GEM TN-92-85

GEM Collaboration Meeting - Tucson

March 8-11, 1992

Abstract:

Agenda, attenders and transparencies of the GEM Collaboration Meeting held in Tucson on March 8-11, 1992.

AGENDA
GEM COLLABORATION
Tucson, Arizona
March 7-11, 1992

SUNDAY MARCH 8

Informal meetings all day

MONDAY MARCH 9 PLENARY MEETING

8:30	B Barish	The State of GEM
9:00	G Sanders	The GEM Project at SSCL
9:45	M.Harris	GEM Facilities at IR5
		Video of GEM Installation
10:00	BREAK	

BASELINE DISCUSSIONS

10:30	GEM Baseline Overview	M.Marx
10:50	Magnet	R Stroynowski
11:20	Muons	F Taylor
11:50	Tracker	C Baltay
12:20	LUNCH	
1:30	Physics Talk: Sekhar Chivakula "The Dynamics of Electroweak Symmetry Breaking"	

BASELINE CONTINUED

2:30	Calorimeter (Liq Argon/BaF2 + Hadronic)	Y Kamyshkov

3:15 Forward Calorimeter J Rutherfoord

3:45 BREAK

4:15 GEM Triggering Shaevitz/Marlow

4:45 Discussion of the Baseline
and Working Group Formation

5:30 Physics Talk: Ian Hinchliffe

6:30 Adjourn

TUESDAY MARCH 10 WORKING GROUPS

8:30 - 2:30

1 Forward Regions - calorimetry,muons,magnet,beam pipe and vacuum
(D. Lee,J. Rutherfoord, K. Morgan)
Radiation levels vs Resolution vs Missing Et....

2 A Re-examination of the tracker design driven by physics requirements
(J.Brau, C.Baltay, L.Rosenson, R.Stroynowski)
Volume (Radius&Length),Goals,Preradiator,High L,B Field

3 Detector Alignment
(J.Branson,J.Paradiso,D Veal)
Alignment of Muons Chambers
Aligning Detector Components to the Vertex

4 Calorimeter Depth, Muon Backgrounds
(F. Taylor,H.Gordon,R.Mcneil)

5 Pattern Recognition,Acceptance and Redundancy in Tracking and Muons
(G. Mitselmakher,M. Atiya,F.Paige, J.Musser)

6 Modelling the Detector
(K.McFarlane,N.DiGiacomo,M.Shupe)
How to go from Engineering specs to simulation
Detector data base - what's in it and how to store/access

10:00-10:20 BREAK

2:30- 3:00 BREAK

3PM Cross Disciplinary Group

Integration (Marx,Harris)

Simulation (McFarlan,Lane)

Triggering (Marlow,Shaevitz)

7:30 BANQUET

WEDNESDAY MARCH 11 PLENARY SESSIONS

8:00 REPORT ON LHC EVIAN MEETING (Marx)

8:30 REPORTS OF WORKING GROUPS AND ISSUES FOR FUTURE

10:00 BREAK

10:30 INITIATION OF DETECTOR COSTING G SANDERS

11:00 WHAT'S NEXT? W. WILLIS

11:30 FINAL DISCUSSION OF BASELINE

12:00 ADJOURN

12:15 EXECUTIVE COMMITTEE

GEM COLLABORATION MEETING

Attenders

GEM COLLABORATION MEETING
March 7-12, 1992
Tucson, Arizona

NAME	AFFILIATION
Abolins, Maris	Michigan State Univ.
Akchurin, Nural	Univ. of Iowa
Alam, M.S.	U. of Albany
Allen, Charles C.	UT Austin
Amory, Jacque Pier	SSCL
Atiya, Maged	BNL
Ballard, Luann	SSCL
Baltay, Charles	Yale
Barabash, Leonid	SSCL
Barber, Ronald	LANL
Barish, Barry	Caltech
Berridge, Steve	Univ. of Tennessee
Bonushkin, Y	SSCL
Botlo, Michi	SSCL
Bower, Charles	Indiana Univ.
Bowers, Joel	LLNL
Brau, Jim	Univ. of Oregon
Brooks, Melynda	LANL
Brower, William	UCSD
Bugg, W. M.	Univ. of Tennessee
Burrows, Philip	MIT
Castoldi, Clara	INFN-Pavia (Italy)
Chae, Steven M.	ORNL
Chapman, Gerry	SSCL
Chargin, Anthony K.	LLNL
Chen, Zemin	Duke U.
Chen, Zukun	SSCL
Chen, Gang	Beijing Glass Research inst.
Chu, Teh-Ling	Academia Sinica Taiwan
Cleland, W.E.	University of Pittsburgh
Cohn, Hans Otto	ORNL
Cook, Victor	Univ. of Washington
Cooke, Brad	LANL
Cormell, Larry	SSCL
Crosette, Dario	SSCL

David, Ram Ber	Yale
Deis, Gary	LLNL
DiGiacomo, Nick	Martin Marietta
Dingus, Peter	SSCL
Du, Peter	Univ. of Tennessee
Durden, Holly	SSCL
Easom, Brian	Martin Marietta
Eberle, Cliff	ORNL
Edelstein, Richard M.	Carnegie Mellon Univ.
Egorov, Serguei	Sci. Res. Inst. Russia
Eklund, Michael	U. of Arizona
Engler, Arnold	Carnegie Mellon Univ.
Fanourakis, George	U. of Rochester
Ferbel, Tom	U. of Rochester
Ferguson, M. I.	U. of Arizona
Fischer, Richard	SSCL
Fissiak, Iouri	SSCL
Flickinger, Henry	Draper
Forden, Geoff	UA
Frey, Raymond	Univ. of Oregon
Furuno, Koichiro	SLAC
Gober, Norman	SSCL
Golutvin, Andrey	Inst.Theo.&Exp.Russia
Golutvin, Igor	Inst of Nuc Phys Russia
Gordon, Howard	BNL
Gu, Yi fan	Inst. of HEP Beijing
Hale, Phylis	SSCL
Harris, Mike	SSCL
Hinchcliffe, Ian	LBL/ SDC member
Johnson, Charles	LANL
Johnson, Coleman	LLNL
Johnson, Tony	SLAC
Jones, Mark	SSCL
Jung, Chang Kee	SUNY
Kamyshkov, Yuri	UT/ORNL
Kendall, Henry W.	M.I.T.
Killian, Ken	Martin Marietta
Kim, C.O.	Korea Univ.
Kobrak, Hans	U.C. San Diego
Konstantinov, Yury	Sci. Res. Inst. Russia
Korytov, Andrey	M.I.T.
Lane, Kenneth	Boston Univ.
Lee, David M.	LANL

Leltchouk, Mikhail	Columbia Univ. Nevis
Li, Pejung	Inst. of Ceramics Sanghai
Liu, Gang	Caltech
Lissauer, David	BNL
Lowry, Mark E.	LLNL
Lubatti, Karen E.	U. of Arizona
Lynch, Harvey	SSCL
Ma, Hong	BNL
Marlow, Daniel R.	Princeton Univ.
Marston, Peter	M.I.T.
Marx, Michael	SSCL
Mason, Lyle	Martin Marietta
Mayes, Bill W.	U. of Houston
McCammon, Kent	LLNL
McCliment, Edward	
McFarlane, Kenneth	SSCL
McKee, Shawn	Univ. of Michigan
McNeil, Roger	Louisiana State Univ.
Miller, Robert	Michigan State Univ.
Mills, Geoffrey B.	LANL
Mitselmakher, Gena	SSCL
Mockett, Paul	Univ. of Washington
Mohammadi, Mohammad	SUNY
Moore, Brent R.	U. of Mississippi
Morgan, Kate	SSCL
Mount, Richard P.	Caltech
Musser	Indiana Univ.
Mzavia, David	Sci. Res. Inst. Russia
Newman, Harvey B.	Caltech
Nimblett, Frank	Draper
Onel, Y.	U. of Iowa
Osborne, Louis	M.I.T.
Paar, Hans	UCSD
Paige, Frank	SSCL
Paradiso, Joseph	Draper
Pare, John	E-Systems
Parsons, John	Columbia Univ. Nevis
Plasil, Franz	ORNL
Pless, Irwin A.	MIT
Polychronakos, V.A.	BNL
Prosapio, Tom	SSCL
Read, Kenneth	ORNL
Reardon, Paul J.	SSCL

Reidy, Jim	Univ. of Miss.
Rennich, Mark	ORNL
Richardson, Robert A.	SSCL
Riley, Richard	Draper
Ritchie, Jack	UT Austin
Roberts, Lee	SSCL
Rosenson, Lawrence	M.I.T.
Rutherfoord, John	Univ. of Arizona
Sabin, Emile	SSCL
Samsonov, Velodia	FNAL
Sanders, Gary	LANL
Sarantsev, Viktor	SSCL
Scipioni, Brian	SSCL
Seman, Michal	Columbia Univ. Nevis
Sen, Sumit	Yale
Shaevitz, Michael	Columbia Univ. Nevis
Shank, James	Boston Univ.
Shaver, Leif	Univ. of Arizona
Shi, Xiaorong	Cal. Tech.
Shmakov, Konstantin	Univ. of Tennessee
Shupe, Mike	UA
Sidorov, V.	Sci. Res. Inst. Russia
Simmons, Elizabeth H.	Harvard Univ.
Smith, Bradford	M.I.T.
Smith, Brian	LANL
Stockes, Frank	SSCL
Stroynowski, Richard	S. Methodist Univ.
Sulak, Lawrence	Boston Univ.
Sullivan, Dan	Draper
Sullivan, J.D.	M.I.T
Takashima, Makato	SSCL
Taylor, Frank	M.I.T.
Teng, Ping-Kun	Inst. of Phys. Taiwan
Thomas, Jennifer	SSCL
Titus, Peter	MIT
Todd, Richard A.	ORNL
Tomasz, Skwarnicki	Syracuse Univ.
Tomlinson, Donna	Caltech
VanBibber, Karl	LLNL
Vaniachine, Alexandre	SSCL
Vasiliev, Vladimir	Sci. Res. Inst. Russia
Venuti, John	Vanderbilt
Villasenor, Luis	SSCL

Walton, Ed	SSCL
Wang, Jing Jin	Inst. of Phys. Beijing
Wang, Ming-Jer	Academia Sinica Taiwan
Warren, Richard	LLNL
Waters, Laurie	LANL
Webb, Robertt C.	Texas A&M
Weidemann, Achim W.	Univ. of Tennessee
Wenaus, Torre J.	LLNL
Whitaker, Scott	Boston University
Widgoff, Mildred	Brown University
Wigmans, Richard	TTV
Wilburn, Colin	Micronsemiconductor
Willis, William	Columbia Univ. Nevis
Wineman, Sarah	LLNL
Winn, David	Fairfield Univ.
Wisniewski, Bill	Caltech
Wolin, Elliott	Yale
Womble, Ed	Draper
Woody, Craig	BNL
Woolley, Ronn	SSCL
Worstell, William A.	Boston Univ.
Yamamoto, Robert	LLNL
Yan, Nai-Guo	FNAL
Yanagisawa, Chiaki	SUNY
Yao, Nai Guo	FNAL
Yost, George	SSCL
Young, Kathy G.	ORNL
Yu, Xiao, Qi	UofSci.&Tech Zhejiang
Zhu, Ren-yuan	CALTECH
Zielinski, Marek	U. of Rochester

GEM COLLABORATION MEETING

TUSCON

Agenda

Monday March 9, 1992

Monday March 9, 1992 Plenary Meeting - Morning

8:30	B.Barish	The State of GEM
9:00	G.Sanders	The GEM Project at the SSCL
9:30	M.Harris	GEM Facilities at IR5
	E. Sabin / M. Prosapio	Underground Hall / Surface Facilities
10:05	Break B. Richardson	Cryogenics
10:30	M.Marx	GEM Baseline Overview
10:50	R.Stroynowski	Magnet
11:20	F.Taylor	Muons
11:50	C.Baltay	Tracker
12:20	Lunch	

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

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Monday March 9, 1992		Plenary Meeting - Afternoon.
1:30	S.Chivukula	"The Dynamics of Electroweak Symmetry Breaking"
2:30	Y.Kamyshkov	Calorimeter
3:15	J.Rutherfoord	Forward Calorimeter
3:45	Break	

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Monday March 9, 1992		Plenary Meeting - Afternoon
3:45	Break	
4:15	Shaevitz,et al	GEM Triggering
4:45	Marx	Baseline Discussion/ Working Group Formation
5:30	I. Hinchcliffe	"Physics Considerations for SDC"
6:30	Adjourn	

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

The State of GEM

B. Barish

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

GEM STATUS

- Collaboration formed 6/92
- Expression of Interest 7/92
  EOI - Approved.
- Letter of Intent 12/92
  LOI - Approved.

- Next Milestones —
  - Budget Review 5/92
  - PAC Review 7/92
  - Magnet / Lehman 9/92 ?
  - Technical Design ~11/92 ?
    (TDR)

DETECTOR DESIGN

LOI - The concept
Technologies

Evolution - Optimization
Detailed Specifications

Magnet:
- Increased Radius
- Fixed Central Membrance
  Mobile Halves
- Forward Flux Concentrator

Muons:
- Increased BL^2 for Resolution
- Improved Forward Resolution

Calorimeters:

- BaF_2 Panel - Rad Hard Crystals
- Beam Tests
- Program for e-m decision in August

Tracker:

- New Baseline (Silicon + IPC's)
- Review

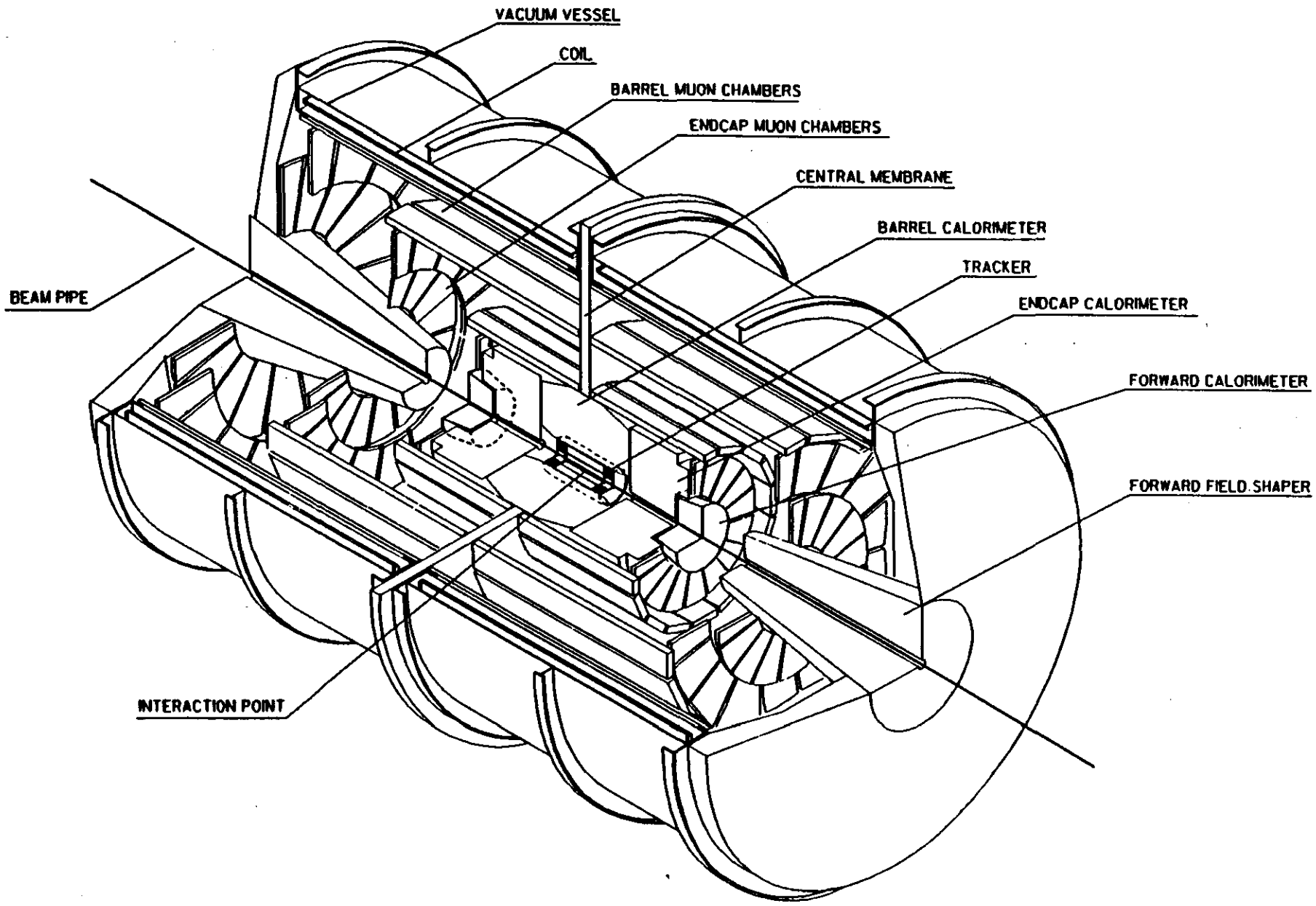
Facilities:

- Hall + Surface Facilities
- East vs West
- Title I ?

Costing:

- Schwitters Memo (Develop detailed plan for constructing GEM)

GEM DETECTOR



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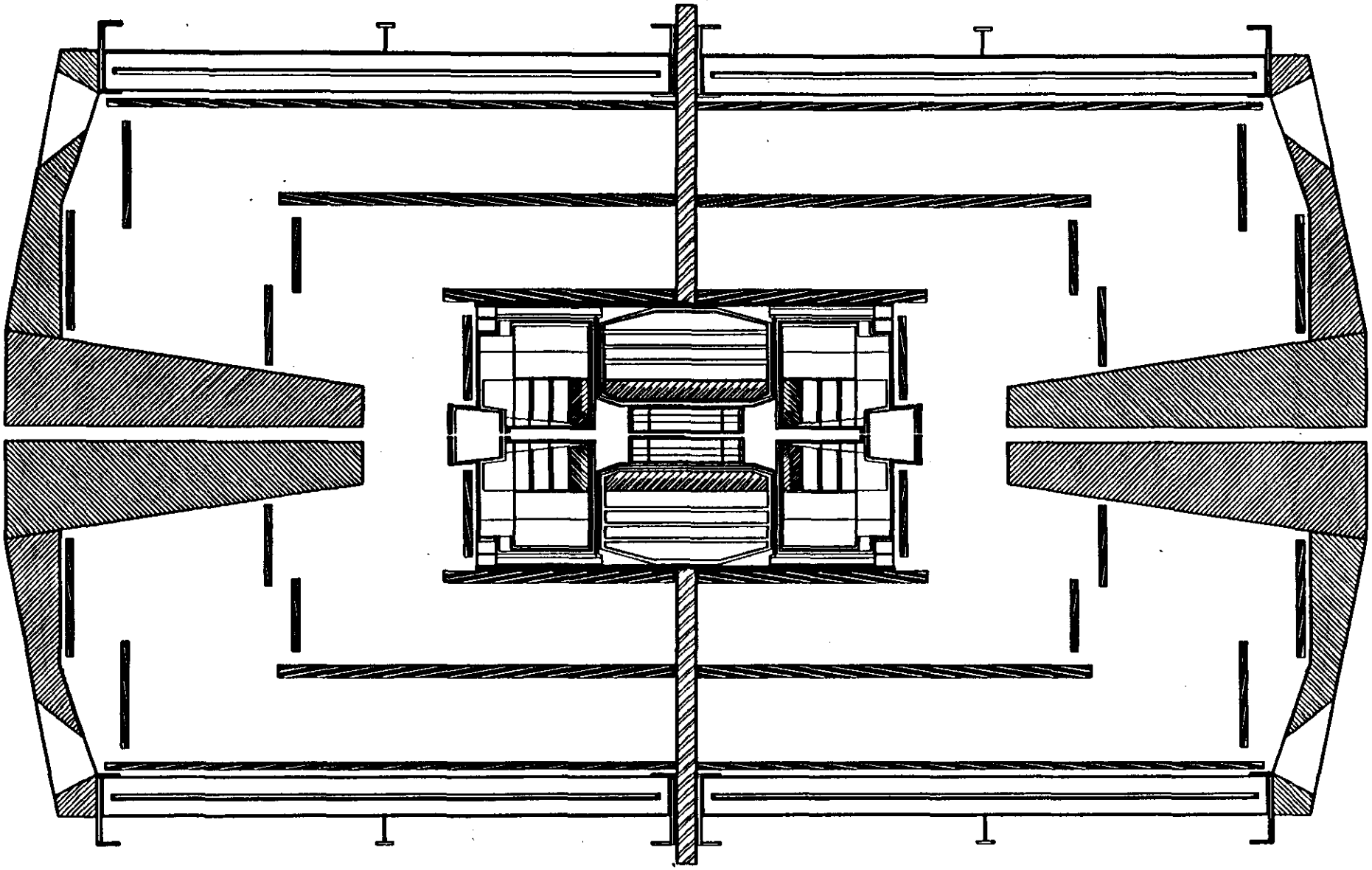
GEM DETECTOR



TUCSON MEETING PLAN

→ • Critique "Proposed GEM Baseline" ←

⇓

• Result → "Tucson GEM Baseline"

* FREEZE * (~months)

- Costing + Plan for Building
- Detailed Engineering, Integration Plan for Assembly
- Performance/Simulation Studies

• Changes; Evolution of Baseline

- Outstanding Technical Decisions
  (eg. BaF_2 vs Liq Argon - e-m Cal)
  (LSDT vs PDT - μ's)
- Changes; Improvements
  (Procedure)
  Official New Versions Documented.

TUCSON AGENDA

Monday -
- Project Management Report
- Facilities Report
- Review of Baseline / Discussion
- Physics Talks

Tuesday
- Parallel Working Groups (Special Topics)
- Mixed Groups

Wednesday -
- EVIAN / LHC Report
- Costing
- Working Group Reports
- Final Discussions

- INTERNATIONAL COMMITTEE (TUES LUNCH)
- EXECUTIVE COMMITTEE (WEDNESDAY NOON - 3 PM

OTHER ITEMS

GEM ORGANIZATION COMMITTEE :

- BALTAY (chairman)
- BRANSON
- PLESS
- REIDY
- RUTHERFOORD
- SAMIOS
- STROYNOWSKI

BYLAWS

ORGAN. PLAN for TDR.

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DATES :

	Coll. Council	April	30	
	Coll. Council	June	4	
Tentative	Coll Council	July	2	? (PAC)
	Coll Council	Aug	5	? (Conf.)
	Coll Council	Sept	3	
	Gen. Collab.	~ Oct		EAST COAST ?

The GEM Project at the SSCL

G. Sanders

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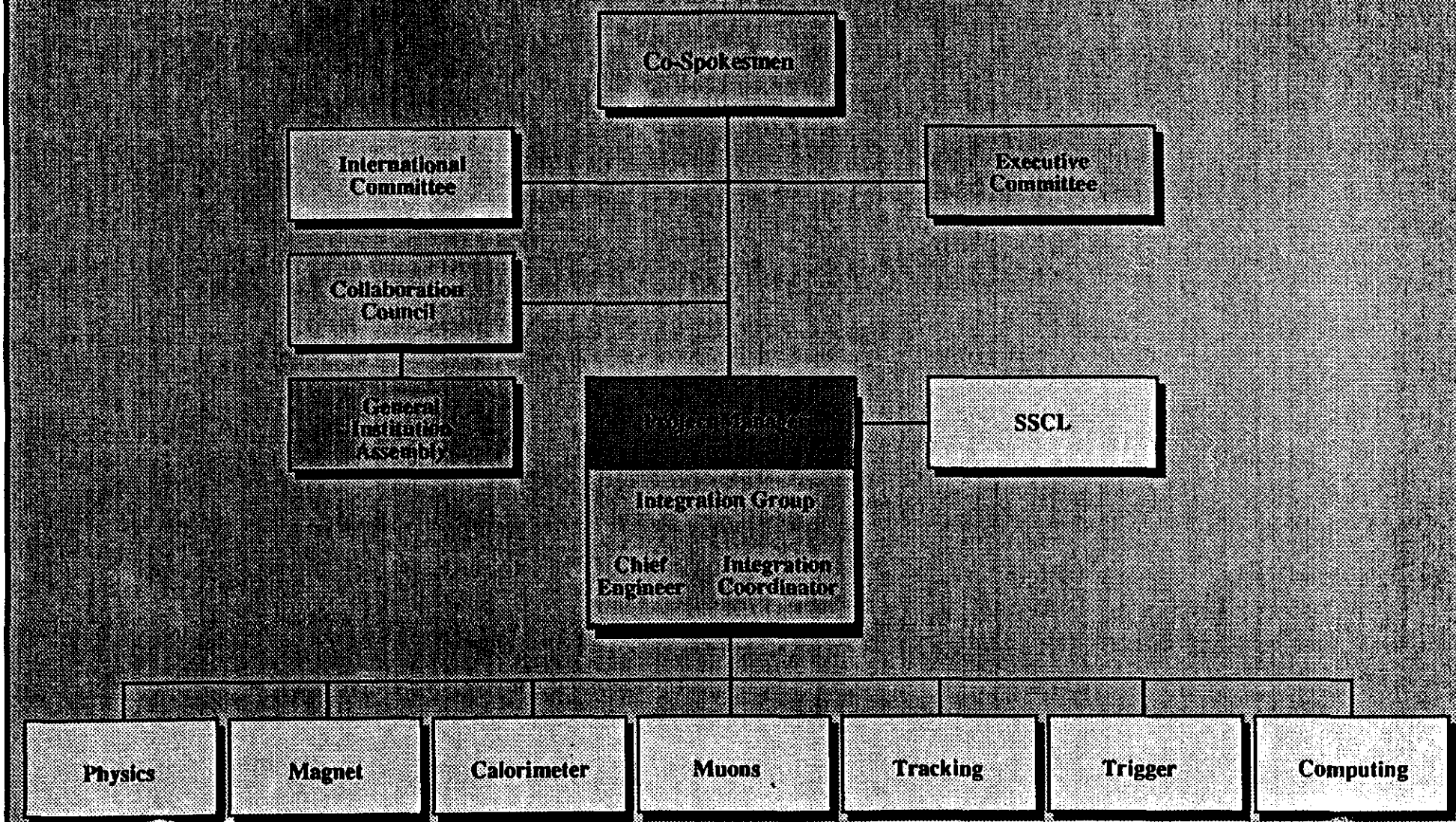
The GEM Project Organization

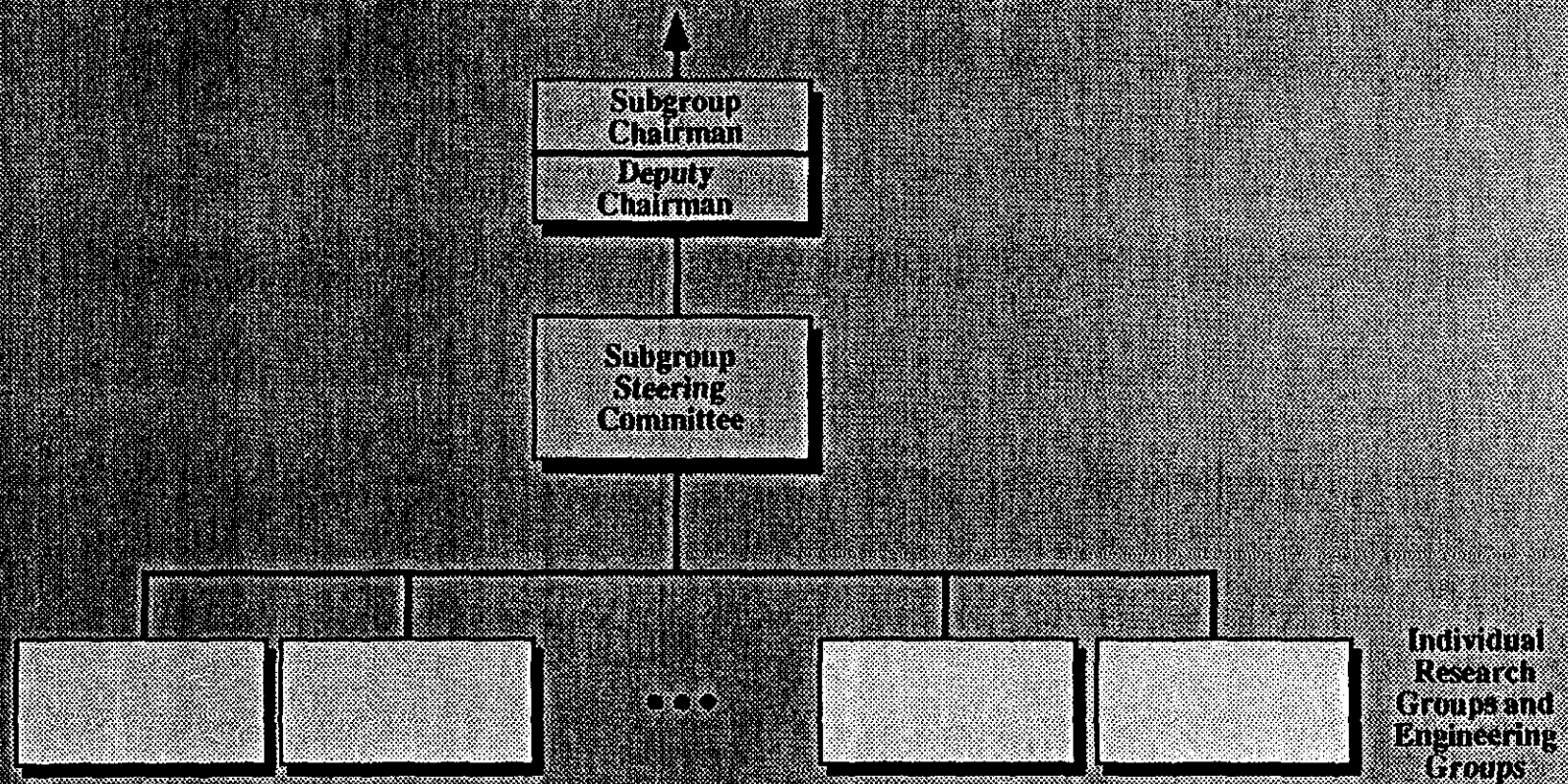
Gary Sanders

March 9, 1992

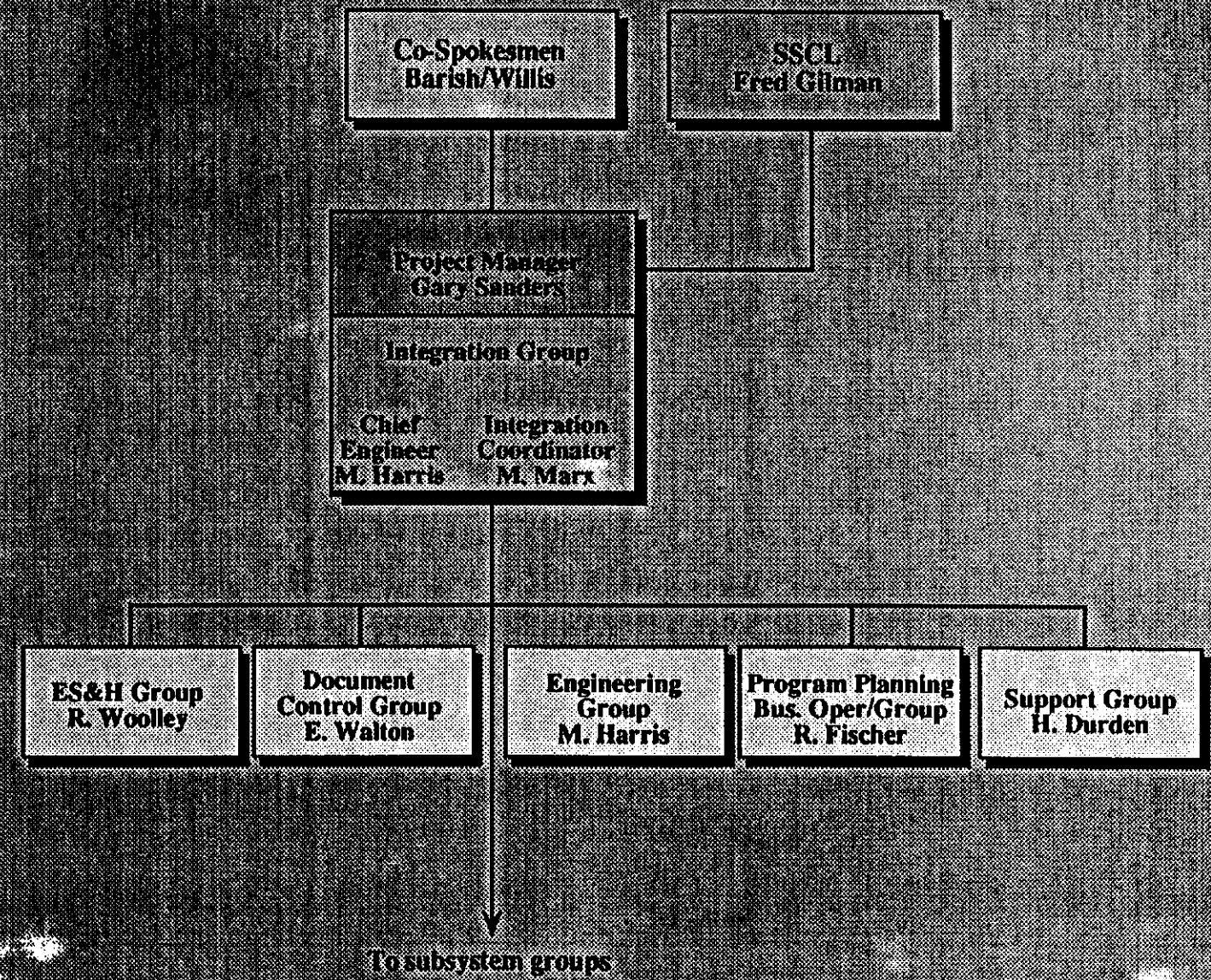
GEM


Co-Spokesmen
International Committee
Executive Committee
Collaboration Council
General Institutional Assembly
Project Manager
SSCL
Integration Group
Chief Engineer
Integration Coordinator
Physics
Magnet
Calorimeter
Muons
Tracking
Trigger
Computing

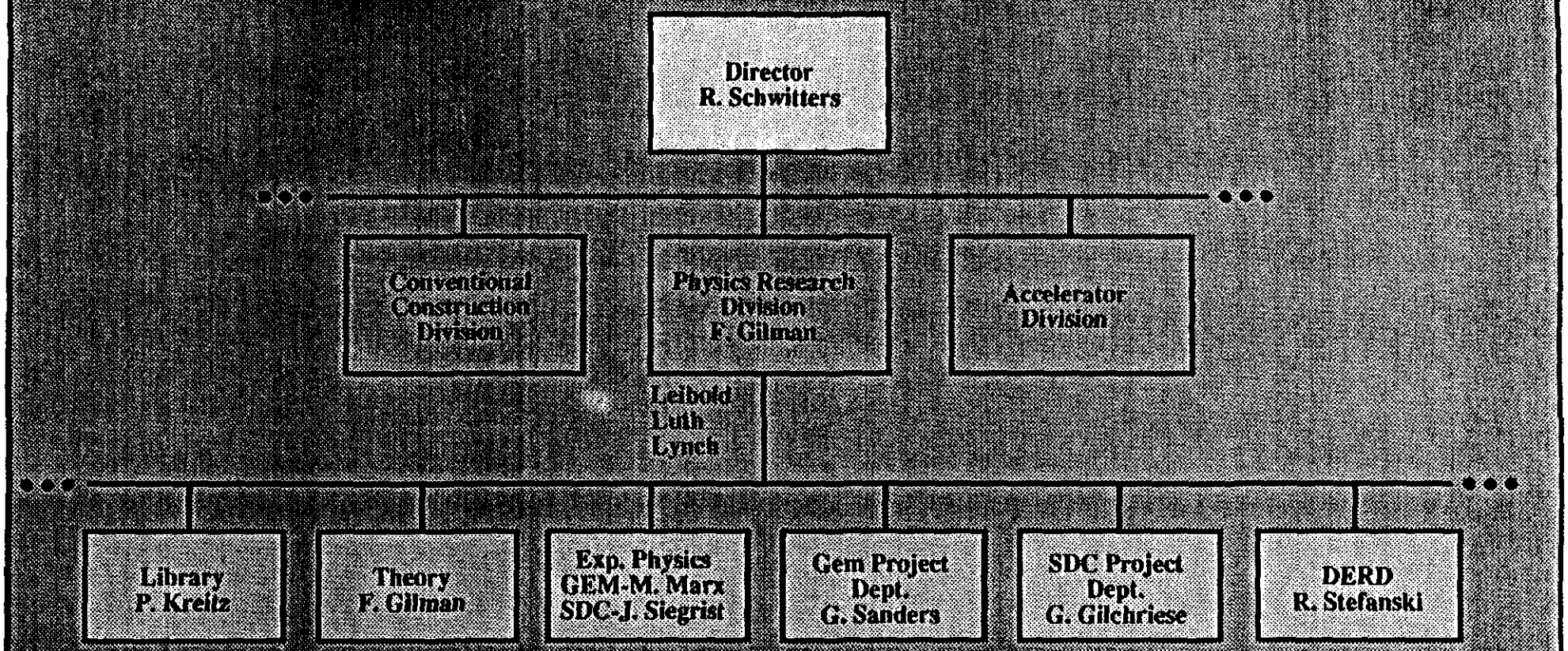
Typical GEM Subgroup Today



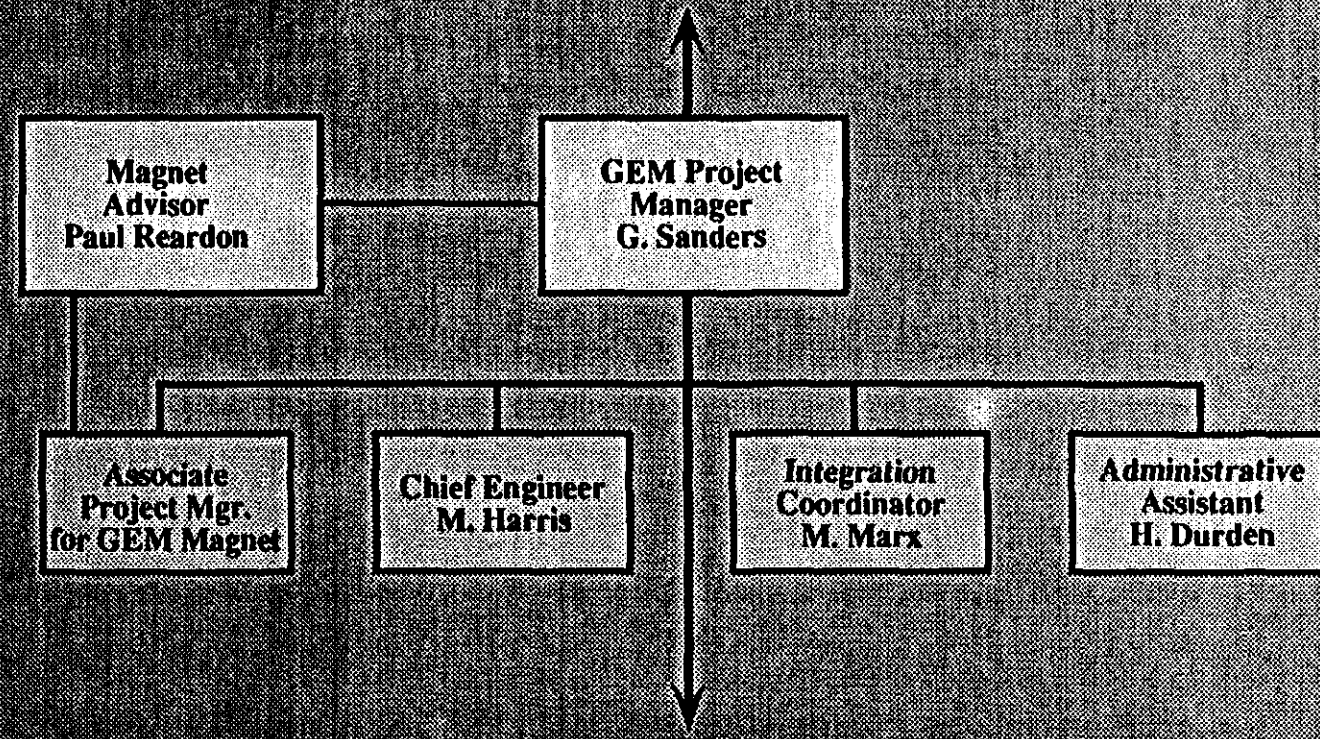
GEM Project Management



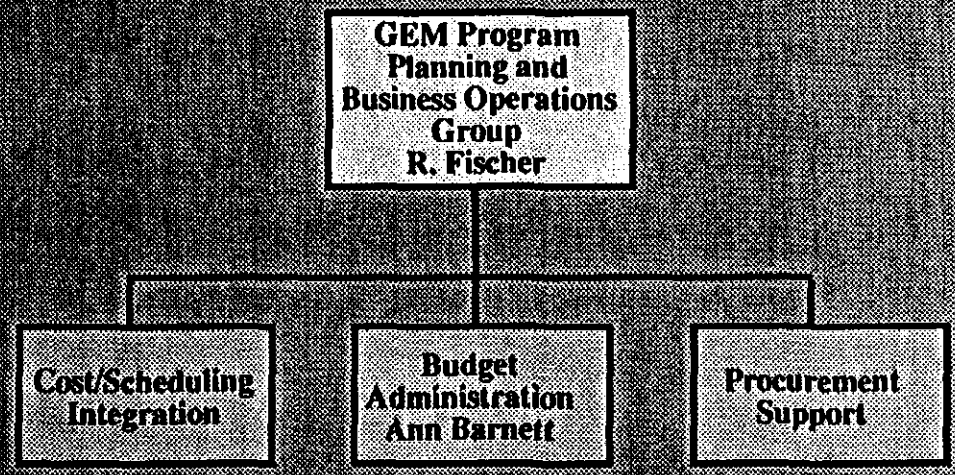
GEM Project Department in SSCL



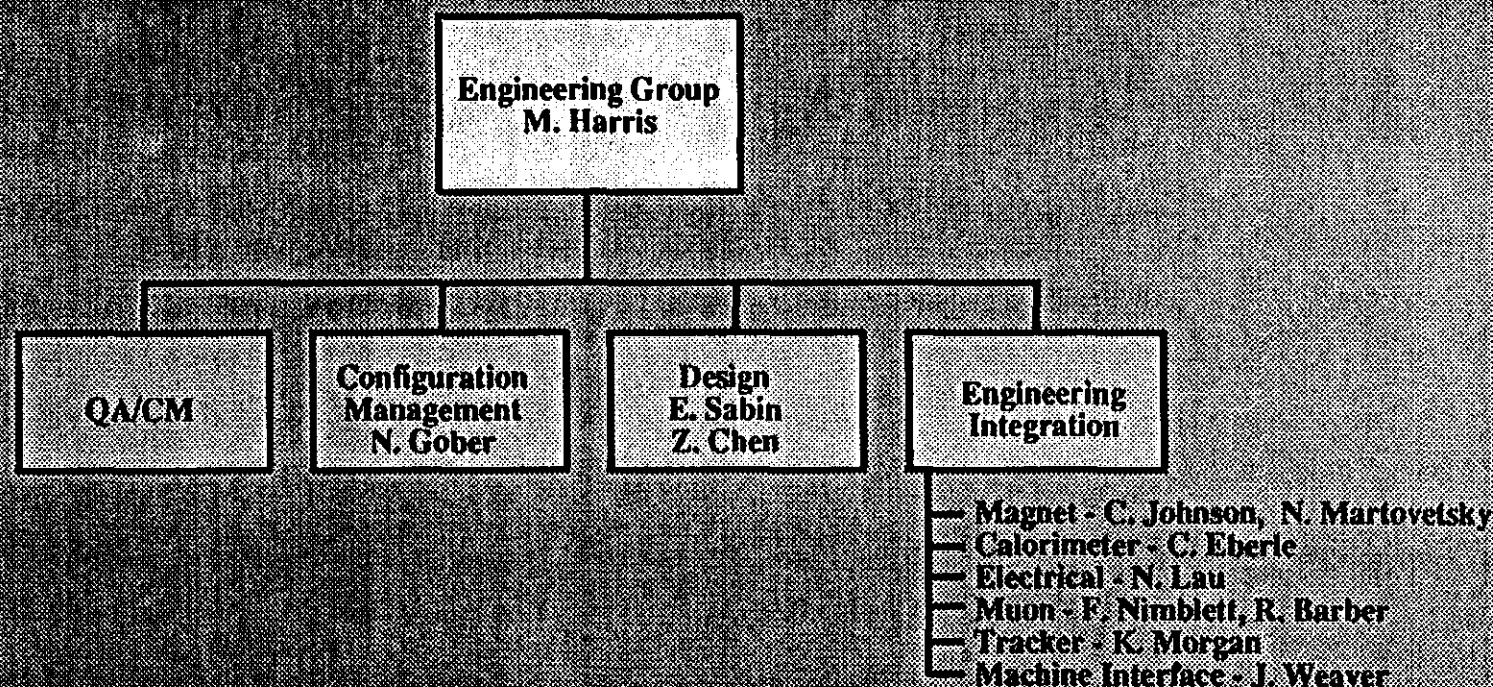
GEM Project Management Office



GEM Project Department



GEM Project Department



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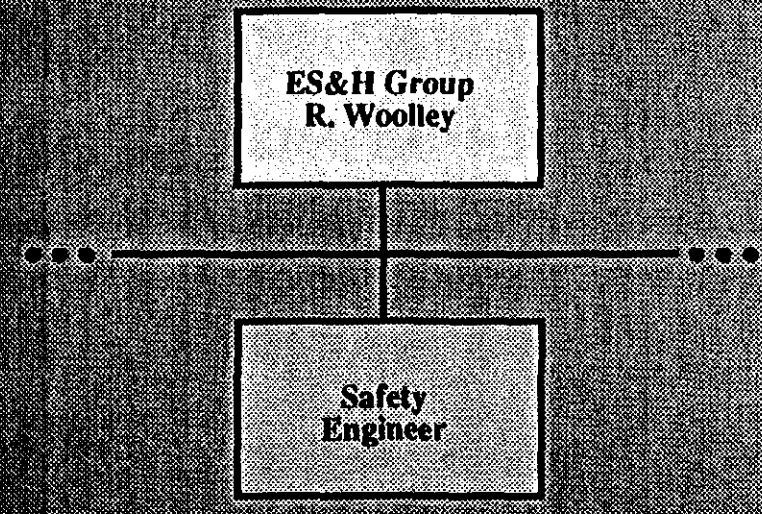

GEM Project Department

GEM Document Control E. Walton — — — — — — George Yost

GEM Project Department

GEM Document Control Center

Ed Walton

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Phone:
(214) 708-6138

George Yost

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Physics Research Division
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Dallas, TX 75237

E-Mail:
Yost@SSCVX1.SSC.GOV

Phone:
(214) 708-6028

GEM Document Control Center (cont'd)

Collect:

- Meeting materials—Transparencies, agenda, minutes, attendees, and/or other contributions from formal meetings.
- Documents—The original of every document to be distributed and/or printed. An abstract is to be submitted with the document.
- Monthly Reports—Each institution will send a copy of its monthly report.

Organize:

- Meeting materials, documents, and monthly reports into a standard format before printing and distributing.
- A document number for each document. When distributing a document, obtain a document number from the DCC before distribution.
- DTASS (Document Tracking System). All documents are indexed on DTASS. DTASS is option "5" in GEMLIB on the VAX.

GEM Document Control Center (cont'd)

Distribute:

- Technical and physics notes—Distributed to the institutional contact person.
- Formal meeting materials—Distributed to the institutional contact person and attendees (when a list is provided).
- Individual documents—will be distributed upon special request.

Maintain:

- An original of each document.
- Copies of each document for distribution upon request.
- All titles, authors, abstracts on SPIRES.

GEM Document Control Center (cont'd)

Institutional Contact Person

The institutional contact person list is incomplete.

To have an institution added to the contact list, send Ed Walton an e-mail to SSCVX1::GEMDCC with the contact persons name, e-mail and mailing address.

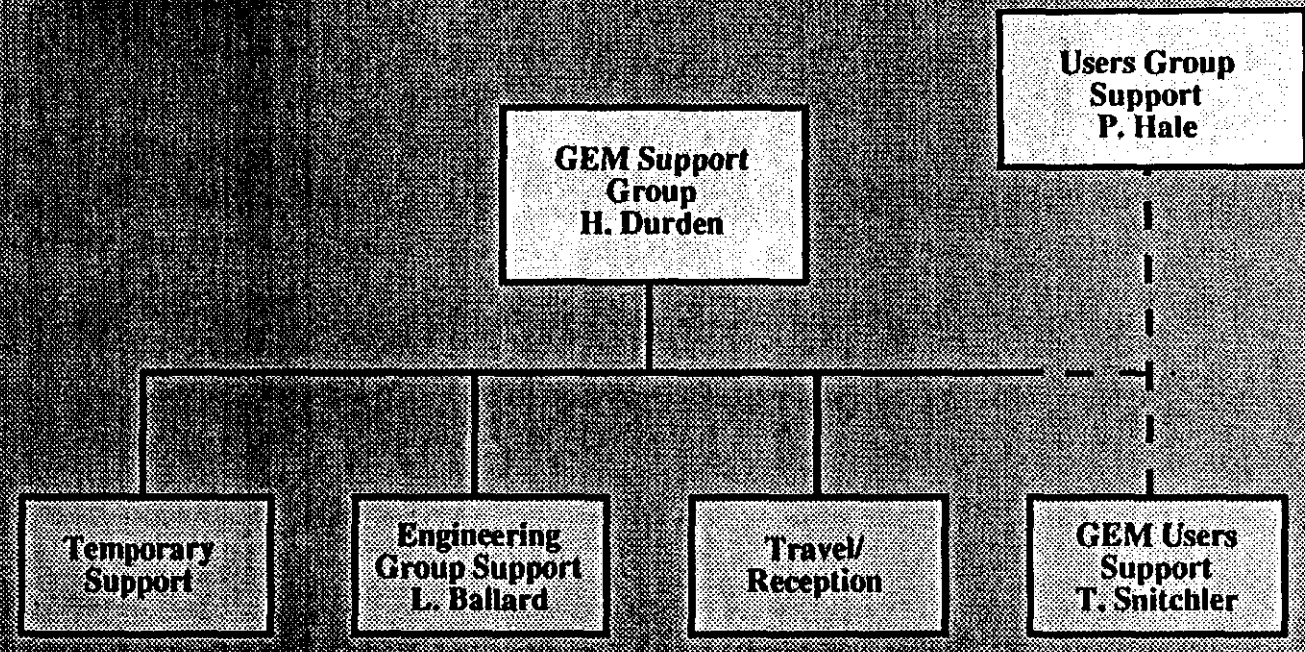
Monthly reports on all R&D/Engineering activities
due each month to
Ed Walton
at GEMDCC@SSCVX1
or by hard copy

Cost tracking will be done by Program Planning Group

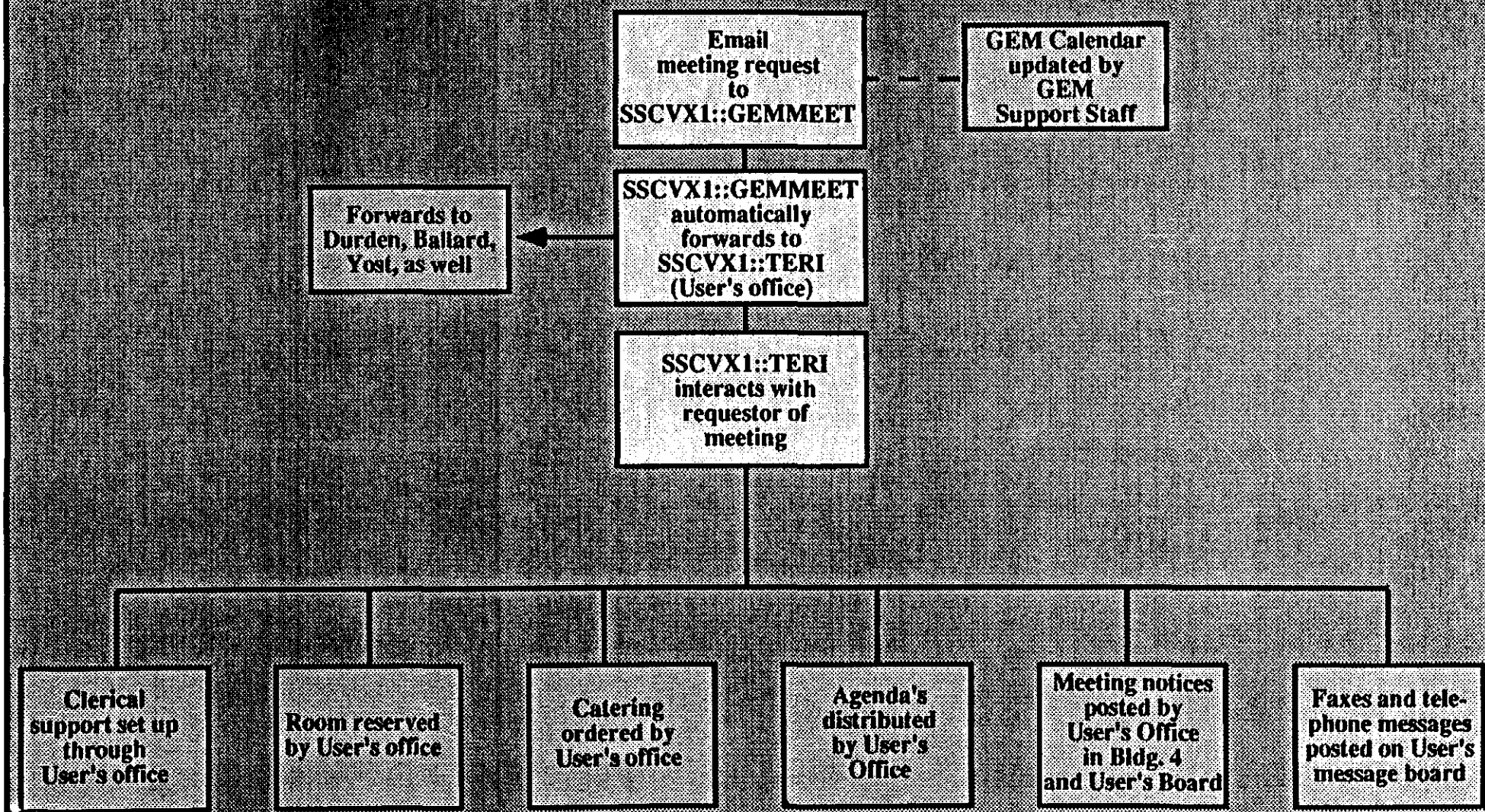
GEMLIB

- A GEM account on SSCVX1 — SSCVX1::GEMLIB
  GEMLIB@SSCVX1
- No password required to log in.
- Menu displays available features.
- Access to Document Tracking System (DTASS)
- GEM_NEWS bulletin board (like VAXmail)
  - Send news items to GEMLIB
  - GEM calendar on GEM_NEWS, send items to GEMLIB
- whoGEM facility, look up your collaborators, send new entries or corrections to GEMLIB
- To get GEM bulletin board installed on your networked VAX, send mail to SSCVX1::SYS_SLEEN. Identify yourself clearly. All bulletins will propagate to your VAX.

GEM Project Department



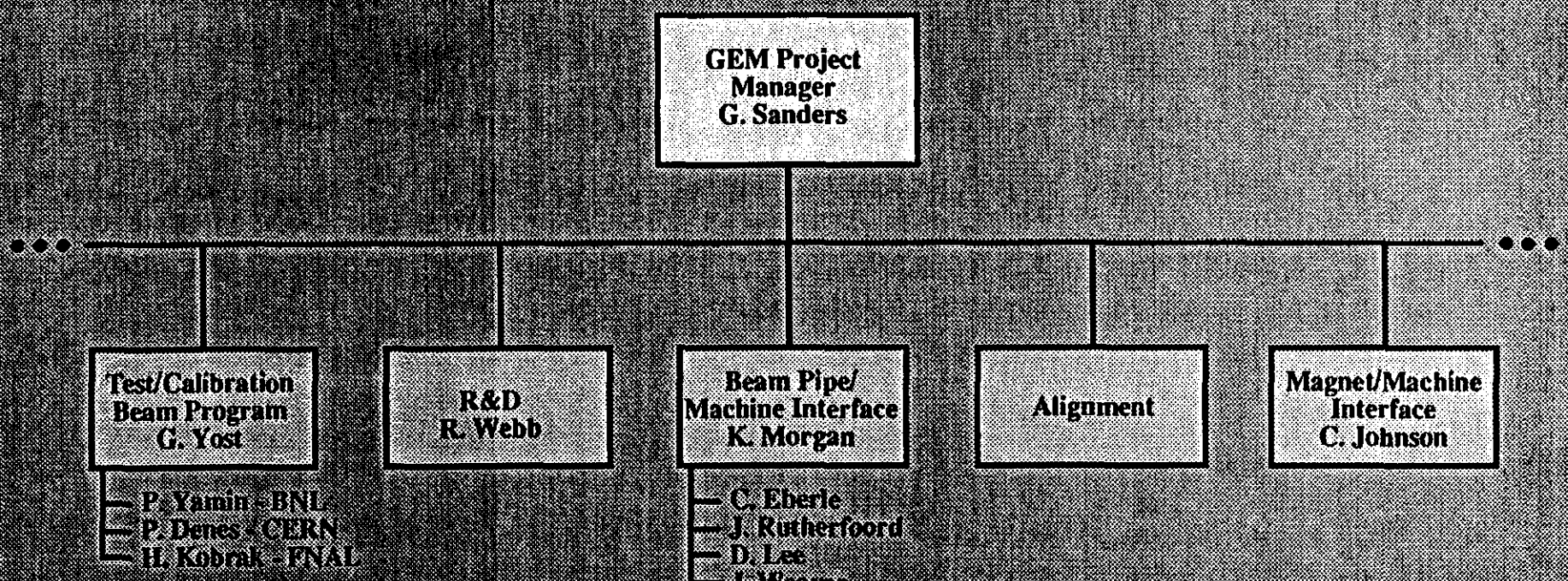
GEM Meeting Setup



Meeting Procedure

- The User Group is set up for handling our meeting requirements
- We must train ourselves to use this procedure.
- This meeting procedure (if we change our habits) will eliminate past confusion over meetings.
- The User's Office will:
  - Make all our meeting room reservations
  - Provide clerical support for our meetings
  - Take care of our catering needs
  - Will copy and distribute the agendas for our meetings
  - Post notices for our meeting in Building 4 lobby and the User's Bulletin Board
  - The User's Office will post messages and faxes on the User's Message Board
  - Mail copies of meeting papers that are requested by the user.
- LET'S GIVE THE USER'S OFFICE A CHANCE TO HELP US.

GEM Project Task Force



GEM Test/Calibration Beam Task Force

G. Yost (SSCL-chair) - acts as Principle Investigator
P. Denes (Princeton) for all GEM test beam
H. Kobrak (UCSD) experiments.
P. Yamin (BNL)

- Beam above 50 GeV available in next few years only from CERN, Protvino
- CERN dedicated 100 GeV (upgradable to 200 GeV) beam available at a cost to GEM.
- FNAL beam possible beyond 1995. A GEM FNAL beam proposal is in preparation.
- SLAC beam possible by end of year.
- BNL beams available and used by GEM this year.
- SSCL equipment pool for use in test beam running is being proposed.

Availability driven by good and urgent proposals, and GEM/SSCL priority.

Technical Proposal Organization-Discussion Proposal

VOLUME	CONTENTS (first draft date)	PAGES	RESPONSIBLE
1	Executive Summary (overview, physics goals, description)	50	Barish, Willis
2	Magnet Preliminary Design Report (6/12/92)	150	Stroynowski, Deis, Marston
3	Muon System Conceptual Design Report (5/29/92)	150	Taylor, Nimblett
4	Calorimeters Conceptual Design Report (5/29/92)	150	Kamyshkov, Rennich
5	Tracker Conceptual Design Report (5/29/92)	150	Baltay, Barber
6	Electronics (all subsystems) CDR (5/29/92)	150	Marlow, Shaevitz, Lau
7	Computing/Analysis/Simulation/Control/ Communications CDR (5/29/92)	50	McFarlane, Cormell
8	Physics Goals, Performance, Simulations (5/29/92)	100	Paige, Lane
9	GEM Parameters (3/27/92)	50	Marx, Gober
10	GEM Experimental Facilities User Requirements (3/27/92)	100	Harris, DERD
11	Integration/Assembly/Installation Plan (6/12/92)	50	Marx, Harris

GEM Project Department

Technical Proposal Organization-Discussion Proposal

VOLUME	CONTENTS (first draft date)	PAGES	RESPONSIBLE
12	Cost Estimate/Responsibility Matrix/Funding Plan (4/30/92)	100	Sanders, Barish, Willis
13	GEM Project Management Plan (5/29/92)	50	Sanders, Fischer, Barish, Willis
14	Preliminary Safety Analysis Report/ES&H (5/29/92)	50	Woolley
15	Draft GEM Acquisition and Assistance Plan (7/31/92)	25	Fischer
16	GEM Operational Plan/Upgrades (6/12/92)	25	Marx, Sanders
17	R&D/Engineering/Test & Calibration Plan (6/12/92)	50	Webb, Sanders, Harris, Yost
		1450	

NOTE: Separate report to the PAC for Wood's Hole review due in draft form about 6/12/92, borrowing heavily upon above drafts available by that date, Barish and Willis responsible for organization.

NOTE: EACH LEAD AUTHOR SHOULD PROVIDE OUTLINE OF VOLUME TO PROJECT DEPARTMENT BY APRIL 15 FOR REVIEW PRIOR TO EXECUTIVE COMMITTEE MEETING APRIL 29.

Proposed Outline for Subsystem CDR Volumes

1. PHYSICS GOALS: Physics measurement goals of subsystem. What is added to GEM? How are goals justified?
2. PERFORMANCE REQUIREMENTS: Technology independent performance requirements. Simulations. Justification.
3. BASELINE TECHNOLOGY: Choices, justification, performance, options, issues, simulations of baseline performance.
4. PARAMETERS
5. MECHANICAL ENGINEERING CONCEPTUAL DESIGN
6. ELECTRONICS ENGINEERING CONCEPTUAL DESIGN
7. R&D/ENGINEERING PLAN
8. CONSTRUCTION/ASSEMBLY/INSTALLATION SCHEDULE
9. ES&H ISSUES
10. STAGING/UPGRADE OPTIONS

LEAD AUTHORS OF VOLUMES 3-6 SHOULD COLLABORATE IN PROPOSING A GENERIC OUTLINE TO PROJECT DEPARTMENT BY APRIL 15. LEAVE COST, FUNDING PLAN, RESPONSIBILITY MATRIX OUT OF THESE VOLUMES TO MAINTAIN INDEPENDENCE WITH VOLUME 12.

1992 Milestones for TDR

MARCH	9-11	Baseline established Drafts of TDR volumes begin
	23	Magnet baseline established
APRIL	1-30	Cost reviews
	30	Cost Estimate Book
	29-30	Executive Committee and Collaboration Council
May	11?	SSCL Cost Review
	29	TDR volume drafts (group 1)
June	2	Baseline review and revision
	3-4	Exec. Comm. and Collaboration Council
	12	TDR volume drafts (group 2) Report submitted to PAC
July	10-15	PAC review at Woods Hole Review of magnet by PAC prior to RFP with industry
August		Baseline revisions? PAC followup
September		DOE review of magnet Draft Technical Proposal
November		TDR to SSCL

GEM Baseline Overview

M. Marx

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

M. MARX
Tucson
3/9/92

GEM BASELINE I

1) Need to freeze global parameters
   → coherent detector simulation
   → give engineers written specs
   → establish cost base

2) Need to establish control over process of change
   - configuration control
   - establish procedures
   - establish future practice major/minor changes
   - ALL changes must be requested
     authorized
     documented
     distributed
   - Discipline dictated by size of project and collaboration (Hubble !)

3) Eventually (~TDR) final baseline established
   - all changes discouraged

Baseline I is first step in iterative process

Expect global iteration (June?) based on results costs/engineering feasibility/schedule/simulations

Object of current exercise to establish good starting point

PLAN –

Draft before Tucson

Subsystem Presentations Today

Discuss Issues

Consensus + Exec. Comm. Wednesday

All systems supply drawings + specs
by Friday 3/20

Issue Baseline I

– Brief Overview – Changes since LoI

DRAFT

ENGINEERING AND INTEGRATION GROUP

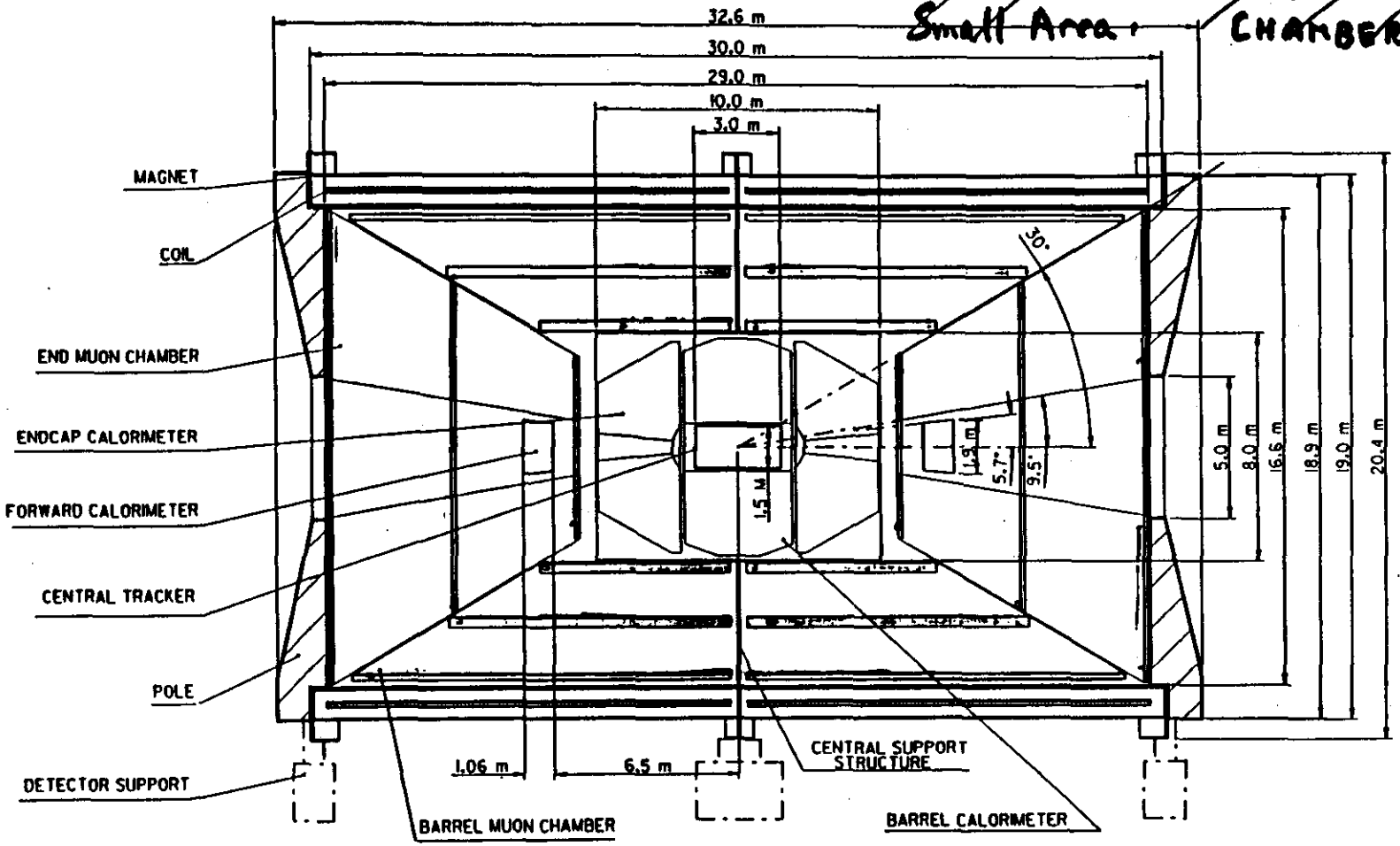
Overall Integration	B. Barish, M. Harris, M. Marx, G. Sanders, W. Willis
Underground Hall	M. Harris, E. Sabin
Surface Facilities	M. Harris, T. Prosapio
Magnet	G. Deis, C. Johnson, P. Marston, R. Stroynowski
Muon	J. Pier-Amory, F. Nimblett, F. Taylor
Calorimeter	C. Eberle, H. Gordon, L. Mason, M. Rennich
Tracker	R. Barber, K. Morgan
System Engineering & Configuration	N. Gober
ES&H	R. Woolley
Computer	K. MacFarlane, G. Yost
Forward Calorimeter	J. Rutherfoord, L. Shaver
Trigger/Electronics	N. Lau, D. Marlow
Survey	M. Jones, D. Veal
Beam Line	G. Chapman, K. Morgan
Cryogenics	R. Richardson
Physics	B. Barish, M. Marx, F. Paige, G. Sanders

LOI 12/91

END CAPS

High Rate
Small Area:

INTERPOLATING PAD CHAMBERS

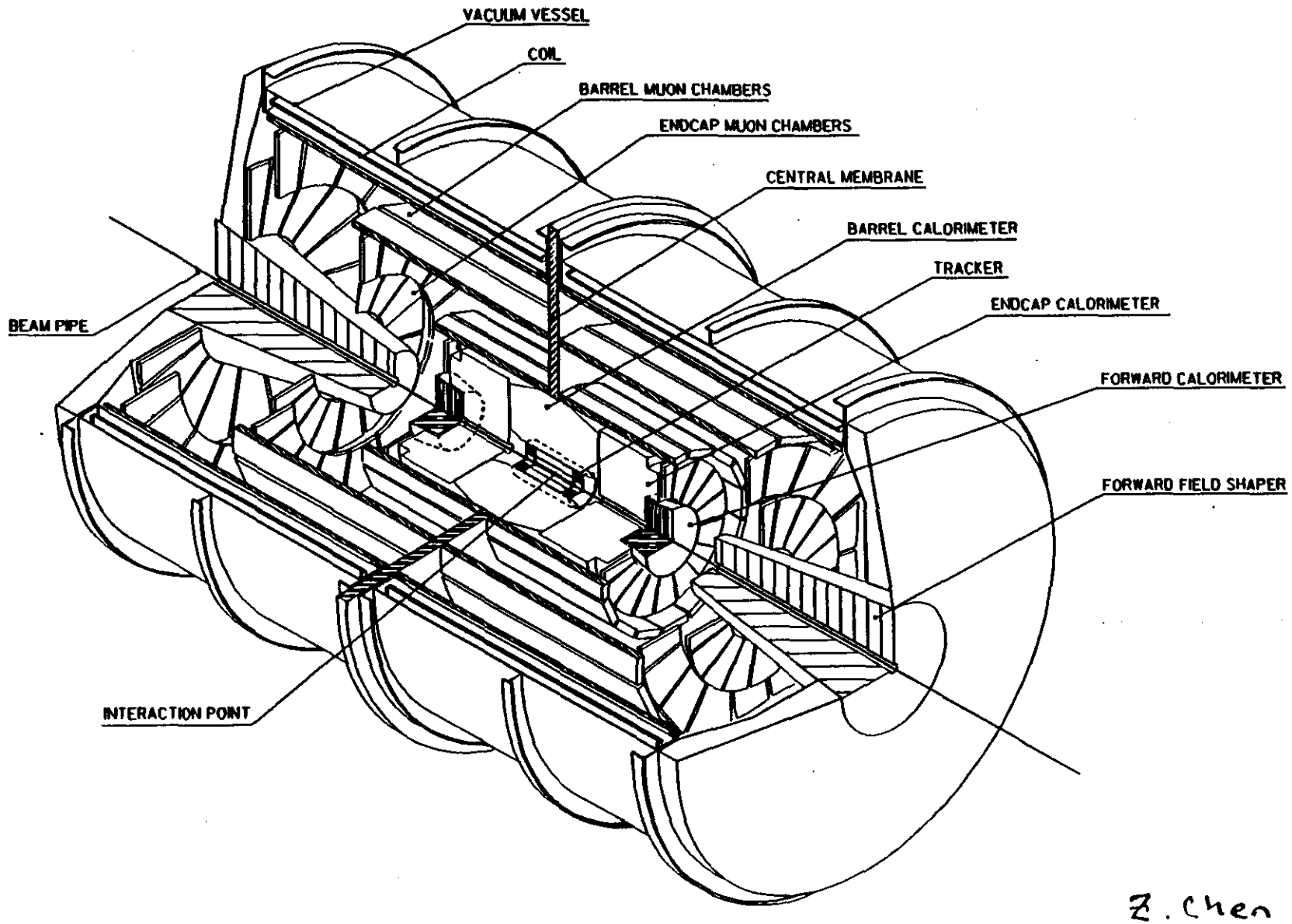


Barrel: Pressurized Drift Tubes
or
Limited Streamer Drift Tubes

Low Rate
Large Area

TRIGGER: Resistive Plate Chambers

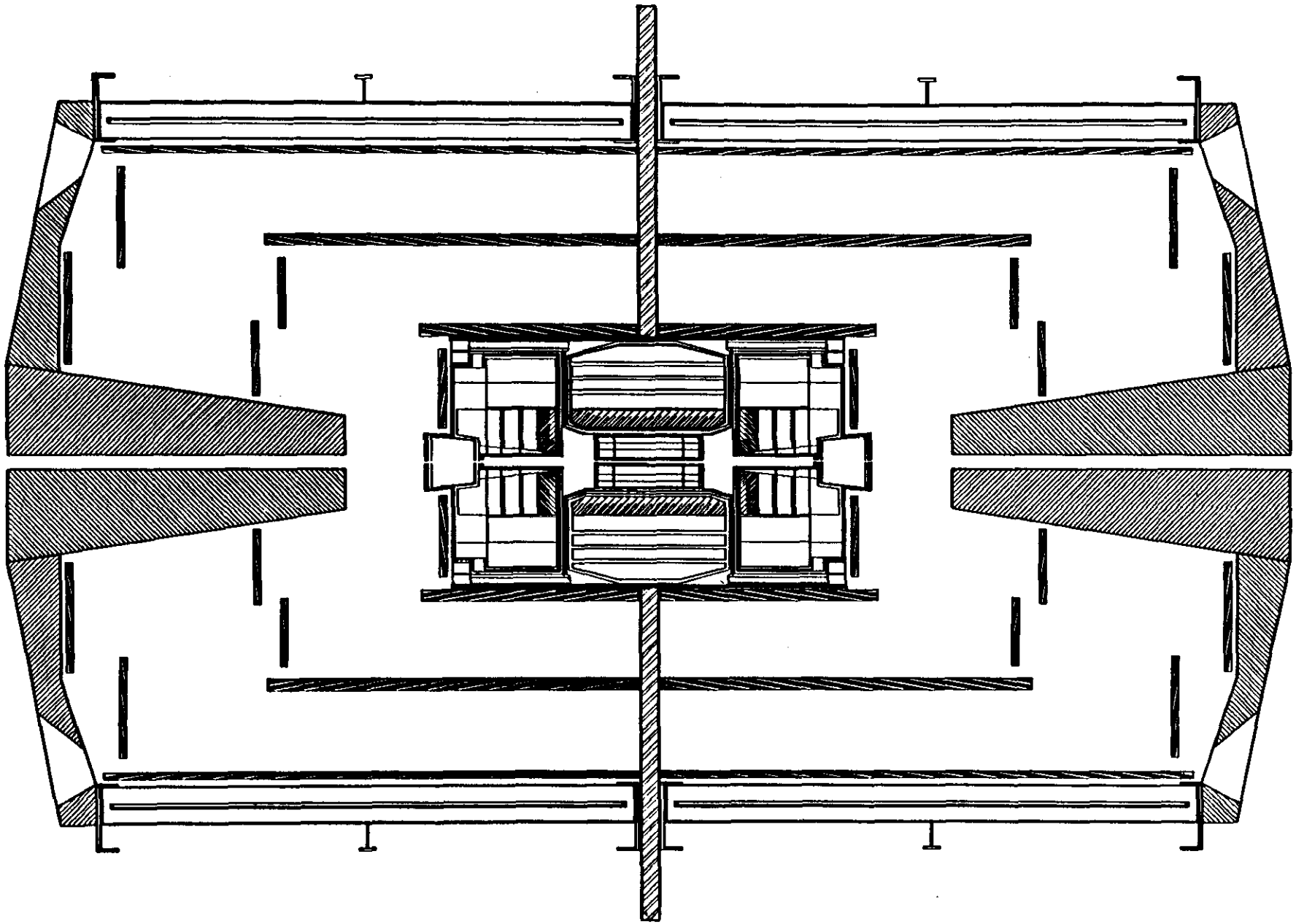
GEM DETECTOR



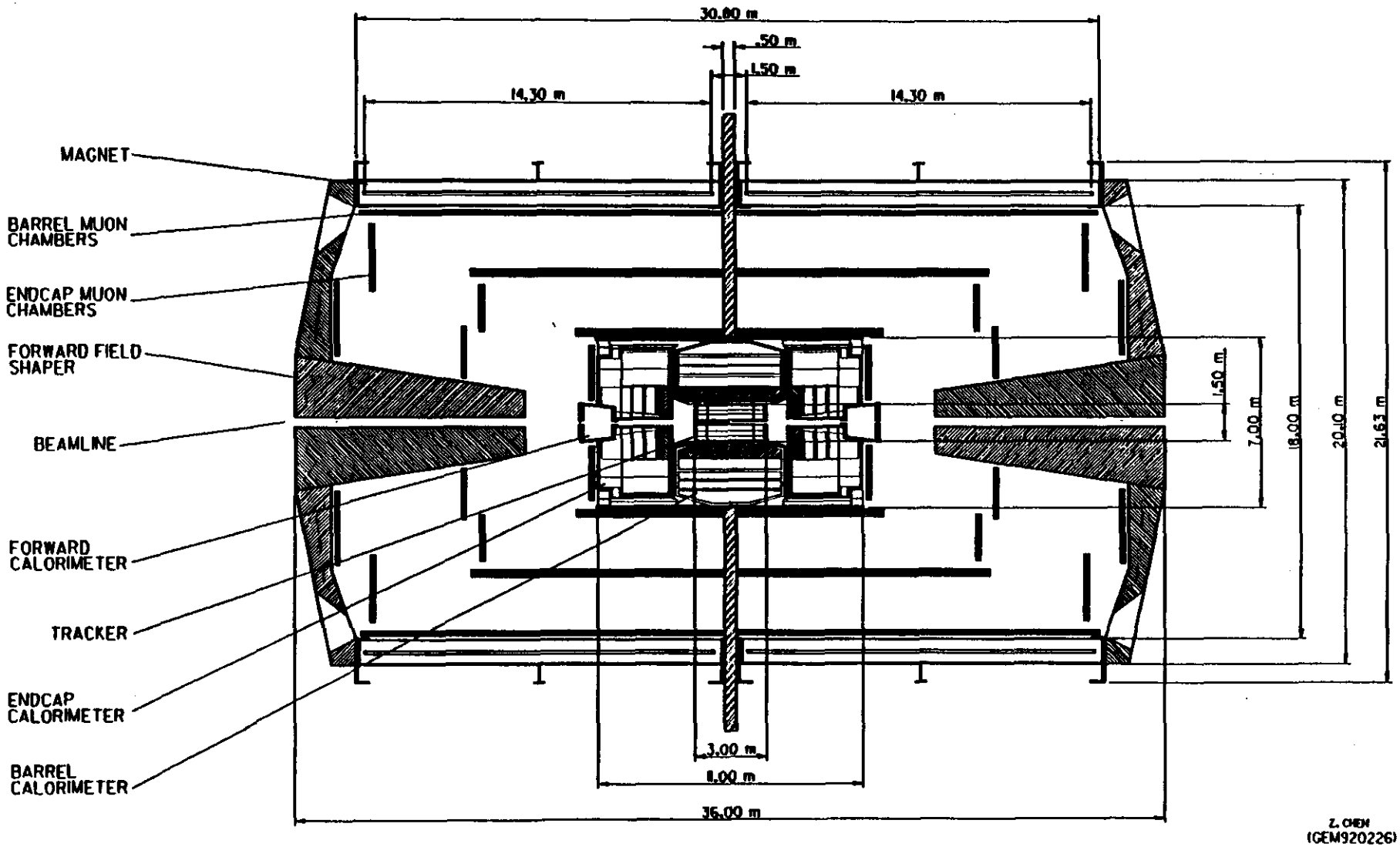
Z. Chen

(ISOMETRIC GEM920305. ZC)

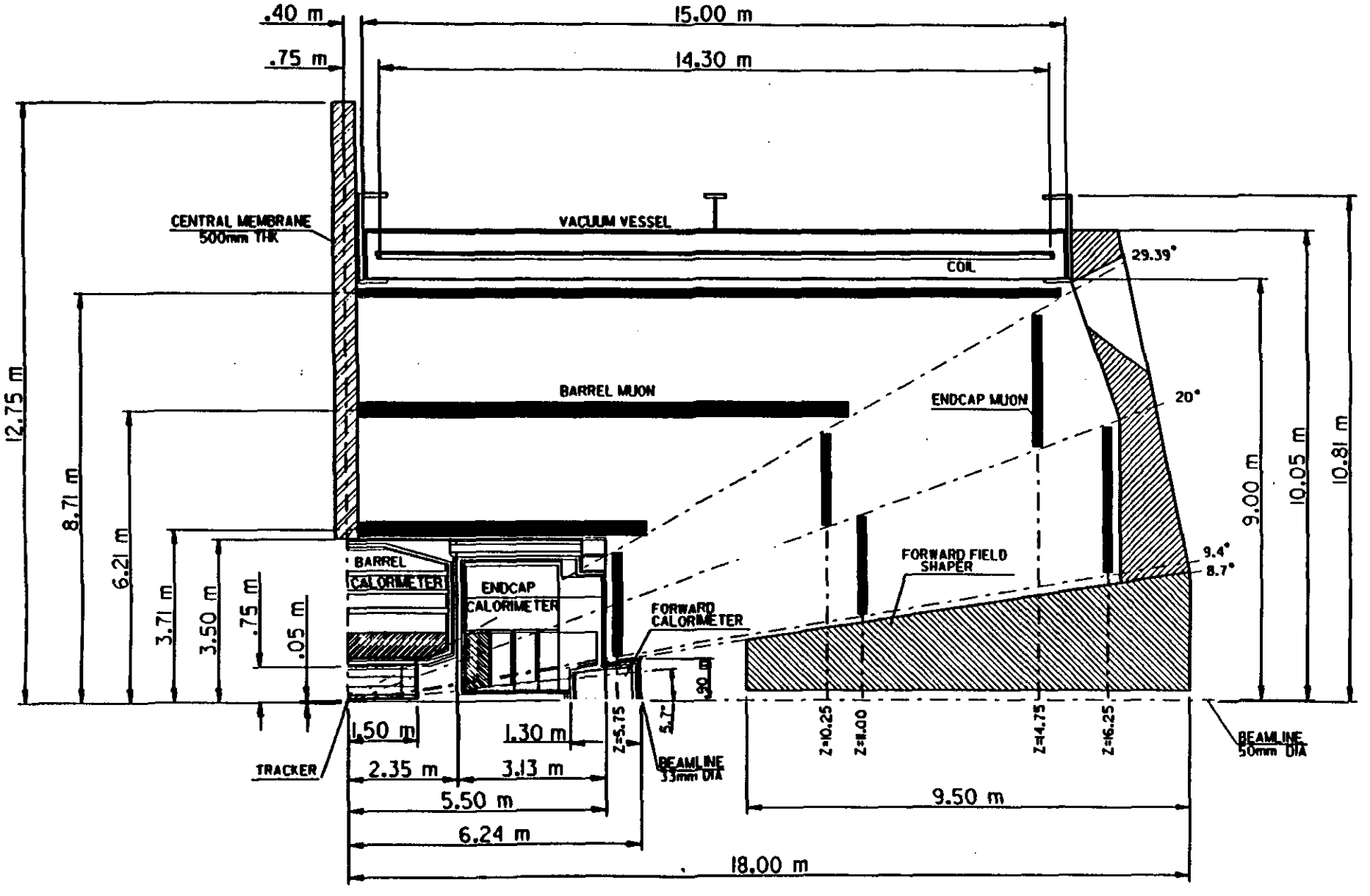
GEM



GEM DETECTOR LAYOUT

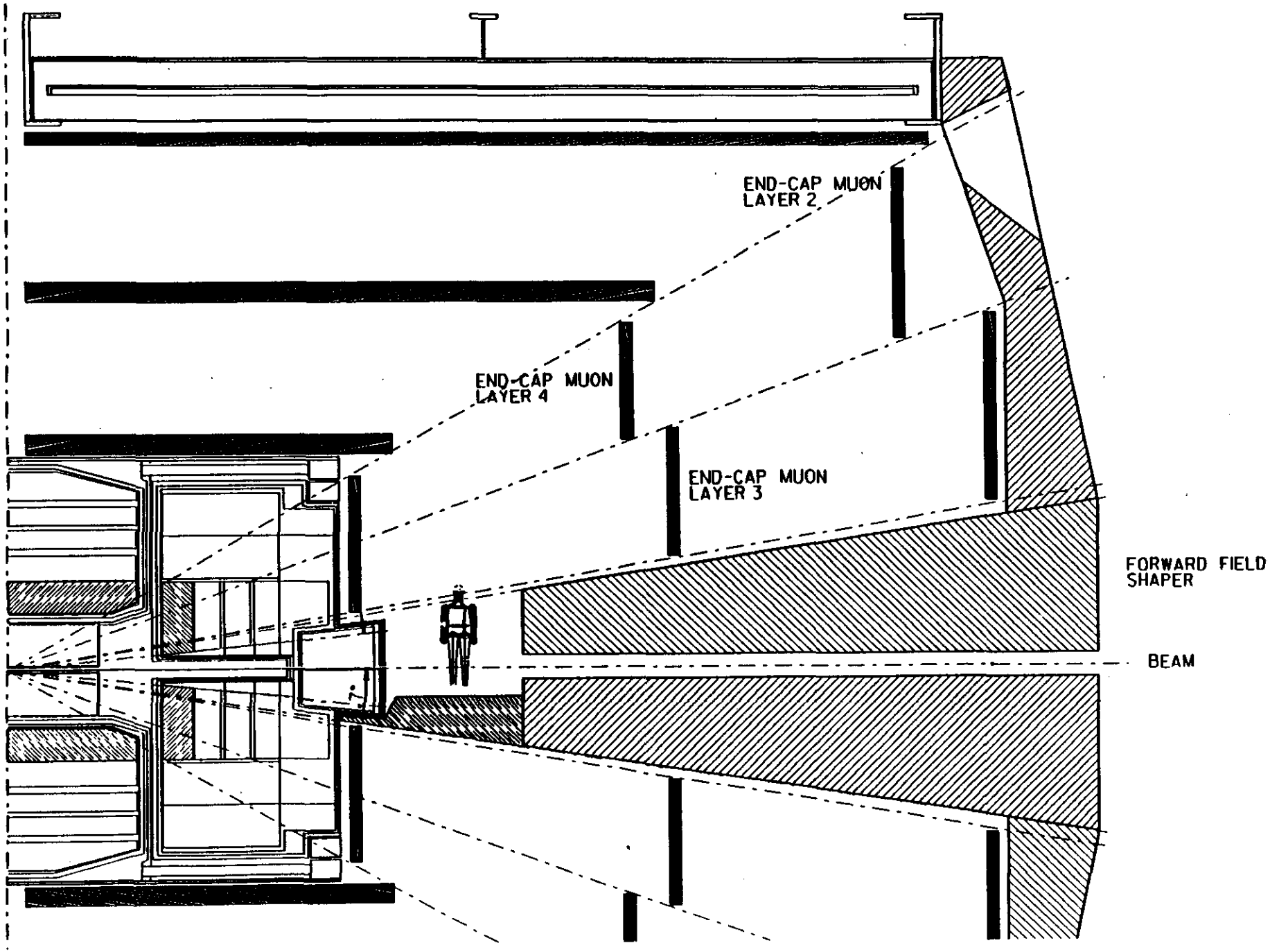


GEM DETECTOR ELEVATION



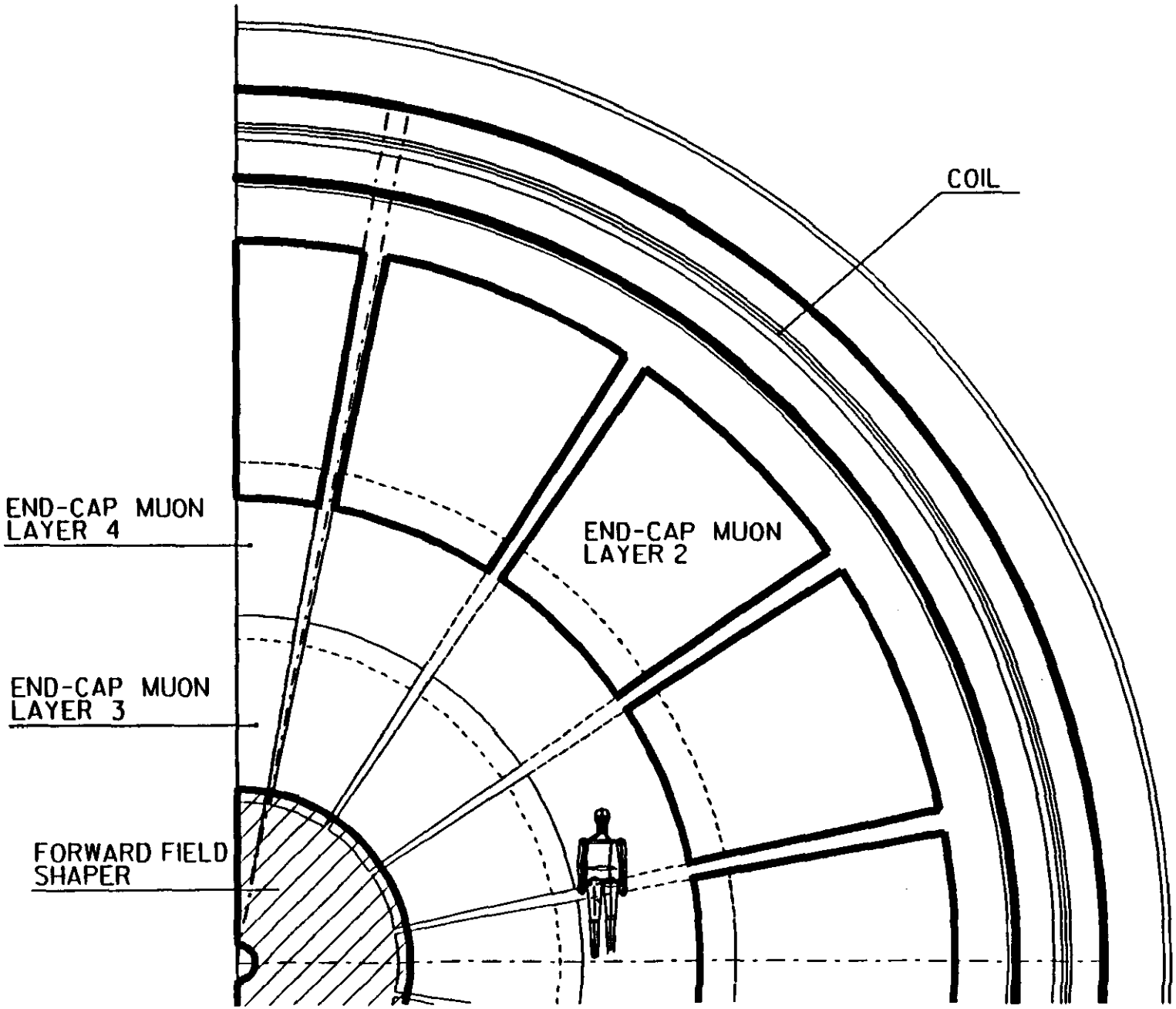
Z. CHEN
(GEM920226)

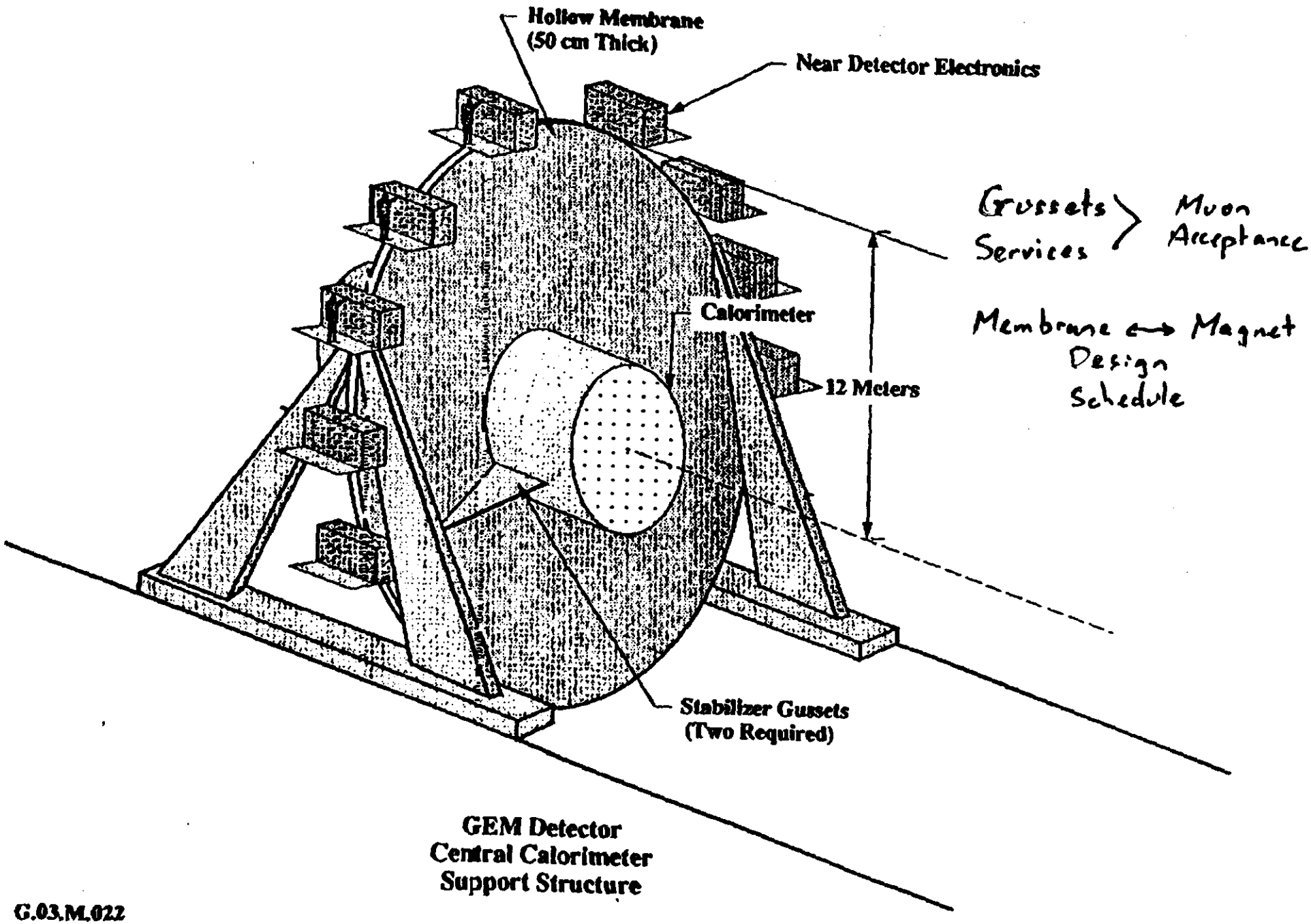
EMERGENCY ENTRANCE ELEVATION



EMERGENCY ENTRANCE

RIGHT VIEW



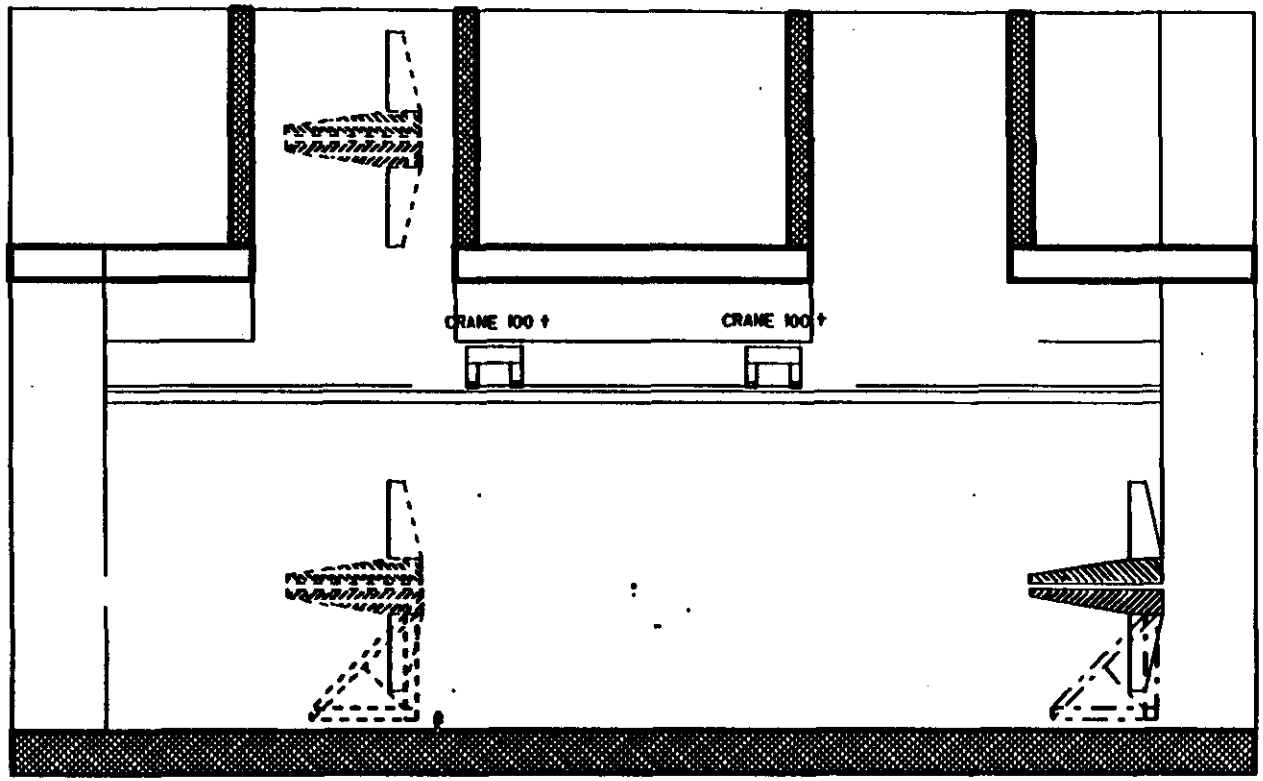


GEM Detector
Central Calorimeter
Support Structure

G.03.M.022

Rennich/Eberle

PHASE I
FORWARD FLUX CONCENTRATOR NORTH



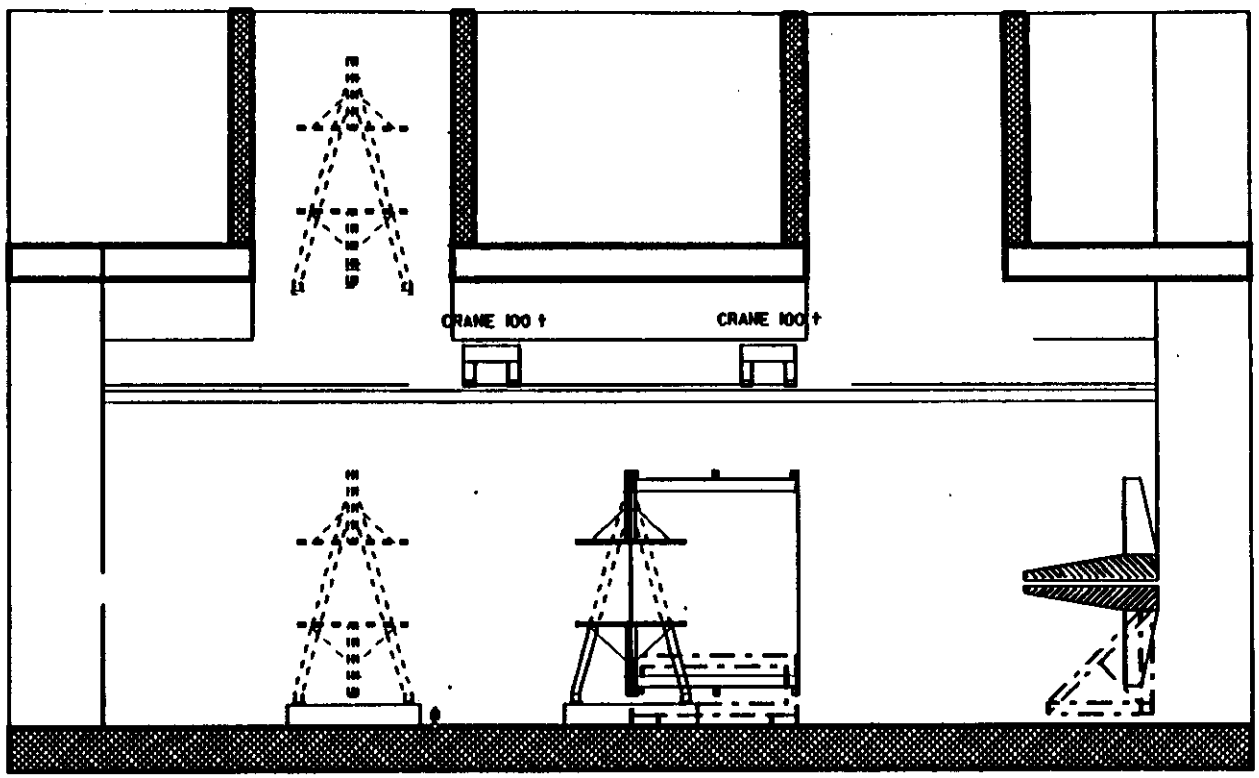
SSC

GEM'S DETECTOR
INSTALLATION SEQUENCE
PHASE I

GDD - 000 047-0

PHASE 3

CENTRAL MEMBRANE-SUPPORT END CAP CALORIMETER



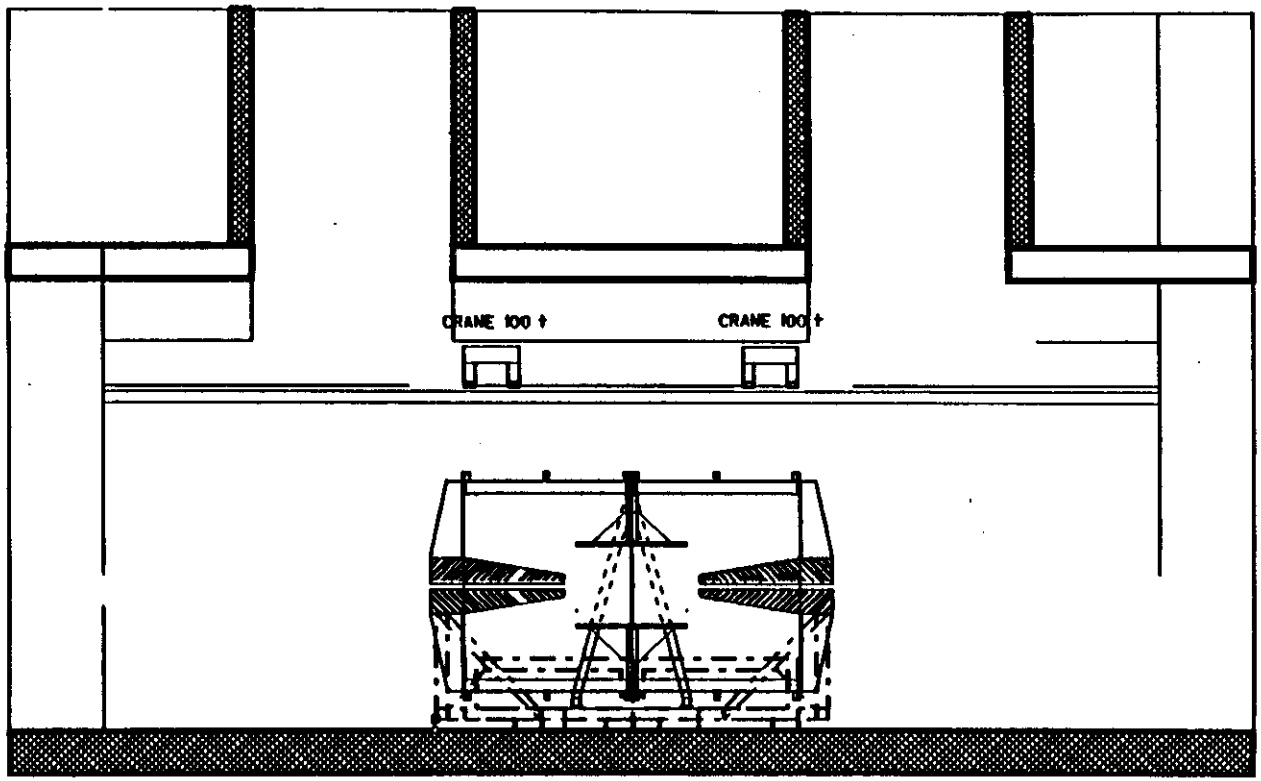
SSC

GEM'S DETECTOR
INSTALLATION SEQUENCE
PHASE 3

GDD - 000 049-0

PHASE 5

FLUX CONCENTRATOR SOUTH - TESTS

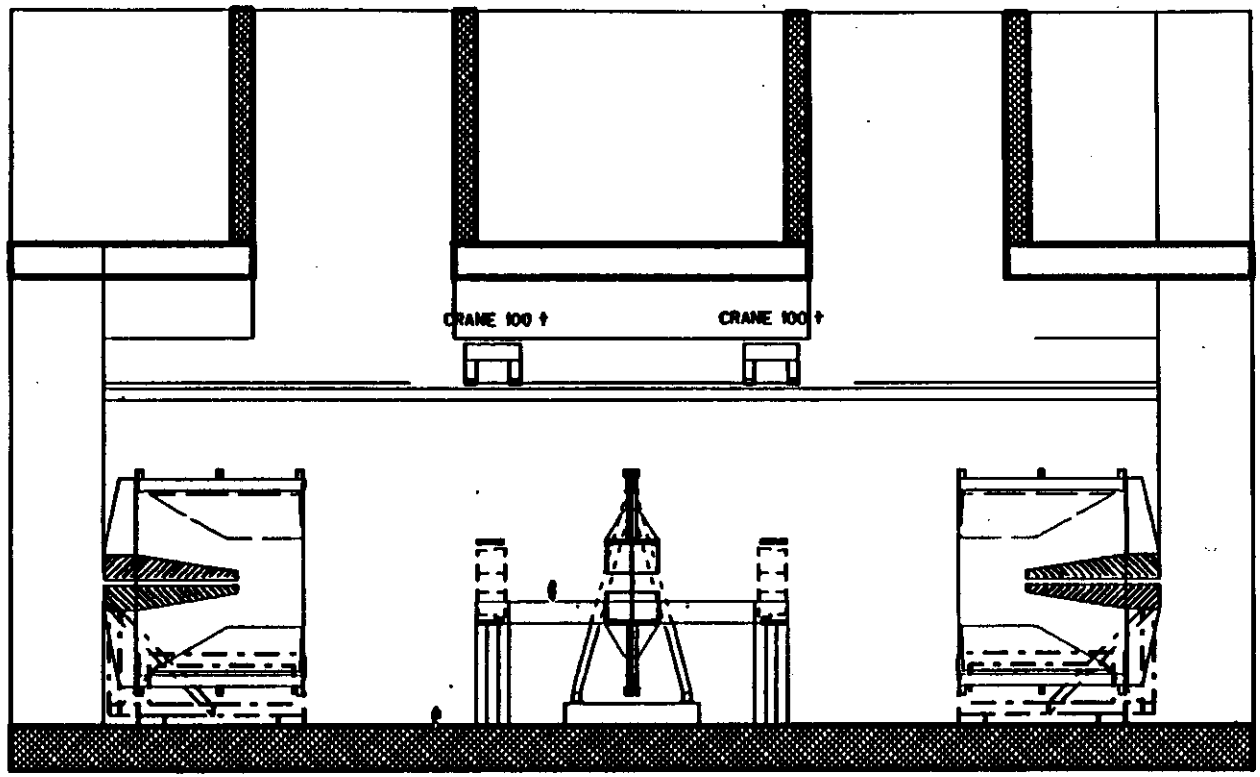


SSC

GEM'S DETECTOR
INSTALLATION SEQUENCE
PHASE 5

D CDD - 000 052-D

PHASE 6
CALORIMETER ASSEMBLY AND BARREL MUON CHAMBERS

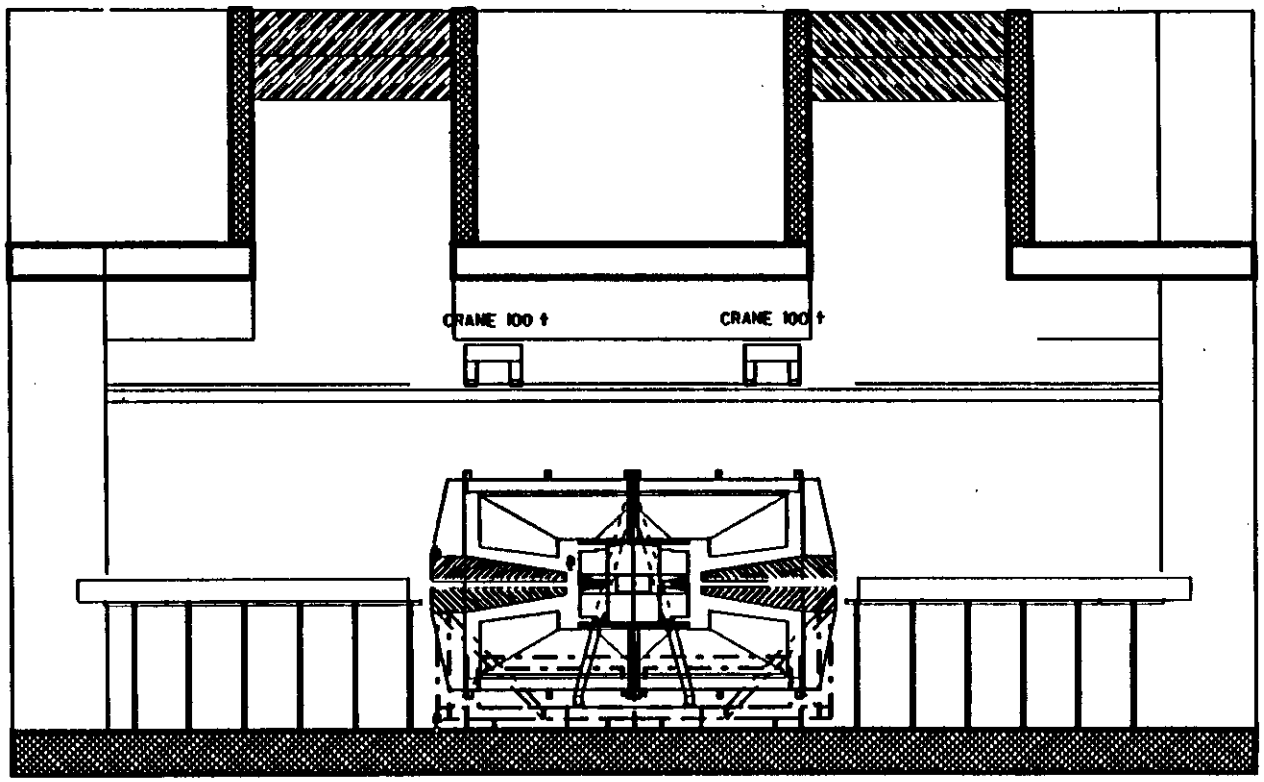


SSC

GEM'S DETECTOR
INSTALLATION SEQUENCE
PHASE 6

CDD - 000 058-0

PHASE 8
VACUUM PIPES - CONNECTIONS - QUADRUPOLES

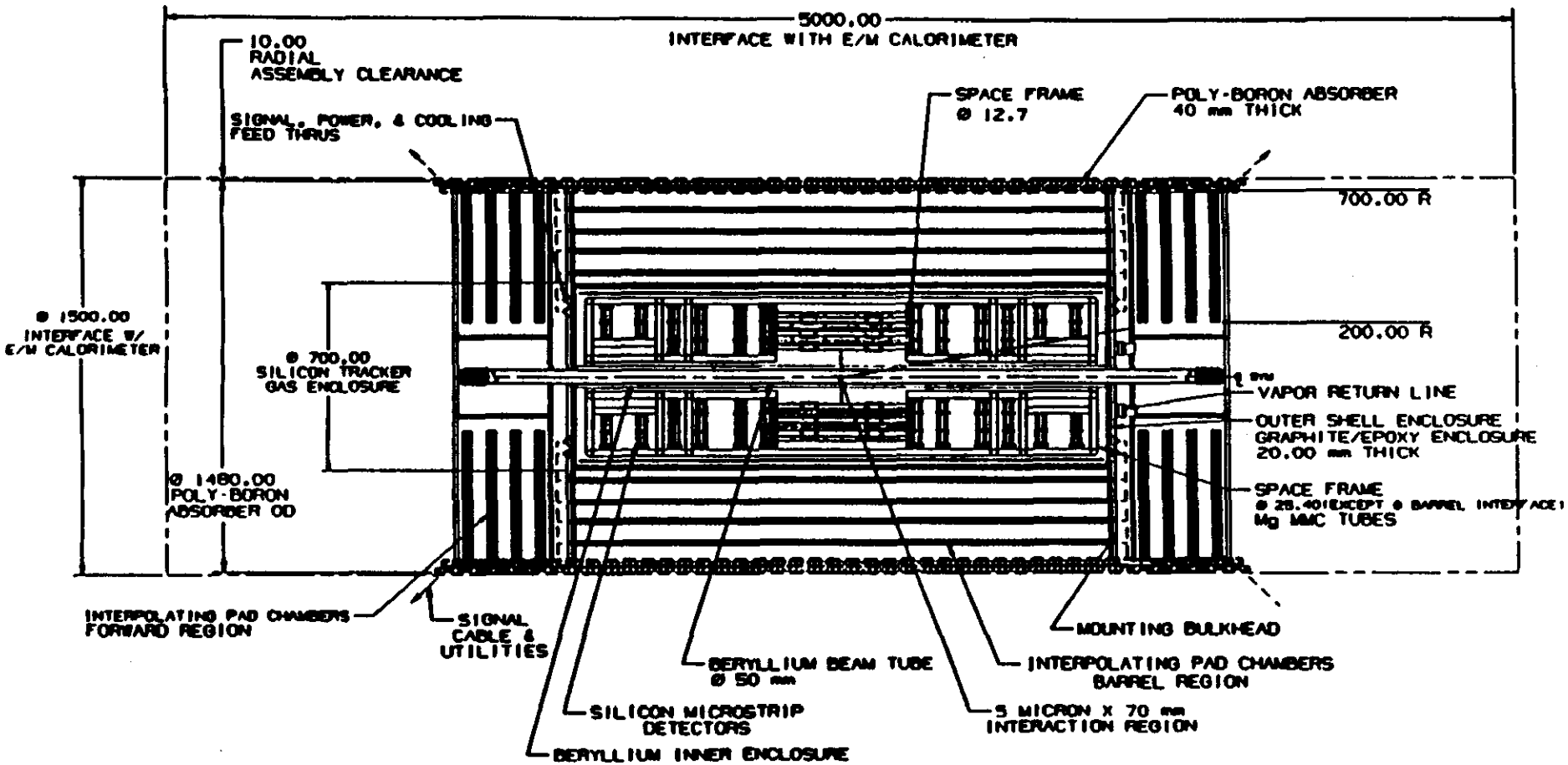


SSC

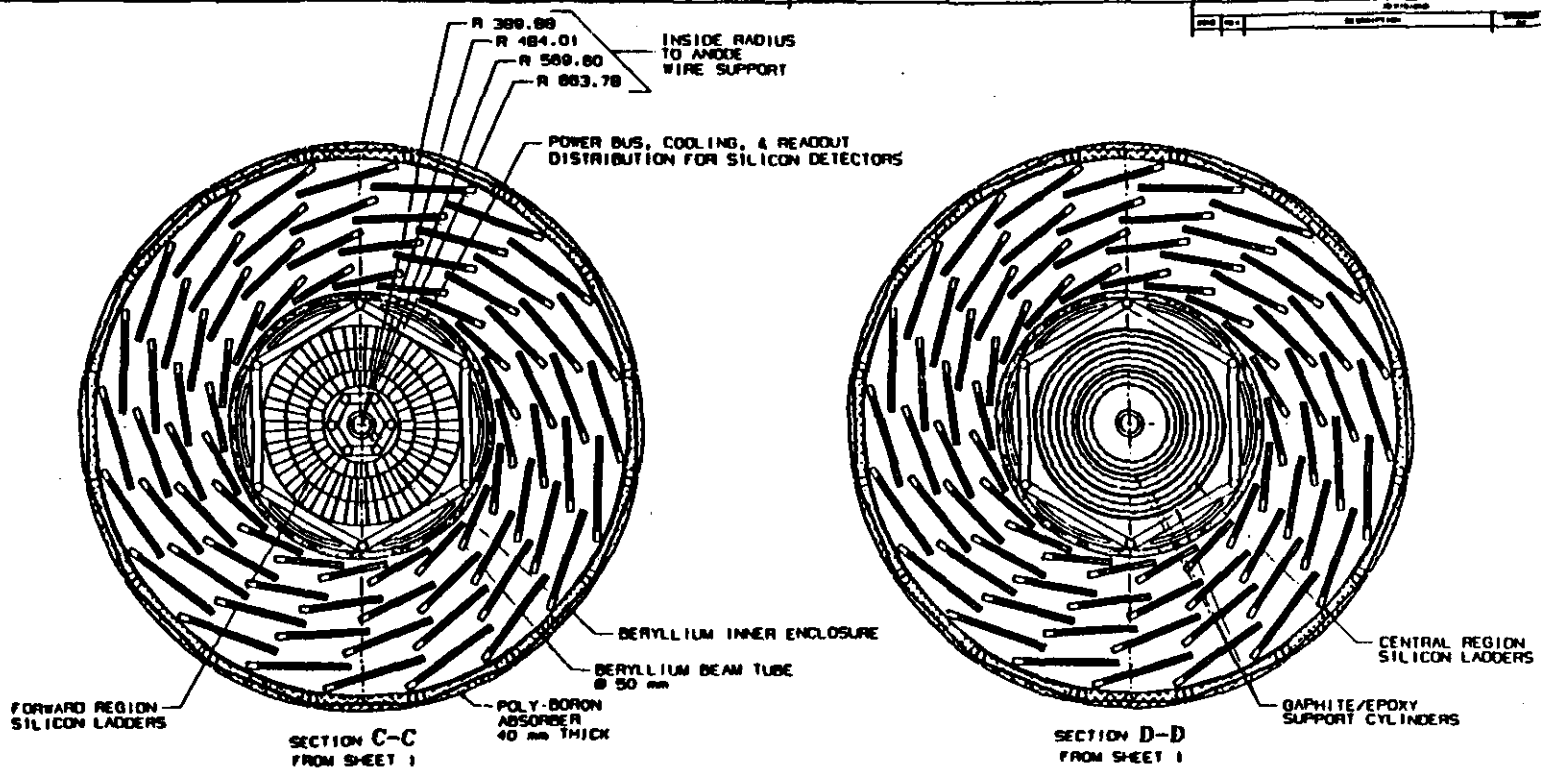
GEM'S DETECTOR
INSTALLATION SEQUENCE
PHASE 8

GDD - 000 061-0

Issues: Material
Schedule
Resolution *



GEM CENTRAL TRACKER



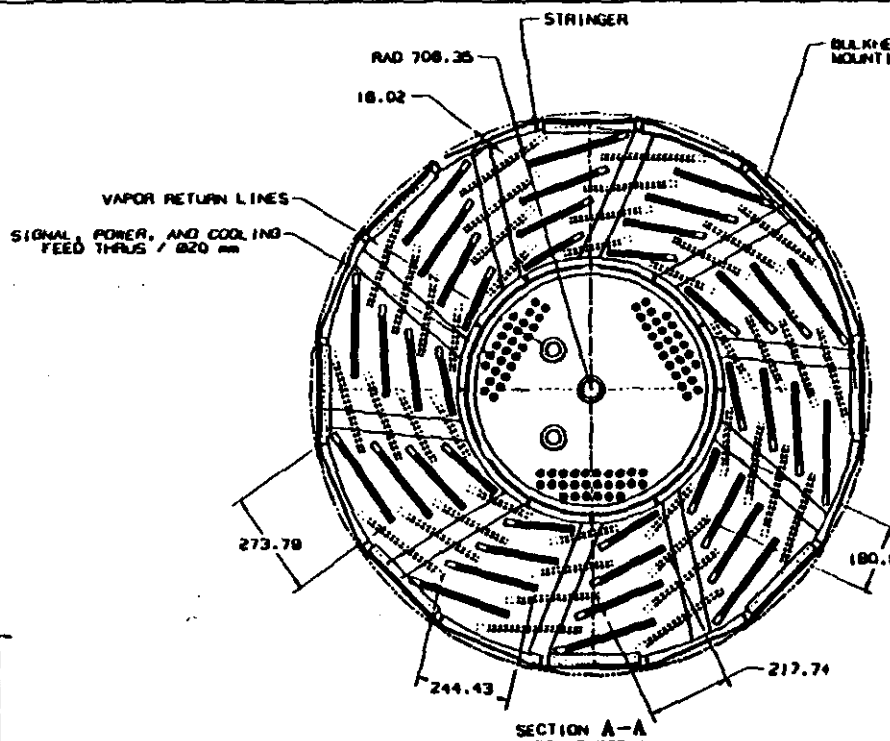
METRIC

THIRD ANGLE PROJECTION

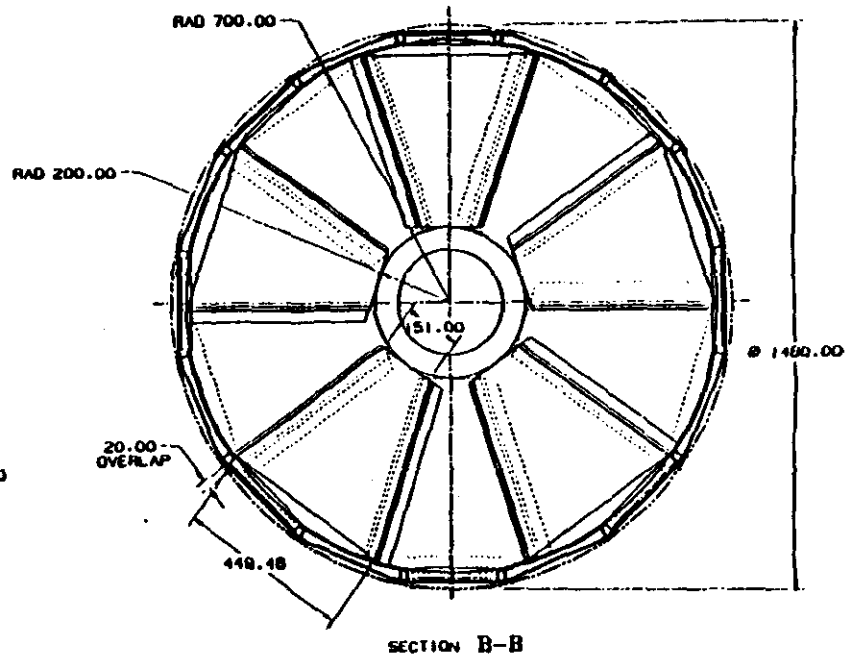
Los Alamos

GEM CENTRAL TRACKER WORKING LAYOUT

A1 SK-GEM12-009A 3



SECTION A–A
FROM SHEET 1



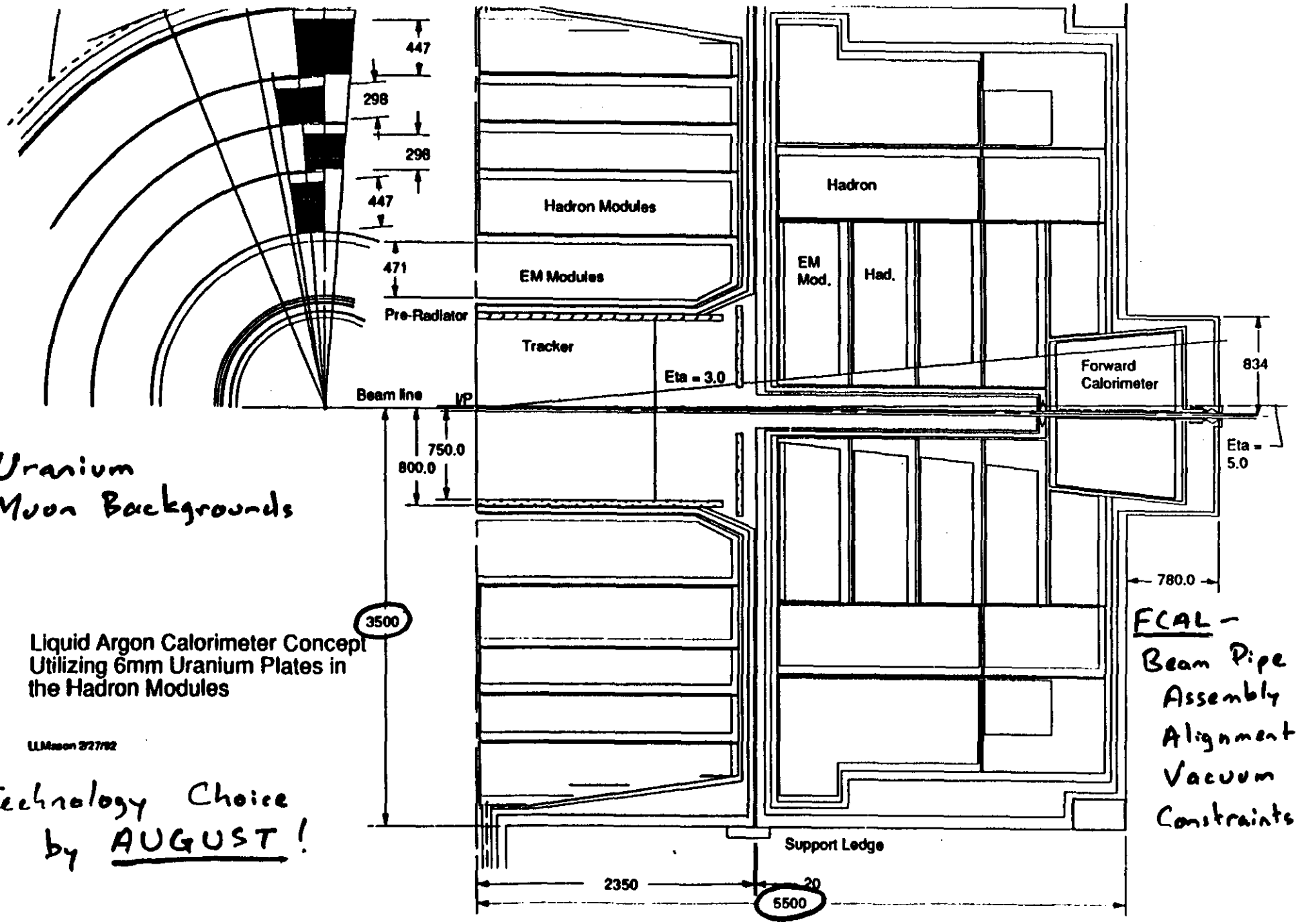
SECTION B–B
FROM SHEET 1

NOTE: EACH LEVEL OF 10 SECTORS ROTATED 9 DEGREES RELATIVE TO ADJACENT LEVELS (4 LEVELS IN TOTAL)

INTERPOLATING PAD CHAMBERS (BARREL REGION)
20 SECTORS OF 4 SUPERLAYERS EACH LORENZ ANGLE OF 12 DEGREES EACH LEVEL ROTATED 4.5° RELATIVE TO ADJACENT LEVELS 2 LAYERS PER SUPERLAYER DIMENSIONS FOR CHAMBERS ARE FOR ACTIVE WIDTHS (ADD 5 CM FOR OVERALL WIDTHS)

METRIC
THIRD ANGLE PROJECTION

Los Alamos
GEM CENTRAL TRACKER
WORKING LAYOUT
A1 SK-GEM12-008A



{Uranium
{Muon Backgrounds

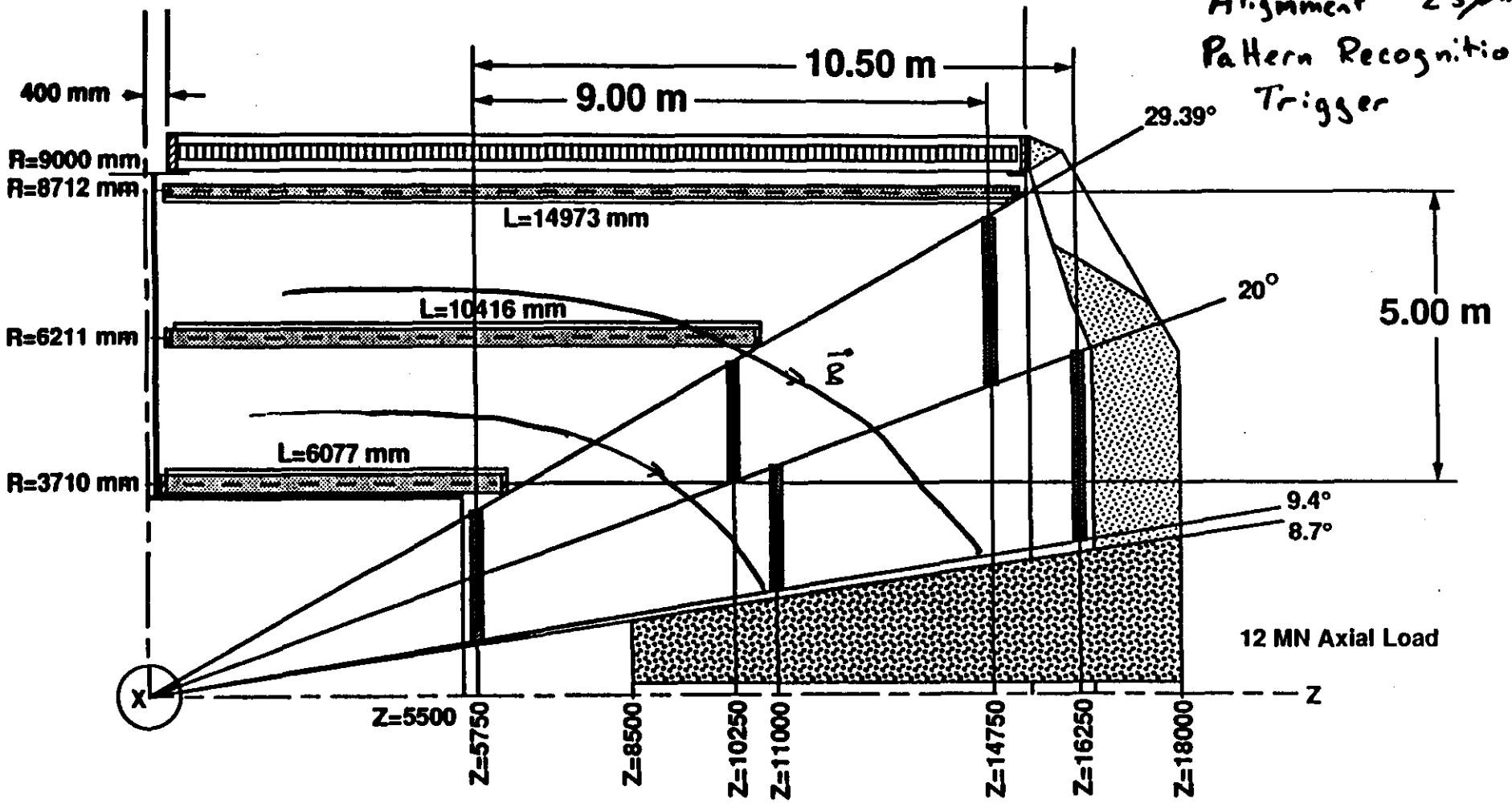
Liquid Argon Calorimeter Concept Utilizing 6mm Uranium Plates in the Hadron Modules

LLMason 3/27/92

Technology Choice by AUGUST!

FCAL – Beam Pipe Assembly Alignment Vacuum Constraints *

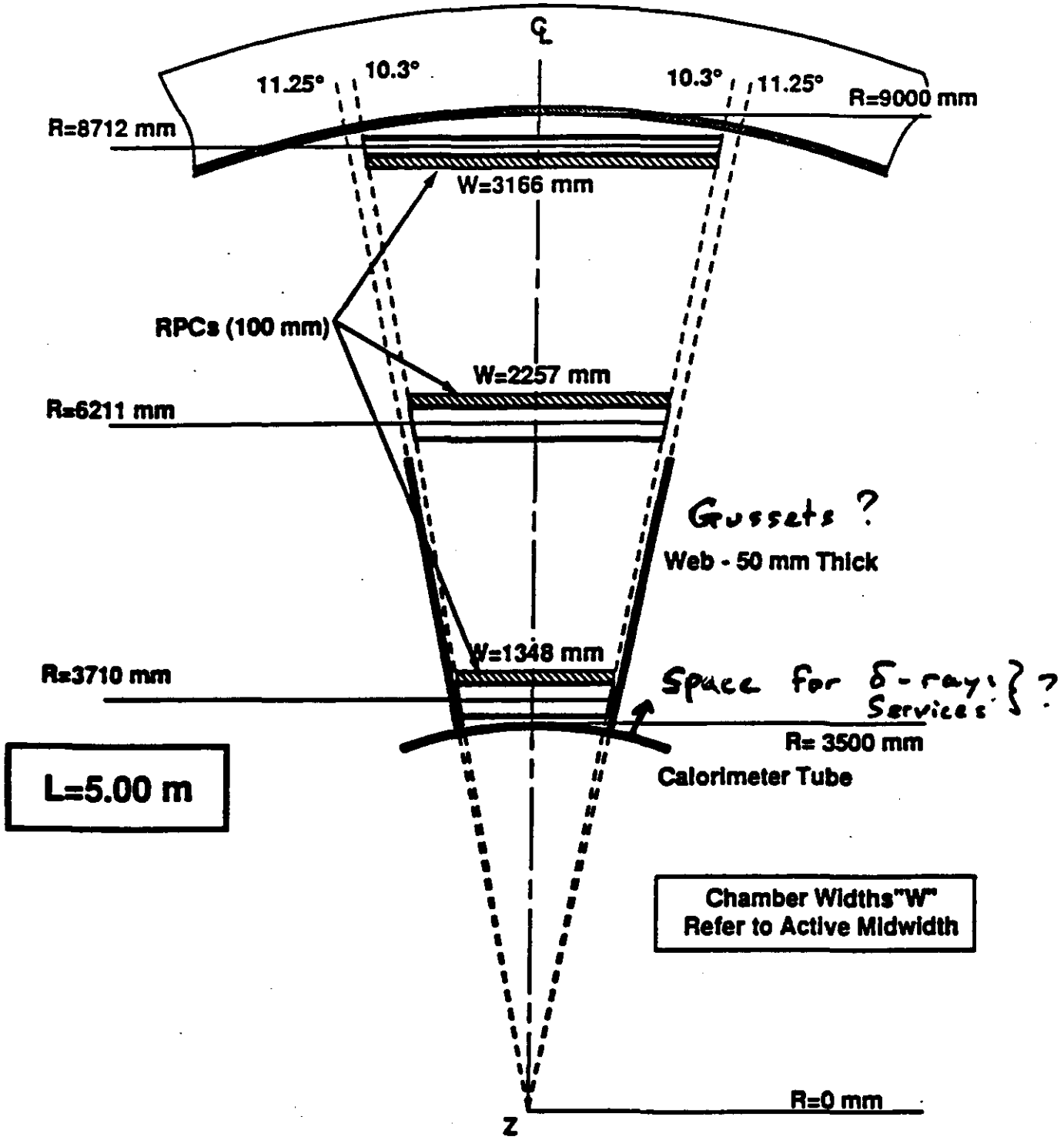
CHAMBERS
Forward $\sigma = 50\mu m$
Alignment $25\mu m$!!
Pattern Recognition
Trigger



GEM PDT 18/7 (8/8/4) Barrel
(4/4/4) Endcap
ELEVATION
(Calorimeter 7m OD x11m Long)
(Extended Forward Field Shaper 18000mm Long)
(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. NIMBLETT
GEM920226

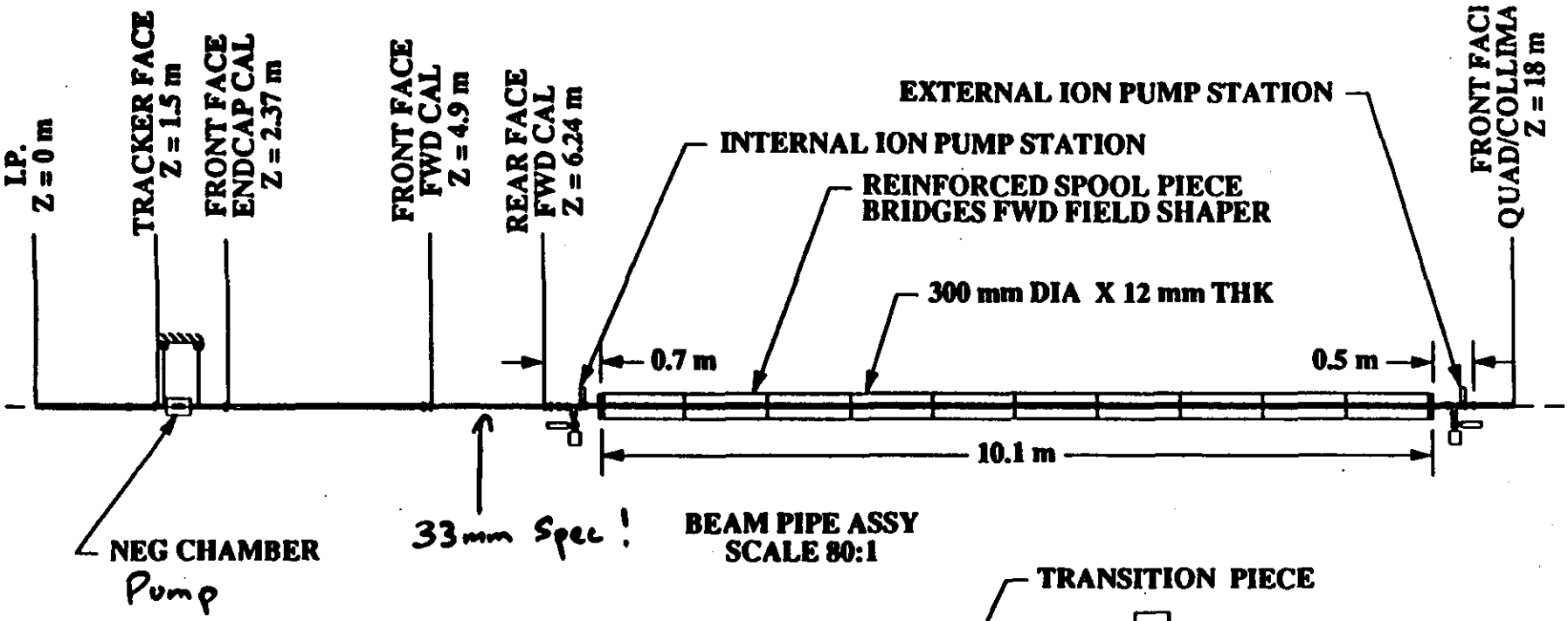
MAGNET
Procurement / Spec / Design
Schedule
Field Map
Test



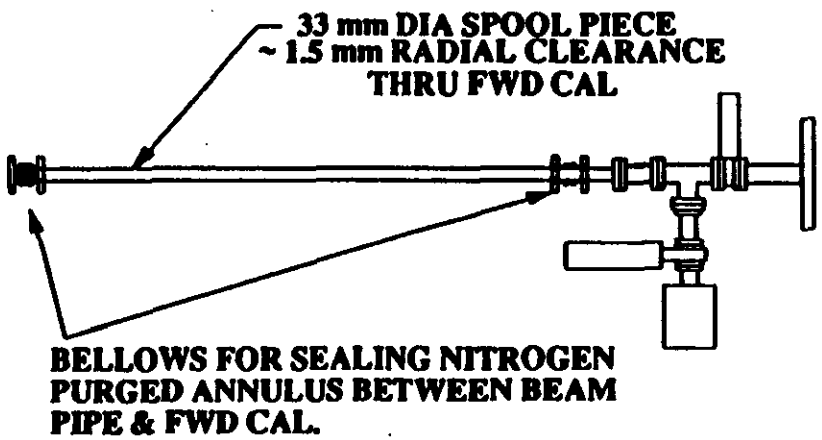
PDT 18/7 (8/8/4)
(Barrel Region Endview)

F. Nimblett
GEM 920215

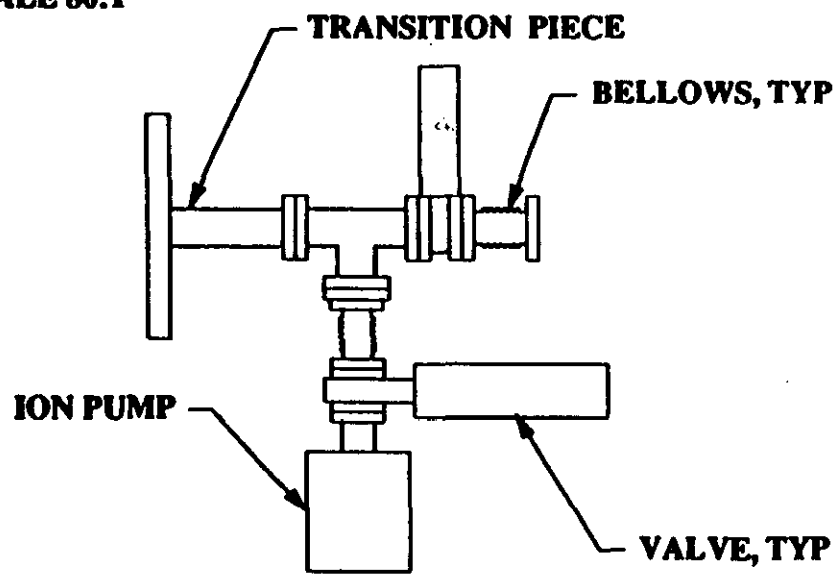
Beam Pipe



BEAM PIPE ASSY
SCALE 80:1

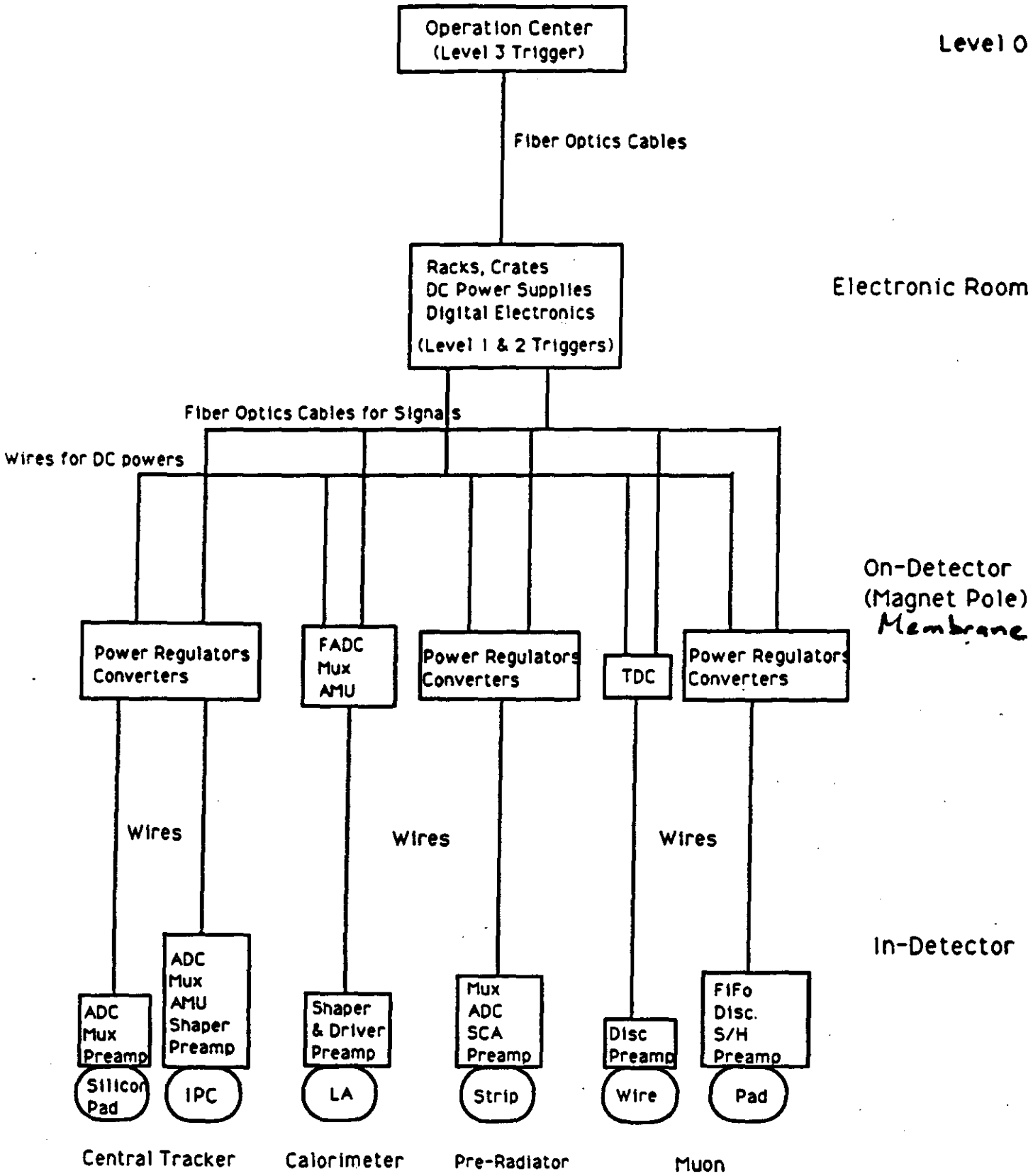


INTERNAL ION PUMP STATION
SCALE 20:1



EXTERNAL ION PUMP STATION
SCALE 10:1

DRAFT
Eberle 02/28/92

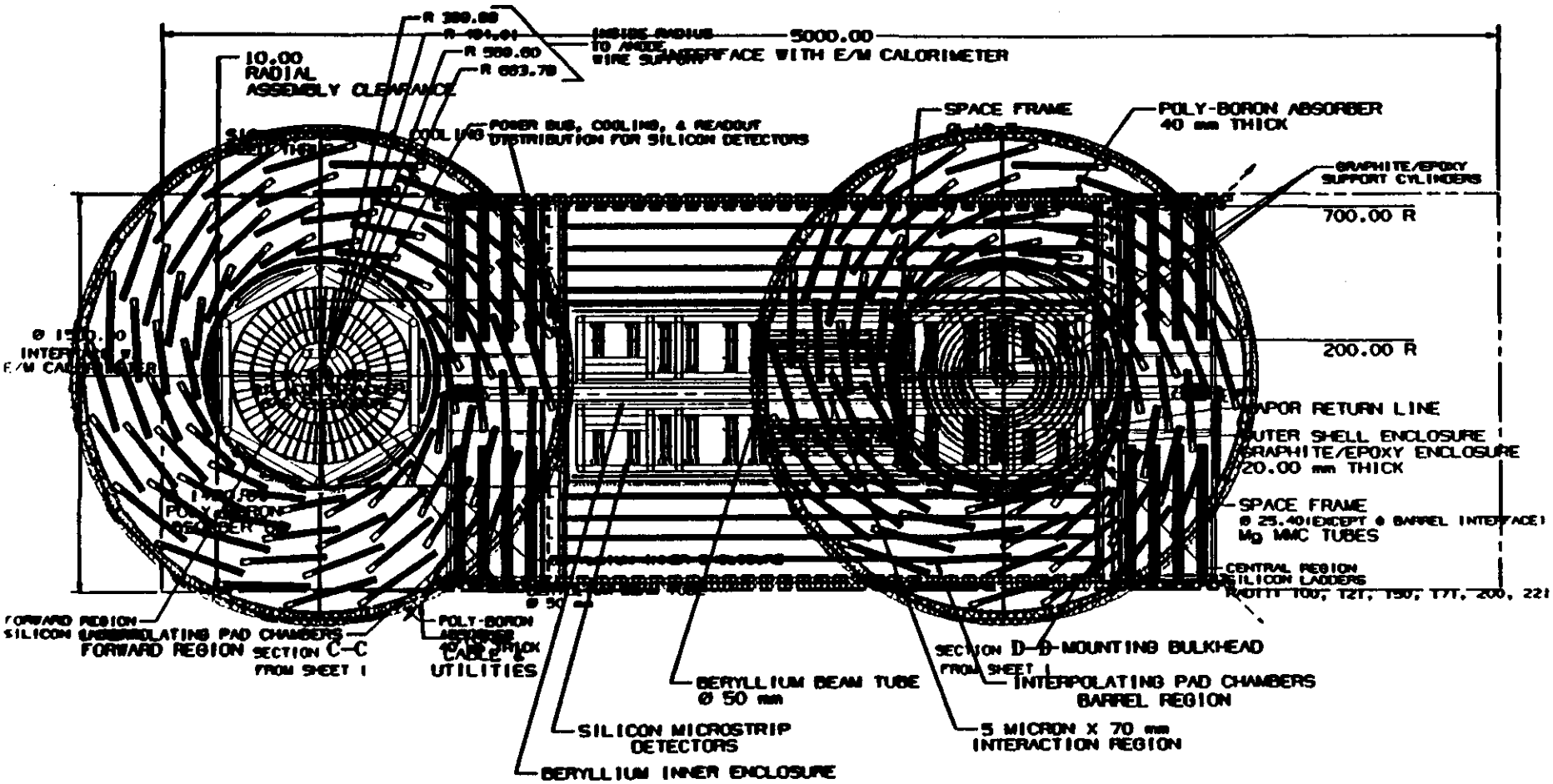


Electronics System Layout

Tracker

C. Baltay

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ



GEM CENTRAL TRACKER

GEMG-1069-JV 3-02-92

TECHNOLOGIES CONSIDERED

1. For Inner Tracker

   Silicon Microstrips
   Silicon Pixels
   Long Drift Length Silicon

2. For the outer tracker

   Straw Tubes
   Scintillating Fibers
   Interpolating Pad Chambers
   Silicon (microstrip or other)

For the present Baseline Design, chose:

- Silicon Microstrip Inner Detector
- Interpolating Pad Chamber Outer Det.

Reasons for choice of Silicon Microstrips

1. The very fine segmentation possible combined with proven high radiation resistance make this detector ideal as the element closest to the interaction point

2. Very high spatial resolution allows precise impact parameter measurement and therefore secondary vertex detection

3. Silicon Microstrips are a mature technology, which are presently in use in a number of fixed target and collider experiments with relatively well understood performance, radiation resistance, and cost properties.

- Silicon pixels - unproven technology, Potentially very expensive

- Long Drift Length Silicon — Not very mature radiation resistance unknown

The 3-D nature of these two devices are very attractive. We will watch their progress in the next few years carefully.

Reasons for choosing Interpolating Pad Chbrs

1. All Silicon system prohibitively expensive

2. Pad sizes of a few cm^2 are natural. This allows for a low occupancy even at 10^{34} cm^{-2} sec^{-1}. Straws or Fibers would have considerably higher occupancies.

3. The pads approach "3-D" points which makes tracking easier in high multiplicity environment of SSC. Straws and Fibers are stereo or projective devices which make pattern recognition much harder

4. Interpolating Pad Chambers are a proven technology. Resolution we need in chamber sizes similar to what we need have been demonstrated. Shaping time, Data rate?

Outer Radius	70 cm
Length	± 150 cm
Rapidity Coverage	$\lvert\eta\rvert \leq 2.5$
Magnetic Field	0.8T
Occupancy	
at $\mathcal{L} = 10^{33} cm^{-2} sec^{-1}$	$\leq$1%
at $\mathcal{L} = 10^{34} cm^{-2} sec^{-1}$	$\leq$10%
Charge separation at 95% c.l.	$p \lesssim 400$ GeV/c
Momentum Resolution at 90°	
at high momenta (measurement limited)	$\Delta p/p^2 \sim$(1 to 3) x 10^{-3} (GeV/c)$^{-1}$
at low momenta (multiple scattering limited)	$\Delta p/p \sim$ 2 to 4%
Vertex Resolution	
along beam direction	$\delta z \sim$1 mm
impact parameter	$\delta b \sim 30 \mu$m above 10 GeV/c

Table 2.1: Design Parameters for the Central Tracker

Physics Processes	Id. Primary Vertex	e/γ Separation	e, μ, γ Isolation Cuts	e/h Separation	Muon Momentum Check	$e\pm$ Sign Separation	Secondary Vertex	Low Momentum Track	Full Event Reconstr.
$H^0 \rightarrow \gamma + \gamma$	X	X	X						
$H^0 \rightarrow e^+e^-l^+l^-, e^+e^-\nu\bar{\nu}, e^+e^-$ *jetjet*	X	X	X	X		X			
$H^0 \rightarrow \mu^+\mu^-l^+l^-, \mu^+\mu^-\nu\bar{\nu}, \mu^+\mu^-$ *jetjet*	X		X		X				
Gluino Pair Prod $\tilde{g}\tilde{g} \rightarrow e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
Techni eta $\eta_T \rightarrow b + \bar{b}$ or $t + \bar{t}$	X		X				X		
WW Scattering $W^\pm W^\pm \rightarrow e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
$Z^1 \rightarrow e^+e^-$ Asymmetry	X	X	X	X		X			
B Physics, e.g. $B \rightarrow \Psi$, etc.	X						X	X	X
Top Physics $t \rightarrow W + b$, etc.	X		X				X	X	X

CENTRAL TRACKER PHYSICS STUDIES

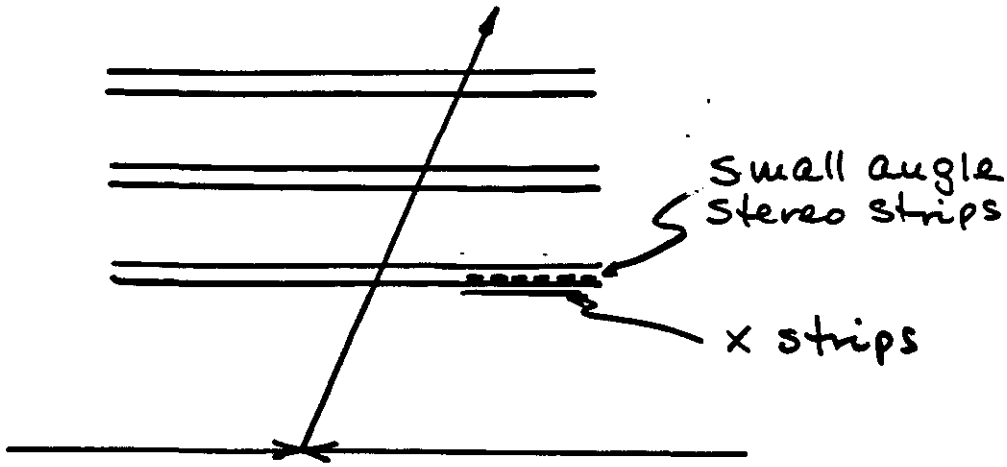
Table 2.3

Silicon microstrips resolution	10 μm
Silicon alignment stability	10 μm
Pad chamber resolution	50 μm
Pad chamber alignment stability	25 μm

Table 2.2

Silicon Microstrip Inner Detector

- 6 layers of double sided silicon detectors
- Strips 50 μ wide × 12 cm long



- Occupancy at innermost layer near 90°

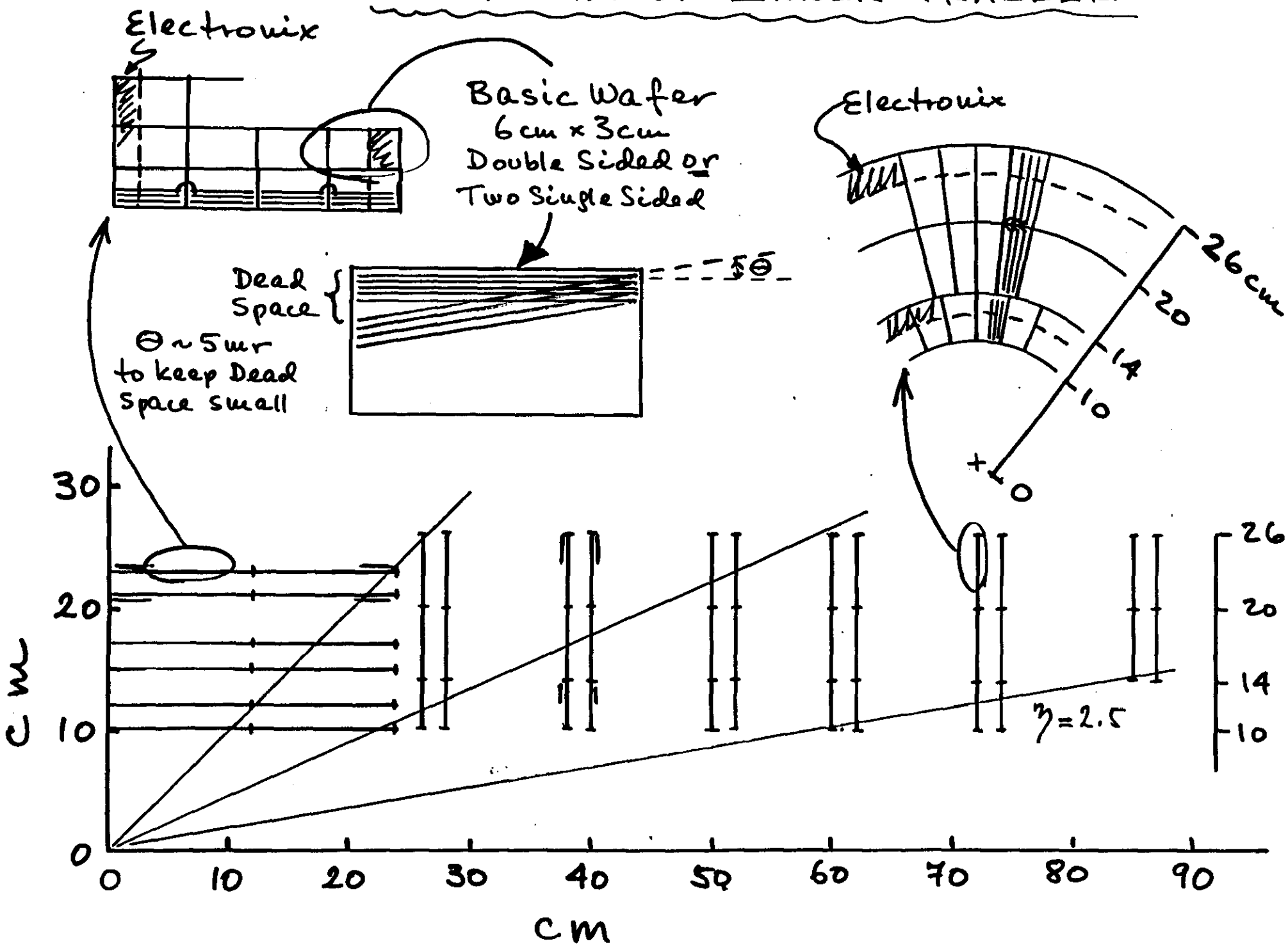
  $\lesssim 2 \times 10^{-3}$

- Total area $\sim 7\ m^2$
- 3×10^6 strips

  digital output, highly multiplexed

  ~2000 Readout channels

GEM Silicon Inner Tracker



Interpolating Pad Chambers

In use in Experiment E814 at Brookhaven AGS (Heavy Ion Coll) with chambers up to 50 cm × 200 cm (built for ~$3000/m²)

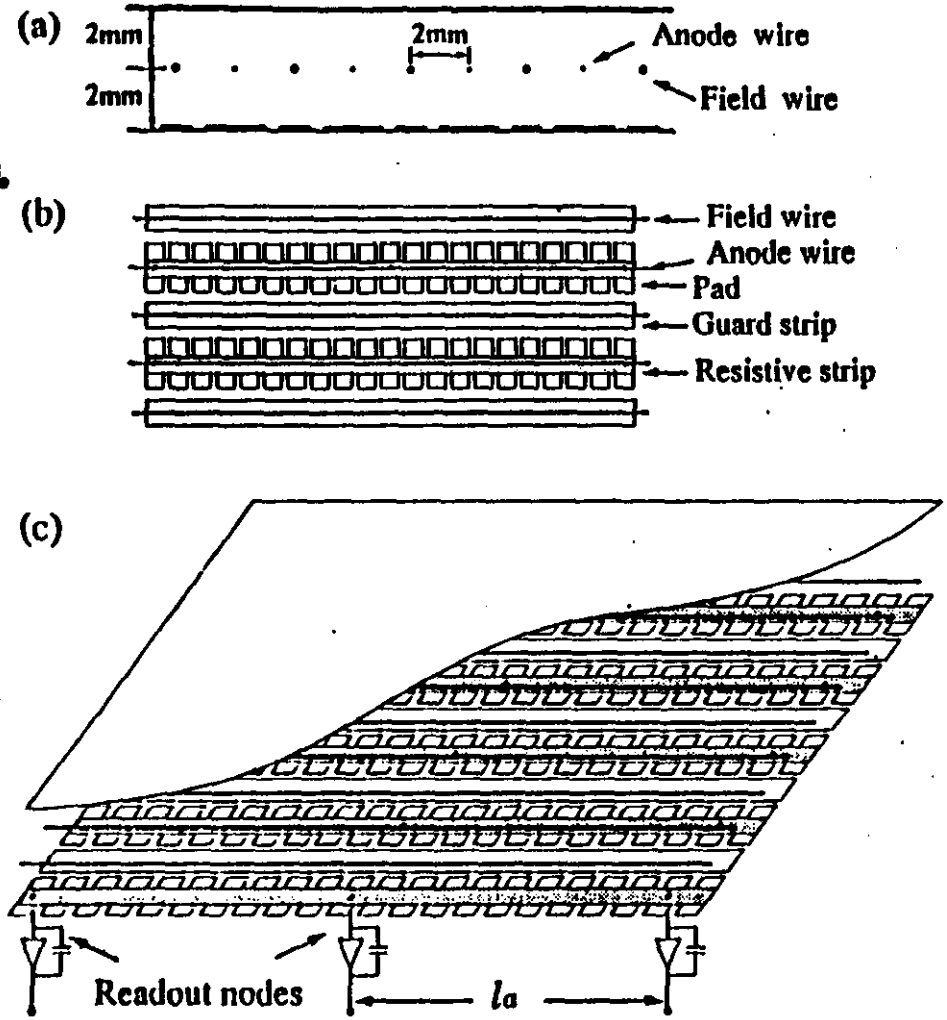


Figure 3.4.1: Schematic of a Pad Chamber. (a) Cell geometry viewed end-on to the anode/field wires. (b) Looking down onto the cathode plane. (c) "3-D" view of the Pad Chamber.

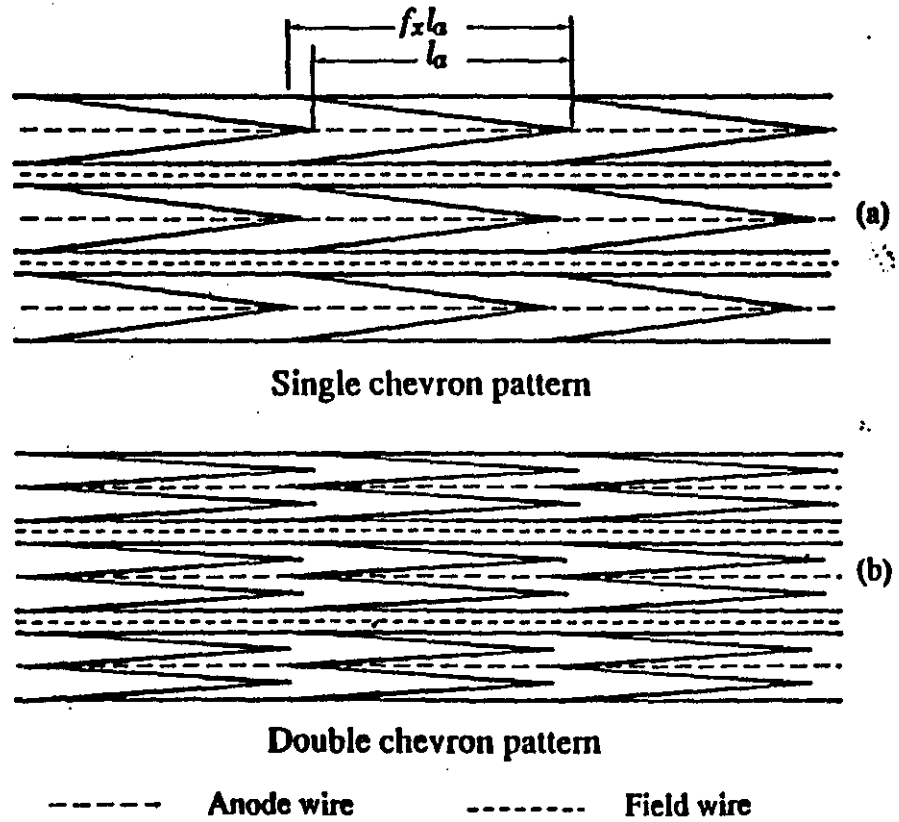


Figure 3.4.2: Two types of chevron pad cathode

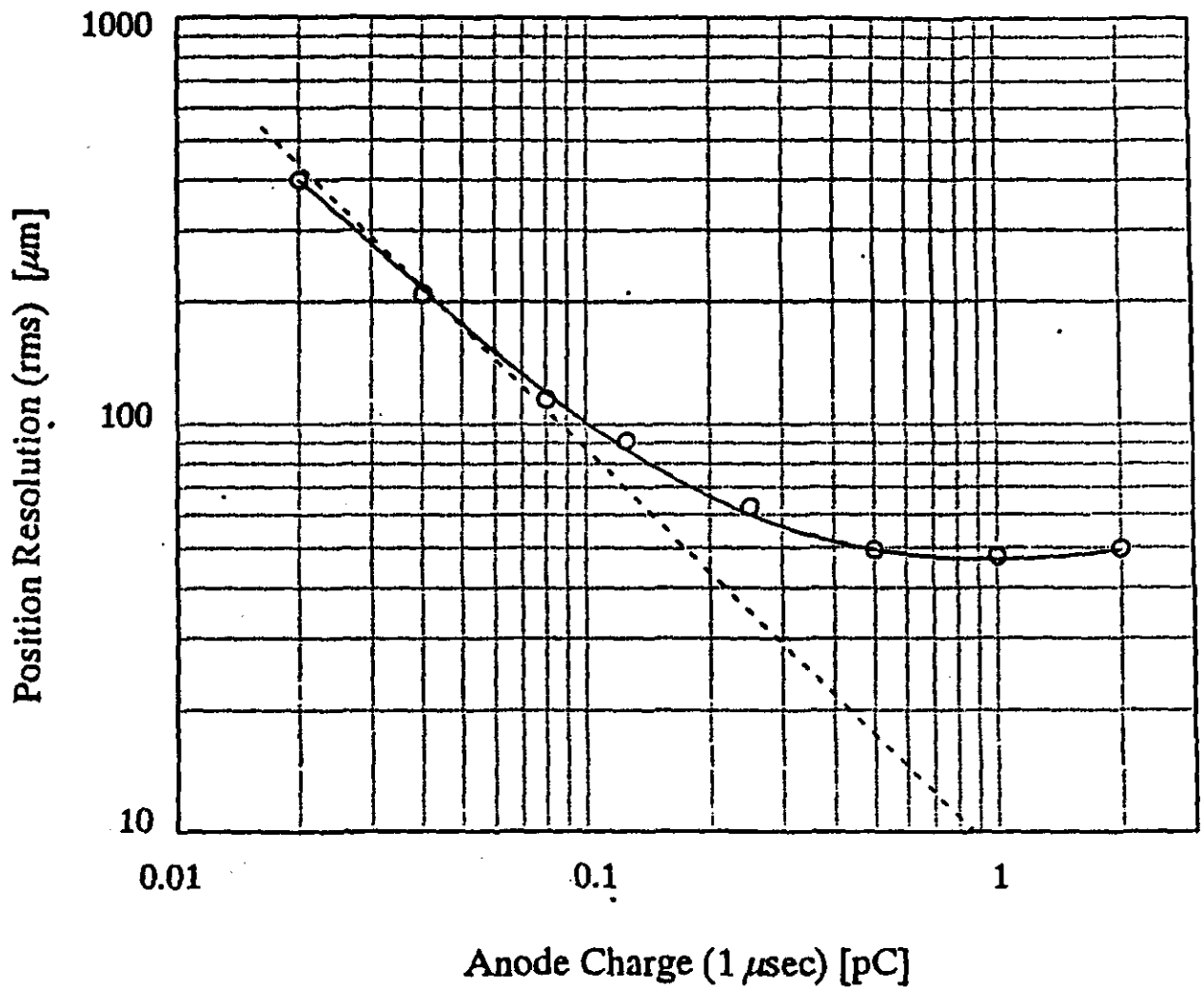
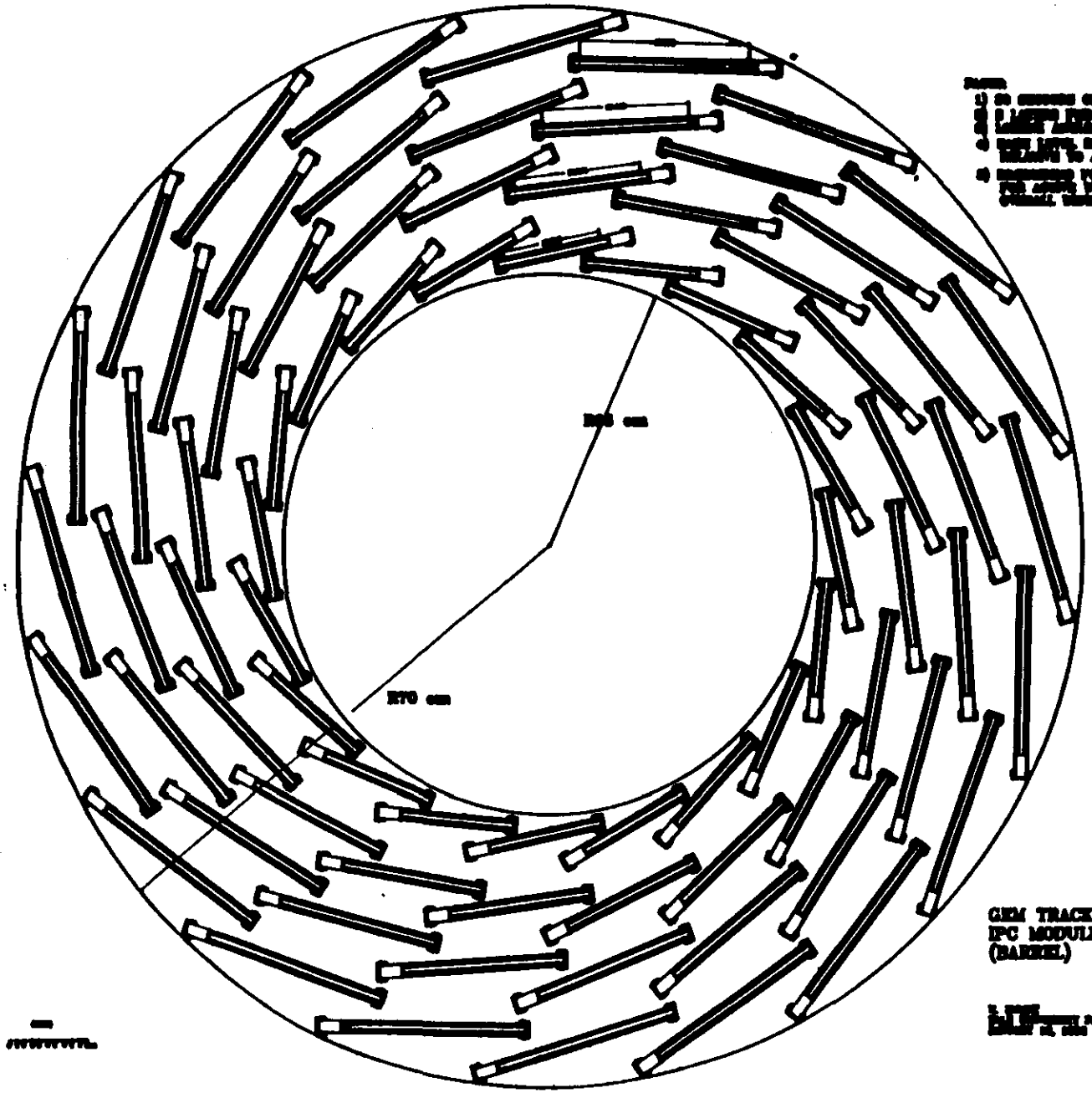
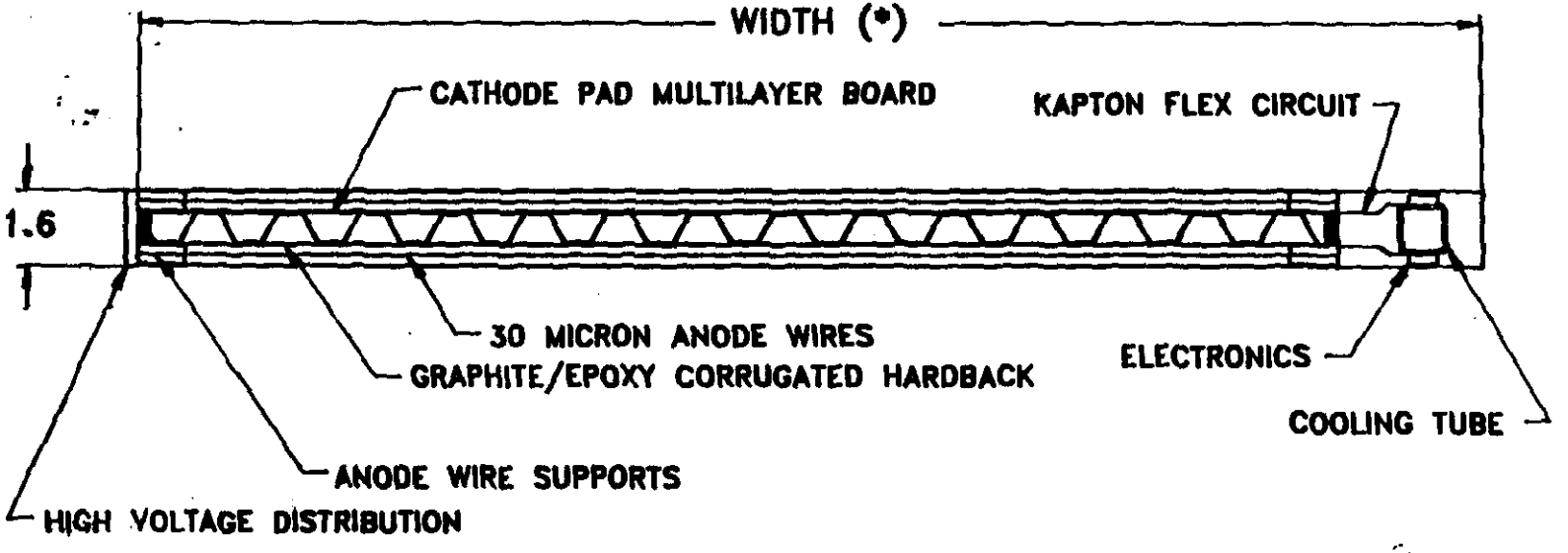


Figure 5.3.2: Position resolution vs anode charge. Results were measured from a 12 mm single cl... ...ode. using cent... finding electronics



GEM TRACKER
IPC MODULE LAYOUT
(BARREL)



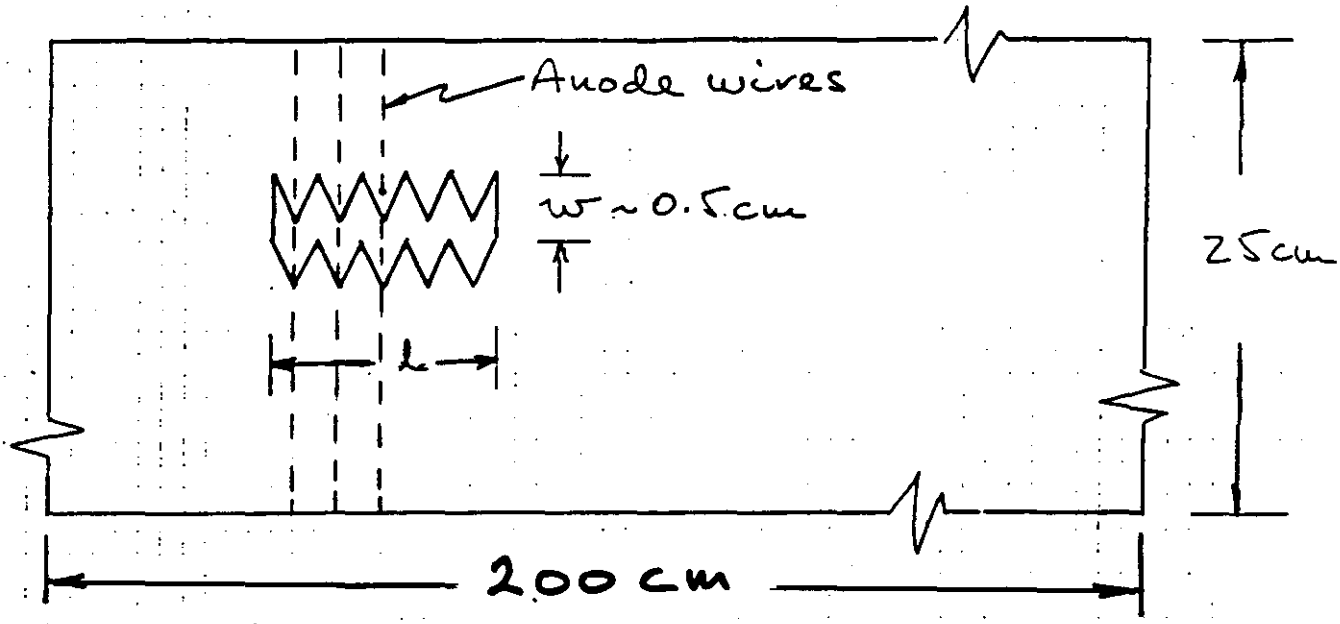
GEM TRACKING IPC SUPERLAYER

SECTIONAL OF TYPICAL BARREL MODULE

W. EMMET
YALE PPG 22-JAN-1992

Pad Chamber Parameters

a) Barrel Chambers

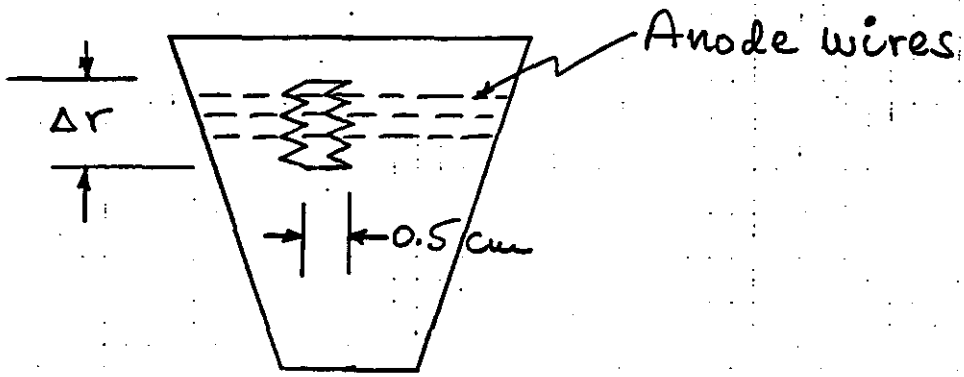


Resolution $\sigma \sim 1\%$ of $W \sim 50\mu$

Length of Pads $l \sim 3$ cm to 30 cm

Anode wire spacing ~ 2 mm

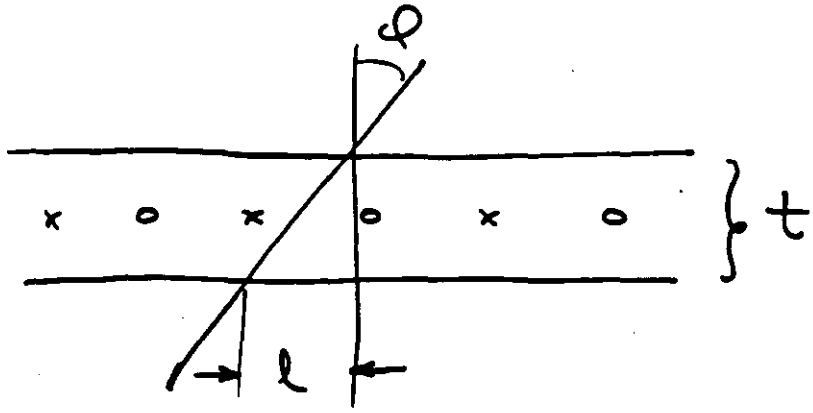
b) End Cap Chambers



Keep 0.5 cm width for 50 μ resolution

Length of pads $\Delta r \sim 1$ to 8 cm

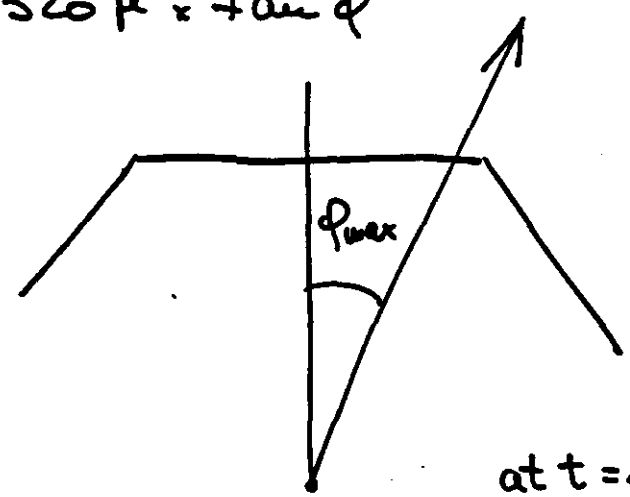
Loss of Resolution at Non-normal incidence



$\sigma \sim 0.08\, l$ $\qquad$ $l = t \tan\phi$

for $t = 4$ mm

$\sigma = 320\mu \times \tan\phi$



Configuration	ϕ_{max}	at t = 4mm σ_{max}	at t = 3mm σ_{max}
Octagon	22.5°	133 μ	99 μ
12 sided poly	15°	86 μ	64 μ
16 sided poly	11.25°	64 μ	48 μ
20 sided poly.	9°	51 μ.	38 μ

Occupancy, Numbers of Pads and Readout Channels

- Occupancy from Pileup of MinBias events

  $dn/d\eta\, d\phi \sim 1$ charged track / event

  Assume pileup from 2 crossings, we expects ~ 3 events at $\mathcal{L} = 10^{33}$

  $dn/d\eta\, d\phi \sim 3 \Rightarrow 5$ (2nd any interactions loopers, γ conv. etc)

- Pad Size $\Delta\eta\, \Delta\phi = 0.0007$

  Occupancy per pad ~ 1/3 % at 10^{33}, ~ 3% at 10^{34}

  Occupancy per 3 pads ~ 1% at 10^{33}, ~ 10% at 10^{34}

  NOT including the signal event

- Pad Area $\sim r^2\, \Delta\eta\, \Delta\phi \sim 1\ cm^2$ at 35 cm

  $4\ cm^2$ at 70 cm

- Number of Pads

  Tracker $\Delta\eta\, \Delta\phi \sim (\pm 2.5)(2\pi) \sim 31.4$ sq units

  Pads/layer $\sim \dfrac{31.4}{0.0007} \sim 45000$

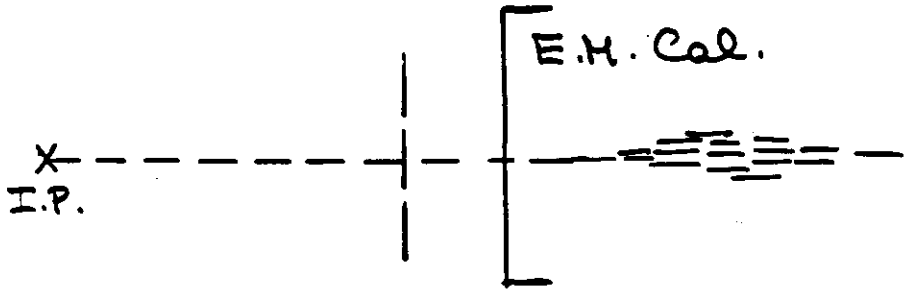
  8 layers $\Rightarrow \doteq 400{,}000$ pads total

- Multiplex 256 pads to 1 Readout channel

  ~ 1600 channels

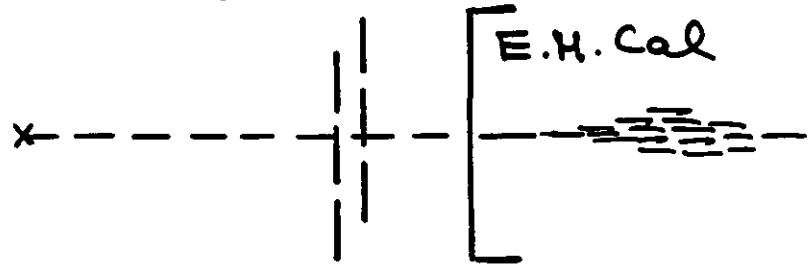
OCCUPANCY CONSIDERATIONS

1. For electron trigger or e/γ separation
Consider em shower in em calorimeter



single pad occupancy is relevant
probability of a stray track faking $e^{\pm}$
is $\sim 1/3\%$ at 10^{33}, $\sim 3\%$ at 10^{34}

<u>N.B.</u> will probably stagger pads in two layers of each superlayer



can <u>reduce</u> probability of fake $e^{\pm}$ by <u>factor of 2</u>

2. For momentum measurement of a track of interest (like $e^{\pm}$ sign separation)
need 3 pads for precision interpolation.
A background track in the same pad or the nearest neighbour on either side will compromise the interpolation precision.
In this case occupancy per cell of 3 pads is relevant i.e. $\sim 1\%$ at 10^{33}, $\sim 10\%$ at 10^{34}.

GEANT simulation Sumit Sen, Yale

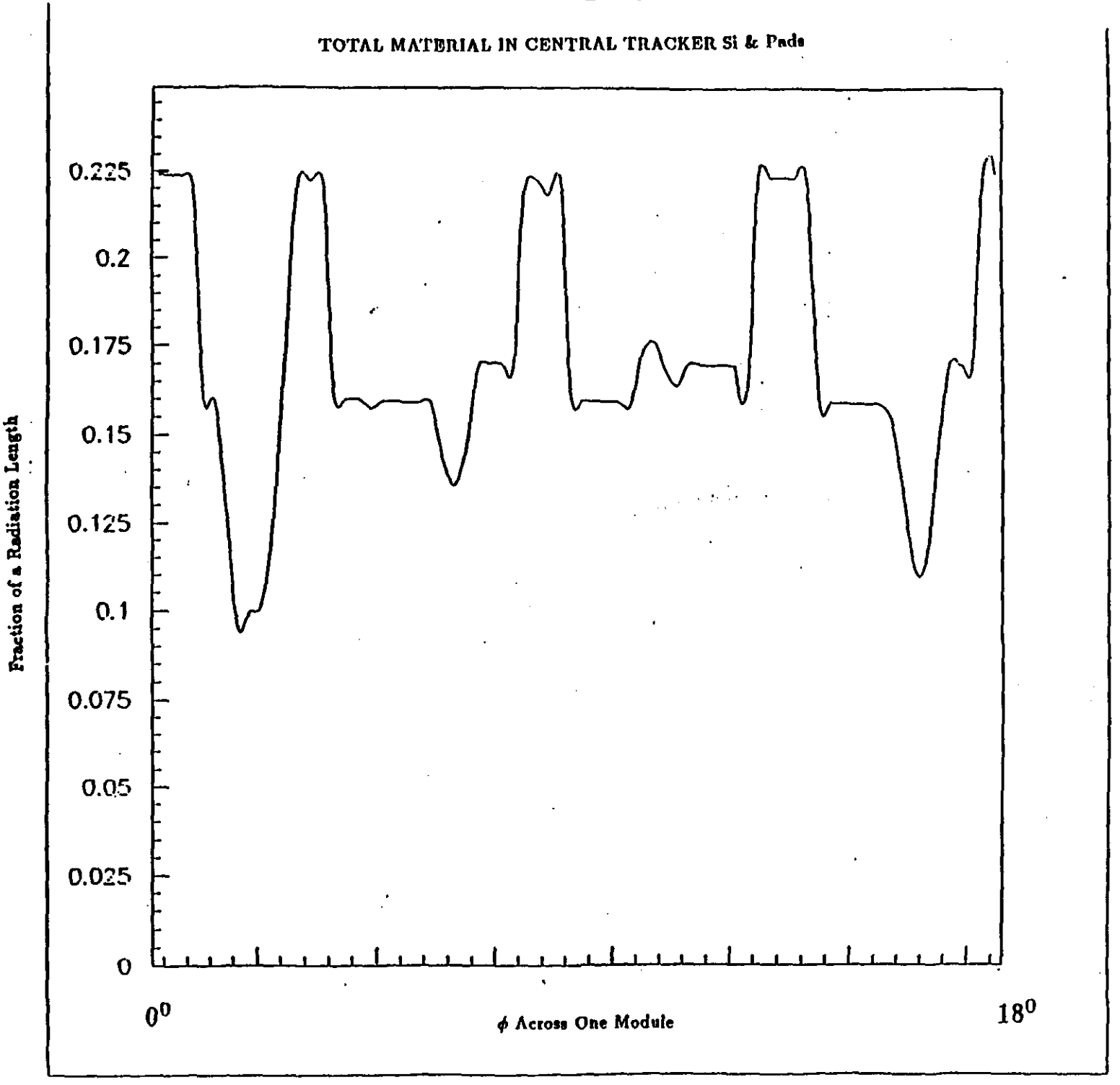


Figure 2.1

Schmit Sew
Yale

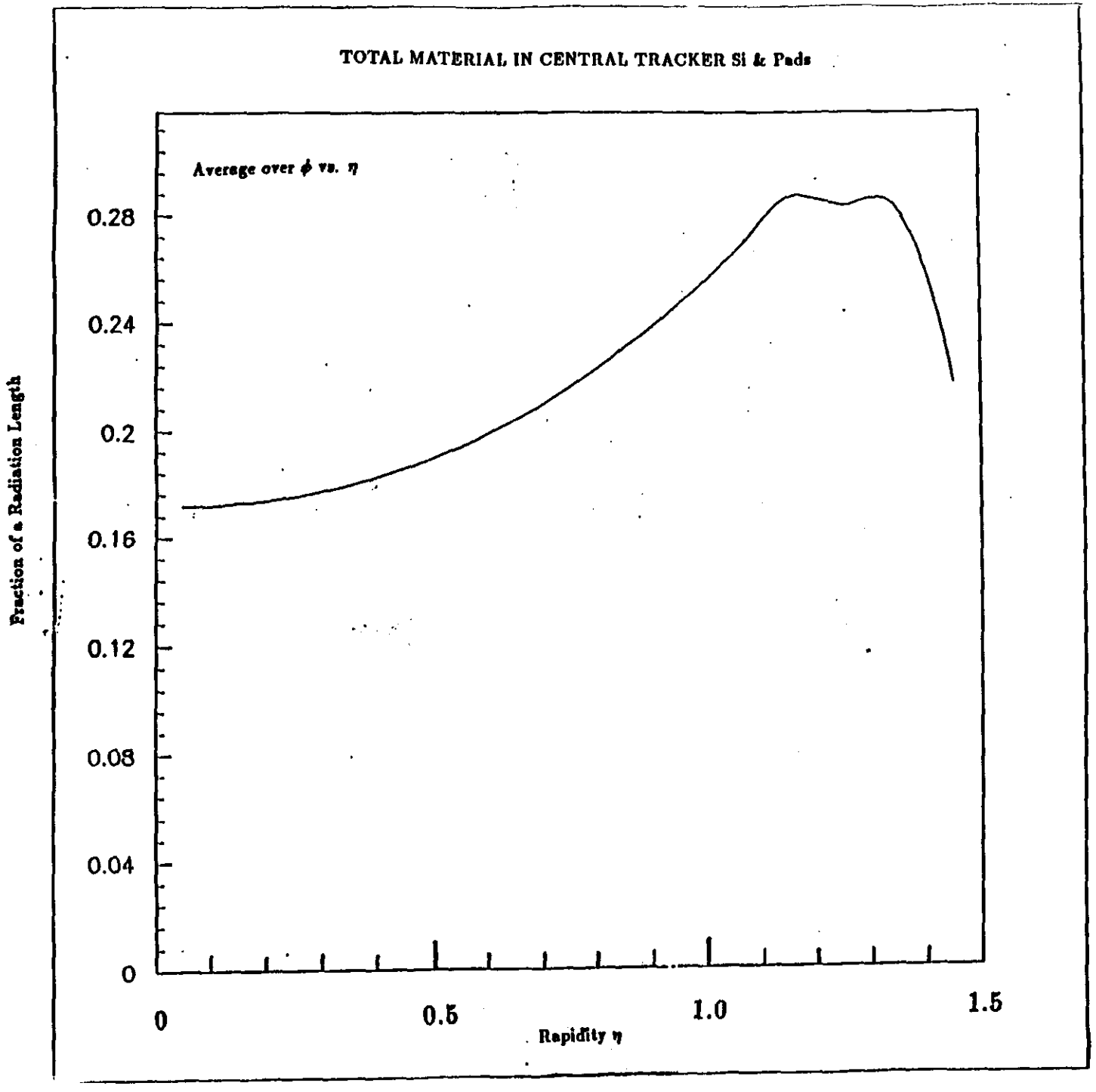


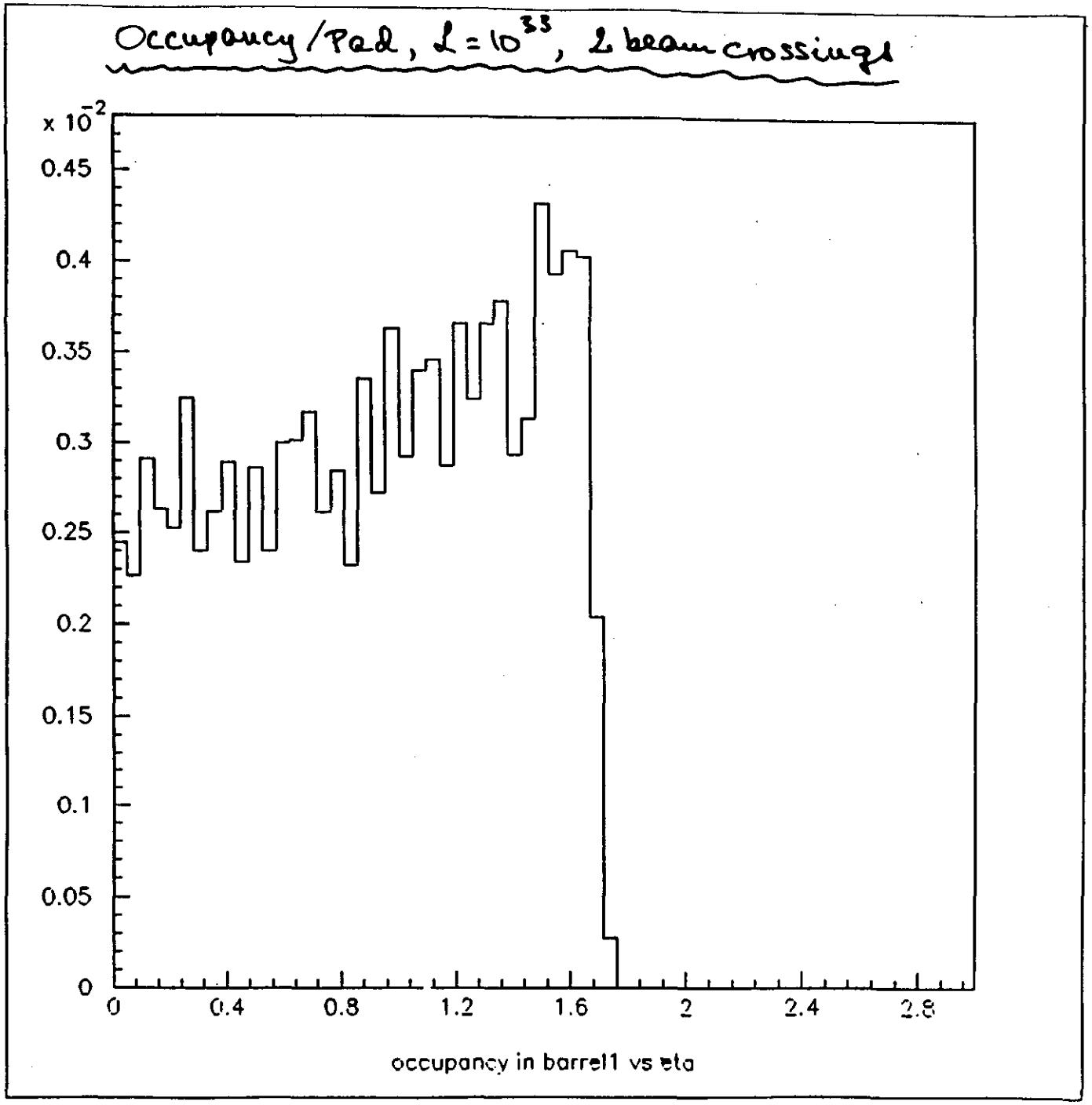
Figure 2.2

Sumit Sen
Yale

1 MeV cuts

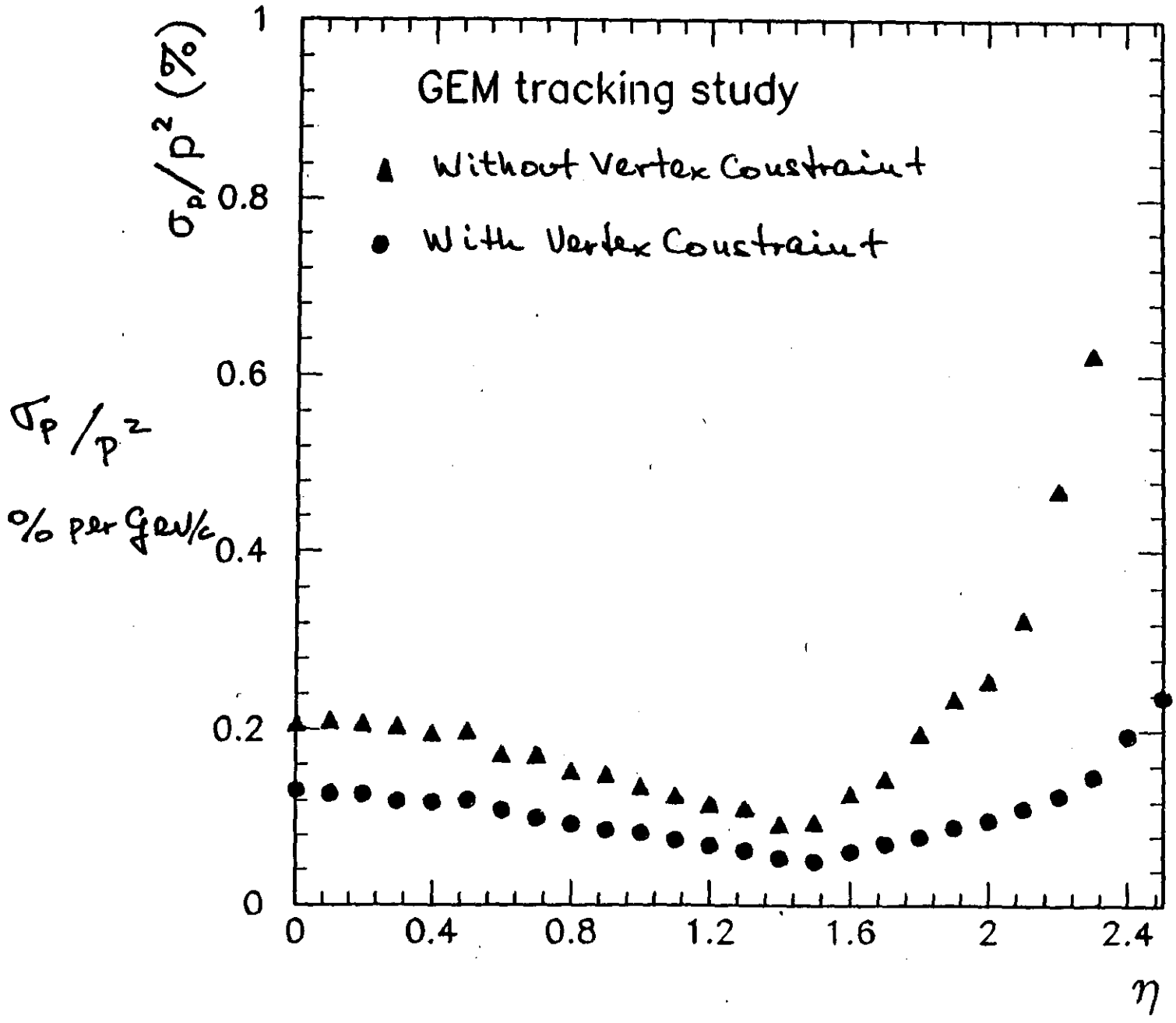
GEANT Simulation includes:

- Loopers in B = .8T
- Secondary ints.
- γ conversions
- Delta's



Resolution at high P (neglect mult. scatt)

Sumit Sen, Yale



GEANT Simulation, Including Multiple Scattering

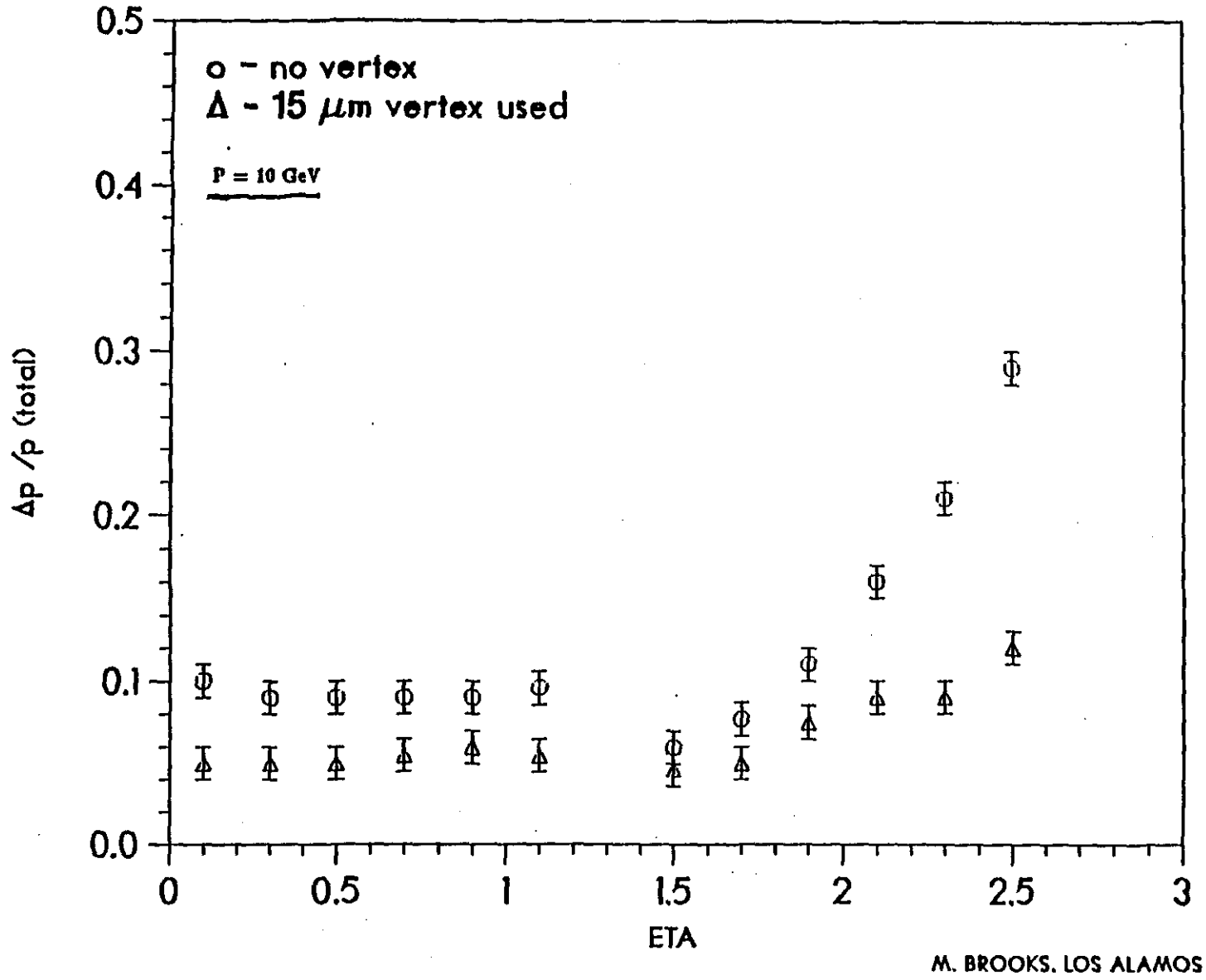


Figure 2.3a

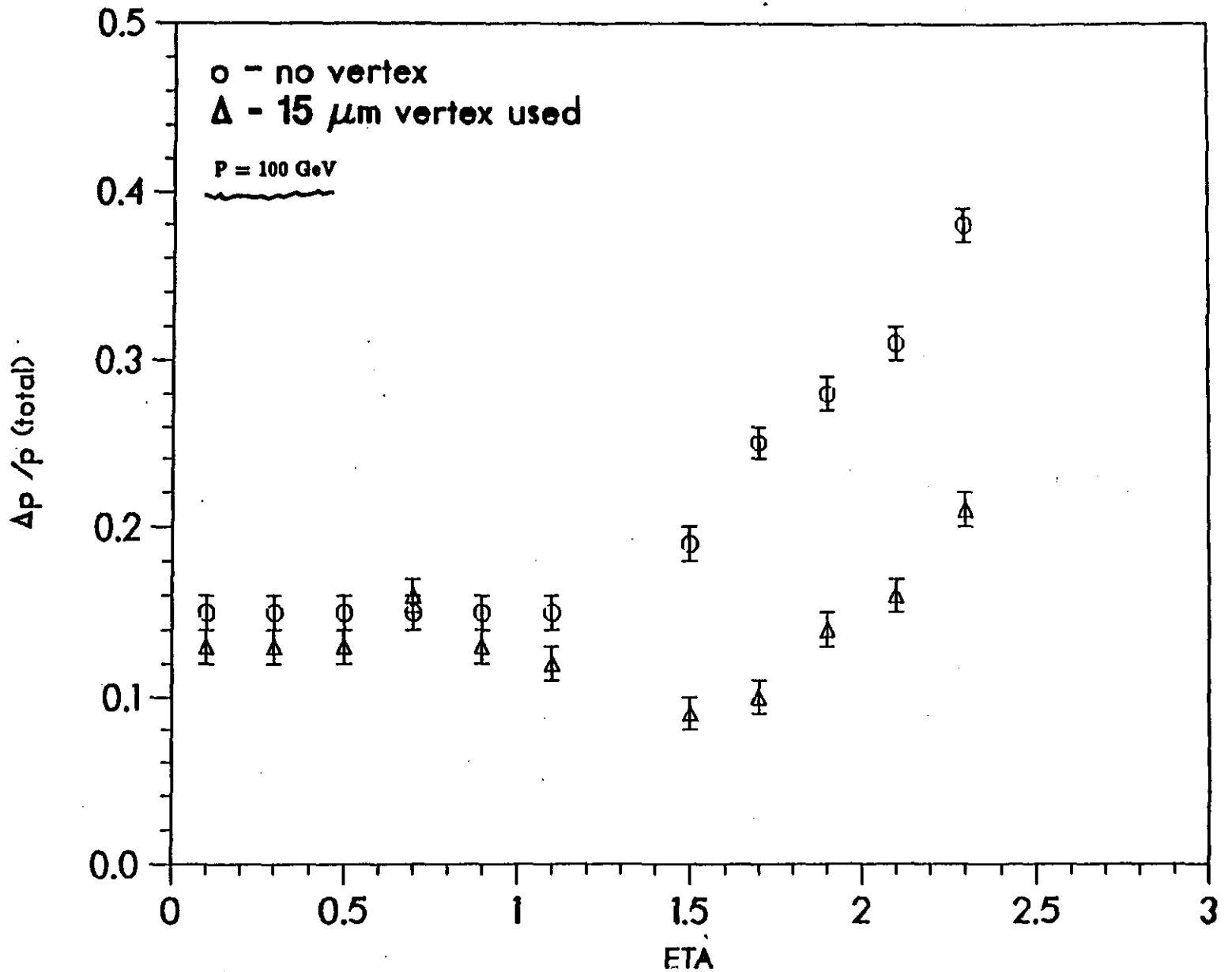
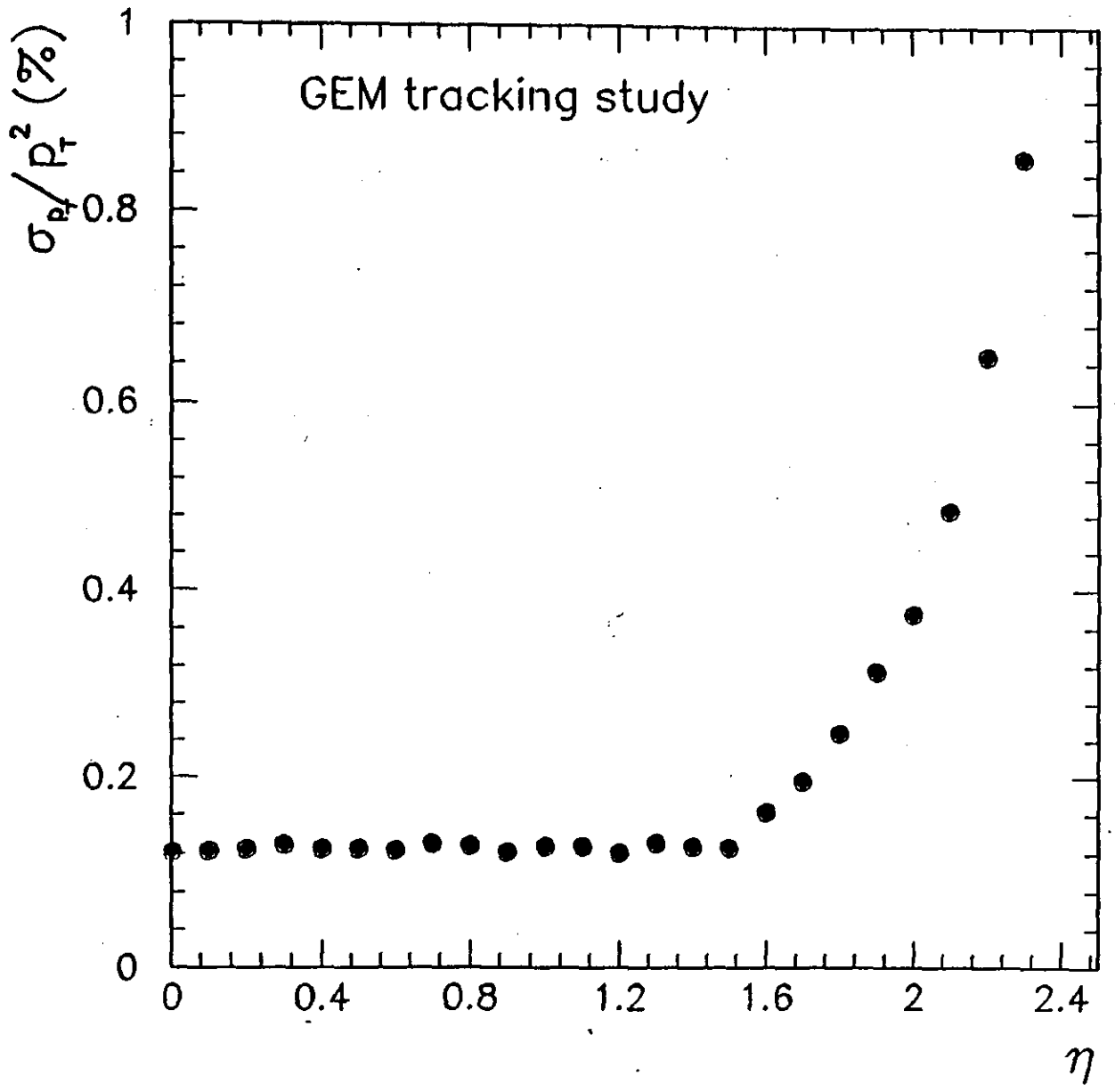

o - no vertex
Δ - 15 μm vertex used
P = 100 GeV
Δp /p (total)
0.0
0.1
0.2
0.3
0.4
0.5
0
0.5
1
1.5
2
2.5
3
ETA
M. BROOKS, LOS ALAMOS

Figure 2.3b

SUMIT SEN
YALE UNIV.

Resolution at high P_t, neglecting mult. scatt.

