  The CPU can also originate and interpret Slow R/W traffic to/from either of its two crates, as required in the execution of its monitoring operations. In this regard, it has as much power over the two crates as the system controller.

- **Local Trigger Generation** - By virtue of its control over the Clock Distribution function, the CPU function can choose between two sources of the the complete Fast Signal set--Clock, Triggers and Resets. One source is the calorimetry system's Global Trigger processor; the other is the source located within the Clock Distribution function. The latter is essential during stand-alone operation.

  The CPU also has control over the generation of triggers to the lasers that inject test light pulses into the scintillators.

- **Stand-alone Operation** - Once downloaded with the requisite application programs, the CPU function can operate its two-crate system in a stand-alone mode for testing or diagnostics. In this mode, the crates can be exercised exactly as if part of the complete calorimetry system. The CPU will be able to command the generation of arbitrary patterns of Level 1 and Level 2 triggers, for example, as mentioned in section 4.10.2.

- **Analyses of Crate Event Data** - The CPU will be able to extract segments of the Crate Event Data stream that passes through the Buffer Memory function. This may enable it, for example, to analyze the performance of various entities in the front-end blocks, to collect error statistics, etc.

APPENDIXES

Appendix A - Uniform Event Data Format

At all points in the system, event data are uniformly formatted as 16-bit words. Each word has two fields: a 4-bit Code field, and a 12-bit Value field.

Code	Value
4bits	12-bits

The following table lists the codes and the value ranges expected for each code. It also lists the point in the system at which the coded word is inserted into the event data stream.

CODE	NAME	SOURCE	VALUE RANGE
0	Null Word	Data Collector	0
1	Beam Crossover Number	SCA Card/RO Control	0-4095
2	SCA Card Slot Number	SCA Card/RO Control	0-20
3	SCA Card Channel Number	SCA Card/ADC Buffer	0-255
4	Event Datum	SCA Card/ADC	0-4095
5	SCA Card Error	SCA Card	See Error table
6	Level 1 Accept Number	SCA Card/RO Control	0-4095
7	Crate Number	Data Collector	0-127
8	Start of Block	Data Collector	0
9	End of Block	Data Collector	0
10	Word Count	LDCB Buffer	0-4095

Notes:

Null Word: Null words are used as 'fillers' to preserve the word synchronization of a data path. They may be stripped out of the stream by downstream buffering functions.

SCA Card Slot Number: The physical position (card slot) of the card in the Front-end crate.

SCA Card Channel Number: For primary (non-redundant) scintillators, even-numbered values refer to low-level ranges; odd-number to high-range. The primary scintillator associated with an event datum can be inferred by ignoring the least significant bit of the SCA Card Channel Number.

Event Datum: The magnitude of the signal for a particular channel.

SCA Card Error: The following table lists the significance of various error values that have been assigned. More assignments may be made as the design progresses.

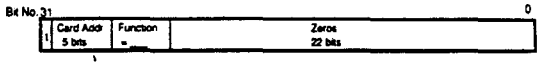
VALUE	SIGNIFICANCE
0	No Error
1	ADC Buffer Overflow
2	ALP Buffer Overflow
3	Busy/Unable to respond
4	
5	

Appendix B - Slow Read/Write Bus Packet Formats

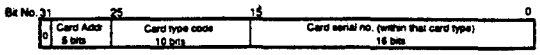
The basic specifications of the Card Slow R/W system are given in Section 4.5. In this appendix, the specific formats for many of the Write and Read packets are listed.
Each type of Write packet has a unique Function code. These function codes have not yet been assigned.

B1.0 Card ID mechanism

Each card in the crate (including the R/W Seq and Buffer card) has a Card Identification, which can be read over the Slow R/W bus. The Card Identification consists of two fields, a 10-bit Card Type code, and a 16-bit Card Serial Number. Each unique card type has its own Card Type code; cards within that type have a unique serial number. The format for the write packet requesting a card id is:



The format for the read packet response is:



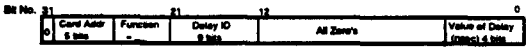
By means of this mechanism, a remote system controller can 'map' the crate contents.

B2.0 SCA Card Digital Delay Function

On the SCA card, the time delay for each signal in the Fast Signal set may be individually adjusted within a limited range. The set points for each delay are received in Slow R/W Write packets. For this purpose each delay is assigned a 'Delay ID' in the range 0-262. The delay of each signal passing through the digital delay function is independently adjustable. The range of adjustment is 16 nsec; the precision of adjustment is 1 nsec.
The signals of the Fast Signal set that have adjustable delays and their Delay ID's are:

- Level 1 Accept (Delay ID = 256)
- Level 1 Reject (= 257)
- Level 2 Accept (= 258)
- Level 2 Reject (= 259)
- Clock (62 Mhz) (= 260)
- Test Trigger (= 261)
- Card Reset (= 262)

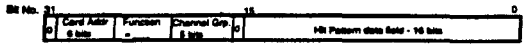
The format of a typical Slow R/W Write packet setting the delay of a particular signal is:



B3.0 SCA Card Calibration Function

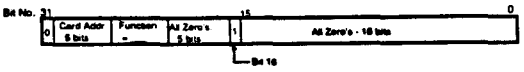
B3.1 Hit pattern packet

The Channel Group field defines a group of 16 channels to which the Hit Pattern applies. (The four least significant bits of Channel number are omitted from the Channel Group field.) The Hit Pattern field contains 1's and 0's to control (1 = on, 0 = off) the application of the calibration pulse to each of the 16 channels in the channel group. The result of this Write packet is to update 16 of the 256 bits in the Input Buffers Hit Pattern register. Up to 16 such Write packets are necessary to define a Hit Pattern covering all 256 channels on an SCA card.



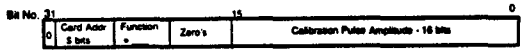
B3.2 Reset Hit Pattern packet

This resets to zero all Hit Pattern bits stored in the Input Buffers Hit Pattern register (all 256 channels not hit).



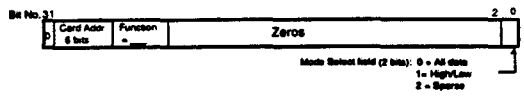
B3.3 Amplitude Control packet

A 16-bit field carries the Calibration Pulse amplitude for the SCA card. Any subsequent Test Event Strobes received by the card will inject pulses of this amplitude into channels enabled by the Hit Pattern register.

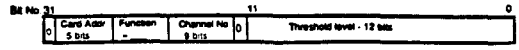


B4.0 SCA Card Event Data Mode Select

Section 4.6.6 lists three data modes for the ADC and Buffers function of the SCA card. A particular mode is selected by a Write packet. The format is:



For the Sparse mode, threshold levels are transmitted to the ADC & Buffers function via the Slow R/W data bus. The format on the Card slow R/W bus is:

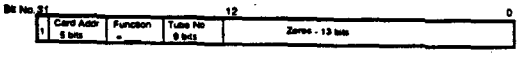


B5.0 Phototube Monitor Card

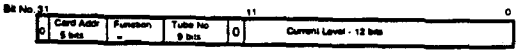
B5.1 PM Monitoring Channel Selection and Readout

Selection of the particular phototube whose anode current is to be monitored is accomplished via a Write packet. Reception of this packet by a Phototube Monitor card causes the current monitor ADC to be triggered and to develop a 12-bit number representing the present value of the current.

The Write packet format is:

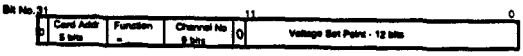


The Read packet in response to the above is:



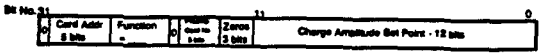
B5.2 Phototube HV set

The high-voltage supplied to each phototube is controlled by a DAC. The format for the Write packet that loads a particular DAC is:



B5.3 Charge Amplitude control

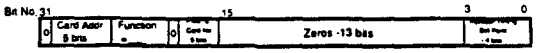
The format for the Write packet that loads a particular DAC is:



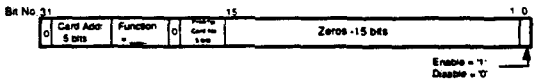
In this Write packet, the five most significant bits of the Channel No. field select a particular DAC; the three least significant bits are 'don't care' bits.

B5.4 Control of Timing and Disabling of injection strobes

The format of the Write packet that loads a particular Injection Timing delay is:



The format for enabling/disabling an injection strobe to a preamplifier card is:



Appendix C - Slow Read/Write Bus Protocol

Appendix D - SCA Card internal data bus

Appendix E - Crate Event Data Bus

5. Work Breakdown structure

The work breakdown structure for the scintillating calorimeter electronics is shown below. Each subdivision includes a short description that along with the description is Section 4 defines what is contained in the area of the work breakdown structure. Note to convert to SDC WBS numbers replace the leading 5 by 5.1.3.

5.1 System design document

Effort to define, document, simulate, design and test critical aspects of the system are contained in this category. The preliminary design review held at the end of this phase will be used to verify the design before starting the prototype phase. Material produced for the review will include requirements, interface specification, mechanical layouts, system design, schematics and updated costs and schedules.

5.2 Prototype electronics

5.2.1 Prototype front end electronics

This sections contains all costs to design and prototype the front end electronic cards. Costs of cables and bins are in a different part of the work breakdown structure.

5.2.1.1 Prototype front end cards

All costs to design and prototype the front end cards are contained in this section.

5.2.1.1.1 Prototype preamplifiers card

All costs to design and prototype the preamplifiers card are contained in this section. The preamplifier is most likely a combination of integrated and discrete components. In addition to the the test stand, operators and maintenance manuals are included.

5.2.1.1.2 Prototype photomultiplier current monitors card

All costs to design and prototype the photomultiplier current monitor card are contained in this section. This card is a 256 to 1 multiplexer and ADC. Band width is less than 0.01 Hertz. In addition to the the test stand, operators and maintenance manuals are included.

5.2.1.1.3 Prototype SCA, readout, calibration and zero suppression card

All costs to design and prototype the SCA, readout, calibration and zero suppression card are contained in this section. This is a very complex multi-layer PC card with about 120 IC's. In addition to the the test stand, operators and maintenance manuals are included.

5.2.1.1.4 Prototype data collector card

All costs to design and prototype the data collector card are contained in this section. This is a simple card with approximately 50 IC's. In addition to the the test stand, operators and maintenance manuals are included.

5.2.1.1.5 Prototype R/W sequencer and buffers

All costs to design and prototype the R/W sequencer and buffer card are contained in this section. This is a card of little complexity with a 2 layer pc board. In addition to the the test stand, operators and maintenance manuals are included.

5.2.1.2 Prototype front end integrated circuits and gate array

All cost to design and prototype the front end integrated circuits are contained in this section.

5.2.1.2.1 Prototype preamplifier IC/hybrid

All costs to design and prototype the preamplifier IC/hybrid circuit are contained in this section. The is a medium complexity analog design. These costs are for 1 incremental change to the R&D phase demonstration preamplifier assembly. In addition the cost to program the testing system are included.

5.2.1.2.2 Prototype slow read write IC

All costs to design and prototype this CMOS FPGA contained in this section. This is a

medium low complexity digital design. In addition the cost to program the testing system are included.

5.2.1.2.3 Prototype input buffer IC

All costs to design and prototype this small CMOS IC are contained in this section. This is a medium complexity analog design. The IC is estimated to contain 8 line receivers, and a summing amplifier. These costs are for 1 incremental change to the R&D phase demonstration input buffer IC. In addition the cost to program the testing system are included.

5.2.1.2.4 Prototype digital delay IC

All costs to design and prototype this small CMOS IC are contained in this section. This is a low complexity digital design. The IC is estimated to contain 4 programable digital delays, with delays variable from 10 to 26 ns in 16 steps. In addition the cost to program the testing system are included.

5.2.1.2.5 Prototype nonlinear 8 bit ADC IC

All costs to design and prototype this CMOS IC are contained in this section This is a high complexity analog and digital design. If commercial ADC are found (cost less than $70 ea.) There use will be substituted for this development. In addition the cost to program the testing system are included.

5.2.1.2.6 Prototype switched capacitor array IC

All costs to design and prototype this CMOS IC are contained in this section. This is a high complexity analog and digital design. These costs are for 1 incremental change to the R&D phase demonstration SCA IC. In addition the cost to program the testing system are included.

5.2.1.2.7 Prototype address list processor IC

All costs to design and prototype this CMOS IC are contained in this section. This is a high complexity digital design. these costs are for 1 incremental change to the R&D phase demonstration address list processor IC. In addition the cost to program the testing system are included.

5.2.1.2.8 Prototype ADC and buffer IC

All costs to design and prototype the ADC and buffer IC are contained in this section. This is a analog and digital IC of moderate complexity. Some prototype work has been done. In addition the cost to program the testing

system are included.

5.2.1.2.9 Prototype readout control IC

All costs to design and prototype this FPGA are contained in this section. This is a high complexity digital design. It is estimated that this FPGA can share the development kit expense with the slow bus interface FPGA. In addition the cost to program the testing system are included.

5.2.1.3 Automatic IC test stand

All costs to select purchase and install the automatic IC test stand are contained in this section.

5.2.2 Prototype remote electronics

All costs to design the remote electronic cards are contained in this subsection of the work breakdown structure.

5.2.2.1 Prototype remote Electronic cards

All costs to design and prototype remote electronic cards.

5.2.2.1.1 Prototype buffer memory card

All costs to design and prototype the buffer memory card are contained in this section. This is a card of medium complexity with approximately 60 ICs. In addition the test stand, operator and maintenance manuals are included.

5.2.2.1.2 Prototype clock distribution and slow communications card

All costs to design and prototype the clock distribution and slow communications card are contained in this section. This is a simple digital card with approximately 50 ICs plus optical cables. In addition the test stand, operator and maintenance manuals are included.

5.2.2.1.3 Prototype processor card

All costs to select purchase and program the processor prototype card are contained in this section.

5.2.3 Prototype crates

All costs to define and construct a prototype front-end and remote crate are contained in this section. Two crates of each kind will be constructed. The front end crate is a VMI type (9U high by 240 mm deep cards). The remote crate is a VME crate (6U by 160 mm deep).

5.2.3.1 Prototype front end crate

All cost to develop and fabricate two front and crates are contained in this section. The crate assembly contains a crate, power supply (see 5.2.4), fan, mounting hardware and heat exchanger. There are 21 slots in the crate on 0.8 inch centers. Each crate is assumed to dissiparate 1000 watts. Temperature rise in the crate is defined to be 5-10 degrees C above

the water temperature. The crates are mounted as a single unit on the outside of the calorimeter in 20 or more locations per end. In addition the front-end crate system is documented.

5.2.3.2 Prototype remote crate

All cost to prototype the remote crate are continued in this section. This crate is most likely a standard 6U 160 deep VME crate. In addition the remote crate system is documented.

5.2.4 Prototype AC/DC power

All cost to design and prototype the AC/DC power system for the crates is contained in this section. Two front-end and remote crates are equipped with power.

5.2.4.1 Prototype front end AC/DC power

All costs to design and prototype the AC/DC power system for the front end crates is contained in this section. In addition the front end AC/DC power system is documented. It is assumed that four power supplies are needed to support a crate (5V at 150A, -5V at 10A,+7V at 20A and -7V at 20a). Switching supplies are assumed to be used with and AC input of 115V. The AC is assumed to exist in the area where the crates will be mounted.

5.2.4.2 Prototype remote AC/DC power

All costs to design and prototype the AC/DC power system for the remote crates. In addition the remote crate system is documented. It is assumed that each crate will have a 5V at 200A and +- 12V at 10A power supplies. The AC power is at the crate location and the racks containing cooling exist.

5.2.5 Prototype cable system

All costs to prototype the cable system are contained in this section. Sufficient cables will be fabricated to completely equip 1.3 crates of electronics.

5.2.5.1 Prototype front end cable system

All cost to perform the system engineering and build prototypes for the cable system are contained in this section. Each phototube group of 8 needs a cable of 16 coaxes for the signal (4 m long) and a 3M type cable(4 m long) that is used for PM current monitoring, test pulses and DC power. There are 128 sets of these cables per front end crate. 140 sets of these cables will be fabricated. Each crate uses 64 trigger cables (optical fibers 100 M long). 70 trigger cables will be fabricated. In addition each crate needs the following optical cables:

7 ea. clock and trigger
2 ea. slow read/write and
1 ea. data.

Three sets of these cables will be fabricated

In addition the front end cable system is documented.

5.2.5.2 Prototype of remote cable system

All costs to perform the system engineering and build prototypes of the remote cable system. The cable needed to support a remote crate are listed below:

1 ea. communication network 20 m long
6 ea. Trigger optical cables 10 m long
1 ea. event collector cable 10 m ling
- 1 ea. Optical fiber to laser trigger

Three sets of these cables will be fabricated. In addition the remote crate cable system is documented.

5.2.5.3 Cable testing system

All costs to develop and build the cable testing system are contained in this section. In addition an operators manual is written.

5.2.6 Calorimeter defect location and calibration software

It is assumed the processor is a 68k+20 of equivalent and the operating system is VxWorks. The software is that required to locate defects in the system and calibrate the front end stand alone system. In addition a operators manual is provided.

5.2.7 Prototype system assemble and test.

All costs to assemble and test the prototype system are contained in this section. In addition the system operators manual is written and the critical design document is produced. After the critical design review the production phase will be started.

5.3 Production of electronics

5.3.1 Production of front end electronics cards and IC's

All production costs of the front end electronic cards and IC's are contained in this section.

5.3.1.1 Production of front end cards

All production costs for the front end cards is contained in this section.

5.3.1.1.1 Production of preamplifier card/hybrid

All costs to build and debug the calorimeter preamplifiers are contained in this section. Each card has 8 channels of preamplifiers.

5.3.1.1.2 Production of photomultiplier current monitor cards

All costs to build and debug the photomultiplier current monitor cards are contained in this section.

5.3.1.1.3 Production of SCA, readout, calibration and zero suppression card

All costs to build and debug the SCA, readout, calibration and zero suppression cards are contained in this section.

5.3.1.1.4 Production of data collection card

All costs to build and debug the data collection

cards are contained in this section.

5.3.1.1.5 Production of R/W sequencer and buffers

All costs to build and debug the R/W sequencer and buffer cards are contained in this section.

5.3.1.2 Production of gate arrays and integrated circuits

All costs to build and test the integrated circuits and gate arrays are contained in this section.

5.3.1.2.1 Production of preamplifier IC/hybrid

All costs to build and test the preamplifier IC/hybrids are contained in this section.

5.3.1.2.2 Production of slow read write IC

All costs to build and test the slow read write ICs are contained in this section.

5.3.1.2.3 Production of input buffer IC

All costs to build and test the input buffer ICs are contained in this section.

5.3.1.2.4 Production of digital delay IC

All costs to build and test the digital delay ICs are contained in this section.

5.3.1.2.5 Production of nonlinear ADC IC

All costs to build and test the nonlinear ADC ICs are contained in this section.

5.3.1.2.6 Production of switched capacitor array IC

All costs to build and test the switched capacitor array ICs are contained in this section.

5.3.1.2.7 Production of the address list processor

All costs to build and test the address list processor ICs are contained in this section.

5.3.1.2.8 Production of readout control IC

All costs to build and test the readout control ICs are contained in this section.

5.3.2 Production of remote electronics

All costs to build and debug the remote electronics are contained in this section.

5.3.2.1 Production of remote cards.

All costs to build and debug the remote cards.

5.3.2.1.1 Production of buffer memory card.

All costs to build and debug the buffer memory cards are contained in this section.

5.3.2.1.2 Production of clock distribution and slow communications cards.

All costs to build and debug the clock distribution and slow communications cards are contained in this section.

5.3.2.1.3 Purchase of processor cards.

All costs to purchase and test the processor cards are contained in this section.

5.3.3 Production of crates

All costs to build and debug the front-end and remote crates are contained in this section.

5.3.3.1 Production of front-end crates

All costs to build and debug the front end crates

are contained in this section.

5.3.3.2 Production of front-end power system
All costs to build and debug the front end power systems are contained in this section.

5.3.4 Production of remote and front-end power system
All costs to build and debug the remote and front-end power systems are contained in this section.

5.3.4.1 Production of front-end power system.
All costs to build and debug the front and power system are contained in this section.

5.3.4.2 Production remote power system
All costs to build and debug the remote power systems are contained in this section.

5.3.5 Production cable system
All costs to build and debug the cable system are contained in this section.

5.3.5.1 Production of front-end cable system
All costs to build and debug the front-end cable system are contained in this section.

5.3.5.2 Production of remote cable system
All costs to build and debug the remote cable system are contained in this section.

5.4 Subsystem assembly and test
All costs to install and debug the barrel and end cap calorimeter electronics is contained in this section. It are assumed that each logical system will be debuged and tested then sent to the SSCL for installation and beam testing.

5.5 Management
All costs for management of the barrel and endcap calorimeter electronics are contained in this section. Technical management contains effort to plan, schedule, monitor, review, report and define interfaces.

6.0 Cost estimate
The cost estimate contains areas of costing that may belong to other subsystems. These items are contained here because it is not clear at this time if they are common to other subsystems. It is assumed that the development cost may move but the production costs will remain in this cost estimate. A listing of the development costs for the items that may move are show below:

WBS number	Short title	Cost K$
5.2.3	Prototype crates	132
5.2.4	Prototype AC/DC power	75
5.2.1.2.2	Prototype slow read write IC	39
5.2.1.2.4	Prototype digital delay IC	95
5.2.2.1	Prototype memory card	227
5.2.2.2	Prototype clock distribution and slow communications	145
5.2.2.3	Prototype processor card	153
Total cost of item that may be moved to other subsystems		766 K$

Total project cost is 8581K$ when the items to be moved are subtracted. The EDIA cost is about 30% of the total cost. The rates used were 8.98K/MM engineer and 6.53K/MM technician.

The detailed cost estimate followed by the unit cost and contingency analysis is shown on the following pages:

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

COST SUMMARY — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.1	SYSTEM DESIGN DOCUMENT					
	subtotal	27	10	307.0	25	332.0
5.2	PROTOTYPE ELECTRONICS					
	subtotal	190.75	131.75	2645.1	588.5	3233.5
5.3	PRODUCTION ELECTRONICS					
	subtotal	45.95	122.0	1224.1	3665.3	4889.4
5.4	MANAGEMENT					
	subtotal	65	36	818.0	72	890.0

	ENG	T&D	LABOR	MATL	TOTAL
CALORIMETER ELECTRONICS	338	301	4896	4351	9347
	MONTHS	MONTHS	K$	K$	K$

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.1 SYSTEM DESIGN DOCUMENT — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.1	SYSTEM DESIGN DOCUMENT					
5.1.1	ENGINEERING (M)	27	0	242.5	0	242.5
5.1.2	SUPPORT EFFORT (M)	0	10	65.3	0	65.3
5.1.3	TRAVEL	0	0	0	25	25

	ENG	T&D	LABOR	MATL	TOTAL
SYSTEM ENGINEERING	27	10	307.8	25	332.8
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2579

5.2 PROTOTYPE ELECTRONICS SUMMARY — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1	PROTOTYPE FRONT END ELECTRONICS					
5.2.1.1	FRONT CARDS(M)	56.25	52.25	846.3	190	1036.3
5.2.1.2	FRONT END ICS (M)	56	25	666.1	76	742.1
5.2.1.3	AUTO TEST STAND	5	6	84.1	135	219.1
	subtotal	117.25	83.25	1596.5	401	1997.5
5.2.2	PROTOTYPE REMOTE ELECTRONICS					
5.2.2.1	REMOTE CARDS	24.5	18.25	339.2	80	419.2
	subtotal	24.5	18.25	339.2	80	419.2
5.2.3	PROTOTYPE CRATES AND BINS					
5.2.3.1	FRONT CRATES (M)	6	5	86.5	10	96.5
5.2.3.2	REMOTE CRATES (M)	1.25	2.25	25.9	5	30.9
	subtotal	7.25	7.25	112.4	15	127.4
5.2.4	PROTOTYPE AC/DC POWER					
5.2.4.1	FRONT AC/DC (M)	2	2.75	35.9	3	38.9
5.2.4.2	REMOTE AC/DC (M)	2	2	31	2	33
	subtotal	4	4.75	66.9	5	71.9
5.2.5	PROTOTYPE CABLE SYSTEM					
5.2.5.1	FRONT CABLES (M)	7	4.5	92.2	23.6	115.8
5.2.5.2	REMOTE CABLES (M)	1.75	1.25	23.9	3.9	27.8
5.2.5.3	CABLE SYSTEM (M)	5	3.5	67.8	35	102.8
	subtotal	13.75	9.25	183.9	62.5	246.4
5.2.6	DEFECT LOCATION AND CALIBRATION SOFTWARE					
	subtotal	12	0	187.8	0	187.8
5.2.7	TEST OF PROTOTYPE SYSTEM					
	subtotal (M)	20	9	238.4	25	263.4

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE ELECTRONICS SUMMARY	188.75	131.75	2645.1	588.5	3233.6
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2580

5.2.1 PROTOTYPE FRONT END ELECTRONICS — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1.1	PROTOTYPE FRONT END CARDS					
5.2.1.1.1	PROTOTYPE PREAMPLIFIER CARDS					
5.2.1.1.1.1	ENG	3	0.75	31.8	2	33.8
5.2.1.1.1.2	SUPPORT	1	2.75	26.9	0	26.9
5.2.1.1.1.3	FAB	3.75	4.5	63.1	24	87.1
5.2.1.1.1.4	TEST STND	1.75	1.5	25.5	4	29.5
5.2.1.1.1.5	OP MAN	0.5	0.5	7.8	0	7.8
5.2.1.1.1.6	MAINT MAN	0.5	0.5	7.8	0	7.8
	subtotal	10.5	10.5	162.9	30	192.9
5.2.1.1.2	PROTOTYPE PHOTOMULTIPLIER MONITOR CARDS					
5.2.1.1.2.1	ENG	2	0.5	21.2	0	21.2
5.2.1.1.2.2	SUPPORT	0.75	2	19.8	0	19.8
5.2.1.1.2.3	FAB	1.5	2	26.5	16	42.5
5.2.1.1.2.4	TEST STND	1	1.75	20.4	3	23.4
5.2.1.1.2.5	OP MAN	0.5	0.5	7.8	0	7.8
5.2.1.1.2.6	MAINT MAN	0.5	0.5	7.8	0	7.8
	subtotal	5.25	7.25	103.5	19	122.5
5.2.1.1.3	PROTOTYPE SCA,READOUT,CALIBRATION CARDS					
5.2.1.1.3.1	ENG	5	0.75	49.0	2	51.0
5.2.1.1.3.2	SUPPORT	1	5.25	43.3	0	43.3
5.2.1.1.3.3	FAB	4	4	5	60.6	70	136.6
5.2.1.1.3.4	TEST STND	17.5	0	209.4	45	254.4
5.2.1.1.3.5	OP MAN	0.5	0.5	7.8	0	7.8
5.2.1.1.3.6	MAINT MAN	0.25	0.5	5.5	0	5.5
	subtotal	28.25	20	384.3	117	501.3

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2581

5.2.1 PROTOTYPE FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1.1	PROTOTYPE FRONT END CARDS (cont)					
5.2.1.1.4	PROTOTYPE DATA COLLECTOR CARDS					
5.2.1.1.4.1	ENG	2	0.5	21.2	1	22.2
5.2.1.1.4.2	SUPPORT	0.5	2.25	19.2	0	19.2
5.2.1.1.4.3	FAB	1	1.5	18.0	8	26.0
5.2.1.1.4.4	TEST STND	1.5	1.75	24.9	3	27.9
5.2.1.1.4.5	OP MAN	0.5	0.5	7.8	0	7.8
5.2.1.1.4.6	MAINT MAN	0.5	0.5	7.8	0	7.8
	subtotal	6	7	99.7	12	111.7
5.2.1.1.5	PROTOTYPE R/W SEQUENCER CARDS					
5.2.1.1.5.1	ENG	1.25	0.75	16.1	0	16.1
5.2.1.1.5.2	SUPPORT	0.5	2.25	19.2	0	19.2
5.2.1.1.5.3	FAB	1	1.75	20.4	0	20.4
5.2.1.1.5.4	TEST STND	1.5	1.75	24.9	4	28.9
5.2.1.1.5.5	OP MAN	0.5	0.5	7.8	0	7.8
5.2.1.1.5.6	MAINT MAN	0.5	0.5	7.8	0	7.8
	subtotal	5.25	7.5	96.2	12	108.2

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE FRONT END CARDS	56.25	52.25	846.3	190	1036.3
	MONTHS	MONTHS	K$	K$	K$

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2582

5.2.1 PROTOTYPE FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1.2	PROTOTYPE FRONT END ICs					
5.2.1.2.1	PROTOTYPE PREAMP IC/HYBRIDS					
5.2.1.2.1.1	ENG	2	0	18	0	18
5.2.1.2.1.2	SUPPORT	0	0.5	3.3	0	3.3
5.2.1.2.1.3	FAB/TEST	3	2	40	4	44
	subtotal	5	2.5	61.2	4	65.2
5.2.1.2.2	PROTOTYPE SLOW READ WRITE ICs					
5.2.1.2.2.1	ENG	2	0	18	0	18
5.2.1.2.2.2	SUPPORT	0	0.5	3.3	0	3.3
5.2.1.2.2.3	FAB/TEST	1	1	15.5	11	26.5
	subtotal	3	1.5	36.7	11	47.7
5.2.1.2.3	PROTOTYPE INPUT BUFFER ICs					
5.2.1.2.3.1	ENG	2	0	18	0	18
5.2.1.2.3.2	SUPPORT	0	0.5	3.3	0	3.3
5.2.1.2.3.3	FAB/TEST	3	2	40	3	43
	subtotal	5	2.5	61.2	3	64.2
5.2.1.2.4	PROTOTYPE DIGITAL DELAY ICs					
5.2.1.2.4.1	ENG	4	0	35.9	0	35.9
5.2.1.2.4.2	SUPPORT	0	1	6.5	0	6.5
5.2.1.2.4.3	FAB/TEST	4	2	49	9	58
	subtotal	8	3	91.4	9	100.4
5.2.1.2.5	PROTOTYPE NON-LINEAR 8BIT ADCs					
5.2.1.2.5.1	ENG	8	0	71.0	0	71.0
5.2.1.2.5.2	SUPPORT	0	2	13.1	0	13.1
5.2.1.2.5.3	FAB/TEST	4	2	49	20	69
	subtotal	12	4	133.9	20	153.9

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.1 PROTOTYPE FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1.2	PROTOTYPE FRONT END ICs (cont)					
5.2.1.2.6	PROTOTYPE SWITCHED CAPACITOR ARRAYS (SCA)					
5.2.1.2.6.1	ENG	2	0	18	0	18
5.2.1.2.6.2	SUPPORT	0	1	6.5	0	6.5
5.2.1.2.6.3	FAB/TEST	4	2	49	11	60
	subtotal	6	3	73.5	11	84.5
5.2.1.2.7	PROTOTYPE ADDRESS LIST PROCESSOR ICs					
5.2.1.2.7.1	ENG	2	0	18	0	18
5.2.1.2.7.2	SUPPORT	0	1	6.5	0	6.5
5.2.1.2.7.3	FAB/TEST	4	2	49	6	55
	subtotal	6	3	73.5	6	79.5
5.2.1.2.8	PROTOTYPE ADC AND BUFFER ICs					
5.2.1.2.8.1	ENG	3	0	26.9	0	26.9
5.2.1.2.8.2	SUPPORT	0	1	6.5	0	6.5
5.2.1.2.8.3	FAB/TEST	2	2	31	8	39
	subtotal	5	3	64.5	8	72.5
5.2.1.2.9	PROTOTYPE READOUT CONTROL ICs					
5.2.1.2.9.1	ENG	4	0	35.9	0	35.9
5.2.1.2.9.2	SUPPORT	0	0.5	3.3	0	3.3
5.2.1.2.9.3	FAB/TEST	2	2	31	4	35
	subtotal	6	2.5	70.2	4	74.2

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE FRONT END ICs	56	25	666.1	75	742.1
	MONTHS	MONTHS	K$	K$	K$

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.1 PROTOTYPE FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.1.3	AUTOMATIC IC TEST STAND					
5.2.1.3.1	EVAL	3	0	26.9	0	26.9
5.2.1.3.2	PURCHASE	0	0	0	135	135
5.2.1.3.3	INSTALL	2	6	57.1	0	57.1
	subtotal	5	6	84.1	135	219.1

	ENG	T&D	LABOR	MATL	TOTAL
AUTOMATIC IC TEST STAND	5	6	84.1	135	219.1
	MONTHS	MONTHS	K$	K$	K$

5.2.1 TOTAL PROTOTYPE FRONT END ELECTRONICS

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE FRONT END ELECTRONICS	117.25	83.25	1596.5	401	1997.5
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.2 PROTOTYPE REMOTE ELECTRONICS — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.2.1	PROTOTYPE REMOTE CARDS					
5.2.2.1.1	PROTOTYPE MEMORY CARD					
5.2.2.1.1.1	ENG	4	0.75	40.0	2	42.0
5.2.2.1.1.2	SUPPORT	0.75	3.5	29.5	0	29.5
5.2.2.1.1.3	FAB	2.25	3	39.0	25	64.0
5.2.2.1.1.4	TEST STND	4.5	1.75	51.0	15	66.0
5.2.2.1.1.5	OP MAN	0.5	0.5	7.0	0	7.0
5.2.2.1.1.6	MAINT MAN	0.5	0.5	7.0	0	7.0
	subtotal	12.5	10	177.5	42	219.5
5.2.2.1.2	PROTOTYPE CLOCK DISTRIBUTION AND SLOW COMMUNICATIONS					
5.2.2.1.2.1	ENG	1.75	0.5	19	1	20
5.2.2.1.2.2	SUPPORT	0.5	2.5	20.0	0	20.0
5.2.2.1.2.3	FAB	1.25	1.75	22.7	12	34.7
5.2.2.1.2.4	TEST STND	3.5	1.25	39.5	10	49.5
5.2.2.1.2.5	OP MAN	0.5	0.5	7.0	0	7.0
5.2.2.1.2.6	MAINT MAN	0.5	0.5	7.0	0	7.0
	subtotal	8	7	117.5	23	140.5
5.2.2.1.3	PROTOTYPE PROCESSOR CARD					
5.2.2.1.3.1	SELECTION	1	0.25	10.5	0	10.5
5.2.2.1.3.2	PUR/EVAL	3	1	33.5	15	48.5
	subtotal	4	1.25	44.1	15	59.1

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE REMOTE ELECTRONICS	24.5	18.25	339.2	80	419.2
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.3 PROTOTYPE CRATES AND BINS — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.3.1	PROTOTYPE FRONT END CRATES					
5.2.3.1.1	ENG	4	2	49	0	49
5.2.3.1.2	FAB AND TEST	1	2	22	10	32
5.2.3.1.3	DOCUMENTATION	1	1	15.5	0	15.5
	subtotal	6	5	86.5	10	96.5
5.2.3.2	PROTOTYPE REMOTE CRATES					
5.2.3.2.1	ENG	0.5	0.5	7.0	1	8.0
5.2.3.2.2	FAB AND TEST	0.5	1	11	4	15
5.2.3.2.3	DOCUMENTATION	0.25	0.75	7.1	0	7.1
	subtotal	1.25	2.25	25.9	5	30.9

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE CRATES AND BINS	7.25	7.25	112.4	15	127.4
	MONTHS	MONTHS	K$	K$	K$

C-11

2587

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.4 PROTOTYPE AC/DC POWER — REV 1.11

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.4.1	PROTOTYPE FRONT END AC/DC POWER					
5.2.4.1.1	ENG	1	1	15.5	0	15.5
5.2.4.1.2	FAB AND TEST	0.5	1	11	3	14
5.2.4.1.3	DOCUMENTATION	0.5	0.75	9.4	0	9.4
	subtotal	2	2.75	35.9	3	38.9
5.2.4.2	PROTOTYPE REMOTE AC/DC POWER					
5.2.4.2.1	ENG	1	0.5	12.2	0	12.2
5.2.4.2.2	FAB AND TEST	0.5	1	11	2	13
5.2.4.2.3	DOCUMENTATION	0.5	0.5	7.8	0	7.8
	subtotal	2	2	31	2	33

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE AC/DC POWER (n)	4	4.75	66.9	5	71.9
	MONTHS	MONTHS	K$	K$	K$

C-12

2588

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.5 PROTOTYPE CABLE SYSTEM — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.5.1	PROTOTYPE FRONT END CABLE SYSTEM					
5.2.5.1.1	ENG	5	2	58	0	58
5.2.5.1.2	FAB AND TEST	1	2	22	23.6	45.6
5.2.5.1.3	DOCUMENTATION	1	0.5	12.2	0	12.2
	subtotal	7	4.5	92.2	23.6	115.8
5.2.5.2	PROTOTYPE REMOTE CABLE SYSTEM					
5.2.5.2.1	ENG	1	0.5	12.2	0	12.2
5.2.5.2.2	FAB AND TEST	0.25	0.5	5.5	3.9	9.4
5.2.5.2.3	DOCUMENTATION	0.5	0.25	6.1	0	6.1
	subtotal	1.75	1.25	23.9	3.9	27.8
5.2.5.3	CABLE TESTING SYSTEM					
5.2.5.3.1	ENG	3	1	33.5	0	33.5
5.2.5.3.2	FAB AND TEST	1	2	22	35	57
5.2.5.3.3	DOCUMENTATION	1	0.5	12.2	0	12.2
	subtotal	5	3.5	67.8	35	102.8

	ENG	T&D	LABOR	MATL	SUBTOTAL
PROTOTYPE CABLE SYSTEM	13.75	9.25	183.9	62.5	246.4
	MONTHS	MONTHS	K$	K$	K$

C-13

2589

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.6 DEFECT LOCATION AND CALIBRATION SOFTWARE — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.6	CALORIMETER DEFECT LOCATION AND CALIBRATION SOFTWARE					
5.2.6.1	SYSTEM DESIGN	4	0	35.9	0	35.9
5.2.6.2	CODING AND TEST	6	0	53.9	0	53.9
5.2.6.3	DOCUMENTATION	2	0	18	0	18
	subtotal	12	0	107.8	0	107.8

	ENG	T&D	LABOR	MATL	TOTAL
PROTOTYPE REMOTE ELECTRONICS	12	0	107.8	0	107.8
	MONTHS	MONTHS	K$	K$	K$

2590

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.2.7 PROTOTYPE SYSTEM — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.2.7	PROTOTYPE SYSTEM					
5.2.7.1.1	ASSEMBLE FOR TEST	2	4	44.1	15	59.1
5.2.7.1.2	TEST LABOR,MATL	8	3	81.4	18	181.4
5.2.7.1.3	SOFTWARE SUPPORT	5	0	44.9	0	44.9
5.2.7.1.4	OPERATORS MANUAL	3	0	26.9	0	26.9
5.2.7.1.5	EM&S REVIEW	2	2	31	0	31
TEST OF PROTOTYPE SYSTEM		20	9	238.4	25	263.4
		MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3 PRODUCTION ELECTRONICS SUMMARY — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.1	PRODUCTION FRONT END ELECTRONICS					
5.3.1.1	FRONT END CARDS	9.7	25.1	251	1955.2	2206.25
5.3.1.2	FRONT END ICS	11.5	35.5	335.1	594	929.1
	subtotal	21.2	60.6	586.1	2549.2	3135.35
5.3.2	PRODUCTION REMOTE ELECTRONICS					
5.3.2.1	REMOTE CARDS	3.5	4.6	61.5	271	332.5
	subtotal	3.5	4.6	61.5	271	332.5
5.3.3	PRODUCTION CRATES & BINS					
5.3.3.1	FRONT END CRATES	1.5	3	33.1	98.7	131.8
5.3.3.2	REMOTE CRATES	0.5	2.25	19.2	15.5	34.7
	subtotal	2	5.25	52.2	114.2	166.4
5.3.4	PRODUCTION POWER SYSTEMS					
5.3.4.1	FRONT END POWER	2.5	4	48.6	84	132.6
5.3.4.2	REMOTE POWER	0.7	2.8	24.6	15	39.6
	subtotal	3.2	6.8	73.1	99	172.1
5.3.5	PRODUCTION CABLE SYSTEMS					
5.3.5.1	FRONT END CABLES	2	1.05	24.8	535.1	559.9
5.3.5.2	REMOTE CABLES	0.8	0.6	11.1	31.55	42.65
	subtotal	2.8	1.65	35.9	566.65	602.55
5.3.6	PRODUCTION SUBSYSTEM TESTS					
	subtotal	14.25	44	415.3	65.2	480.5
		ENG	T&D	LABOR	MATL	TOTAL
PRODUCTION ELECTRONICS SUMMARY		46.95	122.9	1224.1	3665.3	4889.4
		MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.1 PRODUCTION FRONT END ELECTRONICS — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.1.1	PRODUCTION FRONT END CARDS					
5.3.1.1.1	PRODUCTION PREAMPLIFIER CARDS (QTY = 5600)					
5.3.1.1.1.1	COORD (M)	2	1	24.5	1	25.5
5.3.1.1.1.2	PARTS	0	0	0	420	420
5.3.1.1.1.3	PC CARDS	0	0	0	168	168
5.3.1.1.1.4	ASSLY/QA	0.9	7	53.8	392	445.8
5.3.1.1.1.5	DEBUG	0.5	4	30.6	14	44.6
	subtotal	3.4	12	108.9	995	1103.9
5.3.1.1.2	PRODUCTION PHOTOMULTIPLIER MONITOR CARDS (QTY=200)					
5.3.1.1.2.1	COORD (M)	1	1	15.5	1	16.5
5.3.1.1.2.2	PARTS	0	0	0	25	25
5.3.1.1.2.3	PC CARDS	0	0	0	77	77
5.3.1.1.2.4	ASSLY/QA	0.1	1	7.4	30	37.4
5.3.1.1.2.5	DEBUG	0.1	1	7.4	1	8.4
	subtotal	1.2	3	30.4	134	164.3
5.3.1.1.3	PRODUCTION SCA,READOUT,CALIBRATION CARDS (QTY=350)					
5.3.1.1.3.1	COORD (M)	2	2	31	1	32
5.3.1.1.3.2	PARTS	0	0	0	306.25	306.25
5.3.1.1.3.3	PC CARDS	0	0	0	214	214
5.3.1.1.3.4	ASSLY/QA	0.1	0.7	5.5	193	198.5
5.3.1.1.3.5	DEBUG	0.6	4.4	34.1	18	52.1
	subtotal	2.7	7.1	70.6	732.25	802.85

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.1 PRODUCTION FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.1.1	PRODUCTION FRONT END CARDS (cont)					
5.3.1.1.4	PRODUCTION DATA COLLECTOR CARDS (QTY=45)					
5.3.1.1.4.1	COORD (M)	1	1	15.5	1	16.5
5.3.1.1.4.2	PARTS	0	0	0	6	6
5.3.1.1.4.3	PC CARDS	0	0	0	18	18
5.3.1.1.4.4	ASSLY/QA	0.1	0.25	2.5	2	4.5
5.3.1.1.4.5	DEBUG	0.1	0.25	2.5	0	2.5
	subtotal	1.2	1.5	20.6	27	47.5
5.3.1.1.6	PRODUCTION R/W SEQUENCER CARDS (QTY=45)					
5.3.1.1.5.1	COORD (M)	1	1	15.5	1	16.5
5.3.1.1.5.2	PARTS	0	0	0	41	41
5.3.1.1.5.3	PC CARDS	0	0	0	18	18
5.3.1.1.5.4	ASSLY/QA	0.1	0.25	2.5	7	9.5
5.3.1.1.5.5	DEBUG	0.1	0.25	2.5	0	2.5
	subtotal	1.2	1.6	20.6	67	87.5
		ENG	T&D	LABOR	MATL	TOTAL
	PRODUCTION FRONT END CARDS	9.7	25.1	251	1955.2	2206.25
		MONTHS	MONTHS	K$	K$	K$

(continued on next page)

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.1 PRODUCTION FRONT END ELECTRONICS (cont) — REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.1.2	PRODUCTION FRONT END ICs					
5.3.1.2.1	PRODUCTION PREAMP IC/HYBRIDS (QTY = 49,300)					
5.3.1.2.1.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.1.2	FAB COST	0	0	0	67	67
5.3.1.2.1.3	TEST	1	9	67.8	5	72.8
	subtotal	1.5	9	72.2	72	144.2
5.3.1.2.2	PRODUCTION SLOW READ WRITE ICs (QTY=605)					
5.3.1.2.2.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.2.2	FAB COST	0	0	0	19	19
5.3.1.2.2.3	TEST	0.5	0.5	7.8	1	8.8
	subtotal	1	0.5	12.2	20	32.2
5.3.1.2.3	PRODUCTION INPUT BUFFER ICs (QTY=5160)					
5.3.1.2.3.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.3.2	FAB COST	0	0	0	47	47
5.3.1.2.3.3	TEST	1	4	35.1	5	40.1
	subtotal	1.5	4	39.5	52	91.6
5.3.1.2.4	PRODUCTION DIGITAL DELAY ICs (QTY=1848)					
5.3.1.2.4.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.4.2	FAB COST	0	0	0	51	51
5.3.1.2.4.3	TEST	1	2	22	5	27
	subtotal	1.5	2	26.5	56	82.5
5.3.1.2.5	PRODUCTION NON-LINEAR 8BIT ADCs (QTY=5160)					
5.3.1.2.5.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.5.2	FAB COST	0	0	0	150	150
5.3.1.2.5.3	TEST	1	7	54.7	5	59.7
	subtotal	1.5	7	59.2	163	222.2

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.1 PRODUCTION FRONT END ELECTRONICS (cont) REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.1.2	PRODUCTION FRONT END ICs (cont)					
5.3.1.2.6	PRODUCTION SWITCHED CAPACITOR ARRAYS (SCA) (QTY=6160)					
5.3.1.2.6.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.6.2	FAB COST	0	0	0	158	158
5.3.1.2.6.3	TEST	1	7	54.7	5	59.7
	subtotal	1.5	7	55.2	163	222.2
5.3.1.2.7	PRODUCTION ADDRESS LIST PROCESSOR ICs (QTY=1540)					
5.3.1.2.7.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.7.2	FAB COST	0	0	0	47	47
5.3.1.2.7.3	TEST	1	5	41.6	1	42.6
	subtotal	1.5	5	46.1	48	94.1
5.3.1.2.8	PRODUCTION READOUT CONTROL ICs (QTY=385)					
5.3.1.2.8.1	COORD (M)	0.5	0	4.5	0	4.5
5.3.1.2.8.2	FAB COST	0	0	0	19	19
5.3.1.2.8.3	TEST	1	1	15.5	1	16.5
	subtotal	1.5	1	20	20	40

	ENG	T&D	LABOR	MATL	TOTAL
PRODUCTION FRONT END ICs	11.5	35.5	335.1	594	929.1
	MONTHS	MONTHS	K$	K$	K$

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SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.1 PRODUCTION FRONT END ELECTRONICS (cont) REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$

5.3.1 TOTAL PRODUCTION FRONT END ELECTRONICS

	ENG	T&D	LABOR	MATL	TOTAL
PRODUCTION FRONT END ELECTRONICS	21.2	62.6	586.1	2549.2	3135.35
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.2 PRODUCTION REMOTE ELECTRONICS REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.2.1	REMOTE CARDS					
5.3.2.1.1	PRODUCTION MEMORY CARD					
5.3.2.1.1.1	COORD (M)	1	1	15.6	1	16.5
5.3.2.1.1.2	PARTS	0	0	0	26	26
5.3.2.1.1.3	PC CARDS	0	0	0	9	9
5.3.2.1.1.4	ASSLY/QA	0.1	0.25	2.5	9	11.5
5.3.2.1.1.5	DEBUG	0.1	0.25	2.5	2	4.5
	subtotal	1.2	1.5	20.6	47	67.6
5.3.2.1.2	PRODUCTION CLOCK DISTRIBUTION AND SLOW COMMUNICATIONS					
5.3.2.1.2.1	COORD (M)	1	1	15.5	1	16.5
5.3.2.1.2.2	PARTS	0	0	0	58	58
5.3.2.1.2.3	PC CARDS	0	0	0	7	7
5.3.2.1.2.4	ASSLY/QA	0.1	0.25	2.5	5	7.5
5.3.2.1.2.5	DEBUG	0.1	0.25	2.5	2	4.5
	subtotal	1.2	1.5	20.6	65	85.6
5.3.2.1.3	PRODUCTION PROCESSOR CARD					
5.3.2.1.3.1	COORD (M)	1	1	15.5	1	16.5
5.3.2.1.3.2	PURCH/QA	0.1	0.6	4.8	158	162.8
	subtotal	1.1	1.6	20.3	159	179.3

	ENG	T&D	LABOR	MATL	TOTAL
PRODUCTION REMOTE ELECTRONICS	3.5	4.6	61.5	271	332.5
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS

5.3.3 PRODUCTION CRATES, & BINS REV 1.21

ITEM	DESCRIPTION	ENG	T&D	LABOR	MATL	SUBTOTAL
		MONTHS	MONTHS	K$	K$	K$
5.3.3.1	PRODUCTION FRONT END CRATES (QTY=42)					
5.3.3.1.1	COORD (M)	0.5	1	11	0	11
5.3.3.1.2	PARTS	0	0	0	98.7	98.7
5.3.3.1.3	ASSLY	0.5	1	11	0	11
5.3.3.1.4	QA/DEBUG	0.5	1	11	0	11
	subtotal	1.5	3	33.1	98.7	131.8
5.3.3.2	PRODUCTION REMOTE CRATES (QTY=15)					
5.3.3.2.1	COORD (M)	0.5	0.5	0	0	0
5.3.3.2.2	PARTS	0	0	0	15.5	15.5
5.3.3.2.3	ASSLY	0	1.25	0	0	0
5.3.3.2.4	QA/DEBUG	0	0.5	0	0	0
	subtotal	0.5	2.25	19.2	15.5	34.7

DESCRIPTION	ENG	T&D	LABOR	MATL	TOTAL
~~FRONT END~~ CRATES, ~~CRATES, POWER~~	2	5.25	52.2	114.2	166.4
	MONTHS	MONTHS	K$	K$	K$

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2599

5.3.3 PROD [redacted] END CRATE [redacted] POWER — REV 1.21

ITEM	DESCRIPTION	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	SUBTOTAL K$
5.3.3.1	PRODUCTION FRONT END POWER SYSTEM (QTY=42)					
5.3.3.2.1	COORD	1.5	2	26.5	0	26.5
5.3.3.2.2	PARTS	0	0	0	80	80
5.3.3.2.3	ASSLY	0.5	1	11	4	15
5.3.3.2.4	QA/DEBUG	0.5	1	11	0	11
	subtotal	2.5	4	48.6	84	132.6
5.3.4.2	PRODUCTION REMOTE POWER SYSTEM (QTY=15)					
5.3.4.2.1	COORD	0.2	0.5	5.1	0	5.1
5.3.4.2.2	PARTS	0	0	0	15	15
5.3.4.2.3	ASSLY	0	1.3	8.5	0	8.5
5.3.4.2.4	QA/DEBUG	0.5	1	11	0	11
	subtotal	0.7	2.8	24.6	15	39.6

	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	TOTAL K$
PRODUCTION POWER	3.1	6.8	73.2	99	172.1

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2600

5.3.5 PRODUCTION CABLE SYSTEMS — REV 1.21

ITEM	DESCRIPTION	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	SUBTOTAL K$
5.3.5.1	PRODUCTION FRONT END CABLE SYSTEM					
5.3.5.1.1	COORD (M)	2	0	18	0	18
5.3.5.1.2	PRODUCTION					
5.3.5.1.2.1	PM/CRATE	0	0.53	3.5	214.8	218.3
5.3.5.1.2.2	TRIGGER	0	0.27	1.0	276	277.0
5.3.5.1.2.3	CRATE/LCL	0	0.25	1.6	44.3	45.9
	subtotal	2	1.05	24.8	535.1	559.9
5.3.5.2	PRODUCTION REMOTE CABLE SYSTEM					6.7
5.3.5.2.1	COORD (M)	0.75	0	6.7	0	6.7
5.3.5.2.2	PROD					
5.3.5.2.2.1	CPU.COMM	0.05	0.2	1.8	0.85	2.65
5.3.5.2.2.2	TRIGGER	0	0.1	0.7	29	29.7
5.3.5.2.2.3	MEM/EVNT	0	0.3	2	1.7	3.7
	subtotal	0.8	0.6	11.1	31.55	42.65

	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	TOTAL K$
PRODUCTION CABLES	2.8	1.65	35.9	566.65	602.55

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2601

5.3.6 PRODUCTION SUBSYSTEM TEST — REV 1.21

ITEM	DESCRIPTION	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	SUBTOTAL K$
5.3.6	SUBSYSTEM TEST					
5.3.6.1	INSTALL FRONT END CRATES	0.25	1.2	10.1	1	11.1
5.3.6.2	INSTALL FRONT END CABLES	3	25.2	191.5	20	211.5
5.3.6.3	INSTALL REMOTE TEST CRATES	0	0.3	2	0	2
5.3.6.4	INSTALL AND DEBUG ELEC	6	10	119.2	20	139.2
5.3.6.5	ELECTRONIC REPAIR	1	3.3	30.5	0	30.5
5.3.6.6	TRAVEL	0	0	0	22.2	22.2
5.3.6.7	TESTING	4	4	52	2	54

	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	TOTAL K$
SUBSYSTEM TEST	14.25	44	415.3	65.2	480.5

ONSITE INSTALLATION

NOTE: THE FOLLOWING COSTS FOR INSTALLATION OF THE CALORIMETER ELECTRONICS IS COSTED ELSEWHERE AND INCLUDED HERE FOR REFERENCE

..1	INSTALL REMOTE CRATE CABLES	0	0.6	5.2	0	5.2
..2	INSTALL REMOTE CRATES & DC	0	0.3	2	0	2
..3	DEBUG ELEC	6	10	119.2	20	139.2
..4	ELECTRONIC REPAIR	1	3	28.6	0	28.6
..5	ACCEPTANCE TESTING	4	0	35.9	0	35.9
..6	EM&S COMPLIANCE REVIEW	2	1	24.5	0	24.5

	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	TOTAL K$
SUBSYSTEM TEST	13	15.1	215.4	20	235.4

SOLENOID DETECTOR COLLABORATION — CALORIMETER ELECTRONICS — 2602

5.4 MANAGEMENT — REV 1.21

ITEM	DESCRIPTION	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	SUBTOTAL K$
5.4	MANAGEMENT					
5.4.1	ENGINEERING	65	0	503.7	0	503.7
5.4.2	SUPPORT EFFORT	0	36	235.1	0	235.1
5.4.3	TRAVEL	0	0	0	72	72

	ENG MONTHS	T&D MONTHS	LABOR K$	MATL K$	TOTAL K$
MANAGEMENT	65	36	810.8	72	880.8

cal-unit

SCINTILLATION CALORIMETER UNIT COST

WBS #	DESCRIPTION	COST/ CARD	COST($)/ CHANNEL
5.1	System design document	na	8.1
5.2	Prototype electronics	na	78.9
	Total prototype		87
5.3.1.1.1	Prod. preamp. card and		
5.3.1.2.1	Prod. preamp. IC	233	27.9
5.3.1.1.2	Prod. PM current monitor	822	3.2
5.3.1.1.3	Prod. SCA card and		
5.3.1.2.2-8	Prod. all IC's except preamp.	4536	35.4
5.3.1.1.4	Prod. data collector card	1855	1.1
5.3.1.1.5	Prod. R/W sequencer card	1944	1.9
5.3.2.1.1	Prod. memory card	1502	1.5
5.3.2.1.2	Prod. clock dist. and slow communication	1902	1.9
5.3.2.1.3	Prod. proccessor card	7471	3.6
5.3.3.1	Prod. front-end crate	3138	3.1
5.3.3.2	Prod. remote crate	2891	0.5
5.3.4.1	Prod. front-end power	2946	2.9
5.3.4.2	Prod. remote power	3300	0.6
5.3.5	Prod. cables	na	14.7
5.3.6	Subsystem assembly and test	na	11.7
	Total production		118
5.4	Management		21.7
	Grand total		218.7

conting.wk1

SCINTILLATION CALORIMETER CONTINGENCY ANALYSIS

WBS #	DESCRIPTION	RISKS ASSES TECH	COST	SCH	WEIGHT FAC. TECH	COST	SCH	CONT %	COST K$	COST + CONT.
5.1	Sys. design	8	1	2	2	1	1	19	333	396
5.2.1.1.1	Proto. preamp.	6	4	4	2	2	1	24	193	239
5.2.1.1.2	Proto. PM mon.	6	4	4	2	2	1	24	123	152
5.2.1.1.3	Proto SCA card	8	4	4	2	2	1	28	501	641
5.2.1.1.4	Proto. data col	6	4	4	2	2	1	24	112	138
5.2.1.1.5	Proto. R/W seq.	6	4	4	2	2	1	24	108	133
5.2.1.2.1	Proto preamp IC	2	4	4	2	2	1	16	65	75
5.2.1.2.2	Proto. R/W IC	6	4	4	2	2	1	24	48	59
5.2.1.2.3	Proto. buff. IC	2	4	4	2	2	1	16	64	74
5.2.1.2.4	Proto. delay IC	6	4	4	2	2	1	24	100	124
5.2.1.2.5	Proto. ADC IC	6	4	4	2	2	1	24	154	190
5.2.1.2.6	Proto. SCA IC	2	4	4	2	2	1	16	85	98
5.2.1.2.7	Proto. ALP IC	2	4	4	2	2	1	16	79	91
5.2.1.2.8	Proto. ADC buff	6	4	4	2	2	1	24	72	89
5.2.1.2.9	Proto. RO cont	6	4	4	2	2	1	24	74	91
5.2.1.3	IC test stand	6	4	4	2	2	1	24	219	271
5.2.2.1.1	Prot. mem. card	6	4	4	2	2	1	24	220	272
5.2.2.1.2	Proto. clk comm	6	4	4	2	2	1	24	141	174
5.2.2.1.3	Proto. proc.	2	4	4	2	2	1	16	59	68
5.2.3.1	Proto. FE crate	4	4	4	2	2	1	20	97	116
5.2.3.2	Proto. R crate	4	4	4	2	2	1	20	31	37
5.2.4.1	Proto. FE AC/DC	4	4	4	2	2	1	20	39	46
5.2.4.2	Proto. R AC/DC	4	4	4	2	2	1	20	33	39
5.2.5.1	Proto. FE cable	6	4	4	2	2	1	24	116	143
5.2.5.2	Proto. R cable	4	4	4	2	2	1	20	28	33
5.2.5.3	Cable tester	6	4	4	2	2	1	24	103	127
5.2.6	Cal & debug SW	6	4	4	2	2	1	24	108	133
5.2.7	Proto. sys test	6	4	4	2	2	1	24	263	326
	Prototype total								3568	4375
	Prototype contingency							22		

WBS #	DESCRIPTION	RISKS ASSES TECH	COST	SCH	WEIGHT FAC. TECH	COST	SCH	CONT %	COST K$	COST + CONT.
5.3.1.1.1	Prod. Preamp.	6	4	4	2	2	1	24	1104	1368
5.3.1.1.2	Prod. PM mon.	6	4	4	2	2	1	24	164	203
5.3.1.1.3	Prod. SCA card	6	8	8	2	2	1	36	803	1092
5.3.1.1.4	Prod. data coll	6	4	4	2	2	1	24	48	59
5.3.1.1.5	Prod. R/W seq.	6	4	4	2	2	1	24	87	107
5.3.1.2.1	Prod. preamp IC	2	3	4	2	2	1	14	144	164
5.3.1.2.2	Prod. R/W IC	2	3	4	2	2	1	14	32	36
5.3.1.2.3	Prod. buff. IC	2	3	4	2	2	1	14	92	104
5.3.1.2.4	Prod. delay IC	2	3	4	2	2	1	14	83	94
5.3.1.2.5	Prod. ADC IC	2	3	4	2	2	1	14	222	253
5.3.1.2.6	Prod. SCA IC	2	3	4	2	2	1	14	222	253
5.3.1.2.7	Prod. ALP IC	2	3	4	2	2	1	14	94	107
5.3.1.2.8	Prod readout IC	2	3	4	2	2	1	14	40	45
5.3.2.1.1	Prod. mem card	6	4	4	2	2	1	24	68	84
5.3.2.1.2	Prod clk & comm	6	4	4	2	2	1	24	86	106
5.3.2.1.3	Prod. processor	6	4	4	2	2	1	24	179	221
5.3.3.1	Prod. FE crate	4	4	4	2	2	1	20	132	158
5.3.3.2	Prod. R crate	4	4	4	2	2	1	20	35	42
5.3.4.1	Prod. FE AC/DC	4	4	4	2	2	1	20	133	159
5.3.4.2	Prod. R AC/DC	4	4	4	2	2	1	20	40	48
5.3.5.1	Prod. FE cable	4	4	4	2	2	1	20	560	672
5.3.5.2	Prod. R cable	4	4	4	2	2	1	20	43	51
5.3.6	Prod. assem.	6	4	8	2	2	1	28	481	615
	Production totals								4892	6041
	Production contingency							23		
5.4	Management	4	4	4	2	2	1	20	891	1069
	Grand totals								9351	11485
	Grand contingency							22		

7.0 Schedule and mile stones

7.1 Schedule

The top level schedule assuming a starting date of October 1991 is shown below.

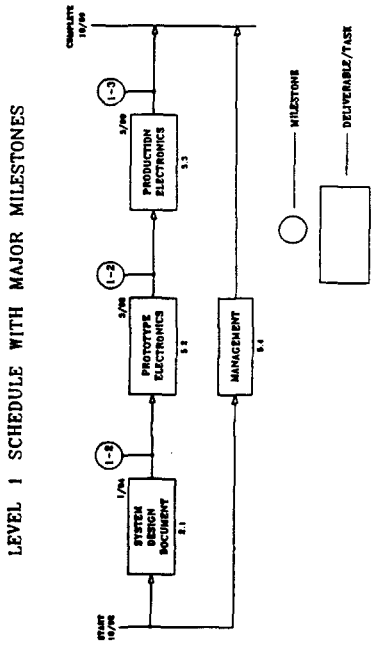


Figure 7.1a

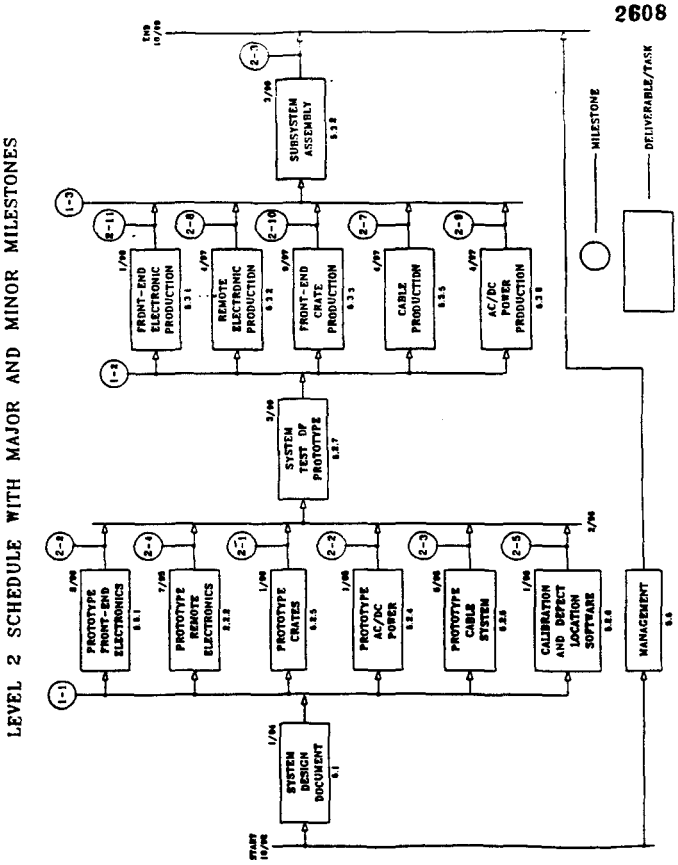


Figure 7.1b

7.2 Milestones

The milestones for the top level schedule are shown listed below

MAJOR MILE STONES

MILESTONE	DATE	DESCRIPTION
1-1	1/94	System design document is produced and the preliminary design review has recommended starting the prototype stage.
1-2	3/96	The prototype system test is complete and the critical design review board has recommended starting the production phase.
1-3	3/99	Production has been completed and the electronics are installed on-the-calorimeter wedges.

MINOR MILE STONES

MILESTONE	DATE	DESCRIPTION
2-1	1/95	Prototype crates have been designed, constructed and tested.
2-2	1/95	Prototype AC/DC power system have been designed, constructed and tested.
2-3	6/95	Prototype cable systems have been designed, constructed and tested.
2-4	7/95	Prototype remote electronics have been designed, constructed and tested.
2-5	11/96	Calibration and defect location software is coded and tested.
2-6	2/96	Prototype front-end electronics designed, constructed and tested.
2-7	4/97	Cables have been fabricated and tested.
2-8	4/97	Remote electronics have been fabricated and tested.
2-9	4/97	AC/DC power systems have been fabricated and tested.
2-10	8/97	Front-end crates, cables and power systems have been fabricated and tested.
2-11	1/98	Front-end electronic cards have been fabricated and tested.

7.3 Manpower loading

The manpower loading assuming a start date of 10/92 is shown in Table 7.3 below:

TABLE 7.3

MANPOWER LOADING (IN MAN MONTHS)

WBS NUMBER		10/92	10/93	10/94	10/95	10/96	10/97	10/98	TOTAL
5.1 System Design Document	E	20	7						27
	T	7	3						10
5.2 Prototype Electronics	E		68	84	47				199
	T		32	64	36				132
5.3 Production Electronics	E				10	20	15	2	47
	T				20	41	38	24	123
5.4 Management	E	10	10	10	10	10	10	5	65
	T	5	6	5	5	5	5	5	36
TOTAL	E	30	85	94	67	30	25	7	338
	T	12	41	69	61	46	43	29	301
TOTAL LABOR		42	126	163	128	76	68	36	639
TOTAL PERSONNEL		4.1	12.2	15.8	12.4	7.4	6.6	3.5	

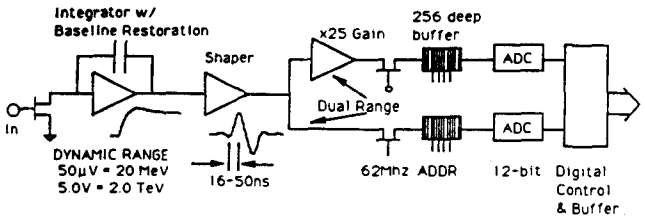
Scheduled at 10.3 MM/Person year
E = ELECTRONICS ENGINEER
T = ELECTRONIC TECHNICIAN

Front-End Electronics for the SSC

2611

Participants: R. Ely, R. Jared, I. Kipnis, F. Kirsten, S. Kleinfelder, M. Levi, T. Merrick, O. Milgrome

Task: Development of Analog Readout Circuits for Calorimetry



Requirements:

1) High Speed -- 62.5 Mhz
2) Large Dynamic Range -- 18 bits Constructed from Dual Range of 12 bits each
3) 256 Storage Locations (4 µsec Memory)
4) Digitize Data After Trigger Decision
5) Store Signal Transient
6) Random Access Analog Memory
7) Simultaneous Read & Write
8) Hold Data Pending Trigger Decision
9) On Chip ADC
10) Digital Storage Buffer

2612

SCINTILLATION CALORIMETER UNIT COST

WBS #	DESCRIPTION	COST/ CARD	COST($)/ CHANNEL (cal-unit)
5.1	System design document	na	8.1
5.2	Prototype electronics	na	78.9
	Total prototype		87
5.3.1.1.1	Prod. preamp. card and		
5.3.1.2.1	Prod. preamp. IC	233	27.9
5.3.1.1.2	Prod. PM current monitor	822	3.2
5.3.1.1.3	Prod. SCA card and		
5.3.1.2.2-8	Prod. all IC's except preamp.	4536	35.4
5.3.1.1.4	Prod. data collector card	1055	1.1
5.3.1.1.5	Prod. R/W sequencer card	1944	1.9
5.3.2.1.1	Prod. memory card	1502	1.5
5.3.2.1.2	Prod. clock dist. and slow communication	1902	1.9
5.3.2.1.3	Prod. processor card	7471	3.6
5.3.3.1	Prod. front-end crate	3138	3.1
5.3.3.2	Prod. remote crate	2891	0.5
5.3.4.1	Prod. front-end power	2946	2.9
5.3.4.2	Prod. remote power	3300	0.6
5.3.5	Prod. cables	na	14.7
5.3.6	Subsystem assembly and test	na	11.7
	Total production		110
5.4	Management		21.7
	Grand total		218.7

2613

SCA CARD
- PROTOTYPES $1397 K
- PRODUCTION 3844 (200K ASICS)

PREAMP
- PROTOTYPES $268 K
- PRODUCTION $816 K

CRATES + POWER
- PROTOTYPES $199 K
- PRODUCTION 833

CABLES
- PROTOTYPES $247 K
- PRODUCTION 769

MANAGEMENT $891 K

PROCESSOR CARD
- PROTOTYPES 59 K → DAQ
- PRODUCTION ~~430 K~~

TESTING 480

BUFFER MEMORY
- PROTOTYPES 220
- PRODUCTION 161

CURRENT MONITOR
- PROTOTYPES 122
- PRODUCTION 257

CLOCK DISTRIBUTION
- PROTOTYPES 191 → TRIGGER
- PRODUCTION ~~206~~

DESIGN DOCUMENT 323

2614

READ/WRITE SEQ
- PROTOTYPES 108
- PRODUCTION 204

PROTOTYPE ASSEMBLY 263

INSTALLATION 235

DATA COLLECTOR
- PROTOTYPES 112
- PRODUCTION 111

SOFTWARE 105

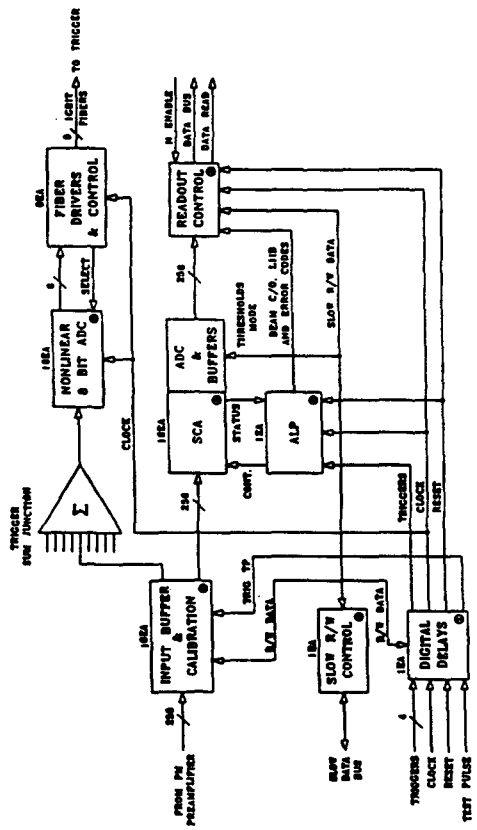
12804

CONTINGENCY 0.22 2817

15621

10% SPARES

SCA READOUT, CALIBRATION & ZERO SUPPRESSION



266 Mb/s OPTICAL LINK CARD

Product Description

The 266 Mb/s Optical Link Card (OLC) is a laser based data communications link for computer interconnect applications. The OLC 266 features two full-duplex optical ports utilizing low-cost high-performance optical components.

The electronics includes serializer, deserializer, and clock recovery functions, laser drive and automatic power control circuits, and laser safety functions including open fiber control.

Technology Leadership

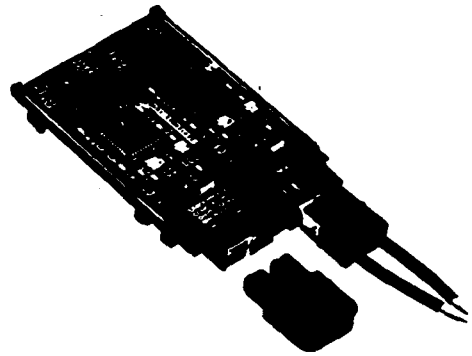
The OLC 266 represents industry leadership in key areas of laser safety, laser reliability, and modal noise solutions for multi-mode fiber applications. Cards are compatible with personal computer and workstation environments.

Highlights

- 266 Mb/s Transmission Rate up to 2km Distance
- Certified to be in Conformance with International Laser Safety Regulations
- High Reliability Optics
- Low Loss SC Type Push-Pull Connectors
- Parallel 10 Bit Data I/O Interface Compatible with ANSI FCS 8B/10B Coding
- Double Sided Surface Mount Technology

Laser Safety

The OLC 266, employing a unique open fiber control, prevents any emissions from exceeding Class 1 laser safety limits. The OLC 266 is certified in the U.S. to conform to the requirements of DHHS 21 CFR§ and internationally to conform to IEC 825 for Class 1 laser products. Class 1 is the least restrictive laser product classification and requires minimal labeling and documentation.

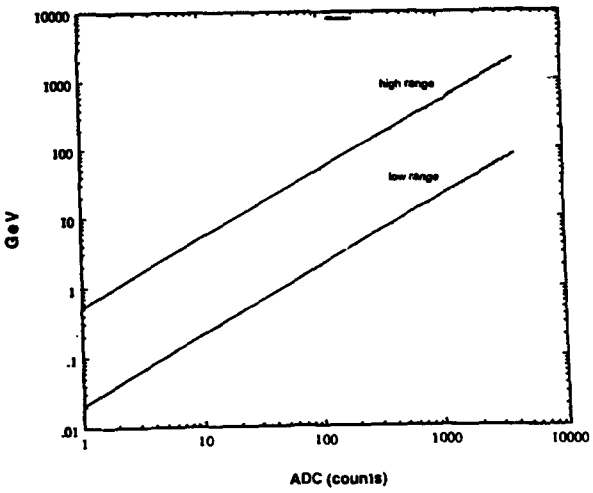


OLC 266

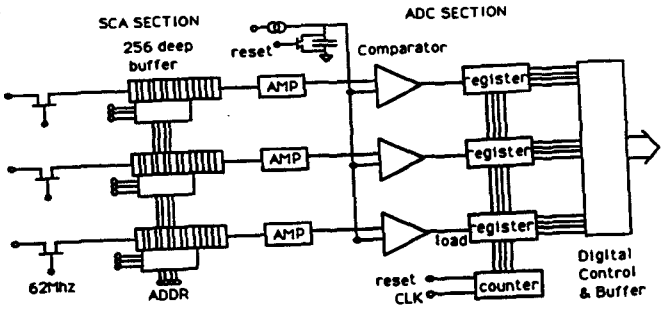
IBM

Dynamic Range

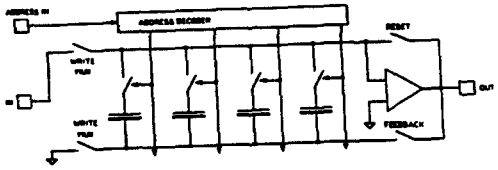
- Two 12-bit ranges (1:4096)
- Dual range extends the dynamic range to 1:100000
- Least count is 20 MeV
- Greatest count is 2 TeV
- Fractional Accuracy is always < 1%



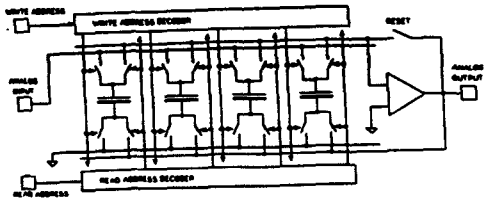
A 256 Element 16 Channel Switched Capacitor Array With a 12-bit Single Slope ADC



Basic Cell of Switched Capacitor Array:



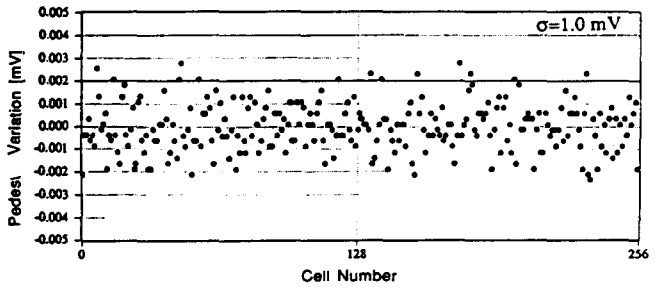
Basic Cell with Simultaneous Read/Write Capability:



SCA Pedestal Variation

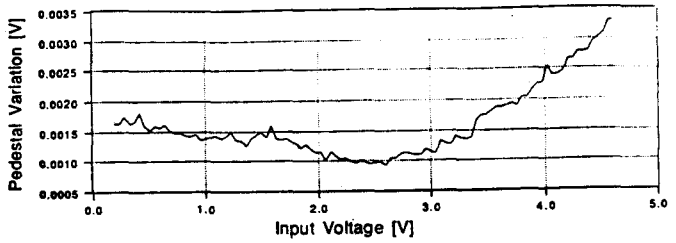
⇒ Single shot variation dominated by kT+1/f noise

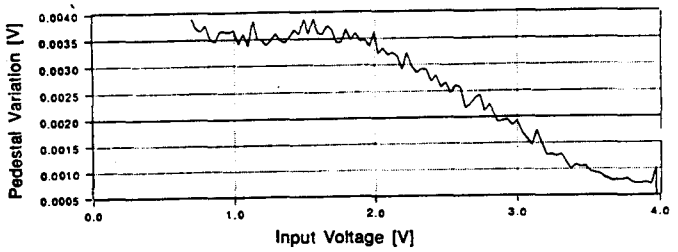
⇒ Differential inputs with 10 volt effective input swing.

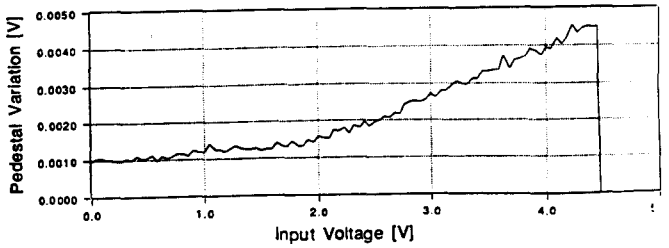


⇒ Pedestal variation must be ≤ 1.2 mV rms in a 5V range to achieve 12-bit dynamic range (1:4096).

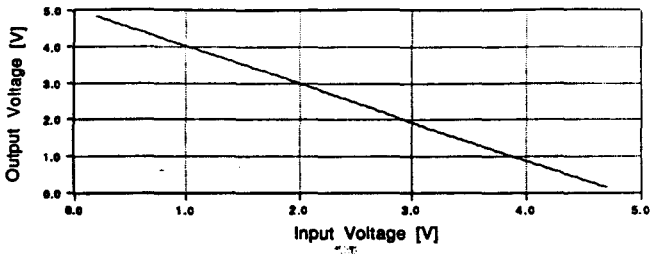
SCA Pedestal Variation

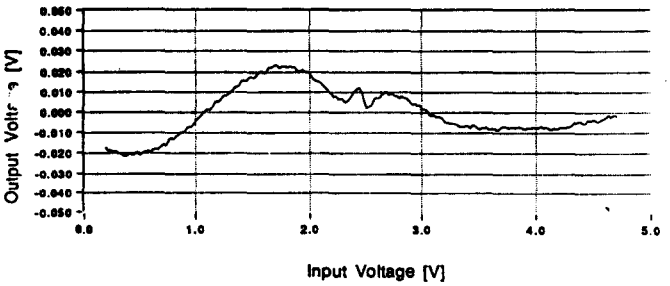






SCA Linearity





Chip Parameters:

SCA Parameters	Achieved Performance
No. channels/chip	16
No. of elements/channel	256
Power/channel	10 mW
Non-linearity	+/- 0.1%
Pedestal variation	0.5 mV rms
Charging time constant	1.5 ns
Channel dynamic range	5000
Maximum sample rate	90 MHz
Maximum readout rate	200 KHz
Noise floor	0.7 mV rms
Input voltage range	0.2-4.8 Volts
Capacitor droop rate	0.1 mV/msec
Output Settling Time	1.2 µsec (to 0.02%)

Current Status:

Work continuing on maintaining large dynamic range.

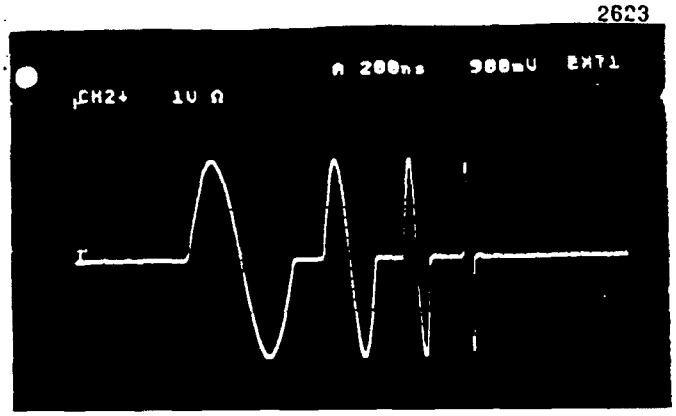
Learning how to reduce effects of digital noise.

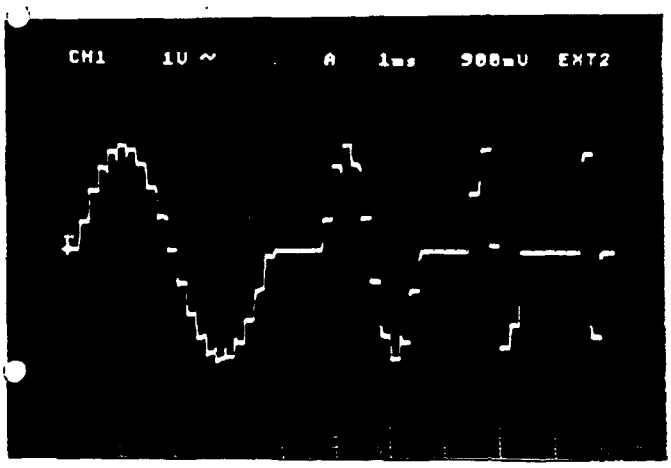
ADC being integrated with SCA.

Design Work in Progress:

1) Design an Analog Store with 5 volt Differential Inputs
2) Address Generation & Pointer Manipulation
3) High Speed Preamp & Shaper

2623





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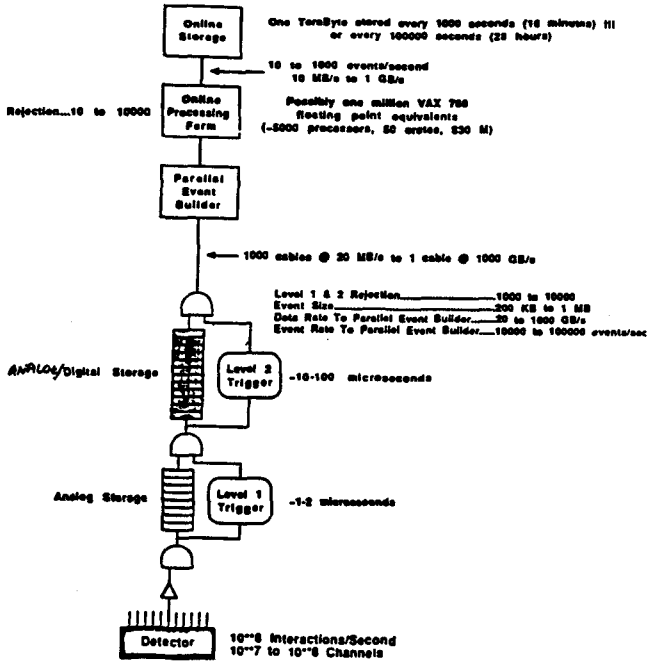
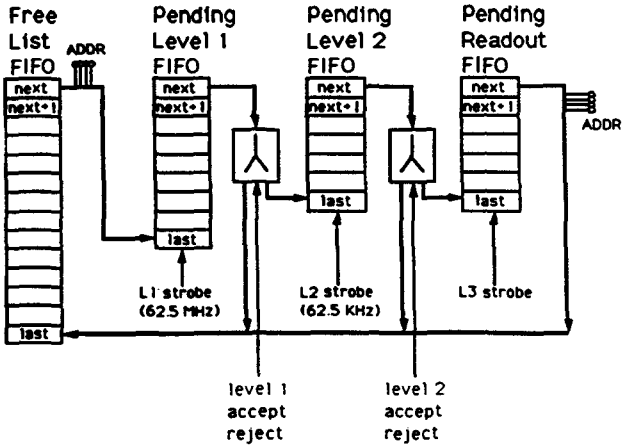


2625

Address List Processor

Address Generation & Pointer Manipulation:

1) Generates input storage locations for the SCA at 62.5 MHz.
2) Maintains a list of saved data until trigger decision is complete.
3) Propagates the list of pointers through the multi-tiered trigger decision chain.
4) Generates addresses for SCA readout.
5) Consists of four high-speed First-In First-Out memories.



