GEM TN-92-251

Collaboration Council Meeting - SSCL

December 10, 1992

Abstract:

Agenda and presentations of the GEM Collaboration Council Meeting held at the Holiday Inn in Duncanville, Texas on December 10, 1992.

Collaboration Council Agenda
December 10, 1992

9:00	Announcements, scheduling of future Council meetings	Yost
9:20	News of the GEM Collaboration, feedback from the PAC meeting	Barish
10:00	Progress in Calorimetry	Willis
10:45	TDR Status	Newman
11:00	Break	
11:15	Project Managers Report	Sanders
11:30	Physics Simulation	McFarlane
12:00	Lunch	
1:00	Muon Systems Progress	Taylor, Golutvin, Nimblett
1:20	Tracker Status	Baltay
1:40	Triviality	Lane
2:00	Test Results of the Indiana University GEM IPC Prototype	Bower
2:20	Dynamic Range at Zero Suppression and the GEM Calorimeter Readout	Prebys
2:40	Precision Timing in a Liquid Ionization Calorimeter	Takai
3:00	Adjourn	
3:15	Executive Committee Meeting	

gem

γeμ

Presentation by:

George Yost

10st

GEM Collaboration Council

Please be sure to register.

Next meetings Feb 4
March 18

TOR DUE APRIL 30.

FOLLOWING THIS – GENERAL COLLABORATION MEETING.

SUGGESTED DATE: THURSDAY MAY 20.

LOOKING FOR VOLUNTEERS TO [illegible] THIS.

U.S. WEST COAST?

FOLLOWING THIS: PAC REVIEW END JULY

∴ SUGGEST MID JULY: 8, 15, 22

DATE T.B.A. PLEASE SEND ME ANY CONFLICTS.

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Presentation by:

B. Barish

Barish

GEM News
12/10/92

- PAC Meeting Results

  TDR April 30
  Review May 24-29
  Summer PAC July 31 - Aug 6

- Magnet RFP almost out the door
- U.S./Russia Cooperation (Sanders)
- Chinese "Leading Committee"
  Lin visit next week
- Korean Delegation [redacted] Jan/Feb visit
- Baseline 2 'freeze?'
- TDR Organization (Newman)
- R+D/Engineering for FY93

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Presentation by:

W. Willis

Willis

GEM CALORIMETER

BASELINE 2 FOR T.D.R.

IMPROVEMENTS WITH CONTINUITY

- LKR / PB IN BARREL

  σ_{EM} 7.5 → 5.7 ; e/h = LA/Cu

- FINE FRONT EM

  $\sigma_\theta \Rightarrow 39\,mr/E^{1/2}$, π^0 REJECT. 2-3

  KEEP "CLEAN" E.M. ELECTRODES

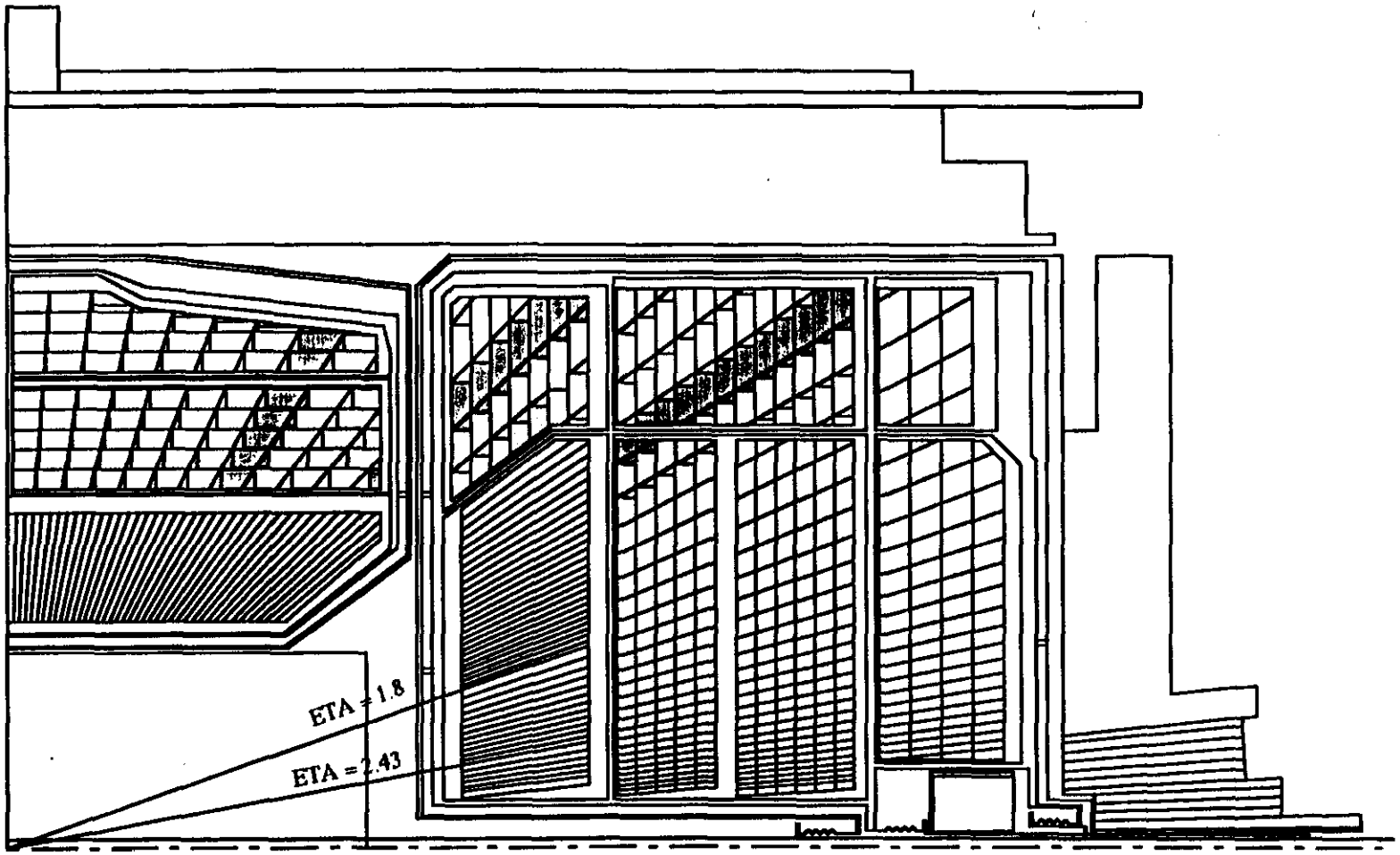
- LIQUID CALORIMETER $\lambda = 12 \rightarrow 6$

- HYBRID PERFORMANCE DESCRIPTIONS ≈ UNCHANGED

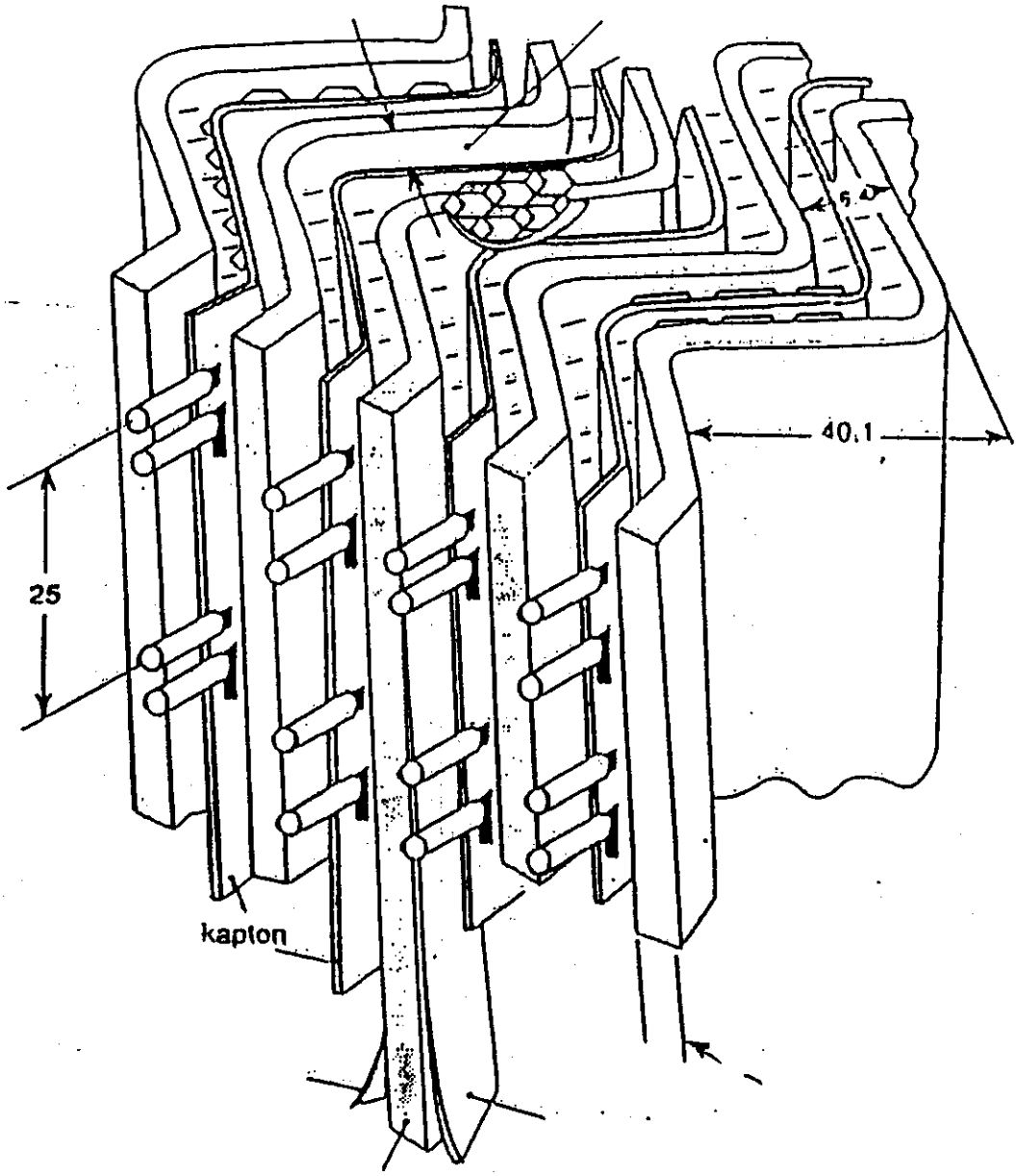
* BEAM PIPE AND NEUTRON CONSIDERATIONS REQUIRE CHANGES IN FORWARD CAL

SEGMENTATION IN ETA: EM = .0261
HADRONIC = .08

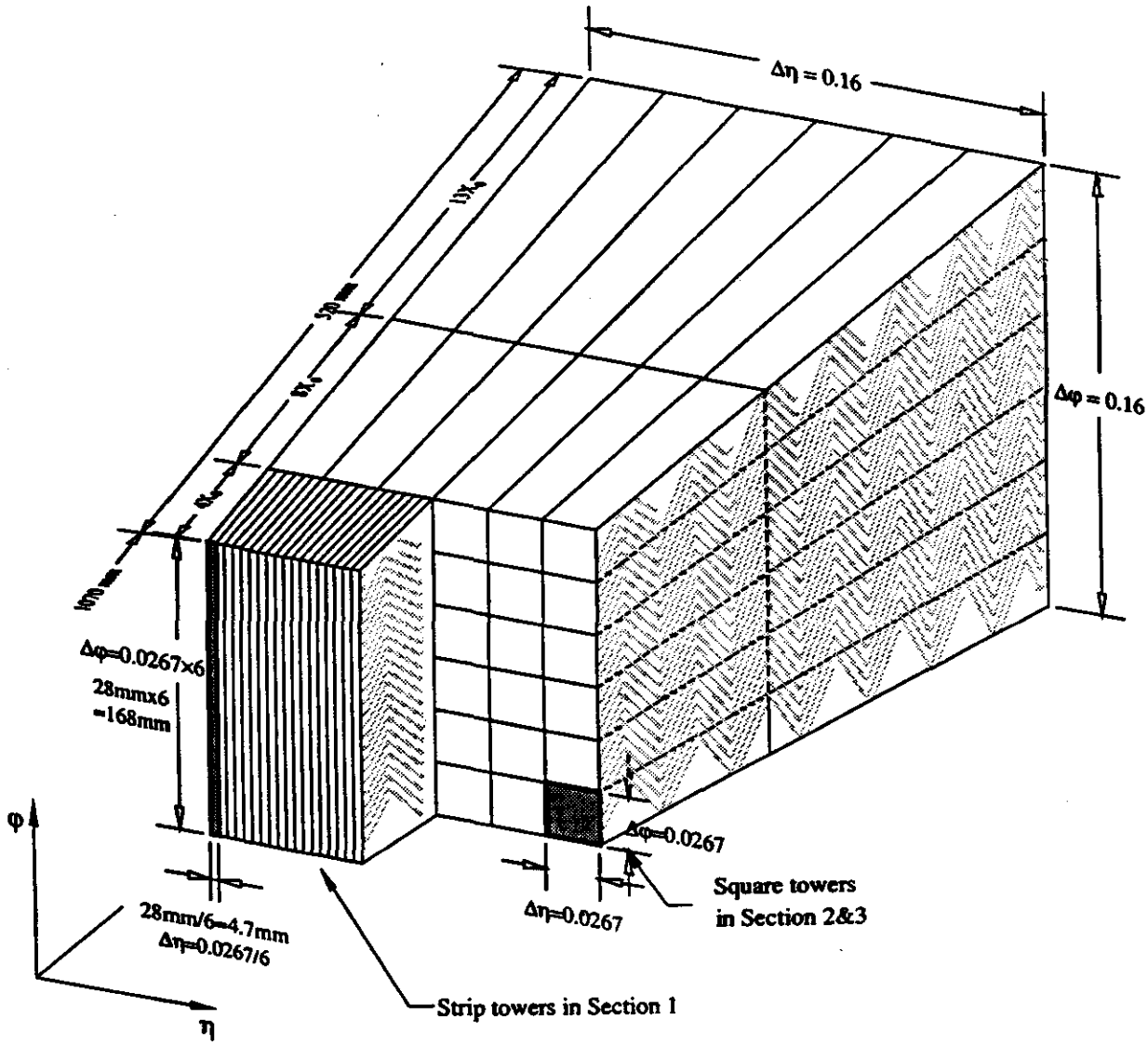
2 CM MINIMUM TOWER



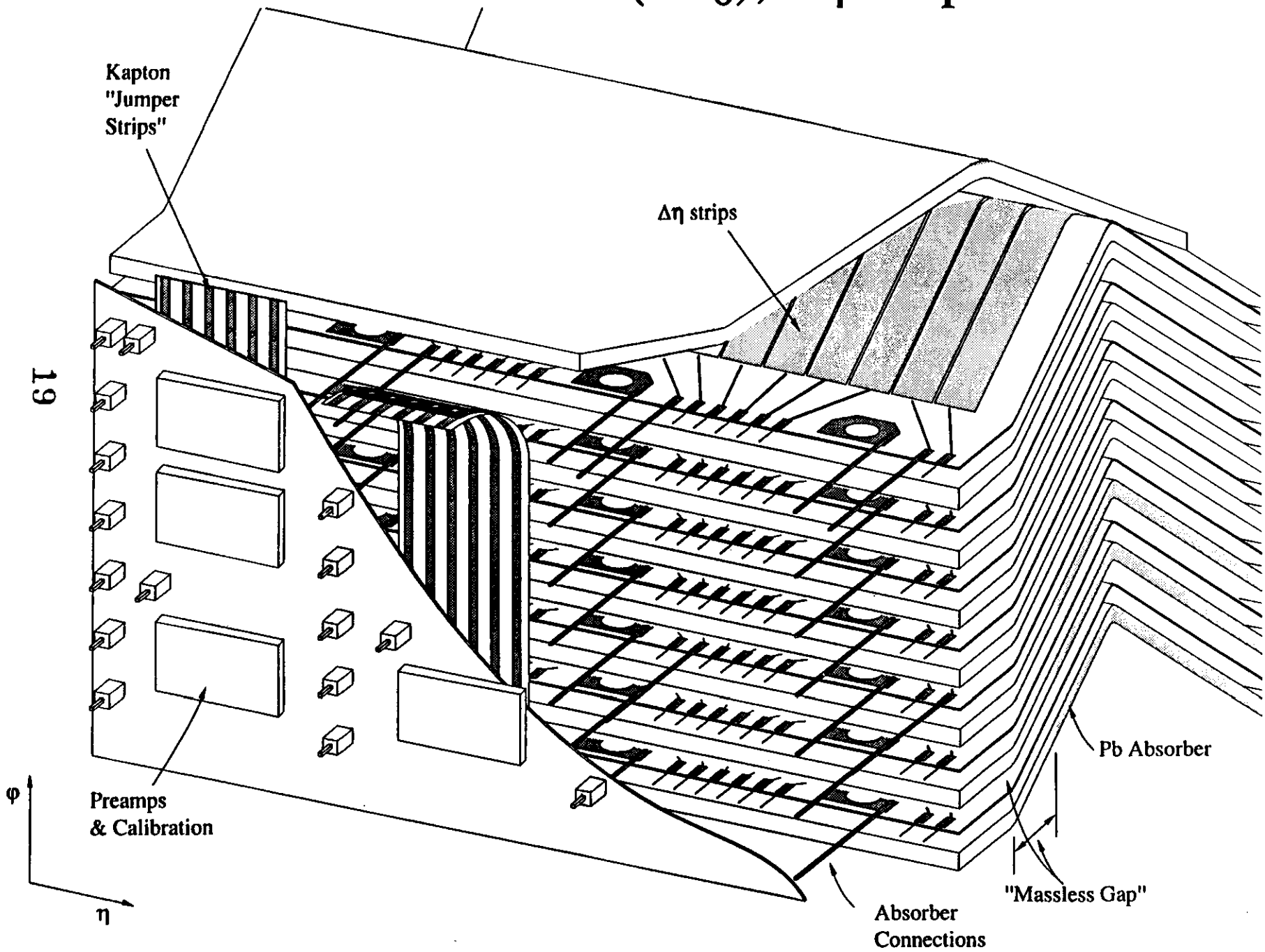
ADAMS:BL2SEG:11/30/92


40.1
25
kapton

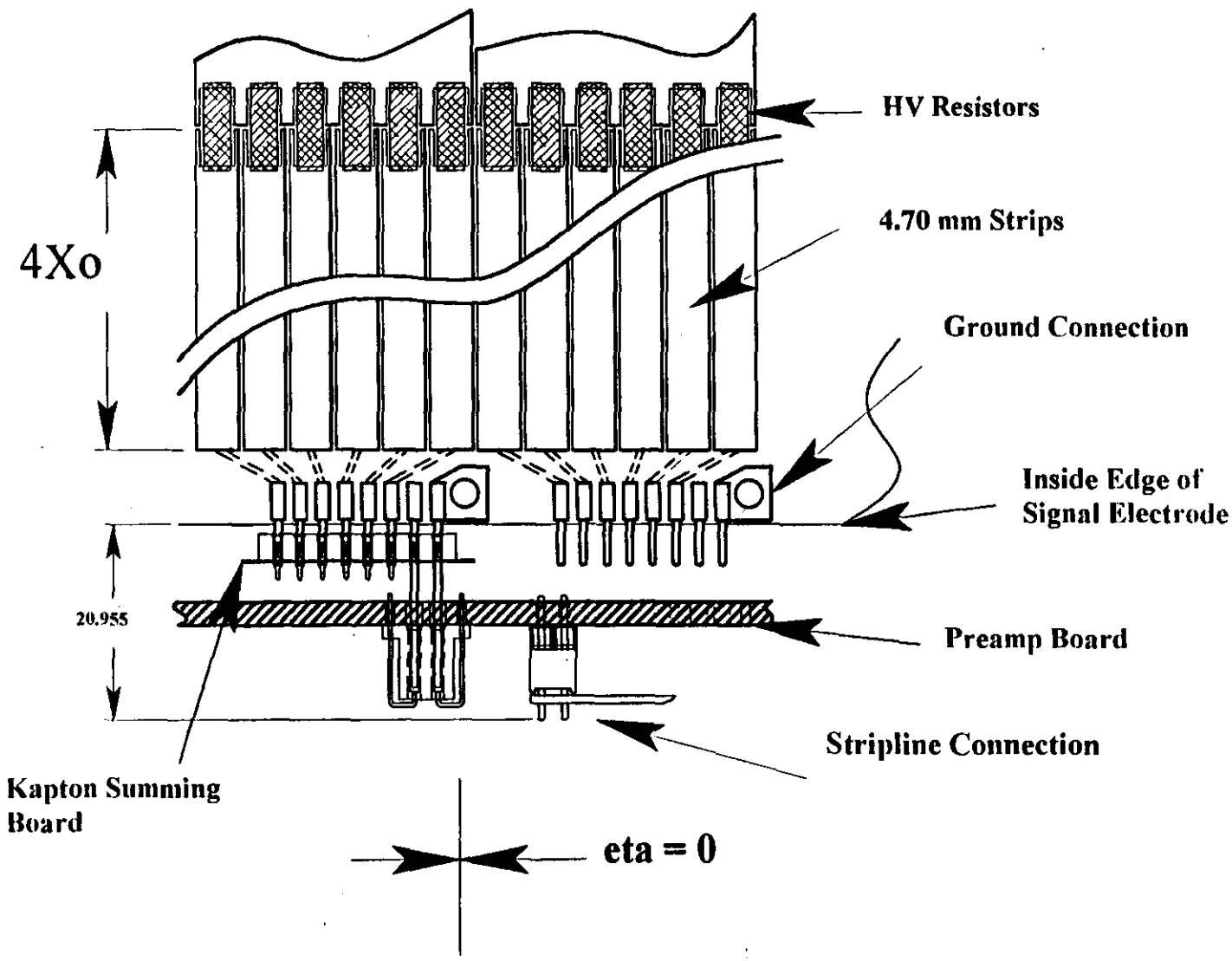
EM Accordion Segmentation



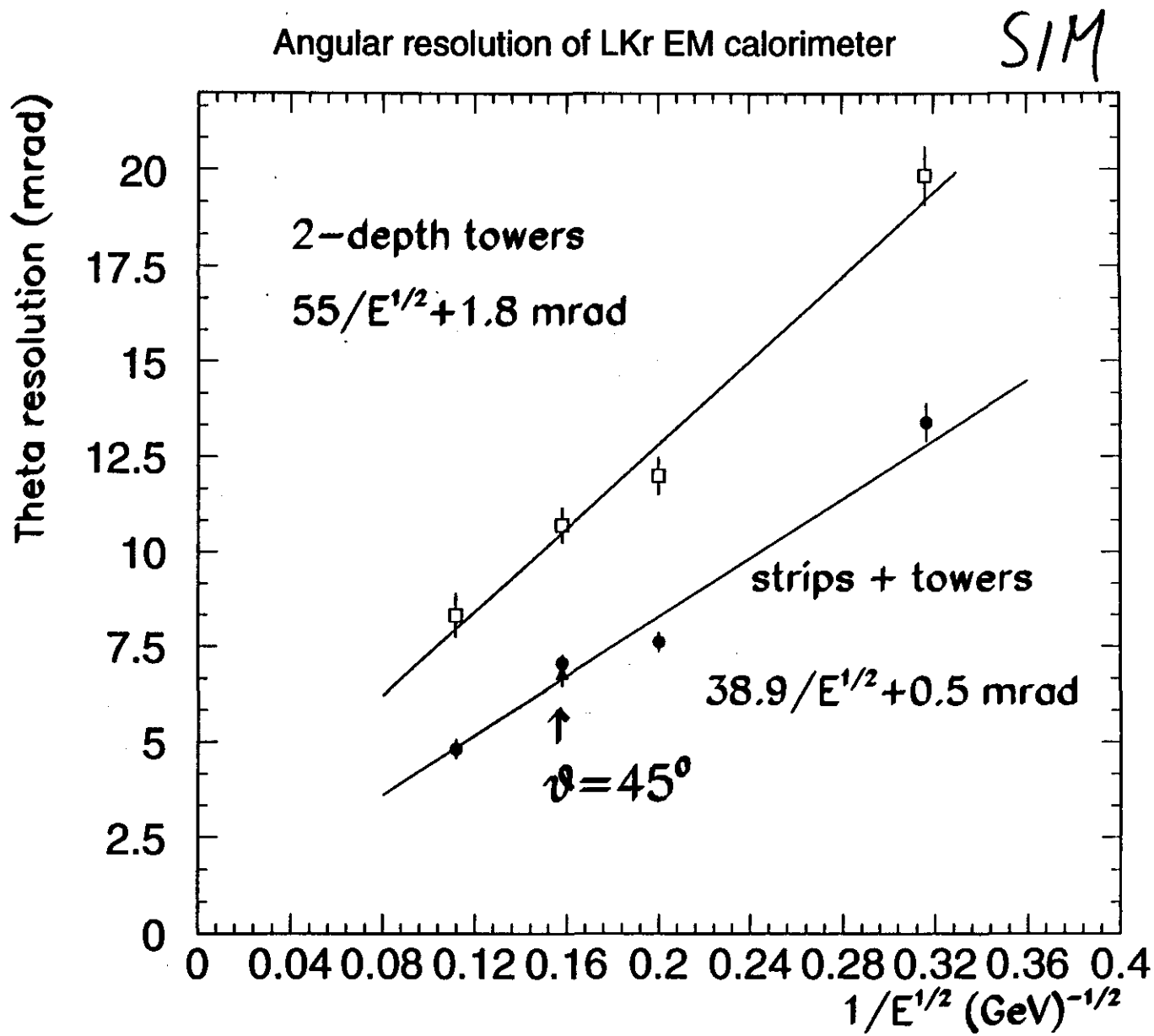
EM Accordion Electrodes
1st Section ($4X_0$), $\Delta\eta$ Strips



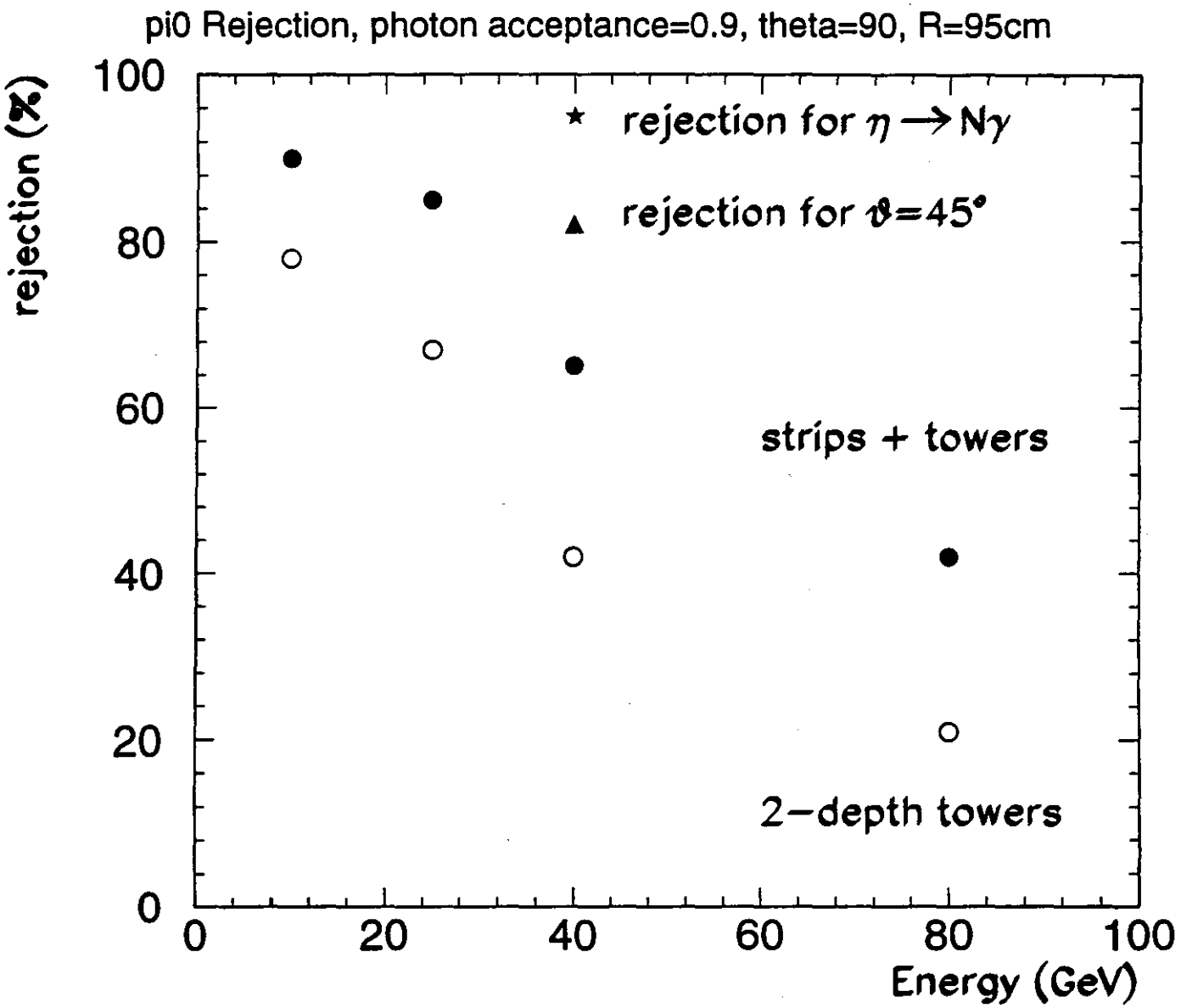
Position Detector

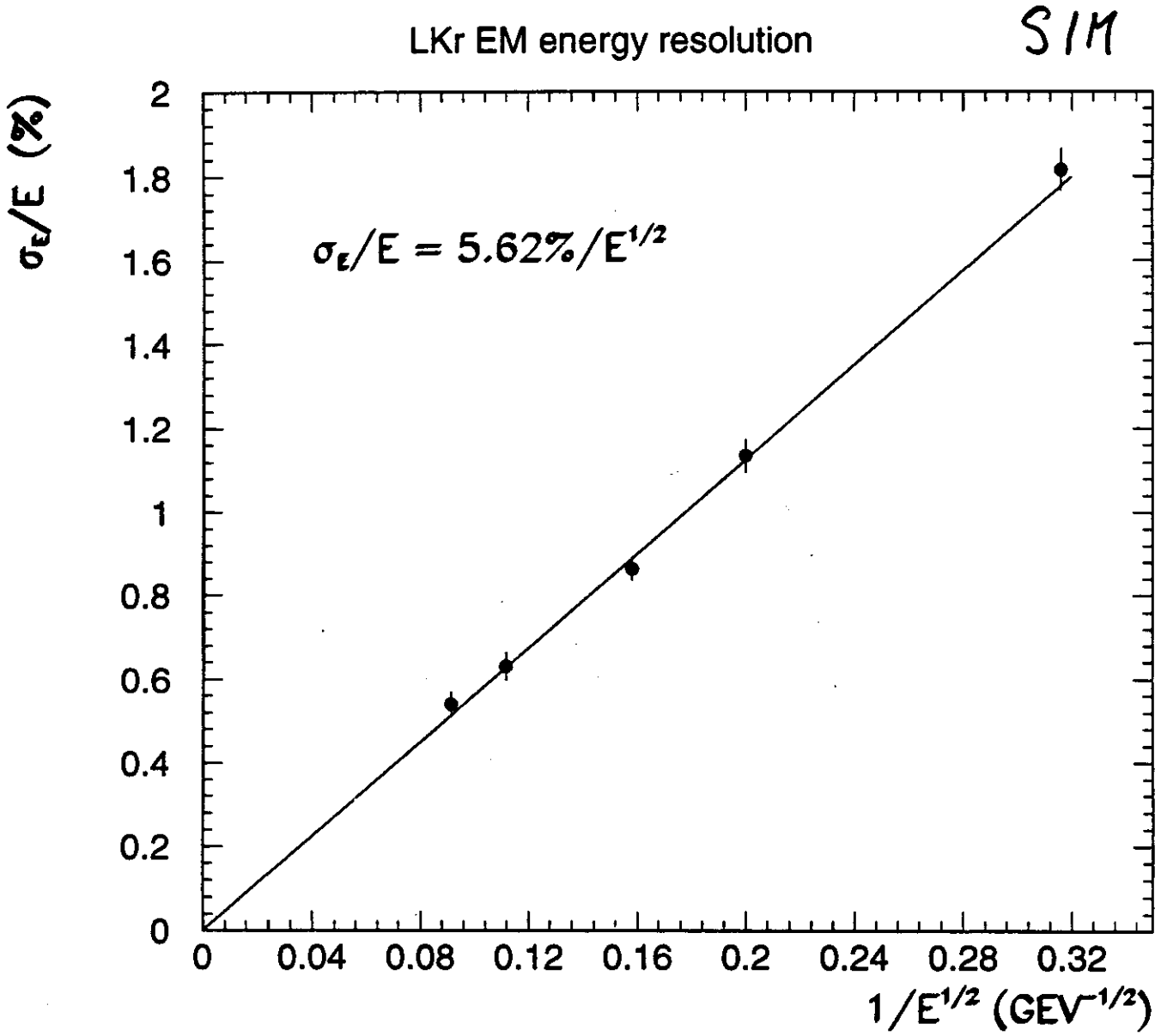


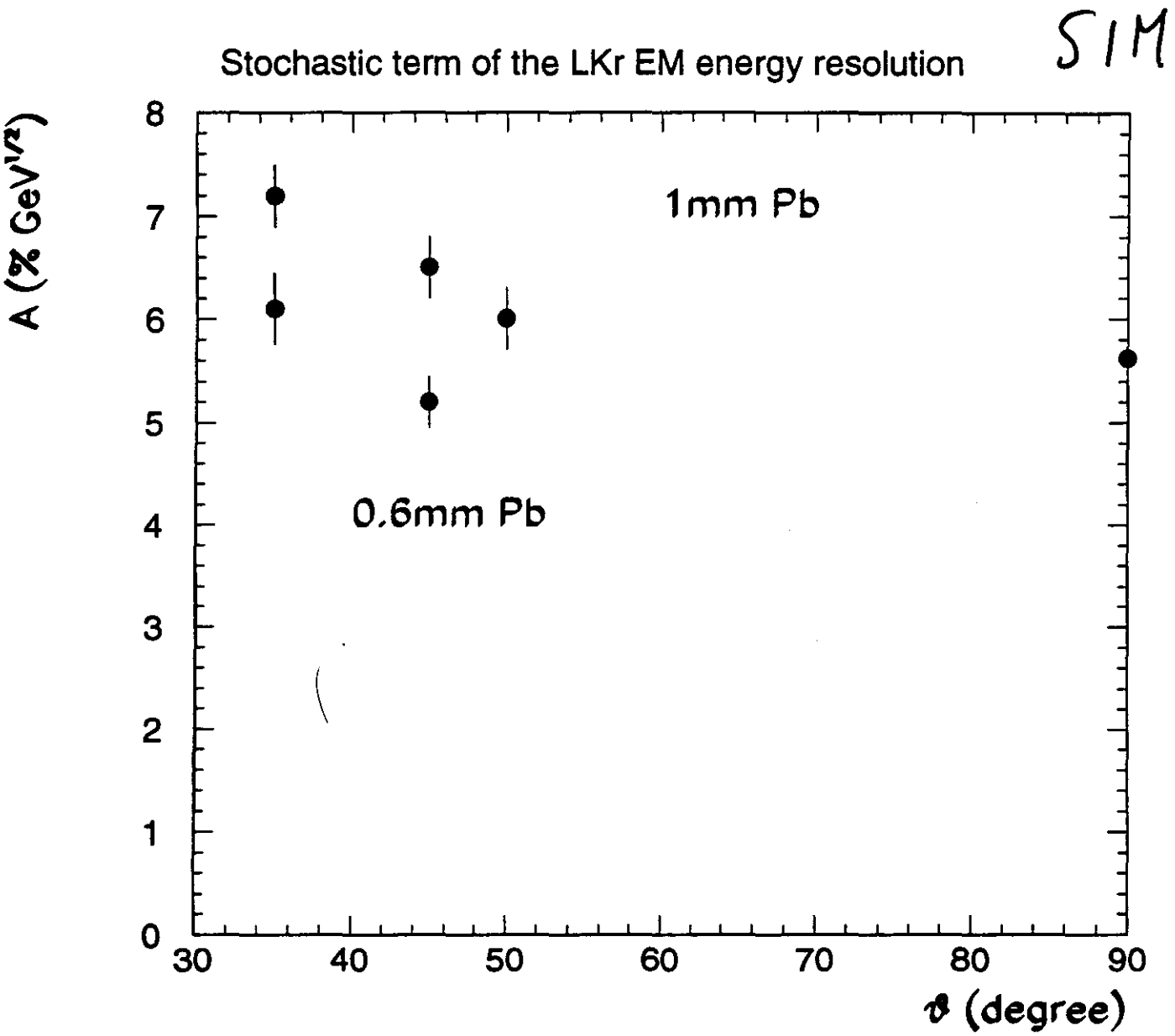
DSM


Angular resolution of LKr EM calorimeter
SIM
Theta resolution (mrad)
20
17.5
15
12.5
10
7.5
5
2.5
0
2-depth towers
55/E^1/2+1.8 mrad
strips + towers
38.9/E^1/2+0.5 mrad
ϑ=45°
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
1/E^1/2 (GeV)^-1/2

SIM


pi0 Rejection, photon acceptance=0.9, theta=90, R=95cm
rejection (%)
100
80
60
40
20
0
0
20
40
60
80
100
Energy (GeV)
rejection for $\eta \rightarrow N\gamma$
rejection for ϑ=45°
strips + towers
2−depth towers


LKr EM energy resolution
SIM
$\sigma_E/E = 5.62\%/E^{1/2}$
σ_E/E (%)
$1/E^{1/2}$ (GEV$^{-1/2}$)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32


SIM
Stochastic term of the LKr EM energy resolution
A (% GeV^1/2)
8
7
6
5
4
3
2
1
0
30
40
50
60
70
80
90
ϑ (degree)
1mm Pb
0.6mm Pb

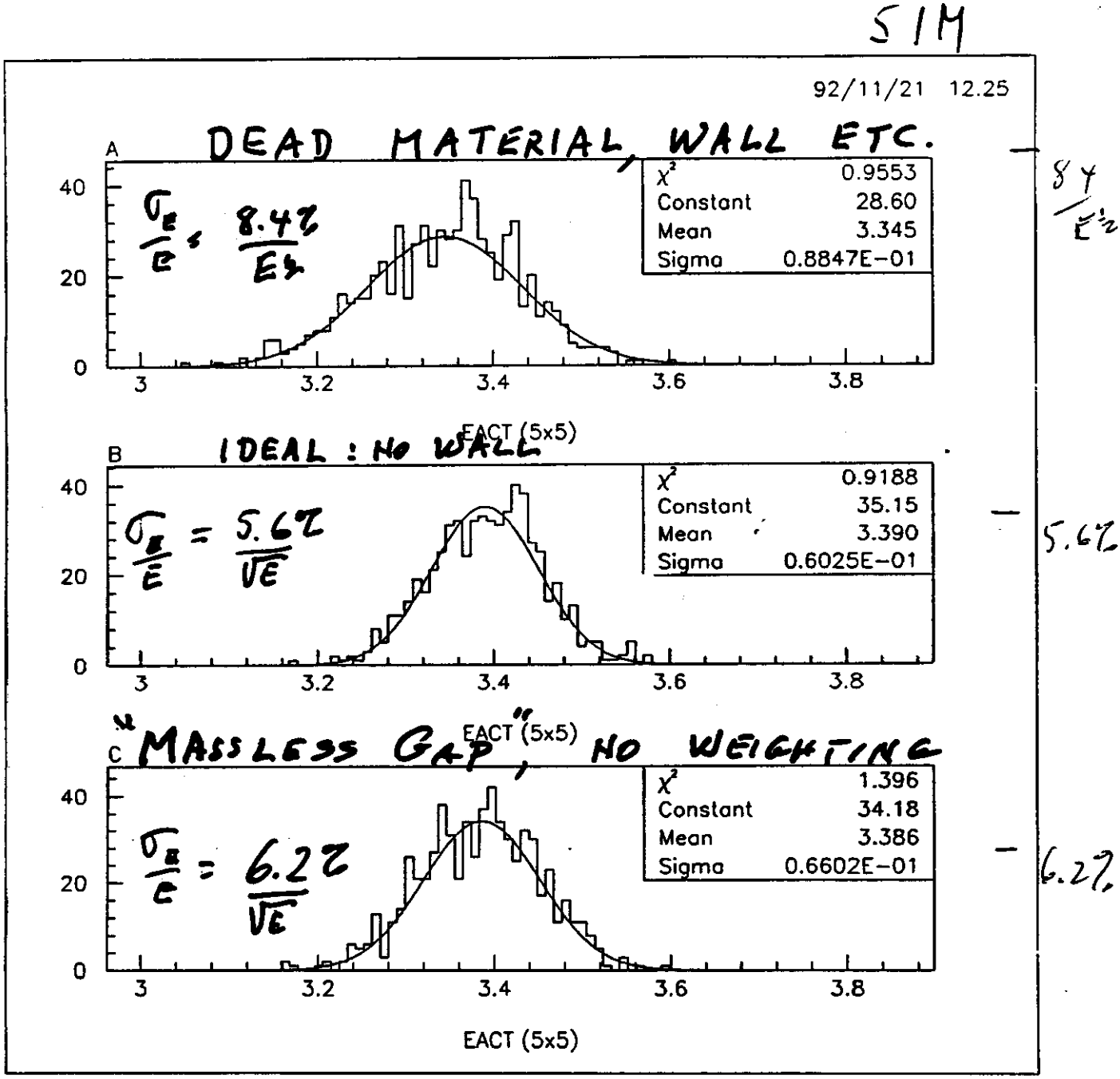


Figure 2: Energy in active medium for 10 GeV photons at $\theta = 45°$,
upper: with dead material but no massless gap;
middle: without dead material;
lower: with dead material and massless gap.

Liquid Krypton Calorimeter Test Results

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], J. Rabel[7], 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]

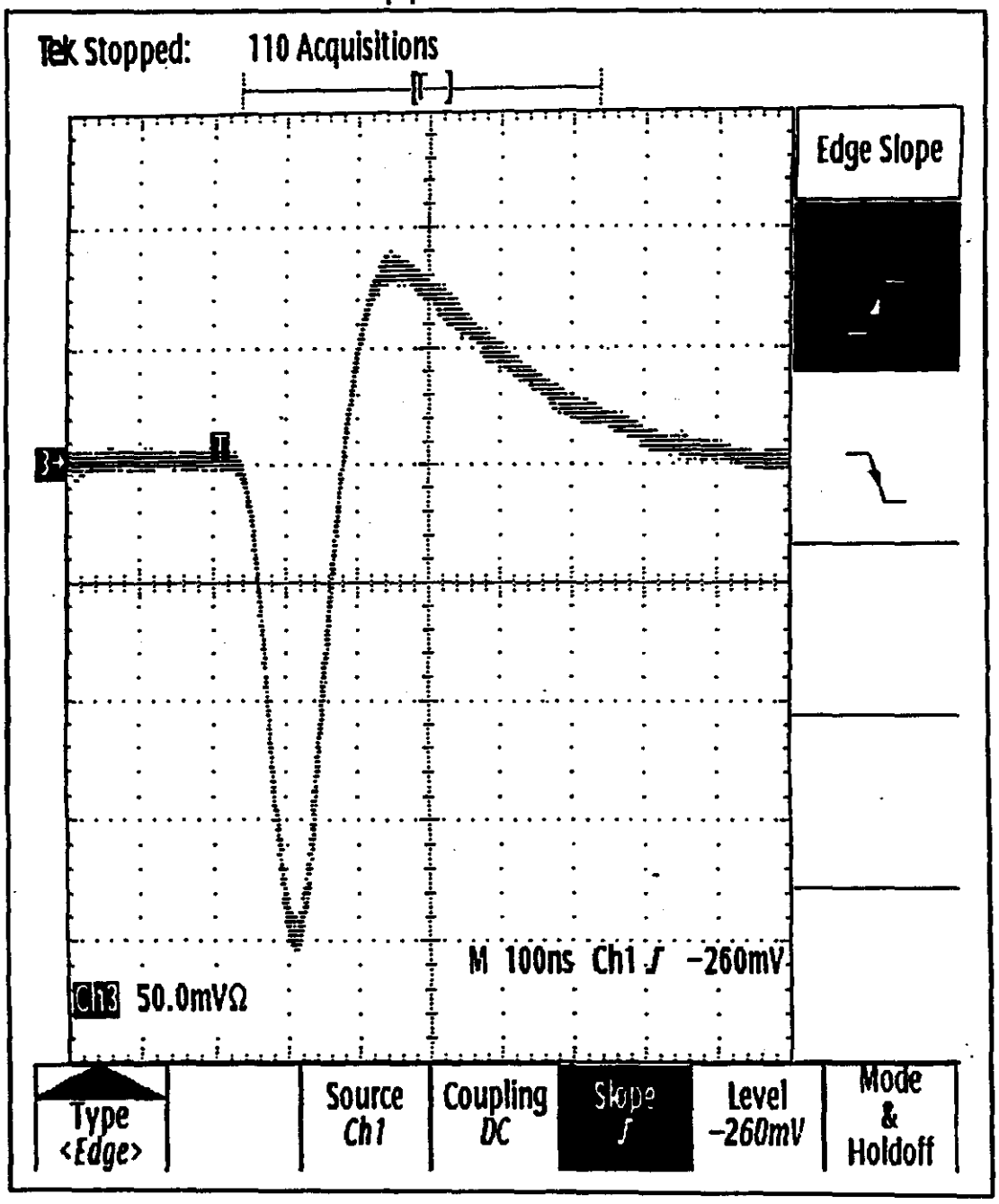
1. Adelphi University, Garden City, NY 11530
2. University of Arizona, Tucson, AZ 85721
3. Brookhaven National Laboratory, Upton, NY 11973
4. Budker Institute for Nuclear Physics, Novosibirsk, Russia
5. Columbia University, New York, NY 15633
6. Oak Ridge National Laboratory, Oak Ridge, TN 37831
7. University of Pittsburgh, Pittsburgh, PA 15260
8. SUNY at Stony Brook, Stony Brook, NY 11794
9. Tel-Aviv University, Tel-Aviv, Israel

On-line Pulse Shape

LKr, 2mm stack, 1.5kV

Beam Momentum = 20 GeV

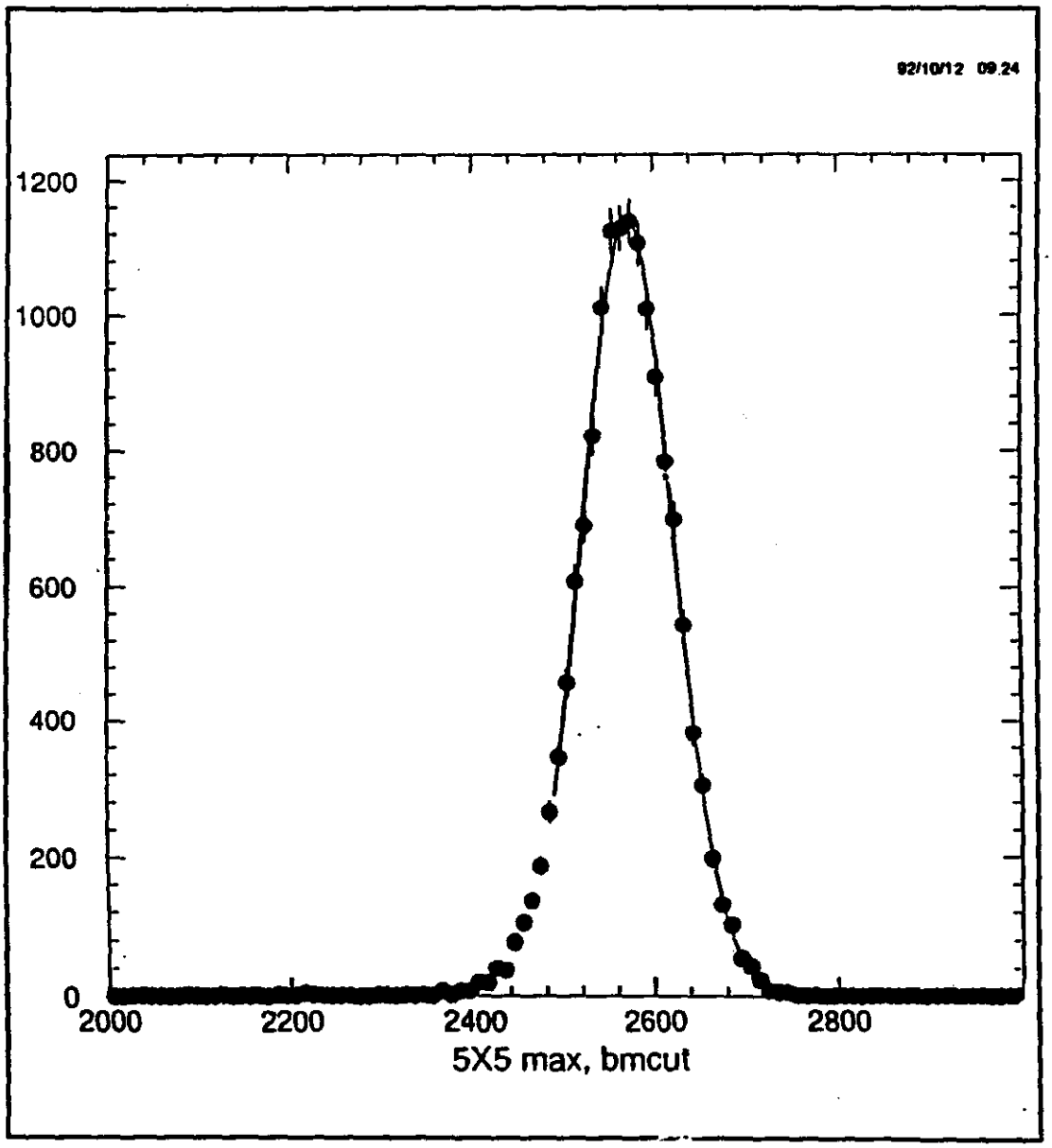
Sum of approx. 150 channels



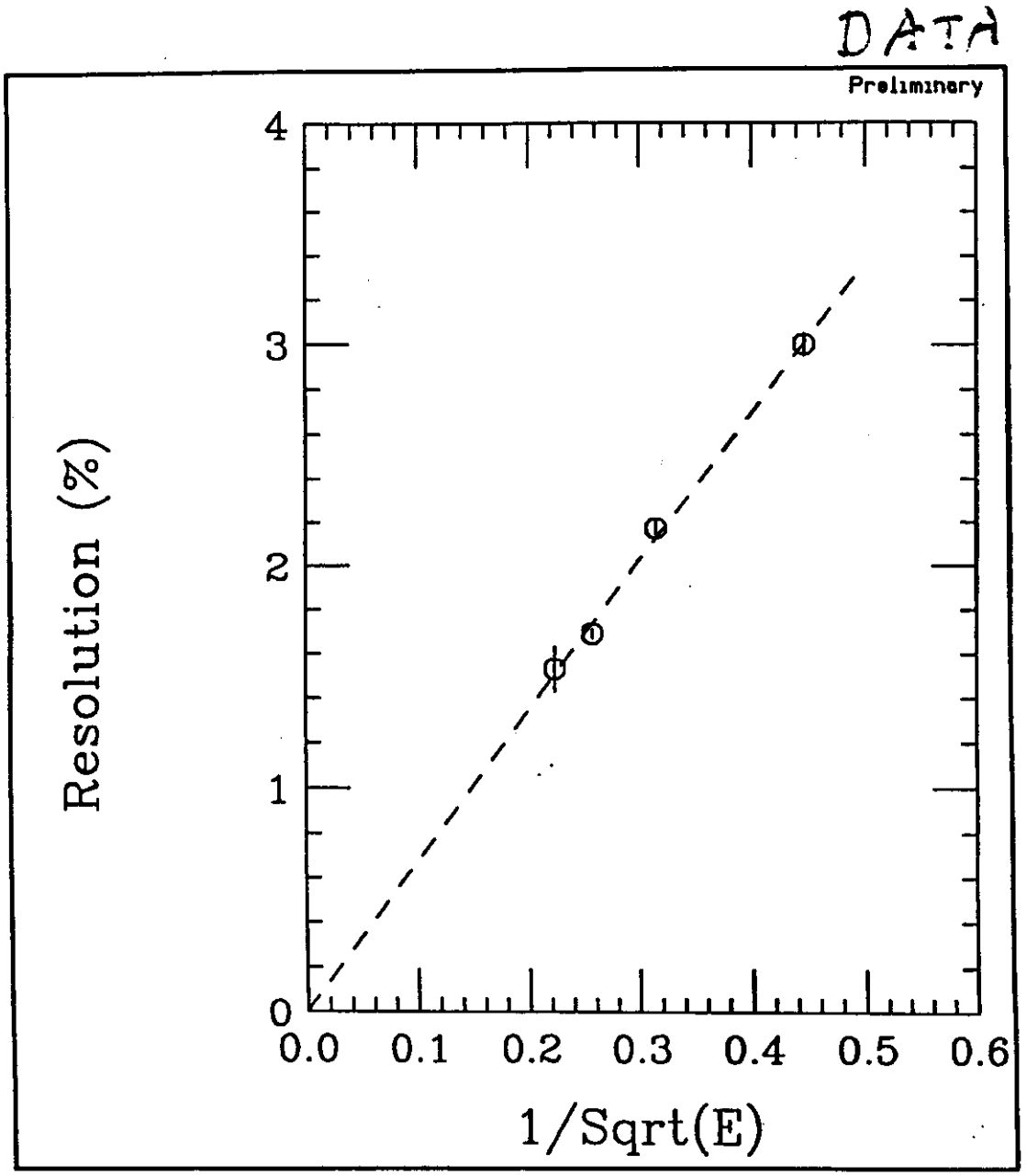
Multiple trace - variable persistence ! !

Calorimeter Response for 15 GeV electrons

DATA

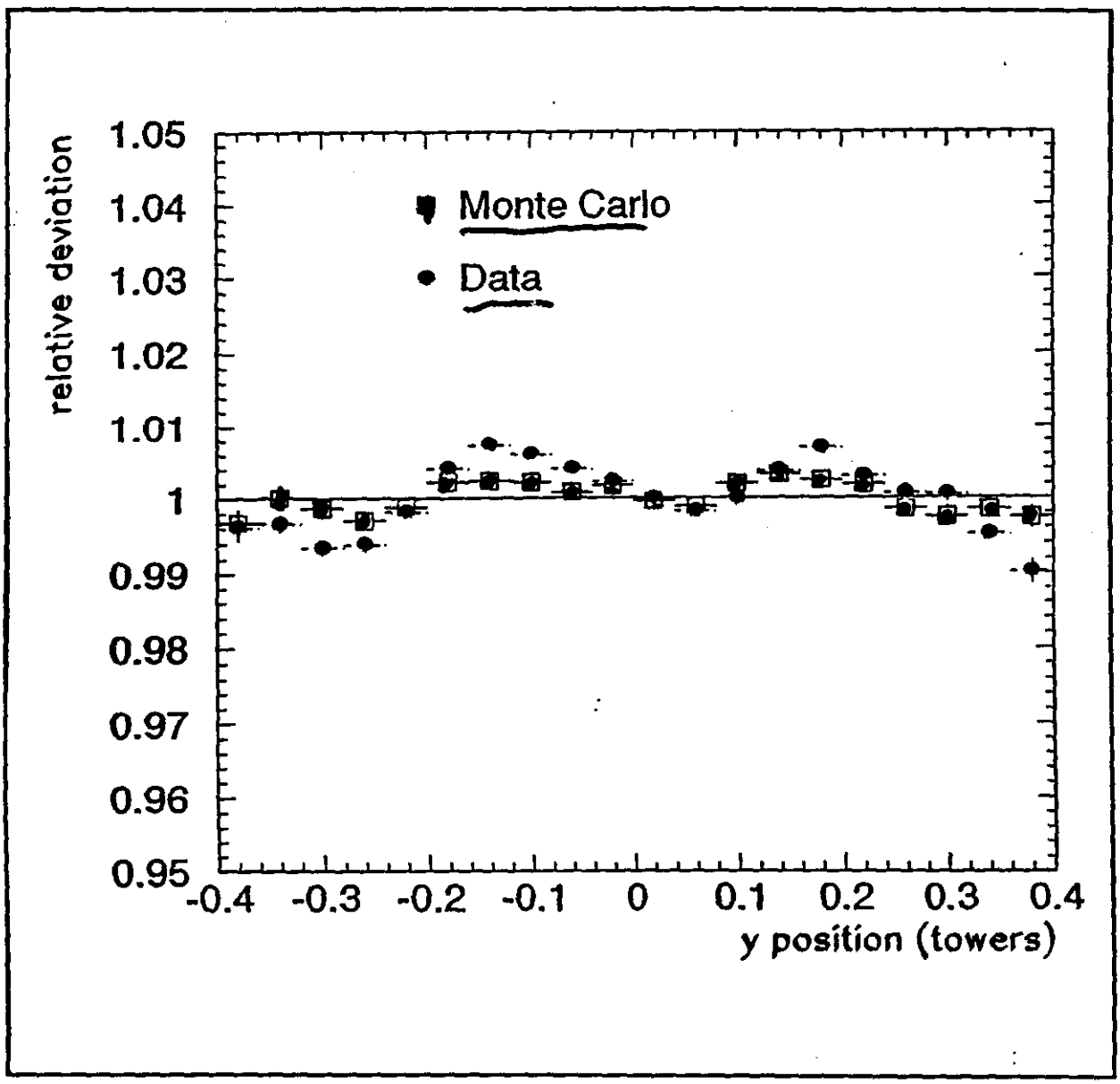


Energy Resolution



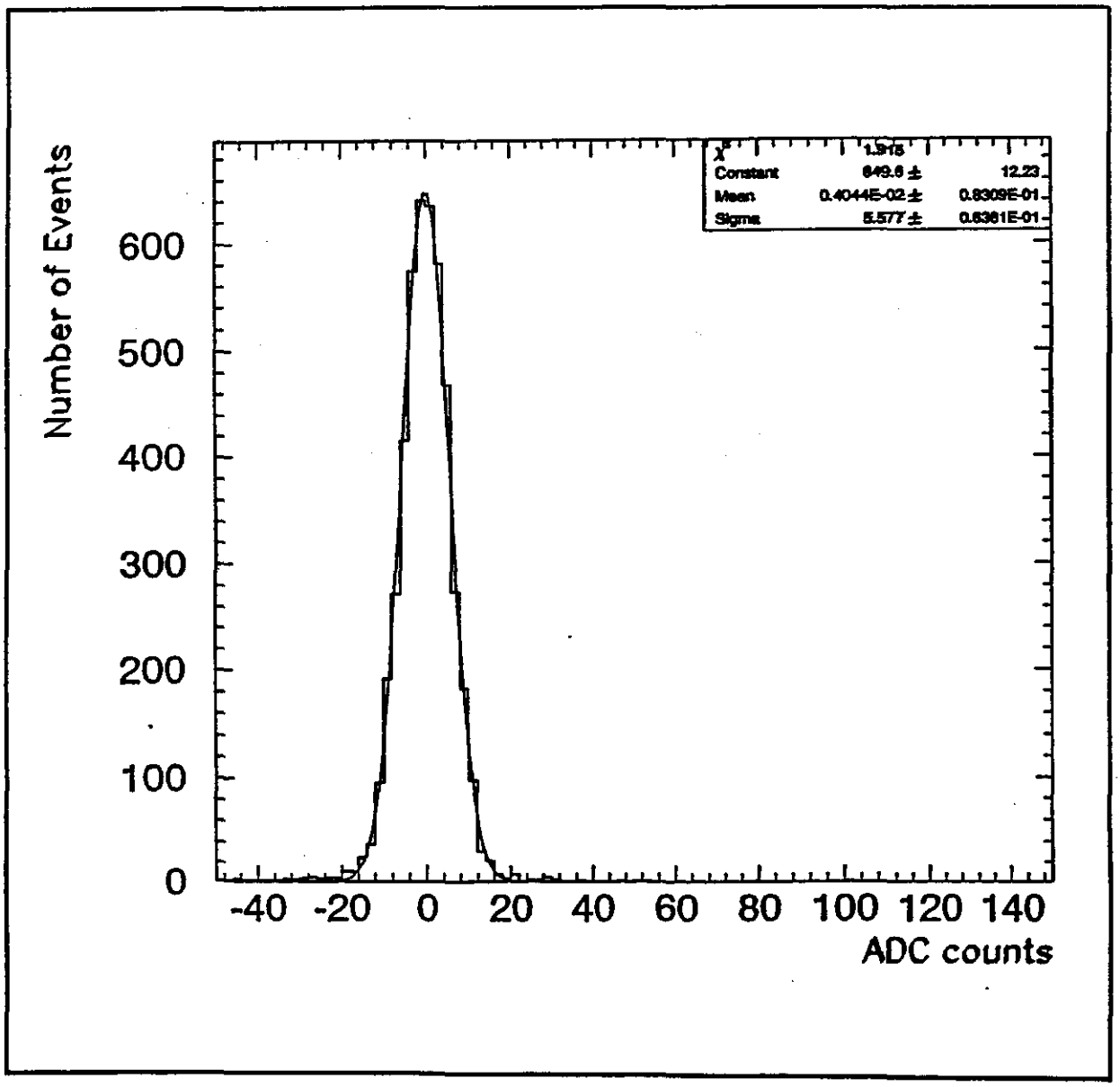
$$\frac{\Delta E}{E} = (0.0 \pm 0.2)\% \oplus \frac{(6.72 \pm 0.04)\%}{\sqrt{E}} \oplus \frac{0.080 GeV}{E}$$

