GEM TN-92-216

Collaboration Council Meeting - SSCL

October 8, 1992

Abstract:

Agenda, attendees, and presentations of the GEM Collaboration Council Meeting held at the SSC Laboratory on October 8, 1992. Agenda items are: GEM News; Statement by Incoming Council Chair; Project Manager's Report; Calorimetry Decisions and Plans; Muon Decisions; and Tracker Status and Progress Toward TDR.

Council Meeting
October 8, 1992

Auditorium

9:00	GEM News (Barish)
9:30	Statement by Incoming Council Chair (Yost)
9:45	Project Manager's Report (Sanders)
10:15	BREAK
10:30	Calorimetry Decisions and Plans (Barish/Kamyshkov)
11:45	Discussion
12:00	Lunch
1:00	Muon Decisions (Taylor/Sawicki/Whitaker/Wuest/Osborne/Bromberg)
2:45	Tracker Status and Progress Toward TDR (Baltay/Morgan)

Executive Committee Meeting

Directorate #2

3:00	Executive Committee Meeting (continues Friday)

Participants List

10/12/92

LAST NAME	FIRST NAME	AFFILIATION
Adams	Lyn	Eurus Technologies
Allen	Charles C.	University of Texas at Austin
Antos	Jaroslav	Institute of Physics, Academia Sinica
Baker	Howard	Draper Laboratory
Baltay	Charles	Yale University
Barish	Barry C.	California Inst. of Technology
Branson	James G	University of California - San Diego
Bugg	William M.	University of Tennessee
Chargin	Anthony K.	Lawrence Livermore National Laboratory
Cohn	Hans O.	Oak Ridge National Laboratory
Eisenberg	J.	University of Washington
Fackler	Orrin D.	Lawrence Livermore National Laboratory
Gordon	Howard	Brookhaven National Laboratory
Gratchev	V. T.	St. Petersburg Nuclear Physics Inst.
Kamyshkov	Yuri	Inst. for Theor. and Exper. Physics, (ITEP)
Lane	Kenneth D.	Boston University
Lissauer	David	Brookhaven National Laboratory
Liu	Gary	California Institute of Technology
Mauger	Joe	Lawrence Livermore National Laboratory
McKee	Shawn	University of Michigan
Miller	Robert J.	Michigan State University
Mrenna	Stephen	California Inst. of Technology
Nimblett	Frank	Draper Laboratory
Olness	Fredrick	Southern Methodist University

Participants List

10/12/92

LAST NAME	FIRST NAME	AFFILIATION
Onel	Yasar	University of Iowa
Osborne	Louis S.	Massachusetts Institute of Technology
Panvini	Robert S.	Vanderbilt University
Plasil	Frank	Oak Ridge National Laboratory
Polychronakos	Venetios A.	Brookhaven National Laboratory
Prokofiev	O. E.	Brookhaven National Laboratory
Rennich	Mark	Oak Ridge National Laboratory
Rutherfoord	John P.	University of Arizona
Shaevitz	Michael	Columbia University
Shaver	Leif	University of Arizona
Slattery	Paul F.	University of Rochester
Stroynowski	Ryszard	Southern Methodist University
Sullivan	Greg	University of Chicago
Taylor	Frank E.	Massachusetts Institute of Technology
Tchernlatin	Valeri	Moscow Physics Engineering Institute
Todd	Richard A.	Oak Ridge National Laboratory
VanBibber	Karl	Lawrence Livermore National Laboratory
Vogel	Helmut	Carnegie-Mellon University
Wang	Ming-Jer	Academia Sinica
Webb	Robert C.	Texas A&M University
Whitaker	Scott	Boston University
Willis	William	Columbia University
Wuest	Craig R.	Lawrence Livermore National Laboratory
Yamamoto	Hiroaki	California Institute of Technology

Participants List

10/12/92

LAST NAME	FIRST NAME	AFFILIATION
Yanagisawa	Chiaki	State Univ. of New York at Stony Brook
Zhou	Bing	Boston University
Zhu	Ren-yuan	California Inst. of Technology

PARTICIPANTS LISTING

LAST NAME	FIRST NAME	INSTITUTION
DiGiacomo	Nicholas Joseph	Martin Marietta Astronautics Group

PARTICIPANTS LISTING

LAST NAME	FIRST NAME	INSTITUTION
Dingus	Peter	SSC Laboratory
Glebov	Vladimir	SSC Laboratory
Golutvin	Andrei	SSC Laboratory
Guo	Ya-Nan	SSC Laboratory
Harris	Mike	SSC Laboratory
Marx	Mike	SSC Laboratory
McFarlane	Kenneth	SSC Laboratory
Milner	Edward	SSC Laboratory
Mitselmakher	Gena	SSC Laboratory
Morgan	Kate	SSC Laboratory
Ostapchuk	Andrey	SSC Laboratory
Paige	Frank	SSC Laboratory
Reidy	Jim	SSC Laboratory
Sanders	Gary	SSC Laboratory
Shang	Rencheng	SSC Laboratory
Sheer	Irwin	SSC Laboratory
Shypit	Rick	SSC Laboratory
Stocker	Frank	SSC Laboratory
Vaniachine	Alexandre	SSC Laboratory
Villasenor	Luis	SSC Laboratory
Xia	Song-Jiang	SSC Laboratory
Yost	George P.	SSC Laboratory

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Presentation by:

George Yost

GEM COUNCIL (YOST)

"LEGITIMIZE AND APPROVE THE GEM ORGANIZATION AND SELECT OR APPROVE THE SELECTION OF "GEM MANAGEMENT PEOPLE

ONE REPRESENTATIVE FROM EACH INSTITUTION

CHAIR ELECTED BY THE I.R.'S –

ONE YEAR TERM, RENEWABLE ONCE

FUNCTIONS OF THE CHAIR

- REPRESENT THE COUNCIL (AND, BY EXTENSION, THE WHOLE COLLABORATION)

  TO MANAGEMENT

  IN MANAGEMENT (VIA MEMBERSHIP ON EXECUTIVE COMMITTEE, OTHER COMMITTEES)

DATES

COUNCIL MEETINGS

DECEMBER: PAC MEETS 2-4.

NO REAL ADVANTAGE TO MEETING THIS WEEK. COULD HAVE DRY RUNS BEFORE THE PAC, BUT NO NEED TO INVOLVE THE FULL COUNCIL.

PROPOSAL: DEC 10

1993: TDR DUE JAN 31.

MEET BEFORE? POSSIBLE, BUT MAY ONLY INTERFERE WITH TDR WORK.

PROPOSAL: FEB 4

TIME TO START RECOVERY FROM TDR, CHART COURSE FOR NEXT STAGES OF THE EXPERIMENT.

MARCH, 1993: PAC REVIEW FOR AN ENTIRE WEEK, THE FIRST WEEK IN MARCH.

PROPOSAL: MARCH 18

GOOD TIME TO REVIEW FEEDBACK FROM PAC AND DISCUSS PROCEEDING TOWARD CONSTRUCTION

BROOKHAVEN GENERAL COLLABORATION MEETING

GEM Collaboration Meeting

at BNL Nov. 4-6, 1992

All meals will be included in the fee to encourage FULL participation.

Housing Requests and Fees must be sent to

Doris Rueger
Physics Dept. 510 A
Brookhaven National Laboratory
Upton, NY 11973
rueger@bnlcl1

$125 (if received* before Oct. 15, 1992)
$175 (after Oct. 15!)

*Postmark date or Email date of request

COUNCIL MEETING FORMAT

WE ARE PASSING THROUGH THE MAJOR DECISIONS PHASE.

NEED TO REFINE THE FORMAT A LITTLE IN RESPONSE TO CHANGING CONDITIONS.

IF WE JUST GO THROUGH A SUCCESSION OF 6-WEEKS UPDATES WE WILL BORE OURSELVES TO TEARS.

PROPOSED NEW FORMAT

- BRIEF STATUS REPORTS
- CURRENTLY HOT TOPICS
- RESEARCH REPORTS FROM COLLABORATION:
  15-20 MIN FORMAT (TYPICAL)
  - KEEP COLLABORATION INFORMED
  - GET FEEDBACK
  - INVOLVE LOTS OF PEOPLE, INCLUDING
    - UNIVERSITY PEOPLE
    - YOUNG PEOPLE

LOOKING FOR SUGGESTIONS / VOLUNTEERS FOR DECEMBER

SSCVX1:: YOST
OR YOST@SSCVX1

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Presentation by:

Gary Sanders

Project Manager's Report

1) Project Controls Meetings — Progress and problems
2) Magnet status
3) TDR Plan
4) R&D/Engineering Funding in FY93
5) Integration
6) Facilities
7) Staffing
8) PM 3-month schedules

Project Controls Meetings

1) Each subsystem leader reports 3 things to Project Manager
   a. 3-month activities schedule
   b. Progress of each task/institution
   c. Ranked problems.

2) Minutes of meetings serve as:
   a. Monthly progress summary
   b. Corrective action items
   c. Track previous action items.

3) Held same week as Collaboration Council
   (Wednesday noon-1:30)

4) Subsystem leaders hear progress and problems in other systems

5) Puts progress report burden directly on subsystem leaders. Keep current brief progress reports in place.

Magnet Status

1) Acquisition Plan approved

2) Draft RFP comments from industry incorporated

3) SSA, SSB appointment requested of Director

4) Industry alerted

5) SSCL final magnet review of design and management next Tuesday

6) RFP could be released shortly after

FY93 SSC Program Planning in progress.
This may affect nature and timing of magnet procurement.

Proposed TDR Organization and Dates

Vol	Contents	Pages	Lead Authors
1	Executive Summary	25	Barish, Willis
2	Magnet TDR Due complete Nov. 20	100	Stroynowski
3	Muon Drafts due Nov. 6, Dec. 4, Jan. 4	100	Taylor, Marx
4	Calorimeters Drafts due Nov. 6, Dec. 4, Jan. 4	100	Kamyshkov
5	Tracker Drafts due Nov. 6, Dec. 4, Jan. 4	100	Baltay
6	Electronics Drafts due Nov. 6, Dec. 4, Jan. 4	100	Marlow, Shaevitz
7	Computing, Controls, Communication Drafts due Nov. 6, Dec. 4, Jan. 4	25	McFarlane, Cormell
8	Physics Goals, Performance, Simulations Drafts due Nov. 6, Dec. 4, Jan. 4	80	Barish
9	Summary of GEFUR Drafts due Nov. 6, Dec. 4	25	Harris
10	Installation Plan Drafts due Dec. 4, Jan. 4	25	Harris
11	Summary Cost Estimate/Responsibility Matrix Funding Plan Drafts due Dec. 4, Jan. 4	10	Sanders, Barish, Willis
12	Summary of GEM Project Management Plan Drafts due Nov. 6, Dec. 4	10	Sanders, Baltay
13	Summary Safety Analysis Drafts due Dec. 4, Jan. 4	10	Woolley
14	Operational Plan/Upgrades Drafts due Dec. 4, Jan. 4	20	Barish, Willis
15	Test & Calibration Plan Drafts due Nov. 6, Dec. 4, Jan. 4	20	Yost
		750 pages	

Separate documents

GEM Project Management Plan Drafts due Nov. 6, Dec. 4	Sanders, Baltay
Cost/Schedule Baseline and WBS Dictionary Drafts due Dec. 4, Jan. 4	Sanders, Fischer
GEM Conceptual Safety Analysis Report Drafts due Dec. 4, Jan. 4	Woolley

ALL PAGE NUMBERS INCLUDE FIGURES AND TABLES

" Politics are almost as exciting as war, and quite as dangerous. In war, you can be killed only once, but in politics many times."

WINSTON CHURCHILL

FY93 R&D/Engineering Funding

1) FY93 SSCL-wide planning quite mature.

2) Gilman, Kirk and Sanders reviewing guidance and plan to meet with John Rees

3) Webb, Sanders, Harris awaiting revised proposals from muon and calorimeter groups

4) Possible budget targets to large subsystems communicated.

5) Some urgent disbursements already acted upon.

6) Expect to finalize at BNL meeting, though some funds disbursed before.

7) TNRLC deadline November 1.

8) GEM first round university budgets disbursed by mid-November.

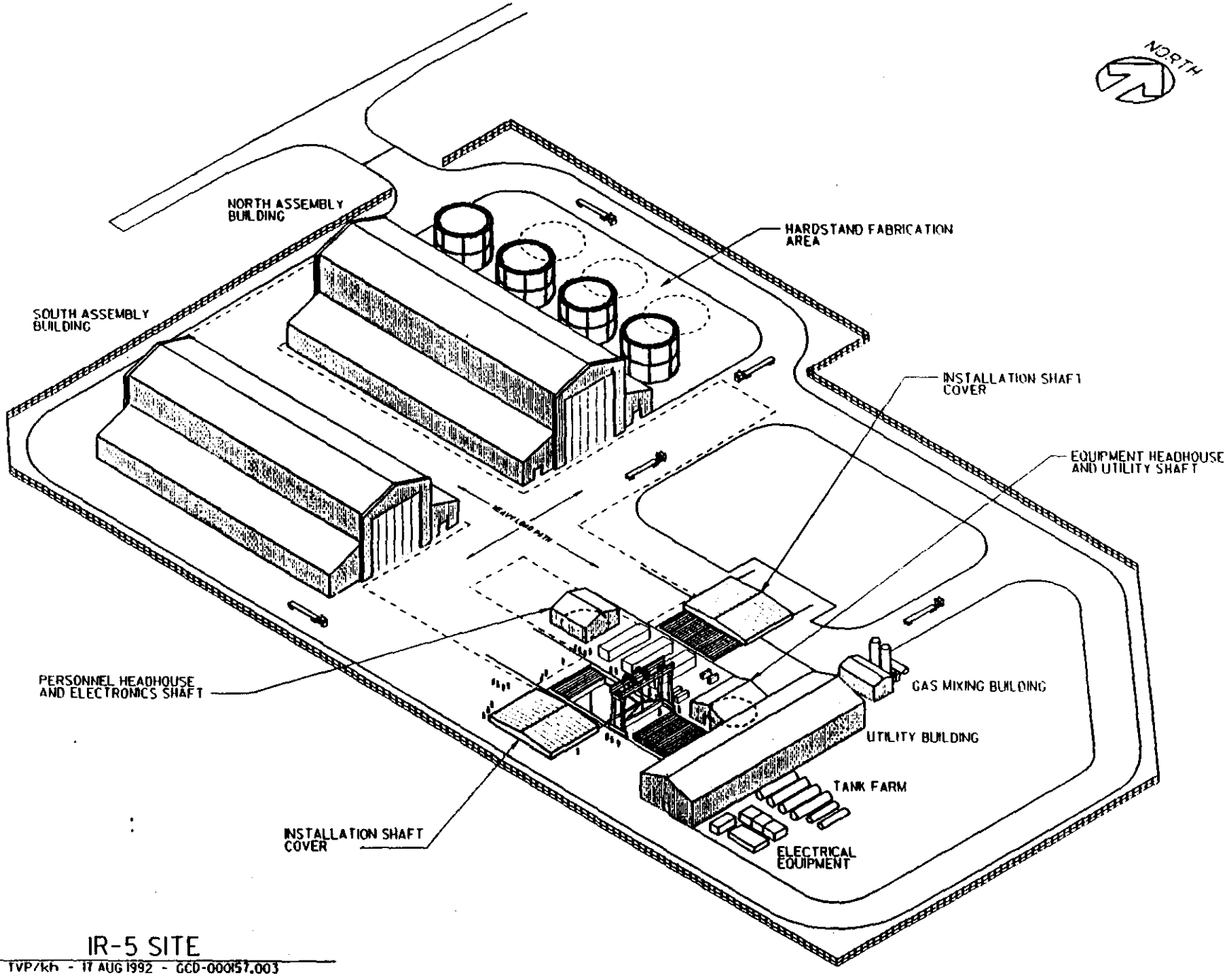
9) Detail MOUs required for each allocation.

Integration and Facilities

1) Integration now coordinated by Barish, Sanders, and Harris through regular Engineering Meetings and Task Forces.

2) Facilities have made major progress —
   a) Surface facilities in Title I
   b) Underground hall in Title I with Title I for hall shell now complete.
   c) Shell Title II commences next month.

Title I = 30% of all construction design drawings
Title II = Ready to build design package complete
Title III = Construction management, changes, and inspection.



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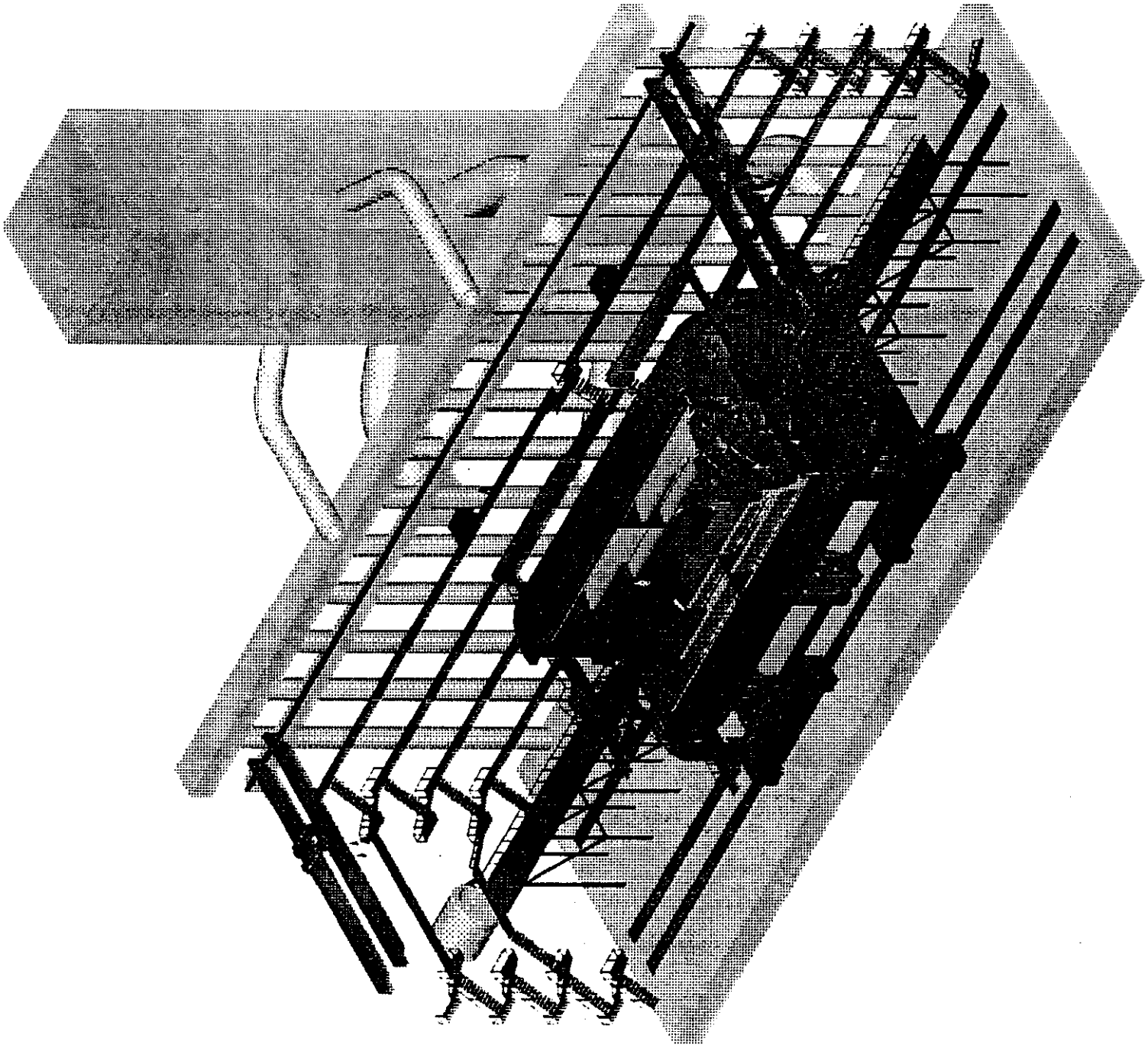

Staffing

Key Project staff slots now being recruited.

1) **Magnet construction/control**

2) **Lead GEM systems engineer**

3) **Subsystem Project Managers**

4) **Requisition Coordinator**

5) **Cost/schedule analysts**

   a) **Cost/schedule baseline being put together by very talented temporaries. Teams visiting subsystems.**

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Presentation by:

Yu. Kamyshkov

Hybrid Calorimeter

LKr EM

+

Sci.Fiber Hadronic

Yu. Kamyshkov, ORNL

Oct. 8, 92

Hybrid Option (Liquid EM + Scintillator HC)

- Was considered by GEM Exec. Committee in May and was recommended for engineering and MC studies. MC and engineering studies were performed during June-July
- Was presented to PAC in July
- After the e-m decision Hybrid Calorimeter Task Force Group has been formed to study agressively the issues related to hybrid option

Members of the Group:

Cliff Eberle, Howard Gordon, Mike Harris, Yuri Kamyshkov, Lyle Mason, Mark Rennich, Gary Sanders, Larry Sulak, Bill Wisniewski (chairman)

Direction of the Group:

Evaluate the potential of a hybrid calorimeter with liquid krypton electromagnetic and scintillating fiber hadronic sections. Identify show-stoppers. If there are no show stoppers, identify attractive features of the hybrid calorimeter, list areas which need more work, and evaluate major risks.

Meetings and proceedings :

Three very effective meeting of Task Force in September. Official report is being presently prepared and will be ready within few days (Bill Wisniewski)

I will present my personal perceptions and conclusions which I believe closely and correctly reflect the oppinion of the majority of the Group

July '92.

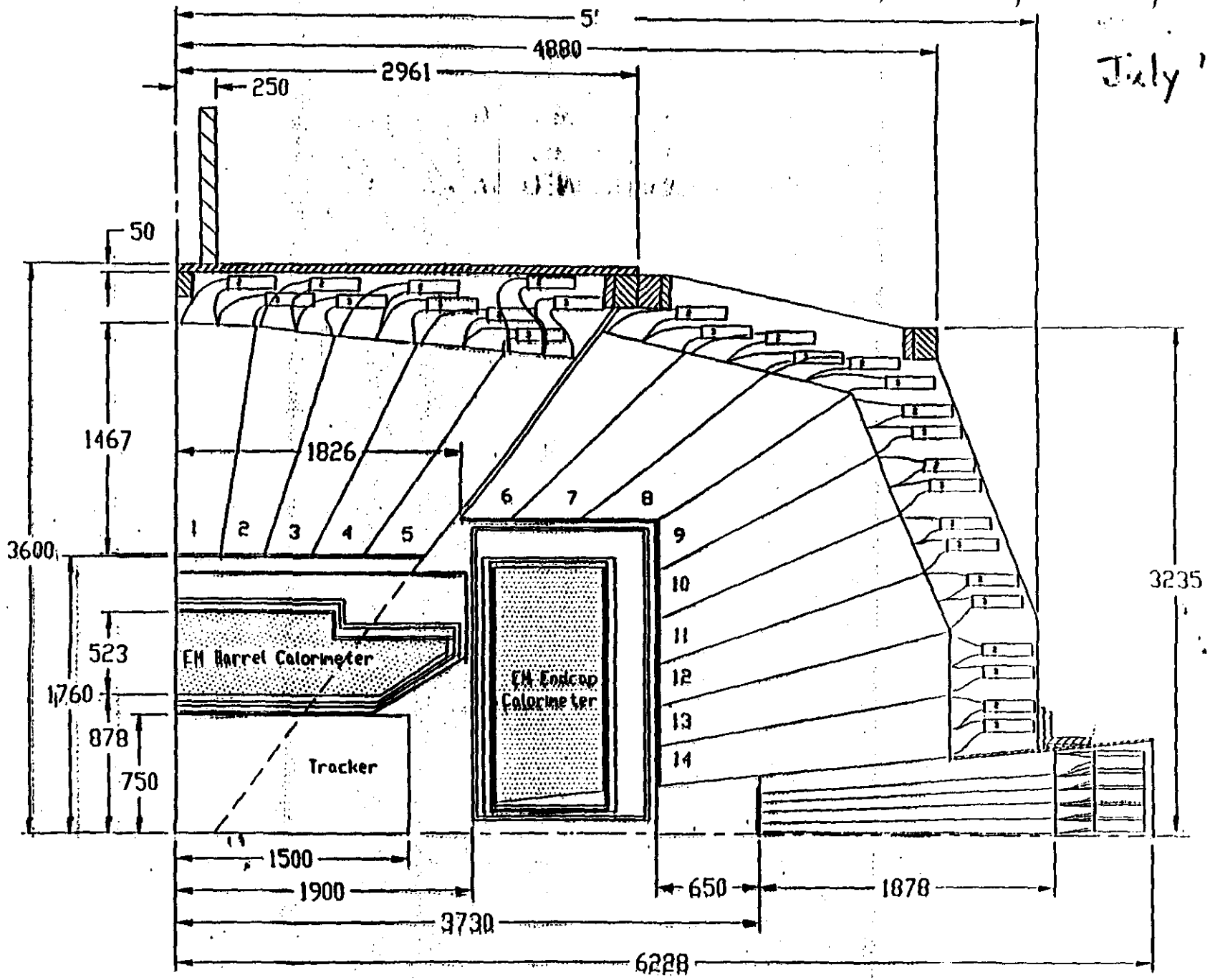
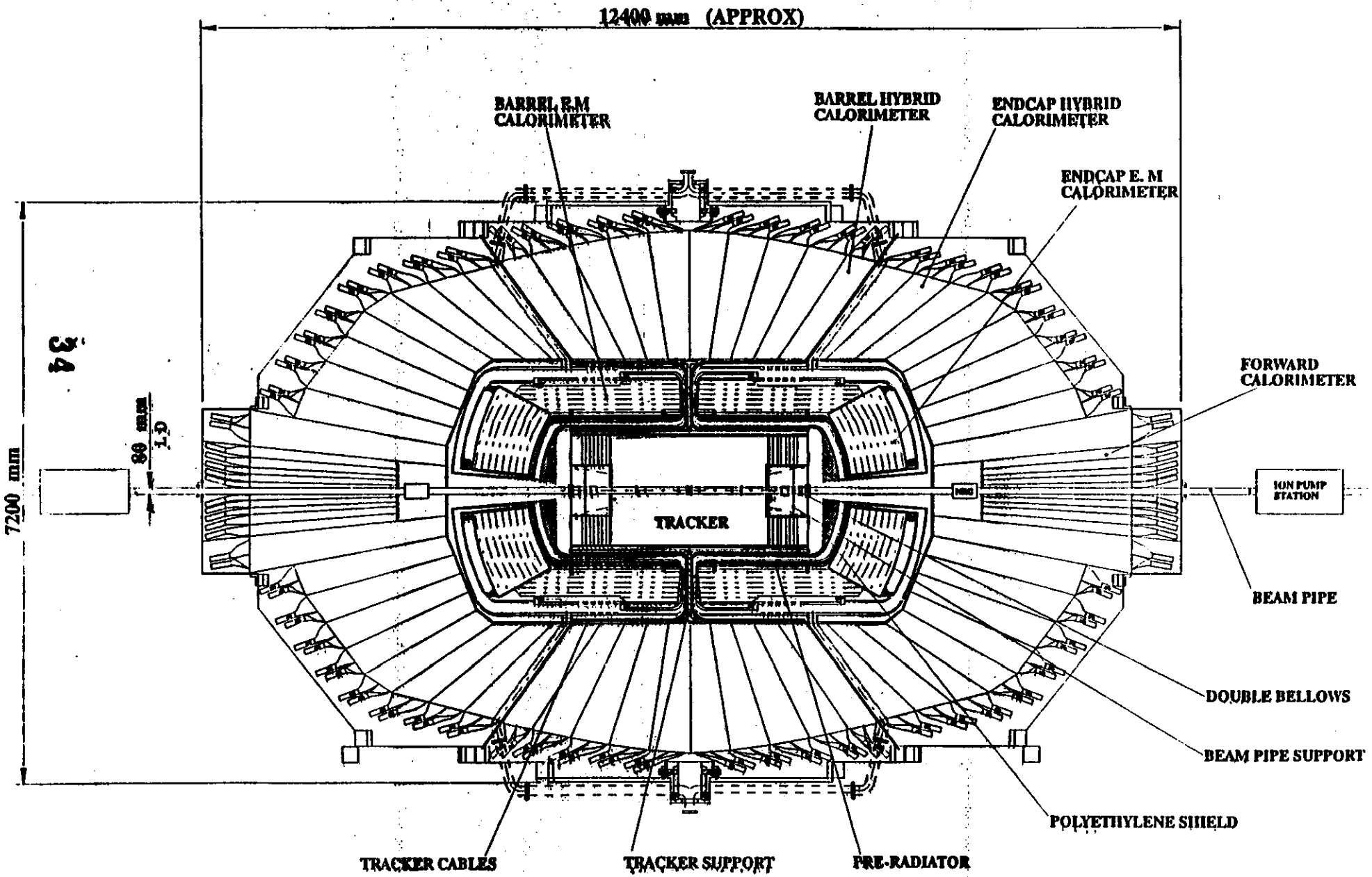


Figure 13

GEM DETECTOR
Fiber Hadron Calorimeter
Fiber with Current LKr Design

HYBRID CALORIMETER



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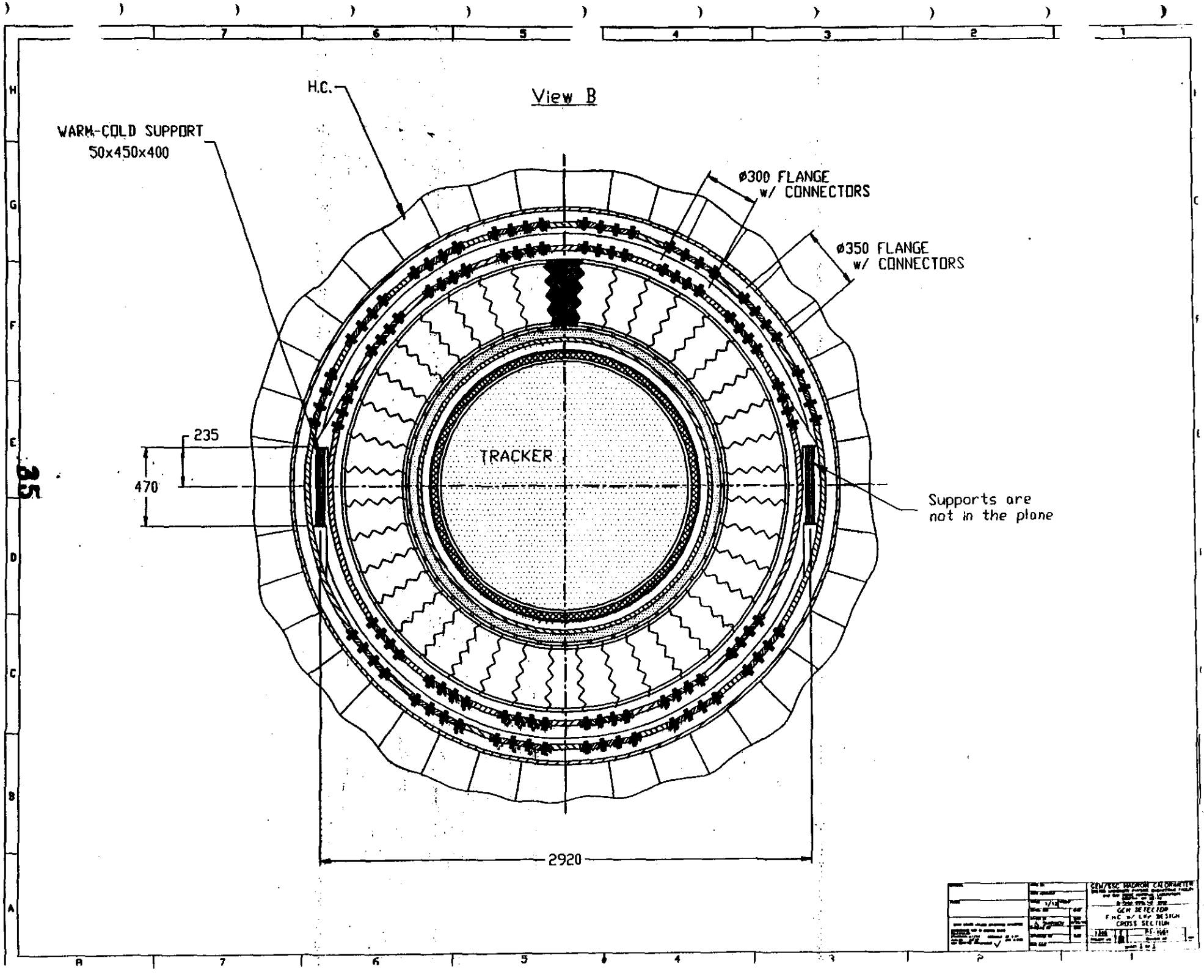
View B
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WARM-COLD SUPPORT
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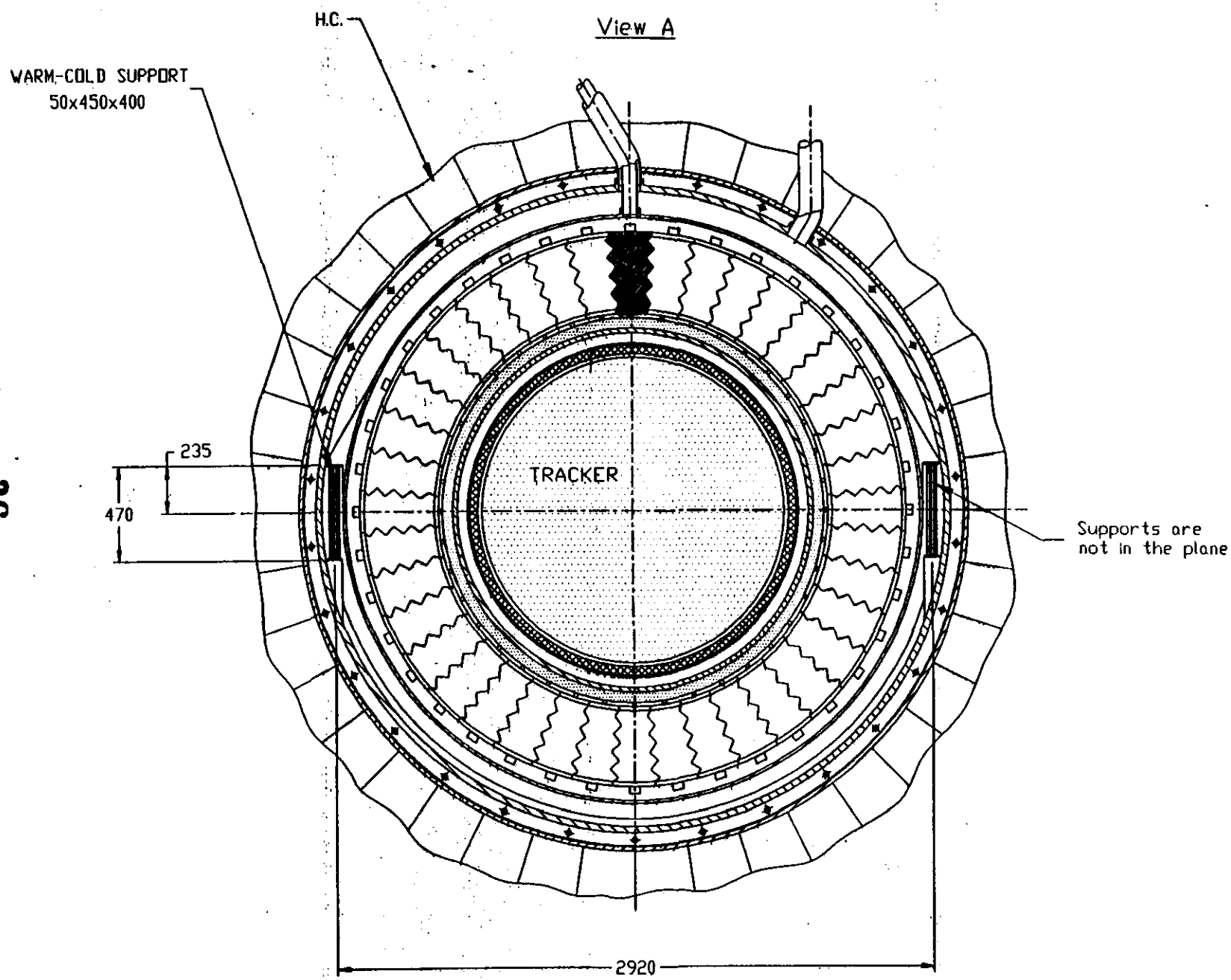
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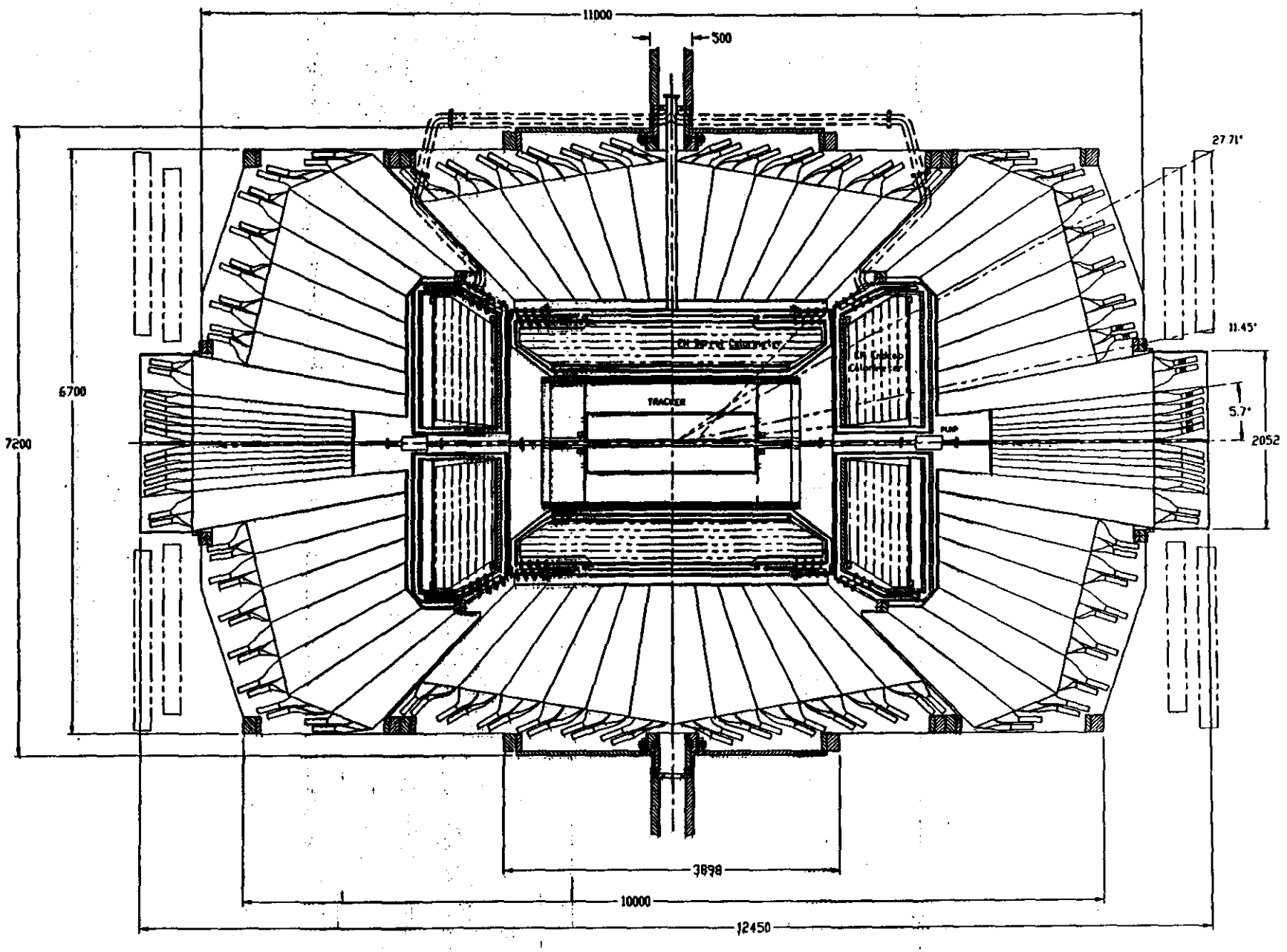


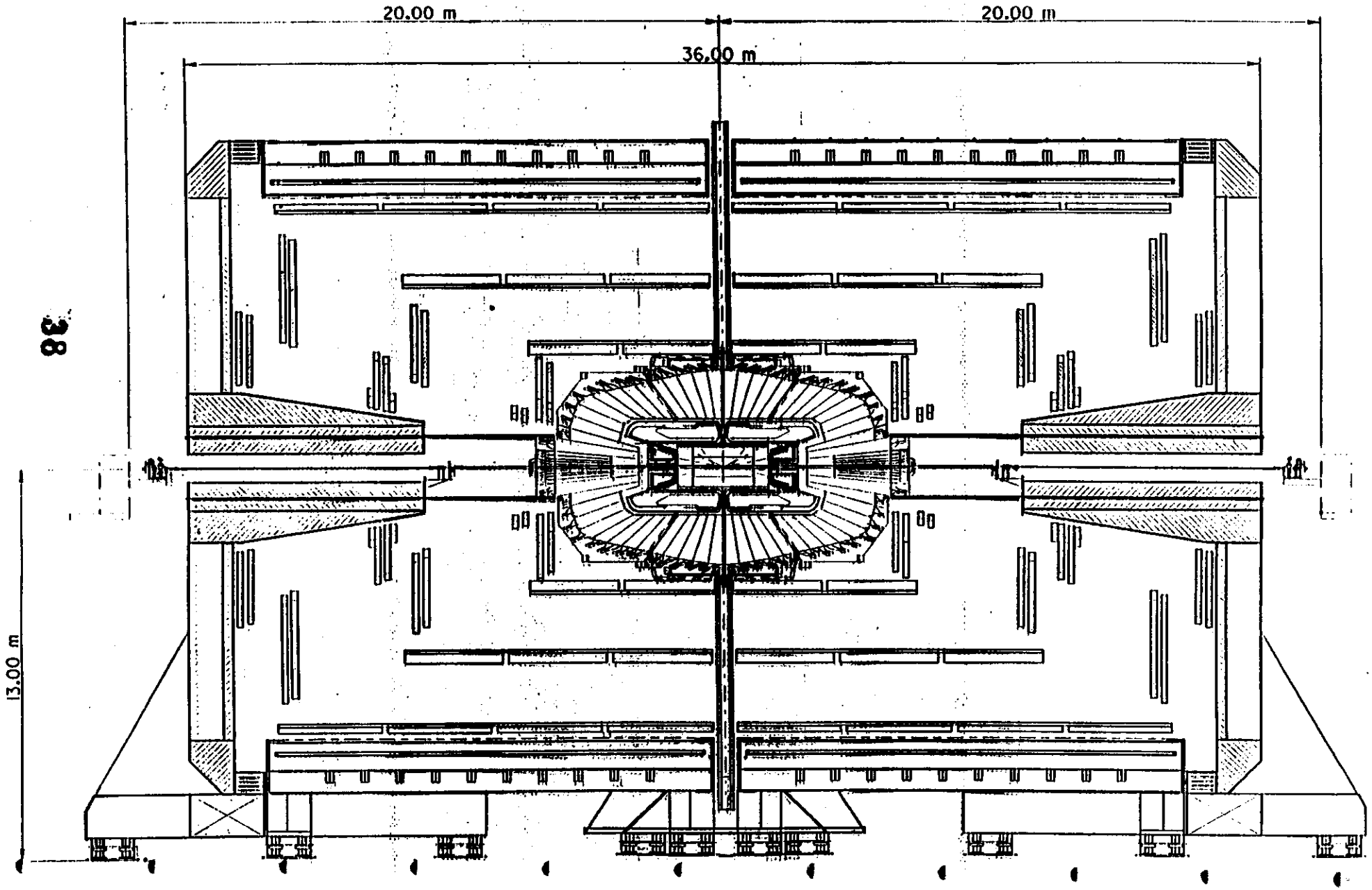
GEM/SSC HADRON CALORIMETER

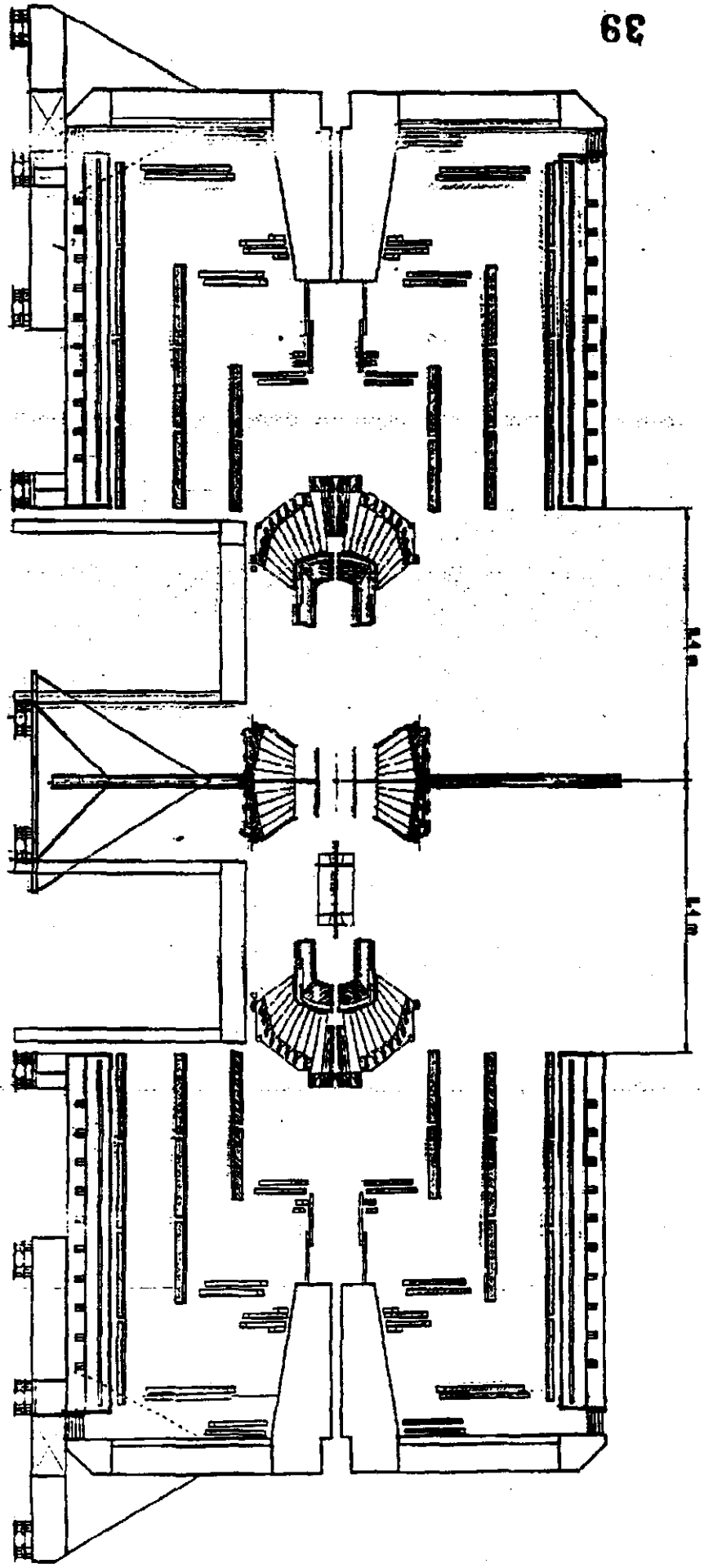
GEM DETECTOR

FIBER HADRON CALORIMETER

FIBER W/ CURRENT LAYER DESIGN

GEM DETECTOR D.C
E.M. CALORIMETER : Liq Kr CALORIMETER : FIBER
VACUUM SYSTEM : OPTION 1 or 3

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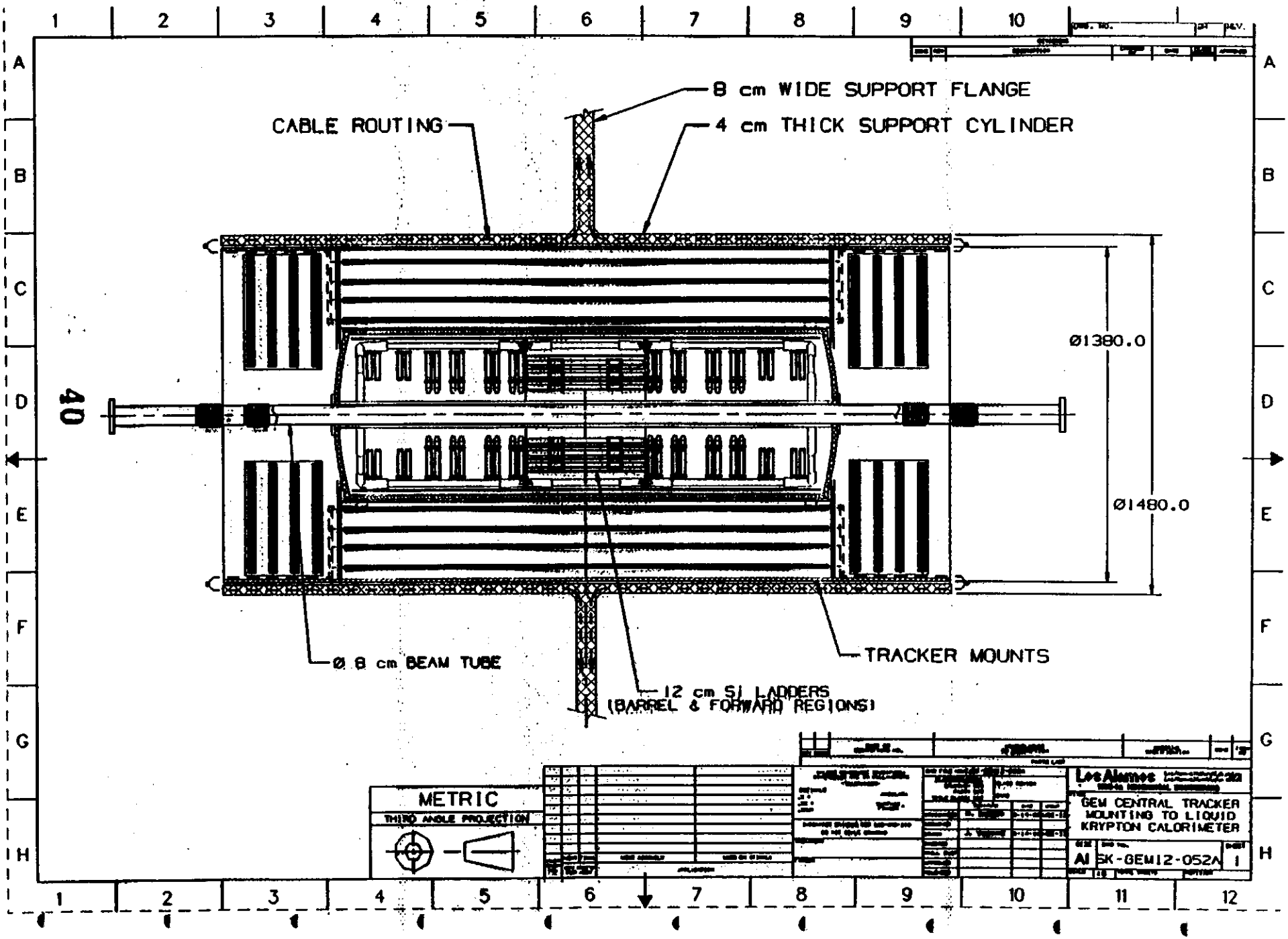
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Ø 8 cm BEAM TUBE
TRACKER MOUNTS
12 cm SI LADDERS
(BARREL & FORWARD REGIONS)
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THIRD ANGLE PROJECTION
Los Alamos
GEM CENTRAL TRACKER
MOUNTING TO LIQUID
KRYPTON CALORIMETER
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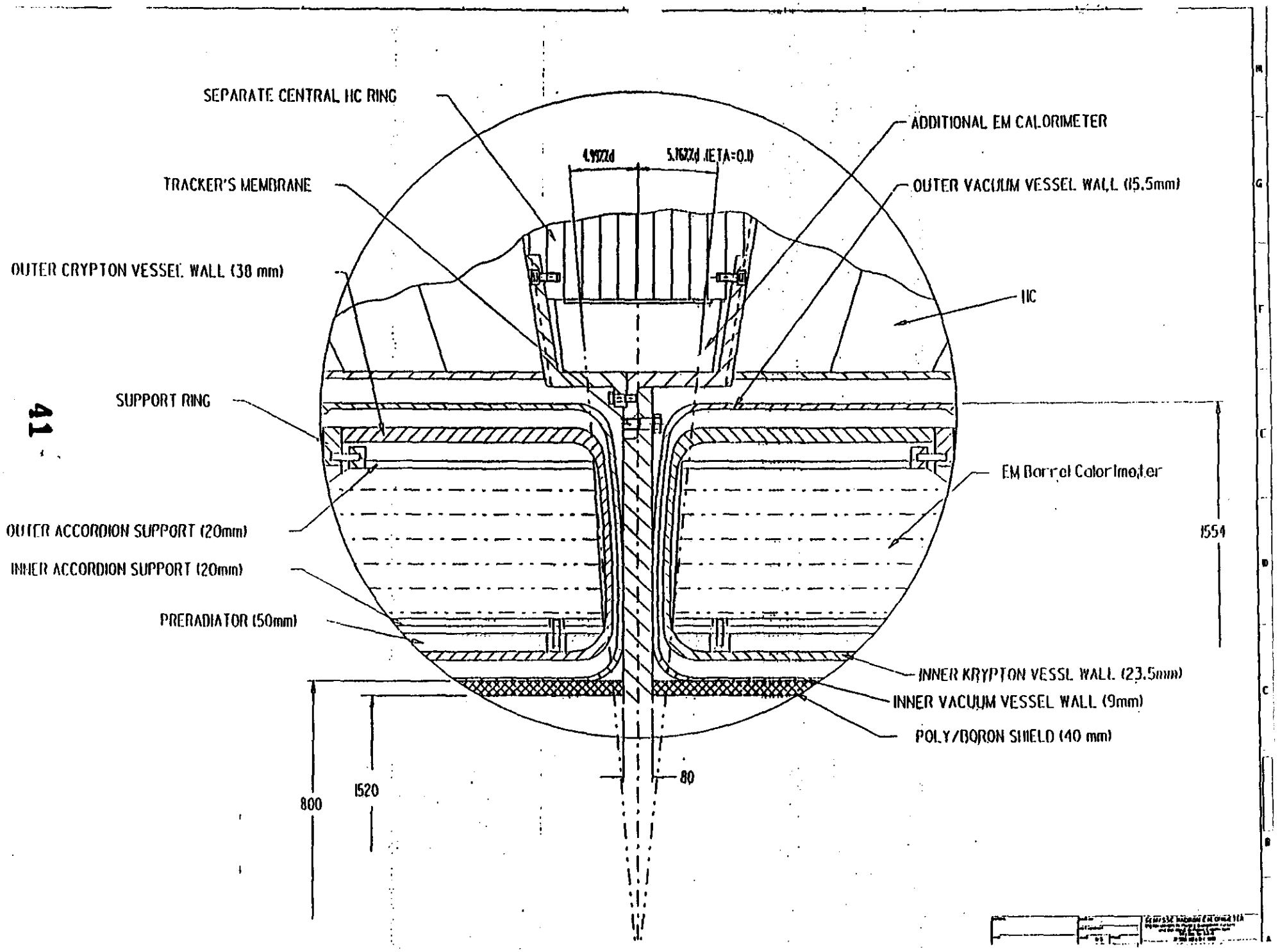
SEPARATE CENTRAL HC RING
TRACKER'S MEMBRANE
OUTER CRYPTON VESSEL WALL (38 mm)
SUPPORT RING
OUTER ACCORDION SUPPORT (20mm)
INNER ACCORDION SUPPORT (20mm)
PRERADIATOR (50mm)
ADDITIONAL EM CALORIMETER
OUTER VACUUM VESSEL WALL (15.5mm)
HC
EM Barrel Calorimeter
INNER KRYPTON VESSL WALL (23.5mm)
INNER VACUUM VESSEL WALL (9mm)
POLY/BORON SHIELD (40 mm)
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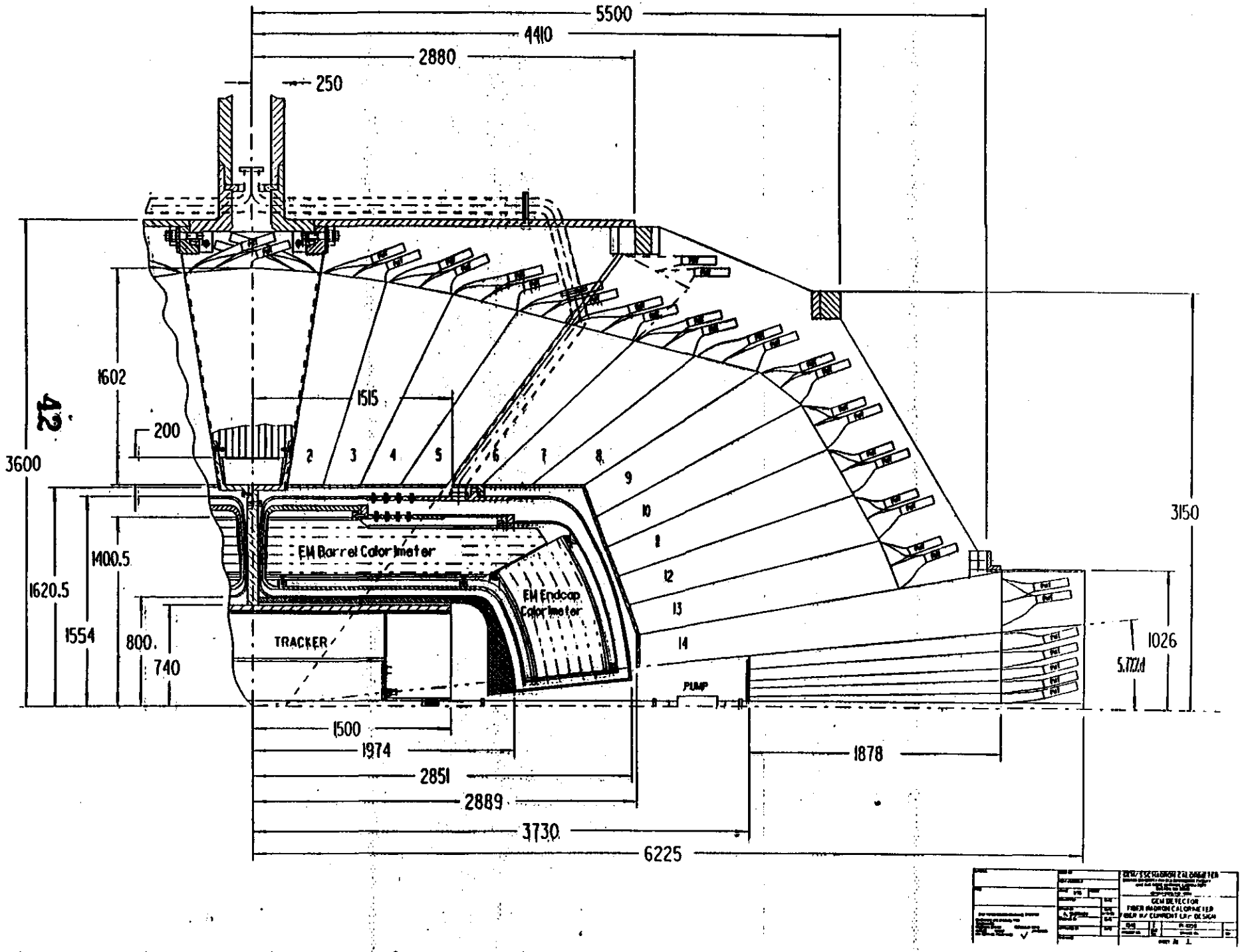
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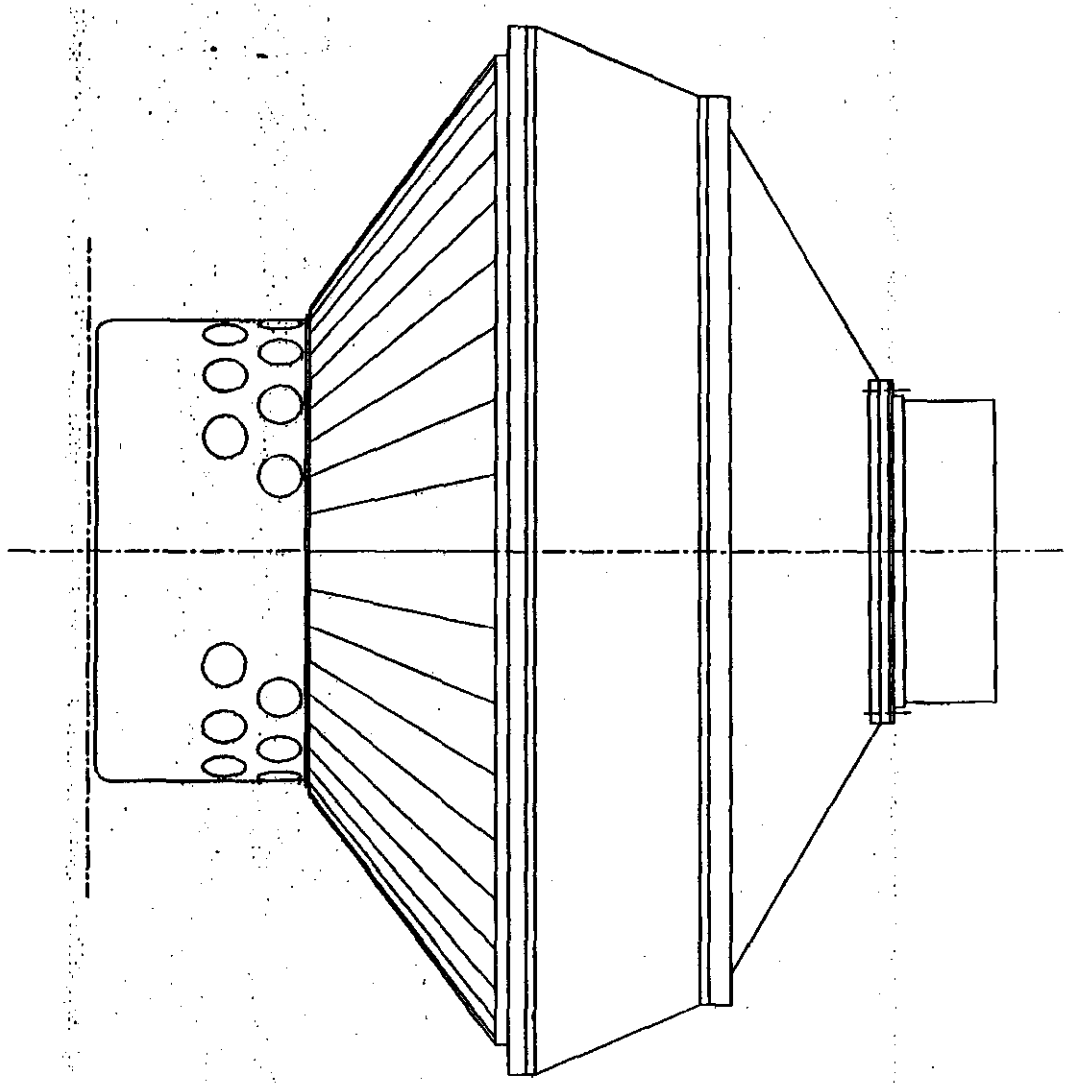

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GEM DETECTOR

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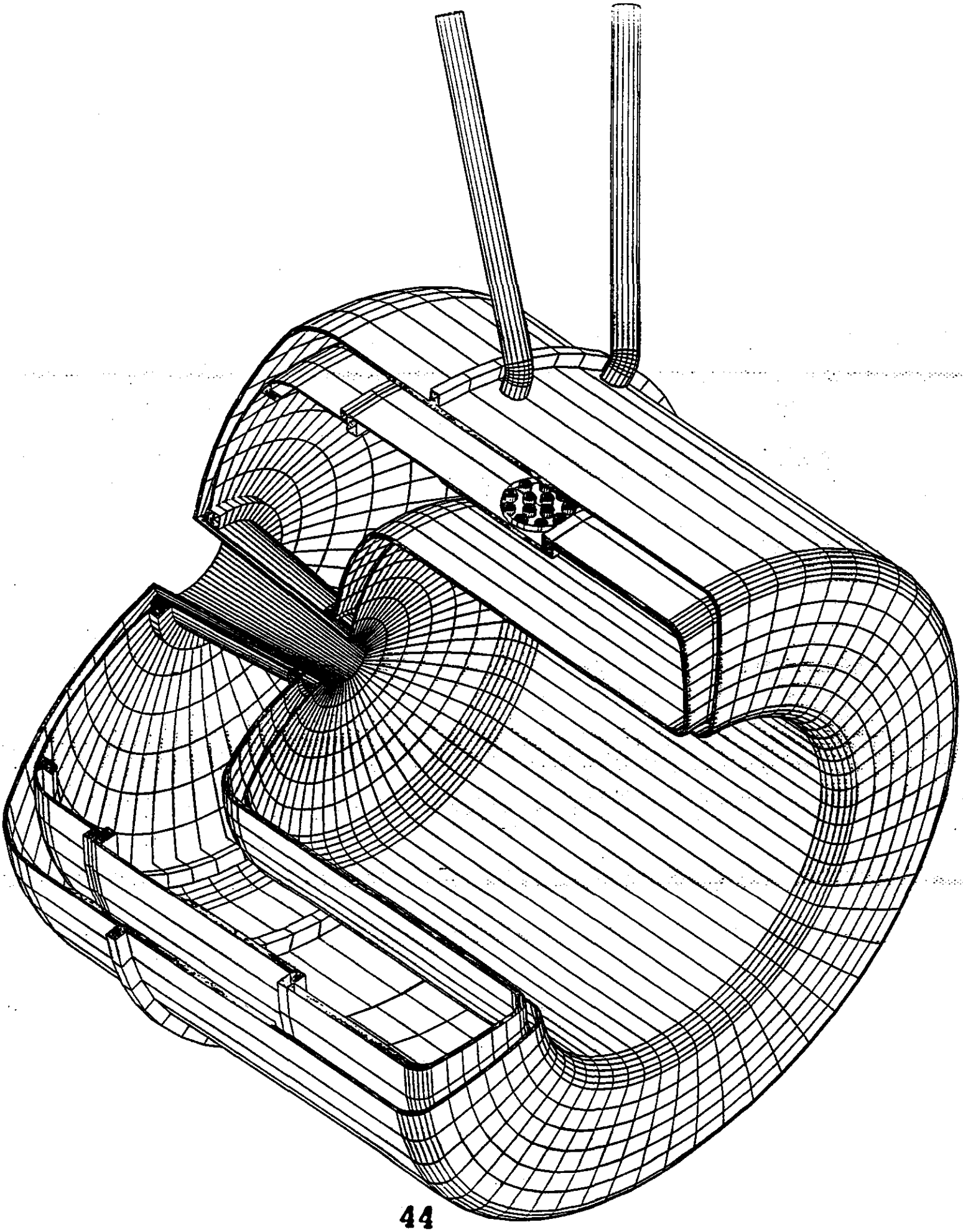

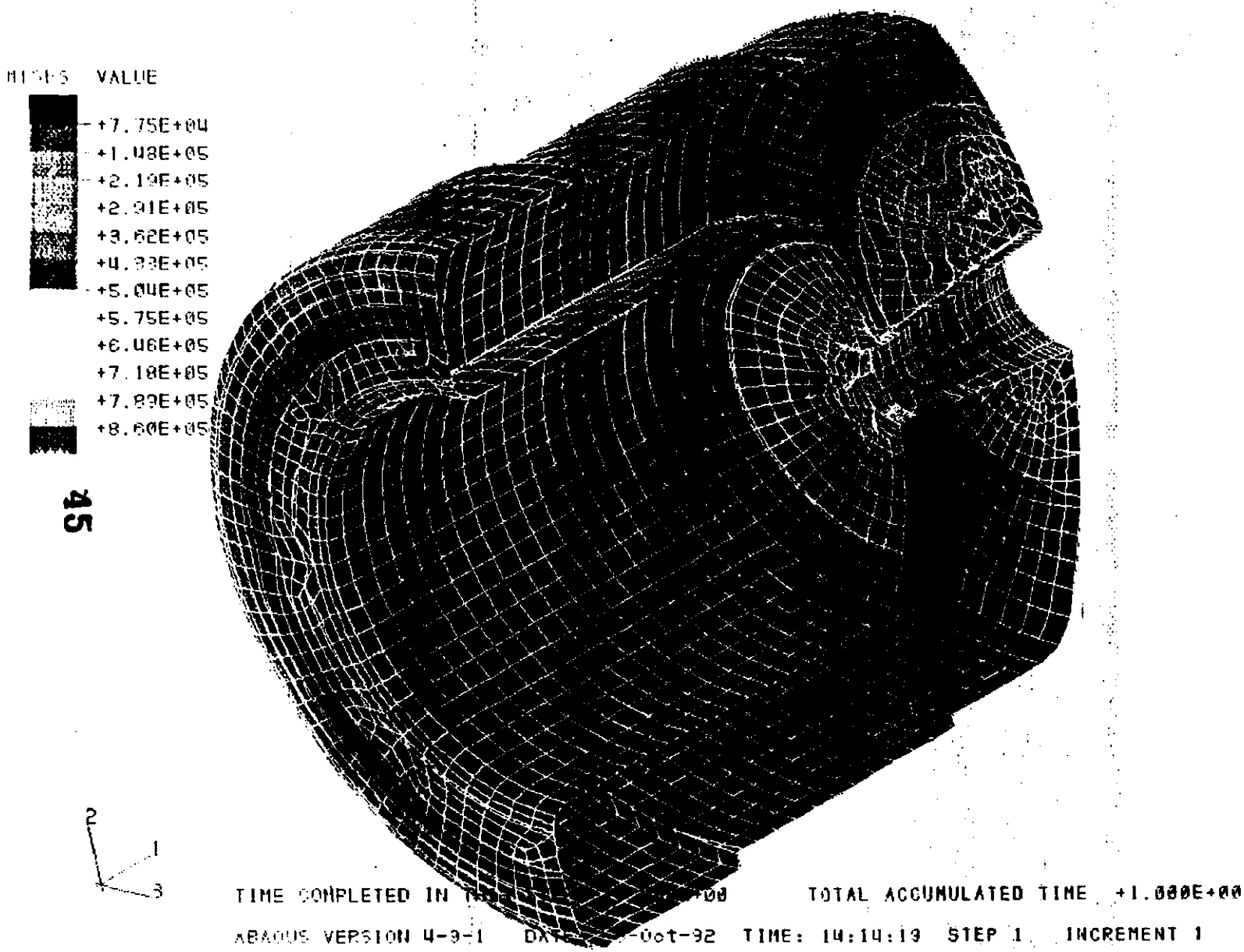

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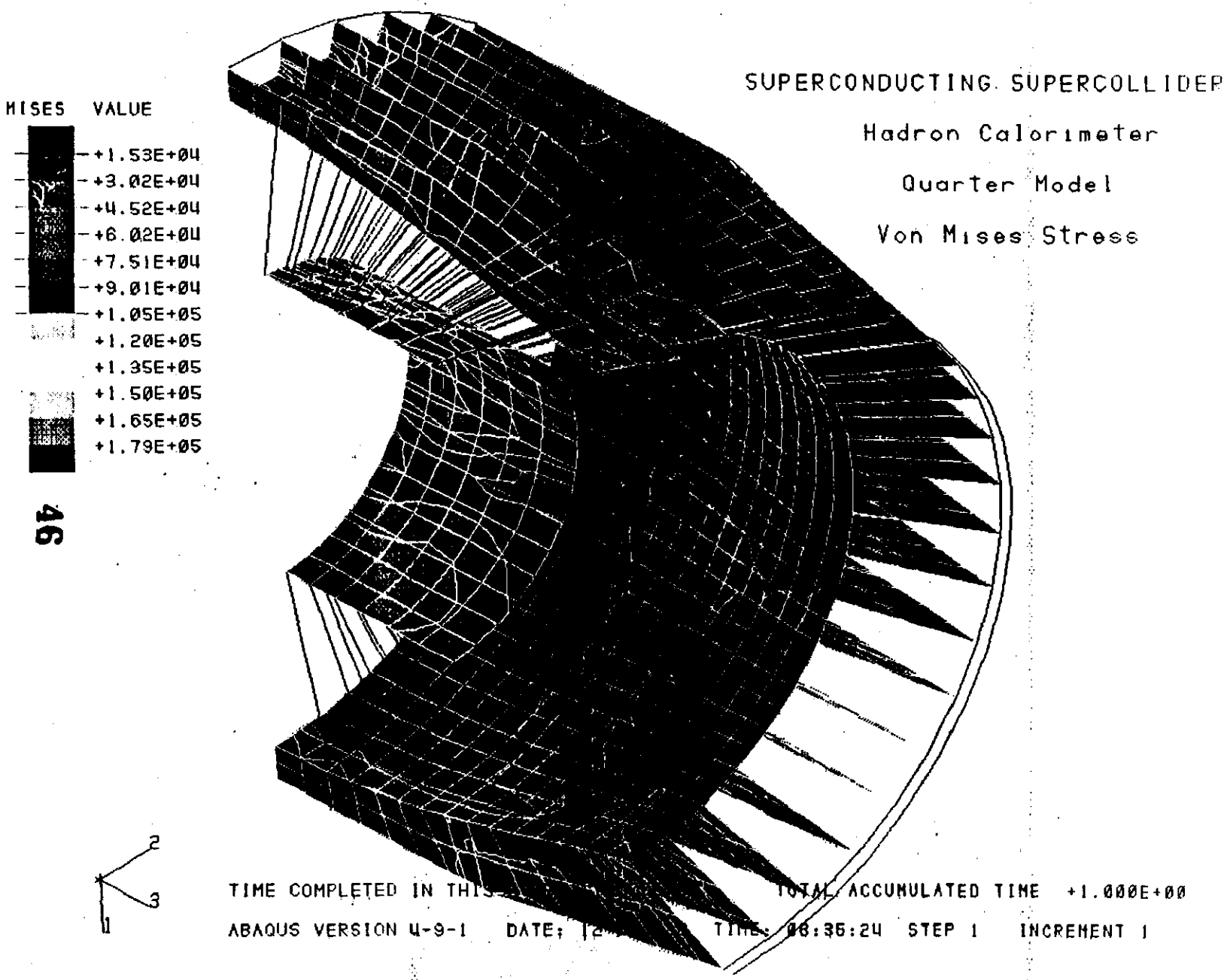
SUPERCONDUCTING SUPERCOLLIDER
Hadron Calorimeter
Quarter Model
Von Mises Stress
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+6.02E+04
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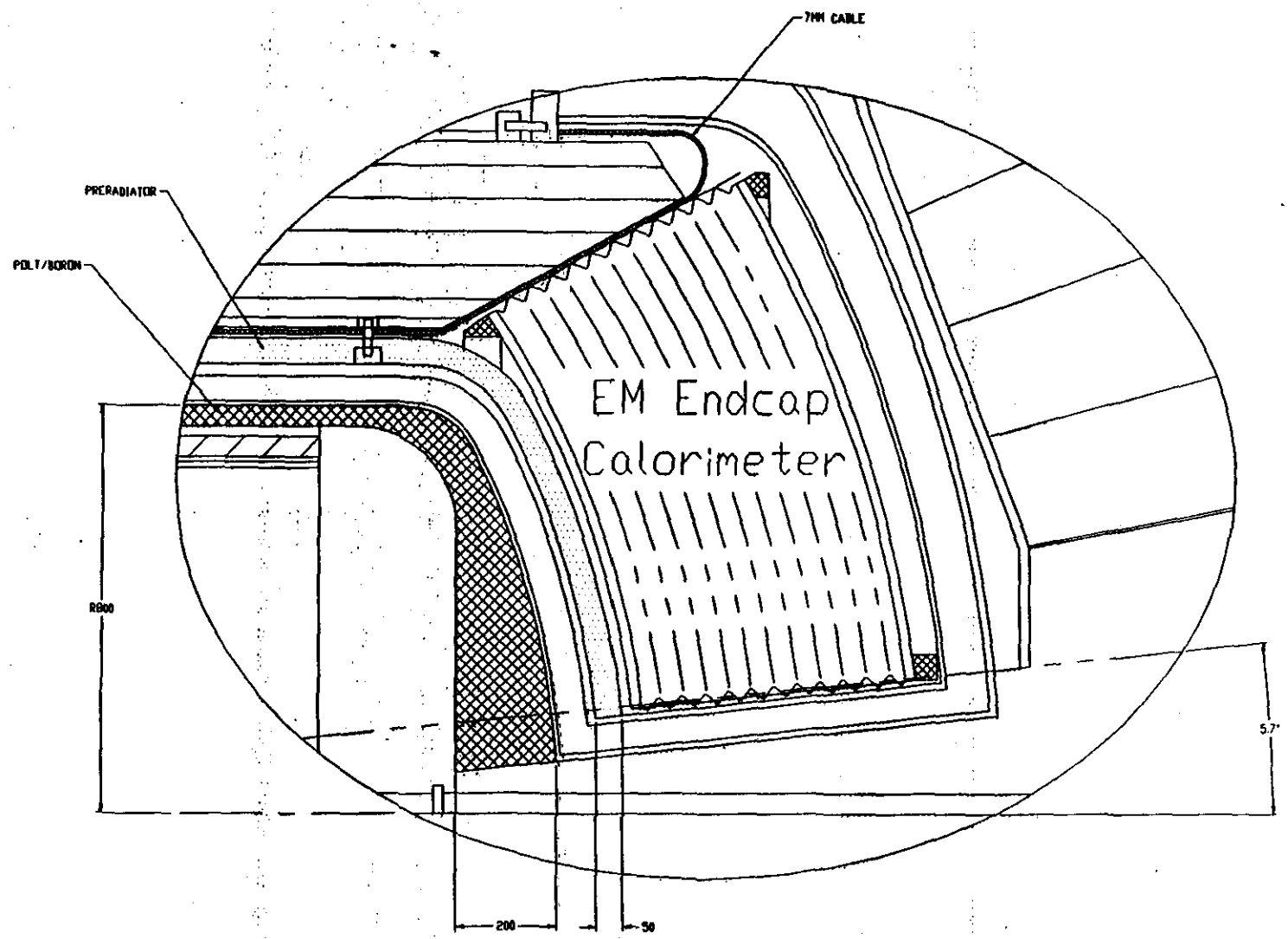

DO NOT REVISE MANUALLY

ORIGINAL ISSUE

NOTE: DIMENSIONS ARE IN MILLIMETERS

GEM DETECTOR
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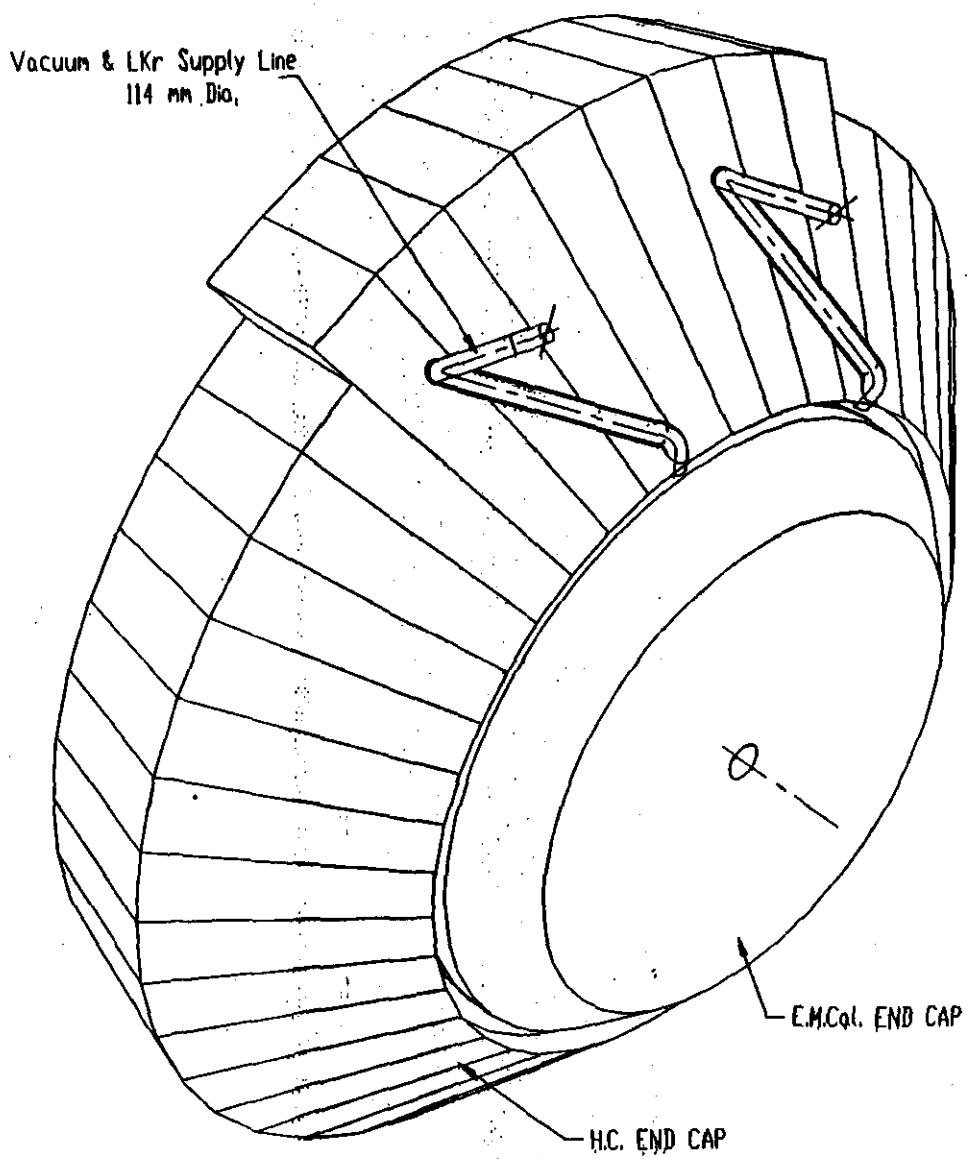

MATERIAL	USED ON	GEM/SSC HADRON CALORIMETER BOSTON UNIVERSITY PHYSICS ENGINEERING FACILITY and OAK RIDGE NATIONAL LABORATORY BOSTON, MA 02146 (617)353-8023; FAX -6025
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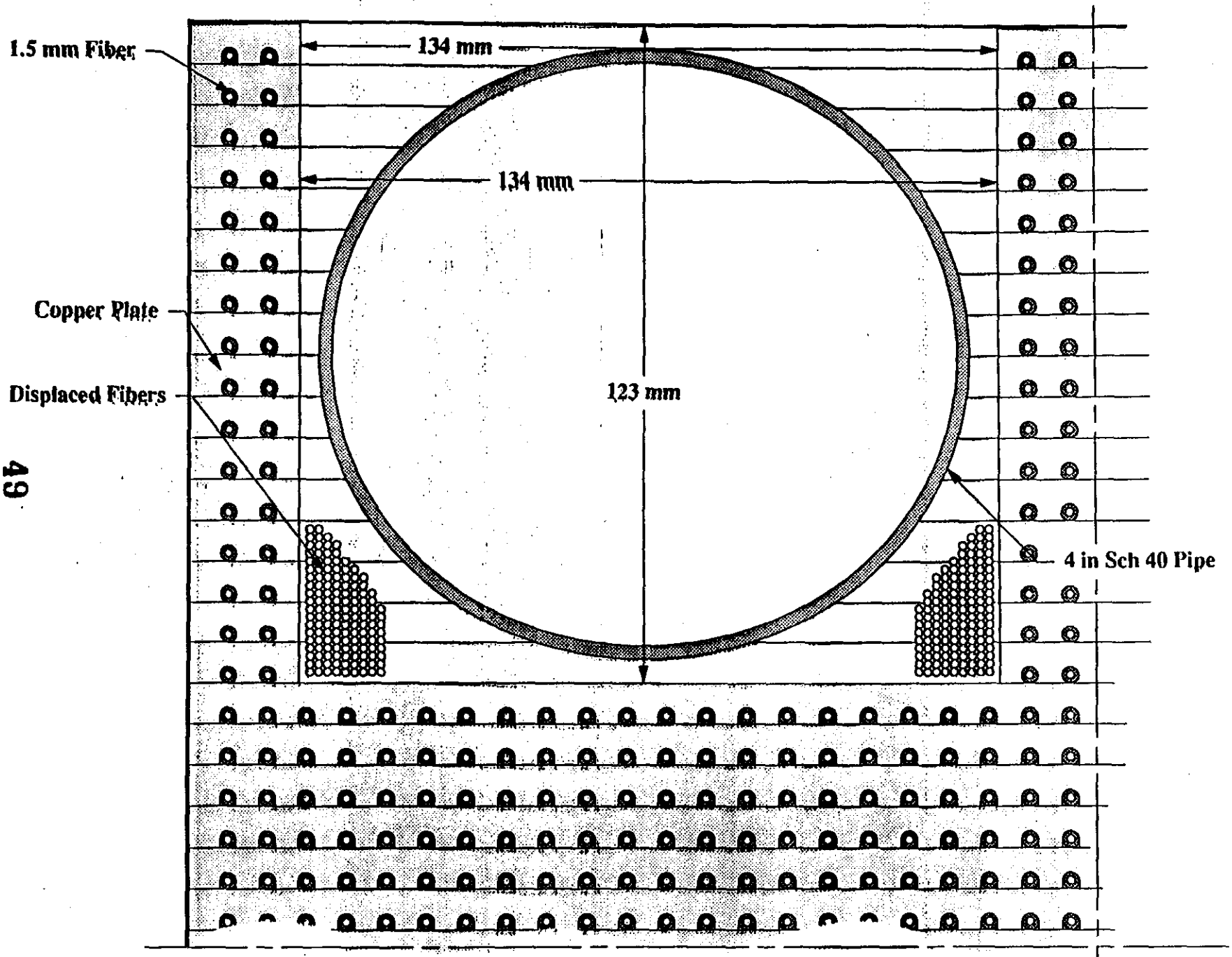

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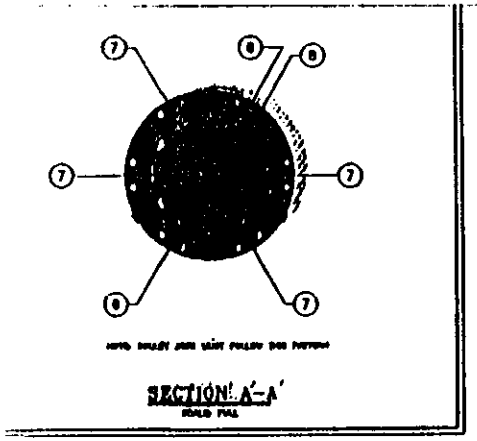
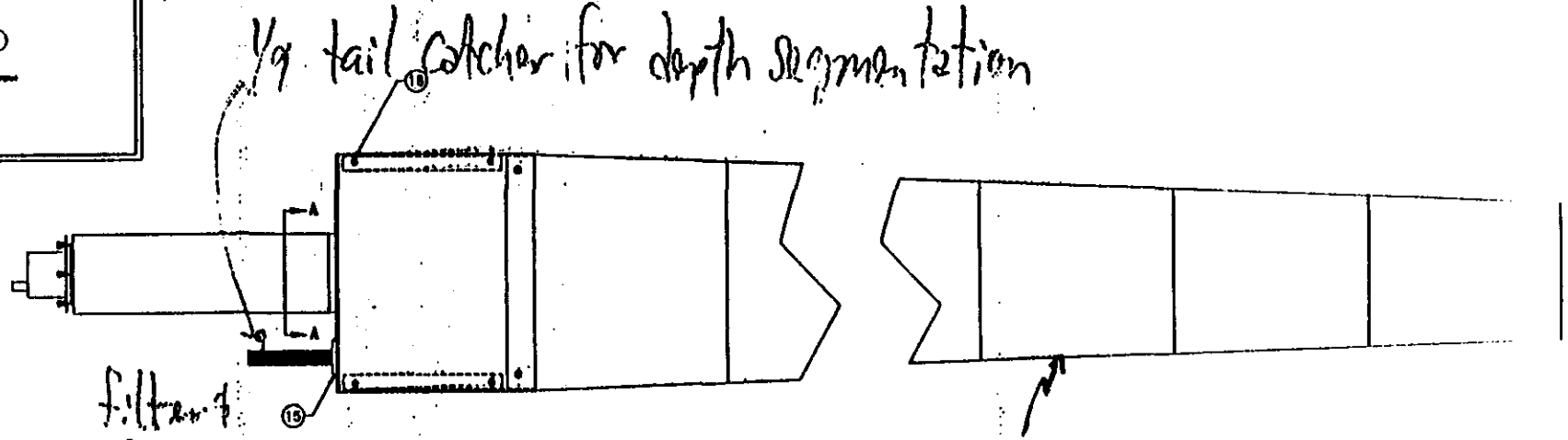
Liquid Argon,EM Vacuum Line
Feedthru,Fiber Hadron

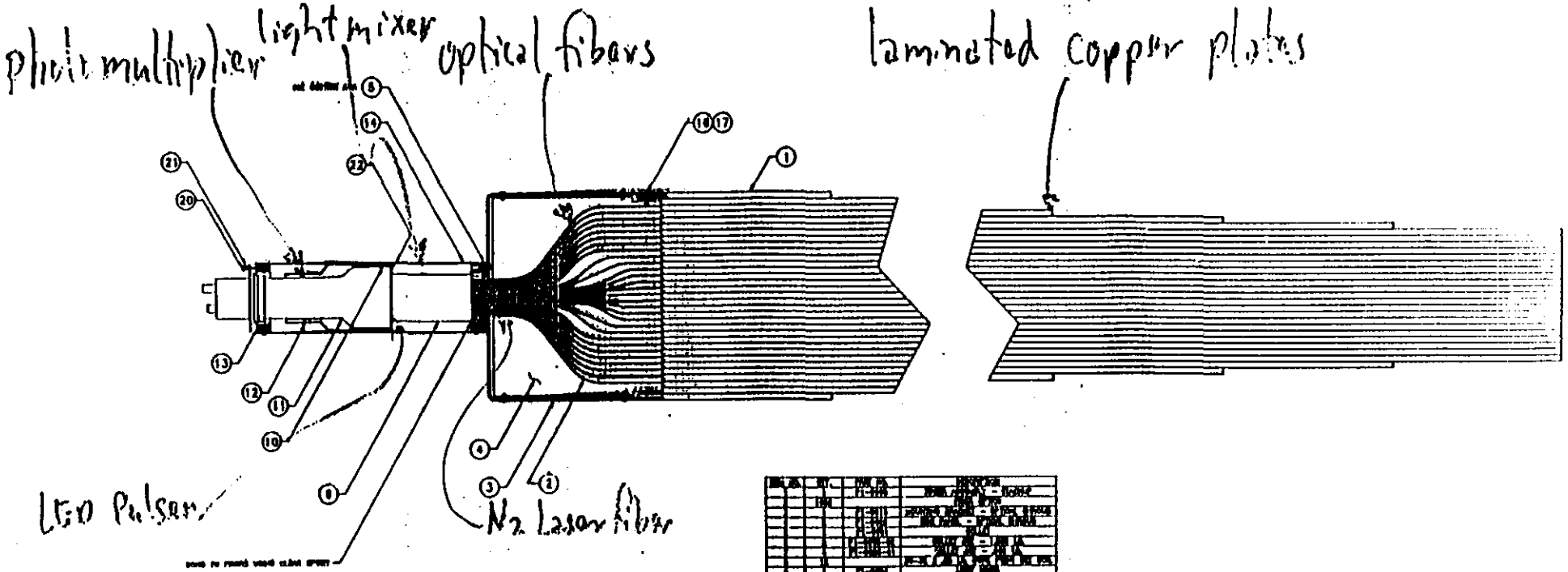
ORNL
August 21, 1992

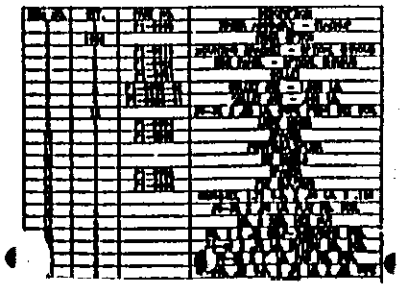
PROTOTYPE TEST: 5 Tons / 4 modules

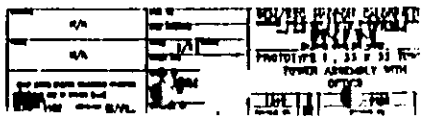
... the basic module of the hadron calorimeter ...