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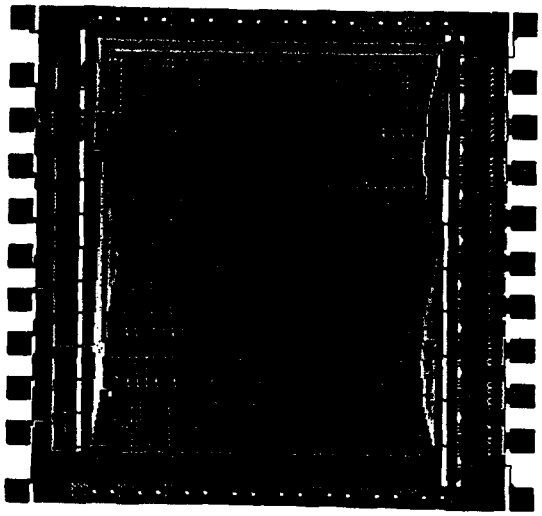

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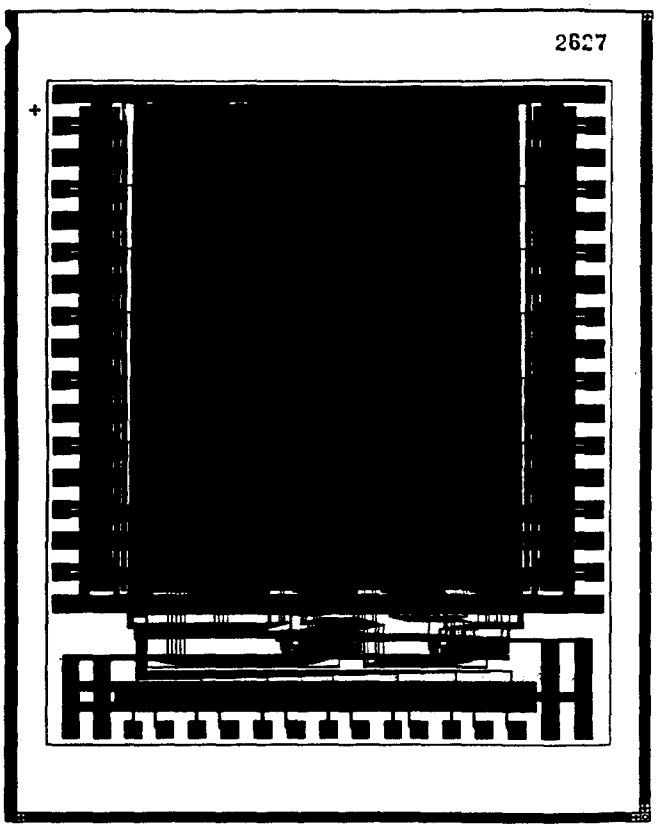


2628

12 BIT MULTICHANNEL ANALOG TO DIGITAL CONVERTER

B. MILGROME, S. KLEINFELDER, M. LEVI

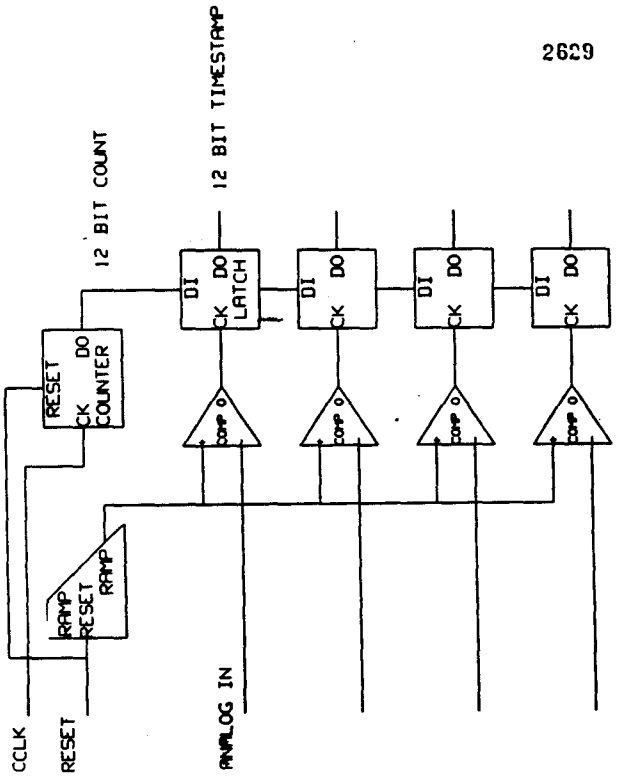
LAWRENCE BERKELEY LABORATORY

PURPOSE: READOUT SCA AFTER TRIGGER

TARGET SPECS	RESULTS ACHIEVED
RESOLUTION > 1/4096	1/4096
LINEARITY > 1/128	1/4096
CONVERSION SPEED < 64US	< 32US
POWER PER CHANNEL < 10MW	5MW

2629

MULTICHANNEL SINGLE SLOPE ADC



2630

ADC

Counter

12-bit pipelined gray code counter.
Counts on every edge of 125 MHz clock (250 MHz effective rate).
5MW

Analog Ramp

5V ramp in 32 µsec.
Excellent linearity due to improved error amplifier
4 mW

Comparator

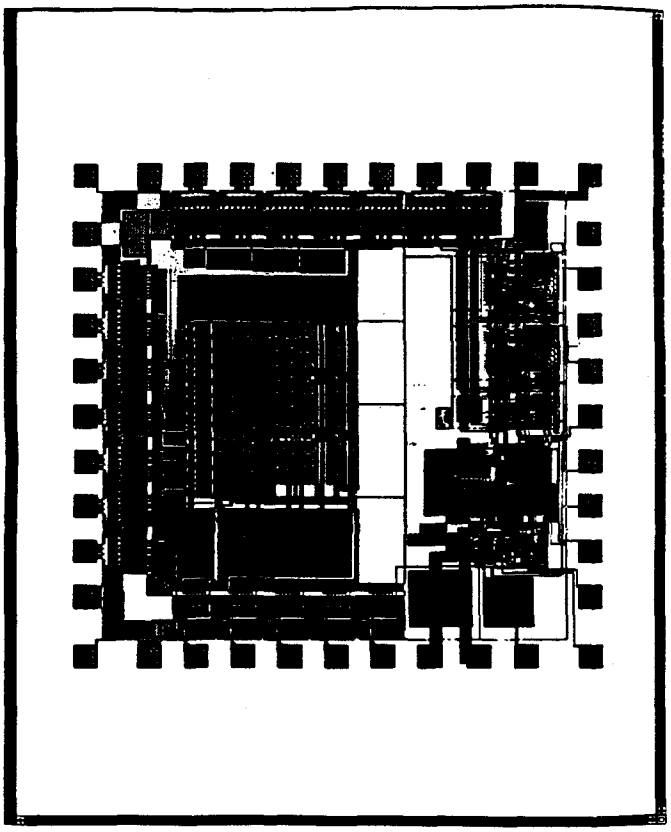
5 stage linear amplifier with hysteresis
DC gain of 10^8
sensitivity ≤ 1 mV
5 mW/channel

Operation

12 bit conversion with ~~64~~ 32 kHz throughput.

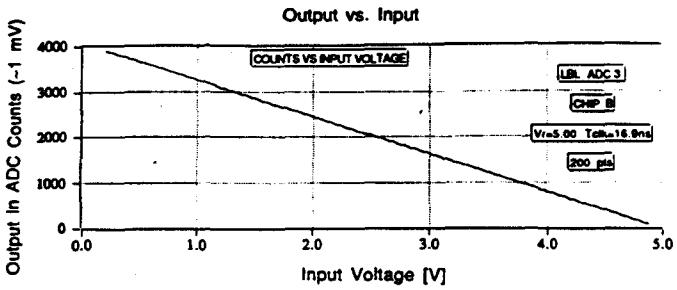
Integrated circuit successfully combines high speed CMOS f_{clk} = 62 MHz with analog signals smaller than 1 mV

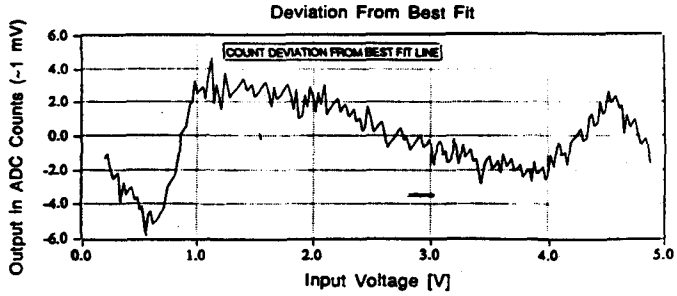
2631



ADC Linearity

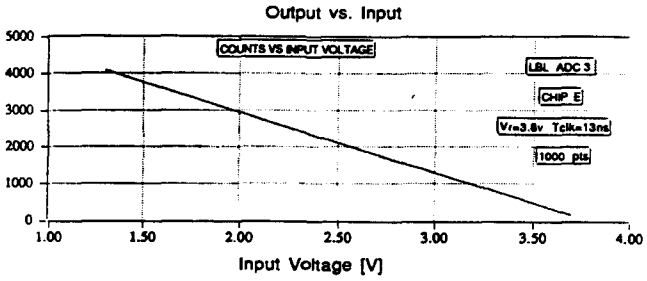
2632

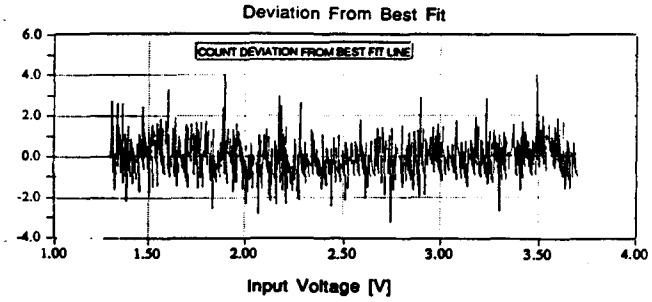




ADC Linearity

2633





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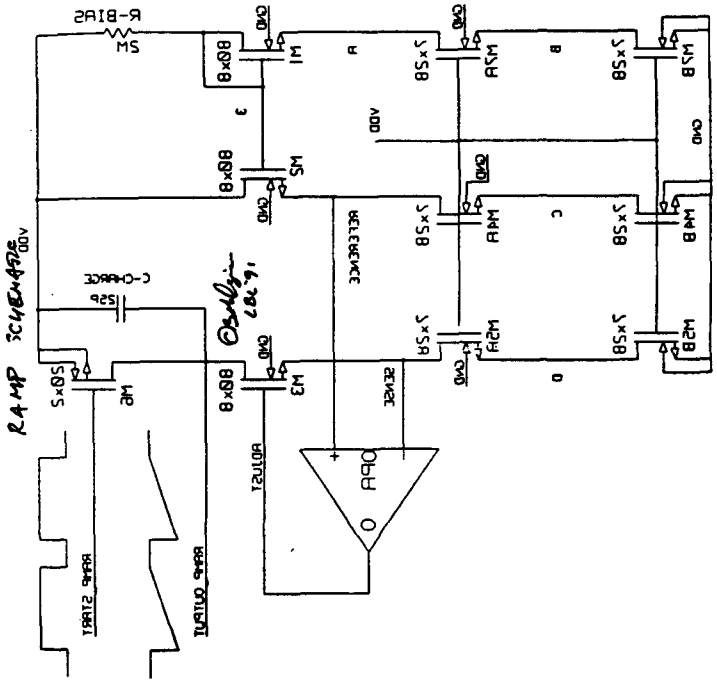

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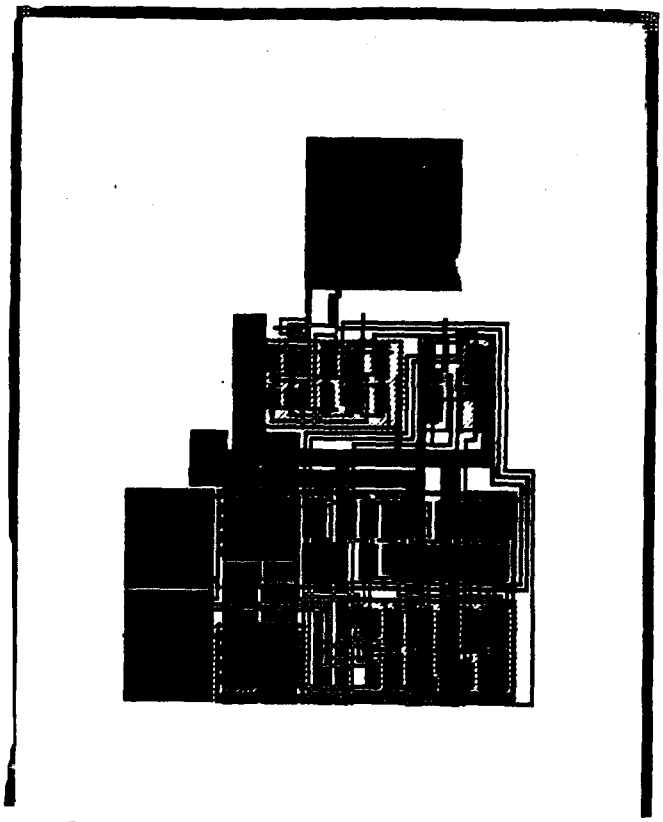
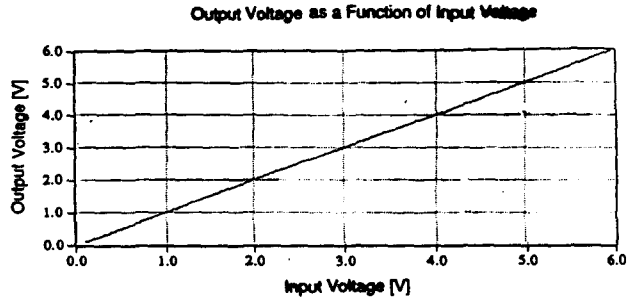
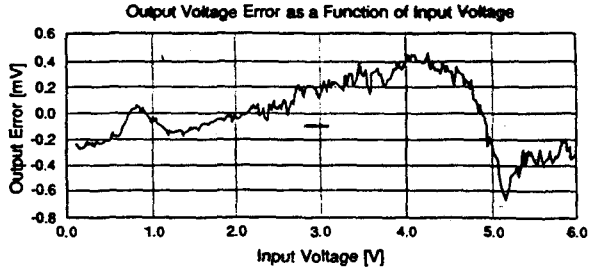


2636

Op-Amp Linearity





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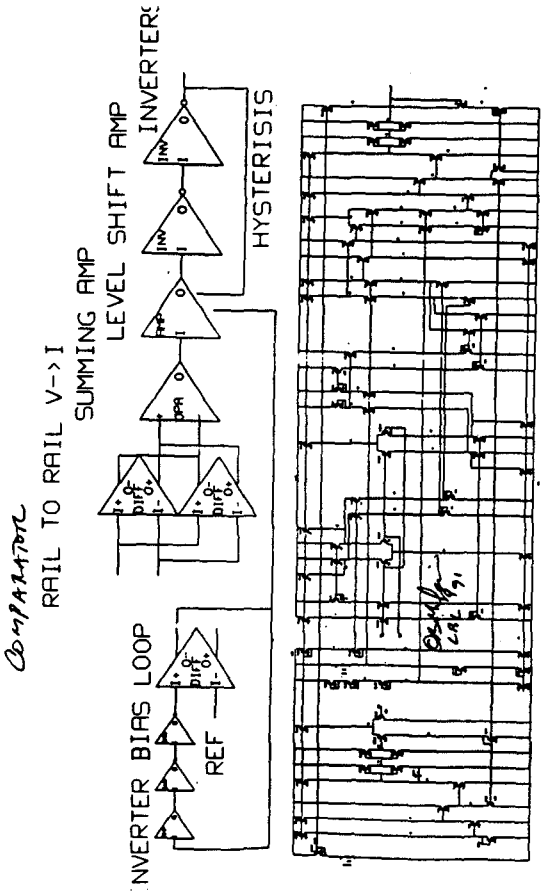
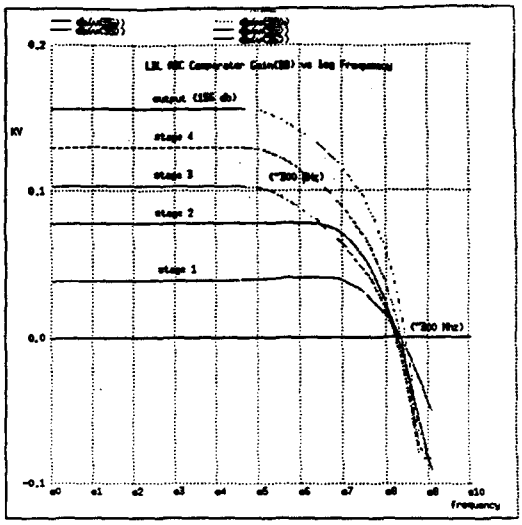


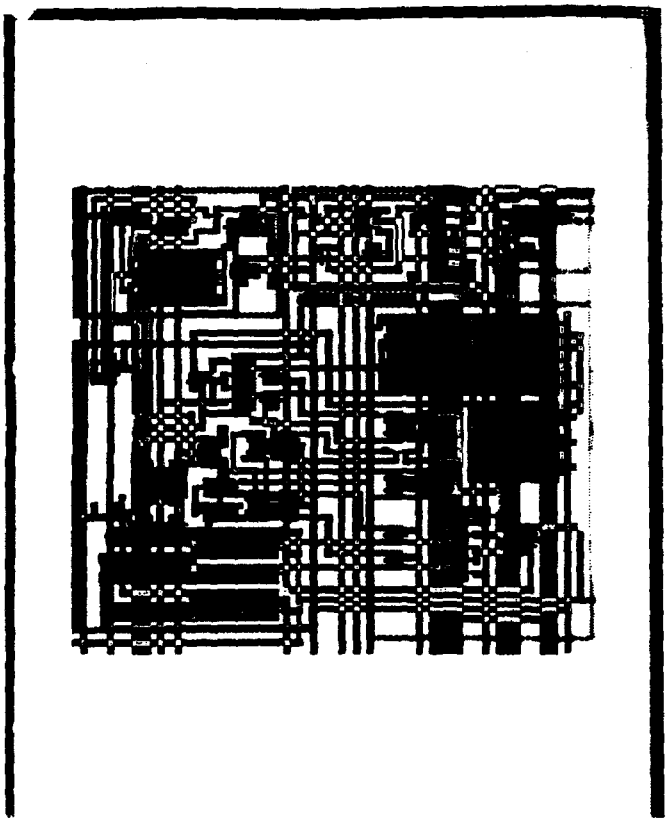
2638



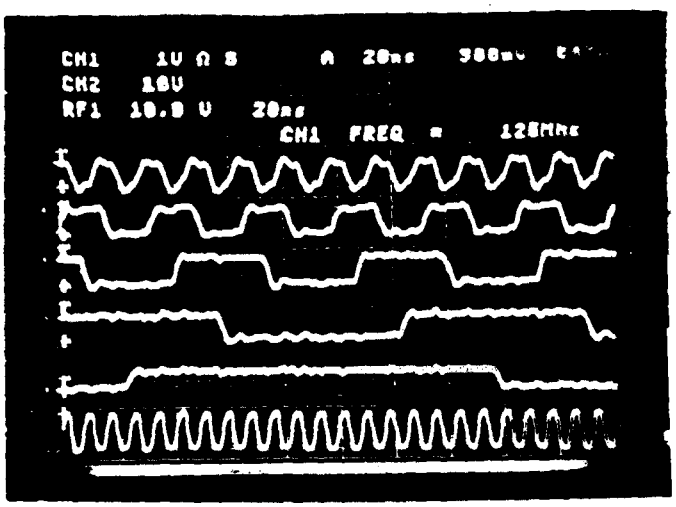
COMPARATOR GAIN-BANDWIDTH = 300 MHz

DC OPEN LOOP = 65×10^6

2639

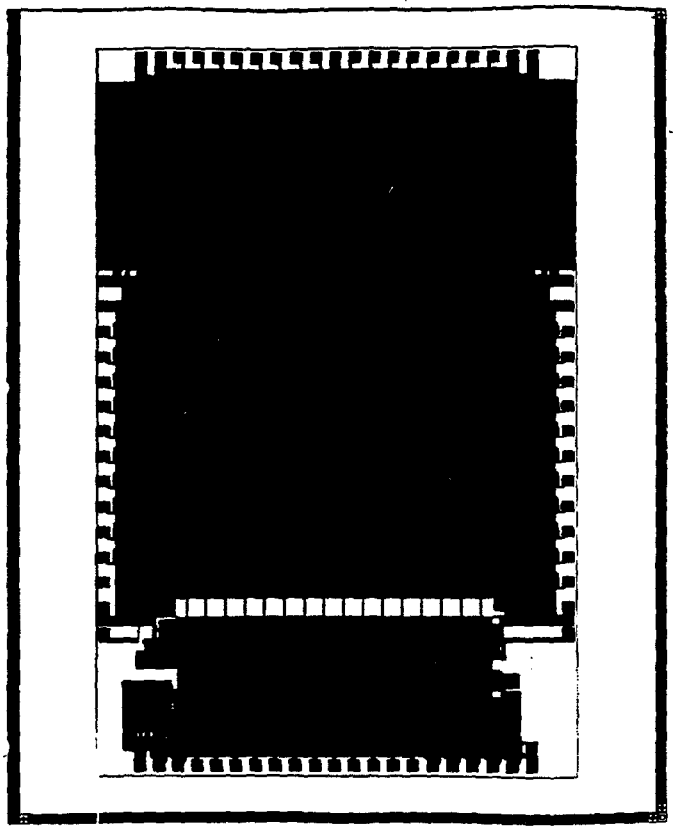


2640



125 MHz INPUT CLOCK, BUT COUNTS ON EVERY CLOCK EDGE

2641



2642

Conclusions

1) Completed conceptual and baseline design for calorimeter front-end electronics based on switched capacitor readout.

   Design is compatible with a variety of calorimetric detectors (*e.g.* barrel, end-cap, shower max.), and a variety of calorimetric technologies (*e.g.* scintillator or liquid argon).

2) First version of 12-bit ADC functional.
   - 32 μsec conversion time at 2 mW in 2μm CMOS.
   - 16 μsec conversion time with faster clock.

3) SCA moved to advanced technology 1.2 μm CMOS process. Version with 256 elements/channel just fabricated.

4) L1/L2/Readout Architecture chip (ALP) layout completed in 1.2 μm CMOS.
   - FIFO memory fabricated in 2 μm CMOS and tested at speeds up to 330 MHz.

5) Design of preamp for low gain scintillator PMT initiated.

6) Design of multi-channel board begun.

- Decision point later this year for SDC electronics
- Barrel/Endcap Calorimeter Electronics
- Detector at EM Shower Maximum

The ShowerMax Electronics

(descoped scheme)

Summary of the Saclay group investigations

P. Bonamy, E.Beuville, JC Brisson, J. Ernwein,
R. Hubbard, J. Lugiez, P. Le Dû,

V2.0

July 1991

The ShowerMax ... an overview

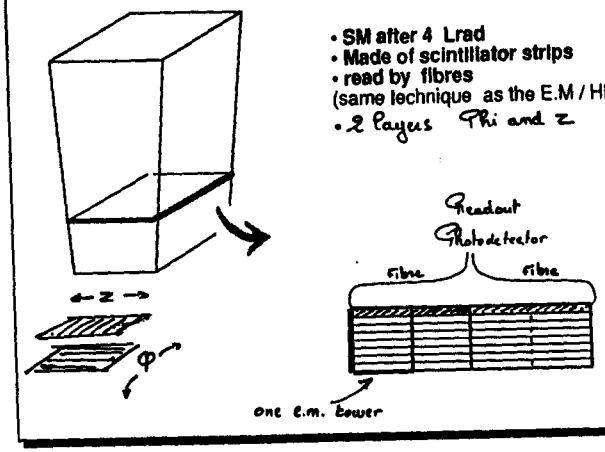
Multipurpose device ---->

- electron trigger (L1 ? & L2)

---> increase the calorimeter granularity (isolation criteria ..)

---> track match

Mechanical Design



- SM after 4 Lrad
- Made of scintillator strips
- read by fibres

(same technique as the E.M / HD calorimeter)

- 2 layers Phi and z

Physical segmentation & channel count

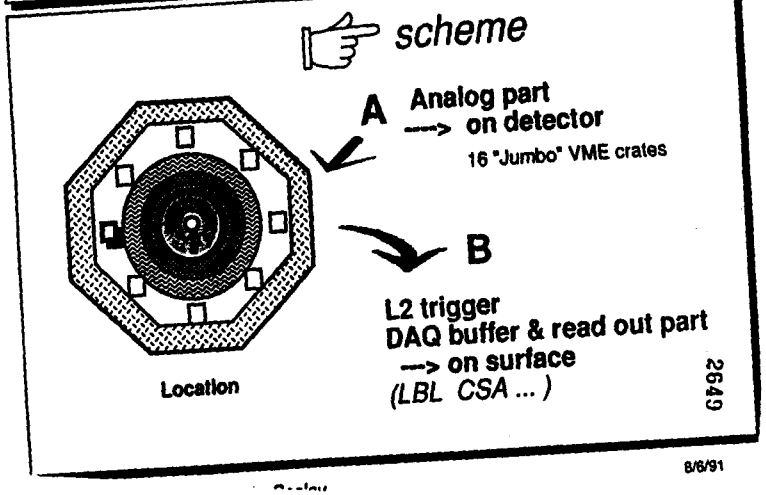
Compatibility with EM/hadron scintillating tile calorimeter

Barrel	End cap
• 8 wedges	• 32 sectors x 2 end caps
• 128 phi x 64 eta	• 48 pads / sector
• 8192 "towers"	• 1536"pads" x 2
---> 8 ch / 4 towers "Phi"	---> 16 ch. / 4 pads
---> 8 ch / 4 towers "z"	= 12288 channels
= 32768 channels	

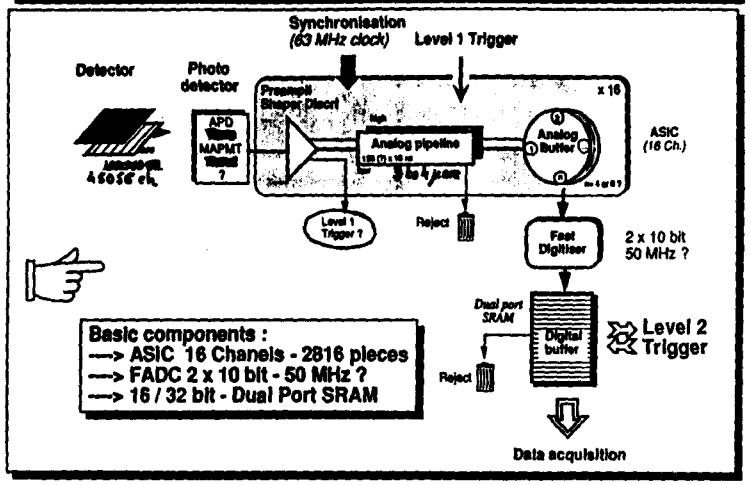
1024 "phi" segmentation

- Total = 45056 Channels

Electronics : topological layout

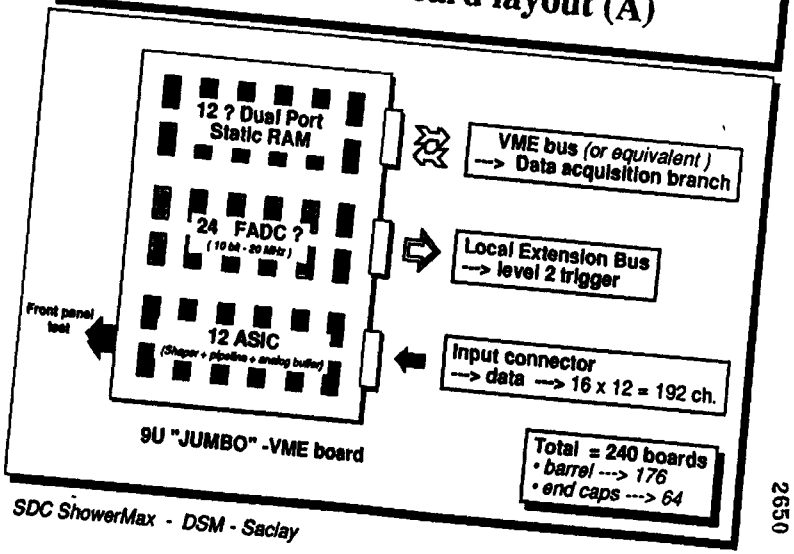


Front end read out scheme



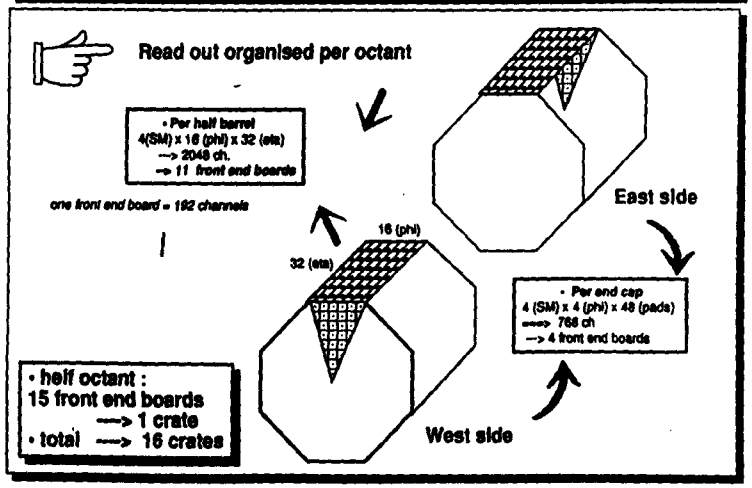
SDC ShowerMax - DSM - Saclay 8/6/91 2647

Front end board layout (A)



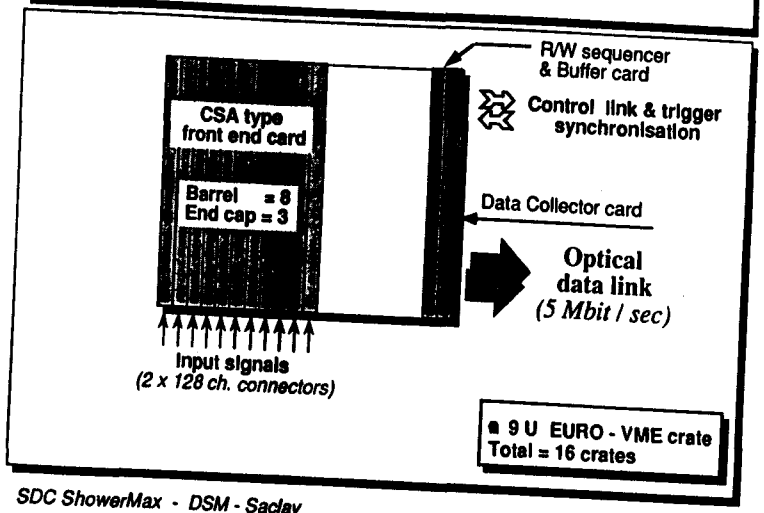
SDC ShowerMax - DSM - Saclay 8/6/91 2650 8

Front end read out partition



SDC ShowerMax - DSM - Saclay 8/6/91 2648

Front end Crate (B)



SDC ShowerMax - DSM - Saclay 8/6/91

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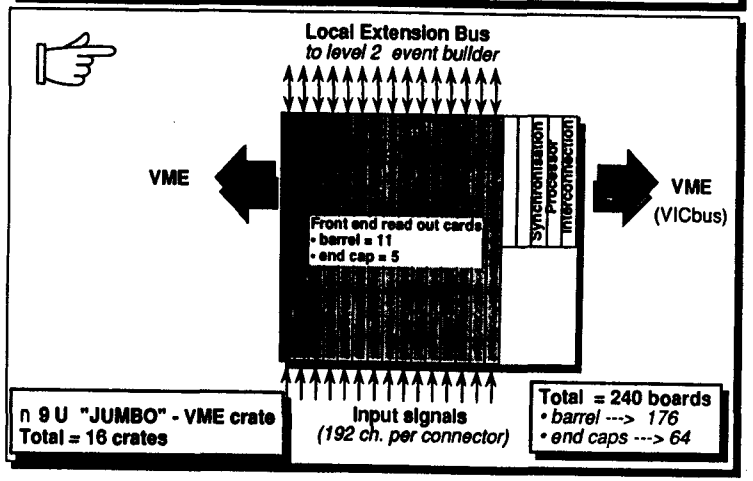
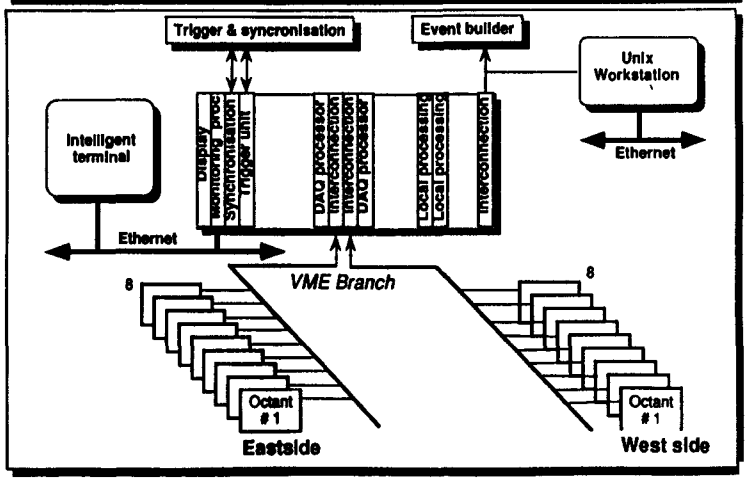
Front end Crate (A)



SDC ShowerMax - DSM - Saclay 8/6/91

2651 9

Data acquisition



SDC ShowerMax - DSM - Saclay 8/6/91

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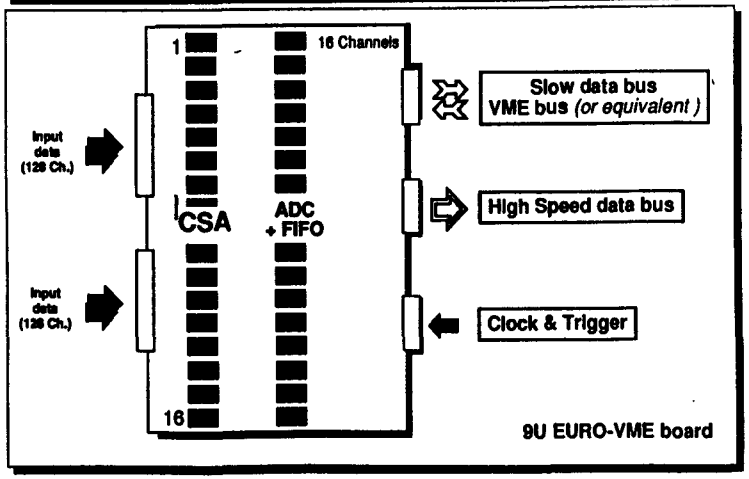
Front end board layout (B)



SDC ShowerMax - DSM - Saclay 8/6/91

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The Showermax at the Level 1 trigger

Efficient & cost effective solution to increase the selectivity of "Isolated" electrons and reduce the background rate as soon as possible

- **Extract one bit per "phi" bin at the front end ASIC level**
  ----> 1024 x 4 = 4096 bit (2 barrel + 2 end cap)
  ----> merge with EM local or global
  ----> merge with "tracking" ???

Front end board cost

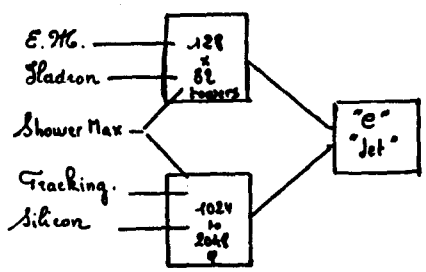
The principal ingredient is the front end board

	Component		Nb	FF	$	Total (FF)	Total ($)
	PC board	6 layers type (classe 4)	1	1500	250	1500	250
	Connectors	VME type	2	60	10	120	20
	Connector	data 196 pins	1	500	83.3	500	
?	ASIC	shaper +pipeline+analog buffer	12	300	50	3600	600
??	FADC	10 bit - 20 MHz	24	300	50	7200	1200
?	Static RAM	50 ns - 16 bit x 1024	12	100	16.7	1200	200
	Control logic	VME + clock ...	1	1000	167	1000	167
	Cabling & test		1	2000	333	2000	333
	Cost per board					17120	2770
	Cost per channel					89	14
	EM cost /ch	(Fermilab Flash encoder)					155

? = Upper limit

The Showermax at the level 2 trigger

use the 2 layers (phi & Z) digitized data to refine the level 1 calorimeter trigger
----> isolated electron
----> electron cluster
----> topological cut
----> fine tracking merge



Technique
- DSP
- MMP
- Transputer

Summary & Cost

Components	Description or type	Number	cost/ unit KFF	cost/ unit K$	Total MFF	Total M$
Photodetector & Cables	APD, VLPC	45056	0.12	0.02	5.407	0.901
Front end						
Front end card	192 ch. digitiser	240	17	2.833	4.080	0.680
Crate	9U Euro-VME	18	18	3	0.288	0.048
Processor (Acquisition)	FIC	18	18	3	0.288	0.048
Synchro & trigger	LTU	18	9	1.5	0.144	0.024
Processor (Monitoring)	FIC	2	18	3	0.036	0.006
Crate interconnection	VIC	16	15	2.5	0.240	0.040
DAQ						
Crate	VME	1	18	3	0.018	0.003
Processors	FIC & RAID	5	30	5	0.150	0.025
Crate interconnection	VIC	3	15	2.5	0.045	0.008
Cables	optical fibres...				0.300	0.050
Workstation & Periph.	SUN4...				0.500	0.083
TOTAL					11.496	1.916
add 10% (protos,spares)					12.645	2.107

240 FF or 40 $ per channel
(Photodetector + Front end + DAQ)

FIBER TRACKER ELECTRONICS INTERFACES

A. BAUMBAUGH

PCDR for Fiber tracker:

1) Requirements:
DAQ
Trigger system
VLPCs
Fibers

2) Conceptual design:

The Sci-Fi tracking system for the barrel region is envisioned as follows.

The fibers are arranged in some as yet undetermined set of "super layers" having both axial and narrow angle stereo fibers. These scinillating fibers are connected to clear fiber waveguides which transport the light to photo-sensitive devices such as the VLPCs (Visual Light Photon Counters) which detect and amplify the light signal and produce, in the end, a digital signal for each fiber. Thus, each fiber channel has a digital signal for each beam crossing which is a 1 if there was light in the fiber and a 0 otherwise.

These signals are transported to the Sci-Fi readout crate via fine pitch ribbon cables. These cables terminate on the readout cards within the crate. Each card will accomodate upto 640 fibers. Also transported on the ribbon cables, are power for the VLPCs and Bias and temperature monitoring signals.

The readout card has receivers for the incoming signals, these line receivers may be included in the first level storage ASIC. This readout card is envisioned to be a standard 9U X 400 mm Eurocard with a VME interface to the backplane. Crate ocupancy is a maximum of 9 readout cards/crate, also in the crate will be a clock and trigger distribution card and 1 or more CPUs to pass data to the DAQ system.

The clock and trigger distribution card receives RF clocks and level 1 and 2 trigger accepts or rejects from the trigger system and passes these signal on the the readout cards. This board provides time skewing of these signals to the readout cards to assure that signals and data are correctly timed.

On the readout board the digital signals from each channel of VLPCs is passed to the level 1 storage/delay ASIC. Each ASIC accomodates 64 channels of VLPC and provides a digital storage pipeline for the level 1 trigger delay. This storage is organized as a FIFO of fixed length and an input to this ASIC for "level 1 accept" is used to pass the data on to a smaller Level 2 FIFO within the ASIC. This Level 2 FIFO requires 2 additional inputs to the ASIC, "Level 2 accept" and "Level 2 reject", both of these will cause the data from the level 2 FIFO to be removed from the level 2 buffer, however, only the accept signal will cause it to be passed to the "readout FIFO" within the ASIC. This final FIFO holds the data for reading by the DAQ. Thus the Level 1 storage ASIC provides all of these features. It may also provide some level of track segment finding for use in the trigger. (However, at this time I believe that there is no fiber trigger in the baseline design.)

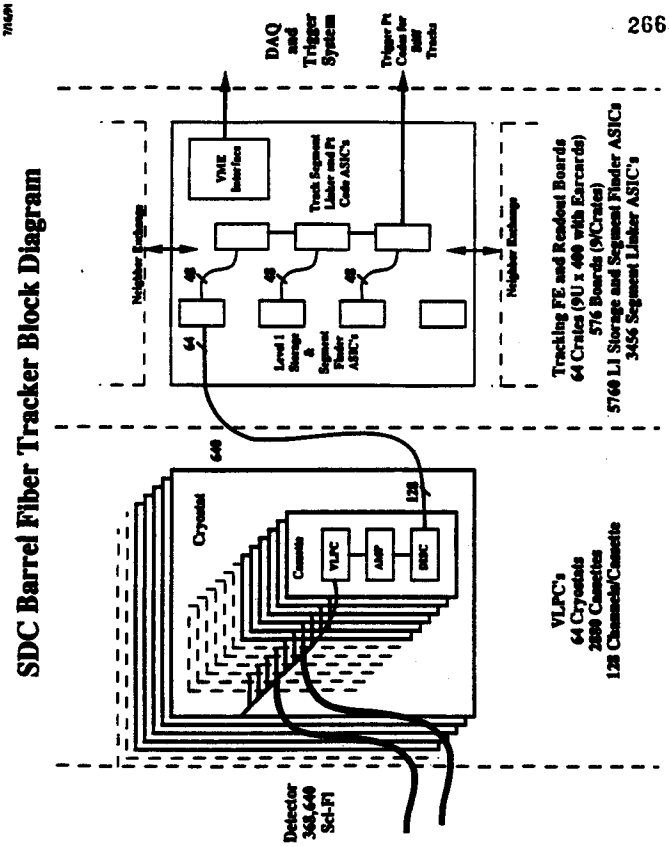
The Sci-fi trigger, if it exists, would only use axial fibers and is provided by a 2 or 3 level system of ASICs. The first level would be provided as part of the level 1 storage ASIC, this ASIC would provide a set of 24 outputs which correspond to the possible segments which might exist in the 64 fibers which are inputs to the ASIC. These 24 output are provided as 8 positions and 3 dip angles for each position. Each position is a fiber

Key Features / Issues

- Assumptions:
  - Fast Detectors
  - Efficient Trigger
  - Scintillating Fiber Tracking
  - Scintillating Tile Calorimeter
- DAQ uniformity
- System redundancy
- Given systems may need 100 → 1000 channels as test.

Key Assumptions

- Minimum Pt for trigger purposes is 10 Gev
- System has full 1 / 512 symmetry (Card to card boundaries are the same as crate to crate)
- Fiber diameters are adjusted to maintain this symmetry in each layer
- Fiber counts in each layer have a convenient least common factor (64)
- System redundancy is an important issue
- Full digital pipeline running at 62.456762 MHz
- One thousand events / sec are read off the detector
- Simulated data can be downloaded to test the system



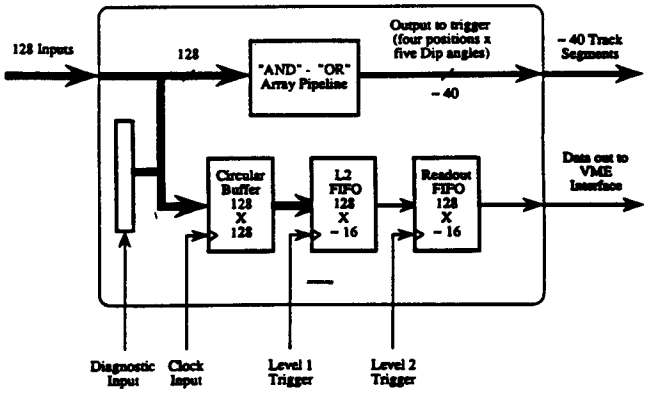
SDC
Tracking/Trigger ASIC 1

(7.0K Required)

Stores all "Hit" information locally while trigger is formed

Provides serial readout of selected events

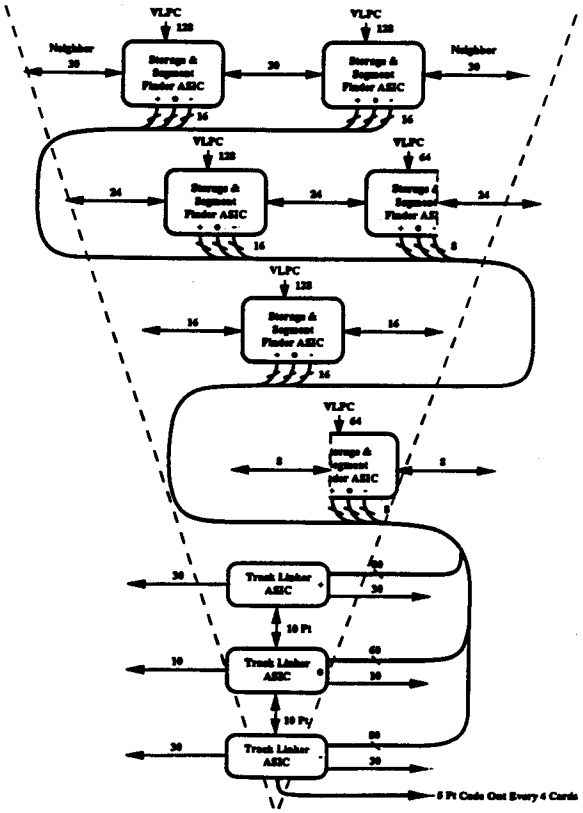
Provides "Track Segments" for trigger

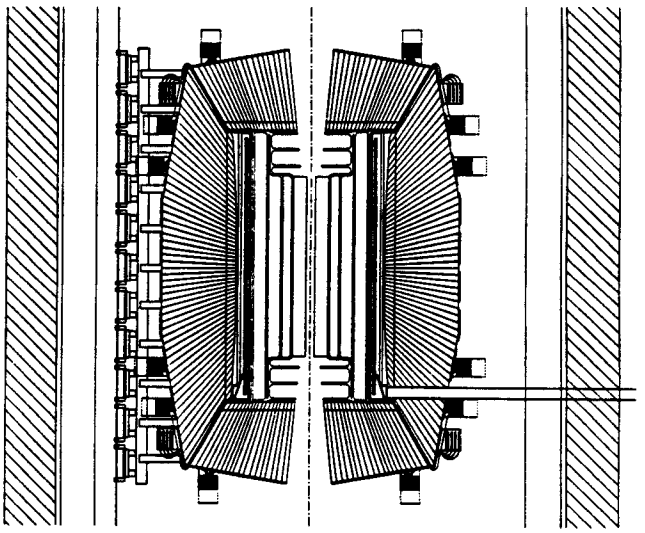


(ASIC 2 is similar for segment linking, 3.5K required)

Level 1 Track Finder

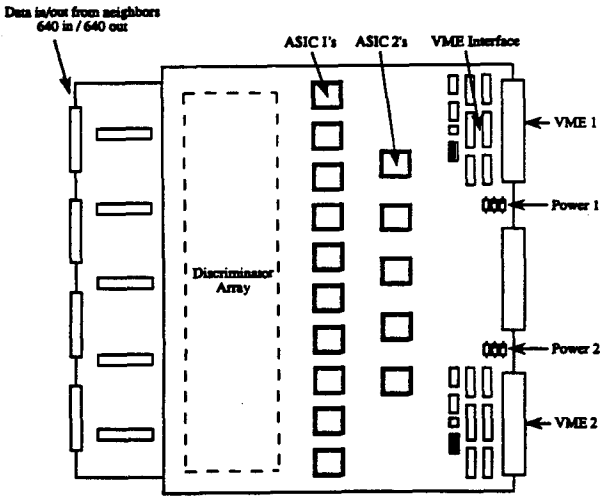
(1 Card ~ 640 Inputs)





SDC Fiber Tracker Reciever Board

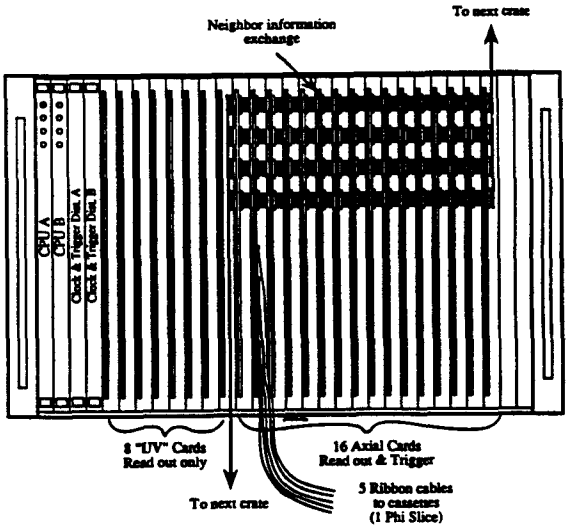
9 U x 400mm (14.437" x 15.750") Printed Circuit Board



SDC Fiber Tracking Crate

24 Tracking/Readout Cards

30 Slots @ 1 inch



diameter. These track segments are passed to the second level ASIC which uses combinatorial logic to link these segments into tracks. These segment linking ASICs would have programable parameters for the Pt bins of tracks they are linking. Thus the output of the segment linker would be a series of bits corresponding to tracks at certain positions with certain Pt values. The third level of ASIC, which might be included inside the segment linker, would be a track parser. This track parser would take track bits and parse them into bins of highest Pt which correspond to calorimeter towers or phi bins for the Muon system. These parsed track bins or bits would passed from the card to the trigger system on ribbon cables or optical fiber links.

3) block diagram showing functionality

4) block diagram showing layout

5) The sci-fi tracker interfaces with 2 or 3 other systems, the DAQ and the trigger systems certainly, and perhaps with the calorimeter for local electron ID. The interface with the DAQ is via standard VME protocol. Note: slow control and monitoring are also provide via the VME interface although they may have a separate CPU within the crate for these functions. Interface to the trigger system consist of trigger inputs to the crate as described above and track information out to the trigger system which would be via ribbon cable or optical fiber.

6) Critical components in the system are the VLPCs and the ASICs. We have working samples of the VLPCs and as far as the ASICs are concerned work is progressing on the storage ASIC for both tile calorimetry and Sci-fi tracking. We have working prototypes of a storage pipeline ASIC which we are testing.

7) Packaging solutions:

The readout crate would be a standard eurocard crate which is readily available from a variety of sources. We may wish a custome backplane for distribution of clock and trigger signals. The VLPCs require a cryostat which would be about the same size as the crate and would be located as close as is practical to the readout crate. The VLPCs would be installed in the cryostat in cassettes which would be easily removed for service and would have quick connects for both optical fibers and electronics signals.

8) Resource requirements:

Space: as stated each wedge half (32 per half detector) should require a cryostat for the VLPCs and a readout crate. This crate would only be half full as it could be a short crate or could be shared with other systems.

NOTE: IT IS IMPERITIVE THAT EACH SYSTEM DWN UP TO THE DATA RATES REQUIRED FOR THAT SYSTEM.....OTHERWISE THERE IS NO WAY TO MERGE THE SYSTEMS INTO A REASONABLE DAQ SYSTEM. IE. we cannot share a crate with a system if it needs 10 times the VME backplane data rate. IT IS TIME EACH SYSTEM BE HONEST AND TELL WHAT ITS DATA RATES ARE.

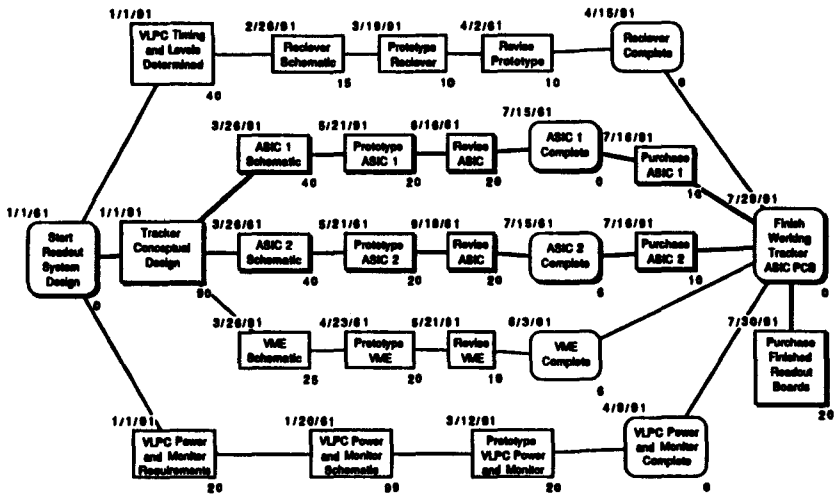
Power: Each crate will require 1000 watts of power for the readout cards and CPU. This is also the amount of cooling required

Cabling: Cables from the VLPC cryostat to the crate are short length fine pitch ribbon cables. The trigger system interface could be ribbon cable or optical fiber link (1/crate). The DAQ interface cable would probably be 1 or 2 optical fibers/crate.

System Data Rates

- **368,640 Sci-Fibers ~ 5,760 Fibers per crate**
  (~ 1920 Bytes/Crate/Crossing)
- **Raw Data - CPU; VME limited data rate**
  VME 40 Mb/sec, 720 Bytes yields 0.018ms
  VME Limit would be 55,500 Events/sec/CPU (111,000 Events/sec)
- **10% Occupancy Absolute Upper Limit**
  576 Hits/Crate
- **Modified "Run Length" Compression ~ 4 bits / hit pixel**
  2,304 Bits or 288 Bytes/Crate/Crossing
- **Compacted Data - Ethernet (80% - 800KB/sec)**
  (288 Bytes - 0.36ms/Event - 2,770 Events/sec/Ethernet)
- **5,500 Events/sec limited by Ethernet for worst case occupancy**

Crate Readout Board



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Power Dissipation Estimate
Sci-Fi Receiver Card

Each Board	Power
Each receiver card has 640 inputs	
640 Discriminators @ 50 mw	32
10 ASIC I 's @ 2 Watts (Pipeline store & Segment Finder)	20
5 ASIC II 's @ 2 Watts (Track Finder)	10
2 VME Interfaces @ 2 Watts	4
Total Power Dissipation Watts / board	66

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SDC91INPUTsciFi 5 11

	A	B	C	D	E	F	G	H	J	K	L	M	N
1		WBS OR ACTIVITY DESCRIPTION	UNIT	QTY	UNIT COSTS	DIRECT	OVERHEAD	MATERIAL	OH MAT	SUBCONTRACT	AD MAT	ADMIN MAT	TOTAL
2	5 1 1	Scintillating Fiber Tracker Front end Electronics											
3	5 1 1 1	Sci-Fi front end electronics design document				200		100	100				100
4	5 1 1 1 2	R & M Report Document				50							
5	5 1 1 2	Prototype electronics											
6	5 1 1 2 1	Front-end electronics											
7	5 1 1 2 1 1	Front-end design				200							
8	5 1 1 2 1 2	Mounted Cards		16	1.5	50							
9	5 1 1 2 1 3	VLPC interface				20							70
10	5 1 1 2 1 4	VLPC Cooling											
11	5 1 1 2 1 5	L1 Storage and Segment Finder ASIC											
12	5 1 1 2 1 5 1	ASIC design				500		100	50				200
13	5 1 1 2 1 5 2	ASIC Manufacture		200	0.05								50
14	5 1 1 2 1 6	Develop protocol											
15	5 1 1 2 1 6 1	Design interface				20							20
16	5 1 1 2 1 6 2	Prototype interface				5							20
17	5 1 1 2 2	Electronic Crates											
18	5 1 1 2 2 1	Crate design				100							50
19	5 1 1 2 2 2	Crate mechanics						50					
20	5 1 1 2 2 3	Crate Backplane		3	1.5	100							50
21	5 1 1 2 2 4	Crate Power											
22	5 1 1 2 2 4 1	Power design				20		10					
23	5 1 1 2 2 4 2	Power System		3	5								15
24	5 1 1 2 2 5	Cabling											
25	5 1 1 2 2 5 1	Cable design				40							
26	5 1 1 2 2 5 2	Cables											40
27	5 1 1 2 3	Produce system tests		200	0.01	100							200
28	5 1 1 3	Production Electronics											
29	5 1 1 3 1	Front end electronics											
30	5 1 1 3 1 1	Front end design											
31	5 1 1 3 1 2	Increase Crates		70	1			50					50
32	5 1 1 3 1 2 1	Crate mech				10							
33	5 1 1 3 1 2 2	Crate mechanics				10							
34	5 1 1 3 1 2 2 1	Car card refinements				10							10
35	5 1 1 3 1 2 2 2	Car cards		2300	0.1			10					
36	5 1 1 3 1 2 3	Crate Backplane		70	2	20							
37	5 1 1 3 1 2 4	Crate Power											
38	5 1 1 3 1 2 4 1	Power supply mech				5							
39	5 1 1 3 1 2 4 2	Power Supplies		70	10								
40	5 1 1 3 1 2 5	Cabling											
41	5 1 1 3 1 2 5 1	Cable design refinements				5							
42	5 1 1 3 1 2 5 2	Cables		256	0.01		20						30
43	5 1 1 3 1 2 5 3	Connectors		512	0.005		30						30
44	5 1 1 3 1 3	VME											
45	5 1 1 3 1 3 1	VME interface				20		10					30
46	5 1 1 3 1 3 2	VME Cabling		16000	0.02	10							20
47	5 1 1 3 1 4	L1 Storage and Segment Finder ASIC											
48	5 1 1 3 1 4 1	ASIC design refinements				200							100
49	5 1 1 3 1 4 2	ASIC Manufacture		12000	0.05		50	40					
50	5 1 1 3 1 5	Mounted Board		600	1.5	50			50				50
51	5 1 1 3 1 5 1	Subassembly tests				200							
52	5 1 1 3 1 5 2	Test Industry											
53	5 1 1 3 1 5 2 1	ASIC test fixtures											
54	5 1 1 3 1 5 2 1 1	Design				100		50					50
55	5 1 1 3 1 5 2 1 2	Test Industry		3	10	30							150
56	5 1 1 3 1 5 2 2	Board Test Fixtures											
57	5 1 1 3 1 5 2 2 1	Design				100		50					50

Page 1

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Power Dissipation Estimate
Sci-Fi Receiver Crates

Each Crate	Power
Each crate holds 24 receiver cards	
24 Sci-Fi Receiver cards @ 66 Watts	1,584
2 VME Processor Cards @ 25 Watts	50
2 Trigger & Clock Distribution @ 30 Watts	60
Total Power Dissipation Watts / Crate	1694

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9) Cost estimate: See WBSbs docs.

10) Schedule:
VPLCs working
Fiber splicing/connectors
Sci-fi trigger Yes/No ?
ASIC designs

11) Crucial R&D: The most critical R&D items are the VLPCs and Scintillating fibers. The ASICs are also critical but to a much lower extent. It si possible that within a short time the level of complexity needed in the ASICs will be available as FPGA(Field Programmable Gate Arrays) devices, this would reduce the cost of the ASICs greatly. These could be used for the segment linker and track parser ASICs. The Level 1 storage ASIC could be the same as the storage ASIC for the Calorimeter, thus reducing engineering cost.

Preliminary

Conceptual Design of Straw-Tube Readout with TMC

Y. Arai and Y. Watase
(KEK)

SDC Meeting at LBL, Aug. 5-10, 1991

1. Requirements for the straw-tube readout system

a. Time resolution

final position resolution σx = 150 μm
drift velosity in the tube 100 μm/nsec

150 μm =>1.5 nsec (chamber +elect.)
=> 0.75 nsec (elect.)

$(0.75)^2 = (\Delta t^2/12 + 0.43^2)$

Chip intrinsics

Digitization error

0.6 nsec = Δt / SQRT(12)

==> TMC resolution Δt = 2 nsec

b. Radiation hardness

Inner radius of Straw-tube = 70 cm
Dose rate = 10 kRad/y
Rad. hardness required is 300 kRad
for the detector life of 10 years.

c. Power consumption

less than 30 mW/ch within the detector wall

Total power inside= 150kch x 0.03 W
= 4.5 kW

d. Level 1 buffer depth = 3 - 4 μsec

e. Deadtime less readout

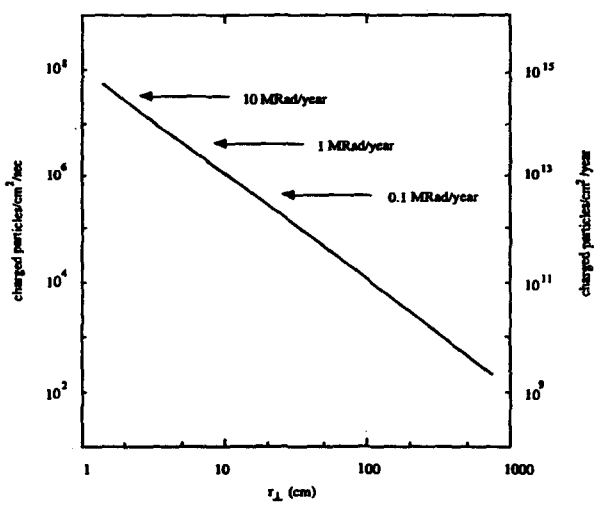
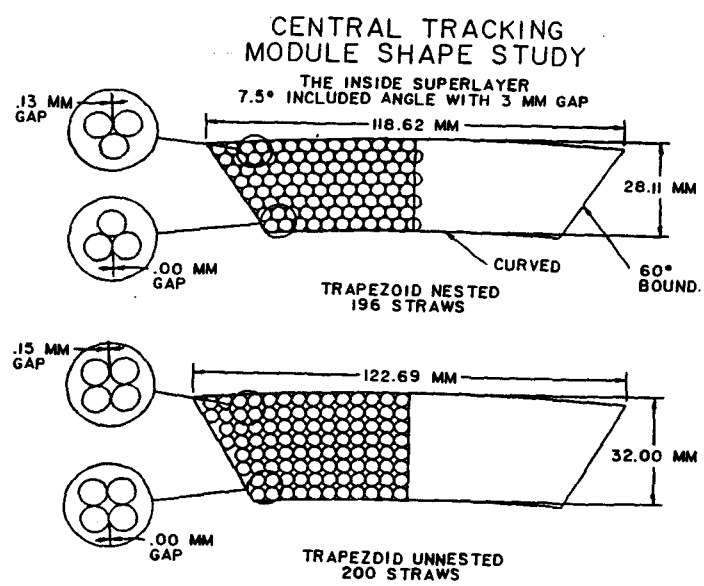


Fig. 3.3.1 Charged particle rate at $L = 10^{33} cm^{-2} s^{-1}$.



2. Conceptual Design

2.1 Straw-tube Detector Parameters

Inner radius	> 50 cm
Outer radius	= 170 cm
Length	= 8 m
Wire configuration	
No. of Superlayer	= 8
No. of wire in a superlayer	= 6 - 8
Dimention of tube	= 4 mm diameter
Dimension of Straw Module	= 116 x 21 cm
No. of wires in the Module	= 159
Total number of channels	= 150,000

2.2 Key Components of the system

Pre-Amp/ Shaper/ Disc.

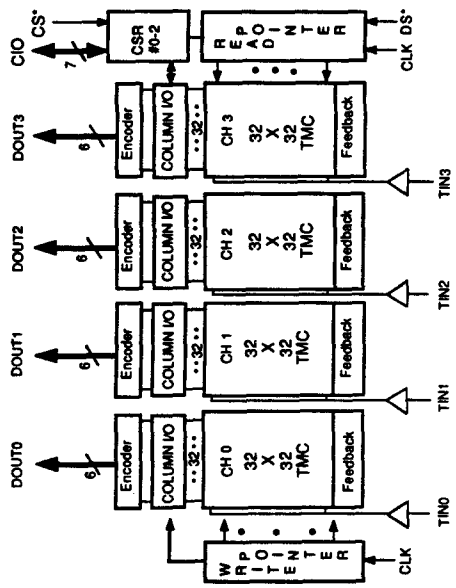
8 ch per chip
Gain= 300 mV/ $10^5 e^-$
Peaking time = 2.3 - 4.5 nsec
Rad. Hard: 1 MRad for γ
10^{13} neutrons cm^{-2}

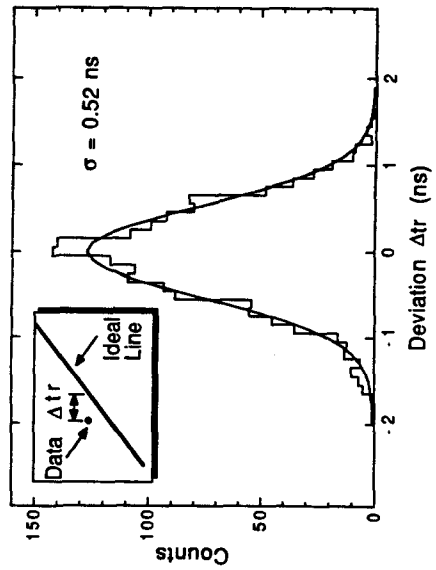
TMC

Time-to-digital converter
4 ch / chip
Time resolution Δt= 2 nsec
First level data buffering for 3 - 4 μsec
16 bit to 4 bit encoder
Trigger signal for a stiff track
Rad. Hard: 1 MRad (power off) for γ
(NTT BiCMOS)

Buff/Encoder

Second level data buffering
Control logic for TMC
Row data to 8 bit encoder
Data compress with Zero suppressing
Trigger data output for second level trigger
Rad. Hard : NTT BiCMOS (?)





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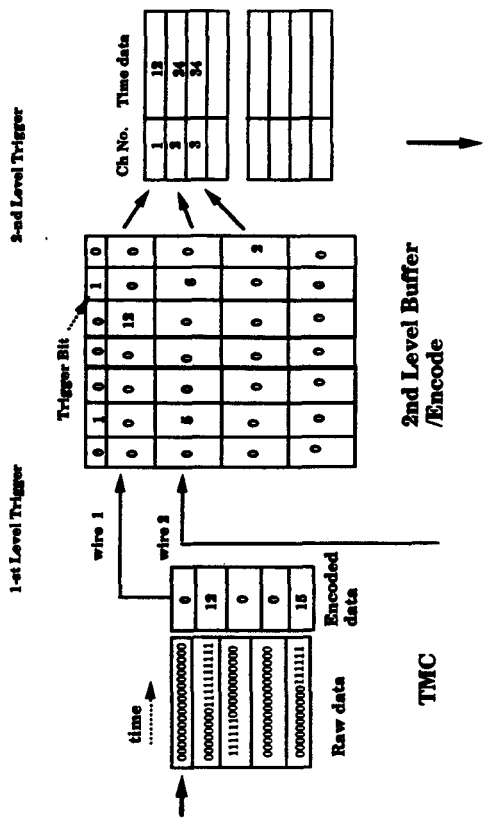

DATA FORMAT

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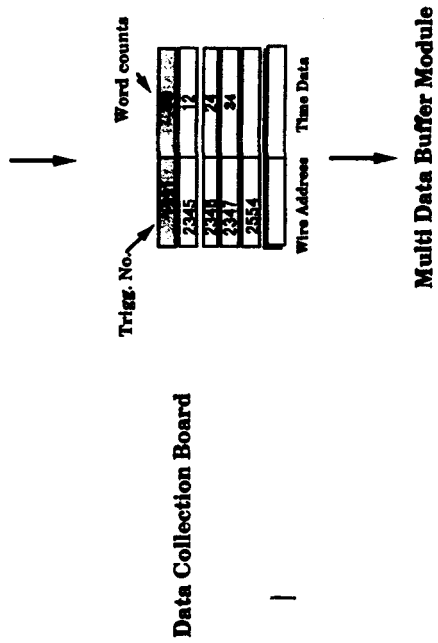

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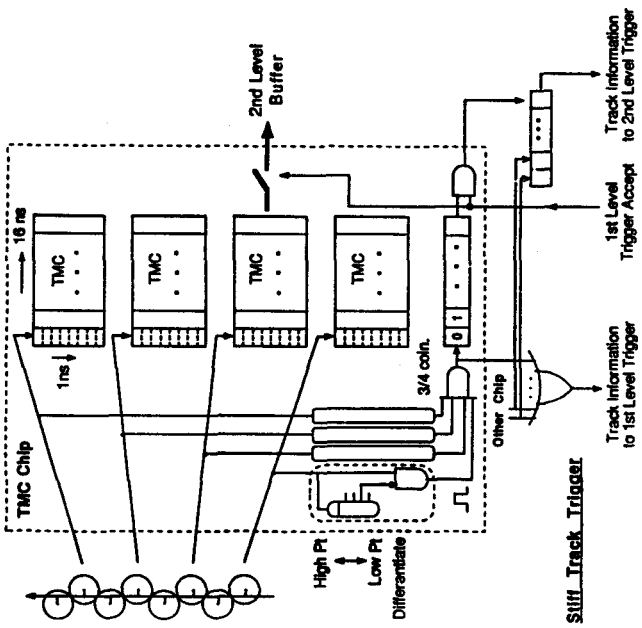

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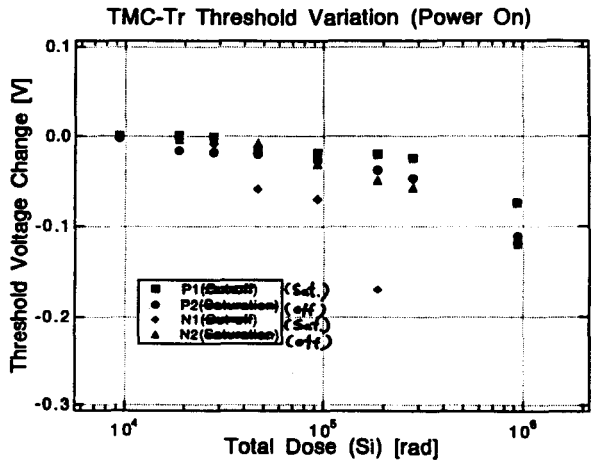
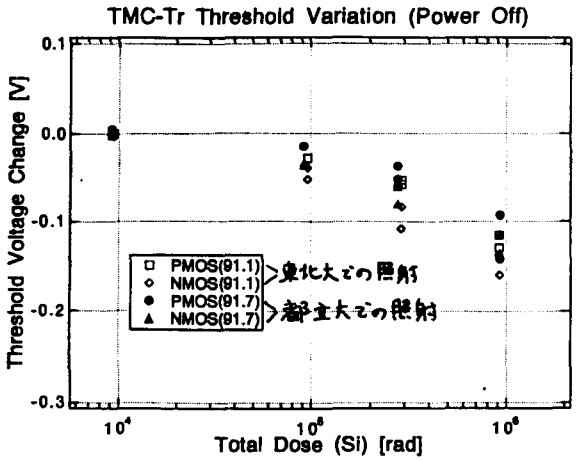


- PMOS Tr は Saturation, Cut-off とも $|\Delta Th| < 0.15$ V で OK.
- NMOS Cut-off Tr も $|\Delta Th| < 0.15$ V
- NMOS Saturation Tr は特性がおかしくなる。



・前回の東北大での結果を再現

Frontend Board

Contains pre-amp, TMC and Buff/Encoder .
Be mounted on the Straw-tube Module.
A Frontend Borad for one Straw Module
;256 ch per Board

Data Collection Board

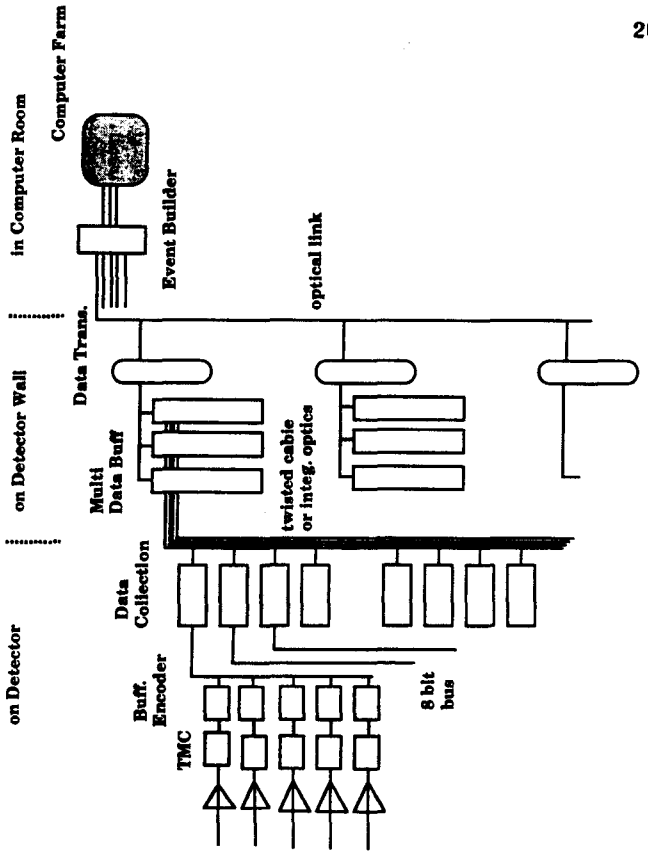
Local controller for readout
Rough dimension: 12 x12 cm
Data collection from Frontend Boards through 8 bit data bus
Data memory of 16 kB
Trigger number counter
Serial output of the track data to MDB
Network link for overall control
Clock distribution
1-st and 2-nd level trigger regeneration
Analog/digital test pulse generation

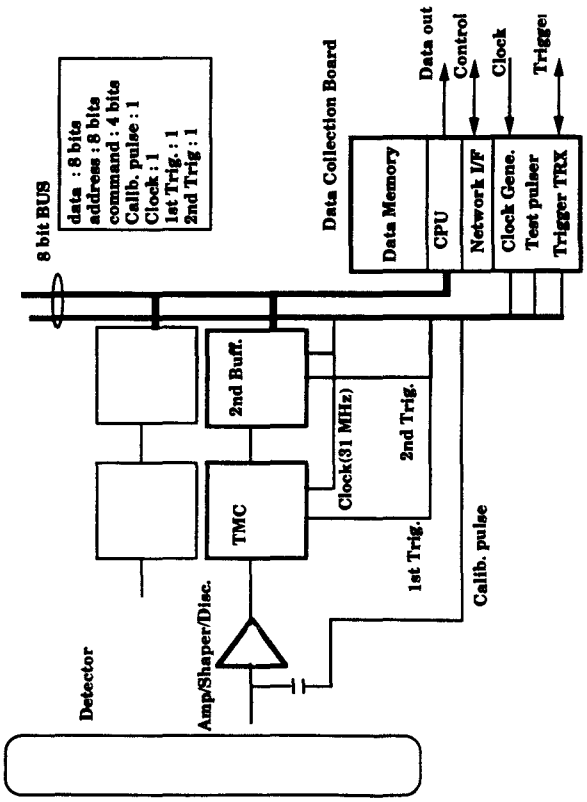
Multi Data Buffer Module i.e. 9 U VME module
Accept 4 serial data inputs from Data Collection Boards

Buffer memory 1 MB

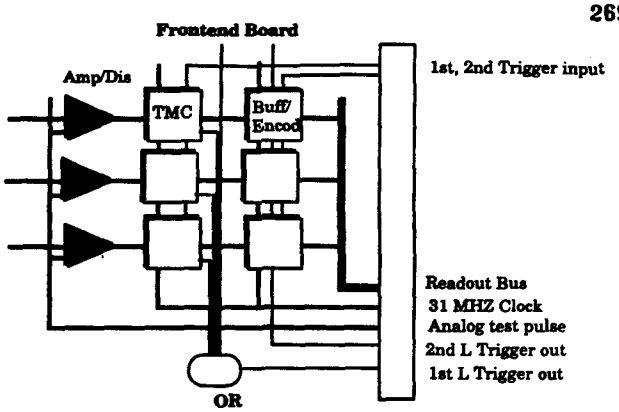
—

Data Transmission Module i.e. 9U VME
Collect data in the crate(10 MDB modules)
Data output for optical data link to Event builder

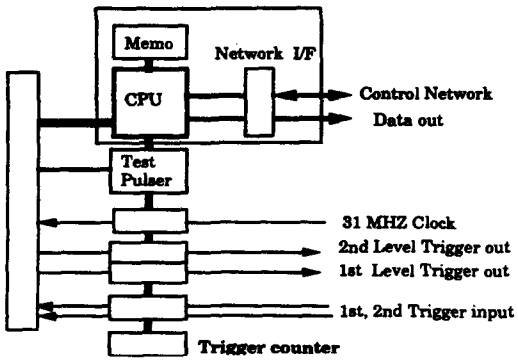




2695



Data Collection Board

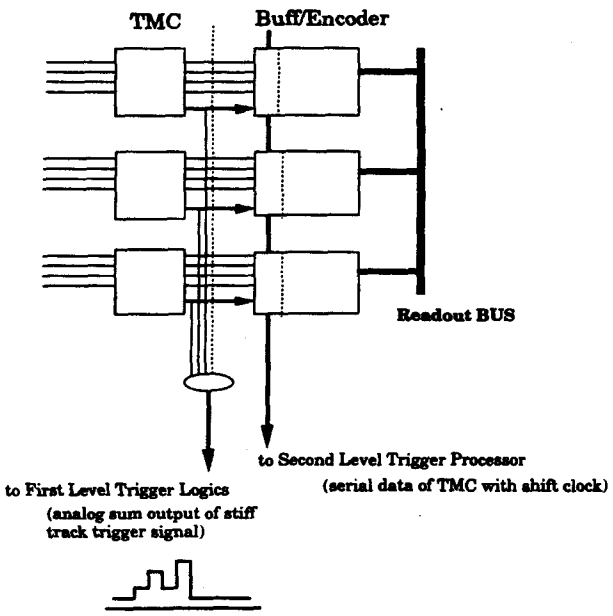


2696

3. **Interface to DAQ system**
4. **Interface to Trigger system**
5. **Control Scheme**

2697

Interface to Trigger System



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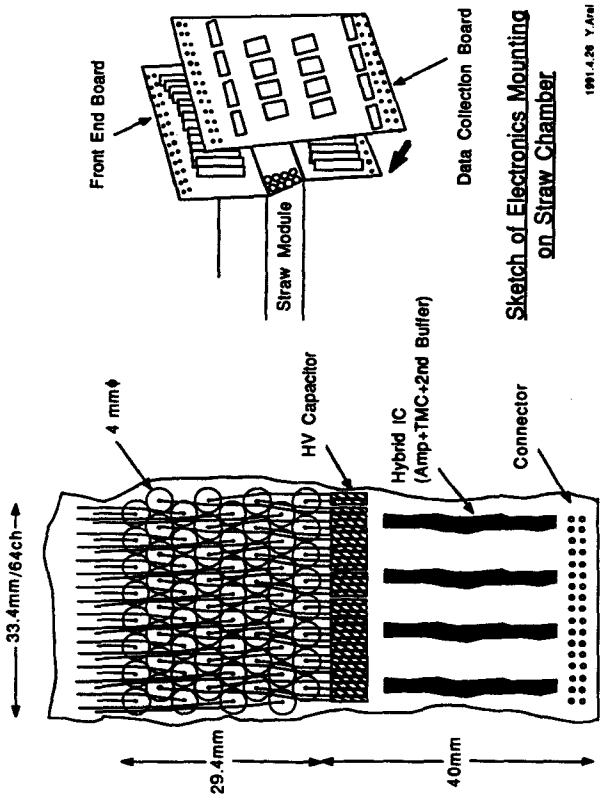
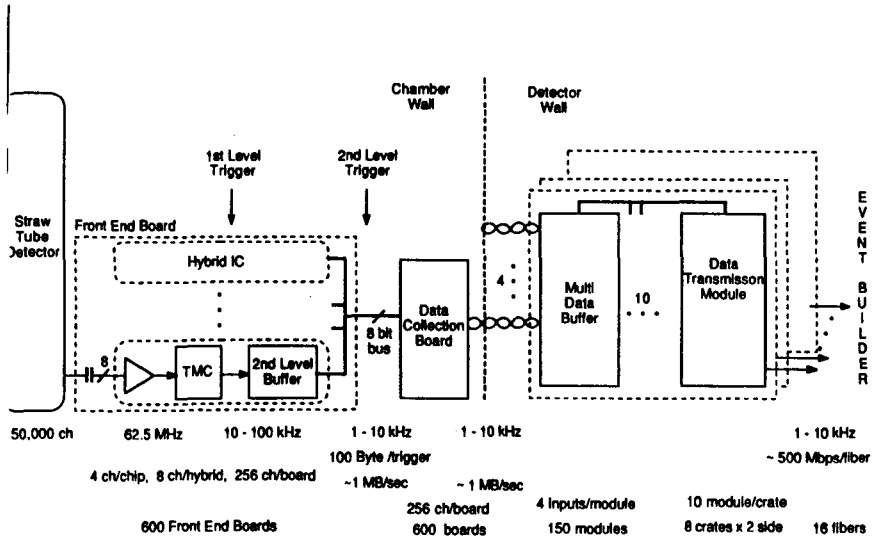


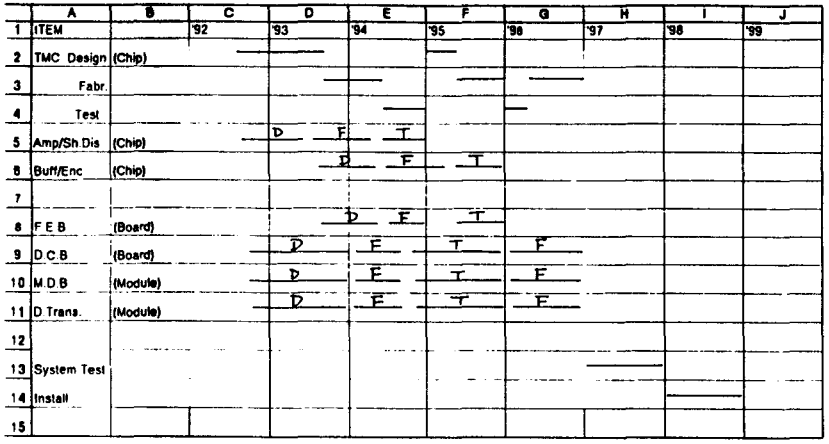


Data Flow Diagram of the Straw Tube Readout

STRAW Readout Element

	A	B	C	D	E	F	G	H	I	J	K	L
1			Crate	D.Trans.	M.D.B		D.C.Board	F.E.Board	TMC	Channels		Power(W)
2												
3	PreAmp/Dis									9	0.008	0.064
4	TMC									4	0.007	0.028
5	Buff/Encod									4	0.02	5.08
6											0.036	
7												
8	F.E.Board							1 F.E.B	64	256	5.5+5.96	9.45
9												
10	D.C.Board						1 DCB	1 F.E.B	64	256	9.0+9.45	13.45
11												
12	MDB				1 MDB	1 cable(4 p)	4 DCB	4 F.E.B	256	1024	20.0+49.8	69.8
13												
14	Crate	1 Optical	1 Crate	1 DT	9 MDB	9 cable	36 DCB	36 F.E.B	2304	9216	50.0+628.2	678.2
15												
16	1 Side	8 Optical	8 Crates	8 DT	72 MDB	72 cable	288 DCB	128 F.E.B	18432	73728		5426
17												
18	2 Sides	16 Optical	16 Crates	16 DT	144 MDB	144 cable	576 DCB	576 F.E.B	36864	147480		10852
19												
20												
21												

TMC ScheduleStraw Tube Readout Time Schedule



6. Cost Estimation

(Very tentative estimate of the each elements per channel)

Item	Yen/ch
Amp/Shaper/Disc. Chip	1,000
TMC Chip	3,000
Buff/Encod Chip	2,000
Frontend Board	1,200
Data Collection Board	2,000
Cable	100
Multi Data Buff. Module	500
Data Transmitter Module	250
Crate	200
Total	10,250 (US $ 73)

Straw Tracker System - TVC Option
Data Formats and Rates

9/2/91 - EVB

Module Level Data Packet

Header + Flags	6 bits ?
Physical Address	1 Byte
L1 Trigger I.D.	1 Byte
Bunch Counter	2 bits
Fine Time	7 bits
Total per bit	4 Bytes

Data Rate - 60 MHz Crossing Rate
10% Occupancy/crossing, 3 crossing overlaps
10,000 L1*L2 Rejection
180 Straws per Module
14 Modules per crate
48 Crates per system
121k Straws Total

1.30E+06 Bytes per second

PI/PO (Crate) Level Data Packet

Header + Flags	10 bits ?
Module Address	4 bits
Physical Address	1 Byte
L1 Trigger I.D.	1 Byte
Bunch Counter	2 bits
Fine Time	7 bits
Total per bit	5 Bytes

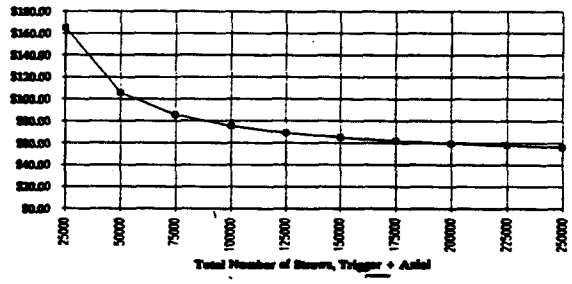
2.27E+07 Bytes per second

Straw System Level Packet

Header + Flags	10 bits ?
Crate Address	6 bits
Module Address	4 bits
Physical Address	1 Byte
L1 Trigger I.D.	1 Byte
Bunch Counter	2 bits
Fine Time	7 bits
Total per bit	6 Bytes

1.31E+09 Bytes per second

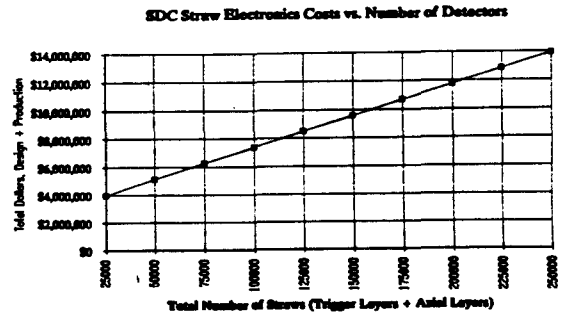
Plus Additional Packets for Monitoring and Calibration



TIME LINE Task Report							
Schedule Name : SDC STRAW ELECTRONICS - August 1991							
Responsible : R. Van Berg							
As-of Date : 10/1/92							
Schedule File : C:\TL4\DATA\STRWAU91		Number of Trigger Straws			41600		
Includes Proj. Man., some costs to DAQ		Number of Axial Straws =			80000		
		Total number of straws =			000		
		Name =		121600			
		Total $					
WBS	Task Name	(EAC)		Variance		Cost(Name)	
						Name = 121	for 150k
WBS ID	TASKNAME	TLDOLLAR					
5.1.2	Straw Tracker	$8,462,577				$8,462,577	
5.1.2.1	Electronics Design Document	$31,638		F	1	$31,638	
5.1.2.2	Prototype Electronics	$1,876,067					
5.1.2.3	Front End	$1,074,511					
5.1.2.3.1	High Voltage Dist. on Modules	$73,702					
5.1.2.3.1.1	Capacitors and Resistors	$3,500		F	1	$3,500	
5.1.2.3.1.2	At Anode HV Substrate	$26,608		F	1	$26,608	
5.1.2.3.1.3	Second HV Substrate	$29,746		F	1	$29,746	
5.1.2.3.1.4	Anode Connection	$5,603		F	1	$5,603	
5.1.2.3.1.5	Cathode Connection	$8,245		F	1	$8,245	
5.1.2.3.2	Active Components	$683,961					
5.1.2.3.2.1	Preamplifier/Shaper	$113,963		F	1	$113,963	
5.1.2.3.2.2	Discriminator	$104,213		F	1	$104,213	
5.1.2.3.2.3	TVC/AMU	$299,209		F	1	$299,209	
5.1.2.3.2.4	DCC	$116,503		F	1	$116,503	
5.1.2.3.2.5	Trigger	$0		F	1	$0	
5.1.2.3.2.6	Passive Components	$15,072		F	1	$15,072	
5.1.2.3.3	Active Substrate	$225,477					
5.1.2.3.3.1	Substrate	$131,011		F	1	$131,011	
5.1.2.3.3.2	Mounting	$17,984		F	1	$17,984	
5.1.2.3.3.3	Bonding	$66,482		F	1	$66,482	
5.1.2.3.4	Test of Module(s)	$991,372		F	1	$991,372	
5.1.2.3.2	Cable - Module to PI/PO Box	$303,990					
5.1.2.3.2.1	Cable	$114,192		F	1	$114,192	
5.1.2.3.2.2	Connector (PI/PO end)	$17,627		F	1	$17,627	
5.1.2.3.3	Assy to Module	$35,779		F	1	$35,779	
5.1.2.3.2.4	Test of Cable Assy	$36,332		F	1	$36,332	
5.1.2.3.3	Pos In/Pos Out Box	$314,346					
5.1.2.3.3.1	Crate	$29,142		F	1	$29,142	
5.1.2.3.3.2	Backplane	$80,990		F	1	$80,990	
5.1.2.3.3.3	Module Rcvr./Drvr.	$144,734		F	1	$144,734	
5.1.2.3.3.4	Fiber Interface	$0		F	1	$0	
5.1.2.3.3.5	Flow Interface	$0		F	1	$0	

5.1.2.3.3.6	Crate Cooling	$0	F	1	$0	
5.1.2.3.4	Low Voltage Power	$56,883				
5.1.2.3.4.1	Regulators - 300W -DC or 400Hz	$32,251	F	1	$32,251	
5.1.2.3.4.2	Cabling Within Crate	$14,043	F	1	$14,043	
5.1.2.3.4.3	Cabling on Detector	$10,589	F	1	$10,589	
5.1.2.3.5	High Voltage Power	$36,194				
5.1.2.3.5.1	HV Regulator	$0	F	1	$0	
5.1.2.3.5.2	Cabling - Module to PIPO	$18,009	F	1	$18,009	
5.1.2.3.5.3	Cabling - PIPO to Regulator	$18,184	F	1	$18,184	
5.1.2.3.6	System Level Tests	$190,302	F	1	$190,302	
5.1.2.3	Production Electronics	$6,164,835				
5.1.2.3.1	Front End	$4,374,875				
5.1.2.3.1.1	HV Dist. - Trigger Modules	$341,381				
5.1.2.3.1.1.1	Capacitors and Resistors	$143,300	L	1	$143,300	
5.1.2.3.1.1.2	At Anode HV Substrate	$53,000	L	1	$53,000	
5.1.2.3.1.1.3	Second HV Substrate	$53,000	L	1	$53,000	
5.1.2.3.1.1.4	Anode Connection	$5,300	L	1	$5,300	
5.1.2.3.1.1.5	Cathode Connection	$5,300	L	1	$5,300	
5.1.2.3.1.1.6	Assembly of Modules	$81,581	L	1	$81,581	
5.1.2.3.1.2	HV Dist. - Axial Modules	$625,021				
5.1.2.3.1.2.1	Capacitors and Resistors	$226,800	L	1	$226,800	
5.1.2.3.1.2.2	At Anode HV Substrate	$132,500	L	1	$132,500	
5.1.2.3.1.2.3	Second HV Substrate	$132,500	L	1	$132,500	
5.1.2.3.1.2.4	Anode Connection	$9,000	L	1	$9,000	
5.1.2.3.1.2.5	Cathode Connection	$9,000	L	1	$9,000	
5.1.2.3.1.2.6	Assembly of Modules	$115,221	SQRT	1	$115,221	
5.1.2.3.1.3	HV Production Test	$61,414	SQRT	1	$61,414	
5.1.2.3.1.4	Active Components	$1,629,720				
5.1.2.3.1.4.1	Preamplifier/Shaper	$387,500	L	1	$387,500	
5.1.2.3.1.4.2	Discriminator	$387,500	L	1	$387,500	
5.1.2.3.1.4.3	TVC/AMU	$402,000	L	1	$402,000	
5.1.2.3.1.4.4	DCC	$116,720	L	1	$116,720	
5.1.2.3.1.4.5	Trigger	$86,000	L	1	$86,000	
5.1.2.3.1.4.6	Passive Components	$15,000	L	1	$15,000	
5.1.2.3.1.5	Active Substrate Trigger	$473,683				
5.1.2.3.1.5.1	Substrate	$227,000	L	1	$227,000	
5.1.2.3.1.5.2	Mounting	$42,400	L	1	$42,400	
5.1.2.3.1.5.3	Bonding	$128,000	L	1	$128,000	
5.1.2.3.1.5.4	Assembly of Module	$66,283	SQRT	1	$66,283	
5.1.2.3.1.6	Active Substrate-Axial	$1,072,333				
5.1.2.3.1.6.1	Substrate	$545,000	L	1	$545,000	
5.1.2.3.1.6.2	Mounting	$106,000	L	1	$106,000	
5.1.2.3.1.6.3	Bonding	$305,280	L	1	$305,280	
5.1.2.3.1.6.4	Assembly of Module	$106,053	SQRT	1	$106,053	
5.1.2.3.1.7	Test of Module(s)	$158,339	SQRT	1	$158,339	
5.1.2.3.1.8	Test of Cable/Module Assy	$33,093	SQRT	1	$33,093	

5.1.2.3.2	Cable - Module to FI/FO Box	$649,841					
5.1.2.3.2.1	Cable	$565,500		L	1	$565,500	
5.1.2.3.2.2	Connector (FI/FO end)	$16,500		L	1	$16,500	
5.1.2.3.2.3	Assy to Module	$33,750		SQRT	1	$33,750	
5.1.2.3.2.4	Test of Cable Assy	$34,091		SQRT	1	$34,091	
5.1.2.3.3	Fan In/Fan Out Box	$396,300					
5.1.2.3.3.1	Crate	$12,800		L	1	$12,800	
5.1.2.3.3.2	Backplane	$76,800		L	1	$76,800	
5.1.2.3.3.3	Module Rcvr./Drvr.	$487,500		L	1	$487,500	
5.1.2.3.3.4	Fiber Interface	$0		L	1	$0	
5.1.2.3.3.5	Slow Interface	$0		L	1	$0	
5.1.2.3.3.6	Crate Cooling	$19,200		L	1	$19,200	
5.1.2.3.4	Low Voltage Power	$84,800					
5.1.2.3.4.1	Regulators - 500W -DC or 400Hz	$38,400		SQRT	1	$38,400	
5.1.2.3.4.2	Cabling Within Crate	$22,200		F	1	$22,200	
5.1.2.3.4.3	Cabling on Detector	$24,200		F	1	$24,200	
5.1.2.3.5	High Voltage Power	$87,600					
5.1.2.3.5.1	HV Regulator	$0		F	1	$0	
5.1.2.3.5.2	Cabling - Module to FIFO	$44,200		F	1	$44,200	
5.1.2.3.5.3	Cabling - FIFO to Regulator	$43,400		F	1	$43,400	
5.1.2.3.6	FI/FO Box Tests	$61,830		SQRT	1	$61,830	
5.1.2.3.7	System Level Tests	$220,228		F	1	$220,228	
5.1.2.3.8	Assembly to Detector	$31,500		SQRT	1	$31,500	
5.1.2.3.9	Full Detector Tests	$57,060		F	1	$57,060	
5.1.2.3.10	Commissioning	$0					
5.1.2.4	Project Management	$390,840		F	1	$390,840	
						$8,462,577	
			Cost per straw =			$70	



SDC Straw Tracking Electronics Conceptual Design

Draft Version 1.4
February 6, 1991

F.M. Newcomer, R. Van Berg, H.H. Williams
Pennsylvania

1 Introduction

In order to make reasonable estimates of dollar costs, design and manufacturing schedules, cable access needs, material budgets, cooling loads, and installation (and repair) strategies, it is necessary to have a complete conceptual design of the straw readout system. The following design is based upon the work that we have done in making a detailed electronic design for the straw readout. The numbers and materials are based upon the Pennsylvania TVC design, but are, we believe, in large measure consistent with the KEK TMC design. We are describing a system that goes from a contact at the straw anode (and cathode) and contains all of the DAQ and trigger functionality necessary for full SSC operation up to but not including a fiber optic transmission cable(s) going to the off-detector DAQ and Trigger systems. While much of the following is fairly obvious or part of the *perceived wisdom* of the community, there are many places where we have had to make assumptions or extrapolations with little or no hard justification. In general we will try to note all such assumptions.