Vertex constraint

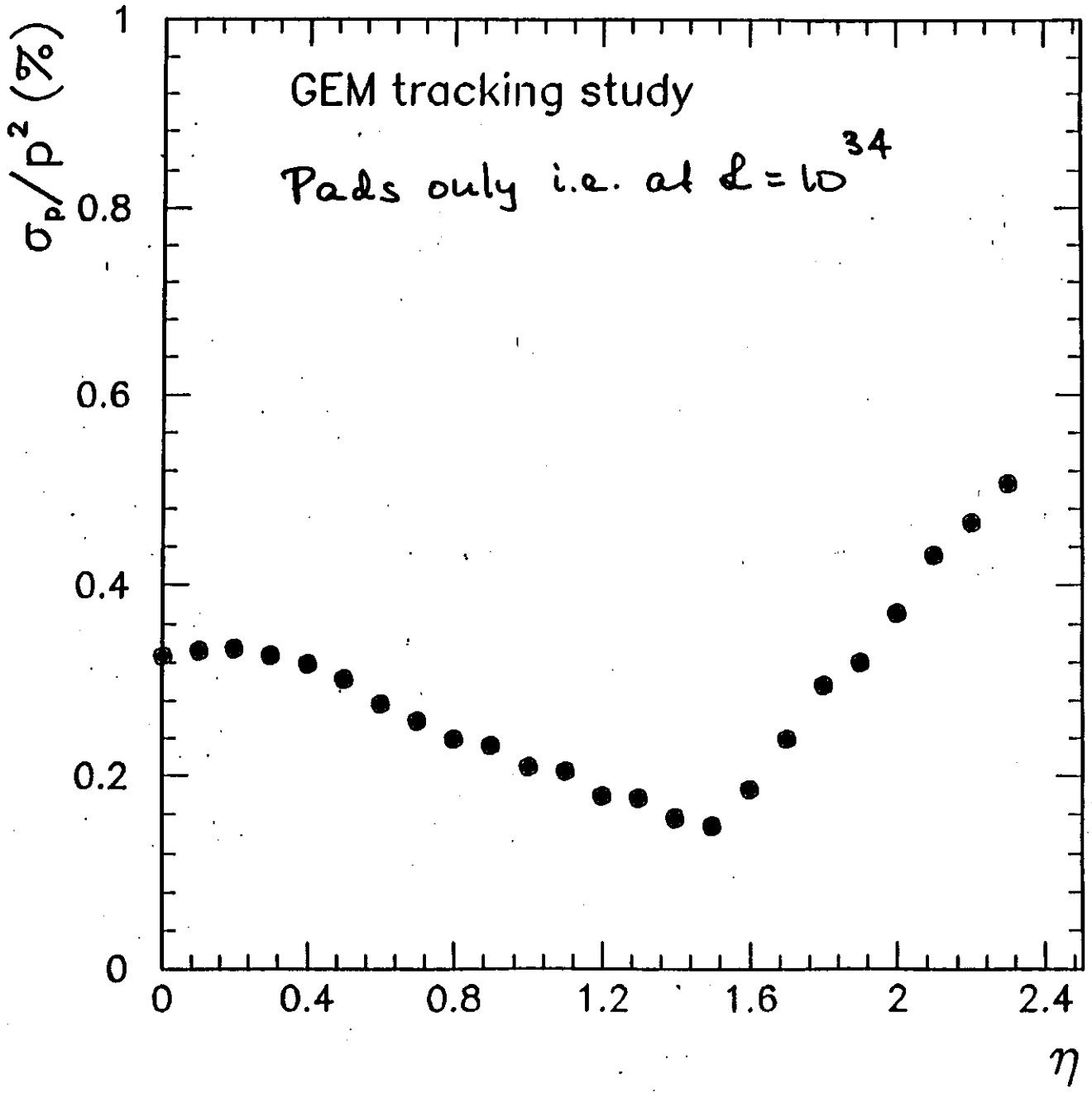


σ_{P_t}/P_t

% per GeV/c

Sumit Sen
Yale Univ.

pads + vertex
without Silicon



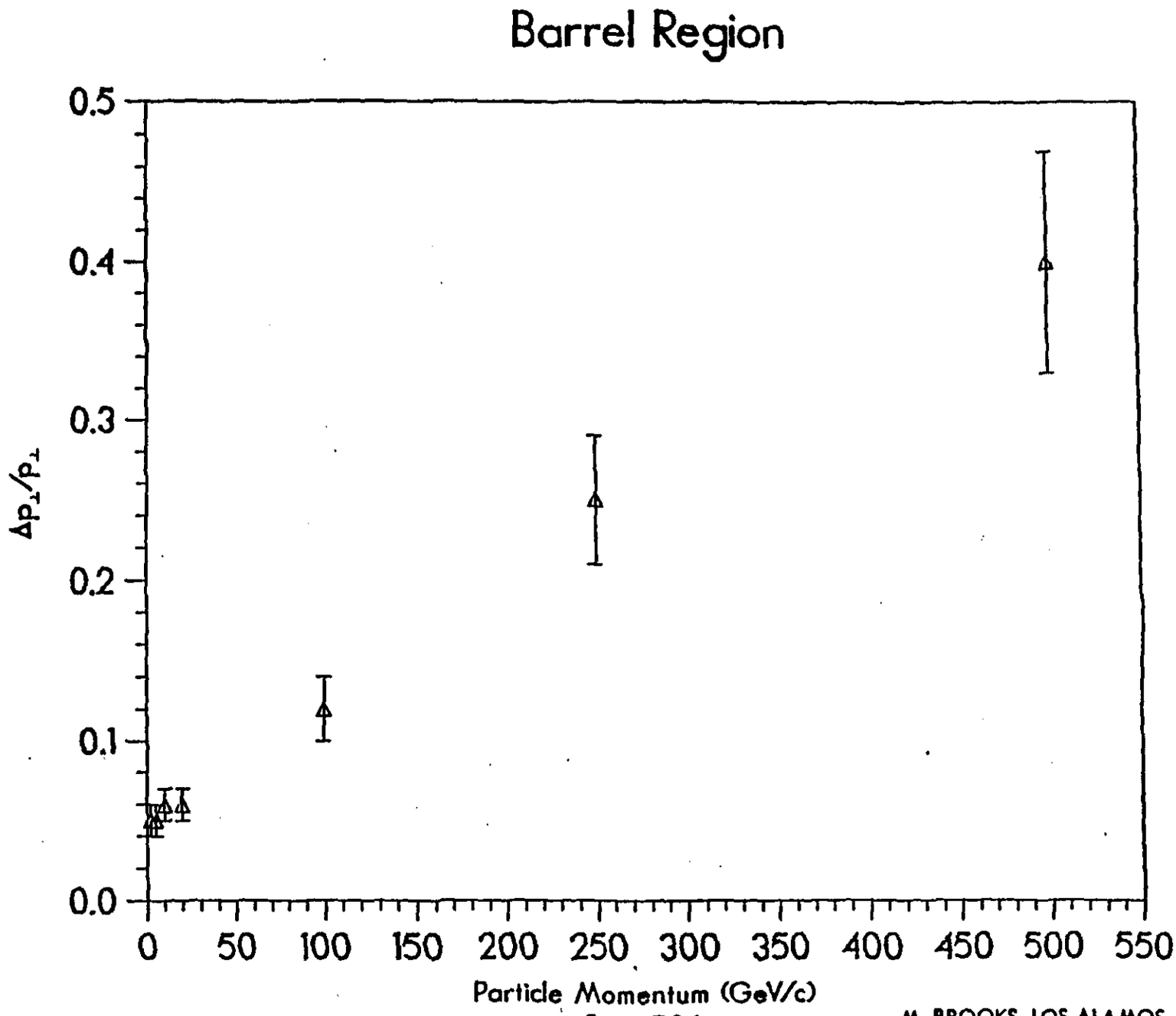


Figure 7.3.4

M. BROOKS, LOS ALAMOS

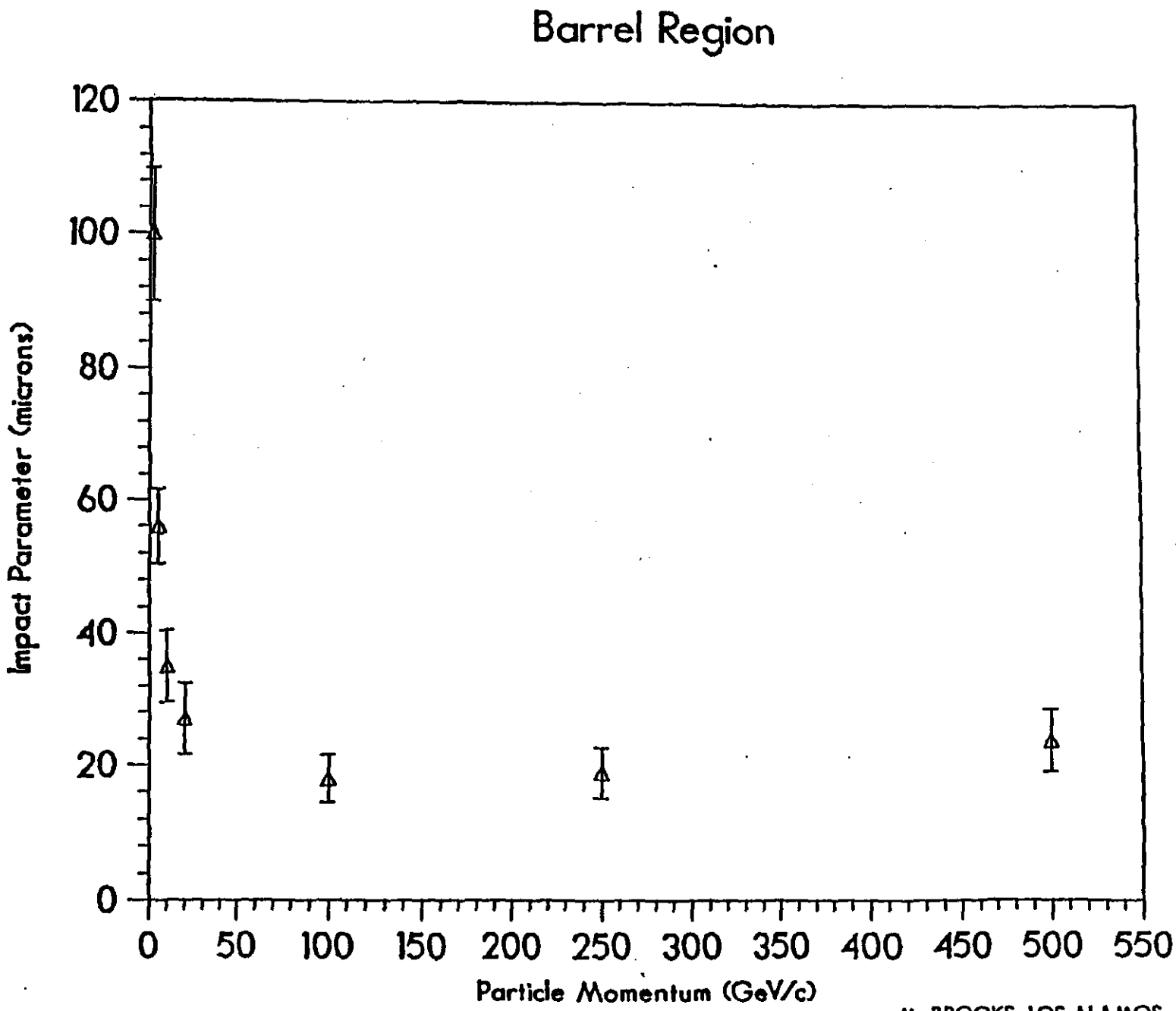


Figure 7.3.3

M. BROOKS, LOS ALAMOS

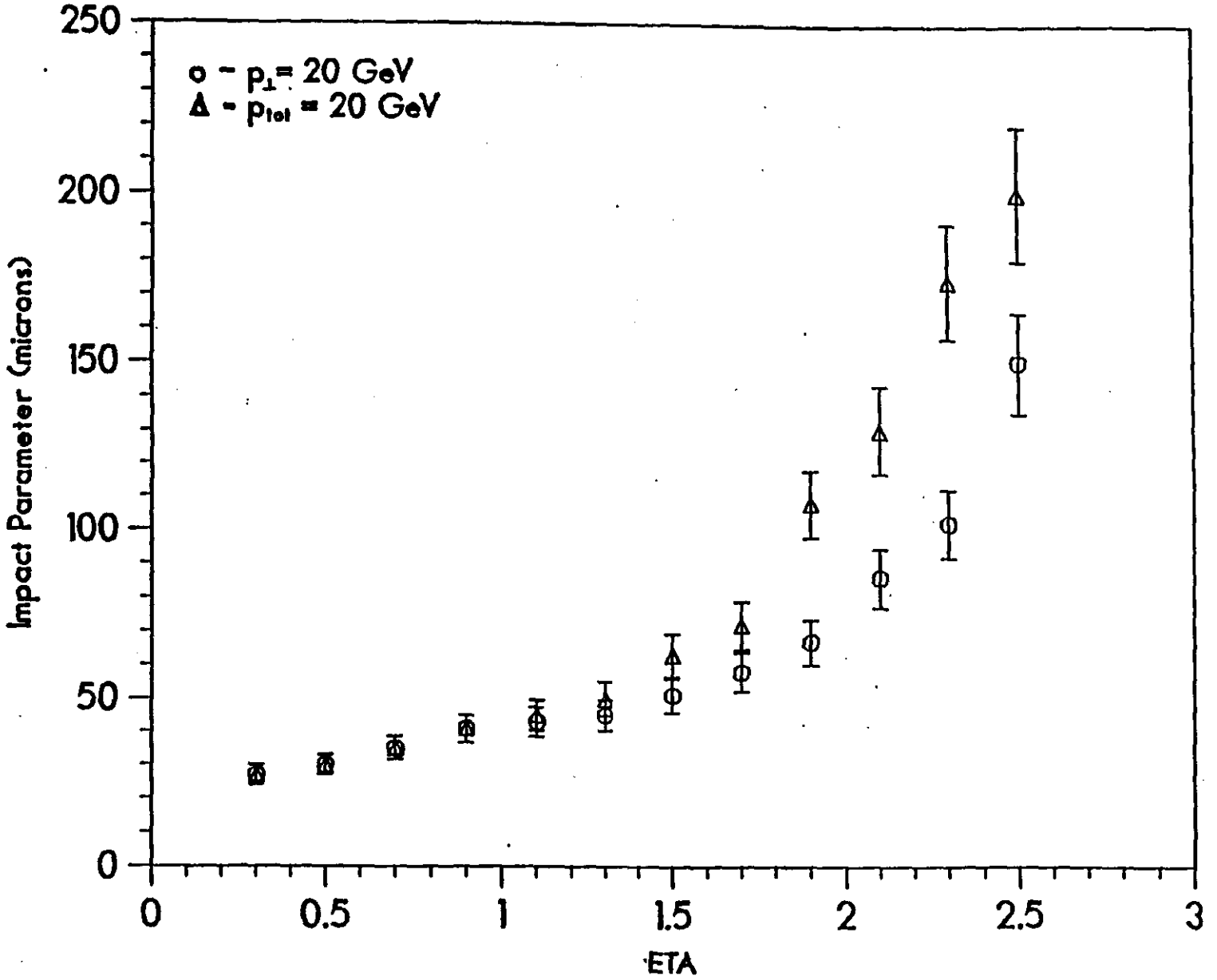
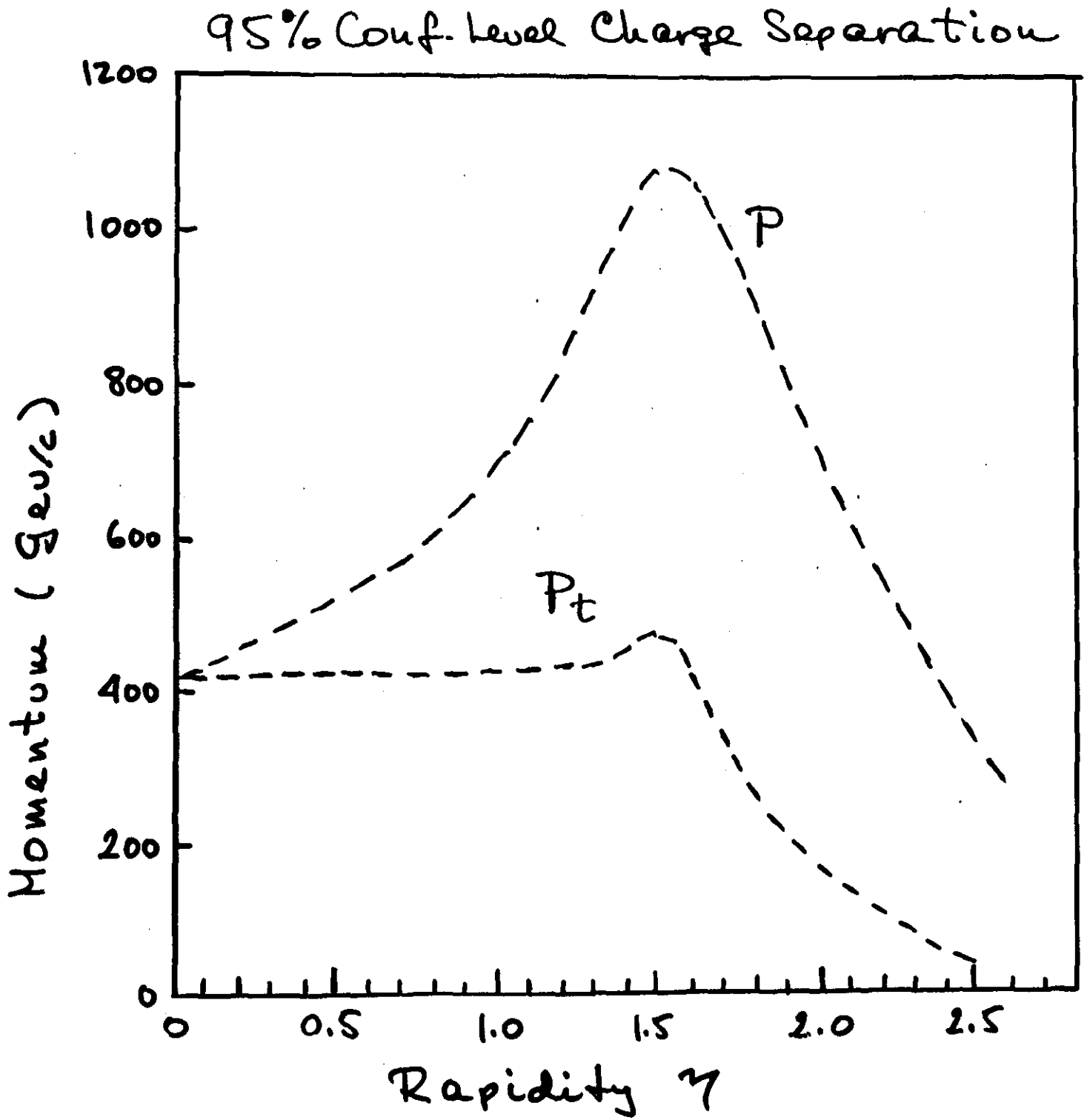
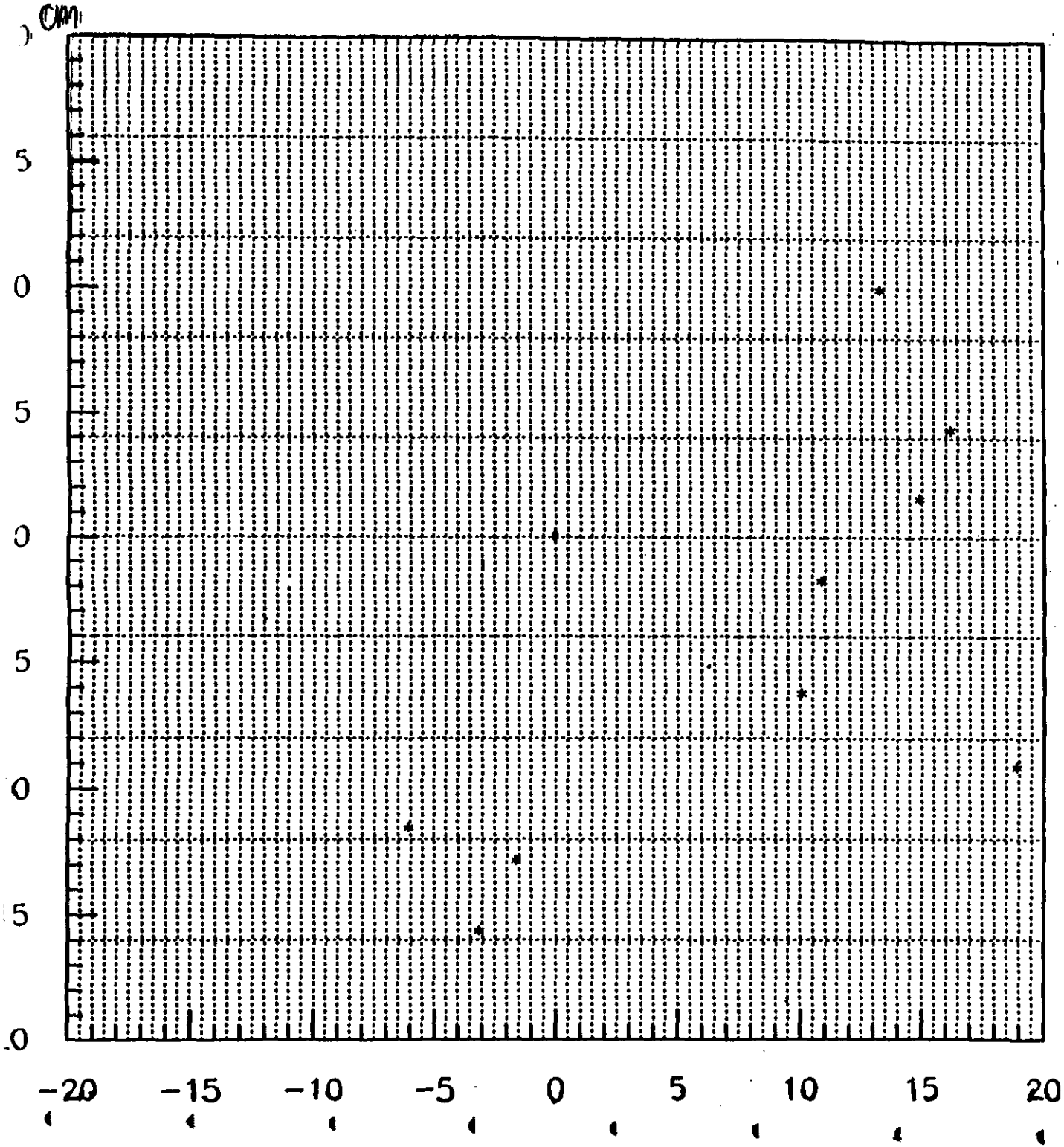


Figure 7.3.7

M. BROOKS, LOS ALAMOS


95% Conf. Level Charge Separation
1200
1000
800
600
400
200
0
Momentum (GeV/c)
P
Pt
0
0.5
1.0
1.5
2.0
2.5
Rapidity η

Dan Dong, Yale Univ.



xybt38.dat

B quark jet

$p^\mu = (28, 24.5, 5.9, 3.1)$

$\begin{cases} \theta = 83^\circ \\ \varphi = 13.5^\circ \end{cases}$

$(x, y) = (11.8, 6.2)$

center (0,0) is B-image.

9 points out of 28.

$r = 50$ cm

$L =$

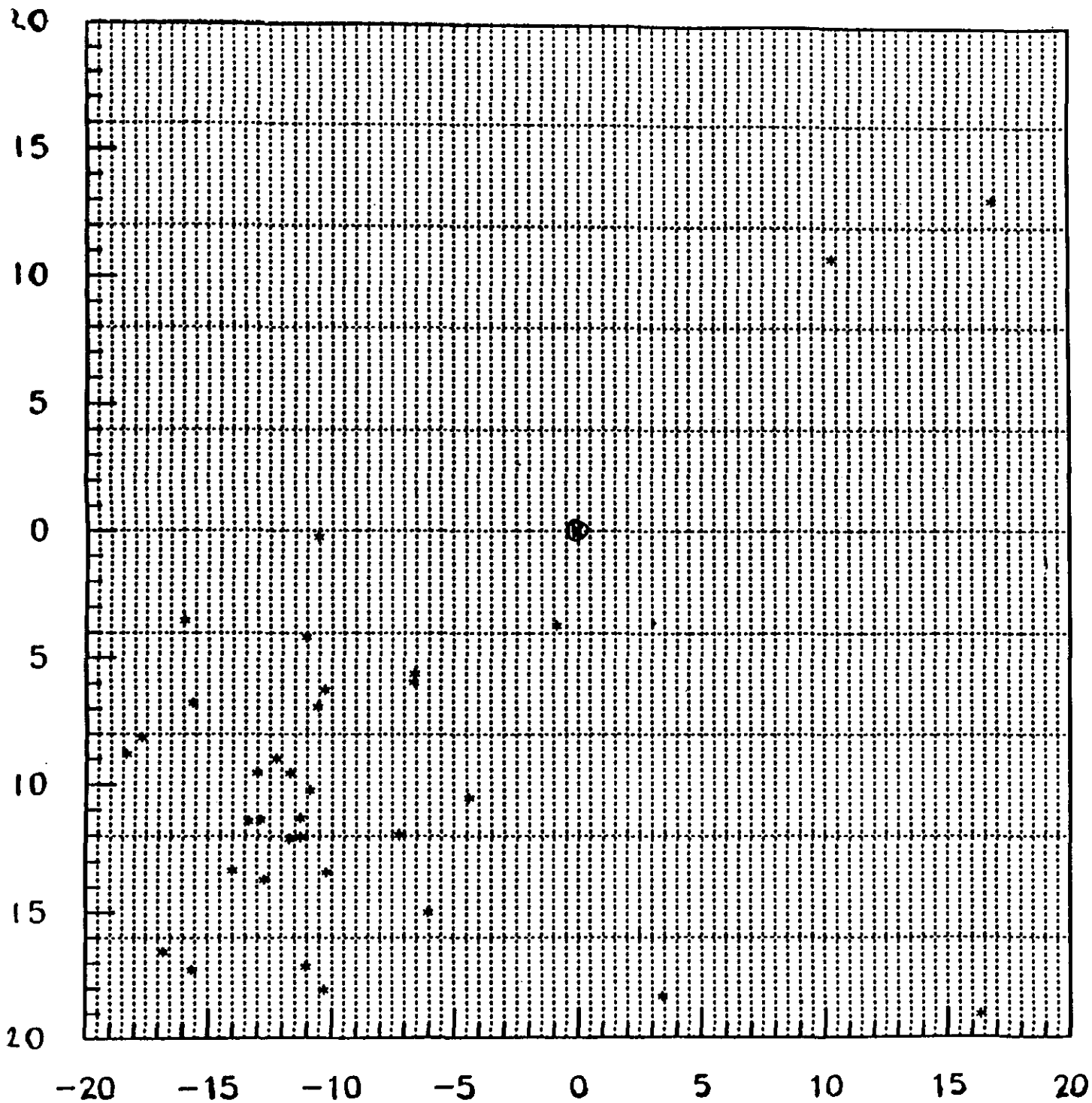
28 gev b jet

ISAJET

$p + p \to b + \bar{b} + \ldots$

11/12/91

Dr. Doug, Ed.



xytop28.dat

top quark jet

$p^\mu = (240, -24, 183, -62)$

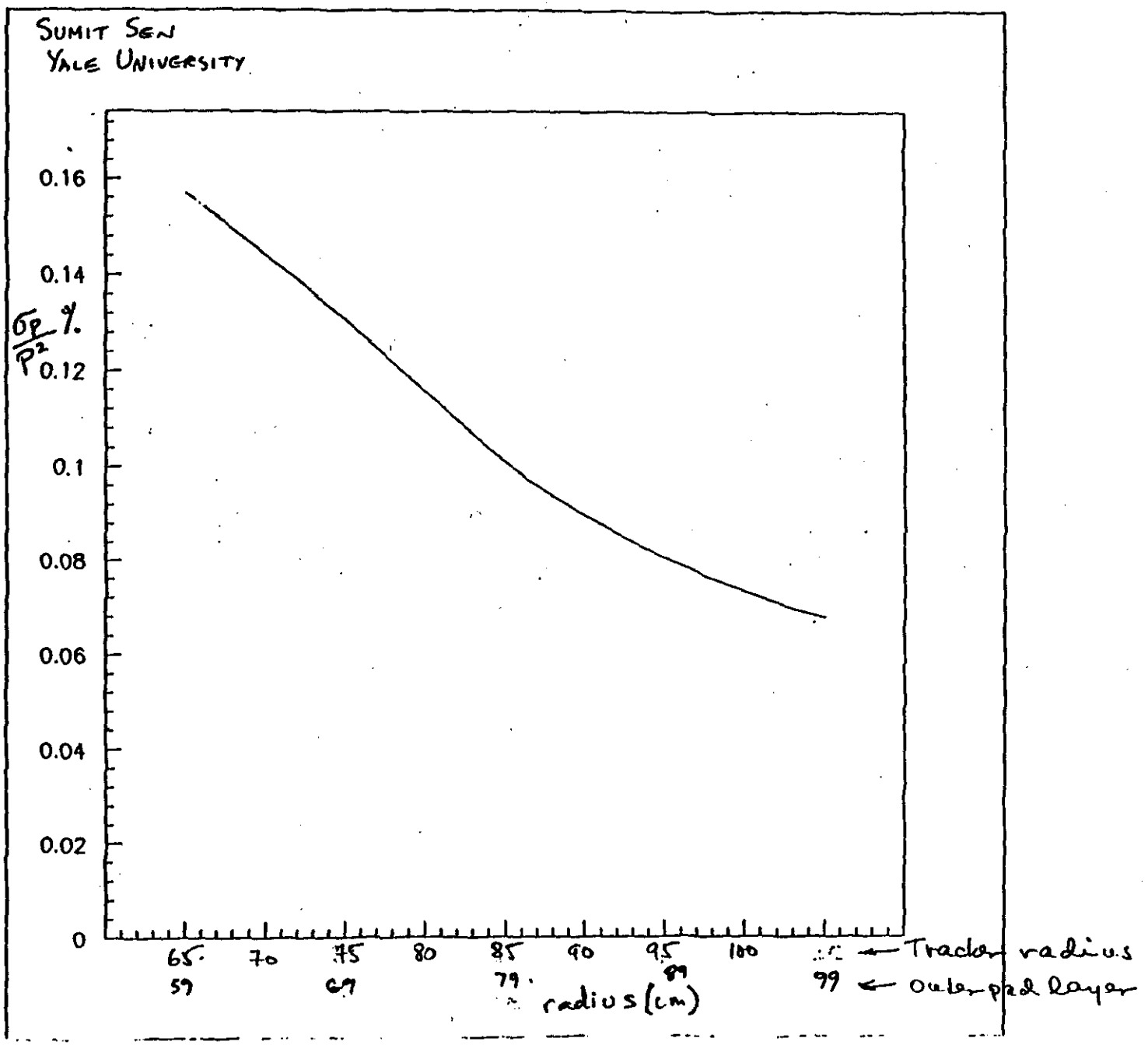
$\theta =$

$\varphi =$

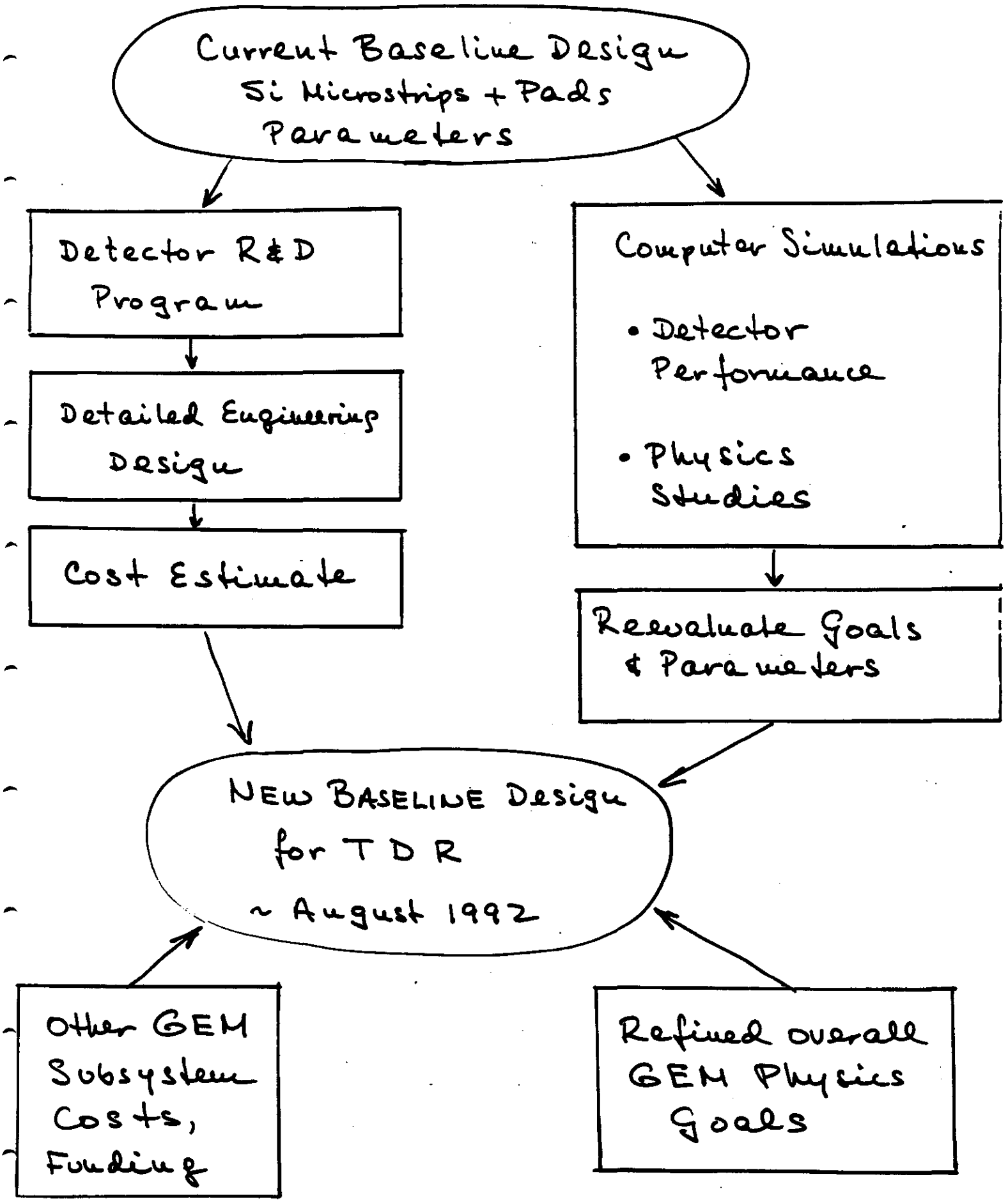
$\begin{cases} x = 240 \\ y = 35 \end{cases}$

34 out of 58.

240 gev t jet


SUMIT SEN
YALE UNIVERSITY
0.16
0.14
$\frac{\sigma_p}{p^2}$ %
0.12
0.1
0.08
0.06
0.04
0.02
0
65
70
75
80
85
90
95
100
59
69
79
89
99
radius (cm)
← Tracker radius
← outer pad layer

PLANNING FOR THE TECHNICAL DESIGN REPORT



Physics Processes	Id. Primary Vertex	e/γ Separation	e, μ, γ Isolation Cuts	e/h Separation	Muon Momentum Check	e± Sign Separation	Secondary Vertex	Low Momentum Track	Full Event Reconstr.
$H^0 \to \gamma + \gamma$	X	X	X						
$H^0 \to e^+e^-l^+l^-, e^+e^-\nu\bar{\nu}, e^+e^-$ *jetjet*	X	X	X	X		X			
$H^0 \to \mu^+\mu^-l^+l^-, \mu^+\mu^-\nu\bar{\nu}, \mu^+\mu^-$ *jetjet*	X		X		X				
Gluino Pair Prod $\tilde{g}\tilde{g} \to e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
Techni eta $\eta_T \to b + \bar{b}$ or $t + \bar{t}$	X		X				X		
WW Scattering $W^\pm W^\pm \to e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
$Z^1 \to e^+e^-$ Asymmetry	X	X	X	X		X			
B Physics, e.g. $B \to \Psi$, etc.	X						X	X	X
Top Physics $t \to W + b$, etc.	X		X				X	X	X

CENTRAL TRACKER PHYSICS STUDIES

Table 2.3

Central Tracker – Fall Back Options

★ We have made working decisions about the technologies to use in Central Tracking
- Silicon Microstrips
- Interpolating Pad Chambers

★ We are supporting no other technologies with our MEAGER R&D Funds at this time.

★ What if we hit some show stoppers?

1. Silicon Microstrips
   - Costs escalate out of reach
   - Radiation length of cooling, supports etc. too large

   → Reduce size of system

   Si Pixels or Long Drift not likely to be better, but we will keep open mind

2. Pad chambers
   - Radiation length of Tracker
   - Cost of Electronics Prohibitive
   - Can not find satisfactory working parameters

   → Reduce system to a few outer layers

   R&D on Straws & Fibers are pursued by other Expts. Keep an eye on this just in case

A HARDER SET OF QUESTIONS

What if Physics Simulation Studies indicate that improved tracker performance is important ?

1. Improving Momentum Resolution, Charge Separation

a) Increase B - 0.8T to 1.2T
Increase Radius - 75 cm to 100 cm

Improvement - 2.7
ΔCost (Tracker) - Small
ΔCost (Magnet, Cal, μ's) - large

b) Go to an all Silicon Tracker

Improvement - 2
ΔCost - 50 to 100 M$?

c) Replace Outermost Pad Superlayer by a single layer of Silicon

Improvement ~ 1½
ΔCost ~ 20 to 30 M$

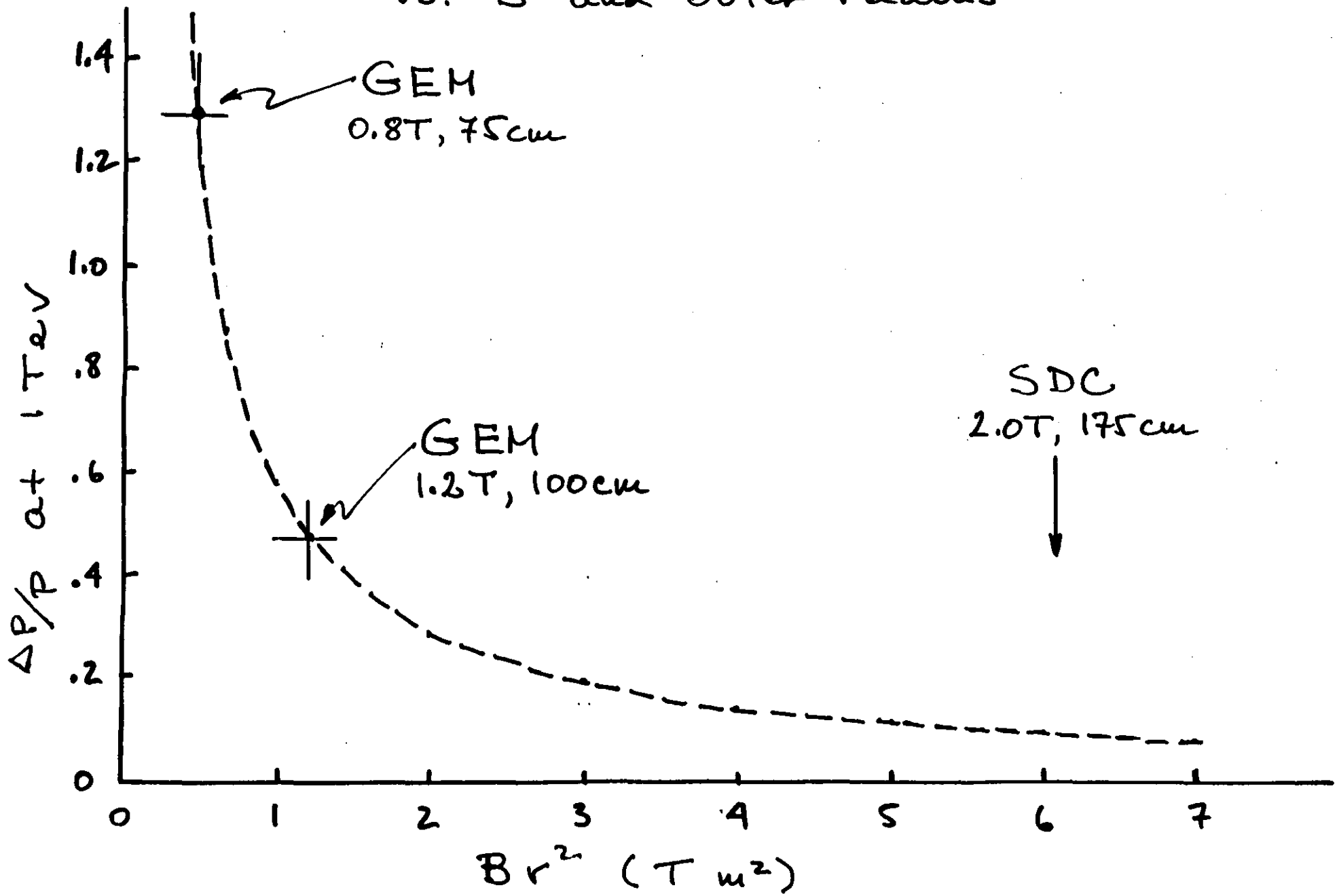
d) Add more Pad Layers

8 layers → 12 layers

Improvement - 20%
ΔCost - 5 to 10 M$

CENTRAL TRACKER MOMENTUM RESOLUTION

vs. B and outer radius



2. Improve Vertex Z Resolution

We are now planning to instrument one layer of wires / superlayer

Could instrument both layers

Improvement – $\sqrt{2}$

Δ Cost ~ 1 M\$

3. Decrease Occupancy, Improve two track resolution in jets

Decrease Pad Sizes by factor of 2

Improvement in occupancy ~ 2

Δ Cost of electronics ~ 10 M\$

4. Improve Pattern Recognition

Add More Layers

Silicon	6 → 10
Pads	8 → 12

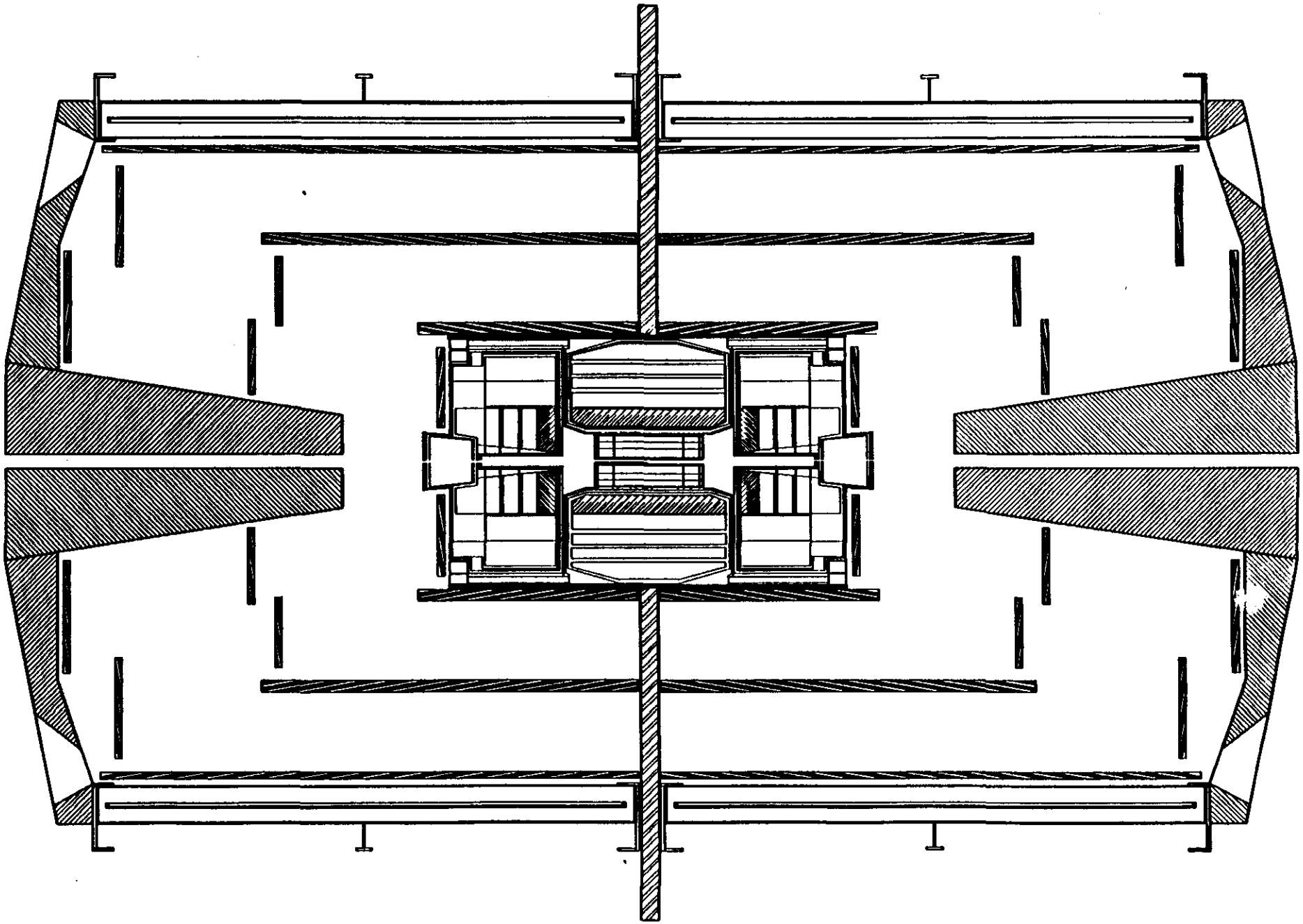
Δ Cost ~ 20 M\$

Magnet

R. Stroynowski

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

GEM



MAGNET

CHANGES SINCE LOI

- MOTIVATED BY PHYSICS REQUIREMENTS

- MUON RESOLUTION IN THE BARREL ~5% @ 90° FOR P_T = 500 GEV/C

OPTIONS - INCREASE FIELD (LARGER COST, MUCH HIGHER RISK)

- INCREASE RADIUS

SOLUTION:

INCREASE INNER RADIUS OF THE MAGNET FROM 8.4m TO 9.0 m

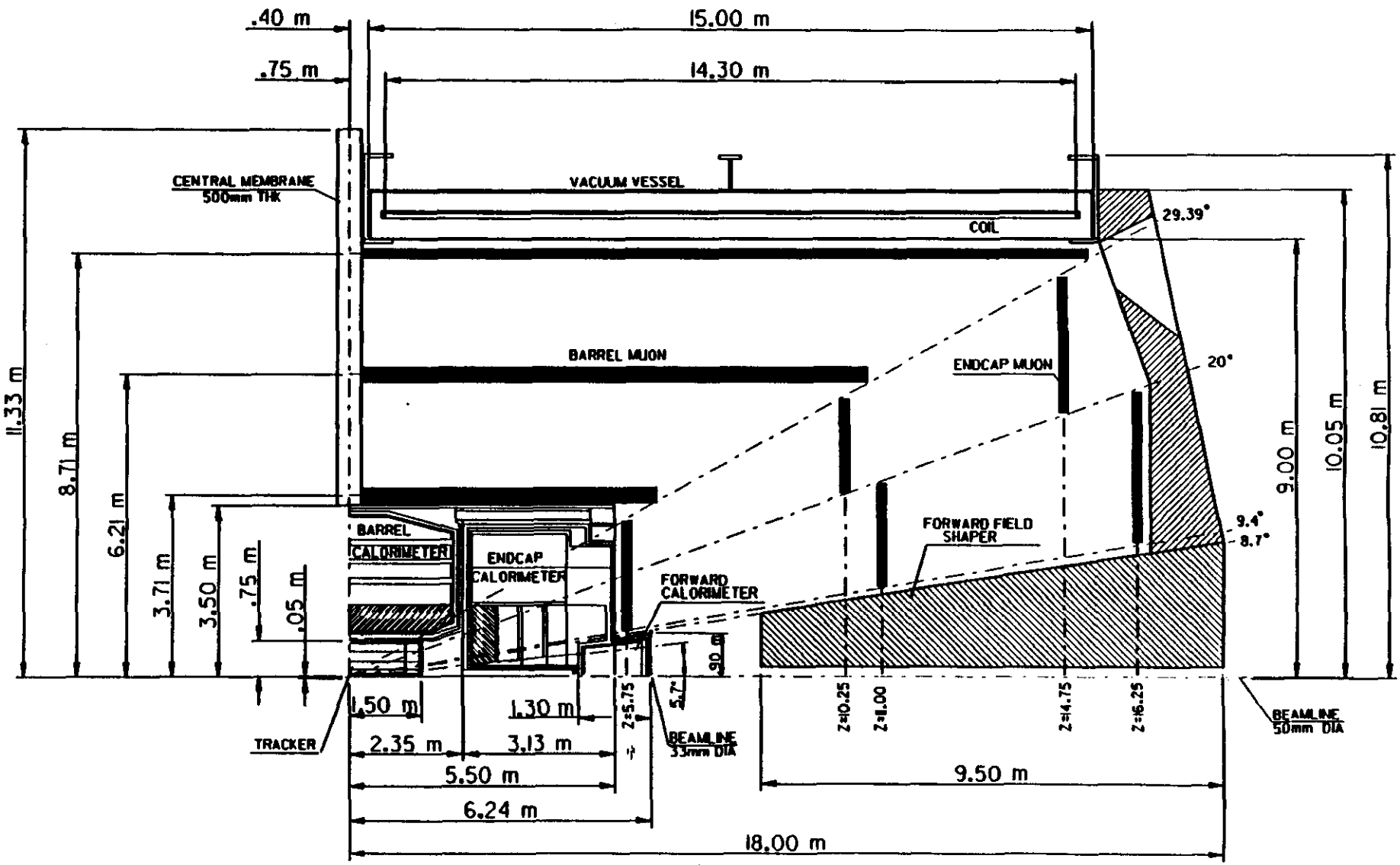
CONSEQUENCES:

RADIUS OF THE WINDINGS	8.9m → 9.5m
OUTER RADIUS	9.45m → 10.8m
STORED ENERGY	2.04 GJ → 2.5 GJ
CONDUCTOR LENGTH	24 km → 27.2 km
OPERATING CURRENT	52.5 kA → 50.2 kA

- THESE CHANGES PROPAGATE TO EVERY ASPECT OF THE MAGNET DESIGN INCLUDING DIMENSIONS OF THE CONDUCTOR, CRYOSTAT, VACUUM VESSELS, SUPPORTS etc., FORCES ON THE CONDUCTOR AND CRYOSTAT, FRINGE FIELD etc

e.g. PEAK FRINGE FIELD AT EARTH SURFACE INCRESES FROM 40 TO 47 GAUSS.

GEM DETECTOR ELEVATION



Z. CHEN
(CEM920226)

- MUON RESOLUTION IF FORWARD DIRECTION

$\sim 10\%$ AT $\eta = 2.5$ FOR $p_T = 500$ GeV/c

OPTIONS
- WARM COIL (~ 20 MW)
- SUPERCONDUCTING COIL (NEED ~ 5 T)

SOLUTION:

REPLACE MAGNET POLES WITH FLUX CONCENTRATORS ALONG BEAM DIRECTIONS

$Z_{MIN} = \cancel{8.5\,m} - 10\,m$

$Z_{MAX} = 18.0\,m$

INNER RADIUS = 20 cm

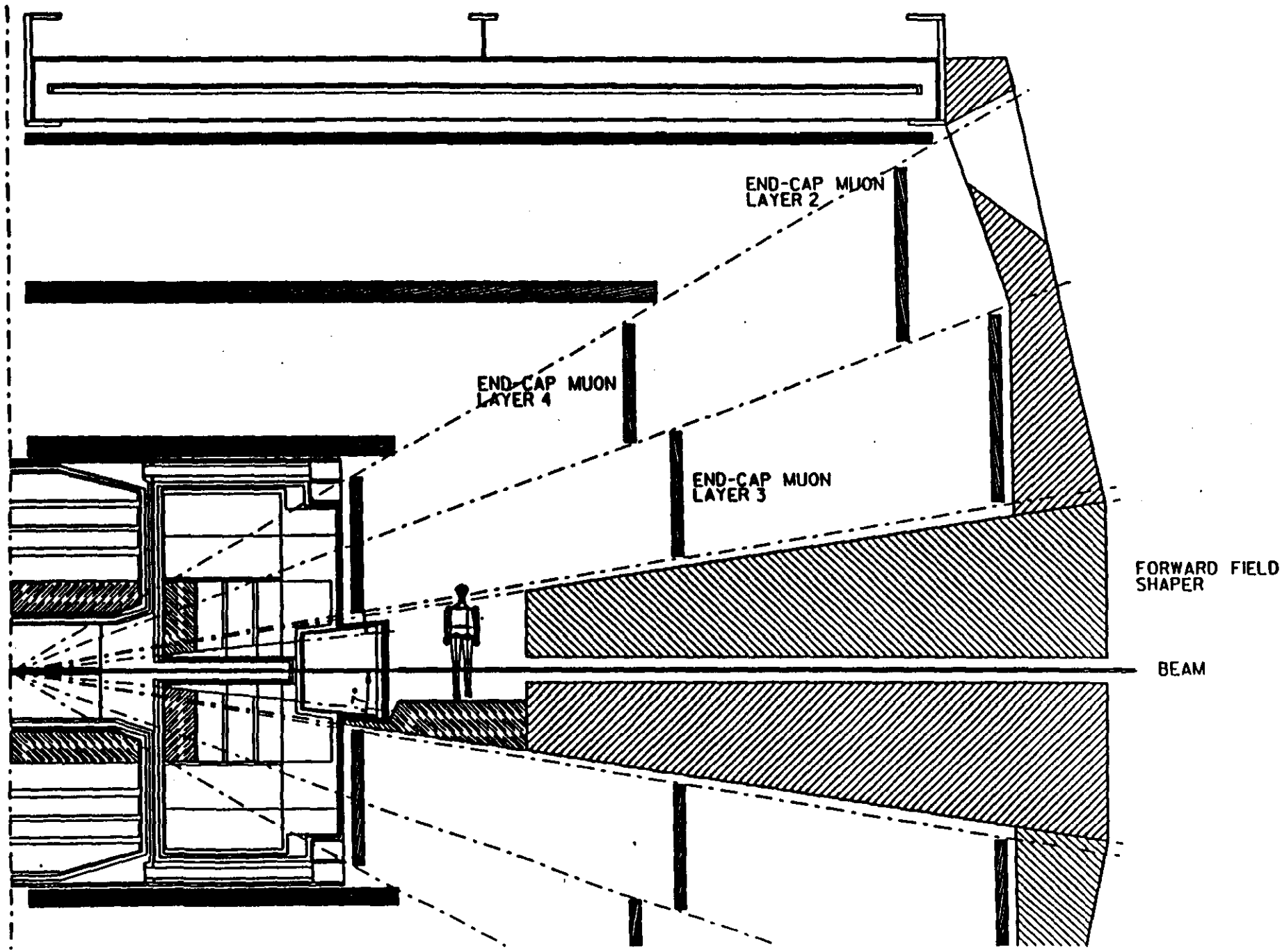
OUTER EDGE = 8.7°

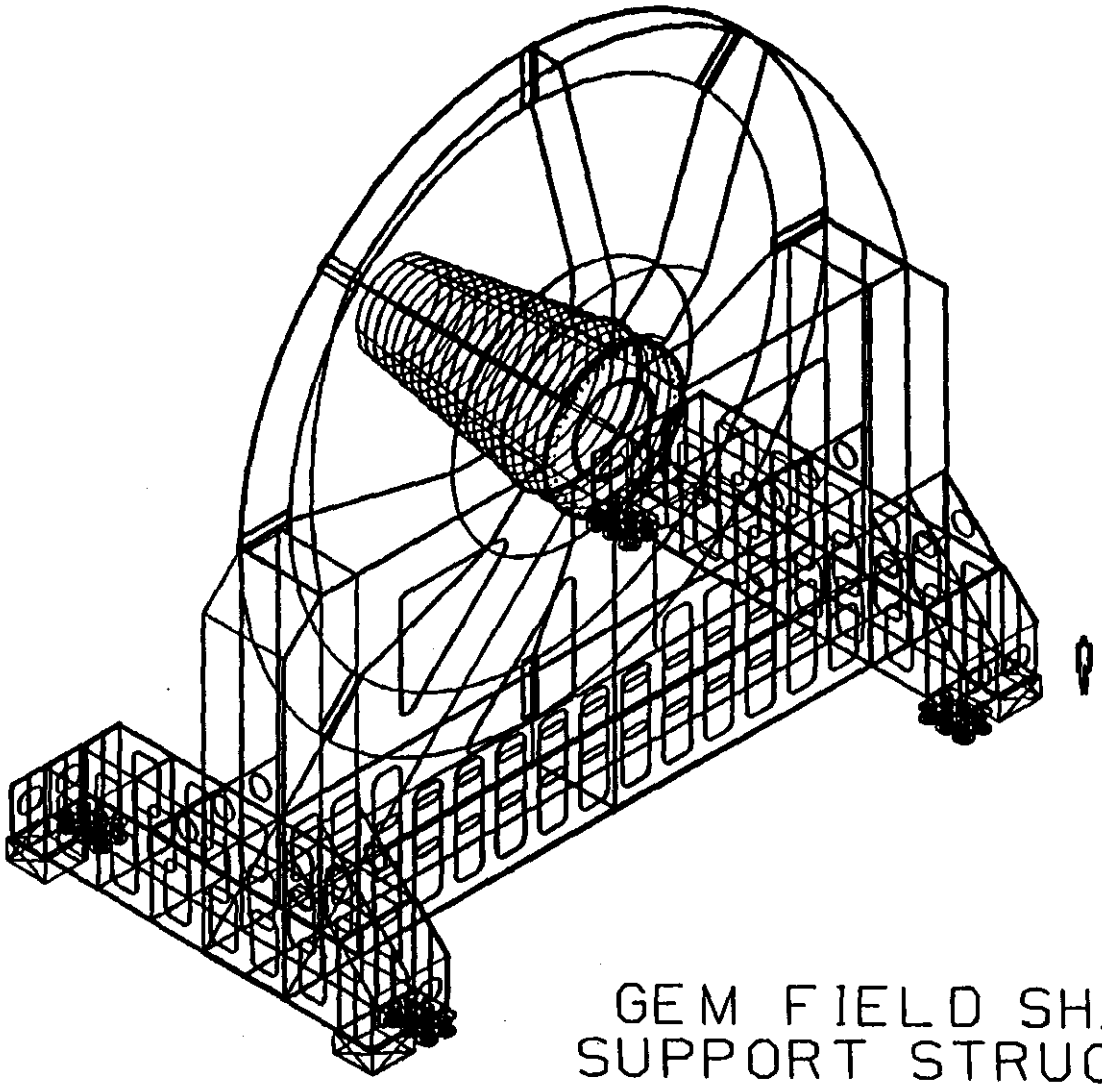
MASS (EACH) ~ 990 t

SUPPORT MASS (EACH) ~ 370 t

- FLUX CONCENTRATOR WILL NEED SUBSTANTIAL SUPPORT STRUCTURE INDEPENDENT OF THE MAGNET
- THE COMPRESSIVE FORCE WILL BE TRANSMITTED TO THE CRYOSTAT
- MAGNETIC FIELD BECOMES HIGHLY NON-UNIFORM NOT ONLY IN THE REGION OF MUON CHAMBERS BUT ALSO IN THE CALORIMETERS

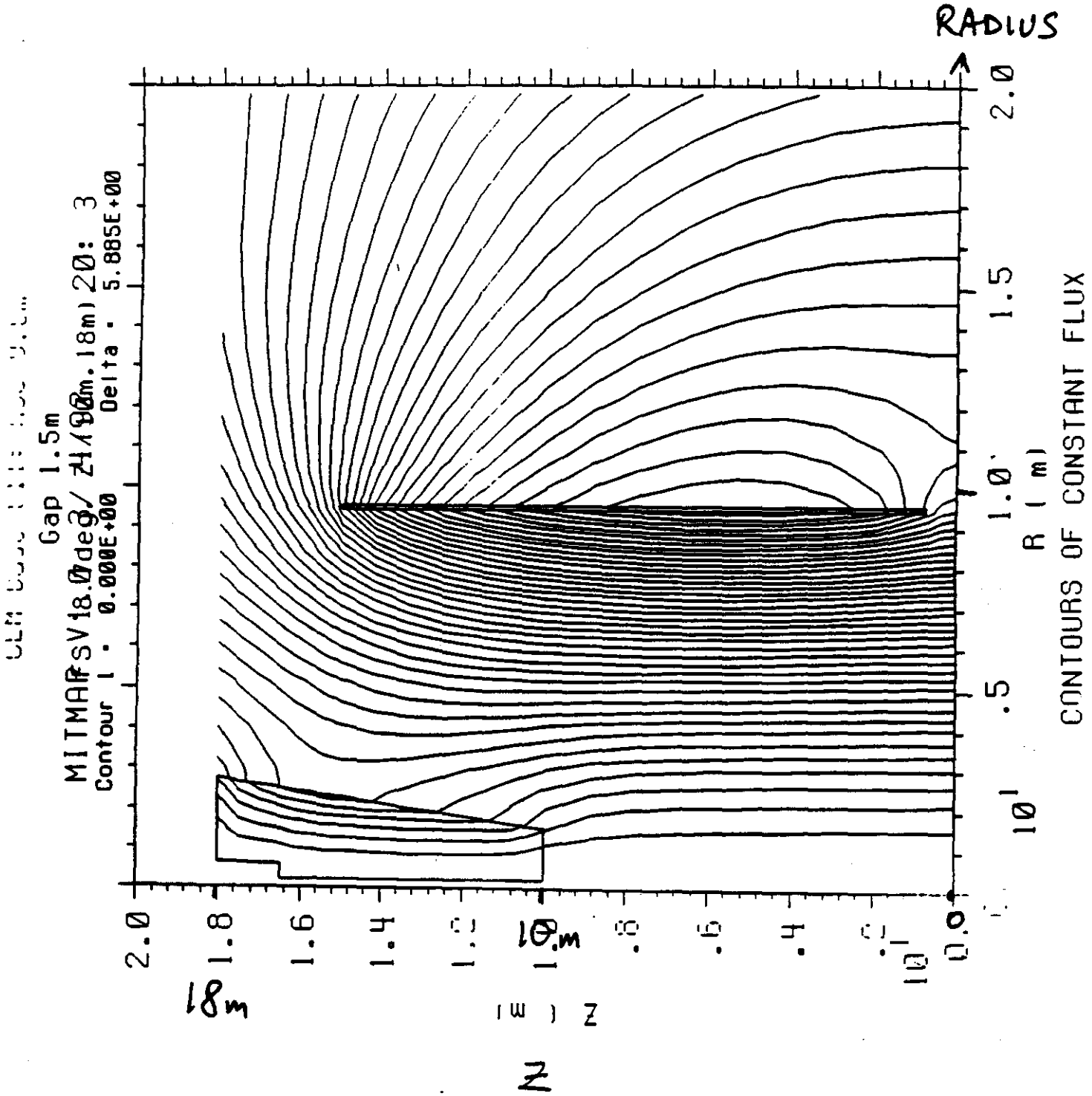
EMERGENCY ENTRANCE ELEVATION



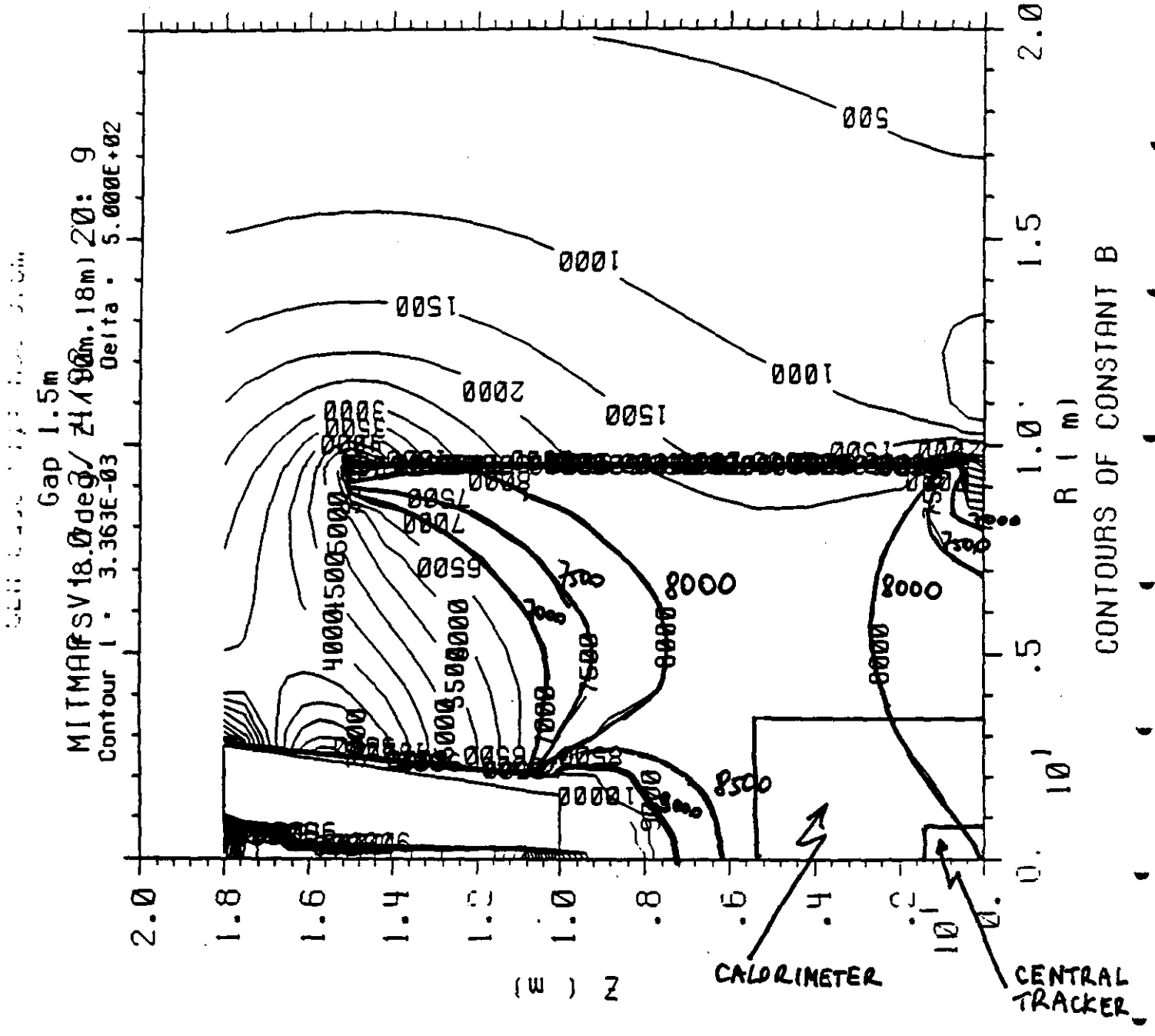


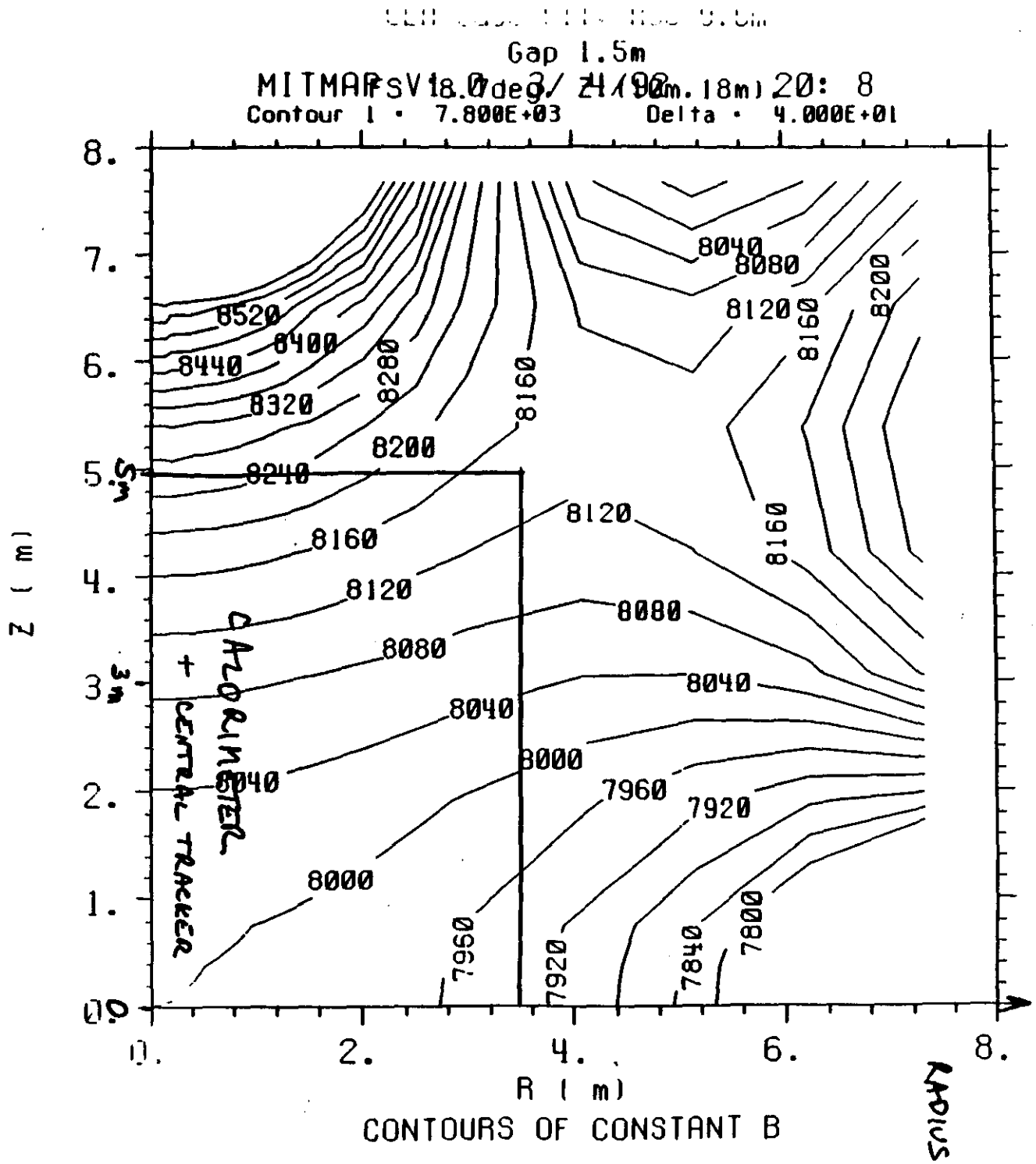
GEM FIELD SHAPER
SUPPORT STRUCTURE
ISO VIEW

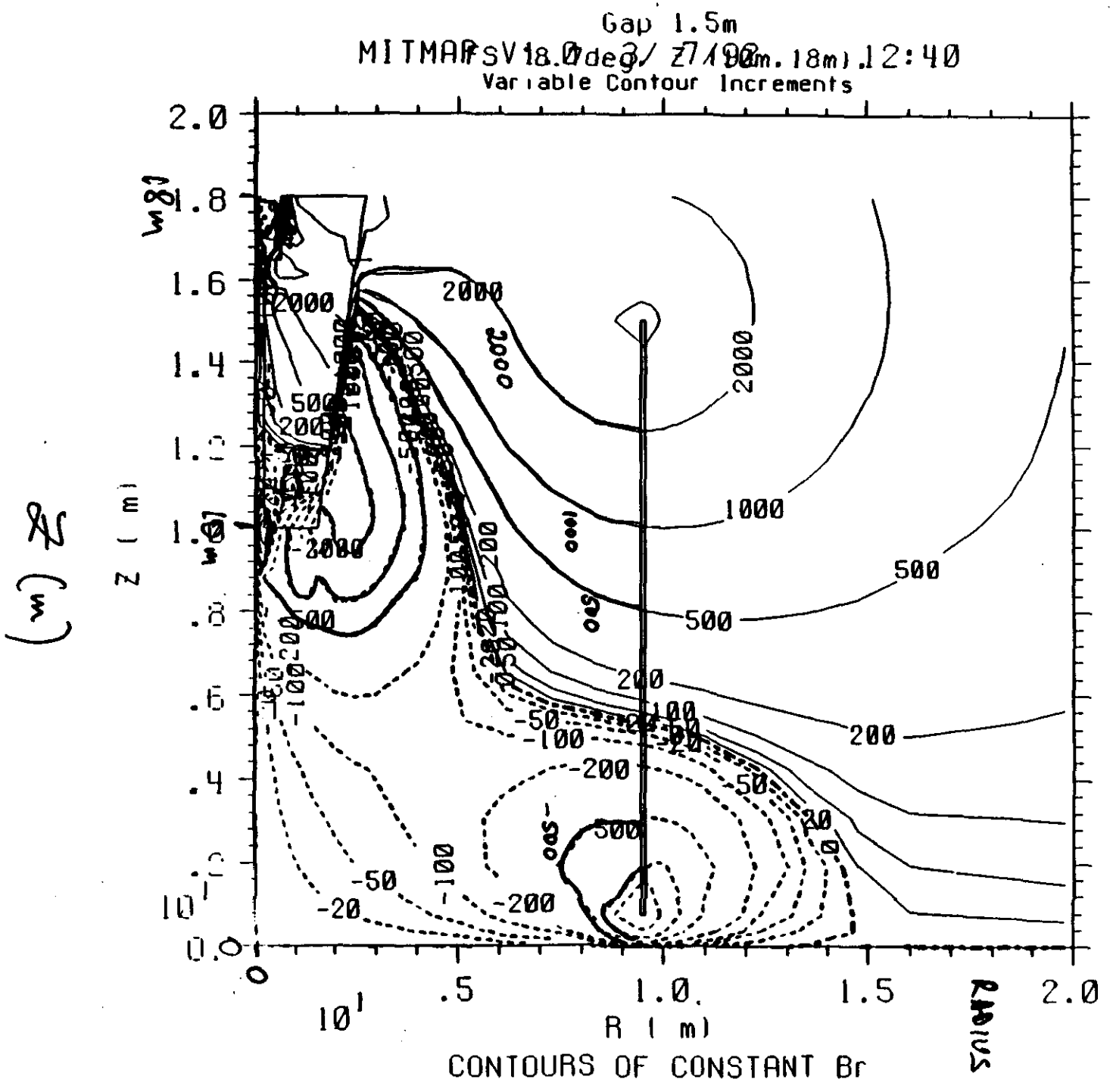
CONTOURS OF CONSTANT FLUX



CONTOURS OF CONSTANT FIELD




Gap 1.5m
MITMAPSV18.0deg/ 24/90m.18m) 20: 8
Contour 1 • 7.800E+03 Delta • 4.000E+01
8520
8400
8440
8320
8280
8240
8200
8160
8120
8080
8040
8000
7960
7920
7840
7800
Z (m)
R (m)
CONTOURS OF CONSTANT B
CHLORINATOR + CENTRAL TRACKER
CONTOURS OF CONSTANT FIELD
RADIUS



CONTOURS OF CONSTANT RADIAL FIELD

Z (m)

CHANGES MOTIVATED BY SYSTEM INTEGRATION

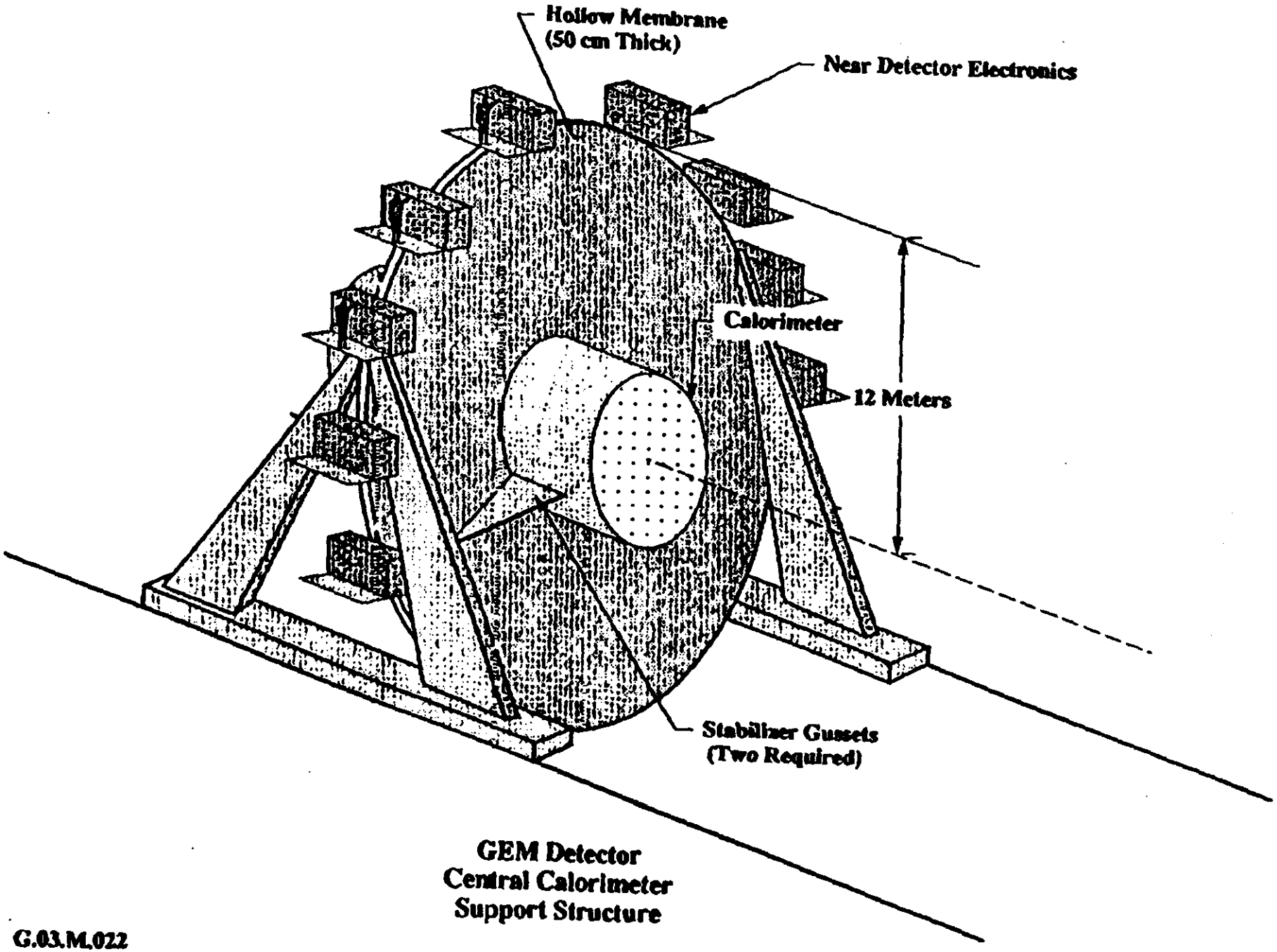
- FREE-STANDING CENTRAL MEMBRANE
  - ALLOWES FOR INSTALLATION OF CALORIMETERS AND TRACKER INDEPENDENTLY FROM THE INSTALLATION OF MUON CHAMBERS.
  - PROVIDES FOR BETTER ACCESS TO THE DETECTOR
  - ALLOWES FOR DETAILED DESIGN OF THE CENTRAL PART OF THE MEMBRANE ON THE TIME SCALE OF THE CALORIMETRY DECISION (i.e. LATER THAN MAGNET TR)
  - WILL NEED SUBSTANTIAL, INDEPENDENT SUPPORT SYSTEM NON-INTERFERING WITH MAGNET SUPPORT
  - WILL NEED SOLUTION FOR THE TRANSMITTAL OF COMPRESSIVE FORCES BETWEEN MAGNET HALVES.
- INCREASED GAP BETWEEN COILS

  50 cm → 150 cm

  PROVIDES SPACE FOR UTILITIES AND CABLES
  PROVIDES POSSIBLE ACCESS ROUTE

  INTRODUCES NON-UNIFORMITY OF THE B-FIELD NEAR $z = 0$

  INTRODUCES SMALL ACCEPTANCE LOSS NEAR $\eta = 0$



GEM Detector
Central Calorimeter
Support Structure

G.03.M.022

Rennich/Eberle

- MOBILE MAGNET

A SOLUTION TO THE PROBLEM OF ACCESS TO THE TRACKER: TWO HALVES OF THE MAGNET CAN MOVE APART EXPOSING FREE STANDING CENTRAL MEMBRANE WITH CALORIMETER AND TRACKER.

PROPOSED CONCEPT - GREASE PADS TRANSPORTERS

STEPS : - LIFT MAGNET FROM SUPPORT CRADLE ONTO GREASE PADS JACKS

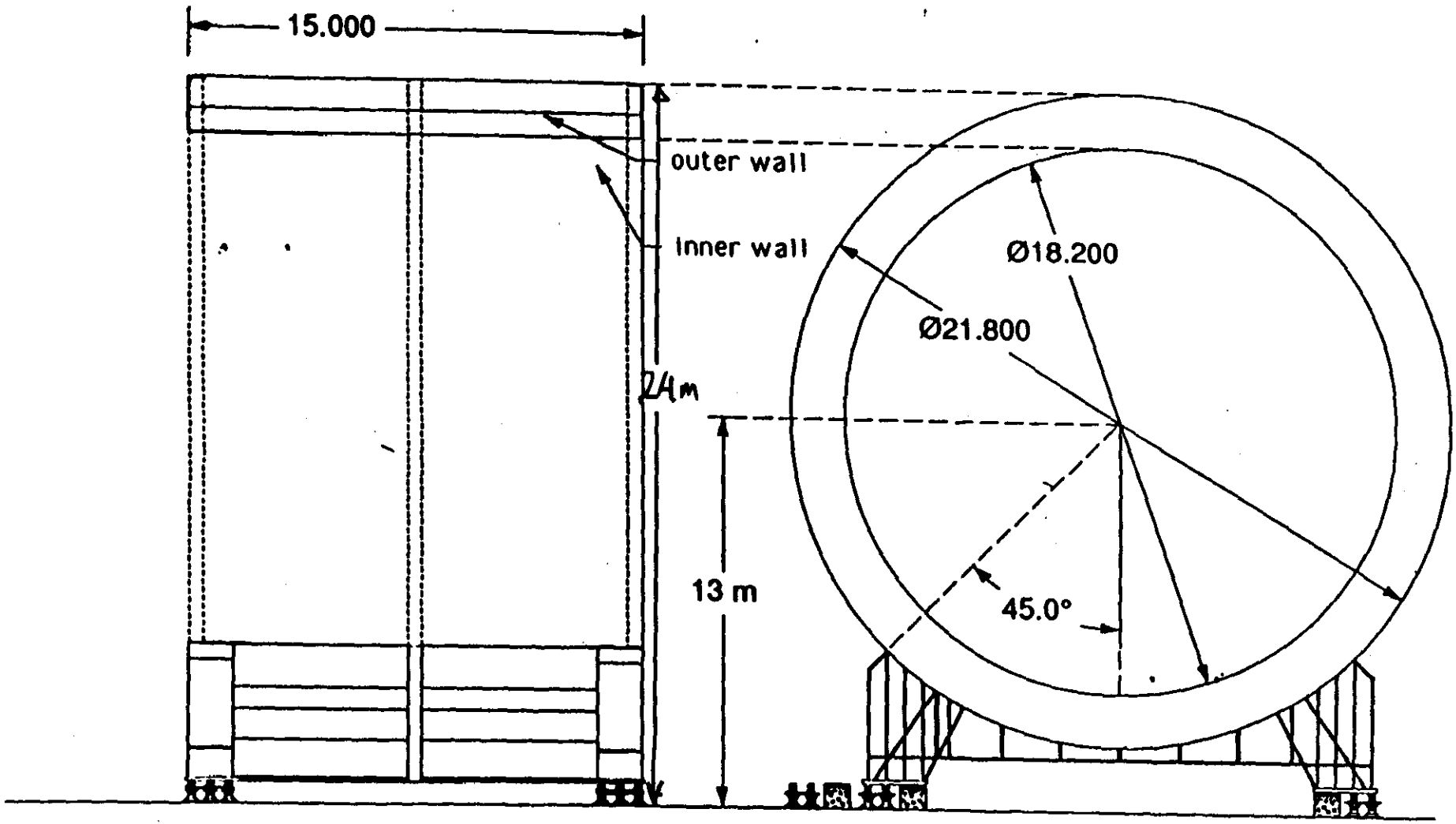
- PRESSURISE GREASE PADS

- USE HYDRAULIC WINCHES TO MOVE THE MAGNET

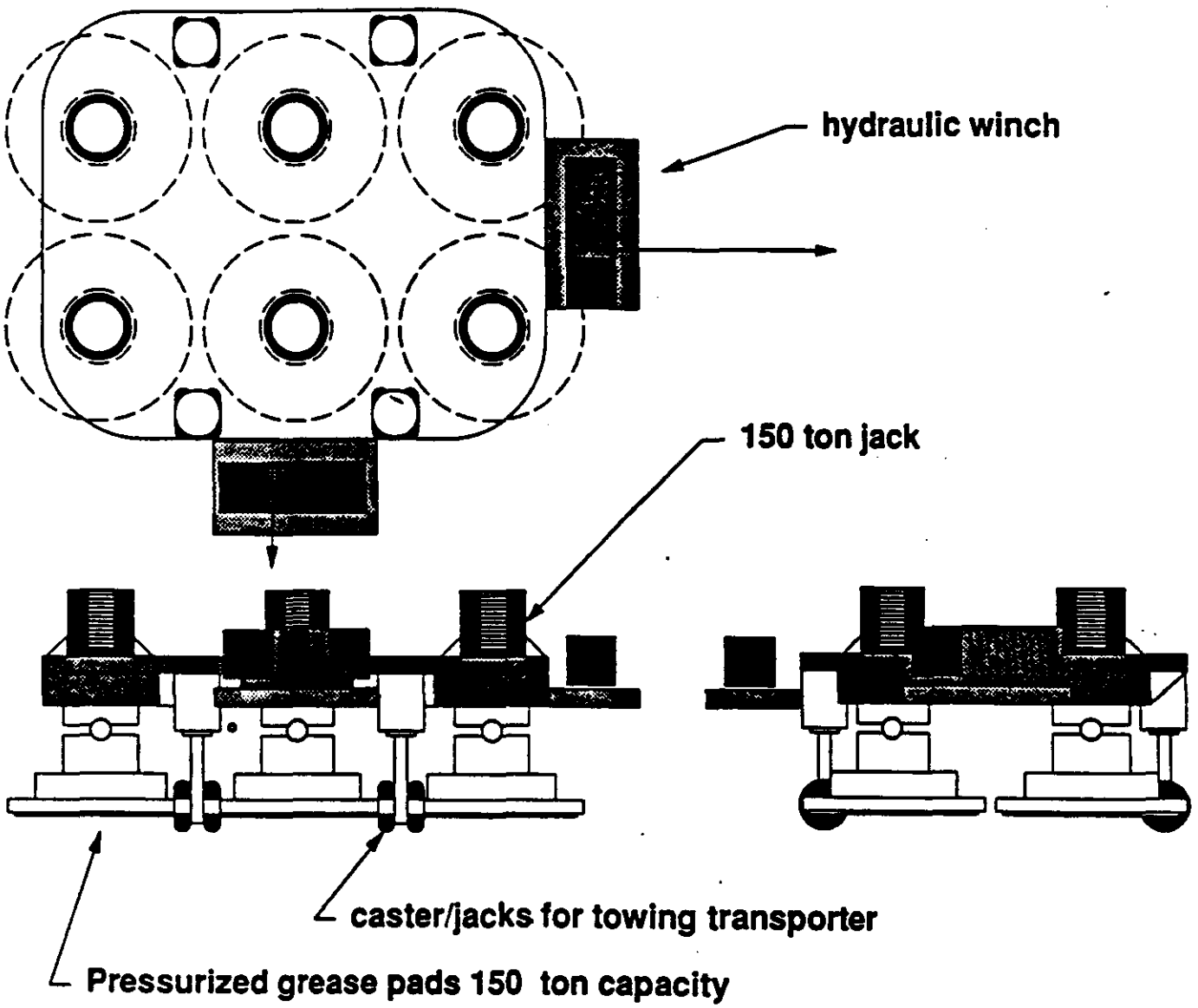
- EACH CORNER HAS 2-D CONTROLS
- WILL NEED PARKING CRADLES AND FLOOR RAILS

<u>NOTE:</u> AT PRESENT TOP OF THE MAGNET IS 24 m OFF THE FLOOR OF IR HALL.
THE 3 m MUON UPGRADE SPACE HAS NOT BEEN PRESERVED ON THE BOTTOM
MAY NEED TO LOWER THE FLOOR BY ANOTHER ~2 m IF UPGRADE ACCEPTANCE IS IMPORTANT

Grease pad concept



Grease pad transporter assembly
900 ton capacity, 2.25" lift

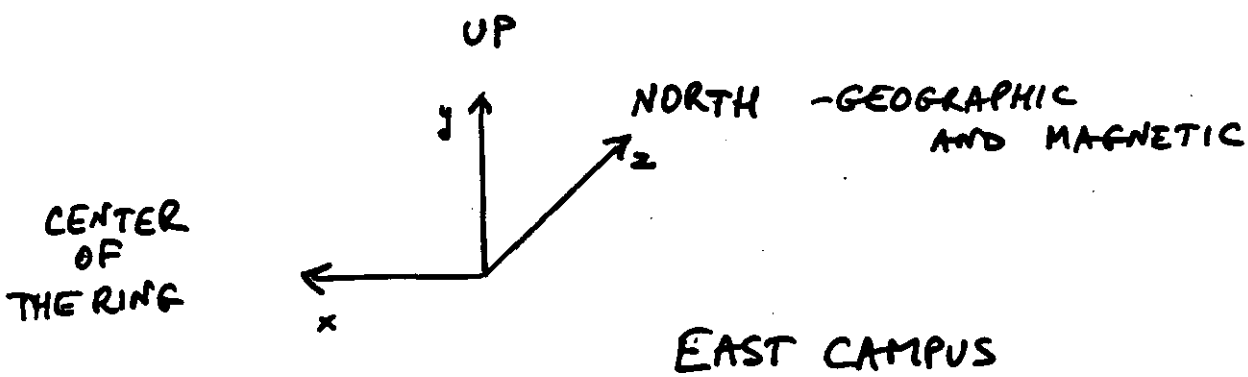


COST CHANGES (GUESSTIMATE)

	$M
INCREASE MAGNET RADIUS	+4.8
REPLACE IRON POLES WITH FLUX CONCENTRATOR	-4.7 ÷ +0.7
ADD CENTRAL GAP AND FREESTANDING MEMBRANE	+1.0 ÷ +8.4
MAKE MAGNET MOBILE	-0.5 ÷ +2.5
TOTAL	0.6 ÷ 16.0

PART OF THE RANGE IS DUE TO UNCERTAINTY IN MAGNETIC VS NON-MAGNETIC STEEL FOR STRUCTURAL SUPPORTS.

CHOICE OF COORDINATE SYSTEM (McFARLAN)

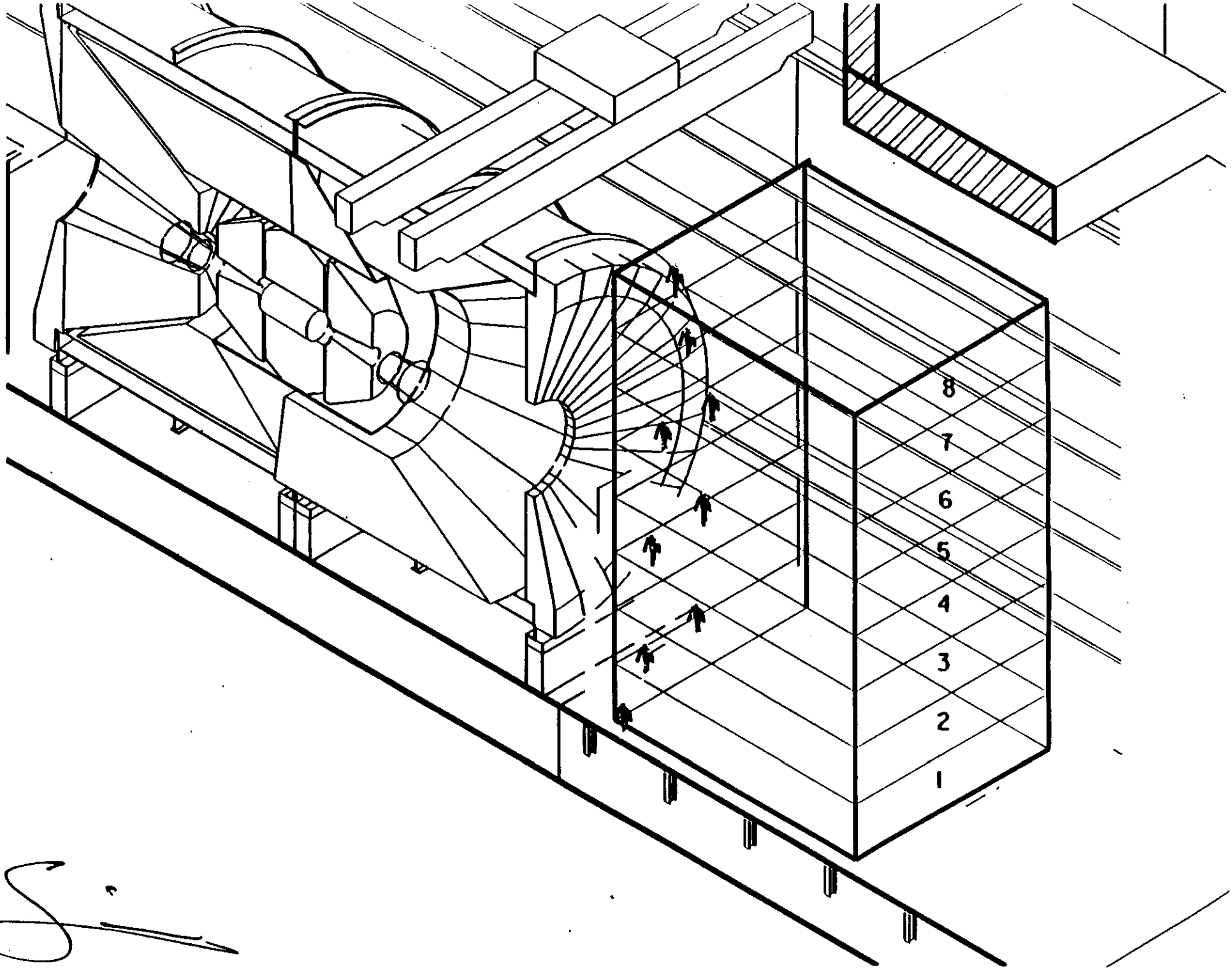


Radius-Increase Cost Guesstimate

Design Change	Cost Increase, $M
• Larger coil form	1.3
• More conductor	0.7
• More ass'y and tooling cost	0.7
• Larger vac vessel	1.2
• Misc	0.9
Total	4.8

Note: based on cost-scaling at component level

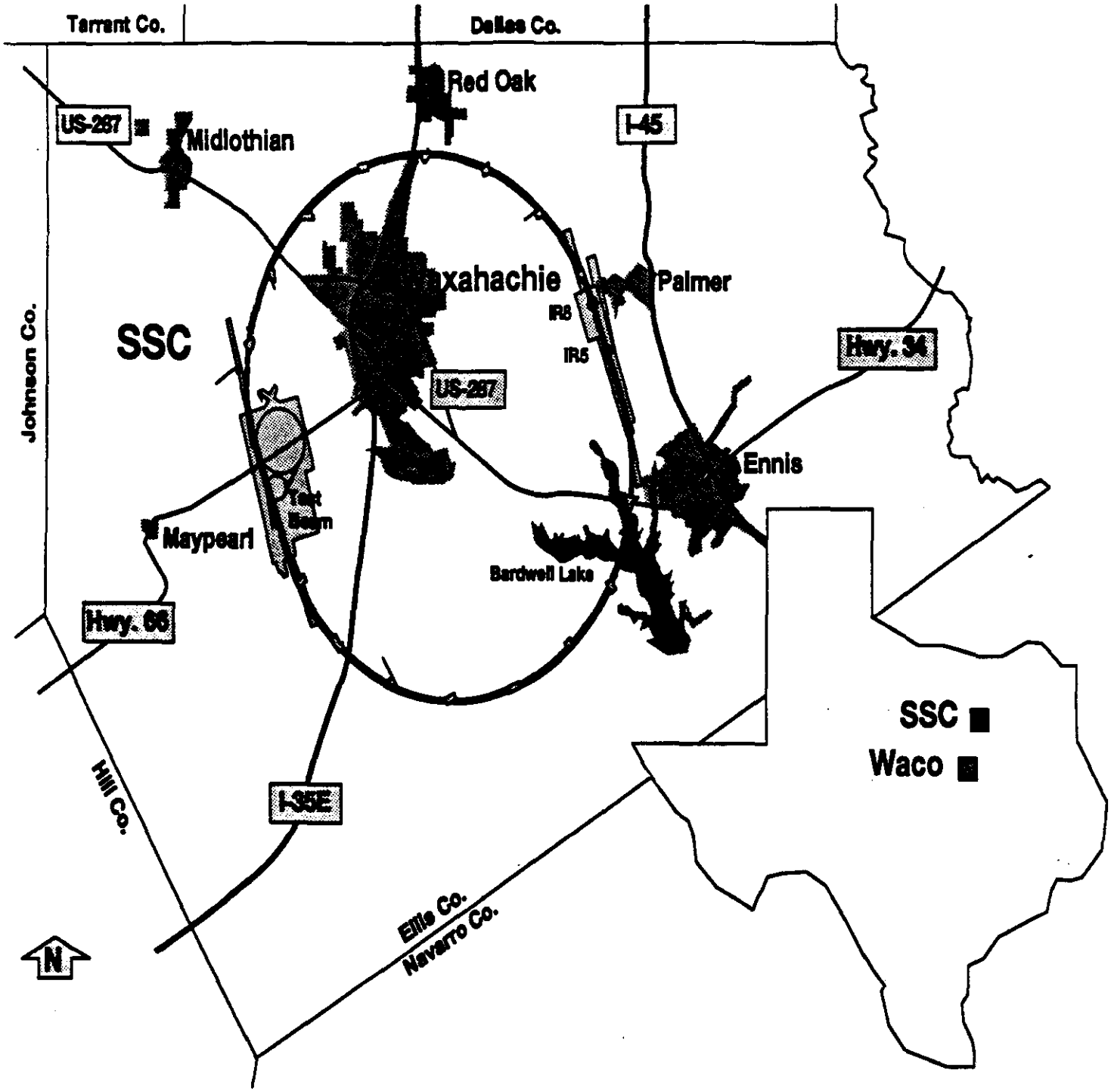
VG-GEM-92-007-3
3/6/92


8
7
6
5
4
3
2
1

GEM Facilities at IR5

M. Harris

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ


Tarrant Co.
Dallas Co.
Red Oak
US-287
Midlothian
I-45
xahachie
Palmer
IR8
IR5
SSC
Johnson Co.
Hwy. 34
US-287
Ennis
Test Beam
Maypearl
Bardwell Lake
Hwy. 66
SSC
Waco
Hill Co.
I-35E
Ellis Co.
Navarro Co.
N

TIP-00833

First Facilities Milestone

G GEM
E EXPERIMENTAL
F FACILITIES
U USERS
R REQUIREMENTS

Document will be reviewed by the collaboration March 31, 1992

Schedule

Three Critical Paths

1. Underground Hall
2. Magnet Design and Procurement
3. Magnet Coil Winding Building

Underground Hall Schedule

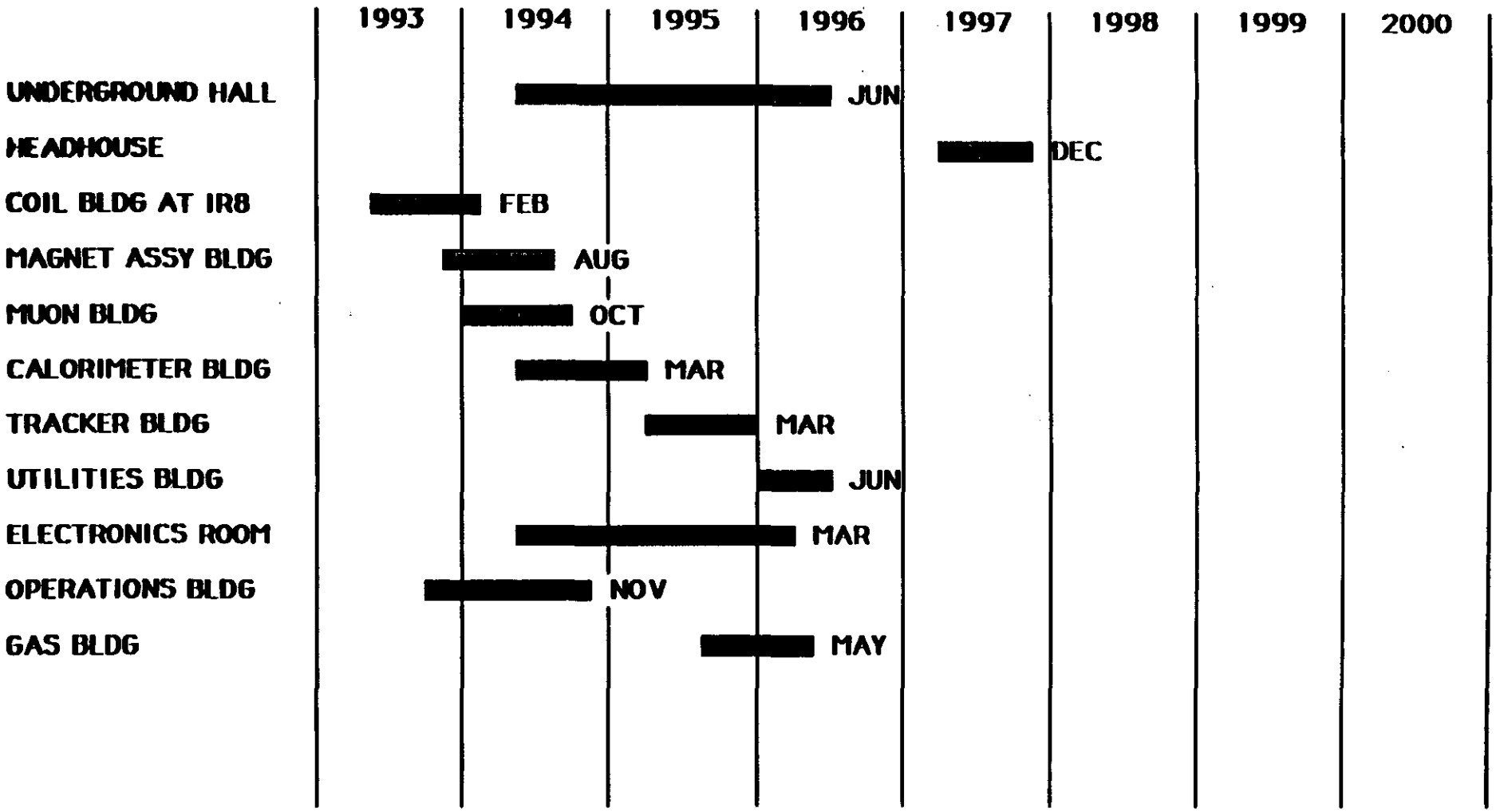
Baseline	January 1996
Current Projection	February 1997
Possible Compromise	June 1996

GEM Engineering

Magnet Coil Building Ready

February 1994

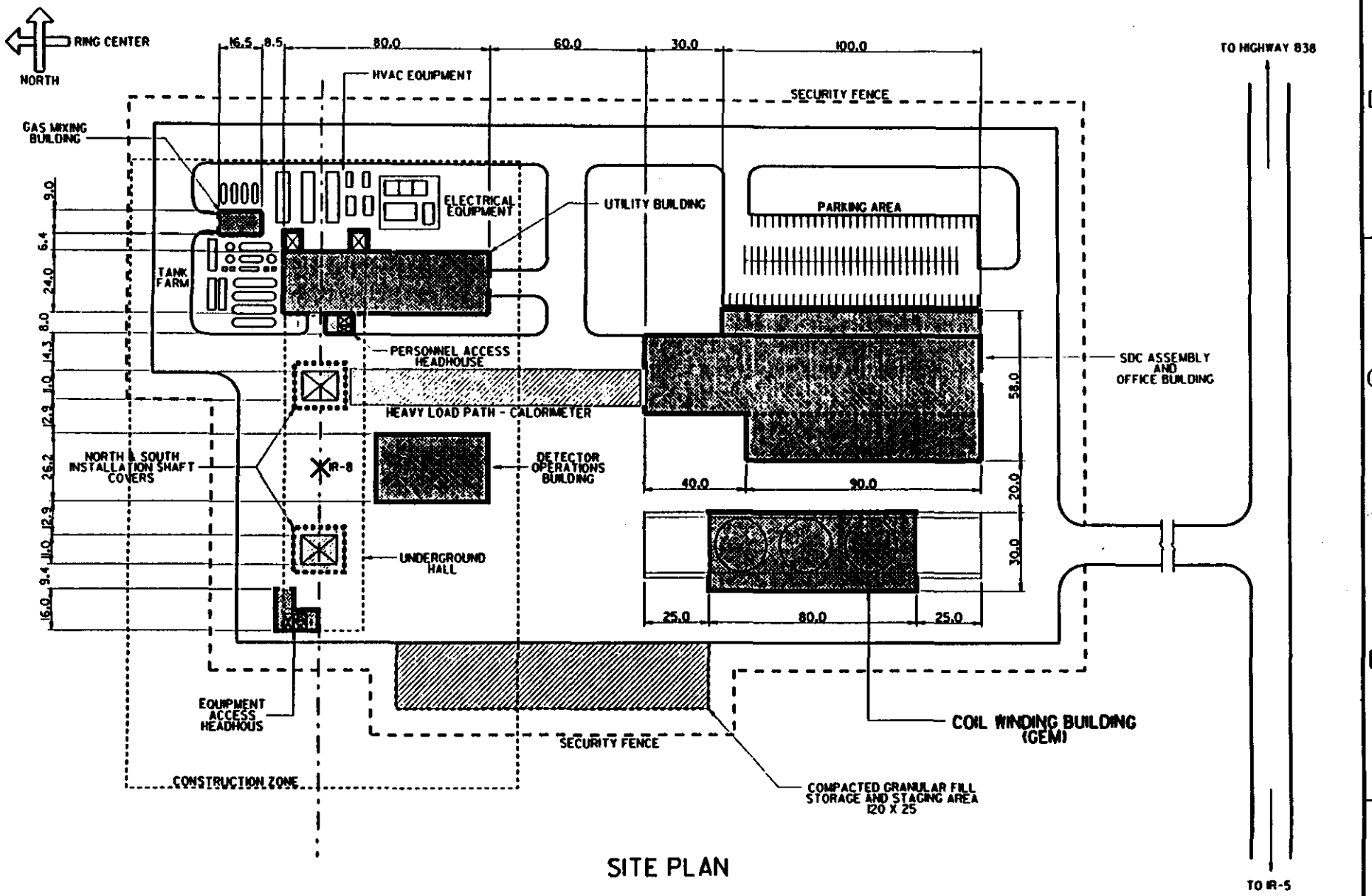
GEM DETECTOR SCHEDULE REQUIREMENTS FOR SITE BUILDINGS



MH 3/6/92

Name	Earliest Start	Earliest Finish	Latest Start	Latest Finish
L.O.I.	**12/1/91**	**12/1/91**	**12/1/91**	**12/1/91**
PREPARATION FOR TITLE I	**12/2/91**	**4/7/92**	**12/2/91**	**4/7/92**
START SURFACE FACILITY DESIGN	**4/7/92**	**4/7/92**	**4/8/92**	**4/8/92**
START CONCEPT. INFRASTRUCTURE DESIGN	12/1/91	12/1/91	2/6/92	2/6/92
CONCEPTUAL MAGNET DESIGN	12/2/91	7/6/92	4/15/92	11/16/92
PRELIMINARY DESIGN OF DETECTOR HALL (TITLE I)	**4/8/92**	**11/16/92**	**4/8/92**	**11/16/92**
PRELIMINARY DESIGN DETECTOR	**12/2/91**	**10/14/92**	**12/2/91**	**10/14/92**
DESIGN EXTERNAL IRON FABRICATION AREAS	4/8/92	10/14/92	8/3/93	2/11/94
CONC. DESIGN MUON ASSY BLDG	4/8/92	1/25/93	11/4/93	8/18/94
DESIGN COIL WINDING BLDG	**4/8/92**	**1/25/93**	**4/8/92**	**1/25/93**
CONC. DESIGN PERSONNEL HEADHOUSE	4/8/92	1/25/93	11/23/94	9/7/95
CONC. DESIGN MECH SYSTEM	4/8/92	1/25/93	7/7/95	4/19/96
CONC. DESIGN GAS MIXING HOUSE	4/8/92	1/25/93	4/22/96	2/5/97
CONC. DESIGN CALOR. ASSY BLDG	4/8/92	1/25/93	5/17/94	3/2/95
CONC. DESIGN TRACKER ASSY BLDG	4/7/92	4/7/92	12/29/94	12/29/94
CONC. DESIGN UTILITY BLDG	4/8/92	12/18/92	2/20/96	10/25/96
CONC. DESIGN OPERATION CENTER	4/8/92	12/18/92	10/5/93	6/16/94
CONC. DESIGN CONSTRUCTIONHEADHOUSE	4/8/92	1/25/93	11/23/94	9/7/95
ESTABLISH DETECTOR BASELINE	**3/9/92**	**11/16/92**	**3/9/92**	**11/16/92**
CONC. DESIGN GAS SYSTEM	4/8/92	1/25/93	3/16/94	12/28/94
DESIGN MAGNET ASSY BLDG	4/8/92	1/25/93	4/15/94	1/31/95
CONC. DESIGN SAFETY SYSTEMS	4/8/92	1/25/93	1/13/94	10/20/94
CONC. DESIGN CRYO SYSTEM	4/8/92	1/25/93	4/15/94	1/31/95
DESIGN INFRASTRUCT.	12/2/91	9/14/92	2/6/92	11/16/92
SUBMITTED TO PAC	**11/16/92**	**11/16/92**	**11/17/92**	**11/17/92**
DESIGN MUON ASSY BLDG	1/26/93	8/2/93	8/19/94	3/2/95
DESIGN MECH SYSTEM	1/26/93	11/3/93	4/22/96	2/5/97
DESIGN GAS MIXING HOUSE	1/26/93	8/2/93	2/6/97	8/12/97
DESIGN GAS SYSTEM	1/26/93	11/3/93	12/29/94	10/9/95
DESIGN PERSONNEL HEADHOUSE	1/26/93	11/3/93	9/8/95	6/21/96
DESIGN CONSTRUCTIONHEADHOUSE	1/26/93	11/3/93	9/8/95	6/21/96
DESIGN CRYO SYSTEM	1/26/93	11/3/93	2/1/95	11/8/95
DESIGN OPERATION CENTER	12/21/92	6/30/93	6/17/94	12/28/94
FINAL DESIGN OF U/G DETECTOR HALL (TITLE II)	**11/17/92**	**9/1/93**	**11/17/92**	**9/1/93**
DESIGN SAFETY SYSTEMS	1/26/93	11/3/93	10/21/94	8/7/95
BID & AWARD GAS HOUSE	8/3/93	11/3/93	8/13/97	11/14/97
DESIGN CALOR. ASSY BLDG	7/1/93	1/12/94	3/3/95	9/7/95
DESIGN UTILITY BLDG	7/1/93	1/12/94	10/28/96	5/8/97
START BID & PURCHASE CRYO SYS	11/3/93	11/3/93	11/9/95	11/9/95
START BID & PURCHASE MECH SYS	11/3/93	11/3/93	2/6/97	2/6/97
START BID & AWARD FOR IRON FAB. AREAS	10/15/92	12/18/92	2/14/94	4/14/94
BID AND AWARD COIL WINDING BLDG	**1/26/93**	**4/28/93**	**1/26/93**	**4/28/93**
PAC MAGNET DESIGN REVIEW	**11/17/92**	**12/18/92**	**11/17/92**	**12/18/92**
START BID & PURCHASE GAS SYSTEMS	11/3/93	11/3/93	10/10/95	10/10/95
BID & AWARD MUON ASSY BLDG	8/3/93	11/3/93	3/3/95	6/5/95

DESIGN TRACKER ASSY BLDG	7/1/93	1/12/94	12/29/94	7/6/95
DESIGN OF ACCESS ROAD TO COIL BLDG	12/2/91	4/7/92	8/13/92	12/18/92
SUBMIT PROPOSAL	12/18/92	12/18/92	4/29/93	4/29/93
START BID & AWARD INFRASTRUCT.	9/14/92	9/14/92	11/17/92	11/17/92
START BID & PURCHASE SAFETY SYS	11/3/93	11/3/93	8/8/95	8/8/95
BID &AWARD U/6 HALL CONTRACT	**9/2/93**	**12/8/93**	**9/2/93**	**12/8/93**
BID & AWARD CRYO SYSTEM	11/4/93	5/16/94	11/9/95	5/21/96
BID & AWARD GAS SYSTEMS	11/4/93	5/16/94	10/10/95	4/19/96
PURCHASE SAFETY SYSTEM COMPONENTS	11/4/93	5/16/94	8/8/95	2/19/96
BID & AWARD MECH SYSTEM	11/4/93	3/15/94	2/6/97	6/10/97
CONSTRUCT GAS HOUSE	11/4/93	5/16/94	11/17/97	5/28/98
BID & AWARD UTILITY BLDG	1/13/94	4/14/94	5/9/97	8/12/97
BID & AWARD OPERATION CENTER	7/1/93	10/4/93	2/20/96	5/21/96
BID &AWARD TRACKER ASSY BLDG	1/13/94	4/14/94	7/7/95	10/9/95
ACCESS ROAD TO COIL WINDING BUILDING	4/8/92	8/12/92	12/21/92	4/28/93
BID & AWARD INFRASTRUCT.	9/15/92	12/18/92	11/17/92	2/25/93
REVIEW/ APPROVE PROPOSAL	12/21/92	2/25/93	4/29/93	6/30/93
BIDS & AWARDS	12/21/92	6/30/93	4/15/94	10/20/94
CONSTRUCT COIL WINDING BLDG	**4/29/93**	**2/11/94**	**4/29/93**	**2/11/94**
BID &AWARD MAGNET ASSY BLDG	1/26/93	4/28/93	2/1/95	5/3/95
CONSTRUCT CRYO SYSTEM	5/17/94	6/21/96	5/22/96	6/29/98
BID &AWARD CALOR. ASSY BLDG	1/13/94	4/14/94	9/8/95	12/13/95
CONSTRUCT SAFETY SYSTEMS	5/17/94	6/5/95	2/20/96	3/7/97
BID & AWARD CONSTRUCTION HEADHOUSE & LARGE SHAFT	11/4/93	5/16/94	6/24/96	1/6/97
CONSTRUCT MECH SYSTEM	3/16/94	4/3/95	6/11/97	6/29/98
UP-DATE MAGNET CONCEPTUAL DESIGN	12/21/92	2/25/93	3/30/93	5/31/93
COMPLETE MAGNET CONTRACTS AND PROCUREMEN	**12/21/92**	**9/1/93**	**12/21/92**	**9/1/93**
CONSTRUCT GAS SYSTEMS	5/17/94	6/21/96	4/22/96	5/28/98
CONSTRUCT ROADS & CIVIL SITEWORK	12/21/92	10/4/93	2/26/93	12/8/93
CONSTRUCT MUON ASSY BLDG	11/4/93	9/20/94	6/6/95	4/19/96
PROVIDE MIN 15 MVA UTILITY POWER	12/21/92	3/26/98	2/14/94	5/17/99
CONSTRUCT CALOR. ASSY BLDG	4/15/94	3/2/95	12/14/95	10/25/96
PROVIDE MIN 1500 KVA UTILITY POWER	12/21/92	1/12/94	5/22/96	6/10/97
CONSTRUCT WATER & GAS SYSTEMS	12/21/92	12/8/93	6/24/96	6/10/97
EXCAVATE U/6 HALL & SHAFTS	**12/9/93**	**10/20/94**	**12/9/93**	**10/20/94**
CONSTRUCT COOLING POND	12/21/92	1/12/94	5/22/96	6/10/97
BOD COIL WINDING BLDG	**2/11/94**	**2/11/94**	**2/14/94**	**2/14/94**
INSTALL SURFACE SUBSYSTEMS	6/6/95	9/7/95	3/10/97	6/10/97
BEGIN CONSTRUCTION U/6 HALLS & SHAFTS	**10/21/94**	**3/20/96**	**10/21/94**	**3/20/96**
TEMPORARY SUPPLIES	12/18/92	12/18/92	4/15/94	4/15/94
CONSTRUCT TRACKER BLDG	4/15/94	3/2/95	10/10/95	8/23/96
CONSTRUCT OPERATION CENTER	10/5/93	10/20/94	5/22/96	6/10/97
CONSTRUCT MAGNET ASSEMBLY BLDG	10/5/93	8/18/94	5/4/95	3/20/96
BACKFILL AROUND HALL	**3/21/96**	**6/21/96**	**3/21/96**	**6/21/96**
CONSTRUCT UTILITY BLDG	6/24/96	5/8/97	8/13/97	6/29/98
INFRASTRUCTURE COMPLETE	1/12/94	1/12/94	6/11/97	6/11/97
PARTIAL INFRASTRUCTURE CONSTRUCTION COMPLETE	10/4/93	10/4/93	4/15/94	4/15/94



SITE PLAN

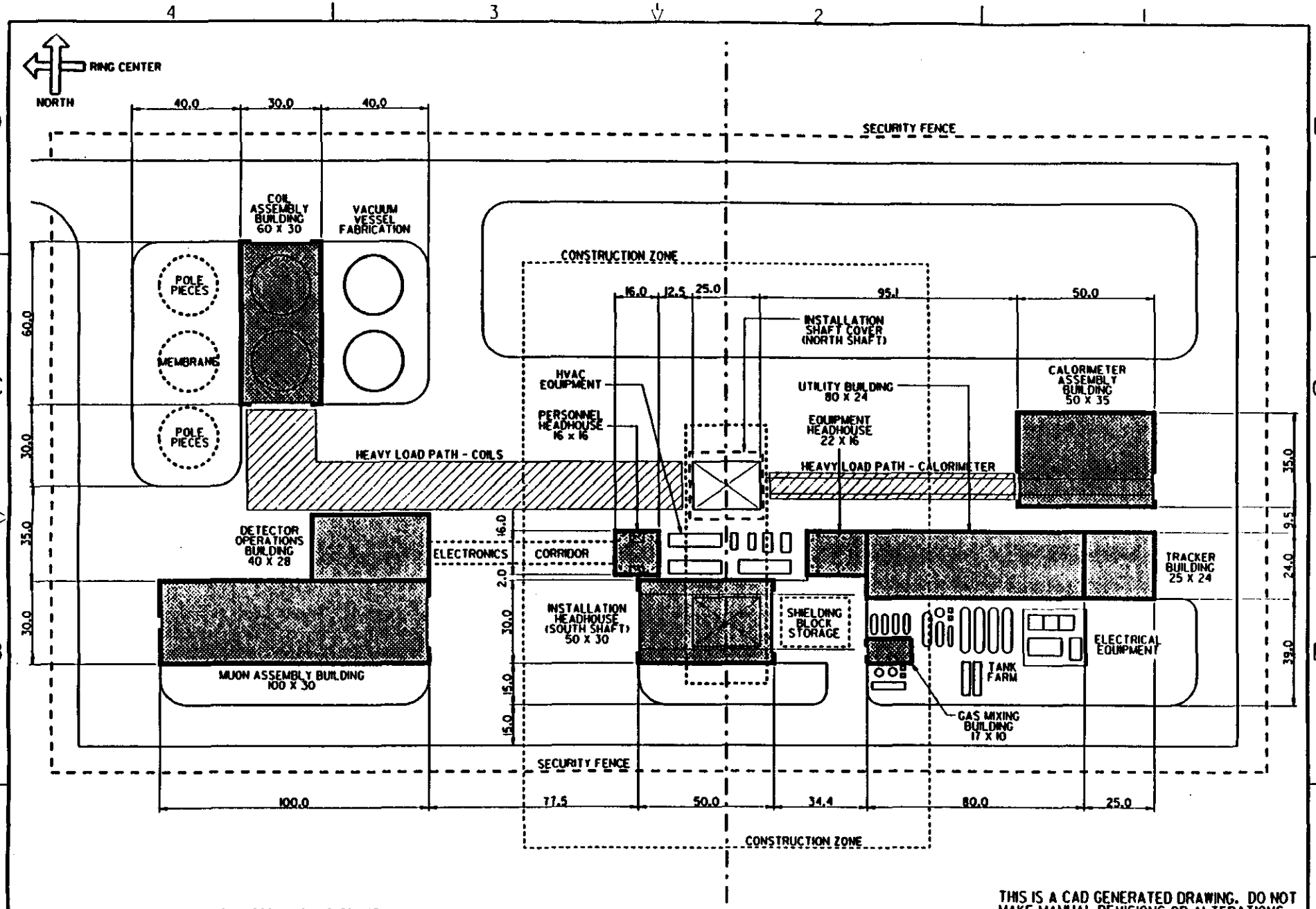
DIMENSIONS ARE IN SHOWN IN METERS UNLESS NOTED OTHERWISE.

THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.

R. HAWKES	PHYSICS RESEARCH DIVISION	SSC	SDC EXPERIMENTAL FACILITIES
T. PROSAPIO			SITE PLAN
			IR-8

SCD0000199

SCD-000199



DIMENSIONS ARE IN SHOWN IN METERS UNLESS NOTED OTHERWISE.

THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.

PHYSICS RESEARCH DIVISION

SSC

CONTRACT NUMBER DE-AC35-89ER40486

GEM EXPERIMENTAL FACILITIES

SITE PLAN

IR-5

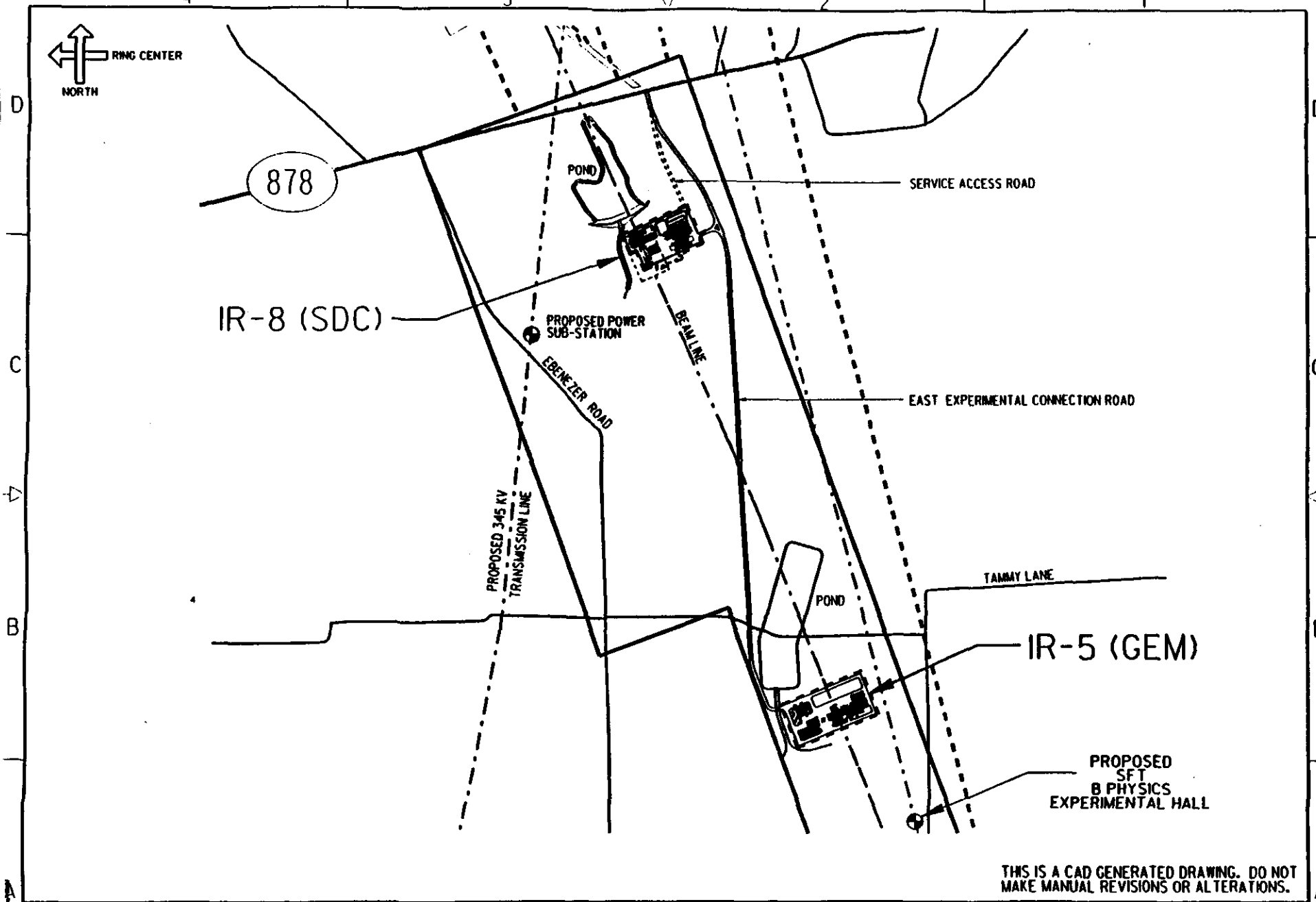
SCALE NONE

DATE 2-28-92

SIZE C

DRAWING NUMBER GCD000116

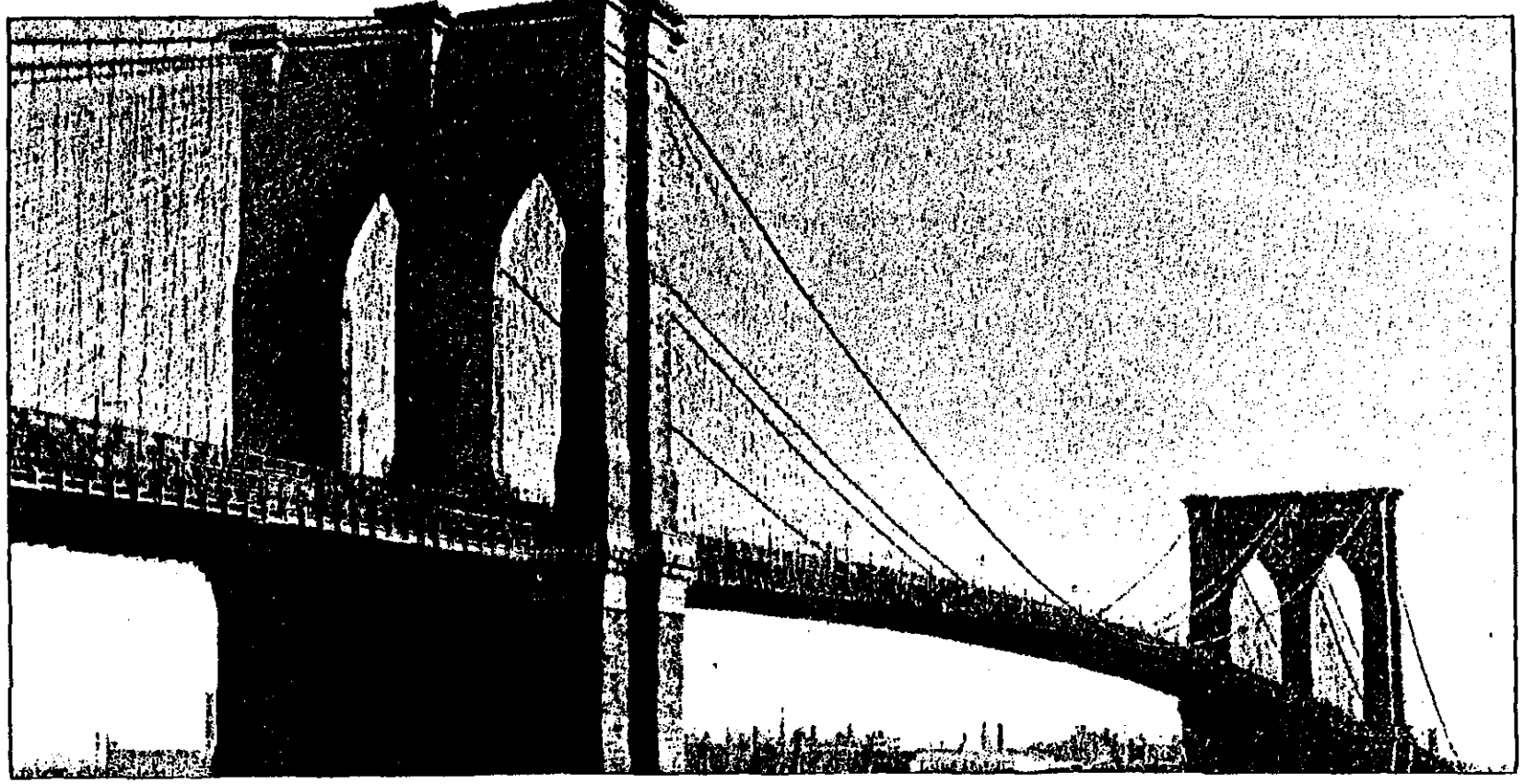
DOCUMENT CONTROL NUMBER GCD-000116



THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.

HAWKES / T. PROSAPIO	PHYSICS RESEARCH DIVISION	SSC	EXPERIMENTAL FACILITIES
		CONTRACT NUMBER DE-AC35-89ER40486	EAST CAMPUS INFRASTRUCTURE
			SCALE NONE / DATE 3/15/92 / SIZE C / DRAWING NUMBER R20000487 / R20-0004B7

IT TOOK 1,600 MEN 14 YEARS TO BUILD THE BROOKLYN BRIDGE...



Muons

F. Taylor

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

FET

GEM MUON SYSTEM BASELINE 3/8/92

Resolution design criterion:

pt = 500 GeV/c

$\delta pt/pt \approx 5\ \%$ for $\eta \approx 0$
$\delta pt/pt \approx 10\ \%$ for $\eta \approx 2.5$

Forced design changes: fig. of merit $BL^2/\sigma_{\text{resoln}}$ (ch. align)

(1) Larger bore magnet:

radius of cryostat increased from 8.3 m to 9.0 m

(2) Longer lever arm in forward direction:

Z-postion of last EC ch. increased from 14.4 m to 16.5 m
Coil halfs separated by 1.5 m

(3) More compact calorimeter:

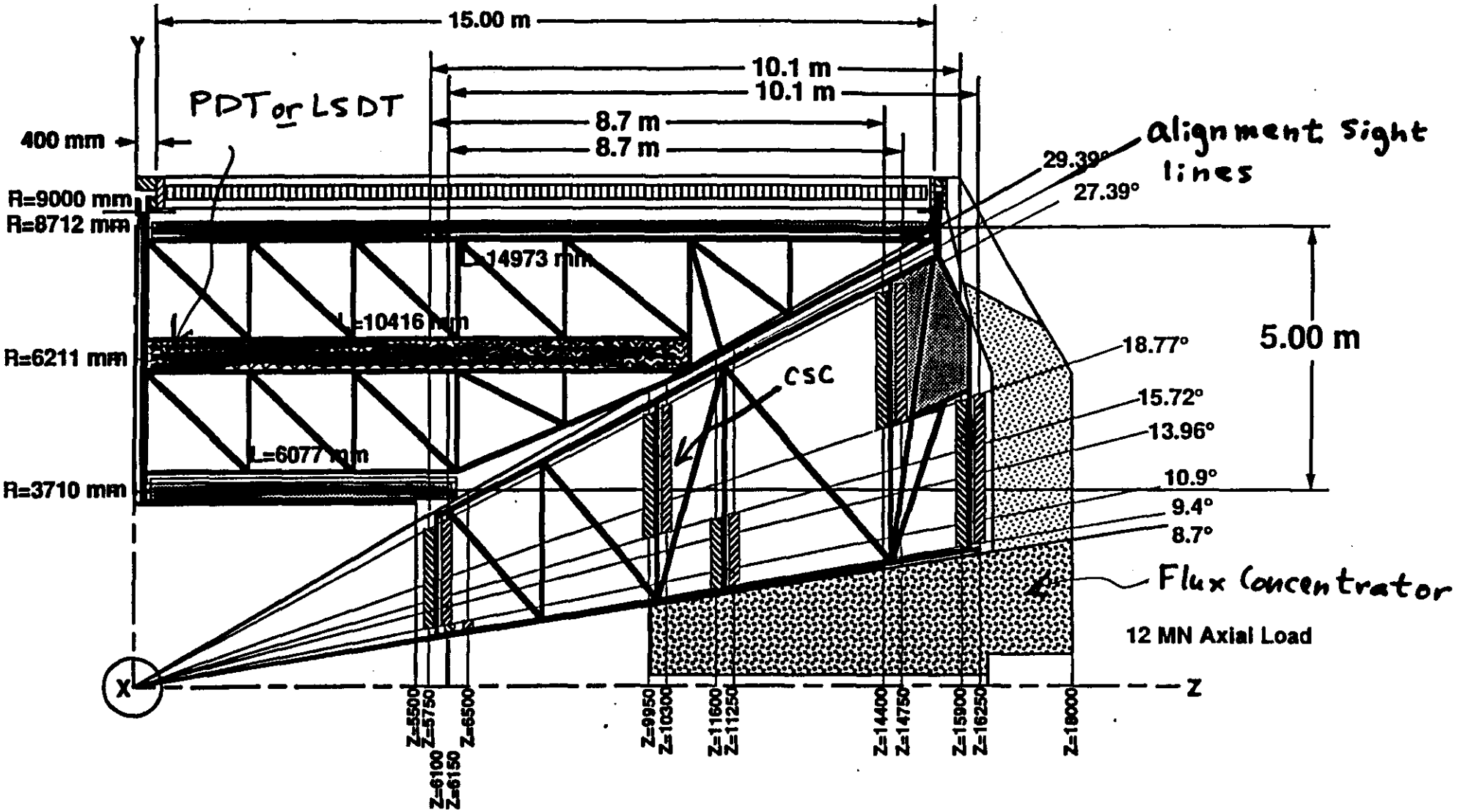
outer radius decreased from 4 m to 3.5 m
length decreased from 6 m to 5.5 m

(4) Field shaping in forward direction:

solid iron flux concentrator from 10 m to 18 m

(5) Very good position measurement needed:

σ layer $\approx$ 100 µm to 75 µm (chamber layer resolution)
σ internal $\approx$ 50 µm (alignment of chamber wires/strips)
σ external $\approx$ 25 µm (alignment of superlayer-to-superlayer)



GEM PDT 18/7 (8/8/4) Barrel or LSDT

Fig. 2.1

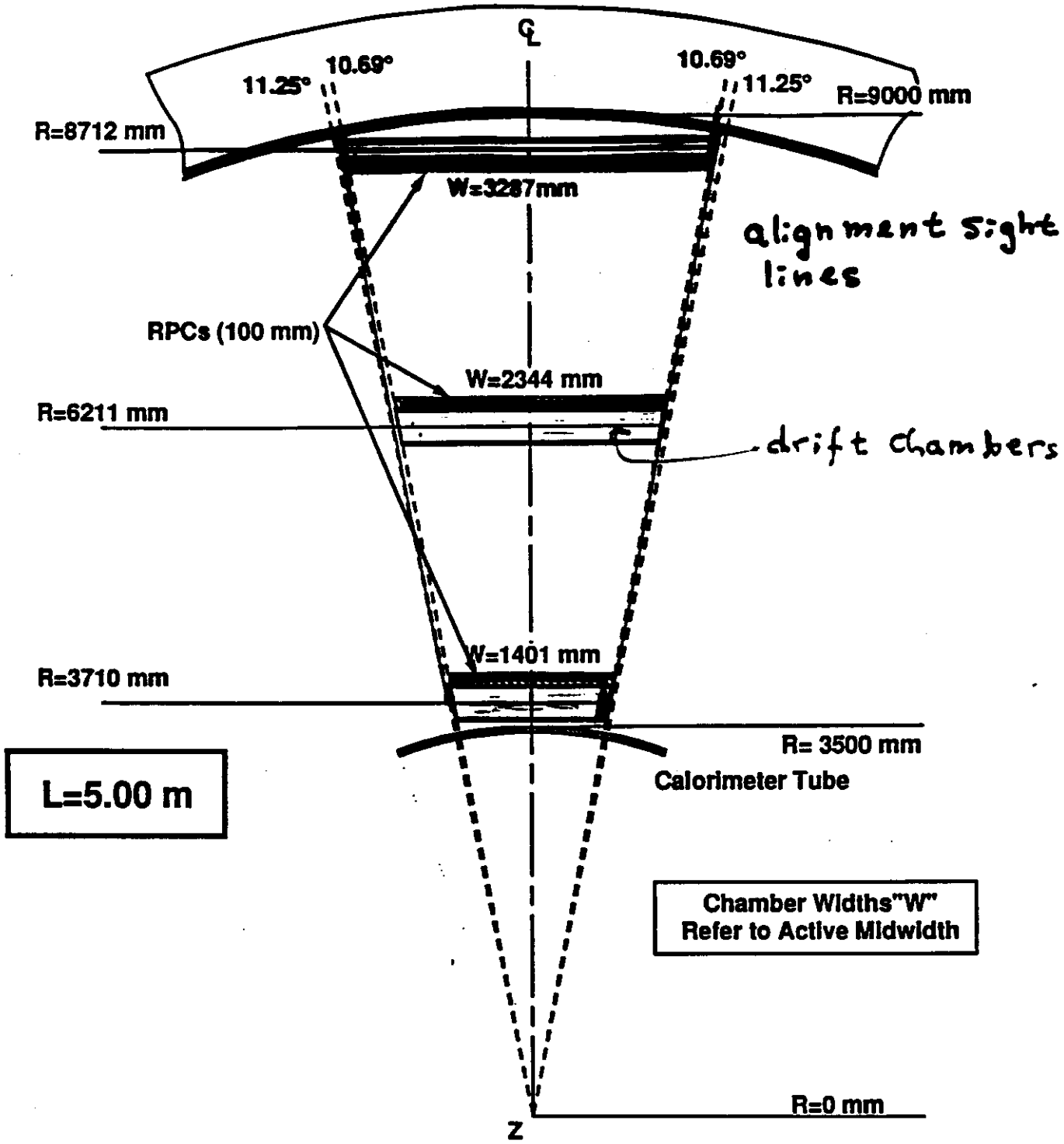
CSC Endcap (Modules A& B)

(Calorimeter 7m OD x11m Long)

(Extended Forward Field Shaper 18000mm Long)

(100 mm RPCs O/O/I)(Magnet half displaced along Z)

F. Nimblett
Draper Lab.
GEM920306



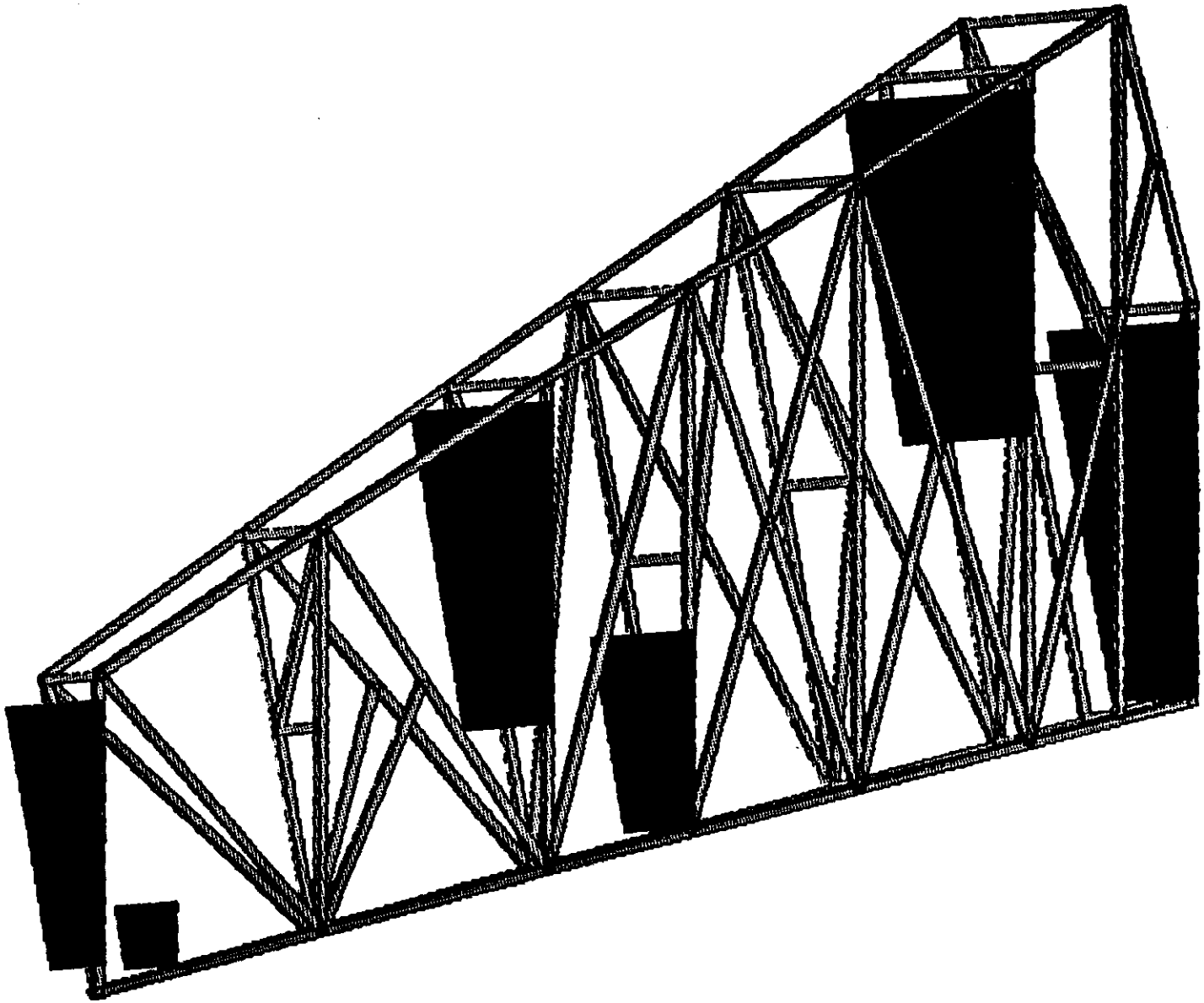
PDT 18/7 (8/8/4)

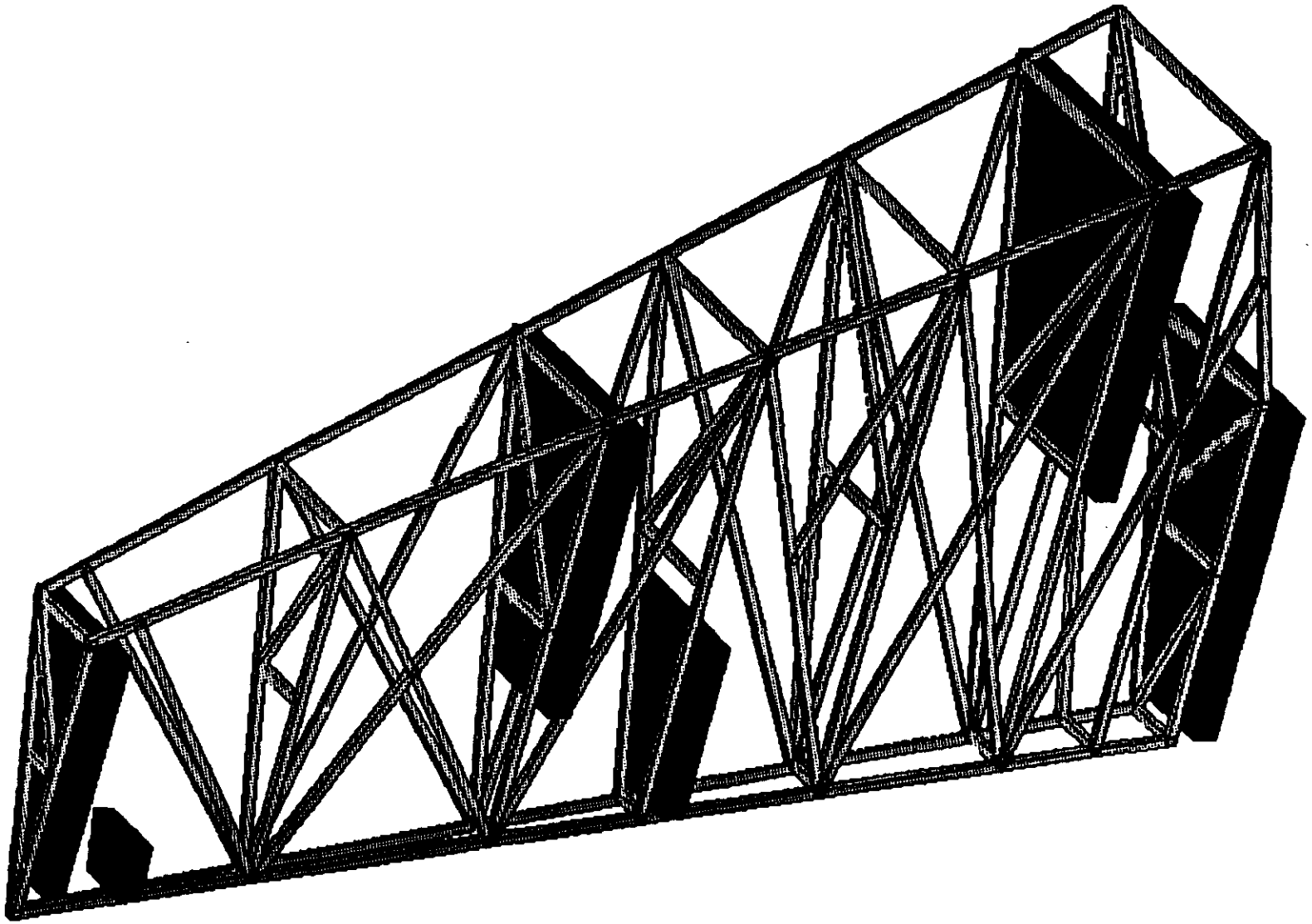
95% Acceptance

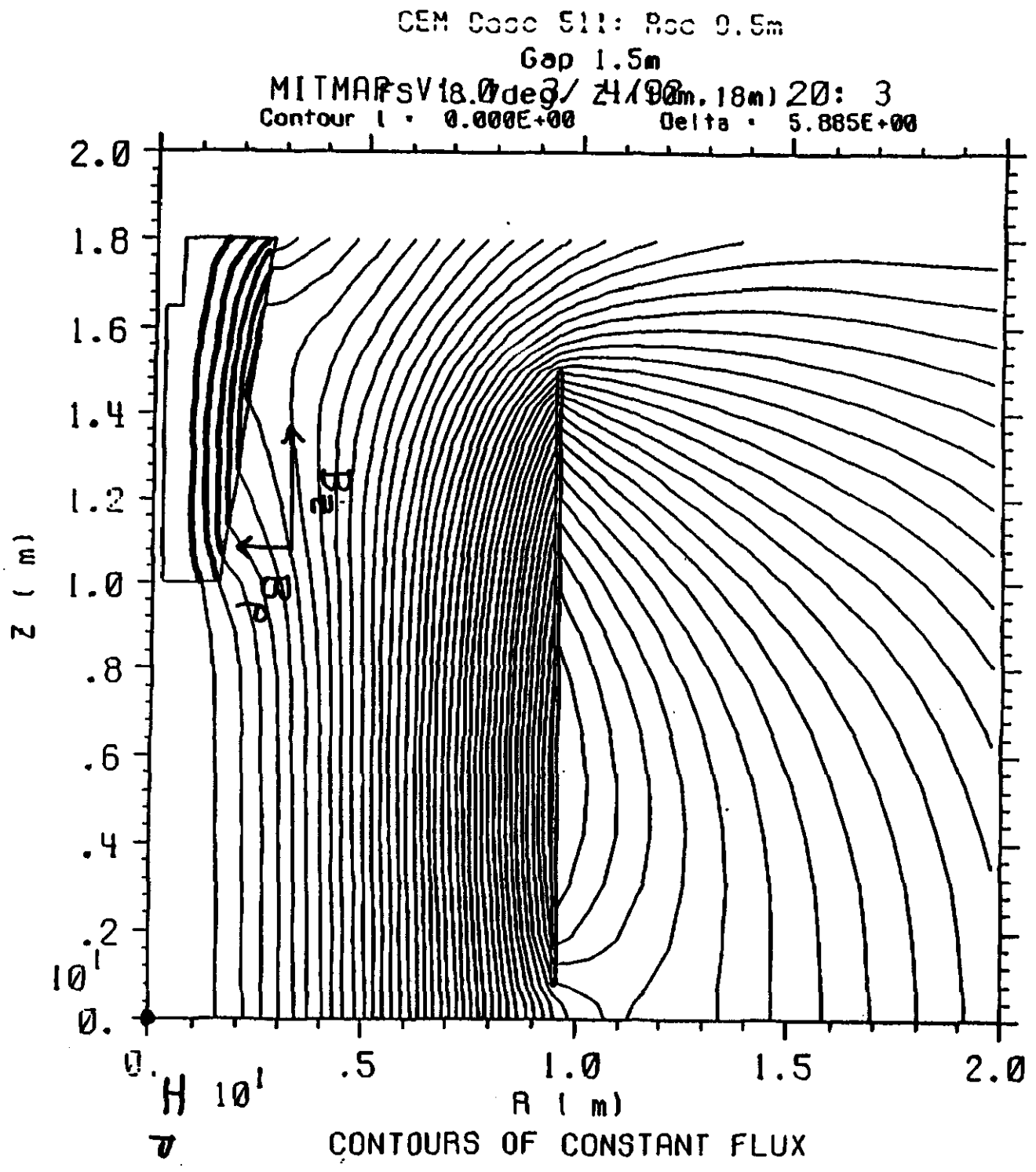
(Barrel Region Endview)

Fig. 2.4

F. Nimblett
GEM 920306







CONTOURS OF CONSTANT FLUX

Flux Concentrator

B = 0.8 T at HP

Fig. 3.3 b

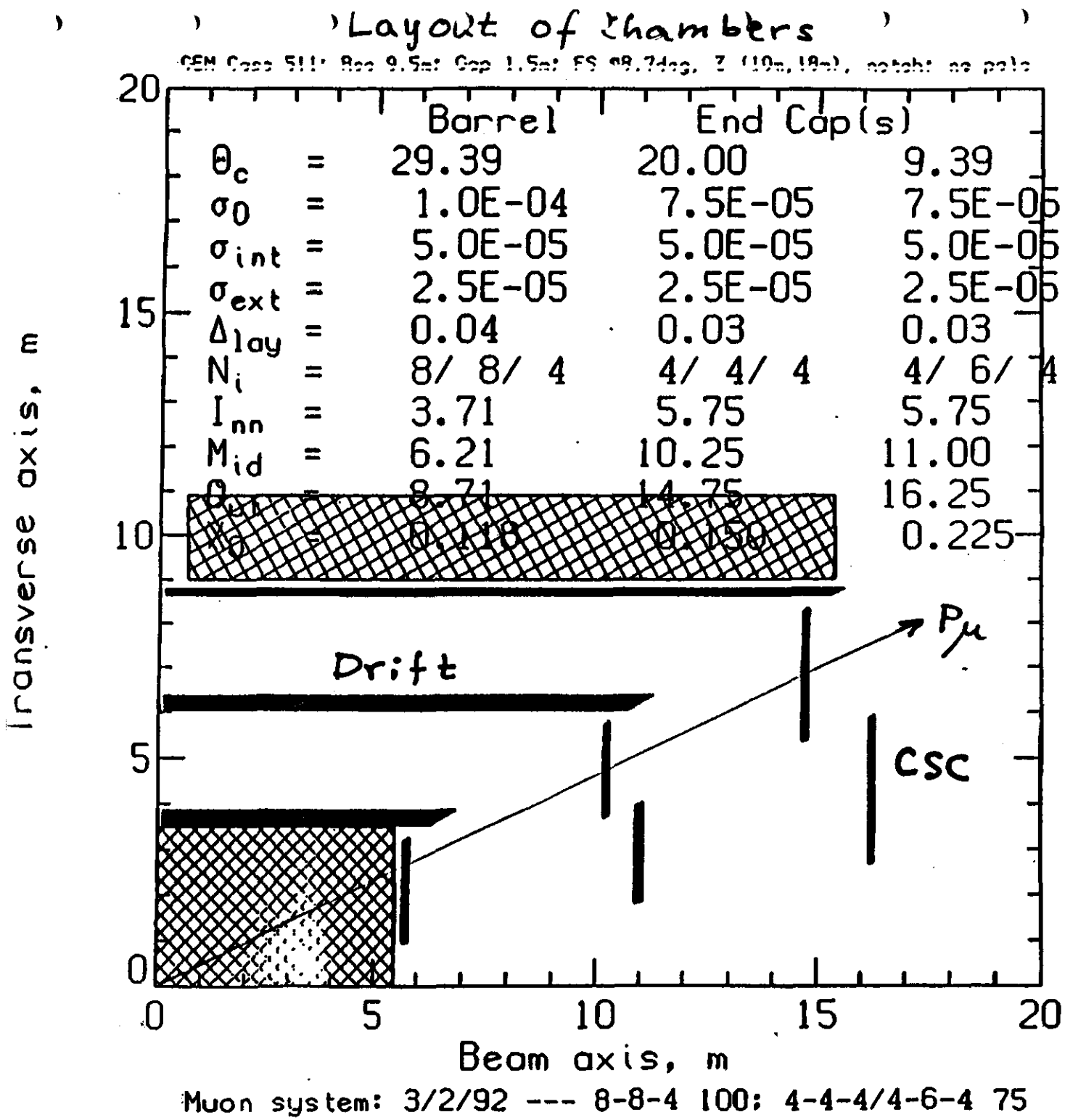

Layout of Chambers
Barrel
End Cap(s)
θ_c = 29.39 20.00 9.39
σ_0 = 1.0E-04 7.5E-05 7.5E-05
σ_{int} = 5.0E-05 5.0E-05 5.0E-05
σ_{ext} = 2.5E-05 2.5E-05 2.5E-05
Δ_{lay} = 0.04 0.03 0.03
N_i = 8/ 8/ 4 4/ 4/ 4 4/ 6/ 4
I_{nn} = 3.71 5.75 5.75
M_{id} = 6.21 10.25 11.00
O_{ut} = 8.71 14.75 16.25
γ_0 = 0.118 0.150 0.225
Drift
CSC
P_μ
Transverse axis, m
Beam axis, m
0
5
10
15
20
Muon system: 3/2/92 --- 8-8-4 100: 4-4-4/4-6-4 75

Fig. 1.1

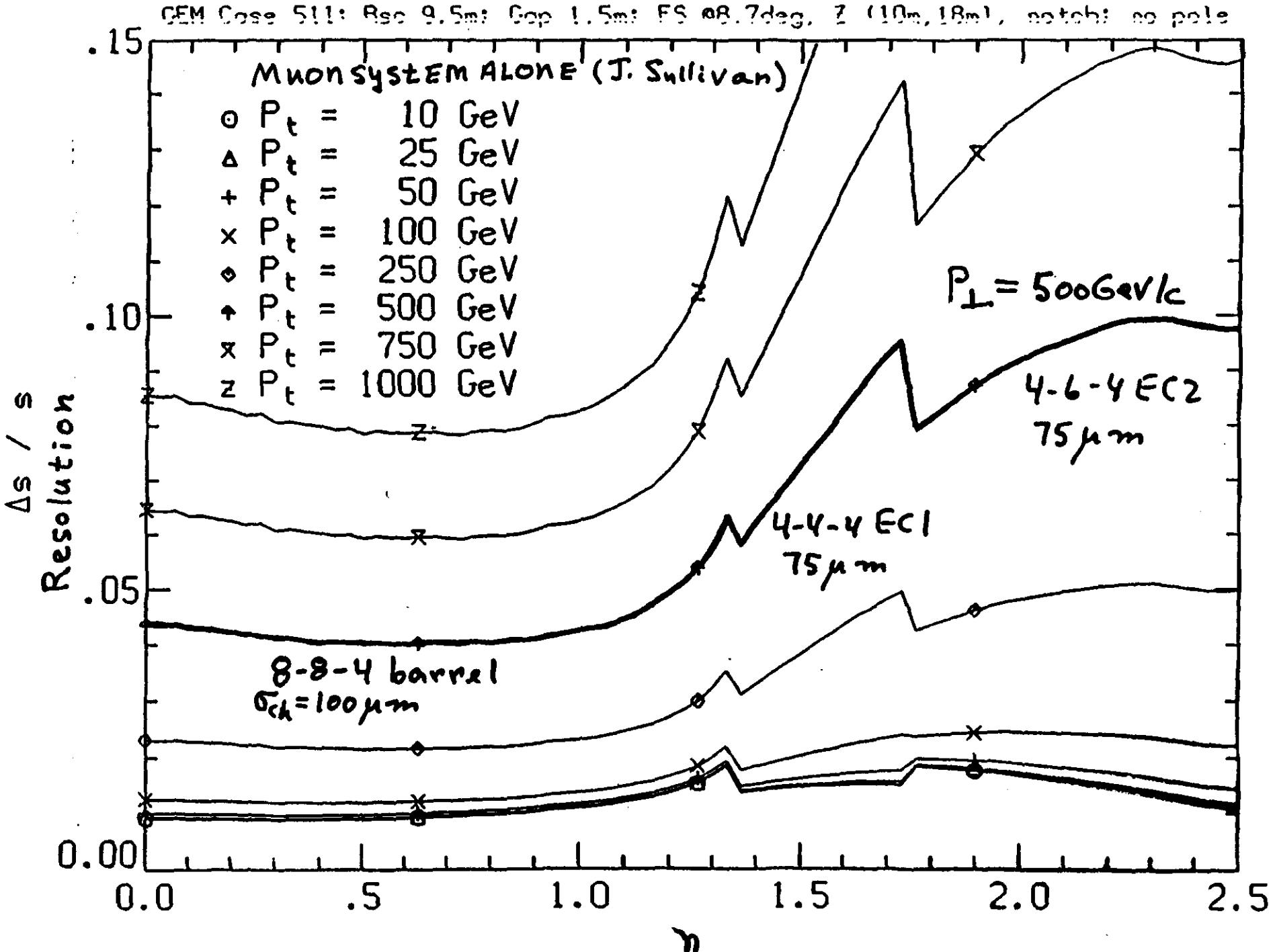


Fig. 5.1.1 Muon system: 3/2/92 --- 8-8-4 100; 4-4-4/4-6-4 75

Consequences of nonuniform B-field

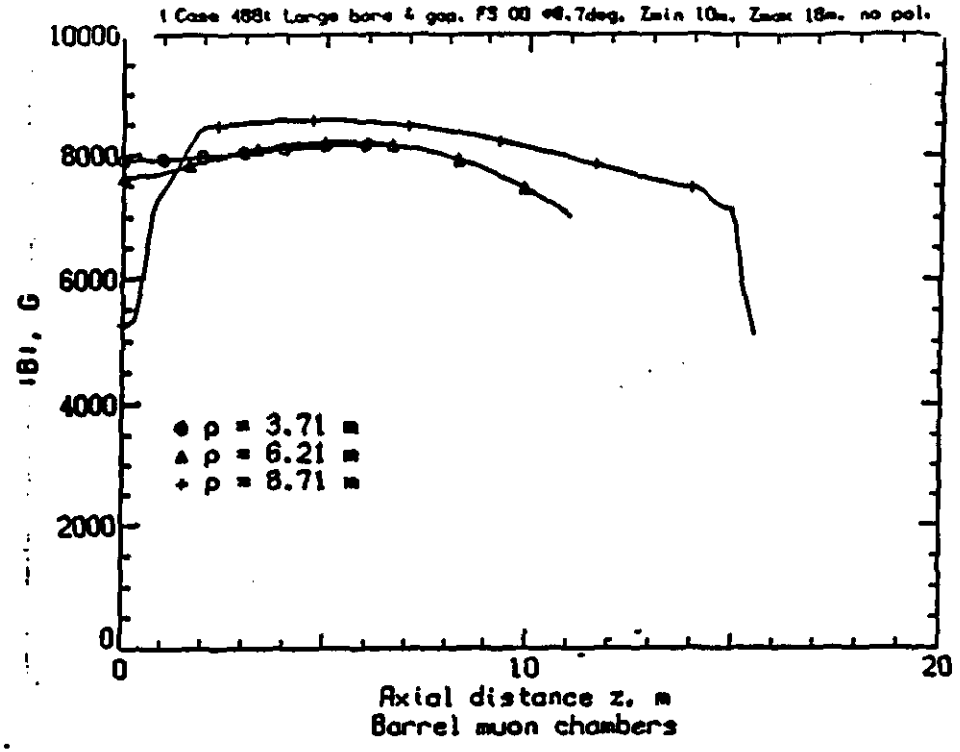
(in process of evaluation)

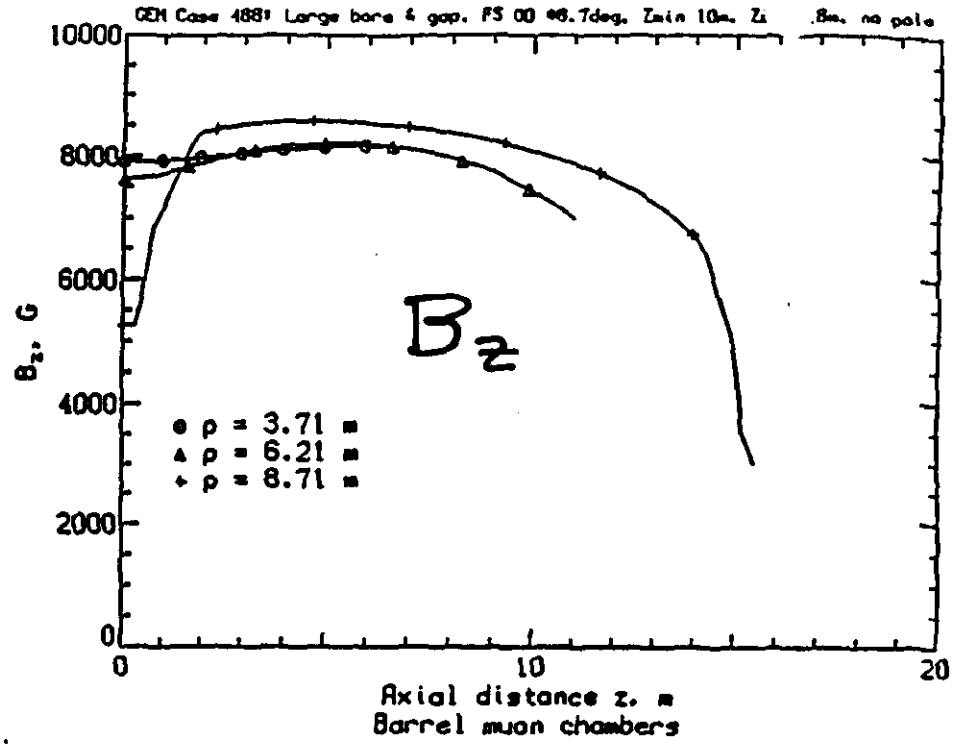
(1) Lorentz angle correction more complicated:

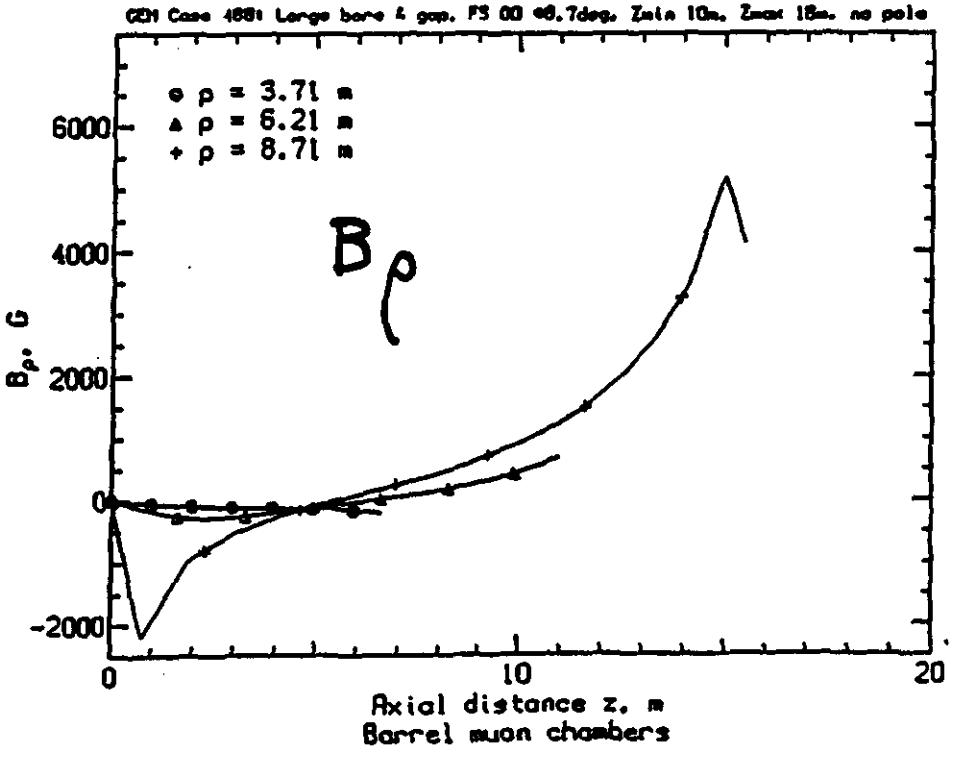
EC chambers see large radial as well as axial components
Barrel chambers have a significant radial component at large Z

(2) Field integral measurements mandatory:

Criterion: $\delta (BL^2) / BL^2 \approx 0.5$ %
especially critical at $\eta \approx 2.5$

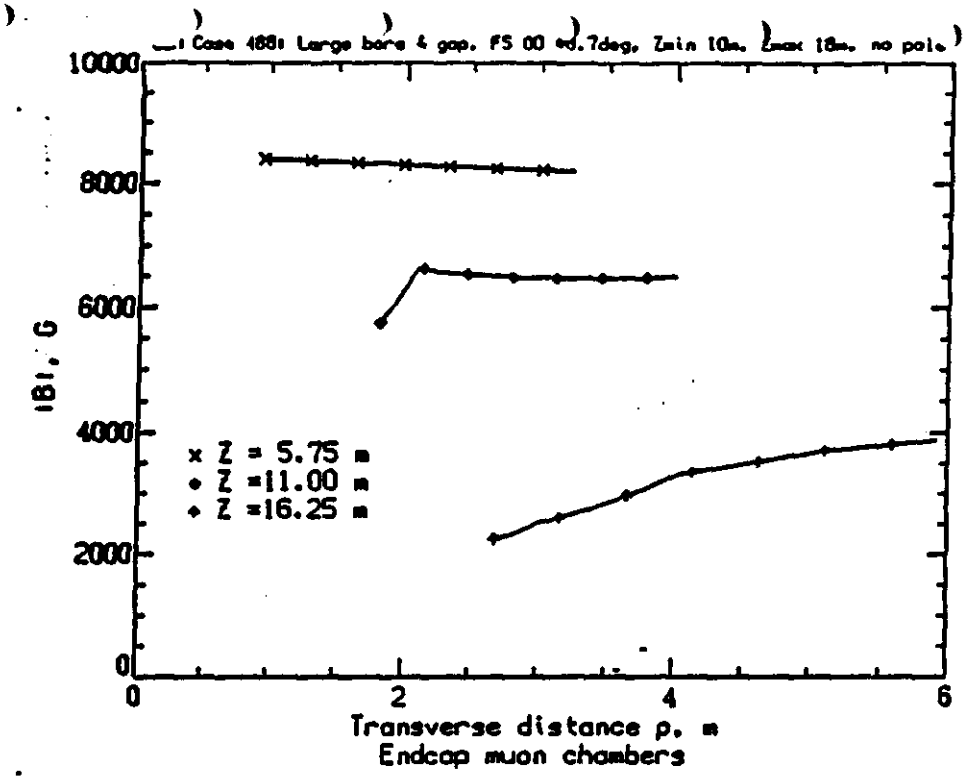


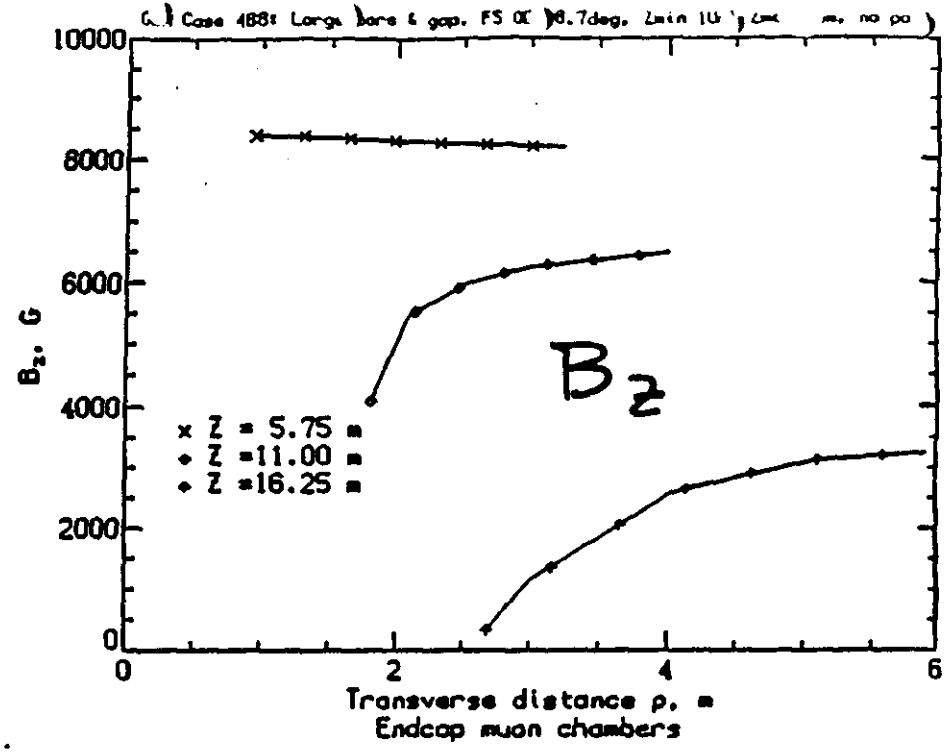


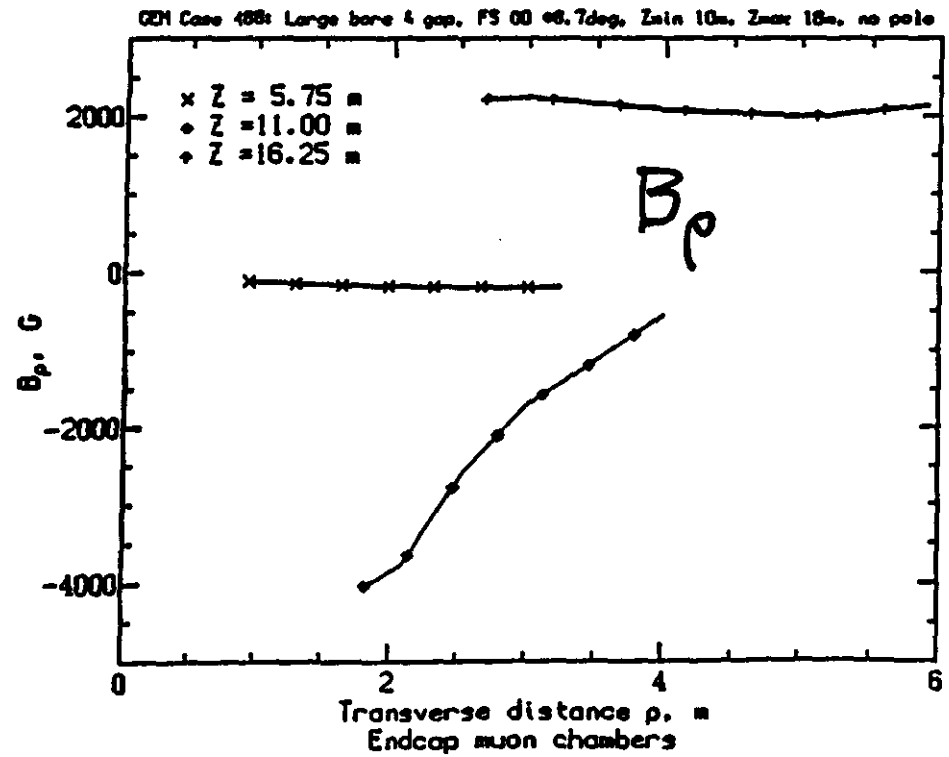


Field Components – Barrel

Fig. 3.4 a







Field Components – EC

Fig. 3.4 b

Field Mapping Concept:

Use a finite number of measurements and an analytic fit to determine field in active detector volume.

Only need measure one component of the field as $B = \nabla \Psi_m$,

$$\Psi_m = c^i f_i$$

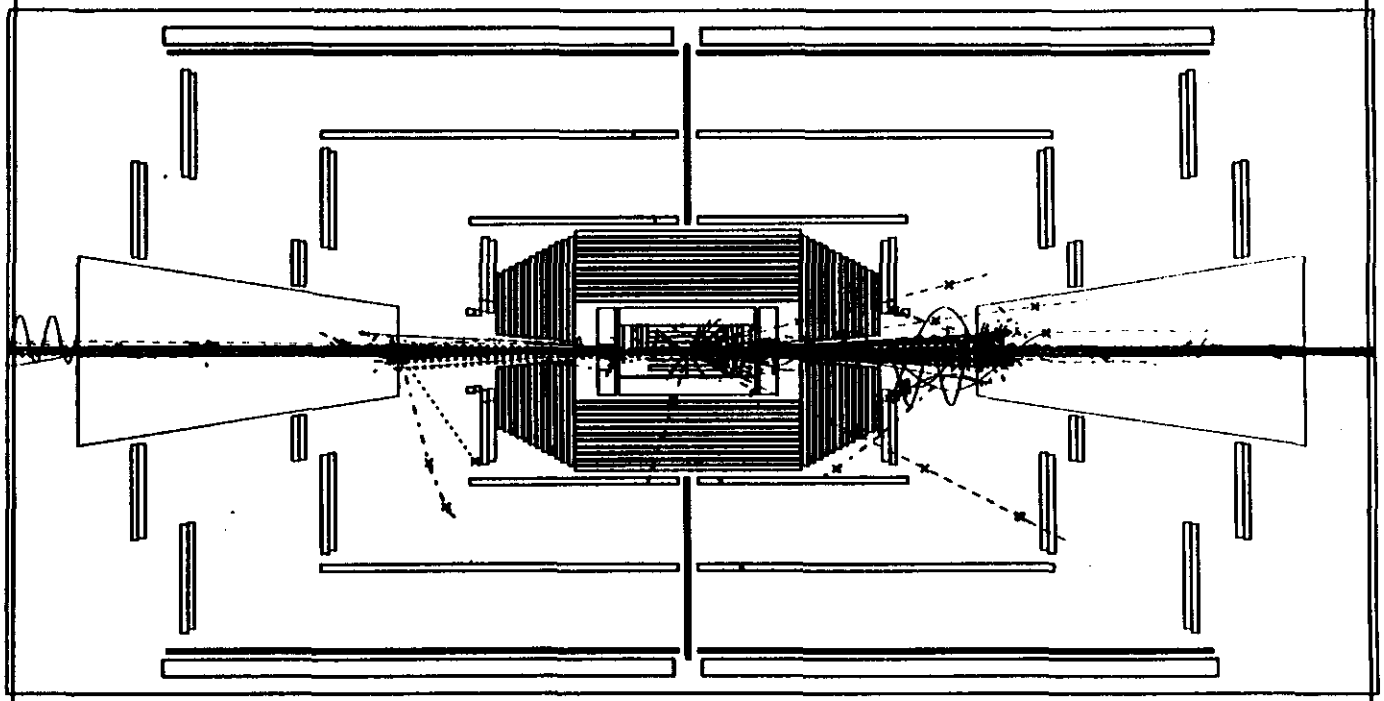
where Ψ_m is the magnetic scalar potential, c^i are the coefficients, and f_i are basis functions. So that,

$$B_\rho = \frac{1}{\rho}\frac{\partial \Psi_m}{\partial \rho} = \frac{c^i}{\rho}\frac{\partial f_i}{\partial \rho}$$

GEM

GEM Endcap Muon System

3/ 3/92



Properties of the Calorimeter:

(1) Hadron Punchthrough:
(R. McNeil)

Barrel Region: $0 < \eta < 1.3$

Criteria for determining calorimeter depth:

(1) For $L \approx 10^{34}$ /cm^2 sec rate of particles in first superlayer should be < 20 Hz/cm^2.

Find number of $\lambda > 10$

(2) The overall rate of particles exiting the calorimeter from hadron punchthrough should be much less than the sum of rates from prompt muons and π/K decay muons.

Find number of $\lambda > 12$

(3) The rate of particles with transverse momenta above a trigger threshold from hadron punchthrough should be less than that from prompt muons and π/K decay muons.

Find number of $\lambda > 10$

Conclusion:

Number of interaction lengths in barrel section of calorimeter should be thicker than 12 λ.

Endcaps will probably require 14 λ (being evaluated).

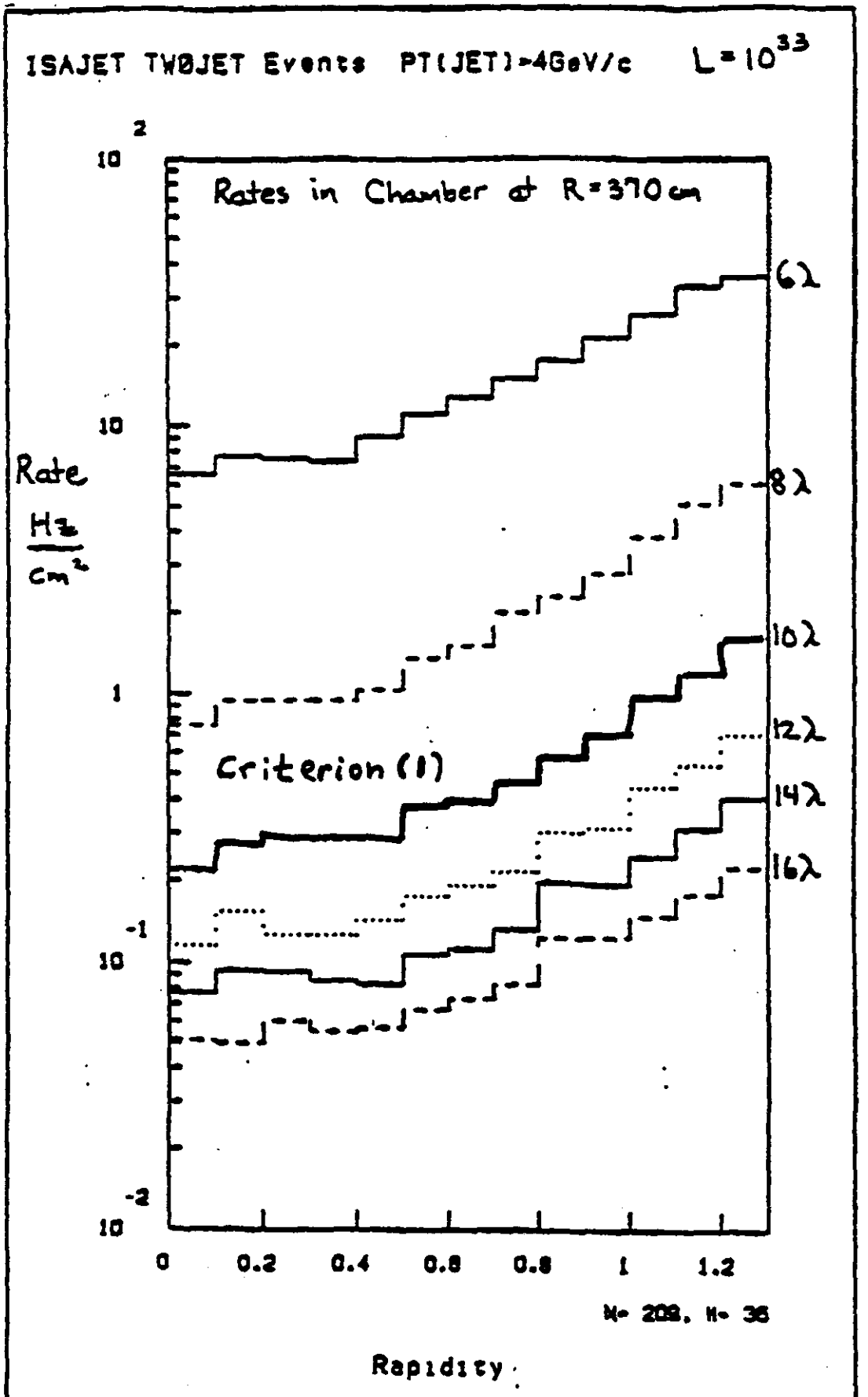
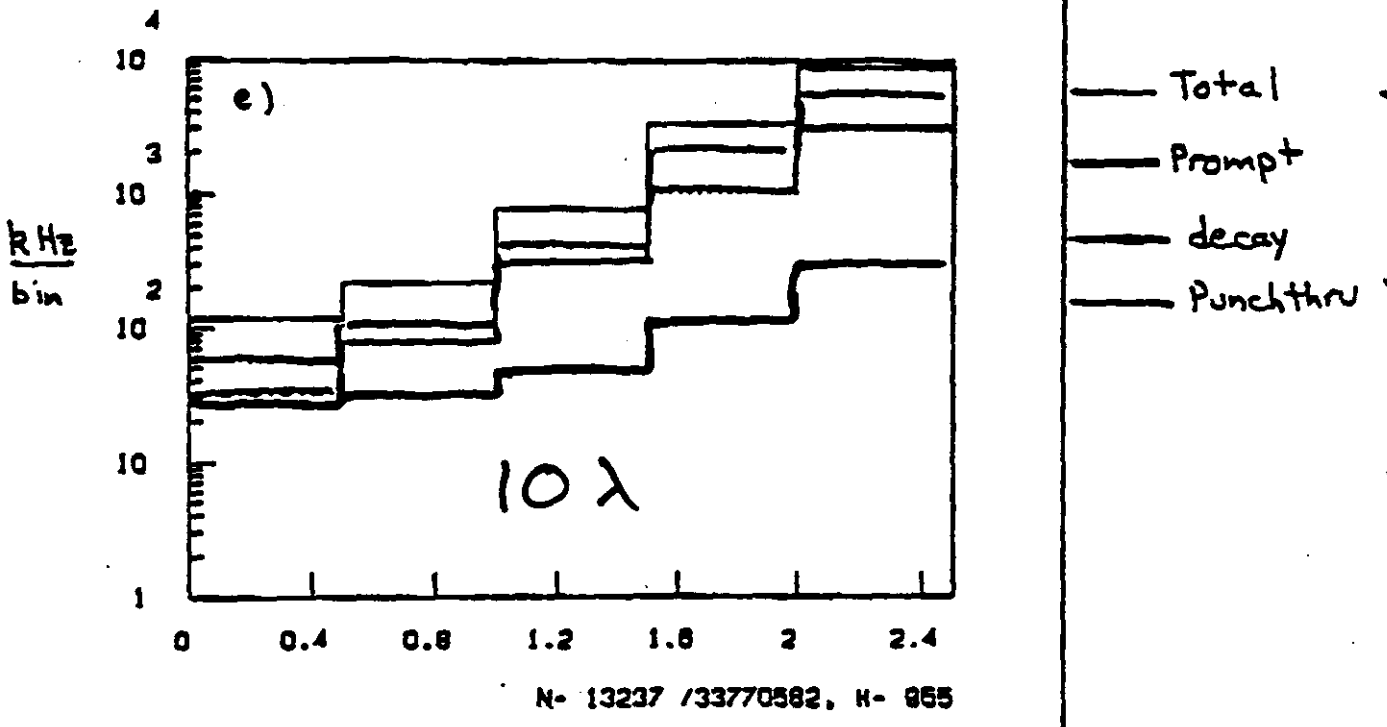
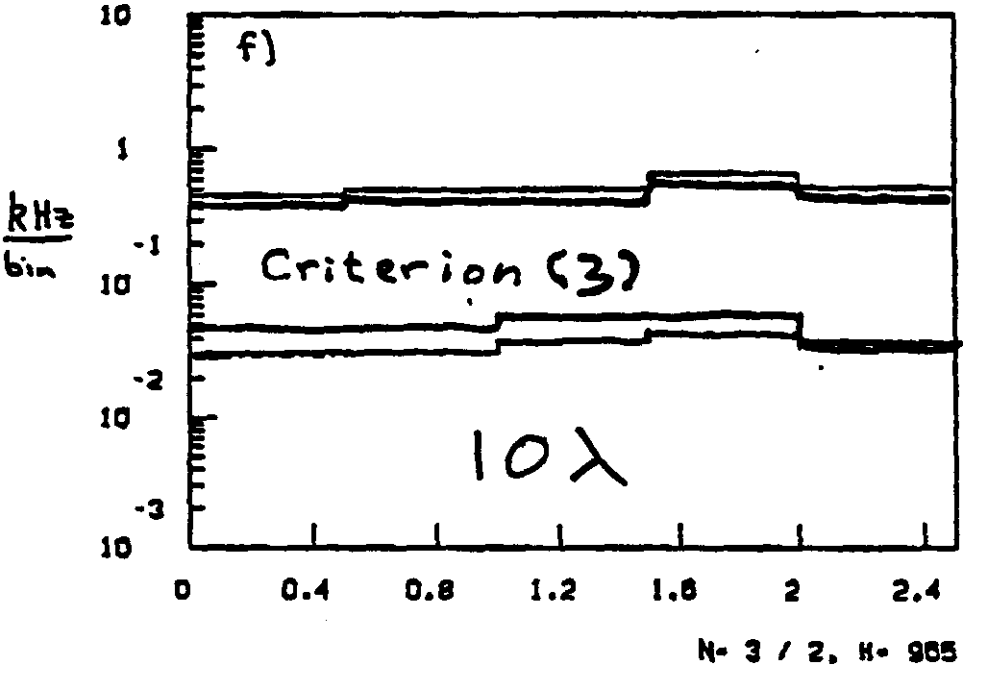

ISAJET TWOJET Events PT(JET)>4GeV/c L=10^33
Rates in Chamber at R=370 cm
Rate Hz/cm^2
6λ
8λ
10λ
12λ
14λ
16λ
Criterion (1)
Rapidity
Rates after Constant Thickness Calorimeter

Figure 3

ISAJET TWØJET Events PT(JET)>4GeV/c L=10^{33}



|ETA| All PT

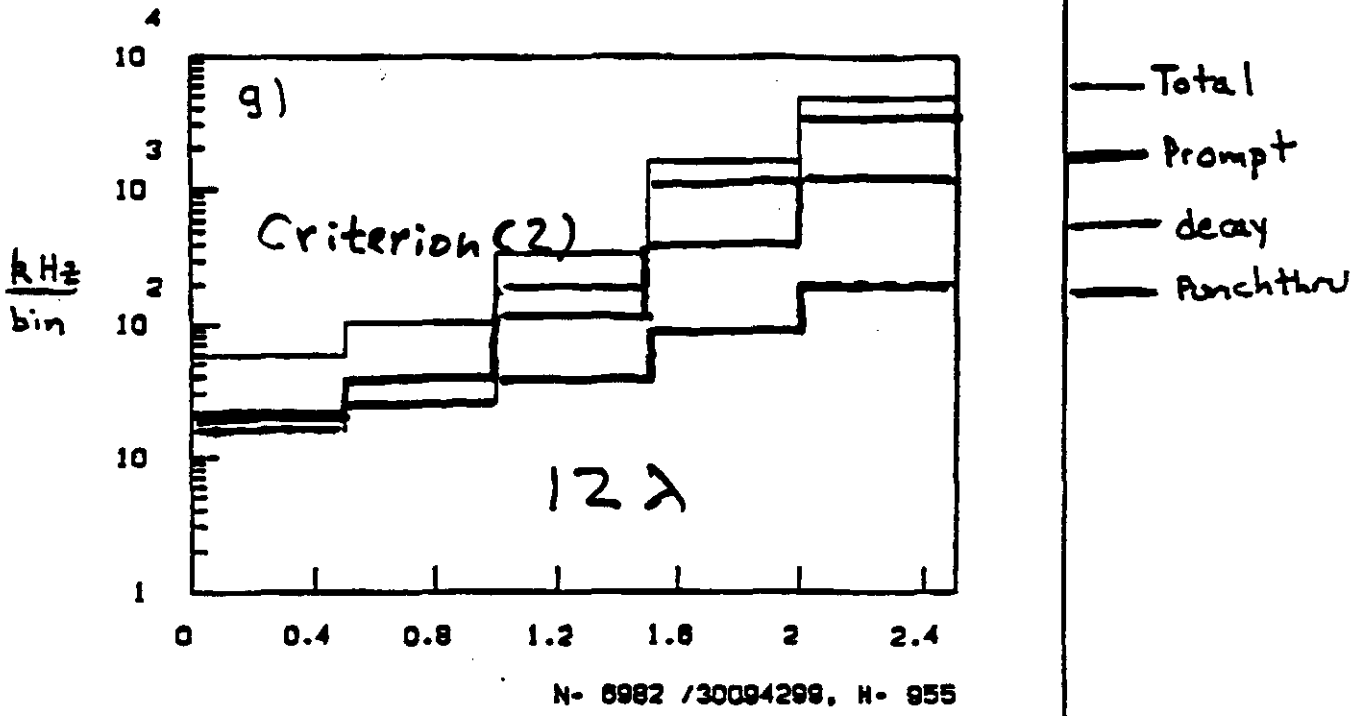


|ETA| PT .gt. 10GeV/c

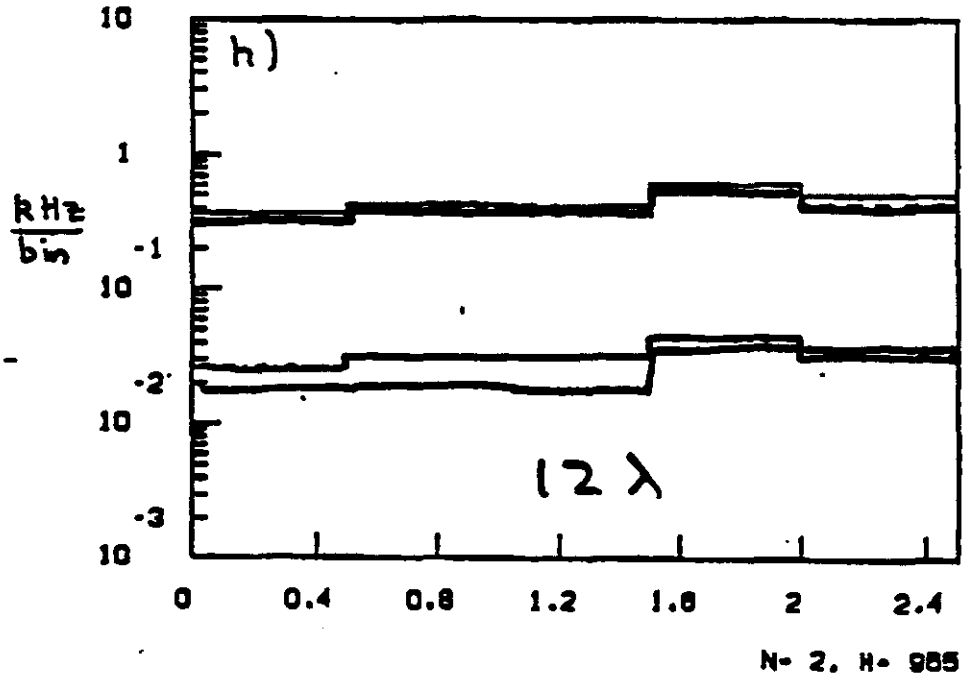
Rates after Constant Thickness Calorimeter - 10λ

Figure 4e-f

ISAJET TWØJET Events PT(JET)>4GeV/c $L=10^{33}$



|ETA| All PT

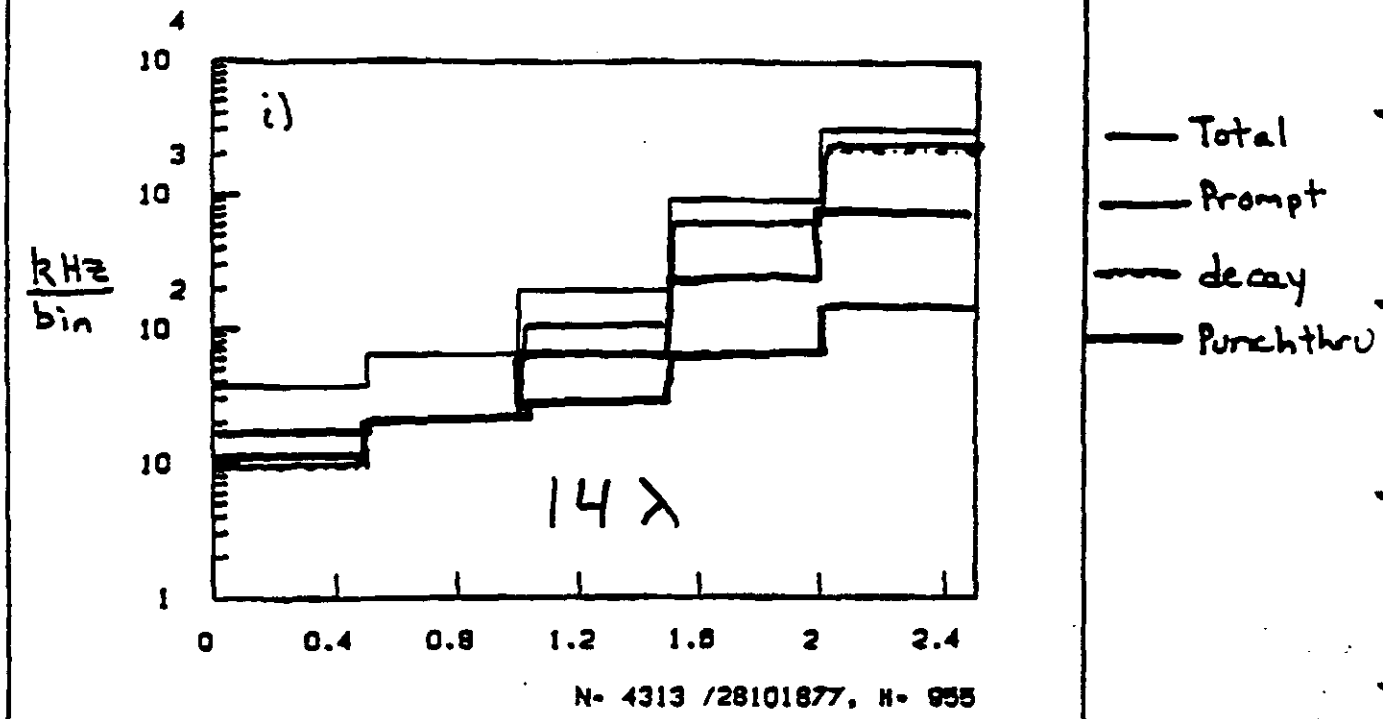


|ETA| PT .gt. 10GeV/C

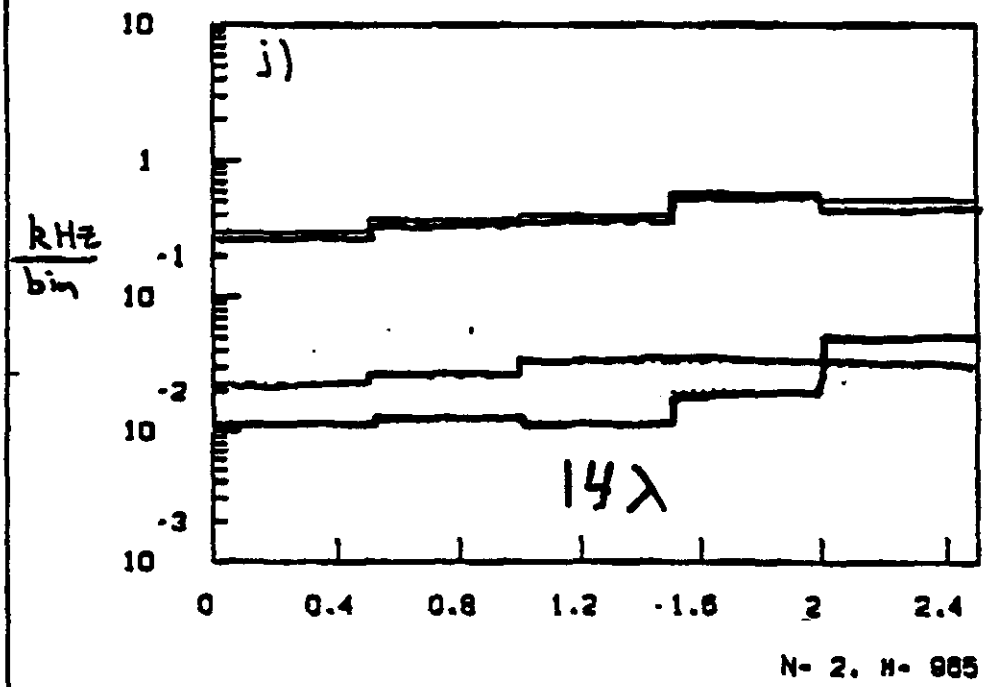
Rates after Constant Thickness Calorimeter - 121

Figure 4 g-h

ISAJET TWØJET Events PT(JET)>4GeV/c $L=10^{33}$



|ETA| All PT



|ETA| PT .gt. 10GeV/c

Rates after Constant Thickness Calorimeter - 141

Figure 4 i-j

(2) Fluctuations of energy loss in calorimeter:

(R. McNeil and F. Taylor)

Problem:

Landau $\Delta E\mu$ in calorimeter can not be measured

How Bad?

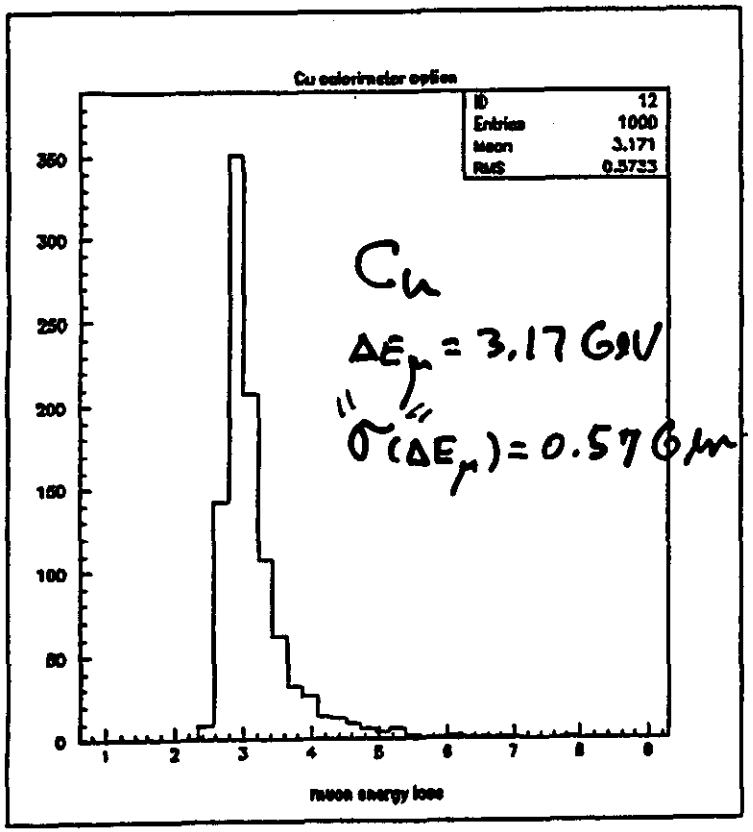
Use GEANT to simulate $\Delta E\mu$ distribution
Compute RMS($\Delta E\mu$)/$E\mu$ versus $E\mu$. Add to resolution smearing of magnet system.

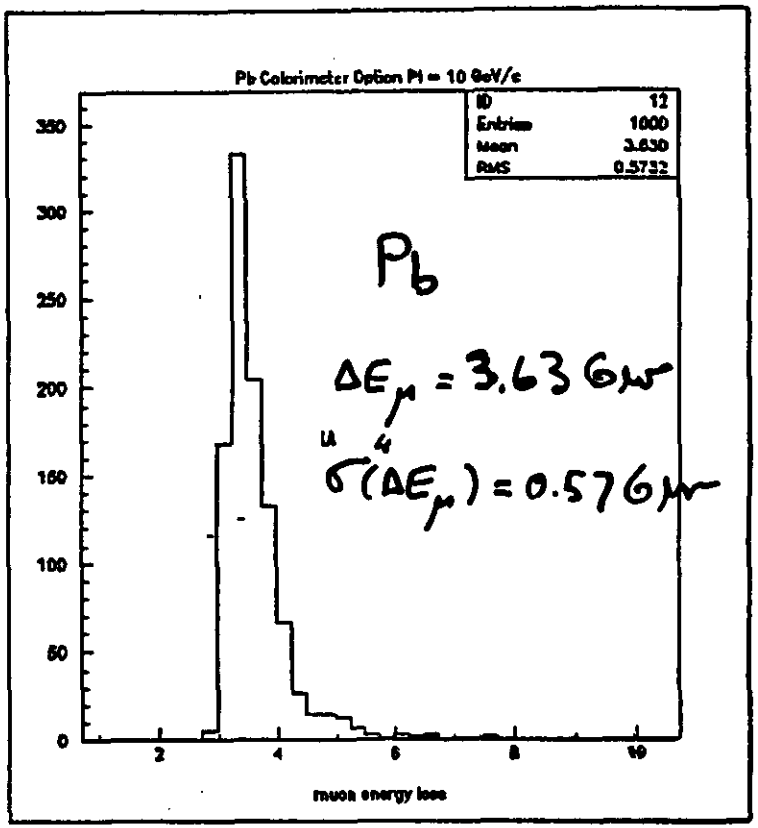
Conclusion:

Find significant contribution at low $E\mu$:
Effect dominates for $10 < E\mu < 100$ GeV
Cu calorimeter better than Pb

Fig. 5.2.2 a

E_μ Loss through 12 λ





"σ" = RMS (ΔE_μ)

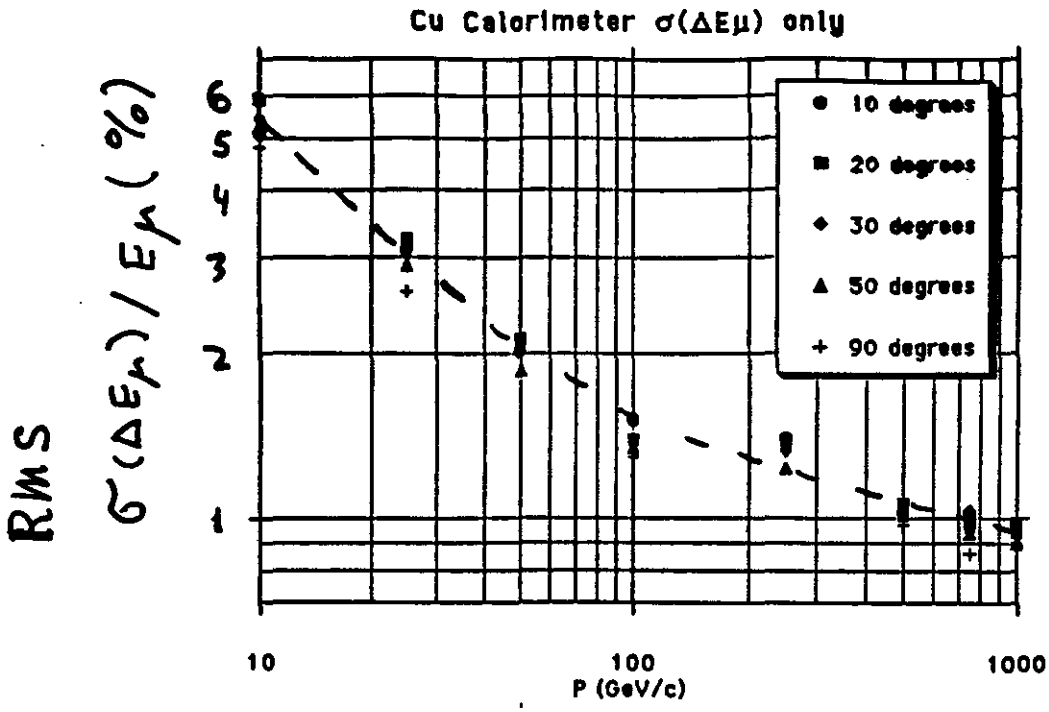


Fig. 5.2.3 a

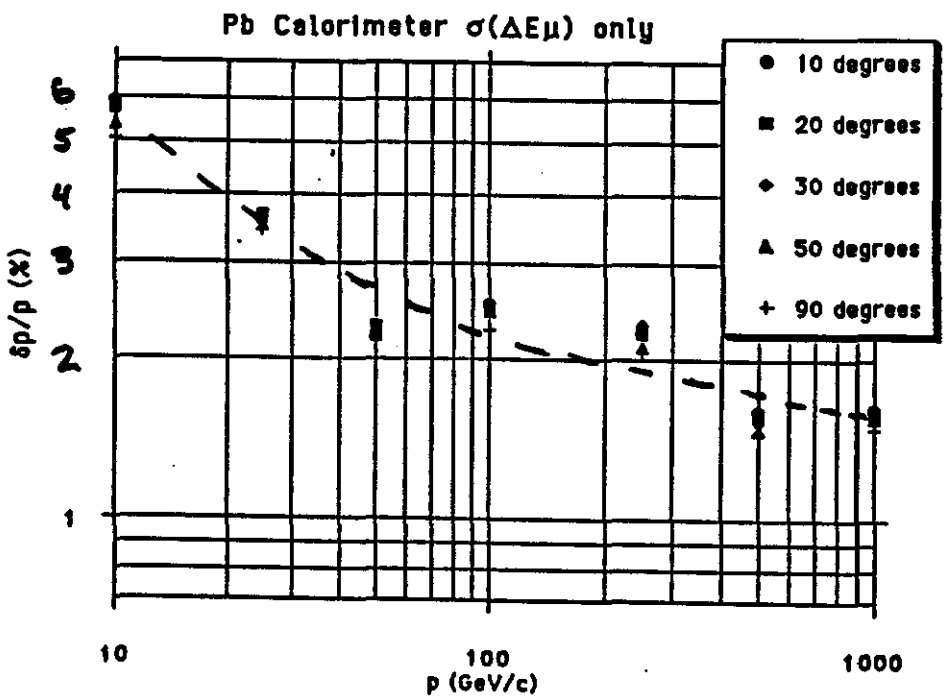
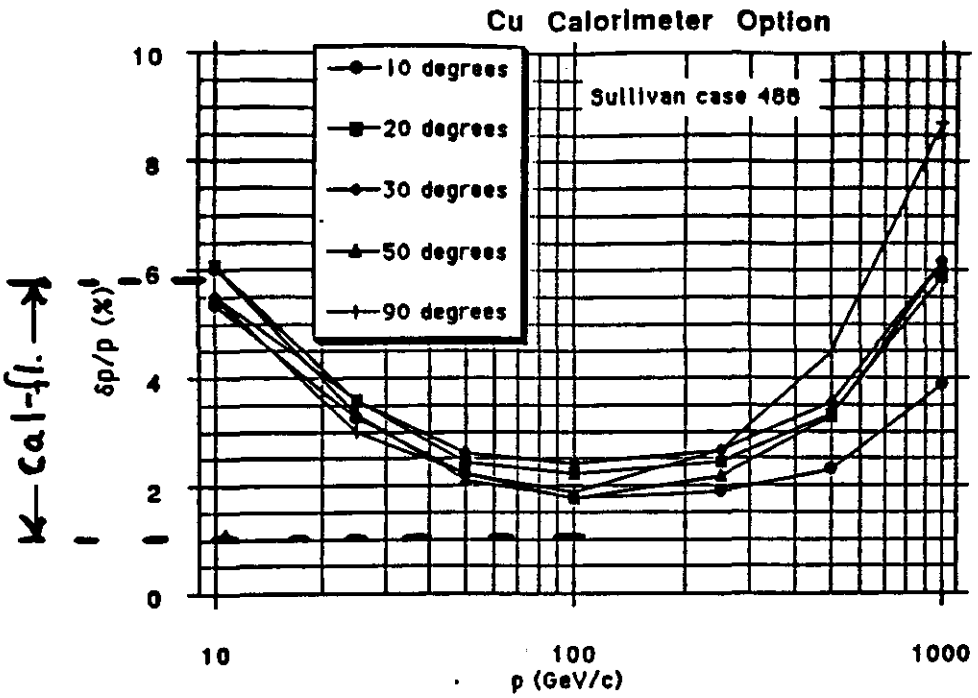


Fig. 5.2.3 b

Resolutions with $\sigma(\Delta E_\mu)$



Cu better choice than Pb

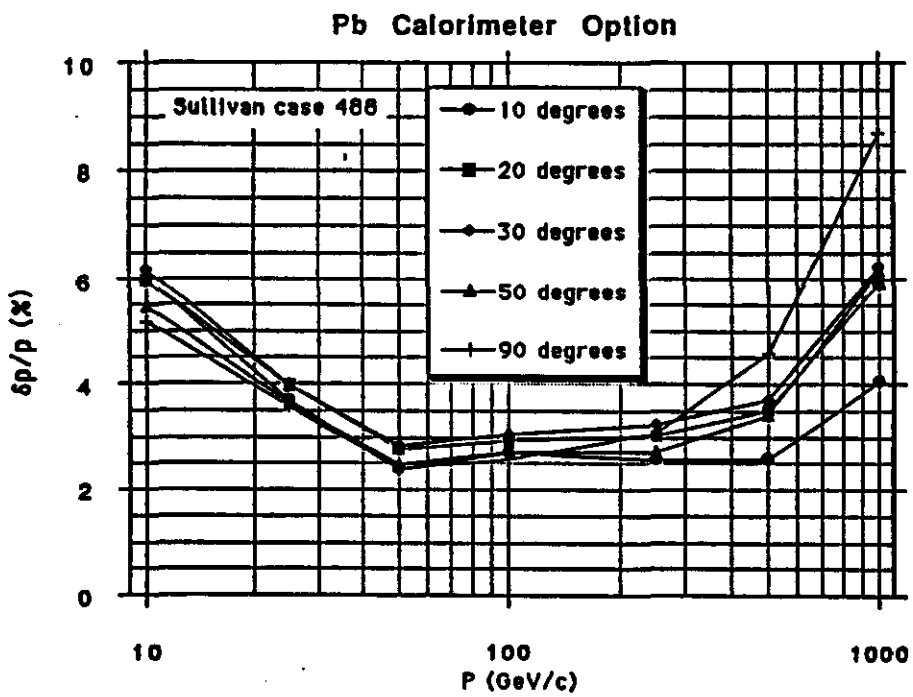


Fig. 5.3.1

Resolution of θ (non bend)

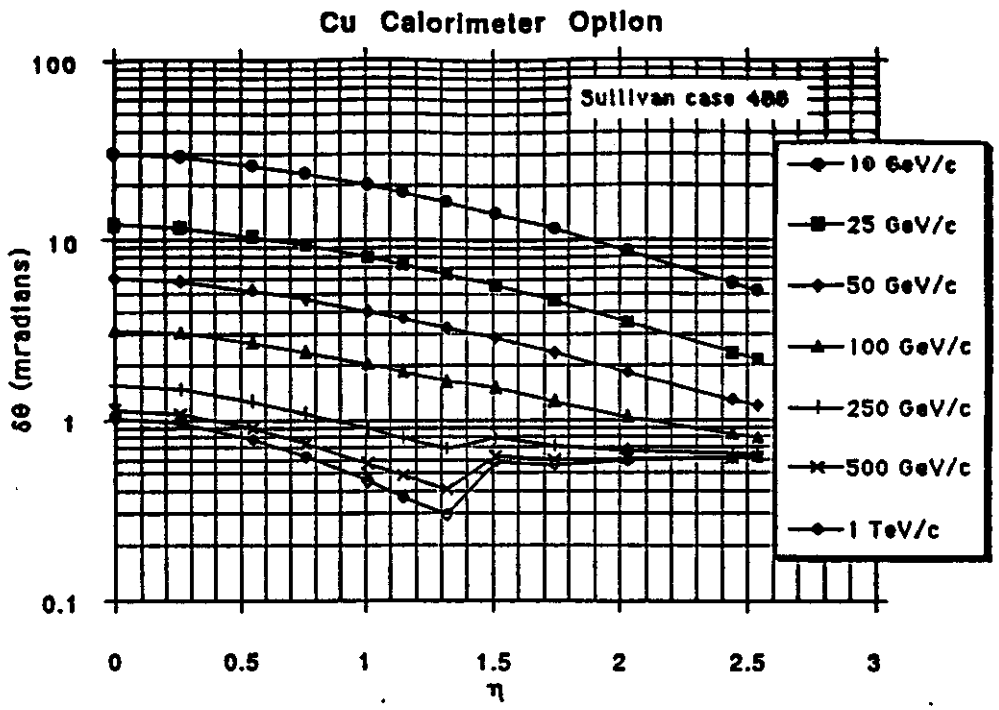


Fig. 5.2.4 a

Cu better choice than Pb

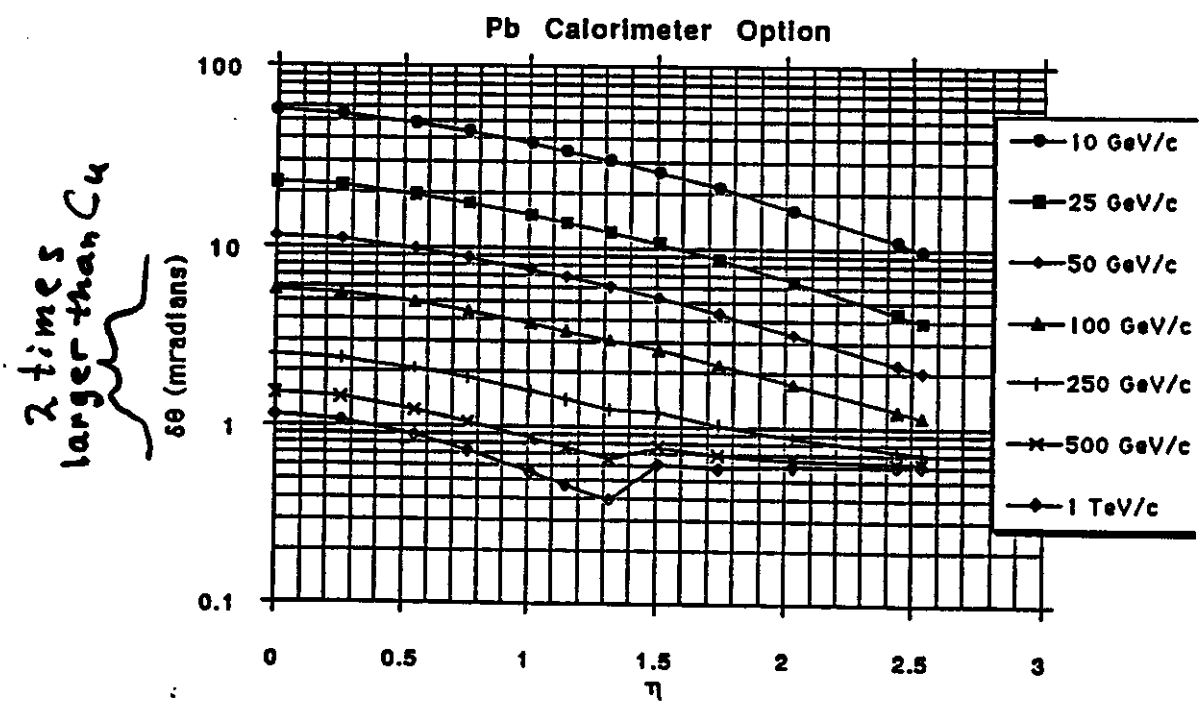


Fig. 5.2.4 b

Improvement of high momentum resolution:

(L. Rosenson)

(1) External chambers in the barrel region

(2) Constrain the primary vertex

Conclusion:

- Improves resol'n for $P_\perp \gtrsim 500$ GeV/c
- Will make muon system more robust ($\delta P_\perp / P_\perp$ only 2x worse if 1st superlayer lost.)