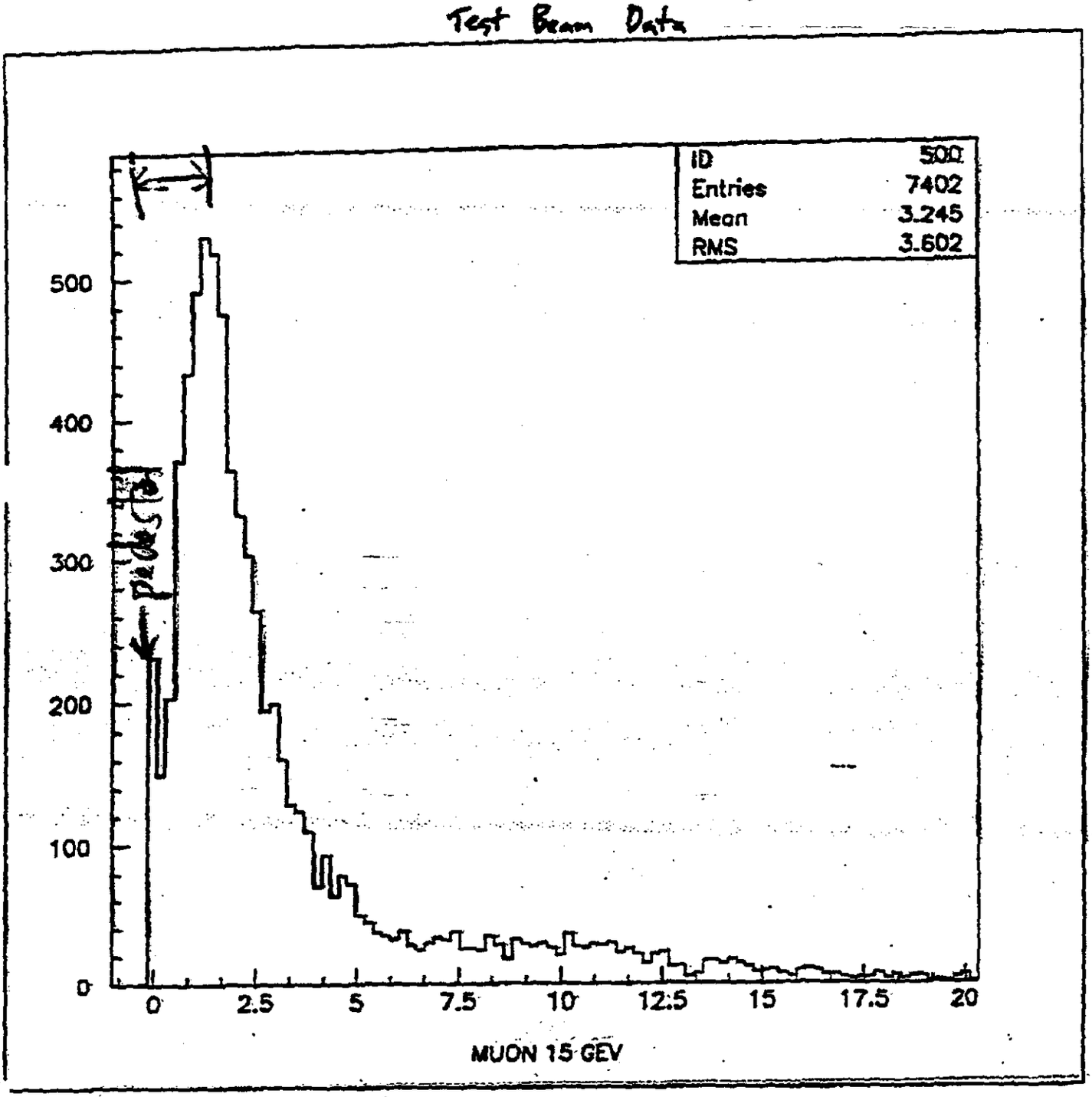


Landau Distribution clean

Muons

0°, 1.5° w.r.t. fibers
horz. vert.

Test Beam Data



TOTAL P.26

π signals fast

$\Rightarrow$ good isolation cut at high Luminosity

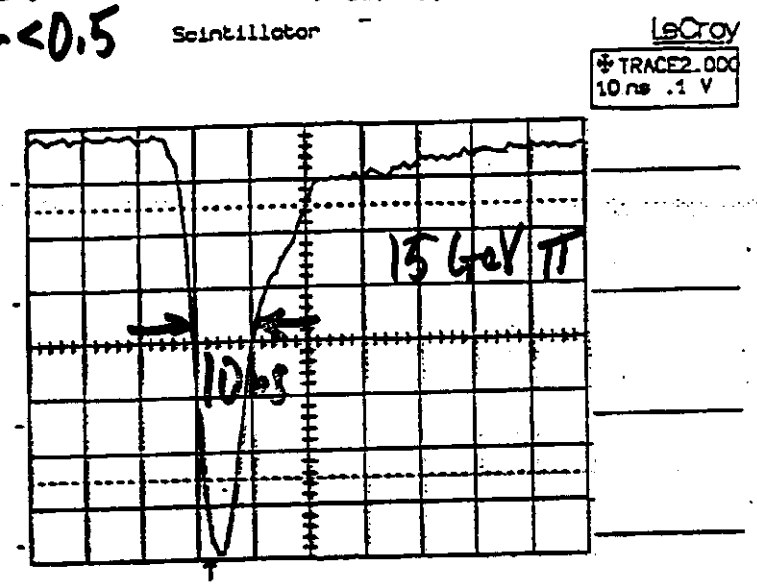
Test Beam Data

Figure 8

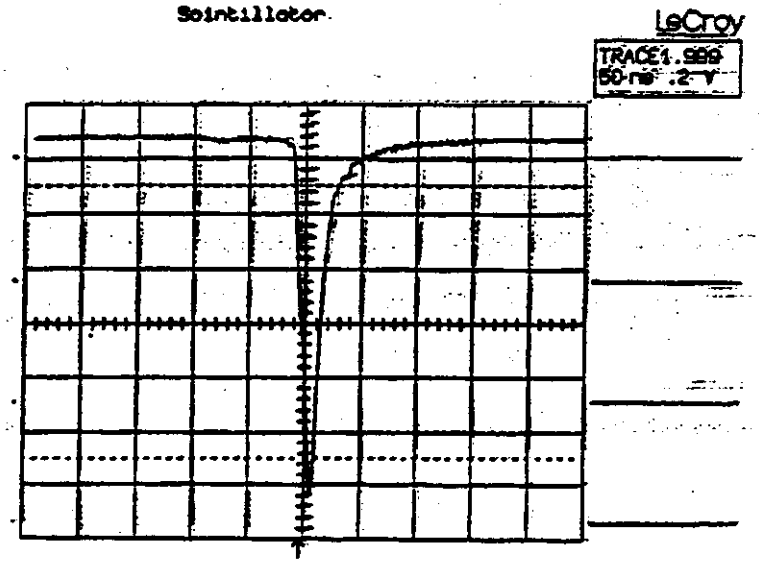
15 GeV π

... only < 1 GeV noise in $r < 0.5$

Scintillator



Scintillator

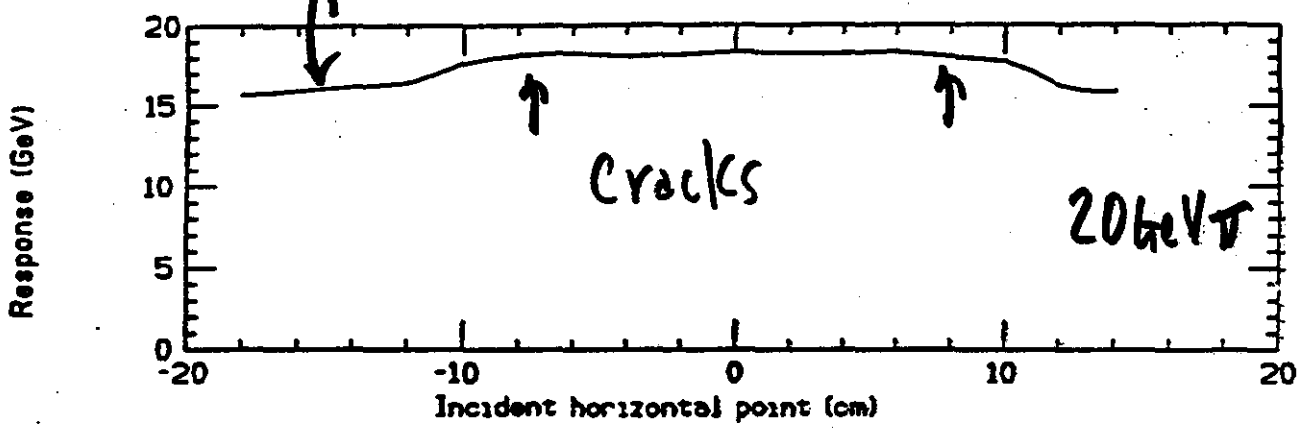


Smooth response across boundaries

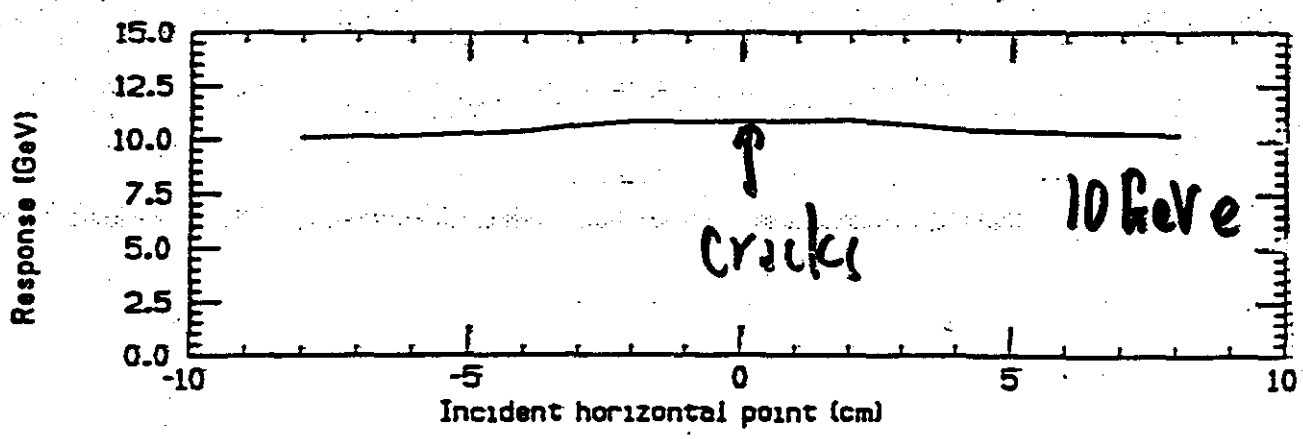
containment loss

Test Beam Data

Response to 20 GeV pions vs. Incident position



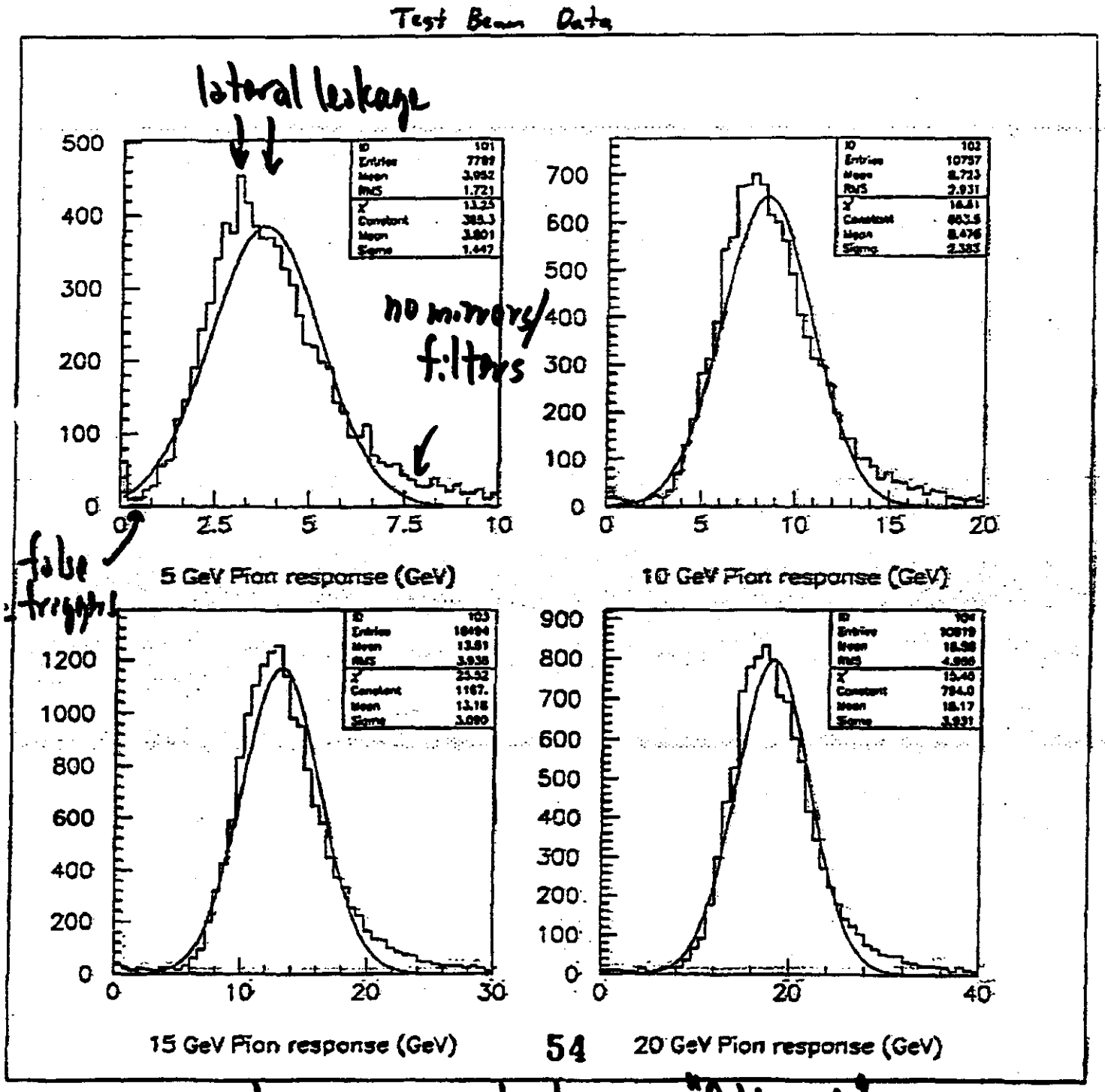
Response to 10 GeV Electrons vs. Incident position



On line test beam response ...

Figure 1

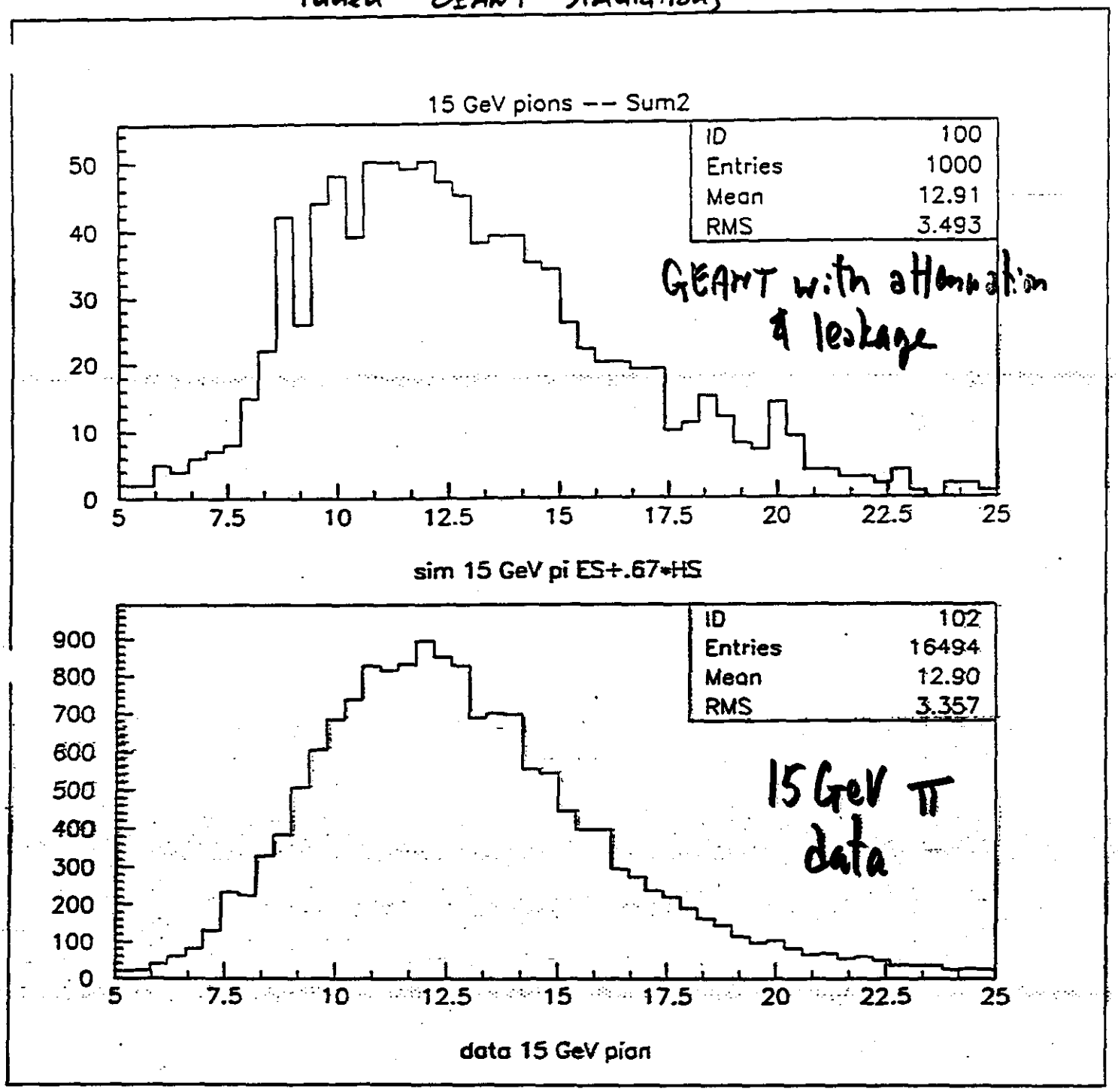
⇒ 90 pe/GeV for baseline design



1) run stopped prematurely ... no "filtered" run
2) 3 months from order to beam ... no time to mirror fibers

Figure: Simulated detector response by tuning [illegible] to agree with data

'Tuned' GEANT Simulations



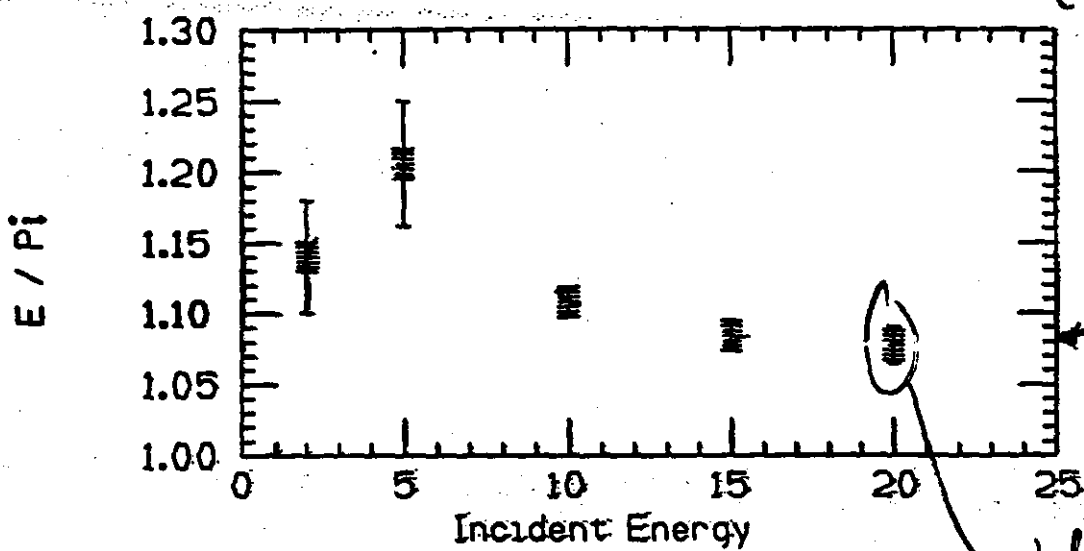
Resolution and e/π match, CALOR 89 & GEANT 3.15
& BASELINE I

Figure 2

Test Beam Data

Uncorrected E/Pi

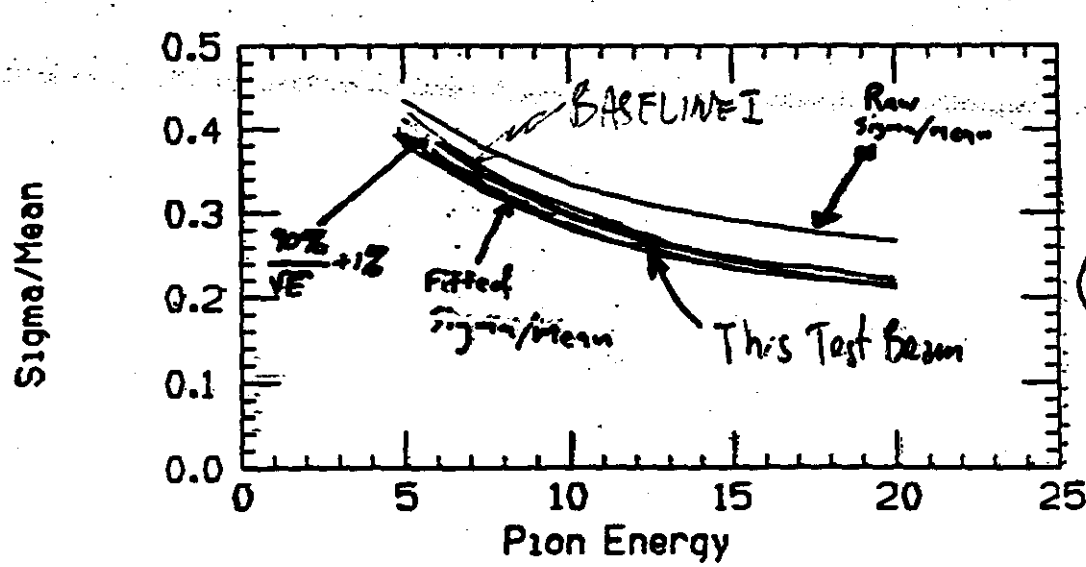
with { no leakage corrections
no attenuation "



BASELINE I:
$1^{+0.1}_{-0.05}$
1.08 ± 0.02
vs
1.05 ± 0.03 CALOR89

different runs
the confidence level

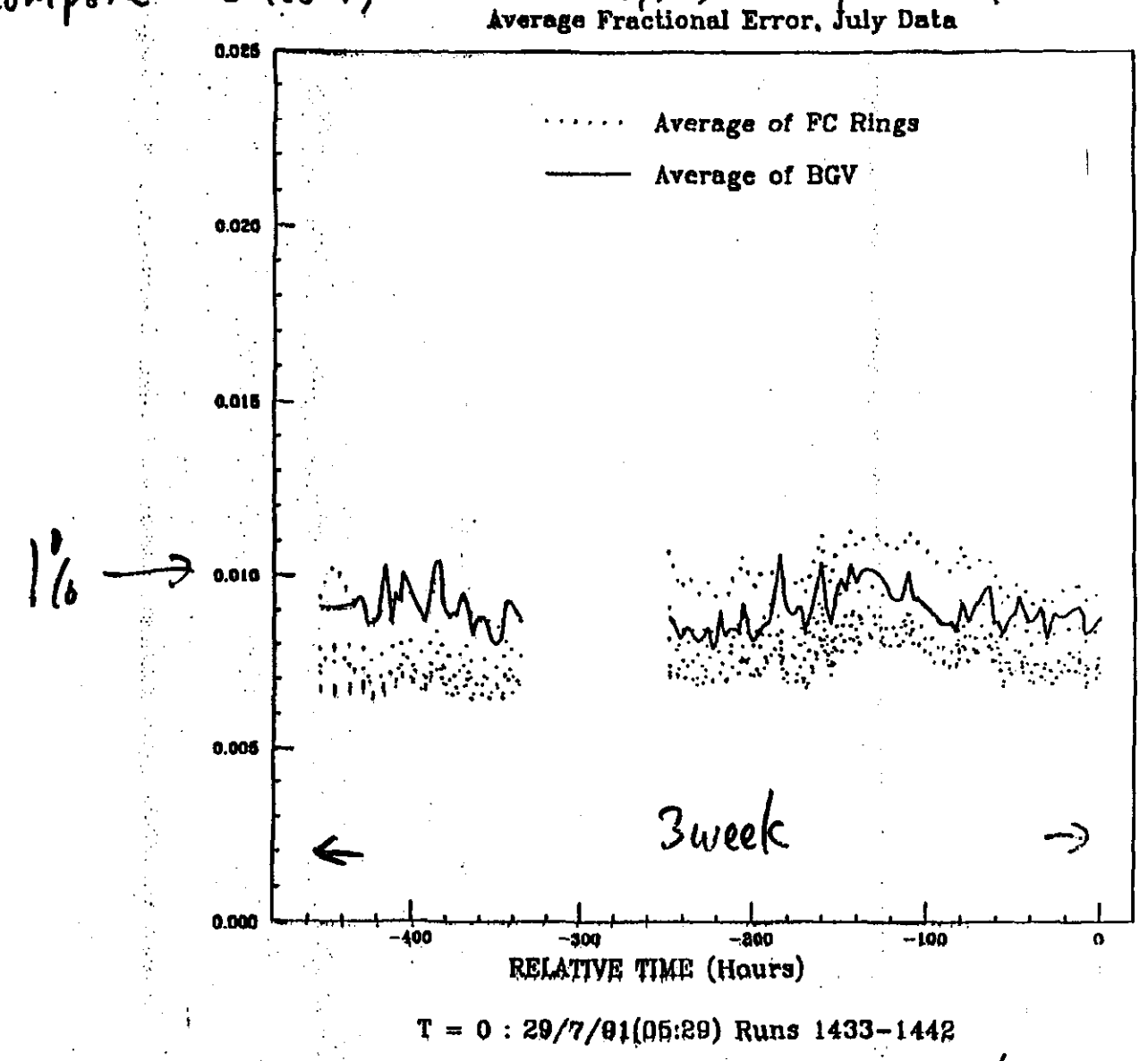
Hadronic Resolution - No Corrections



At 10 GeV,
91%/√E ...
vs
CALOR89
(93% ± 5%)/√E
vs
90%/√E BASELI

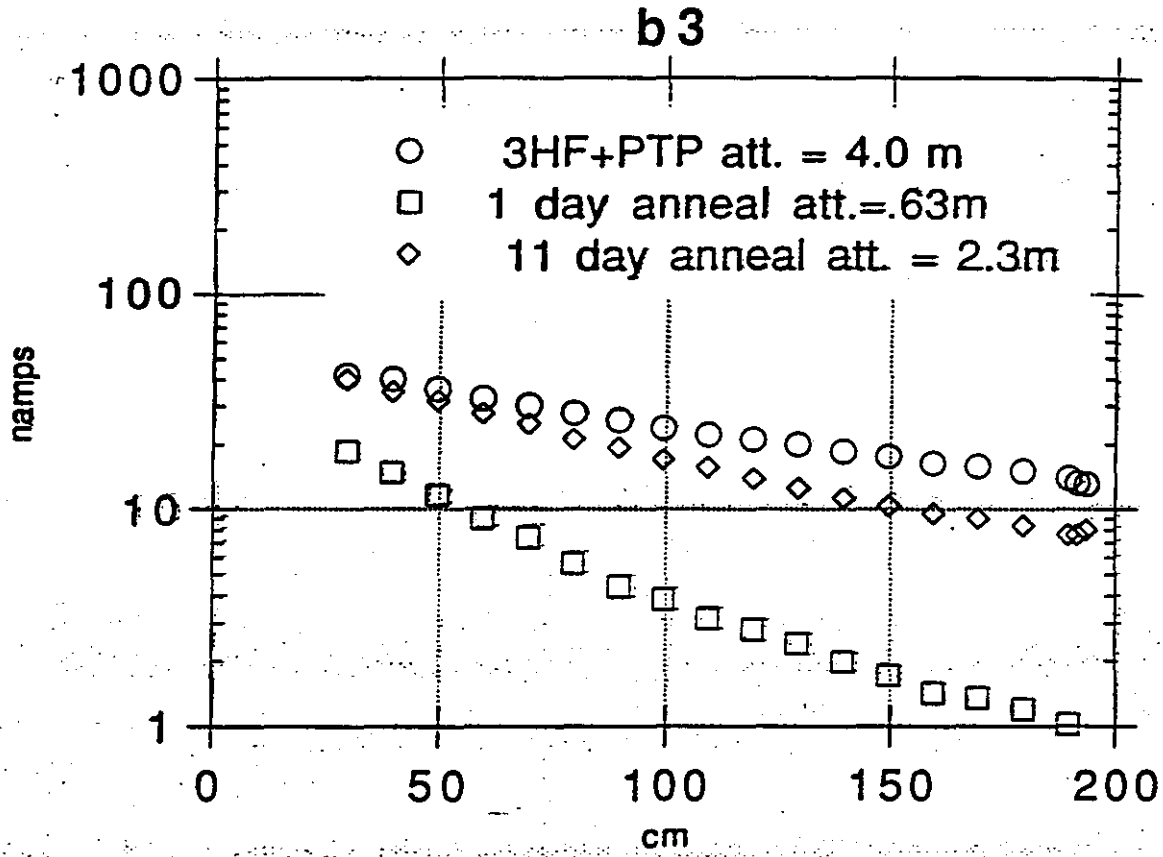
DF, ZEUS, JETSET ... all have long term stability of < 1%

JETSET: Compare N_2 laser, thru hadrons/μ, π^0 peak for 300 fiber towers



... with no effort at temperature control (in LEAR hall)
or High Voltage (LeCroy 256 channel)

Radiation Tolerance of fibers used in prototype



ORNL tests

$\Rightarrow$ > 3 years at 10^{34} at $\eta = 3$

GEM-TN-xxxx
9/21/92

REPORT OF THE TASK FORCE ON A HYBRID CALORIMETER

edited by
J. Womersley

Simulations performed by
Yu. Efremenko, A. Savin, and K. Shmakov

additional Task Force members:
H. Ma, P. Mockett, X. Shi, I Stumer, B. Worstell

AIM OF THE TASK FORCE

The task force was convened to address the option of building the GEM barrel calorimeter with a three layer structure, as below:

- Liquid Krypton EM section
- Liquid Argon hadronic section, thickness "a few" absorption lengths (we assumed 0—3)
- SPACAL hadronic section

The issues to be addressed in this geometry were its performance for:

- EM energy measurement, and leakage
- electron-pion discrimination
- missing ET measurements
- jet energy resolution

All as a function of varying the thickness of the liquid argon hadronic layer from zero to 3 λ. The control for comparison purposes was the baseline I, all-liquid-argon option.

INDIVIDUAL REPORTS

SEP 23 '92 19:12 FSUHEP 135 P02

SUMMARY

1.EM energy leakage

Savin has studied high energy EM shower leakage for 1 TeV electrons and photons. He has compared his results with those of Zeus and also of X. Shi for BaF_2. If no correction is made for leakage, then at these energies it will strongly damage the spectrum of energy response and reduce the number of events in the peak. However, a hadronic calorimeter with a relatively poor EM resolution (of even 40-80%/$\sqrt{E}$) is adequate to correct for energy lost and restore a Gaussian lineshape. This will work even with a relatively thick (2.8 X_0) cryostat wall behind the EM section. Alternatively, segmenting the last 1X_0 of the EM section separately can be used to correct for leakage. The proposed 8+17 X_0 front-back segmentation will not do the job of leakage corrections.

2. Electron-Pion discrimination

Yu. Efremenko has simulated electron-pion discrimination in Baseline I and hybrid geometries. The pion rejection is better in the LKr + SPACAL geometry by a factor of up to 2 (for 95% electron efficiency). For the 3 λ LAr hybrid the performance is similar to that of the baseline. The reason for this improved rejection is that the cryostat wall between the LKr section and the SPACAL absorbs the tails of EM showers, making them look more different from hadronic showers. So the extra discrimination would come at the expense of worsened resolution, and is probably not itself a good reason to go this route.

3. Missing E_T

K. Shmakov has studied missing E_T effects of energy loss fluctuations in cryostat walls. Events were generated in PYTHIA; GEANT was used to generate and parametrize individual shower energy loss distributions and then the parametrized distribution was sampled to obtain an E_T mismeasurement in each event. This was compared with the "irreducible" missing E_T due to neutrinos. The baseline I scheme has the best performance, followed by the hybrid with 1 λ LAr section, followed by LKr + SPACAL, but in all cases the missing E_T created by the cryostat walls is not significant compared with the irreducible E_T from neutrinos.

4. Hadronic resolution

Efremenko has found that a study of how to weight the various layers in the calorimeter to achieve the best hadronic resolution yields very similar final resolutions for Baseline I, LKr+SPACAL and hybrid (with 3 λ LAr section). Since some weighting is unavoidable anyway (the various layers will unavoidably have different sampling fractions) this gives no reason to choose one geometry over another.

CONCLUSIONS

On the physics performance grounds studied, these simulations give no particular reason to prefer any one of the following designs over another:

Baseline I (LAr)
Hybrid (LKr + LAr + SPACAL)
LKr + SPACAL

Any of them would appear to be able to perform adequately; the extra cryostat walls have no terrible effects. It is suggested that the choice be made on grounds of cost, complexity or inherent performance (noise, constant term in resolution, calibratability) of the various technologies, which have not been looked at here.

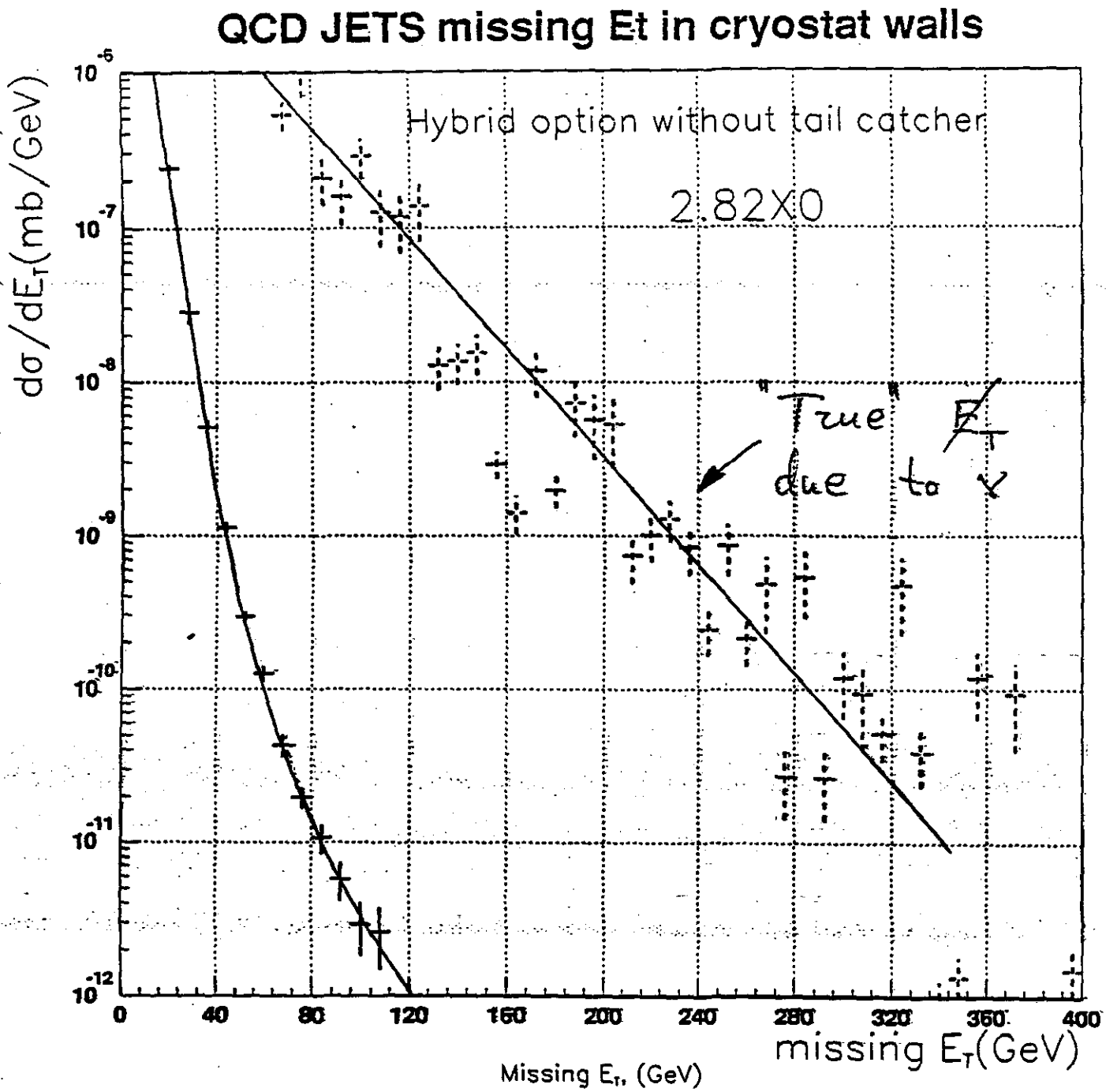

QCD JETS missing Et in cryostat walls
Hybrid option without tail catcher
2.82X0
"True" $\not{E}_T$ due to ν
$d\sigma/dE_T$(mb/GeV)
missing E_T(GeV)
Missing E_T, (GeV)

Fig. 12

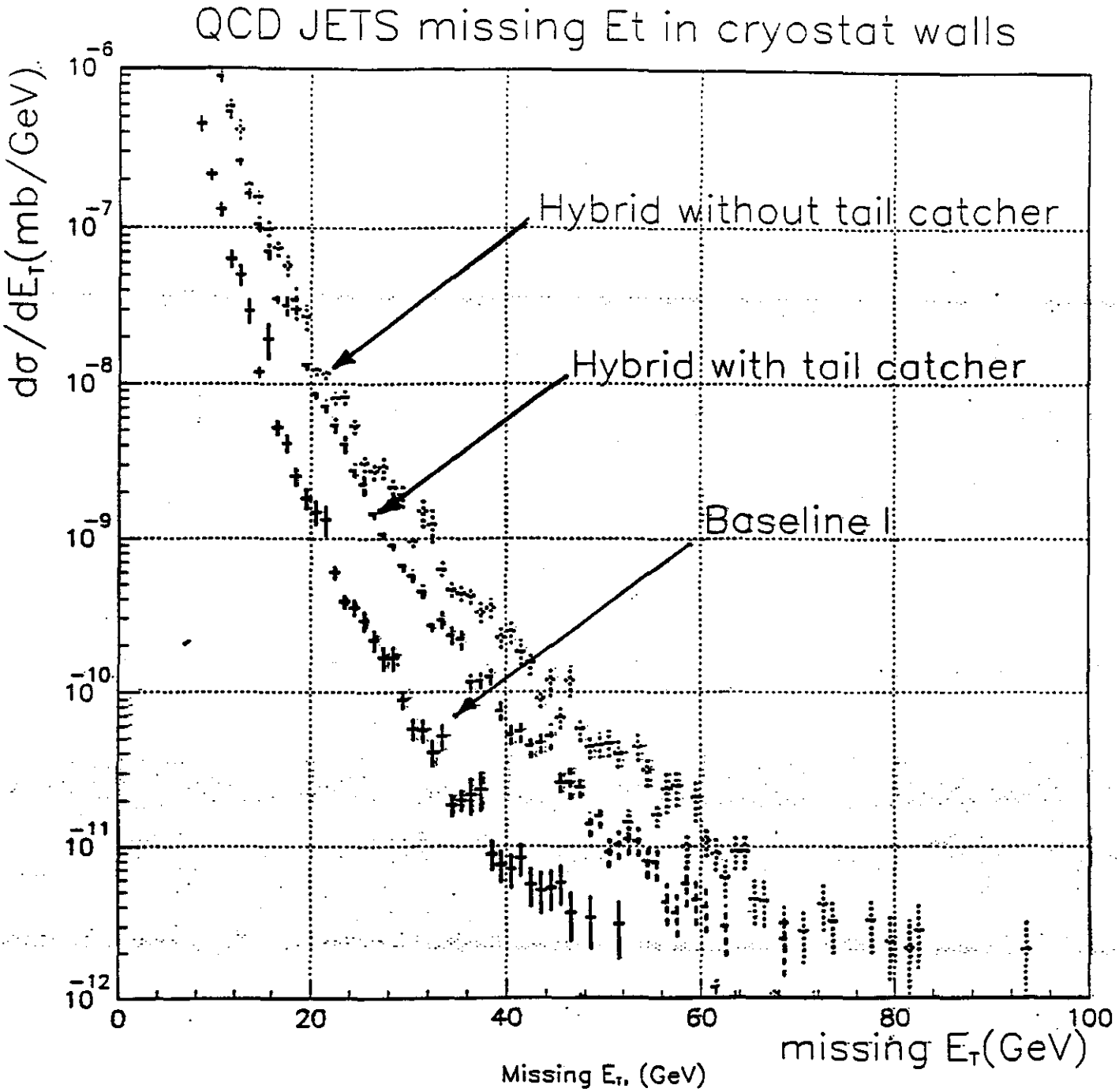
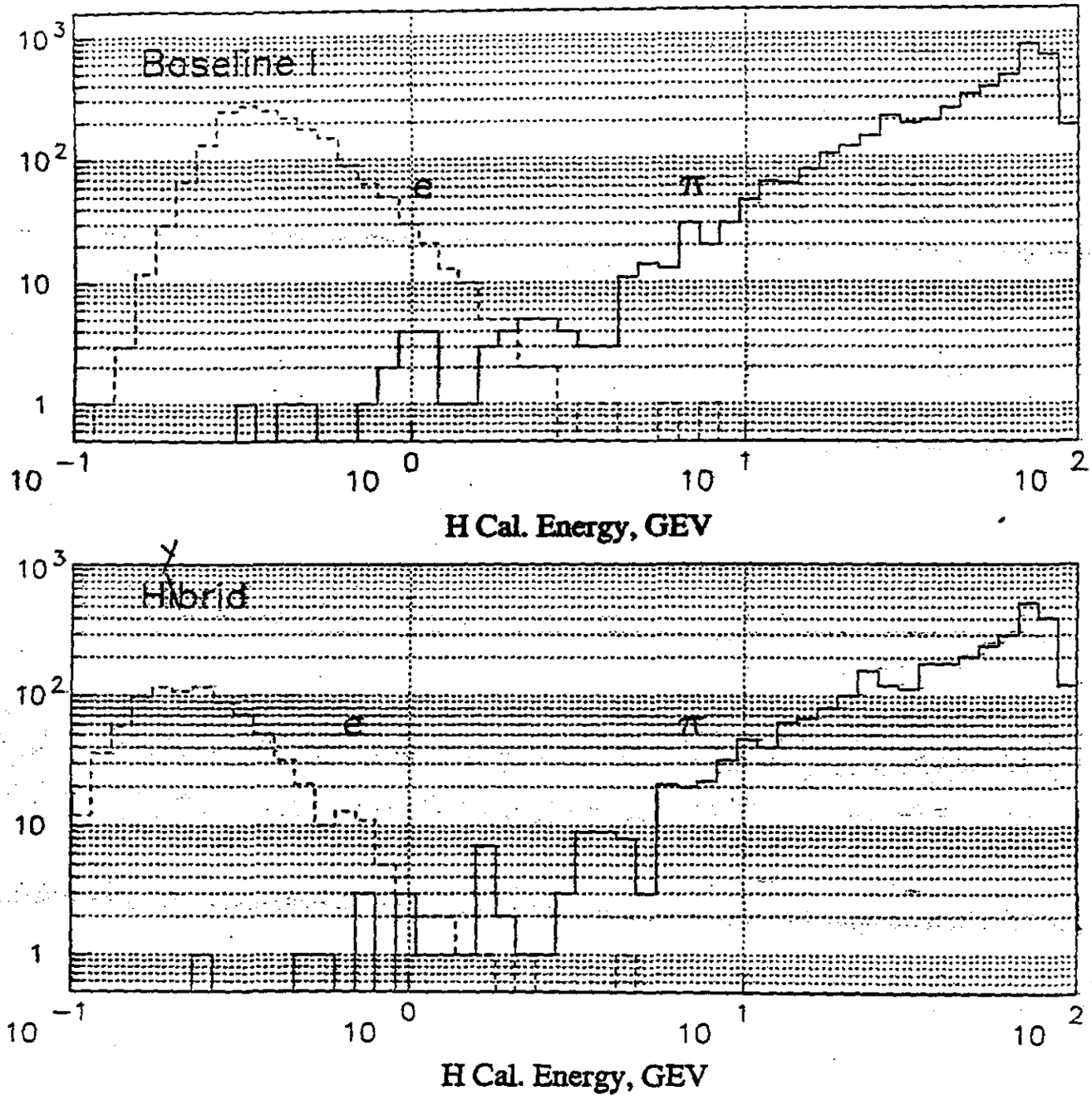
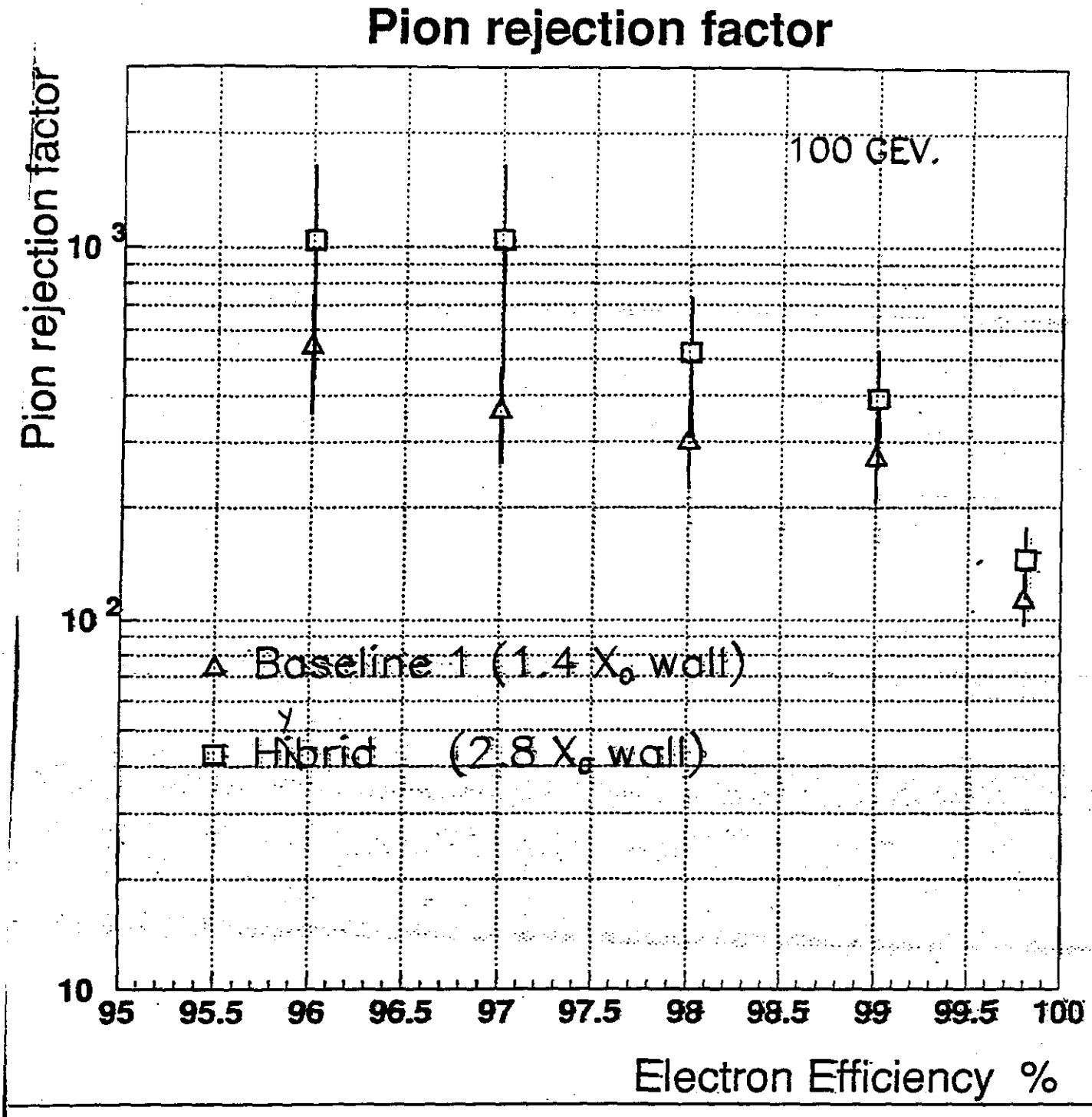

QCD JETS missing Et in cryostat walls
dσ/dE_T(mb/GeV)
Hybrid without tail catcher
Hybrid with tail catcher
Baseline I
missing E_T(GeV)
Missing E_T, (GeV)

Fig. 13

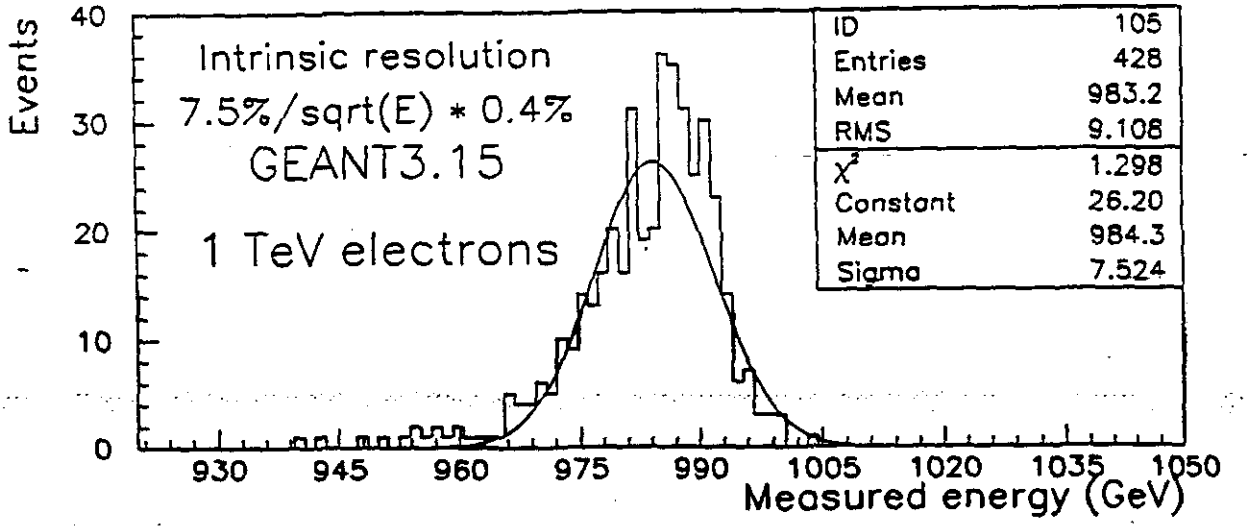
Energy in HCAL, 100 GEV.

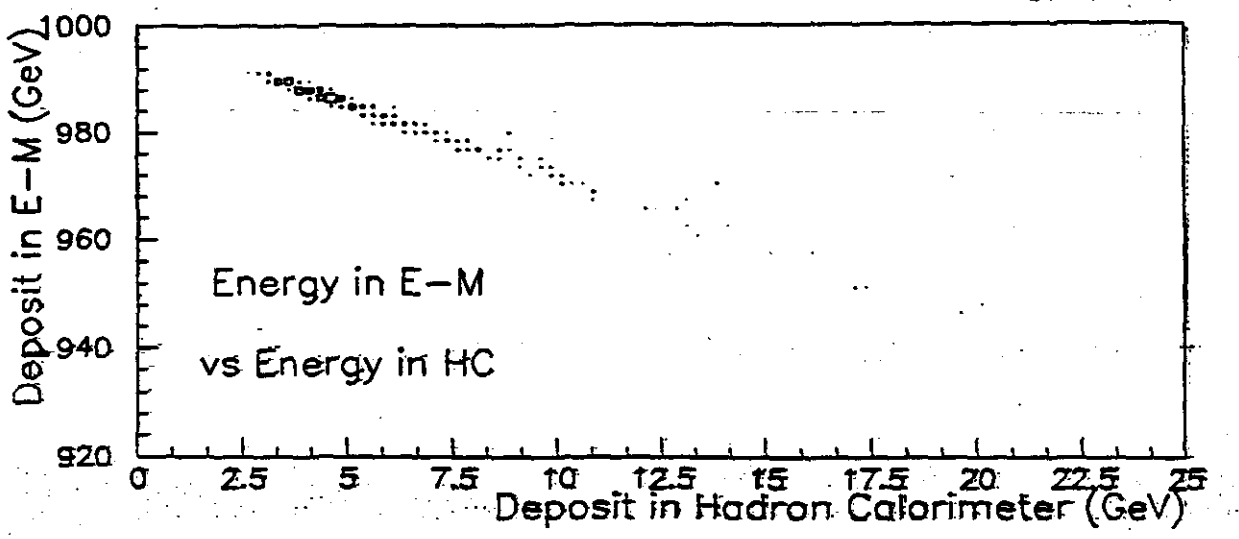


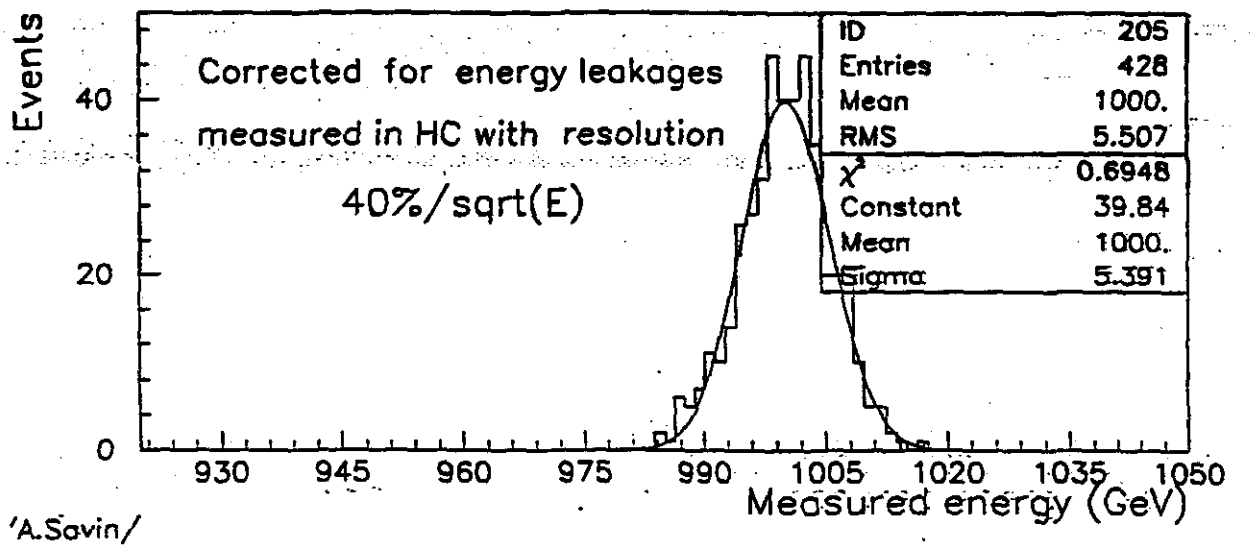

Pion rejection factor
Pion rejection factor
100 GEV.
10^3
10^2
10
Baseline 1 (1.4 X_0 wall)
Hybrid (2.8 X_0 wall)
95
95.5
96
96.5
97
97.5
98
98.5
99
99.5
100
Electron Efficiency %