We first will describe the necessary electrical connections and components and then describe a scheme for actually implementing the physical interconnections and support required. In all of the following, we are assuming a module of 256 active straws per readout assembly. The number 256 is close to the modularity (at least of electronics) of both the Duke and Indiana mechanical designs, and has an attractive simplicity of its own. A final design will probably be divided at about this level and we do not believe that any of the cost or material estimates depend strongly on this assumption. A module is an independent subsystem that may be bench tested and verified independent of detector and central DAQ and Trigger connections. A group of 16 (or so) modules connect to a Fan In / Fan Out Box (FI/FO) which is located in the Electronics/Access area outside of the calorimeter as indicated in Fig. 4. The FI/FO is also independently testable with or without modules or DAQ/Trigger connections in place.

2 Circuit Description

The major components necessary for the electrical operation and readout of the straw tube module are indicated in the block schematic Fig. 1. These are described in some detail in the sections below. The Part Name and quantity per module are indicated at the right end of each sub section header.

2.1 High Voltage $R_H(256), C_{FH}(8)$

High voltage power ($\sim 2KV$ at up to a few μA per straw at $\mathcal{L}=10^{33}$) for an individual straw is brought in through a decoupling resistor, R_H, ($\sim 1M\Omega$, 1 KV) from a local HV bus which will have one or more HV filter capacitors, C_{FH} ($\sim 500pF, 2.5KV$) per module. The local HV bus will be carried on a separate physical substrate which will also mount the filter capacitors and the HV channel decoupling capacitors.

2.2 Termination

For short straws of less than 1 meter, no termination should be necessary. However, for long straws (certainly longer than 2 meters), termination is probably mandatory. The proper electrical termination

REQUIREMENTS & CHIPS

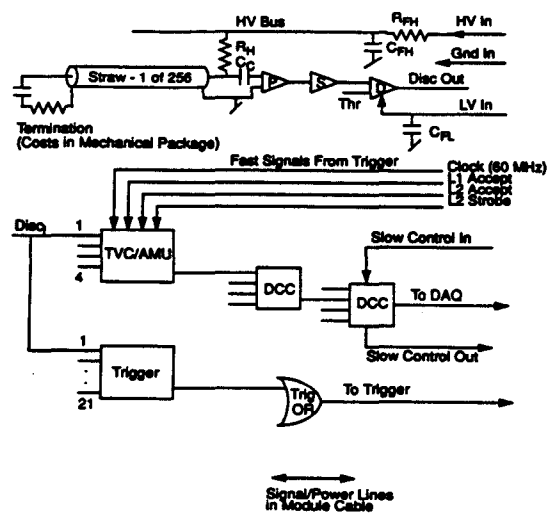


Figure 1: Block Schematic of a Straw Readout Module. Note that in this case we are describing a system with the straw anode at positive HV, it is also possible to operate the anode at ground (or near ground) potential and use a negative HV on the cathode. The negative HV scheme has some advantages in terms of the number of required HV capacitors per module but may have some disadvantages in terms of increased sensitivity to breakdown. Until further work is completed on both possibilities, we have chosen to describe the positive HV scheme both because it is somewhat more conservative and because it is, perhaps, a trifle more obvious to the reader.

for a typical 4 mm diameter straw is about 300 Ω in series with about 60 pF. In the positive HV design, this implies a separate HV decoupling capacitor for each straw. In terms of noise the 300 Ω resistor is an additional source of thermal noise, and significant improvement can be made in signal to noise (S/N) if an active termination is used (essentially a preamp input stage with no output). An active termination is, however, more complex and will require more power (~ 3mW) per channel. For the purposes of this cost estimate we have assumed a passive termination and the cost of this termination is included in the detector cost estimate not in this electronics estimate. If noise performance were to force the use of an active termination, then that cost would have to be added to the total.

2.3 Coupling to Preamplifier $C_C(256)$

At the preamplifier it is also necessary to have a HV coupling capacitor for each channel. This capacitor should be large enough to pass significant signal (for at least one τ_m) but small enough to limit the damage caused by HV discharges into the preamplifier. The final value is likely to be about 100 pF at 2500 V. We are making the implicit assumption that the preamplifier will be sufficiently sturdy to withstand a straw discharge (at operating voltage of about 1800 V). If the preamplifier were not able to withstand likely discharges, it would be necessary to provide protective diodes and snubbing resistors at each input. The prohibitive size of such components argues strongly for including the protection necessary on chip. It is also true that additional components would add significant kT noise to the system. Radiation tests are now underway to check the hardness of possible on chip Schottky protection diodes.

2.4 Preamplifier, Shaper, Discriminator $P/S(64), D(64)$

The low noise preamplifier, shaping amplifier, and discriminator are all fabricated in a single high speed bipolar process. The cost estimates are based upon quotations for quantities of high speed wafers fabricated in processes demonstrated to have adequate radiation hardness. Because of the speed of the discriminator output and the extreme sensitivity (a few femto-coulombs) of the input stage, coupling from input to output may be a problem in the final design. While it is possible that all three functions can be combined on a single die, to be conservative in costing and space planning we have assumed that two different die will be necessary. In any event the final configuration will have four channels per die and the individual die will be about 2 mm × 2 mm (this is constant whether or not the discriminator is included because of input/output pad sizes).

2.5 Time Measuring Circuit $TVC/AMU(64)$

The time to voltage conversion circuitry, analog storage, and analog to digital conversion are all contained on a single small feature size CMOS chip. If a sufficiently dense (0.5 to 0.5 μm) process can be obtained, it should be possible to pack eight channels of TVC/AMU per chip. For the purposes of this estimate, we have assumed only four channels per chip and have used preliminary quotations for radiation hard 1.2 μm processes.

2.6 Data Collection Chip $DCC(5)$

The Data Collection Chip (DCC) collects output data from a local group of TVC/AMU chips via a polling scheme and then puts data packets out to a higher level DCC (and then ultimately to some data path into the DAQ system). This tree structure continues until either all channels in a physical module are collected or the output bandwidth of the DCC is saturated. For 256 straws, a simple calculation of data rates yields:

- 10^6 events per second
- 10% occupancy
- 10^4 L1 + L2 rejection

- — 10^3 hits per second per straw
- ×8 bytes per hit (Flags[1], Trigger I.D.[2], Address[3], Data[2])
- — 10^4 bytes per second per straw
- — 2.5×10^6 bytes per second per module

which is well within the limits for the proposed DCC byte wide protocol.

Thus for 256 straws we have included four DCC chips for the first level of the tree (64 straws per DCC) and then one additional DCC to serve as the top of the tree.

2.7 Trigger Formation $Trig(15)$

A fast trigger can be formed by looking for stiff (i.e. radial) tracks in any given superlayer. Jay Chapman (Michigan) has shown that a simple triplet input mean-timer circuit will work quickly enough and with great enough resolution to be interesting. While the final configuration is nowhere near certain, a possible arrangement would have 21 straw inputs per trigger chip, then about 15 chips per module.

2.8 Low Voltage Power $C_{PL}(16)$

Low voltage DC power to the straw electronics will likely be split about ground and will require multiple analog and digital voltages. For this estimate it is sufficient to calculate the total power. At 30 mW per channel, a 256 channel module will require about 5 W or 1 A at 5 V. The 16 filter capacitors included here are arbitrary but probably close to the final number.

It is assumed in this estimate that no regulation will be done on the chamber for power reasons (low voltage linear regulators are not much more than 50 % efficient), which means that the power distribution from the regulators to the chamber must be very low impedance. The additional conductor required to maintain a low impedance connection may cause multiple scattering which would overweigh the problems associated with extra power dissipation. Only a detailed iteration of the design for the entire system can properly select the best power distribution scheme.

3 Cable

The cable(s) connecting the straw module with the outside world must provide:

- Power input and return
- Fast control signals in
- Slow control signals in and out
- Fast Trigger signals out
- Data out

The number and size of the power conductors are determined by the load and allowed voltage drop. The logical signals in and out of the module could be carried by optical fiber or copper conductors and copper could be either single ended or differential. Because the mass (and multiple scattering) is dominated entirely by the power cabling, the extra complexity of fibers is not attractive for any of the signal groups.

3.0.1 Optical vs. Electrical Transmission

From a pickup point of view the inherently single ended drive for fiber transmitters (unless one wished to provide a dummy transmitter to keep the currents differential) is far worse than a differential copper transmitter or a slow rise time single ended driver. From a power point of view there is nearly a factor of ten increase in transmission power required for optical rather than direct coupling just from the electro-optical conversion processes. In addition, optical receivers tend to require somewhat more power than equivalent bandwidth copper receivers unless the launched optical power is very large. Optical modulators may provide a mechanism for removing almost all of the power dissipation from the tracking region and successful demonstration of such devices may change the power part of the decision. The additional complexity of technologies and physical connections associated with optical techniques is unlikely to disappear.

3.1 Power Transmission

To provide power to a module a cable 50 mm wide with 50μm of copper would give a voltage drop of 45 mV over 3 m and 90 mV for a 6 m length for a 1 A current at 5V. This voltage drop is probably near the limit of what would be acceptable, so a full 50 mm by 50μm Cu foil mounted on thin Kapton or other flexible substrate has been assumed. This laminate would be insulated on the outside with a very thin layer of the same insulator. It is possible to imagine using aluminum rather than copper to decrease the effect of multiple scattering, but the increased difficulty of connection may make this option prohibitive. So, again for reasons of conservativism, we will estimate using copper.

3.2 Number of Conductors

The logical signals for control of the module and for trigger and data output could be accomodated on the obverse side of the flat power cable described above. If all of the fast signals are differential (a worst case design) then the number of conductors will be approximately as described in Table 1.

If we assume that normal growth will take the 41 total above to 50 conductors, and assume that very conservative design rules of 0.5 mm conductor, 0.5 mm space are used for the signals, then our 50 conductors fit nicely onto the 50 mm wide power cable described above. Since some cable manufacturers (cf. Hughes) are capable of building cables a factor of ten denser than these estimates, there should be plenty of room for even extensive expansion in the number of conductors (not that we wish to advocate such growth), certainly enough to include extra ground conductors to allow very conservative differential transmission lines made with gnd, sig+, sig-, gnd configurations.

The other class of signals not covered in Table 1 are the fast trigger outputs. The number of signals in this category depends upon the resolution needed in matching tracking and calorimeter information. At the outer radius of the central tracker, the straw module occupies about 10 cm of circumference and if 1 cm resolution in the calorimeter is desired, then about ten fast trigger output signals need to be transferred – no additional 20 conductors. At the inner radius the angular spread is about three times as great so that as many as sixty conductors might be necessary. If trigger outputs are needed from the inner super layers, a slightly more aggressive cable technology would be required.

4 Packaging

While there a multiple possibilities for fitting the electronics on the end of the straw modules, a system with all of the electronics mounted on a plane perpendicular to the long axis of the straw would allow all of the interconnections to be made in one plane and avoid the problems (reliability, material, and complexity) associated with mother board / daughter board schemes. However, we are attempting to fit rather a lot of functionality [1] in this area and it is useful to crudely calculate whether the density

[1] It might be noted that one of two 10 × 13 cm modules is the equivalent of 20 eight channel preamp cards, four amplifier shaper discriminator boards, 2.5 further TDC cards, and about fifty miles of Amphy cable - all operating at about 200 times

Signal	Conductors
Timing and Control	
Clock	2
L1 Accept	2
L2 Accept	2
L2 Strobe	2
Resyncb	2
Reset	2
Test Time	2
Total T & C	14
Data Path	
Data Ready	2
Grant	2
Data Bus	18
Total Data	22
Slow Control	
Data In	1
Clock	1
Data Out	1
Shift/Load	1
Read/Write	1
Total Slow Control	5
Grand Total	41

Table 1: Signal count for the Module Output DCC to upstream connections.

required is even feasible.

The ends of the straws themselves, for 256 straws in a module, occupy an area of 30mm × 120mm for a total of 3,600mm² and the area between super layers will offer at least an area of 60mm × 120mm for a grand total of about 11,000mm².

However, the total area required by active silicon is not small and must be considered. Using the estimates above, we see that we need the following pieces of silicon:

Active Electronics - Silicon

Chip	Ch/Chip	Chip/Mod	Size mm	Tot. Area mm²
Bipolar - F/A	4	64	2 × 2	250
Bipolar - Disc	4	64	2 × 2	250
CMOS - TVC	4	64	6 × 6	2,300
Trig	21	15	6 × 6	550
DCC		5	8 × 8	350
Total				3,700

This is about 34 % active silicon. For comparison, 50 mil pitch chip carriers are 1.5 % active silicon and even large pin grid array packages (PGA) are only about 9 % silicon.

The *swing* green is an emerging set of thin film technologies using IC class lithography on silicon, quartz, or ceramic substrates and polymer dielectrics. These thin film technologies have many different proprietary names and parameters, but concentrate on providing multi-chip packaging and are capable of reaching packing densities of from 30 to over 80 % depending upon the die to substrate bonding technology. In even the least exotic form with wire bonding from die to substrate, densities are around 30 % and flip chip or tab bonding offers significant additional improvements. Figure 2 shows a cartoon version of the module and cable system with active silicon area indicated by shaded blocks.

4.1 High Voltage Capacitors and Resistors

The high voltage sections of the module, of course, would not fit well into a multichip module approach and will require a separate substrate (either ceramic or laminate). The HV substrate is the obvious place to have the first level interconnects from the straw anode and cathodes. The connections to the straws ought to be removable, if possible, and pin and socket, spring loaded pins to pads, and elastomeric pad to pad connectors are all possibilities. Considerable work has gone into defining this area at both Colorado and ORNL and we will not go into any further details here.

The HV capacitors are a particular worry since they are both physically large (~ 3mm × 3mm × 2mm) and, in some cases, composed of high Z materials.

The materials question must be addressed by a relatively extensive R&D effort to find the best materials and manufacturers, but the physical size can be accomodated at both the readout and termination ends by stacking the capacitors between two substrates with one substrate carrying the anode and cathode connections and the other carrying the HV bus and the printed decoupling resistor, R_H, on one side and connections to the active electronics on the other side of the substrate. The connection between the second HV substrate and the active substrate could be either permanent or removable as desired. At the termination end the active terminators could be supported on the HV substrate so no additional substrate is included in the cost or material estimate.

the speed of present collider systems.

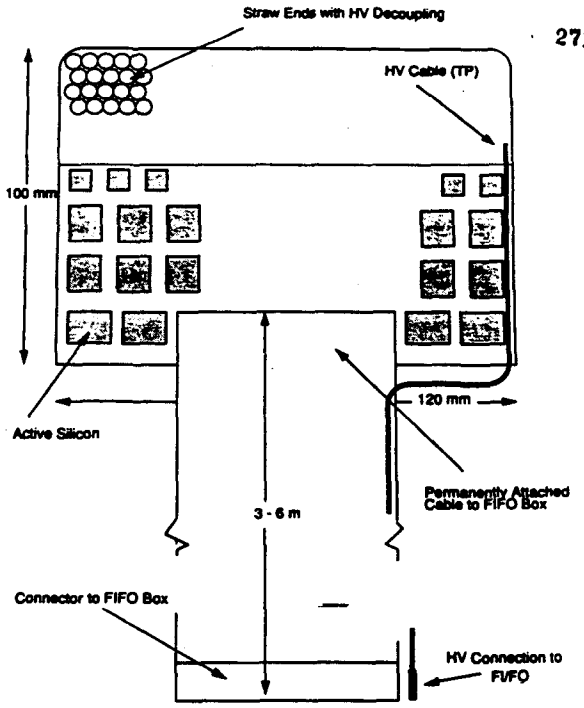


Figure 2: Approximate layout of the electronics module and attached cable.

5 Interconnection

As is obvious from the above, interconnection technologies will play an important part in determining the final functionality of the straw readout system (as well as for other types of detectors) and a significant effort must begin immediately to qualify and develop commercial vendors of various advanced packaging technologies.

We can not attempt to cover all of the possibilities in this note, but we will describe below the basic technolgy that we are assuming for the purposes of making this cost and material estimate.

5.1 HV Substrate to Active Substrate

For simplicity we are assuming that the HV substrates form a rigid beam (separated by the HV capacitors) and that the active substrate is assembled (after separate qualification testing) to the HV assembly via a permanent soldered (or epoxied) connection. The part of the HV substrate in the inter super layer gap is available for low voltage decoupling networks, HV filtering, and attachment of cables – HV and the combined LV / Data cable described above.

5.2 Chip to Substrate

Chip to active substrate connections will be either wire bonds or, more likely, tab bonds (photo-lithographically produced frames carrying all of the connections to a given chip and attached via indium or gold solder bumps to both the chip and substrate pads), or full flip chip connections (where the chip is inverted and gold or indium bumps are used directly to attach the chip pads to the substrate pads). The choices are governed by density, cost, and reliability considerations (the list above is ordered by both increasing density and increasing cost - in a low volume application such as ours). [2]

5.3 Substrate to Cable

In order to keep the mass and complexity at a minimum, we are assuming that the LV / Signal cable is permanently attached to the straw electronics module and disconnects only at the Fan-In end. While there are a variety of possibilities for connecting the cable to the electronics module, we are assuming a very simple standard soldered connection for both the wide voltage supply connections and the multiple signal connections. There would, however, need to be some sort of strain relief to prevent accidental tearing of the connections.

5.4 Cable to Fan-In

The cable must disconnect at the Fan-In in order to allow construction of the system, but the Fan-In is, by definition, in a relatively high density part of the detector and so any commercial connector technology (consistent with the cable design) would be appropriate. Even a standard 0.1in × 0.1in pin and socket connector would have high enough density and power handling capabilities.

6 Fan-In

In order to keep the material at the ends of the straws at a minimum and in order to avoid many cross connections from module to module, we have placed a minimum set of electronics and connections at the detector end. The connection to the *outside* world is via a single low mass flexible cable. In order, however, to provide reasonable power to the electronics on the detector and in order to collect signals from the detector to go to the trigger and DAQ systems the cable from the straw module must terminate fairly

[2] To still the immediate reaction, high volumes in the semiconductor world starts at roughly 10^6 to 10^7 identical objects - our 10^5 or 10^6 channels are getting packaged many per chip. The SSC has increasing volumes for many of the smaller (especially Rad Hard) operations, but it is nowhere near *high* volume.

close to the central tracking volume. From a power point of view a cable longer than about 6 m would require local regulation at the module – increasing the cooling and density problems somewhat. From a signal transmission point of view, the differential signals should retain their integrity over distances up to 20 or 30 m. For this estimate we have assumed no local power regulation on the straw electronics module and a 3 to 6 m cable length to the Fan-In box which would provide power regulation and conditioning - probably from a relatively high voltage DC input.

The Fan-In would also provide an opportunity to bring together enough of the straw modules to make up a bandwidth appropriate for launching into a DAQ fiber and would provide space to add together a wedge of central detector tracker and look for linked high P_T tracks.

Mechanically the FI /FO box shown in Fig. 3 is a standard board and backplane system with power supplies and cooling provided in standard commercial fashion.

6.1 Inputs

The Fan-In connects to cables from about 16 straw modules - in the version that we are imagining here each Fan-In defines a pie slice of the central detector for ease of trigger formation. It is possible that reliability concerns would dominate and a single Fan-In would serve some more complex section of the tracker, but for simplicity we will assume a pie slice going from one module at the inner super layer to about three modules at the outer layer as shown in Fig 4.

6.2 Trigger Collection

Fast trigger signals from the modules indicate *stiff* tracks in some given angular region which is matched to the calorimeter and muon system resolution. If it is desired to use more than the outer super layer for triggering at Level 1 or 2, then signals from different super layers must be compared to see whether or not a *linked* track can be found to extrapolate toward the calorimeter. The obvious place to do this linkage is at the Fan-In box, thus greatly reducing the amount of fast cabling needed to the outside world. The linking logic required for this task is essentially a fast look up table and so is both compact and relatively inexpensive. It is, however, necessary to bring all the trigger signals together into this one physical location.

6.3 Trigger Left/Right Connection

Because even stiff tracks will have some curvature and because the modules will not break at the same ϕ position at each super layer, it is necessary to interchange signals from the outer edges of each super layer with the Fan-In box to the left or right of the present Fan-In box. Given that the Fan-In is in a relatively high density (of detector) area and the number of signals needed per edge module is at most two or three, this extra connection should add little to the system cost. A single thirty signal (60 conductor) cable between adjacent Fan-Ins should suffice.

6.4 Data Collection

The basic design of the DCC envisions tracing of the chips until a full fiber data rate is reached at the output of the top of the tree. Sixteen modules would have a total data rate of about 40 Megabytes per second or 320 Megabits per second consistent with present day fiber optic technology. As it is unlikely that the normal DCCs will be constructed to run at very high speeds, it is likely that the last stage of the pyramid or tree will be constructed of discrete integrated circuits, culminating in a standard parallel to serial fiber optic driver (such as the AMD or Gazelle devices). Since the Fan-In box is at the top of the straw detector pyramid, we have included circuitry to buffer, serialize, and drive out the full DAQ bit stream onto an optical fiber. The cost of a fiber connection is included here but the fiber cable and protection is viewed (arbitrarily) as being outside the scope of this estimate.

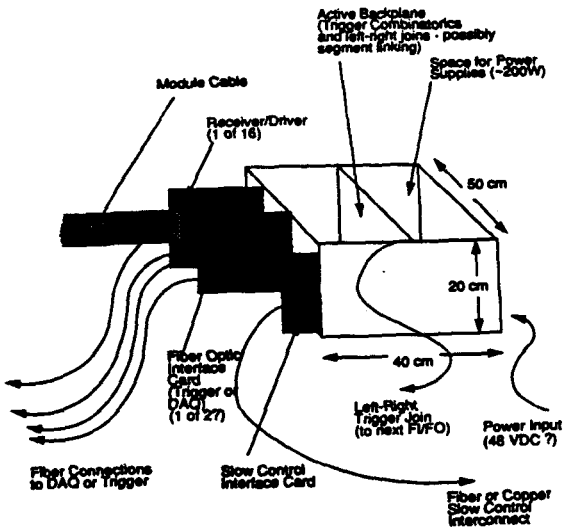


Figure 3: Possible Fan In / Fan Out Box mechanical design and cabling interface.

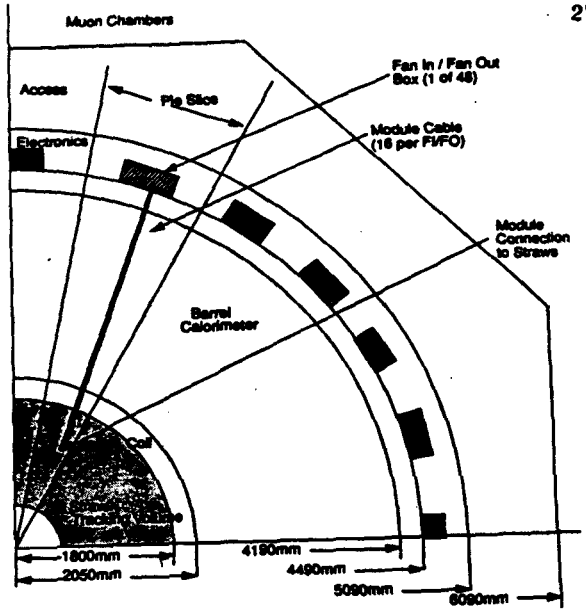


Figure 4: Module and FI / FO Box physical placement on the detector. The assumed granularity of 16 modules per FI/FO implies about 48 FI/FO boxes for a 200,000 straw detector (depending upon triggering constraints) - distributed evenly over each end of the barrel calorimeter.

6.5 Power Distribution

For the purposes of this estimate we have assumed that there is good local regulation of power at the Fan-In box and that this power is then distributed to the individual modules via the module cables. Power input to the Fan-In box comes from supplies located a few tens of meters outside the detector - either on the outside of the calorimeter or on the walls or floor of the pit. The Fan-In box is also a consumer of power for the various DAQ and Trigger functions - we have assumed that there is as much power dissipated at the Fan-In as at all the modules which it serves, for lack of detailed designs for the internal components. Sixteen modules at five Watts apiece would yield 80 Watts for a total input power of 160 Watts plus 25% for regulation giving a total power input of 200 W. The power distribution from the power input cables, which could be simple 12AWG pairs or triplets (with shields), is by the FI/FO regulators to the backplane or motherboard and then to each of the module cable connectors.

6.6 Output Cables - Trigger and DAQ

The cable from the FI/FO box to the DAQ is a single strand of optical fiber (plus spare??), but the cabling to the trigger system is much more complex as not only the fast inputs to the trigger system must be presented, but all of the fast control signals from the trigger system must be fanned out to the individual modules. It is not entirely obvious at the moment whether fiber or copper is best for this task (the decision depends at least somewhat on the physical location of the trigger system - a local trigger preprocessor, for instance, would certainly use copper cabling). Because of this uncertainty we have not included any cost estimates for fiber drivers for the trigger system, and have only included a simple multi-pin copper connector.

6.7 Fast Control Fan Outs

As noted above the Clock, Trigger, Reset, and Busyack lines must fan out from the FI/FO box and logic must be incorporated in the box to buffer these fast signals and then to retransmit them to the modules. We have also included some additional cost to cover the possibility that it will be necessary to adjust the relative timing of these signals on a module by module basis.

6.8 Slow Control System

The slow control (or scan path) system which provides much of the system self test facility is much simpler to buffer and needs only a small amount of logic (for switching paths and local self test) and some drivers/receivers. To be conservative we have assumed a separate small five conductor cable from the Fan-In to the slow control system - again copper conductor for simplicity, electrical isolation is easy to obtain via transformers or optical isolators for these very slow (microsecond or longer transition time) signals.

6.9 High Voltage Power and Distribution

It is not obvious what the correct granularity is for HV distribution. We have chosen to use a module as a single entity and guess that within a factor of four we would either not want finer or be able to tolerate coarser control of the HV. For costing purposes we are assuming a HV cable from each module to the Fan-In (24 AWG twisted pair, Teflon insulation) and then out again from the Fan-In to a power supply located in some external area. We have used the very conservative case of a Droege NIM supply to provide the read-back and over current protection provided. It is clear that a somewhat cheaper and more directly controlable supply would be actually provided, perhaps the HV would be generated and controlled in the FI/FO box.

7 Cable Count

From the straw module out to the Fan-In there are two cables:

- A flat Kapton (or other) cable 50 mm by 1 mm
- A HV twisted pair (jacketed?) about 3 mm in diameter

From the Fan-In to adjacent fan-ins there is one 60 conductor flat cable.

From the Fan-In to the DAQ switch (or event builder, or ...) there is one fiber - 6 mm in diameter including protective sheath.

From the Fan-In to the trigger system there is a flat Kapton cable about 50 mm by 1 mm.

From the Fan-In to the low voltage power supplies there is a multiple conductor cable (with shield) about 1 cm in diameter.

From the Fan-In to the HV power supplies is a 16 pair teflon jacketed cable about 50 mm by 3 mm.

8 Cost Table

Table 2 tries to include all of the subsidiary pieces documented above. Where the conceptual design is fuzzy, the pieces are of necessity larger and fuzzier. The material budgets are based upon the best present designs, where radiation lengths are not known (such as HV capacitors) they are left blank - things will be worse than this. The dollar cost estimates are based upon actual commercial quotes, experienced estimates, or wild guesses as indicated. The overall confidence factor should be about 30% as electronics is one of the few areas where some costs actually decrease with time. The estimates are in present U.S. dollars with no escalators.

The total cost of $10,907 is then divided by 256 channels to give a per straw electronics cost of $42.60. This cost is about 30% higher than our estimate of 15 February 1990. The previous estimate did not include HV or LV power, the Fan-In box, or the fast trigger system. These components account for about half of the difference, the remainder is a reflection of our increased conservatism relative to the complexity of the packaging technology involved.

9 Schedule

The schedule shown in Fig. 5 extends only to tasks and sub-tasks as they are presently understood. This schedule is, however, calculated from a much more detailed set of estimates. The time estimates assume that the design and construction process is limited only by industrial turn around times and our understanding of the art. A serious short-fall in design resources would extend the overall time scale and would require a complete revision and re-estimate of both the time and cost.

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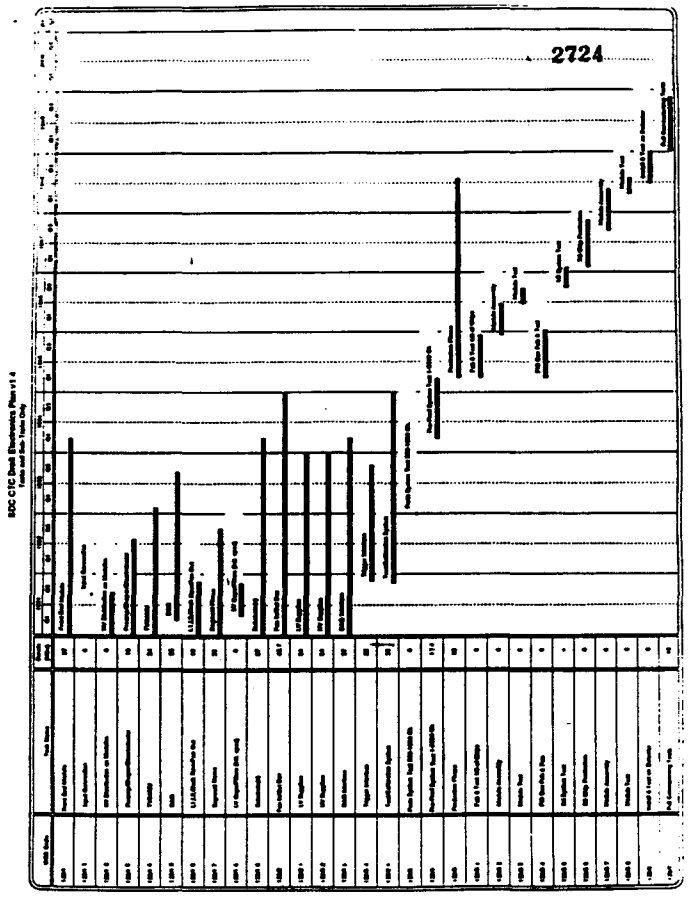
Item	Quan. per Mod.	Size - mm w x l x h	Material	Rad Lon.	Tot RL (over area)	Cost each	Cost Total	Basis
R_H	256	.1x1x0	ink	200	0	.20	5.00	EE
C_{FH}	8	3x3x2	ceramic	?	?	2.50	20.00	CQ
C_C	256	3x3x2	ceramic	?	?	2.50	1300.00	CQ
P/S	64	2x2x.3	Si	94		10.00	640.00	CQ
Disc	64	2x2x.3	Si	94		10.00	640.00	CQ
TVC/AMU	64	4x4x.3	Si	94		16.00	1000.00	CQ
DCC	5	8x8x.3	Si	94		20.00	100.00	CQ
Trig	15	4x4x.3	Si	94		16.00	240.00	CQ
C_{FL}	16	2x2x2	ceramic	?	?	2.00	32.00	CQ
Cable	1	50x3000x1	Cu+plast.			1000.00	1000.00	WG
HV Subs. 1	1	100x120x1	G-10	194		250.00	250.00	EE
HV Subs. 2	1	100x120x1	G-10	194		250.00	250.00	EE
Anode Con.	250	1x1x1	Cu	14		0.10	25.00	EE
Cath. Con.	250	1x1x1	Cu	14		0.10	25.00	EE
Active Subs.	1	100x100x0.3	Si	94		1000.00	1000.00	WG
Bonding		all pads				2000.00	2000.00	WG
Assy.	1	HV+Active				1000.00	1000.00	EE
Test	1	assy.				500.00	500.00	EE
Pan-in	1/16	assy.				4800.00	300.00	WG
LV Power	1/16	1 mod.				480.00	30.00	CQ
LV Cable	1	10x10x10 m	Cu	14		100.00	100.00	EE
HV Power		1 mod.				350.00	350.00	CQ
HV Cable	1	3x3x10 m	Cu	14		100.00	100.00	EE
Total							$ 10,907.00	
per Channel							$ 42.60	

Table 2: Estimated cost of a 256 channel straw module.

2724



2725

TRIGGER WORKING GROUP

W. SMITH - ORGANIZER

2726

DAQ R&D AT KEK

M. NOMACHI

2727

OPTICAL TRANCEIVER

development at KEK

6U VME module

8 MB/sec max with TAXI (120Mbps)

is made for SDC test module

will be used at KEK B-factory

SDC Meeting at LBL

August, 1991

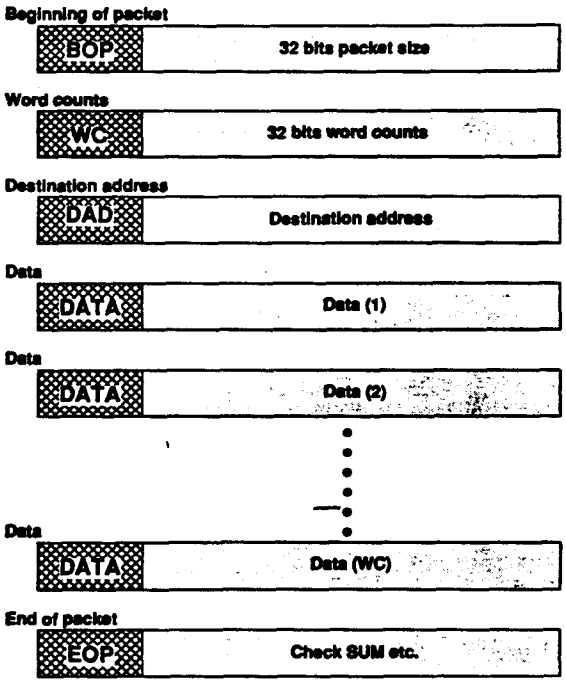
Masaharu NOMACHI

KEK online group

LBL 1-a
M. Nomachi
29-july-1991
@fnal

2728

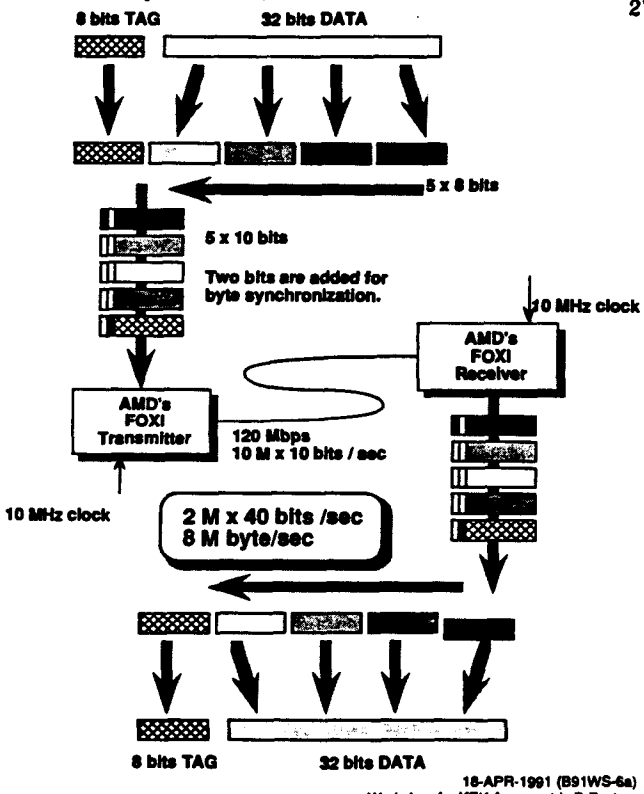
Fiberoptic Data Link
Packet Structure



18-APR-1991 (B91WS-6b)
Workshop for KEK Asymmetric B-Factory

Fiberoptic Data Link

2729



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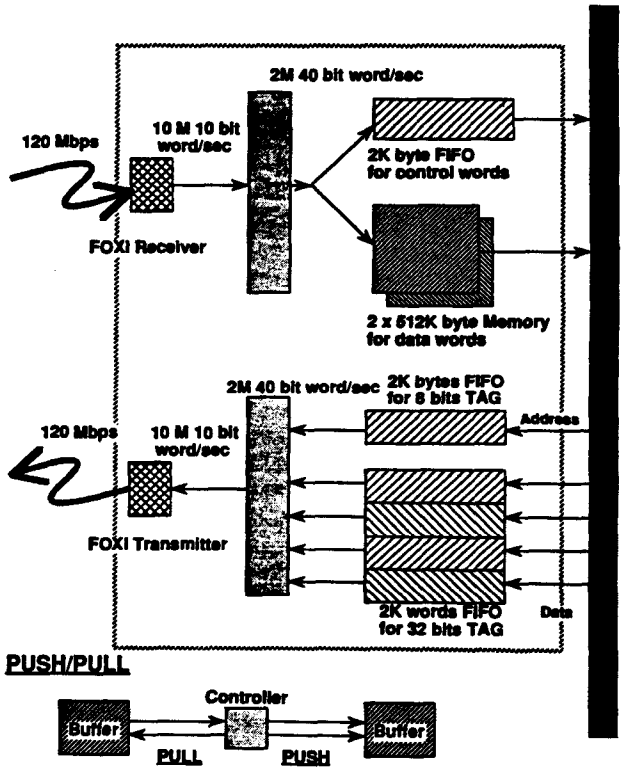
Push Type Optical Data Transceiver

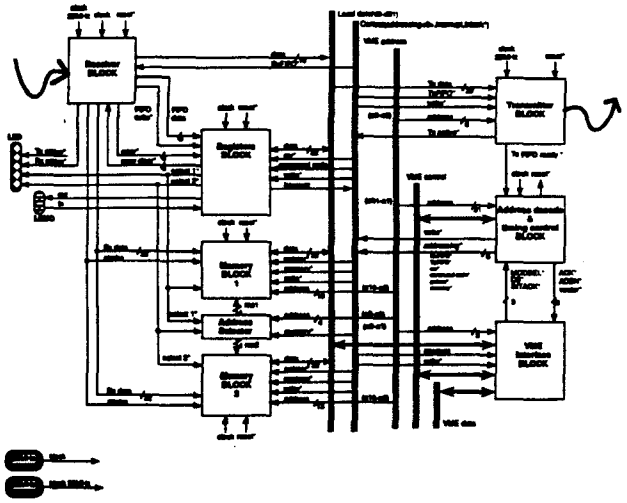
2730



18-APR-1991 (B91WS-7)
Workshop for KEK Asymmetric B-Factory

2731

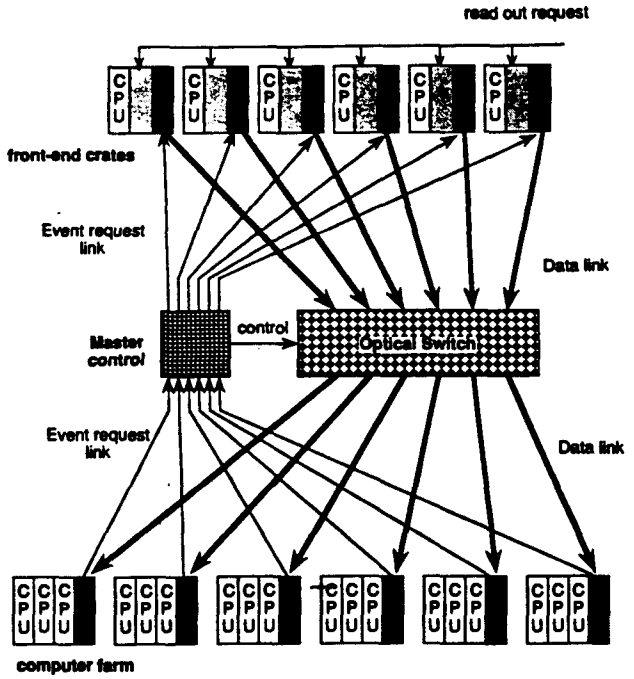
Push Type Optical Data Transceiver



18-APR-1991 (B91WS-8)
Workshop for KEK Asymmetric B-Factory

2732

Parallel event builder using Switch

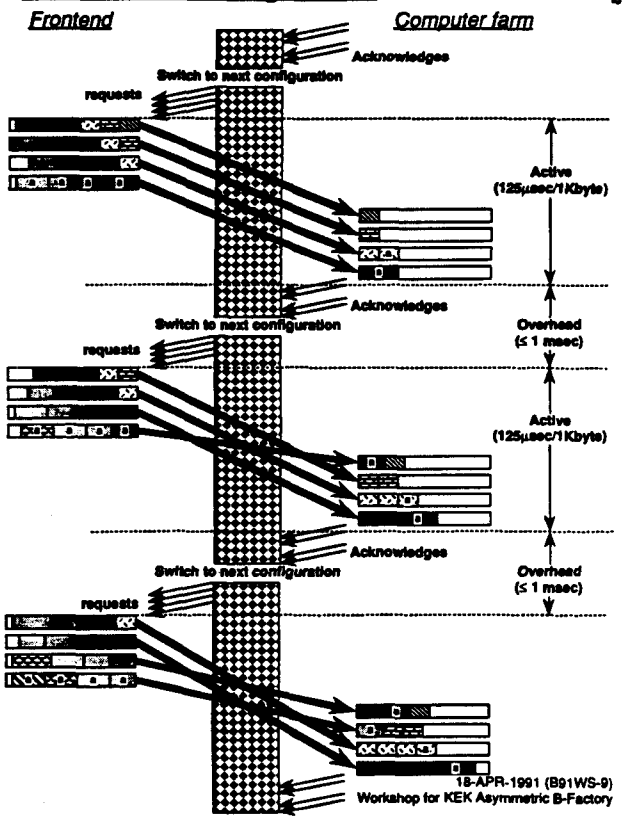


Fiberoptic data link
Push type optical data transceiver
Packet handshake
Optical barrel shifter

18-APR-1991 (B91WS-4)
Workshop for KEK Asymmetric B-Factory

Event Builder using Switch

2733



18-APR-1991 (B91WS-9)
Workshop for KEK Asymmetric B-Factory

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R & D on 1Gbps switching
- optical switch
- ECL (FUJITSU) switch

SDC Meeting at LBL

August, 1991

Osamu SASAKI

KEK electronics group

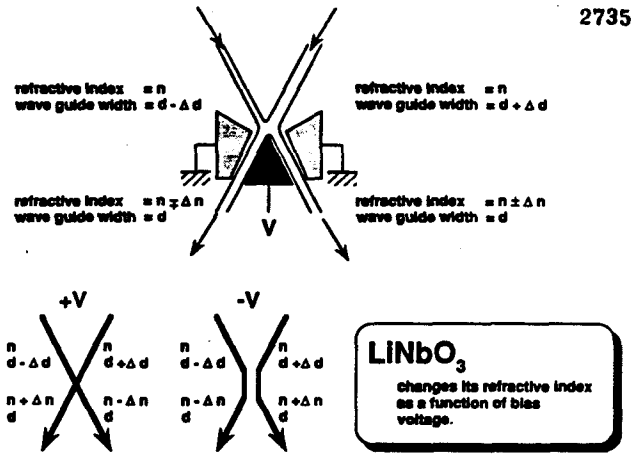
Masaharu NOMACHI

KEK online group

LBL 1-b
M. Nomachi
29-july-1991
@final

Optical Switch

2735



$LiNbO_3$

changes its refractive index as a function of bias voltage.

Optical Crossbar Switch

4 x 4 is already available.

Drive voltage 17 V
Cross talk -15 dB

8 x 8 will be available soon. → 8 x 8MB/s = 64 MB/s

Up to 1 Gbps → 8 x 1 Gbps = 800 MB/s

(SDC91MAY-OPTa)
13-MAY-1991 SDC DAQ meeting

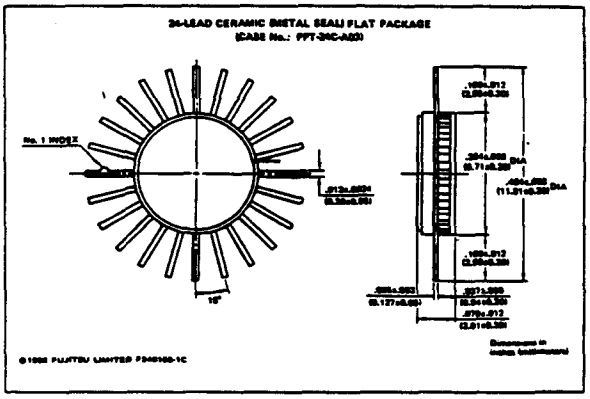
1.5 Package

The package for the E128H is the 24-pin circular flat package. This package is intended for an efficient conductive cooling, achieving a low junction-to-case thermal resistance.

* Dimensions : Shown below (Case NO. FPT-24C-A03)
* Thermal Resistance : 6 °C/W (Junction to Case)

Note : The bottom (heat-spreader) of the package is connected to VEE.

(FPT-24C-A03)



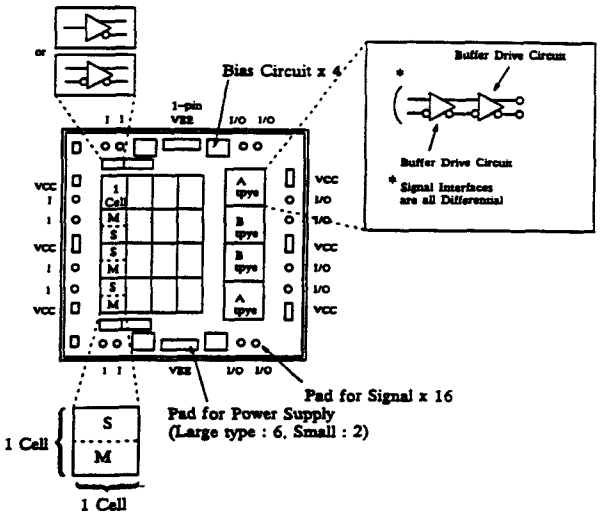
1.4 E128H Circuit Structure

1.4.1 Chip Layout

The E128H chip structure is shown in the figure below. It contains:

* 16 (4x4) Internal Cells to implement customer specific logic functions
* 8 Output Buffers which generate clear output signals
* 4 Delay Gates for signal timing adjustment
* 4 Bias Voltage Generator circuits
* Input Signal Sharpener for sharpening input signals from the test equipment

The Internal Cells are arranged in a 4 x 4 matrix with wiring channel area surrounding each of the Internal Cells.

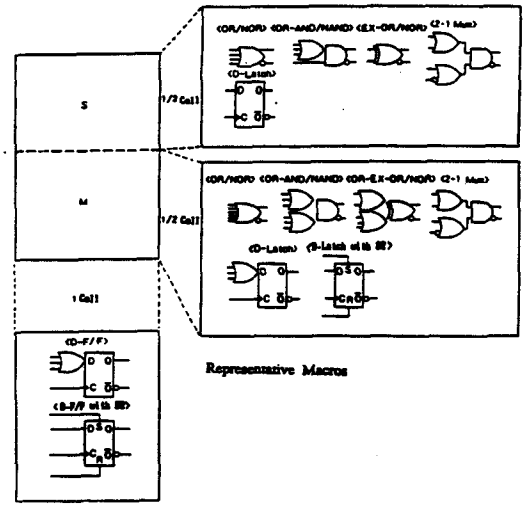


1.4.2 Internal Cell

The E128H contains 16 Internal Cells. Each Internal Cell consists of two sections called "M-part" and "S-part", and a cell bias circuit. To implement a logic function, the series gate circuit technology is used so that a logic function is realized with the minimum amount of components.
The figure below shows representative logic macros which can be implemented in an Internal Cell.

There is a family of logic functional macros predefined for customer's logic designs. These macros are specified in the "MACRO SPECIFICATION" (document#GATI0318A).

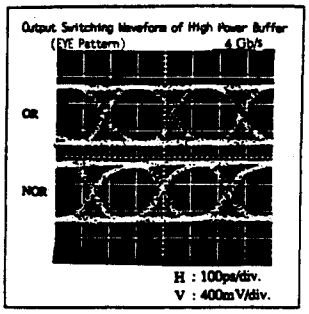
The cell bias circuit is locally used to supply bias voltage within the Internal Cell. It is not used only when the Internal Cell is left unused at all.

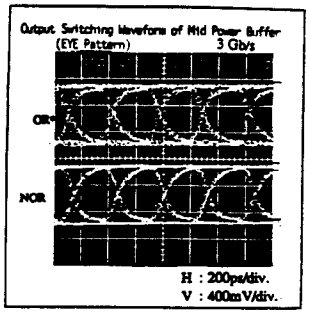


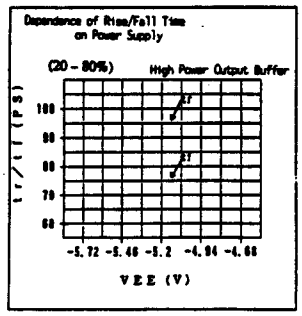
Representative Macros

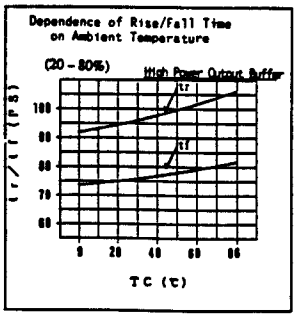
3.7 Characterization Curves (Cont'd)

Output Buffer AC Characteristics









3.6 AC Characteristics

3.6.1 AC Characteristics

Parameter		Symbol	Output Type	Min.	Typ.	Max.	Unit
Output Rise Time	Differential Output	tr	Low Power Middle Power High Power	– – –	230 130 95	330 195 135	ps
	Single Ended Output		Low Power Middle Power High Power	– – –	230 180 145	330 + tdr** 255 + tdr** 195 + tdr	
Output Fall Time	Differential Output	tf	Low Power Middle Power High Power	– – –	220 100 75	315 155 110	
	Single Ended Output		Low Power Middle Power High Power	– – –	220 120 85	315 + tdf** 180 + tdf** 125 + tdf	
Toggle Frequency		ftog	–	3.0	4.0	–	GHz
Propagation Delay Time		tpd***	–	–	–	*	ps

Note * : Only the maximum propagation delay time will be specified for 4 or less paths with the following equation:

tpd (max) = tds x 1.3 + tdd** + 30 ps

where, tds is determined by Fujitsu with the results of Spice simulations. tdd is the delay by the output simultaneous switching. Please refer to the section 5.6.6 in this manual.

Note ** : tdr, tdf, and tdd are the delay by the output simultaneous switching. Please refer to the section 5.6.6 in this manual.

Note *** : tpd is measured using the "Feed Through input". This means that the tpd is the propagation delay time between the input monitor pin and the output pin. And tpd does not include the package delay.

All AC characteristics values are specified by Fujitsu for each design of the E12KH based on the values tabulated above and under the test restrictions described in the section 6 of this design manual.

Temperature Condition : Tc = 25 °C

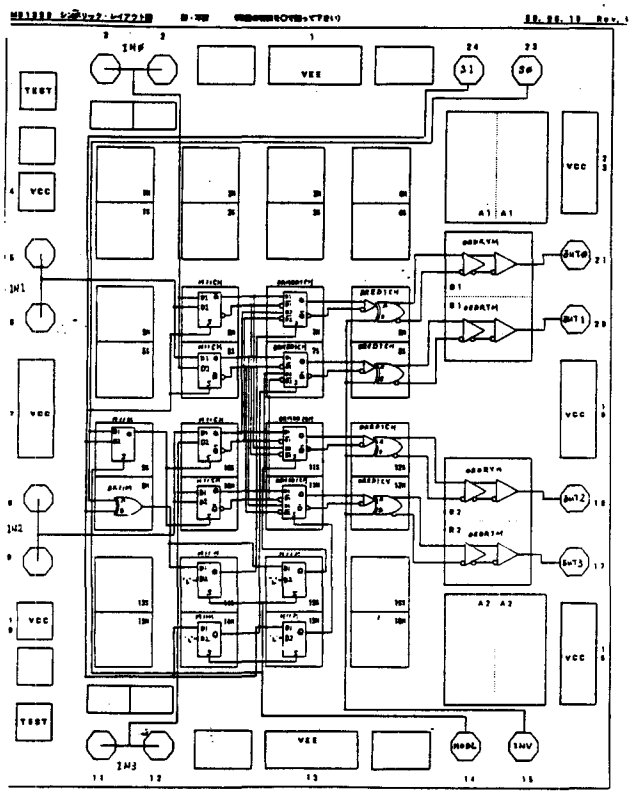
Power Supply Voltage Conditions:

VCC (Pin# 4, 7, 10, 16, 19, 22) = +2.0 V
VEE (Pin# 1, 13) = -3.2 V

Output Termination:

50 Ω to VT = Ground

2741

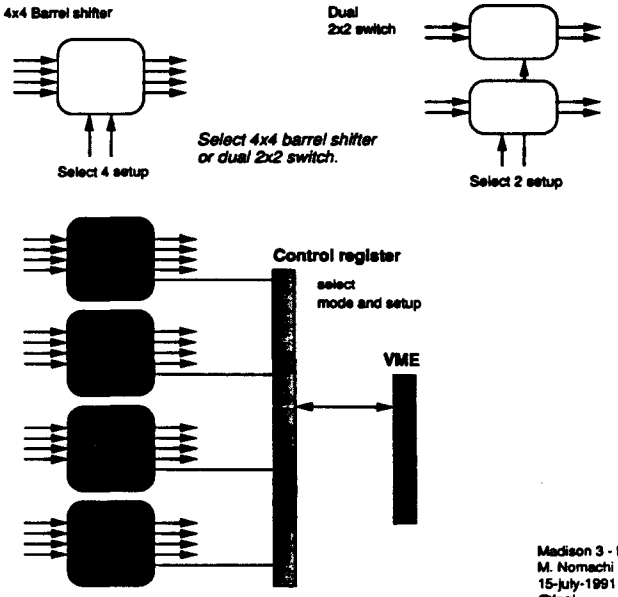


2742

SWITCH

6U VME module
Controlled via VME
Four 4x4 barrel shifters
works at 1 Gbps

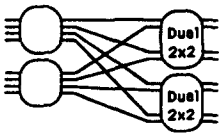
FUJITSU's custum ECL



Madison 3 - b
M. Nomachi
15-july-1991
@final

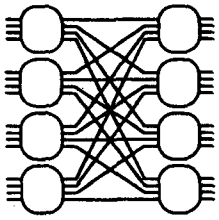
2743

8 x 8 Barrel shifter



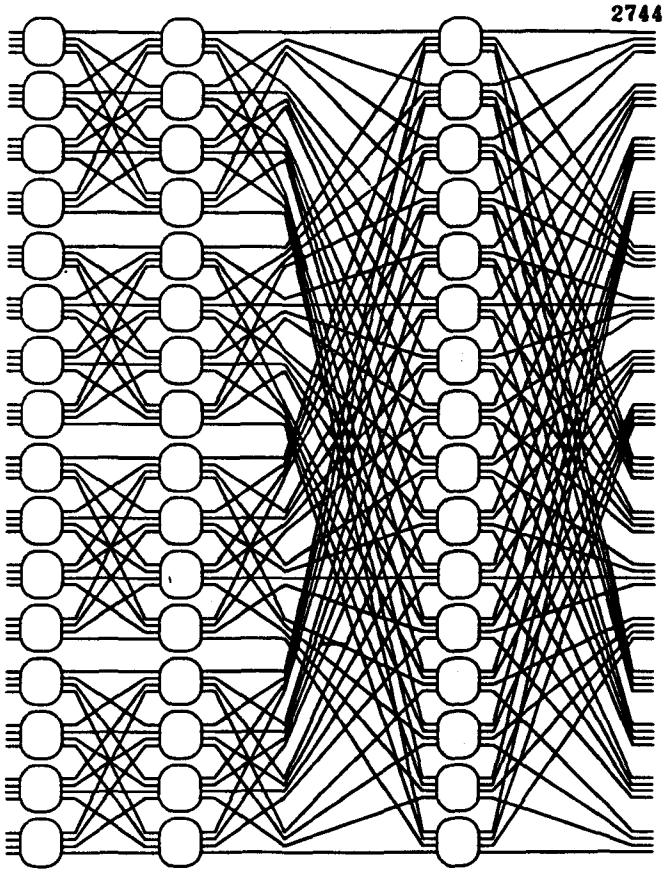
One module

16 x 16 Barrel shifter



two modules

2744



2745

Large scale barrel shifter using high speed ECL chip

- ECL (FUJITSU) switch
- 512 x 512 barrel shifter
- Addressable FIFO

SDC Meeting at LBL

August, 1991

Masaharu NOMACHI

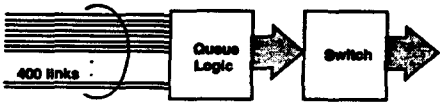
KEK online group

2746

Link speed

bit rate	actual data byte rate
800 Mbps -->	80 MB/sec
625 Mbps -->	62.5 MB/sec (sync. to SSC clock)

Data flow



62.5 MB/sec/link x 400 links = 25 GB/sec
** If size of event fragment is well balanced.

Size of event fragment

Data balancing logic is possible, but it may not help. It must be done before links.
Data balancing logic at readout crate is very difficult.

Average size of event fragment should be less than 6 KB. If it is more than 6KB, use two links.

If the size of event fragment is not balanced, readout buffer must be big enough.

6 KB x 10KHz (Max level 2 trigger) = 60 MB/sec

1 MB / 400 crate = 2.5 KB (average fragment size)

2747

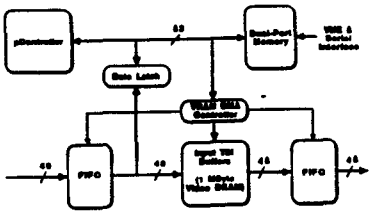


Figure 11 Input TSI (one channel)

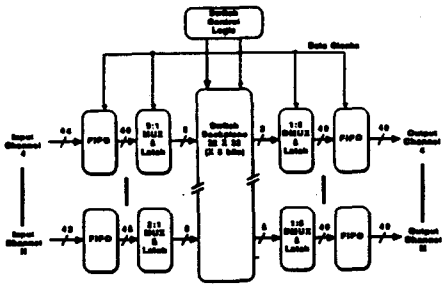


Figure 12 Time Multiplexed Switch

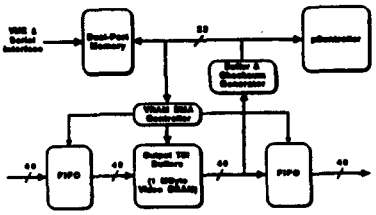


Figure 13 Output TSI (one channel)

(SDC91MAY-FNAL2)
13-MAY-1991 SDC DAQ meeting

2748

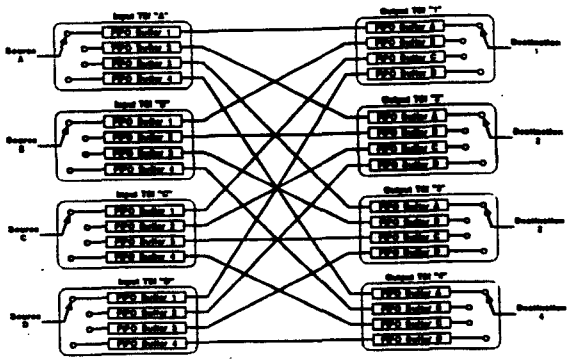


Figure A4 "Logical" Switch Interconnection

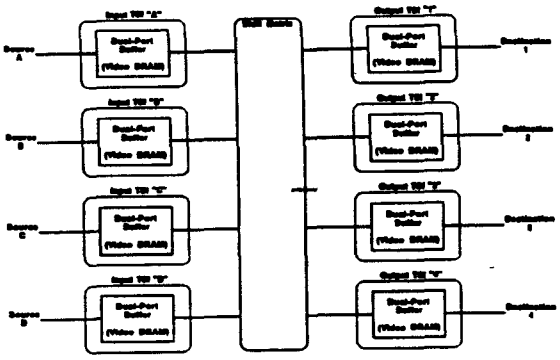


Figure A3 Switch with Time Slot Interchange Buffers

(SDC91MAY-FNAL1)
13-MAY-1991 SDC DAQ meeting

2749

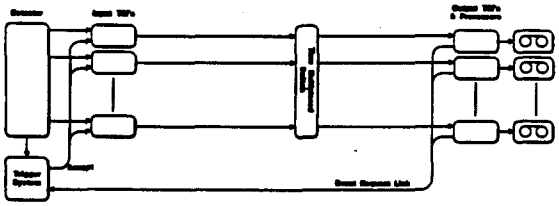


Figure 5 Control Flow

Most of the switch area is used in conversion between serial and parallel data formats. The use of optical or opto-electronic switches (figure 6) will eventually allow serial data transmission from the Input TSIs to the High Level Processors without intermediate conversions. A 512 channel switch could then be implemented in a single crate.

Switching networks are replacing standard busses as the preferred interconnect for most commercial parallel processing systems. With some additional data buffering, these machines could serve as both Event Builders and high-level processors.

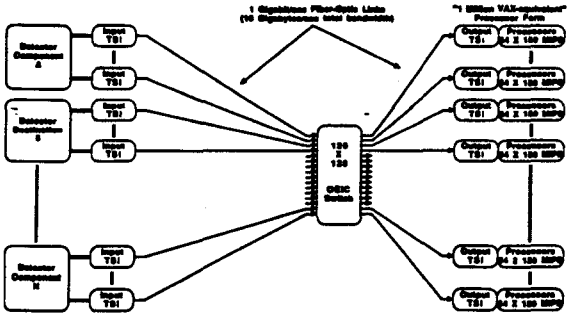
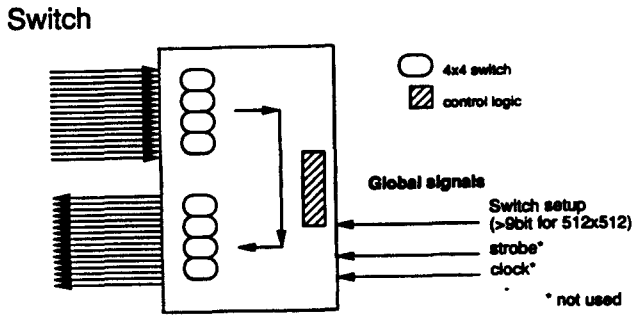
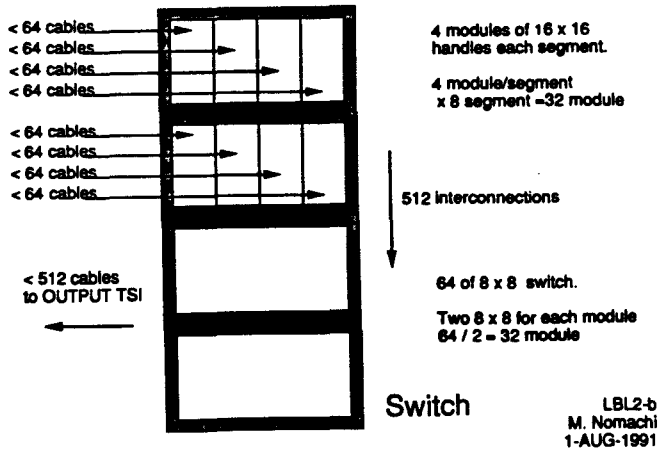


Figure 6 Future Switch Implementation

2750



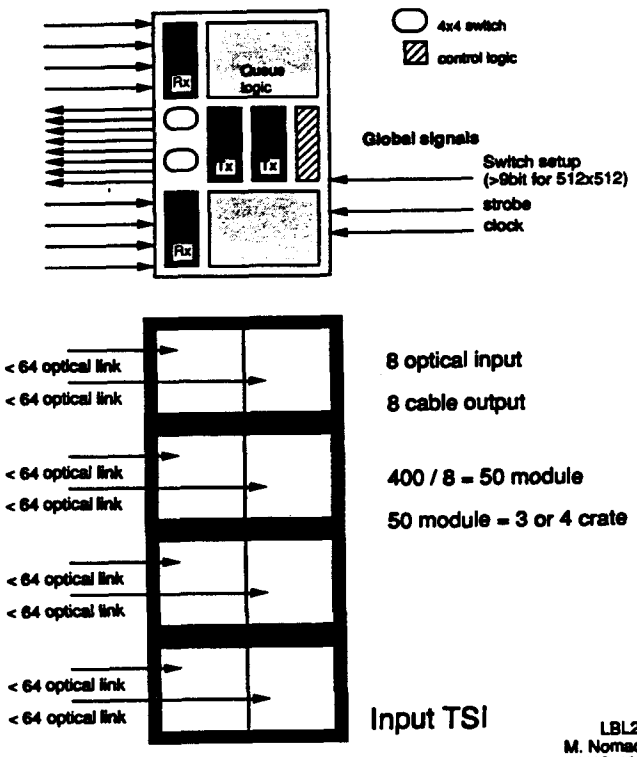
16 x 16, dual 8 x 8, or quad 4 x 4



LBL2-b
M. Nomachi
1-AUG-1991

2751

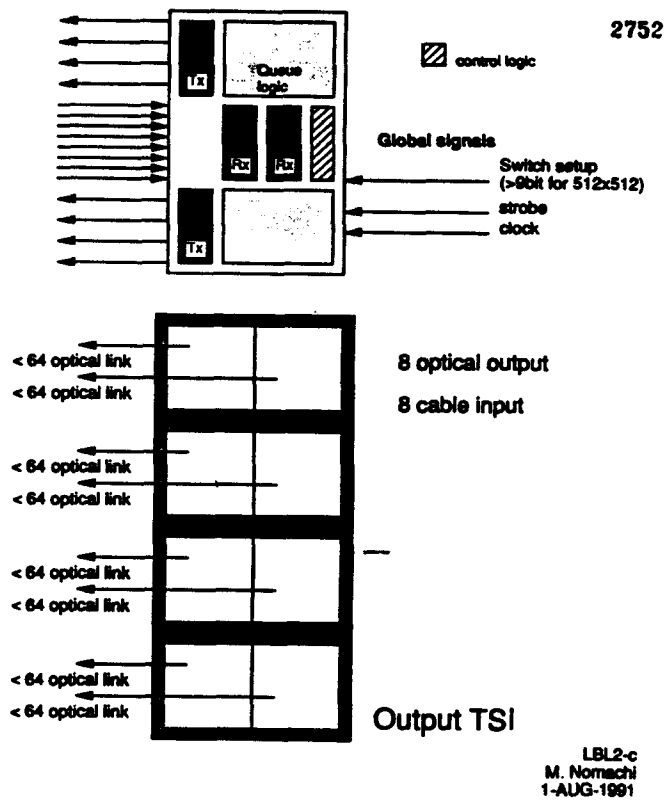
Input TSI



LBL2-a
M. Nomachi
1-AUG-1991

2752

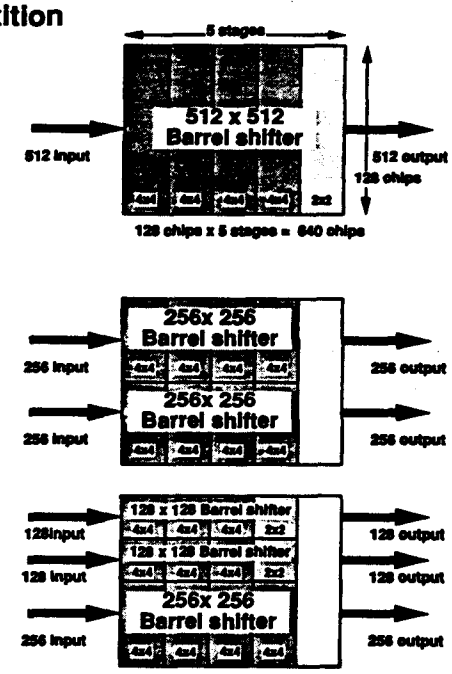
Output TSI



LBL2-c
M. Nomachi
1-AUG-1991

2753

Partition



Binary partition is easy and costs notthing additional.

partition
M. Nomachi
1-AUG-1991

2754

Richard Partridge
LBL SDC Workshop
August 5, 1991

TECHNICAL PROPOSAL BASELINE DESIGN OPTIONS

- Current baseline design adopted primarily for costing DAQ
- For technical proposal, we must:
  - Provide a baseline DAQ design that the DAQ group believes is the best design available at this time within the cost constraints and DAQ requirements. The baseline design may need to provide options and alternatives where technical choices are not clear at this time.
  - Demonstrate that the design is credible and meets the requirements. Simulation results are essential to demonstrate the credibility of the design. Furthermore, the baseline design should be based on straight-forward extrapolations of proven techniques and not rely on exotic technology, Where unproven techniques show promise, there should be an alternative option using proven technology.
- Baseline design should have maximum input rate of ≈ 5 kHz, with a capacity for 10 kHz.
- Event size calculations indicate an average event size of 100-200 kB, which indicates 1 GB/s is probably sufficient for turn-on, with expansion capability to 2 GB/s in the future.
- DAQ meeting Sept. 5 at Fermilab to discuss technical proposal baseline design and other topics

BASELINE DESIGN OPTION II

- Front End crates with DAQ readout sequencer
- Subsystem crates to provide data collection for each subsystem and provide links to the subsystem computer, local trigger interface, and DAQ control interface to trigger and DAQ supervisor.
- Farm crates with DPM event builder and commercial CPUs
- Subsystem computers to provide local control/logging of subsystems in stand-alone mode
- DAQ supervisor to determine availability of farm processors and assign event routing

FRONT END CRATE

CPU	DAQ READOUT	TRIG/CLOCK	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE	FEE

FRONT END CRATE COMPONENTS

CRATE: VME 9U 400 mm with standard J1, J2 backplanes. Clock and trigger distribution on custom J3 Backplane.

CPU: Commercial CPU for monitor, download, calibration, and control. CPU includes Ethernet link to slow-control network.

DAQ READOUT: Readout sequencer to read out FEE cards over VME backplane. Data is sent to DAQ using fiber optic link.

TRIG/CLOCK: Trigger/Clock interface card. Provides clock and trigger signals to FEE and DAQ READOUT cards using J3 backplane. **FEE:** Front-end electronics cards. Provides Level 1/Level 2 buffering and makes digitized data available via VME following a Level 2 trigger.

SUBSYSTEM CRATE

CPU	DAQ	LOCAL	UNUSED	UNUSED	UNUSED	UNUSED	UNUSED	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA
	CONTROL	TRIG						COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT	COLLECT

SUBSYSTEM CRATE COMPONENTS

CRATE: VME 9U 400 mm with standard J1, J2 backplanes. DAQ control on custom J3 Backplane.

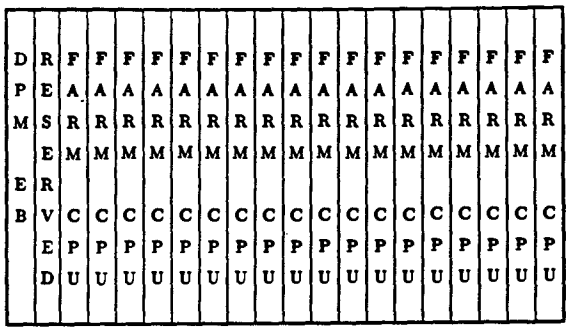
CPU: Commercial CPU for monitoring and spying on the data. In local mode, CPU provides readout of events to subsystem computer using Ethernet link.

DAQ CONTROL: Generates busy signal using and sends it to global trigger logic or LOCAL TRIG card. Receives event routing information from DAQ Supervisor and supplies it to DATA COLLECT cards.

LOCAL TRIG: Local trigger module for generating pulser and calibration triggers for subsystem when in local mode.

DATA COLLECT: Data collection card. Collects data from up to 8 DAQ READOUT cards in front end crates for the subsystem. Provides data output to DPM EB cards in farm using high speed fiber optic link. In local mode, data can be read by the CPU using VME. CPU can also sample incoming events for monitoring and calibration during data taking mode. Adds routing information to packet header that indicates one (or more) destination CPU's in Level 3 farm. Provides DAQ CONTROL with indication of pending DAQ busy condition.

FARM CRATE



FARM CRATE COMPONENTS

CRATE: Standard Futurebus+ crate. Could be a different bus standard if one is adopted and widely supported by industry.

DPM EB: Dual-port memory event builder card. Accepts 16 high speed fiber optic links that carry data from subsystem crates. Stores events with appropriate routing headers in local memory. Makes event data available to FARM CPU cards using Futurebus+ backplane.

FARM CPU: Commercial CPU for Level 3 processing of events. Uses DMA transfer over Futurebus+ to acquire event data. Uses FDDI network link for downloading, remote console, and output of accepted events from Level 3 algorithms.