y-position dependence



μ Pedestal

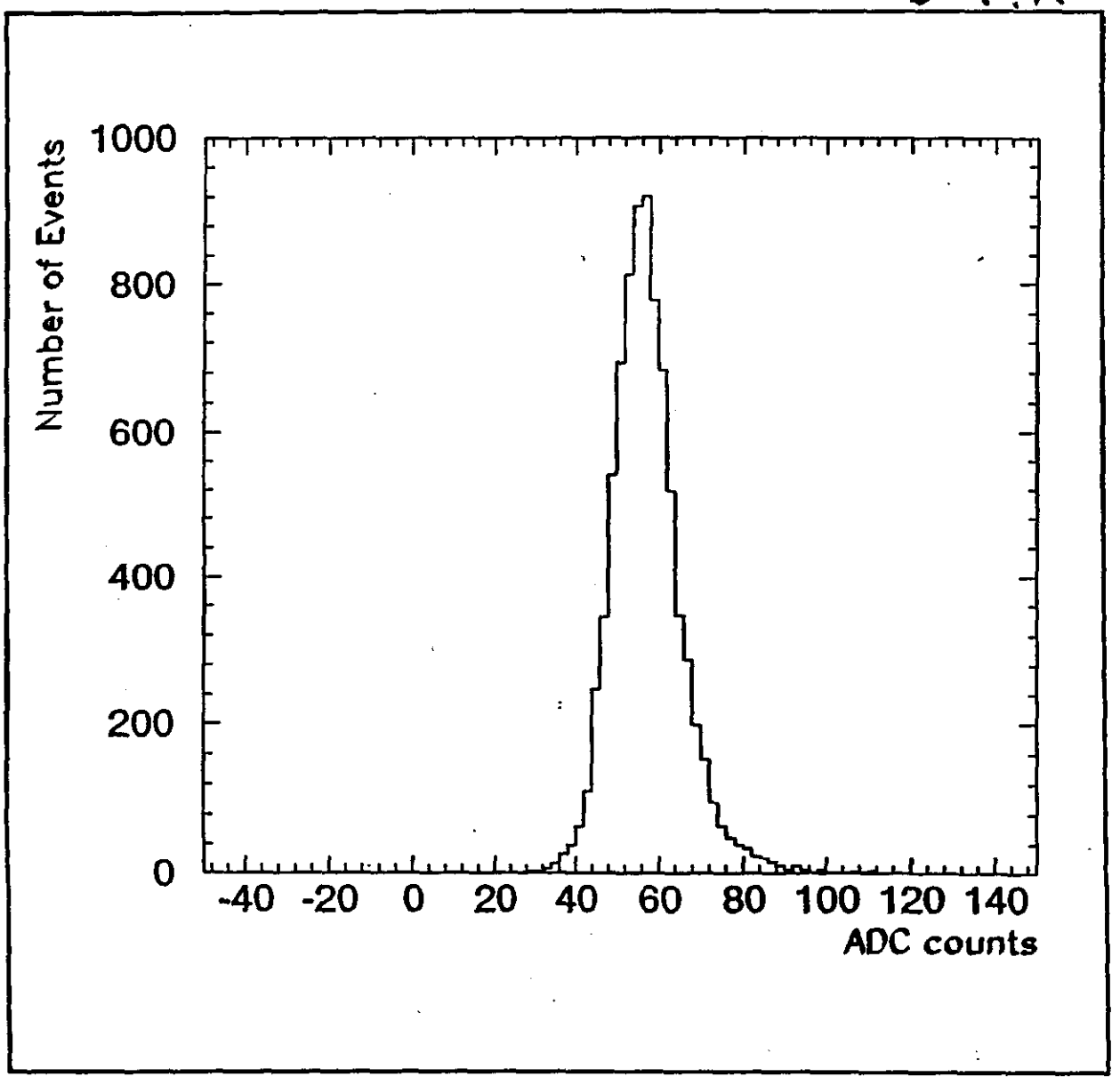
LAr - run



μ Response

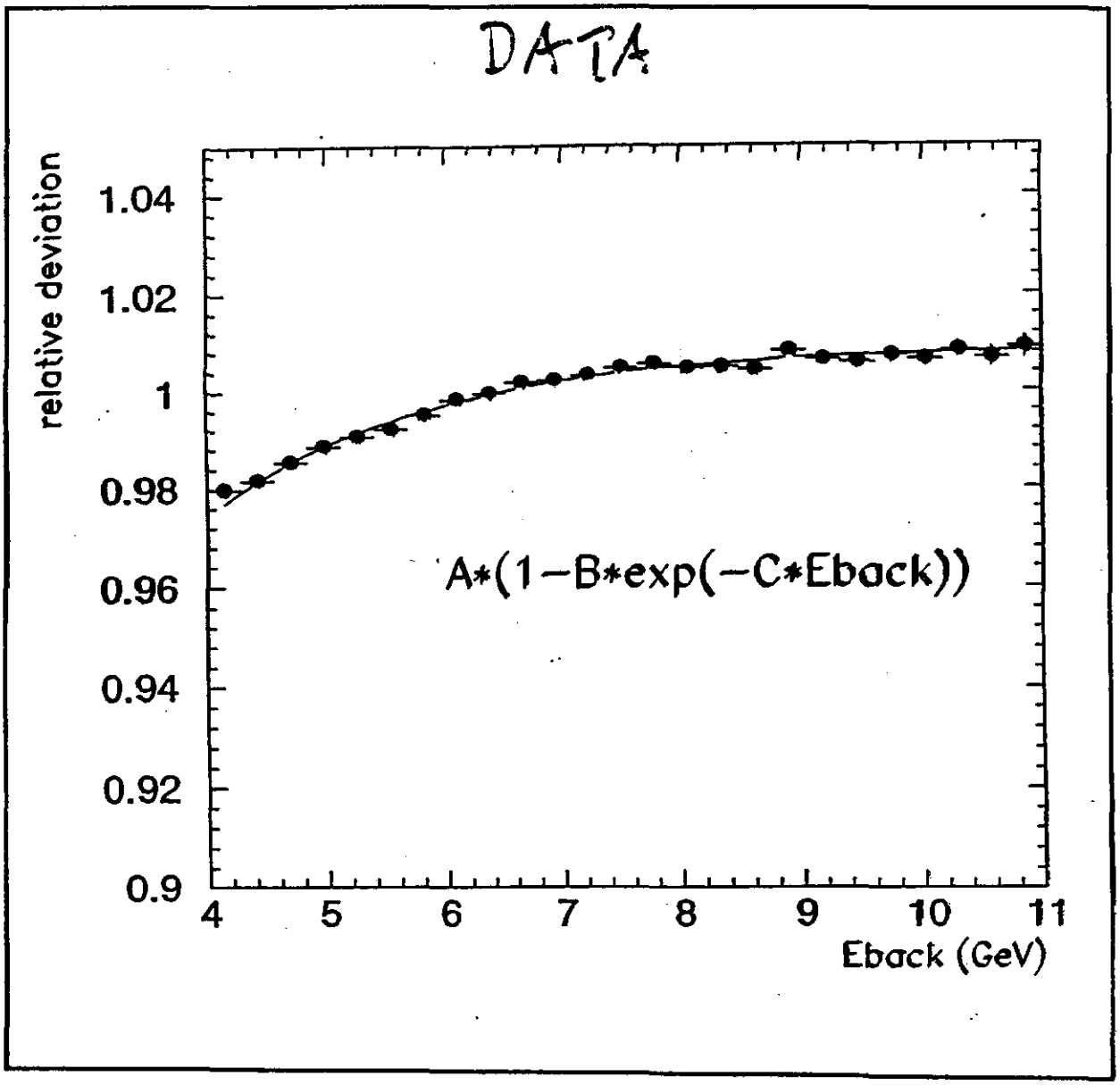
LKr - 15GeV

DATA



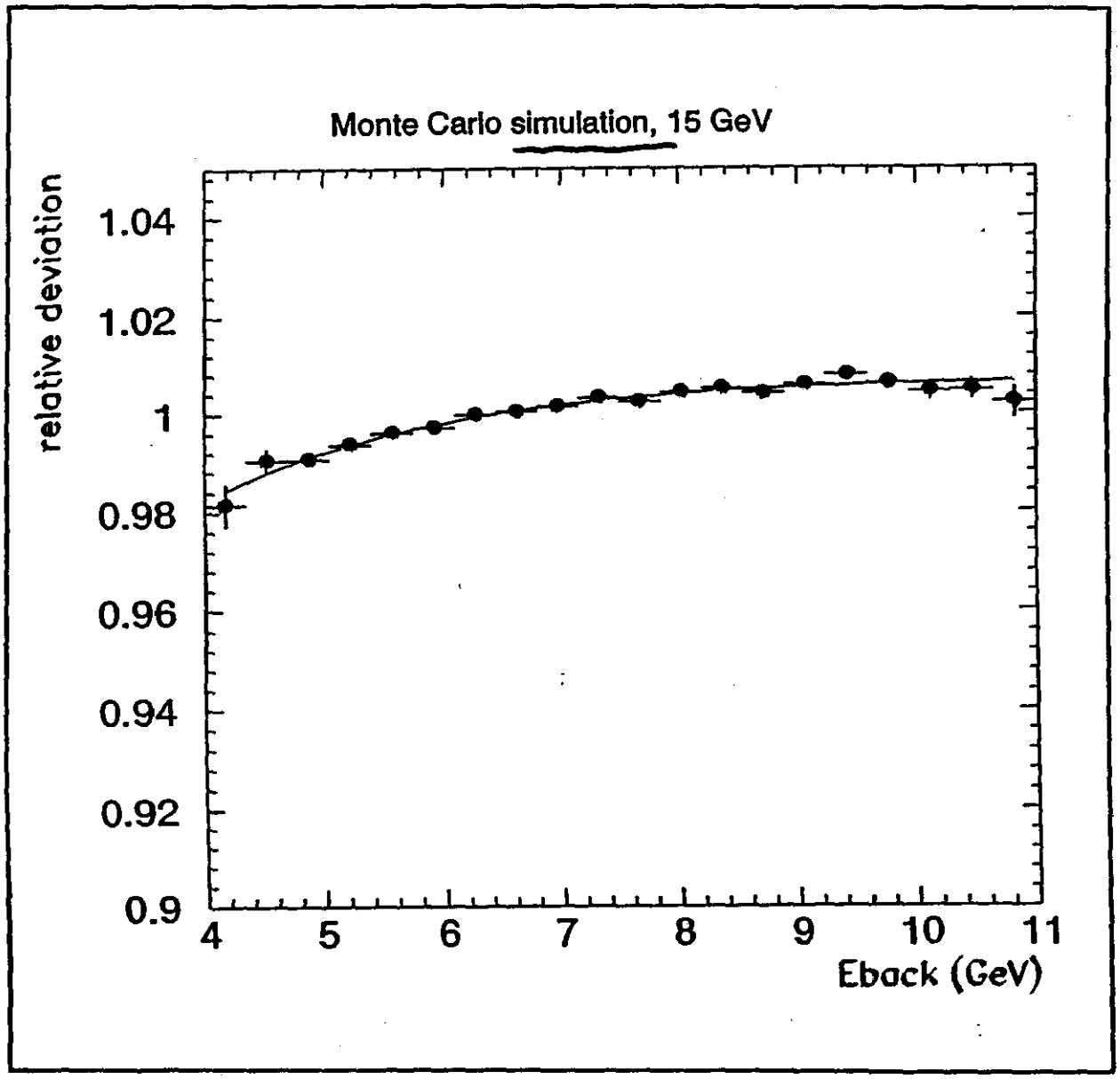
Ratio front/back

~~Simulation~~



Ratio front/back

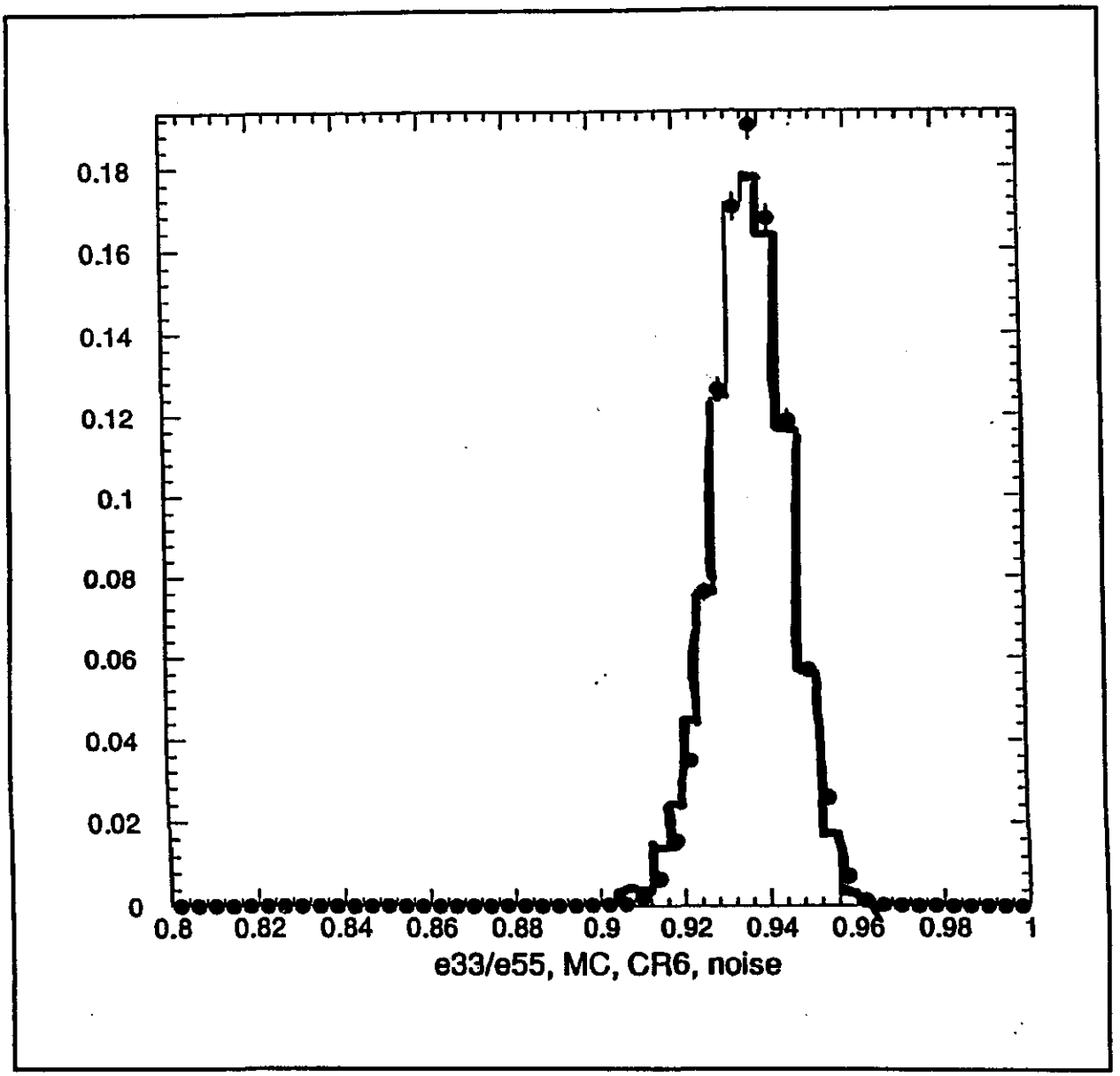
Data

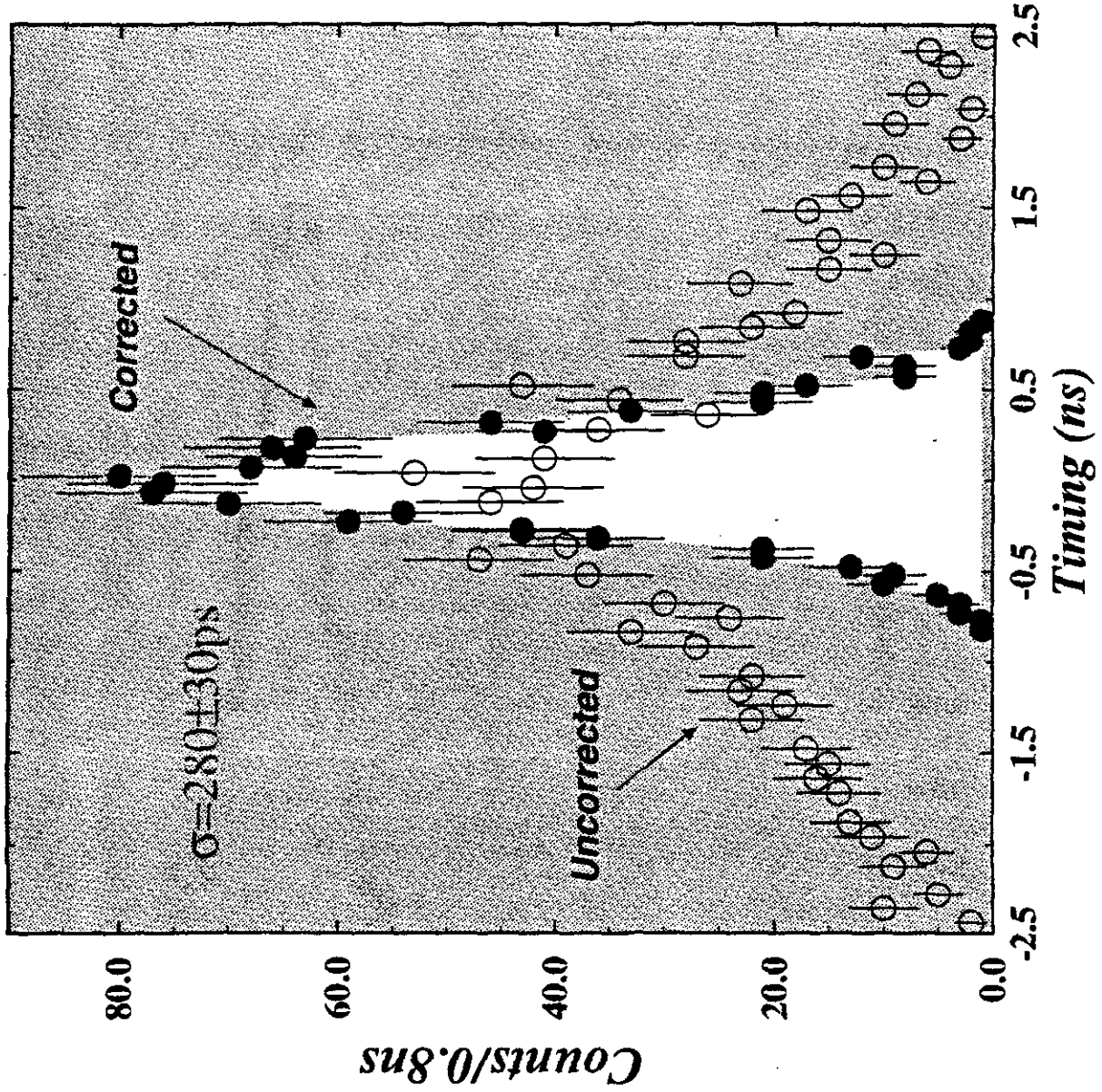


Ratio [3x3]/[5x5]

15 GeV

Data • Simulation —




Corrected
σ=280±30ps
Uncorrected
Counts/0.8ns
80.0
60.0
40.0
20.0
0.0
-2.5
-1.5
-0.5
0.5
1.5
2.5
Timing (ns)

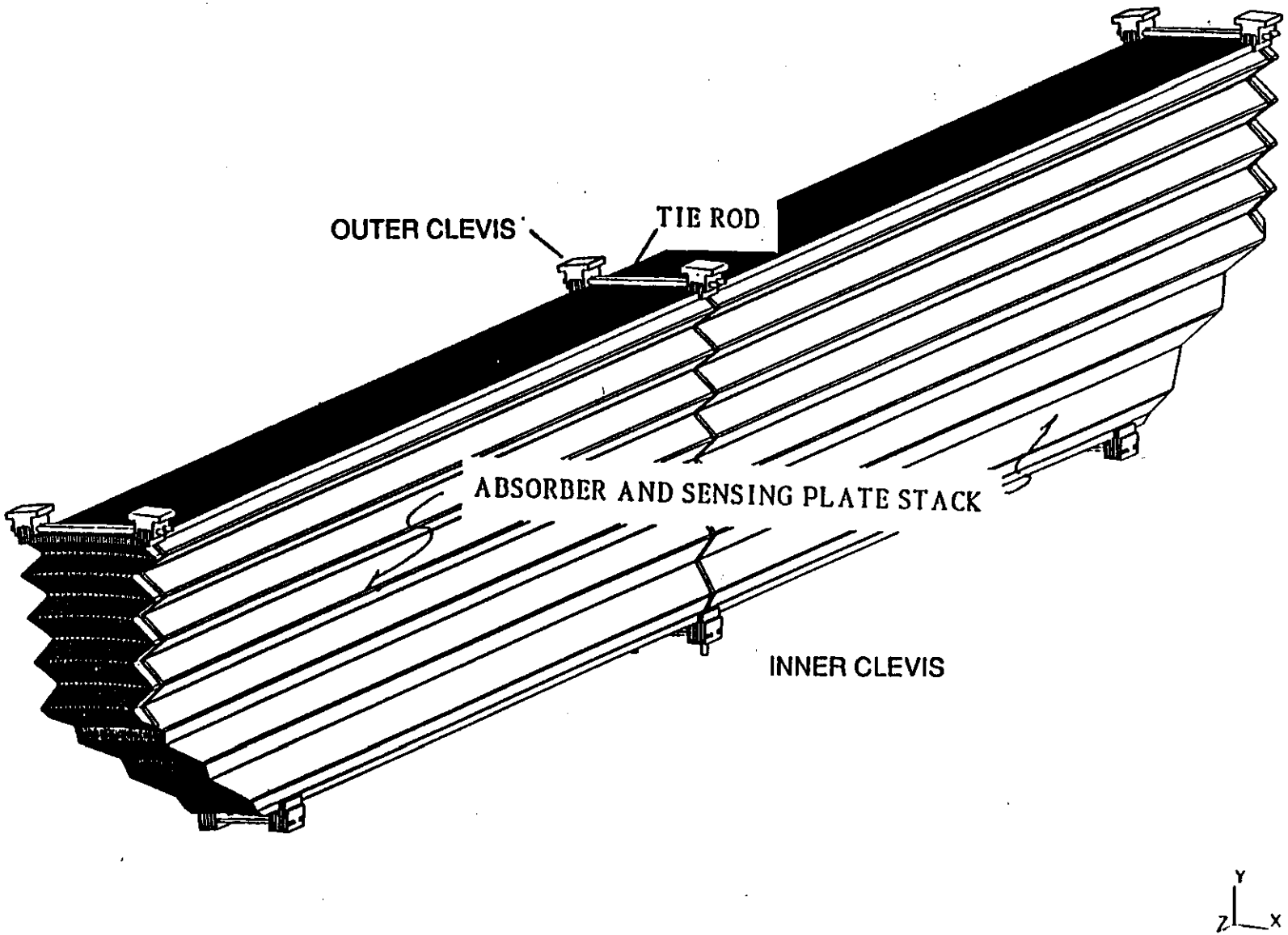
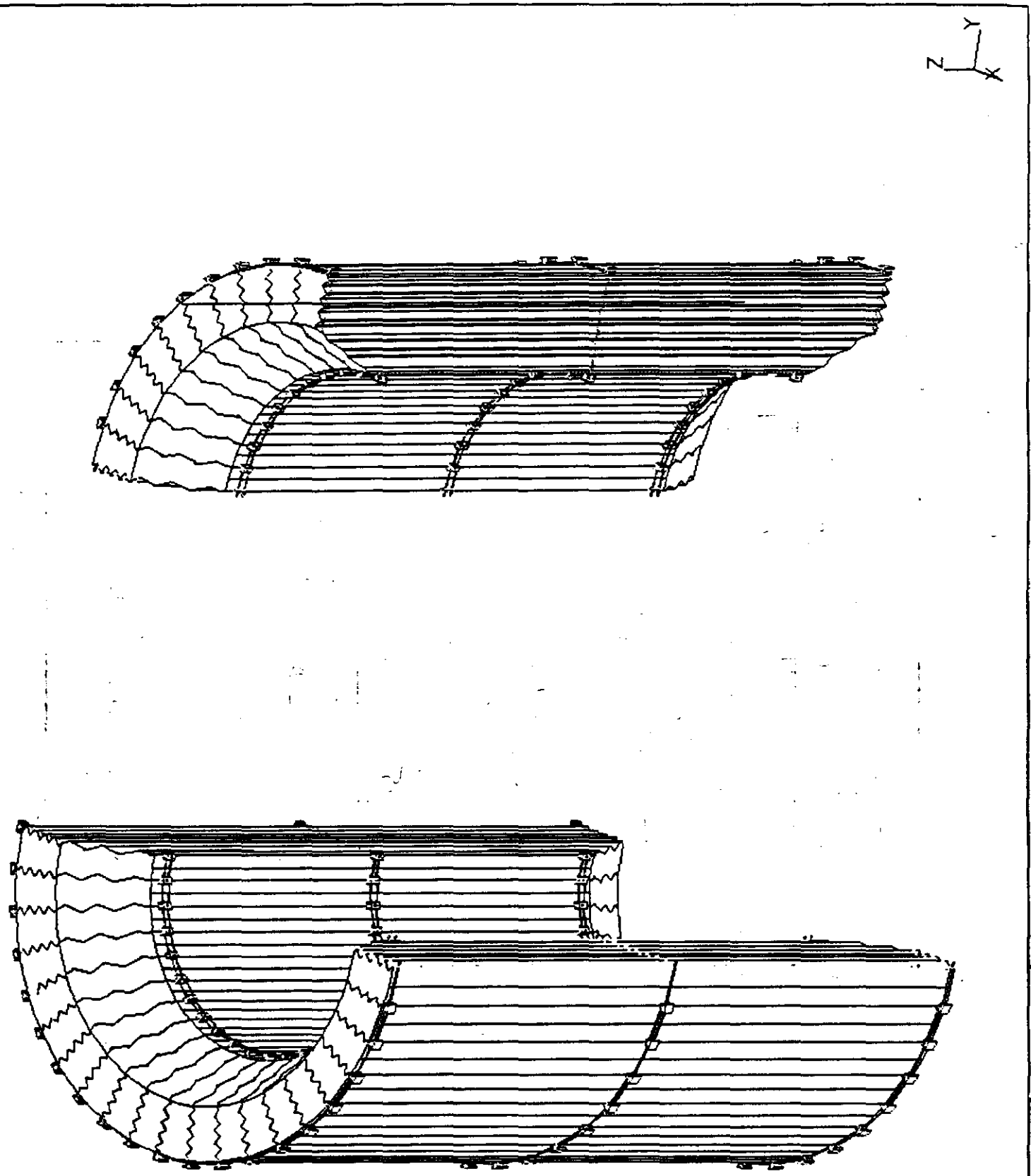


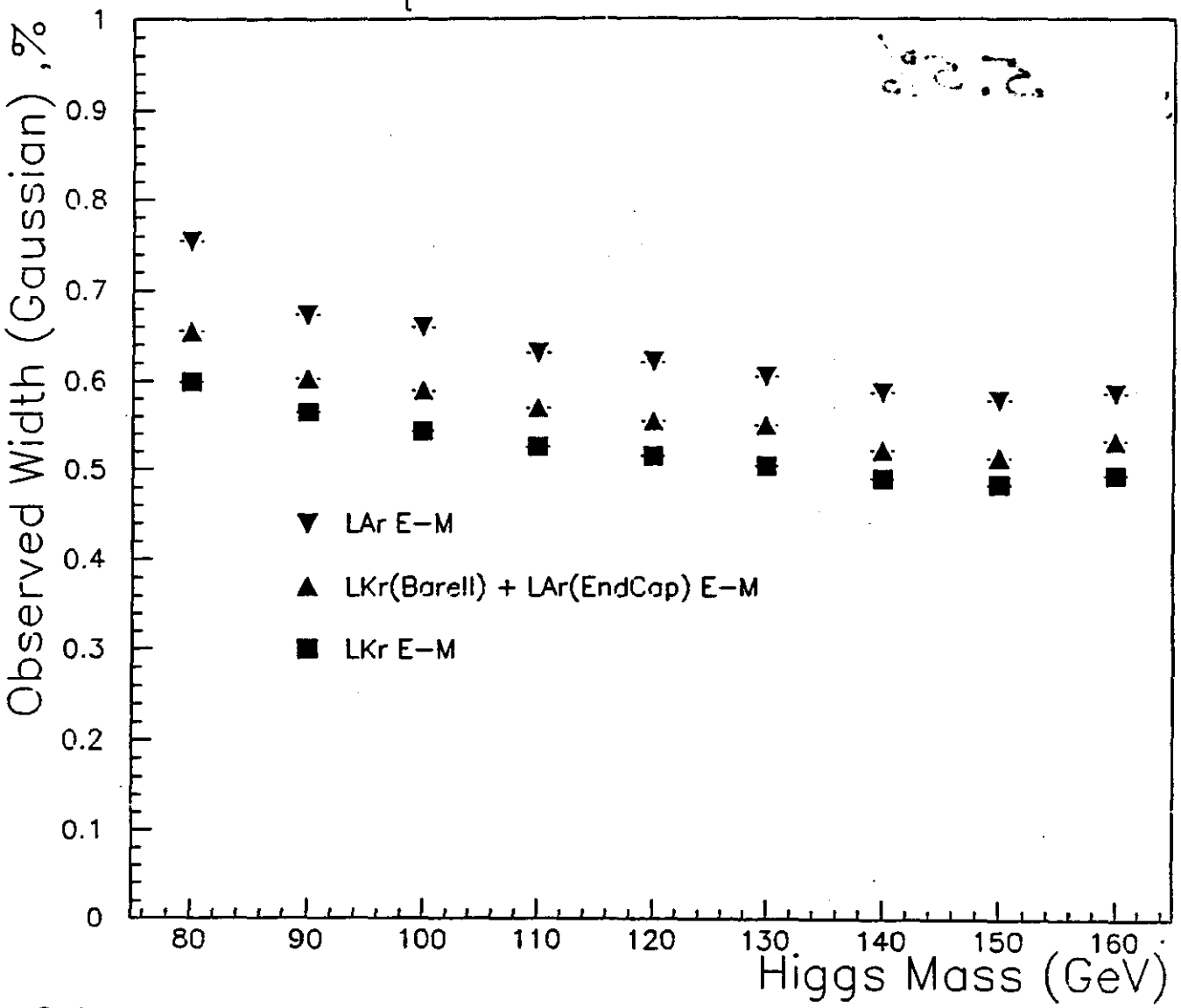
Figure 1-1 Barrel EM Module Assembly


Y
Z
X

92/11/30 08.53

HIGGS MASS RECONSTRUCTION

PYTHIA5.6 m_t = 150 GeV ,perfect position resolution



A.Savin

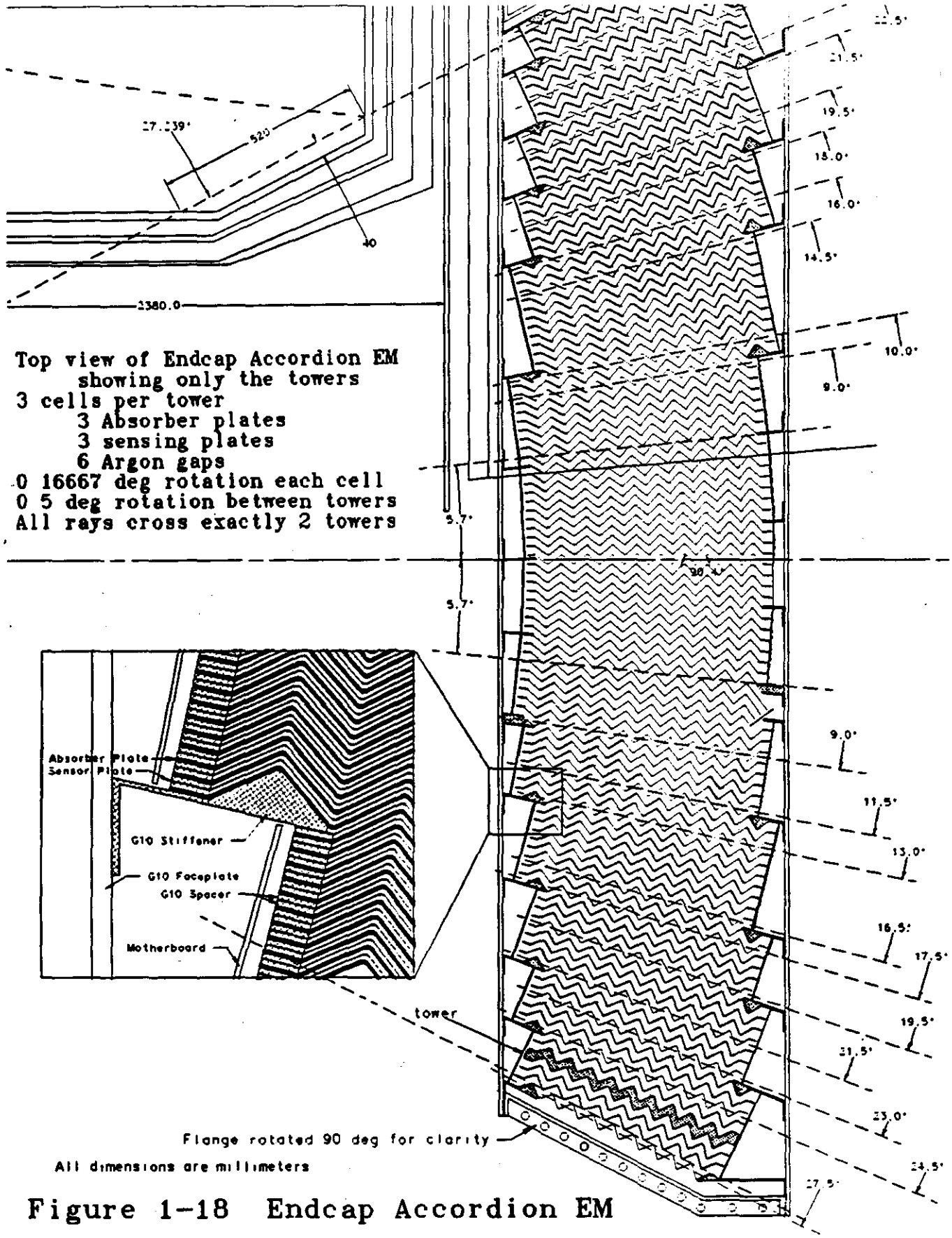
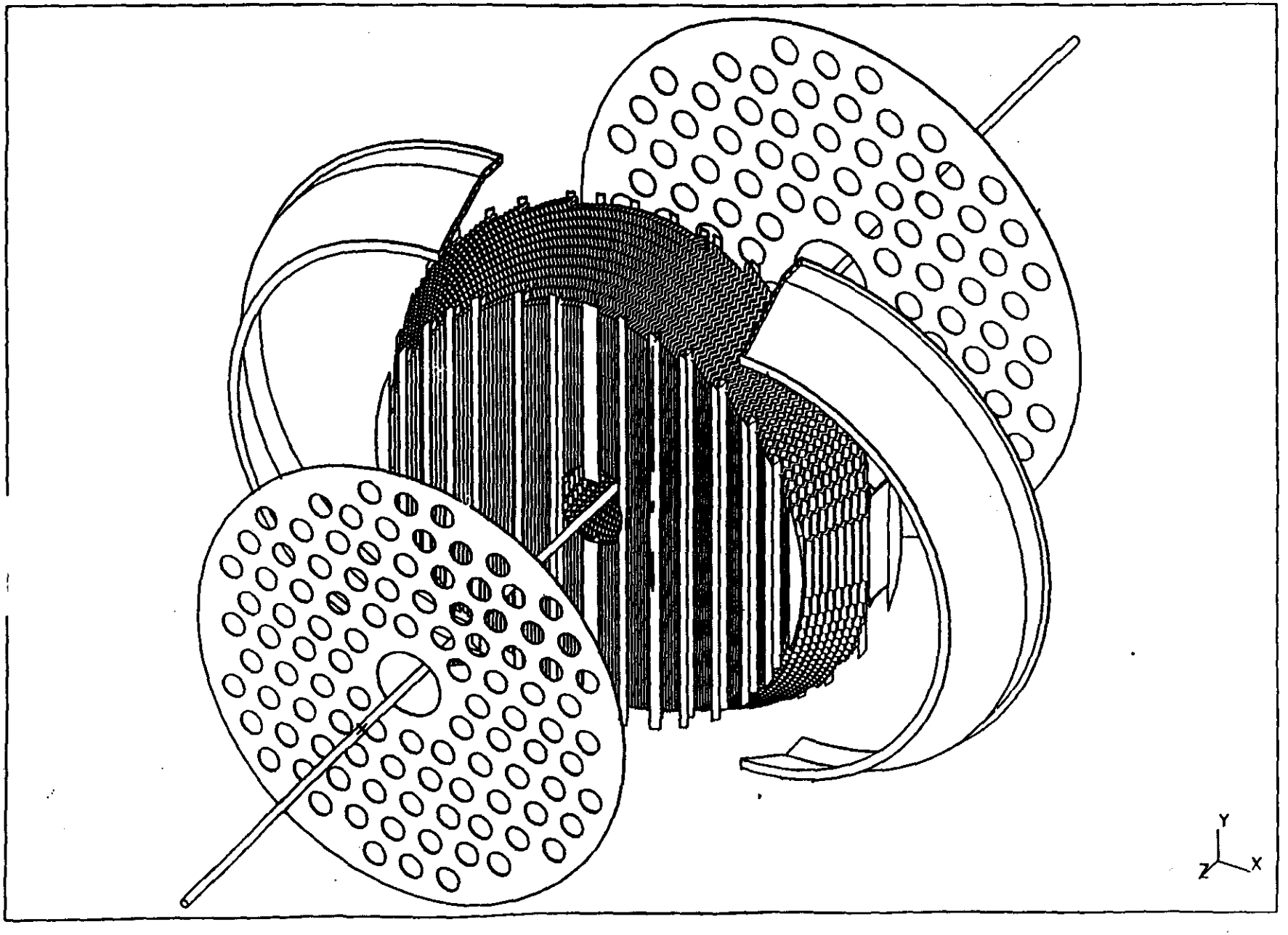


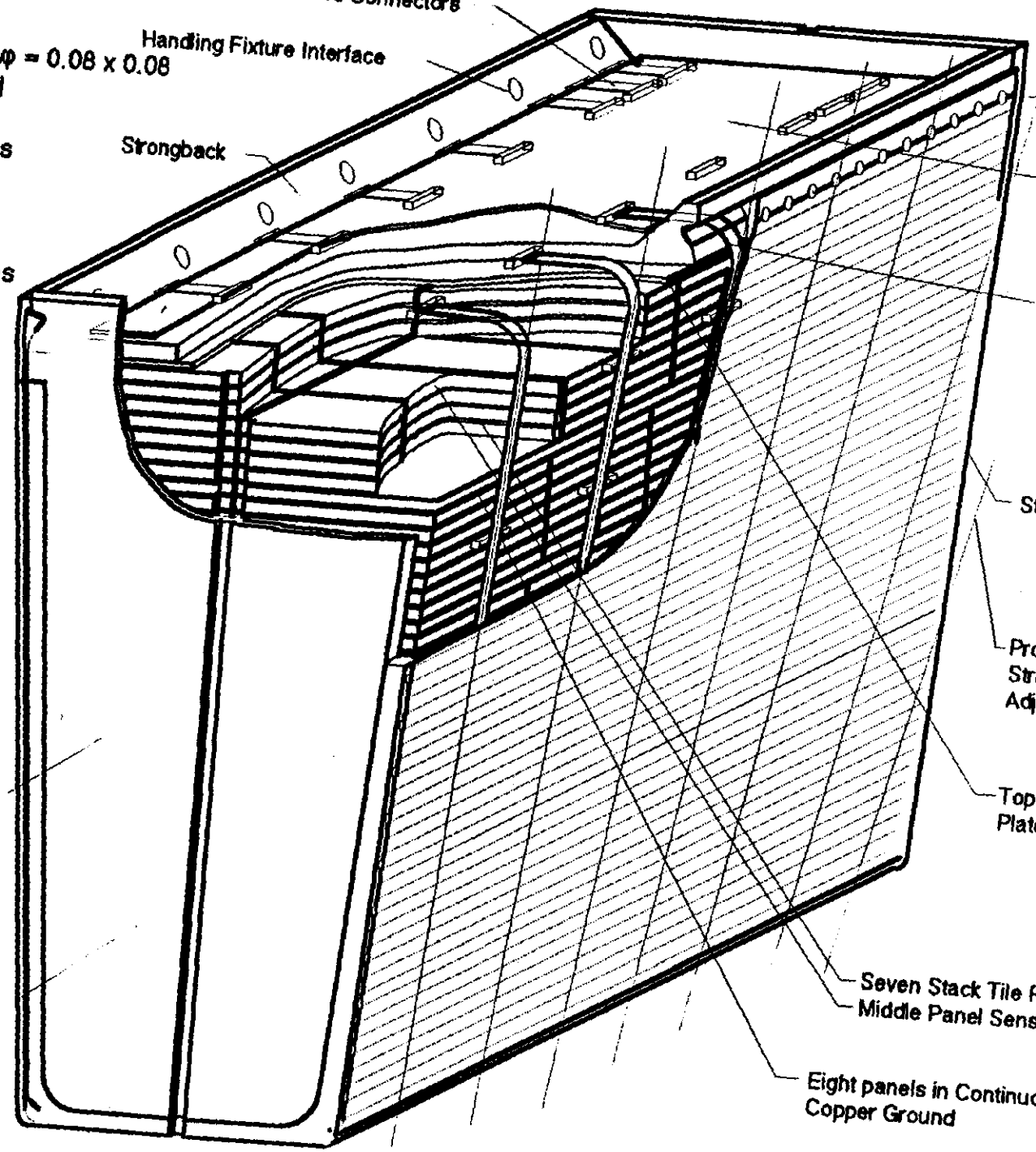
Figure 1-18 Endcap Accordion EM

Endcap EM Module



Barrel Inner Hadronic

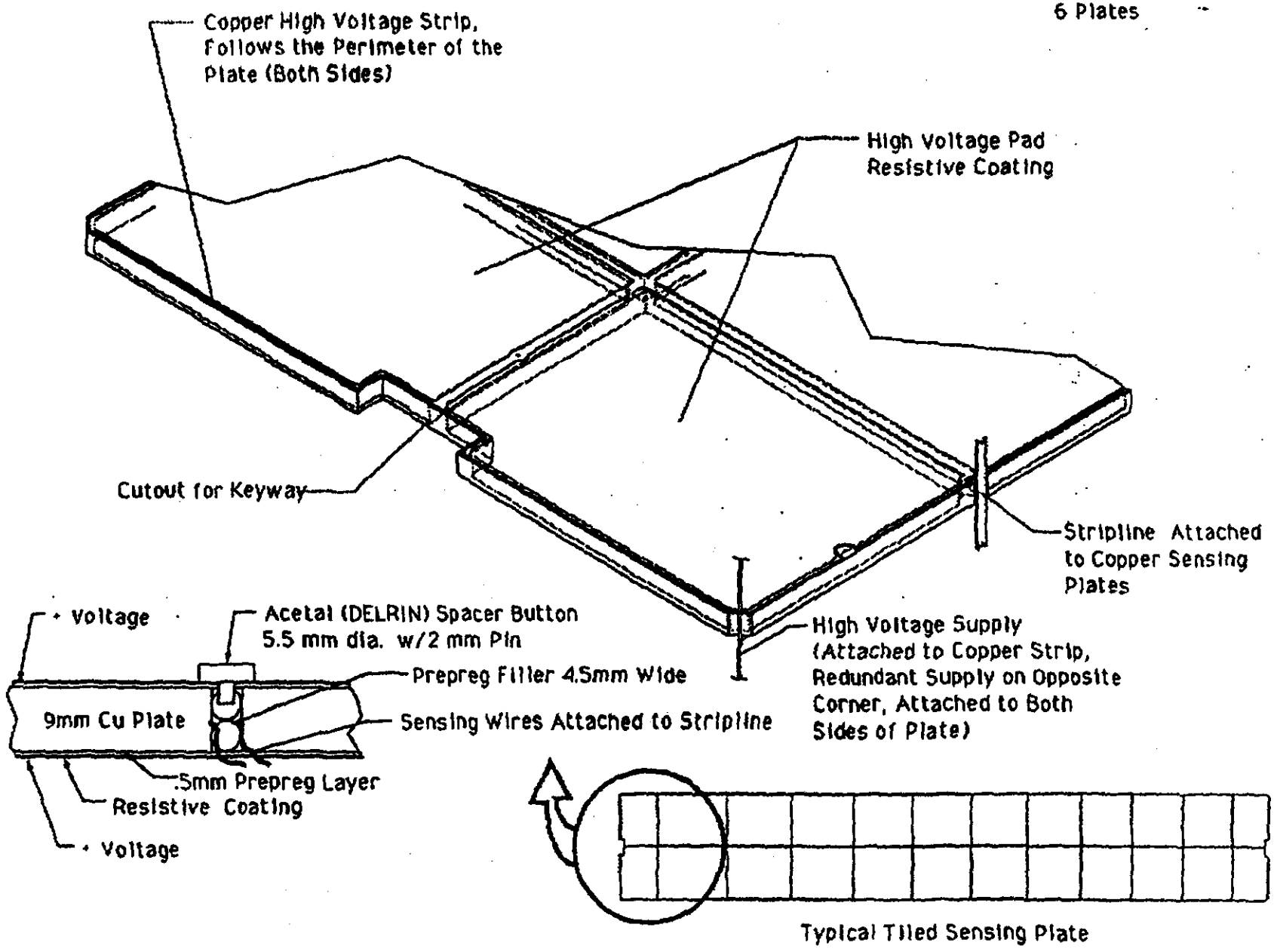
5 Cells Depth
Segmentation $\Delta\eta \times \Delta\varphi = 0.08 \times 0.08$
80 Modules Required
Wt. = 2.38 MT each
Each Module Contains the Following:
1 - Top Ground Plate
1 - Bottom Gnd Plate
4 - Included Gnd Plates
30 - Tile Plates
5 - Sensing Plates
1 - Strongback
1 - Structural Shell
2 - End Plates
Lines and Electronics

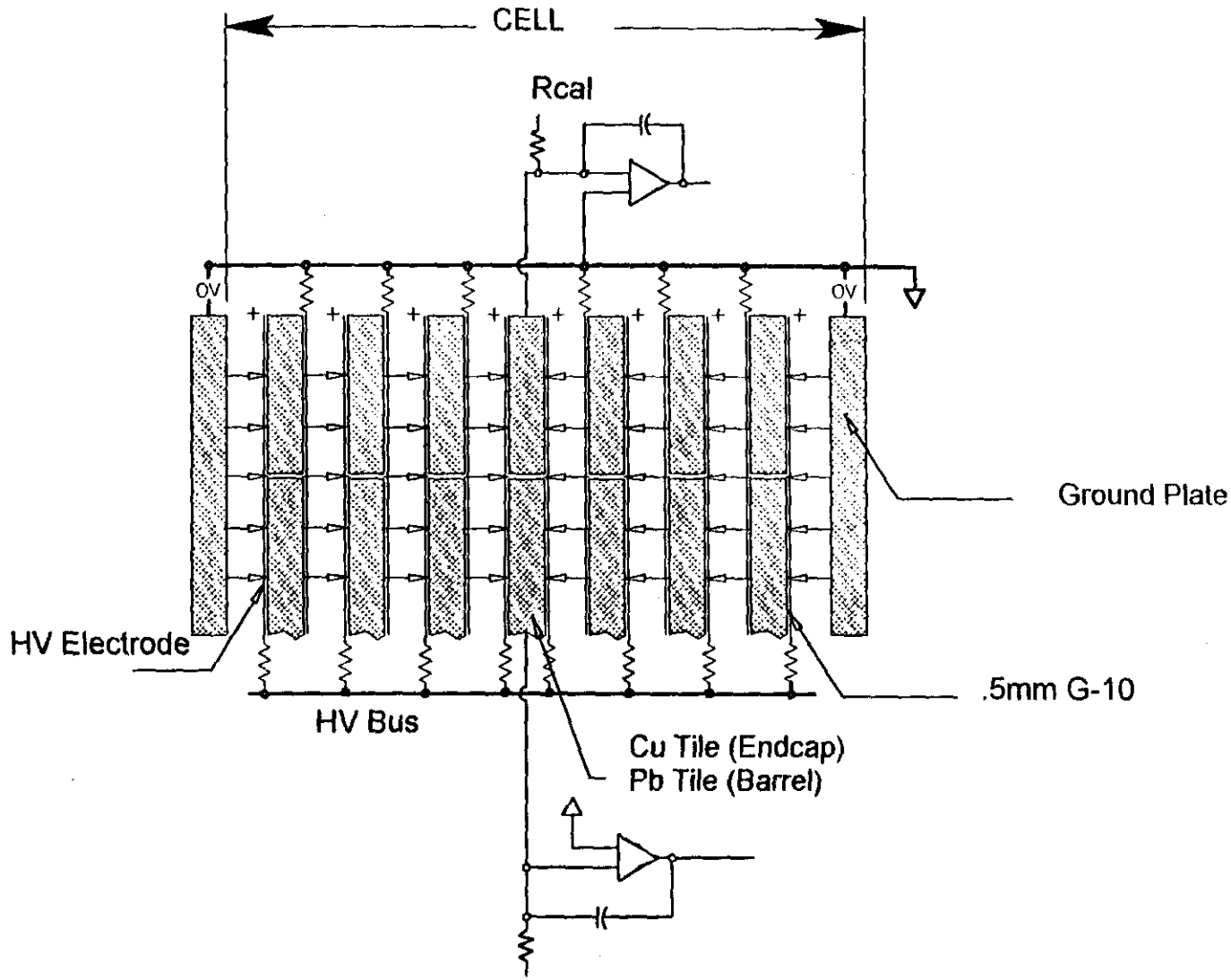


LLMason GEMLAC.HadModDetail 11/15/92

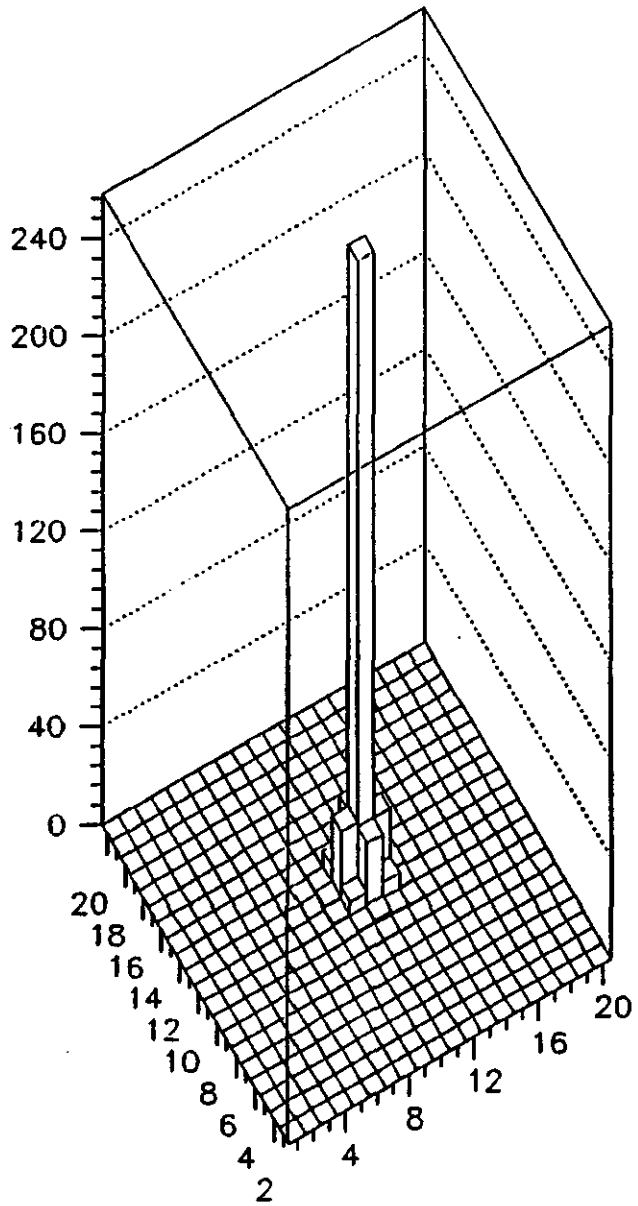
SENSING PLATE (Module #2)

6 Cell Depths
6 Resistive Coating Templates
6 Plates

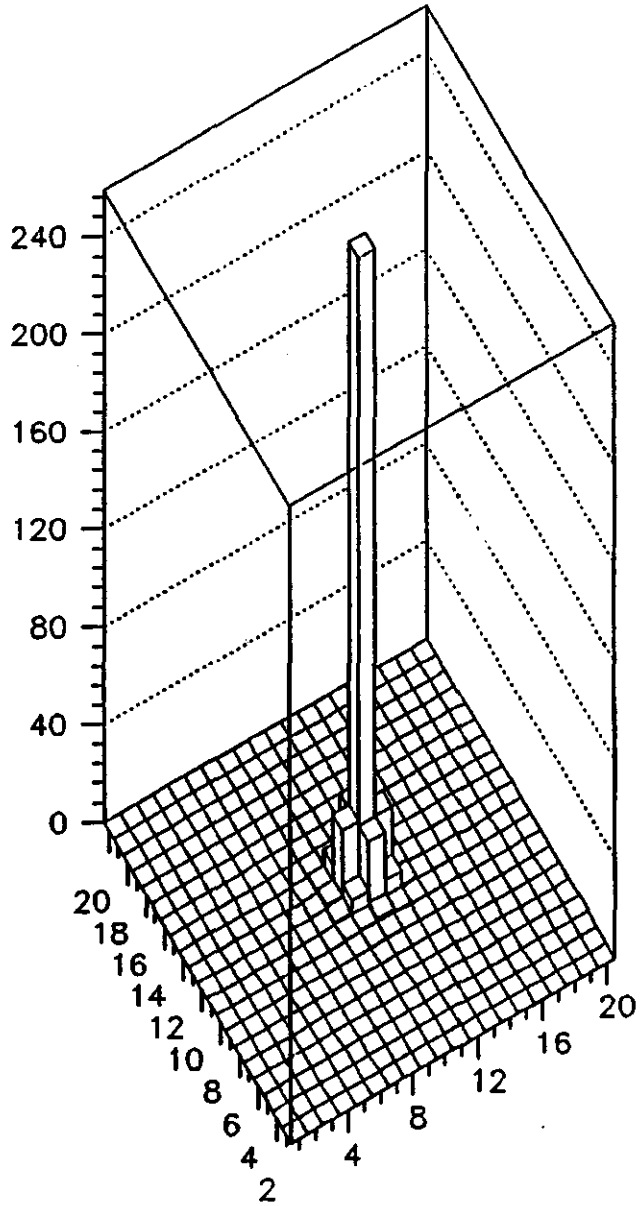




Hadronic Configuration with Electrostatic Transformer

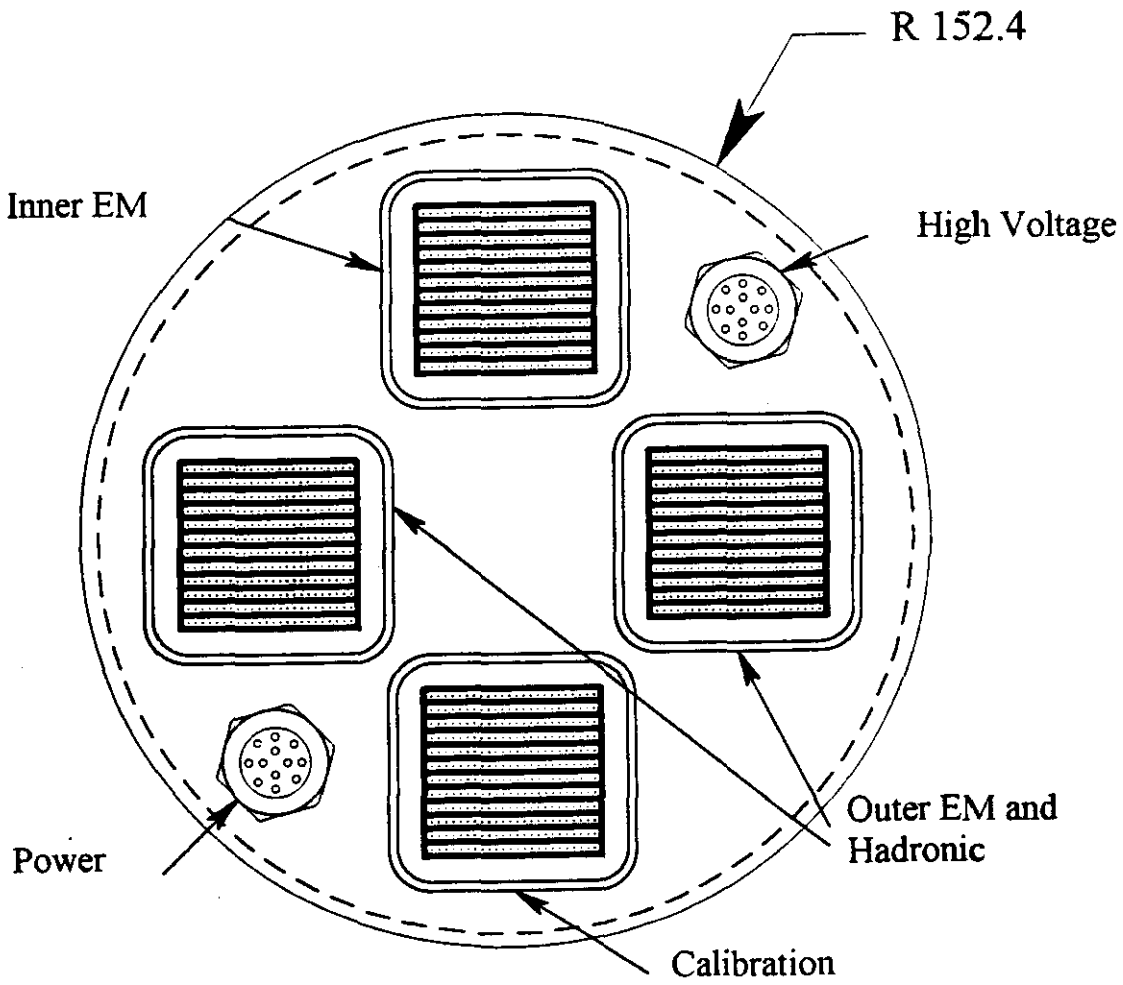


energy flow in the calorimeter



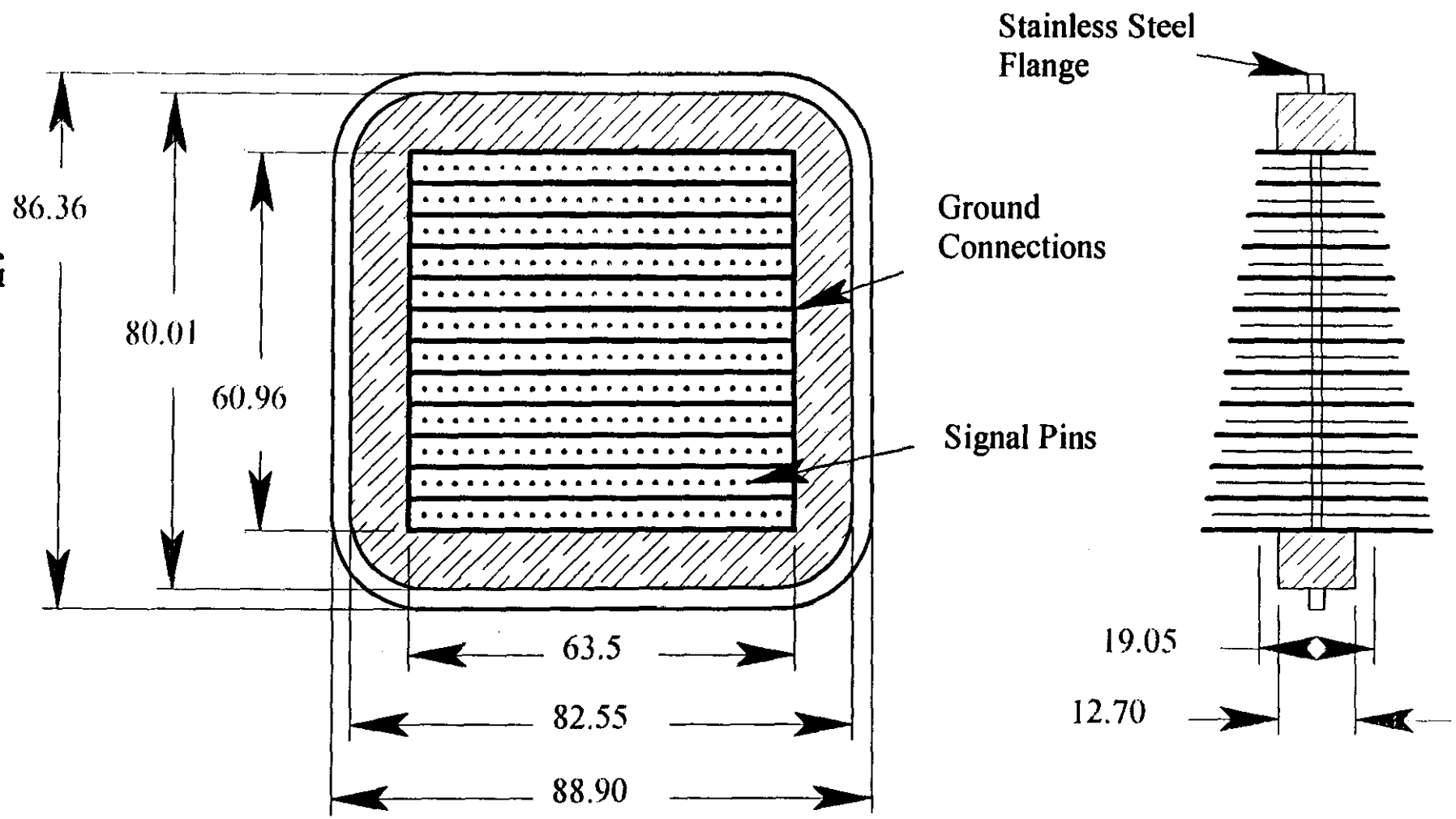
energy flow in the EST calorimeter

Feedthrough Flange
(9 deg. Sector)



DSM

High Density Ceramic Feedthrough (288 channels)



DSM

Fit 8 parameters $P_1 = 0.7$

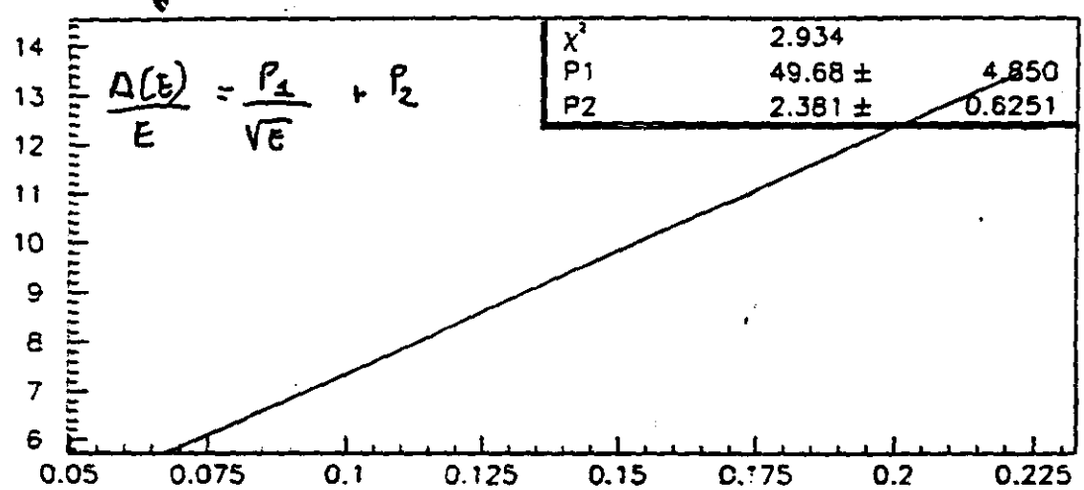
RD3 – P. Battaglia, L. Cossi, L. Persini

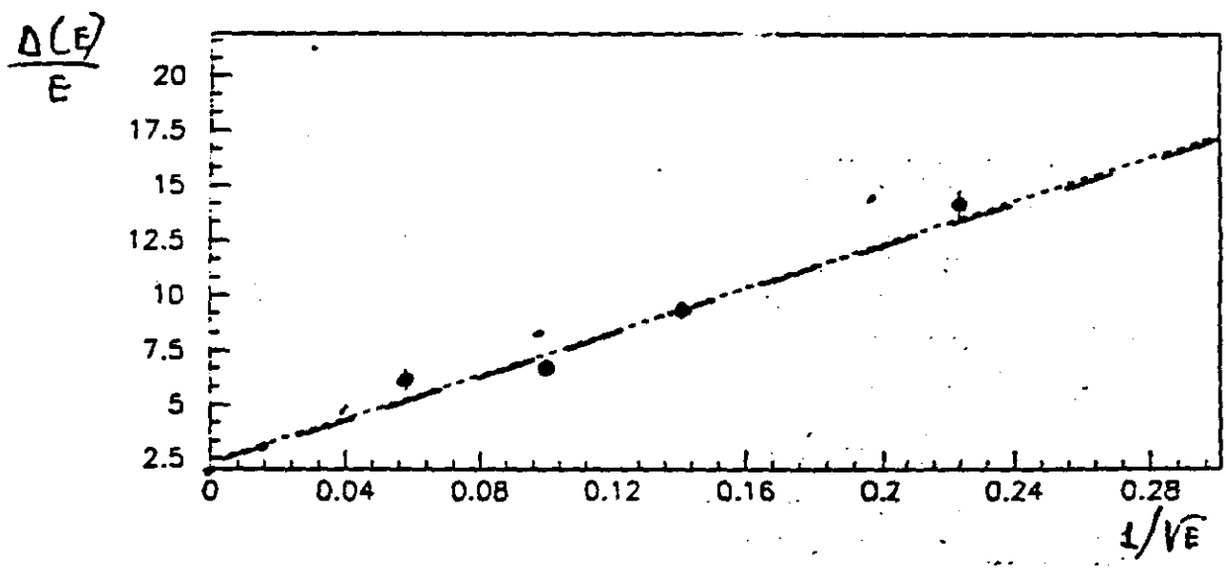
10/12/92

Accordion + Fe/LAr

Pythia Jets 20–300 GeV

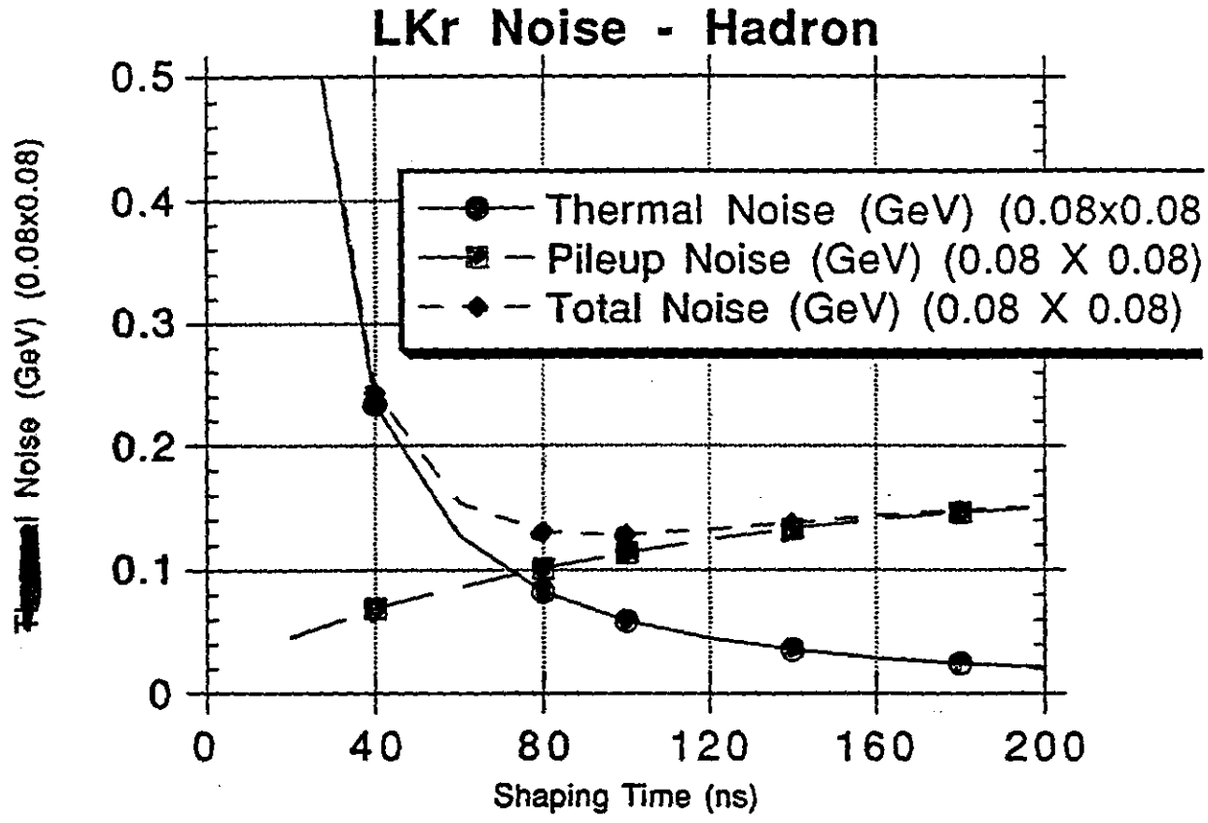
GEANT 3.15+ FLUKA





$$\frac{50 \pm 5\%}{\sqrt{E}} \oplus 2.4 \pm 0.6\%$$

8 parameters – 1 for each longitudinal division but NOT energy dependent


LKr Noise - Hadron
0.5
0.4
0.3
0.2
0.1
0
0
40
80
120
160
200
Shaping Time (ns)
Thermal 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)

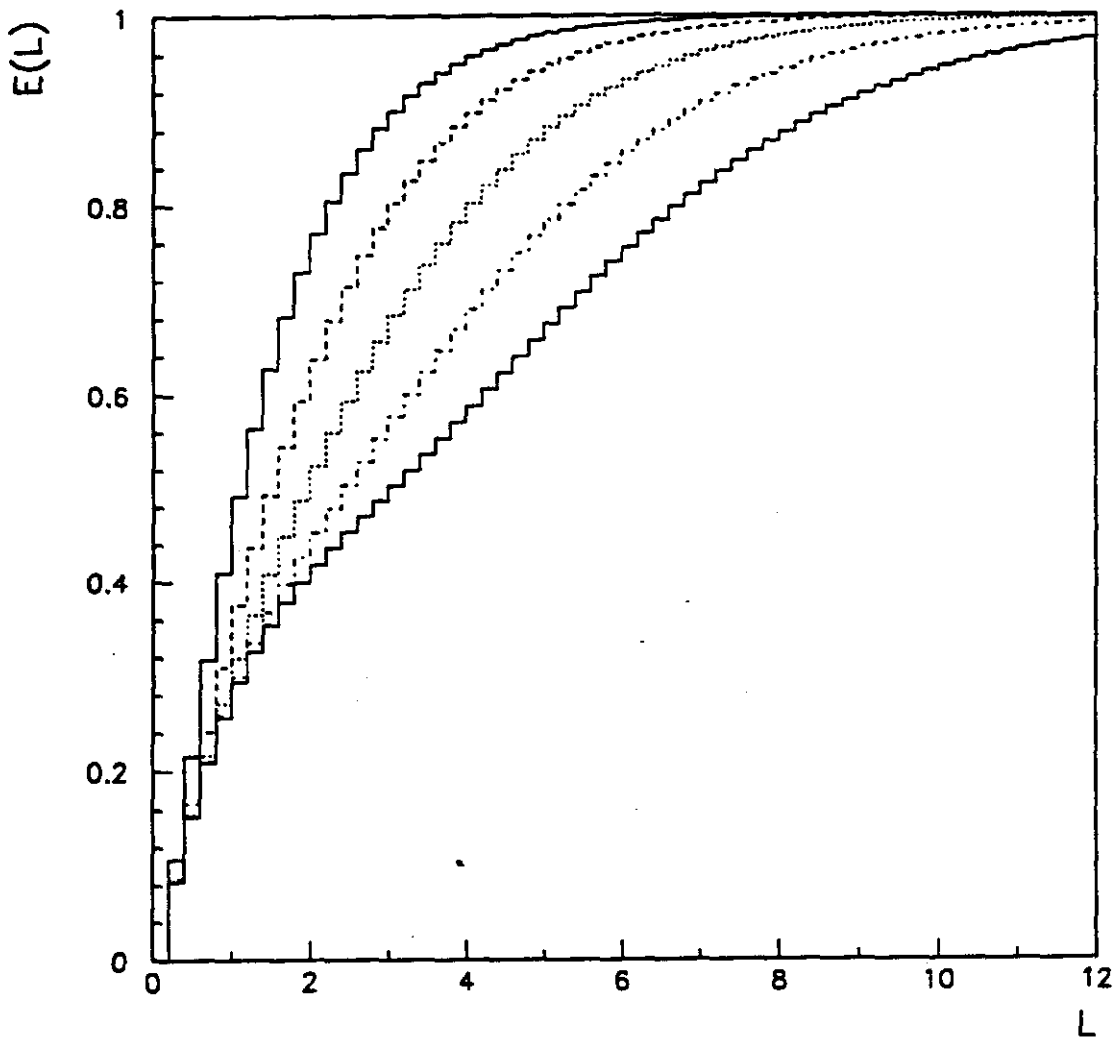
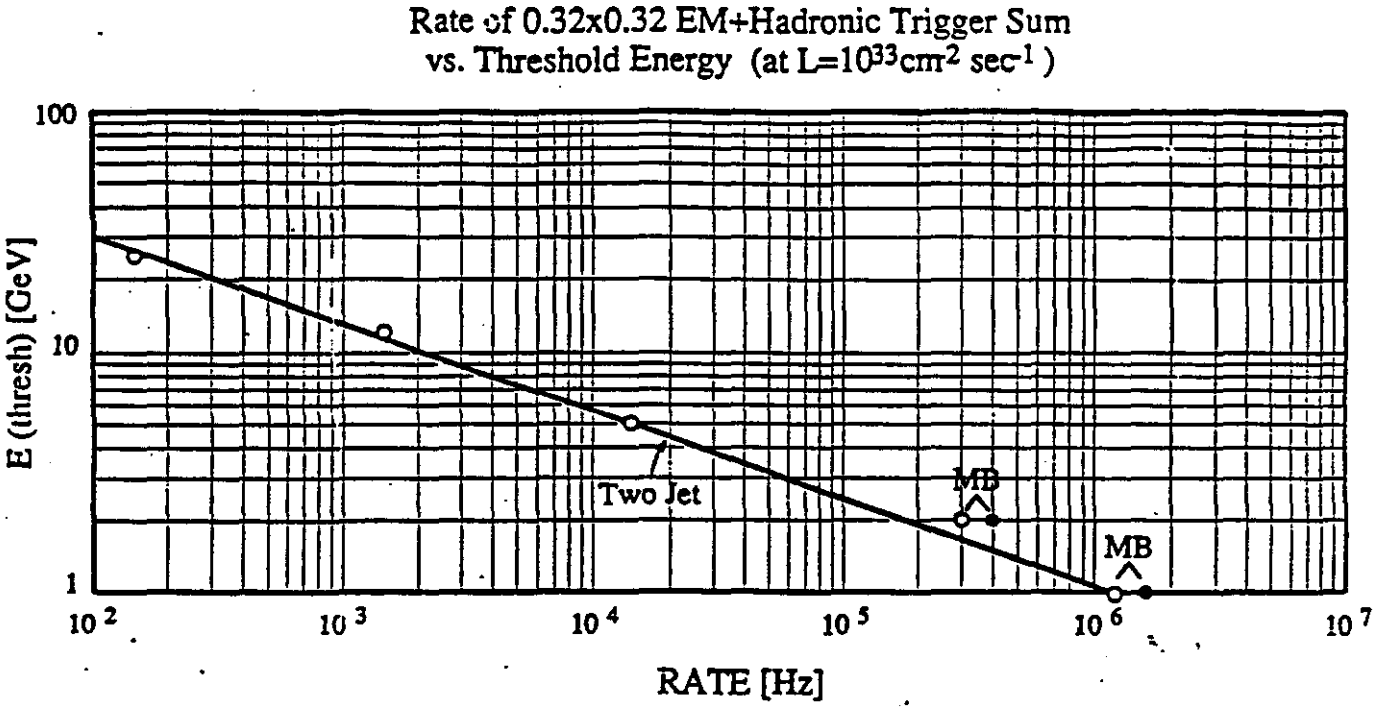


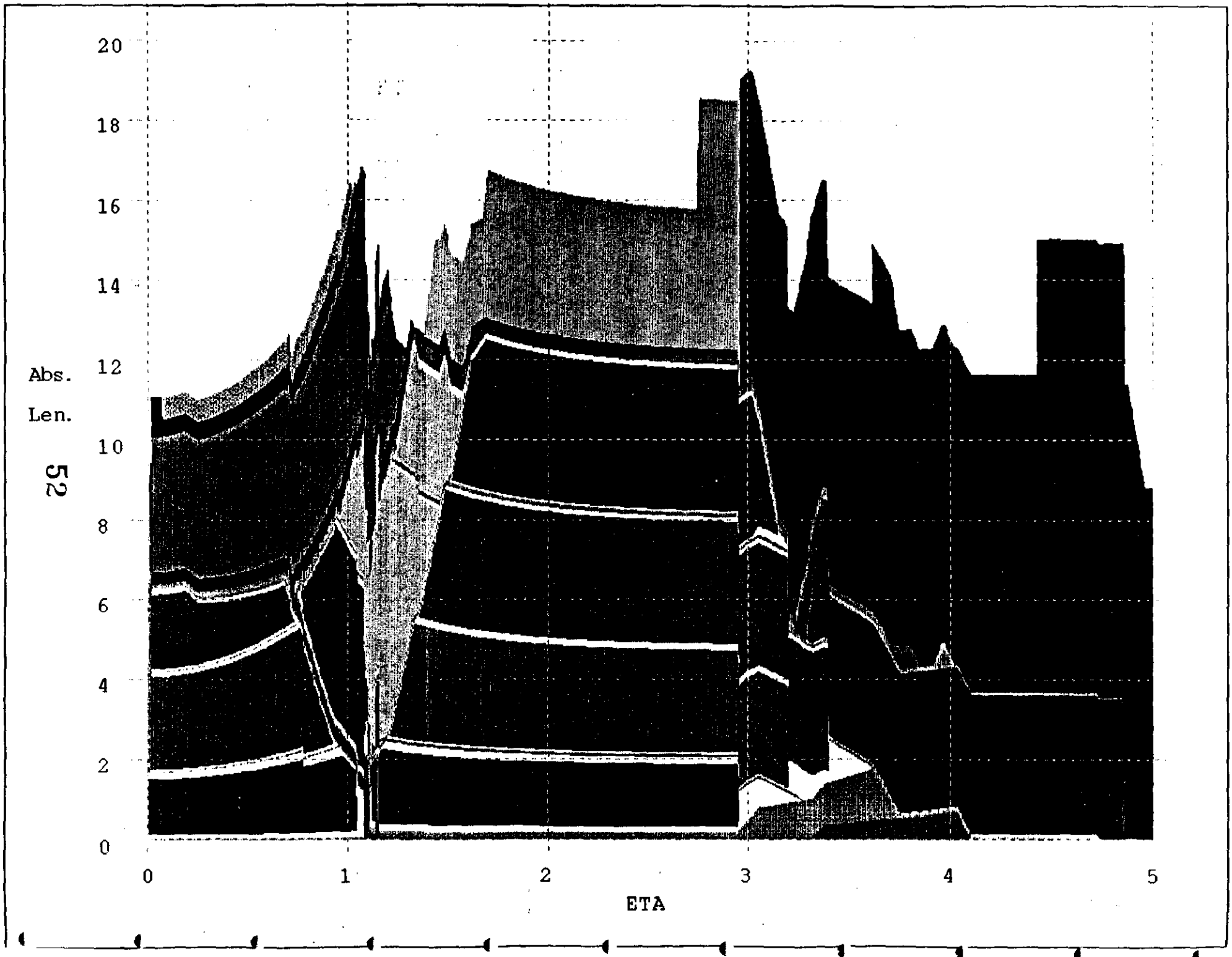
Figure 1: $\bar{E}(L)/E$ vs L for $E = 1$, 10, 100, 1000, and 10000 GeV.