2.8 X0 dead material between E−M and Hadronic section

24.5 X0 E−M calorimeter





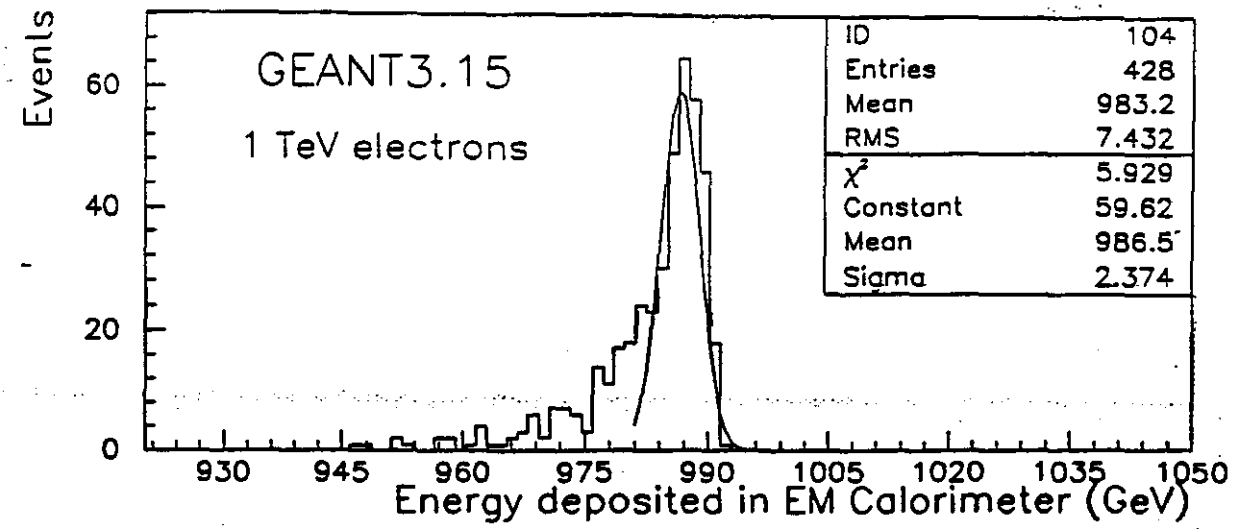


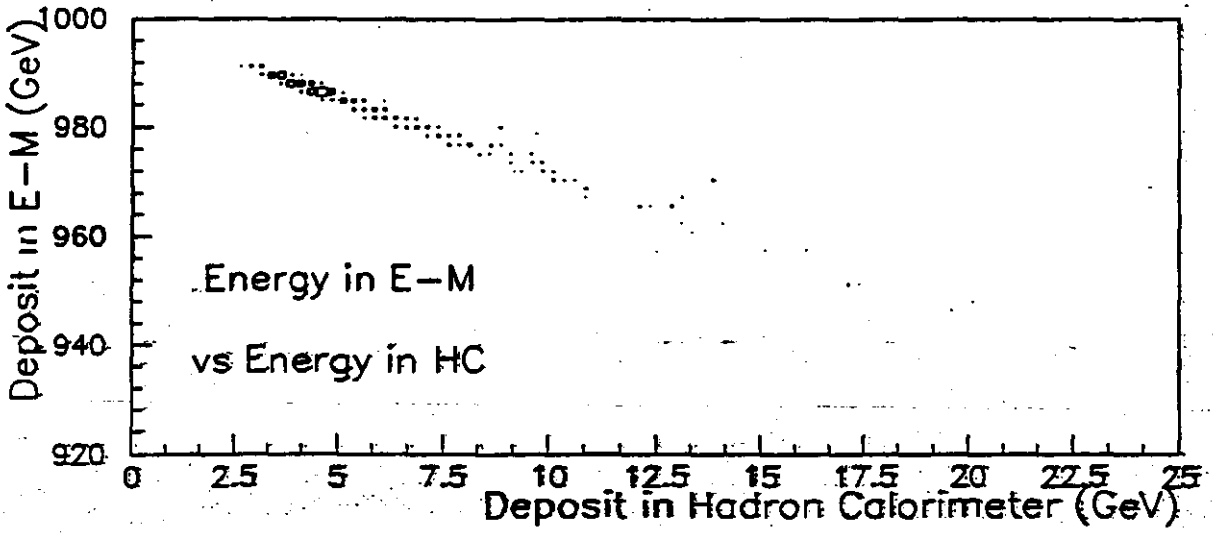
'A.Savin/

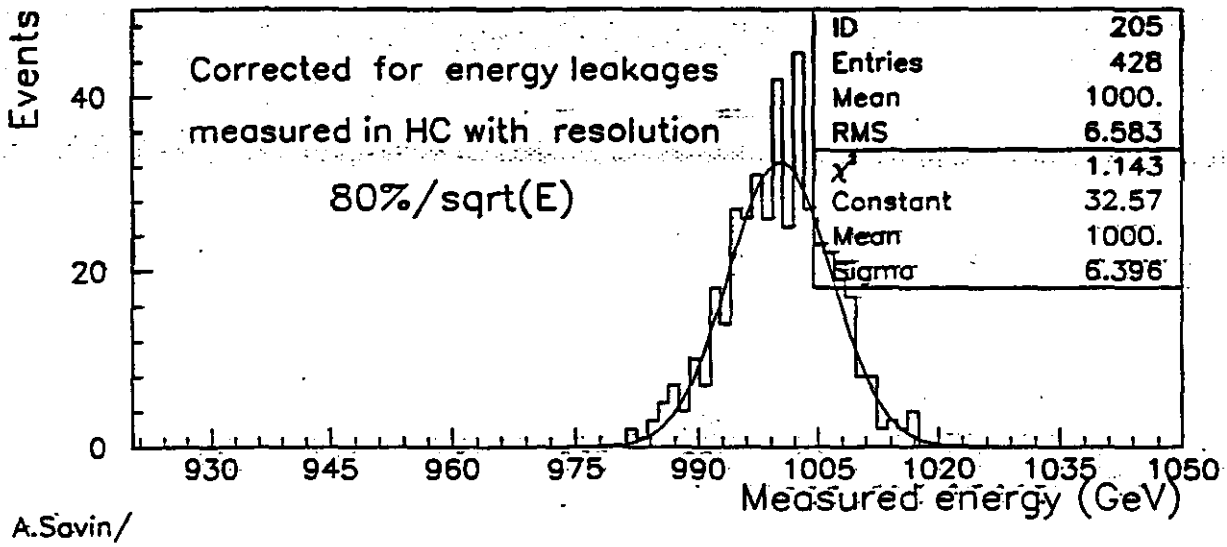
Fig II-2

24.5 X0 E−M calorimeter

2.8 X0 dead material between E−M and Hadronic section





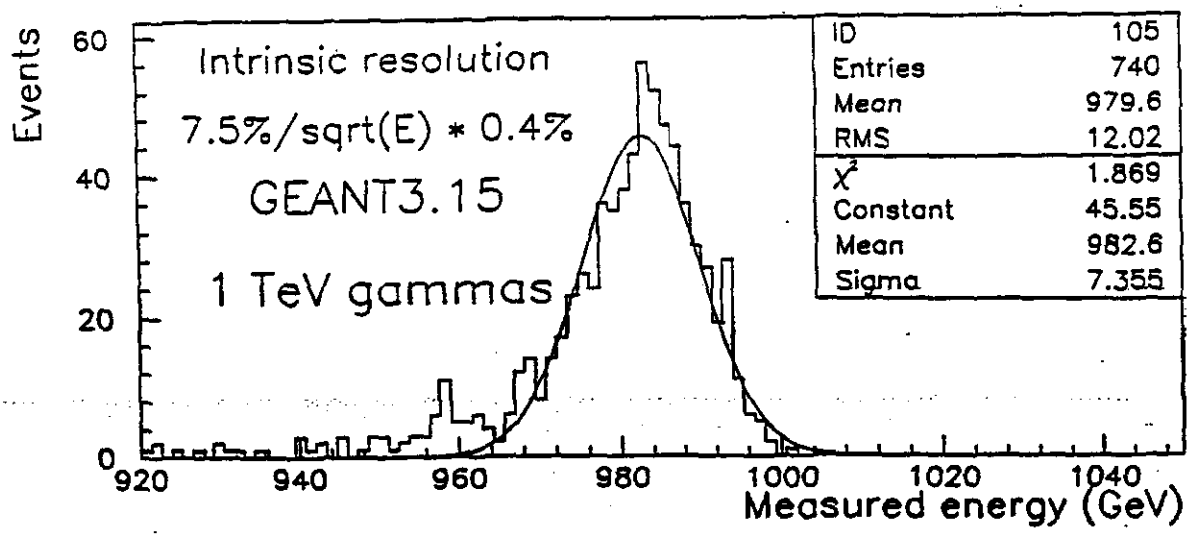


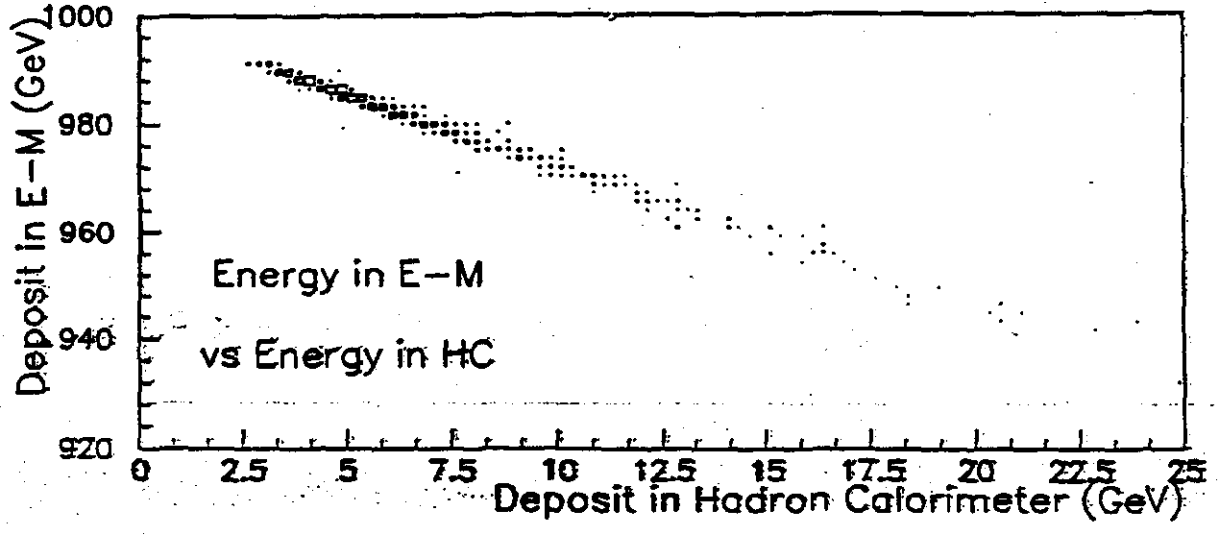
A.Savin/

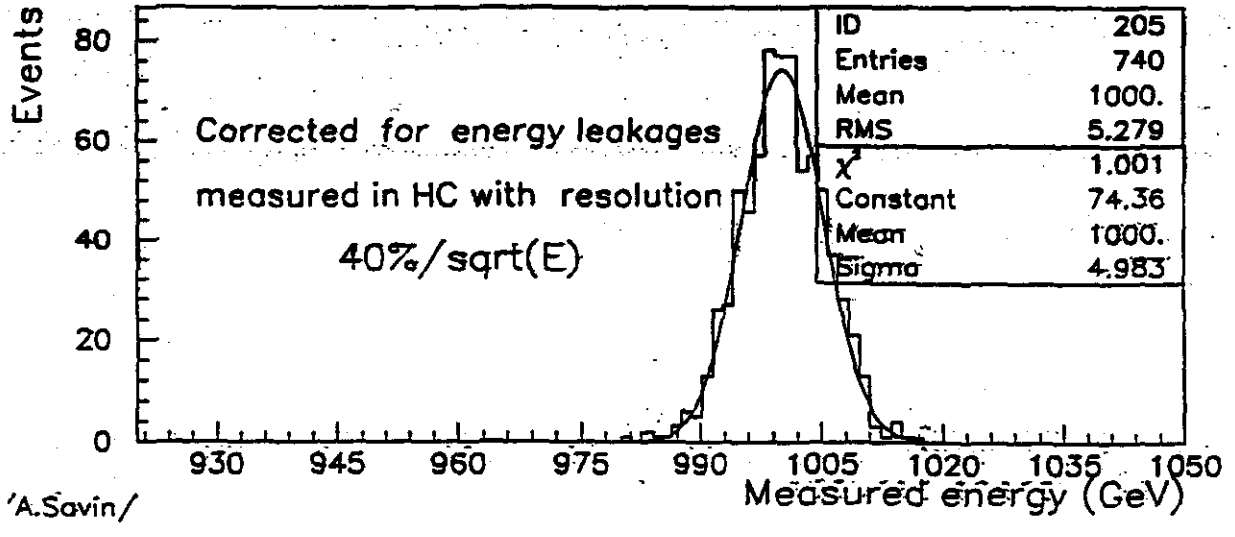
Fig II-3

2.8 X0 dead material between E−M and Hadronic section

24.5 X0 E−M calorimeter





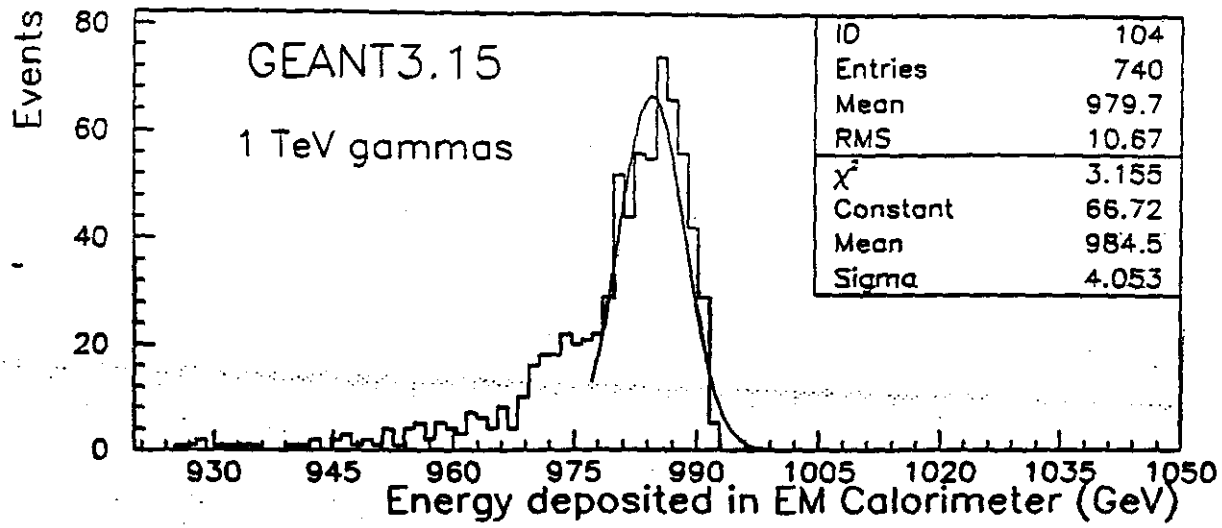


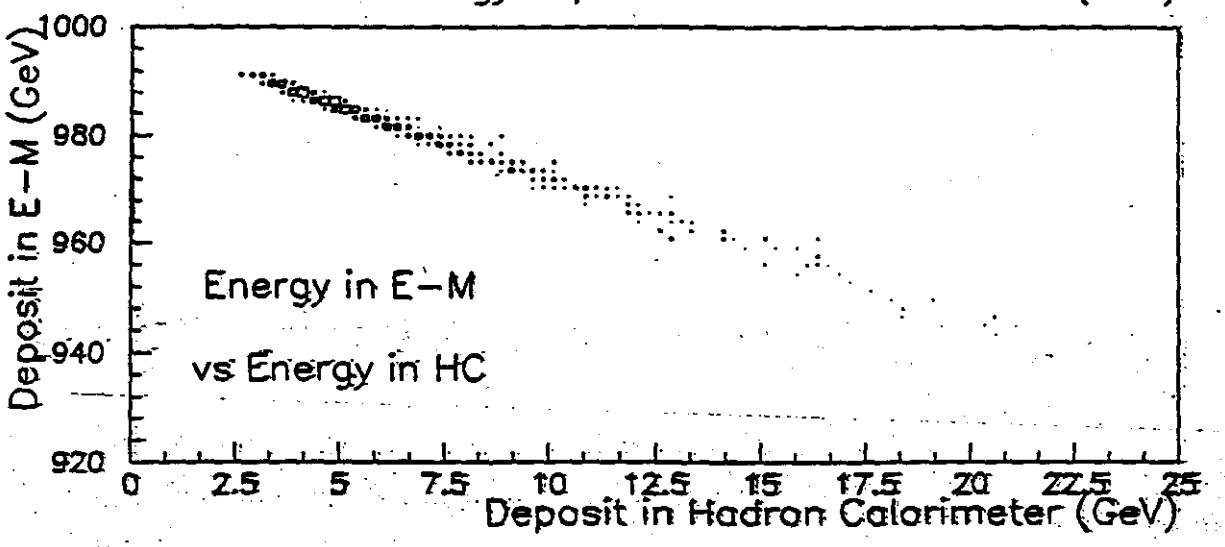
'A.Savin/

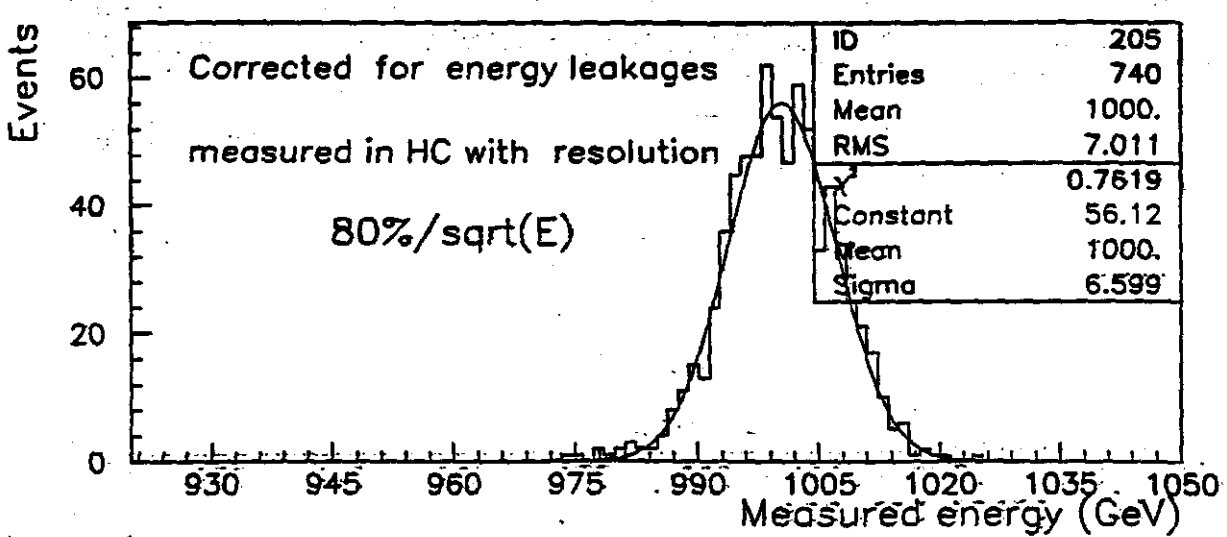
Fig IV-2

24.5 X0 E−M calorimeter

..8 X0 dead material between E−M and Hadronic section







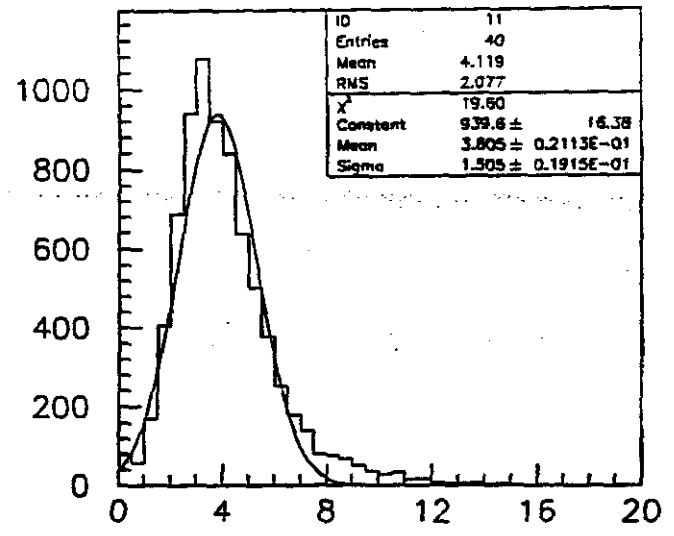
'A.Savin/

Fig. IV-

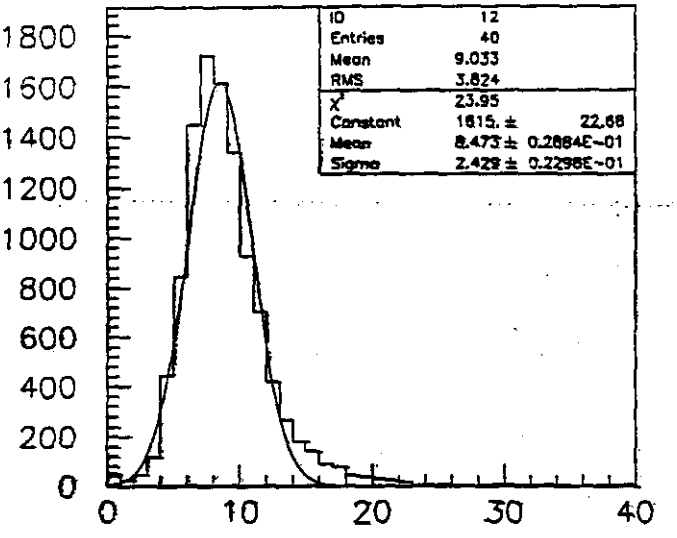
92/09/21 20.36

Beam Test results

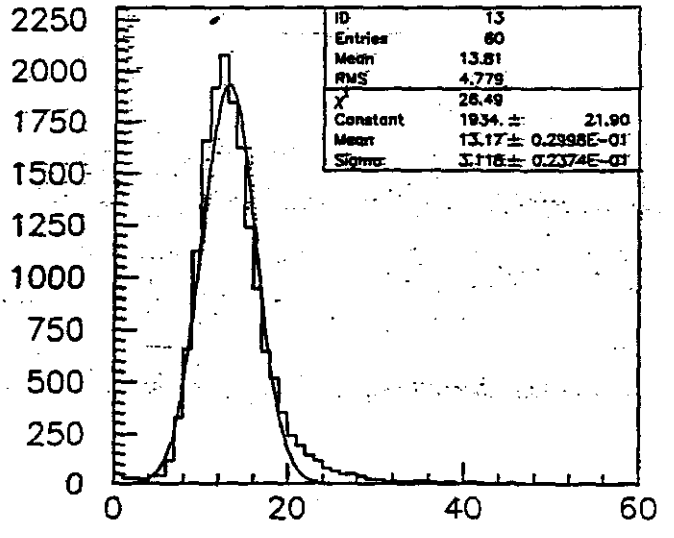
Pions beam pitch=1.5°



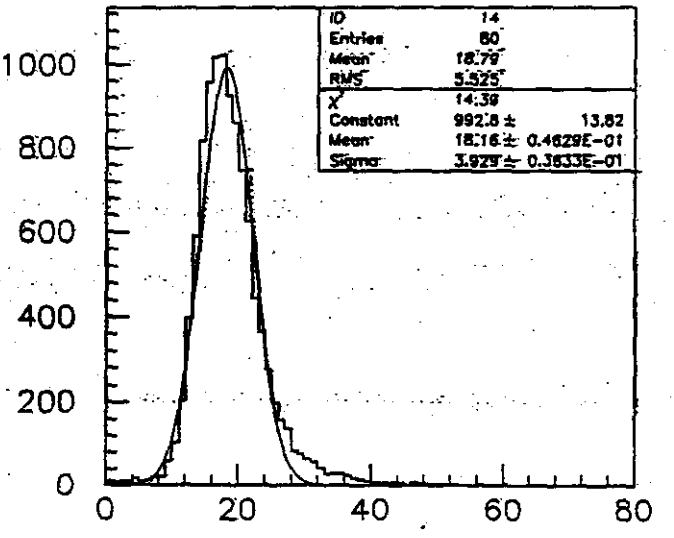
5GEV



10GEV



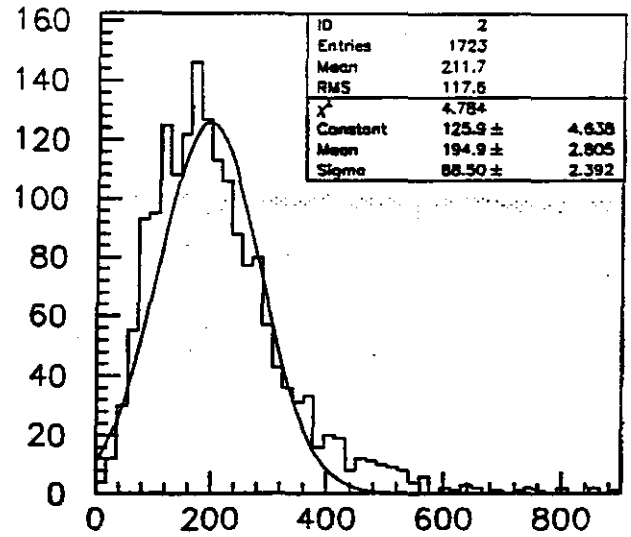
15GEV



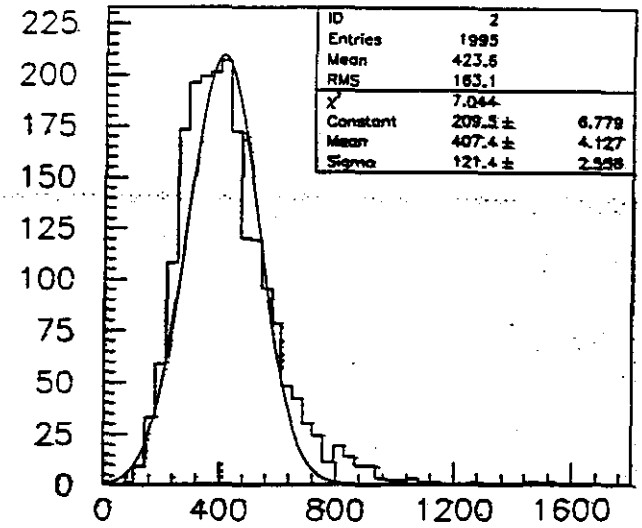
20GEV

GEANT3.15 simulation

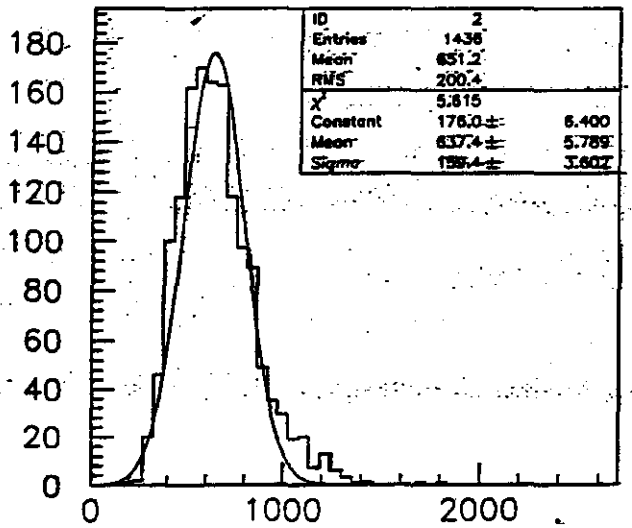
92/09/21 20.37



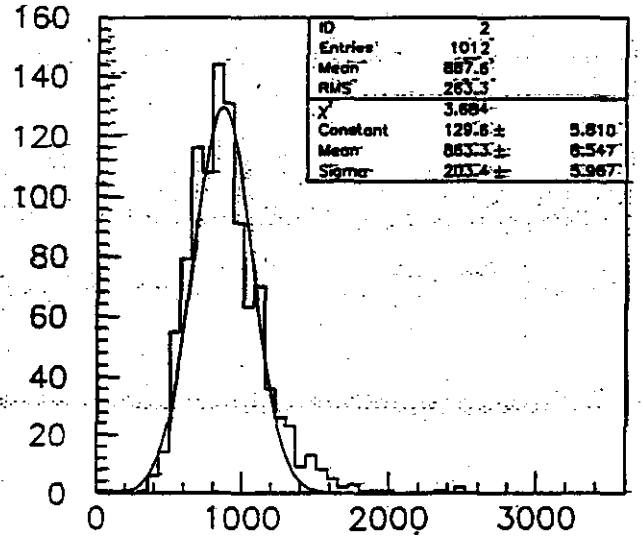
5 GeV



10 GeV

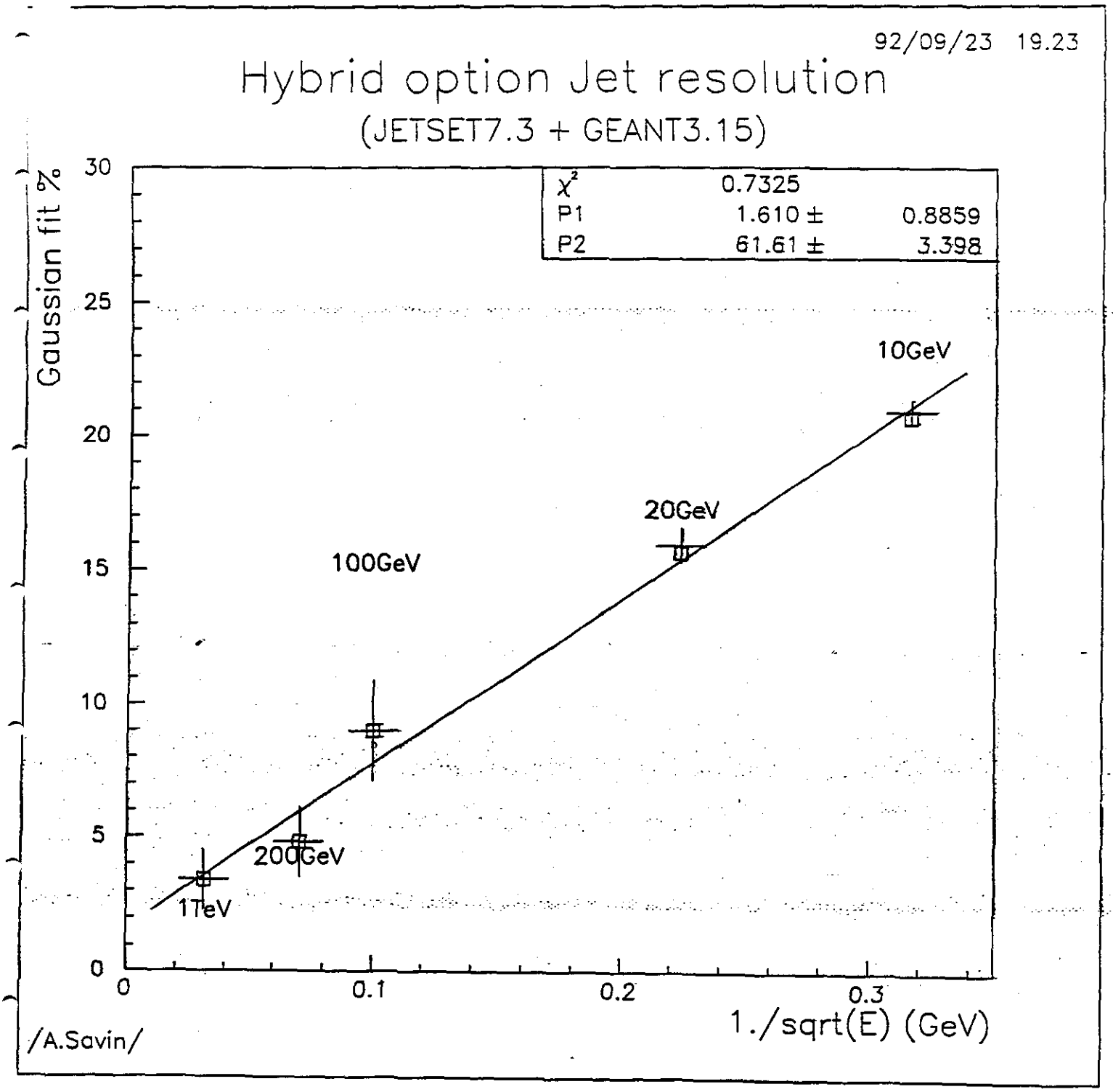


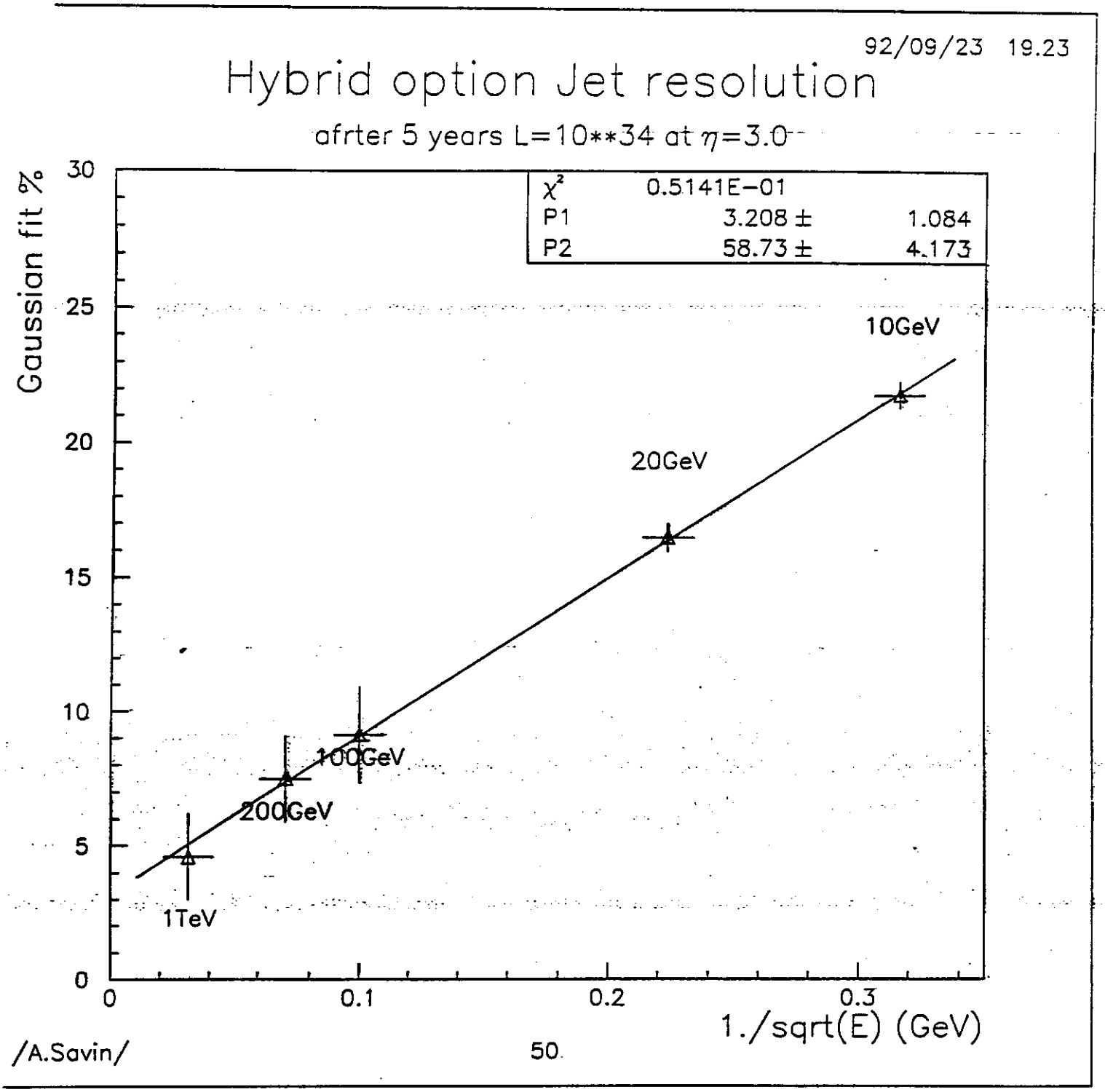
15 GeV



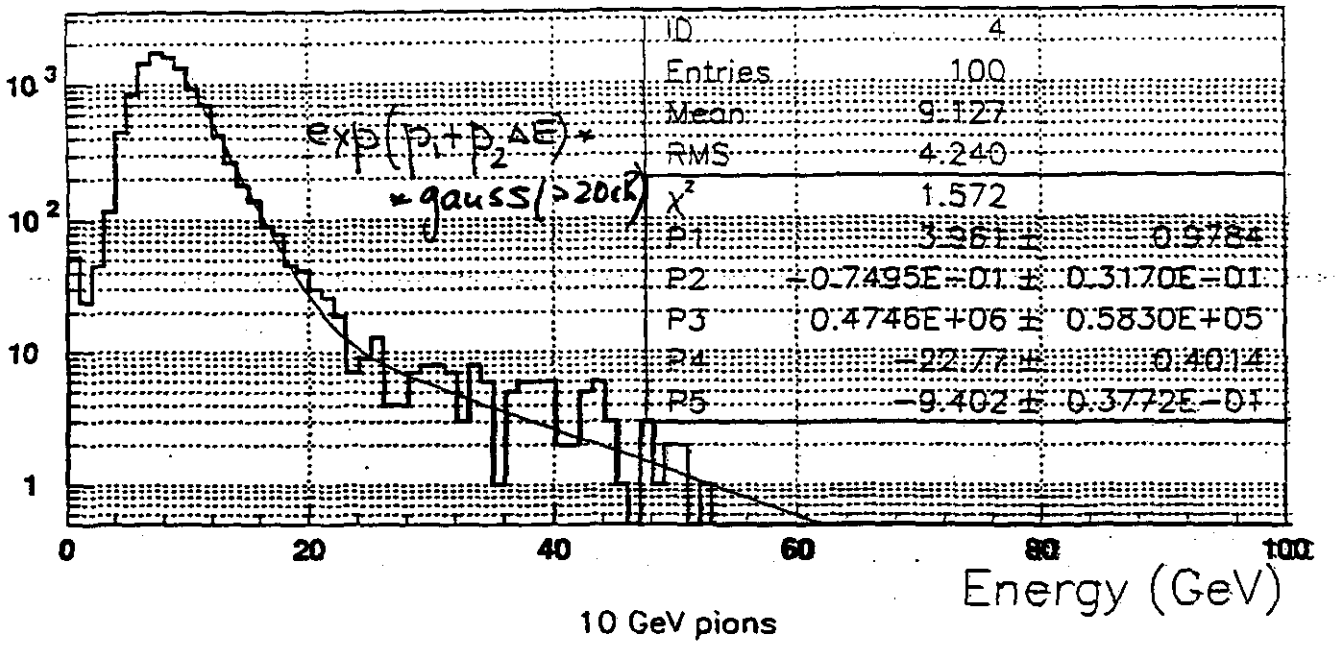
20 GeV

/A.Savin,

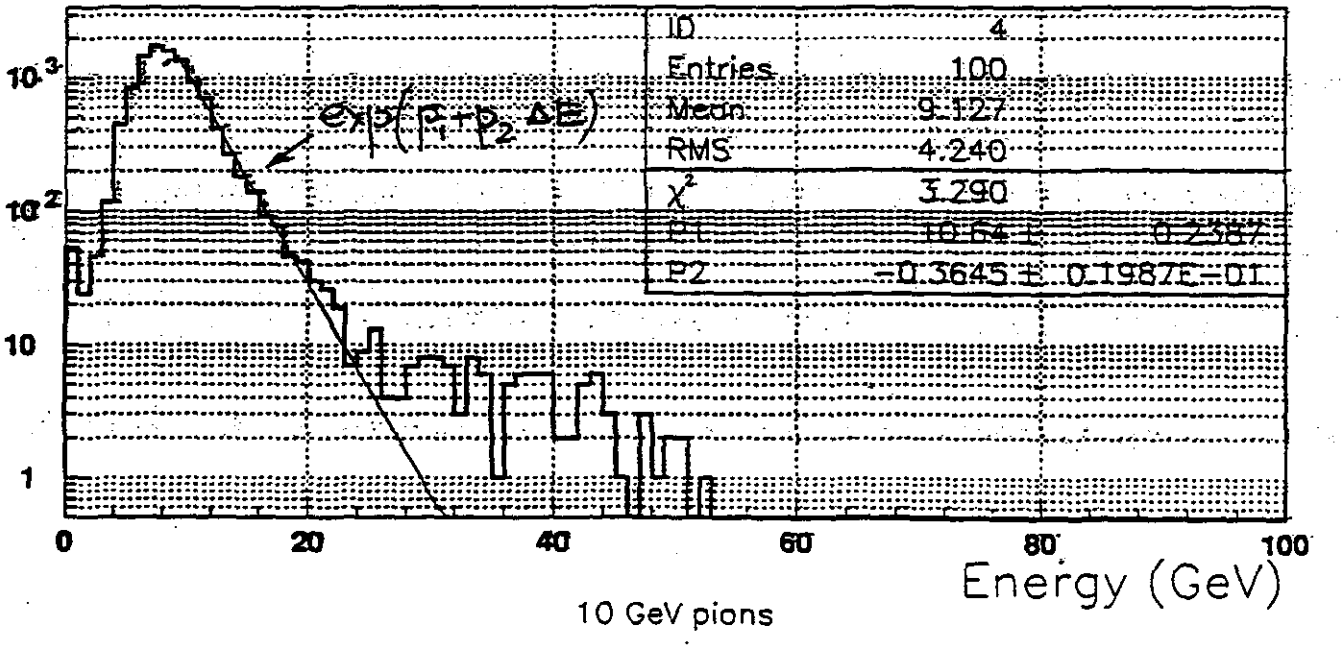

92/09/23 19.23
Hybrid option Jet resolution
(JETSET7.3 + GEANT3.15)
Gaussian fit %
χ^2 0.7325
P1 1.610 ± 0.8859
P2 61.61 ± 3.398
10GeV
20GeV
100GeV
200GeV
1TeV
1./sqrt(E) (GeV)
/A.Savin/


92/09/23 19.23
Hybrid option Jet resolution
afrter 5 years L=10**34 at η=3.0
χ² 0.5141E-01
P1 3.208 ± 1.084
P2 58.73 ± 4.173
10GeV
20GeV
100GeV
200GeV
1TeV
Gaussian fit %
1./sqrt(E) (GeV)
/A.Savin/
50

Fitting by exp(-kx) and gauss*exp(-kx)

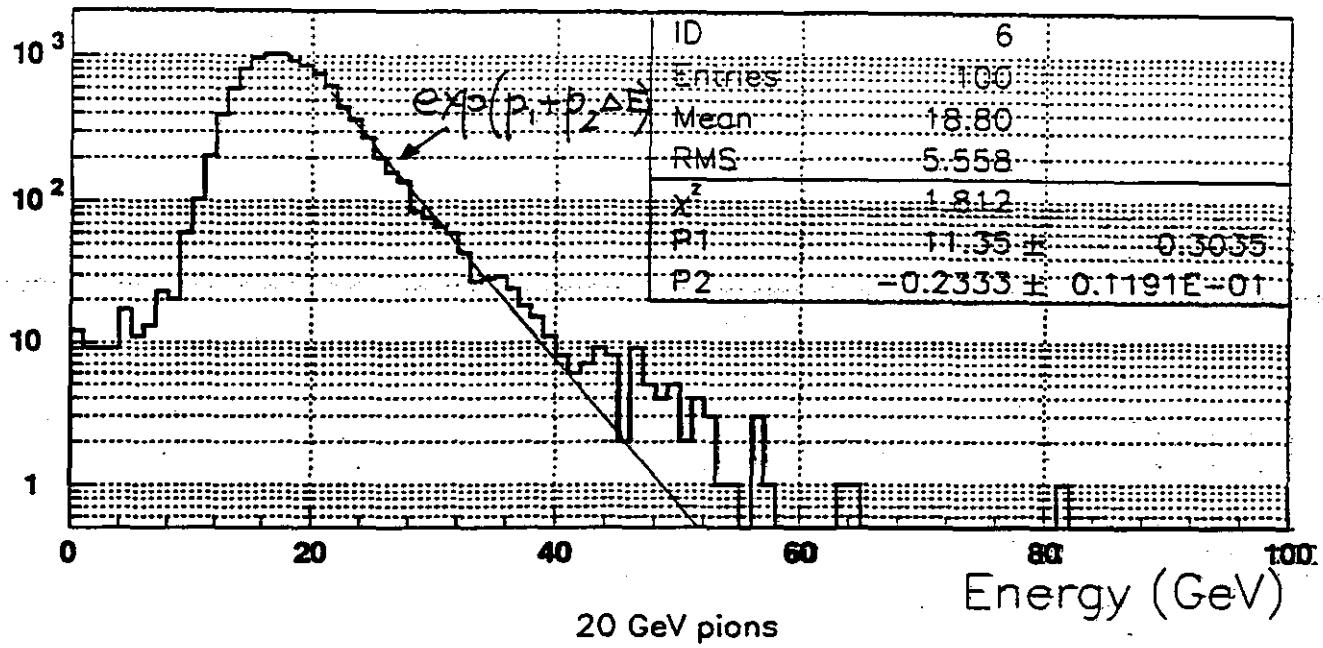


10 GeV pions

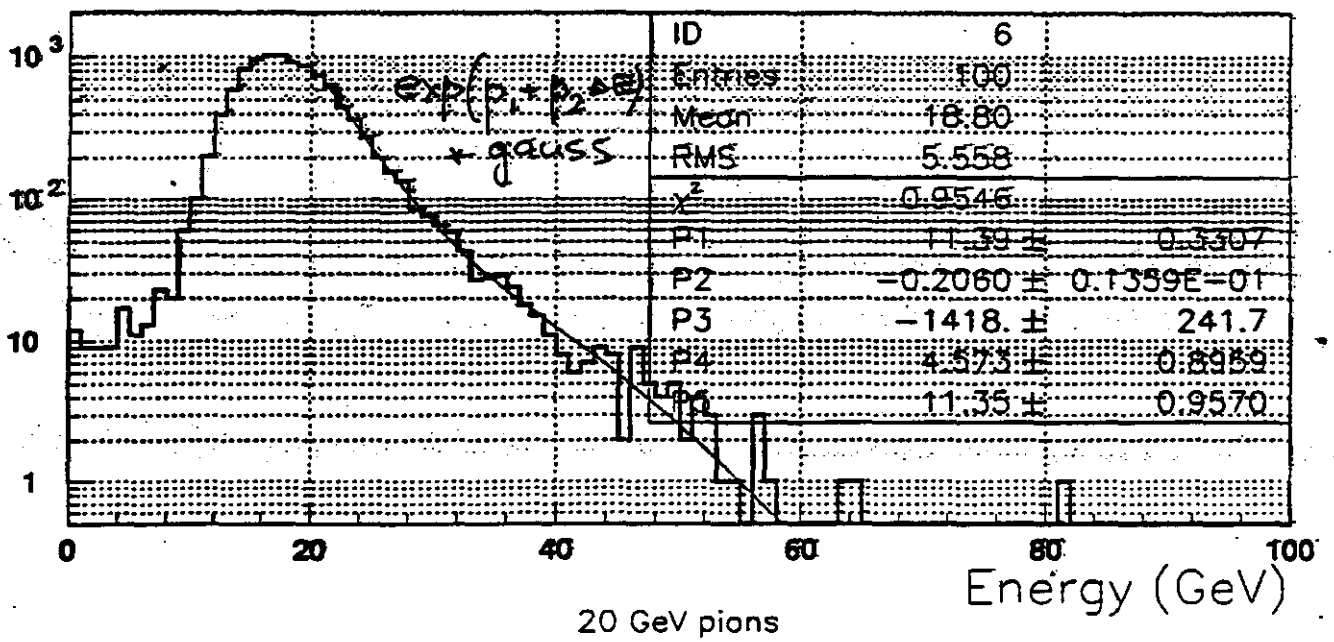


10 GeV pions

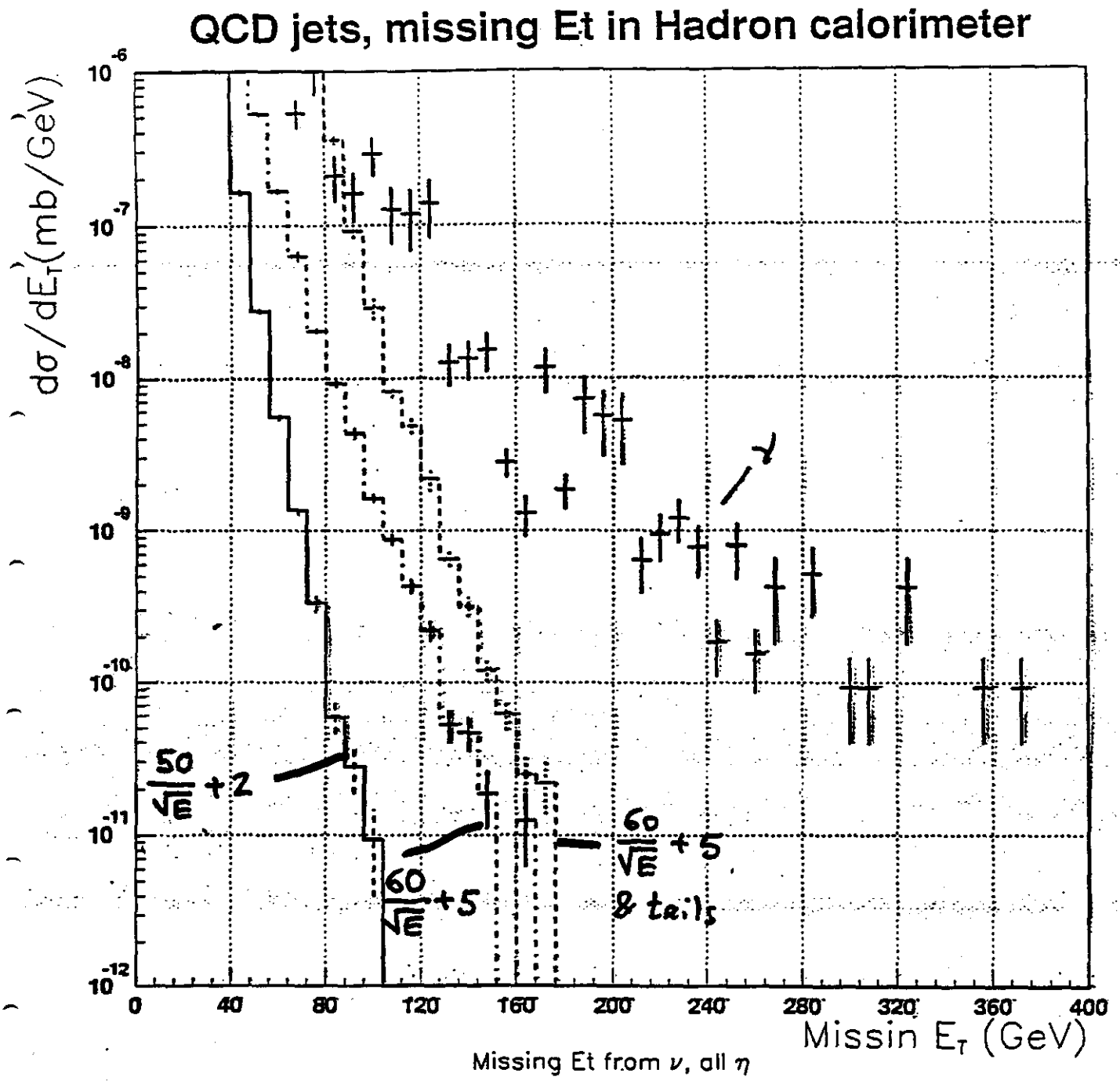
Fitting by exp(-kx) and gauss*exp(-kx)

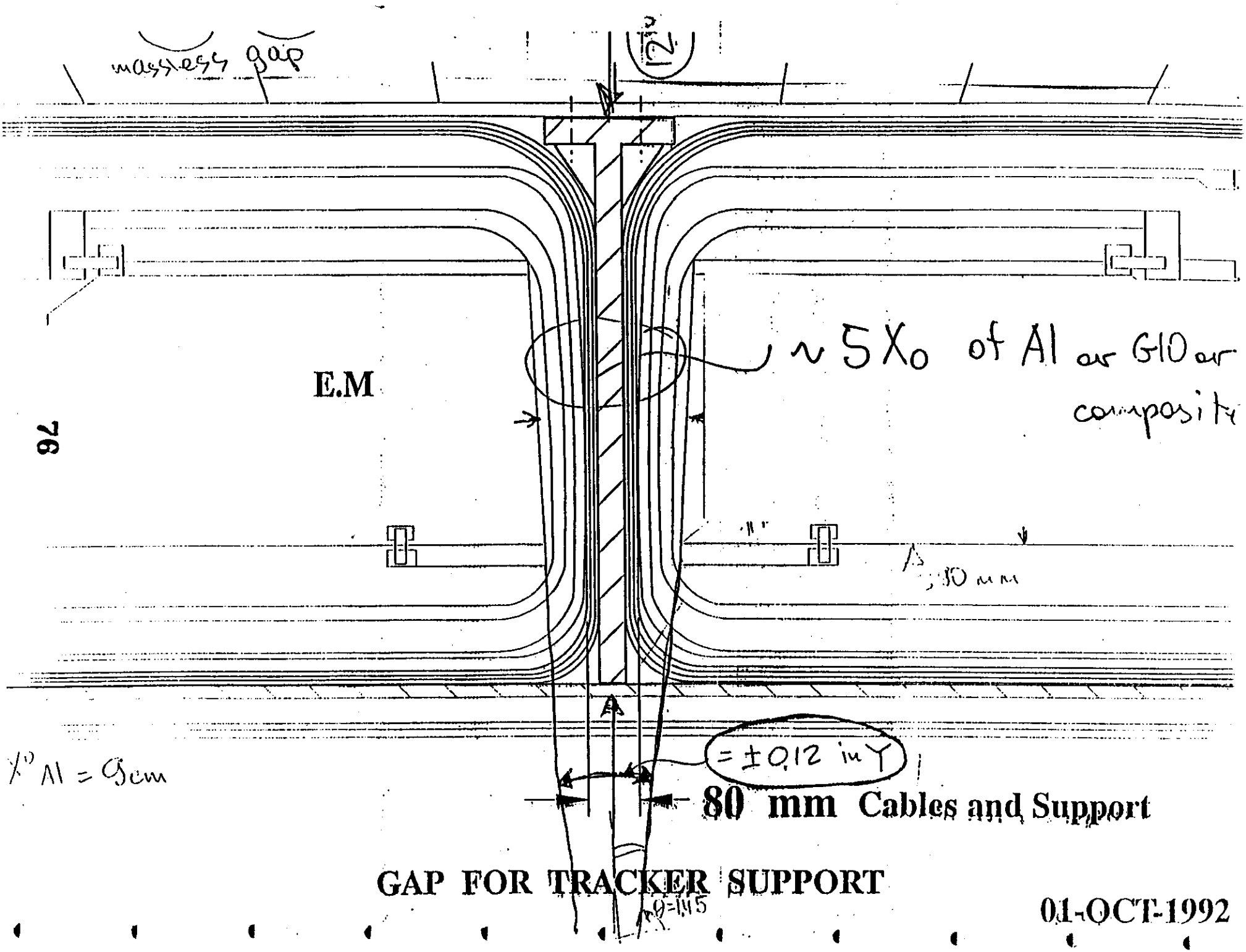


20 GeV pions



20 GeV pions

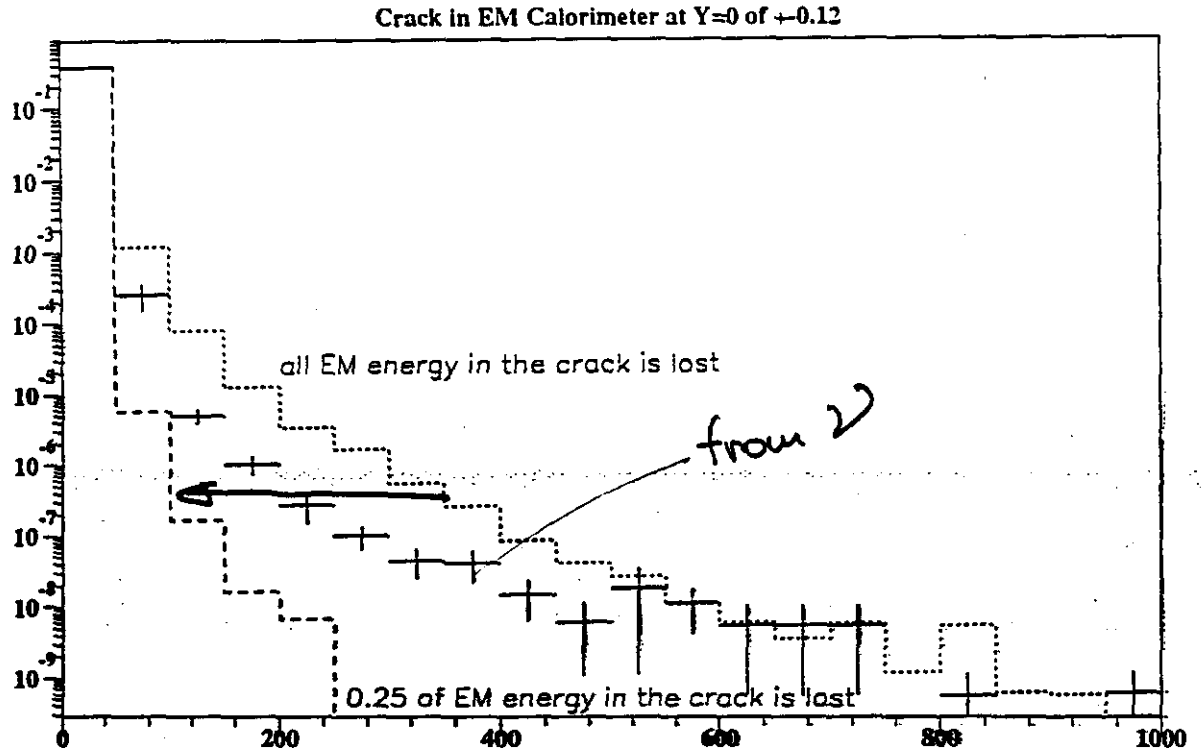

QCD jets, missing Et in Hadron calorimeter
dσ/dE_T(mb/GeV)
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
0
40
80
120
160
200
240
280
320
360
400
Missin E_T (GeV)
Missing Et from ν, all η
50/√E + 2
60/√E + 5
60/√E + 5
& tails
ν

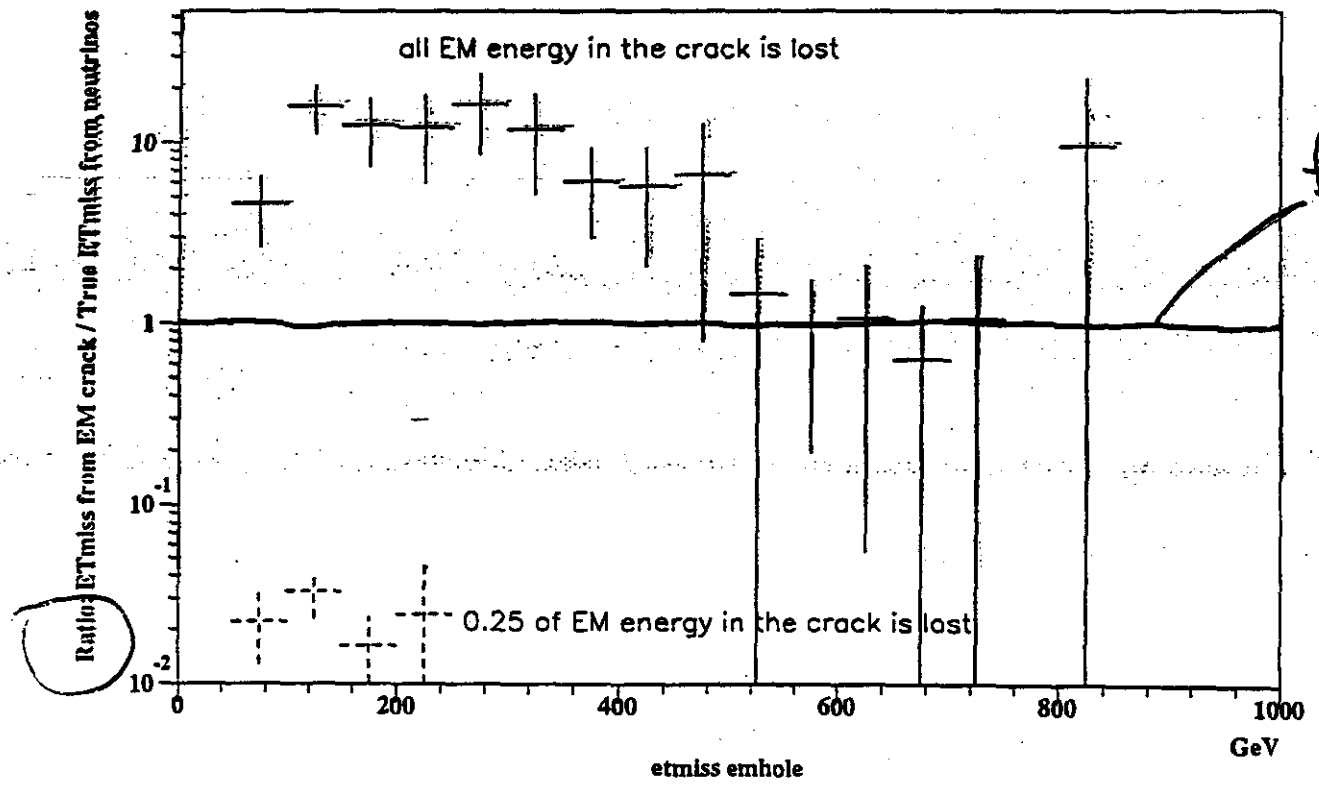

massless gap
12°
E.M
~5 X0 of Al or G10 or composite
50 mm
X0 Al = 9cm
= ±0.12 in Y
80 mm Cables and Support
GAP FOR TRACKER SUPPORT
θ=145

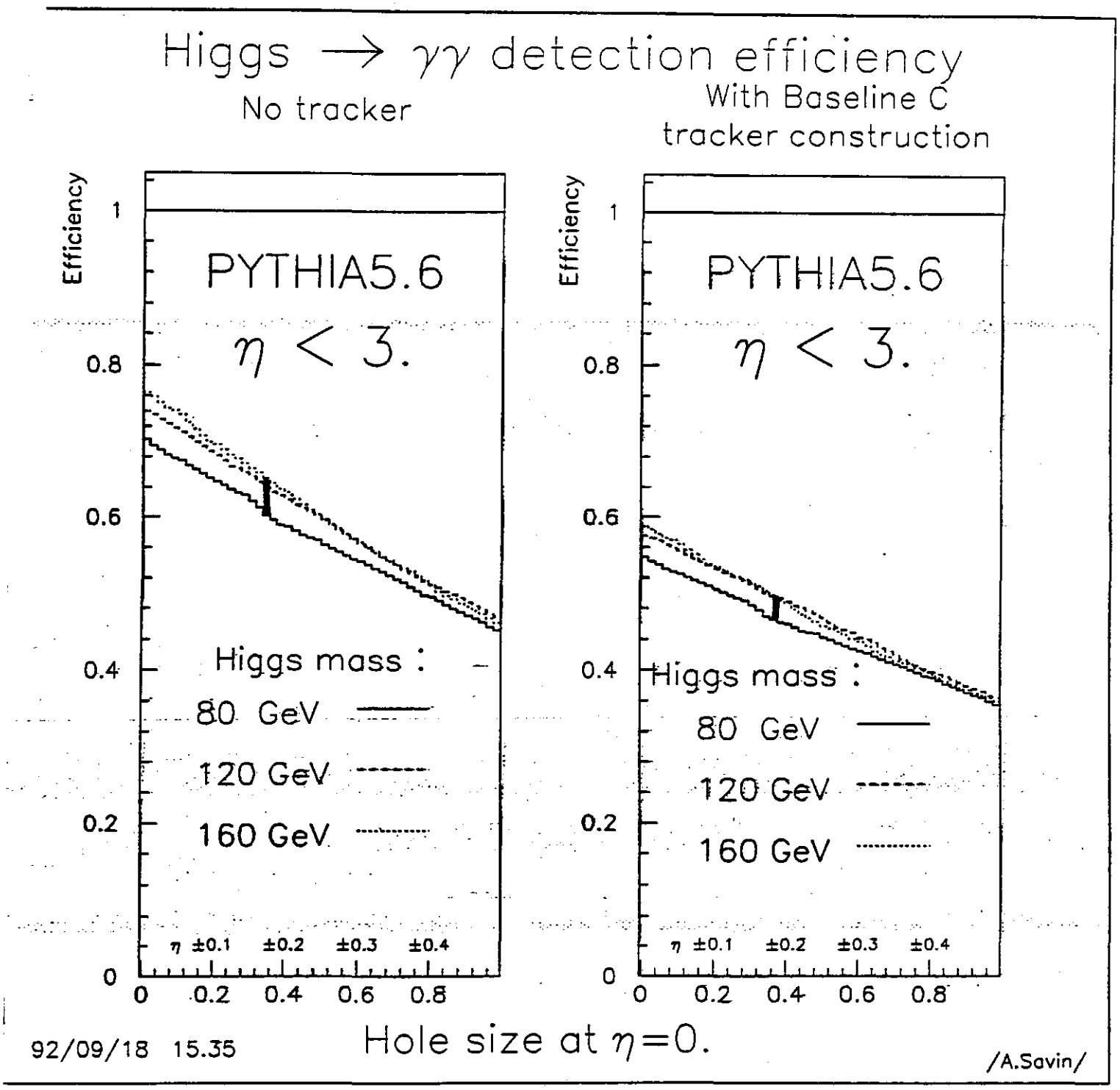
01-OCT-1992

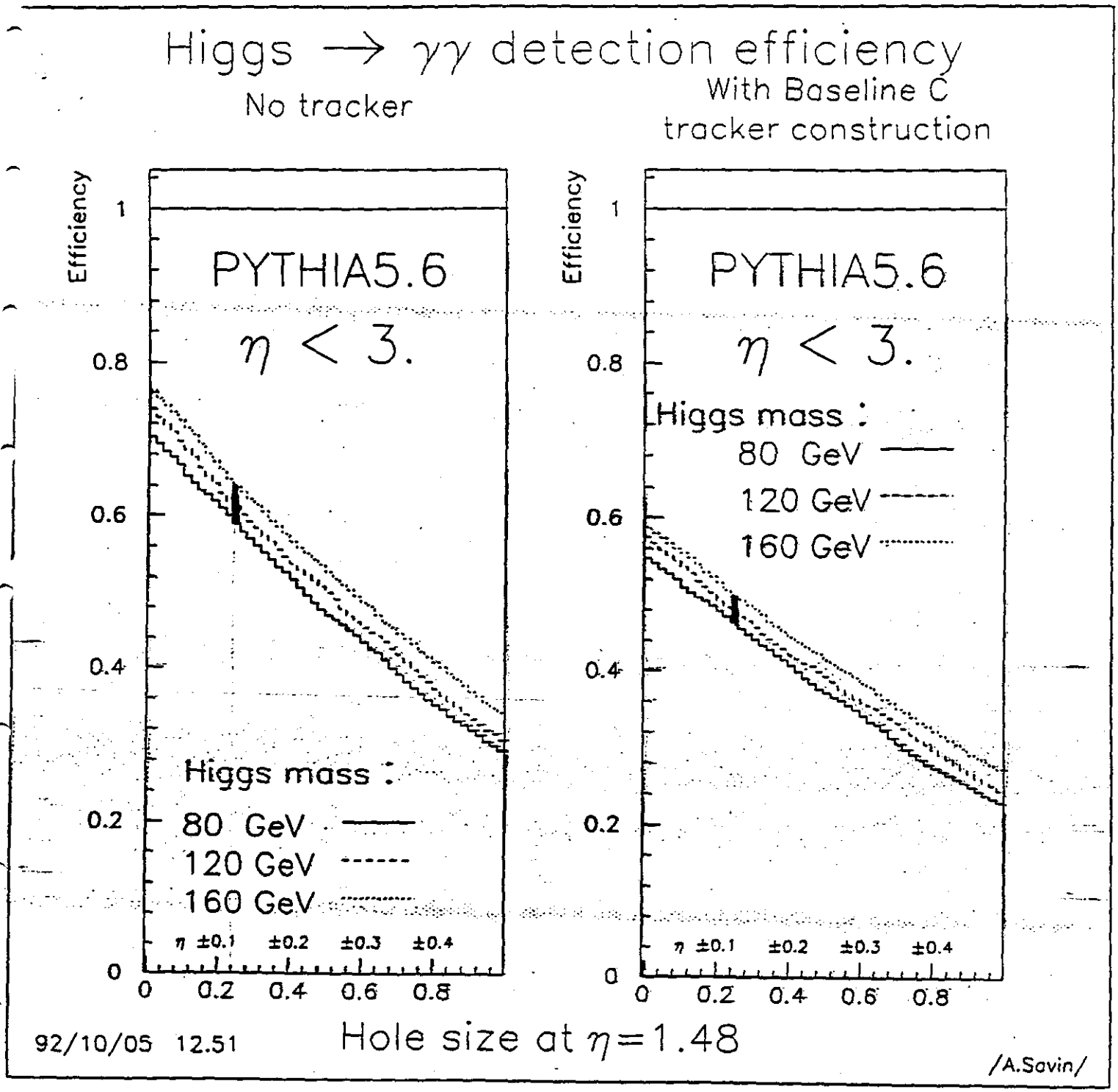
EM resolution within crack : $\frac{100\%}{\sqrt{E}} \oplus 0.4\%$

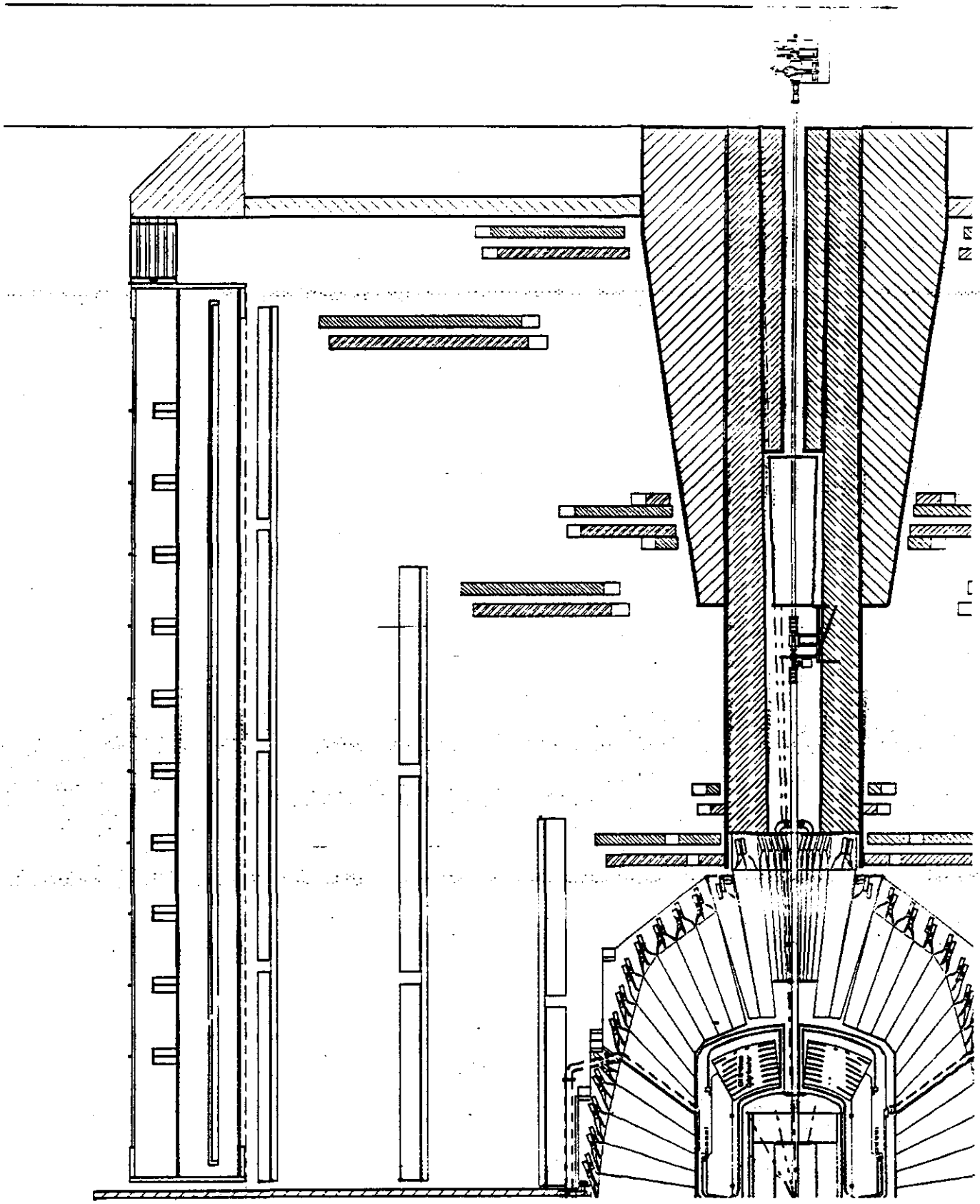
92/10/07 11.50






Higgs → γγ detection efficiency
No tracker
With Baseline C
tracker construction
Efficiency
PYTHIA5.6
η < 3.
Higgs mass :
80 GeV
120 GeV
160 GeV
η ±0.1 ±0.2 ±0.3 ±0.4
0 0.2 0.4 0.6 0.8 1
Hole size at η=0.
92/09/18 15.35
/A.Savin/


Higgs → γγ detection efficiency
No tracker
With Baseline C
tracker construction
Efficiency
PYTHIA5.6
η < 3.
Higgs mass :
80 GeV
120 GeV
160 GeV
η ±0.1 ±0.2 ±0.3 ±0.4
0 0.2 0.4 0.6 0.8 1
92/10/05 12.51
Hole size at η=1.48
/A.Savin/



Preliminary Conclusion of the Working Group:

We identified no show-stoppers in the proposed hybrid design. The majority of the working group is convinced that the design has many attractive features which make it the viable alternative to the integrated cryogenic calorimeter design. Much progress has been made in a very short time, however, the design is still in an developmental stage. The robustness of the concept will, the majority believe, allow optimization of the design if this option is selected.

Attractive features of the hybrid option

- maximum absorbtion length within given radial calorimeter extention which enforce the robustness of muon system;
- fast response (less pileup) and low noise in HC leading to independent isolation criteria made with Hadron Calorimeter only Corresponding isolation cut complements robust measurement of photons and leptons;
- fast rise and fall time, assuring reliable beam crossing assignm and minimizing pile up contribution to missing Et measurement;
- e/h close to 1 - approx. compensated performance;
- hermetic registration of jets and missing Et;
- better seal of muon system in the endcap and forward directions against neutron leaks;
- generally lower neutron fluxes due to presence of hydrogenious material in the hadronic section;
- simple low risk design, construction and operation;
- better E-M calorimeter because E-M group effort is better focused and concentrated;
- flexible production and installation schedule;
- low cost;
- possibility to reduce the cost of the calorimeter system via international collaborations;
- broader international and US participation in GEM calorimetry;

Non-Attractive Features:

- More material due to tracker support and additional layer of cabl in front of LKr E-M two-cups design (0.17 Xo)
- No longitudinal segmentation in the sci. hadronic section (except for the last 2-3 lambda section with separate readout)
- Smaller surface area to accomodate large amount of feedthroughs (if that will be required by preradiator design with large number of readout channels - 50% more is still OK)
- In two cup design option split of E-M at eta=0 degrades the E-M resolution at the place where the tracker works the best

Risks:

1. Krypton loss. In the very improbable event of loss of a substantial volume of Krypton, replacement will take at least months, as well as being expensive.

2. Beam availability - Many HCal modules must be beam tested before test beams become available at SSCL. Test beam availability elsewhere is presently uncertain.

3. Reliability of estimates that the electronics can be adequately cooled in all noble liquid options.

4. Ability to purify the krypton.

5. Fiber radiation damage.

6. Perceived weaknesses in the current calorimeter groups' efforts.

gem

γeμ

Presentation by:

D. Lissauer

An Integrated Noble Liquid Calorimeter

1. Physics Req
2. Overview
3. Hadronic Cal.
4. Forward Cal.
5. E. m Cal.
6. Conclusion.

D. Lissauer
B.N.L

Physics Objectives:

Robust Detector : γ, e, μ (GEM)

+ Jets, $\not{E}_T$.

γ, e : e.m Calorimeter.

Jets, $\not{E}_T$ } Integrated Perfor.
μ } em + Had.

$\mathcal{L}$: 10^{34} Capability.

Higgs $\to \gamma\gamma$ (Not only Assoc. production)

$\to ZZ$
$\hookrightarrow$ jet jet High Mass.

quark Substructure : Jet resolution

Supersymmetry : $\not{E}_T \geq 100$ GeV.

I. Physics Requirements:

EM calorimeter Specifications

- Energy Resolution: $\delta E/E = 6.0\%/\sqrt{E} \oplus 0.4\%$.
- γ/Jet separation, γ/π^0 separation. (Isolation cuts)
- Pointing: Mass resolution at high luminosity.
- Position resolution $5\text{mm}/\sqrt{E}$
- Transverse granularity $\Delta\eta$ x $\Delta\phi$ = 0.032x 0.032
- η coverage up to 3.

Hadronic calorimeter specifications

- Energy resolution 60 $\%/\sqrt{E} \oplus 2\%$
- e/π between 0.9 to 1.3
- Total active depth of 9-10 λ for Jet and missing energy measurments.
- Total active depth for μ measurements.
  11 λ at $\eta = 0$ and 14 at $\eta = 3$.
- Transverse granularity : $\Delta\eta$ x $\Delta\phi$ =0.08 x 0.08
- Longitudinal segmentation :

  λ_1 = 2.5-3. λ_2 = 2.5-3.

  λ_3 = 2.0-2.5 λ_4 = 1.5-2.5

Forward Calorimeter

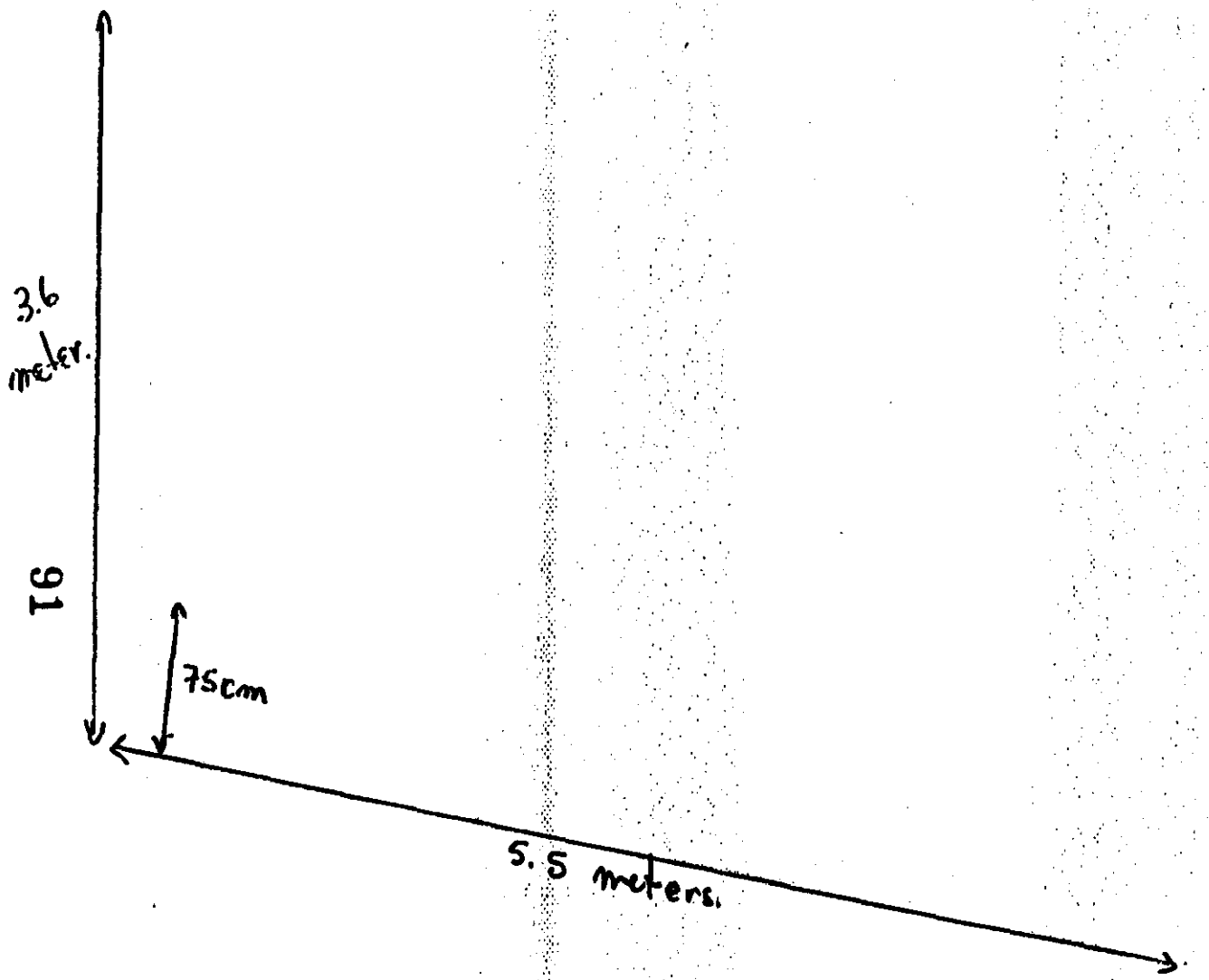
- η coverage up to 5.5
- P_T resolution of better than 10%.

Calorimeter Trigger Information

The calorimeter system has to provide a major part of the information that is needed by the trigger system. This imposes a number of constrains on the design .

The information we need:

- isolated em shower : $P_T >$ 15 Gev/c. 1,2 or 3 candidates.
- isolated em shower : $P_T >$ 35 Gev/c. 1 or 2 candidates.
- Jet : $P_T >$ 100 , 200 , 500 , 1000Gev/c 4 Levels for Jet trigger.
- E_T^{total} : $E_T >$ 200, 500 , 1000 Gev/c 3 Levels for the E_T trigger
- E_T^{em}: $E_T >$ 35 Gev/c.
- SPT- Single Particle trigger : $E_T >$ 50, 100 , 500 Gev/c. 3 levels for the Single particle trigger.
- Missing E_t: $E_T^{miss} >$ 100 GeV.



Barrel: Liquid Krypton

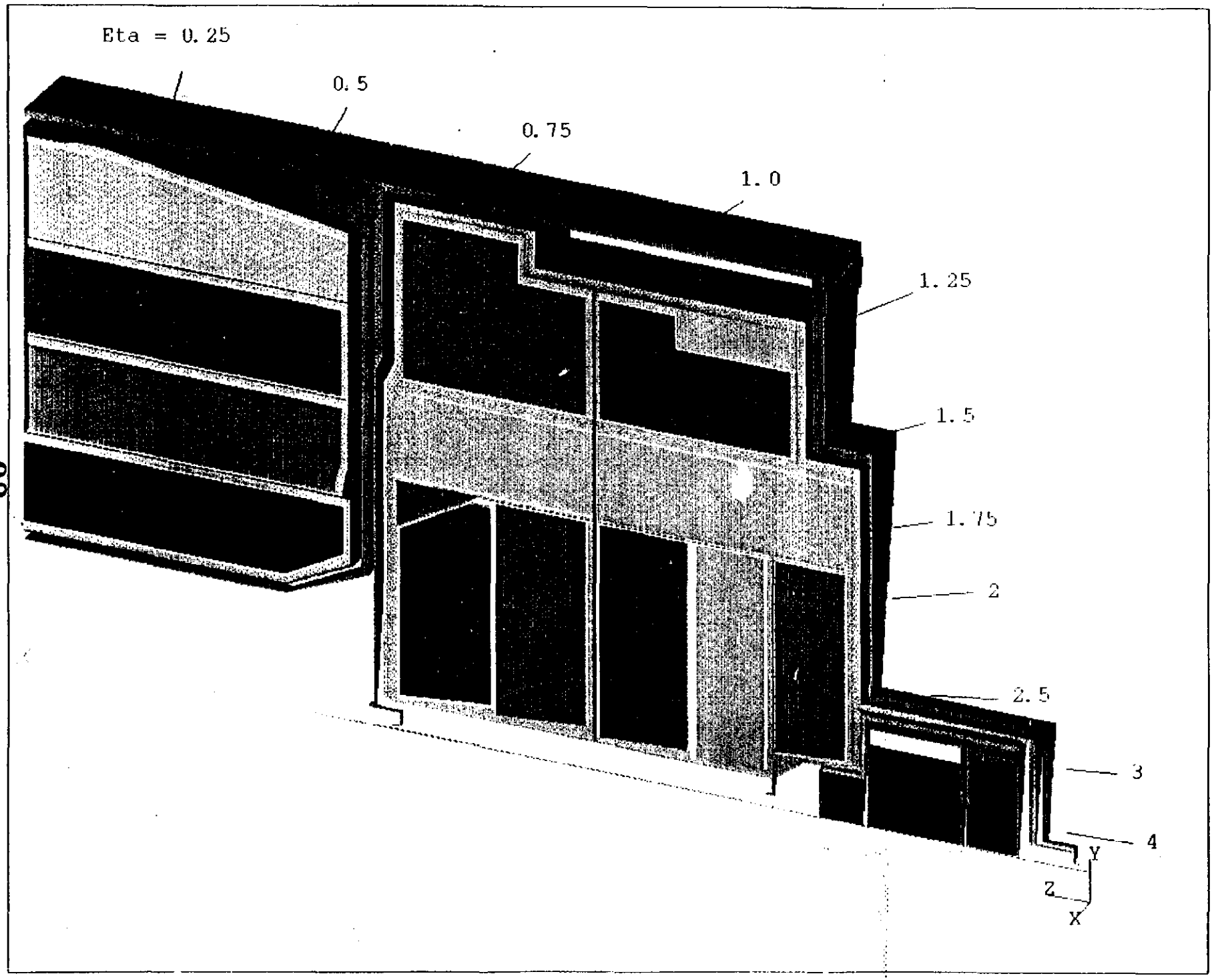
end Cap : Liquid Argon

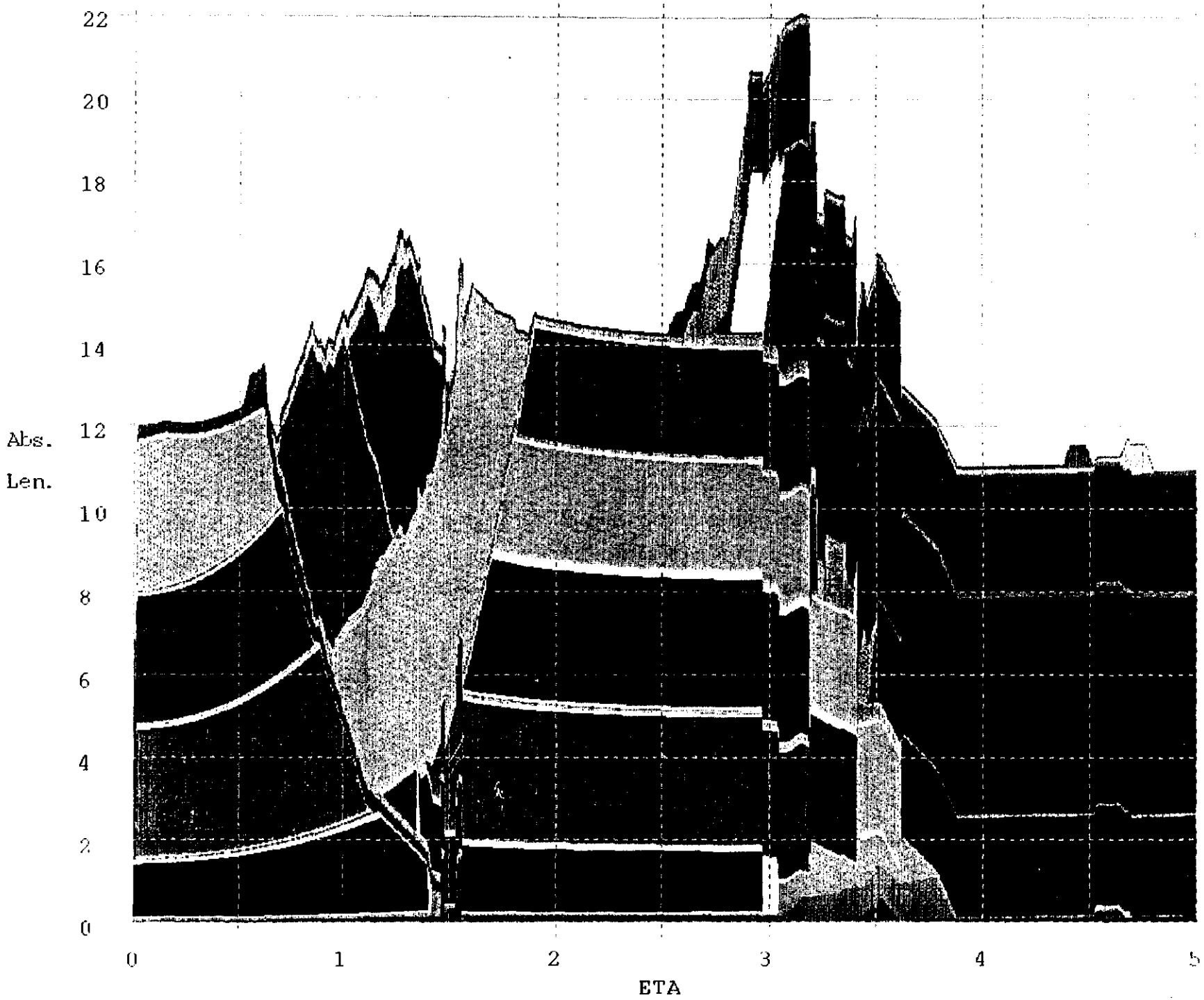
E.m: Accordion

Had: EST III plate.

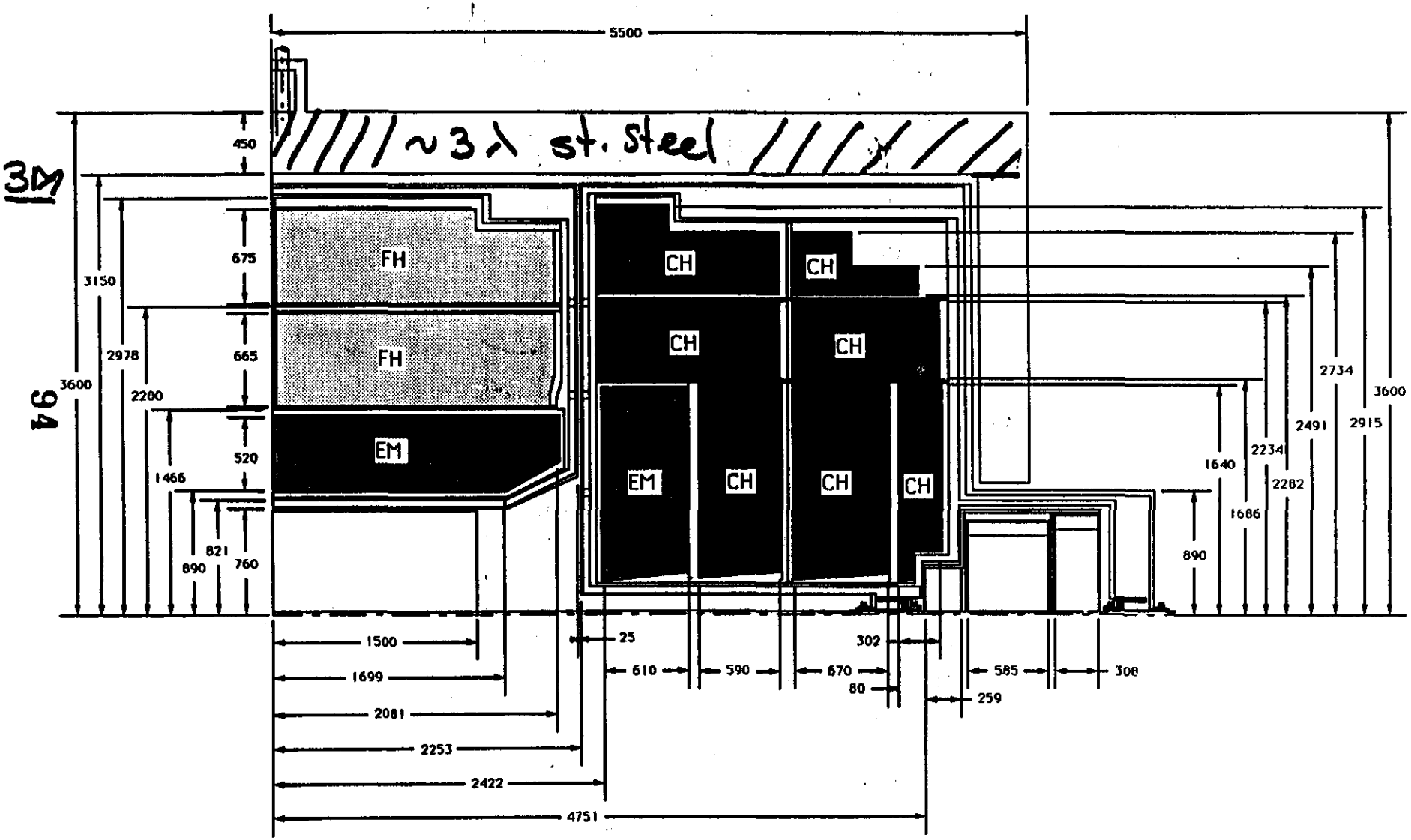
Forward: Tube

~100 -200 μ gap


Eta = 0.25
0.5
0.75
1.0
1.25
1.5
1.75
2
2.5
3
4
Y
Z
X


Abs.
Len.
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
ETA

9 x 11 Lambda - Dimensions



K Barnstable 9x11 Config

9-11 λ

Motivation

PAC suggestion - trade active hadron calorimetry for EM capability

Roger McNeil calculation - effect on μ's

9λ with 20%/√E better than

12λ with 35%/√E

Advantages

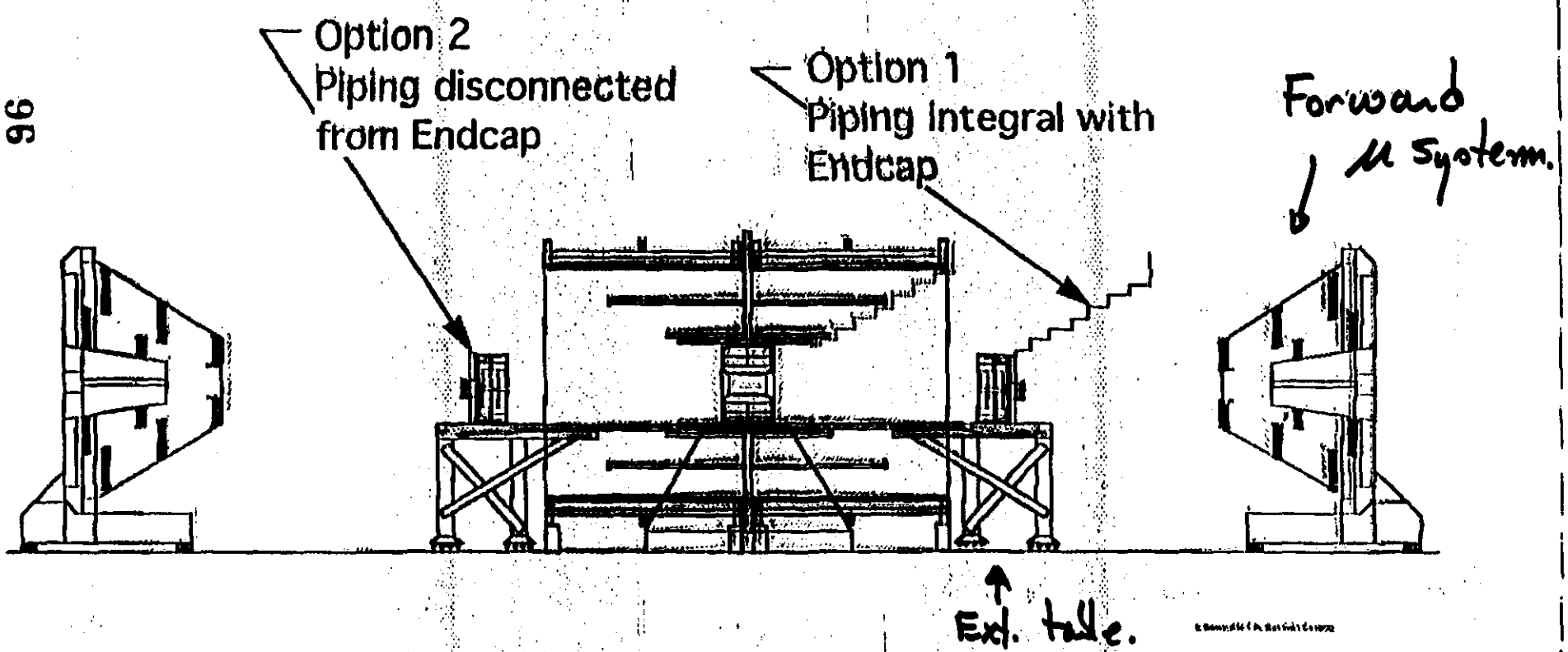
1) Lower cost of hadron $10-15M
   Less active hadron modules $8.5M MMA
   Less Kr volume
2) More Flexibility in installation - connection to central detector support.
3) Decoupling of structure from cryostat
4) Smaller cryostat - ~ SLD magnet
   ∴ can be transported from overseas
5) Incorporation of Borated Poly in same structure?

Tracker Maintenance - 1 Piece Support Tube Calorimeter

Tracker access is similar with each cabling and piping option:

1. With Option 1, the roll transfer cradle will include provisions for supporting the cabling and piping while accessing the tracker.

2. With Option 2, all cabling and utilities must be disconnected.



9' x 11' Lambda - Dimensions

Hadron: 4 Long. Seg.

$\Delta\eta \times \Delta\varphi$: 0.08 x 0.08

$\frac{\Delta E}{E} = 50\%/\sqrt{E} \oplus 2\%$*

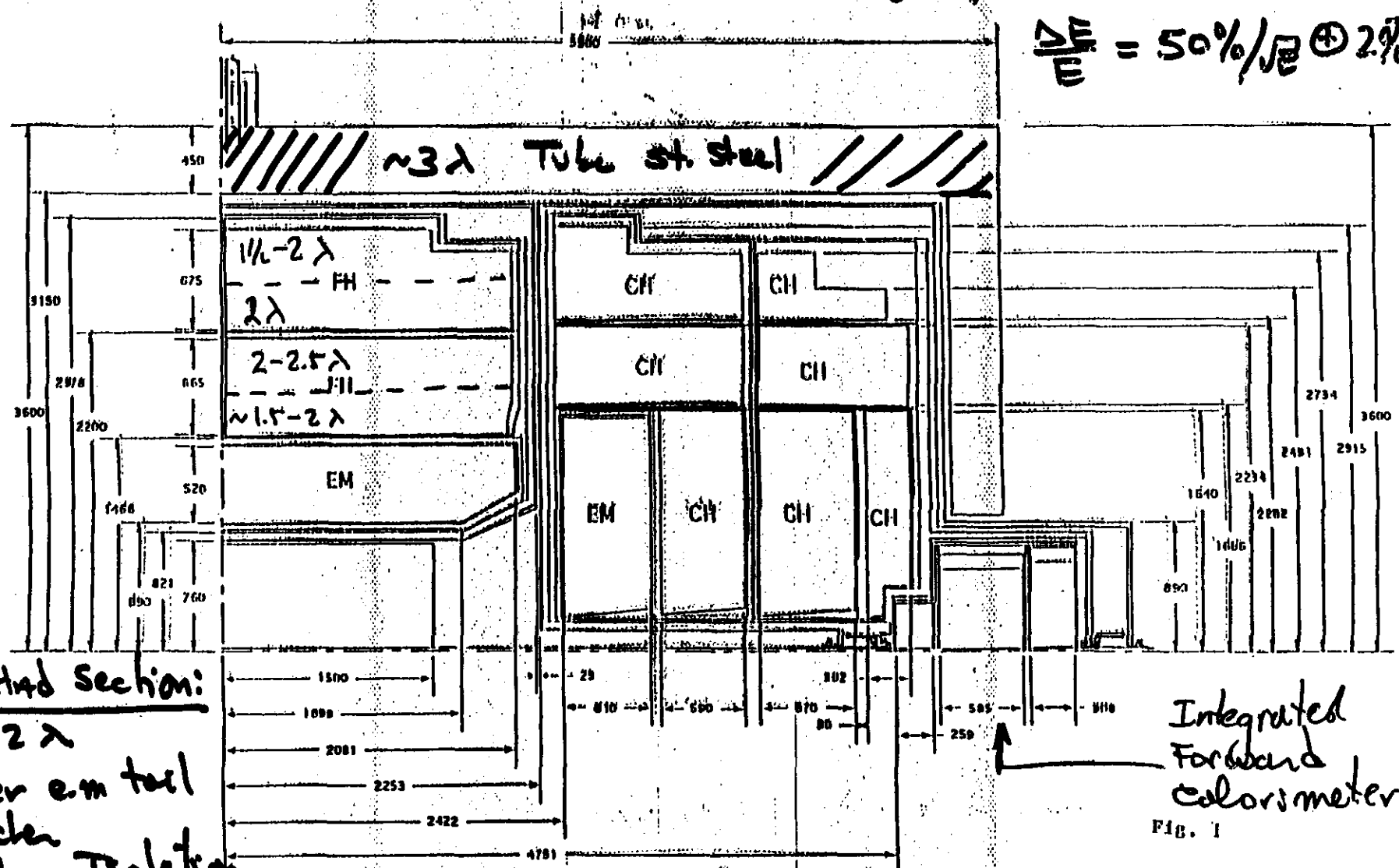


Fig. 1

1st Had Section:

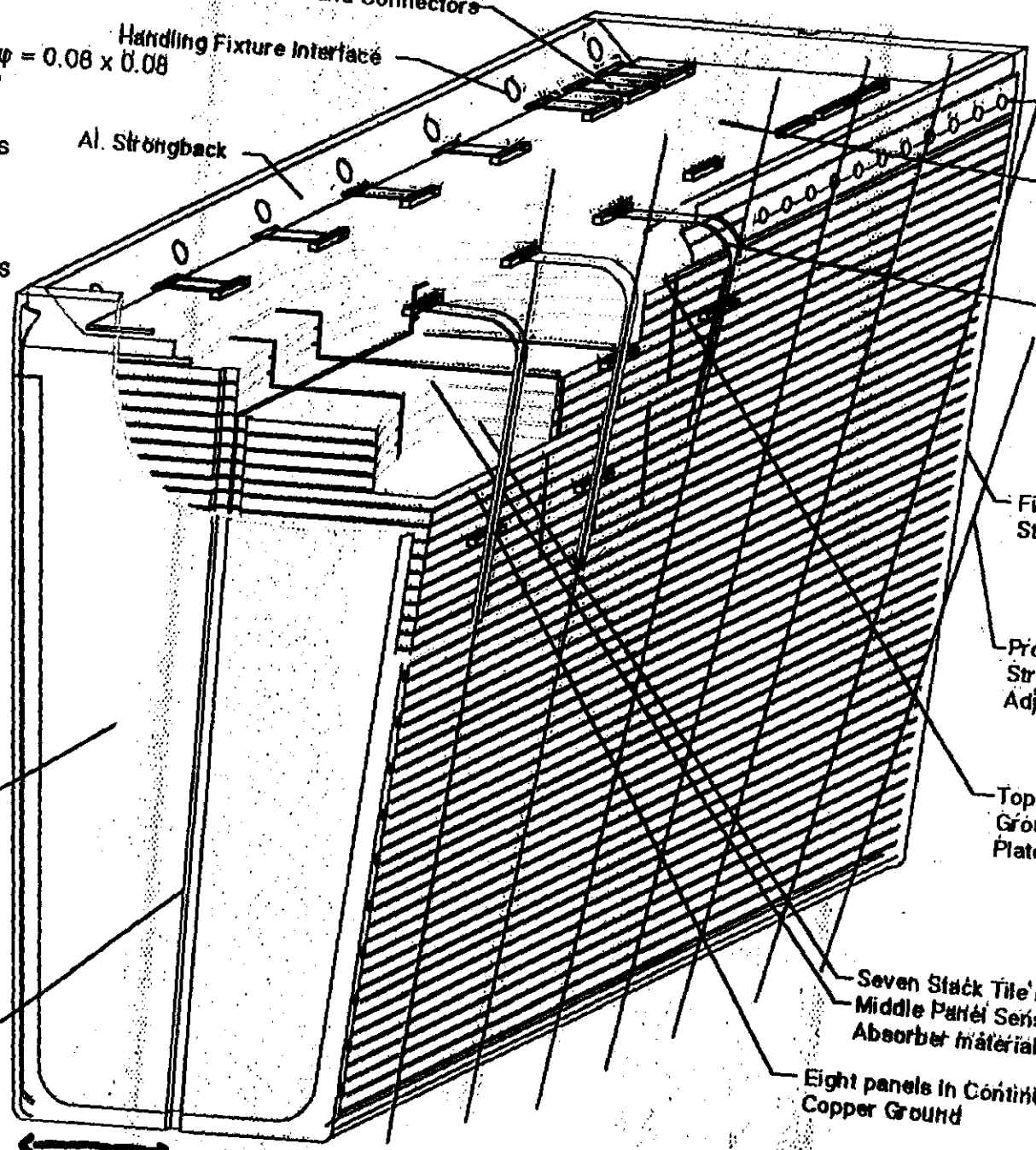
~1-2 λ

- better e.m tail catcher
- better Isolation.