DATA PATH COST

Item	Quantity	Unit Cost	W&S	Total Cost
DAQ READOUT	300	2K	200K	800K
DATA COLLECTION	40	3K	300K	420K
DAQ CONTROL	10	2K	100K	120K
DPM EB	30	5K	300K	450K

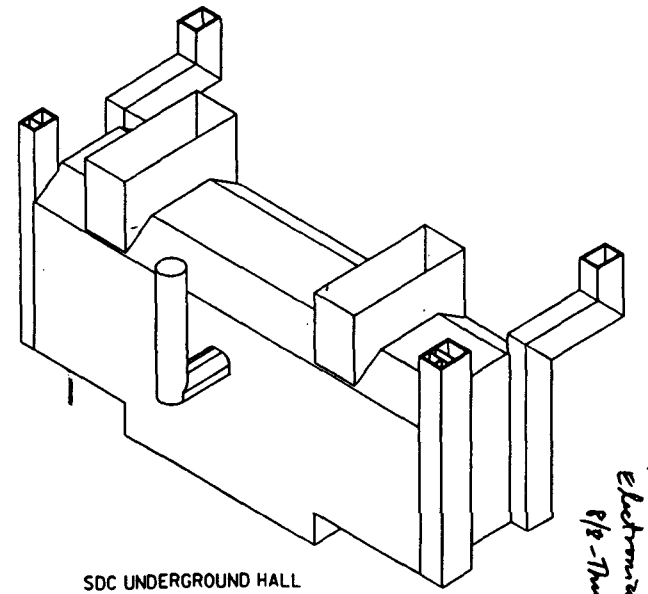
Total cost of data path: 1790K

Many other DAQ costs not included, but are common to other designs

SURFACE FACILITIES FOR ELECTRONICS

C. BEBEK

2763

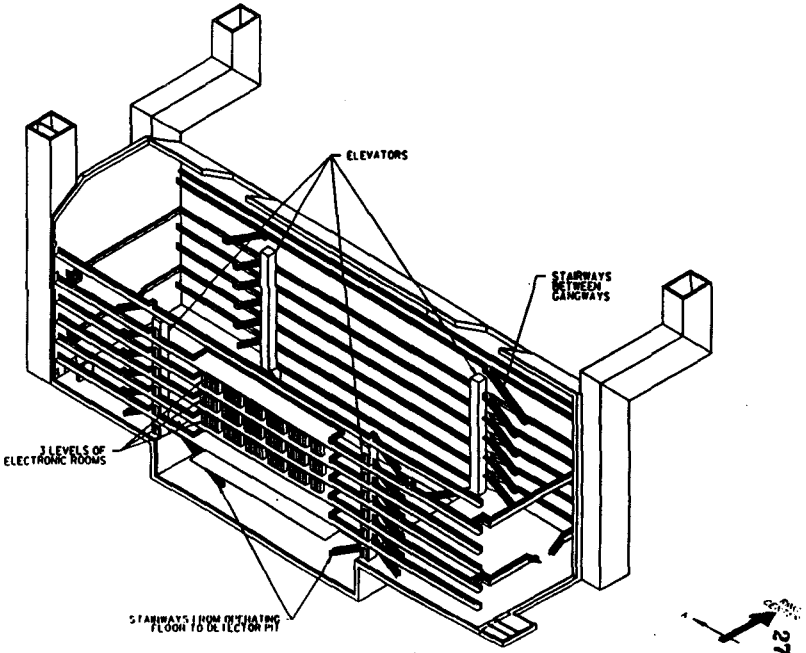


SDC UNDERGROUND HALL

FIGURE 4.1.1-a

Bebek 2764
Electronics
P/P-Thurs

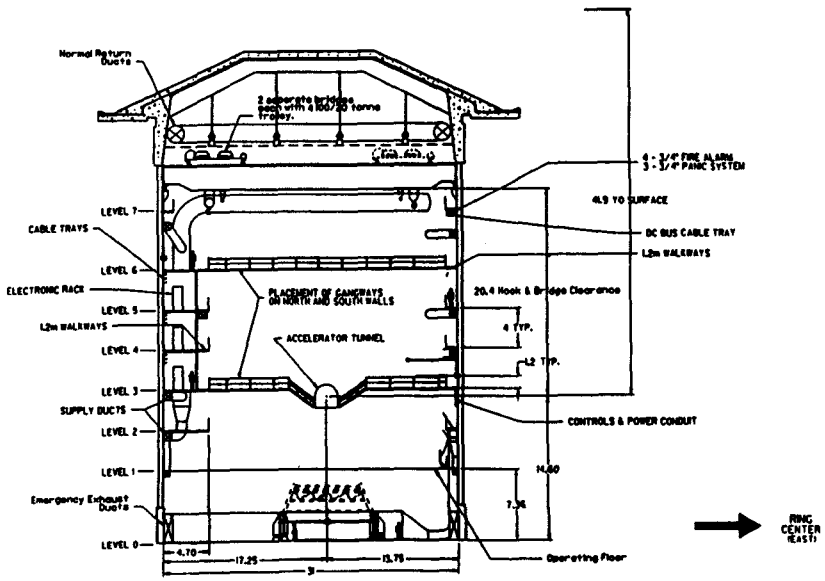
4.1-2



HALL INFRASTRUCTURE
FIGURE 4.1.2.4.b

2765

4.1-10



HALL GANGWAYS

FIGURE 4.1.2.4-a

2766

4.1-9

2767

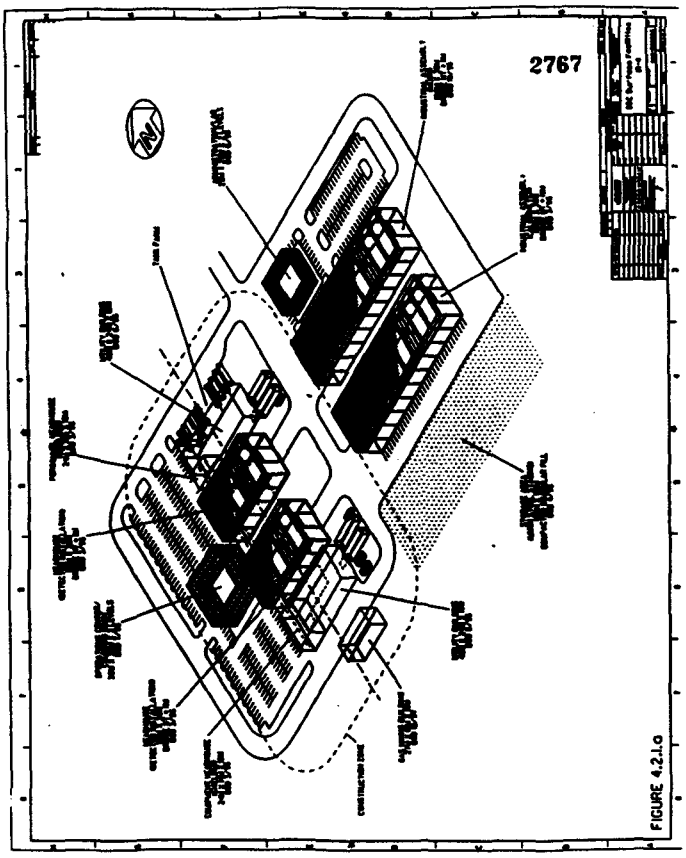
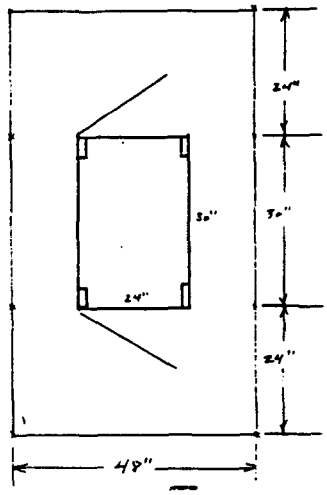


FIGURE 4.2.1.0

2768

Rack



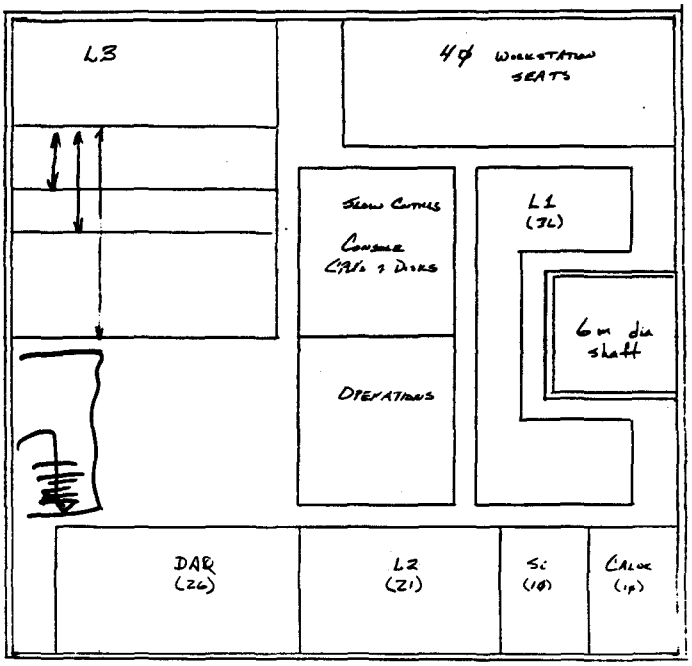
= 5 ft² / 2.4 m²

1 m² ≈ 10.75 ft²

2769

	Racks		A(m²)
L1	16	space for 3/4	75
L2	21		54
Si	10		24
Calor	10		24
DAR	26		64
Controls			56
40 ws seats			88
L3	128	8 cpu/rack	220
(10³ CPUs)	64	16 cpu/rack	140
	40	8 cpu/rack 3 racks/rack	100
Operations			56

2770



Building is 30 m x 30 m

PIPELINE LENGTH

W. SMITH

TRANSMIT TRIGGER SIGNAL TO COMPONENT PIPELINE

	Cause of Delay	Time (crossings)
1.	GFLTB -> pipeline controller (nearby)	1
2.	Pipeline setup & synchronization	2
3.	Pipeline Controller -> Pipeline Fanout (far)	50
4.	Local Fanout to Pipeline	10
5.	Phase between pipeline and sample	+/- 0.5
6.	Loss of sample where pipeline stops	1
7.	Particle interaction -> pipeline front	-5
8.	Presamples	6
9.	Signal shaping for sample of rise	-1
	Total	**64**

A total offset of 64 crossings requires the GFLT accept to be issued at a time 64 crossings less than the pipeline length.

TRIGGER DECISION TIME

Cause of Time Delay	Time (in Crossings)
Calorimeter through Global:	
1. Propagation to Detector	6
2. Digitization (incl. synch.)	4
3. Local Pattern Logic	21
4. Regional Pattern Logic	12
5. Regional Correlations btw. Components	6
6. Transmission to Component Global Logic	14
7. Component Global Logic	15
8. Transmission to GFLT	50
9. GFLT Calculation	20
Total	**148**
Muon through Global:	
1. Propagation to Chamber	2
2. Drift in Chamber	50-100
3. Propagation along Wire	2
4. Segment Finder	2
5. Segment Linker	6
6. Transmission to GFLT	50
7. GFLT Calculation	20
Total	**132-182**

TOTAL PIPELINE LENGTH

Cause of Time Delay	Time (in Crossings)
Calculation of Trigger Decision	
Calorimeter thru Global = 148*	
Muon through Global = 132 - 182	
	148* - 182
Propagation of Trigger to Pipeline	64
Total	**212* - 246**
	= 3.4* - 3.9 μsec

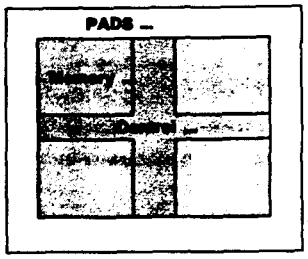
*Note: Additional speedup in calorimeter trigger calculations can reduce 148 crossings below 132, reducing the minimum total pipeline length to 196 crossings or 3.1 μsec.

TMC-SSC Spec. Plan

- Timing Resolution = 0.6 ns.
- Least Count = 2 ns (~0.6 x √12)
- 4 channels
- Memory = 16 bit x 96 rows
  = 1536 bit (3.072 μs)
- Si area

TMC1004 : = 28mm²
(4ch x 1kb) =12.8 mm² + 6.9 mm²+ 8.3 mm²
(Pads) (Control) (Memory)
↓ x √1.5 ↓ ↓ x 1.5

TMC-SSC : =15.7 mm² + 6.9 mm² + 12.5 mm²
(4ch x 1.5kb) = 35.1 mm² (25% increase)

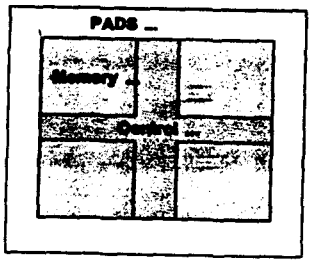


TMC-SSC Spec. Plan II

- Timing Resolution = 0.6 ns.
- Least Count = 2 ns (~0.6 x √12)
- 4 channels
- Memory = 16 bit x 128 rows
  = 2048 bit (4.096 μs)
- Si area

TMC1004 : = 28mm²
(4ch x 1kb) =12.8 mm² + 6.9 mm²+ 8.3 mm²
(Pads) (Control) (Memory)
↓ x √2 ↓ ↓ x 2

TMC-SSC : =18.1 mm² + 6.9 mm² + 16.6 mm²
(4ch x ~~1.5~~ 2kb) = 41.6 mm² (50% increase)



Electronics and Fiber Tracking Joint Meeting

August 8- Thursday

VLPC Device and Packaging Development	E. Anderson(Rockwell)
Scintillating Fiber Tracking for the SSC Using VLPC	M. Atac(UCLA)

LPBautz:8/20/91

HISTE

PERIOD OF PERFORMANCE: JULY 30, 1990 - DECEMBER 31, 1991

VALUE: $435K

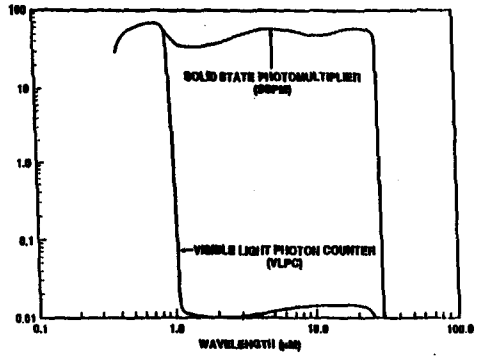
GOALS:

- PROVIDE DETECTORS FOR FIBER TRACKING EXPERIMENTS (SSPM/VLPC)
- DEMONSTRATE VLPC OPERATION
- IMPROVE VLPC PERFORMANCE

Rockwell International Science Center

VISIBLE LIGHT PHOTON COUNTER (VLPC)

CALCULATED SPECTRAL QUANTUM EFFICIENCY



- IMPURITY BAND CONDUCTION DEVICE
- ULTRA-SENSITIVE PHOTON DETECTOR IN VISIBLE SPECTRUM
- PRACTICALLY BLIND IN INFRARED SPECTRUM (> 1.1 μm)
- APPLICABLE TO

  ASTRONOMY
  HIGH ENERGY PHYSICS
  MEDICINE

OPENS DOOR TO IBC DETECTOR APPLICATIONS TO HIGH ENERGY PHYSICS.

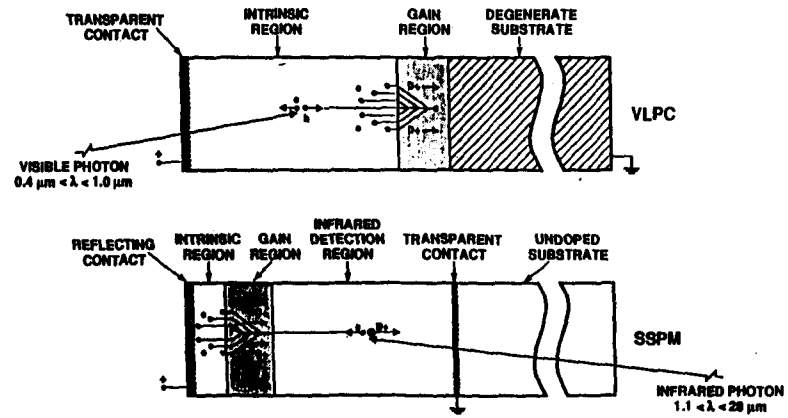
Rockwell International Science Center

HISTE STATUS

- FIRST VLPC MATERIAL GROWN AND PROCESSED ON IR&D, WITH IR&D MASK SET
- DEVICES TESTED ON CONTRACT
  - OPERATE AS EXPECTED FROM MODEL
  - PERFORMANCE NOT ADEQUATE FOR FIBER TRACKING
- DESIGNED AND FABRICATED HISTE MASK SET
  - SSPM MATERIAL
  - FABRICATED AND TESTED ON CONTRACT
- SECOND LOT OF VLPC MATERIAL GROWN
- FABRICATED AND TESTED DEVICES
  - VLPC CONCEPT DEMONSTRATED
  - FURTHER IR SUPPRESSION REQUIRED
- THIRD LOT OF VLPC MATERIAL GROWN
  - DEVICES IN FABRICATION
  - COMPLETION BY LATE AUGUST
- DEVICE CHARACTERIZATION
  - SEPTEMBER, OCTOBER
  - VERIFY VISIBLE PERFORMANCE, IR SUPPRESSION
  - EXPECT UNRESTRICTED DEVICES
- DEVICE DELIVERIES
  - PROVIDE DEVICES FOR FIBER TRACKING EXPERIMENTS
  - LATE OCTOBER, NOVEMBER

Rockwell International

SCHEMATIC CROSS-SECTIONS OF VISIBLE LIGHT PHOTON COUNTER (VLPC) AND SOLID STATE PHOTOMULTIPLIER (SSPM)



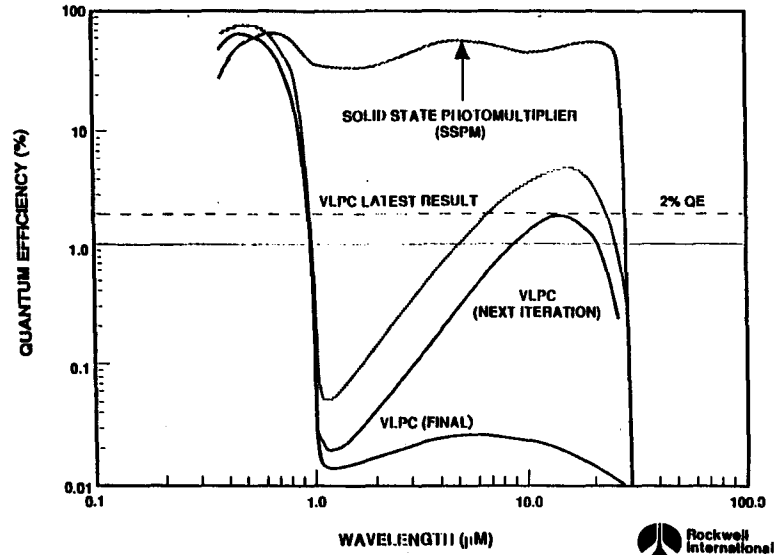
Rockwell International Science Center

CASSETTE/CRYOSTAT CONCEPTUAL DESIGN STUDY STATUS AND PLANS

- **VLPC CONCEPTUAL DESIGN STUDY WILL PROVIDE ENGINEERING NEEDED TO SUPPORT SDC PROPOSAL**
  - DEFINE A FEASIBLE CASSETTE/CRYOSTAT DESIGN CONCEPT
    - FINALIZE REQUIREMENTS
    - PACKAGING TRADES (DESIGN, MATERIALS)
    - PRE-AMPLIFIER TRADES (COLD/WARM)
    - CRYOGENIC DESIGN
    - CABLING AND CONNECTORS
    - CRITICAL INTERFACES
    - HANDLING/RELIABILITY/MAINTAINABILITY
  - CONCEPTUAL DESIGN REVIEW TO BE HELD FOR COMMUNITY REVIEW
  - SUPPORT DEFINITIZED DEVELOPMENT AND PRODUCTION COST ESTIMATES
  - FINAL REPORT TO BE AVAILABLE FOR INCLUSION IN SDC PROPOSAL
- **LOI FUNDING STATUS**
  - CONCEPTUAL DESIGN STUDY TO BE FUNDED THROUGH FERMILAB
  - CURRENTLY FINALIZING TERMS AND CONDITIONS WITH FERMILAB PROCUREMENT
  - PURCHASE ORDER TO BE ISSUED ONCE T&Cs FINISHED (POTENTIALLY BY SEPTEMBER 1, 1991)

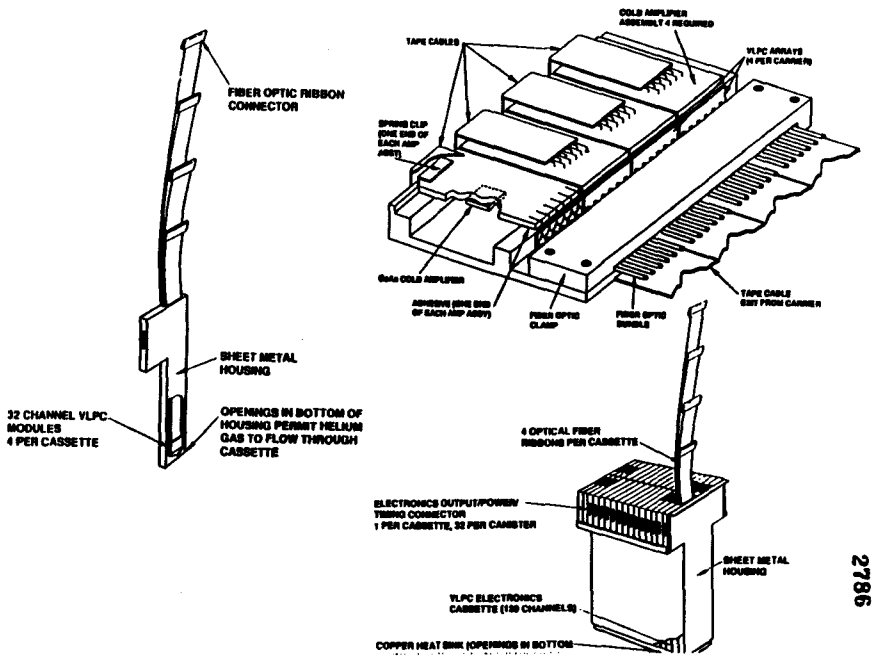
Rockwell International

VLPC SPECTRAL QUANTUM EFFICIENCY



Rockwell International Science Center

SUPERCONDUCTING SUPERCOLLIDER (SSC)



VLPC DEVELOPMENT – FY'92 PLANS

- DESIGN AND FABRICATE NEW MASK SET
  - CASSETTE APPROACH
- HIGHER IMPLANT DOSE FOR TRANSPARENT CONTACT
  - REDUCED CONTACT RESISTANCE
  - LWIR FILTER
- IMPROVED AR COATING
  - INCREASE QE
- MAXIMIZE RESPONSE AT FIBER SCINTILLATION WAVELENGTH
- FABRICATE REFINED VLPC LOT
- CHARACTERIZATION/TESTING
- SCREENING, PACKAGING, DELIVERY OF 1024 DEVICES
- TECHNICAL SUPPORT
- CHARACTERIZE EFFECTS OF NEUTRON AND GAMMA RADIATION

Rockwell International

PERFORMANCE SPECIFICATION

The scintillating fiber readout system shall function as a phototransducer with single-photon counting capability. It is to be a pixel system which converts photon pulses to standardized digital electrical pulses. Performance requirements listed below are based on the photon signal from a tracking element consisting of a 4-meter long, 0.75 mm diameter scintillating fiber spliced to a 4-meter long, 0.75 mm diameter clear readout fiber. The photon signal due to charged particles traversing the scintillating fiber will have a dynamic range of 1 to 30 photons. The time-domain representation of the photon signal is a Poisson interval distribution that has a mean interval of 500 nsec and is truncated at 16 nsec by the time structure of the accelerator.

A. Quantum Efficiency
> 70% for the wavelength range 500 to 600 nanometers

B. Single Photon Counting Efficiency
> 60%

C. Background Counting Rate
< 5 KHz

D. Cross Talk
< 2% for 1 to 30 photon pulses

E. Time Slewing
< 5 nsec between 1 and 30 photon pulses

F. Long Term Timing Stability
relative drift between pixels less than +/- 2 nsec

G. Output Characteristics

connector	25-mil pitch, as per Spectrastrip 845-x-xxx-P-ALA00
cable	single-ended ribbon, 53 ohms to ground plane
logic levels	(work-in-progress)
pulse width	14 nsec
bit rate	62.5 Mbs

H. Self Testing Feature
JTAG diagnostic port for loading/reading back test patterns

PHYSICAL PARAMETERS AND CONSTRAINTS

A. Footprint
36" wide by 20" high by 20" deep

B. Orientation
vertical to allow pool boiling helium option

C. Subassembly Size
replaceable unit containing 1024 pixels

D. Assembly Size
16 subassembly units containing a maximum of 16384 pixels

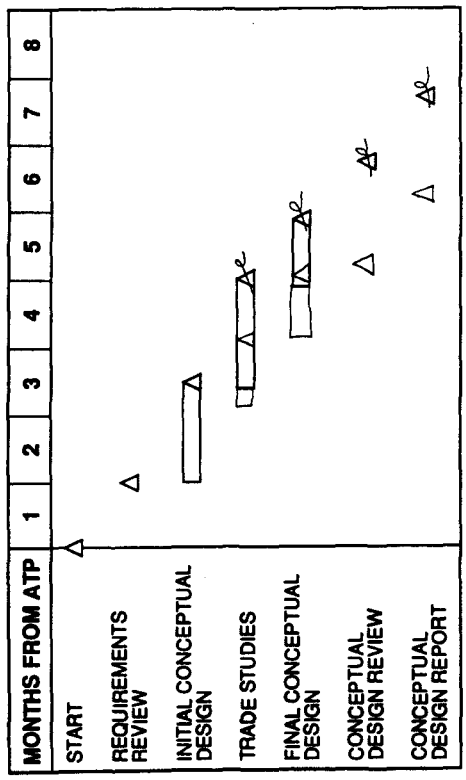
E. Reliability
300 years mean time to failure per pixel

F. Useful Lifetime and Number of Thermal Cycles
10 year lifetime
50 thermal cycles per subassembly

G. Cooldown and Replacement Times
6-8 days for cooldown of a full assembly
3-4 hours cooldown for swapping one subassembly
(subassembly capable of being withdrawn cold)

H. Environmental Factors
external environment is at room temperature
helium and nitrogen vapor recovery is required

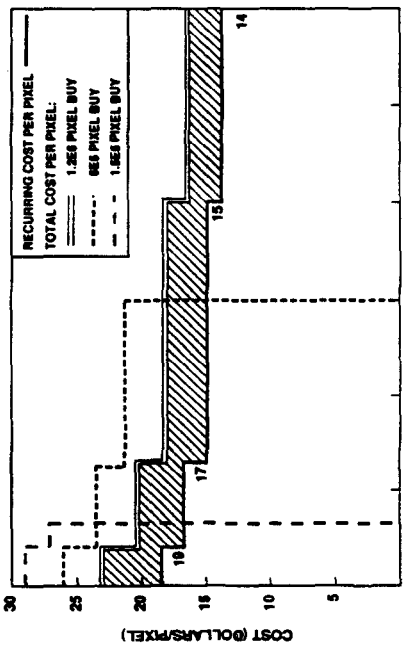
CONCEPTUAL DESIGN STUDY SCHEDULE



Rockwell International

PRELIMINARY ROUGH DEVELOPMENT AND PRODUCTION - ESTIMATED COSTS VERSUS VOLUME

• BASED ON EXTRAPOLATED LEARNING CURVE



Rockwell International

UCLA-PPH0094-7/91

Scintillating Fiber Tracking for the SSC Using Visible Light Photon Counters

M. Atac, K. Arisaka, D. Cline, D. Chrisman, D. Roberts,
J. Kolonko and J. Park
UCLA, Los Angeles
M. Petroff
Rockwell International Science Center, Anaheim, CA
E. Anderson
Rockwell International Electro-Optical Center, Anaheim, CA

Presented by M. Atac*

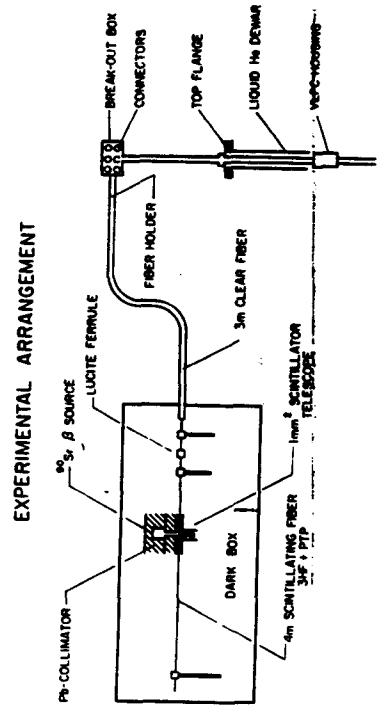


Fig. 5 - Experimental arrangement for measuring detected photon by a VLPC using a 4 meter length of scintillating fiber of 0.8 mm core (3HF+ PTP in polystyrene). The scintillating fiber is spliced to a 3 meter long optical clear fiber that carries the photons to the VLPC.

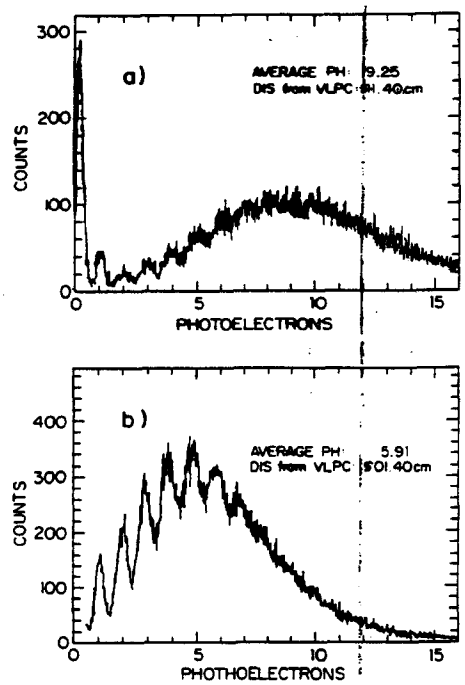


Fig. 6 - Four samples of pulse height spectra obtained at the indicated sources positions. The weighted average number of detected photons are given on the figures.

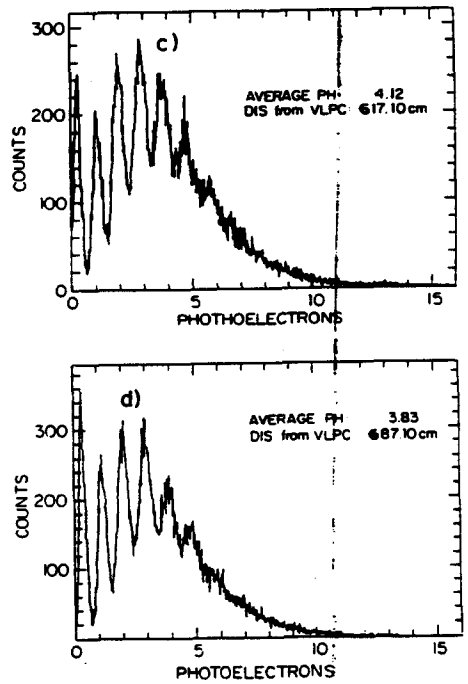


Fig. 6 - Four samples of pulse height spectra obtained at the indicated sources positions. The weighted average number of detected photons are given on the figures.

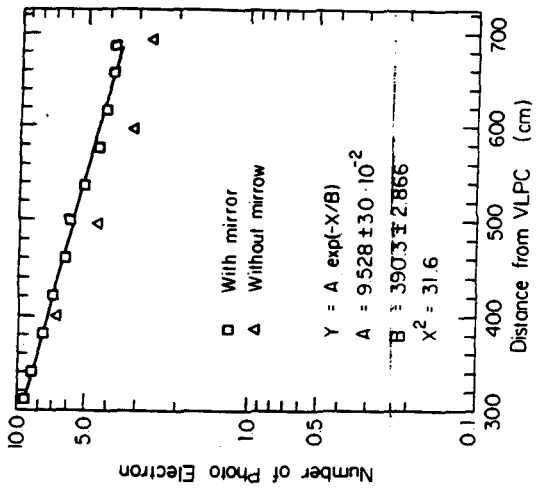


Fig. 7 · Detected number of photons as a function of source positions from the VLPC are indicated with and without a mirror at the end of the scintillating fiber

SCINTILLATING FIBER- VLPC TRACKING TESTS WITH COSMIC RAYS AT U C L A

M. Atac, J. Park and D. Chrisman
University of California at Los Angeles

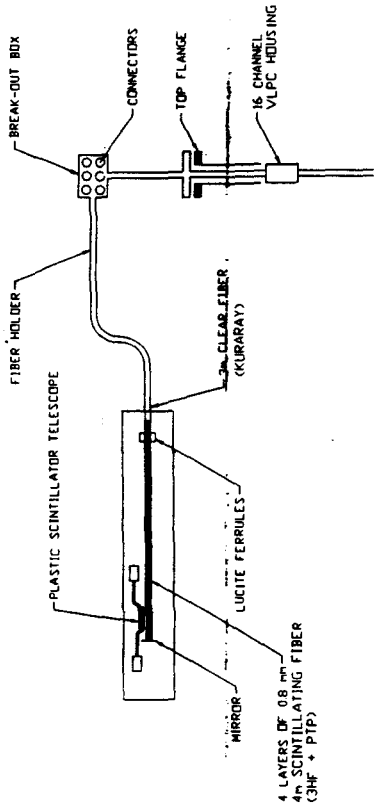
M. Petroff
Rockwell International Science Center

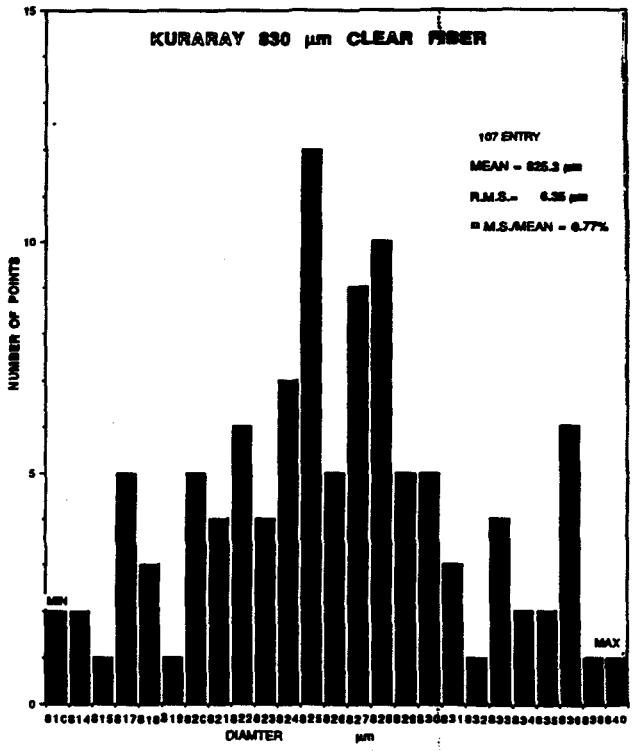
R. Ruchti, B. Baumbaugh and M. Kelly
University of Notre Dame

D. Koltick, R. Davies and B. Abbott
Purdue University

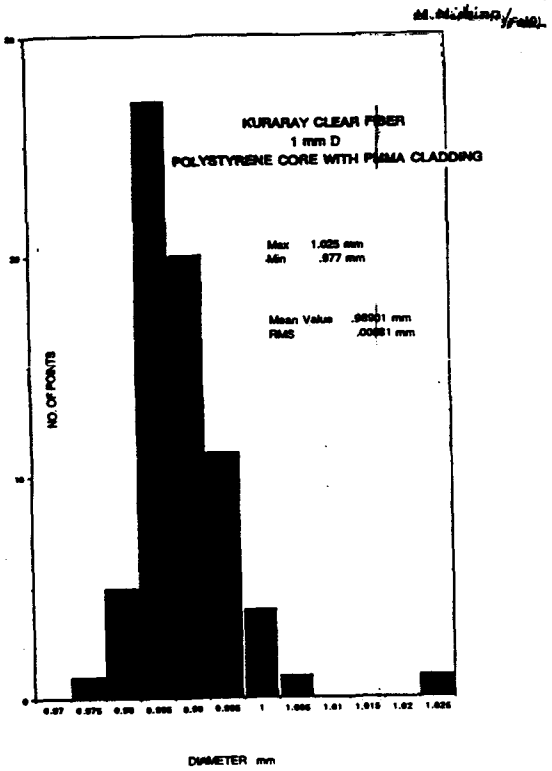
K.MORGAN , SSC

We have carried out some tests at UCLA using 16 fibers which were coupled to two VLPC chips of 8 elements each. Scintillating fibers, BICRON BC-05 , were 3.2 meter long and epoxied together to make ribbons of 8 fiber wide. Core size of the scintillating fiber was 0.8 mm. 3 meter long clear fibers (produced by Kuraray Co.) were spliced to the scintillating fibers that carried the photons to the VLPCs. All VLPC channels were run at a bias voltage of 6.8 / 6.5 volts. The temperature of the VLPCs were kept around 6.5 K. A simple pair of scintillator telescope with a size of 7mm x 12mm was used for triggering on Cosmic-Rays. In the attached there are some samples of tracks detected by the scintillating fiber tracker.





2799



2800

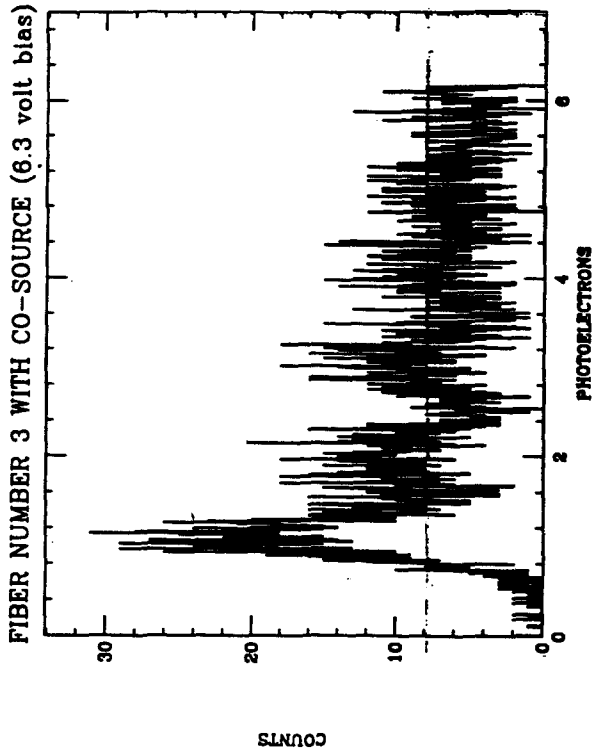


Fig 1

2801

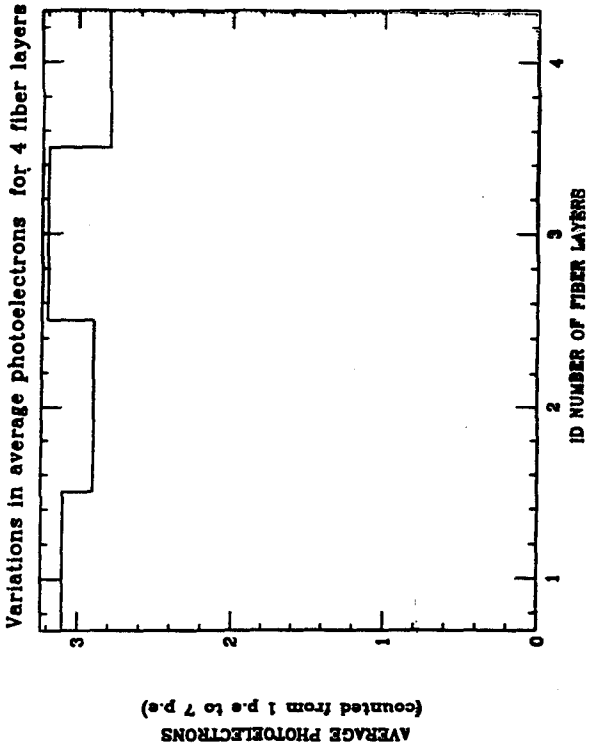
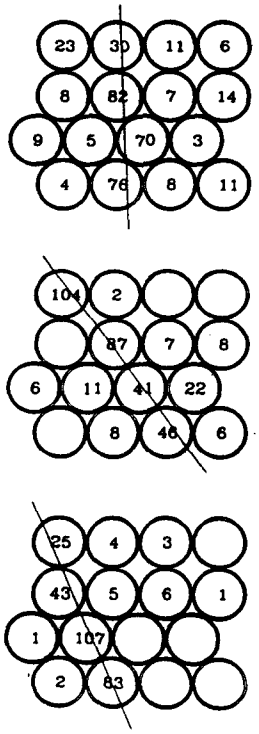


Fig 6

2802

UCLA FIBER TRACKING EXPERIMENT RESULTS

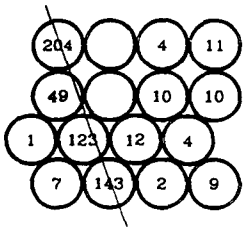
Cosmic ray tracks indicated by ADC counts given for each fiber. Each picture represents a separate cosmic ray event.

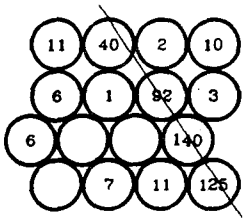


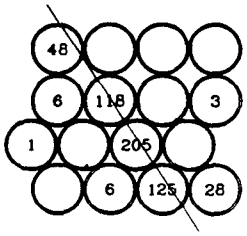
UCLA FIBER TRACKING EXPERIMENT RESULTS

2803

Cosmic ray tracks indicated by ADC counts given for each fiber.
Each picture represents a separate cosmic ray event.



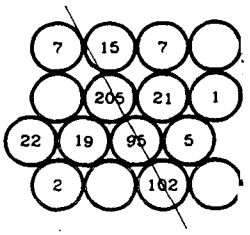


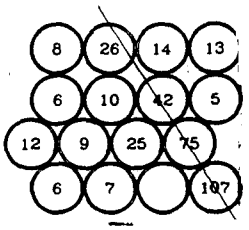


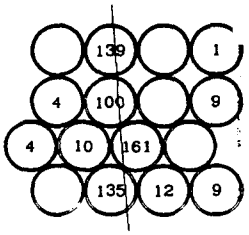
UCLA FIBER TRACKING EXPERIMENT RESULTS

2804

Cosmic ray tracks indicated by ADC counts given for each fiber.
Each picture represents a separate cosmic ray event.



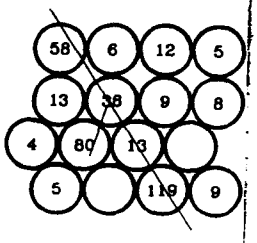


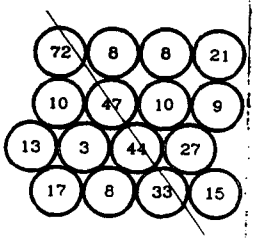


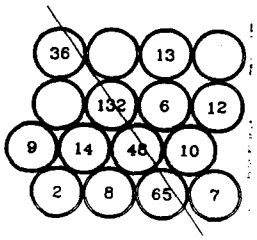
UCLA FIBER TRACKING EXPERIMENT RESULTS

2805

Cosmic ray tracks indicated by ADC counts given for each fiber.
Each picture represents a separate cosmic ray event.



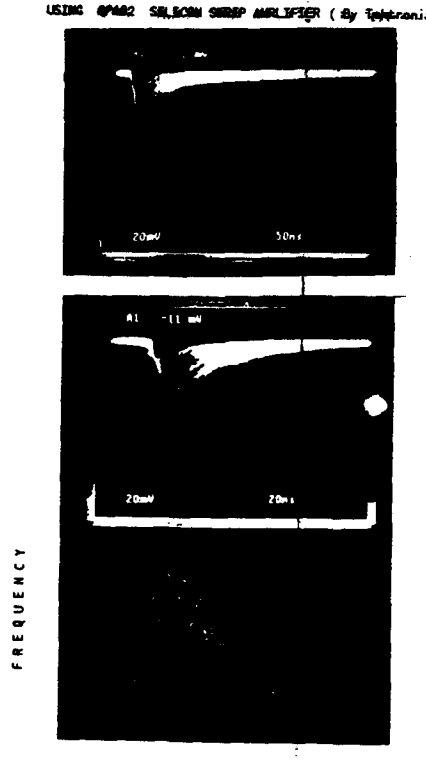


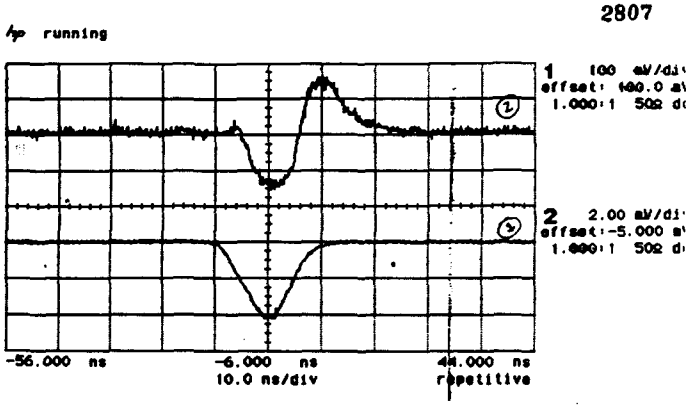


M.Petroff;M.Atac,D.Chr[illegible] J.Park
UCLA, Jan.28/1991

USING 6P482 SILICON SHEEP AMPLIFIER (By Tektronix)

2806





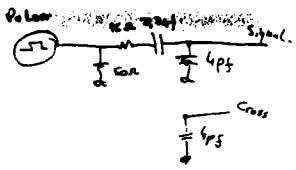
1 -87.50 mV

	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	100 mV/div	100.000 mV	1:1	dc	50 ohm
Channel 2	2.00 mV/div	-5.00000 mV	1:1	dc	50 ohm

Trigger Mode: Edge
On the Positive Edge of Channel1
Trigger Level(s)
Channel1 = -87.5000 mV (noise reject OFF)
HoldOff = 40.000 ns

Gold plated SS ribbon 14Ω/14' , 4 pf Cap

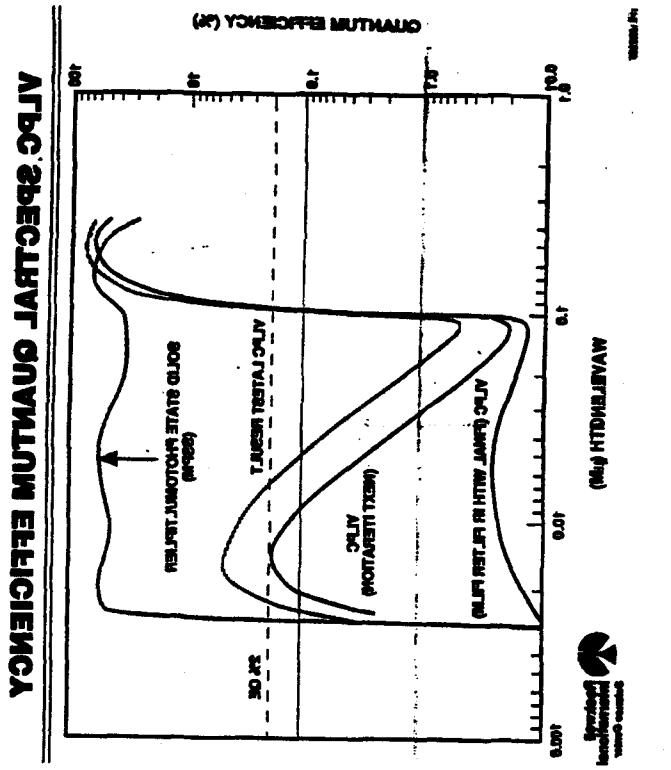
G S G S G S G



PROPERTIES OF THE VLPC (VISIBLE LIGHT PHOTON COUNTER)

PARAMETER	VALUE
Pulse Rise Time	< 8 ns
Average Gain	3.0×10^4
Gain Dispersion	< 30%
Effective Quantum Efficiency	0.25
Dead Time	3022 (continuous)
After Pulses	none (<.01%)
Dark Pulse Rate	5×10^3/s
Saturation Pulse Rate	2.5×10^7/s
Average Current	(200+300xOcc.) nA
Average Power	~ 1.3μW
Breakdown Voltage	7.5V
Operating Voltage	6.5V
Neutron Damage Level	$> 10^{10}$ n/cm^2
Operating Temperature	6K -17K

Magnetic Field has no effect up to 14 kG



VLPC DEVELOPMENT - FY'92 PLANS

- DESIGN AND FABRICATE NEW MASK SET
  - CASSETTE APPROACH
- HIGHER IMPLANT DOSE FOR TRANSPARENT CONTACT
  - REDUCED CONTACT RESISTANCE
  - LWIR FILTER
- IMPROVED AR COATING
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- MAXIMIZE RESPONSE AT FIBER SCINTILLATION WAVELENGTH
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- SCREENING, PACKAGING, DELIVERY OF 1024 DEVICES
- TECHNICAL SUPPORT
- CHARACTERIZE EFFECTS OF NEUTRON AND GAMMA RADIATION

BIAS AND TEMPERATURE DEPENDENCE OF $\lambda = 560$nm QUANTUM EFFICIENCY (QE), FAST GAIN (G_F), AND DARK COUNT RATE C_D FOR VLPC ARRAYS

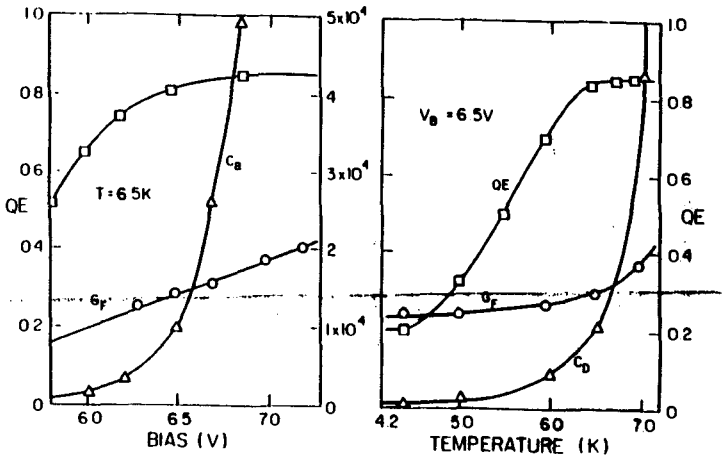
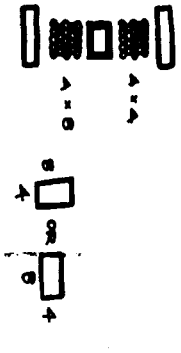


Fig. 4 - Quantum efficiency of an AR coated VLPC as functions of bias voltage and temperature is shown. Dark pulse rate and gain are also indicated.

FUTURE PLANS?

- INSERT NEW [HOPEFULLY BETTER] FIBER RIBBONS WITH MORE PRECISE STACKING AND KEEP TAKING DATA.
- SIMULTANEOUSLY PREPARE SIMILAR CRYOSTAT WITH 32 VLPC CHANNELS.
- BORROW PETROFF'S LARGE NECK DEWAR FOR RUNNING WITH 48 CHANNELS.



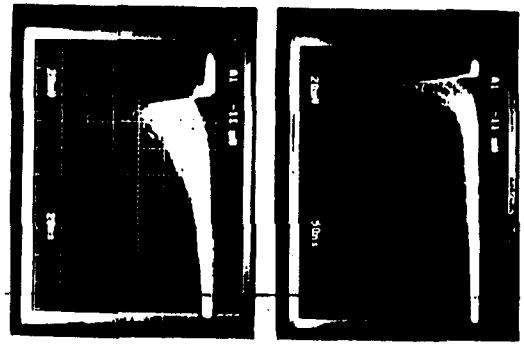


Fig. 5 - Fast pulses are obtained using a CRAC2 amplifier. Pulse rise-time is about 8 nsec. It is limited by the lead capacitance to the amplifier.

Computing

August 5 - Monday

IBM Presentations	
Overview/Status	T. Elam(IBM)
Computer Modelling/RESQME	T. Elam for W. Kossack
Operations Concept, Requirements Development	R. Ennis(IBM)
GEANT, PATCHY, PAW	J. West(IBM)
Software Architecture	G. Kubena(IBM)
Offline Requirements and Architecture Discussion led by E. May(ANL)	

August 6 - Tuesday

Cpmputing Standards - Status	C. Day(LBL)

August 8 - Thursday

Database Computing Project	L. Price(ANL)
Database Project: ObjectStore	C. Day(LBL)
Software Development	I. Gaines(Fermilab)
Code Management Experiments	A. Fry(SSCL)

LPBautz:8/26/91

2815

IBM PRESENTATIONS

OVERVIEW/STATUS

T. ELAM

AGENDA / TOPICS — Tony Elam

2816

– overview / STATUS	TONY ELAM
– Computer modeling / RESQME	TONY ELAM (for Bill)
– OPERATIONS CONCEPT	Bob Ennis
– Physics SIM & TOOLS EXP	JIM WEST
– S/W ARCHITECTURE	GLENN KUBENA
– OOA / DATA Modeling	KEN LIAO
– OTHER Items of Interests	TONY ELAM
– PVS	
– NSFNET	
– Parallel Computing	

AGENDA / TOPICS — Tony Elam

2817

– overview / STATUS	TONY
– Computer modeling / RESQME	TONY (for Bill)
– OPERATIONS CONCEPT	Bob
– Physics SIM & TOOLS EXP	JIM
– S/W ARCHITECTURE	GLENN
– OOA / DATA Modeling	KEN
– OTHER Items of Interests	TONY
– PVS	
– NSFNET	
– Parallel Computing	

SIMIUS UPDATE

2818

JUNE 19 – IBM Houston G.M. – A. MacIna
– Lunch w/ Dr. Trilling
– Meeting w/ Dr. Schutters

June 20-21 – SDC MEETING DALLAS (SSCL)
(TONY, Glenn, Jim, Denis)

July 10-11 – SDC Computing Meeting (SSCL)
S/W Arch & Conf Mgmt
(Glenn, Denis)

July 16 – Meeting with Chris DAY (LBL)
Info model & SW Arch
(Glenn, Ken)

July 17-18 – Meeting with Soren & Harald (SSCL)
on GEANT, PATCHY, PAW
(Jim)

July 29 – Gregg Chartrand - Visit to Houston
IPAD & NASA Networking / Comm Tech
(TONY, Ed, Bob Coyne)

Other Related Activities

2819

July 15-16	-	DATA Information Systems (ARL) (Bob Coyne)
July 18-19	-	EOSDIS Review (TONY ELAM)
Aug 1	-	OBJECT STORE Seminar (Glenn, Ken)
Aug 1-2	-	IBM Internal Parallel Computing (TONY)

IBM Houston TEAM

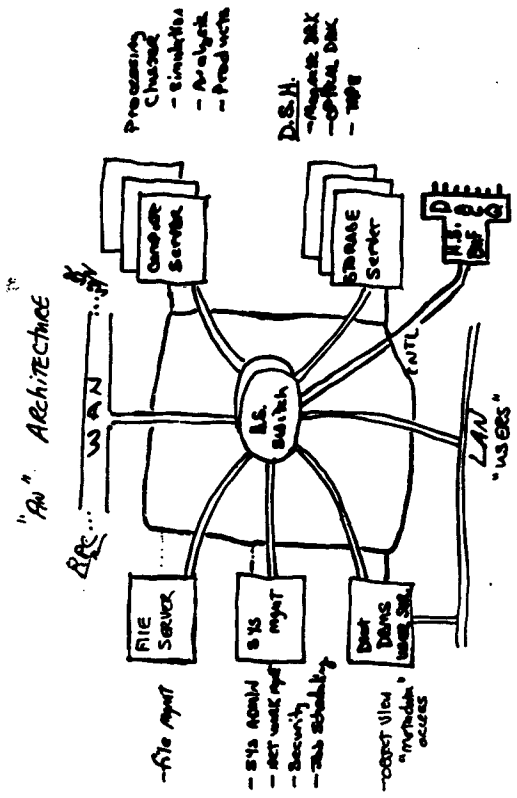
2820

NAME	REP	(713) 282-	@ HOUVMSCC.VMET.IBM.CE
TONY ELAM	PGM MGMT, SYS ARCH	8776	AELAM
Glenn Kubena	S/W ARCH, SYS ARCH	7635	Kubena
KEN Liao	DATA MGMT, DATA MODEL	7061	Liao
Bob Ennis	SYS REQ, OPS CON	8958	BobEnnis
Jim West	Physics APPL S/W & TOOLS	8722	WEST

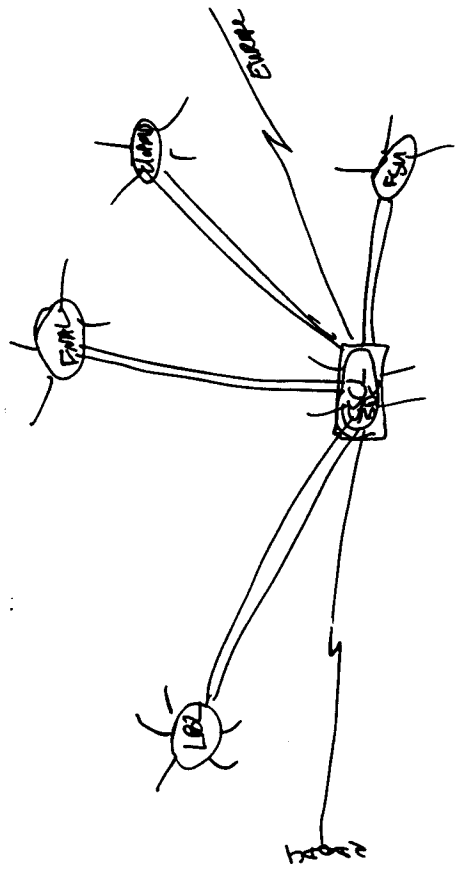
SUPPORT

Bob Coyne - IBM Houston IR&D
ED Poole - SYS MGMT / NETWORKING / STDS
Lester Buck - DATA MGMT / File Server
Merritt Jones - Computer SYS ARCH
Bill Kossack - Computer Modeling

2821



2822



ELAM

2823

MODELING WITH RESQME (THE RESEARCH QUEUEING PACKAGE)

W. S. KOSSACK

8/2/91

IBM INTERNAL USE ONLY

2824

Contents

IBM

HISTORY 1
FEATURES (PORTABILITY) 2
FEATURES (GUI) 3
FEATURES (ANIMATION) 4
FEATURES (MODEL TYPES) 5
FEATURES (MODELING NODES) 6
PERFORMANCE MEASURES 7
SAMPLE MODELS 8
MODELING STEPS (DATA COLLECTION) 12
MODELING STEPS (APPROACH) 13
MODELING STEPS (STATUS) 14

2825

FEATURES (PORTABILITY)

IBM

PORTABLE MODELS

- PORTABLE TO ANY RESQ PLATFORM
- TEXT MODEL DESCRIPTION FILES
  - CAN BE READ OUTSIDE OF RESQME
  - CAN BE EDITED OUTSIDE OF RESQME

(ACTUAL MODEL DESCRIPTION BUILT USING RESQME)

```
/* ****************************************
MODEL: BAKEOPN
   METHOD: SIMULATION
   NUMERIC PARAMETER: BATCHSIZE
   NUMERIC PARAMETER: IAT
   DISTRIBUTION PARAMETER: BAKEST
/* ****************************************
SUBMODEL: BATCHSE
   NUMERIC PARAMETERS: BATCHSIZE
   DISTRIBUTION PARAMETERS: PROCESSTIM
   CHAIN PARAMETERS: CH
   GLOBAL VARIABLES: NUMINBATCH BATCHTIME
      NUMINBATCH: 0
      BATCHTIME: 0
QUEUE: PROCESSQ
TYPE: ACTIVE
SERVERS: BATCHSIZE
DSPL: FCFS
CLASS LIST: PROCESS
   WORK DEMANDS:CONSTANT(BATCHTIME)
SERVER-
   RATES:1
QUEUE:CYCLETIMEQ
```


2826

FEATURES (ANIMATION)

IBM

- MODEL ANIMATION

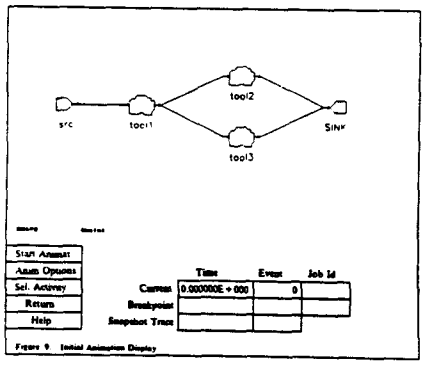


Figure 9. Initial Animation Display

- SHOWS
  - DATA FLOW
  - TIMINGS
  - QUEUE LENGTHS
- CAN BE SAVED AND VIEWED LATER
- SELECTABLE DURING ANIMATION
  - ANY PORTION OF MODEL
  - ENTIRE MODEL
  - ANY PART OF SIMULATION RUN
  - SPEED OF ANIMATION

FEATURES (MODELING NODES)

IBM

DIFFERENT NODE TYPES

- ALLOCATE NODE
  - USED TO CONTROL WAITING FOR RESOURCE
- AND ALLOCATE
  - WAITING FOR RESOURCES FROM MULTIPLE QUEUES
- OR ALLOCATE
  - WAITING FOR RESOURCES FROM ONE OF MULTIPLE QUEUES
- TRANSFER, AND RELEASE NODES
- DISTROY AND CREATE NODES

DESCRIPTIVE PARAMETERS

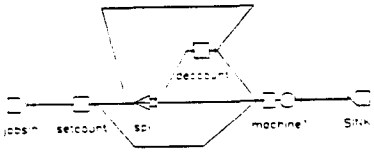
- NUMERIC
- DISTRIBUTIONS
- NODES
- CHAINS

SAMPLE MODELS

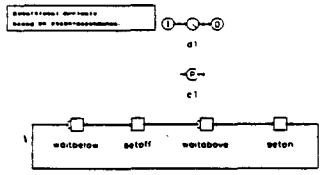
IBM

LARGE SET OF PREVIOUSLY DEVELOPED MODELS

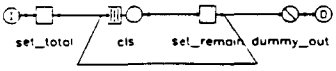
- **BULK ARRIVALS**



- **CONDITIONAL ARRIVALS**



- **ROUND ROBIN SCHEDULING**

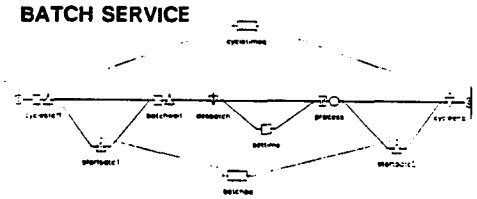


SAMPLE MODELS ...

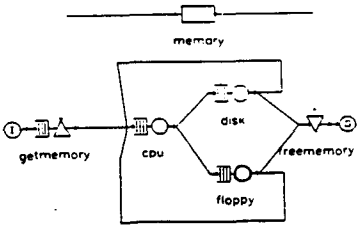
IBM

- **COMPUTER SYSTEMS**

- **BATCH SERVICE**



- **MINICOMPUTER**



MODELING STEPS (DATA COLLECTION)

IBM

DATA COLLECTION

- **MODELING TIME FRAME**
  - COMPLEXITY AND ACCURACY OF MODEL IS DEPENDENT UPON THE DURATION OF MODELING EFFORT
- **WHAT INFORMATION IS AVAILABLE?**
  - SYSTEM DESIGN
  - USER REQUIREMENTS
    - RESPONSE TIME

ACCEPTABLE TIME DELAY BETWEEN USER REQUEST AND COMPLETION OF TRANSMISSION OF DATA

- FREQUENCY OF USER REQUESTS
- SIZE OF DATA REQUESTED

MODELING STEPS (STATUS)

STATUS

- DATA COLLECTION BEGUN
- MODIFYING SIMPLE NETWORK MODEL
  - LOOKING INTO ADDING LONG HAUL NETWORK FEATURES

Operations Concept, Requirements Development

August 2, 1991

Robert J. Ennis

IBM Federal Sector Division
Houston, Texas
(713) 282-8958

Operations Concept

Description

The SDC computing system operations concept:

1. Is a descriptive "model" of how SDC computing will be done.
2. Is documented in terms that are understood by the intended users of the system

Operations Concept

Purposes

The SDC computing system operations concept:

1. Promotes user involvement in the process of defining the system.
   - It communicates the planned system to its intended users.
   - It provides a framework for user input to the process.
2. Drives requirements definition and analysis.
3. Drives problem domain analysis.
4. Helps to validate the system requirements and design.
5. Is a starting point for the development of operational procedures.

Operations Concept

Contents

The SDC computing system operations concept:

1. Identifies and describes user/system interactions.
2. Identifies non-human elements (e.g., sensors, other facilities) with which the SDC computing system interacts, and describes those interactions.
3. Identifies and characterizes the classes of users.
4. Describes the major functional scenarios supported by the system:
   - Each scenario is factored into a sequence of activities.
   - For each activity, the element (system component, organization, ...) responsible is identified.
   - Activity inputs and outputs are identified.
5. Identifies programmatic goals and constraints that drive the SDC computing system

6. Identifies any assumptions implicit in the operations concept.

System Requirements

1. System requirements are specifications.

   They specify:

   - The functional capabilities the system must supply.
   - The performance levels the system must achieve.
   - The computational and storage capacities the system must provide.
   - Other mandatory operational characteristics.
2. They are targeted at those responsible for system development/aquisition.

Plans

1. General:

   To support the Computing and Analysis Software Subcommittee in the development of an operations concept and system requirements for the SDC computing system.
2. Specific:
   - Refine/extend operations concept material in draft SDC Proposal.
   - Refine/extend requirements in draft SDC Proposal.

J. W. West

2839

GEANT,
PATCHY,
PAW

- IBM received CERNLIB from SSCL June, 1991
- I visited Sven & Harald at SSCL July 17th and 18th
  - Tutorial on PATCHY
  - Process 3 sample problems on GEANT on PDSF
  - Simple use of PAW
  - Discuss GEANT 3.15

2840

Observations on CERNLIB

- Extensive system knowledge required to install, modify, and use
- Extensive program logic required to utilize GEANT
  - Many user required subroutines
  - Does programming distract physicist from physics ???
  - Does SDCSHELL simplify Monte Carlo simulation task ???

2841

Observations on CERNLIB

- Documentation is limited
  - Places special problems on the remote user
  - Classes on CERNLIB would be of benefit
  - Normal learning mode via colleagues
- What would work with a large user group ???
- Conclusion:

  I have much to learn!

2842

IBM RS-6000 Experience

- Linker problems
  incorrect listing of un-resolved externals
- XLF Library problem
  (place "-lc" first in xlf.cfg)
- CERNLIB "Make" very complicated
  - references 3 other makes
  - creates many libraries
  - many functions in 1 file
  - → Could not rebuild CERNLIB libraries with "-g" option for debugging.
- Spoke with Markus Baertschi of IBM CERN
  - discuss IBM experience at CERN
  - about 12 IBM physicists at CERN
  - work closely with CERNLIB Developers

IBM Software Defects Support
for RS-6000 AIX Austin

1-800-426-3333

1-512-823-2001

Additional Technical support
24hr/day for a fee
"System Extra"

Future Possibilities . . .

— GEANT 3.15
- new geometry package
- CAD Interface

— Visit CERN Development group
- Learn CERN Development process
- Study CERN USER Support and user interaction
- Meet IBM CERN Colleagues

— SDCSHELL
- install at IBM FSD Houston
- Become familar with it
- Learn capabilities / features

— Explore Integrating physics routines from GEANT with the general purpose structure of MCNP/LAHET/etc.
- Good/bad idea ???

IBM Invitation:

IBM FSD has an
ES9000 IBM Mainframe
available for use by
HEP nights and weekends
running AIX
?? — Opportunity — ??

— Much to learn!
* different approach to Monte Carlo

Everything depends
on (Tony's) funding!

SOFTWARE ARCHITECTURE

G. KUBENA

Glenn Kober
Ken Liao

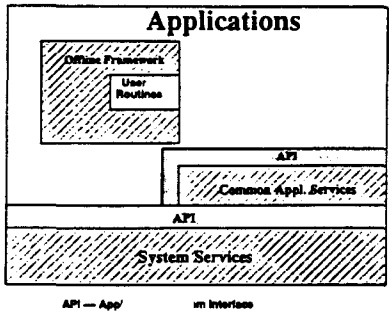
Activities Started

2847

- Software Infrastructure
- Object Oriented Analysis of Problem Domain
  1). Identifying Problem Domain Subjects
  2). Finding Problem Domain Objects
  3). Identifying Structures
  4). Identifying Attributes
  5). Identifying Services

Software Infrastructure

2848



2849

Software Infrastructure Cont'

What:

- **Components**
  - System Services
    1). OS + Real Time Ext. + Security
    2). Network Communication
    3). User Interface
    4). Data Structure Management
    5). Batch Interface
    6). Parallel Processing OS
    7). System Management
  - Common Application Services
    1). Event Selection
    2). Tally System & Histogramming
    3). Experiment Monitoring & Diagnostic

2850

Software Infrastructure Cont'

- **Characteristics**
  - Portable API's
  - Inter–Operability
  - Platform Independent
  - Reusable Libraries

Software Infrastructure Cont'

Why:

- More Common Services (less cost)
- Separation of Concerns
  1). API's Are The Only Visible Part of The Services
  2). Applications Concern Only How To Use The Services
- Isolates Platform Independence & Inter–operability
- Promotes Use of Standards
- Can Support Multi–Language API's (FORTRAN, C, C++, etc)
- Allows Delay of Hardware selection as long as possible
- Less Sensitive to Underlying Hardware Environment (e.g. centralized or distributed architecture. API Services may be local or distributed).

Software Infrastructure Cont'

When:

- Early Because Applications Need Services Underneath.

How:

- Analyze Requirement and Determine Common Components.
- Search For Existing Standard Packages (e.g. COTS)
- Search For Existing Reusable Libraries (cernlib, C++lib, etc.)
- Solicit Contributions

Software Infrastructure Cont'

System Service Component Alternatives:

1). OS: OSF/1 or other POSIX OS
   - Real Time Ext.: POSIX 1003.4 or Custom
   - Security: NCSC C2

2). Network Comm.: OSI TCP/IP, DECnet

3). System Management: OSI/CCITT X.700, POSIX 1003.7

4). User Interface
   - Windows: X–Window
   - Graphics: Data Views, PEX, GKS
   - GUI: MOTIF, OPEN LOOK, SAMMI

5). Data Management
   - Data Base: OODBMS, RDBMS, Custom DBMS
   - Data Storage: IEEE Mass Storage Ref. Model

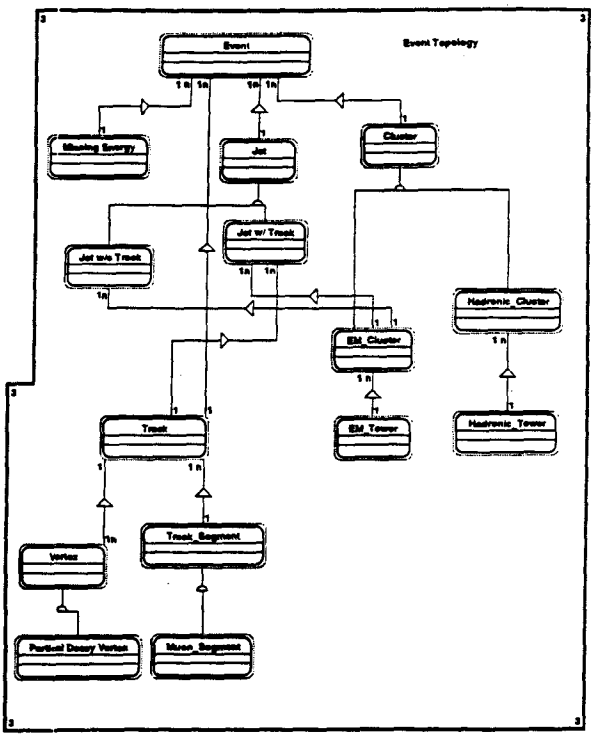
SW Infrastructure Cont'

6). Distributed Environment Support: OSF/DCE

7). Batch Interface: NQS (Network Queuing System)

8). Parallel Processing OS: Custom

2855



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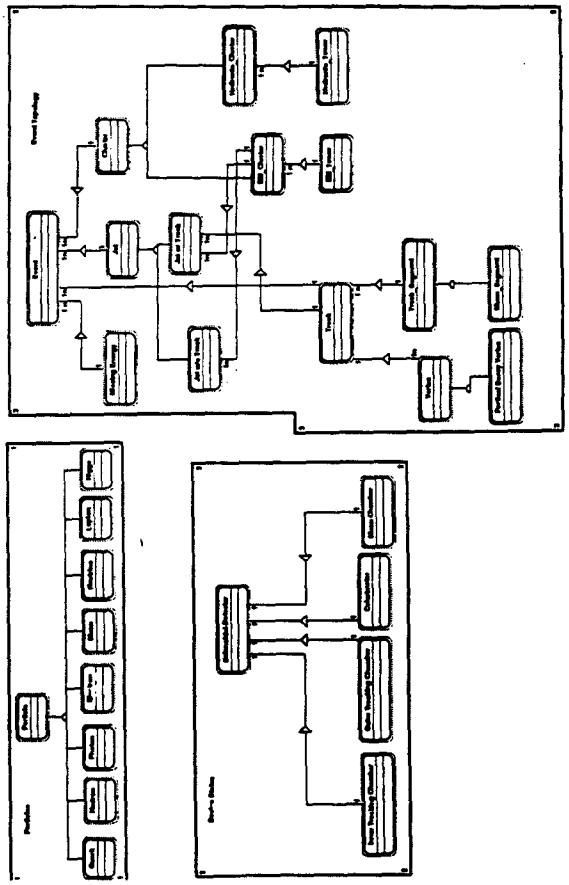


2857

ObjectStore Work

C. T. Day
ICSD/STA
Lawrence Berkeley Lab

2858

ObjectStore Features

- Type (and language) independent persistence *via* distributed persistent virtual memory
- Database object access *via* navigation, *i.e.*, pointers persist and can be followed with no special code
- C++ classes provided to support collections of objects and queries on such collections
- C library access to all ObjectStore features (=> FORTRAN access?)
- C++ class layout automatically stored
  - Detects attempted restructuring
  - Allows for data browser
  - Makes database "self-describing"

2859

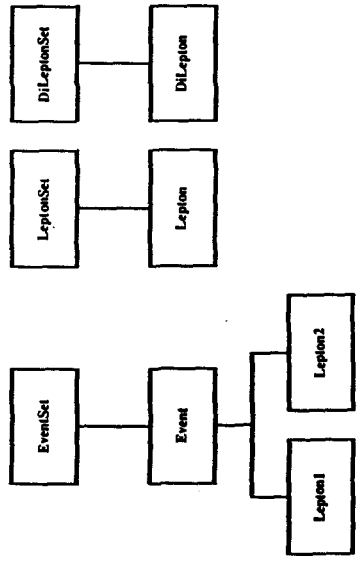
Very Simple Ψ Data

- 7638 events
- ASCII file
- For each event:
  - Run number
  - Event number
  - Z position
- For each lepton in each event:
  - Lepton 4-momentum
  - Charge

3

2860

ObjectStore Classes for VS Ψ Data



2861

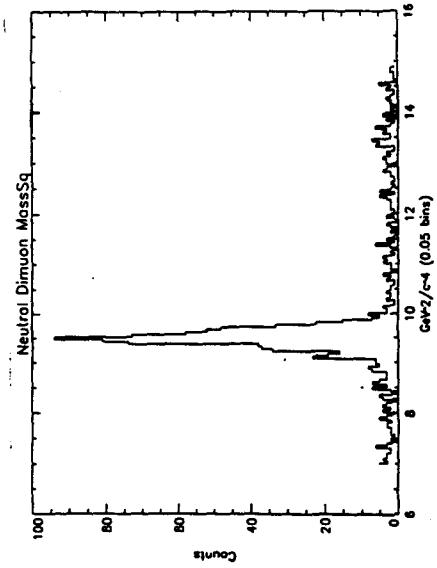
Query Structure

- Select EventSet such that "Lepton1->charge == – Lepton2->charge"
- Create DiLeptonSet from above EventSet
- Select DiLeptonSet such that "7.0 <= massSq && massSq <= 15.0"
- Write out selected massSq's.

5

2862

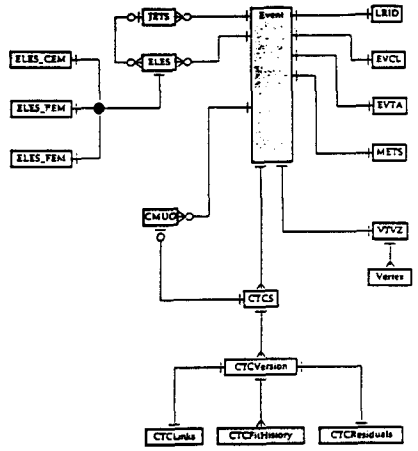
Ψ Plot



6

Real Ψ Data Structure

Event Structure for CDF Psi Events



One A is associated with one B:	A — B
One A is associated with one or more B's:	A — B
One A is associated with zero or one B:	A — B
One A is associated with zero, one, or more B's:	A — B

What's Next

- Install local ObjectStore
- Translate real Ψ and μ data
  - 250 MByte Ψ
  - 1 GByte μ
- Verify I/O gains
- Interactive queries
- Model larger systems
- ...

U.S. Department of Energy
Grant Application Budget Period Summary

Organization: Lawrence Berkeley Laboratory

Period Covering: From October 1, 1991 To September 30, 1992

FOR DOE USE ONLY

Principal Investigator (P.I.)/Project Director (P.D.): Joseph M. Jaklevic, Principal Investigator

	DOE Funded Person-Mos.	Funds Requested By Applicant
1. J. M. Jaklevic, Principal Investigator	1	7,260
2. J. K. Katz, Staff Senior Scientist	2	14,520
3. W. H. Benner, Staff Scientist	6	43,953
4.		
5.		
6. a. TOTAL SENIOR PERSONNEL	9	65,733
6. b. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)		
(1) POST DOCTORAL ASSOCIATES	12	37,616
(2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	3	16,081
(3) GRADUATE STUDENTS		
(4) UNDERGRADUATE STUDENTS		
(5) SECRETARIAL-CLERICAL		3,583
(6) OTHER		
TOTAL SALARIES AND WAGES (A + B)		123,013
7. FRINGE BENEFITS (EXPRESS AS DIRECT COSTS)		27,678
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)		150,691
8. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM)		
Data Acquisition System	6,000	
Time to Amplitude Pulse Height Analyzer	15,000	52,000
Digital Recording Scope	11,000	
Time of Flight Vacuum System	20,000	
TOTAL EQUIPMENT		
9. TRAVEL (a. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)		4,000
b. FOREIGN		2,000
10. OTHER DIRECT COSTS		
a. MATERIALS AND SUPPLIES		45,000
b. PUBLICATION, DOCUMENTATION, COMMUNICATION, NETWORKING COSTS		2,000
c. CONSULTANT SERVICES		
d. COMPUTER (ADPE) SERVICES		
e. SUBCONTRACTS AND SUBGRANTS		
f. OTHER Support Burden 13% of (A1+A2+B+associated part of C)		12,590
TOTAL OTHER DIRECT COSTS		59,590
11. TOTAL DIRECT COSTS (SUM OF ITEMS 1 THROUGH 10)		268,281
12. INDIRECT COSTS (SPECIFY RATE AND BASE)		
TOTAL INDIRECT COSTS 55% of all costs except D (Equipment)		118,955
13. TOTAL DIRECT AND INDIRECT COSTS (9 + 12)		387,236
14. APPLICANT'S COST SHARING (IF ANY)		
15. TOTAL AMOUNT OF THIS REQUEST (ITEM 13 LESS ITEM 14)		387,236

PI/PD TYPED NAME & SIGNATURE: Joseph M. Jaklevic — DATE: August 8, 1991

INST. REP. TYPED NAME & SIGNATURE: Phillip D. Phythian — DATE: August 8, 1991

U.S. Department of Energy
GRANT APPLICATION
PROJECT PERIOD SUMMARY

Categories	01 Budget Period	02 Budget Period	03 Budget Period	04 Budget Period	05 Budget Period
A. Senior Personnel Totals	65,733	69,316	72,796		
B. Other Personnel Totals	57,280	98,825	103,786		
C. Fringe Benefits Totals	27,678	37,664	43,560		
Total of A, B & C	150,691	205,805	220,142	---	
D. Equipment	52,000	54,600	---		
E. Travel 1. Domestic	4,000	4,200	4,410		
2. Foreign	2,000	2,100	2,205		
F. Other Direct Costs	59,590	65,430	72,237		
G. Total Direct Costs	268,281	332,135	298,994		
H. Total Indirect Costs	118,955	152,644	164,467		
I. Total Direct & Indirect Costs	387,236	484,779	463,461	---	
J. Applicant's Cost Sharing (if any)	---	---	---		
K. Total Amount of Request (Item I Less Item J)	(1)* 387,236	(2) 484,779	(3) 463,441	(4)	(5)

* This should equal Item K on Budget Period Summary (ER/F 4620.1)

ESTIMATE

TOTAL COST OF PROJECT

$ 1,335,456

(add K(1) thru (5))

1. WORK PACKAGE NUMBER	2. TASK NO	3. REV NO	4. PROJECT NO	5. DATE PREPARED	6. CONTRACTOR NUMBER
				August 8, 1991	ENG-05

7. TASK TITLE	8. WORK PACKAGE TITLE
Advanced Detectors for Mass Spectrometry	

10. DETAIL ATTACHMENTS

Attachment 20 (c) - Purpose:

A number of applications in the biological sciences exist where the ability to determine the size of large macromolecules using mass spectrometry will contribute significantly to the progress of research. An example is the recent use of matrix assisted laser desorption time-of-flight mass spectrometry to determine the mass of proteins.[1,2] These results have strongly suggested a potential DNA sequencing strategy in which mass spectrometry would replace gel-electrophoresis as the means for determining the length distribution of DNA fragments in Maxam-Gilbert or Sanger sequencing procedures. The potential advantages of such a high throughput DNA sequencing strategy for the Human Genome Project would be enormous. The replacement of gel-based size assessments with mass spectrometry could also impact other areas of mapping and sequencing technology. Examples include the rapid analysis of DNA fragments amplified by the polymerase chain reaction and the mapping of transposon insertion sites in transposon-facilitated DNA sequencing protocols.

The evolution of mass spectrometer design has been driven by the ability to create individual ions and release them into an evacuated measurement chamber. Existing technology has been optimized to function with molecules with charge to mass ratios (m/z) of approximately 1000.[3] Recently, the capability to release large molecules in mass region beyond 100,000 daltons has been successfully demonstrated.[4] The analysis of high-mass, singly-charged proteins has been accomplished using time-of-flight mass spectrometry due to the unlimited mass range of these analyzers. Ions as large as 300,000 daltons have been measured and the potential exists to analyze even larger molecules. The inability to observe ions larger than m/z = 300,000 is probably a consequence of inefficient ion detection, not ion formation. There are data to suggest that the present approach to ion detection is fundamentally limited for large, low-velocity ions. Successful application of mass spectrometry to the analysis of DNA fragments requires that instrumentation capable of efficient operation in the larger size regime be available.

The purpose of the present study is to systematically assess the factors which affect the detection of large molecules and evaluate the potential of alternative methods. The project involves both theoretical and experimental studies directed toward the development of improved and more generally applicable methods than are currently available. The goal of the project is the development of a mass spectrometry capability which addresses the problem of large molecule detection for biological applications. The program will involve a collaborative effort among physicists and engineers at LBL and chemists and biologists at the California Institute of Technology. The LBL experience is focused in the area of instrumentation development with emphasis on problems associated with particle detection in a number of experimental environments. The group at the California Institute of Technology is involved in large scale DNA sequencing of the T-cell receptor in man and mouse and methodology development for DNA sequencing by mass spectrometry.

Attachment 20 (d) - Background:

Mass spectrometry has important potential applications in the measurement of molecular masses relevant to the goals of the Human Genome Project.[5] To the extent that direct instrumental measurements of molecular size could replace gel-electrophoresis as a routine tool for sequencing separations and general molecular biology experimentation, a significant saving in time and accuracy could be effected. In the limit of extremely high mass resolution, direct sequencing by the measurement of individual molecular fragments is feasible. In either case, the use of physical methods of measurements could result in improved potential for automation and computer access to the results.

The successful implementation of a mass spectrometry capability for biological molecules requires that several areas of technology be successfully addressed. These include the ability to ionize and mobilize intact large molecules, the dispersion of the molecules according to mass using electromagnetic separation or time-of-flight (TOF), and the detection of the molecules or fragments in a manner which retains the resolution of the separation process.

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Attachment 20 (d) - Background (cont.):

Recent developments have largely solved the problem of vaporizing large biological molecules and releasing them intact into the dispersive elements of a mass spectrometer. Plasma desorption[6], matrix-assisted laser ablation[7] and electrospray ionization[8] methods have been shown to produce intact molecules up to 220,000 daltons. Magnetic analyzers and time-of-flight systems are then capable of dispersing the fragments according to momentum and energy in order to affect mass separation. Commercial systems based on variants of these approaches are currently available. Preliminary studies performed using existing instrumentation have demonstrated that there are several factors which limit the sensitivity for large fragment identification. Matrix effects can affect the uniformity of the fragment sizes and charge state thereby broadening the m/z distribution. This can degrade the resolution and, to a lesser extent, the sensitivity of the method. Problems associated with these effects can be reduced by appropriate choice of matrix material and ionizing method. However, the current inability to observe ions larger than m/z = 300,000 is determined by a significant reduction in the ion detection efficiency for large molecules. This is a fundamental limitation requiring innovative technology development and is the focus of the proposed activity.

The problem of ion detection can be illustrated with the example of a typical TOF mass measurement. Fragments are released from the matrix with a pulsed laser and accelerated to a final velocity through a fixed potential. After drifting through a flight tube for a fixed distance, molecules are detected and the time-of-flight calculated. The detector used in this procedure must detect a single incident molecule and determine its arrival time to a high degree of precision. The most common type of detector used in mass spectrometers is a channel electron multiplier (CEM) or an array of CEM's called a microchannel plate. Ions with a characteristic velocity determined by the acceleration potential in the mass spectrometer (typically 10 kV) induce the emission of secondary electrons when they strike the CEM surface. This initiates a cascade multiplication of secondary emission resulting in a total signal of 1×10^6 electrons at the output of the detector. The advantages of CEM detectors are their high sensitivity to keV ions and electrons, fast response and recovery time, and compact size. Disadvantages of CEM's are that they are somewhat fragile with respect to physical damage and contamination, degrade with time, are costly, and, most fundamentally, are of uncertain utility for detecting large ions such as large DNA fragments.[9]

The limitation of CEM devices for large molecule detection can be shown to be primarily determined by the limited velocity of the incident ions. Analysis of mass spectrometry measurements of measurements by Fenn et al.[3] using an electrospray ionization source for the analysis of polyethylene glycol, indicates that the maximum detectable mass corresponds to a velocity of the molecule incident on the detector of 2.4×10^6 cm/sec. Laser desorption measurements on DNA fragments indicate a similar velocity limit for the maximum molecular size determined.[10] Beuhler et al.[11,12] have performed direct measurements of the yield of secondary electrons from copper and aluminum surfaces bombarded with water clusters. They established a threshold for secondary electron emission of approximately 1.8×10^6 cm/sec. Although there is some variation observed in the threshold velocity for secondary electron emission due to particle mass effects[13], the basic idea of a threshold for emission remains a consistent experimental observation.