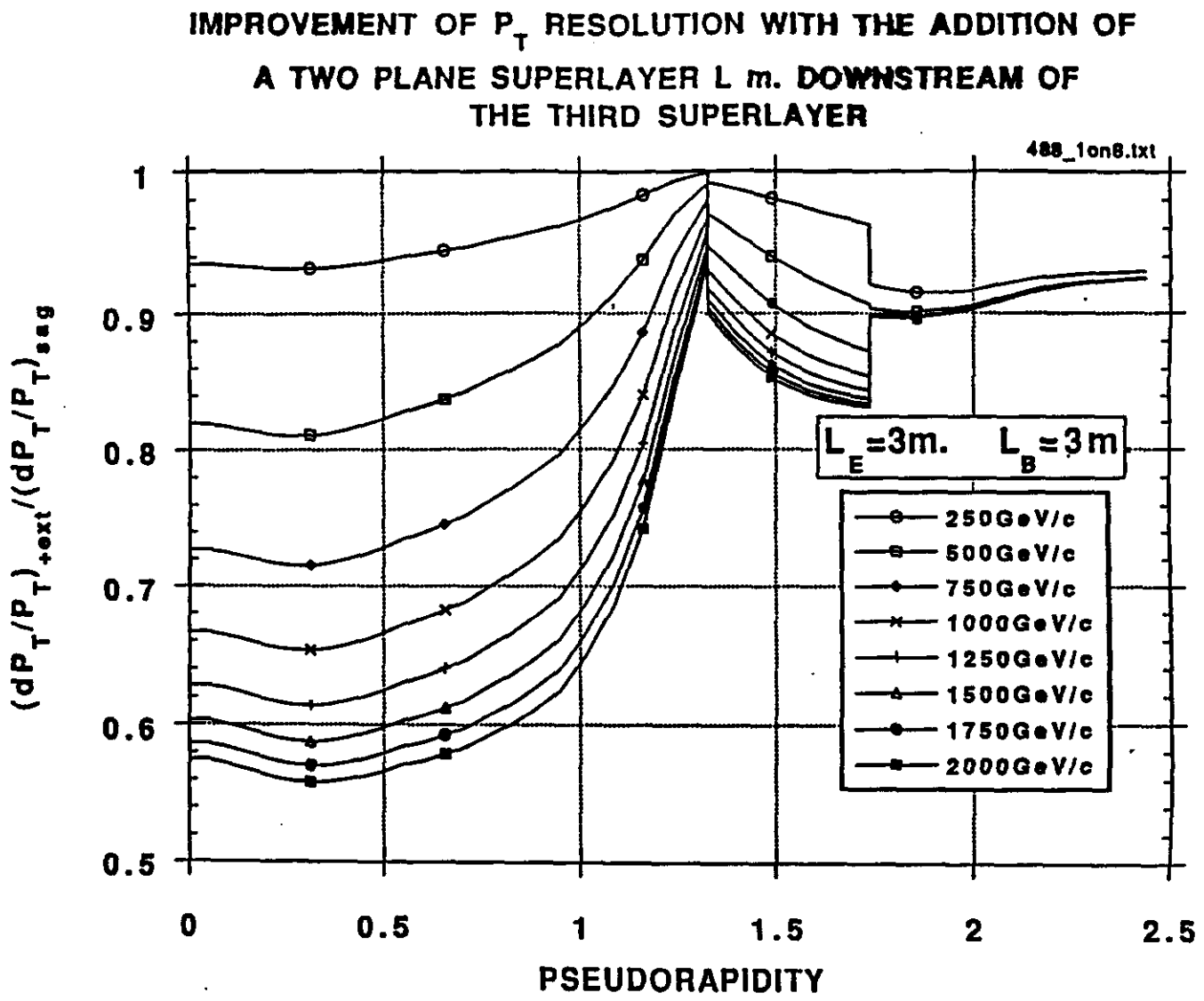

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A TWO PLANE SUPERLAYER L m. DOWNSTREAM OF
THE THIRD SUPERLAYER
488_1on8.txt
$(dP_T/P_T)_{+ext}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E=3m. L_B=3m
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.2

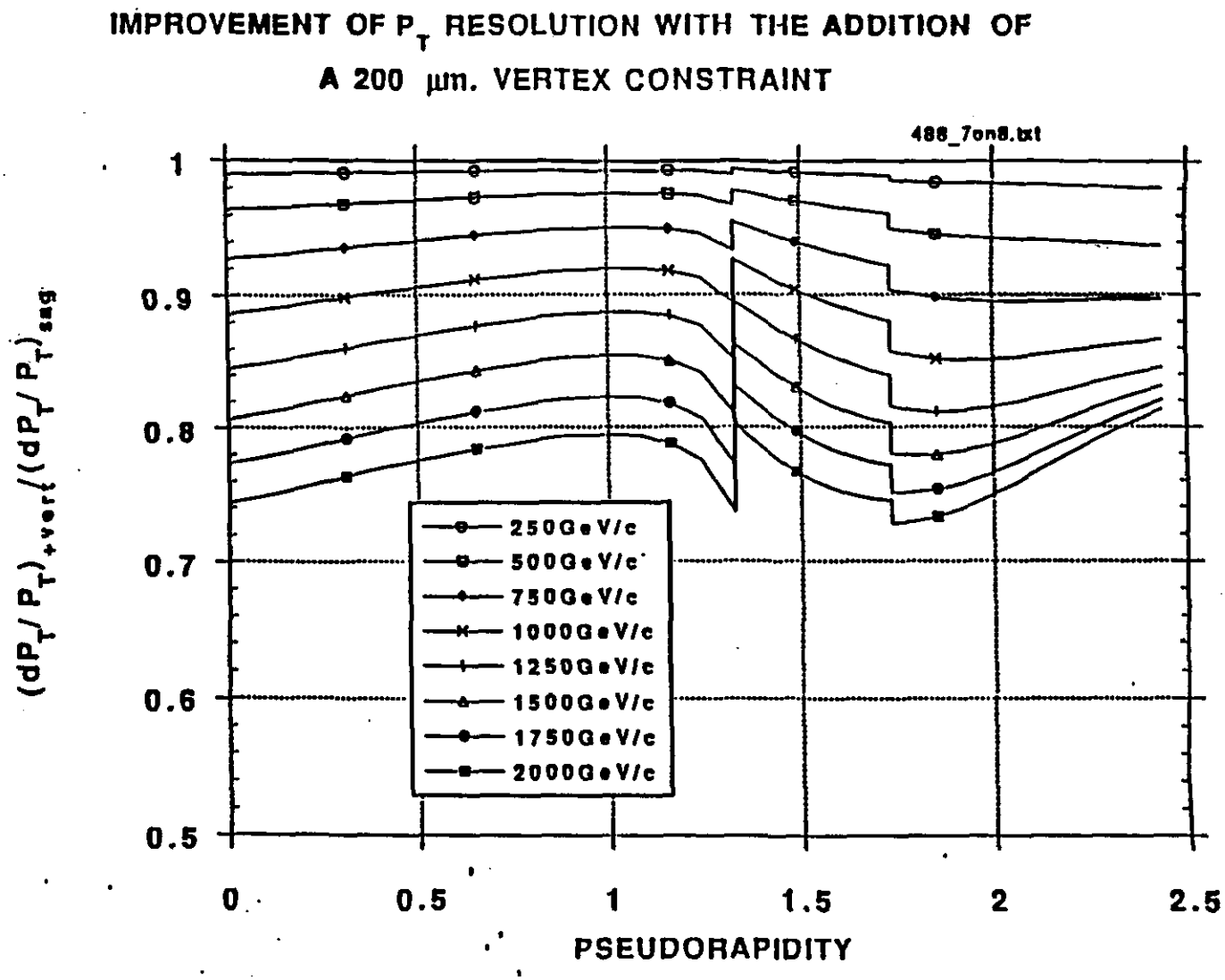

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
A 200 μm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
250GeV/c
500GeV/c
750GeV/c
1000GeV/c
1250GeV/c
1500GeV/c
1750GeV/c
2000GeV/c

Fig. 8.5

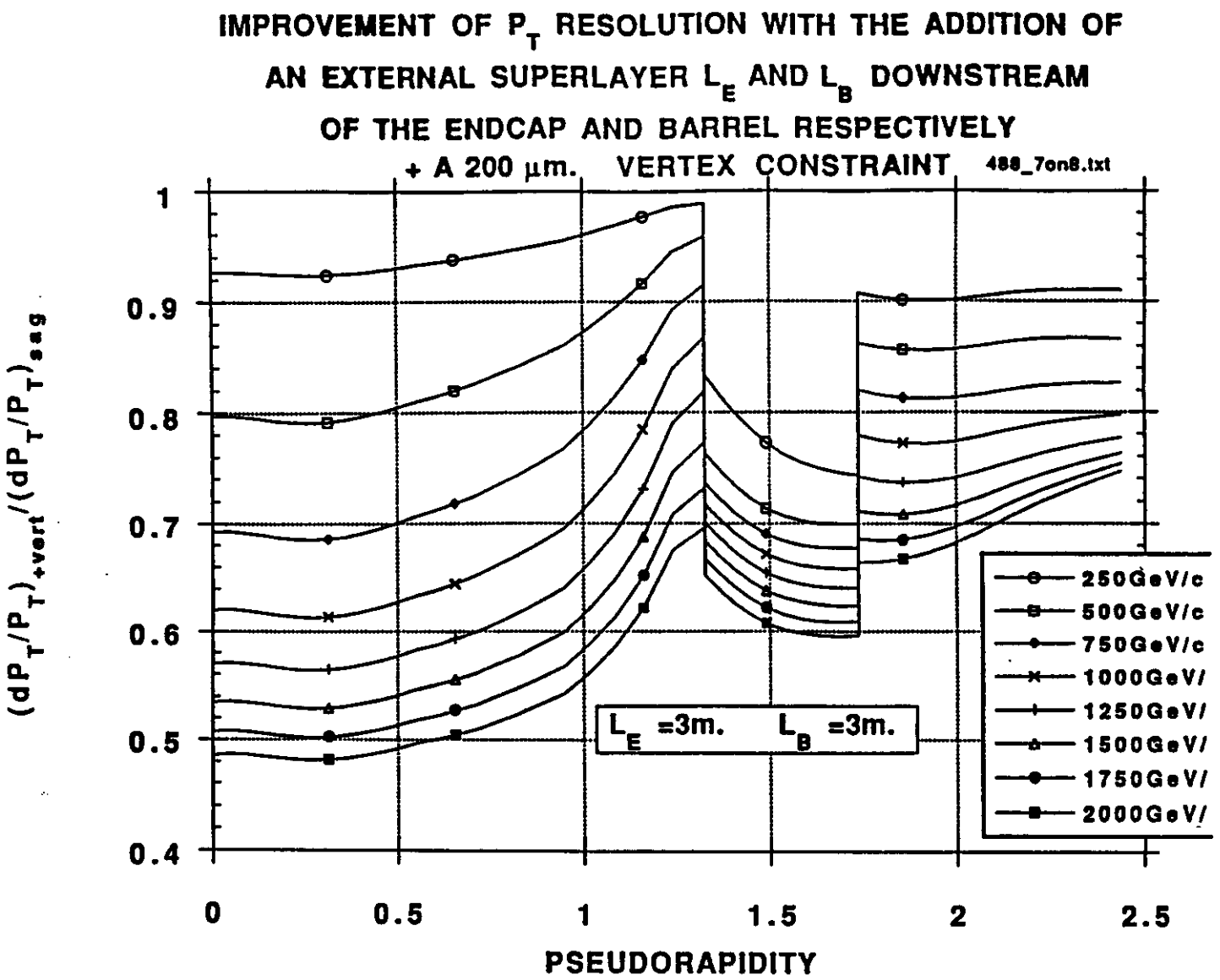

IMPROVEMENT OF P_T RESOLUTION WITH THE ADDITION OF
AN EXTERNAL SUPERLAYER L_E AND L_B DOWNSTREAM
OF THE ENDCAP AND BARREL RESPECTIVELY
+ A 200 µm. VERTEX CONSTRAINT
488_7on8.txt
$(dP_T/P_T)_{+vert}/(dP_T/P_T)_{sag}$
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
2.5
PSEUDORAPIDITY
L_E =3m. L_B =3m.
250GeV/c
500GeV/c
750GeV/c
1000GeV/
1250GeV/
1500GeV/
1750GeV/
2000GeV/

Fig. 8.6

Summary of Design:

Essential Features:

(1) Large bore magnet

(2) Flux concentrator

(3) Good chamber alignment

(4) Cu better than Pb for calorimeter

(5) 12 λ needed for barrel calorimeter

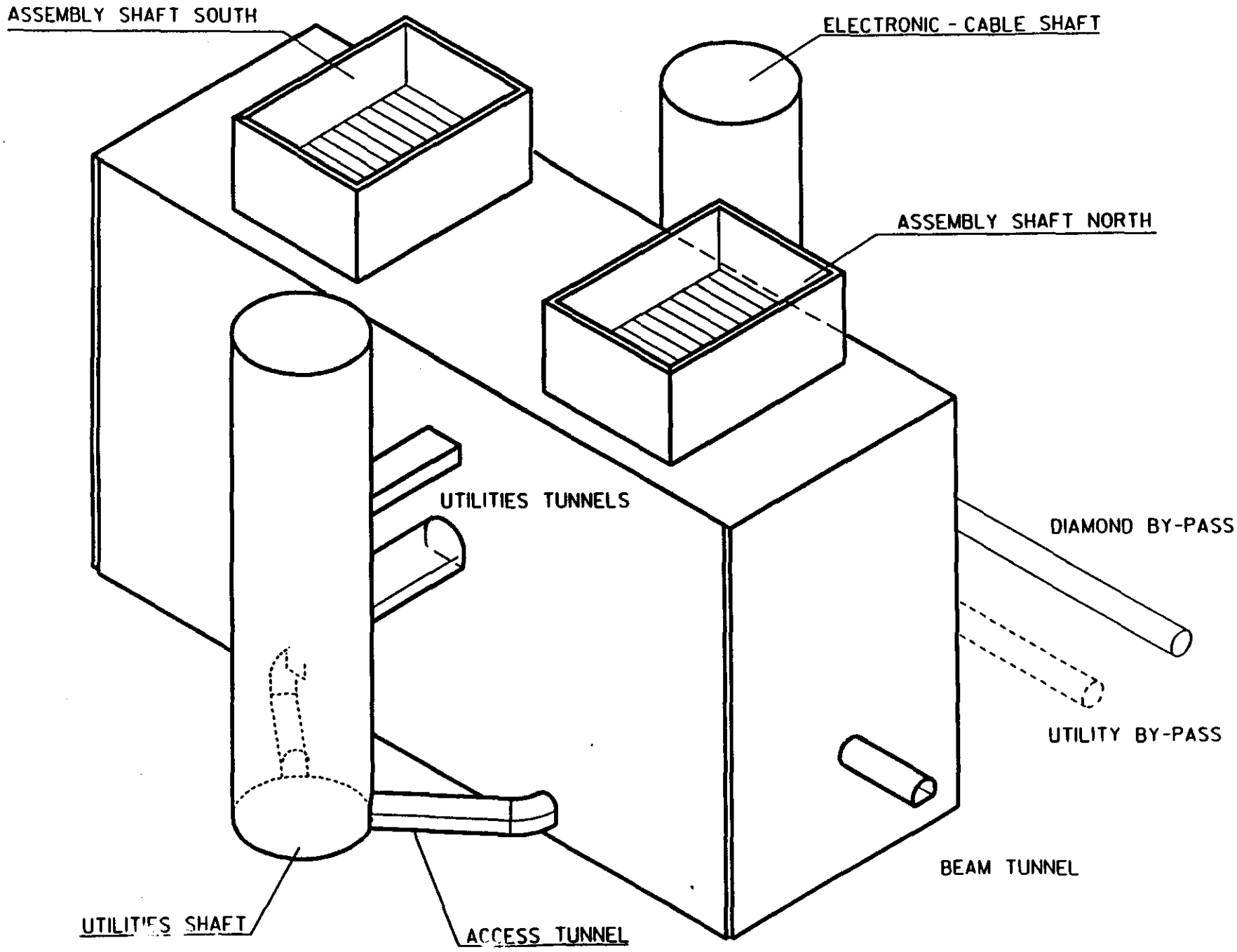
(6) (14 λ needed for endcap calorimeter)

Worthy Enhancements:

(1) External chambers in barrel region

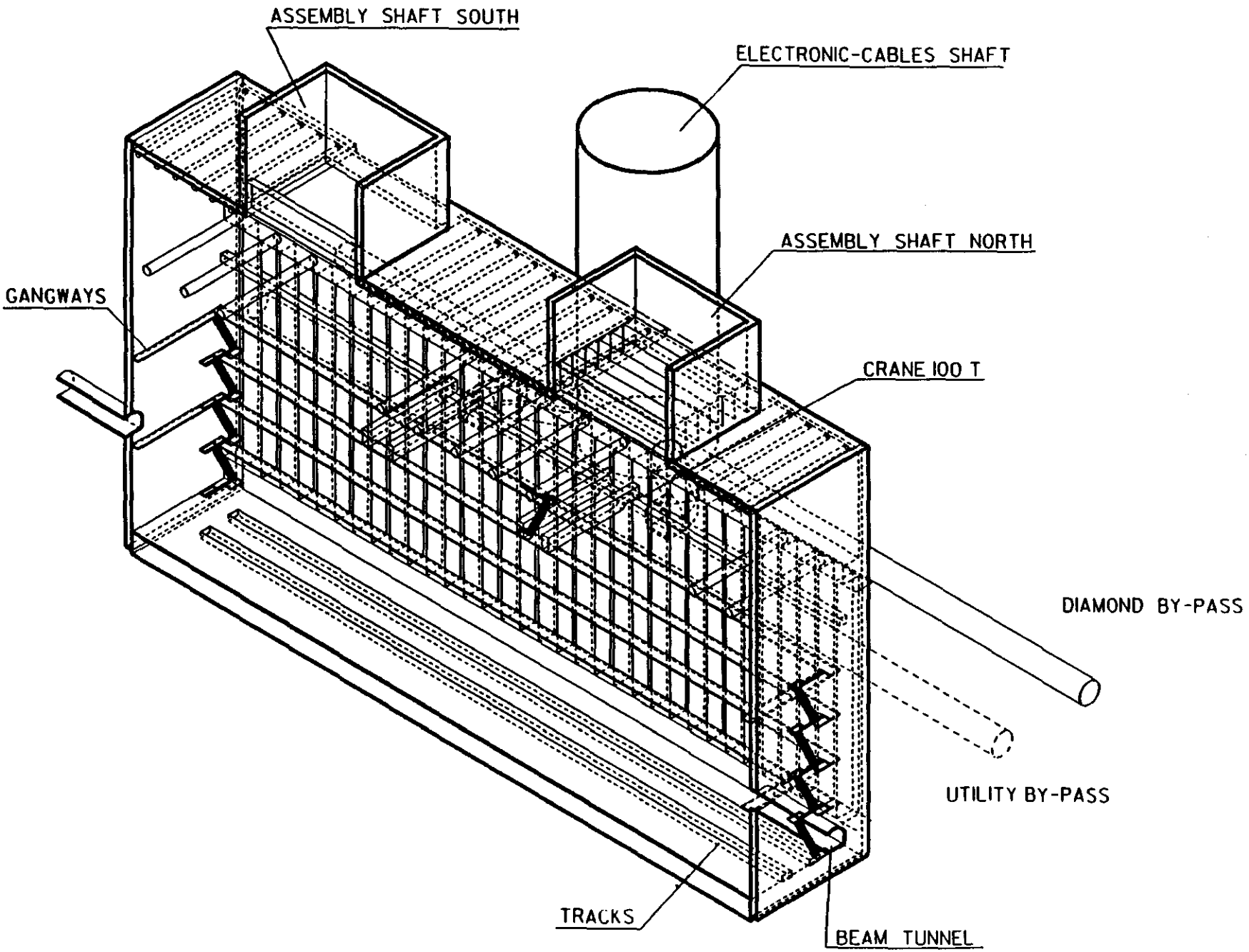
(2) Constrain primary vertex

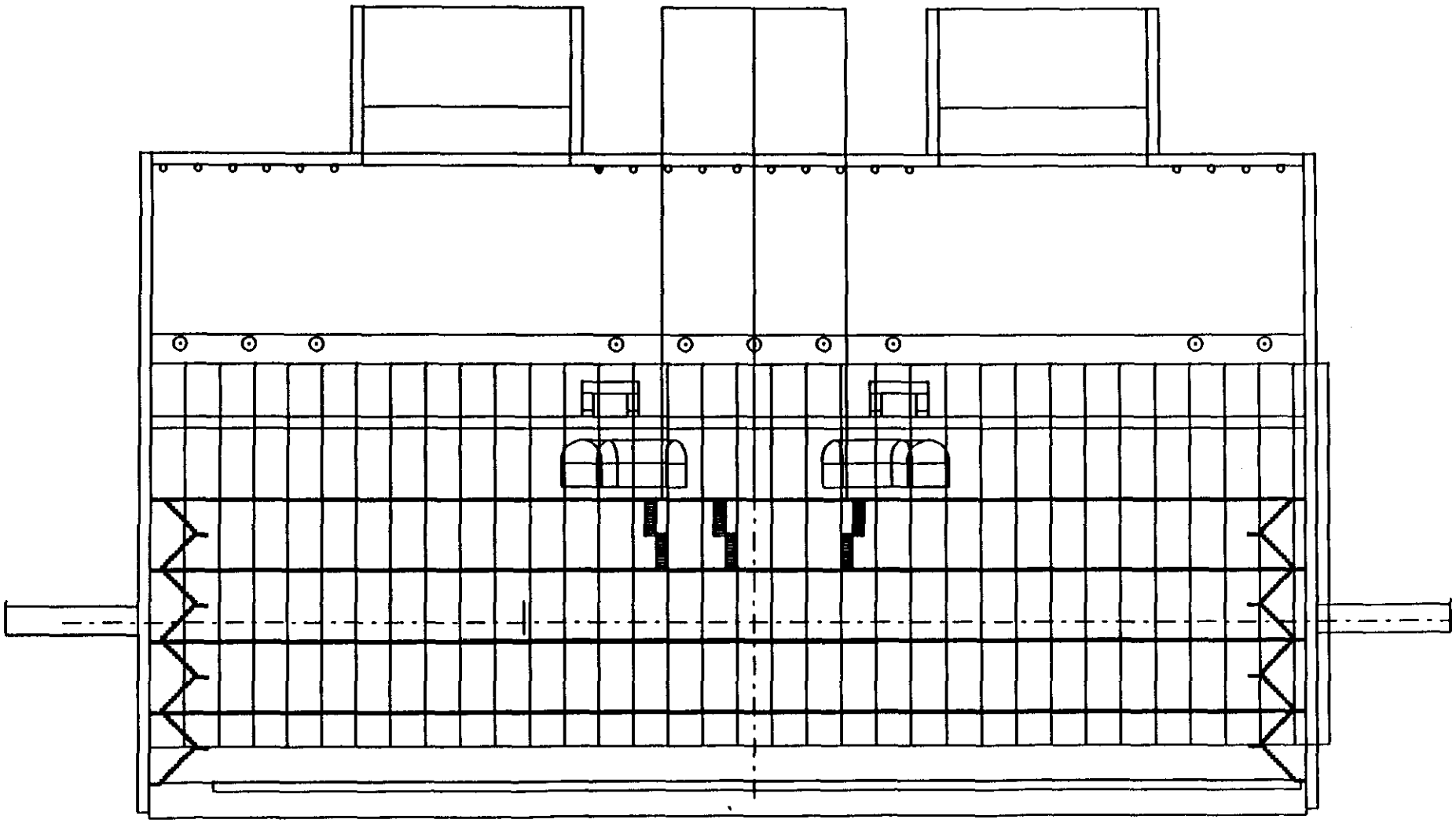
GEM EXPERIMENTAL HALL

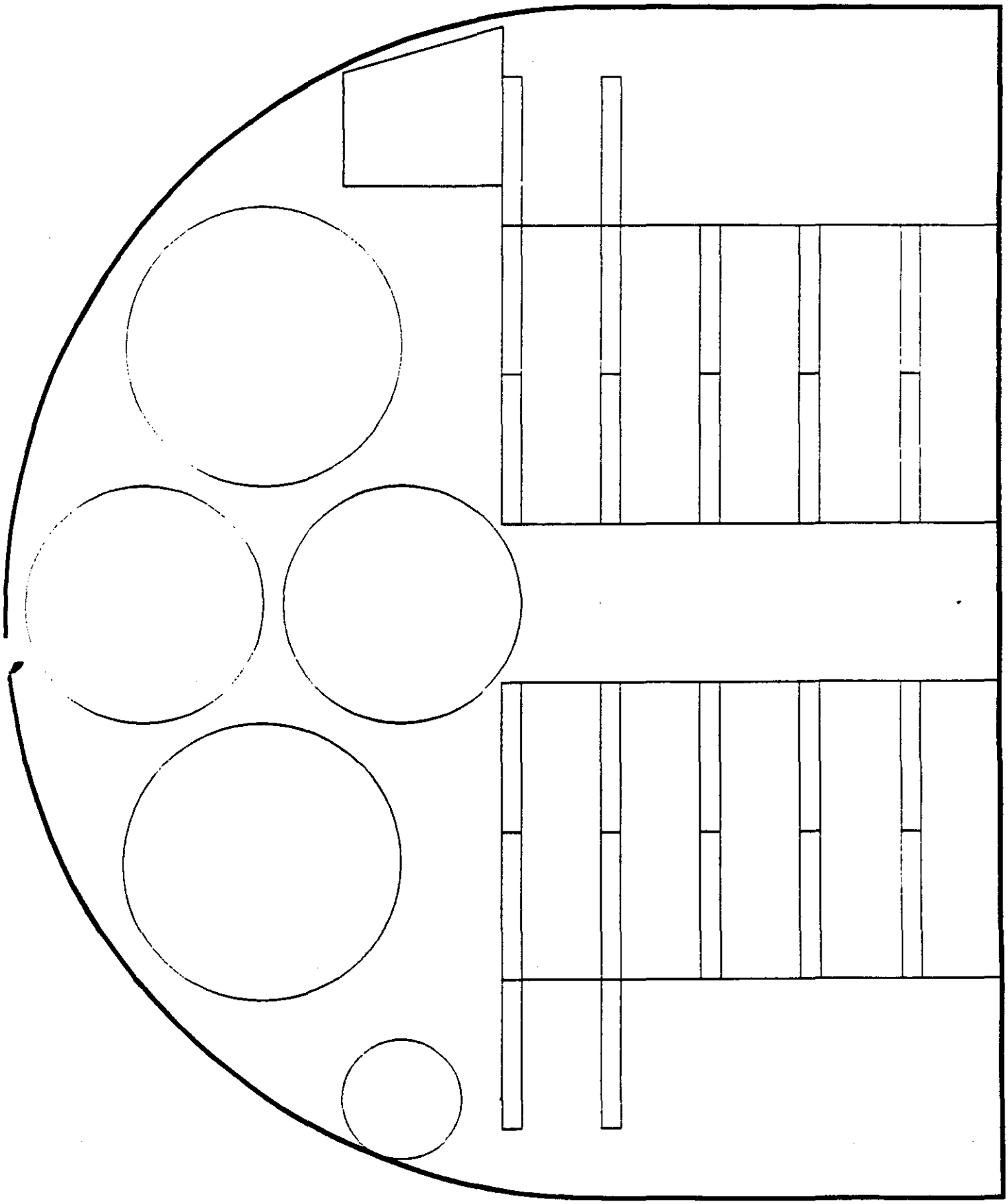


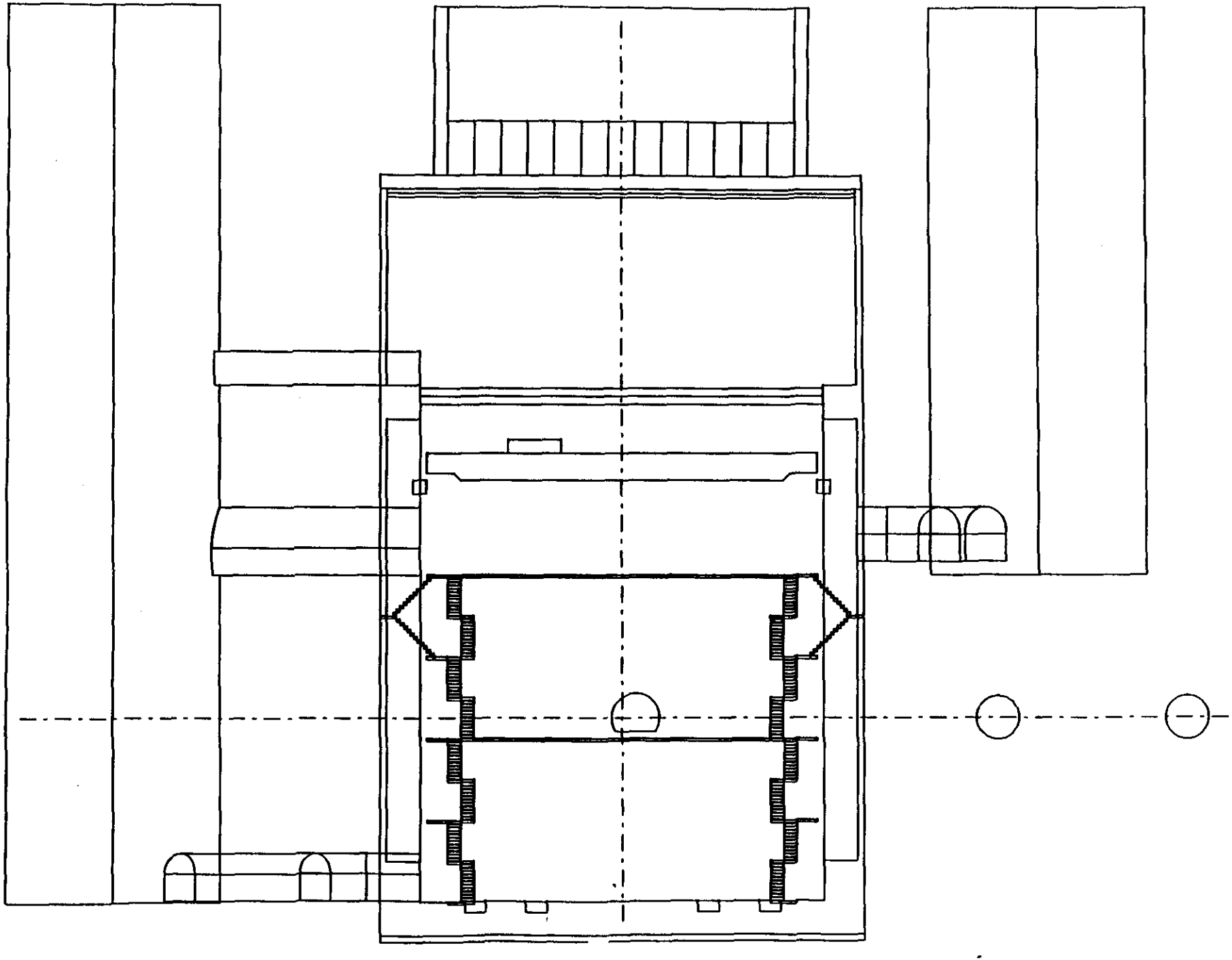
Emile Sabin

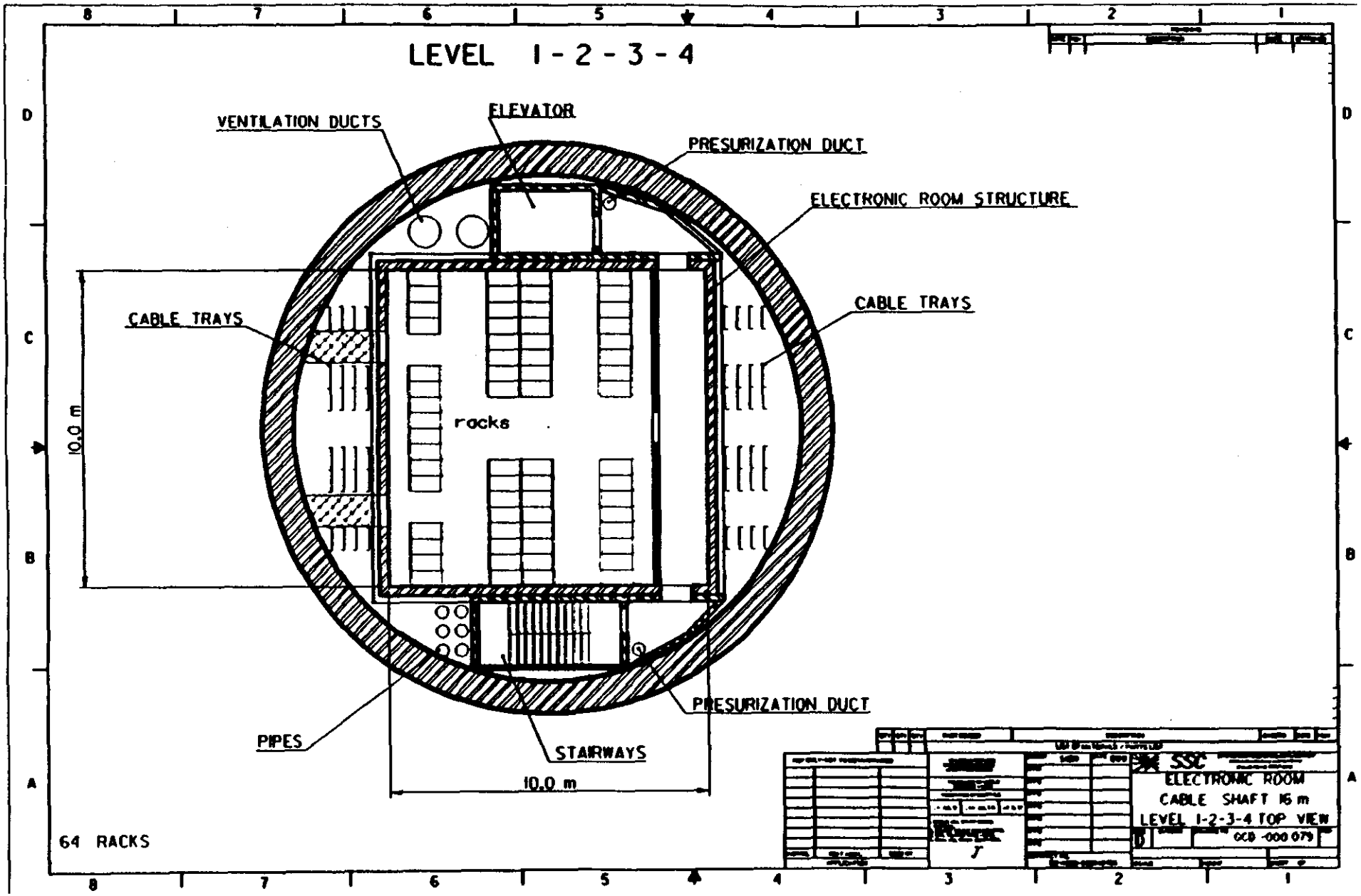
GEM EXPERIMENTAL HALL



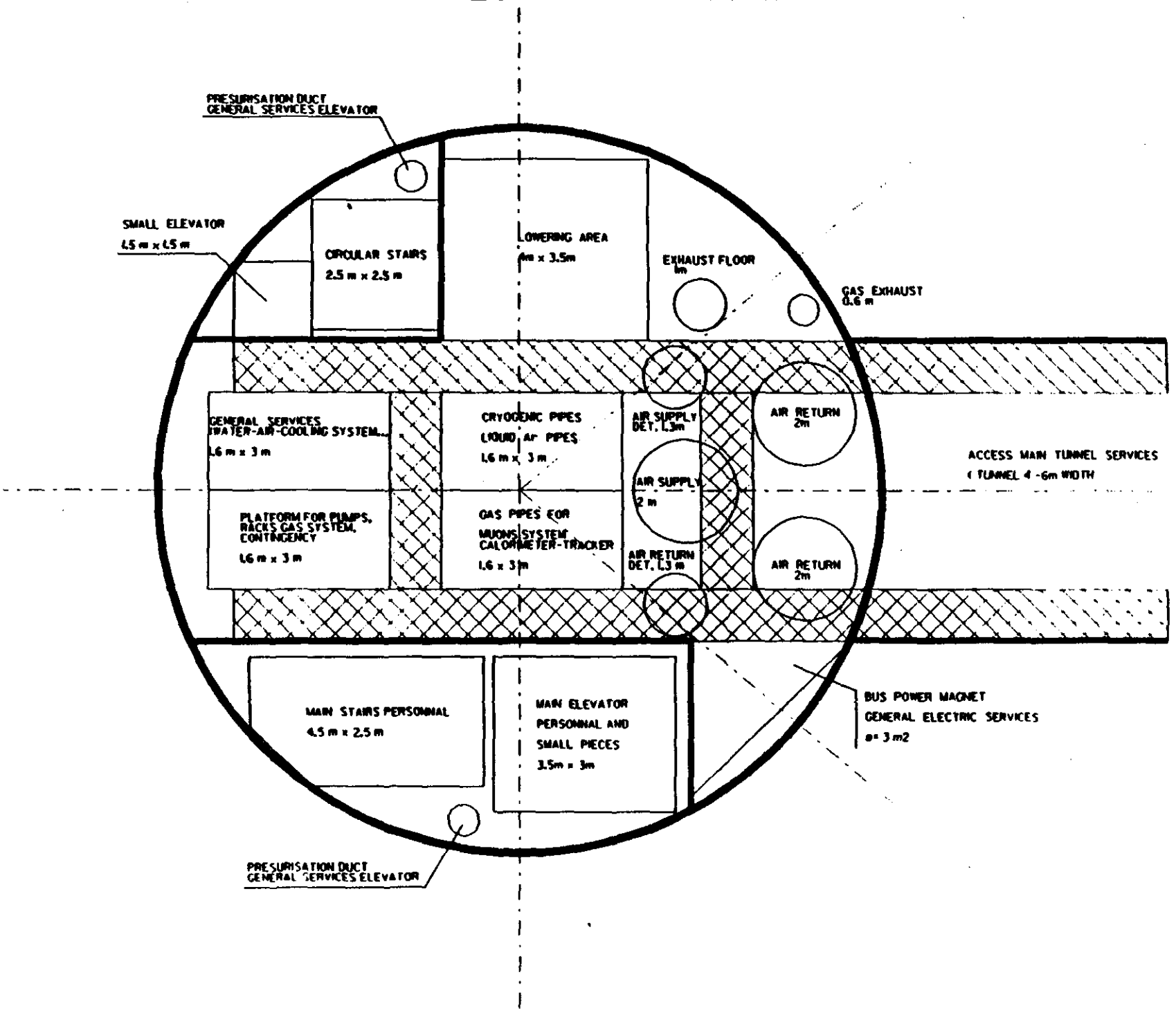




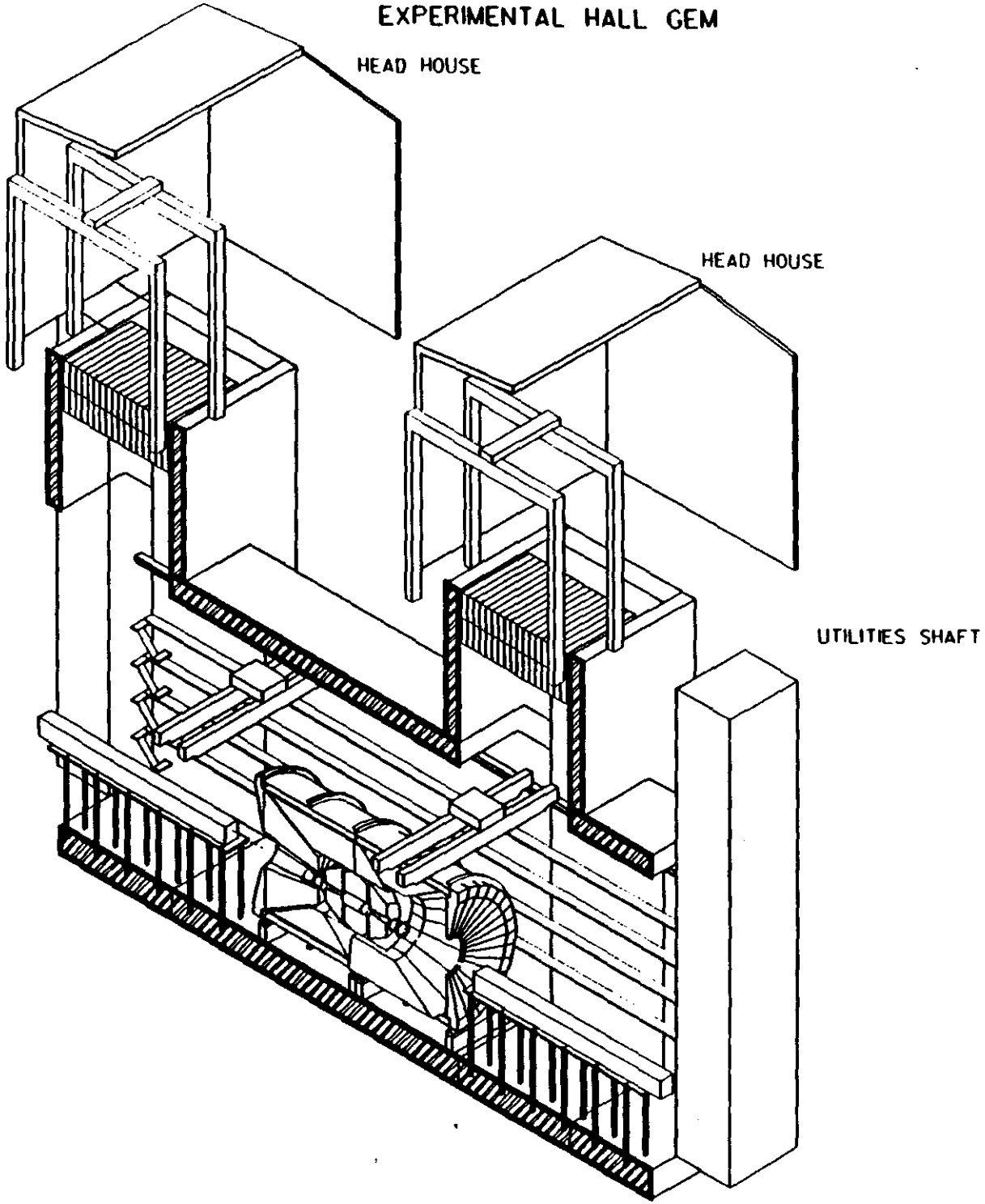



LEVEL 1 - 2 - 3 - 4
VENTILATION DUCTS
ELEVATOR
PRESURIZATION DUCT
ELECTRONIC ROOM STRUCTURE
CABLE TRAYS
CABLE TRAYS
racks
10.0 m
PRESURIZATION DUCT
PIPES
STAIRWAYS
10.0 m
64 RACKS
SSC
ELECTRONIC ROOM
CABLE SHAFT 16 m
LEVEL 1-2-3-4 TOP VIEW
OCD -000 079

UTILITIES SHAFT -14 m



EXPERIMENTAL HALL GEM



The Dynamics of Electroweak Symmetry Breaking

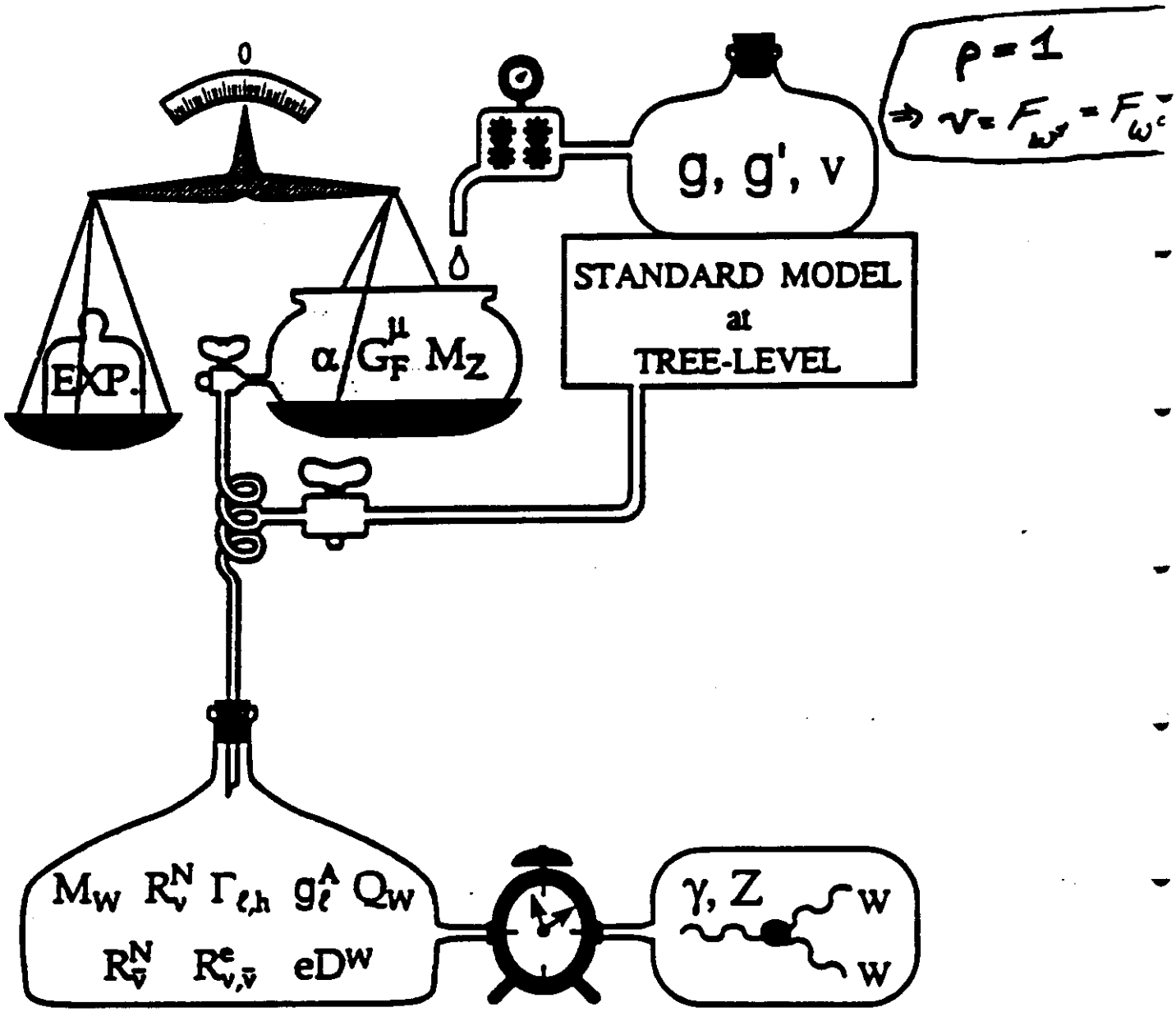
Sekhar Chivukula

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

The Dynamics of Electroweak Symmetry Breaking

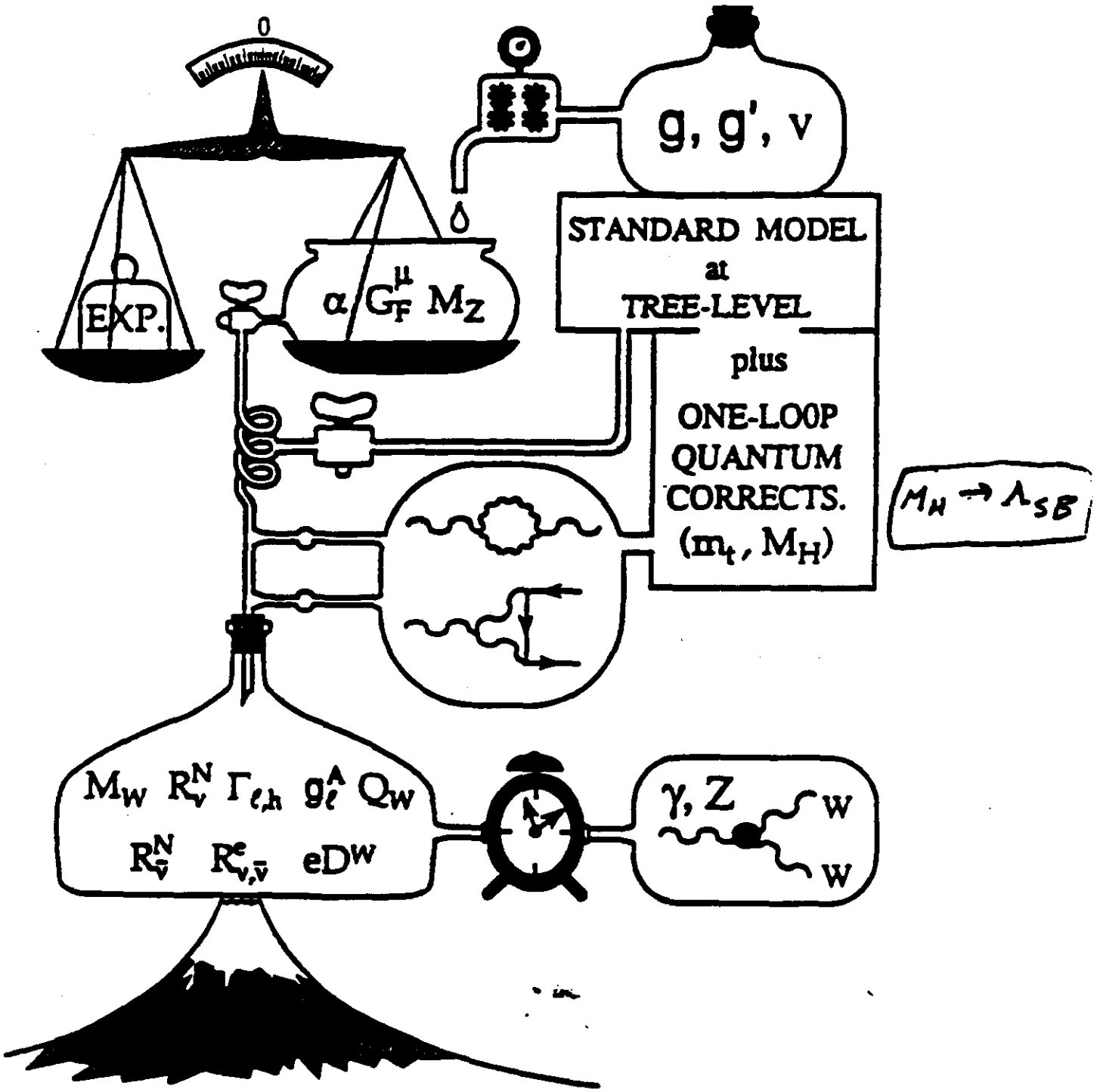
How little do we know?

SU(2)⊗U(1) ELECTROWEAK MODEL



Alvaro de Rújula

SU (2) ⊗ U (1) ELECTROWEAK THEORY



GAUGE INVARIANCE

Mario de Rújula

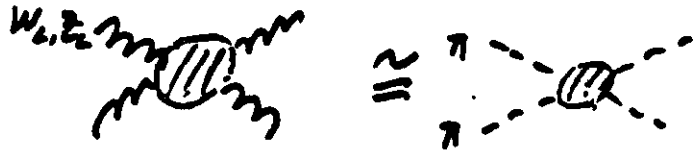
I Conventional Wisdom

Veltman / Lee, Quigg, Thacker

Signs of symmetry breaking must appear at energies at or below ~ 1 TeV.

Equivalence Theorem

Cornwall, Levin, Tiktopoulos (1974)



$$\cong \quad + \mathcal{O}\left(\frac{M_W^2}{E^2}\right) + \mathcal{O}(g^2, g'^2)$$

Chanowitz, Gaillard (1985)

At low energies, $E \ll 4\pi v, m_H, \ldots$, the scattering of goldstone bosons is determined entirely by symmetry.

Low Energy Theorems

Chanowitz, Golden, Georgi

$SU(2) \times SU(2) \to SU(2)_{WI}$
$(\rho = 1)$

$$a_{00} = \frac{s}{16\pi v^2} + \mathcal{O}(s^2) = \frac{s}{(1.7\ \text{TeV})^2} + \mathcal{O}(s^2)$$

$$a_{02} = \frac{s}{32\pi v^2} + \mathcal{O}(s^2)$$

$$a_{11} = \frac{s}{96\pi v^2} + \mathcal{O}(s^2)$$

The issue is: <u>what</u> unitarizes <u>these</u> <u>amplitudes</u>?

"Fundamental" Higgs Doublet

$$\varphi = \begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix}$$

$$\vec{\varphi} \to e^{i g \underbrace{\vec{\alpha}(x)\cdot\vec{\tau}/2}_{SU(2)_w} + i g' \underbrace{\beta(x)/2}_{U(1)_Y}} \vec{\varphi}$$

$$\mathcal{L}_\varphi = (D^\mu \varphi)^\dagger (D_\mu \varphi) - \lambda (\varphi^\dagger \varphi - v^2/2)^2$$

$$\langle \varphi \rangle = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$$

Invariant <u>only</u> under: $\langle \varphi \rangle \to e^{i\theta(x)(\tau_3+1)/2} \langle \varphi \rangle$

$$SU(2) \times U(1) \to U(1)_{em}$$

$$\varphi = U(x) \begin{pmatrix} 0 \\ v + H(x)/\sqrt{2} \end{pmatrix}$$

$$(D^\mu \varphi)^\dagger (D_\mu \varphi) \to \left(1 + \frac{H(x)}{v}\right)^2 \left[-M_W^2 W^{+\mu} W^-_\mu - \frac{1}{2} M_Z^2 Z^\mu Z_\mu \right]$$

$$M_W = \frac{1}{2} g v \quad , \quad M_W = M_Z \cos\theta_W \quad , \quad \tan\theta_W = g'/g$$

Fundamental Higgs (cont'd)

<u>$W_L W_L$ Scattering:</u> $\frac{2H(x)}{v}\left(-M_W^2 W^+W^- - \frac{1}{2}M_Z^2 ZZ\right)$

$$a_{00}(\text{Higgs Exchange}) \xrightarrow[s \gg M_H^2, M_W^2]{} -\frac{s}{16\pi v^2} + \text{const} + \cdots$$

In a fundamental Higgs theory, Higgs exchange cut's off the growth in the longitudinal WW scattering amplitudes.

(Fermion Masses: Yukawa Couplings)
(More Scalars Possible ---)

<u>Problems</u>

1) No evidence for a Higgs ($m_H \gtrsim 50$ GeV)

2) No explanation for EWSB (or for fermion masses).

3) Triviality: Scalar field theories don't exist ---

Triviality

In quantum field theory, fluctuations in the fields "screen" (or anti-screen) charges of all types – i.e. the vacuum acts as a "dielectric" medium. There is an "effective charge" which is a function of distance (or energy) scale.

$\underline{\lambda(\mu)}$: $\quad \mu \dfrac{d\lambda}{d\mu} = \beta(\lambda) \qquad V(\vec{\varphi}) = \lambda\left(\varphi^\dagger\varphi - \dfrac{v^2}{2}\right)^2$

<u>Perturbation Theory</u>: $\qquad \beta \cong \dfrac{3\lambda^2}{2\pi^2}$

$$\Rightarrow \quad \frac{1}{\lambda(\mu)} = \frac{1}{\lambda(\Lambda)} + \frac{3}{2\pi^2}\log\frac{\Lambda}{\mu} \geq \frac{3}{2\pi^2}\log\left(\frac{\Lambda}{\mu}\right)$$

$$\underbrace{\lambda(\mu) \leq \frac{2\pi^2}{3\log\left(\frac{\Lambda}{\mu}\right)}} \to 0 \qquad \Lambda \to \infty \;!$$

(Triviality)

$$\Rightarrow \quad \left(\frac{\Lambda}{\mu}\right) \leq \exp\left(\frac{2\pi^2}{3\lambda(\mu)}\right) \qquad m_H^2 \cong 2\lambda(m_H)\, v^2$$

$$\boxed{\Lambda \leq m_H \exp\left(\frac{4\pi^2 v^2}{3 m_H^2}\right)}$$

$\Rightarrow$ Higgs models not fundamentally consistent.

(*) Light, weakly coupled Higgs may be consistent to a very high energy scale ($m_H \lesssim 350$ GeV, $\Lambda \lesssim 10^{15}$ GeV)

A higgs theory doesn't answer any questions: it "postpones" the answers to a high energy scale.

(**) "Heavy" Higgs ($m_H \sim 1$ TeV) doesn't make sense! (Nonperturbative: LATTICE MC)

$\Lambda \gtrsim 4$ TeV $\Rightarrow$ $m_H \lesssim 640$ GeV !

If no "Higgs" shows up before $\hat{s} \sim (700\text{ GeV})^2$, something interesting and nontrivial is happening at ~ 1 TeV.

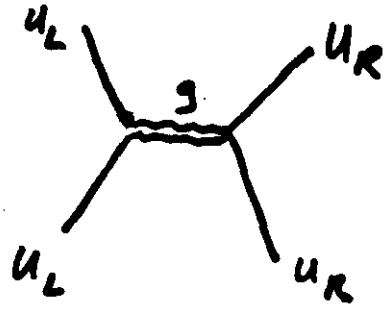
Alternatives?

Aside on QCD:

Chiral Symmetry in QCD:

$$\mathcal{L} = \bar{u}_L i\not{\partial} u_L + \bar{u}_R i\not{\partial} u_R + m_u(\bar{u}_L u_R + \bar{u}_R u_L)$$
$$+ \bar{d}_L i\not{\partial} d_L + \bar{d}_R i\not{\partial} d_R + m_d(\bar{d}_L d_R + \bar{d}_R d_L)$$

in the limit $m_u, m_d \to 0$, the theory has an $SU(2)_L \times SU(2)_R$ (global) symmetry (broken also by electroweak interactions).



QCD attractive in spin-0, color singlet $\bar{u}u$, $\bar{d}d$ channel.

$$\langle \bar{u}_L u_R + \bar{u}_R u_L \rangle = \langle \bar{d}_L d_R + \bar{d}_R d_L \rangle \neq 0$$

$SU(2)_L \times SU(2)_R \longrightarrow SU(2)_{isospin}$

3 goldstone bosons $\Rightarrow \pi^\pm, \pi^0$

[$m_u, m_d \neq 0$, but small $\Rightarrow m_{\pi^+} \cong m_{\pi^0} \ll 16\,eV$]

SAME SYMMETRY STRUCTURE AS Higgs doublet model!

Gauge $SU(2)_L \times U(1) \Rightarrow M_W \cong \frac{g f_\pi}{2}$

$f_\pi = 93$ MeV $\Rightarrow M_W \sim 30$ MeV

Technicolor

Scale up QCD by ~ 2500 !

$f_\pi \to v \cong 250$ GeV

Simplest Model: $SU(N)_{TC}$

$$\begin{pmatrix} P \\ M \end{pmatrix}_L \qquad P_R \quad M_R$$

$$SU(2)_L \times SU(2)_R \to SU(2)_V$$

w/ dynamics such that $F_\pi \cong 250$ GeV.

Phenomenology

$W_L, Z_L \to$ pions of Technicolor

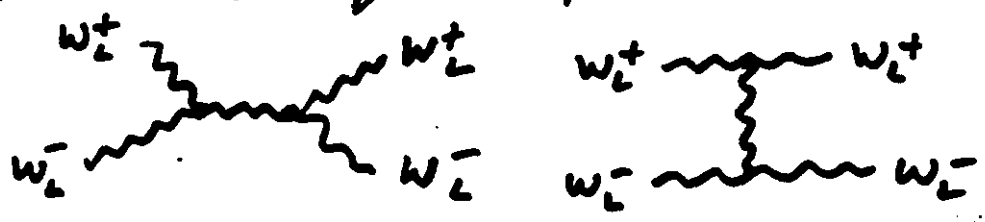
In QCD, the next lightest states are the vector mesons:

$\rho^\pm \to \pi^\mp \pi^0$ $\qquad$ $\rho_{TC}^\pm \to W_L^\pm Z_L$

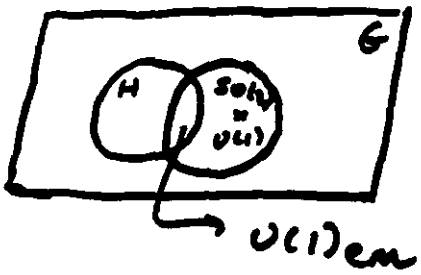
$\rho^0 \to \pi^+\pi^-$ $\qquad$ $\rho_{TC}^0 \to W_L^+ W_L^-$

$\omega \to \pi^+\pi^-\pi^0$ $\qquad$ $\omega_{TC} \to W_L^+ W_L^- Z_L$

Growth of W_L, Z_L scattering amplitudes cutoff by exchange of heavy resonances:

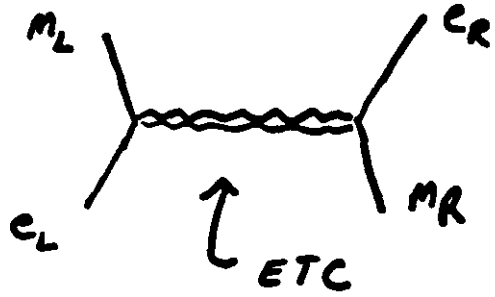


In general, there may be more techniferminons, or a different technicolor group:



Different $G/H \Rightarrow$ different spectrum of techihadrons (esp. pseudoGoldstone bosons), similar phenomenology.

Fermion Masses?



$$\longrightarrow \quad g^2 \frac{(\bar{e}_L e_R)(\bar{m}_R m_L)}{M_{ETC}^2}$$

$$TC \ \chi SB \Rightarrow \quad \bar{e}_L e_R \left(\frac{g^2}{M_{ETC}^2} \langle \bar{m}_R m_L \rangle \right)$$

$$\Rightarrow \quad m_e = \frac{g^2}{M_{ETC}^2} \langle \bar{m}_L m_R \rangle$$

ETC $\Rightarrow$ Dynamical Explanation of Flavor

Flavor Changing Neutral Currents

Extended technicolor interactions must distinguish between the different families of quarks (u, c, t) and (d, s, b).

$\Rightarrow$ Could give rise to interactions of the form $\frac{g^2}{M_{ETC}^2}(\bar{s}\gamma^\mu d)^2$ which can contribute to K^0-$\bar{K}^0$ mixing.

$$\Rightarrow \frac{g^2}{M_{ETC}^2} \lesssim \frac{1}{(1000\,\text{TeV})^2} \Rightarrow m_f \lesssim \frac{\overbrace{\langle \bar{m}_L m_R \rangle}^{(1\,\text{TeV})^3}}{(1000\,\text{TeV})^2}$$

$$\Rightarrow m_f \lesssim 1\,\text{MeV} \;!$$

Hard to explain up and down quark masses, much less s, c, b, t ?!?

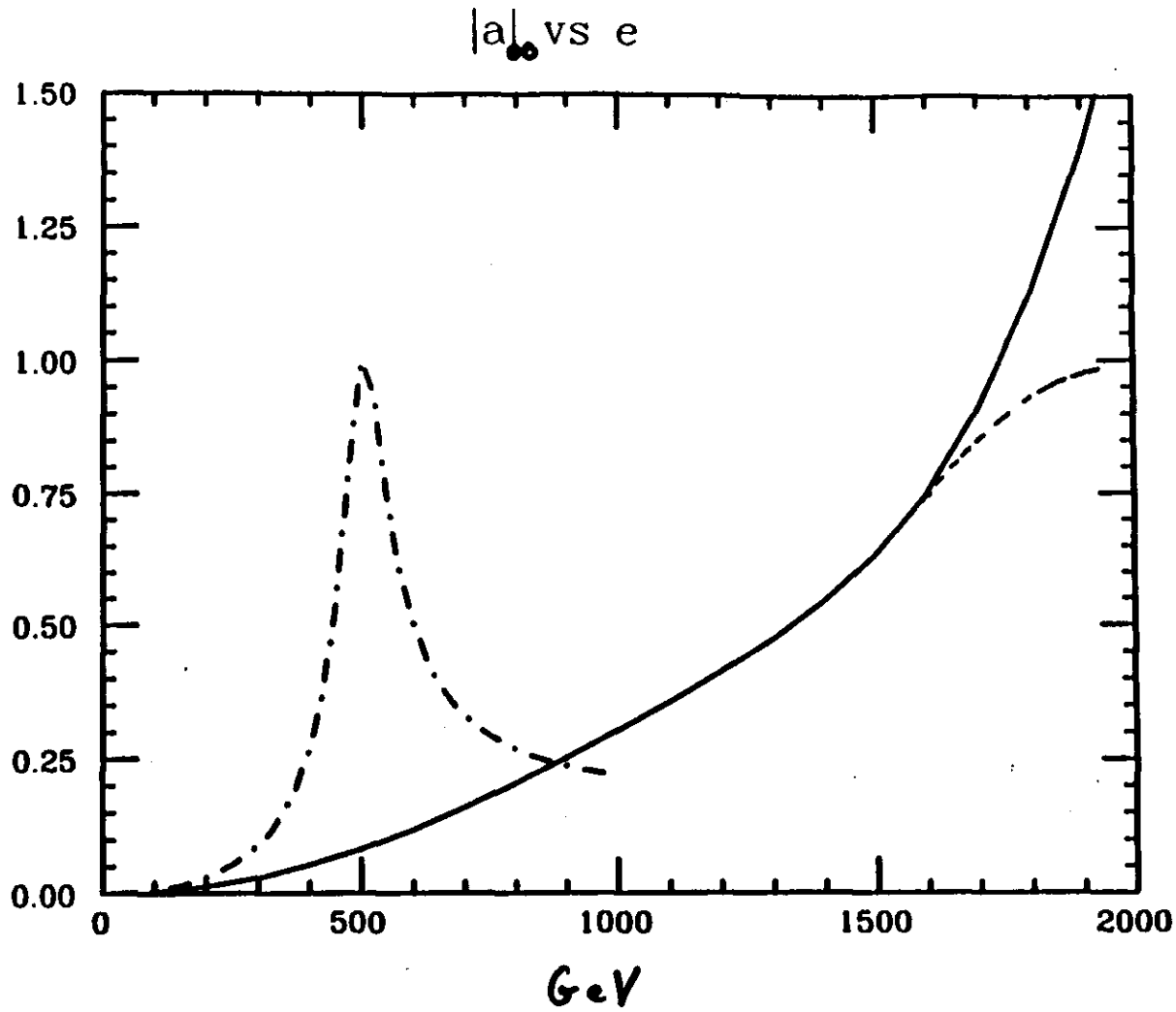
<u>Possible Solutions</u>: (No successful models)

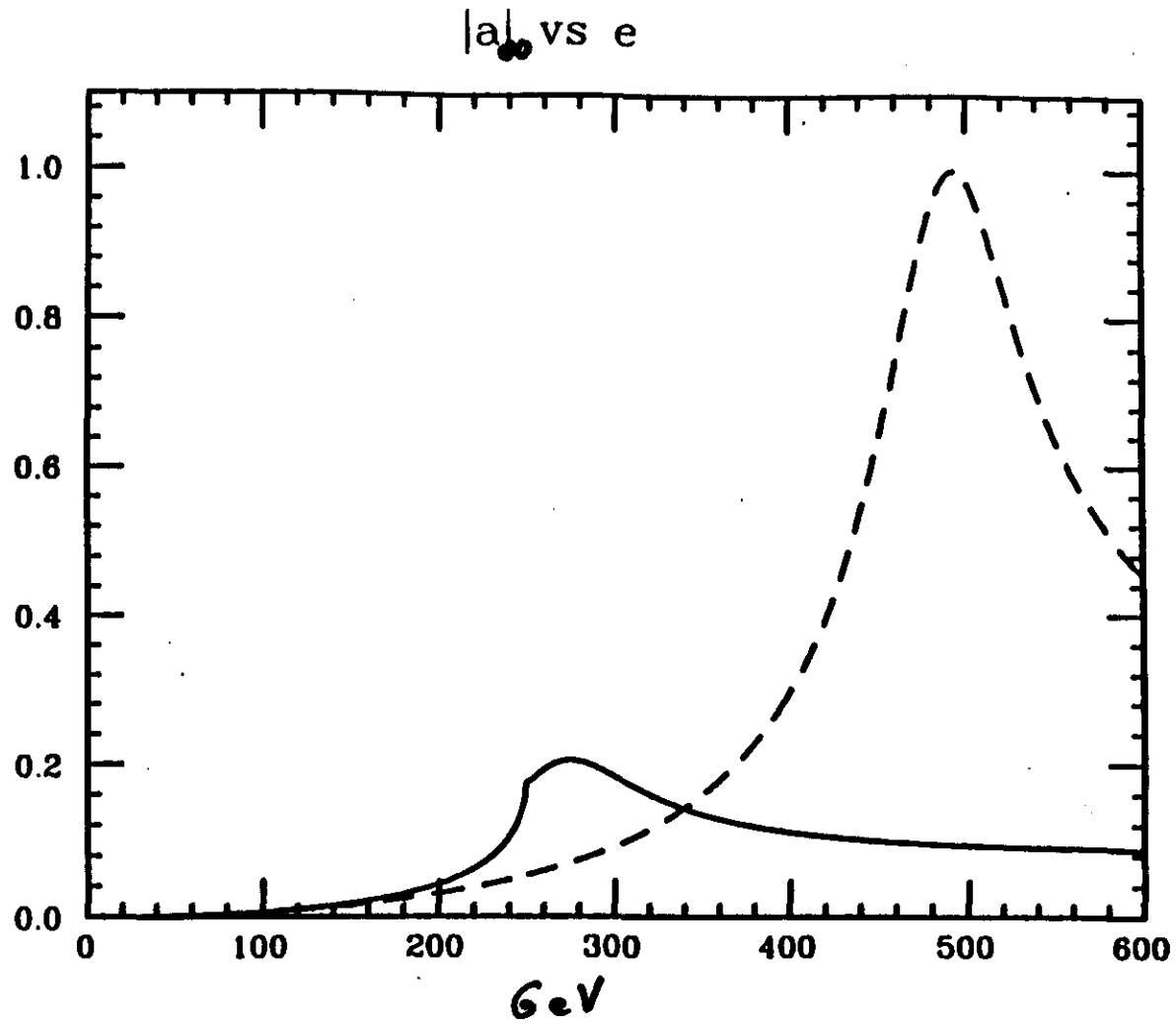
1) Techni GIM

(2) "Enhance"

$$\langle \bar{m}_L m_R \rangle_{ETC} \cong (1\,\text{TeV})^3 \exp\left(\int_{1\,\text{TeV}}^{M_{ETC}} \gamma_m \frac{d\mu}{\mu} \right)$$

Large?


|a|∞ vs e
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
500
1000
1500
2000
GeV


|a| vs e
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
GeV

Motivation

(Soldate, Sondrum)

In models with a large number of pseudo-Goldstone Bosons, the "unitarization" energy can be considerably <u>lower</u> than ~1 TeV.

$SU(n_f) \times SU(n_f)$

$$a_{00} = \frac{n_f s}{32\pi f^2}$$

"One Family" Technicolor Model, $n_f = 8$, $f = \frac{v}{\sqrt{N_D}} = \frac{v}{2}$

$$\Rightarrow a_{00} = \frac{s}{\pi v^2} \cong \frac{s}{(450\ \text{GeV})^2} \ !$$

$W_L W_L$ Scattering?

w/ M. Golden

Cut off at Low Energies $\Rightarrow$ "small"!

Overall theory strong !?

Large <u>inelastic</u> amplitudes !

<u>Large</u> !

In such a theory, it will be crucial to find the Pseudo-Goldstone Bosons!

Phenomenology of EWSB:

Properties of "Resonances"

	NARROW	WIDE
LIGHT	HIGGS	Technicolor/Higgs (MANY Pseudos)
HEAVY	impossible?	Technicolor (few Pseudos)

Higgs → Postpone answers to interesting questions to high energy.

Technicolor → Dynamics @ 1 TeV.

Technicolor/Higgs → Dynamics @ $\lesssim$ 1 TeV

We have NO fundamentally consistent Theory of EWSB.

* Weakly Coupled Higgs "postpones" the answers to all of the interesting questions to very high energies.

** A heavy Higgs ($m_H \sim 1$ TeV) makes no sense. ($m_H \lesssim 700$ GeV).

*** Technicolor is a consistent theory of EWSB with structure at ~ 1 TeV, but we don't know how to accomodate fermion masses.

**** BE PREPARED:

There may be important signatures of EWSB which <u>do</u> <u>not</u> involve W's and Z's!

Calorimeter
Liquid Argon/BaF_2 + Hadronic

Y. Kamyshkov

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

GEM CALORIMETRY

a) baseline option (LAr) and parameters

b) other calorimetry options

Calorimeter system :

- e-m calorimeter (barrel & endcap)
- hadron calorimeter (barrel & endcap)
- forward calorimeter (e-m + hadronic)
- preradiator

Calorimetry Options

E - M : LAr/Kr accordion, BaF_2,
LAr/Kr parallel plates

hadronic : U/LAr , Scintillator
(fibers or tiles)

forward : W/LAr , Liq. scint. fibers ,
High pressure gas

prerad. : LAr/Kr incorporated in e-m ,
3X0 + x-y Silicon strips,
x-y Silicon strips inside BaF_2

GEM DETECTOR

Proposal for a Design Baseline

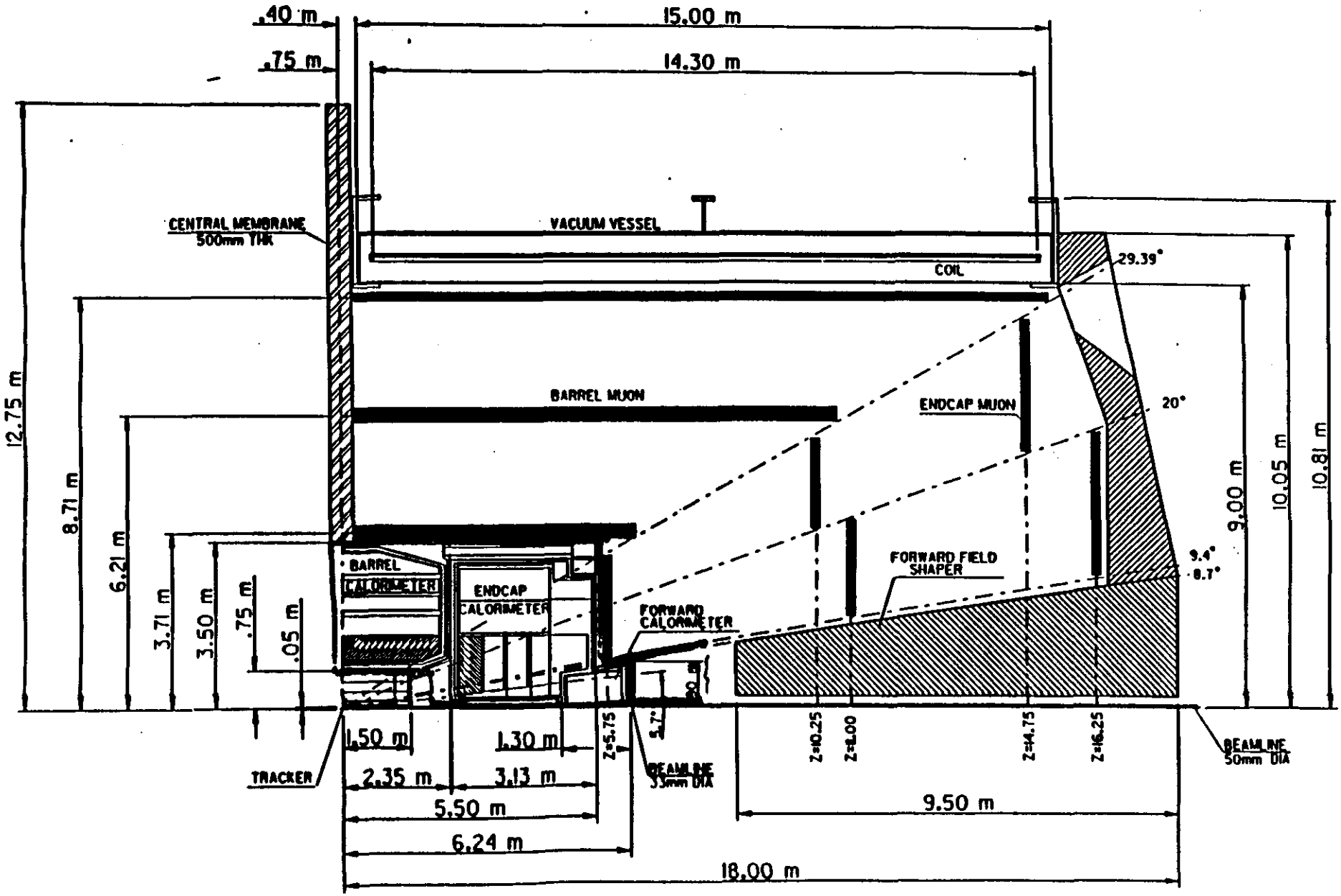
March 9, 1992

Abstract:

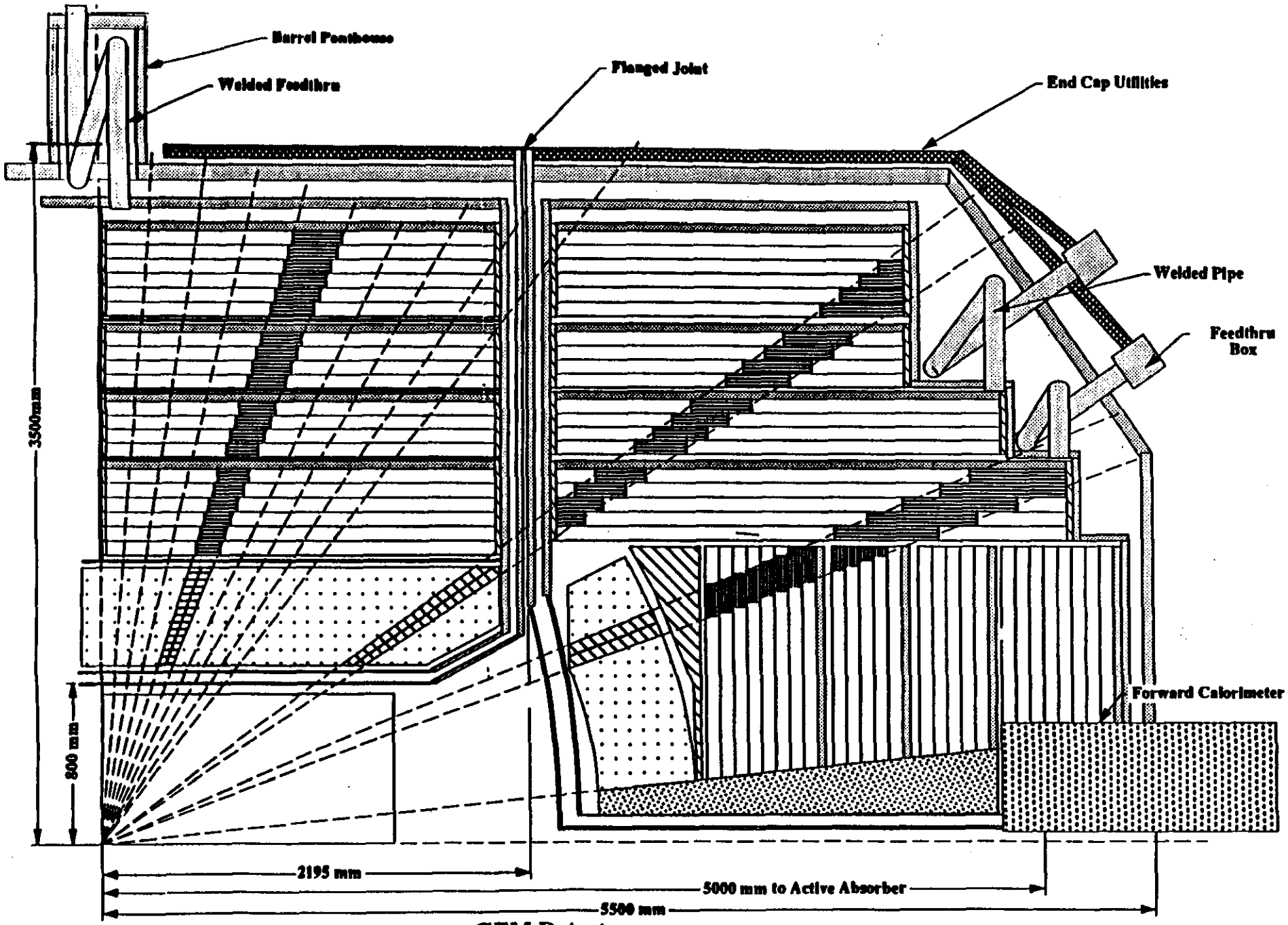
This document proposes changes to the GEM detector proposed in the LOI. These changes could become the basis for a new baseline. Also addressed are cost impacts of changes to the LOI and a list of major issues to be resolved at or following the Tucson meeting.

Following the GEM Collaboration meeting in Tucson, this document will be expanded to contain the controlled baseline configuration.

GEM DETECTOR ELEVATION



Z. CHEN
(GEM9202261)

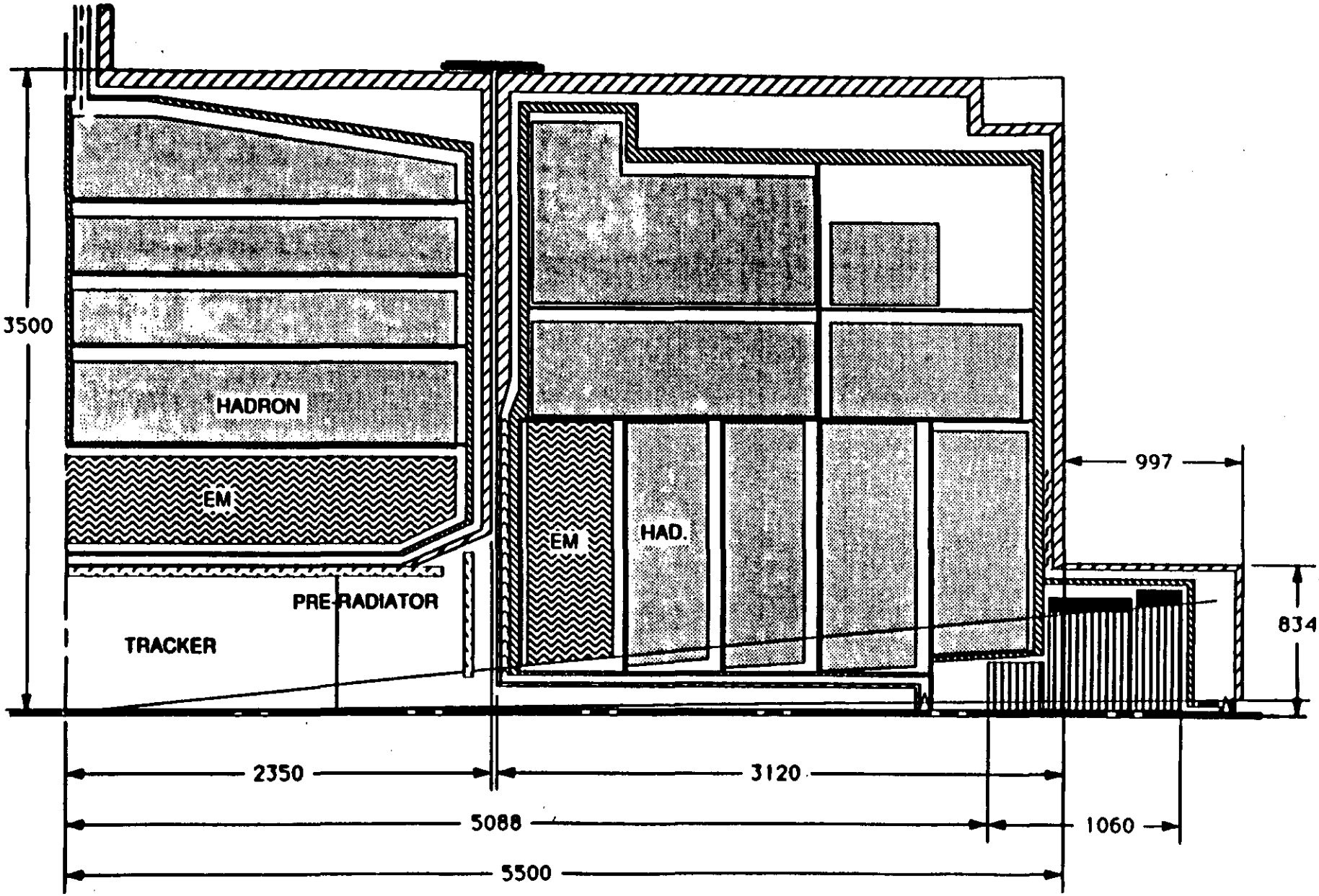


GEM Detector
Liquid Argon Calorimeter
Barrel Module Layout

G.03.LA.052

Rennich

GEM Liquid Argon Calorimeter - 3/6/92



LI.Mason 3/6/92

4.0 CALORIMETER

Liquid Argon Option

Physics Performance (functions of E_T, η and ϕ)

Containment of electrons, photons or single hadrons		$\eta < 3.0$
EM resolution		$\Delta E/E = 7.5\%/\sqrt{(E)} \oplus 0.5\%$
EM position resolution	5	[redacted] mm/$\sqrt{(E)}$
Photon pointing	8	[redacted] mrad @ 120 GeV
Hadron resolution		$\Delta E/E = 50\%/\sqrt{(E)} \oplus 2.0\%$

Physical Parameters (cm, Xo, λ)

Sensitive volume:		liquid argon(krypton) 2 mm gaps	
EM absorber		lead	
Hadron absorber		depleted uranium	
Longitudinal segmentation		2 EM, 4 hadronic	
Inner radius (prerad. included)	75	[redacted] cm	
Outer radius		350 cm	
Half length		550 cm	
Number of radiation lengths		25 at 90 degrees	
Number lambda	11.3	[redacted] at 90 degrees	10.8 λ
		14 at $\eta = 2.5$	
EM segmentation		$\Delta\eta = \Delta\Phi = 0.04$	
Hadron segmentation		$\Delta\eta = \Delta\Phi = 0.08$	
Channel Count		62880	
Barrel		29920	
End Cap (each)		16480	
Total weight	2583	~~2900~~ tonnes	
Barrel	952	~~1700~~ tonnes	
End Caps (each)	790	~~600~~ tonnes	
Total liquid volume		200000 litres	

~~Barrel~~

~~Modules~~

~~Physical Dimensions~~	~~TBD~~
~~Active Area~~	~~TBD~~
~~Dead Area~~	~~TBD~~

~~Plates~~

~~Physical Dimensions~~	~~TBD~~

~~Gaps~~

~~Physical Dimensions~~	~~TBD~~

SOURCE: Rutherford/Eberle/Rennich
UPDATED: 2/28/92 (original)

End Cap

Physical Dimensions (cm, Xo, λ)	TBD
Channel Count	TBD
~~Modules~~	
~~Physical Dimensions~~	~~TBD~~
~~Active Area~~	~~TBD~~
~~Dead Area~~	~~TBD~~
~~Plates~~	
~~Physical Dimensions~~	~~TBD~~
~~Gaps~~	
~~Physical Dimensions~~	~~TBD~~

Forward

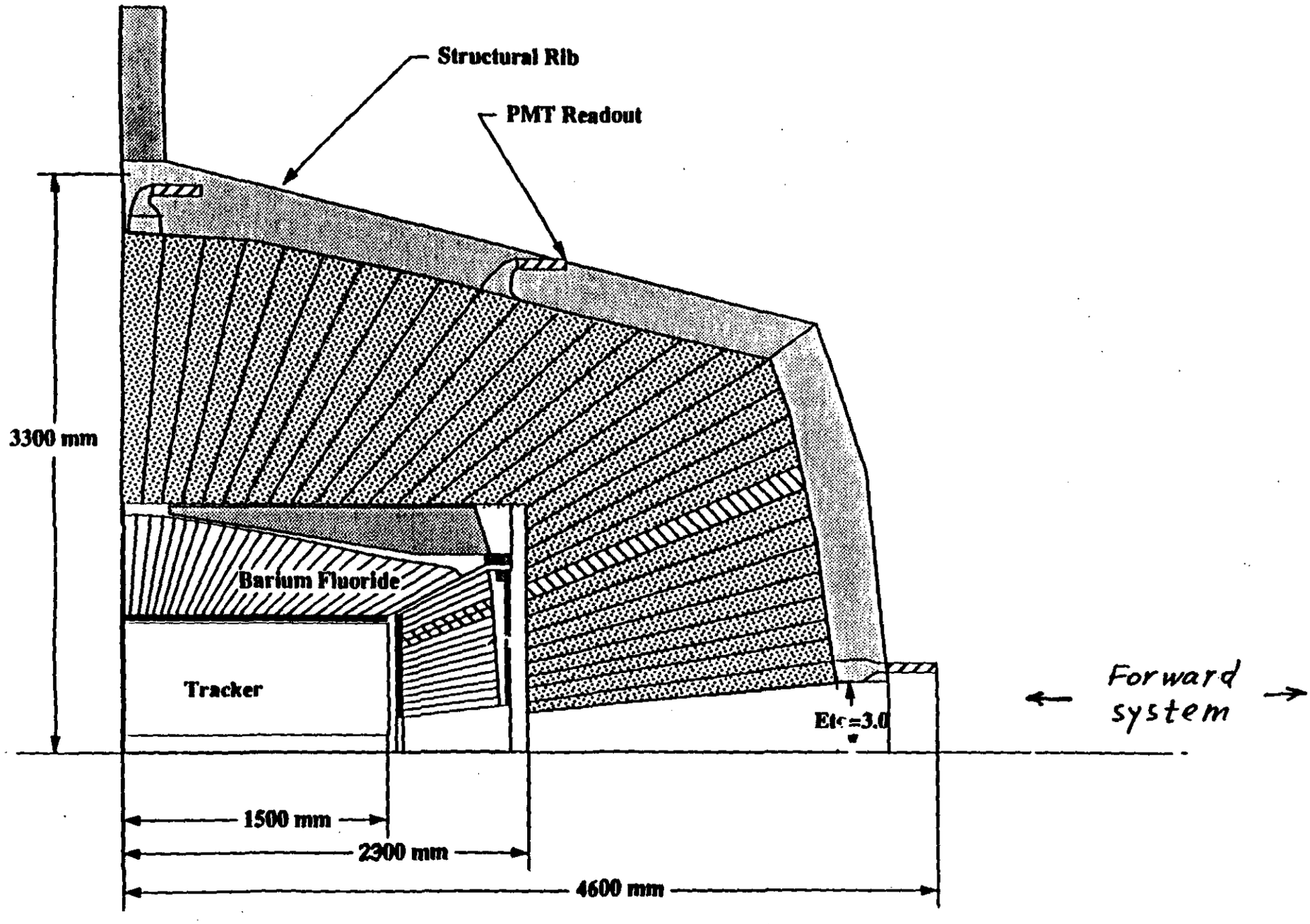
Distance to near face (Z_1)	4.95 m
Distance to far face (Z_2)	6.24 m
Inner Radius	
Near face	20 mm
Far face	24 mm
Outer Radius	
Near face	650 mm
Far face	720 mm
Number of plates	72
Weight (each)	27 tonnes
Channel count (each)	1070
Sensitive Volume	Liquid argon, 1mm gaps
Absorber	Tungsten
Longitudinal segmentation: ("EM", Hadronic, Tail catcher)	3
Cryostat	(share with endcap)
Resolution	$\Delta E_T/E_T \leq 10\%$
Containment of single hadron shower	$3.0 < \eta < 5.0$
Integration time	≤ 50 nsec
Trigger timing	≤ 10 nsec
Absorbtion Lengths	10

Preradiator

TBD

SOURCE: Rutherford/Eberle/Rennich
UPDATED: 2/28/92 (original)
JNG

DRAFT



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Barium Fluoride EM Calorimeter

G.03.SC.00079

Barium Flouride EM Option

Physical Parameters (cm, Xo, λ)	
Total crystal volume	~~10610328 cc~~ 10.6 m^3
Barrel crystal volume	~~8994418 cc~~ 8.4 m^3
End cap crystal volume (each)	~~1107952 cc~~ 1.1 m^3
Crystal size	
η = 0.0	3.11x3.11x5.07x5.07 cm
η = 2.5	2.03x2.20x2.94x2.72 cm
Total number of crystals	15584
Number of crystals in barrel	10880
Number of crystals in end cap (each)	2352
Length of cyrstals	500 mm
Channel count	15584
Total weight of assembly	55.78 tonnes
Weight of barrel	44.13 tonnes
Weight of end cap (each)	5.81 tonnes
Inner radius	750 mm
Outer radius	1400 mm
Total length of assembly	4600 mm
Calibration system	RFQ Accelerator
Segmentation $\Delta\eta \approx \Delta\varphi$	0.04

SOURCE: Rutherford/Eberle/Rennich
UPDATED: 2/28/92 (original)
JNG

DRAFT

GEM PARAMETERS

Spaghetti Hadron Option (Copper/Solder Filled)

Physics Performance (functions of E_T, η and ϕ)

Segmentation $\Delta\eta \simeq \Delta\phi$	0.12
~~From longitudinal depth~~	~~[redacted]~~
~~Full longitudinal depth~~	~~[redacted]~~
~~Back longitudinal depth~~	~~[redacted]~~
Total absorption length (at η = 0.0)	λ = 10
Active absorption length (at η = 0.0)	λ = 8.73
Passive absorption length (at η = 0.0)	λ = 1.27
Total absorption length (at η = 3.0)	λ = 12.12
Active absorption length (at η = 3.0)	λ = 11.00
Passive absorption length (at η = 3.0)	λ = 1.12

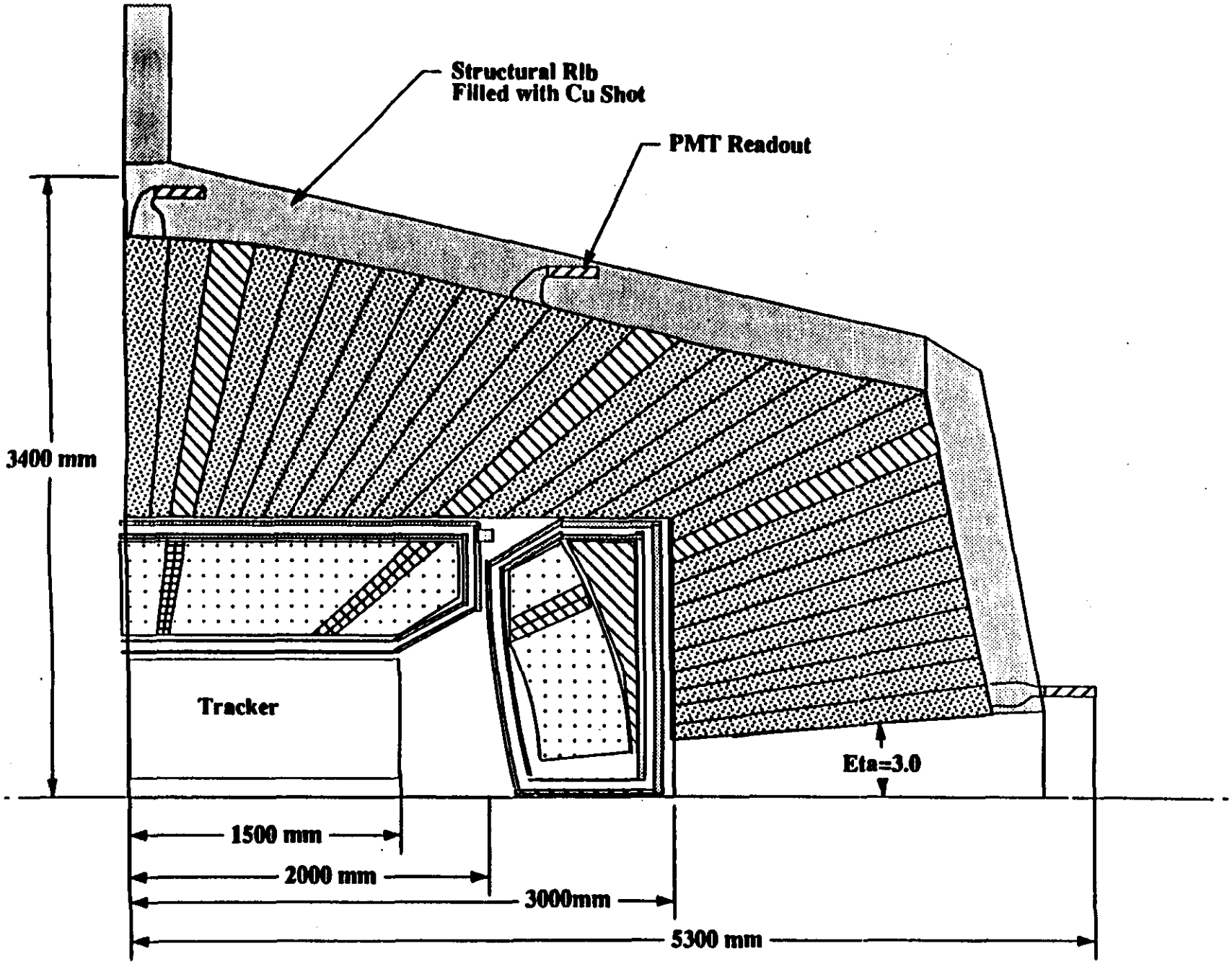
only hadronic section

Physical Parameters (cm, Xo, λ)

Absorber volume		173 m^3
Number channels		4692
Number photomultipliers		4692
Total weight	1310	[redacted] tonnes
Copper shot		796 tonnes
Solder (40Sn/60Pb)		429 tonnes
Copper tube		124 tonnes
Structural components (stainless steel)		35 tonnes
Sheaths (copper)		6 tonnes
Inner Rings (stainless steel)		5 tonnes
Number mechanical towers		1564
Number assemblies	3	[redacted]
[redacted] Barrel weight	2x	438 tonnes
End cap weight (each)		264 tonnes
Length of [redacted] fiber Sci		[redacted] m 3,200 km
Number of [redacted] fibers Sci		[redacted] 1.7 M
Length of copper tubes		[redacted] m 2,250 km
Inner radius	1400	[redacted] mm
Outer radius	3300	[redacted] mm
Length		9200 mm

SOURCE: Rutherford/Eberle/Rennich
UPDATED: 2/28/92 (original)
JNG

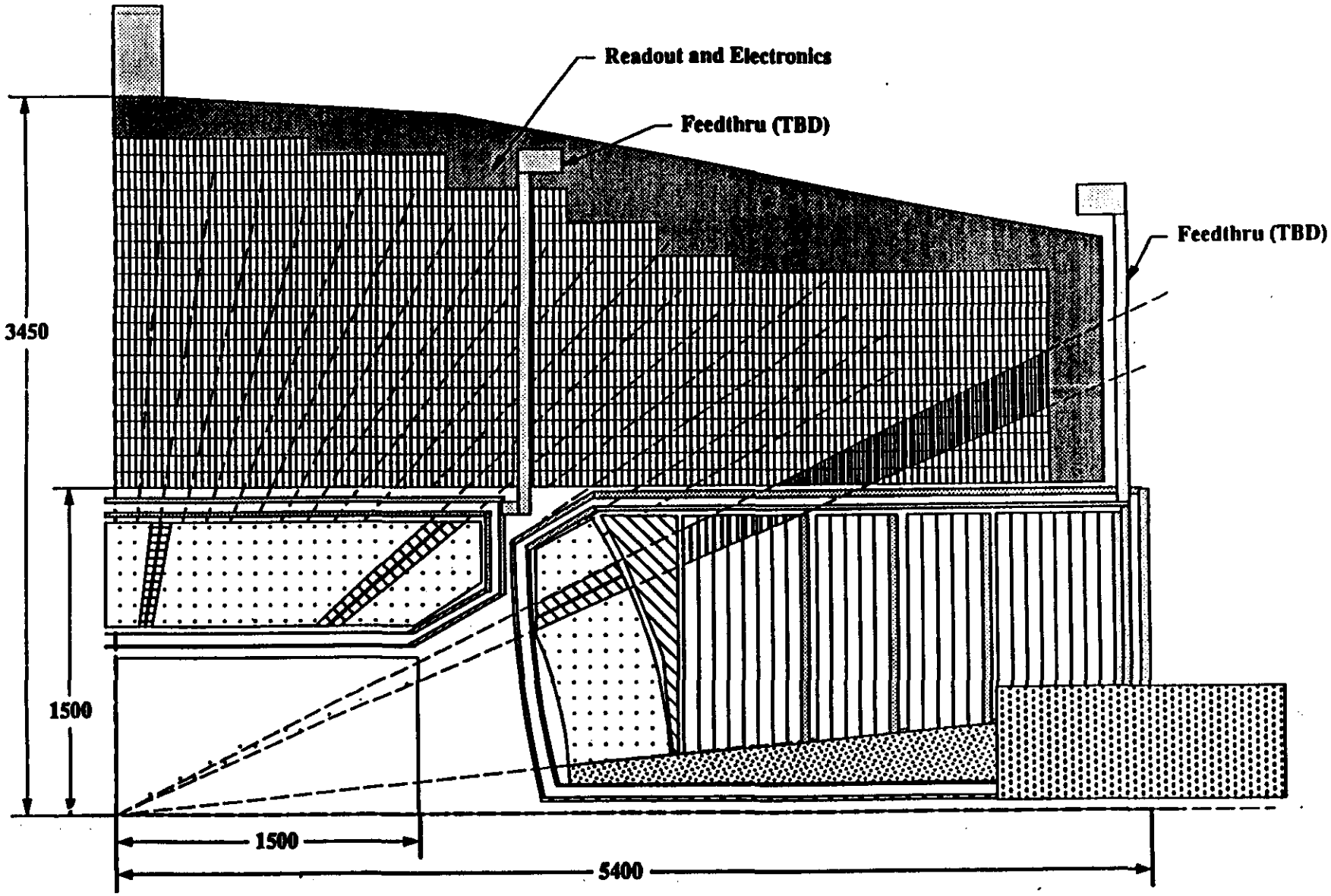
DRAFT



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Liquid Arg M Calorimeter

G.03.SC.00080

Rennich



GEM Detector
Plastic Tile/Copper
Hadron Barrel Calorimeter,
LAr EM - Hadron End Cap and
LKr EM Barrel Calorimeter

G.03.T.018

Rennich

EAGLE internal note .
CAL-NO-006
22 November 1991

AN ECONOMIC CONCEPT FOR A BARREL HADRON CALORIMETER WITH IRON SCINTILLATOR SAMPLING AND WLS-FIBER READOUT

O. GILDEMEISTER, F. NESSI-TEDALDI, M. NESSI
CERN, Geneva

cost ~ 25 MSFr !?

ABSTRACT

An unconventional concept for a hadr . calorimeter with scintillator plates and WLS fiber readout is discussed. It leads a simple and low-cost design.

1. Introduction

We propose a concept for a barrel hadron calorimeter with scintillator plates positioned - inside the iron absorbe structure - in R-Φ planes, instead of the usual Φ-Z orientation. Wavelengthshifting LS) fibers coupled to the two radial edges of the scintillator plates can thus be kept s ight in radial direction. Outside the absorber structure they are grouped according to the ted segmentation of the calorimeter and coupled to photomultiplier tubes (PMT).

This configuration can be made very hermetic and has the additional advantage that the absorber can be built up from "*self supporting*" plates in R-Φ planes.

For close to zero rapidities the plate structure is about parallel to the primary particles. Most of those will have interacted already in the EM-calorimeter in front, to be about one interaction length in depth. To prevent high energy particles from travelling over long distances in the scintillator the individual plates are kept short and are staggered with respect to each other (Fig. 1). (The proposed structure would not be adequate for an EM-calorimeter).

2. GEANT simulations

GEANT simulations have been made to check the effect of this particular geometry on the energy resolution. They used a calorimeter model consisting of a conventional liquid argon EM compartment, 25 X_0 in depth, with 3 mm lead plates and 4 mm gaps, in front of the hadron compartment of Fig. 1, with ℓ = 10 cm, a = 1.4 cm, d = 0.6 cm and a depth of 9.5 interaction lengths. Jets from 25 to 300 GeV were generated at 1.2 m distance from the EM-compartment and at different impact points.

The results of the energy resolutions lead to a fitted parametrization of

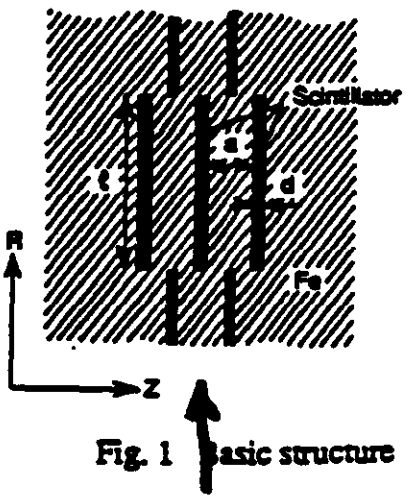
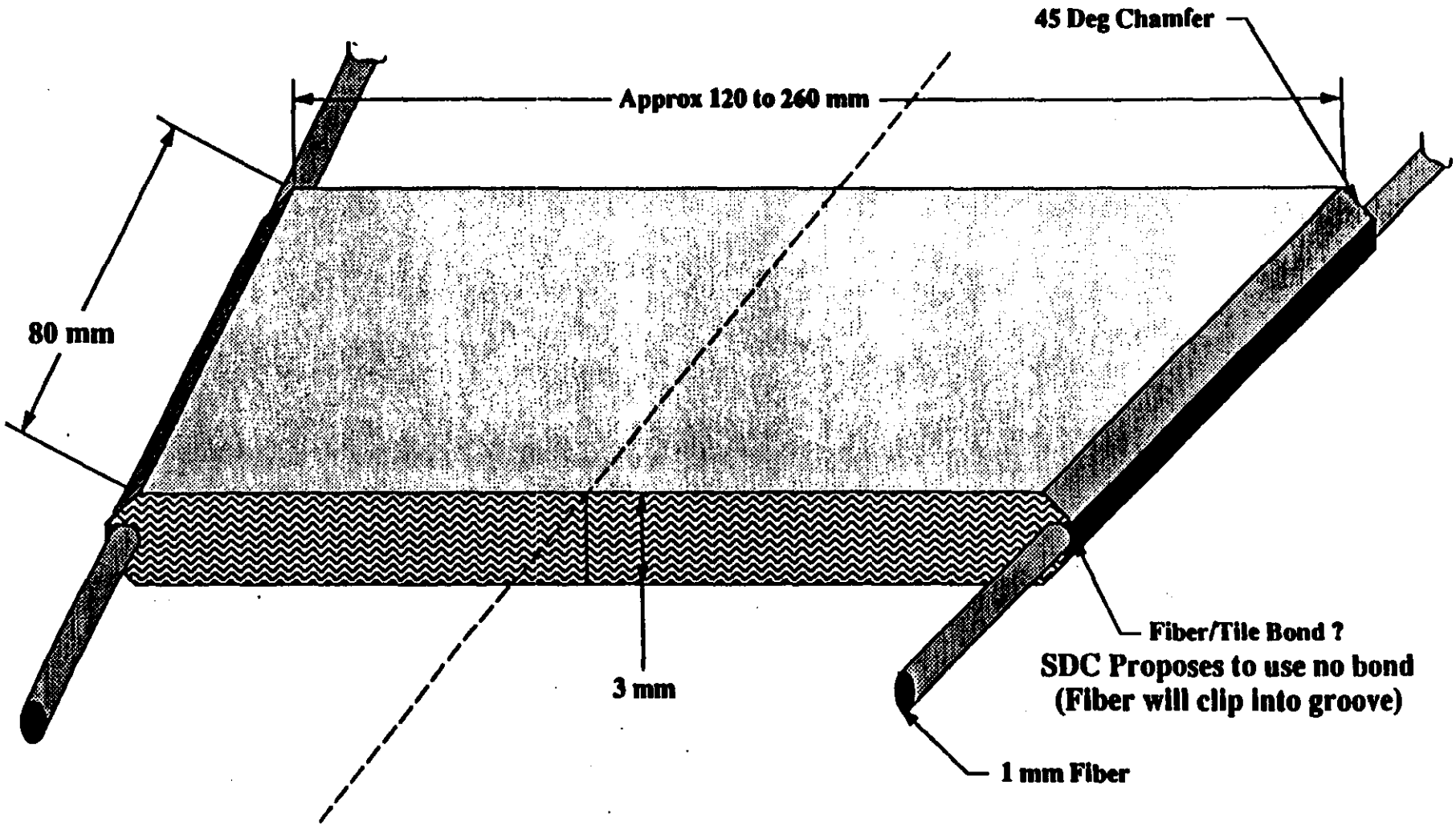


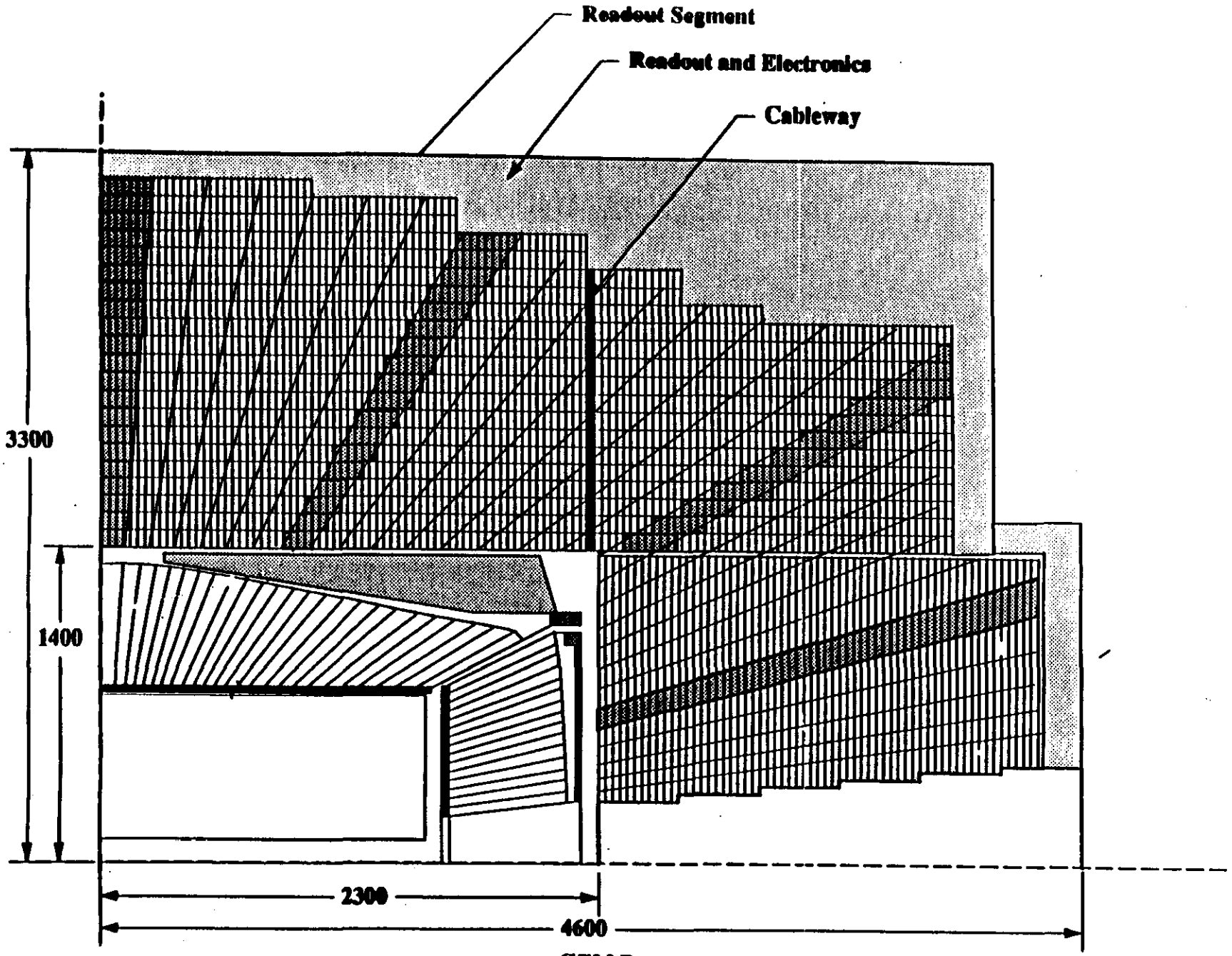
Fig. 1 asic structure

$$\frac{\sigma_E}{E} = \frac{41\%}{\sqrt{E}} + 2\% \text{ (E in GeV)}$$



GEM Detector
Plastic Tile Calorimeter
Tile Configuration

Rennich



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
(Theta Segmentation)

Projective readout

G.03.T.001

Rennich

Compact hadronic calorimeter

Absorber/detector	Pb/Sci	U/LAr	Cu/Sci	W/Sci
Absorb. length (pure absorber)	17.1 cm	10.9 cm	15.1 cm	10.2 cm
Equivalent plate structure absorber + detector + gap [mm]	20+5+1	6+2+0	30+3+1	15+3+1
Expected hadronic resolution ($1/\sqrt{E}$)	60%	55%	80%	75%
Effective absorbtion length [cm]	21.1	16.3	16.8	12.6

Radial extention (various options)

$$L_{90^\circ}^{abs} = 11.7\ \lambda_o$$

E-M	hadron	cm
Pb/LAr	+ U/LAr (11.3 λ_o)	75 - 350
BaF2	+ Cu/Sci. fibers	75 - 330
	+ Cu/Sci. tiles	75 - 330
	+ W/Sci. fibers	75 - 310
	+ W/Sci. tiles	75 - 290
Pb/LKr	+ Cu/Sci. fibers	75 - 345
	+ Cu/Sci. tiles	75 - 345
	+ W/Sci. fibers	75 - 325
	+ W/Sci. tiles	75 - 305

Calorimeter Absorbtion Thickness

Report from the Calorimeter Depth Task Force

February 18, 1992 at SSCL :

Recommendation to make barrel Calorimeter

$$> 12\ \lambda_{abs}$$

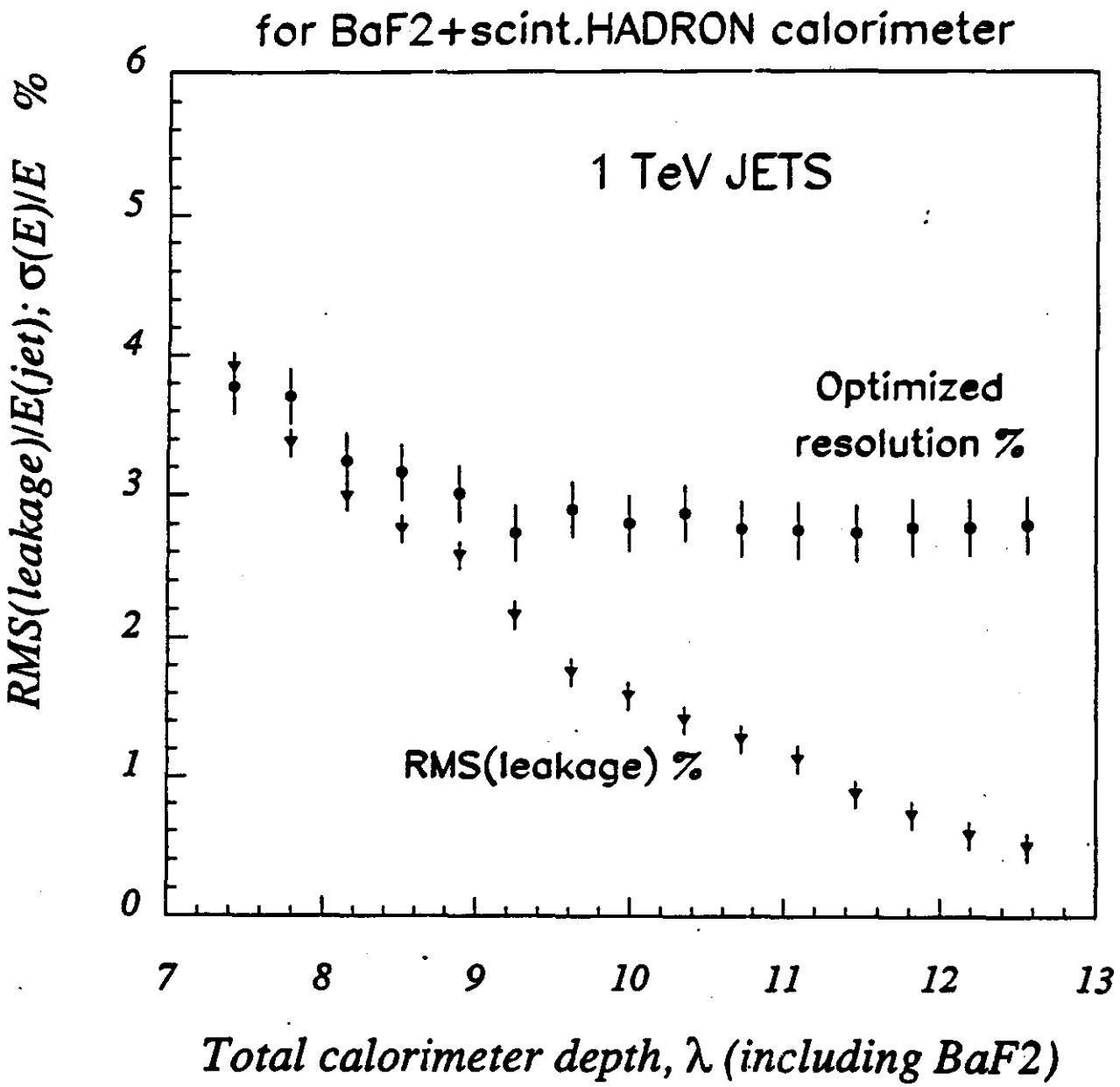
in the region $1.5 < \eta < 3.0$ thickness assumed

$$> 14\ \lambda_{abs}$$

in the forward region $\eta > 3.0$ sufficient thickness

$$> 10\ \lambda_{abs}$$

LEAKAGE FLUCTUATIONS IN CALORIMETER



Calorimeter Transverse Segmentation

E-M section 0.04 x 0.04 - well defined

hadronic section : 0.08 x 0.08 for LAr option
0.12 x 0.12 for spaghetti

neither is well justified !

After fine-segmented e-m calorimeter hadronic segmentation is less significant.

It seems that hadron calorimeter can have segmentation shoosen from trigger requirements.

Comparison of Current GEM Calorimeter Options

		Option A	Option B	Option C	Option D	Option E	Option F	Opt C
		Baseline	Alterna.					
ElectroMagnetic								
Barrel		Pb/LAr	BaF2	BaF2	Pb/LKr	Pb/LKr	Pb/LKr	BaF_2
End Cap		Pb/LAr	BaF2	BaF2	Pb/LAr	Pb/LKr	Pb/LKr	BaF_2
Hadronic								
Barrel		U/LAr	Cu/Fiber	Cu/Tile	Cu/Tile	Cu/Tile	Cu/Fiber	Pb/Fiber
End Cap		U/LAr	Cu/Fiber	Cu/Tile	U/LAr	Cu/Tile	Cu/Fiber	
Forward		W/LAr	TBD	TBD	W/LAr	TBD	TBD	
PreRadiator		TBD	TBD	TBD	TBD	TBD	TBD	
Wght (EM+Had)	Mt	2531	1372	1457	2018	1773	1718	
Active Volume	M^3	176	183	171	190	217	227	
Inner Radius	mm	750	750	750	750	750	750	750
Outer Radius	mm	3500	3300	3300	3450	3450	3450	3500
Inner Lenght	mm	4400	3000	3000	4000	4000	4000	
Outer Lenght	mm	11000	9200	9200	10800	10800	10600	
Channels		62,880	19,748	33,620	43,684	51,328	36,052	
EM		31,360	15,056	15,056	31,360	31,360	31,360	
Hadron		31,520	4,692	18,564	12,324	19,968	4,692	
Trans/Long Seg								
EM		0.04/2	0.04/1	0.04/1	0.04/2	0.04/2	0.04/2	
Hadron		0.08/4	0.12/3	0.08/4	0.08/4	0.08/4	0.12/3	
Eta Coverage								
EM	eta	3.00	2.50	2.50	3.00	3.00	3.00	
Hadron	eta	3.00	3.00	3.00	3.00	3.00	3.00	
Inter Lgh @ 90°		11.30	11.70	11.70	11.70	11.70	11.70	10.2
Inter Lgh @ 5.7°		14.00	14.00	14.00	14.00	14.00	14.00	
Cost Est	$ M							

Expected energy resolution for two major GEM e-m calorimeter options

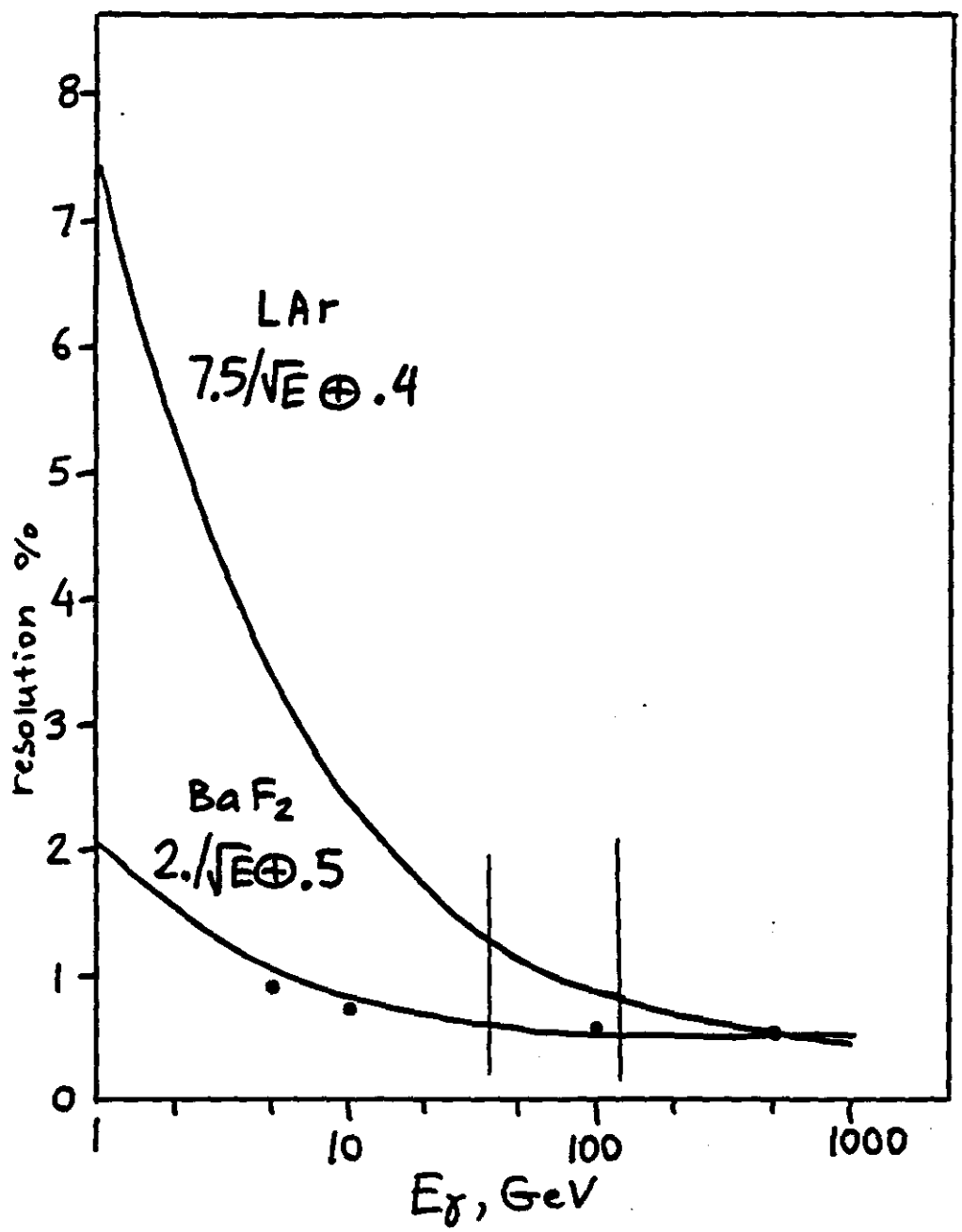


Table 2.4-1 Effect of Energy Resolution: a and b

a =	2.0	5.0	7.5	10	15
b = .25	0.63	1.2	1.7	2.2	3.3
b = 0.5	1.0	1.4	1.8	2.3	3.4
b = .75	1.4	1.7	2.1	2.6	3.6
b = 1.0	1.8	2.1	2.4	2.9	3.7

BaF2

LAr

LAr accordion
beam test CERN '91
non-projective

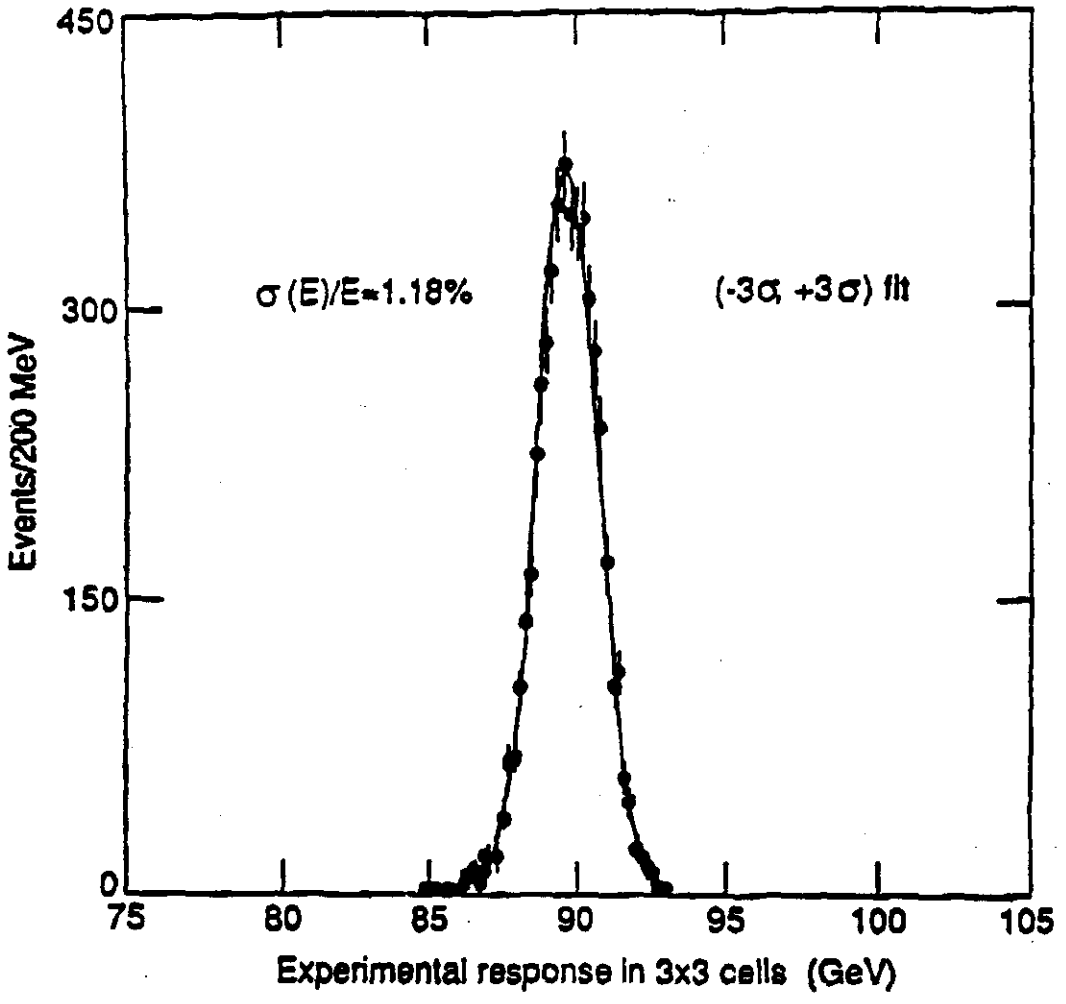


Fig. 8

$$\frac{9.61 \pm 0.24\%}{\sqrt{E}} \oplus 0.32 \pm 0.04\% \oplus \frac{0.326 \pm 0.015}{E} \text{ GeV}$$

NIM A276
(1989) 456-467

Table 3a
Measured and calculated energy resolutions for various calorimeters employing scintillator as active material. The values given for σ are fractional energy resolutions scaled to 1 GeV showers. The contribution of photoelectron statistics has been subtracted to the measured values. Otherwise they appear in parentheses.

Absorber	t [mm]	s [mm]	σ_{exp} [%]	σ_{EGS} [%]	$\sigma_{exp}/\sigma_{EGS}$	Ref.
Pb	1.0	5.0	5.0	4.0	1.2	[20]
Pb	1.0	5.0	6.0	4.0	1.5	[24]
Pb	2.0	5.0	7.5	6.3	1.2	[25]
Pb	2.1	6.3	9.0	6.1	1.5	[15]
Pb	2.5	4.0	(10.5)	7.8	1.3	[26]
Pb	3.2	5.0	12.0	8.6	1.4	[27]
Pb	3.5	4.0	(14.0)	9.8	1.4	[28]
Pb	4.0	5.0	11.6	10.0	1.2	[29]
Pb	4.2	12.6	10.8	7.9	1.4	[15]
Pb	6.0	5.0	13.6	13.1	1.1	[30]
Pb	6.0	2.5	17.5	16.0	1.1	[31]
Pb	8.4	25.2	14.7	10.3	1.4	[15]
Pb	9.4	6.4	(18.2)	16.5	1.1	[32]
Pb	10.0	2.5	22.6	22.6	1.0	[33]
U	1.6	2.5	(11.0)	9.7	1.1	[34]
U	2.0	2.5	(13.9)	11.3	1.2	[35]
U	3.0	2.5	(16.3)	15.0	1.1	[36]
U	3.2	5.0	(14.8)	12.7	1.2	[37]
U	3.2	3.0	(15.0)	14.8	1.0	[37]
U	10.0	5.0	(28.0)	27.9	1.0	[38]
Fe	4.8	6.3	10.1	6.8	1.5	[15]
Fe	25.0	5.0	(23.0)	20.0	1.1	[7]

Table 3b
Measured and calculated energy resolutions for various calorimeters employing liquid argon as active material. The contributions of electronic noise and calibration errors have been subtracted to the measured values. Otherwise they appear in parentheses.

Absorber	t [mm]	s [mm]	σ_{exp} [%]	σ_{EGS} [%]	$\sigma_{exp}/\sigma_{EGS}$	Ref.
Pb	1.0	2.0	8.0	5.0	1.6	[39]
Pb	1.2	3.6	(8.5)	5.0	1.7	[40]
Pb	1.5	5.0	7.5	5.4	1.4	[41]
Pb	1.5	2.0	8.0	6.4	1.3	[42]
Pb	1.9	3.0	9.0	6.9	1.3	[43]
Pb	2.0	5.0	(10.0)	6.5	1.5	[44]
Pb	2.0	3.0	(10.8)	7.1	1.5	[45]
Pb	2.0	2.0	9.6	7.7	1.2	[46]
Pb	2.0	2.0	(10.3)	7.7	1.3	[47]
Pb	2.2	2.0	9.5	7.7	1.2	[48]
Pb	2.4	2.8	11.2	8.1	1.4	[43]
U	2.0	1.6	14.0	11.5	1.2	[49]
Fe	1.0	1.0	2.8	3.7	0.8	[50]
Fe	1.5	1.5	9.5	4.4	2.2	[51]
Fe	1.5	2.0	6.9	4.1	1.7	[52]
Fe	1.5	2.0	(7.4)	4.1	1.8	[53]
Fe	2.0	2.0	6.1	4.9	1.2	[46]

Table 3c
Measured and calculated energy resolutions for various calorimeters employing a gas as active material

Absorber	t [mm]	s [mm]	σ_{exp} [%]	σ_{EGS} [%]	$\sigma_{exp}/\sigma_{EGS}$	Ref.
Pb	1.1	5.0	11.2	14.0	0.8	[54]
Pb	1.3	12.7	17.0	13.0	1.3	[55]
Pb	1.4	10.0	14.0	14.0	1.0	[56]
Pb	2.0	6.0	15.0	18.4	0.8	[57]
Pb	2.0	3.2	16.0	20.5	0.8	[58]
Pb	2.8	11.6	17.0	19.5	0.9	[59]
Pb	2.8	12.4	17.5	19.3	0.9	[60]
Pb	2.8	9.5	17.0	20.2	0.8	[61]
Pb	3.0	7.0	24.0	22.0	1.1	[62]
Pb	5.0	9.0	28.0	27.4	1.0	[63]
Pb	6.0	2.0	27.0	38.8	0.7	[64]

Pb / LAr

$$\frac{\sigma_{EXP}}{\sigma_{EGS}} \sim 1.4$$

Parametrized MC predictions:

Accordion resolution

LoI 2mm option:

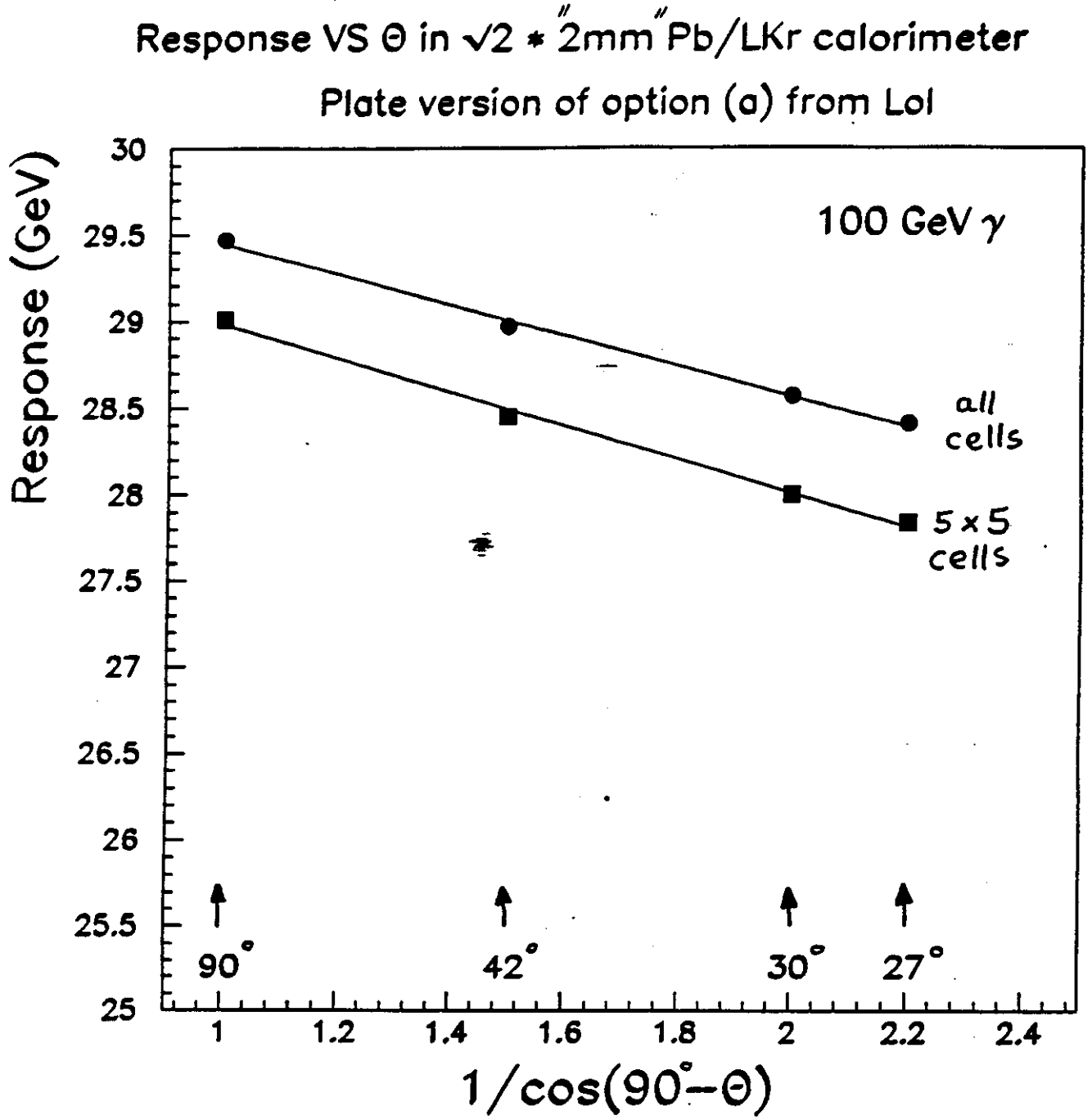
LAr – 6.5% × 1.4 ⇒ 9.1%
LKr – 5.3% × 1.4 ⇒ 7.5%

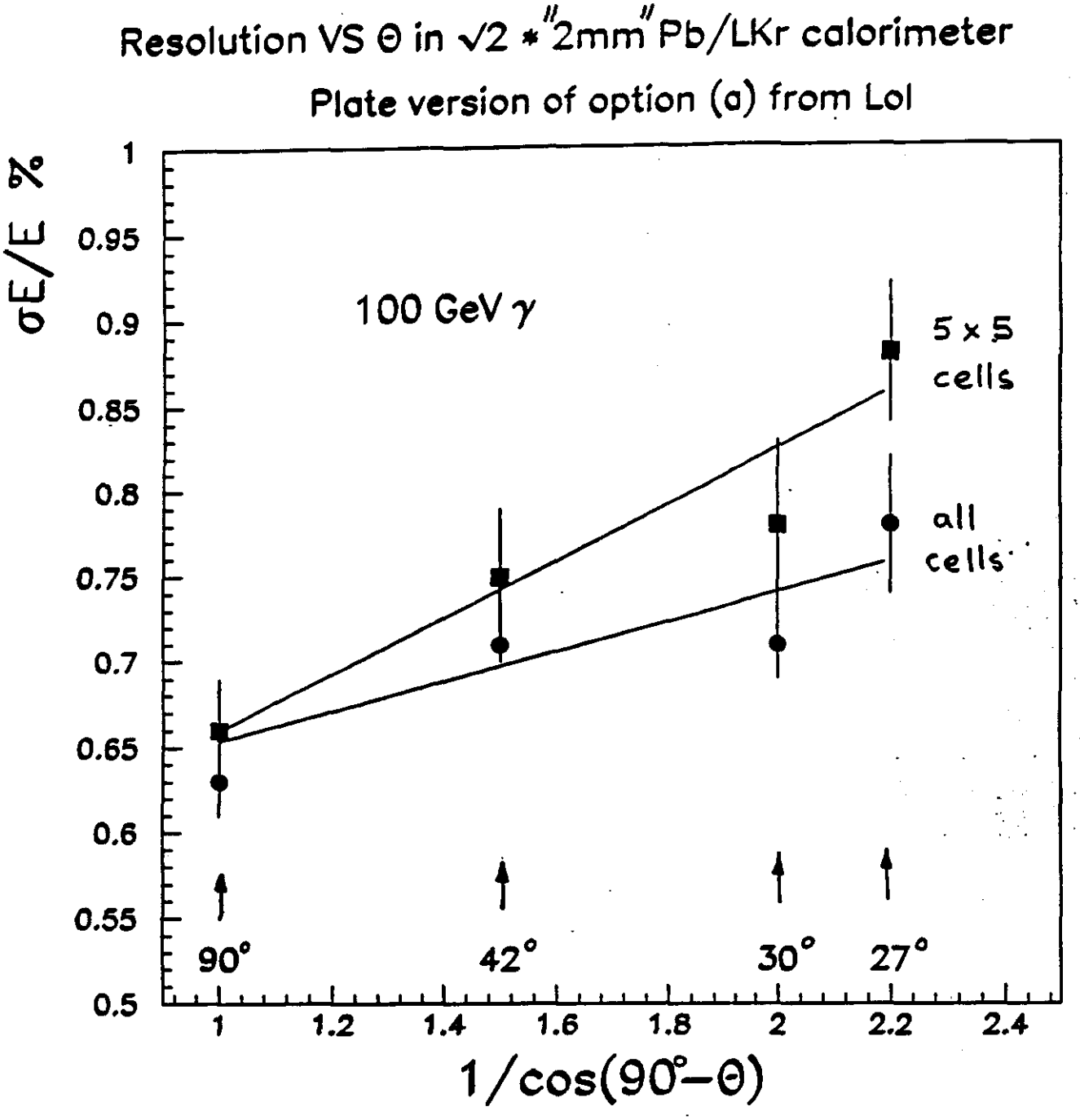
LoI 1mm option:

LAr – 5.5% × 1.4 ⇒ 7.8%
LKr – 4.5% × 1.4 ⇒ 6.4%

Expected constant term: 0.4%

Best achieved c.t. (non-projective) 0.3 ± 0.05%


Response VS Θ in √2 * "2mm" Pb/LKr calorimeter
Plate version of option (a) from LoI
Response (GeV)
30
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
100 GeV γ
all cells
5 x 5 cells
90°
42°
30°
27°
1
1.2
1.4
1.6
1.8
2
2.2
2.4
1/cos(90°−Θ)


Resolution VS Θ in √2 * "2mm" Pb/LKr calorimeter
Plate version of option (a) from LoI
σE/E %
100 GeV γ
5 x 5 cells
all cells
90°
42°
30°
27°
1/cos(90°−Θ)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
1
1.2
1.4
1.6
1.8
2
2.2
2.4

Flat plates LKr em

(Paul Mockett)

92 plates (1mm Pb + 4mm Kr) 25 X_0 (474 mm)

resolution : 3.7% × 1.4 ⇒ 5.2%
EGS (P.M.) 4.4%

115 plates (0.7 mm Pb + 4mm Kr) 25 X_0 (558 mm)

resolution : 3.0% × 1.4 ⇒ 4.2%
EGS (P.M.) 3.6%

Radiation Thickness of Tracker

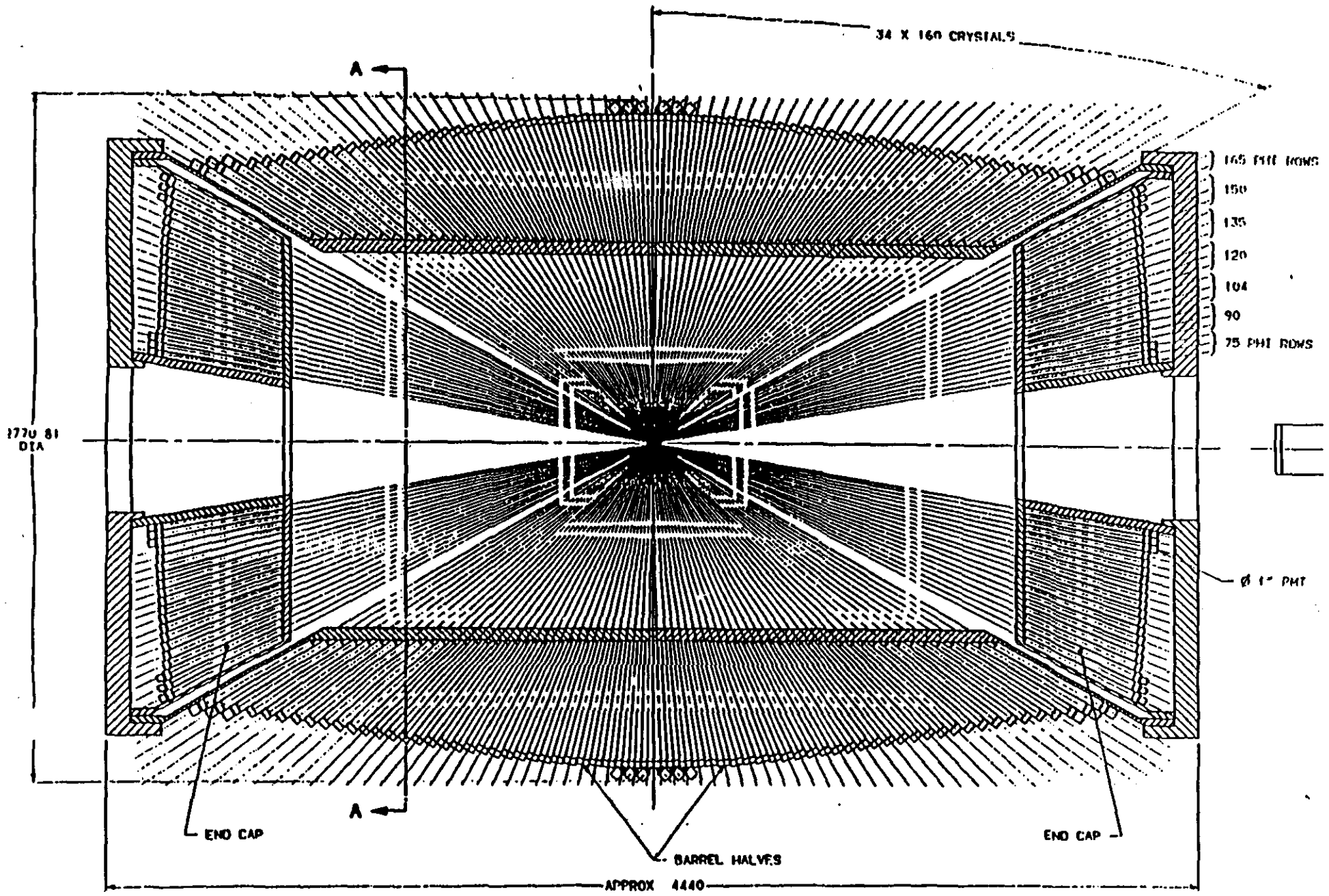
up to $0.5X_0$ total doesn't affect the e-m resolution, but converts γ's and spoils e measurement / identification.

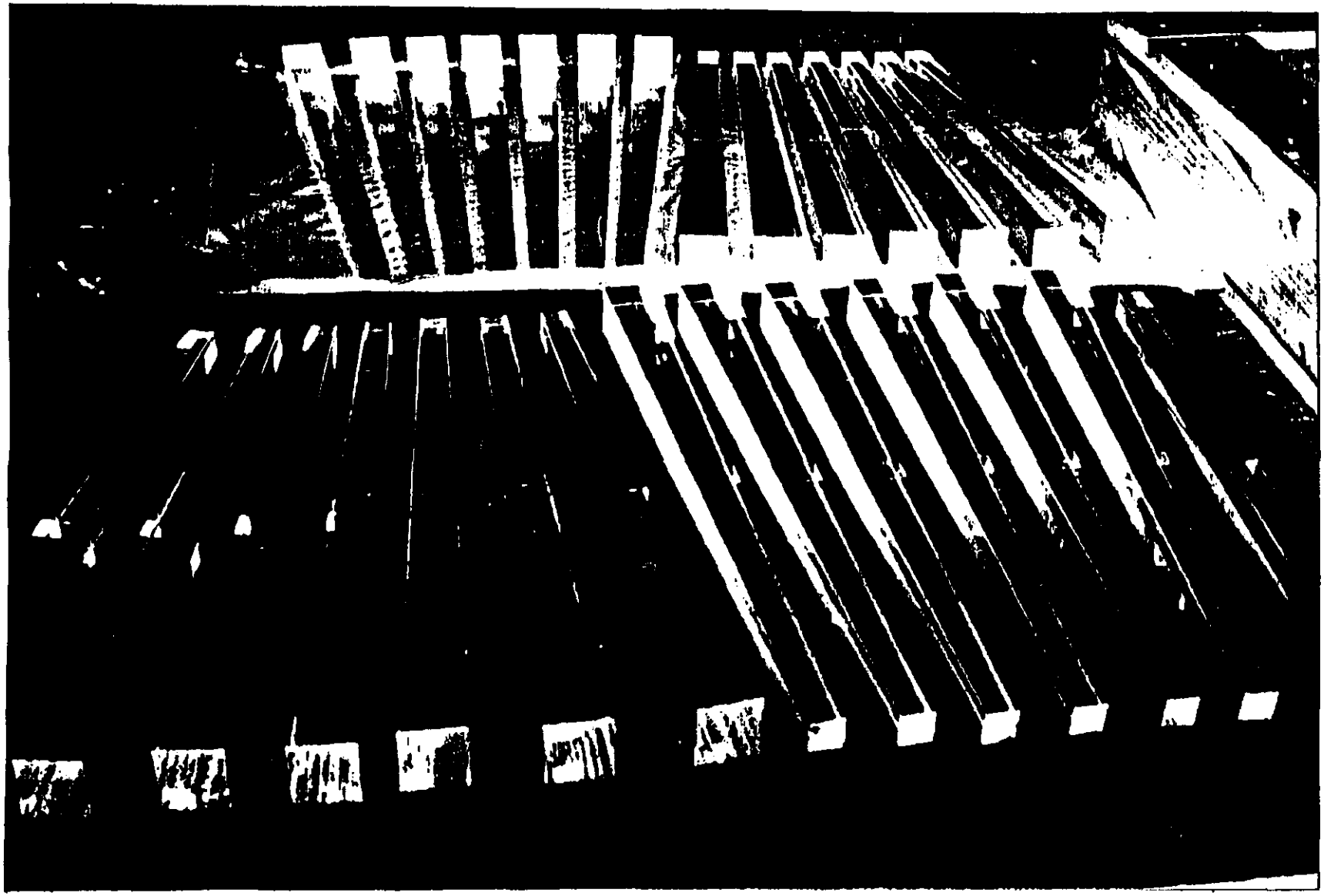
Should not exceed $\boxed{\sim 0.2\ X_0}$

including supports and cables in the

all range of $|\eta| < 3$

(LAr cryostat wall is already $\sim 0.3X_0$)

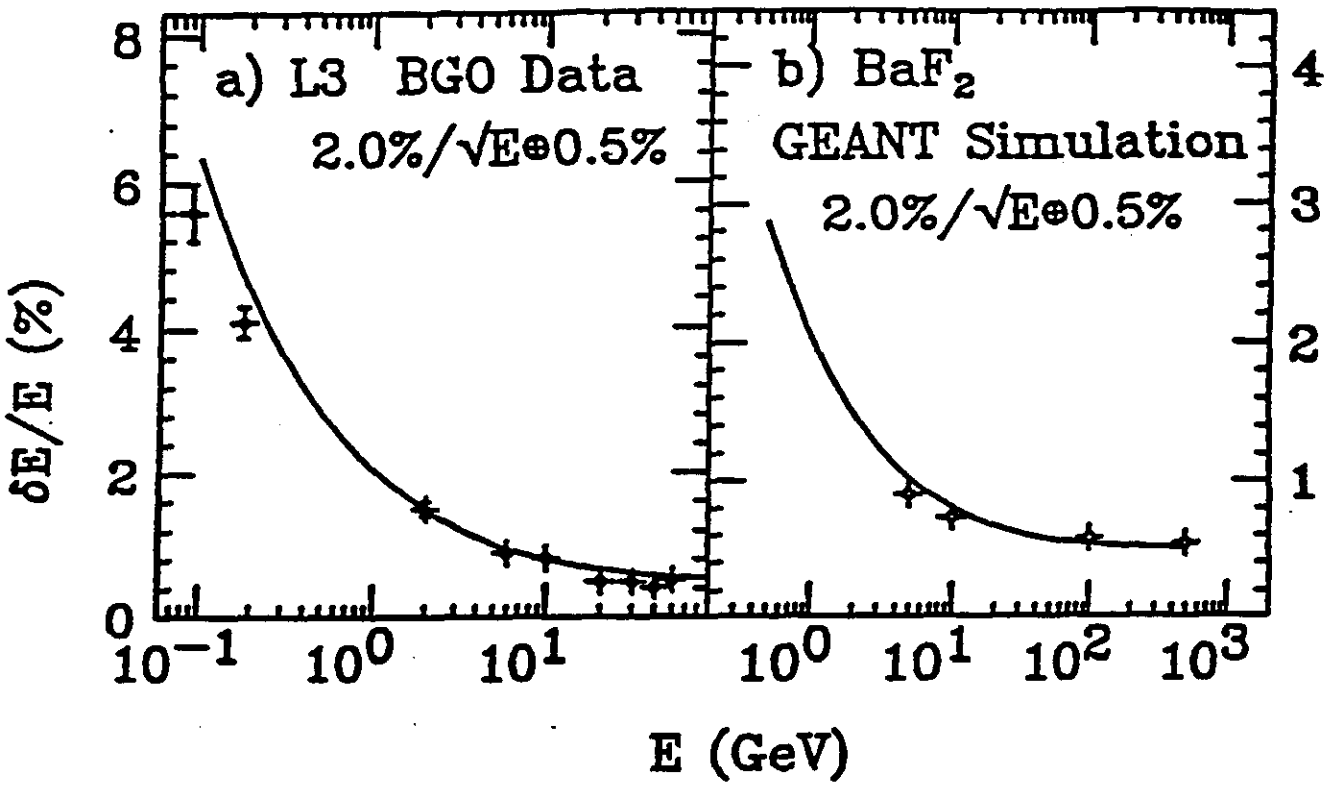

34 X 160 CRYSTALS
A
A
165 PHI ROWS
150
135
120
104
90
75 PHI ROWS
DIA
Ø 1" PMT
END CAP
END CAP
BARREL HALVES
APPROX 4440



ENERGY RESOLUTION:

(a) L3 BGO Test Beams; 4000 Crystals

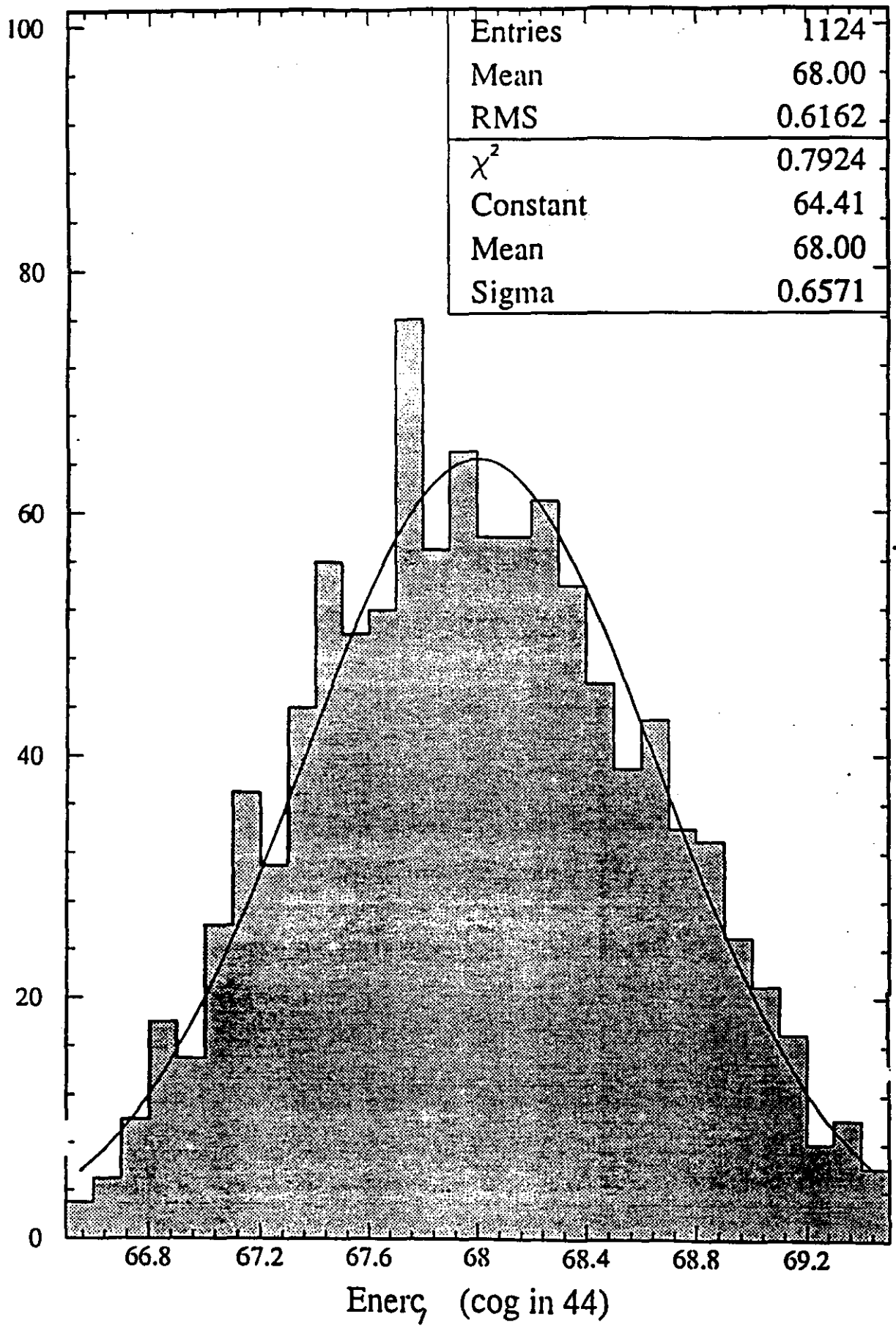
(b) BaF_2: GEANT Simulation



Contributions to the Energy Resolution (%)

E (GeV)	5	10	100	500
Electrical Noise	0.4	0.2	0.02	0.004
Photoelectrons	0.2	0.14	0.045	0.02
GEANT	0.67	0.56	0.42	0.36
Intercalibration	0.40	0.40	0.40	0.40
Total	0.90	0.73	0.58	0.54

1% resolution on (E_{BaF_2} - P_{beam})
in 20mm X 20mm area. (front face of center crystal)



gaussian fit within (~2.25σ) ±1.5 GeV

BaF_2 EM CALORIMETER
12/91 BEAM TEST

- CALORIMETER RESOLUTION:
  BaF_2-SPECTROMETER DIFFERENCE
  - Resolution 20×20 mm^2: 1.0%
  - Instrumental Contributions
    - * Spectrometer Resol'n: $0.5 \pm 0.2\%$
    - * Pedestal Diff. Linearity: 0.4%
  - BaF_2 Matrix Resolution (at 68 GeV):
    $0.77\ (+0.12 - 0.18)\%$

  - Further Contribution (Not Subtracted):
    Crystal Non-Uniformity: $0.5 \pm 0.1\%$
  - Possible Calorimeter Resolution:
    $0.6 \pm 0.2\%$

SIMULATIONS AND LAB TESTS:

Demonstrate High Resolution
Maintainable In Situ
Max. Constant Term 0.6%

EFFECTS TO BE INCLUDED

- Residual Non-Uniformity (As Installed)
- Non-Uniformity Due to Radiation:
  Non-Saturation Or Annealing In Situ
- Accuracy of Intercalibration
  (From Calibration Studies)
- Short Term Instabilities of Readout System.
- Linearity, Linearity Calibration and
  Dynamic Range of Readout System.

BaF_2 CALIBRATION

- RFQ: Radiative Capture Photons
  - RFQ Test (3.85 MeV) At AccSys 6/92
  - L3 System Installed At LEP 3/92
- MIP Calibration
  - Test at UCSD Cosmic Ray Stand
- UV Laser Monitoring System (CMU, UCSD)
- Check: Inclusive $Z^0, \Upsilon \rightarrow e^+e^-$

Forward Calorimeter

John Rutherfoord

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

J. Rutherfoord
GEM Collab Mtg.
Tucson 3/9/92

GEM Forward Calorimetry

Physics Goals

Hermetic measurement of global $\overline{p}_T$

Forward tagging jets

Critical Parameters

Mean density ? calorimeter (As high as possible)

Diameter of beam hole (As small as possible)

Engineering Baseline

LAr tube - integrated

Studies

Activation
Muon spray
Neutron albedo
} L. Waters, D. Lee

Positive ion build-up

Poisoning

Mechanical - construction

Electronics

Physics Requiring a Forward Calorimeter

Missing E_T

Higgs

$$H \rightarrow ZZ \rightarrow \ell^+\ell^-\nu\bar{\nu}$$
$$H \rightarrow ZZ \rightarrow \ell^+\ell^-\tau\bar{\tau}$$

New heavy quarks

SUSY

Technicolor

$$\rho^{\pm}_{TC} \rightarrow W^{\pm}Z^o \rightarrow \ell^{\pm}\nu\ell^+\ell^-$$

Leptoquarks $gg \rightarrow P_3P_3 \rightarrow b\tau\bar{b}\bar{\tau}$

New Gauge Bosons

$$W'^{\pm} \rightarrow \ell^{\pm}\nu$$

Other sources of boson pairs

$$W^{\pm}Z^o \rightarrow \ell^{\pm}\nu\ell^+\ell^-$$
$$W^{\pm}W^{\pm} \rightarrow \ell^{\pm}\nu\ell^{\pm}\nu$$
$$W^+W^- \rightarrow \ell^+\nu\ell^-\nu \text{ if separable from } t\bar{t}$$

Forward Jets

VV scattering with forward jet tagging

Low x physics via forward di-jets

Paige - Vazyashin

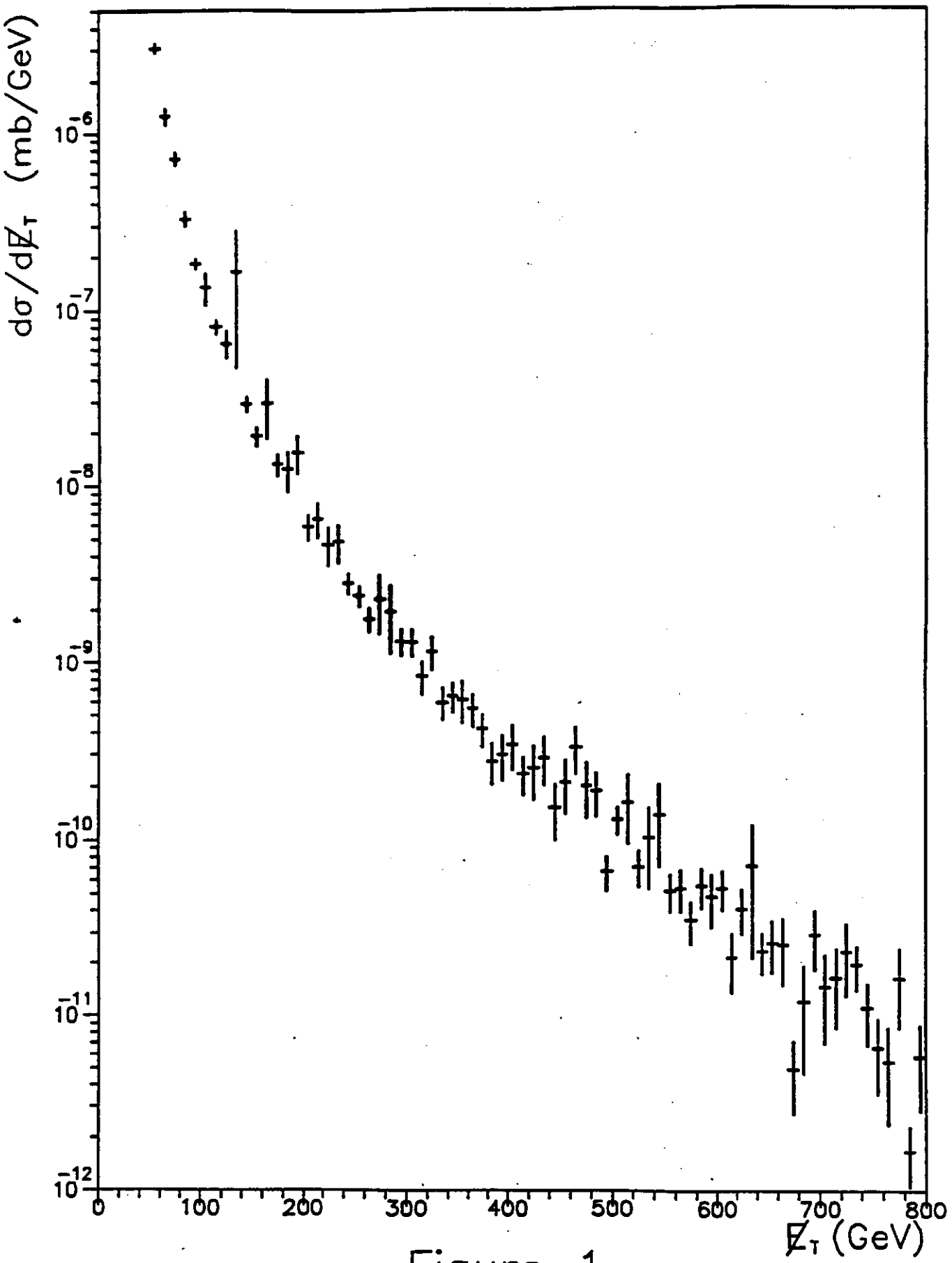


Figure 1

Paige - Vanyashin

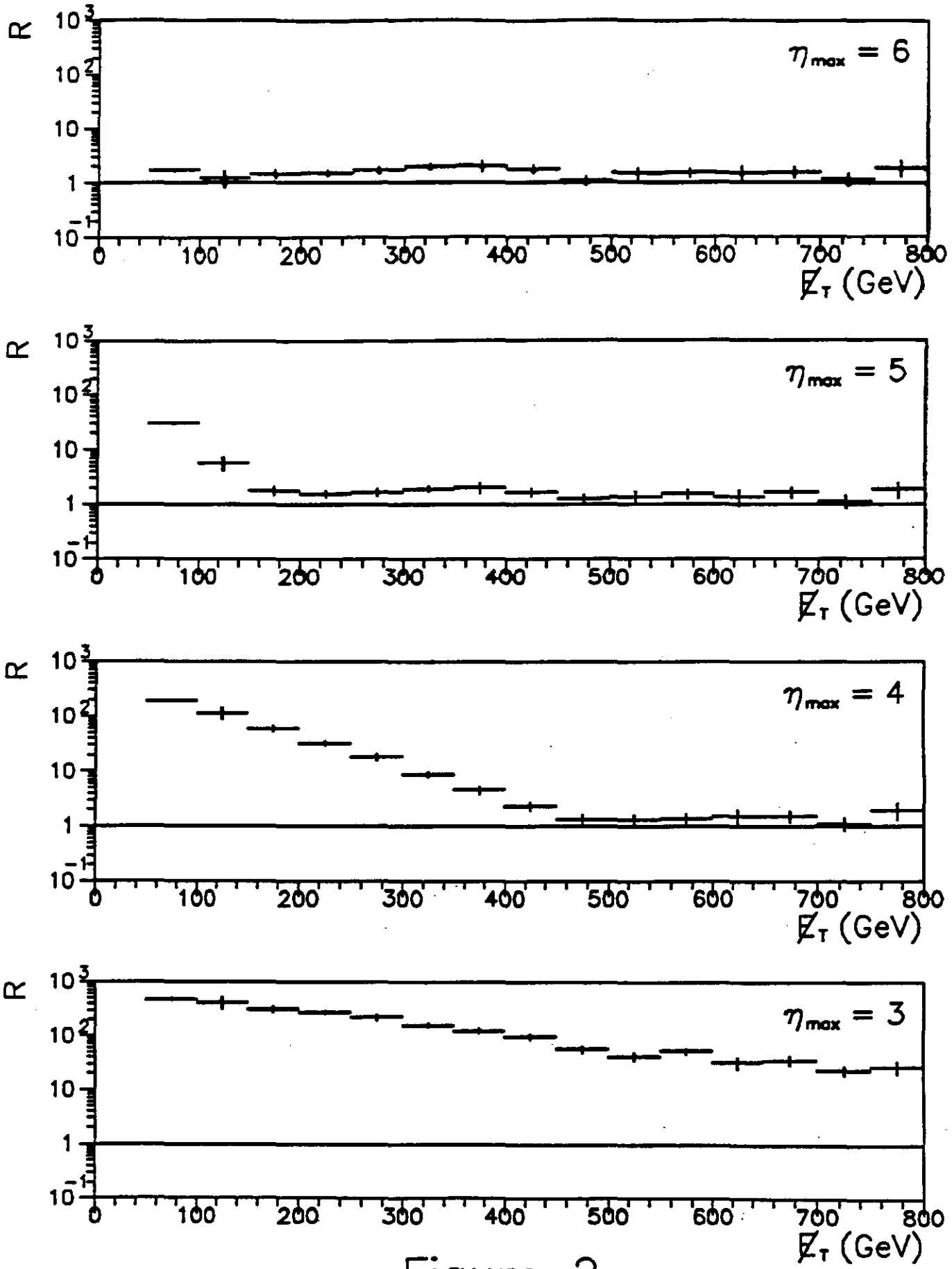
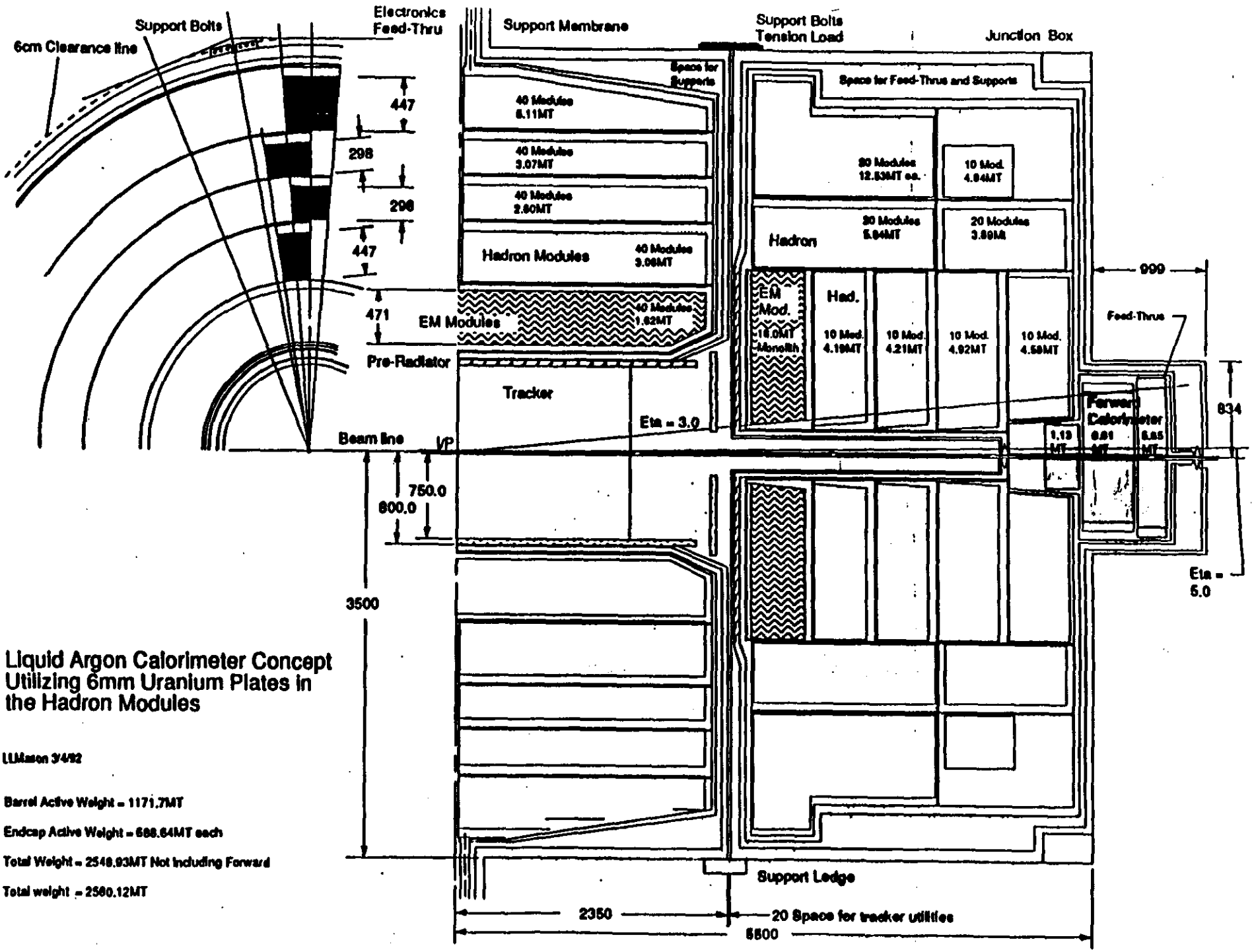


Figure 2



Liquid Argon Calorimeter Concept Utilizing 6mm Uranium Plates in the Hadron Modules

LLMason 3/4/92

Barrel Active Weight = 1171.7MT

Endcap Active Weight = 688.64MT each

Total Weight = 2548.93MT Not Including Forward

Total weight = 2560.12MT

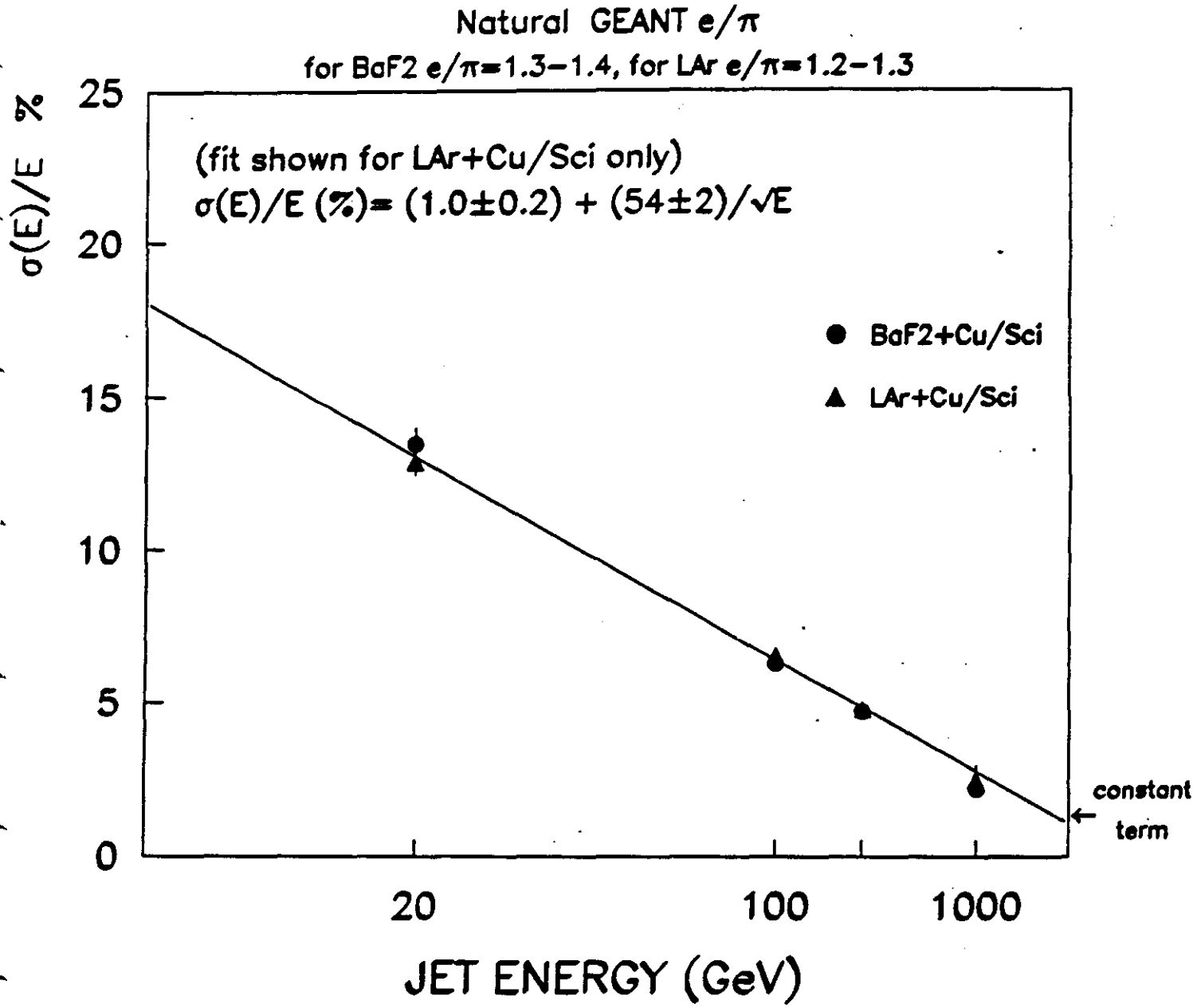
Expected jet energy resolution

$$\sim \frac{50\%}{\sqrt{E}} \oplus 2\%$$

GEANT jet resolution simulation exists, but ...

How reliable are GEANT simulations?

JET RESOLUTION FOR 12 λ– GEANT3.14



GEM Triggering

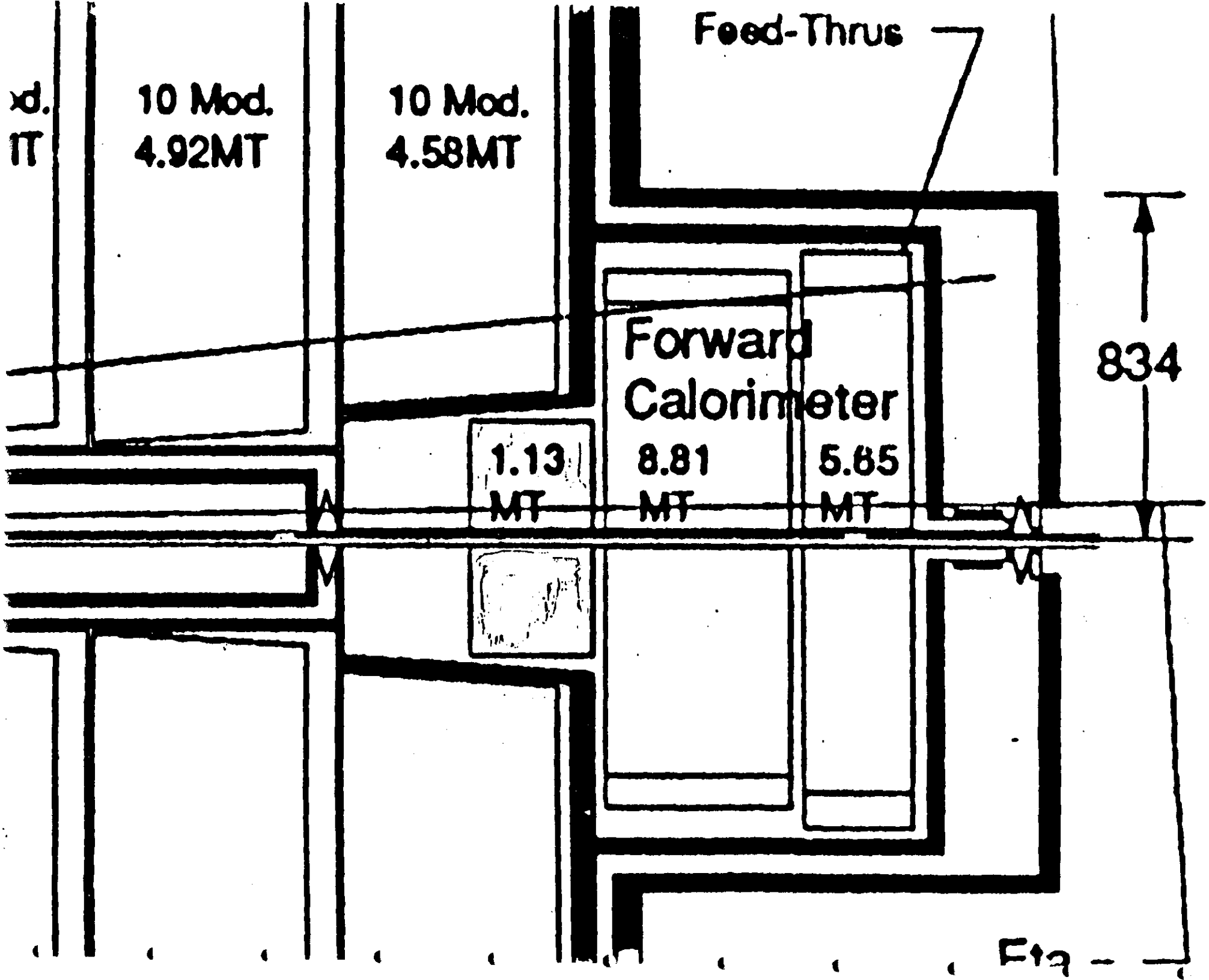
Shaevitz/Marlow

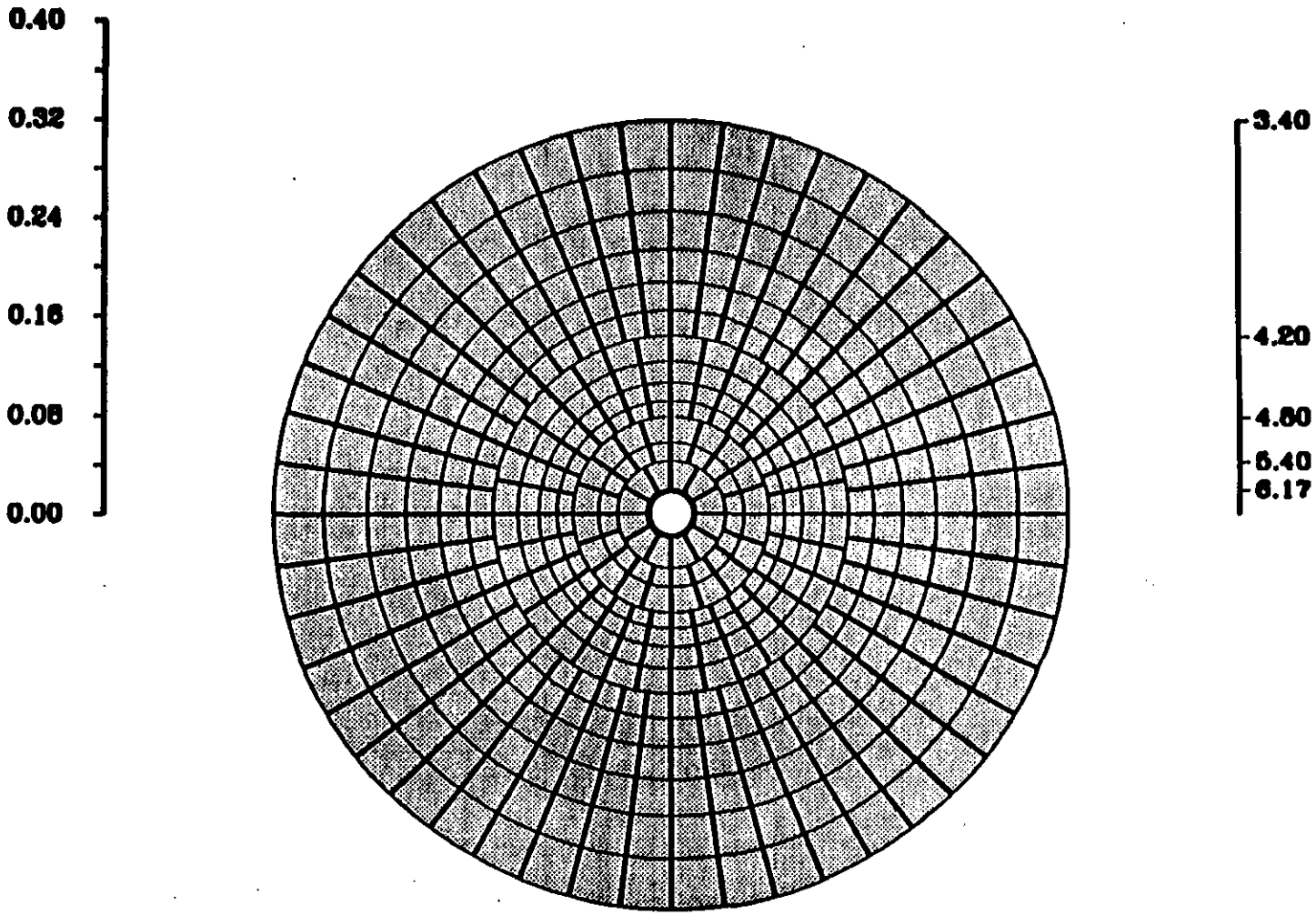
GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

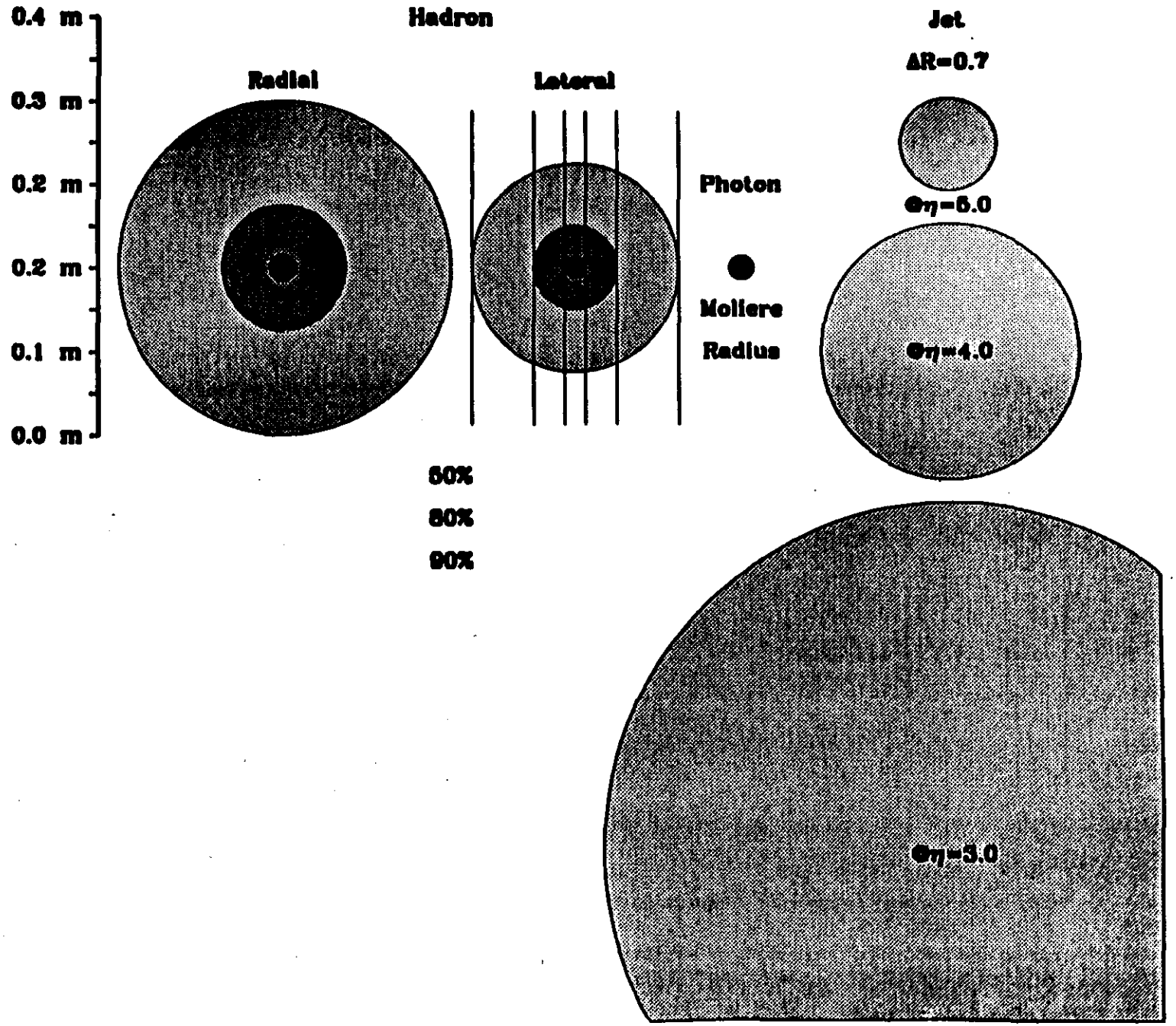
GEM Trigger/DAQ Design Goals (circa LoI)				
Level	Rate In	Rate Out	Latency	Comments
1	62 MHz	10 kHz	3 μs	Synchronous, Pipelined
2	100 kHz	300 Hz	100 μs	Asynchronous, Monotonic
3	3 kHz	10 Hz	—	CPU Ranch

GEM Trigger/DAQ Design Goals (Under Study)				
Level	Rate In	Rate Out	Latency	Comments
1	60 MHz ●	5 kHz ●	2 μs ●	Synchronous, Pipelined
2	50 kHz ●	300 Hz	? μs ○	Asynchronous, Monotonic
3	3 kHz	10 Hz	—	CPU Ranch

- ● Somewhere along the line the machine people changed this!
- ● Reduce rate into Level 2 to ease burden on calorimeter and IPC digitization rates.
- ● Reduce Level 1 latency to simplifiy SCA design. Note that cable transit sets an irreducible delay of ~ 1 μs.
- ○ We (I) can't claim to understand the Level 2 latency. Long latencies could be very serious if we digitize after Level 2.


Feed-Thrus
10 Mod.
4.92MT
10 Mod.
4.58MT
Forward
Calorimeter
1.13
MT
8.81
MT
5.65
MT
834


0.40
0.32
0.24
0.16
0.08
0.00
3.40
4.20
4.80
5.40
6.17


0.4 m
0.3 m
0.2 m
0.2 m
0.1 m
0.0 m
Hadron
Radial
Lateral
Photon
Moliere
Radius
50%
80%
90%
Jet
ΔR=0.7
Θη=5.0
Θη=4.0
Θη=3.0

GEM FCal
Technologies

Baseline:

Liquid Argon - Integrated with end cap

Arizona/BNL/ORNL/MMA

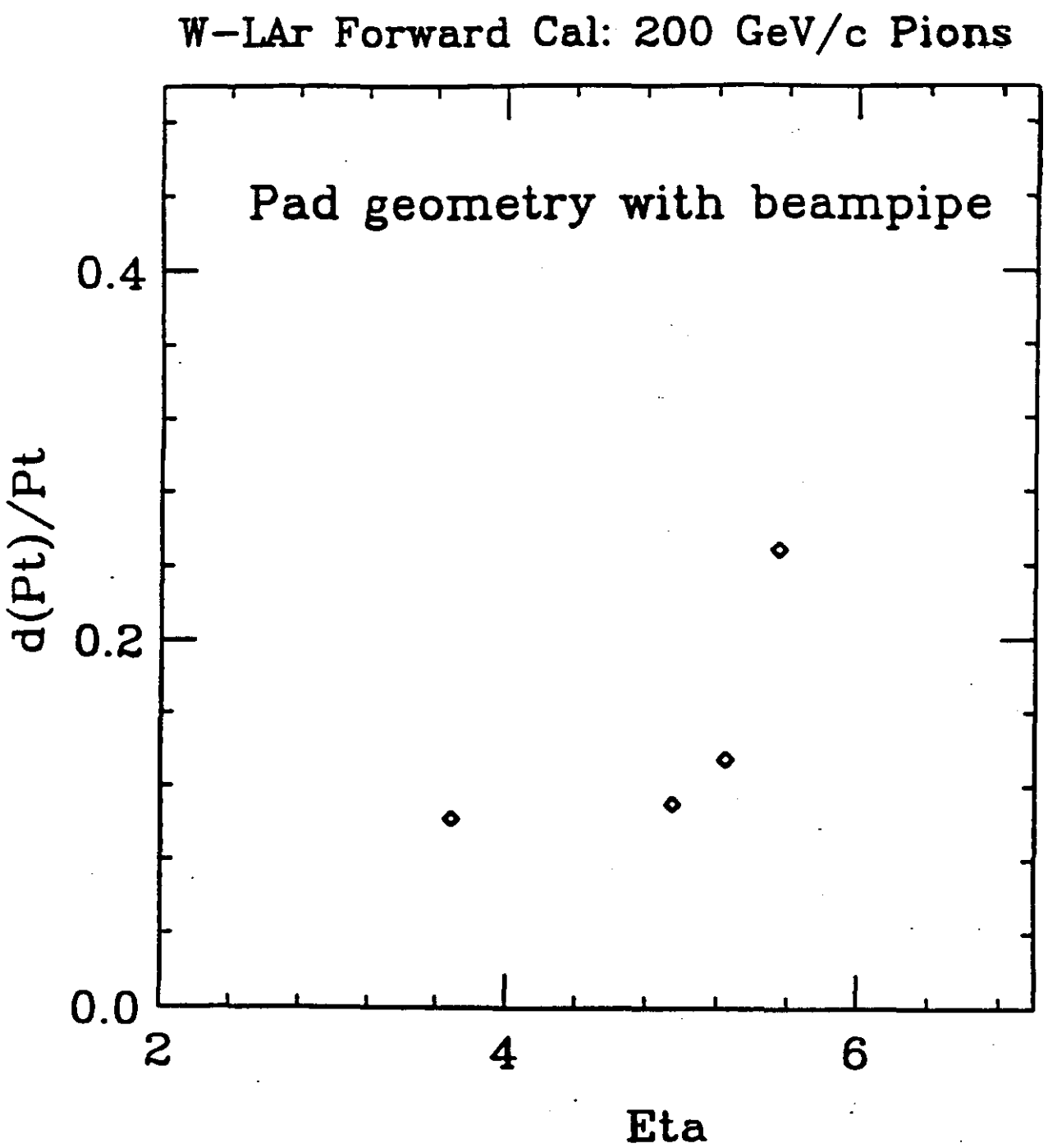
Options:

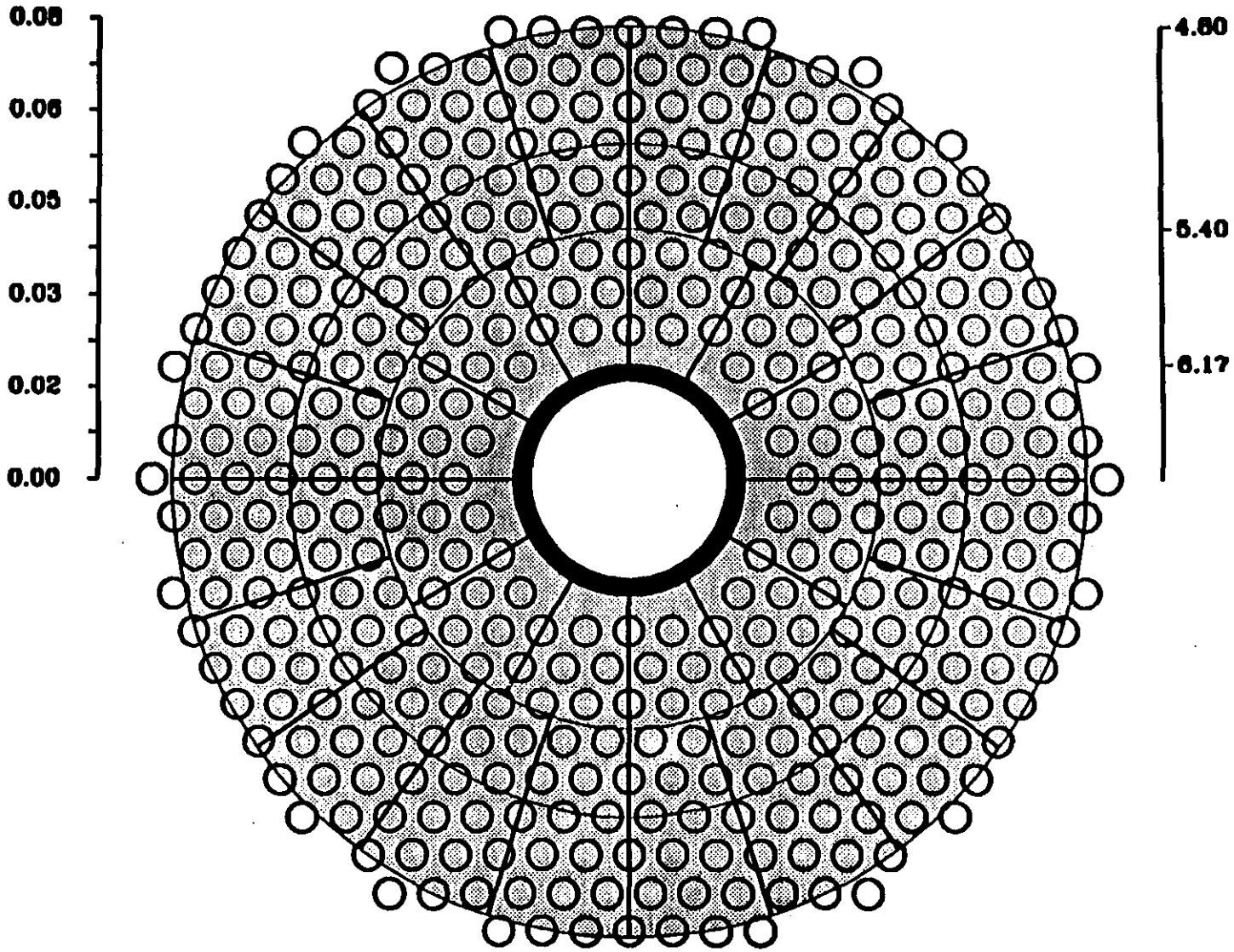
Liquid Scintillor Capillaries

Texas A&M/ORNL

High Pressure Gas

BNL/ORNL/

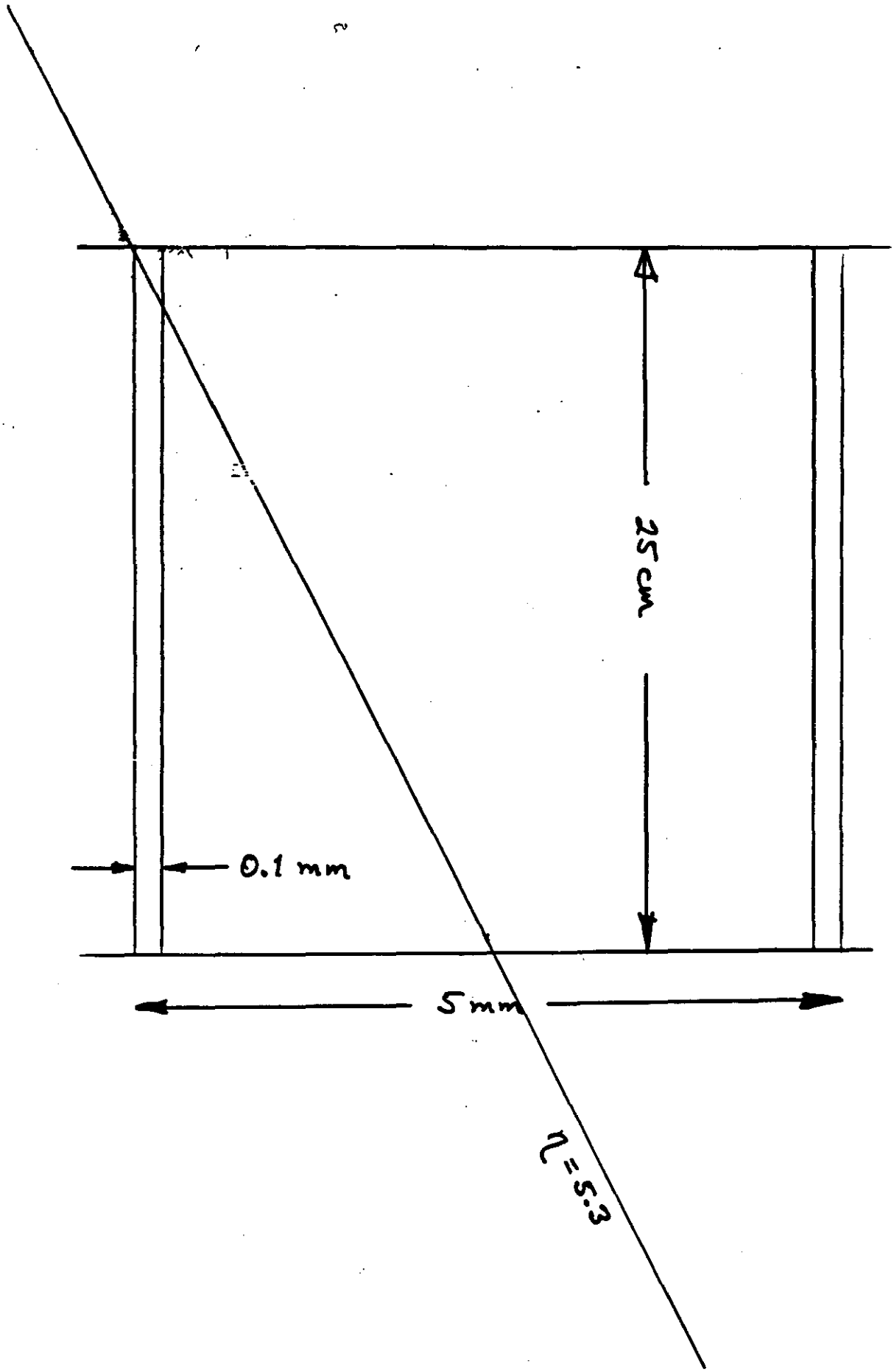

W-LAr Forward Cal: 200 GeV/c Pions
Pad geometry with beampipe
0.4
0.2
0.0
d(Pt)/Pt
2
4
6
Eta

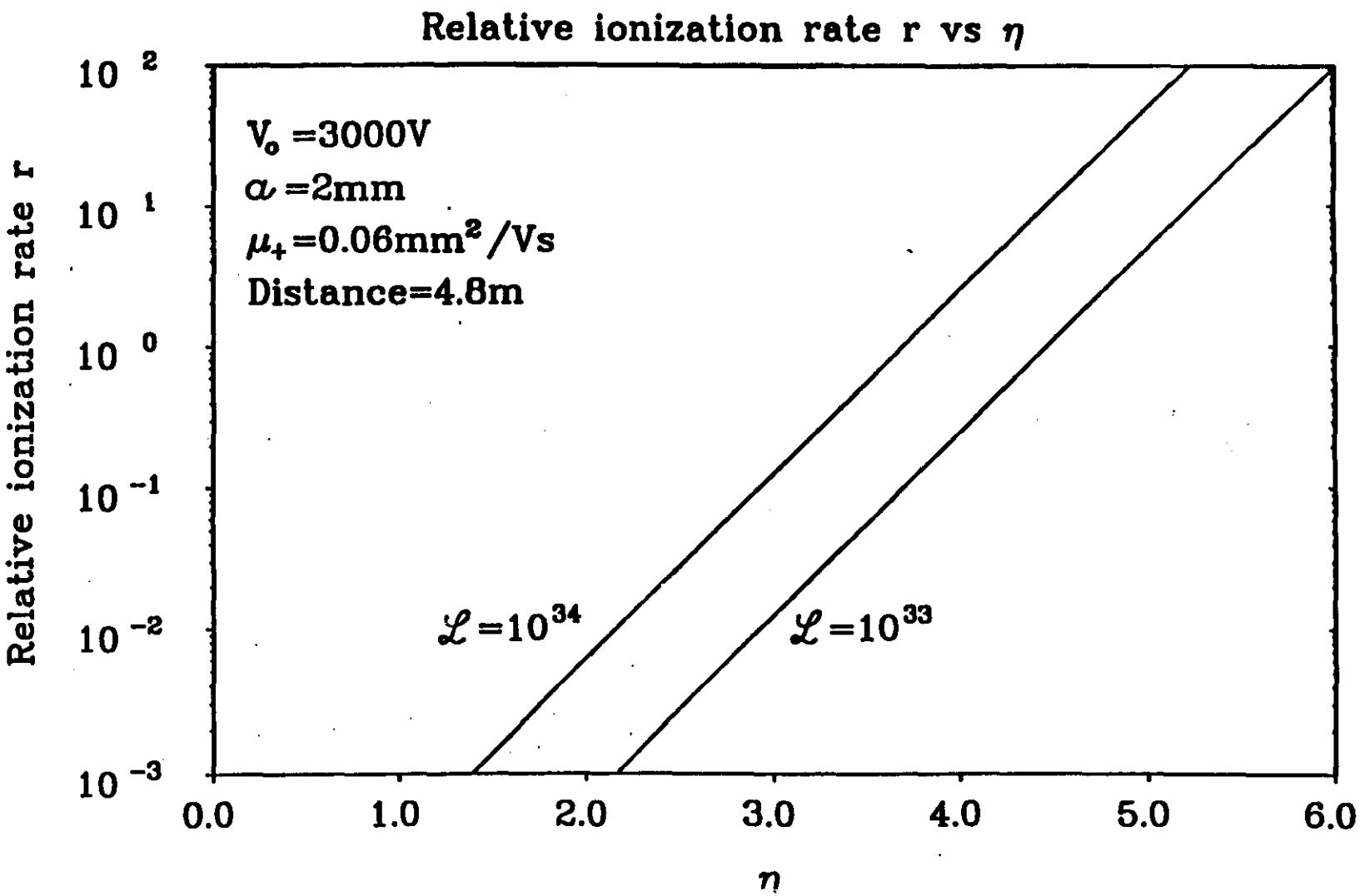

0.08
0.06
0.05
0.03
0.02
0.00
4.80
5.40
6.17

LAr Tube FCal

Parameters:

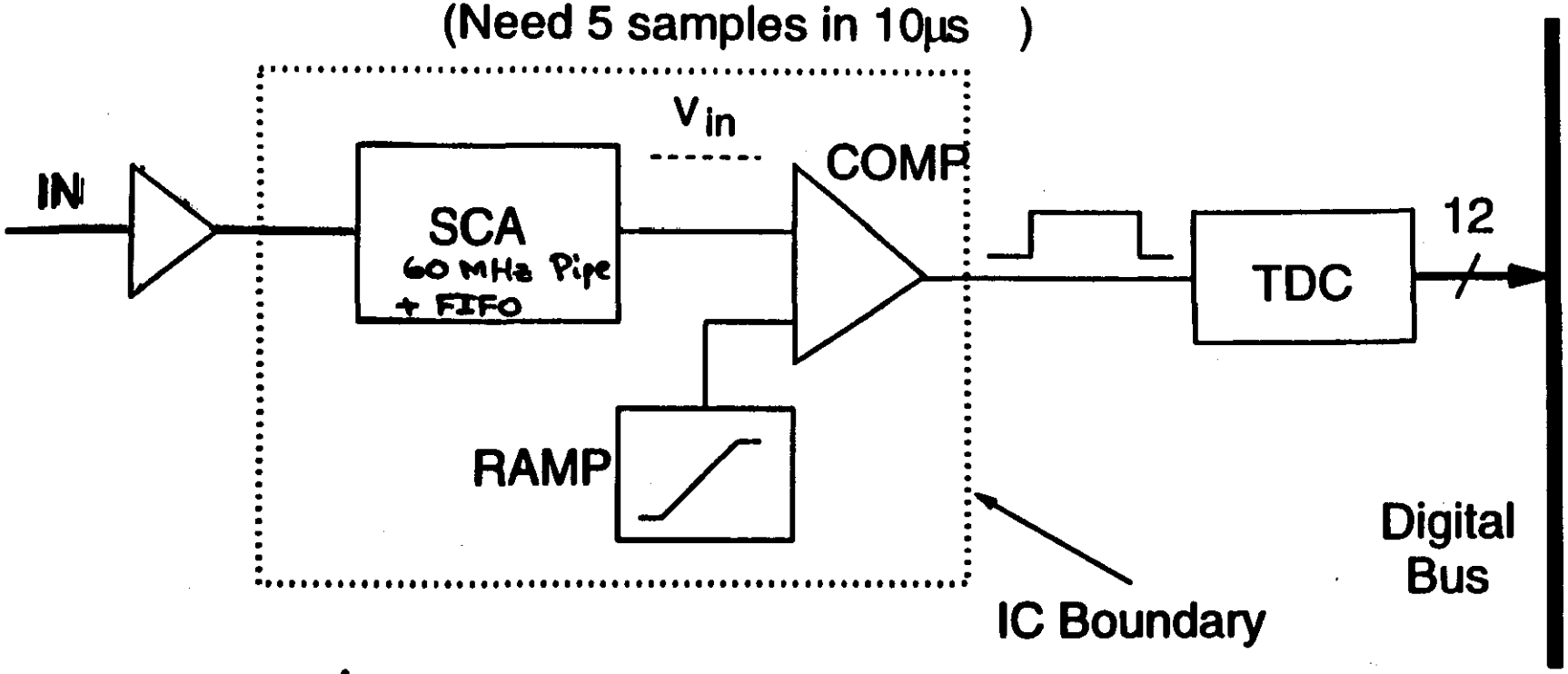
Tube radius	2.5 mm
Gap	0.1 mm
$\hat{C}$	2.2 nF/m
Z	2.0 Ω
t_D	20 ns
V_0	125 volts
Nearest neighbor center-to-center distance	7.5 mm
No. of holes in EM section	6600
Sampling fraction	0.3 %

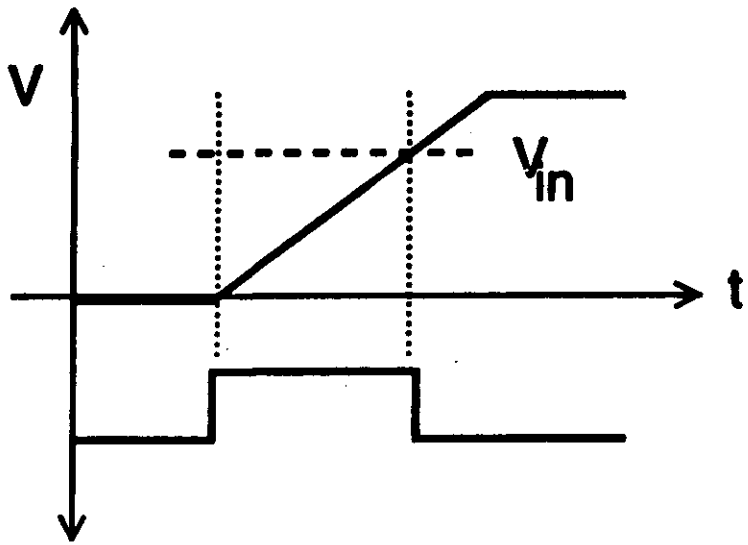

25 cm
0.1 mm
5 mm
η = 5.3


Relative ionization rate r vs η
Relative ionization rate r
10 2
10 1
10 0
10 -1
10 -2
10 -3
V₀ =3000V
a =2mm
μ₊=0.06mm²/Vs
Distance=4.8m
ℒ=10³⁴
ℒ=10³³
0.0
1.0
2.0
3.0
4.0
5.0
6.0
η

Possible Calorimeter ADC Scheme

(Need 5 samples in 10μs)

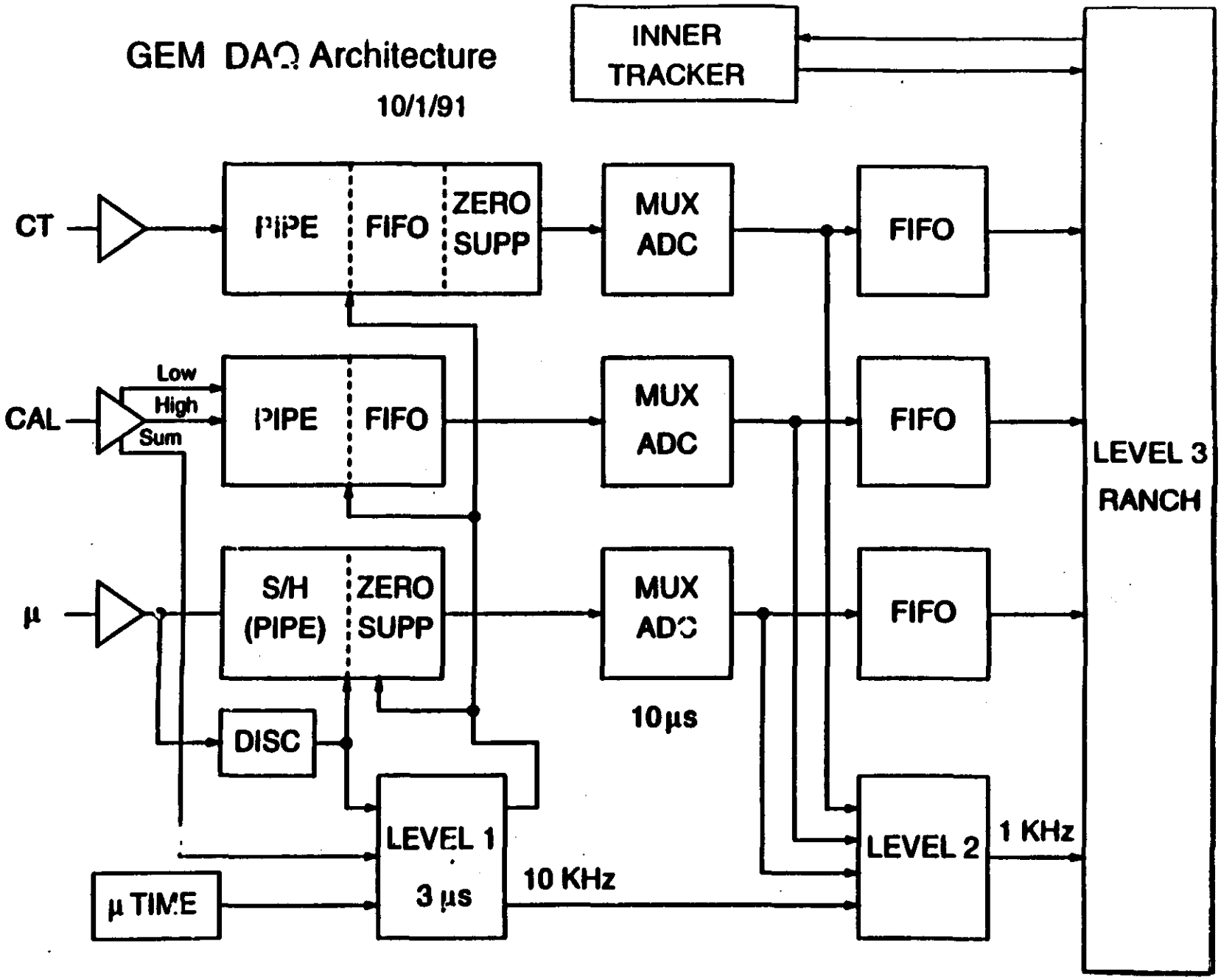




Voltage-->Time-->Digital Converter (Sippach /Neus)

1/2 ns/count ==> 12 bits in 2 μs

(Also need similar channel for high range)

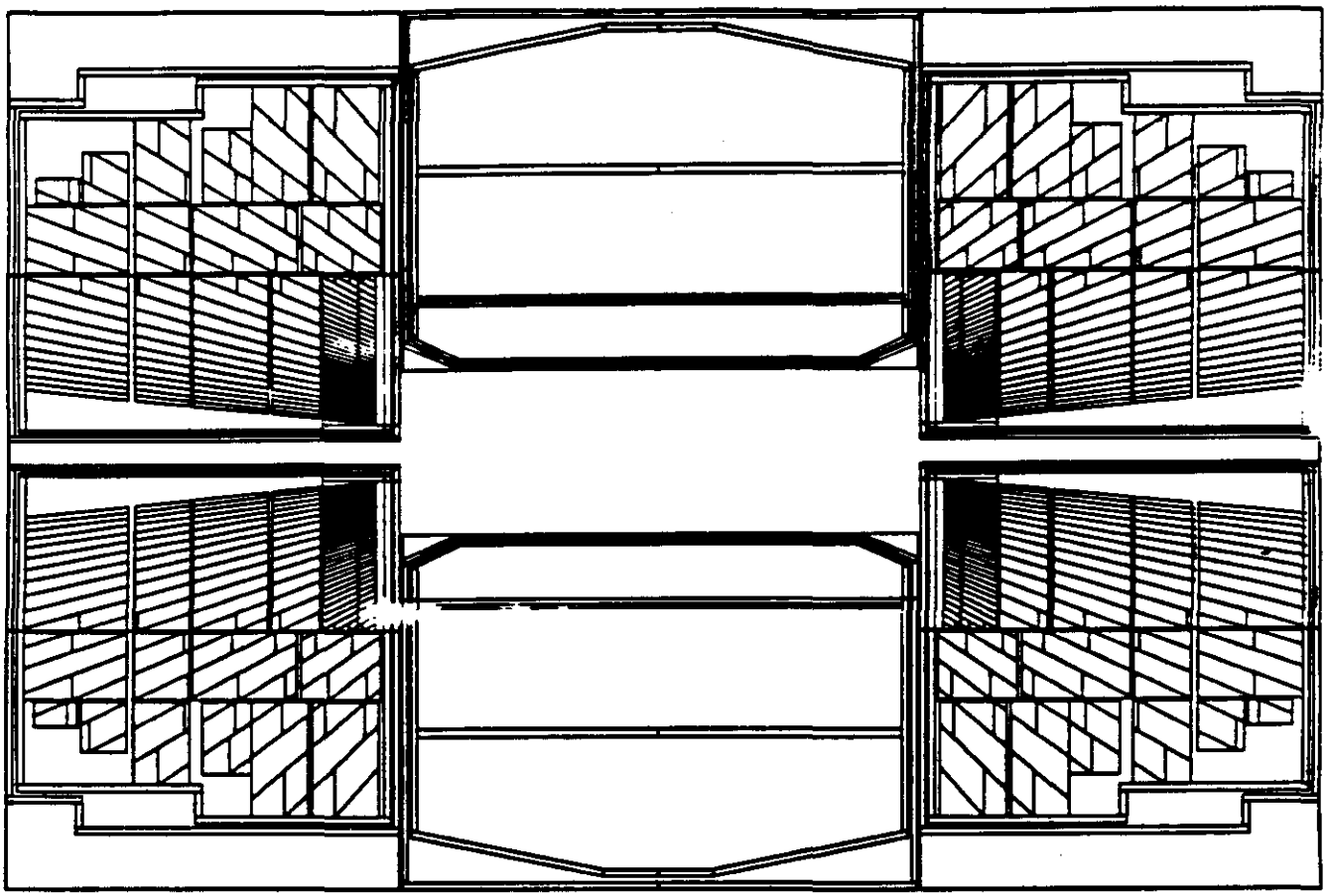

GEM DAQ Architecture
10/1/91
INNER TRACKER
CT
PIPE
FIFO
ZERO SUPP
MUX ADC
FIFO
CAL
Low
High
Sum
PIPE
FIFO
MUX ADC
FIFO
LEVEL 3 RANCH
μ
S/H (PIPE)
ZERO SUPP
MUX ADC
FIFO
10μs
DISC
LEVEL 1
3 μs
10 KHz
LEVEL 2
1 KHz
μ TIME

Calorimeter Readout

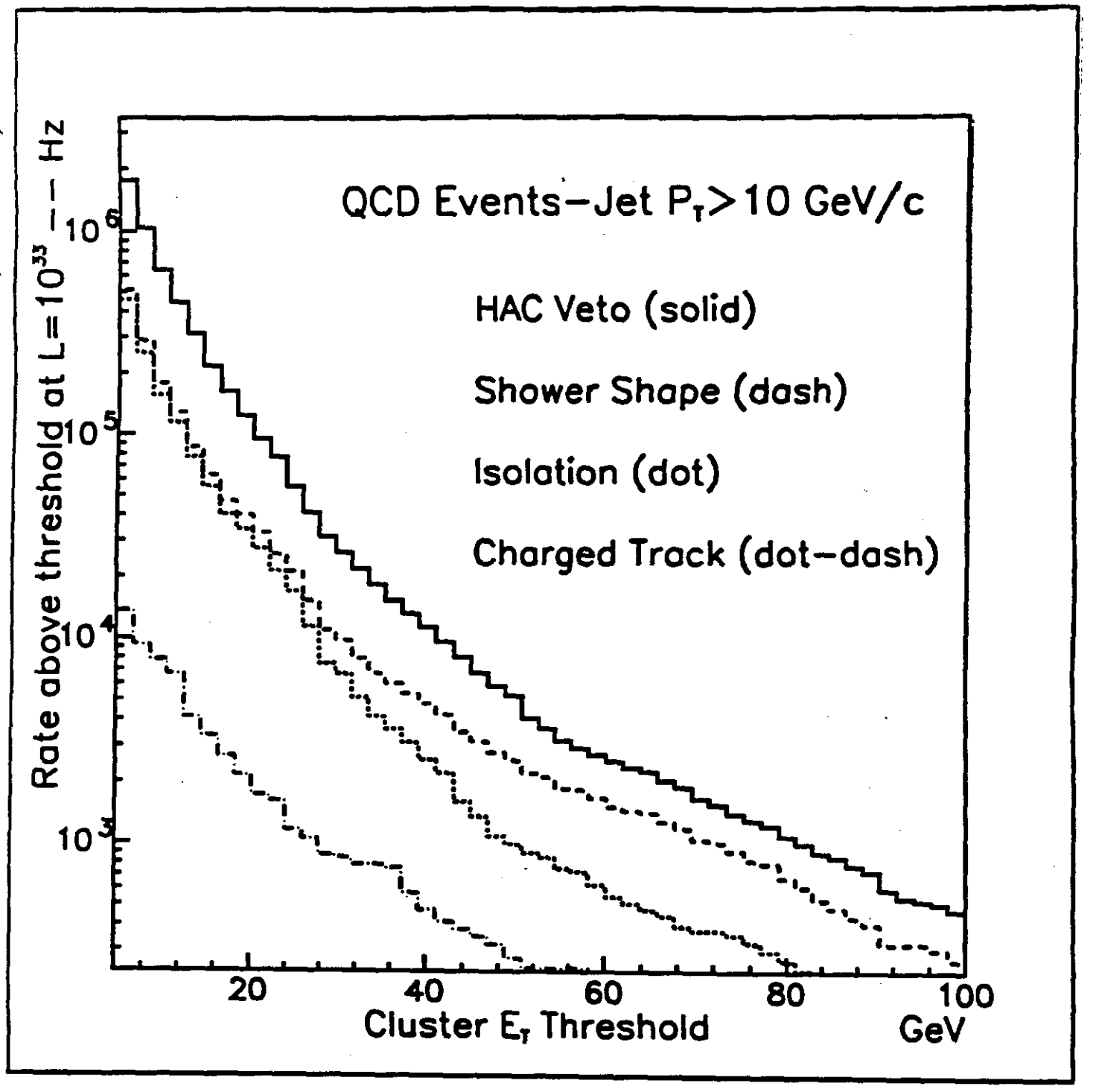
- Physics Goals (e.g. $H \rightarrow \gamma\gamma$) require
  - $\sigma_E/E \leq .1\%$
  - Full granularity at Level 2
  - High System Throughput

- Electrical Specifications
  - 16 ns sample rate.
  - Dynamic Range $\geq 2^{16}$
  - Resolution ≥ 8 bits
  - Total Conversion time $\leq 10\ \mu s$
    (for $\sim 2 - 5$ samples)
    BaF$_2$ LAr