*Note: In Helios/NA34 already had const term below 2%.

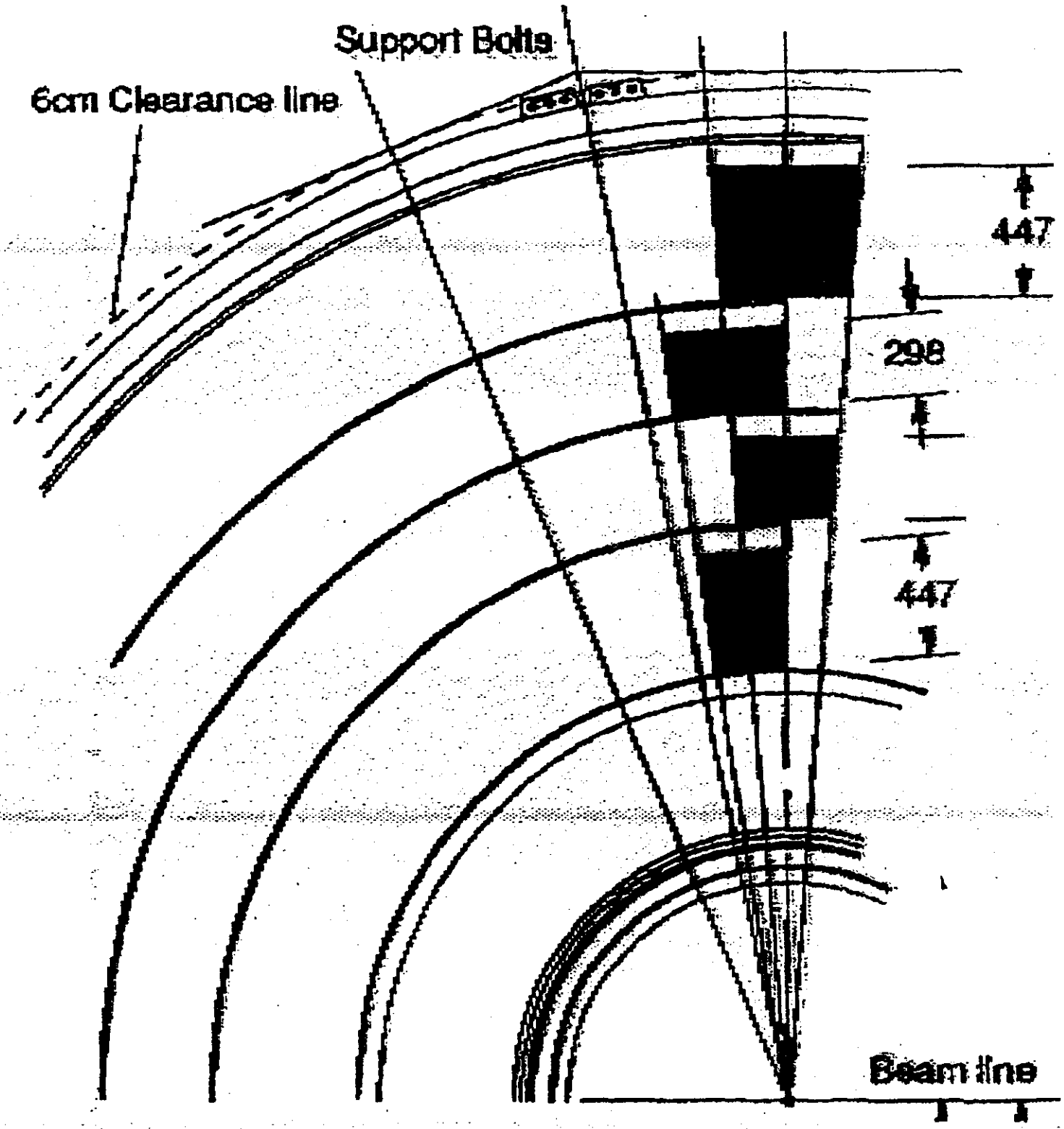
Had on Module # 2

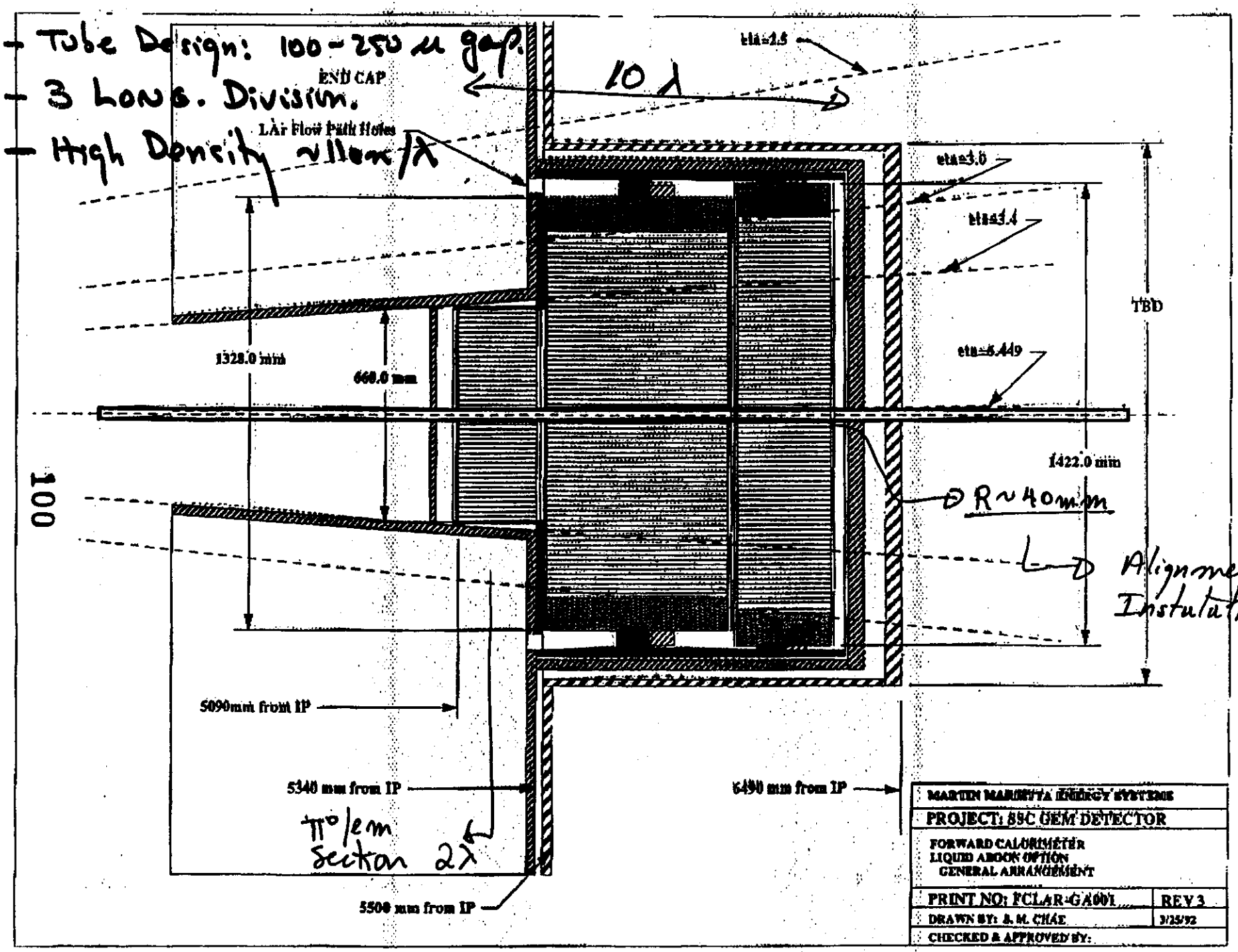
Six Cells Depth
Segmentation $\Delta\eta \times \Delta\varphi = 0.08 \times 0.08$
80 Modules Required
Wt. = 2.38 MT each
Each Module Contains the Following:
1 - Top Ground Plate
1 - Bottom Gnd Plate
5 - Included Gnd Plates
36 - Tile Plates Containing 948 Tile
6 - Sensing Plates Containing 258 Tile
1 - Strongback
1 - Structural Shell
2 - End Plates
28 - Towers with Strip Lines and Electronics
X - Mother Boards

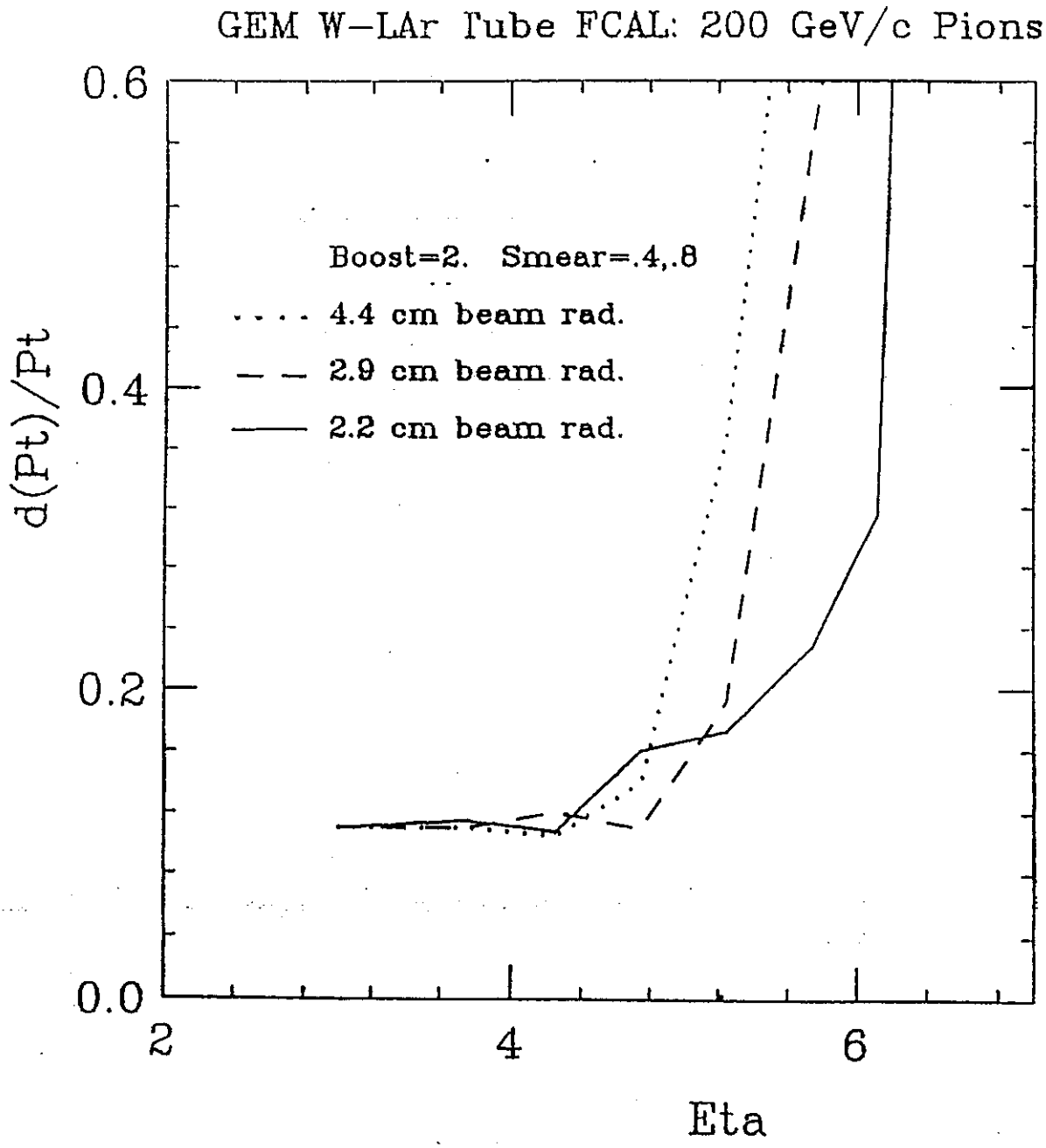


LLMason GEMLAC.HadModDetail 4/18/92

No Projective cracks.

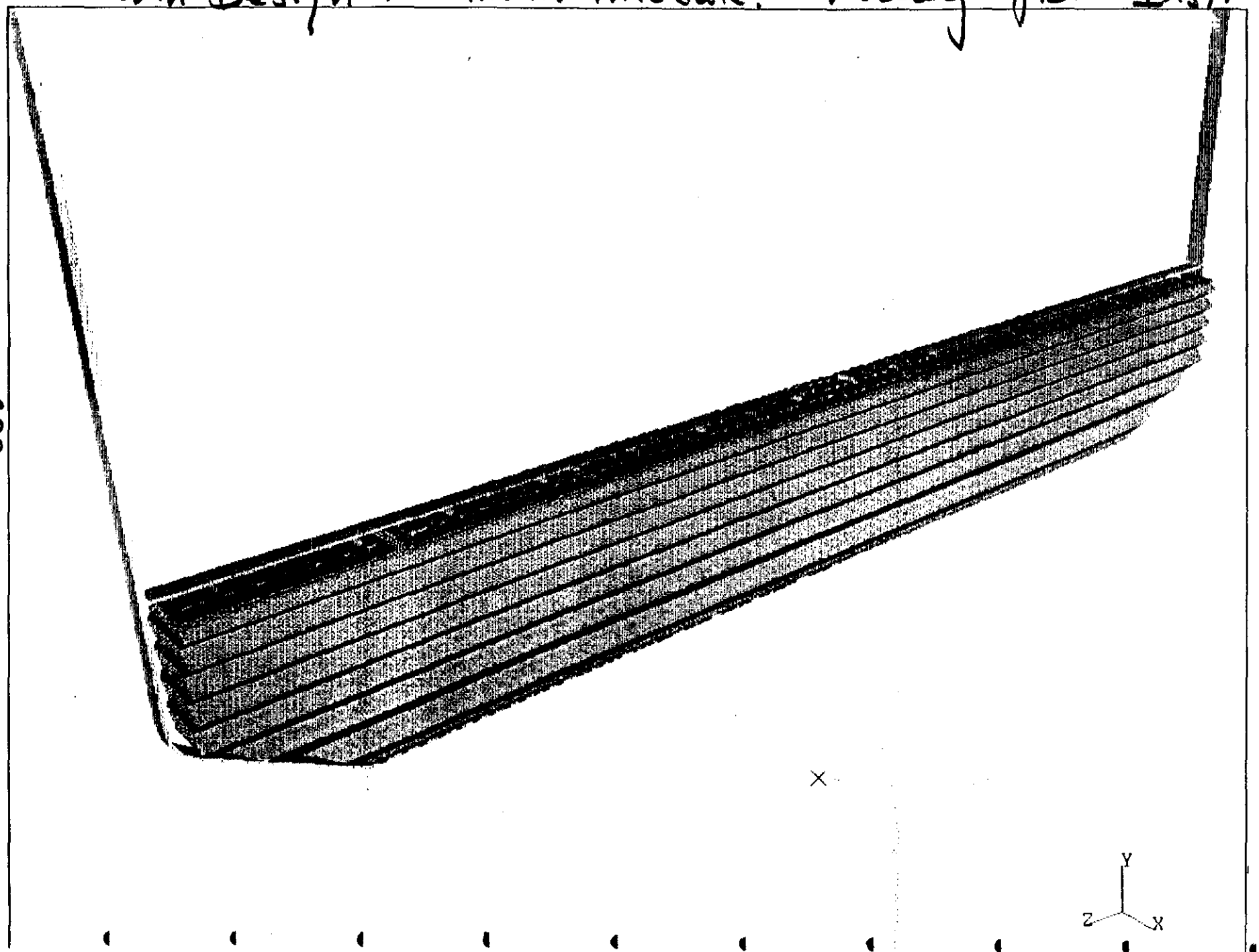



- Tube Design: 100-250 μ gap.
- 3 Long. Division.
- High Density ~1 lam/λ
END CAP
LAr Flow Path Holes
10 λ
eta=1.5
eta=3.0
eta=3.4
eta=5.449
TBD
1328.0 mm
668.0 mm
1422.0 mm
R~40mm
Alignment Instulation
5090mm from IP
5340 mm from IP
6490 mm from IP
5500 mm from IP
π°/cm
Section 2λ
MARTIN MARIETTA ENERGY SYSTEMS
PROJECT: SSC GEM DETECTOR
FORWARD CALORIMETER
LIQUID ARGON OPTION
GENERAL ARRANGEMENT
PRINT NO: FCLAR-GA001
REV 3
DRAWN BY: S. M. CHAE
3/25/92
CHECKED & APPROVED BY:

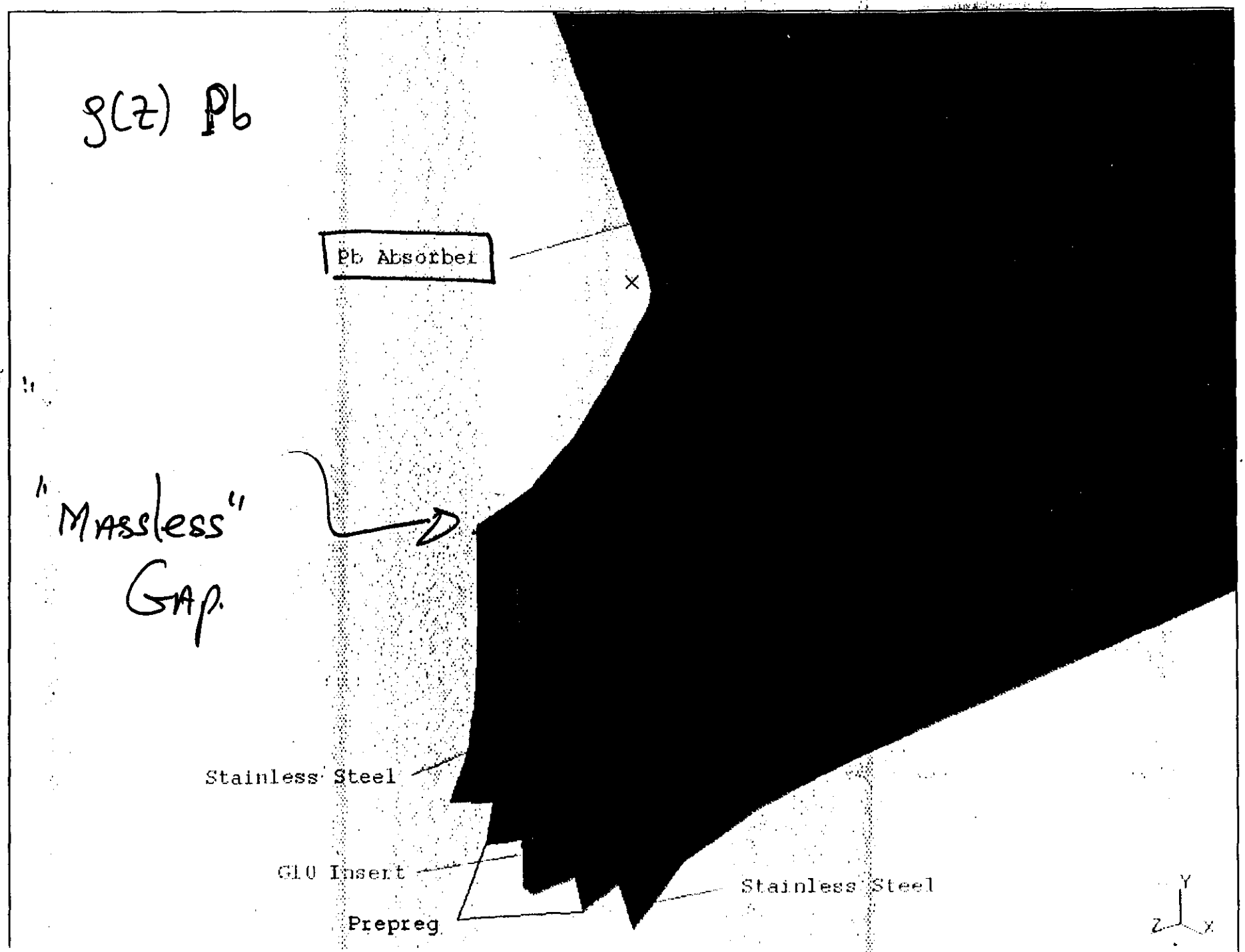

GEM W-LAr Tube FCAL: 200 GeV/c Pions
Boost=2. Smear=.4,.8
4.4 cm beam rad.
2.9 cm beam rad.
2.2 cm beam rad.
d(Pt)/Pt
0.0
0.2
0.4
0.6
2
4
6
Eta

C LINE # 62000

E.M Design : Mini Module, ready for Inst.

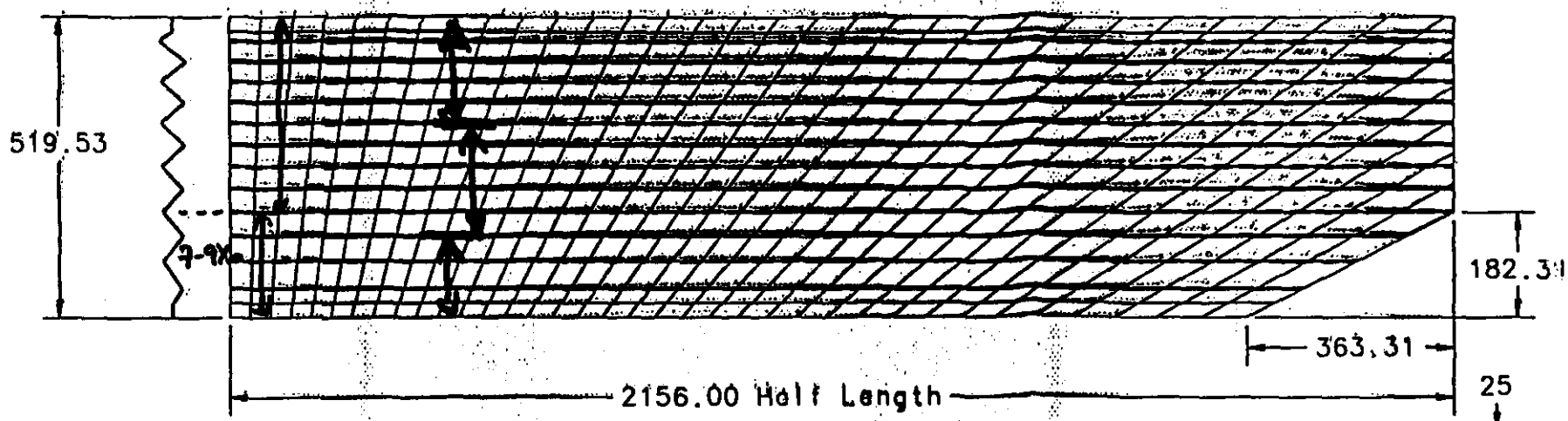


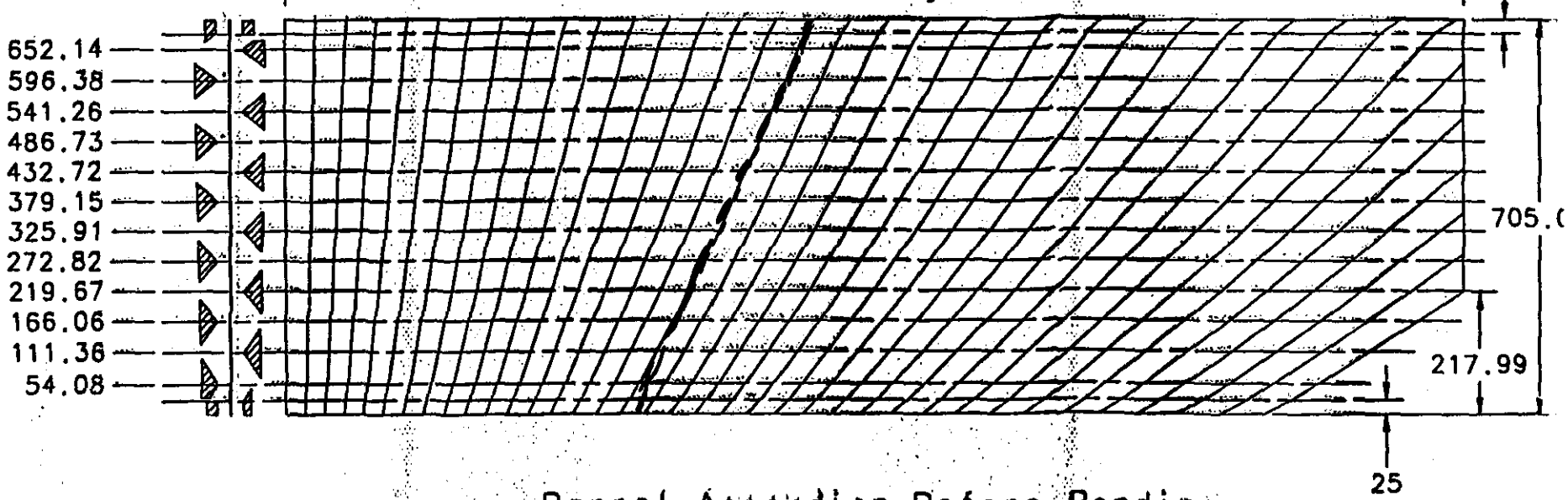
C-LINE # 62000


g(z) Pb
Pb Absorber
"Massless" Gap
Stainless Steel
G10 Insert
Prepreg
Stainless Steel
Y
Z
X

Readout Electrode: Poss. 3 Long. Segm. pointing 25-40% more ch.

Barrel Accordion After Bending

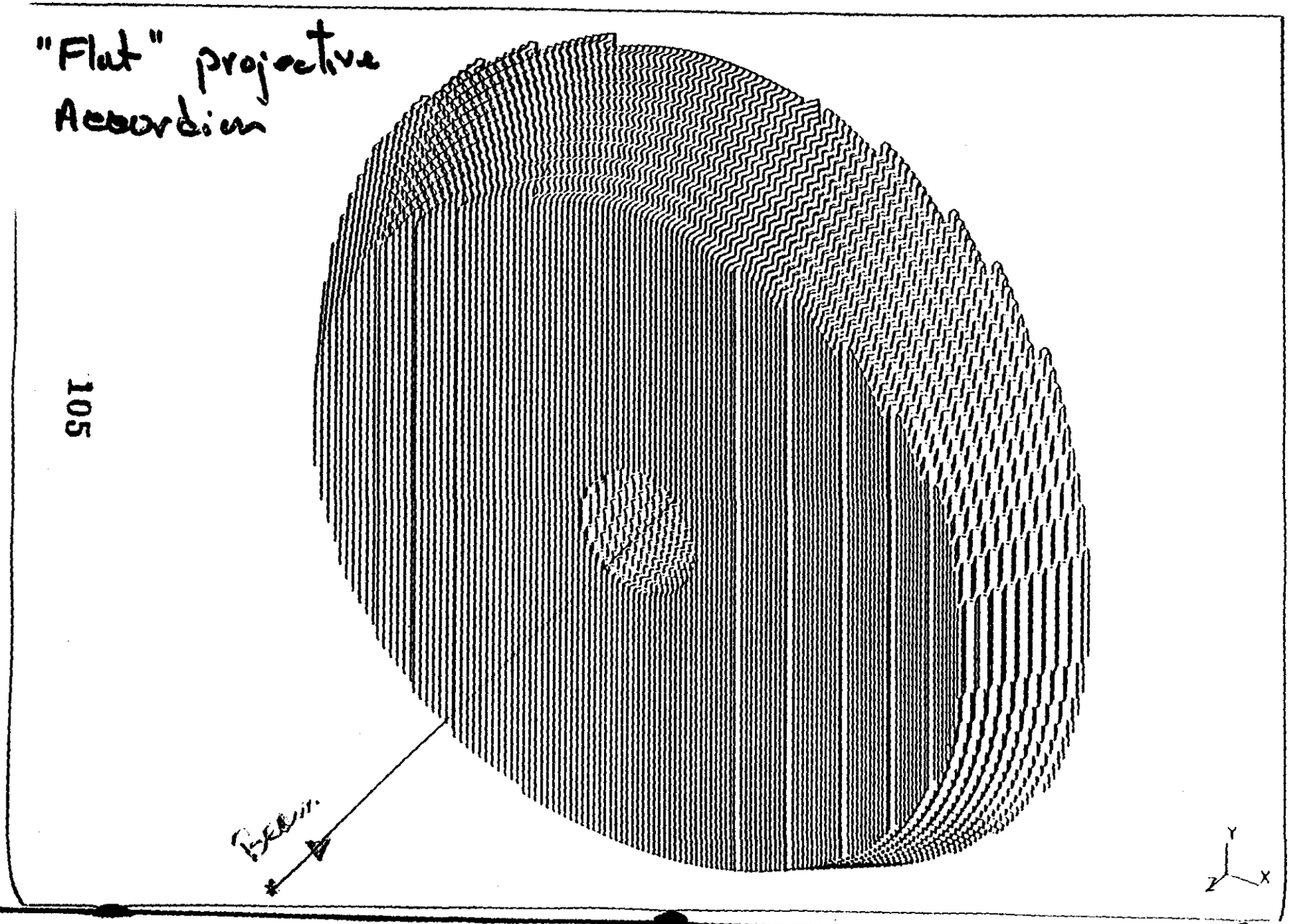




Barrel Accordion Before Bending

Typical but obsolete
200 absorber and 200 sensing plates
with .04 X .04 Segmentation

Endcap Accordion EM



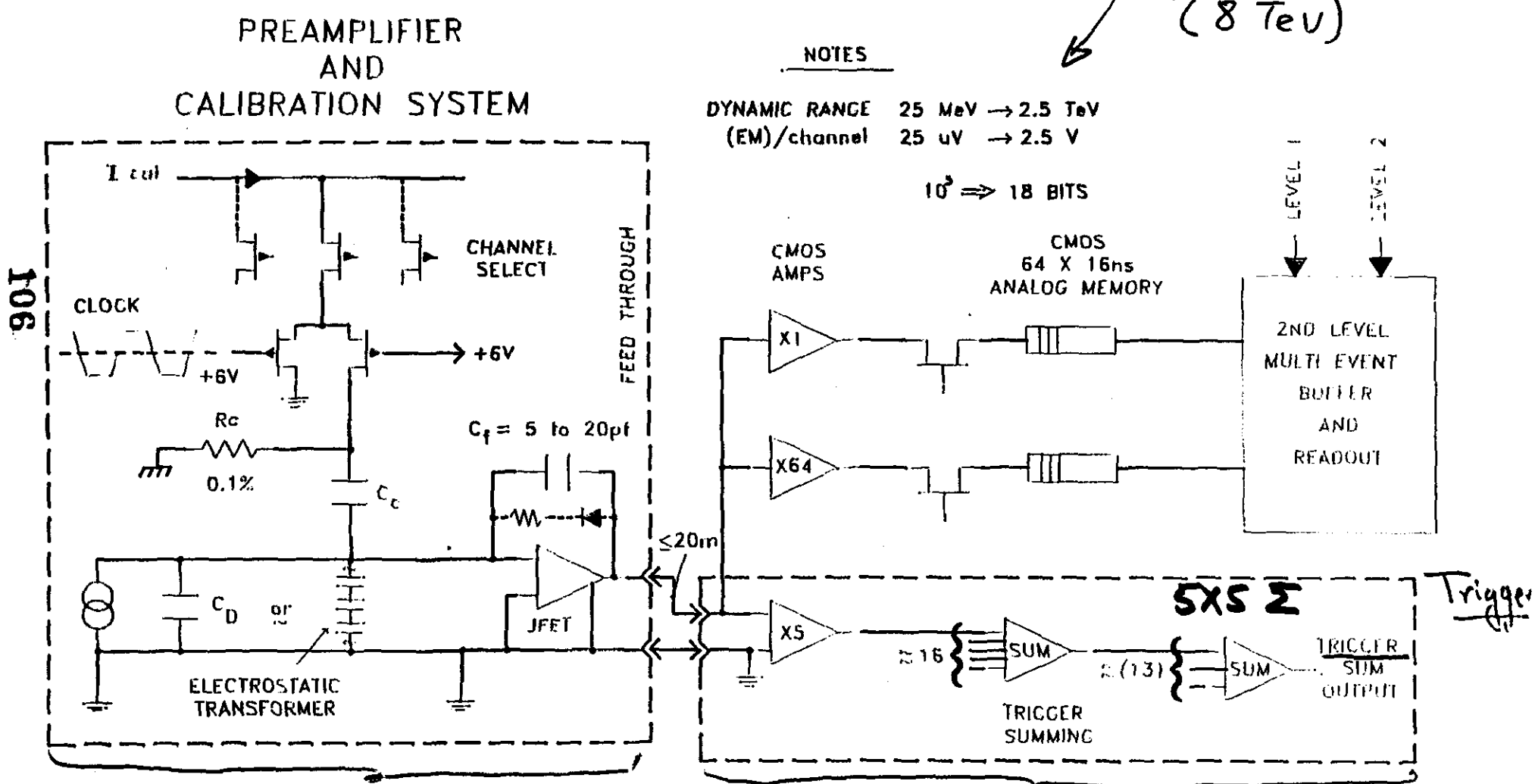
0.1 - 0.2% Calibration.

$\simeq 10^{14}$ n/cm^2

$\simeq$ 10 - 30 Mrad.

Tested to: 5×10^{14} n/cm^2
100 Mrad.

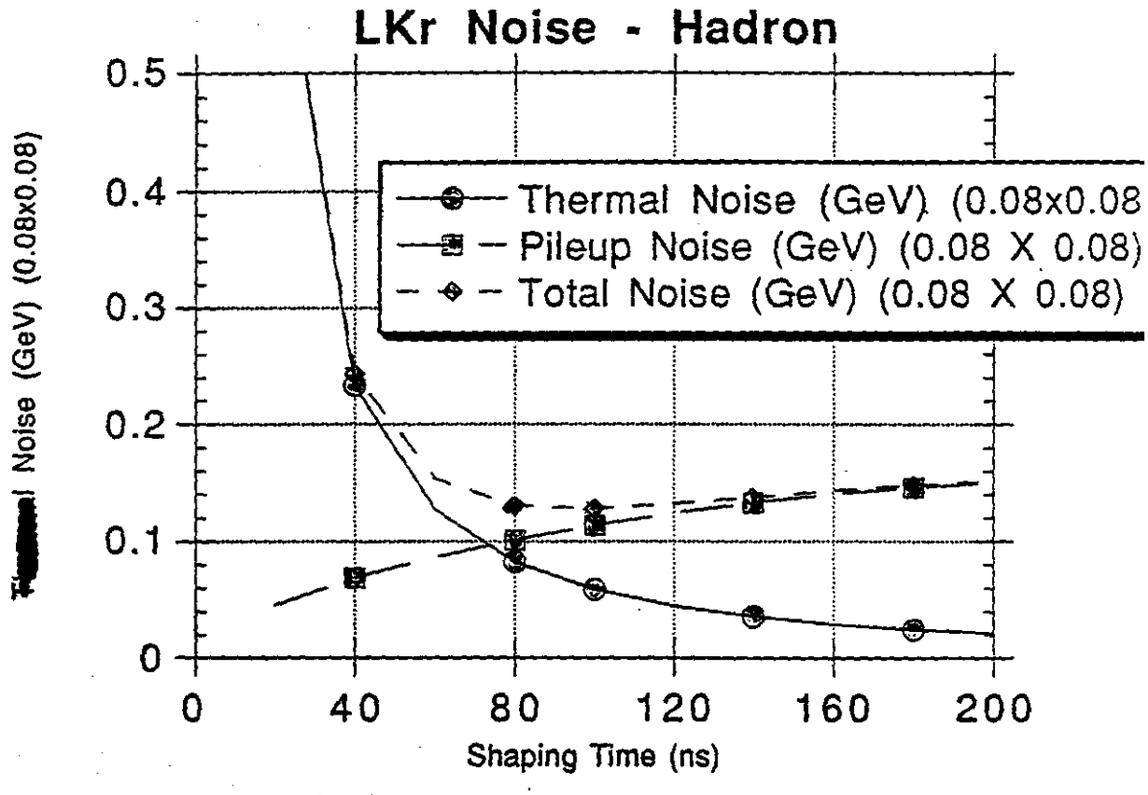
Dynamic Range set by $Z' \to ee$ (8 TeV)



Inside Cryostat.

out Side Mag.

BNL-OMEGA JMH
SSC LA CAL SSCT002

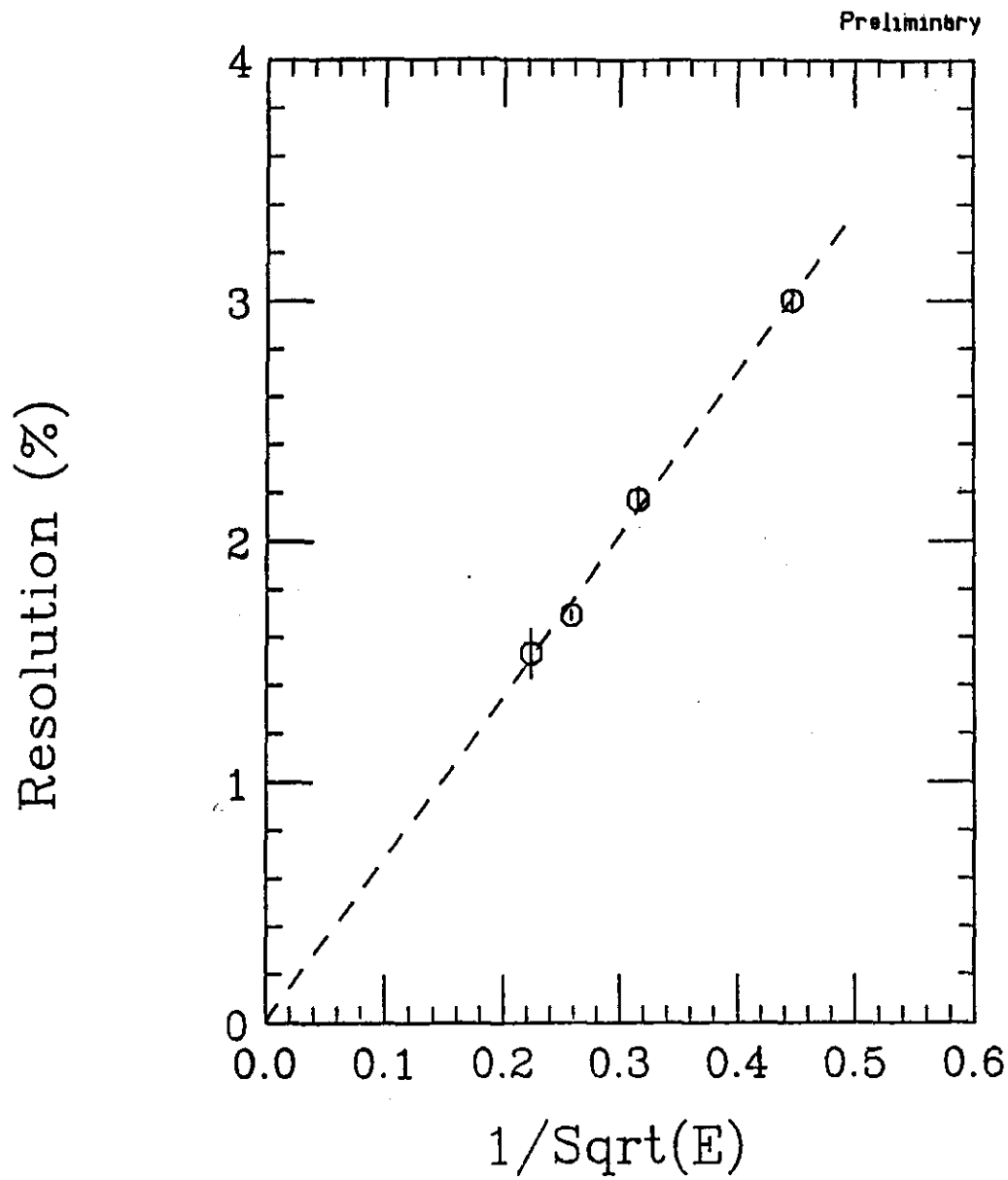

LKr Noise - Hadron
0.5
0.4
0.3
0.2
0.1
0
0
40
80
120
160
200
Shaping Time (ns)
Noise (GeV) (0.08x0.08)
Thermal Noise (GeV) (0.08x0.08
Pileup Noise (GeV) (0.08 X 0.08)
Total Noise (GeV) (0.08 X 0.08)

The 1992 GEM LAr/Kr Accordion Calorimeter Group

92 E.m Test.

O. Benary, [9], S. Cannon, [5], W. Cleland[7],
I. Ferguson[2], C. Finley[5], A. Gordeev[6],
H. Gordon[3], E. Kistenev[3], P. Kroon[3],
M. Leltchouk[5], D. Lissauer[3], H. Ma[3],
D. Makowiecki[3], A. Maslennikov[4], S. McCorkle[3],
D. Onoprienko[6], A. Onuchin[4], Y. Oren[9],
V. Panin[4], J. Parsons[5], V. Radeka[3], L. Rogers[3],
D. Rahm[3], S. Rescia[3], J. Rutherfoord[2],
M. Seman[5], M. Smith[3], J. Sondericker III[3],
R. Steiner[1], D. Stephani[3], E. Stern[7], I. Stumer[3],
H. Takai[3], H. Themann[8], Y. Tikhonov[4]

[1] Adelphi University, Garden City, NY
[2] University of Arizona, Tucson, AZ
[3] Brookhaven National Laboratory, Upton, NY 11973
[4] Budker Institute for Nuclear Physics, Novosibirsk, Russia
[5] Columbia University, New York, NY
[6] Oak Ridge National Laboratory, Oak Ridge, TN
[7] University of Pittsburgh, Pittsburgh, PA
[8] SUNY at Stony Brook, Stony Brook, NY
[9] Tel-Aviv University, Tel-Aviv, Israel



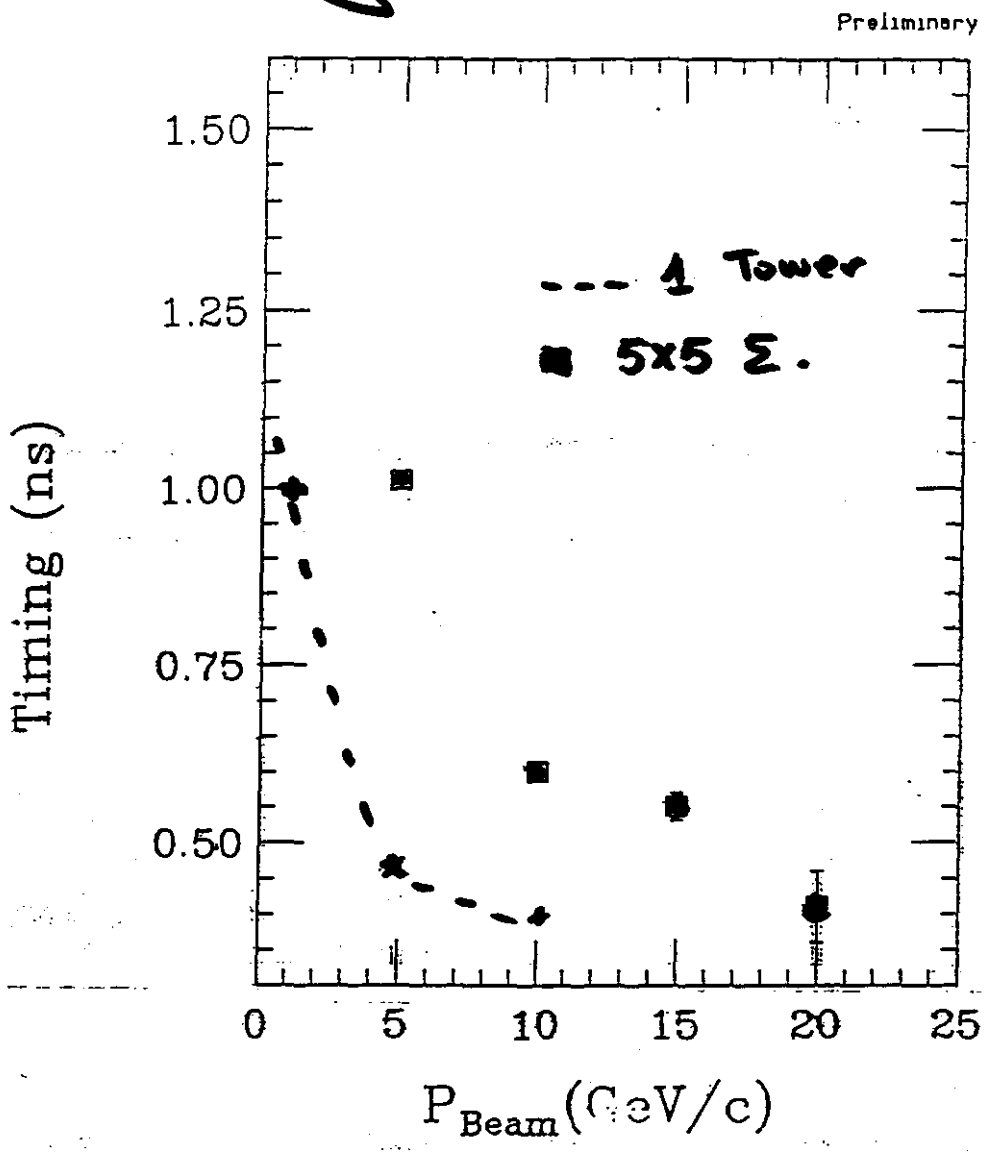
$$\frac{\Delta E}{E} = \frac{a\%}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

$$c = (0.0 \pm 0.2)\%$$

$$\frac{b}{E} = 0.08 \text{ GeV}/E$$

$$\frac{a}{\sqrt{E}} = \frac{(6.72 \pm 0.35)\%}{\sqrt{E}}$$

Timing Resoln.



Resolution: 5 Gev - nsec 5x5 Σ

1 Gev - nsec 1 tower.

9 x 11 Lambda - Dimensions

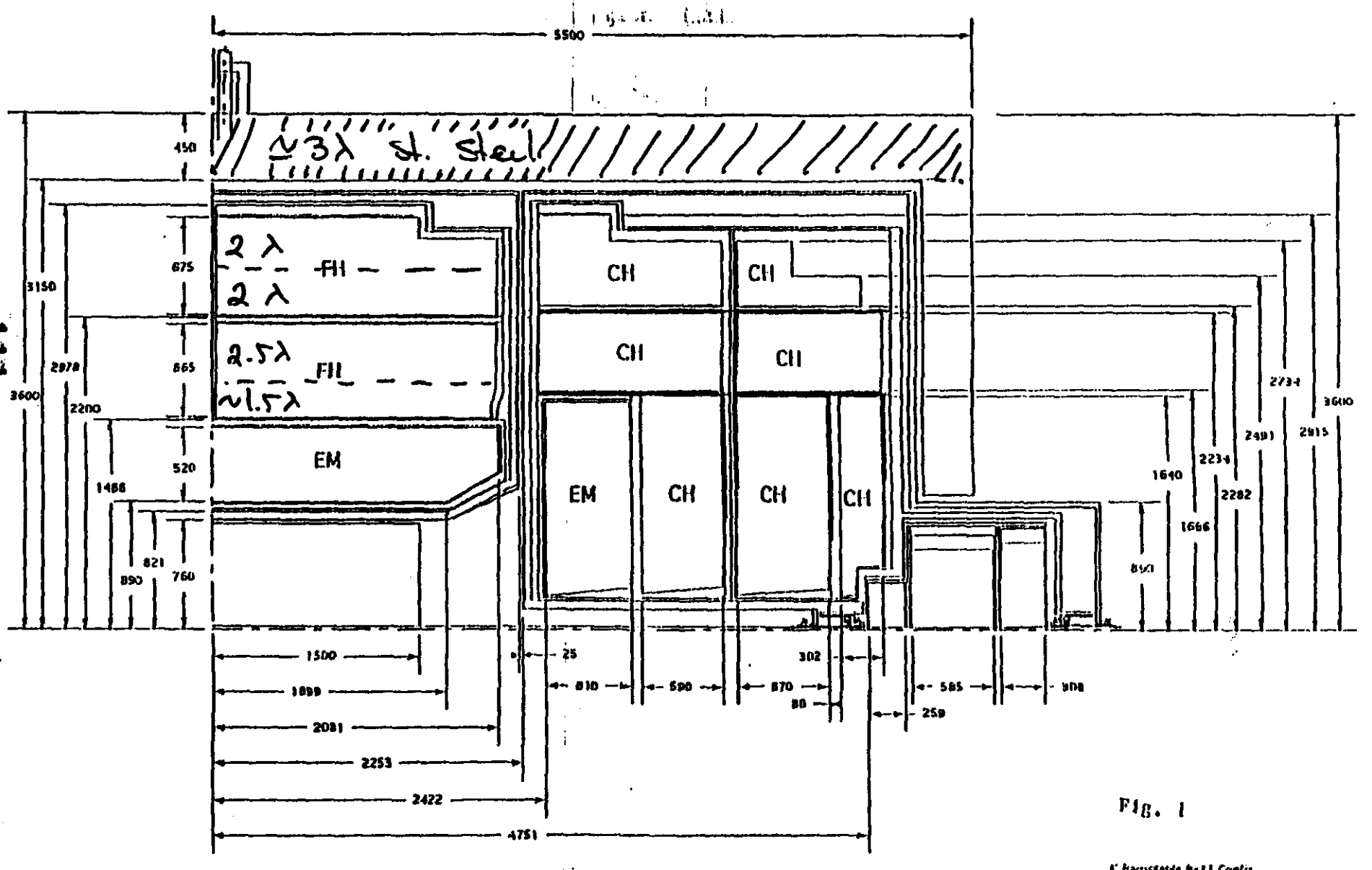


Fig. 1

K Bamstetde 9x11 Config

Integrated Calorimeter:

- Exp. DØ / SLD / H1. SSC in DØ.
- Single technology (including elect readout)
- Complimentary to SDC.
- ≃ "9λ" optimization can be done better for <u>e.m</u>.
  - Had tail catcher for e.m
  - $ saved can be used for e.m optimization.
  - Feedthrough area
- ≃ "9λ" advantages.

  ease and speed of instalation Access.
- Forward Cal design -
- Hermetic - $\not{E}_T$, Jet resol'n optimize.
- Technical Rev. No Show stopper.
- Integ. Design will allow for <u>broad</u> Collaboration based on the <u>Best</u> Cal we can build.

gem

γeμ

Presentation by:

F. E. Taylor

F.E. Taylor 10/8/92

Progress Towards The Muon Technology Decision

• Process	Frank Taylor
• PDT	Carl Bromberg
• LSDT	Louis Osborne
• CSC	Scott Whitaker
• RPC	Craig Wuest
• Mechanical Engineering Assessment	Rick Sawicki
• Muon Steering Committee Consensus	Mike Marx
• General Discussion	

F.E.Taylor

GEM Muon System Technology Review 10/6/92

Panel of Experts
Jim Branson, Chris Fabjan, Ken Foley, Dave Nygren

Definitions:

Proponent Reports are expected to include discussion of the merits of the particular technology, R&D results, how the technology would function in the GEM Muon system, costs, feasibility, and strength of supporting group.

Discussions associated with Proponent Reports are expected to be confined to the relative merits and demerits of particular technology.

The Engineering Assessment will be a standardized comparison of mechanical aspects of each technology with a focus on alignment scheme, robustness, fabrication techniques.
R. Sawicki - Chairperson, M. Gamble, R. Humphreys, C. Johnson, F. Nimblett.

The Electronics Cost Comparison will be a comparison of the relative costs of drift technology with analog technology.

External Comments will allow those outside (or not directly involved) in the other proposals to raise strengths and weaknesses of all proposals. The request to speak can be made on 10/6/92 (in our usual free-style manner), although priority will be given to those who ask prior to the meeting. Written reports would be appreciated because of their greater impact.

October 6, 1992 AGENDA

(1) General Remarks - ground rules	8:00 - 8:30
(2) PDT presentation (Bromberg)	8:30 - 9:15
PDT discussion	9:15 - 9:45
(3) PDT-JINR (I. Golutvin)	9:45 - 10:00
(4) LSDT presentation (Osborne)	10:00 - 10:45
LSDT discussion	10:45 - 11:15
(5) CSC presentation (Whitaker)	11:15 - 12:00
CSC discussion	12:00 - 12:30
LUNCH	12:30 - 13:00
(6) RPC presentation (Wuest)	13:00 - 13:45
RPC discussion	13:45 - 14:15
(7) Engineering Assessment Report (Sawicki)	14:15 - 15:15
(8) Electronics Cost Comparison Report ((Marlow))	15:15 - 16:00
(9) External Comments and discussion (Group)	16:00 - 17:00

Calendar of Muon Chamber Technology Decision Process

Inputs:

Proponent Reports
Panel of Experts
Engineering Assessments
Electronics Cost Assessments (not received 10/2/92)
Discussion at 10/6/92 Meeting

Calendar of Events:

9/28/92	Reports are due (delivered to Expert Panel, Muon Steering Committee Members, and GEM Spokesmen).
8:00 AM 10/6/92	Presentations of Technology Proponents, Engineering, and Electronics Cost Reports.
5:00 PM 10/6/92	Expert Panel meets with Muon Steering Committee, and GEM Spokesmen.
8:00 AM 10/7/92	Expert Panel Executive Meeting
9:00 AM 10/7/92	Muon Steering Committee meets with Expert Panel and GEM Spokesmen.
11:00 AM 10/7/92	Muon Steering Committee Executive Session. Expert Panel is available for consultation.
1:00 PM 10/7/92	Recommendation presented to Muon Group for discussion.
10/8/92 12:45 PM	Recommendation presented to GEM Collaboration Council.
4:00 PM 10/8/92	Recommendation presented to GEM Executive Committee.

Expectation of this Meeting

- Challenge to Technology Proponents:

1. Show construction details of chambers (engineering drawings).
2. Describe how chambers are to be employed in muon system - their sizes, and numbers, and how they will be aligned.
3. Describe what chambers have been constructed and tested.
4. What spatial resolutions from cosmics and/or test beam data have been measured ? Discuss how corrections (geometric, L-angle) are to be made.
5. What are the rate limitations, sensitivity to backgrounds, pattern recognition capabilities of your technology ?
6. Describe trigger scheme for yourtechnology.
7. Outline costs of complete system - including electronics.

Issues for this Meeting

- Barrel Issues:

1. Which is the more attractive drift technology - PDT or LSDT ?
2. Will the RPCs perform in terms of jitter, background sensitivity, and longevity ?
3. In case RPCs are not accepted, is there an alternative trigger for the drift option ?
4. Will the CSCs perform in barrel in terms of resolution, alignment, and costs ?

- Endcap Issues:

1. Will the CSCs perform in terms of resolutions, background, and costs ?
2. Are there any alternatives to the CSCs in the Endcaps ?

Suggested Rules of Game

- Rating of technologies made on 10/6/92 defines **Baseline 2**. Thereafter engineering effort focused by leading technology(s).

- All technologies are carried until TTR tests (as defined by R&D FY92 Program) are completed.

- Final decision of Technology for TDR follows the TTR tests and completion of FY92 R&D program.

- No new Chamber R&D funds until above are finished.

Muon Chambers at the TTR

Technology	Chamber size	TTR delivery date
PDT-JINR	1 m x 4 m x 8 layers	7/28/92 (delivered)
PDT-MSU	1.3 m x 3.8 m x 4 layers	9/29/92 (delivered)
LSDT	1 m x 4 m x 4 layers	9/22/92 (delivered)
LSDT	1 m x 4 m x 4 layers	(under construction)
RPC	1 m x 2 m x 2 layers	9/29/92 (delivered)
CSC-BU	0.5 m x 0.6 m x 3 x 2 layers	RD5-CERN (delivered)
CSC-BU	0.5 m x 0.6 m x 3 x 2 layers	
CSC-BNL	0.6 m x 0.6 m x 2x4 layers	
CSC-BNL	1 m x 1.8 m x 4 layers	
CSC-UH	0.5 m x 1 m x 3 layers	9/92 (delivered)
CSC-JINR	1.1 m x 1.5 m x 2 layers	(under construction)

gem

γeμ

Presentation by:

C. Bromberg

PRESSURIZED DRIFT TUBES

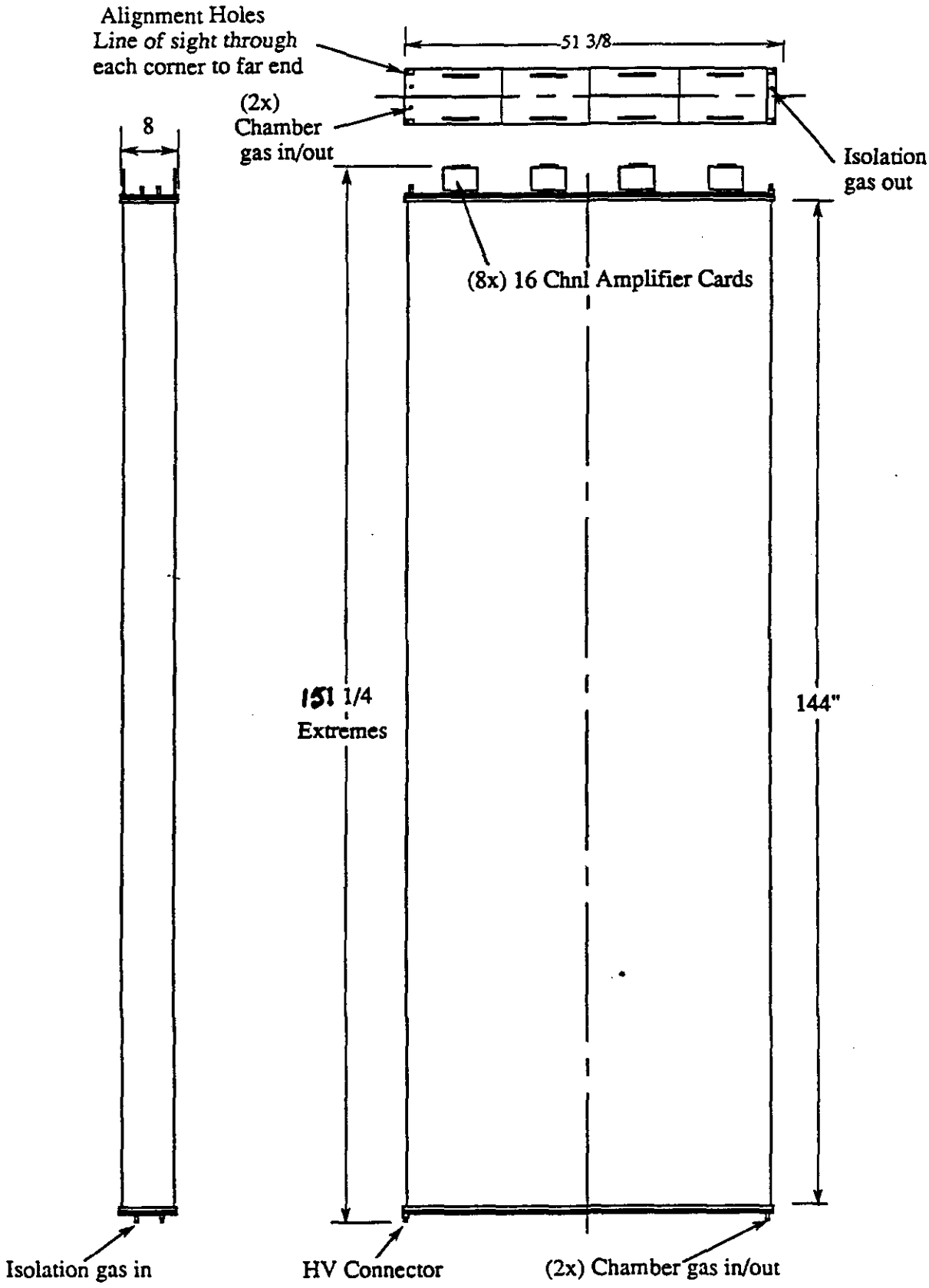
C. Bromberg
For
PDT Group
10/8/92

PDT Characteristics

- Proven high precision technology
- The wire tension is stable
- Non-flammable drift gas and <100μ resolution
  OR FLAMMABLE
- Less susceptible to neutron induced backgrounds • High rate capability, low gas gain — OR STREAMER MODE
- Reliable gas tight seals, secondary gas barrier without need to compensate for atmospheric pressure changes.
- Wires are physically and electronically isolated
- Symmetry of the round tubes for ExB effects
- Laminated tube structure, very strong, very light, supported only at the ends. light, and strong
  up to 5m long
- Alignment of the chamber wires is completely determined from the ends. Sides of a PDT chamber to be free from any interference, Flexible
- Assembly procedure requiring a minimum of technical skill, without jigs, that will be fast.
- Very compact end treatment with a minimum of dead space
- Precision manifold plates of any size (or shape) can be fabricated by splicing smaller plates together on a dedicated jig.

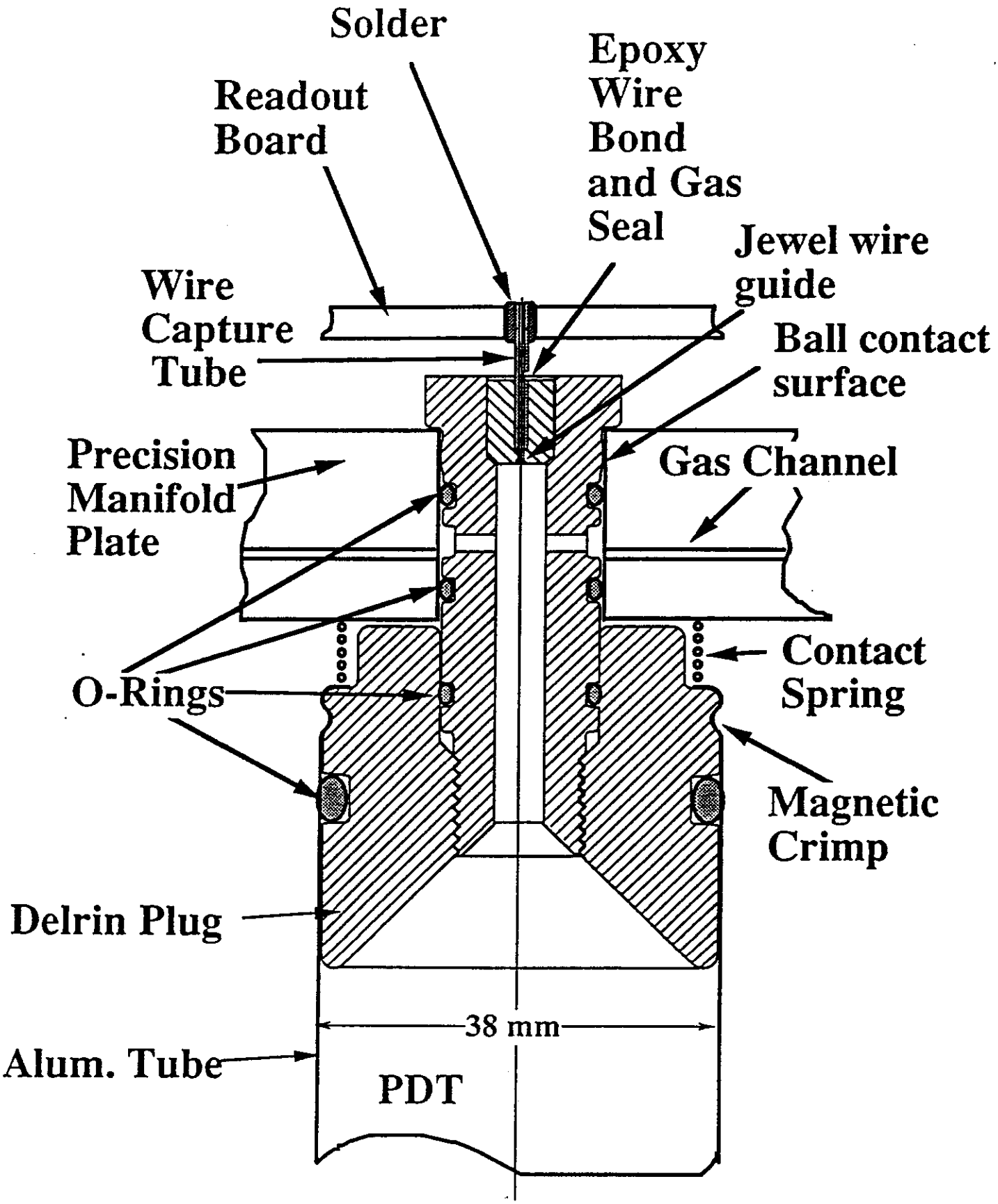
1/2 weight of other techs
$5M cheaper

~0% dead φ
~3% dead in η



GEM PDT Prototype Assembly

HEP01-022-281-D R. Miller 5-14-92


Solder
Readout Board
Epoxy Wire Bond and Gas Seal
Jewel wire guide
Wire Capture Tube
Ball contact surface
Precision Manifold Plate
Gas Channel
O-Rings
Contact Spring
Magnetic Crimp
Delrin Plug
38 mm
Alum. Tube
PDT

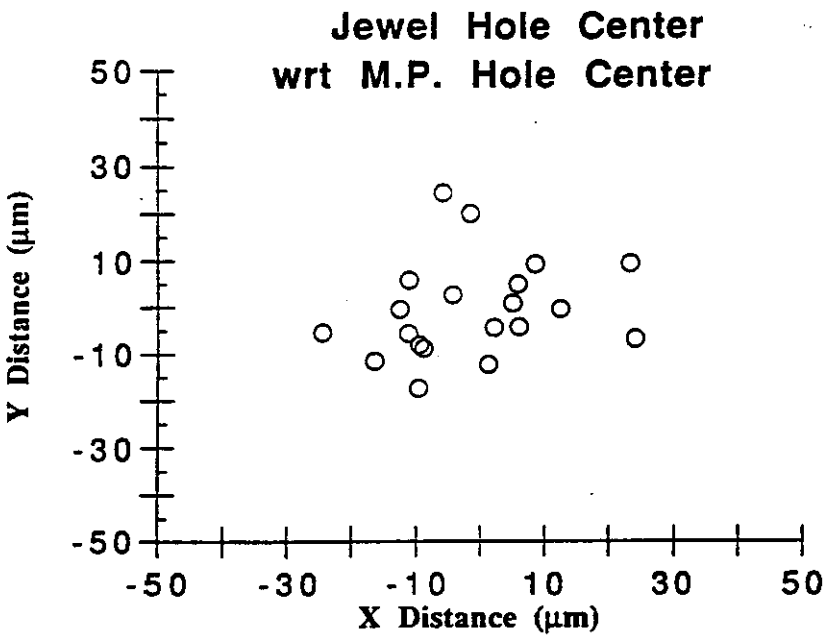
Wire Positioning Accuracy

Both 20μ systematic and 20μ random errors on the wire locations have been achieved in a large PDT prototype, and are sufficient to meet or better all specifications for GEM muon detectors.

There are no other contributions to the systematic error in the wire placement.

The existing plates of the MSU prototype are already within the GEM systematic error limits and they can be made better, cheaper, and larger.

No internal alignment procedures are necessary during or after assembly to achieve the stated resolutions.


Jewel Hole Center
wrt M.P. Hole Center
Y Distance (µm)
50
30
10
-10
-30
-50
-50
-30
-10
10
30
50
X Distance (µm)

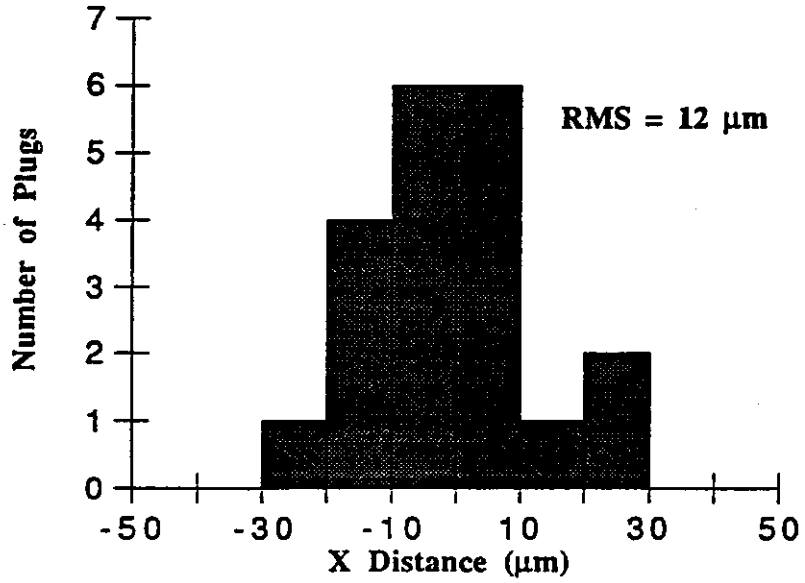
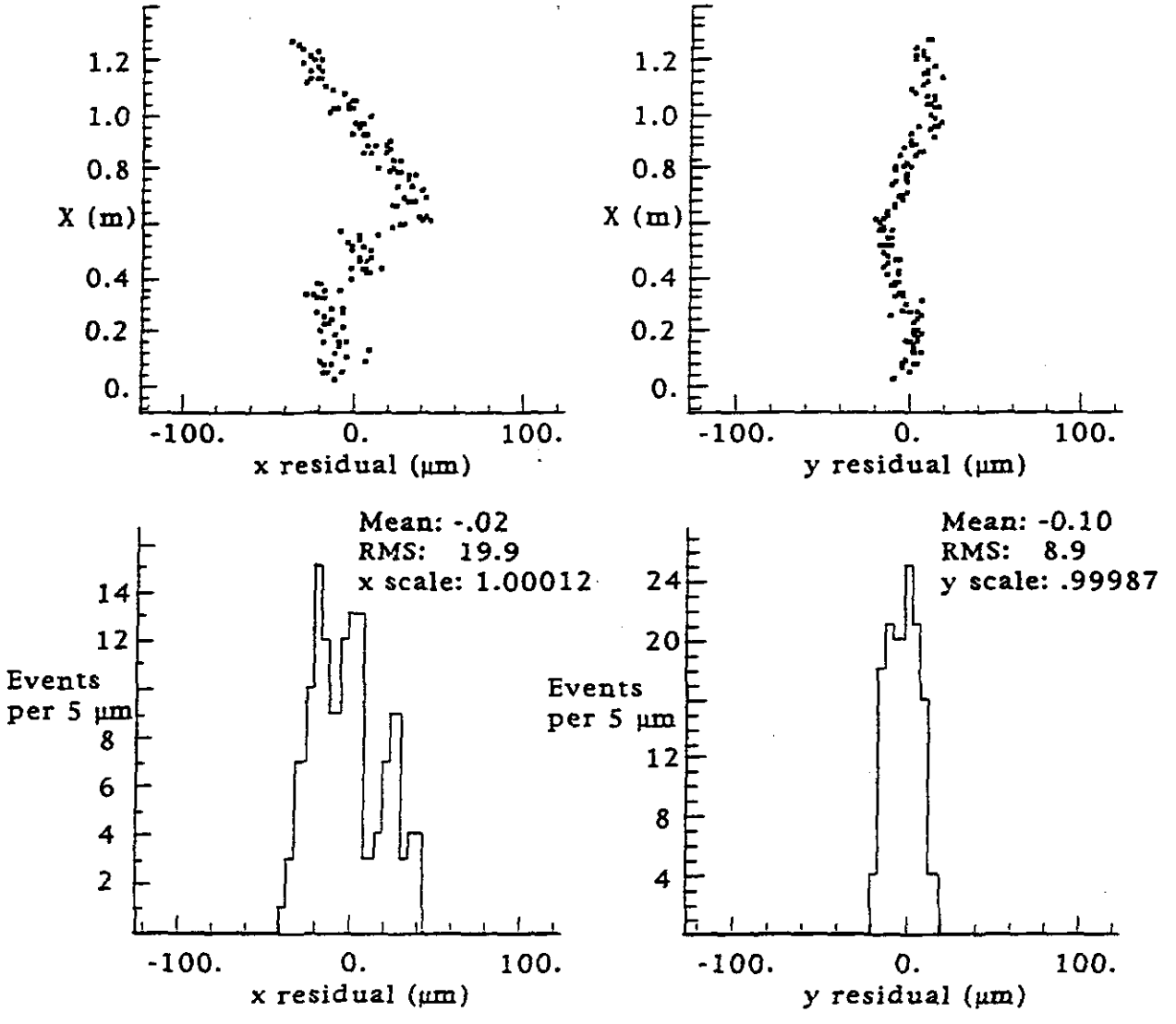

Number of Plugs
7
6
5
4
3
2
1
0
RMS = 12 µm
-50
-30
-10
10
30
50
X Distance (µm)

Fig. 14

Aug. 4, 92

Hole Spacings, PDT Manifold plate #1



Chamber Structure is Very Strong

PDT system is half the mass of any other technology
Tubes laminated together with epoxy.
Secondary Gas Barrier and Tube Protection via 1/4" Hexcell cover.

Superlayer Configuration

16 or 32 sectors are fine

8-8-4 in superlayer stacks

3-3-3 z segmentation (other arrangements possible)

Alignment

Wire tensions can be accurately (1%) set with Tungsten.

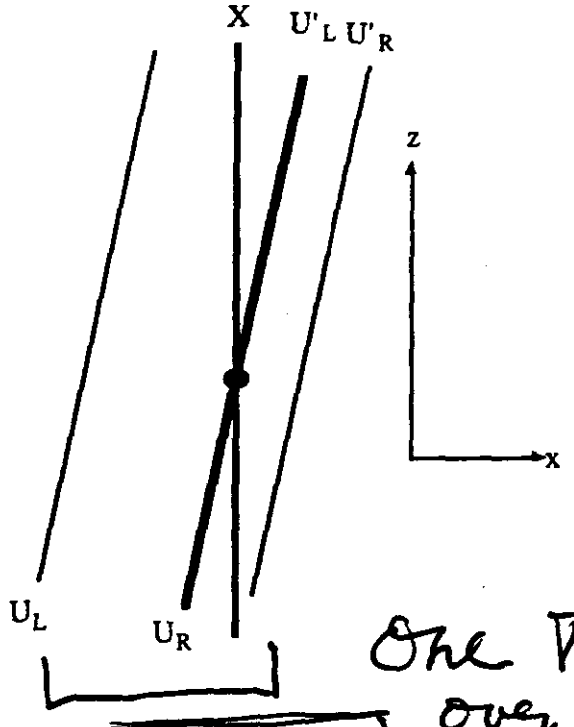
Textron, high-strength, low density fibers (wires).
2km of wire with <20% of the density

Sides of the chamber are completely free of alignment fixtures which will allow overlap of the chambers in phi without difficulty.

Z-Coordinate Measurement with Stereo PDT

Small Stereo Angle : 10 mrad
Z- Resolution: 1 cm

X-U-U' Stereo



One Tube Width over full Z.

1. Add 2 planes of Stereo to superlayer-I
2. Convert 2 planes of superlayer-II to Stereo
3. Add 2 planes of Stereo to superlayer-III.

20% cost over axial tubes

gem

γeμ

Presentation by:

L. Osborne

L. Osborne

LIMITED STREAMER DRIFT TUBES FOR THE GEM MUON SYSTEM

LSDT R & D Group

R. Sumner

LeCroy Corp., Chestnut Ridge, NY

R. McNeil, W. Metcalf

Louisiana State Univ., Baton Rouge, LA

W. Busza, H. W. Kendall, A. Korytov, J. Kelsey, L. S. Osborne,
L. Rosenson, F. E. Taylor, R. Verdier, B. Wadsworth

Massachusetts Institute of Technology

Cambridge, MA

We expect that whatever technologies are chosen most of the present GEM muon group will coalesce around the chosen one(s). Many groups here who have expressed a definite interest in pursuing LSDT's were they selected. Among them:

Joint Institute for Nuclear Research, Dubna, Russia

Institute of High Energy Physics, Beijing, P. R. China

Superconducting Super Collider Lab, Dallas, Texas

University of Houston, Houston, Texas

#PV-119G

K&M Company
TORRANCE, CA 90503

Serendipity
For LSDT

Streamer Mode

↓

Measuring accuracy; 50 to 100 μm

+

Modern Machine Tools

Typical accuracies; 2/10,000" = 5 μm

↓

Accurate Wire Placement

POLYFLEX
#PV-119G
R&M Company
TORRANCE, CA 90503

Streamer Pulse

Fast: 10 nsec rise time

Large: $\sim$ 100 mv

C-LINE #5587
TABBED "TOPPER"

Merits of Streamer-Drift System

1. Preservation of the fast rise time in pulse transmission. 10 nsec. ≈ 100 mV
2. Open structure for laying down wires-allows multiple wire placement and placement checking for ease of construction.
3. Precision wire positioning.
4. Minimum scattering material.
5. No restriction on chamber length.
6. Parts and assembly amenable to mass production.
7. Stiffness in the final chamber to minimize support points.
8. Single wire resolution of $\sim 100\mu m$.
9. Qne tube per one wire minimizes efficiency loss in wire breakage.

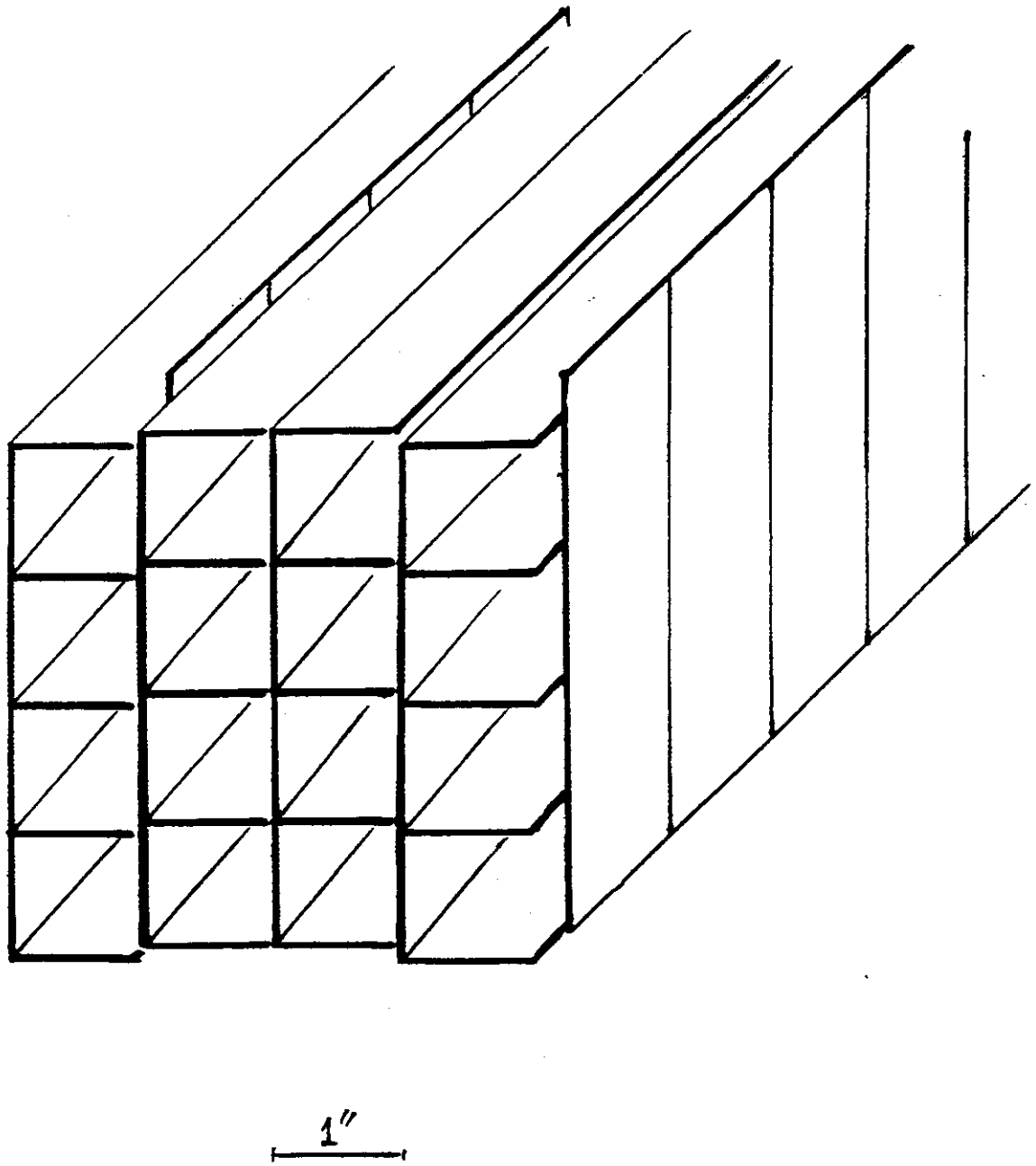
C-LINE #62013 "TOPPER"

Gases Considered

Argon(A), Isobutane(IB) Safety!!
A(few %),IB(10 %), CO_2
A(few %),IB(10%),CO_2,CF_4

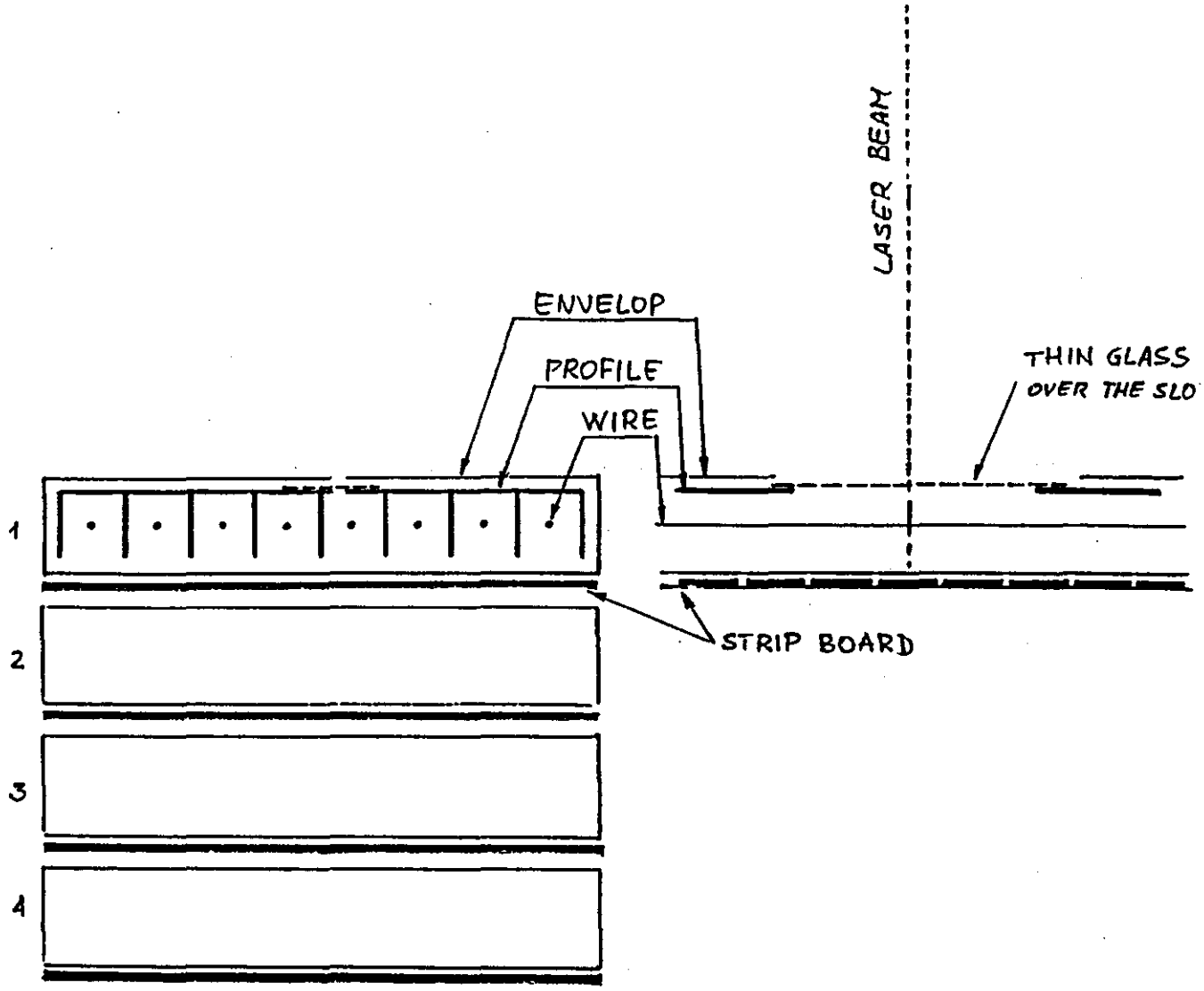
IB($\leq$10%)-non-flammable
CO_2-ohmic,slow,cool
CF_4-flat,fast

C-LINE #62037
C-FAD TOPPED



Fermilab Muon Telescope

C-LINE #62013
"TOPPER"



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CLEAR TOPPER

Fig. 2.2

Table X.1: Resolution* and T_{max} for Drift Readout in 2.5 cm. cells								
Gas⟶	A-IB 25 – 75		A-IB-CO_2 2.5 – 9.5 – 88		CO_2 – CF_4 – IB 20 – 69 – 11		CO_2 – CF_4 – IB 40 – 50 – 10	
Ioniz. Source↓	σ (μm)	T_{max} (n sec)	σ (μm)	T_{max} (n sec)	σ (μm)	T_{max} (n sec)	σ (μm)	T_{max} (n sec)
Laser-no mag. field	35	260	55	830	70	280	70	460
Laser- mag. field(0.8 T)	45	278	60	835	75	295		
0.5 TeV Muons	55				95		75	

* Averaged over all drift times

Table X.2: Resolution* for Pick-up Strip Readout (1.0 cm. strips)		
GasAmpl.Mode ⟶ Ioniz.Source ↓	Proportional	Limited Streamer
Laser	45 μm	100 μm
0.5 TeV Muons	85 μm	

* Averaged over all ionization positions

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Worries Over Cathode Strips

1.) Measuring to 100 μm with 1 cm strip requires a 1% measurement.
   a.) Superb amplifiers though mass produced.
   b.) Very accuratly made strips.
2.) Thermal noise requires long ($\sim$ 1 μsec integrating times.
3.) Thermal noise places upper limits on the size of the strips and, therefore the chambers.
   a.) Needs many small chambers.
   b.) Large number of electronics channels.
4.) Man made noise will be present to some extent; this will not be known quantitatively until turn on day.