The existence of a lower threshold for secondary electron emission is easily understood in terms of a simple classical analysis of the maximum energy transfer which can occur between a massive incident projectile and a stationary, light target particle. The maximum energy transfer occurs in an interaction in which the target particle acquires a final velocity equal to that of the incident, massive projectile. For the atoms in a large molecular cluster with velocities in the range of 1×10^6 cm/sec, the maximum energy transferred to a stationary electron is of the order of 1 eV which is about the energy required for secondary electron emission from a surface. Extension of this argument to alternative detection schemes shows that any methods which depend upon ionization or optical excitation processes suffer from similar limitations.

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Attachment 20 (d) - Background (cont.):

The existence of a fundamental velocity threshold for the operation of CEM devices easily explains the rolloff in efficiency of existing mass spectrometry measurements. For a moderate sized singly ionized molecule of 1000 daltons accelerated through the 10 kV potential difference, as normally used in commercial mass spectrometers, a velocity of 4.4×10^5 cm/sec is achieved. However, for 100,000 daltons and an acceleration potential of 10 kV, the velocity is only 4.4×10^5 cm/sec—well below the measured threshold for secondary electron emission. Although multiple ionization of the molecules in an approach to increasing this velocity with a fixed acceleration potential, there are limits to the magnitude and reproducibility which this approach can achieve. The brute-force approach of increasing the velocity by increasing the acceleration voltage is also limited to a factor of 3 at most by high voltage engineering considerations. One approach used by Tanaka[1] and Spangler[14] which avoids this limit involves the conversion of the primary macromolecule into lower mass secondary species produced by ion bombardment of a surface. This process of secondary ion formation or sputtering is the result of the collisions between the primary ion and the atoms on the surface of the material, causing the atoms on the surface to be released as ions. These secondary ions are then accelerated and used to produce tertiary electron emission in a conventional microchannel plate detector. Although successful in detecting molecules with masses up to 100,000 daltons, it is not clear how efficient this approach is or what its effect would be on time-of-flight methods in which time dispersion of the tertiary electron forming process may be a limiting factor.

The extension of the mass spectrometry to a m/z range where DNA sequencing and related applications become practical requires that limitations in detector performance be reduced. This requires a research and development program focused on the issue of macromolecule detection. A goal of the project will be a practical, cost effective detection system compatible with mass spectrometry in the region of 660,000 daltons or greater corresponding to 1000 base pairs of DNA. This goal is best addressed in an interdisciplinary program involving chemists, biologists, physicists and engineers familiar with the problems and experienced in the design of practical instruments.

Attachment 20 (e) - Approach:

The systematic study of large molecule detectors will consist of activities in several related areas. We will evaluate the capabilities of existing methods and explore methods whereby the range of applicability can be extended. A parallel investigation into the basic parameters which describe the interaction of large molecules with detection surfaces will be undertaken to elucidate fundamental processes which limit the various methods of large ion detection. We plan to first extend the existing secondary emission approach as far as practical while at the same time exploring innovative approaches which offer the promise of dramatic improvement.

The initial approach for evaluating detectors will emphasize the use of laboratory generated submicron particles as surrogates for large biological molecules. This approach has the advantage of providing reproducible, monodisperse particle size distributions for easier control of experimental variables. A laboratory laser desorption system will be constructed and evaluated for use in TOF measurements of the test particles and for use in preliminary studies of biological molecules. The overall approach will emphasize a combined theoretical and experimental approach that builds upon available studies in the literature where possible. Based on the results of these studies, we will develop improved detection systems using either extensions of the existing technology or adaptations of improved techniques if applicable.

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Attachment 20 (e) - Approach (cont.):

Because of the magnetic rigidity of extremely heavy ions such as m/z ≥ 10,000, it is unlikely that mass spectrometry based solely on electromagnetic focusing will be important for biological mass spectrometry in the size range of interest. For this reason our approach focuses on detection of ions in time-of-flight mass spectrometry. This places important constraints on the detection method, namely, the ability to measure the arrival of individual molecules with a time resolution that is small compared to the total flight time. Due to the lack of strong focusing optics in TOF spectrometers, the active area of the detector must also be sufficient to provide an adequate solid angle. These constraints have dictated the choice of secondary electron emission with microchannel plates and are the reason its adaptation for large molecules is an approach which must be seriously explored. Although the emphasis will be on time-of-flight detectors, the basic concepts developed in the study will be applicable to alternative spectrometer designs.

The first effort will be directed toward the study of factors which limit the use of microchannel plate detectors or, more fundamentally, the secondary emission process for electrons. Earlier published results will be duplicated and the results extended to include larger mass particles. The question of secondary emission of ions from surfaces will also be systematically evaluated. In particular, there exists a considerable volume of literature related to the secondary emission of ions from various materials under varied bombardment conditions.[15] This information will be used to guide our experimental studies into optimization of the material, incident ion velocity, and post acceleration conditions required for large molecule detection.

In order to study these fundamental properties in a cost effective manner, we propose to develop a test apparatus capable of accelerating particles or ions in the size range of interest and directing them into a target chamber where measurements can be made. We currently have available in our laboratory a capability to generate small particles that could be used as surrogates for large biological molecules with respect to their interaction with detector surfaces.[16] The use of this facility simplifies testing procedures by allowing the detector testing and development to be separated from problems associated with the generation of a beam of micro-ions in a vacuum. The use of surrogate particles of known composition and controllable size distributions eliminates much of the potential unreliability and irreproducibility associated with the generation of complex biological molecules for detector testing experiments. Test particles of polystyrene latex are available in diameters as small as 0.02 microns and colloidal gold particles as small as 0.001 microns can be commercially obtained. For comparison, a 10^4 base-pair DNA fragment, when collapsed into a dry individual particle, is about 0.02 microns in diameter.

Previous experiences allow us to suspend the test particles in a solute free liquid which is then nebulized to produce droplets of the suspension that contain single test particles. The droplets are subsequently evaporated to leave a dry test particle suspended in air. Using an electrostatic classifier, particles of a known charge will be selected and introduced into a vacuum system via a differentially-pumped capillary skimmer system. A particle charge between 1 and about 100 can be selected by this procedure. The differentially-pumped capillary skimmer will produce a beam of particles which can be directed towards a detector or surface that is undergoing testing. The charged particles can also be accelerated to higher voltages by directing them through a high voltage accelerator column. One of the advantages in using the current system is the ability to accommodate acceleration potentials as high as 150 kV, thereby extending the range of testing well beyond the 10 kV normally available in mass spectrometers.

Experiments performed with this apparatus using test particles and commercially available ion detectors will elucidate the basic properties of secondary electron and ion emission processes. This will enable us to extend the use of this approach to the maximum degree allowed by engineering considerations such as maximum high voltage ratings and particle charge. A prototype detection system based on either high voltage ion acceleration, secondary ion emission, or a combination of both will then be designed, evaluated, and made available for mass spectrometry applications as soon as possible.

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Attachment 20 (e) - Approach (cont.):

In order that the results of these developments be extended to biological systems in an efficient manner, we will also design and test a laser desorption time-of-flight system capable of accommodating the prototype detectors. Many of the vacuum hardware components for such a system are already available. To the extent that this facility successfully demonstrates improvements over existing commercial systems, it will be used in our collaborative effort to develop improved techniques for mass spectrometry of DNA as soon as possible.

Regardless of the success of this phase of the study, it is likely that extension of the detectable mass range beyond that achieved with this "brute force" approach will be desirable. For this reason, we propose to carry out parallel studies on alternative detection schemes which are not limited by secondary ion or electron emission processes. These schemes would be based on mechanisms of interaction between the incident ion and detector which do not depend upon ionization processes. It quickly becomes obvious that, if an incident particle is below the threshold for ionization of loosely bound electrons, the only alternative mode of energy loss is related to the generation of phonons in a solid target. This requires that detection methods which are capable of measuring the minute increase in thermal energy in the detecting medium are necessary. We propose to explore such alternatives as part of a longer term research program.

Our preliminary studies indicate that there are at least four possible detection methods which are worthy of consideration. These are semiconductor diode detectors, low-temperature bolometric devices, thin-film detectors, and systems based on photothermal methods of heat sensing. Although detailed investigation of each may indicate limitations which preclude their use for large molecule detection, preliminary research directed toward evaluation is justified.

Semiconductor diodes are devices commonly used for the detection of ionizing radiation. Energetic charged particles incident on a volume of semiconducting material depleted of free charge carriers will generate free electron-hole pairs which are then collected in an applied field to create a charge signal indicative of the energy of the individual incident particle. Such devices are characterized by low noise and timing characteristics adequate for time-of-flight mass spectrometry. Their utility as detectors for massive ions is questionable even though they possess some desirable properties. The electronic noise for a typical system can be well below 1 keV compared to 10 to 100 keV incident ion energy. However, like the secondary emission process, the creation of electron-hole pairs is also dependent upon ion velocities above a certain threshold. Semiconductor diodes do have the additional property that carriers can be thermally generated if the local temperature is sufficiently high. Since the linear dimensions of a typical molecular cluster is of the order of 0.02 microns and it has a negligible range of penetration into a semiconductor, there exists a period of time in which a local region of the semiconducting material is raised to a temperature at which electron-hole pairs can be thermally excited.[17] These free charge carriers can then be collected in an applied electric field detector to produce an electronic pulse in a manner identical to conventional radiation detectors.

Preliminary calculations of temperature profiles using a theory of temperature spikes in semiconductors and realistic values of incident energy and particle mass indicate that the time interval over which the temperature exceeds a value at which thermal ionization is possible is of the order of 10^{-12} secs.[17] Whether the free carriers can be separated and collected in an applied field during this short interval is a matter for conjecture. However, the model used in the calculations may be overly pessimistic from the point of view of charge collection because of the extreme non-equilibrium conditions which occur during this initial interval. It is also not clear that the incident particle will efficiently deposit its full kinetic energy into the semiconducting medium.

Because of these theoretical uncertainties, the most straightforward experimental approach will be to perform a simple experiment using a silicon surface barrier or diffused junction detector in conjunction with the particle accelerator described above. We have such detectors readily available as part of our existing semiconductor detector research programs. A simple series of measurements would determine the response of a semiconductor diode under various conditions and indicate whether other effects such as materials damage would become a serious limitation in practical applications. Based on these studies, a serious attempt to design an appropriate detector may or may not proceed.

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Attachment 20 (e) - Approach (cont.):

Another direct approach to the detection of small amounts of energy without reference to ionization processes involves the use of cryogenic detectors.[18] In these devices, the lower limit for the detection of particles is determined by the energies associated with quantum thermal excitations instead of ionization thresholds. More simply stated, these devices measure directly thermal energy without requiring intermediate processes such as ionization or electron-hole generation.

There are a number of methods by which such detectors can be implemented. The most straightforward from the point of view of the present application is a low-temperature bolometric detector. In these devices, one measures the transient temperature rise in a cryogenically cooled sensor. Because the heat capacity of materials at low temperature scales as T^3 where T is the absolute temperature, a small addition of energy to the system is reflected in a large increase in temperature. A thermistor can be used to sense this increase. Small volume (<1 mm^3) prototype devices based on this principle have demonstrated an energy resolution below 50 eV for nuclear particle detection.[19] Larger volume devices would exhibit reduced resolution. However, since the available energy from large ion acceleration in mass spectrometry is of the order 10 to 100 keV, there should be no limitations due to sensitivity. The use of direct temperature measurements for particle detection does introduce limitations associated with the characteristic thermal time constant of the detection process. Rise times of a few microseconds have been observed in the prototype devices.

If the timing resolution associated with the detection process becomes a limiting factor, there are alternative cryogenic detection schemes that could be explored. One additional possibility worthy of mention is a low-temperature dielectric microcalorimeter. This device takes advantage of the strong temperature dependence of the dielectric constant of certain ferroelectric materials. A small change in temperature can be made to induce a measurable change in the voltage applied across a capacitor due to the change in dielectric constant. Although the device as described requires operation at cryogenic temperatures, there are indications that it exhibits a measurable response at more elevated temperatures including ambient.[20]

Although the development of cryogenic detectors represents a significant departure from the technology currently available for mass spectrometer detectors, our research activities in this area will rely heavily on research that is already underway in other projects. Much of the current research in cryogenic detectors is directed towards use in particle astrophysics where a number of significant advances have already been achieved. Our work in this area will consist mainly of adapting the concepts and designs of detectors to the mass spectrometry problem. We are fortunate in that one of the more innovative efforts in the development of cryogenic detectors involves a collaboration between physicists and engineers at LBL and at Lawrence Livermore National Laboratory who are also closely associated with members of our Genome Instrumentation Group. We have discussed the technical issues with them and anticipate the possibility of a closer association as the project may require.

Finally, there are a number of other possible detection approaches which are feasible and which may be included as significant activities at a later time depending on the success or failure of the earlier developments. Other methods which are potentially applicable to particle detection include measurements of thermal expansion, thin membrane displacement, and piezoelectric effects on thin films. These approaches will undergo preliminary evaluation during the early stages of the program. Some, like photoacoustic spectroscopy for thermal expansion, are relatively well-developed fields and could be readily implemented if found applicable. Others are less known but are currently undergoing active investigation for other purposes and results could be adapted from these studies.

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Attachment 20 (g) - Future Accomplishments:

The first year of the study will emphasize the development of hardware necessary for generating surrogate particles for detector testing and the evaluation of the more straightforward detector concepts. These would include measurements of velocity vs. yield curves for secondary electron emission using a conventional microchannel plate detector. In addition, secondary ion yield measurements will be performed on a variety of surfaces which are indicated in the literature as potential secondary ion converters. It is presumed that a workable, improved secondary ion detector will be available at the end of this portion of the study.

The evaluation of semiconductor diodes as potential detectors involves measurements which are straightforward once the particle source is available. Assuming that the concept of semiconductor diode detection is practical, the implementation of a usable device should occur quickly because the technology is well developed at our laboratory and readily available.

We will also explore collaborative studies in the area of cryogenic detectors with researchers at LBL and elsewhere who are expert in their use. Theoretical predictions of the performance of such devices as large molecule detectors can be generated using currently available knowledge. Experimental implementation of practical detectors will be a longer term effort although it is possible that existing detectors could be adapted for testing in the particle accelerator with minimum modifications. In this case experimental measurements will be included in the study.

Alternative methods of particle detection will continue to be an active area of discussion and evaluation. The realization of practical devices will again depend upon assessments of feasibility based on theoretical and experimental studies.

Attachment 20 (h) - Relationship to Other Projects:

The project will be conducted in association with the LBL Human Genome Center. In addition, there exist a number of particle detector research and development programs at LBL which perform work related to the activities in this proposal. These include semiconductor detectors for synchrotron applications and detector research directed toward the needs of particle astrophysics.

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FIELD TASK PROPOSAL/AGREEMENT
DETAIL ATTACHMENTS

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Budget Justifications:

Personnel

Principal Investigator, J. Jaklevic, 1.0 work months
The responsibility of the principal investigator is to establish research direction, coordinate the work of the group, and provide the initial interface for the collaborative interaction with the CalTech group. In addition, he will contribute technically in areas where he is most experienced.

Co-principal Investigator, J. Katz, 2.0 work months
As the most knowledgeable and experienced individual in the area of detector readout and data processing electronics, he will be responsible for advising on these areas of activities and coordinating design and fabrication projects related to detector electronics.

Co-principal Investigator, H. Benner, 6.0 work months
The most active individual in terms of carrying out the day-to-day research and development efforts. His experience in the area of aerosol generation and detection will be directly applicable to the early stages of evaluation using surrogate particles. He will also be responsible for directing the design and evaluation of most of the experimental hardware.

Post-doc, full time
The success of the project will depend upon a close interaction between those involved in hardware design and evaluation directed toward detector development and those involved in applying the method to biological systems. We propose to recruit a post-doc (staff scientist level 1 in later stages) in order to carry out those phases of the experimentation directly concerned with mass spectroscopy of biological molecules. It is anticipated that this individual would be deeply involved in the collaborative interactions with the CalTech group and would develop many of the biological applications as the technology matured.

Scientific Technician, 3.0 work months
We have available a number of experienced electronics/mechanical technicians in the instrumentation group. They will perform major roles in facilitating and tuning much of the experimental hardware.

Equipment

The first year request is 52K$ to acquire specialized equipment to initiate the studies. Items include a high-speed data acquisition system, time-to-amplitude converter with pulse height analysis for TOF measurements, a digital recording scope for recording transient detector events, and mechanical hardware with which to construct a TOF test stand. Much of the vacuum hardware and routine test equipment for particle generation is available as part of continuing projects in the group. The following year, we are requesting equipment with which to fabricate a dedicated TOF spectrometer based on the detector technology developed during the initial period.

Travel

For each year of the project we anticipate 6 trips between LBL and CalTech, 2 domestic trips to conferences and workshops, 1 domestic vendor trip and 1 foreign trip.

CENTER FOR MOLECULAR BIOTECHNOLOGY
AN NSF SCIENCE AND TECHNOLOGY CENTER

August 7, 1991

Dr. Joseph M. Jaklevic
Mailstop 70A03363
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Dear Joe:

This is a letter to acknowledge the formal collaboration that I have with Dr. Joe M. Jaklevic in support of the the LBL proposal in the area of developing detectors for large ions for application in mass spectrometry. At Caltech we have an active research and development program which is applying mass spectrometry to DNA sequencing. This instrumentation advance could be a critical asset of our exploitation of the time of flight instrument for DNA sequencing. We have on our staff Drs. John Yates, Patrick Griffin, and Graeme Currie who are all versed in the areas of mass spectrometry as applied to biological macromolecules. Indeed, Dr. Currie has performed preliminary studies with the Finnigan time of flight instrument that demonstrate DNA fragments ranging from 7 mrs to 49 mrs can be readily visualized. Clearly, one of the key advances that must be made if this technology is to become feasible is to develop detectors that have appropriate sensitivity and indeed this is exactly what our collaboration with LBL hopes to do. I would say this is one of the real opportunities for technology development in the area of mass spectrometry as applied to DNA sequencing.

I have the greatest respect for Dr. Joseph Jaklevic. I look forward to our collaboration with the LBL group. We anticipate that our existing expertise in the area of DNA sequencing and mass spectrometry of large biological molecules will be complementary to their experience in the areas of instrumentation and technological development. We are looking forward to the immediate application of any advances to fundamental biological problems concerned with the genome initiative.

Sincerely yours,

Leroy Hood

Leroy Hood
Bowles Professor Biology and
Director, NSF Science and Technology
Center for Molecular Biotechnology

CALIFORNIA INSTITUTE OF TECHNOLOGY
Division of Biology 139-74, Pasadena, CA 91125
Telephone (818) 397-2765 o Fax (818) 793-6527

CURRICULUM VITAE

JOSEPH M. JAKLEVIC

Occupation: Physicist, Staff Senior Scientist II
Department Head, Engineering Science Department
Lawrence Berkeley Laboratory
University of California

Education:
College: Rockhurst College, Kansas City, Missouri
A.B. Physics 1962.
University: University of Notre Dame, Notre Dame, Indiana
Ph.D. Nuclear Physics 1966.

Professional Societies: American Association for the Advancement of Science
American Physical Society
Materials Research Society

Professional Experience:

1977 to date	Staff Senior Scientist, Section Leader, Electronics Engineering Department, Lawrence Berkeley Laboratory, Berkeley, California.
1969 to 1977	Physicist, Lawrence Berkeley Laboratory, Berkeley, California.
1967 to 1969	Post-Doctoral Physicist, Lawrence Berkeley Laboratory, Berkeley, California.
1966 to 1967	Post-Doctoral Physicist, University of Notre Dame, Notre Dame, Indiana.

3/21/91

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7/30/91

2881

CURRICULUM VITAE

Joseph E. Katz - Senior Scientist/Engineer II
Group Leader and Deputy Section Head
Lawrence Berkeley Laboratory

Education

B.S. Electrical Engineering, 1957, Cum Laude
City College of New York, New York, NY

M.S. Electrical Engineering and Computer Science, 1967
University of California, Berkeley, CA

Professional Societies

IEEE Nuclear and Plasma Science
IEEE Computer Society

Professional Experience

1977 to date	Senior Scientist/Engineer II Group Leader and Deputy Section Head General Systems Section Engineering Division Lawrence Berkeley Laboratory Berkeley, CA
1963 to 1977	Staff Scientist/Engineer Electronics Engineering Department Engineering Division Lawrence Berkeley Laboratory Berkeley, CA
1962 to 1963	Physicist M.H.D. Research, Inc. Newport Beach, CA
1957 to 1962	Electronics Engineer Lawrence Livermore National Laboratory Livermore, CA

Revised 3/20/91

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1. M.F. Maestre and J.E. Katz, "A Circular Dichroism Microspectrophotometer," *Biopolymers International Journal of Research on Biological Macromolecules* 21, 1899-1908 (1982).
2. J.E. Katz, P.W. Davies, J.E. Crowell and G.A. Somorjai, "Design and Construction of High Stability, Low-Noise Power Supply for use with High Resolution Electron Energy Loss Spectrometers," *Rev. Sci. Instrum.* 53(8) (1982).
3. M.H. Katz, J.T. Nichols, F. McLarnon, E.J. Cairns and J.E. Katz, "Computer-Controlled Multiple-Channel System for Electrochemical Experiments," *Journal of Power Sources* 10(2), 149-165 (1985).
4. J.E. Katz, S. Wells, D. Ussery, C. Bustamante and M.F. Maestre, "Design and Construction of a Circular Intensity Differential Scattering Instrument," *Rev. Sci. Instrum.* 55(10), 1574-1579.
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6. D.F. Ogletree, J.E. Katz and G.A. Somorjai, "Low Energy Electron Diffraction and Counting Techniques," poster paper presented at Northern California Amer. Vacuum Soc. meeting, UC Berkeley Campus (December 1985).
7. J.J. Barton, S.W. Robey, C.C. Bahr, J.E. Katz, Ji-Ren Lou, Z. Hussain and D.A. Shirley, "A Time-of-Flight, Angle-Resolved, Paraboloidal Mirror Electron Energy Analyzer," poster paper presented at Amer. Phys. Soc. meeting (March 1986).
8. D.F. Ogletree, J.E. Katz and G.A. Somorjai, "A New System for LEED Intensity Measurements using a Real-Time Digital Video Processor," *Rev. Sci. Instrum.* 57(12), 3012 (1986).
9. M. Nakamura, J.E. Katz and A.C. Thompson, "A Multi-Channel, High Linearity Current Digitizer for Digital Subtraction Angiography," *IEEE Trans. Nucl. Sci.* (1987).
10. T.B. Beebe Jr., T.E. Wilson, D.F. Ogletree, J.E. Katz, R. Balhorn, M.B. Salmeron and W.J. Siekhaus, "Direct Observation of Native DNA Structures with the Scanning Tunneling Microscope," *Science* 243, 370-372 (1989).
11. W.F. Kolbe, J.E. Katz, S.E. Lewis and J.M. Jaklevic, "Experimental Apparatus for Pulsed Field Electrophoresis Research," poster presented USDOE Human Genome Program Contractor/Grantee Workshop, Santa Fe, NM (November 1989). LBL-28032.

Revised 3/20/91

DATABASE COMPUTING FOR THE SSC

2883

L. E. Price

Data Handling Problem

- 100 - 1000 TB/yr
- Up to 10^4 times the data handling of CDF
- Probably breaks the present model of repeated serial passes over the data
- "Harder" problem than cpu requirement of $n \times 10^5$ MIPS

2884

Database approach to data handling

- Take advantage of extensive development in academic and commercial computing sectors
- Technology emphasizes random access to data and responsiveness to interactive queries
- Use of indices and keys for fast access to a subset of events
- Ability to read into a computer only the data from a given event that will actually be used
- Flexible creation of individualized views of the data replaces successive writing of micro-DST's
- Appropriate query language reduces programming effort
- Linked tables allow frequently-used data to be kept locally, while full data for an event is available at a central archive

2885

High Performance Computing and Communication Initiative (HPCC)

- Presidential initiative starting in FY 1992
- Extend US technological leadership in high performance computing and computer communications
- Provide wide dissemination and application of technologies
- Spur gains in US productivity and competitiveness
- Components
  - High performance computing systems
  - Advanced software technology and algorithms
  - National Research and Education Network
  - Basic research and human resources

2886

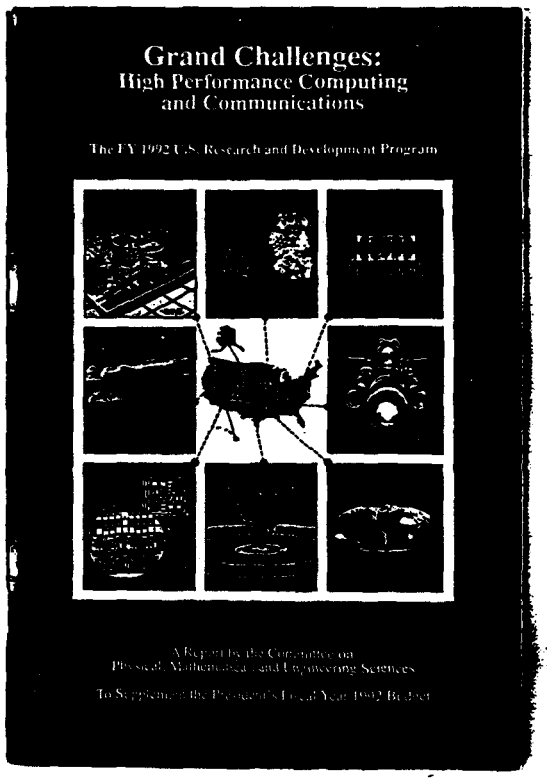


Figure 1 **The High Performance Computing and Communications Program**

Goals: Strategic Priorities

Extend U.S. technological leadership in high performance computing and computer communications.

Provide wide dissemination and application of the technologies both to speed the pace of innovation and to serve the national economy, national security, education, and the global environment.

Spur gains in U.S. productivity and industrial competitiveness by making high performance computing and networking technologies an integral part of the design and production process.

Strategy: Integrating Priorities

Support solutions to important scientific and technical challenges through a vigorous R&D effort.

Reduce the uncertainties to industry for R&D and use of this technology through increased cooperation between government, industry, and universities and by the continued use of government and government-funded facilities as a prototype user for early commercial HPCC products.

Support the underlying research, network, and computational infrastructures on which U.S. high performance computing technology is based.

Support the U.S. human resource base to meet the needs of industry, universities, and government.

Program Components

High Performance Computing Systems
- Research for Future Generations of Computing Systems
- System Design Tools
- Advanced Prototype Systems
- Evaluation of Early Systems

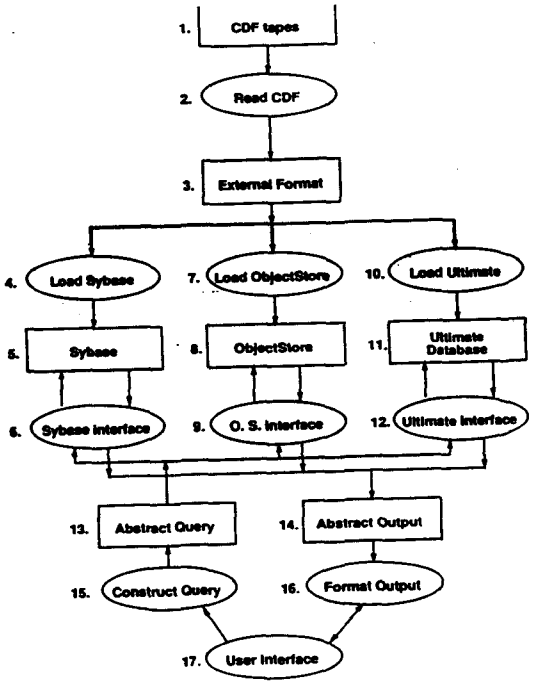
Advanced Software Technology and Algorithms
- Software Support for Grand Challenges
- Software Components and Tools
- Computational Techniques
- High Performance Computing Research Centers

National Research and Education Network
- Interagency Interim NREN
- Gigabits Research and Development

Basic Research and Human Resources
- Basic Research
- Research Participation and Training
- Infrastructure
- Education, Training, and Curriculum

SDC/HPCC Project

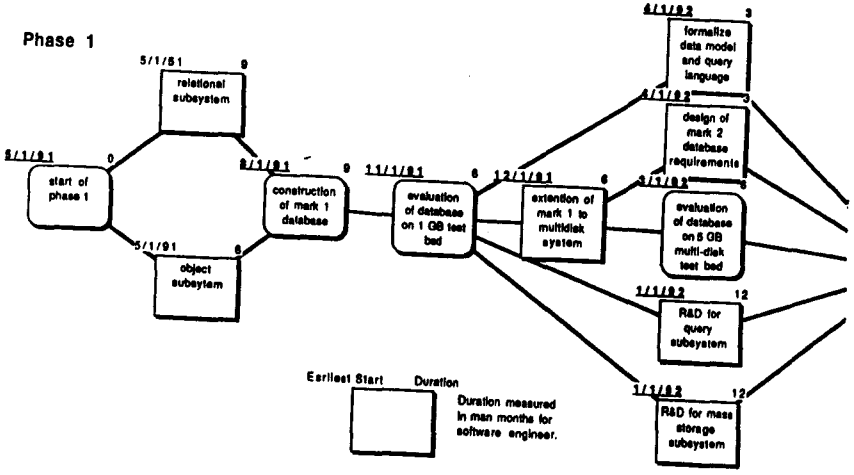
- Argonne, LBL, U. Maryland, UIC, SSCL
- FY 1991
  - Construct a demonstration database for HEP data, using existing collider data, on a single computer and single disk.
    - a) Relational (Sybase)
    - b) Object Oriented (Object Store)
  - Up to 1 GB of data
  - Implement example queries
  - Performance measurements on demonstration systems.
  - Analyze and evaluate initial experience with the two database approaches
    - Performance
    - Large data samples
    - Queries
    - Access methods



- Phase 1 (1992-1993)
  - Proof of concept
  - Up to 5 GB data on multiple disk volumes
  - Develop full data model
  - Query model and language
  - Extensive performance analysis to plan future directions
- Phase 2 (1993-1994)
  - Experimental prototype data system
  - Demonstrate critical technologies for full scale system
  - mass storage manager
  - object manager
  - Query manager
  - Analysis manager
  - Up to 1 TB on multiple distributed computers

- Phase 3 (1995-1996)
  - Working Prototype
  - Ready to migrate to production system
  - 10-100 TB database
  - Full performance and functionality analysis
  - Plan for migration to production system

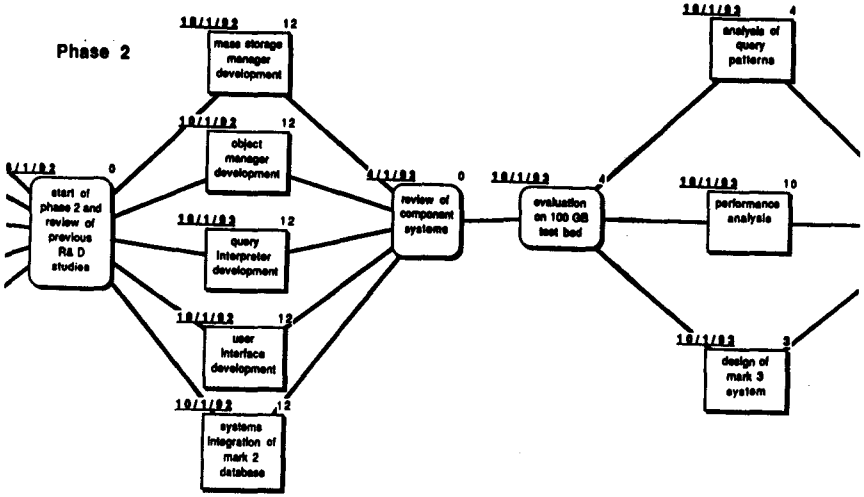
Phase 1



The goal of Phase 1 is to demonstrate a proof of concept for a database computing approach to the analysis of HEP data.

Database Computing Project
draft of June 3, 1991
revised June 7, 1991
R. Grossman

Phase 2



The goal of Phase 2 is to build an experimental protoype (the Mark 2 database), demonstrating the critical technologies required to build a full scale system.

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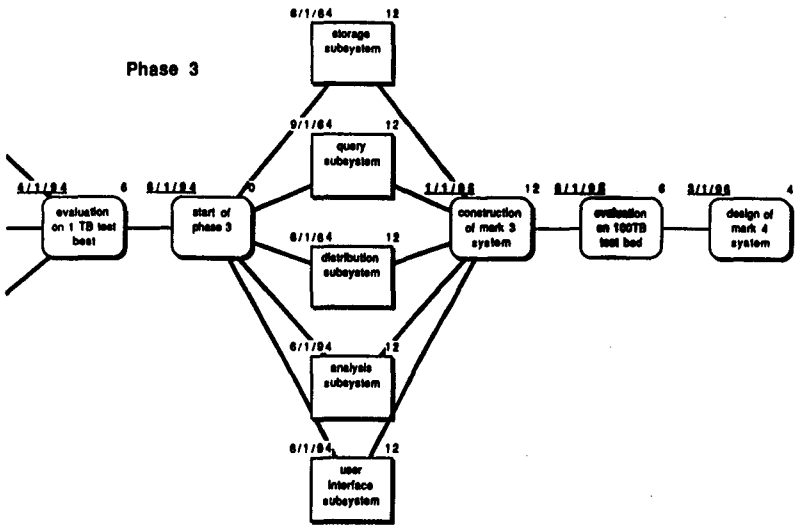
Phase 3



The goal of Phase 3 is to build an working prototype (the Mark 3 database), that can be migrated into a full scale production system (the Mark 4 database).

Database Computing Project
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revised June 7, 1991
R. Grossman

Demonstration Database - Sybase

2895

- Simple summary file of dimuon data put into simple Sybase tables - 13 columns
- Use of Sybase tools
  - ISQL Command line SQL
  - DWB Data Workbench interface VT100 + X11

  SQL Scripts to query database and format results

  Derived tables created and queried
  - 2 μ 4-vectors
  - 2 μ mass

  Lists of data prepared for histo display

2896

DATABASE PROJECT DEMONSTRATION

L. E. Price, July 17, 1991

1 GB CDF file in Object Store and Sybase
Entity Relationships
Outline of HEP query language
- Compare FORTRAN and query language

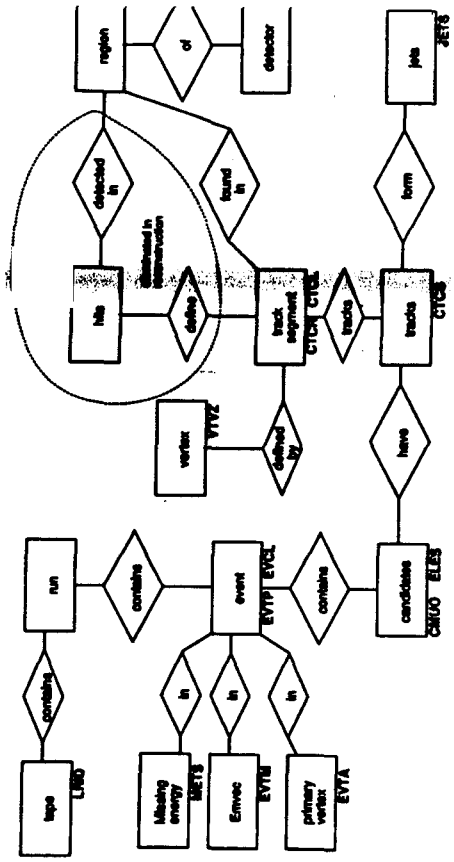
Example queries implemented
Rudimentary but suggestive user interface
- A few Reason-like aspects
  - Rebin on fly with variable histo parameters
  - Vary cuts on fly
    - Point to cuts on one (or more) histo while watching effect on other
  - Highlight region on one (or more) histo and see selected part of other histos
  - Call for variable cut in query language?

Set up direct comparisons with PAW
Demonstrate specific database aspects
- Read only what is needed from disk
- Indices and access methods

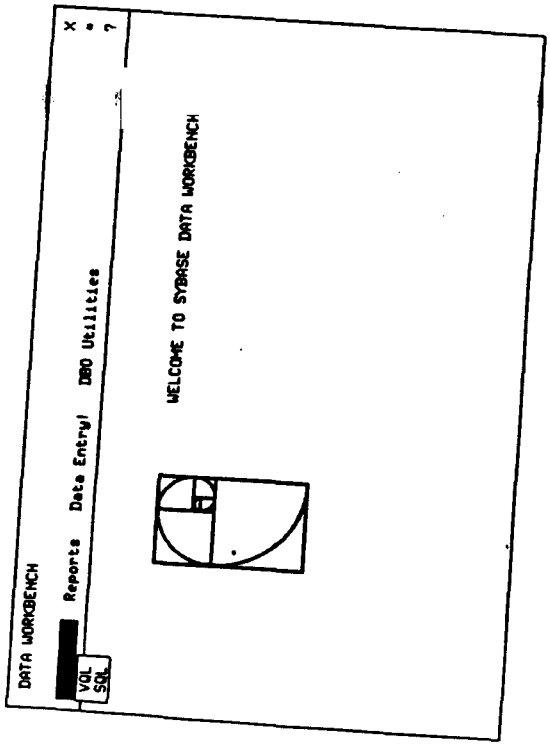
Demonstration:
- Run analysis with
  - Cuts on a few quantities
  - Calculation of new quantities
  - Histogramming of several quantities
  - Interactive manipulation of cuts and histograms

Point of demonstration:
- Speed of analysis based on indexing (?)
- Ease of expressing analysis process
- Interactive twiddling for optimization
- ...Compared with FORTRAN analysis + PAW on whole data sample

2897



2898



DATA WORKBENCH

SQL

Recall Command Save Command Edit

Display Results
Print Results
Save Results ->

```
/* this is psi2.3.sql */
use psi2
/* Get an order set ready for histogramming */
select m from two_particle_mass where m > 80. order by m asc
```

2901

DATA WORKBENCH

SQL

Run Command Recall Command Save Command Edit

```
use psi2
select count(*) from dimuons2
select run_number, event_number, e=lepton_1_energy+lepton_2_energy,
pz=p1z+p2z, py=p1y+p2y, px=p1x+p2x
into two_particle_4v from dimuons2 where charge_1+charge_2=0
select count(*) from two_particle_4v
select run_number, event_number, m=sqrt(e*e-pz*pz-py*py-px*px)
into two_particle_mass from two_particle_4v
select run_number, m from two_particle_mass where m > 70 order by m asc
```

2899

DATA WORKBENCH

SQL

DISPLAY RESULTS

Format! Next Results! Rerun! System Format!

run_number	m
20484	70.54
20484	77.60
19882	79.64
19367	81.47
19883	81.82
19970	83.82
20514	84.26
18743	84.98
19604	85.44
19220	86.76
19404	87.31
20502	88.16
19575	89.02
20355	89.83
19153	90.24
19294	90.31
19153	90.39
19441	90.86
19152	91.89
20052	91.92

2902

DATA WORKBENCH

SQL

DISPLAY RESULTS

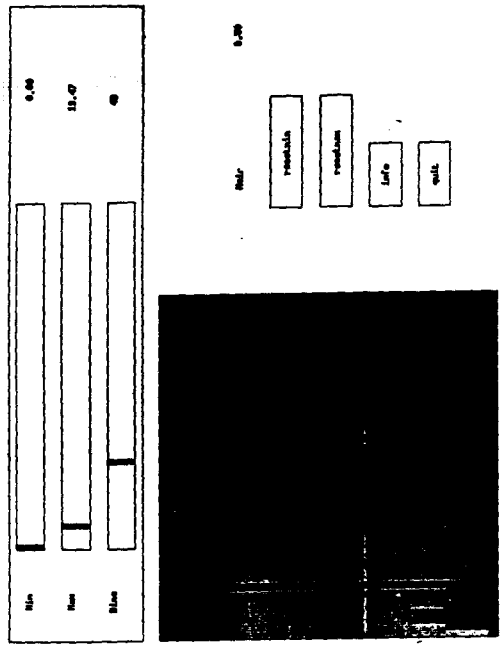
Format! Next Results! Rerun! System Format!

run_number	event_number	z_coordinate	lepton_1_energy
20498	96	-37.57	6.68
20501	34	0.89	3.56
19441	59	-10.77	4.05
26949	31	0.45	3.78
19102	86	13.31	3.14
19213	63	1.04	4.78
19225	77	-2.55	3.50
19116	89	28.72	4.79
19250	54	13.81	4.42
19283	92	-17.05	6.72
19311	28	-1.45	8.61
19414	67	-4.96	3.07
19180	83	59.57	4.06
19181	87	-58.53	4.15
19422	36	-5.80	12.00
19184	12	-30.04	3.97
19453	94	32.17	4.18
20060	56	-54.78	3.56

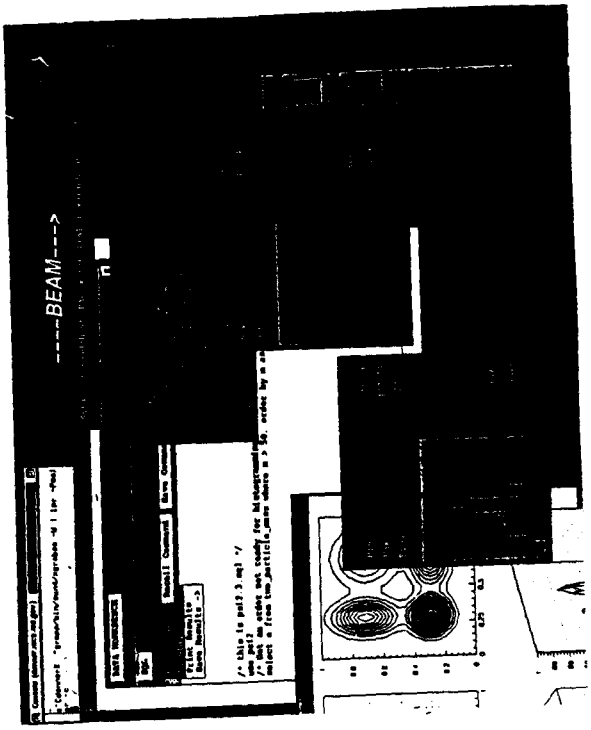
*** END OF QUERY RESULTS -- 18 ROWS SELECTED ***

2900

2903



2904



2905

Translating dimuon data from full YBOS form to Sybase st... with linked tables

Banks

- *LRID Logical Record ID
- CTCL central tracker seg ...
- CTCR
- * CTCS
- * VTVZ
- EVTA
- * CMVO
- JETS
- METS
- * EVCL
- ELEB

Interesting aspects

CTCS is variable and requ... linked tables for repeat ...

VTVZ variable but can be handled by repeated entries of fixed length

Intermediate files exist now for most banks which can be rea... by Sybase (or probably object store)

2906

- Simple user interface being developed
- Exploration of presentation via PAW, apE, AVS, ...

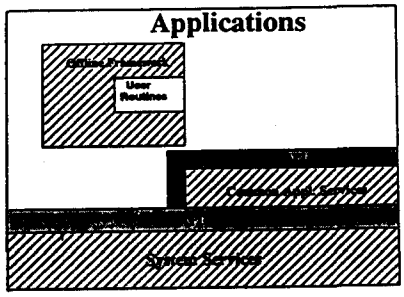
Day
Computing
9/6

Computing Standards — Status

C. T. Day
ICSD/STA
Lawrence Berkeley Lab

Software Infrastructure

Software Infrastructure



API — Application Program Interface

Standards Users

User role

- An ideal framework would isolate user from other standard APIs.
- Frameword API should be as portable and interoperable as possible.

- Developer role
  - Must use available standards and SDC conventions to implement the framework.
  - For maintanence reasons, the broadest applicable standards should be used.
  - In rare instances where only once copy of the system will run, e.g., the online or the central production facility, narrower interfaces may be used for efficiency.

From Adele Goldberg

- "A framework is a domain specific description of how parts should interact." I.e., they capture in a program outline much of the domain specific behavior described in operations concepts documents.
- "Object systems are more like fractals than biological hierarchies." I.e., they have complex structure at many scales. Standards sets are similarly intricate.

Standards Components

- Syntax definition — how to access it
  - Exact, explicit name of the function along with numbers and types (where appropriate) of arguments.
  - Different syntax for each language (or command shell) supported.
- Semantic definition — what it does
  - Exact, explicit description of the behavior invoked by the function including error responses, side effects, etc.
  - Described in terms of a computational model for the standard, not in terms of any particular implementation. The more general the model, the more general the standard.
  - Ideally, the semantics are language independent.
  - Very hard to get right and a prime source of loopholes.

Standards Sources

- US
  - POSIX = IEEE 1003.x committees
    - Institute of Electrical and Electronic Engineers
  - ANSI — American National Standards Institute
  - NITS — National Institute of Technologies and Standards, nee National Bureau of Standards
  - X Consortium — MIT Athena Project, IBM, DEC and everybody else
  - OSF and USL — Open System Foundation and Unix System Laboratories
- Europe
  - ISO — International Standards Organization
  - X/Open — Industrial consortium pushing standard Unix.

Some Relevent Standards — Operating System

- POSIX.1
  - Program interface to operating system for simple programs.
  - Unix-like interface, but VMS is/will be POSIX.1 compliant.
  - C binding is standard now, FORTRAN binding by years end. C compliant systems available now, FORTRAN systems in 18 months?
  - NITS test suites in place to ensure compliance.
- POSIX.4a
  - Real time system extensions.
  - Light weight threads for building concurrent servers.
  - Semaphores, mutexes for interprocess synchronization. Slow in coming.

Some Relevent Standards — Operating System (cont.)

- NCSC C2 level security (POSIX.6)
  - Don't panic. Only after the equivalent of discretionary Access Control Lists, not normally a part of Unix.
- OSF/1 or System V Release 4
  - Full operating system API from program viewpoint.
  - Base implementation from vendor viewpoint.
  - Cover more ground than just POSIX.
  - Should allow platform independent applications.
  - Market success unclear.
  - There are two of them.

Some Relevent Standards — Network Communication

- From SDC's viewpoint, DECnet vs. TPC/IP vs. ISO/OSI should be left to the technical specialists.
- X/Open Transport Interface
  - Provides network independence and transparency.
  - Comes with OSF/1. SVR4's TLI is very similar.
  - Still pretty low level.
- OSF/DCE — Distributed Computing Environment
  - Does not assume OSF/1.
  - Provides RPC standard, IDL compiler, world-wide name service, threads, etc.
  - Early stages, compliant systems just appearing, market success unclear.

Some Relevent Standards — Graphical User Interfaces

- X Window System
  - No significant competition.
  - Low level interface.
- OSF/Motif, OpenLook
  - Two contenders for interaction framework. The use of a common interaction framework is meant to increase "user portability".
  - Motif seems to be pulling ahead a bit. Motif is also deliberately compliant with Window 3.0 and OS/2's Presentation Manager.
  - Neither framework really addresses the content of user graphics.

Some Relevent Standards — Application Graphics

- Xlib
  - Always available given X. Tedious to use. Graphics model in pixels explicitly (Motif can ease this problem).
- Custom Xt widgets
  - Always possible with X. Could be developed commercially for SDC. Some sets may appear commercially anyway. Begs the question of what the widget writer uses as graphics API.
- DataViews
  - Similar to custom widgets. Good for online, but expensive.
- GKS-on-X
  - Provides the standard GKS 2d graphics API running on top of X. At least one such implementation identified.
- PEX (Phigs on X)
  - Similar to GKS-on-X but 3d. Supposed to be part of X11R5, due any day now. May need hardware support on X server end for reasonable performance.

Miscellaneous Other Standards

- Distributed Batch Services
  - NQS from NASA is current de facto standard for Unix. Basis for POSIX.15
- Data Storage
  - IEEE Mass Storage Model is developing standard for automatic migration of data to archival storage for very large data sets.

Summary

- A great deal of activity, not necessarily all compatible.
- We need to track what is going on and do some experiments.
- We should think about compiling our own AES, Application Environment Specification.

Software Development

Code Management
continuation of workshop

Languages

CASE

Computer Physics Communications 57 (1989) 239–243
North-Holland

CODEBASE: A COMMERCIALLY DEVELOPED CODE MANAGEMENT SYSTEM AND CODE TRANSFER FACILITY

K. MUELLER and P. PFEIFER
BASE GmbH, Flachweg 31, D-5000 Köln 40, Fed. Rep. Germany

The CODEBASE package has been developed by the commercial software house BASE GmbH according to requirements agreed for large HEP collaborations. CODEBASE runs currently on IBM/MVS, IBM/VM, VAX/VMS, and UNIX environments. An implementation on CRAY's under UNICOS is foreseen. With code being developed by geographically distributed teams, priority has been given to powerful tools for code distribution and for well documented version keeping. Truly alternative versions of code are supported. Ease of use is provided by a menu-type full-screen interface which is common to all installations and which itself is translated to the respective local editor.

1. History

The basic requirements for a code management and distribution facility to be used for HERA experiments were laid down in close cooperation between DESY and BASE in October 1987.

A corresponding license agreement was signed by DESY and BASE in March 1988 for use of CODEBASE on the DESY computers and for software development connected with ZEUS and H1 experiments on any other computer. The systems covered in the contract are IBM/MVS, IBM/VM, VAX/CMS, GOULD/UNIX, APOLLO workstations and CRAY/UNICOS.

In April 1989 the CODEBASE system is fully operational with quite a few enhancements with respect to the initial requirements. Installations pending are on APOLLO and CRAY, and on IBM/VM the full-screen interface is being finalized. Marketing of the CODEBASE system in the commercial market has been started using a fully operational MS-DOS version for demonstration purposes.

2. General overview

CODEBASE is a computer independent code management and distribution system. It allows easy administration of code updates, versions (also truly parallel), macro insertions and conditional code. CODEBASE works on specific file structures which, although being system dependent, are transparent to the user. In the following, a file with such a structure will be called a CODEBASE-Library.

2.1. CODEBASE-Library

A CODEBASE-Library is subdivided into units called modules. The name of a module can be up to 8 alphanumeric characters long (to ensure system independency when transferring a module to a local file for editing) and can be preceded by a prefix in pointing hierarchy (equivalent to a directory, e.g. (PREFIX)MODULE). The total length of names and prefix may not exceed 24 characters. For inline comments generated by certain CODEBASE functions (MERGE, EXPAND) the computer language is stored along with the module. All well known computer languages are supported. Addition of new languages is straightforward.

2.2. User interface

All CODEBASE functions are invoked by calling a basic program with up to 11 parameters.

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(North-Holland)

Computer Physics Communications 57 (1989) 251–258
North-Holland

CMZ – A SOURCE CODE MANAGEMENT SYSTEM

M. BRUN
D. Gross-Pauly, France

R. BRUN
CERN, CH-1211 Geneva 23, Switzerland

A.A. RADEMAKERS
SIEMENS-AG/CERN, CH-1211 Geneva 23, Switzerland

In this paper we discuss a new code management system called CMZ. CMZ is an advanced, interactive, fast, extensible, machine-independent and PATCHY compatible source code management system for FORTRAN 77 source code and related text files.

1. Introduction

CMZ was created because of the unsatisfactory situation that existed at CERN concerning code management systems (the existing systems, PATCHY and HISTORIAN, were all geared towards batch style usage). CMZ was designed to perform as its best on the now commonly available interactive personal workstations.

We call CMZ *advanced* because it offers code management facilities that go beyond simple bookkeeping and version archiving. CMZ supports the developer during the project development phase: instantaneous access to any routine in the local editor; check for undefined variables; automatic indentation of routines; renumbering of statement labels; reordering of decks in alphabetical order; merge of related decks in directories; single command to compile a routine and update the object library; import and export of source and text files. In the maintenance phase CMZ offers the user: an extensive history mechanism; generation of a correction set by comparing the changed routines with the routines in the master library; using the correction set for generating a new object library; updating the master library by applying the correction set.

We call CMZ *interactive* because it provides a UNIX like shell in which you give commands. Every command gives you direct feedback. In case you issue a wrong command, argument or parameter you get an appropriate error message and in case of ambiguous completion you get a new prompt. CMZ also provides a *batch mode* to execute a series of commands without intervention from the user.

CMZ is *fast* because it stores the source code in a RZ direct-access file. This makes it possible to access any routine instantaneously for editing, copying, compiling, searching, etc. RZ is the database management part of the ZEBRA * [3] package.

Extensible means that you can redefine or rename CMZ commands. For example, if a user prefers to use the UNIX ls command to list the contents of a directory instead of the CMZ command DIR, ls/dir can have it. It is also possible to write entirely new commands using a MACRO facility. In a MACRO you can combine a number of commands to act as one new command. These

* Name the origin of the name CMZ: Code Management system using Zebra.

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Computer Physics Communications 45 (1987) 293–298
North-Holland, Amsterdam

USE OF THE ADAMO DATA MANAGEMENT SYSTEM WITHIN ALEPH

Z. QIAN, S. TANG, W. ZHAO *
IHEP, Academia Sinica, Beijing, China

S.M. FISHER *, J. HARVEY
Rutherford Appleton Laboratory, Didcot, GB

M. BOANO, J. BUNN, R. McCLATCHEY, V. EMILIANI, P. PALAZZI *
CERN, Geneva, Switzerland

R. BRAZIOLI *, A. PUTZER
HEP, Heidelberg University, Fed. Rep. Germany

M.G. GREEN
Royal Holloway College, Univ. of London, GB

and R. FANTECHI
Istituto di Fisica, Pisa, Italy

ADAMO is a data management system for defining data and manipulating them from FORTRAN programs. A form of the Entity–Relationship (ER) model and the data flow diagrams of structured analysis have been combined to provide a system aimed at algorithmic work. The FORTRAN interface consists of calls to a subroutine package with a few data manipulation processors. Data items are visible in variables carrying meaningful names; the code is compact and readable. The ER data structures, mapped into tables, are compatible with a relational data base management system. Tools have been written to copy tables to and from a relational data base. The system has been used for several applications in the fields of event simulation and reconstruction, online systems, detector descriptions, support tools and packages.

1. Introduction

The Aleph DAta MOdel (ADAMO) system was developed as an independent project within the ALEPH * collaboration, its aim being to cope with the complexity of data in a modern particle physics experiment. It has been stated that

PROGRAMS = ALGORITHMS
+ DATA STRUCTURES,

and in the past much attention has been devoted to the algorithms. Now that detectors are larger and more complex, data structures and data management have become increasingly important. The design of ADAMO has been influenced by clear trends in the software industry, such as the prominence of relational data bases, increasing use of engineering practices, data abstraction and the importance of a programming environment with adequate software development tools.

In defining and constructing the system, it was decided to distinguish between the INTERNAL (machine) and EXTERNAL (programmer, user) view of the data, defining a CONCEPTUAL view in which they can both refer [1]. To achieve this a DATA MODEL was adopted, with a set of data structures, manipulation operators and validation

* Between those who are the authors of the ADAMO system.
* ALEPH is an experiment at the LEP collider at CERN.

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(North-Holland Physics Publishing Division)

GNF Note No. 510

SOME MMS/MAKE BASED TOOLS FOR LIBRARY UPDATES

Version 1.04

27 June 1991

David R. Querrie

Fermilab MS510
P.O. Box 500
Batavia IL 60510
Tel: (312) 840-3075

DECnet Node Name : BONEST
BITNET Node Name : FNALBO
User Name : QUARRIE

ABSTRACT

The DEC/MMS (Module Management System) and the UNIX/MAKE provide a powerful mechanism for maintaining Object Libraries and ensuring consistency in Source Code updating. Unfortunately MMS/MAKE is cumbersome to use and requires that all the dependencies between Source and Include Files be explicitly specified. I have developed some procedures for generating these dependencies automatically and have applied these to the Offline Package in order to produce a mechanism for updating Libraries within this Package using the full power of MMS/MAKE.

Article 5875 of comp.software-eng
Path: [illegible]
From: [illegible] (Richard Harter)
Newsgroups: comp.software-eng
Subject: Re: Who check CM some group?
Summary: Two types of checks
Keywords: configuration management
Message-ID: [illegible]
Date: 24 Jul 91 05:11:20 GMT
Article-I.D.: [illegible]
References: [illegible] <7190[illegible].UUCP> <1991Jul22.1[illegible]>
Organization: SMDS Inc., Concord, MA
Lines: 92

In article <1991Jul22.1[illegible]>, [illegible] (Paul Stachour) writes:

> I too would like to see a newsgroup on configuration management.
> I have lands of questions, such as:

> "How does one reconcile use of a standard CM tool which requires
> that the person who checked out a file check it in,
> with a development policy that requires disinterested auditing, thus
> that a person who checks out a file may never check it in?"

First point of confusion - version control is not the same thing as configuration management. Second point of confusion - change control is not the same thing as configuration management. There is a third point, not touched on above - build management is not the same thing as configuration management. Configuration management subsumes all three and coordinates them.

Now to the question asked: In a well developed CM system, these issues come under change control. A formalized system might run such as follows:

(1) A change request is made. This automatically gets routed to the authority who can authorize the change.

(2) Said authority can (a) immediately authorize the change, (b) route it to the appropriate group for study, or (c) deny the change.

(3) Assuming the change is authorized, it is routed to the person in charge of assigning that class of change.

(4) Said person assigns to the implementor or implementation team. As part of the assignment process and implementation environment is automatically created. [Note: at this point the cooperation of build management and version control systems is needed. However we are still talking the change control cycle.]

(5) The implementation group implements said change in a segregated implementation environment. In the course of implementation they check out sundry files for modification. There are a host of policy decisions here - locking issues, fixed base versus floating baseline, etc. The main point for change control is that the files ultimately come back in a group class

(6) The implementation group submits the change for approval. The immediate effect of this is to root the altered software to an automated certification process. Ideally the certification process includes automated regression testing. Furthermore the implementation group has also submitted proposed additional certification testing for the change.

(7) If the proposed change fails automated testing it is sent back to the implementation group who either (a) reworks the change or (b) proposes changes to the testing procedures to encompass the effects of the new change. Either route leads to

(8) The QA department che either accepts or rejects the change. The analysis and ruling of the QA department is routed both back to the implementation group and the approving authority.

(9) In the event that the implementation survives QA it is routed to the integration group who is responsible for integrating the change (which by now is a parallel branch) into the appropriate main line version sequence. Integration in turn cycles through automated testing and QA approval. At this point the change may survive all its travails, it may be sent back to the implementation group for rework, or a new change proposal (for integration work) may be spawned.

(10) At long last the change gets to the approving authority who signs off on it, rejects it, or sends it off for review.

All of this may seem hairy and bureaucratic. Before throwing your hands up in horror, it is worth remembering several things. Firstly much of what happens is [should be] automated. Secondly, in an informal or small organization, a number of the steps happen implicitly. Thirdly, again in small and informal organizations, people may wear more than one hat. Finally, there are other models of change control. However the above model covers the key elements.

Now that we have that small parenthetical remark out of the way, to deal with the original question:

File check out/check in is a separate process from auditing and should be treated as a separate process.

--
Richard Harter: SMDS Inc. Net address: uunet!smdsirh Phone: 800-260-7300
US Mail: SMDS Inc., PO Box 555, Concord MA 01742. Fax: 800-260-8272
In the fields of Hell where the grass grows high
Are the graves of dreams allowed to die.

From: [illegible] "Bill Courtney" 6-AUG-1991 [illegible]
To: [illegible]
CC:
Subj: Forwarding note re: Distributed Code Management System For Scientific Ap[illegible]

Received: from CUNYVM2(MAILER) by FNALA with Jnet id 4584
for [illegible]; Tue, 6 Aug 1991 13:31 CDT
Received: from CUNYVM by CUNYVM.BITNET (Mailer R2.07) with BSMTP id 8384; Tue, 06 Aug 91 14:31:12 EDT
Received: from vnet.ibm.com by CUNYVM.CUNY.EDU (IBM VM SMTP R1.2.2MEM) with TCP; Tue, 06 Aug 91 14:31:06 EDT
Received: from [illegible] by vnet.ibm.com (IBM VM SMTP V2R1) with BSMTP id 5343; Tue, 06 Aug 91 14:30:23 EDT
Date: Tue, 6 Aug 91 13:31:56 CDT
From: "Bill Courtney" <bcourtn@dalvmic1.vnet.ibm.com>
To: [illegible]
Subject: Forwarding note re: Distributed Code Management System For Scientific Application

Here are some answers from Bernard's post to the comp.software-eng list. We wanted you to have these for possible relevance to the code management discussions at the SDC meeting.
Cheers
Bill Courtney
---------- Note follows ----------
Received: from SSCNET.SSC.GOV by vnet.ibm.com (IBM VM SMTP V2R1) with TCP; Tue, 06 Aug 91 13:29:18 EDT
Received: from sscsg0.ssc.gov by SSCNET.SSC.GOV with PMDF#10206; Tue, 6 Aug 1991 12:25 CST
Received: by sscsg0.ssc.gov (5.52/090607.SGI) (for @sscnet.ssc.gov:bcourtn@dalvmic1.vnet.ibm.com) id AA11050; Tue, 6 Aug 91 12:28:45 CDT
Date: Tue, 6 Aug 91 12:28:45 CDT
From: travers@sscsg0 (Bernard Traverset)
To: bcourtn@dalvmic1.vnet.ibm.com
Message-Id: <9108061728.AA11050@sscsg0.ssc.gov>

Bill,

Glad to be back in the state..Here are the answers I got back. You may want to forward them to Chris and Irvin.

From bolk@cernvax.cern.ch Mon Aug 5 17:21:29 1991
Date: Tue, 6 Aug 91 00:19:42 +0200
From: bolk@cernvax.cern.ch (andrew bolk)
To: travers@sscsu1
Subject: Re: Distributed Code Management System For Scientific Application
Newsgroups: comp.software-eng
References: <9108051654.AA042618@sscsu1.ssc.gov>

In comp.software-eng you write:

>I have been asked by the Computing Working Group of the
>Solenoidal Detector Collaboration (SDC) to solicit this newsliet
>for comments about and recommendations of code management tools.
>It appears that if a separate list for the discussion of
>configuration management is formed that this request should be
>placed there.

>The SDC was formed to design and build a general purpose detector
>for high energy physics research to be conducted at the
>Superconducting Super Collider. The collaboration is made up of
>physicists and engineers drawn from many institutions through out
>the world. The software to be used for this project will be a
>combination of commercially available and collaboration written

Andy Bolk

... Andy ...

Message 5:
From CS.UCLA.EDU!trainum!trainum.com!eggert Mon Aug 5 20:39:49 1991
Date: Mon, 5 Aug 91 17:34:05 PDT
From: eggert@trainum.com (Paul Eggert)
To: travers
Subject: Re: Distributed CODE management for Scientific Application
Newsgroups: comp.software-eng
References: <9108051643.AA18212@sscsg0.ssc.gov>

If you're looking for low-cost software, you might take a look at the Revision Control System (RCS). It's not fancy, but it's reliable, and the price is right: it's free. It's used fairly widely in the Unix world, and it's widely ported not only to Unix but also DOS and OS/2. Several vendors support it or interfaces to it (I'm thinking of HP, IBM, Sun[illegible] among others). You can FTP the source code from prep.ai.mit.edu in pub/gnu/rcs-5.5.tar.Z; while you're at it you should get diff-1.15.tar.Z.

Three distributed source code management systems are rare even in the commercial world. A group in Ireland did write a Distributed RCS (DRCS), but I haven't used it. If you're willing to wait, there's a nice product by a company whose name I can't recall (it's a spinoff from HP/Apollo's DSEE project, which you should also look into) that will come out sure for (among others) SGI and Sun machines.

Message 6:
From root@sscsu1 Tue Aug 6 00:05:00 1991
From: sscsu1!jjuhasz!uudo!rh
Date: Tue, 6 Aug 91 00:02 EDT
Apparently-From: jjuhasz!uudo!rh
To: sscsu1!jjuhasz!sscsu1.ssc.gov!travers
Subject: Re: Distributed Code Management System For Scientific Application
In-Reply-To: your article <9108051654.AA042618@sscsu1.ssc.gov>
Uucp-Path: jjuhasz!lostroid!transfer!samsung!uce!osphad.cpg.ohio-state.edu!ohtel[illegible]
[illegible]!sscsu1.ssc.gov!travers

If I understand your requirements correctly, there are at least three code management systems that you may wish to consider:

1) CDC Update (Only available on CDC mainframes)

2) Historian Plus — an independent part of CDC update which runs on a variety of platforms, principally mainframes.

3) Aide-de-Camp — A general software management system that runs on UNIX machines, VMS, and Prime. [illegible] markets Aide-de-Camp.

The common feature that these systems have that is relevant is the ability to transport selected code changes from a repository on one machine to one on another.

If you would like more information on Aide-de-Camp, you can send a fax to 508-369-8272, a mail request to uunet!uudo!rh, or UUmail to

Software Maintenance and Development Systems Inc
PO Box 565, Concord MA 01742

Richard Hunter

Richard Hunter: CDC Inc. Net address: uunet!uudo!rh Phone: 508-369-7398
UU Mail: [illegible] Inc., PO Box 565, Concord MA 01742. Fax: 508-369-8272

applications (mainly Fortran and C).
The number of and geographical dispersion of the software developers for this project place unusual requirements on the code management system. It is unlikely that there will be an simple vendor platform used by the collaboration members for [illegible] development work. It is also unlikely that a single programming language will be used for development.

>In short we are looking for tools to ease the management of code
>development by 100's of amateur programmers at a lot of different
>locations.

>Please send comments (e-mail) to me and I will summarize if there
>is sufficient interest.

>| BRCnet: SSCVX1::TRAVERSAT Fax: (216)708-8143

Hi Bernard,
I worked for the ALEPH collaboration at LEP and we had the identical problem (though perhaps on a slightly smaller scale).

The tools available to manage software projects in the multi-vendor arena are fairly scarce - we opted for Historian (other experiments still use PATCHY - an old CERN product). It is a very crude tool for managing source code and source code versions, but it does give you a portable INCLUDE utility for FORTRAN (the problem doesn't arise with C). For more information about Historian you should contact Florence Ranjard (VXCERN::RANJARD or FLA@CERNVM.CERN.CH) who uses it all the time. She should at least give you an idea of what is involved. The new CERN code management system is called CMS. It is much more full-featured than PATCHY but is built on top of Sohra and does only what several PD Unix utilities offer in a rather less than friendly way. But then I've had to use Sohra partly for two years and it's made me biased ...

On the online side (where I worked for half the time) we used only Vaxes and micros (OS-9). For the source code management some people used CMS very successfully - keeping the micro code on the Vax. If you can assume one platform for the central version control, then, I would think, in principle you can use all the gee-whiz products that come with it. (I'm thinking more of a Sun, Unix and RCS/CVS, but the same idea applies). I'm sure several people will mail you details of these. As far as working versions/backup is concerned we finally ended up with a Development/Production/Old three-tier system. Any one of the three versions of a software package could be selected with a simple command. This was very useful. Contact Olivier Callot or myself if you want any more information about this part. We got the idea in part from CDF - Dave Quarrie - who is now at CERN?. I think you can get him on quarrie@cdhafvax.bitnet.

As a very interesting example of software support across multiple platforms, you may be interested in how the GNU project (Free Software Foundation) supply compilers and utilities that run on basically any Unix-like Operating system. Essentially all their code is in C. One of the gnu... groups is probably appropriate for this question. From the examples I've seen they do a very good job of limiting machine-dependent bits of code to one file.

Lastly, something we have found incredibly useful is electronic communication (obvious probably). A news system to relay changes and releases and other matters, plus widespread use of e-mail. At CERN we use a package called ALEPHMS which is an adaptation of something from a UNICOS tape. Contact Olivier Callot (VXCERN::CALLAOT) for more info. But perhaps you have it already - you have a news system anyway.

I'm now a CERN fellow working for the UNP accelerator division where the [illegible] have quite a lot of code and project management ... ;-)

In the fields of hell where the grass grows high
Are the graves of dreams allowed to die.

Message 8:
From [illegible] Tue Aug 6 09:02:00 2001
Date: Tue, 6 Aug 1991 09:13:06 -0400
From: Roy Underhill <roy@socks.Eng.McMaster.CA>
Subject: Distributed code management
To: travers
X-Envelope-To: travers@sscsg0.ssc.gov

Hi,

I would certainly be interested in the results. I do my research in the numerical simulation of solid mechanics problems. Some of the codes we use and develop are enormous! Please post or mail a summary. Thank you.

Roy

--

Roy Underhill, (416) 525-9140 x4306 roy@socks.eng.mcmaster.ca
Dept. of Mechanical Engineering
McMaster University, Hamilton,
Ontario, Canada L8S 4L7

Message 9:
From uunet.uu.net!richsun!lagogly Tue Aug 6 11:20:24 1991
Date: Tue, 6 Aug 91 10:53:21 CDT
From: lagogly@richsun.cpg.trs.reuter.com
To: travers@sscsu1
Subject: Re: Distributed Code Management System For Scientific Application
Newsgroups: comp.software-eng
In-Reply-To: <9108051652.AA042598@sscsu1.ssc.gov>
Organization: Reuters Client Site Systems, Oakbrook,IL
Cc:

In article <9108051652.AA042598@sscsu1.ssc.gov> you write:

>In short we are looking for tools to ease the management of code
>development by 100's of amateur programmers at a lot of different
>locations.

Good luck. The first thing I'd do in your situation is develop some clear and unambiguous guidelines for accepting code, for reviewing code on your end, and make sure the "amateur programmers" understand them (I hope they're being passed good detailed designs to work from, and if not there's provision in your methodology for reviewing and approving any designs they do come up with ... if you pass out requirements to hundreds of hackers and hope to come up with anything resembling an integratable and maintainable system, you've got a lot more faith than I do!).

Your choice of tool(s) depends on your environment and methodology. Will there be a common OS environment? Hardware platforms? Do you want remote check-out/lock/check-in capabilities? Assignment and tracking of change requests? Management of multiple concurrent baselines? An integrated change management/source control environment? I'd suggest understanding and documenting your "requirements" and the "methodology" you'll use for managing these programmers in detail before evaluating any tools!

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Thats you may want to look at include (depending on your OS: I've listed the OSs for each tool):

- Side-By-Comp, Software Maintenance & Development Systems, Inc., [illegible], Concord MA 01742 (508)369-7398. Unix, Prime, Ncmix, [illegible], Xenix.
- SEC, Softool Corp., 340 South Kellogg Ave., Goleta CA 93117 (805)683-5777. VMS, MVS/TSO, Unix, AOS/VS, ECX, RS/6K, MPE/XL, VM/CMS, [illegible], Ultrix, HP/UX.
- SMF, Imperturbase Inc., 3235 Kifer Road, Suite 220, Santa Clara CA 95051-0904 (408)746-0706. Unix, Xenix.
- DDTS, Qualtrak Corp., 3315 San Felipe Rd., San Jose CA 95135 (408)274-0047. Unix [possibly other platforms?]
- MENEVOR/MVS, Business Software Tech. Inc., Westboro Executive Park, 114 Turnpike Rd., Westborough MA 01581 (508)870-1900. MVS.
- Histories Plus, GPCODE, Inc., 7740 Highway 290 West, Ste. 600 Austin TX 78736 (512)440-0916. Aegis, MDS, MDS/BE, MDS/VE, LPDS, SCOPE 2, VMOS, MMMOS, PRCON OS, VULCAN, VOS, HP UX, OS, VM.
- PVCS Polytron Version Control System, SAGE Software Inc., 2800 Tower Oaks Boulevard, Rockville MD 20852 (301)230-3200. HP-UX, VMS, Unix, OS/2.
- SABLIME, ATST, Room 3A36 Liberty Corner, Building 2, 10 Independence Blvd., Warren NJ 07060-0911 (201)580-6269. Unix.
- SCCS, Corporate Computer Systems, 33 West Main St., Holmdel NJ 07733 (201)946-3000. RTE, MPE.
- VAXset, DEC, 110 Spit Brook Rd., Nashua NH 03062-2698 (603) 881-2341. VMS.

This information is in part from the Testing Tools Reference Guide 1991 edition, from Software Quality Engineering, 3000-2 Hartley Rd., Jacksonville FL 32257 (904)268-8639.

I looked at literature for several of these tools (the Unix ones), and got a demo copy of DDTS in to look at. The only solution that integrates change/version management and source control is SABLIME; we chose SABLIME because of that, and because our home-brewed system for source control was similar to SABLIME (we have a lot of ex-ATST employees here). DDTS was flexible and highly customizable, but we didn't feel we had the time to hassle with it and to do the integration of source control into DDTS. Also, the focus was on bug fixes rather than on change management in general. Many of the above tools focus on management of change information but not source control, or do a good job of source control but not of managing the associated change information. As I recall, CCC and CMF were also good looking tools for configuration management.

Steer clear of RCS which is a free source control tool; it doesn't buy you diddly-squat over plain old SCCS (and is way overpriced for something with near-zero functionality :-).

I highly recommend getting literature on the tools of interest to you and getting a demo copy to look at first. Also, make sure you do understand your requirements first!

Hope this helps rather than confuses.

-- Will Tuvoofv

2932

From: BETHEP::WATTS 1-AUG-1991 14:01:36.09
To: fnal::gaines
CC:
Subj: FWD: requirements for C2M package - user view

From: BETHEP::WATTS 24-JUL-1991 12:44:45.98
To: SSCVAX1::FRY
CC: WATTS
Subj: requirements for C2M package - user view

Alan - Here is my attempt at the job we signed up for. You will see, I hope, that it mixes patchy/update/etc ideas with cms/sccs ideas, trying for the best of both. If you have anything written, or comments on this, let me know.
- Terry.

Requirements on a Code and Configuration Management (C2M) Package
from a physicist user's viewpoint.
T.Watts, Rutgers/SDC, 7/91.

1. Module based - Developers and users should deal with modules (and correction sets, see below) as a whole and not with line numbers. A restricted form of cms generations should be allowed, e.g. like pam file versions. C2M czars only should generate new generations of modules; developers make correction sets.

2. Correction sets should be allowed which span more than one module and should be easy to use (e.g. more like the patchy family than the class mechanism in cms extended to correction sets). The C2M package should generate correction sets from edited modules returned by developers. Correction sets which span more than one library perhaps should also be allowed.

2a. There should be configurations, i.e. selection of modules, their versions, and their correction sets, to make up binary libraries, executable images, or other integrated selections. Configurations should span more than one C2M library.

3. There should be a locking or reservation mechanism for modules.

4. There should be a history mechanism for actions on modules, correction sets, library changes, etc, including history lines in extracted modules.

5. It should be easy for managers to supply remote users with updated read-only copies of the C2M libraries. It should be easy for remote users to make reservations/locks while working remotely.

6. Developers should be able to update modules and make corrections sets without explicit approval of a czar in each case. Control of the list of developers must be possible by a czar with relative ease.

7. It should be easy for any user to discover what module generation and which correction sets were used in any executable he links from C2M libraries. (This is also a requirement on human management techniques perhaps).

8. A user should be able to construct a personal configuration and publish it for others to use in an easy fashion. This ability is given to users rather than developers because a configuration is likely to span several C2M libraries and a developer is likely to not have update access to all of them.

9. What does a C2M czar do? Decides when to create new generations or versions of modules. Resolves conflicts between correction sets, and between configuration developers.

2933

Requirements for Code Management System

USER's point of view:
Ability to define a "version" of the code containing whatever generations of each module desired
Ability to create his own incremental changes to any "version" of the code
Latest bug fixes and improvements to all code modules must be available within 24 hours, and can be used or not as desired
Must be able to refer to reference copies of release versions of code
Must be able to recover any desired historical version of code

DEVELOPER's point of view:
Fixes to code must take effort in all variations of the code
Must be able to use any desired local tools (editors, debuggers, etc)
Several people at different locations should be able to develop code at the same time
Should have the ability to lock out other changes to code while working on a module
Code management system should aid in preparation of code documentation
Must have easy way (eg, preprocessor) to maintain platform and environment dependencies in code

CZAR's (librarian's) point of view:
Must be able to create a "release" version of code by specifying a particular generation for each code module; afterwards this release can be referred to symbolically
Must have automated tools to distribute code and updates
Must be able to determine who is responsible for all original code modules and all changes
Means can make changes in earlier versions of code
Must have automated tools to test compilation, linking and running of a tentative release version of the code
Code management system must handle all types of text files

!934

From: JnetX"WOJCIK@FRCPN11" "Wojciech WOJCIK" 25-JUL-1991 21:24:21.74
To: GAINES Irwin <gaines@fnal.BITNET>, JONCKHEERE Alan M <jonckheere@fnal.BITN
CC:
Subj: AI Workshop announce

Received: From UICVM(MAILER) by FNALA with Jnet id 1670
for GAINES@FNAL; Thu, 25 Jul 1991 21:16 CDT
Received: by UICVM (Mailer R2.07) id 5406; Thu, 25 Jul 91 19:21:40 CDT
Date: 25 Jul 1991 22:23:32 EST
From: Wojciech WOJCIK <WOJCIK@FRCPN11>
Subject: AI Workshop announce
To: GAINES Irwin <gaines@fnal.BITNET>,
JONCKHEERE Alan M <jonckheere@fnal.BITNET>,
KALETKA Mark Owen <kaletka@fnal.BITNET>,
LIDINSKY William Paul <lidinsky@fnal.BITNET>,
NASH Thomas <nash@fnal.BITNET>

SECOND INTERNATIONAL WORKSHOP ON

SOFTWARE ENGINEERING, ARTIFICIAL INTELLIGENCE

AND EXPERT SYSTEMS FOR HIGH ENERGY AND NUCLEAR PHYSICS

1992

January 13 - 18

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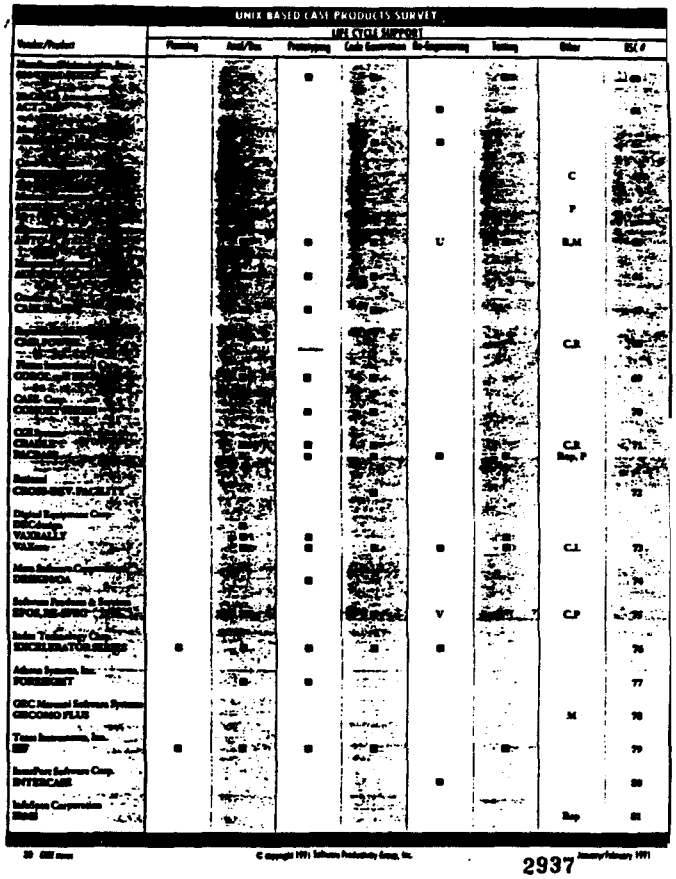
Article 1599 of comp.software-eng:
Path: sunova!linac!att!pacbell.com!mips!odd.hp.com!uscirp!ighost.unimi.it!cdc835!netnews
From: alfonso@mailer.cefriel.it (Alfonso Fuggetta)
Newsgroups: comp.software-eng
Subject: Third European Software Engineering Conference
Summary: Call for participation and advance program
Message-ID: <1991Jul16.160024.241370@cdc835.cdc.polimi.it>
Date: 16 Jul 91 16:00:24 GMT
Sender: netnews@cdc835.cdc.polimi.it (News Admin)
Organization: CEFRIEL
Lines: 289
Nntp-Posting-Host: alfonso.cefriel.it

Third European Software Engineering Conference - Call for participation

Milano (Italy)

21-24 October 1991

ESEC 91 (European Software Engineering Conference) is the third edition of a cycle of conferences which has now become a regular date for professional and researchers interested in the most recent research activities in the Software Engineering field.
Researchers, developers and users from both the academic and the industrial world meet to share experiences, evaluate results and explore new ideas which can contribute to improving the quality and cost-effectiveness of the software production process.
ESEC is organized every two years under the supervision of a committee which groups together the representative of six national computer societies operating in Europe: ATI for Spain, AFCET for France, SI for Switzerland, GI for Germany, BCS for Great Britain and AICA for Italy.
The articles submitted to the program committee have been more than 130, coming from european, american and asian countries: of these, 22 have been selected and will presented during the conference. The conference program foresees also 4 tutorials, 3 panels, and 6 invited speakers, who will provide valuable insights and evaluations on relevant issues of the software engineering field. This third edition of ESEC will be held in conjunction with other two important events: CQS 91 and the Sixth IEEE International Workshop on Software Specification and Design (IWSSD 6).
CQS is the most important annual event organized in Italy regarding problems of software quality and productivity, and has now reached its fifth edition. Organized for the first time in 1987 under the title of "Italian Software Quality Observatory", the CQS met with immediate success, highlighted by the high number of participants (700 in 1987, more than 2,000 in 1988 and more than 3,000 in 1989 and 1990). The CQS is a non profit-making event financed by a large number of Sponsors, both users and suppliers of EDP and software technologies.
The large numbers of highly qualified participants have always made the CQS the most important "shop-window" for the presentation of products and services for CASE, and many suppliers now tend to focus the campaigns for presenting their new CASE products on the CQS.
ESEC attendees will have free admission to all the initiatives of CQS 91.
IWSSD 6, the sixth International Workshop on Advanced Techiniques for the Specification and Design of software , will be held in Como on 25th and 26th October, just after the conclusion of ESEC 91.



Article 1574 of comp.software-eng:
Kref: sunova comp.specification:194 comp.software-eng:1574 comp.arch:4018
Path: sunova!linac!pacific.mps.ohio-state.edu!zaphod.mps.ohio-state.edu!rpi!batcomputer!cornell
From: hoebel@cs.rochester.edu
Newsgroups: news.announce.conference,comp.specification,comp.software-eng,comp.arch
Subject: KBSE conference program schedule
Message-ID: <9107112104.AA027736@slate.cs.rochester.edu>
Date: 11 Jul 91 21:04:58 GMT
Sender: hoebel@cs.rochester.edu (Lou Hoebel)
Organization: Computer Science Department University of Rochester
Lines: 305

****
CONFERENCE ANNOUNCEMENT
****

THE 6TH KNOWLEDGE-BASED SOFTWARE ENGINEERING
(KBSE-91) CONFERENCE

Sponsored by Rome Laboratory
In-Cooperation with
A A A I
and
A C M

September 22-26, 1991
Syracuse University Sheraton
Syracuse, NY

Sponsored by Rome Laboratory (RL) formerly Rome Air Development Center (RADC) and In Cooperation with AAAI, The American Association for Artificial Intelligence and the ACM, Association for Computing Machinery .

Keynote Speakers:
Dr. Barry Boehm, DARPA/ISTO
Thomas Cheatam, Harvard University

There will be 25 technical presentations, 3 panel discussions, introductory mini-tutorials on Sunday plus demonstrations of software systems on Monday and Tuesday.