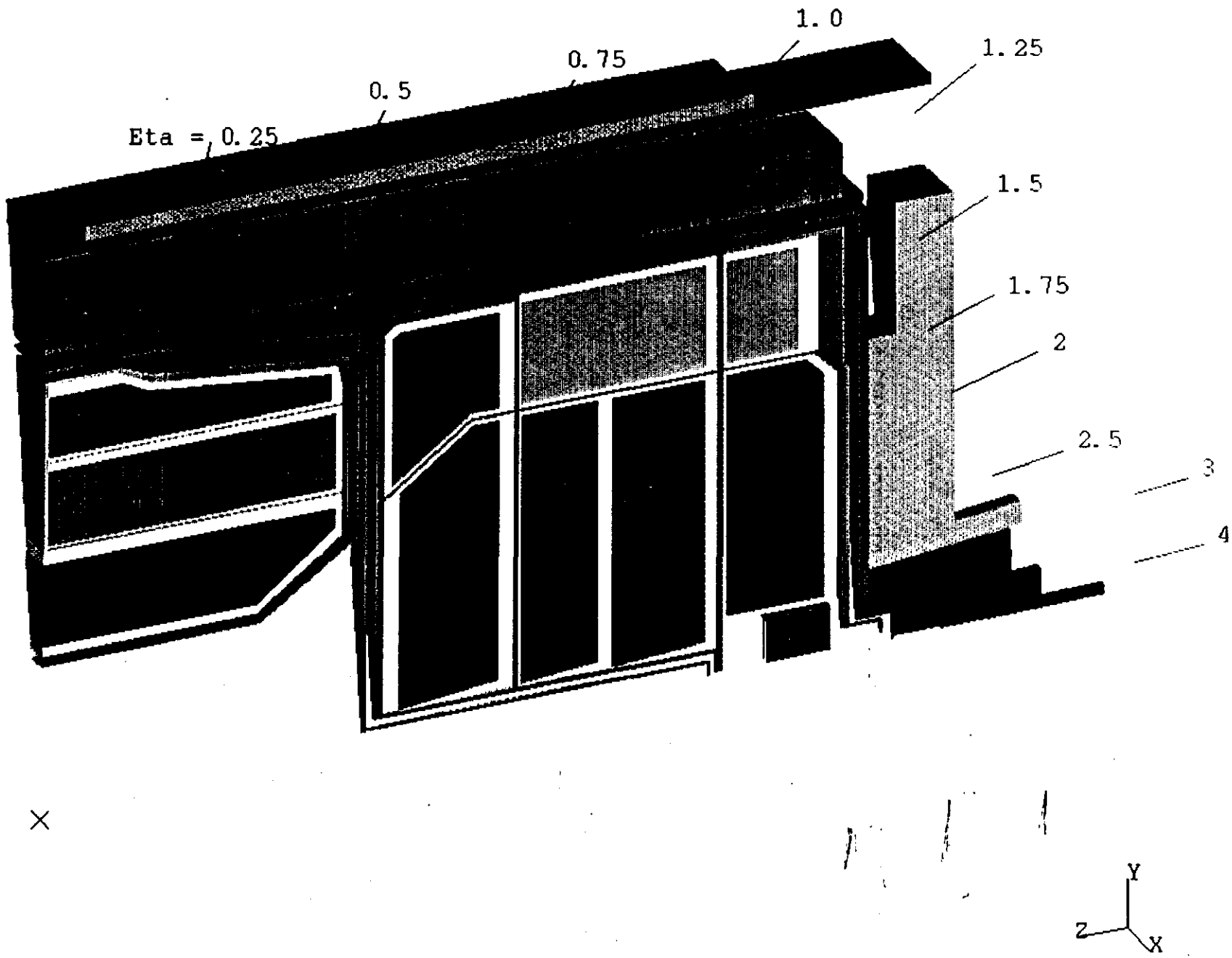
BACKGROUND AND PHYSICS RATES



- Bunch crossing 16ns
- Interactions/b.c. 1.6 @ $L=10^{33}$ cm^{-2} s^{-1}
- Highly selective trigger necessary (rejection factor of 1000–10000). Level 1 decision latency≈ 2–3 μsec.
- Very low physics rate:
  Higgs-->4 leptons (M=500MeV) 10^{-5} s^{-1}
- Signal path of all calorimeter channels has a storage element to accomodate for Level 1 decision time.
- Level 1 trigger will tag all signals pertaining to the corresponding bunch crossing for further storage (Virtual Level 2) or for transfer/digitization.

Even at LHC, consensus is that LAr is an excellent choice for calorimetry.


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


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

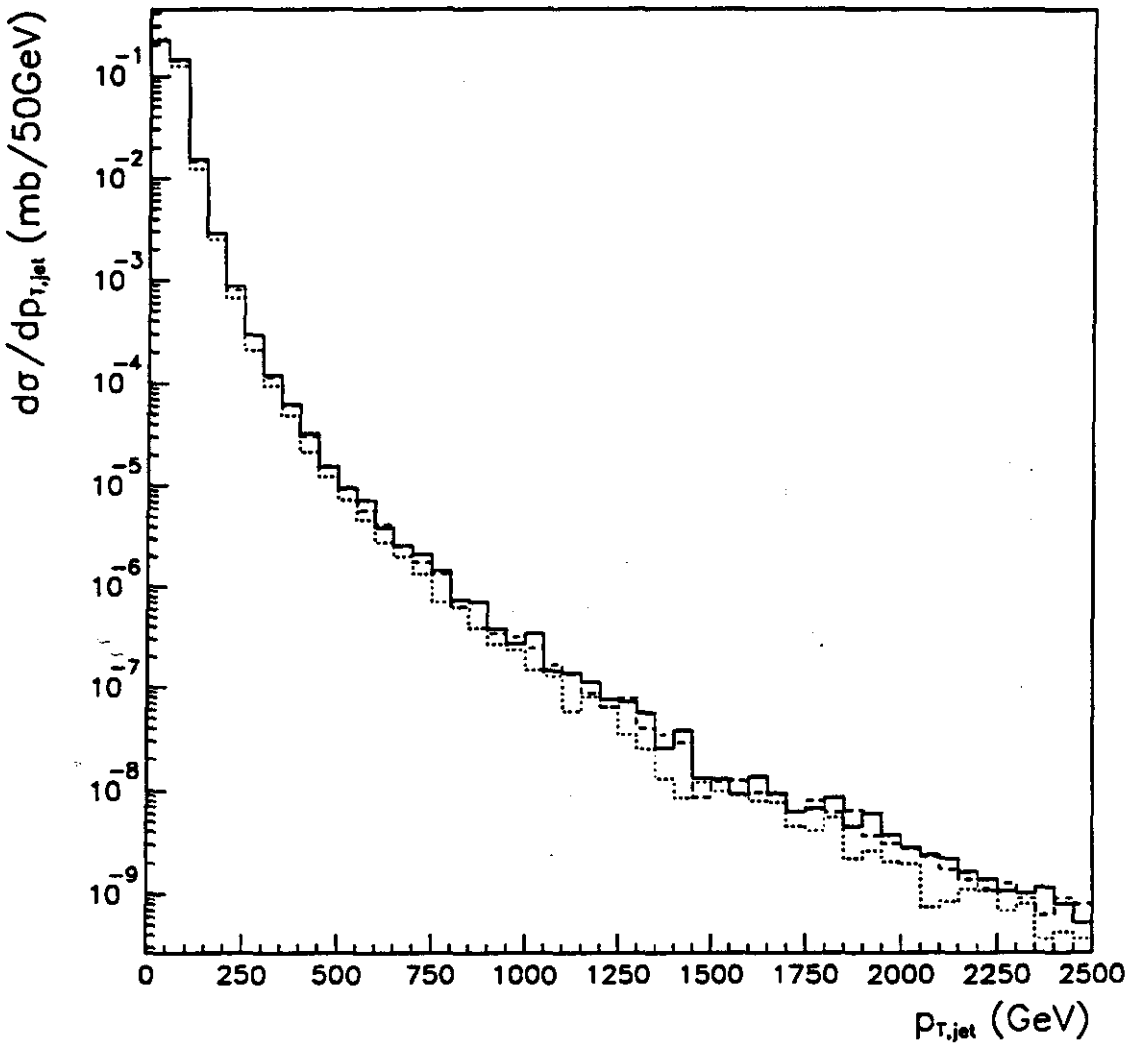


Figure 5: Inclusive jet cross section. Solid: Full calorimeter. Dash: 6λ calorimeter. Dot: 3λ calorimeter.

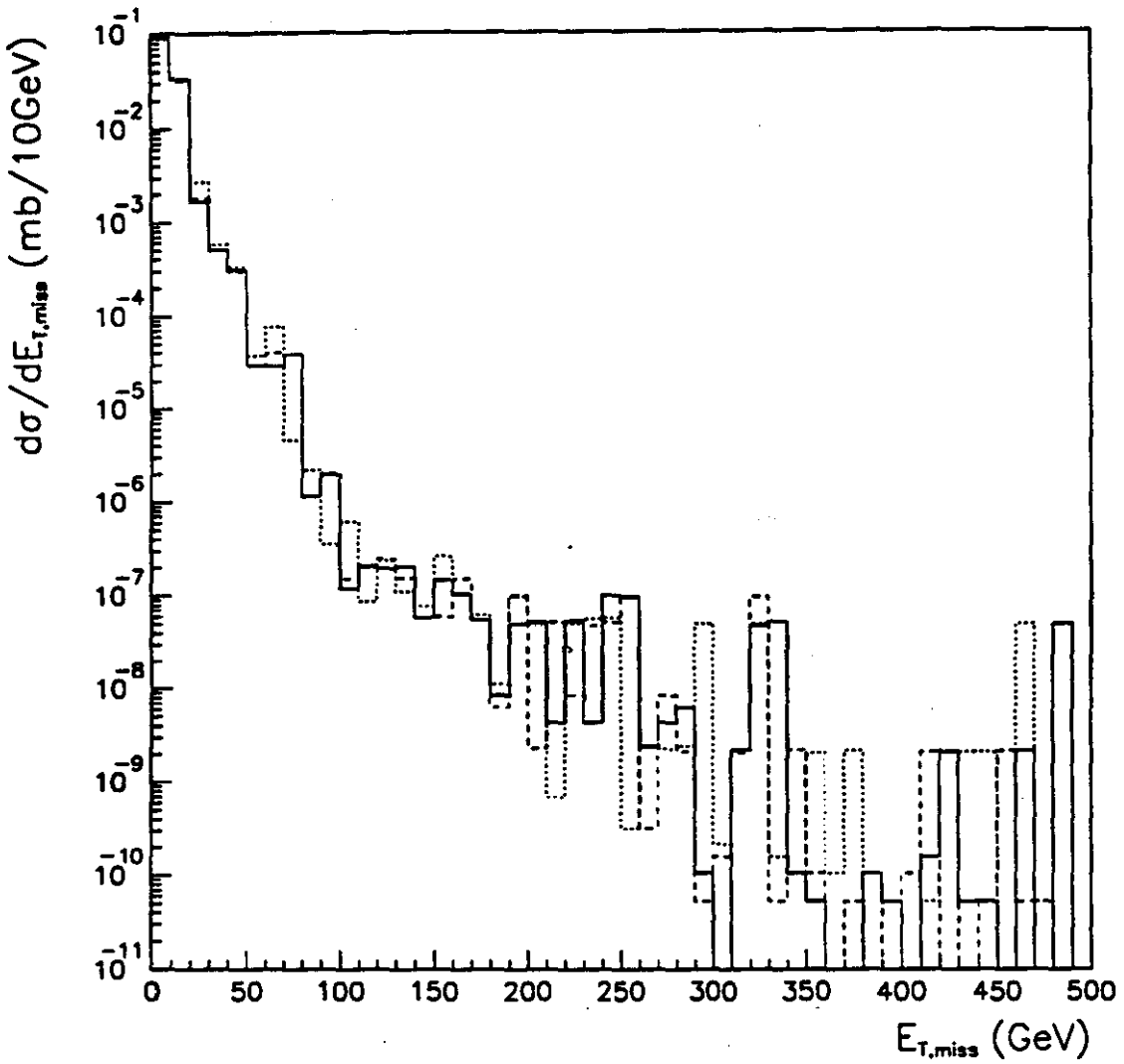


Figure 2: Inclusive $\not\!\!E_T$ cross section. Solid: Full calorimeter. Dash: 6λ calorimeter. Dot: 3λ calorimeter.

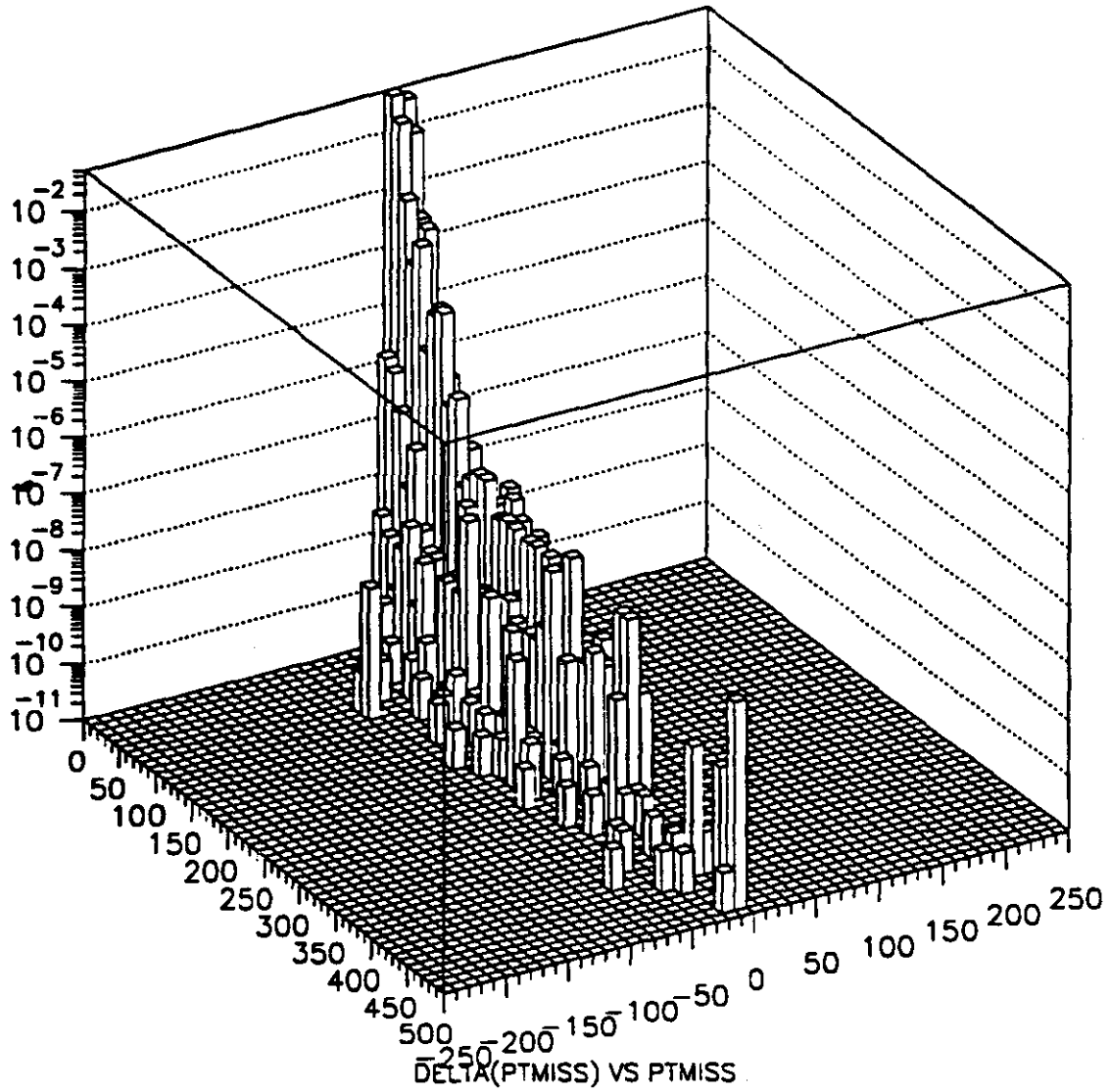
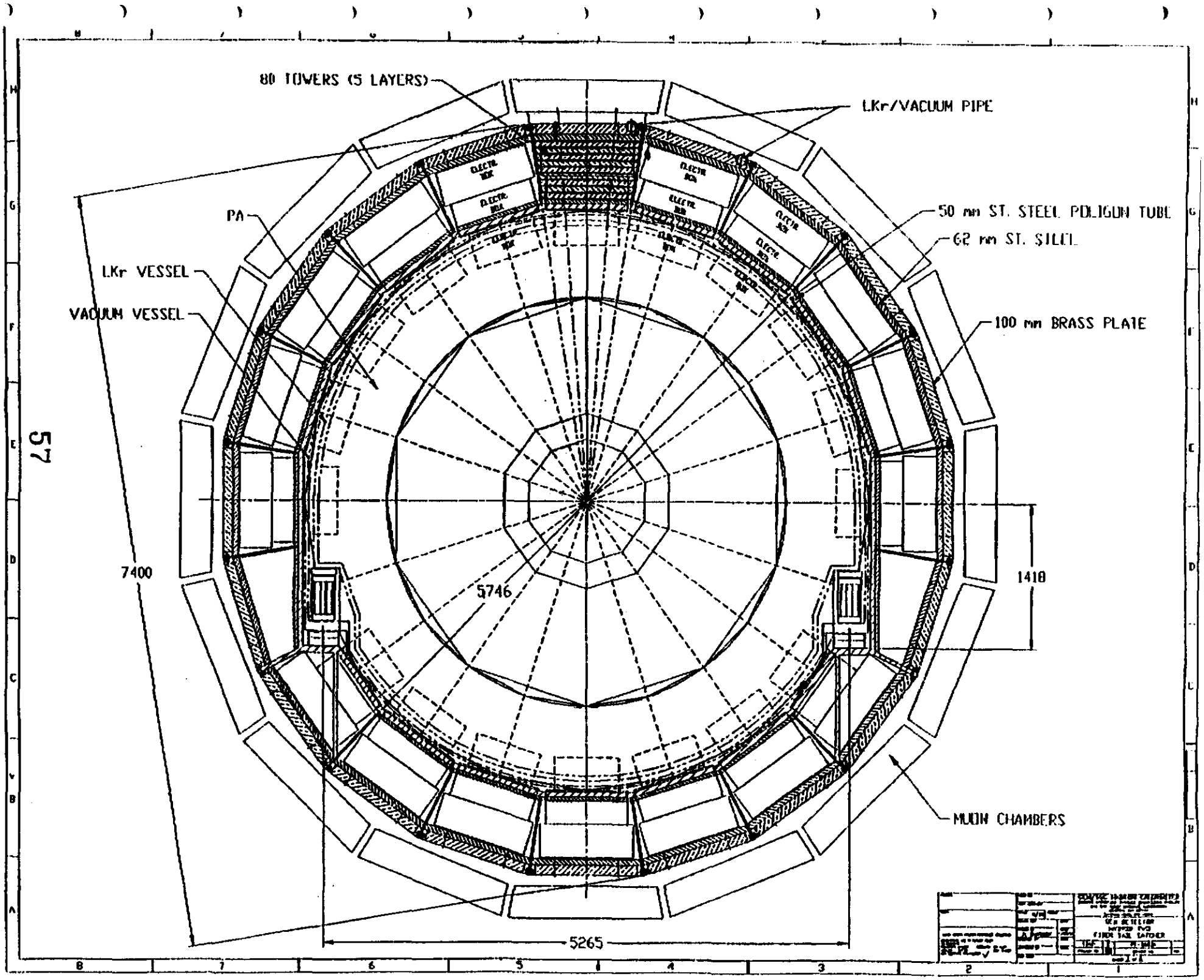


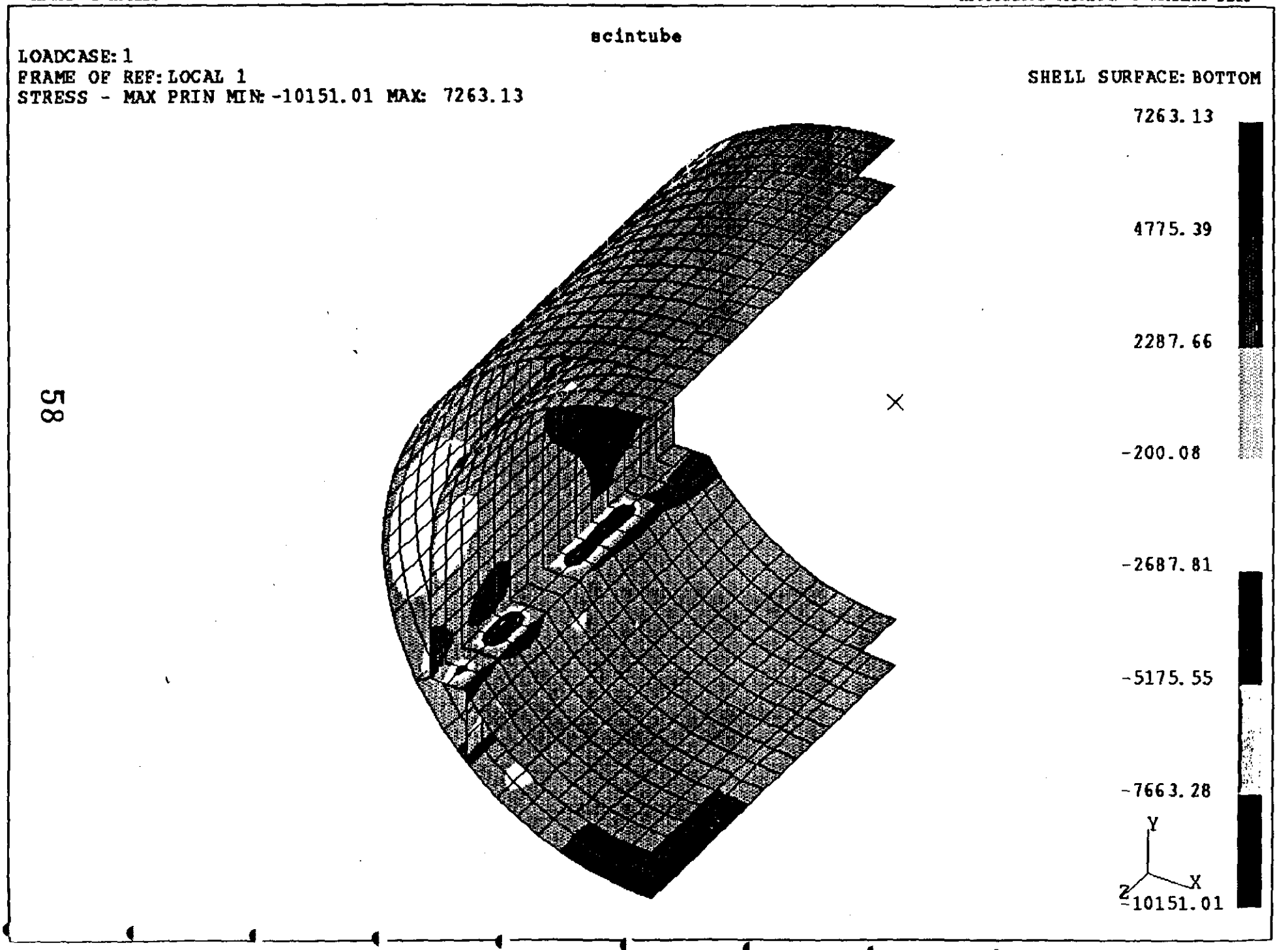
Figure 3: Lego plot of $\not{E}_{T,6\lambda} - \not{E}_{T,\mathrm{full}}$ vs. $\not{E}_{T,\mathrm{full}}$.


80 TOWERS (5 LAYERS)
LKr/VACUUM PIPE
PA
LKr VESSEL
VACUUM VESSEL
50 mm ST. STEEL POLIGON TUBE
62 mm ST. STEEL
100 mm BRASS PLATE
7400
5746
1410
MUON CHAMBERS
5265

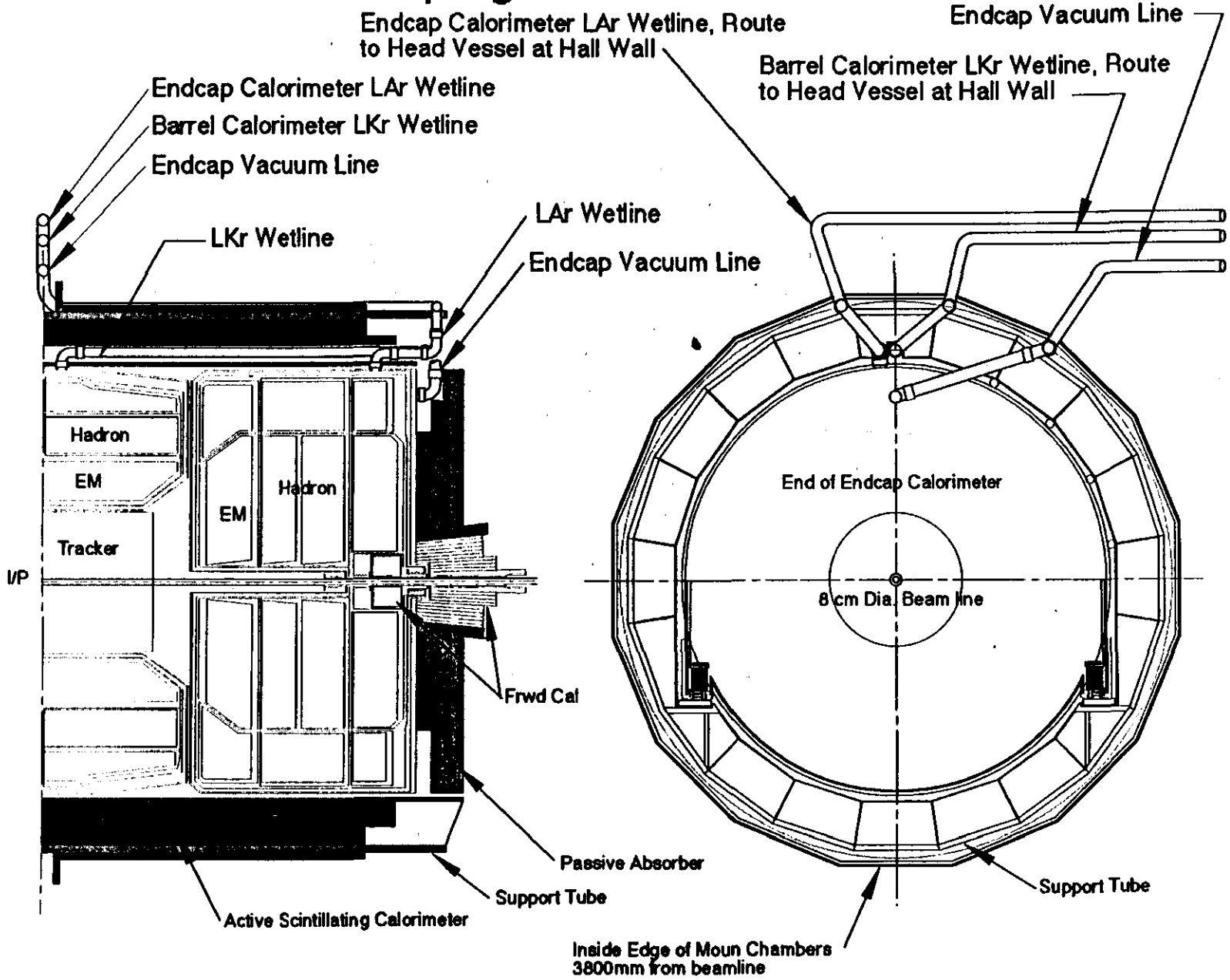
SDRC I-DEAS V: FE_Modeling_&_Analysis 13-NOV-92 09:01:03

Database: scintube
View : No stored View
Task: Post Processing
Model: 2-MODEL2

Units : IN
Display : No stored Option
Model Bin: 1-MAIN
Associated Workset: 3-WORKING SET3



GEM Calorimeter Piping Plan

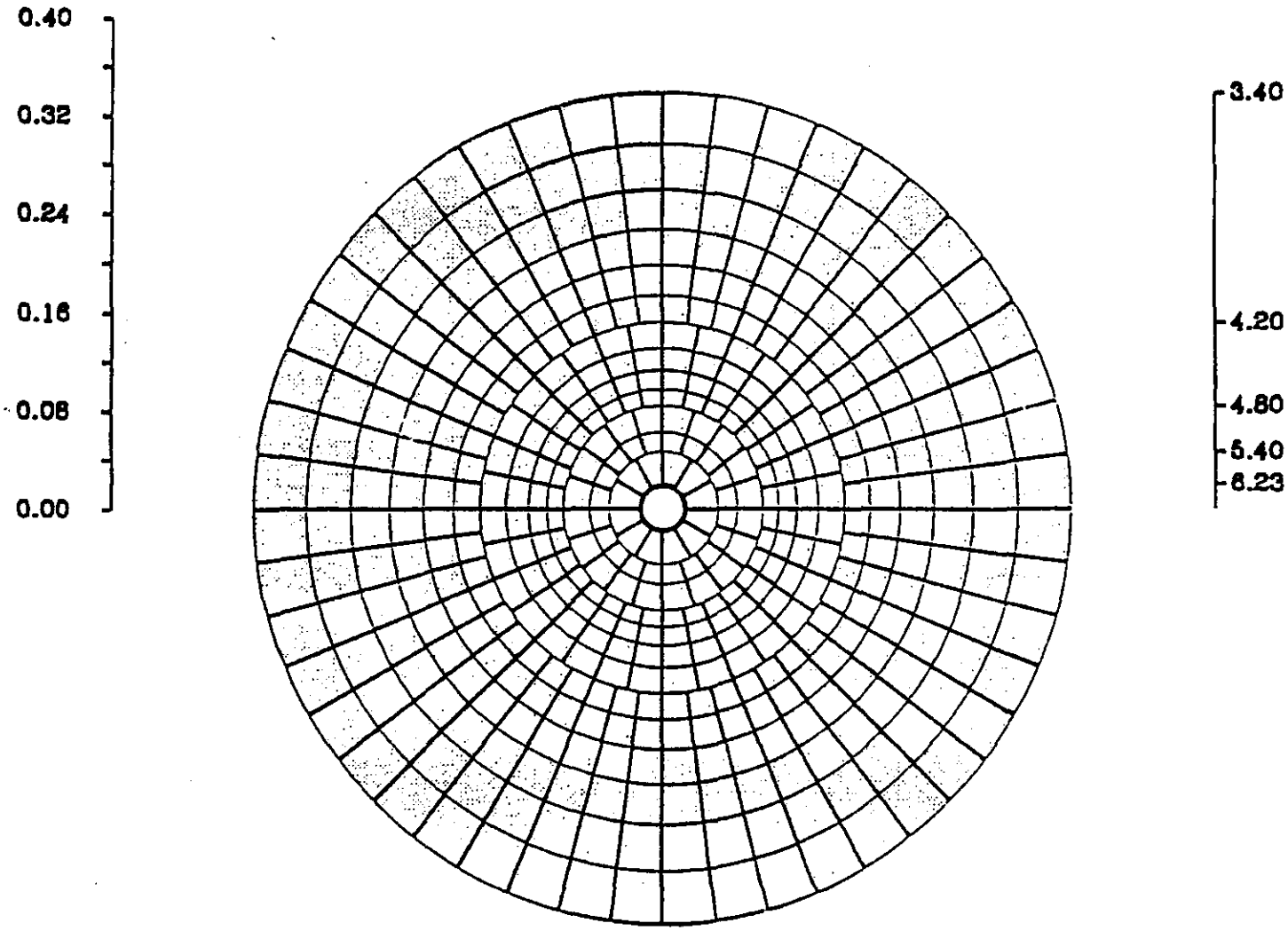


Half Section - GEM Calorimeter

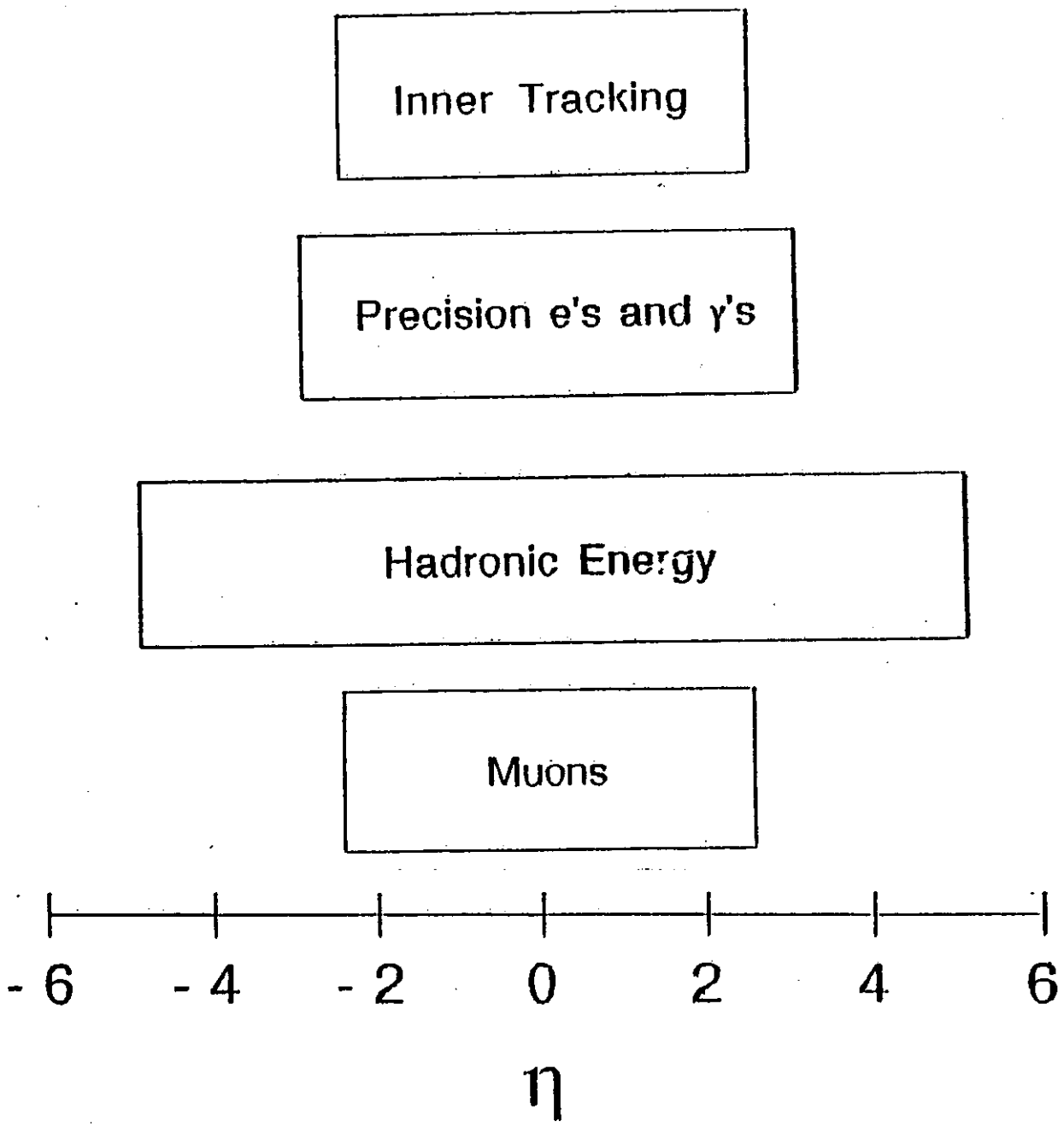
End View - Gem Calorimeter

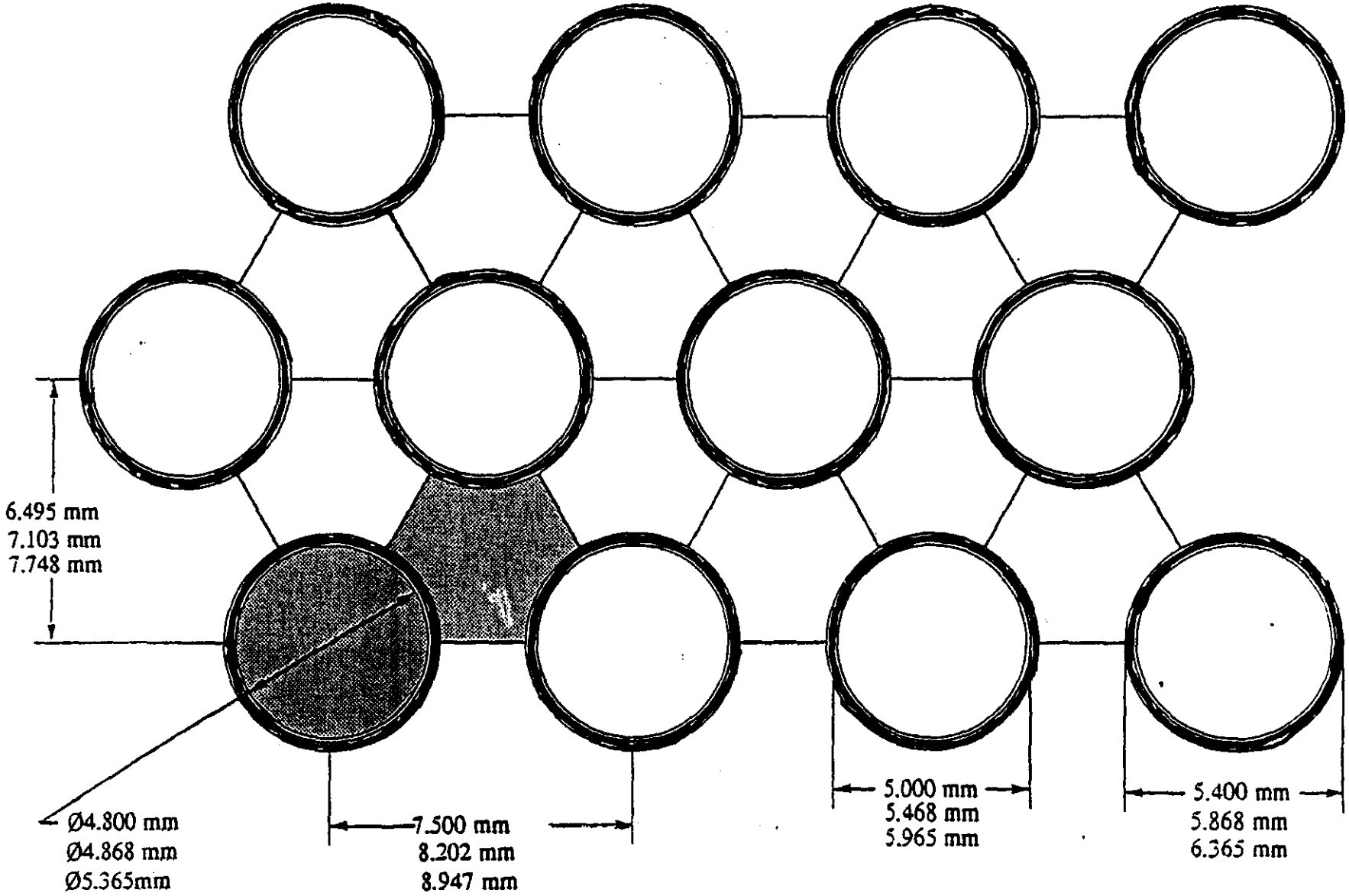
LLMason:Calorimeter Piping:11/16/92

10000
900


0.40
0.32
0.24
0.16
0.08
0.00
3.40
4.20
4.80
5.40
6.23

GEM Coverage

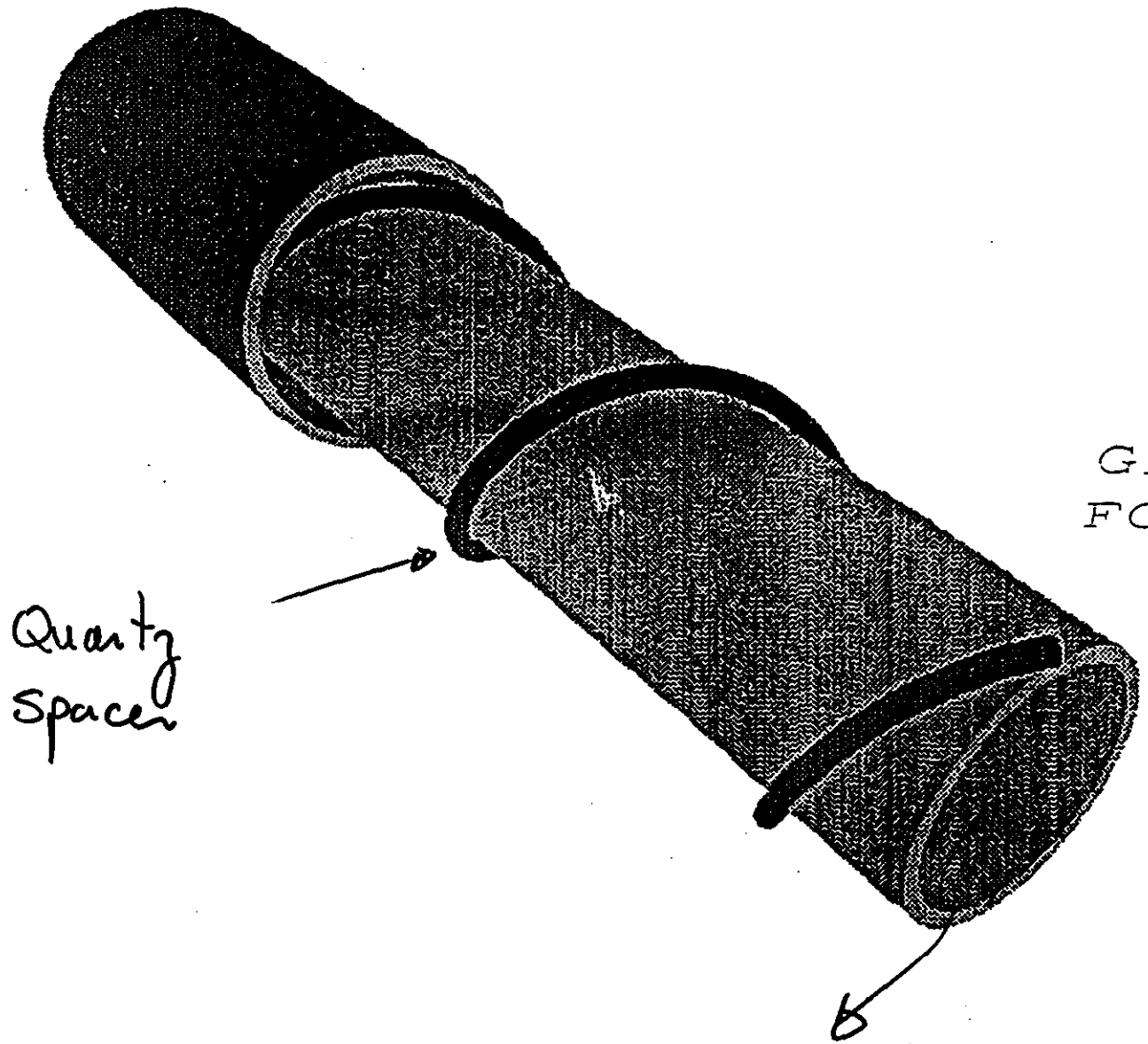




FCAL MODULE - TUNGSTEN ARRAGEMENT

LAR MODULE-DEFORM

SM CHAE


GEM LAC
FCal Tube
Quartz
Spacer
Tungsten Rod.

CONCEPTUAL GOALS

- FIX SCINT. CAL. REQUIREMENTS

  (MUON CONCEPTS ⇒ MUON GROUP)

- DETERMINE FORWARD CALORIMETER CONFIGURATION FROM INTEGRATED STUDY OF
  - NEUTRONS
  - MUONS
  - BEAM PIPE
  - FORWARD / VERY FOR. CAL.

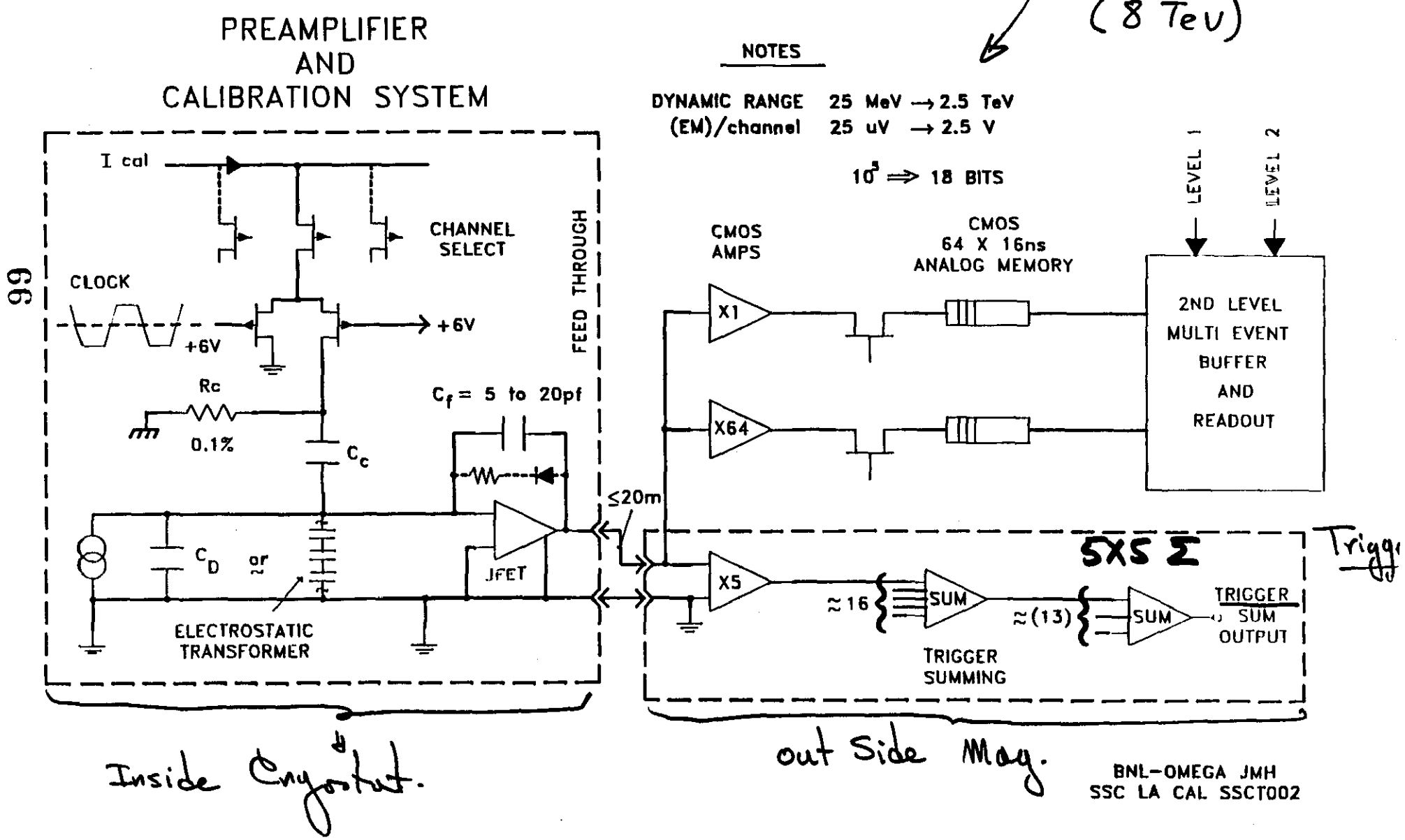
* 0.1 - 0.2% calibration.

$\simeq 10^{14}$ 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)



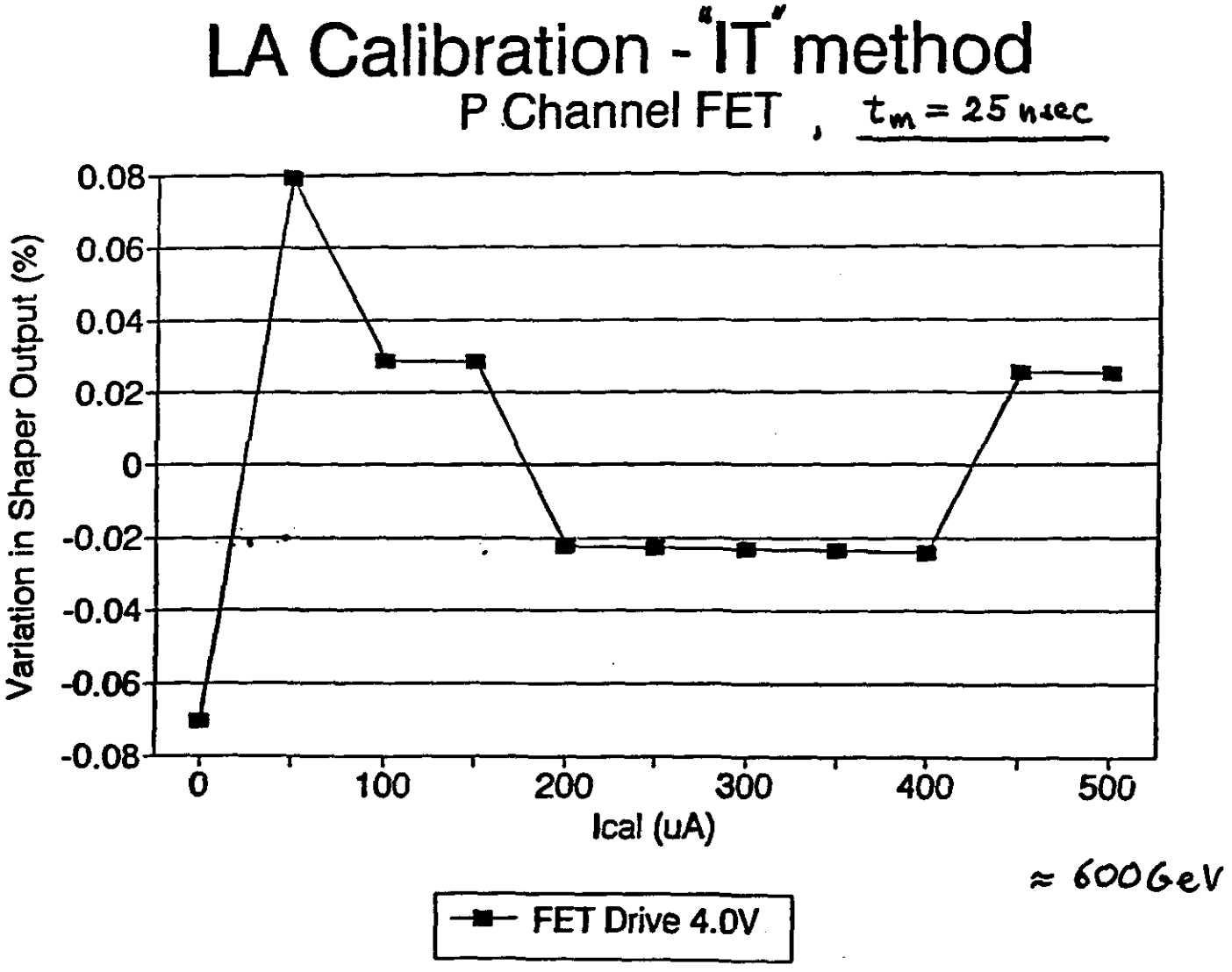
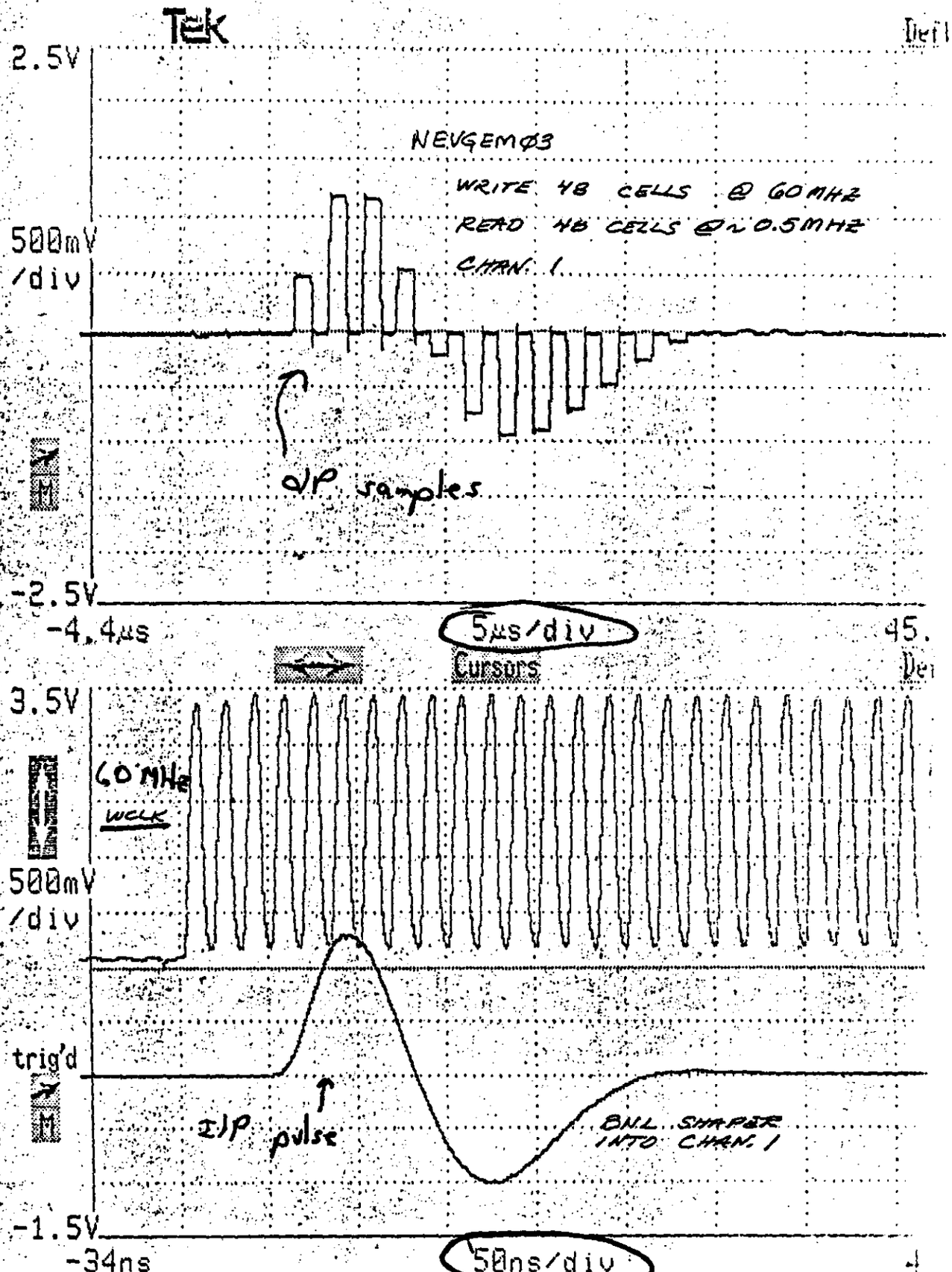

LA Calibration - "IT" method
P Channel FET , t_m = 25 nsec
Variation in Shaper Output (%)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
100
200
300
400
500
Ical (uA)
≈ 600 GeV
FET Drive 4.0V

Fig. 5

11402 DIGITIZING OSCILLOSCOPE [exp:3.7,dig:3.91,asy:3.3]
date: 2-SEP-92 time: 7:47:17 Instrument ID# B010270



Vertical Desc	Horizontal Desc	Acquire Desc	Lower Graticule	Trace Se
Avg(C2)	Window @ 1024 pts	Avg# >32	Linear	-2div Trace Se -2div

GEM Full Scale Barrel Calorimeter Prototype

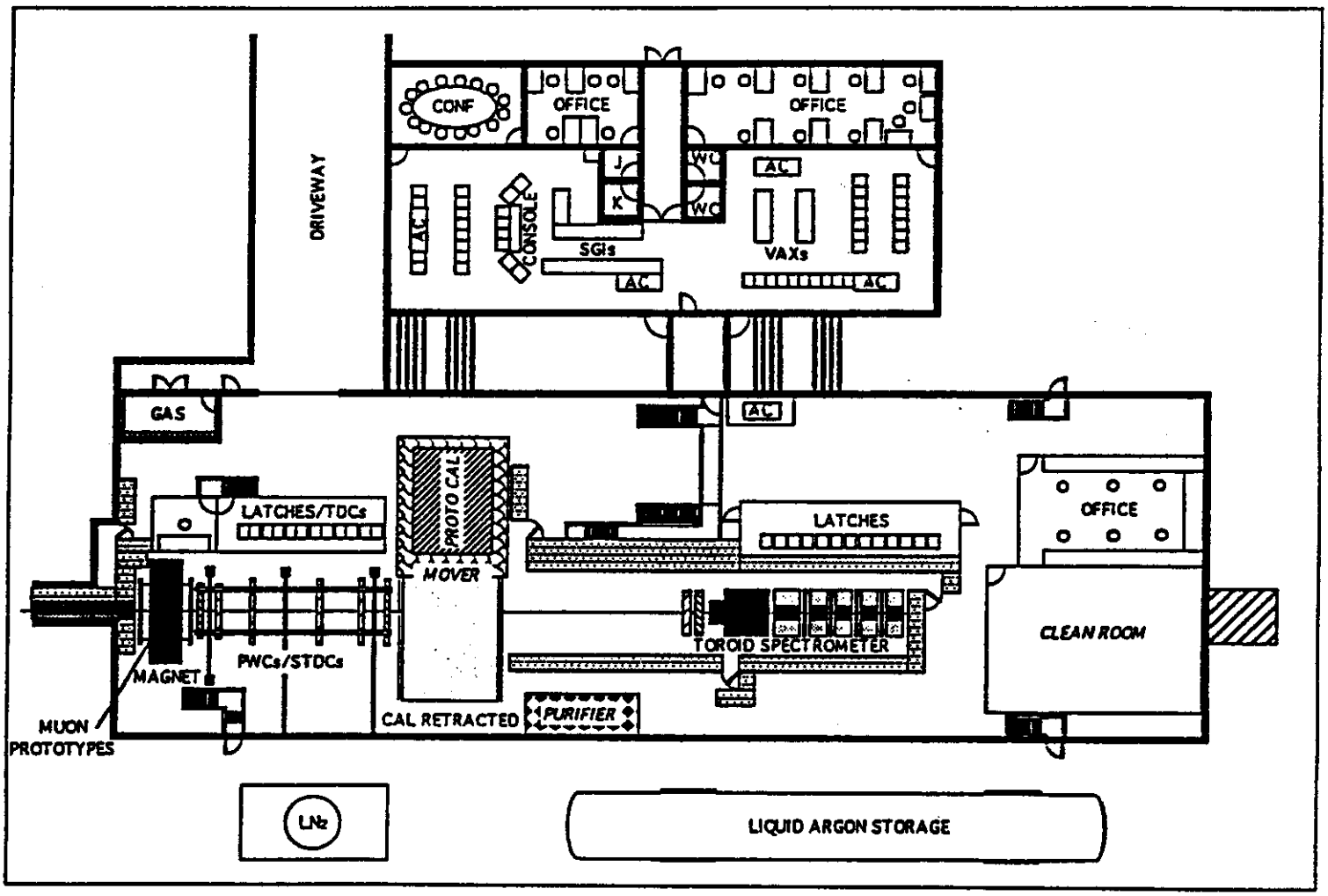
- Full Shower Containment
  [~5% Azimuthal Coverage]
  - EM Accordion Calorimetry
    2 – 3 Full-Length 9° Sectors
  - Parallel Plate Hadronic Calorimetry
    3 – 4 Half-Length 9° Sectors
  - Limited End Cap Calorimetry
    [Hadronic Portion of 1st Layer]
  - External Scintillating Calorimetry
- Cylindrical Aluminum Cryostat
  [5.5 m long; Liquid Krypton Fill]
- Versatile Calorimeter Transporter
  [Horizontal; Vertical; Rotation; Tilt]

GEM Barrel Calorimeter 1994-95 FNAL Beam Test

- Goals
  - Full Scale Engineering Studies [Mechanical; Electrical; Cryogenic]
  - Achieve System Integration [EM; Hadronic; External]
  - System Test of Readout Electronics
  - Resolution Studies at High Energies
  - Detailed Studies of Cracks & Gaps
  - Investigation of Barrel to End Cap Transition [Extending into 1996]

MWEST at FNAL

- Layout for GEM Muon Studies – Phase I



For Schematic Purposes Only – Not Drawn to Scale

gem

Calorimeter PM
G. Sanders

Calorimeter Eng
M. Harris

Subsystem Leader
B. Willis

Calorimetry PM

Calorimetry Engineer

Integration Phys
B. Wisniewski

Integration Eng
C. Eberle

Cryogenic Eng
D. Richied

Scintillating Calorimeter Physics
Yu. Kamyshkov
L. Sulak

Liquid Calorimeter Physics
V. Hadeka

Scintillating Calorimeter Engineer
M. Rennich

Liquid Calorimeter Engineer
L. Mason

Forward Calorimeter
"THE TEAM"

WORKING GROUPS

WORKING GROUPS

SCINTCAL HADRONS: SHMAKOV
+ SAVIN +

SCINTCAL MUONS: CAREY
+ BROMBERG + M°NEIL + SULLIVAN +

DETECTOR DESIGNS: WORSTELL + WYNN
+

FRONT END ELECTRONICS + PMT: AKCHURIN +
HAZEN +

SIMULATION: WOMERSLEY + ..