C-LINE #62037
CLEAR TOWER II

NEEDED

1.) A box, with precision milling but only at bridge support points.

2.) Bridges: with precision grooves.

3.) U-shaped cathode planes.

4.) Z-strip planes.

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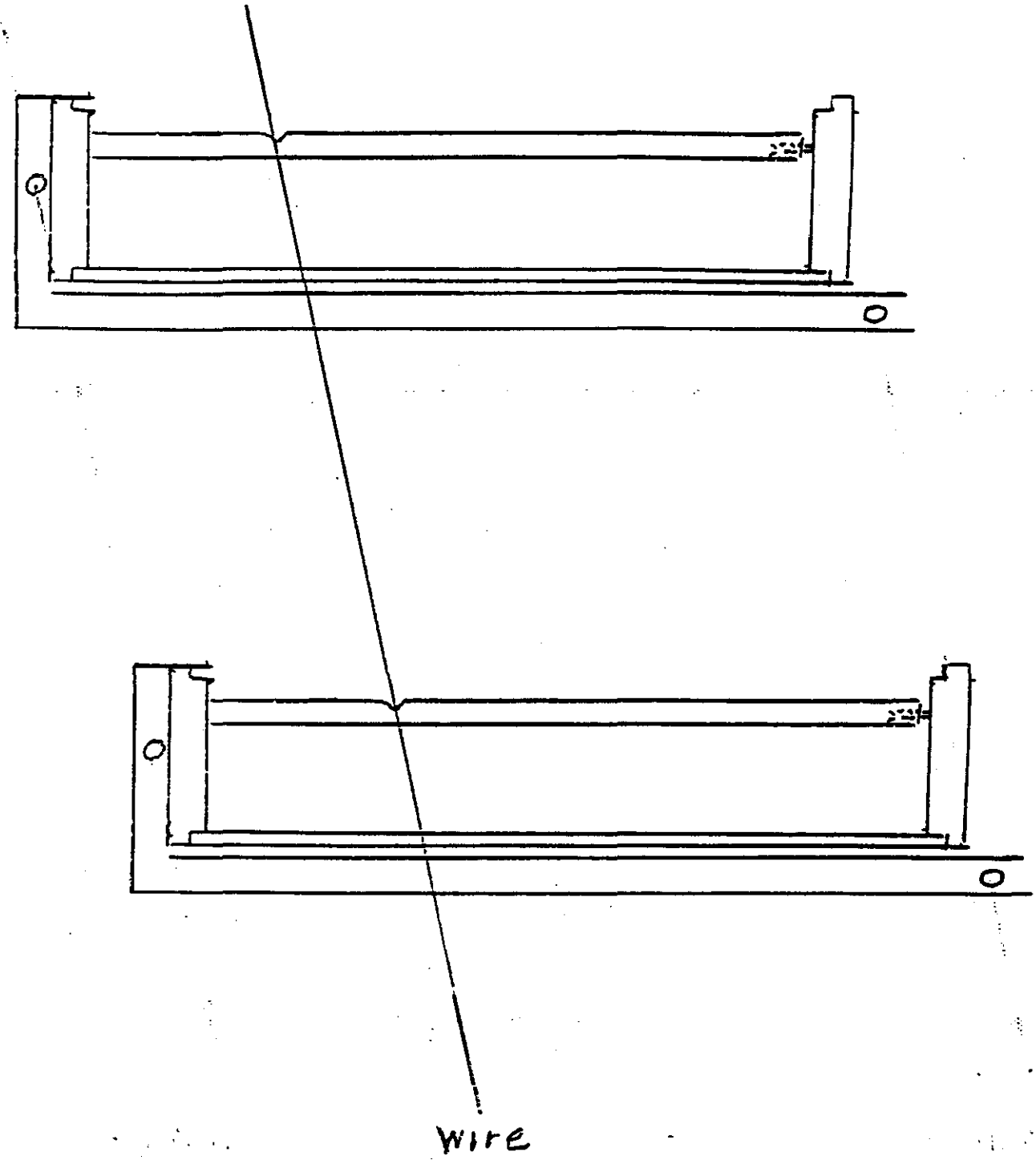
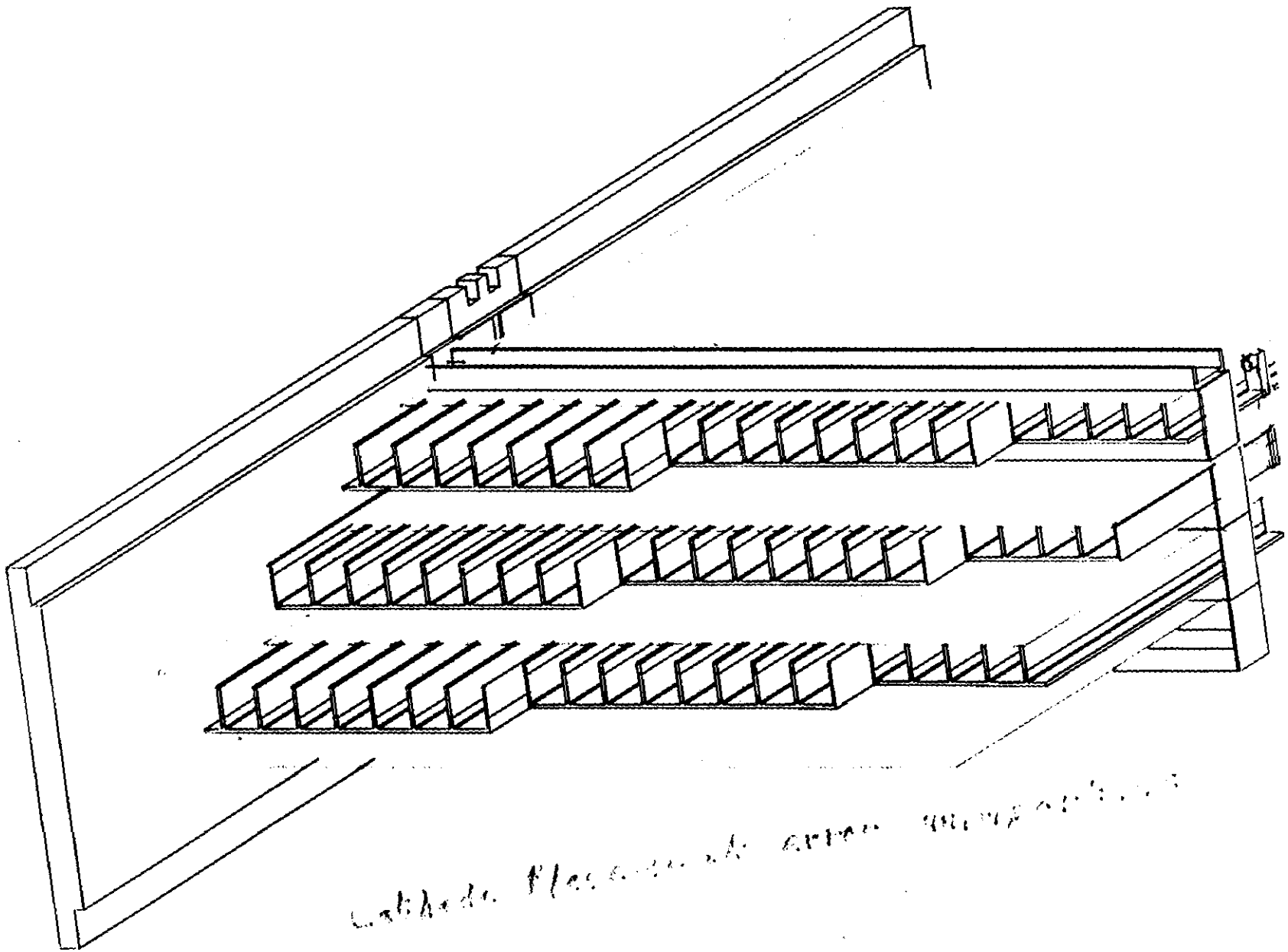
TABBLD "TOPPER"

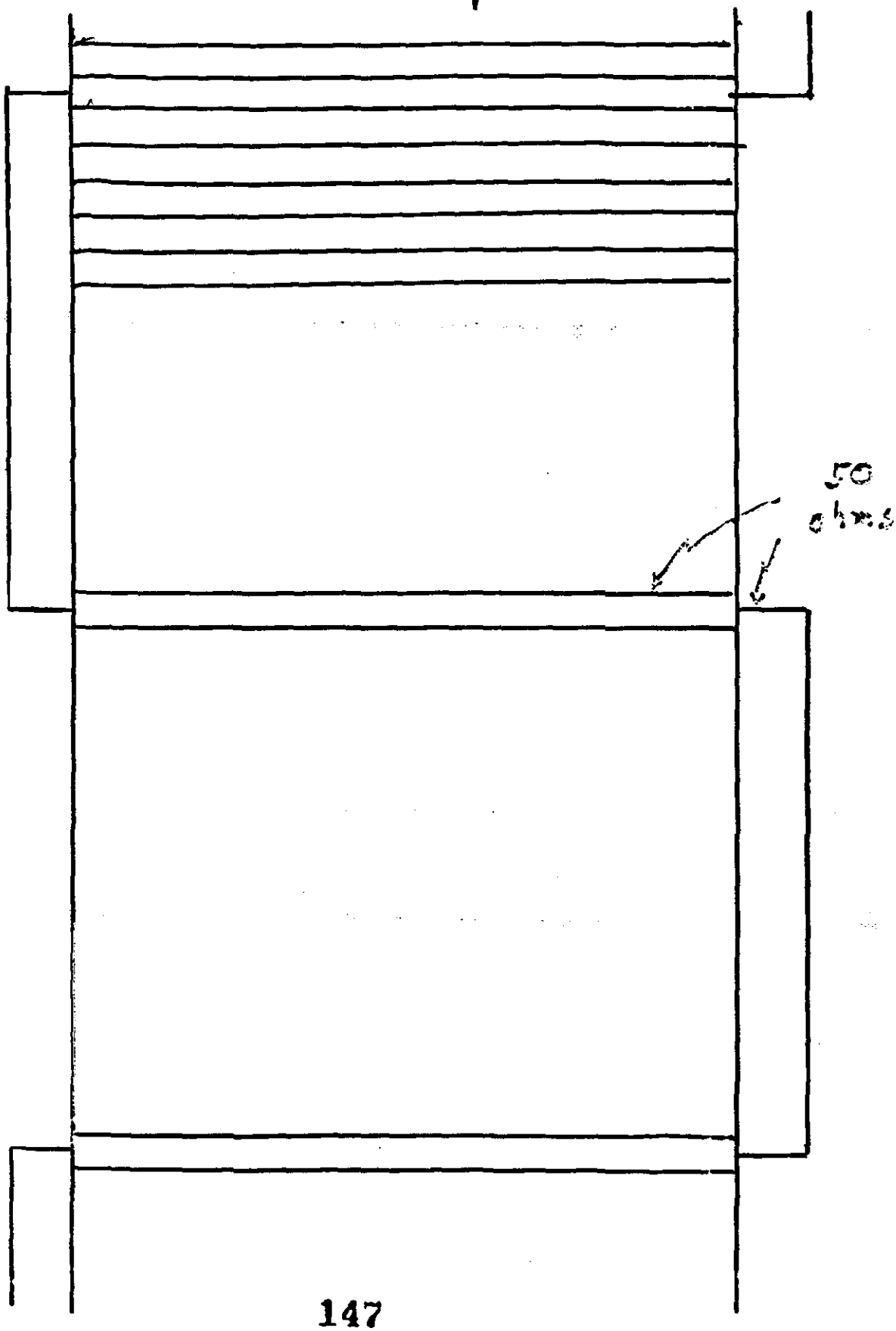


CLINE #62037
CLAUTOPTER

C-LINE #62037
CLEAR TOPPER



Z - strips



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CLEAR TOPPER

C-LINE #62037
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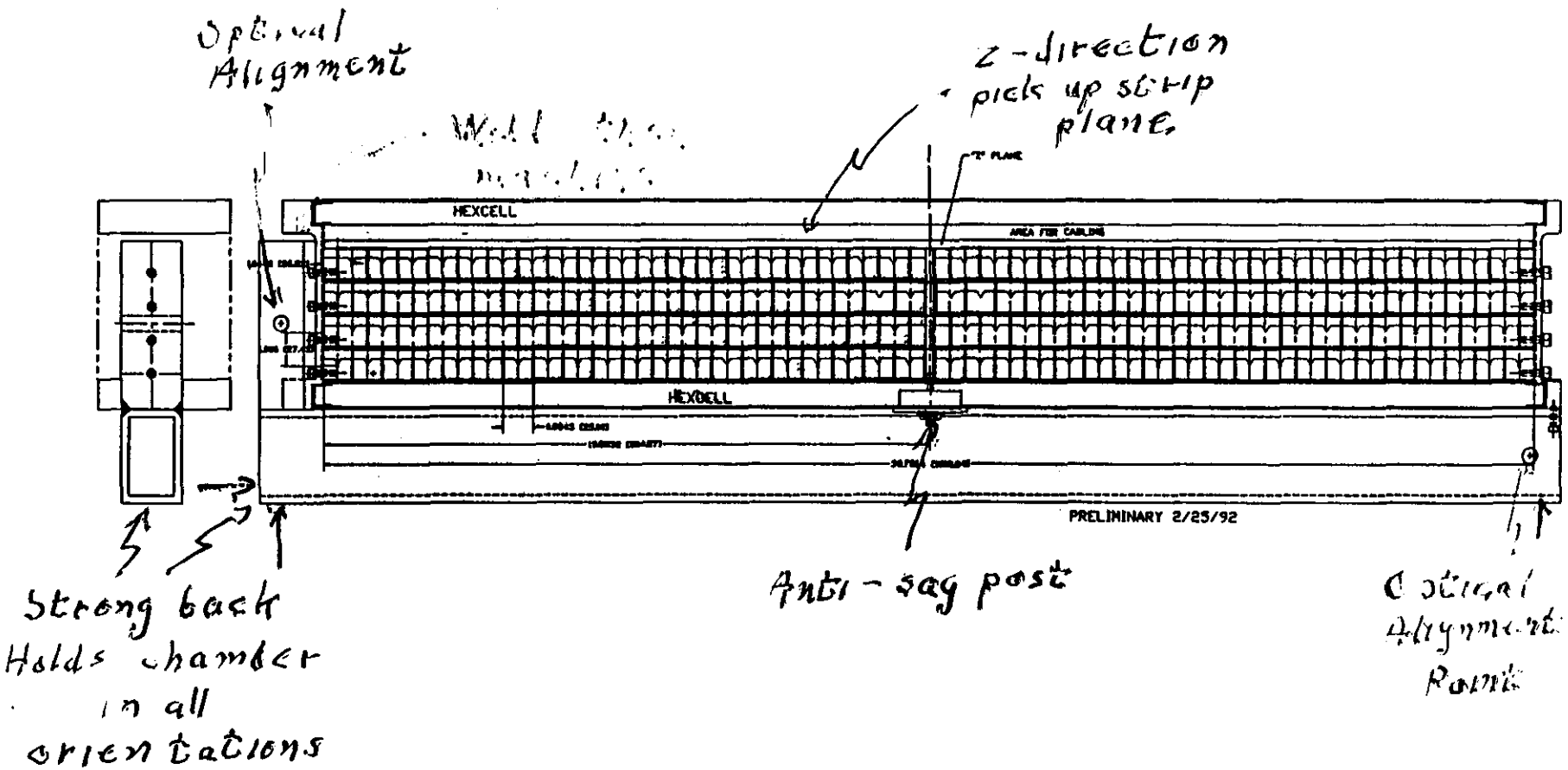
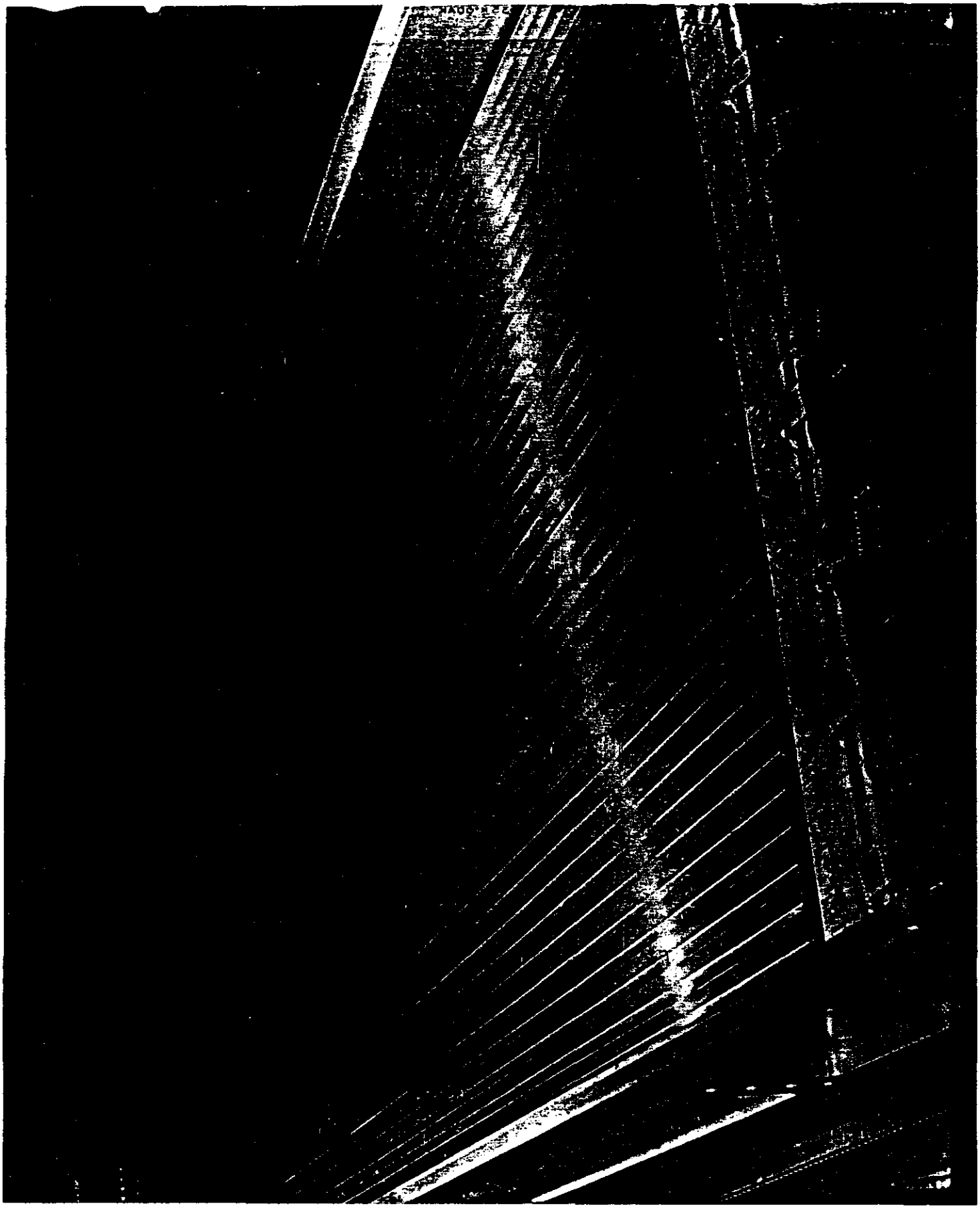
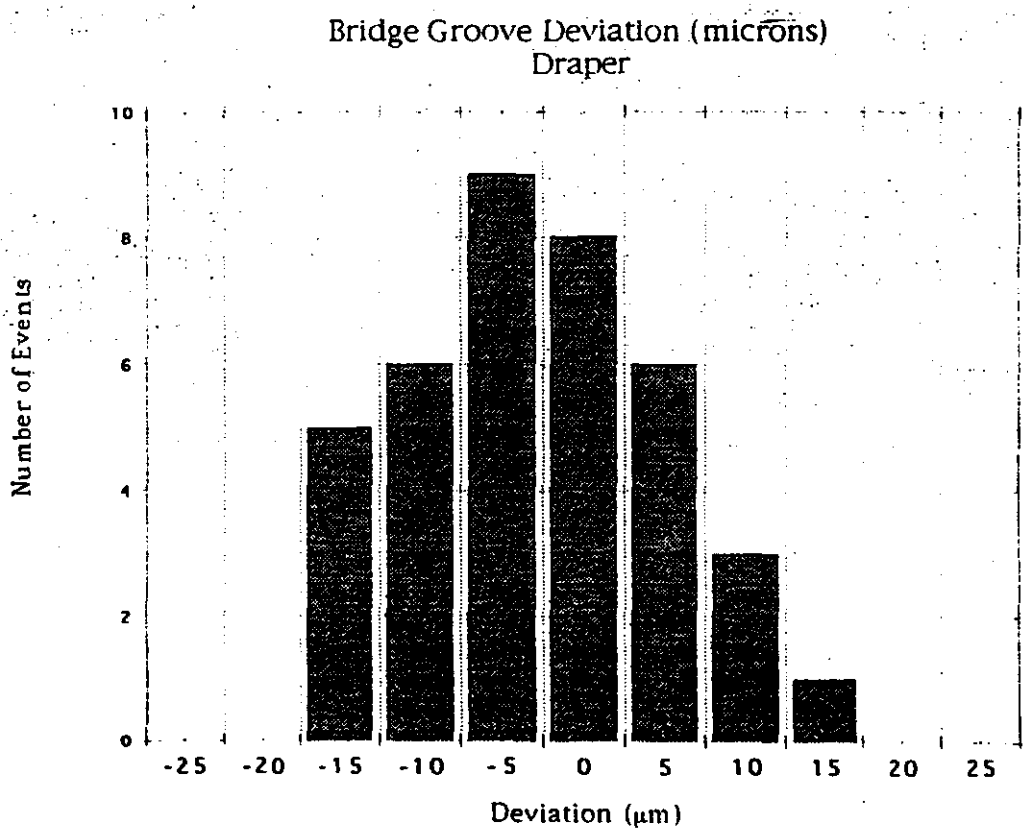


Support Points





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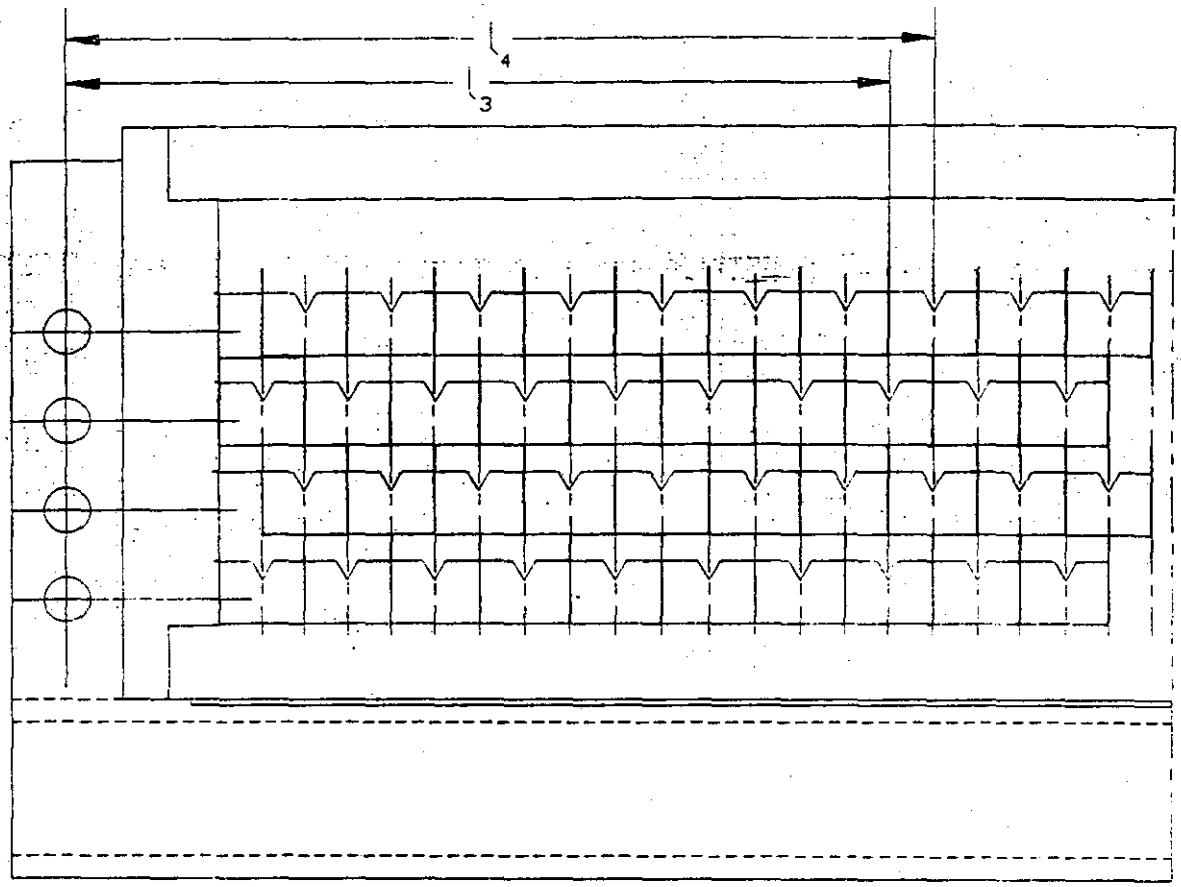
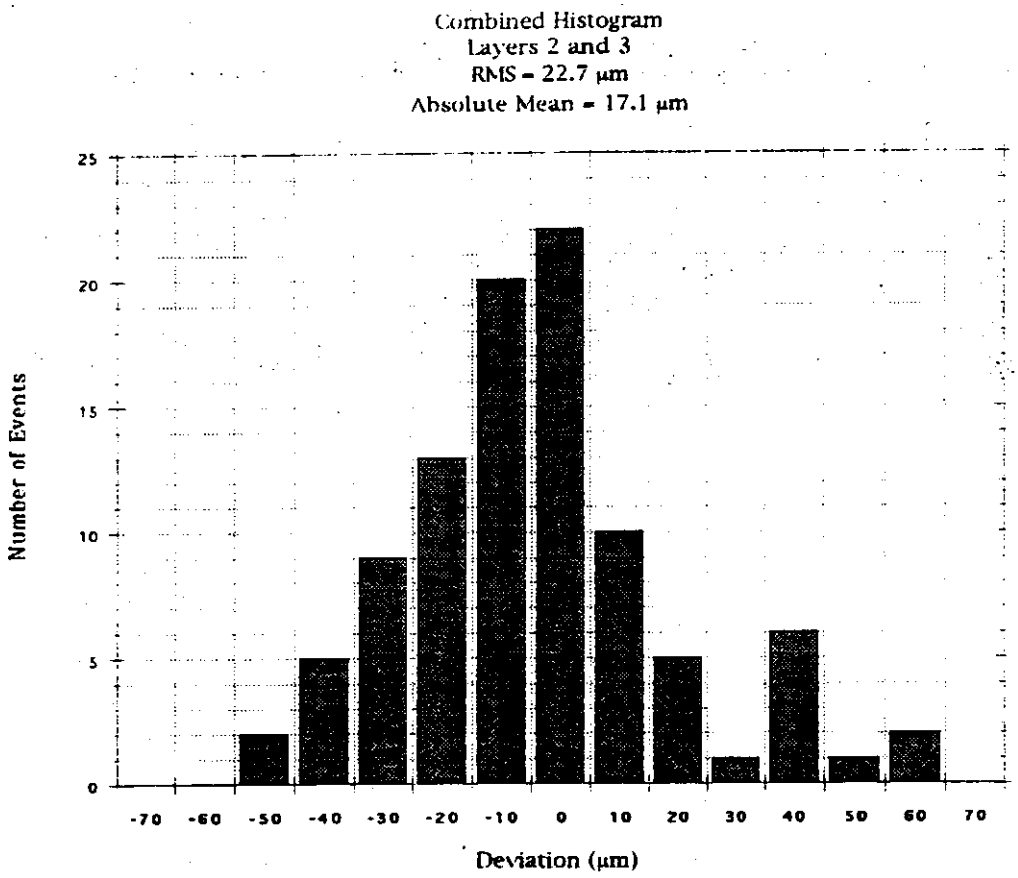


$l_3+(l_4-12.63)$ FOR 3 LAYERS, 3 BRIDGES

254.619
254.629
254.619
254.627
254.647
254.607
254.631
254.621
254.625

C-LINE #62037
CLEAR TOPPER



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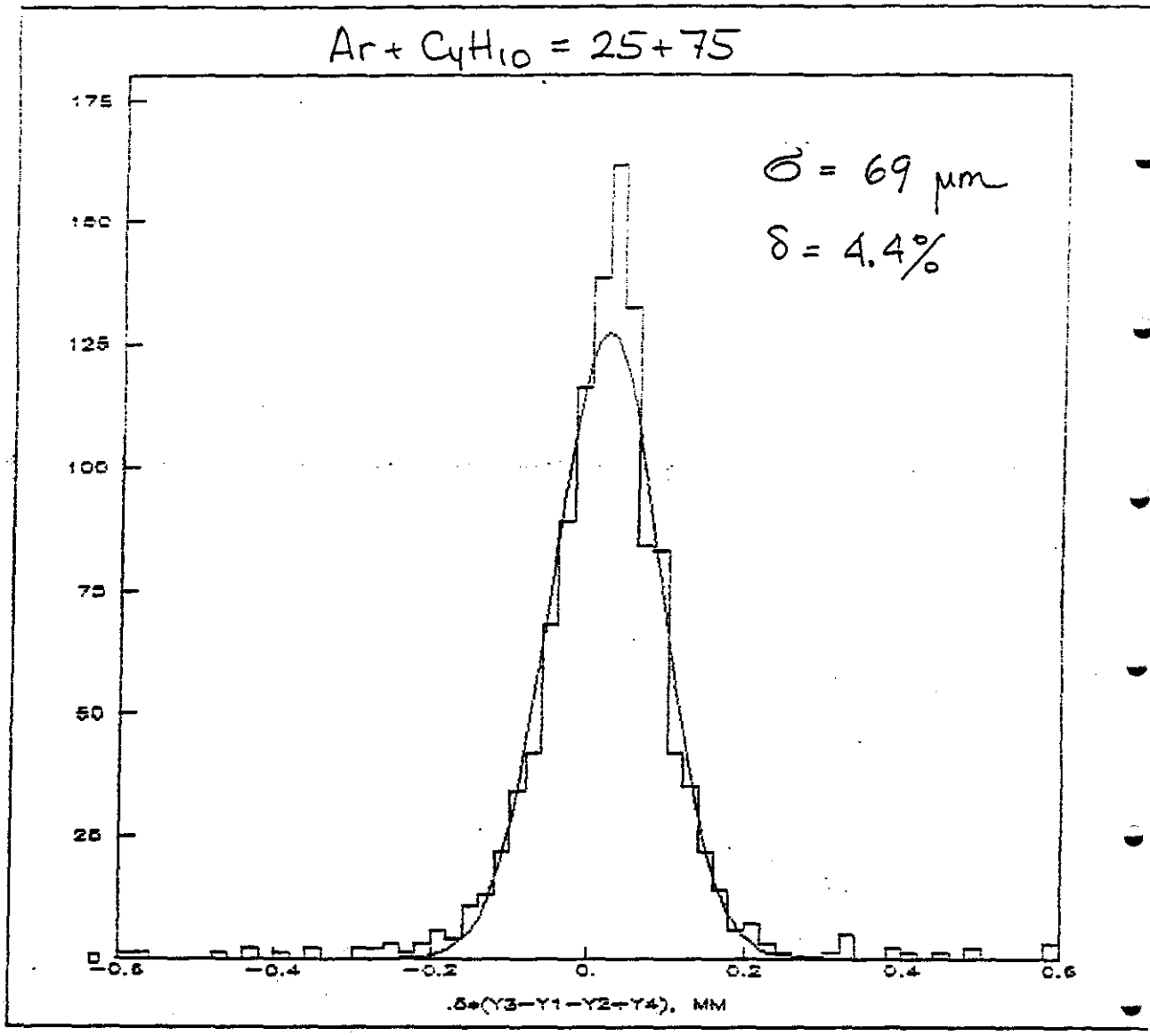
PRELIMINARY 9/20/92



ALL TRACKS GOING BETWEEN WIRES
($\sigma_\alpha \sim 4°$)

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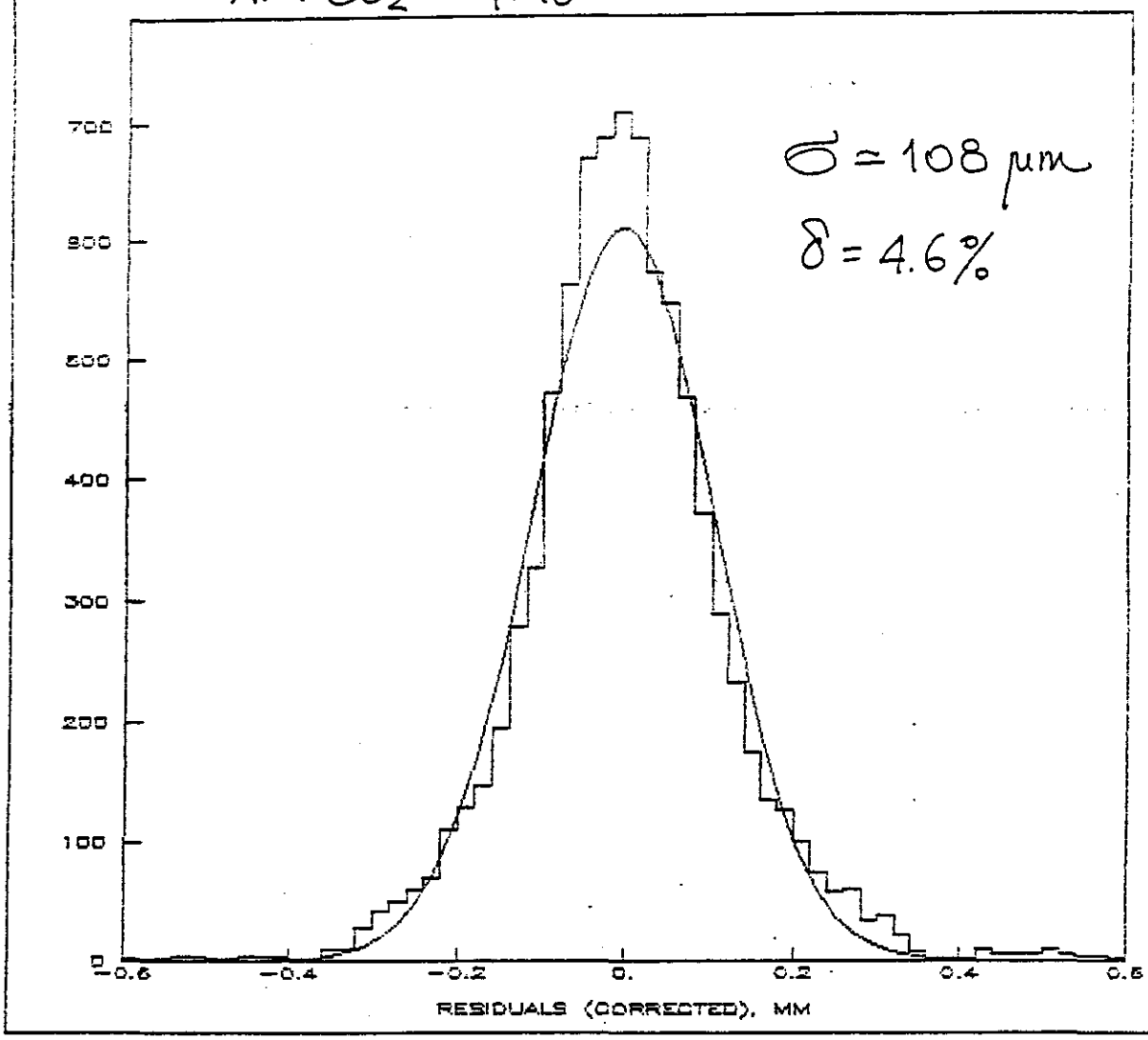
CLEAR TOPPER

PRELIMINARY 9/18/92

$Ar + CO_2 + C_4H_{10} = 2.5 + 88 + 9.5$



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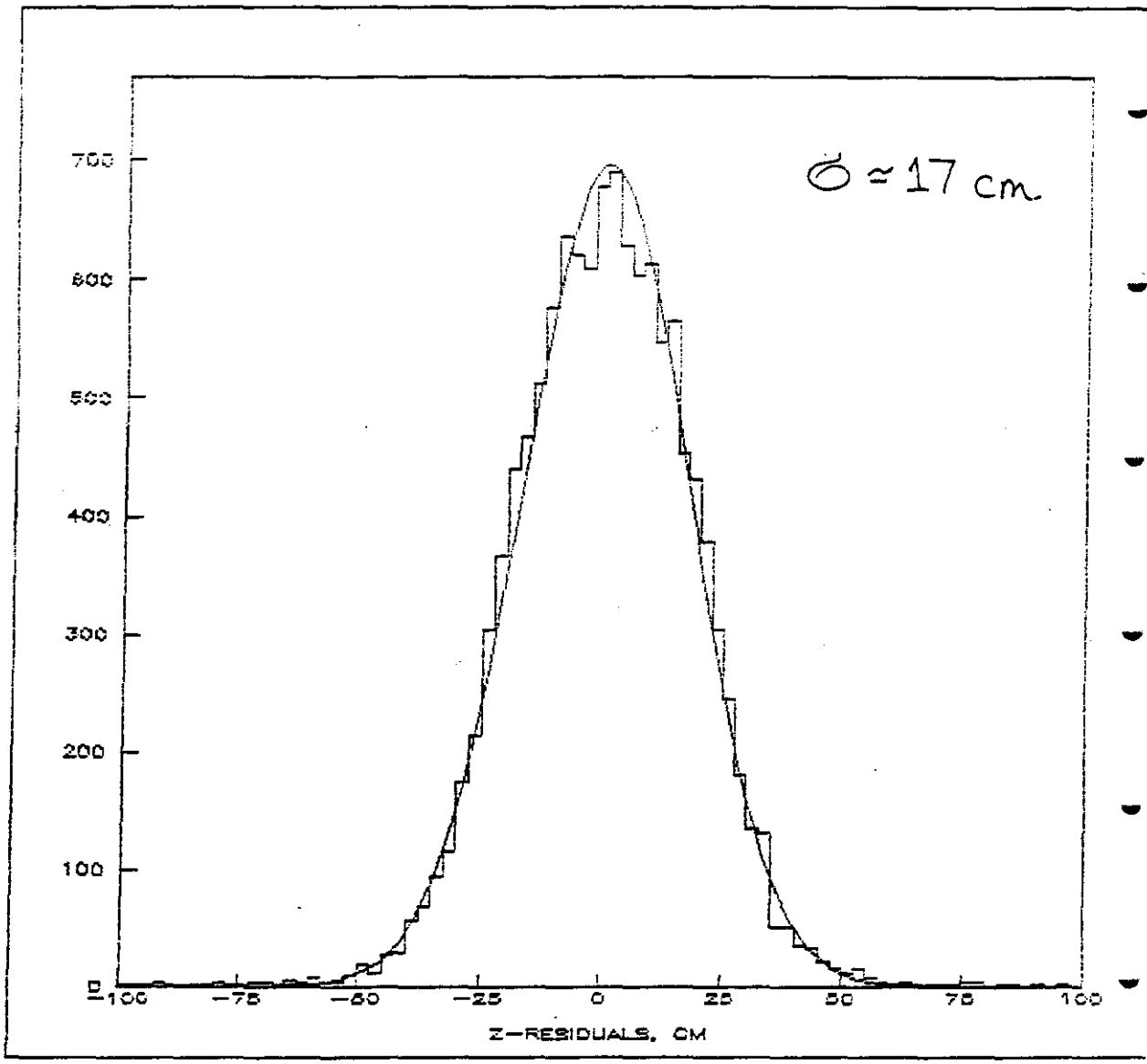
CLEAN TOPPER

#3 $|\alpha| \leq 5°$ $\sigma = 108$ μm

PRELIMINARY 9/18/92



C-LINE#5587
TABBED«TOPPER»

OVERLAP

1.) Sector to Sector

2.) In Superlayers

a.) along ϕ

b.) along θ

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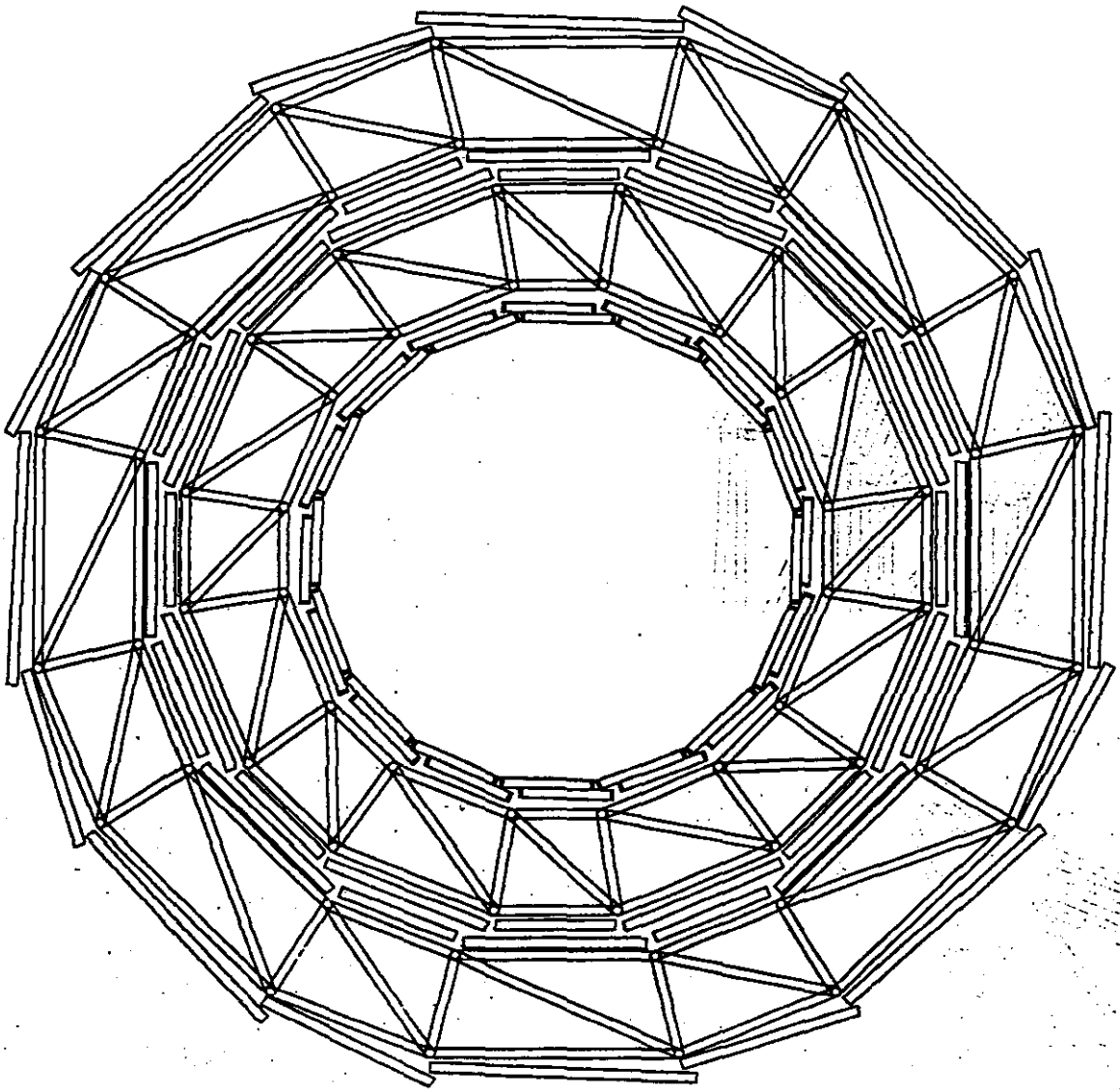
TABBED "TOPPER"



CLINE #32037
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C-LINE #62037
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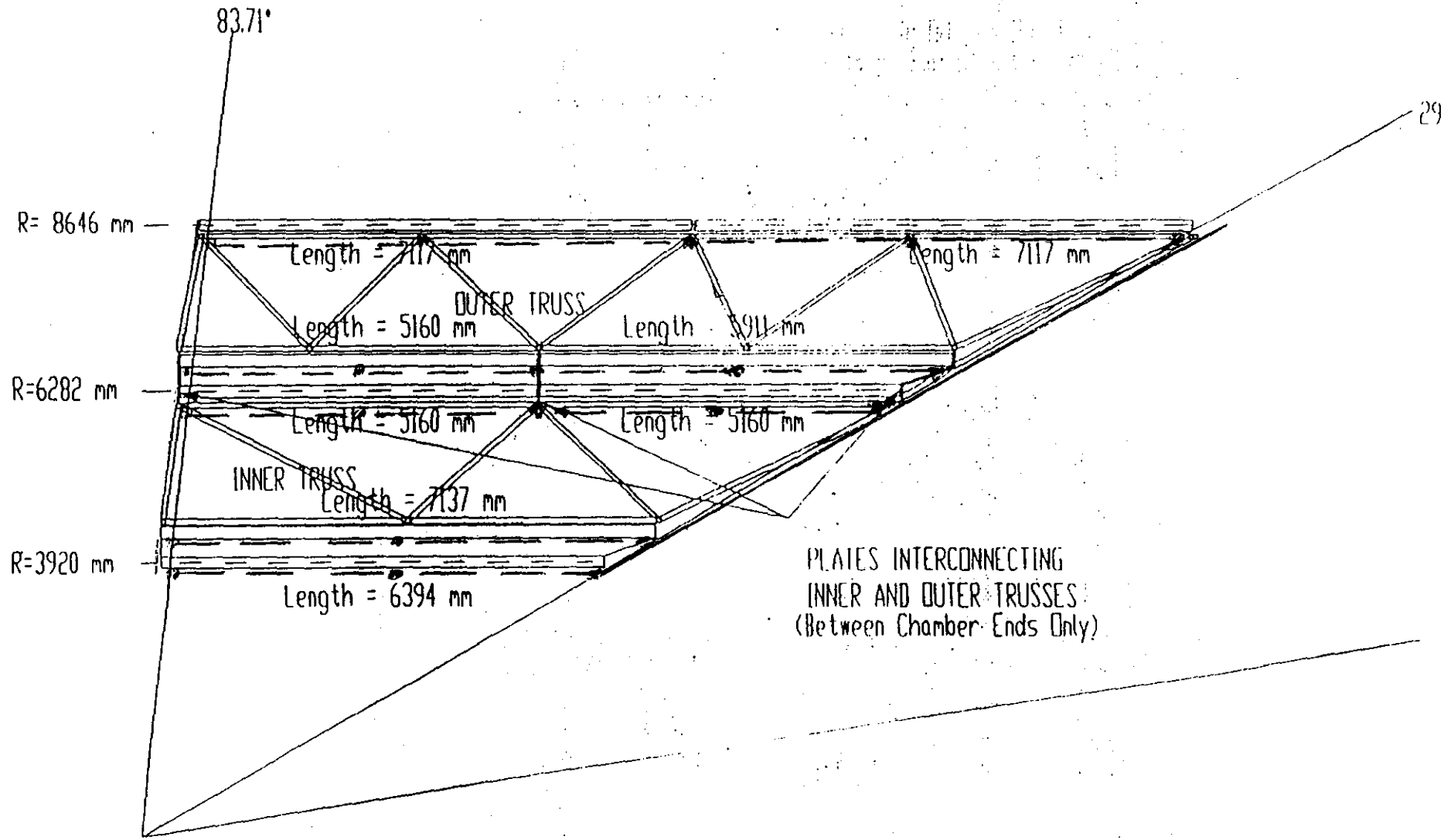
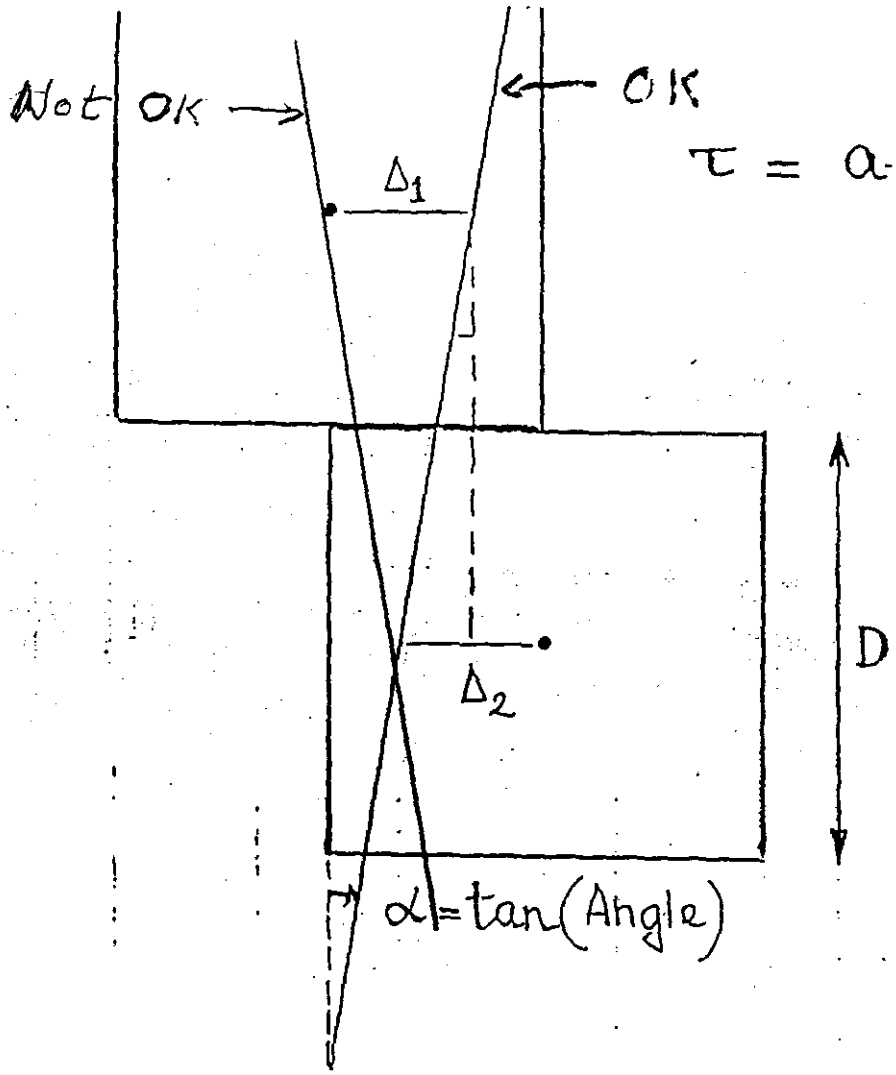


A.1.10. Side view of LSDT chamber layout.



$$\tau = a \cdot \Delta + b \cdot \Delta^2$$

$$T_0 = \frac{T_1 + T_2}{2} - \frac{a \cdot C_0}{2} - \frac{b}{4}\left(C_0^2 + \frac{(\Delta T)^2}{(a + bC_0)^2}\right)$$

$$C_0 = \frac{D}{2} + \alpha \cdot D$$

Fig. A. IV. 5

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eps=.000 Terror(ns)=0.0 Aerror(rad)=.000

P= 10. GeV:	Nyes-Nno-Nwrong=	9998	0	2
P= 20. GeV:	Nyes-Nno-Nwrong=	10000	0	0
P= 40. GeV:	Nyes-Nno-Nwrong=	10000	0	0
P= 80. GeV:	Nyes-Nno-Nwrong=	9998	0	2
P=160. GeV:	Nyes-Nno-Nwrong=	9999	0	1
P=320. GeV:	Nyes-Nno-Nwrong=	10000	0	0

0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	796	1003	1162	1199	1239	1245
7	2293	2593	2639	2642	2656	2716
8	5104	4673	4596	4510	4449	4417
9	1640	1565	1426	1468	1444	1447
10	165	162	171	176	208	166
11	2	2	5	5	4	7
12	0	2	1	0	0	2

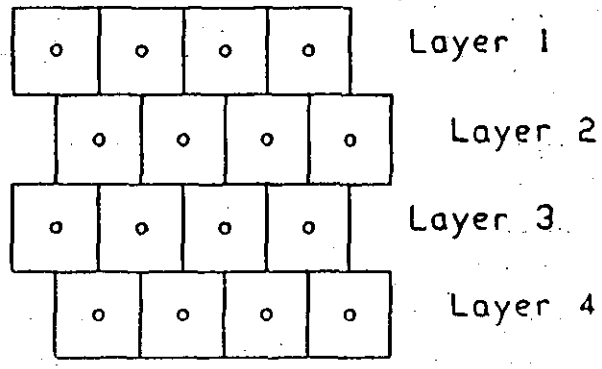
COINCIDENCE LEVEL

P=10 GeV/c	=20	=40	=80	=160	=320

Table 1

C-LINE #62037
CLEAR TOPPER

C-LINE #62037
CLEAR TOPPER



Basic Trigger Group

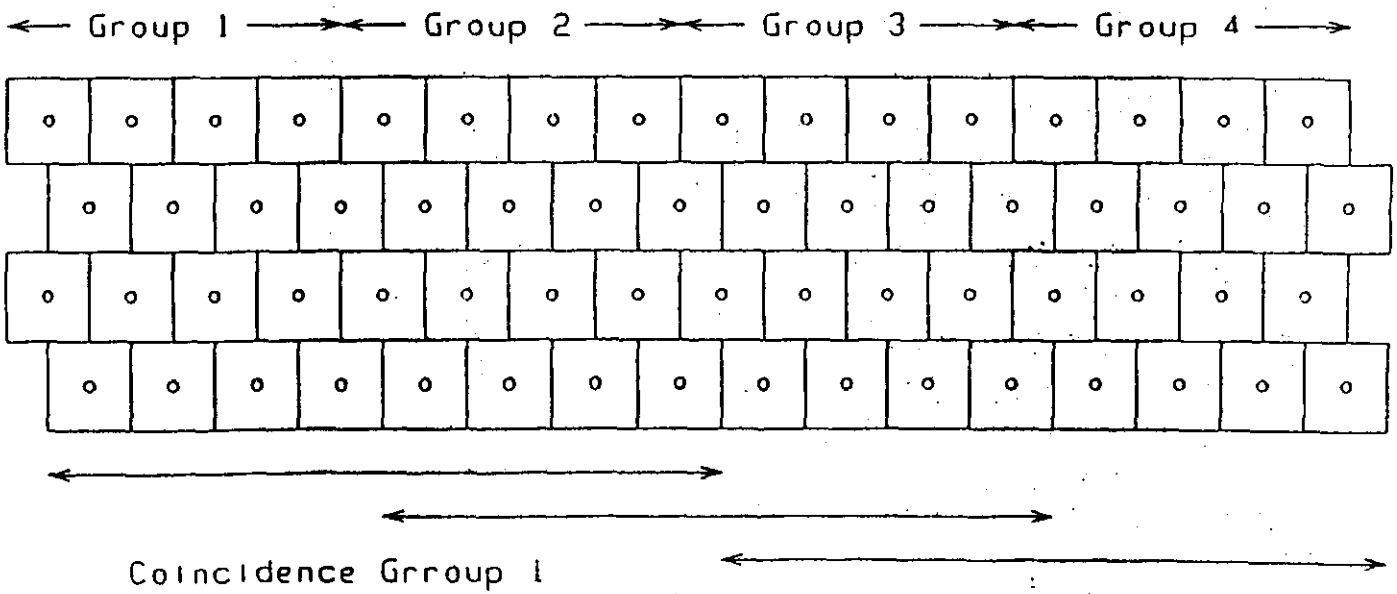


Fig.A.VII.1

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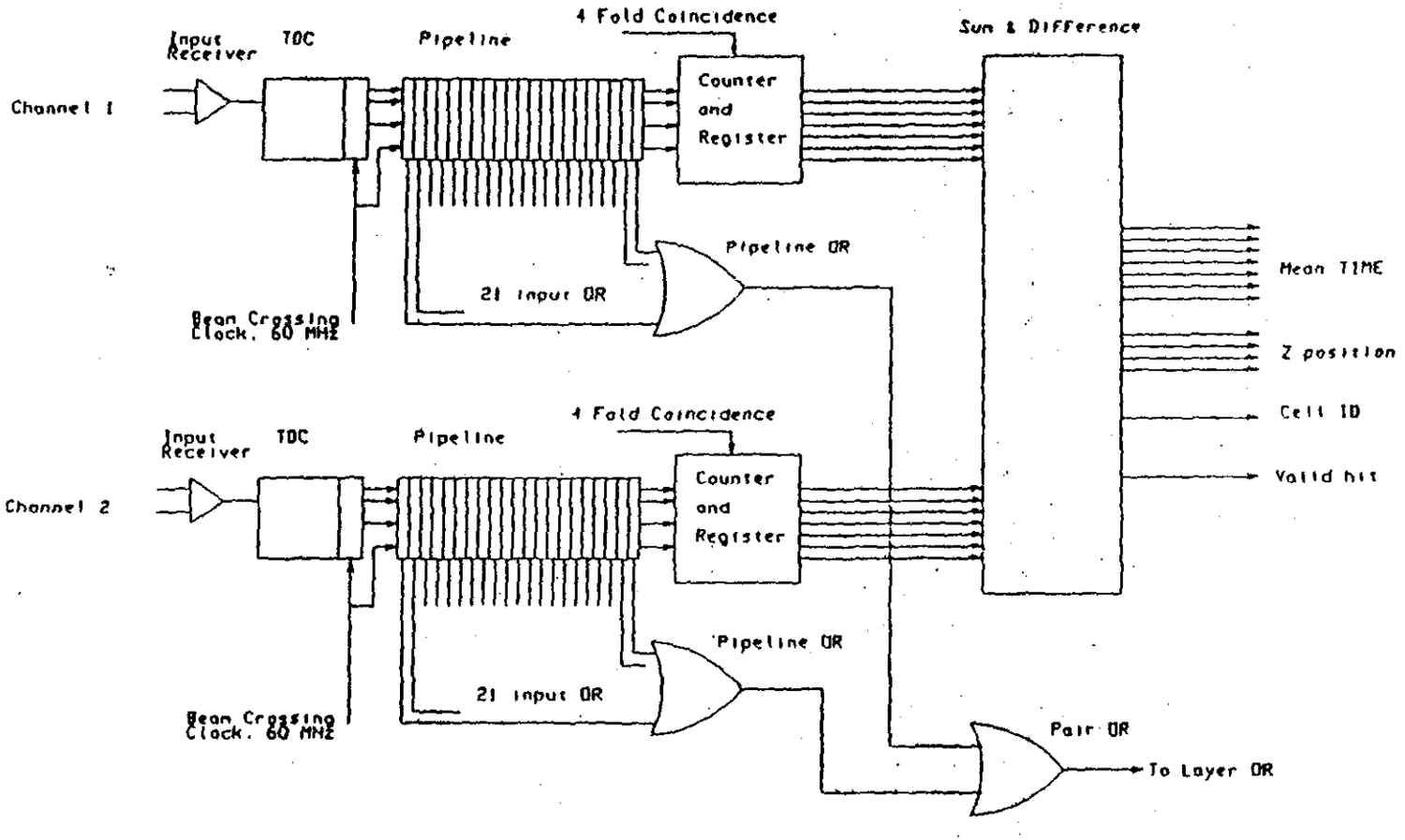
CLEAR TOPPER



Muon Trigger TDC

Fig.A.VII.2

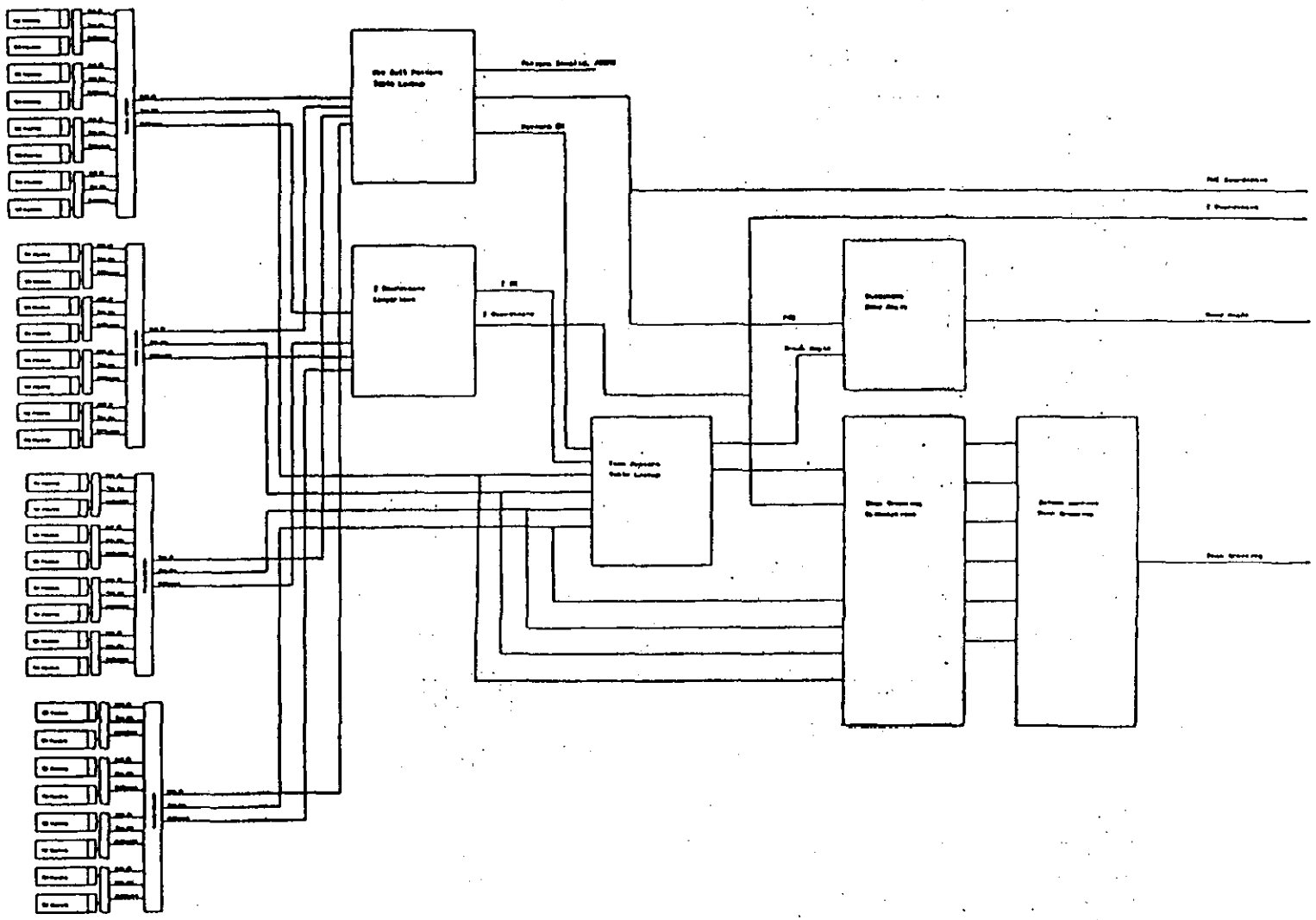
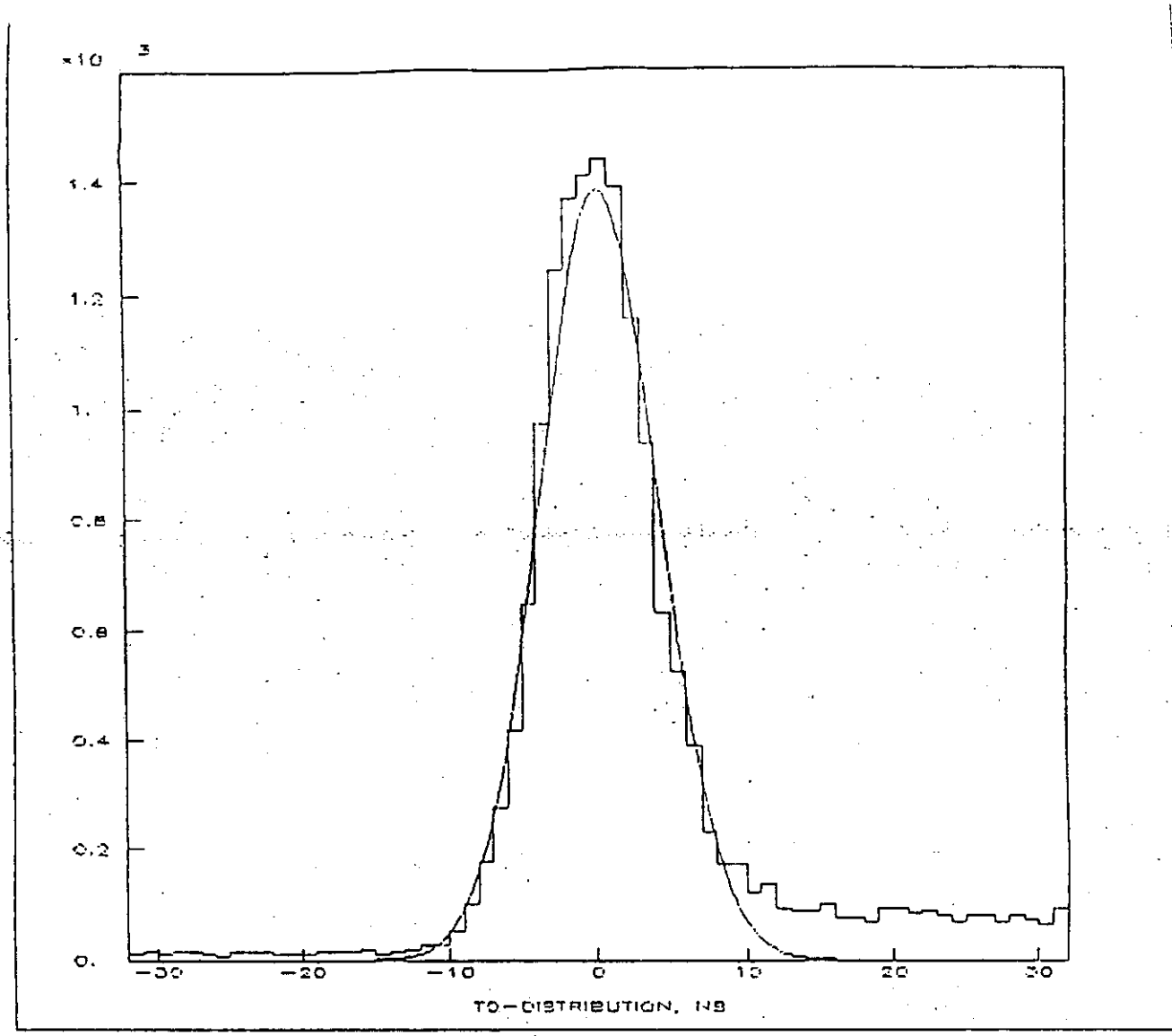


Fig.A.VII.3



C-LINE #62037
CLEAR TOPPER

Fig.A.IV.12(a)

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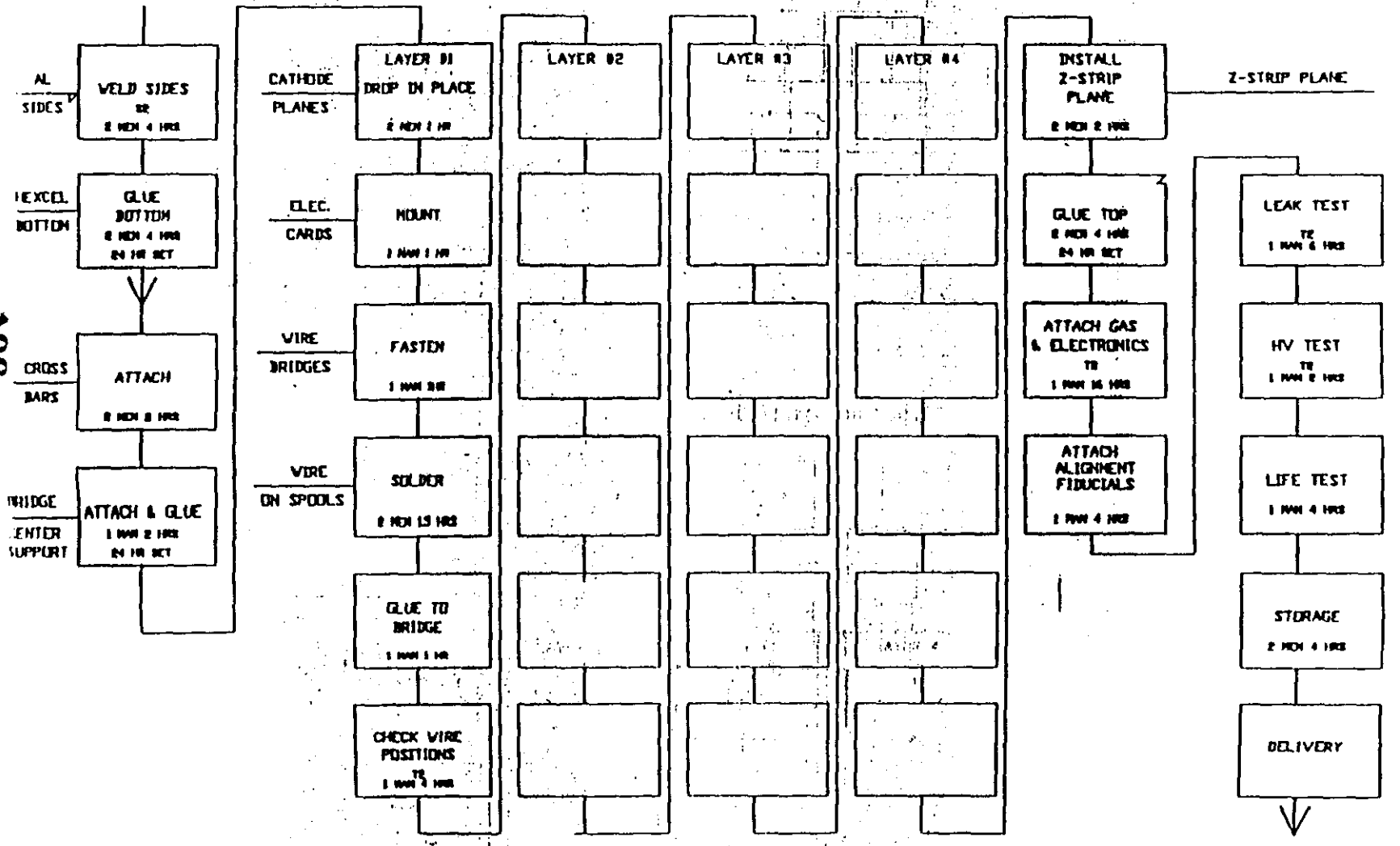

A.1.13. Diagrammatic flow of a chamber assembly procedure.

APPENDIX-NEUTRON BACKGROUND PROBLEMS

Given the neutron efficiency of our chamber and Laurie Waters' calculation of neutron fluxes then is the background rate disturbing?

Waters tells me by letter that the flux of neutrons after the calorimeter and 10 cm of borated polyethylene is 1.15×10^3 per cm^2 per second.

With our "efficiency" of 4×10^{-3} and typical single tube area of 2.5 cm x 1000 cm we get 11.5 kHz/wire. at the first layer.

Wire aging: Taking $\sim$ 50 picoCoulombs/pulse I get 5.75×10^{-3} Coul./cm of wire/year. It would take 174 years to get to the danger point, 1 Coul./cm. or 17.4 years at 10^{34} luminosity.

What is the chance rate to get a vector from 3 out of 4 layers firing within the drift time? I take the worst drift time , 0.5 μsec, i.e. using a CO_2 gas. I get 2.6 Hz. This does not make a level 1 trigger rate; one would require 2 such vectors in adjoining 4 layered chambers of a superlayer not to mention requiring near collinearity in the 3 superlayers.

CAVEATS:

1.) The neutron flux calculation includes only the neutrons exitting from the nearby parts of the calorimeter. Reflections of the higher fluxes at smaller angles back into the barrel region are not yet calculated- the magnet acting as a bottle.

2.) There will be capture gammas associated with the neutrons, also not calculated. However these should be of the same number as the neutrons.

3.) The total amount of B-poly moderator is not decided.

4.) Can one add Boron to the copper of the calorimeter. It makes a better compensated calorimeter and captures more neutrons, although the bad and more numerous neutrons are the "high" energy ones i.e. > 5 kev.

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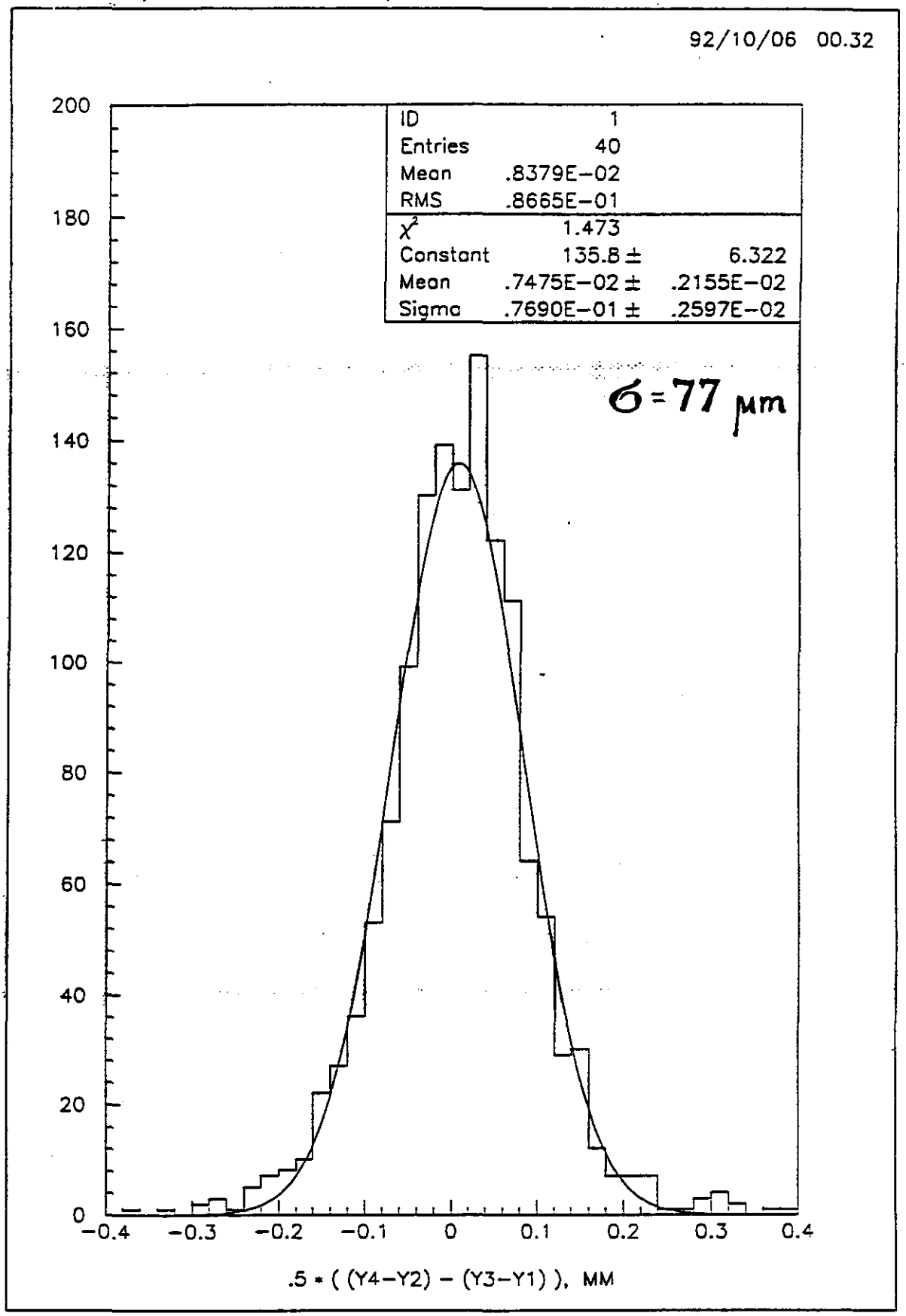
PRELIMINARY



C-LINE#5587
TABBED "TOPPER"

gem

γeμ

Presentation by:

Scott Whitaker

GEM TN-92-199

COLLABORATION COUNCIL
8 OCTOBER

presented by
SCOTT WHITAKER

The GEM Muon System Based on Cathode Strip Chambers

Beijing Institute for High Energy Physics
Boston University
Brookhaven National Laboratory
Draper Laboratory
Hofei University
Institute for Theoretical and Experimental Physics, Moscow
Joint Institute of Nuclear Research/Dubna
Minsk Institute of Nuclear Problems
Oak Ridge National Laboratory
Princeton University
St. Petersburg Nuclear Physics Institute
SSC Laboratory, Dallas
State University of New York at Stony Brook
Tsinghua University
University of Houston

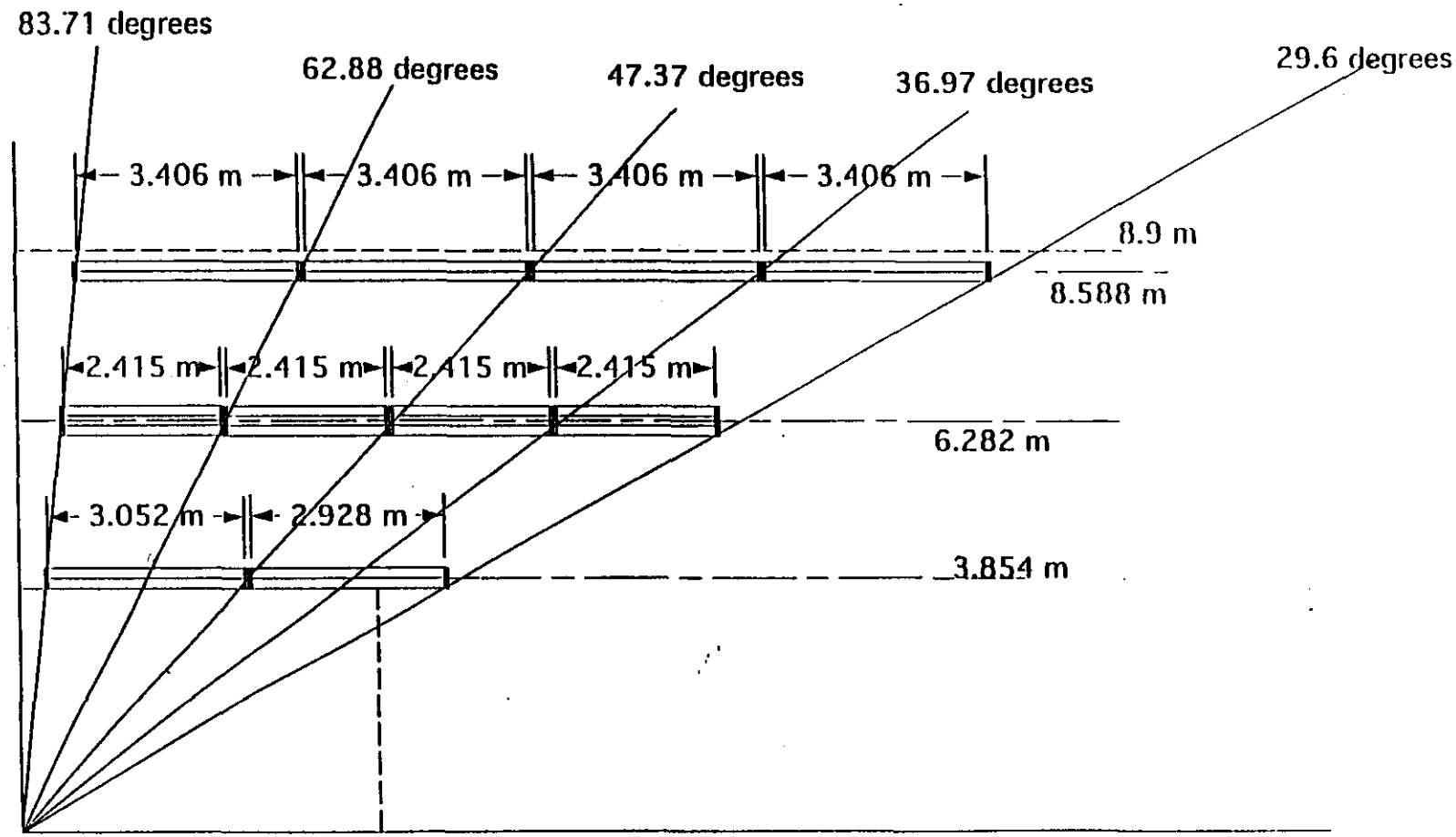
September 28, 1992

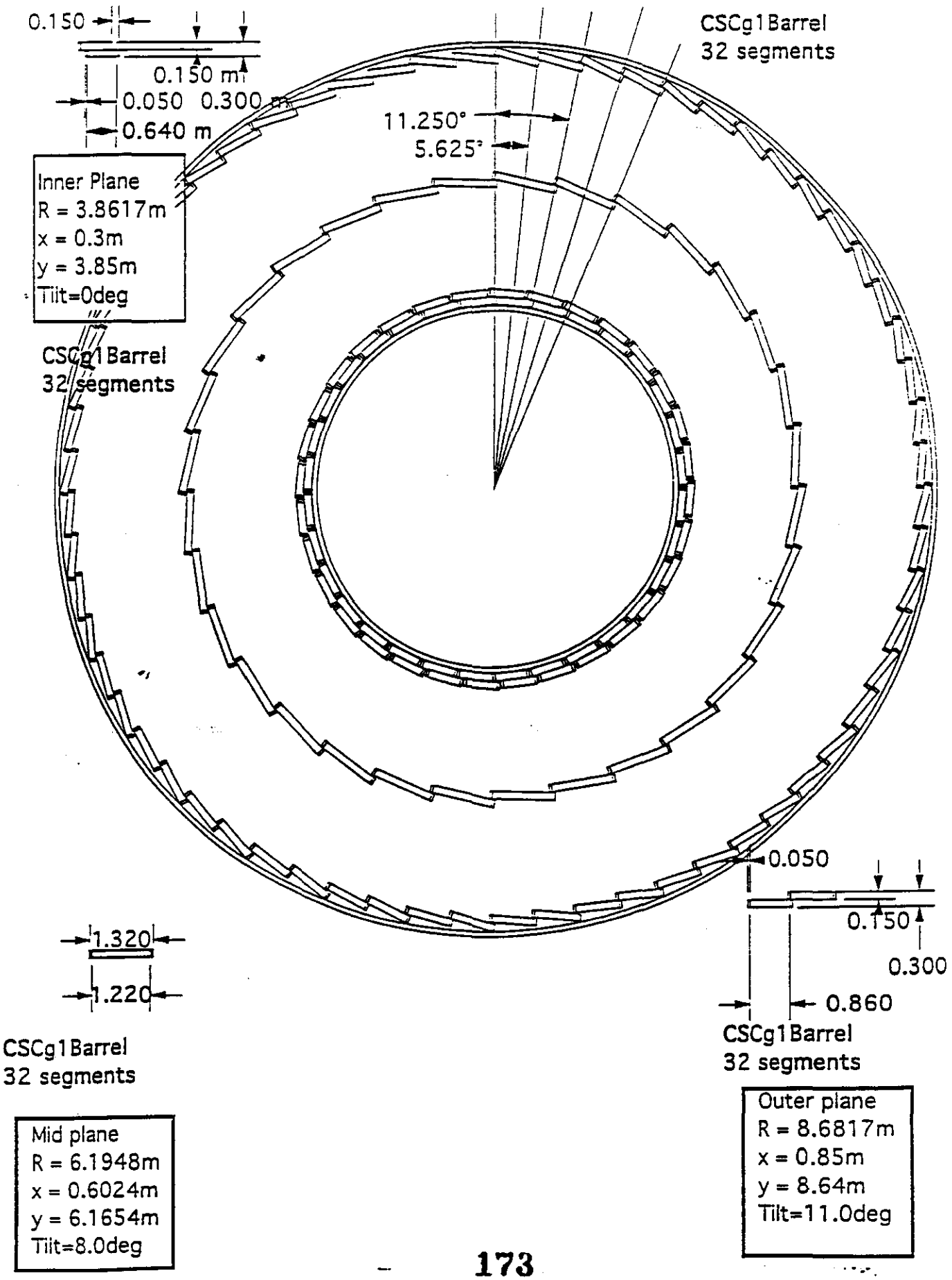
Abstract:

This document proposes to show that the Cathode Strip Chambers (CSC) Technology represents the best choice for the GEM muon system.