Program Chair:
Peter G. Selfridge
AT&T Bell Laboratories
Room 3C-441
Murray Hill, NJ 07974
pgs@research.att.com

Program Committee:

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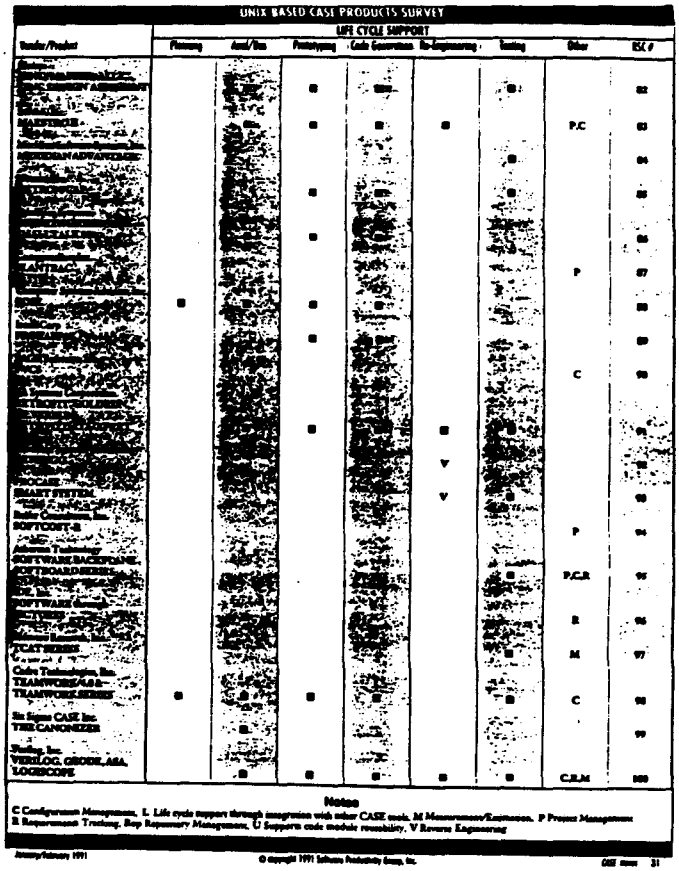

From: com%"bcourtn@dalvmic1.vnet.ibm.com" "Bill Courtney" 23-JUL-1991 15:02:..
To: ema@anhep2.hep.anl.gov, gaines%FNAL.bitnet@cunyvm.cuny.edu
CC:
Subj: SERC

2939

Received: From CUNYVMV2(MAILER) by FNALA with Jnet id 2595
for GAINES@FNAL; Tue, 23 Jul 1991 15:02 CDT
Received: from CUNYVM by CUNYVM.BITNET (Mailer R2.07) with BSMTP id 9905; Tue, 23 Jul 91 15:54:39 EDT
Received: from vnet.ibm.com by CUNYVM.CUNY.EDU (IBM VM SMTP R1.2.2MX) with TCP; Tue, 23 Jul 91 15:54:34 EDT
Received: from DALVMIC1 by vnet.ibm.com (IBM VM SMTP V2R1) with BSMTP id 9105; Tue, 23 Jul 91 15:25:33 EDT
Date: Tue, 23 Jul 91 14:26:18 CDT
From: "Bill Courtney" <bcourtn@dalvmic1.vnet.ibm.com>
To: ema@anhep2.hep.anl.gov, gaines%FNAL.bitnet@cunyvm.cuny.edu
Subject: SERC

This is information about the Software Engineering Research Center. Ed, I I mentioned this to you at the end of the last computer working group meeting. You might also be interested in the fact that Cadre announced last week a package for doing reverse engineering on FORTRAN code.
Cheers,
Bill Courtney

IBM 20-04-Q26 Phone: (214) 280-4765
1605 LBJ Freeway Internet: bcourtn@dalvmic1.vnet.ibm.com
Dallas, TX 75234 : bc2@pinet.aip.org
RE: Info on Software Engineering Research Center
From: spaf@cs.purdue.EDU (Gene Spafford)
Date: 14 Dec 90 00:26:05 GMT

It's been some time since I posted any information on the SERC so I bet that many of you haven't heard the information. People interested in research on testing, debugging, metrics, prototyping, CASE tools, programming aids, analysis tools, user interface design, and more will probably be interested in this material.

First, a "complete" bibliography with abstracts of all SERC technical reports is updated monthly for ftp. You can get the file, along with other information about the SERC, by anonymous ftp from arthur.cs.purdue.edu look in the directory ~ftp/pub/serc

What follows is the "About-SERC" file from that directory:

A decade or so ago, the National Science Foundation established a program to encourage cooperative research between academia and industry. The goal of the program was to establish self-sufficient research centers of excellence in areas of critical technology. These centers would be located at universities, and staffed principally by faculty and student researchers. Those researchers would cooperate closely with scientists and engineers at partner US industrial concerns, and conduct research into critical topics of near-term importance.

The idea was simple enough -- industry folks would provide guidance and feedback, funding, and some cooperative research. Most importantly, they would provide real-world data and experience to help the researchers in their work. Meanwhile, the university researchers would contribute their time and talent, using (mostly) the research facilities of their universities, to conduct innovative research into topics that the companies were interested in but not able (or currently willing) to pursue. The industrial concerns would get first crack at licensing or developing the results of this research as a direct pay-back for their investment.

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The researchers gain from this because they get access to real-world data and experience to validate their models and guide their research. They get to explore ideas they might not otherwise get to investigate. Furthermore, they gain in the interaction with researchers at affiliate companies, and they gain access to some stable, long-term funding for their work. The companies gain by having immediate access to innovative research that is often outside the areas they can support. They get to interact with some world-class researchers, and they often get to take advantage of new graduates, summer internships, and possibilities of sending their personnel for advance degrees while working on company-specific projects.

It's a win all the way around.

The SERC is one of over 50 such centers established by NSF, and the only one devoted to software engineering. It was founded in 1986. It has been self-supporting since its inception. The program is known at NSF as the Industry-University Cooperative Research Center program (IUCRC for short).

The SERC is co-located at Purdue University and the University of Florida in Gainesville. We also have active research associations with faculty and students at Ball State University, the University of West Florida, the University of Central Florida, the University of Minnesota, Georgia Tech, the University of Houston, UC Irvine, and the University of Massachusetts. We have a number of affiliate organizations -- our industry partners (see the "affiliates" file). And, of course, NSF is still a supporter of our work.

We have had faculty and students from CS, EE, Industrial Engineering, Management, and Systems Engineering all involved with SERC projects. To go through an entire list would take too much space (we can send a tech report list on request). We've had projects in prototyping, user interfaces, CASE technology, design methods, software testing, program debugging, maintenance tools, management-oriented metrics, real-time analysis, management methods, object-oriented design, and more. Our research is also supported by outside funding sources as well as our affiliates. Currently, we have an approximate annual expenditure rate of over $1 million dollars.

Our affiliates get to leverage into all this research and activity for a total committment of $30K per year. Yup, only $30,000 -- about 1/3 to 1/4 the cost of a MS-level software engineer. However, a chunk of that $30K comes right back as a special tax credit (the government very much wants these centers to continue their great success). Admittedly, there are some additional costs -- the company needs to have someone come to management meetings, and someone needs to take the time to read all the research information we send out) Overall, the cost is *very* reasonable for value received, and that is one reason the program has been so successful.

We've got lots of other things we've been doing, too, including an extensive publications series, seminars, participations and sponsorship in workshops and symposia, national boards, and so on. The list goes on, but if you follow these things, you've already seen us listed. If not, we can send you further details if you want.

I can send some printed info on the SERC, including an up-to-date tech report list and some past newsletters if you send me your postal (surface) address. I am also willing to follow-up to any e-mail or phone questions you may have. We have a short presentation we can make, in person or if you'd like to visit us and see some demos of our work. Just let us know.

Current Commercial Affiliates:

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Andersen Consulting Co.
AT&T Bell Labs
Bellcore
Bell Northern Research
Computer Sciences Corporation
Contel
Digital Equipment Corporation
GTE Data Services
Harris Corporation
IBM Corporation
Magnavox Government and Industrial Electronics

Current Organizational Affiliates and Contacts:

Florida High Technology and Industry Council
National Science Foundation
US Army Information Systems Engineering Command

Joining (early 1991):

Rockwell Corporation
Sun Microsystems
Westinghouse (Savannah River Plant)

—
Gene Spafford
NSF/Purdue/U of Florida Software Engineering Research Center,
Dept. of Computer Sciences, Purdue University, W. Lafayette IN 47907-2004
Internet: spaf@cs.purdue.edu uucp: ...!{decwrl,gatech,ucbvax}!purdue!spaf

2942

Could you please send me the following SERC technical reports:

SERC-TR-33-P- A Methodology for Early Software Size Estimation
SERC-TR-2-P- A Tool for Evaluating Software Engineering Environments
SERC-TR-8-P- Building an Empirical Case for CASE
SERC-TR-15-P- An Evaluation of Excelerator
SERC-TR-16-P- An Evaluation of Teamwork
SERC-TR-19-P- An Evaluation of DesignAid
SERC-TR-20-P- An Evaluation of SA Tools
SERC-TR-28-P- An Evaluation of EPOS
SERC-TR-87-P- An Evaluation of DCDS
SERC-TR-86-P- A Usability Comparison of DCDS with Five Popular CASE Tools
SERC-TR-85-P- Software Development Information Supported by DCDS
SERC-TR-77-P- Software Development Information Supported by Typical CASE Tools
SERC-TR-73-P- The Challenge of Software Engineering Project Management: Ten Years Later

My address is:

Irwin Gaines
Fermilab MS-127
PO Box 500
Batavia, IL 60510

I am working on software systems for an SSC experiment, and we are in the process of choosing software engineering tools now. The above reports will be extremely helpful to us.

Thank you very much.

Irwin Gaines

CODE MANAGEMENT EXPERIMENTS

A. FRY

SUN

SCCS & MAKE

- WELL INTERFACED
  - MAKE automatically seeks SCCS files
- MAKE EXTENSIONS
  - DETECTS INCLUDE FILE DEPENDICIES
- POWERFUL PATTERN MATCHING RULES
- Got RCS to work on SUN
  FAILED ~~to~~ ON VMS

Fry

ATTEMPT TO Extract SDCSHELL FROM PATCHY

Short answer:

Cannot be done automatically because of mix of machine, version, dependence in PATCHY

3-DAY ANSWER

+SEQ name, IF= ~
↳ #if
#include
#endif

+KEEP name, IF= ~
↳ #if
#include
#endif } separate include file

+DECK 2 → file (source)

+SELF , IF=
#if
#include
#endif

+KEEPORD +SEQORD +YESIF options into YTUBCD to build new release

- preserves
  KEEP
  SEQ
  IF sequences
- but its not THAT SIMPLE
  switch dependence in external patches is lost

Bottom line

- TRIVIAL to put cpp into PATCHY
- CONVERSE requires equivalent of writing "PATCHY"

Computing and DAQ Joint Meeting

August 8 - Thursday

Online Requirements and Architecture A. Fry(SSCL)

LPBautz:8/20/91

Fry

c - preprocessor

f77 test.F

fine on UNIX
useless on VMS
↳ GNU-C for VMS may be ok

#include filename
#define macro string
#undefine macro
#ifdef macro
#ifndef macro

#if
#elif
#endif

- - - - - - - - - - -

#pragma
#error
#line
} sometimes used

May 91 SSCVX1 :: Fry

Requirements Version I - (Rutgers meeting)

Outline of On-Line Computing Section of SDC Technical Proposal

1) Overview: The On-Line Computing System consists of an environment for running on-line tasks (including the necessary hardware), a set of tools used by on-line processes, and a selection of special (privileged) processes providing certain standard services.

2) Functional Requirements:
   a) Acquiring and recording data
      Event data
      "Non-event" (environmental) data
      Calibration data
      Run Control
   b) Insuring data integrity
      Detector performance monitoring
      Parameter and configuration management
      Calibration services
      Error detection and alarms
      Diagnostic services
      Data base/history services
   c) Physics processing
      Graphical data displays
         Event displays
         Interactive data analysis
      Preparation and management of streams of selected events (event pools)
      "Full" analysis of selected events in off-line analysis framework

   These functions will be implemented by a collection of host CPUS, workstations, consoles, subsystem CPUs, compute servers, disks, mass storage systems, networks and other peripherals sufficient to meet the needs.

   d) Software Tools: The on-line system will require standard software packages for code management, data management, code development, data bases, graphics and human interfaces. These should be the same packages used in off-line systems.

3) Relationships with other subsystems
   The on-line computing system overlaps a number of other detector subsystems. Here we describe the boundaries between on-line and these other systems.
   a) Front-end electronics
   b) Level 1 and level 2 trigger systems
   c) Level 3 trigger system
   d) Data Acquisition
   e) Slow Control
   f) Off-line computing
   g) User code

4) On-line Computing Architecture
   a) Hardware block diagram
   b) Software block diagram

5) Design philosophies and methodologies
   a) hardware
   b) software

c) modeling and simulation

6) On-line Computing Components (detailed descriptions)
   a) Hardware
      "host" computers
      Workstations/consoles
      subsystem CPUs
      compute servers
      disks
      mass storage systems
      networks
      printers and other peripherals
   b) Software
      Commercial software packages
         Code management
         Data management
         Code development
         Data base
         Graphics
         Human Interfaces
      Run control
         Process control
         Configuration management
         Calibration services
      Encapsulated services
         control interface
         monitoring interface
         data access interface
      Data monitoring services
         Run monitoring
         Event displays
         interactive analysis services
         event pools
         off-line analysis framework
      Condition monitoring services
         "non-event" data acquisition
         interface to accelerator, HV, temp, etc.
         insertion into data stream
      Alarms/limits
         notification/correction
         insertion in data stream
         local logging
         graphical interface
         automatic histogram checking
      Error logging
      Run summary logging

7) Schedule
      Milestones
      Technology Choices

8) Needed R&D

Requirements for SDC On-Line Computing

a) Acquiring and recording data
   Event data:
      100 Hz of 1 MByte events to permanent storage
      >20 streams of mostly disjoint (<20% overlap) events
         (open question: combining non-disjoint streams for analysis)
      Express line stream: 1 Hz of selected data (which is fully duplicated in other streams) goes directly to off-line analysis systems. A further 1% reduction (event selection/event compaction) reduces this 10 TB/year stream to 100GB/year permanently resident data.
   "Non-event" (environmental) data
      All data (including calibration process outputs as well as HV, magnet currents, environment, etc) goes to at least a master stream for permanent storage (looks just like an event stream). <100 KB/sec. May also go to a database.
   Calibration data
      Maximum event size 20 MByte (all channels on)
      Local (subsystem) calibration requirements (for bandwidths and processing power) are specified in DAQ and subsystem requirements.
   Run Control
      Run control automatically starts all required on-line processes. It can be run by 2 semi-skilled physicists at least 90% of the time.
      Cold start: <30 min
      Warm start: <10 min
      Stop/start new run: <5 min (need to wait for pipelines/level 3 to flush)
      Less than 5% downtime
      Can accept and log data from other sources besides level 3, including playback from "tape" of real or simulated data, unselected data passing through level 3, and condition monitoring data.
      The experiment process monitor component of run control is location independent.
b) Insuring data integrity
   Detector performance monitoring
      At least 1 data monitoring process for each subdetector (may be further geographical divisions)
      Each process runs at 1 Hz (higher bandwidth monitors can run in level 3 or in subsystem CPUs)
      Each process will have 16 MB of data space to accumulate histograms or tables (this implies roughly 30*16=500MB of "baseline" data available for comparison with current conditions)
      Software to automatically compare data with historical conditions and flag discrepancies will be available.
      A few additional data monitoring processes will be available for non-event data. These may need to run at rates of up to 50 Hz.
   Parameter and configuration management
      Configurations will only be changed between runs.
      400 MB (10 words/channel) are required to store a configuration.
   Calibration services
   Error detection and alarms
      Alarms can be handled at >10Hz peak rate
      Errors can be logged at >100Hz
   Diagnostic services
   Data base/history services

      On-line data base will include recent configurations, brief run summaries for the entire experiment, and full run summaries from the last month. Total space 100 GB.
c) Physics processing
   Graphical data displays
      Event displays
         At least 5 stations for interactive event displays
      Interactive data analysis
         At least 10 stations for interactive data analysis (dynamic histogram definition, etc.)
   Preparation and management of streams of selected events (event pools)
      Users will have the capability of defining event selection criteria that will automatically create "pools" of selected events for analysis. These pools can be shared by more than 1 user.
      There can be up to 10 separate event streams, with an integrated rate of <2Hz, and no more than 0.5 Hz in any single stream.
   "Full" analysis of selected events in off-line analysis framework
      Dynamic linking of user routines into a constantly running full offline analysis framework will be supported. It is assumed that a selection of fully reconstructed events is available and that full analysis requires 100 Mip-sec/evt. 100 Mips are thus required to provide 1Hz capacity.

   These functions will be implemented by a collection of host CPUS, workstations, consoles, subsystem CPUs, compute servers, disks, mass storage systems, networks and other peripherals sufficient to meet the needs.
d) Software Tools: The on-line system will require standard software packages for code management, data management, code development, data bases, graphics and human interfaces. These should be the same packages used in off-line systems.

   The on-line systems will provides standard interfaces to the slow control system, to monitoring processes, and to data streams, as well as the variety of software tools implied in the requirements listed above for event logging, monitoring and analysis.

Disclaimer

This a paraphrase of the "point form" requirements. It is in no way official or approved

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Section 9: Online Computing
DRAFT DRAFT DRAFT June 19, 1991

9.1 Overview

The online computing system provides services, resources, and generally an environment for tasks associated with data-taking. These consist largely of standard packages and tools, which are incorporated into template programs so that the various processes necessary for data taking have a somewhat uniform structure and differ mostly in the kind of user code they contain within the standard online encapsulation. The online system must perform not only high level run control, but also the functions of recording data on permanent media and of monitoring the data and data-taking process to insure that data integrity is maintained.

9.2 Methodology and Philosophy

First we identify the functional requirements of an online system. These requirements focus on the goal of recording data on permanent media in a form in which it can be reconstructed. If data is lost or corrupted in some way, then the online system has failed. This means we must achieve a high degree of reliablity and extensively monitor not only the data, but all relevant parameters and processes which affect the data taking process and ultimately the physics results of the experiment. Where possible correction of abnormal conditions should be done automatically. If reconstruction of the data offline requires further information than that recorded on permanent media during data-taking, the online system is incomplete. Care must be taken to record all information necessary.

The online system contacts Level III, DAQ, Trigger, Slow Controls, Front end electronics, and offline data processing. Extreme care must be taken to insure that compatible interfaces exist between these sub-systems. We must strive to keep the points of contact minimal and simple so that parallel development may proceed in each of the sub systems without excessive interdependence requiring an unrealistic degree of cooperation and organization. This philosophy extends even inside the online system software where interdependence of processes and code must be minimised. The points of contact must be specified at an early date so that development will not be held up and effort wasted.

The cost of an online system is non-neglible. We attempt where possible to use generic hardware and software. Where possible online processes will function independently of the specific location of their host cpu, thus allowing failure redundancy and multiple uses of a single cpu. A large part of the cost will be to implement and maintain the online system software. To this end, we must search for appropriate commercial software and devote the most effort to creating software building blocks which are system wide standards so that the

number of lines of code which must be created are minimized and debugging and maintainance are simplified.

9.3 Requirements

9.3.1 Data logging

The online system will be capable of recording up to 100 MBytes per second of event data. This corresponds to the standard maximum rate after level III processing of 100 MHz of 1 MByte events. The data will be separated into several streams (on order 20) for recording on permanent media, however, there is some concern as to whether such streams will be sufficiently disjoint and whether non-disjoint streams will introduce difficulties in the physics analysis of the data. An express line stream will accept data at up to 1 Hz for immediate analysis and reduction. We estimate that after reduction this stream will require 100 GB/year of permanently resident data. Additionally, all other parameters necessary for offline reconstruction will be recorded as necessary to a single stream. This is data on various experimental "conditions", including the detector HV's, the magnet, various temperatures and environmental variables, and configuration parameters. We estimate that this stream will be less than 100 KBytes/sec.

It will be necessary for the online system to record events from sources other than level III, not only for experimental condition data, but also for testing various parts of the system. An alternate event source will be provided to manage such data, enabling routing of test data into level III, bypassing of level III and otehr such tests as may be necessary. Occasionally, it will be necessary for the online system to record calibration events. These events may be much larger than physics events. The online system will be able to process events up to 20 MBytes in length corresponding to our best guess as to an "all channels on" situation.

9.3.2 Run Control

High level run control is the responsibility of the online system. This will be highly automated perhaps employing an expert system to decide logical actions. The human interface for run control will be location independent, although certain actions will be permitted only from certain locations. A high level screen management package will be used to interact with the human operators so that day to day adjustments, additions, and other modifications to the human interface will be mostly confined to simple edits of particular "screens" defined using a screen editor. Screens should perform the function of display of online system data and interaction with human operators simultaneously. A online system programmer should be able to implement a new screen in the online system in less than one day's work. It should be possible to interact using simple command lines, point and click, function keys, and probably voice.

9.3.3 Operability and Reliability

The system must operate in a "normal" mode at least 9 out of 10 days of data taking and in this mode operation should require no more than two physicists who do not have special skills in online operation. Failure to meet this requirement will almost certainly mean failure to meet the next requirement which is that the system must have less than a 5% failure rate as measured by the ratio of time the accelerator provides beams for physics to the time the online system is recording data. This of course does not include rate dependent dead-time introduced by DAQ and Trigger systems. From time to time, it will be necessary to "re-configure" the online system. This should take no more than 5 minutes. We recognise that there will be an initial "shake-down" of the entire detector and data-taking systems where these requirements may not be met. Further to requirements of online system readiness, we believe that it should be able to be restarted in less than 10 minutes and a "cold" start requiring rebooting and loading of DAQ, Trigger, etc. parameters should be able to be accomplished in less than 30 minutes.

9.3.4 Data Monitoring

It will be necessary to monitor the data as it is acquired and written to the mass storage system. The online system must be capable of routing specified kinds of data to various "data-monitoring" processes. These processes will be capable of looking at about 1 Hz of events and the number of such processes will correspond to the number of sub-systems requiring such monitoring. Some additional processes will be required to monitor "non-event" data such as HV's and environmental conditions as well as the operation and condition of the online system itself. Some of these will operate at rates up to 50 Hz.

9.3.5 Services

Standard services will be provided where possible. There will be a standard error logging and detection service which can handle 10 Hz of "alarm" messages and 100 Hz of logged error messages. An alarms and limits package will provide a standard method of detecting abnormal conditions through comparisons of current conditions with historical conditions. This package will be capable of tracking the value of a variable over time and determining significant variation in a general way, such as by by comparison of histogram to a standard histogram.

It will be necessary to provide software to manage calibration data and calibration sequences. Sometimes it will be necessary to log calibration data for offline processing and at other times calibrations will be processed in the online/DAQ systems and only the derived constants logged to the offline system.

The online system will require a database to store the details of recent configurations, brief run summaries for the duration of the experminent and full run summaries for recent runs (over the past month). We anticipate that this will require 100 GB of disk space.

Physics Processing

Users will have the capablility of dynamically defining selection criteria to create "pools" of events which can then be shared by several users who wish to do physics analysis. The online system should be capable of supporting up to 10 "event-pool" streams with an individual rate of no more than 0.5 Hz and an integrated rate over all streams of no more than 2 Hz. There should be 5 workstations provided for interactive analysis , viewing of event-pool data, and graphical display of events.

A single stream of fully reconstructed events will be provided to a constantly running system that can dynamically allow the user to insert his own analysis subroutines into an analysis framework. This stream will be provide events as needed by the analysis routines up to a maximum rate of 1 Hz.

Documentation

Effort will be required to document the online system code and operational procedures. The human interface will provide prompting and help when the user requests it. Documentation from DAQ, Trigger, etc., should also be available to and probably organised in the same way as the online documentation. It will be difficult to maintain uptodate documentation in a rapidly evolving system. We will use self-documenting code so that some documentation can be generated automatically. Documents should be managed using the code management system.

Software Tools

The online system will require standard software packages for code management, data management, code development, data bases, graphics, and human interfaces. Where possible, the same standards should be found in the offline system. Standard interfaces will be required between online processes, as well as between online processes and processes in other sub-systems. In particular, standard means of passing control messages and information, and of passing event and non-event data will be provided. These standards will be incorporated into template programs which the user will use to execute his own user code. Extensive use of MAKE will ensure that pieces of the online system are uptodate with one another and that unecessary compilations and links are not performed.

9.4 Relationships with Other Systems

The online system contacts directly and indirectly with a number of detector subsystems. Generally, it acts as a "host" which provides services to the subsystems, like cross-compilers, configuration parameters, and file management and storage. The online system has direct and intimate contact with DAQ, Trigger, Slow Controls, and Level III. It has contact with user code from all of the various detector sub-sections and this user code may be of "offline" or other variety. It has an additional formal offline contact through the data which it writes to the mass storage system and the mass storage system itself.

Front-end Electronics

The online system will archive relevant parameters and be capable of supplying them to the front end on demand. It will be possible to "login" to processors in the front end from "online" computers.

Level I and II Trigger systems

The online system will archive relevant parameters and be capable of supplying them to the trigger systems on demand. It will be possible to "login" to processors in the trigger systems from "online" computers. A trigger monitor process will run in online containing user code from the trigger group. The online system is also responsible for high level trigger control and configuration. The online system can receive and log data directly from the trigger system as necessary.

Data Acquisition

The online system will archive relevant parameters and be capable of supplying them to the DAQ systems on demand. It will be possible to "login" to processors in the DAQ systems from "online" computers. A DAQ monitor process will run in online containing user code from the DAQ group. The online system is also responsible for high level DAQ control and configuration. The online system can receive and log data directly from the DAQ system as necessary.

Slow Control

The online system will archive relevant parameters and be capable of supplying them to slow control systems on demand. It will be possible to "login" to processors in the slow control systems from "online" computers. The online system will have a few condition monitoring processes which will primarily access data from slow controls concerning various environmental parameters. The online system will be able to both monitor and control HV's in the slow control system.

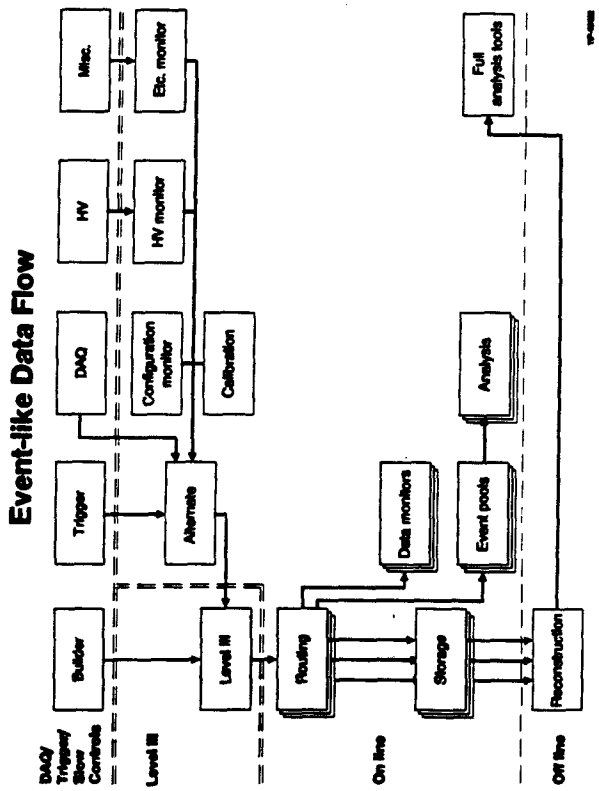
User Code

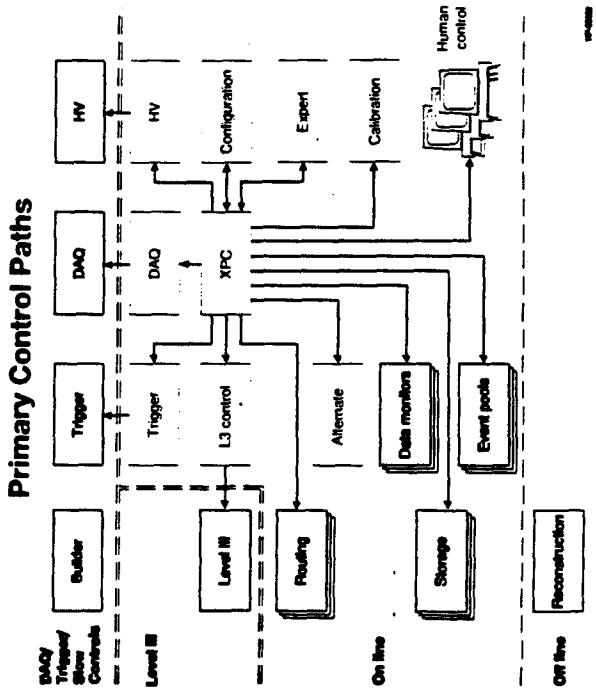
The online system must be able to run, control, and monitor various types of user code. These codes appear in the data monitoring processes, condition monitoring processes, configuration monitoring and control processes and other sub

system control processes. The online system will provide standard templates to encapsulate user code so that externally it has an "online" appearance and functionality.

Offline Computing

The online system must provide offline with "complete" data on permanent media. It is the responsibility of online to insure that the data is complete and uncorrupted. However, occasionally problems will be detected offline which require online correction. Online will be capable of receiving messages from offline programs. It will also be capable of receiving a stream of reconstructed events for online monitoring at rate of up to 1 Hz.





Integration

August 6 - Tuesday

Status Report on Underground, Surface and Facilities Systems	W. Harris(SSCL)
Cost and Schedules: Installation	D. Etherton(SSCL)
SEFUR Summary; Milestones	T. Thurston(SSCL)
Hall Parameters	J. Piles(SSCL)
Toroid Supports	J. Western(SSCL)
Electrical Systems	W. Kampmeier(SSCL)
Mechanical Systems	M. Hecht(SSCL)
Cryogenics	B. Richardson(SSCL)
Detector ES&H	B. Lavelle(SSCL)
Detector Construction Planning	J. Brown(Kaiser)
Report of the Task Force on Magnet/ Tracking Configuration	T. Ryan(LBL)
Integration for LA, Tile/Fiber	D. Bintinger(SSCL)
Update on Electronics Integration	
Straw Electronics	D. Van Berg (Pennsylvania)
Muon Supermodules	F. Feyzi(Wisconsin)
Electronics within Barrel, Status and Request for Feedback	A. Dubois(LBL)
Layout of Forward System	A. Dubois(LBL)
Preliminary Integrated SDC Schedule	W. Edwards(LBL)

LPBautz:8/23/91

AGENDA

Cost and Schedules; Installation	Dave Etherton
SEFUR; Milestones	Tim Thurston
Hall Parameters	Jon Piles
Toroid Supports	Jeff Western
Electrical Systems	Warren Kampmeier
Mechanical Systems	Marvin Hecht
Cryogenics	Bob Richardson
Surface Facilities	Tom Prosapio
Detector ES&H	Bob Lavelle
Test Beams	Ray Stefanski

COST AND SCHEDULES: INSTALLATION

D. ETHERTON

Cost of Experimental Facilities Construction

Underground Facilities - IR4

- 106m X 31m clear Hall with (2) Construction shafts
- Current costing exceeds baseline costing, major areas of increase are:
  - Floor Slab and Reinforcing
  - Caissons
  - Finishes and Installed Systems (Mechanical/Electrical Systems)
  - Interior Special Systems (Catwalks, Electronics rooms, In-hall Elevators)
- Will need to address optimization to include:
  - Decrease hall length
  - Decrease hall width
  - Eliminate (1) construction shaft
  - Simplify interior systems

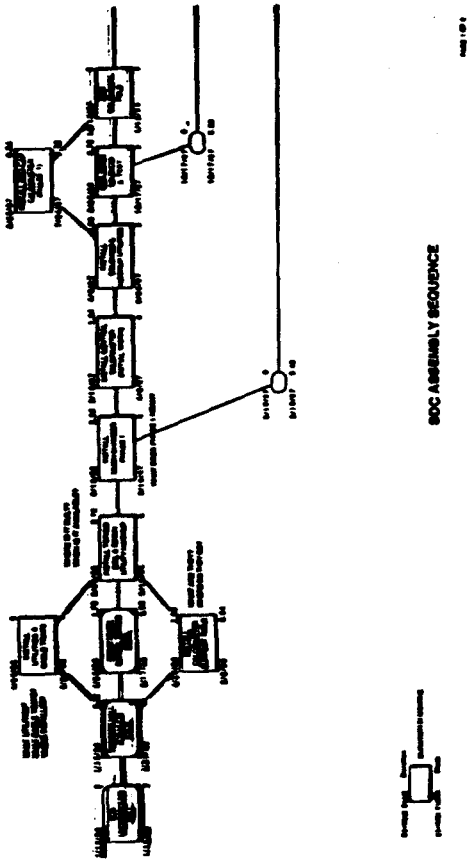
Surface Facilities - IR4

- SDC Facilities as specified in June 7 & 13 "requirements"
- Current costing exceeds baseline costing, major areas of increase are:
  - Increase in total area of surface facilities
  - Increase in facility unit pricing
- Will need to address optimization to include:
  - Simplify facilities to lower unit costs
  - Explore alternatives including phasing, leasing, grouping buildings

Overall IR4 Area

- May need to reduce by 10% (or more) across U/G and Surface Facilities

DLE 8/6/91



TASK TITLE: Prepare Hall for Mount Steel Structure		TASK NUMBER: 1
TASK SYNOPSIS: This task describes the installation of the support structure for the SDC detector. It consists of the installation and alignment of an hydraulic jacking system plus steel girders, trusses, and cross members.		
TASK START DATE: 1/15/96	TASK FINISH DATE: 6/15/96	TASK DURATION: 5 months
DEPENDENT FINISHED TASKS: BOD of experiment hall		

APPROXIMATE SIZE AND WEIGHT OF EQUIPMENT TO BE INSTALLED:

Item	Length	Width	Height	Weight
Hydraulic Jacks (80 each)				1 tonne
Horizontal Girders (4 each)				60 tonnes
Cross Members (40 each)	9 m	0.2 m	0.5 m	8 tonnes
Inclined Plates (6 each)	10 m	0.3	3 m	75 tonnes
Space Truss (3 each)	10 m	10 m	1 m	5 tonnes
Hydraulic Controls & Readout Equipment				

FACILITIES, EQUIPMENT & TOOLING, POWER, UTILITIES FOR TASK:
Headhouse hoist (100 tonnes)
Detector Hall hoist (100 tonnes)
Optical Alignment Equipment
Scaffolding and Work Platforms

ATTACHMENTS (check appropriate box):	
DRAWING (Number)	
DRAWING (Number)	
DRAWING (Number)	
DIAGRAMS	
TABLES	
OTHER SUPPORTING DOCUMENTS (Identify)	
SCHEDULE	
LOGIC FLOW DIAGRAM	X
ACTIVITY SEQUENCE DESCRIPTION	X

ELEMENT SPECIFICATION

FOR THE

SOLENOIDAL DETECTOR COLLABORATION (SDC)

EXPERIMENTAL FACILITIES

(USER REQUIREMENTS)

SCT-000001

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4.3.2.2.12 Grounding System
4.3.2.2.13 Public Address System
4.3.2.2.14 Panic Alarm Stations
4.3.2.2.15 Radio Communication System
4.3.2.2.16 Video System
4.3.2.2.17 Emergency Telephone System
4.3.2.2.18 Technical Specifications
4.3.2.2.18A Electrical Specification Section

4.3.2.3 Cryogenics
4.3.2.3.1 Underground Equipment
4.3.2.3.1.1 Detector Equipment
4.3.2.3.1.2 Piping Access and Maintenance

4.3.2.3.2 Surface Routing
4.3.2.3.3 Surface Equipment
4.3.2.3.4 Electrical & Mechanical Utility Requirements
4.3.2.3.4 Safety
4.3.2.3.4 Interfaces

5.0 SCHEDULE

5.1 Detector Schedule
5.1.1 Summary SDC Project Schedule

5.2 IR4 Underground Facility Schedule
5.2.1 IR4 Underground Facility Summary Schedule

5.3 IR4 Surface Facilities Schedule
5.3.1 IR4 Surface Facilities Summary Schedule

5.4 IR4 Utilities and Infrastructure Schedule
5.4.1 IR4 Utilities and Infrastructure Summary Schedule

6.0 MODIFICATIONS TO THE DETECTOR HALL REQUIRED FOR LAC OPTION 2

Proposed
FY91-92 Milestones
SDC Experimental Facilities User Requirements

SEFUR Rev. A	Aug 02 '91	
	Aug 05 '91	Collaboration Meeting (LBL)
SEFUR Rev. B	Sep 01 '91	
	Oct 01 '91	U/G Pre-Title I Report Complete
SEFUR Rev. C	Oct 01 '91	
	Oct 15 '91	U/G Title I Design Begins
SEFUR Rev. D	Jan 01 '92	
	~Feb 15 '92	Site Infrastructure Title I Begins
SEFUR Rev. E	Mar 01 '92	
	Mar 15 '92	U/G Title I Report Complete
	Apr 15 '92	U/G Title II Design Begins
SEFUR Rev. F	Jun 01 '92	
	Jul 15 '92	Initial Surface Facility Design Begins

Proposed
FY 91-92 Milestones
Experimental Facilities and Detector Engineering

• Interim Chief Engineer at SSCL (PRD)	Aug 01 '91
• Initiate Installation Planning at SSCL (PRD)	Aug 01 '91
• Facilities Interface/Integration Transition to SSCL Begins (PRD)	Aug 01 '91
• Cost/Schedule/Tracking Transition to SSCL Begins (PRD)	Aug 01 '91
• Scope decision (new cost baseline) (SDC)	Aug 10 '91
• Mechanical Integration Transition to SSCL Begins (PRD)	Oct 01 '91
• Document Control Transition to SSCL (PRD)	Oct 01 '91
• SDC Support Approved Conceptual Design and Scope of Work (PRD)	Oct 01 '91
• Fix Baseline for Technical Proposal (SDC)	Oct 15 '91
• Initial Installation Plan Release (PRD)	Nov 01 '91
• First Draft of Technical Proposal (SDC)	Jan 15 '92
• First Draft of Cost/Schedule Book (SDC)	Jan 15 '92
• Internal Reviews (SDC)	Jan 20 '92
• SDC Support Technical Review (PRD)	Mar 01 '92
• E.S. & H Review of Detector (PRD)	Mar 01 '92
• Technical Proposal Submitted (SDC)	Apr 01 '92
• Cost/Schedule Book Submitted (SDC)	Apr 01 '92
• Project Mgmt. Transition to SSCL Complete (PRD)	Apr 01 '92
• Begin Detector Construction (SDC) Oct 01 '92	

HALL PARAMETERS

J. PILES

I. Underground Hall (Civil)

A. Location
1. Located at IR4 on west campus.
2. Depth to beam line of 41.9 meters.

Thurston

B. Hall Structure
1. Useful width 31 meters
2. Useful length 105 meters
3. IR point offset to the East and North walls.
4. North operating floor 30 meters long.
5. South operating floor 35 meters long.
6. Detector pit length of 50 meters.

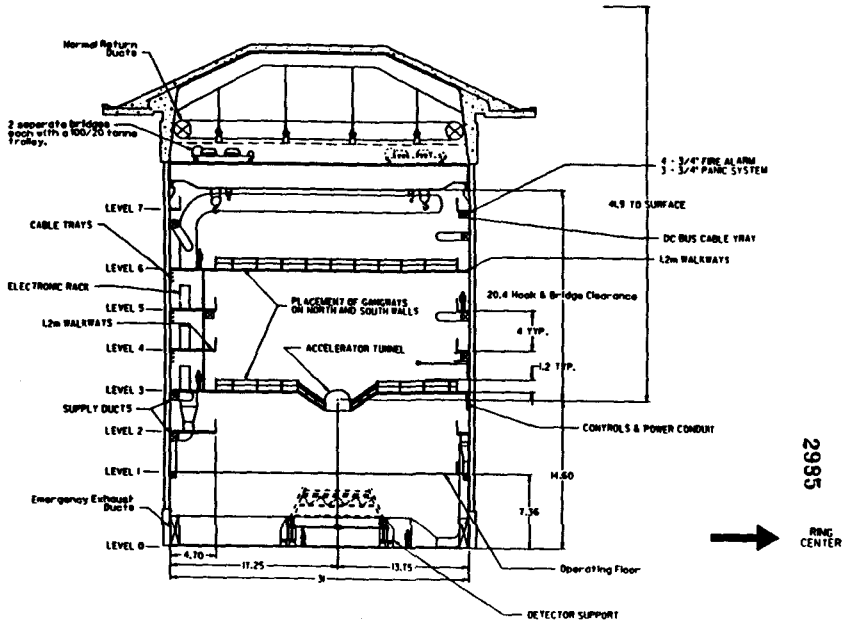
C. Hall Shafts
1. Two offset utility shafts (4 x 6)
2. North Personnel Shaft (5.4 x 4.9)
   a. Positive pressure 4000 lb elevator
   b. Positive pressure stair shaft
3. South Equipment/Personnel Shaft
   a. Positive pressure 2000 lb elevator
   b. Positive pressure stair shaft
   c. Guided hoistway (4 x 3)
4. Cable Shaft (6 m dia.)

II. Underground Hall (Equipping)

A. Lifting Devices
1. Two overhead 100/20 tonne bridge cranes.
2. Small equipment lift in cable shaft. (1 x 2)
3. Guided hoist will be defined with surface facility.

B. Interior Access in U/G Hall
1. Seven levels of walkways on East and West walls.
   a. One thru six on west wall are 4.7 m wide.
   b. All others are 1.2 m wide on both walls.
   c. Level seven for crane access.
   d. Spaced 4 meters apart.
2. Two levels of walkways on North and South walls.
   a. Corresponds to levels 3 and 6 of side walls.
3. Stairs
   a. Four flights connecting all levels of gangways.
   b. Four flights connecting operating floors to pit.
4. Four service elevators
   a. Two on west side minimum capacity of 2000 lbs.
   b. Two on east side minimum capacity of 1000 lbs.

5. Detector assembly shafts.
   a. Located 26 m. north and south of IR point.
   b. 11 x 31 m
   c. Reduced to 11 x 14 m (Location TBD)



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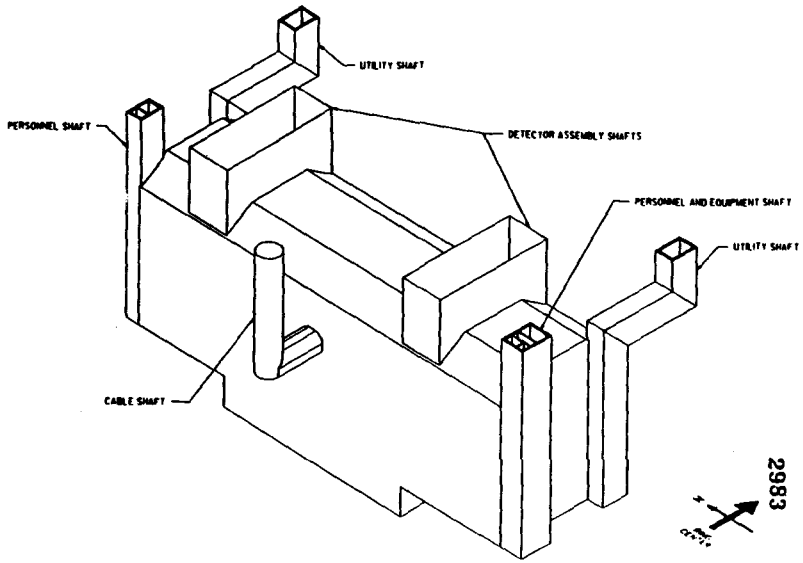

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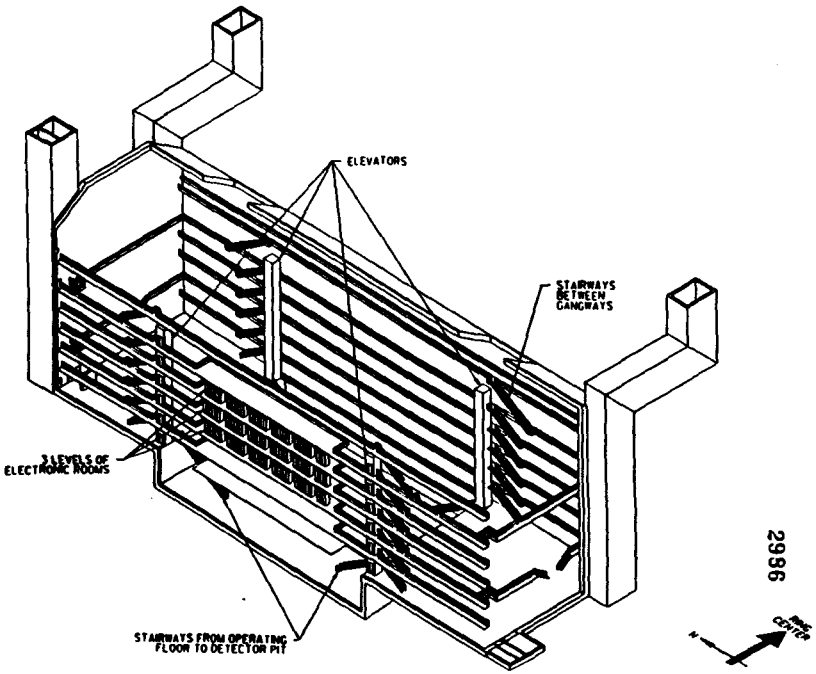
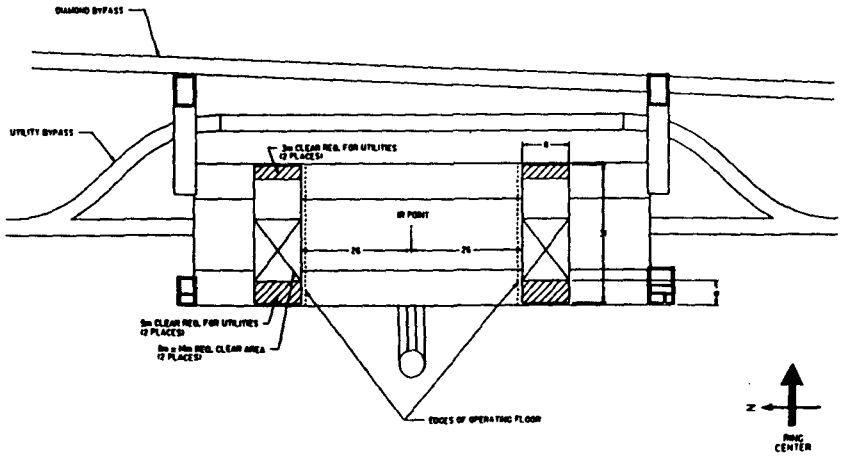


HALL INFRASTRUCTURE
FIGURE 4.1.2.4.4

2986

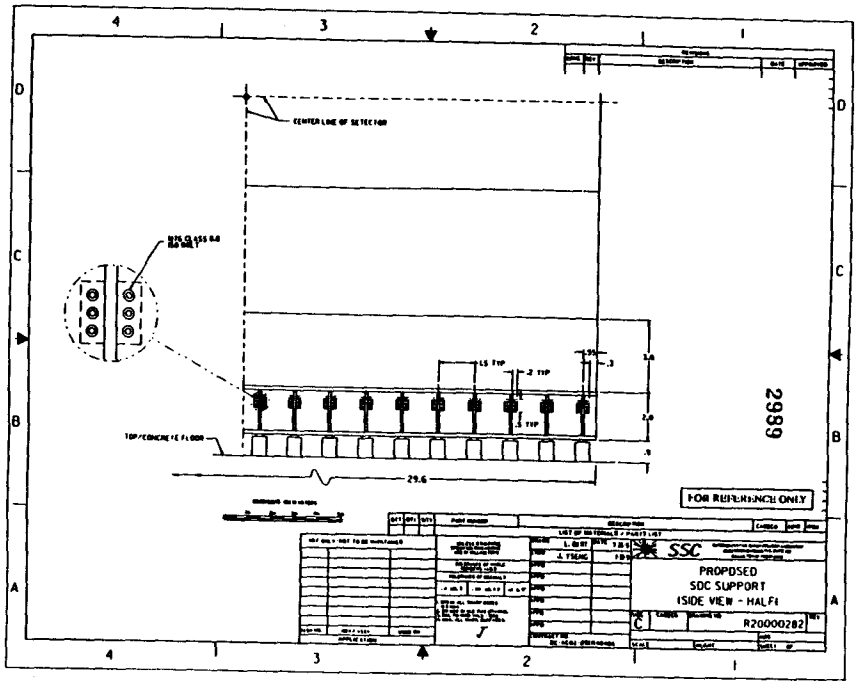


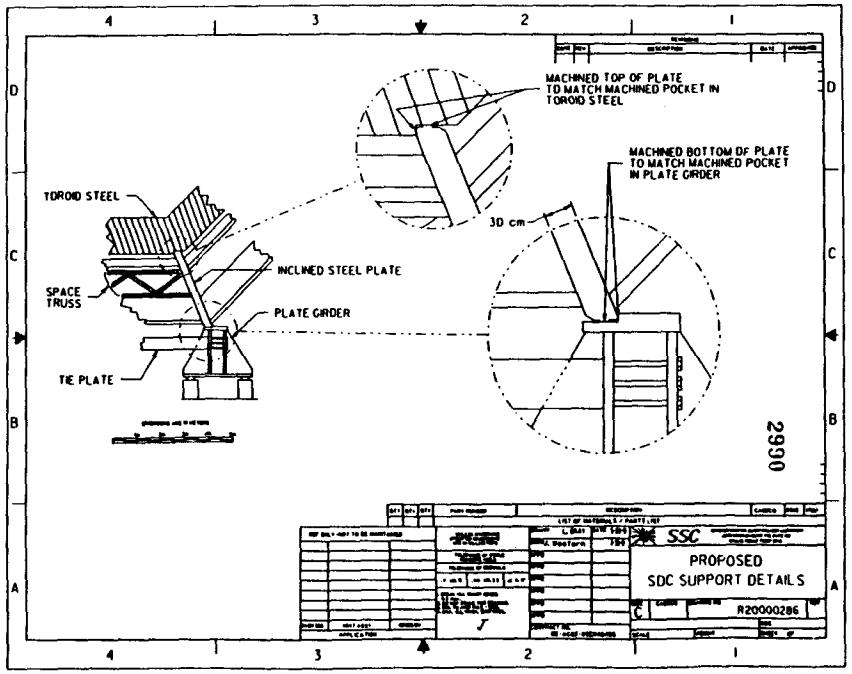
2984

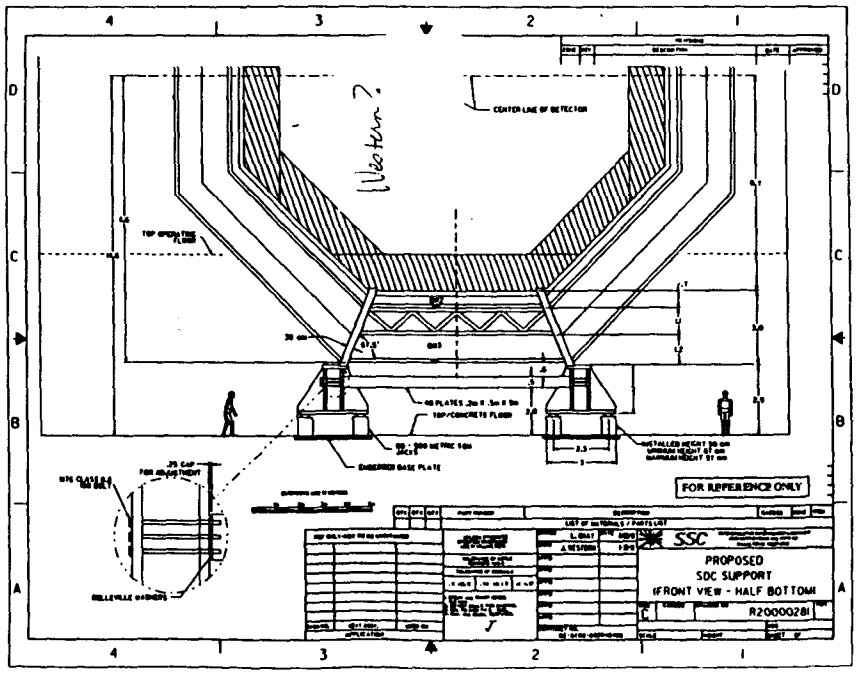
TOROID SUPPORTS

J. WESTERN

2987







2988

SDC - DETECTOR DEFORMATION LIMITS

MAXIMUM DEFORMATION: CANTILEVERED DEFLECTION CAN NOT EXCEED 10 mm OVER A 5 METERS SECTION OF THE DETECTOR

MAXIMUM RIGID BODY DEFLECTION: +30 mm / -70 mm OVER THE ENTIRE DETECTOR LENGTH

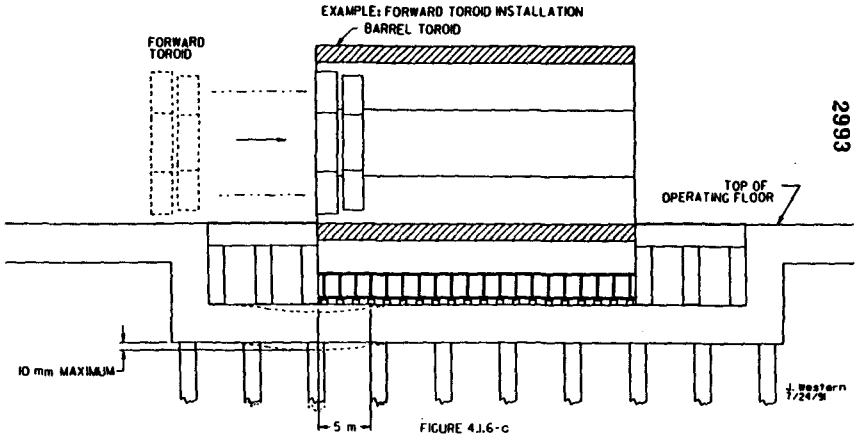


FIGURE 4.1.6-c

2993

SDC - DETECTOR DEFORMATION LIMITS

MAXIMUM DEFORMATION: UNIFORM DEFLECTION CAN NOT EXCEED 20 mm (+/- 10 mm) OVER THE LENGTH OF THE DETECTOR (29.6 METERS)

MAXIMUM RIGID BODY DEFLECTION: +30 mm / -70 mm OVER THE ENTIRE DETECTOR LENGTH

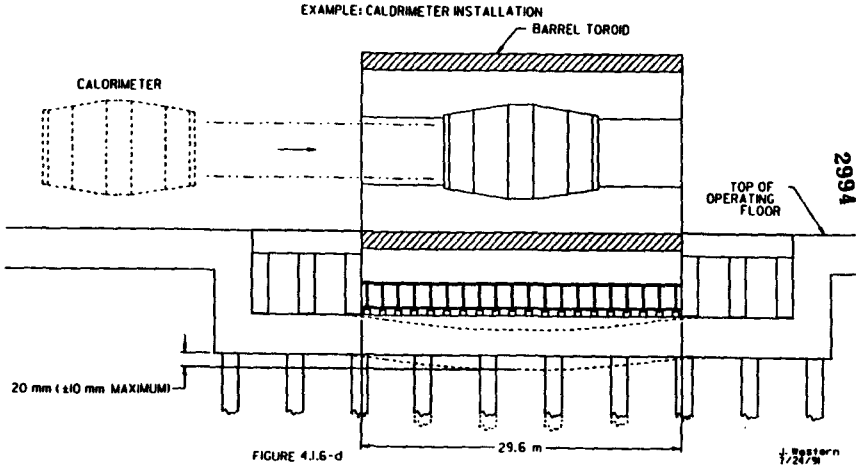
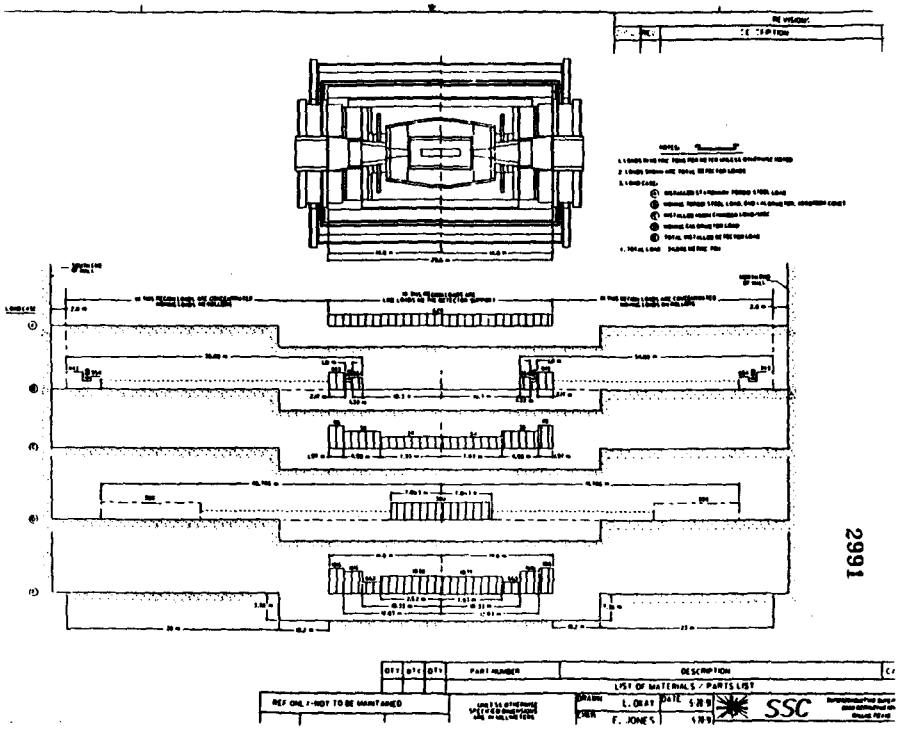


FIGURE 4.1.6-d

2994



2991

SDC DETECTOR SUPPORT MAXIMUM LOADING DIAGRAM

Jeffrey L. Western
July 31, 1991

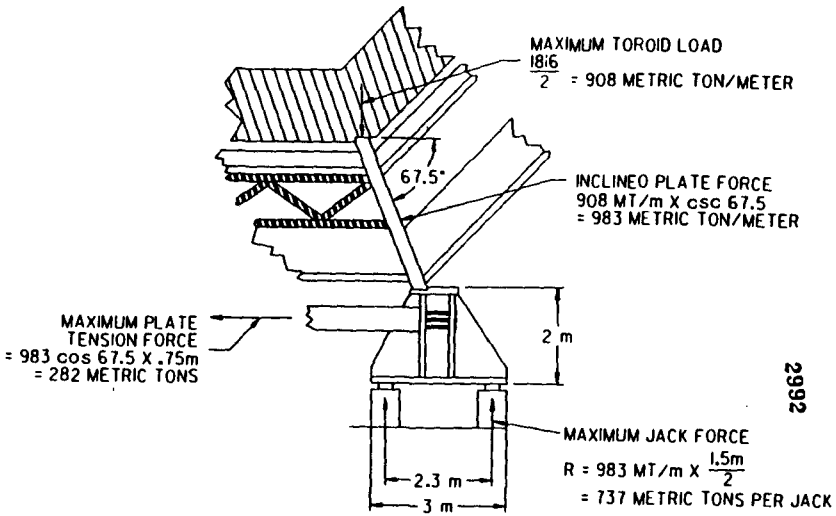


FIGURE 4.1.6-b

2992

4.1.6 SDC Detector Floor Loading Conditions

The following loading conditions represent the combinations of loads as described on drawing R20000357 "SDC Detector Floor Loads" (Figure 4.1.6-a)

4.1.6.1 Operating condition

This is represented by Load Case E.

4.1.6.2 Installation Condition

This is represented by the worst combination of Load Case A, B, C, and D.

4.1.6.3 Maintenance condition

This is represented by either:

a) The worst combination of Load Case A, B, C, and D.

b) Leveling of the detector (load Case E) and there is a failure of a number jacks. The maximum jack loading is 737 metric ton per jack. See the "SDC Detector Support Maximum Loading Diagram". An estimate is that the individual jack loading would increase 20% (120% x 737 metric ton = 884 metric ton maximum) if there was a local jack failure. Design of the floor should include this local 20% increase of Load Case E (Example: one jack fails...load get spread over 5 surrounding jacks, two jacks fail...load gets spread over 10 surrounding jacks).

4.1.6.4 Future Condition

This condition would be best satisfied by assuming a possible 5% increase of any of the loading components as identified in Load Case A, B, C, or D.

4.1.6.5 Deflection Condition

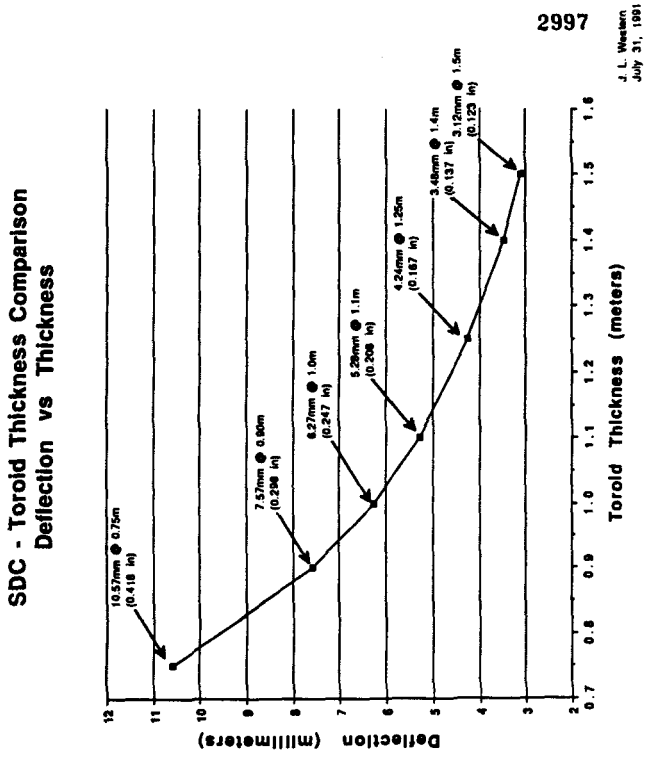
The SDC detector has a tolerance limit of +/- 3 mm over its entire length of which the majority of the tolerance compliance is achieved through the hydraulic jacking system. To assure operational performance of the detector and its support system, the concrete foundation must provide support for the detector such that no differential settlement of more than +/- 10 mm occurs across the jacking plane (plate bending of the jacking plane) throughout the life of the system. Global system (rigid body) settlement of the entire foundation (both displacement and rotation) is an order of magnitude less critical and has a tolerance range of +3 cm (rise of the foundation) / -7 cm (settlement of the foundation).

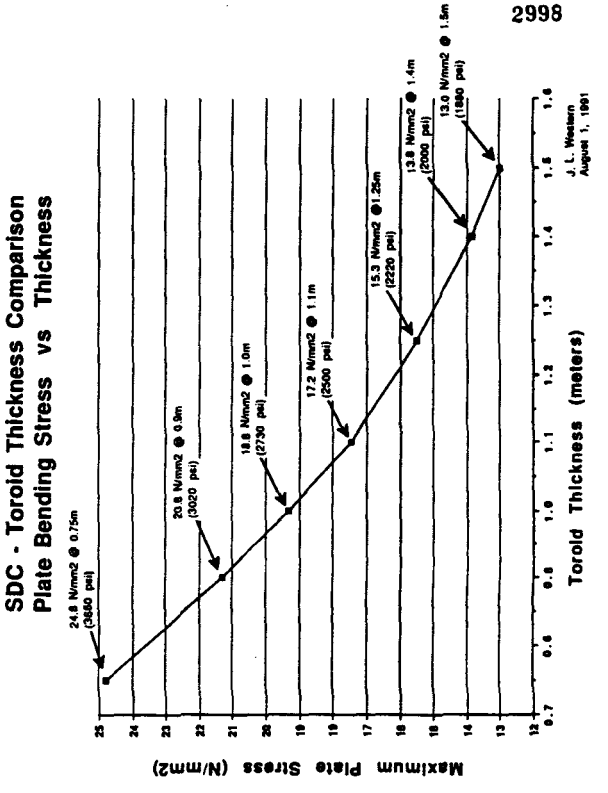
Summary of Data

Toroid Thickness	Maximum Deflection	Maximum (1) Plate Stress	Maximum (2) Bolt Stress
1.5 Meter	3.12 mm (0.123 inch)	13.0 N/mm² (1,880 PSI)	206 N/mm² (29,800 PSI)
1.4 Meter	3.48 mm (0.137 inch)	13.8 N/mm² (2,000 PSI)	210 N/mm² (30,400 PSI)
1.25 Meter	4.24 mm (0.167 inch)	15.3 N/mm² (2,220 PSI)	219 N/mm² (31,770 PSI)
1.1 Meter	5.28 mm (0.208 inch)	17.2 N/mm² (2,500 PSI)	232 N/mm² (33,700 PSI)
1.0 Meter	6.27 mm (0.247 inch)	18.8 N/mm² (2,730 PSI)	246 N/mm² (35,720 PSI)
0.9 Meter	7.57 mm (0.298 inch)	20.8 N/mm² (3,020 PSI)	264 N/mm² (38,300 PSI)
0.75 Meter	10.57 mm (0.416 inch)	24.8 N/mm² (3,600 PSI)	316N/mm² (45,770 PSI)

1. Allowable Plate Stress = 0.6 Fy (AISC Allowable)
   (1010 Carbon Steel) = 0.6 x 210 N/mm² (30,000 PSI)
   = 125 N/mm² (18,000 PSI)

2. Allowable Bolt Stress = 0.33 Fu (AISC Allowable)
   (M56 Class 8.8 Bolt) = 0.33 x 830 N/mm² (120,000 PSI)
   = 275 N/mm² (39,600 PSI)





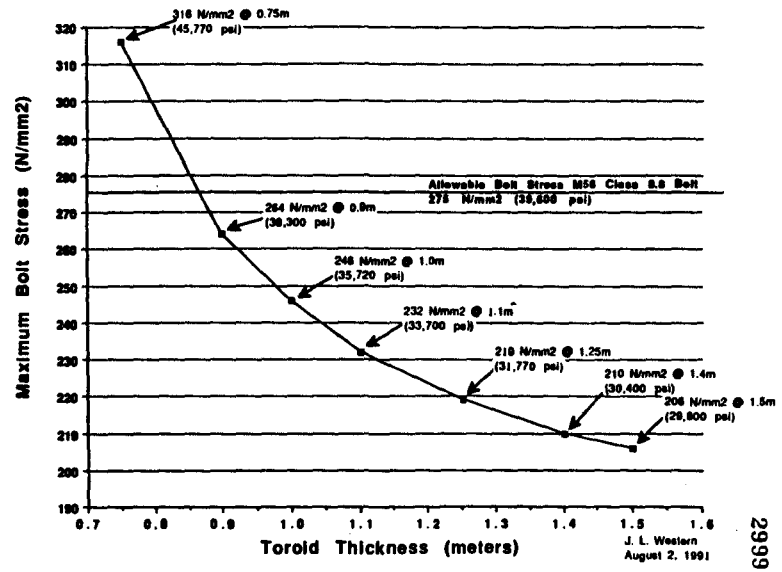
SSC Laboratory Physics Research Division

SDC - Muon Toroid Milestones

- Approved Conceptual Design ... August 1991 (Jeff Cherwinka)
- Technical Review ... March 1992
- Technical Proposal Complete (Preliminary Design) ... April 1992
- Detail Design Complete ... April 1993
- First Steel Piece Made ... January 1994
- Last Steel Piece Made ... September 1995
- Begin Installation ... March 1996
- Installation Complete ... November 1996

J. L. WESTERN 8/1/91

SDC - Toroid Thickness Comparison
Bolt Tension Stress vs Thickness



SSC Laboratory Physics Research Division

SDC - Support Milestones

- Approved Conceptual Design & Scope of Work ... October 1991
  (Internal Review ... September 1991)

  Note: In order to complete the Conceptual Design and Scope of work by October 1991 we need to:
  1) Fix the toroid steel thickness and size by August 9, 1991.
  2) Finalize the support concept by September 2, 1991.
- Selection of Engineering Design Firm ... January 1992
- Technical Review ... March 1992
- Technical Proposal Complete ... April 1992
- Detail Design Complete (15 months) ... April 1993
- Support Fabrication Complete ... February 1995
- Pre-assembly Complete ... November 1995
- Installation Complete ... March 1996

J. L. WESTERN 8/1/91

ELECTRICAL SYSTEMS

W. KAMPMEIER

4.3.2.2 Technical Electric Utilities

Technical electric utilities are described by system below.

Index of Systems

4.3.2.2.1 D.C. MAGNET PS AND BUSING

4.3.2.2.2 CRYOGENIC ELECTRICAL SYSTEM

4.3.2.2.3. HEATING, VENTILATING and AC POWER DETECTOR *

4.3.2.2.4 ACCELERATOR INTERFACE

4.3.2.2.5 BUTANE ELECTRICAL SYSTEM

4.3.2.2.6 LCW SYSTEM POWER

4.3.2.2.7 AIR COMPRESSOR SYSTEM POWER

4.3.2.2.8. HYDRAULIC PUMP POWER **

4.3.2.2.9 415 HERTZ POWER

4.3.2.2.10. ELECTRONICS and CLEAN POWER *

4.3.2.2.11 CABLE TRAYS

4.3.2.2.12 GROUNDING SYSTEM **

4.3.2.2.13 PUBLIC ADDRESS SYSTEM

4.3.2.2.14 PANIC ALARM STATIONS

4.3.2.2.15 RADIO COMMUNICATION SYSTEM

4.3.2.2.16 VIDEO SYSTEM

4.3.2.2.17 EMERGENCY TELEPHONE SYSTEM

4.3.1.2 Conventional Electrical Utilities

Requirements for conventional electrical utilities are described by system below.

Index of Systems

4.3.1.2.1 SITE UTILITIES - ABOVE GRADE

4.3.1.2.2 HALL and UTILITY BUILDING POWER

4.3.1.2.3 ELECTRONICS POWER

4.3.1.2.4 EMERGENCY POWER

4.3.1.2.5 GENERAL HALL LIGHTING

4.3.1.2.6 GROUNDING SYSTEM

4.3.1.2.7 HEATING and VENTILATING POWER FOR HALL

4.3.1.2.8 HEATING and VENTILATING POWER FOR DETECTOR

4.3.1.2.9 TELEPHONE SYSTEM-NORMAL

4.3.1.2.10 ACCELERATOR INTERFACE

4.3.1.2.11 FIRE ALARM SYSTEM

July 20,1991

MECHANICAL SYSTEMS

M. HECHT

SSC Laboratory — Physics Research Division

SDC Detector

Review of Conventional Systems

Hecht(?)

1. *Hall Air Conditioning*
   - a. *Normal Mode - 2 Air Changes.*
     Return air from top of hall only. 25% Outside air
   - b. *Emergency Mode - 4 Air Changes.*
     Air is exhausted from top and bottom of hall. 100% Outside Air
2. *Detector Air Conditioning*
   - a. *Same unit serves both detector and electronic rack rooms.*
     If nitrogen used for detector, it would fill rack rooms also.
   - b. *Air is 100% exhausted.*
3. *Miscellaneous systems for surface facilities*
   - a. *Computer room units.*
   - b. *Clean room areas.*
   - c. *Office type air conditioning.*
   - d. *Forced ventilation for large industrial areas.*

Recent Concepts

1. ***Combining the electronic rack rooms with the detector air conditioning.***
   - ***a. System has additional cooling coils to provide larger delta T.***
   - ***b. Uses 100% outside air which can be useful for smoke removal.***
2. ***Mixed chilled water heat exchanger and pumps moved to pit in Experimental Hall.***
   - ***a. Removes head pressure from electronic rack heat exchanger.***
   - ***b. Chilled water is brought from surface instead of mixed chilled water.***
3. ***Butane refrigerator and glycol heat exchanger moved into pit with Mixed Chilled Water System.***
   - ***a. Equipment can be organized in one area of the pit.***
   - ***b. Location of Butane condenser must be determined.***

8/3/91

4. ***Cooling Pond Water***
   - ***a. Primary source of cooling.***
   - ***b. Provided to Experimental Areas with maximum Temperature of of 90°F (32.2°C)***
5. ***Chilled Water***
   - ***a. Provided by chillers in Utility Building.***
   - ***b. Provides cooling for LTLCW, MCHW***

8/3/91

4.3.1.1.4 INTERFACES

8/2/91

System	Interface with	Location of Interface	Type of Interface: System Type	Type of Interface: Equip.	Drawing No.	System Deg F gpm or cfm	Interface Deg F gpm or cfm
Cooling Pond Water (CPW)	Central Plant Chillers	South Utility Building	All Conventional	n/a	R20000350	60-100	60-45
						6750 gpm	3600 gpm
	HTLCW	South Utility Building	Conventional-Technical	Heat Exch.	R20000349	60-100	140-100
					R20000352	532 gpm	227 gpm
	Cryogenics Compressor	North Utility Building	Conventional-Technical	Isolation Valves	R20000349	60-102/101	60-102/101
						174/520 gpm	174/520 gpm
	Refrig. for Butane Sys	Pit in Hall	Conventional-Technical	Isolation Valves	R20000349	60-100	60-100
						34 gpm	34 gpm
	Makeup for Deion. Sts.	South Utility Building	Conventional-Technical	Make-Up Valve	R20000349	60	60
					R20000352	50 gpm	50 gpm
	Fire Pump	North Utility Building	All Conventional	n/a	R20000349	n/a	n/a
						1000gpm	1000 gpm
Hall HVAC System	None	n/a	All Conventional	n/a	R20000348	55-75*	n/a
						102000 cfm	n/a
Detector / Rack Room HVAC	Detector Ventilation	Experimental Hall	Conventional-Technical	Det. Plenum	R20000351	72.5	75
						20000 cfm	20000 cfm
	Electronic Rack Room Vent.	Experimental Hall	Conventional-Technical	Booster coils	R20000351	55-70*	75
						6000 cfm	6000 cfm
Chilled Water (CHW)	Hall HVAC Units	E of S & N Utility Buildings	All Conventional	n/a	R20000350	45-60	n/a
						600 gpm	n/a
	Det/Rack Rm HVAC Units	E of S Utility Building	All Conventional	n/a	R20000350	45-60	n/a
						356 gpm	n/a
	LTLCW	South Utility Building	Conventional-Technical	Heat Exch.	R20000350	45-60	85-65/80-65
					R20000353	1414 gpm	1040/23 gpm
	Mixed CHW	Pit in Exper. Hall	Conventional-Technical	Heat Exch	R20000350	45-60	75-80
					R20000354	526 gpm	526 gpm
	Rack Rm Water Coils	Experimental Hall	All Conventional	n/a	R20000354	45-60	n/a
						18 gpm	n/a
Common Exhaust	Tracker Exhaust	Experimental Hall	Conventional-Technical	Plenum	R20000356	Low temp.	Low temp.
						3000 cfm	3000 cfm

n/a - not applicable
* - temperature range

C3.1

Review of Technical Systems

1. ***Detector Air Conditioning***
   - ***a. From interface with conventional system into the detector.***
   - ***b. From interface with conventional system into the rack rooms.***
2. ***High Temperature Low Conductivity Water (HTLCW).***
   - ***a. Source of cooling for Toroid Coil Power supplies and bus ducts.***
   - ***b. Cools solenoid power supplies and bus ducts.***
3. ***Low Temperature Low Conductivity Water (LTLCW).***
   - ***a. Major source of cooling for Muon Toroid Coils.***
   - ***b. Cools Silicon Tracker power supplies.***
4. ***Mixed Chilled Water System***

   Used for cooling in heat exchangers in electronic racks
5. ***Butane System***
6. ***Muon Chamber Gas System***

8/3/91

CRYOGENICS

B. RICHARDSON

3011

Richardson(?)
Cryogenics

TOP VIEW

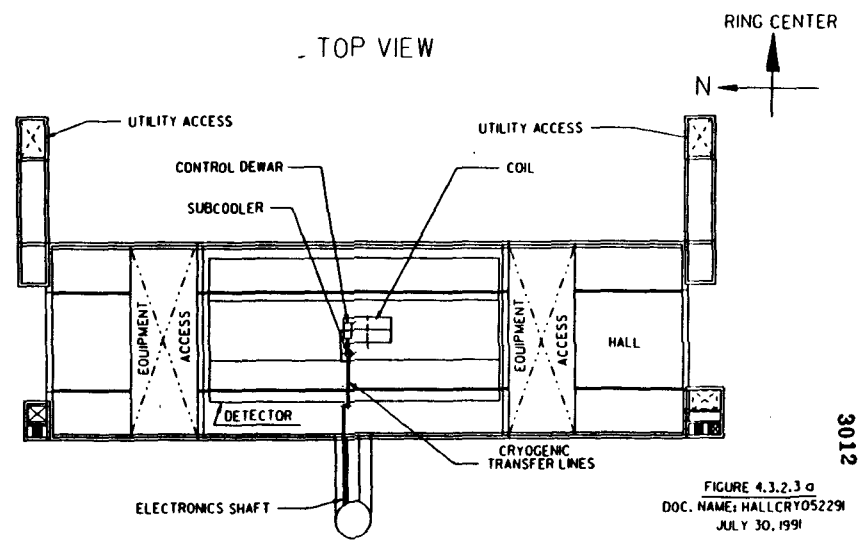


FIGURE 4.3.2.3 a
DOC. NAME: HALLCRYO52291
JULY 30, 1991

3012

ELEVATION LOOKING EAST

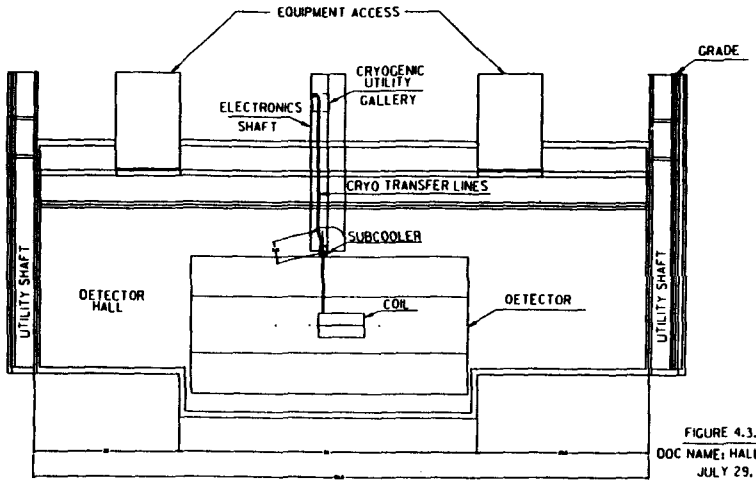


FIGURE 4.3.2.3 b
DOC NAME: HALLCRYO52291
JULY 29, 1991

3013

ELEVATION LOOKING NORTH

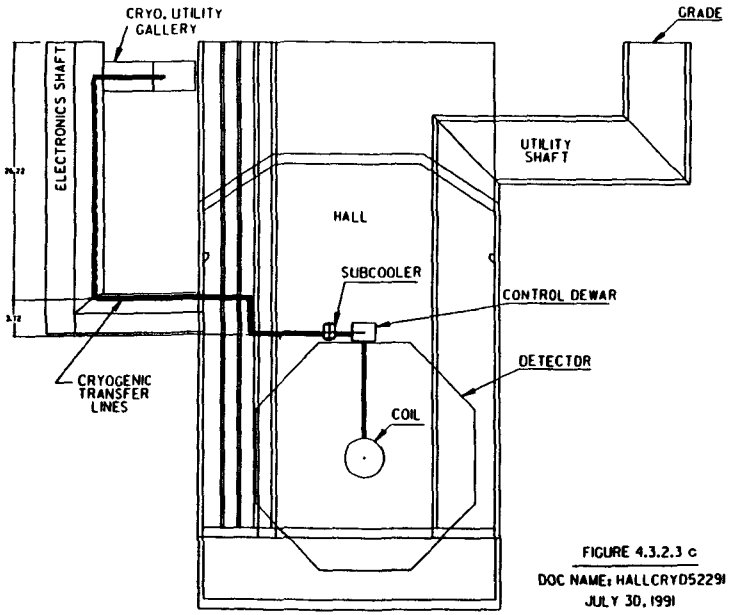


FIGURE 4.3.2.3 c
DOC NAME: HALLCRYO52291
JULY 30, 1991

3014

ELEVATION LOOKING NORTH

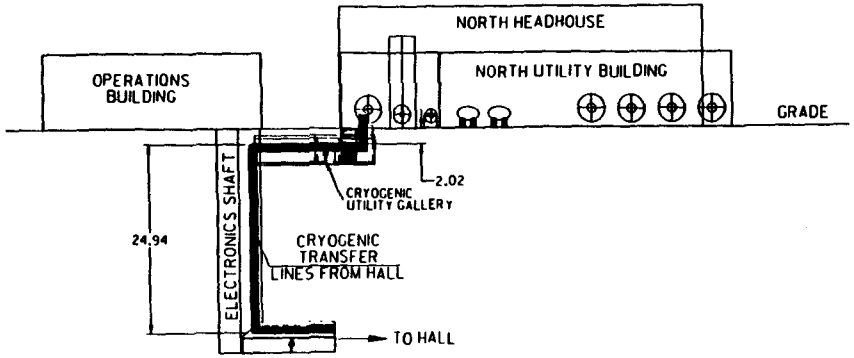


FIGURE 4.3.2.3 f

DOC NAME: SURFACE3.CRYO

JULY 29, 1991

3017

ISOMETRIC VIEW

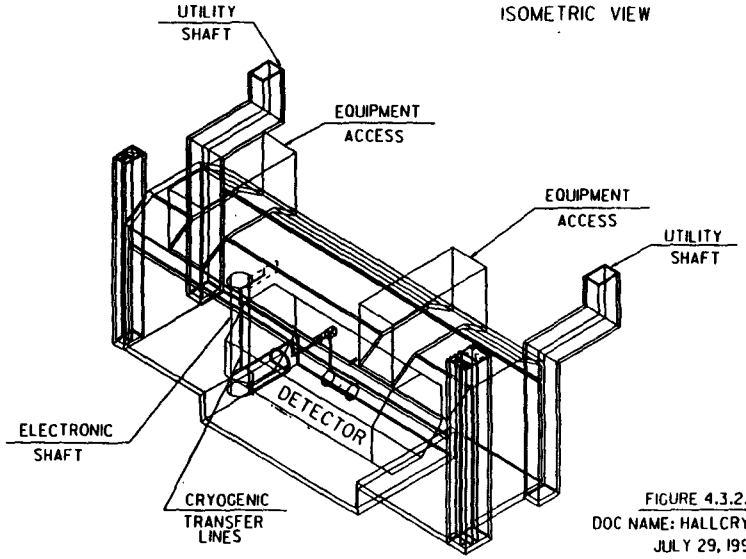


FIGURE 4.3.2.3 d

DOC NAME: HALLCRYO52291

JULY 29, 1991

3015

ELEVATION LOOKING WEST

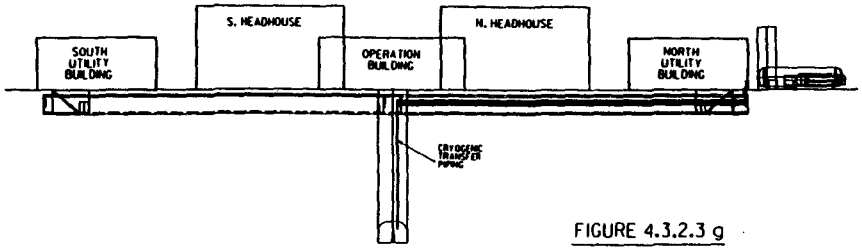


FIGURE 4.3.2.3 g

DOC. NAME: SURFACE3.CRYO

JULY 30, 1991

3018

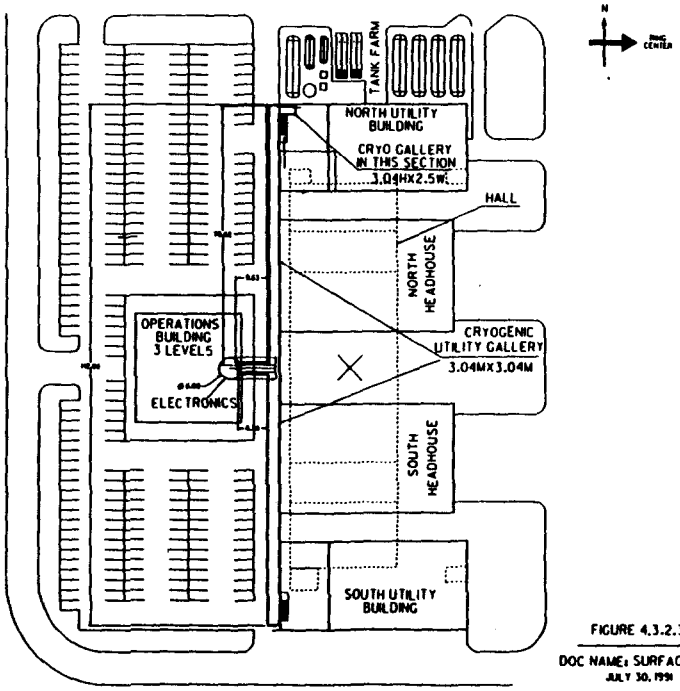


FIGURE 4.3.2.3 e

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JULY 30, 1991

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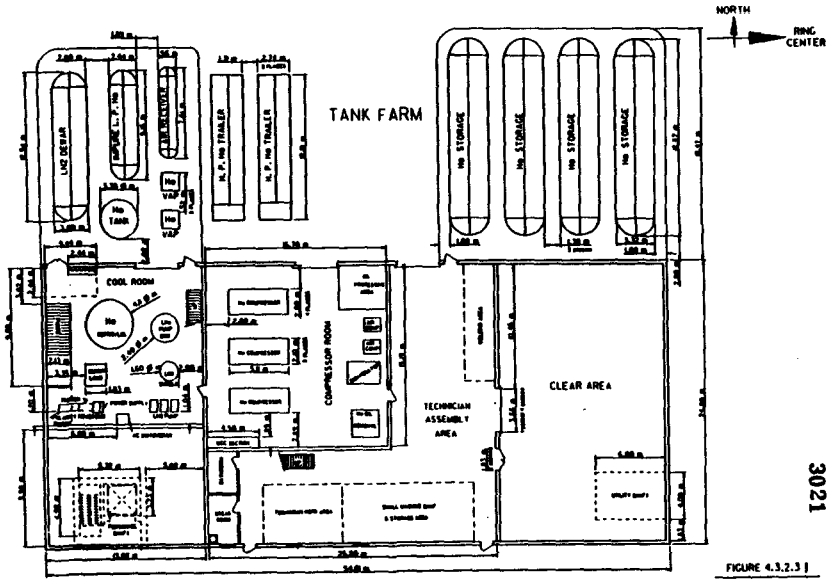

FIGURE 4.3.2.3 I

CRYO EQUPT LAYOUT IN NORTH UTILITY BLDG 1ST FLOOR

DWG # R20000314

July 26, 1991

3021

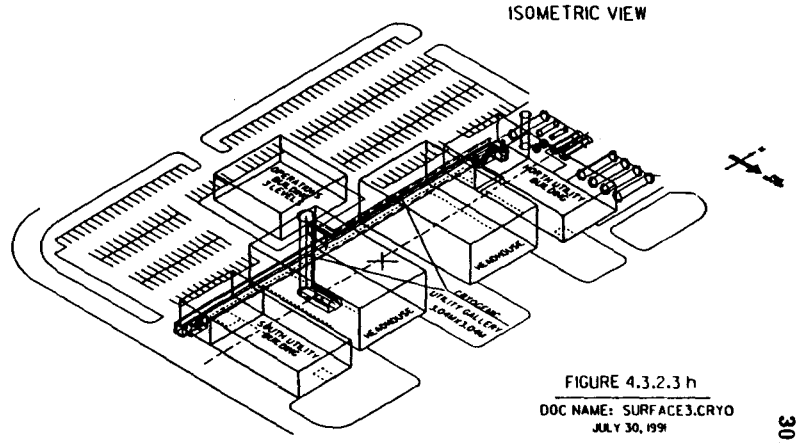

FIGURE 4.3.2.3 h

DOC NAME: SURFACE3.CRYO

JULY 30, 1991

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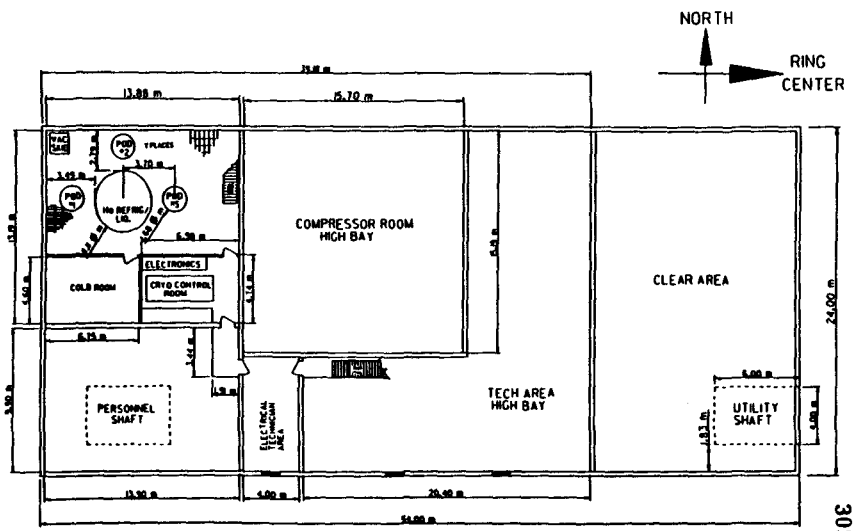


FIGURE 4.3.2.3 k

CRYO EQUPT LAYOUT IN NORTH UTILITY BLDG 2ND FLOOR

DWG # R20000315

JULY 30, 1991

3022

CROSS SECTION OF CRYOGENIIC PIPING AND UTILITIES TUNNEL

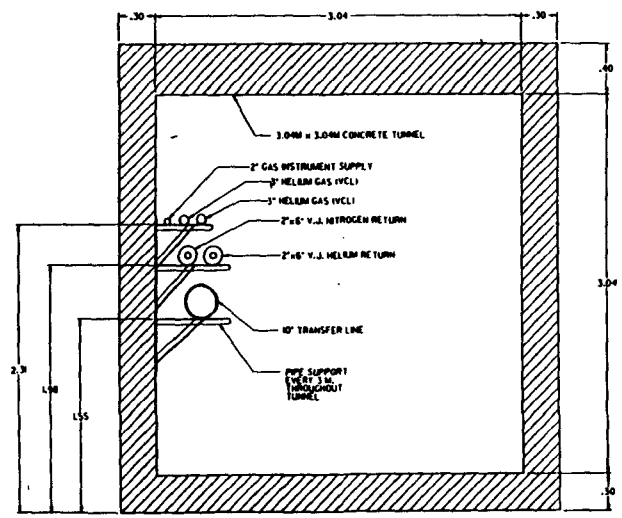


FIGURE 4.3.2.3 I

DOC NAME TUNNEL.CROSS

JULY 30, 1991

3020

Lavelle

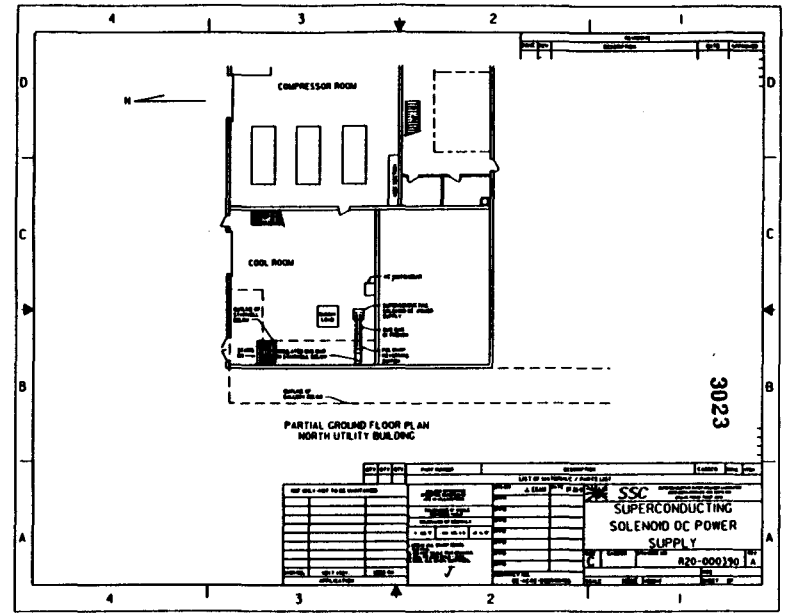
SSC Laboratory | Physics Research Division

SDC Detector ES&H Status 9/5/91

- Liquid Argon Calorimeter PHA Complete . . . Report Pending
- Butane Cooling PHA in Process
- Other Subsystems Scheduled for Analysis by Spring '92
- SDC Safety Committee Under Development as Follows:
- Detector ES&H Program Document Draft Ready (advance copies available this week)
- More Detail on all Topics at September Collaboration Meeting
- Near Term Schedule is as Follows:

Environmental Safety & Health

3025



SSC Laboratory | Physics Research Division

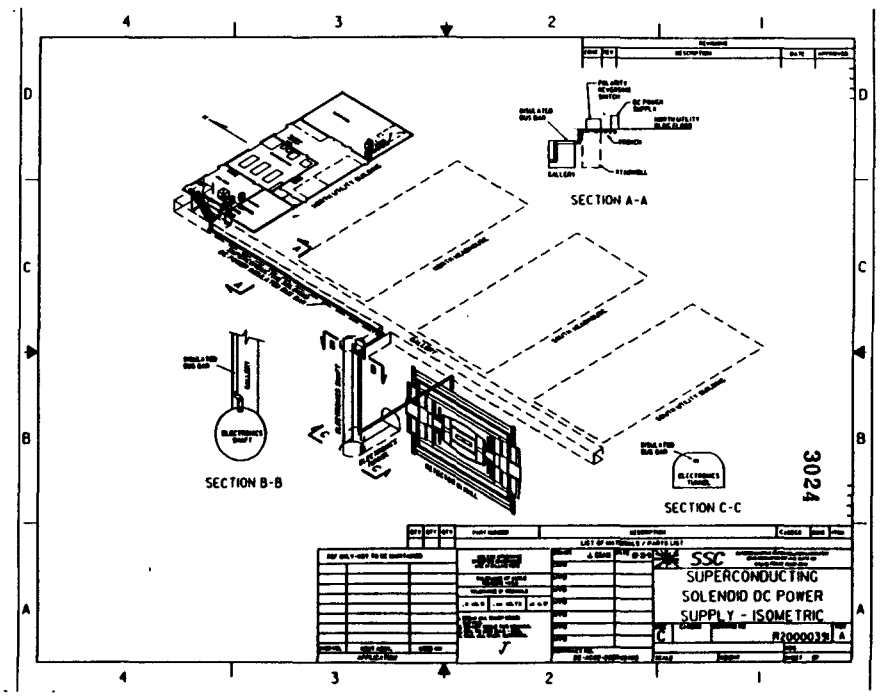
SDC Safety Committee Makeup

CHAIR	SDC
CO-CHAIR	SSCL/PRD
PROJECT ENGINEER	
ACCEL. INT	
SILICON	
BARREL/INT	
COIL	
CENTRAL CAL.	
FORWARD CAL.	
MUON STRUCT./MAGNETS	
MUON CHAMBERS/COUNTERS	
ELECTRONIC SYSTEMS	
RADIATION SAFETY	
EX-OFFICIO	SSCL/PRD E.F. HEAD SDC TECH MANAGER

- Majority will be engineers
- Now working on filling roster
- Will contain at least one "Designated Physicist"
- Primary function will be "Safety" engineering analysis and documentation thereof . . . PHA and DOE SAR's

Environmental Safety & Health

3026



SDC ES&H Near Term Schedule

AUG 16	Selection of SDC Safety Committee Complete
AUG 27	PHA/SAR Orientation Meeting at SSCL
OCT '90	Title I for IR-4
APR 1, '92	Technical Proposal Due / Title II for IR-4
MAY 1, '92	Preliminary Hazard Analysis Report on SDC
MAY 15, '92	PAC Review
JUL '92	Stage I Approval
SEP '92	Preliminary Safety Assessment Report to DOE
OCT 1, '92	Stage II Approval, Start of Construction

Environmental Safety & Health

Test Beams

- FY92, FY93 requirements for BNL, FNAL, CERN
- CERN
  - 100 bm·da in FY92
  - 300 bm·da in FY92/93
- facilities - 40 to 100 tonne coverage
  - 3-4 m beam height
  - 100 GeV hadrons / 50 " electrons in FY92
- milestones
  - a) Corpus Christi for an expression of interest
  - b) Chairman for formal request for beam
- SSCL (200 GeV; 2 to 6 beam) in FY92
- for HEB extraction in Oct, 1991
- for Calibration hall permission in April, 1992

INTEGRATION MEETINGS

AUGUST 1991

DETECTOR CONSTRUCTION PLANNING

SDC

J. Brown (?)

PREPARED BY:
ICF KAISER ENGINEERS INC.