EM: McCARTHY + SEMAN + ..

LIQUID HADRONIC: MOCKETT +
LOBKOWICZ + ..

CABLES, CONNECTORS + FEED THROUGH
MAKOWIECKI + LOBKOWICZ + .

INTEGRATION + INSTALLATION
+ SCHEDULE: WISNIEWSKI, EBERLE
+ RICHIED +

TDR: GORDON +

P.R. CHINA: "LEADING COMMITTEE"

—1st Deputy Prime M. Zhu Rongji
(Economic Development)

—President China Shipbuilding Co.
Zhang Shou

—President Academy of Science,
Zhou Guangzhao

—Chairman State Council on
Science and Technology
Song Jian

—Minister of Aerospace,
Lin Zhongtan–Contact

"The primary aim of this Project is scientific collaboration. Profit is secondary."

gem

γeμ

Presentation by:

H. Newman

REVIEW OF MAJOR SSC EXPERIMENTS

UL 8/24/92

PURPOSE OF REVIEW:

The Technical Design Report (TDR) and associated documents will be the basis for a detailed evaluation of the proposed experiment by the SSC Laboratory, in consultation with the Program Advisory Committee (PAC), and by the DOE. The purpose of this evaluation is to ascertain that the scientific goals stated in the Letter of Intent can be accomplished, that the proposed detector is technically feasible, and that the collaboration has the resources and organization to build the detector according to specifications, on schedule and within the available budget.

The evaluation of a major SSC experiment will proceed in two stages:

STAGE I

The first stage will be primarily the responsibility of the Laboratory which will call on the advice of the PAC, augmented by a number of advisors with expertise in specific technical systems, engineering, fabrication, costing, and project management. It is the purpose of this first round to evaluate the scientific merit, the technical feasibility, the collaboration resources and management, as well as the proposed cost and schedule. The review will be based on the TDR and drafts of the associated documents. A satisfactory review will result in approval of the scientific, technical, cost and schedule goals for the project baseline and a recommendation that the collaboration proceed to draft agreements among the collaborating institutions.

REVIEW OF MAJOR SSC EXPERIMENTS

STAGE II

The second stage follows agreement between the SSCL and the collaboration on the baseline and a credible funding plan, and will involve primarily representatives of the Department of Energy. It will consist of a detailed analysis of the proposed technical, cost, schedule, and management baseline of the project. The review will examine the TDR, the detector-specific Project Management Plan (including plans for quality implementation and advanced acquisition), the status of plans and agreements for institutional assignments, the Cost and Schedule (by WBS), and the Conceptual Safety Analysis Report. A satisfactory review of the project will result in the acceptance of the baseline of the project by the DOE and will permit the start of fabrication of the detector.

CONTENT OF TECHNICAL DESIGN REPORT

The Technical Design Report (TDR) for a major detector should define its scientific goals and technical design and thus represents a very important document for an experimental program that is projected to extend over many years. The total length (including figures, tables, etc.) should not exceed 750 pages. The TDR should include:

- A list of individual members of the collaboration by institution, indicating the contact persons at each institution.
- A description of the physics goals of the proposed experiment and a demonstration of the capabilities of the proposed detector to address those physics goals.
- A description of the proposed detector, including the overall layout and choice of technologies. Major SSC detector projects can be divided into the following subsystems:

  a) superconducting magnet;
  b) tracking systems;
  c) calorimeters
  d) muon system;
  e) electronics, trigger, data acquisition and on-line computing .

For each of these subsystems, the TDR and accompanying Cost and Schedule (including WBS dictionary) and detector-specific Project Management Plan (including plans for quality implementation, advanced acquisition, and configuration management) should contain details on:

- design requirements and performance goals,
- selection of technology and potential risks,
- performance and cost optimization,
- performance of similar systems and R&D results,
- future R&D and prototyping,
- conceptual design of electronics and readout,
- calibration/alignment schemes, and monitoring,
- fabrication methods,
- assembly and installation, Ref.
- procedures for maintenance and repairs, Ref.
- test beam needs at SSCL and elsewhere, Ref.
- costs, schedule, and funding profile Ref.
- options for staging and upgrades, Ref.
- potential environmental and safety issues, and Ref.
- subsystem management and responsibilities of individual institutions for this subsystem. Ref.

- A description of the requirements for the interaction hall and surface facilities, and a list of other resources required from the SSCL.

- An overall plan for assembly, installation, and commissioning of the detector.

- A list of the Environment, Safety, and Health (ES&H) considerations.

In addition, the documents should include:

- A description of the organization and management of the collaboration, as well as interactions with the SSCL.

- A description of the resources of the collaboration in terms of equipment, engineering and fabrication facilities, personnel (engineers, technicians, research scientists), and financial support. The distribution of responsibilities among the members of the collaboration.

- The projected total project cost, including a WBS dictionary, a funding profile, and the project schedule with major milestones. The cost should be expressed in FY1992 dollars, using "U.S. accounting methods," and should include all detector-specific R&D/engineering costs.

- A summary of the financial resources of the collaboration, broken out by WBS in FY1992 dollars, for each fiscal year.

- A list of associated technical notes and publications.

GEM TDR ORGANIZATION

TDR TEAM

- **EDITORIAL BOARD:**
  H. Newman, N. Baggett, J. Reidy, G. Yost,
  F. Paige, O. Fackler, R. Panvini
- **PRODUCTION GROUP:**
  H. Durden, L. Fowler, C. Thomas, L. Ballard; J. Sullivan
- **INTERNAL REVIEW BOARD:**
  Lead Authors, Executive Committee, et al.

GENERAL TASKS

- Overall Document Review, Editing, Layout, Schedule
- Coordination With Lead Authors; One Author Responsible for Each Section Submission
- Centralization at SSC Lab; Coordination by Meetings, Network, Videoconference, etc.

TECHNICAL TASKS

- Text Formatting, Standardization:
  Limited Conversion from TeX, LaTeX
- Version Control: MAC or SSCVX1 File Server;
  Code Management System
- Figure Conversion, Editing, Placement
- Provide Network-Accessible Versions: RTF, ASCII
- File Distribution, Local and Network Access Control

STANDARDS

- MicroSoft Word (MAC or PC)
- Font: Times Roman 11 pt; 14 pt Spacing (Preliminary)
- File Transport (RTF) Via Internet

GEM TDR OUTLINE

Due April 30, 1993

	Chapters	Pages	Lead Authors
1	Executive Summary: Detector Overview	25	Barish, Willis
2	Physics Goals, Performance, Simulations	80	ETBD, Lane, Barish, Paige
3	Magnet Technical Design Report	100	Stroynowski
4	Muon Spectrometer	100	Taylor, Marx
5	Calorimeters	100	Willis, Gordon, Rutherfoord
6	Tracker	80	Baltay
7	Electronics	90	Marlow, Shaevitz
8	Computing, Controls, Networking	25	McFarlane, Cornell
9	Summary of GEFUR	20	Harris
10	Assembly and Installation Plan	20	Harris
11	Detector Operations and Access Plan	20	Wisniewski, Harris
12	Detector Beamline Interface	10	Wisniewski, Morgan, Chapman
13	Detector Upgrades; Staging Options	10	Barish, Willis
14	Neutron Particle Backgrounds and Shielding	20	Marx, Wuest, Waters
15	Beam Testing and Calibration	20	Yost
16	Project Management Plan Summary	10	Sanders, Baltay
17	Environmental, Safety & Health Considerations	10	Woolley
18	Cost Estimate Summary; Responsibility Matrix; Funding Plan	10	Sanders, Barish, Willis
		750 Pages	

Separate Documents	
Project Management Plan	Sanders, Baltay
Cost/Schedule Baseline and WBS Dictionary	Sanders, Barish, Willis
Preliminary Safety Analysis Report	Woolley

GEM TDR: CONCERNS and ISSUES

- PHYSICS CHAPTER
  - Lead Experimentalist: Full Time
  - Time To Complete Studies: 3 Months, Based On Fixed Detector Geometry
  - Depth of Studies: Founded In Subdetector and Specialized Simulations, With Reconstruction
- PROOF OF DETECTOR PERFORMANCE
  - Neutron Fluxes; Hit Rates, Occupancy and Background Energy Spectra
  - Pattern Recognition Studies
  - Reconstruction in Non-Uniform Field, With Background
  - Reliable Estimate of Reconstruction and Particle ID Efficiencies
  - Data Flow: Trigger and Online DAQ Complexity and Cost
  - Detector Calibrations: Test Beams and In Situ
- OPTIMIZATION OF PERFORMANCE/COST
- DETECTOR OPERATION, INTERFACE, EVOLUTION
  - Access Procedures, Steps, Time Required; Including Impact of:
    - * Magnetic Fringe Field
    - * Materials Activation and Handling
  - Beam Pipe and SSC Vacuum Requirements
  - Luminosity: Minibeta Upgrade Plan
- MAGNETIC FIELD
  - Mapping Accuracy, Time To Map
  - Monitoring Instrumentation
  - Use In Muon Reconstruction; Momentum Resolution

GEM TDR SCHEDULE:
DUE TO SSCL
APRIL 30, 1993

MILESTONE DUE DATES	
Intermediate Drafts	12/18, 1/20, 2/17
GEM Internal Board Reviews Completed	1/8, 2/3, 3/1
Final Draft for Review	3/15
Final GEM Internal Review Completed	3/26
Finished Chapters: All Text and Figures	4/9
Document Complete; Submitted To SSCL	4/30

GEM TDR DRAFTS

DECEMBER 18

- Complete Draft of More "Advanced Sections:" Magnet, Tracker, Installation, etc. → NOW PRELIMINARY
- Less Advanced Sections (e.g. Calorimetry, Muons): Complete Detailed Outline, Partial Draft; Plan and Schedule for Final Draft.

JANUARY 20

- Drafts Due For All Sections
- Preliminary Drafts:
  - Complete Section Structure (3 Levels)
  - Summary of All Missing Text, In Place
  - Status Report: Plan, Schedule, Major Tasks for Final Draft

FEBRUARY 17

- Complete Draft for All Sections
- Final Draft for More Advanced Sections
- Status Report and Summary-In-Place of Planned Revisions, For Sections Not In Final Form

MARCH 15 ONWARDS

- All "Final" Drafts Submitted To TDR Team and Internal Review Board; As Many as Possible Prior to March 15
- Weekly Working and Review Group Meetings: General Status, Problem Areas, Scheduled Focus On Individual Sections

APRIL 9 ONWARDS

- Final Chapters In Hand
- Final Chapter-Editing and Global Editing
- Final Document Processing: Text and Figure Layout

APRIL 27 – 30

- Document Reproduction
- Final Check In Time for Submission

GEM TDR DOCUMENT ISSUES

- **REQUESTS TO GEM LEADING CONTRIBUTORS**
  - Serve As Referees On Internal Review Board
  - Additional Manpower for Editorial Board, and Production Team
- **FIGURE and TEXT INTEGRATION**
  - "Figure Czar" (Physicist): Specifically To Review and Track All Figures
  - Technical Support for Figure Import, Editing and Page Layout
  - Professional Lab-Based Or Commercial Support
- **TECHNICAL DETAILS**
  - Font Size and Style
  - PC and MAC System Monitor; Other Features
  - Code Management System for Version Handling: Central File Server; Simple Procedures
  - Symbol Table

GEM TDR

(1) A Proposal to SSCL and DoE;
(2) a Design Report

(1) Proof of PHYSICS CAPABILITY
(2) of TECHNICAL FEASIBILITY } *

UNIFIED TOP-DOWN STRUCTURE

PHYSICS GOALS ↔ SUBSYSTEM "MISSION", CHARACTERISTICS ↔ DETECTOR ENVIRONMENT; OPERATIONS

MISSION ORIENTED
- (ONLY) SUFFICIENT DETAIL TO MAKE THE CASE
- REFERENCES

The Basis for SSCL, DOE REVIEW;
"The Basis" for GEM APPROVAL

* LINES of RESPONSIBILITY
* PHYSICS - DETECTOR OVERSIGHT

• NEXT TDR Meeting : SSCL FRIDAY 12/11 1PM

PAC SUMMER MEETING: 7/31 - 8/6, 1993

During the week-long meeting in July, the PAC will review the status of the GEM TDR evaluation and address any issues left unresolved from the earlier meeting. The GEM spokespersons and key personnel are expected to be available for brief presentations and interactions with PAC members. It is hoped that at this meeting, the PAC, after reviewing the GEM TDR and the overall initial experimental program, will be able to recommend that GEM proceed with the Laboratory to formulate the baseline to be presented to DOE and to draft agreements with the collaborating institutions.

SCHEDULE AND ORGANIZATION OF REVIEW

TDR REVIEW: 5/24 - 5/29, 1993

During the week-long review of its TDR, the Gamma-Electron-Muon (GEM) Collaboration will be given ample time to present the project and to interact with the committee members.

The first day will be reserved for an overview of the project presented by the collaboration in a plenary (and public) session. This will be followed by several days of work in parallel sessions during which the committee members will be given more detailed presentations and have a chance to clarify issues not addressed in the summary. The remaining time will be reserved for preparation of the summary reports and lists of issues that need further attention or clarification. Following oral reports by the subcommittees, written reports to the SSCL will be formulated and discussed.

The members of the review committee (PAC plus experts) will be grouped into two sets of subcommittees with overlapping membership. The first set of subcommittees will meet on days two and three and will focus on the subsystems listed above. The second set of subcommittees will meet on days four and five to address more global issues:

a) interaction hall, surface facilities, installation, and safety;
b) physics performance, trigger, optimization and integration;
c) cost and schedule; and
d) collaboration management and resources.

DOE REVIEW: October 1993 (tentative date)

Following a positive recommendation by the PAC and the approval by the SSCL director to proceed towards the establishment of the project baseline in detail, the Laboratory and collaboration will prepare and submit the following documents:

- Technical Design Report, including updates and addenda;
- Cost and Schedule (including WBS dictionary) identifying separately procurements by the SSC Laboratory as opposed to other funding agencies in the US and abroad, and matched to the projected funding profile for the major SSC detectors;
- ~~SDC~~ Project Management Plan, including plans for quality implementation and advanced acquisitions;
- Safety Analysis Report; and
- Funding Plan, including the status of agreements.

The DOE will organize a thorough review of these documents. An evaluation of resources realistically available to the U.S. and foreign institutions combined with assessment of the management, cost, schedule, and technical risks will form the basis of the review. It is anticipated that the process of arriving at an approved ~~SDC~~ baseline will take several months.

A summary of the proposed schedule and the projected results for the evaluation of the ~~SDC~~ project is appended below.

gem

γeμ

Presentation by:

G. Sanders

Tracker

Si

Silicon tracker mechanical	LANL	$893
silicon	Oregon	200

IPC

Mechanical	LANL	140
Mechanical	Yale	198
chambers	Michigan	110
~~Albany~~ chambers	Albany	40

Test Beam

	SSC	155
	Albany	40
		1796

FY '93 GEM Muon Budget WBS/Org Matrix (10/1/92-3/31/93)

2.0	Task	Task Definition																				Total Task
2.1	1	Develop chamber technologies	BU	BNL	Draper	IHEP	ITEP	JINR	LLNL	LRS	LSU	MIT	MSU	ORNL	PNPI	SSCL	Stony	TU	UA	UH	UT	($Ks)
		KSS-->>																				
2.1.1		CSC R&D	55	250		20		20	25						50					50		470
2.1.2		RDT R&D	35					20				50	65									170
2.1.3		RPC R&D							90			40										130
2.2	2	Chamber Performance Eval.	15	50			15	20			5	20			10	100				25		260
2.3	3	Muon Trigger Research and Dev.		40								10	20									70
2.4	4	R & D of alignment technology			115				95													210
2.5	5	Electronics Evaluation	60	40		10		10				20	30		10					10		190
		(Approval Pending)																				
2.6	6	Simulations							6		10	17										33
2.7	7	Ind Chamb Des & Layo't Cham Fac'ry																				0
		(Post TDR activity)																				
2.8.1	8	Engineering Coordination			10				25													35
2.8.2	8	Muon Cham SS, Shd'g, and Infras'ture			625				125							50						800
2.8.3	8	Eng Design of Chamb Serv.							25							20						45
		Total Org Task Budget ($K)=	165	380	750	30	15	70	391	0	15	157	115	0	70	170	0	0	0	85	0	2413
																					2413	

Calorimeter

Scintillating

Engineering	ORNL	900K
R+D	Scintcal coll.	500K
Forward	TAMU...	150K
BaF_2 closeout	Caltech	200K

Ionization

Engineering	MM	1300
EM R+D	BNL	1000
End cap	Washington	260
Hadron ...	Rochester	400
Forward...	Arizona	255
		~5000K

R+D PLAN

ENGINEERING, FOR TDR+		
	ORNL	0.5 - 0.9
	MMD	1.4 - 1.6
		1.9 - 2.5
START PRODUCTION OF EM CALORIMETER		
	BNL, BEIJING, COLUMBIA, NOVSIBIRSK	1.4 - 1.5
SCINTILLATOR R+D		
	SCINT. CAL UNIVERSITIES	0.4 - 0.6
SCINT. CAL PROTOTYPE	"	0.2 - 0.6
		0.6 - 1.2
(LIQUID) HADRON CAL. PROTOTYPES	U. ROCHESTER	0.4 - 0.5
	U. WASHINGTON	0.26 - 0.35
		.66 - .85
FORWARD CALORIMETER		
	U. ARIZONA, U.T.A.M., FAIRFIELD	0.4 - 0.5
TOTAL		4.96 - 6.55

Magnet budget
and program plan
is procurement
sensitive

FY93 Summary

Magnet	$14 m
Muon	5
Calorimetry	5
Tracker	1.8
Electronics	3.4
Computing	0.5
Interface Systems	1.0
Subsystem Manage.	0.5
Eng / Integration	1.5
Project Management	1.5
Reserve	
	$34.2

total DOE + TNRLC

gem

γeμ

Presentation by:

K. McFarlane

1

Physics | Simulation Progress

K. McFarlane

12/10/92

① Physics Performance of the GEM Detector

- Benchmark Physics Processes = K. Lane, F. Paige
- Study groups, e.g. $H \to \gamma\gamma$ at Cal Tech (all Higgs)

② Tools : gemfast - T. Skwarnicki (SMU) with support from I. Sheer (generators), S. McKee (Tracker), H. Ma, F. Lobowitz (Calor.) P Dungus, T. Wenaus (Muon), M. Shupe (FCAL) H. Uiferwaal (Trigger).

③ Calorimeter Simulations Workshop (Dec 6th-7th)

- focus on tools
- first meeting of Cal. Sim. Working group.

Physics Studies

Steps required:

1. Definition of apparatus — Collaboration
2. Detailed simulations of sub-detectors — subdet. groups
3. Provision of parameterizations of sub-detectors to 'gemfast' czar (T.S.) — subdet. groups.
4. Incorporation of new params. in gemfast — czar
5. Testing of gemfast by subdetectors groups
6. Release of verified gemfast — czar
7. Physics studies — physics groups
8. Review of results — "
9. Report drafted — Lane, Paige, Barish, Exp.
10. Final Report

3 months is a short time for this!
Compare with TDR schedule.

Rolling, iterative process, but final result must be defensible in detail

1. Physicists will see GEM first in the Physics section of the TDR. (e.g. PAC).

2. The GEM that they see will be <u>gemfast</u>.

3. Subdetector groups must <u>ensure</u> that <u>gemfast</u> is a reasonable representation and they must <u>support</u> it. By assigning man power to the steps given before, <u>and</u> by supporting it (e.g. in PAC meeting) if questions are raised.

PHYSICS PERFORMANCE OF THE GEM DETECTOR

8.1 INTRODUCTION

8.1.1 Brief overview of electroweak and flavor symmetry breakings. Other physics beyond the standard model. Physics at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

8.1.2 Brief summary of GEM detector features and strengths – γ, e, μ and $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

8.1.3 Overview / summary of Volume 8.

8.2 GEMFAST – PARAMETERIZED SIMULATION OF GEM

8.2.1 Overview of subsystems: CT, EC, HC, FC, MU, TR/DAQ — General description, coverages, cell sizes, acceptances.

8.2.2 GEMFAST parameterization of subsystem responses.

8.2.3 Plots of momentum resolutions vs. η for CT, MU; charge significances; single-particle energy resolutions in EC, HC, FC; missing E_T resolution, etc.

8.2.4 Jet definition and jet energy resolution.

8.2.5 Trigger strategies and efficiencies; special problems of $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

8.2.5 Shortcomings, approximations of the physics simulations.

3.3 STANDARD MODEL HIGGS PHYSICS

3.3.1 $H^0 \to \gamma\gamma$ ($M_H = 80 - 150\,\mathrm{GeV}$). This and the associated production process should be studied for couplings smaller than standard model (as in the minimal supersymmetric standard model) to determine the limits of intermediate-mass Higgs detectability.

3.3.2 $t\bar{t} + H^0 \to \ell\gamma\gamma + X$ ($M_H = 80 - 150\,\mathrm{GeV}$). This process will be studied at luminosities $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

3.3.3 $H^0 \to Z^0 Z^0 \to \ell^+\ell^-\ell^+\ell^-$ for $\ell = e, \mu$ ($M_H = 140 - 800\,\mathrm{GeV}$). For the 800 GeV Higgs, this process will be studied at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

3.3.4 $H^0 \to Z^0 Z^0 \to \ell^+\ell^-$ jet jet ($M_H = 800\,\mathrm{GeV}$).

3.3.5 $H^0 \to Z^0 Z^0 \to \ell^+\ell^-\nu\bar{\nu}$ ($M_H = 800\,\mathrm{GeV}$).

3.6 New, auxiliary Higgs studies, if any. For example, Z^0, $\ell^\pm$ and decay-plane angular distributions.

.4 HEAVY FLAVOR PHYSICS

.4.1 $t\bar{t}$ production for $m_t = 140\,\mathrm{GeV}$ and $250 - 300\,\mathrm{GeV}$ in standard ($t \to W^+ b$) and non-standard ($t \to H^+ b$ for $m_t \geq 200\,\mathrm{GeV}$) decay modes and mass measurement via the $M_{\ell\mu}$ and multijet distributions. Tagging the $t\bar{t}$ events by an isolated lepton *plus* an inclusive muon from b-decay is a major test of GEM's abilities. The charged Higgs mass will be $M_{H^+} = 150\,\mathrm{GeV}$ and we shall assume the decay modes $H^+ \to c\bar{s}$ and $\tau^+\nu_\tau$ with variable branching ratios. Identification of W^+ and H^+ in dijet decay modes is an important consideration here.

.4.2 If time permits, we shall study the W polarization in $t \to W^+ b$ decay. This involves measuring the angular distribution, in the W rest frame, of the dijet from W decay relative to the W direction in the t-quark rest frame.

.4.3 Single technieta production, $gg \to \eta_T \to t\bar{t}$. The object is to see a peak in the $t\bar{t}$ invariant mass or in the p_T distribution of the top quark.

.5 JET PHYSICS

.5.1 Quark substructure in production of jets with high-p_T and/or invariant mass (deviation from QCD cross sections at $p_T \gtrsim 4\,\mathrm{TeV}$). Studies at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ of the ISO model with substructure scale $\Lambda \cong 15 - 20\,\mathrm{TeV}$. Special attention to jet energy measurement issues!

.5.2 Studies at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Are these feasible? If so, what is the reach in Λ?

.5.3 Devise a program for measurement of the parton distribution functions in experiments at low luminosity and carry out typical simulations (if time permits).

3.6 PHYSICS AT ULTRAHIGH LUMINOSITY

3.6.1 Quark/lepton substructure in $\overline{q}q \to \mu^+\mu^-$ at high invariant mass (a deviation from the Drell-Yan cross section at $\mathcal{M} \gtrsim 2\,\text{TeV}$) and ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$. Determination of the chiral structure of the contact interactions for substructure scale, $\Lambda = 25\,\text{TeV}$. Reach in Λ in one SSCD.

3.6.2 Signal and backgrounds for quark/lepton substructure at the scales $\Lambda = 25\,\text{TeV}$ in the Drell-Yan process $\overline{q}q' \to \mu^\pm\nu$. Chiral structure of the contact interaction will be probed via the η_μ distribution.

3.6.3 Signal and backgrounds for $Z'^0 \to \ell^+\ell^-$, with $\ell^\pm = e^\pm, \mu^\pm$. Precision measurements of mass, width (via e^+e^-) and asymmetries (via $\mu^+\mu^-$) for $M_{Z'} = 4\,\text{TeV}$. Determination of the reach in $M_{Z'}$ in 1 – 2 SSCD.

3.6.4 Signal and backgrounds for $W'^\pm \to \ell^\pm\nu_\ell$. Precision measurements of the mass, width and asymmetry; determination of the reach in $M_{W'}$.

3.6.5 Signal and backgrounds for color-singlet $\rho_T^\pm \to Z^0W^\pm \to \ell^+\ell^-\ell^\pm + \not{E}_T$ and $\ell^+\ell^-$ jet jet.

7 MISSING E_T PHYSICS — SUPERSYMMETRY

7.1 Missing-E_T requirements on the detector.

7.2 $\tilde{g}\tilde{g}$ detection via the $\not{E}_T$ signature.

7.3 $\tilde{g}\tilde{g}$ detection via the likesign dilepton signature. Although not strictly a missing-energy process, this complements the preceding search.

7.4 Squark production and detection via the $\not{E}_T$ signature. (Is squark-gluino production useful and/or interesting?)

8 CONCLUSIONS

9.1 Summary tables of discovery significances, reach, discovery/reach time, mass resolutions, etc. Brief summary discussions.

9.2 Plans for future simulations work – both detector and physics. A set of possible physics simulations is given in the "second priority" list of K. L. 's January 20, 1992 memo, "Physics Simulations for the GEM Technical Proposal". This needs more thought!

Physics Highlights (meeting of Dec 9th, 1992)

① gemfast V1 (Baseline 1) – fixed now.

gemfast V2 (Baseline 2) – initial version released 12/9/92. Not to be used for ~~physics~~ studies.

Next version must include updates from subdetector groups. – 2-3 weeks

② Baseline 2 – B. Barish

③ Discussions of $H \to \gamma\gamma$

L. Y. Zhu, H. Yamamoto

Yu. Efremenko

A. Vaniachine

π^0 Rejection study – H. Ma

④ TDR Schedule – H. Newman

⑤ "Addition of trigger" discussion to physics section.

Tomasz Skwarnicki (SMU

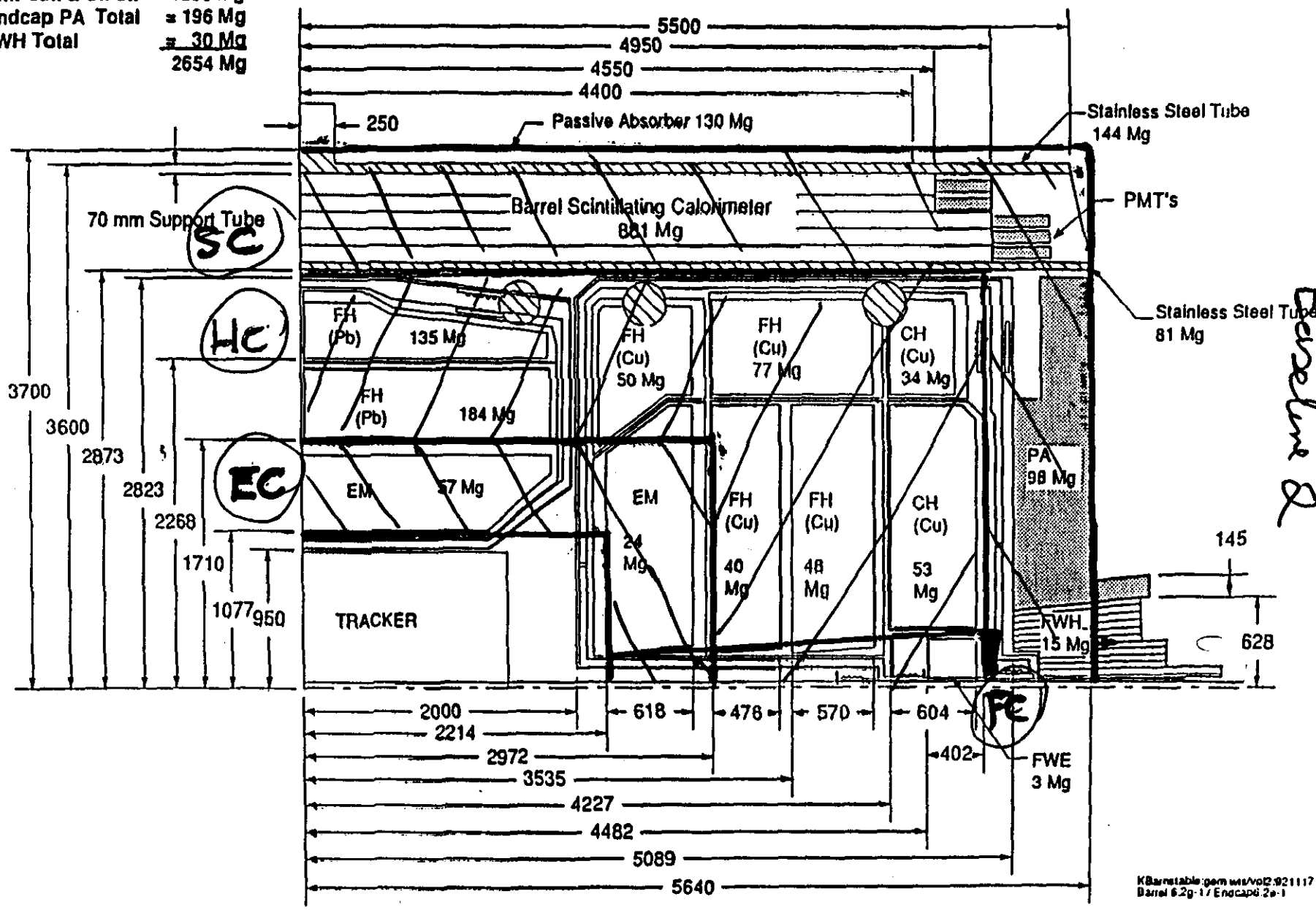
STATUS OF gemfast
(Progress Report)

Many major changes also in output commons seen by user.

Incomplete first Baseline-11 version (v11 003) released yesterday.

GEM Calorimeter

	Weight	Volume
Barrel Calorimeter	= 433 Mg	24135 L. LKr
2 Endcap Total	= 759 Mg	38475 L. LAr
Scint. Cal. & St. St.	= 1236 Mg	
2 Endcap PA Total	= 196 Mg	
2 FWH Total	= 30 Mg	
	2654 Mg	



GEMFAST regions compared with Baseline Q

KBarrstable:gem wts/vol2:921117
Barrel 6.2g-1 / Endcap6.2e-1

Zlll

Background X-Section

H→ $\gamma\gamma$ Searches

	$\gamma\gamma$	γ-jet	2jets
$\hat{p}_t > 20$ GeV	280 pb	240 nb	2.0 mb
$E_T > 20$ GeV, $\lvert\eta\rvert < 2.5$	100 pb	80 nb	530 μb
$M_{\gamma\gamma} > 75$ GeV	42 pb	34 nb	240 μb
Rejection Needed		800	6×10^6
Final Background	31 pb	19 pb	20 pb
Single Photon	31 pb	17 pb	10 pb
Jet Background		2 pb	10 pb

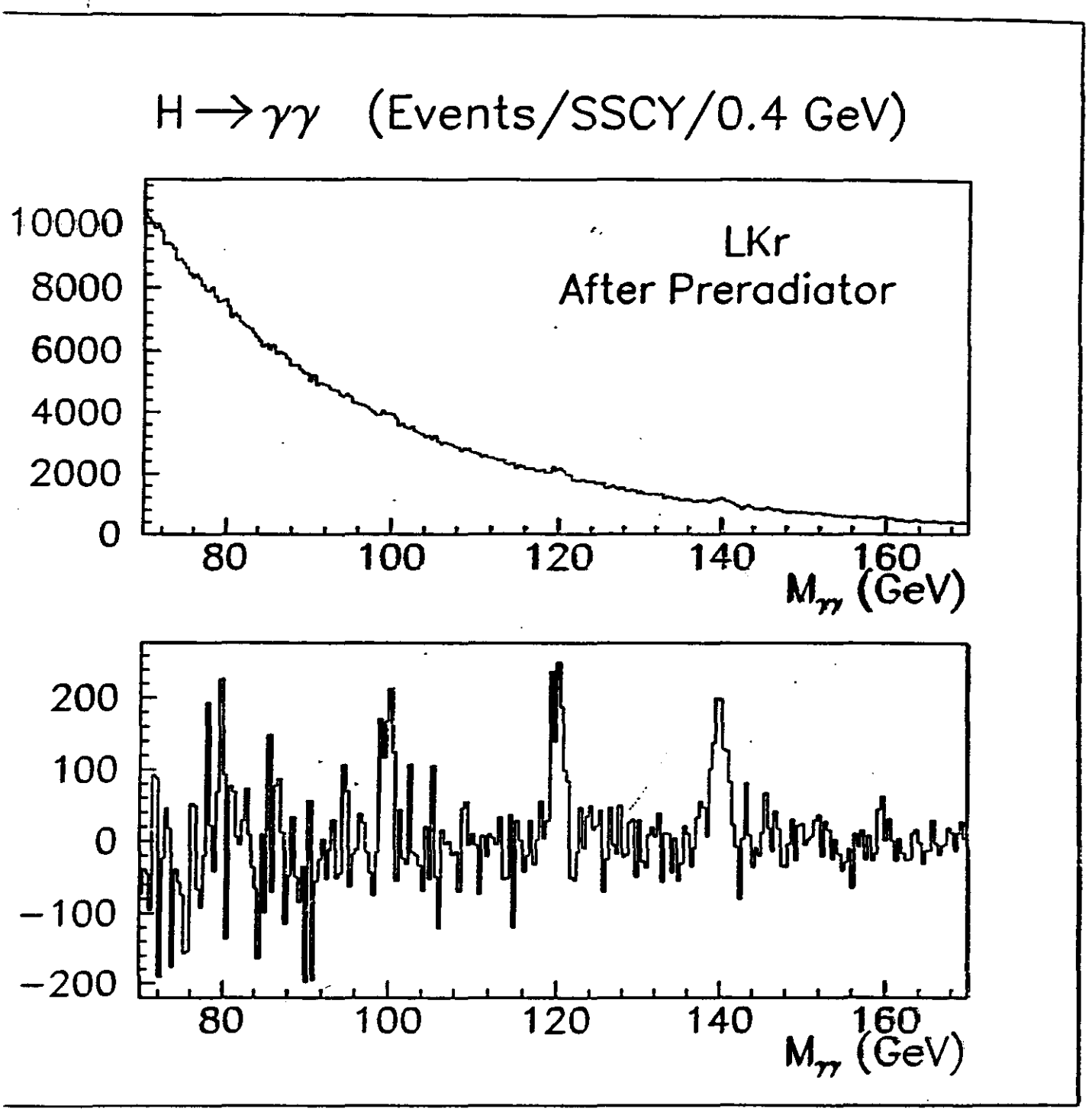
Note, the Jet background may be reduced by optimizing kinematics cut, such as requiring high p_T on photon.

Significance of 80 GeV Higgs

	$\gamma\gamma$ Background	All Background
	3.7	2.8
1.5 k-Factor	5.6	4.2

Note, EHLQ set 1 structure function is used.

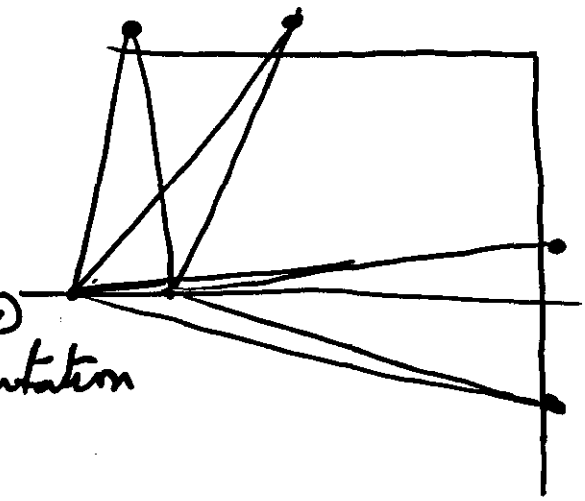
Zhu


H → γγ (Events/SSCY/0.4 GeV)
LKr
After Preradiator
10000
8000
6000
4000
2000
0
80
100
120
140
160
M_γγ (GeV)
200
100
0
−100
−200
80
100
120
140
160
M_γγ (GeV)

Higgs mass resolution study by Yu. Efremenko

- strips (also used for "π^0" rejection)
- Tracker
- longitudinal segmentation of EM.

Contrast
1. Perfect vertex
2. Pointing used to choose among vertices found by tracker
3. Pointing only



Conclusions:

1. Strip-type resolution v. important for endcap (no tracker)
2. not so for barrel, long. segmentation OK.

Note: 1. Strips can reject π^0 in $H(80\,GeV) \to \gamma\gamma$ energy range in <u>barrel</u> but not end cap

2. End cap "strips" are difficult to realize in two dimensions.

GEM

(1)

Calorimeter Simulation Workshop

Dec 7-8th, 1992

Goals

1. Good TDR
2. Good presentation at July PAC
3. Coherent approach to doing physics
4. Integration / Cooperation with other simulation groups (Tracker, Muon, ..)
5. Sharing of techniques, codes..
6. Common pool of software, results, event files ...
7. Formation of Cal. Sim. Working group.
8. Plans for future (next meeting?)

MONDAY DEC 7th

9:00 am. Goals of Workshop -- McFarlane, Womersley
9:15 am Discussion of Agenda and Workshop organization

Goals of simulation -- Group
Important effects (missing energy, resolution, backgrounds, pileup, pointing, pizero)
Simulation types: global, partial.
Physics: key processes
Time scales: TDR, PAC'93, future
Impact on other systems (e.g. muons -- trigger, dE/dx...)

10:15 SSCL/GEM approach -- I. Sheer
10:45 Impact on other systems
Tracker -- Jenny Thomas
Muon System -- P. Dingus

11:15 am GEANT:
GEANT 3.16 (what changes from 3.15) -- Lee Roberts
Volume search algorithm -- Lee Roberts
Optimization strategies -- Lee Roberts, Mike Seman
Speed of searching in different volumes -- ??

11:45 am CALOR89 interface -- Brent Moore

12:15 pm LUNCH

1:30 pm Existing SSCL/GEM simulations
SIGEM structure -- Yu. Fisyak (30 mins)

gemfast structure -- T. Skwarnicki (30 mins)

Parameterizations:
(Parameterization in gemfast -- T. Skwarnicki)
H1 approach (latest version derived from gflash) -- ?? (Stefan Peters will come to a later workshop)
Mixture level descriptions (range of validity) -- ??
Shower parameterization (Range of validity) -- ??
Shower library techniques -- ??

2:30 pm Special Geometries
  Accordion -- Seman/Lelchouk
  Strips ('preradiator') -- H. Ma
  Asymmetric segmentation -- ??
  Plate -- ??
  Axial fiber calorimeter -- ORNL person?
  Simulating fibers in detail -- ??

Speed of simulations
  Comparison of approaches (Gemfast, UAZMIX, SIGEM -- Authors)

Features
  Massless gaps

<6:00 pm Discussion of Working groups/Assignments

TUESDAY DEC 8th

9:00 am Data structures (HITs, DIGItizations information) -- Womersley

Data structures expected from DAQ and algorithms for finding energy and time
  from samples. -- Henk Uijterwaal

More on CALOR -- C. Zeitnitz

Algorithms
  Weighting factors in heterogeneous systems -- ??
  Clustering algorithms in gemfast and CLEO -- T. Skwarnicki
  EM pattern recognition/reconstruction -- ??
    Pointing, pizero rejection
  Jet finding -- ??
  Jet energy reconstruction -- ??

Pile-up and noise
  Simulation and parameterization techniques (10^33 and 10^34) -- A. Vaniachine
   (Pulse shape parameterization -- ??)

Integration Strategy -- Womersley
  GEM calorimeter simulation plans -- can we coordinate to maximize use of
  manpower, computing facilities and optimize results?
  Descriptions of simulations at Columbia, BNL, ORNL, CalTech, Mississippi?
  Coordination of fast, mix and full simulations -- ??
  SIGEM and its data structures -- Yu. Fisyak
  Common MATE, ROTM, GEOM, HITS definitions-- ??
  GEM tracker and muon simulations -- J. Thomas/I. Sheer? and P. Dingus?

Calorimeter Simulation Highlights

① The group (representatives of almost all calorimetry simulation efforts) met for first time.

② Concerned about fiber, because there is so much to do.

③ Concerned about liquid hadronic section, because of low level (~~zero?~~) of effort.
→ U. Rochester

④ Concerned about integration of 3 measurements (EM, HD, SC) into one, for jets, even EM.

⑤ Began on definition of data formats and structures and a single framework

⑦ M. Seman described speed up in accordion structure full simulation in GEANT

Un-optimized – 20 mins. of SGI, 33 MHz

Std. GEANT opt. – 24 secs.

New GEANT opt. – 12 sec.

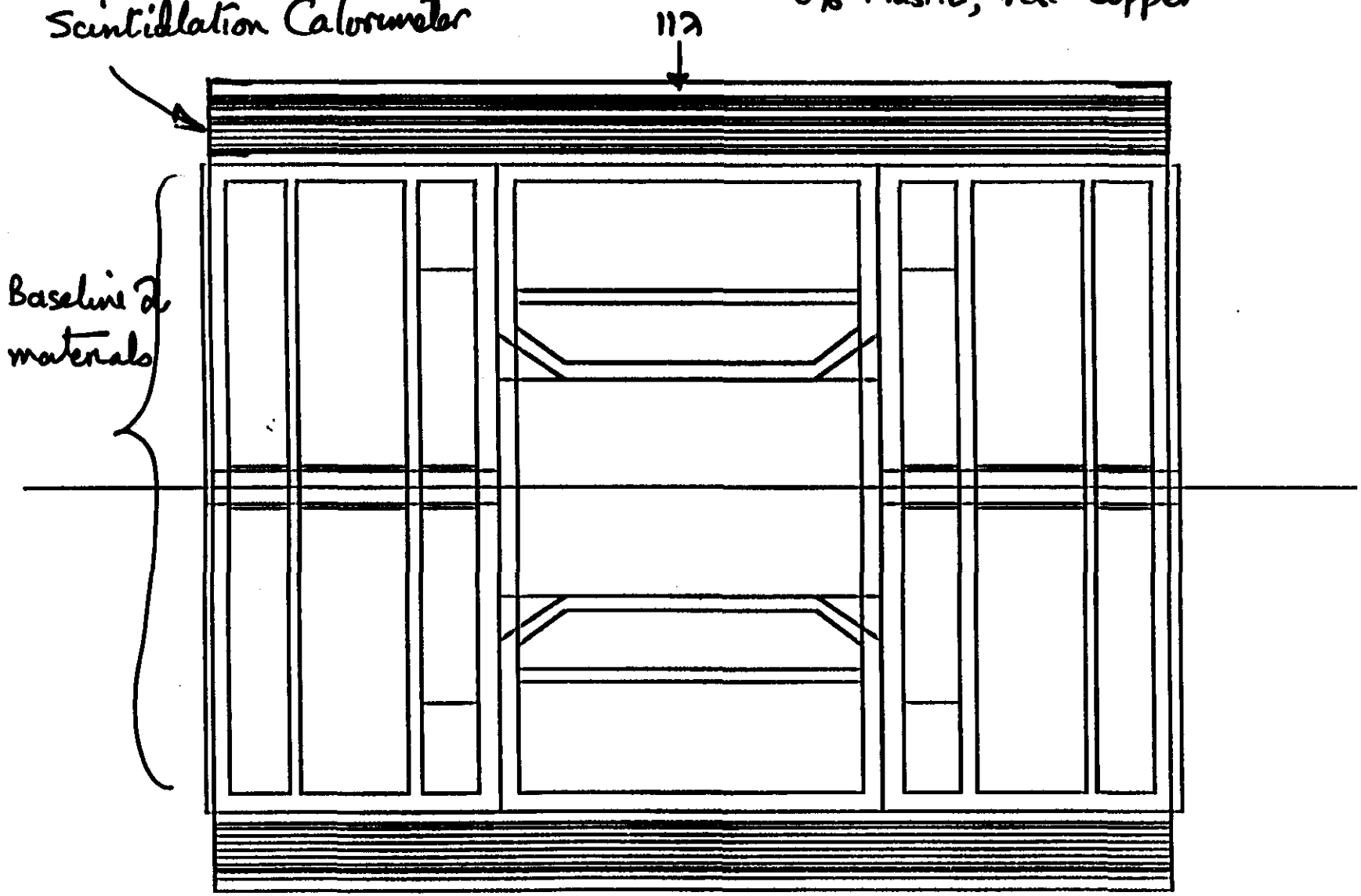
⑧ Discussion of data structure – type and what comes from DAQ.

ORNL (A. Savin, K. Shmakov..)

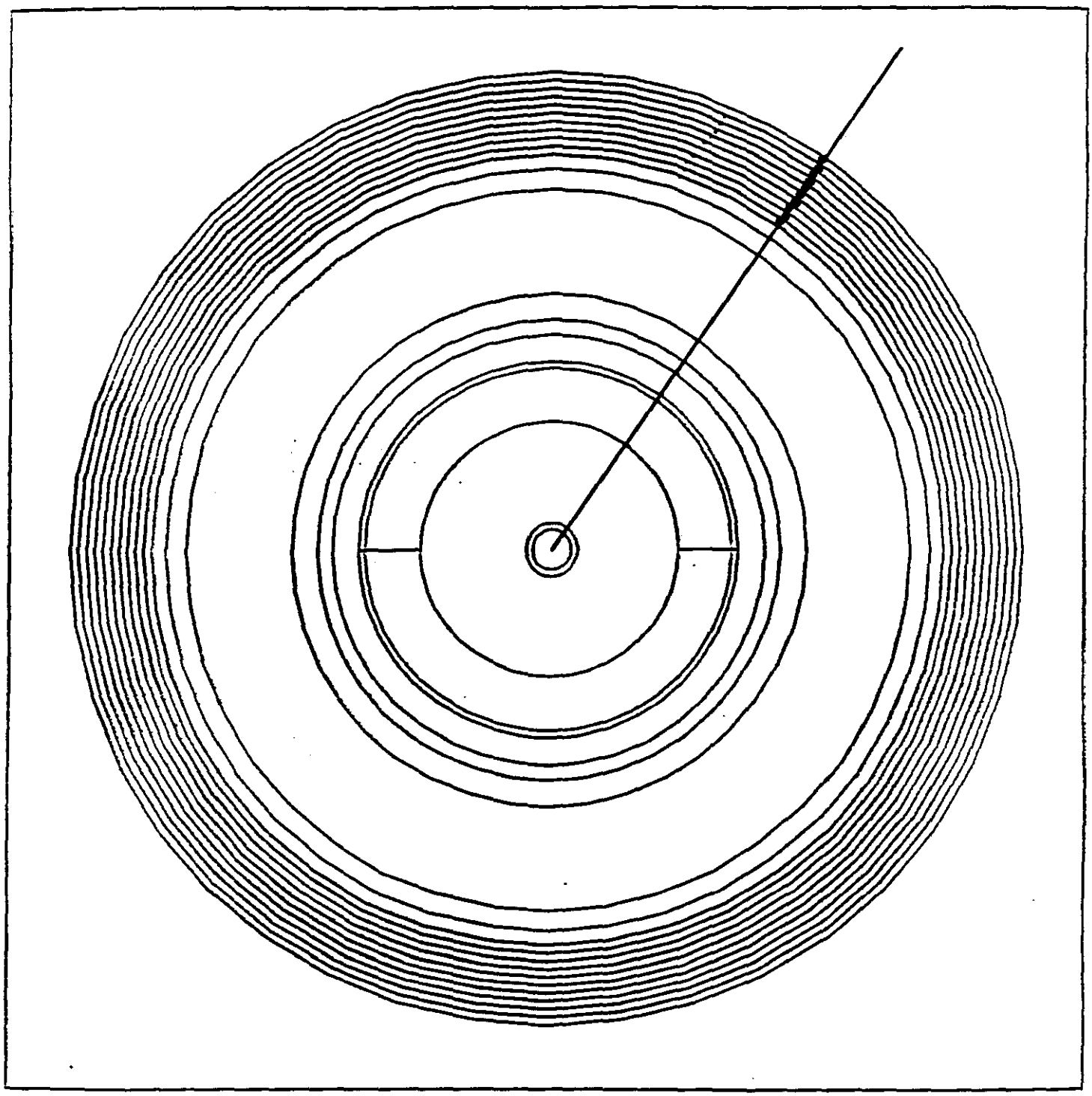
10 layers ; 160 ϕ sections

6% Plastic, rest Copper

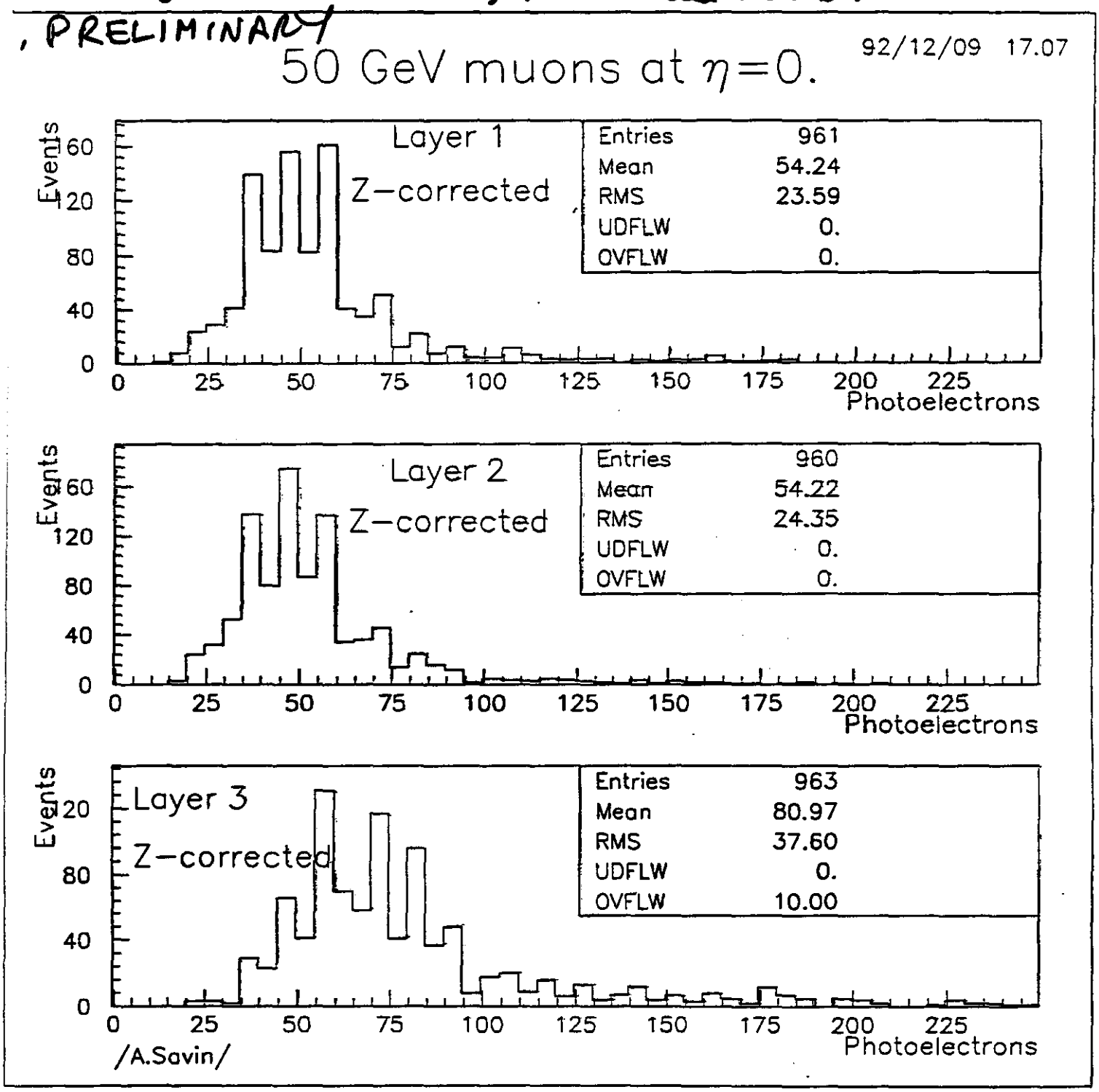
Scintillation Calorimeter



Scintillation Calorimeter (ORNL - Savin, Shmakov).



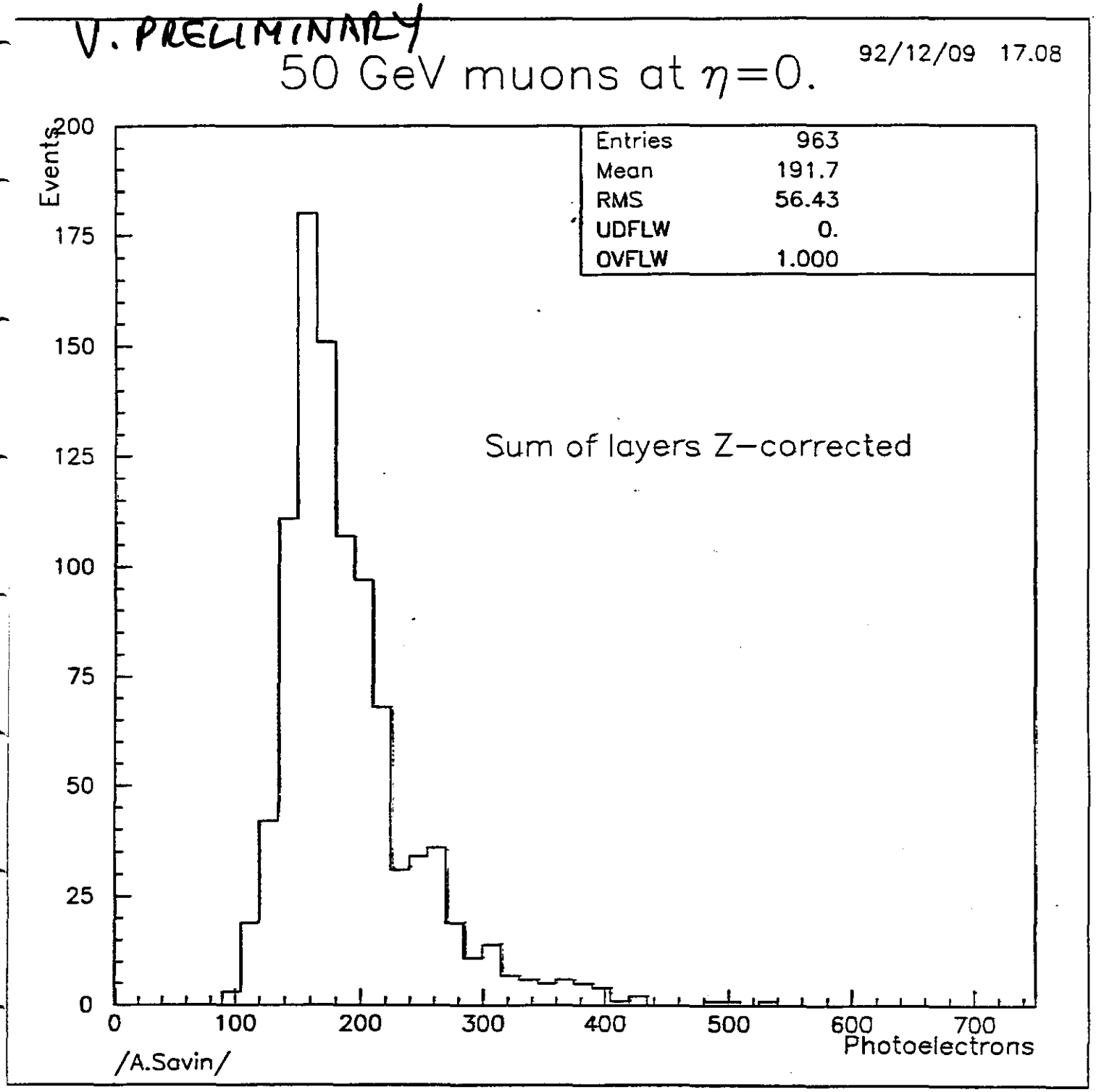
light yield, normalized (ORNL)
gives distribution, not actual numbers



Layers are 'superlayers' of 3, 3, 4 layers of plastic each.

Corrected light yeild

V. PRELIMINARY



u Efficiency (ORNL simulation)

V. PRELIMINARY

No. of superlayers firing (991 events)

Left side \ Right side	1	2	3
1	7	–	3
2	–	–	4
3	6	–	958

Conclusions

1. Physics studies depend on well-understood detector.

2. Detector design must be 'stable'.

3. Understanding is a two-step process (super-step):
   a) Detailed simulation
   b) parameters into gemfast

4. Much to be done!

---

gem

γeμ

Presentation by:

F. Taylor

F.E. Taylor 12/10/92

STATUS of GEM MUON SYSTEM

- **Baseline -2** (post BNL Meeting)

Region:	Barrel	Endcaps
L-1 Triggering*	CSC	CSC
Tracking**	CSC	CSC
Backup option:		
* Trigger	RPC	RPC
** Tracking	RDT	RDT

- **Technology Decision Process:**

1/15/93 - Review R&D results
CSC: resolutions, large chamber, etc.
RDT: deployment in EC, rates, lifetime, L-angle, etc.
RPC: deployment in EC, rates, jitter, etc.