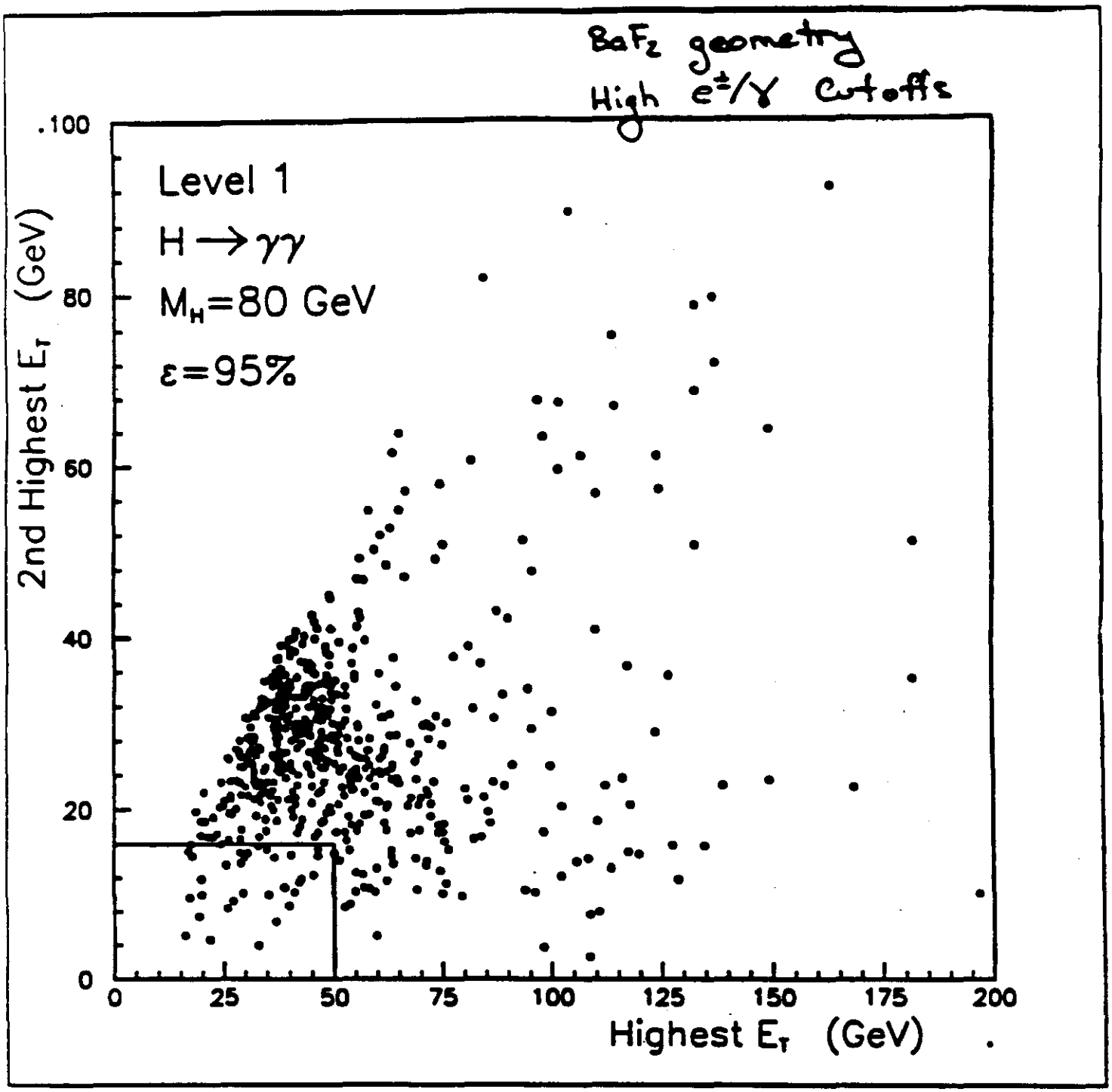
- Technology
  - Switched Capacitor Array (SCA) Baseline
  - Fully digital system also being studied

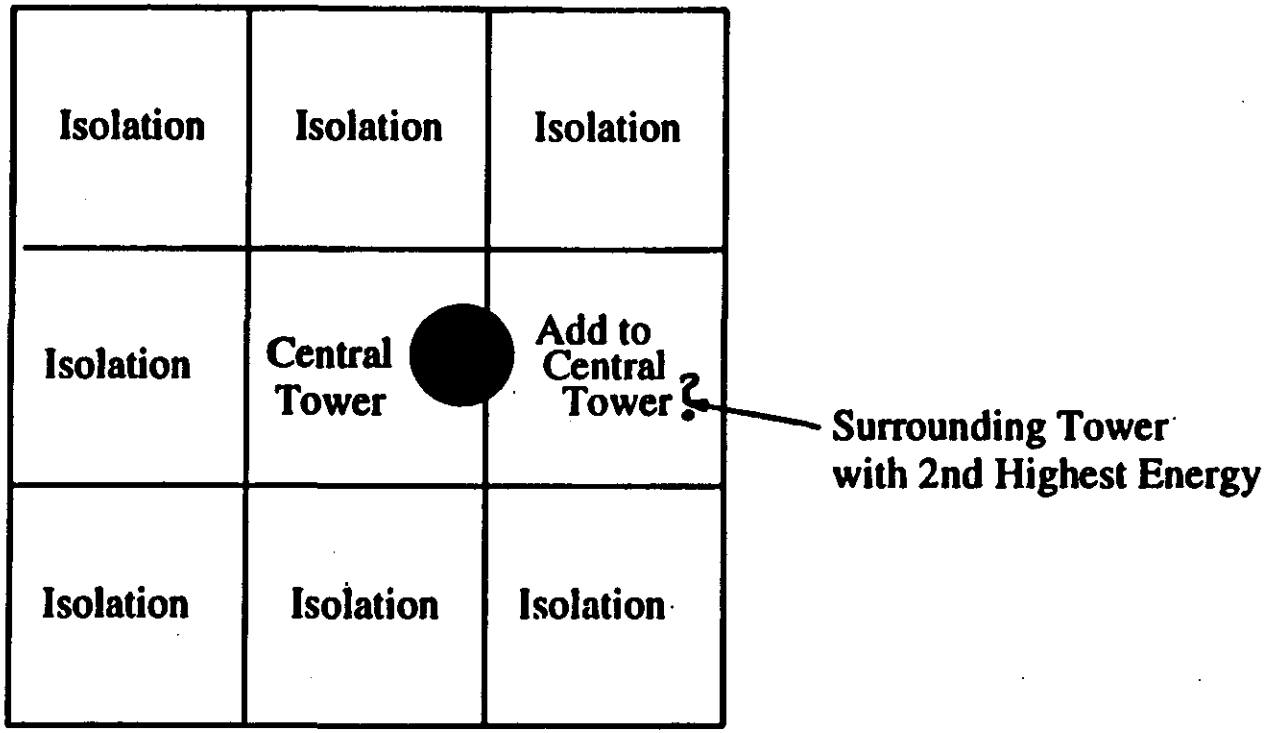


LAr Geometry M. Seman / Nevis



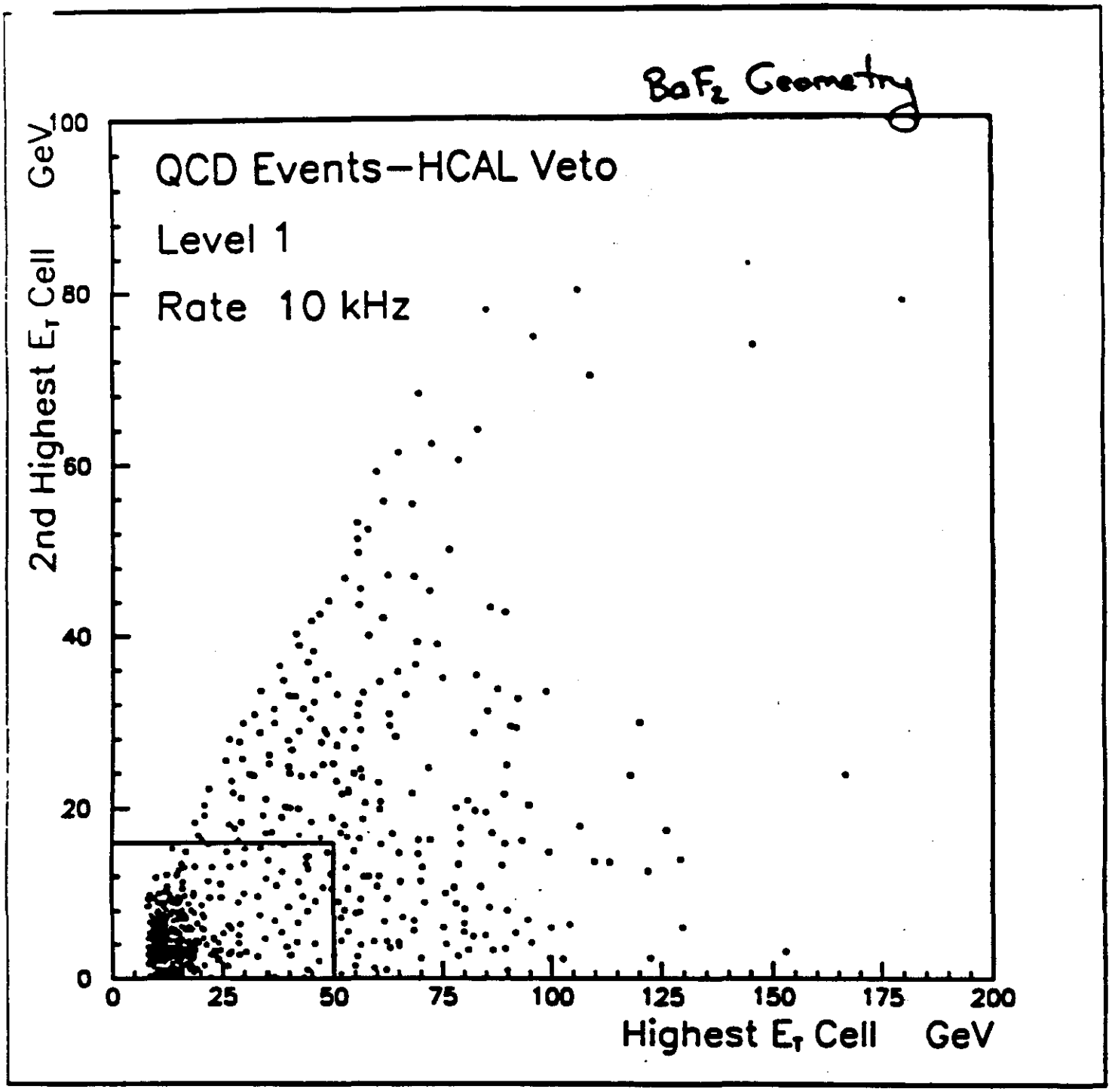
BaF_2 geometry

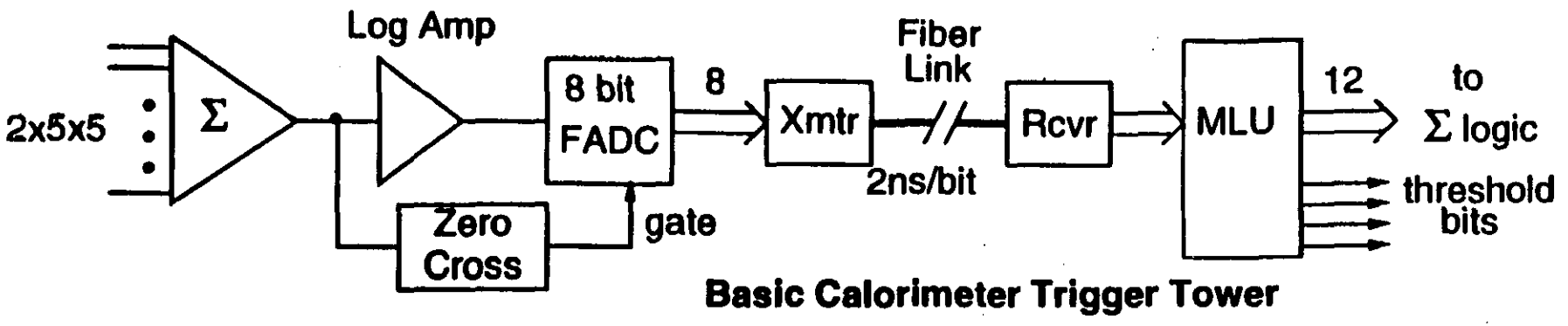

BaF2 geometry
High e±/γ cutoffs
Level 1
H → γγ
M_H=80 GeV
ε=95%
2nd Highest E_T (GeV)
Highest E_T (GeV)
0
20
40
60
80
100
0
25
50
75
100
125
150
175
200



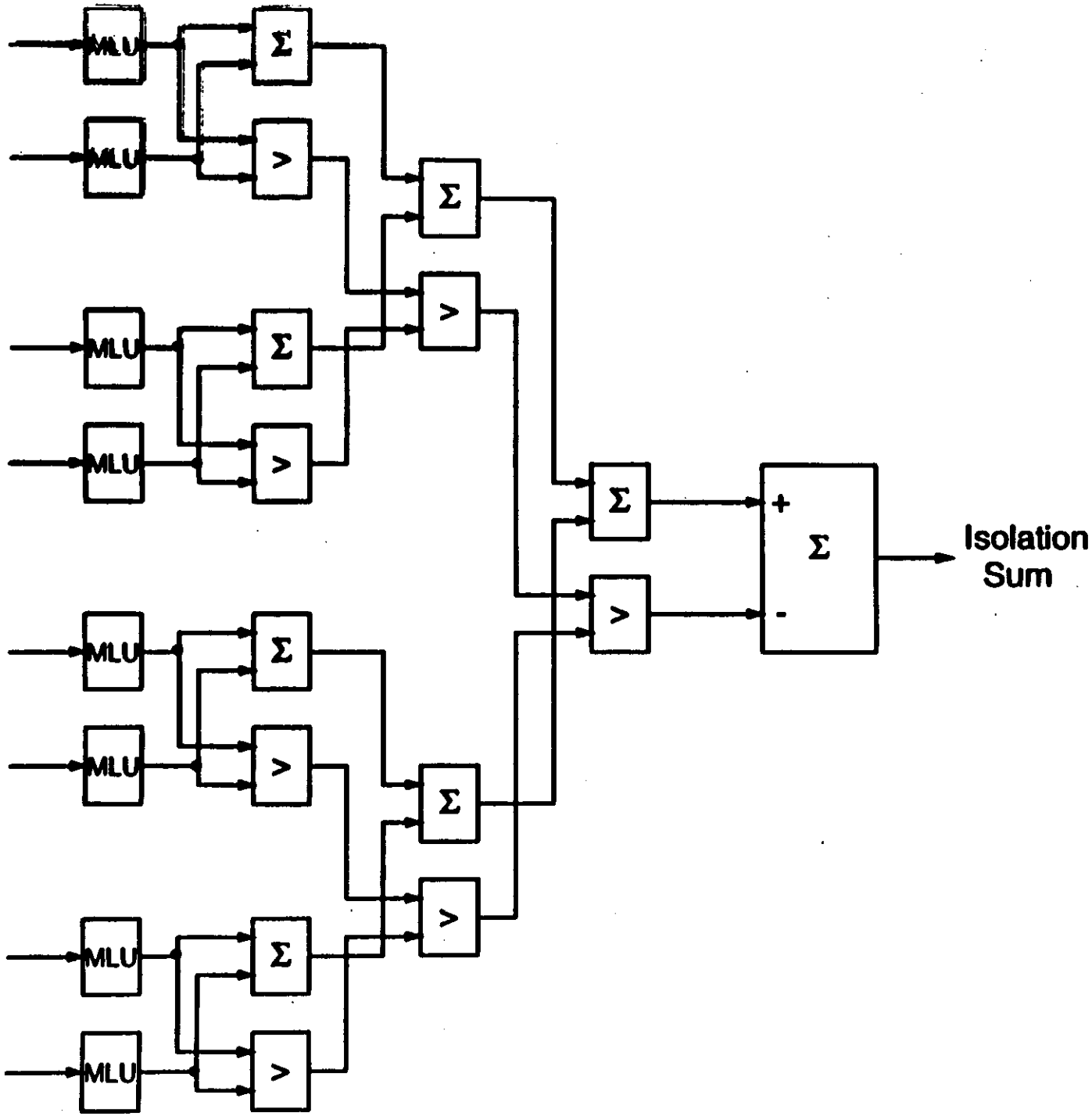
Each block is 5x5 array of .04x.04 Xtals

Each Tower is a Central TowerOnce
and a Surrounding Tower Eight Times


BaF2 Geometry
QCD Events–HCAL Veto
Level 1
Rate 10 kHz
2nd Highest E_T Cell GeV
Highest E_T Cell GeV
0
20
40
60
80
100
0
25
50
75
100
125
150
175
200



Basic Calorimeter Trigger Tower


MLU
MLU
MLU
MLU
MLU
MLU
MLU
MLU
Σ
>
Σ
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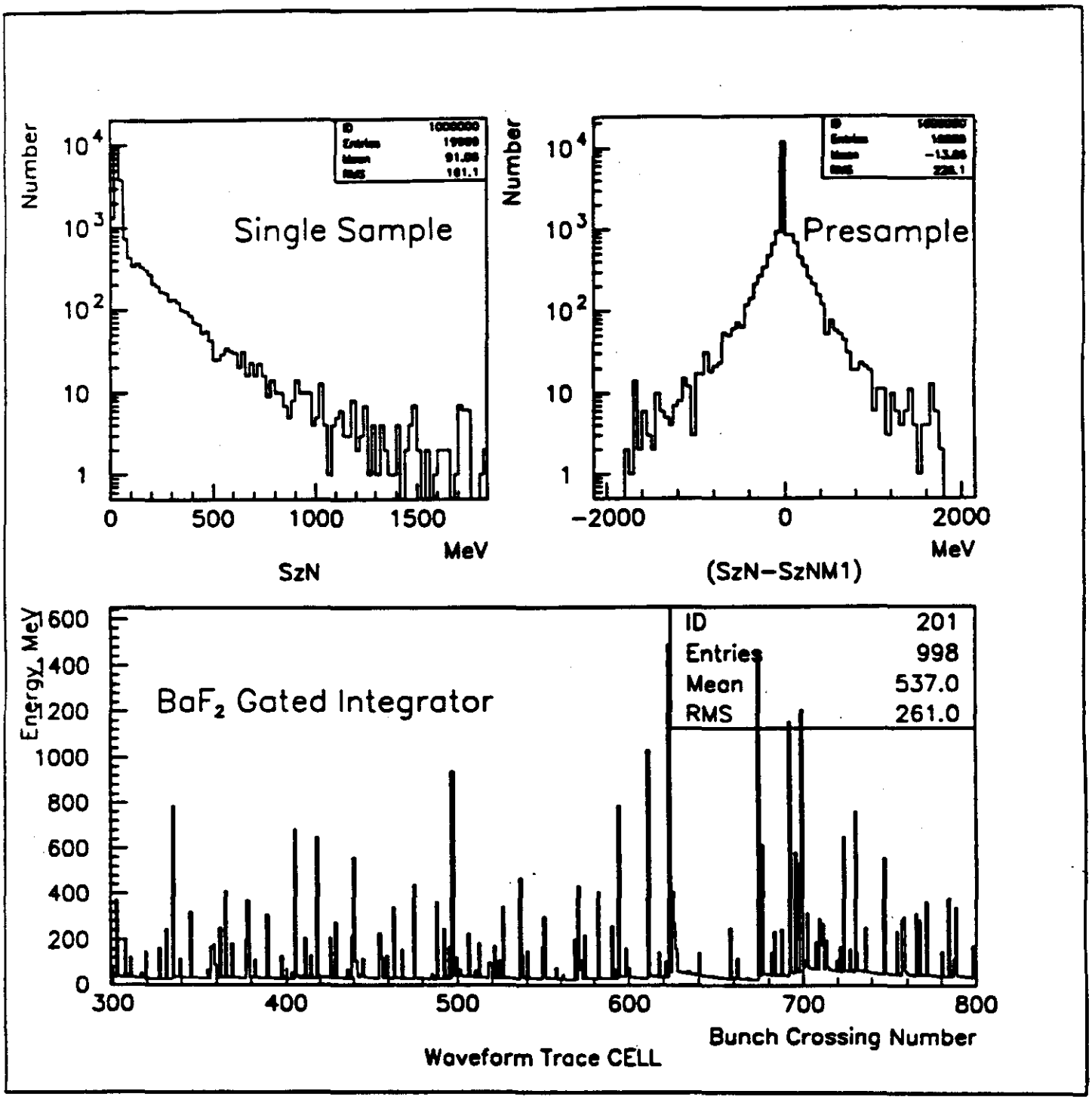
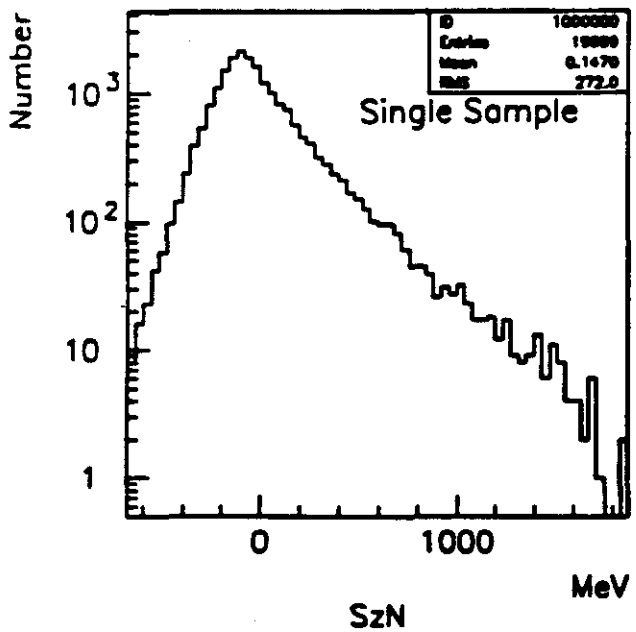
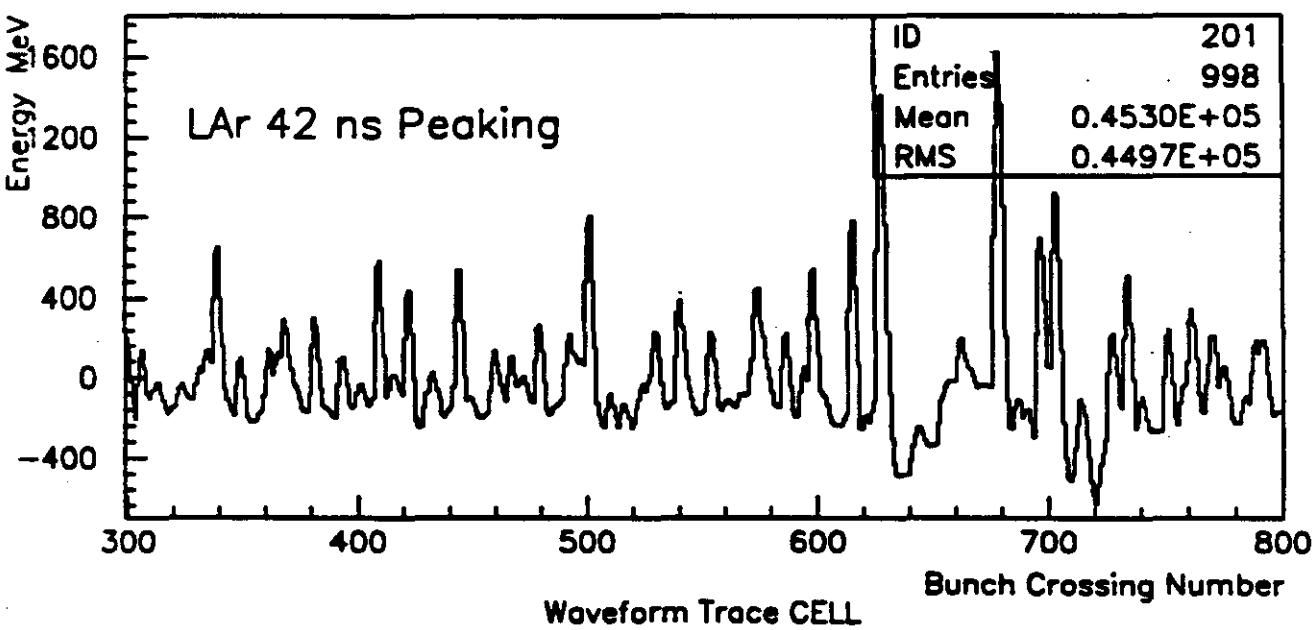
>
Σ
>
Σ
>
Σ
>
Σ
>
+
Σ
-
Isolation
Sum


Number
Single Sample
SzN
MeV
Presample
(SzN−SzNM1)
MeV
Energy MeV
BaF₂ Gated Integrator
ID 201
Entries 998
Mean 537.0
RMS 261.0
Waveform Trace CELL
Bunch Crossing Number



EM Trigger Cell
.2x.2 $\Delta\eta \times \Delta\phi$



Level 1 Rates and Efficiencies for $H \rightarrow \gamma\gamma$ Trigger			
Level 1	$\varepsilon(H \rightarrow \gamma\gamma)$; $M_H = 80$ GeV/c^2		Rate from QCD
Scheme	no Noise	Noise & Pileup	$P_T^{jet} > 20$ GeV/c
Simple Cells	$.91 \pm .01$	$.91 \pm .01$	16 ± 1 kHz
Level 1 Isolation	$.87 \pm .02$	$.84 \pm .02$	$4.1 \pm .6$ kHz
Level 1 Isolation'	$.89 \pm .01$	$.86 \pm .02$	$4.9 \pm .6$ kHz

LAr geometry

Notes:

1) EM towers are $.04 \times .04$; EM Trigger Cells are $.2 \times .2$ (5×5)
2) HC towers are $.10 \times .10$; HC Trigger Cells are $.2 \times .2$ (2×2)
3) "Standard" (RYZ) cuts:

$$\geq 1 \text{ cells with } E_T^{EM} > 50 \text{ GeV}$$
$$\text{OR} \quad \geq 2 \text{ cells with } E_T^{\mathrm{EM}} > 16 \text{ GeV}$$

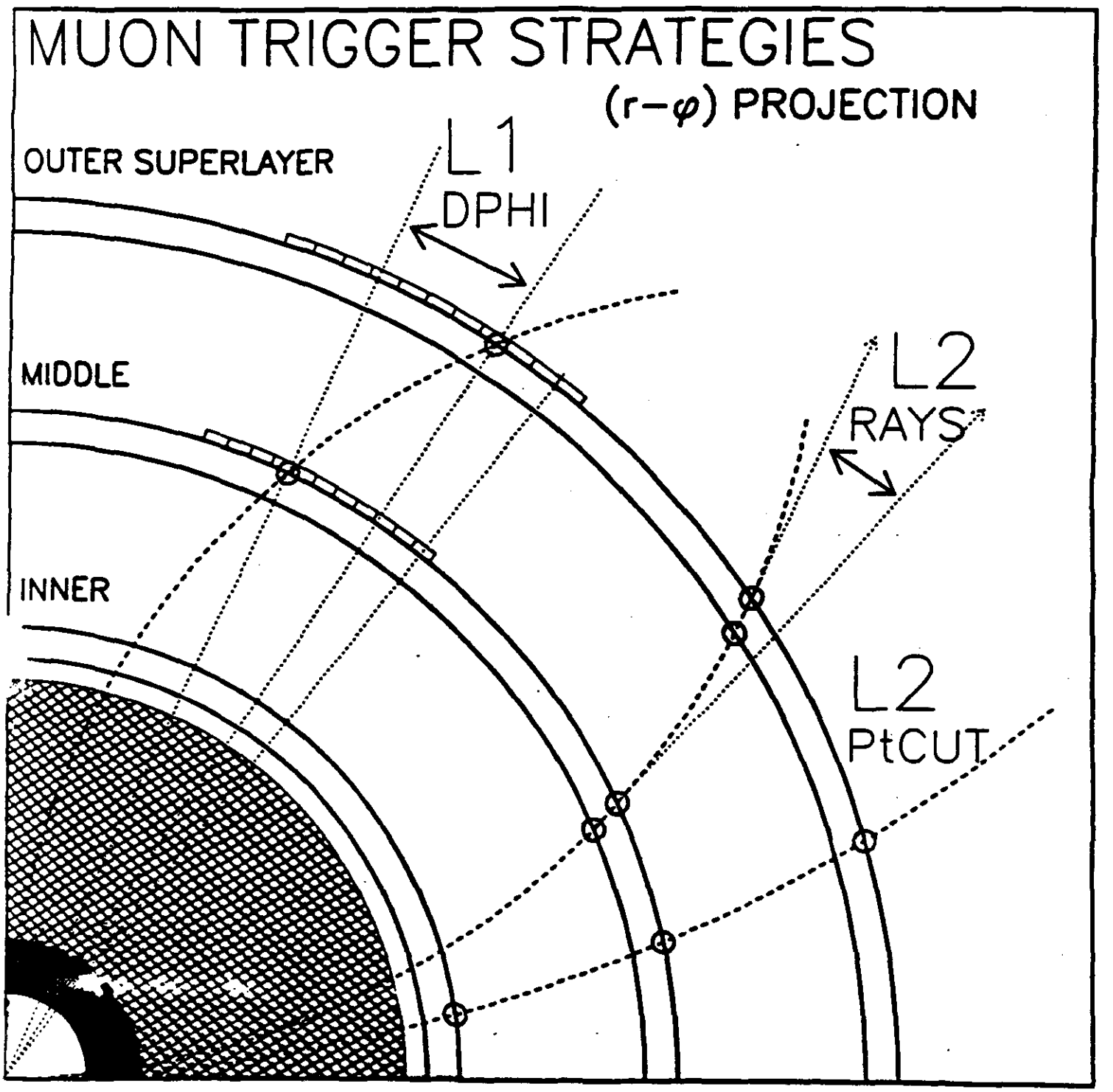
where $E_T^{\mathrm{HC}} < .1 E_T^{\mathrm{EM}}$

4) Level 1 Isolation

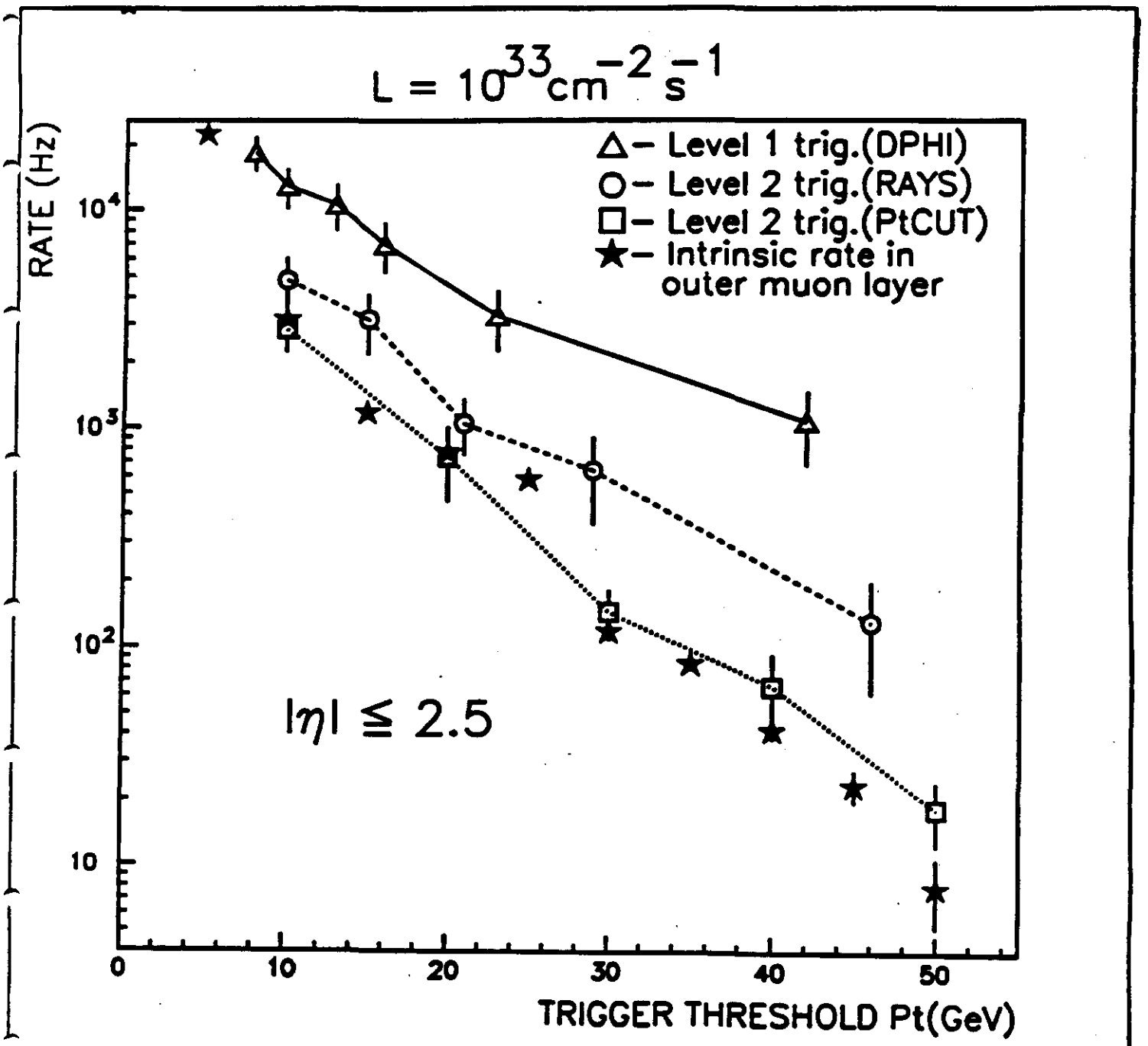
$$E_T^{\mathrm{Iso}} = \sum_{3\times3} E_T^{\mathrm{HC}} + \sum_{3\times3} E_T^{\mathrm{EM}} - E_T^{\mathrm{center}} - E_T^{\mathrm{2nd}} < 7.5 \text{ GeV}$$

5) Level 1 Isolation': same as (4), but applied only when

$$\text{highest } E_T^{\mathrm{EM}} < 80 \text{ GeV}$$
$$\text{AND} \quad \text{2nd highest } E_T^{\mathrm{EM}} < 40 \text{ GeV}$$

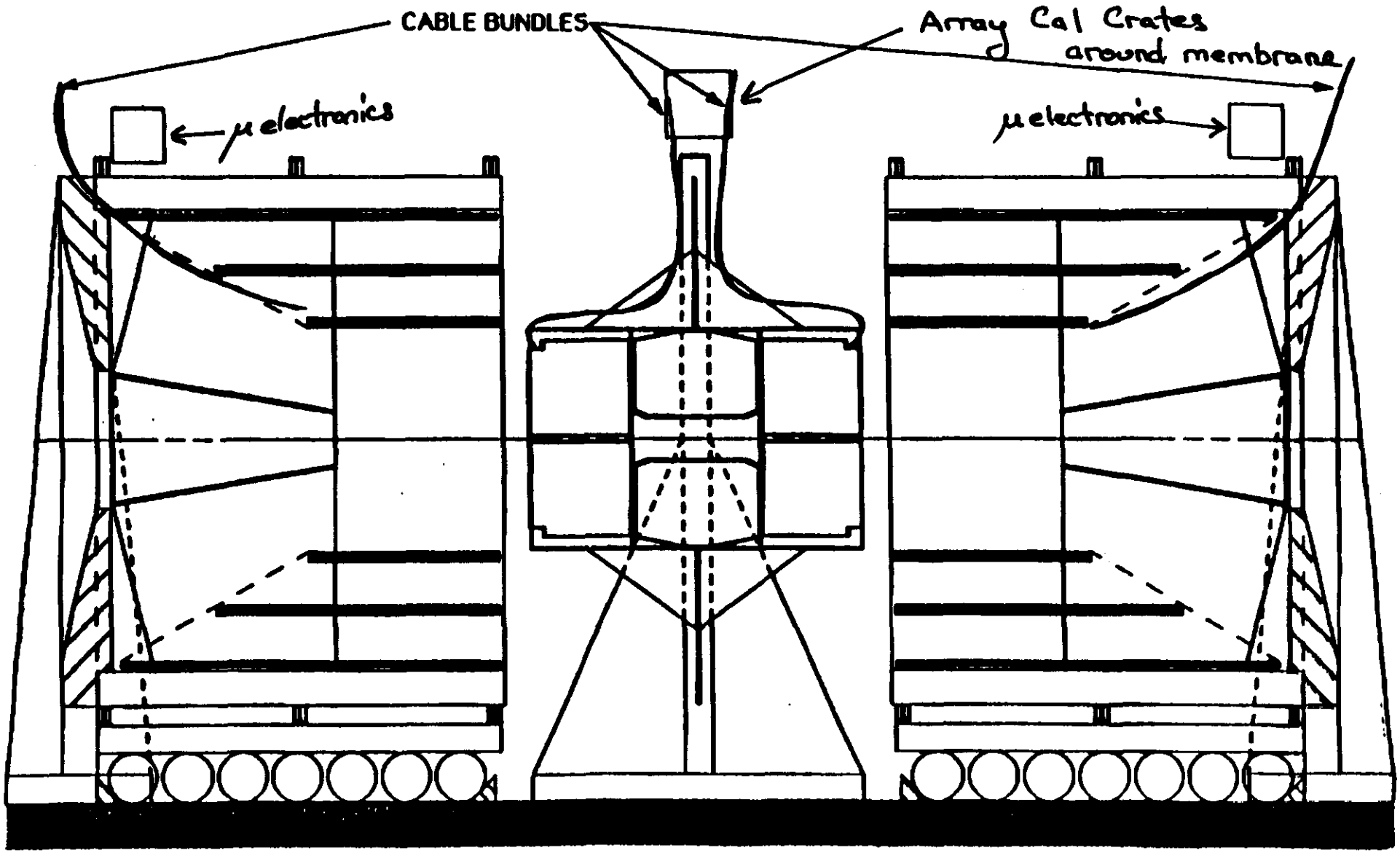


M. Seman / Nevis



INTEGRATED SINGLE MUON RATES

M. Seman / Nevis



all cal cables out center

INTEGRATED CALORIMETER SUPPORT

DRAFT

SCALE 200:1

Eberle 12/20/91

XEROX TELECOPIER
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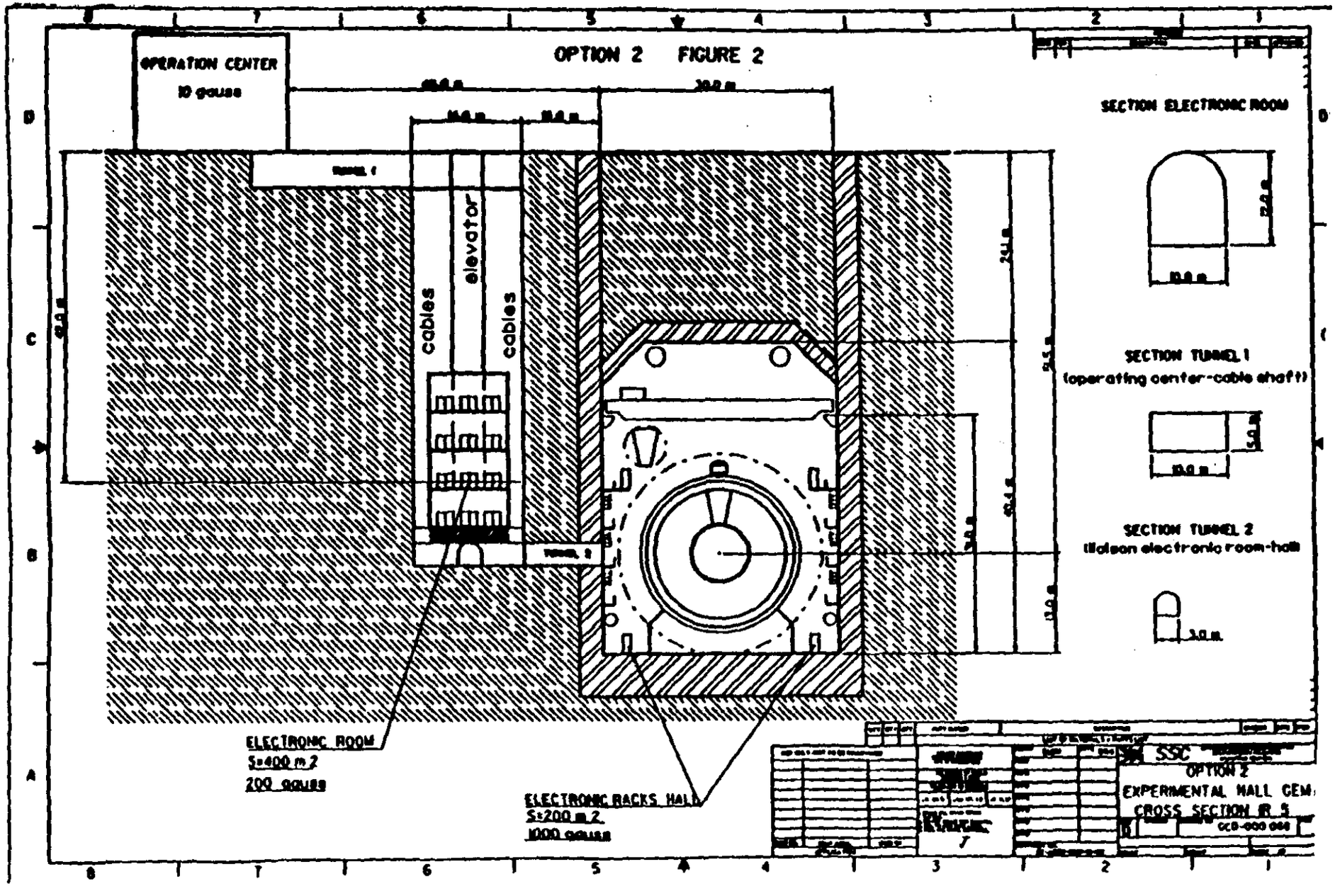
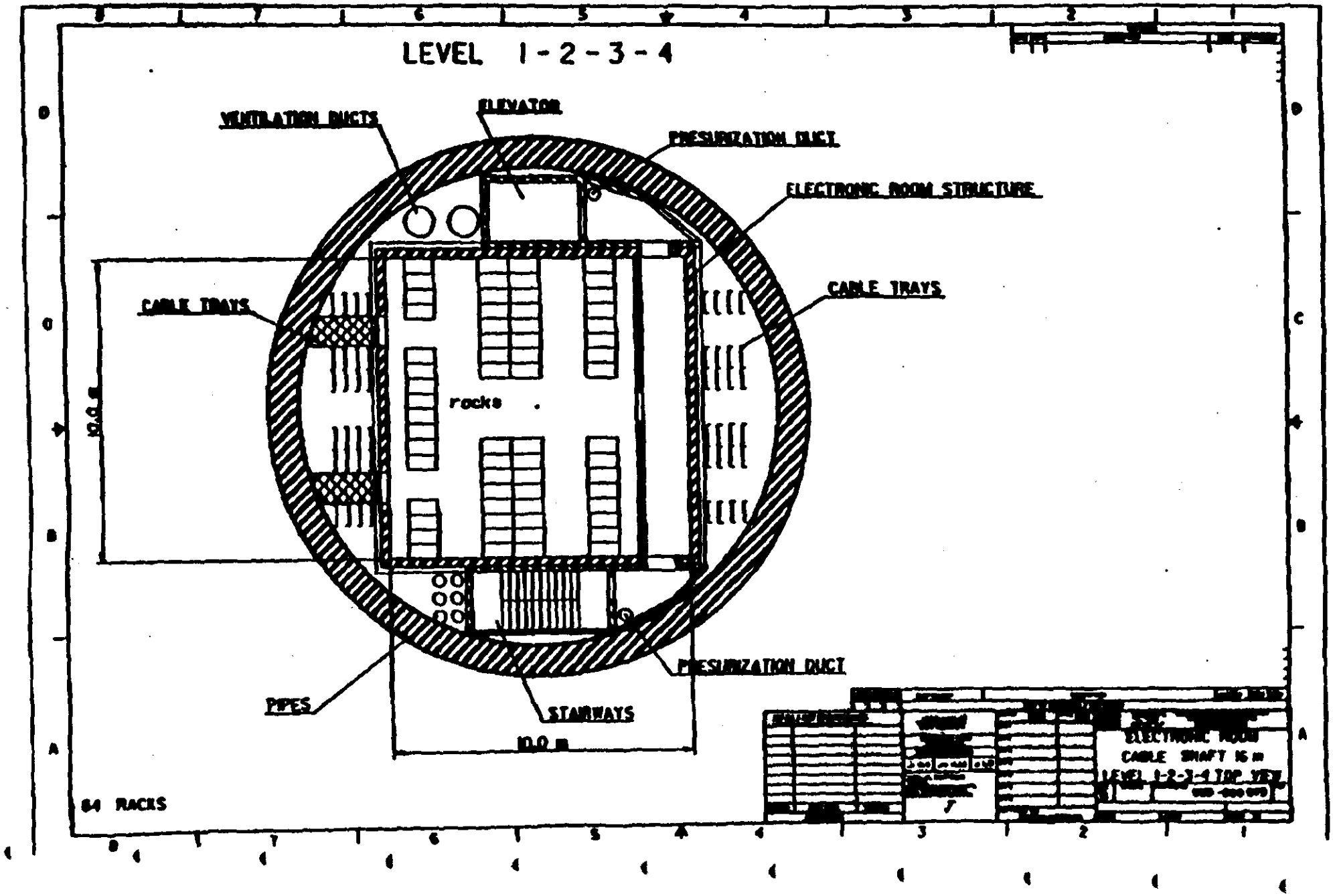
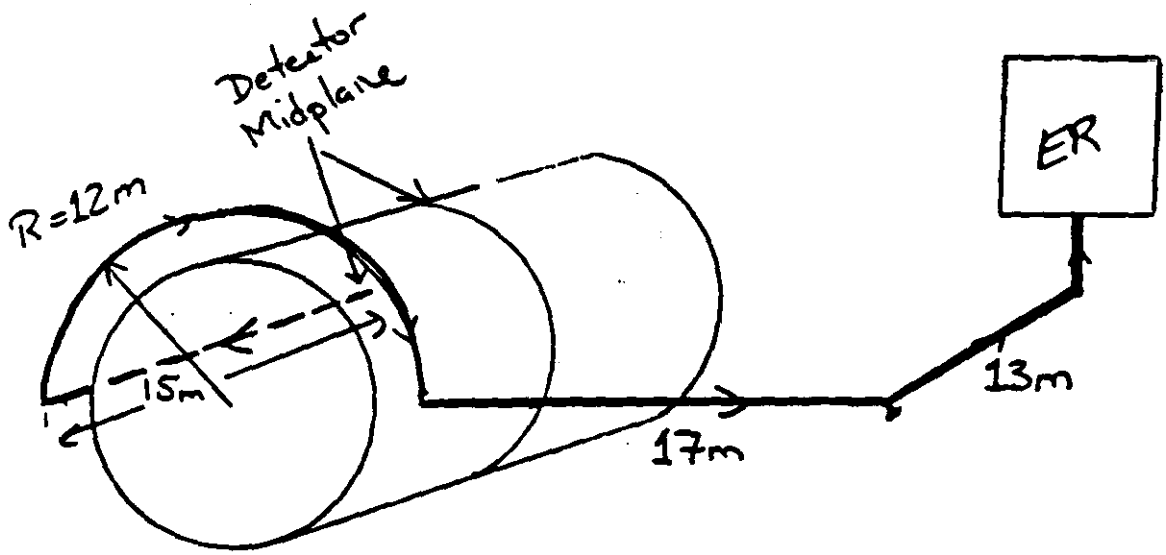



LEVEL 1-2-3-4
VENTILATION DUCTS
ELEVATOR
PRESURIZATION DUCT
ELECTRONIC ROOM STRUCTURE
CABLE TRAYS
CABLE TRAYS
racks
10.0 m
PRESURIZATION DUCT
PIPES
STAIRWAYS
10.0 m
64 RACKS
ELECTRONIC ROOM
CABLE SHAFT 15 m
LEVEL 1-2-3-4 TOP VIEW

Mo-Lou
12/13/91



Midplane to Detector End	15 m
Detector Circumference	38 m
Detector to Dogleg	17 m
Dogleg to ER	13 m
Total	83 m

Level 1 Latency

85m x 2 trips x 5 ns/m = 850ns	→	1 μS
Signal Fanin/Fanout		.5 μS
Level 1 Decision Logic		.5 μS
		2 μS

GEM Detector

Forward Calorimeter Engineering Update

Oak Ridge National Laboratory

March 6, 1992

Steve Chae

Liquid Argon

GEM LoI Cost Estimate Forward Calorimeter

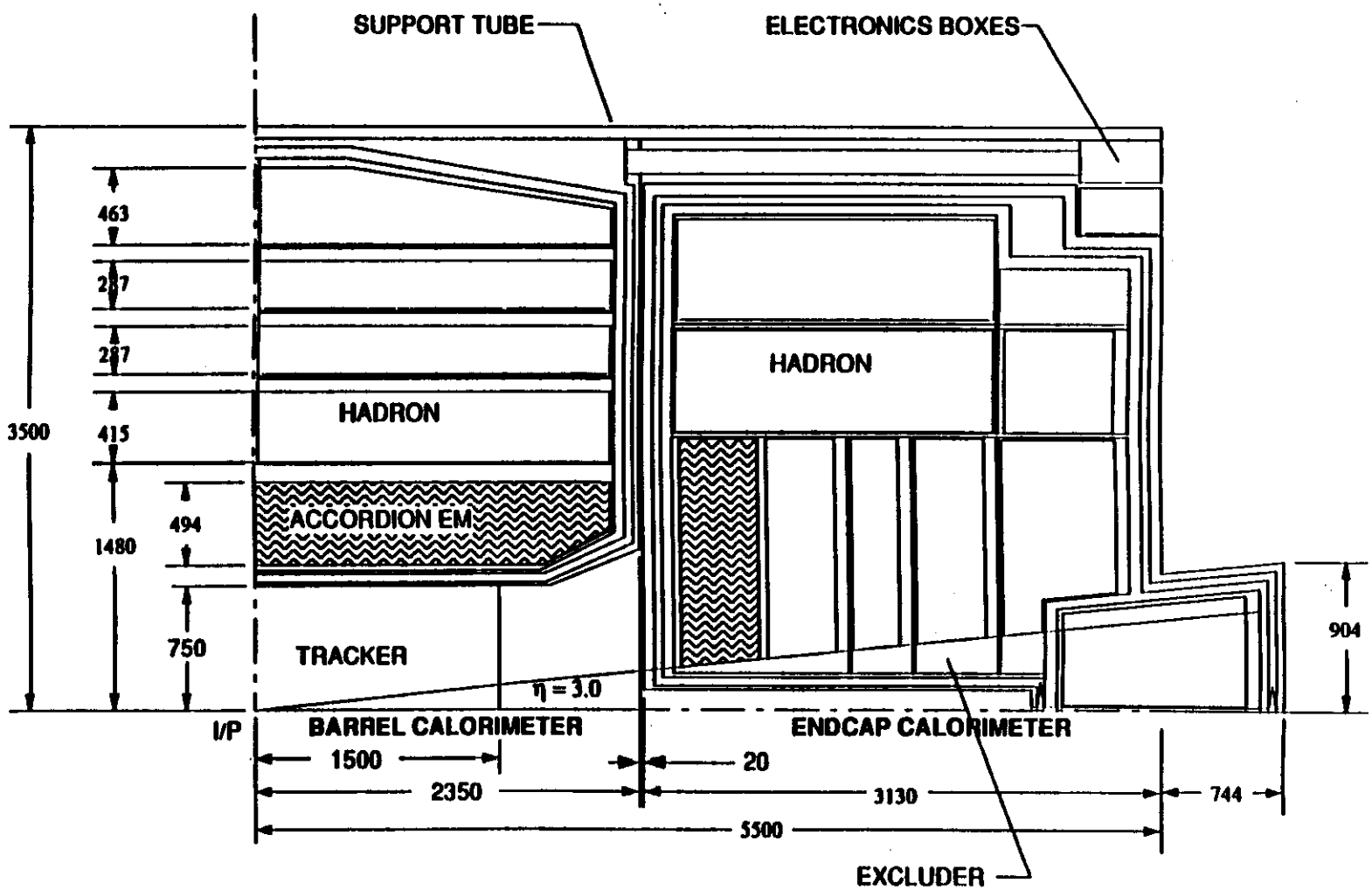
		Engineering/design			M&S	Inspection/Admin			Proc/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Materia	Total	Labor	Material	Subtotal	Conting.	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
1.1.9	LAr Forward calorimeter R&D	3.2	$148	$475	$24			$69	$565	3.5	$81	$282		$282	$825	$589	$1,414	$382	$1,795
1.2.9	Conceptual and Prelim Design	2.0	$146	$292											$292		$292	$79	$371
1.3.9	LAr FCalorimeter Construction	26.4	$146	$3,906	$195	0.6	$109	$589	$4,183	30.8	$83	$2,366		$2,366	$6,860	$4,358	$11,218	$3,029	$14,247
1.3.9.1	Modules	3.0	$146	$438		0.1	$100	$81	$2,992	5.7	$100	$565		$565	$1,084	$2,992	$4,076	$1,101	$5,177
1.3.9.1.1	Absorber	0.5	$146	$73					$2,780						$73	$2,780	$2,853	$770	$3,623
1.3.9.1.2	Module readout Board	0.7	$146	$102					$58						$102	$58	$160	$43	$203
1.3.9.1.3	Other Module Structure	1.3	$146	$190					$154						$190	$154	$344	$93	$437
1.3.9.1.4	Module Assembly/Test	0.5	$146	$73			$100	$81		5.7	$100	$565		$565	$719		$719	$194	$913
1.3.9.2	Cryostat	7.4	$146	$1,080		0.1	$104	$85	$162	4.0	$73	$279		$279	$1,445	$162	$1,606	$434	$2,040
1.3.9.2.1	Argon Vessel	4.7	$146	$686		0.1	$104	$79	$86	3.2	$71	$227		$227	$992	$86	$1,079	$291	$1,370
1.3.9.2.2	Vacuum Vessel	2.7	$146	$394			$104	$6	$75	0.8	$65	$52		$52	$452	$75	$527	$142	$670
1.3.9.2.3	LAr Vessel Cold Mass Support		$146																
1.3.9.2.4	Endcap Roll Support		$146																
1.3.9.2.5	Feedthrus	1.1	$146	$161			$104	$3	$210	0.3	$115	$35		$35	$199	$210	$409	$110	$518
1.3.9.3	Lead/Lead Beam Shield		$146				$104				$115								
1.3.9.4	Forward Calorimeter Support Rails	0.3	$146	$44					$47						$44	$47	$91	$25	$115
1.3.9.5	Tooling/Fixtures	1.7	$146	$249			$104	$21	$167	1.5	$115	$173		$173	$442	$167	$609	$164	$773
1.3.9.6	FCAL Assembly/Test/Checkout	3.2	$146	$467			$104	$141		12.5	$48	$600		$600	$1,208		$1,208	$326	$1,534
1.3.9.7	Transportation	0.2	$146	$29		0.1			$17						$29	$17	$46	$12	$59
1.3.9.8	Test Equipment	0.1	$146	$15					$95	0.2	$115	$23		$23	$38	$95	$133	$36	$168
1.3.9.9	Cryogenic System		$146				$49				$115								
1.3.9.10	Facilities	0.4	$146	$58			$49	$2	$140						$60	$140	$200	$54	$255
1.3.9.11	Test Beam Program		$146						$200							$200	$200	$54	$254
1.3.9.12	Installation & Test	0.5	$146	$73		0.2	$49	$13	$50	1.9	$48	$91		$91	$177	$50	$227	$61	$289
1.3.9.13	Electronics	3.1	$146	$453		0.1	$188	$30	$293	1.7	$141	$175		$175	$657	$293	$950	$257	$1,207
1.3.9.13.1	Preamp	0.6	$146	$88			$104	$4		0.4	$101	$40		$40	$132		$132	$36	$168
1.3.9.13.2	Cable	0.2	$146	$29			$104	$1			$101				$30		$30	$8	$38
1.3.9.13.3	Level 1 Trigger	0.7	$146	$102		0.1	$104	$15		0.2	$101	$20		$20	$137		$137	$37	$174
1.3.9.13.4	ADC	1.5	$146	$219			$104	$10		1.1	$101	$111		$111	$340		$340	$92	$432
1.3.9.13.5	High Voltage	0.1	$146	$15						0.0	$101	$3		$3	$18		$18	$5	$22
1.3.9.14	Subsystem Managemny & Integ	6.5	$154	$1,001	$195	0.1	$143	$215		$3	$136	$460		$460	$1,676	$195	$1,871	$505	$2,377
1.3.9.14.1	Project Management & Admin	4.0	$154	$616		0.1	$132	$99		2.3	$132	$310		$310	$1,025		$1,025	$277	$1,302
1.3.9.14.2	Resource Management	1.0	$154	$154			$110	$9		0.3	$110	$28		$28	$191		$191	$51	$242
1.3.9.14.3	ES&H	0.5	$154	$77			$159	$14		0.1	$159	$14		$14	$105		$105	$28	$134
1.3.9.14.4	Quality Assurance	0.5	$154	$77			$159	$45		0.3	$159	$54		$54	$176		$176	$48	$224
1.3.9.14.5	System Integration	0.5	$154	$77			$159	$48		0.3	$159	$54		$54	$179		$179	$48	$227
1.3.9.14.6	Travel				$195											$195	$195	$53	$248
	Total			$4,673	$219			$658	$4,728								$12,924	$3,489	$16,413

** This cost estimate is a copy of the one presented by MMAS-Denver in 12/91, with changes due to 1) integration of Forward with Central, and 2) change of locati from 6500 mm to 4900 mm from IP. Numbers in ☐ reflect changes and numbers in ~~shaw~~ reflect deleted items due to integration.

S. M. Chae/ORNL/3-4-92

Parameters For GEM Liquid Argon Forward Calorimeter

	One Side	Two Sides	Units
No. of Channels	1,070	2,140	Each
No. of Plates	72	144	Each
No. of Long. Segments	3	6	Each
Total Weight	25,233	50,466	KG
Heavymet Weight	22,919	45,838	KG
G-10 Weight	37	74	KG
Structure Weight	1,740	3,480	KG
Liq. Argon	537	1,074	KG
G-10 Area	1,005,307	2,010,614	Cm^2
Liquid Argon Volume	383	766	Liters
LAr Vessel Volume	1,722	3,444	Liters
Materials			
Vessel Material	Stainless Steel		
Absorber Material	HeavyMet		
Tie Rod Material	Stainless Steel		
Installation Frame	Stainless Steel		



LLMason 2/18/92
Dimensions in millimeters

Liquid Scintillator

GEM Lol Cost Estimate, [illegible]ting Forward Calorimeter

		Engineering/Design			M&S	Inspection/Admin			Prep/Tab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contng	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
5.0.2	GEM																		
5.2.2.1	Research and Development																		
5.2.2.1.3	Scintillating Forward calorimeter																		
1.3.1	Material Tests																		
1.3.1.1	Oil & Fiber Testing	0.2	$160	$32	$1.0				$20	0.2	$55	$11		$11	$43	$22	$64	$27	$91
1.3.1.2	Eutectic Testing/Development	0.2	$160	$32	$1.0				$20	0.2	$55	$11		$11	$43	$22	$64	$27	$91
1.3.2	Single Tower Prototype																		
1.3.2.1	Tower Assembly	0.25	$160	$40	$2.0				$20	0.2	$55	$11		$11	$61	$22	$72	$30	$103
1.3.2.2	Electronics	0.2	$160	$32	$1.0				$10	0.2	$55	$11		$11	$43	$12	$54	$23	$77
1.3.2.3	Assembly/Test Frame	0.1	$160	$16	$0.0				$5	0.2	$55	$11		$11	$27	$6	$33	$14	$46
1.3.2.4	Thermal Control	0.1	$160	$16	$0.0				$5	0.25	$55	$14		$14	$30	$6	$36	$15	$50
1.3.3	Nine Tower Prototype																		
1.3.3.1	Tower Assembly	0.1	$160	$16	$0.0				$75	0.75	$55	$41		$41	$57	$76	$133	$56	$189
1.3.3.2	Electronics	0.1	$160	$16	$0.0				$75	0.75	$55	$41		$41	$57	$76	$133	$56	$189
1.3.3.3	Assembly/Test Frame	0.05	$160	$8	$0.4				$40	0.5	$55	$28		$28	$35	$45	$81	$34	$115
1.3.3.4	Thermal Control	0.08	$160	$13	$0.0				$30	0.5	$55	$28		$28	$40	$31	$71	$30	$100
1.3.3.5	Beam Testing	0.2	$160	$32	$1.0				$50	0.25	$55	$14		$14	$45	$52	$97	$41	$138
1.3.4	Ring Module Prototype																		
1.3.4.1	Outer Ring	0.1	$160	$16	$0.0				$65	0.2	$55	$11		$11	$27	$56	$83	$35	$117
1.3.4.2	Inner Ring	0.1	$160	$16	$0.0				$45	0.25	$55	$14		$14	$30	$46	$75	$32	$107
1.3.4.3	Mock Towers	0.1	$160	$16	$0.0				$40	0.2	$55	$11		$11	$27	$41	$68	$28	$96
1.3.4.4	Support Frame	0.1	$160	$16	$0.0				$50	0.2	$55	$11		$11	$27	$51	$78	$33	$110
1.3.5	Manufacturing Development																		
1.3.5.1	Fiber Cutting	0.1	$160	$16	$0.0				$50	0.25	$55	$14		$14	$30	$51	$80	$34	$114
1.3.5.2	Fiber Insertion	0.05	$150	$8	$0.4				$50	0.25	$55	$14		$14	$22	$50	$72	$30	$102
1.3.5.3	Coating	0.2	$160	$32	$1.0				$50	0.5	$55	$28		$28	$50	$52	$111	$46	$157
1.3.5.4	Readout Assembly	0.2	$160	$32	$1.0				$45	0.5	$55	$28		$28	$50	$47	$108	$44	$150
1.3.5.5	Tower Handling	0.1	$160	$16	$0.0				$40	0.25	$55	$14		$14	$30	$41	$70	$30	$100
1.3.6	Electronics Development	0.25	$160	$40	$2.0				$100	0.5	$55	$28		$28	$67	$102	$169	$71	$240
5.0.2.2	Conceptual and Preliminary Design																		
5.0.2.2.3	Scintillating Forward Calorimeter																		
2.3.1	Preparation of Lol																		
2.3.1.1	Conceptual Design	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.1.2	Costing Studies	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.1.3	Document Preparation	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.2	Preparation of Technical Prop.																		
2.3.2.1	Conceptual Design	0.5	$124	$62	$3.1										$62	$3	$65	$27	$92
2.3.2.2	Costing Studies	0.17	$124	$21	$1.1										$21	$1	$22	$9	$31
2.3.2.3	Manufacturing Studies	0.17	$124	$21	$1.1										$21	$1	$22	$9	$31
2.3.2.4	Installation Studies	0.25	$124	$31	$1.6										$31	$2	$33	$14	$46
2.3.2.5	Preparation of Technical Proposal	0.25	$124	$31	$1.6										$31	$2	$33	$14	$46
5.0.2.3	Construction																		
5.0.2.3.3	Scintillating Forward Calorimeter																		
3.3.1	Tower Modules																		
3.3.1.1	Sheathe	0.75	$108	$81	$4.1	0.27	$107	$29							$110	$4	$114	$29	$143
3.3.1.1.1	Sheetmetal Jacket								$62							$62	$62	$23	$85
3.3.1.1.2	Extention Bracing								$35							$35	$35	$14	$52
3.3.1.1.3	Fasteners								$4							$4	$4	$1	$5
3.3.1.2	Top/Bottom Plates	0.25	$108	$27	$1.4	0.14	$107	$15	$13						$42	$14	$56	$15	$71
3.3.1.3	Spacers	0.25	$108	$27	$1.4	0.14	$107	$15	$1						$42	$2	$44	$14	[illegible]

GEM Lel Cost Estimate, Bc ng Forward Calorimeter

		Engineering/design			M&S	Inspection/Admin			Prep/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contig	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
3.3.1.4	3 mm Tubes								$548							$548	$548	$49	$597
3.3.1.5	Eutectic								$63							$63	$63	$6	$69
3.3.1.6	Tungsten Powder								$1,093							$1,093	$1,093	$98	$1,191
3.3.1.7	Readout Assembly	0.75	$108	$81	$4.1	0.25	$107	$27	$80						$108	$83	$201	$50	$251
3.3.1.7.1	Readout Frame								$34							$34	$34	$13	$47
3.3.1.7.2	Transmission Fiber								$53							$53	$53	$18	$72
3.3.1.7.3	Light Mixer								$48							$48	$48	$23	$71
3.3.1.7.4	PMT Mounting Frame								$24							$24	$24	$8	$32
3.3.1.7.5	Fasteners								$2							$2	$2	$1	$3
3.3.1.8	Assembly																		
3.3.1.8.1	Station One	0.75	$108	$81	$4.1	0.17	$107	$18		2.14	$55	$118		$118	$217	$4	$221	$80	$300
3.3.1.8.1.1	3 mm tube cutting machine								$7							$7	$7	$2	$9
3.3.1.8.1.2	Spacer Alignment Fixture								$8							$8	$8	$2	$10
3.3.1.8.1.3	Spacer Expansion Fixture								$10							$10	$10	$3	$13
3.3.1.8.2	Station Two	0.75	$108	$81	$4.1	0.08	$107	$9		1.23	$55	$68		$68	$157	$4	$161	$58	$219
3.3.1.8.2.1	Spacer/Sheath Assembly Stand								$15							$15	$15	$7	$22
3.3.1.8.2.2	Personnel Platform								$4							$4	$4	$1	$5
3.3.1.8.3	Station Three	0.75	$108	$81	$4.1	0.08	$107	$9		1.5	$55	$83		$83	$172	$4	$176	$63	$240
3.3.1.8.3.1	Readout Fiber Cutting Machine								$7							$7	$7	$2	$9
3.3.1.8.4	Station Four	1.25	$108	$135	$6.8	0.17	$107	$18		1.97	$55	$108		$108	$262	$7	$268	$97	$365
3.3.1.8.4.1	Large Casting System								$125							$125	$125	$46	$171
3.3.1.8.4.2	Molds								$42							$42	$42	$11	$53
3.3.1.8.4.3	Setup Stands								$15							$15	$15	$4	$19
3.3.1.8.4.4	Personnel Platforms								$20							$20	$20	$5	$25
3.3.1.8.5	Station Five	0.75	$108	$81	$4.1	0.08	$107	$9		0.97	$55	$53		$53	$143	$4	$147	$53	$200
3.3.1.8.5.1	Outer Sheath Assembly Stand								$15							$15	$15	$4	$18
3.3.1.8.5.2	Personnel Platform								$4							$4	$4	$1	$5
3.3.1.8.6	Station Six	0.75	$108	$81	$4.1	0.1	$107	$11		0.78	$55	$43		$43	$135	$4	$139	$50	$189
3.3.1.8.6.1	Tower Fixture								$10							$10	$10	$4	$14
3.3.1.8.6.2	Tower Assembly Stand								$15							$15	$15	$5	$20
3.3.1.8.6.3	Personnel Platform								$8							$8	$8	$2	$10
3.3.1.8.7	General Assembly Equipment	0.75	$108	$81	$4.1	0.16	$107	$17							$98	$4	$102	$37	$139
3.3.1.8.7.1	Environmental Control								$50							$50	$50	$25	$75
3.3.1.8.7.2	Clothing								$10							$10	$10	$4	$14
3.3.1.8.7.3	Cleaning Supplies								$5							$5	$5	$2	$7
3.3.1.8.7.4	Tools								$5							$5	$5	$2	$7
3.3.1.8.7.5	ST Monorail								$10							$10	$10	$3	$13
3.3.1.8.7.6	Temporary Use Items								$20							$20	$20	$6	$26
3.3.1.8.7.7	Handling Carts (10 - 100 Tons)								$10							$10	$10	$4	$14
3.3.1.9	Calibration Loops	0.75	$108	$81	$4.1	0.1	$107	$11	$20						$92	$24	$116	$61	$177
3.3.2	Modules																		
3.3.2.1	Outer Structural Rings	0.25	$108	$27	$1.4	0.04	$107	$4	$108						$31	$108	$139	$67	$196
3.3.2.2	Inner Structural Rings	0.5	$108	$54	$2.7	0.04	$107	$4	$107						$56	$110	$166	$62	$230
3.3.2.3	Assembly Equipment																		
3.3.2.3.1	Station Seven	0.5	$108	$54	$2.7	0.04	$107	$4		0.68	$55	$36		$36	$94	$3	$97	$26	$123
3.3.2.3.1.1	Module Assembly Stand								$35							$35	$35	$14	$49
3.3.2.3.1.2	Module Lifting Fixture								$45							$45	$45	$18	$63
3.3.2.3.2	Station Eight	0.5	$108	$54	$2.7	0.1	$107	$11		0.41	$55	$23		$23	$67	$3	$90	$17	$107
3.3.2.3.2.1	Assembly Test Stand								$50							$50	$50	$16	$66
3.3.2.3.2.2	Personnel Platform								$8							$8	$8	$2	$10
3.3.3	Electronics																		
3.3.3.1	Photomultiplier Tubes	0.5	$124	$62	$3.1	0.1	$107	$11	$1,152	0.3	$55	$17		$17	$69	$1,155	$1,244	$274	$1,518
3.3.3.2	Electronic Readout	1.5	$124	$186	$8.3	0.5	$107	$54	$400	2	$55	$110		$110	$350	$409	$839	$302	$1,141
3.3.4	Thermal Control																		
3.3.4.1	Heat Transfer System	0.5	$108	$54	$2.7	0.04	$107	$4	$50	1	$55	$55		$55	$113	$53	$166	$53	$219
3.3.4.2	Heat Exchangers	0.25	$108	$27	$1.4	0.04	$107	$4	$50	0.4	$55	$22		$22	$53	$51	$105	$31	$136
3.3.5	Beam Test/Calibration																		
3.3.5.1	Test Stands	0.5	$124	$62	$3.1	0.08	$107	$9	$250						$71	$253	$324	$94	$418
3.3.5.2	Manpower					0.1	$107	$11							$11		$11	$3	$14
3.3.5.3	Beam Calibration System	0.75	$124	$93	$4.7	0.1	$107	$11	$100						$104	$106	$208	$60	$268

B. M. Chee/ORNL/2-26-92

GEM Lel Cost Estimate, ... ting Forward Calorimeter

		Engineering/design			M&S	Inspection/Admin			Proc/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contng	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
3.3.6	Liquid Handling System																		
3.3.6.1	Pump	0.25	$108	$27	$1.4	0.02	$107	$2	$40	0.12	$55	$7		$7	$36	$41	$77	$22	$99
3.3.6.2	Piping	0.25	$108	$27	$1.4	0.04	$107	$4	$16	0.6	$55	$33		$33	$64	$11	$76	$22	$98
3.3.6.3	Filtration & Purification	0.75	$108	$81	$4.1	0.1	$107	$11	$100	1	$55	$55		$55	$147	$104	$251	$73	$323
3.3.6.4	Storage & Monitoring	0.75	$108	$81	$4.1	0.1	$107	$11	$100	1	$55	$55		$55	$147	$104	$251	$73	$323
3.3.7	System Assembly																		
3.3.7.1	Assembly Stand/Station Mine	0.5	$108	$54	$2.7	0.05	$107	$5		0.93	$55	$51		$51	$114	$3	$116	$31	$146
3.3.7.1.1	Assembly Stand								$50							$50	$50	$20	$70
3.3.7.1.2	Temporary Bracing								$13							$13	$13	$5	$18
3.3.8	Forward Installation																		
3.3.8.1	Manpower	0.5	$154	$77	$3.9	0.4	$107	$43		1.23	$56	$67		$67	$186	$4	$190	$50	$240
3.3.8.2	Equipment																		
3.3.8.2.1	Transport Cart	0.25	$108	$27	$1.4	0.05	$107	$5	$40						$36	$41	$77	$21	$98
3.3.8.2.2	Temporary Bracing	0.25	$108	$27	$1.4	0.04	$107	$4	$26						$31	$21	$53	$14	$67
3.3.9	Subsystem Management																		
3.3.9.1	Project Management	4	$154	$616	$30.8										$616	$31	$647	$233	$880
3.3.9.2	Resource Management	1	$154	$154	$7.7										$154	$8	$162	$58	$220
3.3.9.3	ES&H	0.5	$154	$77	$3.9										$77	$4	$81	$28	$109
3.3.9.4	Quality Assurance	0.5	$154	$77	$3.9										$77	$4	$81	$27	$108
3.3.9.5	System Integration	0.5	$154	$77	$3.9										$77	$4	$81	$30	$111
	Total			$3,660	$184			$464	$6,198								$11,002	$3,457	$16,459

B. M Chee/ORNL/2-26-92

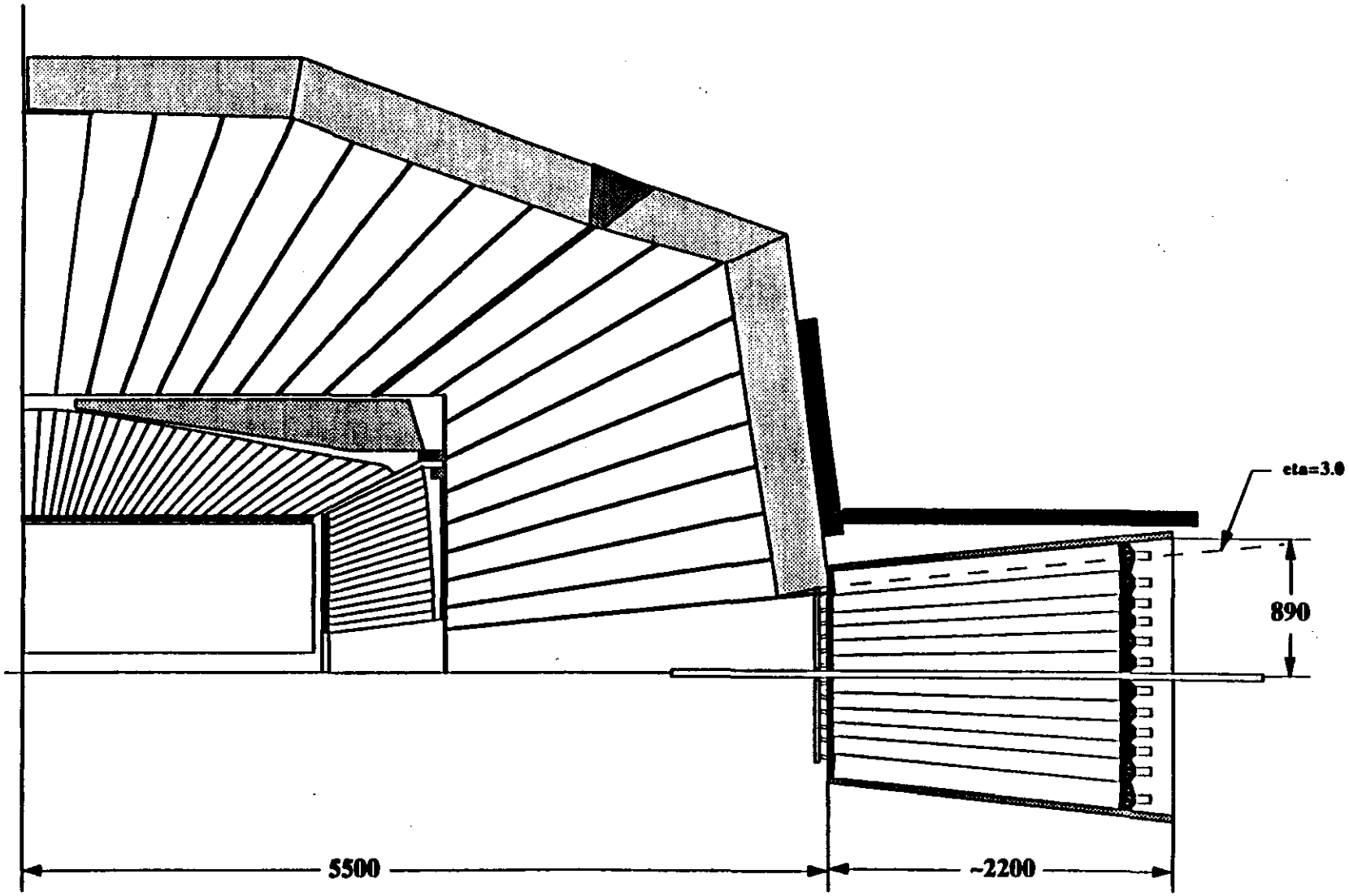
GEM Parameters

Spaghetti Forward Calorimeter

Tungsten / Eutectic (50.0%)

	One Side	Both Sides	
Mechanical Towers	120	240	units
Channels	960	1,920	units
Sheeth Volume	0.3	0.6	M^3
Tube Volume	0.1	0.2	M^3
Oil Volume	0.5	1.1	M^3
Absorber Volume	2.6	5.1	M^3
Tungsten Volume	1.3	2.6	M^3
Eutectic Volume	1.3	2.6	M^3
Volume of End (spacer) Plates	0.1	0.1	M^3
Oil Supply System Volume (oil included)	0.1	0.1	M^3
TOTAL VOLUME	3.7	7.3	M^3
Total Weight of 8 Modules	40.2	80.4	Metric Tons
Tunsten	24.8	49.6	Metric Tons
Eutectic	6.1	12.2	Metric Tons
Sheaths	2.5	5.1	Metric Tons
Structural Components	4.5	8.9	Metric Tons
Outer Ring	3.7	7.3	Metric Tons
Oil Supply System (weight of oil included)	0.3	0.6	Metric Tons
TOTAL WEIGHT (per side)	48.6	97.2	Metric Tons
Active Absorption Lenghth	12.0		Lambda
Passive Absorption Lenghth			Lambda
Lenght of 3mm Tubes	90,867	181,734	Meters
Number of 3 mm Tubes	60,839	121,679	units
Inner Radius	25		mm
Outer Radius	836		mm
Length***	1,872		mm

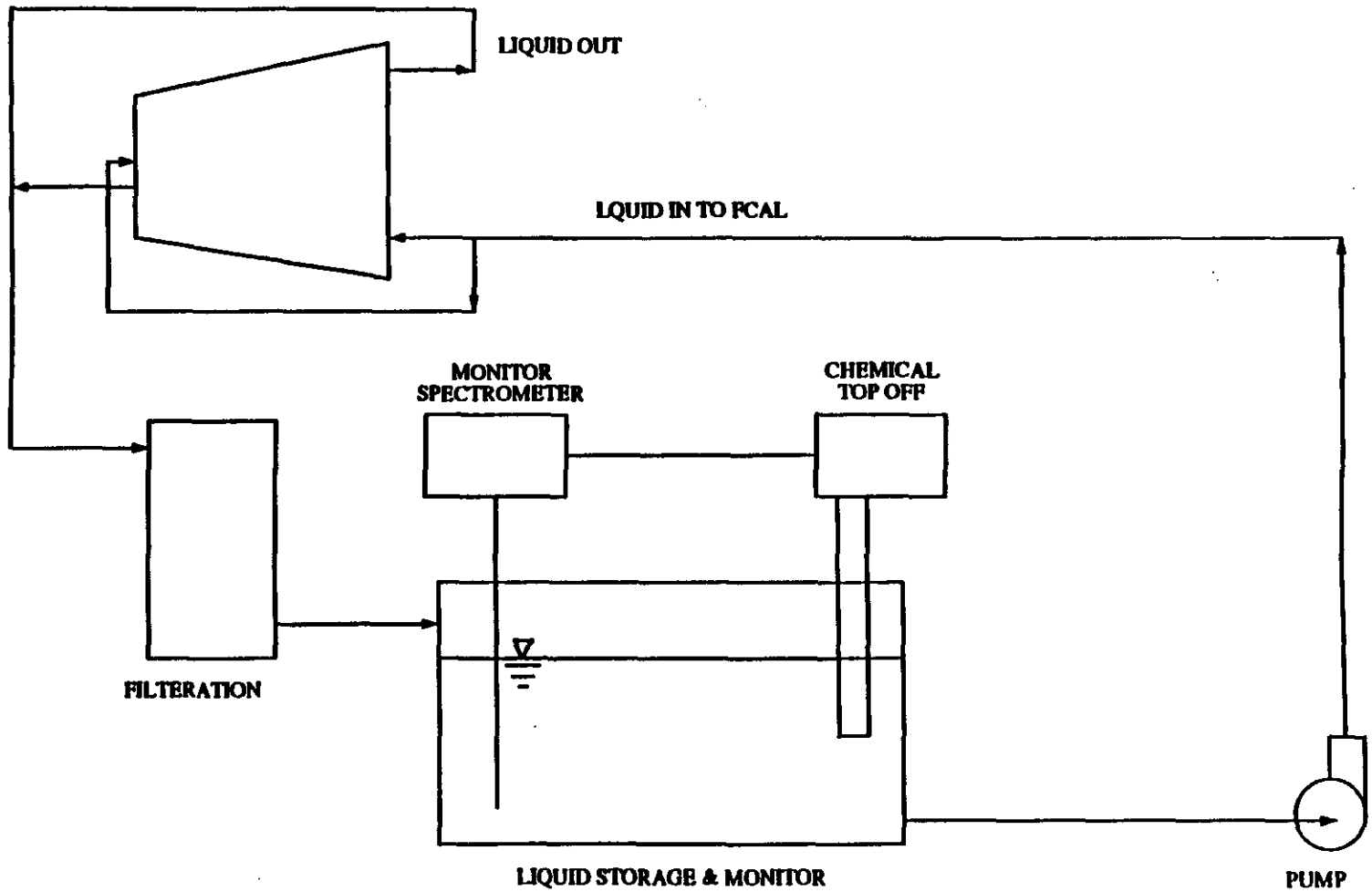
*** The total length shown does not include the PMT and the associated cable length.



GEM Detector
Forward Calorimeter
General Arrangement

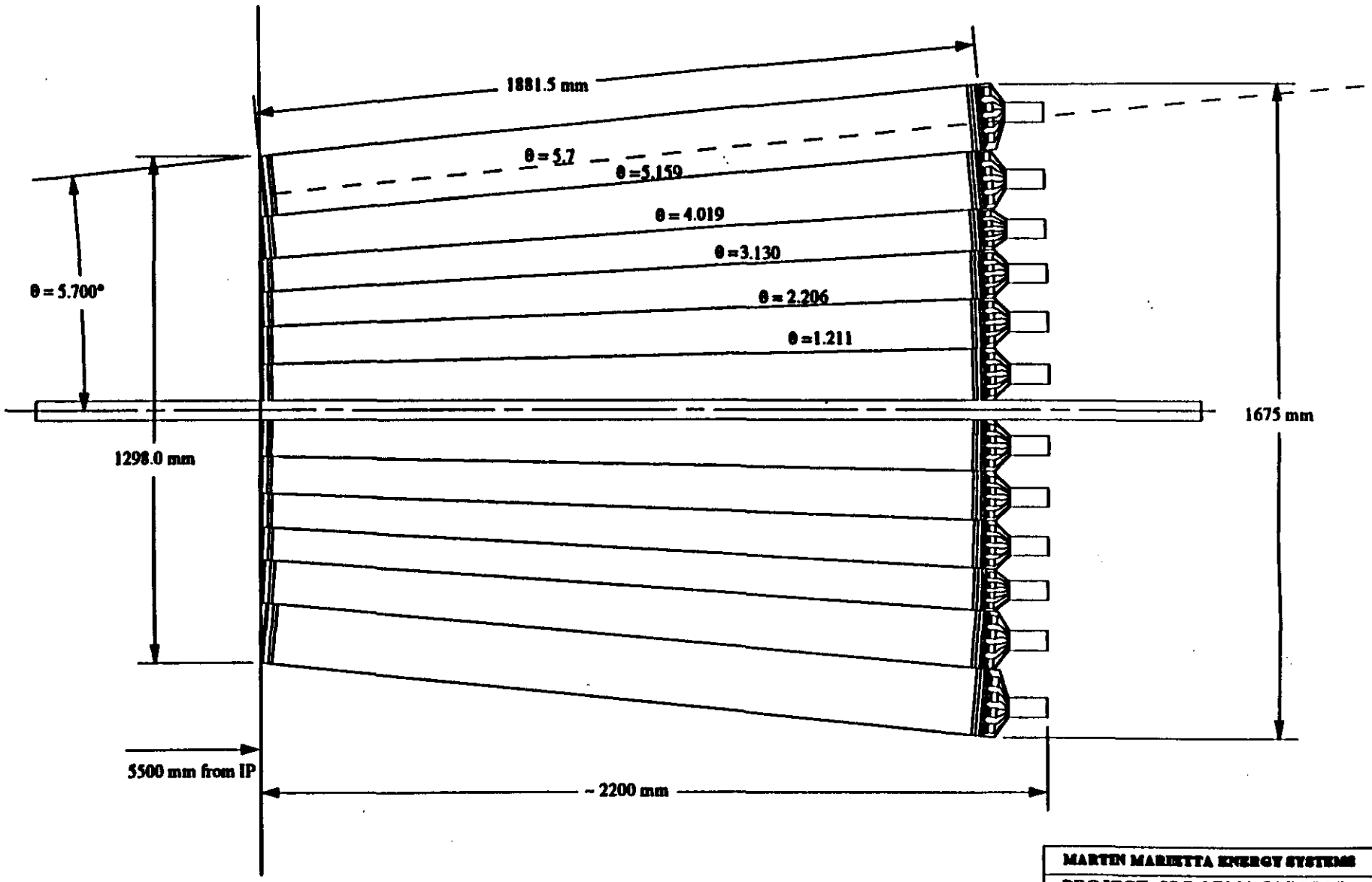
FCAL LOCATION

Rennich/Chae



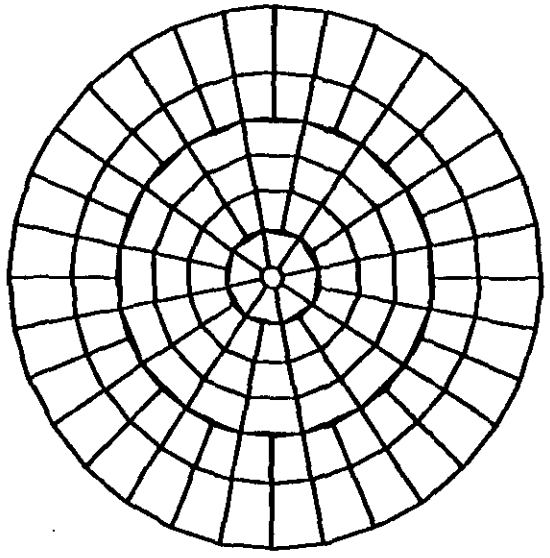
GEM
Spaghetti Forward Calorimeter
Oil Purification System Diagram

Chae

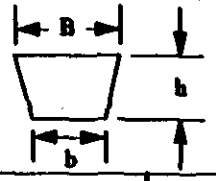


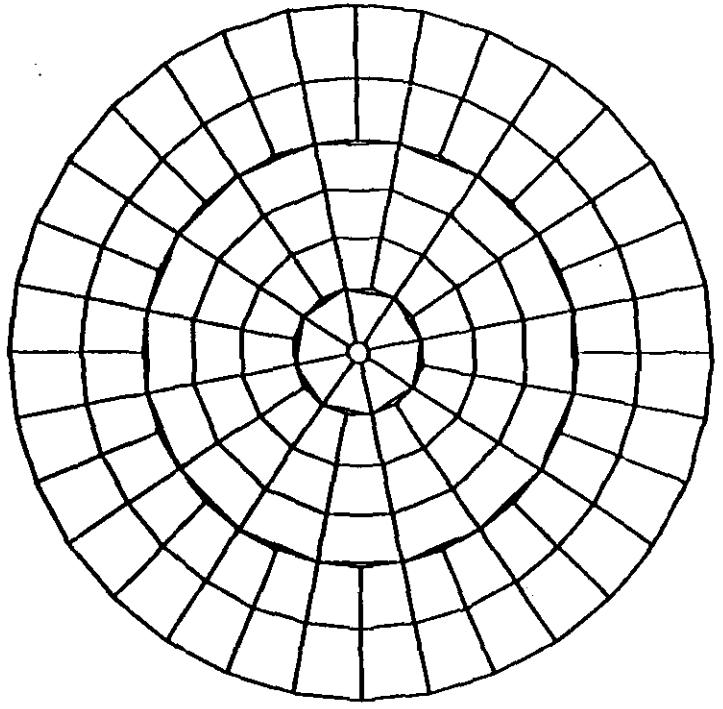
Notes:
1. PMT's shown are not drawn to scale.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER LIQUID SCINTILLATING OPTION SPAGHETTI TOWER & MODULE DESIGN SUPER TOWER ARRANGEMENT	
PRINT NO: D-FCLS-TAMD002	REV 1
DRAWN BY: S. M. CHAE	3/2/92
CHECKED & APPROVED BY:	



INNER FACE
@ 5500 mm FROM IP





OUTER FACE
@ 7361.3 mm FROM IP

Module Number	@ 5500 mm from IP		@ 7361.3 mm from IP		@ 5500 mm from IP			@ 7361.3 mm from IP		
	Eta	Radius mm	Eta	Radius mm	B mm	h mm	b mm	B mm	h mm	b mm
6	6.378	25.00	6.378	25.00	90.72	84.30	19.13	121.44	120.64	19.13
5	4.550	116.25	4.550	155.62	82.67	93.75	45.36	110.66	125.46	60.72
4	3.950	211.88	3.950	283.61	117.36	87.10	82.67	157.13	116.55	110.66
3	3.600	300.79	3.600	402.72	151.50	83.85	117.36	202.76	112.16	157.13
2	3.350	386.40	3.350	517.16	97.34	109.26	75.75	130.28	146.12	101.38
1	3.100	496.55	3.100	664.60	127.31	151.72	97.34	163.64	169.30	130.28
OD	2.830	649.45	2.870	834.74						

MARTIN MARIETTA ENERGY SYSTEMS

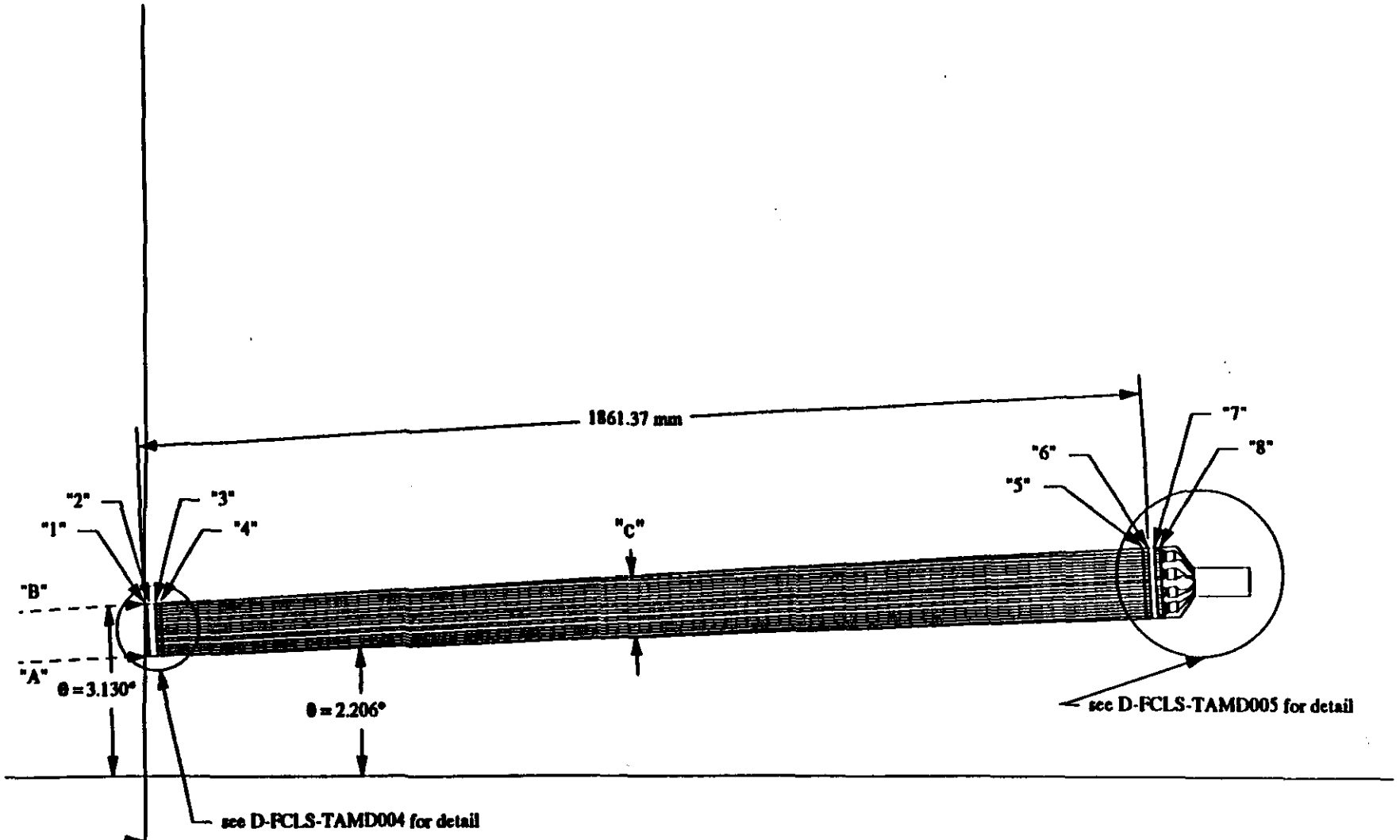
PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
LIQUID SCINTILLATING OPTION
SPAGHETTI TOWER & MODULE DESIGN

PRINT NO: D-FCLS-TAMD001 | REV 4

DRAWN BY: S. M. CHAE | 2/24/92

CHECKED & APPROVED BY:



	1	2	3	4	5	6	7	8
RA	211.96	212.15	212.73	213.11	283.23	283.61	283.65	284.04
RB	300.67	300.95	301.76	302.31	401.77	402.32	402.37	402.92
**Length A	5506.15	5511.15	5526.15	5536.15	7357.52	7367.52	7368.52	7378.52
**Length B	5506.15	5511.15	5526.15	5536.15	7357.52	7367.52	7368.52	7378.52
Length C	87.10	87.18	87.42	87.58	116.39	116.55	116.56	116.72

** The lengths in the table indicate the distance from the interaction point.

MARTIN MARIETTA ENERGY SYSTEMS

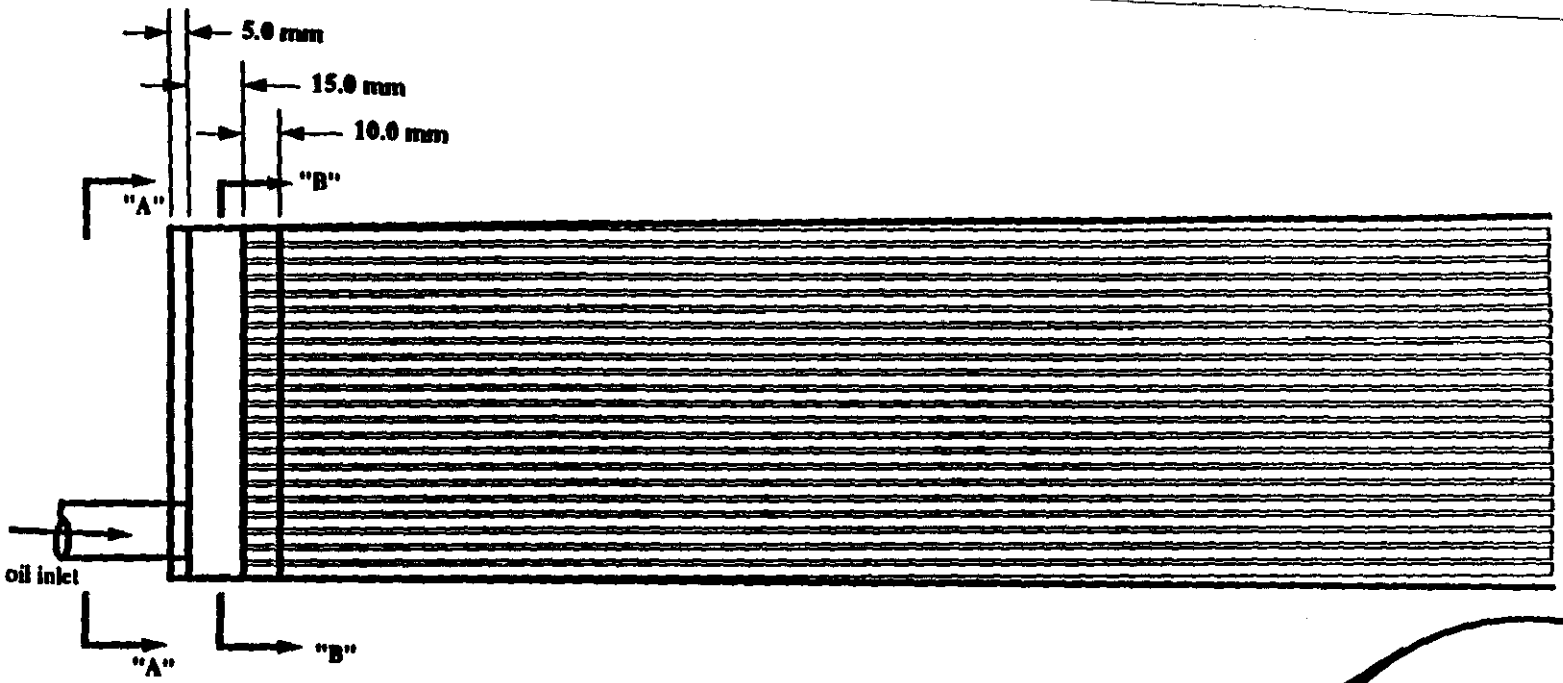
PROJECT: SSC GEM DETECTOR

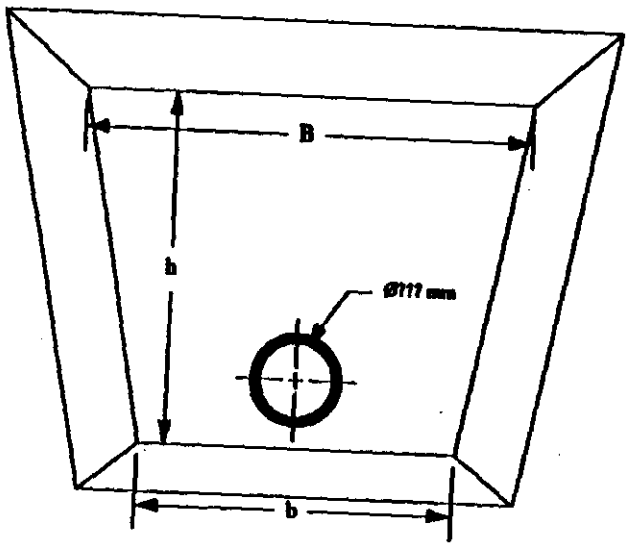
FORWARD CALORIMETER
LIQUID SCINTILLATING OPTION
SPAGHETTI TOWER & MODULE DESIGN
SUPER TOWER OF MODULE 4

PRINT NO: D-FCLS-TAMD003 | REV 1

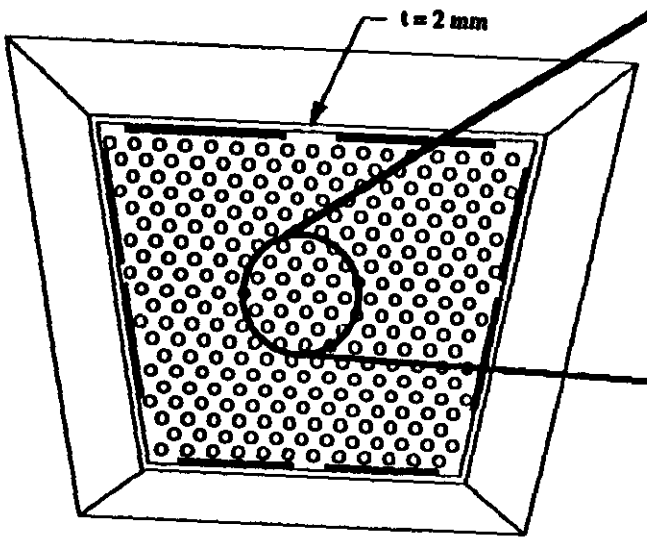
DRAWN BY: S. M. CHAE | 3/2/92

CHECKED & APPROVED BY:





VIEW "A-A"



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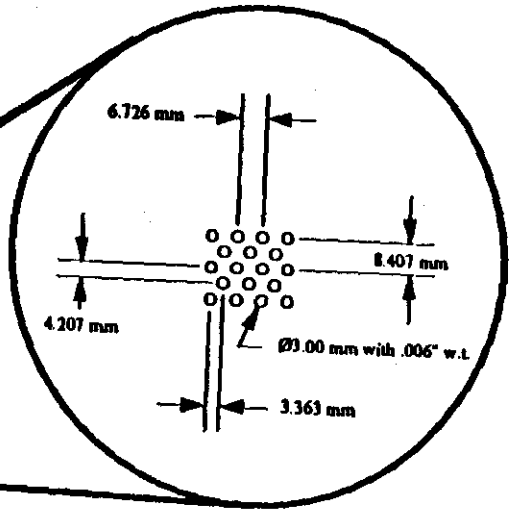
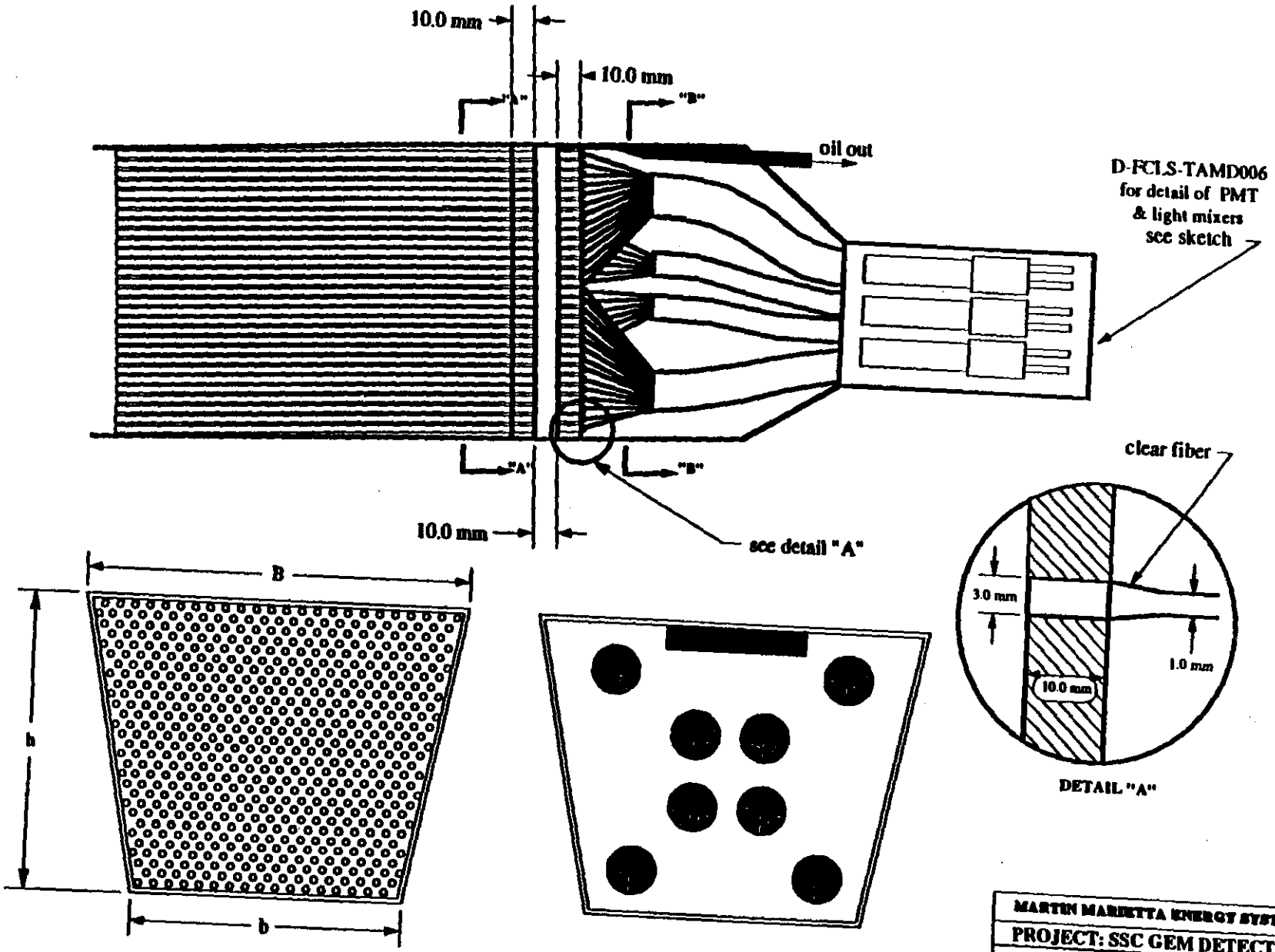


TUBE ARRANGEMENT DETAIL

Note: 1. See DFCLSTAMD001 for dimensions B, b, and h.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER LIQUID SCINTILLATING OPTION SUPER TOWER INNER END FACE DETAIL	
PRINT NO: D-FCLS-TAMD004	REV 1
DRAWN BY: S. M. CHAE	3/3/91
CHECKED & APPROVED BY:	



Note: 1. See DFCLSTAMD001 for dimensions B, b, and h.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER LIQUID SCINTILLATING OPTION SUPER TOWER OUTER END FACE DETAIL	
PRINT NO: D-FCLS-TAMD005	REV 1
DRAWN BY: S. M. CHAE	3/3/92
CHECKED & APPROVED BY:	

High Pressure Gas

GEM Lot Cost Estimate, HP Gas Forward Calorimeter

		Engineering/design			M&S	Inspection/Admin			Proc/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contng.	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
6.6.2	GEM																		
6.2.2.1	Research and Development																		
6.2.2.1.3	HP Gas Forward calorimeter																		
1.3.1	Material Tests																		
1.3.1.1	HP Gas Testing	0.33	$155	$52	$2.6				$20	0.2	$55	$11		$11	$63	$23	$86	$36	$122
1.3.1.2	Eutectic Testing/Development	0.25	$160	$40	$2.0				$20	0.2	$55	$11		$11	$51	$22	$72	$30	$103
1.3.2	Single Barrel Prototype																		
1.3.2.1	Barrel Assembly	0.25	$160	$40	$2.0				$20	0.2	$55	$11		$11	$51	$22	$72	$30	$103
1.3.2.2	Electronics	0.25	$160	$40	$2.0				$30	0.2	$55	$11		$11	$51	$32	$82	$35	$117
1.3.2.3	Assembly/Test Frame	0.1	$160	$16	$0.8				$10	0.2	$55	$11		$11	$27	$11	$38	$16	$53
1.3.2.4	Thermal Control	0.2	$160	$32	$1.6				$10	0.25	$55	$14		$14	$46	$12	$57	$24	$81
1.3.3	Three Barrel Prototype																		
1.3.3.1	Barrel Assembly	0.1	$160	$16	$0.8				$50	0.75	$55	$41		$41	$57	$91	$108	$45	$153
1.3.3.2	Electronics	0.1	$160	$16	$0.8				$40	0.75	$55	$41		$41	$57	$41	$98	$41	$139
1.3.3.3	Pressure Vessel	0.1	$160	$16	$0.8				$45	0.5	$55	$28		$28	$43	$46	$89	$37	$127
1.3.3.4	Hook Assembly	0.2	$160	$32	$1.6				$30	0.5	$55	$28		$28	$58	$32	$91	$38	$129
1.3.3.5	Support Frame	0.2	$160	$32	$1.6				$50	0.25	$55	$14		$14	$45	$52	$97	$41	$138
1.3.3.6	Assembly/Test Frame	0.1	$160	$16	$0.8				$45	0.25	$55	$14		$14	$30	$46	$75	$32	$107
1.3.3.7	Thermal Control	0.1	$160	$16	$0.8				$40	0.2	$55	$11		$11	$27	$41	$68	$28	$96
1.3.3.8	Beam Testing	0.1	$160	$16	$0.8				$50	0.2	$55	$11		$11	$27	$51	$78	$33	$110
1.3.4	Manufacturing Development																		
1.3.4.1	Tube Cutting	0.2	$160	$32	$1.6				$20	0.25	$55	$14		$14	$45	$22	$67	$28	$95
1.3.4.2	Tube Connection to PV	0.2	$160	$32	$1.6				$20	0.25	$55	$14		$14	$45	$22	$67	$28	$95
1.3.4.3	Casting	0.2	$160	$32	$1.6				$45	0.5	$55	$28		$28	$59	$47	$106	$44	$150
1.3.4.4	Readout Assembly	0.2	$160	$32	$1.6				$30	0.5	$55	$28		$28	$59	$32	$91	$38	$129
1.3.4.5	Barrel/PV Handling	0.1	$160	$16	$0.8				$20	0.25	$55	$14		$14	$30	$21	$50	$21	$71
1.3.5	Electronics Development	0.25	$160	$40	$2.0				$100	0.5	$55	$28		$28	$67	$102	$169	$71	$240
6.2.2.2	Conceptual and Preliminary Design																		
6.2.2.2.3	HP Gas Forward Calorimeter																		
2.3.1	Preparation of Lot																		
2.3.1.1	Conceptual Design	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.1.2	Costing Studies	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.1.3	Document Preparation	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.2	Preparation of Technical Prop.																		
2.3.2.1	Conceptual Design	0.5	$124	$62	$3.1										$62	$3	$65	$27	$92
2.3.2.2	Costing Studies	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.2.3	Manufacturing Studies	0.2	$124	$25	$1.2										$25	$1	$26	$11	$37
2.3.2.4	Installation Studies	0.3	$124	$37	$1.8										$37	$2	$39	$16	$55
2.3.2.5	Preparation of Technical Proposal	0.3	$124	$37	$1.8										$37	$2	$39	$16	$55
6.2.2.3	Construction																		
6.2.2.3.3	HP Gas Forward Calorimeter																		
3.3.1	Barrel/PV Modules																		
3.3.1.1	Barrels	0.5	$160	$94	$2.7	0.1	$107	$11							$65	$3	$67	$17	$84
3.3.1.1.1	Barrel Jacket								$35							$35	$35	$13	$48
3.3.1.1.2	Extention Bracing								$2							$2	$2	$1	$3
3.3.1.1.3	Fasteners								$1							$1	$1	$0	$1
3.3.1.1.4	Top/Bottom Plates								$26							$26	$26	$7	$33
3.3.1.1.5	Spacers								$3							$3	$3	$1	$4
3.3.1.2	Pressure Vessel Assembly	0.3	$160	$32	$1.6	0.1	$107	$11							$43	$2	$45	$11	$56
3.3.1.2.1	Pressure Vessel								$268							$268	$268	$67	$335
3.3.1.2.2	Studs								$11							$11	$11	$3	$14

GEM Lel Cost Estimate, HP Gas Forward Calorimeter

		Engineering/Design			M&S	Inspection/Admin			Prep/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contng	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$
3.3.1.2.3	Nuts								$19							$19	$19	$5	$24
3.3.1.2.4	Washers								$3							$3	$3	$1	$4
3.3.1.3	Tube Assembly	0.2	$108	$22	$1.1	0.1	$107	$11							$32	$1	$33	$8	$42
3.3.1.3.1	Inner & Outer Tubes								$181							$181	$181	$48	$239
3.3.1.3.2	Fasteners								$172							$172	$172	$43	$215
3.3.1.4	Eutectic								$24							$24	$24	$6	$30
3.3.1.5	Tungsten Rods	0.16	$108	$17	$0.9	0.1	$107	$11	$1,958						$28	$1,959	$1,987	$497	$2,484
3.3.1.6	Tungsten Powder								$754							$754	$754	$189	$943
3.3.1.7	Electronic	1.75	$108	$189	$9.5	0.29	$107	$27							$216	$9	$225	$56	$282
3.3.1.7.1	Channels								$856							$856	$856	$317	$1,173
3.3.1.8	Assembly																		
3.3.1.8.1	Station One	0.75	$108	$81	$4.1	0.17	$107	$18		1.92	$55	$106		$106	$205	$4	$209	$75	$284
3.3.1.8.1.1	Tube Cutting Machine								$7							$7	$7	$2	$9
3.3.1.8.1.2	Spacer Alignment Fixture								$8							$8	$8	$2	$10
3.3.1.8.1.3	Spacer Expansion Fixture								$10							$10	$10	$3	$13
3.3.1.8.2	Station Two	0.75	$108	$81	$4.1	0.08	$107	$9		0.11	$55	$6		$6	$96	$4	$100	$36	$136
3.3.1.8.2.1	Barrel Assembly Stand								$15							$15	$15	$7	$22
3.3.1.8.2.2	Lifting Fixture								$15							$15	$15	$4	$19
3.3.1.8.2.3	Personnel Platform								$4							$4	$4	$1	$5
3.3.1.8.3	Station Three	0.75	$108	$81	$4.1	0.08	$107	$9		0.13	$55	$7		$7	$97	$4	$101	$36	$137
3.3.1.8.3.1	Large Coating System								$125							$125	$125	$44	$169
3.3.1.8.3.2	Molds								$21							$21	$21	$7	$28
3.3.1.8.3.3	Setup Stands								$15							$15	$15	$4	$19
3.3.1.8.3.4	Personnel Platforms								$20							$20	$20	$5	$25
3.3.1.8.4	Station Four	1.25	$108	$135	$6.8	0.17	$107	$18		1.62	$55	$89		$89	$242	$7	$249	$90	$339
3.3.1.8.4.1	Top Plate Assembly Stand								$15							$15	$15	$6	$21
3.3.1.8.4.2	Lifting Fixture								$15							$15	$15	$4	$19
3.3.1.8.4.3	Personnel Platforms								$4							$4	$4	$1	$5
3.3.1.8.5	Station Five	0.5	$108	$54	$2.7	0.08	$107	$9		0.75	$55	$41		$41	$104	$3	$107	$38	$145
3.3.1.8.5.1	Setup Stand								$15							$15	$15	$4	$19
3.3.1.8.5.2	Personnel Platform								$2							$2	$2	$1	$3
3.3.1.8.6	Station Six	1.25	$108	$135	$6.8	0.1	$107	$11		0.77	$55	$42		$42	$188	$7	$195	$70	$265
3.3.1.8.6.1	Pressure Vessel Fixture								$10							$10	$10	$4	$14
3.3.1.8.6.2	PV/Barrel Assembly Stand								$15							$15	$15	$5	$20
3.3.1.8.6.3	Lifting Fixture								$25							$25	$25	$6	$31
3.3.1.8.6.4	Personnel Platform								$8							$8	$8	$2	$10
3.3.1.8.7	General Assembly Equipment	0.8	$108	$86	$4.3	0.16	$107	$17							$104	$4	$108	$39	$147
3.3.1.8.7.1	Environmental Control								$50							$50	$50	$25	$75
3.3.1.8.7.2	Clothing								$10							$10	$10	$4	$14
3.3.1.8.7.3	Cleaning Supplies								$5							$5	$5	$2	$7
3.3.1.8.7.4	Tools								$5							$5	$5	$2	$7
3.3.1.8.7.5	2T Monorail								$10							$10	$10	$3	$13
3.3.1.8.7.6	Temporary Use Items								$20							$20	$20	$8	$28
3.3.1.8.7.7	Handling Carts (10 - 100 Tons)								$10							$10	$10	$4	$14
3.3.1.9	Calibration Loops	0.75	$108	$81	$4.1	0.1	$107	$11	$20						$92	$24	$116	$61	$177
3.3.2	PV/Barrel Assembly																		
3.3.2.1	Structural Support	0.2	$108	$22	$1.1	0.04	$107	$4	$128						$26	$128	$152	$62	$214
3.3.2.2	Assembly Equipment																		
3.3.2.2.1	Station Seven	1.5	$108	$162	$8.1	0.04	$107	$4		0.27	$55	$15		$15	$181	$8	$189	$51	$240
3.3.2.2.1.1	Assembly Test Stand								$50							$50	$50	$21	$71
3.3.2.2.1.2	Personnel Platform								$8							$8	$8	$2	$10
3.3.3	Thermal Control																		
3.3.3.1	Heat Transfer System	0.5	$124	$62	$3.1	0.05	$107	$5	$50	0.3	$55	$17		$17	$84	$53	$137	$30	$167
3.3.3.2	Heat Exchangers	0.25	$124	$31	$1.6	0.05	$107	$5	$50	2	$55	$110		$110	$146	$52	$198	$71	$269
3.3.4	Beam Test/Calibration																		
3.3.4.1	Test Stands	0.5	$124	$62	$3.1	0.08	$107	$9	$250						$71	$253	$324	$94	$418
3.3.4.2	Manpower					0.1	$107	$11							$11		$11	$3	$14
3.3.4.3	Beam Calibration System	0.75	$124	$93	$4.7	0.1	$107	$11	$100						$104	$105	$209	$60	$269

GEM Lol Cost Estimate, HP Gas Forward Calorimeter

		Engineering/design			M&S	Inspection/Admin			Proc/Fab	Installation/Assembly					Totals				
		Labor	Rate	Total	Material	Labor	Rate	Total	Material	Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Contng.	Total
WBS no.	Item	my	k$/my	k$	k$	my	k$/my	k$	k$	my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
3.3.6	System Assembly																		
3.3.6.1	Assembly Stand/Station Eight	0.75	$108	$81	$4.1	0.08	$107	$8		0.49	$55	$27		$27	$117	$4	$121	$33	$153
3.3.6.1.1	Assembly Stand								$50							$50	$50	$20	$70
3.3.6.1.2	Temporary Bracing								$15							$15	$15	$6	$21
3.3.6	Forward Installation																		
3.3.6.1	Manpower	0.75	$154	$116	$5.6	0.4	$107	$43		1.17	$56	$66		$66	$224	$6	$230	$71	$301
3.3.6.2	Equipment																		
3.3.6.2.1	Assembly Handling Fixture	0.75	$108	$81	$4.1	0.08	$107	$8	$40						$90	$44	$134	$36	$170
3.3.6.2.2	Temporary Bracing	0.5	$108	$54	$2.7	0.04	$107	$4	$20						$58	$23	$81	$22	$103
3.3.7	Subsystem Management																		
3.3.7.1	Project Management	4	$154	$616	$30.8										$616	$31	$647	$233	$880
3.3.7.2	Resource Management	1	$154	$154	$7.7										$154	$8	$162	$58	$220
3.3.7.3	ES&H	0.5	$154	$77	$3.9										$77	$4	$81	$28	$109
3.3.7.4	Quality Assurance	0.5	$154	$77	$3.9										$77	$4	$81	$27	$108
3.3.7.5	System Integration	0.5	$154	$77	$3.9										$77	$4	$81	$30	$111
	Total			$3,031	$102			$204	$8,286								$11,266	$3,652	$14,918

S. M. Chee/ORNL/3-4-92

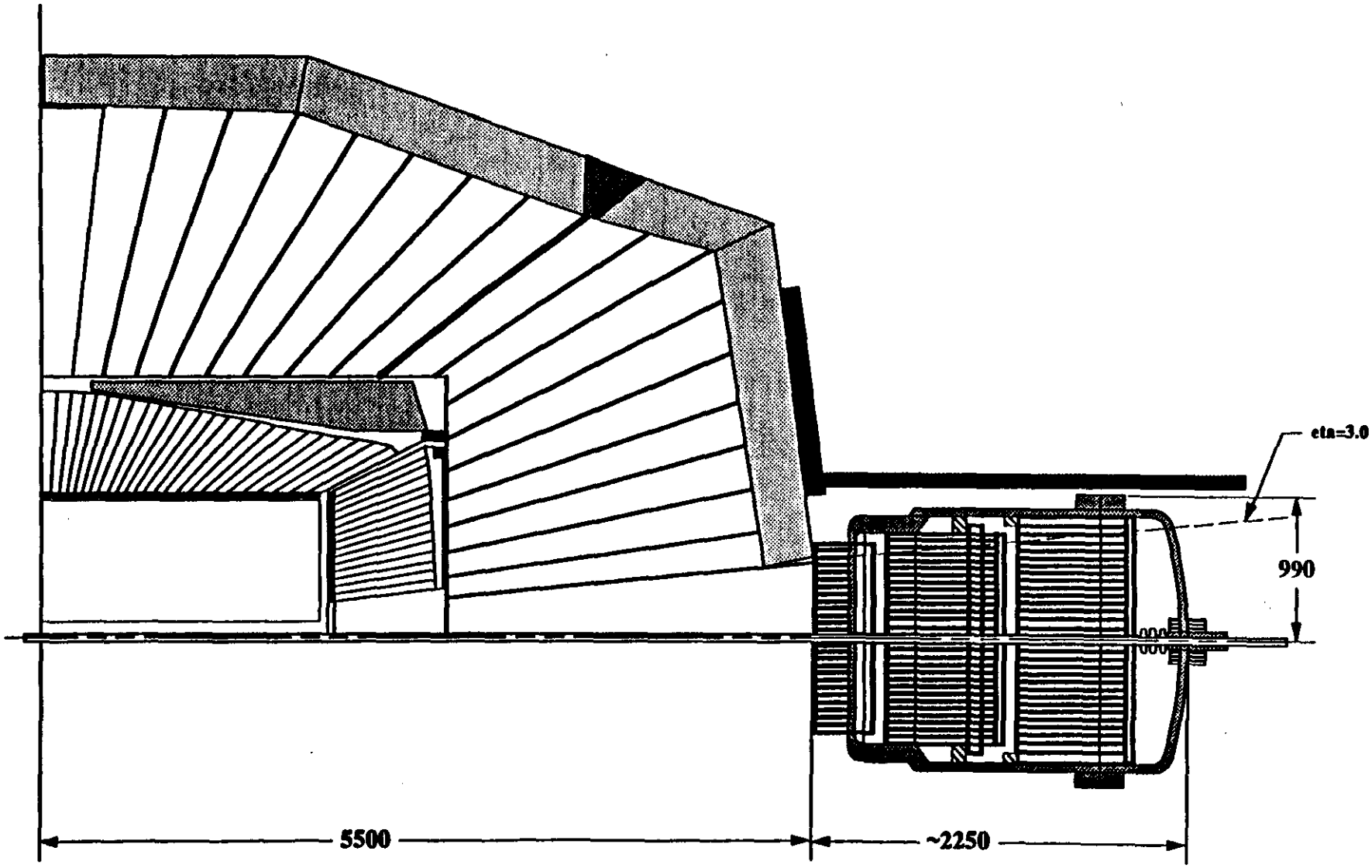
GEM Parameters

High Pressure Gas Forward Calorimeter

Tungsten / Eutectic (20%)

	One Side	Both Sides	
BARRELS	3	6	units
Channels	1,070	2,140	units
Barrel (METAL) Volume	0.2	0.4	M^3
SS Tube Volume	0.8	1.6	M^3
Tungsten Rod Volume	0.8	1.5	M^3
Absorber Volume (80% Tungsten)	1.1	2.2	M^3
Tungsten powder Volume	0.9	1.8	M^3
Eutectic Volume	0.2	0.4	M^3
Volume of Pressure Vessel	1.1	2.3	M^3
Volume of Support Structure	0.6	1.3	M^3
TOTAL VOLUME	4.7	9.3	M^3
Weight of 3 Barrels (Matel)	1.6	3.2	Metric Tons
Weight of SS Tubes	6.4	12.8	Metric Tons
Weight of Tungsten Rods	14.8	29.6	Metric Tons
Absorber Weight (80% Tungsten)	19.2	38.4	Metric Tons
Tungsten Powder	17.1	34.2	Metric Tons
Eutectic	2.1	4.2	Metric Tons
Weight of Pressure Vessel	9.2	18.4	Metric Tons
Weight of Structural Components	5.2	10.4	Metric Tons
TOTAL WEIGHT	56.4	112.9	Metric Tons
Active Absorption Lenghth	12.00		Lambda
Passive Absorption Lenghth			Lambda
Number of 12.7 & 6.35 mm Tubes	7,165	14,330	Units
Number of 22.23 & 15.1 mm Tubes	7,092	14,184	Units
Length of 12.7 & 6.35 mm Tubes	2,535	5,069	Meters
Length of 22.2 & 15.1 mm Tubes	5,641	11,281	Meters
Inner Radius	50		mm
Outer Radius	1,725		mm
Length***	2,140		mm

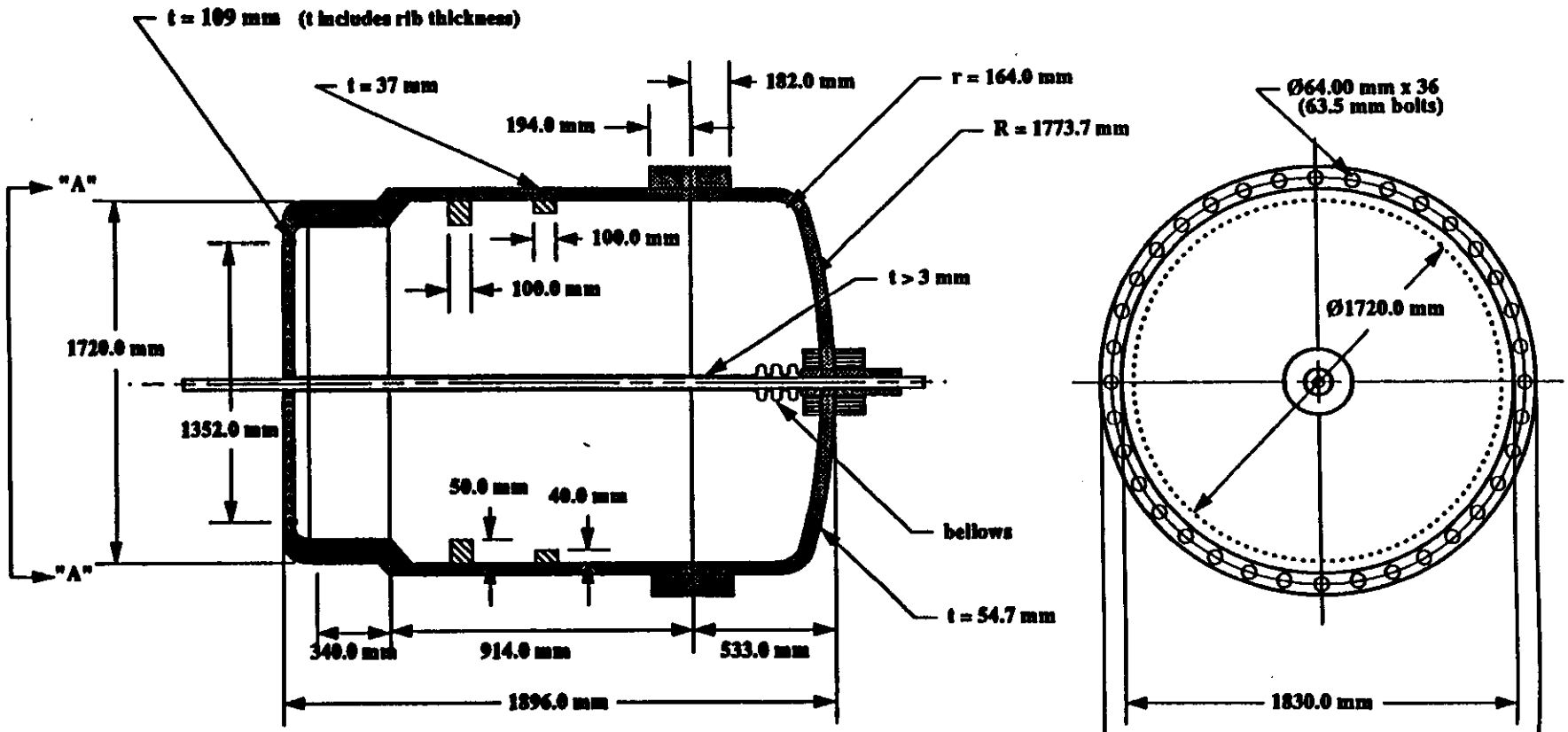
*** The total length shown only includes the three barrels and the space in between them

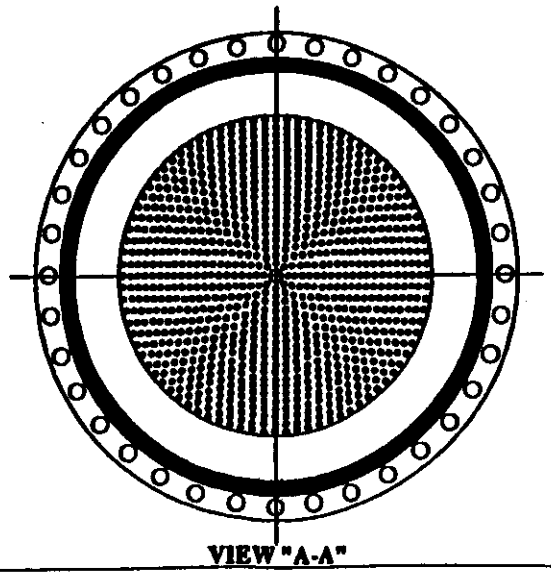


GEM Detector
Forward Calorimeter
General Arrangement

FCAL LOCATION

Rennich/Chae

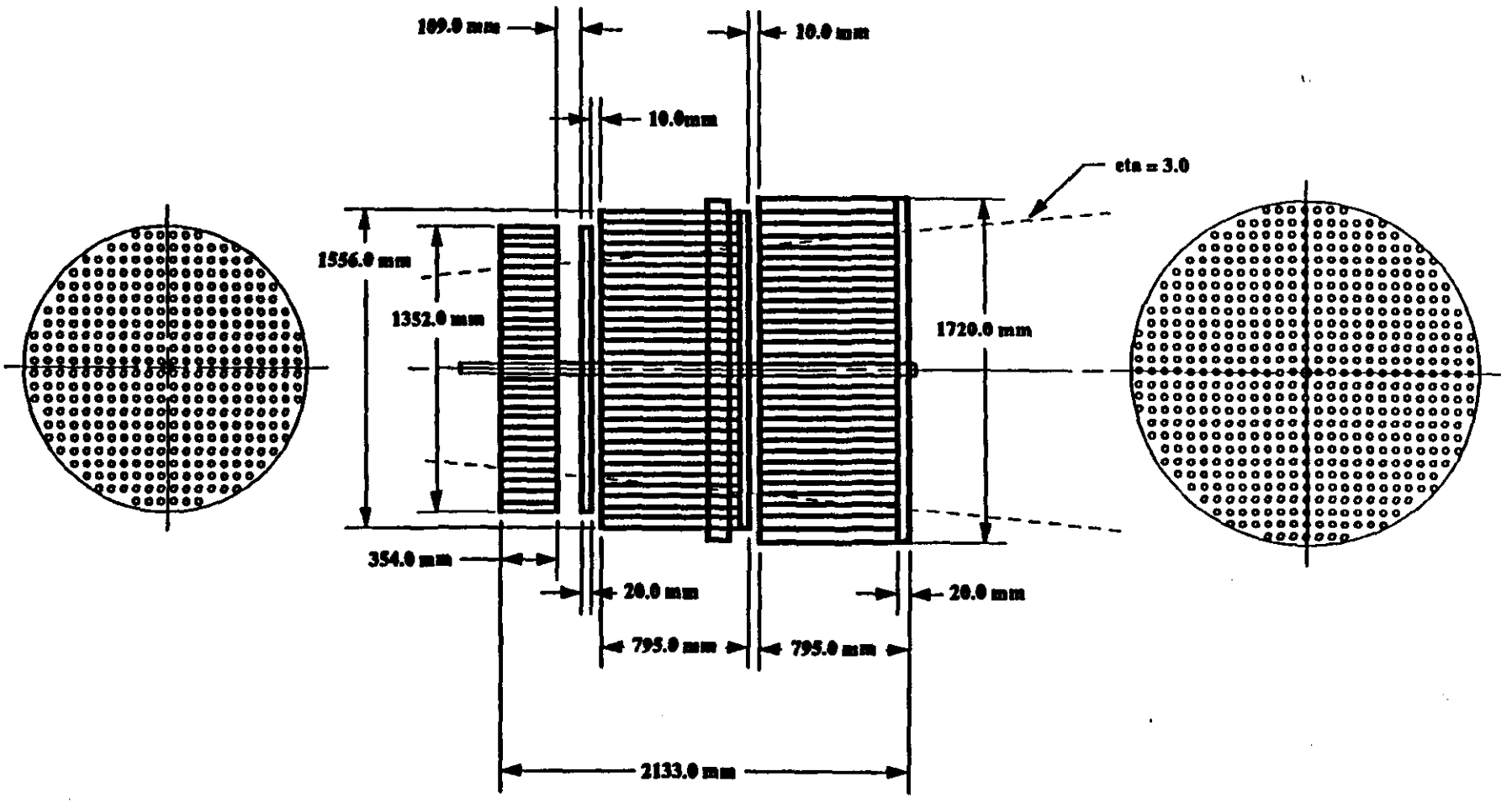




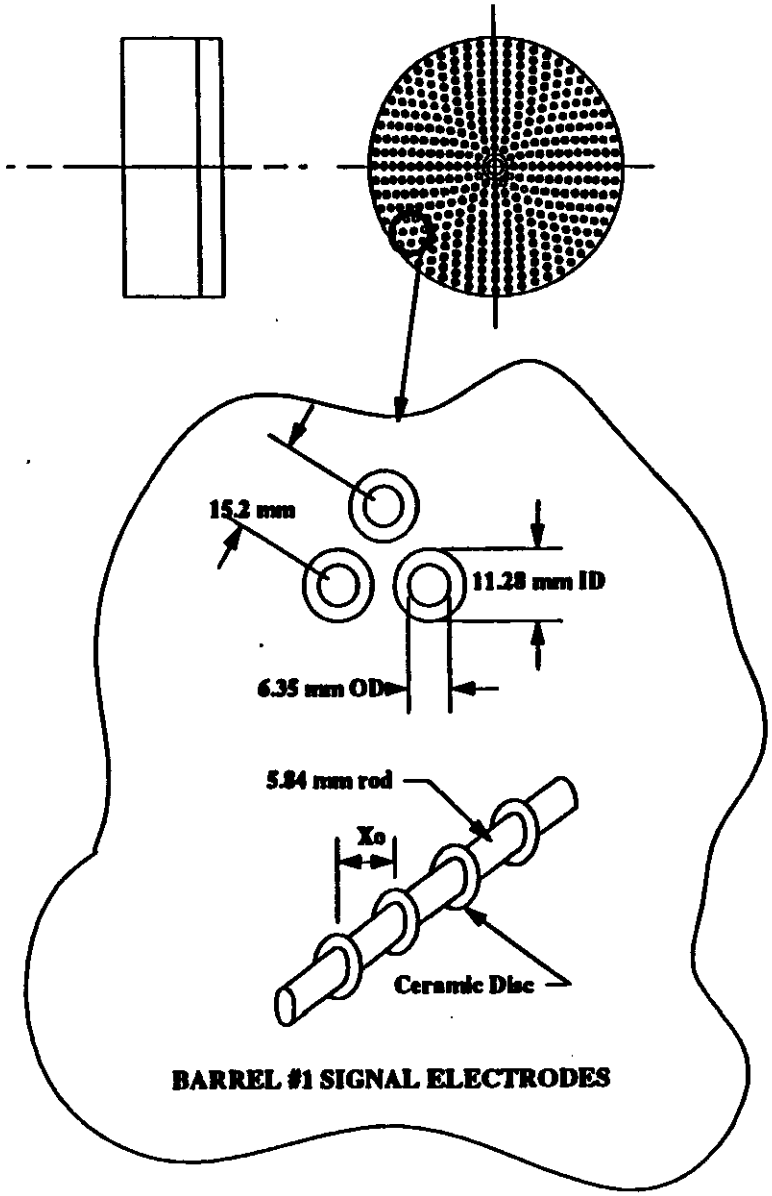
NOTES:

1. Tube positions shown are not per correct pattern.
2. Dimensions shown are approximate numbers.

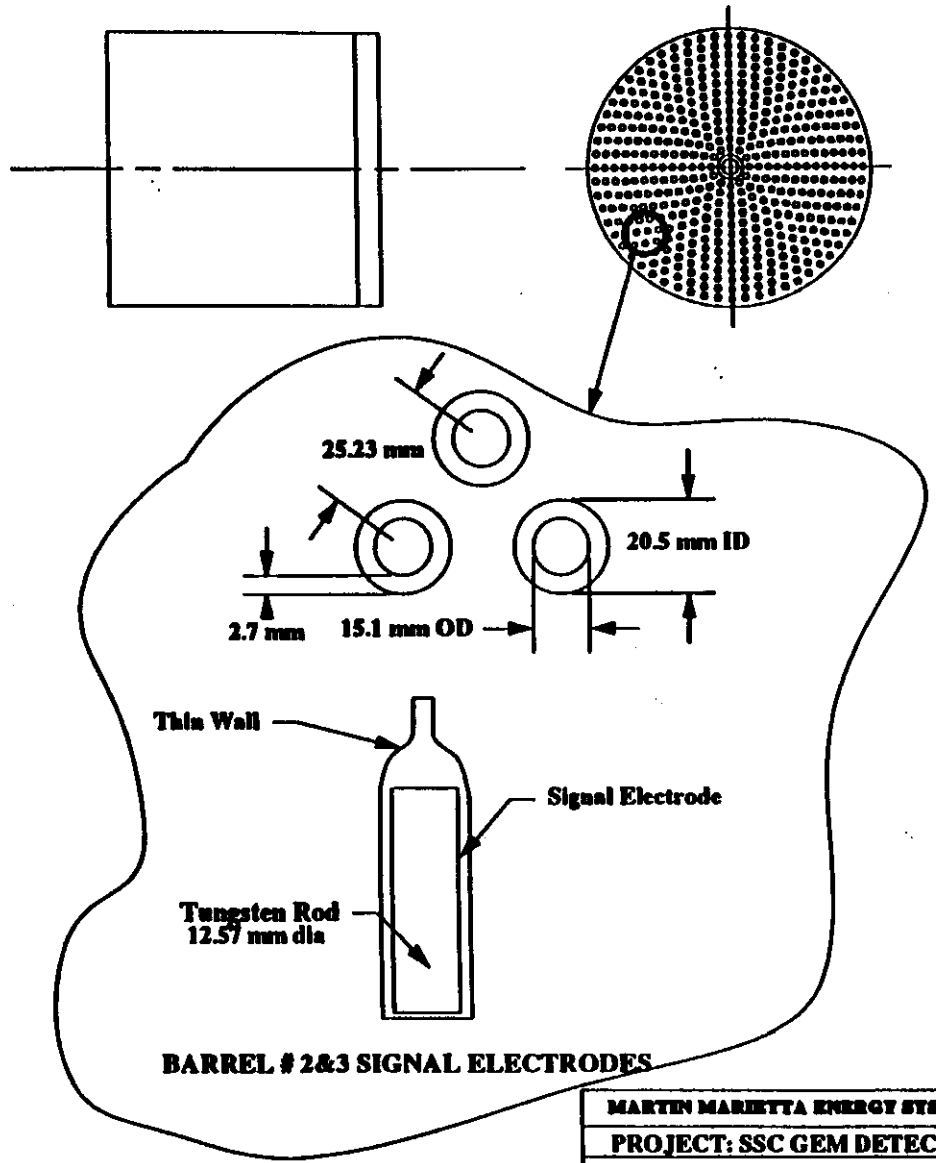
MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION PRESSURE VESSEL DESIGN GENERAL ARRANGEMENT	
PRINT NO: D-FCHPG-PV102	REV 2
DRAWN BY: S. M. CHAE	3/3/92
CHECKED & APPROVED BY:	



MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION PRESSURE VESSEL DESIGN GENERAL ARRANGEMENT	
PRINT NO: D-FCHPG-PV104	REV 2
DRAWN BY: S. M. CHAE	3/3/92
CHECKED & APPROVED BY:	



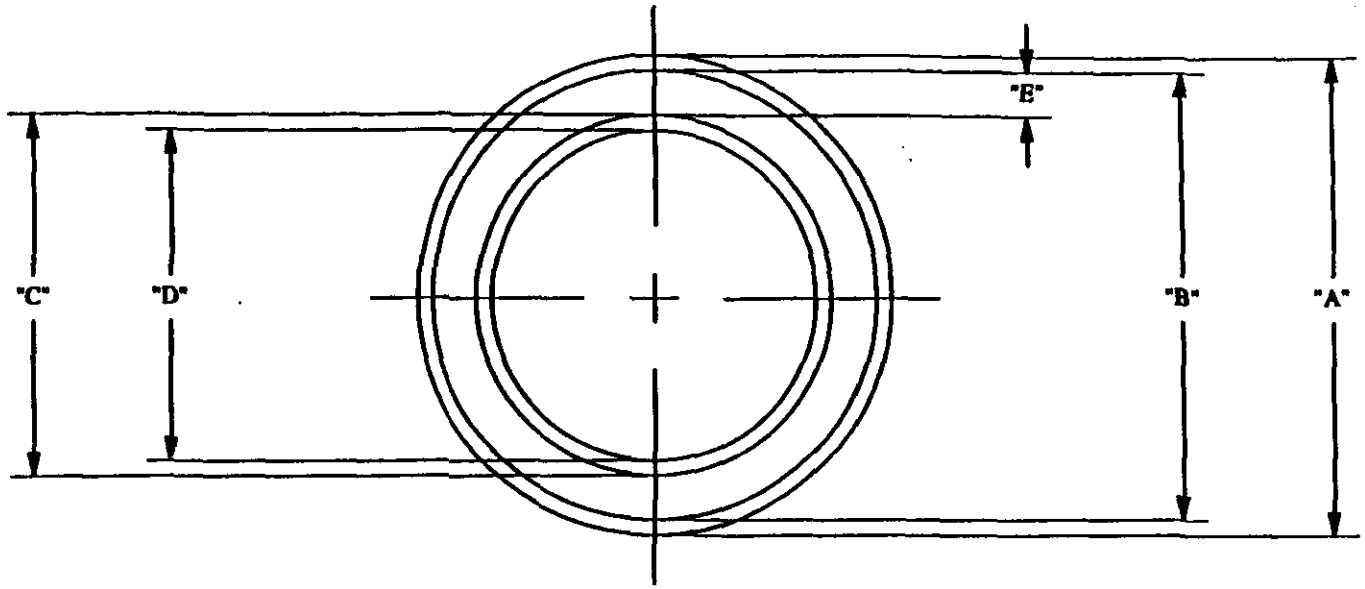
BARREL #1 SIGNAL ELECTRODES



BARREL # 2&3 SIGNAL ELECTRODES

NOTES: 1. The tube locations are per the correct pattern.
2. All numers shown are approximate values.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION TUBE ARRANGEMENTS IN INNER & OUTER BARRELS	
PRINT NO: D-FCHPG-CTD003	REV 1
DRAWN BY: S. M. CHAE	3/3/92
CHECKED & APPROVED BY:	



BARRELS	WALL THICK, IN		A		B		C		D		E	
	REQ'D	AVAIL	mm	in	mm	in	mm	in	mm	in	mm	in
1	0.0203	0.0200	12.700	0.500	11.2776	0.444	6.3500	0.250	5.842	0.230	2.4638	0.0970
2	0.035	0.035	22.225	0.875	20.4470	0.805	15.062	0.593	12.573	0.495	2.6925	0.1060
3	0.035	0.035	22.225	0.875	20.4470	0.805	15.062	0.593	12.573	0.495	2.6925	0.1060

MARTIN MARIETTA ENERGY SYSTEMS

PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
HIGH PRESSURE GAS OPTION
CYLINDER TUBE SIZE DESIGN

PRINT NO: D-FCHPG-CTD001 | REV 1

DRAWN BY: S. M. CHAE | 3/3/92

CHECKED & APPROVED BY:

A Re-examination of the Tracker Design driven by Physics Requirements

J.Brau, C.Baltay, L.Rosenson, R.Stroynowski

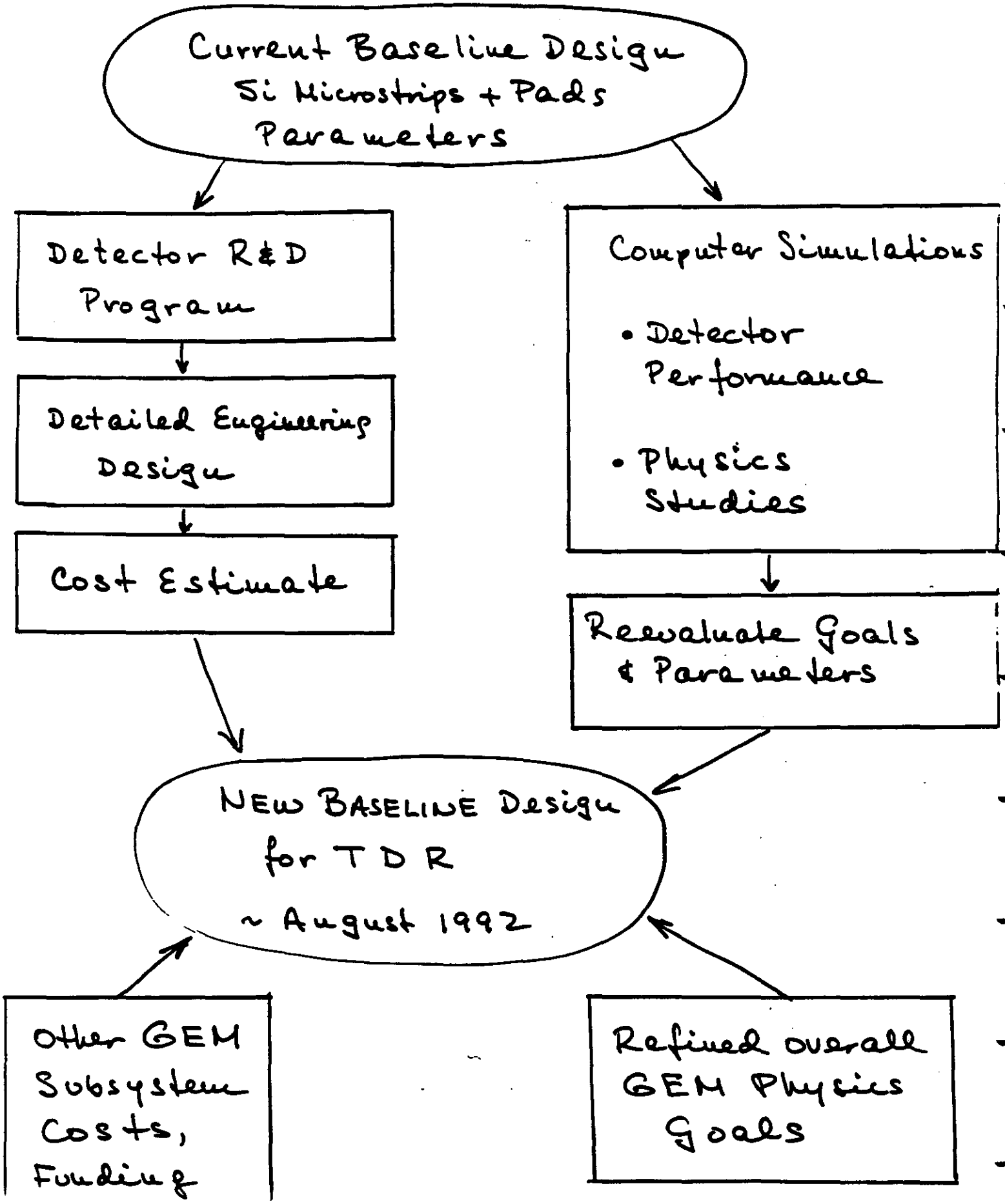
GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

TRACKER DESIGN RE-EXAM

30'	Baltay	Introduction
30'	Paige	Physics Discussion
20'	Wang	WW scattering
15'	Thomas	Additional Comment on Physi.
15'	Frey	Pre-radiator
20'	Stroynowski	Magnet
5'	Serguei	"
25'	Rosenson	Muons
20'	Komyshkov	Calorimetry
10'	Brau	Summary

⋮

PLANNING FOR THE TECHNICAL DESIGN REPORT



A HARDER SET OF QUESTIONS

What if Physics Simulation Studies indicate that improved tracker performance is important?

1. Improving Momentum Resolution, Charge Separation

   a) Increase B – 0.8T to 1.2T
      Increase Radius – 75 cm to 100 cm
      Improvement – 2.7
      ΔCost (Tracker) – Small
      ΔCost (Magnet, Cal, μ's) – large

   b) Go to an all Silicon Tracker
      Improvement – 2
      ΔCost – 50 to 100 M$?

   c) Replace Outermost Pad Superlayer by a single layer of Silicon
      Improvement ~ 1½
      ΔCost ~ 20 to 30 M$

   d) Add more Pad Layers
      8 layers → 12 layers
      Improvement – 20%
      ΔCost – 5 to 10 M$

2. Improve Vertex Z Resolution

We are now planning to instrument one layer of wires / superlayer

Could instrument both layers

Improvement - $\sqrt{2}$

Δ Cost ~ 1 M\$

3. Decrease Occupancy, Improve two track resolution in jets

Decrease Pad Sizes by factor of 2

Improvement in occupancy ~ 2

Δ Cost of electronics ~ 10 M\$

4. Improve Pattern Recognition

Add More Layers

Silicon	6 → 10
Pads	8 → 12

Δ Cost ~ 20 M\$

CENTRAL TRACKER RESOLUTIONS

. Baseline Design Si + Pads

$R_{max} = 68$ cm $\qquad \sigma_p/p^2 = 1.3 \times 10^{-3}$ /gev/c

$R_{max} = 94$ cm $\qquad 0.7$

$(94/68)^2 = 1.9 \qquad 1.3/0.7 = 1.9$

. Silicon only

$R_{max} = 28$ cm, 6 layers $\qquad 5.2$

$= 68$ cm, 14 layers $\qquad 0.84$

$= 68$ cm, 20μ align. $\qquad 1.0$

$(68/28)^2 = 5.9 \qquad 5.2/0.84 = 6.2$

. Pads only (good at 10^{34})

$R_{max} = 68$ cm $\qquad 3.4$

$= 94$ cm $\qquad (1.8)$

$56\mu/13\mu = 4.3 \qquad 3.4/0.84 = 4.1$

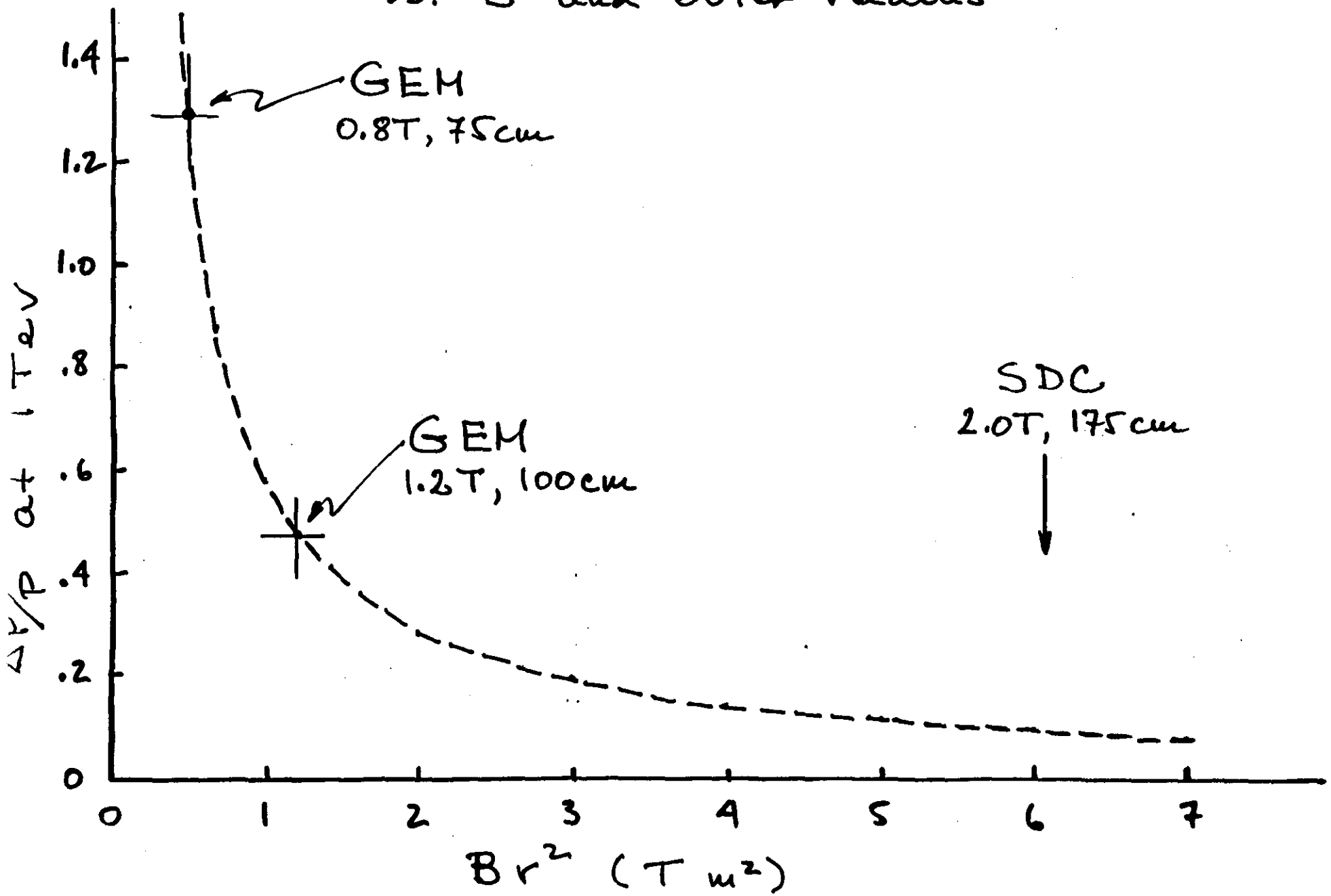
. Baseline with outer Si layer

$R_{max} = 68$ cm, 20μ align. Si $\qquad 1.15$

$\dfrac{22\mu}{56\mu/\sqrt{4}\,?} = \dfrac{22}{28} = 0.8 \qquad \dfrac{1.15}{1.3} = 0.89$

CENTRAL TRACKER MOMENTUM RESOLUTION

vs. B and outer radius



Physics Processes	Id. Primary Vertex	e/γ Separation	e, μ, γ Isolation Cuts	e/h Separation	Muon Momentum Check	$e\pm$ Sign Separation	Secondary Vertex	Low Momentum Track	Full Event Reconstr.
$H^0 \rightarrow \gamma + \gamma$	X	X	X						
$H^0 \rightarrow e^+e^-l^+l^-, e^+e^-\nu\bar{\nu}, e^+e^-$ *jetjet*	X	X	X	X		X			
$H^0 \rightarrow \mu^+\mu^-l^+l^-, \mu^+\mu^-\nu\bar{\nu}, \mu^+\mu^-$ *jetjet*	X		X		X				
Gluino Pair Prod $\tilde{g}\tilde{g} \rightarrow e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
Techni eta $\eta_T \rightarrow b + \bar{b}$ or $t + \bar{t}$	X		X				X		
WW Scattering $W^\pm W^\pm \rightarrow e^\pm e^\pm, \mu^\pm e^\pm$	X	X	X	X	X	X			
$Z^1 \rightarrow e^+e^-$ Asymmetry	X	X	X	X		X			
B Physics, e.g. $B \rightarrow \Psi$, etc.	X						X	X	X
Top Physics $t \rightarrow W + b$, etc.	X		X				X	X	X

CENTRAL TRACKER PHYSICS STUDIES

Table 2.3

E. Wang
Tucson 92

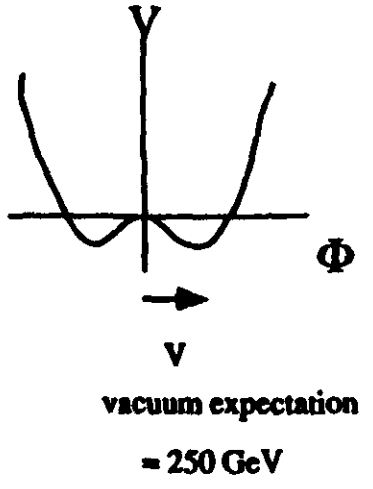
$W_L^+ W_L^+$ Scattering:

Counting Angels on a Pinhead

In the standard model, a fundamental scalar makes the model mathematically consistent.

$$V = \lambda (\Phi - 1/2 \ v^2)^2$$

$$\lambda = 1/2 (M_H / v)^2$$

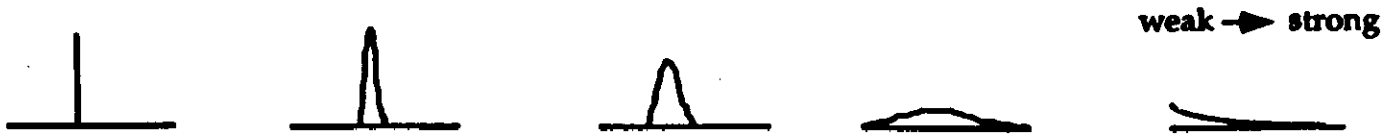


At high energies, do weak interactions stay weak ($M_H << v$) or

or become strong ($M_H >> v$) ?

Lee, Quigg, Thacker 77
Chanowitz, Gaillard 85
Chanowitz, Golden 88
Barger, Cheung, Han, Phillips 90
Dicus Gunion Vega 91
Dicus Gunion Orr Vega 91
Berger, Chanowitz 91

Higgs Properties



M_H	150 GeV	200	400	800	1000
Γ_H	< 1 GeV	2	30	250	500
σ	250 1K	600	500	50	30
	$\gamma\gamma$ ZZ^*		ZZ		$W_L^+ W_L^+$

$H \rightarrow ZZ \rightarrow 4e, 4\mu \;\; 2e2\mu$

Physics Problem:

No Lose Corollary:

Weak Interactions stay weak

$M < 1$ TeV

or Weak Interactions become strong

$\sigma_{W_L W_L}$ observable rate

or descrepancy with Standard Model!

Physics Processes of Interest

$W_L W_L$ scattering

$H \to \gamma\gamma$

ZZ^*

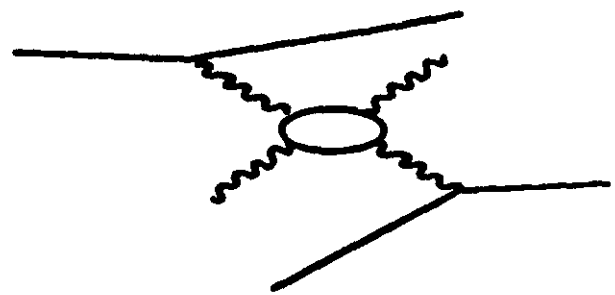
ZZ

physics

consistency in ALL these modes is what constitutes a Higgs search

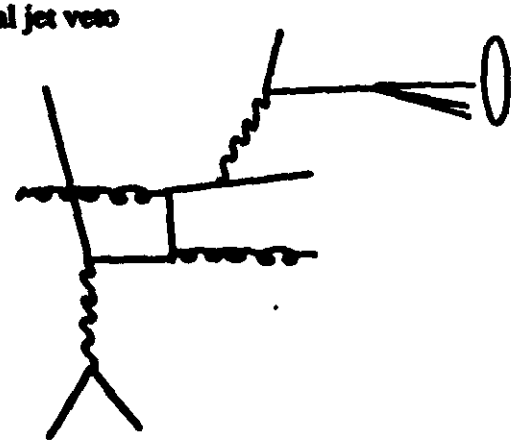
topology

signal



jet tag

central jet veto



isolation

$m_{j\ell}$

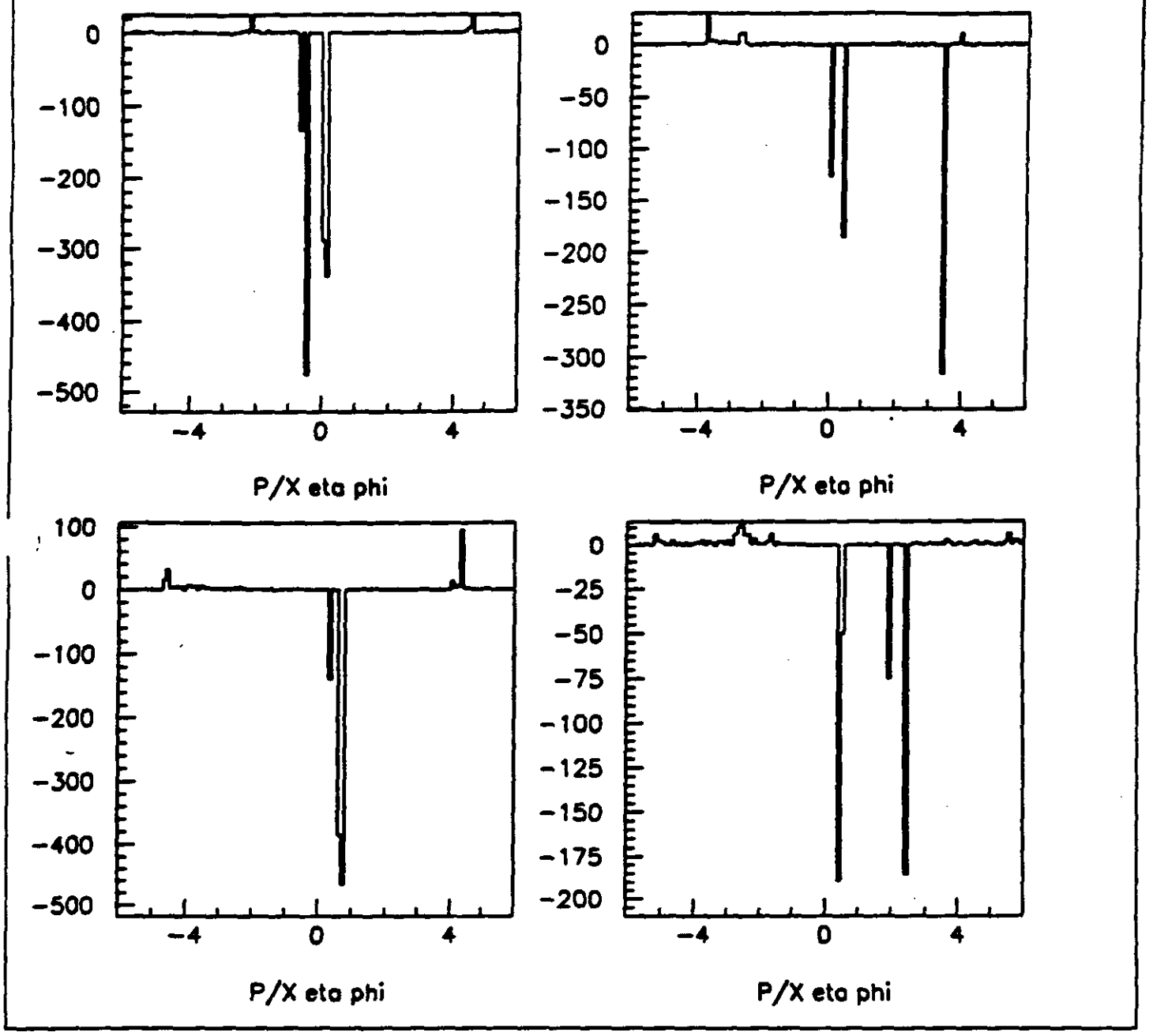
tt backgnd

$t\bar{t} \to W^+ W^- b\bar{b}$

$\hookrightarrow \ell^+ \quad \hookrightarrow \ell^+$

$W_L^+ W_L^+$ Pythia 5.5

Lego Plots

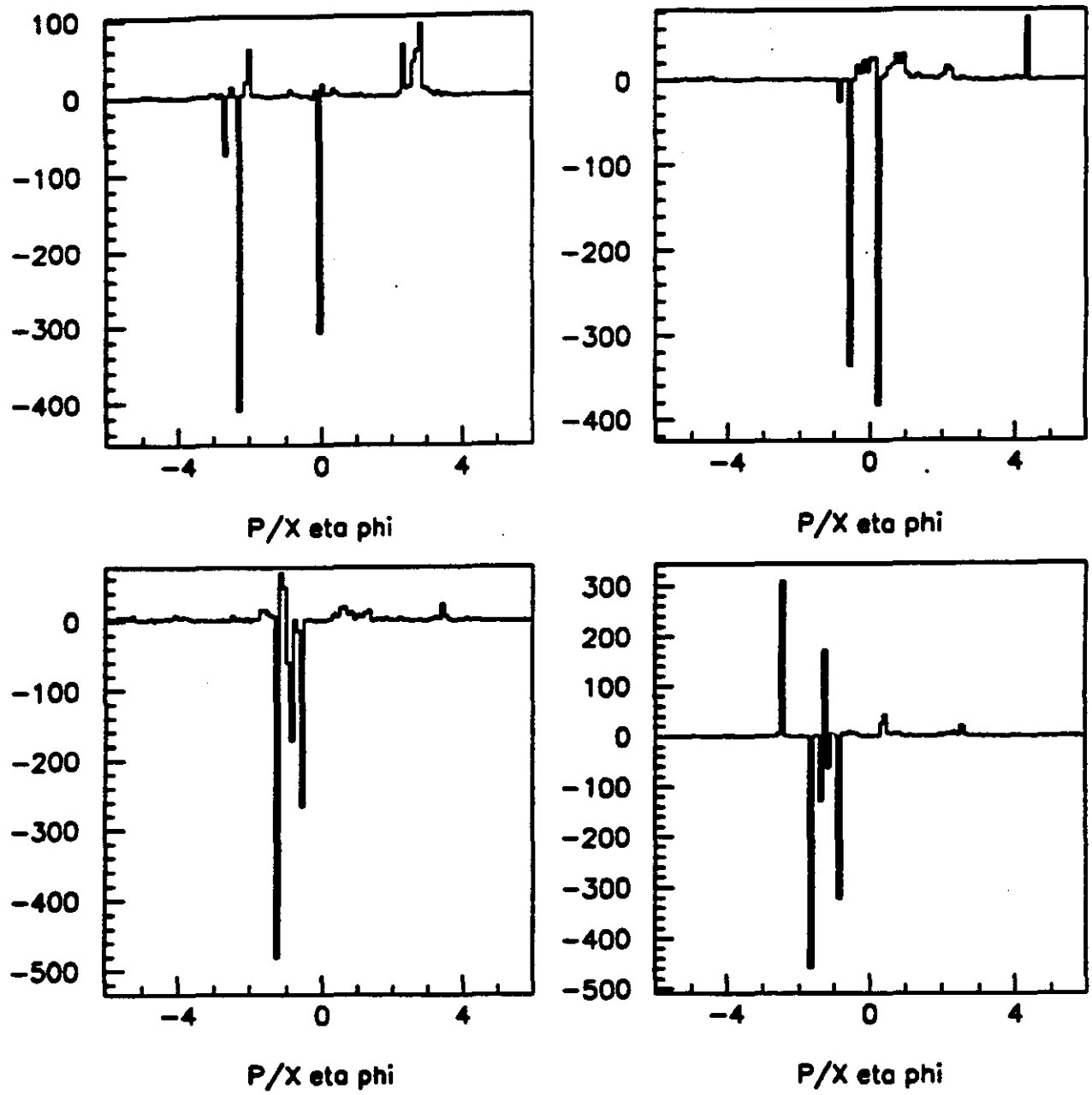


$500 < \hat{s} <$ 2000 GeV

w/ frag.

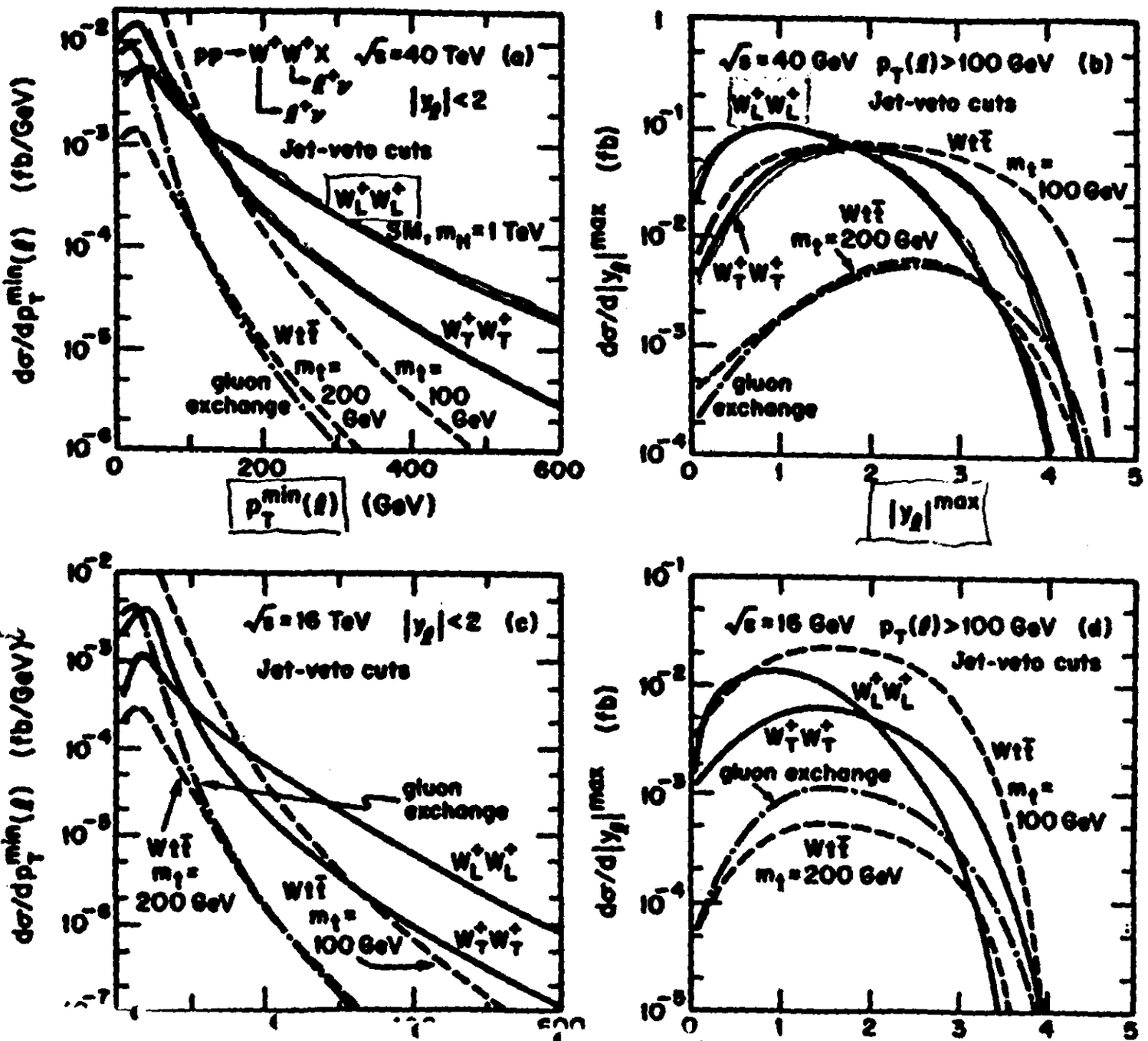
$t\bar{t} \to W W + X$
$\hookrightarrow \ell \quad \hookrightarrow \ell$

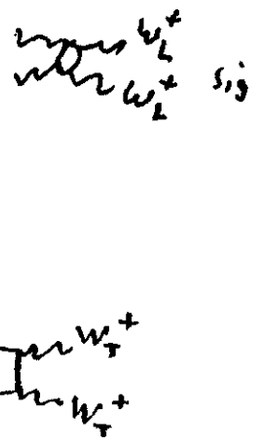
top background
Lego Plots



Note: A few out of a million is an overwhelming background!

Barger et. al.





Pack it in "

What is needed? Dicus, Gunion, Orr, Vega '91

$t\bar{t} \to WWb\bar{b}$
$\hookrightarrow \ell \quad \hookrightarrow \ell$

	e+e+ events per SSC yr lep cuts $y<3.5$ $p_T^\ell<7.5$	ptj<125 GeV	iso or forward jet tag
SM M=1 TeV $W_L W_L$	2.75	1.87	$\Sigma E_T<8$ $R<.25$ (central jet veto)
SM $W_T W_T$	10.23	0.79	$\Delta R_{i\ell}>.5$ $M_{jj}^{min}<200$ GeV
gluon exch	3.19	0.15	• must have jet tag • eff?
$t\bar{t}$	2310	748	need 10^-4 for complete rejection
$t\bar{t}$ g	1980	437	

• fragment?
• beam jets?

$t\bar{t}$

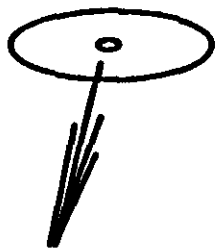
Backgrounds

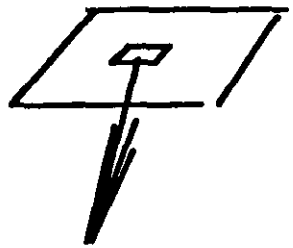
a. $tt \to WWbb$, l^+, l^+

b. $tt \to WWbb$, $l^-_{\text{mis-id}}$, l^+

	how to kill	
a.	central jet veto isolation charge id	$< 10^{-4}$ from Dicus et al
b.	central jet veto charge id	

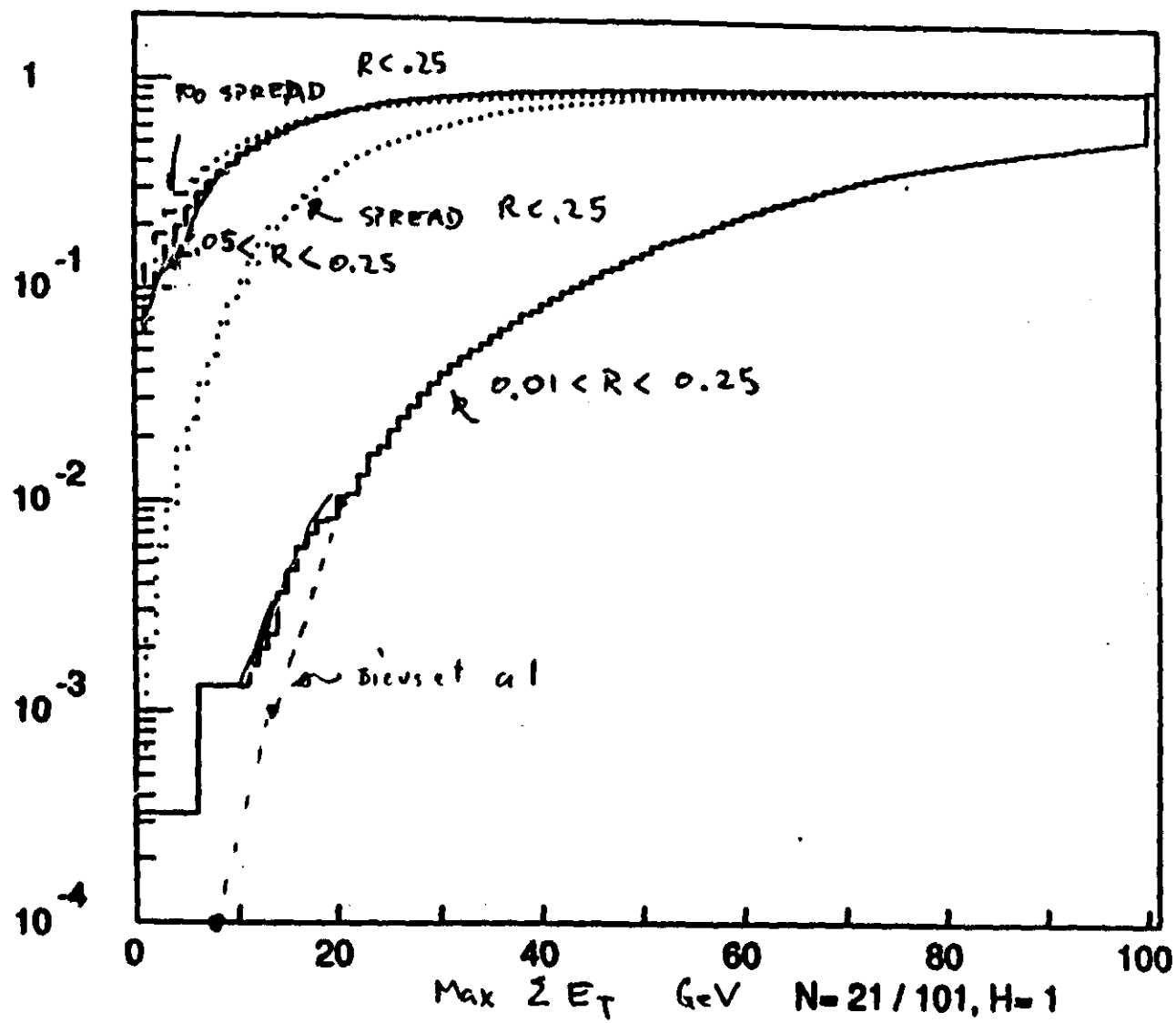
a. Isolation of High Pt electrons from bjets





Σ Et 0.01<R<0.25 → 0.05

Σ Et 4 cell wide boundary (0.05x0.05 cells)



i2_01_ns

ttbar isolation

FIG 1

$H \to WW$; $\bar{b}$

↳ $\ell\nu j$

Isolation results

- isolation in traditional sense ineffective
  as bjet fits in one celi
- need to look at F/B ratio, (trigger studies that $r_{aj} < 10^{-1}$)
- need data + good shower simulation to
  establish longitudinal, transverse segmentation
  requirements in calorimeter
- how about tracks ?

b. Charge Discrimination Req'd

$tt \rightarrow WW\ bb$

- passes isolation
- central jet veto less effective
- requires more than 10^-4 rejection / charge discrim

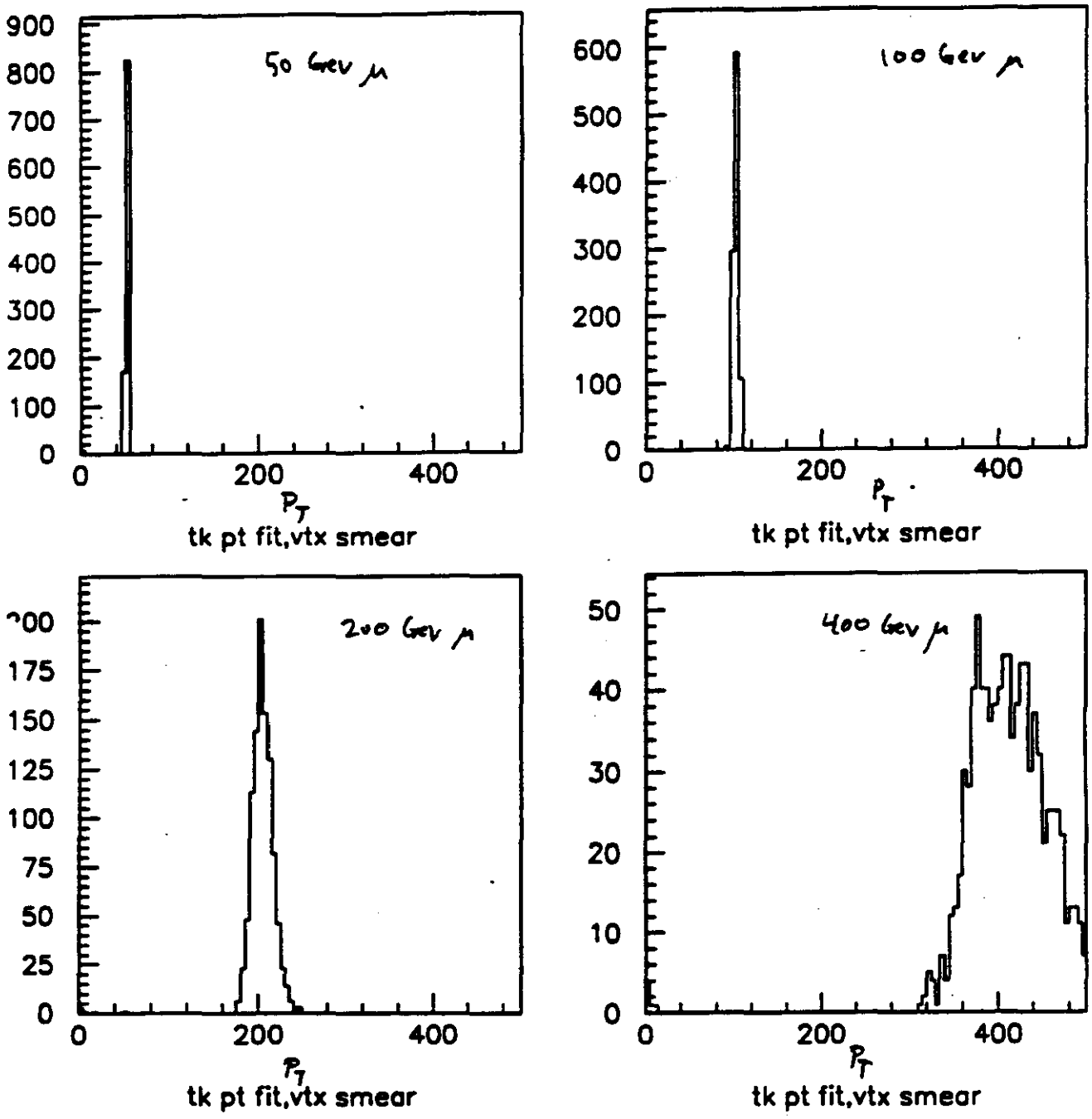
simulation:

- propagate μ or e (50,100,200,400
  Geant w GEM (P. Dingus) and SDC geometry/fields
- smear space points at superlayers
- reconstruct w circle fitter (TASSO adapted by J. Thomas)

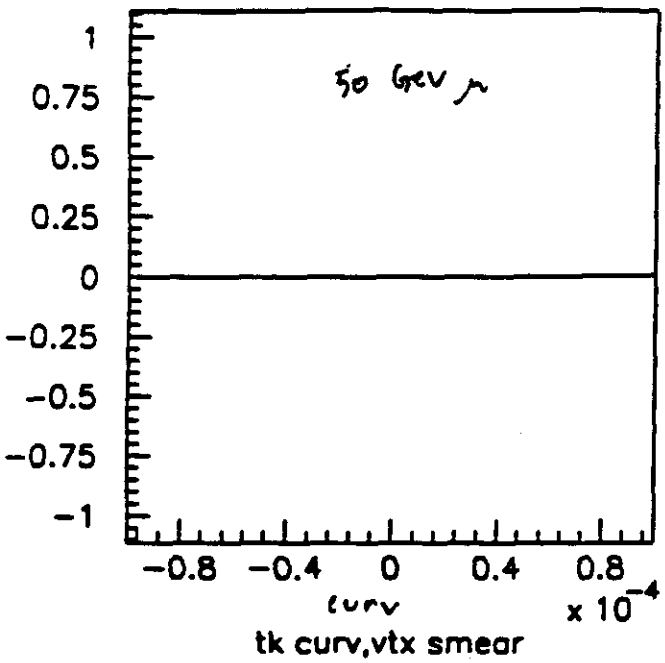
5 x 50μm 4 x 15μm

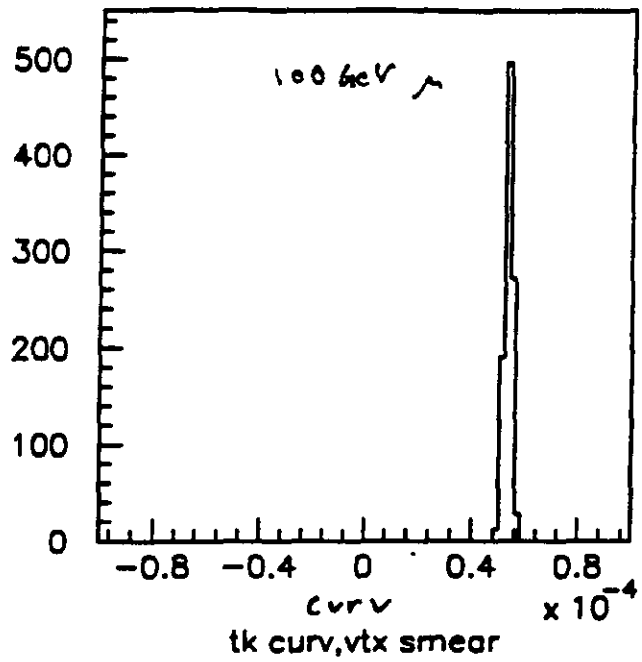
SDC Straw + Si, vtx constraint 15μ.

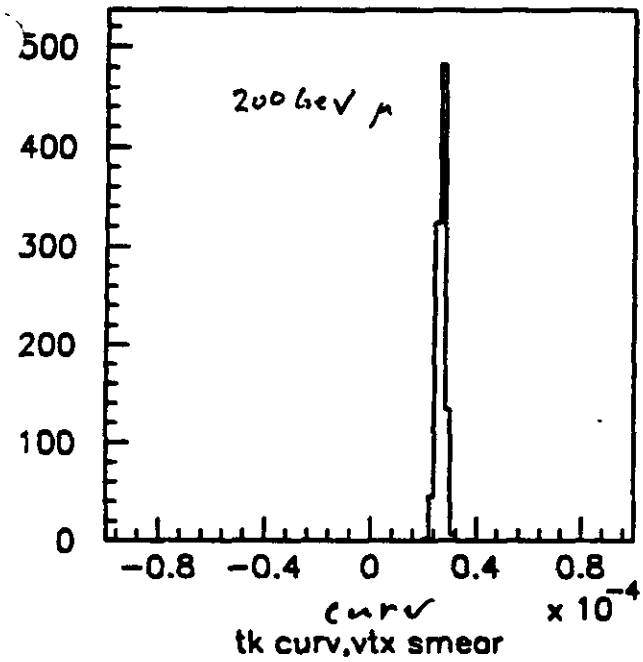
B = 1.8T

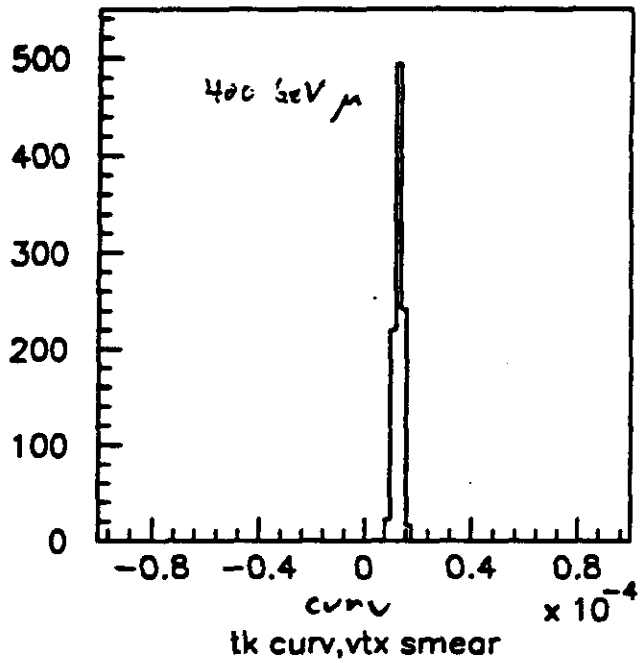


SDC straw + Si


50 GeV μ
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1
−0.8 −0.4 0 0.4 0.8
curv
x 10^-4
tk curv,vtx smear


100 GeV μ
500
400
300
200
100
0
−0.8 −0.4 0 0.4 0.8
curv
x 10^-4
tk curv,vtx smear

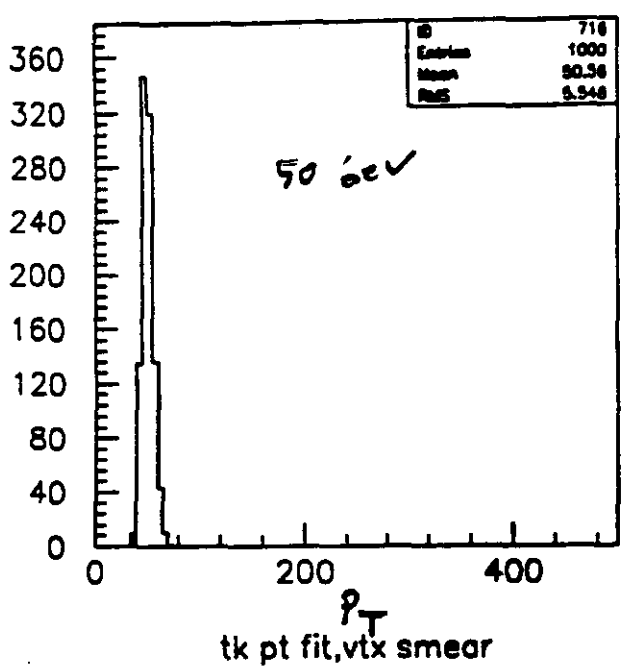

200 GeV μ
500
400
300
200
100
0
−0.8 −0.4 0 0.4 0.8
curv
x 10^-4
tk curv,vtx smear

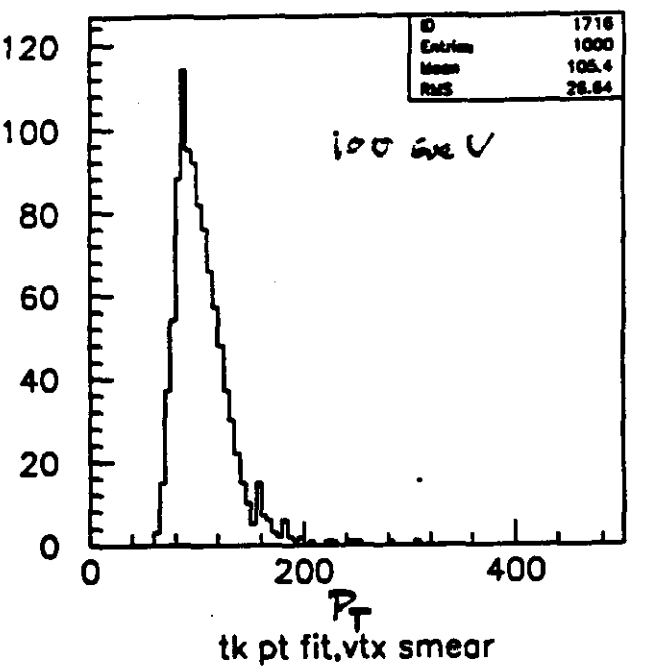

400 GeV μ
500
400
300
200
100
0
−0.8 −0.4 0 0.4 0.8
curv
x 10^-4
tk curv,vtx smear

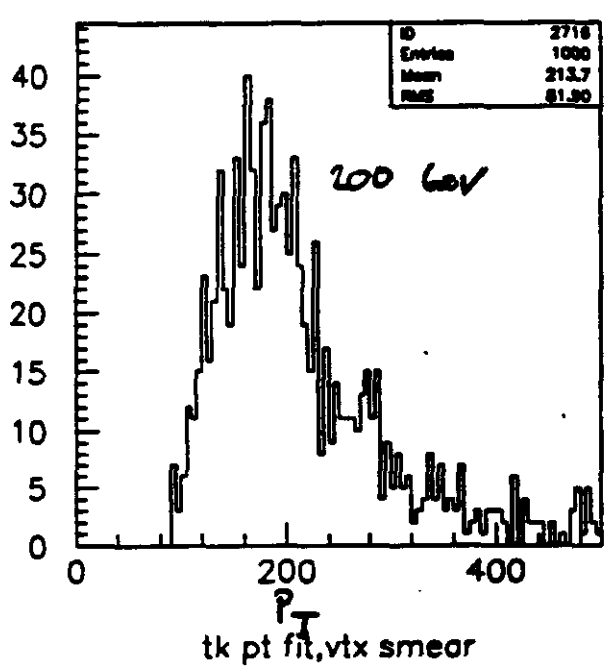
r = 7μm 40μm

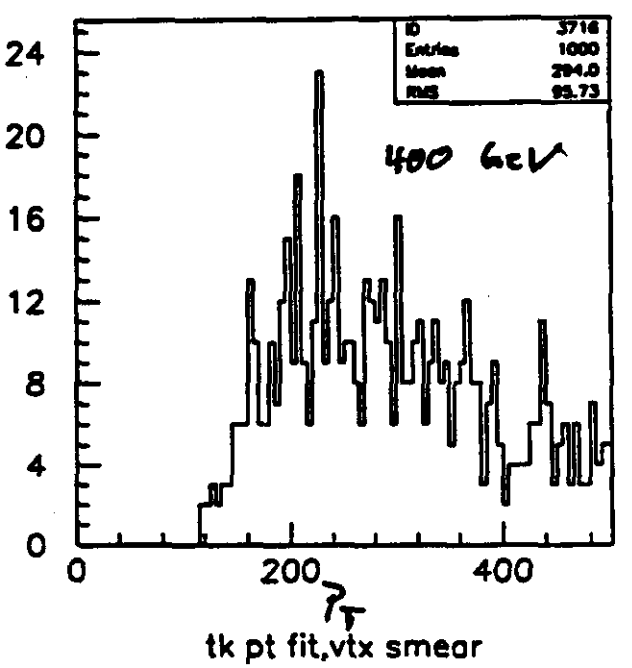
Gem 3 Si + 4 IPC vtx 15μm

12 - 20 - 26 - 38 - 45.5 - 53 - 60.5 cm

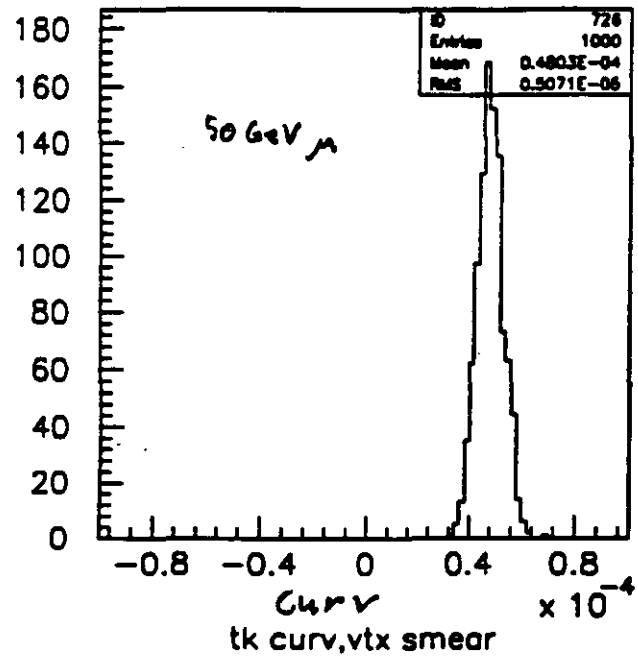


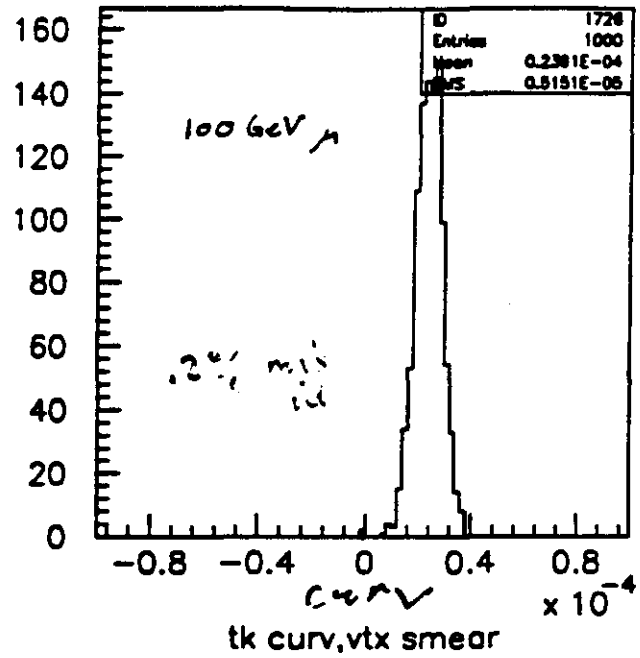


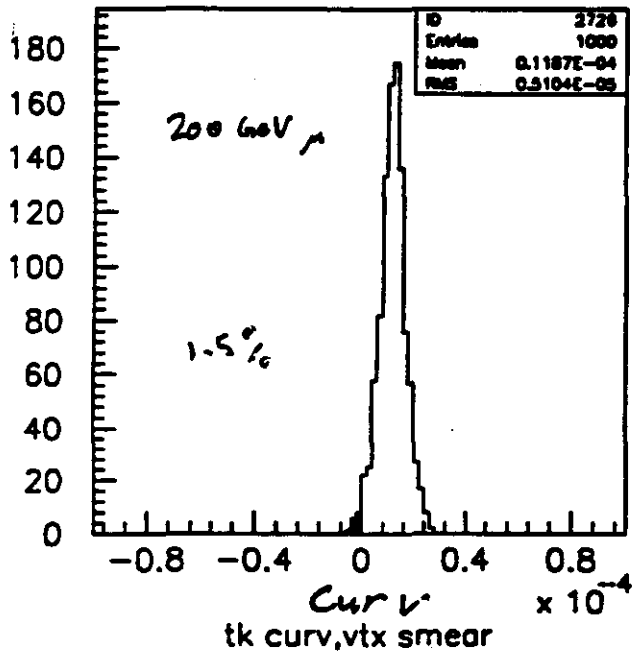


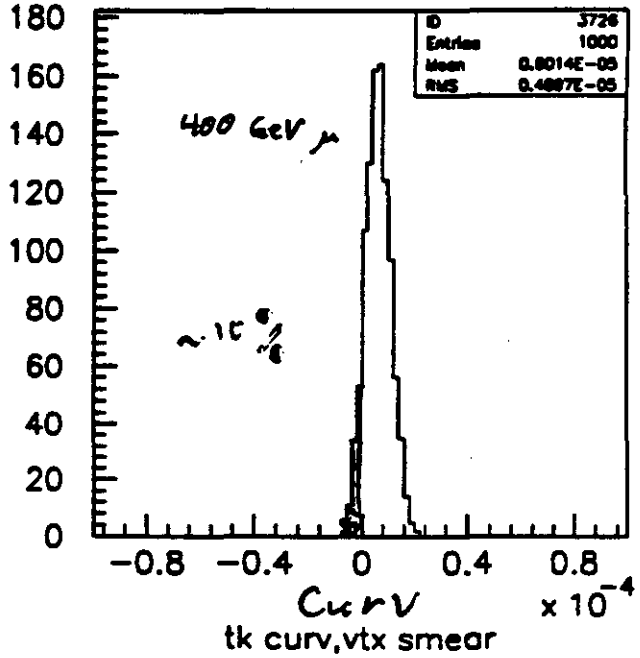


Gem


ID 726
Entries 1000
Mean 0.4803E-04
RMS 0.5071E-05
50 GeV μ
Curv
x 10^-4
tk curv,vtx smear


ID 1726
Entries 1000
Mean 0.2381E-04
RMS 0.5151E-05
100 GeV μ
.2% mis id
Curv
x 10^-4
tk curv,vtx smear


ID 2726
Entries 1000
Mean 0.1187E-04
RMS 0.5104E-05
200 GeV μ
1.5%
Curv
x 10^-4
tk curv,vtx smear

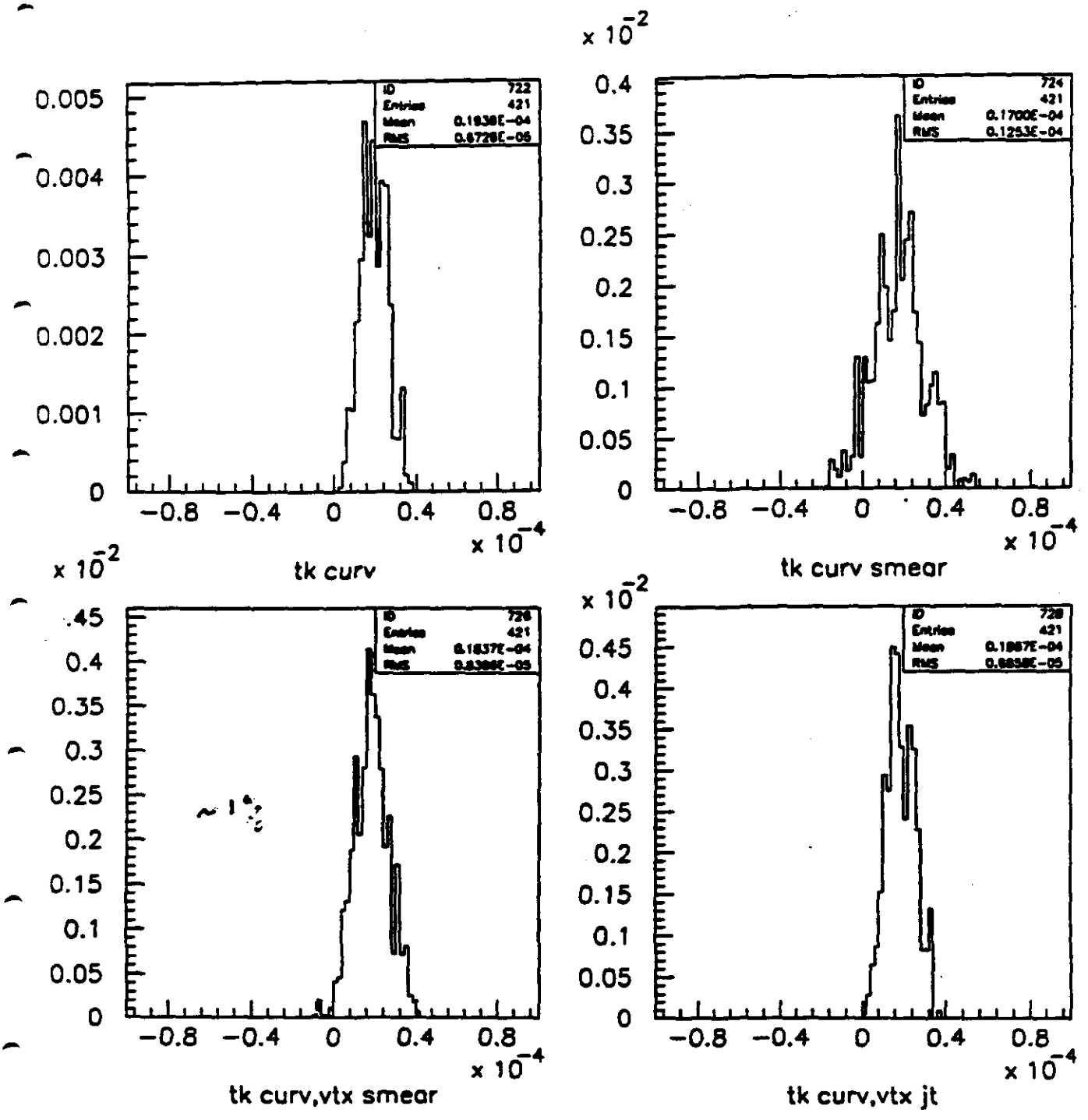

ID 3726
Entries 1000
Mean 0.8014E-05
RMS 0.4987E-05
400 GeV μ
~.1%
Curv
x 10^-4
tk curv,vtx smear

$y^{\ell} < 1.3$ ← central

$P_T^{\ell} > 75$ GeV

$P_T^{\ell\ell}$

$M_{\ell\ell} > 300$ GeV



Conclusions

1. need WW to make higgs search meaningful
   (theoretical efforts to subvert this is in progress) -> but require "new" physics

2. need to get rid of top (wherever it is) to make
   WW search meaningful

   a. need good iso rejection
      or/and
      good forward jet tagging (whatever this is)

   b. need good charge discrimination

3. Not obvious that the GEM can do this physics

Start Counting !

J. THOMAS
MARCH 10. '95

IMPROVED TRACKER OPTION II.

- TO IMPROVE TRACKER FOR WW SCATTERING, INCREASED VOLUME IS BEST
- IF VOLUME NOT AVAILABLE, OUTER DOUBLE LAYER OF SILICON IS AN OPTION

  OUTER RADIUS = 68cm
  ALIGNMENT ERROR = 25μ

→ ANY ADDITIONAL IMPROVEMENT IS FOR SIGN SELECTION NOT MOMENTUM RESOLUTION

(e/π SEPARATION CAN BE HELPED, BUT THERE ARE OTHER HANDLES)

→ SIGN SELECTION EFFICIENCY IS NOT THE SAME QUANTATATIVELY AS P RESOLUTION

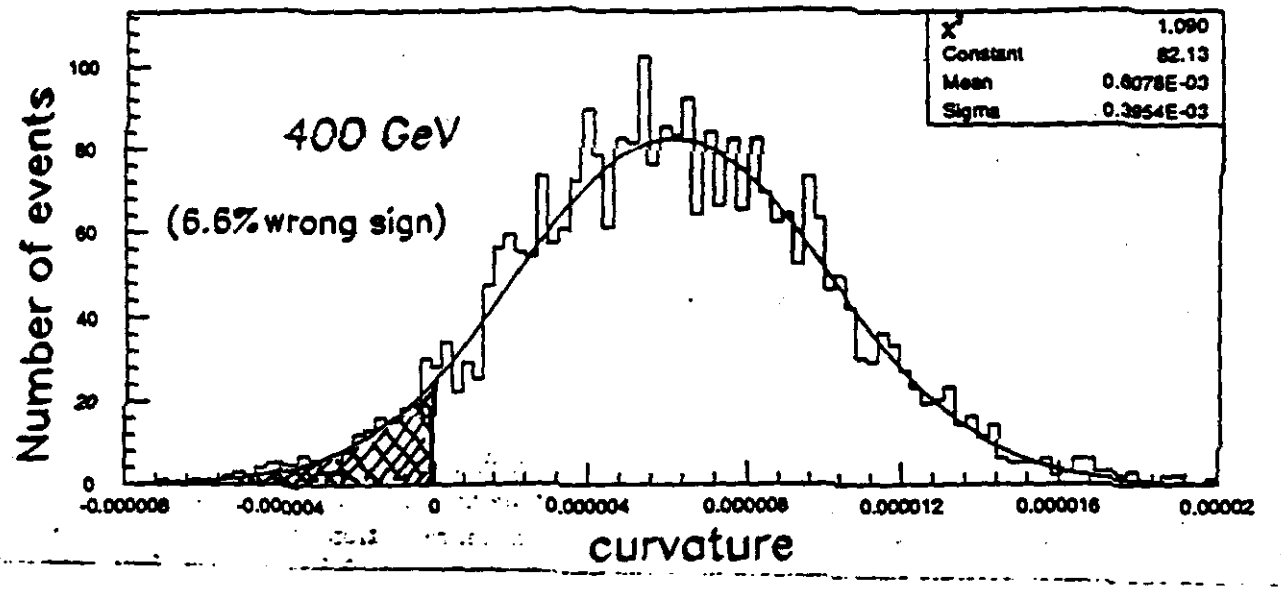
- USING SIMULATED SPECTRUM OF $t\bar{t}$ BACKGROUND ESTIMATE $\sim$ 1% EVENTS WITH WRONG SIGN (MOST TRACKS HAVE $P < 400$ GeV)

- REDUCE THIS TO 0·3% BY FACTOR 3 SIGN SELECTION WITH OUTER SILICON.

- PATTERN RECOGNITION HAS NOT BEEN USED : ALSO NOT FOR 1M VOLUME.

- MORE DETAILED SIMULATIONS ARE UNDERWAY BUT MUST BE FINISHED FOR WW SIGNAL & BACKGROUNDS

- MORE THEORETICAL ACTIVITY IS NEEDED – RADIATIVE CORR. OTHER CHANNELS.



- $\frac{\delta p_T}{p_T} \propto \frac{1}{C}$ C = CURVATURE.
- CURRENT TRACKER GIVES ~ 5% WRONG SIGN @ 400 GeV.
- OUTER DOUBLE LAYER OF SILICON GIVES ~ 1.4% WRONG SIGN

→ ALTHOUGH MOMENTUM RESOLUTION ONLY IMPROVES BY ~20%, SIGN SELECTION IMPROVES BY FACTOR 3.

- 1M RADIUS GIVES ~ 0.3% WRONG SIGN

→ FACTOR 13 IMPROVEMENT!

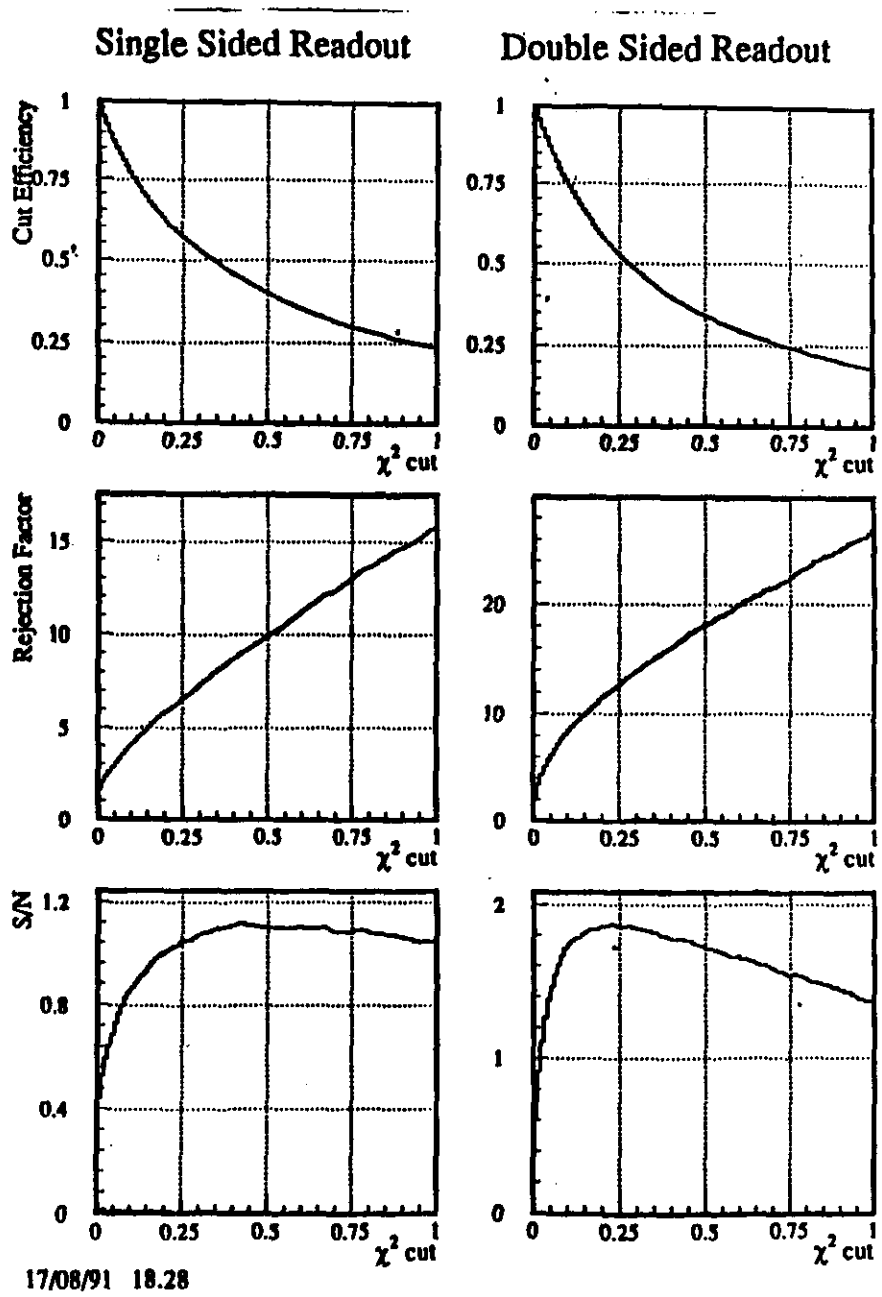
SUMMARY

- WW SCATTERING CAN STILL BE DONE WITH SILICON OUTER DOUBLE LAYER

- CLEARLY MORE DETAILED SIMULATION OF BACKGROUND, PATTERN RECOGNITION IS NEEDED : ALSO, MORE THEORETICAL WORK WILL BE DONE LIKE RADIATIVE CORRECTIONS, OTHER CHANNELS ETC.

- LARGER VOLUME WOULD BE THE BEST OPTION BUT AT WHAT TOTAL COST ? LiAr ONLY

- SILICON OPTION HAS THE ADVANTAGE THAT NO OTHER SUB-DETECTOR IS AFFECTED



b-jet Tagging Study

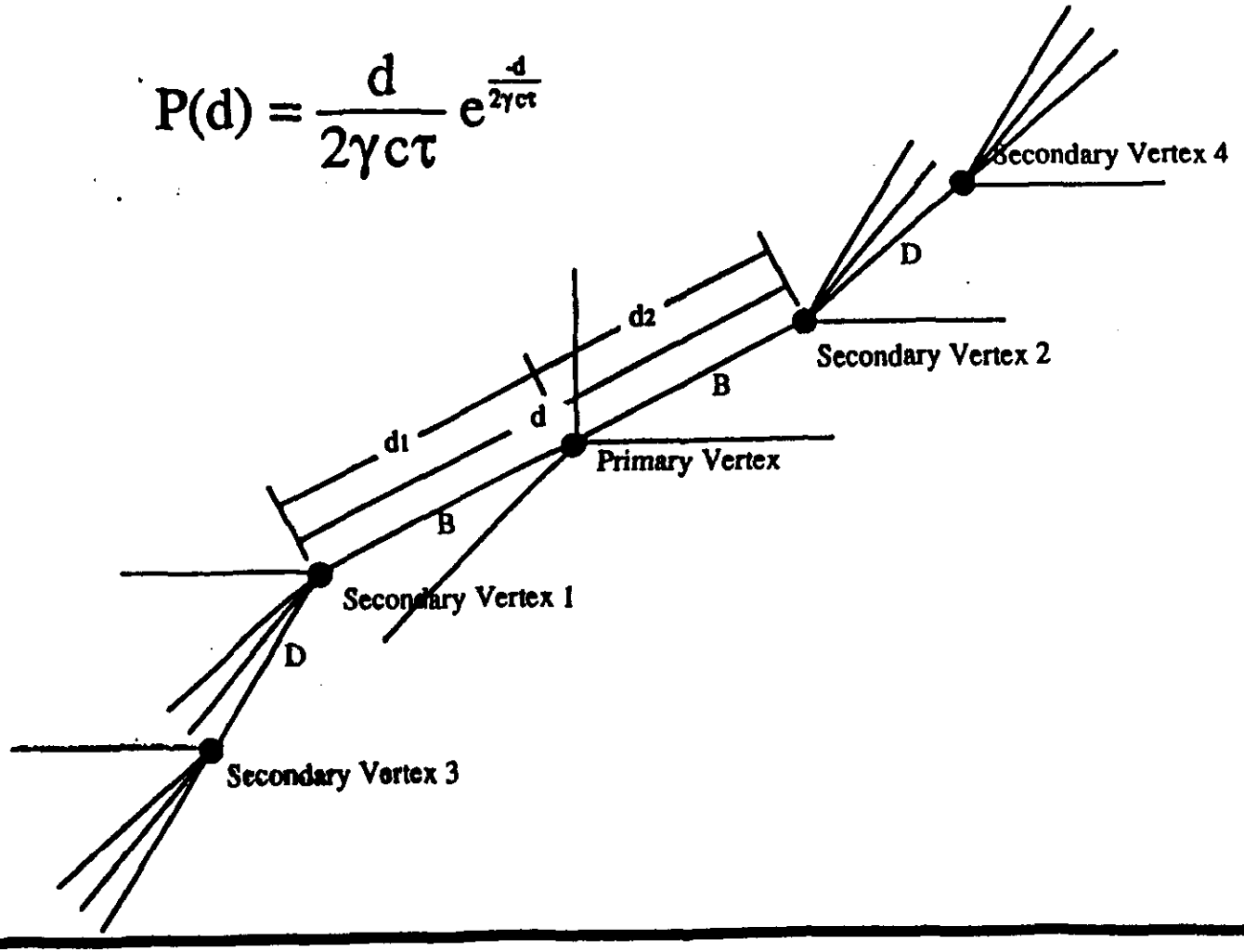
$$\chi^2 = \sum_{\substack{\text{all tracks} \\ P>2.5\text{GeV}}} \left\{ \frac{d_t^2}{\sigma_t^2} + \frac{d_z^2}{\sigma_z^2} \right\}$$

Backgound: $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$

b-jet Vertex Tagging

- In general there are 5 vertices:

$$P(d) = \frac{d}{2\gamma c\tau} e^{\frac{-d}{2\gamma c\tau}}$$



MAGNET ISSUES FOR TRACKING

RESOLUTION $\sim BL^2$

MAGNET FORCES & PROBLEMS $\sim B^2$

RAISING FIELD FROM 0.8T → 1.0T

SCALING FACTOR = 1.5625

STORED ENERGY	$2.5 \cdot 10^9 \rightarrow 3.9 \cdot 10^9$
AXIAL FORCE	52.15 MN → 81.48 MN
CONDUCTOR COST	\$ 9.13 M → \$ 14.3 M
BOBBIN COST	\$ 9.0 M → \$ 14.0 M
COLD MASS SUPPORT	\$ 1.9 M → \$ 3.0 M

COST INCREASE \$ 11.3 M + COST OF SUPPORT STRUCTURES + COST OF SHIELDING + ...