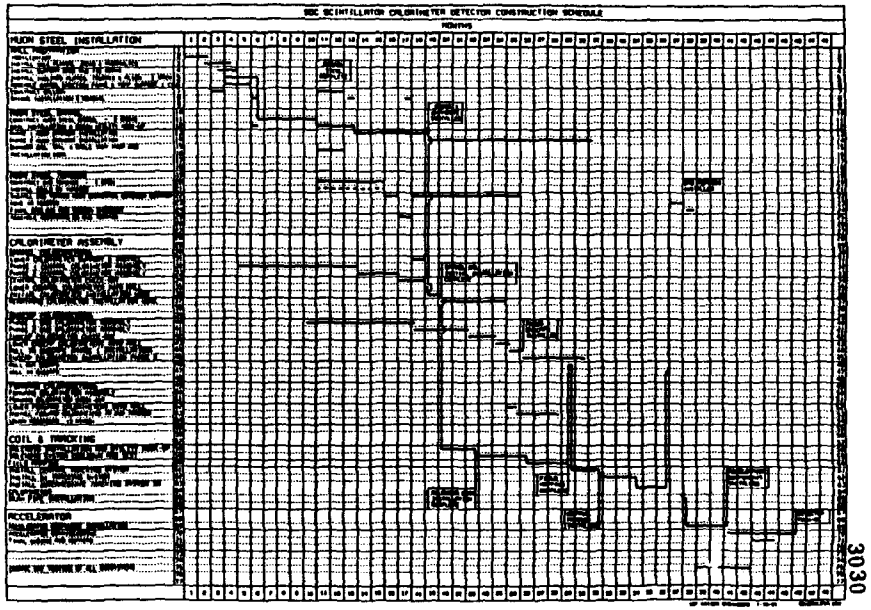
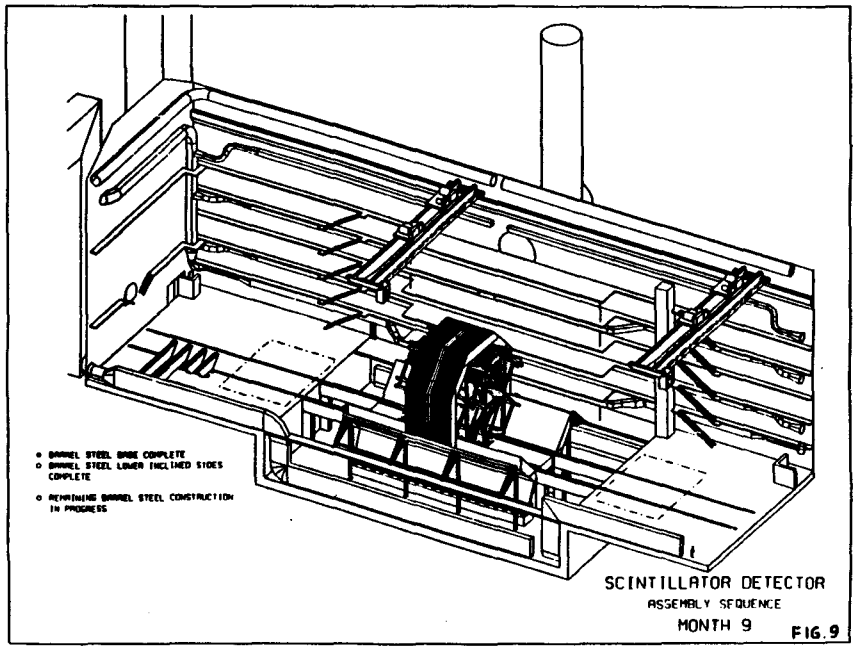


FIG. I



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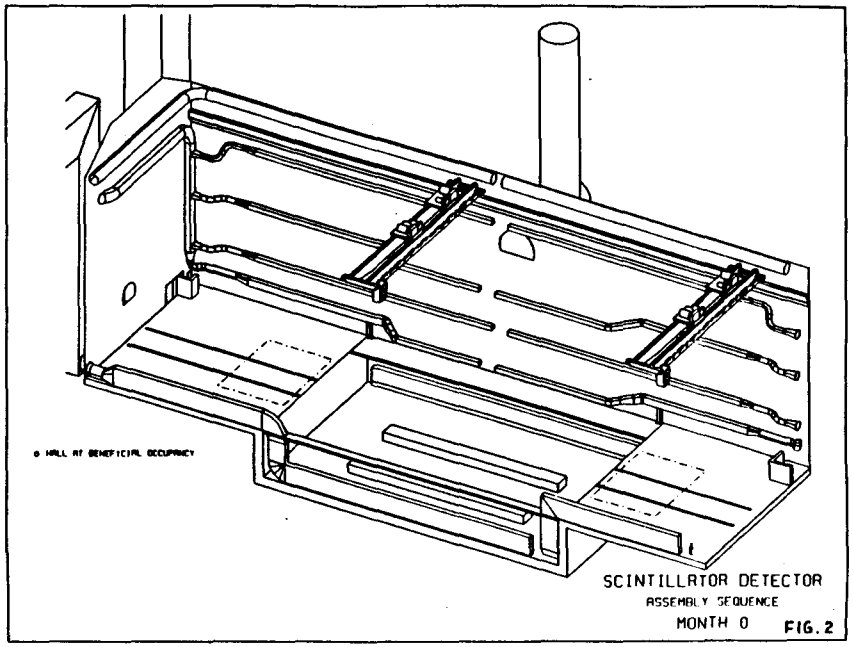

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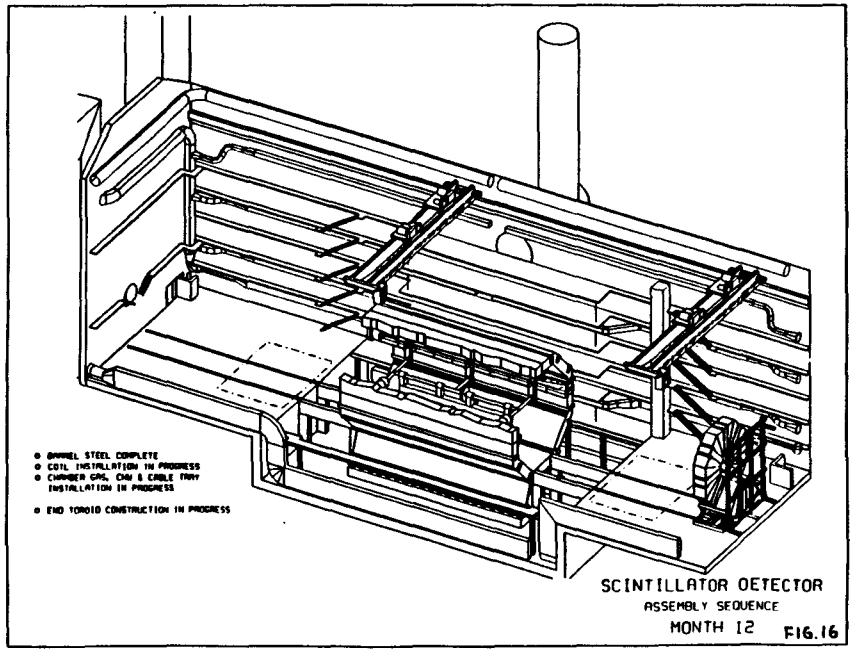

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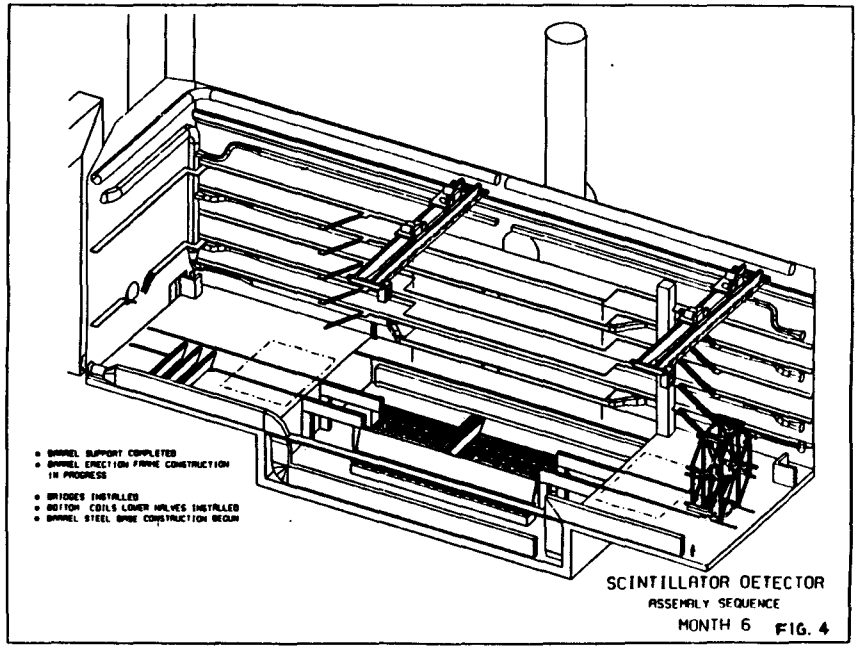

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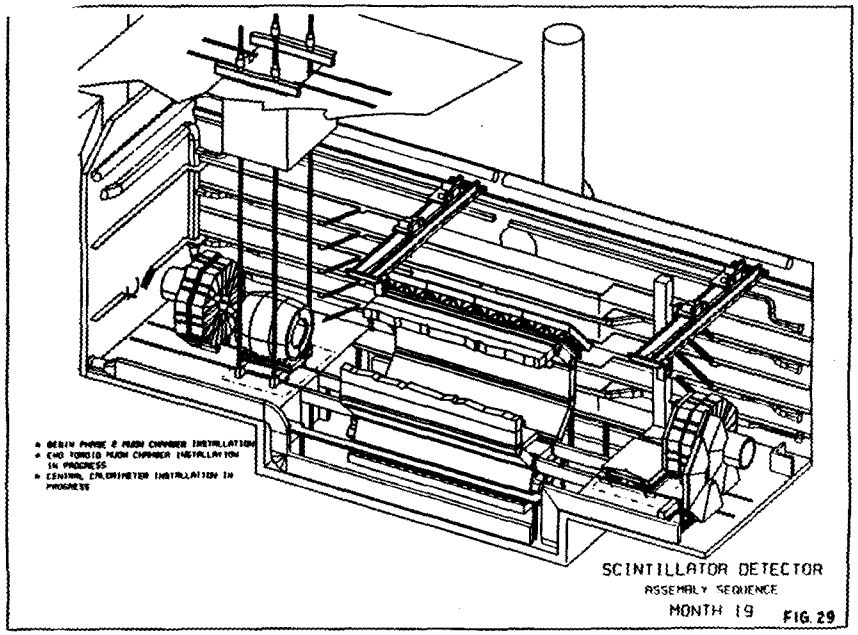

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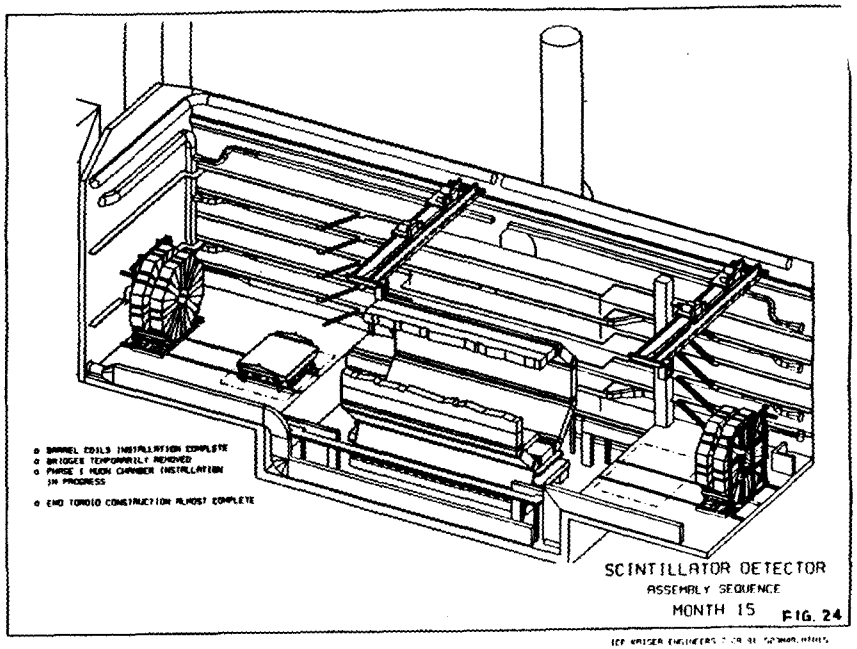

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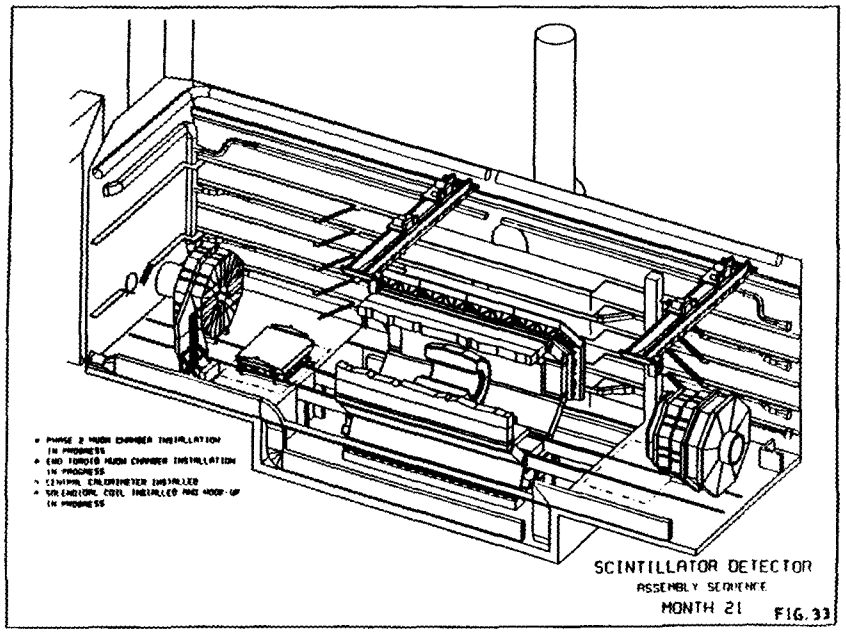

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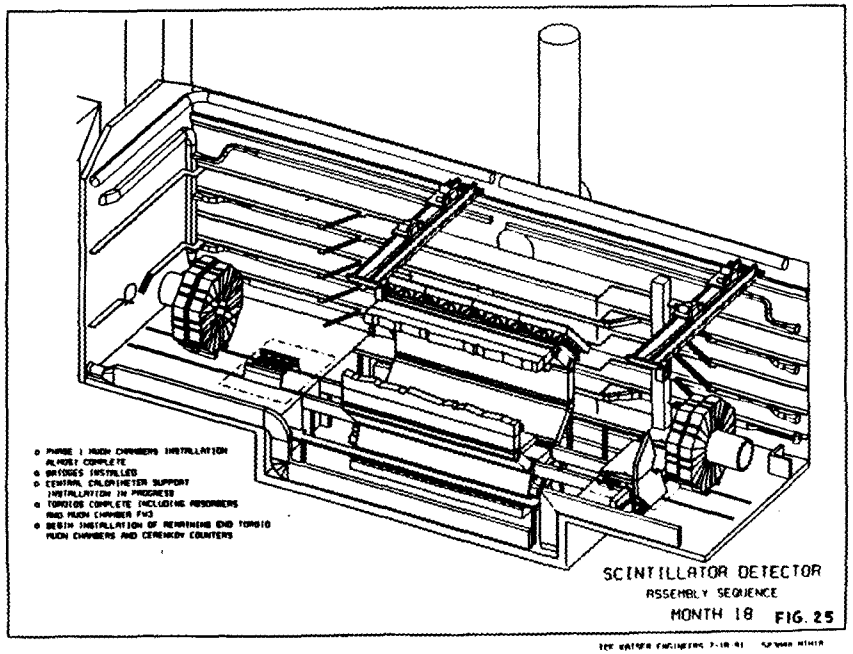

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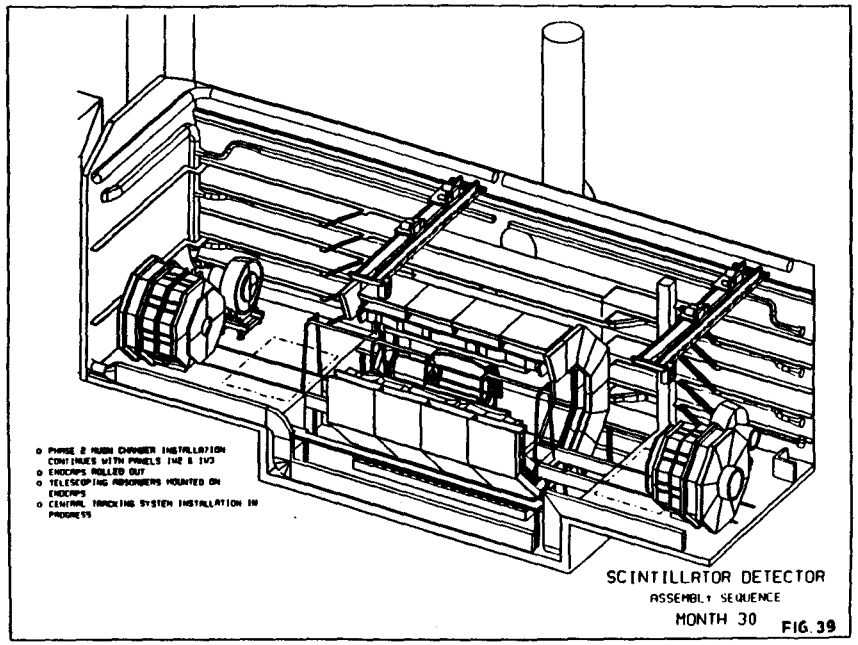


FIG. 39

3041

ICF KAISER ENGINEERS 7-29-91 523948.MIN30

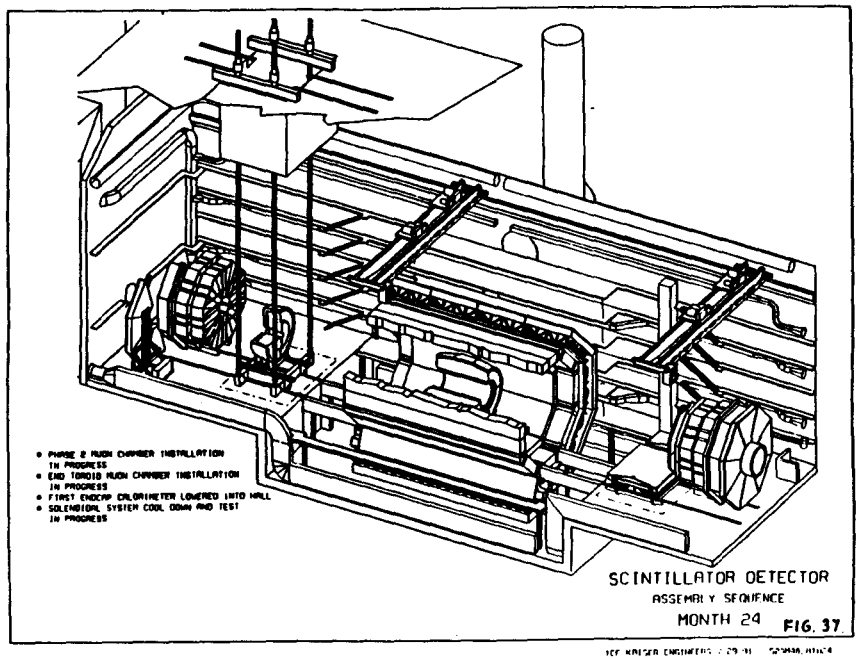


FIG. 37

3039

ICF KAISER ENGINEERS 7-29-91 523948.MIN24

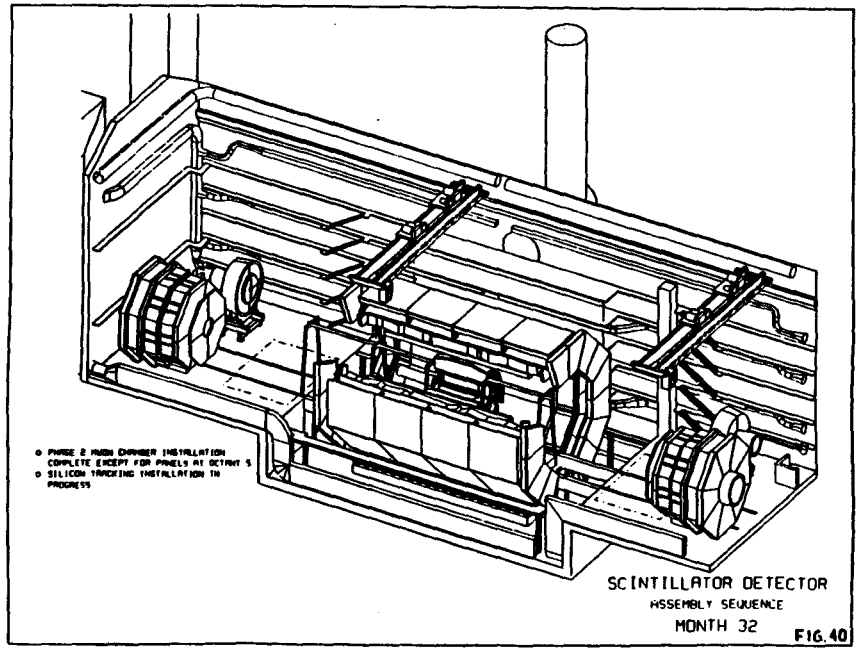


FIG. 40

3042

ICF KAISER ENGINEERS 7-29-91 523948.MIN32

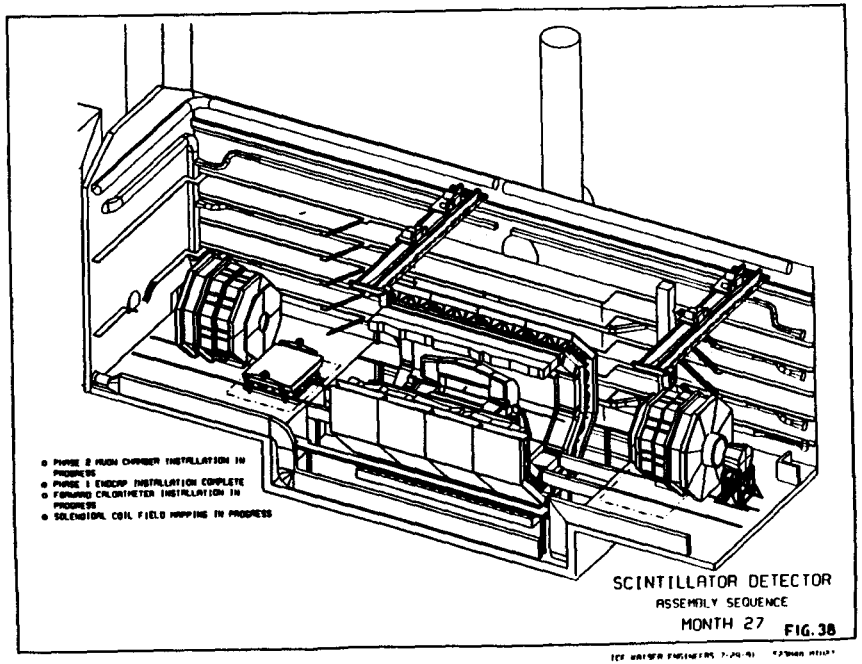
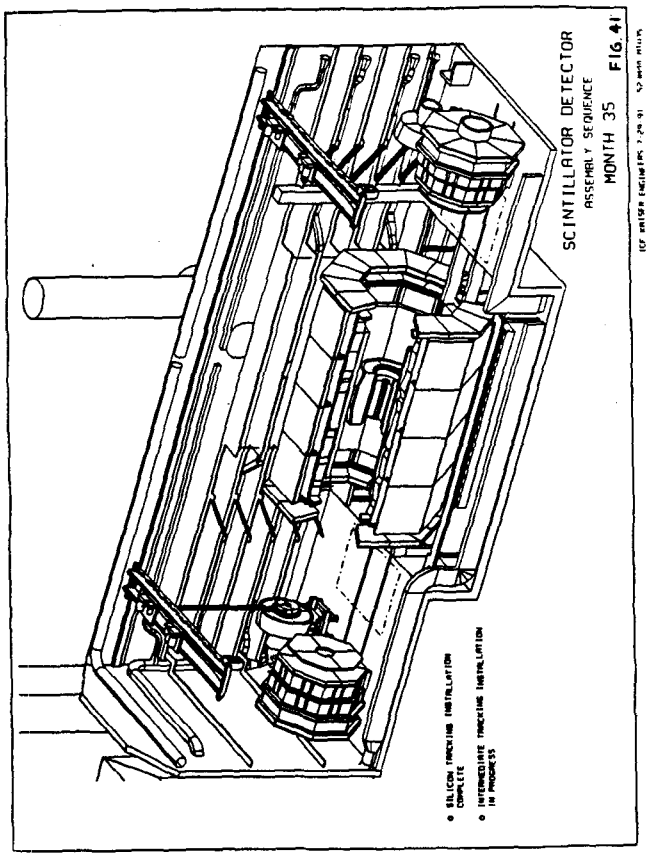


FIG. 38

3040

ICF KAISER ENGINEERS 7-29-91 523948.MIN27

3043



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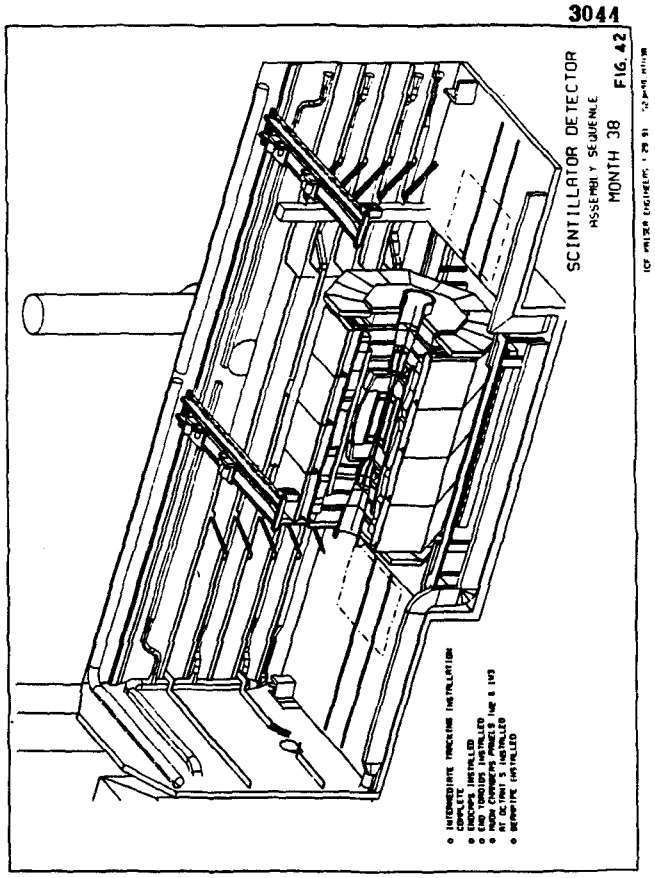

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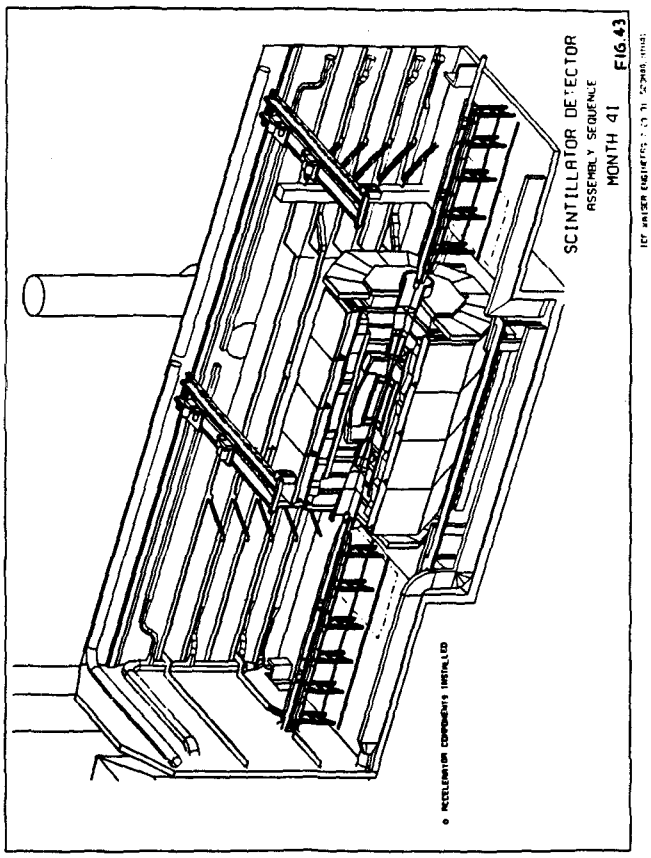


Ryan 3046

FINAL REPORT

from the

TASK FORCE ON
MAGNET/TRACKING CONFIGURATION

August 6, 1991

Lawrence Berkeley Laboratory

T. L. Ryan

CHARGE TO TASK FORCE on MAGNET/TRACKING CONFIGURATION

3047

Dated: 3/26/91

GOAL: To establish a conceptual design framework for future work and not to provide a final design.

The Task Force is charged to assemble and collate information regarding the configuration of the tracking system, the solenoid and its supports and all penetrations (cables, utilities, cryogenics, . . .) through the central calorimeter.

Items to be addressed by the Task Force include:

-support of the silicon tracker and beam pipe from the barrel tracker

-support of the barrel tracker - how is it done?

-support of the intermediate tracker - how is it done?

-cable and utilities plan for the silicon tracker, outer tracker and solenoid - a detailed enumeration of what penetrates the calorimeter

-support requirements placed on the calorimeter

-active alignment and/or monitoring of tracker elements

-access for repair of the tracking elements

-requirements to insert the silicon tracker after commissioning of the SSC. This assumes the central calorimeter, solenoid and outer tracker are in place.

-a detailed accounting of the materials budget within the tracking volume including cables, utilities, supports, . . .

-a detailed account of the power budget within the volume

*Assume baseline design for outer tracker.

3048

SUPPORTS FOR:

- o Silicon Tracker
- o Barrel Tracker
- o Intermediate Tracker

STATUS:

Concepts have been developed and documented in the Magnet and Central Tracker RRR and Interface Control Document, SDC Tech. Note No. SDC-91-00026.

3049

- o **Cable and Utilities Plan Status:**

  Requirements identified and documented

- o **Support Requirements or Calorimeter Status:**

  Concept identified

- o **Active Alignment and/or Monitoring Status:**

  Not resolved. Looks difficult. Need more detail on structure for outer tracker

- o **Access for Repair Status:**

  A first evaluation taken. Benefits of access for baseline design looks low

- o **Inspection of Silicon Tracker After Commission of SSC/SDC Status:**

  Appears reasonable. No reason found that this cannot be done. No major impact on design found.

- o **Detailed Accounting of Material Status:**

  Some information documented, but still need further work. Need more design details

- o **Power Budget Status:**

  Power requirements documented

3050

FUTURE PLANS

- o *Continue to refine and update information on a quarterly basis.*

- o *Add a design requirements document as design is firmed up which provide design details of the outer tracker.*

As a preliminary cut at issues to be addressed in the meeting at SSCL on June 19, 1991, I have started the following list and I am sure that you and others will identify other topics.

1. *What in-place adjustment, if any, must be designed into the tracer?*

2. *Should there be active alignment modules?*

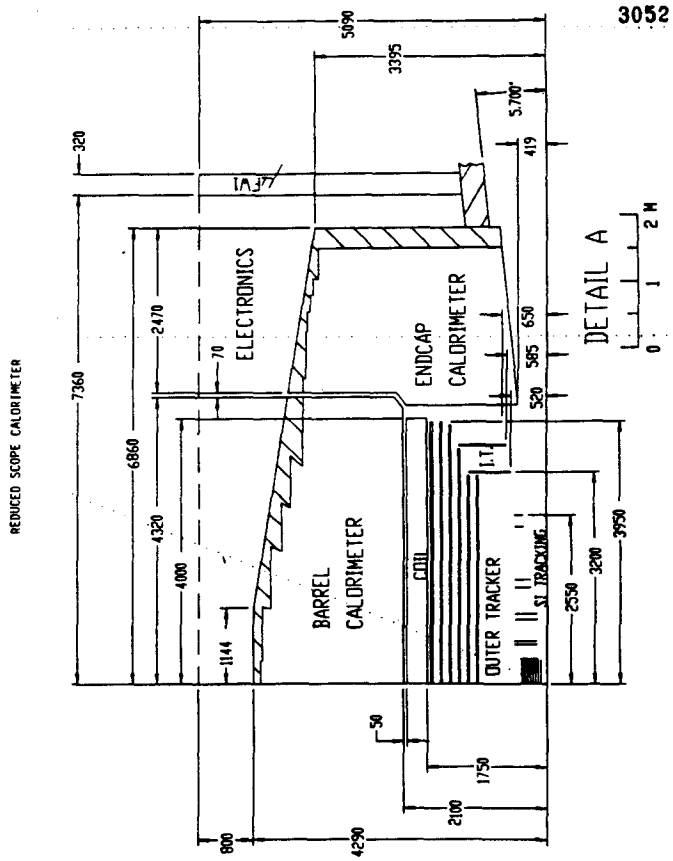
3. *Given a one meter axial access, what maintenance can be done?*

   Answer: *Apparently none for the straw tube electronics.*

4. *With the three meter axial access, what maintenance can be done?*

   Answer: *If platforms can be installed, all straw tube electronics can be accessed.*

5. *Current routing of silicon tracker cooling lines require cut outs in the calorimeter and cut outs or other dimensional changes in the outer and intermediate tracker. The question is, what is the best solution?*



TAKEN FROM STRAW TUBE SUPERLAYER DESIGN CONCEPTS, Dated May 20, 1991

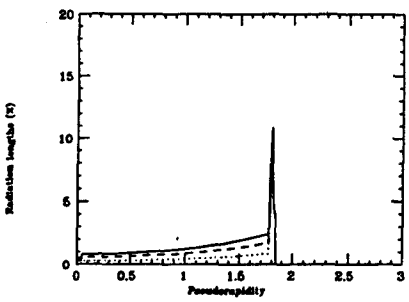


Fig. 4.4. The amount of material in radiation lengths as a function of η due to the straw tracking system. Dotted line: straws and electronics; dashed line: adds the support structure; solid line: adds the shells.

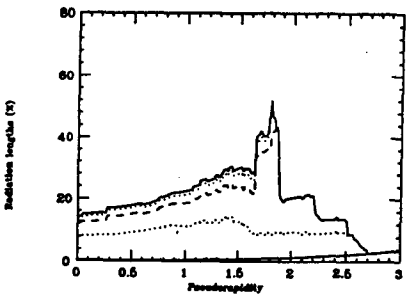


Fig. 4.5. The total amount of material as a function of η from the beam through the tracking system. Solid line near horizontal axis: beam pipe; next higher dotted line: adds the silicon system; dashed line: adds the scintillating fiber system; dotted line adds the straw system with no shells; solid line: adds the shells in the modular approach.

TAKEN FROM STRAW TUBE SUPERLAYER DESIGN CONCEPTS, Dated May 20, 1991

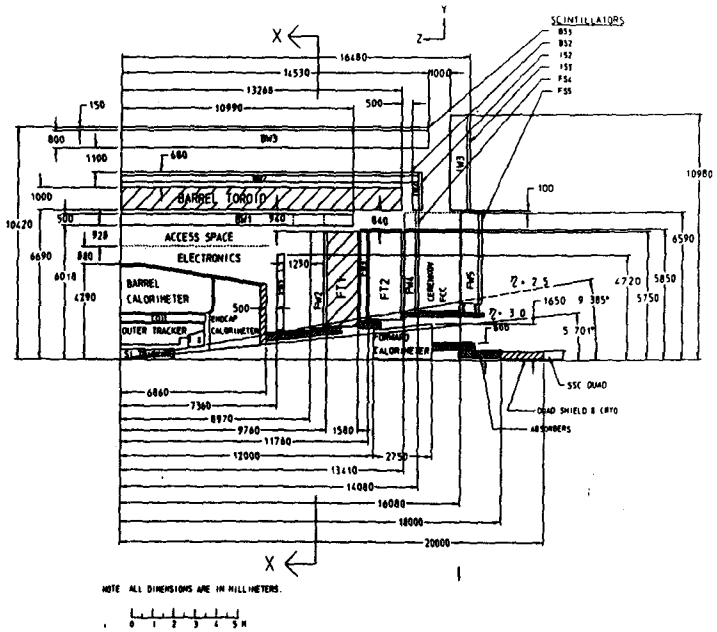
of less than about 0.5 cm of plastic. This would contribute a thickness of about 2% of a radiation length normal to the ends. To this must be added the printed circuit board, electronics, cooling, cabling, and cylinder support struts. Figure 4.4 shows the effect of these items. Figure 4.5 shows the material for the whole tracking system in the baseline design.

tracker component	radiation length(%) at 90 degrees	sum with modules shell	sum without modules shell
Silicon system + beam pipe	8.0	8.0	8.0
fiber system+ supports	5.0	13.0	13.0
support cylinder	0.29		
module shell (10 mil wall)	0.24		
straws and supports	0.32		
support cylinder	0.29		
module shell (10 mil wall)	0.24		
straws and supports	0.32		
support cylinder	0.29		
module shell (10 mil wall)	0.24		
straws and supports	0.32	15.6	14.8
support cylinder	0.29		
module shell (10 mil wall)	0.24		
straws and supports	0.48		

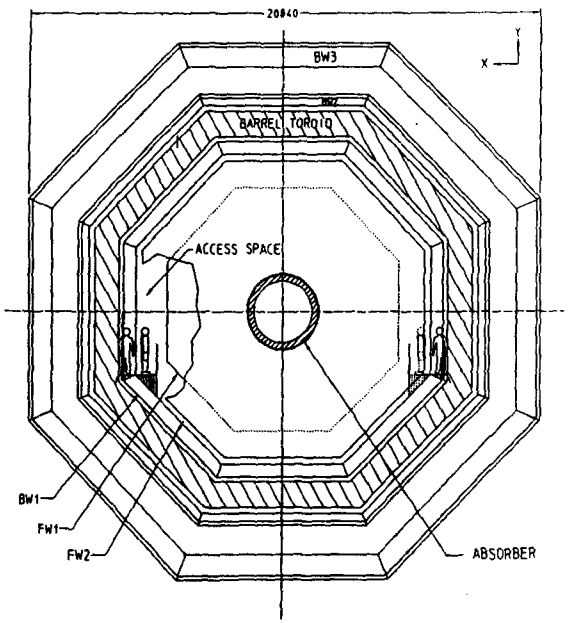
Table 4.2. The material budget for both the single straw and modular approach near 90°.

For the design where tension is taken up by the stable cylinder rather than by the shell, the amount of material at 90° is less than the modular design by about 30%, which is about 0.3% of a radiation length. The thickness of the support cylinder is about the same for all designs because compression load is not the determining factor of the thickness of the cylinder.

The material in the region of the endplates may be slightly higher when the compression load of the wire tension is transferred through the endplates to the base cylinder. However, since a base cylinder requires an end ring for its support, and the end ring will be one of two plates, the increment of the material would be small compared to the modular design. The present design scheme calls for continuous straw tubes without a breakage at η = 0.0. The sense wires are terminated at the middle. This design provides the minimum material near and at η = 0.0.



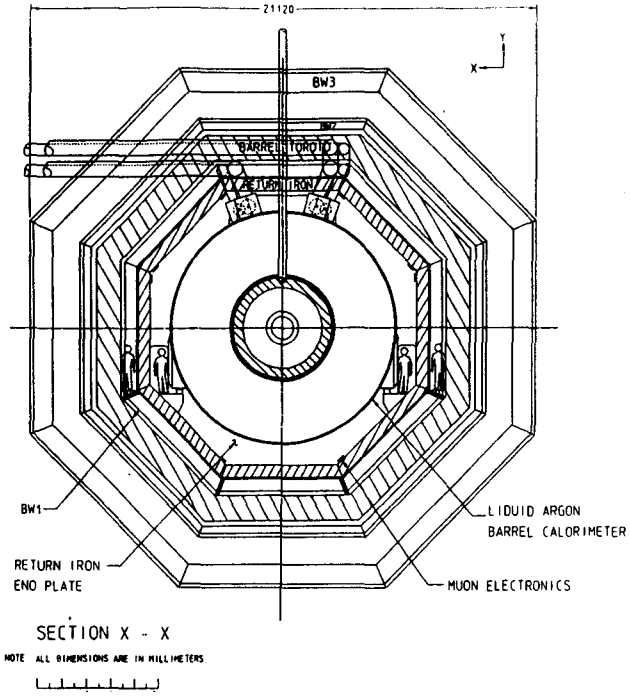
SDC SCINTILLATOR CALORIMETER OPTION
DESCOPE OPTION 1



SECTION X - X
NOTE: ALL DIMENSIONS ARE IN MILLIMETERS

LAC - Scint. Cal. Integration

	LAC	S.C.
Radius	10.56 m	10.42 m
Length (L)	18.27 m	17.03 m
Access Movement	~1 m	~1 m perhaps 3-4 m
BW1 Access	Difficult	OK
Installation	Phase 1 Mass Clm. Install. ~1 yr	Phase 1 Mass Clm. Install. ~6 mos.
BW1 Acceptance	Cryo. Piping	



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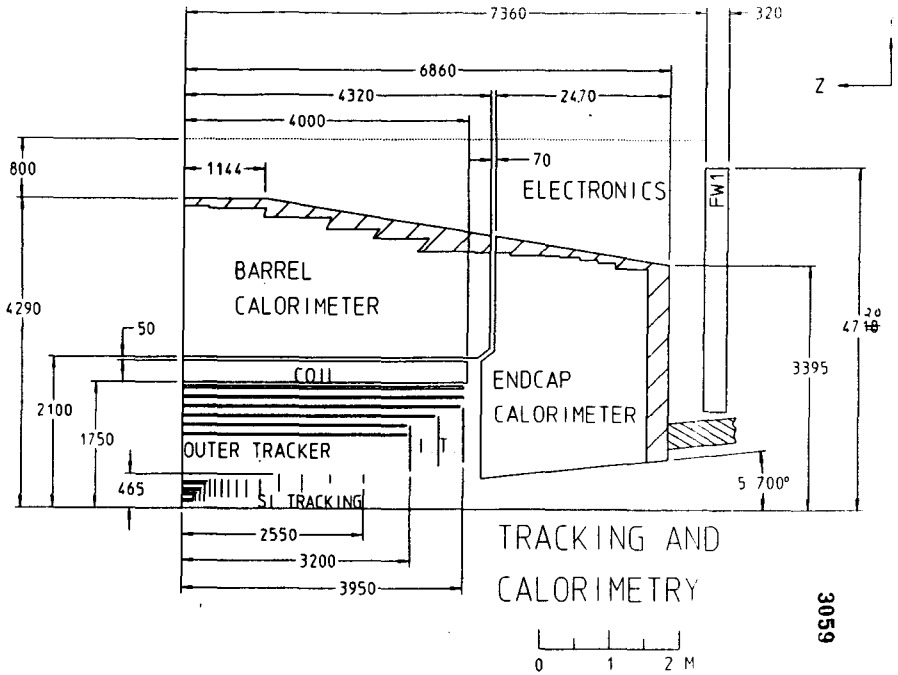

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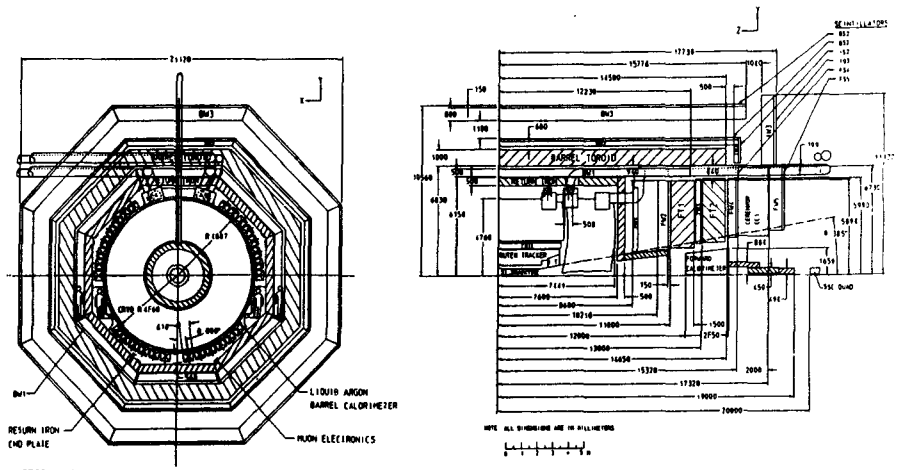

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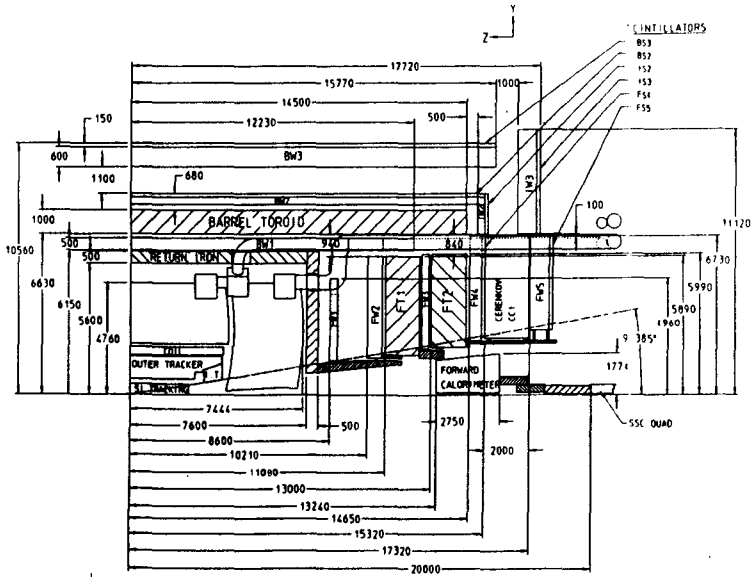

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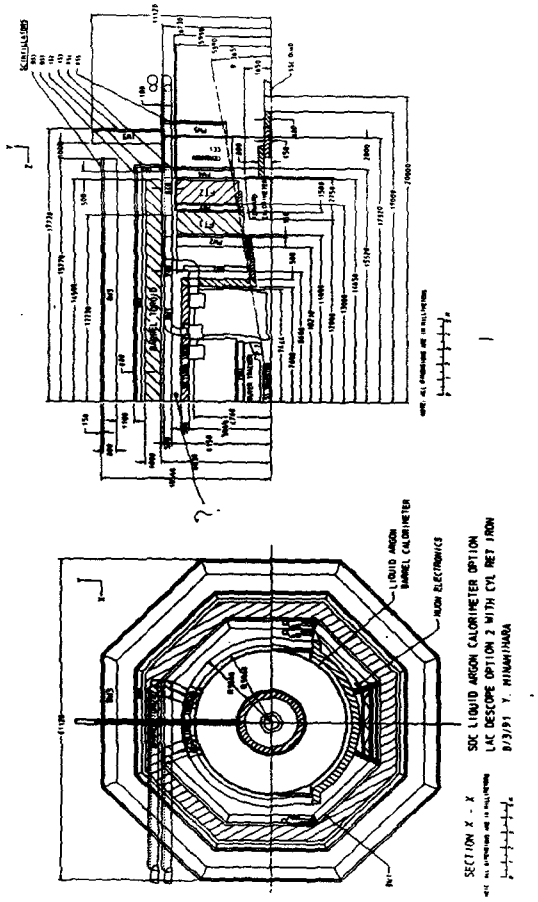

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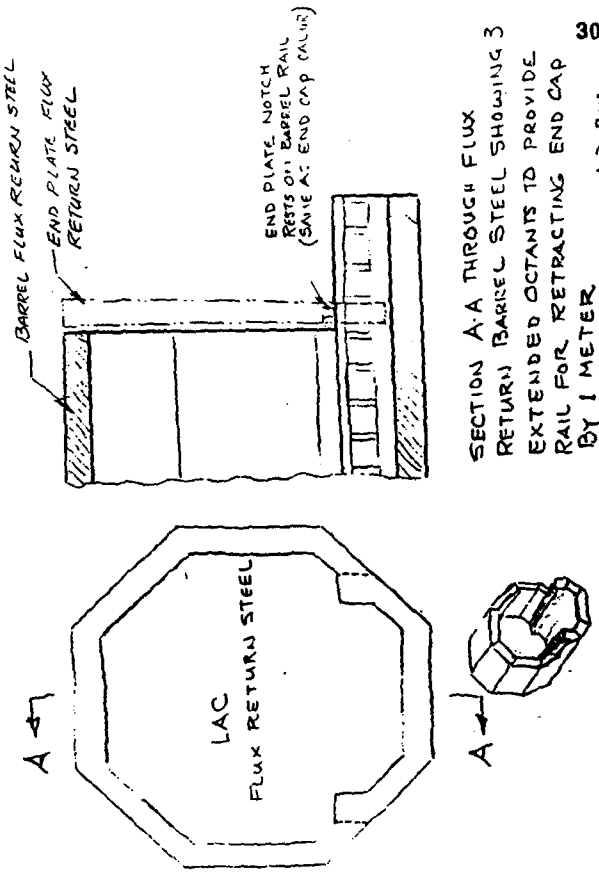

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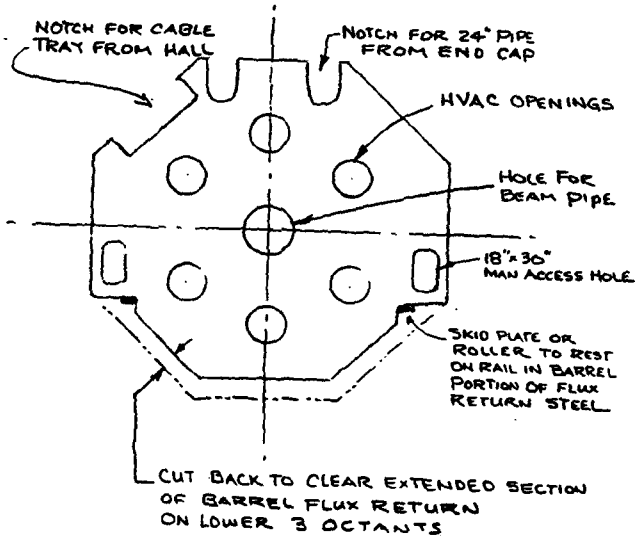


SCHEMATIC ELEV. VIEW OF END PLATE OF FLUX RETURN STEEL

NOT TO SCALE

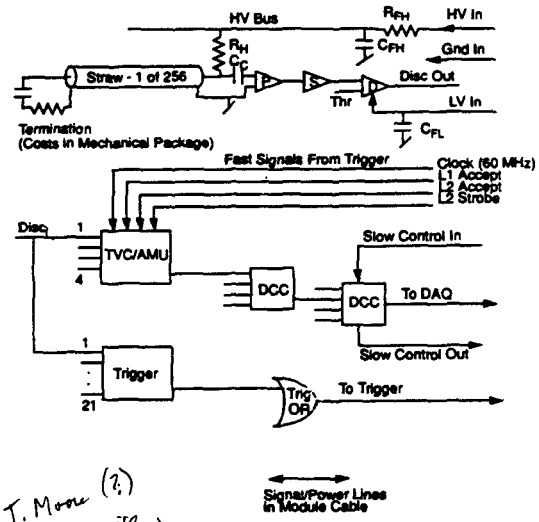
A. DuBois
7-19-91

3066

STRAW ELECTRONICS

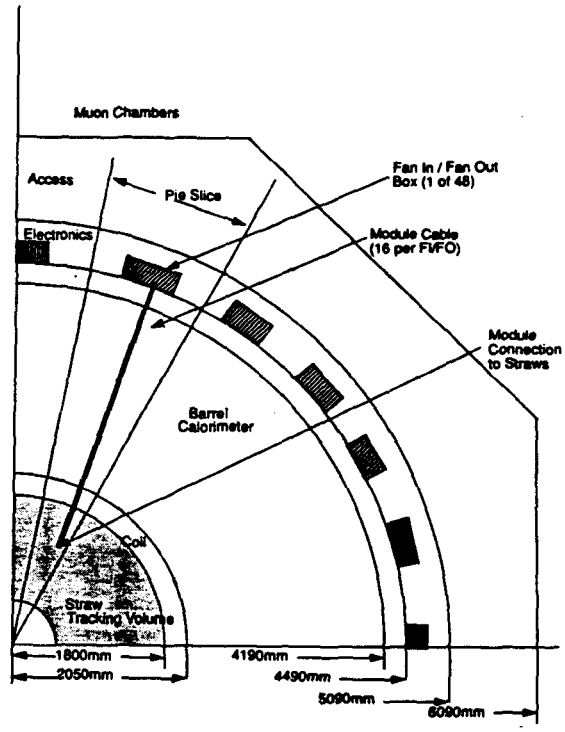
D. VAN BERG

3067



T. Moore (?)
Electronics Integration(?)

3068



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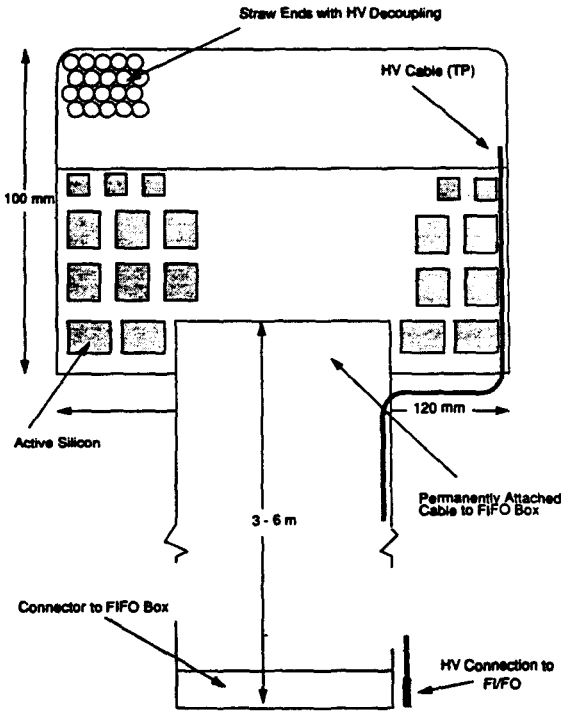
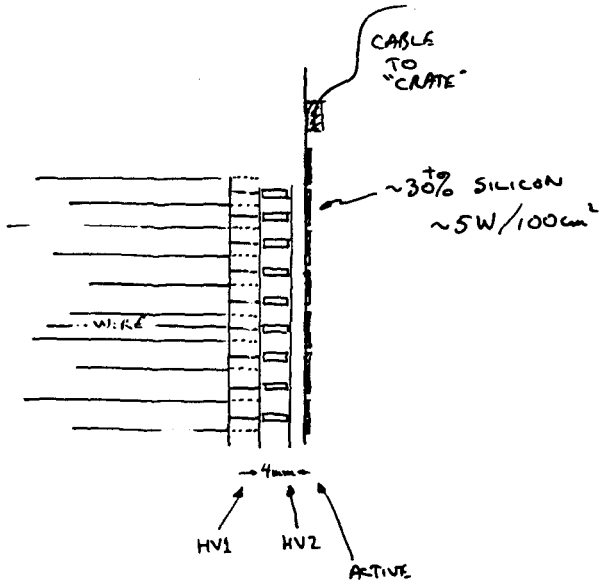
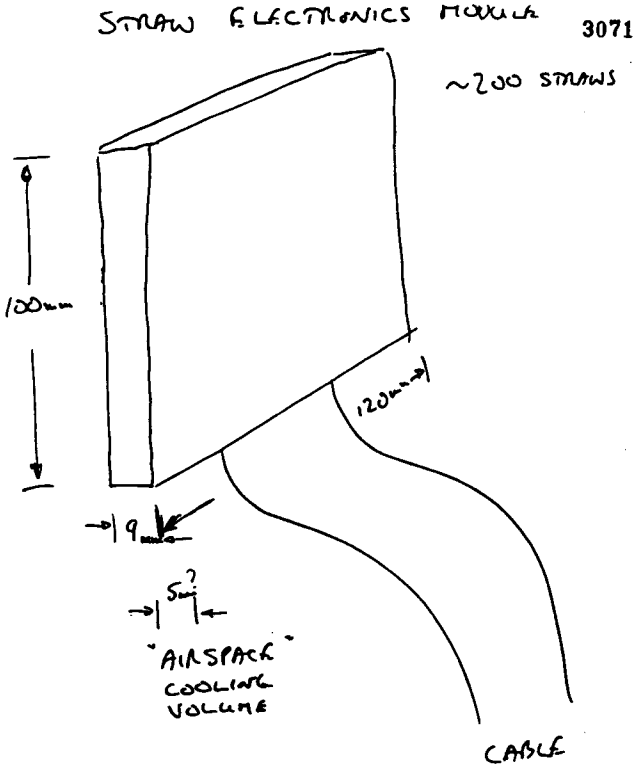


SDC STRAW TRACKER
ELECTRONICS MODULE

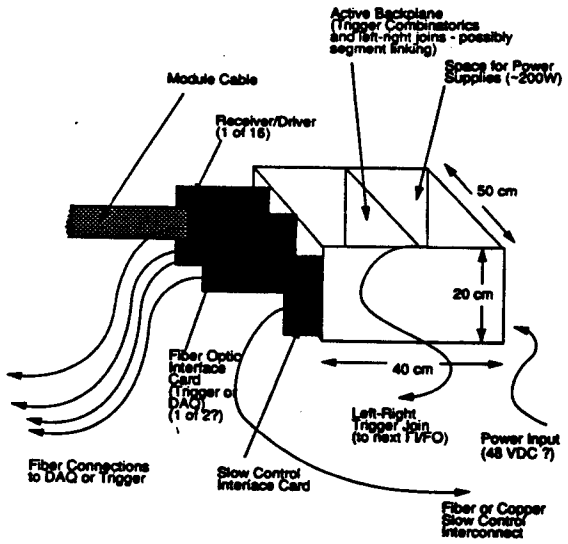
3070



3071



3072

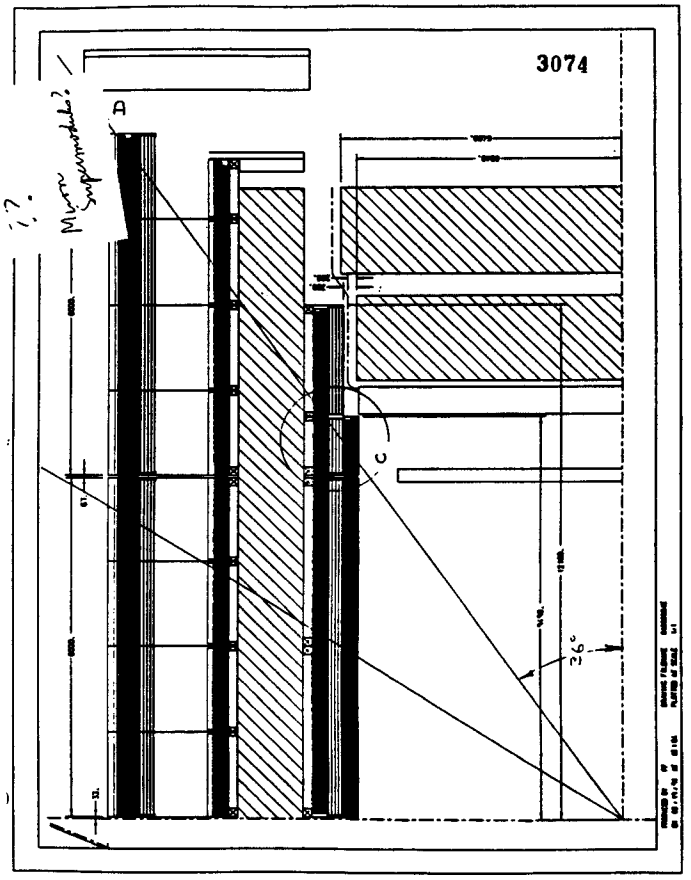


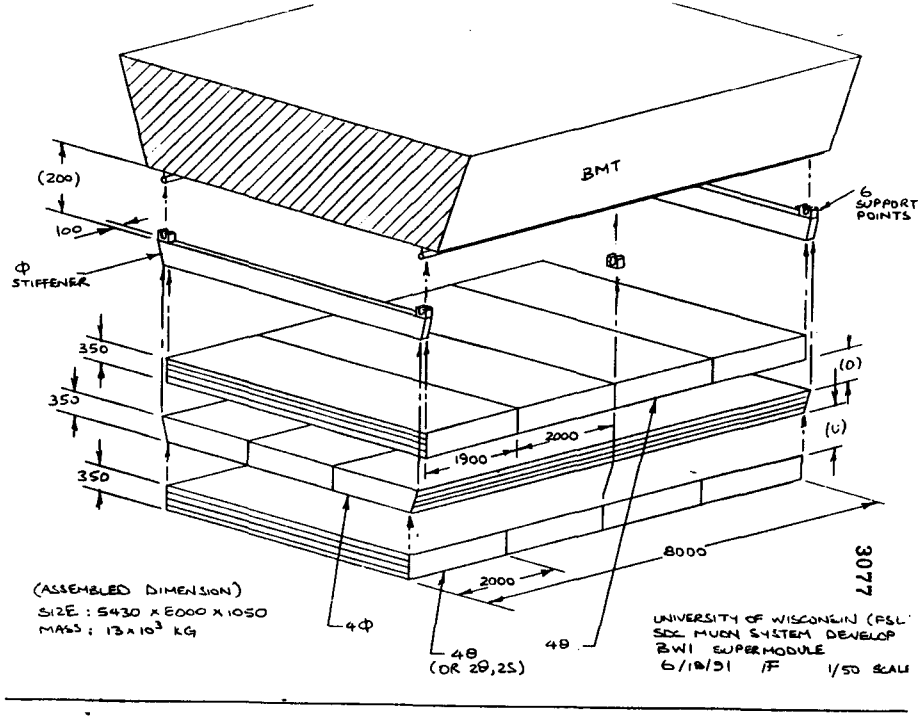
3073

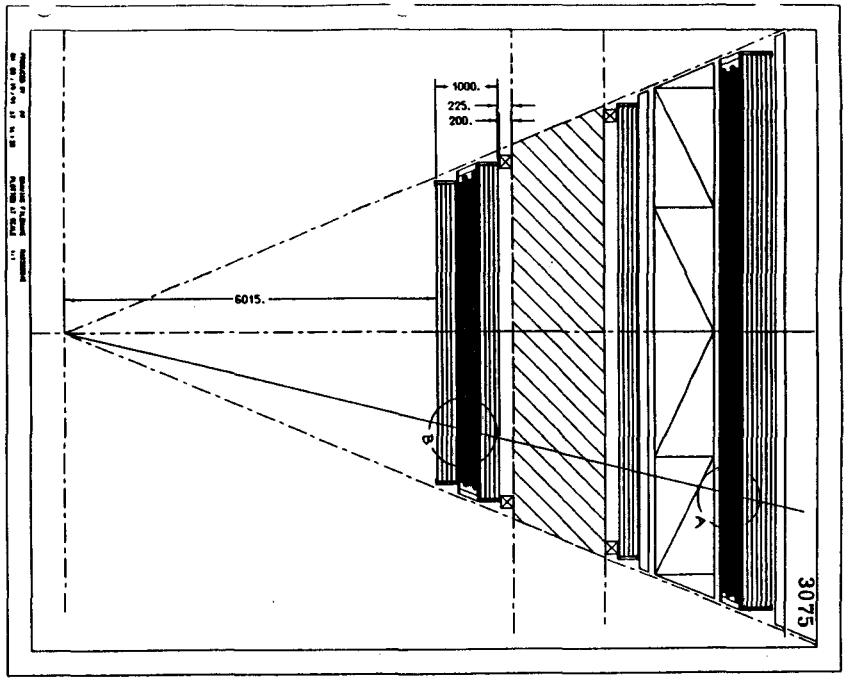
MUON SUPERMODULES

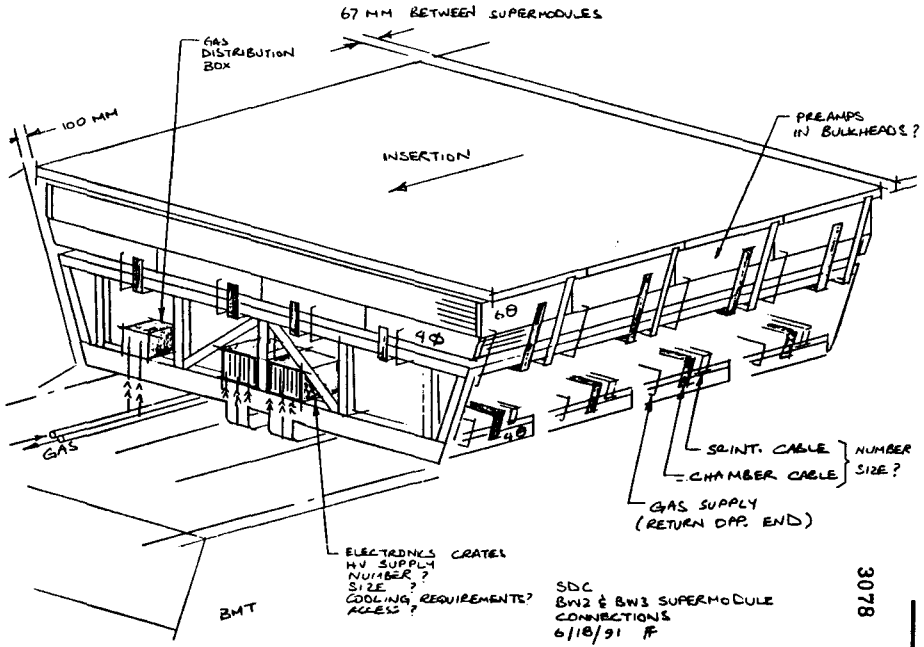
F. FEYZI

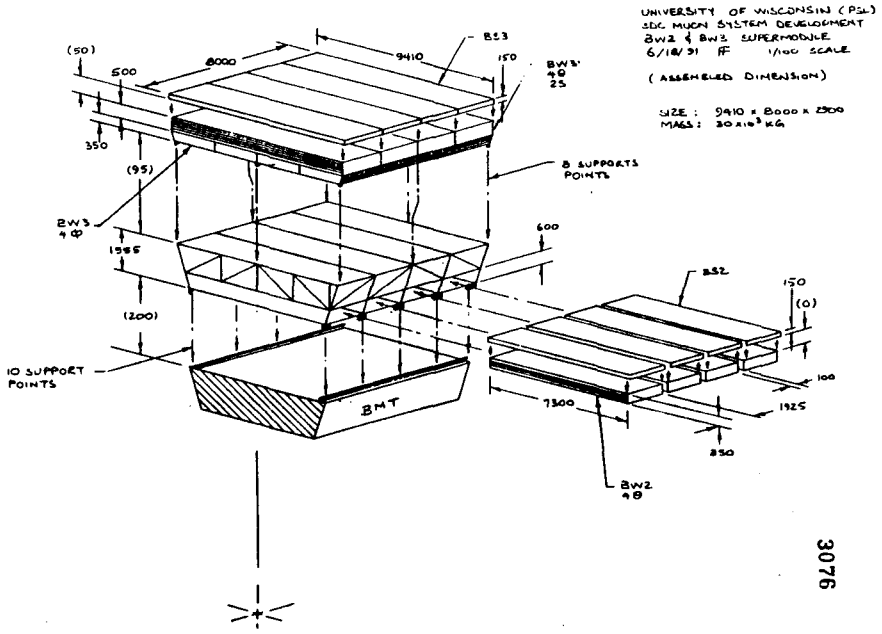
3074




BMT
6 SUPPORT POINTS
(200)
100
Φ STIFFENER
350
350
350
(0)
(U)
1900
2000
8000
2000
(ASSEMBLED DIMENSION)
SIZE : 5430 x 8000 x 1050
MASS : 13 x 10³ KG
4Φ
4θ
(OR 2θ,2S)
4θ
UNIVERSITY OF WISCONSIN (PSL)
SDC MUON SYSTEM DEVELOP
BW1 SUPERMODULE
6/18/91 JF 1/50 SCALE
3077


1000.
225.
200.
6015.
a
3075


67 MM BETWEEN SUPERMODULES
GAS DISTRIBUTION BOX
100 MM
INSERTION
PREAMPS IN BULKHEADS?
6θ
4Φ
4θ
GAS
SCINT. CABLE
CHAMBER CABLE
NUMBER SIZE?
GAS SUPPLY (RETURN OPP. END)
ELECTRONICS CRATES
HV SUPPLY
NUMBER ?
SIZE ?
COOLING REQUIREMENTS?
ACCESS ?
BMT
SDC
BW2 & BW3 SUPERMODULE
CONNECTIONS
6/18/91 JF
3078


UNIVERSITY OF WISCONSIN (PSL)
SDC MUON SYSTEM DEVELOPMENT
BW2 & BW3 SUPERMODULE
6/18/91 JF 1/100 SCALE
(ASSEMBLED DIMENSION)
SIZE : 9410 x 8000 x 2300
MASS : 30 x 10³ KG
(50)
500
8000
9410
BS3
150
BW3 4θ 2S
350
(95)
8 SUPPORTS POINTS
BW3 4Φ
1555
600
(200)
BS2
150
(0)
10 SUPPORT POINTS
BMT
7300
100
1925
250
BW2 4θ
3076

UW-MADISON
PSL
7/12/91

SDC MUON MEASUREMENT SYSTEM (WBS 3.2)

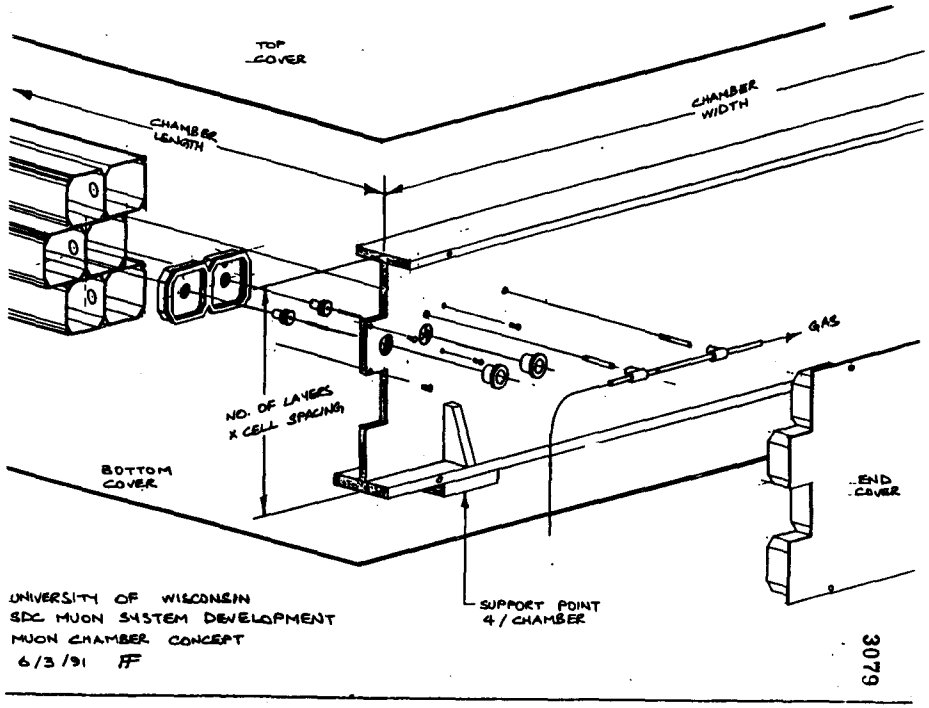
Major Parts Into Surface Building

WBS NO.	NAME	VOLUME (CUBIC METER)*
3.2.1.1	Barrel Chambers	3800
3.2.1.2	Intermediate Chambers	600
3.2.1.3	Forward Chambers	600
3.2.2.1.1	Barrel Trusses	4000
3.2.2.2.1	Intermediate Trusses	1500
3.2.2.3.?	Forward Trusses	800
3.2.6.1	Scintillation Counters	300
3.2.6.2	Cerenkov Counters	400
TOTAL		12000

*From SSC DWG No. R20000256

FF:mk:C:\WP:muon.sdc

3081



3079

UW-MADISON
PSL
7/12/91

SDC MUON MEASUREMENT SYSTEM (WBS 3.2)

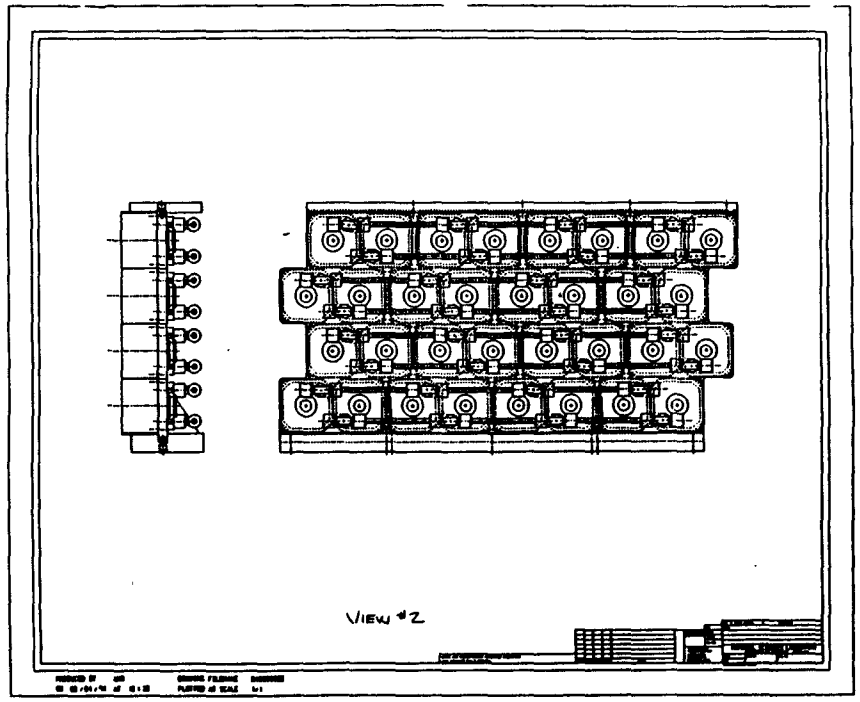
Major Assemblies Out of Surface Building

NAME	QTY*	VOLUME (CUBIC METER)	FOOT PRINT (SQUARE METER)	LABOR (PERS-WK)
BW1	32	45	45	6
BW2, BW3, BS2, BS3, Truss	28	218	80	18
BS2, BW2 Drawers	4	30	60	6
BS3, BW3 Drawers	4	75	80	8
IW2, IW3, IS2, IS3, Truss	16	114	50	18
FW1, FW2, Truss	16	31	20	?
FW4, FW5, FS4, FS5, FCC	16	68	35	?
TOTAL	116			

*Ignores Division Due te Cryostack

FF:mk:C:\WP\muon.mea

3082



3080

..DC INTEGRATION MEETING AUG 3 1991, ELECTRONICS AND A...ESS WITHIN THE BARREL, ANDY DUBOIS, 415-486-6754

ELECTRONICS WITHIN BARREL, STATUS AND REQUEST FOR FEEDBAC

DuBois
Electronics

DESIGN IS PROCEDING IN PARALLEL
- Detector integration is currently at LBL
- Subsystems at many sites in parallel
- All layouts are in flux & not necessarily consistent nor satisfactory
- Interface between the accelerator & SDC remains undefined

CURRENT SITUATION
- Suggested layout drawings of a descoped detector are available for:
  - 1 Scintillator calorimeter with conical forward calorimeter
  - 2 Scintillator calorimeter with plug-type forward calorimeter
  - 3 Liquid argon calorimeter with plug-type forward calorimeter
- Level of detail on these layouts is sparce (particularly for the LAC version)

INTEGRATION GROUP NEEDS YOUR HELP & CRITICISM
- Identify a single-point contact for each subsystem
- Correct the list of needed services
- Identify design constraints not currently included
- Eliminate stuff from detector interior

SDC Integration *Draft* LBL SDC 0035

Detector component identification code

A. DuBois
Revised 7/25/91

This revision attempts to accomodate opinions offered in response to the original draft.