2/15/93 - Review of Costs
Chamber, Electronics, Support Structure, Alignment

For today:

- Progress on Muon Support Structures

  Frank Nimblett - Draper Lab

- Highlights of Chamber R&D Program

  RDT Andrey Golutvin - SSCL/ITEP

  CSC Kwong Lau - UH

gem

γeμ

Presentation by:

I. Golutvin

Andrei Golutvin
ITEP

STATUS REPORT ON TTR TESTS

CSC's:

BNL (0.5 × 0.5)
Dubna (1.5 × 1.2)
UH (1.0 × 0.5)
} at TTR

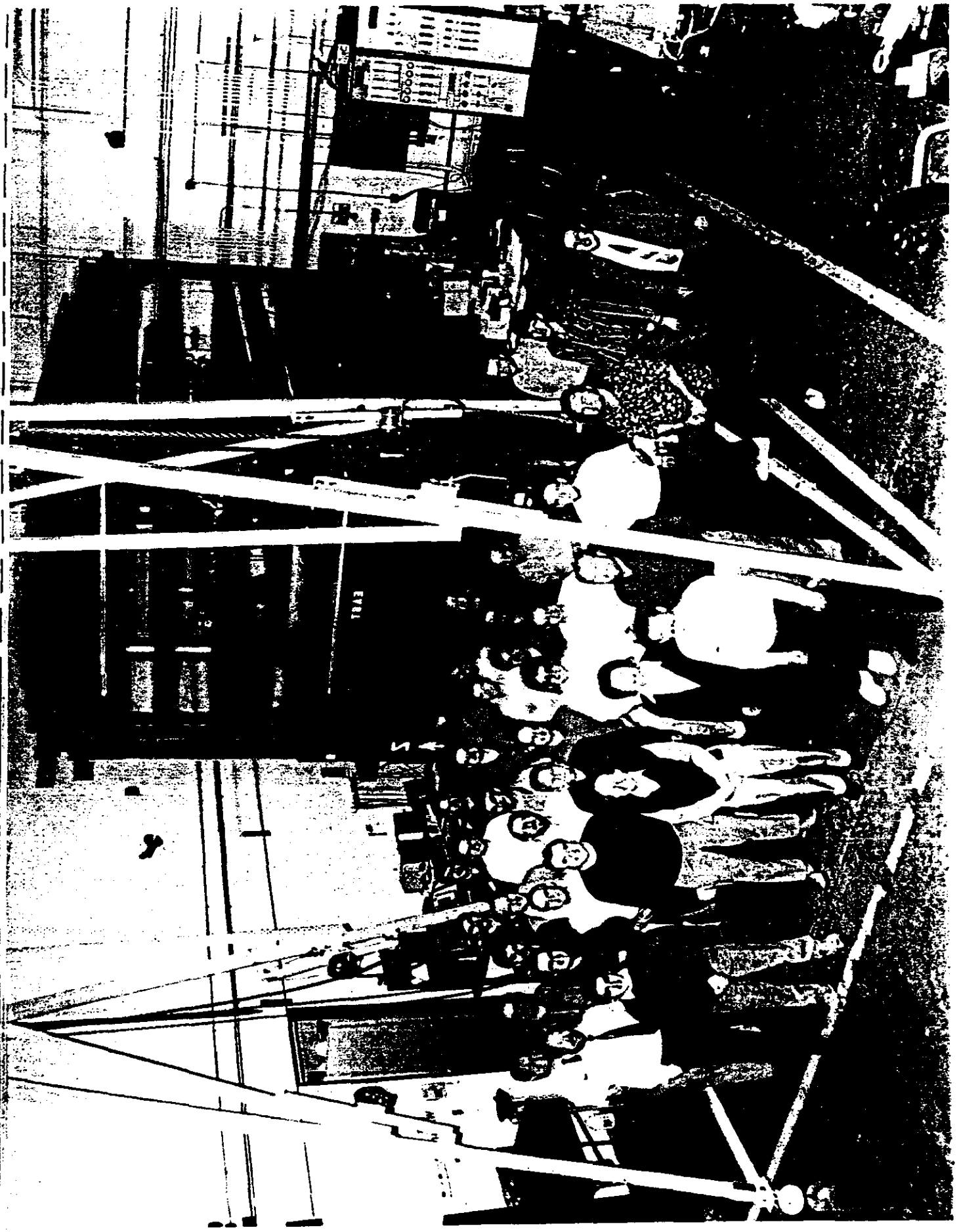
BNL-BU (2.0 × 0.7) in preparation

RDT's:

Dubna (4 × 1)
MSU (4 × 1)
} at TTR

+

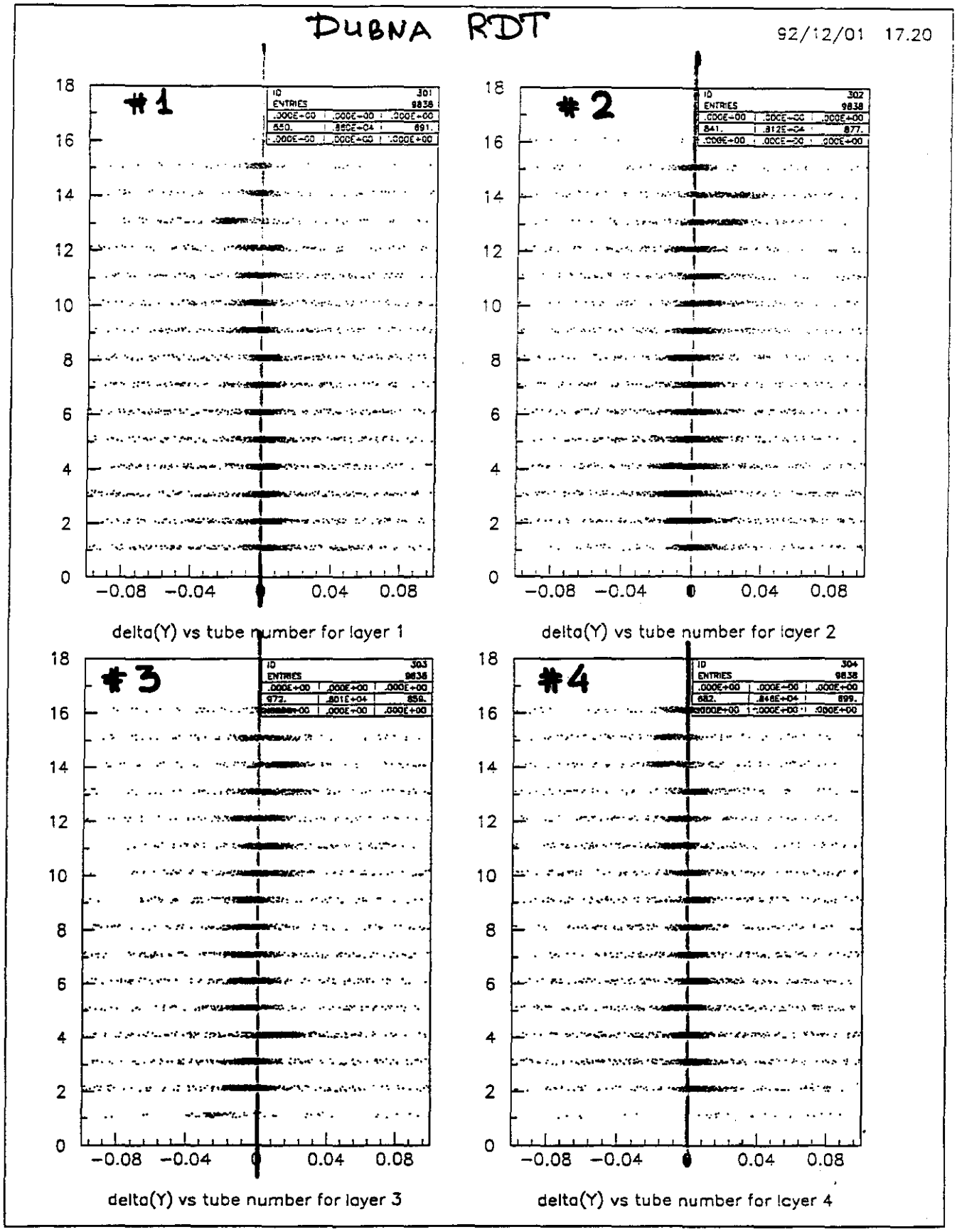
RPC



RDT's

(with allignment of wires within the module)

Residuals as a function of tube number



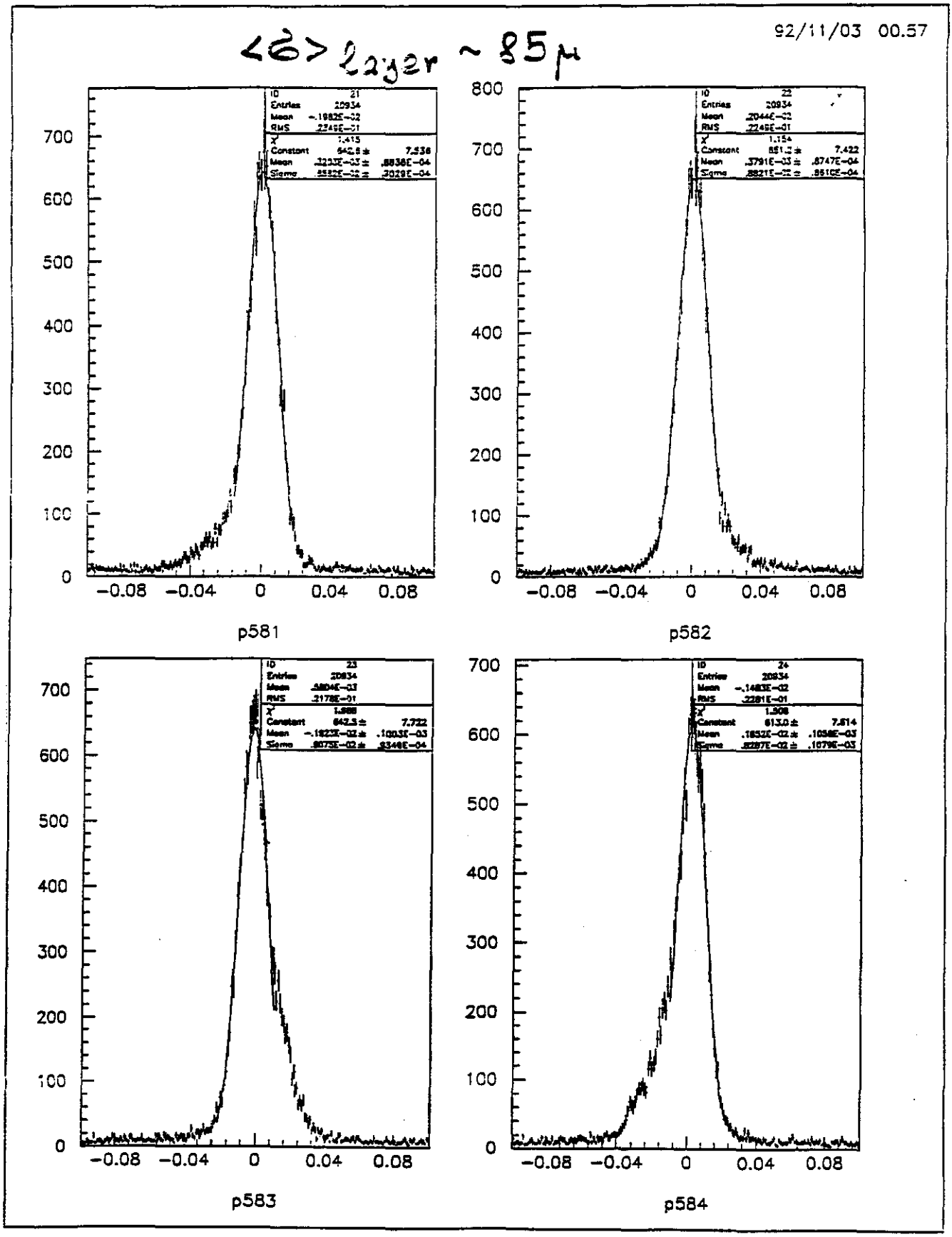
delta(Y) vs tube number for layer 1

delta(Y) vs tube number for layer 2

delta(Y) vs tube number for layer 3

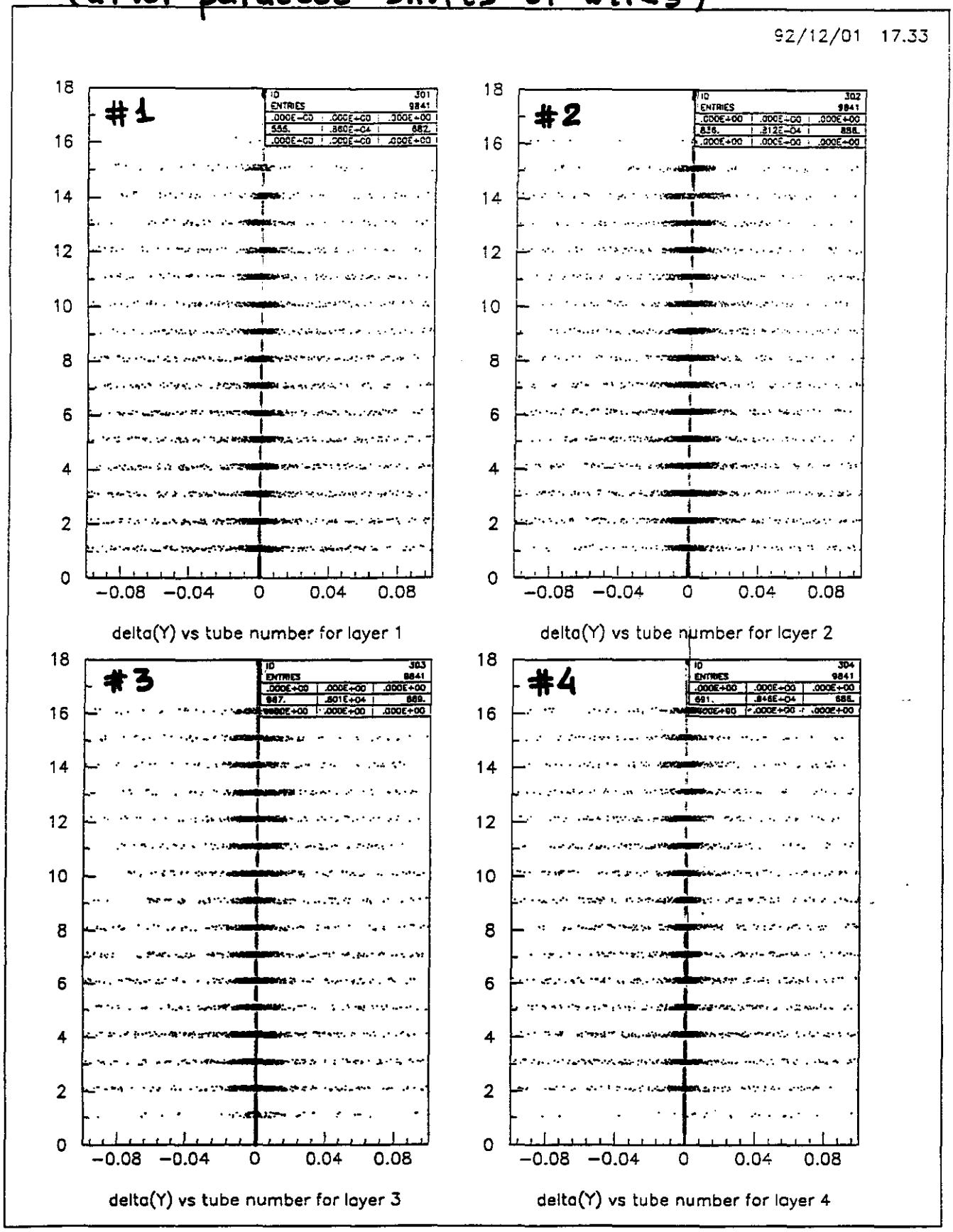
delta(Y) vs tube number for layer 4

DUBNA RDT : Ar-C_4H_{10} (25/75) at 1 atm.



ASYMMETRICAL TAILS ARE DUE TO DISPLACEMENT OF WIRES !

Residuals as a function of tube number (after parallel shifts of wires)



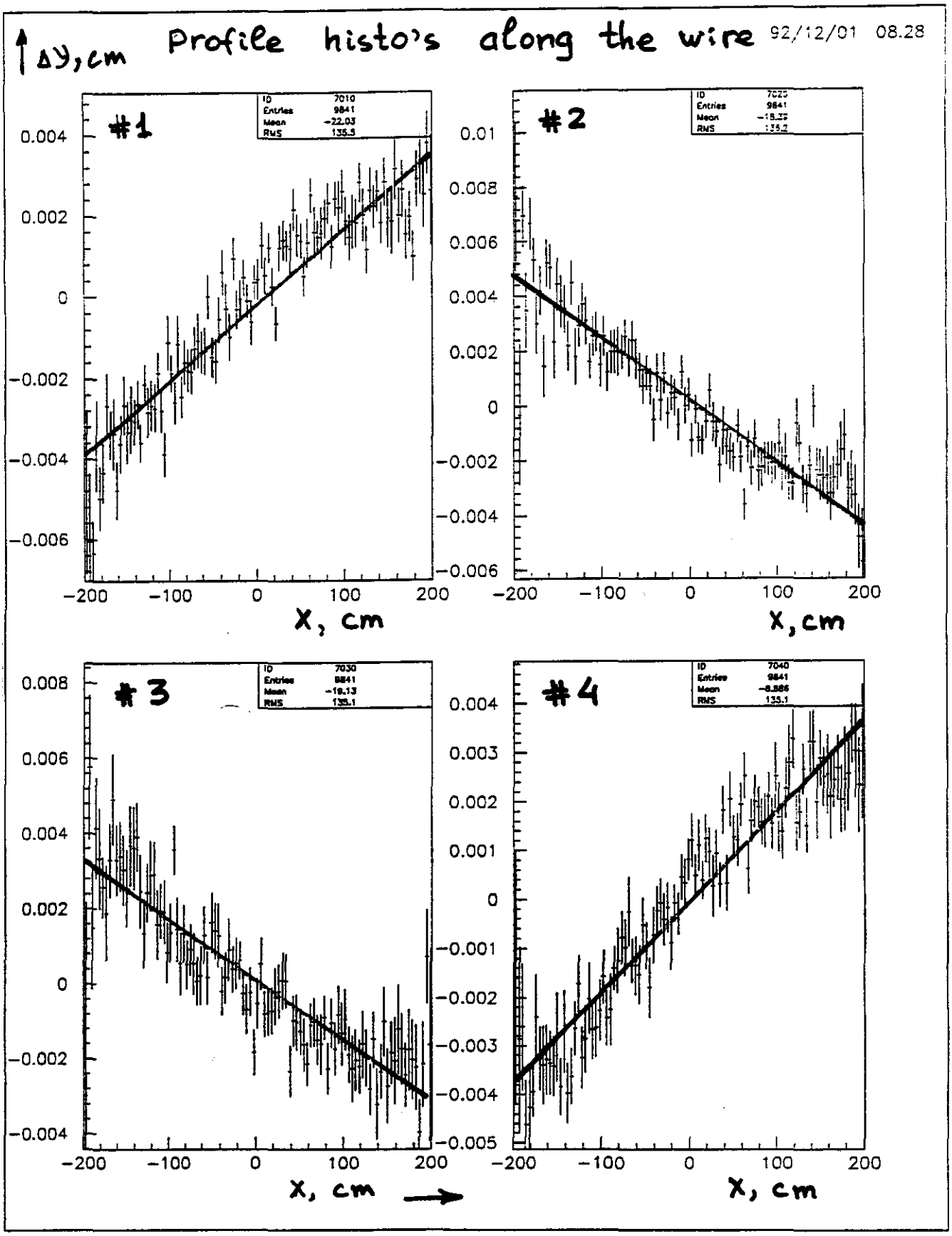
delta(Y) vs tube number for layer 1

delta(Y) vs tube number for layer 2

delta(Y) vs tube number for layer 3

delta(Y) vs tube number for layer 4

Rotation of layers

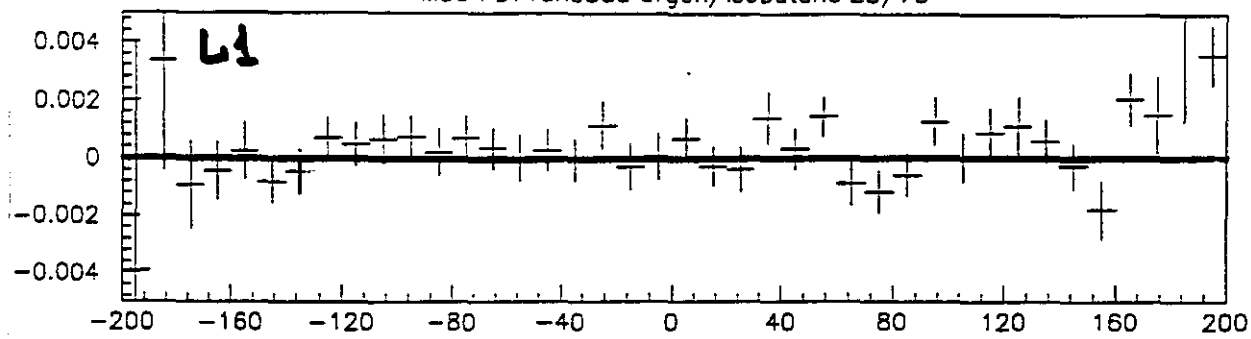


MSU PROTOTYPE

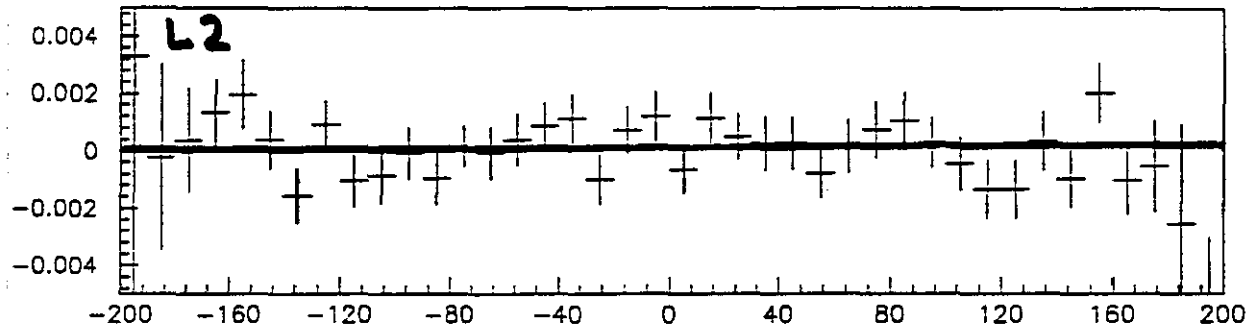
NO LAYER TURNS ARE SEEN!

92/12/08 23.09

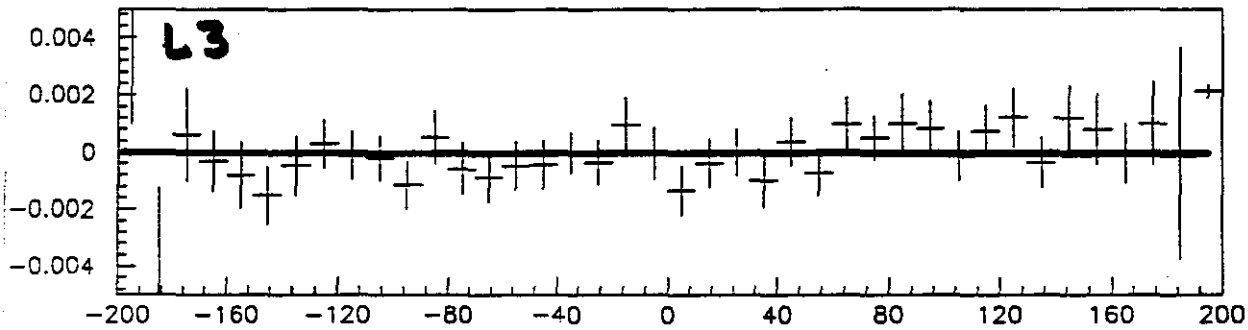
MSU PDT run0388 argon/isobutane 25/75



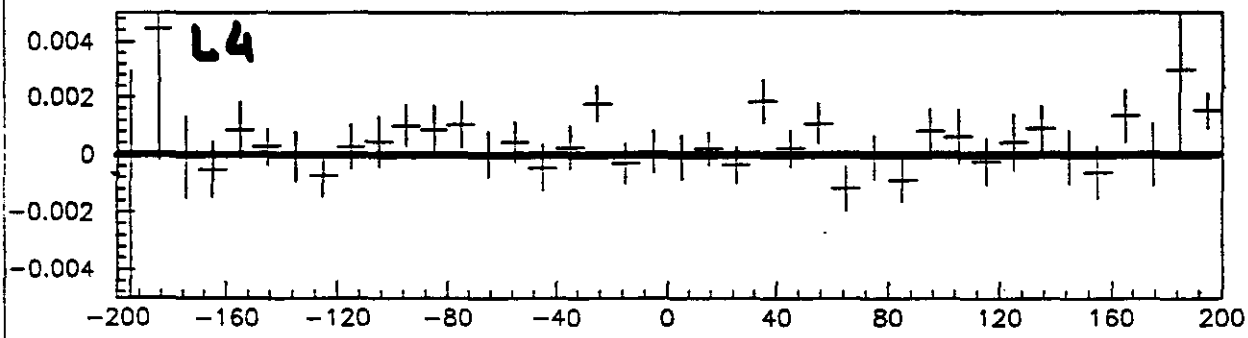
DY vs X for layer 1



DY vs X for layer 2

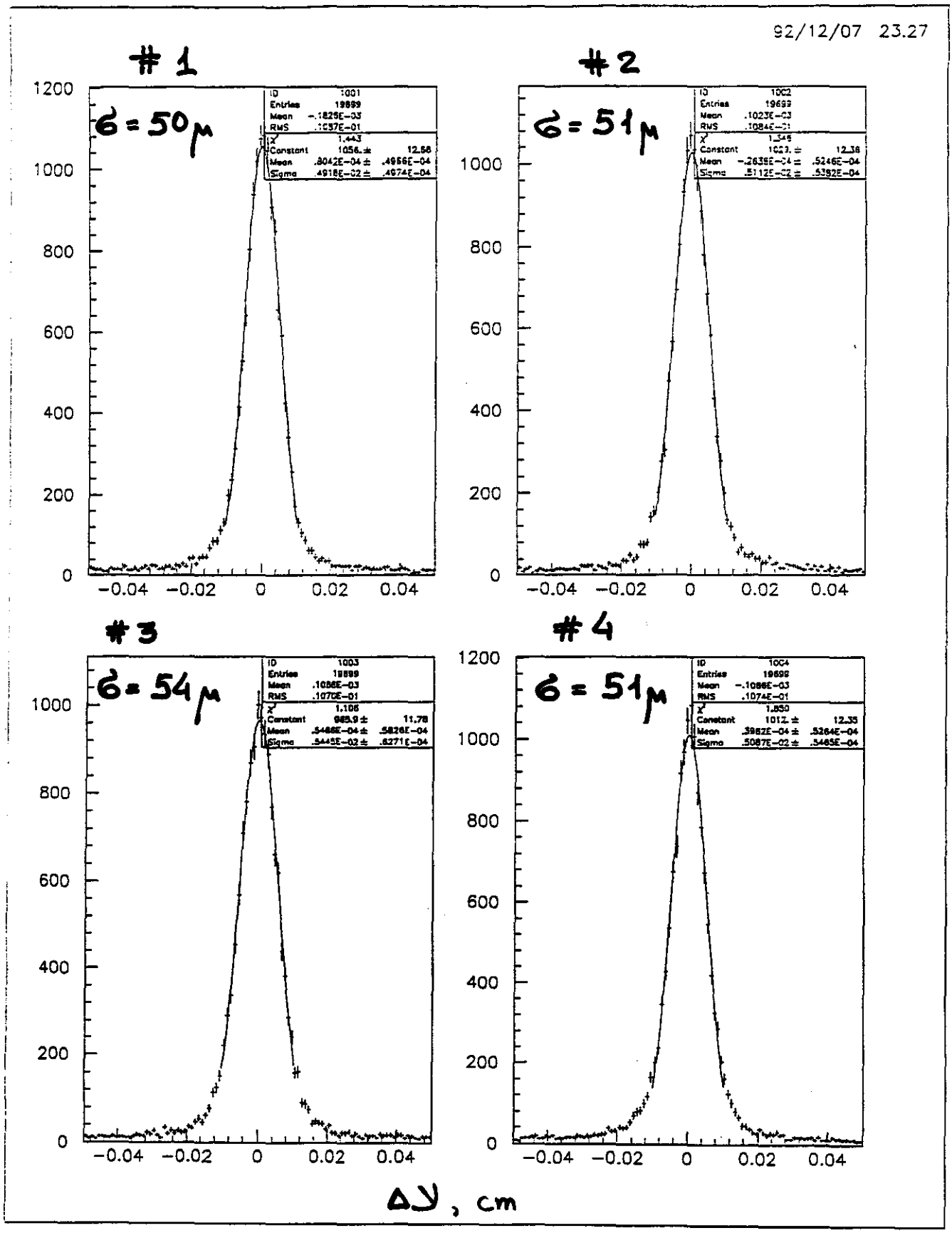


DY vs X for layer 3



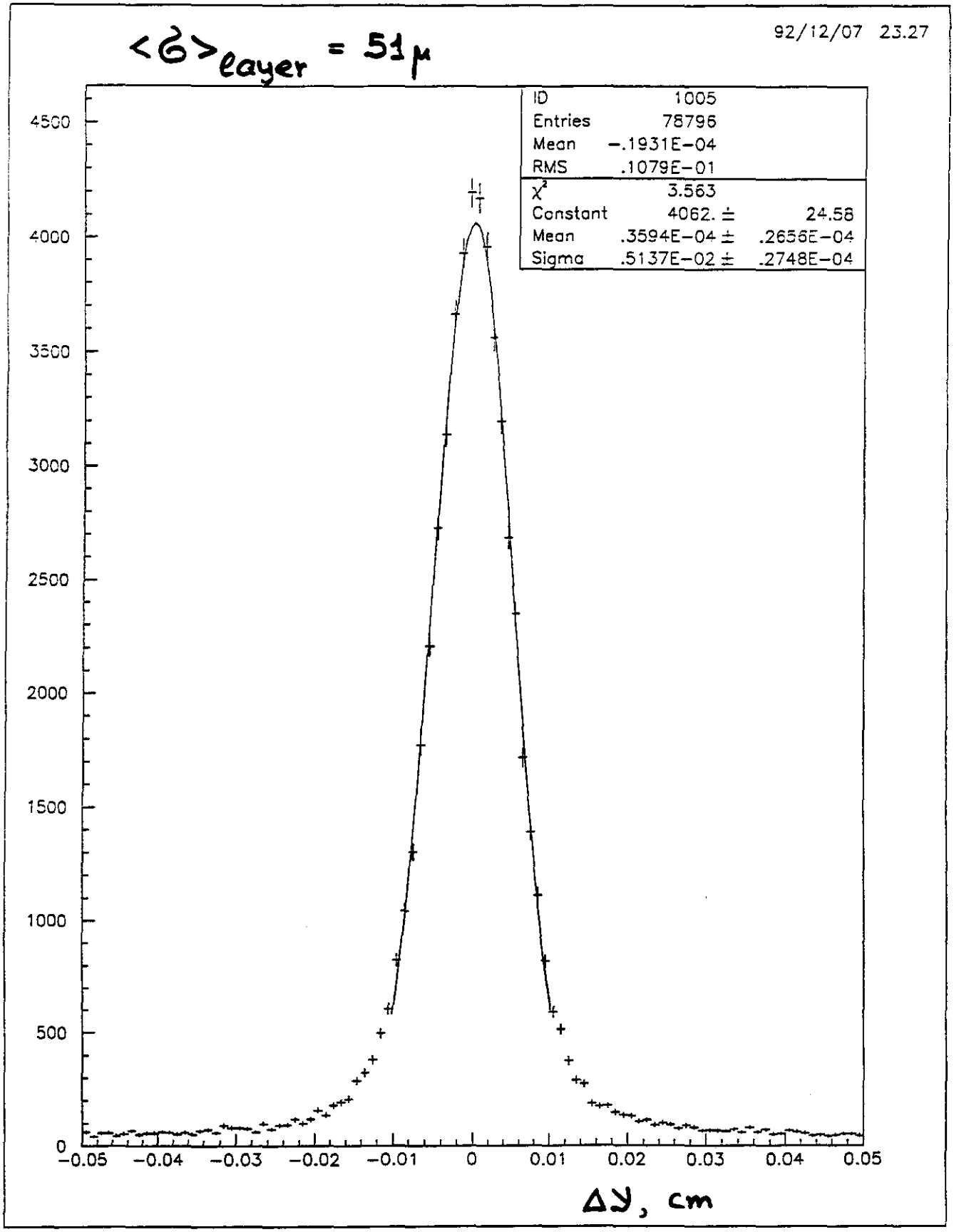
DY vs X for layer 4

RESIDUALS FOR DIFFERENT LAYERS



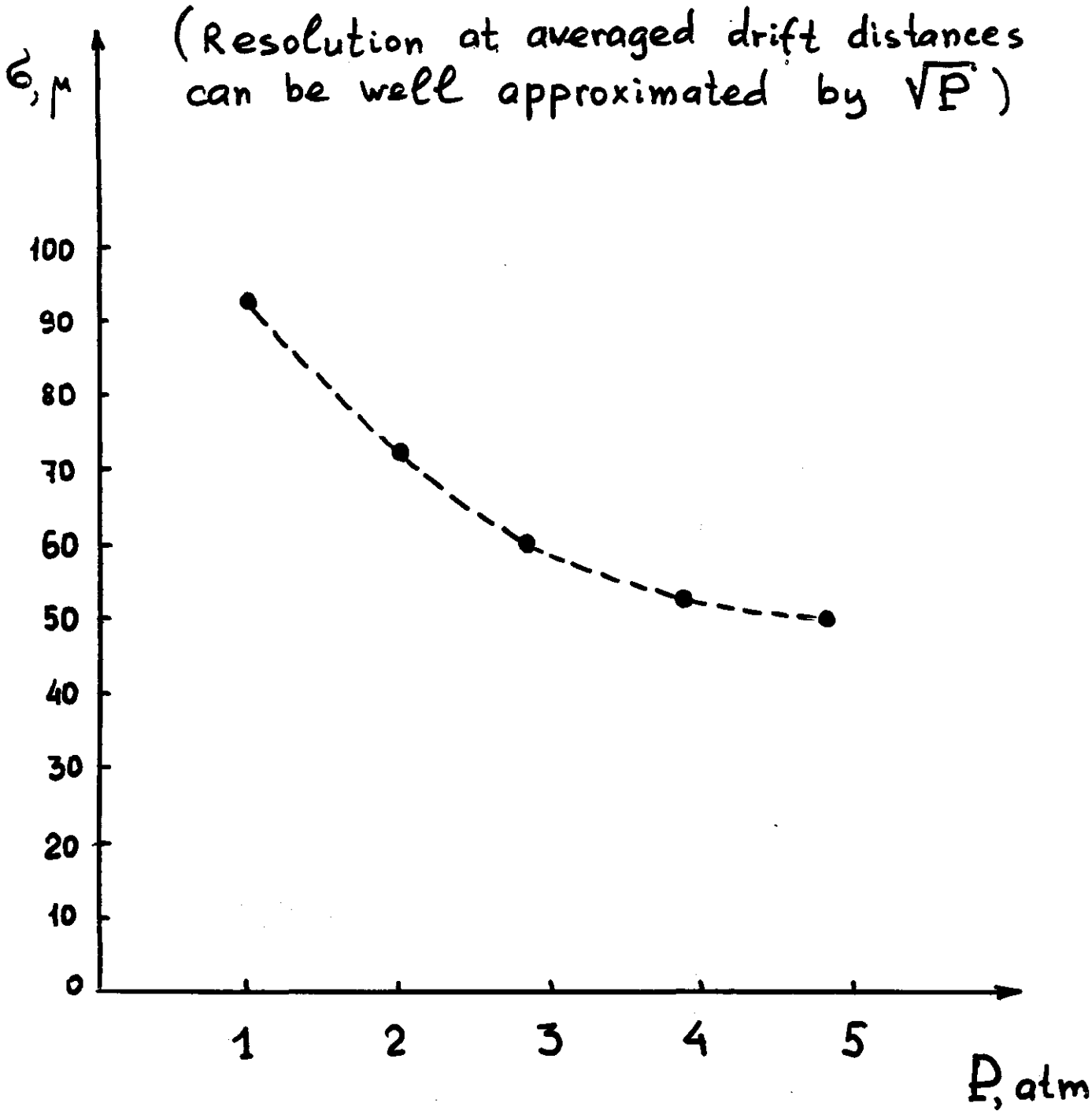
Ar-C_2H_6 at 4.8 atm

$Ar-C_2H_6$ (50/50) at 4.8 atm



Resolution as a function of pressure

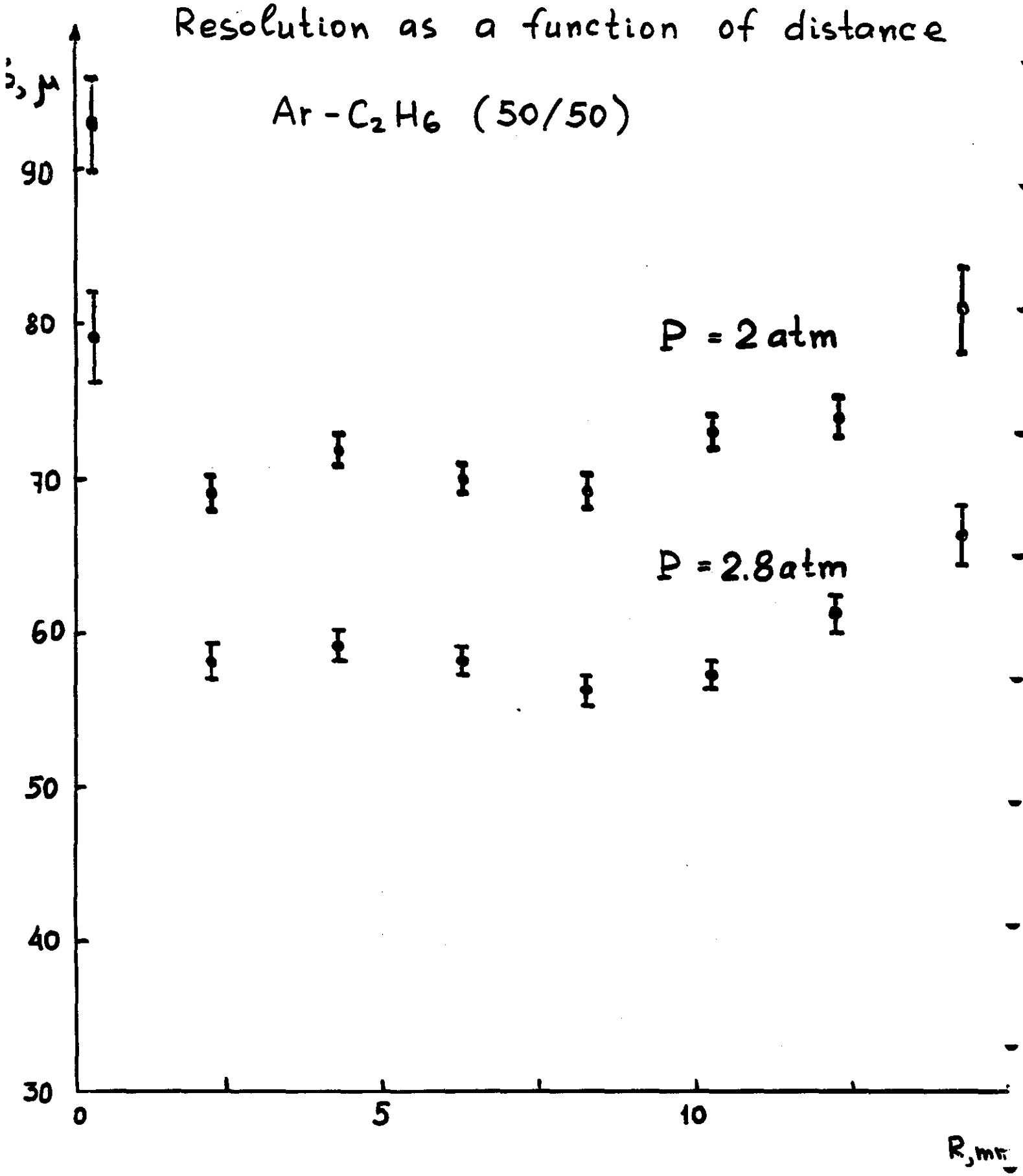
$Ar-C_2H_6$ (50/50)



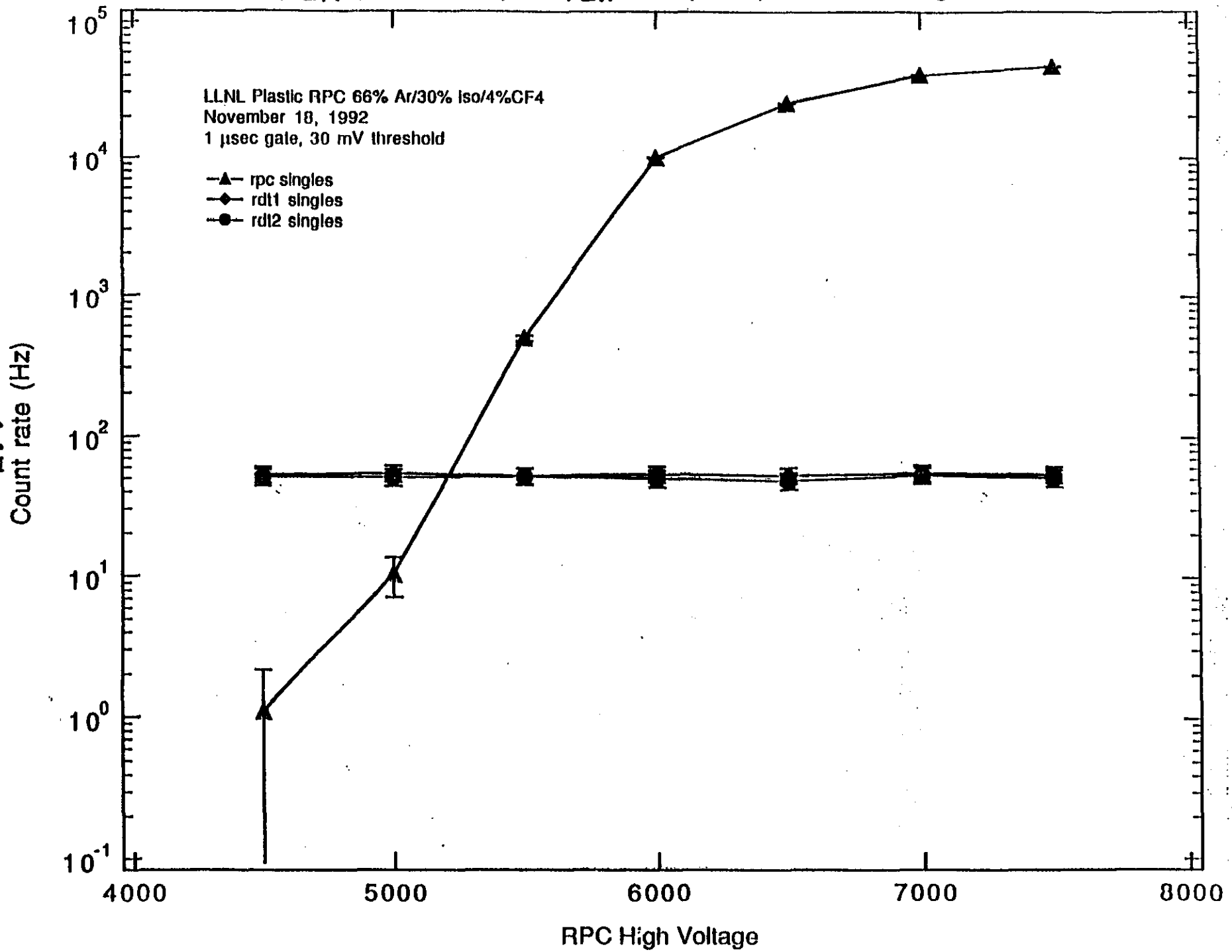
$Ar-C_4H_{10}$ (25/75) at 1 atm

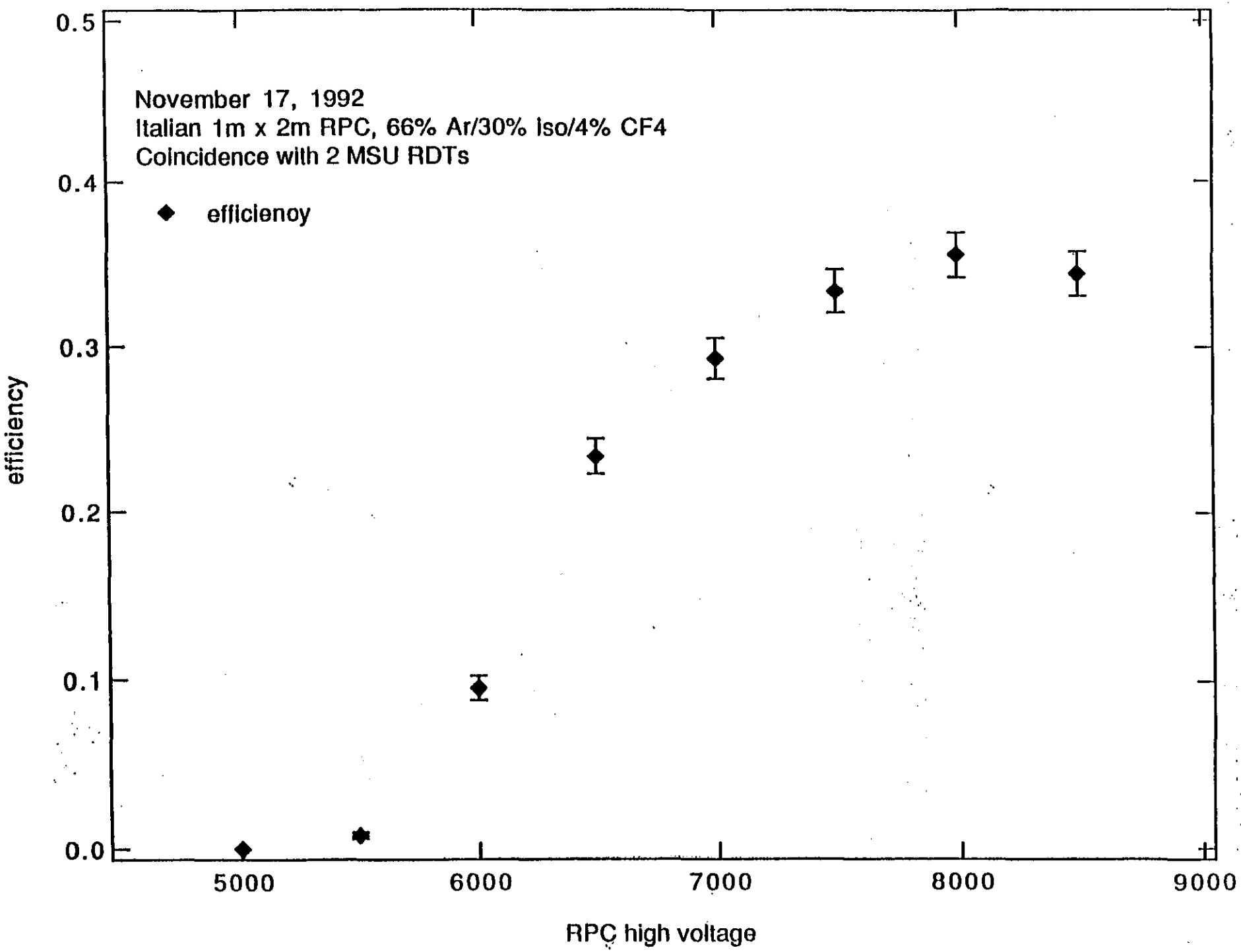
$\langle\sigma\rangle_{layer} = 67\mu$!

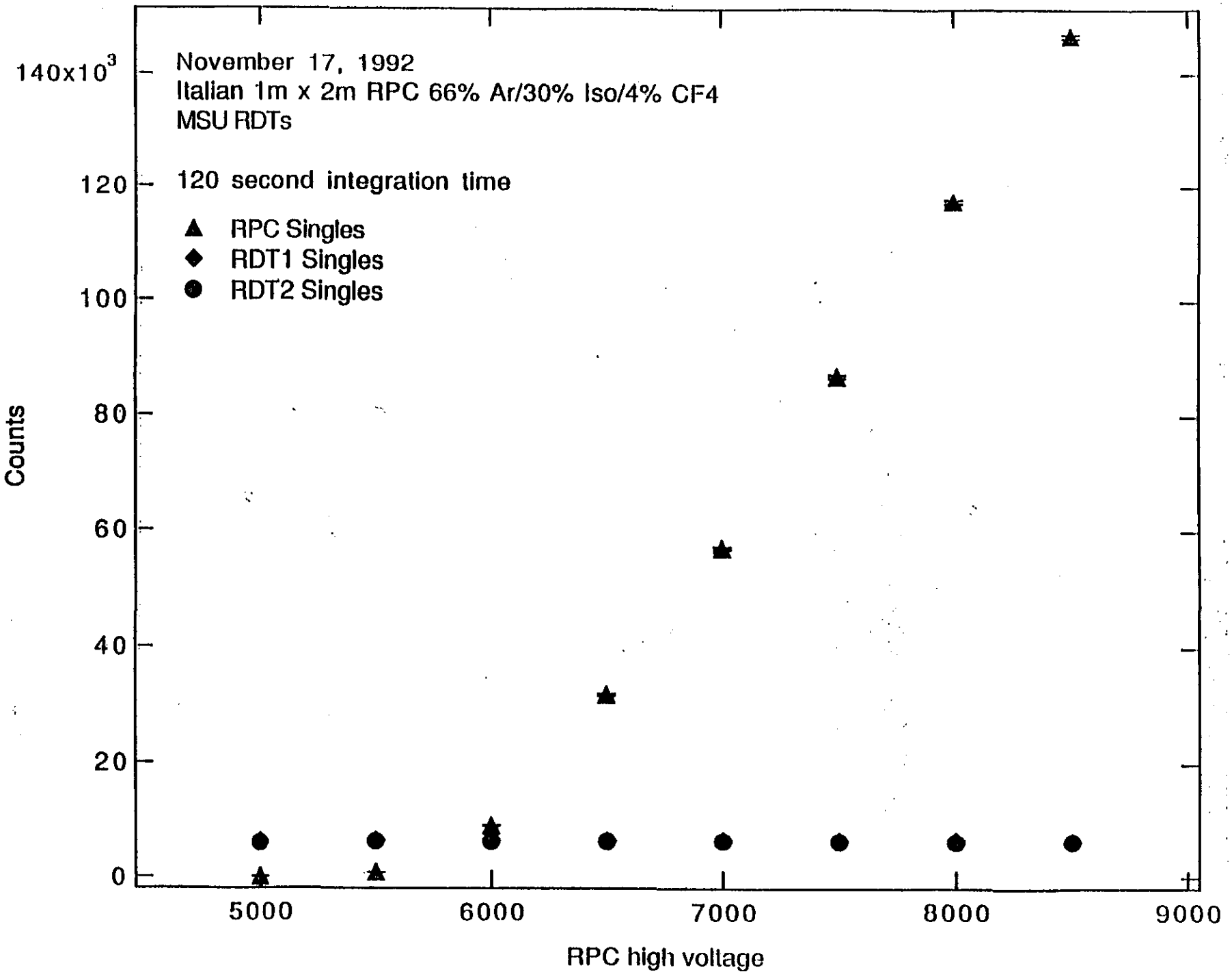
Unfortunately flammable gas


Resolution as a function of distance
Ar - C2 H6 (50/50)
P = 2 atm
P = 2.8 atm
90
80
70
60
50
40
30
0
5
10
R, mm

SIMULTANEOUS OPERATION OF RDT AND RPC




November 17, 1992
Italian 1m x 2m RPC, 66% Ar/30% iso/4% CF4
Coincidence with 2 MSU RDTs
efficienoy
efficiency
RPC high voltage
0.0
0.1
0.2
0.3
0.4
0.5
5000
6000
7000
8000
9000


November 17, 1992
Italian 1m x 2m RPC 66% Ar/30% Iso/4% CF4
MSU RDTs
120 second integration time
RPC Singles
RDT1 Singles
RDT2 Singles
140x10^3
120
100
80
60
40
20
0
Counts
5000
6000
7000
8000
9000
RPC high voltage

CSC's

- preliminary results from BNL and UH prototypes

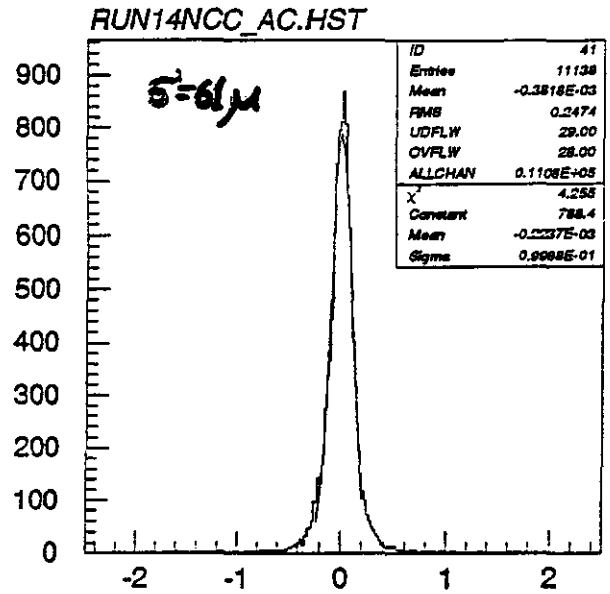
- Dubna prototype is ready for tests at TTR

BNL - CSC

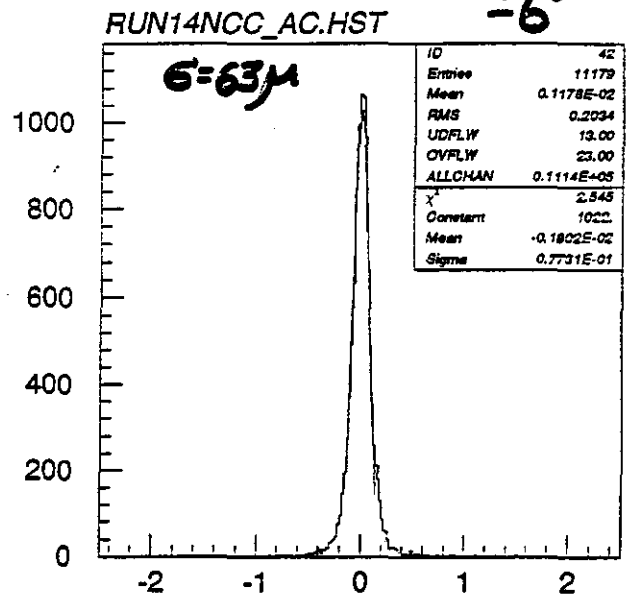
92/12/08 15.56

Run 14 <residual>=0 and phi corrected. ratio used

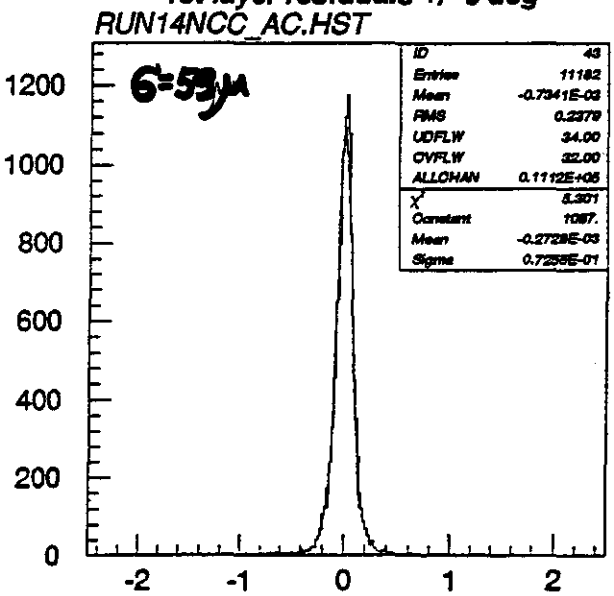
±6°



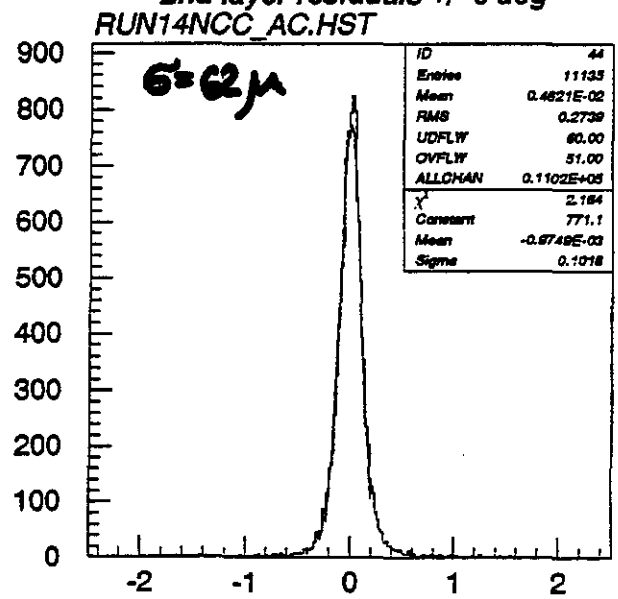
1st layer residuals +/- 6 deg



2nd layer residuals +/- 6 deg



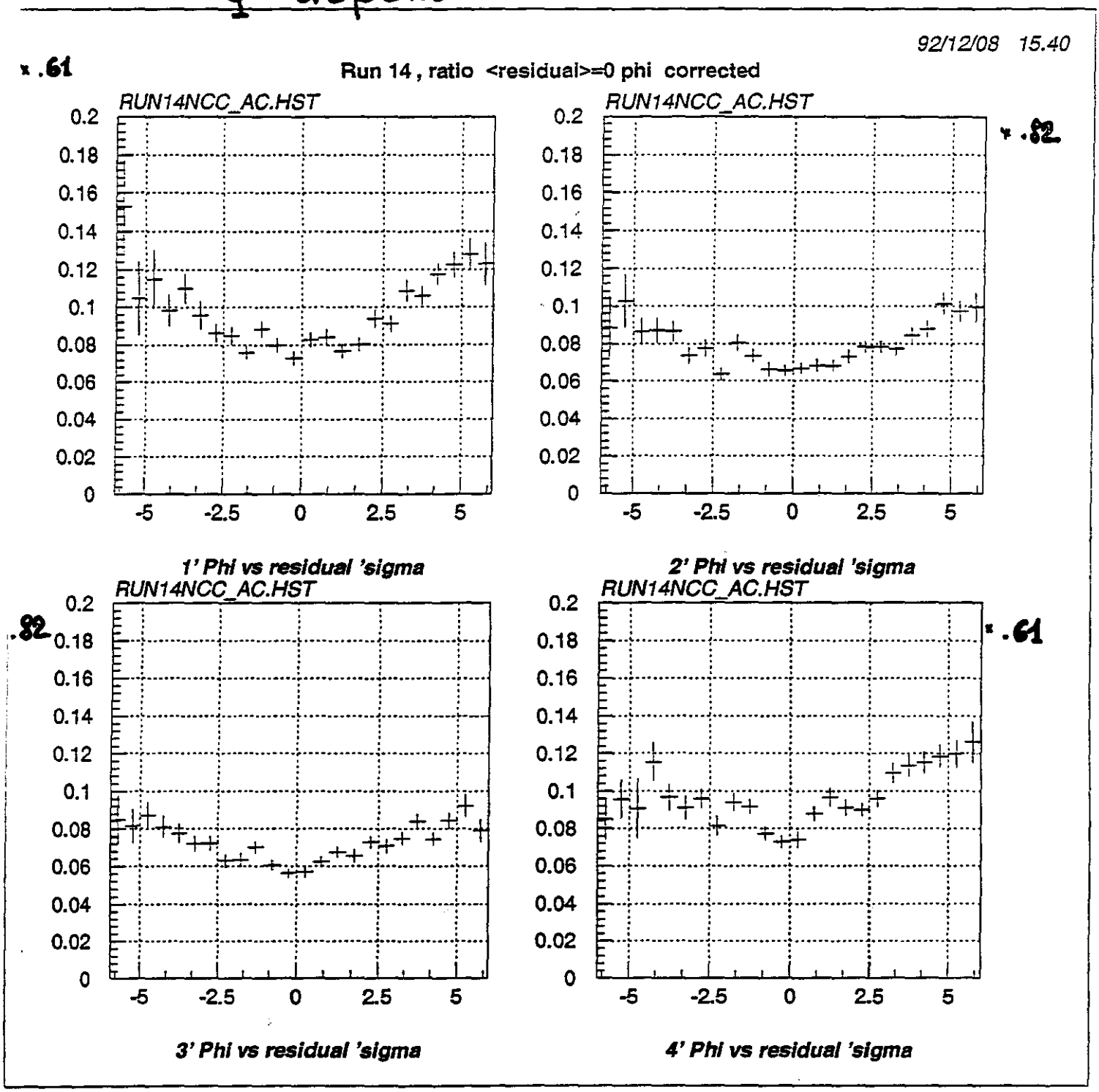
3rd layer residuals +/- 6 deg



4th layer residuals +/- 6 deg

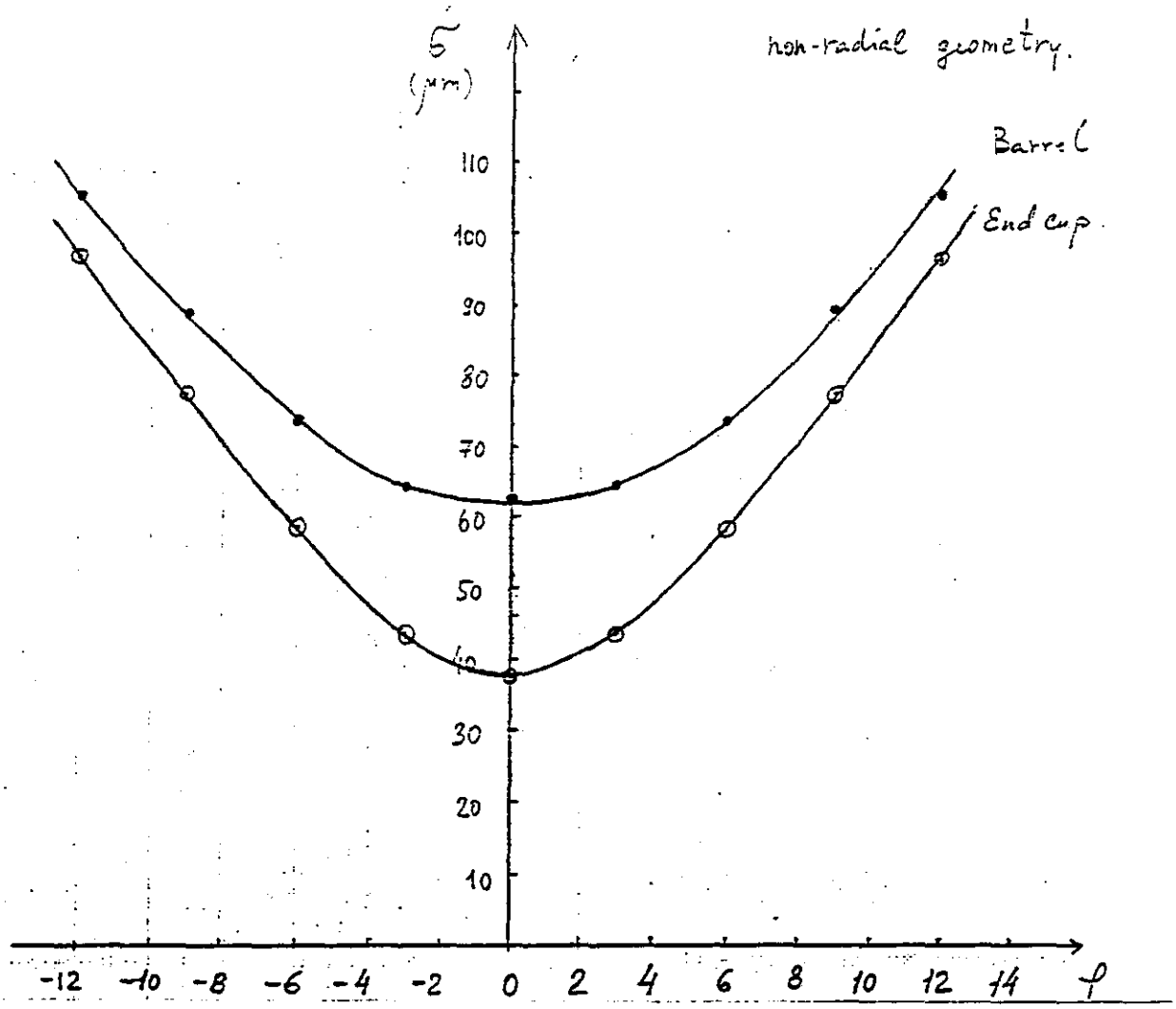
BNL - CSC

φ dependence



FOR VERTICAL TRACKS :

$\sigma \sim 45\mu$ in agreement with MC


σ
(μm)
non-radial geometry.
Barrel
End cap
110
100
90
80
70
60
50
40
30
20
10
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
φ

gem γeμ

Presentation by:

F. Nimblett

GEM MUON SYSTEM

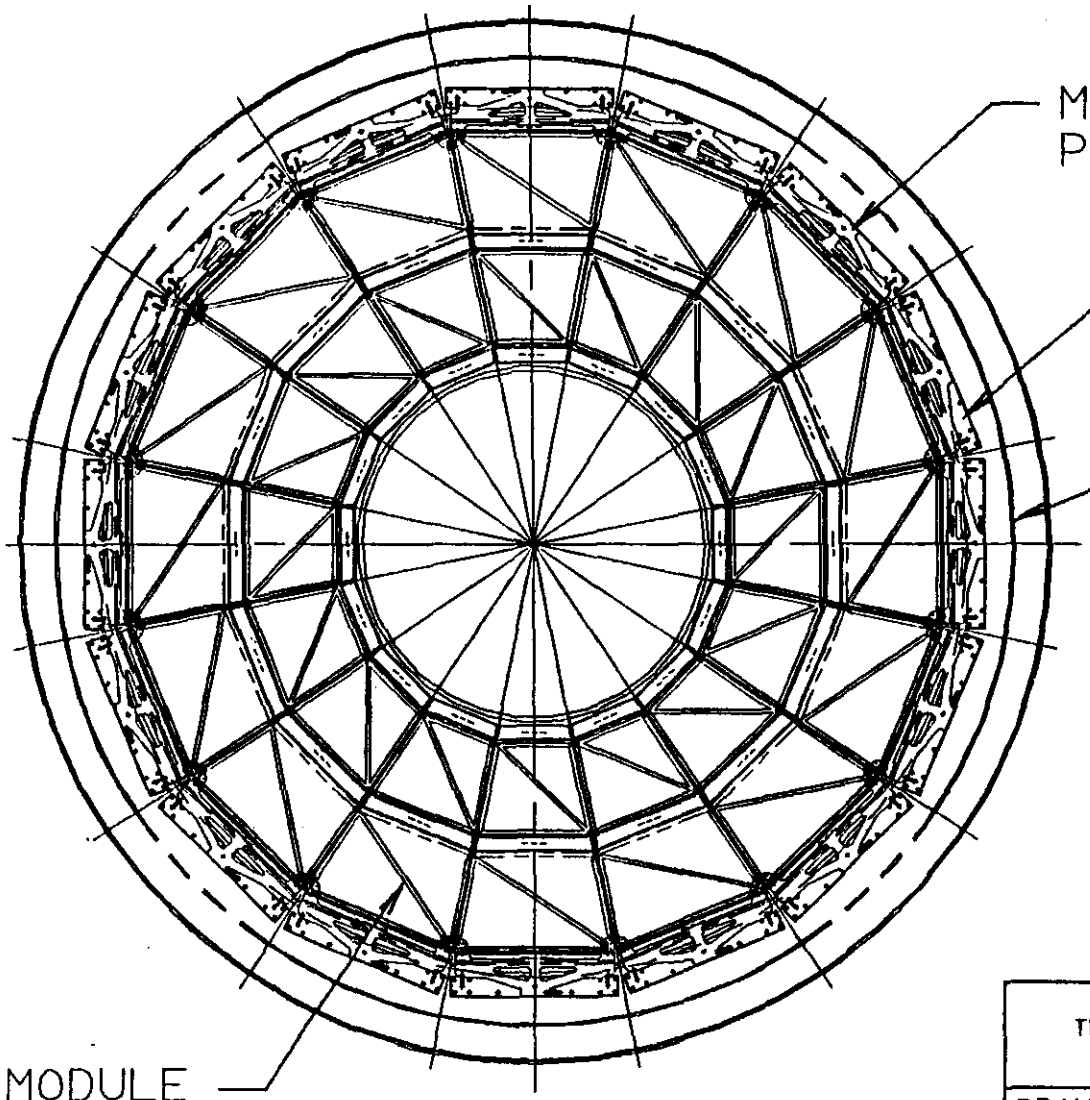
(SUPPORT STRUCTURE STATUS)

F. Nimblett

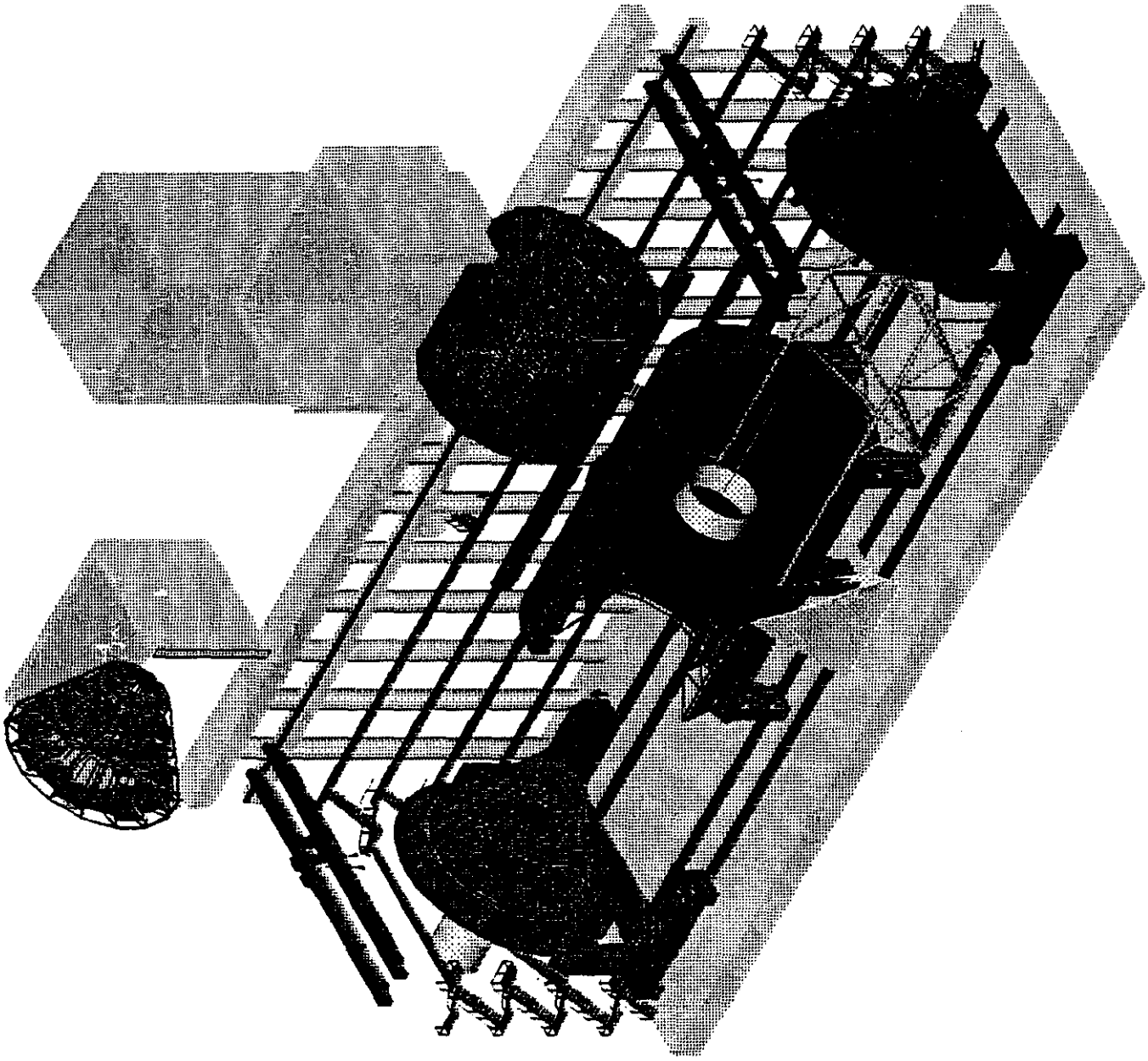
10 December 1992

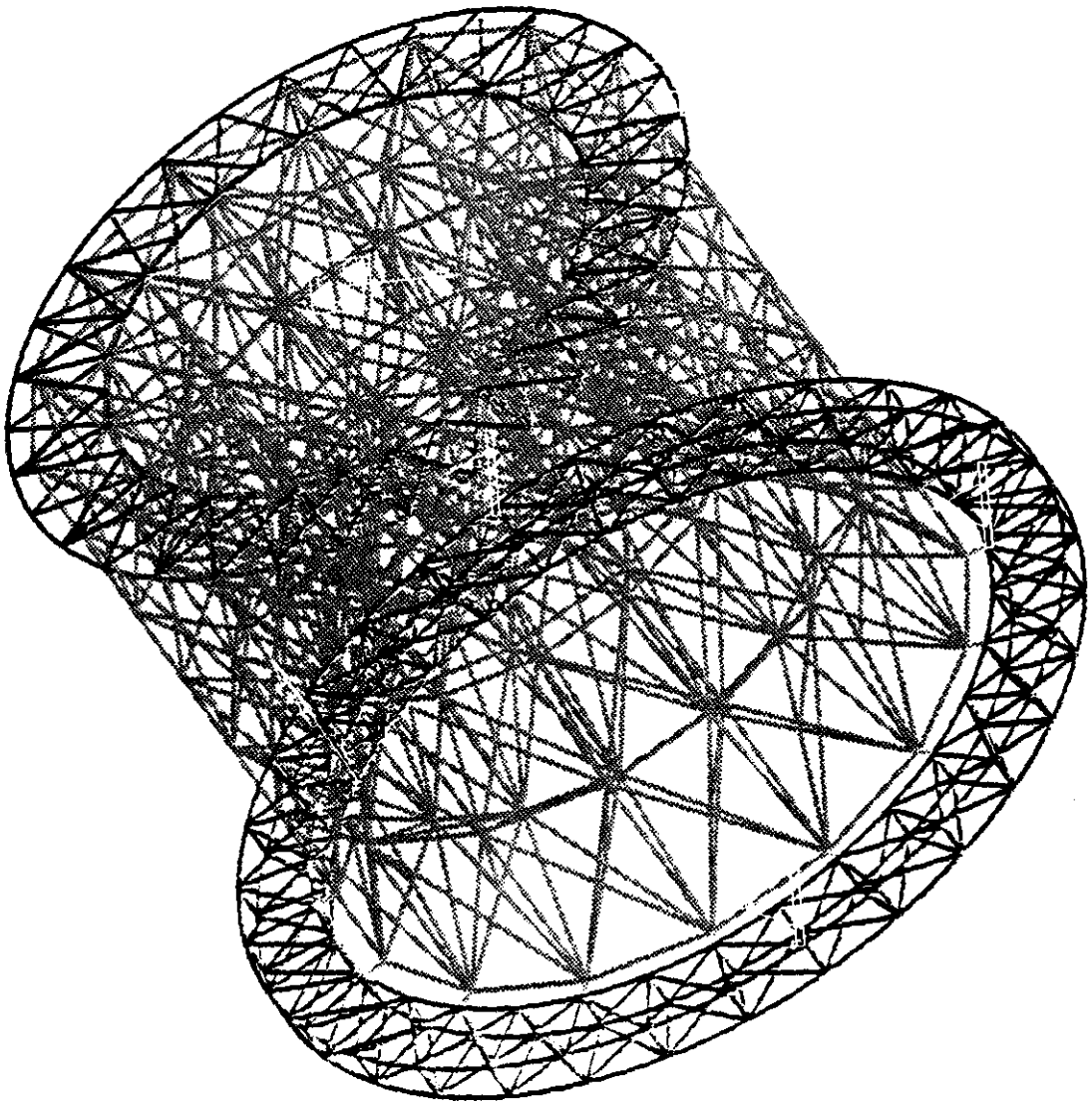
MUON SYSTEM SUPPORT STRUCTURE OPTIONS

- ORIGINAL OPTIONS
  - Modules attached to magnet crown
  - Monolithic barrel region structure "Bigwheel"
- RECENT STRUCTURE OPTIONS
  - Modules built into a monolithic structure with separate end rings.
  - Modules with extra support structure built into the module which are assembled built into a monolithic structure.
  - Minimum structure modules, incomplete structure, which creates the classic "monolithic bigwheel structure".
- RECENT MODULE OPTIONS
  - Independent barrel and endcap region modules
  - "Super- Sector", barrel and endcap regions in a one structure.