OTHER PROBLEMS:

FIELD AT SURFACE → 60 gauss

RADIAL FIELD IN MUON SYSTEM

FIELD IN ELECTRONICS ROOM

OVERRIDING PRINCIPLE OF MAGNET DESIGN – SIMPLICITY

HIGHER FIELD – HIGHER PEAK FIELD IN THE CONDUCTOR

→ PROBLEMS WITH ENDS OF THE COIL

→ PROBLEMS WITH HOOP FORCES

Muon System Considerations

- Give up 25cm on inner calorim. radius - keep 12λ
  - πK decay increase ~25%
- Give up 25cm on inner calorimeter radius → 19λ
  - πK decay → 25%
  - Punchthrough increase
- Give up 25cm. on outer calorim radius / keep 12λ
  - Decrease muon $\frac{dp}{p}$ by 10% (4.3 → 4.8% @ $\eta=0$).
  - Increase chamber costs (barrel)
- Give up 25cm. on outer calorimeter 12λ → 10λ
  - Decrease muon $\frac{dp}{p}$ by 10%
  - Increase punchthrough
  - Increase chamber costs (barrel)

Yu. Kamyshkov
March, 10, 92

Base line Pb/LAr(em) + U/LAr(had)

$R_{in} = 75$ cm $R_{out} = 350$ cm

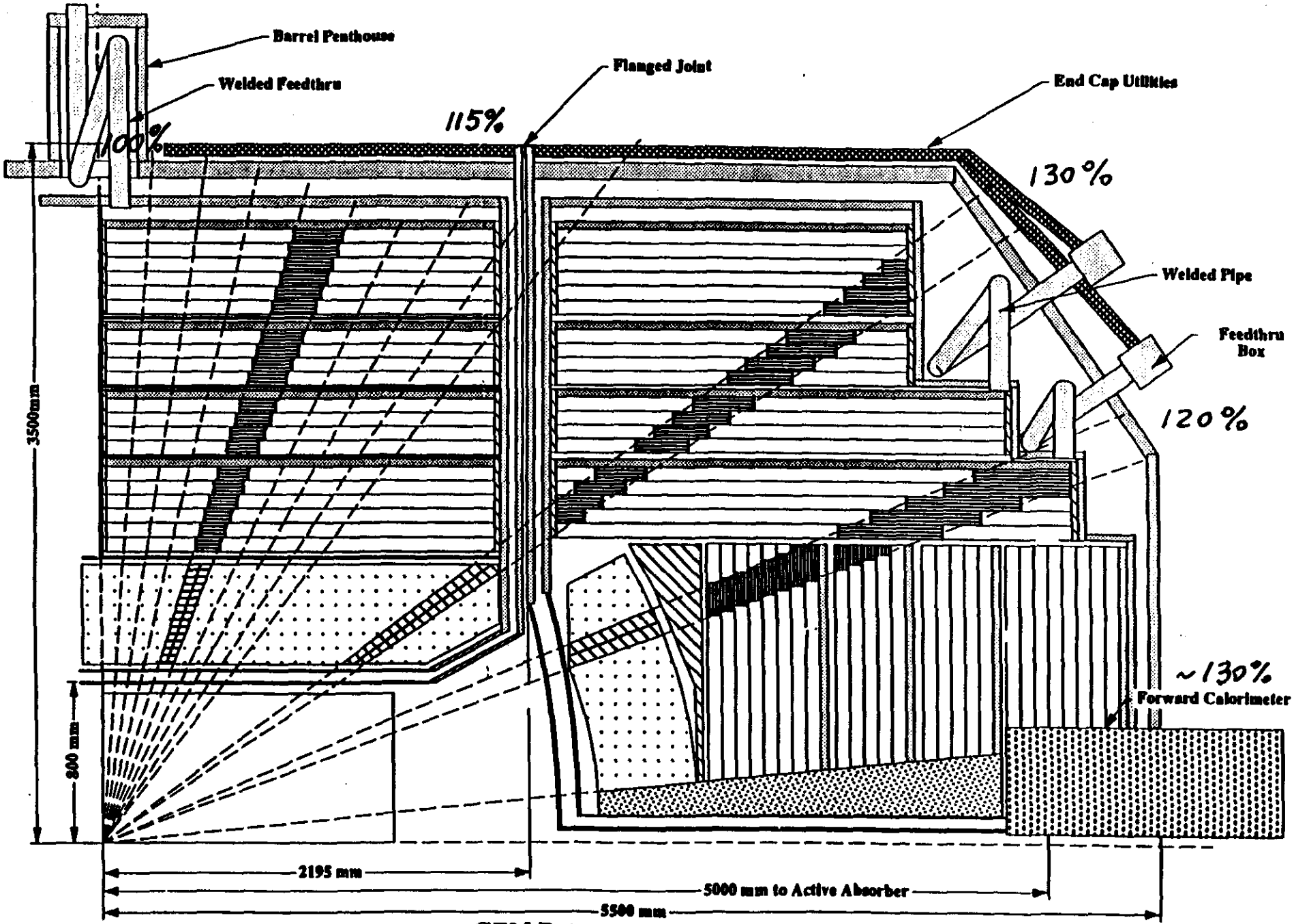
$L_{abs} = 11.3\,\lambda_0$

$1\,\bar{\lambda}_{eff} \sim 16.3$ cm (defined by e-noise)

Increase $R_{in} = 75$ cm $\rightarrow$ $R_{in} = 100$ cm

most likely is ruling out the BaF2

option of e-m calorimeter



GEM Detector
Liquid Argon Calorimeter
Barrel Module Layout

G.03.LA.052

Rausch

Compact hadronic calorimeter

Absorber/detector	Pb/Sci	U/LAr	Cu/Sci	W/Sci
Absorb. length (pure absorber)	17.1 cm	10.9 cm	15.1 cm	10.2 cm
Equivalent plate structure absorber + detector + gap [mm]	20+5+1	6+2+0	30+3+1	15+3+1
Expected hadronic resolution ($1/\sqrt{E}$)	60%	55%	80%	75%
Effective absorbtion length [cm]	21.1	16.3	16.8	12.6

Radial extention (various options)

$$L_{90^\circ}^{abs} = 11.7\ \lambda_o$$

E-M	hadron	cm
Pb/LAr	+ U/LAr (11.3 λ_o)	75 - 350
BaF2	+ Cu/Sci. fibers	75 - 330
	+ Cu/Sci. tiles	75 - 330
	+ W/Sci. fibers	75 - 310
	+ W/Sci. tiles	75 - 290
Pb/LKr	+ Cu/Sci. fibers	75 - 345
	+ Cu/Sci. tiles	75 - 345
	+ W/Sci. fibers	75 - 325
	+ W/Sci. tiles	75 - 305

Modeling the Detector

K.McFarlane, N.DiGiacomo, M.Shupe

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

Modelling the Detector

Tuesday Mar. 10th 1992

8:30–9:15 Engineering to simulation

9:15–10 Detector data base

10–10:20 BREAK

10:30–11 ~~Detector~~ Visualization – T. Swarnicki

11:00–11:30 Modelling radiation environment – L. Waters (see Forward Calorimeter section)

11:30–12:00 Simulation Integration
? TDR working group

Simulation and Physics

3 p.m. Fast Parameterizations

Physics Processes for PAC

" " for TDR

Modelling the detector Tucson 3/10/92

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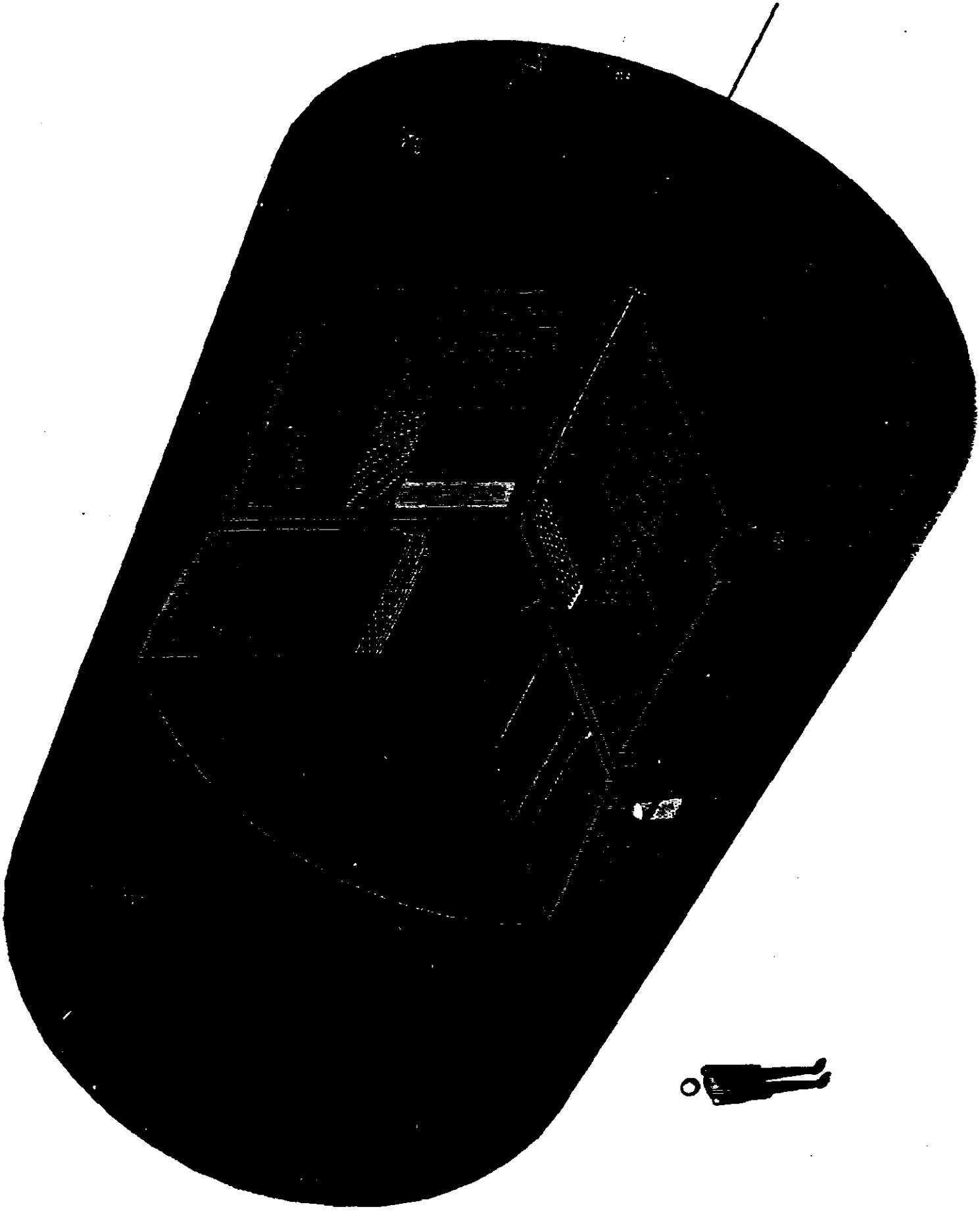
Chen Zemin	Tsinghua U.	Chen@TUVL (before 3/27/92)

Integrated 3D Modeling, and Engineering Physics Simulation Tool

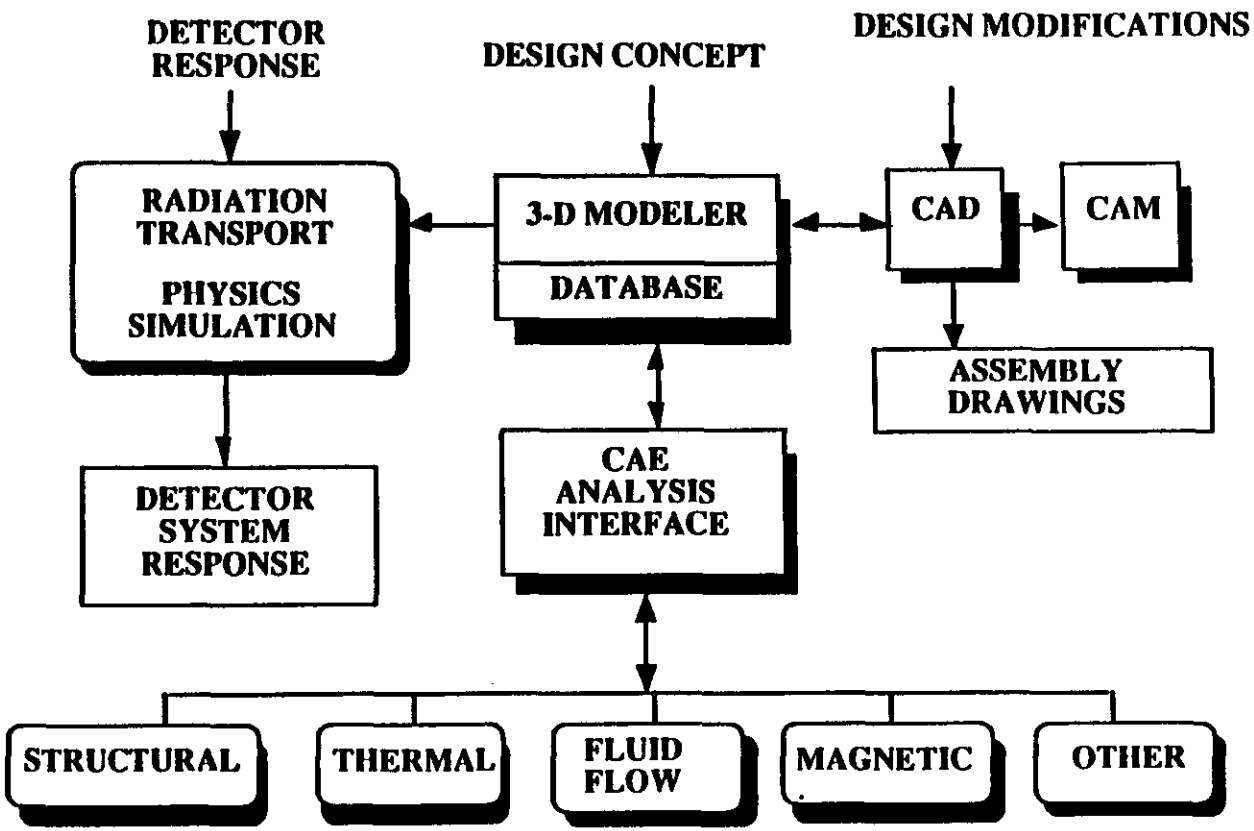
Kendrick Killian

March 1992

MARTIN MARIETTA



CAD/CAE Data Analysis Flow



MARTIN MARIETTA

Present Uses

- Characterize the Detector Geometry

  Total Depth and Active Depth

  Entrance Window Depth

  Location and Thickness of Structure

  Muon System Acceptance

  Geometry for Muon Multiple Scattering
  and Magnetic Bending Estimates

  Single Particle Energy Loss Estimates

- Provide Estimates of the Calorimeter Performance Parameters

  Shower Energy Resolution and Energy Leakage

  Energy lost in Calorimeter Structure

  Electromagnetic dE/dX Estimates

-Includes Code Written by at Least 7 Authors From 6 Institutions or Companies

Geometry Modules

- Based around SDRC's I-DEAS Solid Modeler
  - Geometry Read from the SDRC ASCII geometry file called a "Universal" File
  - Ray Tracing NOT dependent on the modeler licence

- Geometry module are a set of FORTRAN subroutines
  - Geometry Routines Callable from Different Drivers, including Monte-Carlo Programs
  - Geometry Search Routines Optimized to take Advantage of System Hierarchy
  - Able to Simultaneously Track Through Two Independent Geometries

- Existing Geometry Analysis
  - Program Traces Non-Interacting Rays in a "Particle Gun" Type Format
  - "Single Point of Origin" Ray Tracing Through the 3D Models
  - Scans Rays in Theta, Phi, or Pseudorapidity Coordinates
  - Code Ported to Multiple Environments (VAX, SGI UNIX, Macintosh)
  - Reports Ray Intersections and Materials
  - Sorts Intersections on Keywords, Material Types, Relative Positions
  - Fits provide Radiation Lengths and Interaction Lengths

Physics Approximations

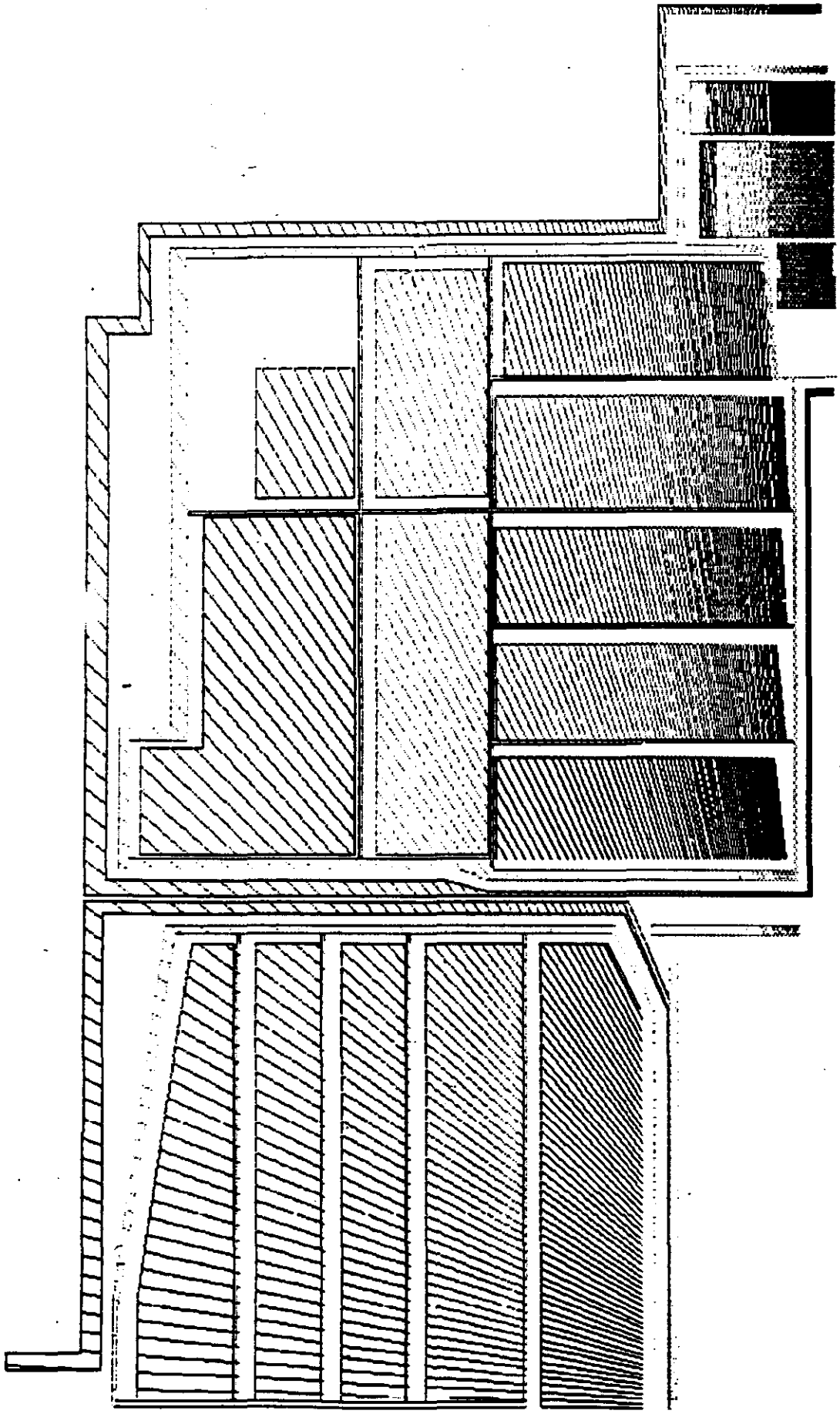
- Material Properties
  - Directly Input
  - Complex Materials are Generated by Combining Elemental Cross Sections

- Provides Interaction Length, Radiation Length, dE/dX as a function of energy, and Atomic Densities

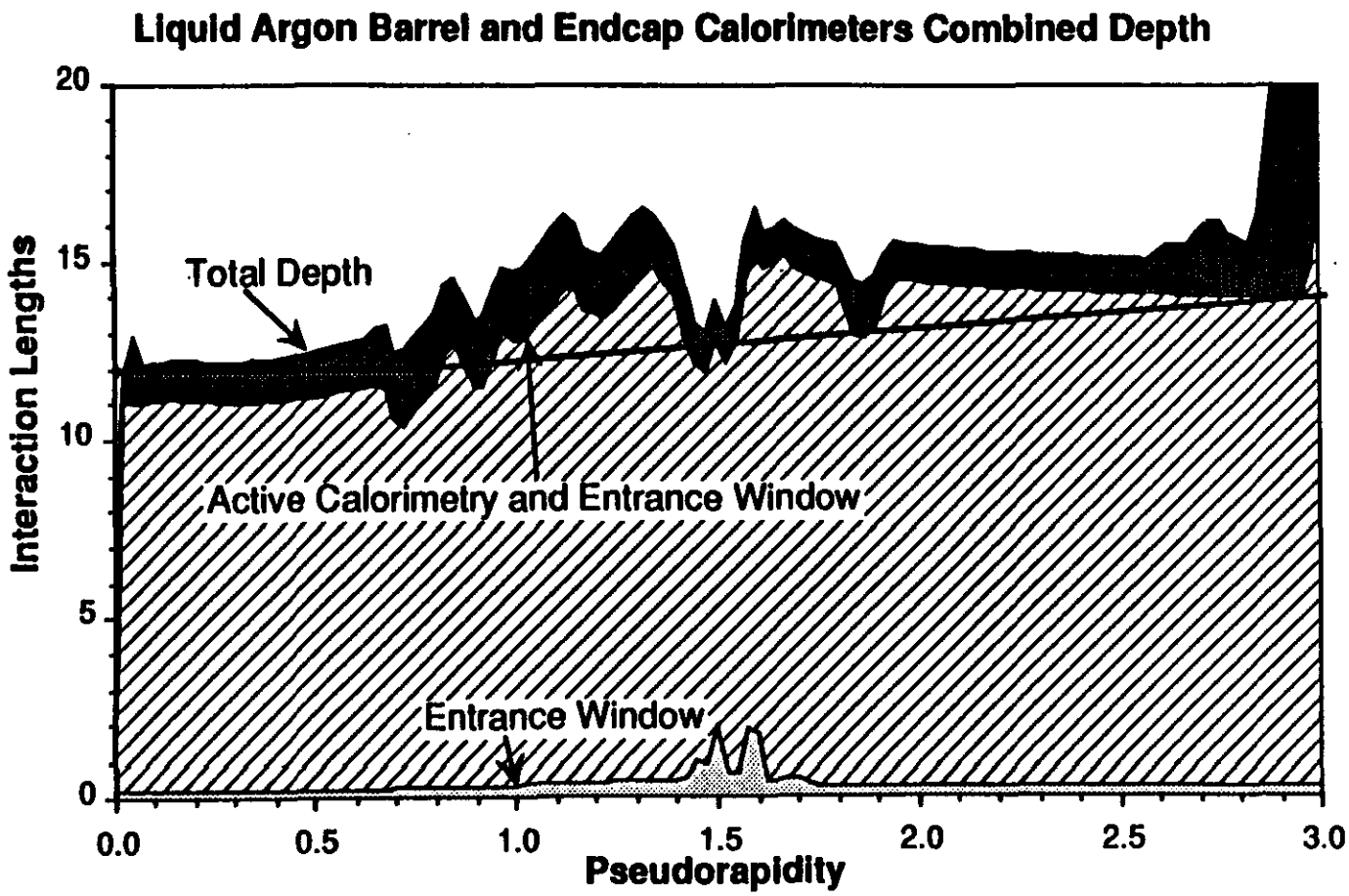
- Interaction Length, and Radiation Lengths Calculated from Fits to Nuclear Interaction Cross Sections and Radiation Length Data

- dE/dX calculated using Beth-Bloch equation and elemental ionization fits
  - elemental ionizations data estimated by fitting J. Janni stopping power tables

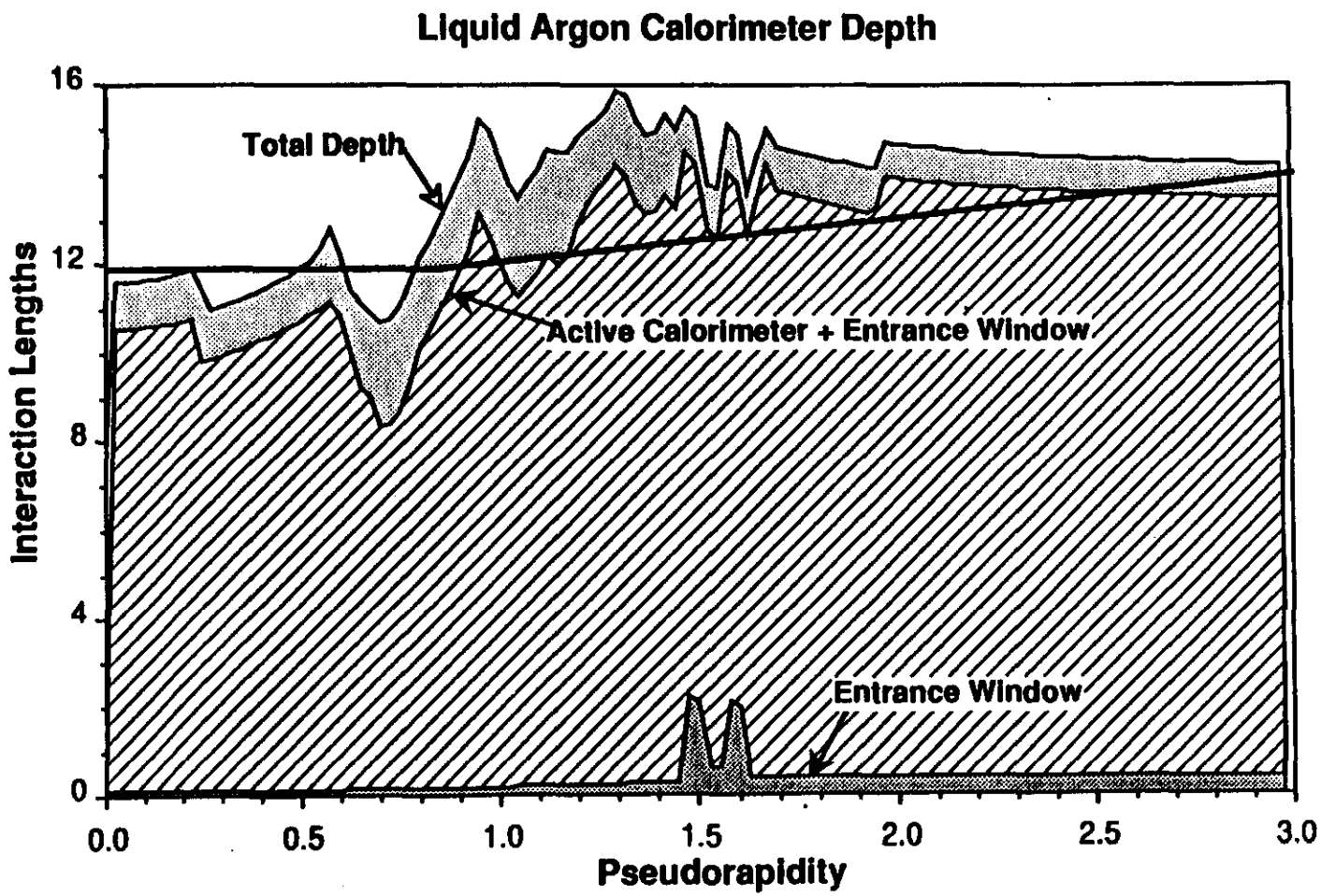
- Calorimeter Simulation
  - Approximate Shower Energy Deposition along a Ray (No Transverse Shower Development)
  - Estimate Energy Lost in Dead Material
  - Estimate Energy Leakage from the Calorimeter
  - Estimate Calorimeter Resolution including dead material and leakage



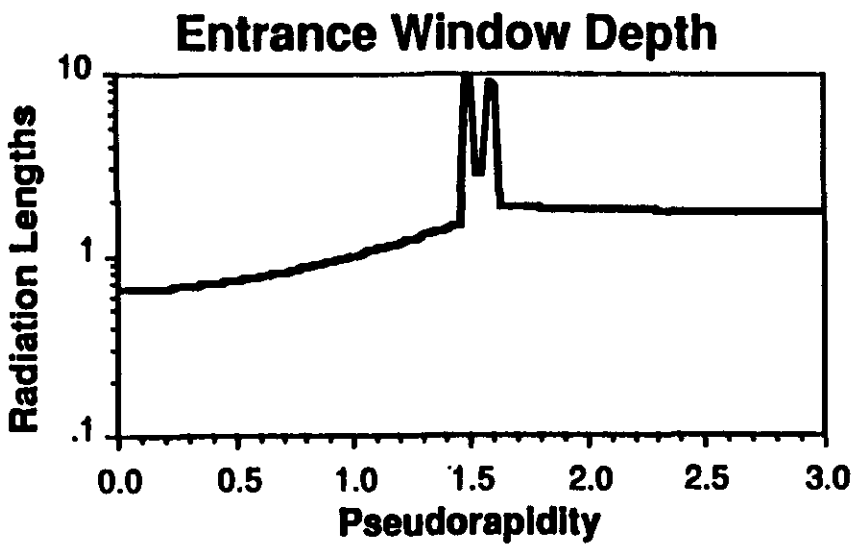
GEM Geometry Analysis (continued)



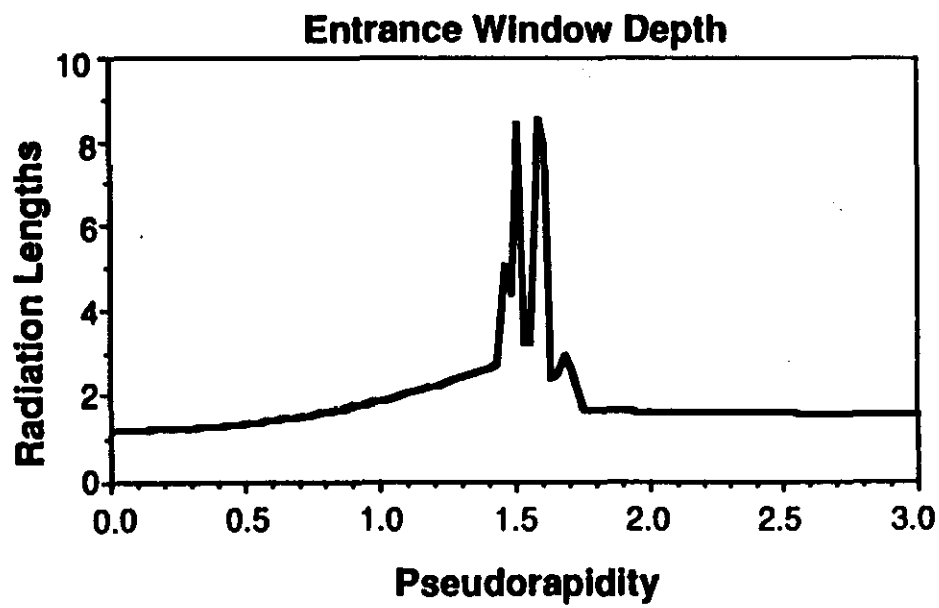
GEM Geometry Analysis

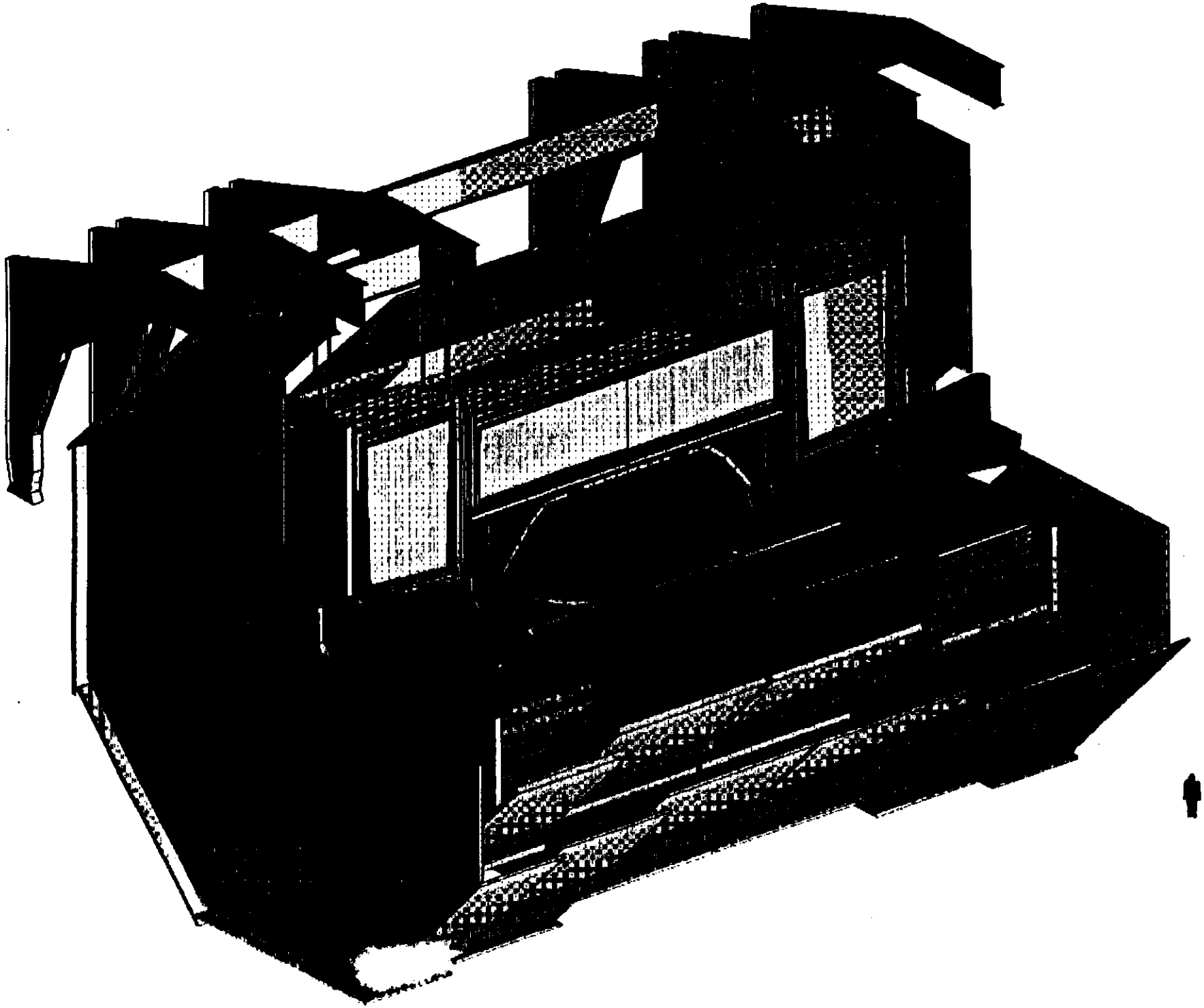


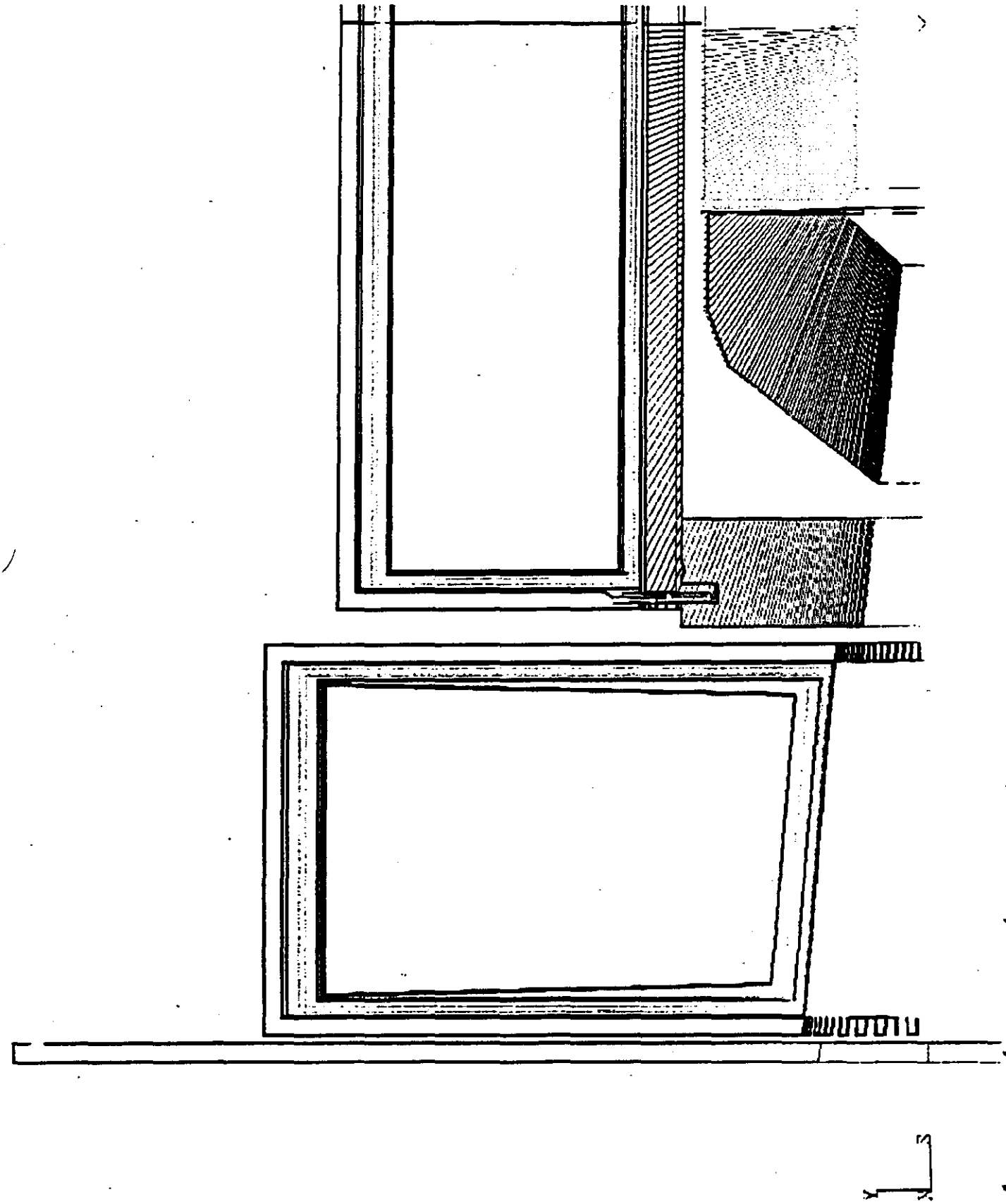
GEM Geometry Analysis (continued)



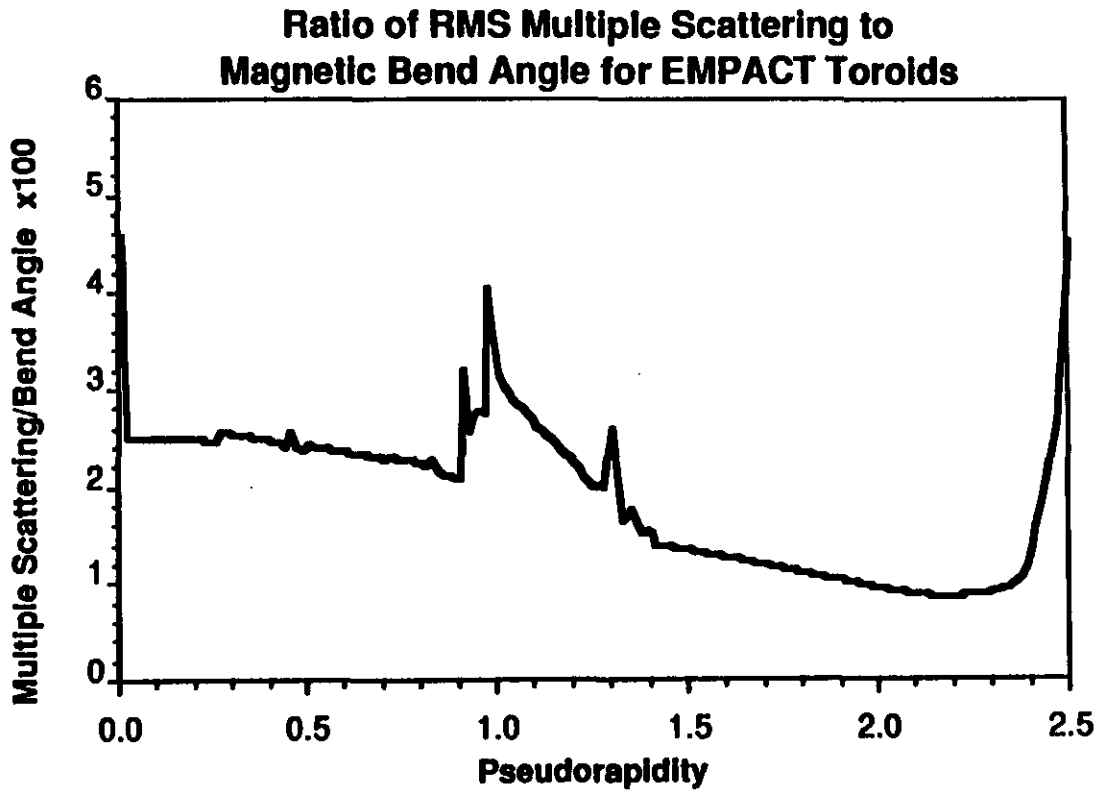
Searched for passive material before active







Geometry Calculations Done for Muon Bending on EMPACT



- Fine Sampling $\Delta\eta = .0125$ Highlights Corner Details

- Engineering Model Transferred to MMAG and used for Ray Tracing
- Ray Intersections Provided Locations of Toroid Superconducting Wires
- Geometry Information Imported to Spread Sheet Program for Evaluation of the Magnetic Field Integrals

Resolution Calculations

- Basic EM and Hadronic module Resolutions are Input as Equations

- Bock Hadronic Shower Parameterization

$$E\left\{w\int_0^x \frac{b^a}{\Gamma(a)} s^{a-1} e^{-bs} ds + (1-w)\int_0^x \frac{\beta^\alpha}{\Gamma(\alpha)} t^{\alpha-1} e^{-\beta t} dt\right\} = E\left\{w\frac{\gamma(a,bx)}{\Gamma(a)} + (1-w)\frac{\gamma(\alpha,\beta x)}{\Gamma(\alpha)}\right\}$$

- Womersley Resolution Ansatz

"Energy in a small shower slice fluctuates with an RMS error ≈ its mean thus if X% of a shower is lost there is an extra X% fluctuation"

$$\sigma^2 = \frac{s^2}{E} + B^2 + \frac{\sum(\Delta E_{layer})^2}{E^2}$$

Where ΔE_{layer} is the energy deposited in the dead material

Resolution Calculations (continued)

- **Longo model used for the Electromagnetic Shower development with the Furuno-Brau Model Used for the Resolution Calculation**

The Longo EM parameterization $\int_0^x \frac{b^a}{\Gamma(a)} y^{a-1} e^{-by} = \frac{\gamma(a,bx)}{\Gamma(a)}$

The Longo parameters were determined by fitting EGS simulations of a tungsten/silicon calorimeter.

The extra term in the resolution is the uncertainty in calculating the lost energy from the derived parameters.

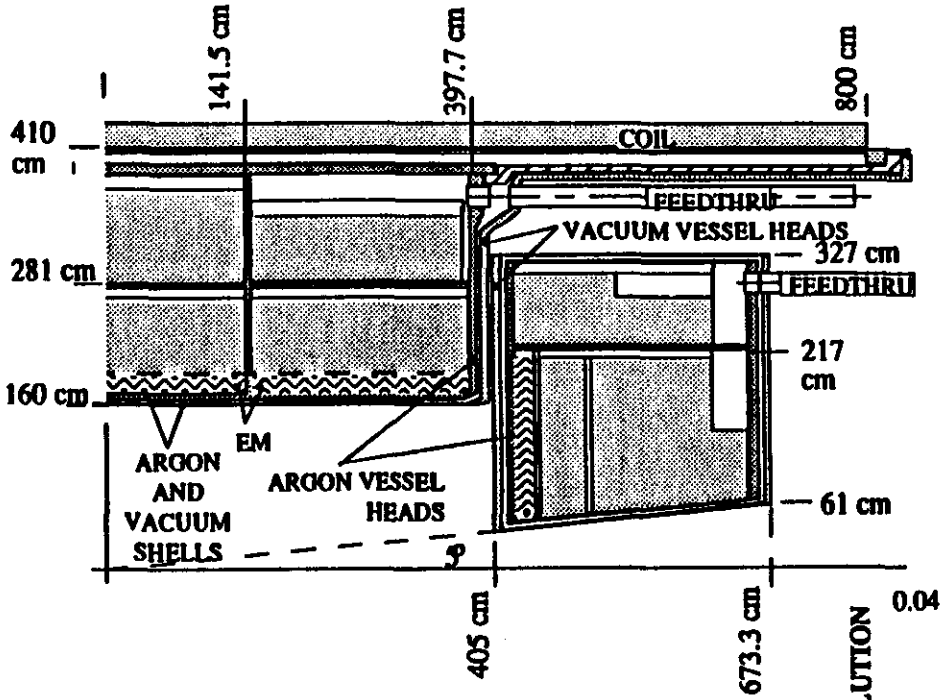
$$\sigma^2 = \frac{s^2}{\left(E - \sum_j \Delta E_j\right)} + B^2 + \frac{\sum_{l=1}^{2}\sum_{m=1}^{2} D_l \langle \sigma_{C_l} \sigma_{C_m} \rangle D_m}{\left(E - \sum_j \Delta E_j\right)^2}$$

Where

$$D_1 = \sum_j \left[\frac{\partial(\Delta E_j)}{\partial C_1}\right], \quad D_2 = \sum_j \left[\frac{\partial(\Delta E_j)}{\partial C_2}\right],$$

$\langle \sigma_{C_l} \sigma_{C_m} \rangle$ is the expected value of the uncertainties for the Longo parameters including standard deviations and the covariance factors

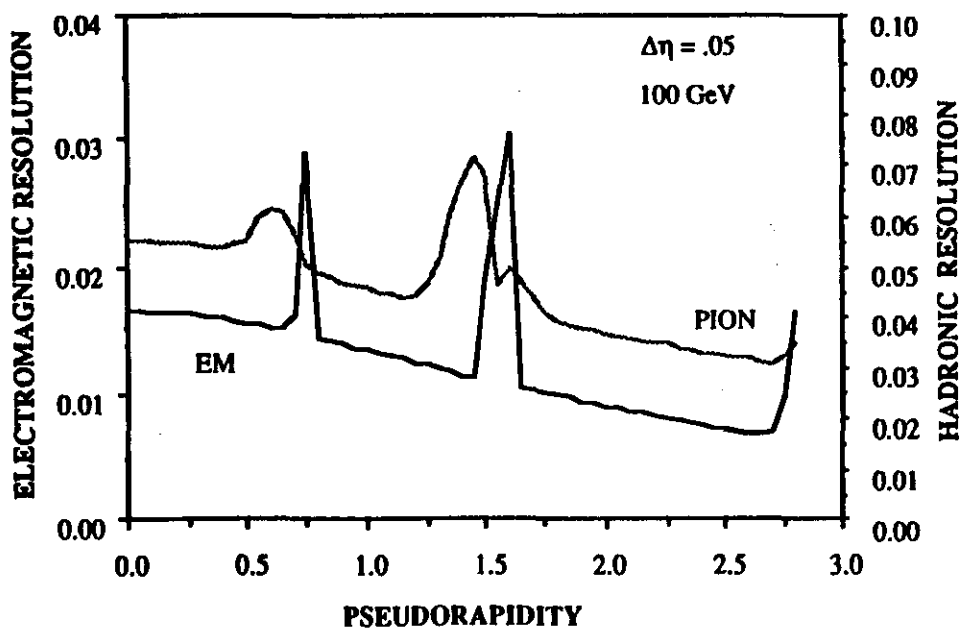
Calorimeter Optimization



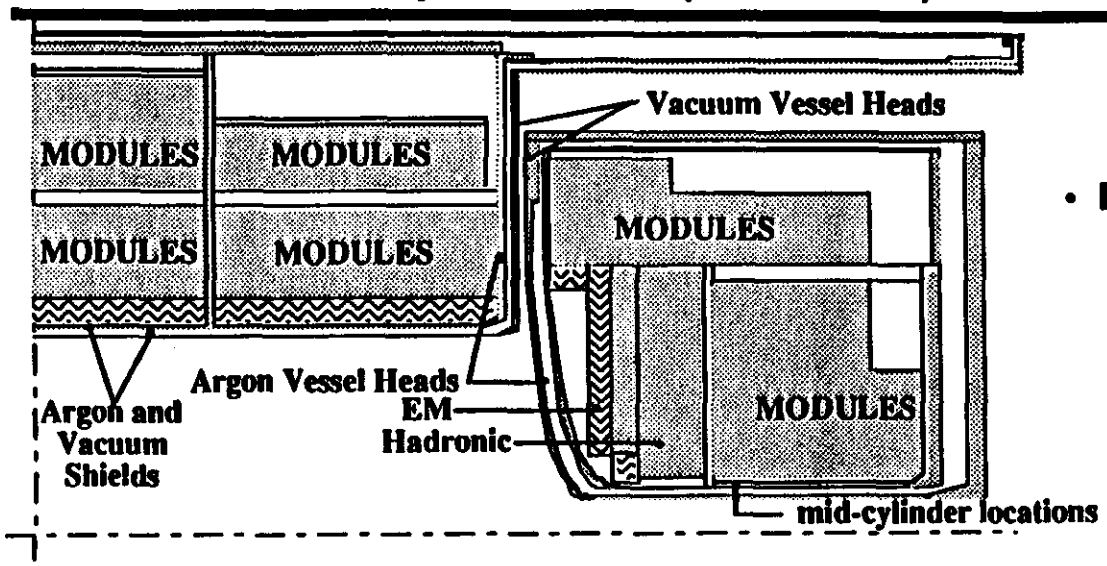
Baseline Configuration

Headwall
Total Rad Length = 2.15
(Argon and Vessel)

Shells
Total Rad Length = 1.13



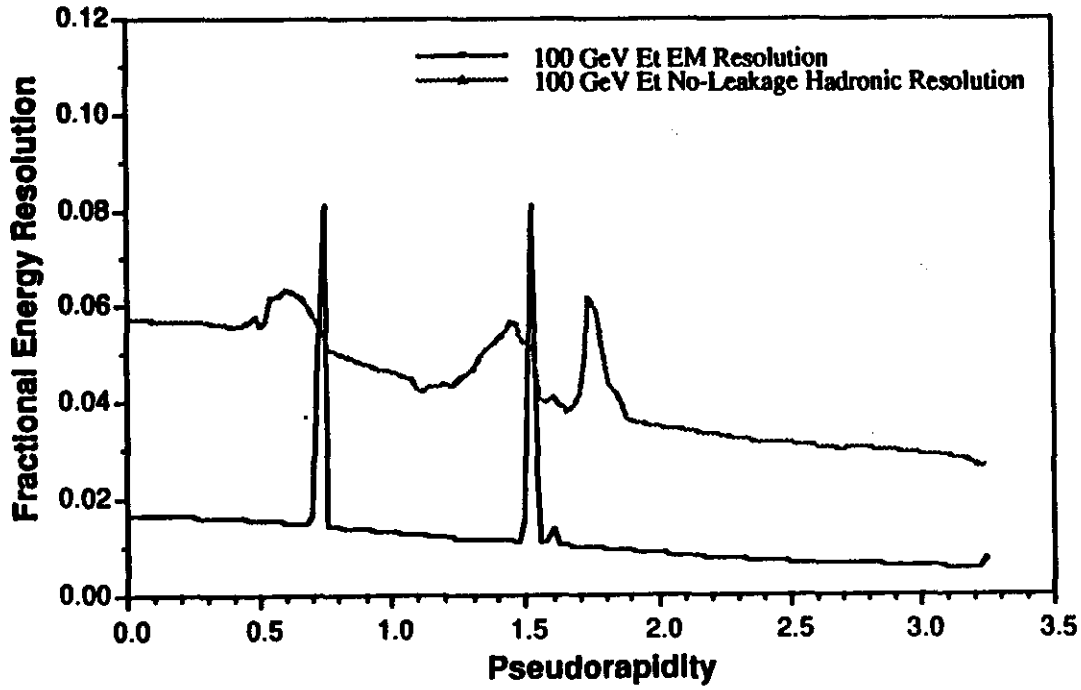
Calorimeter Optimization (continued)



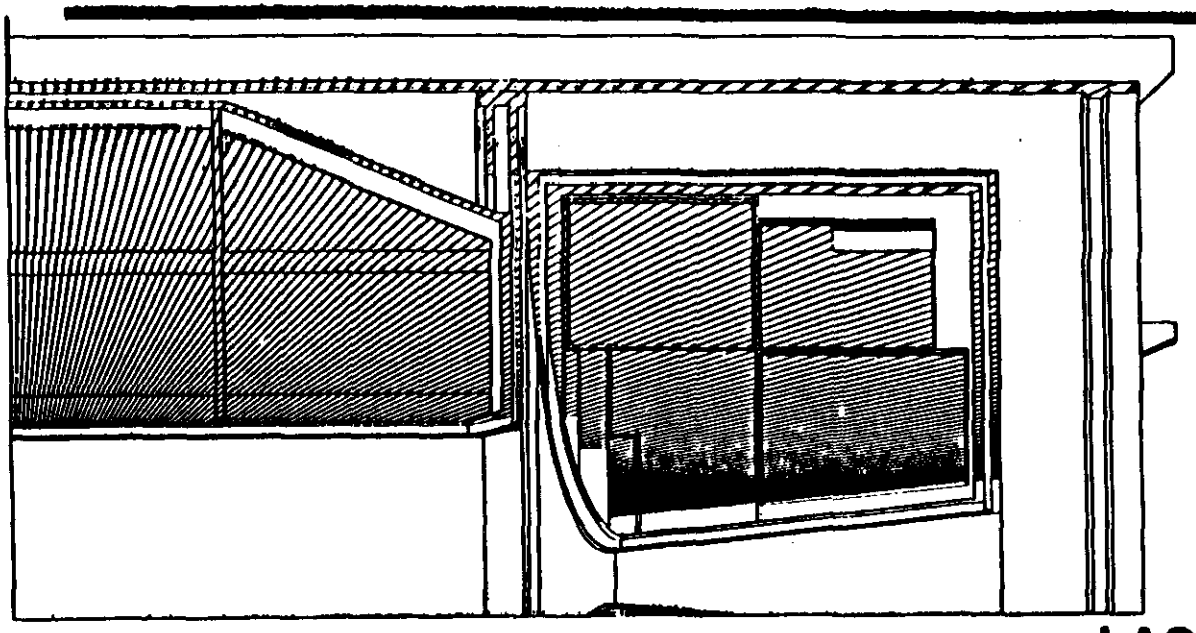
- Elliptical Concave Head Shape

Results:
Headwall Thickness: -43%
Mid Shell Thickness: -36%

- Best Configuration Studied



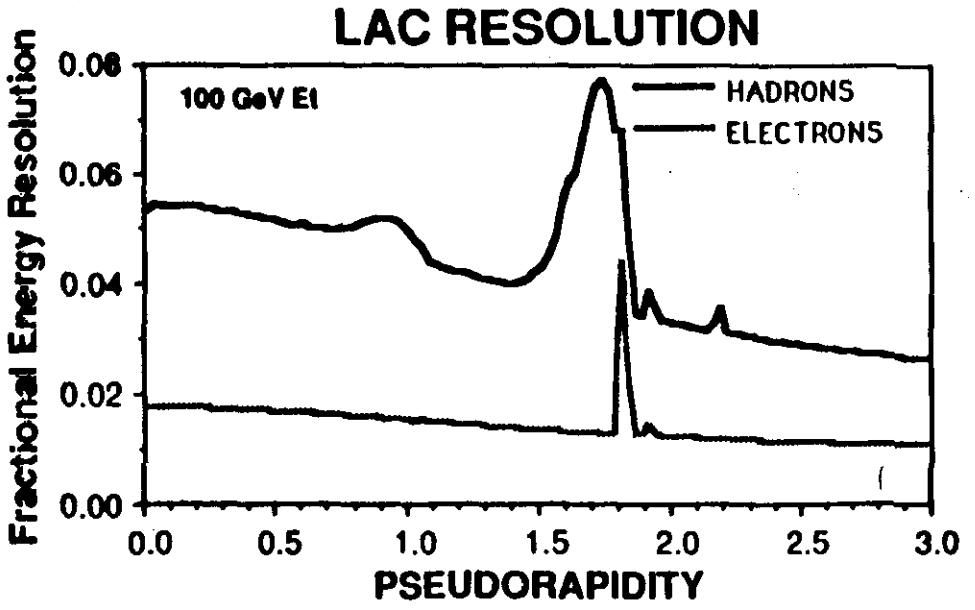
Calorimeter Analysis

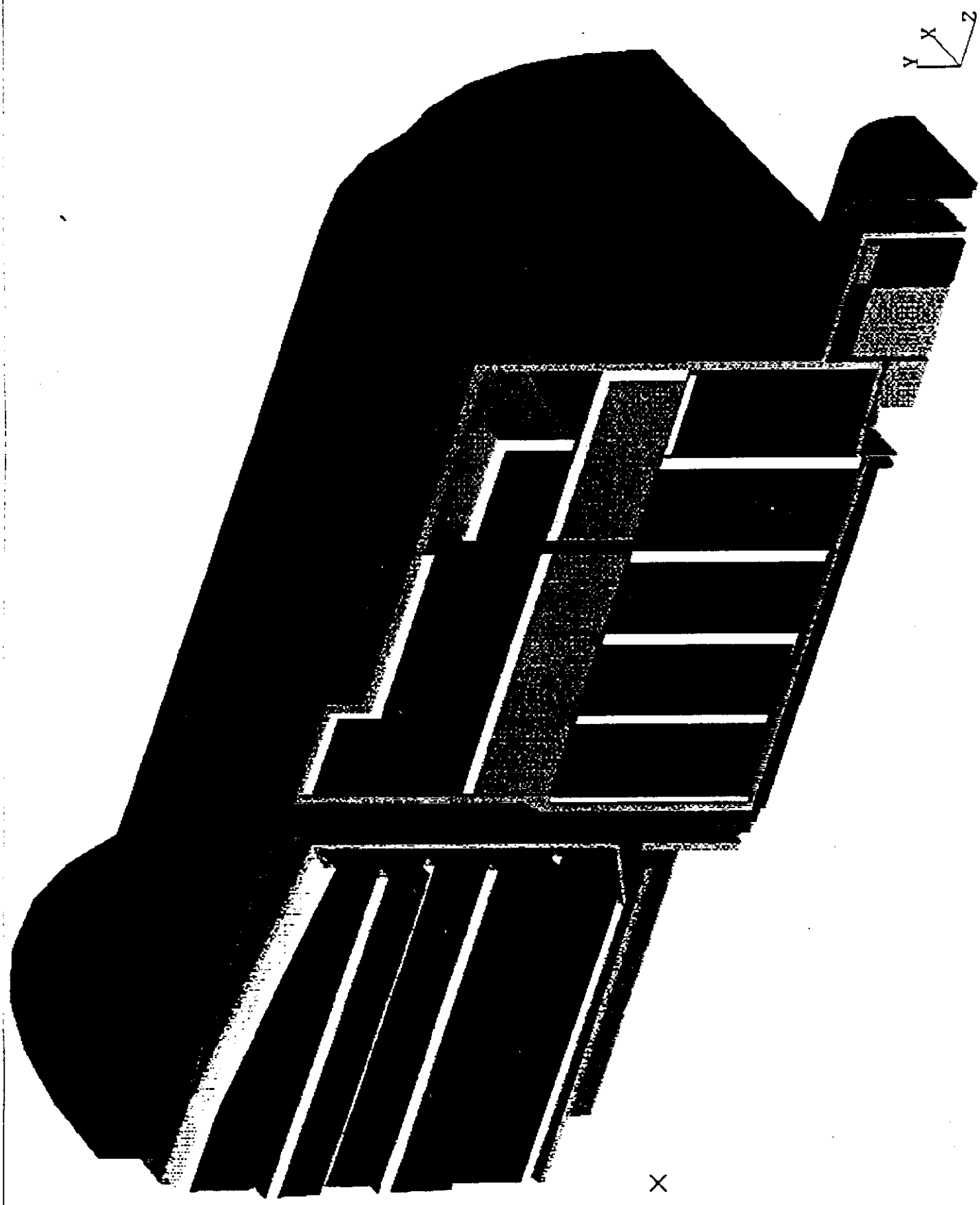


Ray Tracing and Resolution
NO External Processing

Sampling Similar to
EM Segmentation $\Delta\eta = .02$

Plotting Done on Macintosh




Y
X
Z

Conclusion

- Integrated a Flexible Detector Response Analysis Tool into the Design Process
  - Provides Physics Analysis During Design Cycle
  - Greatly Reduces the Turnaround Time between Model Cycles
- Commercial 3D Modeler Minimizes Modeling Time and Errors
- Succesfully used to Optimize 3 LAC Designs and a SPACAL Design
- Upgradable Architecture Allows Rapid Expansion of Capabilities
- Planned Extensions
  - Event simulation (in progress)
  - Transverse shower simulation
  - Extend geometry to Monte Carlo neutron / photon transport (in progress)

Tomasz Skwarnicki/Syracuse University

3D VISUALIZATION IN HEP

workstations become powerful enough to handle high quality 3D graphics

rapid progress in commercial software support

two competing <u>low level</u> 3D graphics models:

PHIGS (led by DEC) ↔ PEX (PHIGS Extended X)

GL (SGI) (Graphics Library) → GL5

extentions to networking (i.e. to X Window type protocol)

} in development phase

programming at this level is time consuming and requires specialized expertise

<u>high level</u> application systems:
define computational structure
come with a large number of standard applications
provide user friendly interface:
- visual programming
- script

easily extensible by user modules.

AVS (Application Visualization System)
Stardent/AVS Inc. (89, 90, 91)
supported by DEC, IBM, HP, CONVEX ...

Xplorer
recent response of SGI

Oct. 91 International AVS Center at North Carolina Supercomputing Center
exchange of user-provided modules

AVS is independent of lower layer graphics software
e.g. DEC implementation based on PHIGS
(PEX if available)
IBM implementation based on GL
and of underlying hardware
minimal display station : X-terminal
for real time rotations and zooming
need graphics accelerator cards

current prizes
AVS ~ $5,000 / work station

Xplorer
must buy at least
lowest level SGI WS
~ $8,000

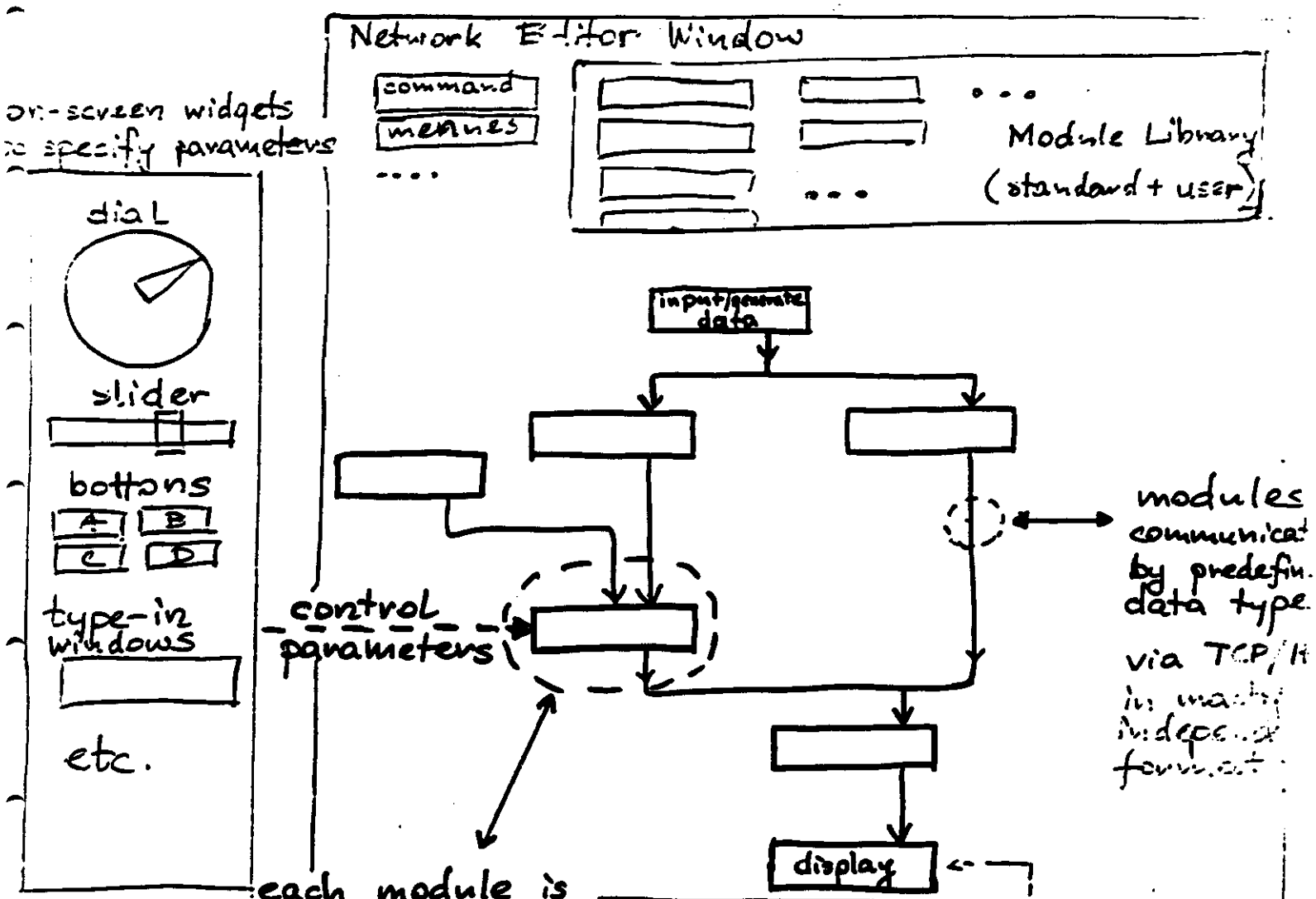
At Syracuse University, we have recently tried to explore usefulness of AVS-type system for HEP.

S.U.: NPAC (Northeast Parallel Architectures Cent
Geoffrey Fox, Wojtek Furmanski, T. Haupt, ...
main expertise in parallel computing
but also involved in many other projec
HEP group in Physics Department
Marvin Golberg, Tomasz Skwarnicki, ...
CLEO, R&D projects with Brookhaven

in particular :
- 3D visualization of abstract HEP data
- 3D visualization of detector geometry

(there are probably many other possible applications we have not tried !)

COMPUTATIONAL NETWORK IN AVS AND ITS VISUAL USER INTERFACE



each module is a UNIX process

different modules can run on different machines

⇓

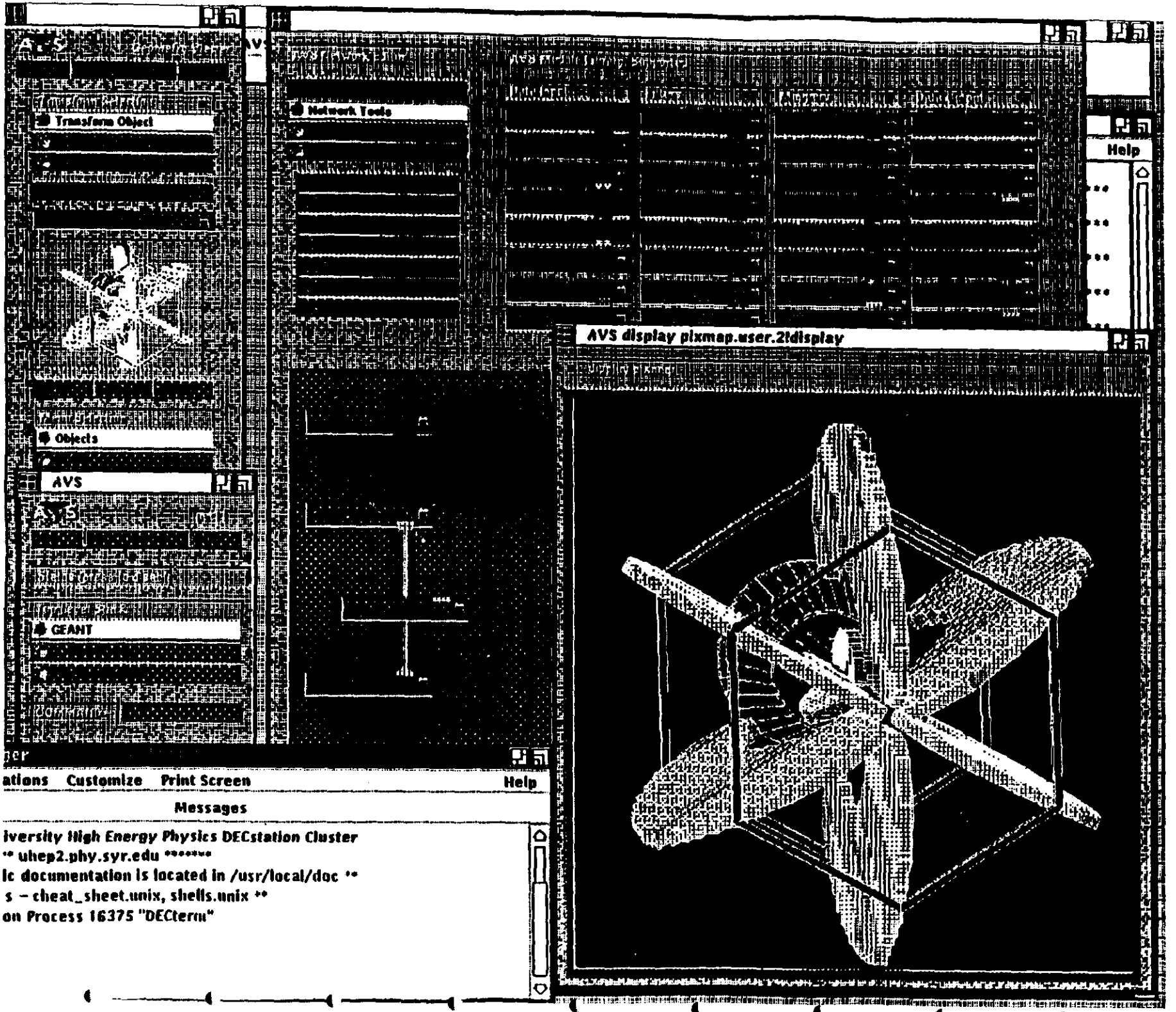
easy DISTRIBUTED computing

one or more display windows

visual programming

almost everything can be done with a mouse

(though all operations also supported in a special script language)


Transform Object
Network Tools
Help
AVS display pixmap.user.2!display
Objects
AVS
GEANT
ations Customize Print Screen Help
Messages
iversity High Energy Physics DECstation Cluster
** uhep2.phy.syr.edu *******
lc documentation is located in /usr/local/doc **
s – cheat_sheet.unix, shells.unix **
on Process 16375 "DECterm"

WHAT STANDARD AVS MODULES CAN DO ?

input modules : convert ASCI files to AVS data type
(it is usually needed to write your own input module)

filters : manipulations on numerical data
(sampling , cuts etc.)

one of the AVS numerical data types :
field — ntupel with arrays as entries rather than vectors } computational space
optionally each entry has position in n-dimensional space } visualization space

mappers : convert numerical data into displayable objects : geometries , pixel maps, images
(e.g. isosurface of 3D field , slices etc.)

output modules : e.g. display pixel map
write postscript file

also filters and mappers for displayable data types (e.g. modify geometry objects
convert pixel map into image)

Some modules are very advanced
- IMAGE VIEWER image processing techniques (e.g. edge detection)
  support for animation
- GEOMETRY VIEWER
  interactive (mouse driven) object transformation
  rotations, scaling, translations
  in real time with high end graphic hardware
  editing of object properties
  visibility, color, transparency
  line or surface rendering
  editing of scene :
  adding many objects
  one or more view points (position, perspective, clipping off)
  one or more lights (direction, color etc.)

CLEO-II data : $\tau^- \to \nu \pi^- 3\pi^0$

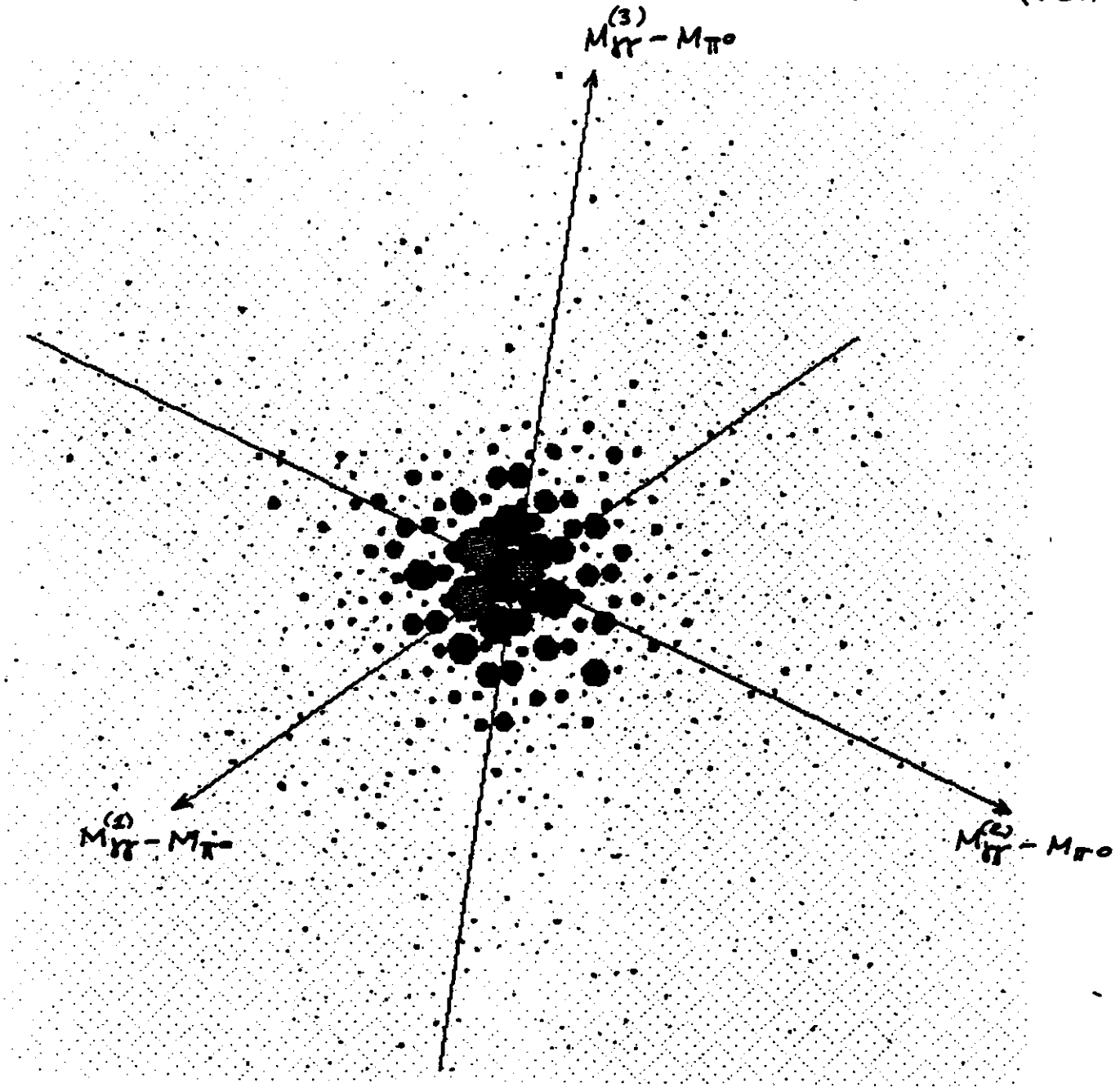
3D binned histogram of $M_{\gamma\gamma}$

bin size : 1σ

range : $[-10\sigma, +10\sigma]$

bin content $\longrightarrow$ radius of a sphere

and color of a sphere (violet - min, red - max)



extention to 4D data :

- 3D scatter plot
  color ↔ 4th dimension

- 3D binned slices put in motion on the screen by scanning 4th dimension

higher dimensions :

- two above combined
- scatter plot represented by finite size objects (not dots)
  size or shape of objects dependent on higher dimensions

at least some of these visualization techniques are likely to become available in standard HEP visualization programs

e.g. CERN has just announced new PAW linked to PHIGS with 3D scatter plots

if needed it should not be too difficult to write a module interfacing PAW to AVS

---

display of geometries strong side of AVS unlikely to be implemented in programs like PAW

distributions (e.g. represented by colors) mapped into detector geometries should be extremely useful for monitoring detector performance (on-line and off-line)

other, obvious application of geometrical part of AVS

DETECTOR AND EVENT VISUALIZATION

while detail specification of detector geometry is a time consuming job we all have to do it for MC purposes

we have written AVS module

GEANT geometry (in ZEBRA banks) $\longrightarrow$ AVS geometry

module is command driven, user specifies

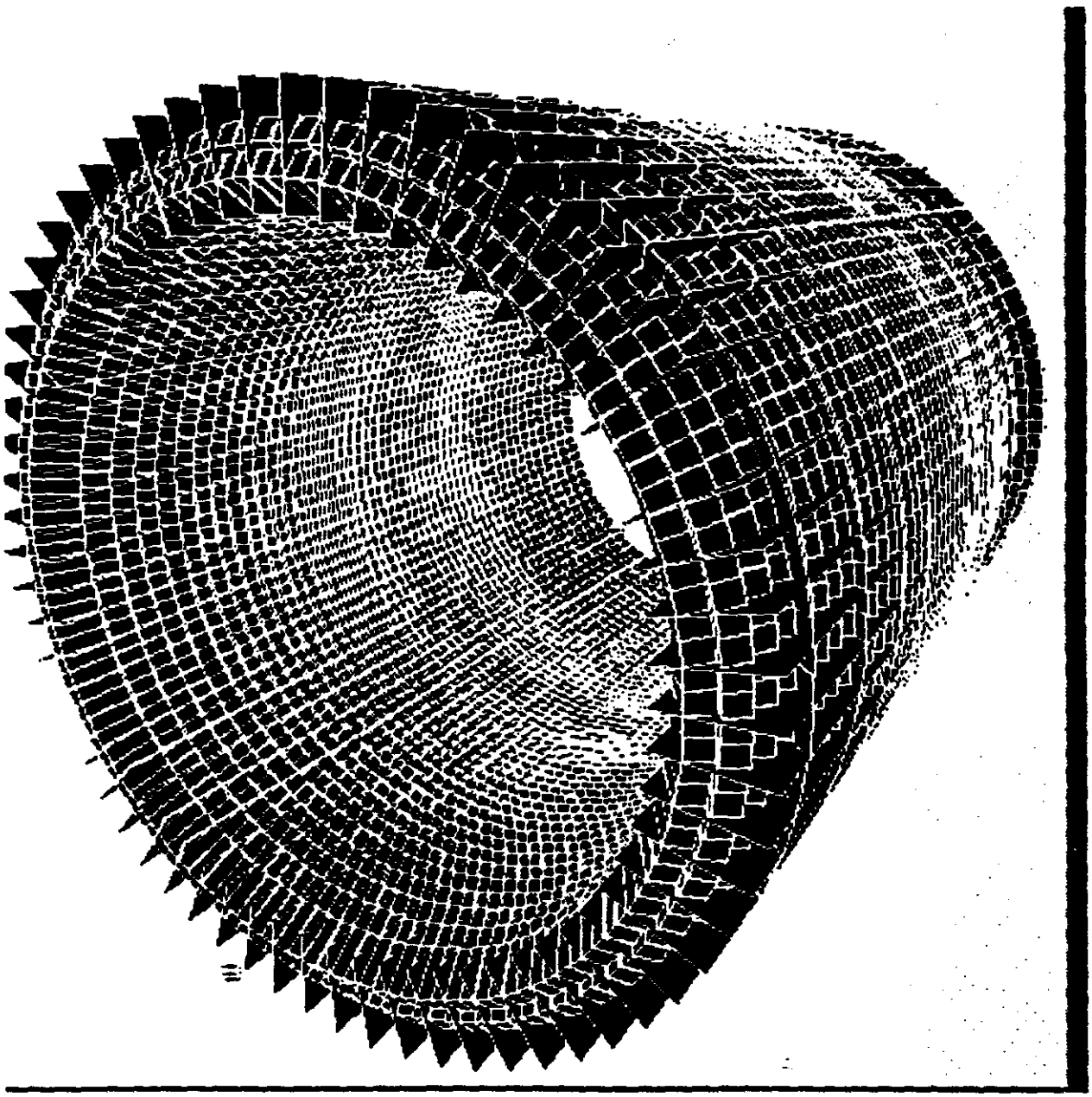
- top volume to visualize
- color, visibility of volumes (if want to overwrite flags set in GEANT
- transparency, rendering method (surface, wire-frame ...)

...

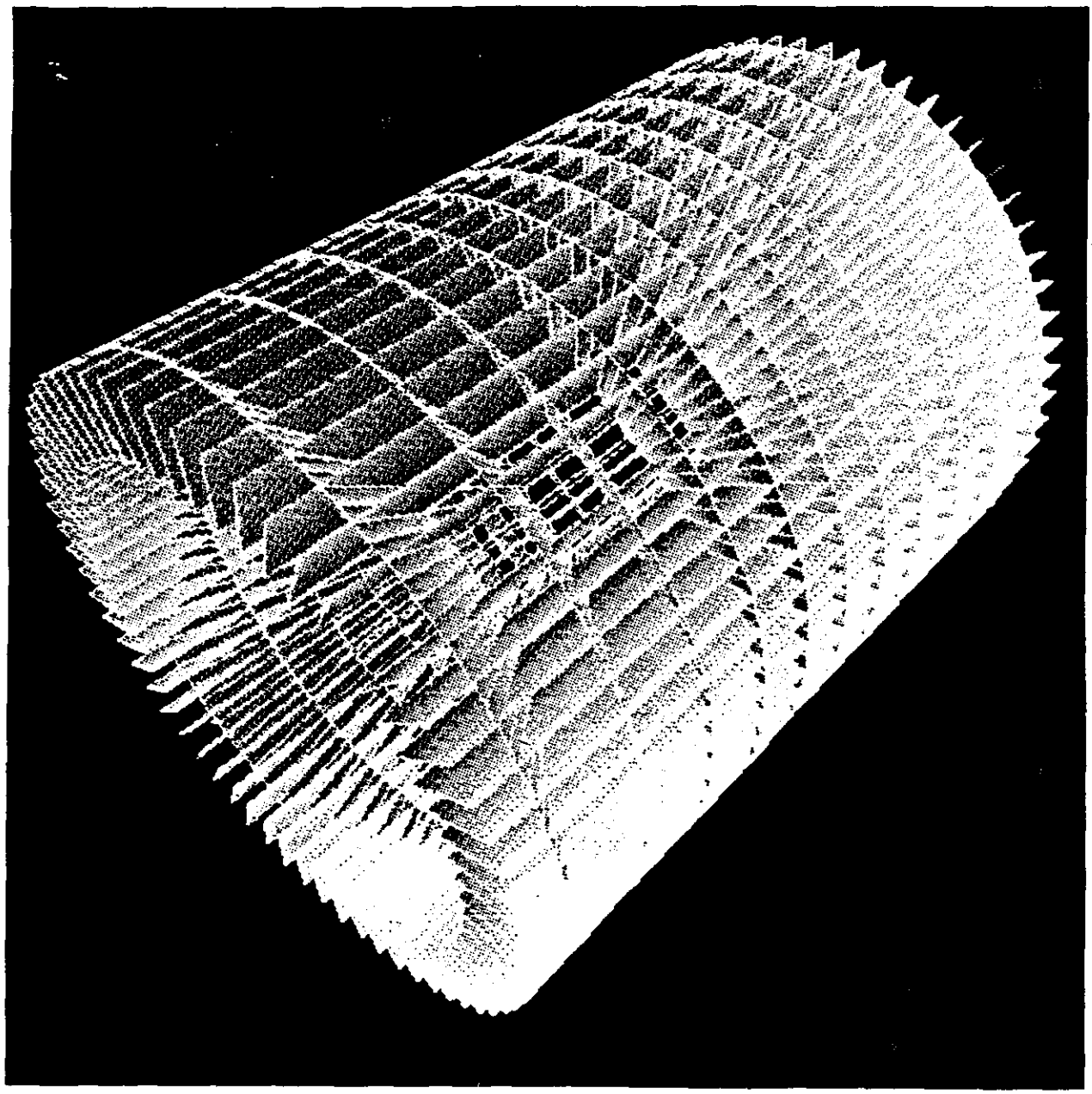
displayed volumes can be tranformed/edited with AVS geometry viewer (or by commands to GEANT-AVS module).

CLEO-II CsI(Tl) barrel calorimeter

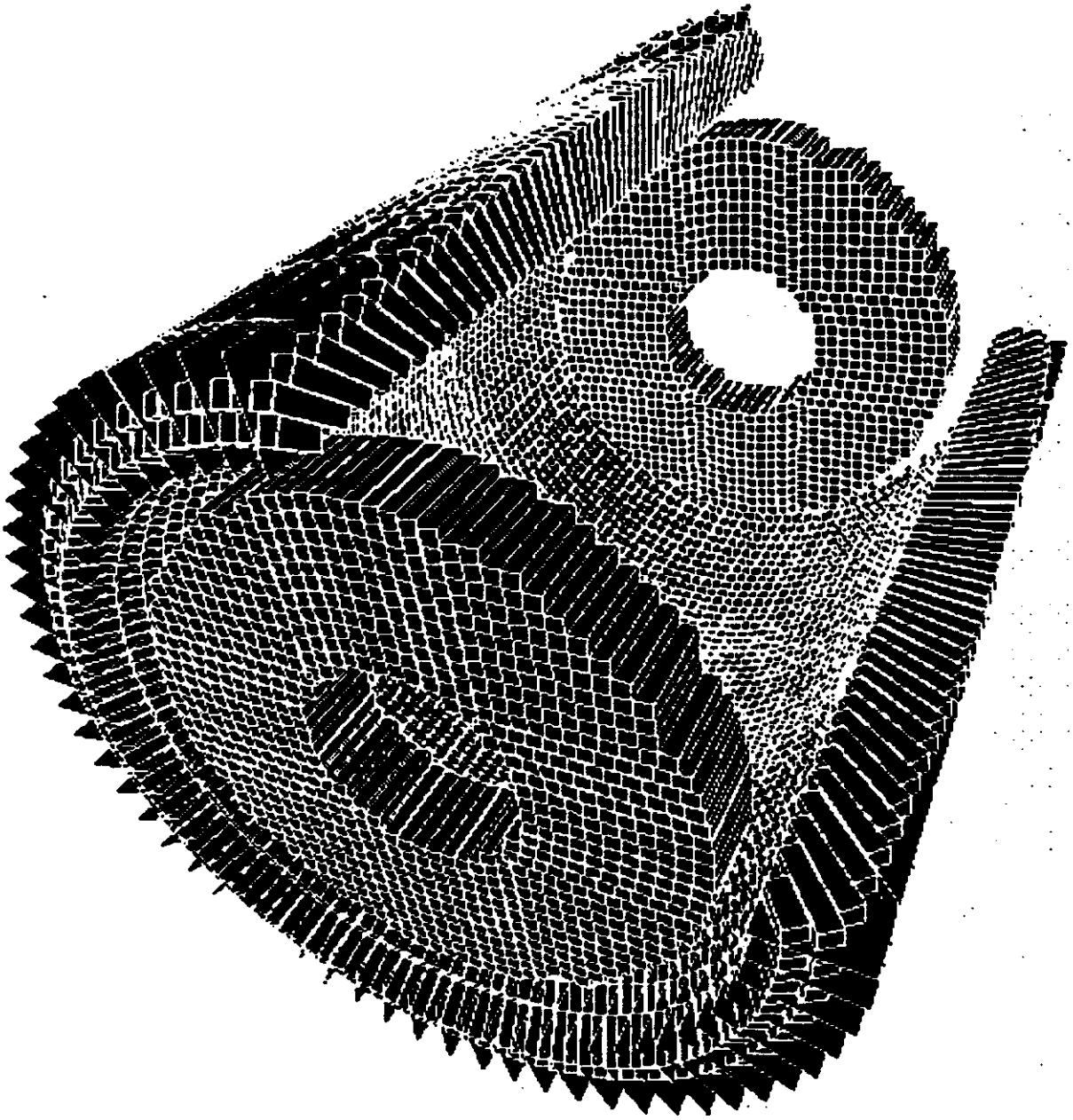
+ support structure

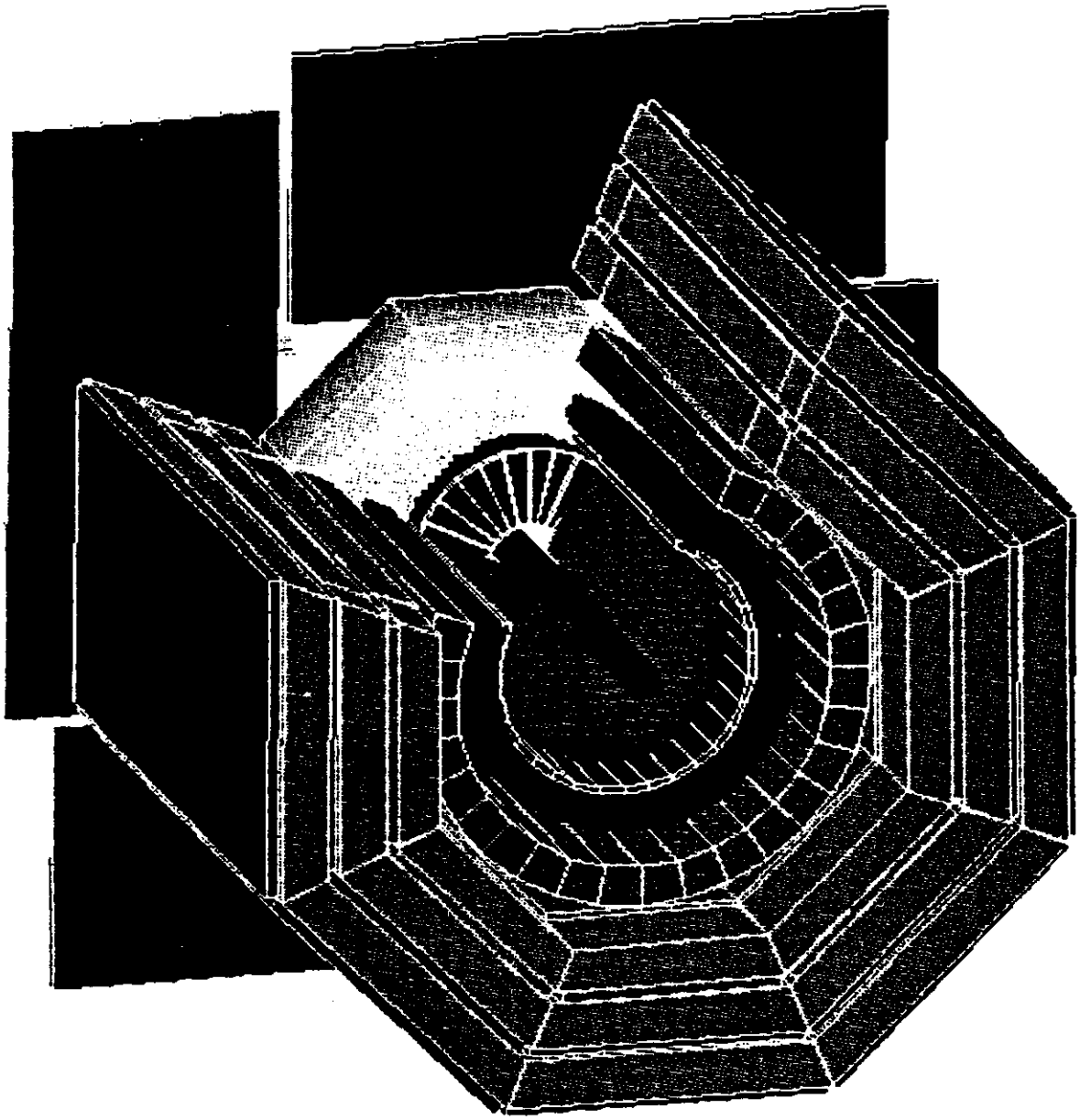


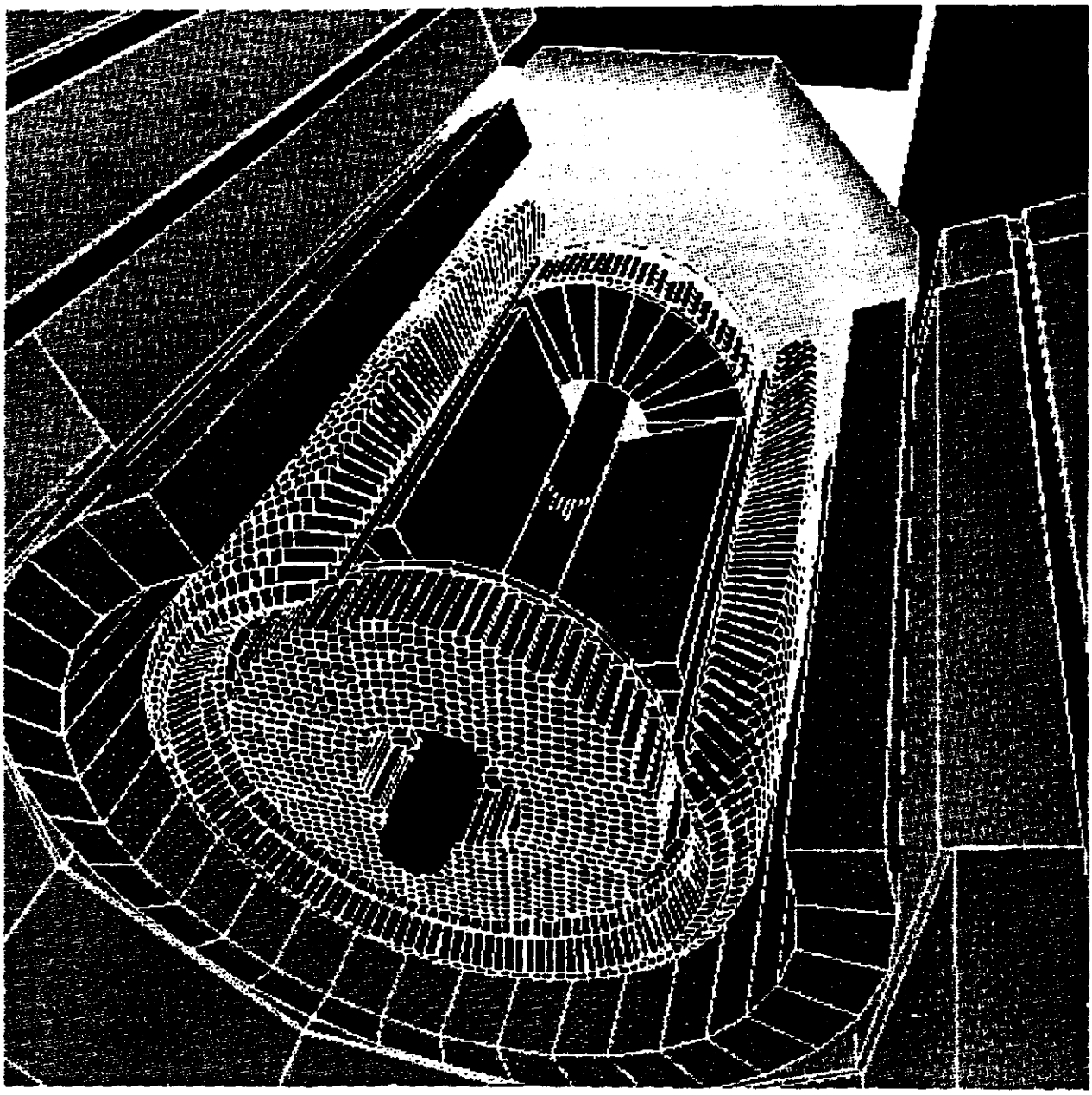
even if you don't have color printer
you can make nice pictures



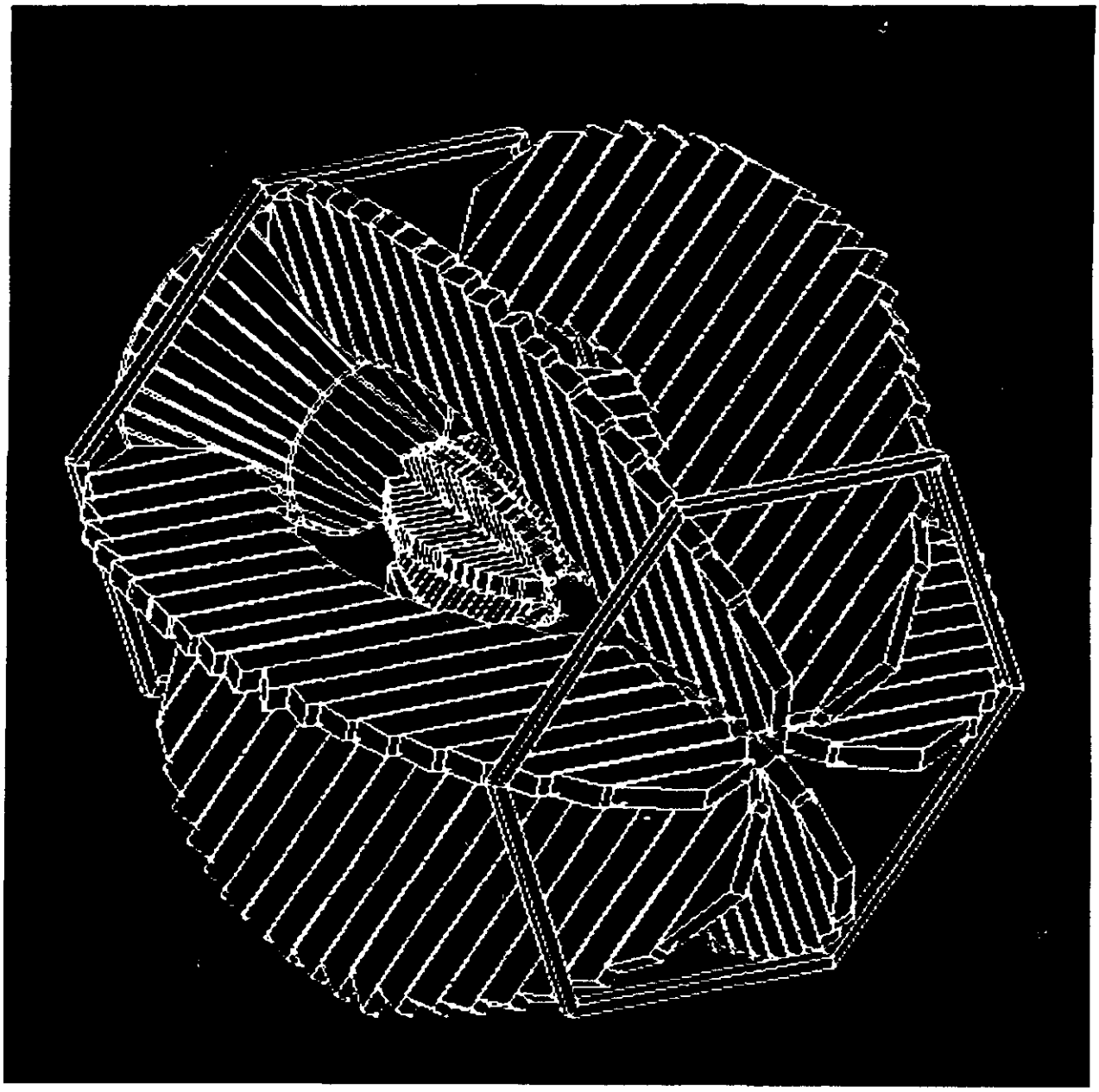
[redacted] : endcaps

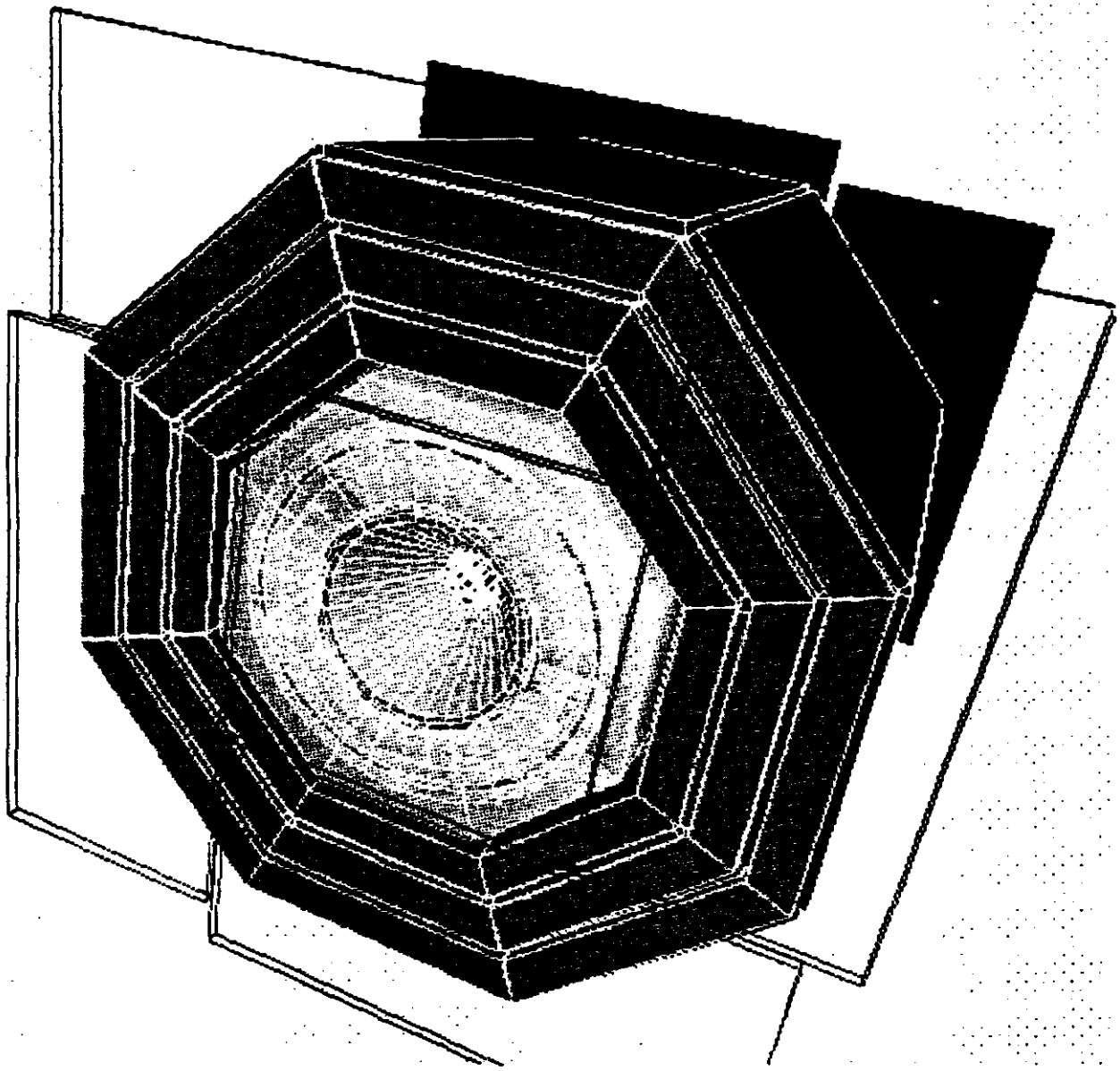


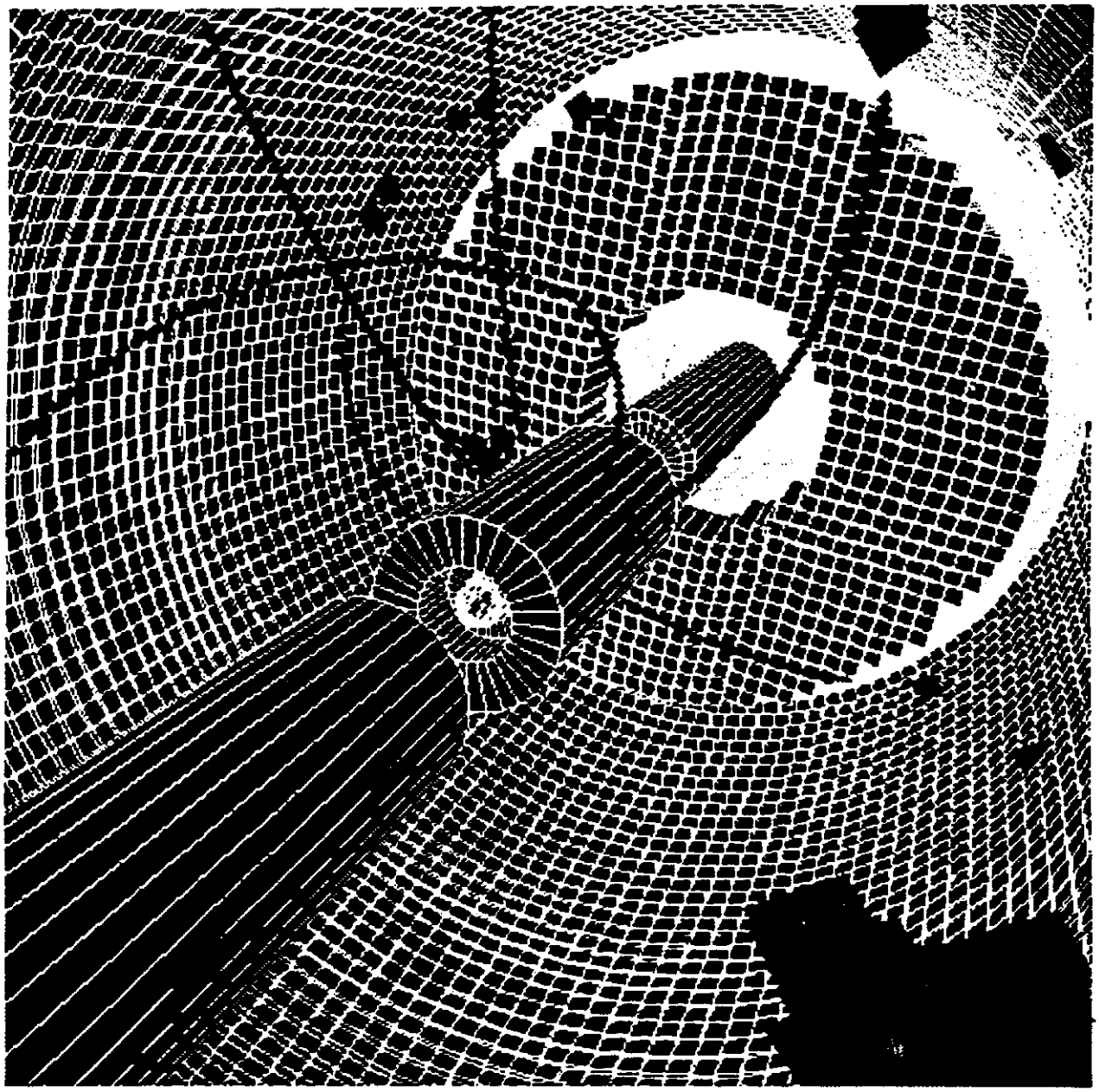


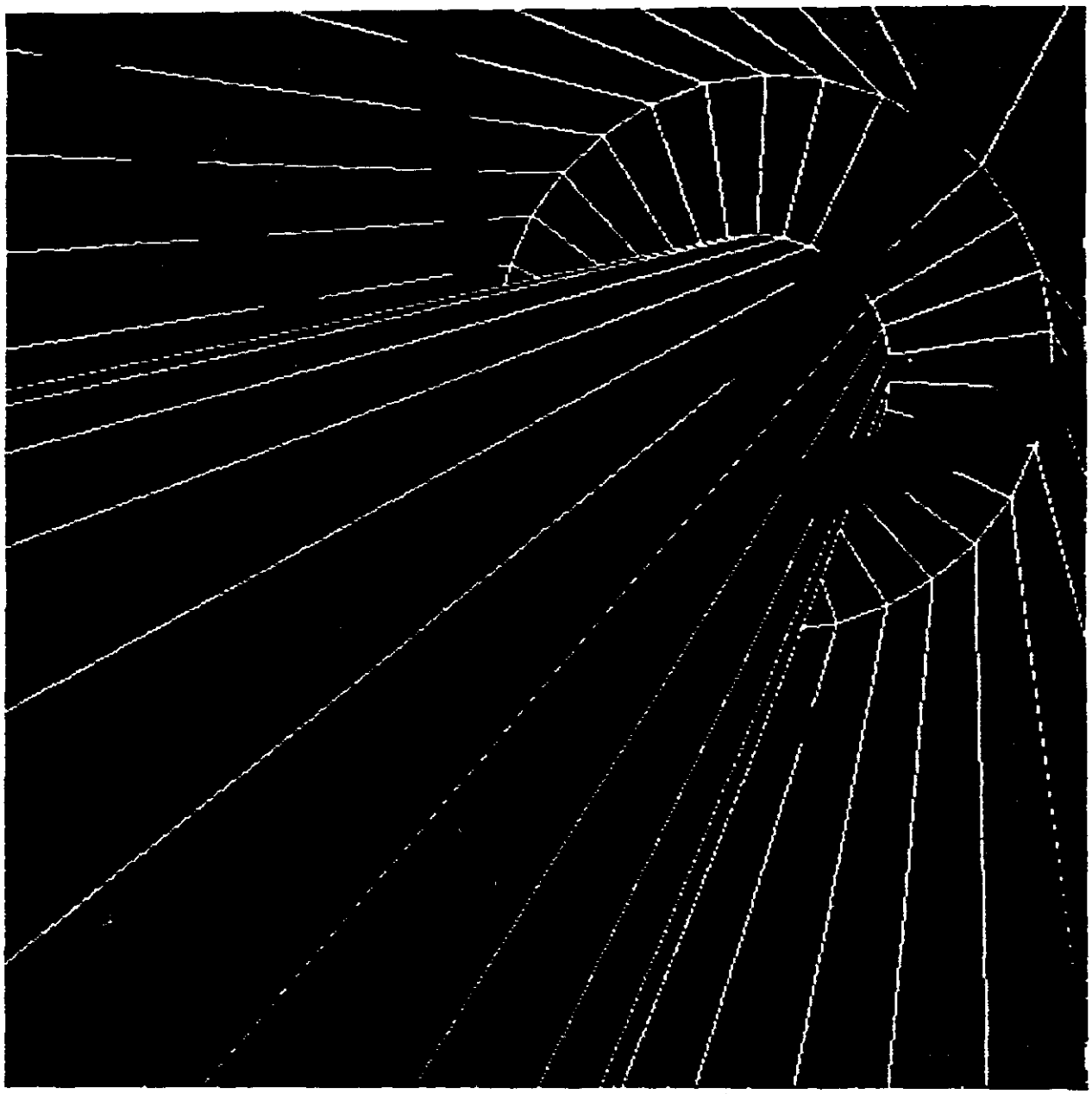


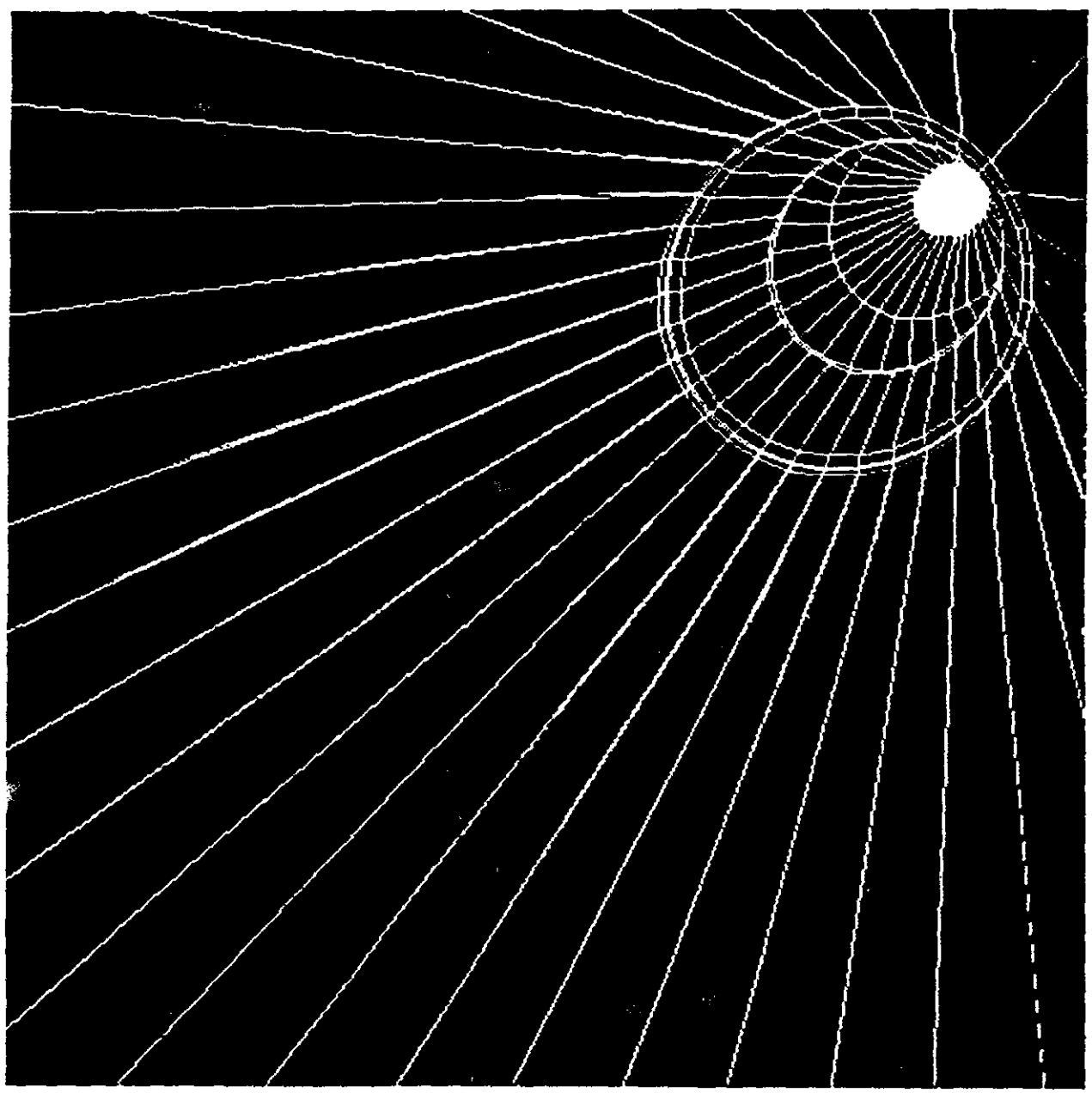
Large Acceptance Spectrometer at CEBAF



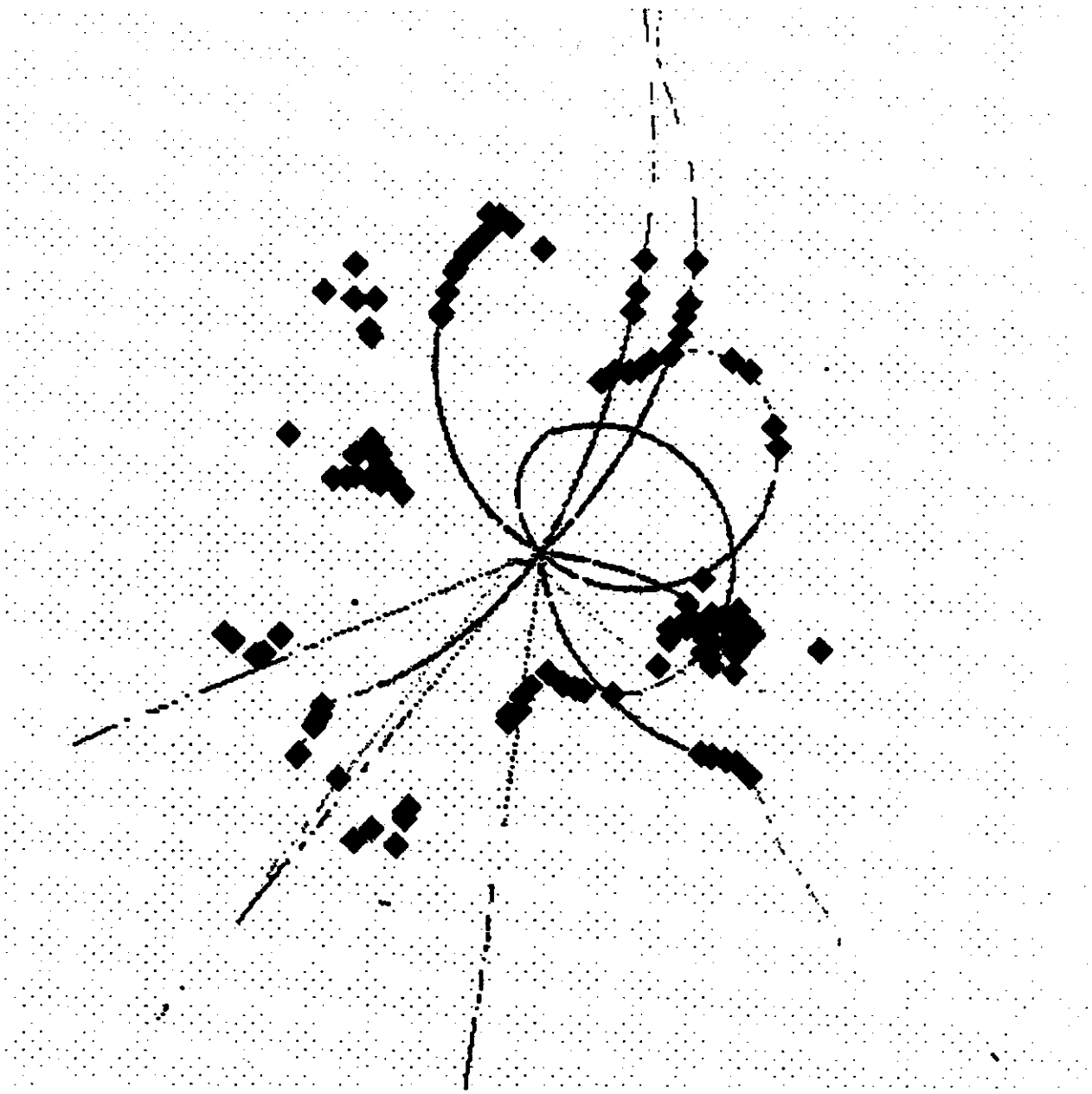








this is very close to "virtual reality" in HEP



CONCLUSIONS

3D visualization techniques bring a new insight into HEP data

- physics analysis
- monitoring of the detector
- detector and event display

because of a long time scale of GEM project we should probably wait for further development of commercial software (and hardware) before investing a lot of work and money into development of specific GEM applications

- but we should watch the market
- and develop further expertise using existing products

GEANT - AVS geometry interface can be useful immediately

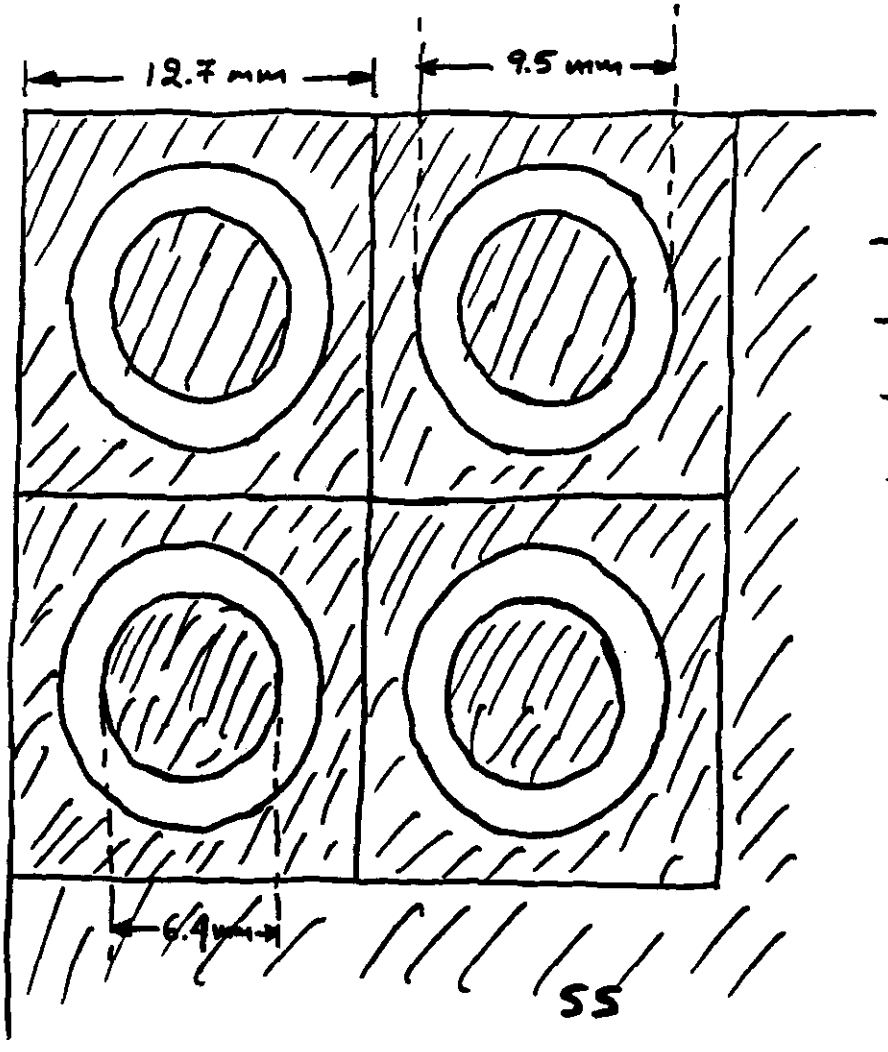
- can help you understand the detector better
- useful for public relations:
  - nice pictures for your talks, proposals
  - could do video describing GEM detector, physics, but need to invest some money (into appropiate hardw. and manpower now

(GEM software should eventually use visual programming and support distributed computing)

e.g. MOVIE system developed by JNPAC

10-Mar-92
G. Fanourakis

current High Pressure gas calorimeter design



1 module

- 64 rectangular tubes
- tube size 12.7 × 12.7 mm
- tube length = 3.05 m
- hole ID = 9.5 mm
- rod diameter = 6.4 mm
- gas gap = 1.6 mm
- module size ≈ 10 × 10 × 300 cm

Laurie Waters

3-7-92

LAHET/MCNP SIMULATIONS

LAURIE WATERS, DAVID LEE
LOS ALAMOS NAT'L LAB.
WATERS@LAMAF 505-665-4127

1] LAHET/MCNP/CINDER90 CODE

2] GEOMETRY, MATERIALS

3] NEUTRON FLUX THROUGH SILICON TRACKER - BORATED POLYETH. LINING

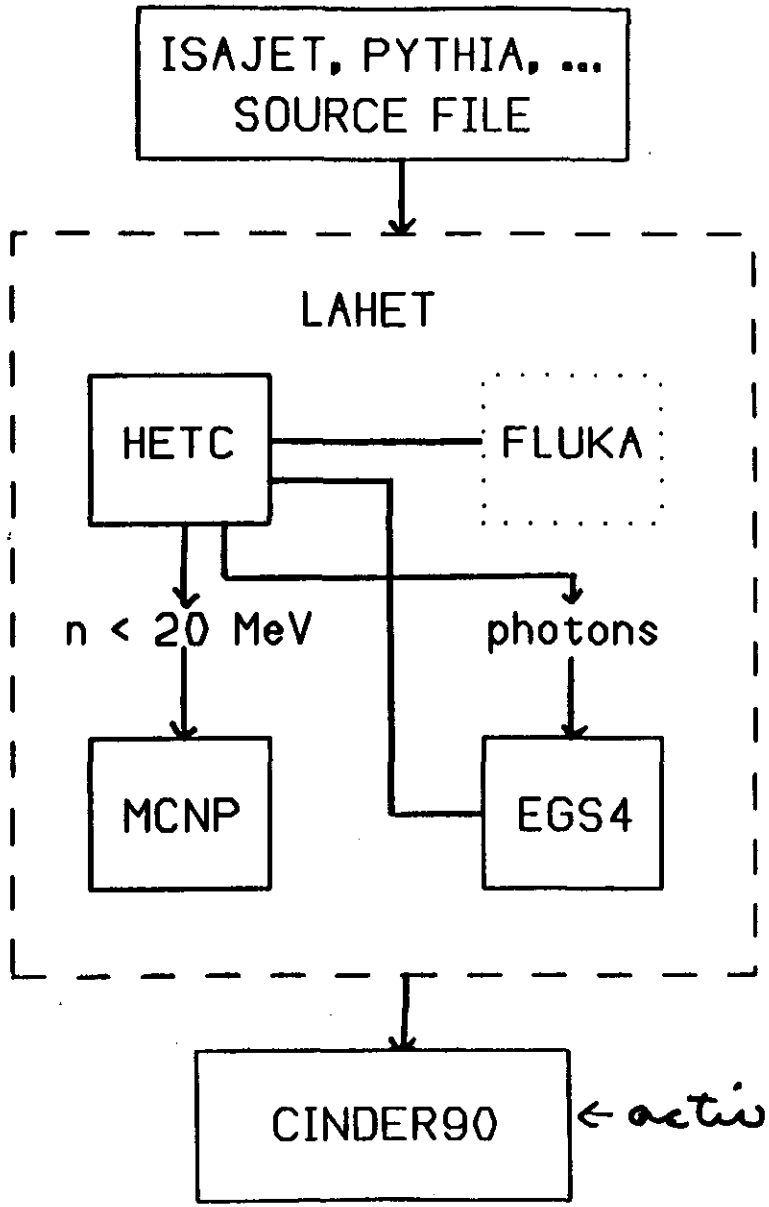
4] NEUTRON FLUX IN ENDCAP CALORIMETERS

5] NEUTRON FLUX IN FCAL

6] NEUTRON FLUX IN 1st MUON CHAMBER (E814 PCAL BENCHMARKS)

7] ACTIVATION - CINDER90 L* RESIDUAL NUCLEI FOR FCAL, EM, HADRONIC

LAHET/MCNP
SIMULATION CODE



← activation calculations

— EXISTING LAHET

— SUPERHET

3/ 3/92 12 46 41
OEM SIMULATION FINE
SEGMENTATION

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(0.000000, 1.000000, 0.000000)
ORIGIN
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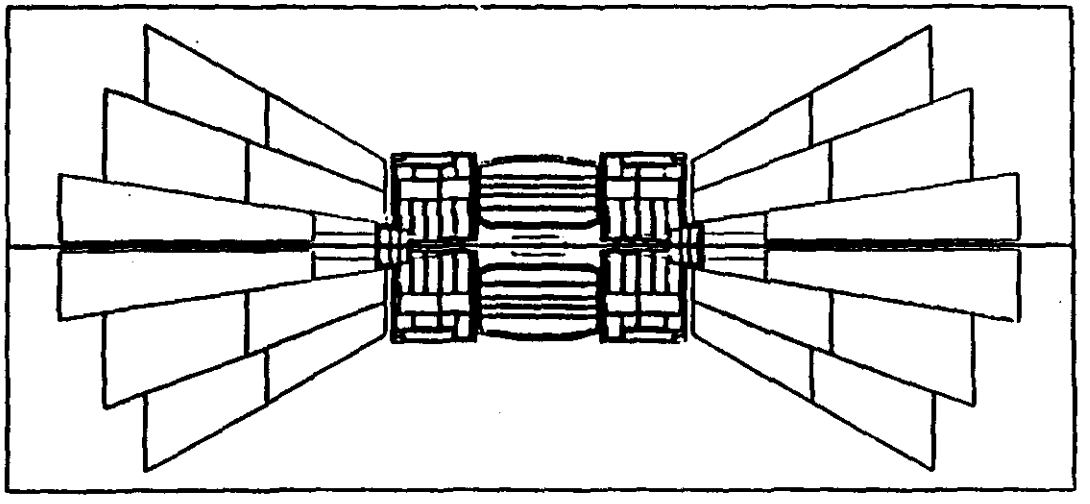

3/ 3/92 12 57 42
GEM SIMULATION FINE
SEGMENTATION

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(0.000000, 1.000000, 0.000000)
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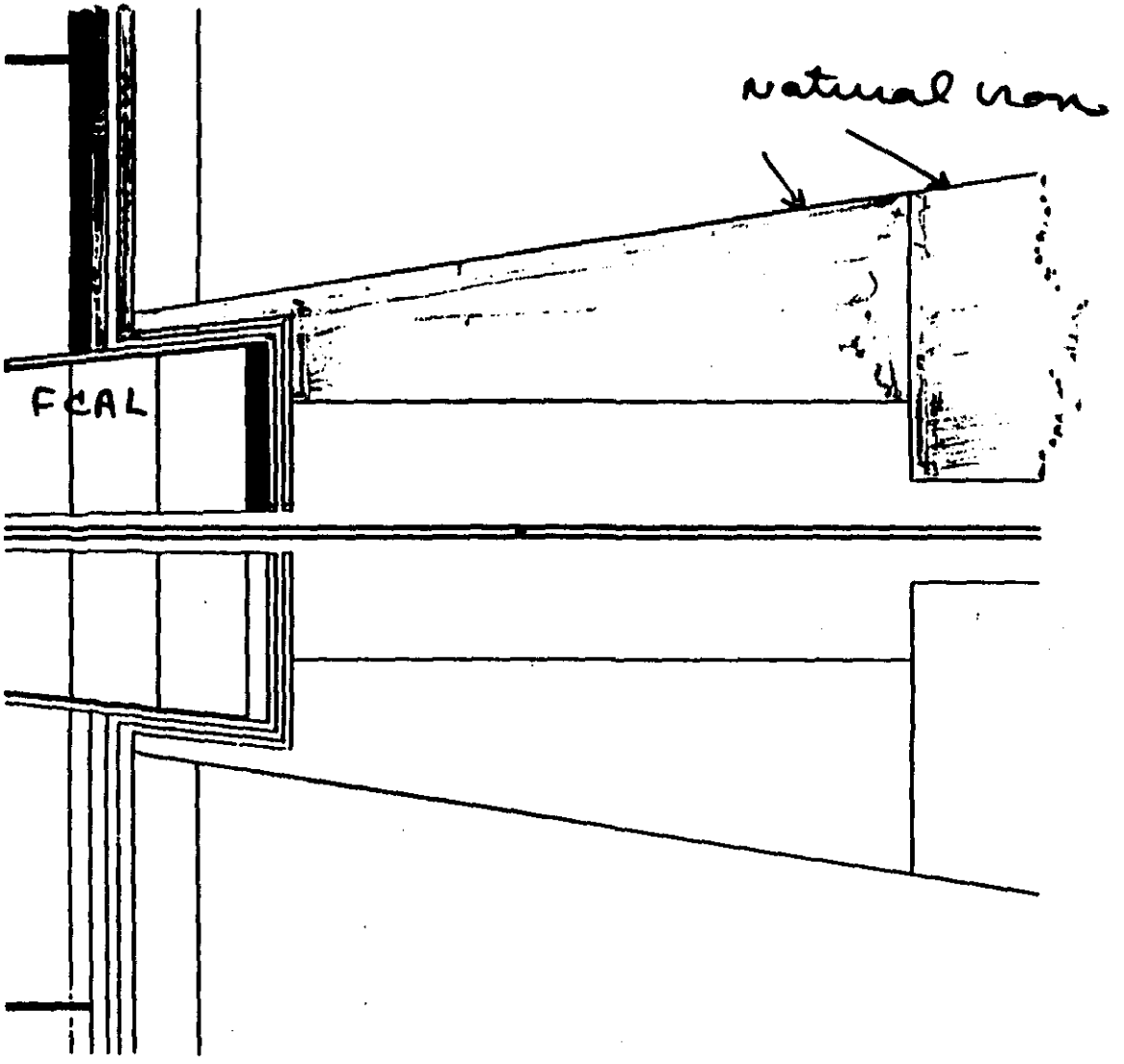

material compositions

	EM	Hadronic	FCAL	LAH
density (gm/cm^3)	4.369	11.861	17.022	1.532
elements (#/b/cm)				
^{1}H	.00155	.00595	.0000904	.01519
^{12}C	.00139	.00355	.000199	.01309
^{14}N		.00029	.0000181	.00074
^{16}O	.00082	.00328	.0000362	.00837
^{28}Si	.00020	.00139		.00356
~~^{28}Si~~ ^{40}Ar	.00135	.00453	.00135	.01266
^{52}Cr	.00112	.00140		
^{56}Fe	.00366	.00461		
^{59}Ni	.00062	.00079	.00607	
^{64}Cu			.00257	.003395
^{184}W			.0526	
^{208}Pb	.00844			
^{238}U		.02703		

waters/3-6-92

HADRONIC

6 mm SS
16 mm LAr
42 mm ^{238}U
10.5 mm G10

FCAL

13.125 mm WN507C
9 mm Ar
.075 mm Kapton
.025 mm Cu

LAr

3 cm LAr
1.8 cm G10
.2 cm Cu

B-Poly

^{12}C 61.2%
H 11.6%
O 22.2%
^{10}B 1%
^{11}B 4%

Al 5083
96% Al
4% Mg

Tracking Thresholds

Particle	Threshold
prot, deut, trit, ^{3}He,α, pbar	0.1 MeV
neutrons in Lahet	20.0 MeV
neutrons in MCNP	0.0 MeV
charged pions	0.149 MeV
muons	0.113 MeV
K+,K-	0.527 MeV

	EM	Hadronic	FCAL	LAR
density (gm/cm^3)	4.369	11.861	17.022	1.532
elements (#/b/cm)				
^{1}H	.00155	.00595	.0000904	.01519
^{12}C	.00139	.00355	.000199	.01309
^{14}N		.00029	.0000181	.00074
^{16}O	.00082	.00328	.0000362	.00837
^{28}Si ^{40}Ar	.00020	.00139		.00356
^{28}Si	.00135	.00453	.00135	.01266
^{52}Cr	.00112	.00140		
^{56}Fe	.00366	.00461		
^{59}Ni	.00062	.00079	.00607	
^{64}Cu			.00257	.003395
^{184}W			.0526	
^{208}Pb	.00844			
^{238}U		.02703		

waters/3-6-92

Particle	Threshold
prot, deut, trit, ^{3}He,α, pbar	0.1 MeV
neutrons in Lahet	20.0 MeV
neutrons in MCNP	0.0 MeV
charged pions	0.149 MeV
muons	0.113 MeV
K+,K-	0.527 MeV

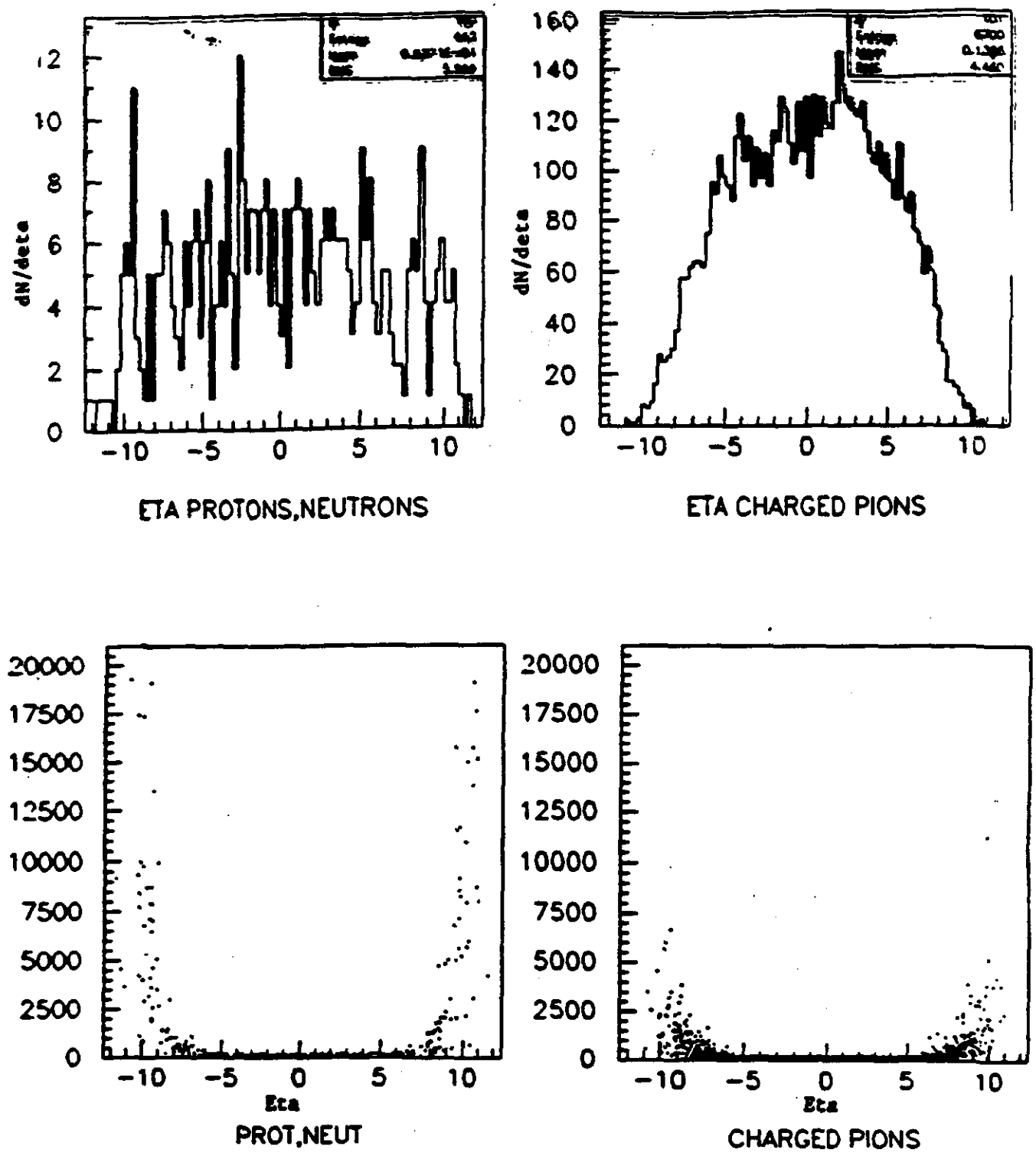

Figure 1: Pseudorapidity distributions, and energy versus η for all protons, neutrons and charged pions from the 50 ISAJET events used in these simulations.

```
   3/ 3/92 12 40 10
DEM SIMULATION  FINE
 SEGMENTATION

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(0.000000, 1.000000, 0.000000)
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(      0.00,    200.00,      0.00)
EXTENT = (    250.00,    250.00)
```
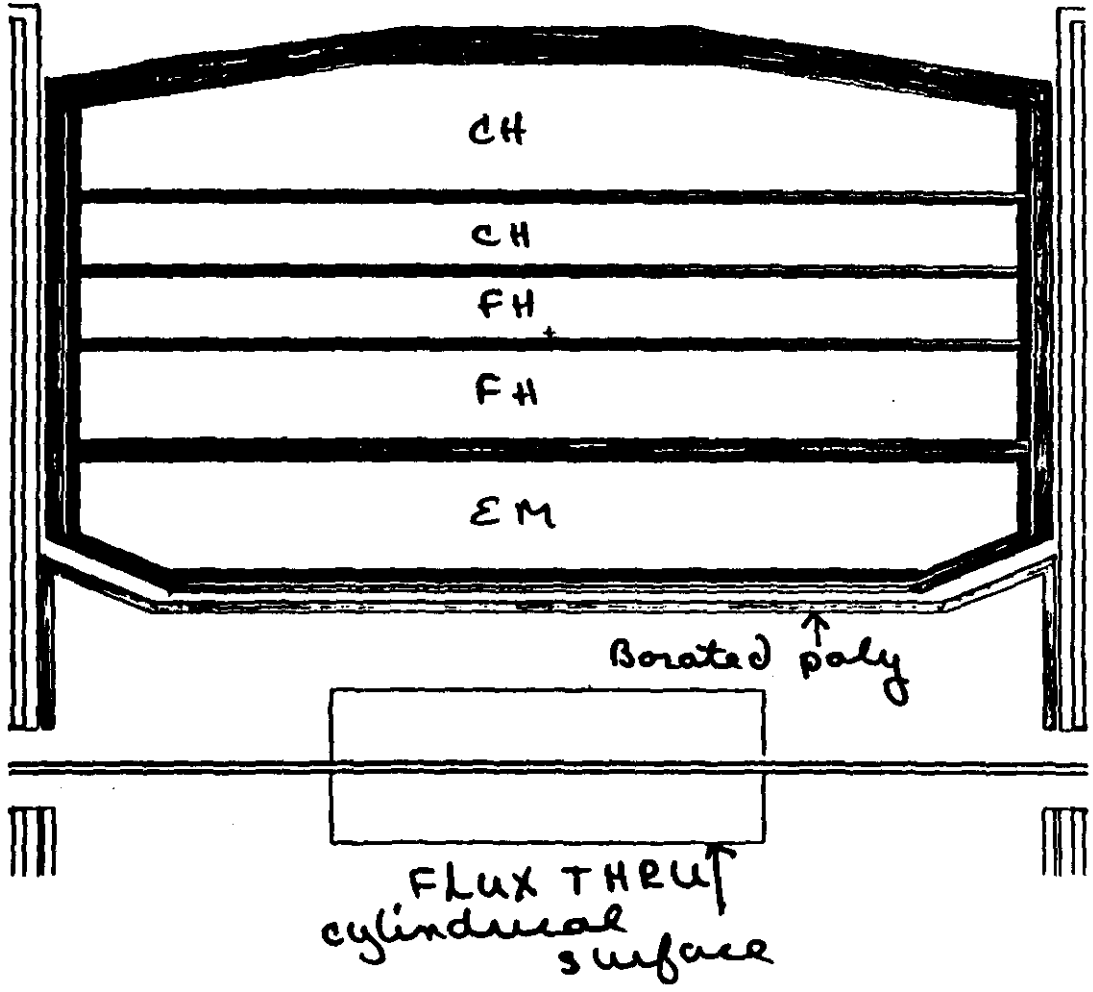



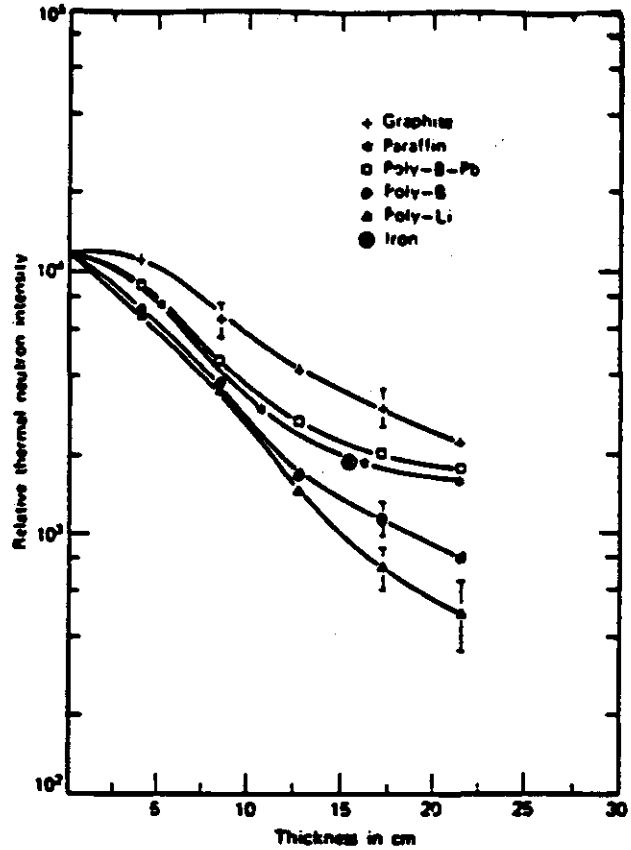


FIGURE 20-7. The relative effectiveness of different shielding materials for 2.6 MeV neutrons as indicated by the thermal neutron flux for various thickness. (From Gujrathi and D'Auria[12].)

Boron-Polyethelyne 201

by weight: C 61.2%

H 11.6%

O 22.2%

B_{nat} 5%

B_{nat} = 20% ^{10}B, 80% ^{11}B

↑

kb cross section for neutron absorption (thermal)

$^{10}B(n,\alpha)$

.48 MeV gamma ray

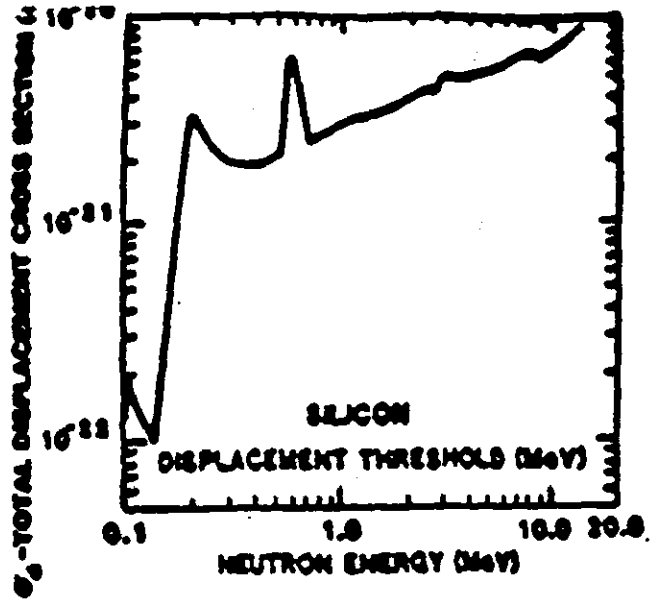


Figure 3 Neutron displacement cross section in Silicon

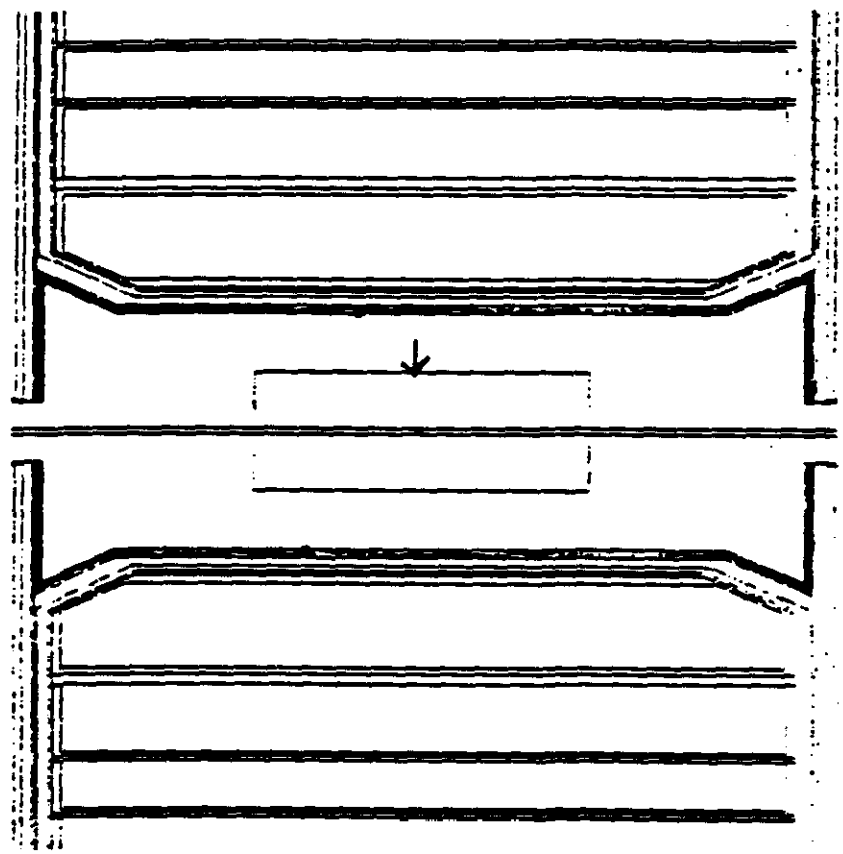
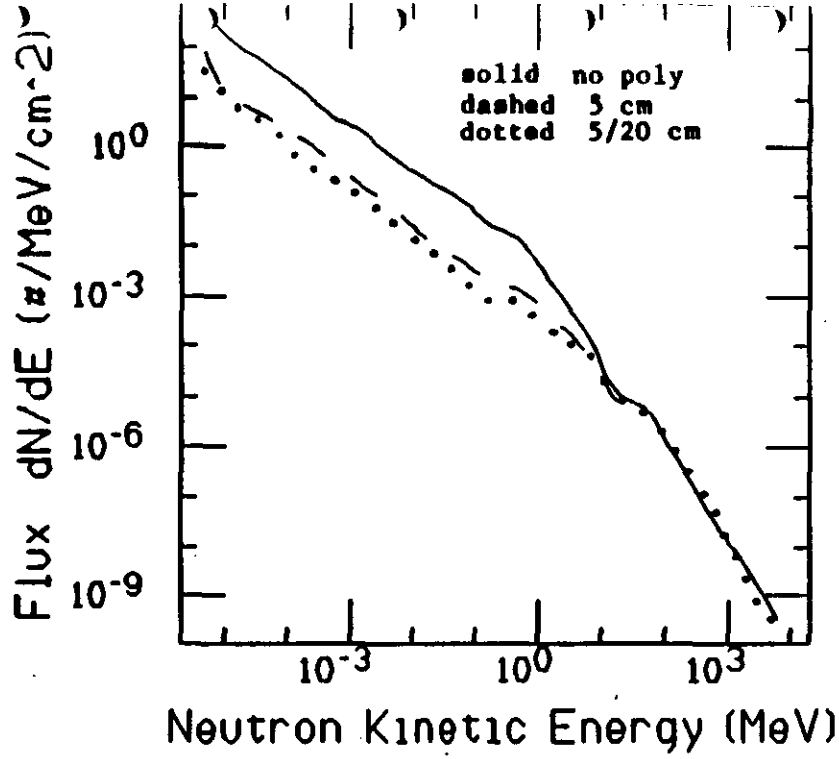
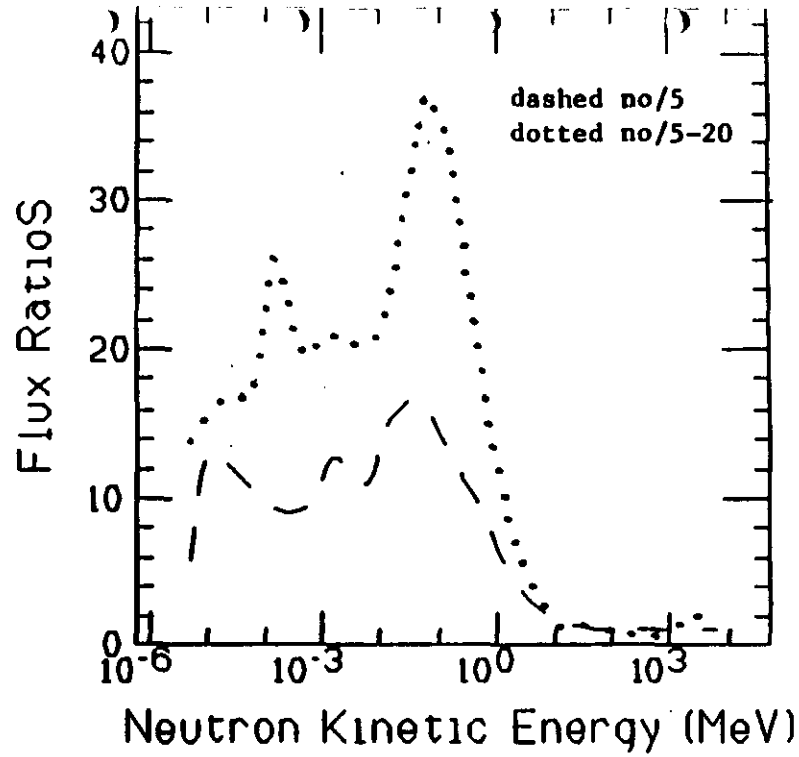
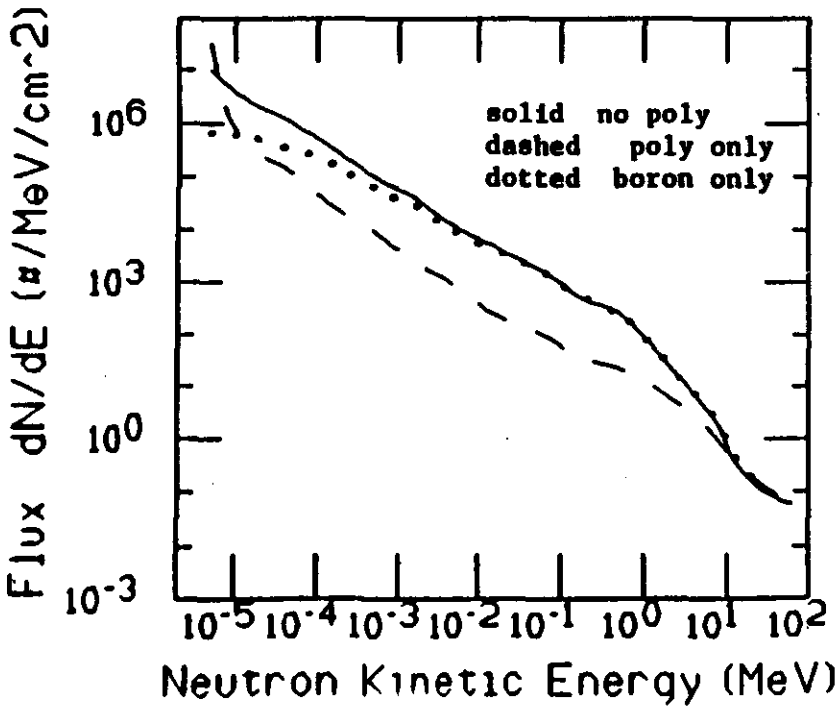


Figure 5 Expanded view of vertex region. B-poly shielding is shaded, and flux is taken across the cylindrical surface marked with an arrow.







1st 3 lines : larger Livingston config
last line : U^{238} config

SETUP	flux < 100 keV	flux > 100 keV	Total Flux
no shield	45.30×10^{12}	15.97×10^{12}	61.27×10^{12}
5 cm	5.27×10^{12}	4.03×10^{12}	9.30×10^{12}
5 + 20 cm	3.30×10^{12}	1.90×10^{12}	5.2×10^{12}
no shield, new setup	23.31×10^{12}	13.96×10^{12}	37.27×10^{12}

Laurie Waters
LANL 2-25-92

flux across cylindrical vertex surface 35 cm in radius, +/- 100cm in Z
energy figures represent upper bin limits
binned values are per event, per MeV, PER CM²
total values are per event
multiply time 1.0E15 to put on yearly basis

MeV energy	Flux 0 to 1musec	relative error	1musec to 1msec		gt 1msec	
1.0000D-05	0.00000D+00	.0000	8.14826D+02	.0341	2.58164D+02	.0408
2.0000D-05	0.00000D+00	.0000	8.89321D+01	.0745	0.00000D+00	.0000
1.0000D-04	0.00000D+00	.0000	2.42246D+01	.0500	0.00000D+00	.0000
2.0000D-04	0.00000D+00	.0000	8.70198D+00	.0696	0.00000D+00	.0000
1.0000D-03	0.00000D+00	.0000	2.43892D+00	.0488	0.00000D+00	.0000
2.0000D-03	0.00000D+00	.0000	8.06315D-01	.0587	0.00000D+00	.0000
1.0000D-02	1.60337D-02	.1041	2.45113D-01	.0526	0.00000D+00	.0000
2.0000D-02	2.01744D-02	.0978	7.85972D-02	.0772	0.00000D+00	.0000
1.0000D-01	1.77168D-02	.0606	2.03977D-02	.0574	0.00000D+00	.0000
2.0000D-01	1.46235D-02	.0577	4.37958D-03	.1051	0.00000D+00	.0000
1.0000D+00	7.76213D-03	.0376	7.82617D-05	.1869	0.00000D+00	.0000
2.0000D+00	2.30996D-03	.0490	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+01	2.45668D-04	.0476	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+01	4.56121D-05	.0907	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+02	1.02016D-05	.0650	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+02	1.35171D-06	.1413	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+03	1.03024D-07	.1487	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+03	7.95791D-09	.3037	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+04	1.78356D-09	.6754	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+04	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
total	1.52068D-02	.0319	1.94825D-02	.0313	2.58164D-03	.0408

energy	time total	
1.0000D-05	1.07299D+03	.0327
2.0000D-05	8.89321D+01	.0745
1.0000D-04	2.42246D+01	.0500
2.0000D-04	8.70198D+00	.0696
1.0000D-03	2.43892D+00	.0488
2.0000D-03	8.06315D-01	.0587
1.0000D-02	2.61147D-01	.0509
2.0000D-02	9.87716D-02	.0674
1.0000D-01	3.81145D-02	.0469
2.0000D-01	1.90031D-02	.0529
1.0000D+00	7.84039D-03	.0376
2.0000D+00	2.30996D-03	.0490
1.0000D+01	2.45668D-04	.0476
2.0000D+01	4.56121D-05	.0907
1.0000D+02	1.02016D-05	.0650
2.0000D+02	1.35171D-06	.1413
1.0000D+03	1.03024D-07	.1487
2.0000D+03	7.95791D-09	.3037
1.0000D+04	1.78356D-09	.6754
2.0000D+04	0.00000D+00	.0000
total	3.72709D-02	.0295
lt 100 keV	2.33108D-02	
gt 100 keV	1.39601D-02	

3/ 3/92 12 50 10
GEMP SIMULATION FINE
SEGMENTATION

PROBID = 3/ 3/92 12 49 49
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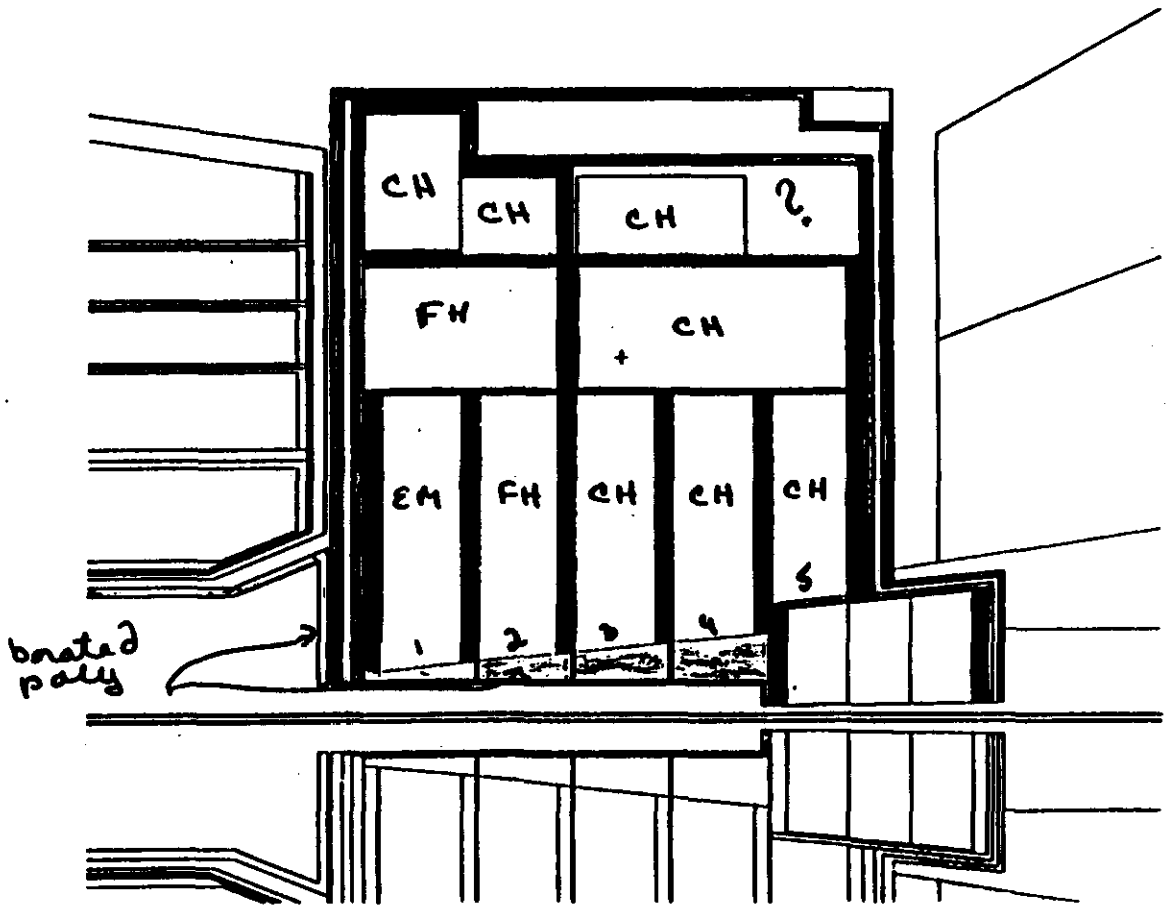
(0.000000, 1.000000, 0.000000)
ORIGIN
(0.00, 200.00, 400.00)
EXTENT = (300.00, 300.00)

#/μ/cm²

1	62.8 ×10¹² (158.7)
2	71.4 (182.1)
3	110.11 (44.07)
4	95.8 (38.8)
5	110.4 (60.5)

numbers in () are flux <100 keV
other numbers are total flux



1/21/92 09 37 05
QEW SIMULATION COARSE
SEGMENTATION

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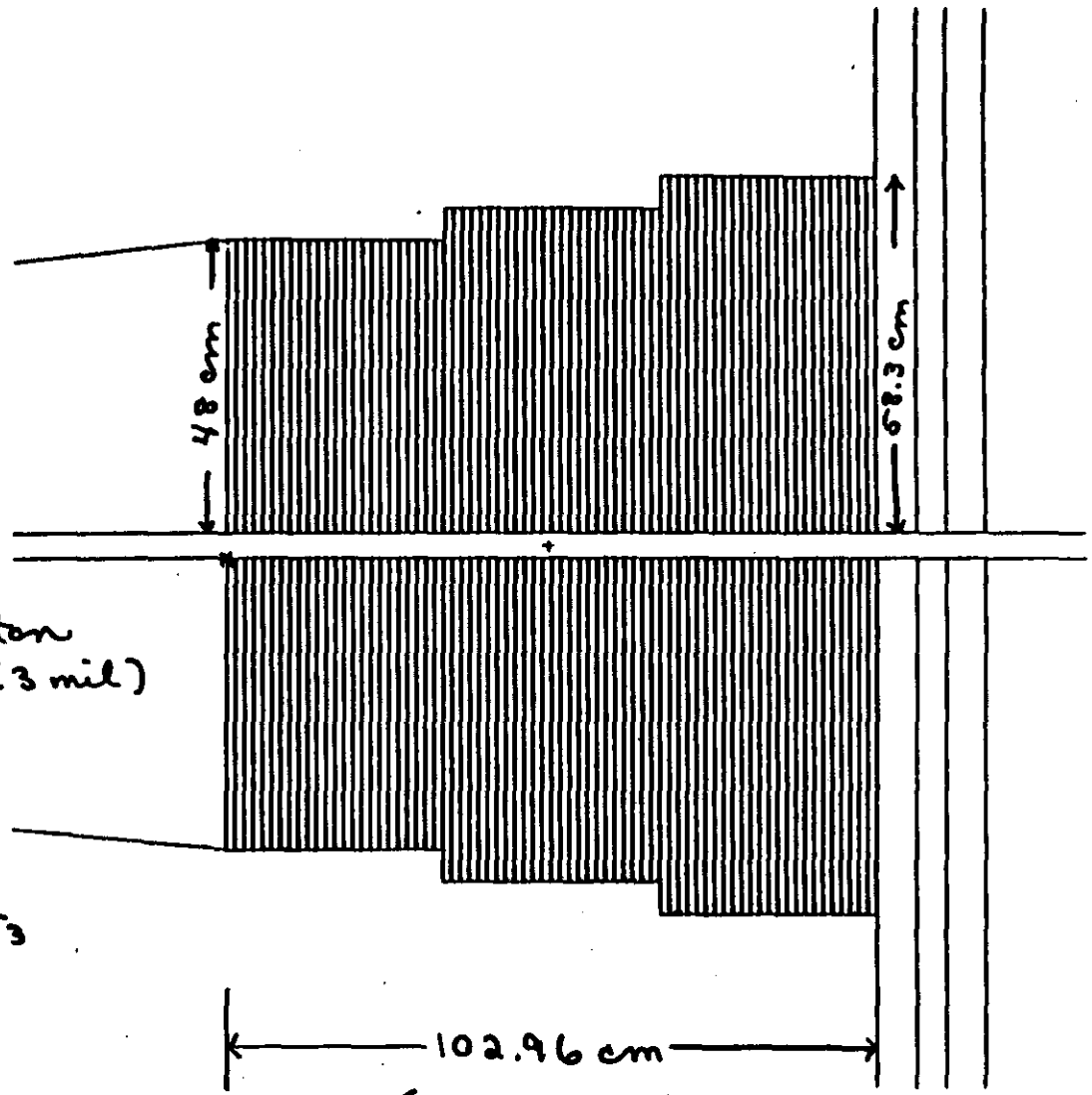


(72 cells)

[W, Ar, Cu, Kapton, Cu, Ar]

1 CELL:

1.3125 cm W
.103022 cm Ar
.006858 cm Cu (2.7 mil)
.00762 cm Kapton $C_{22}H_{10}N_2O_4$ (3 mil)

1.43 cm

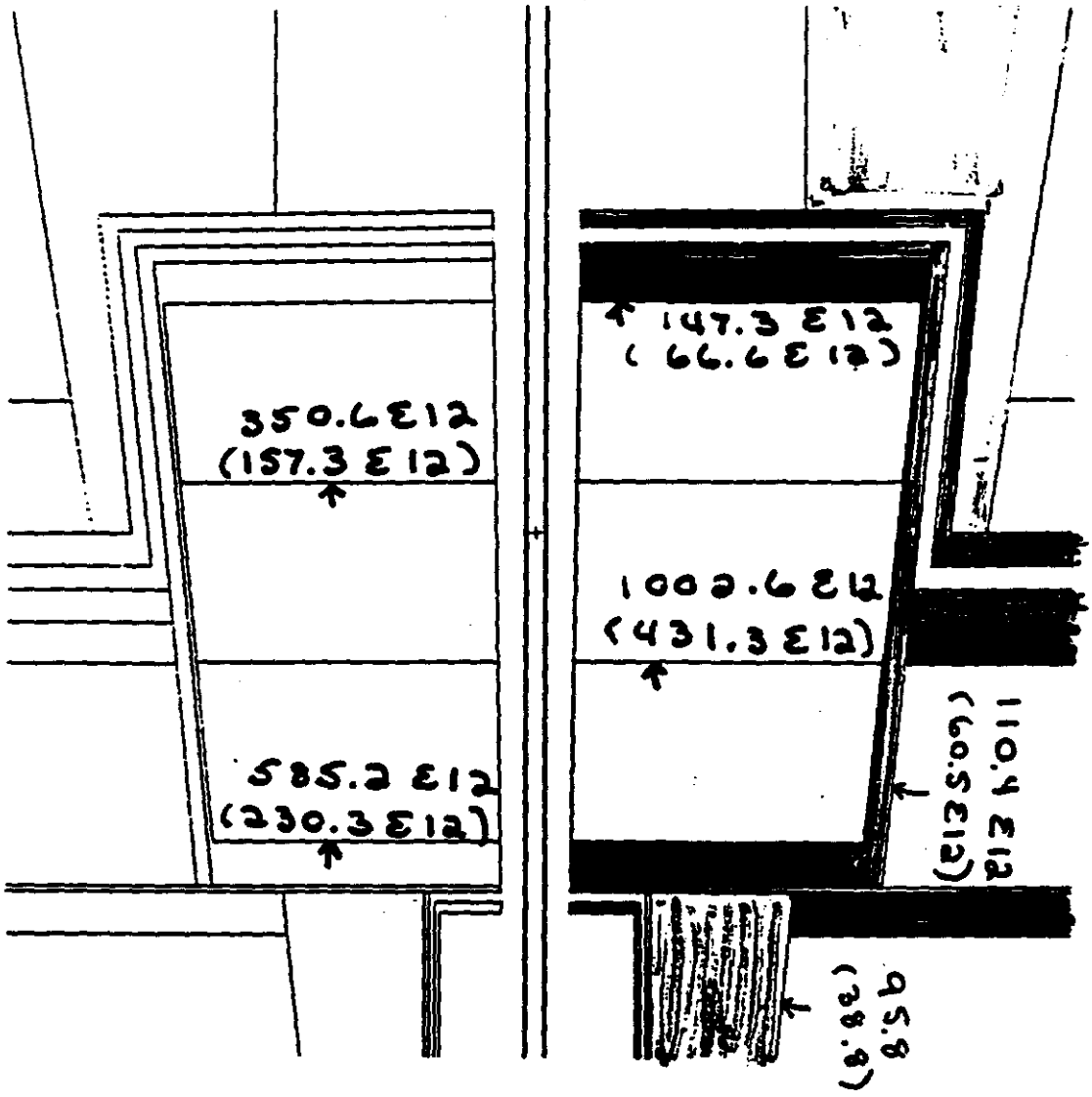
= 17.8629 $\frac{gm}{cm^3}$ avg. density

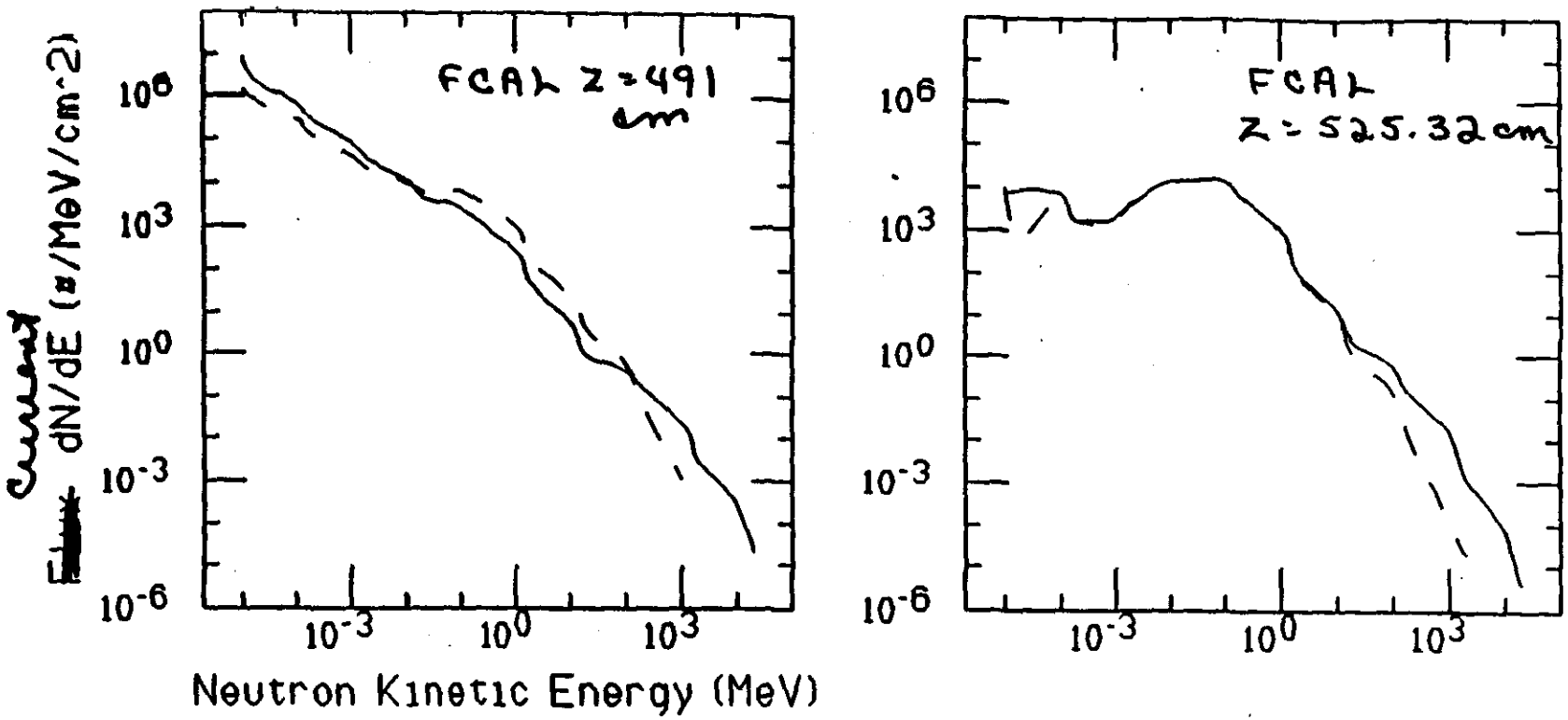
Previously run fine segmentation of FCAL

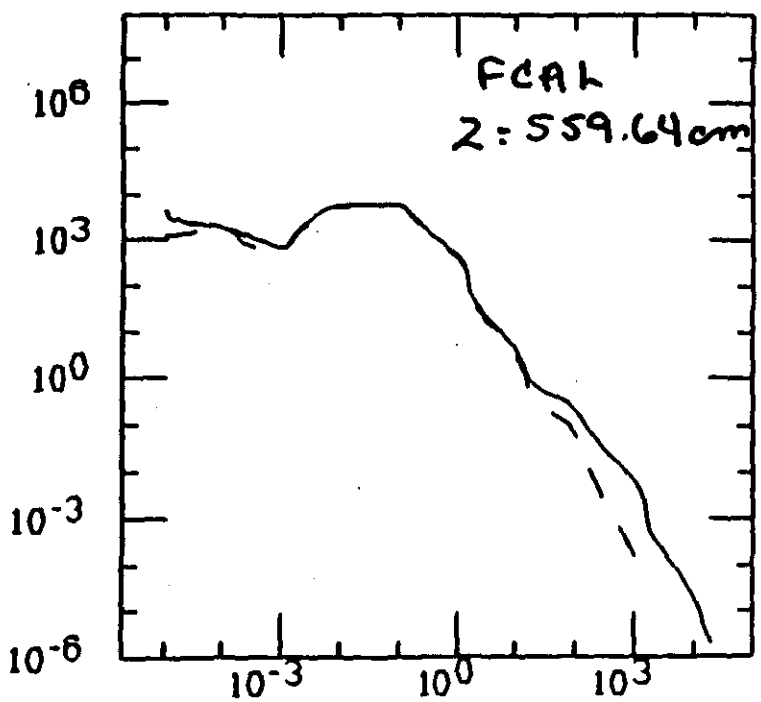
NEUTRON
FLUX IN FCAL

#/SSC YEAR/cm²
(1×10⁷ SEC)

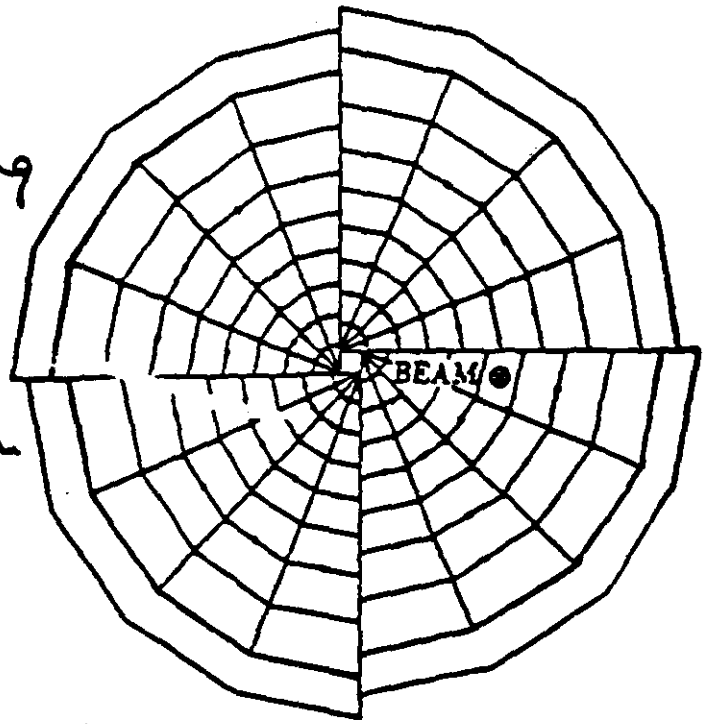
(number in () is flux < 100 keV)
arrows point to flux surfaces



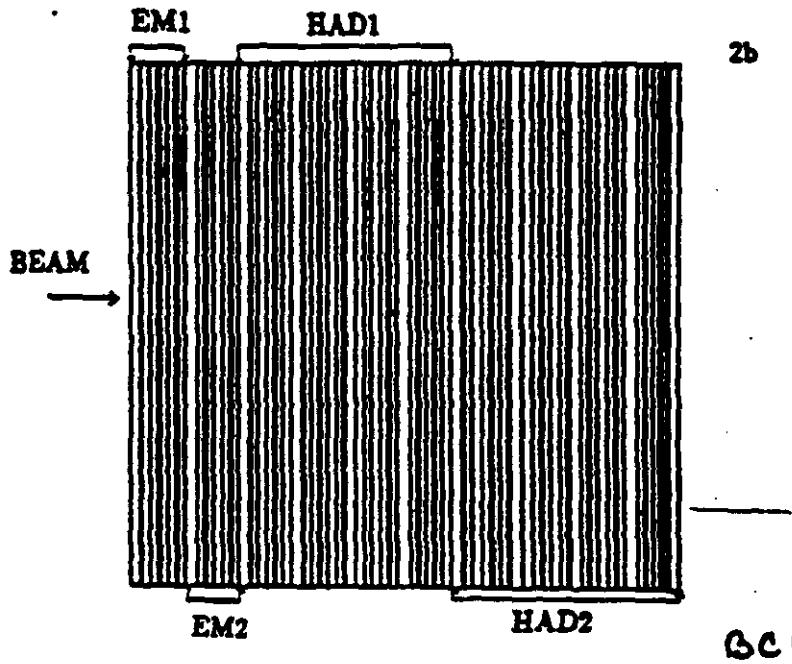

FCAL Z=491 cm
FCAL Z=525.32cm
dN/dE (#/MeV/cm^2)
Neutron Kinetic Energy (MeV)


FCAL Z=559.64cm

Benchmarking Data
E814 PCAL
Pb/scint sampling calorimeter



2a



2b

BC408/
KST1

FIGURE 2: E814 Participant Calorimeter
a) downstream view
b) longitudinal view

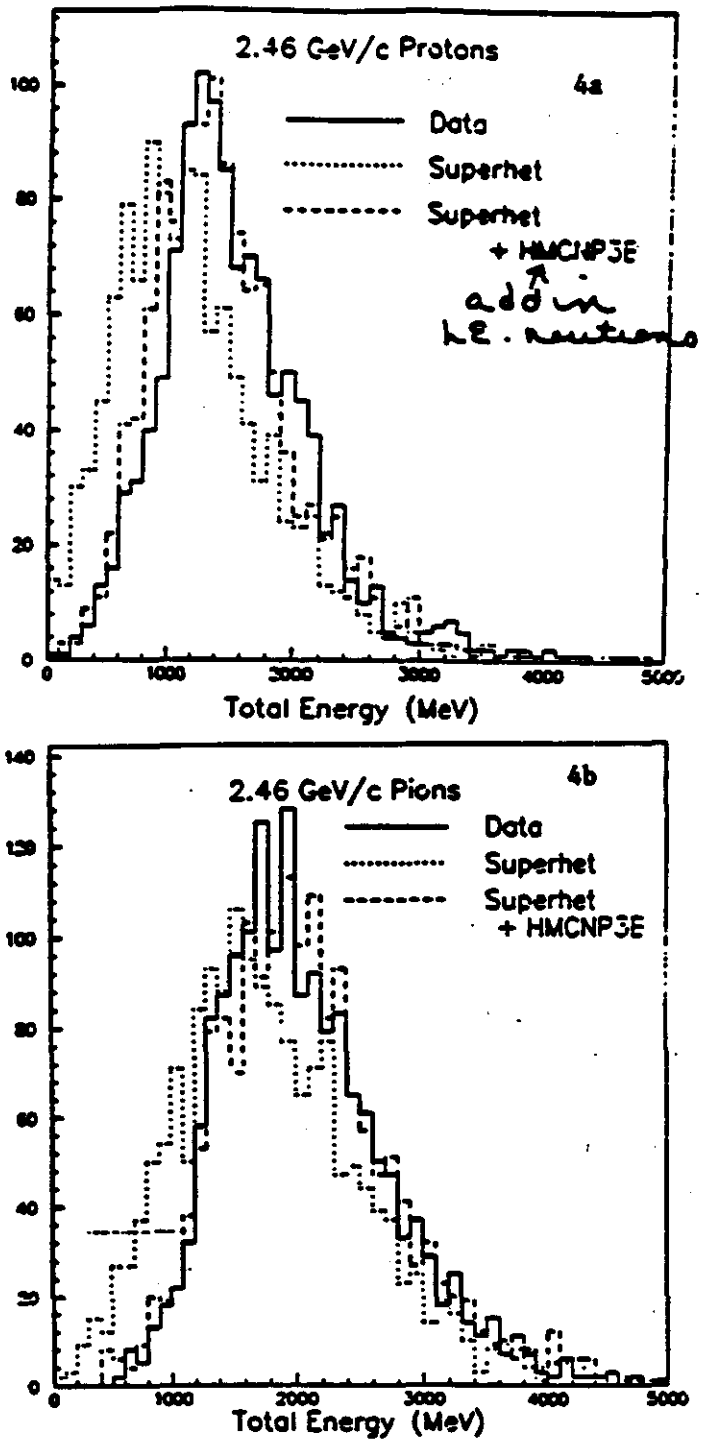


FIGURE 4: Effect of low energy neutrons

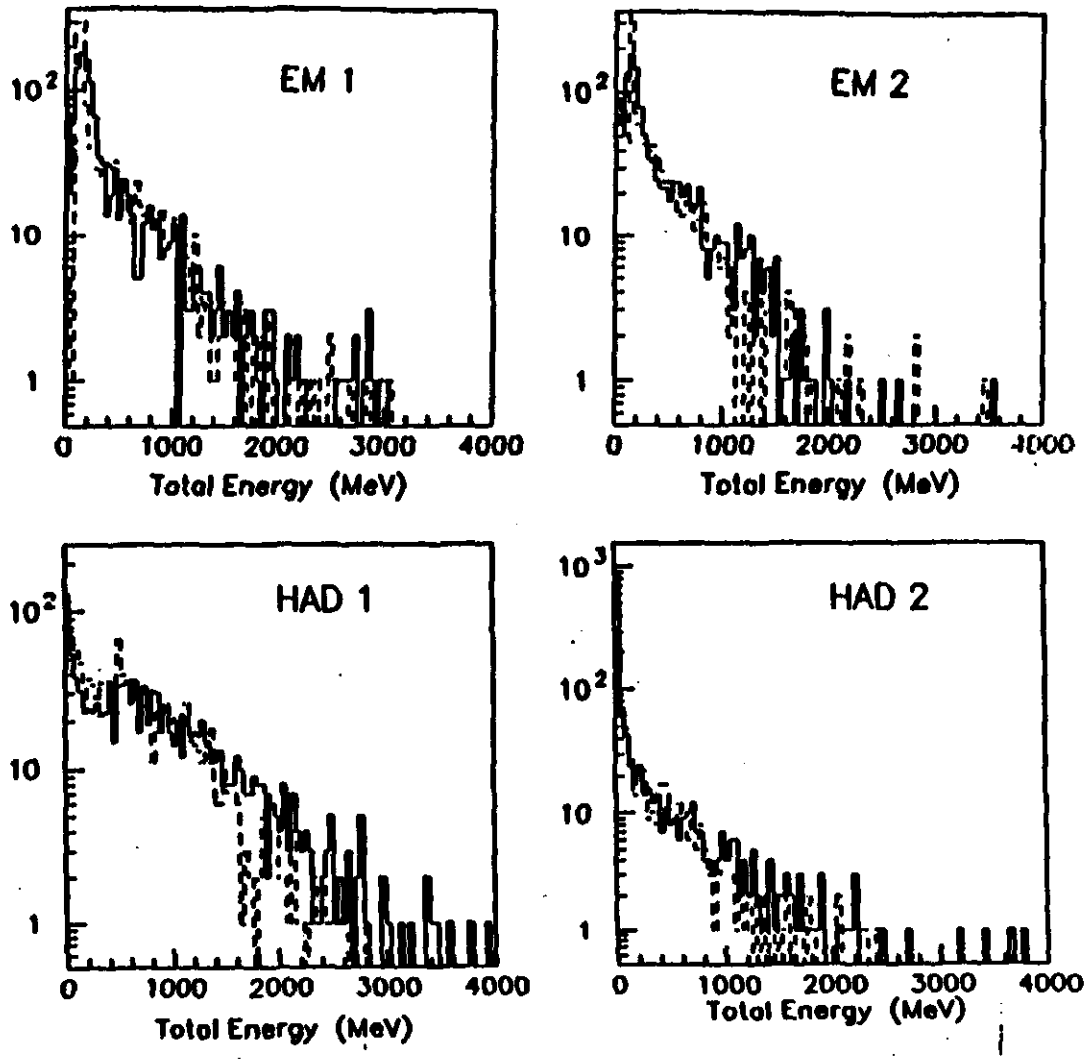


FIGURE 5: 2.46 GeV/c protons, energy deposited in various segments (data - solid) (simulation - dashed)
includes LE neutrons

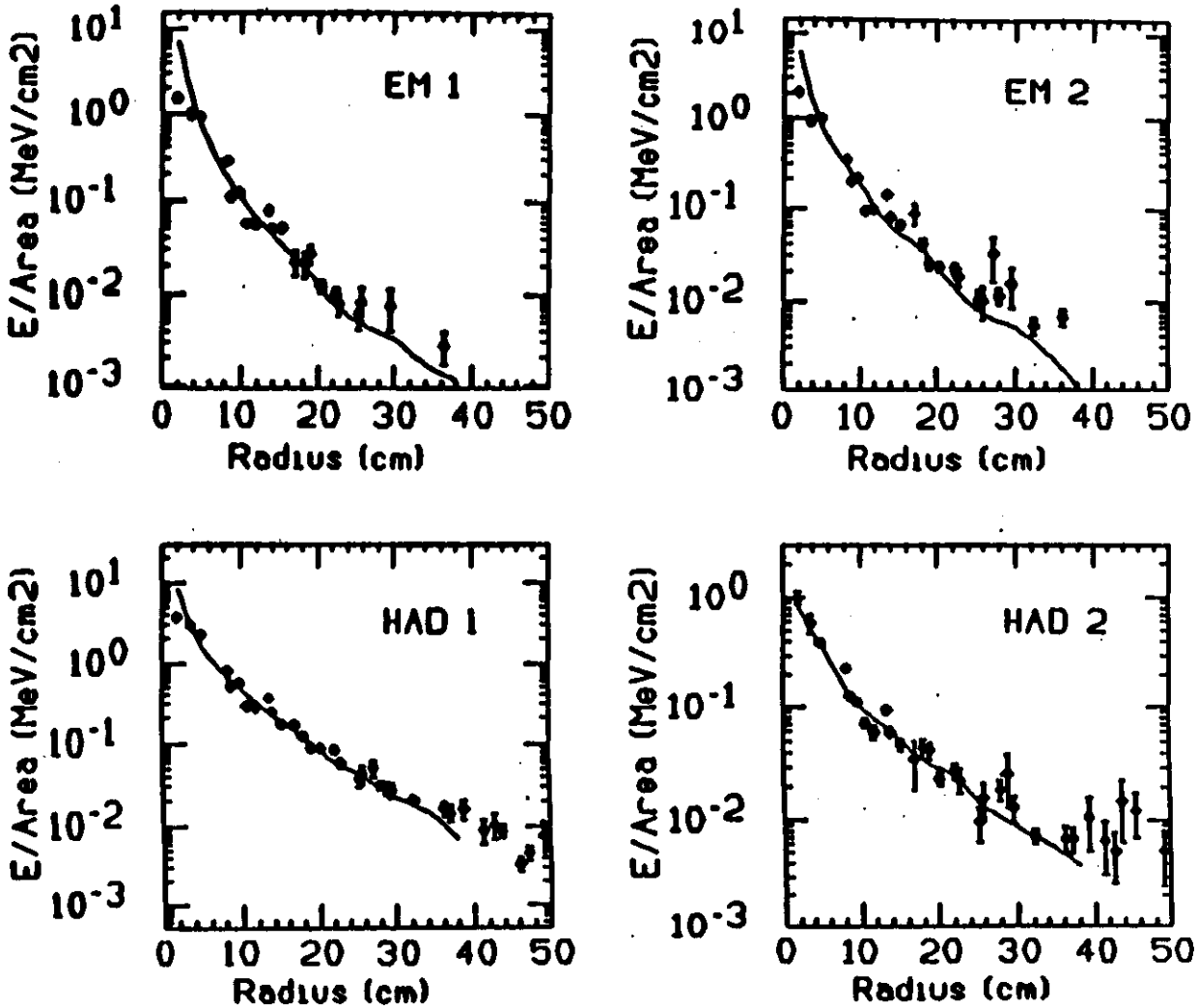


FIGURE 8: 2.46 GeV/c Pions, Radial Energy Distribution

points - data
line - simulations including HE neutrons

	(cm) RADIUS	(deg) ANGLE	<100 keV	>100 keV	(x 10^12 / year) TOTAL FLUX
)	92.5 - 115.2	9.4 - 11.33	3.6442	2.2349	5.8792
1)	115.2 - 135.2	11.33 - 13.23	3.096	1.8874	4.9834
2)	135.2 - 155.2	13.23 - 15.104	2.3536	1.5675	3.921
4)	155.2 - 175.2	15.104 - 16.95	2.2533	1.5587	3.8121
5)	175.2 - 195.2	16.95 - 18.75	1.8923	1.2233	3.1156
6)	195.2 - 215.2	18.75 - 20.52	1.5922	1.1946	2.7868
7)	215.2 - 235.2	20.52 - 22.25	1.478	1.1244	2.6026
8)	235.2 - 255.2	22.25 - 23.93	1.2507	.9135	2.1642
9)	255.2 - 275.2	23.93 - 25.57	1.1007	.8166	1.9173
10)	275.2 - 295.2	25.57 - 27.17	.9349	.7329	1.6679
11)	295.2 - 315.2	27.17 - 28.73	.7909	.6432	1.4340
12)	315.2 - 323.86	28.73 - 29.39	.7399	.5489	1.2889
TAL	92.5 - 323.86	9.4 - 29.39	1.4659	1.149	2.6149

MUON CHAMBERS Z = 575 cm

1st D.C. Z = 575 cm

1.0E12 = .1 Mhz

$$\text{FLUX}_{\text{NEUTRON}} = \sum_i \frac{1}{|\cos \psi_i|}$$

ψ_i = angle between particle direction and surface normal

upper energy bin limit MeV

neutron flux across surface 169 in segment 16

energy	0-1μsec time= 1.000D+03		1μsec-1msec time= 1.000D+06		>1msec time= 1.000D+10	
1.0000D-05	0.00000D+00	.0000	3.05723D+00	.1318	6.49649D-01	.2340
2.0000D-05	0.00000D+00	.0000	8.12633D-01	.2059	0.00000D+00	.0000
1.0000D-04	0.00000D+00	.0000	1.80763D-01	.1283	0.00000D+00	.0000
2.0000D-04	0.00000D+00	.0000	7.97424D-02	.1909	0.00000D+00	.0000
1.0000D-03	0.00000D+00	.0000	4.28944D-02	.1337	0.00000D+00	.0000
2.0000D-03	0.00000D+00	.0000	2.37398D-02	.1378	0.00000D+00	.0000
1.0000D-02	0.00000D+00	.0000	8.90107D-03	.1026	0.00000D+00	.0000
2.0000D-02	0.00000D+00	.0000	2.46252D-02	.0962	0.00000D+00	.0000
1.0000D-01	4.90291D-05	.3503	1.27351D-02	.0923	0.00000D+00	.0000
2.0000D-01	6.63859D-04	.1160	4.01199D-03	.1027	0.00000D+00	.0000
1.0000D+00	5.22224D-04	.1093	2.55122D-04	.1100	0.00000D+00	.0000
2.0000D+00	3.65873D-05	.1820	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+01	2.64958D-06	.1957	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+01	1.73806D-07	.4971	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+02	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+02	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+03	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+03	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+04	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+04	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
total	5.47609D-04	.1057	2.06076D-03	.0924	6.49649D-06	.2340

energy	time total	
1.0000D-05	3.70687D+00	.1228
2.0000D-05	8.12633D-01	.2059
1.0000D-04	1.80763D-01	.1283
2.0000D-04	7.97424D-02	.1909
1.0000D-03	4.28944D-02	.1337
2.0000D-03	2.37398D-02	.1378
1.0000D-02	8.90107D-03	.1026
2.0000D-02	2.46252D-02	.0962
1.0000D-01	1.27842D-02	.0922
2.0000D-01	4.67585D-03	.1009
1.0000D+00	7.77345D-04	.1061
2.0000D+00	3.65873D-05	.1820
1.0000D+01	2.64958D-06	.1957
2.0000D+01	1.73806D-07	.4971
1.0000D+02	0.00000D+00	.0000
2.0000D+02	0.00000D+00	.0000
1.0000D+03	0.00000D+00	.0000
2.0000D+03	0.00000D+00	.0000
1.0000D+04	0.00000D+00	.0000
2.0000D+04	0.00000D+00	.0000
total	2.61486D-03	.0939

TOTAL FLUX ON MUON 1

Z = 575 cm over entire surface, r = 95.2 → 323.86 cm

numbers are #/ per cm²/ISAJET event

multiply × 1E15 to get on SSC yearly basis (1×10⁷ sec)

relative errors also given

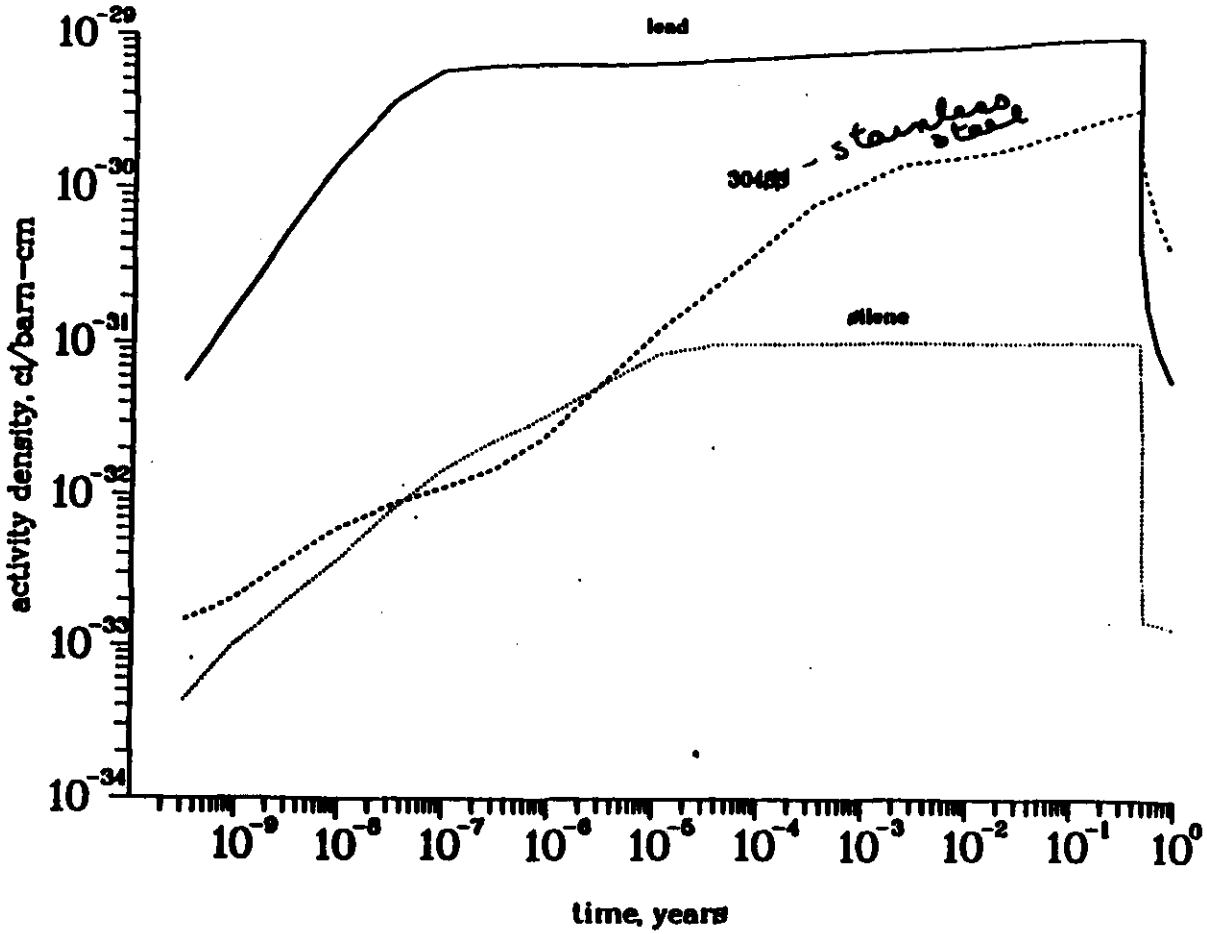


Fig. 6. Calculated activity density in L* hadron calorimeter materials during a 0.5-year irradiation and 0.5-year down period.

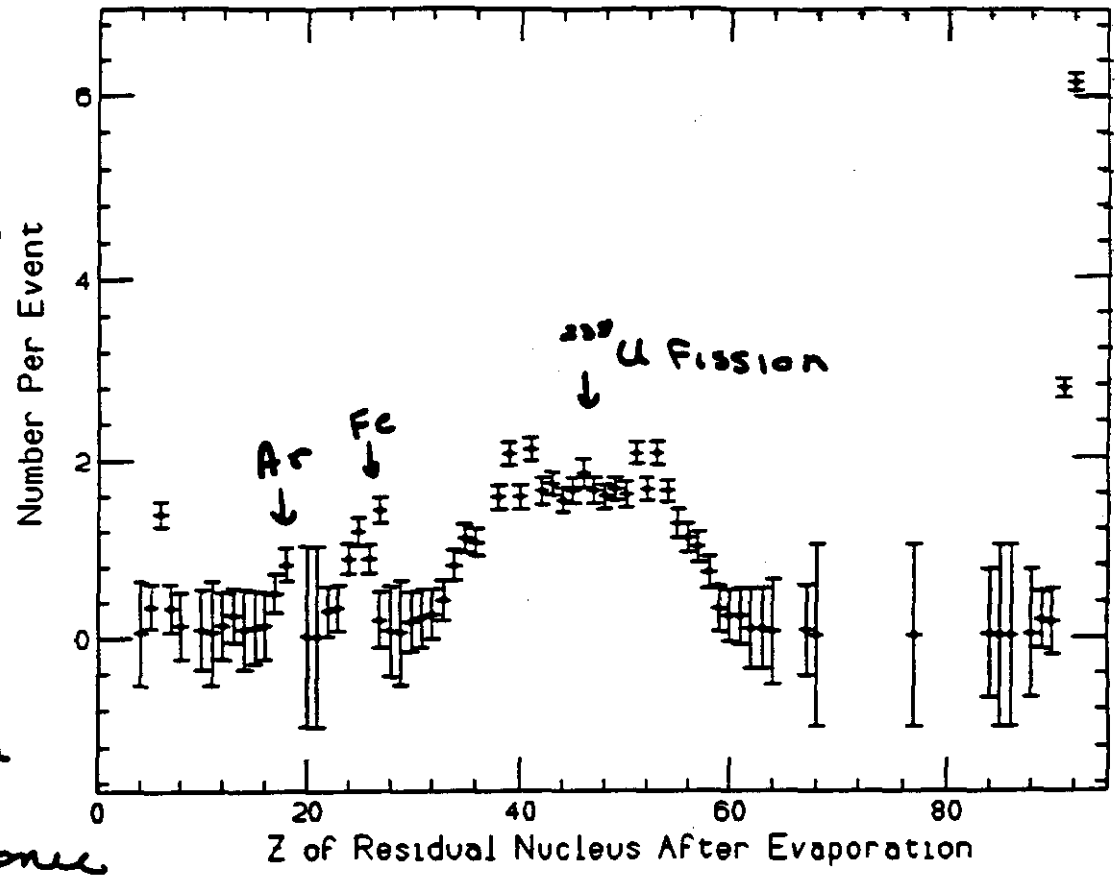
CINDER90

L* FCAL figures

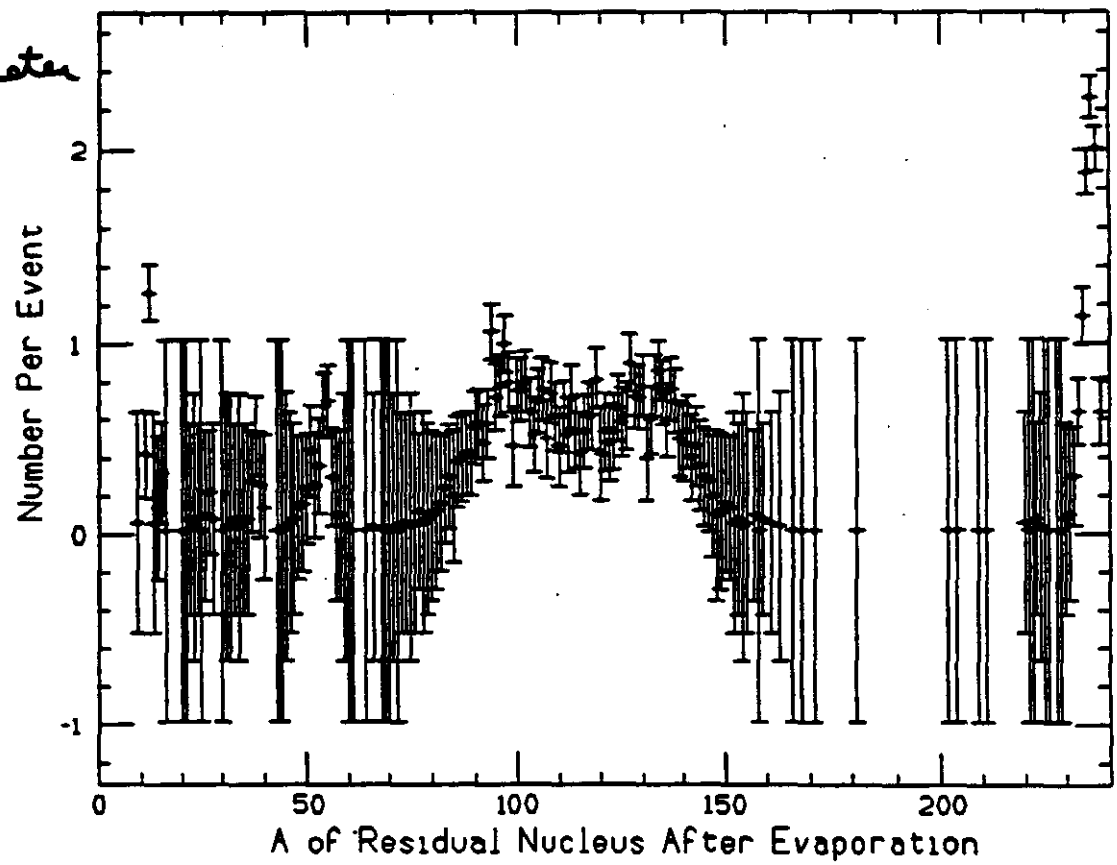
~~REGION~~

ATOMIC FRACTIONS

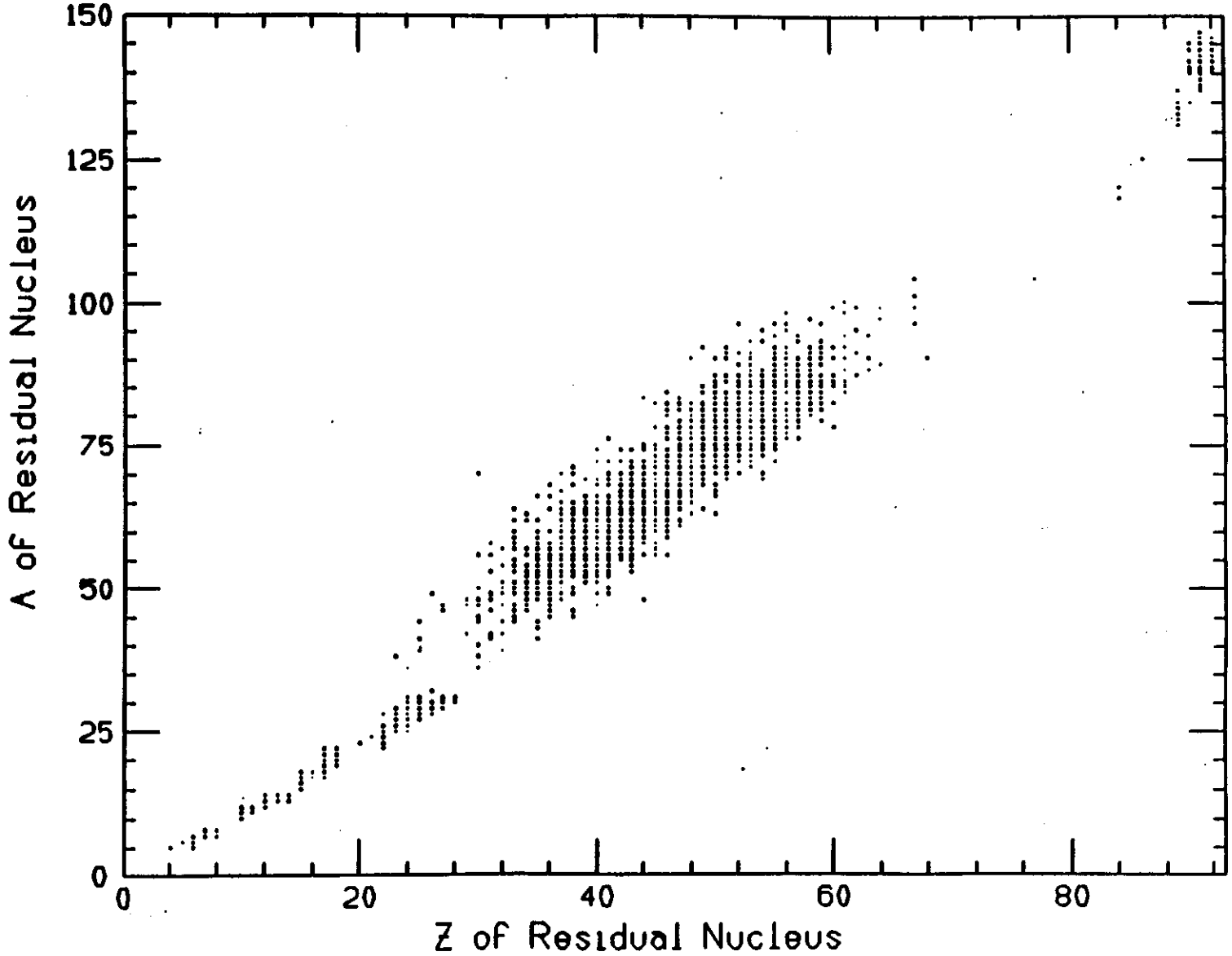
Z	%
1	11.3
6	6.7
7	.5
8	6.2
14	2.6
18	8.6
26	8.7
92	51.2



last Hadronic section closest to beam in calorimeter endcap



REGION 44



ISOTOPE PRODUCTION
IN HADRONIC CALORIMETER

Z	FCAL	HADRONIC	EM
4	0.04	0.06	0.13
5	0.37	0.46	1.19
6	1.55*	1.38 *	5.18*
7	0.11*	3.39 *	0.74
8	0.02*	0.14 *	0.33*
9	0.06	0.01	0.14
10	0.08	0.10	0.11
11	0.06	0.06	0.09
12	0.08	0.14	0.40
13	0.10	0.26	0.58
14	0.19	0.10*	1.09*
15	0.04	0.12	2.00
16	1.33	0.14	5.07
17	3.44	0.50	15.97
18	6.32*	0.82*	25.69*
19	0.23		0.11
20	0.38		0.23
21	0.53	0.02	0.43
22	0.75	0.30	1.20
23	1.38	0.34	3.01
24	2.92	0.87 *	4.91 *
25	5.84	1.88	7.30
26	14.36	0.88 *	6.60 *
27	33.46	0.20	1.28
28	23.56 *	0.08 *	0.25 *
29	10.98 *	0.06	0.04
30	0.15	0.18	0.02
31	0.06	0.22	
32	0.11	0.26	0.04
33	0.15	0.42	0.01
34	0.11	0.80	0.07
35	0.21	1.10	0.07
36	0.15	1.06	0.08
37	0.18	1.42	0.04
38	0.19	1.56	0.07
39	0.15	2.04	0.05
40	0.25	1.56	0.12
41	0.15	2.09	0.03
42	0.21	1.62	0.09
43	0.16	1.70	0.06
44	0.08	1.52	0.06
45	0.39	1.63	0.07
46	0.28	1.82	0.07
47	0.18	1.63	0.05
48	0.56	1.56	0.05
49	0.29	1.64	0.02
50	0.45	1.50	0.02
51	0.29	2.05	0.02
52	0.55	1.64	0.03
53	0.46	2.04	0.06
54	0.25	1.62	0.01
55	0.31	1.25	0.05
56	0.62	1.10	0.04
57	0.37	0.99	0.02

number of ~~atoms~~ nuclei per ISAJET event

* - original composition

58	0.68	0.72	0.02
59	0.38	0.32	0.01
60	0.78	0.24	0.08
61	1.13	0.24	0.04
62	0.85	0.10	0.03
63	1.02	0.10	0.01
64	1.26	0.06	0.05
65	1.23	0.08	0.01
66	1.23		0.03
67	2.68		0.01
68	3.18	0.02	0.04
69	4.62		0.08
70	7.48		0.08
71	16.50		0.07
72	32.50		0.03
73	212.10		0.11
74	792.20 *		0.14
75	0.49		0.11
76	0.01		0.26
77		0.02	0.37
78			0.70
79			0.82
80			3.19
81			14.75
82			63.30*
83			0.03
84		0.04	
85		0.02	
86		0.02	
88		0.04	
89		0.02	
90		0.18	
91		2.70	
92		6.10 *	

[EOB]

Calorimeter Depth & Muon Backgrounds

F.Taylor, H.Gordon, R.McNeil

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

Agenda: Combined Calorimeter Depth / Muon Pattern Recognition

Part I Calorimeter Depth

R. McNeil	Rates vs Cal Depth in Barrel	30 min
M Mohammadi	Rate vs Cal Depth in Endcap	30 min
H. Gordon et al	Cal depth vs outer radius, mat'l, cost	30 min
M. Seiman	Magnetic Field effects on rates	15 min
Atiya / Moore / Weneus / Waters	Neutrons	30 min
McNeil	Energy loss vs Cal depth, mat'l	15 min
F. Taylor et al	Muon system performance vs Calor, costs	15 min
C. Yanagisawa	Muon trigger Performance	20 min

Part II Pattern Recognition

E. Pless	Pattern Recognition	40 minute ~~30 min~~
F. Paige	Muon Acceptance	15 min

Discussion Period.

K. McNeil
3-10-92

Goals of Calorimeter Depth Session

1. Define a set of requirements / recommendations for the design of the GEM Calorimetry
   - from Muon Backgrounds, triggering, momentum resolution and costs considerations

Partial list of requirements / recommendations to define

- Max outer radius, z of CAL
- Minimum depth of cal in λ as function of rapidity

} Fix Baseline GEOMETRY

- Materials (ρ, z, # r.l.)
- Muon energy loss measurement
-
-

2. Identify further issues to address for PAC review and TDR

- Set time schedule / milestones
- Assign tasks.

R. McNeil
3-10-92

How thick should the GEM Barrel Calorimeter Be?

- From a Hadron Punchthrough point of view

Outline

1) Criteria for evaluating the Calorimeter Thickness
2) The simulation
3) Results
4) Summary / recommendations

Criteria for Evaluating the GEM Barrel Calorimeter Thickness

Absolute Rates : Rate limitations for RPCs

Criteria 1 : At the highest SSC Luminosity, the rate of particles exiting the barrel calorimeter should be less than 20 Hz/cm^2.

Highest SSC Luminosity $\equiv$ 10^{34} cm^{-2}
Particle $\equiv$ Charged Particles (neutrons/γs ?)

Punchthrough vs Real Muons

Charged Particles in GEM Muon system are composed of

1. Prompt Muons – c, b, t quark decays } real muons in calorimeter
2. Muons from π/K decays in inner tracker } real muons in calorimeter
3. Hadron Punchthrough

Criteria 2.1 : The overall rate of hadron punchthrough particles should be much less than the rate of prompt muons + muons from π/K decays.

Criteria 2.2 : The rate of particles above some P_T threshold from hadron punchthrough should be much less than that from prompt muons + decay muons.