CSCf2crzBarrellayout

Lengths of active areas




0.150
0.150 m
0.050
0.300 m
0.640 m
Inner Plane
R = 3.8617m
x = 0.3m
y = 3.85m
Tilt=0deg
CSCg1Barrel
32 segments
11.250°
5.625°
CSCg1Barrel
32 segments
0.050
0.150
0.300
0.860
CSCg1Barrel
32 segments
Outer plane
R = 8.6817m
x = 0.85m
y = 8.64m
Tilt=11.0deg
1.320
1.220
CSCg1Barrel
32 segments
Mid plane
R = 6.1948m
x = 0.6024m
y = 6.1654m
Tilt=8.0deg

Beneficial Features of CSC's

Unified Technology -- One detector provides full functionality:

From the cathode strips --

- Precision measurement in the bend coordinate for momentum determination
- Fast hodoscopic measurement of bend coordinate for triggering

From the orthogonal readout (anode wires or orthogonal cathode strips) --

- Measurement of the non-bend coordinate and determination of θ
- Fast timing and bunch crossing tagging

"Simple" Technology

- A single precision element -- the strip cathode
  - Manufactured by industrial vendors, QA/QC
  - Industrializable design
  - Alignment is integrated into the chamber

Common Technology with the Endcap --

CSC's selected for the Endcaps -- only technology well suited to that geometry

Advantages of choosing CSC's also for the barrel:

♥ Focuses effort and resources
  - Common electronics, DAQ
  - Many common engineering issues

♥ Reduces system complexity -- mechanics, utilities, DAQ,...

CSC Electronics Developments

Lots of work in progress at various institutions in U.S. and abroad:

Preamplifier

Designed in MOS, ENC ~ 1000 electrons for shaping time 300 -- 1000 ns
(3000 electrons for 30 ns shaping)

Shaper

Designed in CMOS, in fabrication. Variable peaking time (x2) ~ 1000ns

Readout

Track&Hold -- preamp, fast shaper, slow shaper, dual track&hold
simulated...

Switched Capacitor Array
examples in the marketplace

Timing

4-fold OR gated by 3/4 —> bunch crossing tag

Trigger

Combinational logic
Content-addressable memories

.
.
.

COST

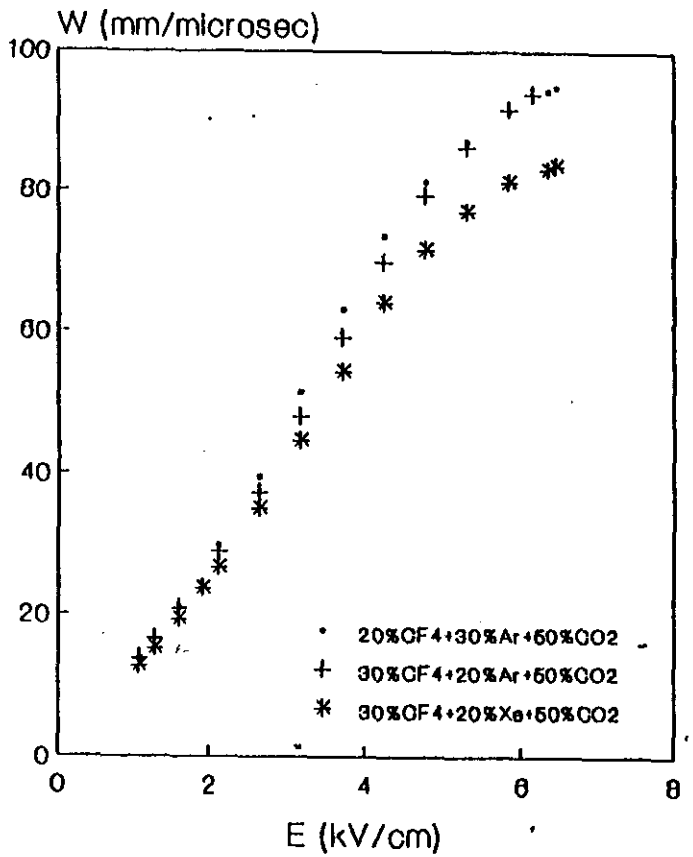
Bottom-up cost analysis in progress --> D. Marlow

Prototype Cathode Strip Chambers

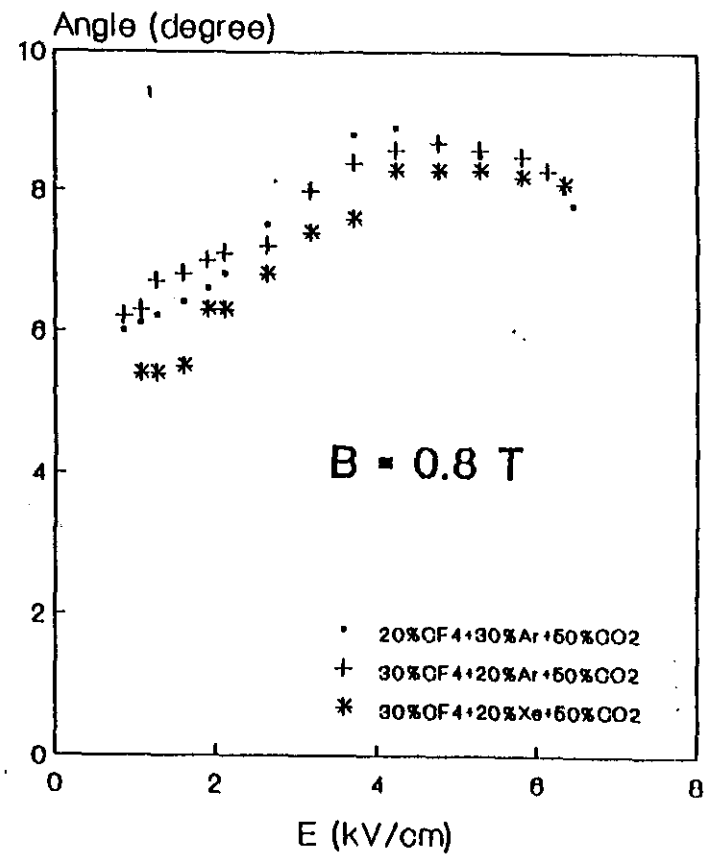
BNL/BU/ ORNL/SB	-- 1m x 2m --	in construction; completion in November
BU	-- .4m x .4m	4 gaps, *running* in RD5 test beam at CERN
UH	-- .5m x 1m --	delivered to TTR
Dubna	-- 1m x 1.5m --	under construction
BNL	-- 14" x 18" --	operating -- results from x-rays, calibration

PNPI: Gas measurements: drift velocity, Lorentz angle for different gas mixtures

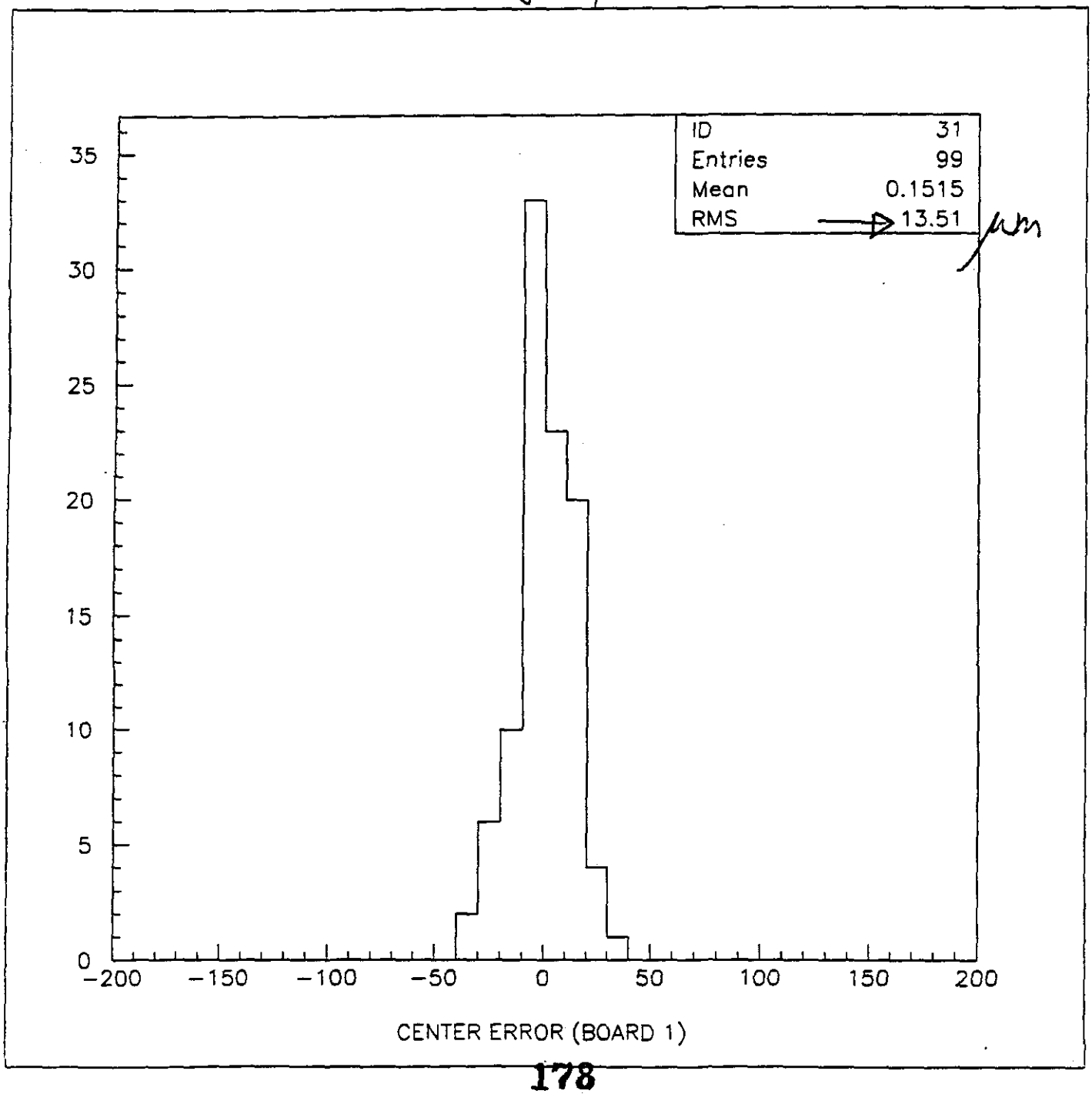
Drift velocity

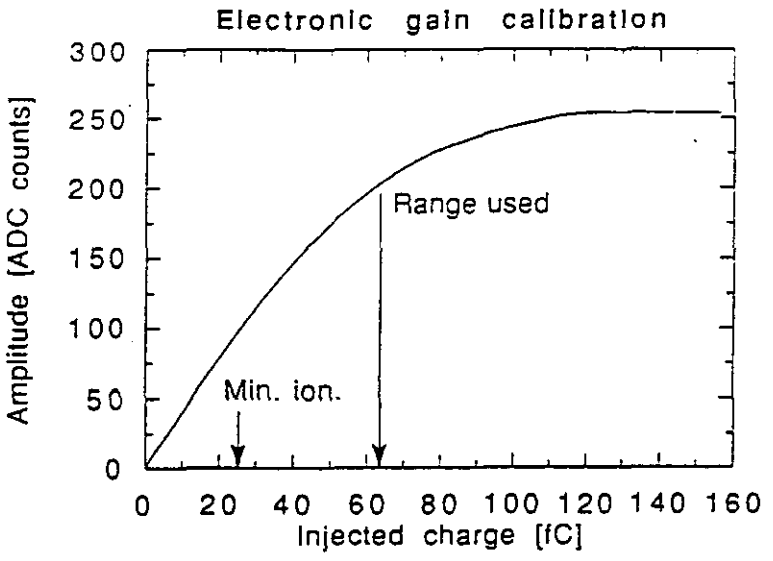


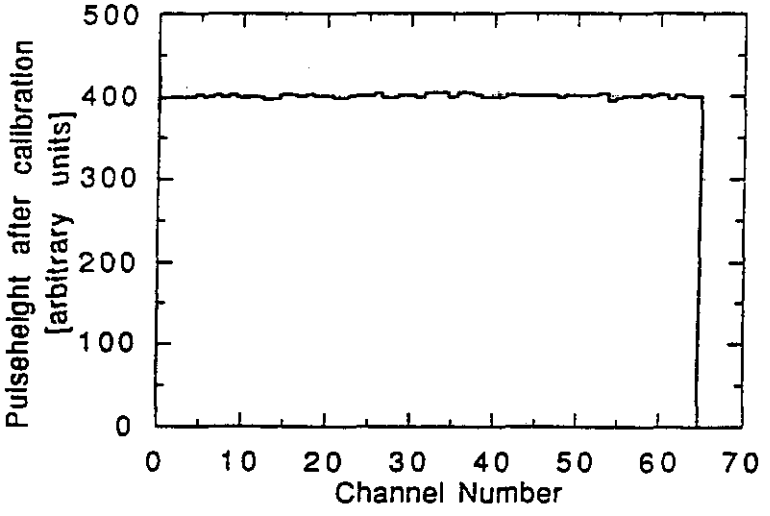
Lorentz angle

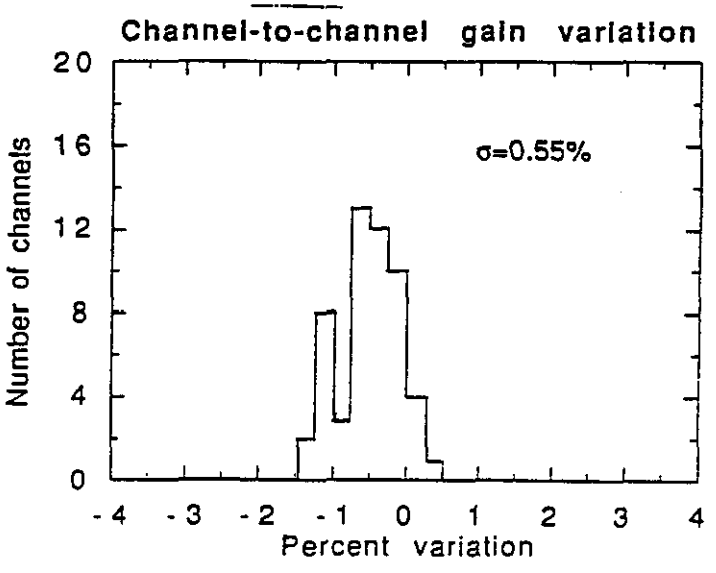


U. of Houston deviations of strip centers from design positions



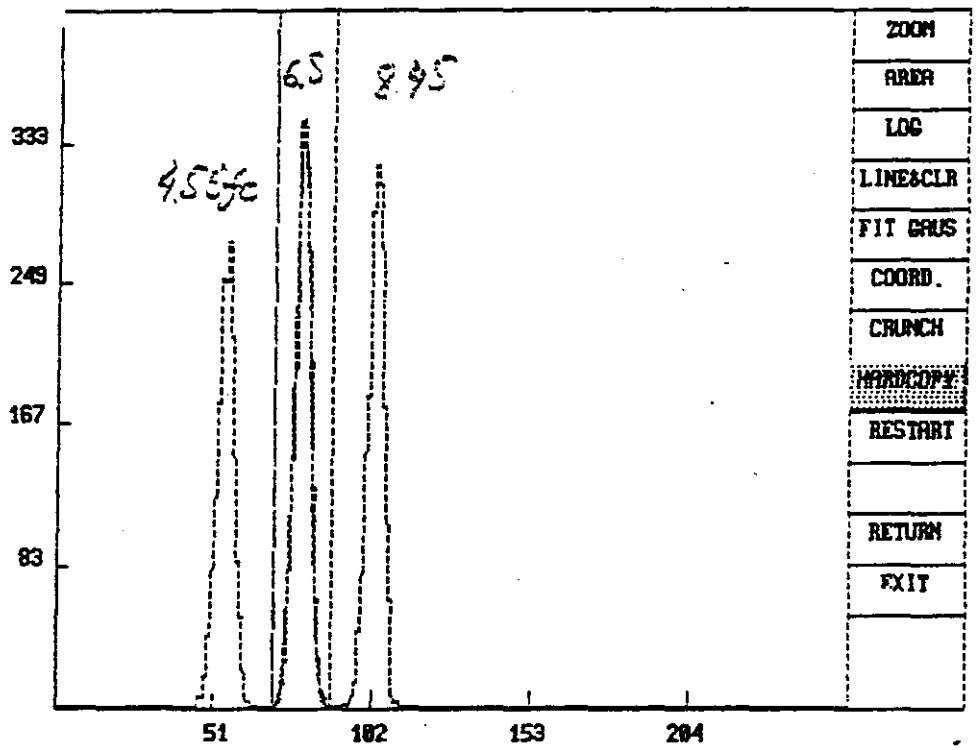

Electronic gain calibration
Amplitude [ADC counts]
300
250
200
150
100
50
0
Range used
Min. ion.
0 20 40 60 80 100 120 140 160
Injected charge [fC]


Pulseheight after calibration
[arbitrary units]
500
400
300
200
100
0
0 10 20 30 40 50 60 70
Channel Number


Channel-to-channel gain variation
Number of channels
20
16
12
8
4
0
σ=0.55%
-4 -3 -2 -1 0 1 2 3 4
Percent variation

St2 #44

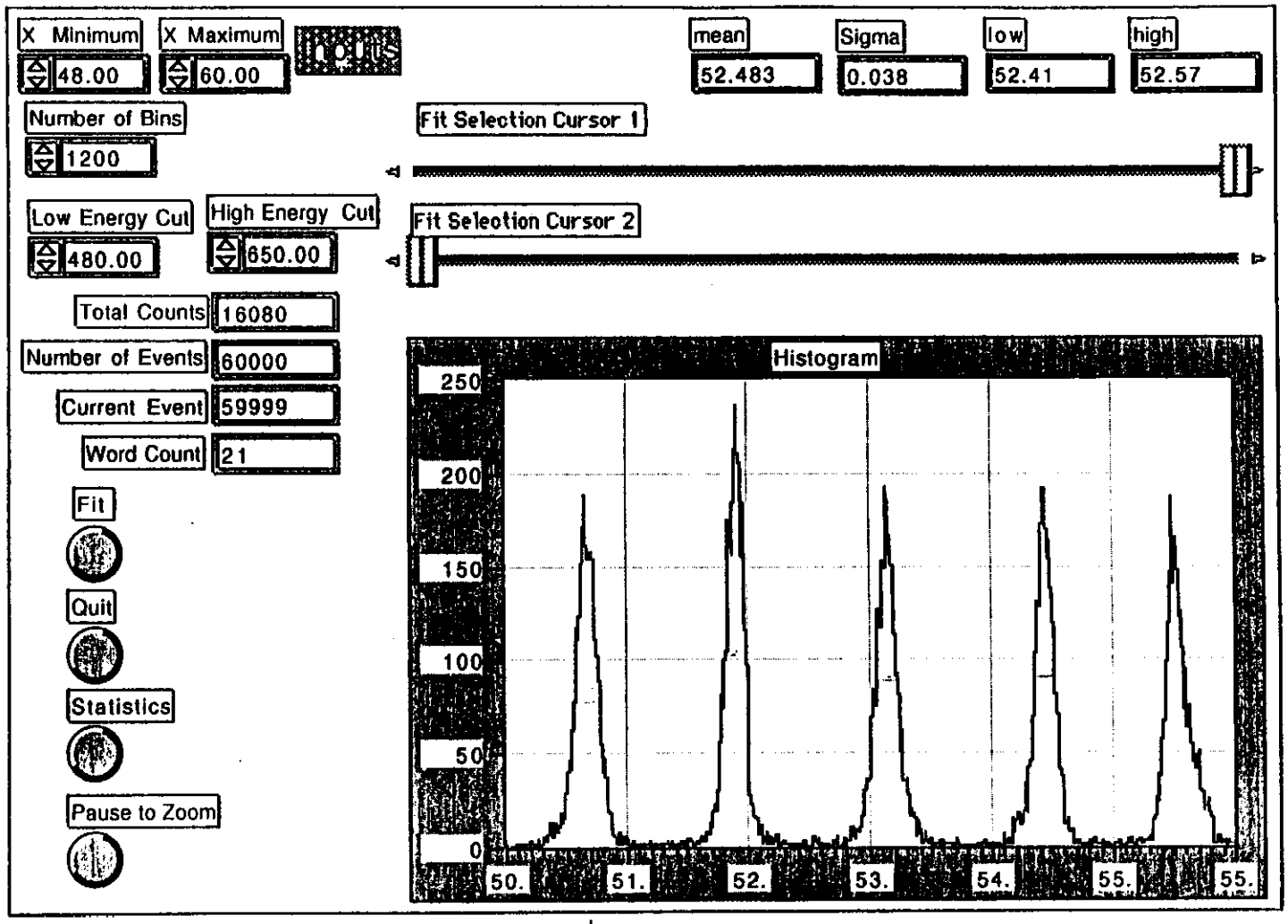
$C_{in} = 0.65 pf$ $A_{gen} = 7mv; 10mv; 13mv$



AMPLI =347.38 CENTROID = 80.39

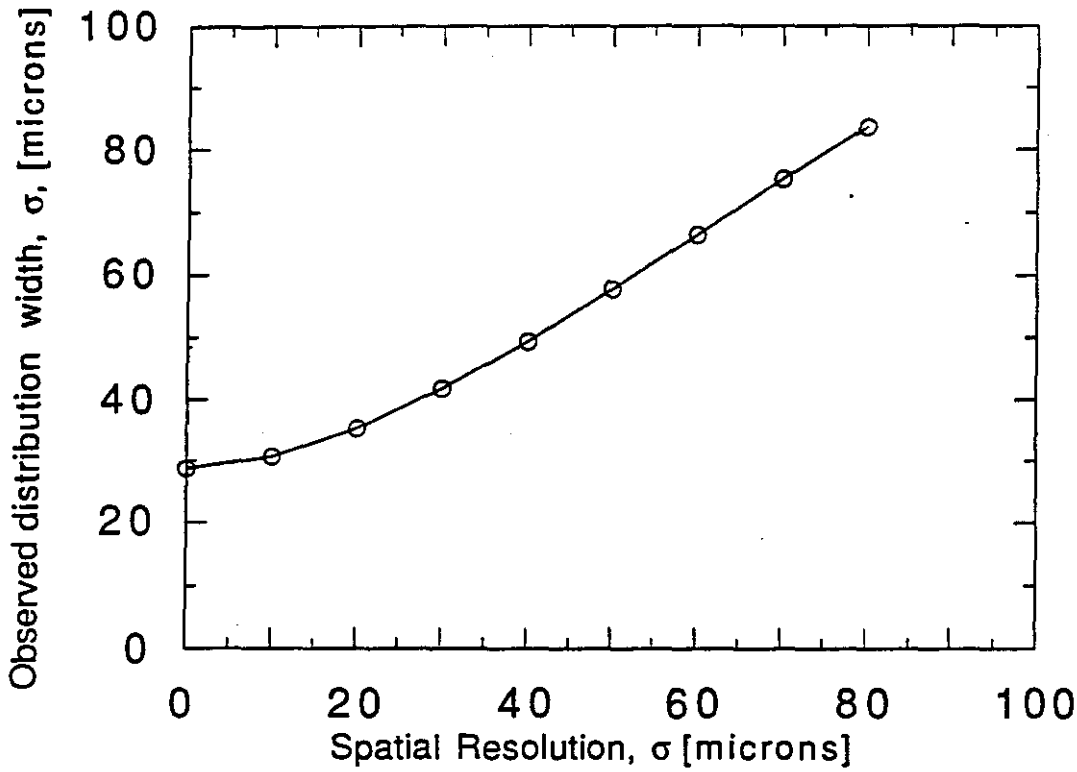
SIGMA = 2.49 SIG/CENT = .31

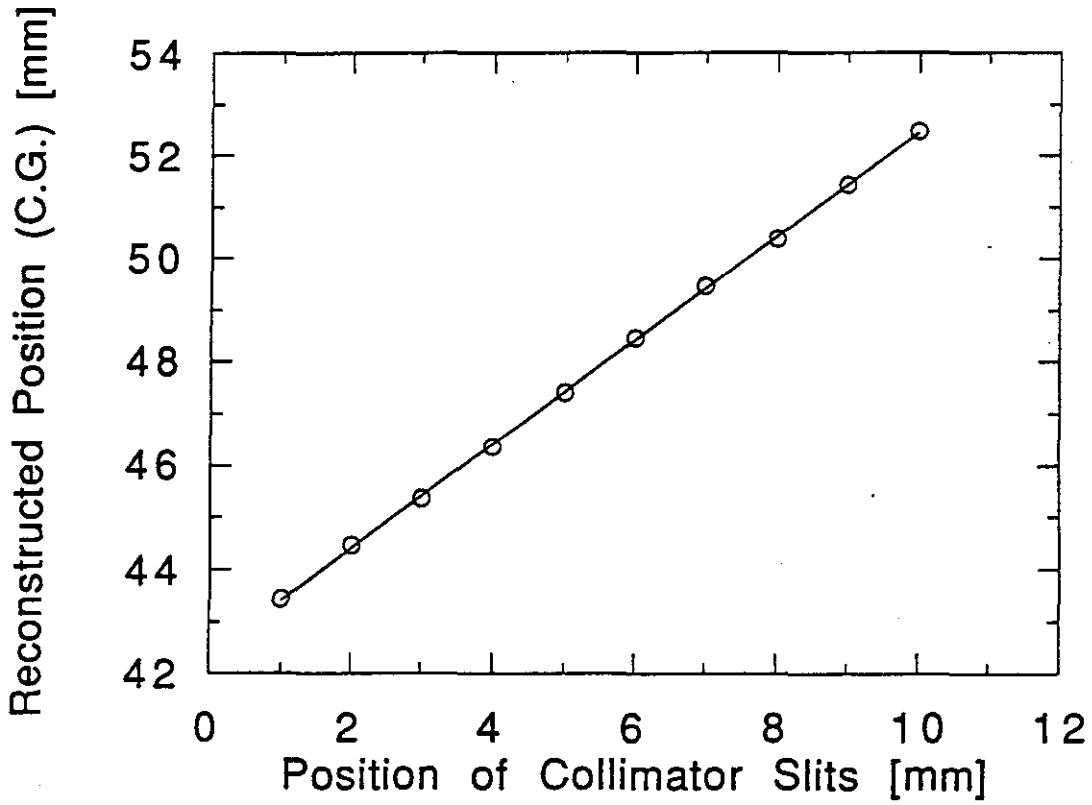
Front Panel

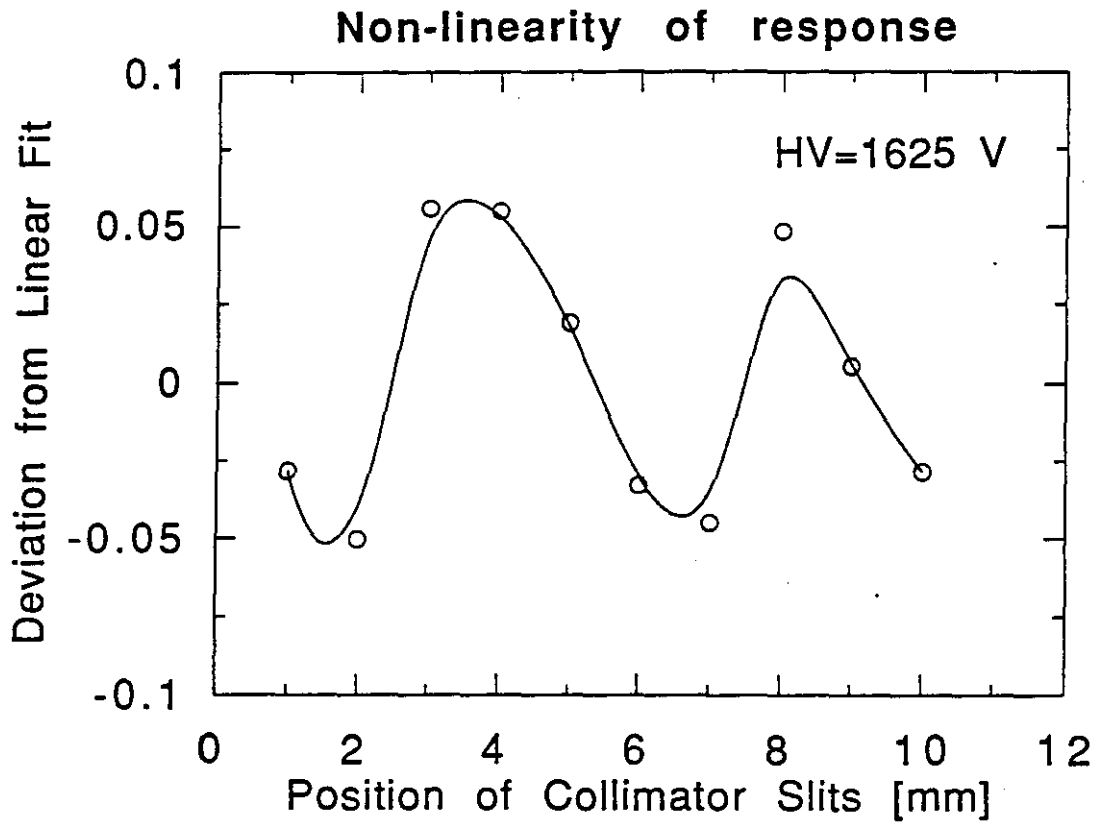


Δ=14 Δ=13 Δ=12 Δ=12

59.6 55.3 σ=51.1 σ=51.1


Observed distribution width, σ, [microns]
100
80
60
40
20
0
0
20
40
60
80
100
Spatial Resolution, σ [microns]


Reconstructed Position (C.G.) [mm]
54
52
50
48
46
44
42
0
2
4
6
8
10
12
Position of Collimator Slits [mm]


Non-linearity of response
HV=1625 V
Deviation from Linear Fit
0.1
0.05
0
-0.05
-0.1
0
2
4
6
8
10
12
Position of Collimator Slits [mm]

gem

γeμ

Presentation by:

C. Wuest

C. Wuest

RESISTIVE PLATE CHAMBER TECHNOLOGY REVIEW

October 6, 1992

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Brown University

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Indiana University

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Y. H. Chang, D. Chen, E. S. Hafen, P. Haridas, M. Lee, I. A. Pless*, S. Yunus
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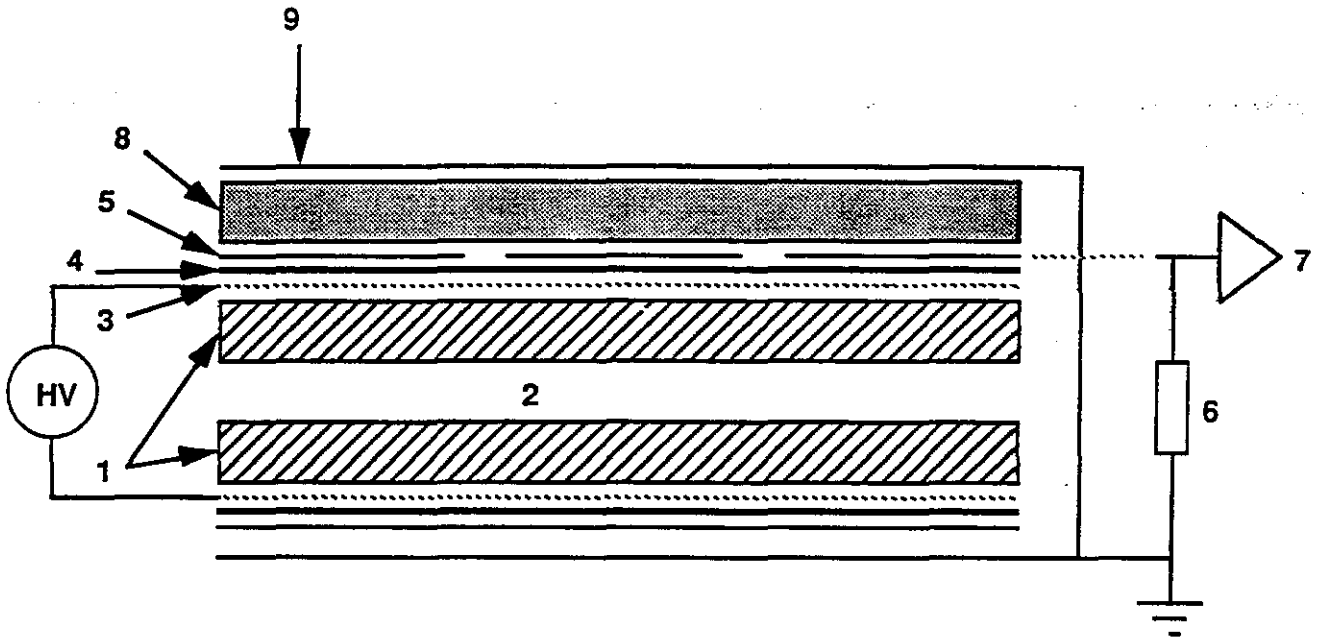
*Co-spokesmen

Resistive Plate Counter Design

- Resistive Plate Chambers (RPCs) have been in operation in experiments throughout the world since 1981.
- The current standard (Italian) design is two meters long by one meter wide with a sensitive gas gap of 2 millimeters.
- There are no wires or conductors anywhere in the sensitive region.
- The walls of the chamber - in contact with the gas of the sensitive volume - consists of a semi-conductor (Bakelite, for example) with a bulk resistance of about 10**11 ohm-centimeters.
- An ioniz ing particle passing through the sensitive volume (2 m x 1 m x 2 mm) breaks down the gap and creates an electrical discharge.
- This discharge is very fast (a few nanoseconds).
- The discharge is capacitively coupled to pick-up strips which are located outside the semiconductor walls of the gas cell.

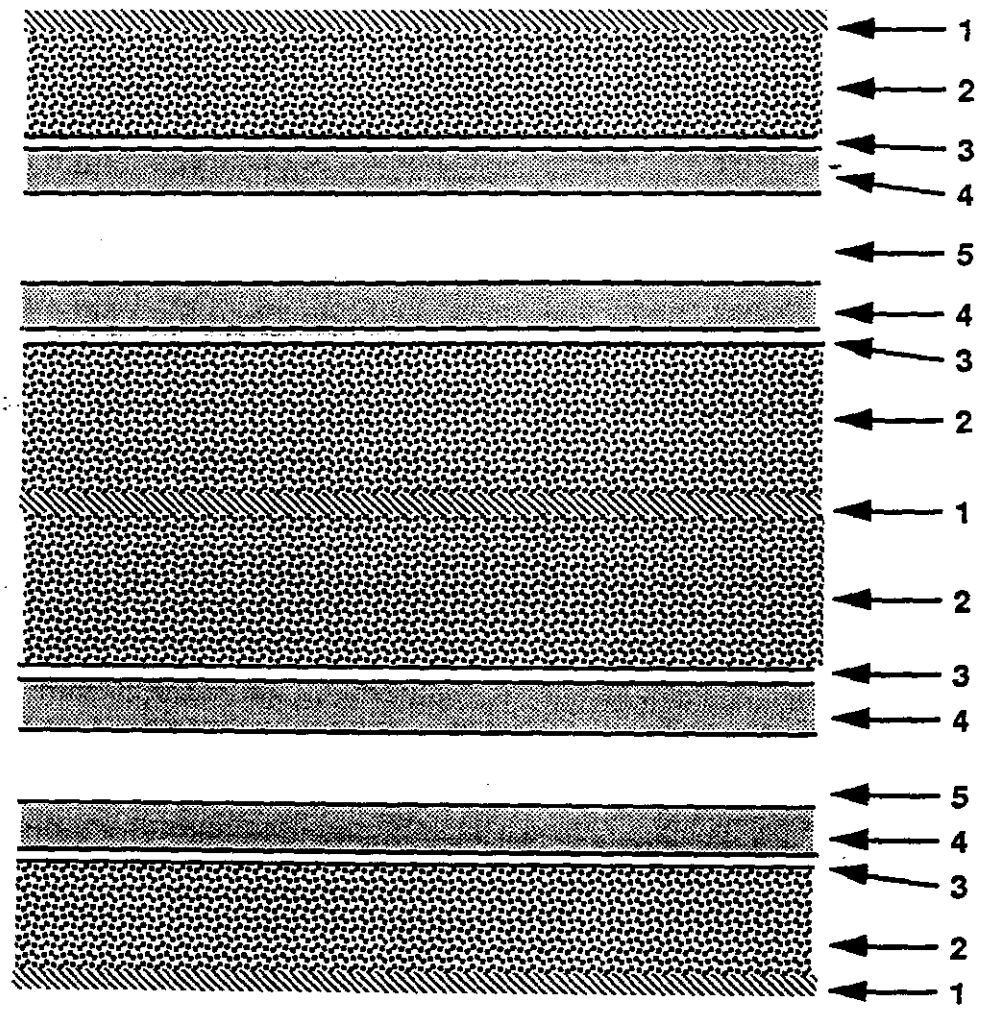
Resistive Plate Counter Design

- Hundreds of these chambers have been produced and are operating in experiments all over the world.
- A set of these chambers have operated at Frascati for 7 years.
- Such chambers are currently being used in E-771 at Fermilab.
- Recently L3 at CERN has ordered 400 of these chambers from General Technica, Colli, Italy, a company that is a commercial supplier of RPCs.
- Not a new technology, but rather a mature technology which is well understood and for which the manufacturing technology has already been transferred to industry.



1 Bakelite plate
2 gas
3 graphite coating
4 insulating foil
5 aluminum strips
6 line termination
7 discriminator
8 foam
9 aluminum ground plane

Figure 1



1. 0.010" aluminum
2. 4 mm foam
3. 0.005" al. mylar
4. 0.015" Bakelite(aquadag coating)
5. 2 mm gas gap

scale ~ 10:1

Figure 2

Nuclear Instruments and Methods in Physics Research A263 (1988) 20–25
North-Holland, Amsterdam

PROGRESS IN RESISTIVE PLATE COUNTERS

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Results of experimental tests on resistive plate counters of 6×0.5 m^2 area are reported. The results show that this technique is suitable for time of flight measurements over large areas with a resolution of the order of 1 ns.

Dc operated gaseous detectors of ionizing particles such as wire or drift chambers and streamer tubes have successfully replaced, in the course of the last 15 years or so, the older technique of the scintillation counter coupled to photomultipliers in experiments requiring a high spatial resolution. Conversely the scintillator is still the most commonly utilized technique to obtain high time resolution in current apparatus for subnuclear research.

The above mentioned detectors are indeed not competitive with the scintillator as far as time resolution is concerned. This is due to the fluctuations of the time needed by the electrons liberated in the gas by an ionizing particle, to drift up to the multiplication region, very close to the wire, where avalanches and eventually streamers are produced. A higher time resolution is clearly achievable if a uniform and intense electric field is used instead of that produced by a charged wire. In this case indeed the sequence of transitions:

free electron → avalanche → streamer

can occur in a very short time and with minimal fluctuations. This possibility was first studied by Keufell [1] and others [2]. More recently it has been shown that substantial advantages can be obtained if high resistivity electrode plates are used to create the field and that time resolutions better than 0.1 ns are achievable in small counters working with high pressure gas [3].

The resistive plate counters (RPC) [4] described in this paper are dc operated particle detectors whose sensitive element is a 2 mm thick gas layer of argon, butane and Freon at normal pressure, under a uniform steady electric field of 4–4.5 kV/mm generated by two parallel electrode plates of phenolic polymers with a volume resistivity of $10^{11 \pm 1}$ Ω cm.

When the gas layer is crossed by an ionizing particle an electric discharge is suddenly initiated by the liberated electrons. This discharge is quenched by the following mechanisms:

1) prompt switching off of the field around the discharge point, due to the large electrode resistivity;
2) UV photon absorption by the butane preventing secondary discharges from gas photoionization;
3) capture of outer electrons of the discharge due to the Freon electron affinity, which reduces the size of the discharge and possibly its transversal dimensions.

The duration of the discharge is typically ~ 10 ns. The relaxation time of the resistive electrode plates is of the order of $\rho\epsilon = \tau = 10^{-2}$ s. The large difference between these two characteristic times insures that during the discharge the electrode plates behave like insulators, so that only a limited area of ~ 0.1 cm^2 around the discharge point remains inactive for a dead time of the order of τ.

Fig. 1 shows the sketch of a "double layer" RPC consisting of two independent counters superimposed on each other in the same mechanical structure. In each counter the 2 mm gap between two resistive plates of phenolic polymers is filled with a gas mixture of argon (2/3 in volume), butane (1/3) and a small amount of Freon at atmospheric pressure. Graphite painted high-voltage electrodes of surface resistivity 200–300 kΩ/□, transparent to the electric pulses originated in the gas, allow a capacitive readout through external pickup electrodes. These are aluminum strips 3 cm wide, facing the grounded copper electrode also shown in fig. 1. These behave as transmission lines of ~ 50 Ω characteristic impedance. Standard double layer RPC moduli have been made with a useful area of 1.92×0.48 m^2. Several moduli can be assembled in a supermodulus as sketched in fig. 2, where a detector of 5.8×0.48 m^2 sensitive area made of three moduli is represented. The gas flows serially from one modulus to the next, and a set of 16 pickup strips on each of the sensitive planes constitut-

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(North-Holland Physics Publishing Division)

Nuclear Instruments and Methods in Physics Research A270 (1988) 190–193
North-Holland, Amsterdam

PLASTIC SPARK COUNTERS WITH PVC ELECTRODES

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Received 16 September 1987 and in revised form 4 January 1988

The performance of a spark counter based on plasticized PVC is described. The relevant features of this detector match the requirements of surface and underground cosmic ray experiments. Its technological characteristics allow large area detector construction.

1. Introduction

In the framework of the study of new apparatus for extensive air showers of cosmic rays, we have considered the application of spark counters. For this purpose a time accuracy of the order of only a few nanoseconds is required [1]. Low cost, reliability and easy monitoring are of relevant importance.

So far the development of plate spark counters [2] with resistive electrodes has shown the possibility of reaching high time accuracies and good space resolution at the same time, but their use has been limited by the strict technological requirements due to the high gas pressure and to the degree of mechanical tolerances needed for gaps of 0.1–0.2 mm. They require electrode materials with volume resistivity in the range 10^9–10^{11} Ω cm, with a sufficient degree of homogeneity; for this purpose some resistive glasses have been successfully proposed, but they are rather expensive and not easily available. In practice all these limitations become prohibitive for large area counters.

In order to reduce the technological difficulties a new type of resistive plate counter (RPC) [3] has been developed, to be employed whenever a time resolution of the order of hundreds of picoseconds is sufficient. In this detector the resistive electrodes are made out of a phenolic thermosetting resin denominated Bakelite. The counter gap is of the order of 1.5–2 mm, and the gas circulation is at atmospheric pressure. Anyway, the RPCs, as the other spark counters, exhibit a noisy operation, i.e. the production of spurious sparks, and the use of thermosetting materials is restrictive as far as the construction technology is concerned.

We describe here a new plastic spark counter based on plasticized PVC. While rigid (unplasticized) PVC has a volume resistivity of the order of 10^{15} Ω cm, the addition of plasticizers to obtain the standard commercial soft PVC, lowers resistivity down to 10^{11}–10^{12} Ω cm [4]; by doping with ionic compounds, a volume resistivity around 10^{8} cm can be easily achieved [5]. We show that the use of commercial plasticized PVC allows the construction of spark counters with noiseless operation and time resolution of the order of 1 ns. Furthermore the use of a material such as PVC makes it possible to exploit the thermoplastic material technology which allows easy construction procedures for large area counters.

2. Prototype description

Fig. 1 shows the cross section of one prototype. The active volume containing the gas mixture is delimited by two parallel plate electrodes made of plasticized PVC, 1 mm thick. The volume resistivity is $\sim 10^{11}$ Ω cm. High voltage is supplied to the PVC electrodes by means of a graphite coating on the surface not in contact with the gas. The varnish is a commercial solution of graphite in methyl-isobutyl-ketone, and the surface resistivity is ~ 10 k$\Omega/\square$. A copper strip provides the electrical contact with the high voltage. The graphite-coated surface

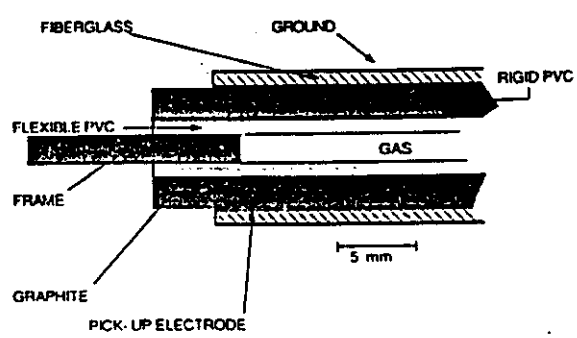

Fig. 1. Cross section of a spark counter prototype.

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(North-Holland Physics Publishing Division)

Preprint ROM2F/91/18
22 July 1991

Muon tracking and hadron punchthrough measurements using Resistive Plate Chambers

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talk delivered by A.Di Ciaccio at the "5th Pisa Meeting on Advanced Detectors", La Biodola, Isola d'Elba, 26-31 May 1991

Abstract

Study of high energy muon tracking and measurements of punchthrough probability for showers of charged hadrons with momenta 40, 70, 80 and 150 GeV/c have been performed at the CERN SPS test-beams using resistive electrode plate chambers. The results are compared with Montecarlo predictions and with measurements from other experiments.

1. Introduction

Resistive Plate Chambers (RPCs) are gaseous detectors that combine good space resolution with a time response of a nsec[1]. They are easy to build, stable and reliable over long periods of operation and therefore well suited for detectors with large area coverage in regions of limited access. These characteristics make the RPCs a good candidate for a fast muon tracking trigger at the future hadron colliders (LHC, SSC)[2]. The main limitation comes from the efficiency reduction of these detectors under high particle fluxes[3]. Charged particle punchthrough measurements as a function of the absorber thickness are crucial to evaluate the expected background rates and therefore the possibility of operating RPCs for muon detection under the high particle fluxes expected from pp interactions at 16-40 TeV centre of mass energy[4].

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN/DRDC/90-36
DRDC/P7
August 30th, 1990

Study of muon triggers and momentum reconstruction in a strong magnetic field for a muon detector at LHC

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M. Mohammad

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN/DRDC/91-53
RD-5 / Status Report
January 13th, 1992

Status report of the RD5 Experiment

A. Böhrer, H. Faissner, T. Moers, R. Priem, H. Reithler, R. Schleichert, H. Schwarthoff, H. Tuchscherer and H. Wagner.
III. Physikalisches Institut A, RWTH Aachen, Germany

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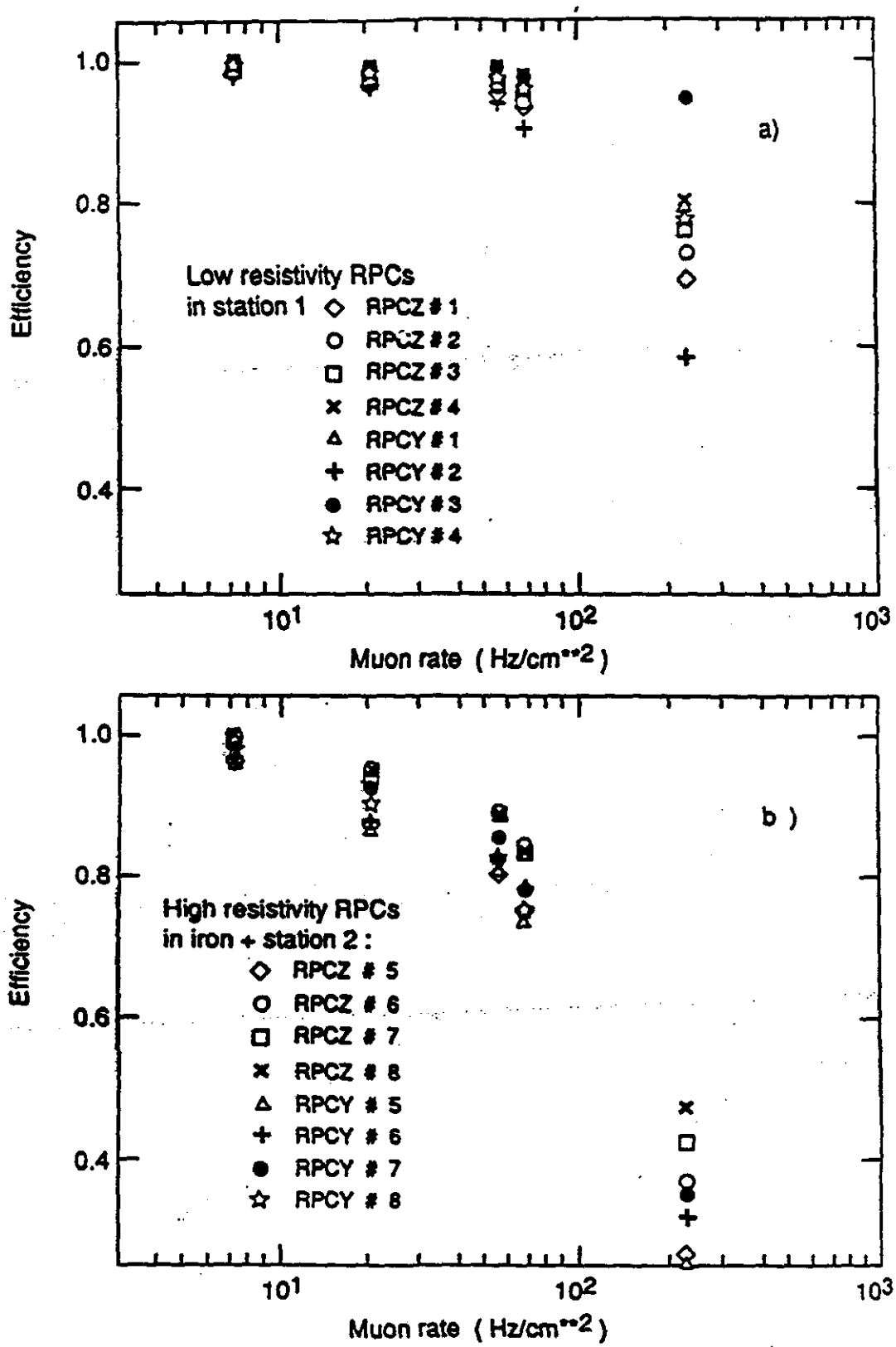
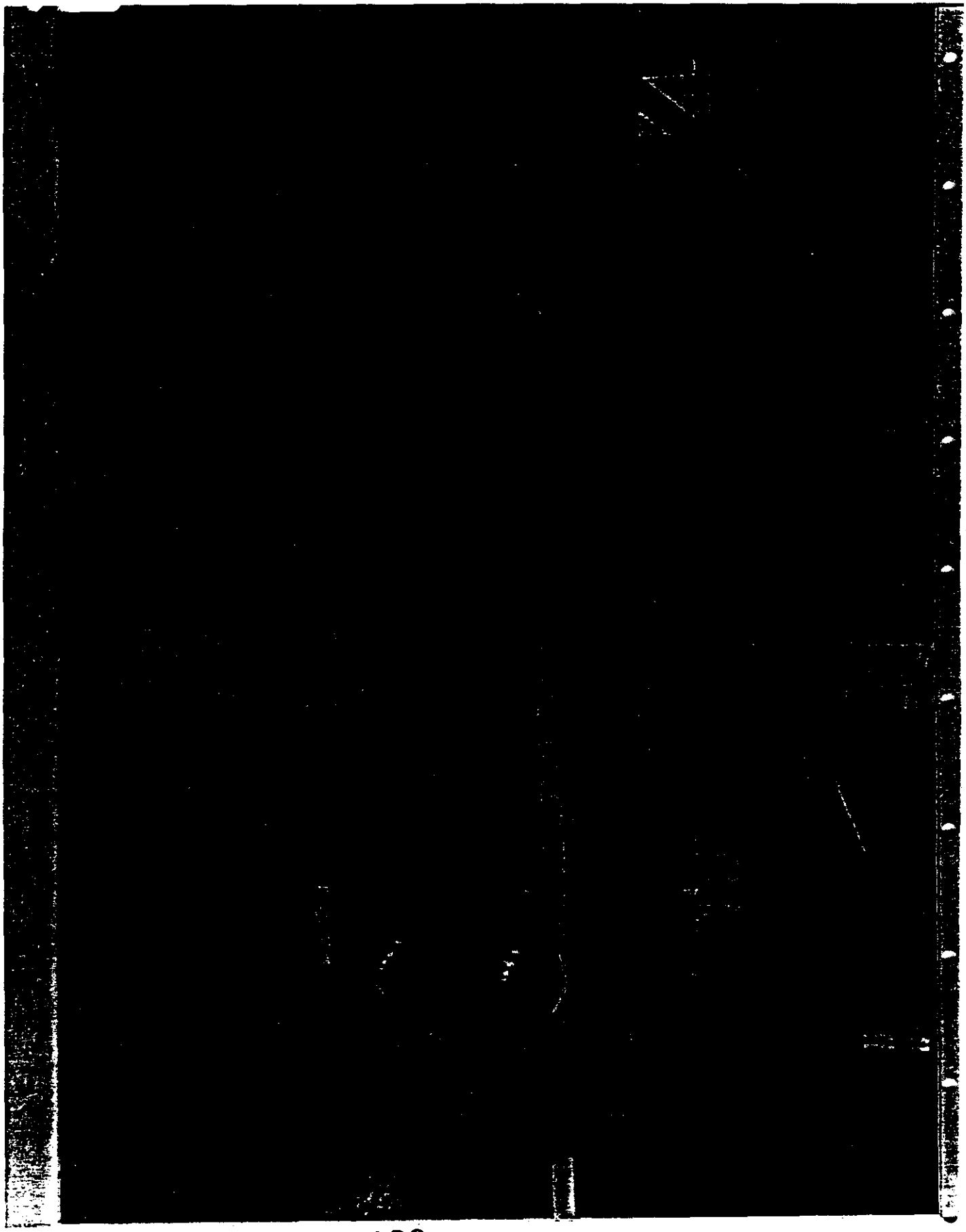
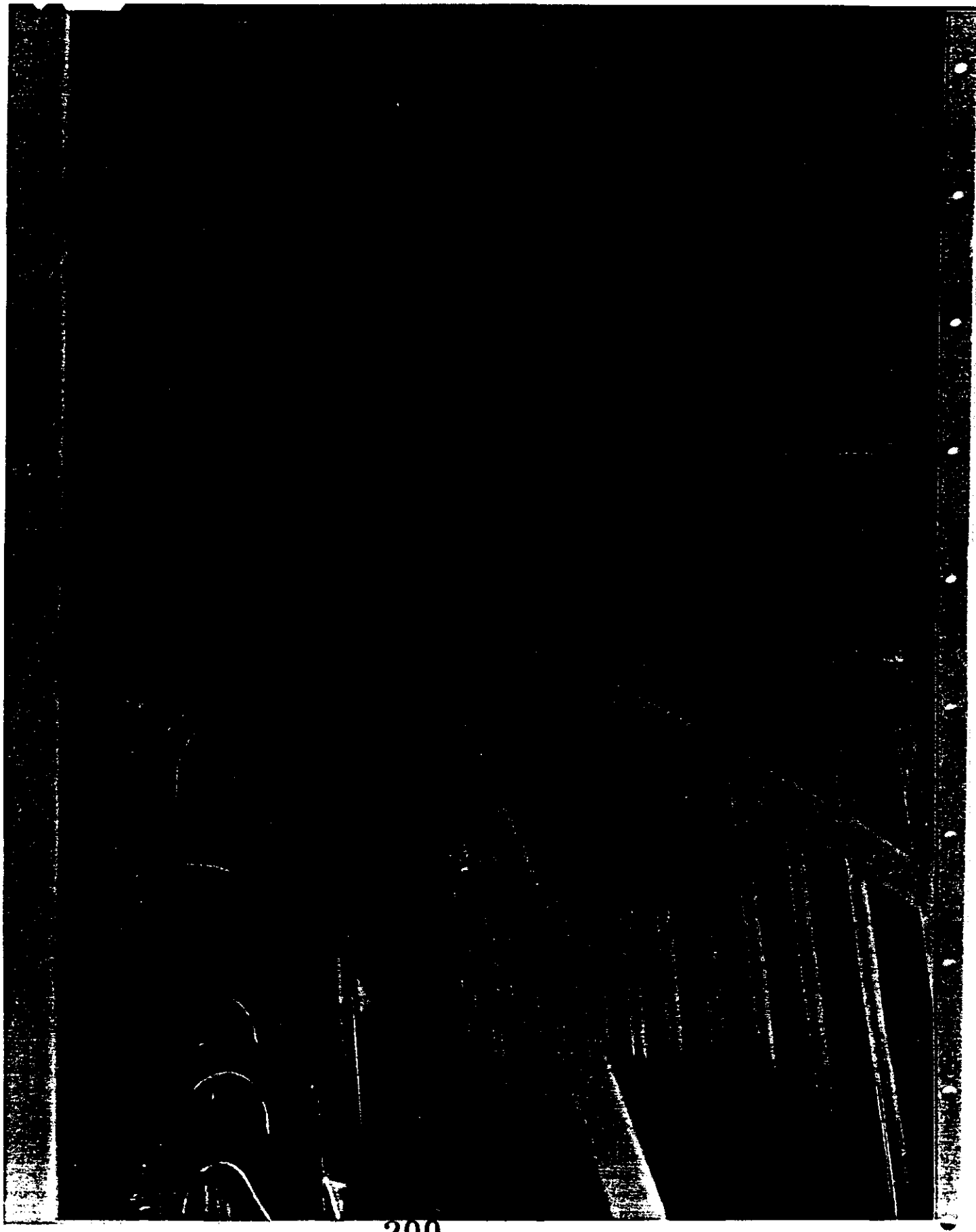
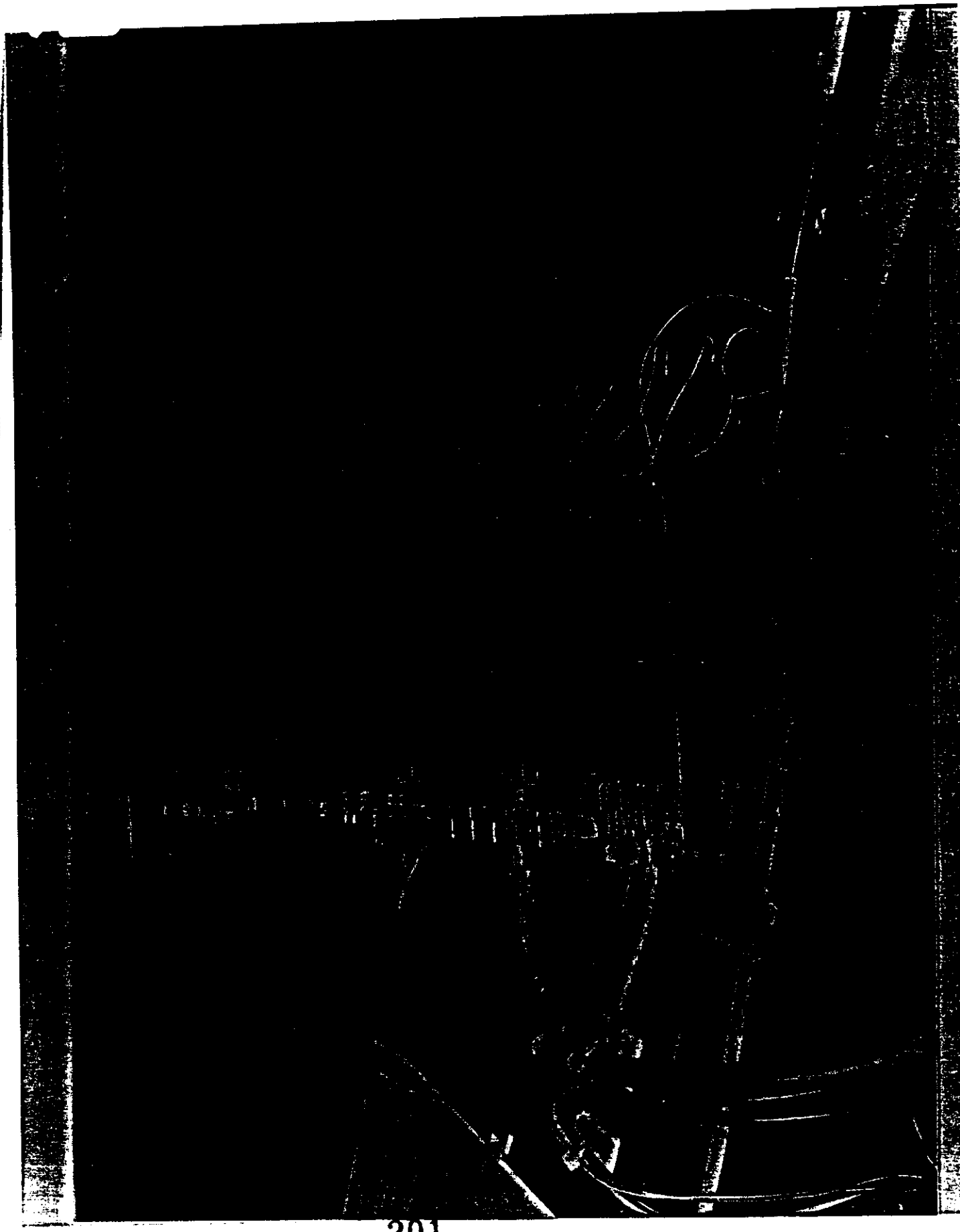
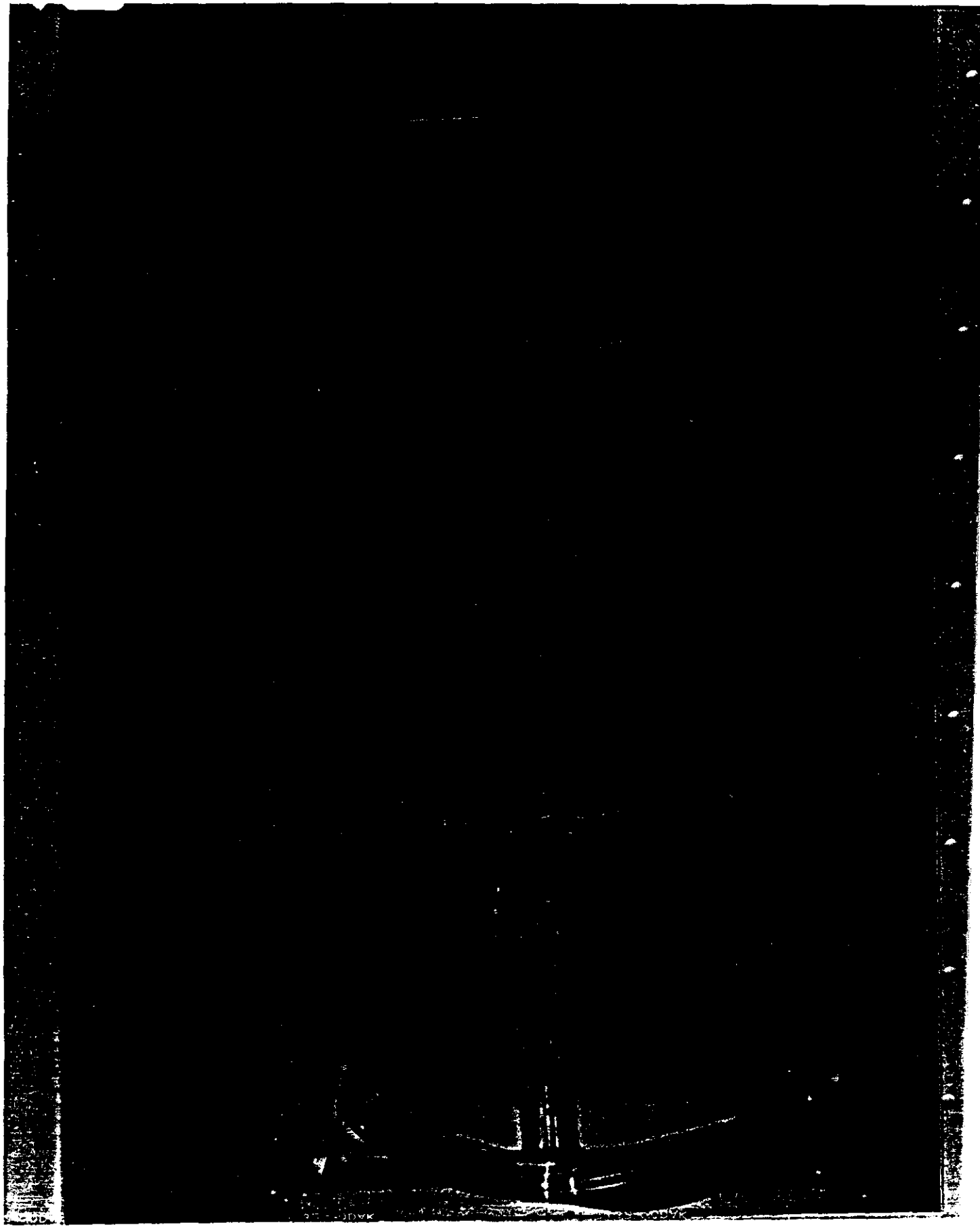

a)
Efficiency
1.0
0.8
0.6
0.4
Low resistivity RPCs
in station 1
RPCZ # 1
RPCZ # 2
RPCZ # 3
RPCZ # 4
RPCY # 1
RPCY # 2
RPCY # 3
RPCY # 4
10^1
10^2
10^3
Muon rate (Hz/cm**2)
b)
Efficiency
1.0
0.8
0.6
0.4
High resistivity RPCs
in iron + station 2 :
RPCZ # 5
RPCZ # 6
RPCZ # 7
RPCZ # 8
RPCY # 5
RPCY # 6
RPCY # 7
RPCY # 8
10^1
10^2
10^3
Muon rate (Hz/cm**2)

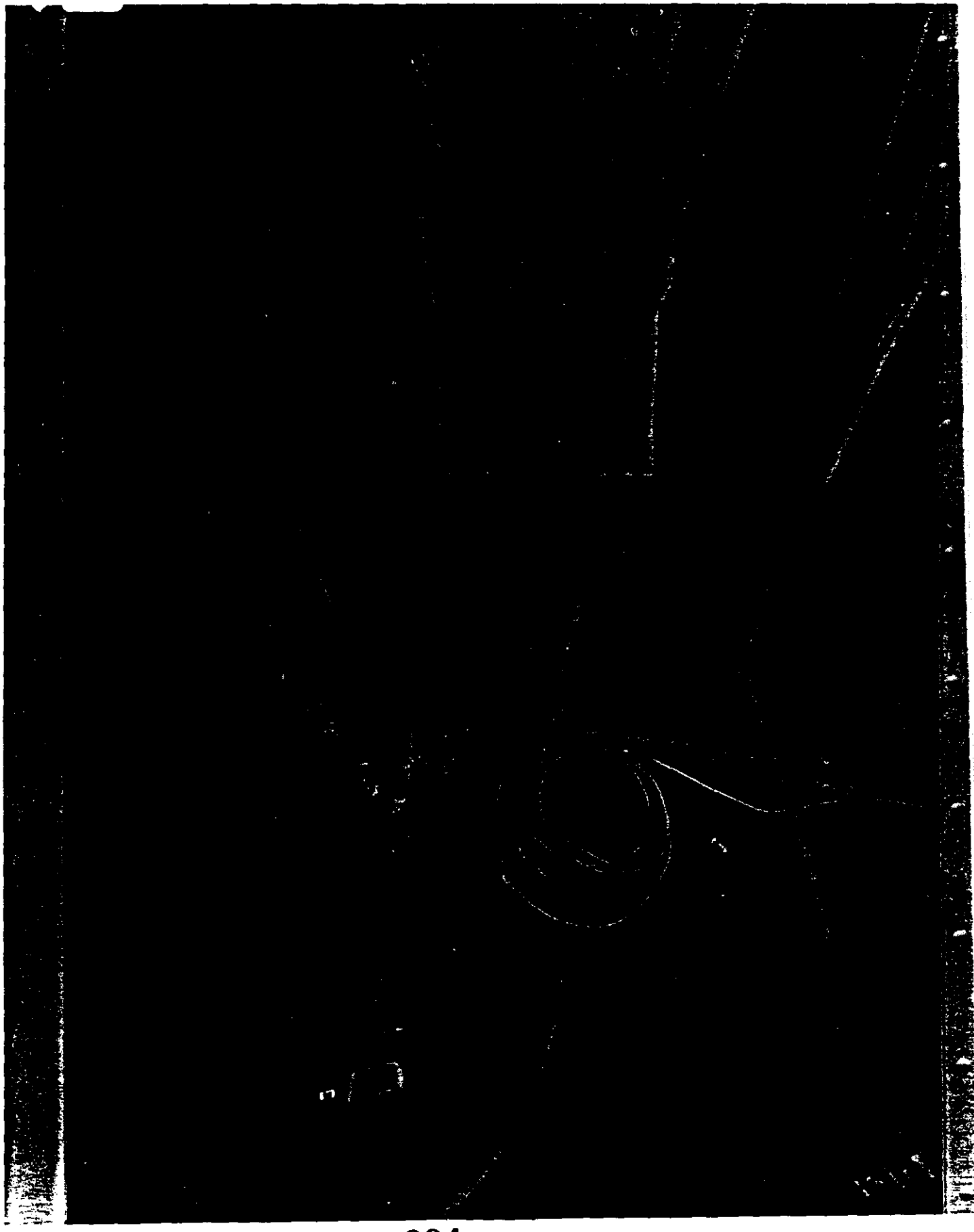
FIG. 20











- In November 1991, the RPC Collaboration submitted its R&D program for the GEM Muon Beam Tagging Trigger and Z-coordinate Measuring System using Resistive Plate Counters.

- Properties of RPCs that have been measured include:

  - Pulse rise-time jitter
  - Maximum counting rate
  - Efficiency
  - Lifetime
  - Noise
  - Response to neutrons and gammas

- A number of RPC prototypes have been fabricated using new materials:

  - Glasses
  - Cermets
  - Plastics

- Results from the RPC R&D program:
  - Pulse rise-time jitter measured on 1m x 2 m Italian RPC - 1.4 ns
  - Pulse rise-time -2.5 ns
  - Pulse width - 50 ns
  - Pulse height - 200-500 mV into 50 ohms without amplification.
  - Saturated counting rate -
    - Glasses - 50-75 Hz/cm^2
    - Bakelite - 560 Hz/cm^2
    - Static-dispersive plastics - 15 KHz/cm^2
  - Efficiency – 95% using cosmic ray scintillator telescope.
  - Lifetime – 1% decrease in efficiency measured for 8.2 SSC years exposure.
  - Noise – 10 x cosmic rays.
  - Neutron sensitivity (1-10 MeV) – 4.8 x 10^-3, same as other technologies.
  - Photon sensitivity (1-10 MeV) – 6.6 x 10^-3.

- Conclusions:
  - The R&D program has successfully addressed the major concerns of RPC counting rate, aging/lifetime, neutron sensitivity, and noise.

Resistive Plate Chamber R&D

- Two RPC prototypes have been constructed at LLNL:
  - 30 cm x 30 cm RPC test stand to study cermet thin films.
  - 30 cm x 50 cm test stand to study bakelite RPCs.
- Cr/SiO cermet thin film RPCs may suffer from damage due to spark interaction. Also, bulk resistivity is measured to be too small for proper operation.
- However, boron thin films may be more robust. Boron films are being deposited now. Bulk resistivity can be controlled by film thickness - e.g. 10 μm boron film = 1MΩ-cm.
- New materials are being tested:
  - static dispersive polymers - bulk resistivity ~ 10^9 - 10^{10} Ω-cm.
  - Westinghouse low resistivity phenolic - bulk resistivity ~ 10^5 - 10^{10} Ω-cm.
- SPICE modeling of RPCs provides insight into rate capability.
- Measurements being made of cross talk on adjacent strips in small test stand with 750 μm glass plates (10^{10} Ω-cm).
- One FTE effort till end of fiscal year to design full-scale gas system for GEM RPC system.

DRAFT

SSC GEM NOTE 1
(92-1)

BEHAVIOR OF LARGE RESISTIVE PLATE COUNTERS

SEPTEMBER 1992

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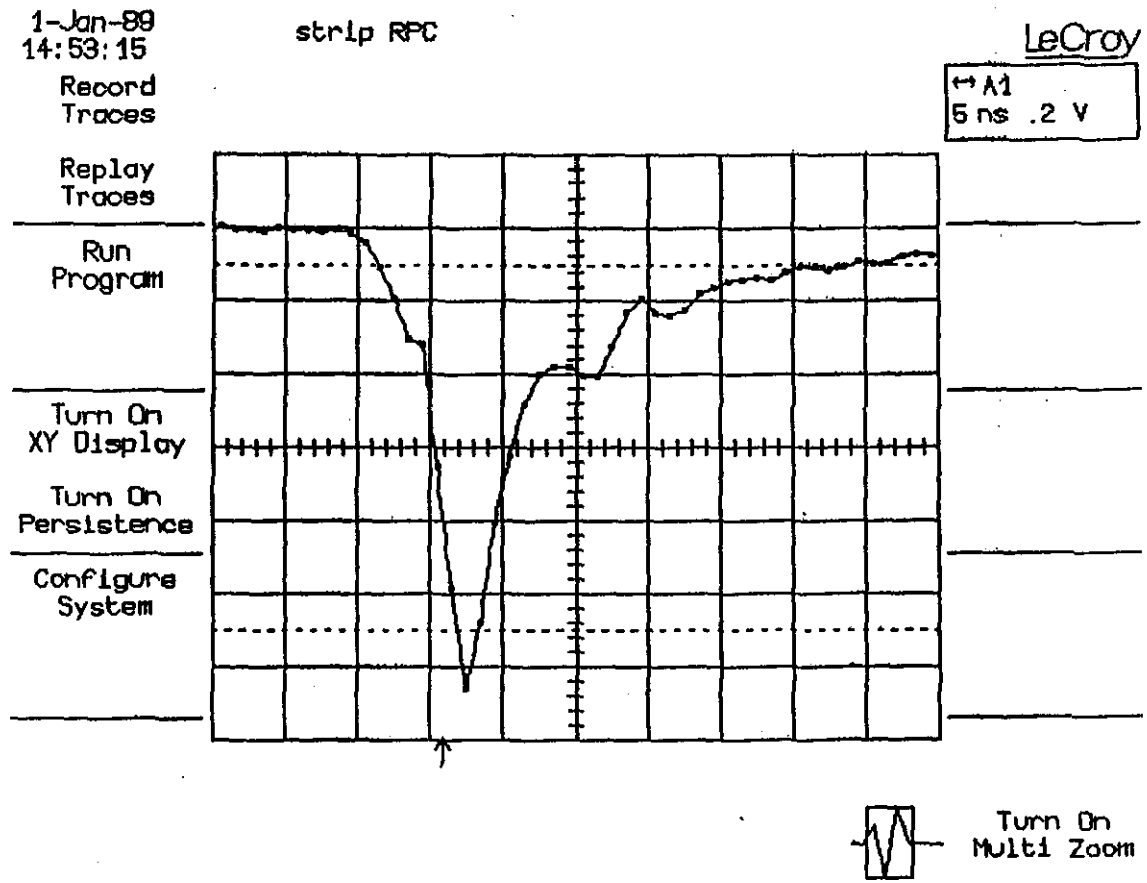
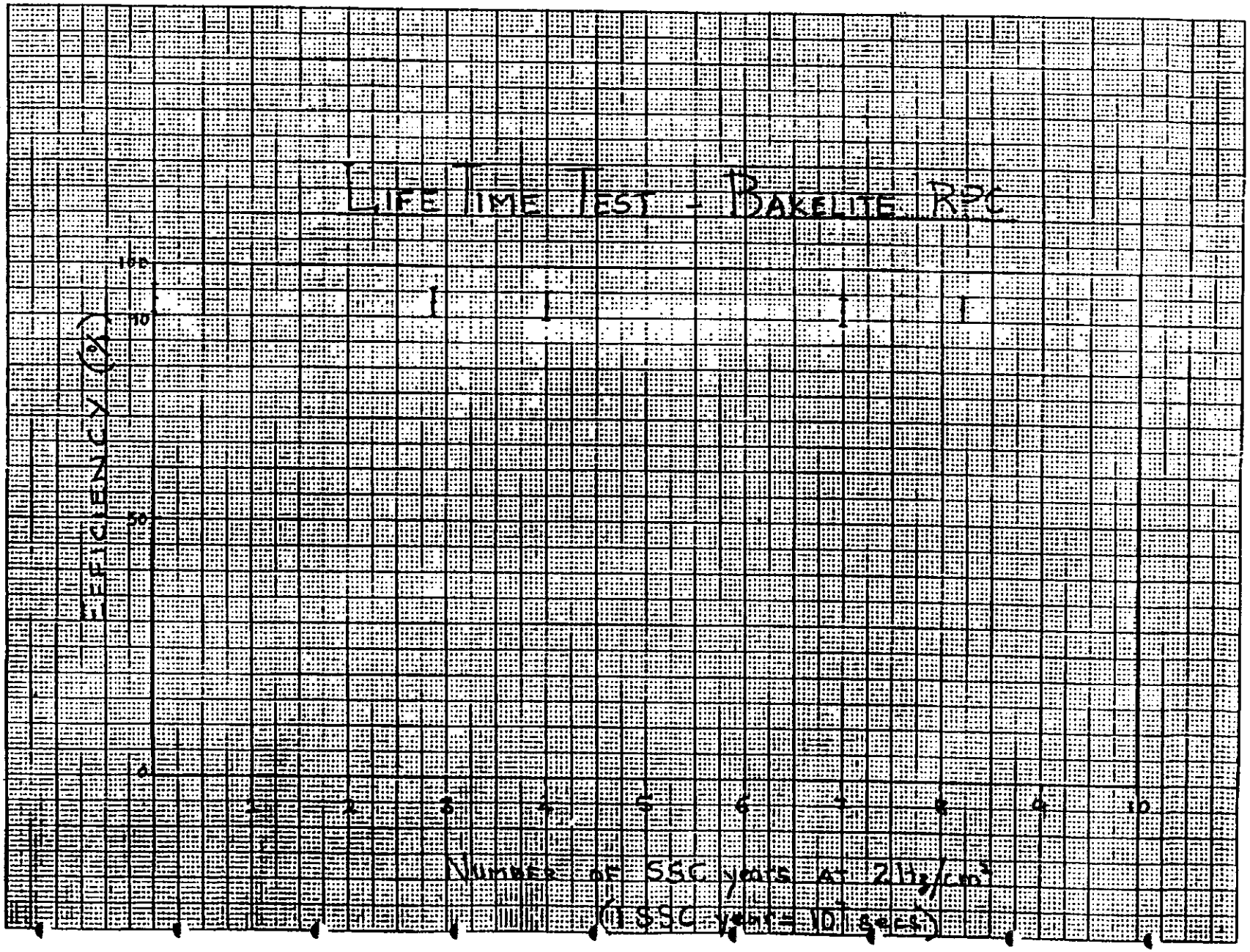
Typical glass RPC signal



K+E 10 X 10 TO THE CENTIMETER KEUFFEL & ESSER CO. 46 1510

Figure 16



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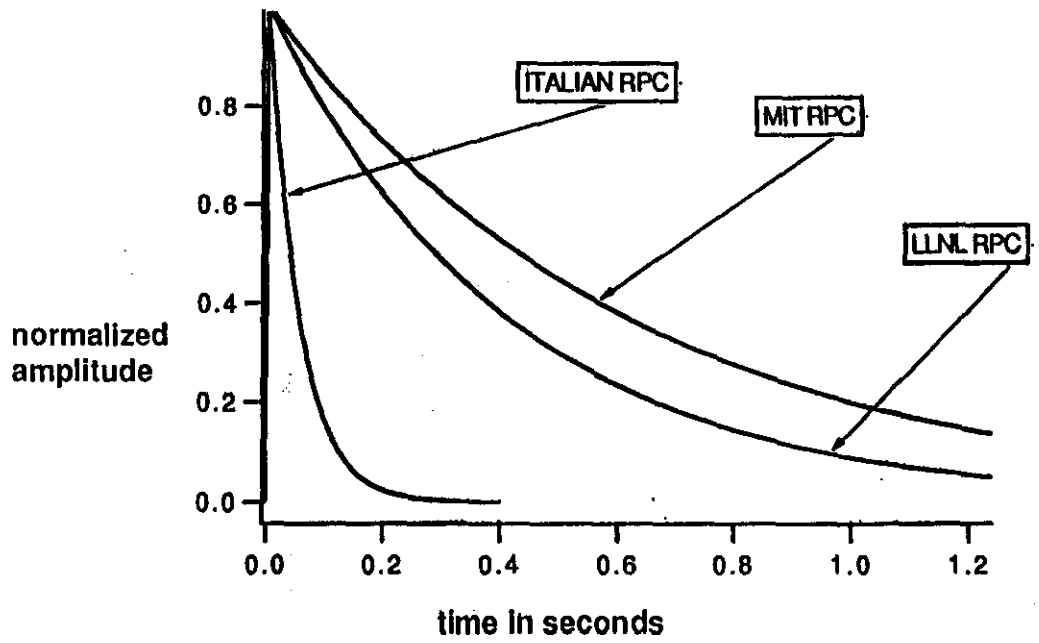
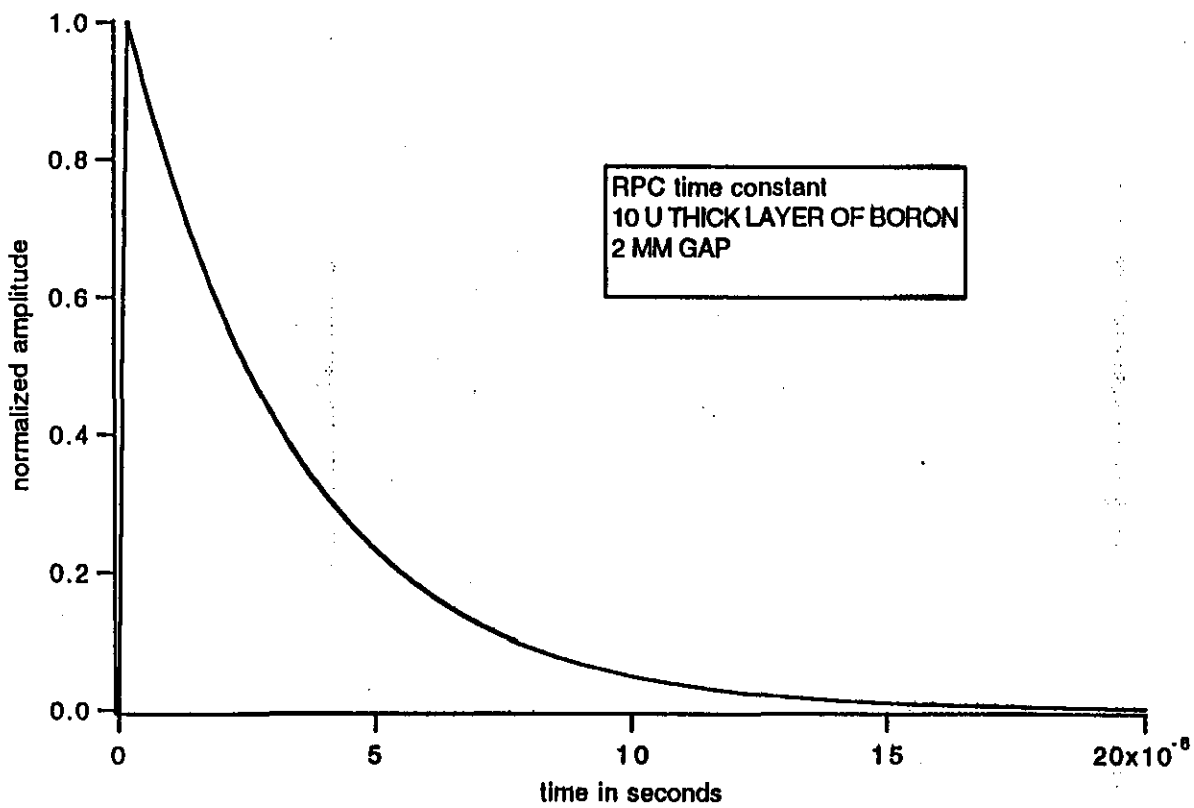
SPICE calculation of different RPC recovery times based on bulk resistivity of materials: bakelite for Italian RPC, glasses for LLNL and MIT RPCs
- note time scale is seconds



SPICE calculation of boron RPC recovery time - note time scale is microseconds



Resistive Plate Counter Technology Review

- Three Cost Reviews have been completed for RPCs:
  - Complete cost with material and assembly labor – $5.7M
  - "the RPC system is clearly the lowest cost technology..."