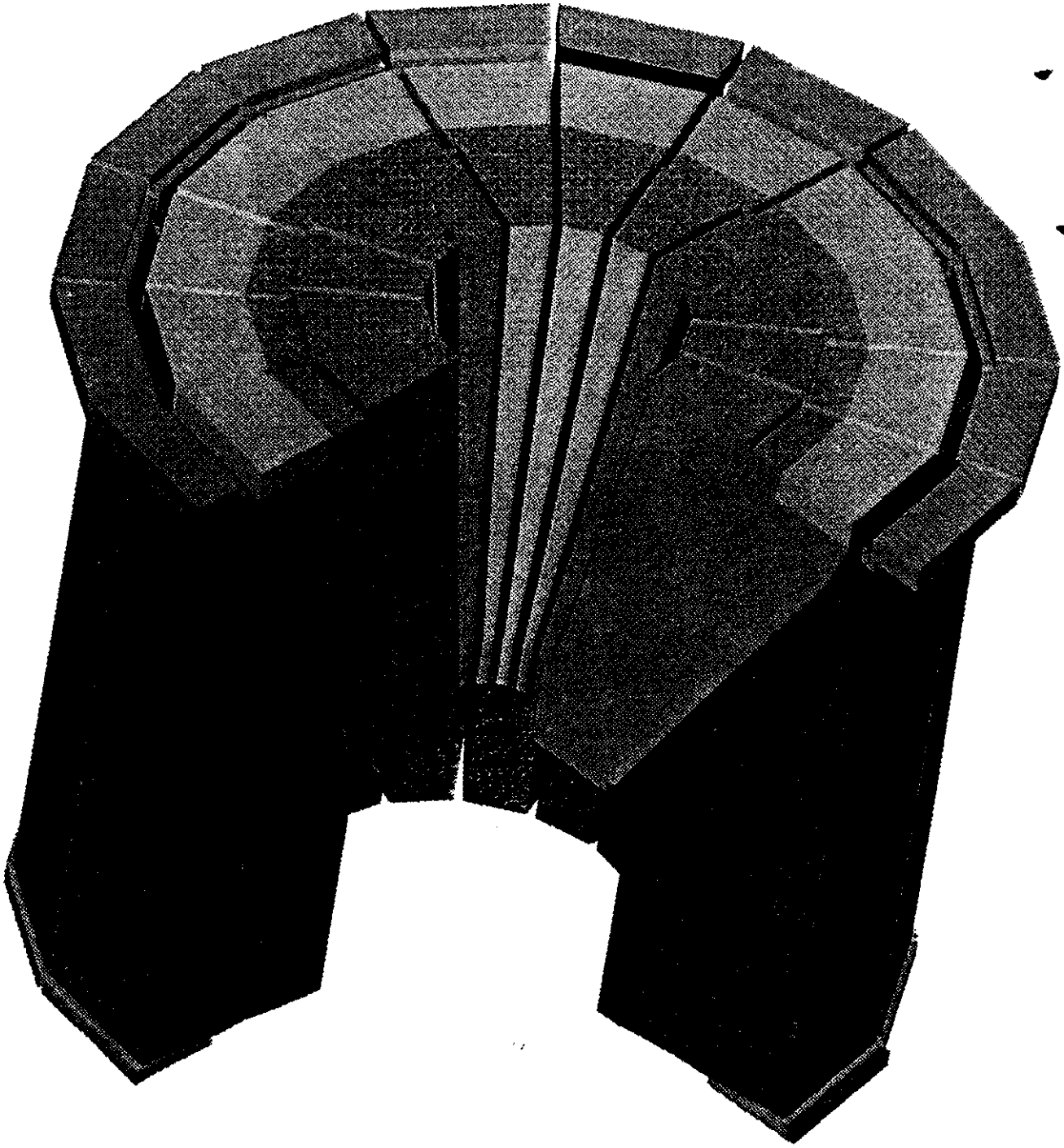


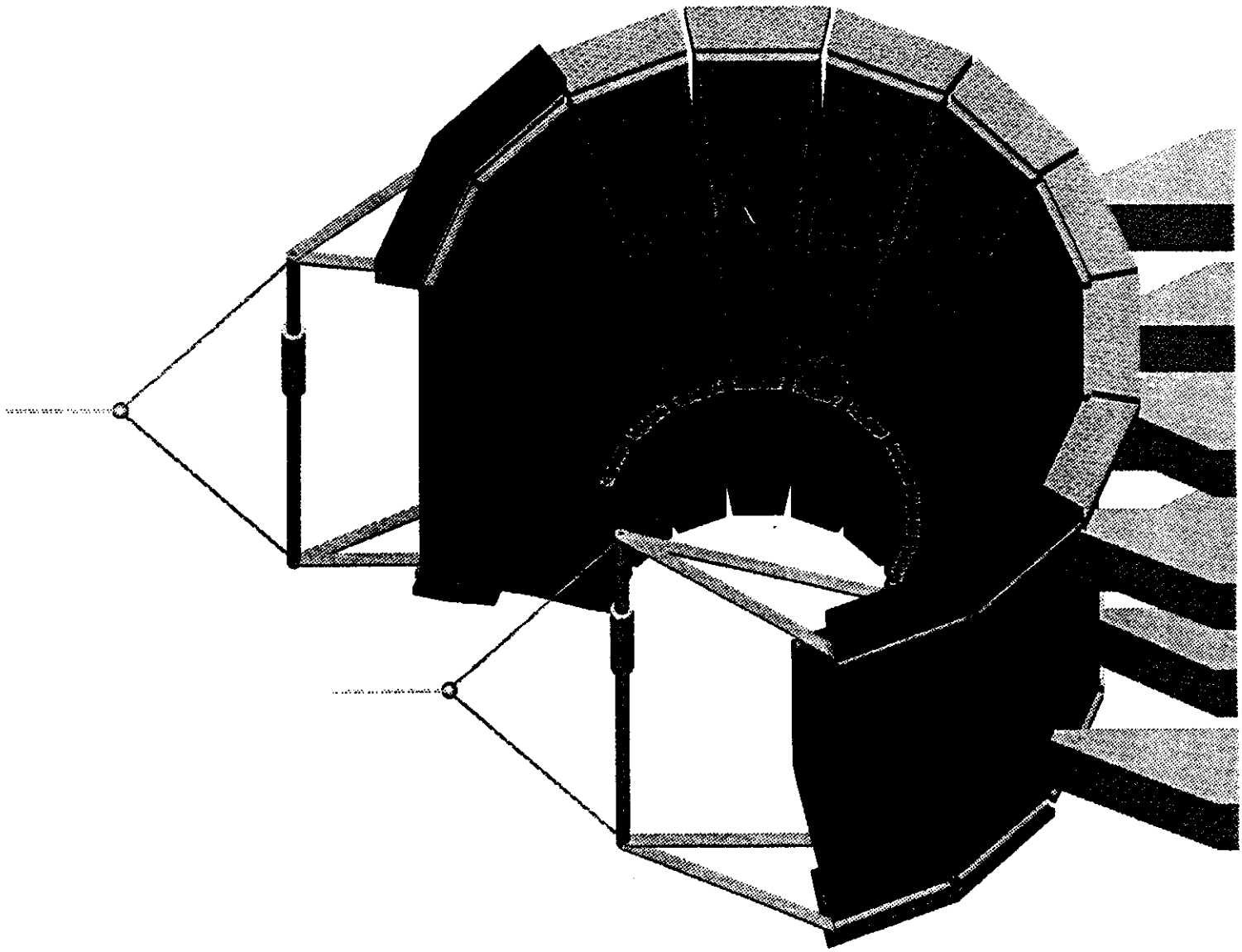
THE CHARLES STARK DRAPER LABORATORY INC. CAMBRIDGE, MASSACHUSETTS, 02139		
DRAWN BY B.D.BIGGIO	APPD BY	DATE 30JUN92
GEM BARREL REGION MUON SYSTEM (END VIEW)		
SIZE A / FSCM NO 51993	DRAWING NO 292932-01	REV –
SCALE NONE		SHEET 1 OF

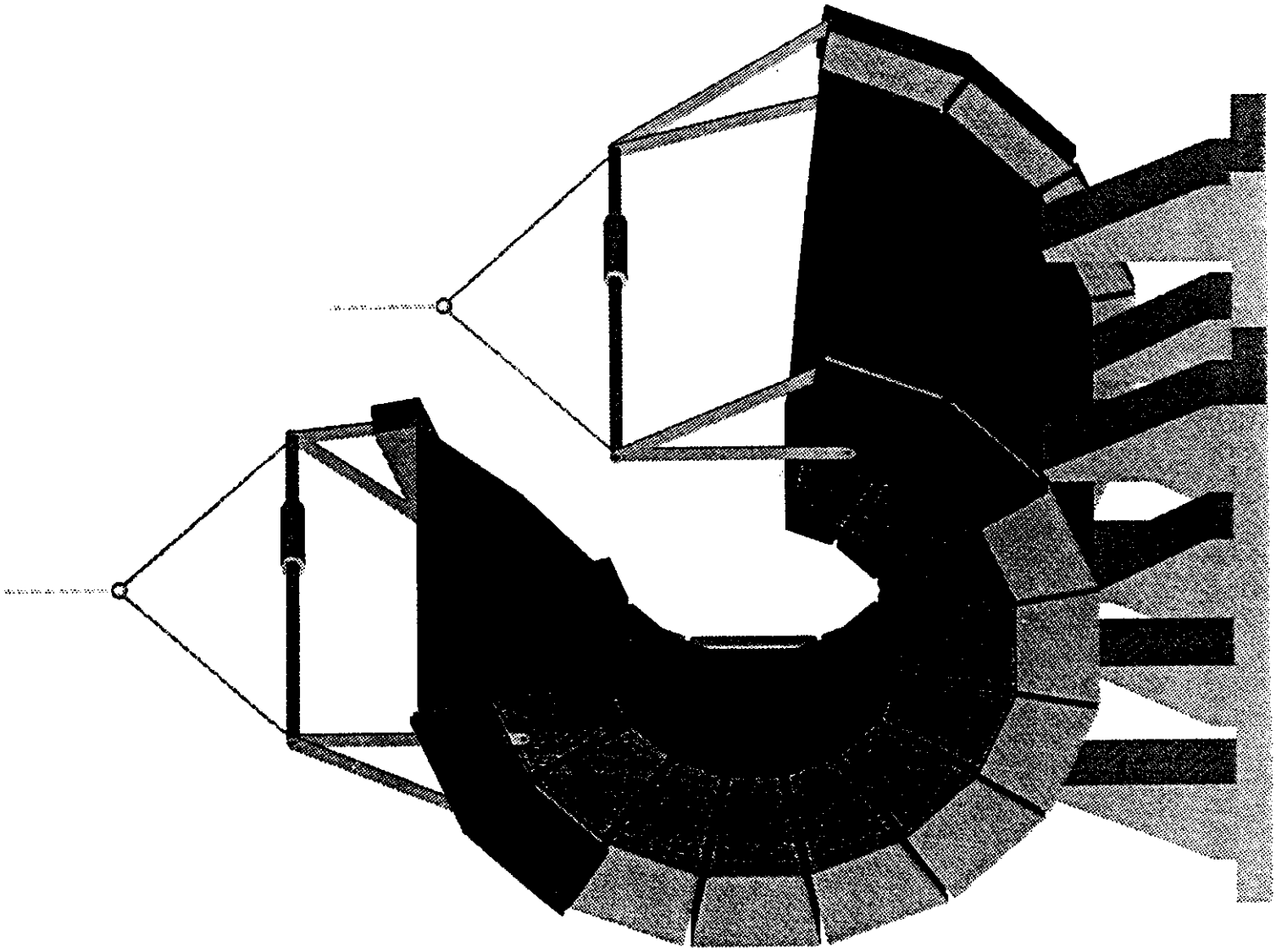




X
Z

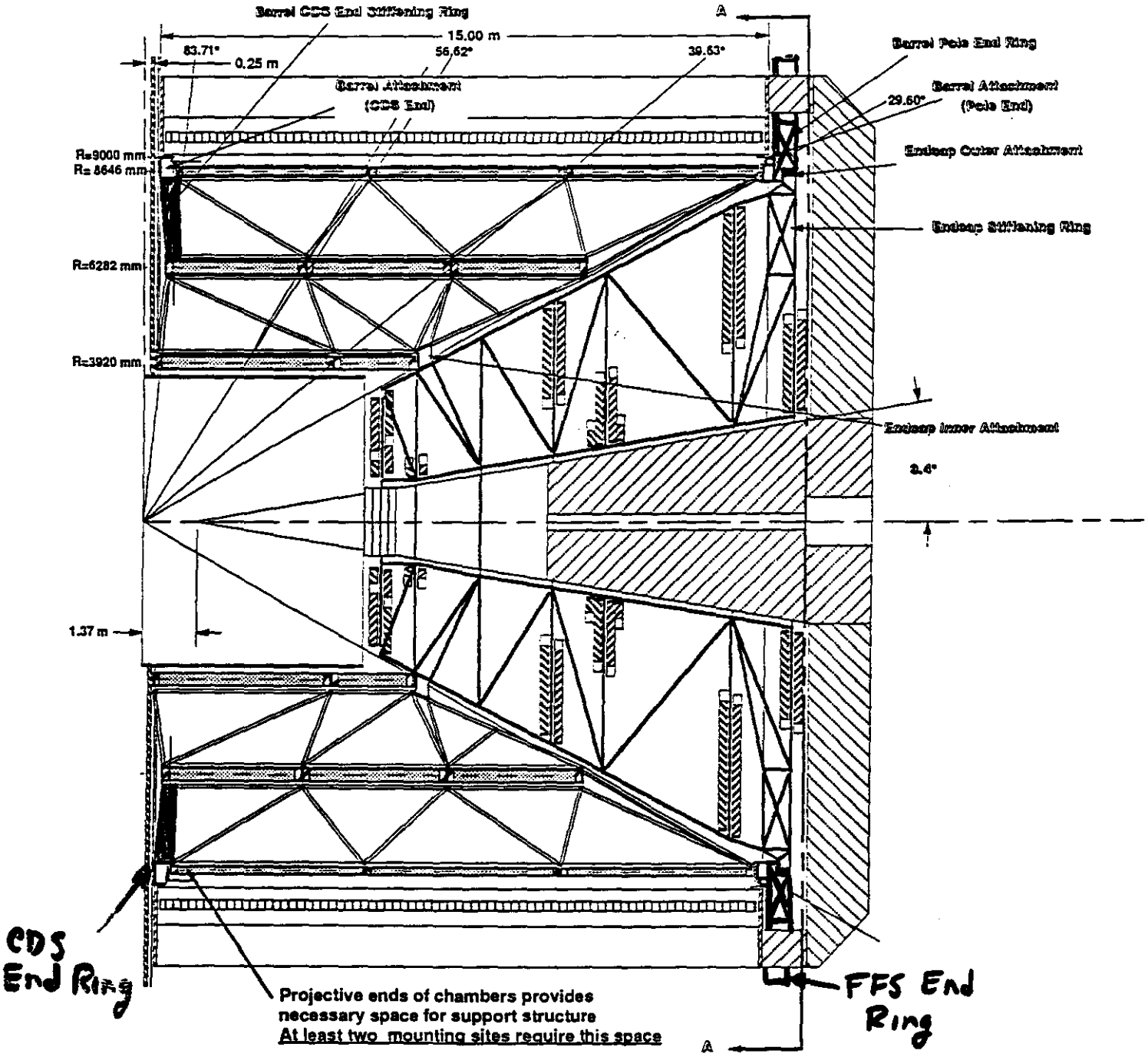






MUON SYSTEM SUPPORT STRUCTURE DECISION FOR TDR

- Muon support structure will be independent monolithic structures for both the barrel and endcap region.
- In the barrel region, the monolith will be fabricated by installing muon modules between two independent support rings.
  - CDS End ring, in the projective space near CDS
  - FFS End ring, in the space between the FFS support structure and the end of the magnet cryostat.
- Endcap monolithic structures will be fabricated from modules whose detail designs are not yet defined.
- Assembly of the monoliths for both regions will be done in the North Assembly building.
- If possible, the two region monoliths will be merged and aligned in the North Assembly building.
- Option for late installation of the endcap region monolith utilizing the the FFS as an installation fixture will be maintained.

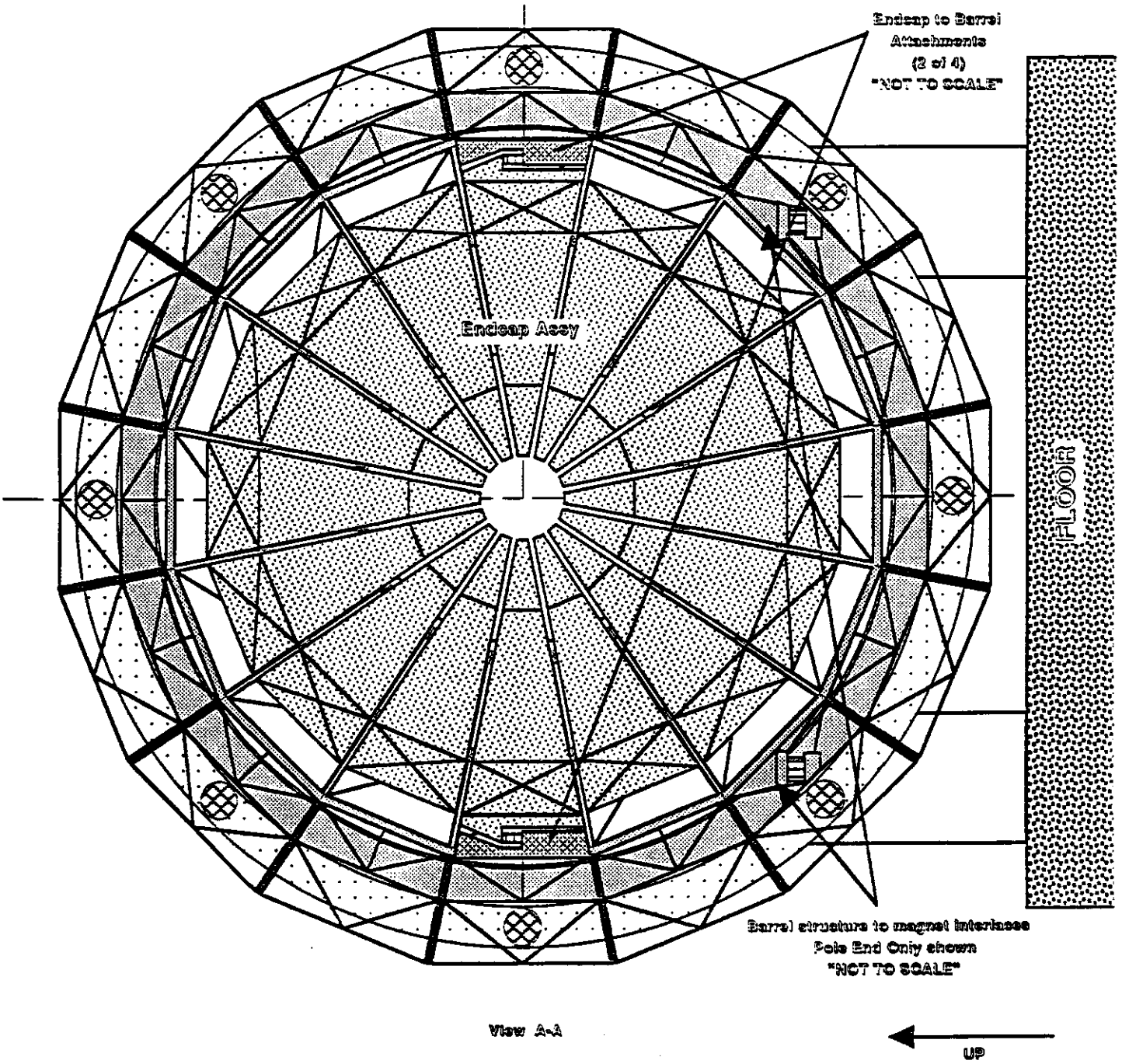


GEM MUON SYSTEM STRUCTURES
BASELINE II
(2,3,3 Chambers per Layer-PROJECTIVE GAPS)
Barrel Interconnecting Plate Structure Illustrated

PLAN VIEW

(Larger end ring)

Draper Laboratory	
GEM Muon System Structures Layout (plan view)	
Drawn By: F. Nimblett	Rev (-)
Dwg. No: GMU0022	11/17/92
Approved by:	



GEM MUON SYSTEM STRUCTURES
BASELINE II
(2,3,3 Chambers per Layer-PROJECTIVE GAPS)
Barrel Interconnecting Plate Structure Illustrated

END VIEW OF BARREL & Endcap

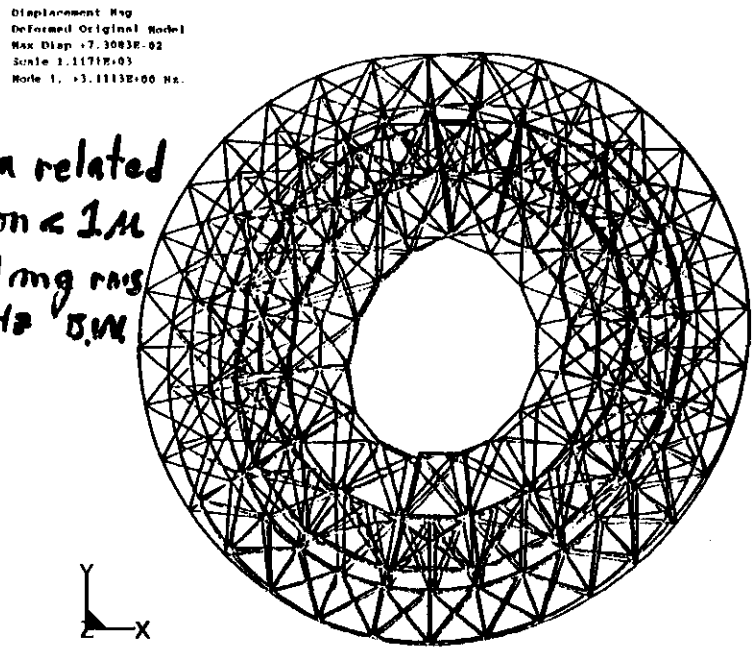
(Larger end ring)

Draper Laboratory	
GEM Muon System Structures Layout (end view, barrel)	
Drawn By: F. Nimblett	Rev (-)
Dwg. No: GMU0022	11/17/92
Approved by:	

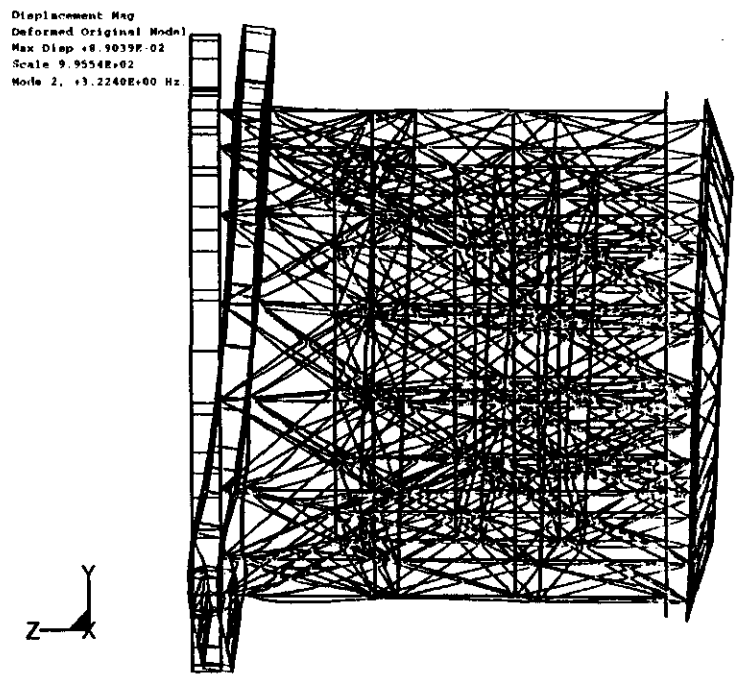
WHY MONOLITHIC STRUCTURES ?

- STABILITY, STABILITY, STABILITY
- Barrel region attachment to magnet at four stable points
- Endcap region monolith attached to barrel region monolith
  Forward Field Shaper can be used for installation only!
- Sensitivity of sagitta related deformations to random vibration inputs through the magnet is 3 to 10 times less than for independent module concept.
  - Less than 1 micron rms (relative lateral displacement of muon superlayer) for conservative ground motion input to magnet of 0.0001 g's rms from 1-20 Hz.
  - Total error budget for sagitta measurement 25 microns rms.
- Down-hole installation time is minimized
- Schedule flexibility enhanced due to assembly and initial alignment in surface facilities

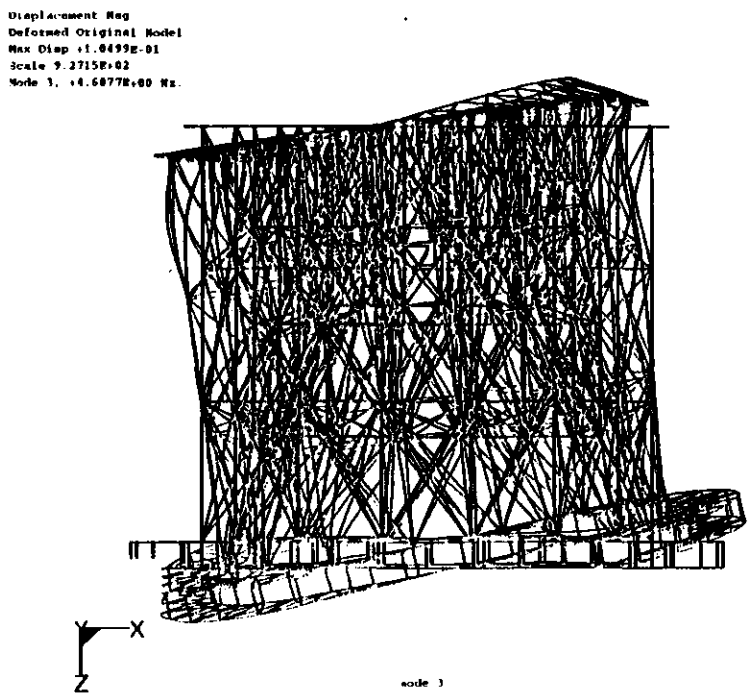
Sagitta related deflection < 1μ for 0.1mg rms 1-20 Hz B.W.



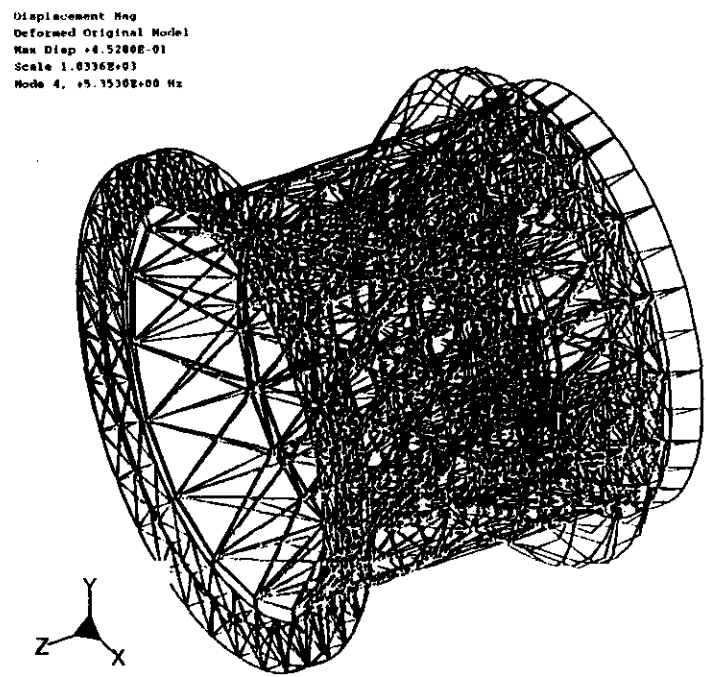
mode 1



mode 2



mode 3



mode 4

WHY MODULES ?

- Ability to have meaningful prototypes !
- Muon tower prealignment can be done in a controlled, safe environment !
- Assembly of muon chambers into modular support structure is easier, safer, and has significant potential for learning curve improvements !
- Independent region modules assembled into independent region monoliths maximize scheduling, maintenance and staging options!

****

WHY MODULES INTO A MONOLITH ?

MAXIMIZE POTENTIAL TO REALIZE THE BEST FEATURES OF EACH STRUCTURE TYPE !!

CONCLUSIONS

- Muon Structure recommendation for muon system for TDR has been made by muon structures engineering staff.

- Structure recommended for barrel is "modules assembled into a monolithic structure utilizing separate end support rings"(4 point mount to the magnet cryostat)

- Structure for the endcap region will also be "modular, assembled in a monolithic structure" (Attached to barrel region monolith)

- Decision on structure permits focused engineering on muon structures as soon as muon chamber layouts are established.

LAST BUT BY NO MEANS LEAST !

- Engineering staff contributing to these structures evaluations

- *SSCL* -- Mike Gamble, Coleman Johnson, Jacques Pier-Amory, Kris Schludermann

- *LLNL* -- Allen House, Rick Sawicki

- *Draper* -- Marty Furey, Tom Hines, Tom Lee, Frank Nimblett, Rick Sapienza

- *Martin Marietta* -- Bob Humphreys

- *GEM* management

gem

γeμ

Presentation by:

K. Lau

Spatial Resolution Measurements of UH (open-profiled) CSC Prototype at TTR

University of Houston

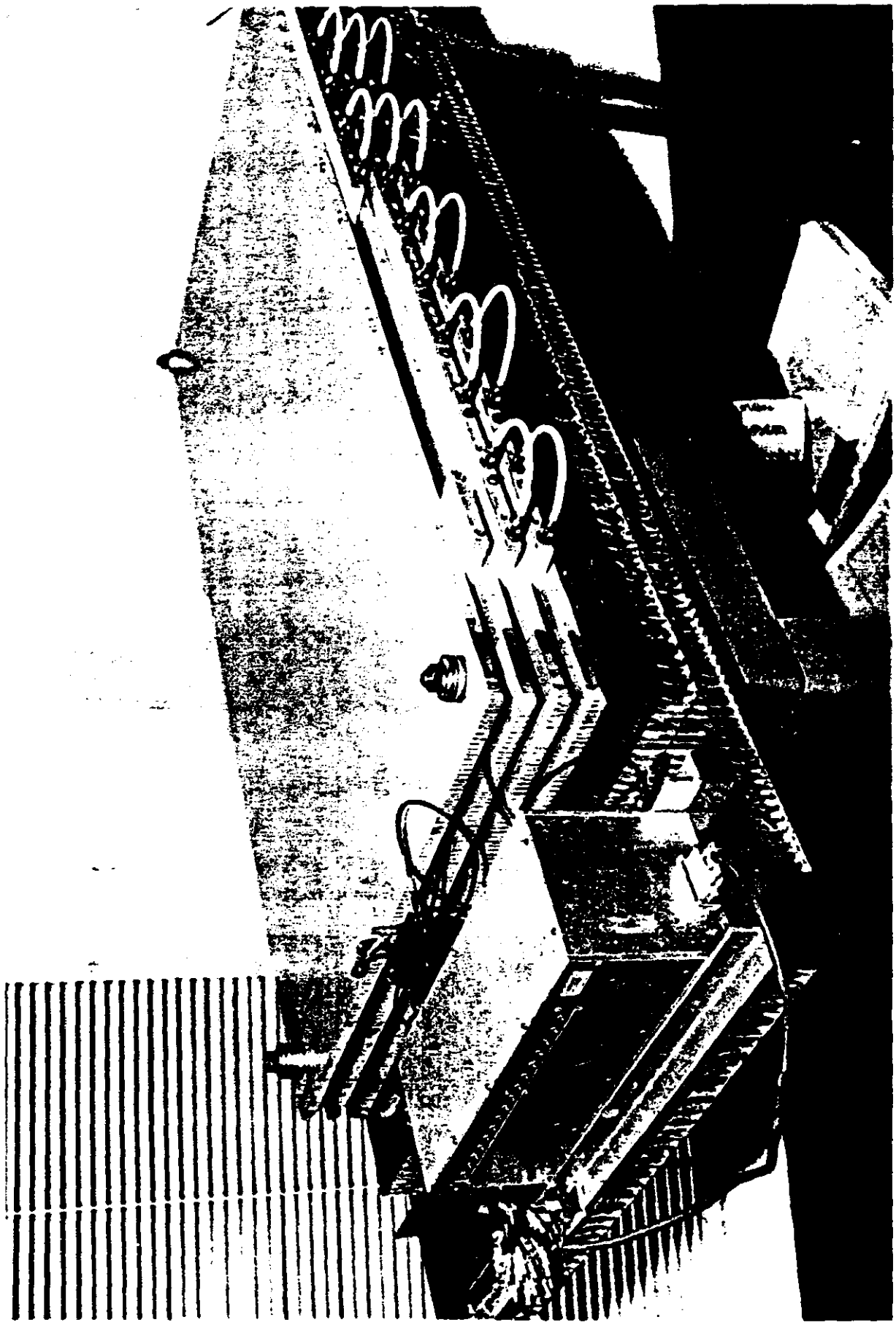
SSCL (TTR)

Dubna

Presented by Kwong Lau

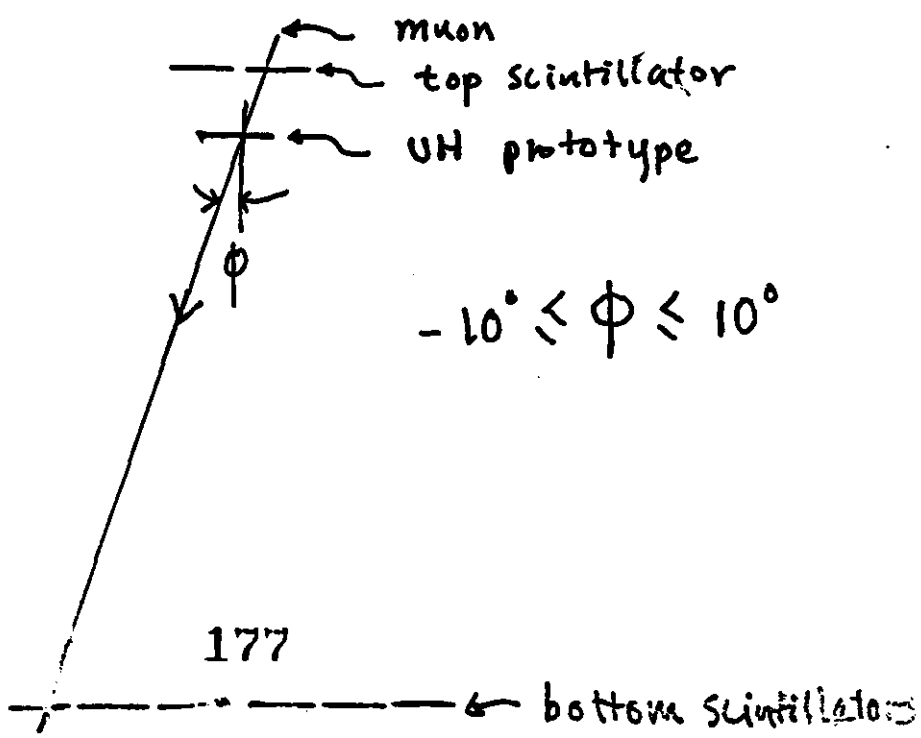
GEM μ-Meeting 12/9/92

GEM CC-Meeting 12/10/92

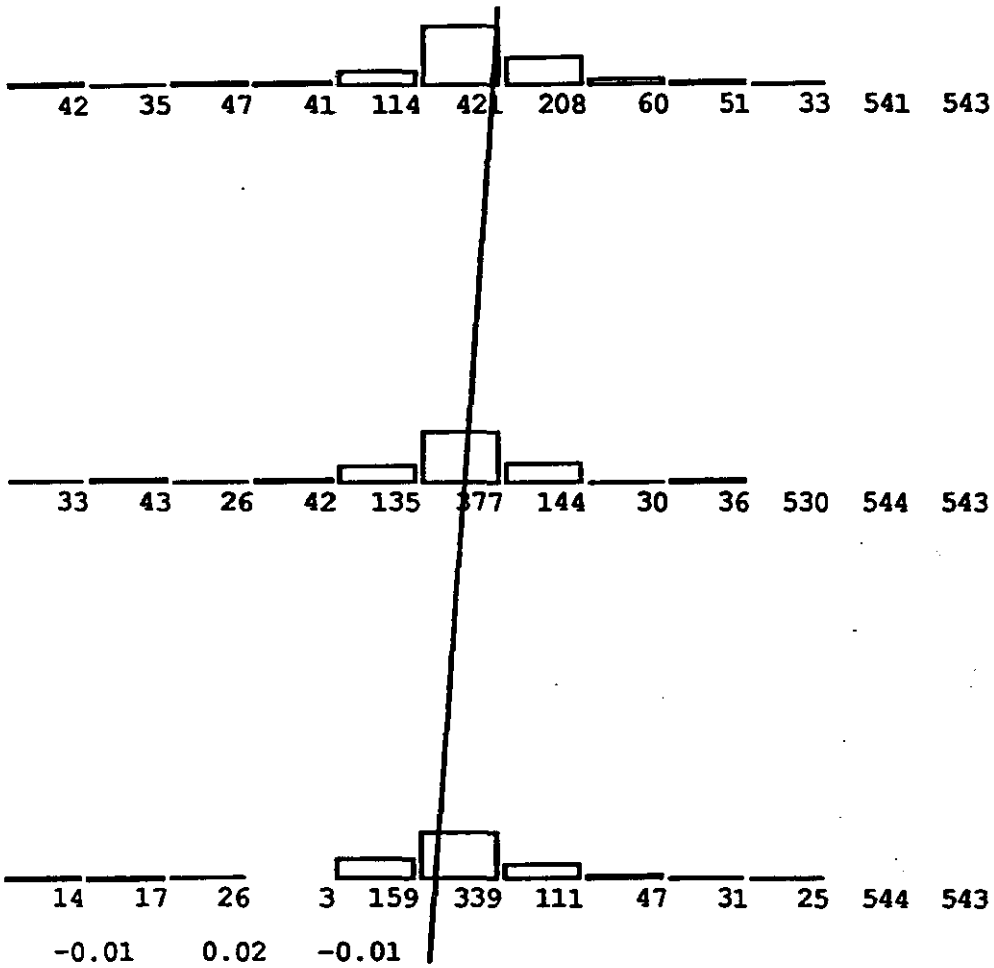


UH CSC Prototype

- 3 layers of 1.0 m (long) x 0.5 m precision strips (pitch = 5.0 mm = 4 mm Cu + 1 mm gap)
- 3 layers (12 chambers per layer) of 66-cm Iarocci-type carbon-coated (4 kΩ per square) profiles with 45 μm gold-plated tungsten wires
- standard (75/25 Isobutane-argon) gas mixture in proportional mode (3.0 - 3.3 kV)
- 10 (top), 9 (middle), and 10 (bottom) strips at center from the three layers are instrumented with preamps (gain $\simeq$ 1000) and ADCs.
- preamp outputs are routed via 53-m RG174 coaxial cables to Lecroy 2249W ADCs with an integration time of 500 ns
- trigger on 2 top scintillators and all bottom scintillators



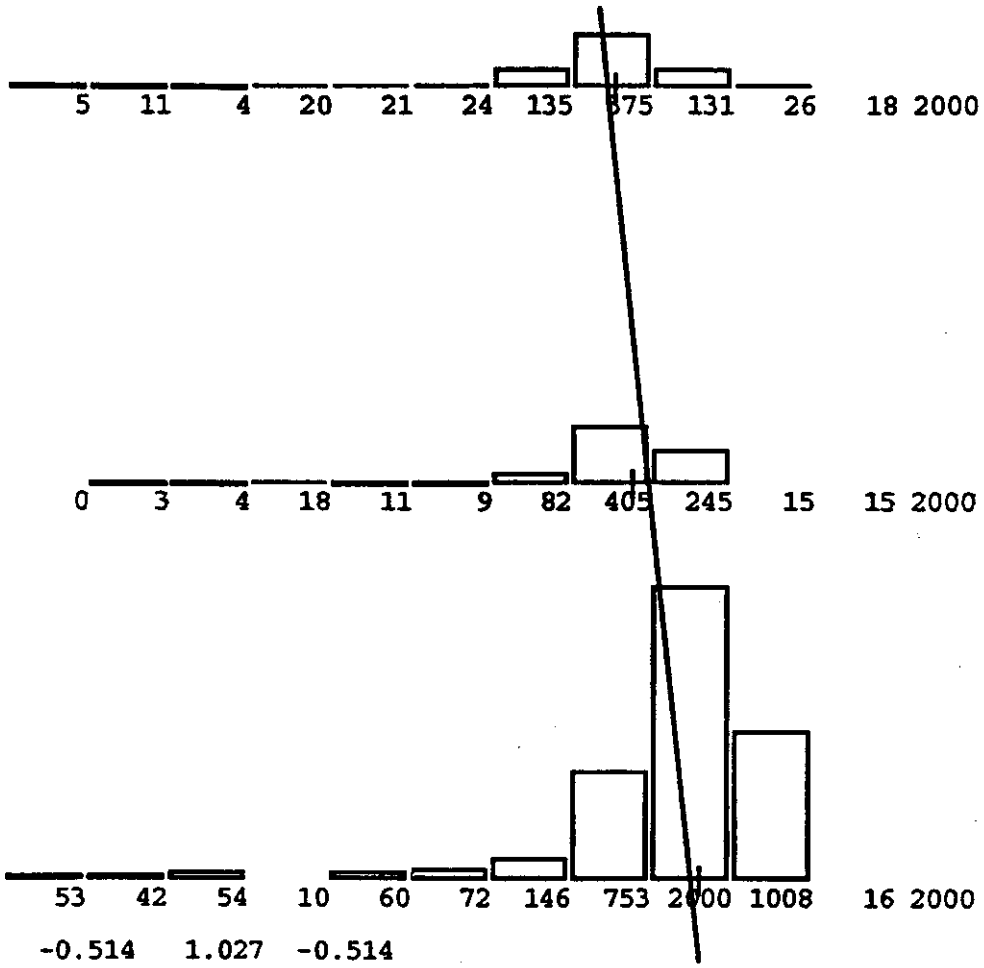
Run#: 666 Events on File: 45442 groups on file: 2
Event#: 4200 Fri, Oct 23, 1992 17:45



$$R_1 = R_3 = -\tfrac{1}{2}R_2$$

$$\sigma = \sqrt{6}\, R_1$$

Run#: 666 Events on File: 48472 groups on file: 2
Event#: 4282 Fri, Oct 23, 1992 17:45



Analysis Procedure

- Fast Filter at TTR
  - select events with at least 1 strip with $\geq$ 100 ADC counts in each layer

- Pedestal and Gain Corrections
  - apply pedestal (20-40 ADC counts) subtraction and gain correction (1.00 $\pm$ 0.10) to all ADC counts.
  - ADC counts set to 0 if corrected counts are $\leq$ 0.

- Fiducial Cut
  - locate peak channel in each layer and require peak channel to be at least 1 or 2 channels from uninstrumented strips

- δ-ray Cut
  - remove any event with 1 or more ADC overflows ($\geq$ 1900 raw ADC counts)

- Locate Cluster Centroid
  - determine c.o.g. of the hits for each layer (z_{cog}) by using a weighted mean of 3-strip ($z^{(3)}$) and 4-strip ($z^{(4)}$) c.o.g.'s

$$z_{cog} = \frac{z^{(3)}}{1 + \frac{2}{w}(z^{(3)} - z^{(4)})}$$

w = strip pitch = 5.0 mm

- Systematic Correction
  - apply a 3-term-Fourier-series systematic correction of the following form

$$\Delta z = A \times [sin(\frac{2\pi z_{cog}}{w}) - 0.077 \times sin(\frac{4\pi z_{cog}}{w}) + 0.041 \times sin(\frac{6\pi z_{cog}}{w})]$$

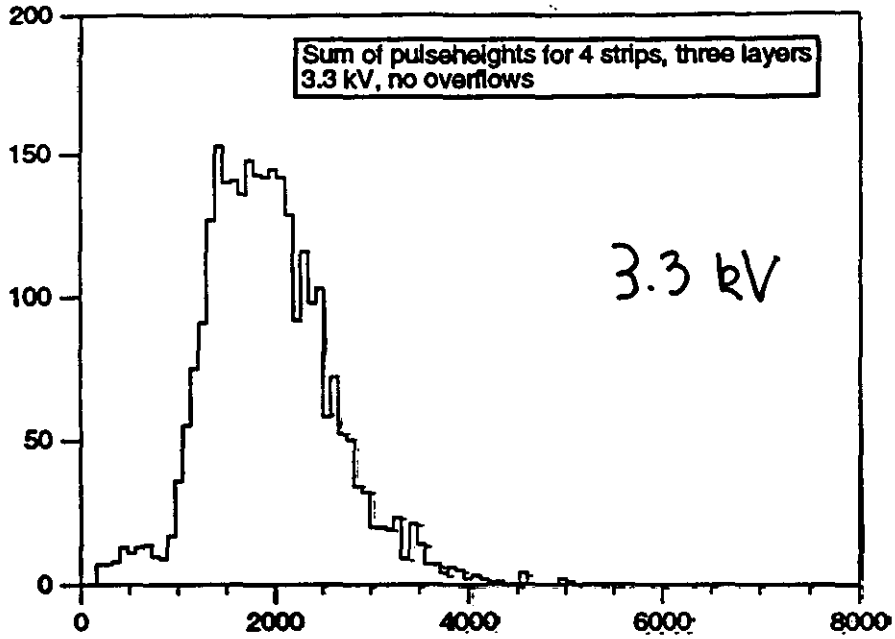
A is varied in the range : $60 \leq A \leq 100$ μm

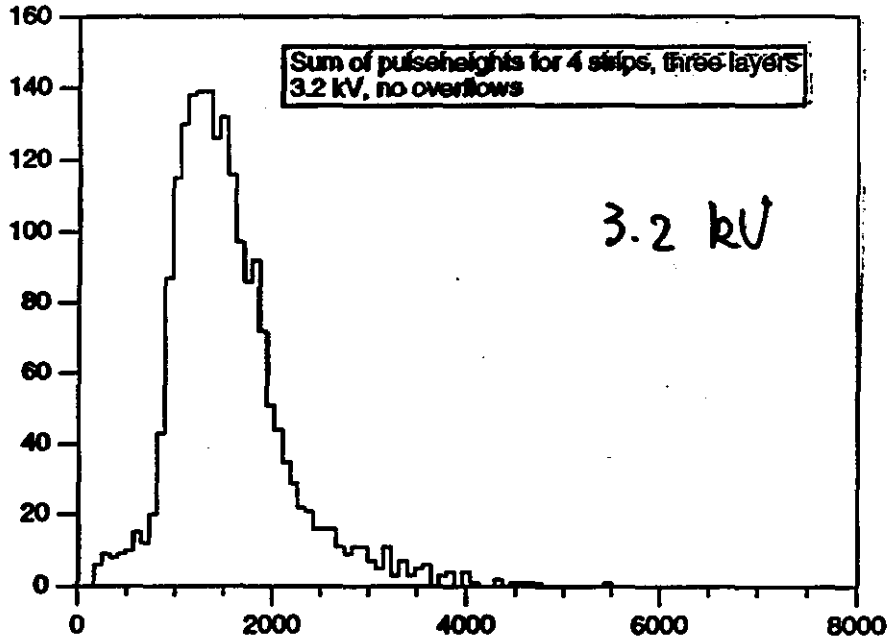
A = 117.1 μm according to monte carlo with a point inducing charge

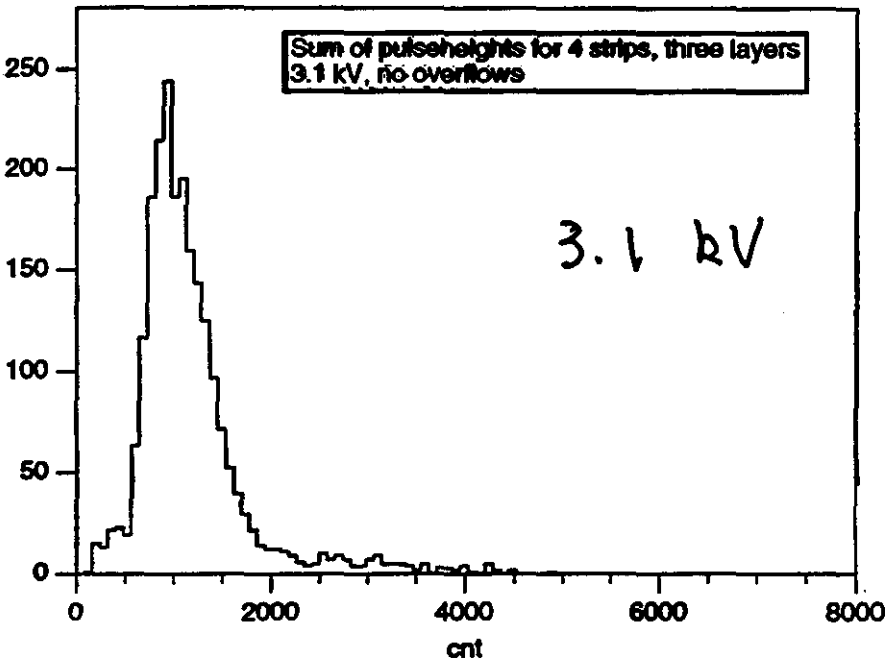
A $\simeq$ 80-90 μm gives best results

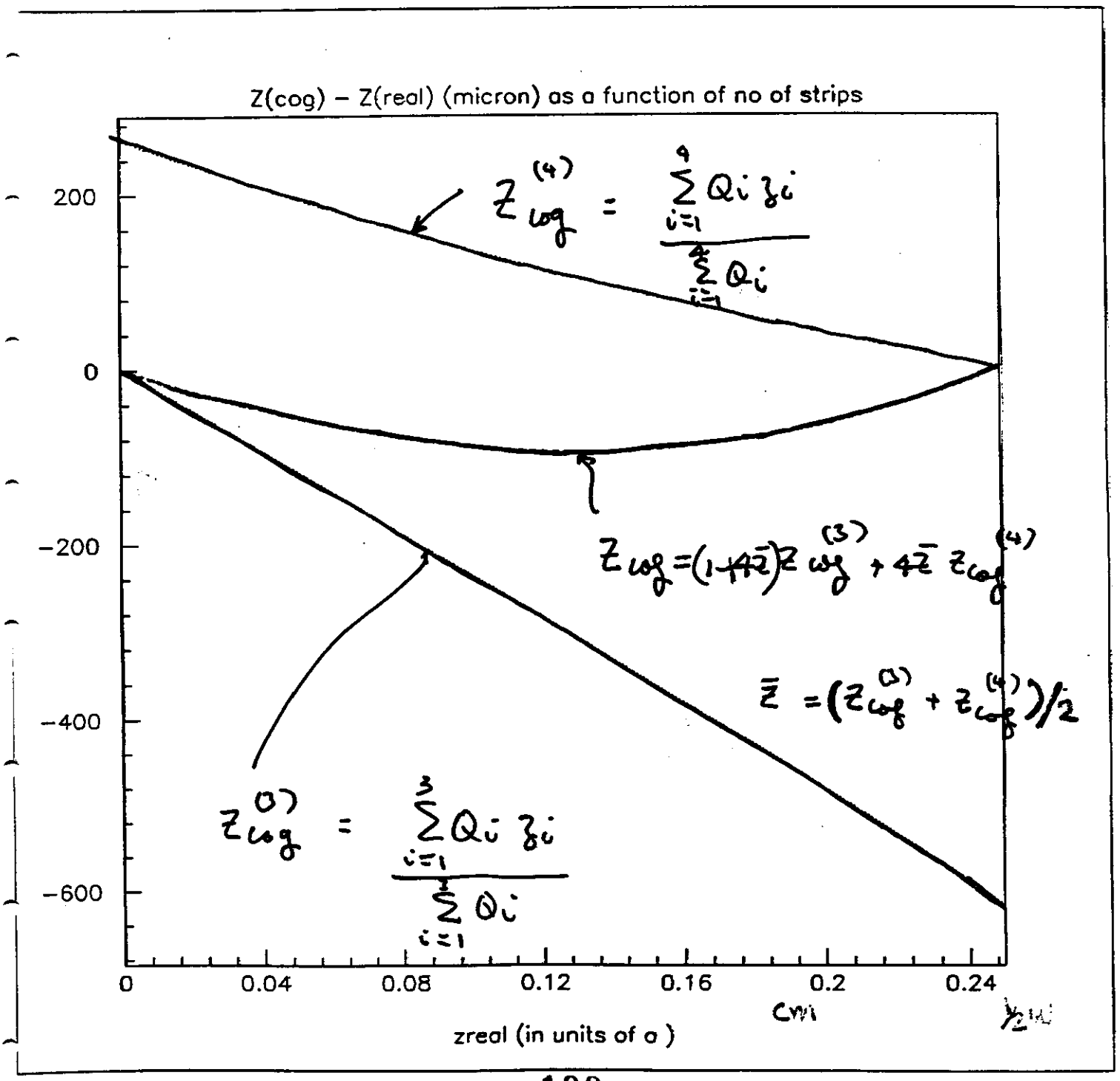
- Systematic Alignment Correction
  - middle plane is found to be off by $\simeq 33 \pm 5$ μm relative to top and bottom layers.
  - correct z_{cog}s in the middle plane by a systematic shift of 33 μm.