Much less than $\equiv$ < 1/3 of total rate
P_T Threshold $\equiv$ 10 GeV/c

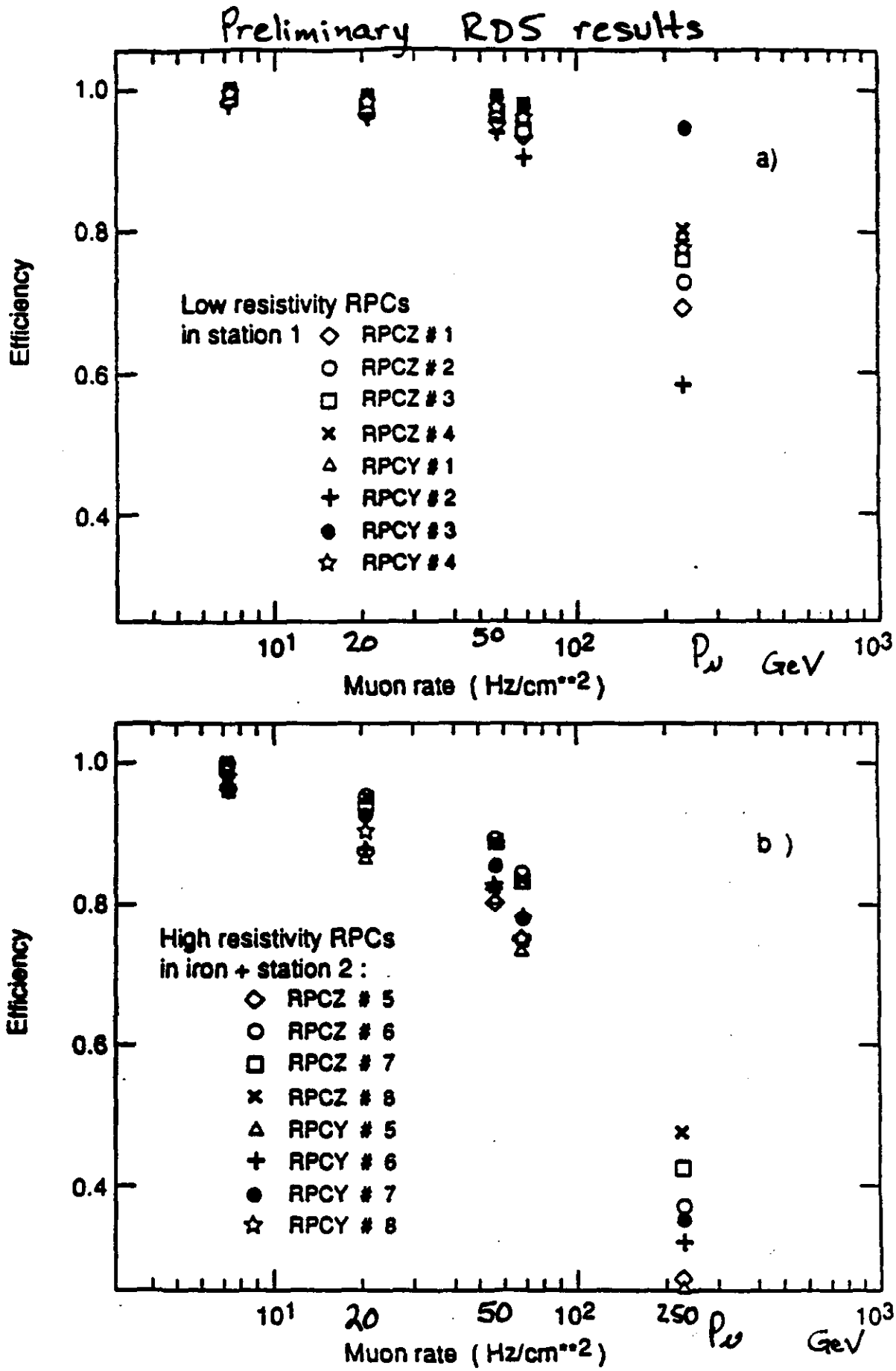

Preliminary RDS results
a)
Efficiency
1.0
0.8
0.6
0.4
Low resistivity RPCs
in station 1
RPCZ # 1
RPCZ # 2
RPCZ # 3
RPCZ # 4
RPCY # 1
RPCY # 2
RPCY # 3
RPCY # 4
10¹
20
50
10²
Pν GeV
10³
Muon rate (Hz/cm**2)
b)
Efficiency
1.0
0.8
0.6
0.4
High resistivity RPCs
in iron + station 2 :
RPCZ # 5
RPCZ # 6
RPCZ # 7
RPCZ # 8
RPCY # 5
RPCY # 6
RPCY # 7
RPCY # 8
10¹
20
50
10²
250
Pν GeV
10³
Muon rate (Hz/cm**2)

FIG. 20

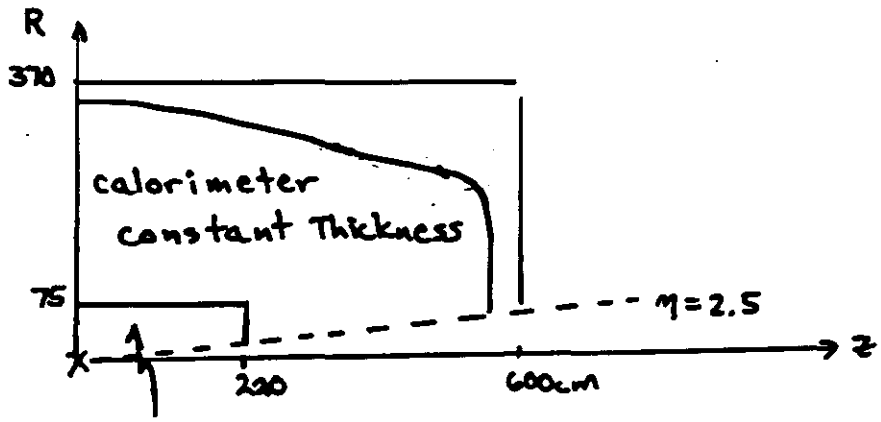
The Simulation

ISAJET TWOJET Events used with

P_T (JET) > 4 GeV/c $M_t = 140\,GeV/c^2$ $\Rightarrow$ $\sigma_{TOT} = 140\,\mu b$

150K events generated in 150 non overlapping P_T bins

Detector



π/K decay in tracking volume 75cm in radius, 440cm in length

Muon energy loss = 218 MeV / λ

PCHTHR called for Stable hadrons ⇒ Punchthrough

In barrel particles with P_T < 1.3 GeV/c curl around and give rise to ≥ 2 hits in muon system

Event Sample run through constant thickness calorimeter 6, 8, 10, 12, 14, 16 λ thick

Rates converted into Hz per area to consider criteria 1 and divided in to source components (and in rapidity bins) to consider criteria 2

ISAJET TWØJET Events PT(Jet)>4GeV/c $L=10^{33}$

After Constant thickness Calorimeter

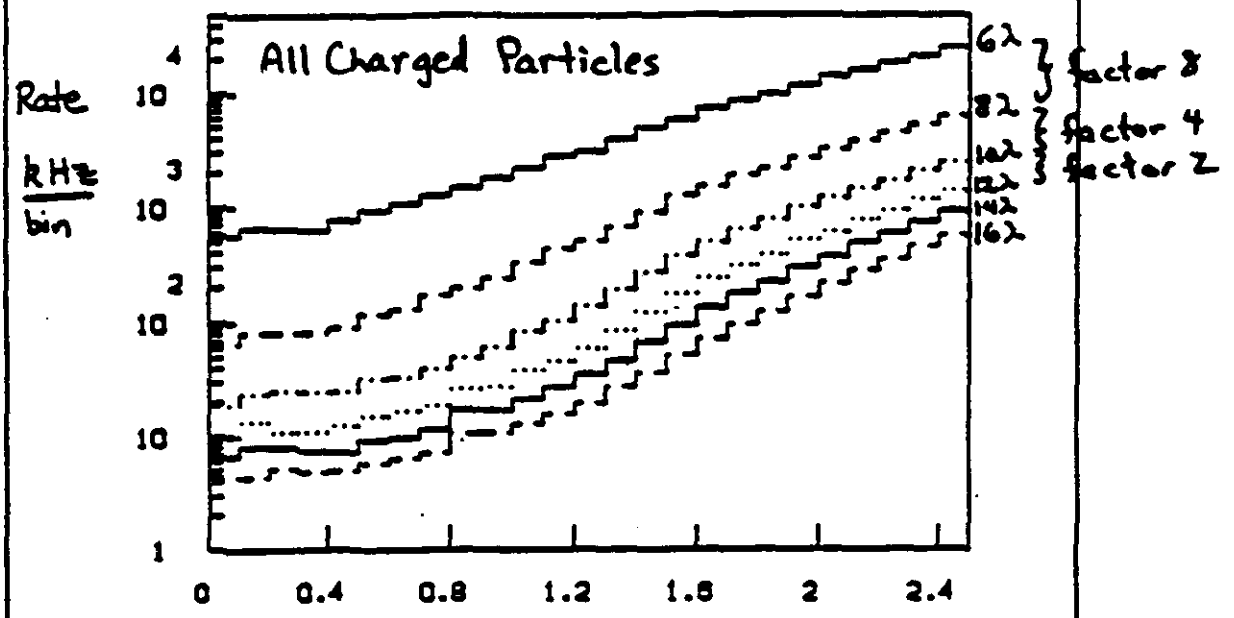
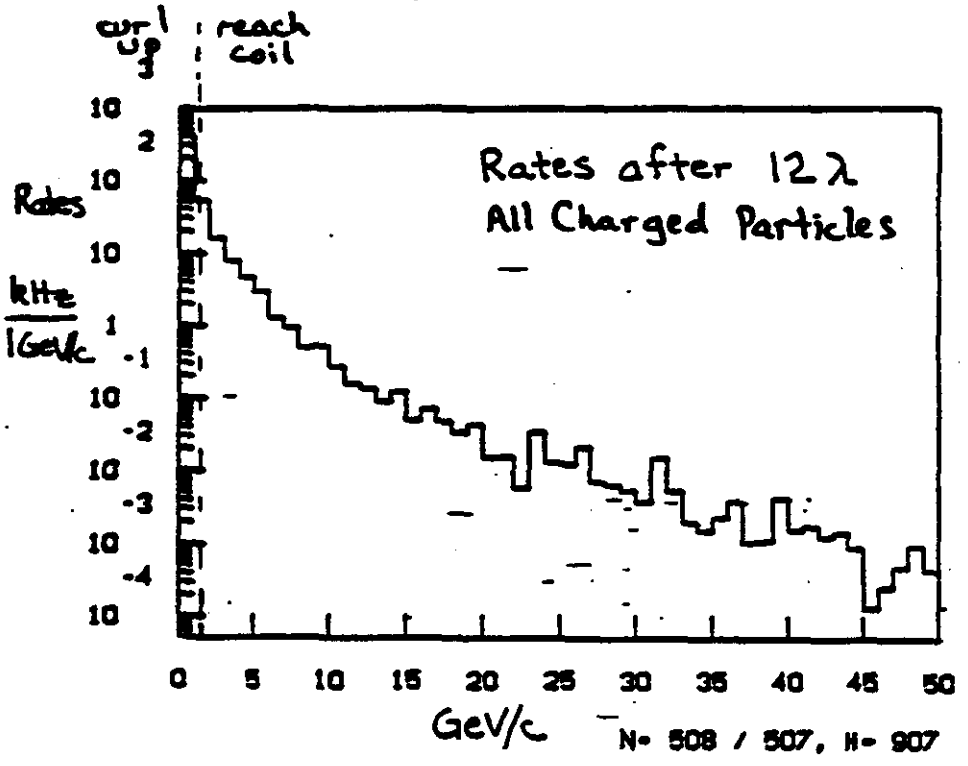


Figure 1

N= 165189 / 165188, H= 11

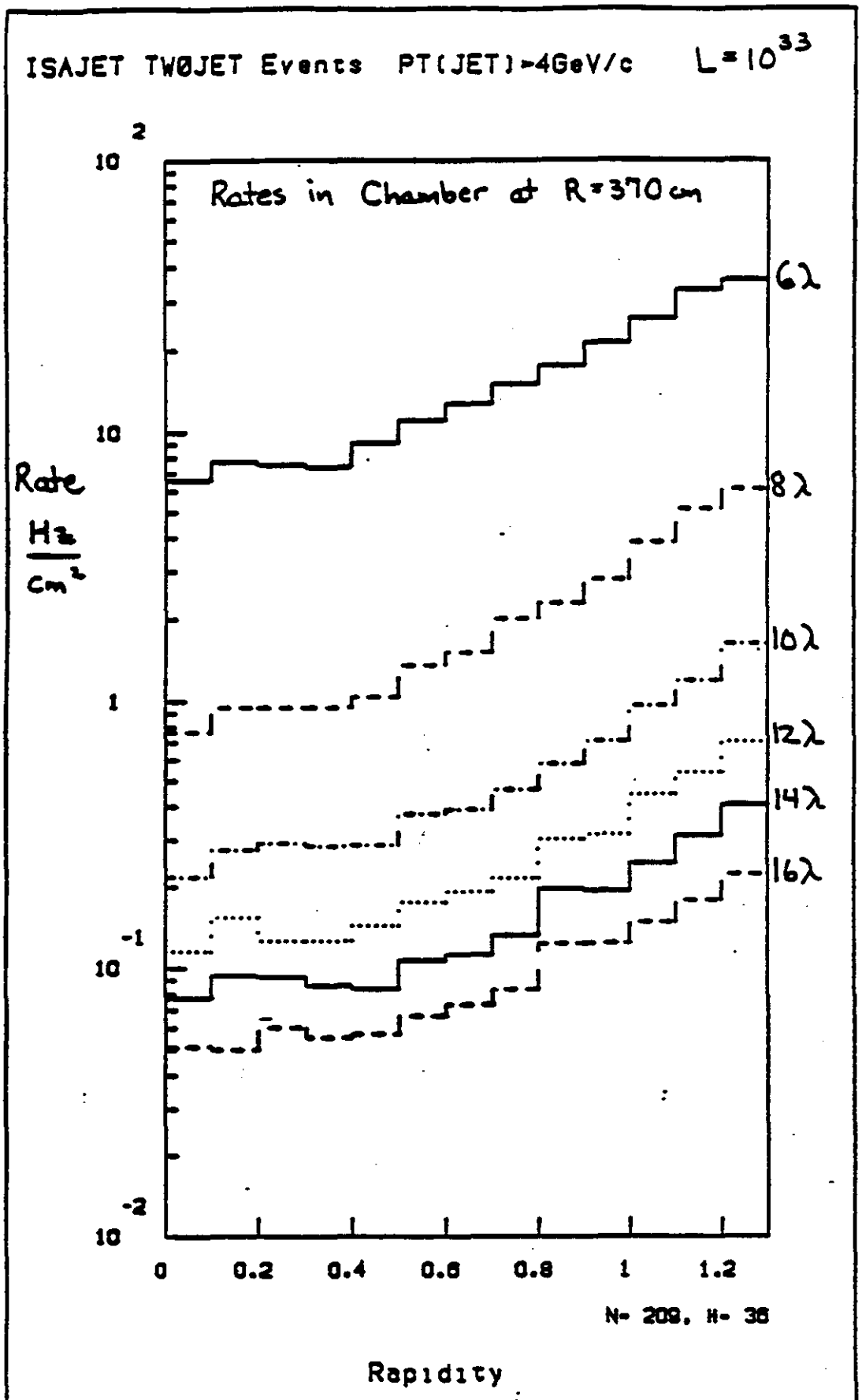
|ETA| All Pt



N= 508 / 507, H= 907

PT 0< ETA <1.5

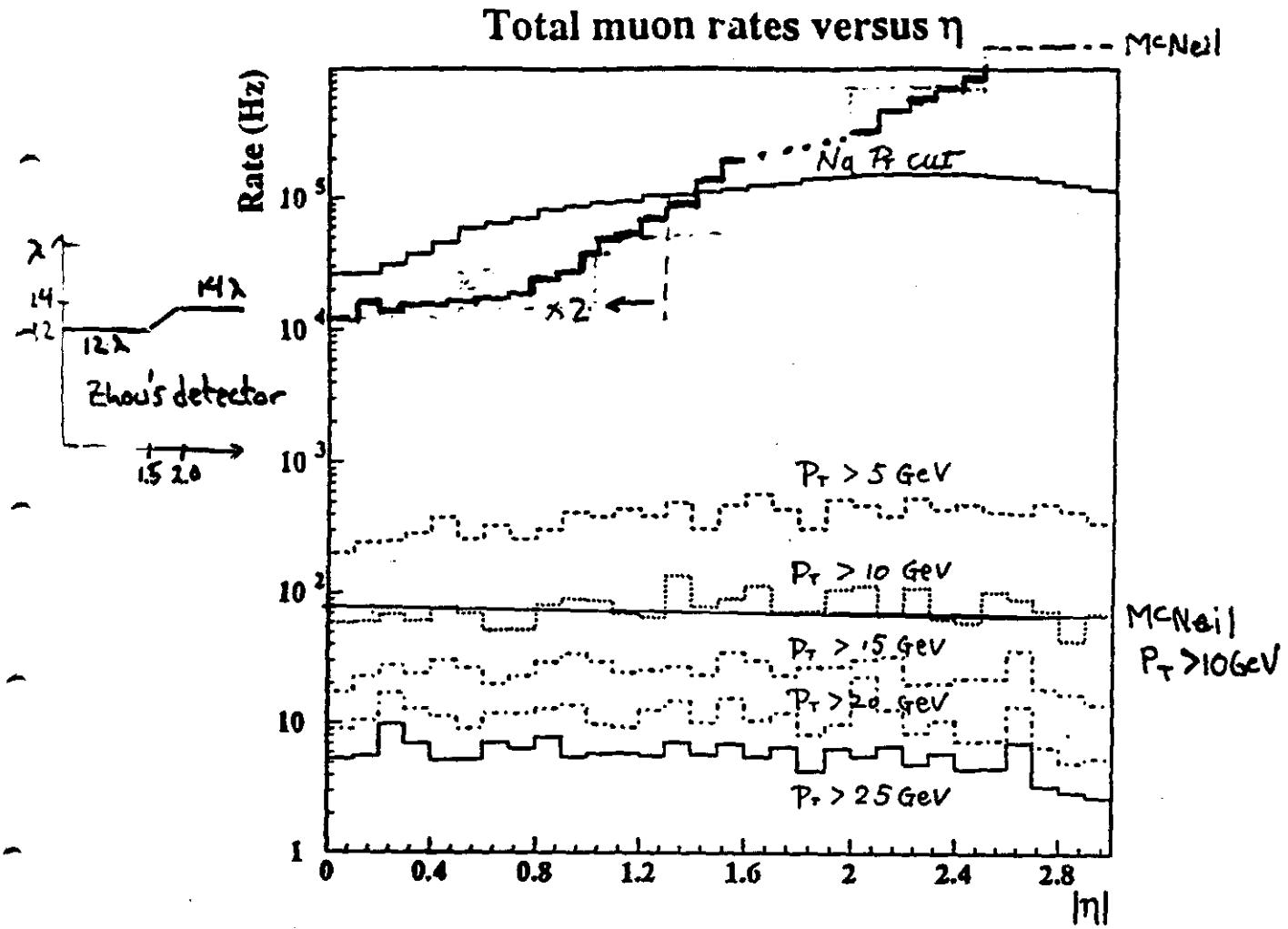
Figure 2



Rates after Constant Thickness Calorimeter

Figure 3

Chang & Zhou - GEM LOI



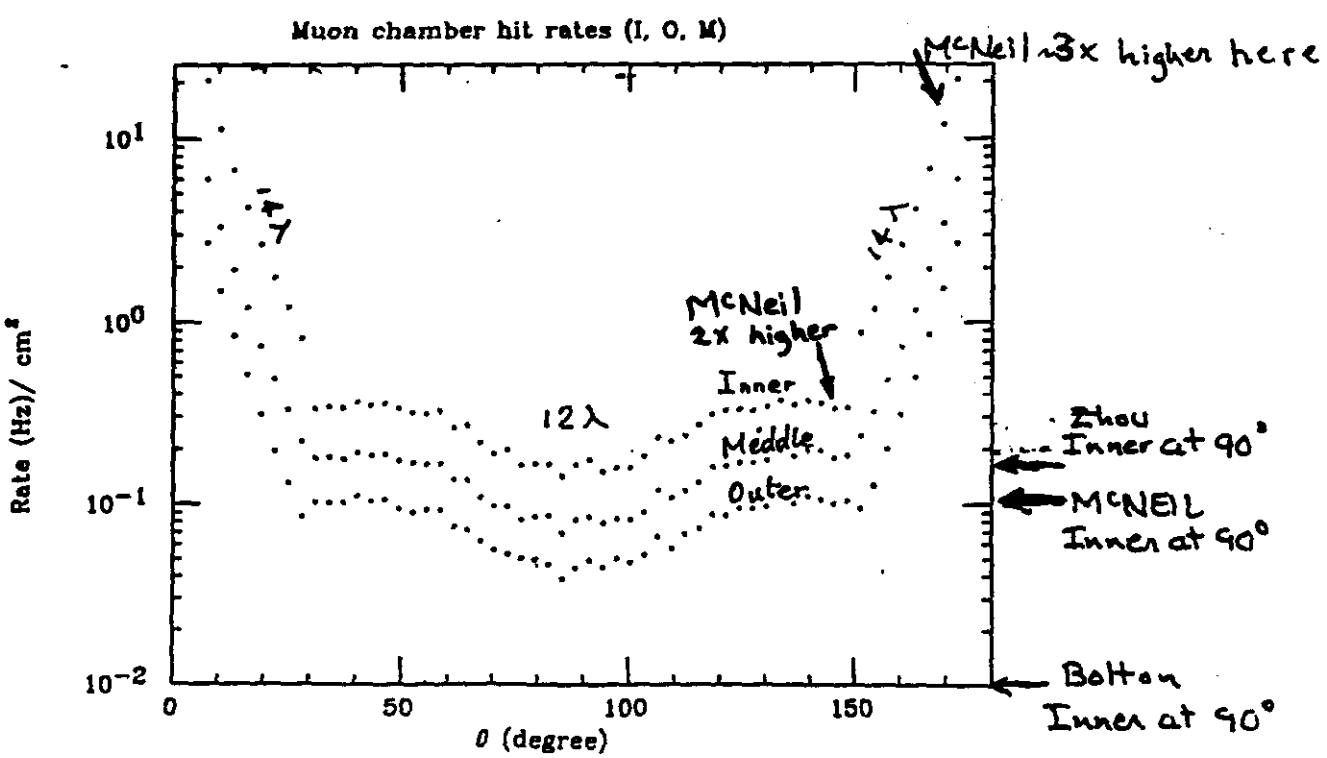


Figure 5

Results

<u>Absolute Rates</u> Summary : Rates @ $10^{34} cm^{-2}$

Cal Depth	$\eta = 0$	$\eta = 1.3$
6λ	70 Hz/cm^2	400 Hz/cm^2
8λ	9	60
10λ	$\boxed{3}$	20
12λ	1.2	$\boxed{7}$
14λ	0.9	4
16λ	0.5	2

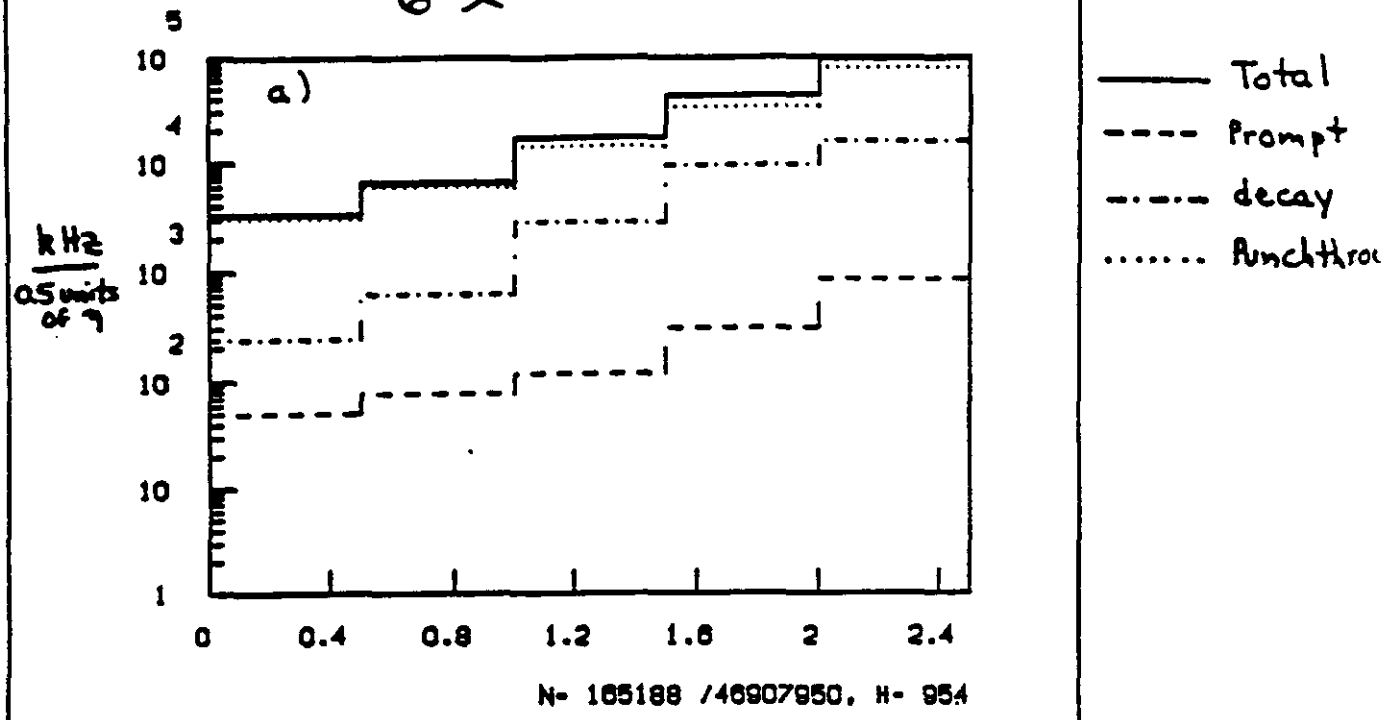
Assuming factor 3 uncertainty

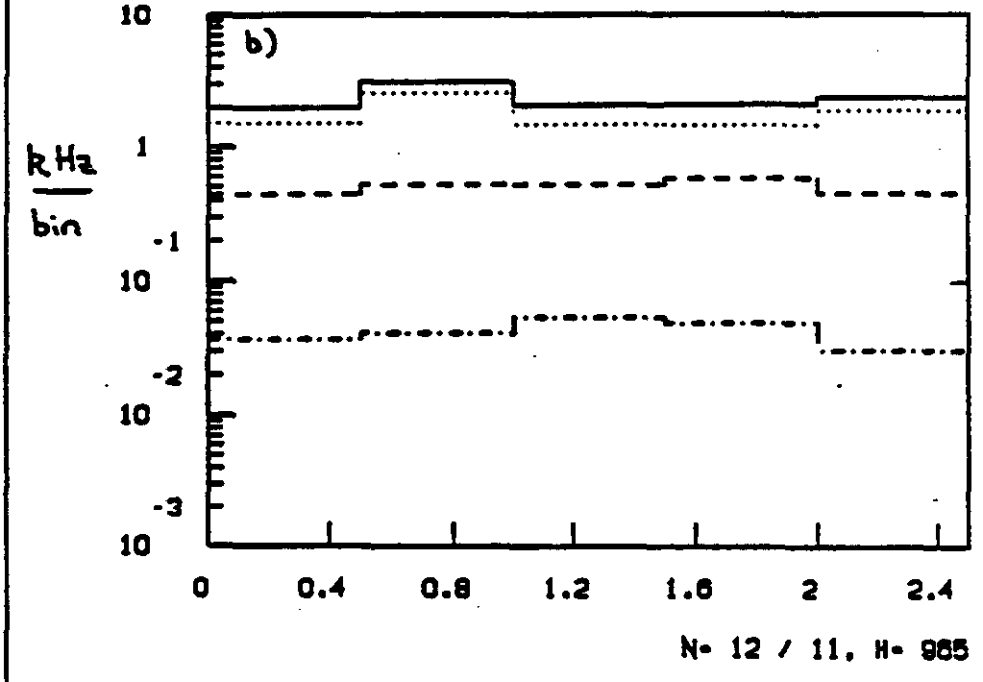
at 90° ($\eta = 0$) a 10λ Calorimeter satisfies Criteria 1

at 30° ($\eta = 1.3$) a 12λ Calorimeter satisfies Criteria 1

ISAJET TWOJET Events PT(JET)>4GeV/c $L = 10^{33}$

62



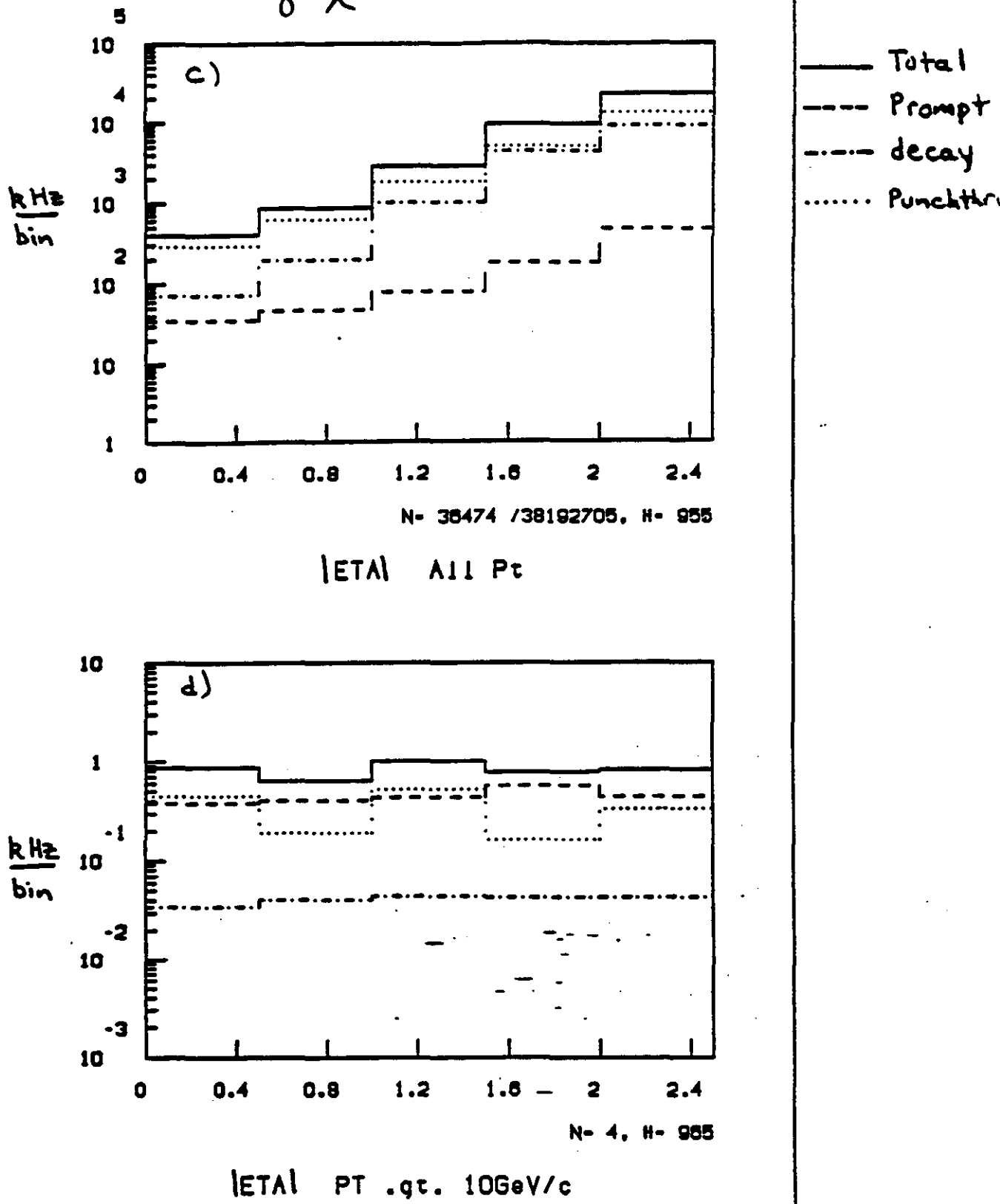


Rates after Constant Thickness Calorimeter - 61

Figure 4a-b

ISAJET TWØJET Events PT(JET) >4GeV/c L= 10^{33}

8 λ

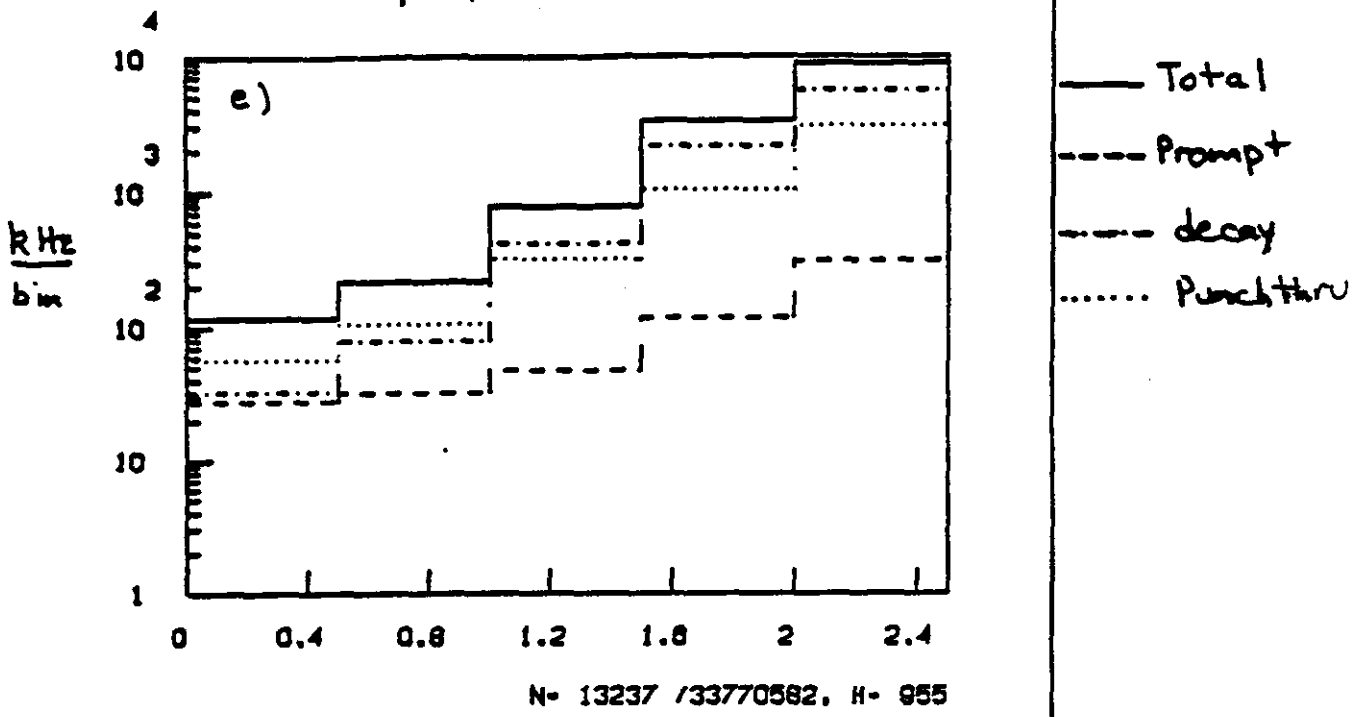


Rates after Constant Thickness Calorimeter - 81

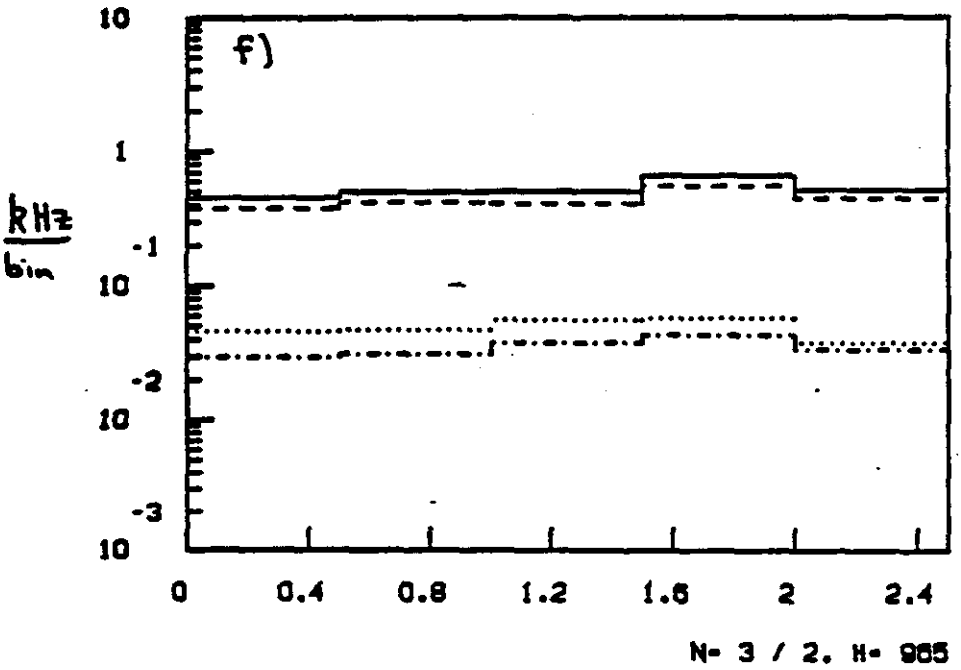
Figure 4 c-d

ISAJET TWØJET Events PT(JET)>4GeV/c L=10^{33}

102



|ETA| All PT



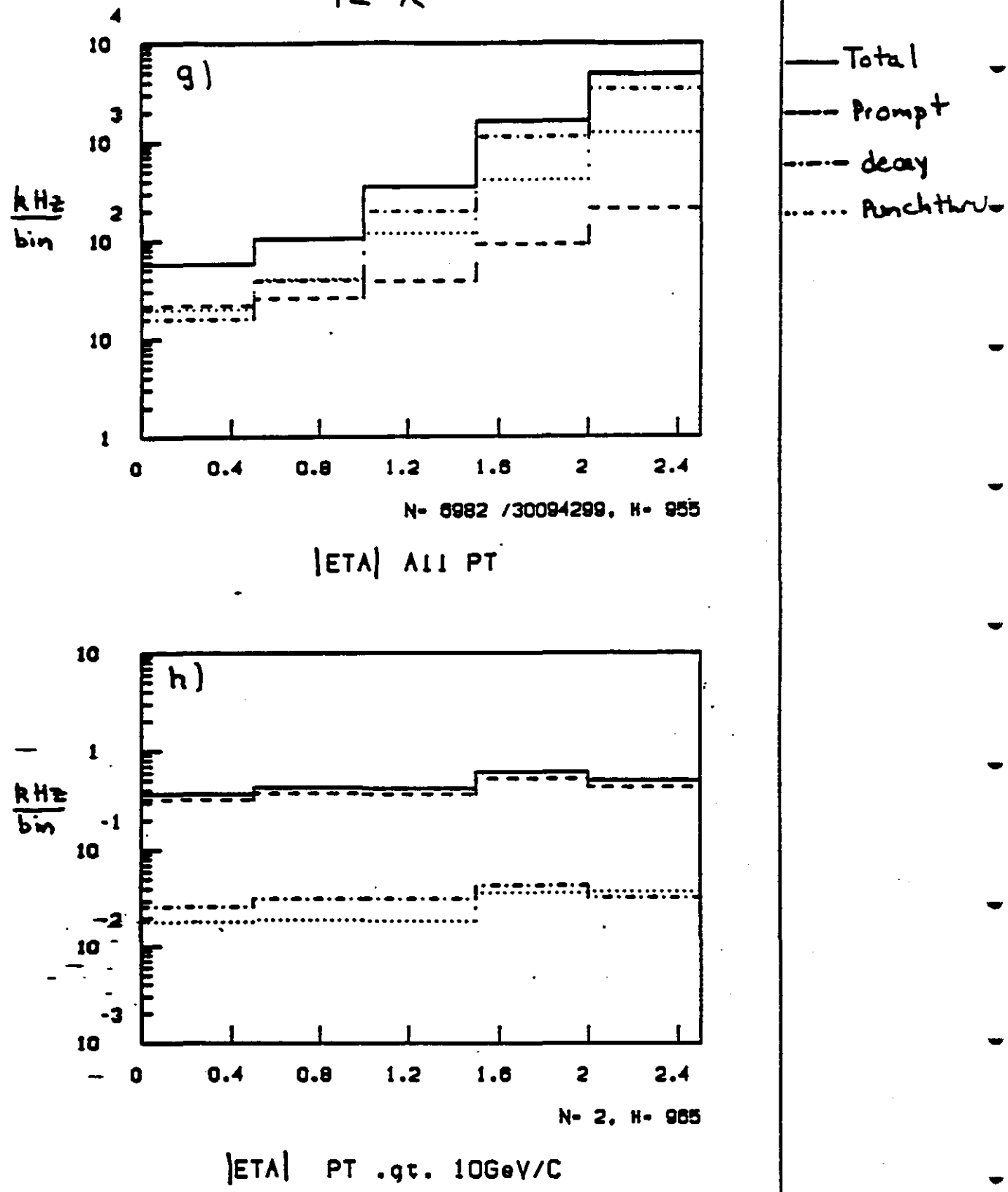
|ETA| PT .gt. 10GeV/c

Rates after Constant Thickness Calorimeter - 101

Figure 4e-f

ISAJET TWØJET Events PT(JET)>4GeV/c $L=10^{33}$

12 λ

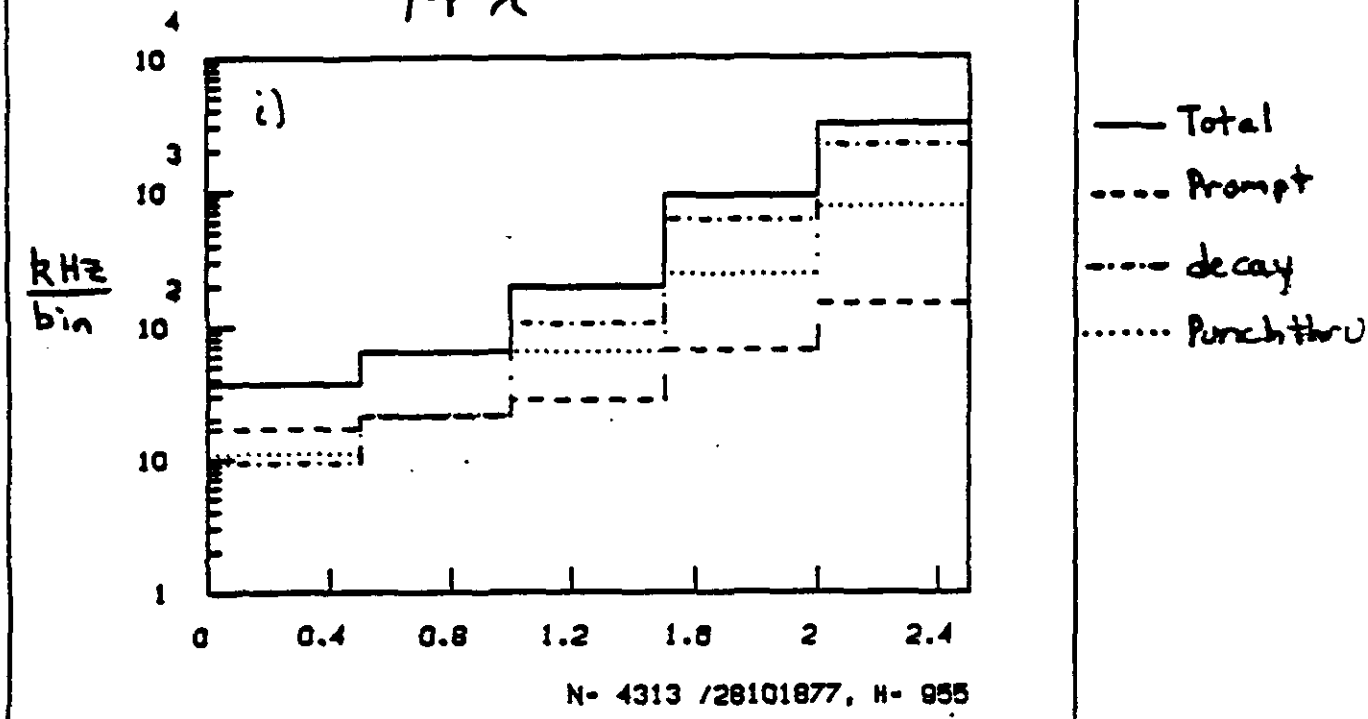


Rates after Constant Thickness Calorimeter - 121

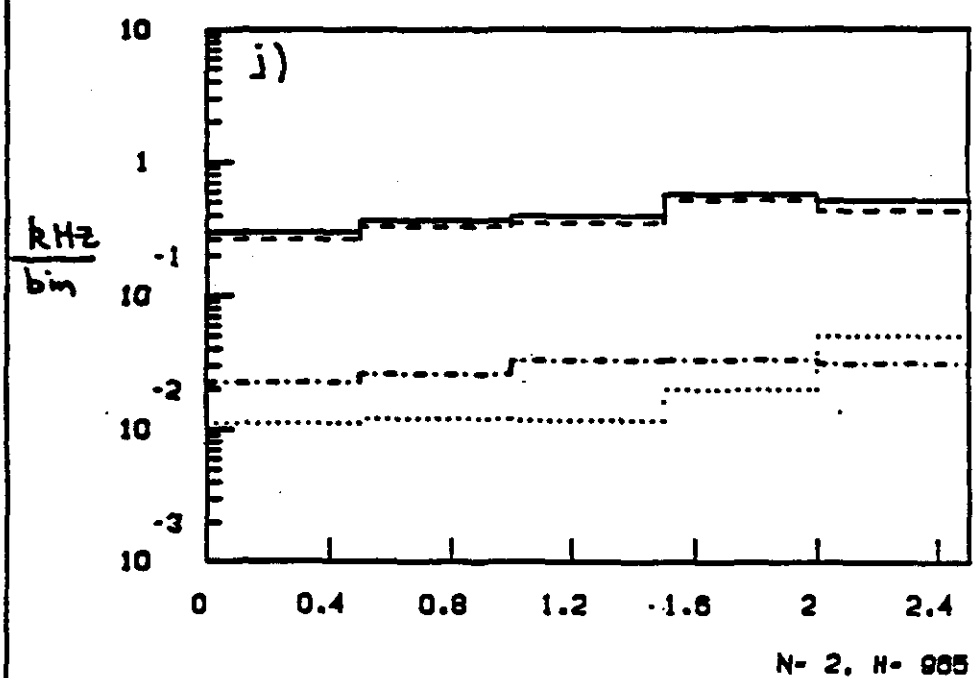
Figure 4 g-h

ISAJET TWØJET Events PT(JET)>4GeV/c $L=10^{33}$

14 λ



|ETA| All PT



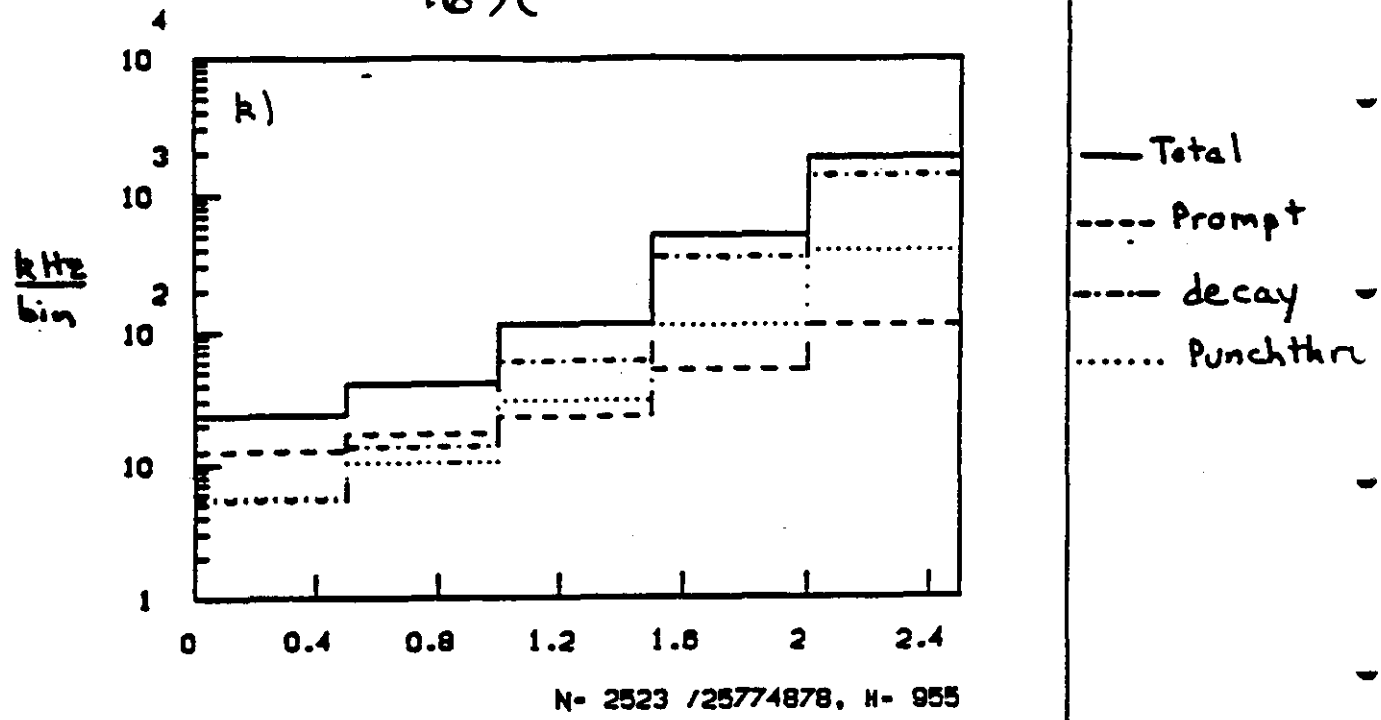
|ETA| PT .gt. 10GeV/c

Rates after Constant Thickness Calorimeter - 141

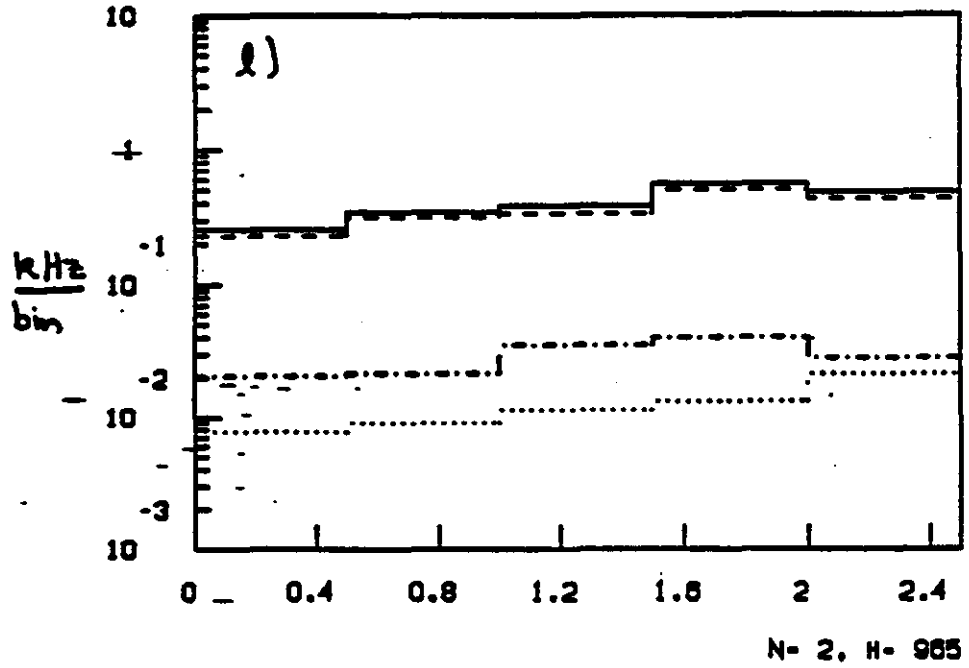
Figure 4 i-j

ISAJET TWØJET Events PT(JET)>4GeV/c $L=10^{33}$

16λ



|ETA| All PT



|ETA| PT .gt. 10GeV/c

Rates after Constant Thickness Calorimeter - 161

Figure 4 k-l

Conclusions

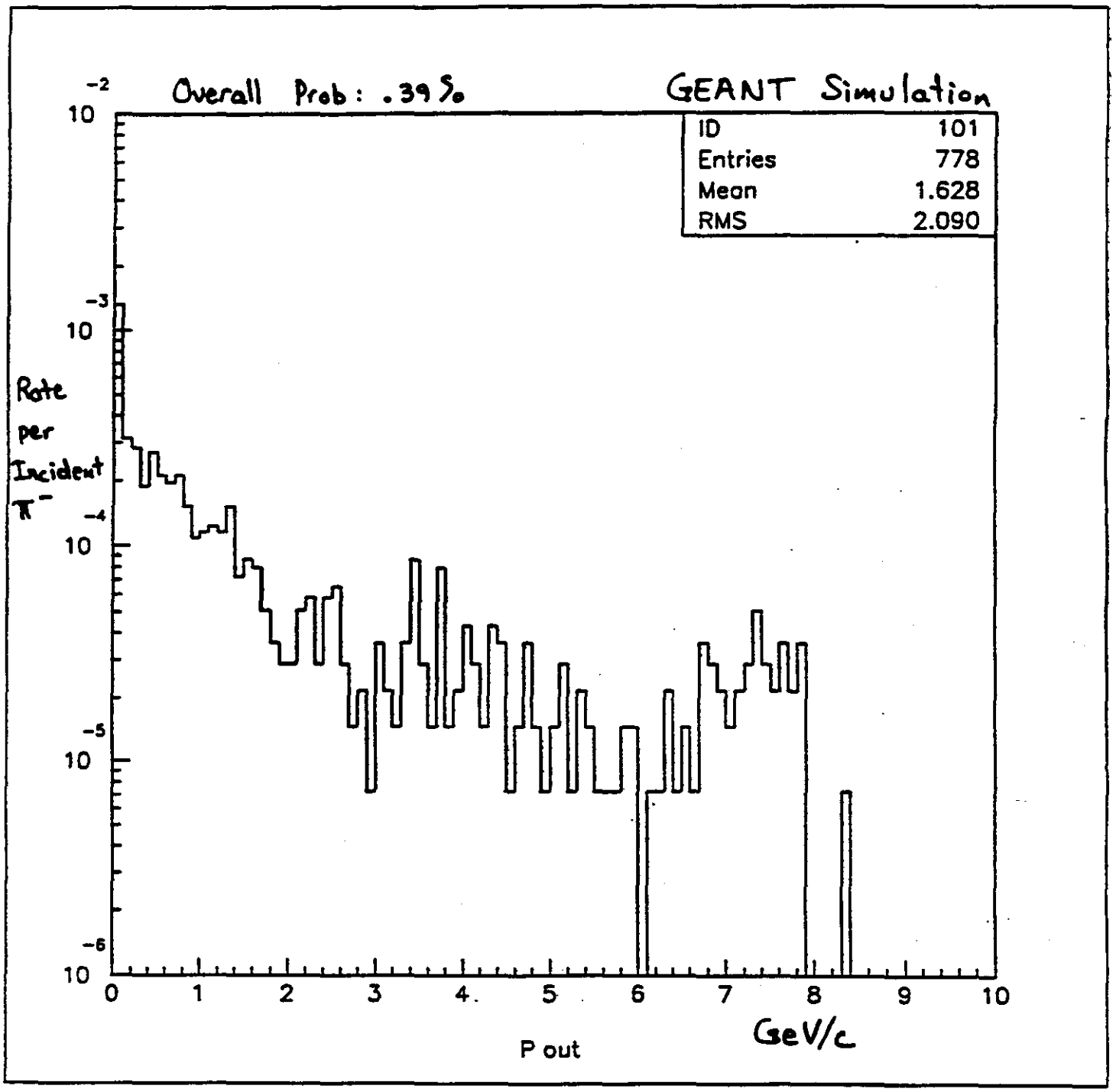
Summary of Barrel Calorimeter Thickness requirements

Criteria	Min Depth $\eta = 0$	Min Depth $\eta = 1.3$
1	10	12
2.1	12	10
2.2	10	10
Both 1 and 2	<u>12</u>	<u>12</u>

These criteria do not include

- detailed trigger requirements
- detailed muon ID requirements
- neutron/γ component of punchthrough

SSCIntcal: 10GeV π^- on 200cm

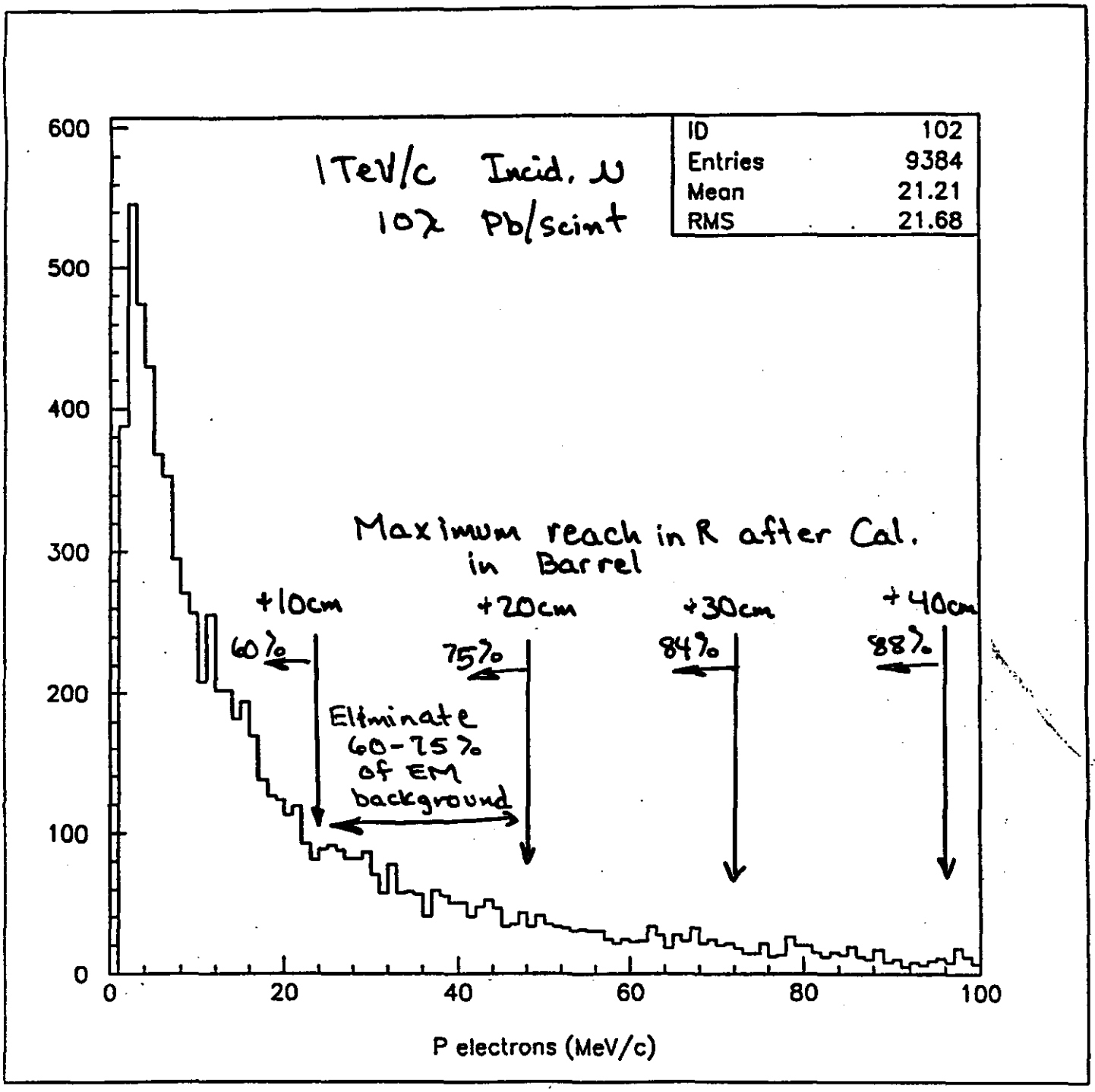


How Close can 1ST μ Layer be to Calorimeter?

$$R = \frac{P_T}{0.3\,9\,B}$$

Put air gap to curl up low momentum particles

Low momentum particles exiting with muon
Avg 2-3 electrons per 1TeV/c μ



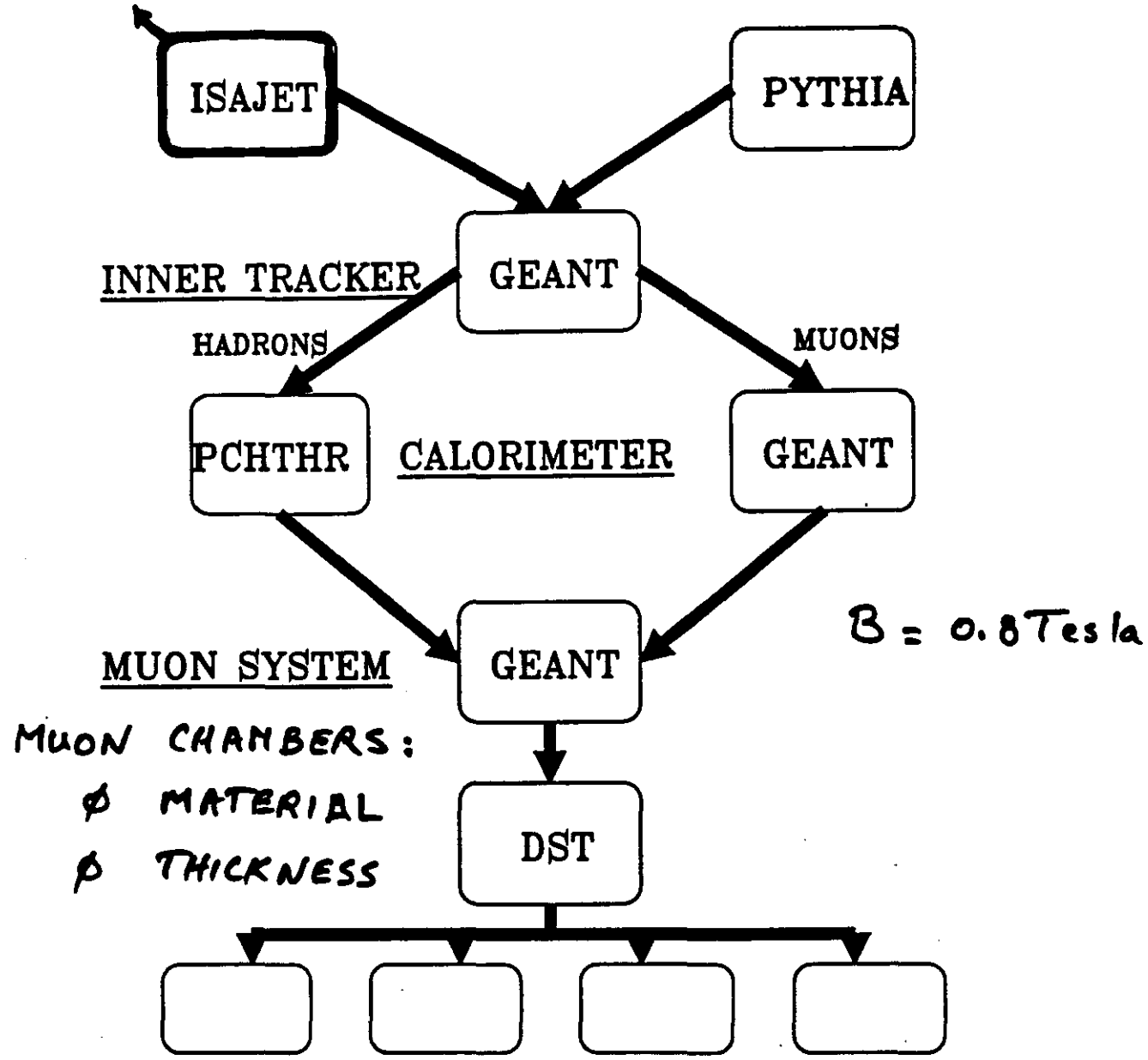
STUDY OF RATES VS CALORIMETER THICKNESS

- MONTE-CARLO
- DETECTOR GEOMETRY
- RATES IN CENTRAL REGION $|\eta| < 1.35$
- RATES IN FORWARD REGION $1.35 < |\eta| < 2.50$
- DISCUSSION

M. MOHAMMADI

MARCH 10, 92

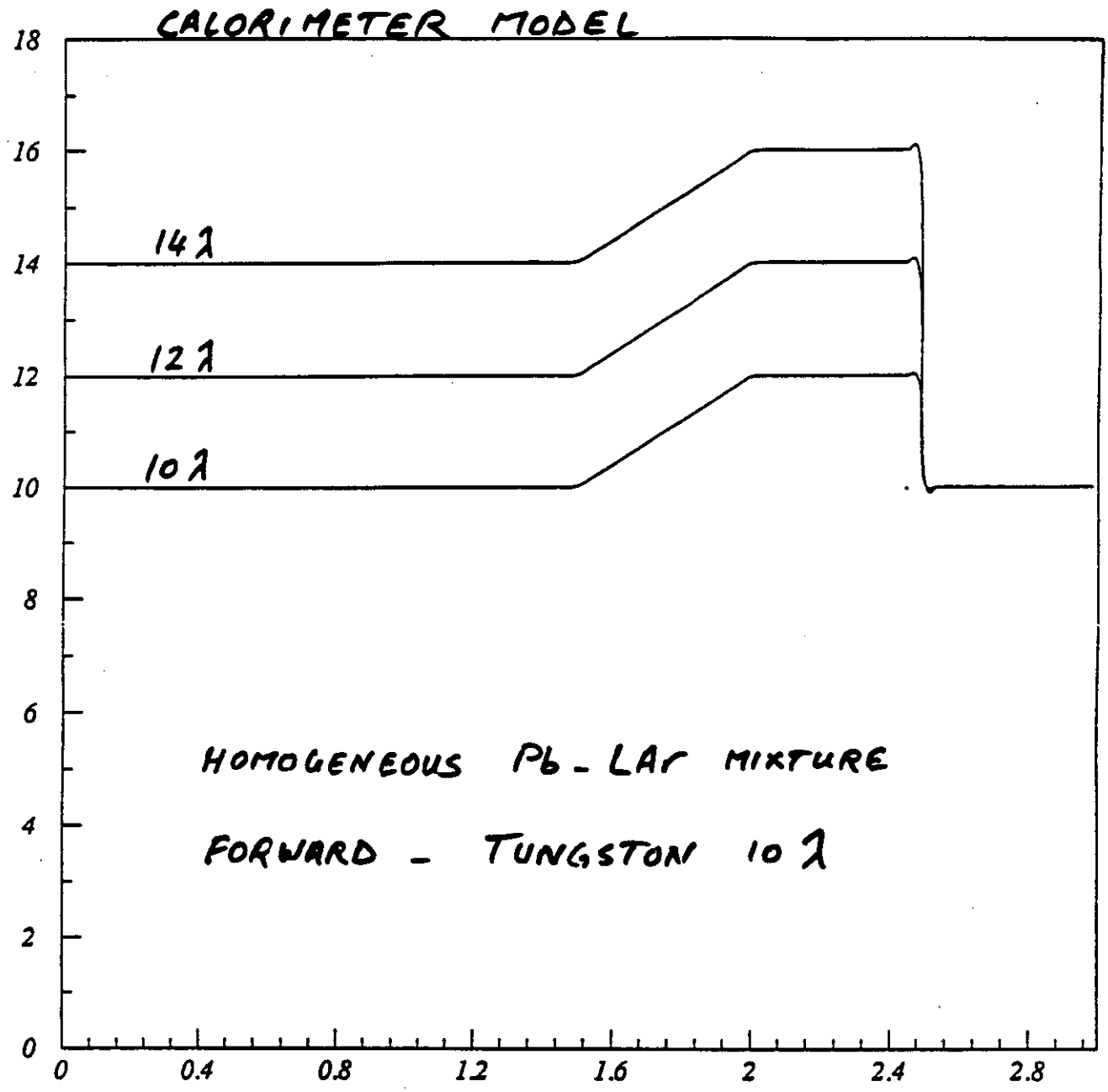
2 JET EVENTS – 8 P_T bins 4 – 1024 GeV/c



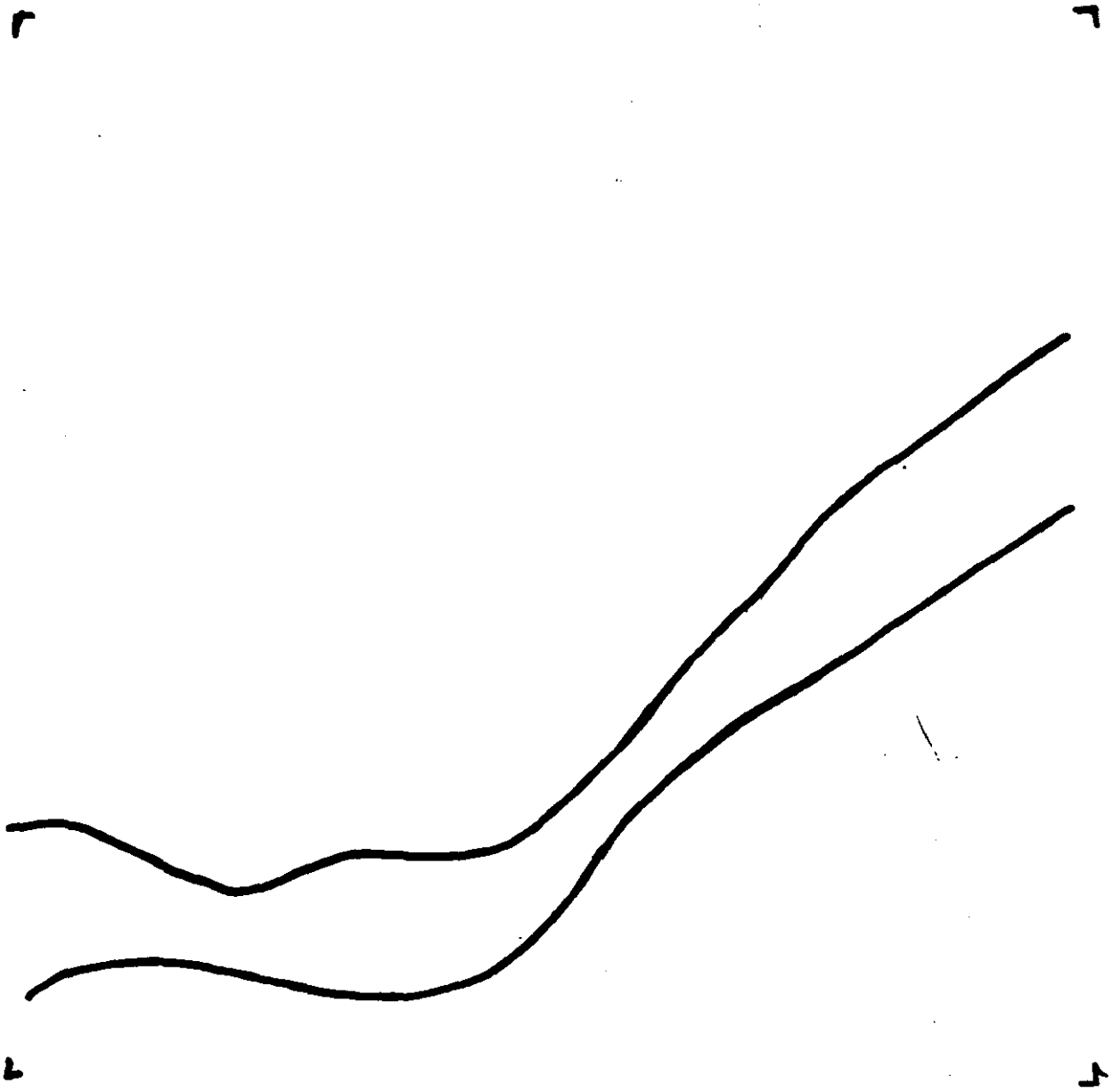
ANALYSIS PROGRAMS

MUON TRIGGER SIMULATION

- CHARGED PARTICLES ONLY – NO γ, NO n
- $\mathcal{L} = 10^{33}\ cm^{-2} s^{-1}$

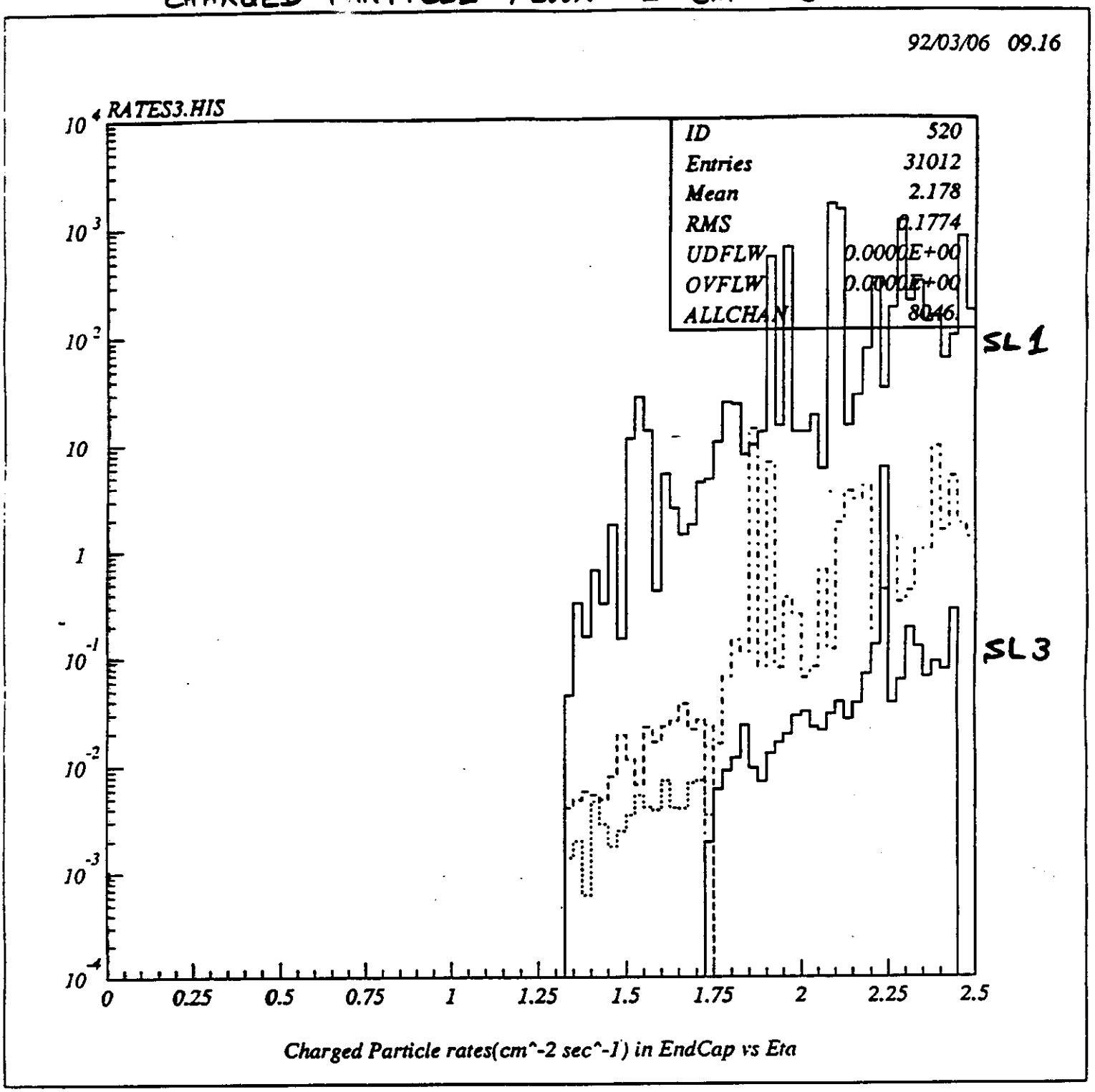


INTERACTION LENGTH VS ETA

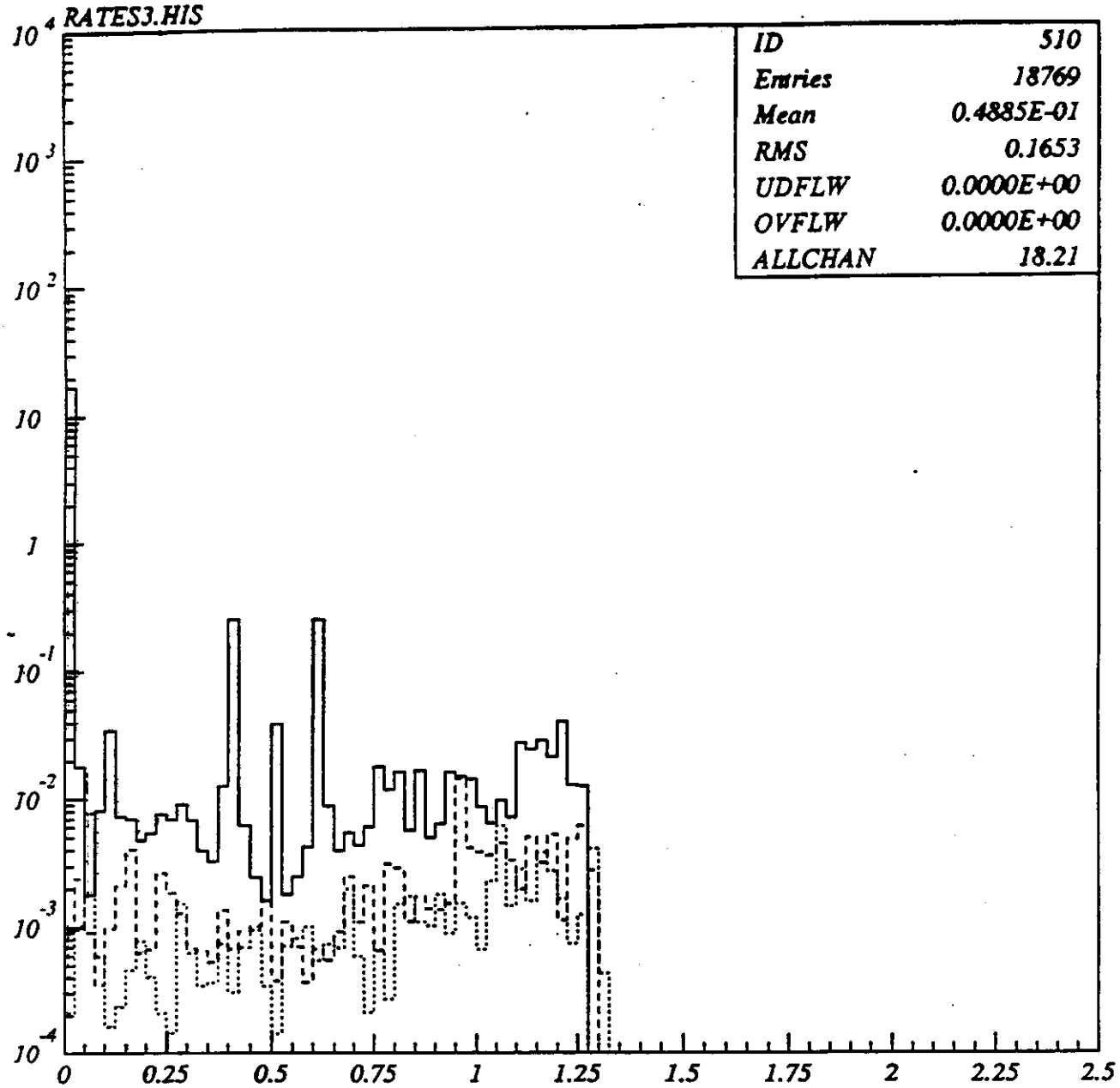


LINES = T. BOLTON RESULTS

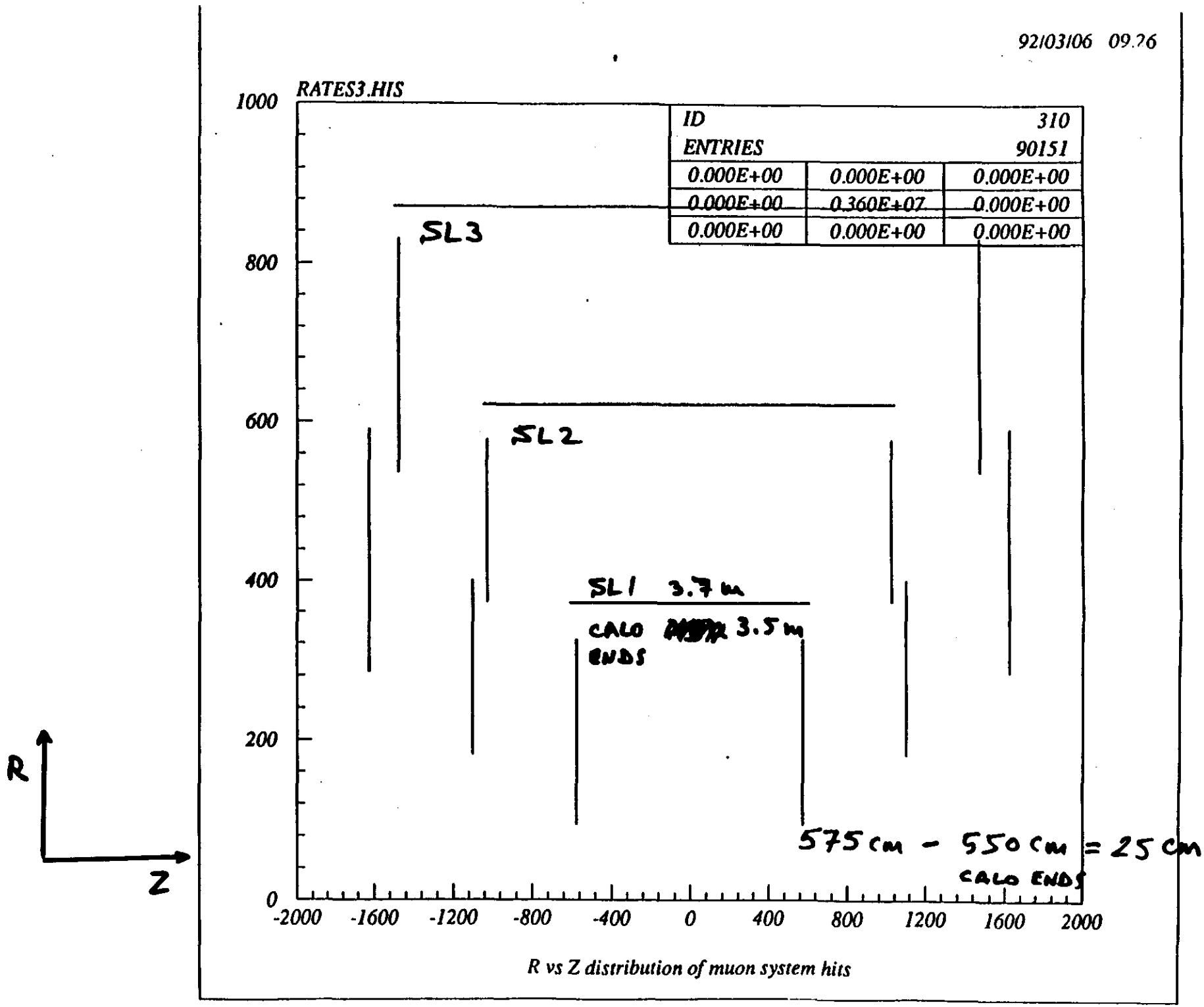
CHARGED PARTICLE FLUX - $cm^{-2}\ s^{-1}$



92/03/06 09.15

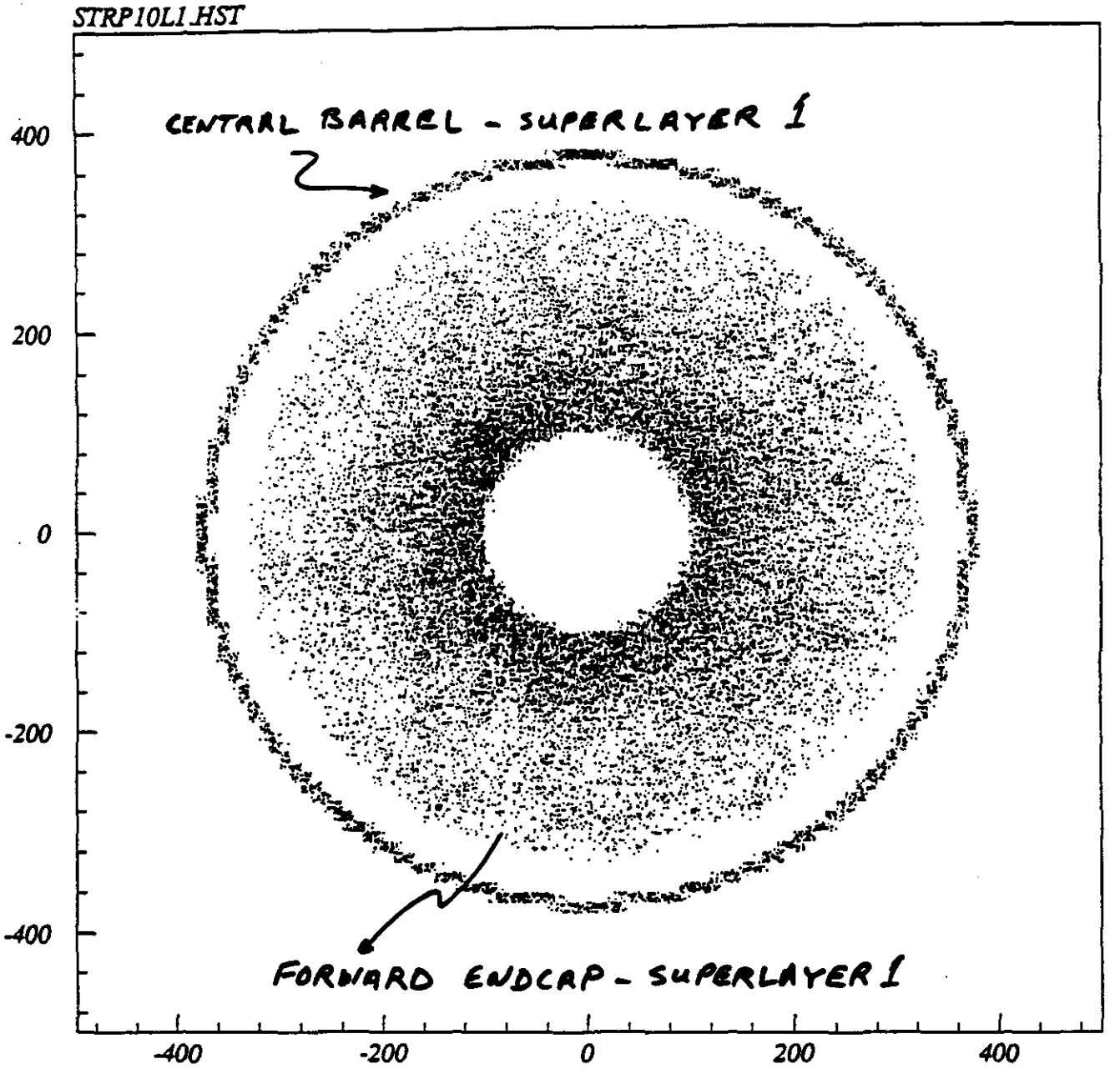


Charged Particle rates(cm^-2 sec^-1) SL3B in barrel vs Eta

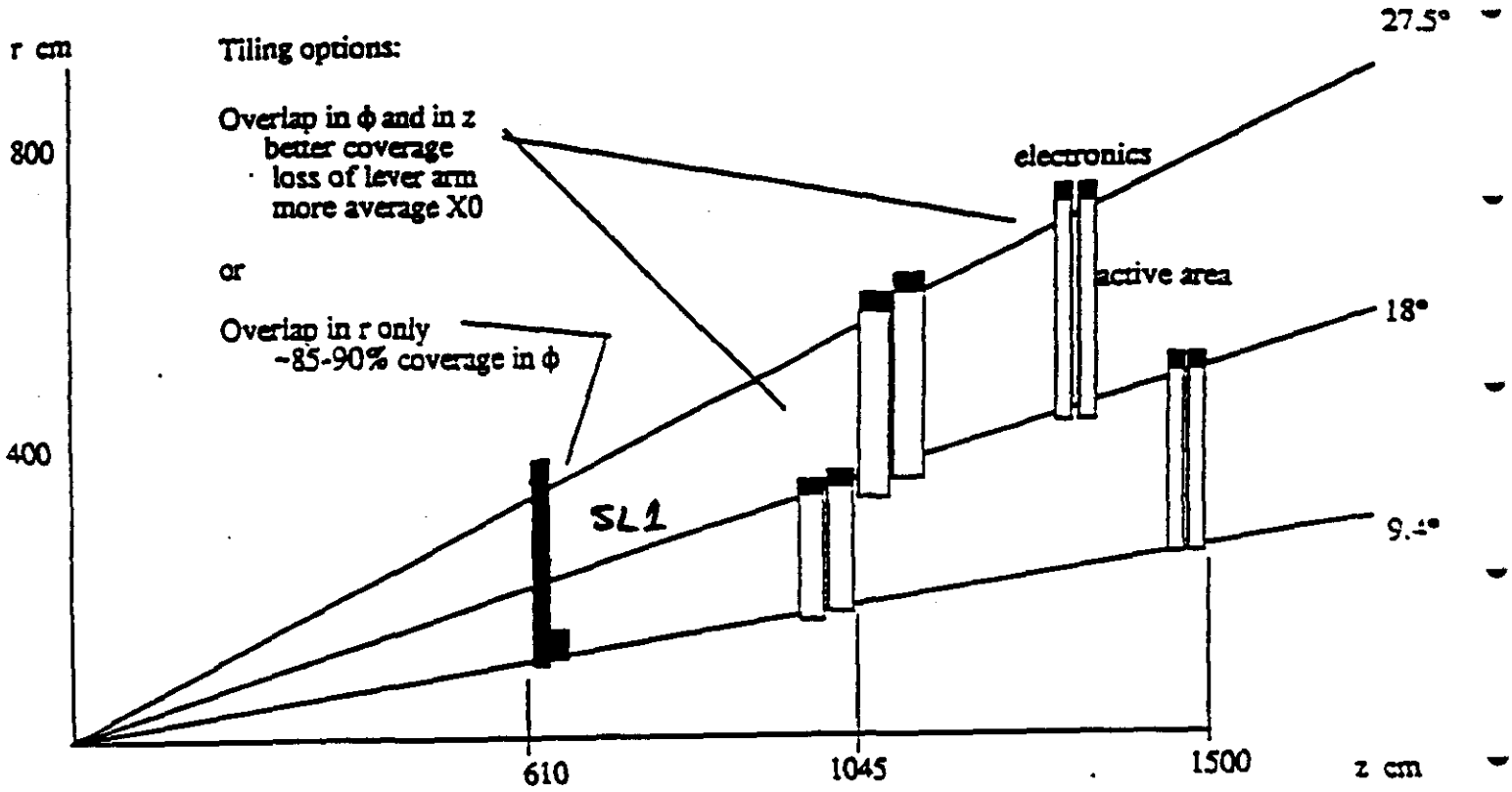

92/03/06 09.26
RATES3.HIS
ID 310
ENTRIES 90151
0.000E+00 0.000E+00 0.000E+00
0.000E+00 0.360E+07 0.000E+00
0.000E+00 0.000E+00 0.000E+00
SL3
SL2
SL1 3.7 m
CALO 3.5 m
ENDS
575 cm - 550 cm = 25 cm
CALO ENDS
1000
800
600
400
200
0
-2000 -1600 -1200 -800 -400 0 400 800 1200 1600 2000
R
Z
R vs Z distribution of muon system hits

92/03/07 18.08

STRP10L1.HST



X vs Y - F-Zone 3



F1 : $\eta = 2.35 \div 2.50$ $\Delta R = 17$ cm $A = 8$ cm^2

F2 : $2.10 \div 2.35$ 33 cm $A = 16$ cm^2

F3 : $1.35 \div 2.10$ 180 cm $A = 87$ cm^2

Note: modules (a) occupy even-numbered sectors
modules (b) occupy odd-numbered sectors

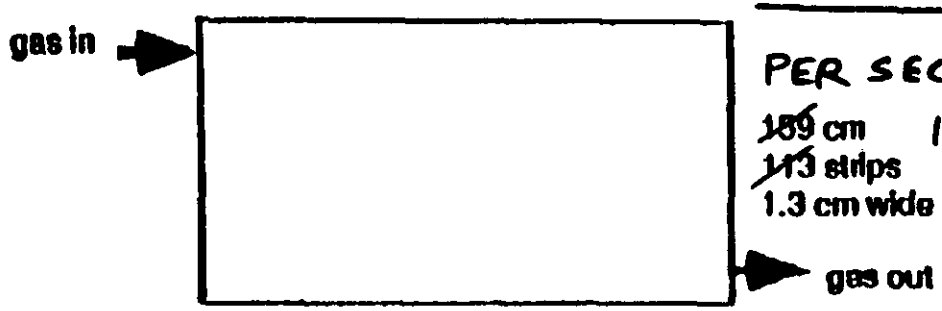
	z	n1	θ1	n2	θ2	R1	R2	dR	S1	S2	area	# strips	strip occ	# r-chans
	m		deg		deg	m	m	m	m	m	m^2	/pl/sctr	/sec	/pl/sctr
Inner modules														
1a)	6.15	2.50	9.39	2.35	10.90	1.02	1.18	0.17	0.40	0.46	0.07	86	101	3
1b)	6.35	2.50	9.39	2.35	10.90	1.05	1.22	0.17	0.41	0.48	0.08	89	104	3
2a)	5.75	2.35	10.90	2.10	13.96	1.11	1.43	0.32	0.43	0.56	0.16	99	88	6
2b)	5.95	2.35	10.90	2.10	13.96	1.15	1.48	0.33	0.45	0.58	0.17	102	91	7
3a)	5.75	2.10	13.96	1.35	29.16	1.43	3.21	1.78	0.56	1.25	1.58	181	65	36
3b)	5.95	2.10	13.96	1.35	29.16	1.48	3.32	1.84	0.58	1.30	1.69	187	67	37
Middle modules														
4a)	11.00	2.50	9.39	1.98	15.72	1.82	3.10	1.28	0.71	1.21	1.20	192	83	26
4b)	11.60	2.50	9.39	1.98	15.72	1.92	3.27	1.35	0.75	1.27	1.34	202	87	27
5a)	9.80	1.98	15.72	1.35	29.16	2.76	5.47	2.71	1.08	2.13	4.26	321	17	54
5b)	10.40	1.98	15.72	1.35	29.16	2.93	5.80	2.88	1.14	2.26	4.80	341	19	58
Outer modules														
6a)	16.05	2.50	9.39	1.80	18.77	2.65	5.46	2.80	1.04	2.13	4.35	316	42	56
6b)	16.25	2.50	9.39	1.80	18.77	2.69	5.52	2.84	1.05	2.16	4.46	320	43	57
7a)	14.55	1.80	18.77	1.35	29.16	4.95	8.12	3.17	1.93	3.17	7.93	510	5	63
7b)	14.75	1.80	18.77	1.35	29.16	5.01	8.23	3.22	1.96	3.21	8.15	517	5	64

$2 \times 16 \times (88 + 101 + 184) = 11936$ STRIPS

TOTAL

SUPER LAYER 1

Inner RPC layer _ BEND PLANE



PER SECTOR

~~189~~ cm 143.5

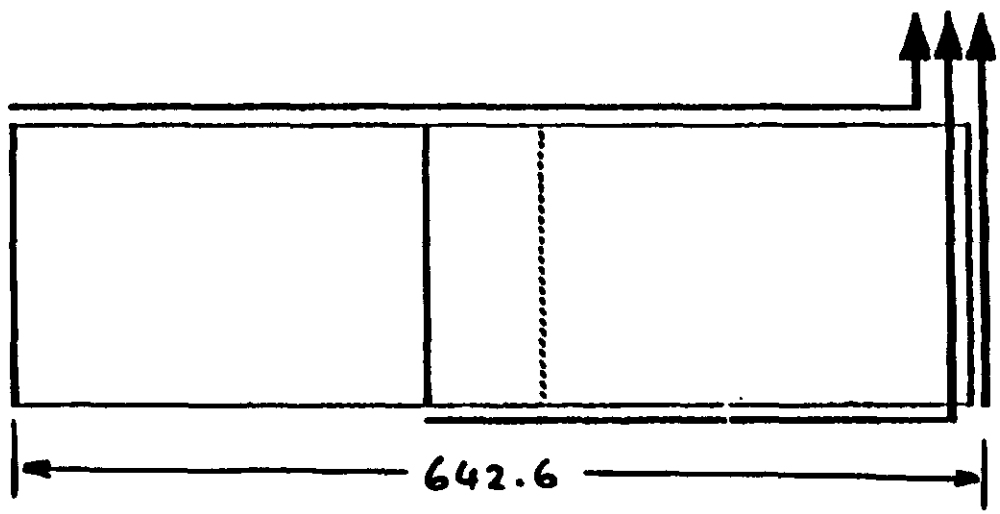
~~113~~ strips 111 STRIPS !

1.3 cm wide

360 cm, 88 strips, 4.1 cm wide

HALF LENGTH IN Z 642.6 cm

RADIUS TO CENTER 394.9 cm



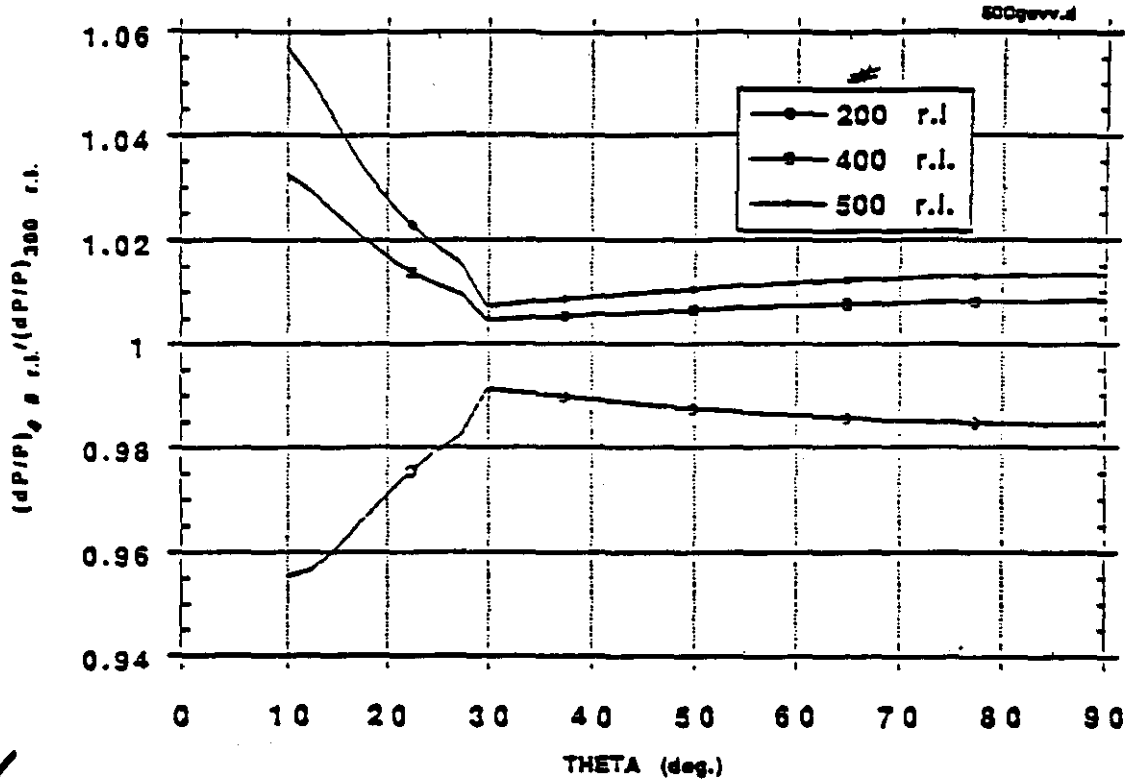
2 overlayed RPC layers
6 strips overlap, don't use first 6 strips on upper RPC. Longitudinal strips are or'd together

$111 \times 16 = 1776 \times 4 = 7104$ STRIPS TOTAL

INNER RPC (SUPERLAYER 1)

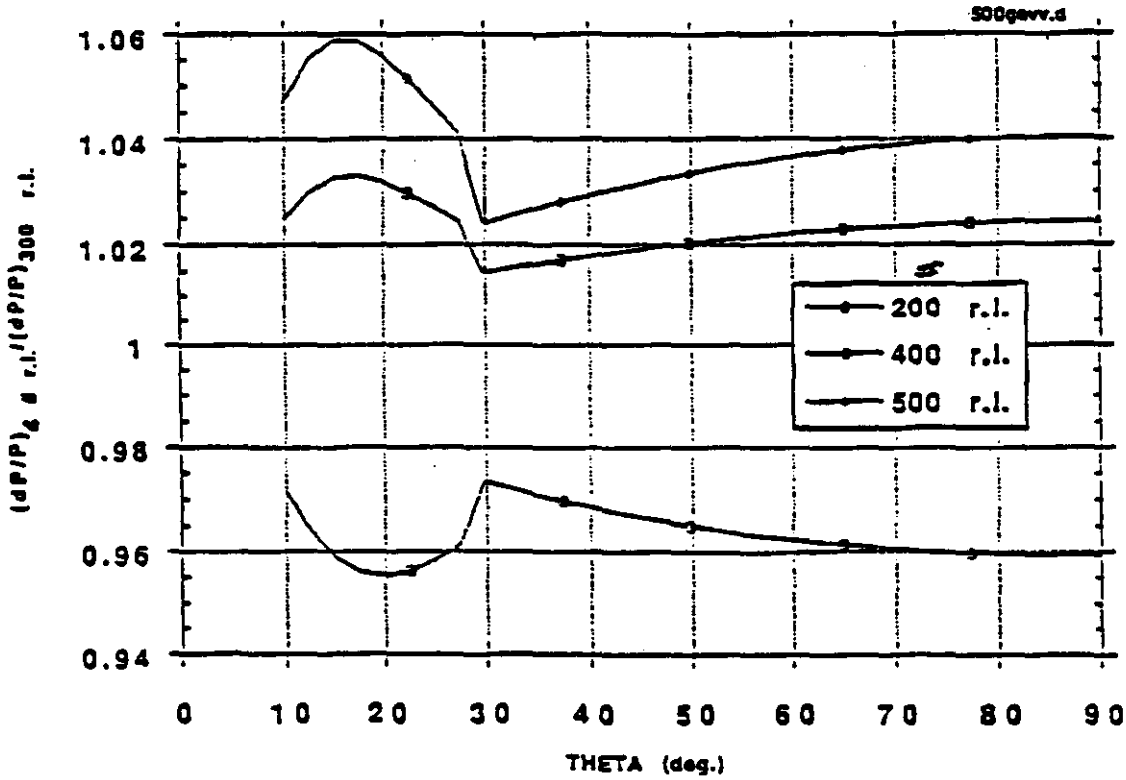
AREA $= 1.3 \times 321.3 = 418\ cm^2$

VARIATION OF MOMENTUM RESOLUTION AT 500 GeV/c
WITH CALORIMETER RADIATION THICKNESS



$\frac{\Delta P}{P} \Big/ \frac{\Delta P}{P}\Big|_{X_0=300}$

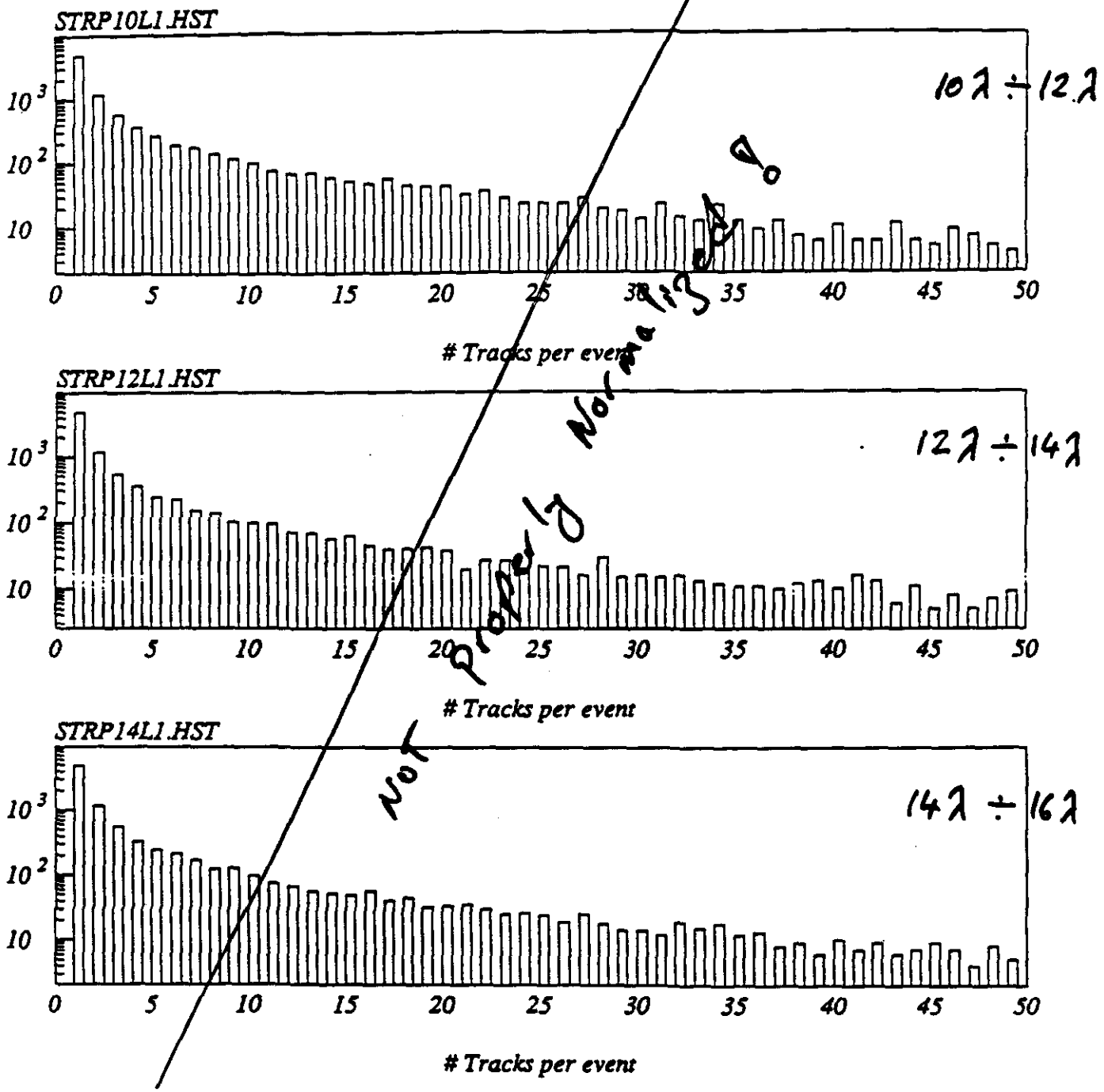
VARIATION OF MOMENTUM RESOLUTION AT 1000 GeV/c
WITH CALORIMETER RADIATION THICKNESS



FORWARD REGION – Rates is CRITERION FOR DETERMINING CALO THICKNESS

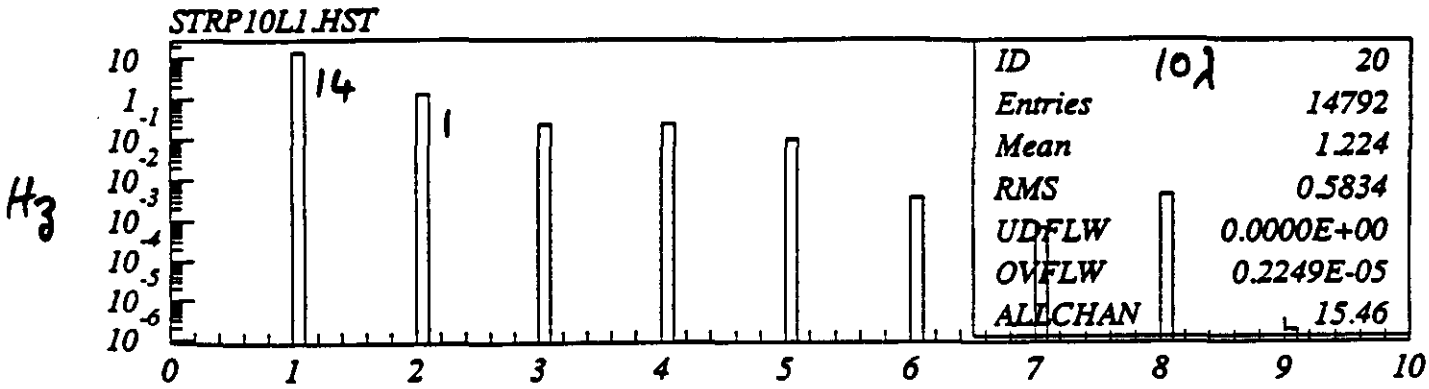
TRACKS BEHIND CALO

92/03/07 16.59

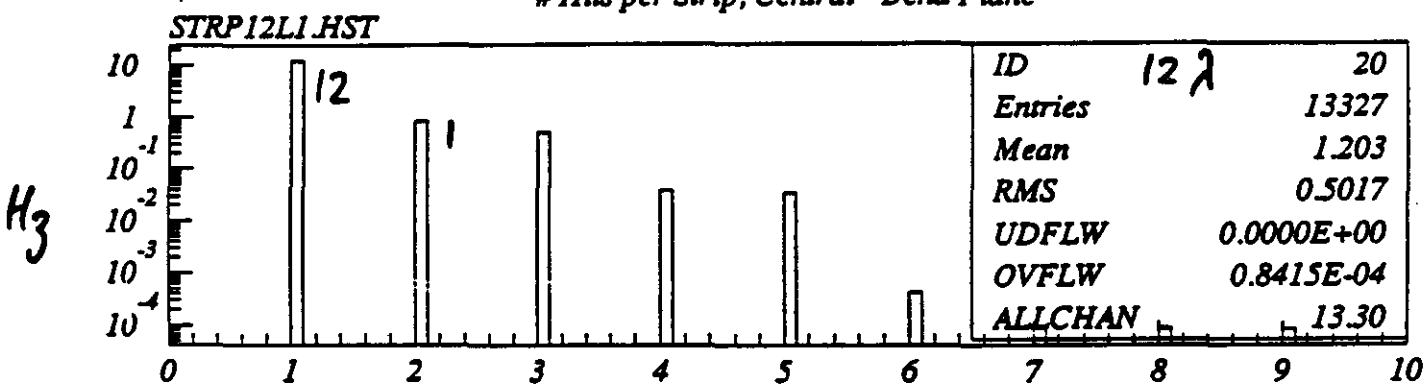


CENTRAL BARREL - SL1 $10^{33}\ cm^{-2}\ s^{-1}$

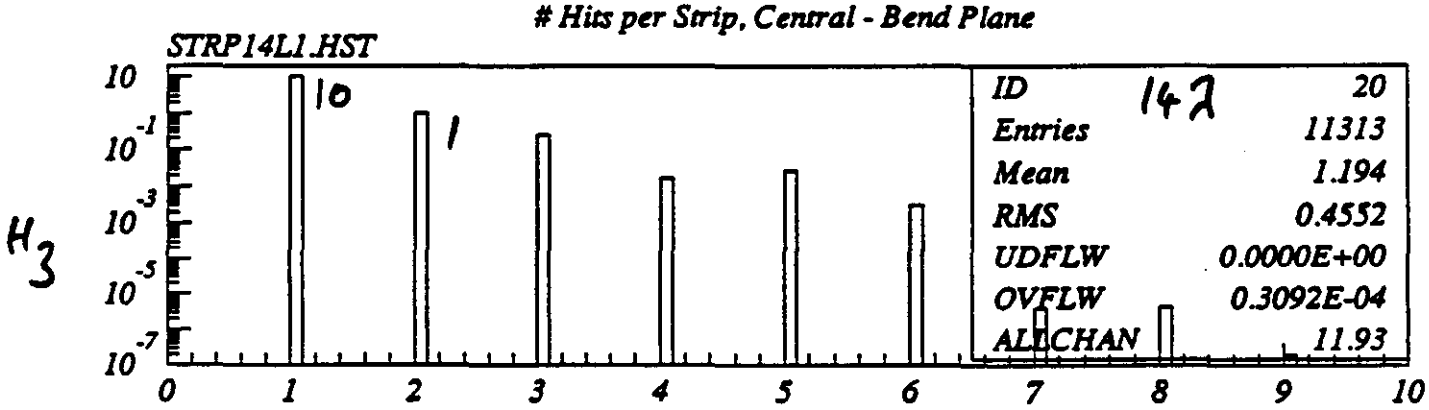
RATE VS. # HITS PER STRIP 92/03/07 16



Hits per Strip, Central - Bend Plane



Hits per Strip, Central - Bend Plane

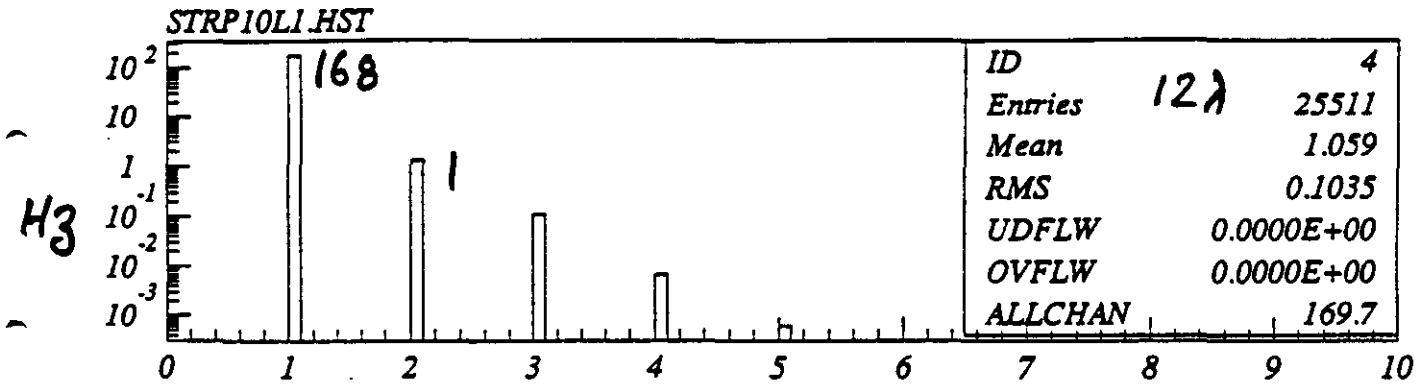


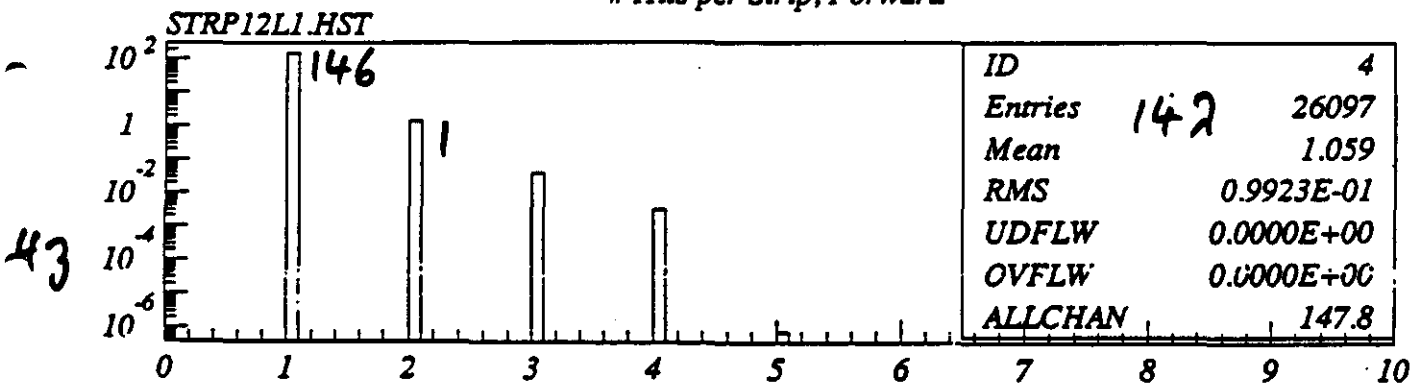
Hits per Strip, Central - Bend Plane

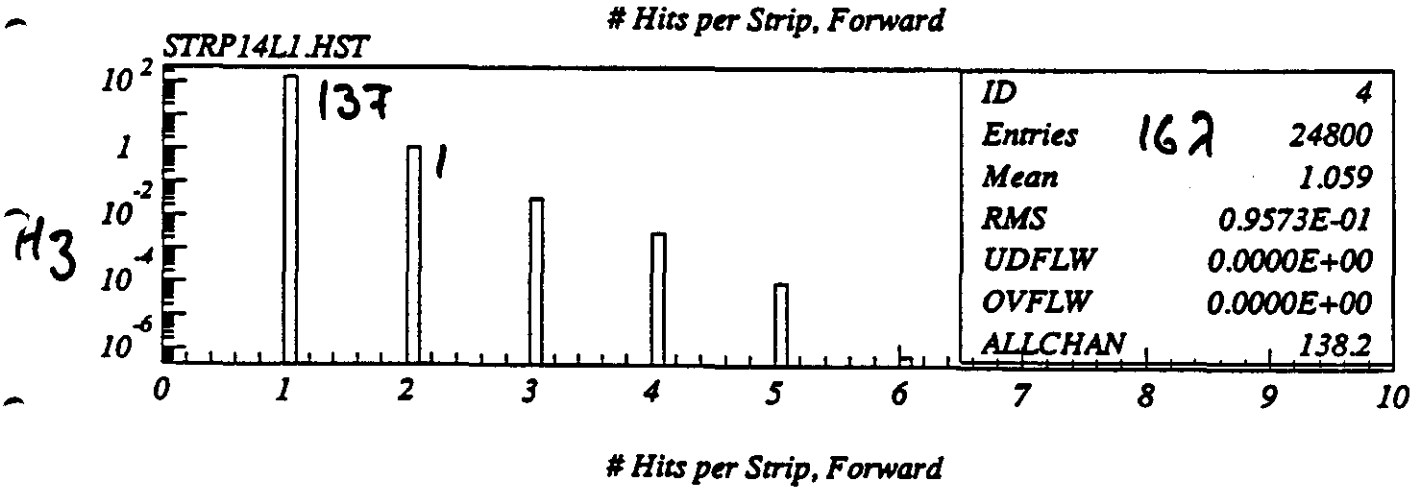
DOUBLE-HIT RATE ≃ 8% SINGLE-HIT RATE !

FORWARD – SL1 10^{33} cm^{-2} s^{-1}

TOTAL RATE VS. # HITS PER STRIP 92/03/07 16.36







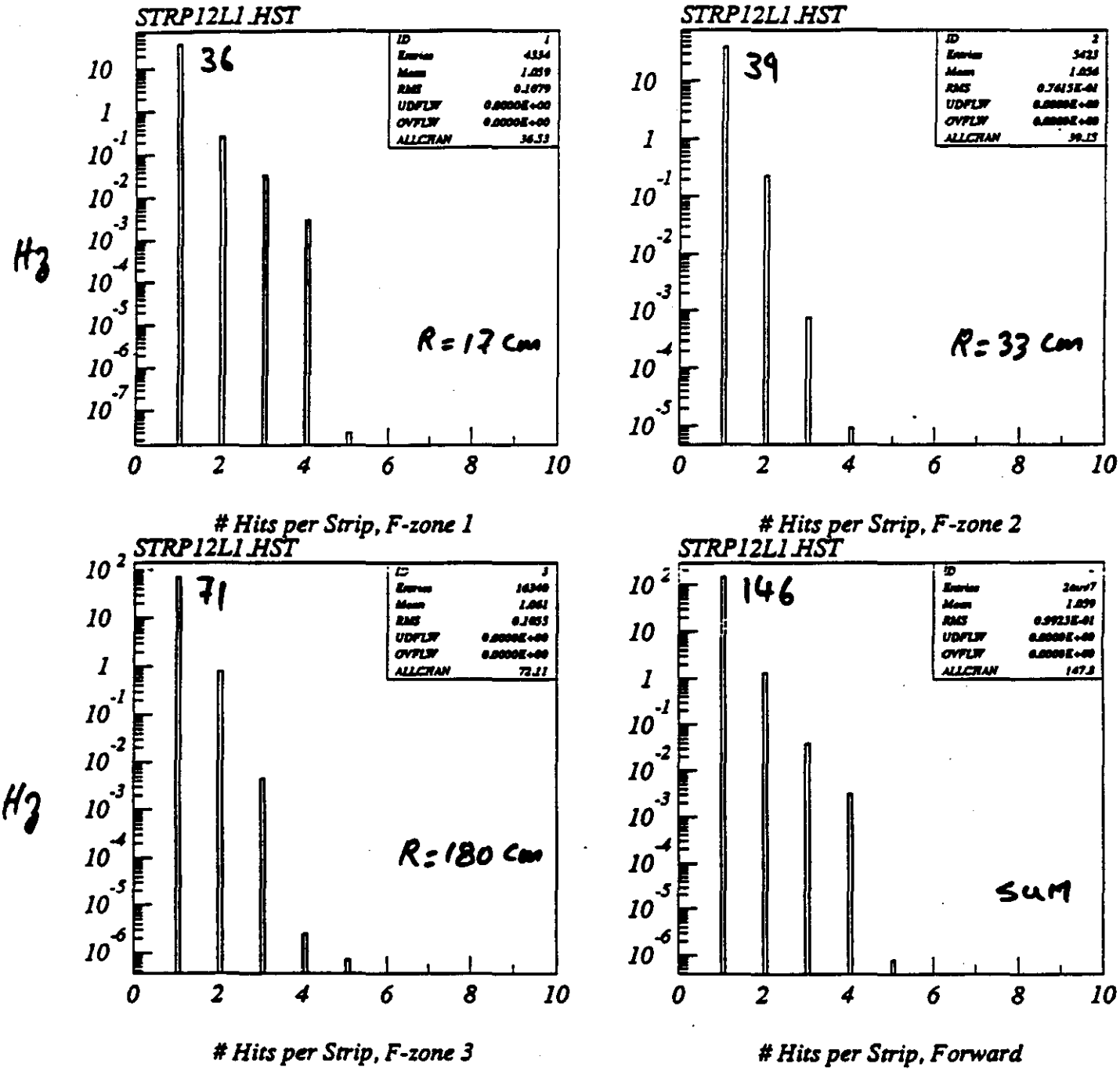
DOUBLE-HIT RATE ≃ 0.7% SINGLE-HIT RATE!

$\mathcal{L} = 10^{33}\ cm^{-2}s^{-1}$

FORWARD REGION – SL1

92/03/07 15.50

RATE vs # HITS PER STRIP



LARGER RATE IN 180 cm ($\eta = 1.35 \div 2.10$) STRIPS

THAN IN 17 cm STRIPS ($\eta = 2.35 \div 2.50$) !

CONCLUSIONS :

- CHARGED PARTICLE RATE AT SL1 IS NOT A VERY SENSITIVE FUNCTION OF CALO THICKNESS IN 10 – 16 λ RANGE.

- BASED ON RATE CONSIDERATIONS ONLY

  CENTRAL CALO THICKNESS = 12 λ
  FORWARD " " = 14 λ

  ARE QUITE ADEQUATE.

- OTHER EFFCTS TO BE CONSIDERED
  - NEUTRONS
  - MULTIPLE-HITS DUE TO CURLY TRACKS
  - PATTERN RECOGNITION REQUIREMENTS

- RATE OF MULTIPLE HITS IS SMALL :

  CENTRAL 8% SINGLE-HIT RATE
  FORWARD 0.7% " "

- BASED ON RATES IN FORWARD ENDCAPS

  SEGMENTATION IN ϕ – OK
  " IN η – NEEDS OPTIMIZATION !

M. SEMAN

EVENTS GENERATION

(Tim Bolton)

- ISAJET with TWOJET option
- 6 bins in transverse momentum (from 4-1024 GeV/c)
- cross section from ISAJET is 139 mb
- Luminosity assumed $10^{33} cm^{-2} s^{-1}$

GEOMETRY :

- simple GEANT model
- homogenous (PbLAr mixture) concentric cylinders in BARREL
- homogenous (PbLAr mixture) cones in ENDCAP

TRACKING :

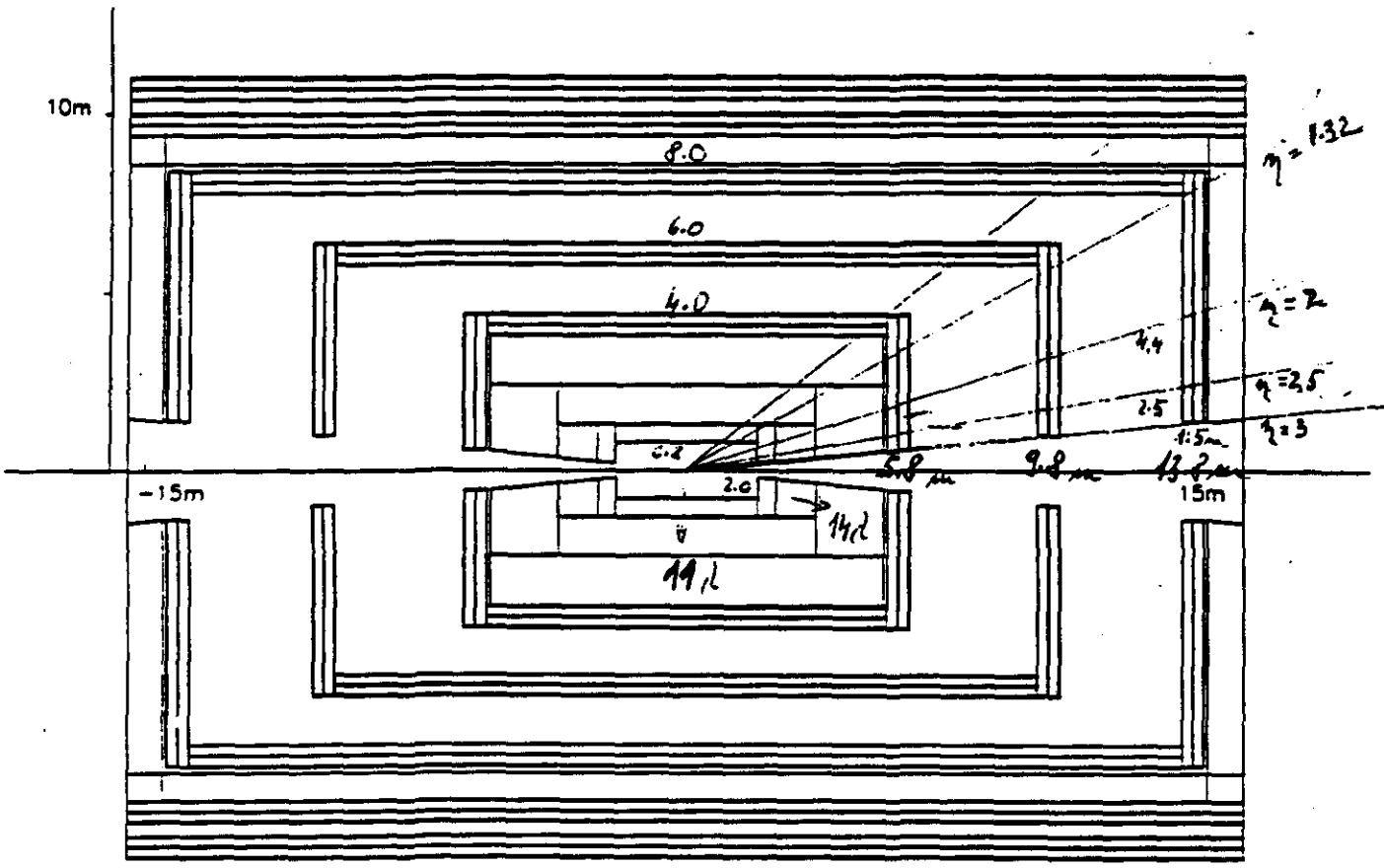
- fully track muons created by primary interaction
  "PROMPT MUONS"
- as well as muons from charged pion and kaon decays
  before the calorimeter "DECAY MUONS"
- "PUNCHTHROUGH MUONS" from hadronic showers in calorimeter
  simulated via R. McNeil's parametrization
- punchthrough of neutrons and photons is not considered
- products of prompt or decay muons which are created in
  the outer third of the calorimeter are tracked

M. GEDAN

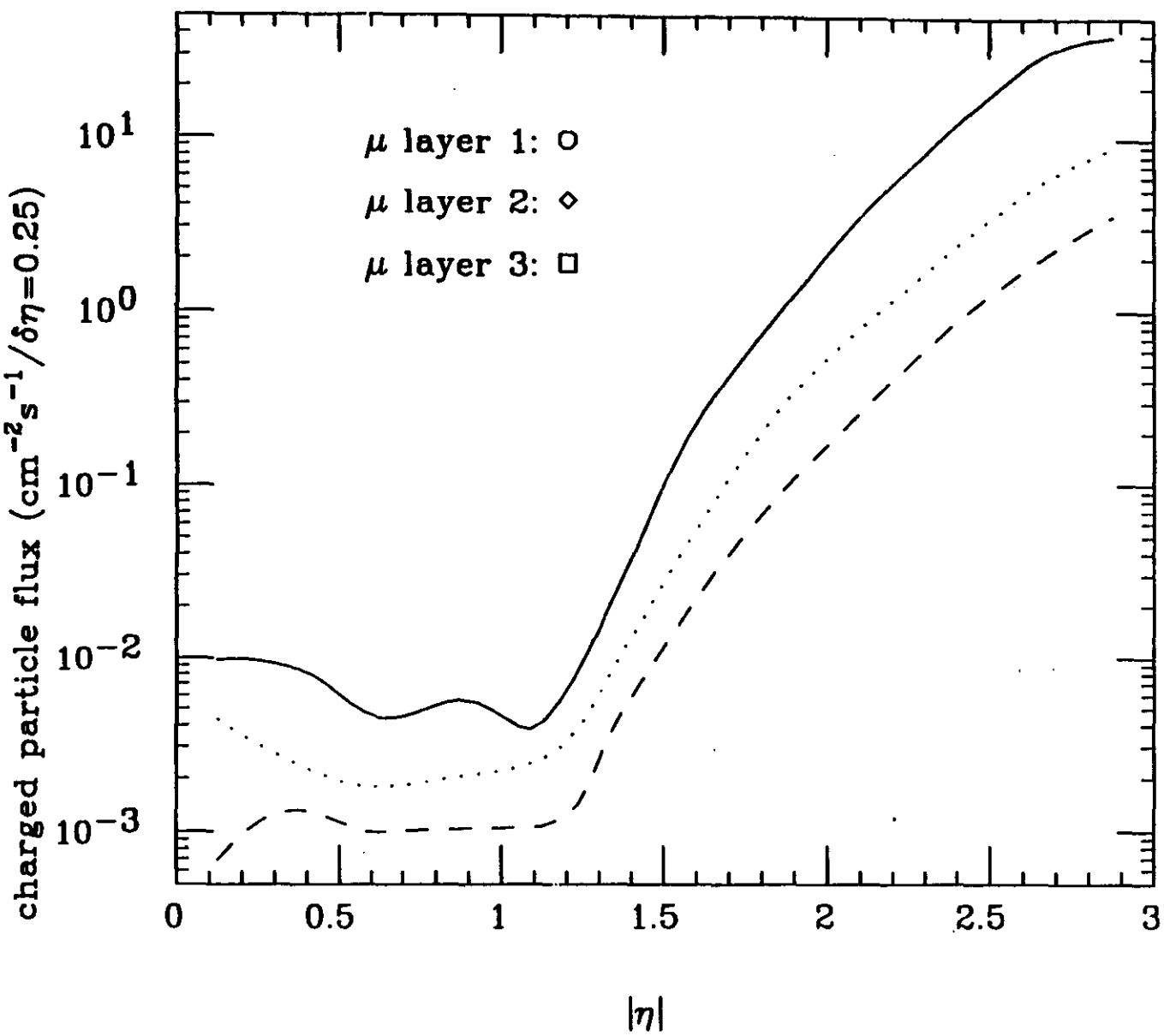
GEM*DETECTOR

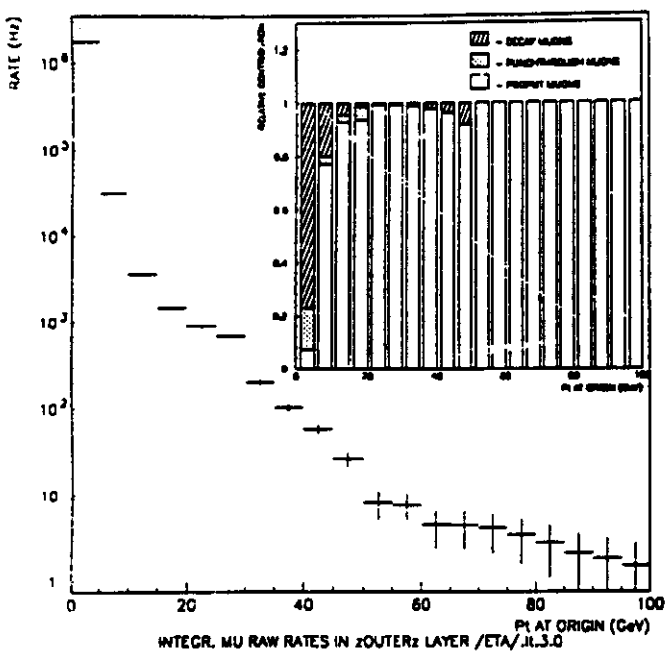
24/ 7/91

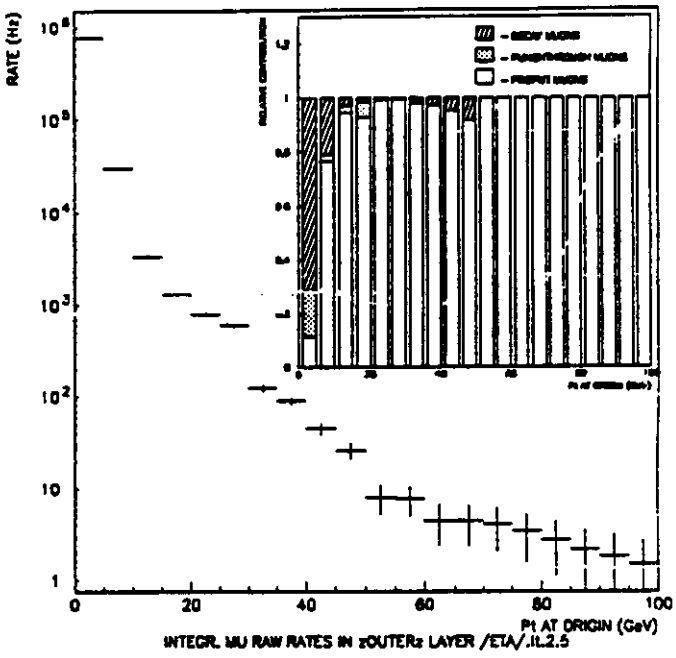
0.8 T

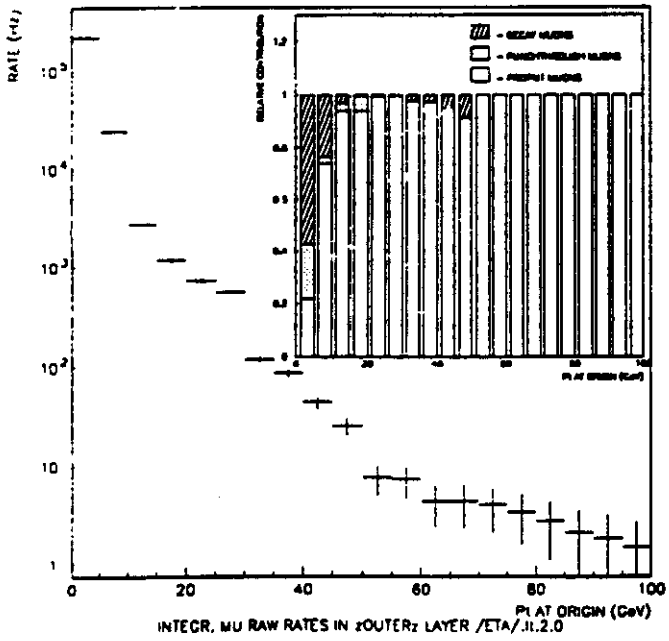


100 cm

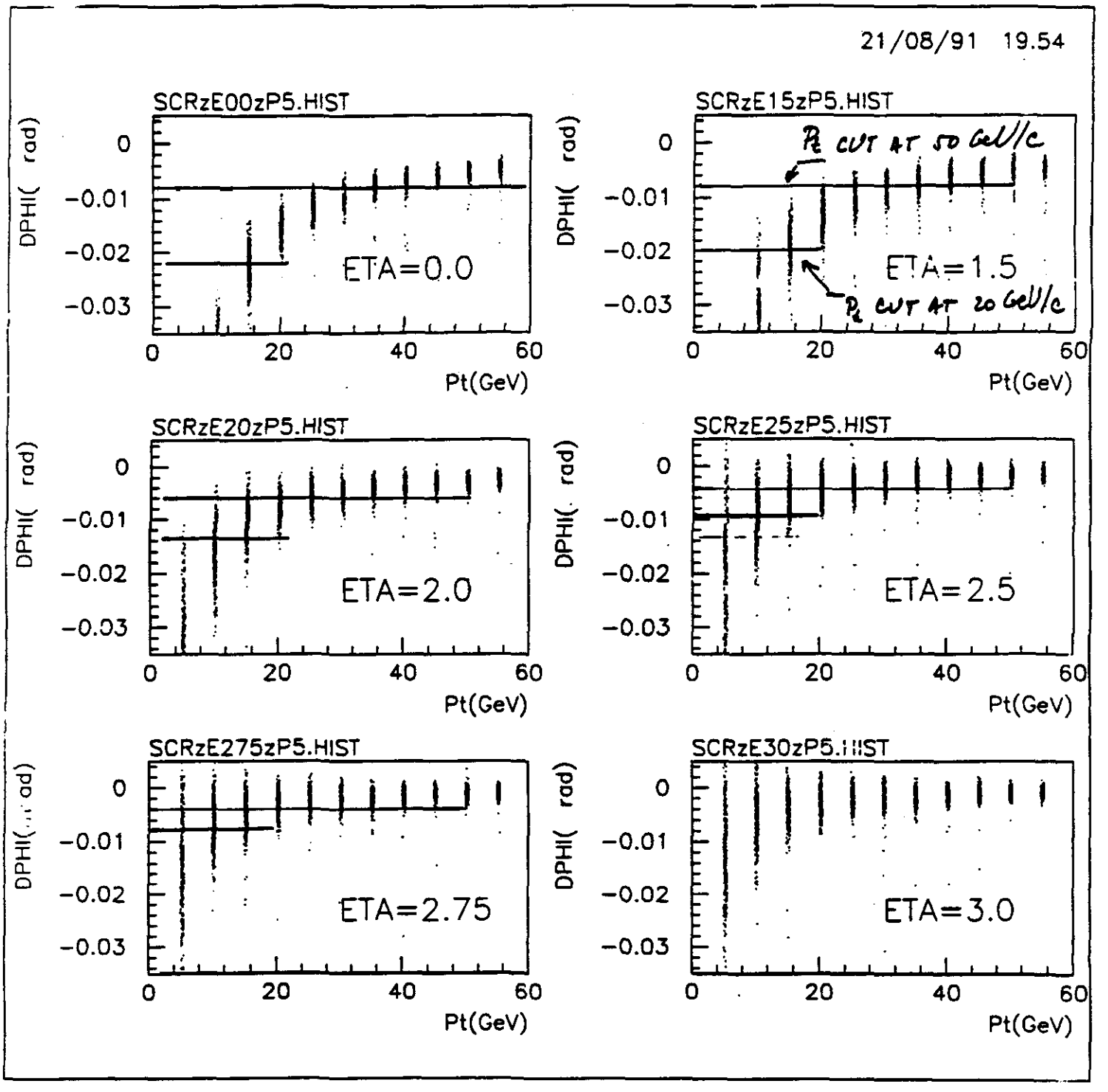

μ layer 1: ○
μ layer 2: ◇
μ layer 3: □
charged particle flux (cm^{-2}s^{-1}/δη=0.25)
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
0
0.5
1
1.5
2
2.5
3
|η|


RATE (Hz)
Pt AT ORIGIN (GeV)
INTEGR. MU RAW RATES IN zOUTERz LAYER /ETA/.IL.3.0


RATE (Hz)
Pt AT ORIGIN (GeV)
INTEGR. MU RAW RATES IN zOUTERz LAYER /ETA/.IL.2.5


RATE (Hz)
Pt AT ORIGIN (GeV)
INTEGR. MU RAW RATES IN zOUTERz LAYER /ETA/.IL.2.0

DPHI


21/08/91 19.54
SCRzE00zP5.HIST
ETA=0.0
SCRzE15zP5.HIST
ETA=1.5
Pt CUT AT 50 GeV/c
Pt CUT AT 20 GeV/c
SCRzE20zP5.HIST
ETA=2.0
SCRzE25zP5.HIST
ETA=2.5
SCRzE275zP5.HIST
ETA=2.75
SCRzE30zP5.HIST
ETA=3.0
DPHI(rad)
Pt(GeV)
0
-0.01
-0.02
-0.03
0
20
40
60

D P H I AND RAYS TRIGGERS

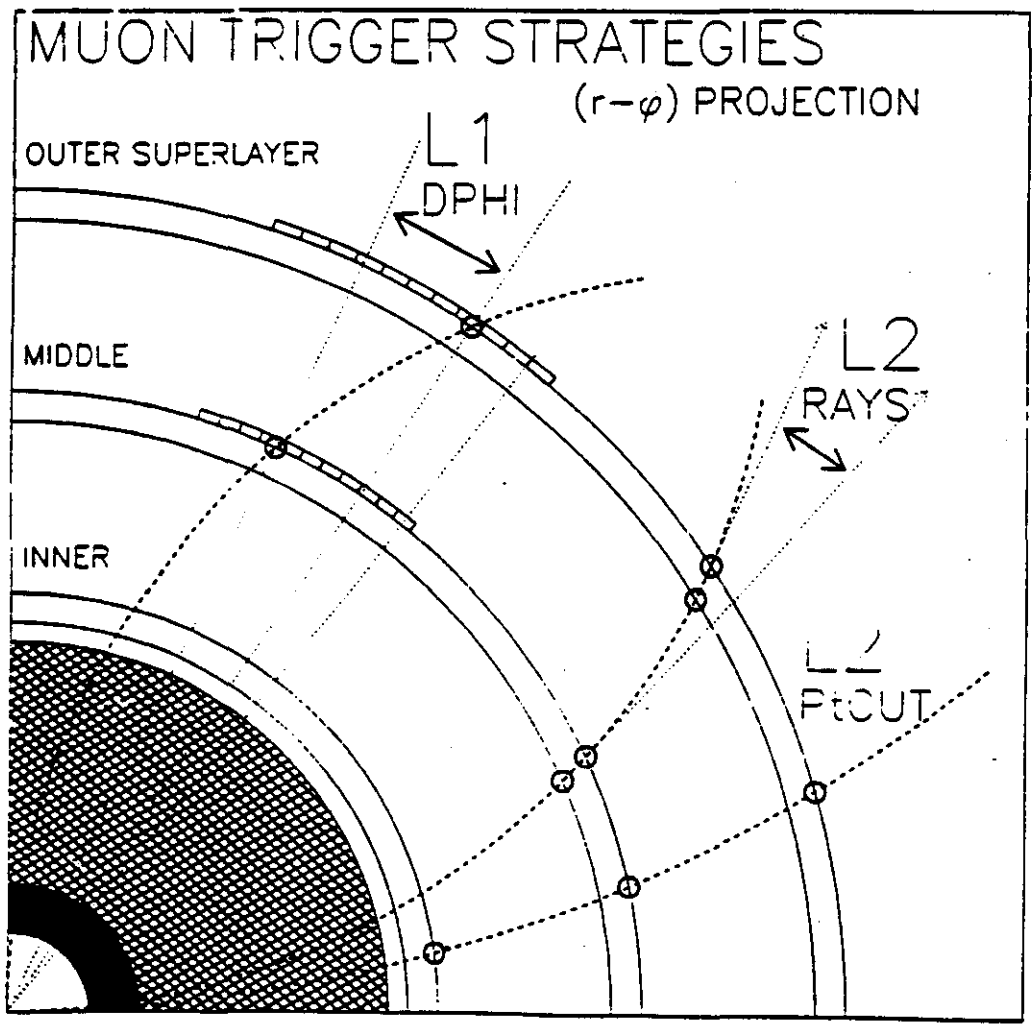
***

D P H I IS A VALID TRIGGER IF THERE IS A COINCIDENCE BETWEEN PADS PHI3(i) AND ONE OF PHI2(i +/- thr)

WHERE thr = 0,1,2,3,....

***

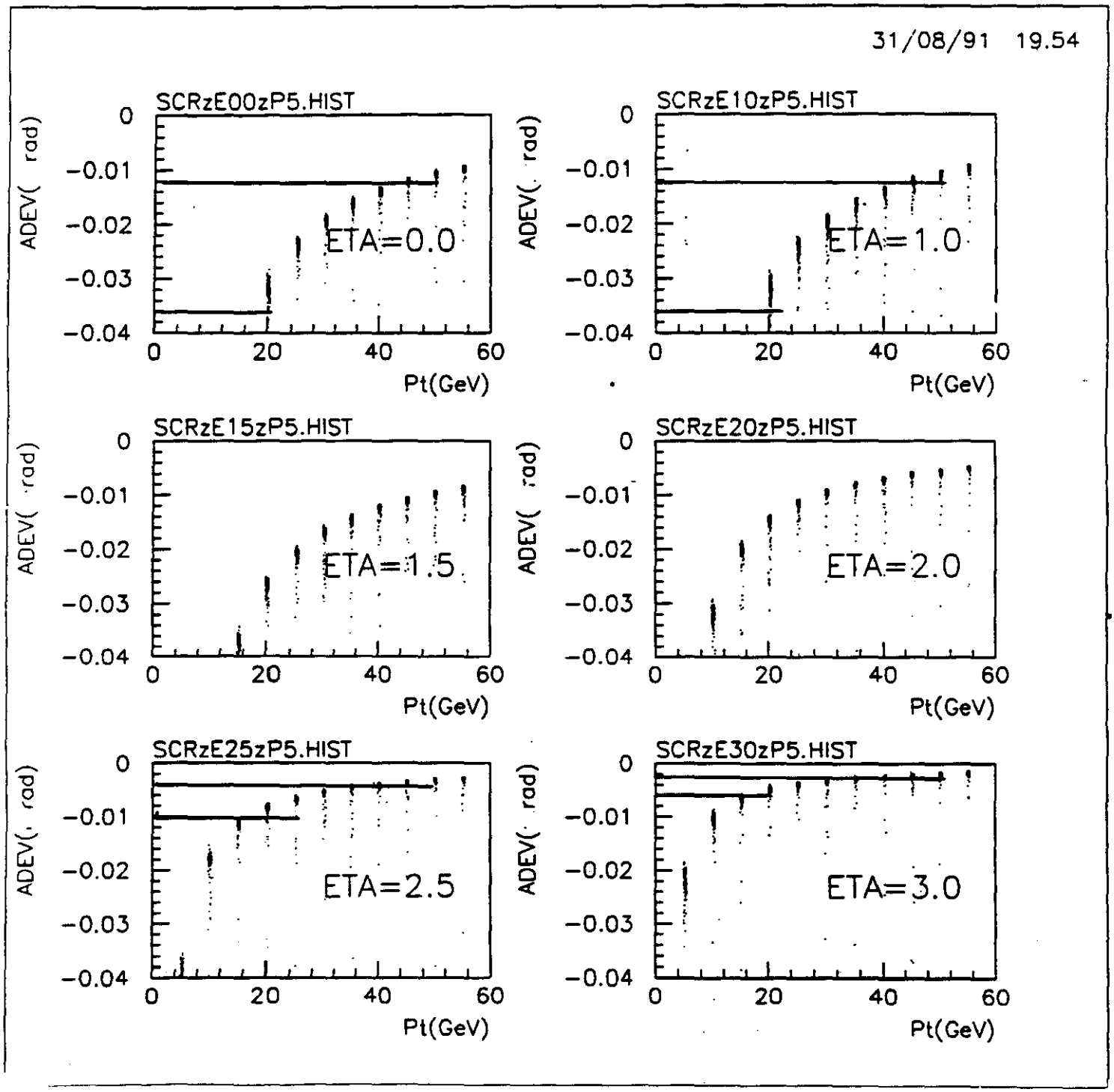
R A Y S IS A VALID TRIGGER IF CALCULATED ANGLE BETWEEN RAY2 AND RAY3 IS SMALLER THAN A GIVEN THRESHOLD

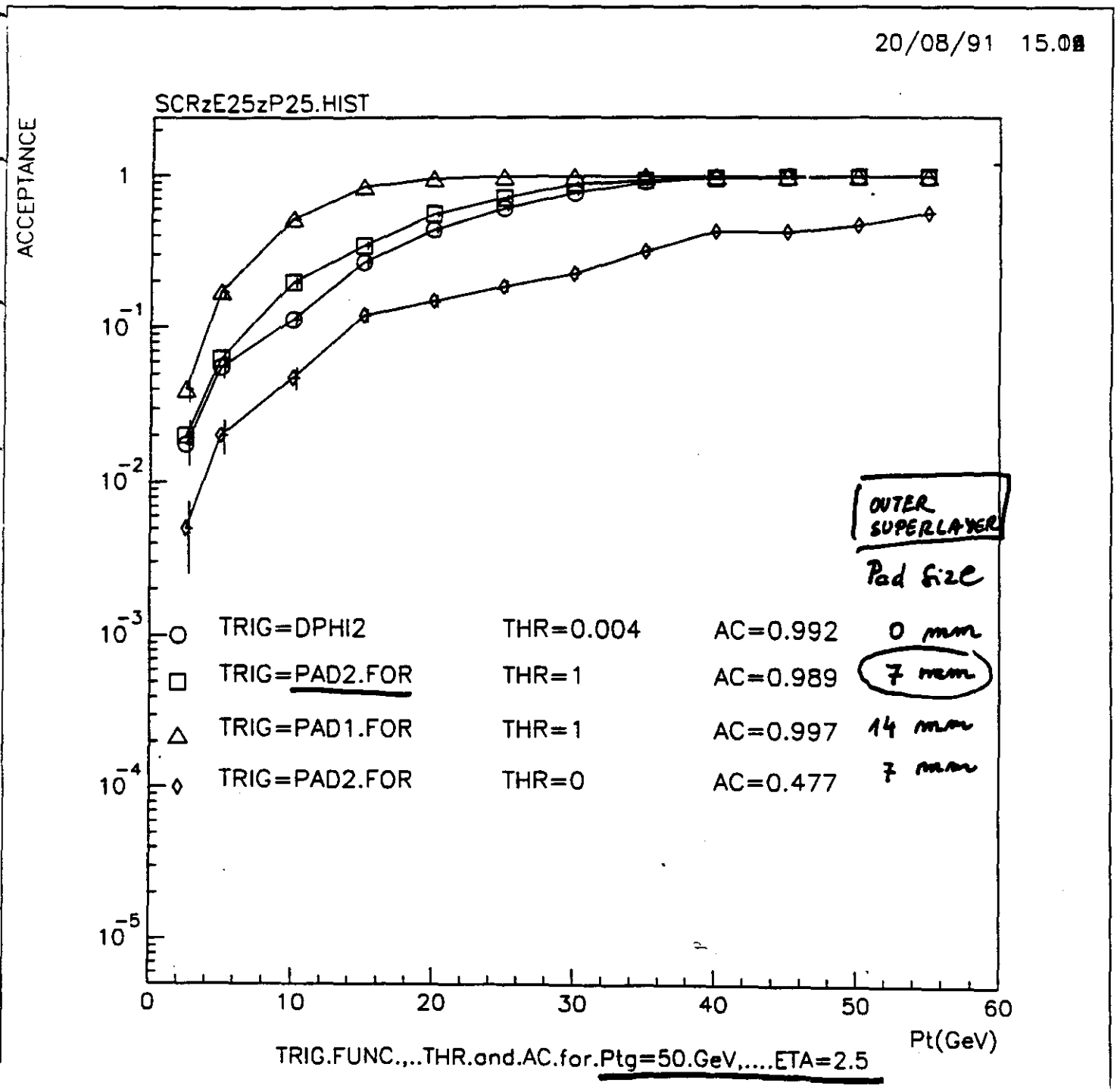


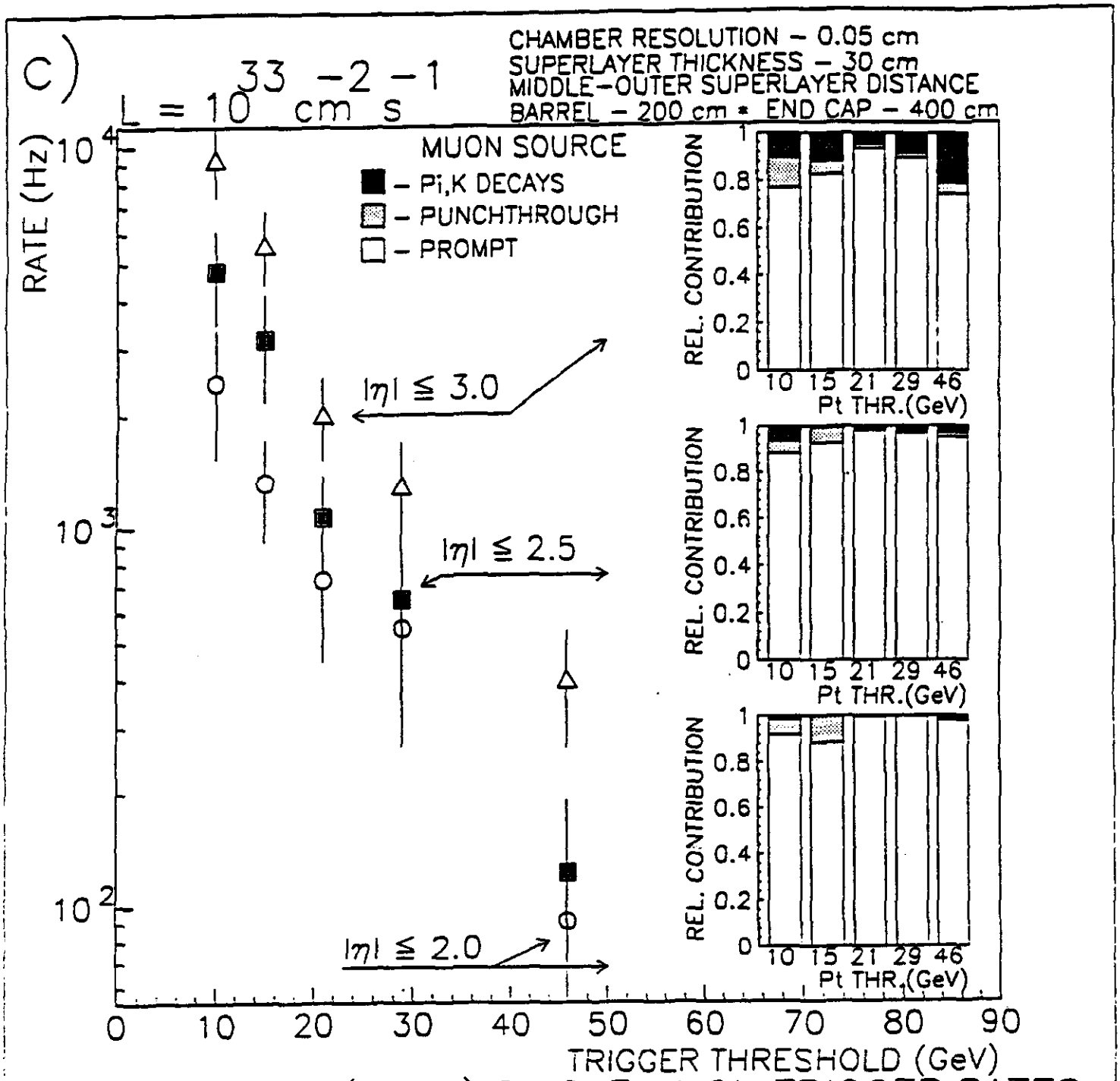
D. REFOL : 0.1 cm

Level 2 Trigger

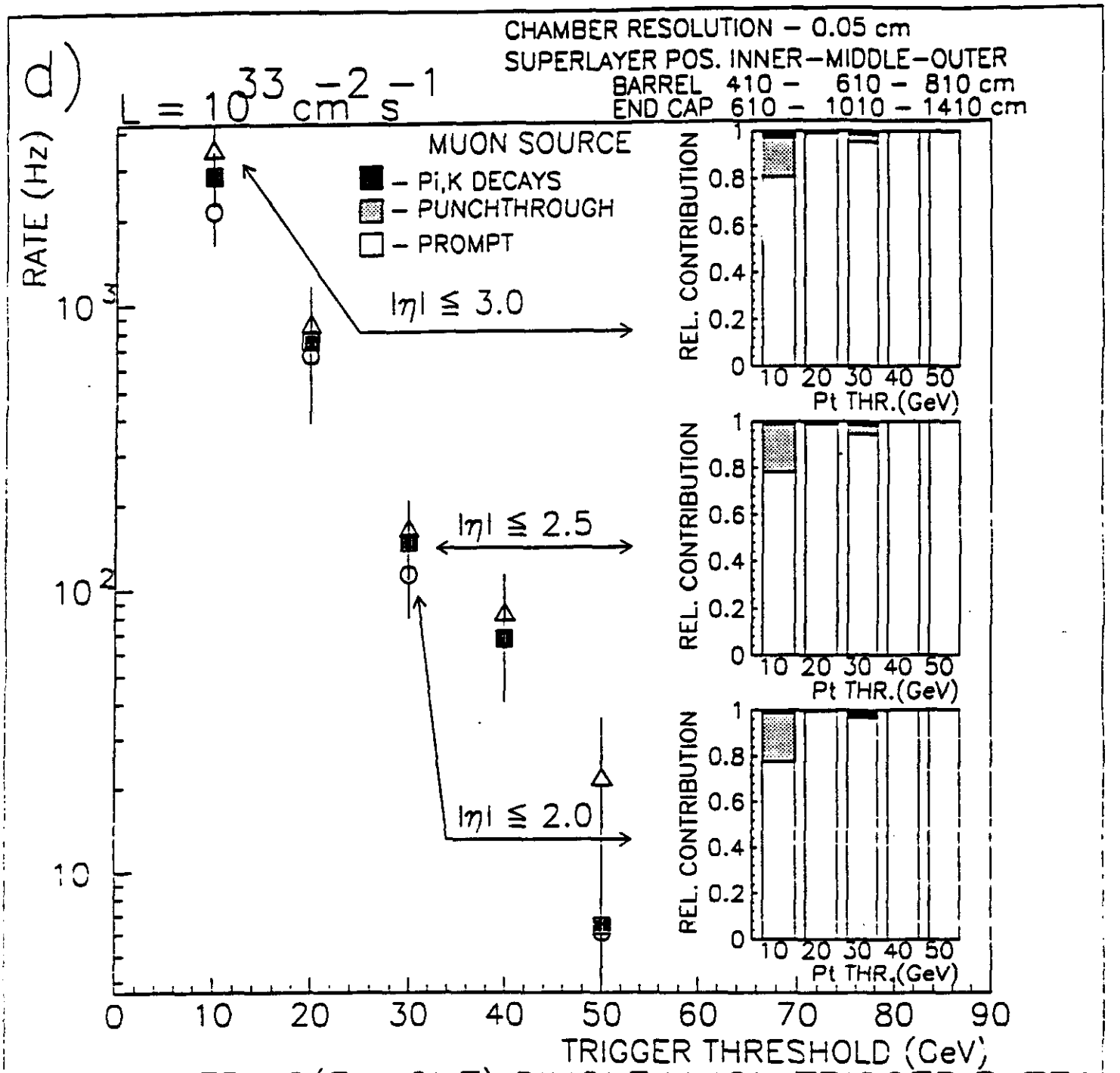
"Ray Trigger"



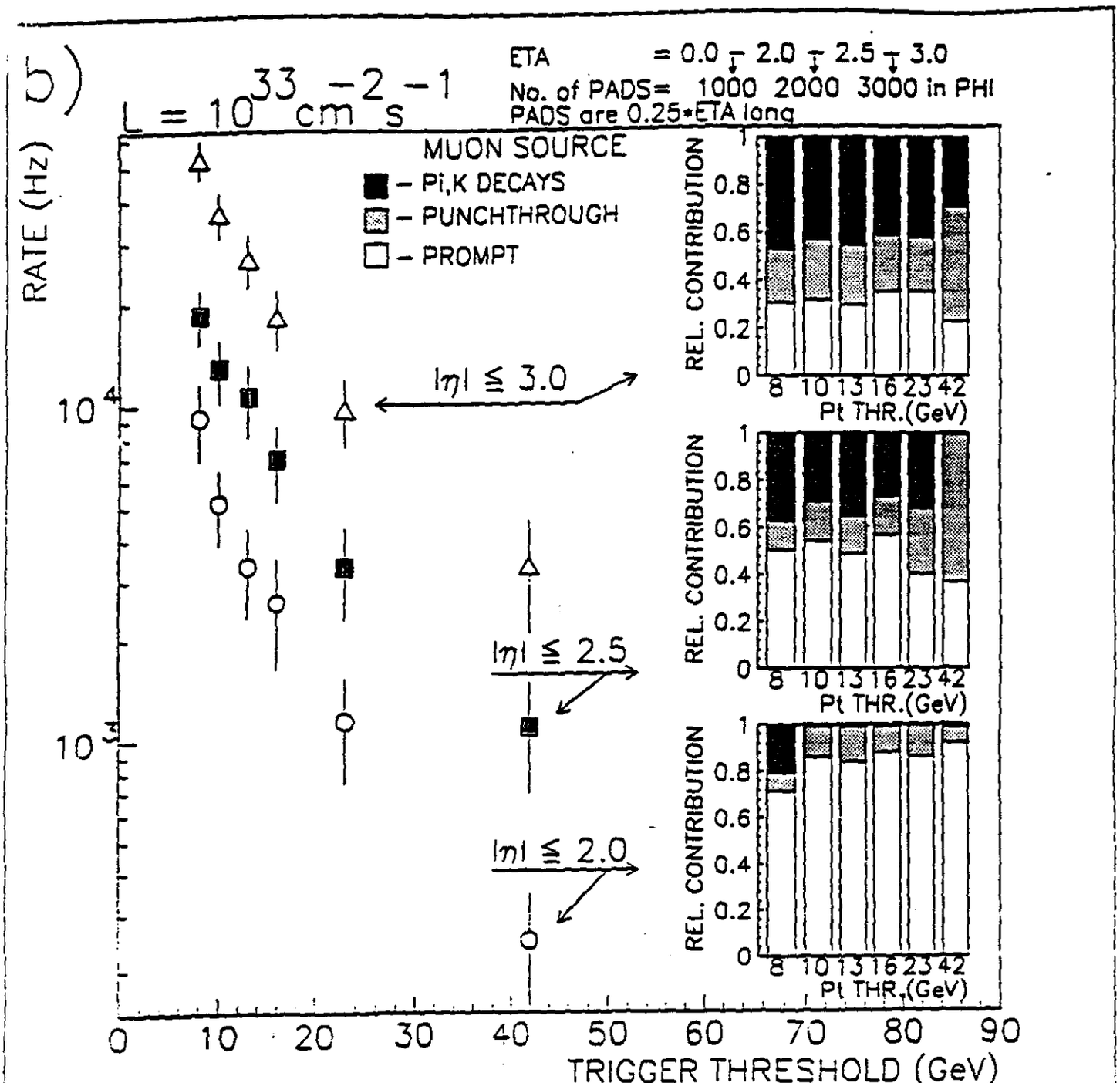

20/08/91 15.08
SCRzE25zP25.HIST
ACCEPTANCE
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
10
20
30
40
50
60
Pt(GeV)
TRIG=DPHI2 THR=0.004 AC=0.992
TRIG=PAD2.FOR THR=1 AC=0.989
TRIG=PAD1.FOR THR=1 AC=0.997
TRIG=PAD2.FOR THR=0 AC=0.477
OUTER SUPERLAYER
Pad size
0 mm
7 mm
14 mm
7 mm
TRIG.FUNC.,..THR.and.AC.for.Ptg=50.GeV,....ETA=2.5



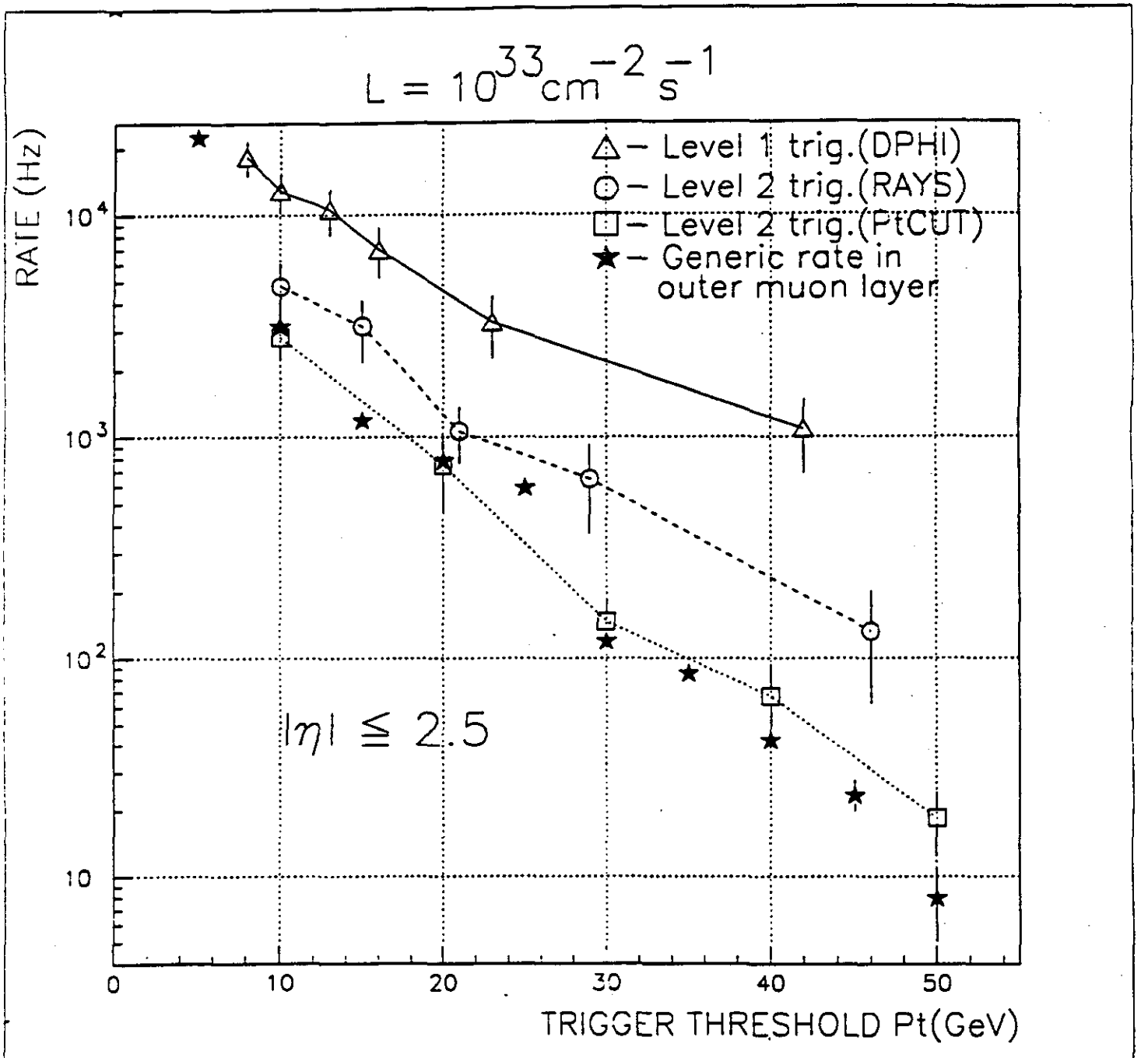
INTEGRATED L2(RAYS) SINGLE MUON TRIGGER RATES



INTEGRATED L2(Pt–CUT) SINGLE MUON TRIGGER RATES



INTEGRATED L1 (DPHI) SINGLE MUON TRIGGER RATES



INTEGRATED SINGLE MUON RATES

- OPTIMIZATION OF PAD DIMENSIONS

- DPHI TRIGGER USING ONLY OUTER LAYER

IF 40 cm thick
AND
SPACE POINT REFOL. OF 0.5 mm
(3 bit interpolation in PAD CH.)

$\Rightarrow \sim 20\%$ increase in L1

- BUT if MIDDLE LAYER ALSO INSTRUMENTED THE SAME WAY

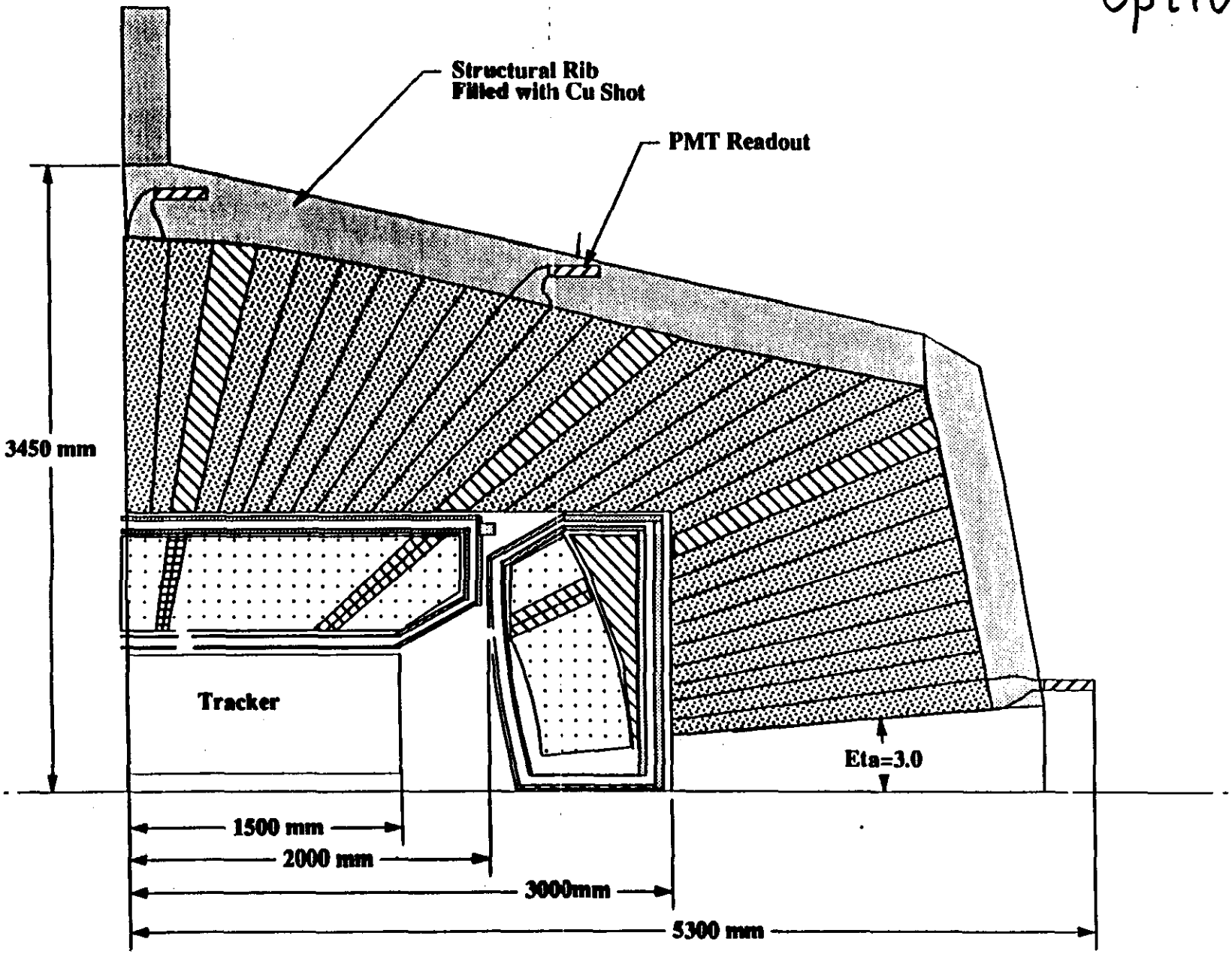
$\Rightarrow$ L1 rates comparable to current L2 (RAYS)

Radial extention (various options)

$$L_{90^\circ}^{abs} = 11.7\ \lambda_o$$

E-M	hadron	cm
• Pb/LAr	+ U/LAr	75 - 350
• BaF2	+ Cu/Sci. fibers	75 - 330
	+ Cu/Sci. tiles	75 - 330
	+ W/Sci. fibers	75 - 310
	+ W/Sci. tiles	75 - 290
• Pb/LKr	+ Cu/Sci. fibers	75 - 345
	+ Cu/Sci. tiles	75 - 345
	+ W/Sci. fibers	75 - 325
	+ W/Sci. tiles	75 - 305

Option F

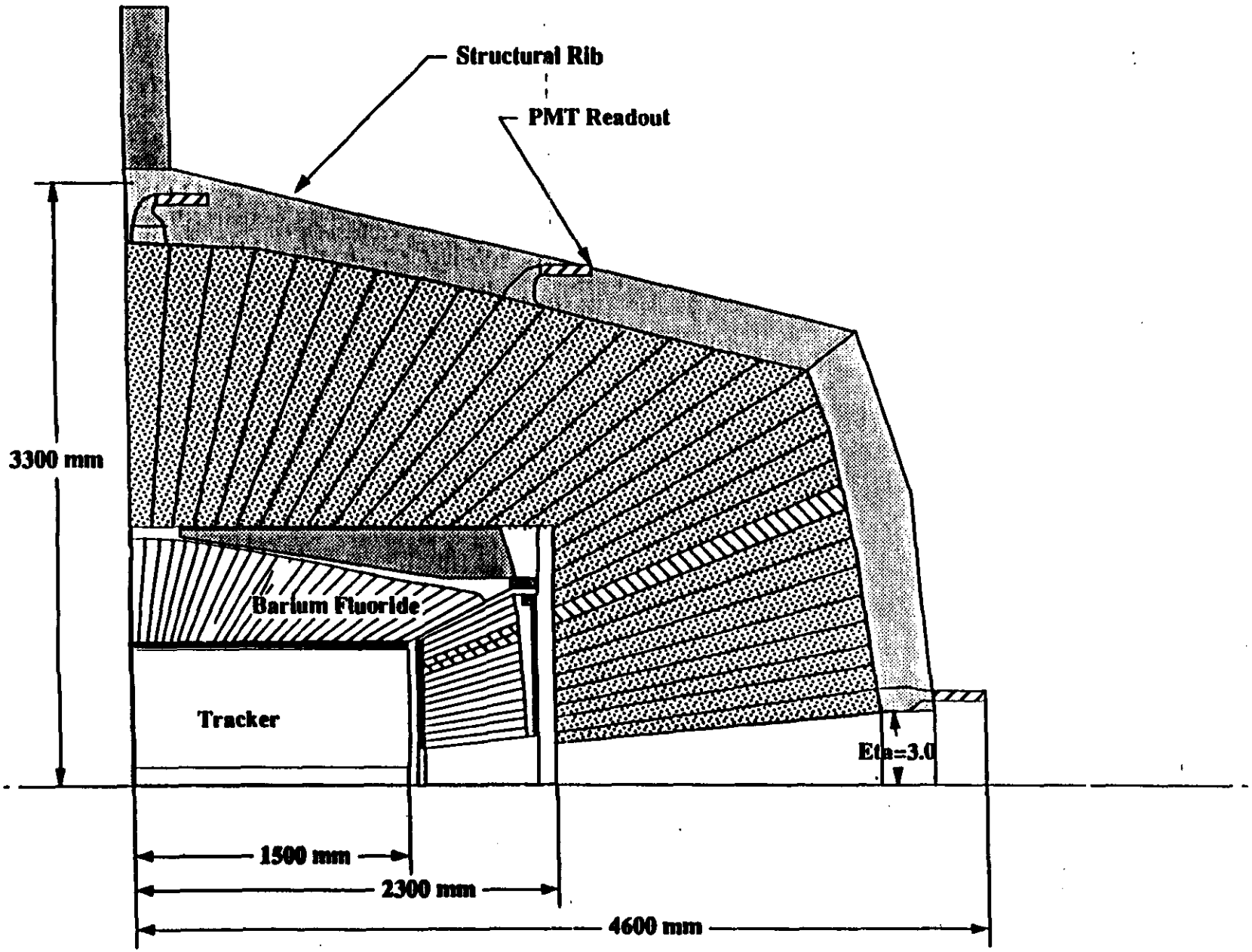


Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Liquid Argon EM Calorimeter

G.03.SC.00080

Rennich

Option B (~LoI)



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Barium Fluoride EM Calorimeter

G.03.SC.00079

Rennich

Suggested issues for Pattern recognition group

1) Setting up a "shell" for systematic study of reconstruction issues

   a) Hit generation

   b) Background & cell memory effects

2) A systematic determination of number of layers in muon system necessary for effective Pattern recognition (Both Barrel & EndCap)

3) Effects of B-field on Pattern recognition
   (J. Sullivan B-field code is now available)

4) Setting up a rudimentary reconstruction code for both μ & inner tracker

5) Study of μ-inner tracker alignment & Vertex determination.

Benchmark reactions

$H \to Z^0 Z^0 + X$

$\quad \llcorner \mu^+\mu^- \quad \mu^+\mu^-$

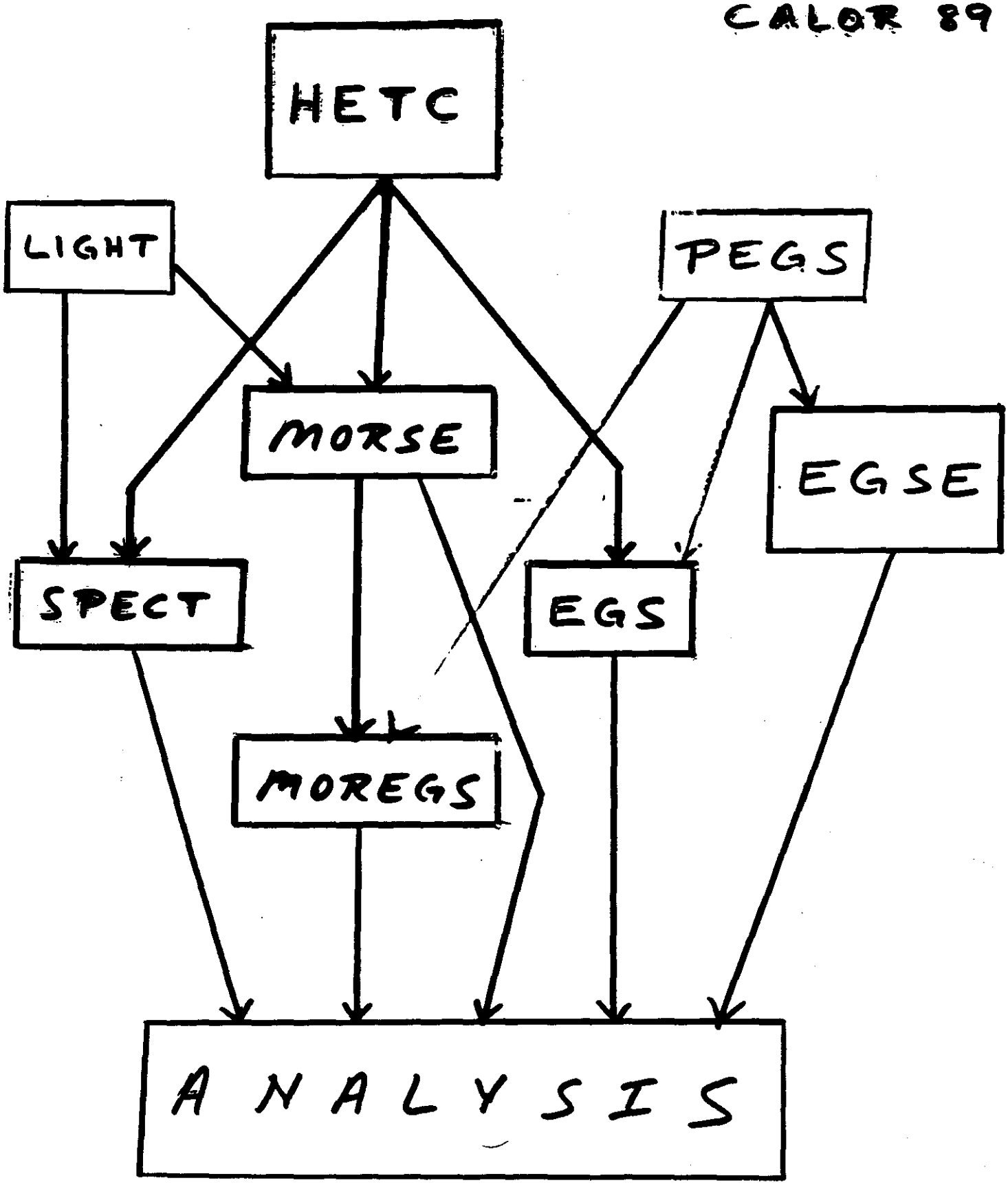
$\quad\quad e^+e^- \quad e^+e^-$

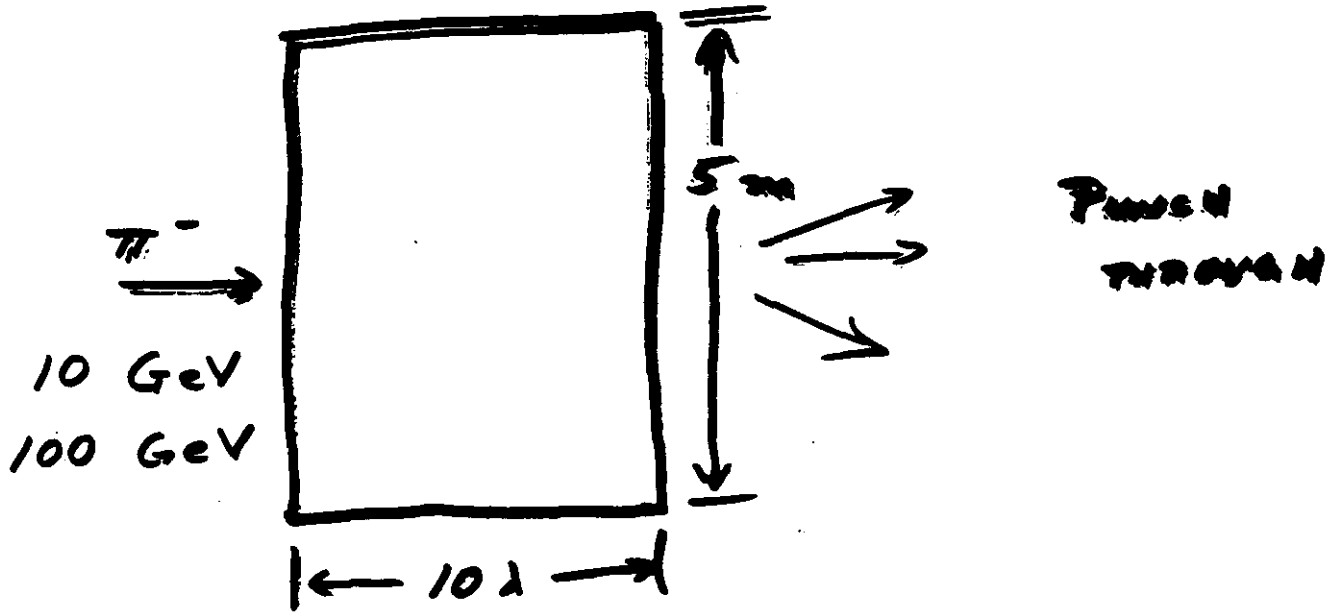
b-jet tagging

$t\bar{t}$ (140 & 200 GeV top mass)

Brent R. Moore

CALOR 89





KE CUTOFFS

p, π, μ, e - 1 MeV

γ - 0.1 MeV

n - $\sim 10^{-3}$ eV

COMPARE TO GEANT:

ALL - 1.0 MeV

INTERESTED IN PARTICLES ESCAPING OUT THE BACK w/ MOMENTUM $\geq 1 \frac{MeV}{c}$

NEUTRON: $p = 1 \frac{MeV}{c} \longleftrightarrow E_k = 0.00053$ MeV

$E_k = 1$ MeV $\longleftrightarrow p \approx 43 \frac{MeV}{c}$

NUMBER OF EVENTS WITH AT LEAST ONE PARTICLE ESCAPING WITH MOMENTUM OF 1 MeV/c

	NEUTRONS	CHARGED PARTICLES	PHOTONS	ALL TYPES
IRON - 10 GeV	25.7 %	0.7 %	1.3 %	25.8 %
IRON - 10 GeV (1 MeV CUT OF ALL)	9.1	0.8	0.3	9.3
IRON - 10 GeV (1 MeV CUT ON NEUTRONS IN MOTRSE)	8.4	0.8	1.9	8.8
IRON - 100 GeV	87.6	19.0	70.7	89.0
LEAD - 10 GeV	62.9 %	0.7 %	11.0 %	63.2 %

MULTIPLICITY

Fe- 10 GeV

#	n	CHARGED	γ	ALL
0	74.3 %	99.3 %	98.7 %	74.2 %
1	10.6	0.4	0.6	10.6
2	4.7	0.2	0.4	4.6
3	2.9	0.1	0.1	2.9
4	1.9	—	0.1	1.8
>5	5.6	—	0.1	5.9

Fe- 100 GeV

0	12.4 %	81.1 %	29.3 %	11.1 %
1	8.0	9.5	14.3	6.4
2	6.0	3.0	9.5	5.3
3	5.7	1.4	7.7	5.1
4	4.4	0.9	6.2	3.6
>5	63.5	4.1	33.0	68.5

MULTIPLICITY

Fe - 10 GeV / 1 MeV CUT ON n IN NETG

#	n	CHARGED	γ	ALL
0	90.9 %	99.2 %	99.7 %	90.7 %
1	5.3	0.6	0.1	5.2
2	1.7	0.2	0.1	1.7
3	0.9	—	—	1.0
4	0.4	—	0.1	0.4
> 5	0.8	—	—	1.0

Pb - 10 GeV

0	37.1 %	99.3 %	89.0 %	36.8 %
1	13.1	0.5	6.9	13.0
2	11.2	0.1	2.5	10.8
3	7.4	—	0.9	7.4
4	4.8	0.1	0.4	4.6
> 5	36.4	—	0.3	27.4

MOMENTUM DIST. - # ESCAPES / EVENT

Fe - 10 GeV

MOM.	n	CHARGED	γ	ALL
0-50 MeV/c	0.8	—	—	0.8
50-100	0.1	—	—	0.1
100-150	—	—	—	—
>150	0.1	—	—	0.1

Fe - 100 GeV

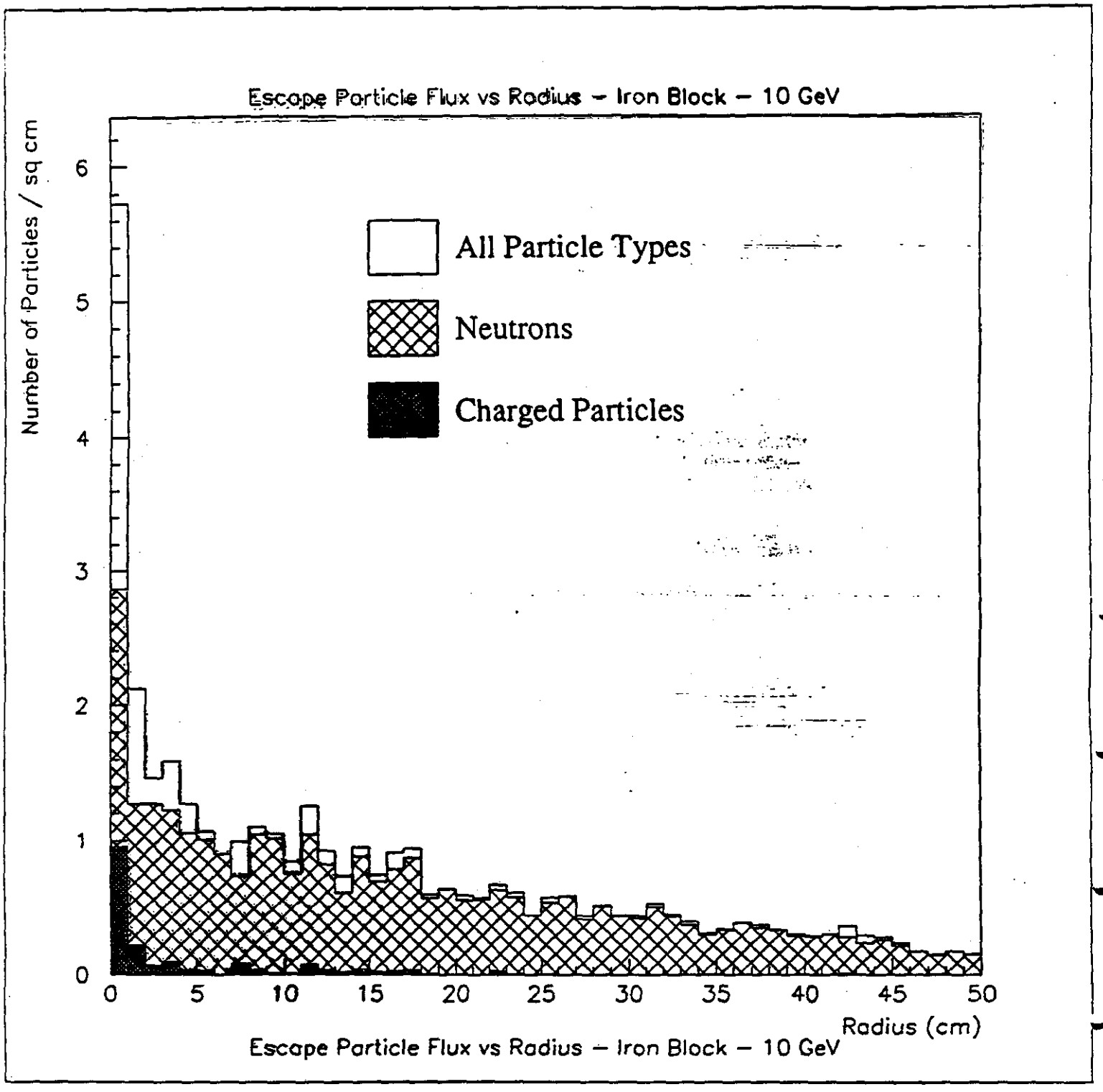
Fe-100 GeV most neutrons 5-35 MeV/c

0-50	14.5	0.2	12.7	27.4
50-100	1.3	0.2	1.0	2.5
100-150	0.3	0.1	0.2	0.6
>150	1.8	0.5	0.2	2.5
	17.9	1.0	14.1	33.0

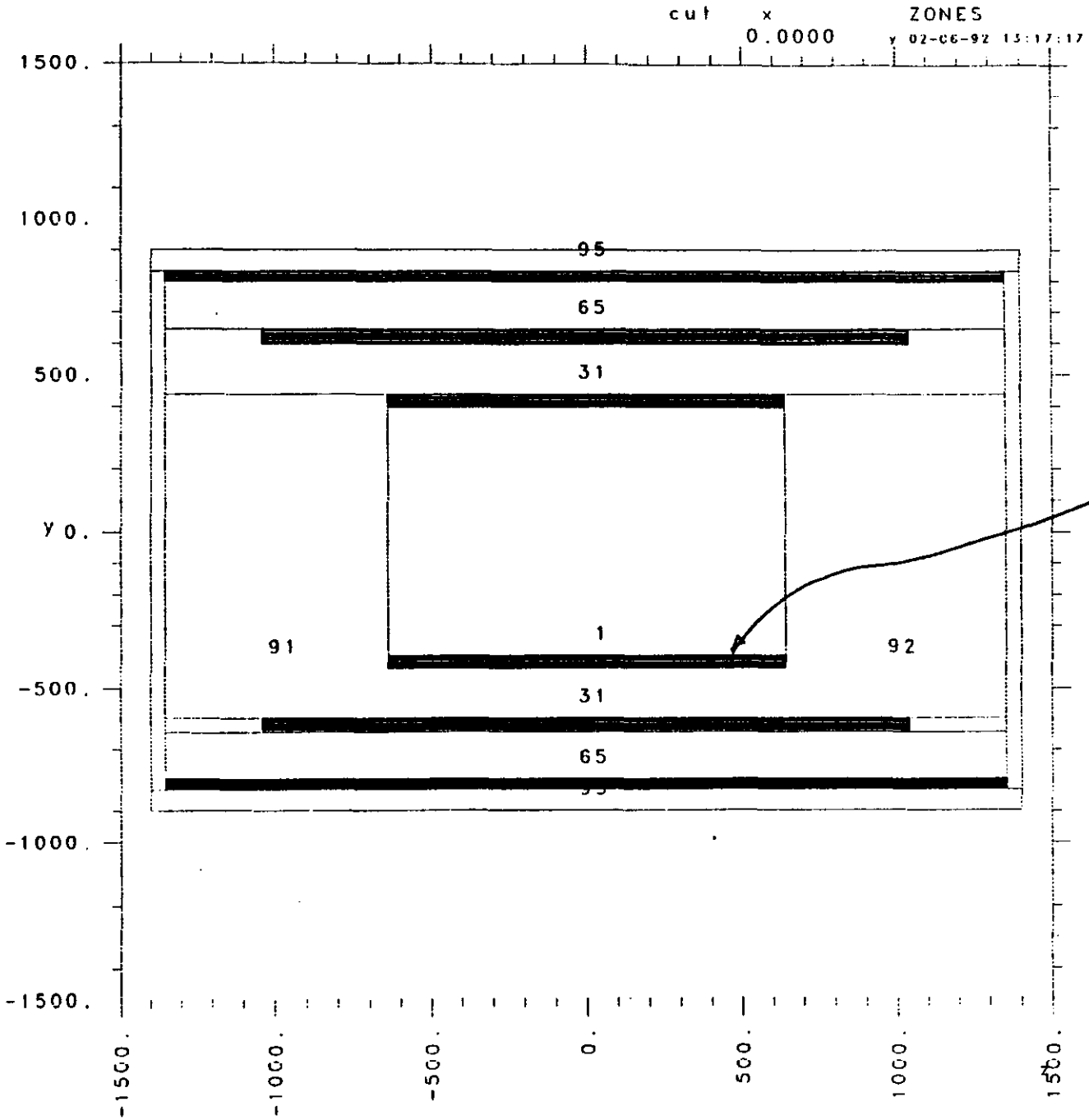
Pb - 10 GeV

Pb-10 GeV most neutrons 20-35 MeV/c

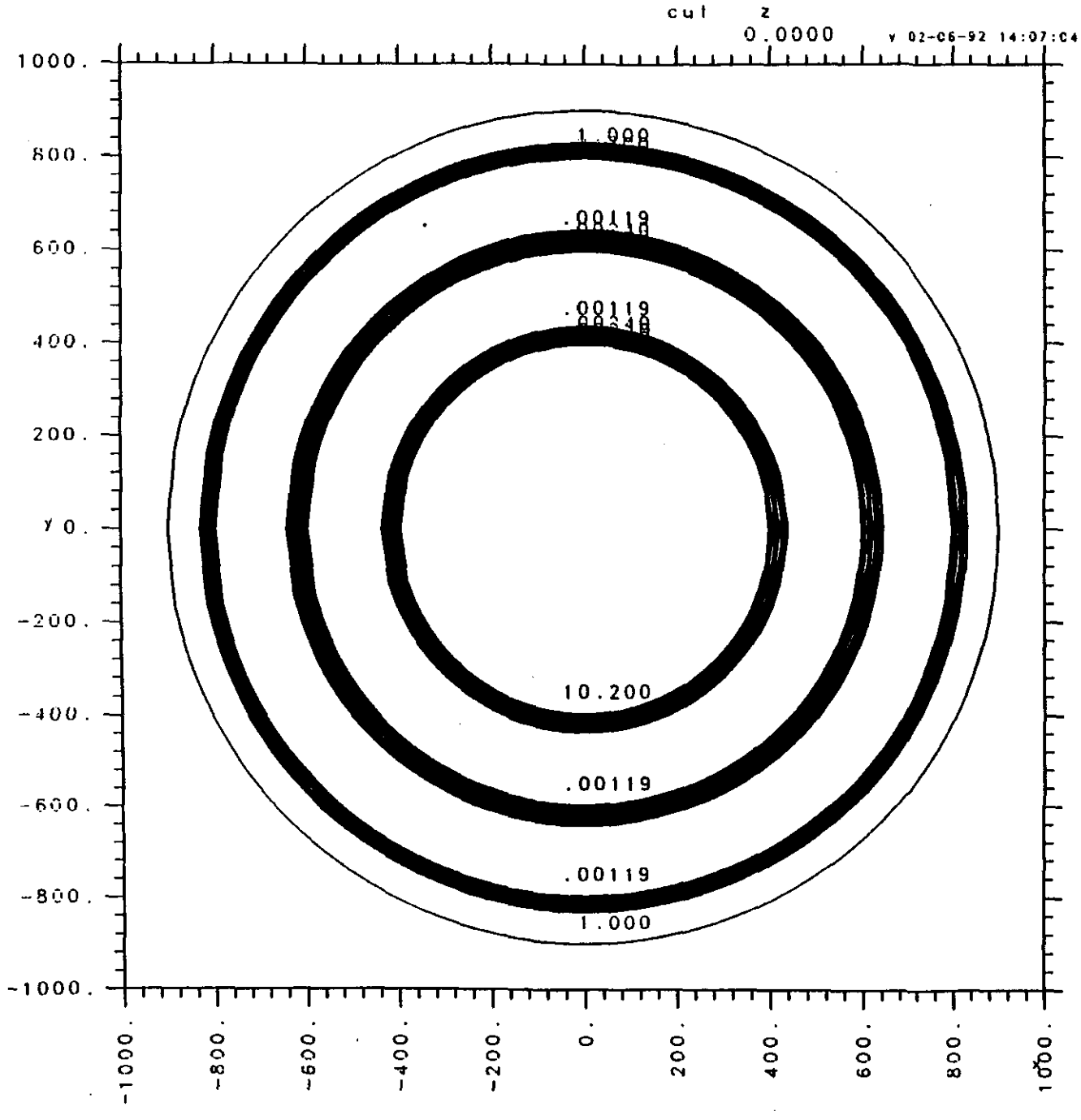
0-50	4.5	—	0.2	4.7
50-100	0.3	—	—	0.3
100-150	—	—	—	—
>150	0.1	—	—	0.1
	4.9		0.2	5.1


Escape Particle Flux vs Radius – Iron Block – 10 GeV
Number of Particles / sq cm
0
1
2
3
4
5
6
All Particle Types
Neutrons
Charged Particles
0
5
10
15
20
25
30
35
40
45
50
Radius (cm)
Escape Particle Flux vs Radius – Iron Block – 10 GeV

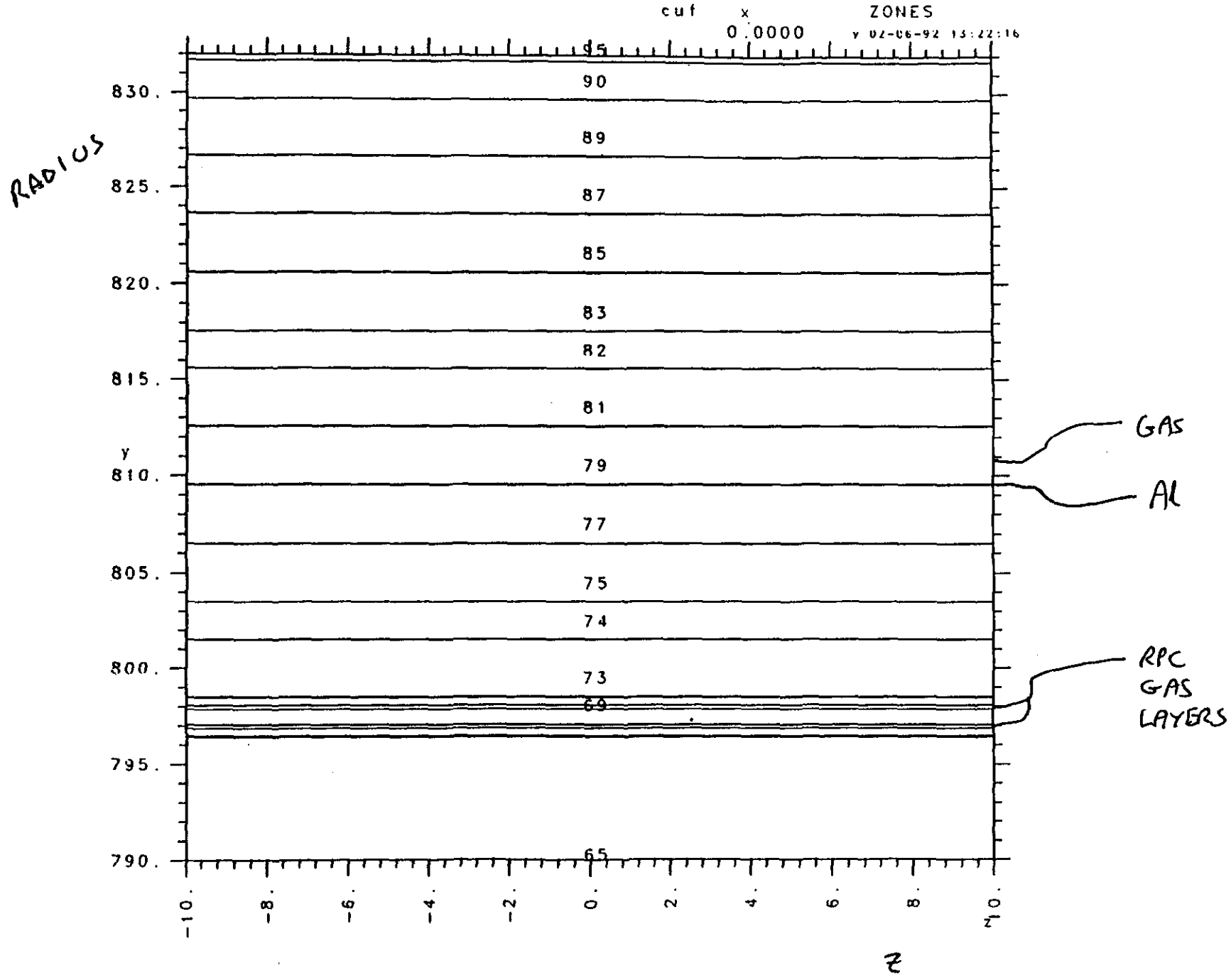
T. Wenaus for Craig West



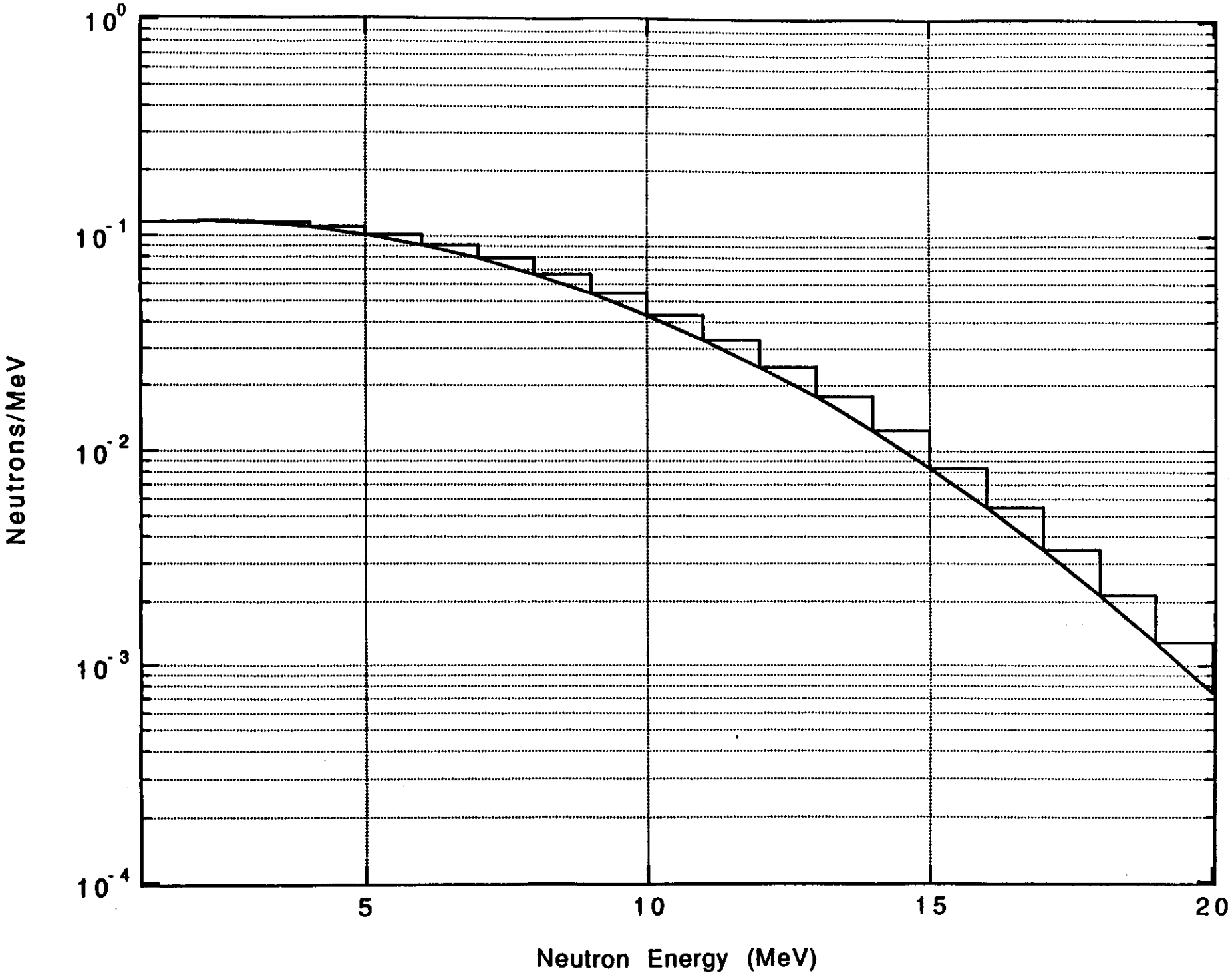
ISOTROPIC
n SOURCE
IN SHELL
AT CALOR
OUTER SURFACE
(LAr/U)

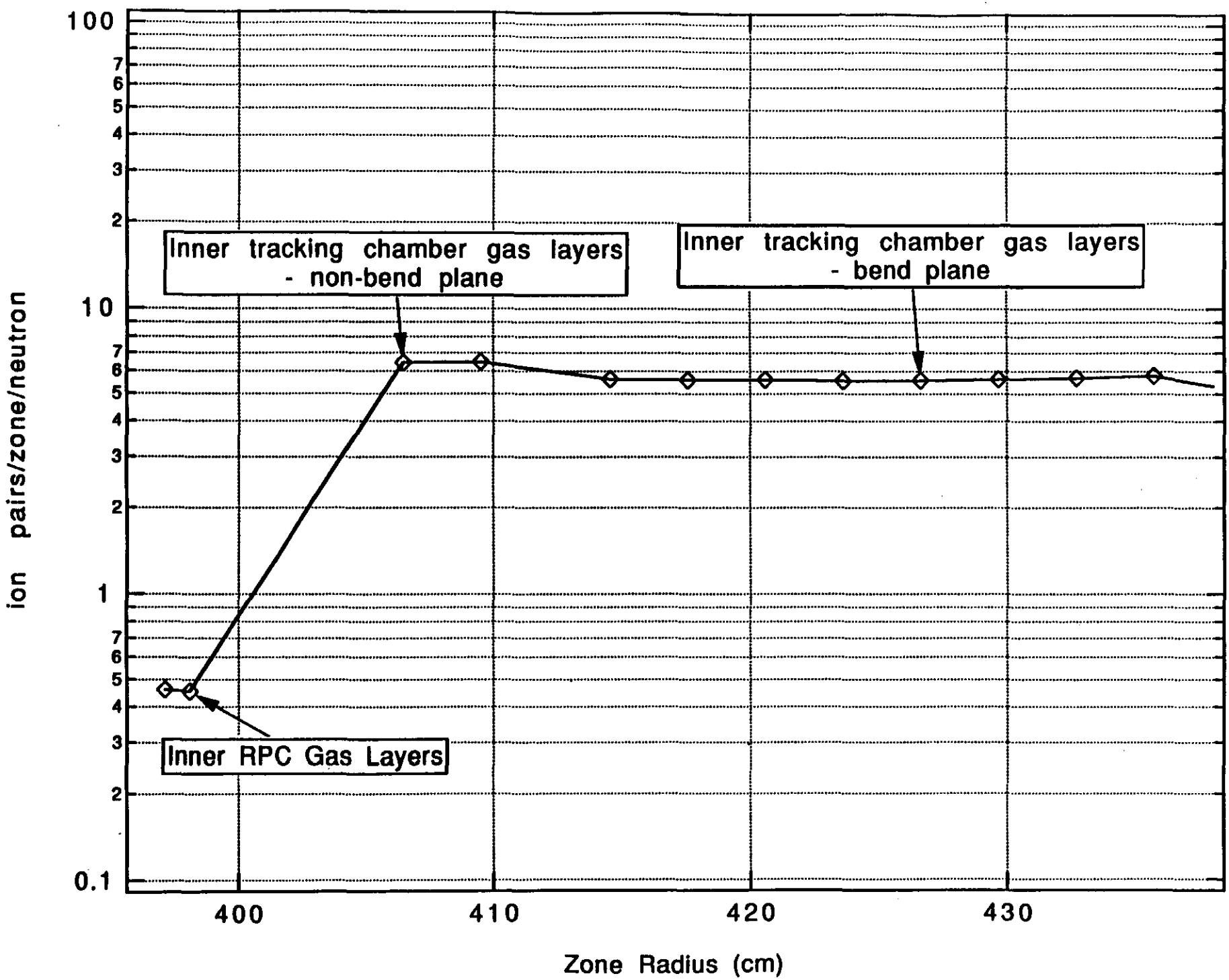

cut z
0.0000
v 02-06-92 14:07:04
1.000
.00119
.00119
10.200
.00119
.00119
1.000
1000.
800.
600.
400.
200.
y 0.
-200.
-400.
-600.
-800.
-1000.
-1000.
-800.
-600.
-400.
-200.
0.
200.
400.
600.
800.
1000.

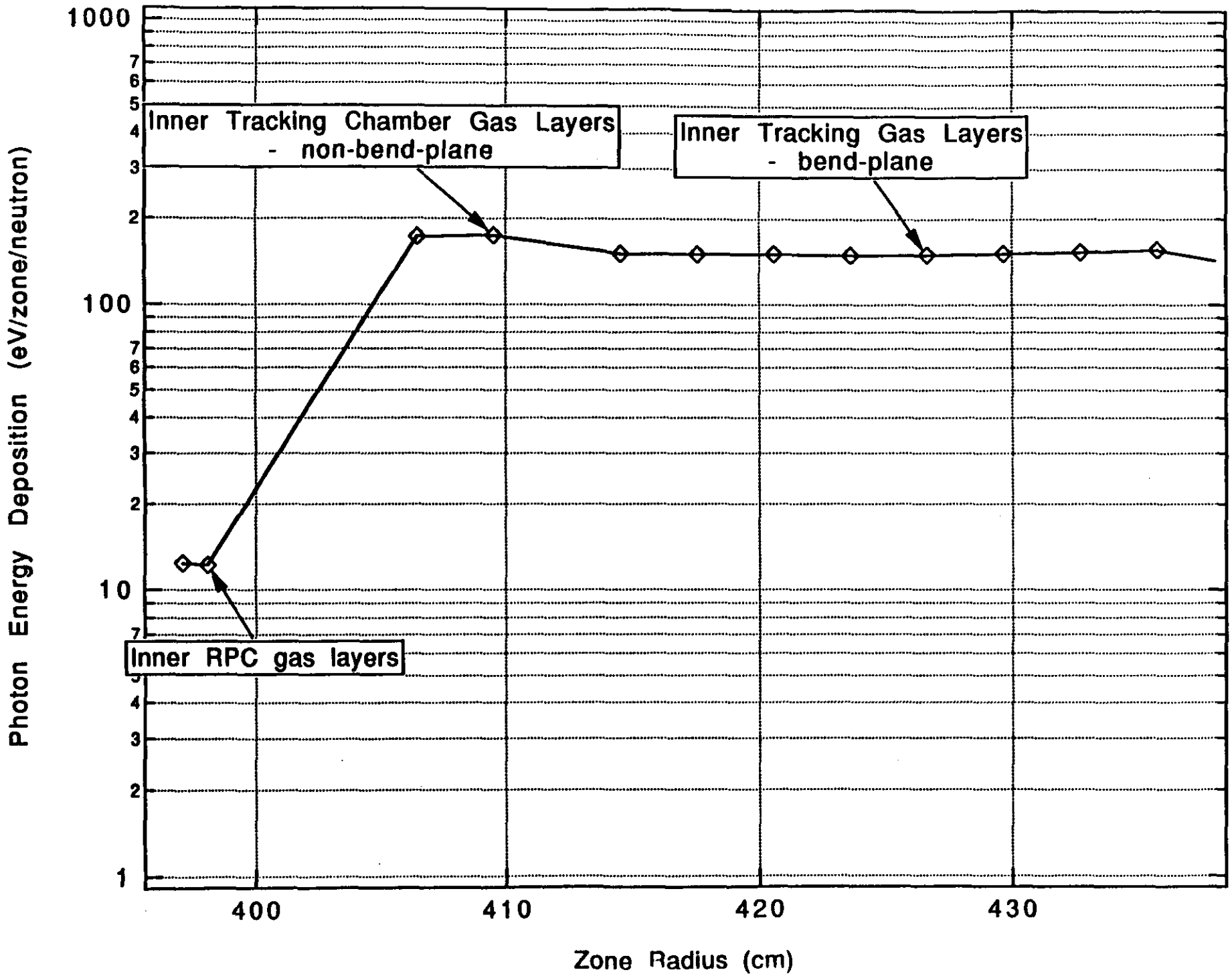
MU DETECTOR ZONES

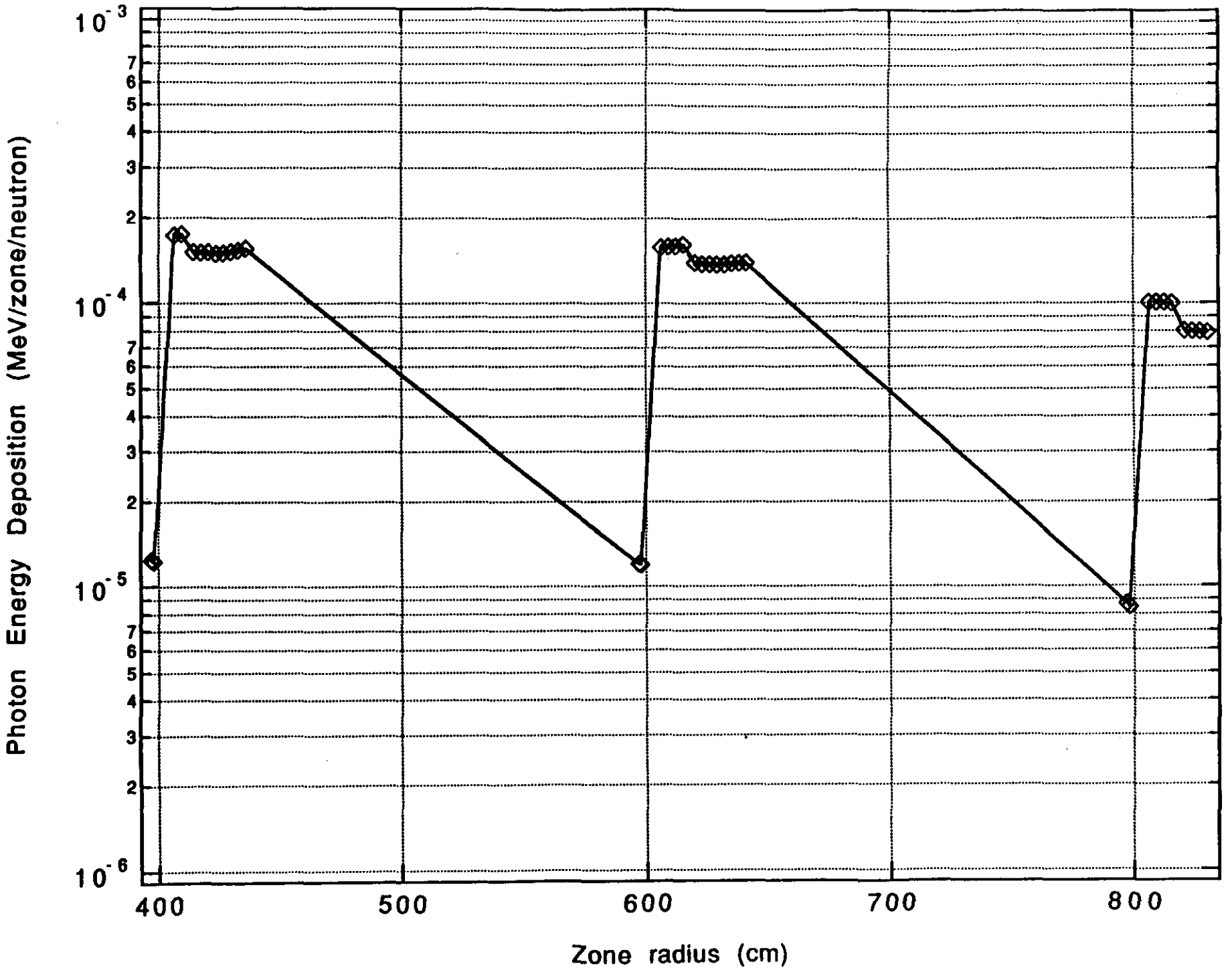


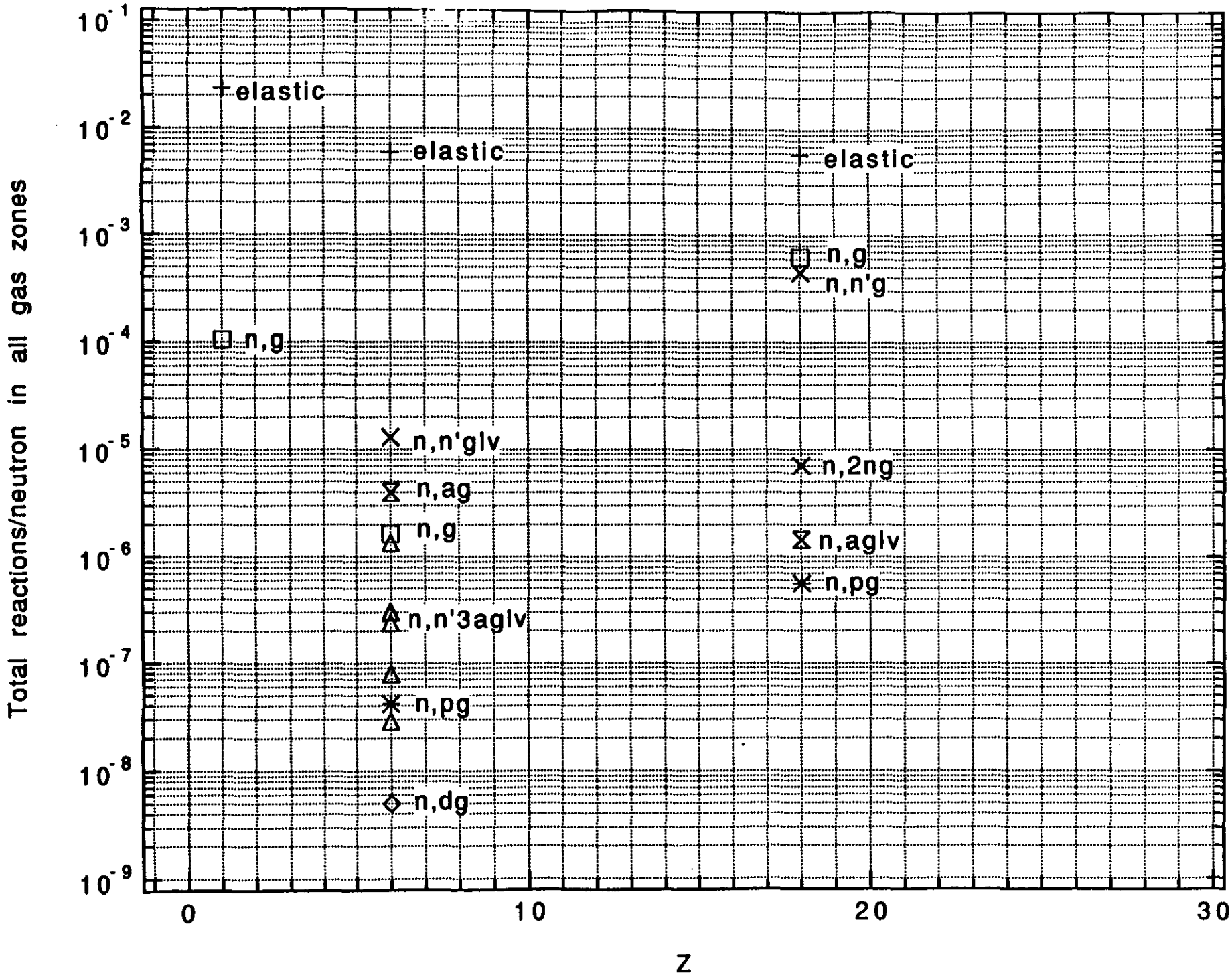
NEUTRON SPECTRUM (DON GROOM, SDG)




Inner tracking chamber gas layers
- non-bend plane
Inner tracking chamber gas layers
- bend plane
Inner RPC Gas Layers
ion pairs/zone/neutron
Zone Radius (cm)
100
10
1
0.1
400
410
420
430


Inner Tracking Chamber Gas Layers
- non-bend-plane
Inner Tracking Gas Layers
- bend-plane
Inner RPC gas layers
Photon Energy Deposition (eV/zone/neutron)
Zone Radius (cm)
1000
100
10
1
400
410
420
430

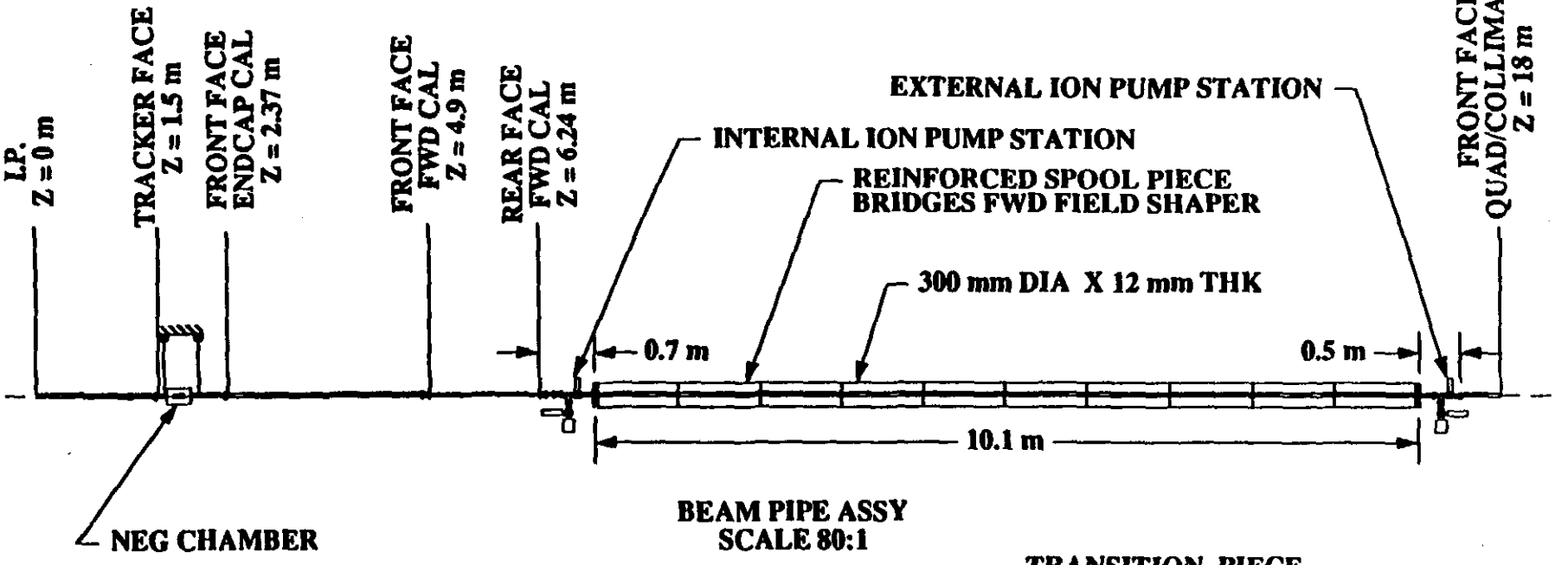

Photon Energy Deposition (MeV/zone/neutron)
10^-3
7
6
5
4
3
2
10^-4
7
6
5
4
3
2
10^-5
7
6
5
4
3
2
10^-6
400
500
600
700
800
Zone radius (cm)


Total reactions/neutron in all gas zones
Z
elastic
elastic
elastic
n,g
n,n'g
n,g
n,n'glv
n,2ng
n,ag
n,g
n,aglv
n,pg
n,n'3aglv
n,pg
n,dg
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
10
20
30

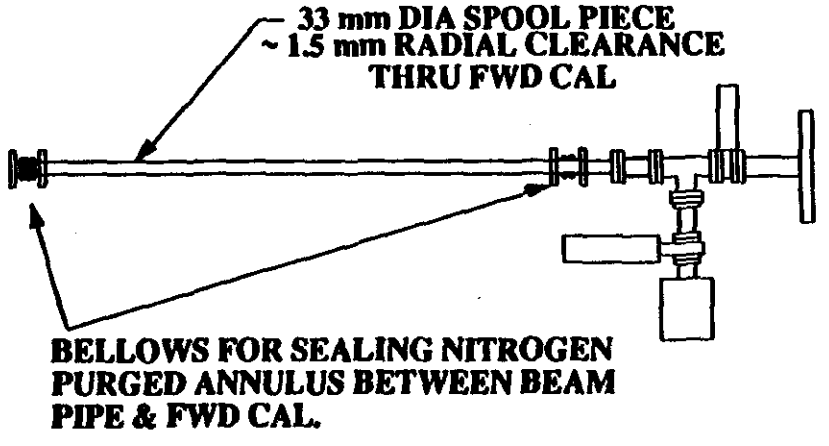
Forward Regions Agenda

Kate Morgan ✓	Beam Pipe Design / Quads
Laurie Waters	Radiation / Activation
Gerry Chapman	Vacuum
Steve Chae	Forward Calorimetry Designs
George Fanourakis ✓	High Pressure Forward Calorimeter
Bill Cleland ✓	Pile up Noise in Forward Cal

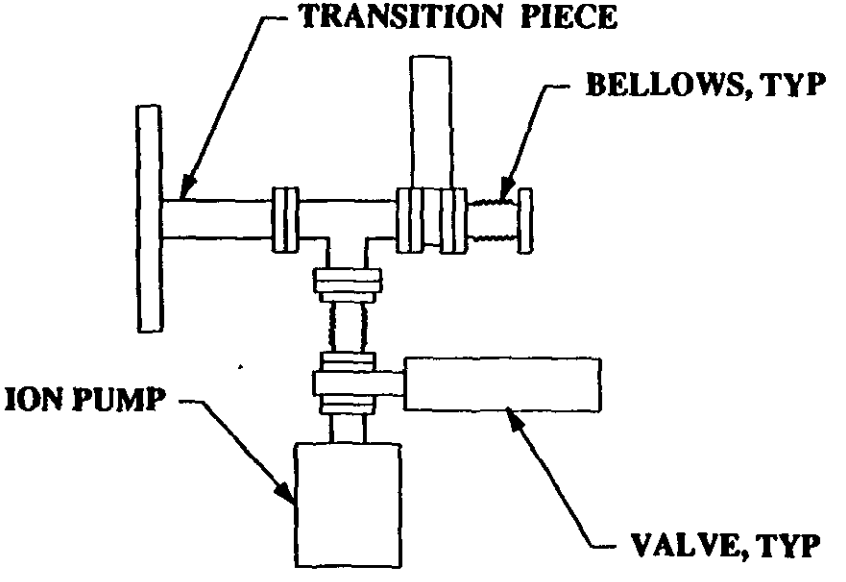
BEAM PIPE DIAMETER IS 50 mm EVERYWHERE EXCEPT THRU FWD CALORIMETER, WHERE IT IS 33 mm DIA. WALL THICKNESS IS ASSUMED TO BE 1 mm.