- Engineering Review of RPC Technology has been completed:
  - "The RPC engineering design is the simplest and most risk free of any of the technologies."
  - "Assembly tolerances are large in comparison with the other technologies .... production processes can be quite simple and rapid."
  - "only the RPC technology presented a design for a gas system."
  - "RPC internal alignment requirements are quite modest in comparison to the other technologies.
  - "Each of the proposed designs, except for the RPCs require high structural stability in order to meet the precision alignment tolerances.

- Concerns included:
  - Gas choice and effects of contamination.
  - Details of the assembly – non-standard sized chambers.
  - Details of the alignment – local and global, strip dimensional tolerances

Resistive Plate Counter Cost Estimate

- Two RPC designs have been costed:
  - Two layer Bakelite RPC - Italian design using existing technology.
  - Two layer Cermet RPC - still in R&D. Promise of reduced mass and cost.
- Materials costs have been estimated in the following manner:
  - direct estimate from vendor - written and oral for quantities needed, e.g. Hexcel
  - LLNL Stores catalogs - quantity discounts not taken into account, e.g. mylar sheet
- Design assumptions based on Baseline I document as much as possible.
- Design of structure based on estimates for other muon technologies.
- LLNL has one designer/draftsman and is hiring one engineer for structure work.
- Design is still evolving as R&D progresses, e.g. RPC readout schemes, etc.

Standard Bakelite RPC design

	Item	Cost ($/m^2)	Total Cost ($K)
1.	Aluminum U-channel	4.3	11.8
2.	Bakelite sheet or Cermet coated plastic film	27.0	74.1
3.	Foam (e.g. polyurethane sheet)	1.2	3.2
4.	Aquadag	16.9	46.4
5.	Aluminized Mylar sheet	15.4	42.2
7.	Spacers , glue	0.36	1.0
	Total Materials	65.16	178.7

	Cost ($/m^2)	Total Cost ($K)
Total Materials (x.25 for mach'g and waste):	**81.45**	**223.4**

	Item	Cost ($/m^2)	Total Cost ($K)
8.	Fabrication cost estimate: $60/hr @ 1m^2/hr	60.0	164.6
9.	Gas fittings edge x 2 for gas manifold)	4.6	12.6
10.	Steel tubing (1/4" diameter, 10.4 km long)	11.52	31.6
11.	RG-174 coaxial cabling (67.5 km)	5.18	14.2
12.	LEMO connectors (2 x 33,184 channels)	80.0	219.4
13.	Gas (Recirculator)	91.14	250.0
Total Miscellaneous		**252.4**	**692.4**

Subtotal:

	Cost ($/m^2)	Total Cost ($K)
Materials, Fab., Gas system, Elect. system:	**333.9**	**915.8**

	Cost ($/m^2)	Total Cost ($K)
RPC Materials, Fab., Gas system	333.9	915.8
Structural supports and integration with drift tubes	300.0	823
Materials contingency (5%)	15.85	43.5
Labor contingency (100%)	60.00	164.4
	Cost ($/m^2)	Total Cost ($K)
TOTAL	709.8	1,947

DRAFT

Mechanical Engineering Evaluation of the Muon Chamber Technology Options

R. Sawicki, chairperson
M. Gamble
R. Humphreys
C. Johnson
F. Nimblett

October 1, 1992

Abstract:

This report summarizes an engineering evaluation of the technologies that are being proposed for the muon subsystem of the GEM detector. A summary of the status of each option is presented along with a comparison of the relative strengths and weaknesses of each design.

Table 1. GEM RPC Specifications

Coverage: 100% - Z, 95% Phi
Areal Mass: projected thickness = 0.7% X_0/layer

Material	Thickness	Rad. Length	% Rad. Length
Al	0.005"	8.9	0.14
Foam	4 mm	424	0.09
Mylar	0.005"	28.7	0.04
Bakelite	0.015"	34.4	0.11
Gas	2 mm	Large	0
Bakelite	0.015"	34.4	0.11
Mylar	0.005"	28.7	0.04
Foam	4 mm	424	0.09
Al	0.005"	8.9	0.14
Foam	4 mm	424	0.09
Mylar	0.005"	28.7	0.04
Bakelite	0.015"	34.4	0.11
Gas	2 mm	Large	0
Bakelite	0.015"	34.4	0.11
Mylar	0.005"	28.7	0.04
Foam	4 mm	424	0.09
Al	0.005"	8.9	0.14
Total:			**1.38**

Nominal Radius (M):	4.0	6.0	8.0
# of chambers	64	96	128
Width (cm)	148.5	239.0	329.6
Length (cm)	330.0	360.0	380.0
Total Length	631.9	1042.1	1475.0
# Bend-plane strips:	114	183	253
# Non-bend-plane strips:	166	166	166
Width of bend-plane strips (cm):	1.3	1.3	1.3
Width of non-bend-plane strips (cm):	3.9	6.5	8.9
Weights (lbs):			
Bakelite:	1877	4943	9593
Aluminum perimeter frame:	1049	1472	2304
Cable:	385	641	963
Connectors, brackets:	1160	2855	5795
TOTAL/Super-layer	4471	9911	18655

TOTAL WEIGHT (TONS) 16.5 TONS

Resistive Plate Counter Design

- There are no sense wires in this technology.
- The pick-up strips are formed on an aluminized mylar substrate.
- The simplest method utilizes a shadow mask as the mylar is aluminized.
- In addition, etching, grinding, and sand-blasting are all viable techniques for creating the strips.
- The required precision for the strips is $\pm$ 500 microns.
- Once the mylar is glued into the RPC stack, the strip positions need to be known with respect to an outside fiducial with a precision of $\pm$ 2 mm.

Resistive Plate Counter Design

- There are no precision requirements necessary for the RPC assembly.
- Standard toler ances on thicknesses of Bakelite and other commercially available laminate materials are sufficient for the proper operation of the RPCs.
- The PVC disk spacers can be turned out using computerized machining with the necessary height tolerance of $\pm$ 100 microns ($\pm$ 4 mils) without difficulty.
- Pick up strips can be laid out by masking aluminized mylar sheet or by machining with fine cutting tools. Either method is capable of providing the necessary dimensional tolerance of $\pm$ 0.5 mm.

Resistive Plate Counter Design

- The chamber will be made up of various layers glued together to form a single self-supporting laminated plate.

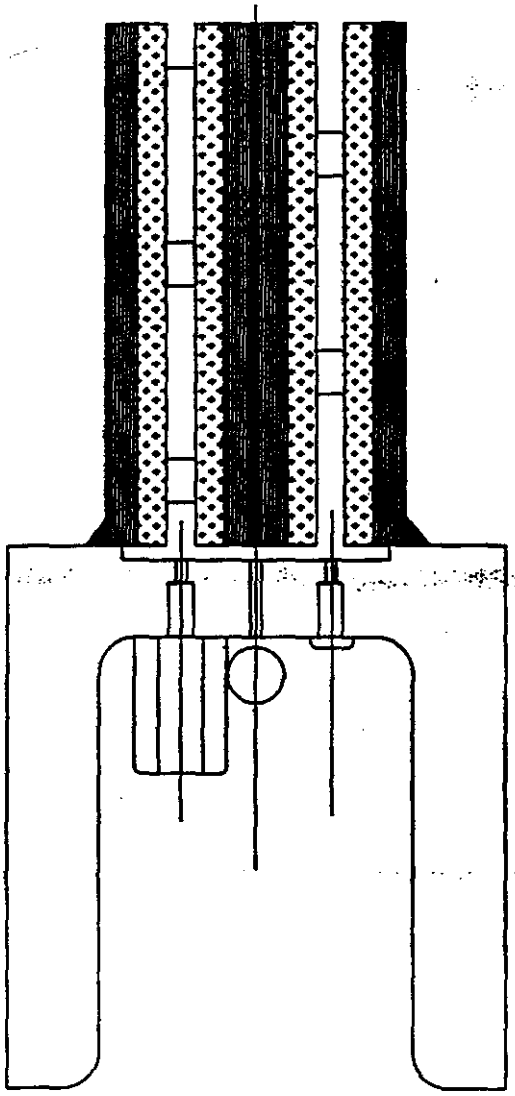
- Spacers are used, consisting of 2 mm thick, 10 mm diameter PVC disks

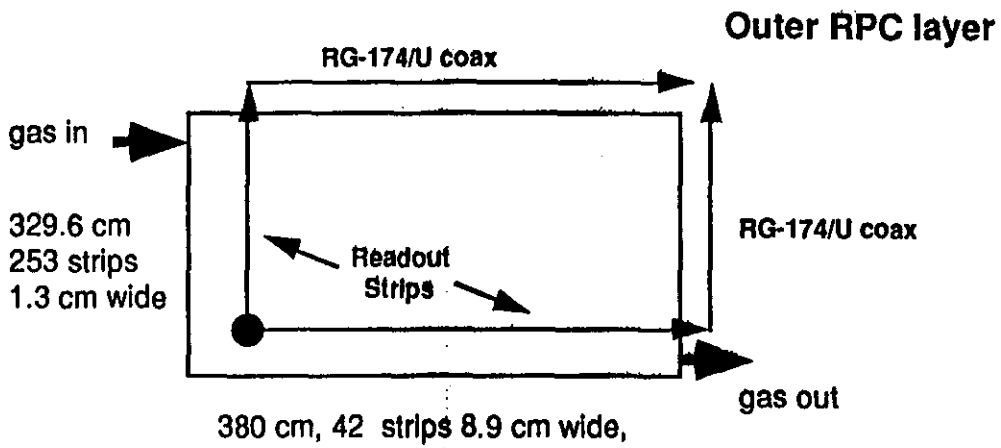
  - Spacers mechanically separate the two Bakelite plates and keep the plates flat with respect to one another by being placed on a 10 cm square grid.
  - They insulate the resistive plates from each other.
  - They transmit the mechanical stresses from one side of the plate to the other.

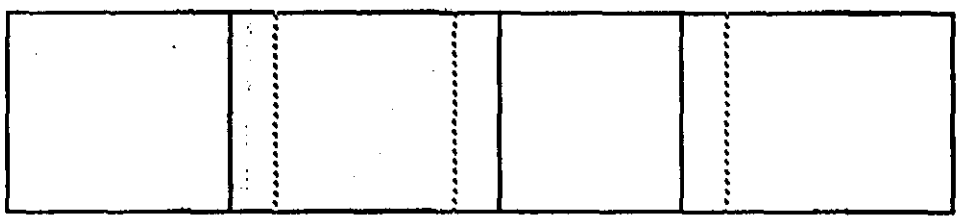
- The edges of the RPCs will be sealed by gluing 1 cm wide, 2 mm thick PVC strips between the Bakelite plates. This stiffens the edges mechanically so that the plate is self-supporting.

- Aluminum U-channel frame will encompass the chamber on all four sides.

  - Protect the edges of the RPC dur ing shipping, handling and installation
  - Stiffen the edges so that the RPC can be mounted by four corners (if necessary)
  - Furnish the base to mount the high voltage connectors, the gas connectors and the LEMO signal connectors.







4 overlayed RPC layers
3 strips overlap, don't use first and last strips on upper RPC s. Longitudinal strips are or'd together.

Cable length and weight (RG-174/U):

(168 x 10 cm) + 6 x (253 x 17 cm) + (253 x 10 cm) - layer Interconnects

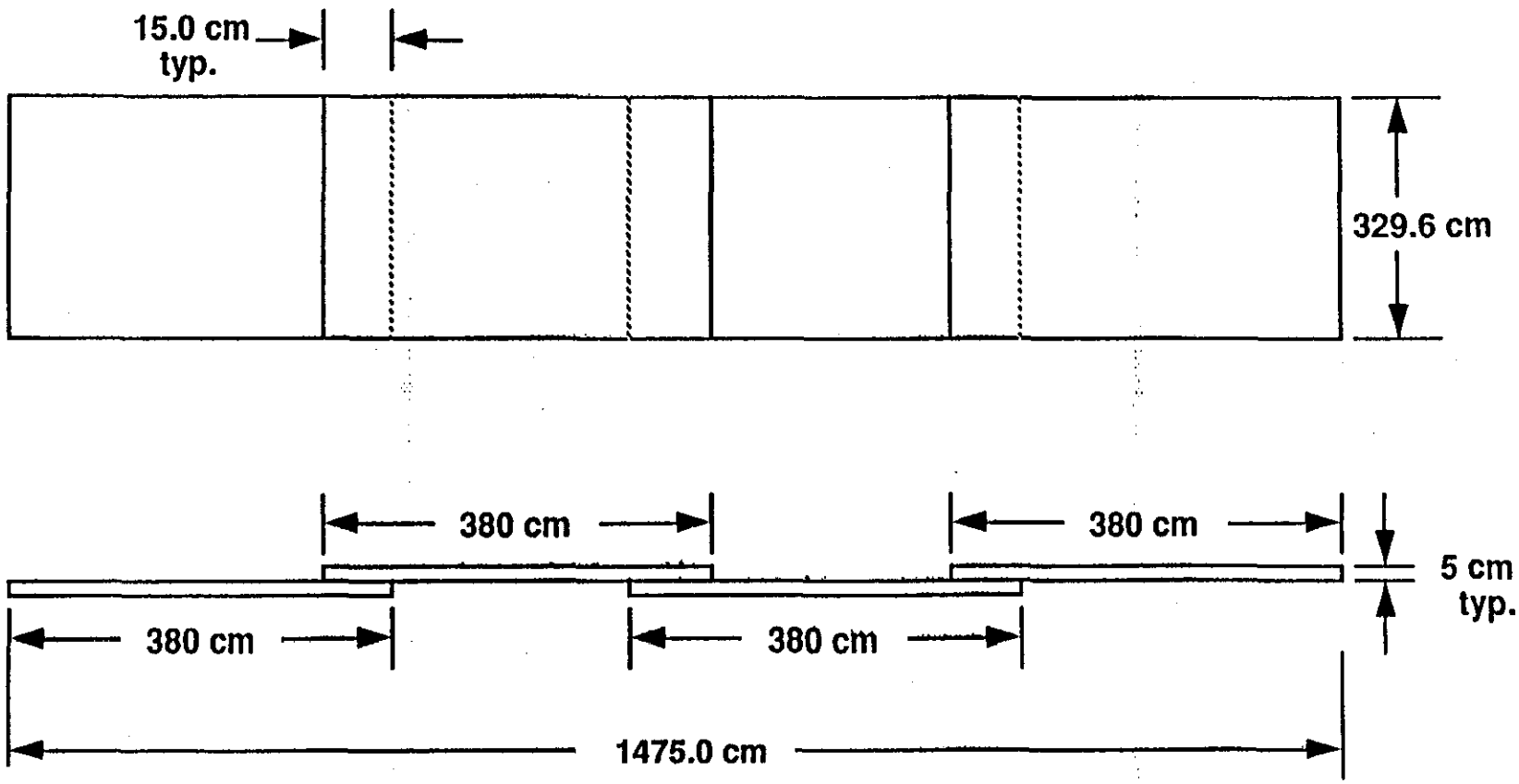
+ (380/2 cm) x 42
+ (350/2 cm) x 40 - non-bend plane strips
+ (380/2 cm) x 42
+ (365/2 cm) x 41

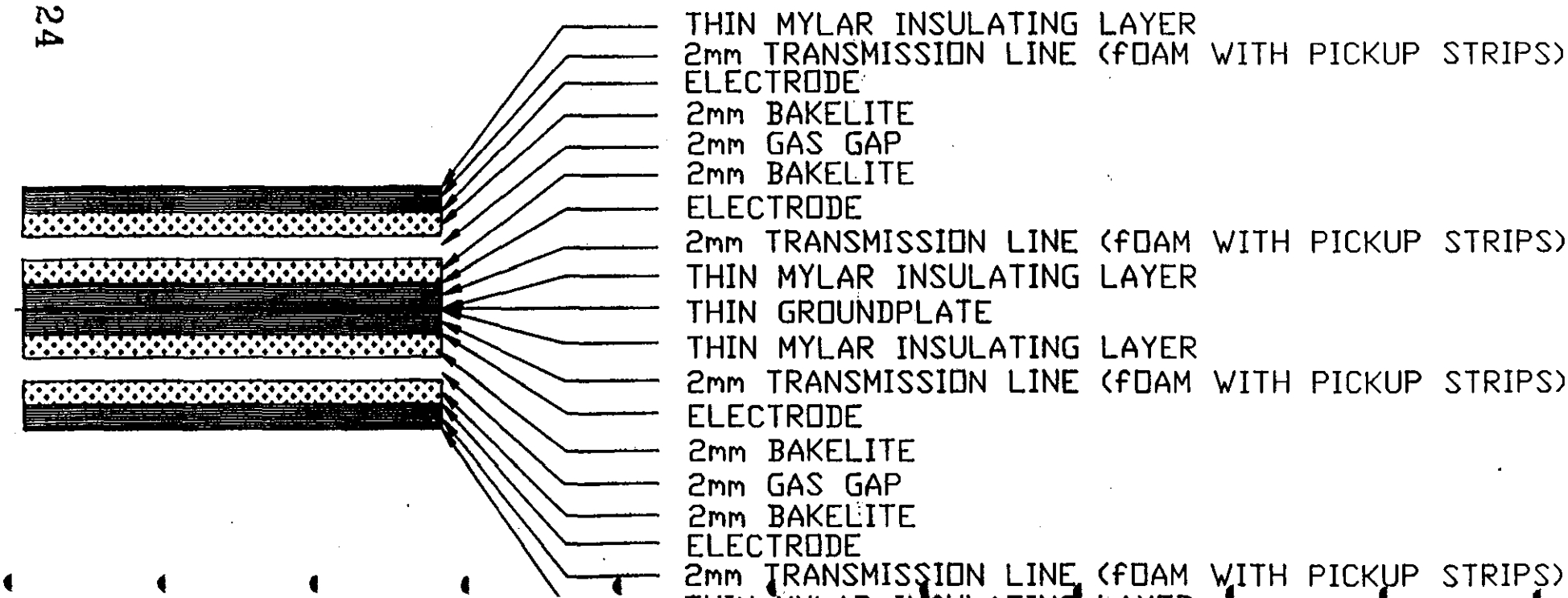
+ (329.6/2 cm) x 253 - bend plane strips

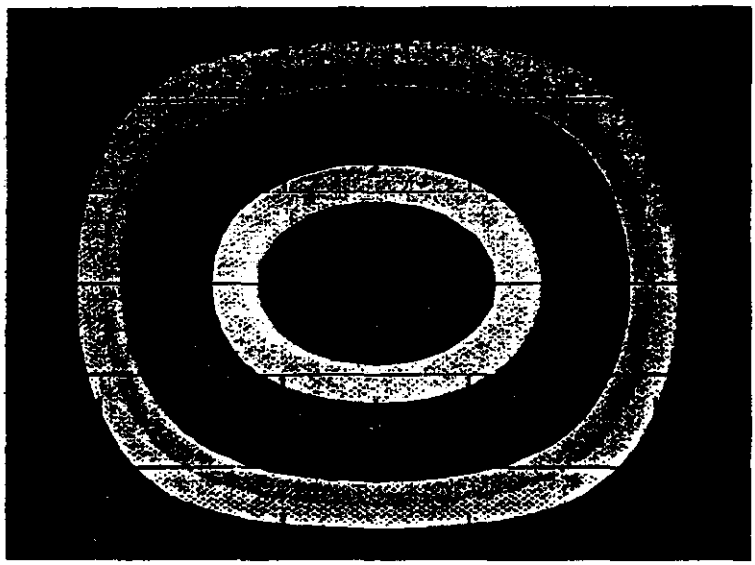
= 1.02 x 10**5 cm x 2.95 x 10**-4 lb/cm = <u>30.1 lb</u>

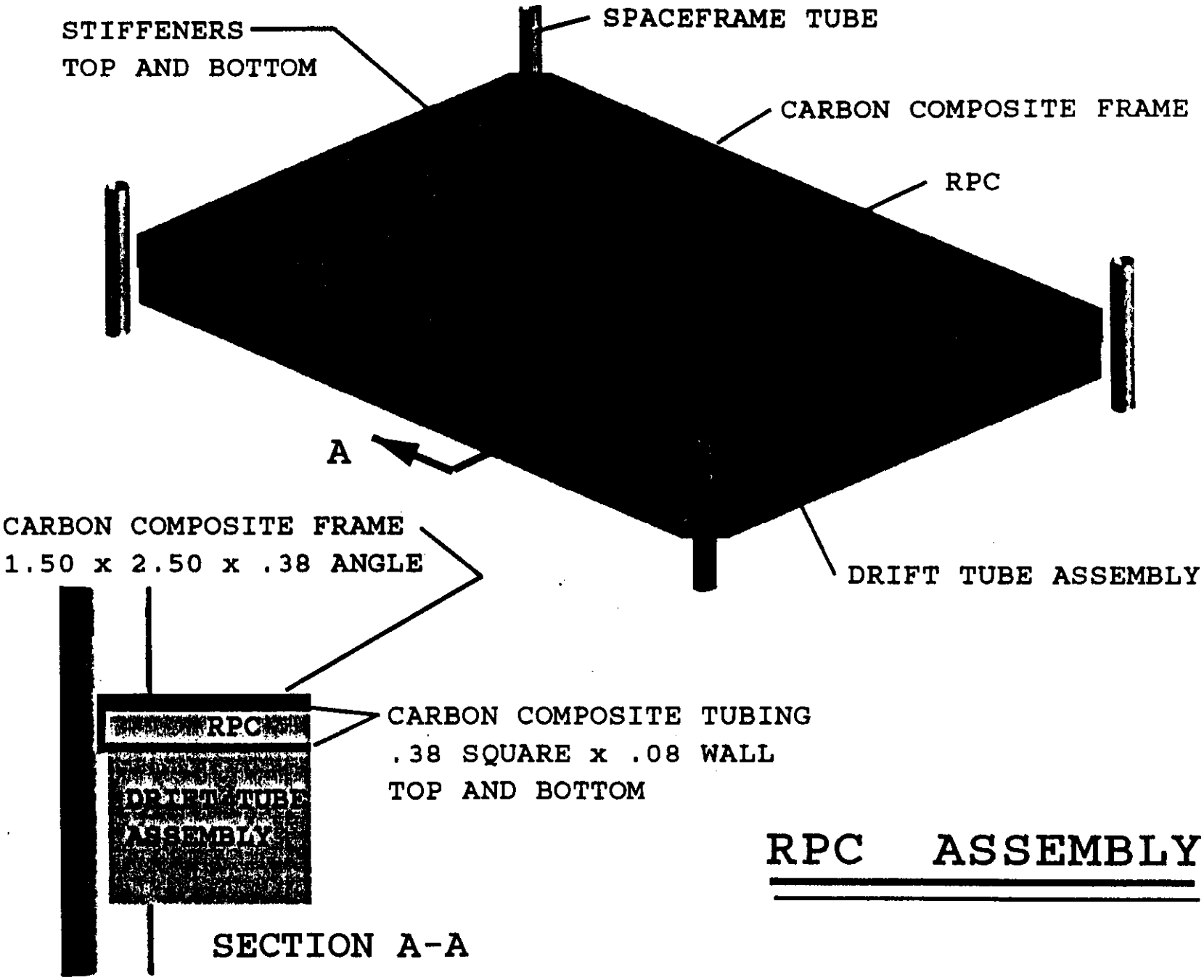
Outer RPC box layout - 4 chambers overlap per sector
x 16 sectors x 2 halves = 128 chambers

- 15.0 cm overlap

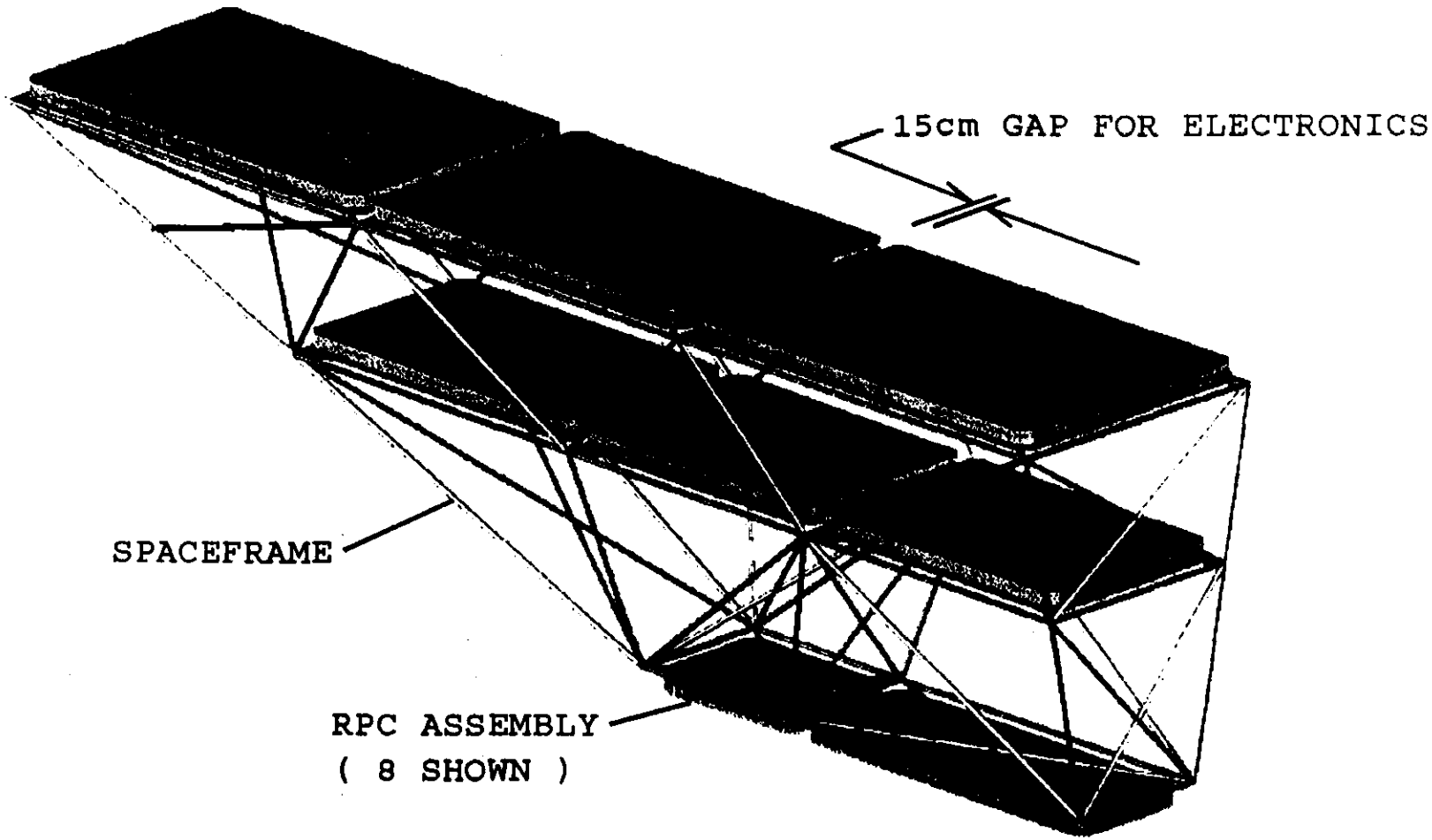



THIN MYLAR INSULATING LAYER
2mm TRANSMISSION LINE (FOAM WITH PICKUP STRIPS)
ELECTRODE
2mm BAKELITE
2mm GAS GAP
2mm BAKELITE
ELECTRODE
2mm TRANSMISSION LINE (FOAM WITH PICKUP STRIPS)
THIN MYLAR INSULATING LAYER
THIN GROUNDPLATE
THIN MYLAR INSULATING LAYER
2mm TRANSMISSION LINE (FOAM WITH PICKUP STRIPS)
ELECTRODE
2mm BAKELITE
2mm GAS GAP
2mm BAKELITE
ELECTRODE
2mm TRANSMISSION LINE (FOAM WITH PICKUP STRIPS)





RPC ASSEMBLY



MUON SEGMENT

Resistive Plate Counter Design

- RPCs, as a Level 1 trigger, do not require precision alignment.
- The RPCs can be mounted either separately from the precision drift tube technology, or co-located with the drift tubes.
- Sufficient care in fabrication will allow strips to be located with an accuracy of about $\pm$ 1 mm with respect to a fiducial placed on the edge of the RPC.
- Sag in the RPC will be within the limits imposed for proper muon timing and momentum determination so that monitoring of the sag will not be necessary.
- In-situ RPC alignment can be performed using cosmic rays or physics events..
- In addition, if the RPC system is incorporated into the drift tube structure, alignment will be coupled to the drift tube alignment system without added cost. This is because the RPC strip readout is referenced to a fiducial that can be referenced to the drift tube align ment system.
- In any event, RPC location to ~2 mm in Z and Φ is sufficient and to ~1cm in R to insure proper operation for Level 1 triggering.

Resistive Plate Counter Design

- The RPC is a very rugged reliable device without sense wires or regions of high fields.
- In case of a failure one half of the double RPC would fail.
- Each RPC gap as a separate chamber. The loss of one RPC gap means a decrease of efficiency of 1%.
- The RPC system is, for practical purposes, 100% redundant.
- Any single failure has a negligible effect on the practical efficiency of the system.
- If one gap fails per year (two orders of magnitude higher failure rate than is indicated by our current experience), then the probability of two gaps failing in the same RPC chamber in ten years of operation is less than 10%.

Resistive Plate Counter Design

- All material and components are off-the-shelf stock items.
- Once the items have been identified, all items and materials can be at the RPC Factory within 120 days of receipt of purchase orders.
- We estimate that construction can proceed at a rate of about 160 square meters per week. Our average chamber has an area of 10 square me ters.
- Hence, we can estimate that this assembly team can assemble about 16 chambers per week or about three chamber per day.
- The total of 288 chambers will therefore take, under this assumption, 18 weeks. A factor of two contingency gives a 36 week estimate for fabrication time.

Resistive Plate Counter Design

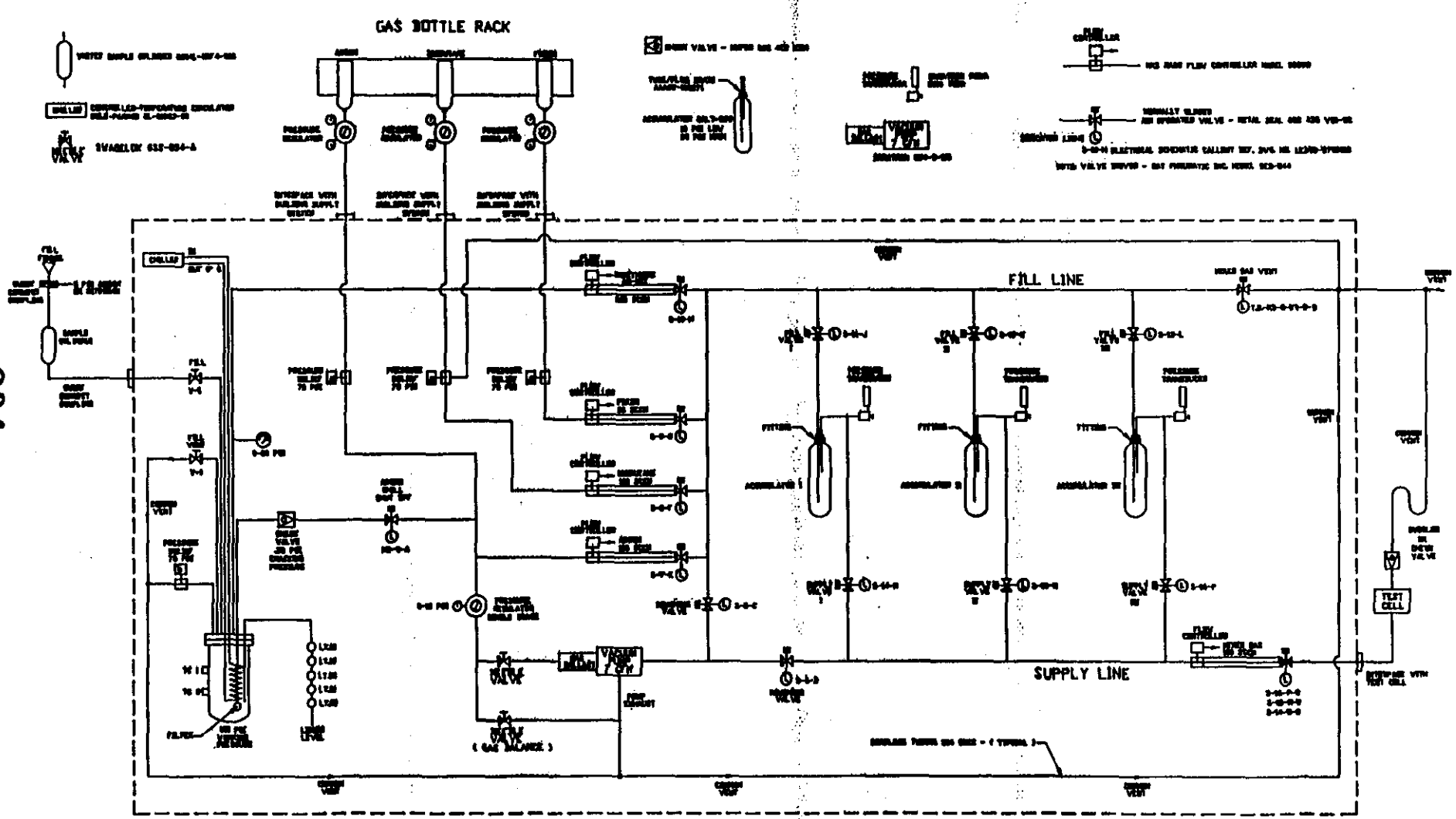
- RPCs have been manufactured in large quantities by Italian University groups for many years - R&D on an Italian RPC with dimensions 1 m x 2 m at MIT.
- A factory to build these RPCs is already in place and is capable of building RPCs to our specifications with minor modifications to their manufacturing process to take into account our new materials.
- If the need arises the manufacturing of RPCs could be carried out in the US at LLNL or MIT or also in China.

Resistive Plate Counter Design

- One year final R&D effort to construct the largest prototype RPC chamber.
- This chamber would be constructed by the members of the RPC Collaboration.
- Second R&D year to set up a proper factory including special jigs and handing tools, and to work out the assembly line bugs.
- Given the appropriate R&D funding for those two years, the first production RPC chamber would appear in January, 1996.

Resistive Plate Counter Design

- LLNL is designing the RPC gas system.
- The envisioned system is a low-flow, simple state-of-the-art recirculating system using standard technology
- All components are standard, off-the-shelf items.
- 2743 square meters of surface area in the three muon super-layers contain 0.4 cm total thickness of gas layers - total gas volume of 10.9 cubic meters.
- Typical RPCs operate with a gas flow rate of about 10% of their volume per hour or about 1.1 cubic meters per hour (18.3 liters per minute).
- The RPC gas system is designed to provide this flow rate for an accurately mixed combination of gases.
- Previous RPC systems have run successfully using a gas mixture consisting of 66% Argon, 32% isobutane and 2% freon. It is unlikely that this mixture of gases will be allowed at the SSC because of its flammable nature.
- Alternative gas mixtures are being explored in R&D. One candidate gas is a non-flammable mixture of 49% CO_2, 49% CF_4, and 2% freon.



GAS MIXING CONTROL

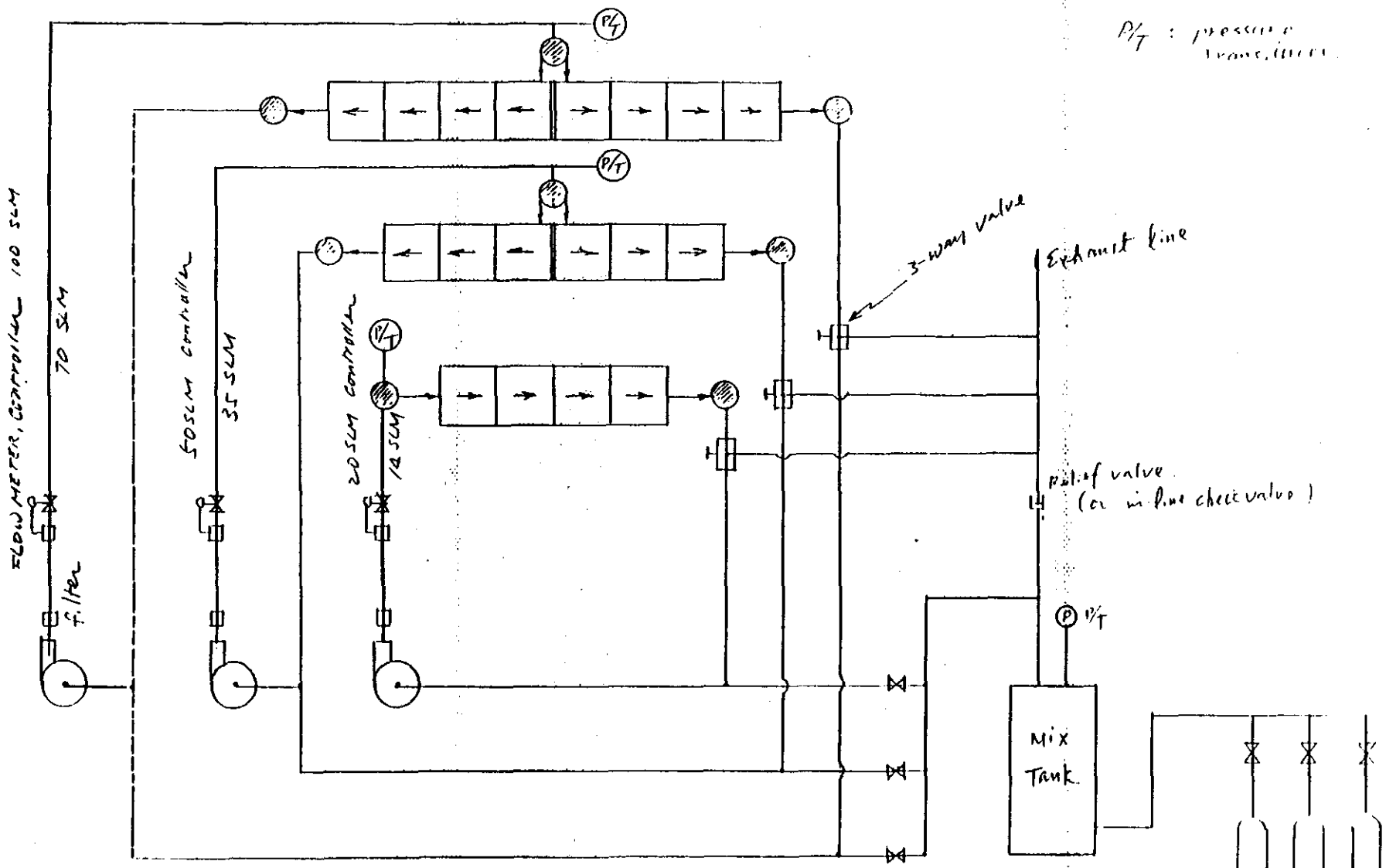

FLOW METER, CONTROLLER 100 SLM
70 SLM
FILTER
50 SLM CONTROLLER
35 SLM
20 SLM CONTROLLER
14 SLM
P/T
3-way valve
Exhaust line
relief valve
(or in-line check valve)
MIX TANK

Figure 4

PRESENTATION TO THE MUON TRIGGER MEETING AT THE SSC LABORATORY 22 JANUARY 1992

IRWIN A. PLESS

BARREL RPC TRIGGER

I. INTRODUCTION

II. RATES

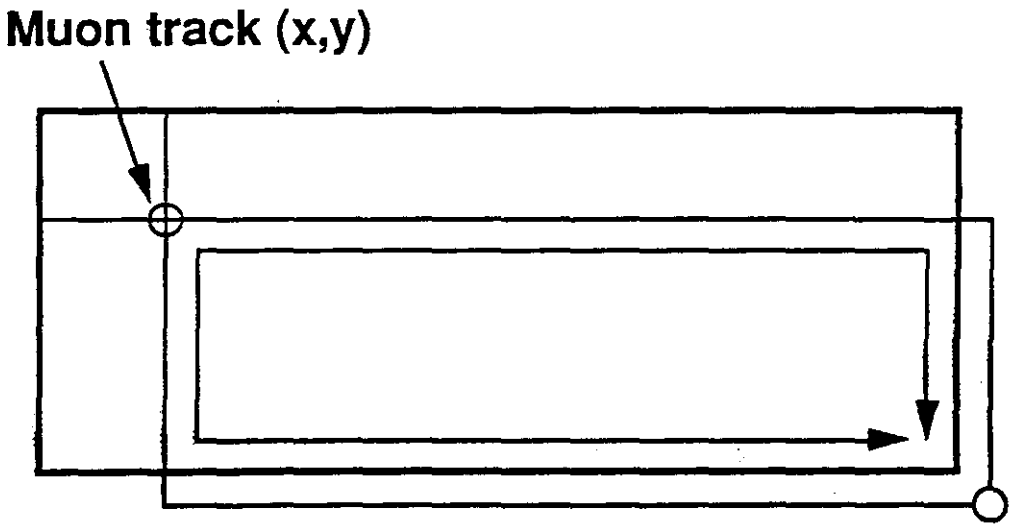
III. TIMING AND TRIGGER WIDTHS

IV. TRIGGER STRATEGY

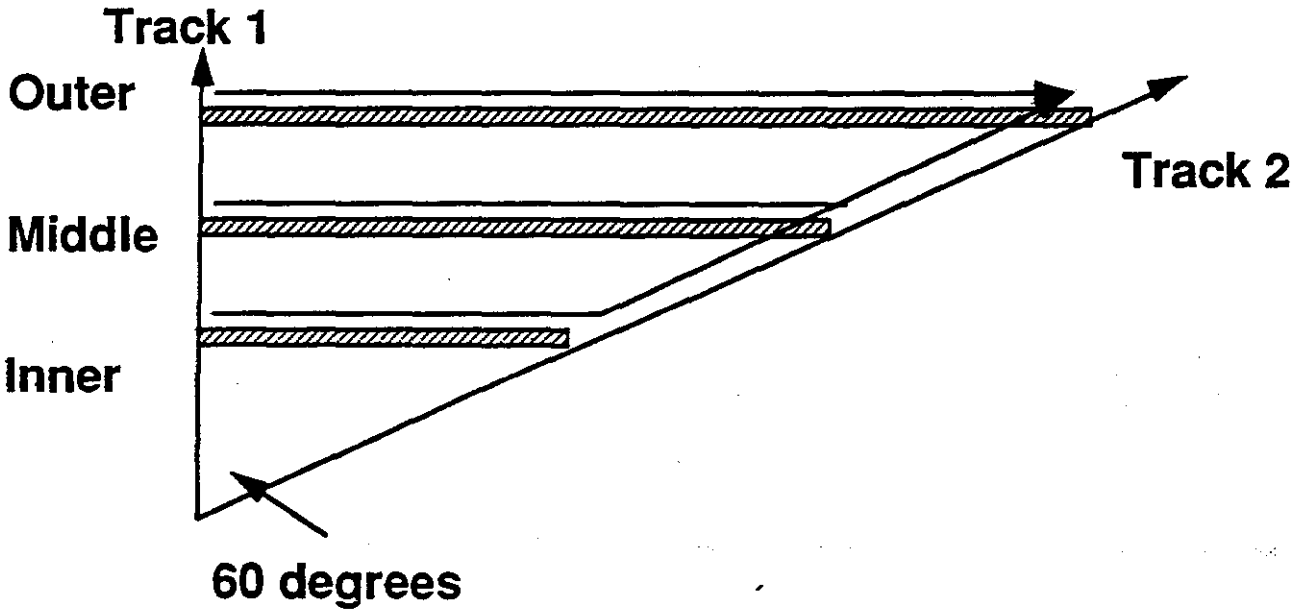
V. HARDWIRE IMPLEMENTATION

VI. ASSOCIATIVE MEMORY IMPLEMENTATION

VII. SUMMARY

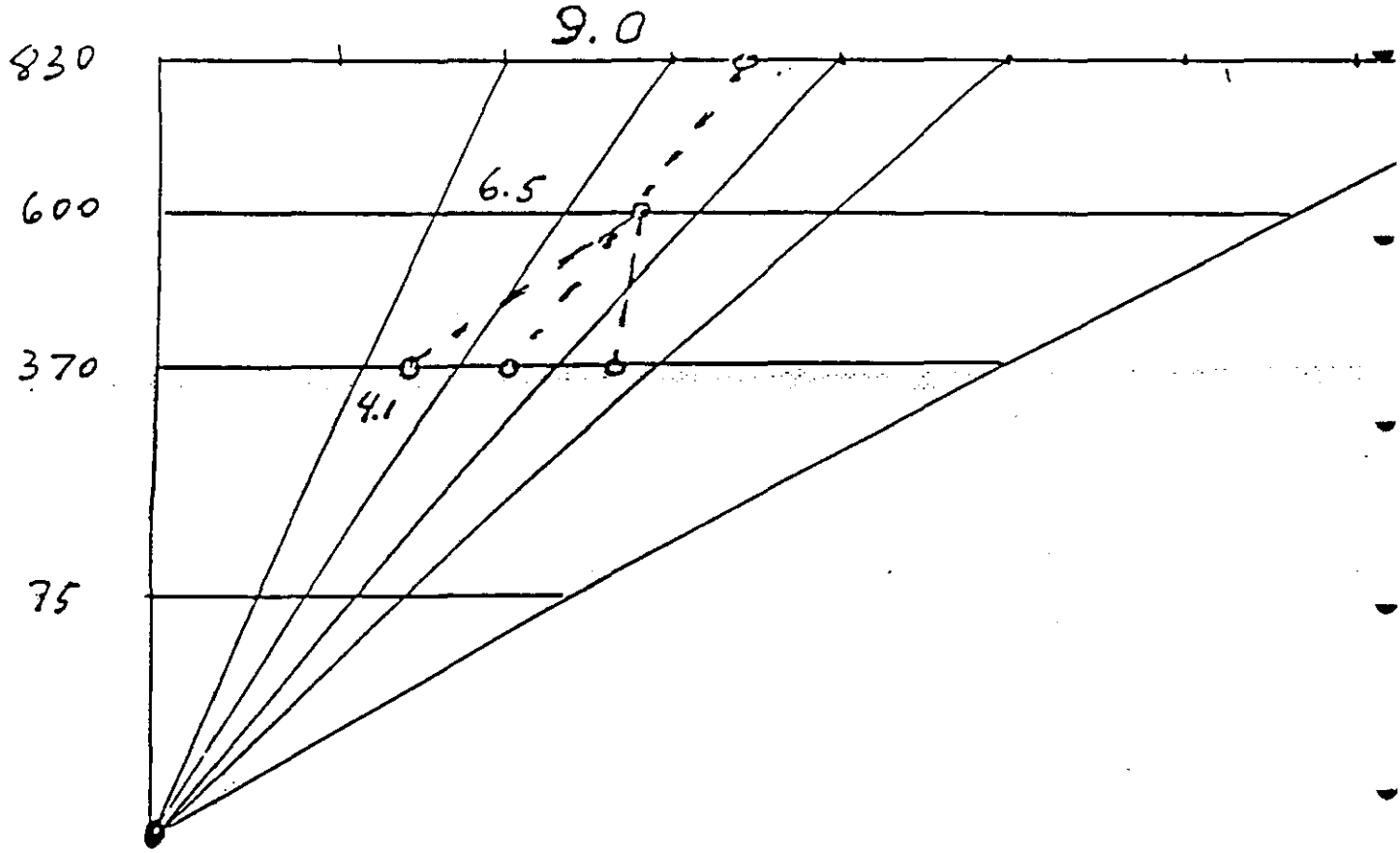


(a)



(b)

Figure 11



For each outer strip there are three, three fold coincidence circuits. Any triple coincidence generates a non-bend trigger.

Tower geometry.

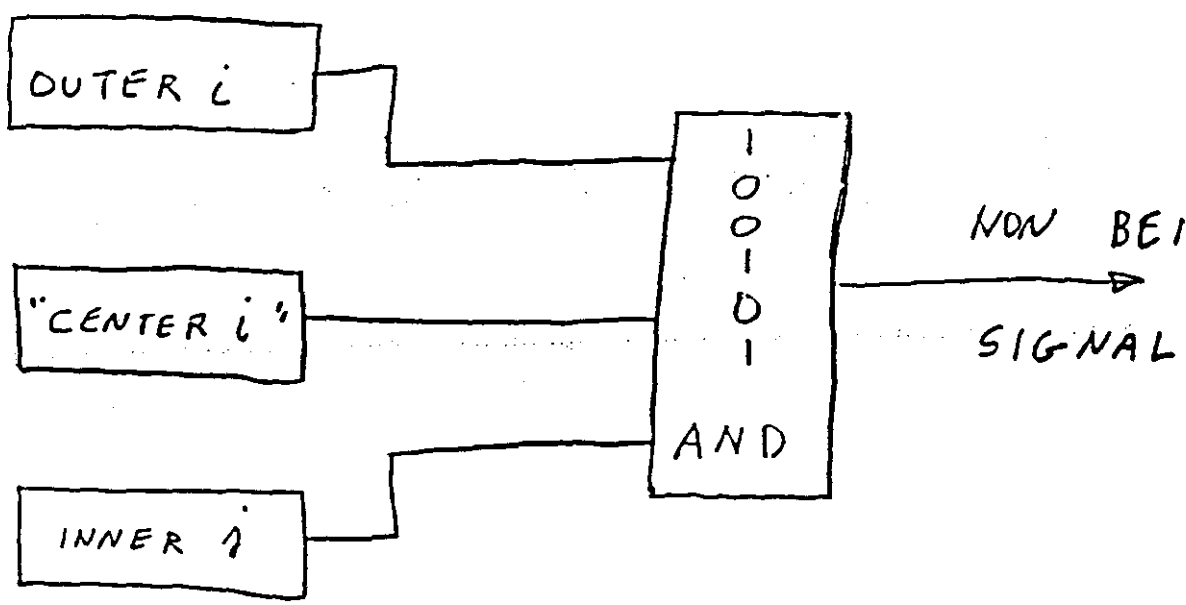
Each plane is divided into 161 strips.

Outer	= 9.0 cm
Center	= "6.5" cm
Inner	= 4.1 cm

Center is really 5 strips OR'd together, each strip is 1.3 cm wide to furnish the z coordinate of the track.

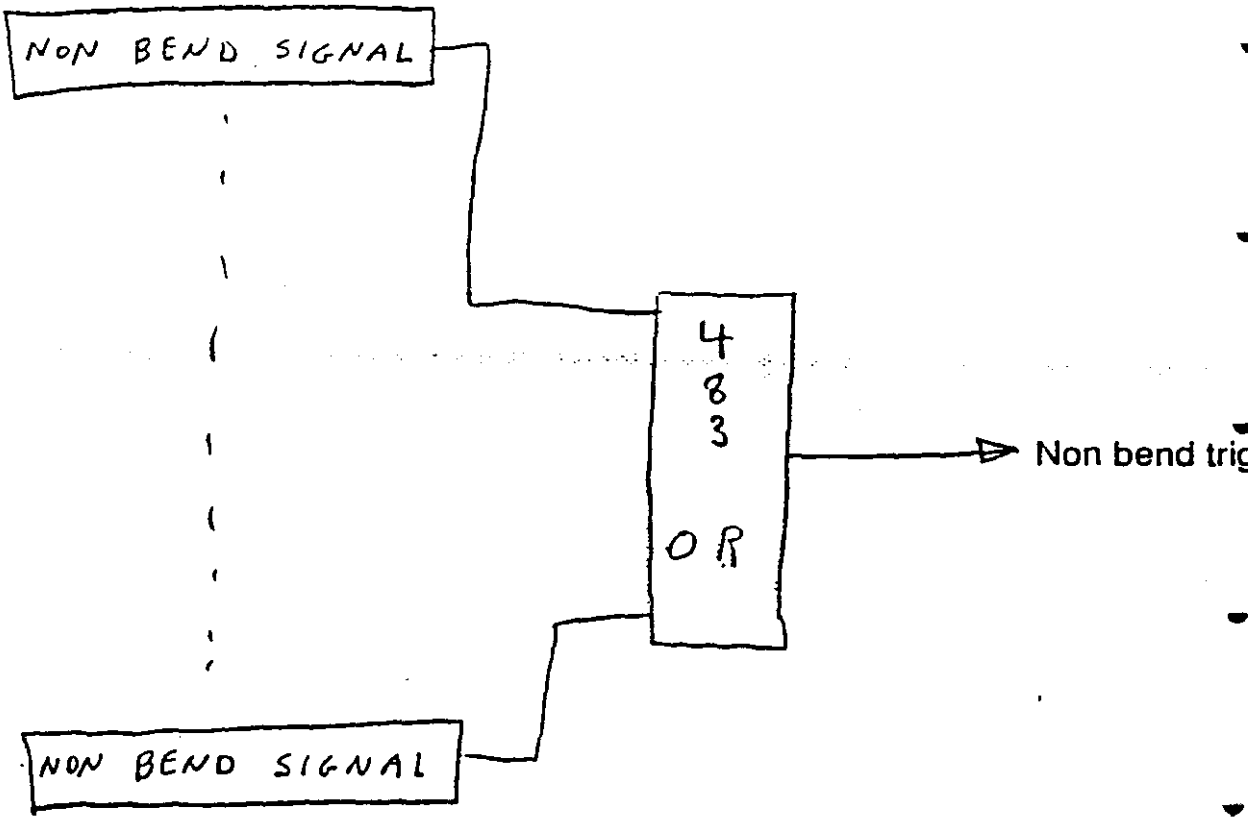
For each outer strip there are three coincidence circuits to account for multiple scattering.

This implies there are 3 x 161 = 483 circuits per sector. Each circuit is as follows:



$j = i-1,\ i,\ i+1$

NON BEND CIRCUIT



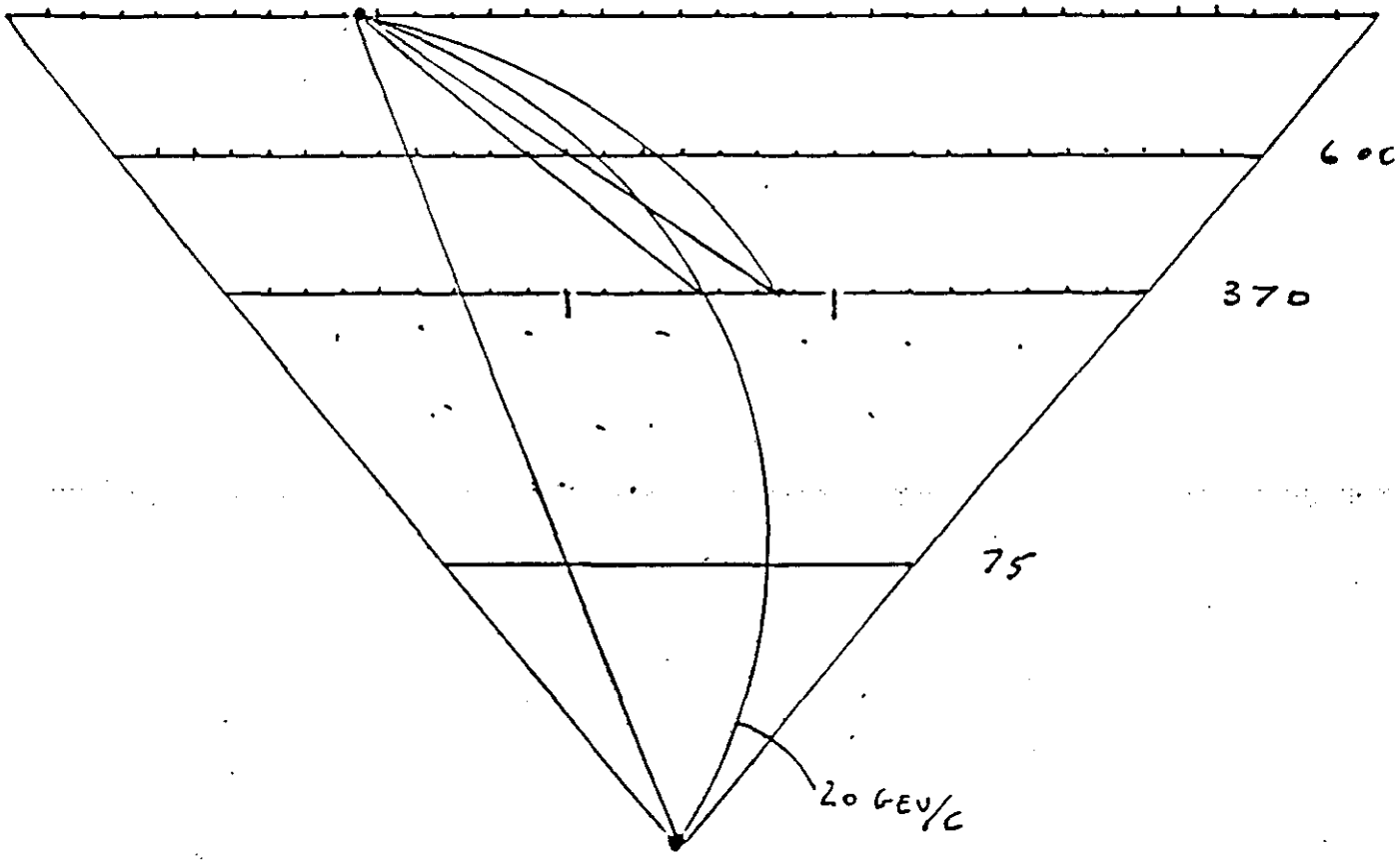
This has 100% acceptance for $P_t > 30$ GeV/c.

This has about 70% acceptance for $P_t = 10$ GeV/c

Acceptance falls rapidly for $P_t < 10$ GeV/c

We have	161 strips	4.1 cm (inne
	161 strips	9.0 cm (oute
	805 strips	1.2 cm (cent

Hence a total of 1127 strips => 1127 discriminators per sector. Trigger box must accommodate 1127 connectors or about 2254 cm linear length.



A 20 GeV/c track has a sigma of 2 strips around the ideal intersection point at R = 370 due to multiple scattering. In order to have a 95% acceptance we have to be able to handle ± 4 strips around the ideal (no multiple scattering) intersection point.

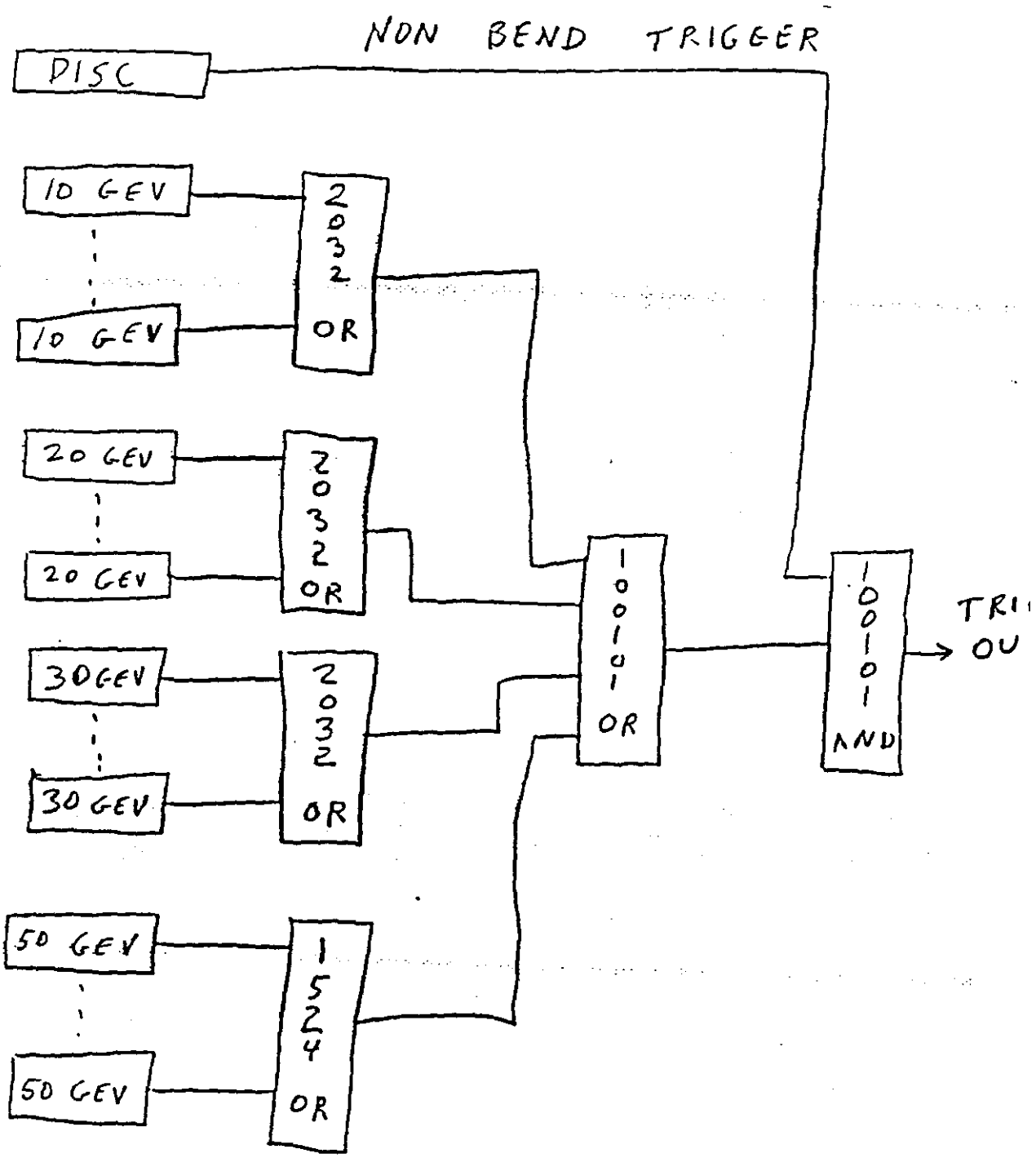
12

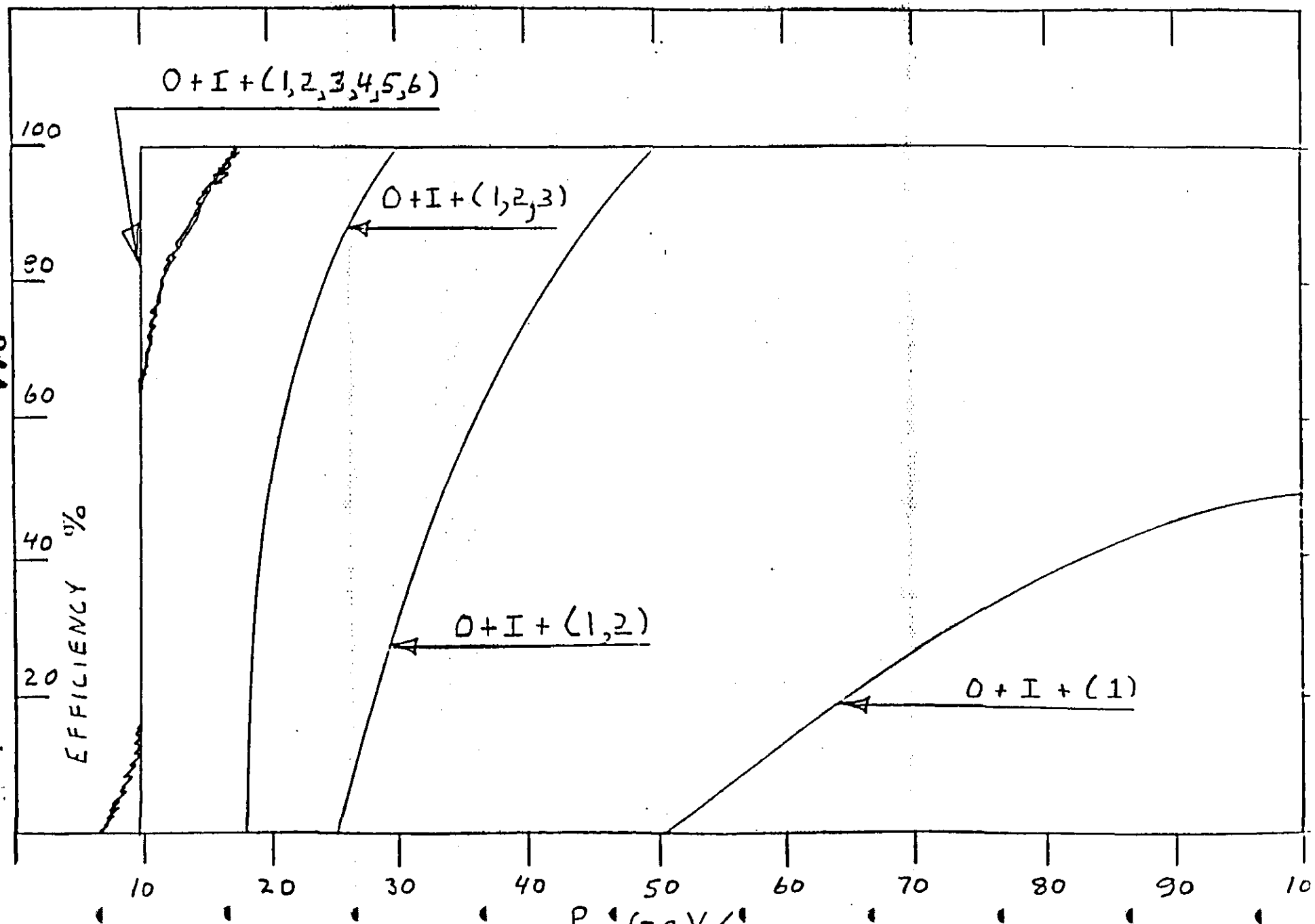
P	S R = 370	S R = 600	σ R = 370	# σ	# STRIPS/2 R = 370	# STRIPS R = 370	# STRIPS S = 600	# STRIPS S = 370
	CM	CM	CM					
10	20.5	6.4	5.0	1	4	8	5	15.8
20	10.2	3.2	2.5	2	4	8	4	7.8
† 30	6.8	2.1	1.7	3	4	8	3	5.2
† 40	5.1	1.6	1.3	3	4	8	3	3.9
50	4.1	1.3	1.0	3	3	6	2	3.2

† 30 AND 40 CANNOT BE SEPERATED

POSITIVE MUON

Trigger > 10 GeV




O + I + (1,2,3,4,5,6)
O + I + (1,2,3)
O + I + (1,2)
O + I + (1)
EFFICIENCY %
100
80
60
40
20
10
20
30
40
50
60
70
80
90

VII. SUMMARY

WE FIND THE FOLLOWING TRIGGER RATES FOR THE BARREL:

$P_t > 0$ GeV/c	1.3×10^6 HERTZ
$P_t > 10$ GeV/c	2,000 HERTZ
$P_t > 20$ GeV/c	400 HERTZ
$P_t > 30$ GeV/c	75 HERTZ

WE CONCLUDE THAT IN ORDER TO OPERATE AT A LUMINOSITY OF 10^{34} WE SHOULD HAVE FOUR TRIGGER LEVELS:

$P_t > 10$ GeV/c
$P_t > 20$ GeV/c
$P_t > 30$ GeV/c
$P_t > 50$ GeV/c

USING OUR PROPOSED WIRING GEOMETRY, WE HAVE THE POSSIBILITY AT THE FIRST LEVEL TRIGGER OF CALCULATING THE EVENT TIME TO THE LEVEL OF THE RISE TIME JITTER OF THE RPC. IF TH RPC RISE TIME JITTER IS LESS THAN 4 NANO-SECONDS, THEN THE BEAM CROSSING IS UNIQUELY IDENTIFIED AT THE FIRST LEVEL TRIGGEF

WE FIND WE CAN DO COINCIDENCES OF THE VARIOUS STRIPS WITH GATE WIDTHS OF 13, 9, AN 6.5 NANO-SECONDS. THIS WILL REDUCE SINGLE RANDOM NOISE HITS BY A FACTOR 7.

WE HAVE SHOWN A TRIGGER STRATEGY THAT CAN BE IMPLEMENTED IN FIXED HARDWARE OR BY USING ASSOCIATIVE MEMORIES. IT WILL TAKE MORE STUDY TO DETERMINE WHICH IS THE OPTIMAL WAY TO GO FOR THE GEM DETECTOR.

Daniel Marlow
June 9, 1992

A Simple Circuit for Time-Deskewing in the GEM RPC's

Introduction

The baseline option for the barrel muon trigger system in GEM is the Resistive Plate Chamber (RPC). The good timing resolution ($\sigma_t \simeq 1 - 2$ ns) of these devices makes realtime bunch-cross tagging possible. This feature helps to simplify many other aspects of the trigger and DAQ system design. Practical complications arise, however, because of the large size of the GEM muon system, which produces considerable variations in arrival times and pulse transit times along the readout strips.

As an example, consider the simple sketch of Figure 1, which approximately corresponds to an outer-layer RPC in the GEM barrel. Muons leaving the vertex at right angles to the beam (trajectory A) travel about nine meters and reach the RPC after roughly 27 ns (to keep the numbers simple, we assume muon flight times 3 ns/m). Although the RPC avalanche develops quickly, the resulting current pulse must propagate to the readout electronics located at the end of the strip, as shown. The total delay is then $27+75 = 102$ ns. In constrast, muons leaving the vertex at the most forward angles (trajectory D) must travel $\sqrt{9^2+15^2} = 17.5$ meters, resulting in a pulse-arrival time of 53 ns. The 50 ns difference in arrival times corresponds to three bunch crossing intervals, which is unacceptable.

Possible Solutions

Perhaps the most straightforward way to address this problem would be to segment each strip in x into lengths short enough to reduce the time variations to less than 16 ns. In practice this would require segmenting the 15-meter-long strip shown into four pieces. Unfortunately, this simple expedient raises the channel count and the attendant electronics costs by a corresponding factor. Other schemes, where the z strips are used to dynamically generate time corrections, have also been proposed, but these are complex and involve 250 MHz logic.

Meantimers for Long Scintillators

A similar problem arises in the readout of long scintillators, where transit time variations produce significant timing jitter if only one PMT is used. However, the average time of arrival of pulses from a pair of phototubes arranged so as to view each end of a long scintillator (see top part of figure 2) is independent of the particle's impact position. In practice, the average arrival time can be generated in real time using either analog or digital circuits, called "meantimers" or "chronotrons". A classic digital approach employing tapped delay lines is shown in the lower portion of figure 2. If the total length of each delay line is chosen to be the same as the time required for light to propagate the length of the counter (ΔT), the output marked "MT" will fire after a fixed delay time ΔT, independent of the position of incidence. The spacing between taps is constant and the number of taps (and the number of AND gates) can be adjusted to give the desired resolution. A tap spacing of δt limits the single-measurement error to $\pm\delta t/2$.