- Track Fitting
  - fit the corrected points (least square) to a straight line
- Resolution per Plane
  - residuals in the top layer (R_1) within $\pm$ 150 μm are fitted to a Gaussian + a constant.
  - resolution per plane $\sigma = \sqrt{6}\ \sigma_{R_1}$

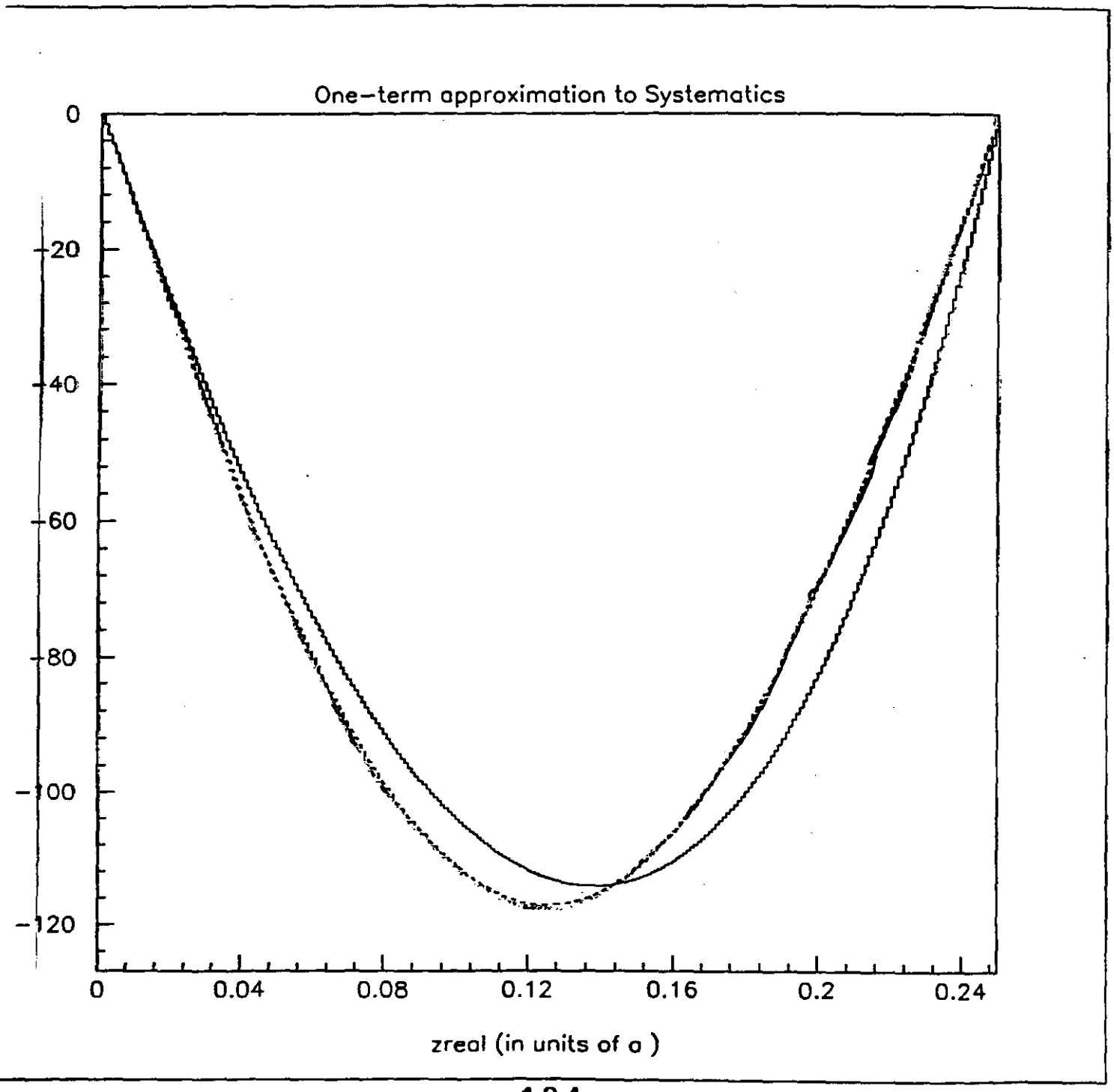

Sum of pulseheights for 4 strips, three layers
3.3 kV, no overflows
3.3 kV
200
150
100
50
0
0
2000
4000
6000
8000


Sum of pulseheights for 4 strips, three layers
3.2 kV, no overflows
3.2 kV
160
140
120
100
80
60
40
20
0
0
2000
4000
6000
8000


Sum of pulseheights for 4 strips, three layers
3.1 kV, no overflows
3.1 kV
250
200
150
100
50
0
0
2000
4000
6000
8000
cnt

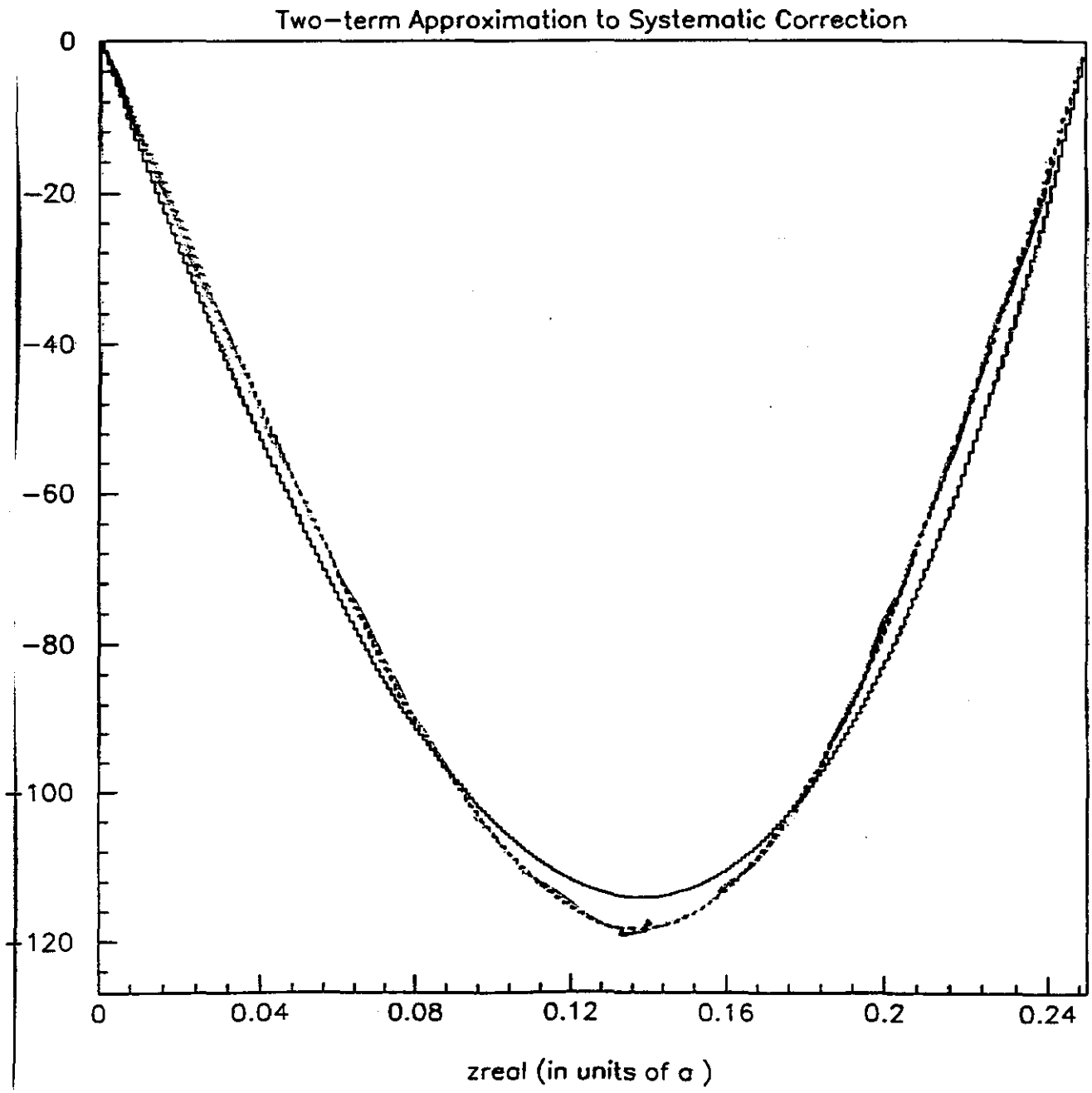

Z(cog) – Z(real) (micron) as a function of no of strips
200
0
-200
-400
-600
0
0.04
0.08
0.12
0.16
0.2
0.24
zreal (in units of a)
$Z_{cog}^{(4)} = \frac{\sum_{i=1}^{9} Q_i z_i}{\sum_{i=1}^{9} Q_i}$
$Z_{cog} = (1-4\bar{z}) Z_{cog}^{(3)} + 4\bar{z}\, Z_{cog}^{(4)}$
$\bar{z} = (Z_{cog}^{(3)} + Z_{cog}^{(4)})/2$
$Z_{cog}^{(3)} = \frac{\sum_{i=1}^{3} Q_i z_i}{\sum_{i=1}^{3} Q_i}$

$$\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,cm}\right) \qquad 0 \le z \le 0.25\,cm$$



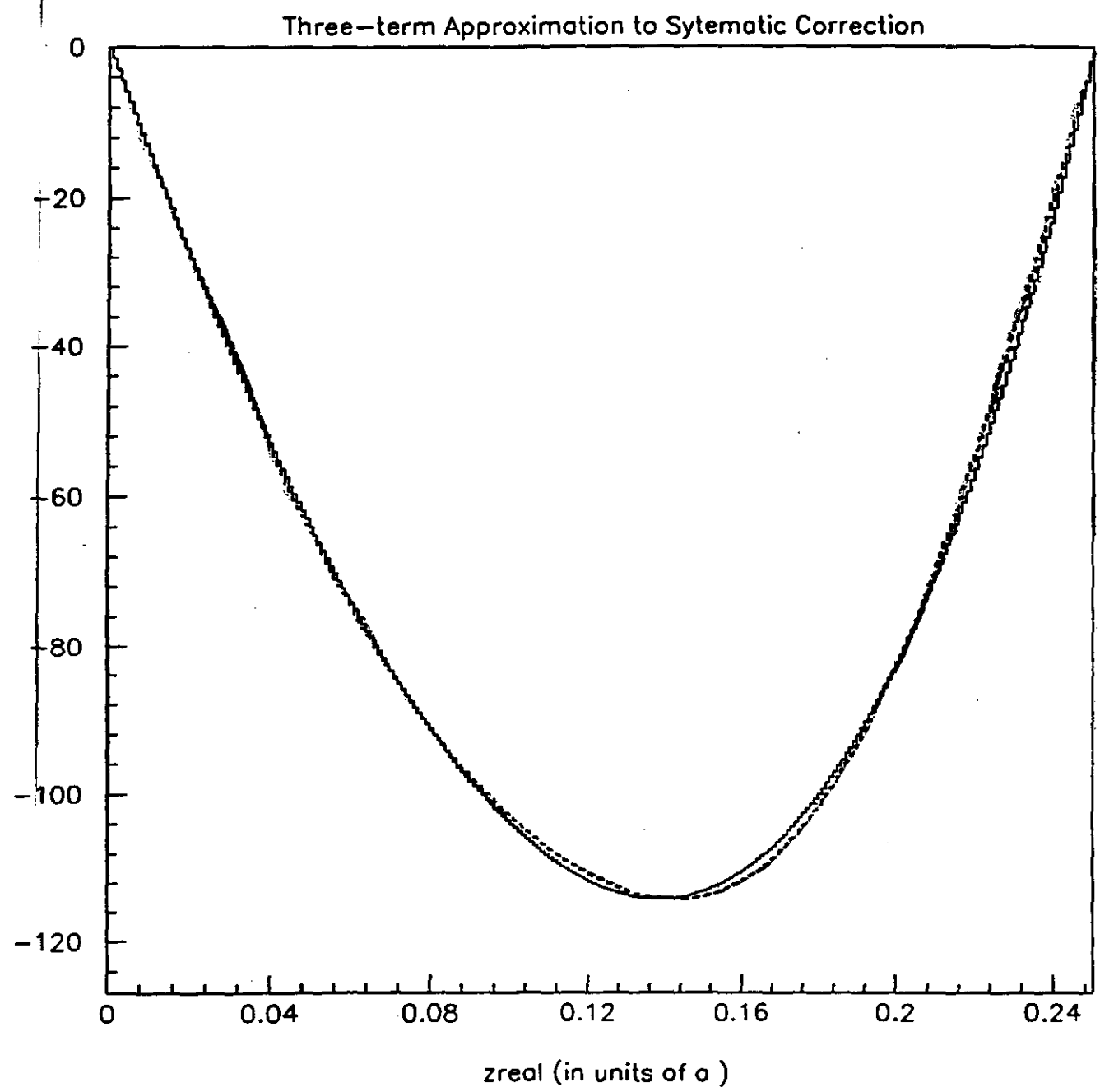
$$\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,cm}\right) + 9.07 \sin\left(\frac{4\pi z}{0.5\,cm}\right)$$

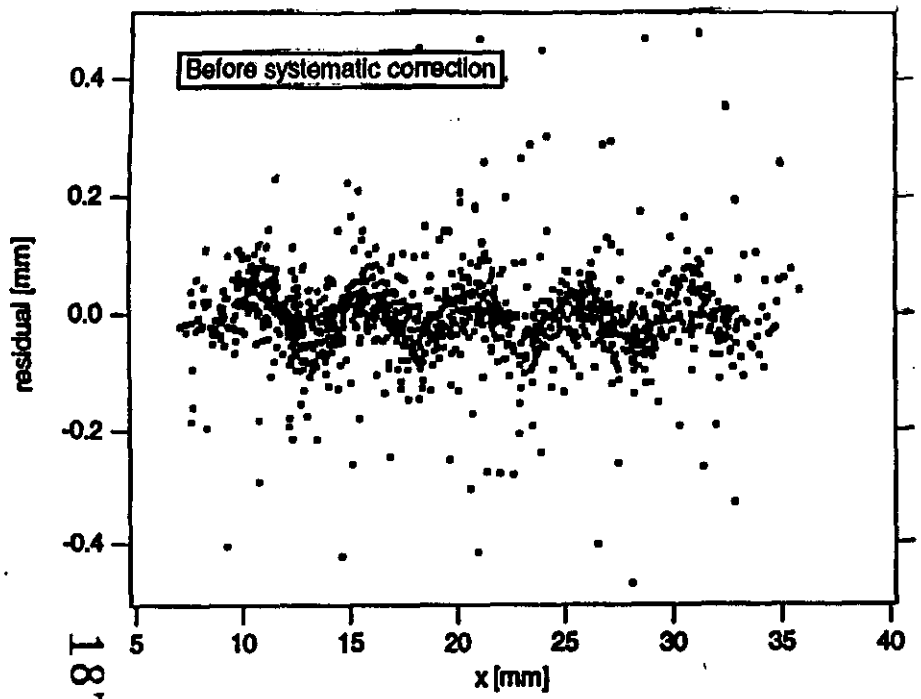
$$0 < z < 0.25\,cm$$

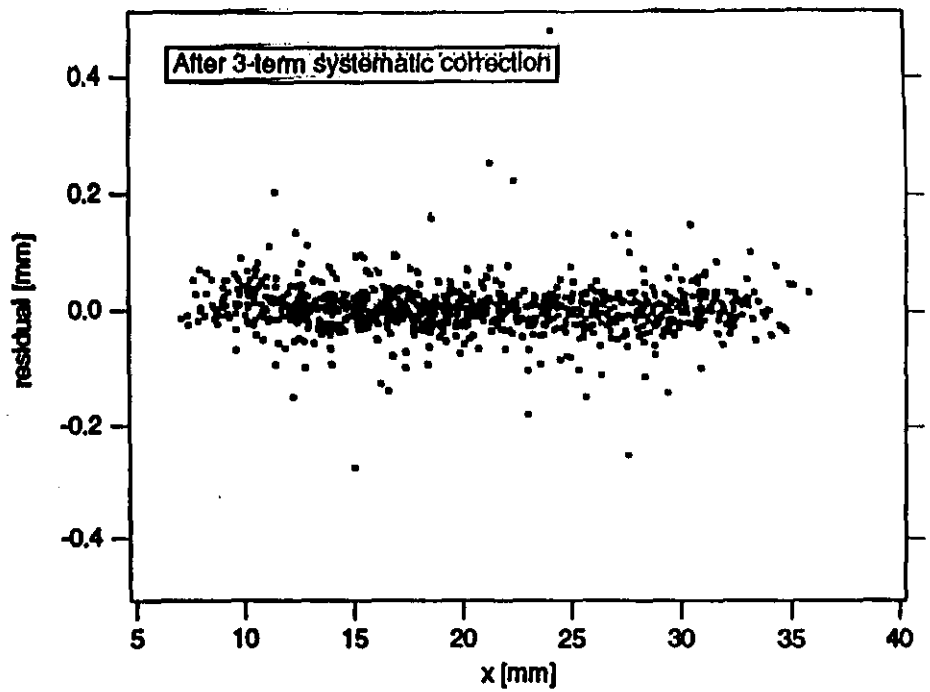


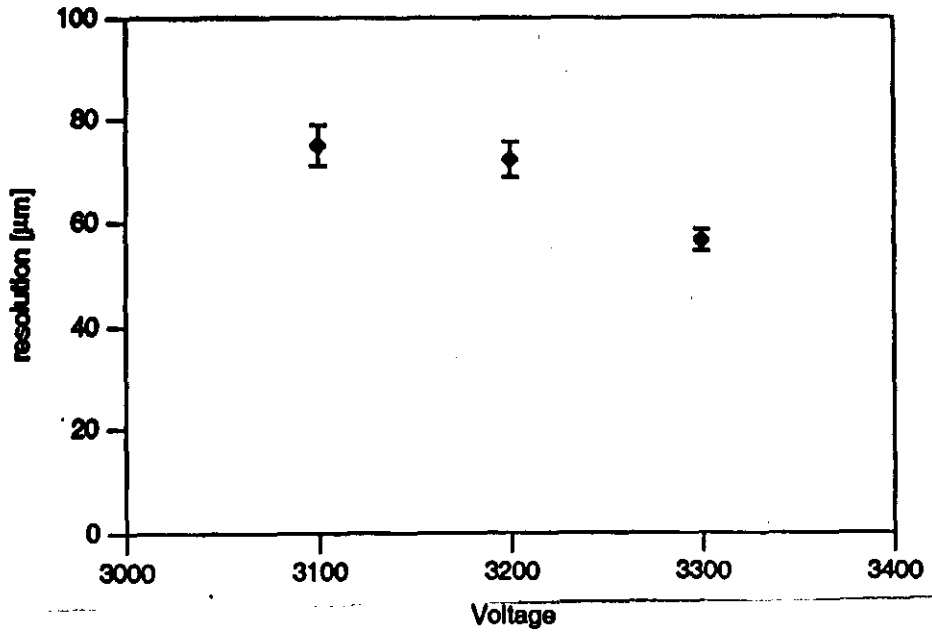
$$\Delta z = -117.07 \sin\left(\frac{2\pi z}{0.5\,km}\right) + 9.07 \sin\left(\frac{4\pi z}{0.5\,km}\right) - 4.85 \sin\left(\frac{6\pi z}{0.5\,km}\right)$$

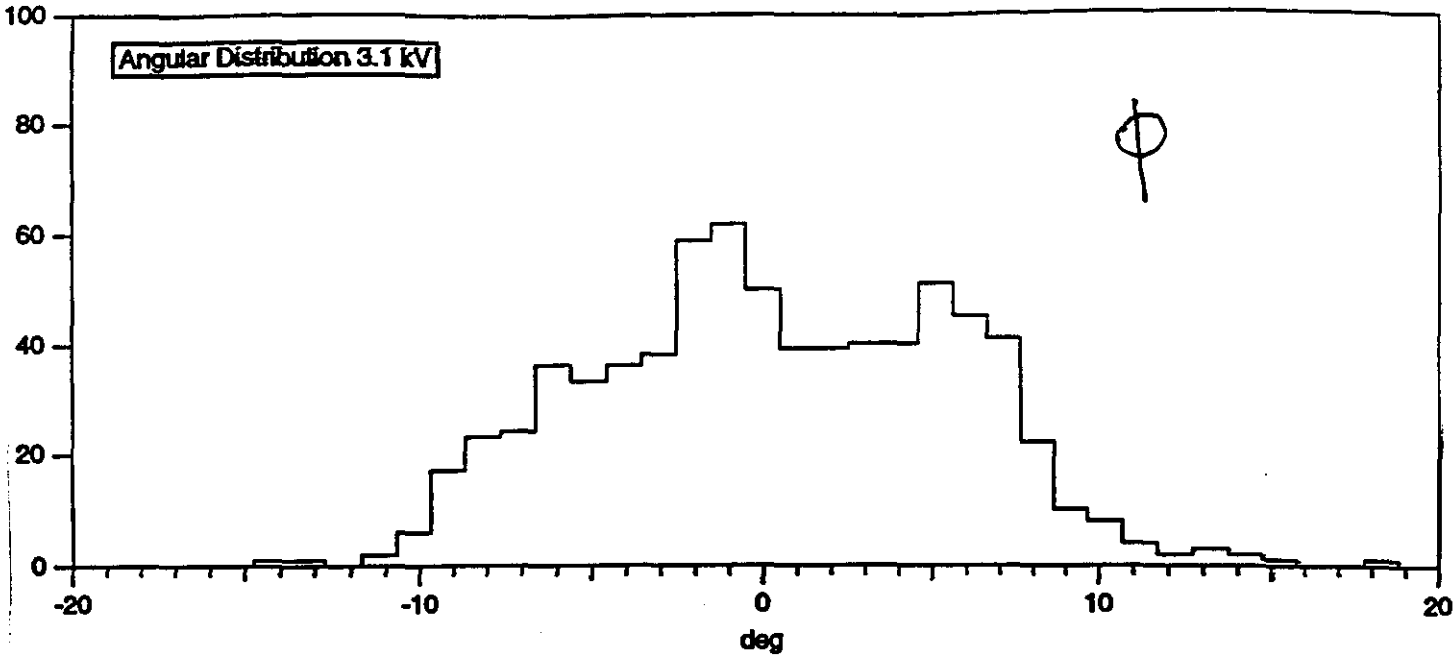
$$0 < z < 0.25\,km$$

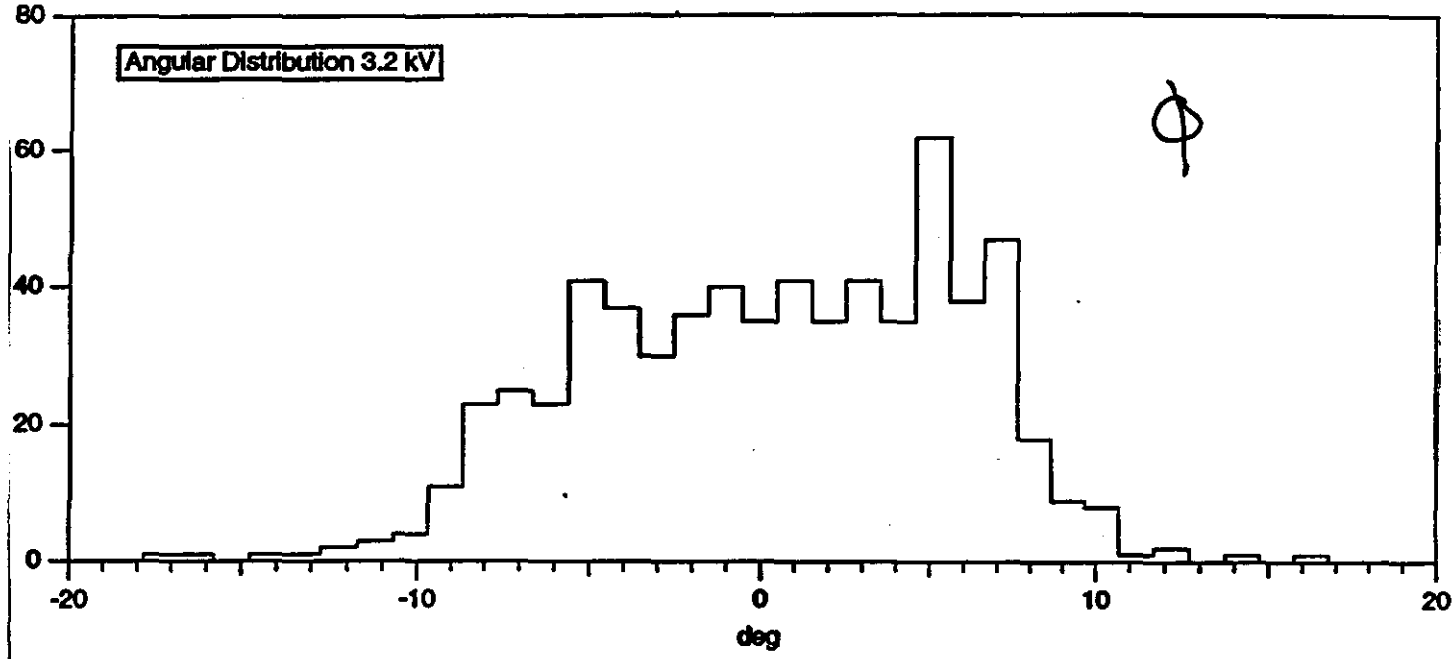


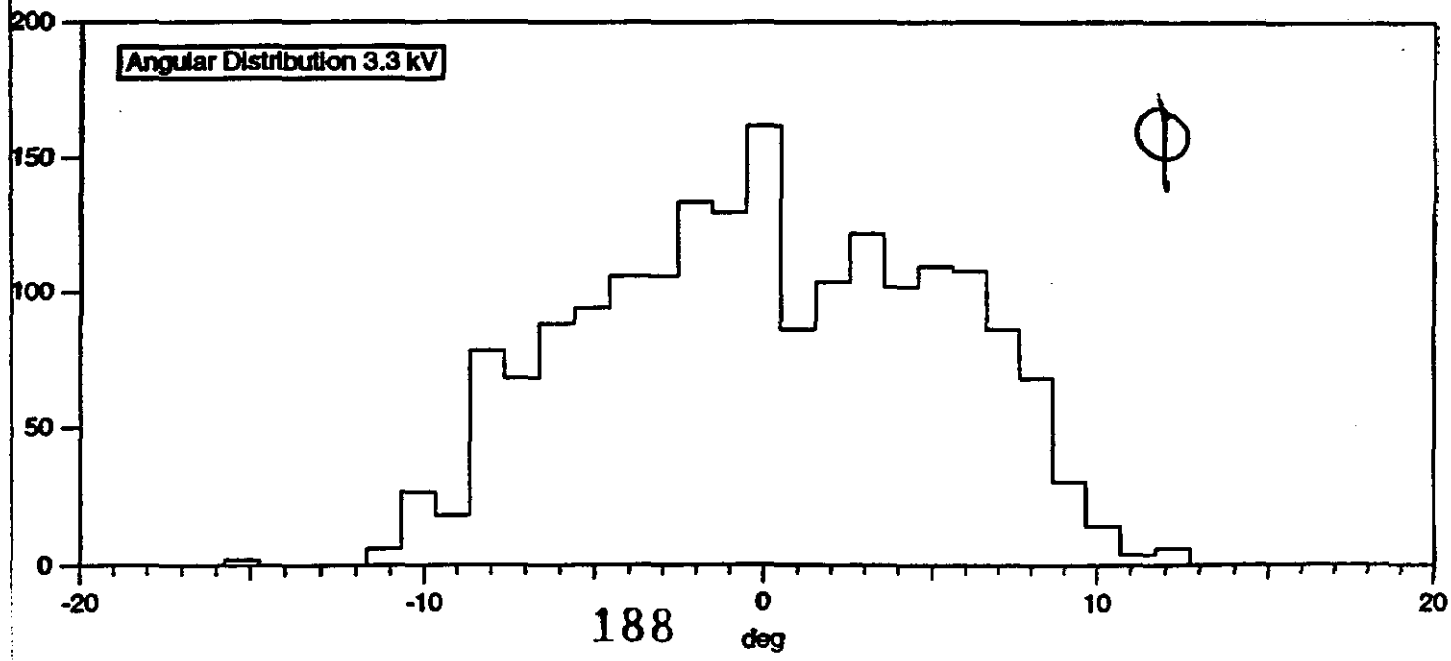

Before systematic correction
residual [mm]
0.4
0.2
0.0
-0.2
-0.4
5
10
15
20
25
30
35
40
x [mm]

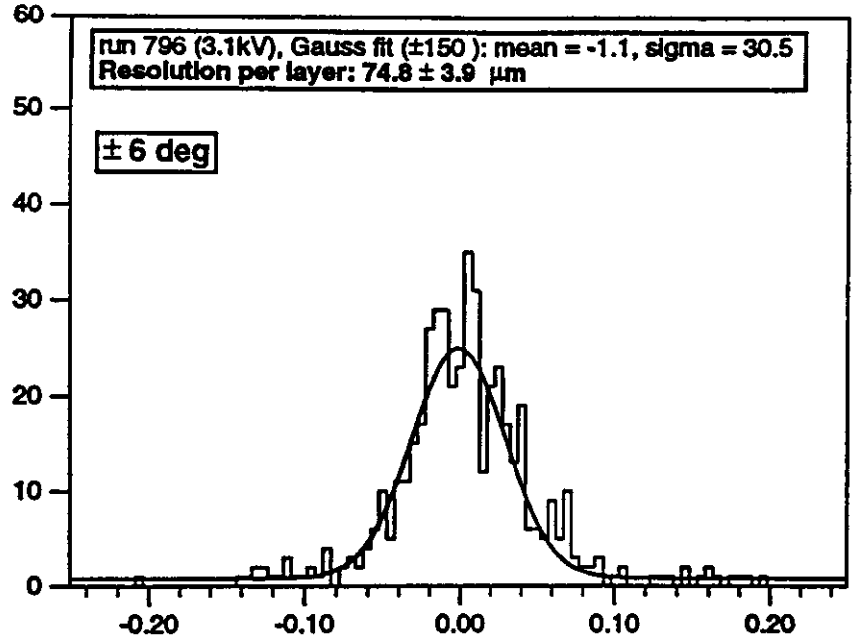

After 3-term systematic correction
residual [mm]
0.4
0.2
0.0
-0.2
-0.4
5
10
15
20
25
30
35
40
x [mm]

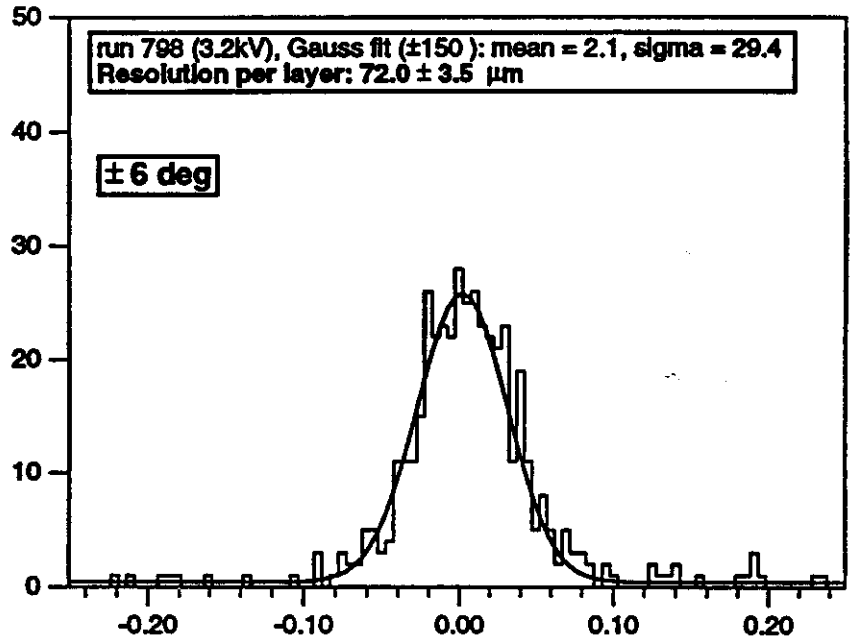

resolution [µm]
100
80
60
40
20
0
3000
3100
3200
3300
3400
Voltage

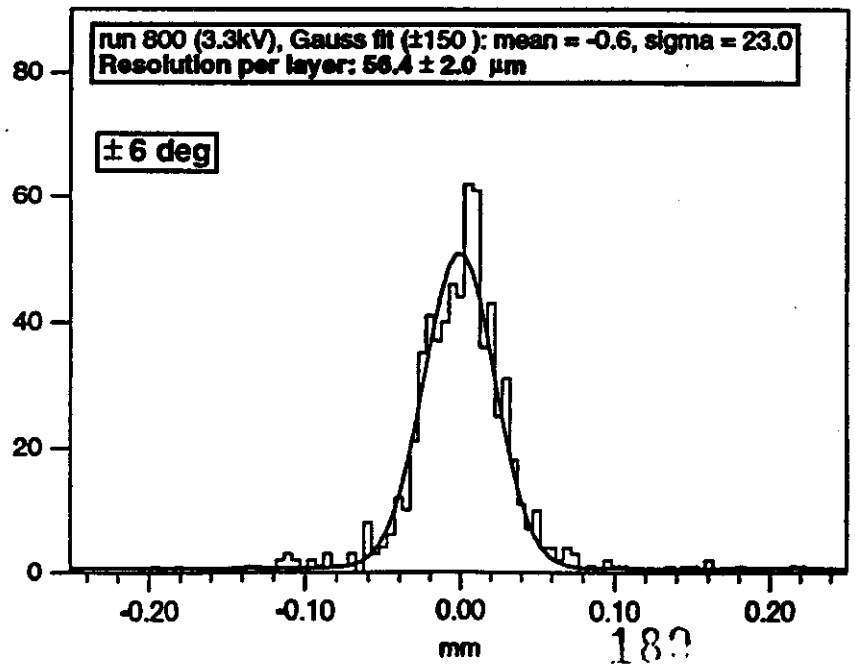

Angular Distribution 3.1 kV
100
80
60
40
20
0
-20
-10
0
10
20
deg

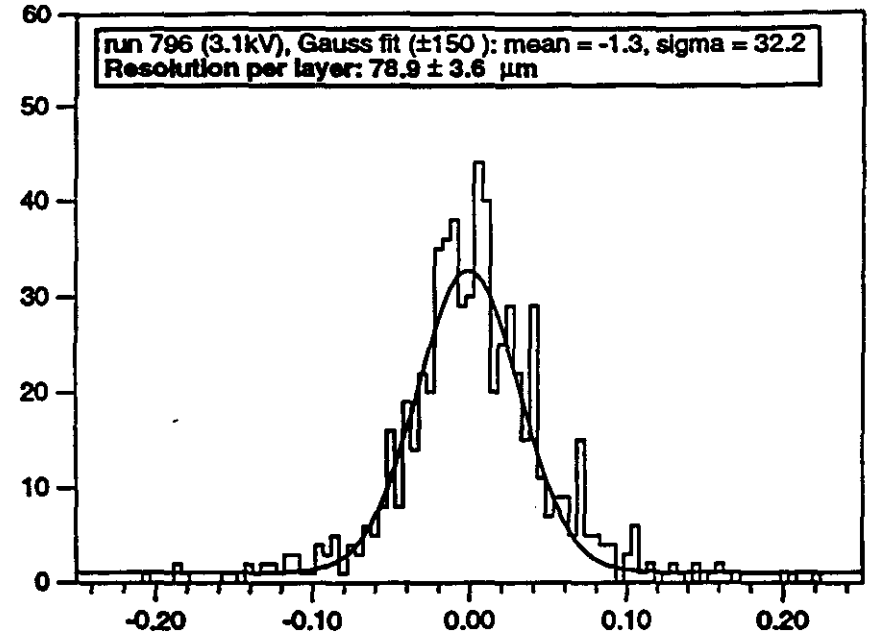

Angular Distribution 3.2 kV
80
60
40
20
0
-20
-10
0
10
20
deg

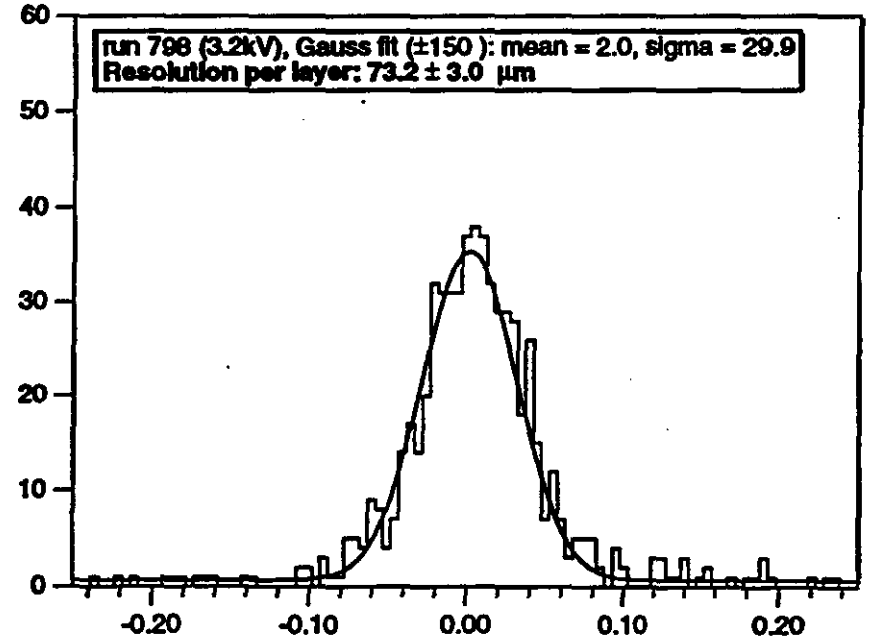

Angular Distribution 3.3 kV
200
150
100
50
0
-20
-10
0
10
20
deg

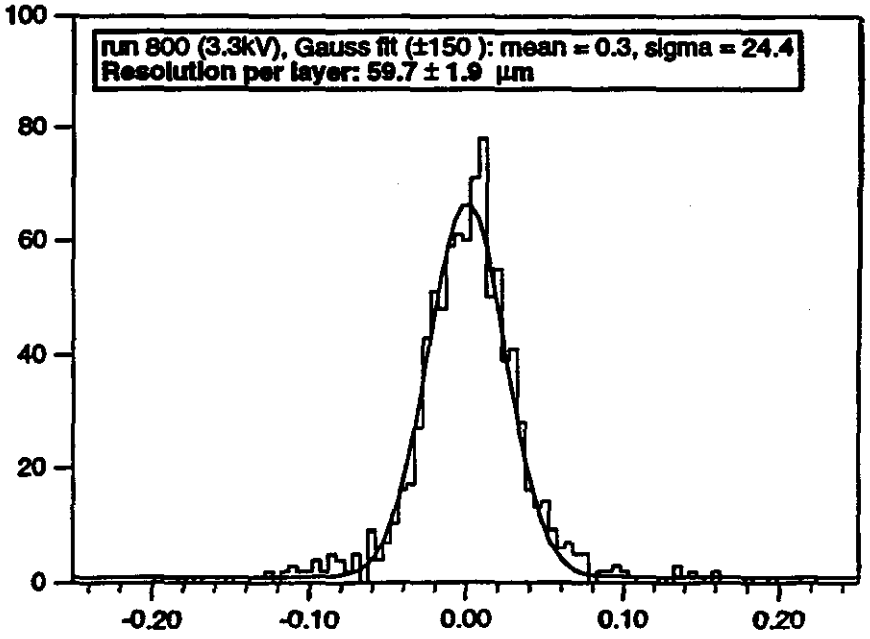

run 796 (3.1kV), Gauss fit (±150): mean = -1.1, sigma = 30.5
Resolution per layer: 74.8 ± 3.9 μm
± 6 deg
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

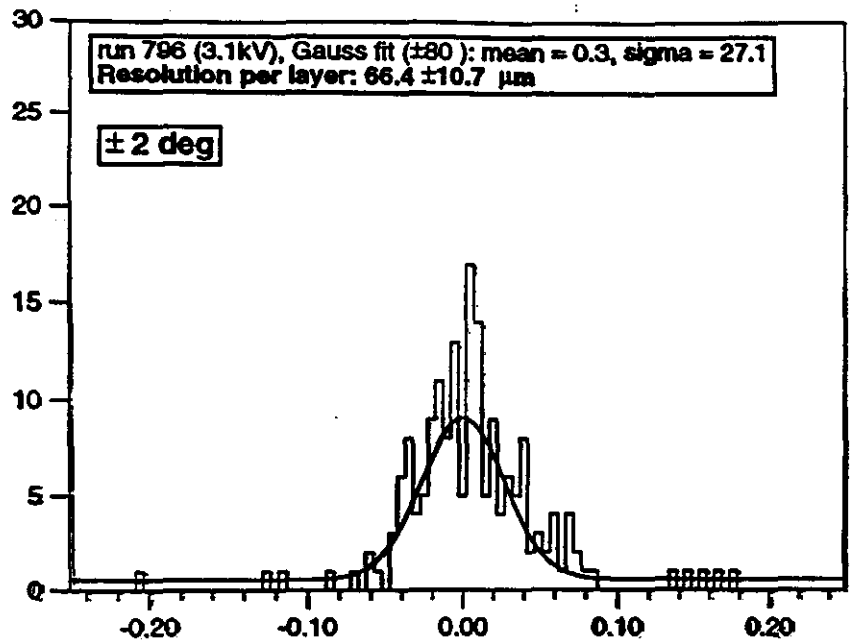

run 798 (3.2kV), Gauss fit (±150): mean = 2.1, sigma = 29.4
Resolution per layer: 72.0 ± 3.5 μm
± 6 deg
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

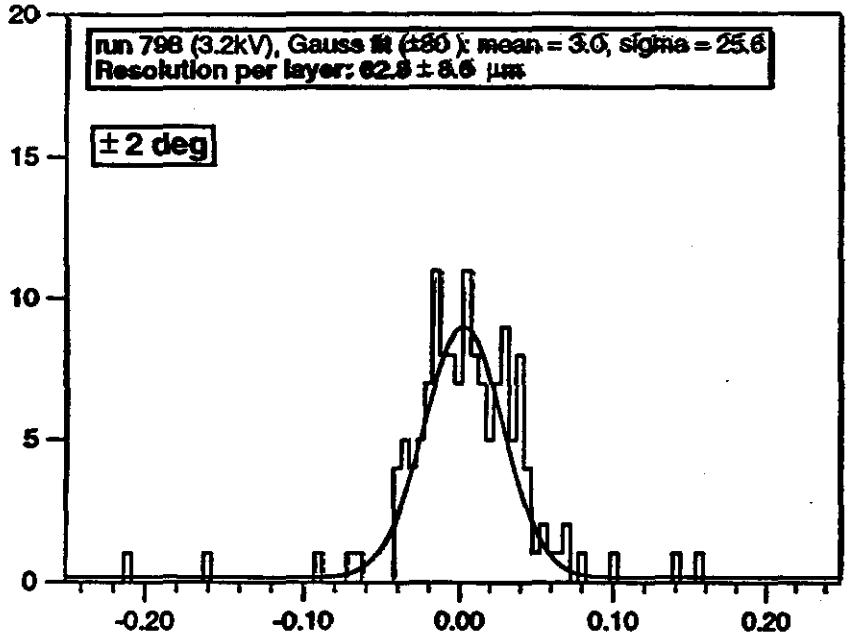

run 800 (3.3kV), Gauss fit (±150): mean = -0.6, sigma = 23.0
Resolution per layer: 56.4 ± 2.0 μm
± 6 deg
80
60
40
20
0
-0.20
-0.10
0.00
0.10
0.20
mm

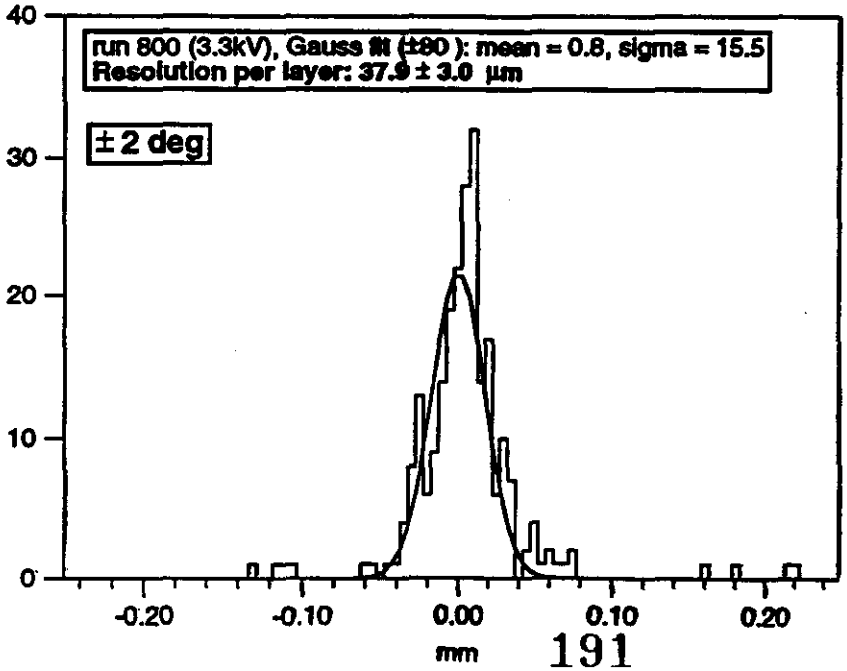

run 796 (3.1kV), Gauss fit (±150): mean = -1.3, sigma = 32.2
Resolution per layer: 78.9 ± 3.6 µm
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

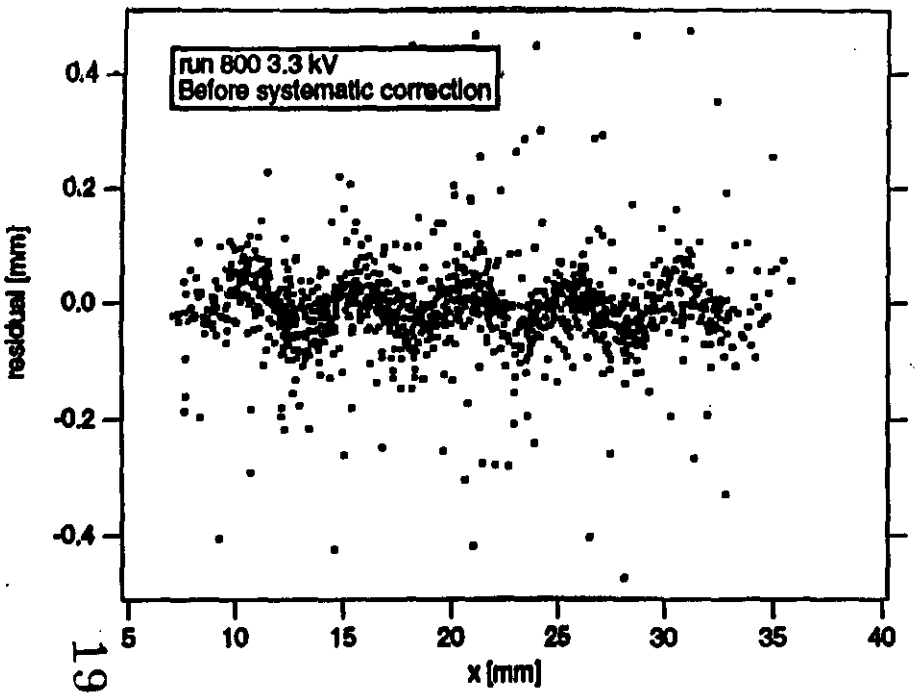

run 798 (3.2kV), Gauss fit (±150): mean = 2.0, sigma = 29.9
Resolution per layer: 73.2 ± 3.0 µm
60
50
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20

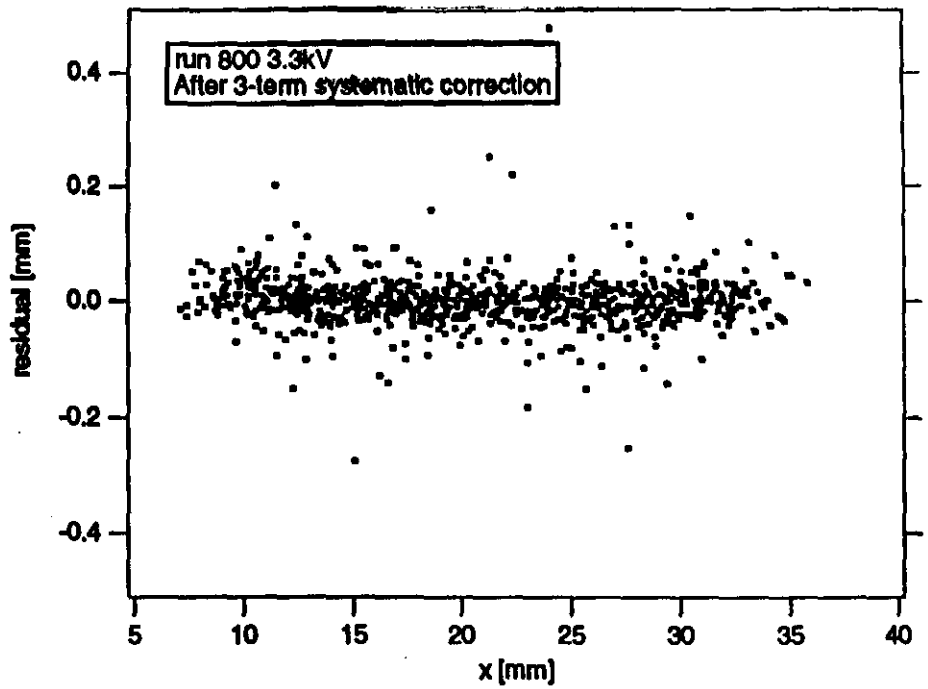

run 800 (3.3kV), Gauss fit (±150): mean = 0.3, sigma = 24.4
Resolution per layer: 59.7 ± 1.9 µm
100
80
60
40
20
0
-0.20
-0.10
0.00
0.10
0.20
mm

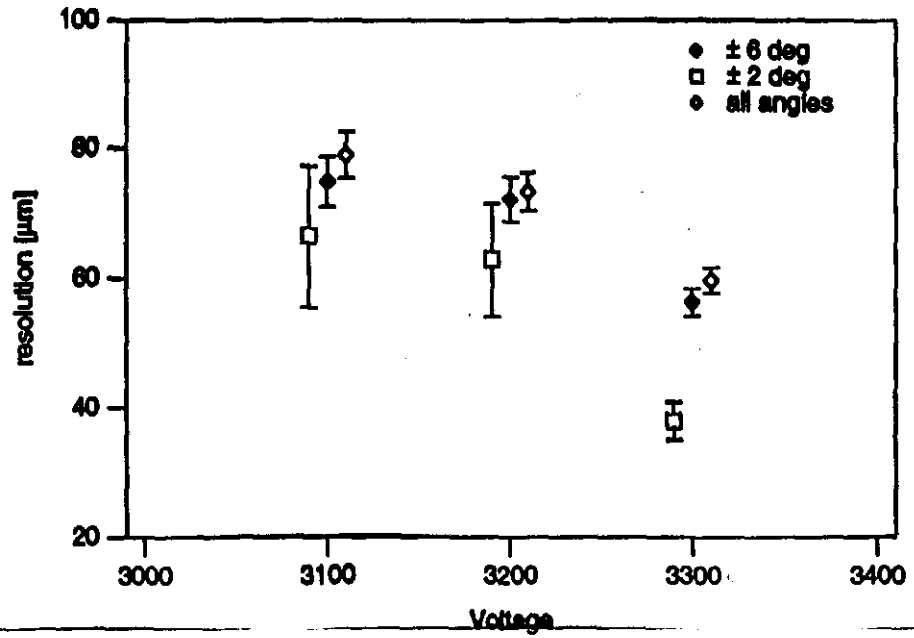

run 796 (3.1kV), Gauss fit (±80): mean = 0.3, sigma = 27.1
Resolution per layer: 66.4 ±10.7 µm
± 2 deg
30
25
20
15
10
5
0
-0.20
-0.10
0.00
0.10
0.20


run 798 (3.2kV), Gauss fit (±80): mean = 3.0, sigma = 25.6
Resolution per layer: 62.8 ± 8.6 µm
± 2 deg
20
15
10
5
0
-0.20
-0.10
0.00
0.10
0.20


run 800 (3.3kV), Gauss fit (±80): mean = 0.8, sigma = 15.5
Resolution per layer: 37.9 ± 3.0 µm
± 2 deg
40
30
20
10
0
-0.20
-0.10
0.00
0.10
0.20
mm


run 800 3.3 kV
Before systematic correction
residual [mm]
x [mm]


run 800 3.3kV
After 3-term systematic correction
residual [mm]
x [mm]


± 6 deg
± 2 deg
all angles
resolution [μm]
Voltage

Summary of Results (Preliminary)

- Averaged over $\pm \simeq 6°$

HV(kV)	$\sigma(\mu m)$
3.1	74.8 ± 3.9
3.2	72.0 ± 3.5
3.3	56.4 ± 2.0

- Averaged over all angles $\pm \simeq 8°$

HV(kV)	$\sigma(\mu m)$
3.1	78.9 ± 3.6 (96.3)
3.2	73.2 ± 3.0
3.3	59.7 ± 1.9

- Normal incidence $\pm$ 2.0°

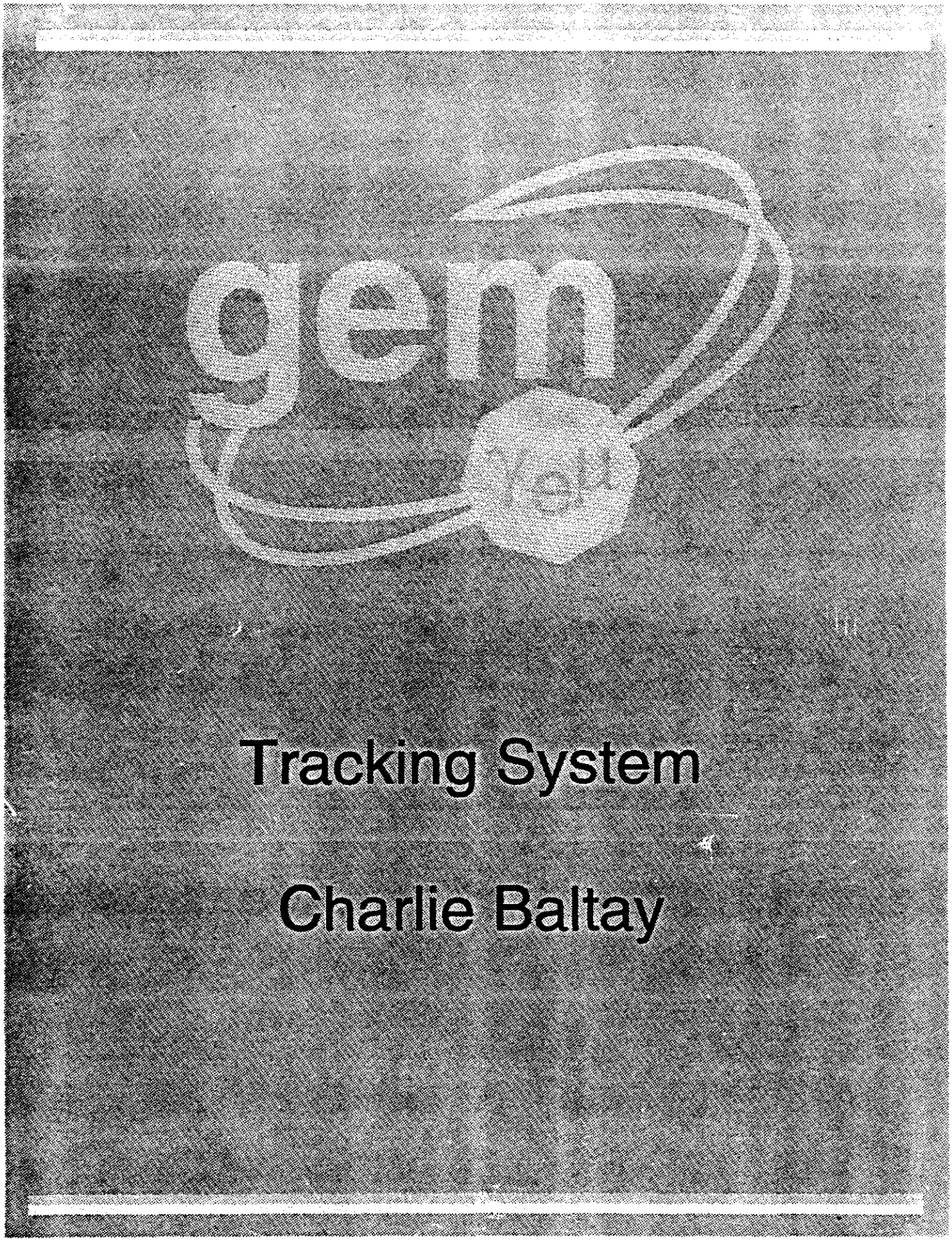
HV(kV)	$\sigma(\mu m)$
3.1	66.4 ± 10.7
3.2	62.8 ± 8.6
3.3	37.9 ± 3.0

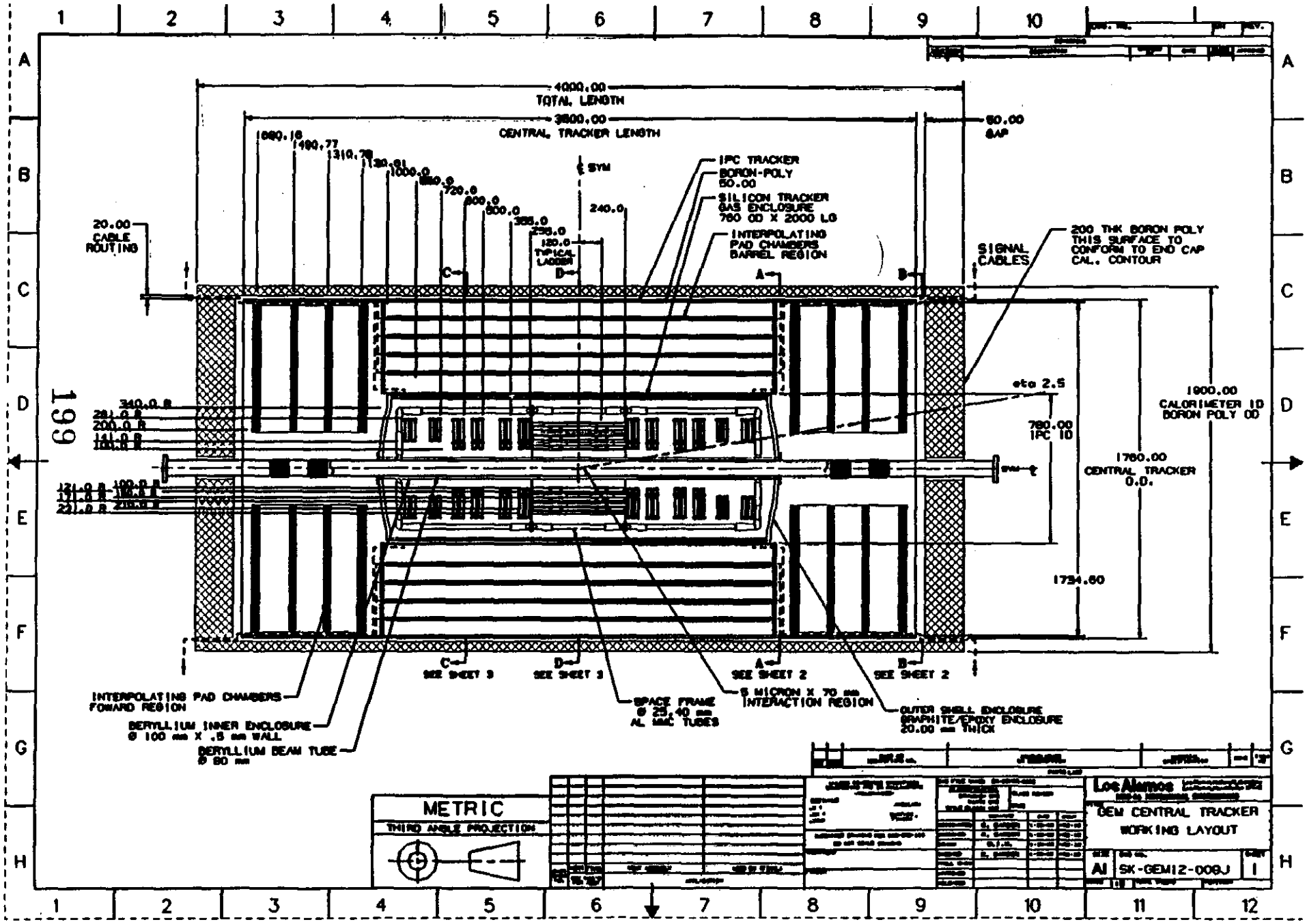
gem

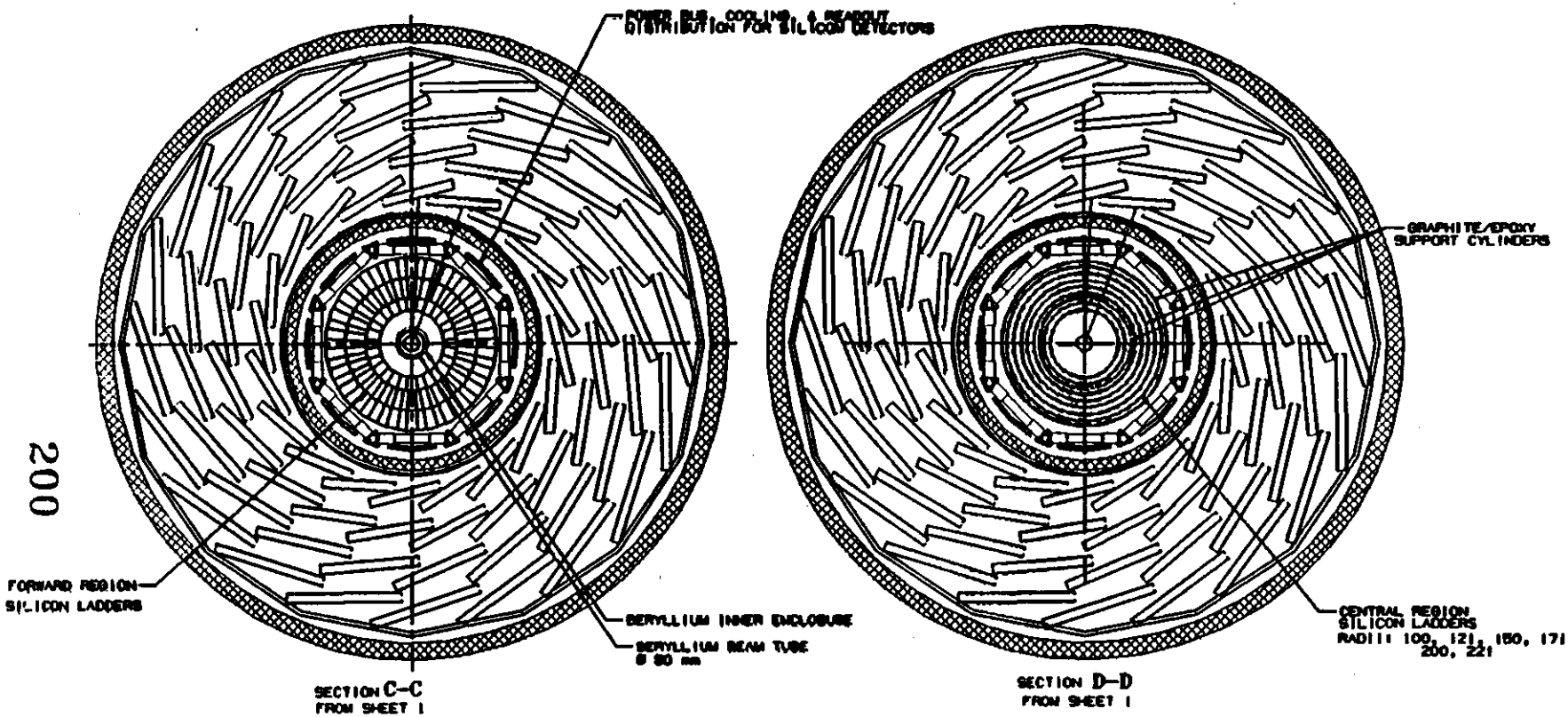
γeμ

Presentation by:

C. Baltay


Tracking System
Charlie Baltay


4000.00
TOTAL LENGTH
3800.00
CENTRAL TRACKER LENGTH
50.00
GAP
1660.18
1490.77
1310.78
1130.81
1000.0
880.0
720.0
600.0
500.0
365.0
256.0
120.0
TYPICAL LADDER
240.0
℄ SYM
IPC TRACKER
BORON-POLY
50.00
SILICON TRACKER
GAS ENCLOSURE
760 OD X 2000 LG
INTERPOLATING
PAD CHAMBERS
BARREL REGION
20.00
CABLE
ROUTING
SIGNAL
CABLES
200 THK BORON POLY
THIS SURFACE TO
CONFORM TO END CAP
CAL. CONTOUR
eta 2.5
1900.00
CALORIMETER ID
BORON POLY OD
760.00
IPC ID
1760.00
CENTRAL TRACKER
O.D.
1734.60
340.0 R
281.0 R
200.0 R
141.0 R
100.0 R
121.0 R
131.0 R
231.0 R
SEE SHEET 3
SEE SHEET 3
SEE SHEET 2
SEE SHEET 2
INTERPOLATING PAD CHAMBERS
FOWARD REGION
BERYLLIUM INNER ENCLOSURE
Ø 100 mm X .5 mm WALL
BERYLLIUM BEAM TUBE
Ø 80 mm
SPACE FRAME
Ø 25.40 mm
AL MAC TUBES
5 MICRON X 70 mm
INTERACTION REGION
OUTER SHELL ENCLOSURE
GRAPHITE/EPOXY ENCLOSURE
20.00 mm THICK
METRIC
THIRD ANGLE PROJECTION
Los Alamos
DEM CENTRAL TRACKER
WORKING LAYOUT
A1
SK-GEM12-008J
1


POWER BUS, COOLING & READOUT DISTRIBUTION FOR SILICON DETECTORS
FORWARD REGION SILICON LADDERS
BERYLLIUM INNER ENCLOSURE
BERYLLIUM BEAM TUBE Ø 50 mm
SECTION C–C FROM SHEET 1
GRAPHITE/EPOXY SUPPORT CYLINDERS
CENTRAL REGION SILICON LADDERS RADII: 100, 121, 150, 171, 200, 221
SECTION D–D FROM SHEET 1

50μ × 12cm strips

10μ resolution, 10μ align. stability

Digital Read out

~3×10^6 strips

~5000 channels

~7 m^2 of silicon if doublesided

~9000 chips 3cm×6cm

GEM SILICON INNER TRACKER

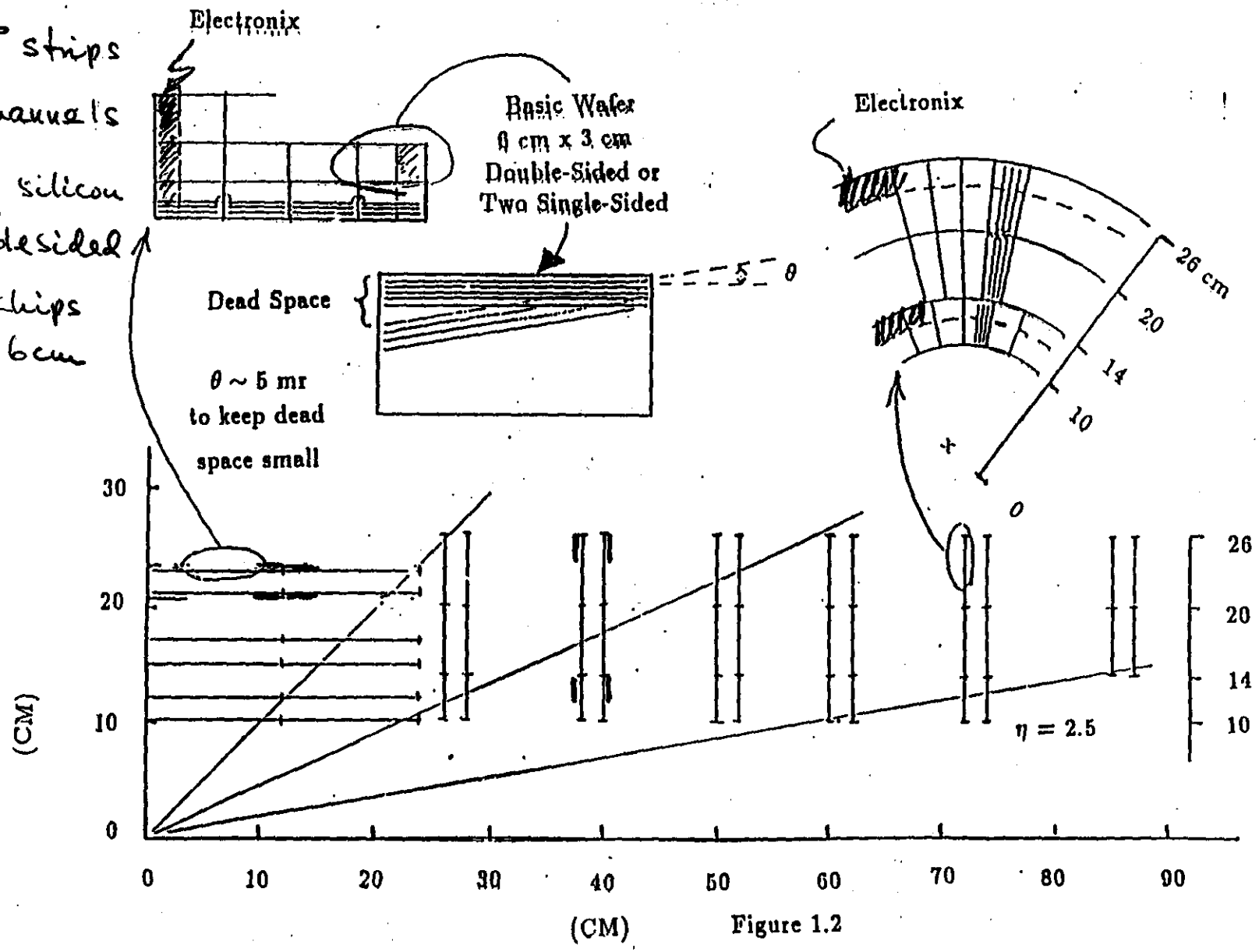
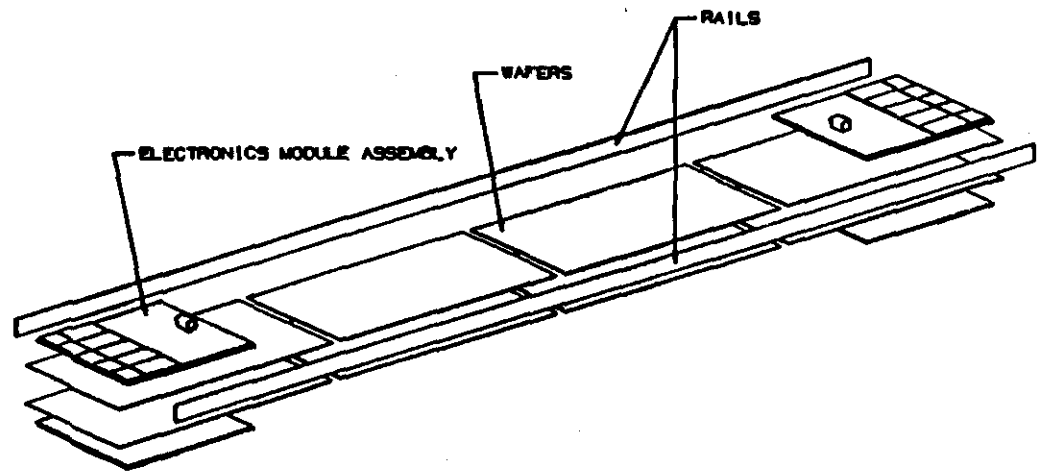


Figure 1.2



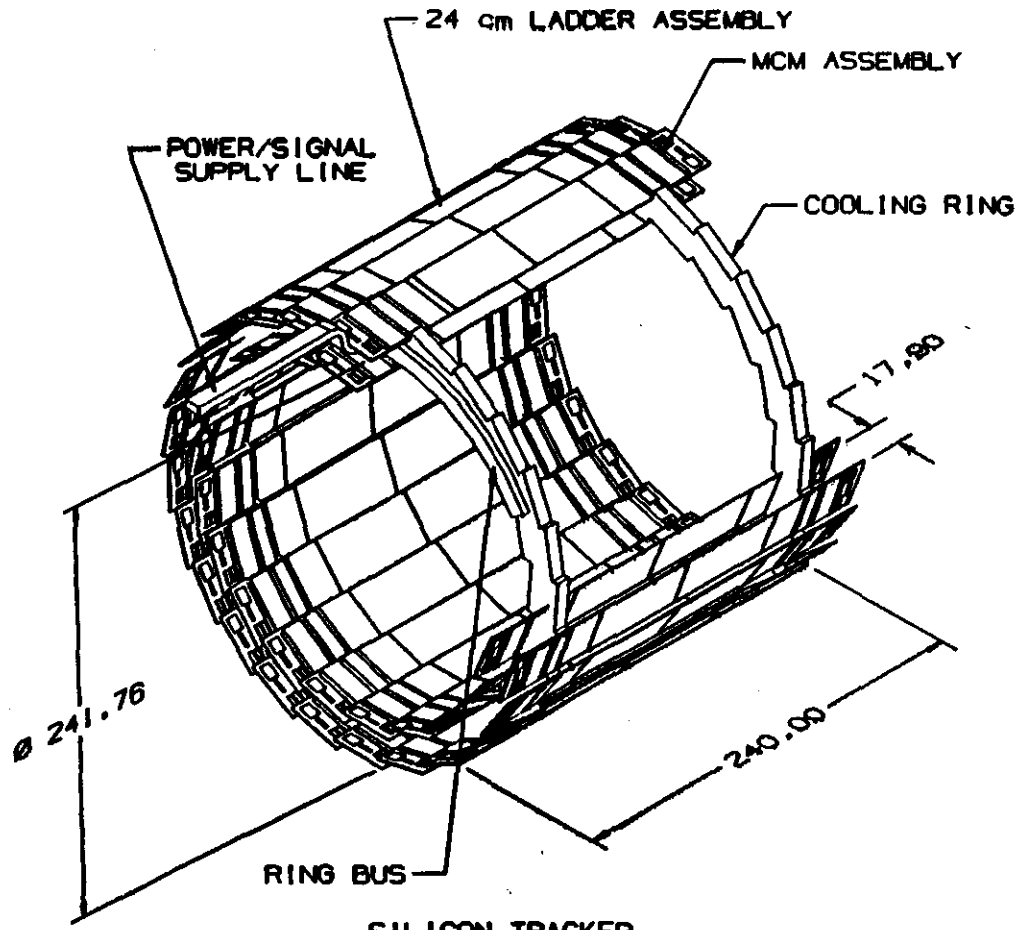
PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