On many drawings and sketches, it is difficult to find room to identify the various detector components in an easy to read fashion. A compact, but widely understood, component identification code would be useful. This note proposes such a code to identify each of the major functional portions of the detector. It is hoped, once the concept is understood, that without memorizing the whole list, the meaning of a specific code can be intuited from the letter/number associations and the context.

The code utilizes a numbering system which is consistent with a right hand coordinate system in which the origin is at the IP (Interaction Point); a positive X vector is directed away from the center of the accelerator; and, a positive Y vector is upward. The positive Z vector is directed northward if the hall is on the west side of the accelerator ring. The octants of the barrel are numbered, from 1 to 8, in a clockwize direction when looking along the positive Z axis. Octant 1 is at the top.

The code is to consist of two blocks of characters. The first block identifies the subsystem in a generic fashion and the second block identifies a specific portion of that subsystem. Often only the generic 3-letter block will be required.

Example: BW3 - 6.2
- Barrel muon, Wire chamber 3 -- is the subsystem
- Octant 6, Section 2 is the specific chamber (Note that the chamber section numbers increase in the +Z direction).

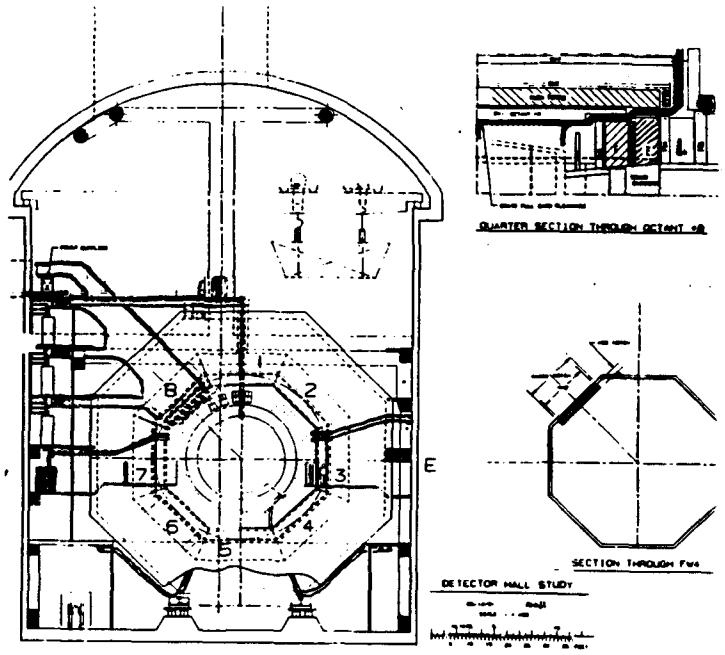
The first three-digit generic code can be followed by an N or S if one wishes to indicate a specific Forward assembly -- example: FCC-N would be the North Cerenkov Counter and FCC-N6 would be the octant 6 portion of that counter.

On the following page is a suggested list of subsystem codes, starting with subsystems nearest to the IP. Where a Ø appears as the *third character*, this identifies the whole device. When the group responsibe for that sub system identifies a set of symbols for sub portions, the Ø can be replaced. For example: TO3 can identify superlayer 3 of the outer tracker. It would also be possible to drop the Ø and use just the first two characters for the whole device. If the context makes it clear that those two characters are being used as a subsystem code.

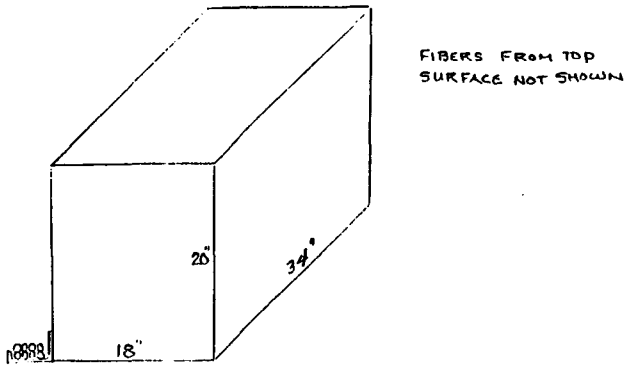
LBL SDC 0035
Page 2

List of three character codes for major components of the SDC

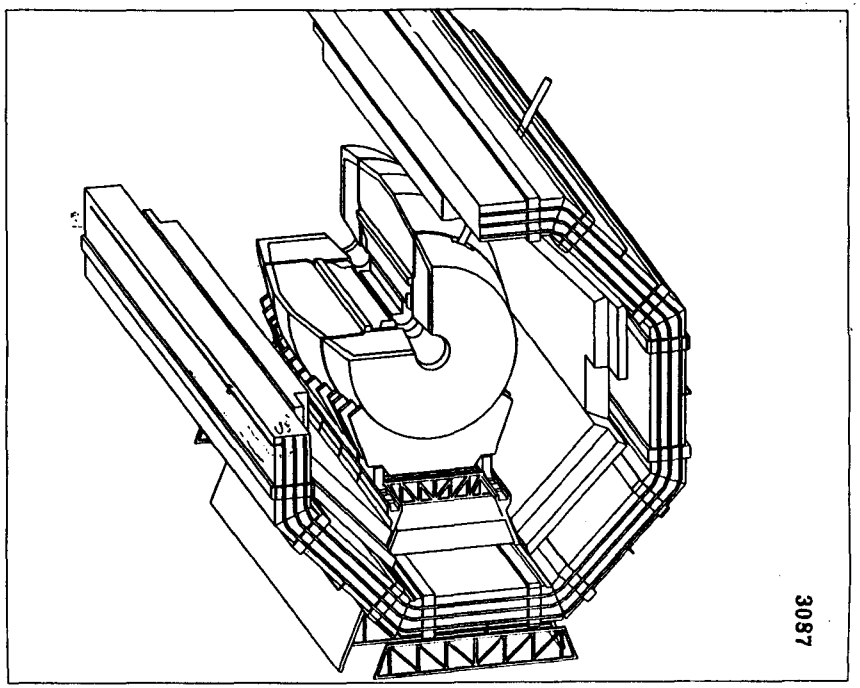
Tracker section			
1	TSØ	Tracker, Silicon	
2	TOØ	Tracker, Outer	
3	TIØ	Tracker,Intermediate	
Magnet section			
4	MSØ	Magnet, Solenoid	
5	MPM	Magnet, Polyethylene Moderator	
Calorimeter section			
6	CBØ	Calorimeter, Barrel	
7	CEØ	Calorimeter, Endcap	
8	CFØ	Calorimeter, Forward	
Barrel muon section			
9	BW1	Barrel muon, Wire chamber 1	(chamber nearest to IP)
10	BT1	Barrel muon, Toroid 1	
11	BW2	Barrel muon, Wire chamber 2	(chamber 2nd nearest to IP)
12	BS2	Barrel muon, Scintillator 2	(scintillator on BW2)
13	BW3	Barrel muon, Wire chamber 3	(chamber 3rd nearest to IP)
14	BS3	Barrel muon, Scintillator 3	(scintillator on BW3)
Intermediate muon section			
15	IW2	Intermediate muon, Wire chamber 2	
16	IW3	Intermediate muon, Wire chamber 3	
17	IS3	Intermediate muon, Scintillator 3	
Forward muon section			
18	FW1	Forward muon, Wire chamber 1	(chamber nearest to IP)
19	FW2	Forward muon, Wire chamber 2	(chamber 2nd nearest to IP)
20	FT1	Forward muon, Toroid 1	(toroid nearest to IP)
21	FW3	Forward muon, Wire chamber 3	(chamber 3rd nearest to IP)
22	FT2	Forward muon, Toroid 2	(toroid farthest from IP)
23	FW4	Forward muon, Wire chamber 4	(chamber 4th nearest to IP)
24	FS4	Forward muon, Scintillator 4	(scintillator on FW4)
25	FCC	Forward muon, Cerenkov Counter	
26	FW5	Forward muon, Wire chamber 5	(chamber 5th nearest to IP)
27	FS4	Forward muon, Scintillator 4	(scintillator on FW5)
28	FA1	Forward muon, Absorber 1	(part near calorimeter)
29	FA2	Forward muon, Absorber 2	(fixed part)



SIFI CRYOSTAT DESCRIPTION

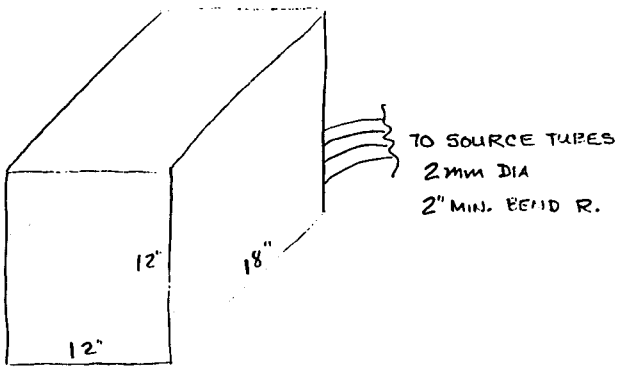


3089



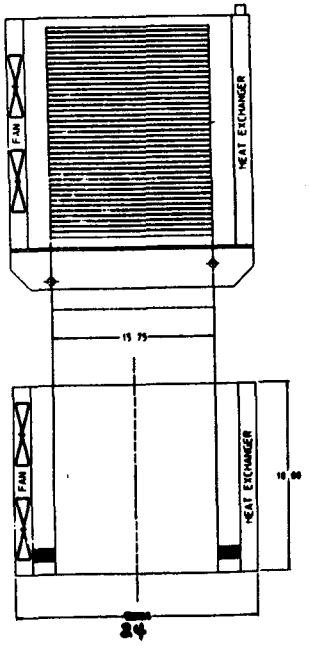
3087

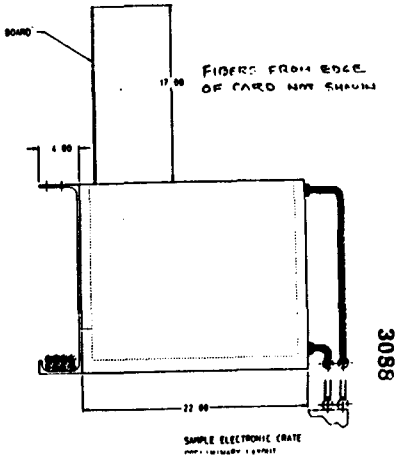
CALIBRATION SOURCE DESCRIPTION



3090

ELECTRONIC CRATE DESCRIPTION





3088

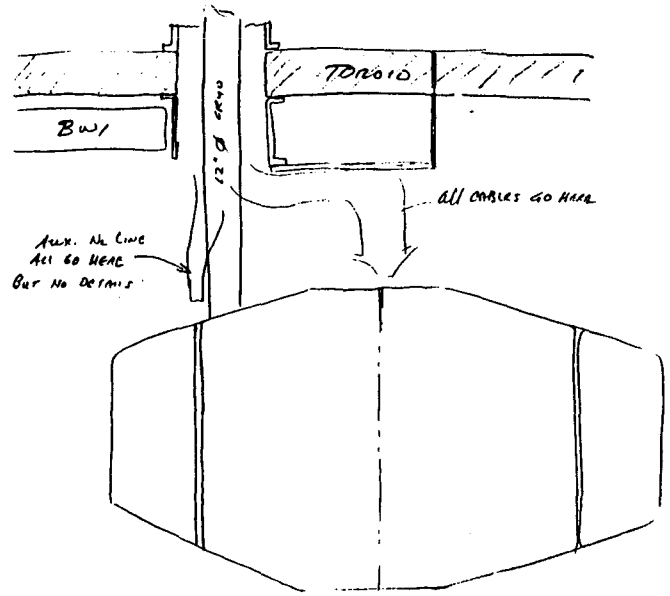
LIST OF CRATES INSIDE THE SCINTILLATION DETECTOR

(Count for May 29 Baseline given in brackets, if changed)

	Electr crates	VLPC cryostats	Calib Sources
Half of silicon Tracker	0	0	0
Half of wire Tracker	8 (16)	0	0
Half of barrel Calorimeter	32	0	32 (0)
Total on hall of barrel calorim	40 (48)	0	32 (0)
Half of intermed SiFi Tracker	16	16	0
One endcap calorimeter	32 (16)	0	32 (0)
Total on one endcap	48 (32)	16	32 (0)
Entire trackr, barrel & endcaps	176 (192)	32	128 (0)

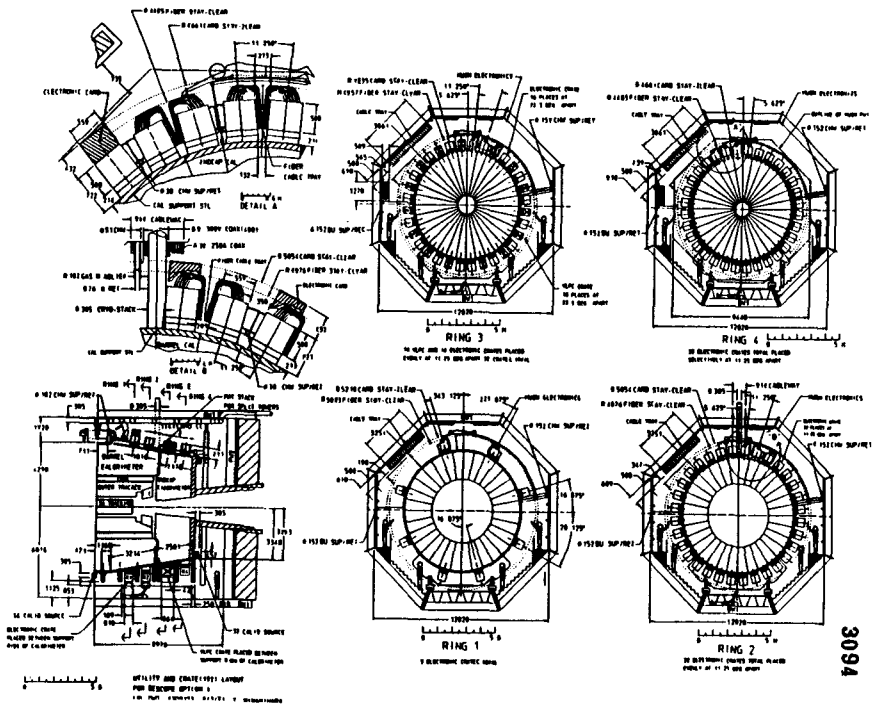
Also added are 768 PMT's on the end of the barrel, at the gap.

3093

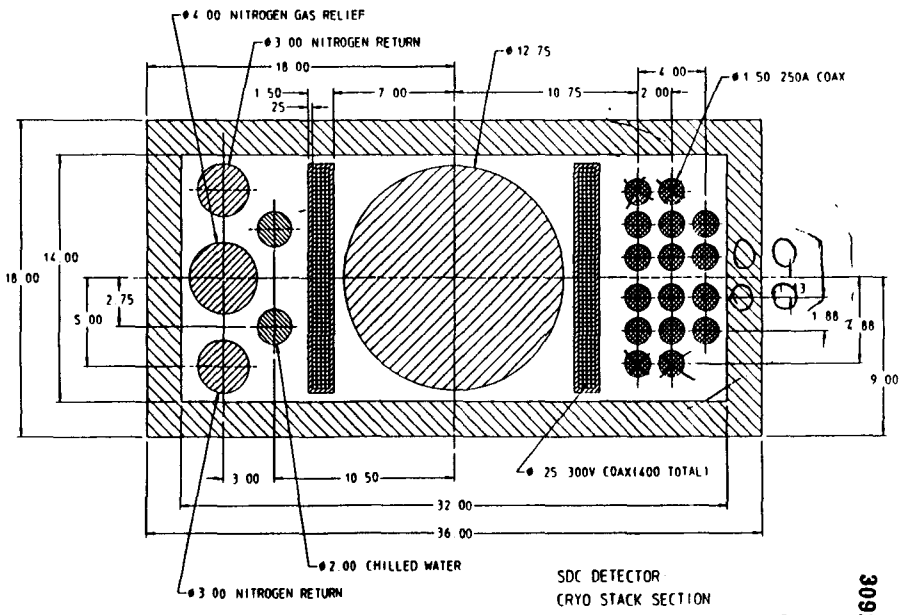


LOWER CRYOSTACK IN ELEVATION SECTION

3091

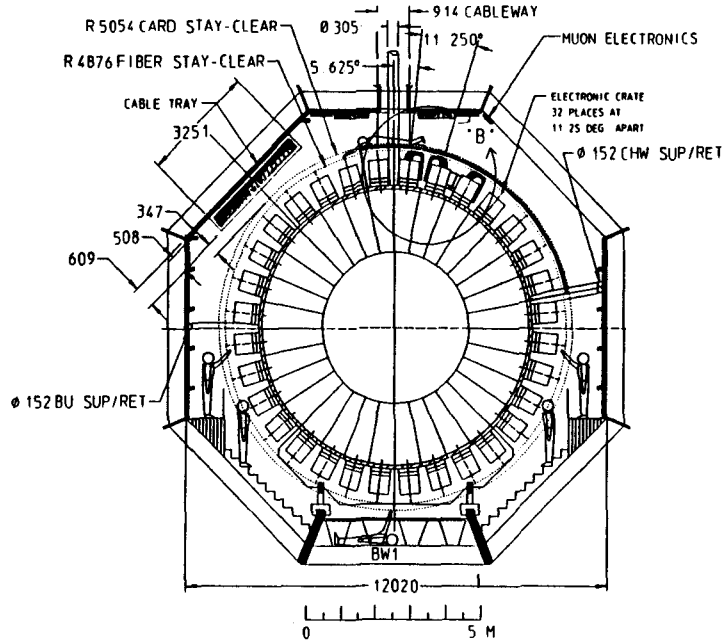


3094



SDC DETECTOR
CRYO STACK SECTION
JUNE 18, 1991 Y. MINAMIHARA

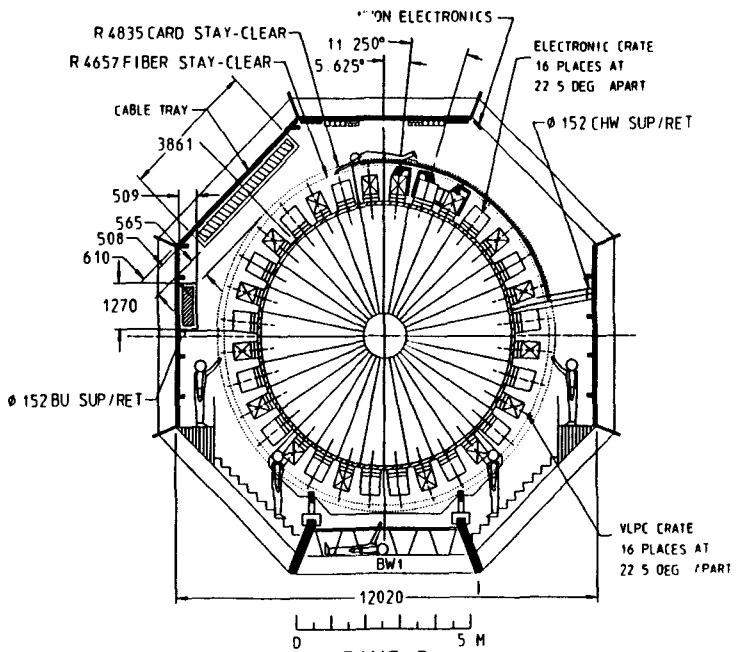
3092



RING 2

32 ELECTRONIC CRATES TOTAL PLACED EVENLY AT 11 25 DEG APART

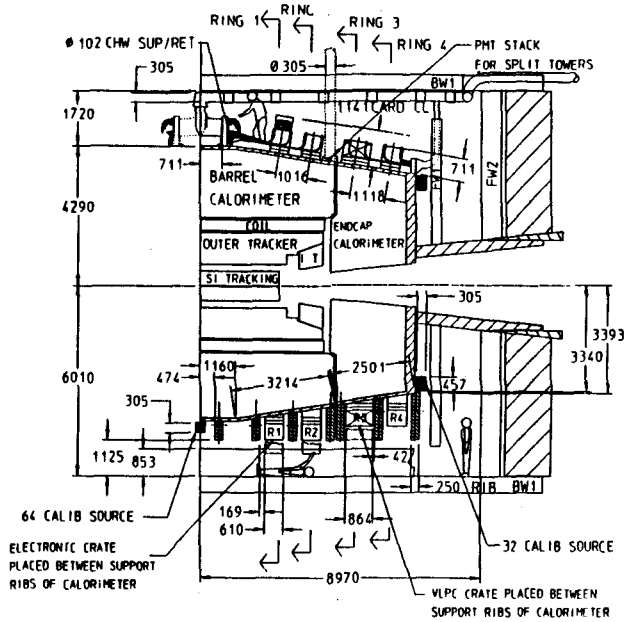
3097



RING 3

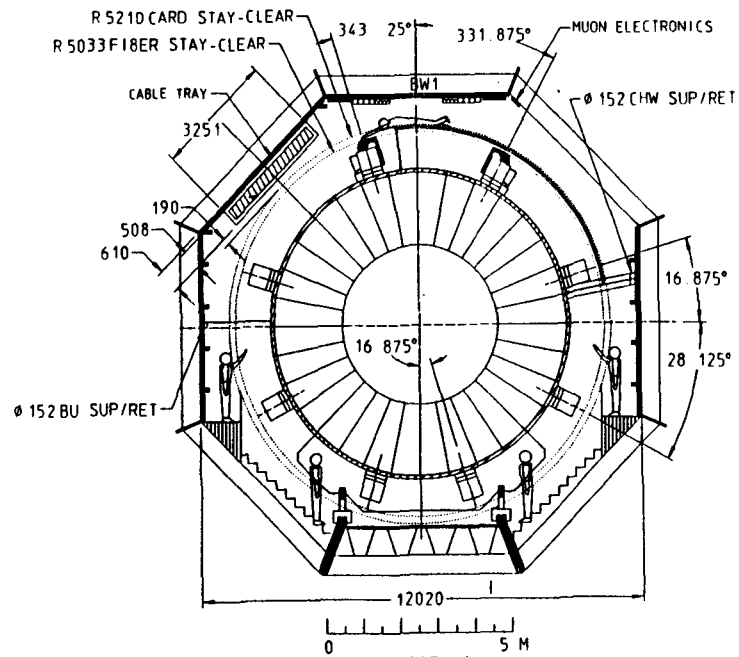
16 VLPC AND 16 ELECTRONIC CRATES PLACED EVENLY AT 11 25 DEG APART 32 CRATES TOTAL

3098



UTILITY AND CRATE(192) LAYOUT FOR DESCOPE OPTION 1

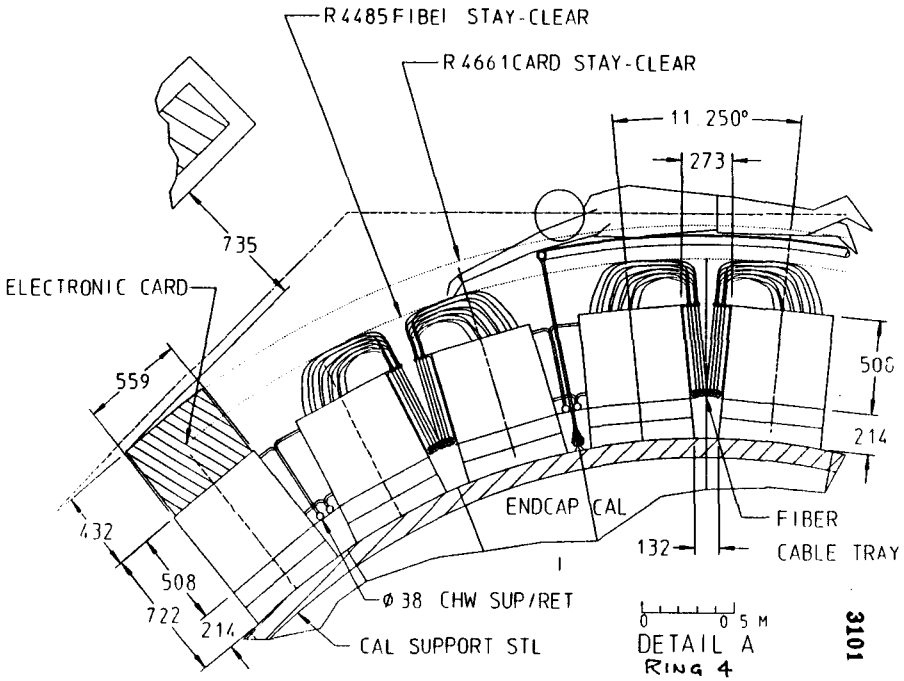
3095



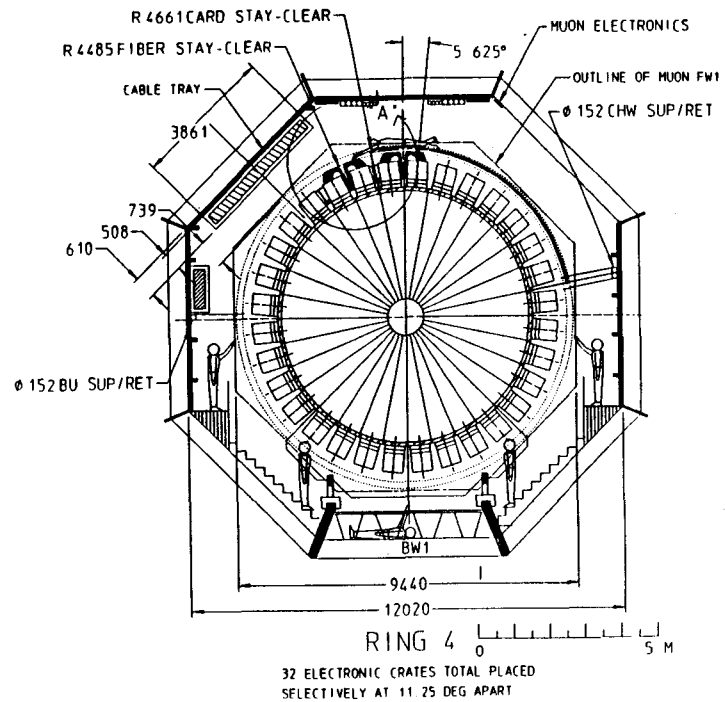
RING 1

8 ELECTRONIC CRATES TOTAL

3096



3101

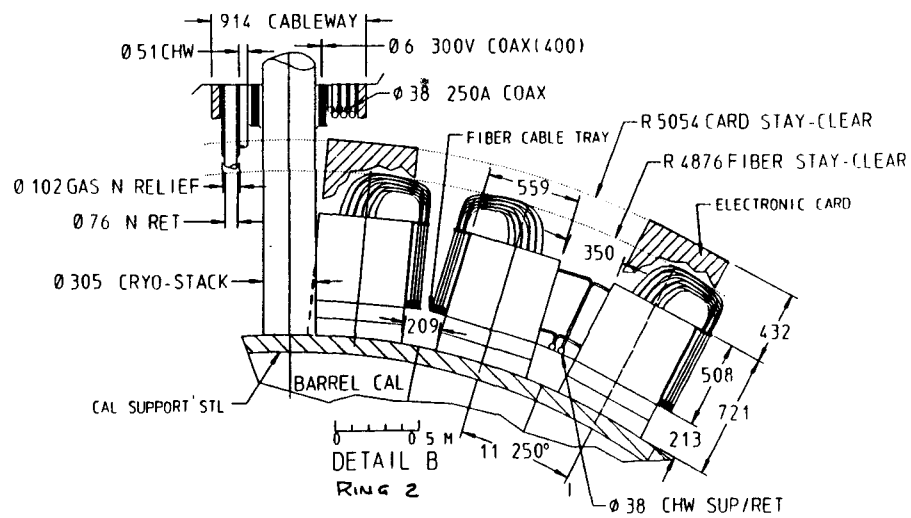


3099

LIST OF CRATES INSIDE THE LIQUID ARGON DETECTOR
(Count for May 29 Baseline given in brackets, if changed)

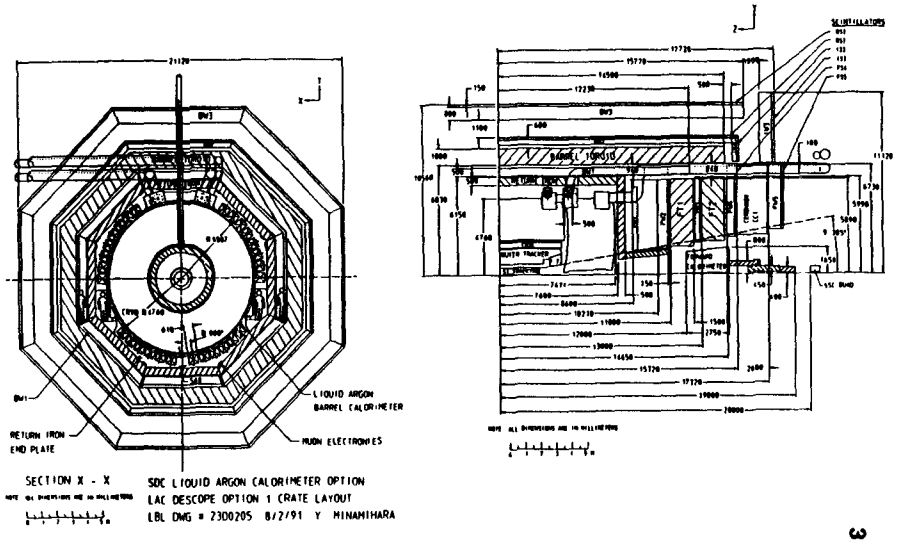
	Electr crates	VLPC cryostats	Calib Sources
Half of silicon Tracker	0	0	0
Half of wire Tracker	8 (16)	0	0
Half of barrel Calorimeter	20	0	0
Total on half of barrel calorim	28 (36)	0	0
No intermed SiFi Tracker	0	0	0
One endcap calorimeter	20	0	0
Total on one endcap	20	0	0
Entire trackr, barrel & endcaps	96 (112)	0	0

No PMT's on the end of the barrel.

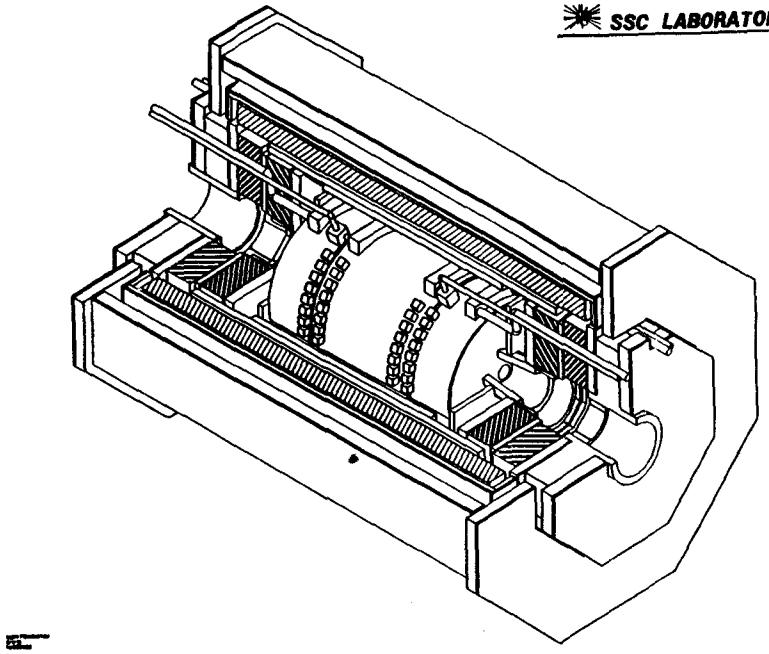


3100

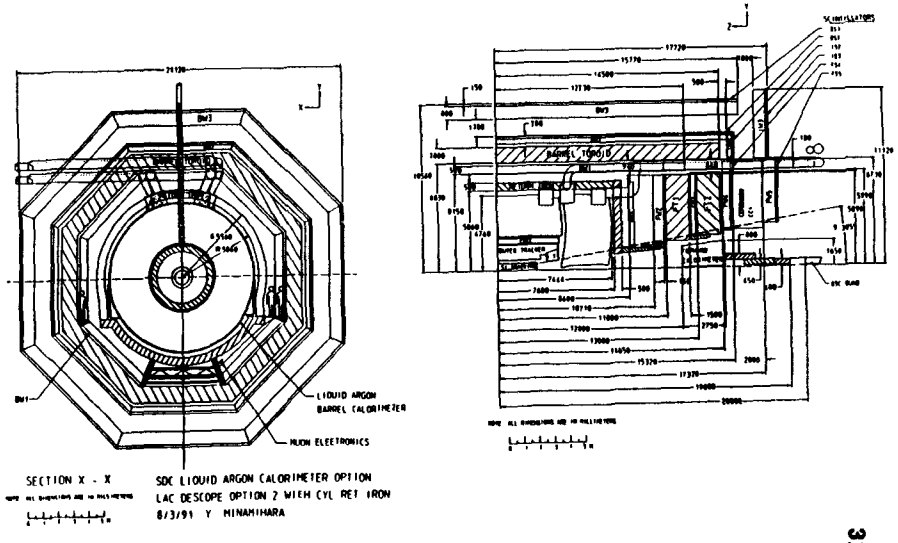
3102



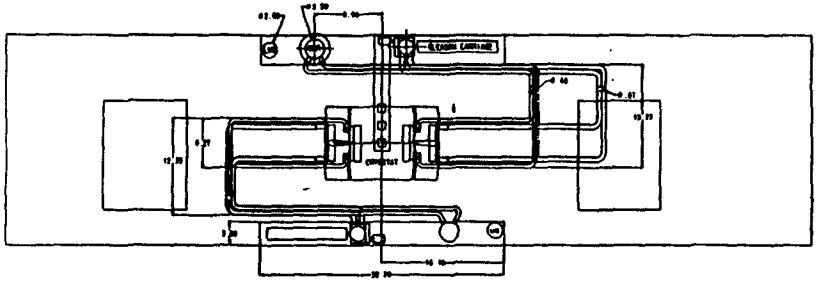
3105



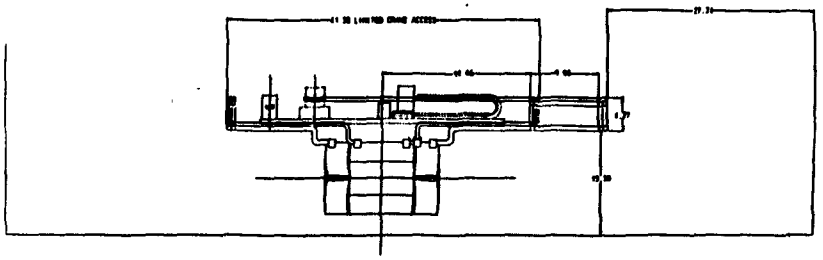
3103



3106

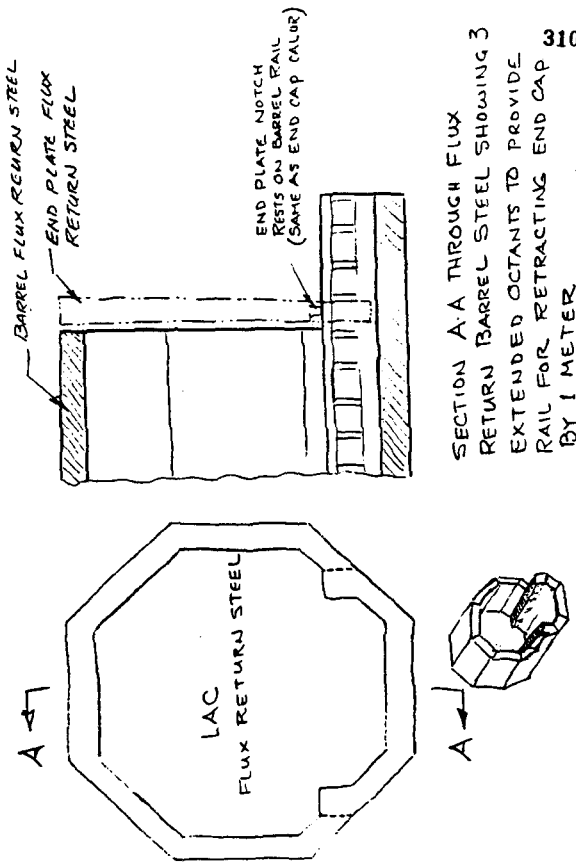


LAC Main Transfer Line Routing (J Rasson)



3104

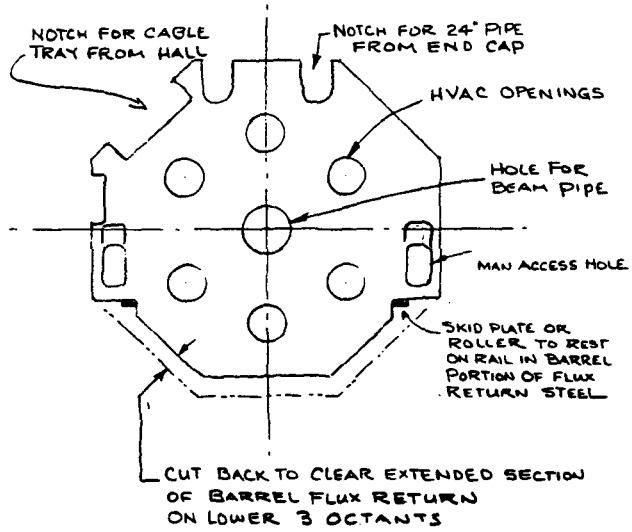
3107



SECTION A-A THROUGH FLUX RETURN BARREL STEEL SHOWING 3 EXTENDED OCTANTS TO PROVIDE RAIL FOR RETRACTING END CAP BY 1 METER

A. DuBois 7-19-91

3108

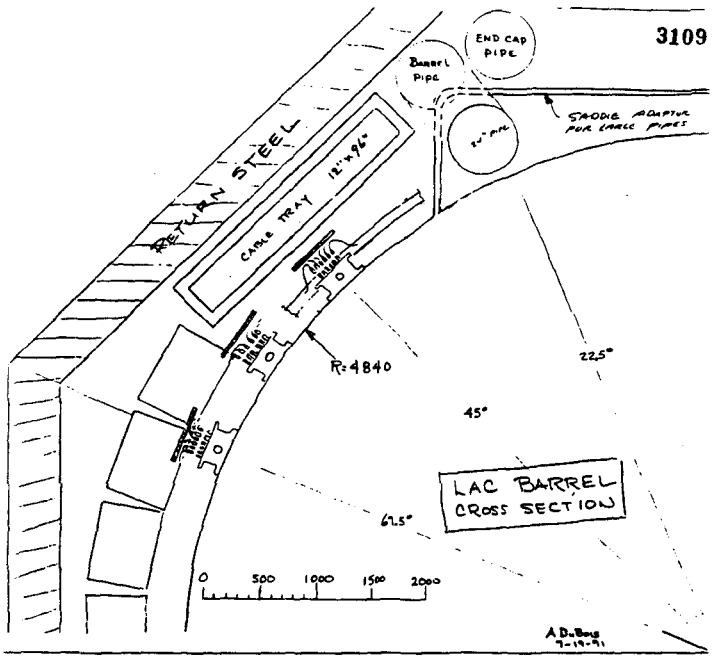


SCHEMATIC ELEV. VIEW OF END PLATE OF FLUX RETURN STEEL

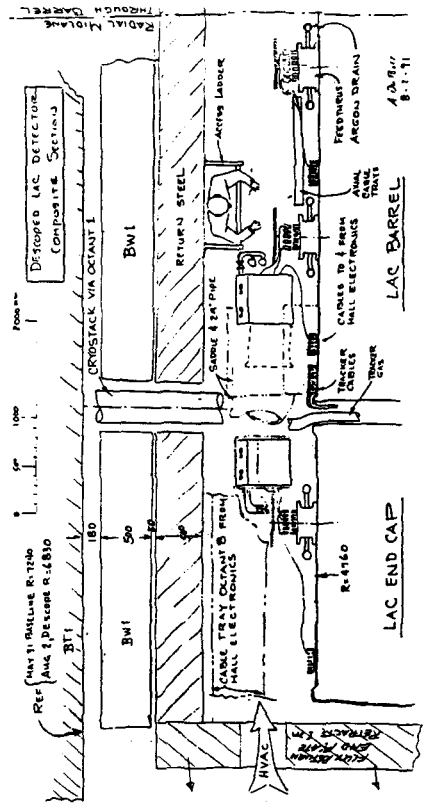
NOT TO SCALE

A. DuBois 7-19-91

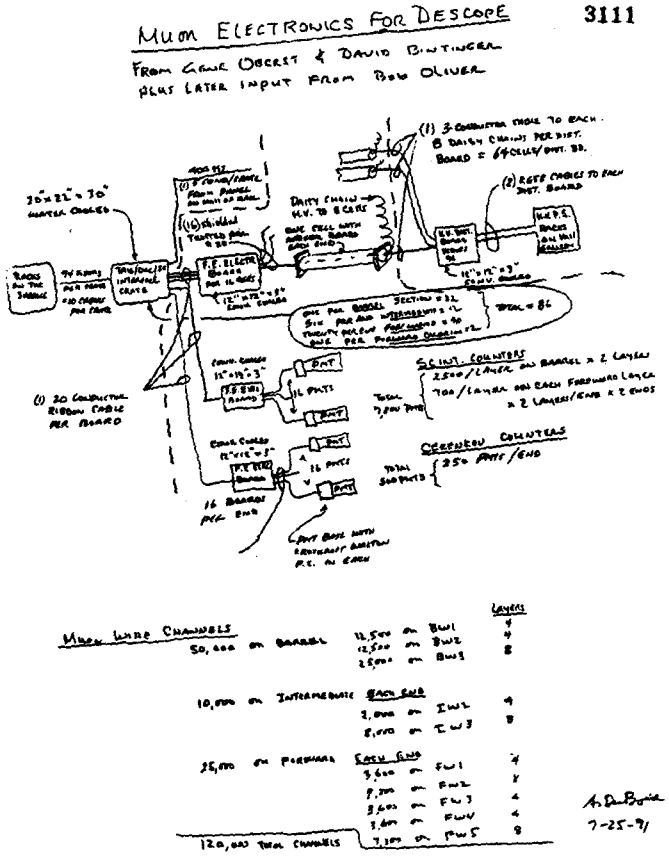
3109



3110



3111

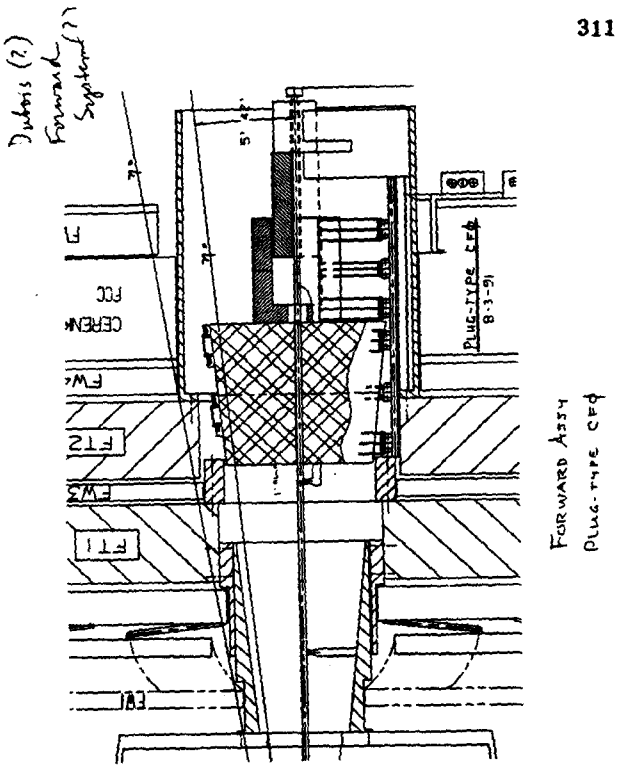


3112

LAYOUT OF FORWARD SYSTEM

A. DUBOIS

3113



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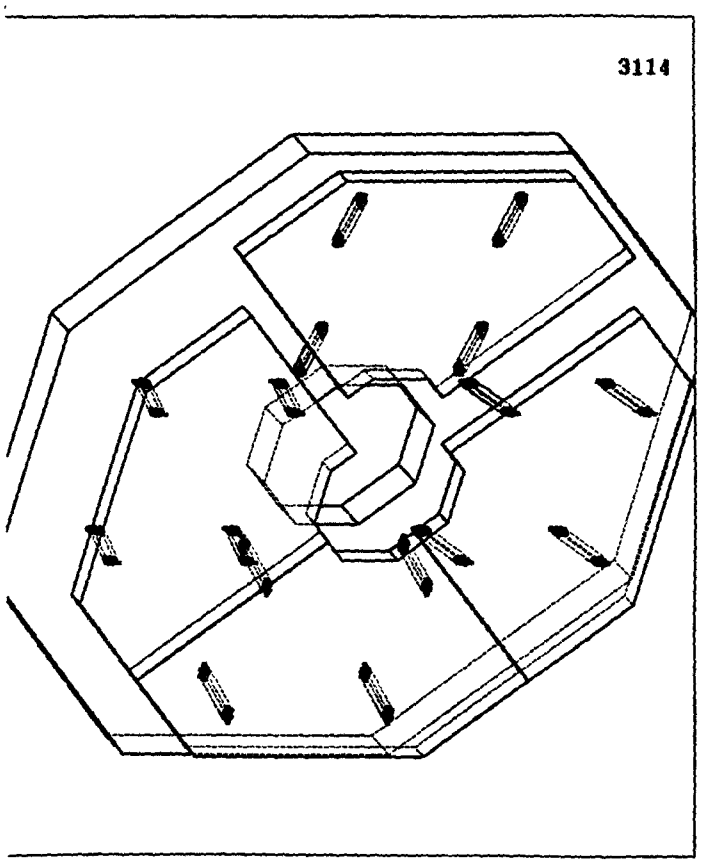

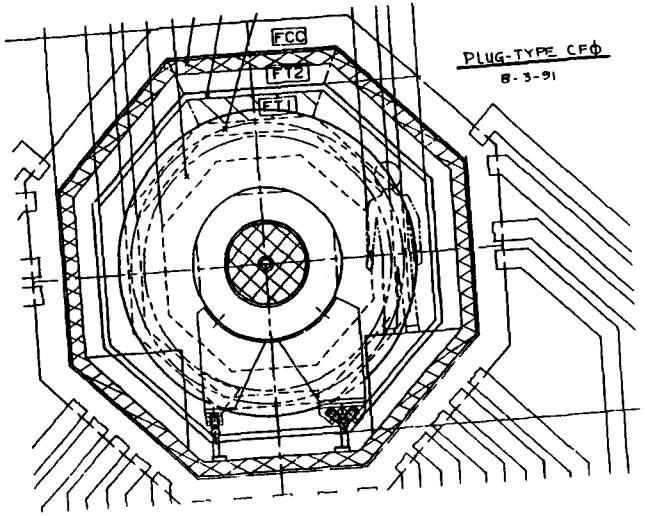

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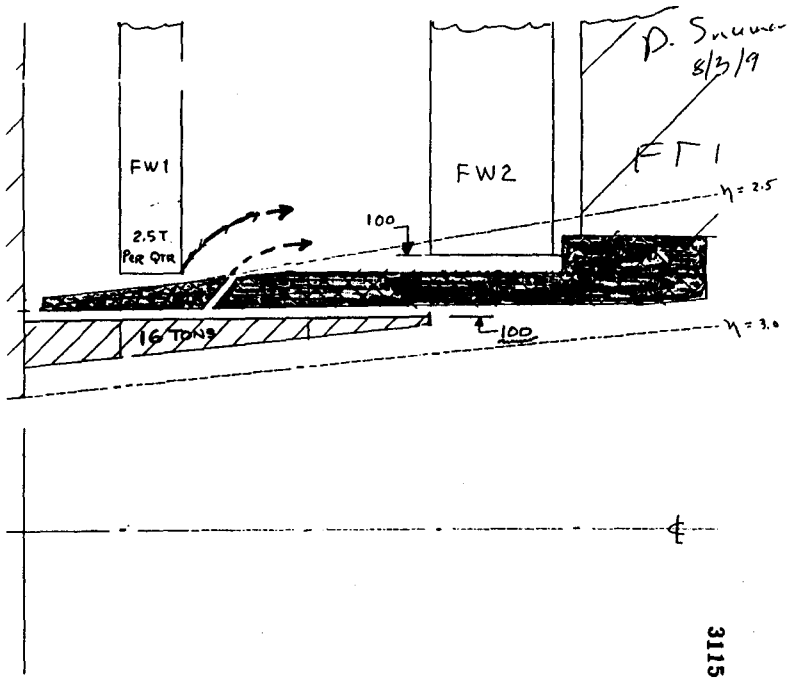

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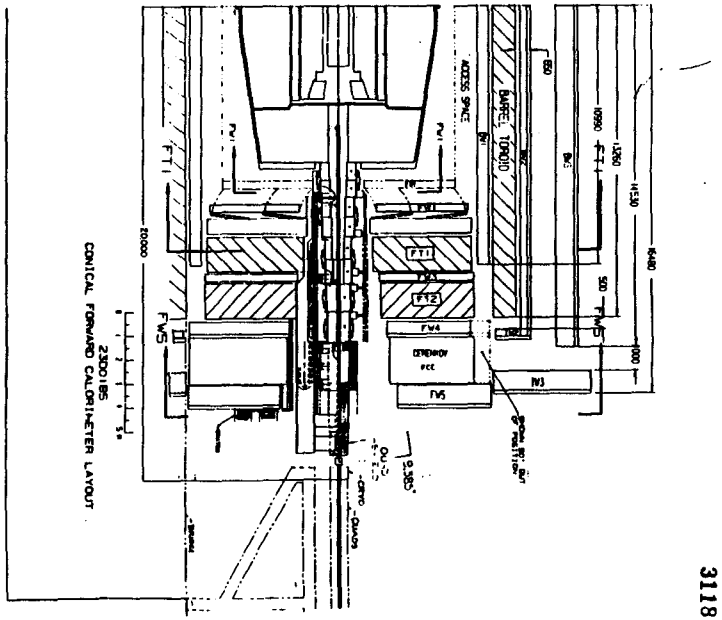

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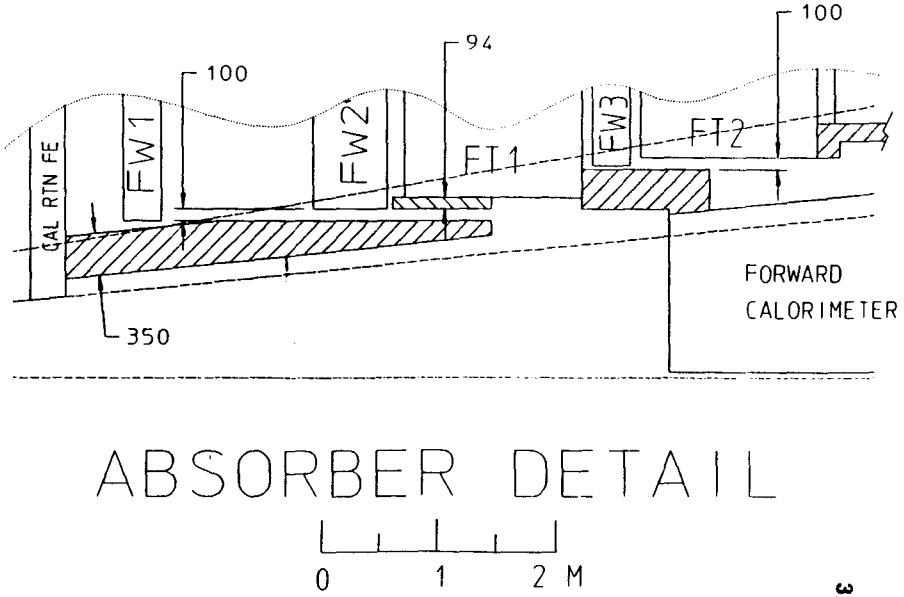

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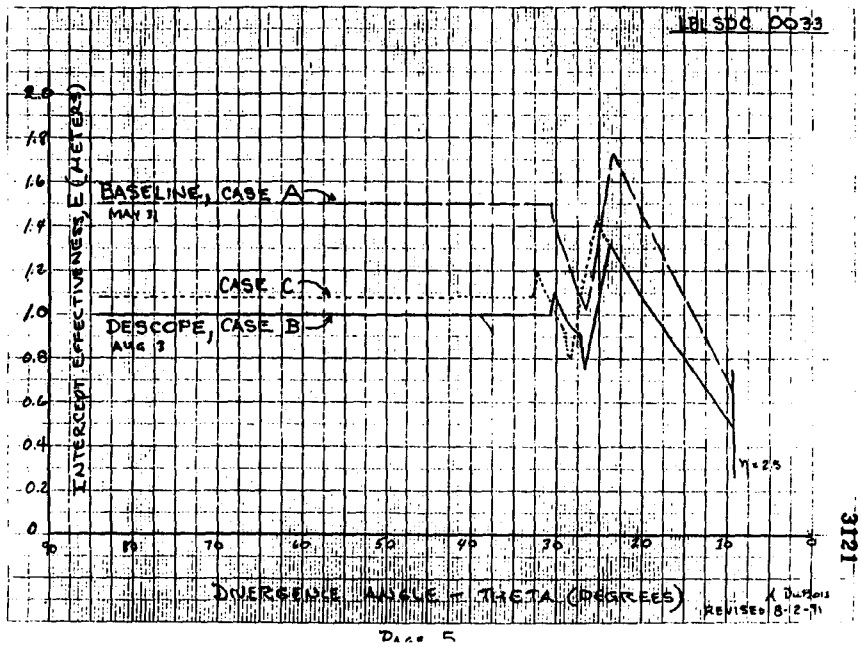

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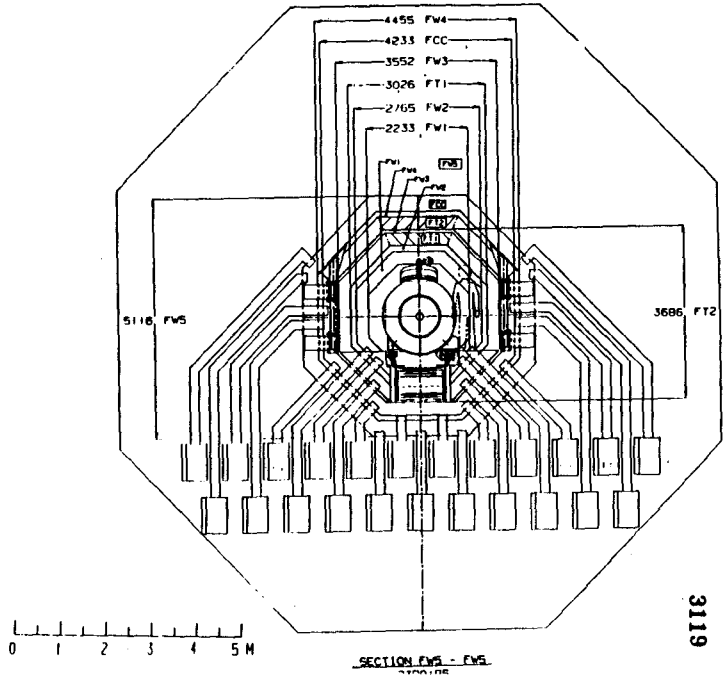

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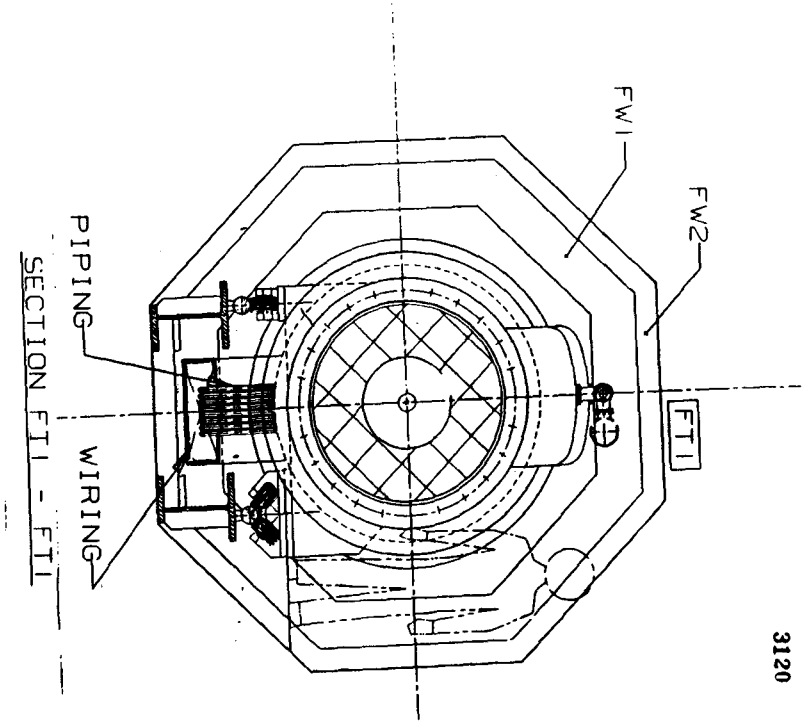

3120

Preliminary Integrated SDC Schedule

Bill Edwards LBL/SDC

August 6, 1991

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Other Scheduling Guidelines

If you use:

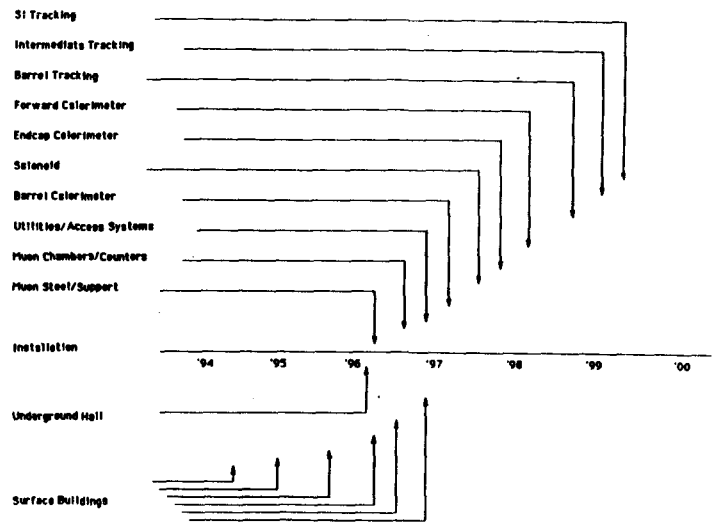
"Realistic" (for your institution) resource levels
"Realistic" task durations

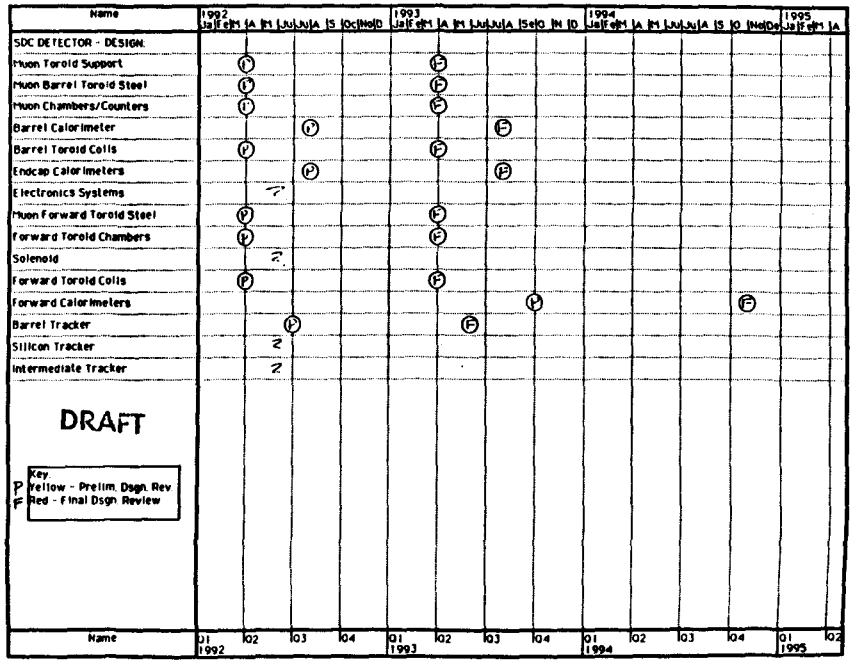
By comparing your milestone dates to SDC installation schedule, we learn if your:

Subsystem has float
Subsystem needs help (near critical path)

If you don't do this:

We don't learn much...





Subsystem Schedule Milestones

System Level Design Reviews
- Preliminary Design Review
- Final Design Review

Other Design Reviews
- Component Level Design Reviews
- Fabrication Reviews

Component Fabrication Start

Subsystem Assembly Start

Ship to SSCL

Arrives at SSCL / Subsystem Re-assembly Begins

"Top of Hole" (at Headhouse ready to be lowered)

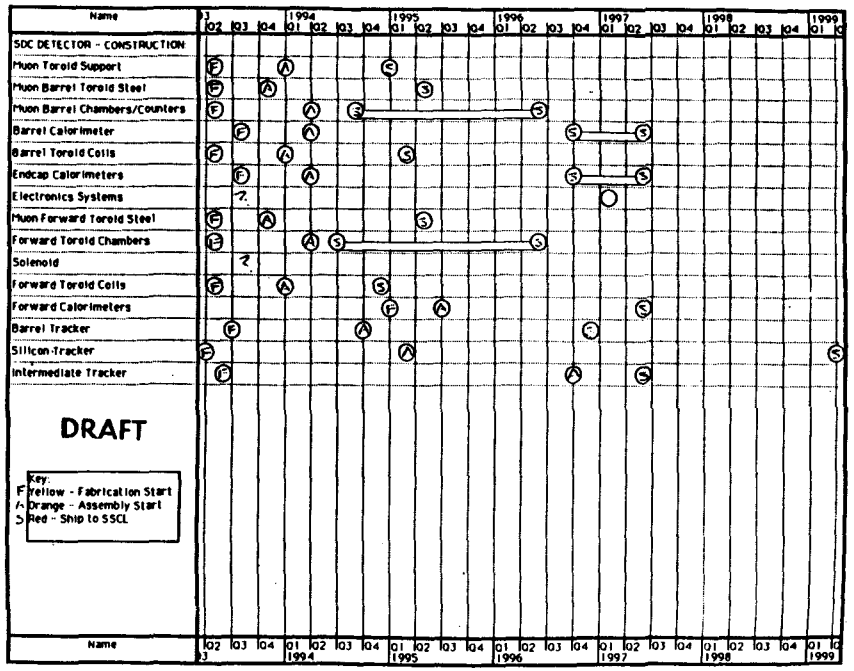
Holes in Integrated Schedule

Big holes:

- Electronics Systems
- Solenoid

Lesser holes (missing milestone dates):

- Entire Tracking System
- Barrel and Endcap Calorimeters



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Preliminary Integrated Construction Schedule

Float Areas (so far):

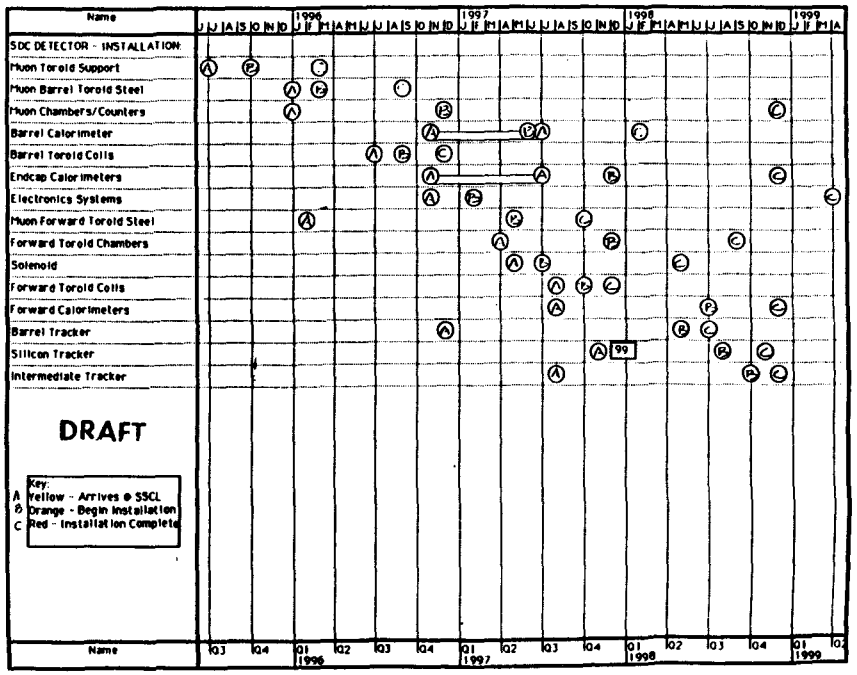
- Forward Calorimeter
- Muon Toroid Coils
- Muon Support System

Potential Critical Path Areas (so far):

- Barrel & Endcap Calorimeters
- Barrel & Intermediate Tracking
- Muon Toroid Steel
- Muon Chambers/Counters

Big Problems (so far):

- Silicon Tracking



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APPENDIX

LIST OF PARTICIPANTS

PARTICIPANT LIST
SOLENOIDAL DETECTOR COLLABORATION WORKSHOP
August 5-10, 1991

Fumio Abe
KEK
Oho 1-1
Tsukuba-shi
Ibaraki-ken,305 Japan

Koya Abe
Department of Physics
Tohoku University
Aramaki Aoba
Sendai, 980, Japan

Gerry Abrams
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

David Adams
Rice University
Houston, Texas 77251

Hiro Aihara
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Salvator R. Amendolia
Univ. and INFN/PISA
via Livornese 582
S. Piero Agrado (PI), Italy 56010

Eric J. Anderson
BD16
Rockwell International
3370 Miraloma Ave
Anaheim, CA 92803

Katsushi Arisaka
Department of Physics
Univ. of California, Los Angeles
405 Hilgard Ave
Los Angeles, CA 90025

Muzaffer Atac
MS 223
Fermilab
P.O. Box 500
Batavia, IL 60510

Jon A. Bakken
Mail Stop DC6069
Martin Marietta
P. O. Box 179
Denver, CO 80201

Michael J. Banas
Fermilab
P. O. Box 500
Batavia, IL 60510

Gene Barasch
Department of Physics
Texas A&M
Houston, TX

Rob Bard
University of Maryland
College Park, MD 20742

Charles R. Barney
Bldg. 90-2148
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Larry Bartoszek
Fermilab
P. O. Box 500
Batavia, IL 60510

Alan E. Baumbaugh
Fermilab
P.O. Box 500
Batavia IL 60510

Laura P. Bautz
Bldg. 50A-2160
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Chris Bebek
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Steve Behrends
Physics Department
Brandeis University
Waltham, MA 02254

Giorgio Bellettini
INFN Pisa
Pisa, ITALY

James Bensinger
Department of Physics
Brandeis University
Waltham, MA 02254

Paul J. Besser
Rockwell International Corp.
(031-BC16)
3370 Miraloma Avenue
Anaheim, CA 92803

Fred Bird
SSCL Lab.
2550 Beckleymead Avenue
Dallas, TX 05237

Robert E. Blair
High Energy Physics Div.
Argonne National Lab
Argonne, IL 60439

Pierre Bonamy
CEN Saclay
DPHPE
Gif-sur Yvette, 91191,

Aesook Byon-Wagner
Fermilab
P. O. Box 500
Batavia, IL 60510

Duncan Carlsmith
Department of Physics
Univ. of Wisconsin, Madison
1150 University Ave
Madison, WI 53106

John Chapman
Department of Physics
University of Michigan
500 E. University
Ann Arbor, MI 48109

Jeff Cherwinka
Physical Sciences Lab.
University of Wisconsin
3725 Schneider Drive
Stoughton, WI 53589

John W. Cooper
MS 318
Fermilab
P.O. Box 500
Batavia, IL 60510

Martyn Corden
S.C.R.I.
Florida State University
Tallahassee, FL

David Coupal
SSCL Lab.
2550 Beckleymead Ave.
Dallas, TX 05237

M. Daigo
Wakayama Medical College
Wakayama, Japan

Mourad Daoudi
Department of Physics
University of Colorado
P. O. Box 390
Boulder, CO 80309

Sergei Denisov

Andrew DuBois
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Bill Edwards
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Kevin Einsweiler
M/S 50-137
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Tony Elam
IBM/Federal Systems
Houston, TX

John E. Elias
Fermilab
P. O. Box 500
Batavia, IL 60510

Tom Elioff
(from SSCL)
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

M.S. Emery
Oak Ridge National Laboratory
Martin Marietta Energy Systems,Inc.
P. O. Box 2008
Oak Ridge, TN 37831

Robert Ennis
Federal Sector Division
IBM
Houston, TX

Geary Eppley
Department of Physics
Rice University
Houston, TX 77251

Jean Ernwein
CEN Saclay
DPHPE
Gif-sur Yvette, 91191,

Ali R. Fazely
Department of Physics
Louisiana State University
Baton Rouge, LA 70803

Gary Feldman
Harvard University
Cambridge, MA

E. Fenyves
Univ. of Texas, Dallas
P. O. Box 830688
Richardson, TX 75083

Farshid Feyzi
Physical Sciences Lab.
University of Wisconsin
3725 Schneider Drive
Stoughton, WI 53589

Richard D. Field
Department of Physics (245WM)
University of Florida
Gainesville, FL 32611

William Ford
University of Colorado
Boulder, CO 80309

Brian Foster
University of Bristol
Bristol B58 1TL England

G. William Foster
Fermilab
P.O. Box 500
Batavia, IL 60510

Jim Freeman
Fermilab
P.O. Box 500
Batavia, IL 60510

Henry Frisch
University of Chicago
Chicago, IL

Bill Frisken
(York University)
Lawrence Berkeley Laboratory
1 Cyclotron Rd.
Berkeley, CA 94720

Alan Fry
SSCL
MS 2001 #3/539
2550 Beckleymead Avenue
Dallas, TX 75237

Erwin Gabathuler
The Univ. of Liverpool
147
Oxford St.
Liverpool, ENGLAND L69 3BX

T.A. Gabriel
Oak Ridge National Lab.
Oak Ridge, TN

Irwin Gaines
Fermilab
P. O. Box 500
Batavia, IL 60510

Lina Gaitieri
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Arthur F. Garfinkel
Department of Physics
Purdue University
West Lafayette, IN 47907

Gil Gilchriese
Bldg. 50A-2160
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley CA 94720

Nikos Giokaris
Mail Stop 223
Fermi National Accelerator Lab.
P. O. Box 500
Batavia, IL 60510

James J. Gorman
Charles Stark Draper Lab.
555 Technology Square
Cambridge, MA 02139

Alfred T. Goshaw
Physics Department
Duke University
Durham, NC 27706

Stephen A. Gourlay
Fermilab
P.O. Box 500
Batavia, IL 60510

Daniel R. Green
Fermilab
P. O. Box 500
Batavia, IL 60510

Gregory Griffin
Univ. of California, Irvine
Irvine, CA

D.E. Groom
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Victor Guarino
Argonne National Laboratory
Argonne, IL

Glen Gunterberg
SSCL
Dallas, TX 05237

Laselo J. Gutay
Physics Dept.
Purdue University
West Lafayatte, IN 47907

Vasken Hagopian
Physics B-159
Florida State University
Tallahassee, FL 32306

Thomas Handler
Physics Dept.
University of Texas
Knoxville, TX 37996

Gail G. Hanson
Department of Physics
Indiana University
Swain West 269
Bloomington, IN 47405

Mike Harris
SSCL
Dallas, TX 05237

Katsuo Hasegawa
Physics Dept.
Tohuku University
Aoba, Sendai JAPAN, 980

Christopher Hearty
Lawrence Berkeley Lab.
1 Cyclotron Rd.
Berkeley CA 94720

Marvin Hecht
SSCL
2550 Beckleymeade
Dallas, TX 05237

Ken Heller
Univ. of Minnesota
School of Physics & Astronomy
116 Church St., S.E.
Minneapolis, MN 55455

Yoshimoto Hoshi
Tohoku Gakuin University
1-13-1 Chuo
Togajo Miyagi 985

Dick Hubbard
CEN Saclay
DPHPE
Gif-sur Yvette, 91191,

James Hylen
Fermilab
P. O. Box 500
Batavia, IL 60510

Hiro Iwasaki
KEK, Lab for Hi-Energy Physics
Oho 1-1
Tsukuba-shi, JAPAN

Kenneth A. Johns
Physics Department
University of Arizona
Tucson, AZ 85721

Doug Johnson
Department of Physics
University of Colorado
P. O. Box 390
Boulder, CO 80309

Harald Johnstad
SSCL
2550 Beckleymeade
Dallas, TX 75237

Warren Kampmeier
SSCL
2550 Beackleymeade
Dallas, TX 05237

Robert D. Kephart
MS 318
Fermilab
P.O. Box 500
Batavia, IL 60510

Terez King
Randall Lab. of Physics
University of Michigan
Ann Arbor, MI 48109

Tom Kirk
Argonne National Lab.
Argonne, IL

Edward Kisteney
Brookhaven National Laboratory
Upton, LI NY 11973

Vladmir Kochitov

David S. Koltick
Department of Physics
Purdue University
West Lafayette, IN 47907

Takahiko Kondo
KEK
1-1 Oho< Tsukuba
Ibaraki, 305 JAPAN

Gordon Kramer
Bldg. E1 M/S C173
Hughes Aircraft Company
2000 E. El Segundo Blvd.
El Segundo, CA 90245

Valery Kubarovsky
IHEP
Moscow, USSR

Glenn Kubena
IBM
Houston, TX

Shuichi Kunori
University of Maryland
College Park, MD 20742

Klaus Lackner
Los Alamos National Lab.
Los Alamos, NM 87545

Andy Lankford
University of Irvine
Irvine, CA 92717

Eric Larson
Fermilab
P. O. Box 500
Batavia, IL 60510

Robert F. Lavelle
SSCL
Dallas, TX 05237

Patrick Le Dû
CEN Saclay
DPHPE
Gif-sur Yvette, 91191,

Michael Levi
Bldg. 50A-2150
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

Raymond A. Lewis
Penn State University
303 Osmond Lab
University PA 16802

Ken Liao
IBM
Houston, TX

Richard D. Loveless
Physics Dept.
University of Wisconsin
1150 University Ave
Madison, WI 53106

Henry Lubatti
Dept. of Physics FM-15
Univ. of Washington
Seattle, WA

Frederick Luehring
Physics Department
Indiana University
Swain West 258
Bloomington, IN 47405

Rick Luther
Fermilab
P.O. Box 500
Batavia, IL 60510

Akihiro Maki
KEK
1-1 Oho, Tsukuba
Ibaraki, 305 JAPAN

Michelangel Mangano
INFN Pisa
Pisa ITALY

Seymour Margulies
Dept. of Physics
Univ. of Illinois at Chicago
P. O. Box 4348
Chicago, IL 60680

John Matthews
Univ. of New Mexico

Philipp Melese
Dept. of Physics
Rockefeller Univ.
P. O. Box 286
1230 York Ave.
New York, NY 10021

Hannu Miettinen
Rice University
Houston, TX 77251

David Miller
Dept. of Physics
Purdue University
West Lafayette, IN 47907

William Miller
MS E533
Los Alamos National Lab.
P. O. Box 1663
MEE-12 Group
Los Alamos, NM 87545

Luke Mo
Physics Department
Virginia Polytechnic Inst./State Univ.
Blacksburg, VA 24061

Thomas Moore
Lawrence Livermore Nat'l Lab
P. O. Box 808 L-280
Livermore, CA 94550

Mike Murbach
Dept. of Physics, MDG.
University of Maryland
College Park, MD 20907

Uriel Nauenberg
Department of Physics
University of Colorado
Campus Box 390
Boulder, CO 80309

Masaharu Nomachi
Fermilab
P. O. Box 500
Batavia, IL 60510

David R. Nygren
M/S 50B-6222
Lawrence Berkeley Laboratory
1 Cyclotron Rd.
Berkeley, CA 94720

Kathy O'Shaughnessey
UC Santa Cruz
Santa Cruz, CA 95064

Eugene F. Oberst
Lawrence Livermore Lab.
P. O. Box 808
L-280
Livermore, CA 94550

Shigeru Odaka
KEK, Lab for High Energy Physics
Oho 1-1, Tsukuba-shi,
Ibaraki, 305, JAPAN

Takashi Ohsugi
Hiroshima Univ.
Higashi-seda 1-1-89, Naka-ku
Hiroshima, JAPAN 730

John Oliver
HEPL
Harvard University
Cambridge, MA

Robert Orr
University of Toronto
Toronto, Canada M5S 1A7

Andrea Palounek
Los Alamos National Lab.
P. O. Box 1663
Los Alamos, NM 87545

Sherwood Parker
University of Hawaii
Honolulu, HI 96822

Richard Partridge
Department of Physics
Brown University
Providence, RI 02912

James F. Patrick
MS 318
Fermilab
P.O. Box 500
Batavia, IL 60510

David Pellett
UC Davis
922 Eureka
Davis, CA 95616

Carl Pfeiffer
Bldg E1 M/S F140
Hughes Aircraft Co.
2000 E. El Segundo Blvd.
El Segundo, CA 90245

Jon Piles
SSCL
2550 Beckleymeade
Dallas TX 05237

Oleg Pogorelko
ITEP
Moscow, USSR

Joe Pohlen
Martin Marietta
P. O. Box 179
Denver, CO 80120

William L. Pope
90-2136
Lawrence Berkeley Lab.
1 Cyclotron Rd.
Berkeley , CA 94720

Larry Price
Argonne National Lab.
Bldg. 362
Argonne, IL 60439

Tom Prosapio
SSCL
2550 Beckleymeade
Dallas, TX

James Proudfoot
Argonne National Lab.
Argonne, IL

Joseph Rasson
Bldg. 90-2148
Lawrence Berkeley Lab.
1 Cyclotron Rd.
Berkeley, CA 94720

Robert S. Reid
Los Alamos National Lab.
1663 M/S J576
Los Alamos, NM 87545

Bob Richardson
SSCL
2550 Beckleymeade
Dallas, TX 05237

Dr. Alan Richardson
Nanoptics Inc.

Salvator Roberto
Amendolia

Françoise Rondeaux
CEN Saclay
DPHPE
Gif-sur Yvette, 91191,

Anatoly Ronzhin
IHEP
Protvino
Italy

Randy C. Ruchti
Dept. of Physics
University of Notre Dame
Notre Dame, IN 46614

Ted L. Ryan
M/S 8055
Oak Ridge National Lab.
P. O. Box2009
Bldg. 9204-1
Oak Ridge, TN 37831

Silvano Sala
INFN High Energy Group
via Celoria, 16
Milano, Italy

Martin Salomon
TRIUMF
4004 Wesbrook Mall
Vancouver, B.C. Canada, V6T 2A3

David W. Scherbarth
Westinghouse STC
1310 Beulah Rd.
Pittsburgh PA 15235

Abraham Seiden
Institute for Particle Physics
University of Santa Cruz
Santa Cruz, CA 95064

Derek Shuman
M/S 90-2148
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

James Siegrist
SSCL Lab.
M/S 2000
2550 Beckleymeade Ave.
Dallas, TX 75237

Alan Sill
Dept. of Physics and Astronomy
University of Rochester
Rochester, NY 14627

Pekka K. Sinervo
Dept. of Physics
Univ. of Toronto
60th St. George St.
Toronto, Ontario, M5S 1A7

Andris Skuja
Dept. of Physics
University of Maryland
College Park, MD 20742

Victor Sionim
University of Colorado
Campus Box 390
Boulder CO 80309

Wesley Smith
Physics Dept.
Univ. of Wisconsin
Madison, WI 53706

Helmuth Spieler
50B-6208
Lawrence Berkeley Lab.
1 Cyclotron Rd.
Berkeley CA 94720

Ray Stefanski
SSCL
2550 Beckleymeade
Dallas, TX 05237

Roger Stone
Lawrence Berkeley Laboratory
1 Cyclotron Rd.
Berkeley, CA 94720

Greg Sullivan
HEP 318
University of Chicago
Enrico Fermi Institute
5640 S. Ellis Avenue
Chicago, IL 60637

Roger L. Swensrud
Westinghouse Electric
1310 Beulah Rd.
Pittsburgh, PA 15235

Yoshinobu Takaiwa
KEK
1-1 Oho, Tsukuba
Ibaraki, 305 JAPAN

Kohji Takikawa
Tsukuba University
Tsukaba-shi, 305,

Paul Taras
University of Montreal
Canada

S. Terada
KEK, Lab for High Energy Physics
Oho 1-1
Tsukuba-shi, 305,

Rudi Thun
University of Michigan
The Harrison M. Randall
Laboratory of Physics
Ann Arbor, MI 48109

Tim Thurston
SSCL
2550 Beckleymeade
Dallas, TX 05237

George Trilling
50A-2160
Lawrence Berkeley Laboratory
1 Cyclotron Rd.
Berkeley, CA 94720

Marc Turcotte
SSCL
2550 Beckleymeade Ave.
Dallas, TX 95104

Yoshinobu Unno
KEK
1-1 Oho, Tsukuba
Ibaraki, 305 Japan

Richard Van Berg
Department of Physics
Univ. of Pennsylvania
209 S. 33rd Street
Philadelphia, PA 19104

David H. Vandergriff
Martin Marietta Energy Systems
2003
Bldg. K1580
Oak Ridge, TN 37831-7

Bill Vinnedge
SSCL
2550 Beckleymeade
Dallas, TX 05237

A.S. Vodopianov
JINR, Dubna
79
USSR 101 000

J.K. Walker
Department of Physics
University of Florida
FL

Yoshiyuki Watase
Osaka Univ./KEK
1-1, Machikaneyamacho
Toyonaka, Osaka 560 Japan

Bill Wenzel
50/ 137
Lawrence Berkeley Laboratory
1 Cyclotron Rd.
Berkeley, CA 94720

Jim West
IBM Corp, MC 5600
3700 Bay Area Blvd.
Houston, TX 77058

Jeff Western
SSCL
2550 Beckleymeade
Dallas, TX 05237

Andrew P. White
University of Florida
215 Williamson Hall
Gainesville, FL 32611

James T. White
Physics Dept.
Texas A&M
College Station, TX 77843

Arthur B. Wicklund
Argonne Nat'l Lab.
9200 S. Cass Ave.
Argonne, IL 60439

Hugh H. Williams
Department of Physics
University of Pennsylvania
Philadelphia, PA 19104-6

Suzanne E. Willis
Northern Illinois Univ.
De Kalb, IL 60115

David Winn
Wilton, CT 06897

Zhongxhin Wu
Dept. of Physics
Rockefeller University
P. O. Box 286
1230 York Ave.
New York, NY 10021

Akira Yamamoto
KEK
1-1 Oho, Tsukuba
Ibaraki, 305 Japan

Julia Yarba
SSCL
2550 Beckleymeade
Dallas, TX 05237

K. Yasuoka
University of Tsukuba
Institute of Physics
Japan

Yuji Yoshizawa
UCLA/Hamamatsu
405 Hilgard Ave
Los Angeles, CA 90025

Saul Youssef
SCRI
Florida State Univ.
Tallahassee, FL 32306-4

Bekzhad Yuldashev
Institute of Nuclear Physics
Tashkent USSR 7000 084

Tianchi Zhao
University of Washington
Seattle, WA

Yuehua Zhou
Fermilab
P. O. Box 500
Batavia, IL 60510

Hans Ziock
Los Alamos National Lab.
Los Alamos, NM 87545