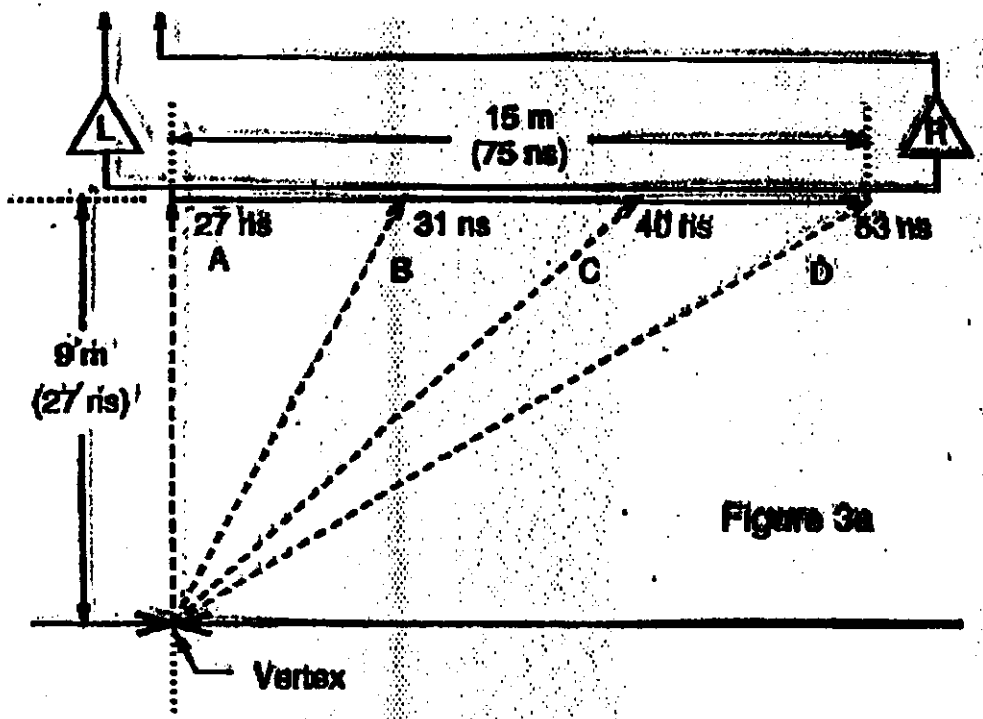


Figure 3a

Arrival Time in ns		
Case	T_L	T_R
A	27	162
B	56	81
C	90	65
D	128	53

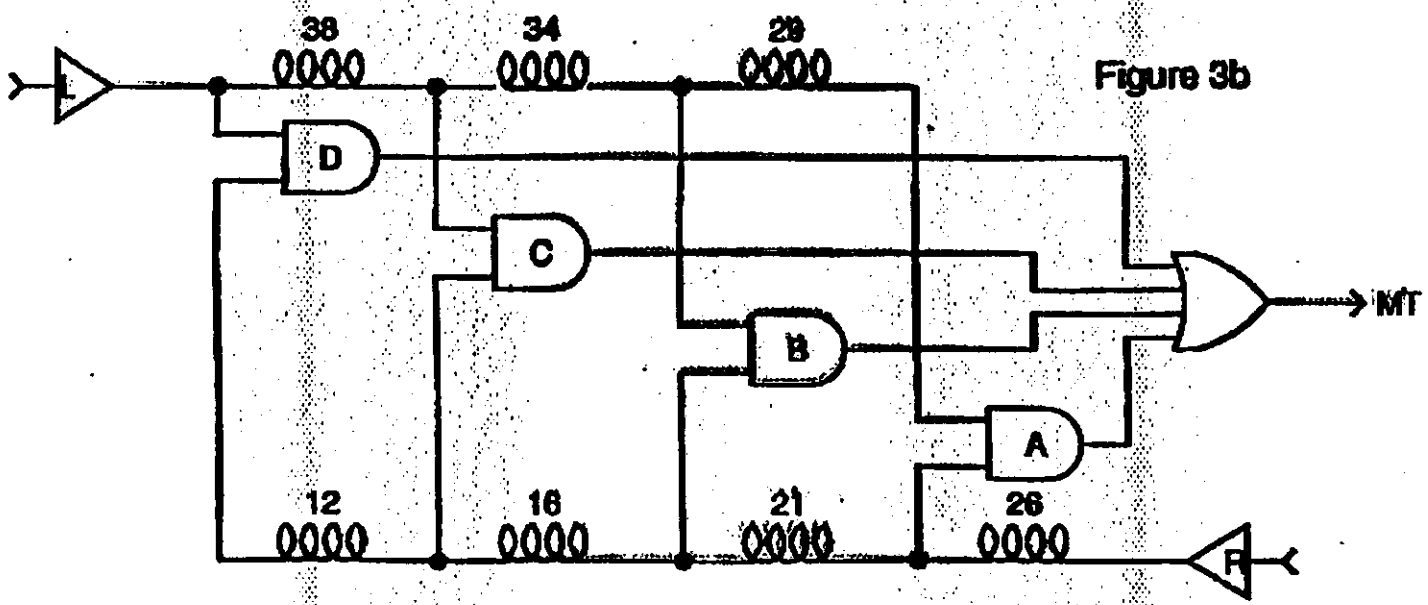


Figure 3b

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Presentation by:

C. Wuest

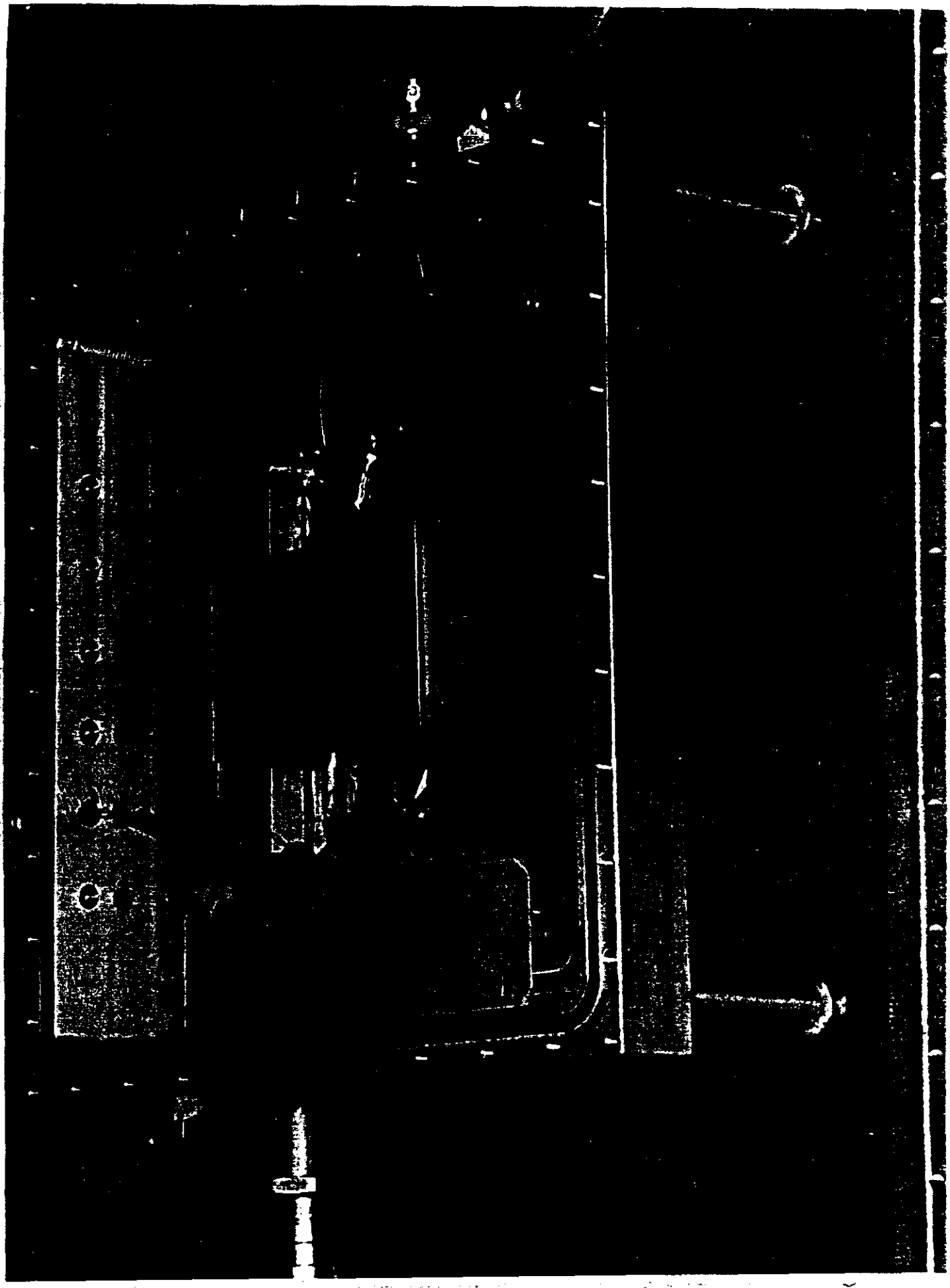
C. Wuest

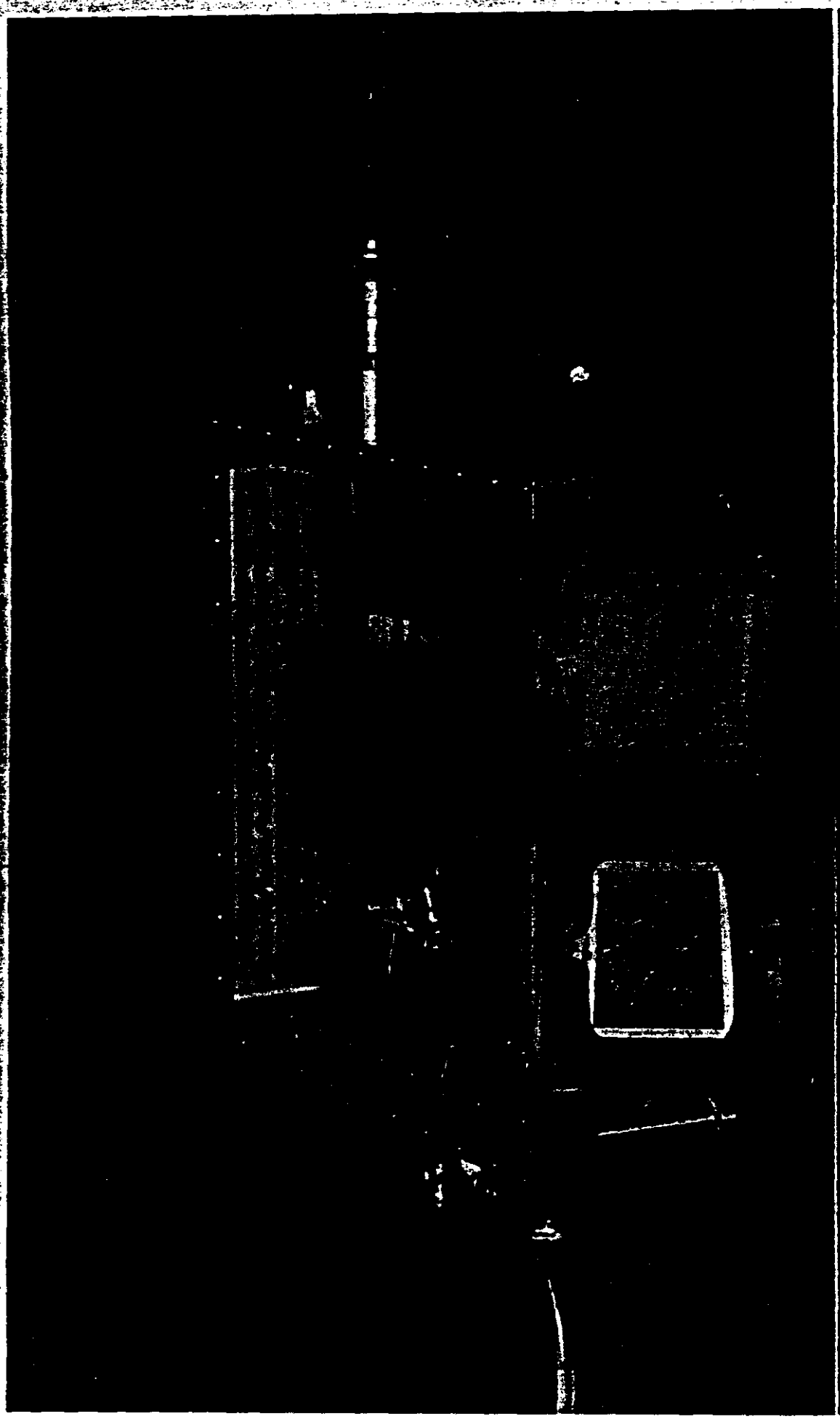
High Rate RPC Materials

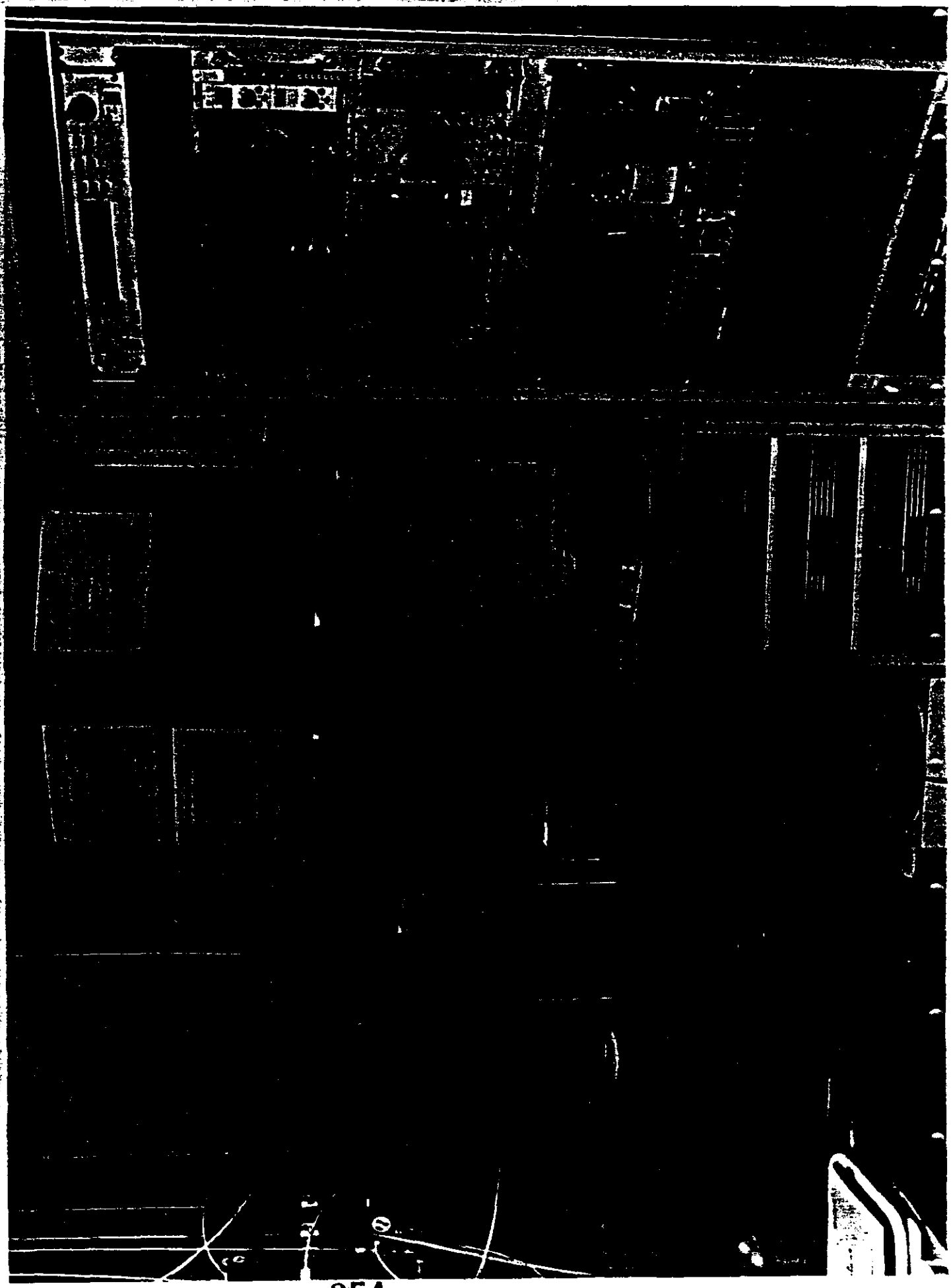
October 6-7, 1992

Presented by:
Richard M. Bionta
Lawrence Livermore
National Laboratories

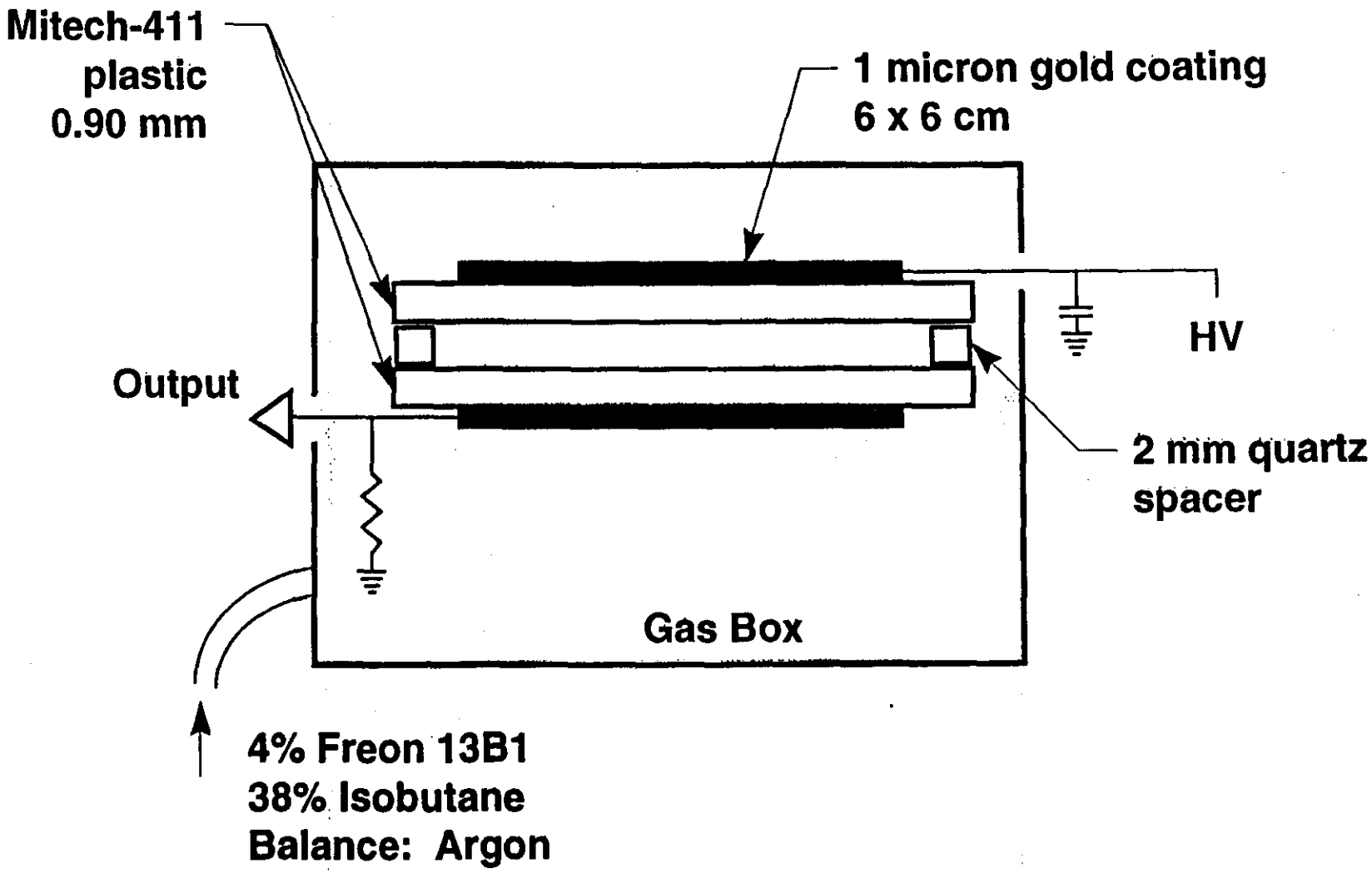
BAK.KA-00/RMB





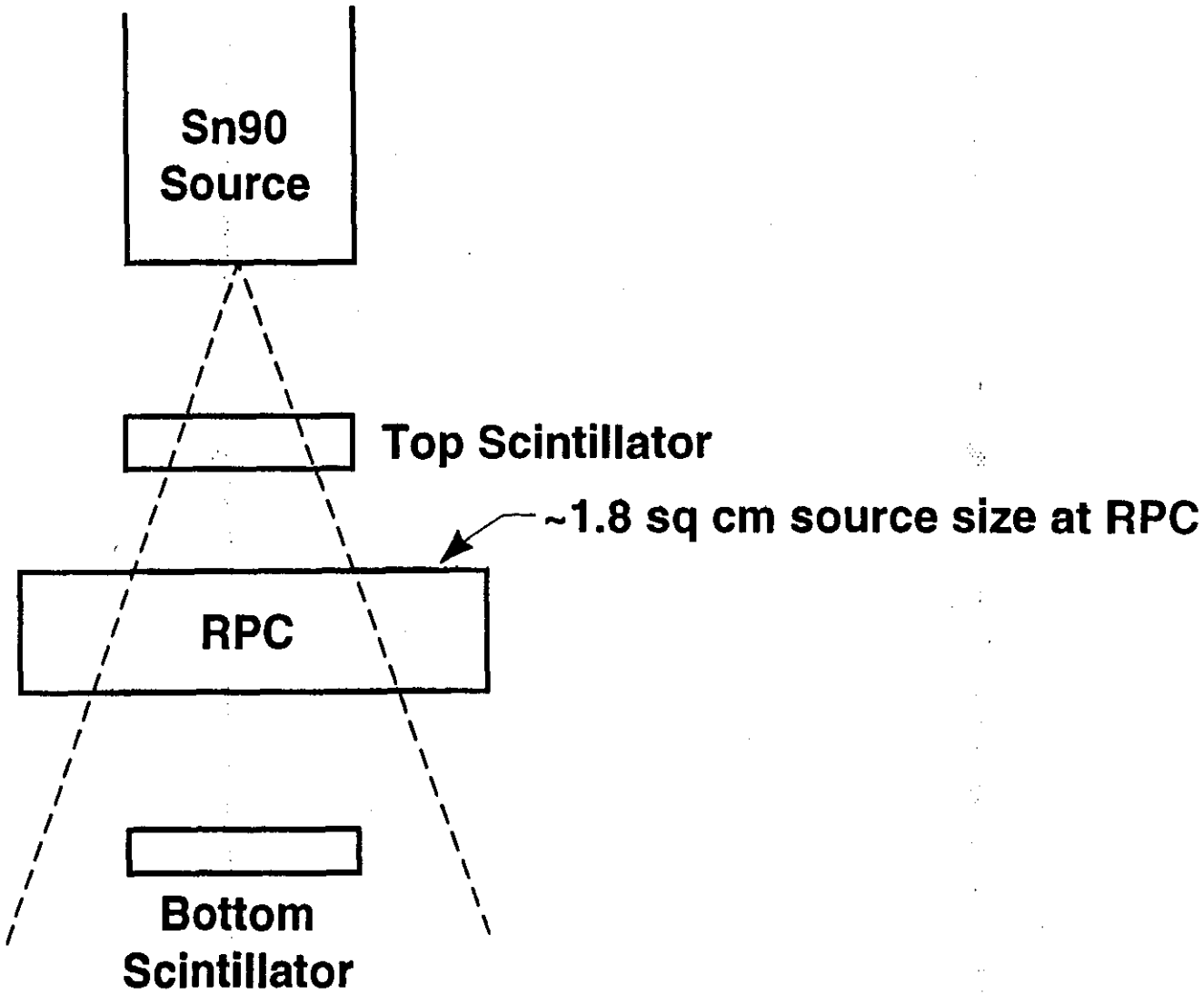


Materials Test Detector



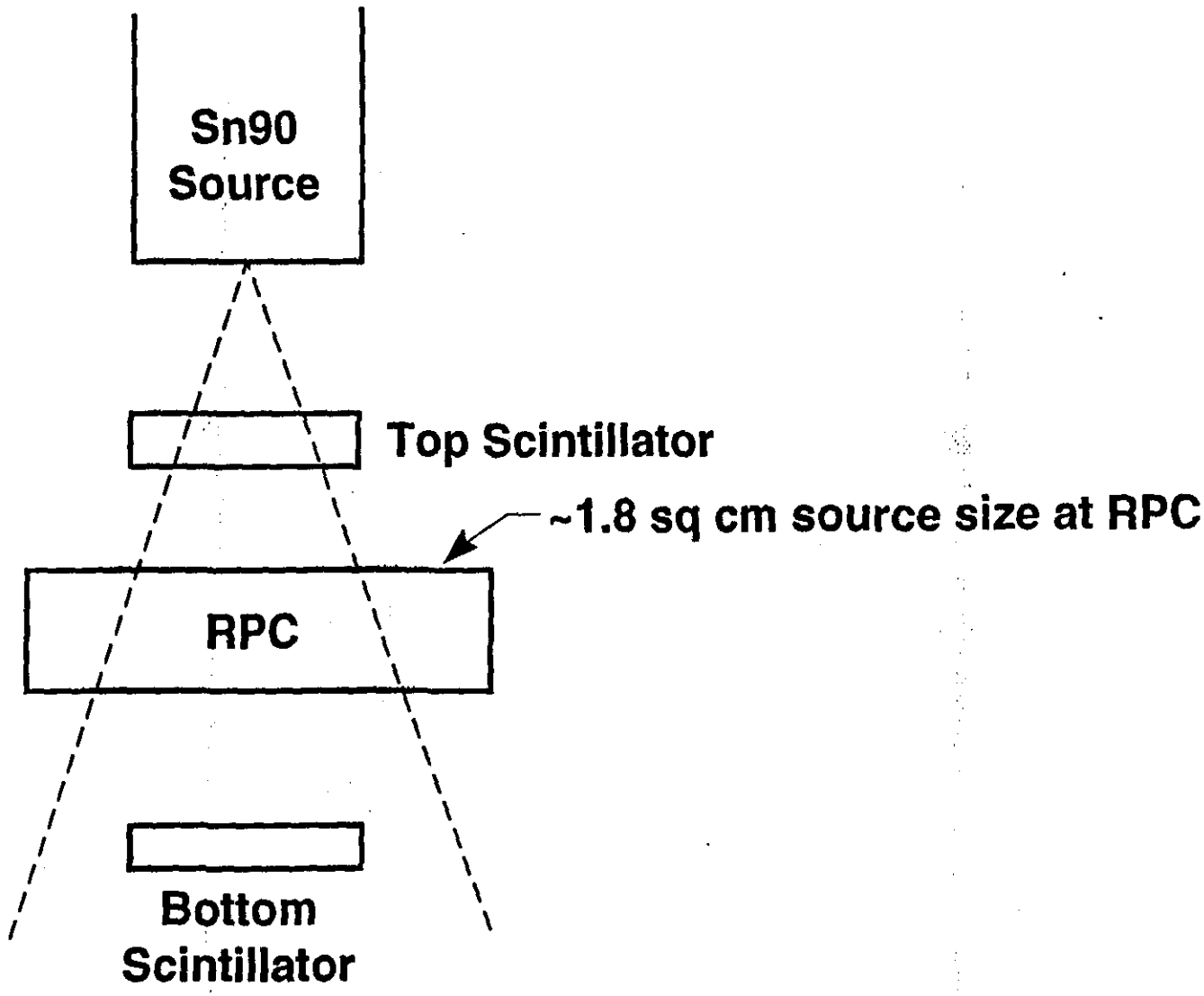
BAK.KA-03/RMB

RPC Source Test



BAK.KA-02/RMB

RPC Source Test

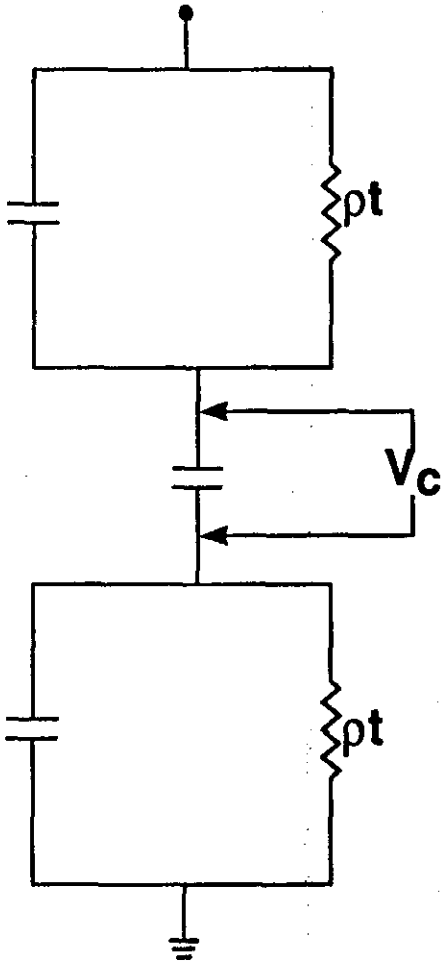


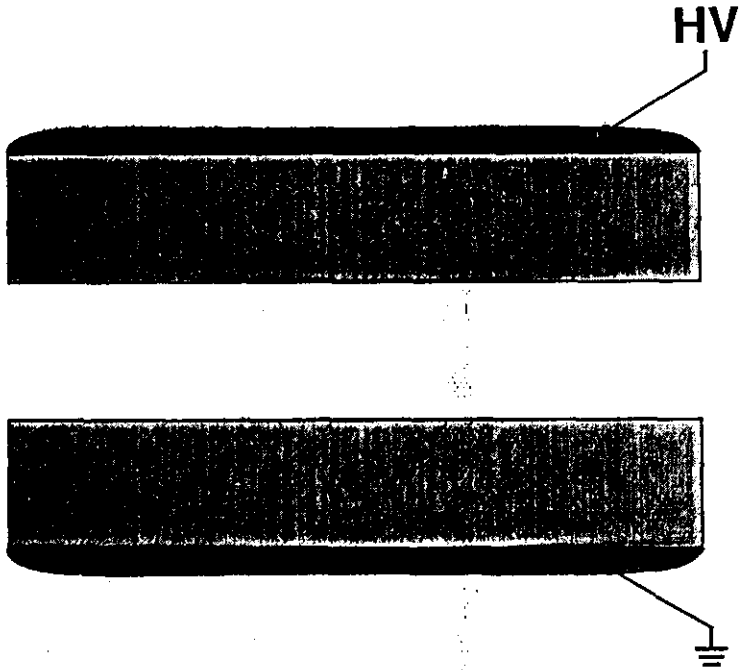
BAK.KA-02/RMB

RPC Candidate Material

Material	Thickness (cm)	Bulk Resistivity (Ωcm)	Arc Resistivity (Ωcm^2)
MIT mirror	.300	5.0×10^{12}	1.5×10^{12}
750 micron mirror	.066	4.9×10^{12}	3.23×10^{11}
Kodak projector glass	.123	6.42×10^{11}	7.89×10^{10}
Italian RPC	.200	1.0×10^{11}	2×10^{10}
Bakelite	.161	4.5×10^{9}	7.24×10^{8}
ABSTAT–M310	.072	5.78×10^{9}	4.16×10^{8}
ABSTAT–M310	.060	5.78×10^{9}	3.47×10^{8}
Mitech–410	.090	2.03×10^{9}	1.83×10^{8}
Mitech–410	.030	2.03×10^{9}	6.19×10^{7}
Corning 0211 glass	.056	6.7×10^{7}	3.75×10^{6}
Boron	.0001	1×10^{6}	1×10^{2}

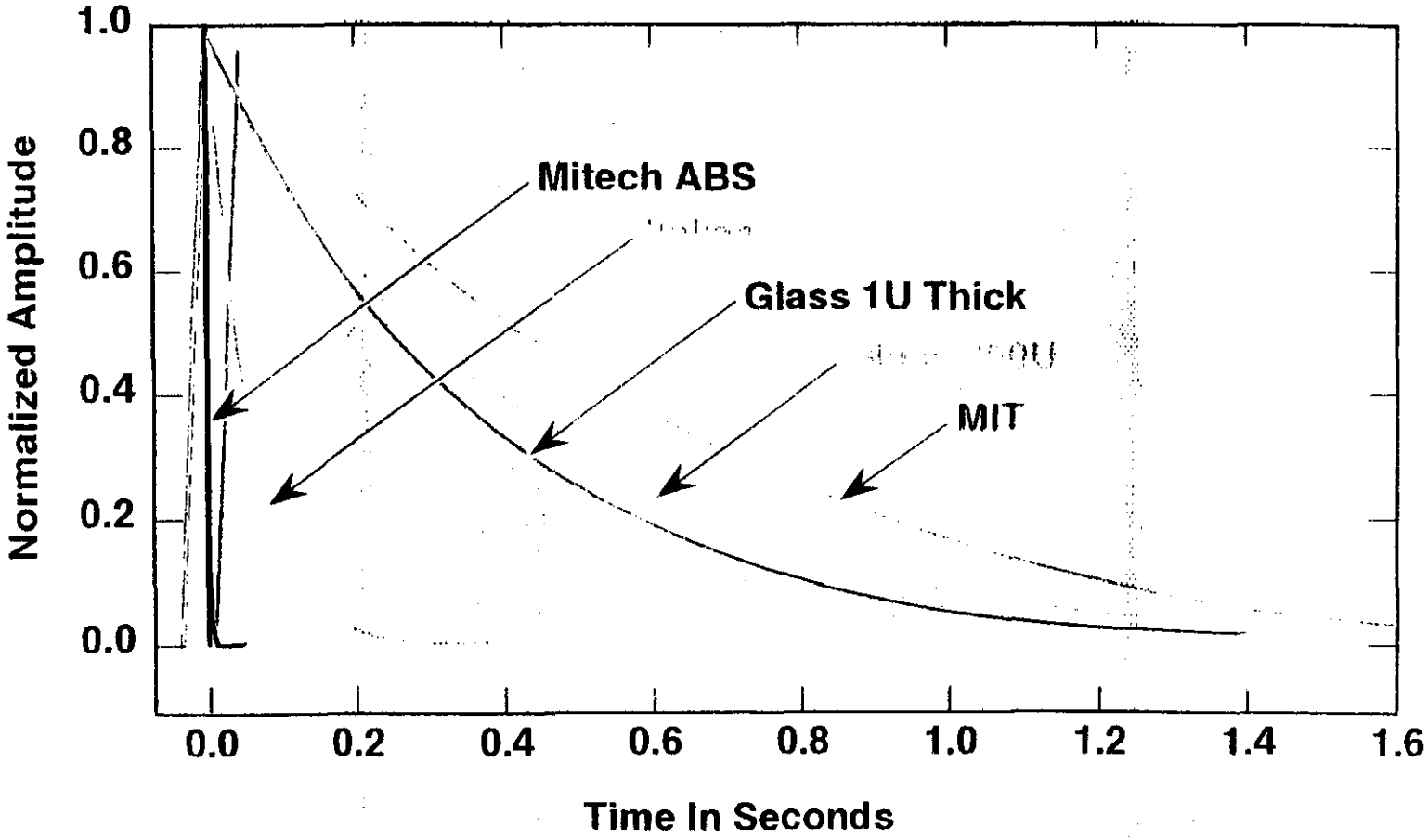
Spice RPC Model



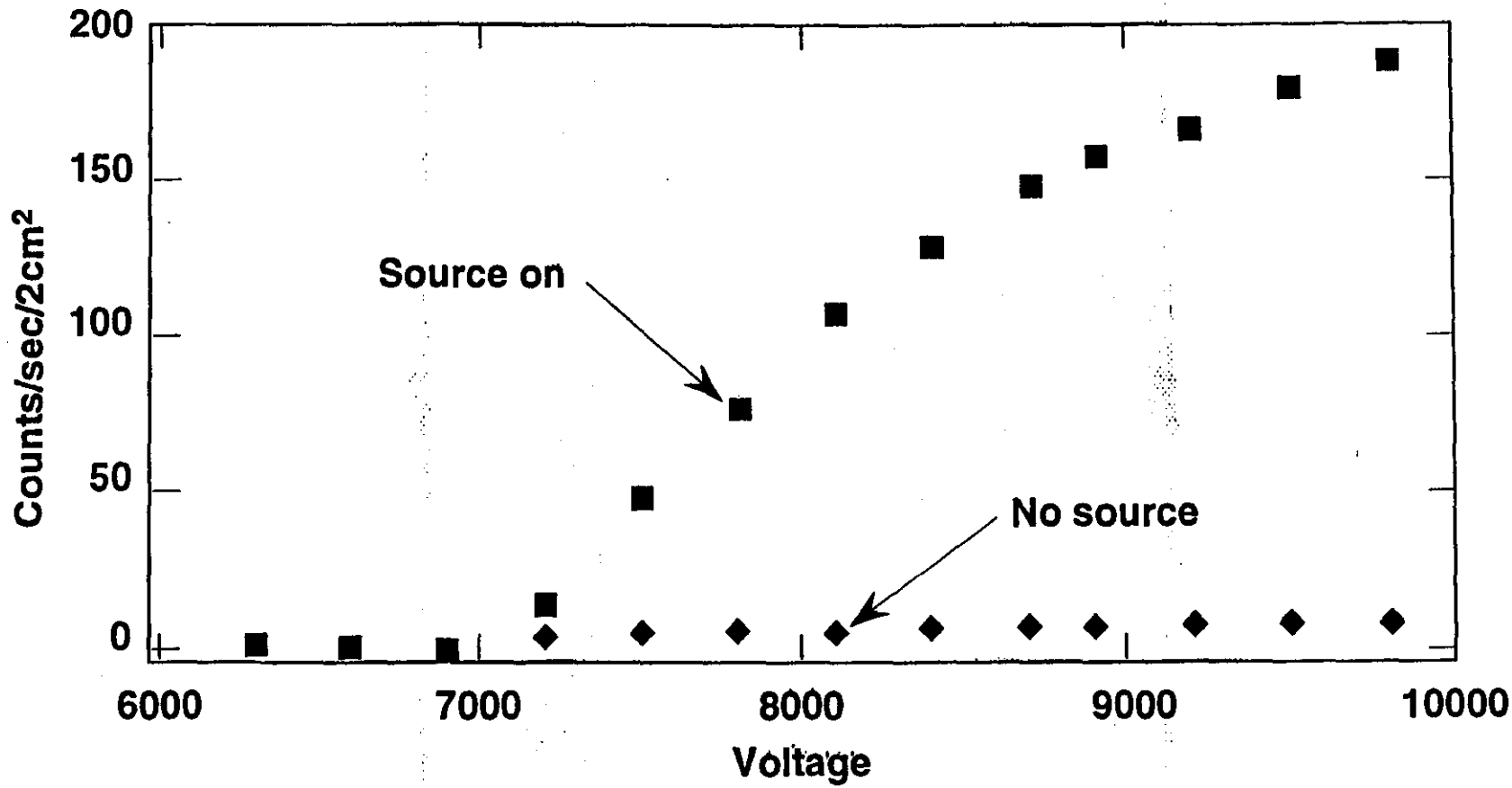


BAK.KA-01/RMB

Spice Calculations of Recharge

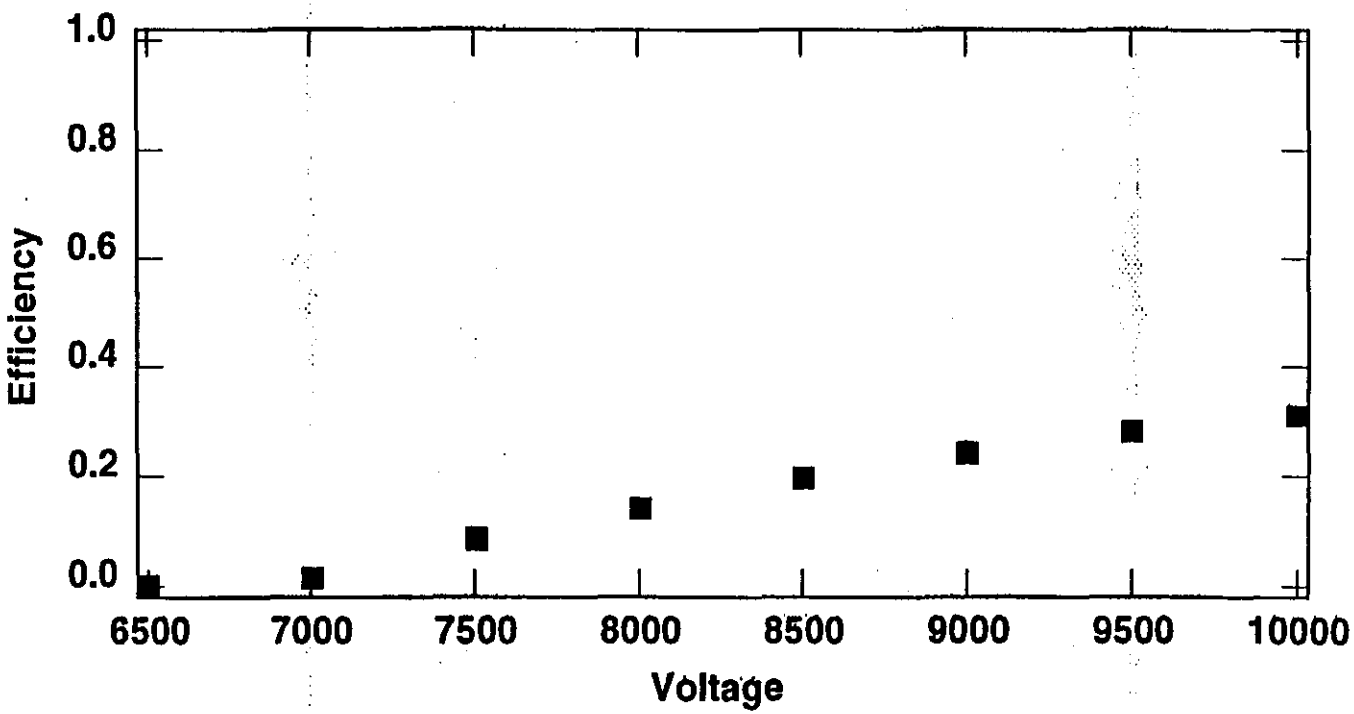


750 Micron Mirror Glass Detector Singles

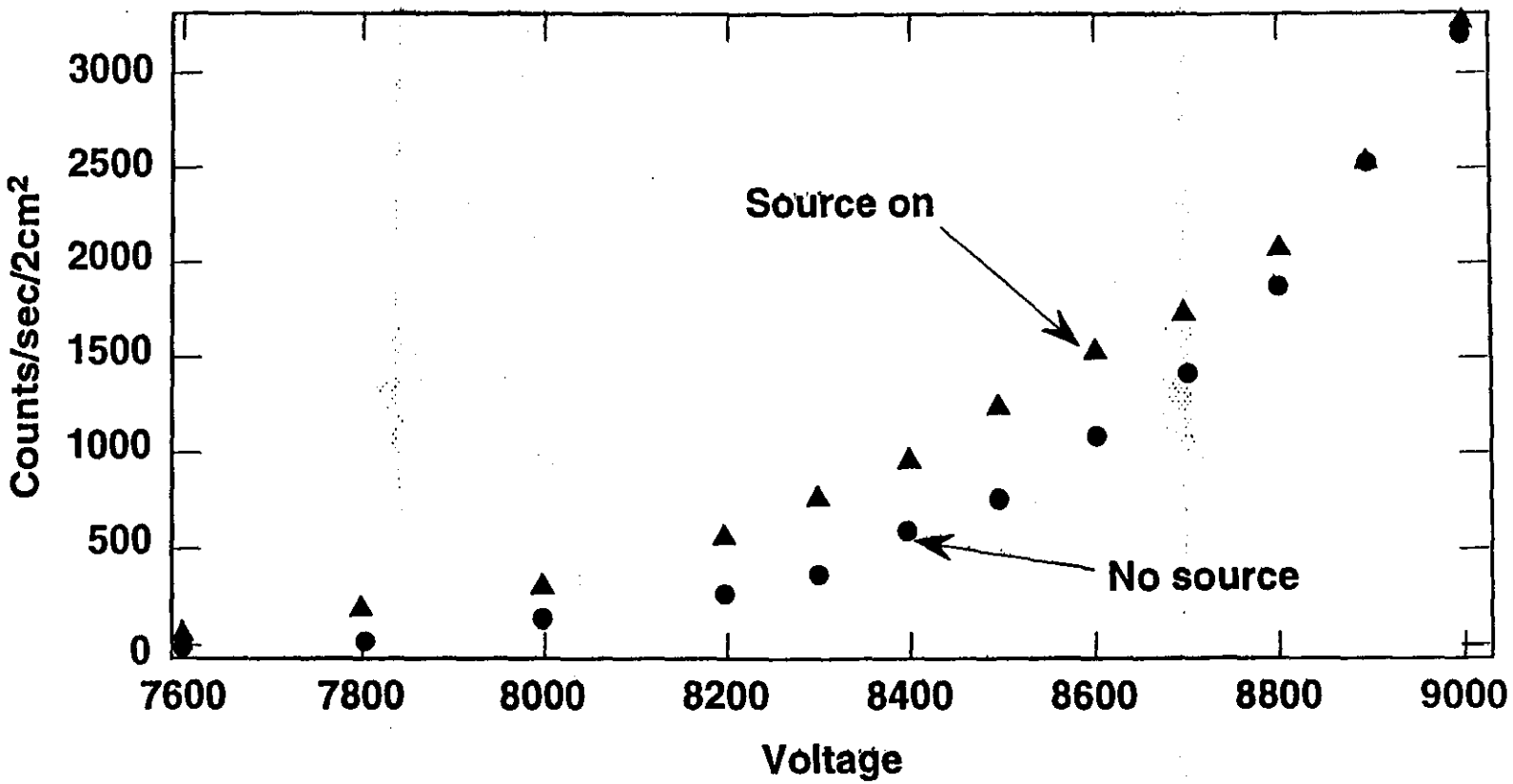


BAK.KA-05/RMB

750 Micron Mirror Glass Plateau

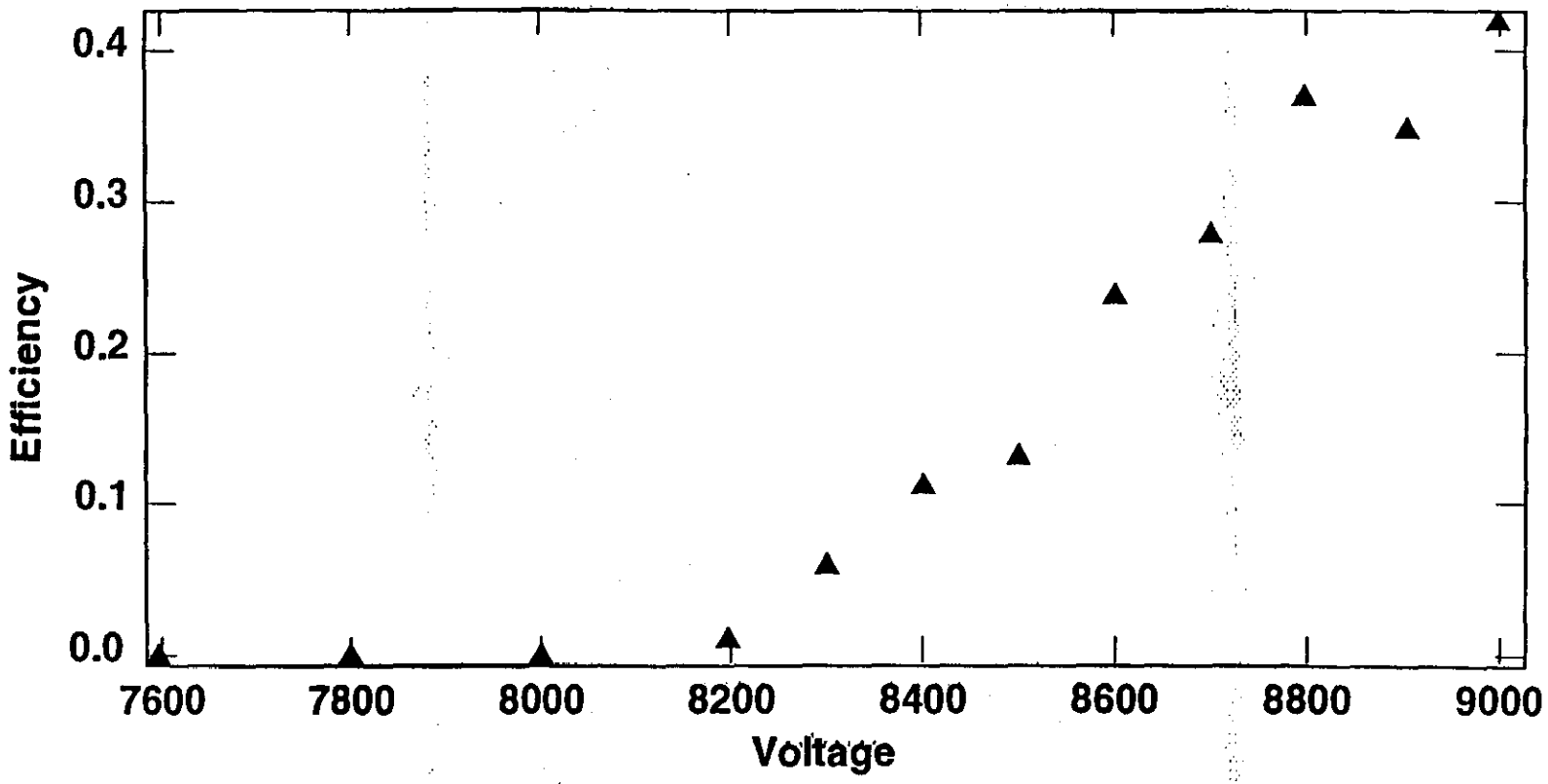


Bakelite/linseed Oil Detector Singles

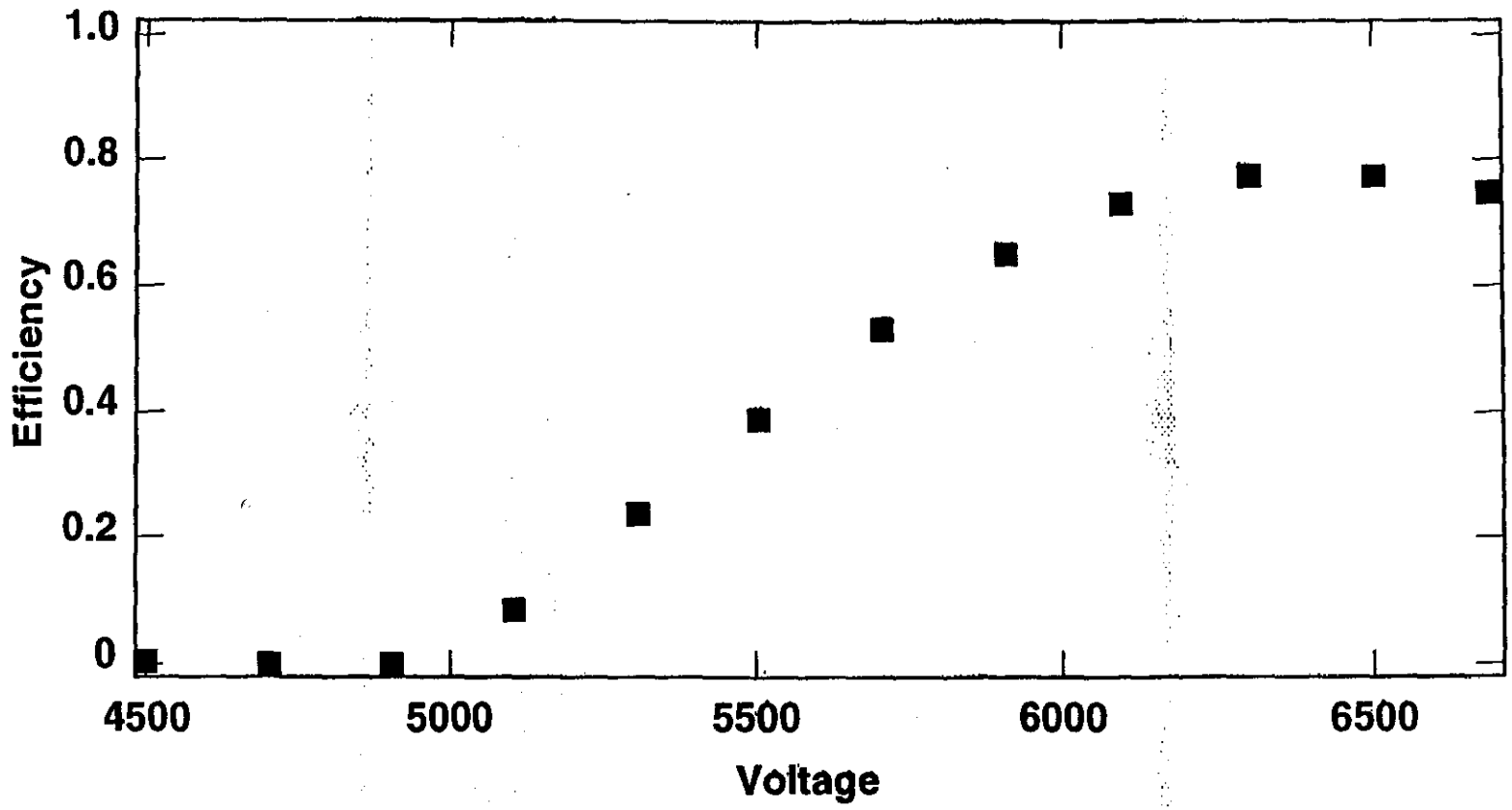


BAK.KA-09/RMB

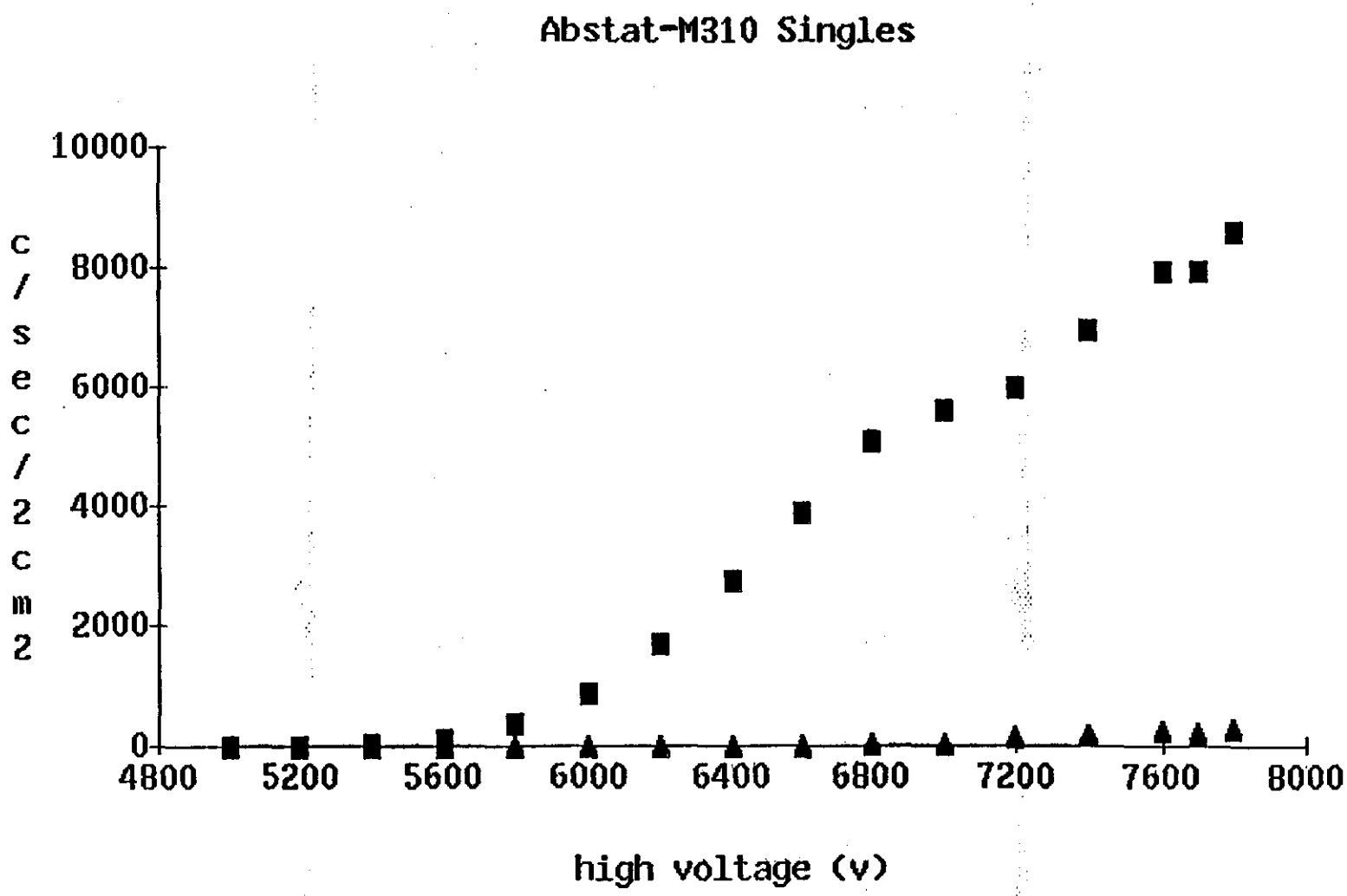
Bakelite/Linseed Oil Detector Plateau

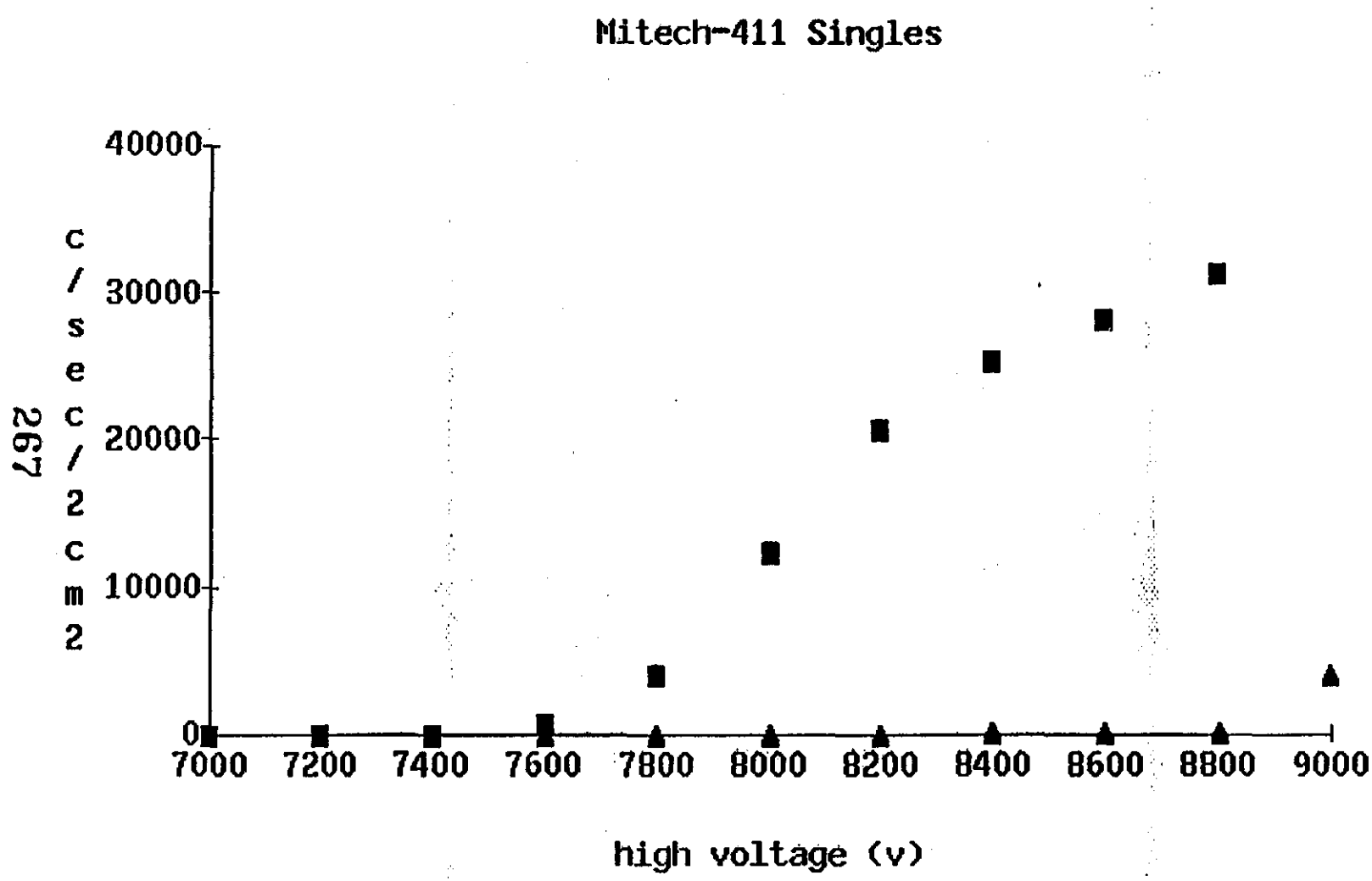


ABSTAT–M310 Lucite Frame Second Build Plateau

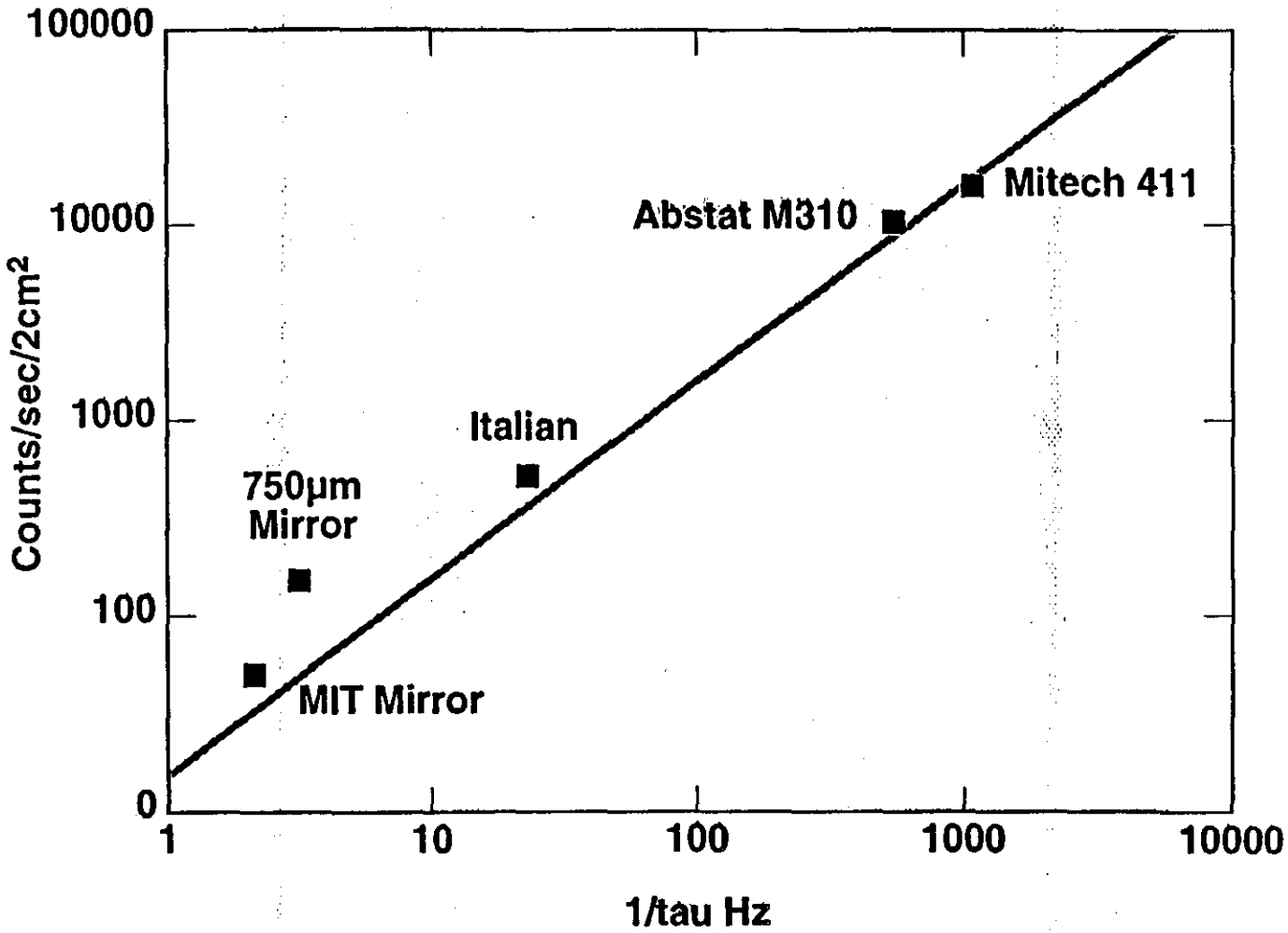


BAK.KA-12/RMB


Abstat-M310 Singles
c/sec/2cm2
10000
8000
6000
4000
2000
0
4800
5200
5600
6000
6400
6800
7200
7600
8000
high voltage (v)


Mitech-411 Singles
c/sec/2cm2
40000
30000
20000
10000
0
7000
7200
7400
7600
7800
8000
8200
8400
8600
8800
9000
high voltage (v)

Saturated Singles Rate vs SPICE 1/tau



BAK.KA-17/RMB

Conclusions

- SPICE model can be used to predict rate handling capability of candidate RPC materials
- RPC performance depends mainly on bulk resistivity
- RPC's built of ABSTAT M310 will be an excellent choice for GEM offering an order of magnitude improvement in rate handling capability and ease of fabrication
- Large multi-channel M310 RPC to be built in FY93'
- Precision measurements of efficiency vs. rate will require test beam time

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Presentation by:

R. Sawicki

Lawicki

Mechanical Engineering Evaluation of the Muon Chamber Technology Options

October 6, 1992

Scope

- From a mechanical engineering perspective, review all four barrel muon technology options
  - cathode strip chambers
  - limited streamer drift tubes
  - pressurized drift tubes
  - resistive plate chambers

- Compile as detailed information as is available on all aspects of the design

- Compare relative strengths of each design

- Identify issues and concerns

Review process

- Charter established on Sept 1, 1992
  - M. Gamble
  - R. Humphreys
  - C. Johnson
  - F. Nimblett
  - R. Sawicki, chairperson

- Convened four oral reviews with Technology leaders
  - CSC - V. Polychronakis
  - LSDT - L. Osborne
  - PDT - Carl Bromberg
  - RPC - C. Wuest

- Each technology leader submitted a written summary which is contained in appendix of report
  - CSC report received too late for review and comment
    - -- CSC vugraphs included in appendix

- Evaluation of each technology written by a single panel member but reviewed and approved by the panel as a whole

Review topics

- Design
  - general design concept
  - weight
  - wire or strip support
  - gas systems
  - chamber structure
  - impact on truss structure design
  - superlayer configuration
  - electronic packaging requirements
  - size limitations
  - utility routing
  - failure tolerance
- Manufacture/assembly
  - approach/philosophy
  - component fabrication
  - precision requirements
  - development requirements
  - vendor availability
  - assembly procedures
  - fixturing requirements
- Alignment
  - internal - wire/wire,plane/plane
  - external - superlayer/superlayer
  - fiducialization
- Structural
  - stiffness requirements
  - dimensional stability
- Coverage
  - acceptance - phi and theta
  - phi overlap potential
- Cost
  - assumptions
  - equipment, material and labor
  - cost uncertainties
- Schedule
  - long lead components
  - component fabrication time
  - assembly time
  - installation time
  - first availability

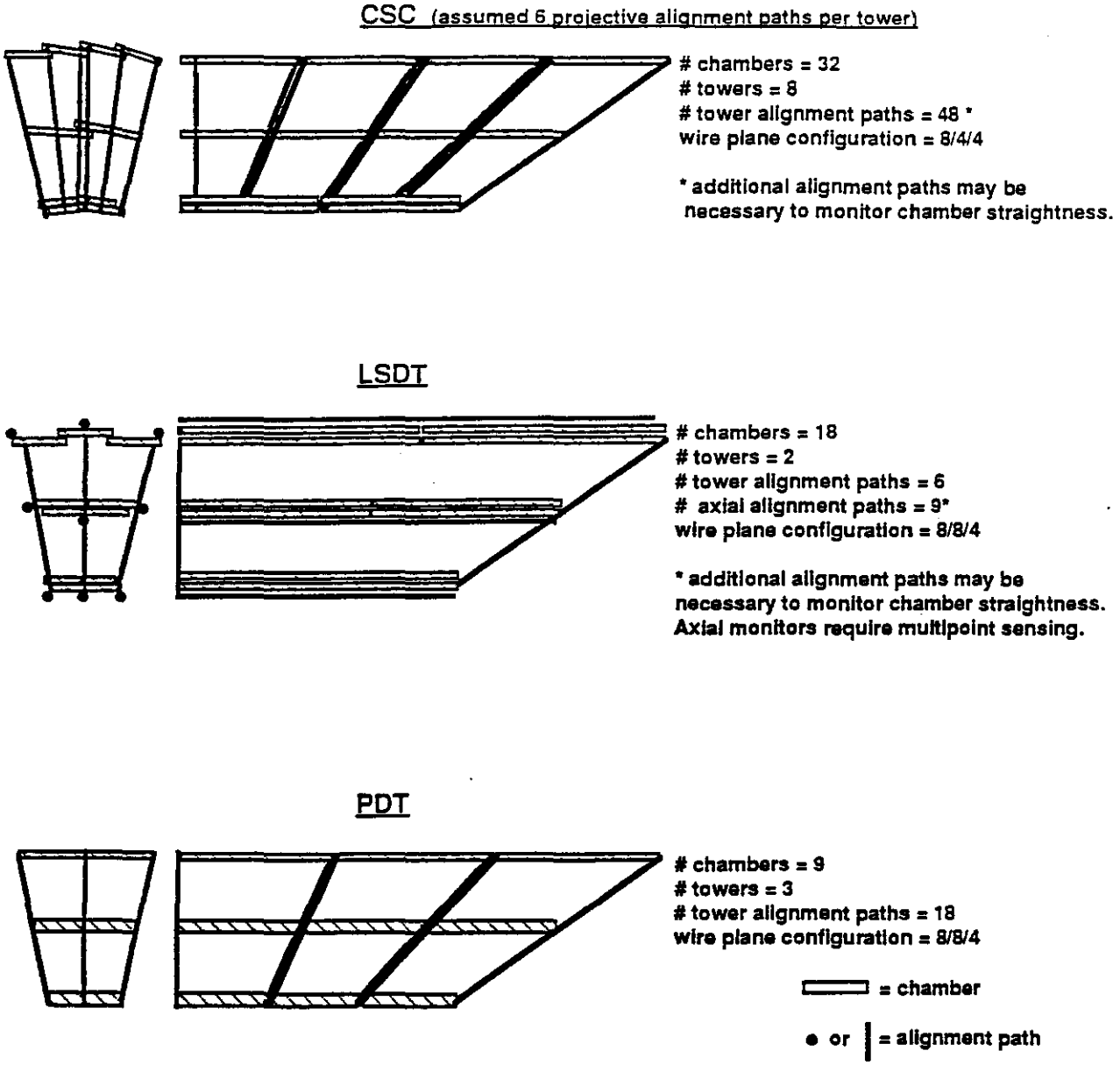

Figure 7.2.1-1. Sector configuration comparison

7.0 Engineering comparison

From a mechanical engineering perspective each of the muon chamber technologies offer very different approaches. Precision wire or strip support mechanisms, alignment strategies, structural characteristics of the chamber assembly, assembly sequence, cost and other characteristics are quite different for each option even though the basic precision measurement requirements are similar. The details of these designs were presented in the previous sections. In this section a comparison of the engineering concepts are summarized to provide visibility into the relative strengths and weaknesses of each design. First a numerical table is presented to quantitatively compare the options in several different key categories. The following sections describe in a more qualitative manner how the designs differ relative to one another and which design have noteworthy strengths or weaknesses in each of the main topics of review.

7.1 Table summary

	CSC	LSDT	PDT	RPC
Max. chamber weight - kg	100	250	470	92
Total chamber weight - kg	117,000	126,400	55,000	20,560
Maximum chamber width - m	1.32	1.2	3.46	3.3
Maximum chamber length m	3.506	7.65	5.0	3.8
Maximum chamber thickness - m	.124	.22	.40	.03
# chambers/sector (1/16)	32	18	9	9
Total # chamber	1024	576	288	288
Inactive chamber edge zone - m	not defined	.065		.04
Phi overlap capable	Yes	Yes	Yes	Yes
Inactive chamber end zone (not including alignment)- m	0.01	0.015		.04
Projected wire-to-wire (strip-to-strip) placement accuracy (random) - microns	50	20	20	1000
Total power dissipation(internal to magnet)- W	100,000	10,000	30,000	NA
Proven performance with non-flammable gas	yes	yes (9.5% isobutane)	yes	no
Operating gas pressure - inches of water	0.1	0.1	30 - 60 (psig)	.25
Total gas volume - m^3	60	456	576	10.9
Total # electronic channels	1,000,000 (with multiplexing	110,000	114,000	33,000
Total material cost - K$	8597	11341	6533	1521
Total labor cost - K$	9520	7949	9322	3417
Total cost - K$	17847	19290	15855	4938

Table 7.1-1. Engineering parameter table

7.2 Design, manufacture and assembly

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Presentation by:

M. Marx

M. Marx

FIRST STEP OF DECISION PROCESS

- PRESENTATIONS
- EXPERT INPUT
- DISCUSSIONS & CONSENSUS

EXPERTS → "ALL TECHNOLOGIES WILL WORK"

RATINGS

BARREL

1) LSDT STAND ALONE
2) LSDT + RPC ⟺ CSC
3) PDT + RPC

END CSC

Major Reasons

- Preference for LS vs High P (Drift Time, Pressure ....)
- Preference for Integrated Solution (p, z, t_0, Trigger)

→ Defines work and priorities for next month

"BASELINE 2"

Major Issues to be Resolved this month

1) Relative Electronics Costs

2) Relative Mechanical System Costs

3) LSDT - viability of Korytov scheme
Trigger, t_0
- chamber support + alignment
↳ structure
- demonstrate full 100μm σ

4) RPC - demonstrate plastic high rate device

5) CSC - reduce barrel chamber/channel count
- demonstrate < 100μm σ

6) CSC, LSDT - acceptance, resolution
- edges, frames, overlap .....
- alignment

7) Complete TTR Program (+ RDS)
- check PDT in LS mode

→ ALL INPUT EVALUATED AT BNL

→ FINALIZE DECISION

(ALSO MOVING TO SECTOR STRUCTURE)

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Presentation by:

K. Morgan

K. Morgan

Tracker Status and Progress Towards TDR

- Taiwan Report
- Integration Issues
  - Support Membrane
  - Material in Additional Cables
- Progress on Material in Tracker
- TDR

10/8/92-KM

Taiwan

- August visit
3 representatives from ITRI (Industrial Technology Research Institute) 5500 Employees
300 M$ Annual Budget
11 Labs or Institutes

David Hsing, Director of ERSO (Electronics Research + Service Organization)

Jong Liu, Manager of Material Science Research Laboratory (MRL)

Larry Tang, Manager of Precision Machining Facility (MIRL)

- Currently a delegation of 9 physicists and engineers in Taiwan for detailed discussions with their homologues to evaluate capability to undertake the construction of the tracker in Taiwan.

10/8/92-KM

Collaboration with Taiwan

ACADEMIA SINICA

Research group of S.C. Lee et al

ITRI Industrial & Technical Research Institute
5500 Employees, ~ 300 M$ Annual Budget
Has 11 Labs or Institutes

ERSO - Electronics Research Service Org.
MRL - Material Science Research Lab
MIRL - Precision Machining etc.
⋮

TAIWANESE UNIVERSITIES

Students, research groups

SCOPE - We are proposing ~ 50 M U.S.$ collaboration

Note from T.T. Lee. Consult at this time.

U.S./Taiwan Project Oriented Collaborative Teams

Project	U.S.	Taiwan
IPC Frontend Electronics Preamp - Shaper	Paul O'Connor Brookhaven	Engineer 1 ERSO
IPC Analog Buffer Switched Capacitor Array	Chuck Britton Oak Ridge	Engineer 2 ERSO
IPC Analog to Digital Pipeline	Gunther Haller SLAC	Engineer 3 ERSO
Silicon Front End Electronics Preamp, Shaper	S. Hahn Los Alamos	Engineer 4 ERSO
Silicon Digital Pipeline	Brad Cooke Los Alamos	Engineer 5 ERSO
Silicon Microstrip Detector Wafers	Jim Brau & U. of Oregon Engineer	Engineer 6 ERSO
IPC Chamber Composite Boards	Will Emmet Yale University	Engineer 7 MRL
Support Structures Carbon, Metal Matrix Composite	R. Barber, T. Thomson Los Alamos	Engineer 8 MRL
Tooling for Composite Lay-ups	Barber, Emmet	Engineer 9 MIRL

U.S./Taiwan Project Oriented Collaborative Teams

Step 1: September - October 1992

U. S. team members visit Taiwan to meet ITRI counterparts

Discuss aims and scope of problem

Step 2: October 1992 - October 1993

Longer visits back and forth at team members' convenience

Develop conceptual designs

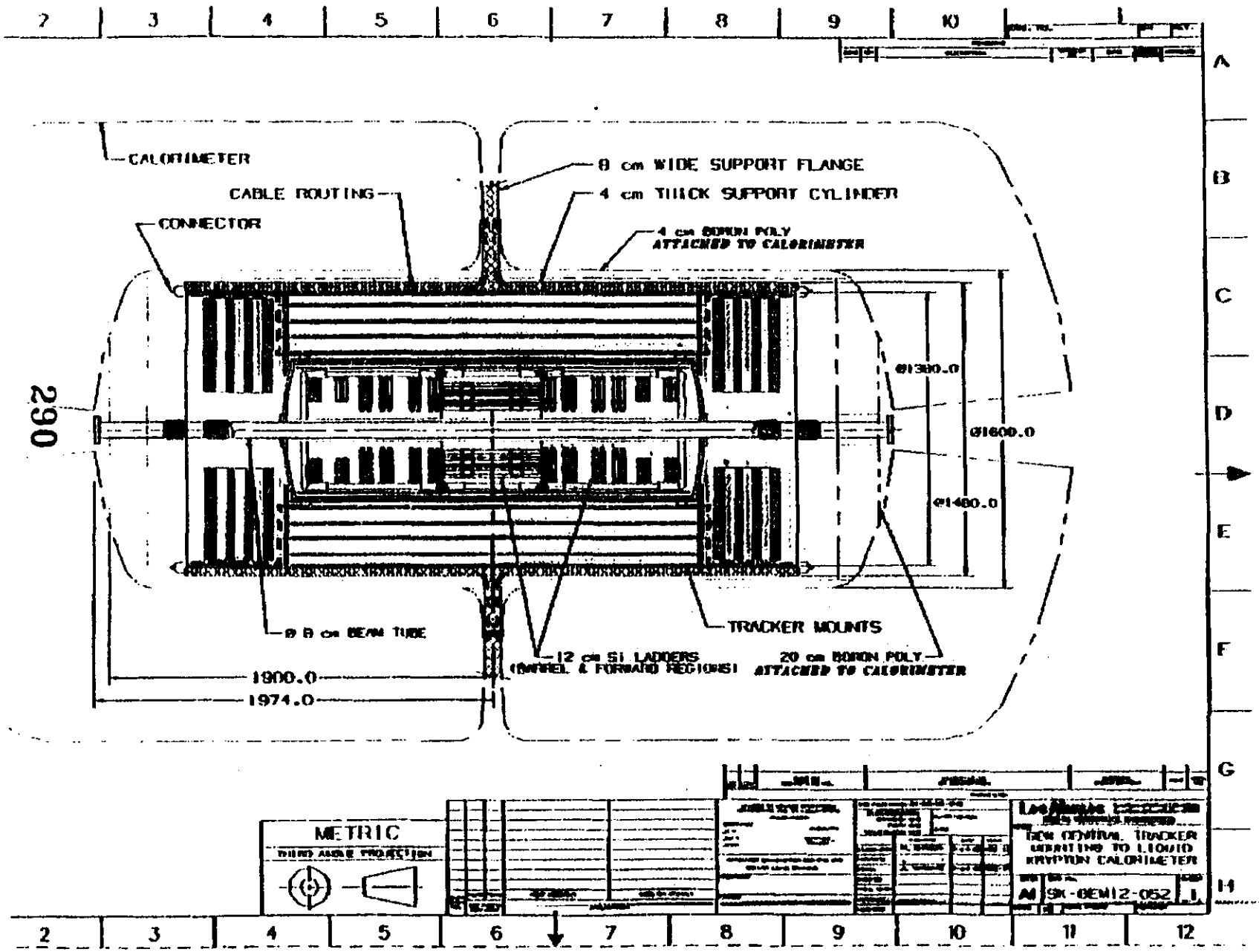
Implement detailed design for fabrication in Taiwan

Step 3: October 1993 - October 1994

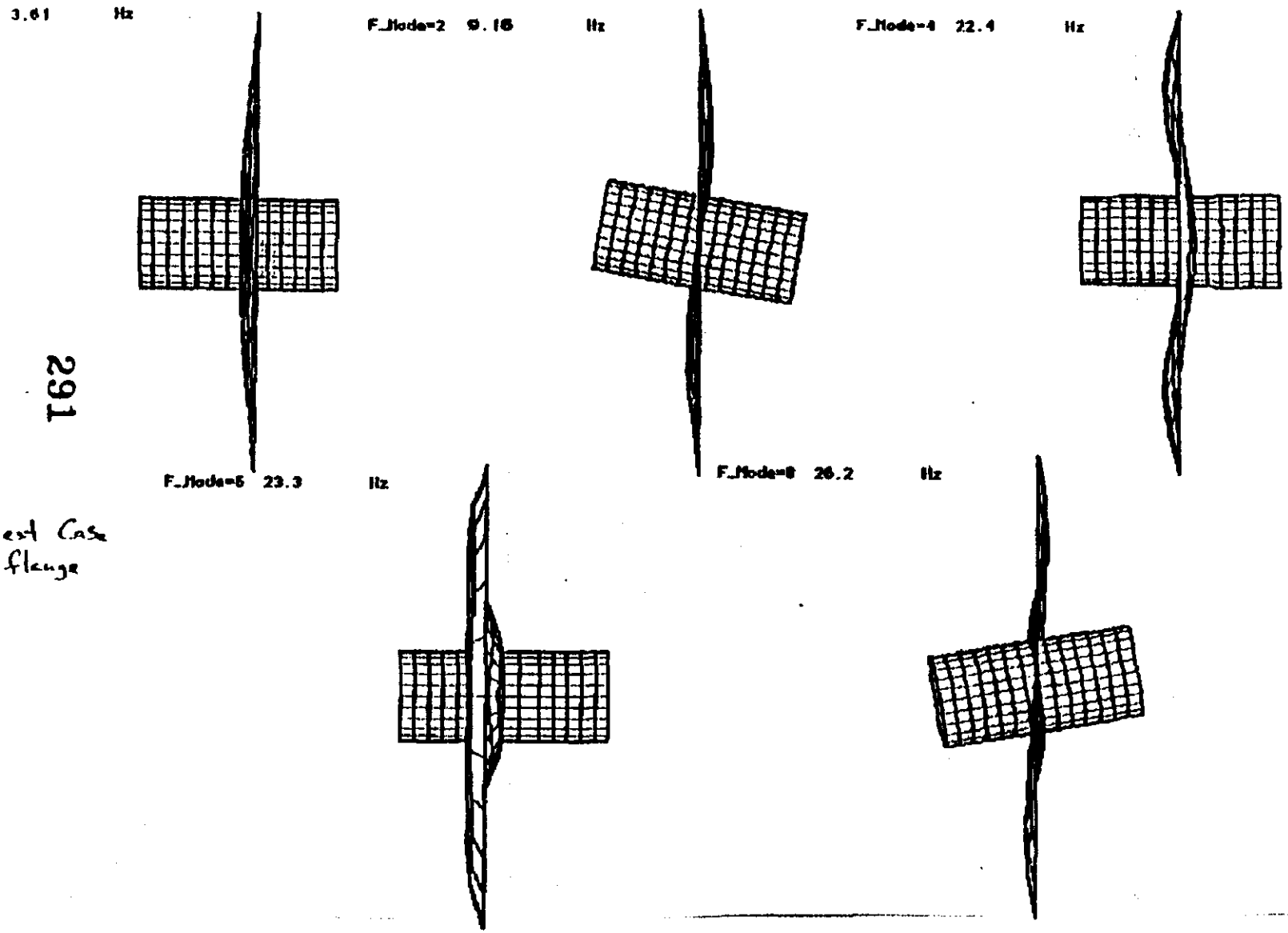
Build first prototypes in Taiwan or elsewhere as necessary

Test prototypes in Taiwan and U.S.

Step 4: ...

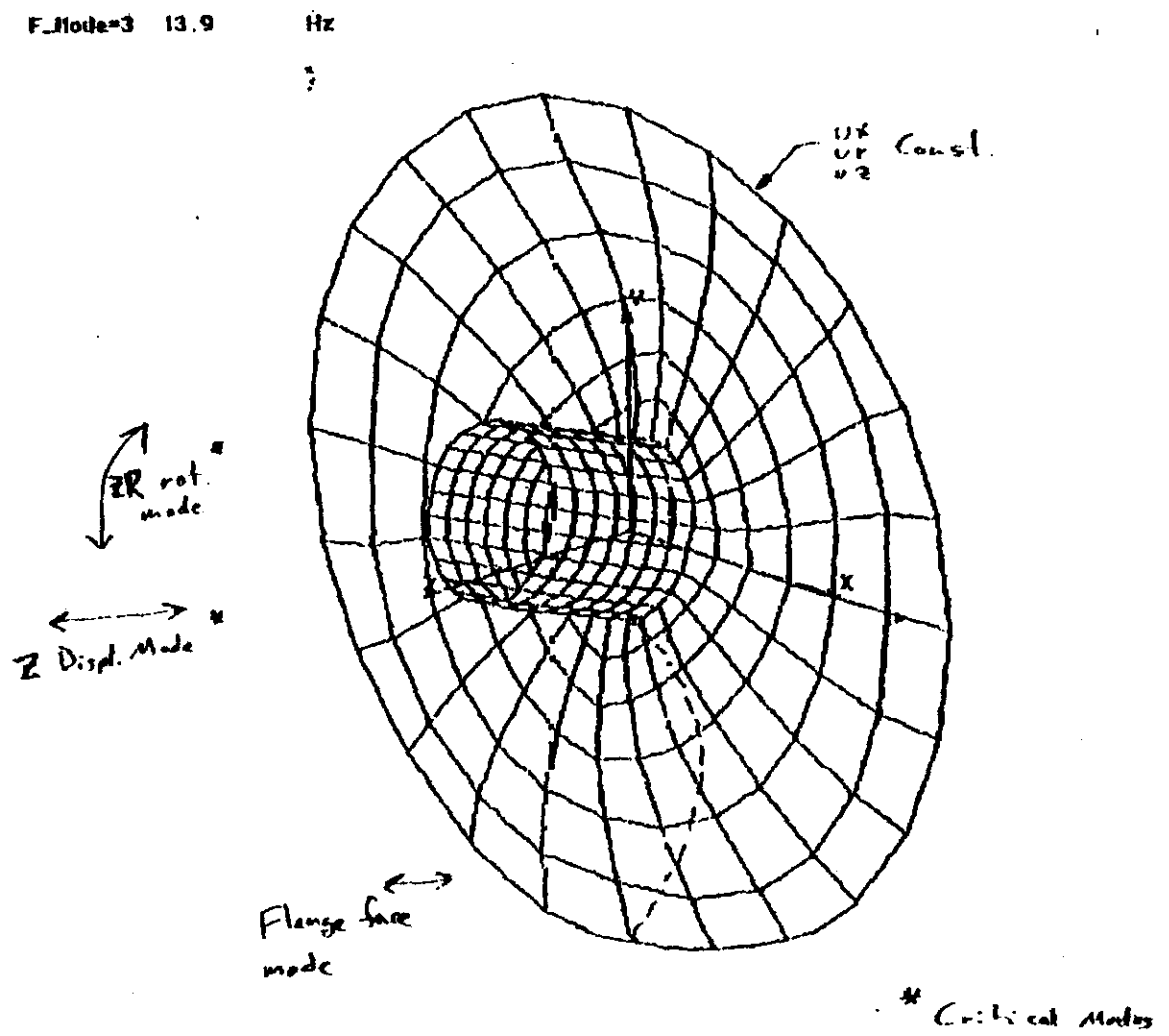

CALORIMETER
CABLE ROUTING
CONNECTOR
8 cm WIDE SUPPORT FLANGE
4 cm THICK SUPPORT CYLINDER
4 cm BORON POLY
ATTACHED TO CALORIMETER
Ø1300.0
Ø1600.0
Ø1480.0
Ø 8 cm BEAM TUBE
TRACKER MOUNTS
12 cm SI LADDERS
(BARREL & FORWARD REGIONS)
20 cm BORON POLY
ATTACHED TO CALORIMETER
1900.0
1974.0
METRIC
THIRD ANGLE PROJECTION
SX-DEM12-052

Support Structure Frequencies and Modes*



ext Case flange

Central Tracker Support



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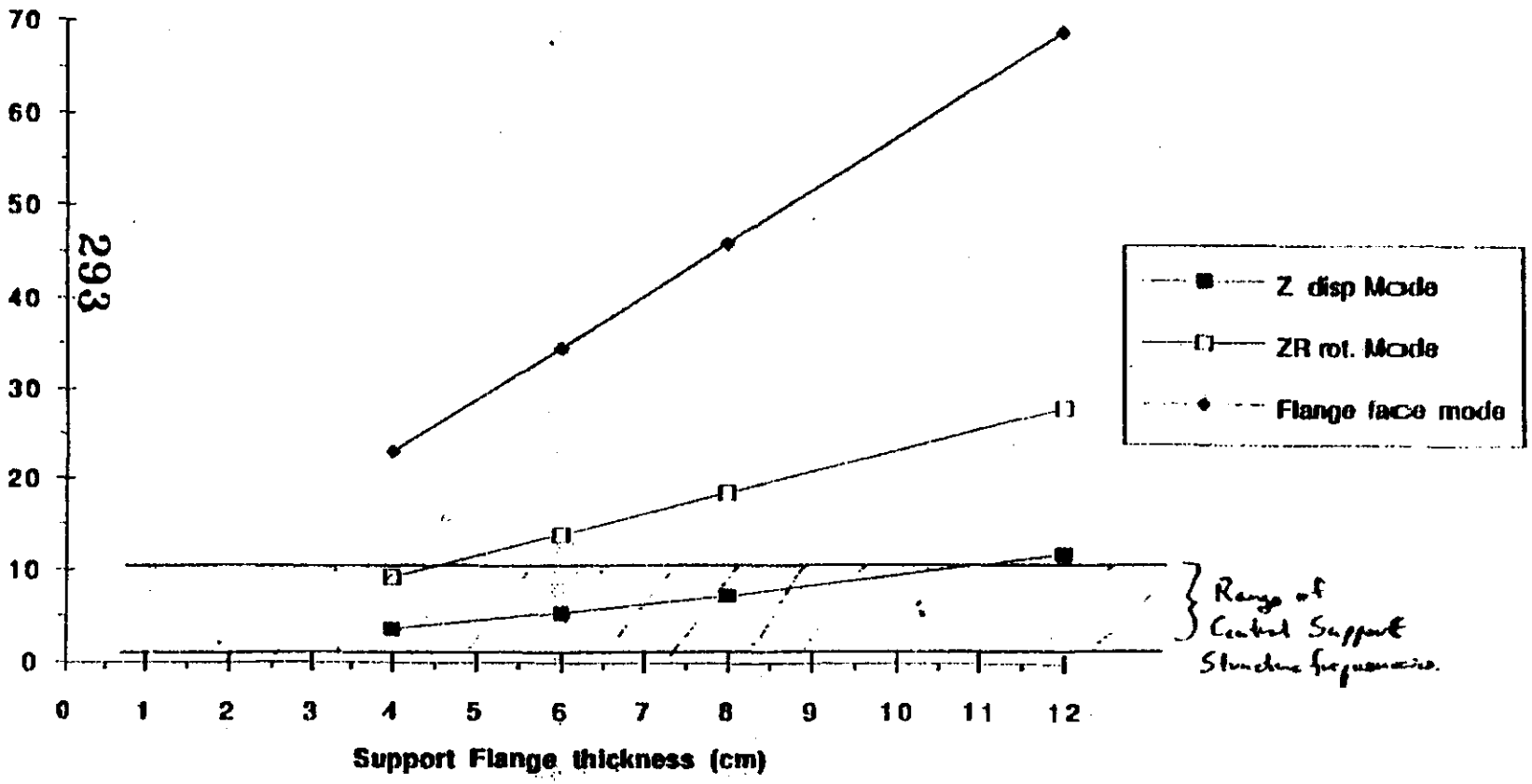
Flange thickness vs. Natural Frequency



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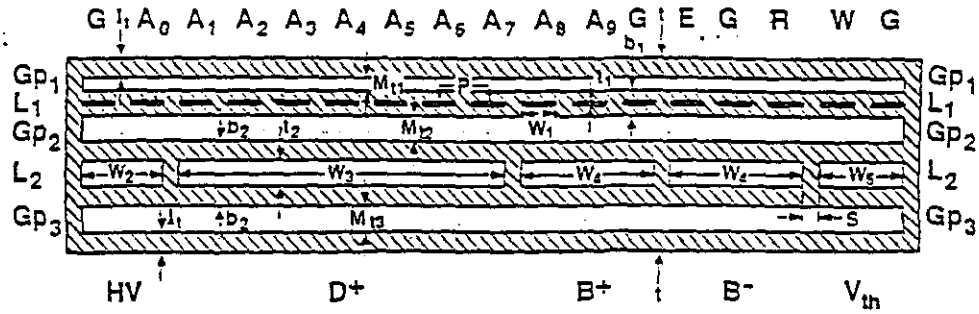
Power/Signal Cabling
Cross Section



G = Ground
A_0-A_9 = Address/Data Bus
E = Enable
R,W = Read, Write Enable

Gp = Ground Plane
HV = High Voltage
D+ = Digital Voltage
B+,B- = Analog Supply
V_{th} = Analog Threshold

Figure 8. Cabling harness cross section

Cable Assembly

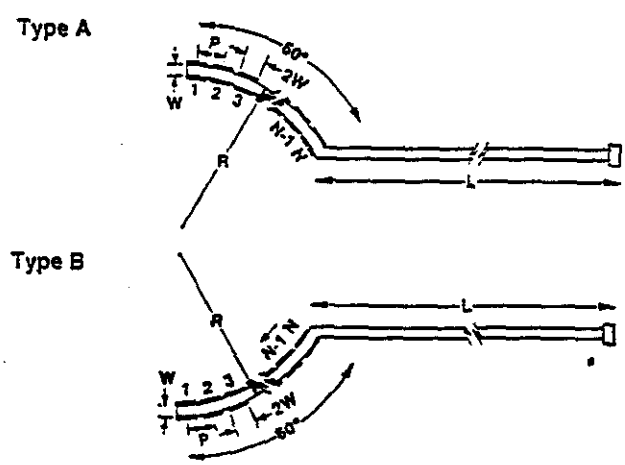


Figure 9. Barrel cable harness assembly

RL, extra cables

				Totals	Totals
	thickness, cm		fraction of RL	Conductor +	cable with
				Insulator	support cylinder
insulator	0.24		0.00836237		
copper	0.185		0.12937063	13.77%	17.32%
aluminum	0.303		0.03091837	3.93%	7.48%
support cyl.	2 skins=0.635		0.0254		
	ribs=7.5% gap(3.365)		0.010095		
		total	0.035495		
	Radiation length				
mylar	28.7				
copper	1.43				
aluminum	9.8				
graphite	25				

9/24/92km

TDR

Draft exists since February

Decisions on final Si details next week.

Simulations group in high gear to produce results with most recent configuration.

Most difficulty will be the result of trying to cut the current 200 pages by half.