BEAM PIPE ASSY
SCALE 80:1



INTERNAL ION PUMP STATION
SCALE 20:1



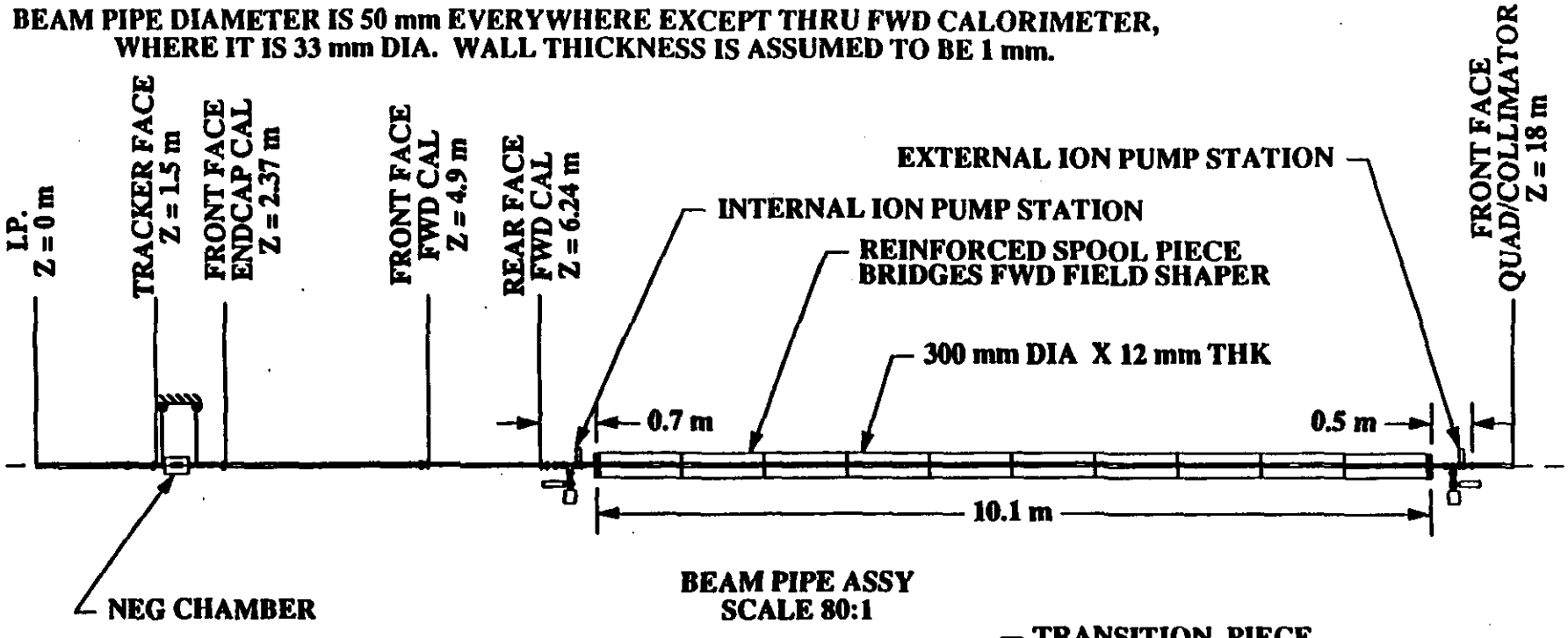
EXTERNAL ION PUMP STATION
SCALE 10:1

DRAFT

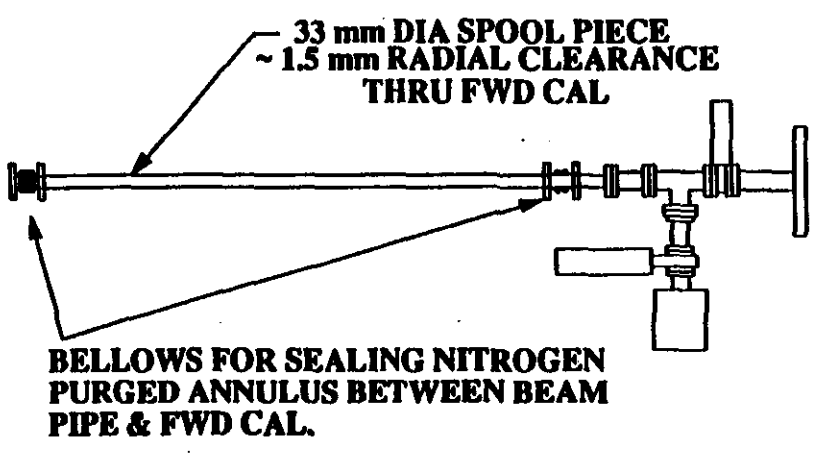
Eberle 02/28/92

Kate Morgan

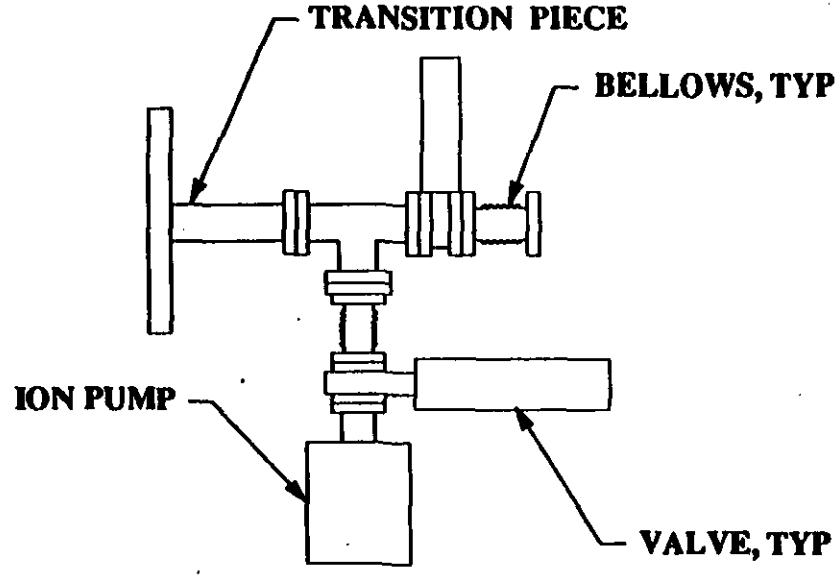
BEAM PIPE DIAMETER IS 50 mm EVERYWHERE EXCEPT THRU FWD CALORIMETER, WHERE IT IS 33 mm DIA. WALL THICKNESS IS ASSUMED TO BE 1 mm.



BEAM PIPE ASSY
SCALE 80:1



INTERNAL ION PUMP STATION
SCALE 20:1



EXTERNAL ION PUMP STATION
SCALE 10:1

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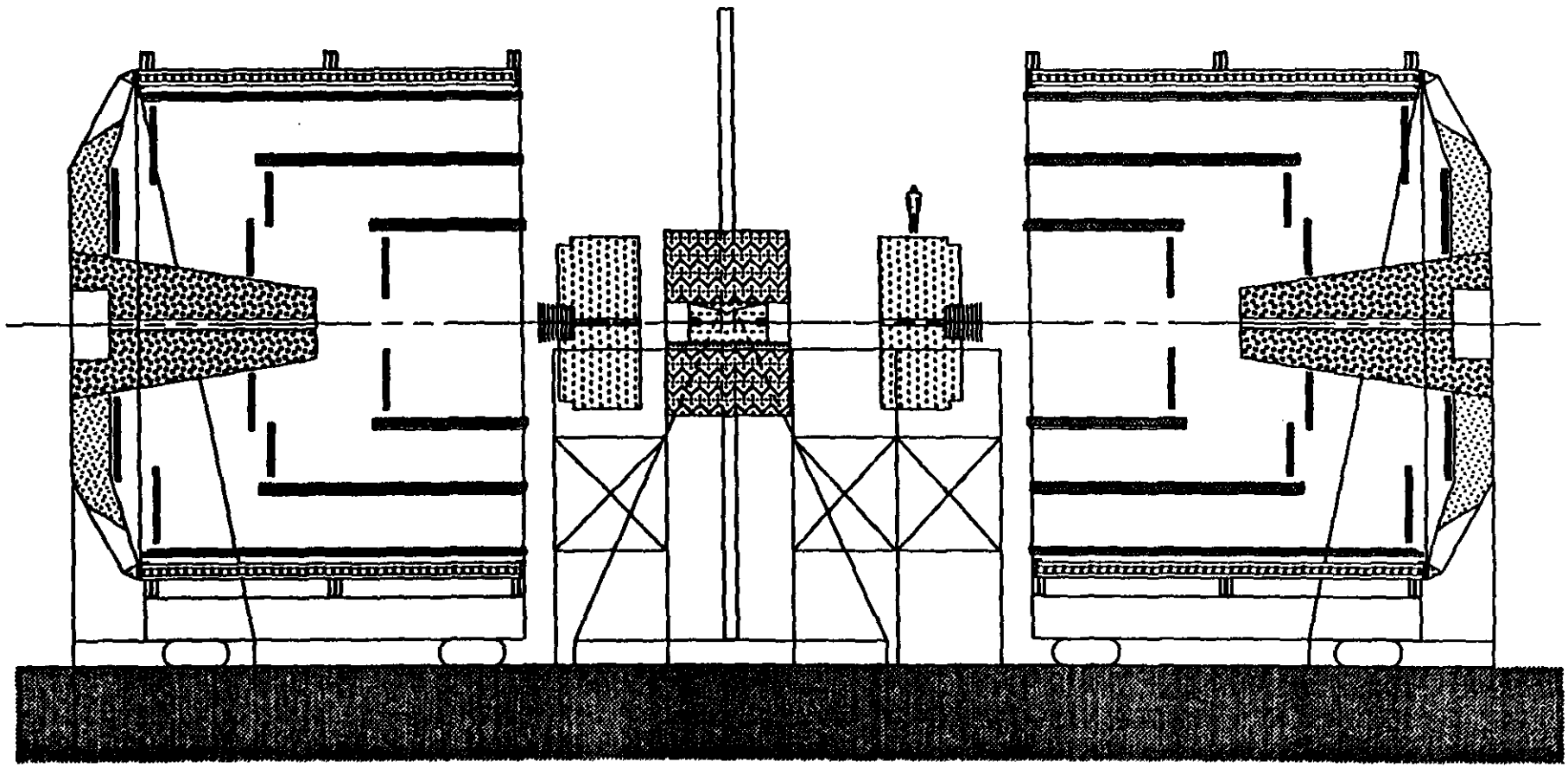
BEAM PIPE INSTALLATION - STEP 0

1. Tracker installed with integral beam pipe.



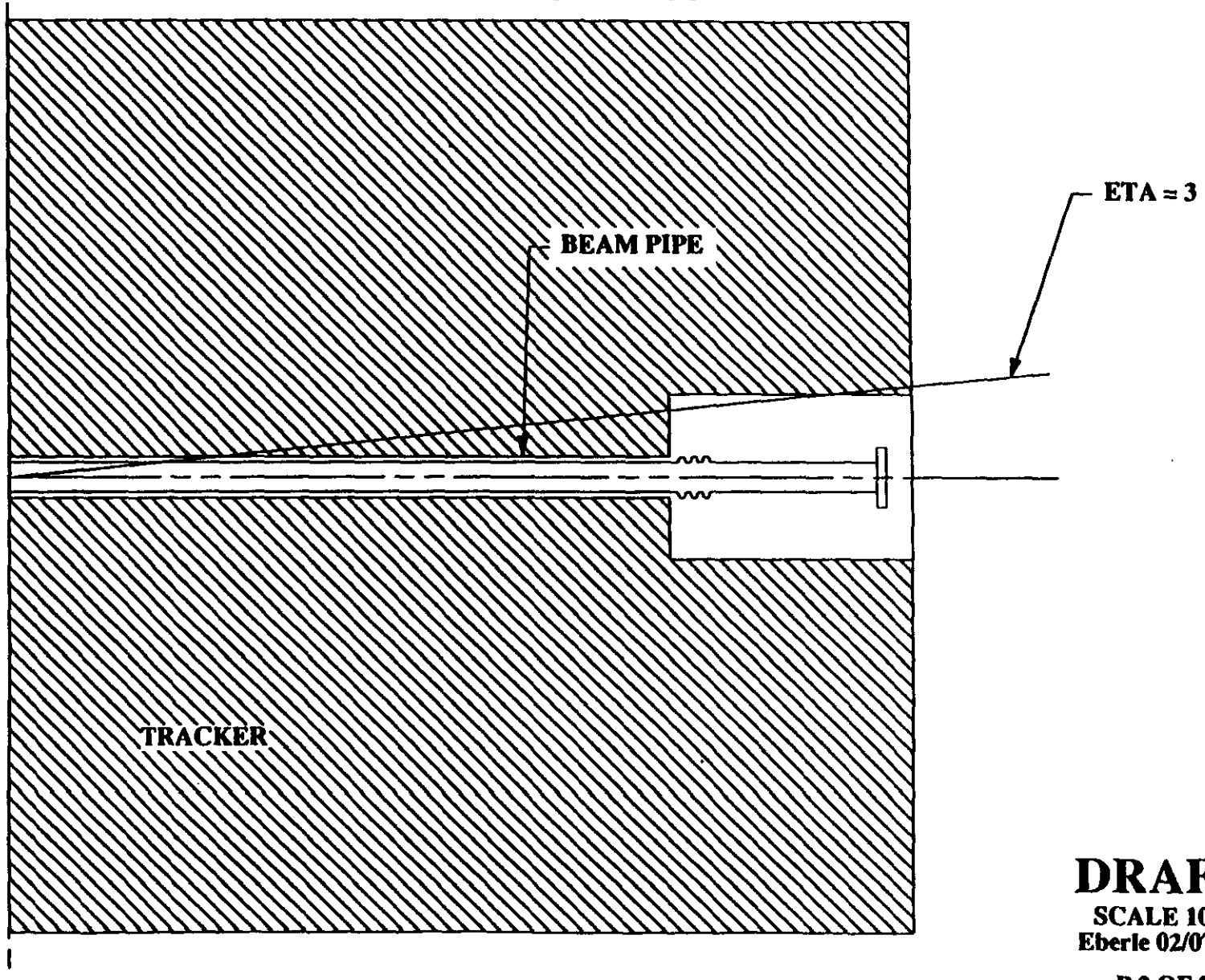
DRAFT

SCALE 250:1
Eberle 02/07/92
Revised 02/27/92

DETECTOR
℄

BEAM PIPE INSTALLATION - STEP 0

1. Tracker installed with integral beam pipe.

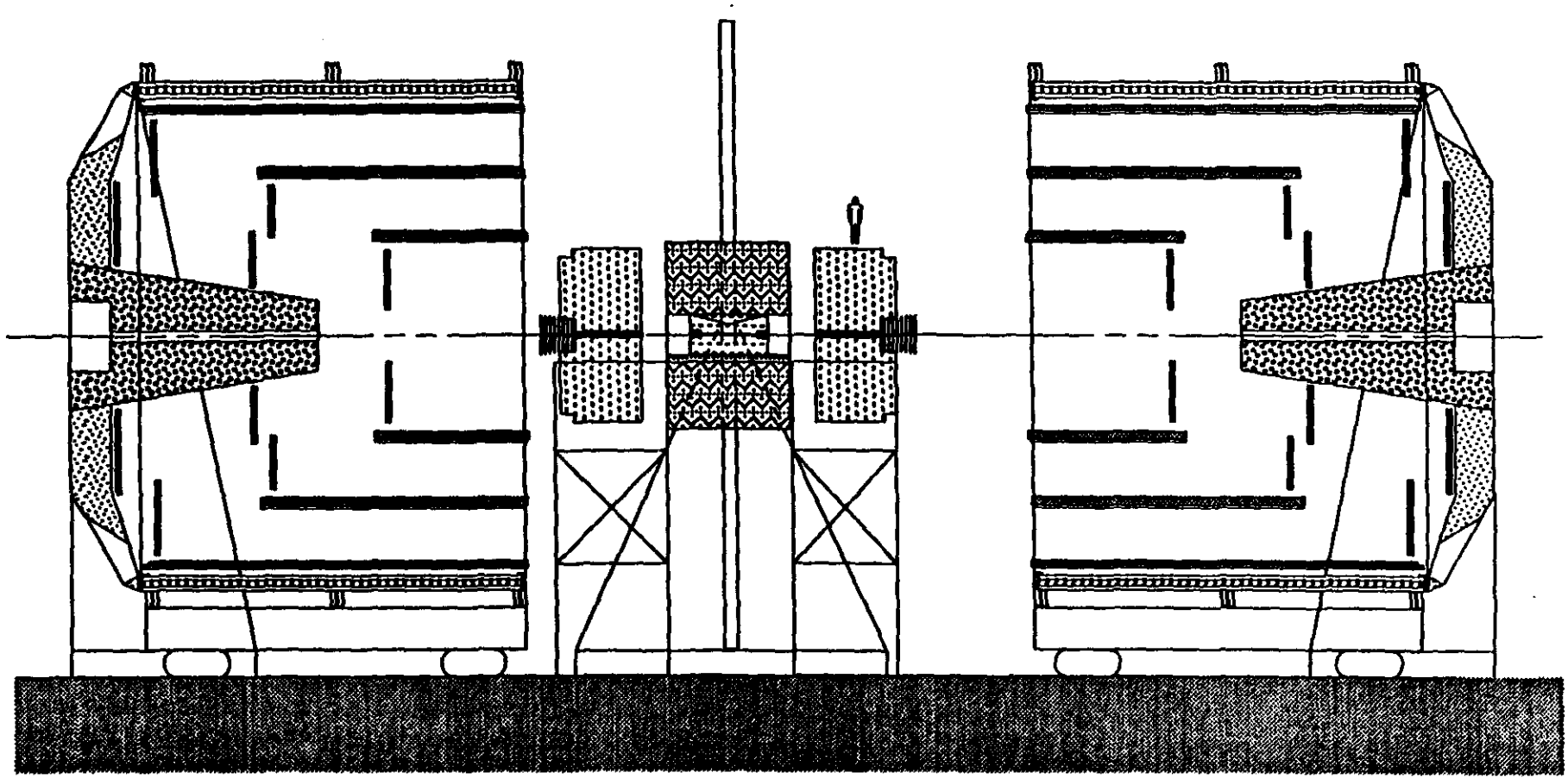


DRAFT

SCALE 10:1
Eberle 02/07/92

BEAM PIPE INSTALLATION - STEP 1

1. Insert 33 mm dia beam pipe section thru endcap calorimeter.
2. Move endcap calorimeter to minimum access position.

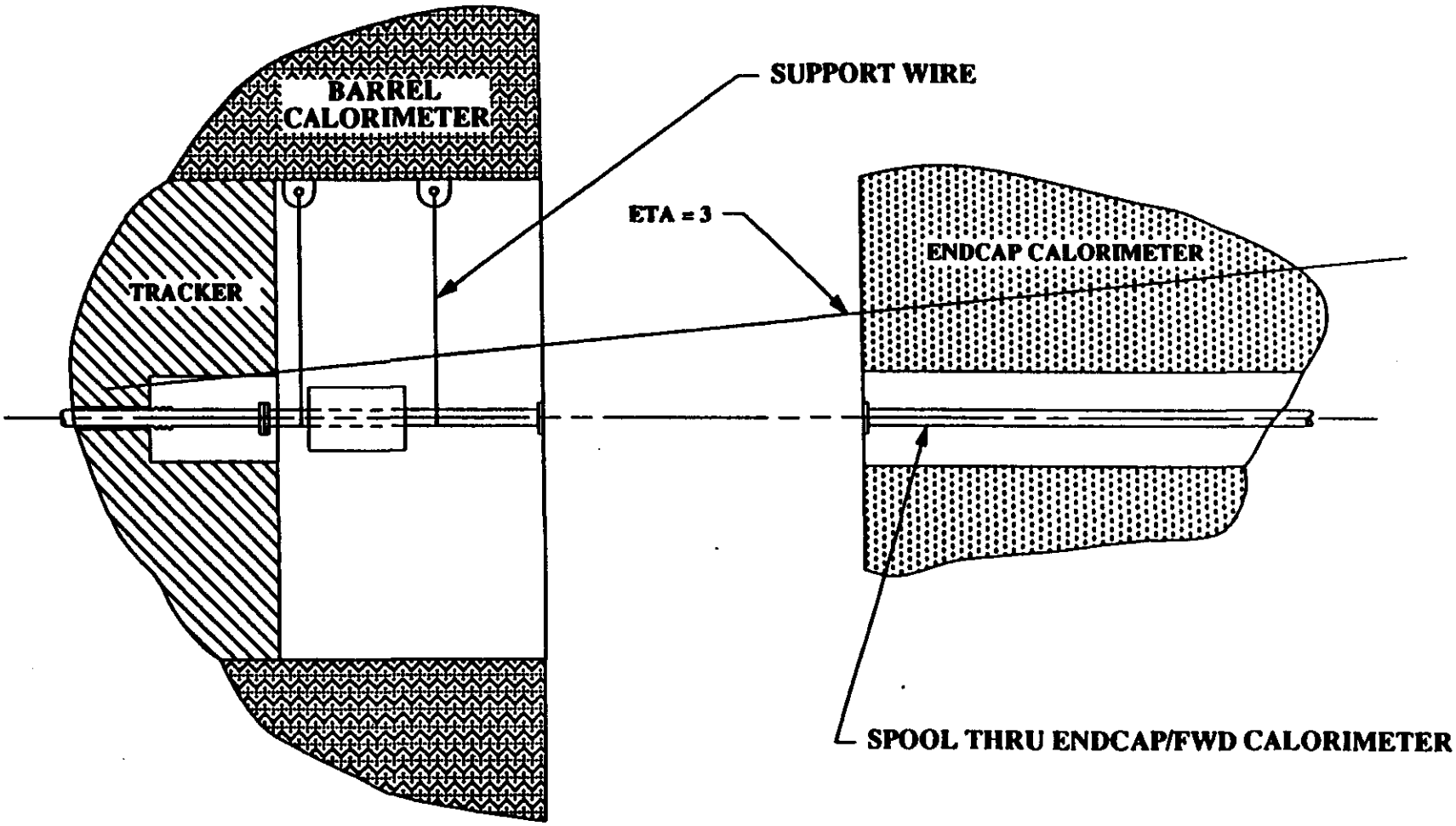


DRAFT

SCALE 250:1
Eberle 02/07/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 2

1. **Install getter chamber, which is supported from the barrel calorimeter.**



DRAFT

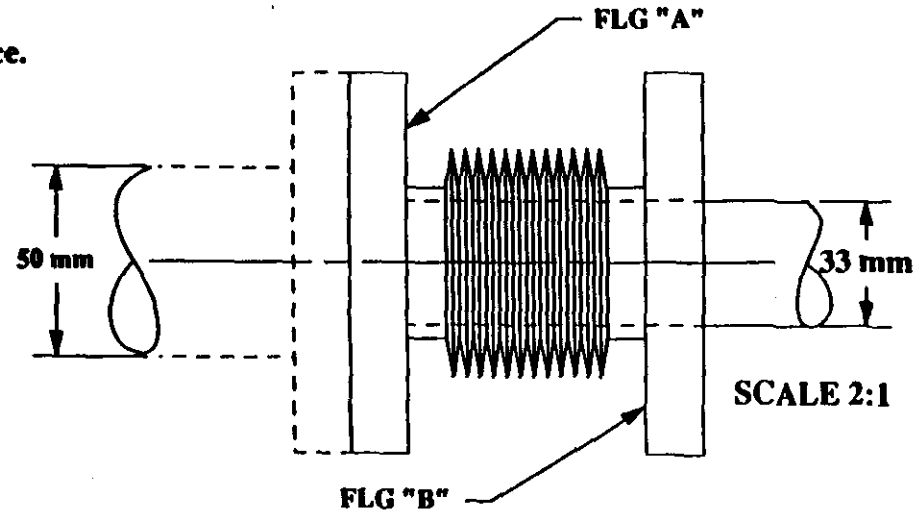
SCALE 20:1

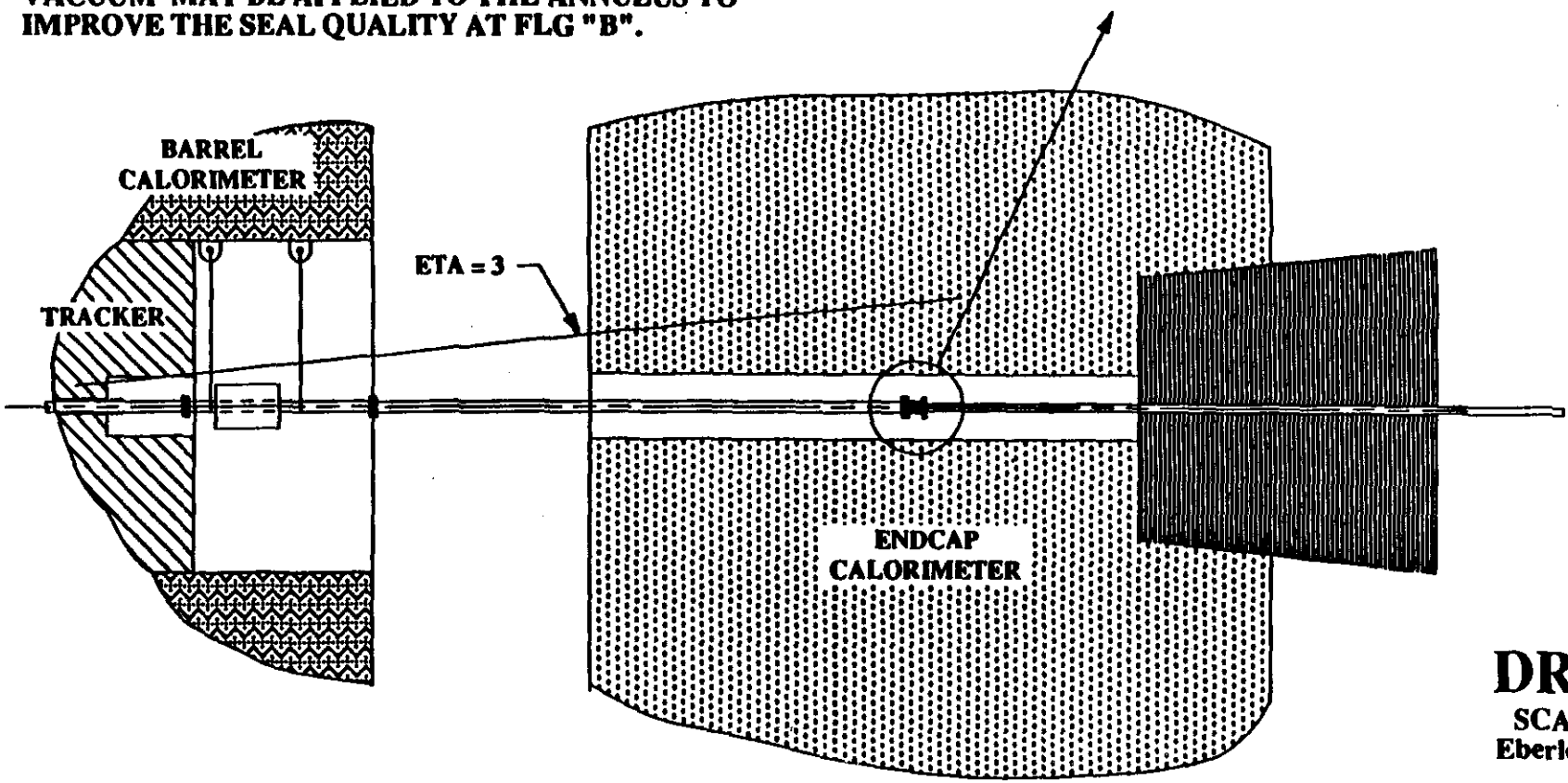
Eberle 02/27/92

BEAM PIPE INSTALLATION - STEP 3

1. **Make joint between getter chamber and mating spool piece.**

FLG "A" IS COMMON TO 33 mm DIA BEAM PIPE SECTION & TO A WELDED BELLOWS WHICH FITS OVER THE 33 mm DIA BEAM PIPE. FLG "B" IS MATED TO A SURFACE ON THE FORWARD CALORIMETER & THE BELLOWS IS COMPRESSED SLIGHTLY TO EFFECT A CRUDE SEAL. A NITROGEN PURGE IS THEN APPLIED TO ANNULAR SPACE AROUND 33 mm DIA BEAM PIPE SECTION TO PREVENT CONDENSATION IN THE ANNULUS. A ROUGH VACUUM MAY BE APPLIED TO THE ANNULUS TO IMPROVE THE SEAL QUALITY AT FLG "B".





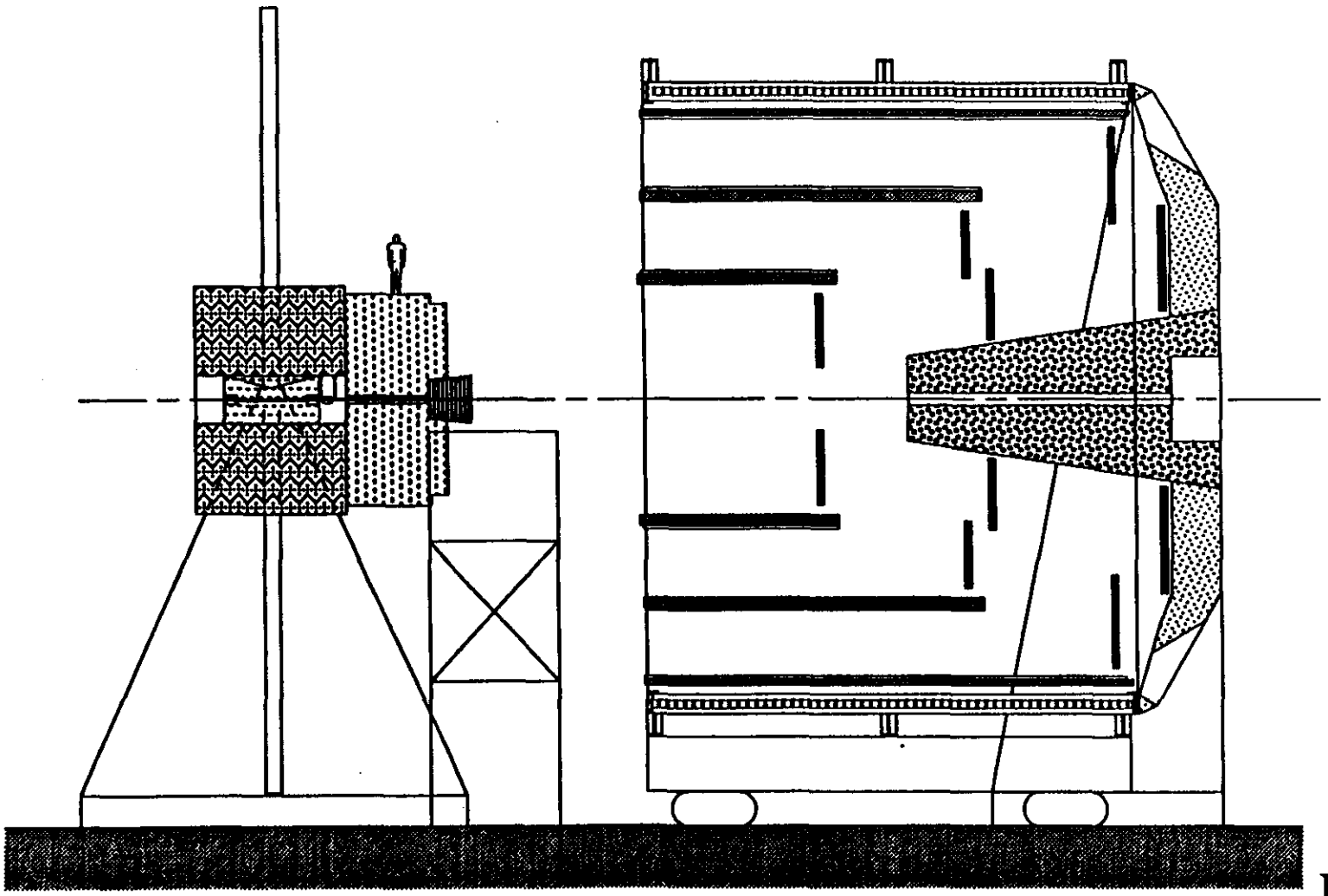
DRAFT

SCALE 32:1

Eberle 02/27/92

BEAM PIPE INSTALLATION - STEP 4

1. Translate endcap calorimeter over beam pipe and into final position.

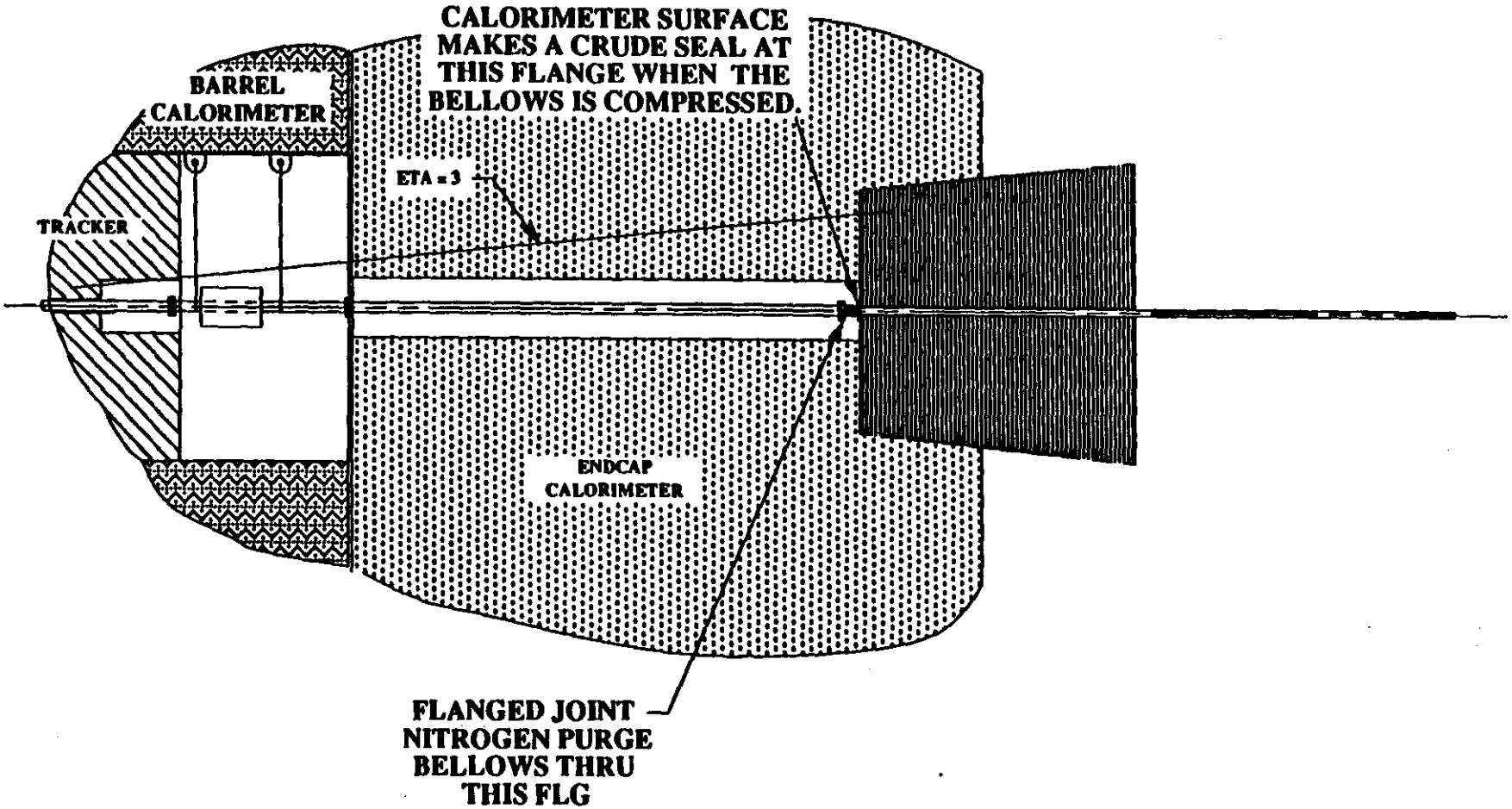


DRAFT

SCALE 200:1
Eberle 02/13/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 4

1. Translate endcap calorimeter over beam pipe and into final position.



DRAFT

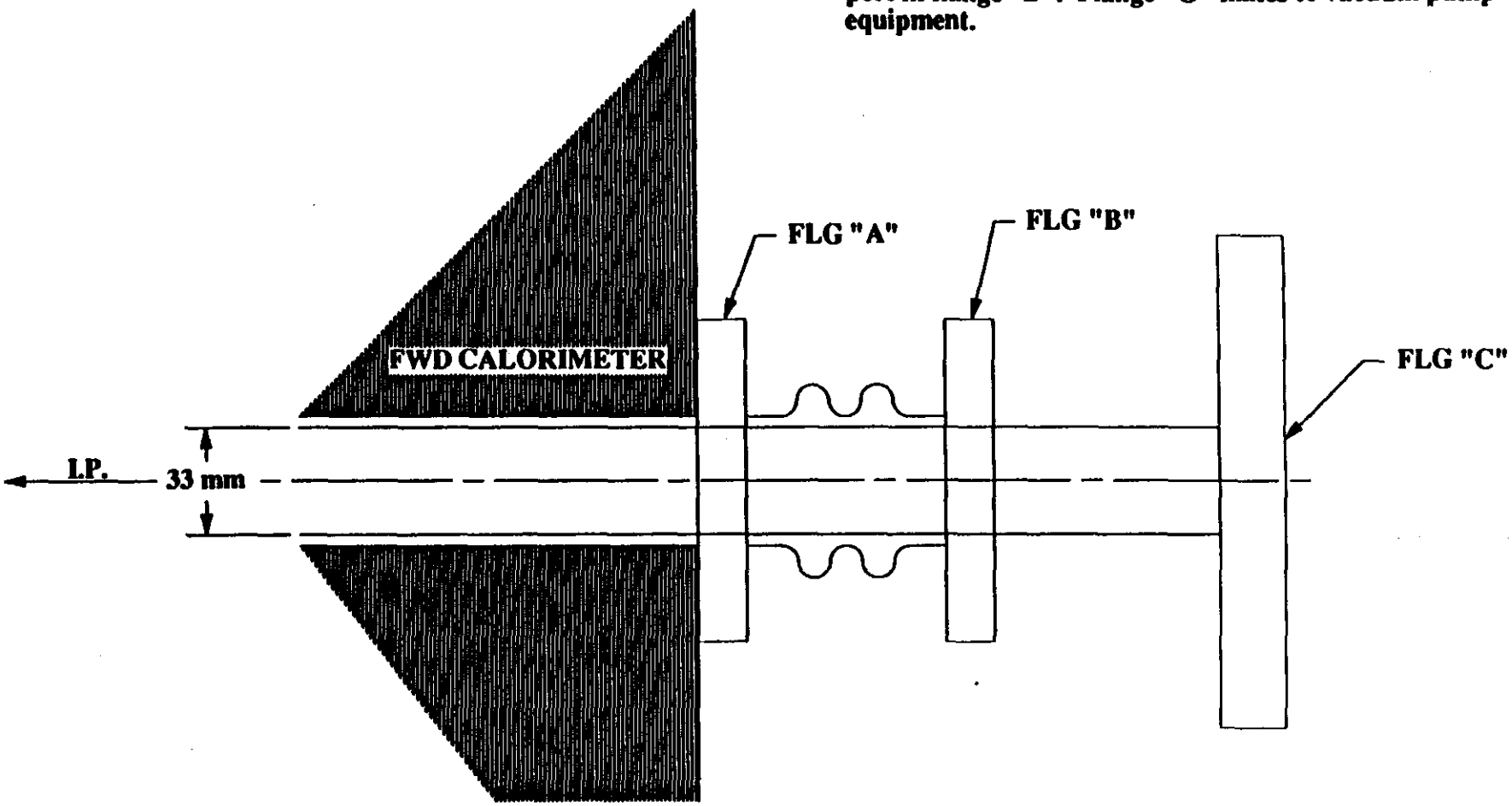
SCALE 25:1

Eberle 02/27/92

BEAM PIPE INSTALLATION - STEP 5

1. Slide bellows assembly over exposed end of beam pipe.
2. Clamp flange "B" to beam pipe.
3. Cut off excess pipe.
4. Weld flange "C" to beam pipe.

When the bellows is compressed, flange "A" makes a crude seal against the calorimeter surface. Removeable flange "B" is clamped to the beam pipe, also forming a crude seal. A dry nitrogen purge thru the annular space between the calorimeter and beam pipe is exhausted from an exhaust port in flange "B". Flange "C" mates to vacuum pumping equipment.

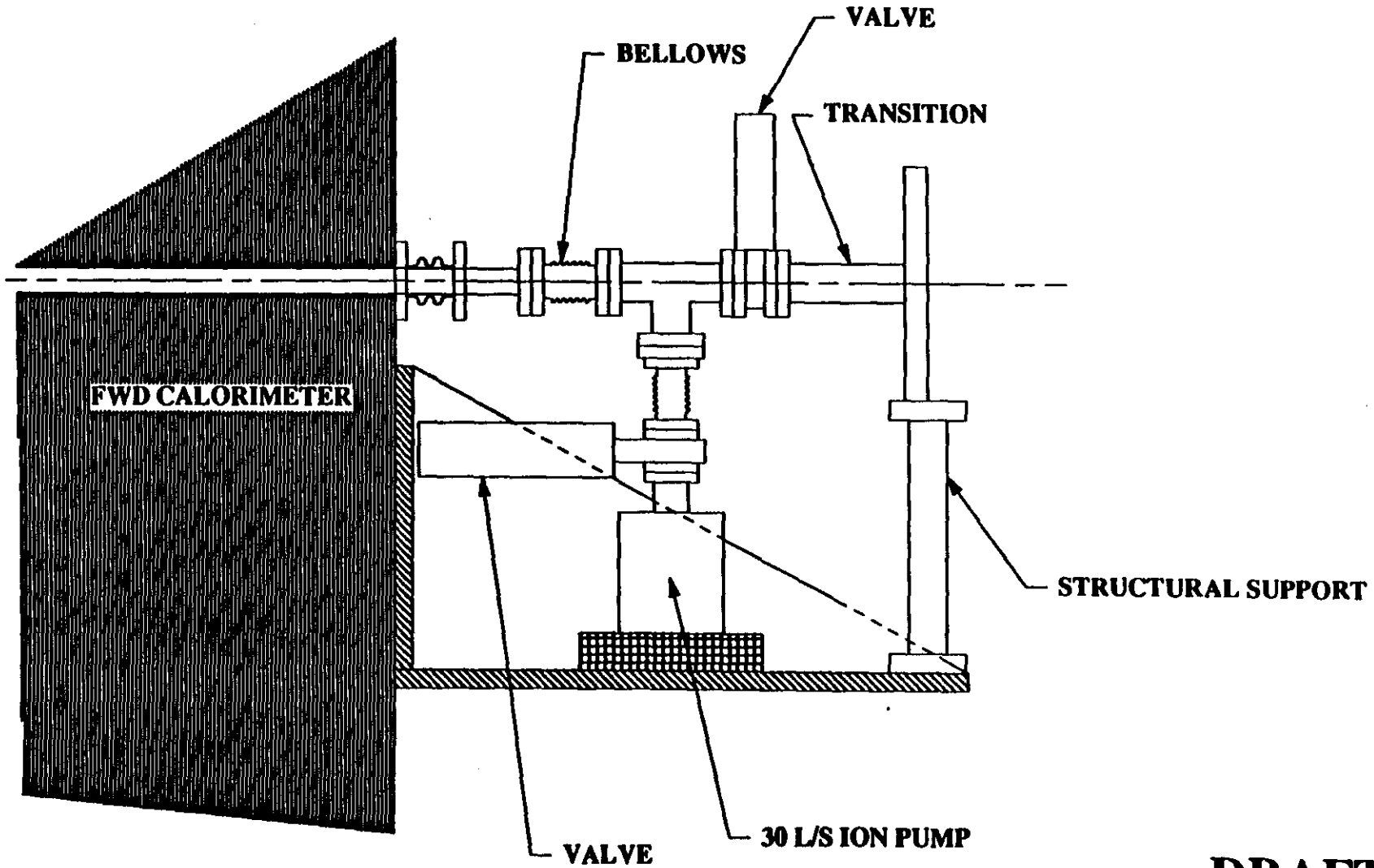


DRAFT

SCALE 2:1
Eberle 02/10/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 6

1. Install internal ion pumping station.

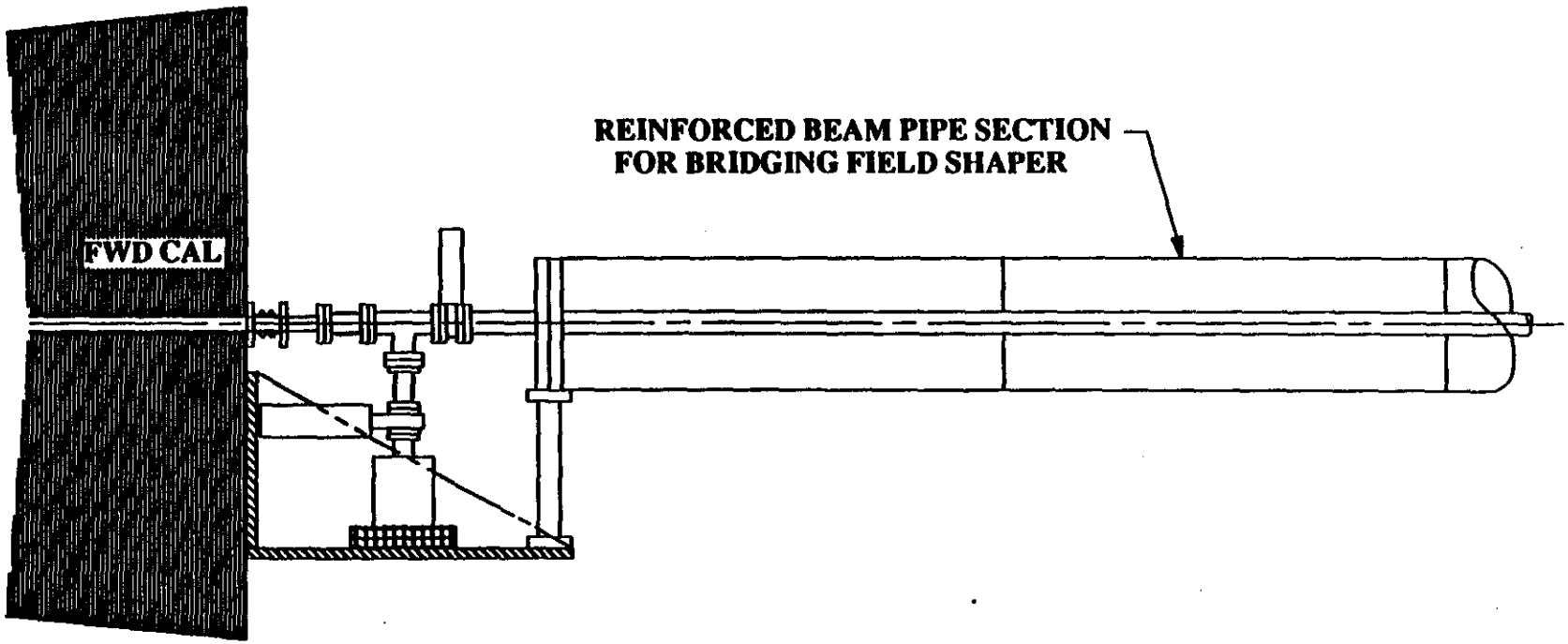


DRAFT

SCALE 8:1
Eberle 02/10/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 7

1. Mate reinforced section of beam pipe which bridges the field shaper to internal ion pump station.

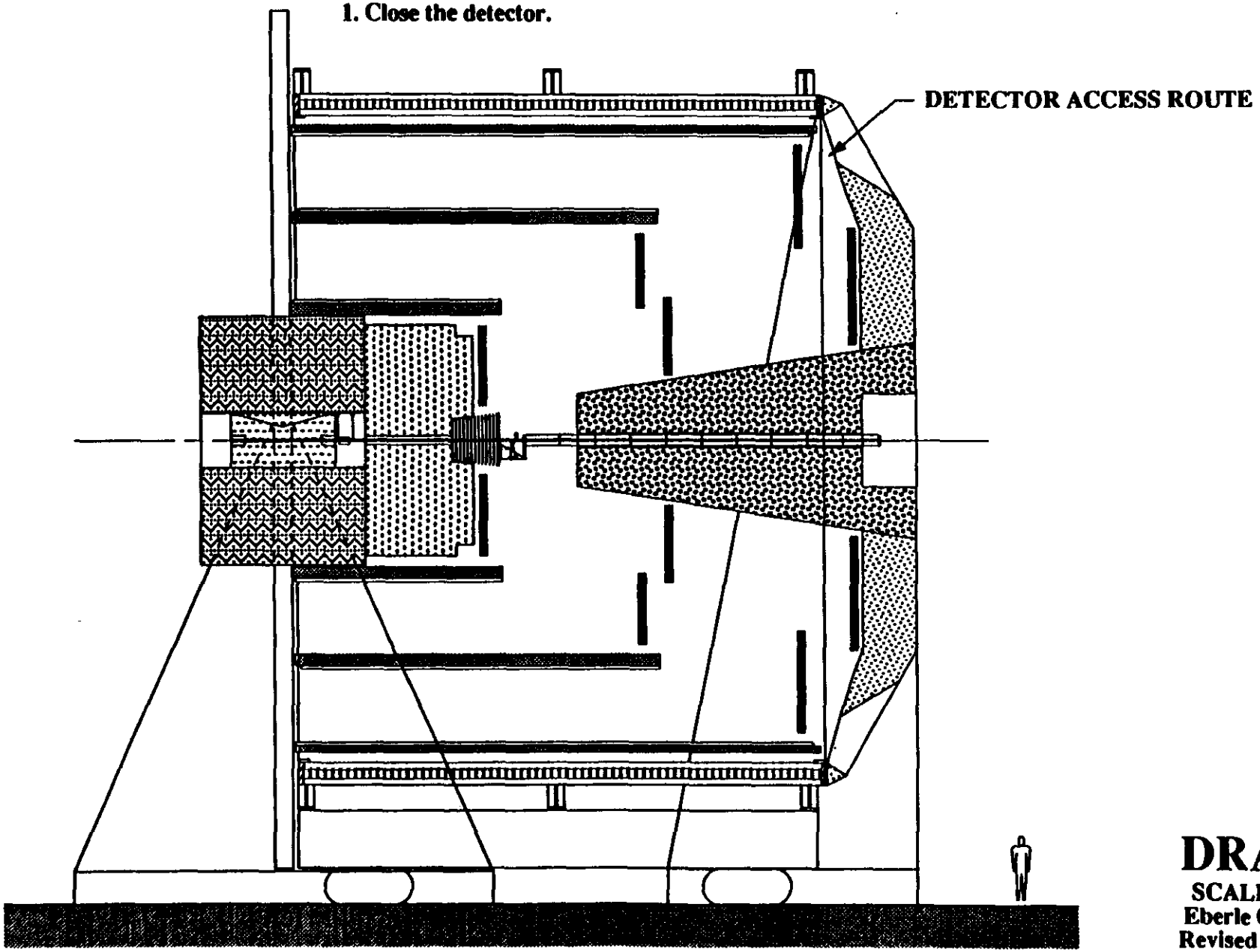


DRAFT

SCALE 16:1
Eberle 02/10/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 8

1. Close the detector.

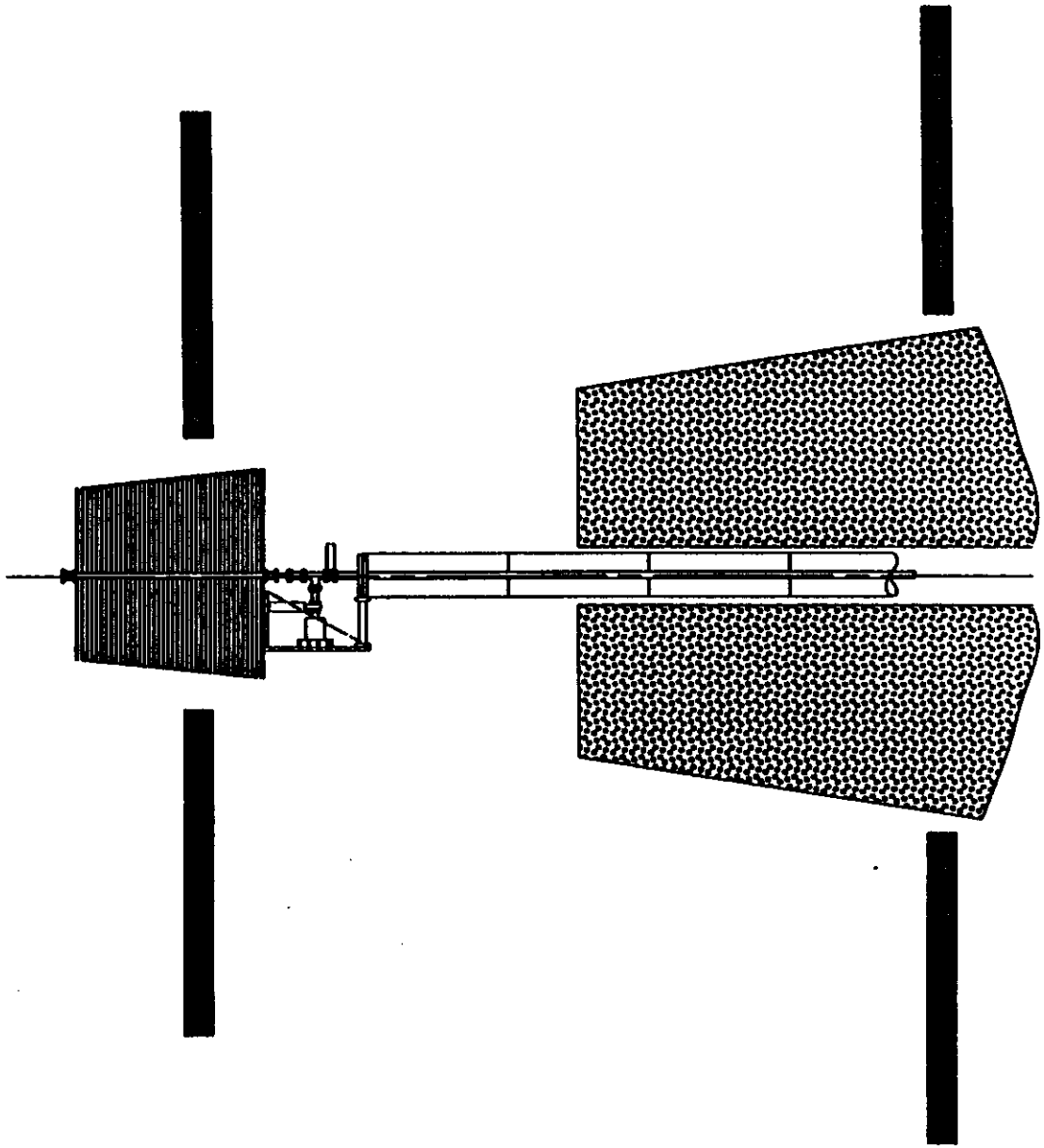


DRAFT

SCALE 160:1
Eberle 02/13/92
Revised 02/27/92

BEAM PIPE INSTALLATION - STEP 8

1. Close the detector.

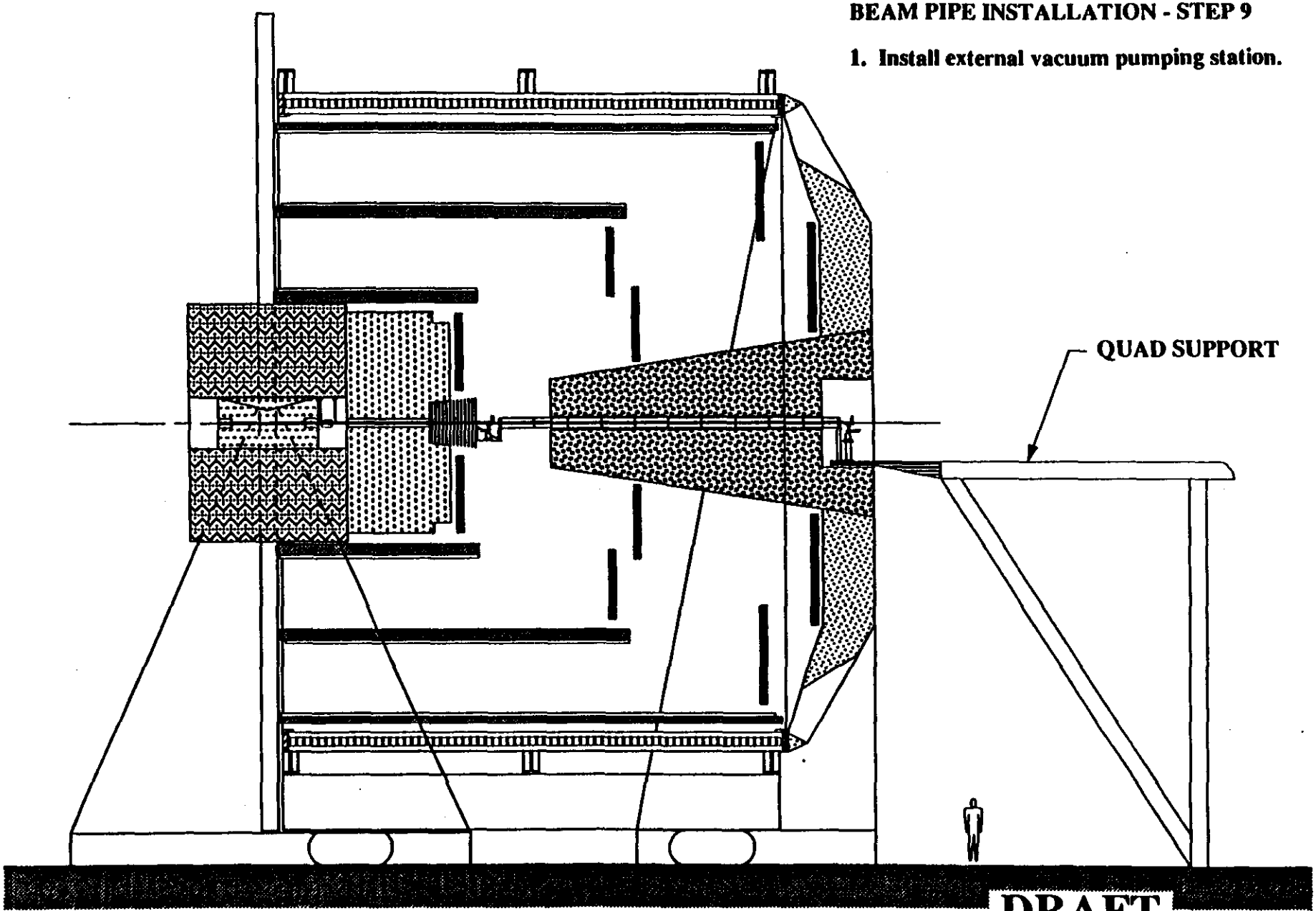


DRAFT

SCALE 50:1
Eberle 02/28/92

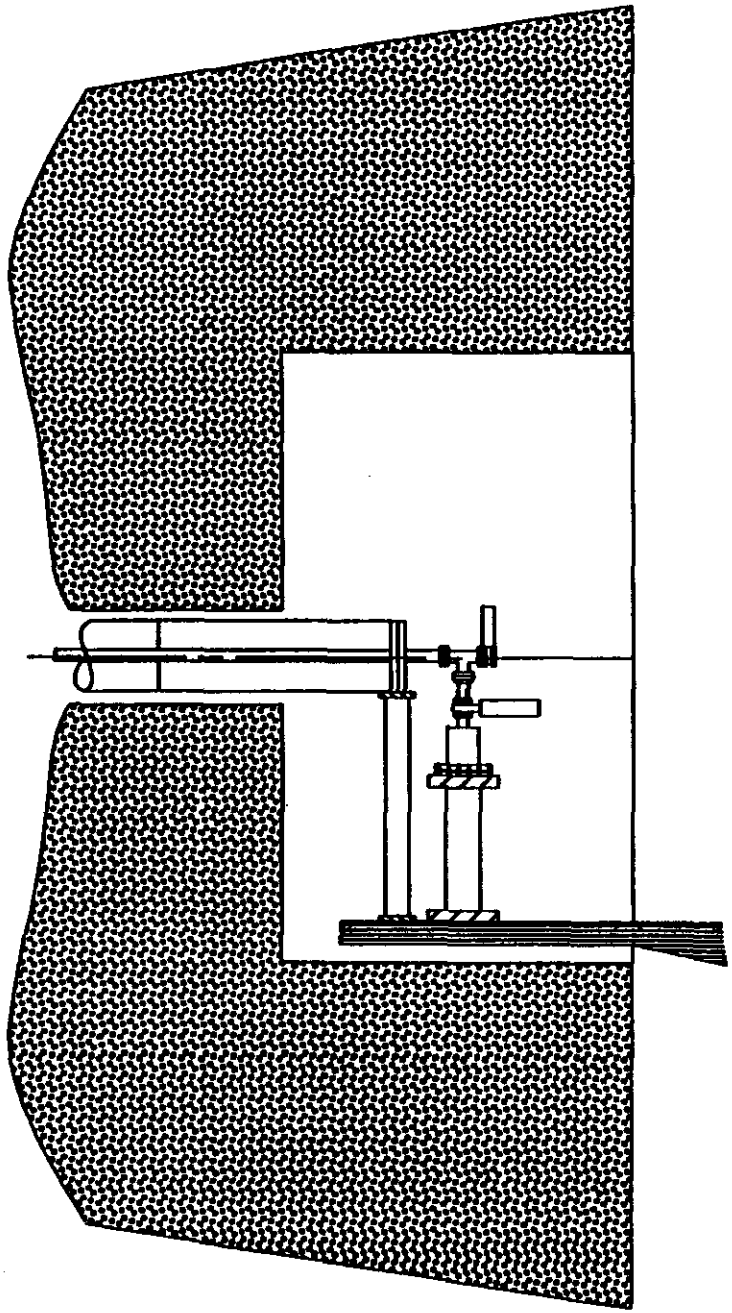
BEAM PIPE INSTALLATION - STEP 9

1. **Install external vacuum pumping station.**



DRAFT

SCALE 160:1
Eberle 02/13/92
Revised 02/27/92



BEAM PIPE INSTALLATION - STEP 9

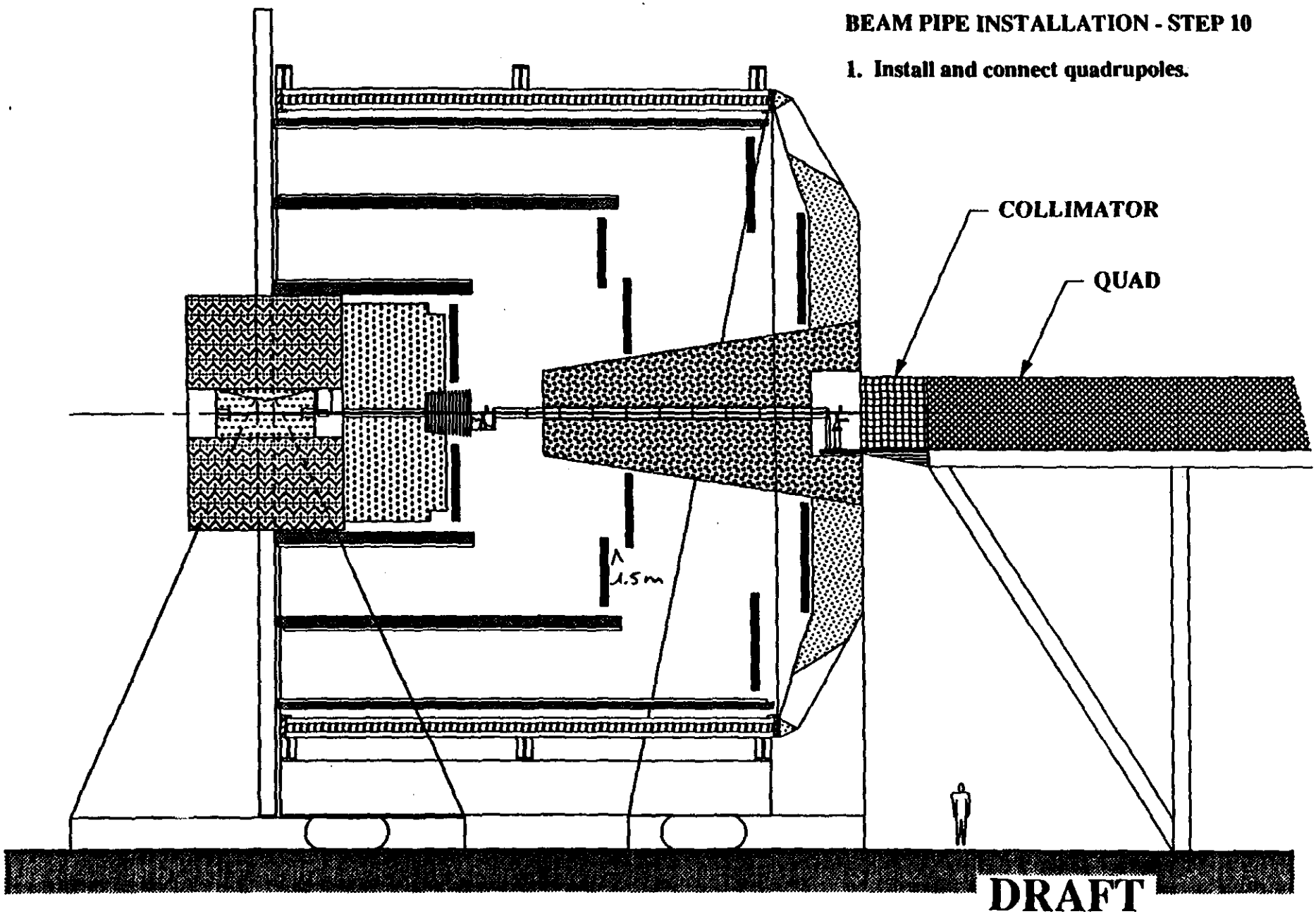
1. **Install external vacuum pumping station.**

DRAFT

SCALE 32:1
Eberle 02/28/92

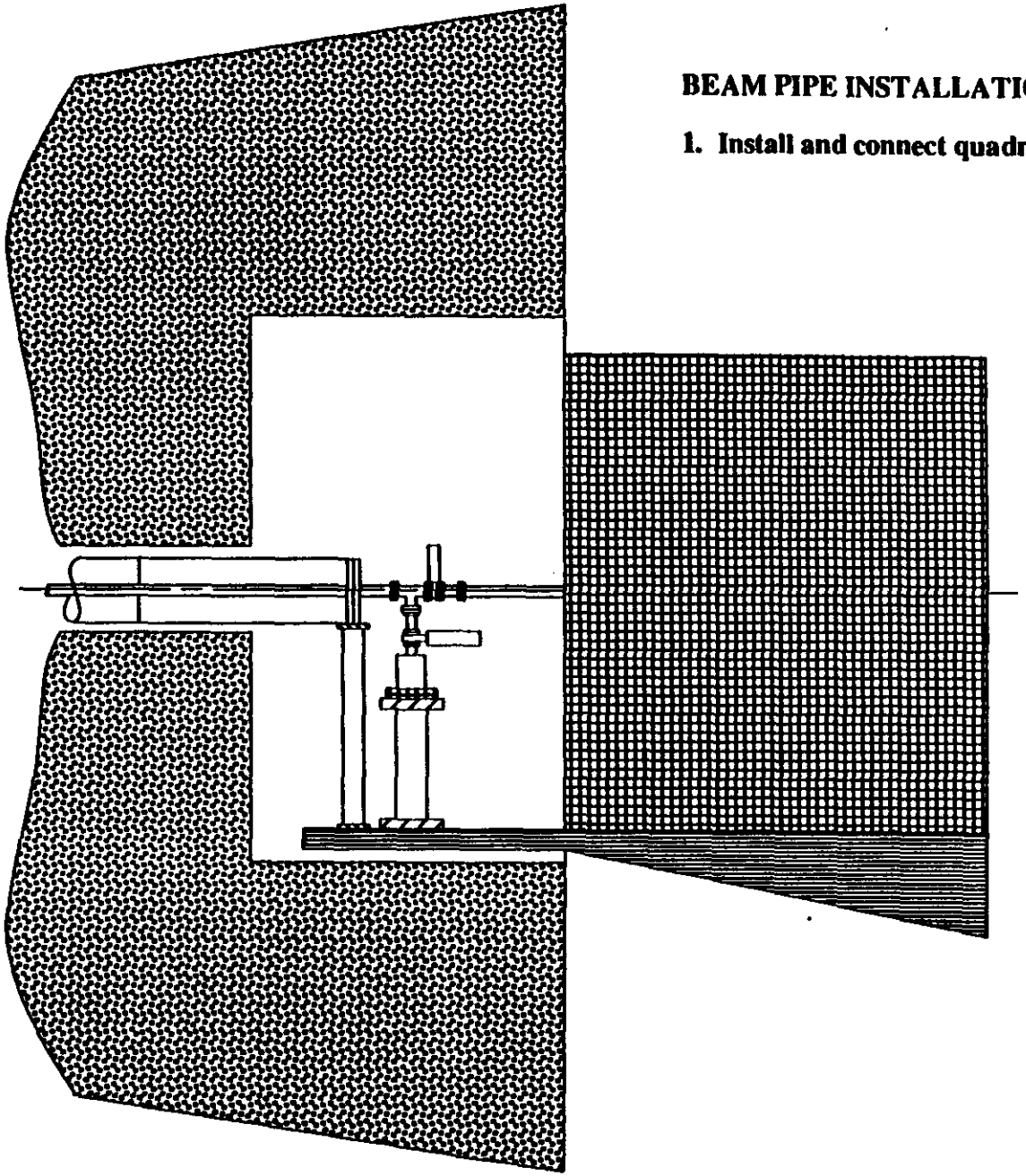
BEAM PIPE INSTALLATION - STEP 10

1. **Install and connect quadrupoles.**



DRAFT

SCALE 160:1
Eberle 02/13/92
Revised 02/27/92



BEAM PIPE INSTALLATION - STEP 10

1. **Install and connect quadrupoles.**

DRAFT

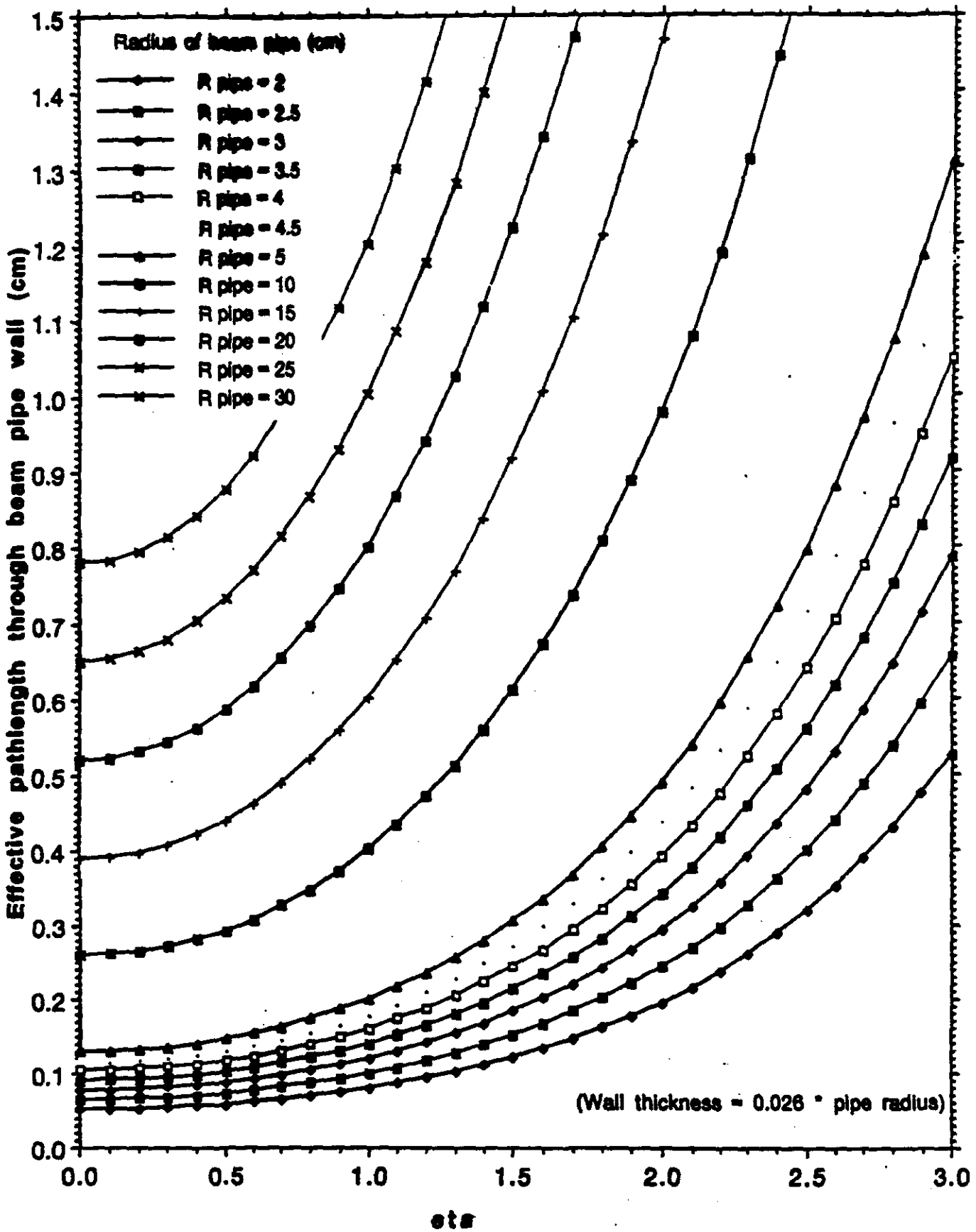
SCALE 32:1
Eberle 02/28/92

From: SSCVX1::ROE 27-FEB-1992 17:39:40.13
To: MORGAN
CC:
Subj: Note from Stiening on a serious halo problem

From: SSCVX1::STIENING 21-FEB-1992 14:26:48.90
To: ROE
CC:
Subj: Diffractive Scattering

The issue that bothers me is described on page 220 of the 1986 SSC conceptual design report. The width of the forward elastic peak is 9 microradians. If this occurs in the arcs of the Collider (and it will at the rate of 10E8/second) the particles will circulate just fine and when they get to the final focus triplets they will be at an amplitude 9E-6 * sqrt(305*9000) = 1.5 centimeters. These particles will hit the beam pipe in the triplet. How many of these strikes can be tolerated?

Constant r pipes, not flared



Be

From: SSCVX1::ROE 4-MAR-1992 15:58:59.81
To: MORGAN,MARX,SANDERS,BARISH
CC:
Subj: FYI--Talk with Stiening for SDC but of interest to you also

Two Items From a Discussion with Rae Stiening 3/4/92
B. Roe

1. One turn halo background. We have a potentially serious problem from having protons beam gas scatter in the arcs of the accelerator and then hit the beampipe walls in the vicinity of the low beta quads.

The calculations are the following:
Consider a collision between a beam proton and a gas proton. To start with let the scattering angle be 0.1 rad in the center of mass system. (We will see this is too large shortly). The beam proton loses about 50 GeV and is scattered through a lab angle of 250 microradians. At the quads, Stiening calculates that x (meters) is approximately theta * sqrt(300 * 9000) for beta* = 0.5 m. (and the 9000 goes to 18000 for beta* = 0.25 meters)
For 250 microradians, x = 41 cm, ie it would have left the beam long ago. However, for 9 microradians in the lab the delta E is even smaller, the pperp is 180 MeV, a typical diffractive scattering size, and x = 1.5 cm. This is of the order of the vacuum pipe size (which is not yet fixed). Rae estimates that there are about 10**8 beam gas interactions per second and 1/4 are diffractive, 0.8 have the right phase, and 0.1--0.01 have theta < 9 microradians. This gives a background of 10**5-10**6 protons per second hitting the vacuum pipe walls in the 100 m long or so low beta quad region.

QUERY FROM RAE: Could we estimate what background rate of these protons is tolerable?

I need help on this. It doesn't seem to me trivial. There are questions of radiation levels, of background in the tracking system and muon background in the forward muon chambers. Can you see if some of this can be calculated?

Another comment which may be pertinent comes from L. Jones who notes that about a fourth of the inelastic cross section interactions end up with a fast forward neutron. The neutrons have an ~300 MeV pperp distribution and very crudely are distributed with a (1-x)**2 distribution. Although we don't have the length of the arcs for this, we do have about a kilometer of straight section at the detector within which we might have these interactions generated. Is this a problem?

2. Quadrupole position. Acting on a suggestion of Dave Ritson's, Rae has calculated optics assuming that the quads are moved back from 20 m to 35 m from the interaction point. The most important change is that the aperture needed to maintain the luminosity is increased by 17%. If the quads remain the same size as now, the luminosity would decrease by the square of this, roughly a 30-35% decrease. Building larger bore quadrupoles would allow us to have no loss of luminosity. Rae estimates the incremental cost for the larger quads as between $1-$10 million. It is likely that it may be at the lower end of this estimate. Further there would be savings in that the quads would not have to be cantilevered out as far as in the present design.

Are we interested in this change? It means that we would not have to disinstall and reinstall the quads to move our detector far apart. It is possible that we will never need to move the detector halves far apart. My own (gut-not factual) feeling is that I would be delighted, but quite surprised, if we did not need to move it apart more than once in the first couple of years of operation. In any case we need to tell the accelerator people what our position is on this point.

Pileup Noise in the Forward Calorimeter

– E. Stern + w.s.c.
Univ of Pittsburgh

$$\sigma_p^2 = \underbrace{\sigma_E^2}_{\text{physics}} \underbrace{\int |g(t)|^2 dt}_{\text{signal processing}}$$

Simple minded model

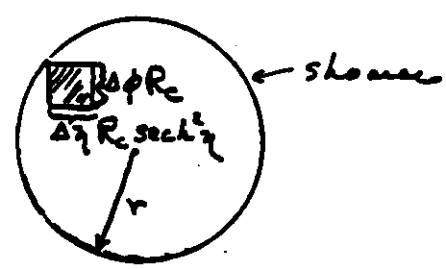
Assumptions

1) $E_t(\text{cell}) = \dfrac{\text{Area of cell}}{\text{Area of shower}} E_t(\text{particle}) = f\, E_t(\text{particle})$

2) $\rho = \dfrac{dN}{d\eta\, d\phi} = \text{constant}$

3) $\dfrac{\#\text{ cells hit}}{\text{incident particle}} = \dfrac{\text{Area of shower}}{\text{Area of cell}} = \dfrac{1}{f}$

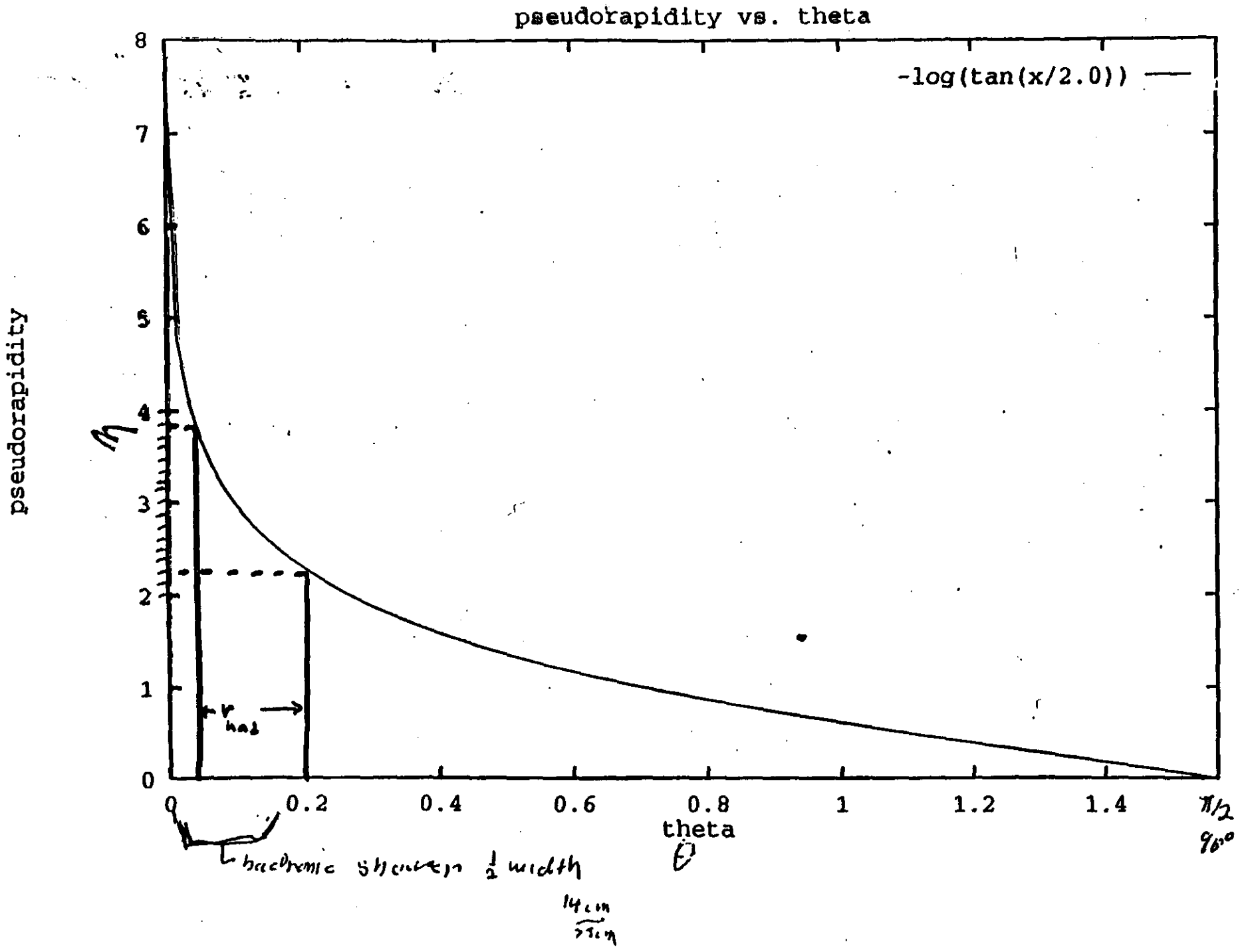
$$f = \frac{R_c^2\, \Delta\eta\, \Delta\phi\, \text{sech}^2\eta}{\pi r^2}$$



$$dN = \rho\, d\eta\, d\phi = \rho \cosh^2\eta\, d\Omega$$

$$n = \rho \cosh^2\eta\, d\Omega \left(\frac{\pi r^2}{R_c^2 d\Omega}\right) = \frac{\#\text{ of cells hit}}{\text{event}}$$

$$E_t(\text{cell}) = \underbrace{\left\{\rho \cosh^2\eta \frac{\pi r^2}{R_c^2}\right\}}_{\text{hit probability}} (E \sin\theta) \underbrace{\left\{\frac{R_c^2 \text{sech}^2\eta\, \Delta\eta\, \Delta\phi}{\pi r^2}\right\}}_{\text{energy spread}}$$


pseudorapidity vs. theta
-log(tan(x/2.0))
pseudorapidity
η
theta
θ
0
1
2
3
4
5
6
7
8
0.2
0.4
0.6
0.8
1
1.2
1.4
π/2
90°
r had
hadronic shower ½ width
14 cm / 75 cm

To calculate pikup noise, we need the variance of E_t.

$$E_t(\text{cell}) = \sum_{i=1}^{n} \underset{\substack{\uparrow \\ \text{particle} \\ \text{energy}}}{E_i} \underset{\substack{\uparrow \\ \text{angle of} \\ \text{cell}}}{\sin \theta_i} \underset{\text{energy spreading}}{f} = \sum_{i=1}^{n} x_i$$

x and n are random variables

$$Var(E_t(\text{cell})) = \bar{n}\, Var(x) + Var(n)\, \bar{x}^2$$

$$\sigma_E^2 = \bar{n} f^2 \sigma^2(E_t) + \sigma_n^2 f^2 \bar{E}_t^2$$

relative fluctuations

$$\left(\frac{\sigma_E}{E}\right)^2 = \frac{\sigma_E^2}{(\bar{n}\bar{E}_t f)^2} = \frac{1}{\bar{n}} \underbrace{\left(\frac{\sigma^2(E_t)}{\bar{E}_t^2}\right)}_{\substack{\text{approx} \\ \text{constant for} \\ \text{QCD jets}}} + \underbrace{\left(\frac{\sigma_n}{\bar{n}}\right)^2}_{\substack{\text{dominant} \\ \text{term in} \\ \text{forward} \\ \text{direction}}}$$

Conclusion: Pikup noise (measured in E_t)

should <u>decrease</u> in forward region.

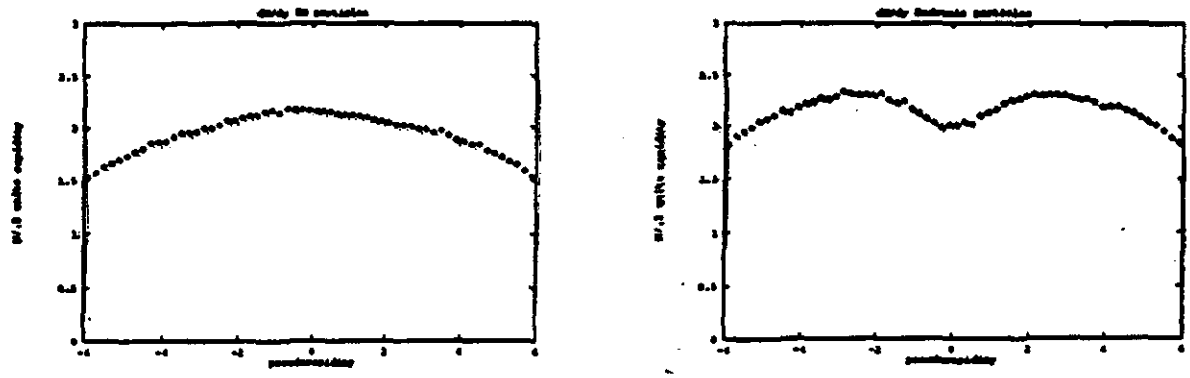


Figure 1.3: The particle density in $d\eta$ for electromagnetic and hadronic particles.

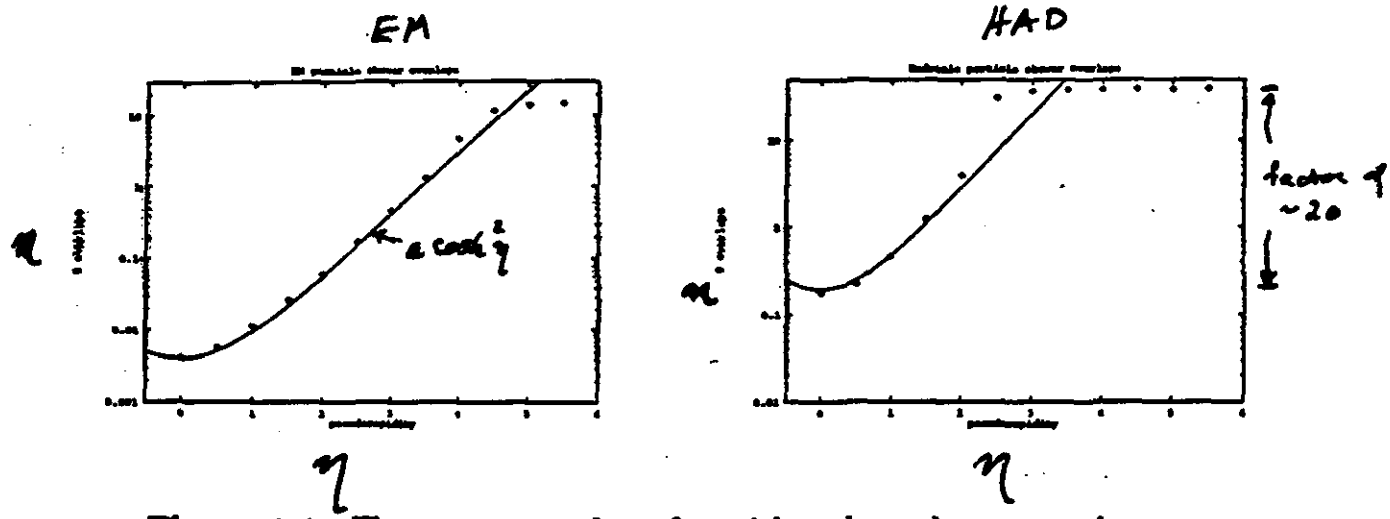


Figure 1.4: The average number of particles whose showers overlap a point at the given η. Electromagnetic particles have smaller showers than hadronic particles, giving fewer overlaps. A plot of $a \cosh^2 \eta$ is overlaid with the appropriate value of a.

We can also look in the ISAJET output directly and count the number of particles that fall within a shower width's radius of specific points in η. The result is plotted in Fig. 1.4 along with the functions defined in Eq. (1.4).

We also plot in Fig. 1.5 the variance (or its square root) of the number of overlaps, which is needed to calculate the variance of the deposited energy. Note that the number of overlaps does not follow Poisson statistics most notably at large η. At large η, the distribution of particles is highly correlated. Particles are produced in localized jets containing many particles. Thus, if a particle is produced in a region, then it is highly likely

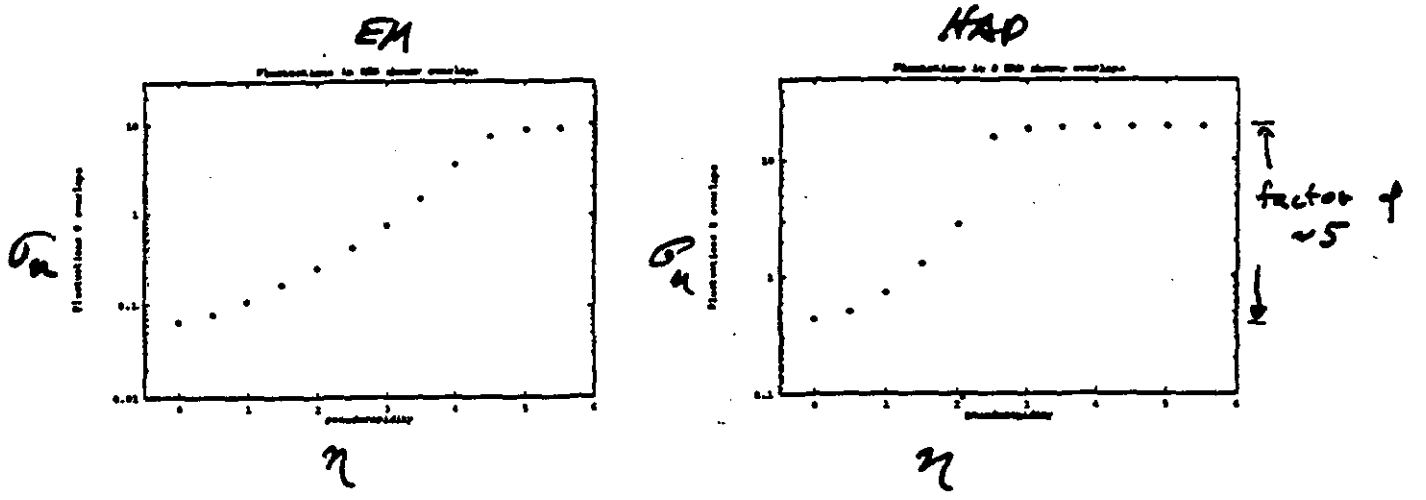
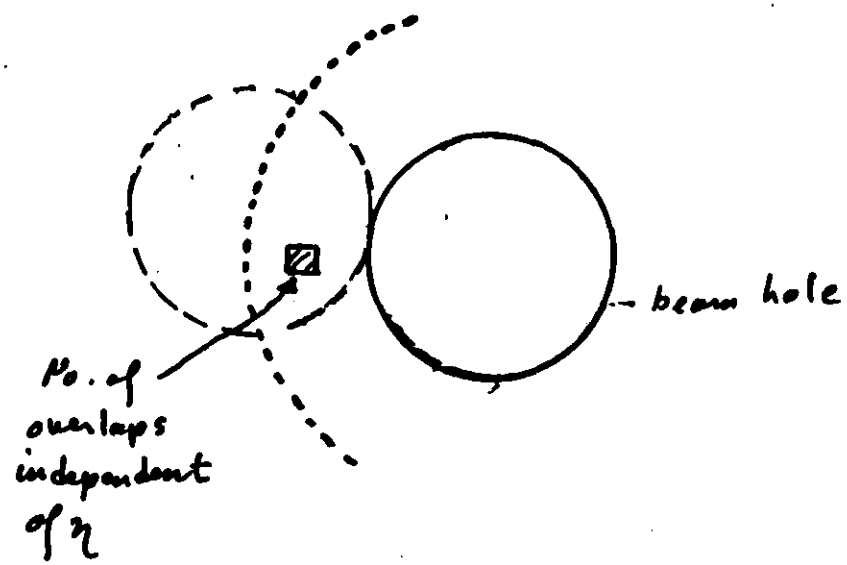


Figure 1.5: The square root of the variance of the the number of showers overlapping a point at any pseudorapidity.

that there will be another particle nearby, whereas Poisson counting assumes that each (particle, event, count) is independent.

At low η, the mean number of overlaps follow the prediction quite well, especially for the electromagnetic case, but at high η the Monte Carlo shows a deviation from the simple model. The model predicts ever increasing numbers of particles as η increases, but this is clearly unphysical past a certain point. A real calorimeter will only have coverage out to a maximum η of 5.5–6. At some point maximal overlap occurs such that all the available particles overlap an extended region in η. We can calculate the point at which this occurs.

A calorimeter with coverage out to $\eta = 6$ goes down to angles of 4.96 mrad. An electromagnetic shower with a width of 2.2 cm in a calorimeter that has a 75 cm radius has a width in θ of 29.33 mrad. So, an electromagnetic particle that showers at $\eta = 4$ corresponding to $\theta = 36.63$ mrad will not overlap the edge of the calorimeter at $\eta = 6$, while a particle showering at $\eta = 4.5$ will. This results in the behavior seen in Fig. 1.4 where the EM overlaps become constant after $\eta = 4.5$. A similar calculation for the wider hadronic showers show that after a pseudorapidity of about 2.5, showers are overlapping the edge of the calorimeter.


beam hole
No. of
overlaps
independent
of η

March 10th, 1992

D. Crosetto

Programmable

II level Trigger

ARCHITECTURES

SUMMARY

- PARALLEL PROCESSING for II level Trig.
  - Connectivity
  - Bandwidth
  - Computing Capability
- PARALLEL PROCESSING "NODE" DESIGN
- II level Trigger OPTIONS
- PROBLEM DEFINITION
  - Case study of the past
    1 . . . .
    2 . . . .
    3 . . . .
  - Case study for GEM

C. Allen, D. Crosetto, D. Marlow, J. Ritchie

- POSSIBLE SOLUTIONS
  - Examples of architectures studied in the past
  - Present GEM

PARALLEL PROCESSING

Connectivity & Bandwidth

Serial (easy)

Parrallel (fast)

Computing capability

chipest & most efficent processor

($6/Mflop)

Problem:

TO DESIGN

AN ARCHITECTURE

- Programmable
- Flexible
- Fast
- Simple & easy to use
- Economical

That will give the possibility to implement most of the "OPTIONS" for a II level Trigger.

ONE ARCHITECTURE is DESCRIBED and as examples a few CASE STUDY for II level Trigger will be considered.

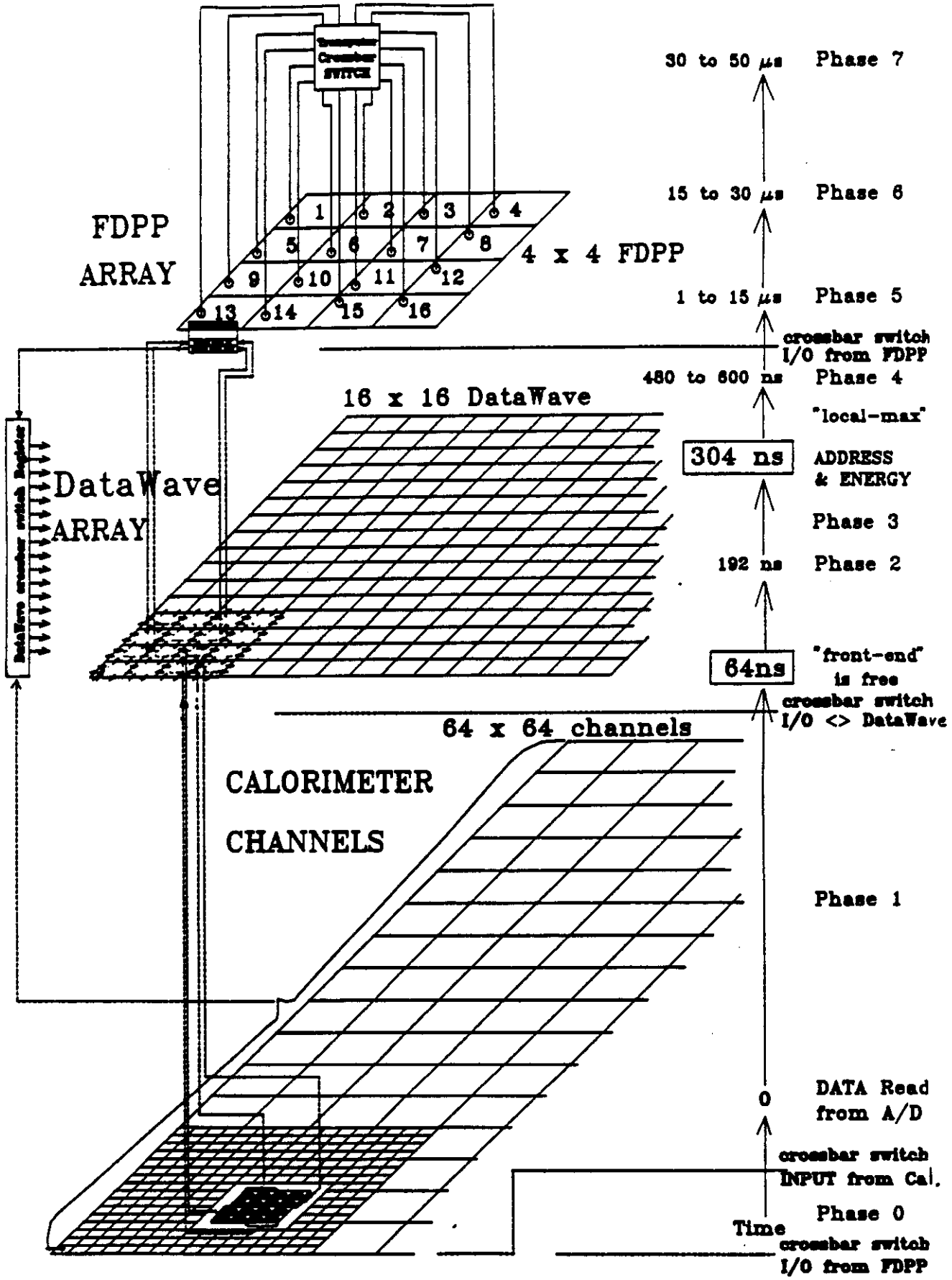
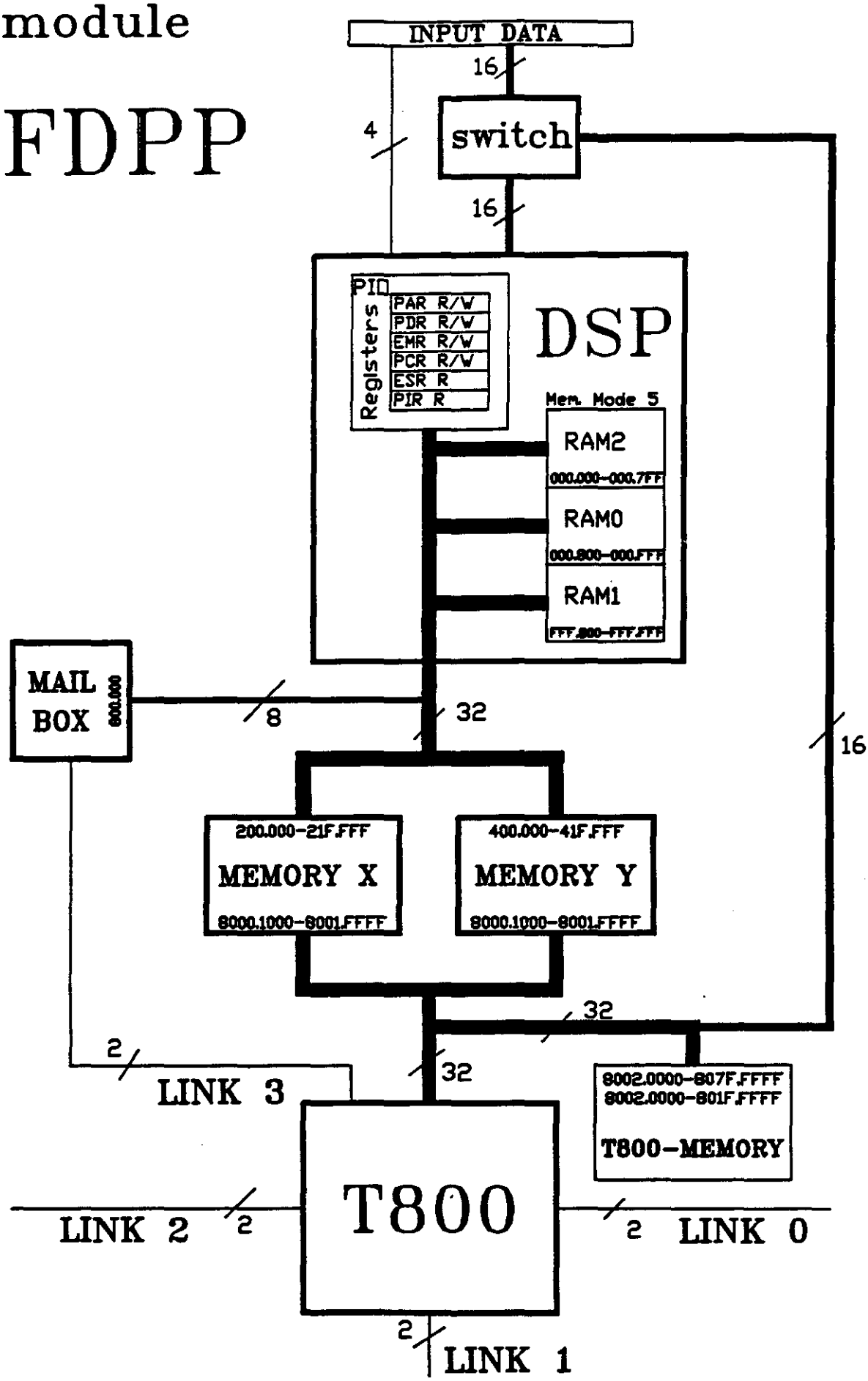


Fig. 1 Fast cluster finding system block diagram. Proceeding from bottom to top, one sees the mapping of calorimeter channels to DataWave processing elements (PE) followed by the mapping of 256 PE's to on FDPP. On the right the data acquisition and reduction phases (described in the text) are aligned in order from bottom to top along with the time duration estimates.

Fast Digital Parallel Processing module

FDPP



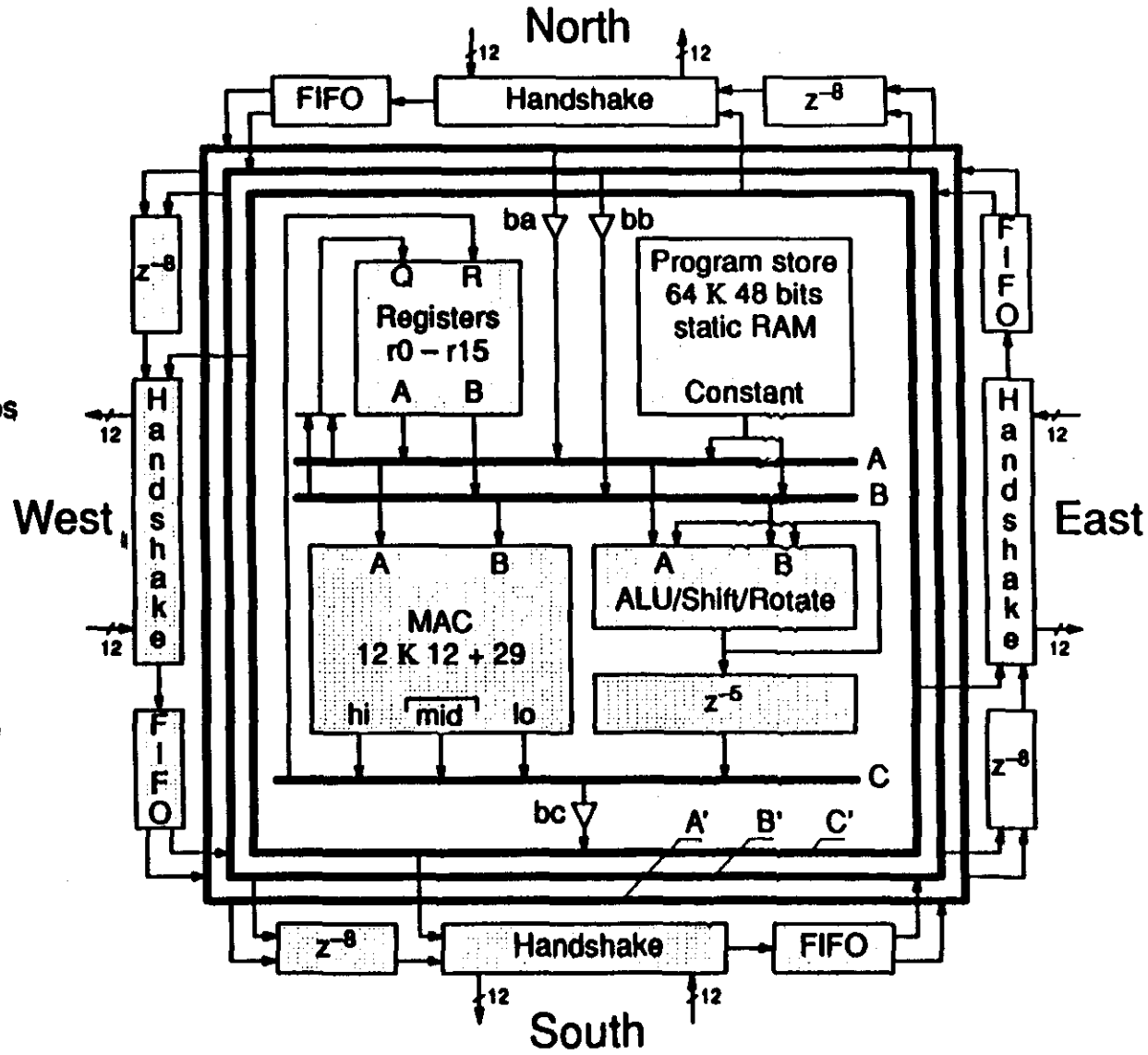
DAVIS Cell Architecture

Architecture

- 125 MHz (8 ns)
- Multiply-Accumulate in every cycle
- 3 ring buses, 3 core buses
- 3 kbits program store (static RAM)
- Four-port register file, 16 registers
- Deep pipeline with short feed-back loops
- 12-bit ALU, 1 cycle delay
- n 1-bit shifts/rotates in n cycles

Intercell Communication

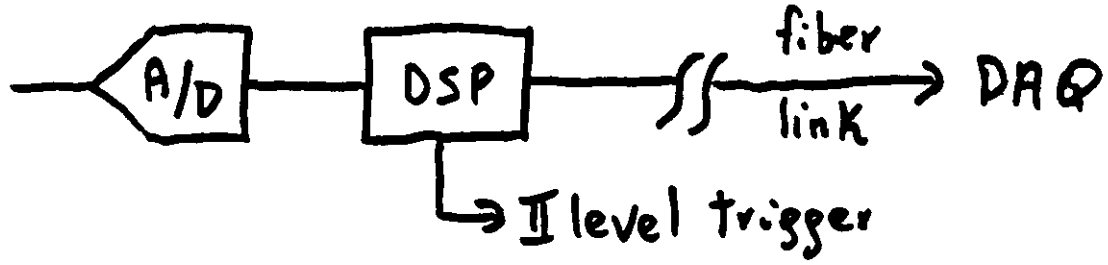
- Up to 6 cell-to-cell transfers every cycle
- Self-timed handshake with FIFOs
- Dual-port circular buffers (8 words)
- Automatic pipeline freeze when waiting



II level Trigger OPTIONS

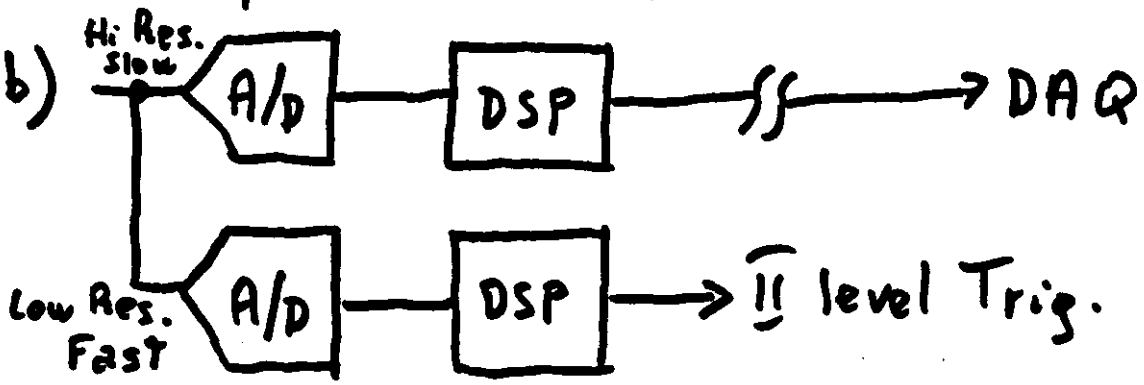
1) Should we have only one electronic chain for DAQ & II level trigger ?

a)



or two separate chains ?

b)



2) Should we have full granularity

a) executing II level trig. on all channels ?

b) or zoom in a particular region ?

3) How many channels do we assign to a processor ~~of~~ the first level trigger

4) How many channels do we assign to a processor of the II level trigger?

5) Should we have more than one sample for each "signal-element" and filter digitally?

6) The filter algorithm, should it be:
   a) on the detector-electronic
   b) or on the II level trigger DSP ?

7) Should we have the possibility to exclude the II level trigger algorithm execution?
   (no zero suppression)

8) Should we have no dead-time ?

9) Which input frequency should we sustain ?
   a) continuously .....?
   b) with intervals ...., ...?

10) How many clusters do we expect (from a Monte Carlo simulation) from the II level Trig. ?

11) For which latency ?

12) How large should be ?

a) the input buffer

b) the output buffer

c) event size

13) No-boundary limitation in the array should be realized with:

a) high bandwidth communication between proc

b) with overlapping areas ?

14) How is coupled with the first level Trig. ? or do we need from Ist level Trig.

a) isolation ?

b) shower-max ?

c) do we use single tower energy threshold for

15) Do we need a large number of array processors in a pipeline mode (e.g. Data Wave) to calculate the above in real-time during the 1st level trigger ?

16) Do we use a small number of array processor not in pipeline mode (e.g. Data Wave) just in order to give the information of the region of interest from the first to the second level trigger. ?

17) Do we need a "Parallel Processing System" for the second level trigger capable to implement all the below II level trigger algorithms, or do we need only part of them ?

II level Trigger Algorithms:

1) $$I/C = \left(\frac{\frac{1}{8} \sum_{i=1}^{8} I}{C} \right)$$ exec time ($5\mu s$)

2) $$O/C = \left(\frac{\frac{1}{16} \sum_{i=1}^{16} O}{C} \right)$$ exec time ($5\mu s$)

3) $$E = C + \sum_{i=1}^{8} I + \sum_{i=1}^{16} O$$ exec. time ($5\mu s$)

(no wig.)

4) $$R_p = \frac{\sum_{i=1}^{25} r_i E_i^{0.4}}{\sum_{i=1}^{25} E_i^{0.4}}$$ exec. time ($15\mu s$)

(GEM)

5) $$\frac{\sum_{3\times3} E}{\sum_{5\times5} E} > .9$$ exec time (?)

6) (Ed) for electron

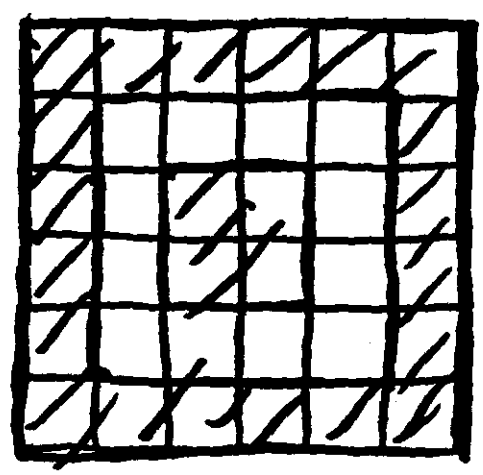
$$\frac{\sum_{20} E_m + Had_{16}}{\sum_{4} E_m} < .2$$

exec time (?)

7) (Ed) for jet

$$\sum_{20} E_m + Had > 100 \text{ Gev}$$

exec time (?)



Typical problems of Digital triggers & Data acquisition/compaction in Calorimetry of High Energy Physics.

For any number of channels:

1. Calculate the total energy and the transverse energy

2. Calculate the geographical address of clusters (local maxima).

3. Apply a threshold to the combined energy of a local maxima and of its neighbors.

4. Isolate from the empty calorimeter channels:
   - the clusters found along with their regions of interest and
   - calculate their cluster shape-factors (e.g. to separate pions/electrons).

PROBLEM DEFINITION:

CASE STUDY 1

Options for the Ist level trigger:

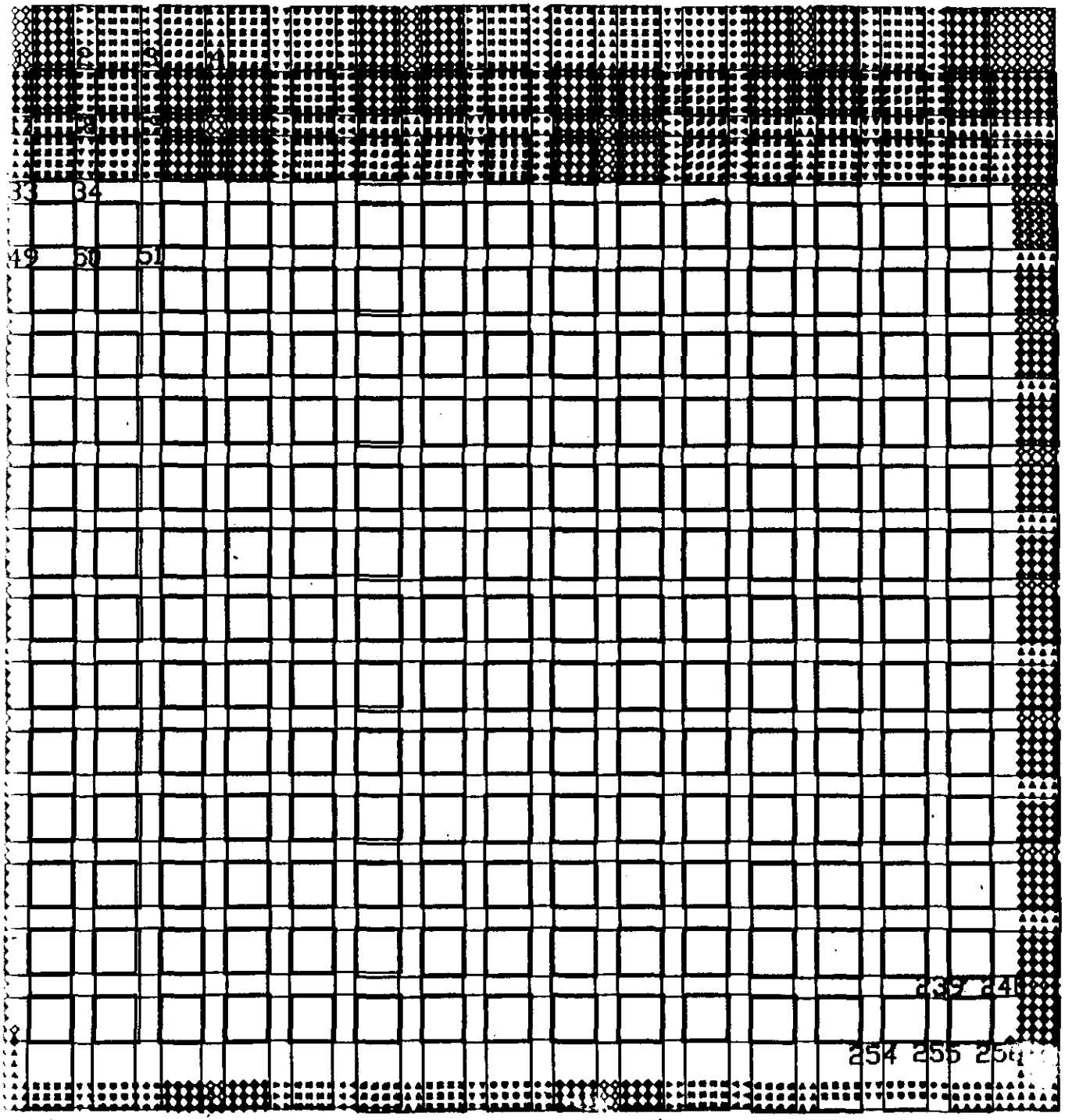
16) no processors at I level

Options for the II level trigger:

1 a) DAQ ≡ II lev. Trig.
2 a) full granularity
4) 1 FDPP = 100 channels
13 b) with ovelapping areas
12 a, b 128 Kbyte (input/output buffer)

POSSIBLE SOLUTION:

e.g. Calorimeter 10,000 Channels



256 x FDPP modules

for HEP real time algorithms

FDPP architecture for an array of 100x100 channels

Each FDPP module analyse 36 channels out of 100 data-in

GENERIC PEAKFINDING

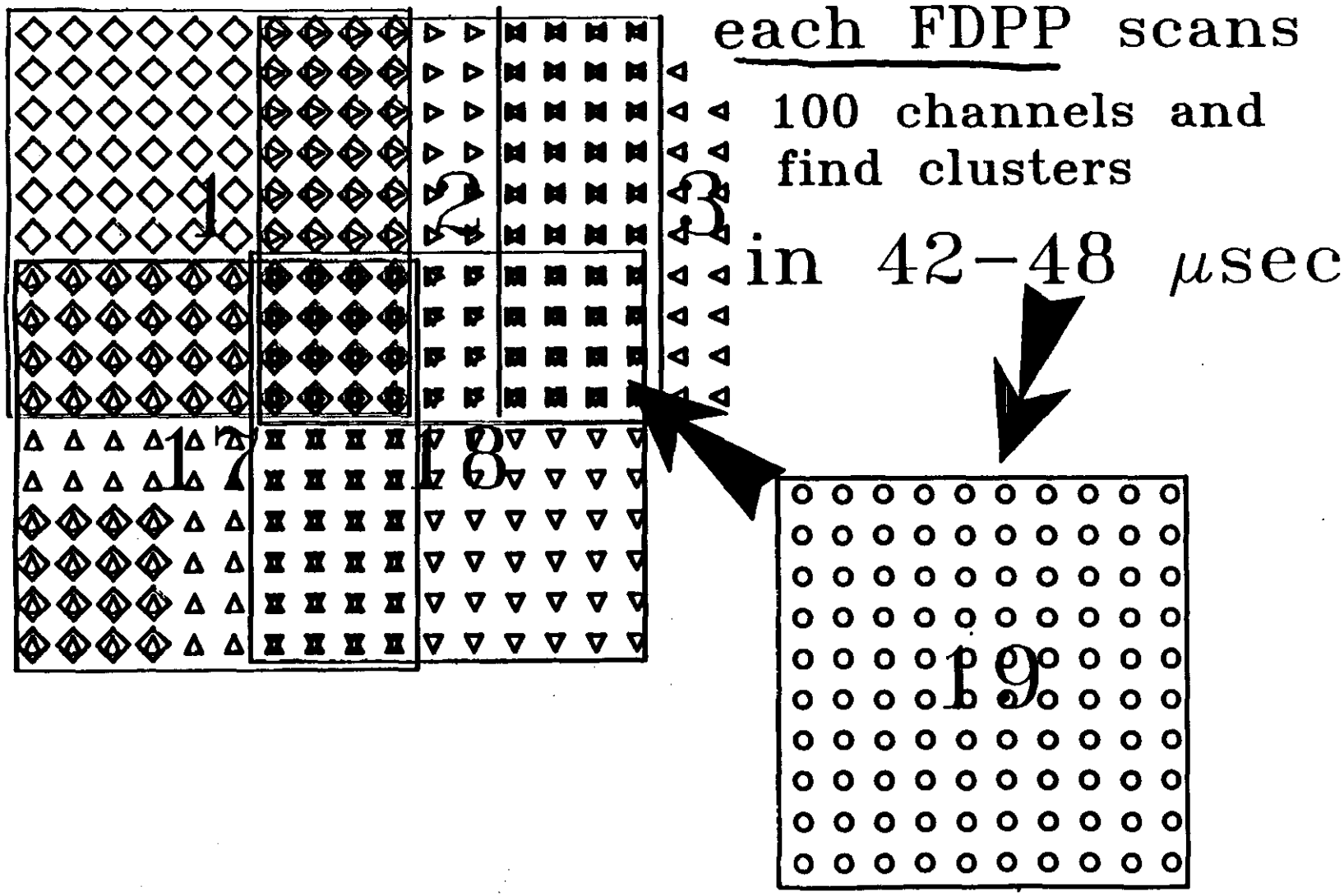
```
  O
 O I O
O I C I O
 O I O
  O
```

All peaks are found in μsec ≈55

CLUSTER-ANALYSIS

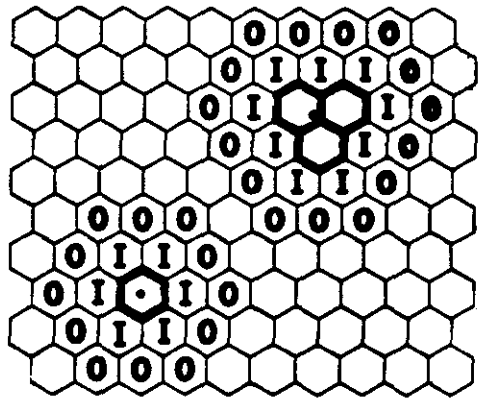
SIMPLE JET/ELECTRON FINDER

```
O O O O O
O I I I O
O I C I O
O I I I O
O O O O O
```


each FDPP scans
100 channels and
find clusters
in 42–48 μsec
1
2
3
17
18
19

Algorithm 3

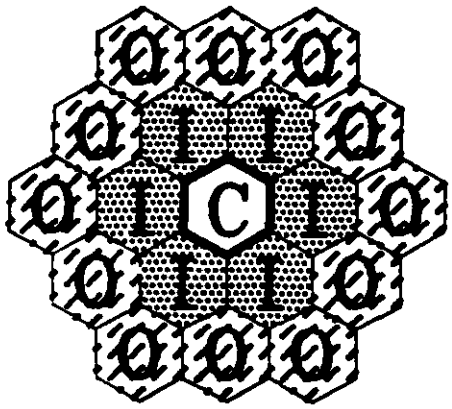
each FDPP



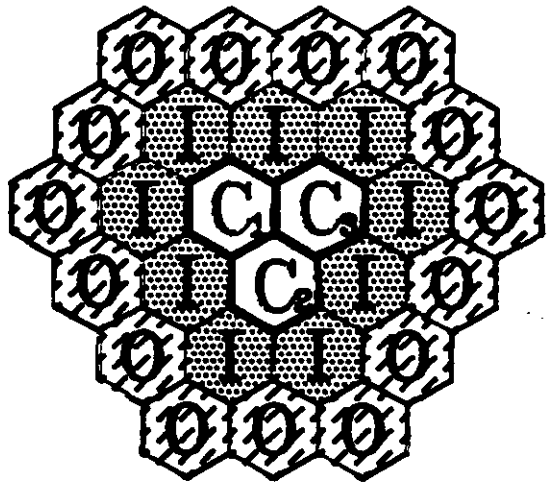
- scans 100 channels
- finds type of hit
- finds local maximum
- calculate E, I/C, O/C for different type of hit

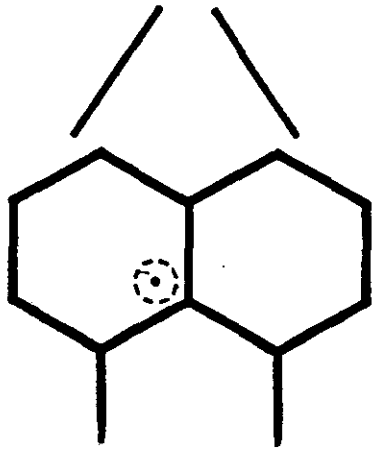
in 62 μsec

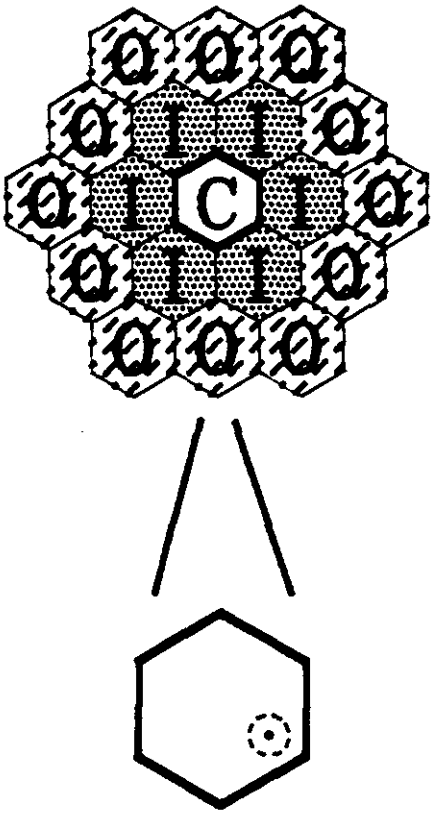
(electron events)



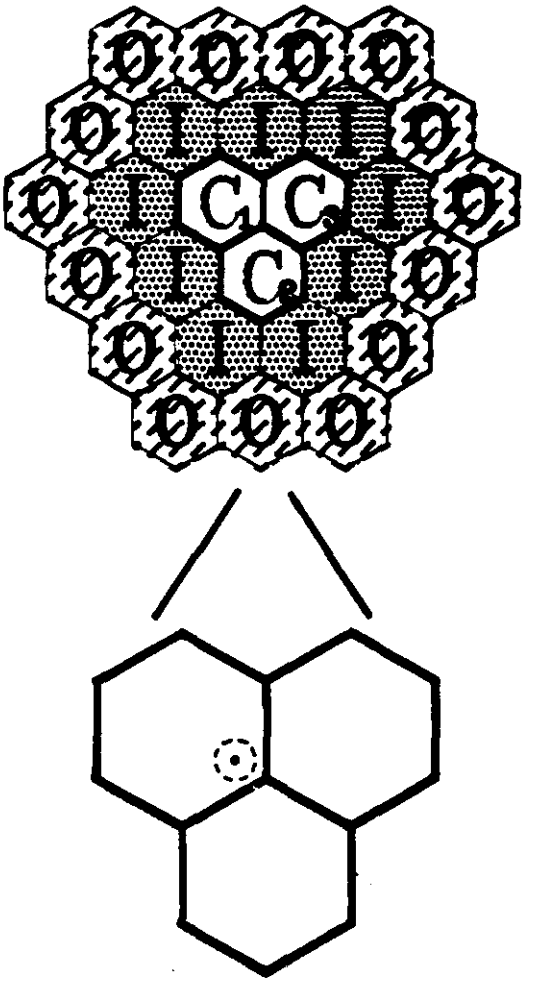
OR







OR



$$C = C_1 + C_2 + C_3$$

$$E_1 = C + \sum_{i=1}^{6} I + \sum_{i=1}^{12} O \qquad E_2 = C_1 + C_2 + C_3 + \sum_{i=1}^{9} I + \sum_{i=1}^{15} O$$

$$(I/C)_1 = (1/6 \sum_{i=1}^{6} I)/C \qquad (I/C)_2 = (1/9 \sum_{i=1}^{9} I)/C$$

$$(O/C)_1 = (1/12 \sum_{i=1}^{12} O)/C \qquad (O/C)_2 = (1/15 \sum_{i=1}^{15} O)/C$$

The same event N.32 from RUN 22531 on SPACAL (1990)

$E_1 = 27.25$ Gev	$E_2 = 28.25$ Gev
$(I/C)_1 = 0.1667$	$(I/C)_2 = 0.2874$
$(O/C) = 0.1544$	$(O/C)_2 = 0.0977$

PROBLEM DEFINITION:

CASE STUDY 2

Options for the I level trigger

3) 34 channel to 1 processor (one tower)
16) send Region of Interest Info to II level trig.

Options for the II level trigger

1 a) DAQ ≡ II level trig.
2 b) zoom in a partic. region
4) 49 channel to 1 processor FDPP
6 a) filter on detector
7) ges (ON/OFF zero suppr.)
12 a,b 128 Kbyte (input/output buffer)
13 b) overlapping areas

POSSIBLE SOLUTION

↳

1. MIMD PARALLEL HYBRID SYSTEM

used for:

- distributing processes over several processors

- concentrating the processing power in the region of the detector where there are some interesting data.

2. DATA FLOW BASED

used in:

(a) CALORIMETER
- fast data correlation

(b) TRACKING DETECTORS
- should be possible to reconstruct tracks using the data flow principle:

Processing Elements execute programs when the input data is available.

FDPP + DATAWAVE system

gives the possibility to realize a

FLEXIBLE ARCHITECTURE

1. MIMD PARALLEL HYBRID SYSTEM

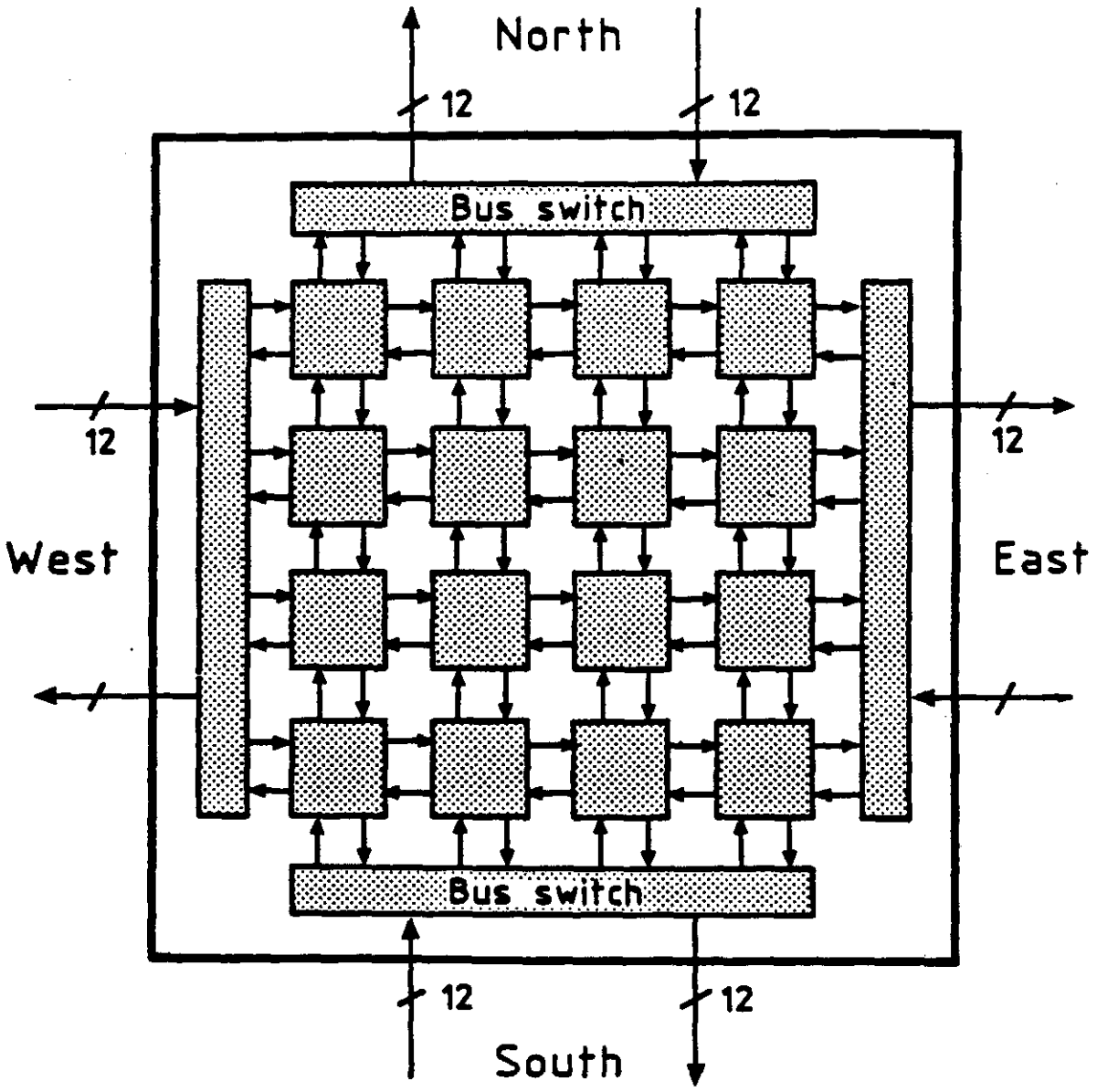
(loosely coupled but with both serial and parallel exchange)
on the higher level array processor
(DSP + Transputers)

- with the possibility to change dynamically the topology of the system (e.g. from a tree structure to a mesh structure)
- with 1.2 Mbyte/s serial links
- with parallel channels of up to 150 Mbyte/s

2. DATA FLOW BASED

on the lower level array processor (DataWave)

- with 750 Mbyte/s maximum transfer rate between chips.


North
12
12
Bus switch
12
West
12
East
Bus switch
12
12
South

DataWave chips

The one described in the magazine Elektronik 12/june 8, 1990 has:

- 16 identical PEs(in program also with one and 64 PEs)

- individually programmable

- working on the data flow principle and organized in a matrix form

- each PE is a RISC processor with 12-bit architecture which operates on the pipeline principle

- each PE communicate with their four nearest neighbors via asynchronous parallel buses

- each PE can have a maximum program length of 64 words of 48-bits each.

52

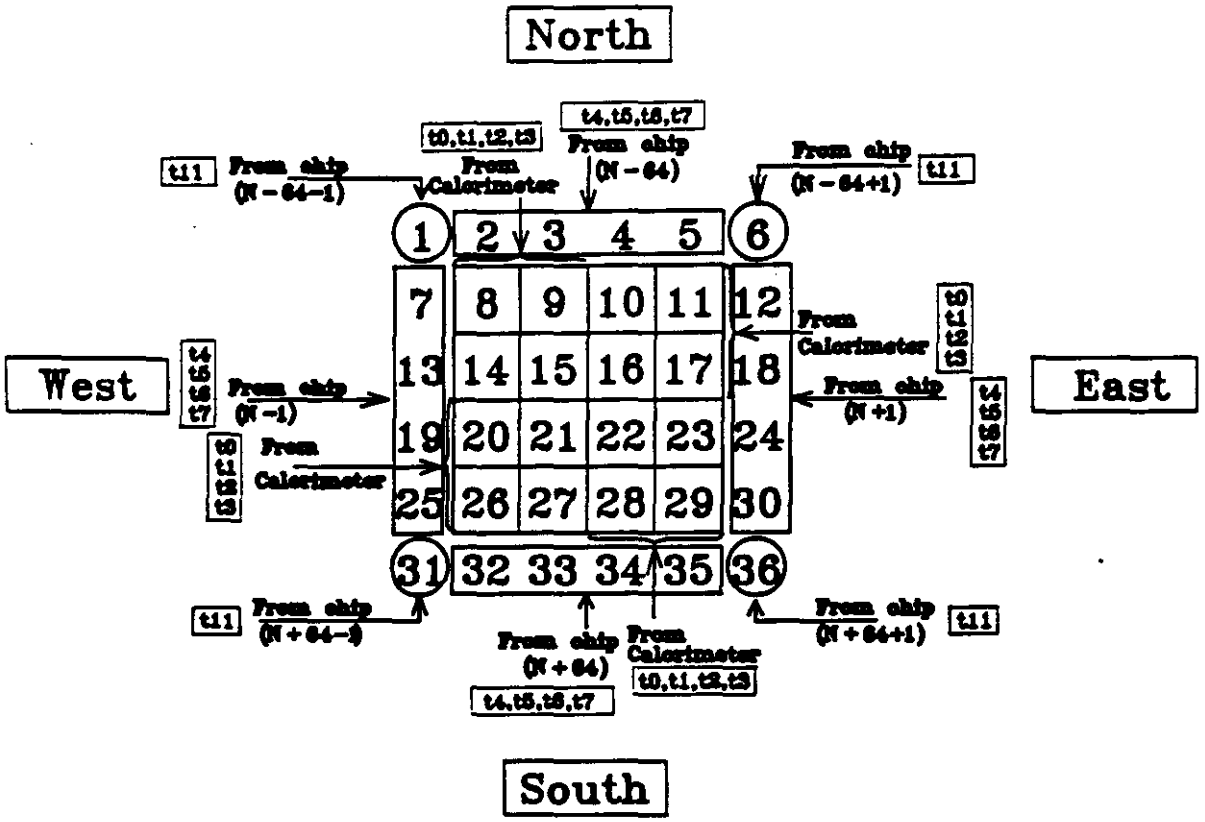
A "local maximum" is a channel value greater than or equal to its neighbors

I	I	I
I	C	I
I	I	I

$$E = \sum_{i=1}^{8} I_i + C$$

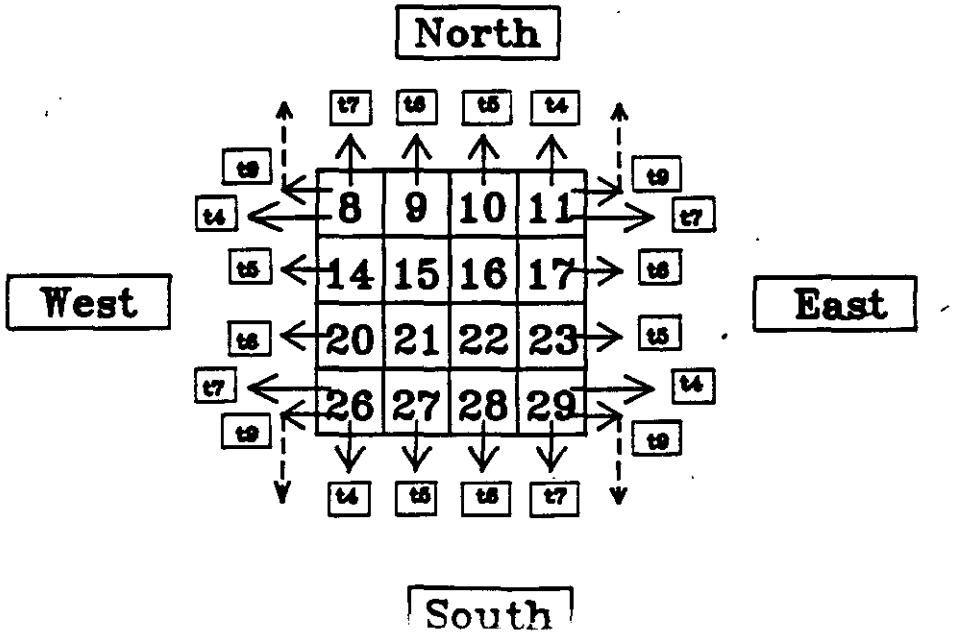
Each DataWave receives DATA from:

- the Calorimeter (A/D converters)
- and from neighboring DataWave chips



Each DataWave sends DATA to:

- neighboring DataWave processors



$E_{TOT} = \sum c_i E_i$ $\quad$ $E_\perp = \sum c_i E_i \cos\vartheta_i$

DataWave program to transfer input data into PE

```
/* START LOADING FROM READOUT ELECTRONIC */
    t0      alu=alu+n*r11,     e=s=r9=n
    t1      alu=alu+n*r12,     e=s=r8=n
    t2      alu=alu+n*r13,     e=s=r5=n
    t3      alu=alu+n*r14,     e=s=r6=n
/* END LOADING FROM READOUT ELECTRONIC */
```

DataWave program to exchange data with neighboring PE

```
/* START TO EXCHANGE DATA WITH NEIGHBORING PE
    t4      r2=n,              w=r5
    t5      acc=r8+r9
    t6      r3=e,              acc=acc+r5
    t7      s=r4=w,            n=r5
    t8      acc=acc+r3
    t9      w=r5,              acc=acc+r6
    t10     n=w,               r7=s
    t11     r1=n,              acc=acc+r2
    t12     acc=acc+r4,        s=alu
/* END OF DATA EXCHANGE WITH NEIGHBORING PE *
```

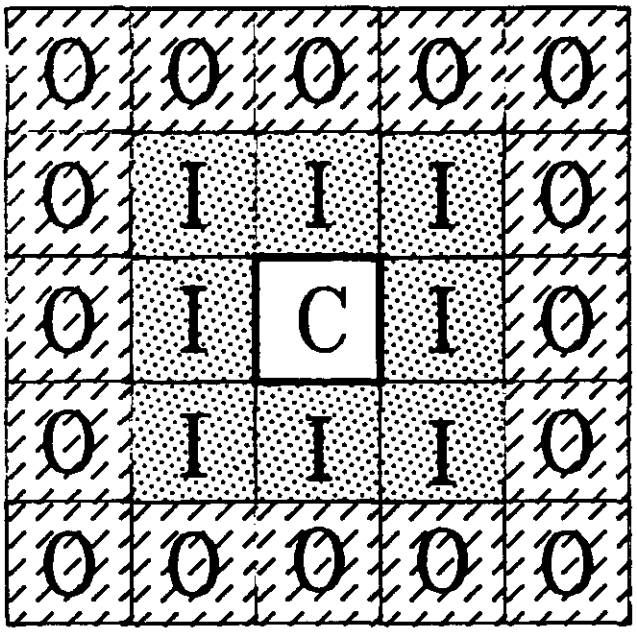
Algorithm 1

each FDPP for the II level trigger

– calculates E, I/C, O/C (in floating point)

in 15 μs

SHAPE FACTORS



$$E = C + \sum_{i=1}^{8} I_i + \sum_{i=1}^{16} O_i$$

5 μs

$$I/C = (1/8 \sum_{i=1}^{8} I_i)/C$$

5 μs

$$O/C = (1/16 \sum_{i=1}^{16} O_i)/C$$

5 μs

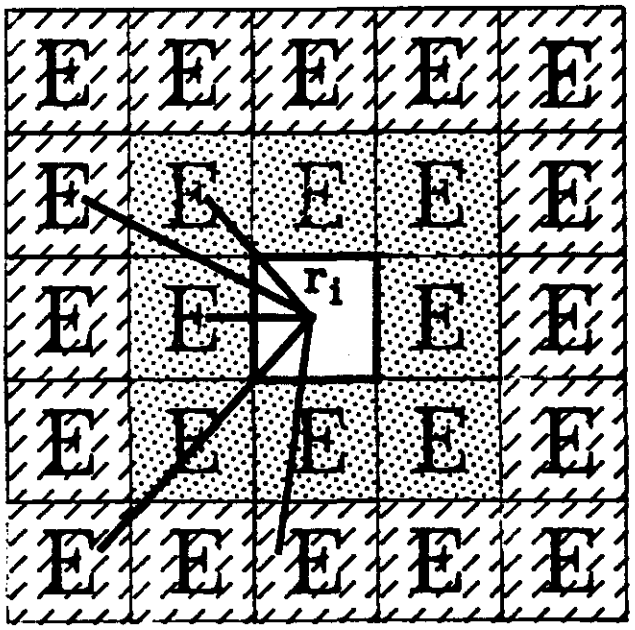
OR

Algorithm 2

each FDPP for the II level trigger

– calculates Rp (in floating point)

in 15 μs



$$Rp = \frac{\sum_{i=1}^{25} r_i E_i^{0.4}}{\sum_{i=1}^{25} E_i^{0.4}}$$

PROBLEM DEFINITION

CASE STUDY 3

Options for the I level trigger

3) 34 channels to 1 processor (1 tower)

15) isolate cluster at I level, give ROI to II

Options for the II level trigger

1 a) DAQ ≡ II level trig.

2 b) zoom in a partic. reagion

4) 49 channels to 1 processor FDPP

6a) filter on detector

7) yes (ON/OFF zero suppr.)

12 a, b 128 Kbyte (input/output buffer)

13 b) overlapping areas

SOLUTION as Case 2 more precise informations from the I level trig. assuming to use a Pipeline array of

PROBLEM DEFINITION:

Case study 4

Options for the I level trigger

16) no processor array

Options for the second level trigger

1a) DAQ ≡ II level trig.
2a) algorithm on all channels
4) 1000 channels to 1 processor (FDPP)
6a) filter on detector
7) yes (ON/OFF zero suppression)
12 a,b 128 Kbyte (Input/Output Buffer)
9 a) 10 KHz input rate
8) no dead-time

POSSIBLE SOLUTION

↳

Example of a DAQ for 60,000 channel Calorimeter

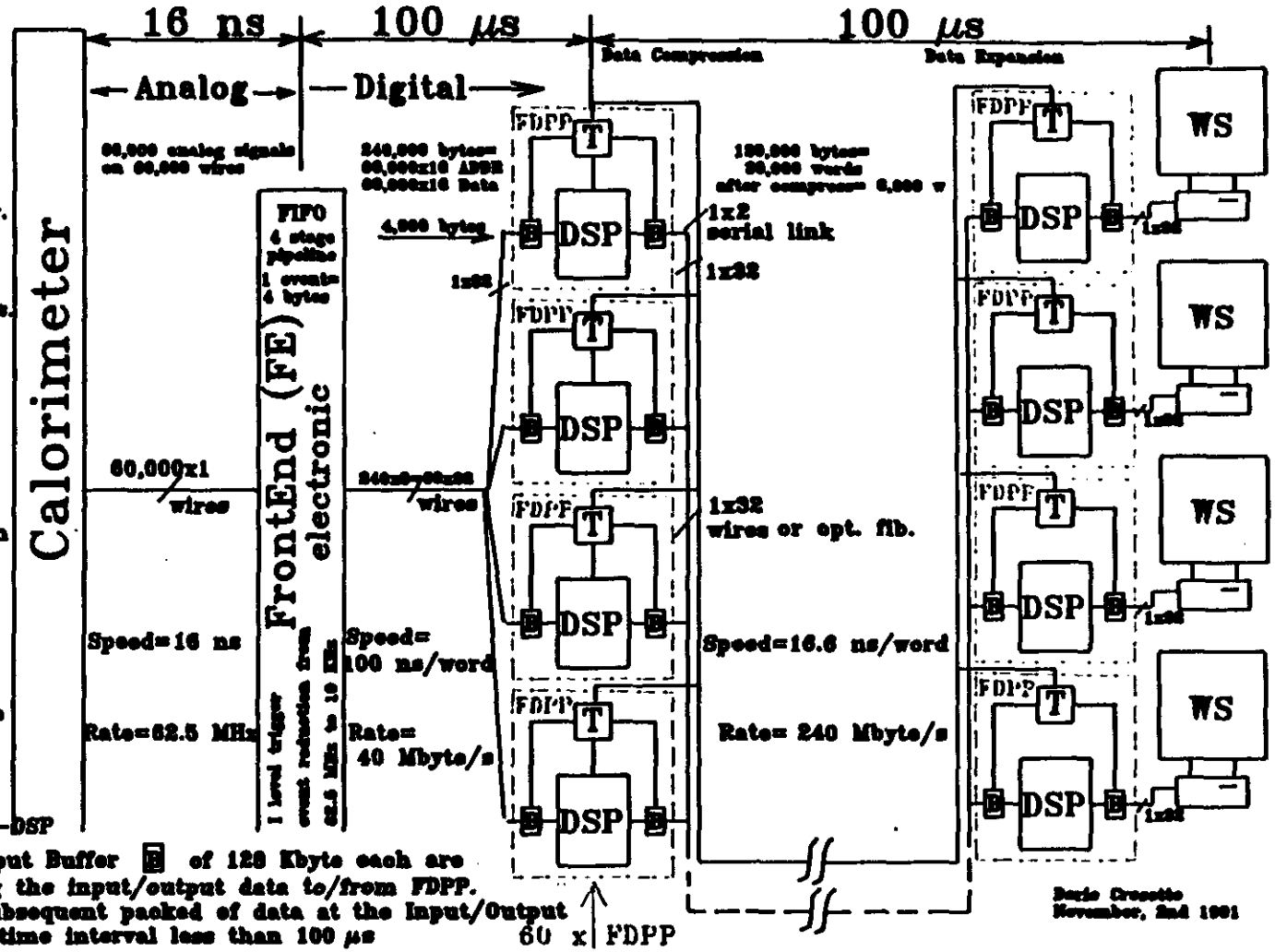
with II level trigger of 10 KHz, no zero suppression and with no dead-time

DSP tasks:

- pedestal subtraction
- calibr. cost.
- suppress addr. & generate lookup-table
- data compress.

T=TRANSPUTER

- data transfer controller
- supervisor & monitoring of the system
- generate the correct seq. among the ACQ-DSP and WS-DSP in order to collect in one WS-DSP all data of an event from different ACQ-DSP



- An Input/Output Buffer ▣ of 128 Kbyte each are derandomizing the input/output data to/from FDPP. This allows subsequent packed of data at the Input/Output to occure at time interval less than 100 μs

PROBLEM DEFINITION:

Case study 5

Options for I level trigger

3) 34 channels to 1 processor (1 tower)

16) small number of processors

Options for II level trigger

1 a) DAQ ≡ II level trig.

2 a) on all channels

4) 25 channels to 1 processor (FDPP)

5) yes, 5 samples

6 a) → 9 a) filter on detector, rate: 50 kHz

6 b) → 9 a) filter on II level trig. DSP, rate: 20 kHz

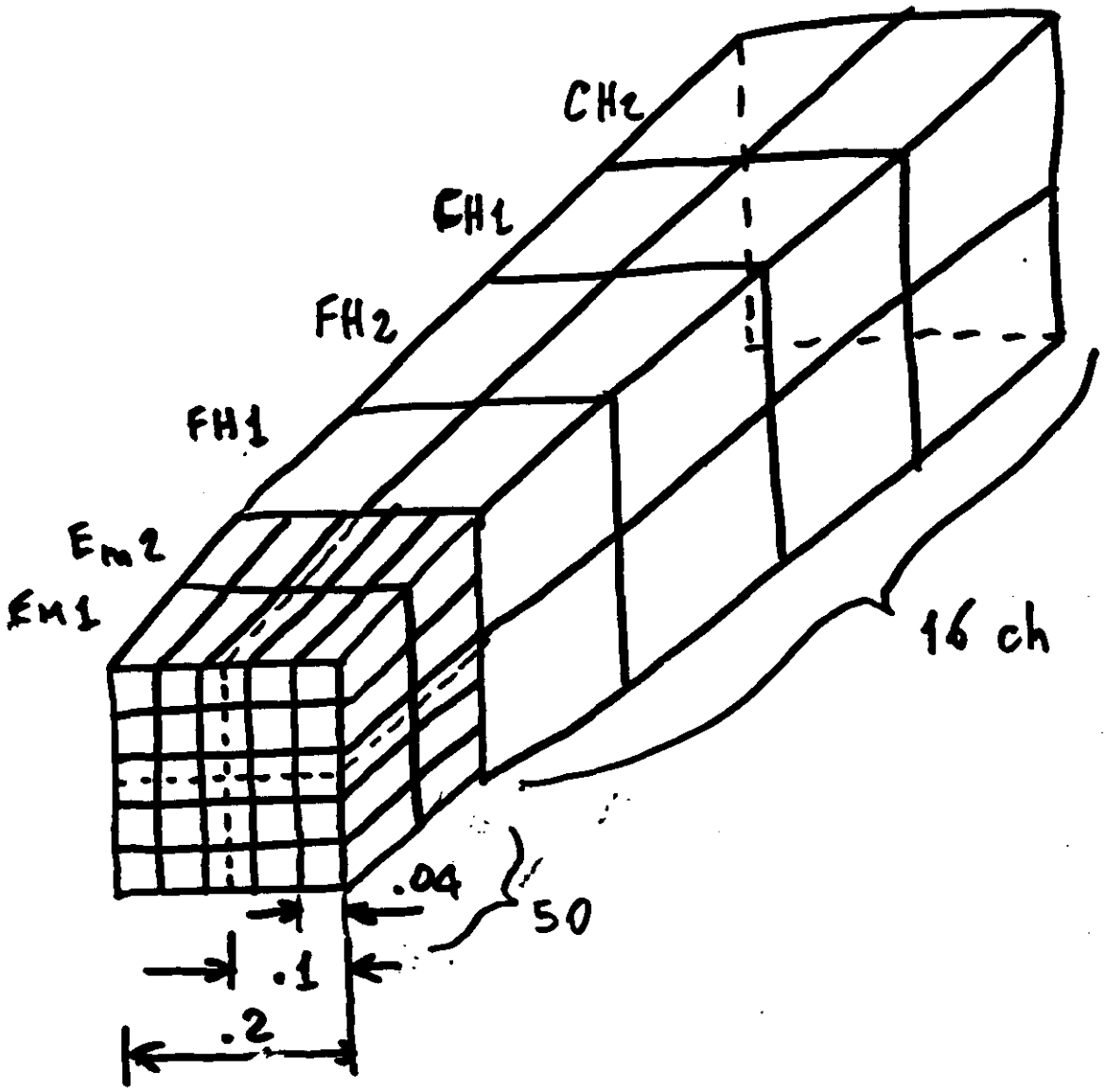
12 a,b 128 Kbyte (input/output buffer)

POSSIBLE SOLUTION

→

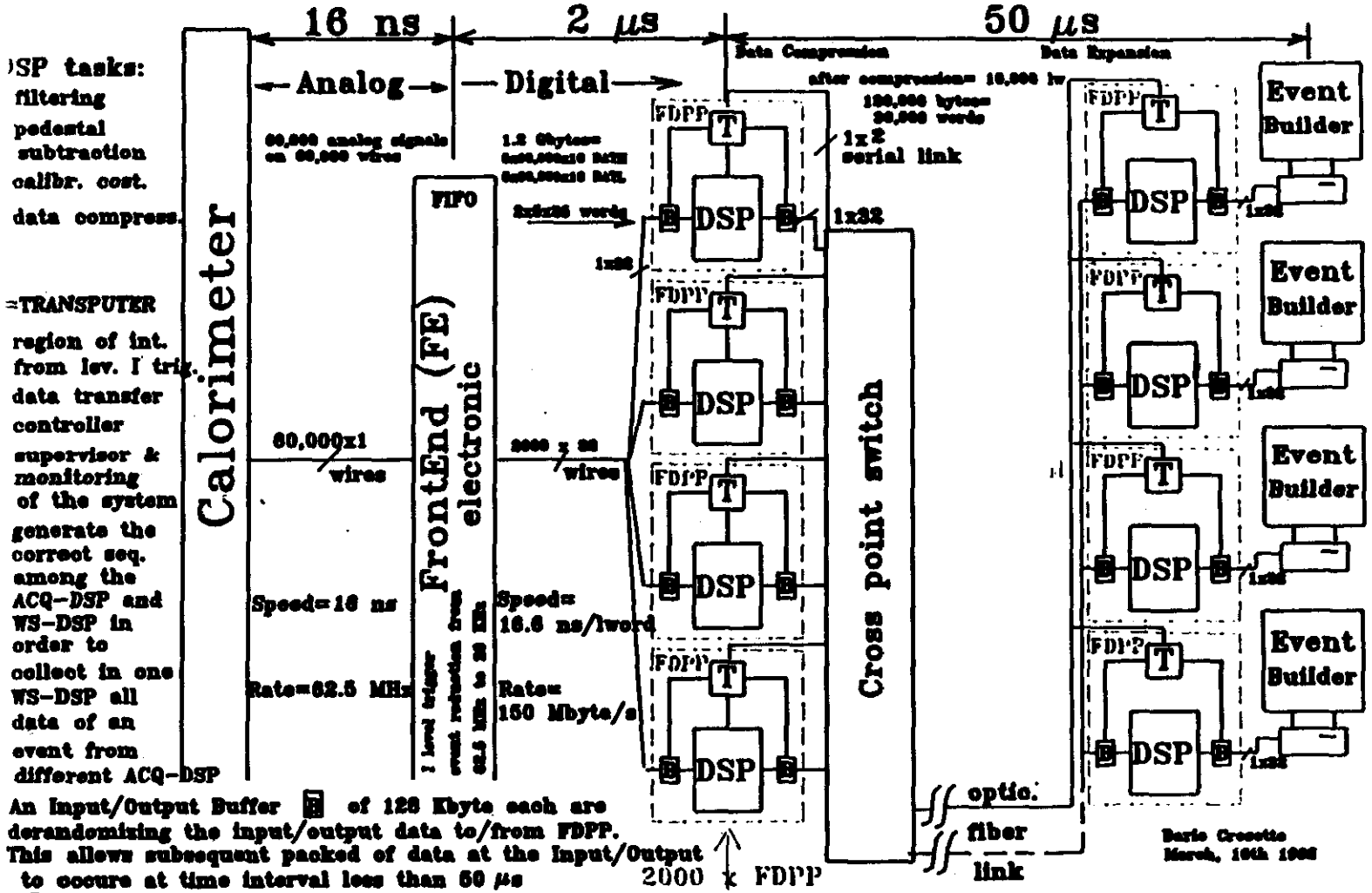
GEM Calorimeter

942 towers



Example of a DAQ for 60,000 channel Calorimeter

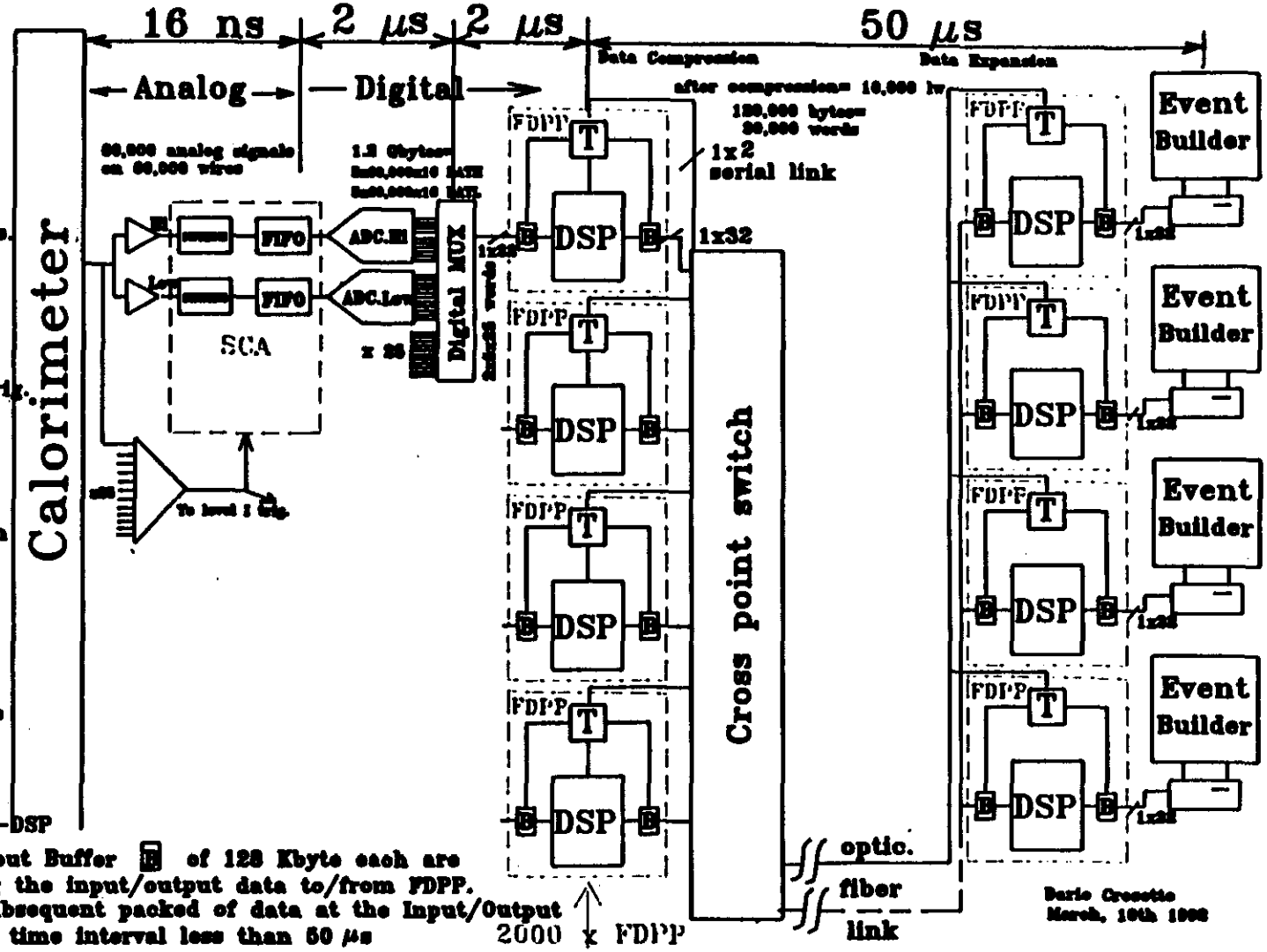
with II level trigger of 20 KHz, on/off zero suppression select, no dead-time



h II level trigger of 20 KHz, on/off zero suppression select, no dead-time

' tasks:
'ering
'lestal
btraction
ibr. cost.
'a compress.

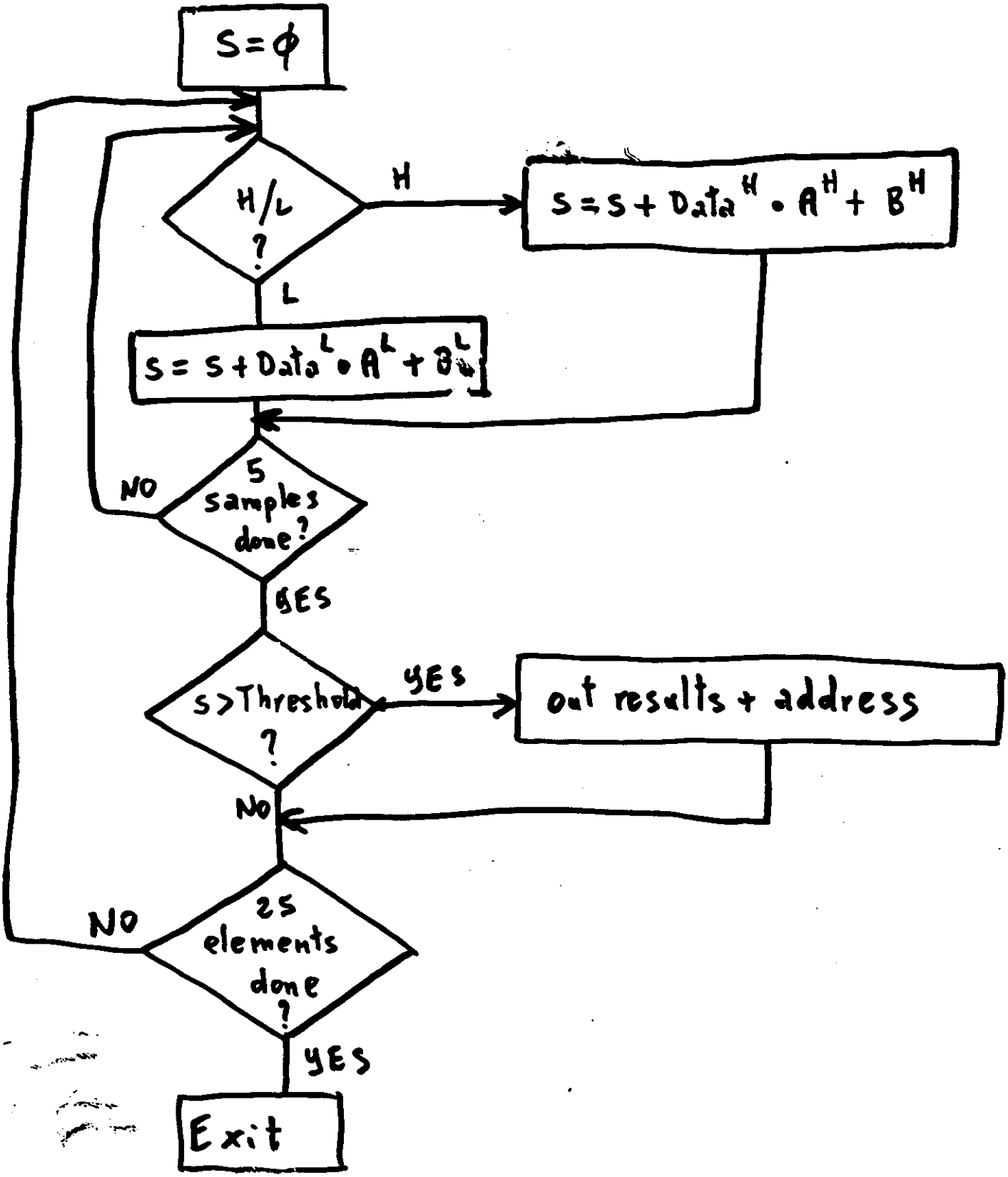
'ANSPUTER
'ion of int.
'm lev. I trig.
'a transfer
'ntroller
pervisor &
'nitoring
the system
'erate the
'rect seq.
'ong the
'Q-DSP and
-DSP in
'er to
'lect in one
-DSP all
'a of an
'nt from
'ferent ACQ-DSP



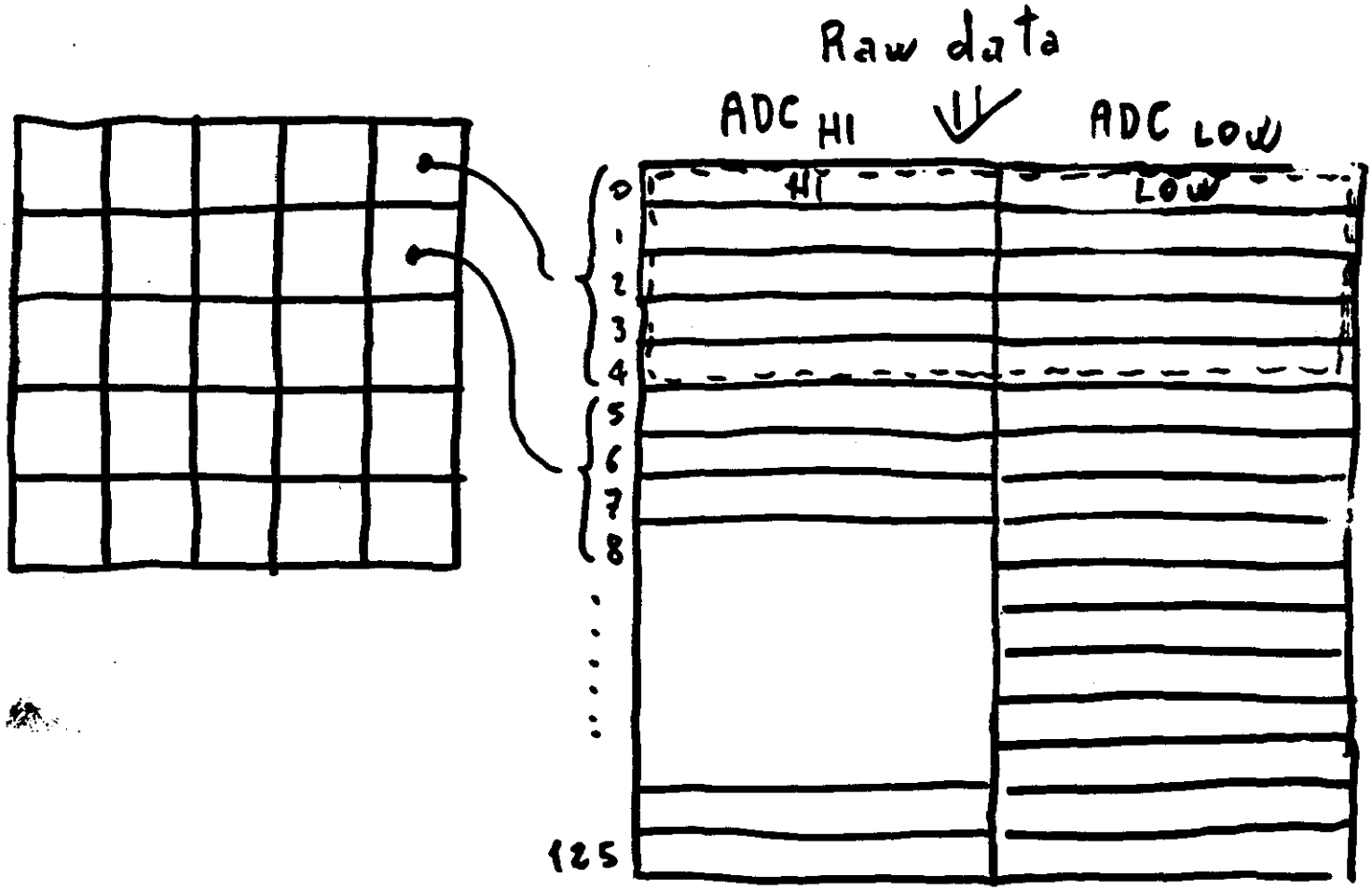
Input/Output Buffer of 128 Kbyte each are
andomizing the input/output data to/from FDPP.
s allows subsequent packed of data at the Input/Output
occure at time interval less than 50 μs

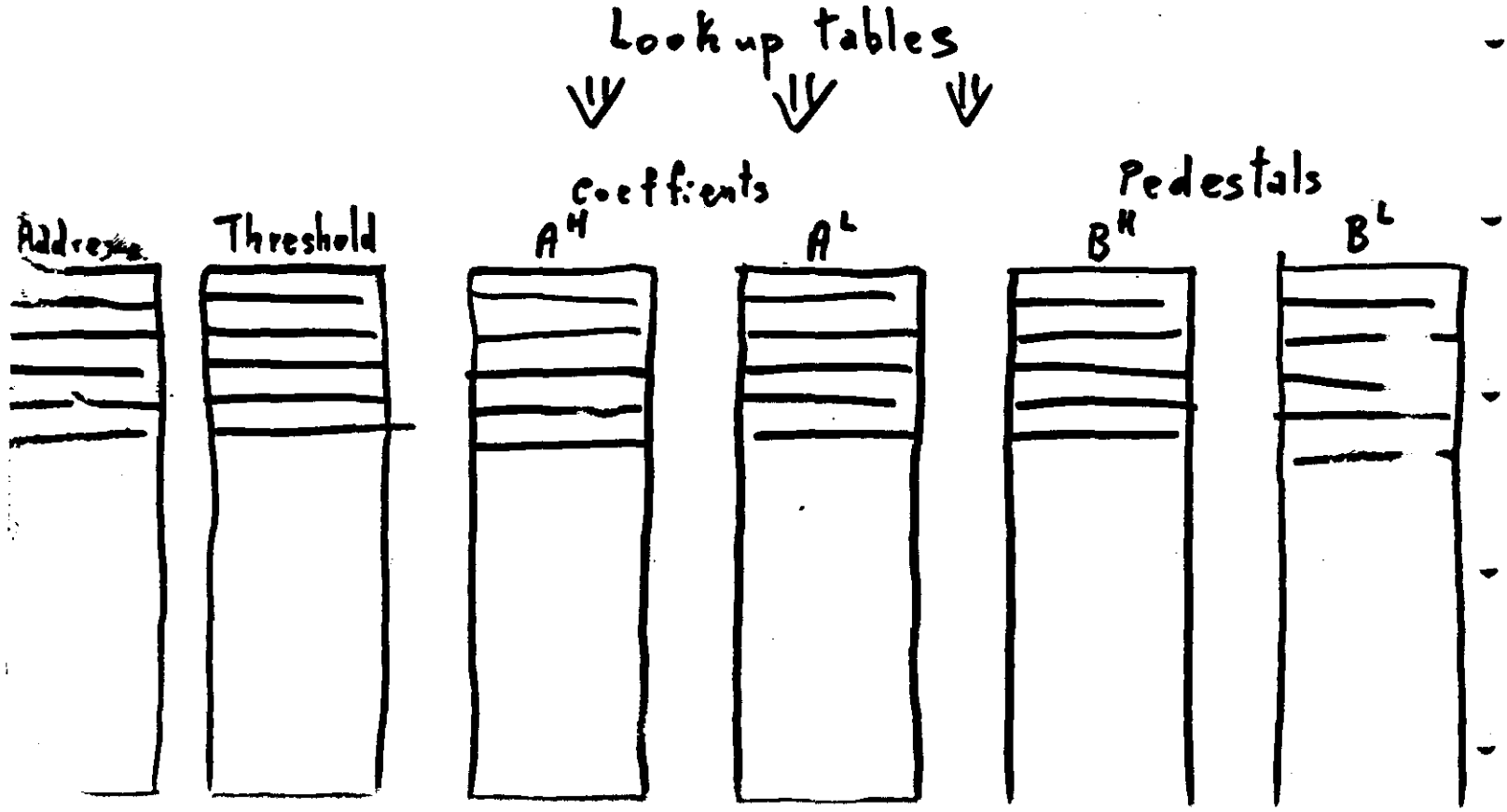
Dario Crosetto
March, 10th 1992

Digital Filter Algorithm



Digital Filter on 5-samples





A - I propose to build a prototype of 4 FDPP_DM because it satisfy all req. for GEM Cal

1) flexibility to test all above algorithms
2) computing capability
3) bandwidth communication of data from front end to VME sys. DAQ.

B To simulate the I level trigger algorithms that I have done on paper (+ others) on a real Data Wave Simulator.

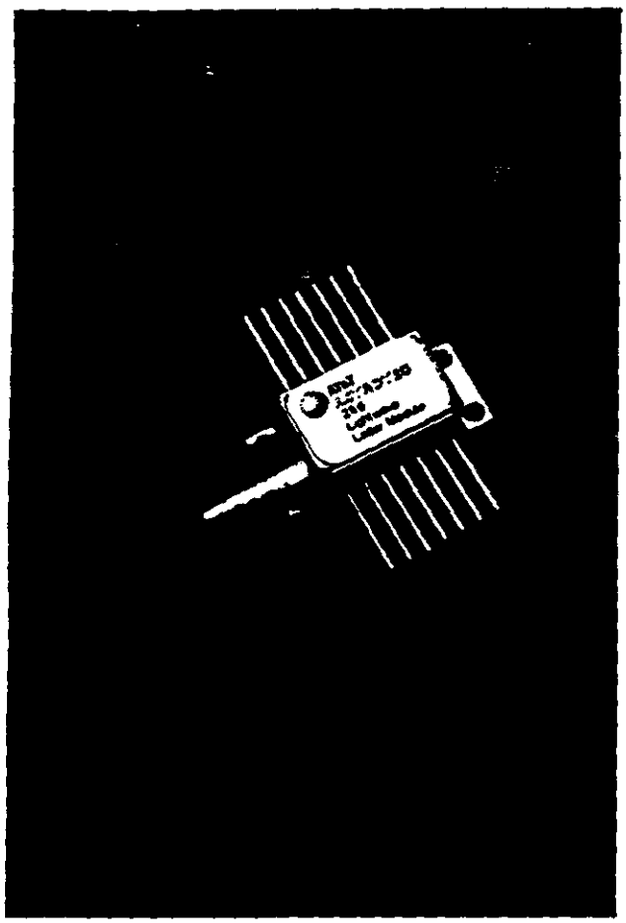
At our Knowledge there are no other chips as close to our need as it is the DataWave.

Preliminary Data Sheet
December 1991

AT&T Microelectronics

$ 6900

246-Type *ASTROTEC*® Digital Isolated DFB Laser Module



The 246-Type Laser Module is available with a 14-pin, hermetic, butterfly package.

Features

- Isolated package providing a minimum of 30 dB isolation
- SONET compatible
- High-performance, distributed-feedback (DFB) laser
- 14-pin, butterfly package
- 25 Ω, impedance-matched, RF input
- 2.5 Gbits/s data rate (NRZ)
- Epoxy-free, hermetic package
- Wide operating case temperature range: −40 °C to +65 °C
- Operation at 1.3 μm or 1.55 μm wavelength
- InGaAs, PIN, photodetector backface monitor
- Low threshold current
- High reliability

Applications

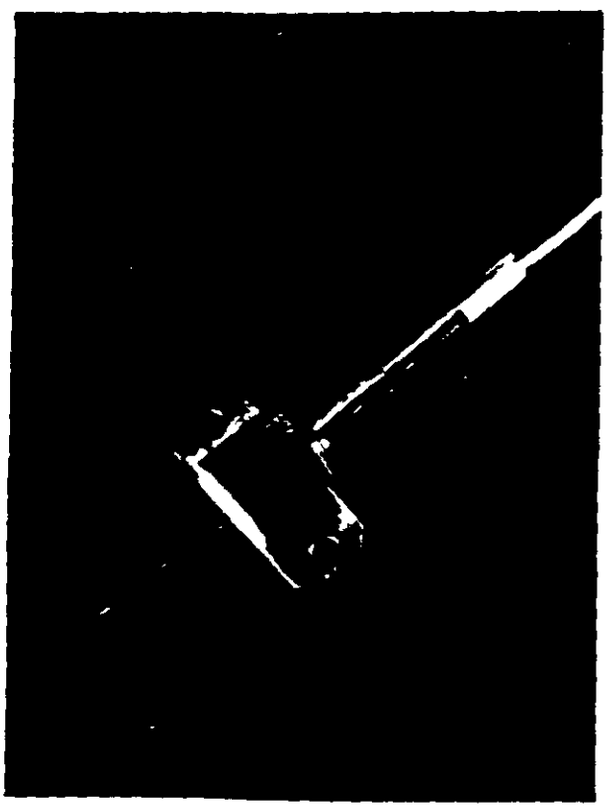
- Telecommunications
  - — SONET
  - — Long-haul
  - — Interexchange
  - — Undersea
- Military
  - — Space stations
  - — Phased-array radar
  - — Microwave

Data Sheet
December 1991

$ 1132 127B

AT&T Microelectronics

127A/B/C *ASTROTEC*®
InGaAs Avalanche Photodetectors



The 127 A/B/C APDs are compatible with industry-standard packages.

Features

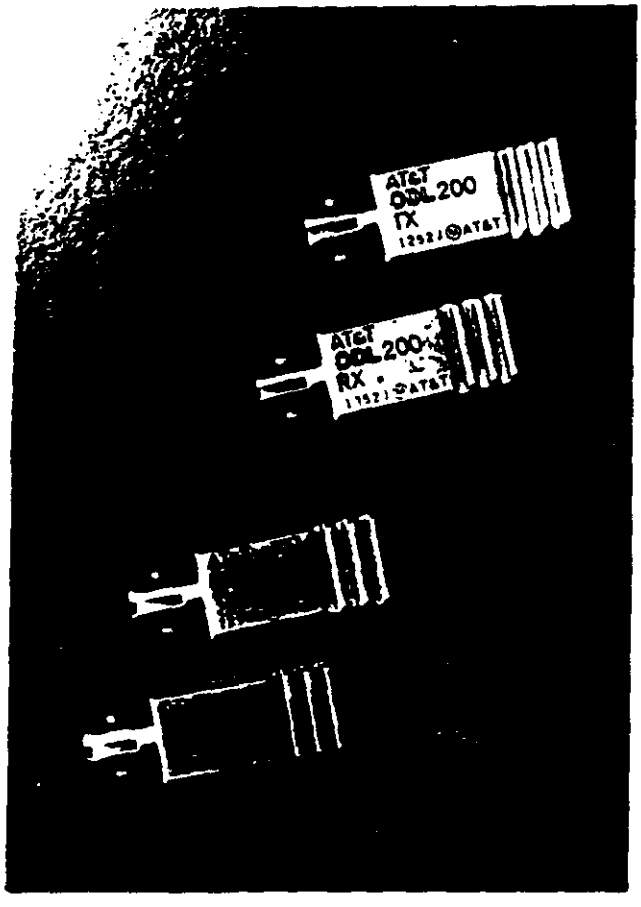
- High performance at both 1.3 µm and 1.5 µm
- Suitable for use in harsh environments
- Higher sensitivity and longer wavelength response than germanium APDs
- Permanently locked fiber alignment and high coupling stability
- Reliable planar structure with InGaAsP layer and guard ring for high-speed performance
- High responsivity from 1.0 µm to 1.6 µm
- Wide bandwidth:
  >1.0 GHz (127A)
  >1.8 GHz (127B)
  >2.5 GHz (127C)
- Compatible with industry-standard packaging
- Applications for high data rates:
  — Up to 1.5 Gbits/s (127A) or 2.5 Gbits/s (127B/C)
- Low capacitance
- Standard pigtail is a multimode fiber with a biconic connector; other pigtails available on request

Applications

- Telecommunications
  — High-speed, long-haul communication systems
  — High-speed metropolitan area networks
  — Submarine cable communication systems
  — High-frequency analog transmission
- Military
  — Very low-noise receivers
  — Satellite transmission
  — Optical radar
  — Free-space optical communication systems

Data Sheet K.t $620

ODL® 200 Lightwave Data Link With Flag



A high-performance optical data link provides electrical isolation and secure transmission between DTE systems.

Benefits

- Data link immunity to EMI/RFI, crosstalk, and ground loops
- Secure data transmission without encryption

Features

- Data rates from 40 Mbits/s to 220 Mbits/s (NRZ) at 1.3 μm wavelength
- New transmitter design with reduced power dissipation
- New receiver design with improved receiver sensitivity and dynamic range
- 100K ECL compatible
- Single power supply
- Ambient temperature: 0 °C to 70 °C (See Thermal Characteristics section.)
- Rugged, connectorized 16-pin DIP
- High reliability (MTBF > 1×10^6 hours)

Applications

- Telecommunications
  - — Network control and timing
  - — PBX module interface
  - — Local loops
- Data Communications
  - — Local area networks (LANs)
  - — Point-to-point communications
  - — Channel extenders
- Security communications
  - — Banking
  - — Military

Forward Regions

Calorimetry, Muons, Magnet, Beam Pipe, Vacuum

L.Waters, J.Rutherfoord, K.Morgan

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

Forward Regions Summary

KHI

Radiation / Activation:

LW Shield calculations for forward muons behind forward calorimeter are in progress

LW Activation profile for entire beam pipe in the IR - will be done

Quads:

We need ≃ 10 meters <u>more</u> to gain access w/o moving Quads. This can be achieved w/ little or no loss in luminosity. The machine also benefits

Alignment Issues

Many and Vague. Terminology problems with Position, Alignment, Stability

- Practical Issue: We must determine the range of motion needed to accomodate long term realignment.
- A BPM in front of FFS could help ~~align~~ determine position of muon chambers

Forward Regions Summary (continued)

Backgrounds

Machine Backgrounds

KH JW — Full extent unknown to us.
Recent "One Turn Halo" problem

Physics Backgrounds

KY KMcF — Study the background from primary particles hitting the beam pipe as a function of
1) Pipe configuration
2) Beam position

Iterate ..... to optimize pipe design

BC Eric Stern — Pile up Noise in Forward Cal. has been studied and looks ok!

Vacuum Requirements

JR — Must be determined

Questions : Machine Interface

Expand list of Questions
Keep track of answers - <u>Updated</u>
Make some assumptions ...

LAHET/MCNP/CINDER SIMULATIONS

Laurie Waters, David Lee
Los Alamos National Lab

CODE: LAHET MCNP CINDER90
HETC, FLUKA, EGS4

EVERY EFFORT TO MAINTAIN MOST CURRENT GEOMETRY/MATERIALS

BENCHMARKS: WNR/LANSCE NEUTRON DATA
E814 PCAL (BNL)
RD10 (BNL)

APPLICATIONS:
NEUTRON (and OTHER PARTICLE FLUXES)

1) SILICON VERTEX DETECTOR
UNSHIELDED - 37×10^{12} NEUTRONS/cm²/yr

REDUCTIONS BY FACTOR OF ~4
POSSIBLE WITH BORATED POLY SHIELD

2) NEUTRON FLUX IN CALORIMETER VOLUMES, FCAL

3) NEUTRON FLUX IN 1st MUON STATION
2.6×10^{12}/yr/cm² averaged over chamber

TIME + ENERGY DISTRIBUTIONS
- LOW ENERGIES COME 1μsec - 1 msec
DC CURRENT

4) RESIDUAL NUCLEI/ACTIVATION CALCULATIONS
EFFECTS OF U^{238} FISSION
ACTIVATION THROUGH TIME

From: SSCVX1::ROE 4-MAR-1992 15:58:59.81
To: MORGAN,MARX,SANDERS,BARISH
CC:
Subj: FYI--Talk with Stiening for SDC but of interest to you also

Two Items From a Discussion with Rae Stiening 3/4/92
B. Roe

1. One turn halo background. We have a potentially serious problem from having protons beam gas scatter in the arcs of the accelerator and then hit the beampipe walls in the vicinity of the low beta quads.

The calculations are the following:
Consider a collision between a beam proton and a gas proton. To start with let the scattering angle be 0.1 rad in the center of mass system. (We will see this is too large shortly). The beam proton loses about 50 GeV and is scattered through a lab angle of 250 microradians. At the quads, Stiening calculates that x (meters) is approximately theta * sqrt(300 * 9000) for beta* = 0.5 m. (and the 9000 goes to 18000 for beta* = 0.25 meters)
For 250 microradians, x = 41 cm, ie it would have left the beam long ago.
However, for 9 microradians in the lab the delta E is even smaller, the pperp is 180 MeV, a typical diffractive scattering size, and x = 1.5 cm.
This is of the order of the vacuum pipe size (which is not yet fixed).
Rae estimates that there are about 10**8 beam gas interactions per second and 1/4 are diffractive, 0.8 have the right phase, and 0.1--0.01 have theta < 9 microradians. This gives a background of 10**5-10**6 protons per second hitting the vacuum pipe walls in the 100 m long or so low beta quad region.

QUERY FROM RAE: Could we estimate what background rate of these protons is tolerable?

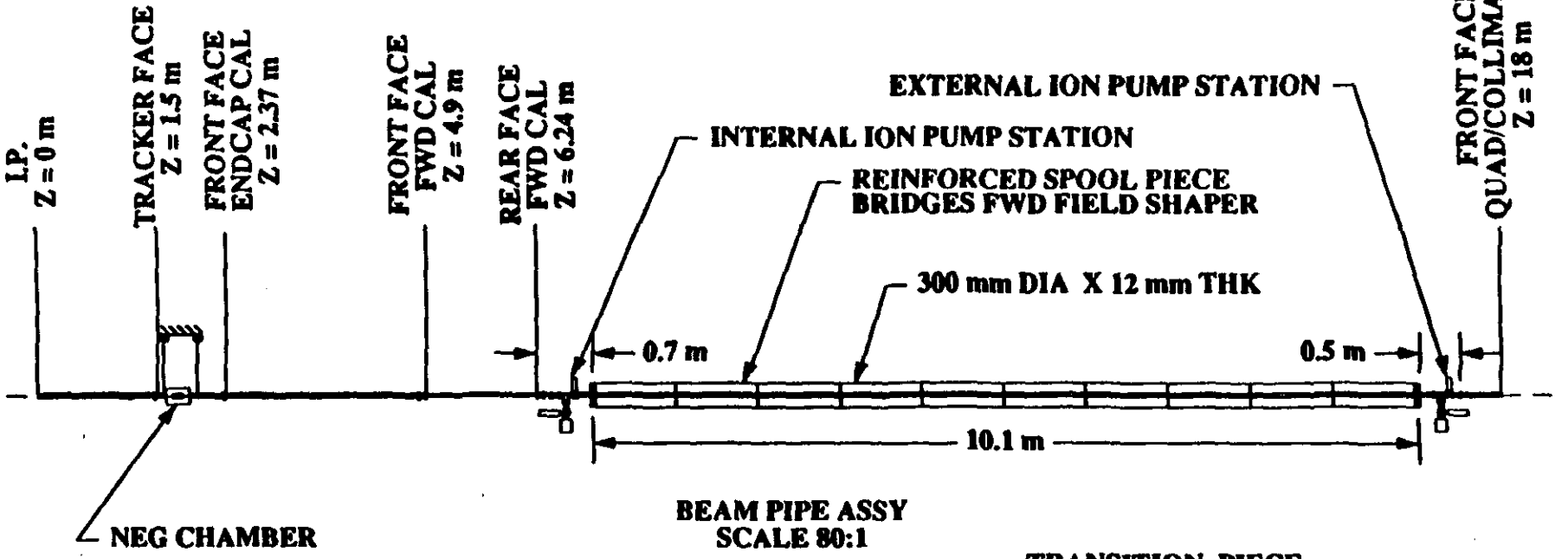
I need help on this. It doesn't seem to me trivial. There are questions of radiation levels, of background in the tracking system and muon background in the forward muon chambers. Can you see if some of this can be calculated?

Another comment which may be pertinent comes from L. Jones who notes that about a fourth of the inelastic cross section interactions end up with a fast forward neutron. The neutrons have an ~300 MeV pperp distribution and very crudely are distributed with a (1-x)**2 distribution. Although we don't have the length of the arcs for this, we do have about a kilometer of straight section at the detector within which we might have these interactions generated. Is this a problem?

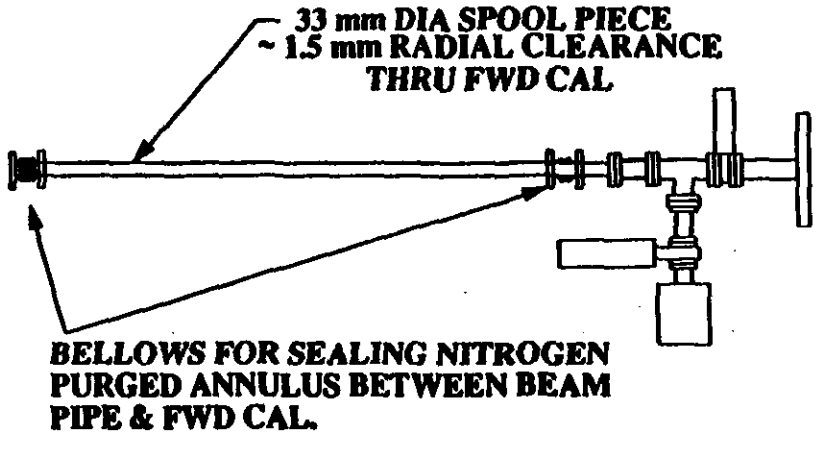
2. Quadrupole position. Acting on a suggestion of Dave Ritson's, Rae has calculated optics assuming that the quads are moved back from 20 m to 35 m from the interaction point. The most important change is that the aperture needed to maintain the luminosity is increased by 17%. If the quads remain the same size as now, the luminosity would decrease by the square of this, roughly a 30-35% decrease. Building larger bore quadrupoles would allow us to have no loss of luminosity. Rae estimates the incremental cost for the larger quads as between $1-$10 million. It is likely that it may be at the lower end of this estimate. Further there would be savings in that the quads would not have to be cantilevered out as far as in the present design.

Are we interested in this change? It means that we would not have to disinstall and reinstall the quads to move our detector far apart. It is possible that we will never need to move the detector halves far apart. My own (gut-not factual) feeling is that I would be delighted, but quite surprised, if we did not need to move it apart more than once in the first couple of years of operation. In any case we need to tell the accelerator people what our position is on this point.

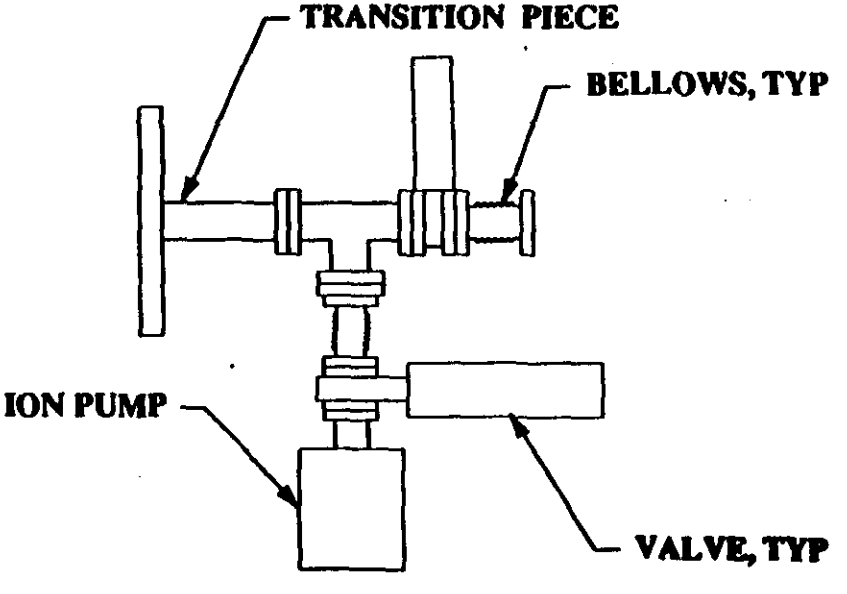
BEAM PIPE DIAMETER IS 50 mm EVERYWHERE EXCEPT THRU FWD CALORIMETER, WHERE IT IS 33 mm DIA. WALL THICKNESS IS ASSUMED TO BE 1 mm.



BEAM PIPE ASSY
SCALE 80:1



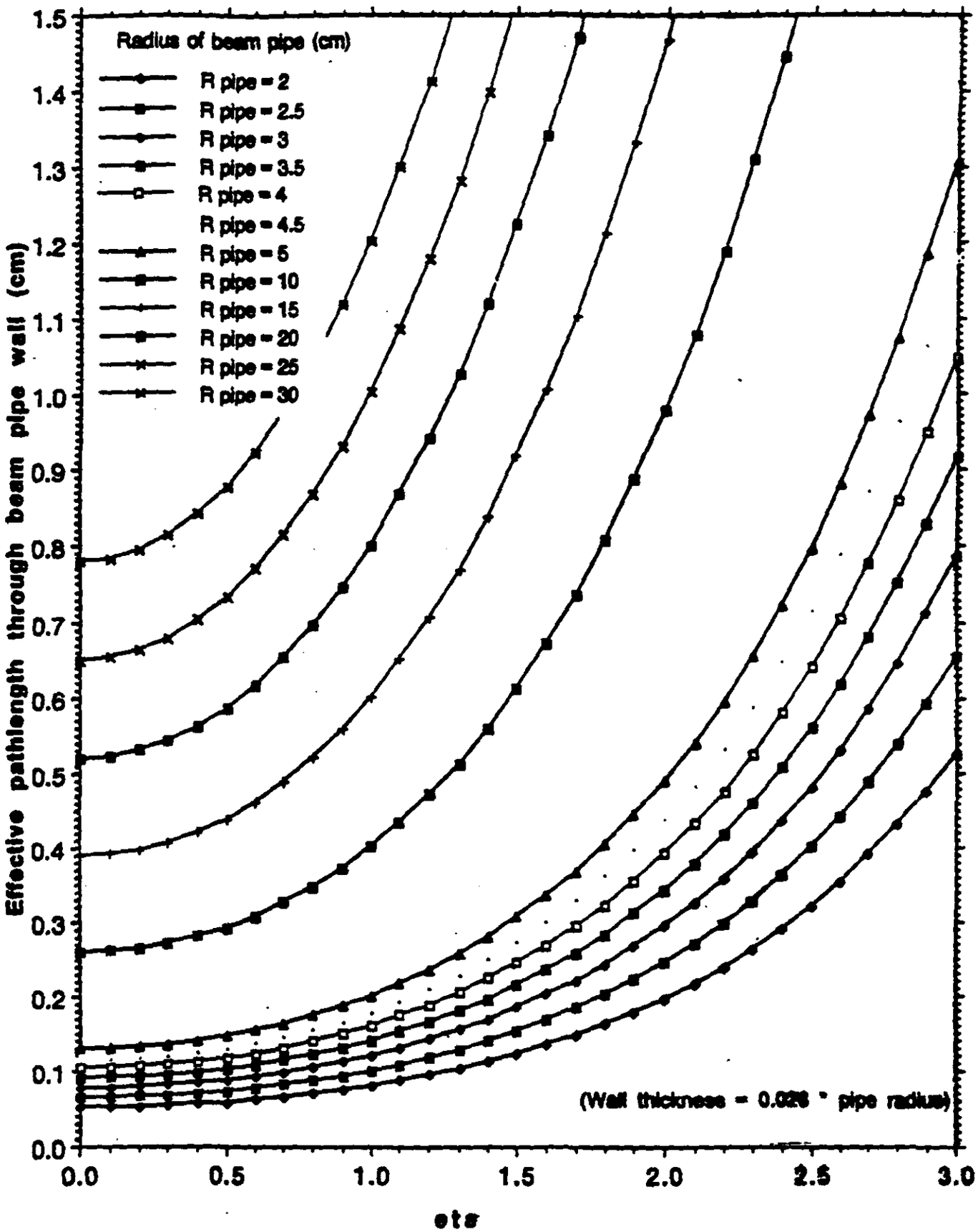
INTERNAL ION PUMP STATION
SCALE 20:1



EXTERNAL ION PUMP STATION
SCALE 10:1

DRAFT
Eberle 02/28/92

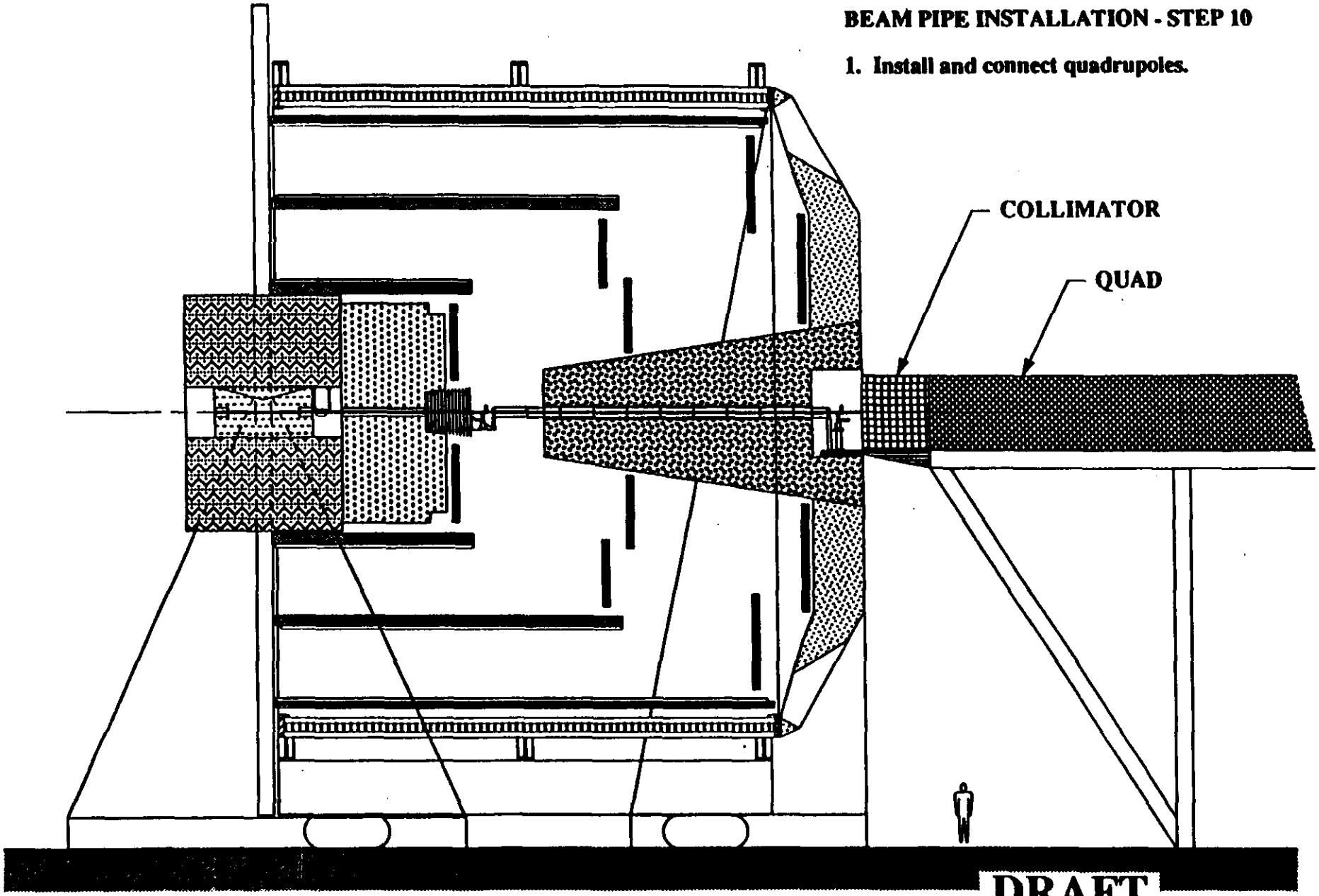
Constant r pipes, not flared



Be

BEAM PIPE INSTALLATION - STEP 10

1. **Install and connect quadrupoles.**



DRAFT

SCALE 160:1
Eberle 02/13/92
Revised 02/27/92

Pileup Noise in the Forward Calorimeter

– E. Stern + w.s.c.
Univ of Pittsburgh

$$\sigma_p^2 = \underbrace{\sigma_E^2}_{\text{physics}} \underbrace{\int |g(t)|^2 dt}_{\text{signal processing}}$$

Simple minded model

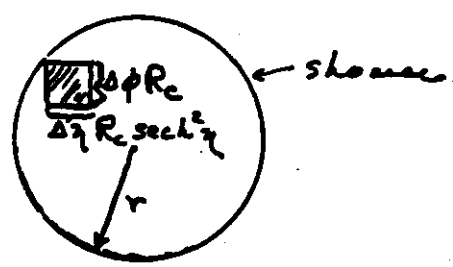
Assumptions

1) $$E_t(\text{cell}) = \frac{\text{Area of cell}}{\text{Area of shower}} E_t(\text{particle}) = f\, E_t(\text{particle})$$

2) $$\rho = \frac{dN}{d\eta\, d\phi} = \text{constant}$$

3) $$\frac{\#\text{ cells hit}}{\text{incident particle}} = \frac{\text{Area of shower}}{\text{Area of cell}} = \frac{1}{f}$$

$$f = \frac{R_c^2\, \Delta\eta\, \Delta\phi\, \text{sech}^2\eta}{\pi r^2}$$



$$dN = \rho\, d\eta\, d\phi = \rho \cosh^2\eta\, d\Omega$$

$$n = \rho \cosh^2\eta\, d\Omega \left(\frac{\pi r^2}{R_c^2 d\Omega}\right) = \frac{\#\text{ of cells hit}}{\text{event}}$$

$$E_t(\text{cell}) = \underbrace{\left\{\rho \cosh^2\eta \frac{\pi r^2}{R_c^2}\right\}}_{\text{hit probability}} (E \sin\theta) \underbrace{\left\{\frac{R_c^2 \text{sech}^2\eta\, \Delta\eta\, \Delta\phi}{\pi r^2}\right\}}_{\text{energy spread}}$$

To calculate pikup noise, we need the variance of E_t.

$$E_t(\text{cell}) = \sum_{i=1}^{n} \underset{\substack{\uparrow \\ \text{particle} \\ \text{energy}}}{E_i} \underset{\substack{\uparrow \\ \text{angle of} \\ \text{cell}}}{\sin \theta_i} \underset{\substack{\nwarrow \\ \text{energy spreading}}}{f} = \sum_{i=1}^{n} x_i$$

x and n are random variables

$$Var(E_t(\text{cell})) = \bar{n}\, Var(x) + Var(n)\, \bar{x}^2$$

$$\sigma_E^2 = \bar{n} f^2 \sigma^2(E_t) + \sigma_n^2 f^2 \bar{E}_t^2$$

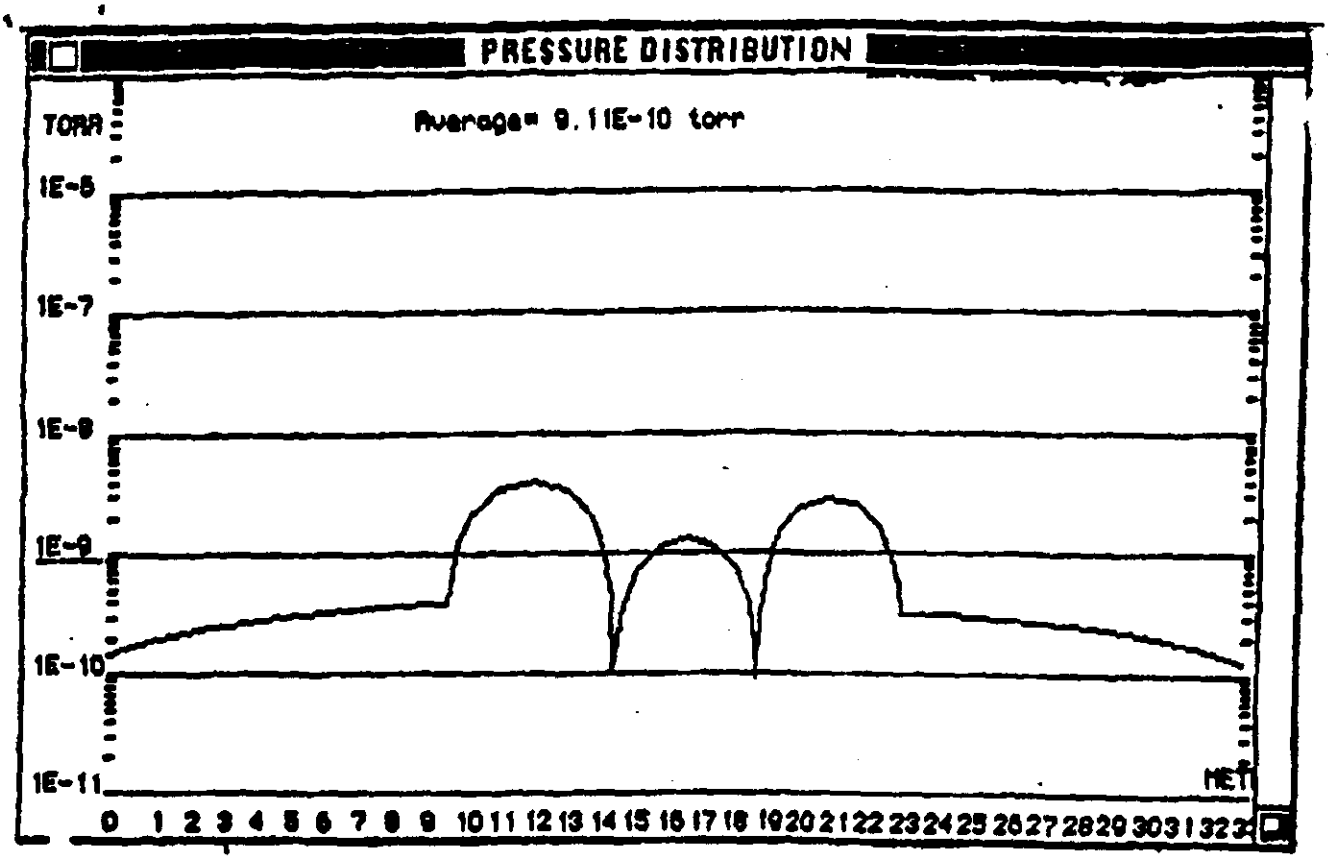
relative fluctuations

$$\left(\frac{\sigma_E}{E}\right)^2 = \frac{\sigma_E^2}{(\bar{n}\bar{E}_t f)^2} = \frac{1}{\bar{n}} \underbrace{\left(\frac{\sigma^2(E_t)}{\bar{E}_t^2}\right)}_{\substack{\text{approx} \\ \text{constant for} \\ \text{QCD jets}}} + \underbrace{\left(\frac{\sigma_n}{\bar{n}}\right)^2}_{\substack{\text{dominant} \\ \text{term in} \\ \text{forward} \\ \text{direction}}}$$

Conclusion: Pikup noise (measured in E_t)

Should <u>decrease</u> in forward region.

Case 4



4

Ø 10 cms / Ø 3.3 cms / Ø 5 cms / Ø 10 cms

30 US 1010 PPS + LUMPED NEG PPS

Calorimeter Depth & Muon Backgrounds

F.Taylor, H.Gordon, R.McNeil

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

Charge to Calorimeter depth group

Arrive at optimal Calorimeter thickness for muon detection, and optimal material (Z)

charge to Pattern recognition group

Study of reconstruction methods and optimization of muon detection & background rejection

Criteria for Evaluating the GEM Barrel Calorimeter Thickness

<u>Absolute Rates</u> : Rate limitations for RPCs

Criteria 1 : At the highest SSC Luminosity, the rate of particles exiting the barrel calorimeter should be less than 20 Hz/cm^2.

Highest SSC Luminosity $\equiv$ 10^{34} cm^{-2}
Particle $\equiv$ Charged Particles (neutrons/γs ?)

<u>Punchthrough vs Real Muons</u>

Charged Particles in GEM Muon system are composed of

1. Prompt Muons – c, b, t quark decays } real muons in calorimeter
2. Muons from π/K decays in inner tracker } real muons in calorimeter
3. Hadron Punchthrough

Criteria 2.1 : The overall rate of hadron punchthrough particles should be much less than the rate of prompt muons + muons from π/K decays.

Criteria 2.2: The rate of particles above some P_T threshold from hadron punchthrough should be much less than that from prompt muons + decay muons.

Much less than $\equiv$ $< 1/3$ of total rate
P_T Threshold $\equiv$ 10 GeV/c

Criteria 3 : Minimize μ energy loss in Calorimeter (Impact of Constant low $P_\perp$ resolution on ZZ^*)

Criteria 4 : Lower neutron rates

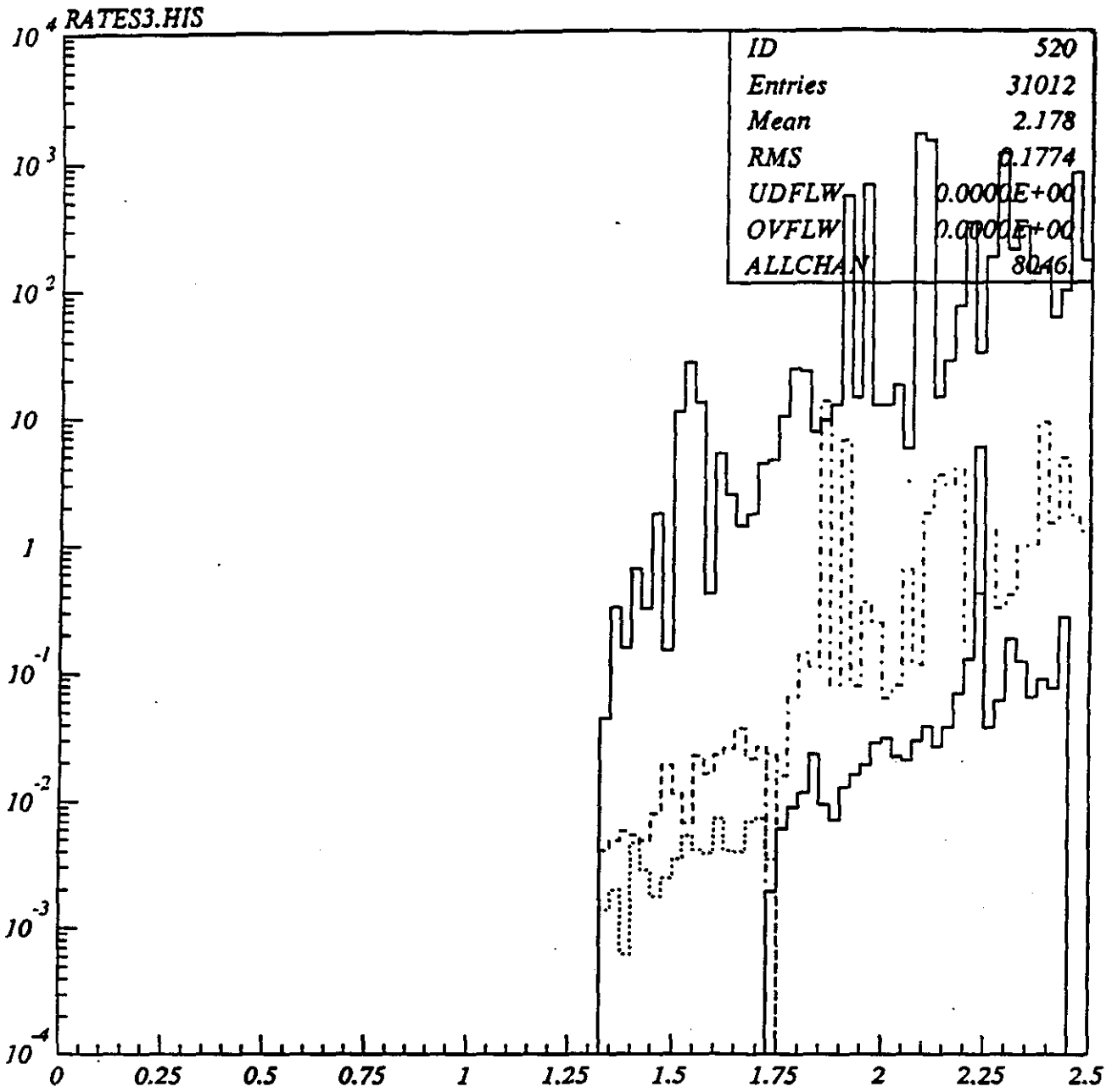
Conclusions

Summary of Barrel Calorimeter Thickness requirements

Criteria	Min Depth $\eta = 0$	Min Depth $\eta = 1.3$
1	10	12
2.1	12	10
2.2	10	10
Both 1 and 2	<u>12</u>	<u>12</u>

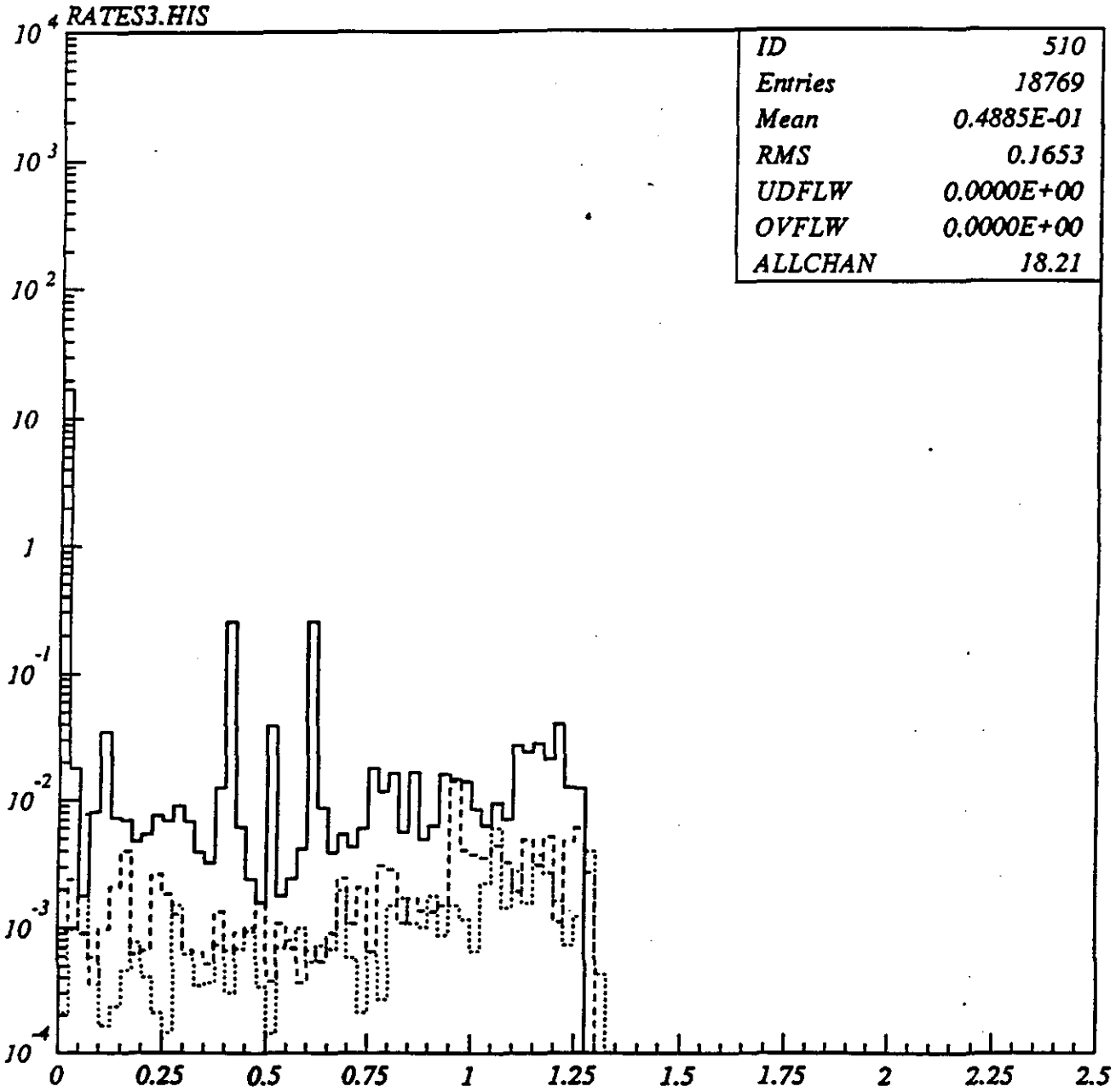
These criteria do not include

- detailed trigger requirements
- detailed muon ID requirements
- neutron/γ component of punchthrough



Charged Particle rates(cm^-2 sec^-1) in EndCap vs Eta

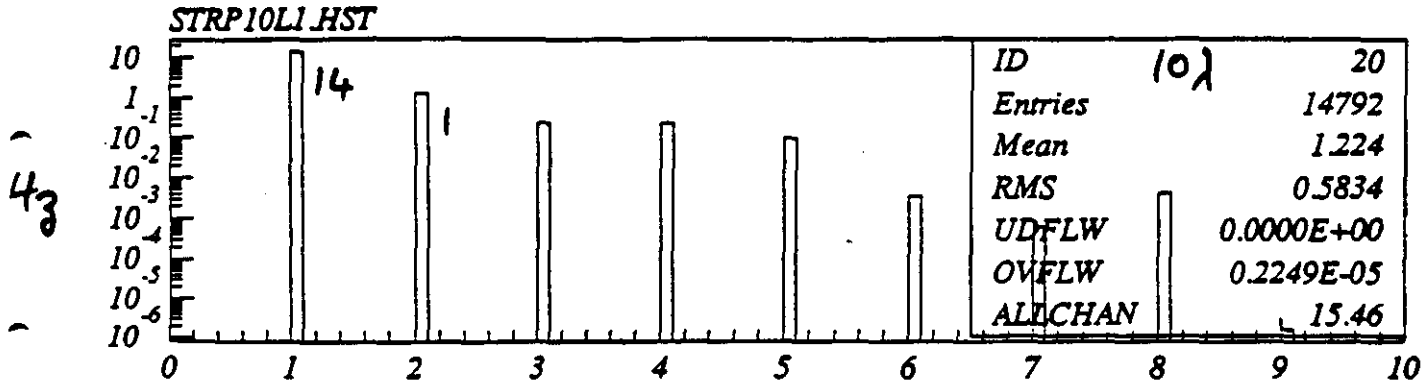
92/03/06 09.15

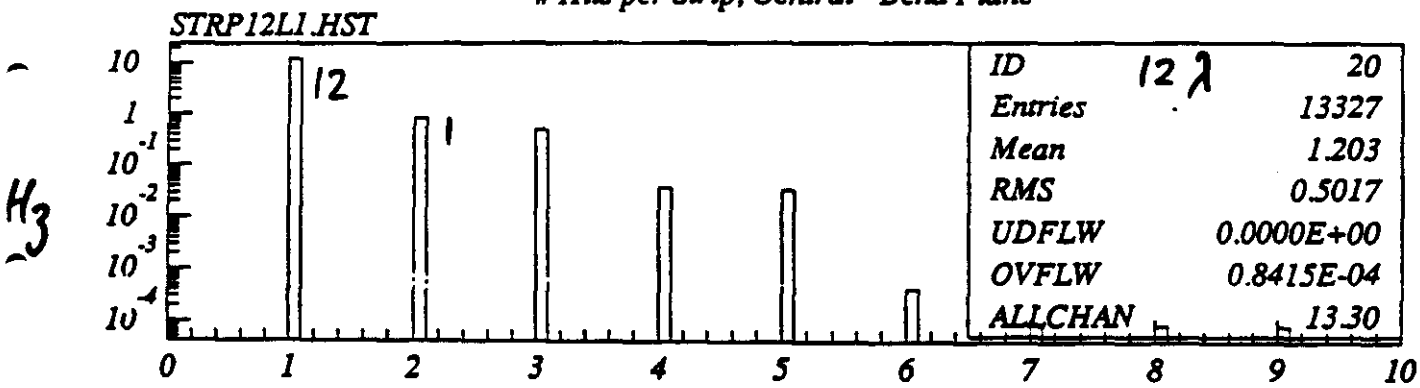


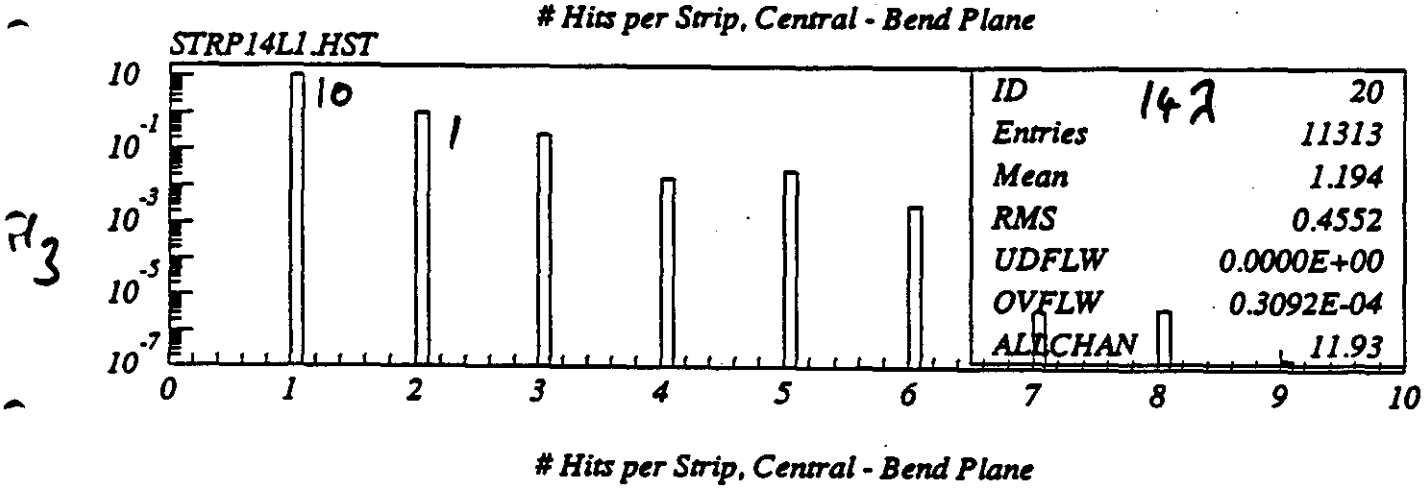
Charged Particle rates(cm^-2 sec^-1) in barrel vs Eta

CENTRAL BARREL - SL1 10^{33} $cm^{-2}s^{-1}$

RATE VS. # HITS PER STRIP 92/03/07 16.51







DOUBLE-HIT RATE ≃ 8% SINGLE-HIT RATE !

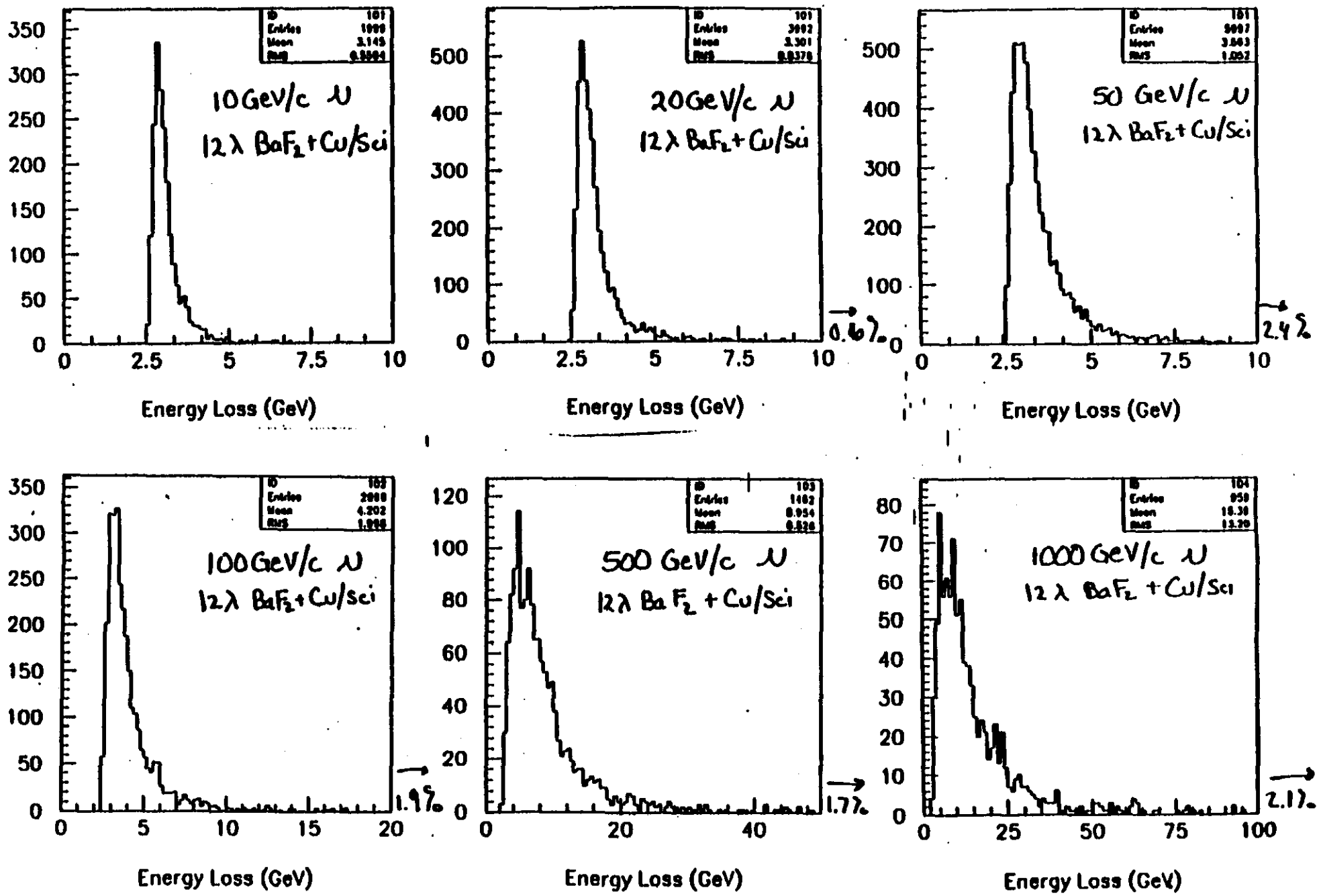


Figure 2.1 GEANT Simulation of BaF_2 + Cu/Scintillator Cal

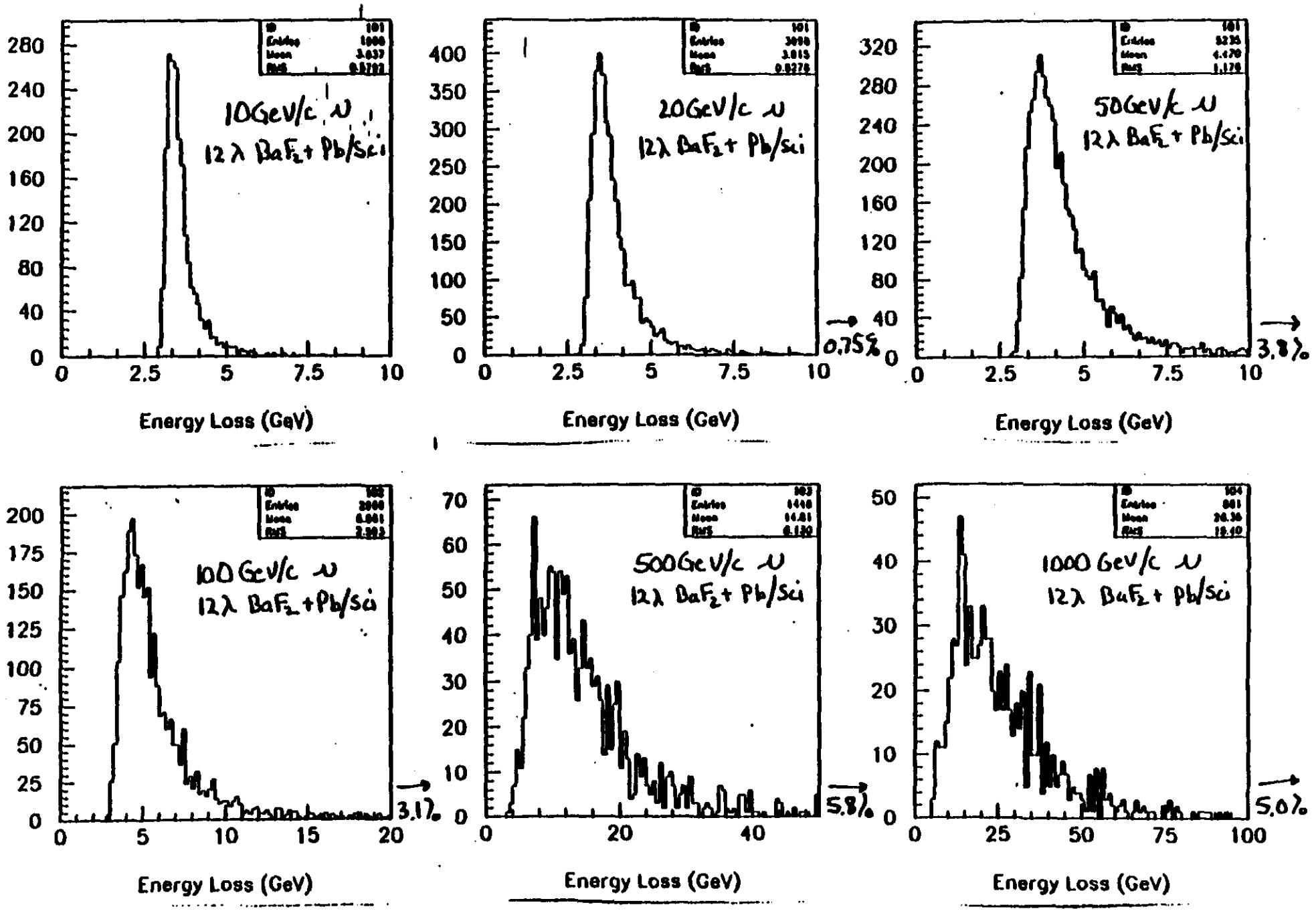


Figure 3. GEANT Simulation of BaF_2 + Pb/Scint Cal

Status of our Understanding of neutron rates

F	U	D
e	n	o
a	c	u
r	e	b
	r	t
	t	
	a	
	i	
	n	
	t	
	y	

	RADIUS	ANGLE	<100keV	>100keV	TOTAL FLUX
1)	92.5 - 115.2	9.4 - 11.33	3.6442	2.2349	5.8792
2)	115.2 - 135.2	11.33 - 13.23	3.096	1.8874	4.9834
3)	135.2 - 155.2	13.23 - 15.104	2.3536	1.5675	3.921
4)	155.2 - 175.2	15.104 - 16.95	2.2533	1.5587	3.8121
5)	175.2 - 195.2	16.95 - 18.75	1.8923	1.2233	3.1156
6)	195.2 - 215.2	18.75 - 20.52	1.5922	1.1946	2.7868
7)	215.2 - 235.2	20.52 - 22.25	1.478	1.1244	2.6026
8)	235.2 - 255.2	22.25 - 23.93	1.2507	.9135	2.1642
9)	255.2 - 275.2	23.93 - 25.57	1.1007	.8166	1.9173
10)	275.2 - 295.2	25.57 - 27.17	.9349	.7329	1.6679
11)	295.2 - 315.2	27.17 - 28.73	.7909	.6432	1.4340
12)	315.2 - 323.86	28.73 - 29.39	.7399	.5489	1.2889
TOTAL	92.5 - 323.86	9.4 - 29.39	1.4659	1.149	2.6149

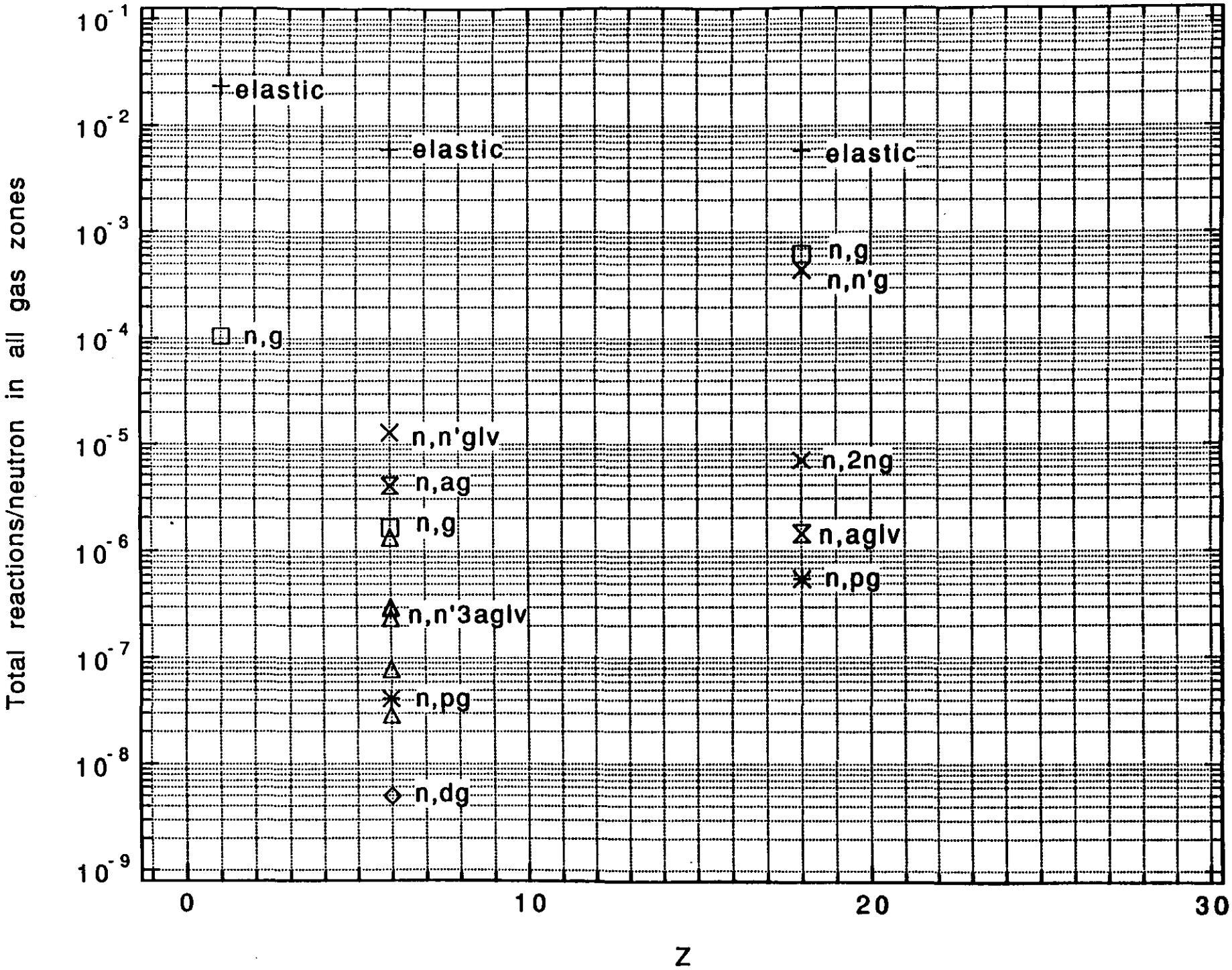
MUON CHAMBERS $Z = 575$ cm

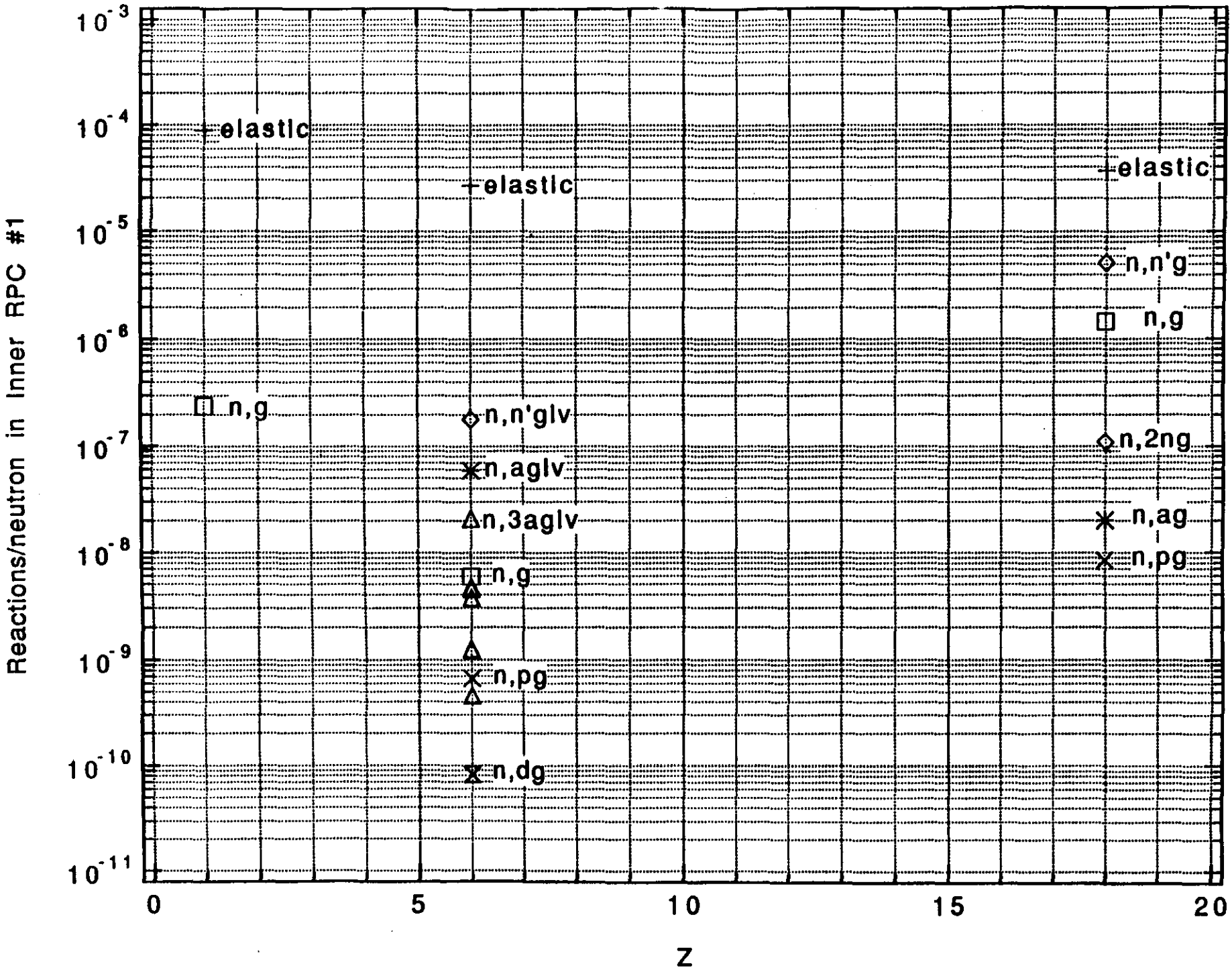
1st DC. $Z = 575$ cm

1.0E12 = .1 Mhz

$$\text{FLUX}_{\text{NEUTRON}} = \sum_i \frac{1}{|\cos \psi_i|}$$

ψ_i = angle between particle direction and surface normal


Total reactions/neutron in all gas zones
Z
elastic
elastic
elastic
n,g
n,n'g
n,g
n,n'glv
n,2ng
n,ag
n,g
n,aglv
n,pg
n,n'3aglv
n,pg
n,dg
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
10
20
30


Reactions/neutron in Inner RPC #1
Z
elastic
elastic
elastic
n,g
n,n'glv
n,aglv
n,3aglv
n,g
n,pg
n,dg
n,n'g
n,g
n,2ng
n,ag
n,pg

upper energy bin limit MeV

neutron flux across surface 169 in segment 16

energy	0-1μsec time= 1.000D+03		1μsec-1msec time= 1.000D+06		>1msec time= 1.000D+10	
1.0000D-05	0.00000D+00	.0000	3.05723D+00	.1318	6.49649D-01	.2340
2.0000D-05	0.00000D+00	.0000	8.12633D-01	.2059	0.00000D+00	.0000
1.0000D-04	0.00000D+00	.0000	1.80763D-01	.1283	0.00000D+00	.0000
2.0000D-04	0.00000D+00	.0000	7.97424D-02	.1909	0.00000D+00	.0000
1.0000D-03	0.00000D+00	.0000	4.28944D-02	.1337	0.00000D+00	.0000
2.0000D-03	0.00000D+00	.0000	2.37398D-02	.1378	0.00000D+00	.0000
1.0000D-02	0.00000D+00	.0000	8.90107D-03	.1026	0.00000D+00	.0000
2.0000D-02	0.00000D+00	.0000	2.46252D-02	.0962	0.00000D+00	.0000
1.0000D-01	4.90291D-05	.3503	1.27351D-02	.0923	0.00000D+00	.0000
2.0000D-01	6.63859D-04	.1160	4.01199D-03	.1027	0.00000D+00	.0000
1.0000D+00	5.22224D-04	.1093	2.55122D-04	.1100	0.00000D+00	.0000
2.0000D+00	3.65873D-05	.1820	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+01	2.64958D-06	.1957	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+01	1.73806D-07	.4971	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+02	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+02	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+03	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+03	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
1.0000D+04	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
2.0000D+04	0.00000D+00	.0000	0.00000D+00	.0000	0.00000D+00	.0000
total	5.47609D-04	.1057	2.06076D-03	.0924	6.49649D-06	.2340

energy	time total	
1.0000D-05	3.70687D+00	.1228
2.0000D-05	8.12633D-01	.2059
1.0000D-04	1.80763D-01	.1283
2.0000D-04	7.97424D-02	.1909
1.0000D-03	4.28944D-02	.1337
2.0000D-03	2.37398D-02	.1378
1.0000D-02	8.90107D-03	.1026
2.0000D-02	2.46252D-02	.0962
1.0000D-01	1.27842D-02	.0922
2.0000D-01	4.67585D-03	.1009
1.0000D+00	7.77345D-04	.1061
2.0000D+00	3.65873D-05	.1820
1.0000D+01	2.64958D-06	.1957
2.0000D+01	1.73806D-07	.4971
1.0000D+02	0.00000D+00	.0000
2.0000D+02	0.00000D+00	.0000
1.0000D+03	0.00000D+00	.0000
2.0000D+03	0.00000D+00	.0000
1.0000D+04	0.00000D+00	.0000
2.0000D+04	0.00000D+00	.0000
total	2.61486D-03	.0939

TOTAL FLUX ON MUON 1

Z = 575 cm over entire surface, r = 95.2 → 323.86 cm

numbers are #/ per cm²/ISAJET event

multiply × 1E15 to get on SSC yearly basis (1×10⁷ sec)

relative errors also given

Situation at $10^{33}/cm^2\,sec$

$$\frac{10^5 \text{ neutron}}{cm^2\ sec} \times \frac{10^{-4} \text{ Counts in RPC}}{\text{neutron}} \approx 10/cm^2 sec$$

↑ Probably Correct

↑ Large Uncertainty Could be $\lesssim 10^{-5}$

Singles Rate in Drift tubes $\sim 10/cm^2 sec \times 2000\ cm^2 \approx 20\,KHz$

For $1\,\mu sec$ aperture time

Wrong hit rate $\sim 2\times10^4 \times 10^{-6} \sim 2\%$

There is a 100% Probability of a few extra hits in muon system /event

Need to Study Reconstruction & Redundancy

$R_{min} = 75$ cm $R_{max} = 350$ cm Baseline

① 12λ Cu Best

② 10λ Cu Possible

③ 12λ U Feared

$R_{min} = 100$ cm $R_{max} = 350$ cm Baseline + Expanded I.T.

① 11λ Cu Probably ok

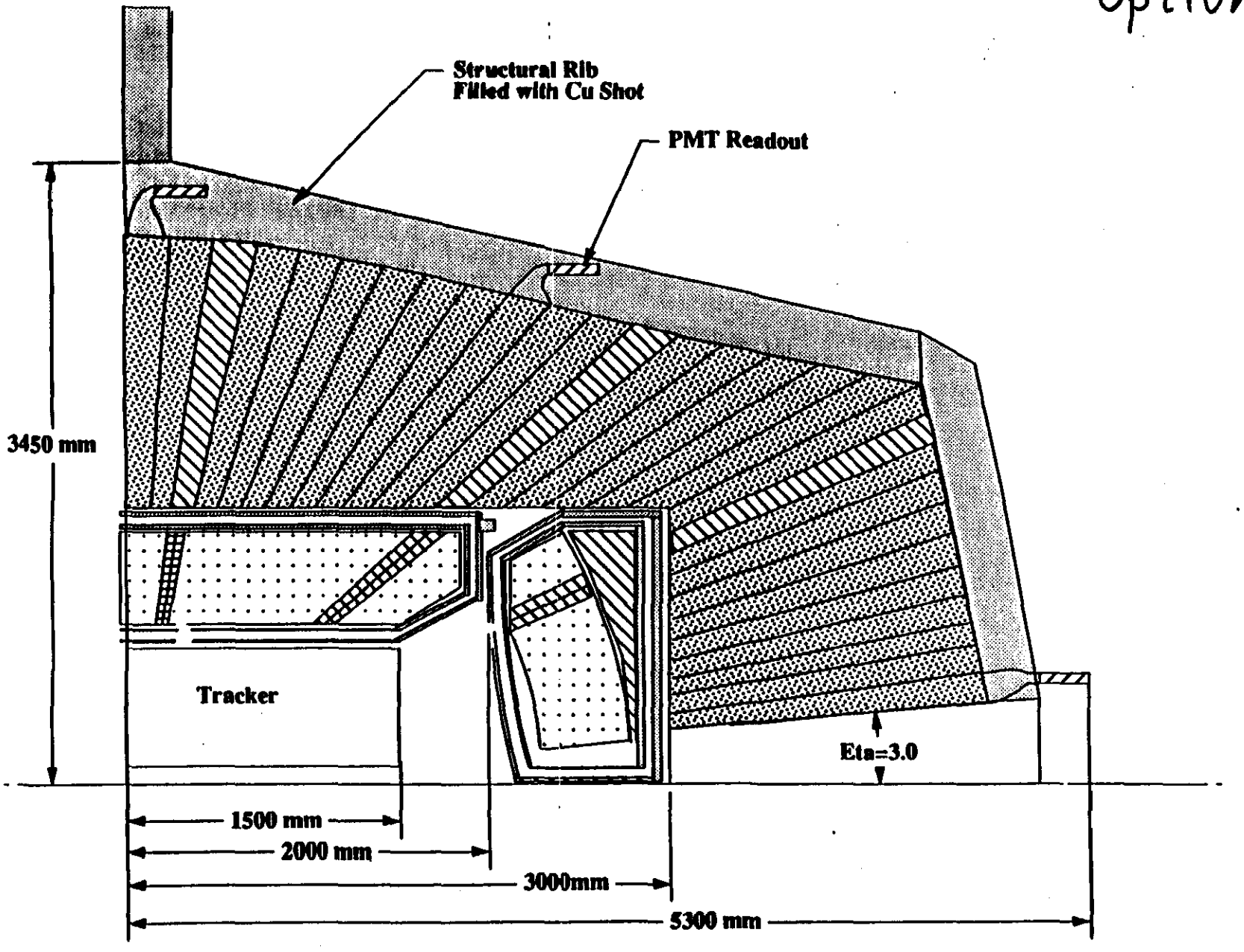
② 11λ W Less favored

③ 10λ U Unacceptable

$R_{min} = 100$ cm $R_{max} = 375$ cm Expanded Baseline

* Same as Baseline
* Would rather accept 10% loss in resolution than lower λ or heavier Z

Option 'F

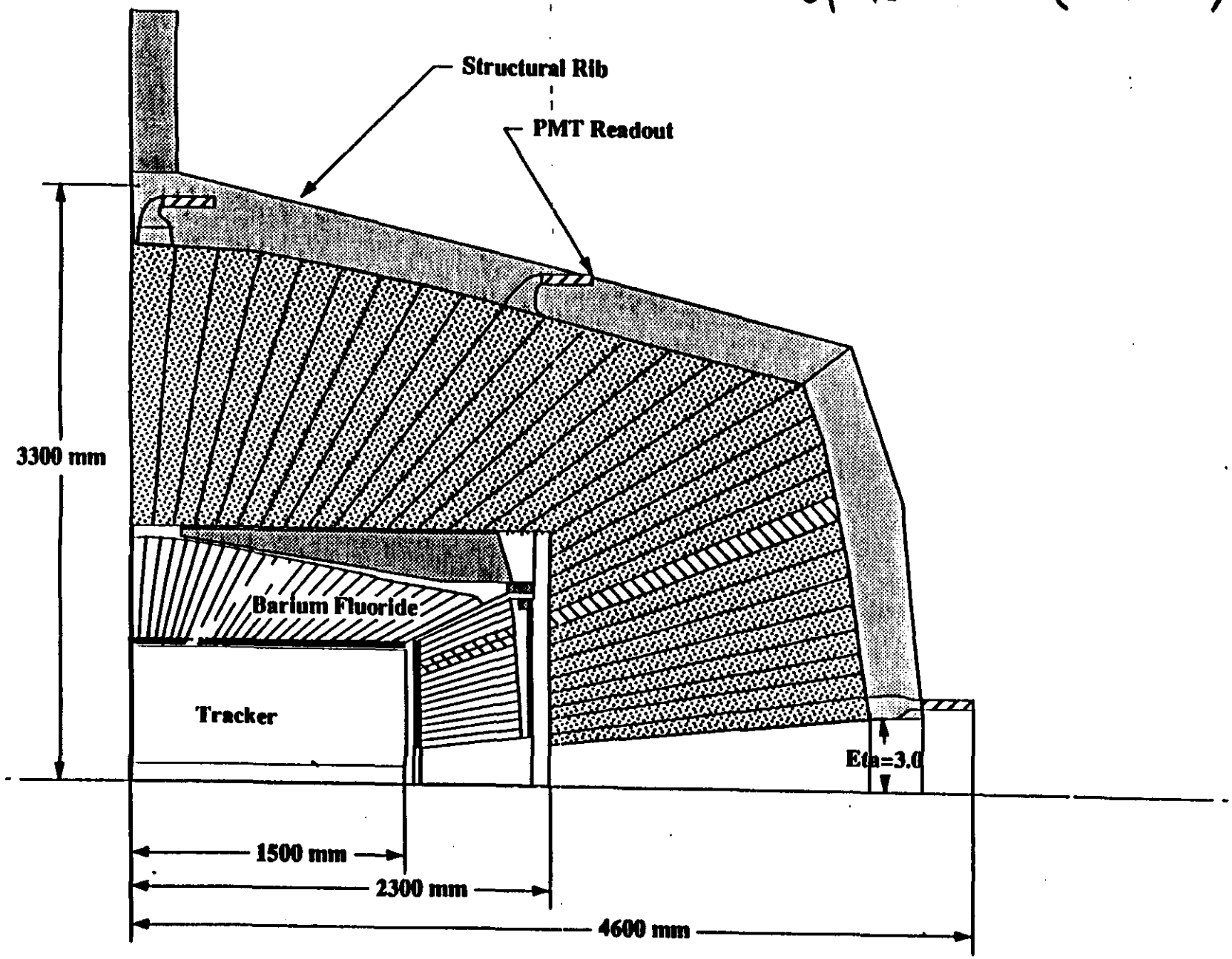


Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Liquid Argon EM Calorimeter

G.03.SC.00080

Rennich

Option B (~LoI)



Spaghetti Hadron Calorimeter
Copper Fill/0.12 Segmentation
Barium Fluoride EM Calorimeter

G.03.SC.00079

Rennich

Future Work

1) More neutron Calculations BNL, LLNL, LANL, UM
2) Measurement of neutron cross sections MIT, BU
3) Pattern recognition group forming SSCL, BNL, SB, LSU
4) Detailed trigger rate Calculations BNL, SB, LSU

Suggested issues for Pattern recognition group

1) Setting up a "shell" for systematic study of reconstruction issues

   a) Hit generation

   b) Background & cell memory effects

2) A systematic determination of number of layers in muon system necessary for effective Pattern recognition (Both Barrel & EndCap)

3) Effects of B-field on Pattern recognition
   (J. Sullivan B-field code is now available)

4) Setting up a rudimentary reconstraction Code for both μ & inner tracker

5) Study of μ-inner tracker alignment & Vertex determination.

Benchmark reactions

$H \rightarrow Z^0 Z^0 + X$

$Z^0 \rightarrow \mu^+\mu^-$, e^+e^- ; $Z^0 \rightarrow \mu^+\mu^-$, e^+e^-

b-jet tagging

$t\bar{t}$ (140 & 200 GeV top mass)

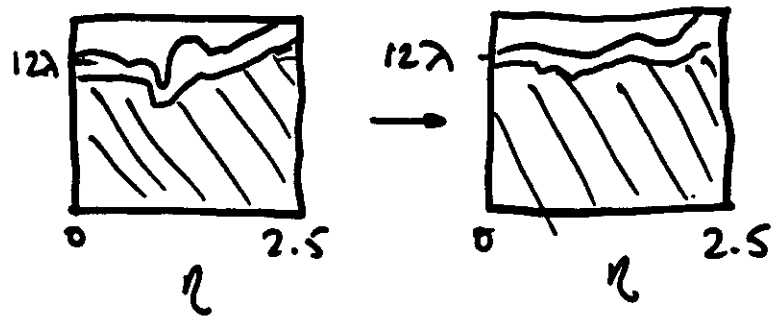
Modeling the Detector

K.McFarlane, N.DiGiacomo, M.Shupe

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

Modelling the Detector

- Engineering to simulation
  - FSU CAD → GEANT
  - GEANT future versions
  - Martin-Marietta system
    - Solid Modeller used for LAr calorimeter
    - Scans in η, ϕ produces plots of material (e.g. λ active, λ dead)



    - uses standard HEP parameterizations to produce resolution vs. η, etc.
    - SSCL Integraph → MM IDEAS
    - Future?
  - Near-term: Hand transfer between CAD and GEANT. – CAD has more shapes (E. Sabin)

Simulation sub groups will:

(1) Check Baseline vs. simulations – GEANT geometries, fill in blanks correct errors (MMarx schedule)

(2) Provide list of parameters which define the GEANT geometries with values.

- Detector Data Base
  - Format of repository
    - text : Mac WORD ? TeX of some variety ?
    - graphics : Integraph ? Some Mac package ? Bitmaps ? PostScript ?
  - Distribution and Accessibility

    N. Gober
- Visualization – T. Skwarnicki (Syracuse)
  - 3D Event displays / detector displays
  - 3D Scatterplots, higher dimensions
  - AVS, Xplorer on 3D workstations (~$25k – $10k)
- Modelling the radiation environment – L. Waters (LANL)
  - LAHET code on PDSF
  - After 1 year, 7 ci / m³ of calorimeter, decays with time const ~days/weeks
- Simulation Integration
  - Existing subsystem simulation groups
  - Many issues ! July
- TDR

CLEO-II data : $\tau^- \to \nu \pi^- 3\pi^0$

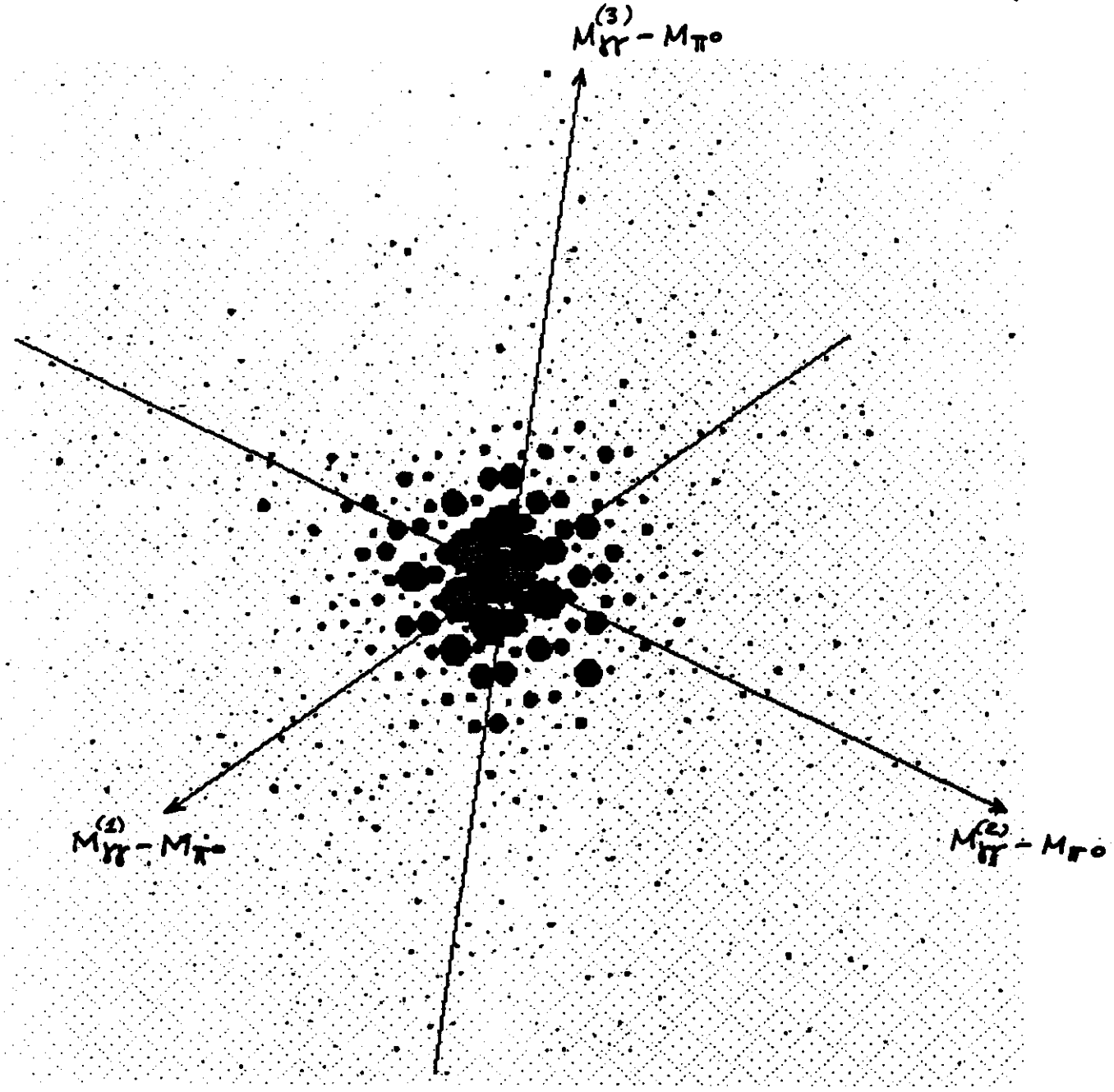
3D binned histogram of $M_{\gamma\gamma}$

bin size : 1σ

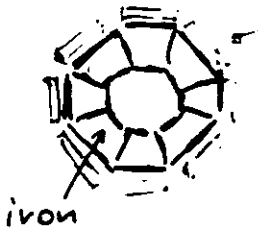
range : $[-10\sigma, +10\sigma]$

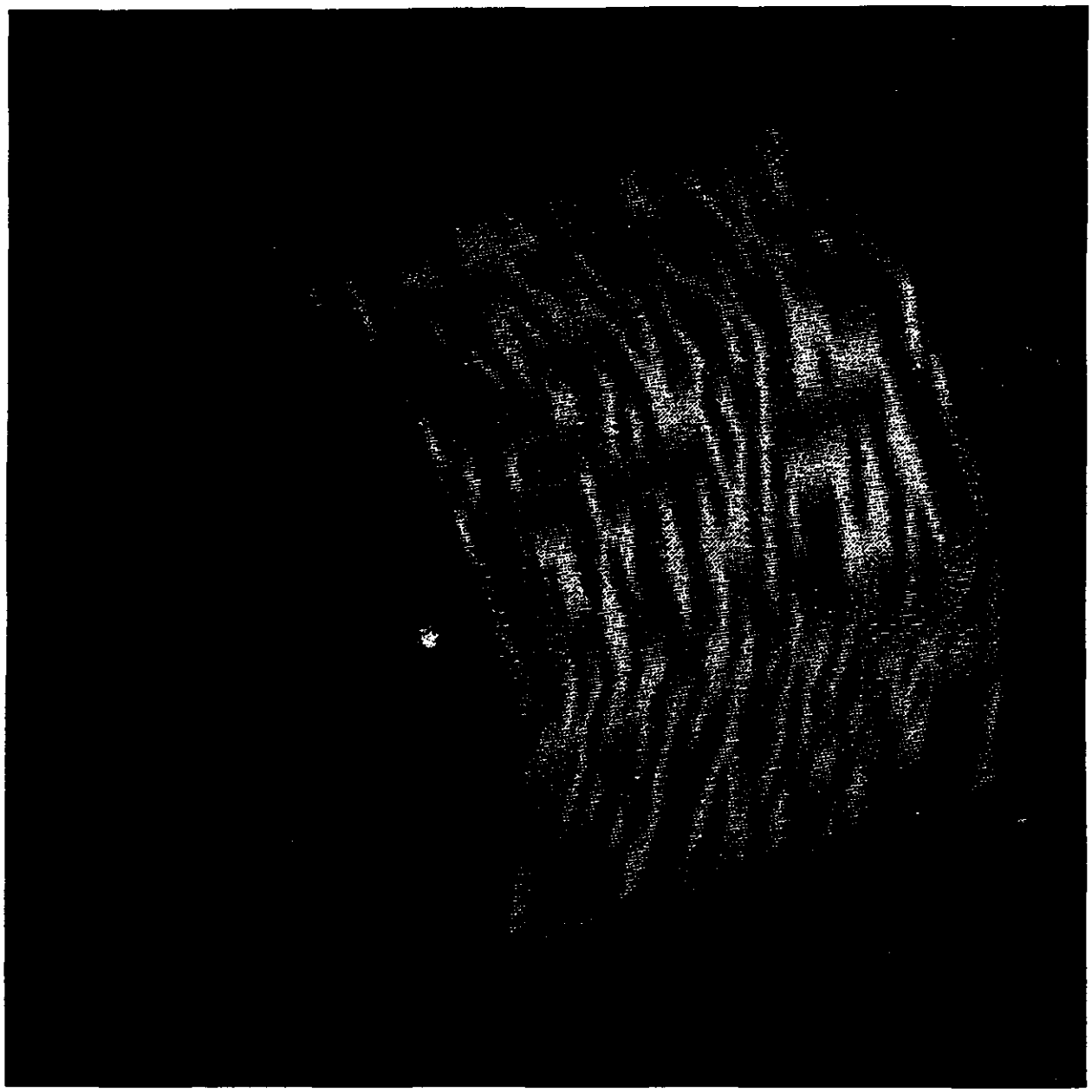
bin content $\longrightarrow$ radius of a sphere

and color of a sphere (violet - min, red - max)

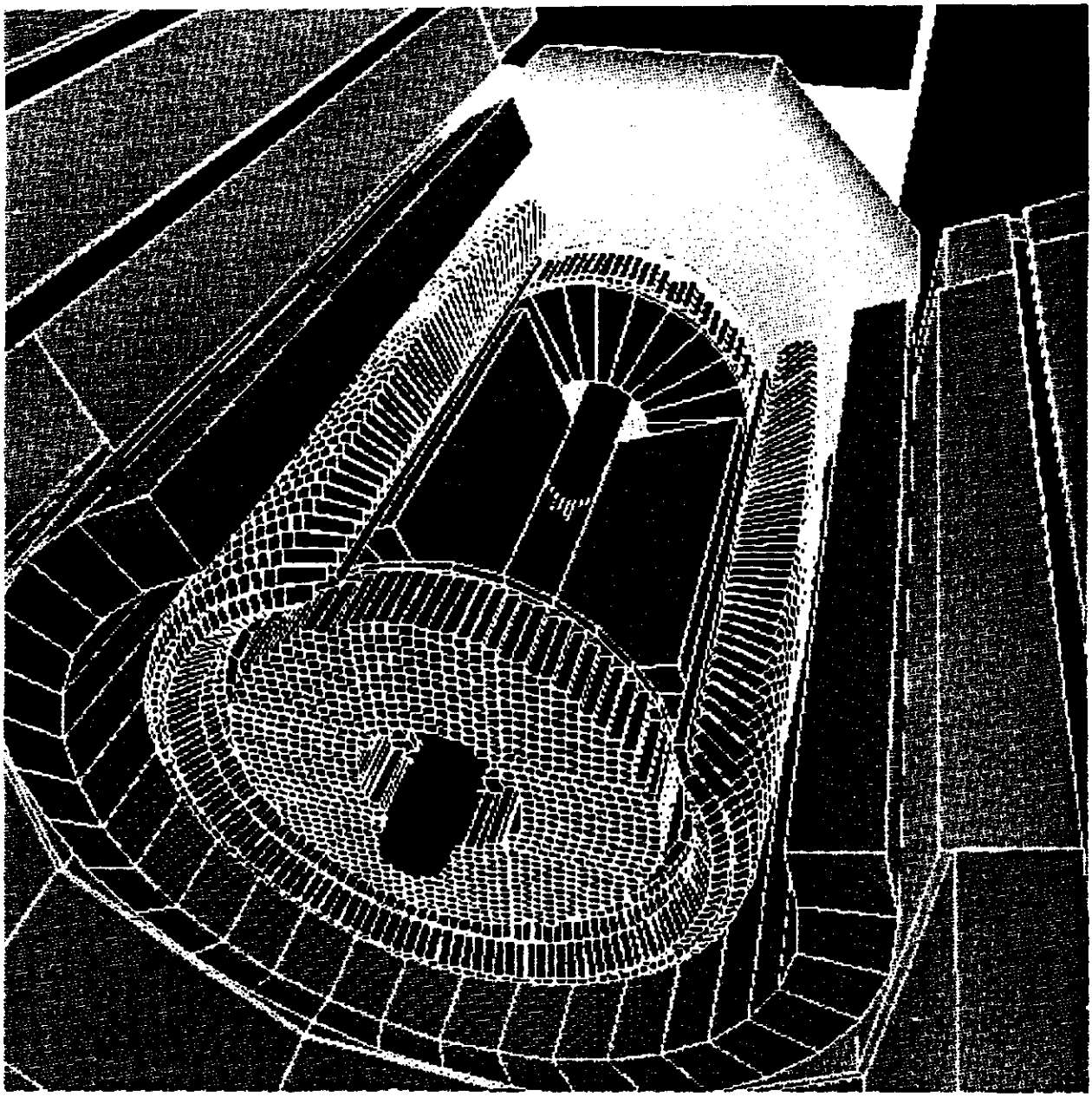


measured efficiency of CLEO-II muon chambers
mapped into true detector geometry
blue - low red - high





(produced by T. Haupt)



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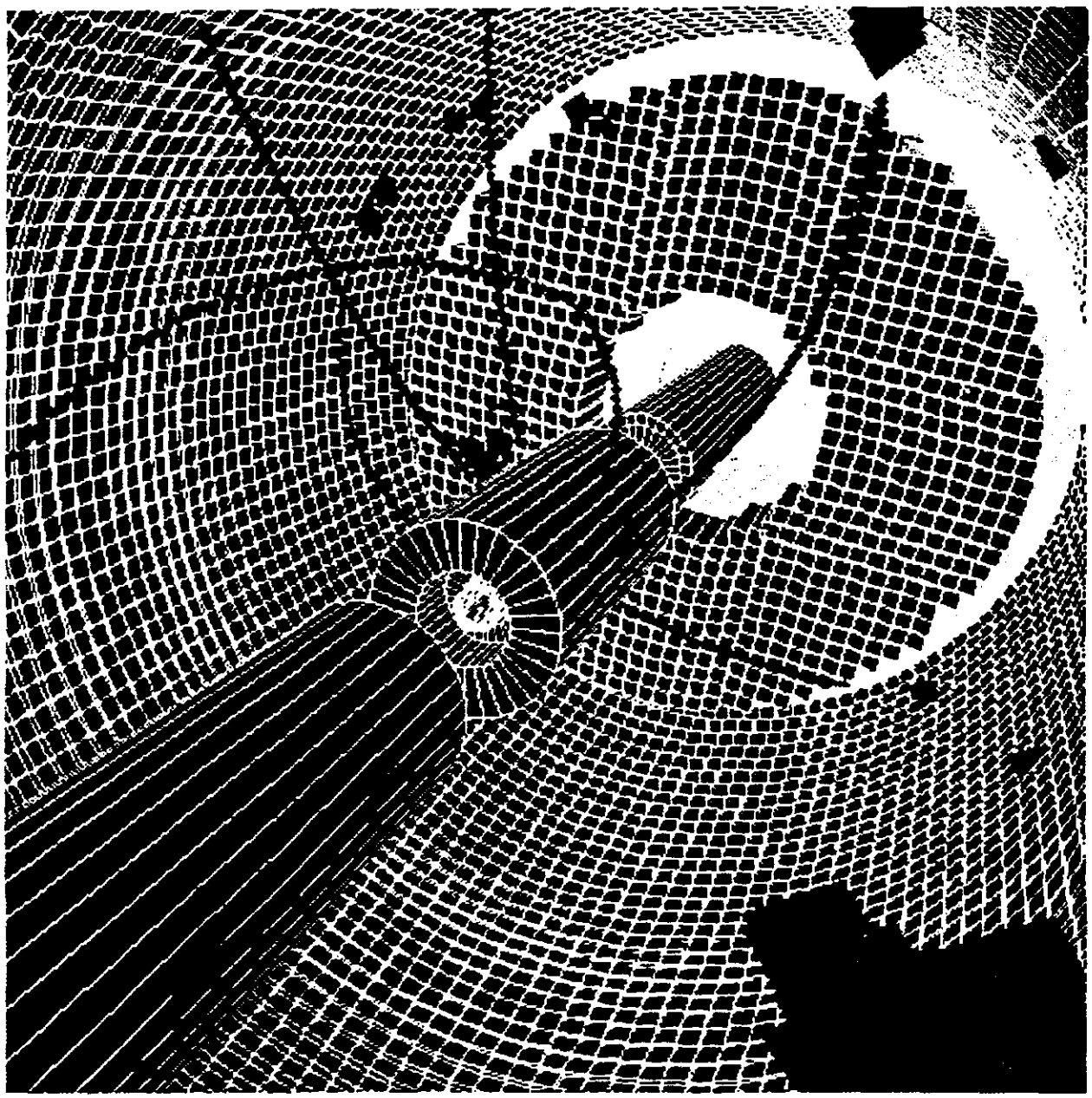

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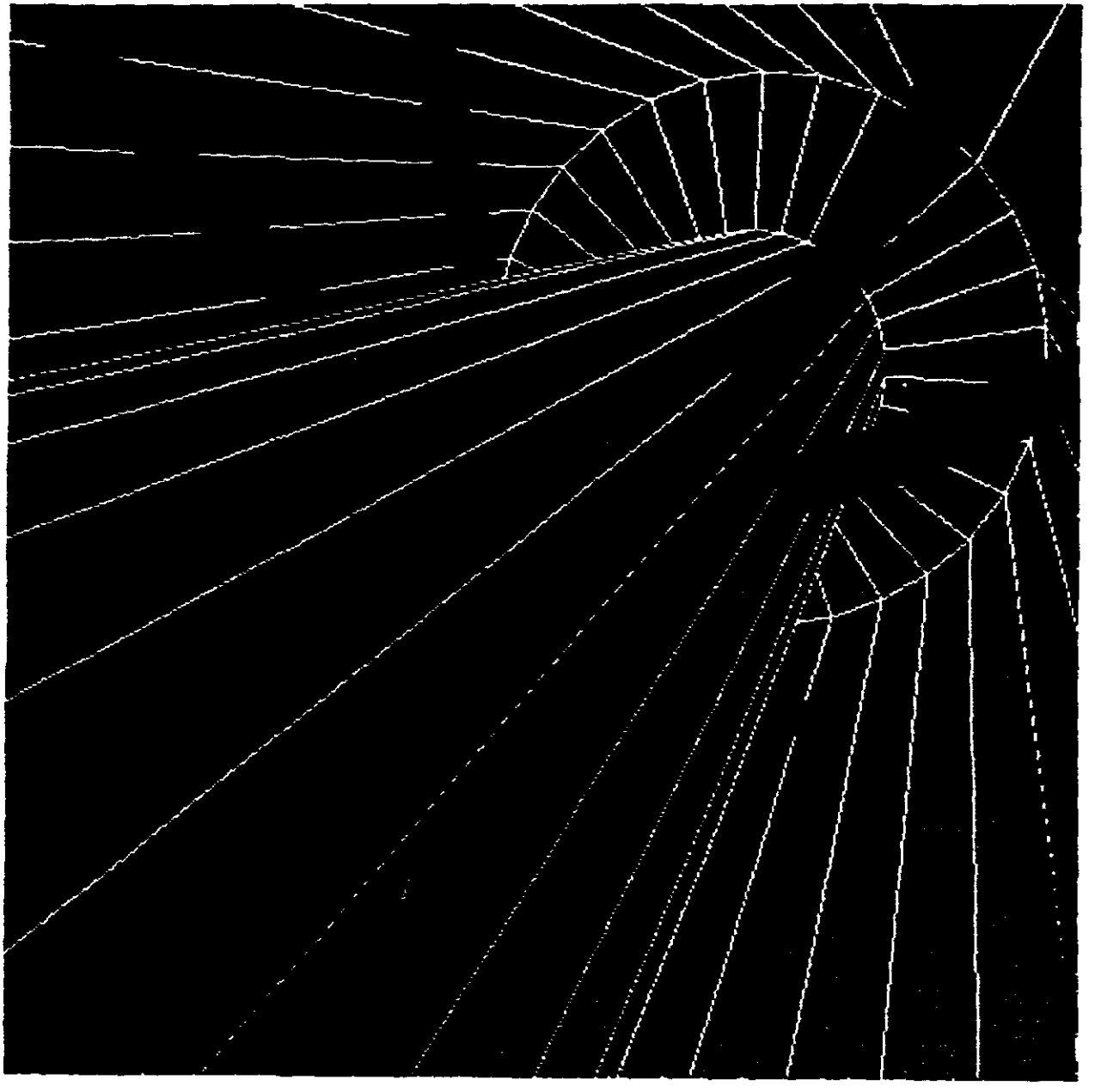
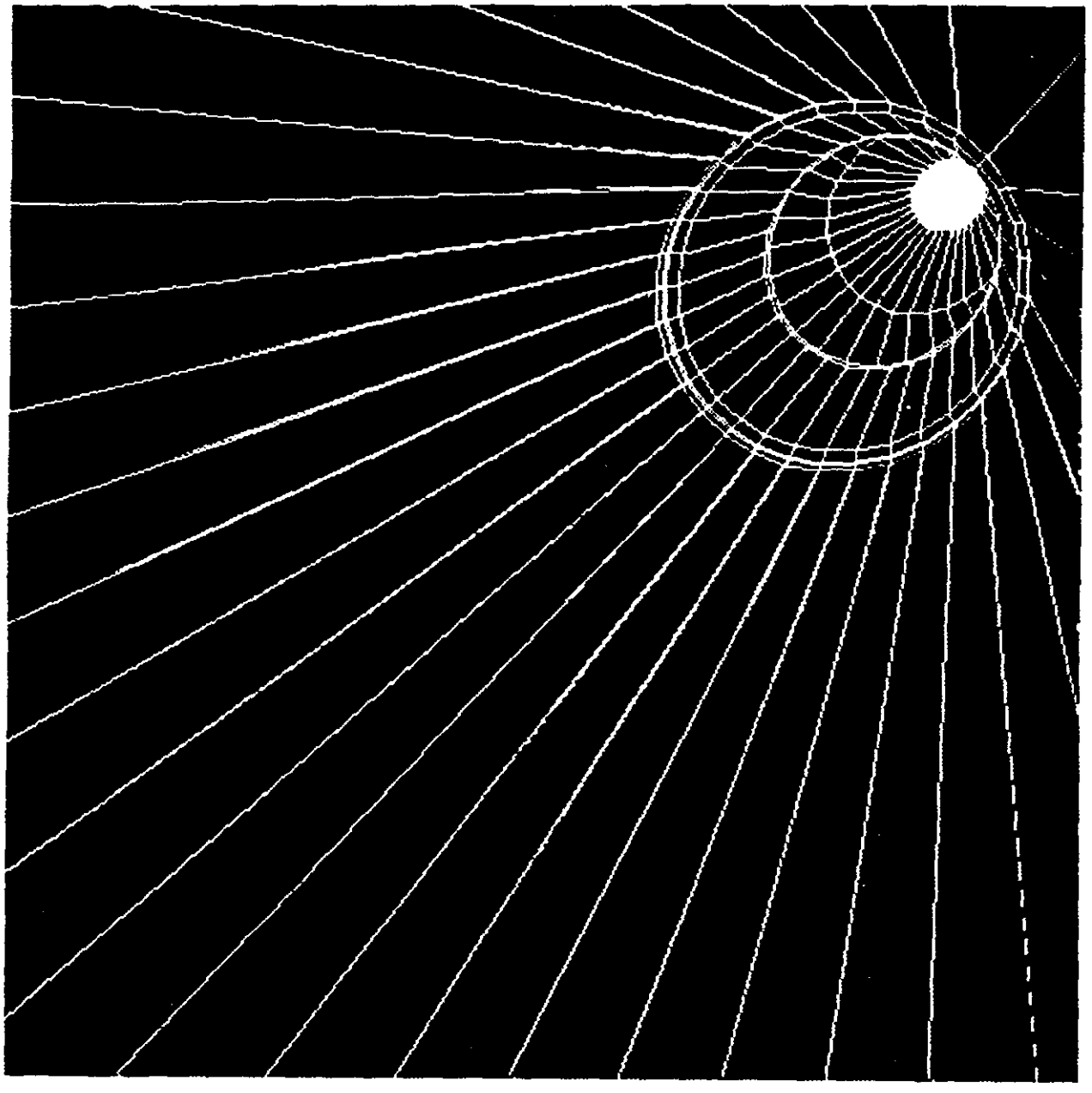
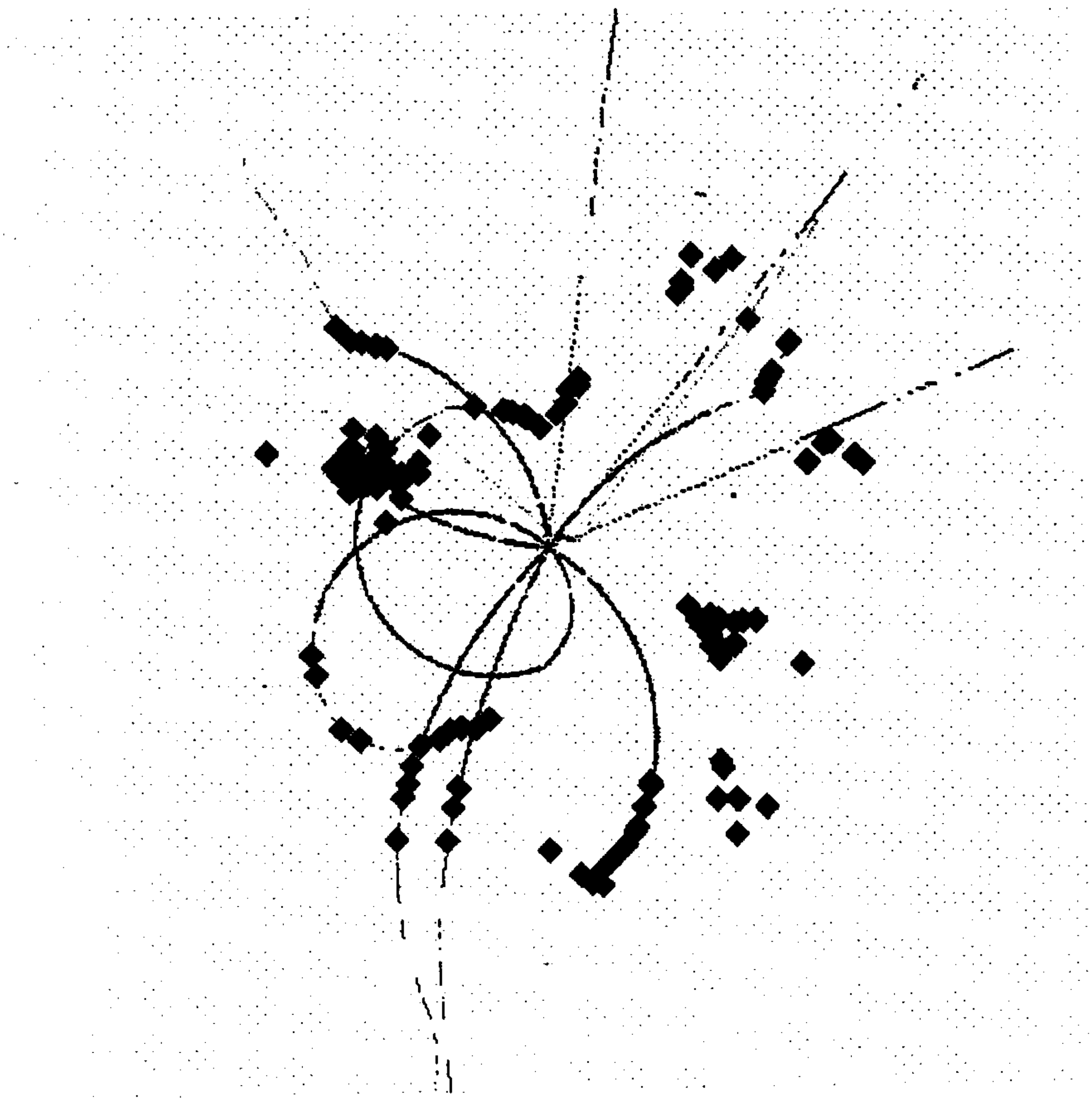




this is very close to "virtual reality" in HEP

A PRINT THIS SIDE



SIMULATIONS & PHYSICS

Tuesday p.m. session

K. McFarlane

incomplete

P. Dunges

Detector and Physics Simulations

I. FASTϕ Status Reports - What's done? What's left??
~45

CT - S. McKee, M. Brooks, E. Wolin...
EC - R.-Y. Zhu (BaF_2), H. Ma (LAr)
HC - H. Ma (LAr), T.B.A. (Sprag.)
FC - M. Shupe
MU - F. Taylor, P. Dinglus, C. Yamagisawa, J. Sullivan, M. Hammond
MG - J. Sullivan, L. Roberts
TR - T.B.A.

II. GEM Baseline Proposal -
~45 1. What's missing?
What's incompletely specified?
→ Feedback to Mark (via K. McF., F. Paige)

2. Incorporating Baseline into FASTϕ.
Deadline 4/15! Need for PAC report - due 6/12

III. Physics Simulations for July PAC Meeting
~45 (2/27/92 Memo) (Deadlines 4/15; ~6/15; 6/12)

1. Set list of processes.
2. Assign tasks - with commitments!
3. Set the schedule.

IV. Simulations for the TDR – 1st Draft due 5/29!

↳ ~ same as PAC rept., but longer

1. Begin planning FAST ϕ upgrade(s).

2. Set the list of physics processes.
   Same as III? More?

3. Assign tasks –

4. Finalize by 4/30 SSCL meeting!

V. Simulation Integration – Ken McFarland –

S. McKee

*** CT PARAMETERIZATION SUBROUTINE ***

CTRACKER(PID,XIN,PIN,XOUT,POUT,ERRP,ERRB,CLZ,RADL,INTL,GRAMS,IERROR)

FUNCTIONAL DESCRIPTION

This subroutine parameterizes the central tracker (CT) response for GEM.

INPUT PARAMETERS

PID:

The particle ID from STDHEP

XIN:

A vector describing the input point (the vertex), X, Y, Z. Values are in centimeters.

PIN:

A 4 vector containing the momentum and energy, Px, Py, Pz, E (total) Values are in GeV/c and GeV/c^2

OUTPUT PARAMETERS

XOUT:

A vector containing the exit point of the particle from the CT region. Currently the CT region is a cylinder of length 300 cm and radius 75 cm. Output values are in centimeter

POUT:

A vector containing the output momentum and energy at the boundary of the central tracker. Values are in GeV/c and GeV/c^2

ERRP:

The error in the measured momentum expressed as a percentage dP/P.

ERRB:

The error in the measured impact parameter. Value is in centimeters.

RADL:

The number of radiation lengths the particle passed through. Value is the number of radiation lengths, i.e., 0.15 is 15% of a radiation length.

INTL:

The number of interaction lengths the particle passed through. Value is the number of interaction lengths, i.e., 0.20 is 20% of an interaction length.

GRAMS:

The amount of material in g/cm^2 the particle passed through.

IERROR:

An error code with the following values:

0: Successful return–no error

1:	Particle below cutoff momentum–not tracked	4:	Unable to find particle charge—bad PID
2:	Intersection with outer CT boundary not found	5:	Undefined error in CTMAT
3:	Origin is OUTSIDE CT region–not tracked	6:	Undefined error in CTMEAS

HMa

This file is in ~ma/sgi/gemsim/readme_1.
All files mentioned in this note are in ~ma/sgi/gemsim .

1) General Outline:

The calorimeter is segmented as 0.04X0.04 for em cells, and 0.08X0.08 for hadron cells.

Energy resolution for the shower are parametrized as

sigma_E=sqrt(A**2/E +B**2)

where A and B could be a function of eta (not yet, but will be soon), and particle type (hadron or em).

Muons only deposit minimum ionizing energy. No multiple scattering and fluctuation are taken into account yet.

Longitudinal shower profile is parametrized using Bock's parameters after the first interaction point with proper energy dependence. The first interaction point is exponentially distributed, according to the interaction (radiation length).

Transverse shower profile is parametrized by exponentials, no energy dependence has be taken into account. Neither is the fluctuation. The fluctuation may be implemented later.

The energy of the particle is then deposited into the cells of the calorimeter, stored as Et in GeV.

Thermal noise and pile-up noise can be added to the cells.

EM calorimeter,	thermal noise /cell	=35MeV
	pile-up noise /cell	=35MeV
Hadron calorimeter	thermal noise /cell=	250MeV
	pile-up noise /cell=	200MeV

The hadron calorimeter thermal noise includes all four that from all longitudinal depths.

Jets can be reconstructed from the calorimeter information, with given cone size, minimum jet Et, and minimum cell Et.

Position resolution and angular resolution for em shower has not yet been implemented. Roughly one may achieve a position resolution of 4.4mm/sqrt(E), and an angular resolution of 100mR/sqrt(E). This assumes a longitudinally segmented EM shower calorimeter, with neither preradiator nor shower max detector.

2) Subroutines in calo.f

SUBROUTINE CALINI
initialize the cells, calculated sin and cos theta, etc.

SUBROUTINE CALOCL
clears calorimeter cells, should be called at beginnin of each event.

SUBROUTINE CALONS(XLUMI)
adds themal and pile-up noise, luminosity =xlumi*10**33

SUBROUTINE CEMHAD
add em and had cell energy together. prepare for CJETS

SUBROUTINE CALOED(ID,VERTEX,P,EM,EHAD)
deposit energy of a particle into cells, return also the measured energy in em and hadron calorimeter.

SUBROUTINE MINION(IEM,E,RADLEN,DE)
calculate energy deposited by minimium ionizing particles,

given the path length in radiation length.

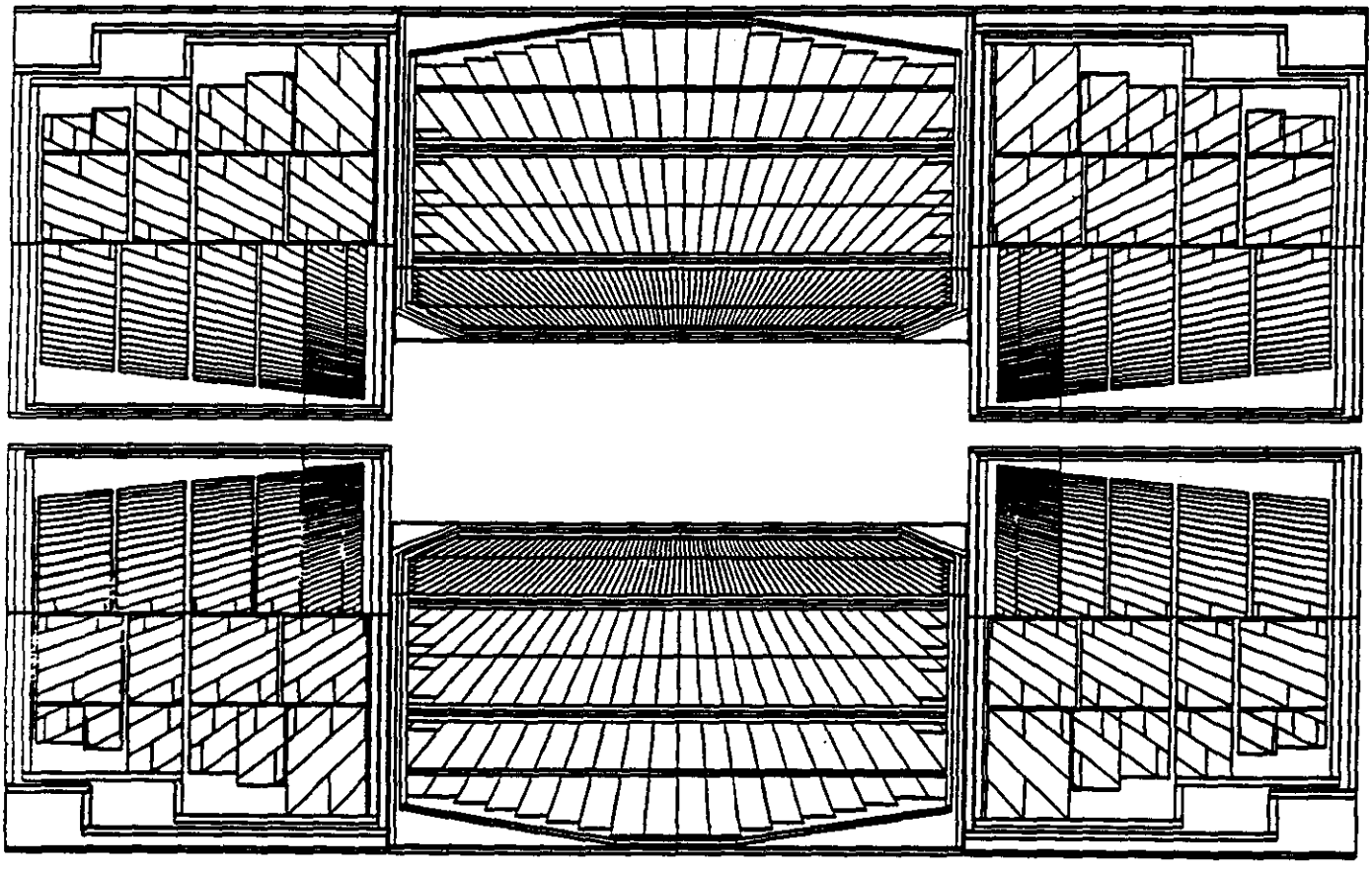
SUBROUTINE CJETS(RJET,EJCUT,ECCUT,ETSTOP)
find jets, with cone size RJET, minimum jet pt EJCUT, minimum cell et ECCUT. ETSTOP is the minimum Et of the starting cell.
SUBROUTINE YPHI(PINT,Y,PHI)
given a four vector PINT, calculates eta and phi.
SUBROUTINE ECONE(PINT,POUT,RJET,ECCUT)
given an axis PINT, calculate a jet with cone size RJET, and minimu cell et ECCUT
SUBROUTINE CDEPTH(ETA,PHI,CRADL,CABSL)
given ETA and PHI, find number of radiation length and abs length of the em and hadron cal.
SUBROUTINE CITRAN
initialize the transverse shower parameterization.
SUBROUTINE CLONG(EE,KK,DF,DD1,DD2,ED)
longitudinal shower profile parameterization.
SUBROUTINE CALORE(ITYPE,ETA,A,B)
calorimeter energy resolution at a given eta.
SUBROUTINE CALDIS(ETA, DIST_EM,DIST_HAD)
distance from em and hadron cal to the interaction point for given eta.

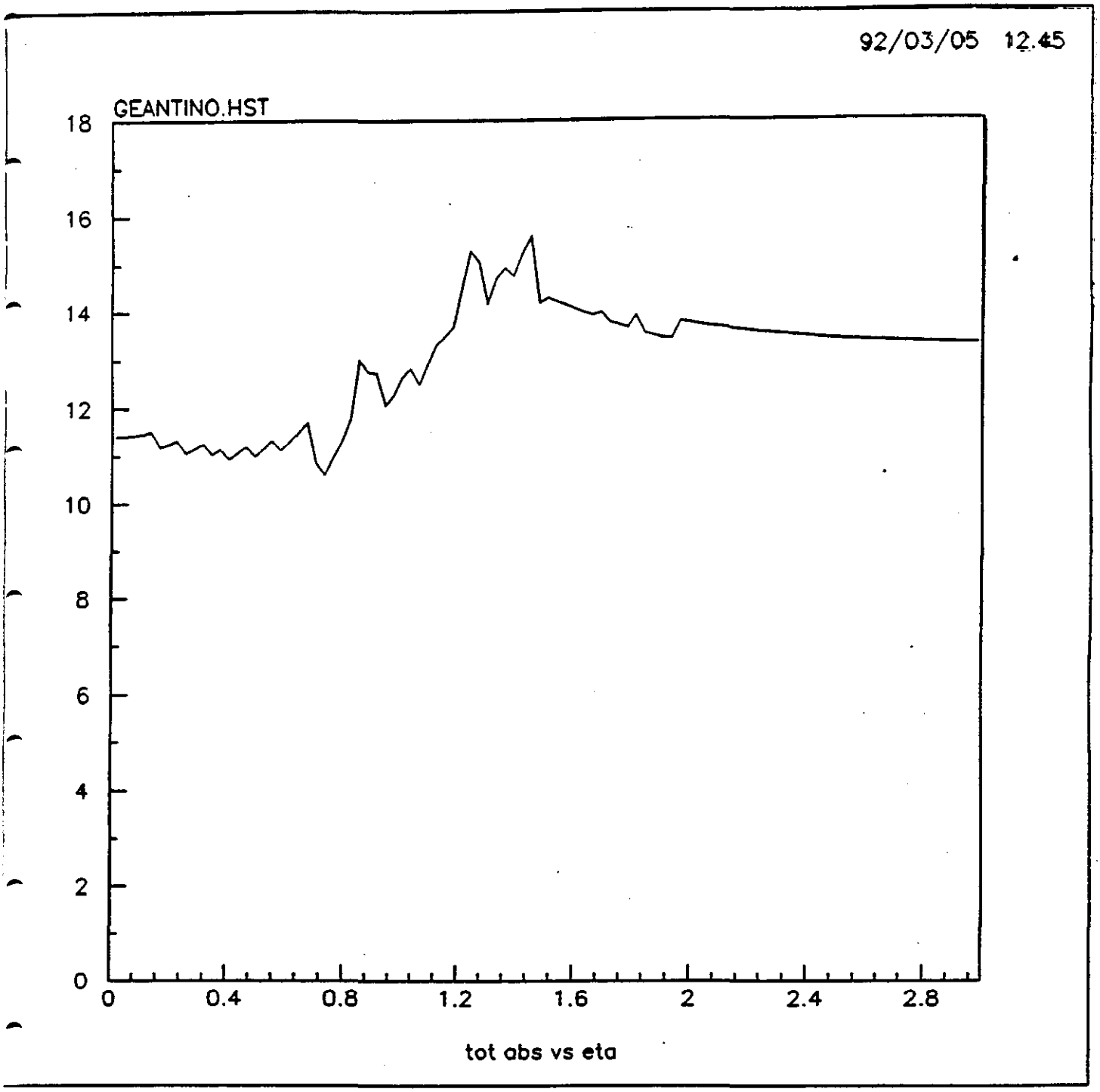
3) example

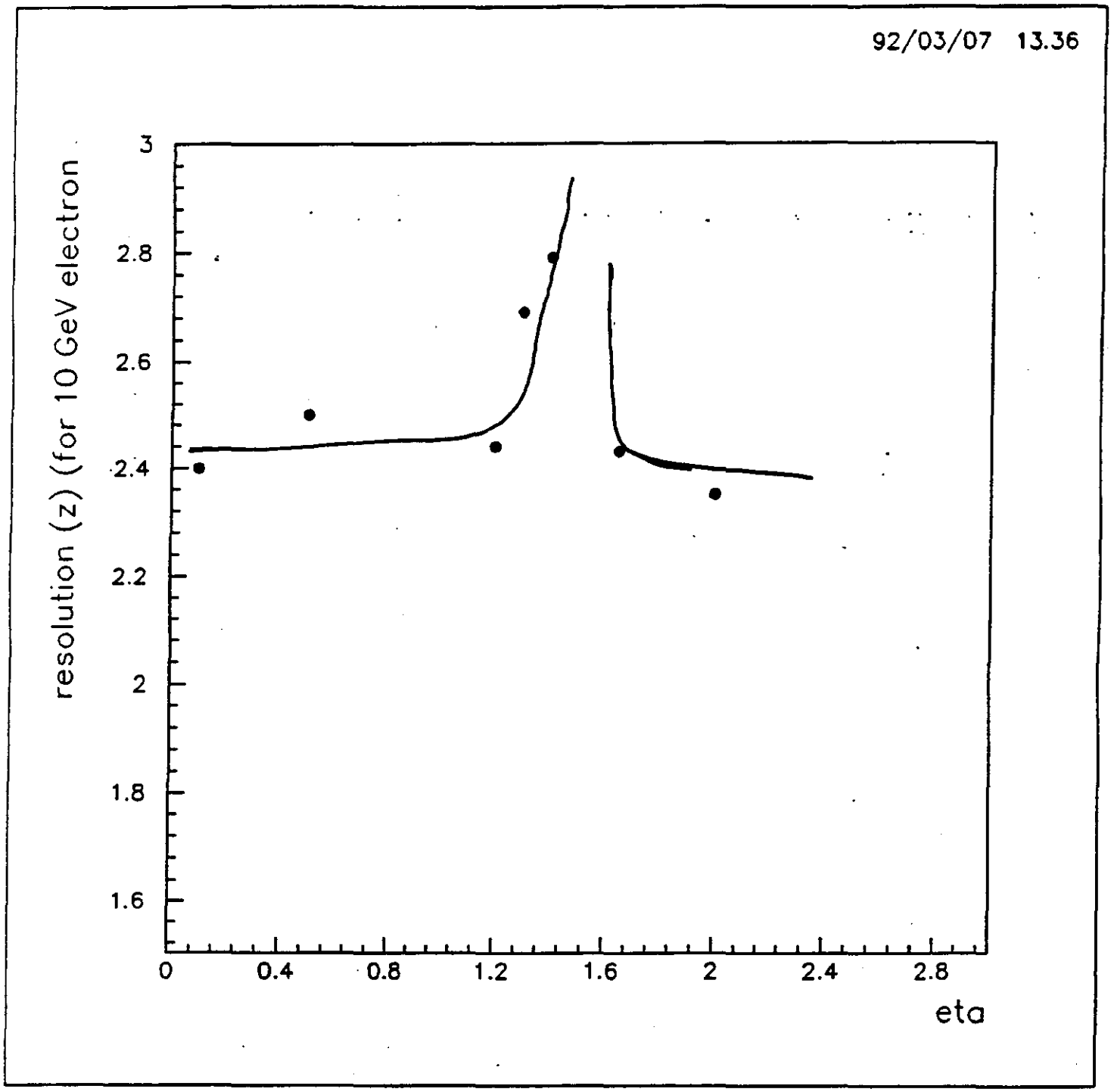
isa_example.f is an example of using the package. It reconstructs H-->ZZ-->mu+mu- jet jet events with Mh=800 GeV.

SUBROUTINE USER
analyzing isajet event.
SUBROUTINE CALSIM
clear cal cell, fill cells with particles, add noise, combine Em and hadron cells.

GEM LAr Calorimeter (GEANT

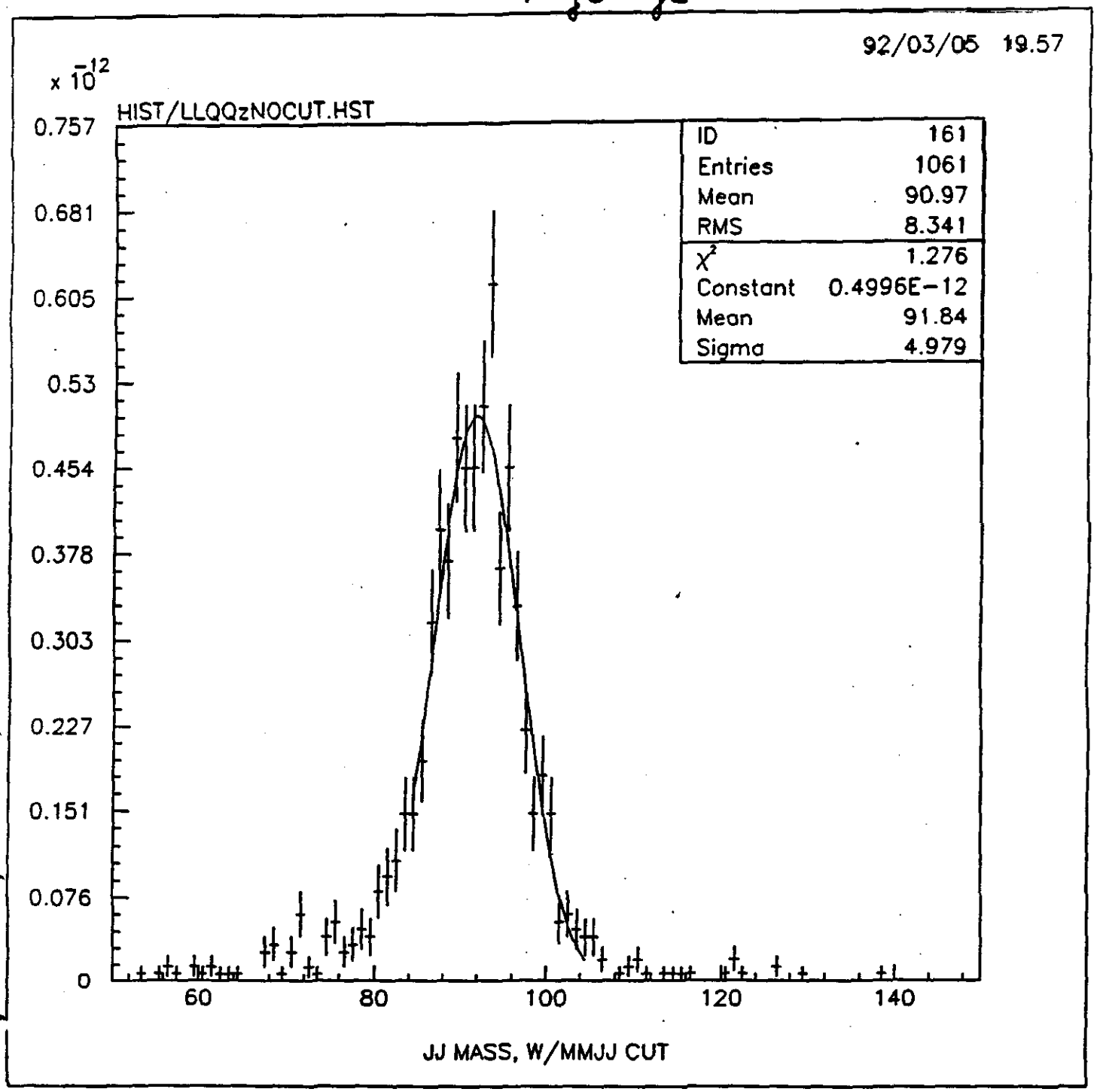


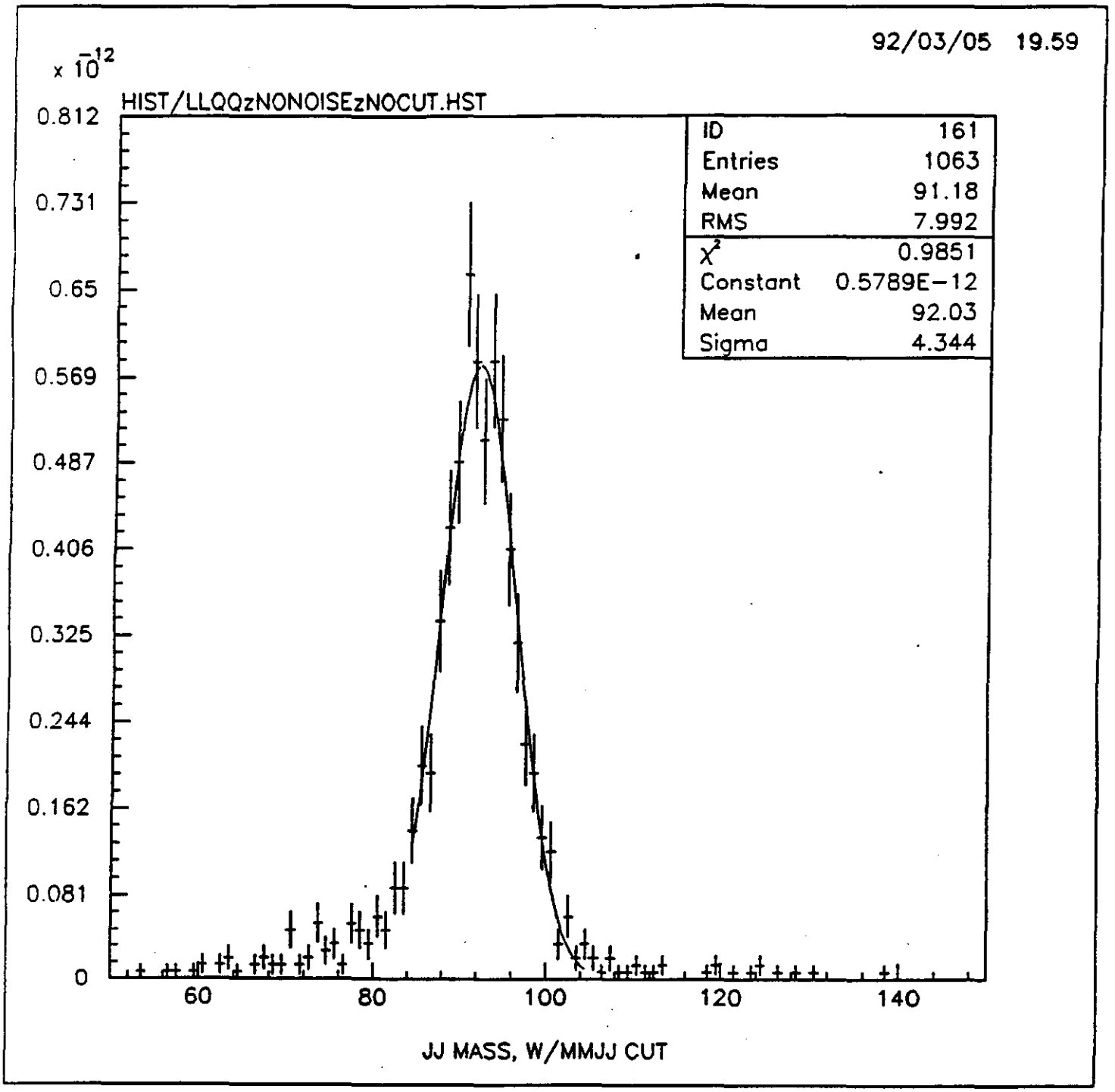

92/03/05 12.45
GEANTINO.HST
18
16
14
12
10
8
6
4
2
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
tot abs vs eta

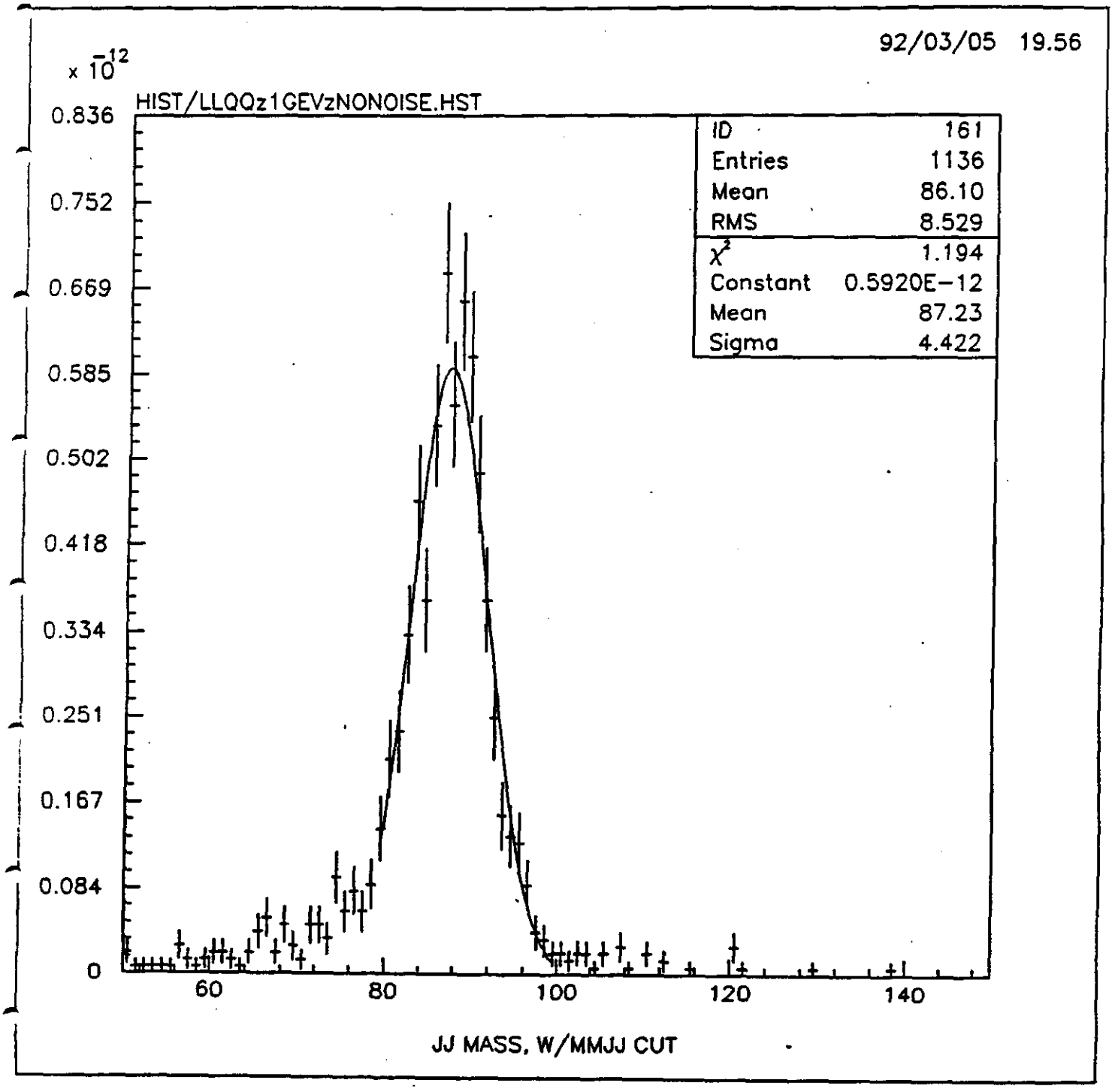

92/03/07 13.36
resolution (z) (for 10 GeV electron
3
2.8
2.6
2.4
2.2
2
1.8
1.6
0
0.4
0.8
1.2
1.6
2
2.4
2.8
eta

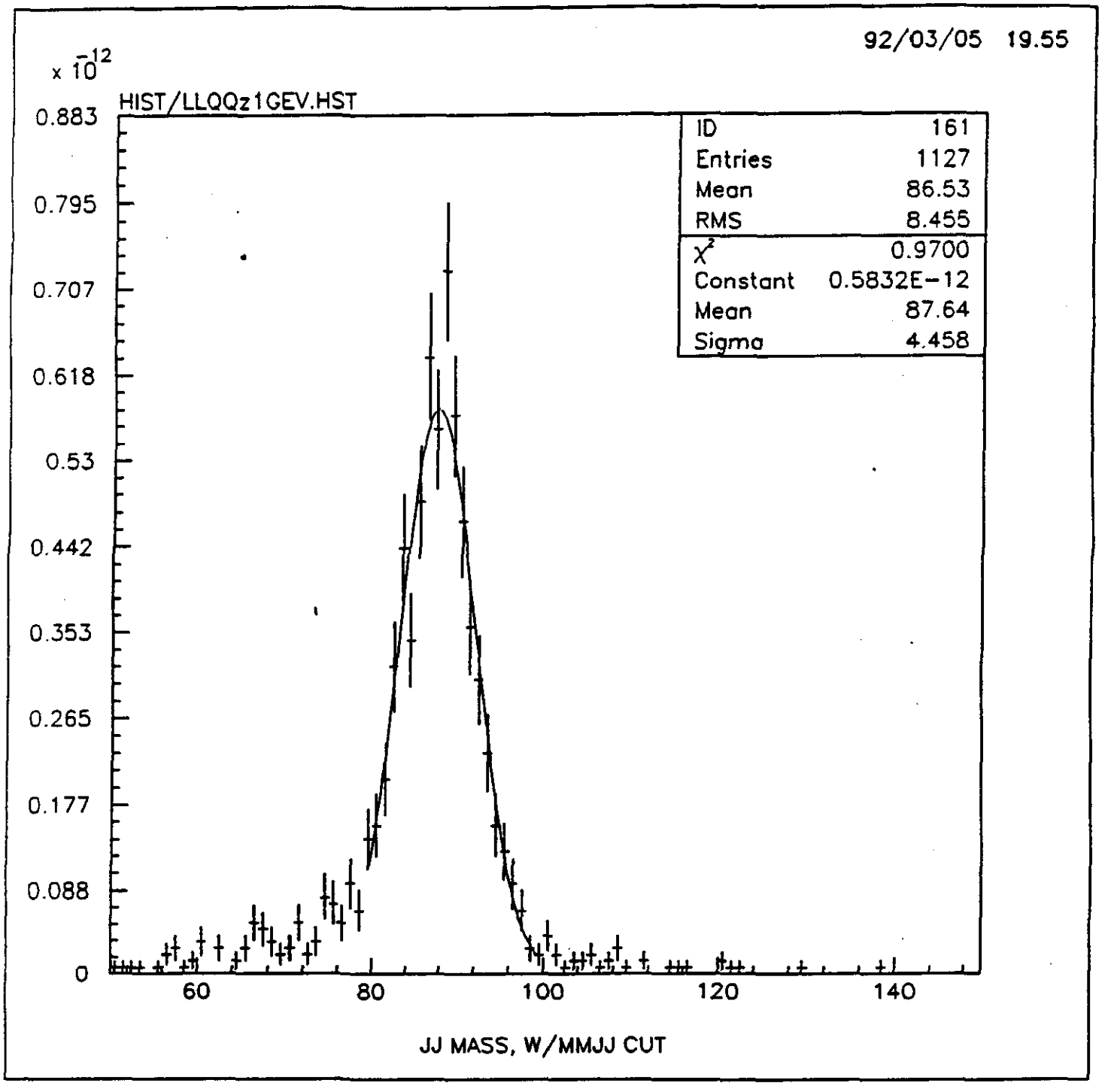
$H \to Z Z \to \mu^+\mu^-$

$\hookrightarrow$ jet jet




92/03/05 19.59
x 10^-12
HIST/LLQQzNONOISEzNOCUT.HST
ID 161
Entries 1063
Mean 91.18
RMS 7.992
χ² 0.9851
Constant 0.5789E-12
Mean 92.03
Sigma 4.344
0.812
0.731
0.65
0.569
0.487
0.406
0.325
0.244
0.162
0.081
0
60
80
100
120
140
JJ MASS, W/MMJJ CUT


92/03/05 19.56
x 10^-12
HIST/LLQQz1GEVzNONOISE.HST
ID 161
Entries 1136
Mean 86.10
RMS 8.529
χ² 1.194
Constant 0.5920E-12
Mean 87.23
Sigma 4.422
0.836
0.752
0.669
0.585
0.502
0.418
0.334
0.251
0.167
0.084
0
60
80
100
120
140
JJ MASS, W/MMJJ CUT


92/03/05 19.55
x 10^-12
HIST/LLQQz1GEV.HST
ID 161
Entries 1127
Mean 86.53
RMS 8.455
χ² 0.9700
Constant 0.5832E-12
Mean 87.64
Sigma 4.458
0.883
0.795
0.707
0.618
0.53
0.442
0.353
0.265
0.177
0.088
0
60
80
100
120
140
JJ MASS, W/MMJJ CUT

W. Worstell

Spaghetti Calorimeter

Input to Parametrications

Test Beam –

- Resolution (Stochastic + Constant term)
- Speed / Noise
- Leakage
- Lateral Shower Development
- Longitudinal Shower Development (Back)

Detailed Simulations –

GEANT

- Resolution – Gaussian + Nongaussian
- Leakage
- Lateral/Longitudinal Fluctuations

CALOR 89

- e/h = compensation
  = linearity + high-energy resolution

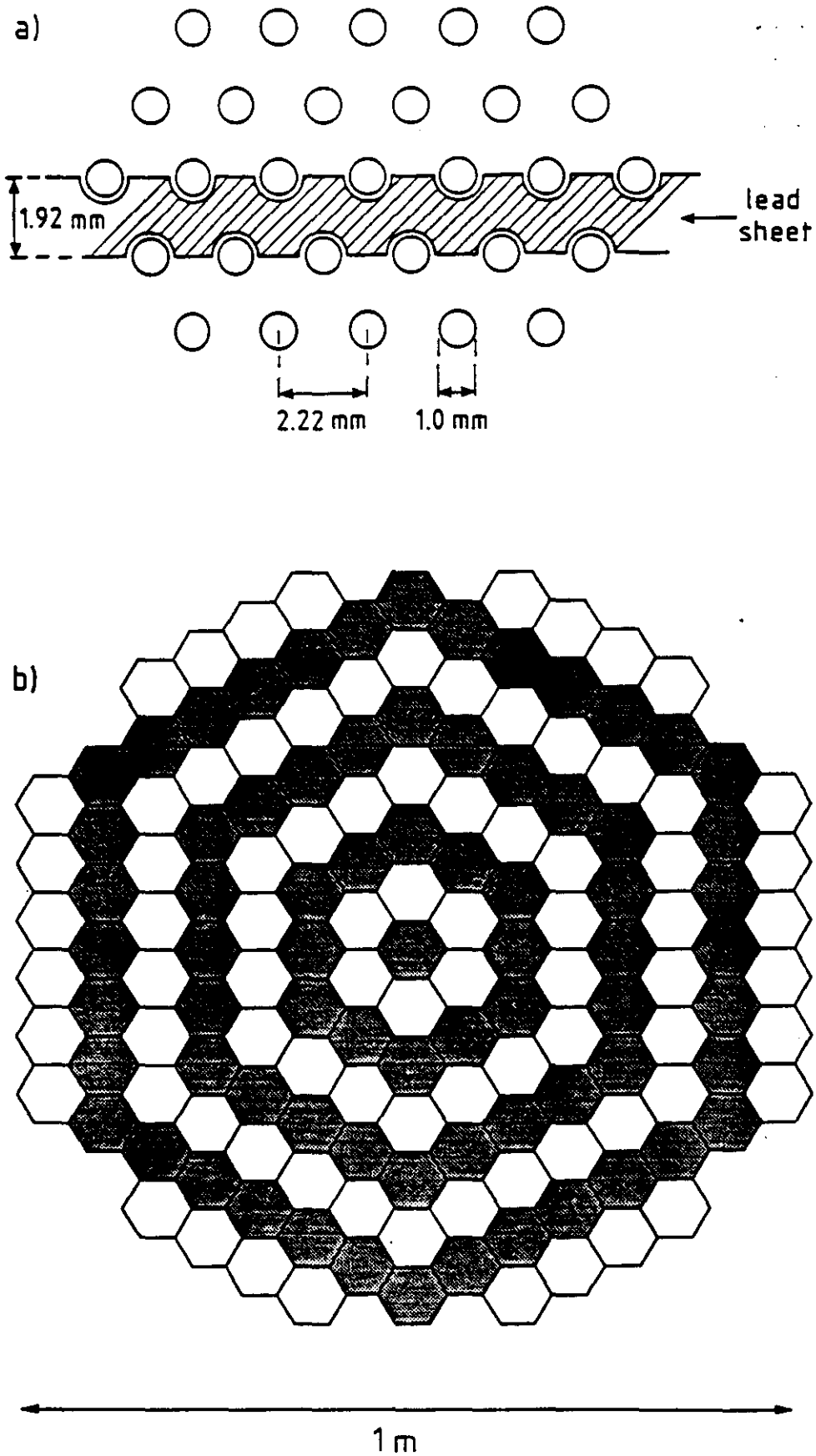


Fig. 1

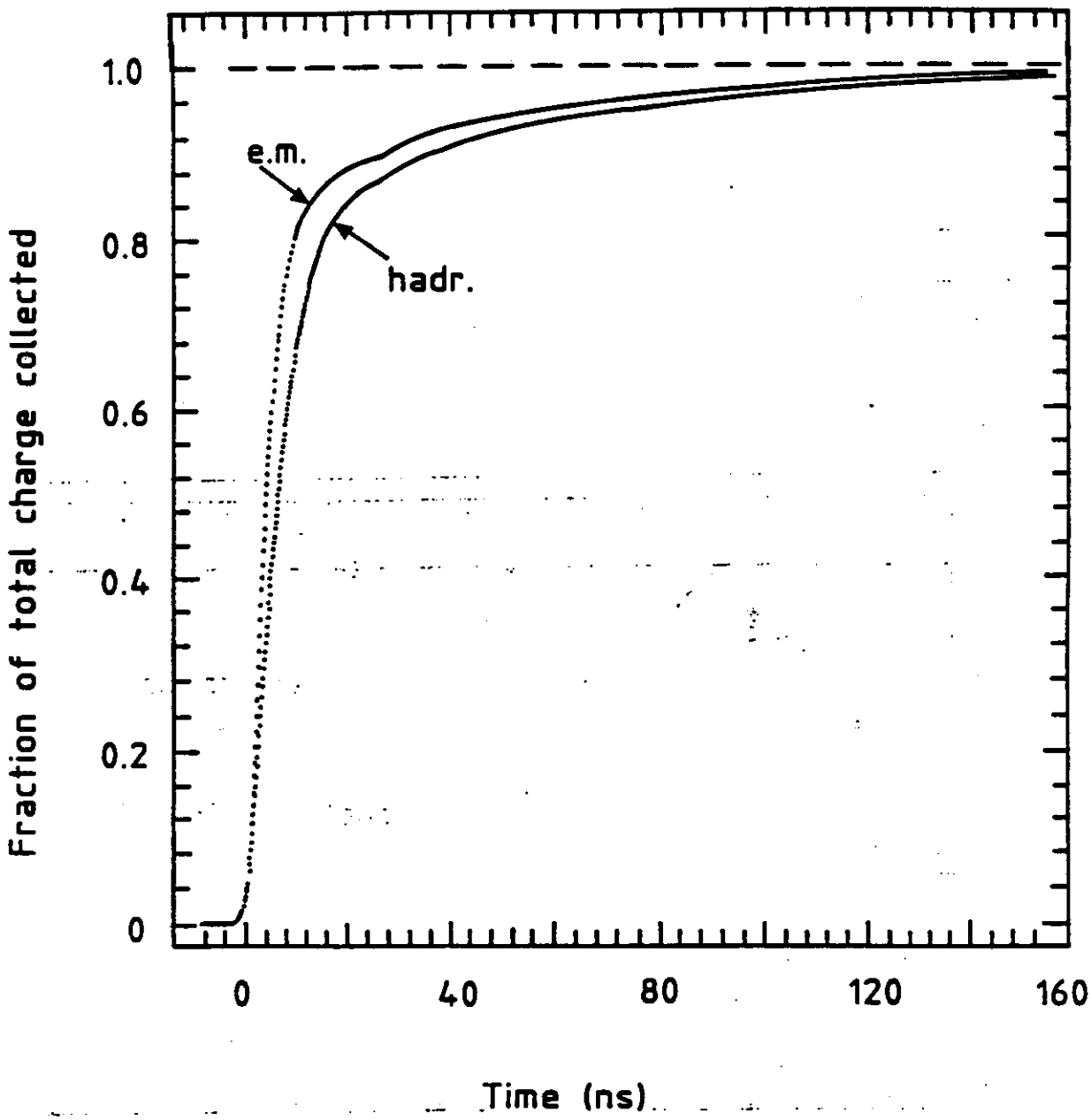

1.0
0.8
0.6
0.4
0.2
0
Fraction of total charge collected
e.m.
hadr.
0
40
80
120
160
Time (ns)

Figure 8

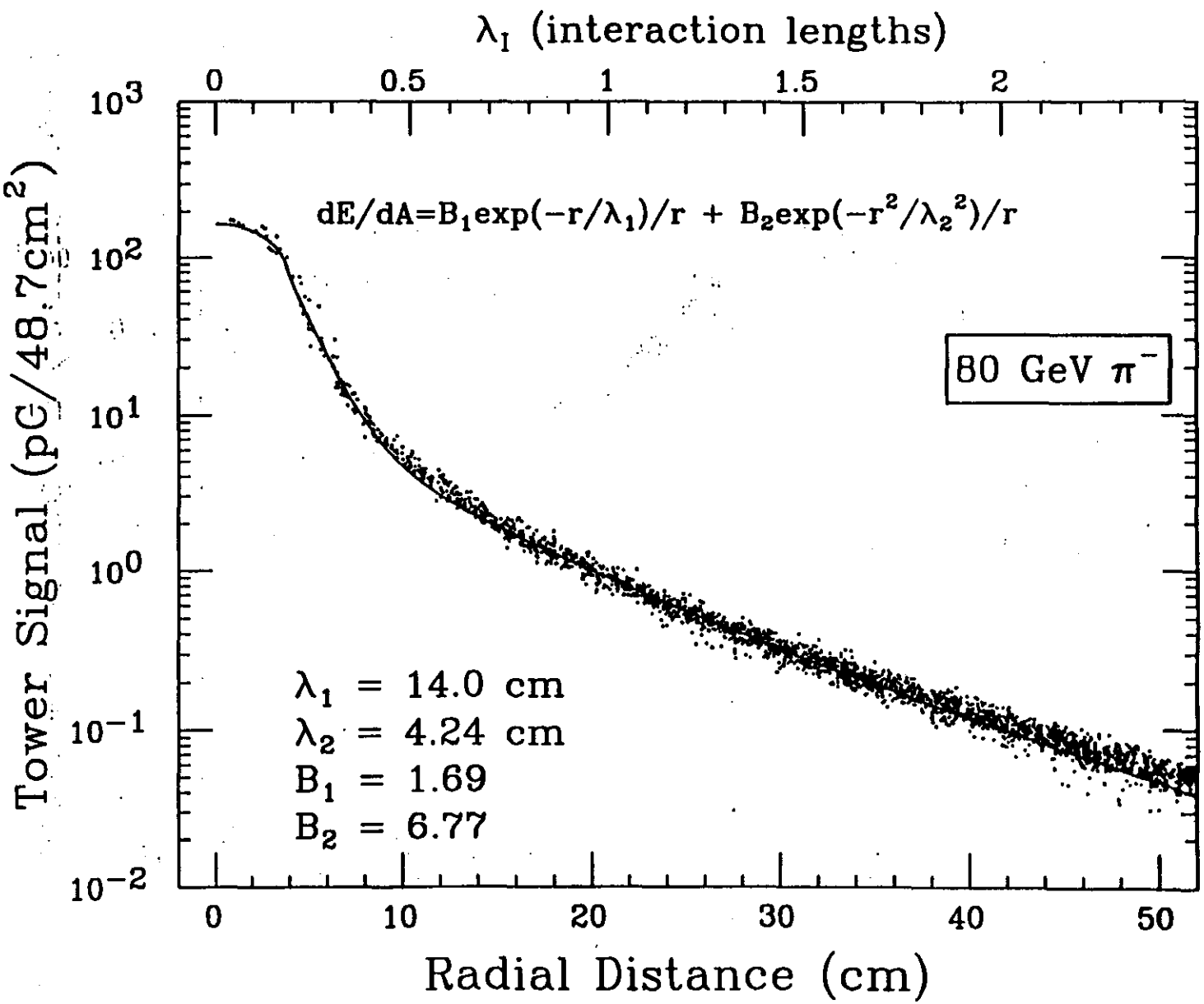

λI (interaction lengths)
0
0.5
1
1.5
2
dE/dA=B1exp(−r/λ1)/r + B2exp(−r2/λ22)/r
80 GeV π−
λ1 = 14.0 cm
λ2 = 4.24 cm
B1 = 1.69
B2 = 6.77
Tower Signal (pC/48.7cm2)
10−2
10−1
100
101
102
103
0
10
20
30
40
50
Radial Distance (cm)

Figure 9

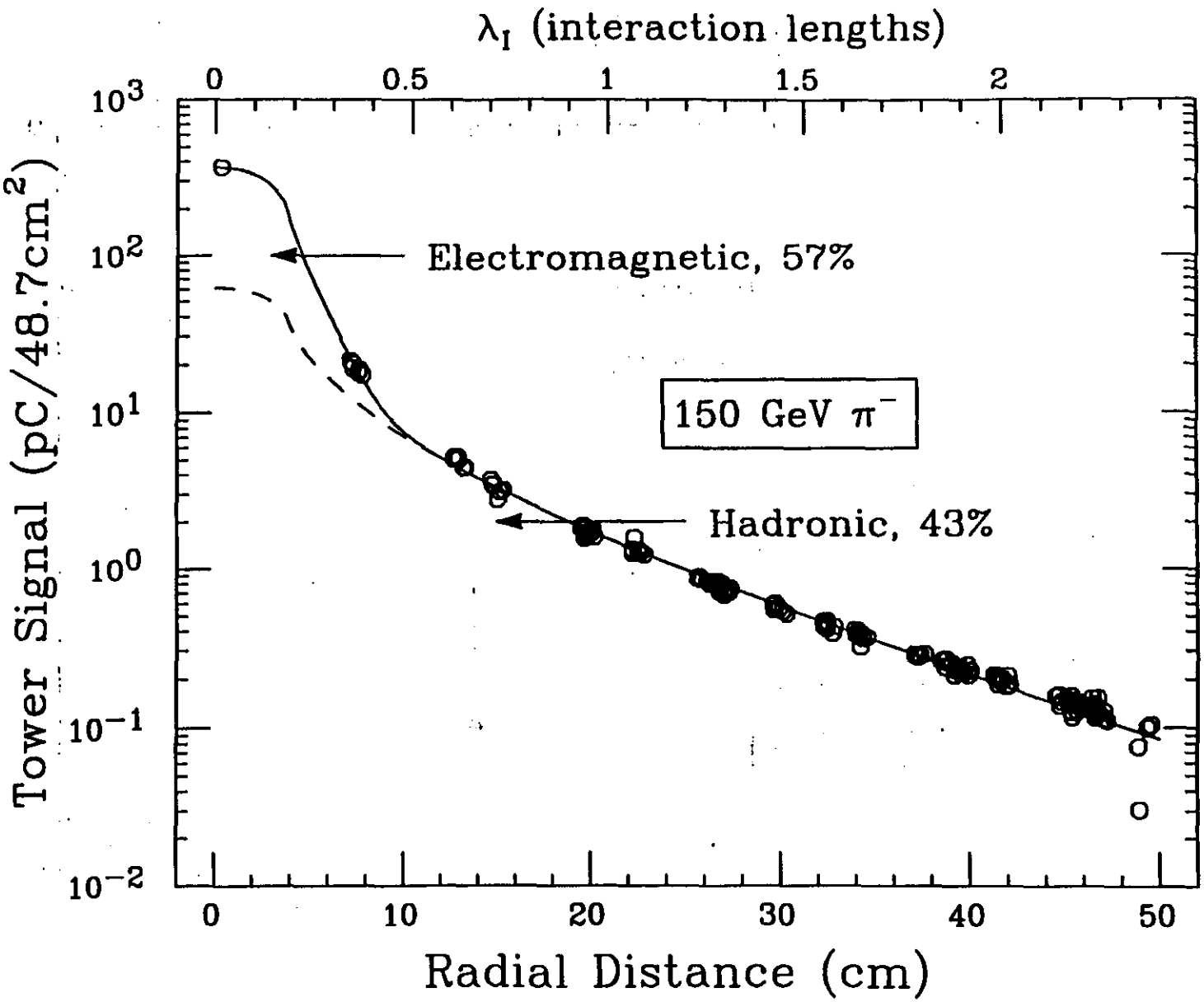

λI (interaction lengths)
0
0.5
1
1.5
2
Tower Signal (pC/48.7cm²)
10³
10²
10¹
10⁰
10⁻¹
10⁻²
Electromagnetic, 57%
150 GeV π⁻
Hadronic, 43%
0
10
20
30
40
50
Radial Distance (cm)

Figure 19

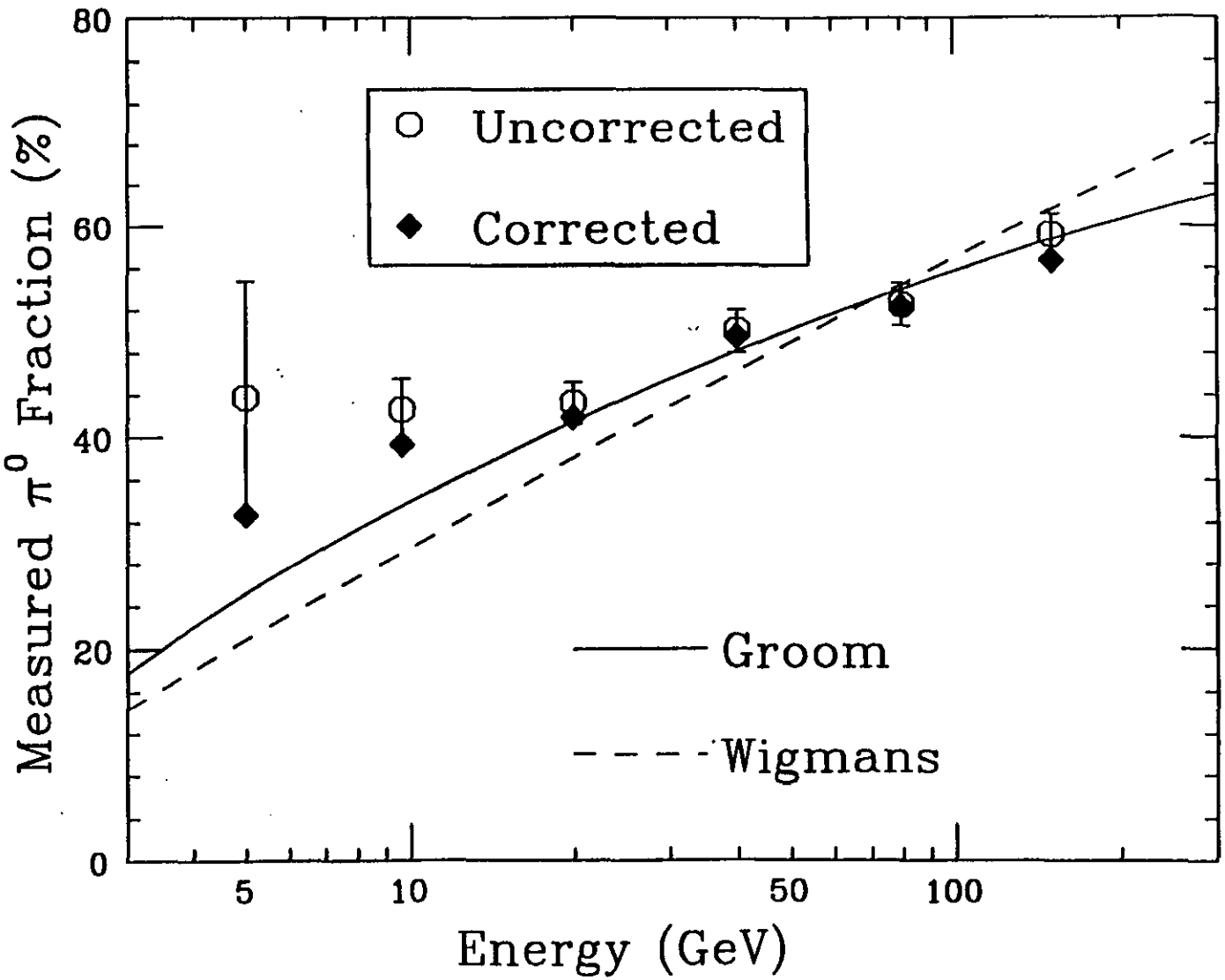
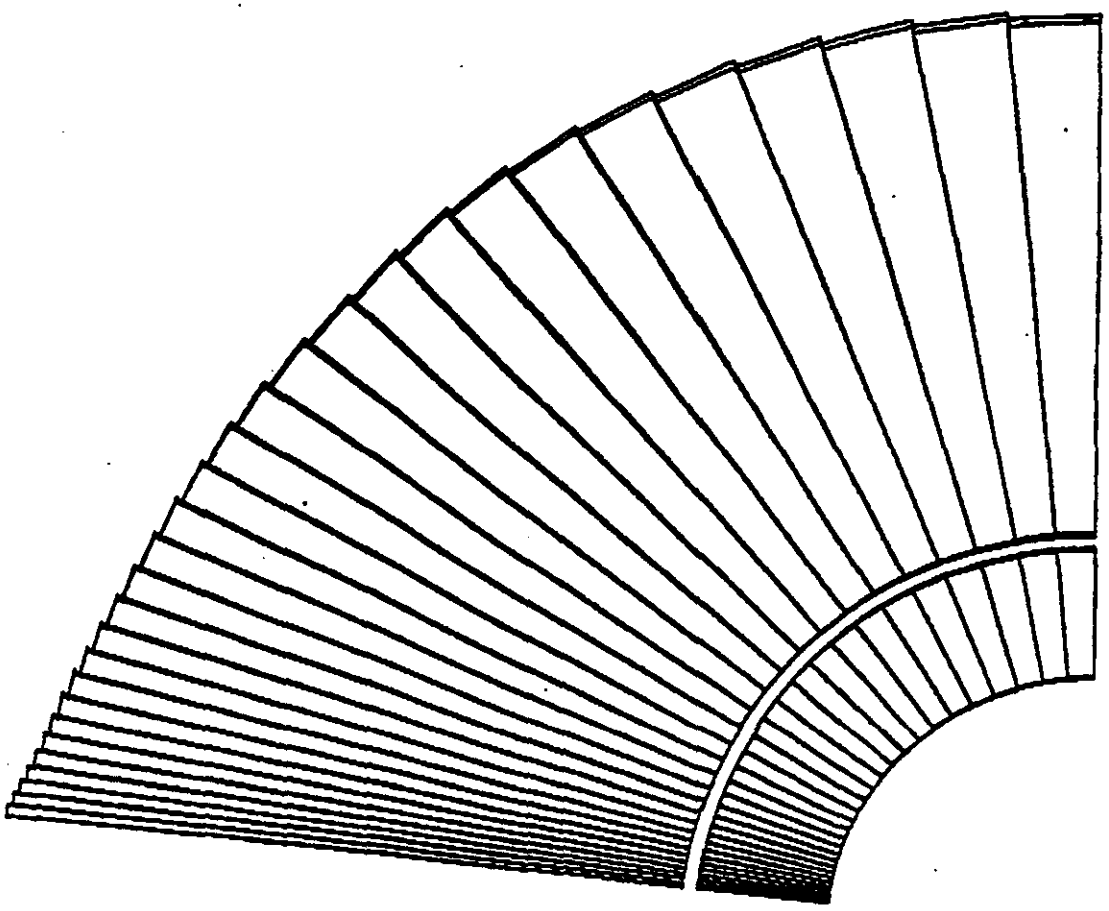
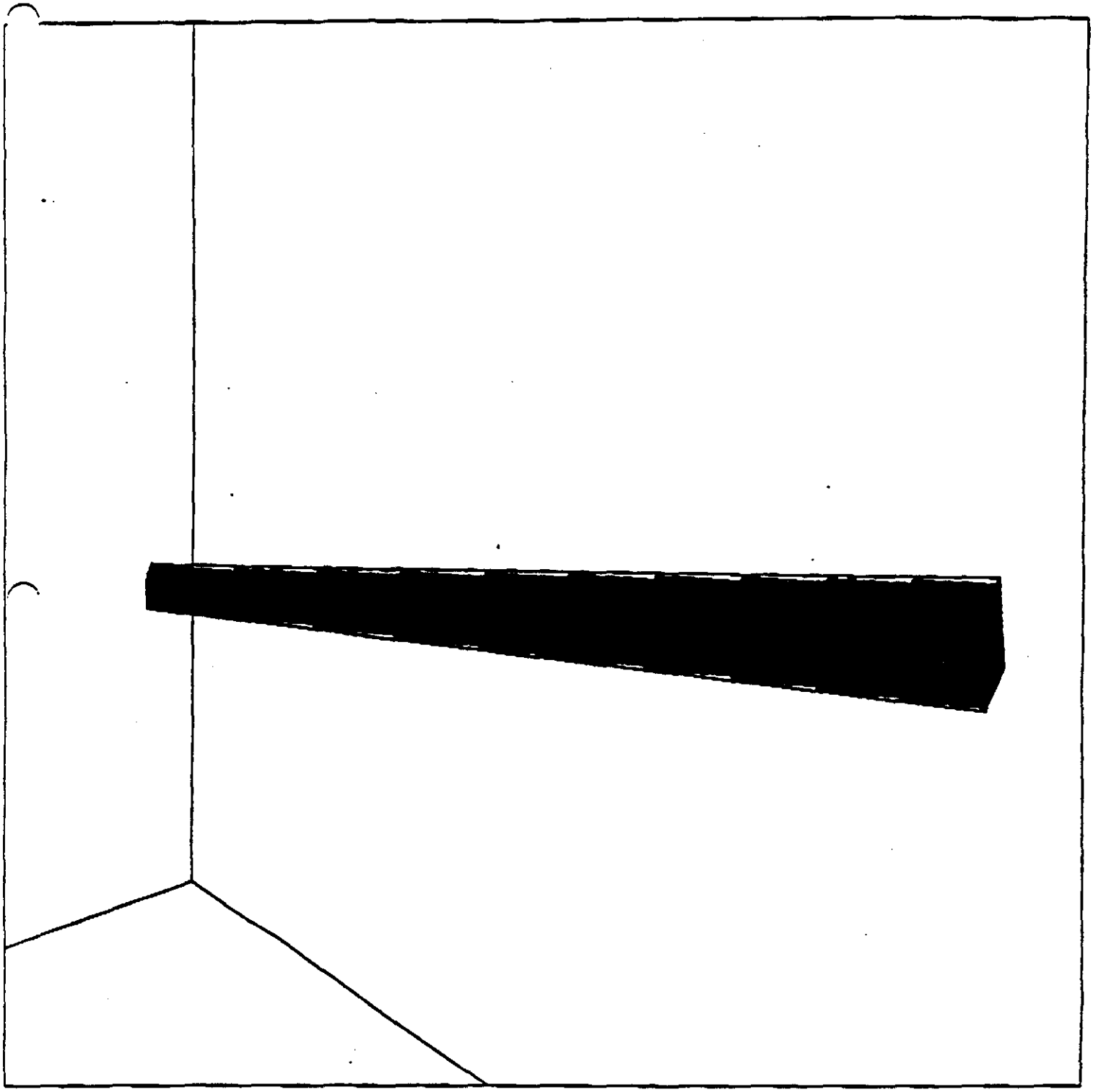
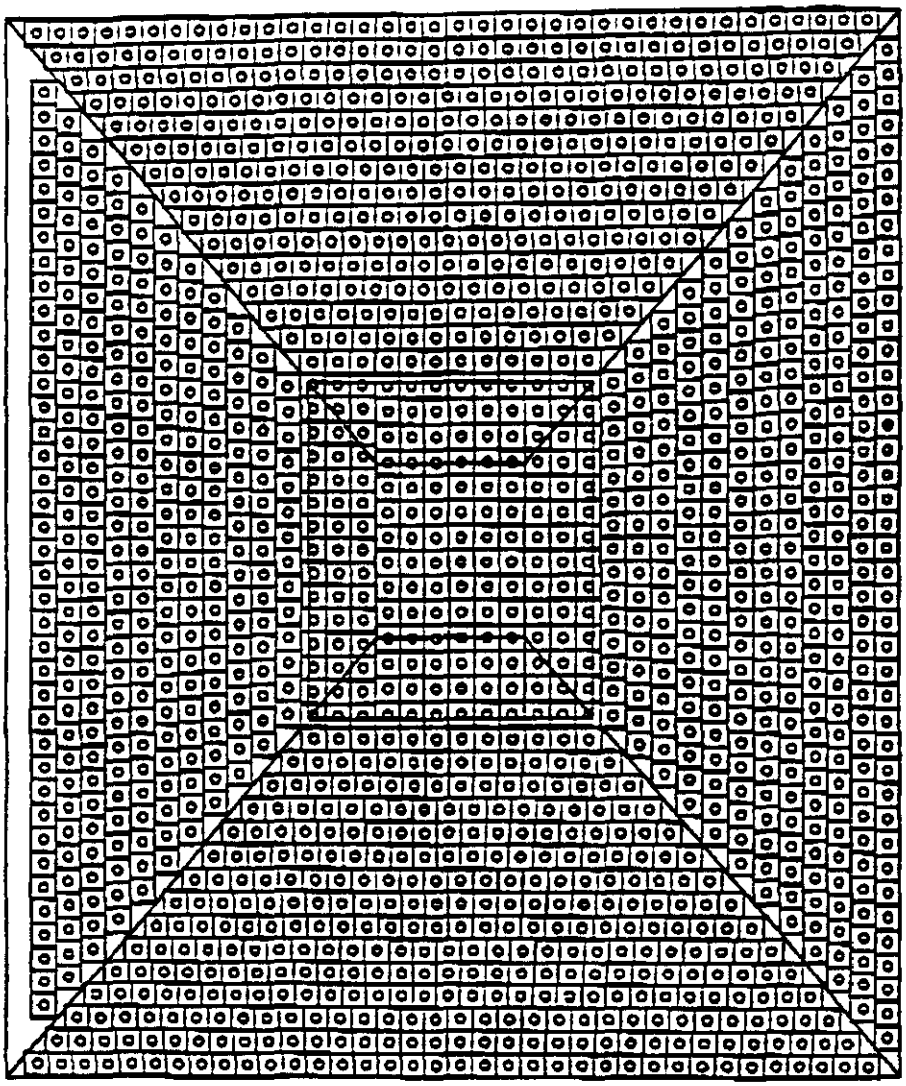

Uncorrected
Corrected
Groom
Wigmans
Measured π^0 Fraction (%)
Energy (GeV)
0
20
40
60
80
5
10
50
100

Figure 20





$\eta = 0$



Summary

Test Beam data from SPACAL
extrapolated to GEM/SSCintCAL

Next new test beam results
June BNL , August CERN

Initial parametrizations will have
fluctuations only in longitudinal
shower starting point

Detailed detector geometry in GEANT
to study fluctuations +
stochastic resolution (on PDSF)

CALOR89 with plate
geometry (tuned to match fiber filling
+ fiber size)
for e/h, compensation studies

Magnetic Field [Final]

GUFLD.FOR

CASE511.BIN

coarse mesh outside detector volume
bilinear interpolation

Muon Resolution [Preliminary]

RESMAG. FOR
(p_t, η, φ)

Provide improved routine with
Rosenson / Whitaker

What else is required?

draft by K. Lane, February 27, 1992 11:30

PHYSICS SIMULATIONS FOR THE GEM TECHNICAL PROPOSAL

Yesterday, I met with Bing Zhou, Rob Carey, Jim Shank and Liz Simmons to discuss who might be involved / recruited to do physics simulations based on the "level-0" detector simulation that is supposed to be ready by Tucson. The physics processes we considered are the 10 given in my "First Priority" list of January 20 *plus* $t\bar{t}H^0 \to$ isolated $\ell^\pm + \gamma\gamma$ *and* $t\bar{t}$ detection and associated mass measurements by tagging isolated $\ell^\pm$ (from $W^\pm$) and inclusive $\mu^\pm$ (from b). These last two processes satisfy two of the complaints that the PAC made about our LOI simulations. I have incorporated the PAC's other complaints into the list of processes. I have also very slightly revised the original list to be more responsive to the PAC (e.g., extending the mass range for $H^0 \to \ell^+\ell^-\ell^+\ell^-$ to 800 GeV and asking if this is doable at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.)

Below is the draft list of names (or groups) we came up. Obviously, we need to recruit others (especially, John Wormersley, Fred Olness and Hallsie Reno). We should try to get as much of this done as possible for presentation at the July PAC meeting, using the best detector simulations we have at that time. For those processes which the PAC specifically commented upon, completion of the simulations by July is mandatory. These are items 1, 2, 3, 4, 6(?), 7, 12. It goes without saying that all physics and detector backgrounds to the processes below must be studied with care.

FIRST PRIORITY PHYSICS SIMULATIONS

1. $H^0 \to \gamma\gamma$ ($M_H \simeq 100\,\mathrm{GeV}$)
   — involves CT, ECAL, (HCAL), TR.

- Renyuan Zhu and coworkers.
  These must be done with worsened resolutions ($10\%/\sqrt{E} \oplus 1 - 2\%$ for LAr and $2\%/\sqrt{E} \oplus 1 - 2\%$ for BaF_2) as well as resolutions from the level-n ($n \geq 0$) detector simulations. The PAC is also concerned with backrounds to $\gamma\gamma$ from misidentified $e^\pm$.

2. Associated production of the light Higgs, $t\bar{t}H^0$, with $H^0 \to \gamma\gamma$ ($M_H \simeq 100\,\mathrm{GeV}$)
   — involves CT, ECAL, HCAL, TR.

- Renyuan Zhu and coworkers.
  These must be done with worsened resolutions ($10\%/\sqrt{E} \oplus 1 - 2\%$ for LAr and $2\%/\sqrt{E} \oplus 1 - 2\%$ for BaF_2) as well as resolutions from the level-n ($n \geq 0$) detector simulations. The PAC is also concerned with backrounds to $\gamma\gamma$ from misidentified $e^\pm$. Is b-tagging by inclusive muons useful? Or is the rate too low?

3. $H^0 \to e^+e^-e^+e^-$ ($M_H \simeq 150 - 800\,\mathrm{GeV}$)
   — involves CT, ECAL, (HCAL), TR.
   - Renyuan Zhu and coworkers.
     These must be done with worsened resolutions ($10\%/\sqrt{E} \oplus 1 - 2\%$ for LAr and $2\%/\sqrt{E} \oplus 1 - 2\%$ for BaF_2) as well as resolutions from the level-n ($n \geq 0$) detector simulations. The PAC is also concerned with electron identification in the end caps. Is $H^0(M_H = 800\,\mathrm{GeV}) \to e^+e^-e^+e^-$ doable at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$?

4. $H^0 \to \mu^+\mu^-\mu^+\mu^-$ ($M_H \simeq 150 - 800\,\mathrm{GeV}$)
   — involves CT, MUON, (HCAL), TR.
   - Jim Shank (BU) will organize this.
     Is $H^0(M_H = 800\,\mathrm{GeV}) \to \mu^+\mu^-\mu^+\mu^-$ doable at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$?

5. $H^0 \to \ell^+\ell^-$ jet jet, $\ell^\pm = e^\pm$ and $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — involves CT, ECAL/MUON, HCAL, TR.
   - Hong Ma should organize this.
     Rob Carey can serve as a resource for spaghetti calorimetry and Jim Shank for muons.

6. $H^0 \to \ell^+\ell^-\nu\bar{\nu}$, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — involves CT, ECAL/MUON, F/B, TR.
   - Mike Shupe and/or Geoff Forden should organize this.
     Jim Shank can serve as a resource for muons. Hong Ma and Renyuan Zhu might serve as electron advisors.

7. $t\bar{t}$ production and mass measurement for $m_t = 250\,\mathrm{GeV}$ in standard ($t \to W^+b$) and non-standard ($t \to H^+b$) decay modes. The signal is an isolated $\ell^\pm$ from $W^\pm$ decay and an inclusive muon from b decay.
   — involves CT, ECAL, HCAL, MUON, TR.
   - Frank Paige will organize this and recruit appropriate muon and electron people as resources / advisors.

8. Leptoquark pair-production and decay, $\mathcal{G}\mathcal{G} \to \pi_{\overline{L}Q}\pi_{\overline{Q}L} \to b\tau^+\bar{b}\tau^-$
   — involves CT, MUON, HCAL, F/B, TR.
   - K. Lane will discuss this with Frank Paige to determine what needs to be done and who should do it.

9. Quark substructure in high-p_T and invariant mass jet production (deviation from QCD cross sections at $p_T \gtrsim 4\,\mathrm{TeV}$)
   — involves ECAL, HCAL, TR.
   - Rob Carey will organize this, with K. Lane as theory advisor. Hong Ma should be involved as a LAr resource. Compensation (e/h) is an important issue here.

10. Quark/lepton substructure in $\overline{q}q \to \mu^+\mu^-$ at high invariant mass (a deviation from the Drell-Yan cross section at $\mathcal{M} \gtrsim 2\,\mathrm{TeV}$) and ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ
    — involves CT, MUON, (ECAL, HCAL), TR.
    - K. Lane and Liz Simmons (and, possibly, Mitch Golden) will organize this, with Bing Zhou and Jim Shank as resources / advisors.

11. $Z'^0 \to \ell^+\ell^-$, with $\ell^\pm = e^\pm, \mu^\pm$. Precision measurements of mass, width (via e^+e^-) and asymmetries (via $\mu^+\mu^-$); determination of the reach in $M_{Z'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}, 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
    — involves CT, ECAL, HCAL, MUON.
    - K. Lane will organize this, possibly with local theorists, and with Shank, Zhou , Zhu and Ma as resources / advisors.

12. Gluino pair production via the $\not{E}_T$ and and likesign-dilepton signatures
    — involves F/B, E/HCAL, CT, MUON.
    - Frank Paige will organize this, with Forden and Shupe aand lepton people recruited as resources.

Additional FASTφ simulations

Pre Radiator — J. Brau, Furono, Mockett

Trigger — C. Allen, UT Austin

Physics Processes

Additional Physics discussions:

R.-Y. Zhu — Toponium as M_t measurements

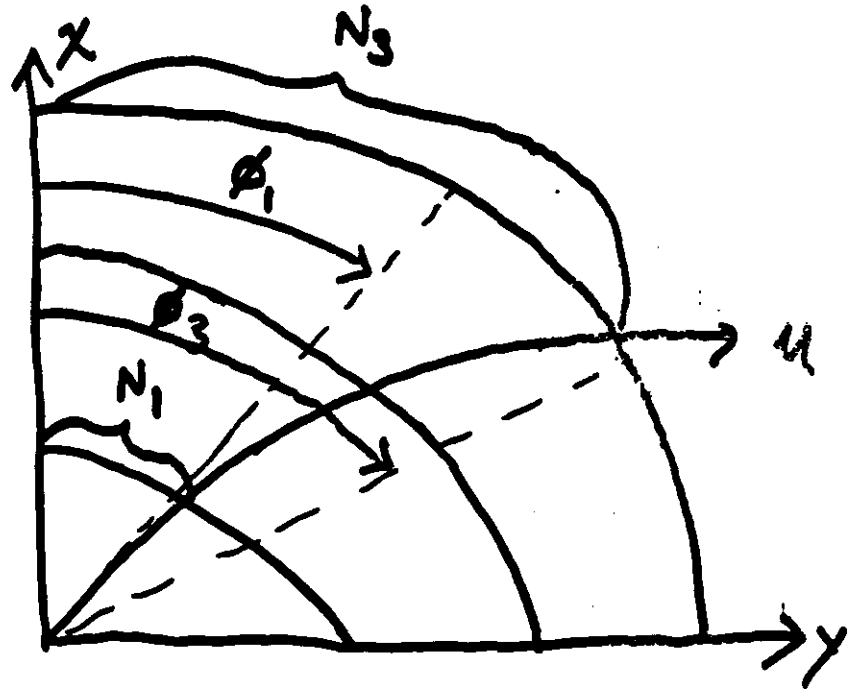
Responsibilities for Physics processes as listed

1. Zhu +
2. "
3. "
4. Shank
5. Ma
6. Forden, Shupe (U.A.)
7. Paige Vannachine
8. (Baltay) +
9. Carey, Lane.
10. Lane, Summons. Mohammadi, (Baltay)
11. "
12. Paige + U.A. + (Baltay)

P. DINGUS SSCL 3/10/92

Trigger PROBABILITY

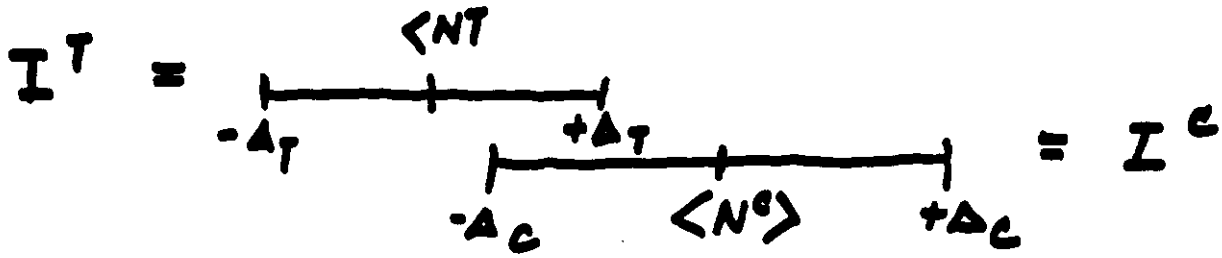
We DeTermine THe PAD DIFFerenCe BeTwee THe 1ST AND 3RD MUON Super-Layers:



For 3cm PADS AS A FUNCTION OF η. GIVEN SOME MOMENTUM CUT WE FIND THE PAD INTERVAL CORRESPONDING TO THATMOMENTUM AT WHATEVER η IS GIVEN for THe CURRENT EVENT. THUS WE ESTABLISH THE CUT INTERVAL:

IPCUT ≡ $-\Delta_I$ $\langle N_p^I \rangle$ $+\Delta_I$

We do this also for the current event, i.e. determine the pad interval corresponding to the muon track;



$I^T \equiv$ Track Interval

$I^c \equiv$ cut Interval

1) For $(\langle N^T \rangle + \Delta_T) < (\langle N^c \rangle - \Delta_c)$

$$P_{TRIG} \equiv 1$$

2) For an over-lap of I^T and I^c

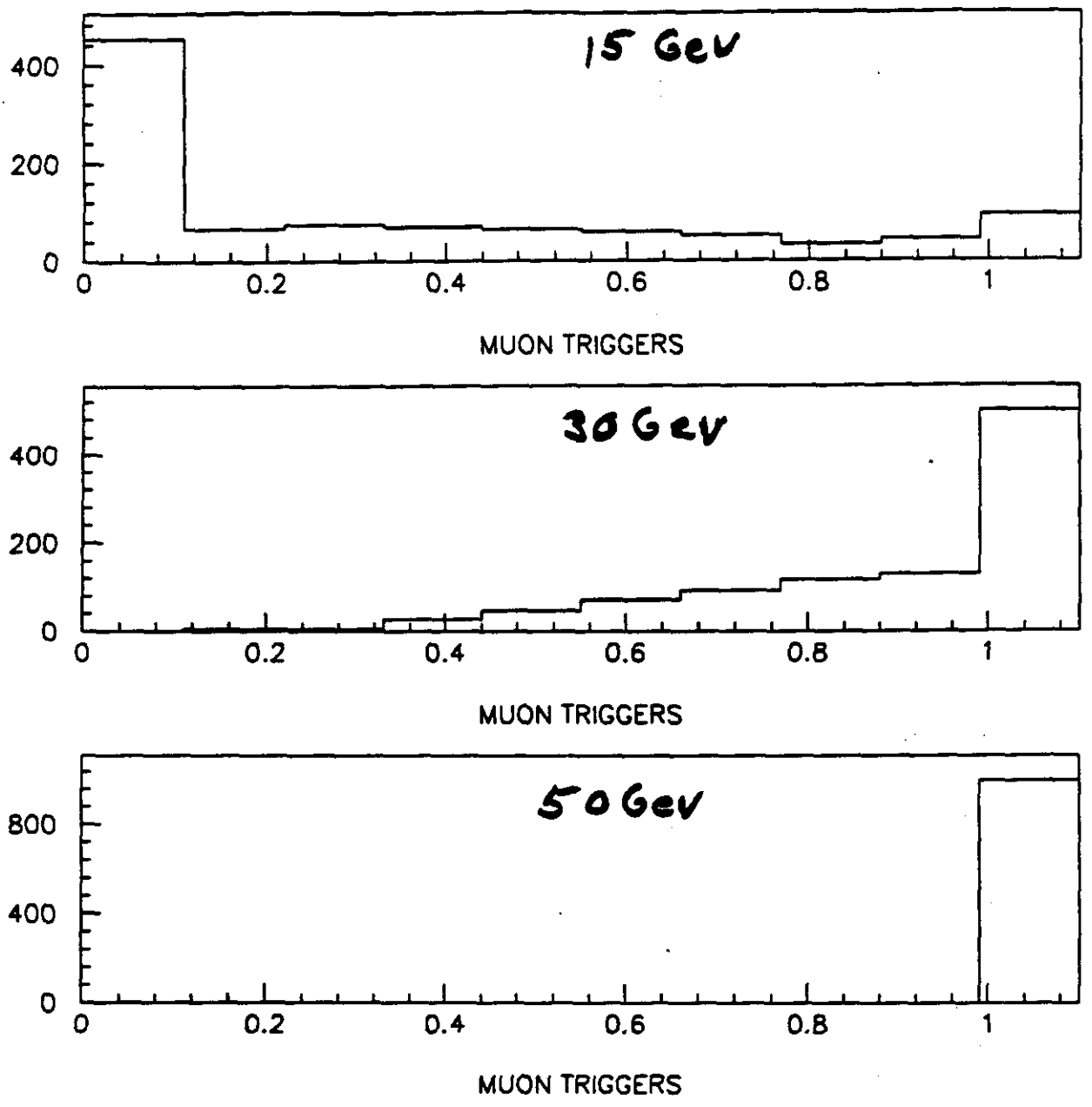
$$P_{TRIG} \equiv \frac{L^{cT}}{I^c}$$

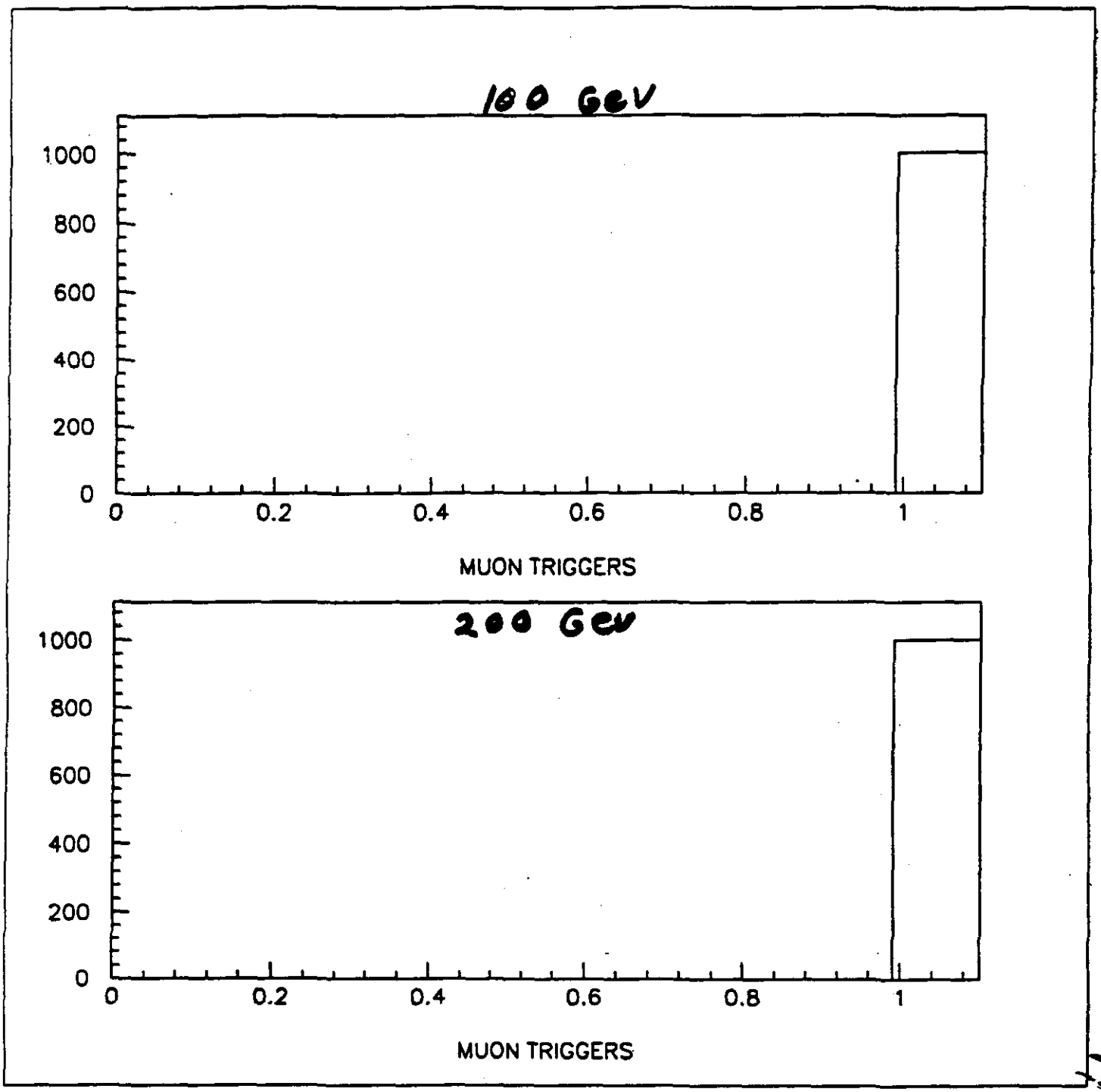
where $L^{cT} = I^c \cap I^T$

3) For $(\langle N^T \rangle - \Delta_T) > (\langle N^c \rangle + \Delta_c)$

$$P_{TRIG} \equiv 0$$

MUON TRIGGER PROB. BY FAST SIMULATION




100 GeV
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
MUON TRIGGERS
200 GeV
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
MUON TRIGGERS

MUON RECONSTRUCTION EFFICIENCY

$$\varepsilon_R \equiv \frac{\text{NUMBER OF DETECTOR ELEMENTS FIRED}}{(\text{TOTAL NUMBER OF ELEMENT/ROAD})}$$

THE PROCEDURE IS TO DETERMINE THE NUM. OF HITS/(RECON-TRACK). AN ESTIMATE WAS MADE BY FINDING THE 5 HOTTEST HITS/SUPER-LAYER. SOME OF THESE WERE DUE TO Δ-RAYS AND CHARGED BACKGROUND FROM THE CALORIMETER. WE ASSUME THE 5 HOTTEST CELLS WOULD ENCOMPASS THE GENERIC CLUSTERING ALGORITHM. FOR EXAM, IT WAS FOUND THAT FOR AN ISOLATE μ OF 100 GEV @ θ ~ 80 AN AVERAGE OF 17 HITS WERE RECORDED ON THE 2ND μ SUPER-LAYER. THE ⟨N⟩/TRACK AS A FUNCTION OF η IS THEN USED AS THE AVERAGE VALUE OF A POISSON DISTRIBUTION, N_0. THE NUMBER N_0 IS THEN USED AS η TOTAL NUM OF HITS IN A BINOMIAL DISTRIBUTION;

$$P(r) = \sum_r \binom{N_0}{r} p^r q^{N_0 - r}$$

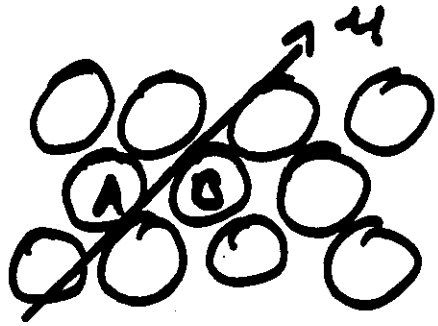
WHERE $N_0 \equiv$ TOTAL $\left(\frac{\#\ \text{ELEMENTS}}{\text{ROAD}}\right)$

AND $r \equiv$ NUMBER OF ELEMENTS THAT FIRED FOR THIS EVENT.

THE PROBABILITY $\Rightarrow P = 95\%$ IS THE PROBABILITY THAT WAS SET TO ENCOMPASS;

1) PROB. TUBE FIRES WHEN HIT

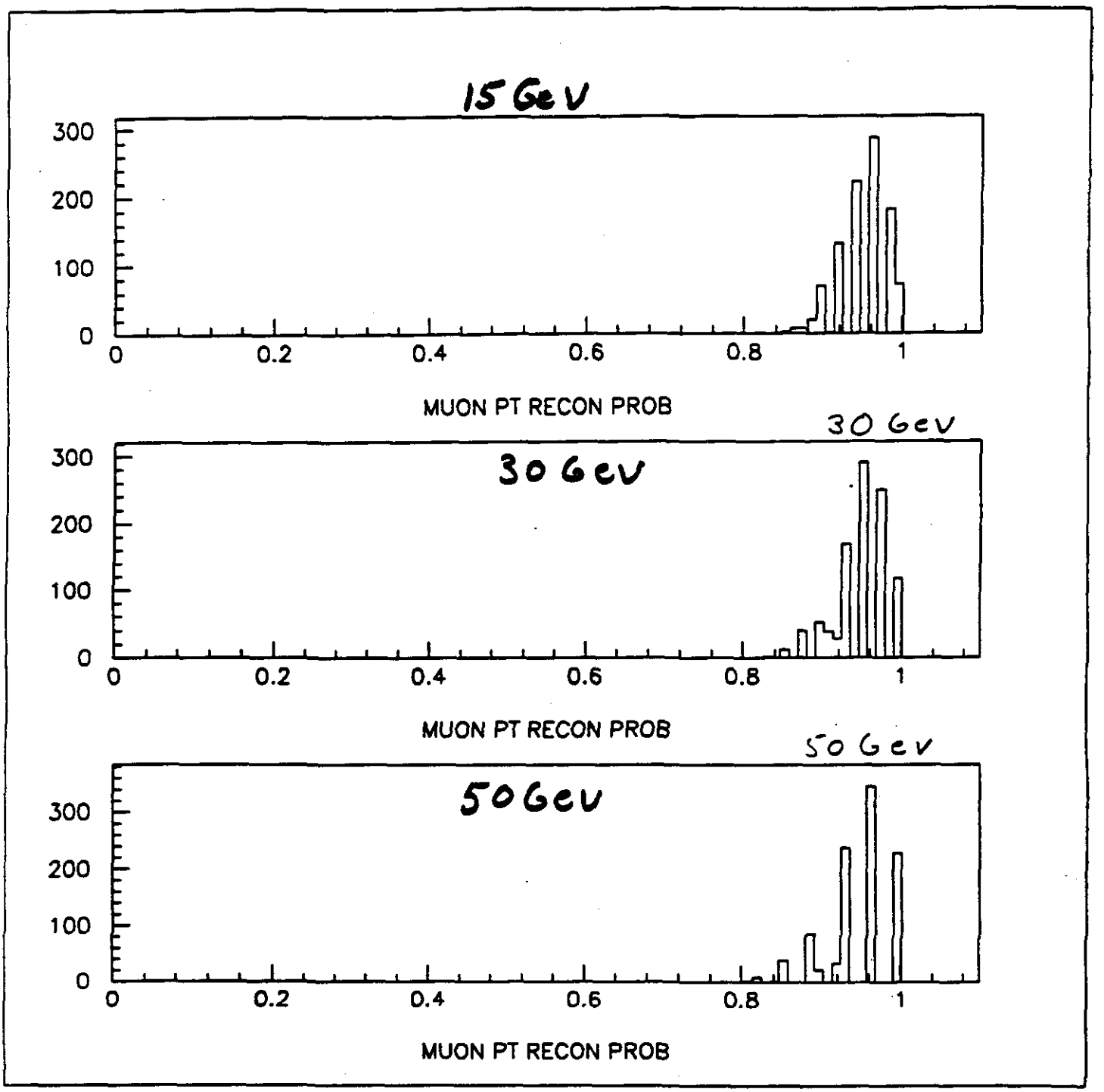
2) GEOMETRIC ANOMALIES

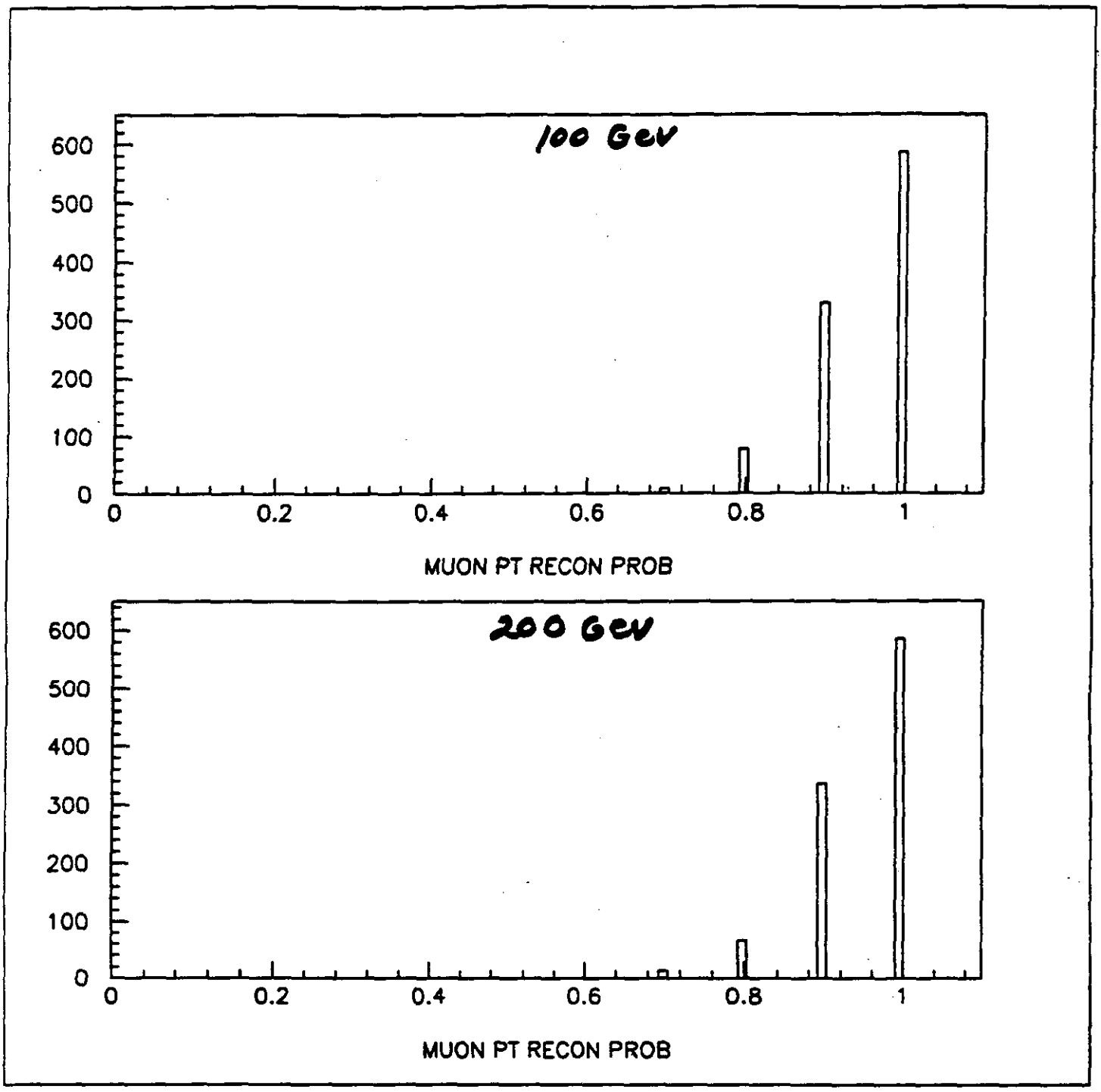


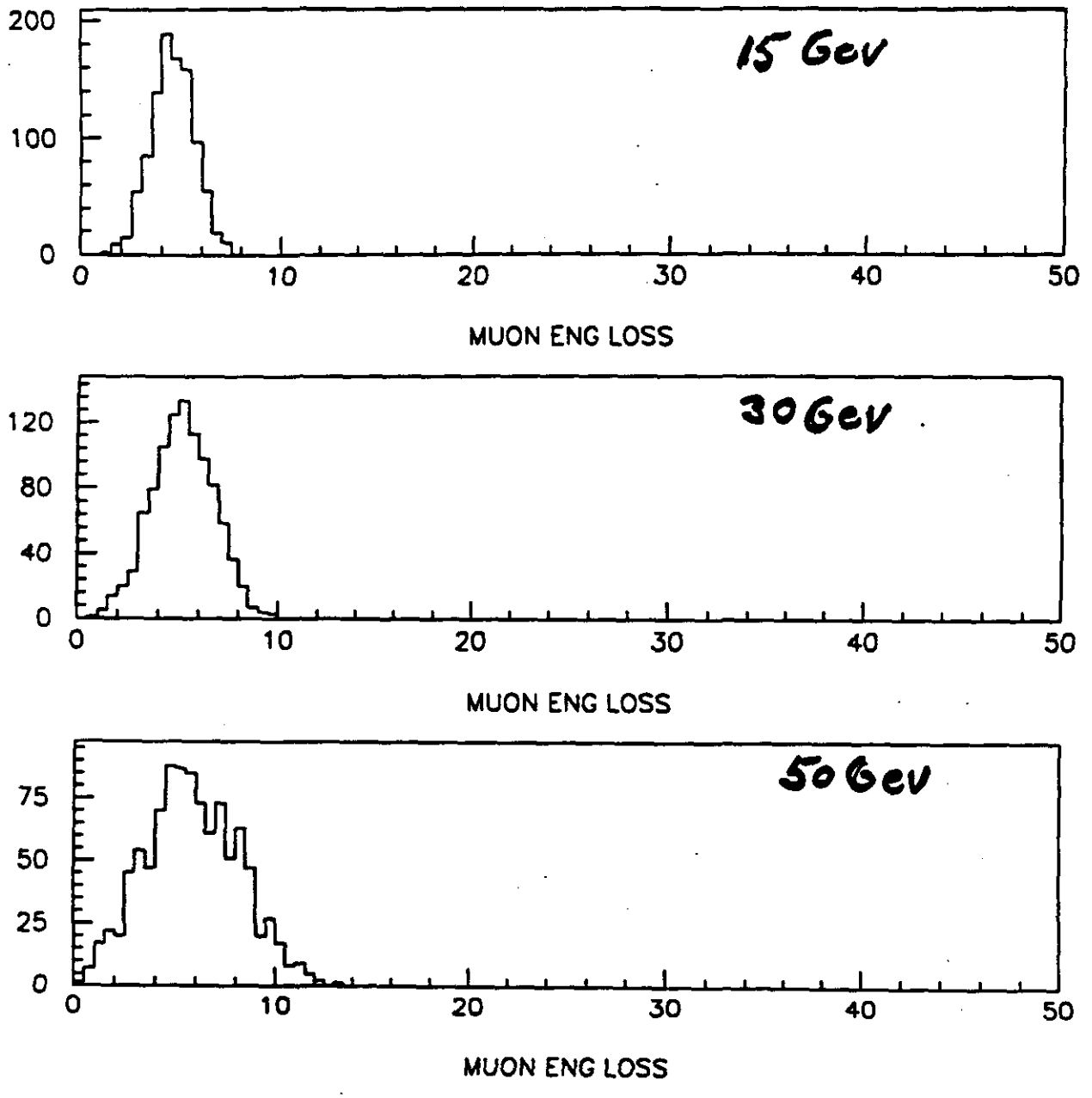
PERHAPS A, B DON'T FIRE

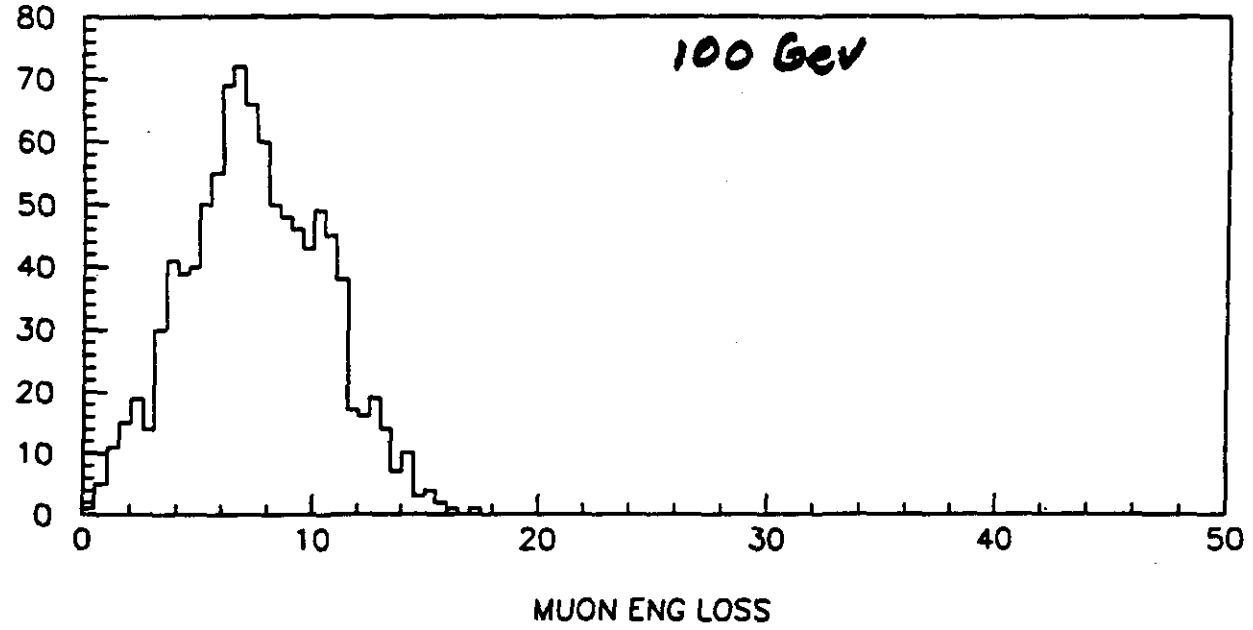
3) PATTERN-RECOGNITION

FINALLY $\varepsilon_r \equiv \frac{r}{N_0}$ FOR AN EVENT


15 GeV
300
200
100
0
0
0.2
0.4
0.6
0.8
1
MUON PT RECON PROB
30 GeV
30 GeV
300
200
100
0
0
0.2
0.4
0.6
0.8
1
MUON PT RECON PROB
50 GeV
50 GeV
300
200
100
0
0
0.2
0.4
0.6
0.8
1
MUON PT RECON PROB


100 GeV
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
MUON PT RECON PROB
200 GeV
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
MUON PT RECON PROB


15 Gev
200
100
0
0
10
20
30
40
50
MUON ENG LOSS
30 Gev
120
80
40
0
0
10
20
30
40
50
MUON ENG LOSS
50 Gev
75
50
25
0
0
10
20
30
40
50
MUON ENG LOSS


100 GeV
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70
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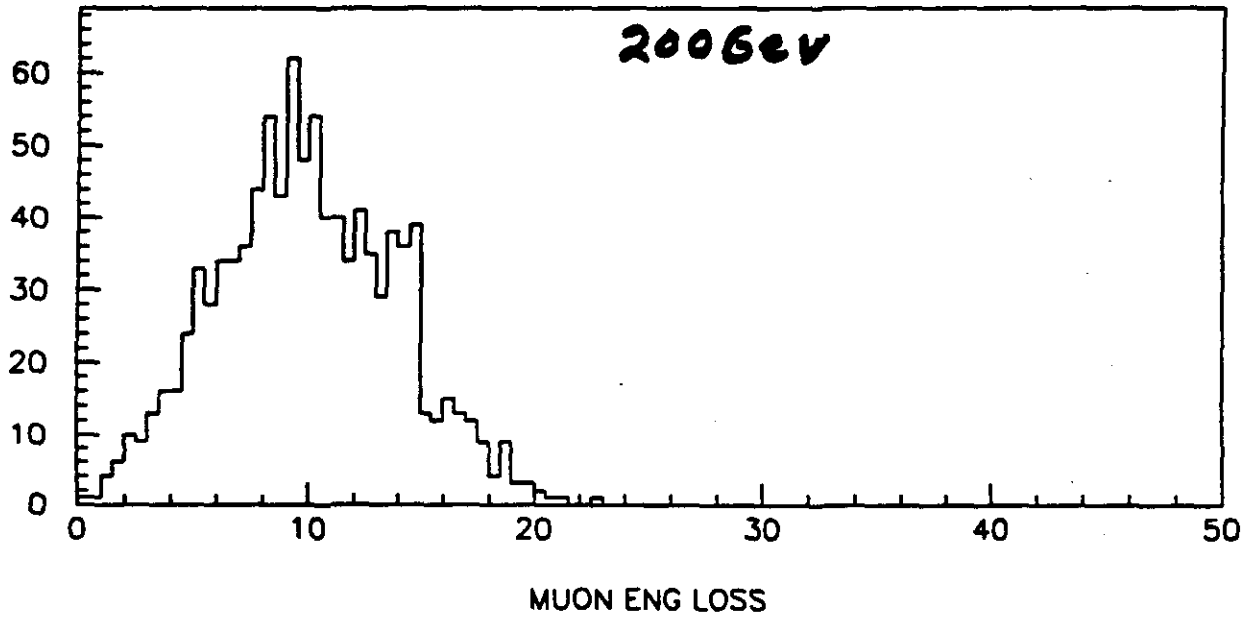
50
MUON ENG LOSS


200GeV
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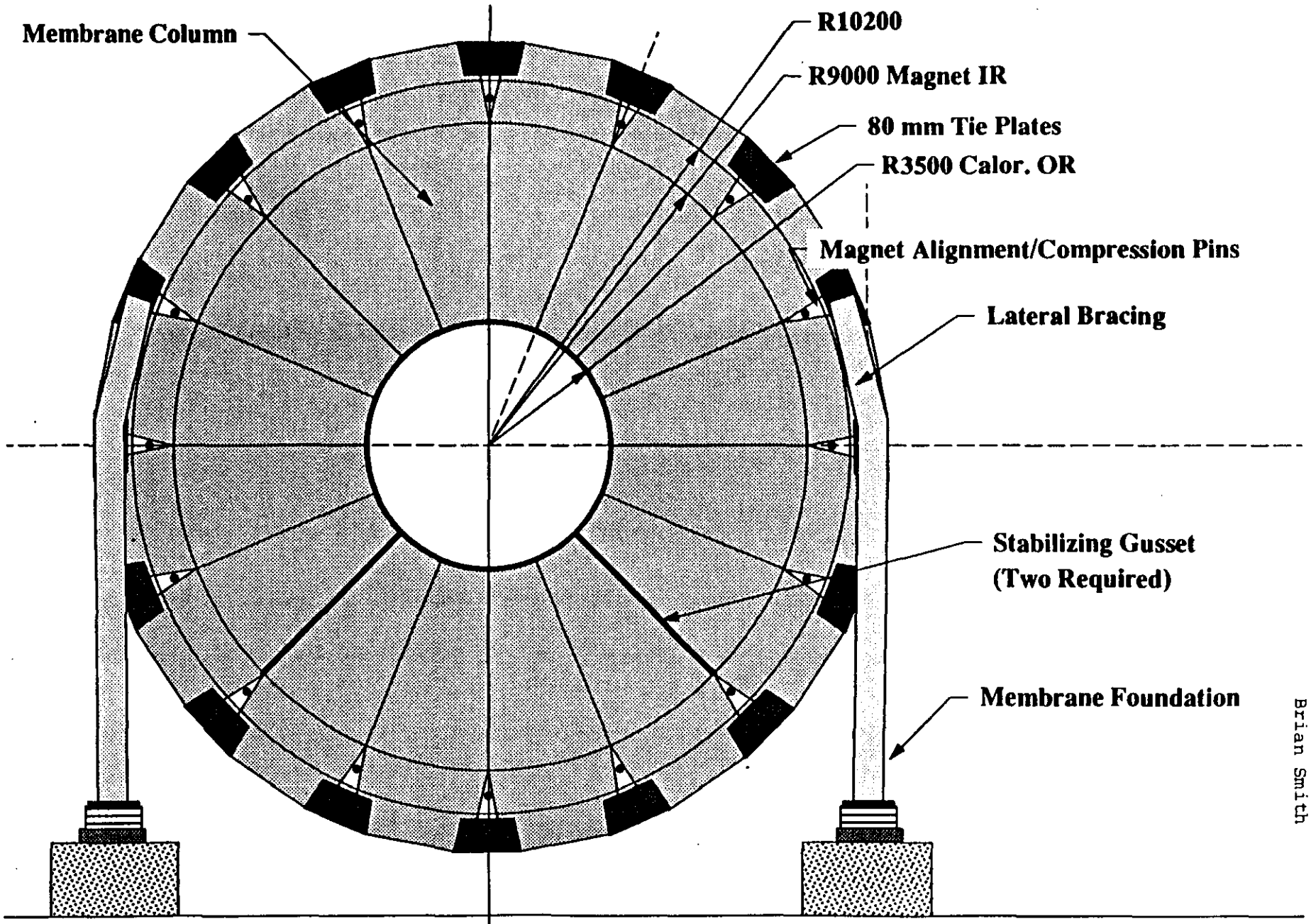
MUON ENG LOSS



Brian Smith

GEM Detector
Integral Calorimeter Support
Central Membrane

G.03.M.001
Sheet 1/2

Rennich

CENTRAL SUPPORT STUDY

Determine if the central support proposed by the calorimeter team "will work."

"Will Work" is define defined merely as having acceptable stress levels and having a linear buckling load factor greater than 1!!!!!

Another point of interest is to determine the minimum number of gussets necessary to work and minimum plate material thickness.

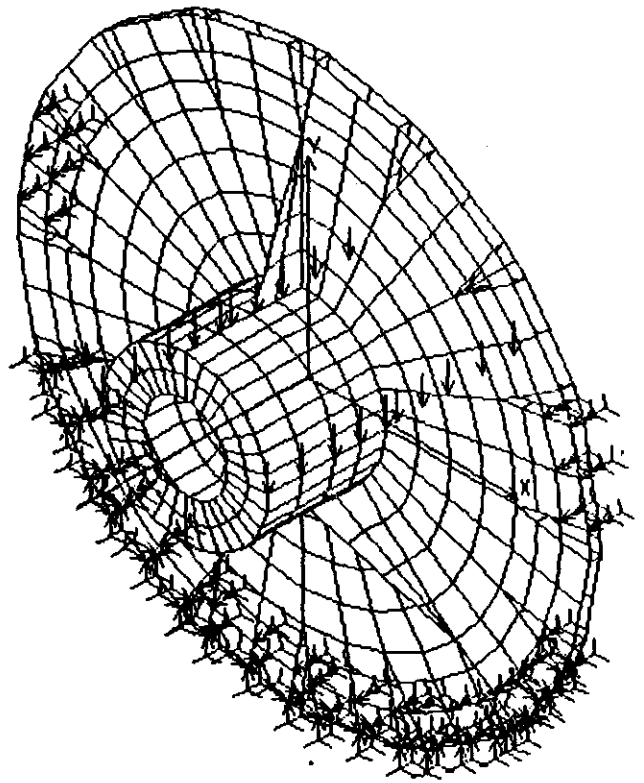
Structural Prameters

(1.) All materials assumed to steel.

(2.) Central support will still be supported from the bottom ie cradle.

(3.) Total calorimeter load is 2500Mt.

(4.) Adequate space for stiffening rings between barrel and end cap calorimeters.



COSMOS/M

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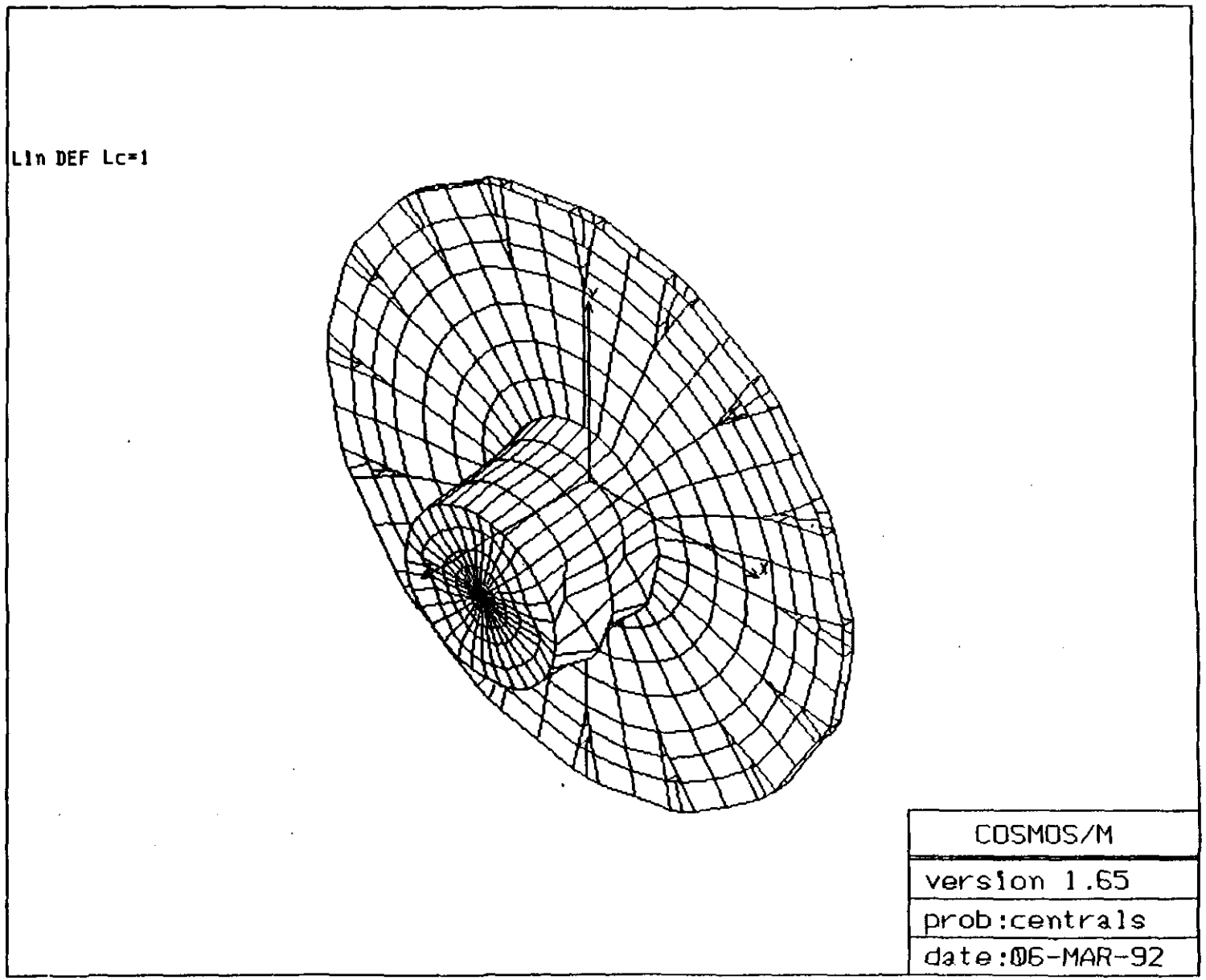
date:06-MAR-92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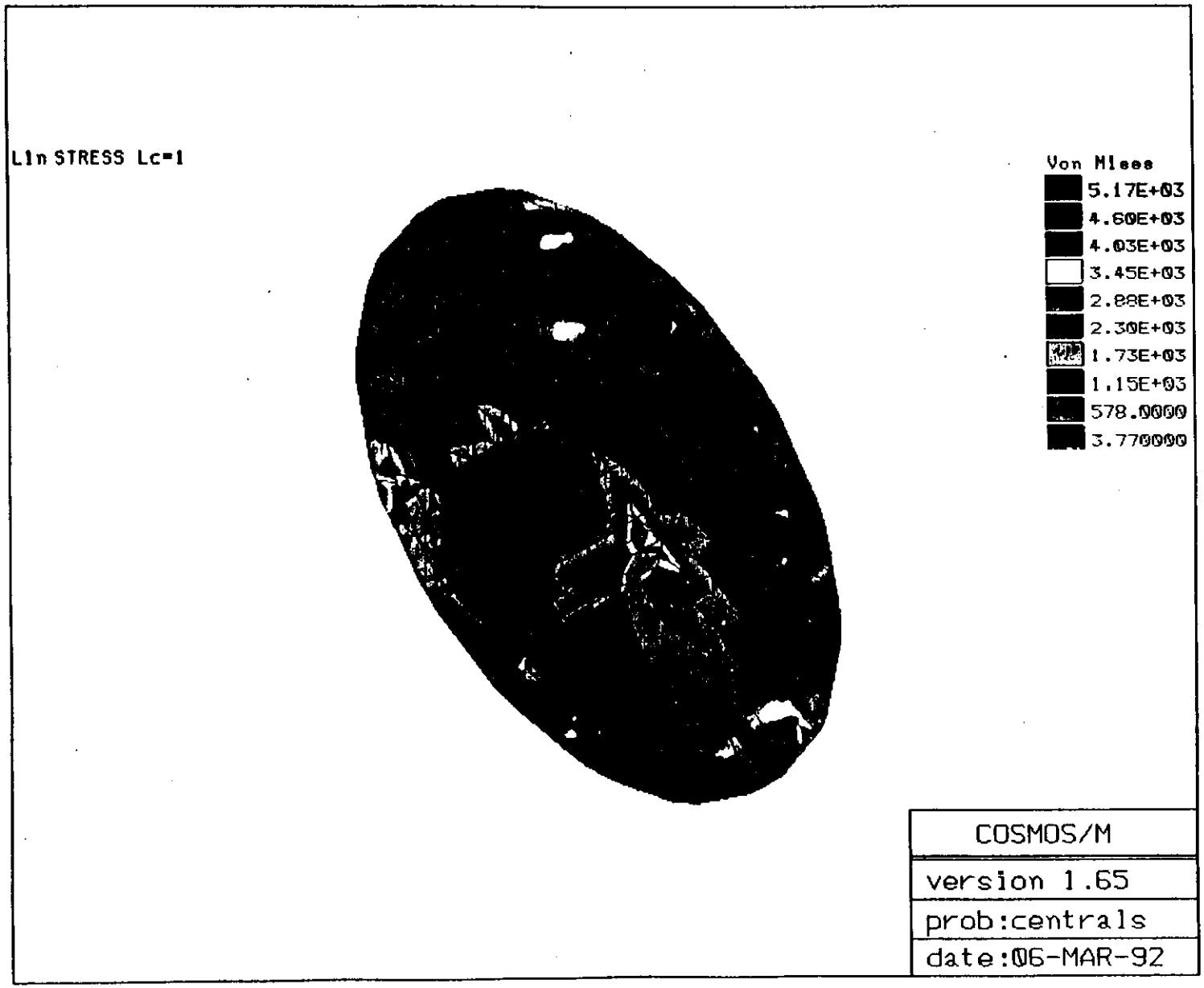
Lin STRESS Lc=1
Von Mises
5.17E+03
4.60E+03
4.03E+03
3.45E+03
2.88E+03
2.30E+03
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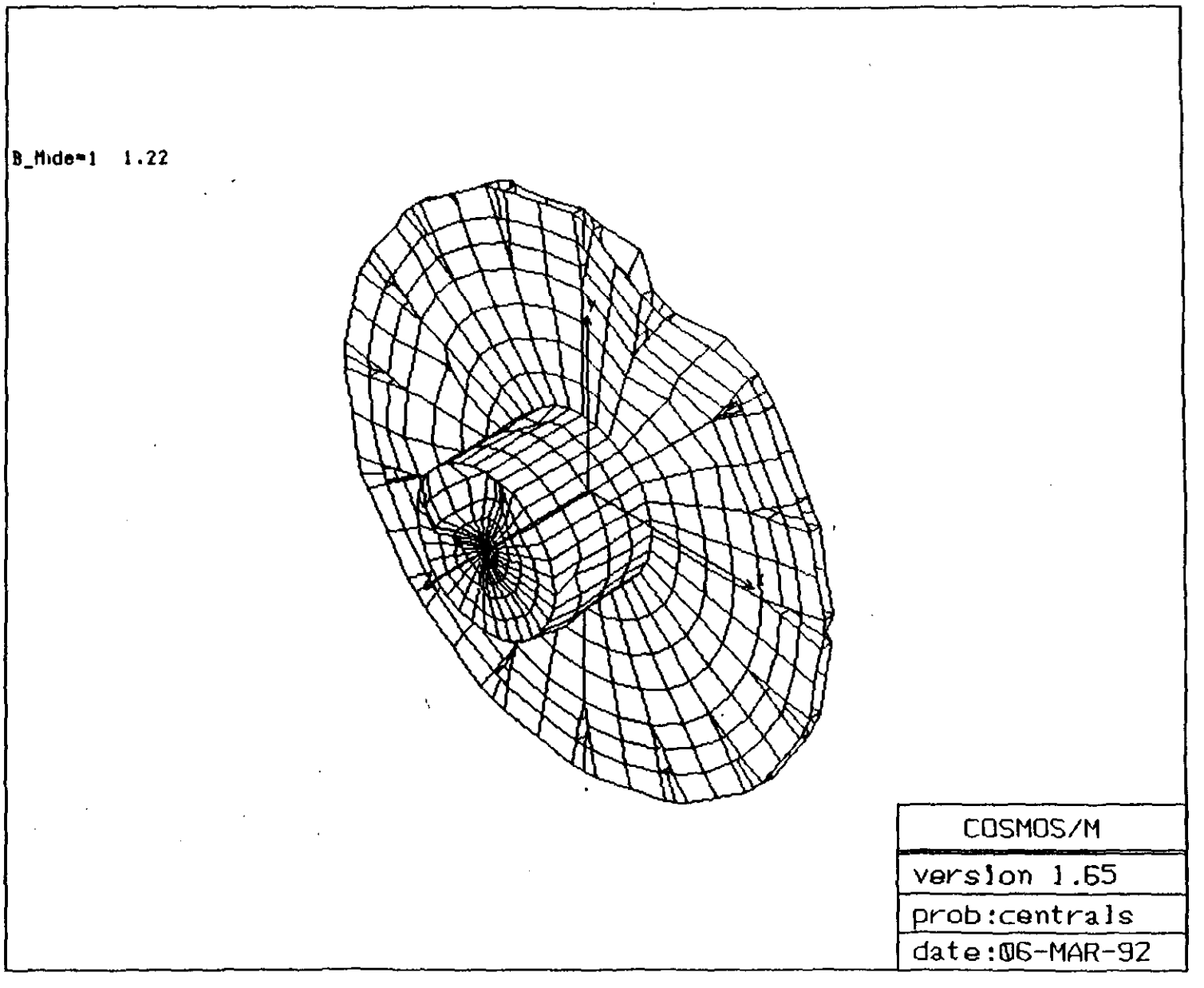
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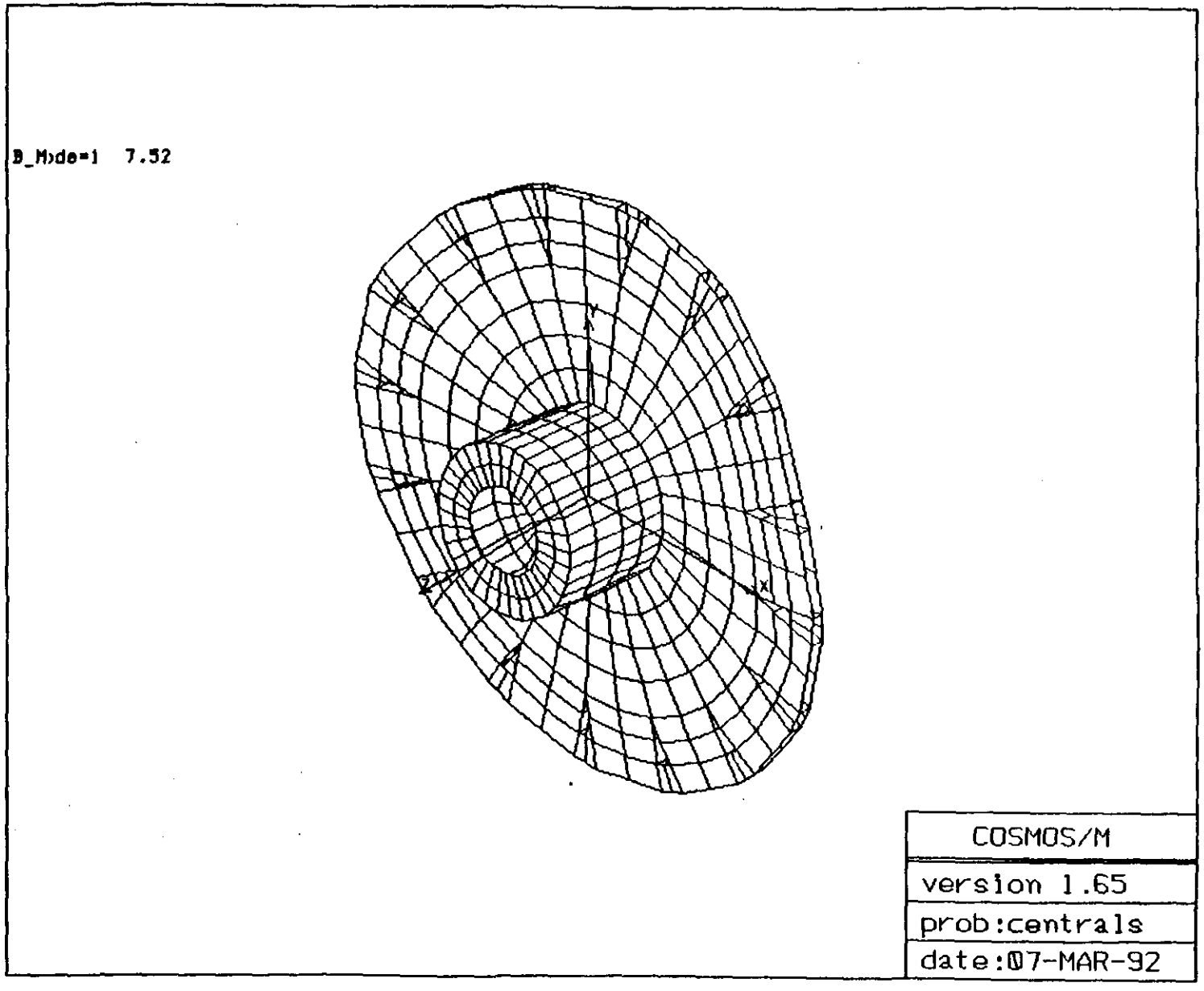
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RESULTS SUMMARIZED

(1.) Structure "will work" with no gussets and column material plate thickness of 4 inches.

(2.) Structure has higher buckling load factors without gussets than with. However, gussets reduce concetrated stress levels.

RECOMMENDATIONS

(1.) For baseline purposes use the proposed central support structure, [redacted]

(2.) Continue analysis to optimize and evalute using more accurate methods.

(3.) Consider different global support techniques.

Initiation of Detector Costing

G.Sanders

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

GEM Project Department

GEM Cost Book Schedule Proposal (3/9/92)

REVISED REVIEW DATES (and related dates):

February 19	WBS reorg. meeting (Sawicki, Fischer, Sanders, Lau...)	SSCL
February 25	Tracker subsystem review - costs presented	SSCL
March 3	Electronics cost meeting, internal	LeCroy
March 19	Electronics (all subsystems) cost review	SSCL
April 1	Magnet bidders conference	SSCL
April 2	Magnet cost review	SSCL
April 3	Muon subsystem cost review	SSCL
April 7	Tracker cost review	SSCL
April 8	Liquid argon calorimeters cost review	SSCL
April 9	Other calorimeters cost review	SSCL
April 14	Electronics cost review	SSCL
April 15	Total rollup, PM, interface systems, computing	SSCL
April 21-22	Remedial reviews	SSCL
April 23	Revised rollup	SSCL
April 30	GEM Collaboration Council meeting and Cost Book submission	SSCL

WEEK OF MAY 11 EXPECTED FOR "THERIOT" REVIEW

What is Required at Cost Reviews?

1. PARAMETERS: What have you estimated? Physics performance parameters and engineering and physical parameters, channel counts...

2. STATUS OF DESIGN: Conceptual, preliminary, detailed, guesswork? Identify team. Identify strengths and weaknesses in design to date.

3. ESTIMATE IN WBS: Cost estimate for subsystem in standard GEM WBS format in printed form and as an EXCEL file on disk, including basis of estimate tables, contingency analysis.

4. WORK SHEETS AND SUPPORTING MATERIALS: All backup materials which support the estimates including vendor estimates, drawings, complete explanation of parametric estimates, and materials from specific analogy studies. All significant cost estimate items in standardized worksheet form containing labor estimates, material estimates, etc.

5. SUMMARY INFORMATION: Tables or graphic charts summarizing top level indicators (contingency, EDI&A, amounts and fractions in engineering, labor, materials, etc.), identify all items which contribute to large fractions of cost, etc.

6. OPTIONS TO DESCOPE: Identify areas of high cost sensitivity and options for staging, descoping at the 10% and 20% levels. Identify areas of potential cost growth.

Attendence at Cost Reviews

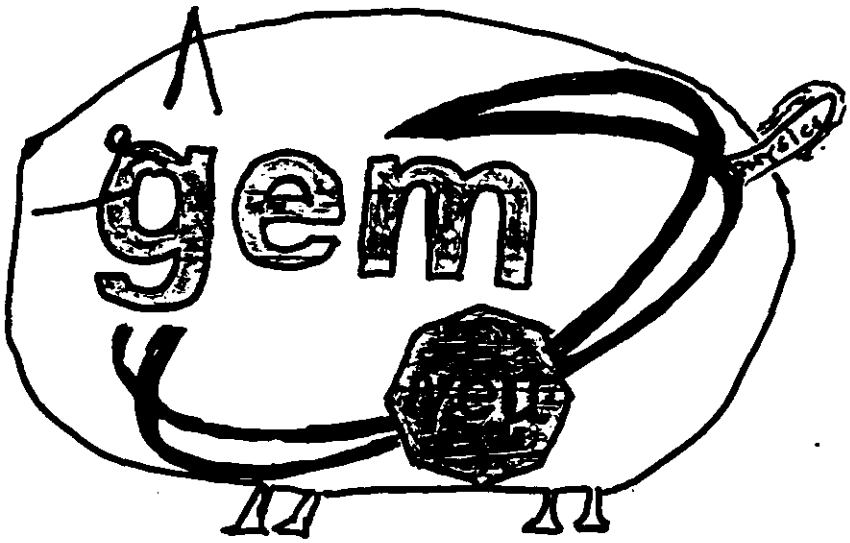
1. Subsystem lead physicists required.

2. Lead design engineers required.

3. Integration team members invited.

4. Cost estimate engineers required.

We must be able to work on cost modifications without undue dependence upon people not present at review. If we need to identify a 10% cost saving, it should be possible to do this at the review.



DETECTOR + PHYSICS SIMULATIONS

- KEN LANE / McFARLANE,
  FRANK PAIGE, REN-YUAN ZHU.
  + ...

Detector and Physics Simulations

I. FAST ϕ Status Reports - What's done? What's left??

CT - S. McKee, M. Brooks, E. Worin...
EC - R.-Y. Zhu (BaF_2), H. Ma (LAr)
HC - H. Ma (LAr), W. Worstell / R. Carey (SPACAL)
FC - M. Snupe
MU - F. Taylor, P. Dinglus, C. Yamagisawa, J. Sullivan, M. Mohammadi
MG - J. Sullivan, L. Roberts
TR - T.B.A.

II. GEM Baseline Proposal -

1. What's missing? → Spec'n of Preradiator → $\frac{\Delta E}{E}$
   What's incompletely specified?
   FEEDBACK to Mark (via K. McF., F. Paige) ASAP (or sooner!)
   and vice-versa!!!
2. Incorporating Baseline into FAST ϕ.
   Deadline 4/15! Need for PAC report - due 6/12

III. Physics Simulations for July PAC Meeting

(2/27/92 Memo) (Deadlines 4/15; ~6/15; 6/12)

1. Set list of processes.
2. Assign tasks - with commitments!
3. Set the schedule.

IV. SIMULATIONS FOR THE TDR – 1ST DRAFT DUE 5/29 !

↳ ~ SAME AS PAC REPT. BUT LONGER

1. BEGIN PLANNING FAST ϕ UPGRADE(S).

2. SET THE LIST OF PHYSICS PROCESSES.
   SAME AS III? MORE?

3. ASSIGN TASKS –

4. FINALIZE BY 4/30 SSCL MEETING !

V. SIMULATION INTEGRATION – KEN McFARLANE –

12 Physics Processes for PAC, TDR

1. $H^0 \to \gamma\gamma$ ($M_H \simeq 100$ GeV)

   Use baseline $\Delta E/E$ as well as
   $10\%/\sqrt{E} \oplus (1\text{-}2)\%$ (LAr), $2\%/\sqrt{E} \oplus (1\text{-}2)\%$ (PAC!)
   Also mis-ID's $e^\pm$ background to γ.

2. $t\bar{t}H^0 \to \ell^\pm_{isol} + \gamma\gamma + \cdots$ ($M_H \simeq 100$ GeV)

   Use baseline as well as worsened $\Delta E/E$.
   Include all backgrounds.

3. $H^0 \to e^+e^-e^+e^-$ ($M_H \simeq 150 - 800$ GeV)

   Baseline and worsened $\Delta E/E$. } PAC concerns
   Electron ID in end caps.
   Is this doable at 10^{34} for $M_H \simeq 800$ GeV?

4. $H^0 \to \mu^+\mu^-\mu^+\mu^-$ ($M_H \simeq 150 - 800$ GeV)

   Doable at 10^{34} for $M_H \simeq 800$ GeV?

5. $H^0 \to Z^0 Z^0 \to \ell^+\ell^-$ JET JET ($M_H \simeq 800$ GeV)

6. $H^0 \to Z^0 Z^0 \to \ell^+\ell^- \nu\bar{\nu}$ ($M_H \simeq 800$ GeV)

7. $t\bar{t}$ PRODUCTION AND m_t MEASUREMENT

- VIA $\ell^{\pm}_{iso}$ + ($b \to$ INCLUSIVE μ)
- $t \to W^+ b$ AND/OR $t \to H^+ b$

8. LEPTOQUARK PAIR PRODUCTION:

$$gg \to \Pi_{LQ}\, \Pi_{\bar{Q}L} \to b\tau^+ + \bar{b}\tau^-$$

9. QUARK SUBSTRUCTURE SIGNAL IN HIGH-P_T JETS

e/h AN IMPORTANT ISSUE.

10. QUARK/LEPTON SUBSTRUCTURE IN $\bar{q}q \to \mu^+\mu^-$

- $M_{\mu\mu} \gtrsim 2$ TeV — REQUIRES $\mathcal{L} \simeq 10^{34}$ FOR $\Lambda \simeq 25$ TeV
- $q \to \mu^-$ ANGULAR DISTRIBUTION DISCRIMINATES FORM OF CONTACT INTERACTION.
- REACH IN Λ AT 10^{34} ?

11. $Z'^0 \to \ell^+\ell^-$ FOR $\ell = e, \mu$; $M_{Z'} = 4$ TeV

- DETAILED STUDIES REQUIRE $\mathcal{L} = 10^{34}$
- PRECISE $M_{Z'}$, $\Gamma_{Z'}$ VIA e^+e^-
- DISCRIMINATE Z'^0 COUPLINGS VIA $\mu^+\mu^-$ ($\theta \to \mu^-$ ANGULAR DISTRIBUTION)
- ULTIMATE REACH IN $M_{Z'}$ AT 10^{34} ?

12. $\tilde{g}\tilde{g}$ PRODUCTION

- DISCOVERY, REACH BY $\not{E}_T$ SIGNATURE
- DISCOVERY, REACH BY $\ell^\pm\ell^\pm$ SIGNATURE ($\ell = e, \mu$).

What's Next?

W.Willis

GEM Collaboration Meeting
March 7-11, 1992 - Tucson, AZ

WHAT NEXT ?
WHAT NOW ?
GEM BASE LINE

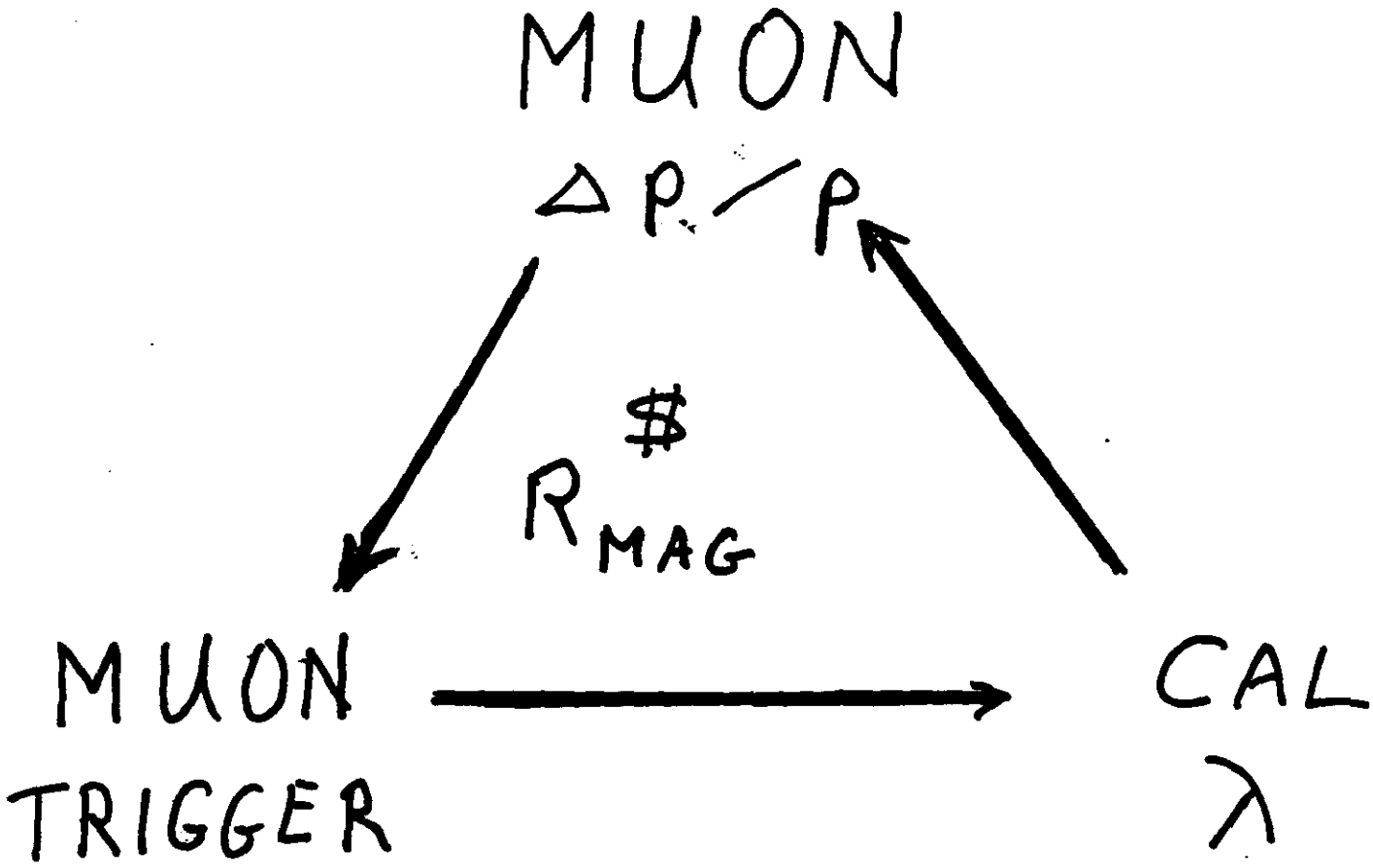
☆ GOOD FORWARD MUONS AND CALORIMETER
"HARDEST PROBLEMS"

☆ BEST E.M. CALORIMETER

* BARREL MUONS - MEET SPECS

* HADRON CALORIMETER -
MEETS SPECS - OUTER RADIUS
COST

* CENTRAL TRACKER -
GOOD REVIEW -
DESIGN SOON (ELECTRON
SIGN AT HIGH ENERGY ?) ✓


MUON
ΔP/P
$
R MAG
MUON
TRIGGER
CAL
λ

NEXT: BASE LINE COST

1ST PEEK ~ 20 APRIL
30 DAYS

SOME COST PROBS. LIKELY

- MAGNET - LITTLE FLEXIBILITY
- CENTRAL TRACKER REVIEW COMMITTIE "DON'T MAKE IT WORSE"
- CALORIMETER SYSTEM - "HOLD LINE, INCLUDE FORWARD CAL. + PRE-RAD.
- HADRON CALORIMETER "CHEAPER, DENSER
- MUONS: ?? TRIGGER "MAKE IT WORK .. TRIGGER, ALIGNMENT!"

THEN: MEMO TO PAC

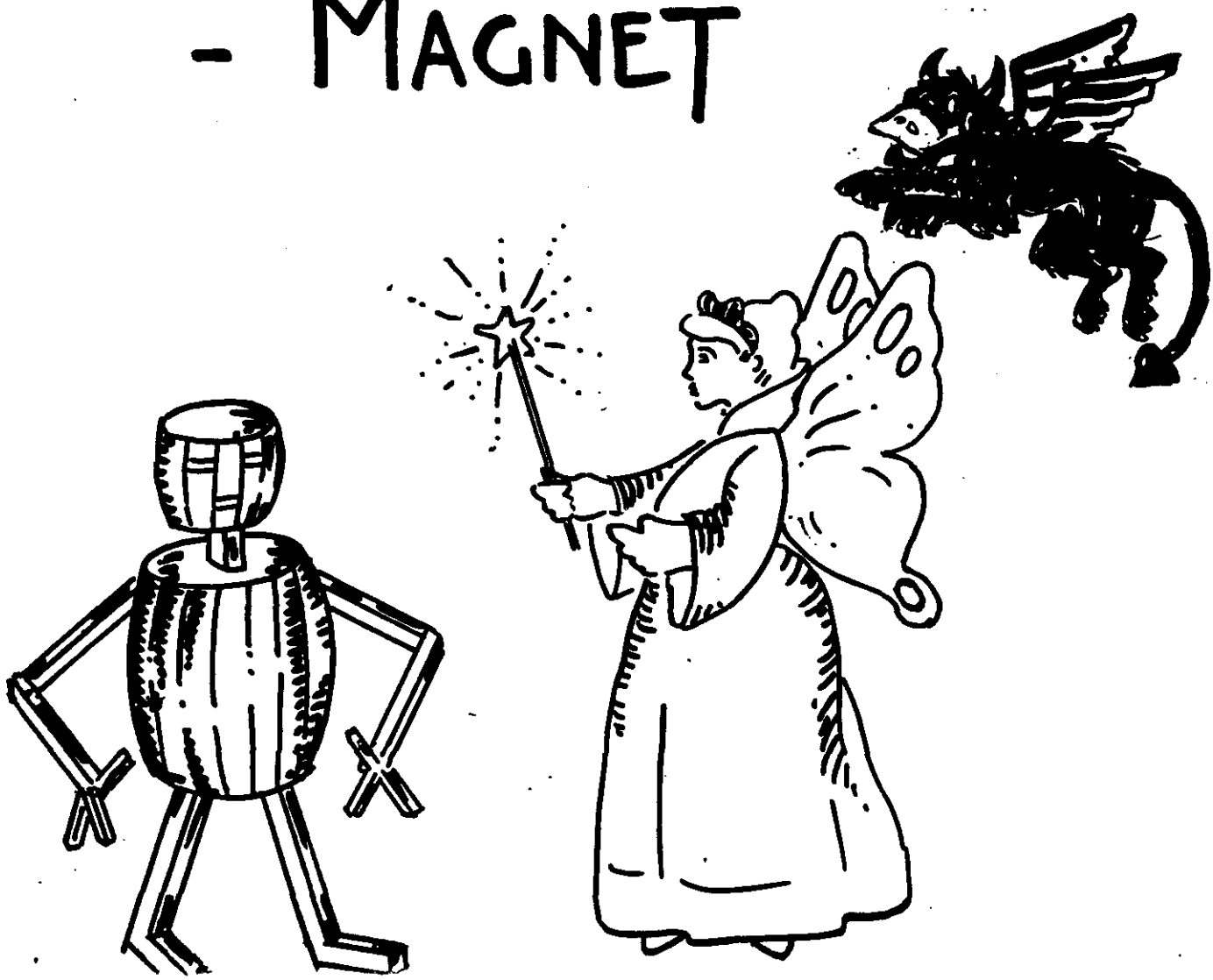
SUBMIT ~ 3 JULY

74 DAYS

- RESPOND TO DECEMBER COMMENTS

  BASE LINE MODIFIED TO FIX COSTS PLUS DECISIONS AS POSSIBLE

- MAGNET



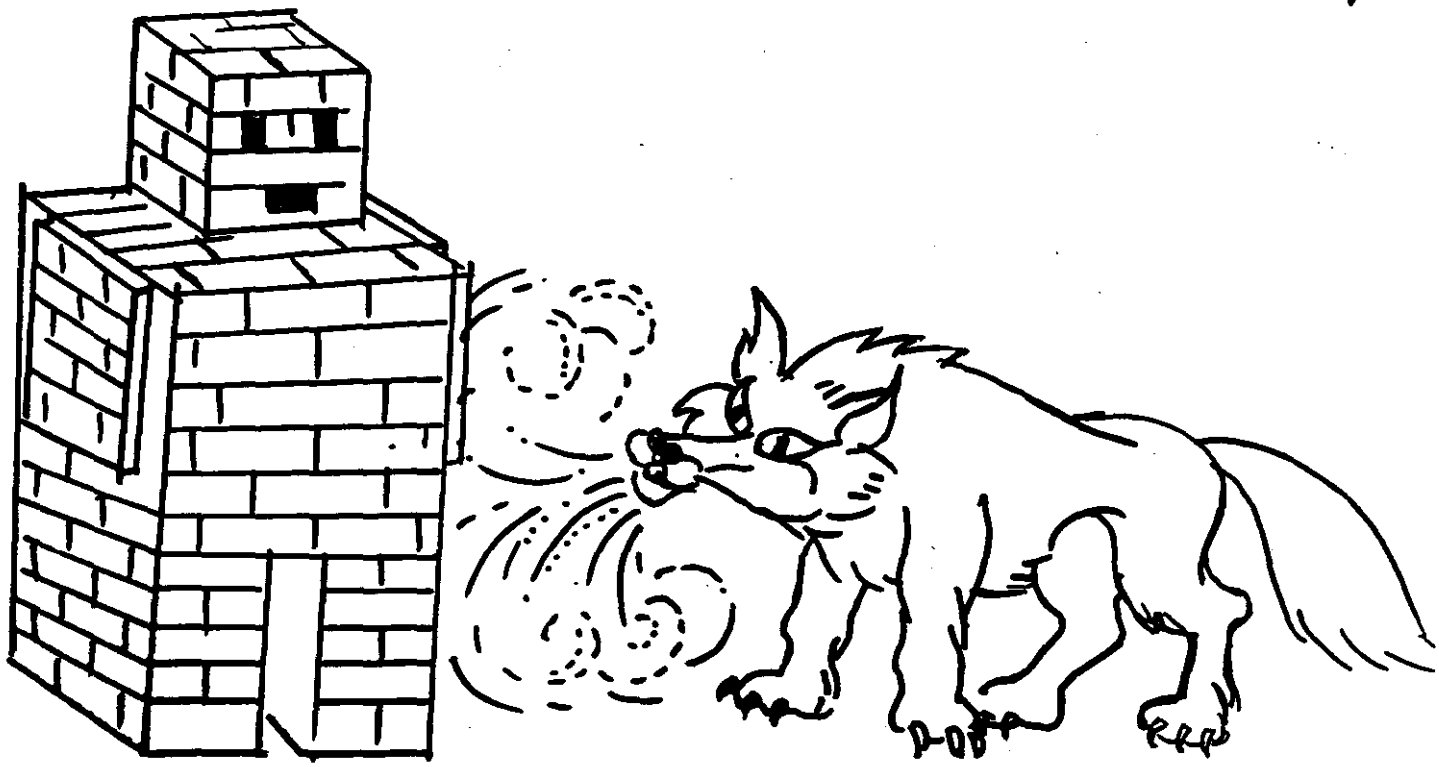
NEXT: LAST DECISIONS

~ 13 AUGUST **41** DAYS

AND THE BIG TDC

SUBMIT ~ 9 NOV. **88** DAYS

- MANAGEMENT! MANAGEMENT! MANAGEMENT!
- TECHNICALLY SOUND
- PAC BLESSED
- COST RELIABLE, < $500 M
  - (BACK DOORS ?!)



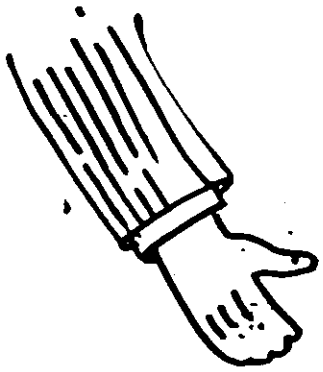
HEPAP SUBPANEL

"FUTURE OF HEP"

c/o E. C. FOWLER
DEPT. OF ENERGY
DIV. OF H.E.P.
WASHINGTON
DC 20585

243 DAYS TO SPIN STRAW INTO BRICKS

WE NEED A LOT OF WORK DONE DURING THIS SHORT, VITAL PERIOD



CAN WE GET HELP FROM PEOPLE NOT YET MUCH INVOLVED ?

PARTICULAR NEEDS ARE: HEPAP

- SIMULATION OF WHOLE DETECTOR
- DATA ACQUISITION
- WRITING AND EDITING

⇒ SSC VISITORS

IF YOU REALLY LIKE GEM, JOIN THE BIG EFFORT FOR FINAL APPROVAL AND TO GET CONSTRUCTION UNDER WAY!