Los Alamos

GEM SILICON TRACKER
EXPLODED LADDER ASSY

A1 SK-GEM12-028 1



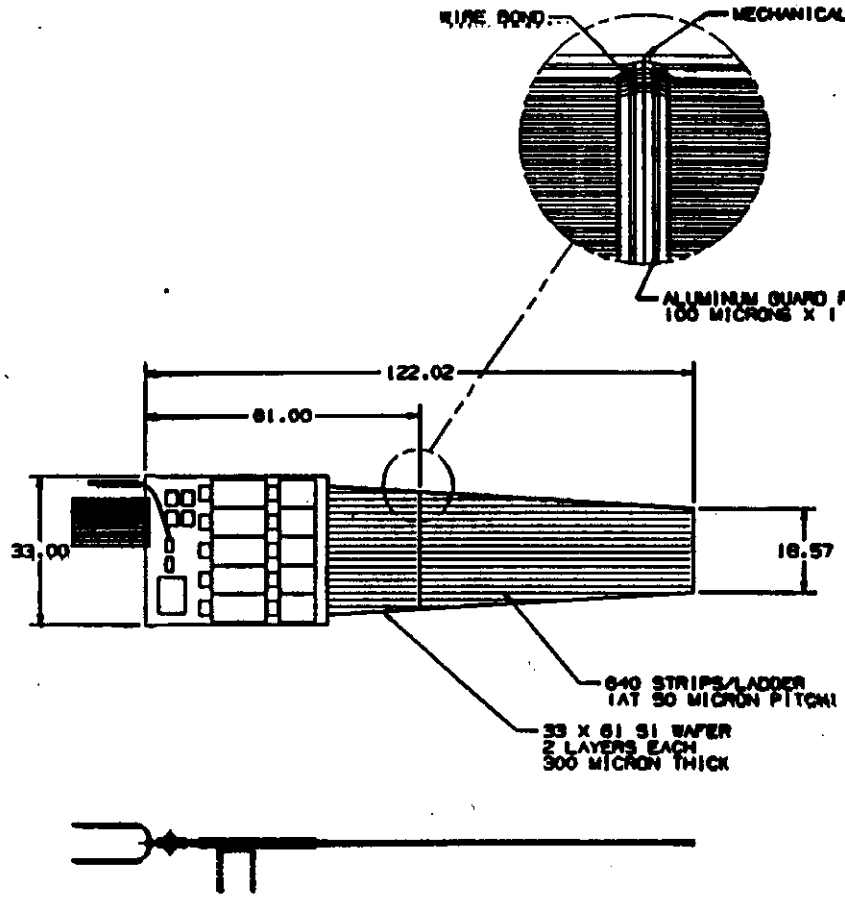
SILICON TRACKER
INNER LAYER 24 cm SHELL ASSEMBLY

METRIC
THIRD ANGLE PROJECTION

Los Alamos

SILICON TRACKER
INNER LAYER
24 cm SHELL ASSEMBLY

A1 SK-GEM12-044 1



ITEM 1 20	1.243g	(.0027 lbs)	2.486g (.0054 lbs)
ITEM 2 20	.915g	(.002 lbs)	1.83g (.004 lbs)
MCM 20	.932g	(.0021 lbs)	1.864g (.0041 lbs)
TOTAL WEIGHT PER LADDER			6.18g (.0135 lbs)

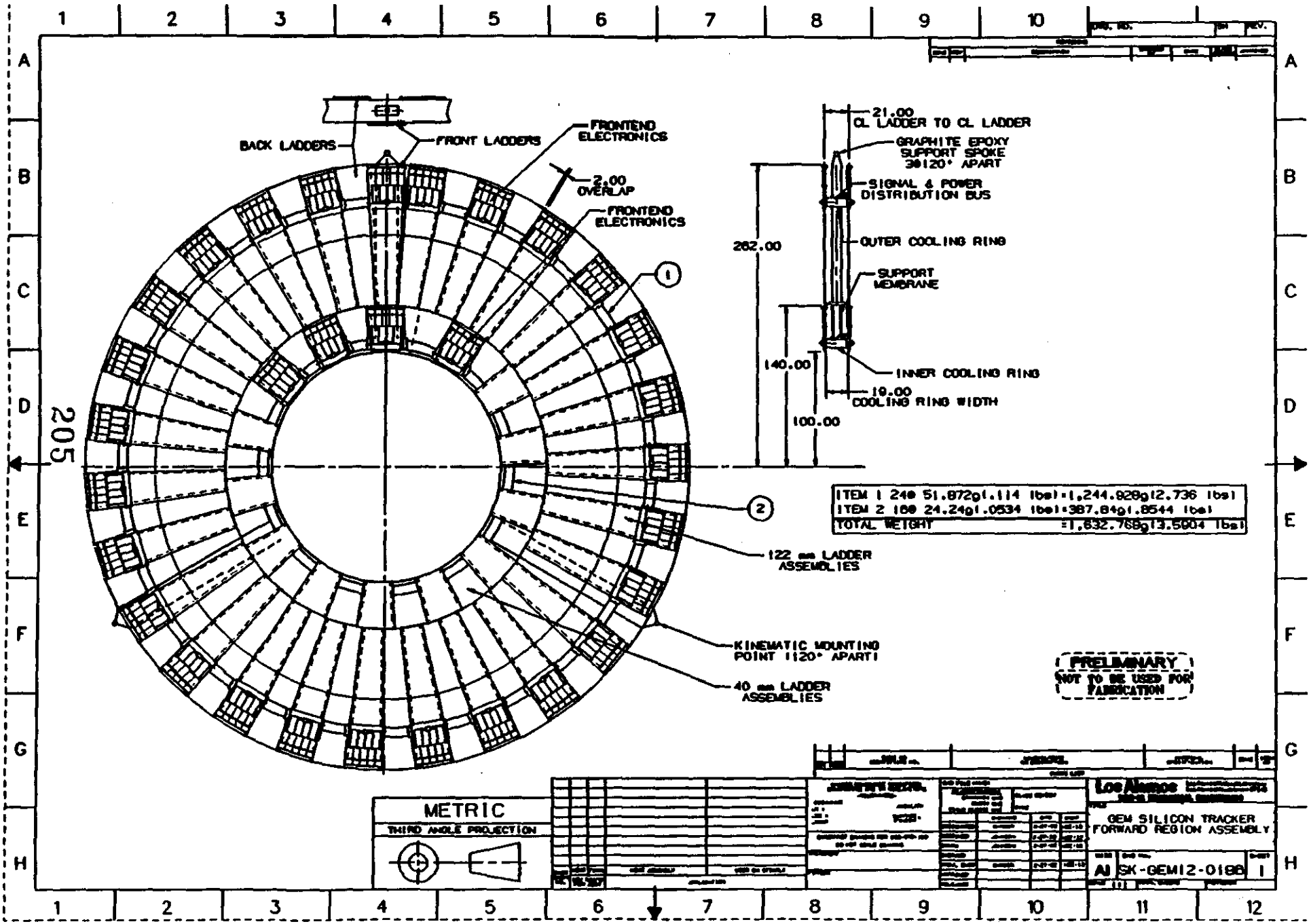
PRELIMINARY
NOT TO BE USED FOR FABRICATION

METRIC
THIRD ANGLE PROJECTION

Los Alamos

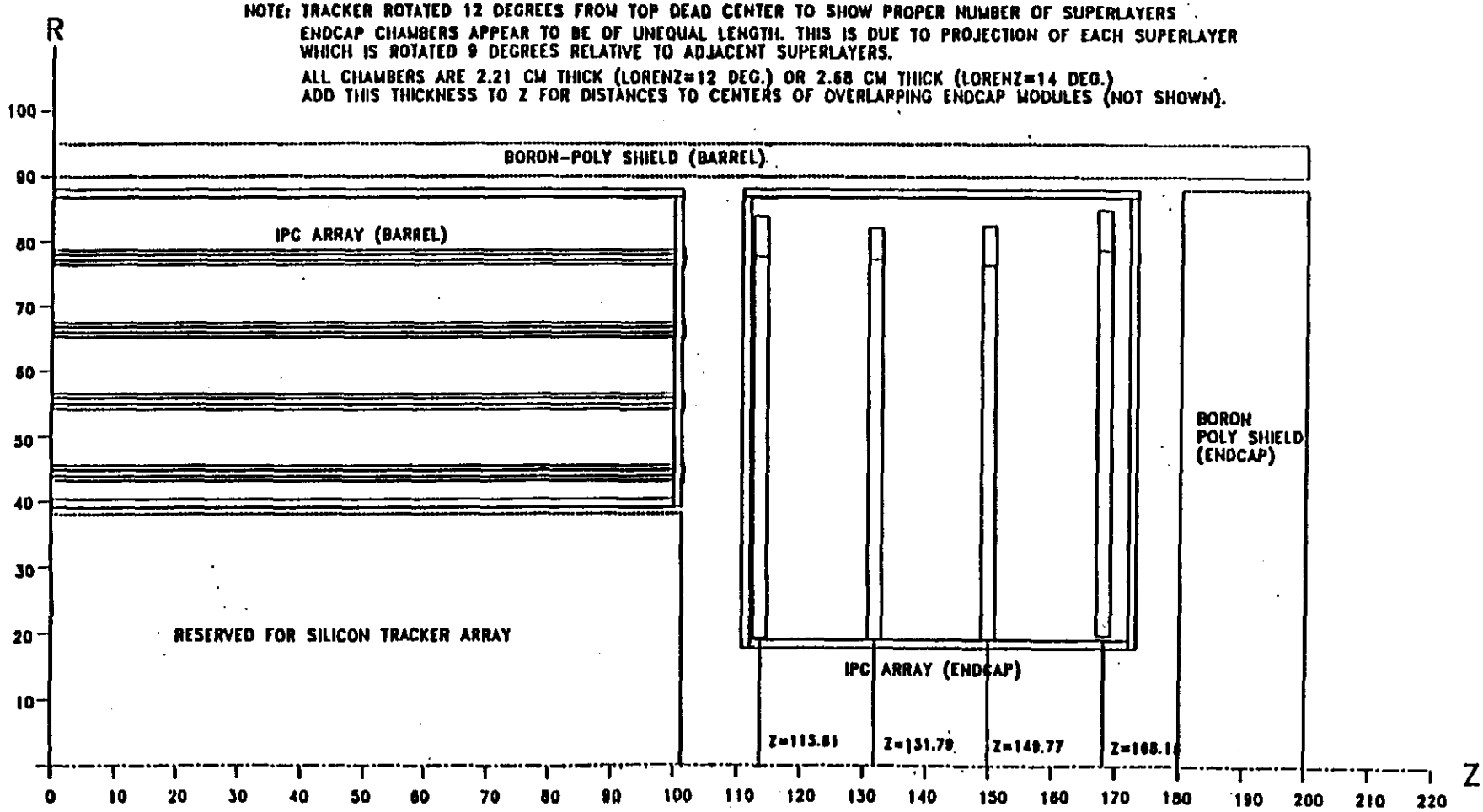
GEM SILICON TRACKER
FORWARD LADDER ASSEMBLY
DETAIL

A1 SK-GEM12-030C 1

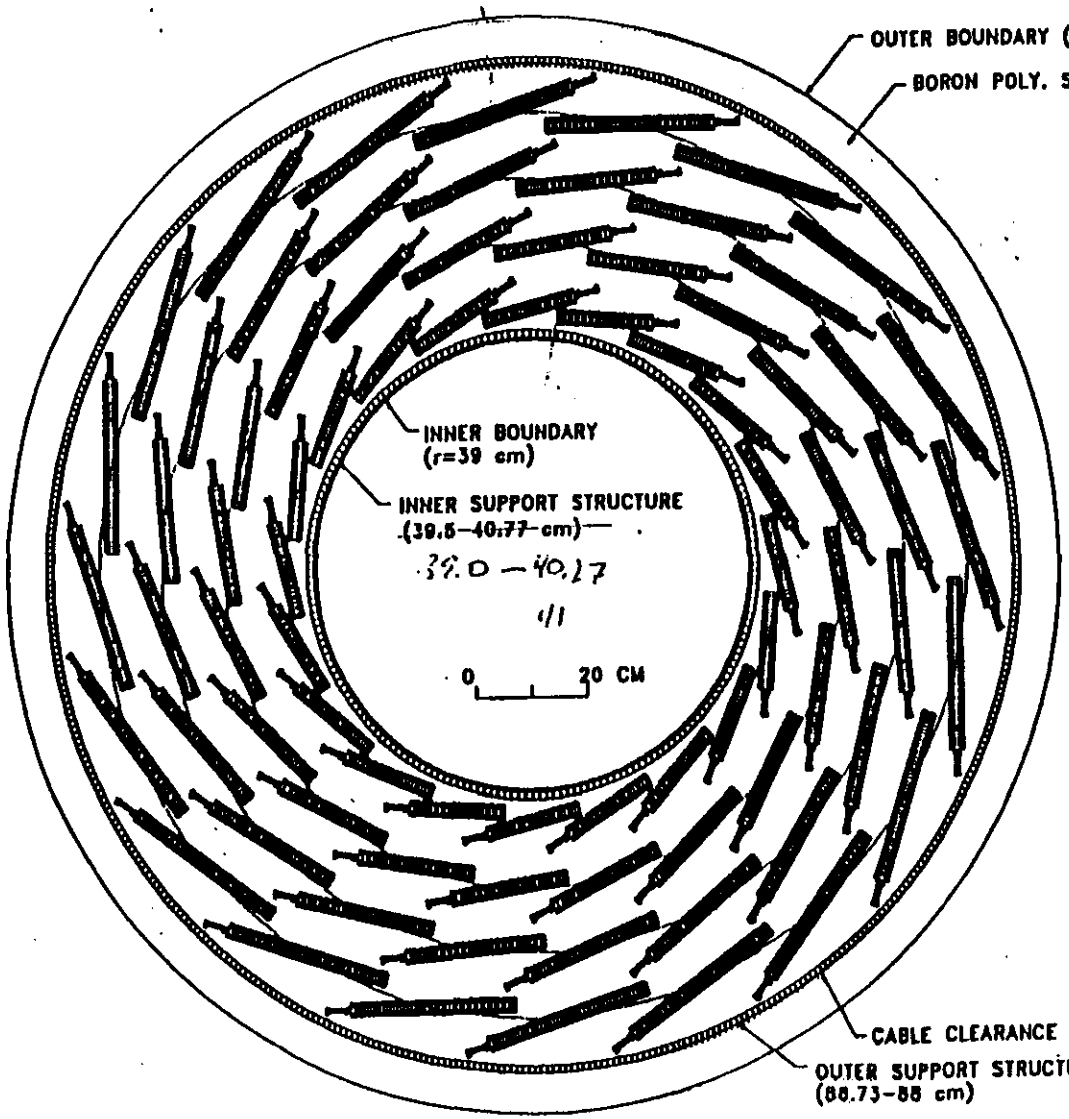

BACK LADDERS
FRONT LADDERS
FRONTEND ELECTRONICS
2.00 OVERLAP
FRONTEND ELECTRONICS
21.00 CL LADDER TO CL LADDER
GRAPHITE EPOXY SUPPORT SPOKE 3@120° APART
SIGNAL & POWER DISTRIBUTION BUS
OUTER COOLING RING
SUPPORT MEMBRANE
INNER COOLING RING
10.00 COOLING RING WIDTH
262.00
140.00
100.00
ITEM 1 240 51.872@1.114 lbs]=1,244.928@12.736 lbs]
ITEM 2 160 24.24@1.0534 lbs]=387.84@1.8544 lbs]
TOTAL WEIGHT =1,632.768@13.5904 lbs]
122 mm LADDER ASSEMBLIES
KINEMATIC MOUNTING POINT [120° APART]
40 mm LADDER ASSEMBLIES
PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
Los Alamos
GEM SILICON TRACKER
FORWARD REGION ASSEMBLY
A1
SK-GEM12-0186
1

GEM CENTRAL TRACKER QUADRANT VIEW
INTERPOLATING PAD ARRAY
BASELINE II

NOTE: TRACKER ROTATED 12 DEGREES FROM TOP DEAD CENTER TO SHOW PROPER NUMBER OF SUPERLAYERS
ENDCAP CHAMBERS APPEAR TO BE OF UNEQUAL LENGTH. THIS IS DUE TO PROJECTION OF EACH SUPERLAYER WHICH IS ROTATED 9 DEGREES RELATIVE TO ADJACENT SUPERLAYERS.
ALL CHAMBERS ARE 2.21 CM THICK (LORENZ=12 DEG.) OR 2.68 CM THICK (LORENZ=14 DEG.)
ADD THIS THICKNESS TO Z FOR DISTANCES TO CENTERS OF OVERLAPPING ENDCAP MODULES (NOT SHOWN).



W. EMMET YALE PPG 11/19/1992



GEM IPC TRACKER (2 METER RADIUS)

CROSS–SECTIONAL OF BARREL

NOTES:

1. LORENZ ANGLE IS 14 DEGREES ✓
2. TWO CHAMBERS PER MODULE
3. 20 MODULES PER SUPERLAYER
4. 4 SUPERLAYERS
5. EACH SUPERLAYER ROTATED 4.5 DEGREES
6. MODULE WIDTHS (NOT INCL. ELECTRONICS):

SUPERLAYER	WIDTH (CM)
I	17.0
II	21.0
III	25.0
IV	30.0

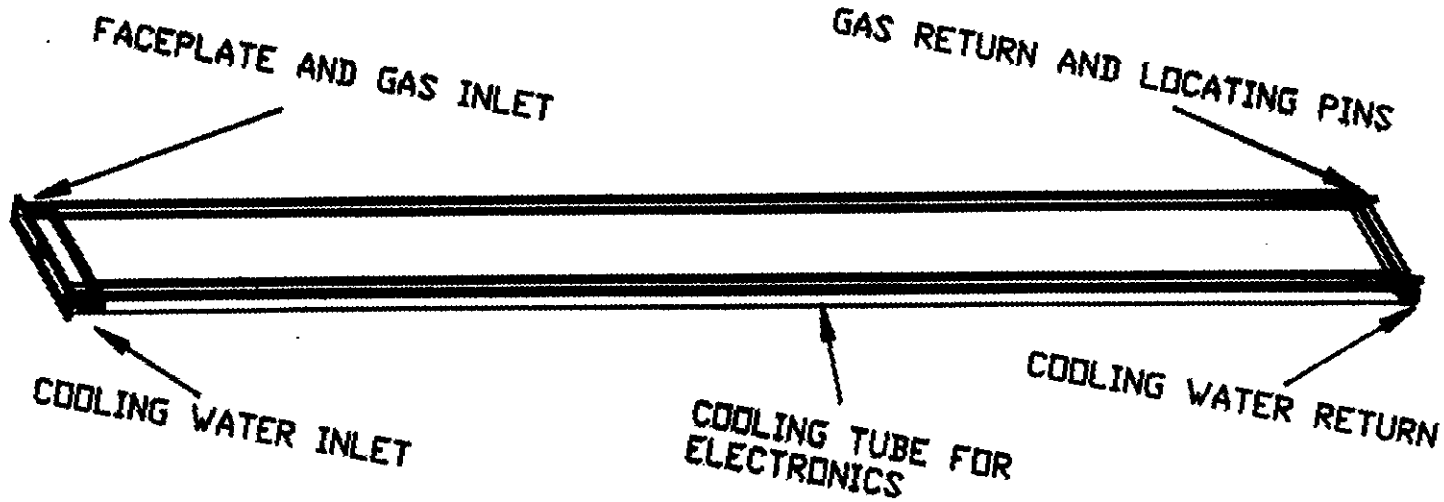
7. RADII OF ANODE WIRE MIDPOINTS (8 CHAMBER LEVELS):

SUPERLAYER	RADIUS (CM)
I(a)	43.68
I(b)	45.41
II(a)	55.03
II(b)	56.75
III(a)	66.36
III(b)	68.09
IV(a)	77.70
IV(b)	79.43

8. MODULE THICKNESS: 2.69 CM

W. EMMET
YALE UNIVERSITY PPG
NOVEMBER 13, 1992

IPC SUPERLAYER



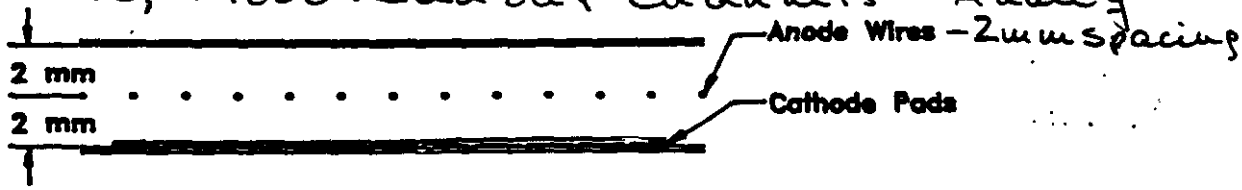
INTERPOLATING PAD CHAMBERS

Pad size $\Delta\eta \times \Delta\phi = 0.0007$ or 2.5 mm x a few cm

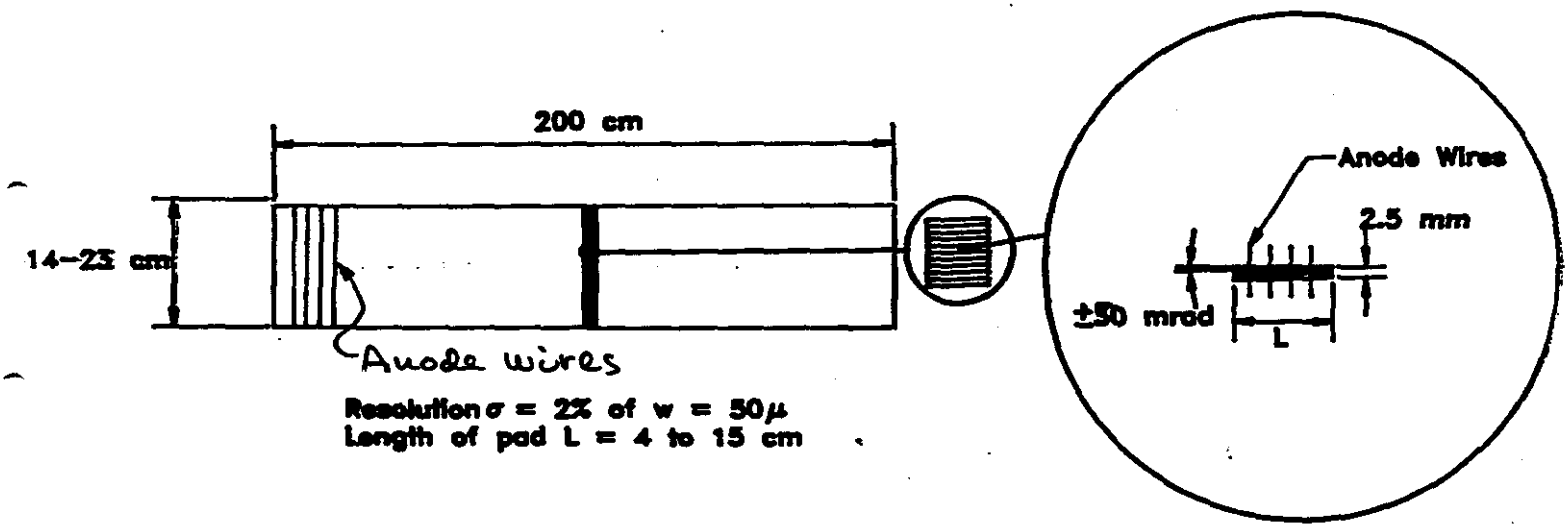
50μ resolution, 25μ alignement stability

±50 mrad stereo to get z resolution of ~600μ

~400,000 Pads, ~1600 read out channels - Analog

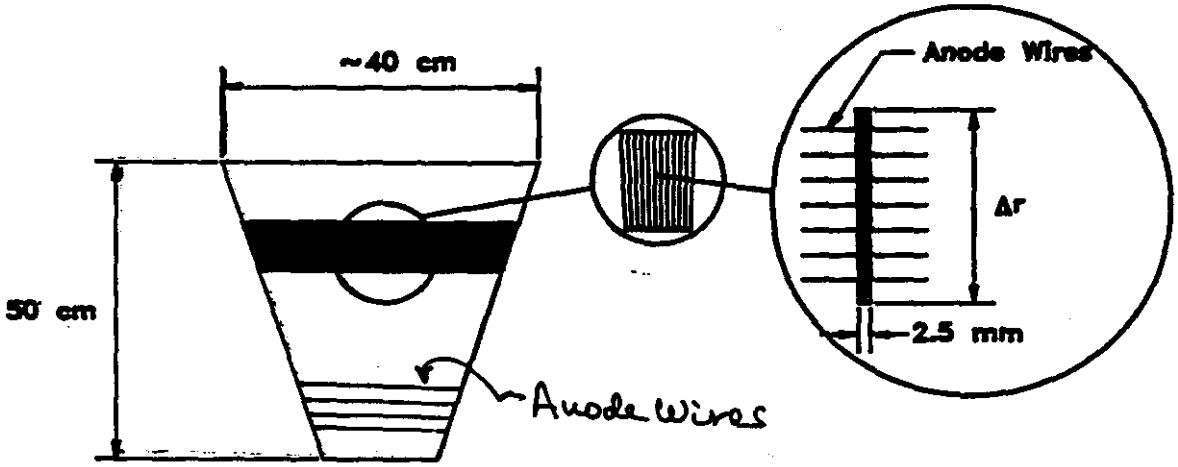


a) Cell Geometry Viewed Along the Anode Wires



Resolution σ = 2% of w = 50μ
Length of pad L = 4 to 15 cm

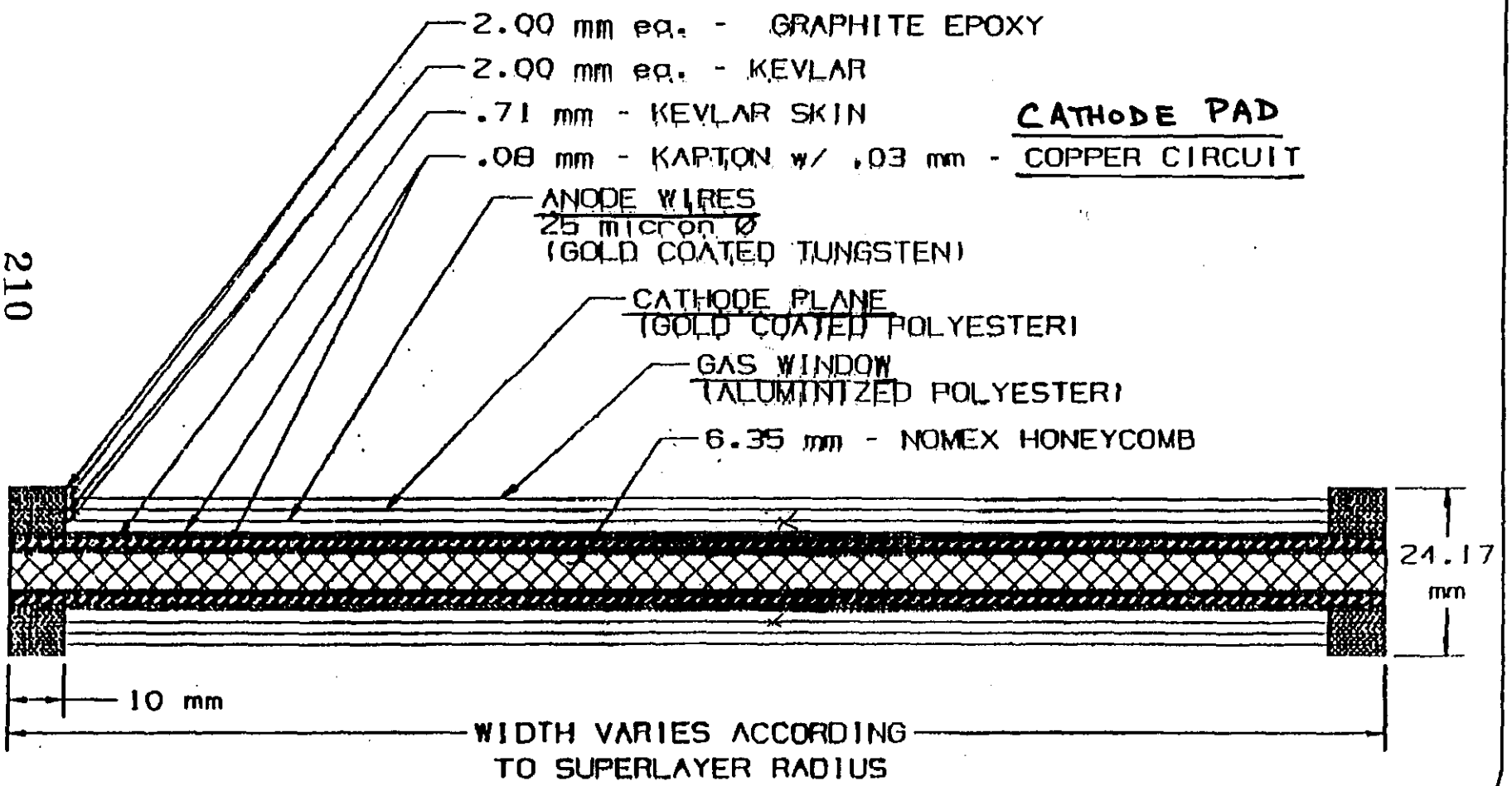
b) Pad Arrangement in the Barrel Chambers (80 chambers total)



Resolution σ = 2% of w = 50μ
Length of pad Δr = 1 to 15 cm

c) Arrangement in the End Cap Chambers (80 chambers total)

GEM IPC SUPERLAYER

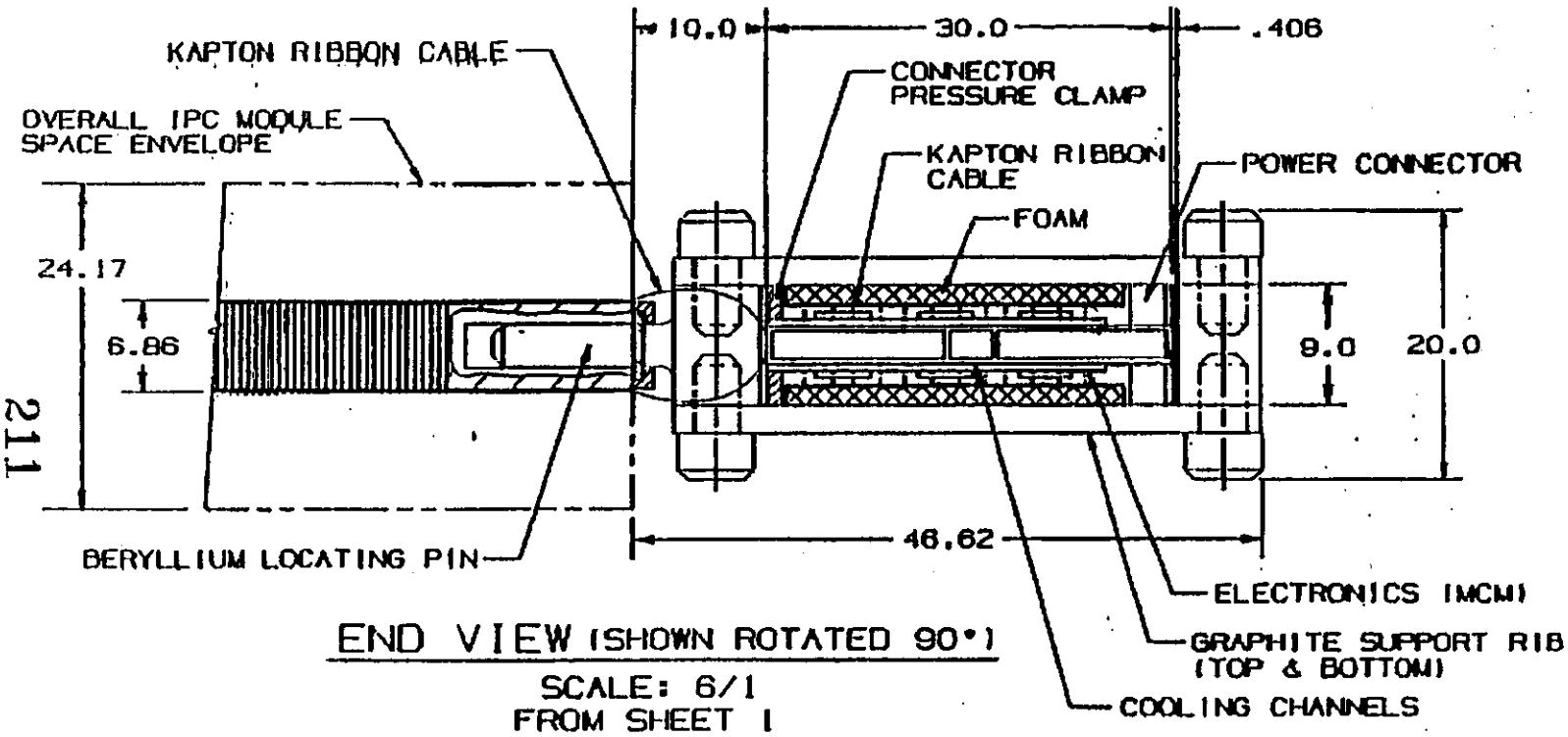


ALL DIMENSIONS ARE IN mm

GEMVG-IPC-SUPERLAYER

gem

LANL



END VIEW (SHOWN ROTATED 90°)

SCALE: 6/1
FROM SHEET 1

PRELIMINARY
NOT TO BE USED FOR FABRICATION

DIMENSIONS ARE SHOWN IN INCHES & (MILLIMETERS)

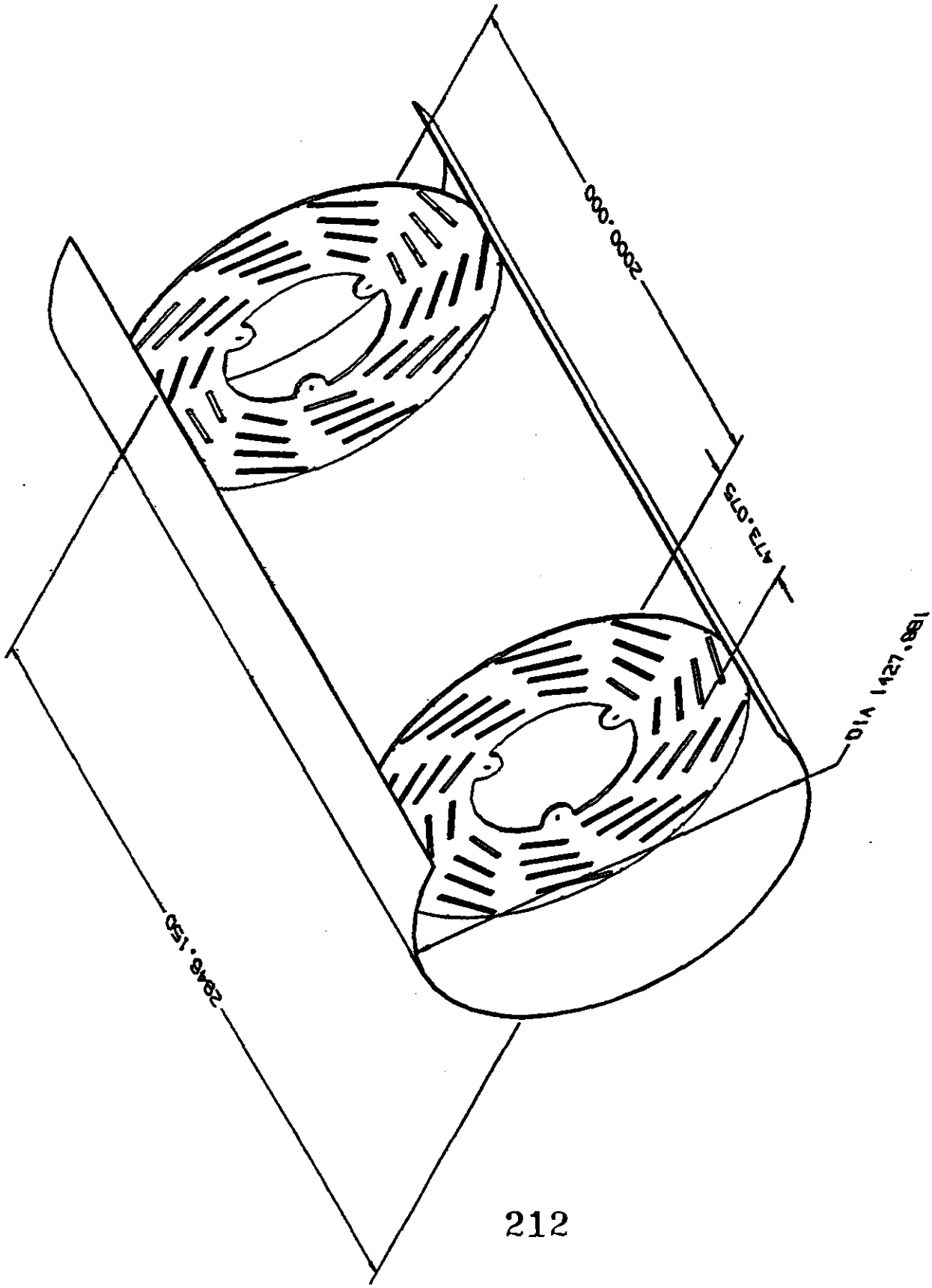
METRIC
THIRD ANGLE PROJECTION

Los Alamos

GEM IPC TRAXXDI
IPC ELECTRONICS
ASSEMBLY

A1 SK-GEM12-050 2

211


2000.000
473.075
DIA 1427.881
2848.150

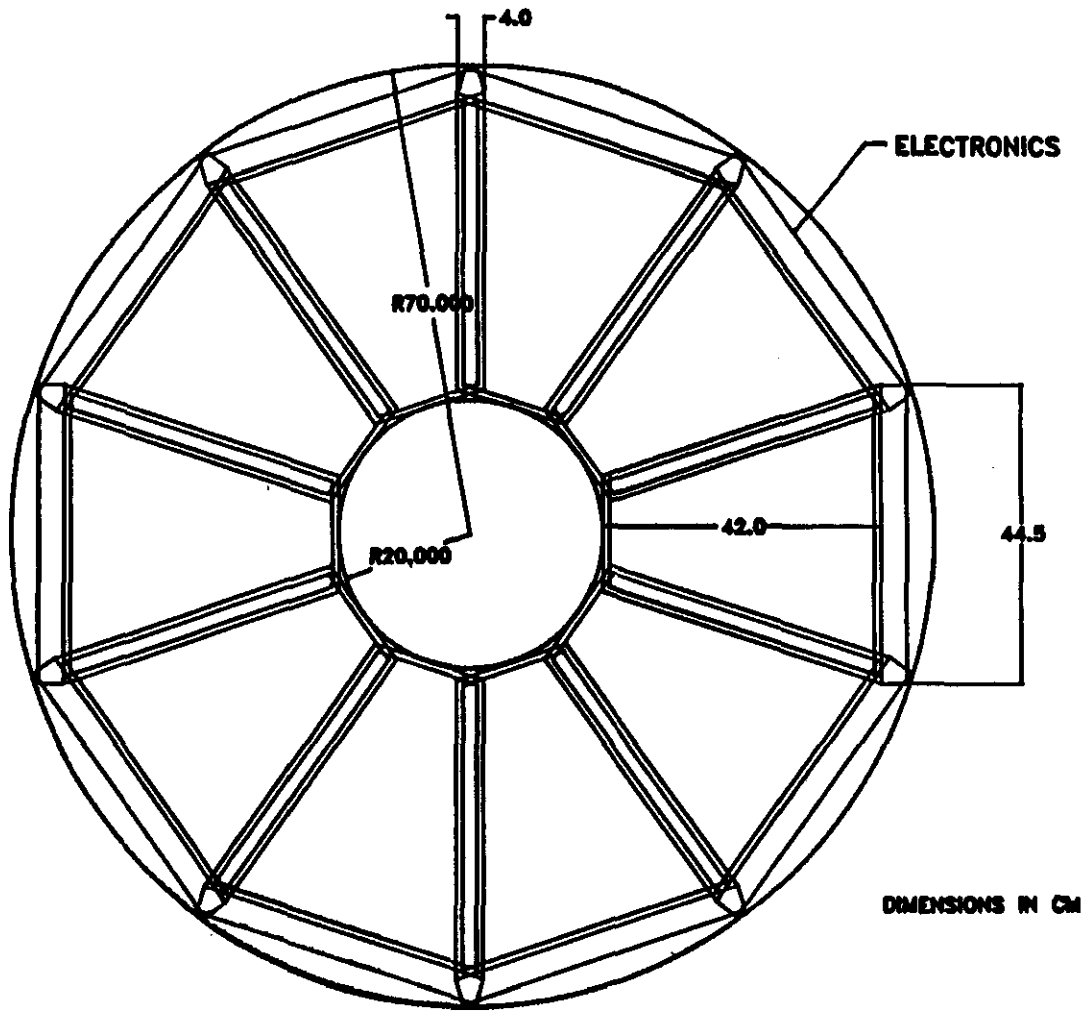


FIGURE 3: GEM IPC TRACKER-FRONTAL VIEW OF ENDCAP
(FIRST OF FOUR SUPERLAYERS SHOWN)

Radiation Hardness of Central Tracker

- Charged particles, including secondary interactions, γ conversions, Delta rays, loopers, etc

	Yearly Radiation Dose		Design for Lifetime Dose
	$\mathcal{L} = 10^{33}$	$\mathcal{L} = 10^{34}$	
Silicon R=10cm	0.4 Mrad/yr	4 Mrad/yr	4 Mrads
Pads R=40cm	0.025 Mrad/yr	0.25 Mrad/yr	2½ Mrads

2. Neutron Flux with Polyethelene Shield

	Yearly Neutron Flux		Design for Lifetime Dose
	$\mathcal{L} = 10^{33}$	$\mathcal{L} = 10^{34}$	
Silicon	$5\times10^{12}/cm^2/yr$	$5\times10^{13}/cm^2/yr$	$5\times10^{13}/cm^2$
Pads	$5\times10^{12}/cm^2/yr$	$5\times10^{13}/cm^2/yr$	$5\times10^{14}/cm^2$

3. Silicon should be good for 10 years at 10^{33}

Pads should be good for 10 years at 10^{34}

Progress on Central Tracker

1. First Draft of Technical Design Report written July 31, 1992

2. Design Optimization & Fine Tuning

   a) No showstoppers or major changes so far

   b) Overall Tracker Dimensions

      Radius 70 cm → 88 cm

      Length 300 cm → 350 cm

   c) Stereo angles

      Silicon 0, +5 mr → ± 5 mr

      Pads ± 30 mr → ± 50 mr

   d) Silicon "Lorentz Angle" (tilt angle)

      9° → 1½°

      pinwheel to staggered geometry

   e) We are considering longer Si strip length

      12 cm → 18 cm (?)

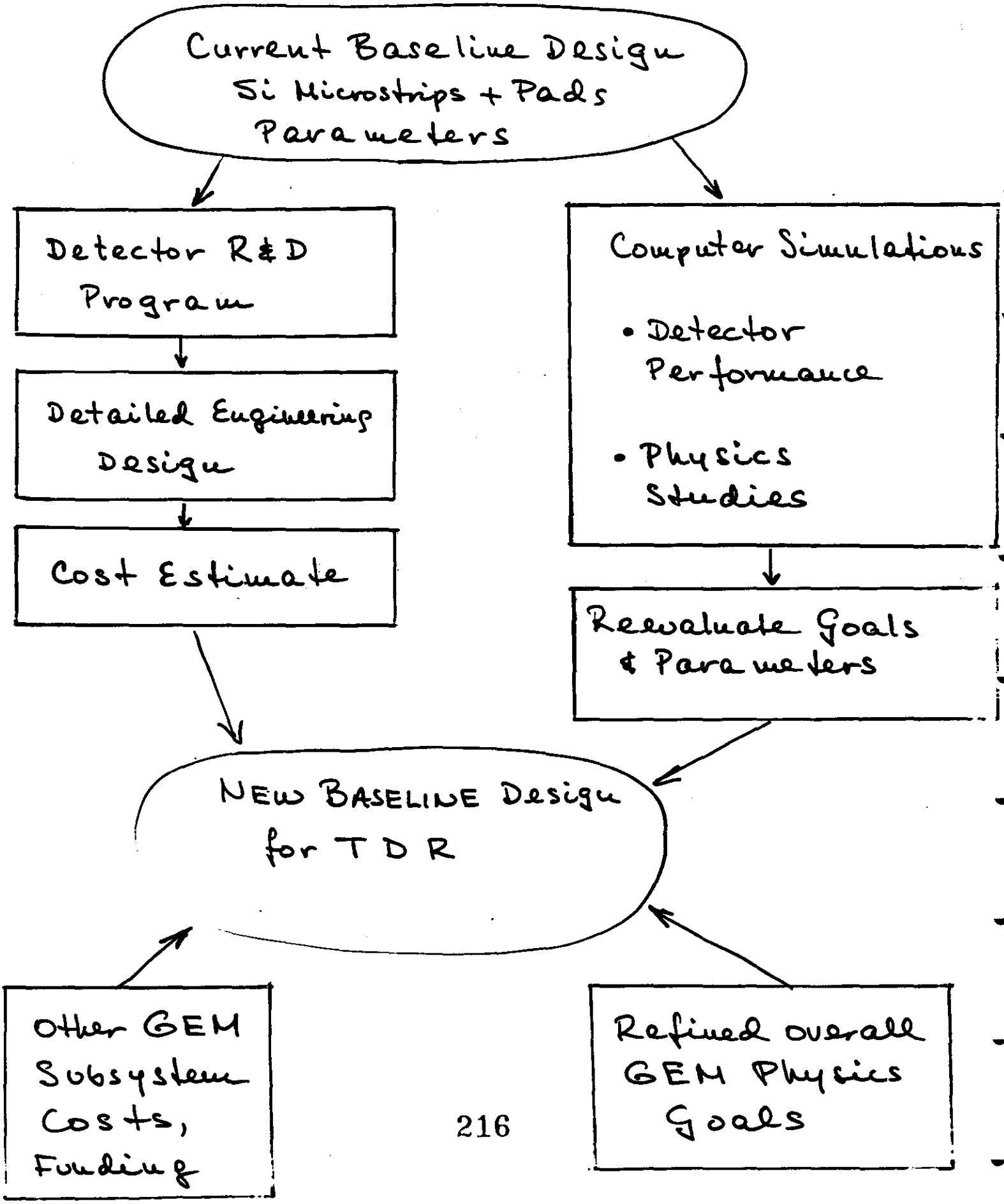
3. Continued detector & physics simulations

4. Prototype work

5. Taiwanese Collaboration

6. Organization and R&D Plan

PLANNING FOR THE TECHNICAL DESIGN REPORT



Overall Tracker Dimensions

1. Choice of Calorimeter allows a somewhat larger volume for Tracker

   Radius 70cm → 88cm
   Length 300cm → 350cm

2. Keep Silicon Detector unchanged

   Keep number of Pad chambers the same

   Keep pads the same $\Delta\eta\,\Delta\phi$ but 2.5mm wide

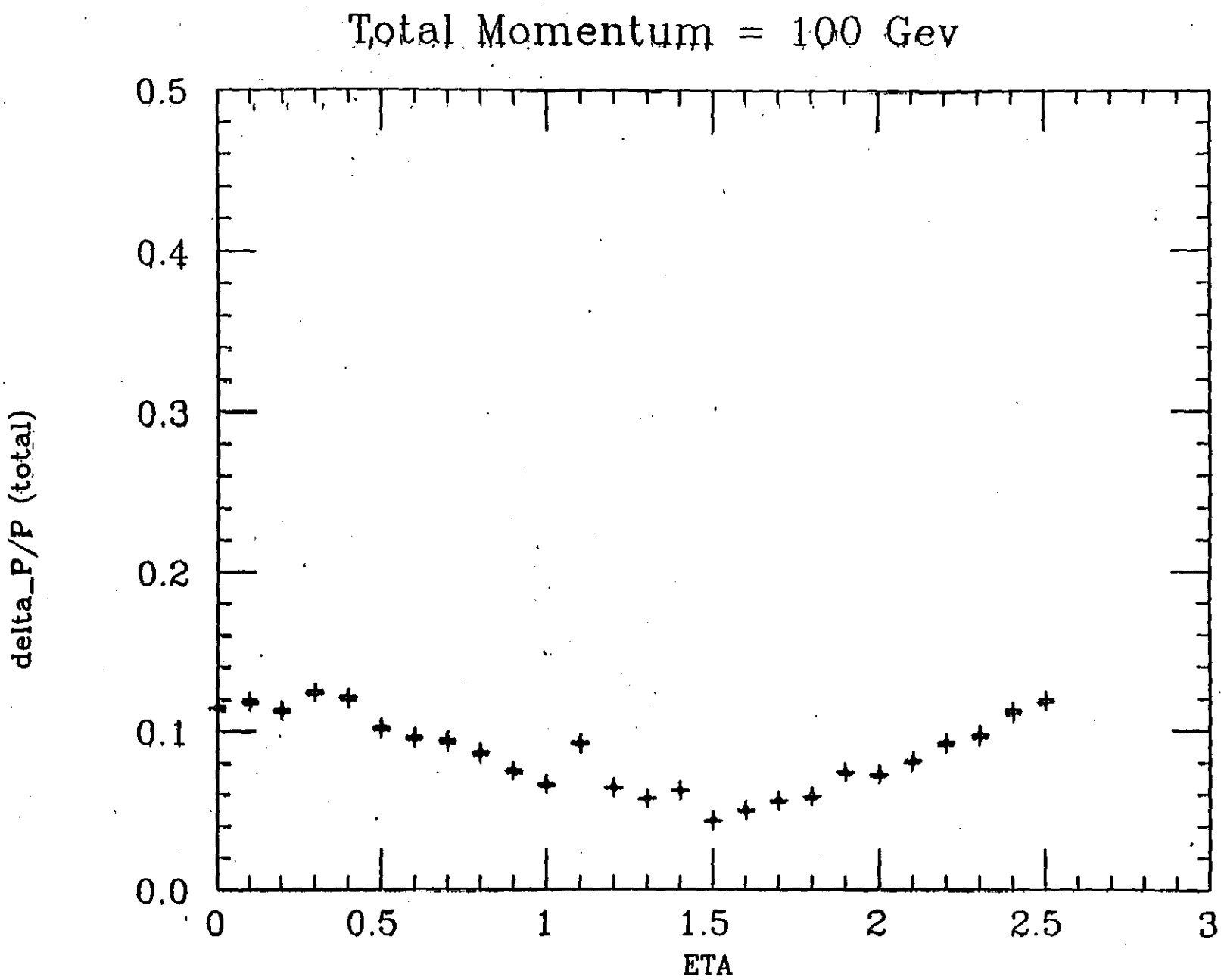
   ∴ same channel count

   Move Pad chambers: expand spacing to fill volume

3. Cost increase to Tracker negligible (~ 1% of Tracker cost)

4. Improve momentum resolution for large p by $\sim \left(\frac{88}{70}\right)^2 \sim 1.6$

   Improve vertex z resolution


Total Momentum = 100 Gev
delta_P/P (total)
0.0
0.1
0.2
0.3
0.4
0.5
0
0.5
1
1.5
2
2.5
3
ETA

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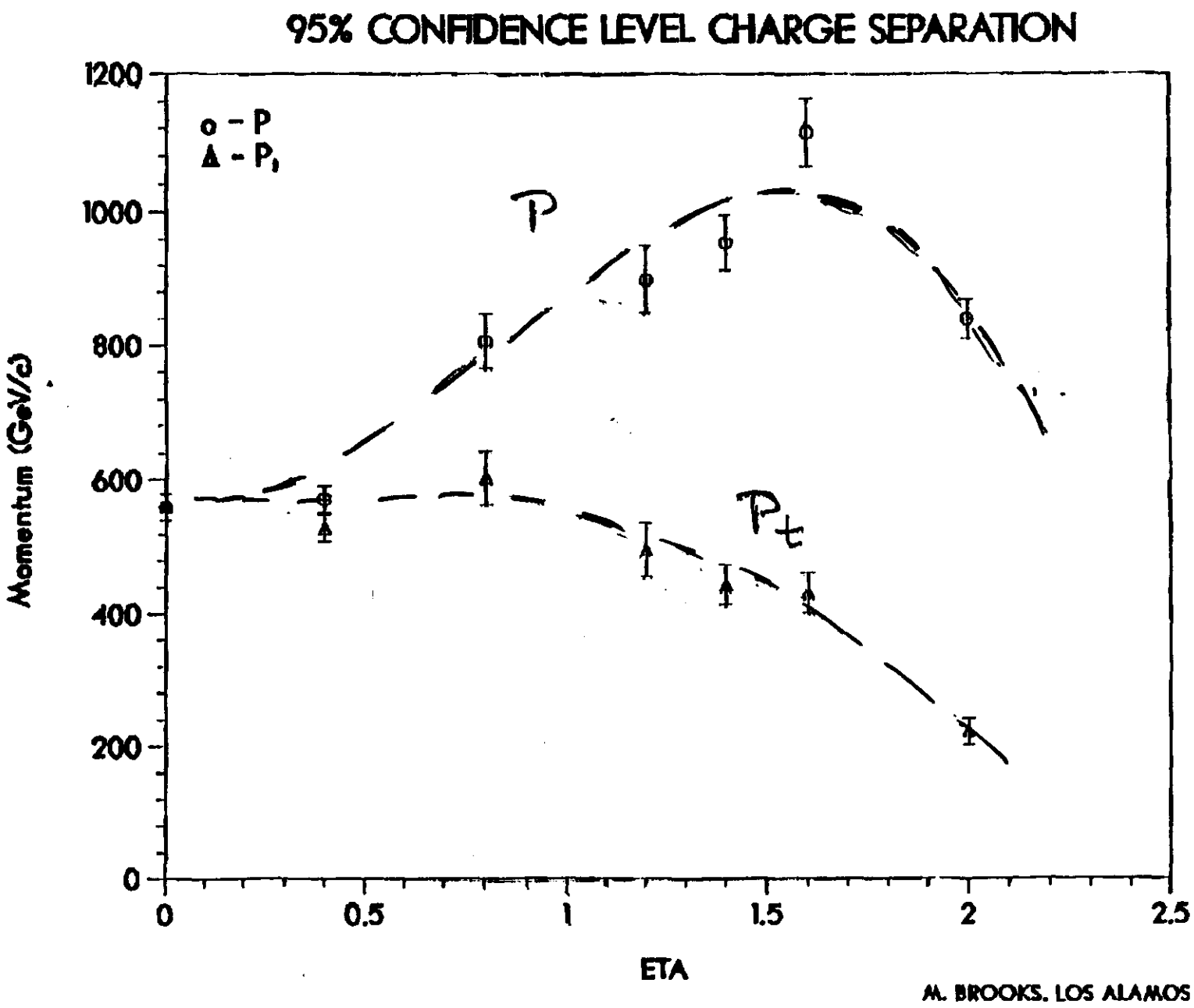
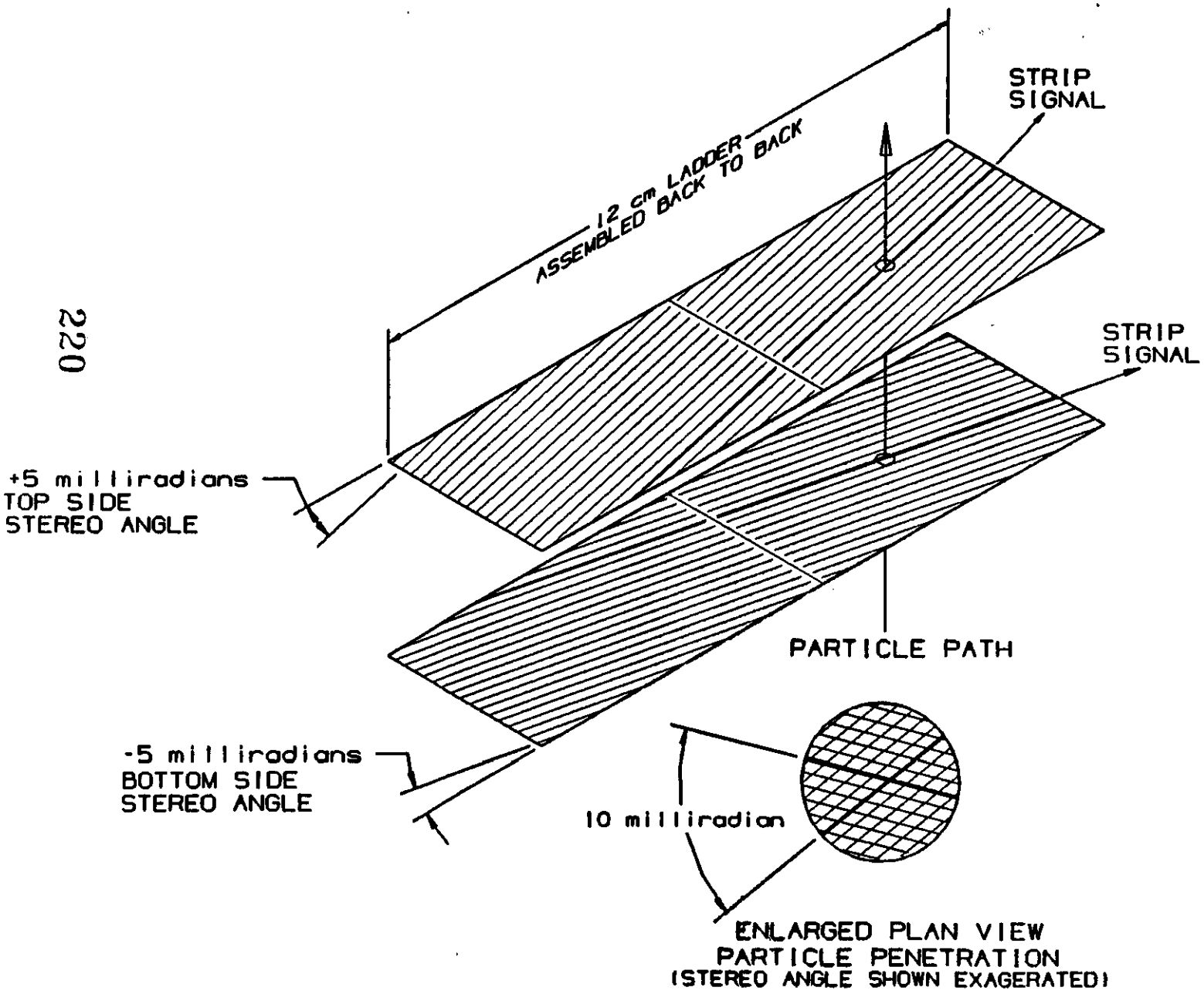
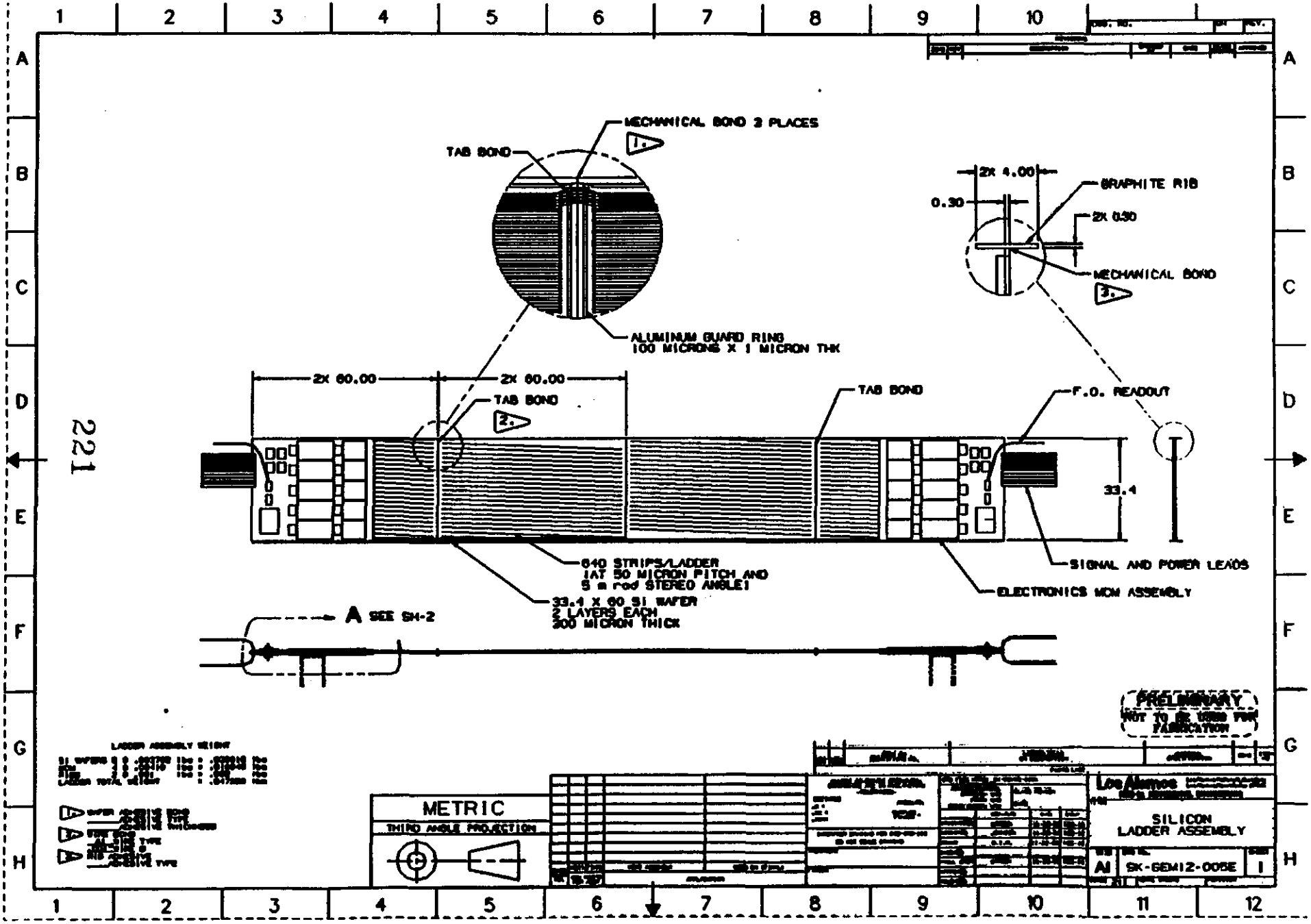
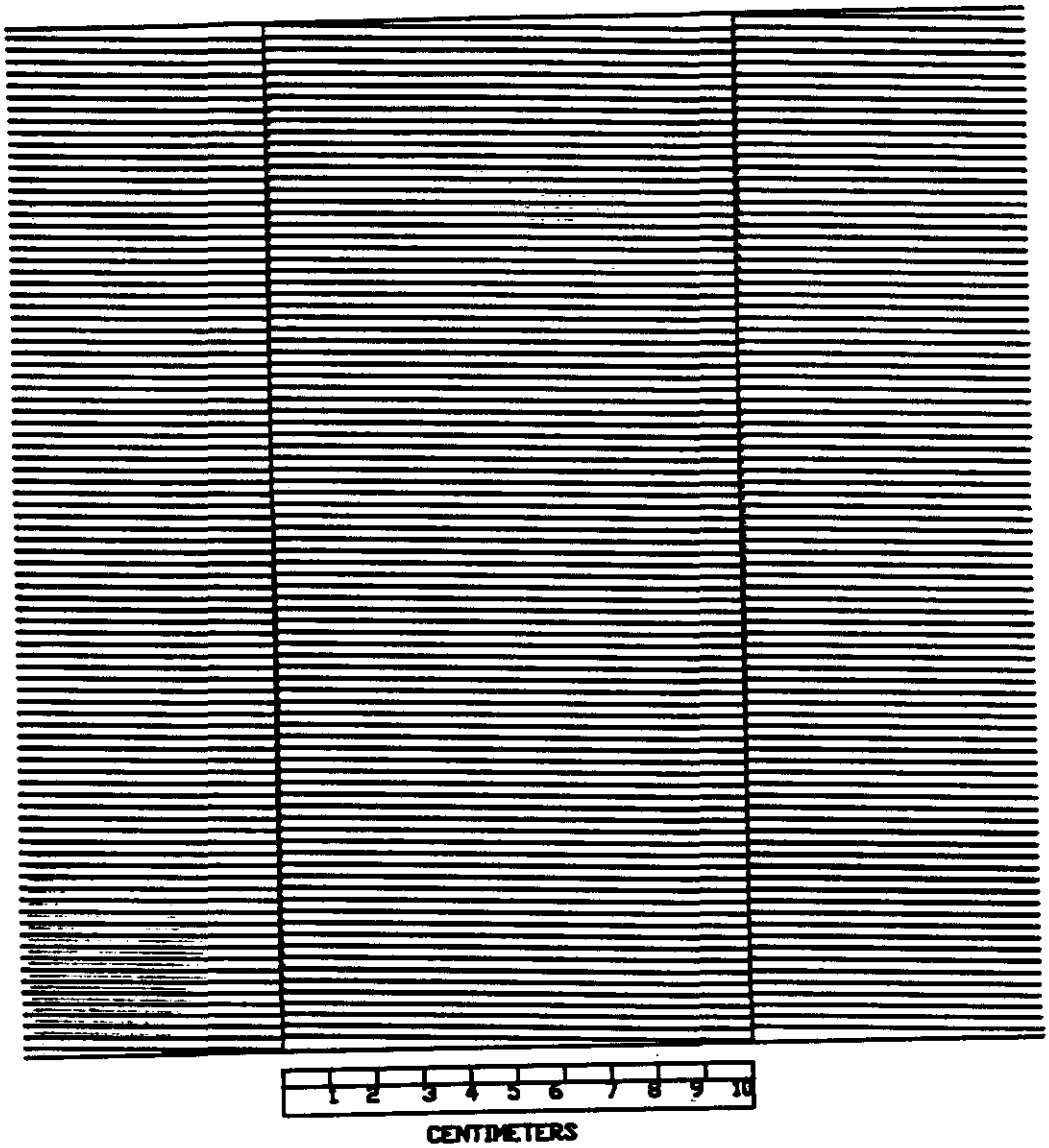
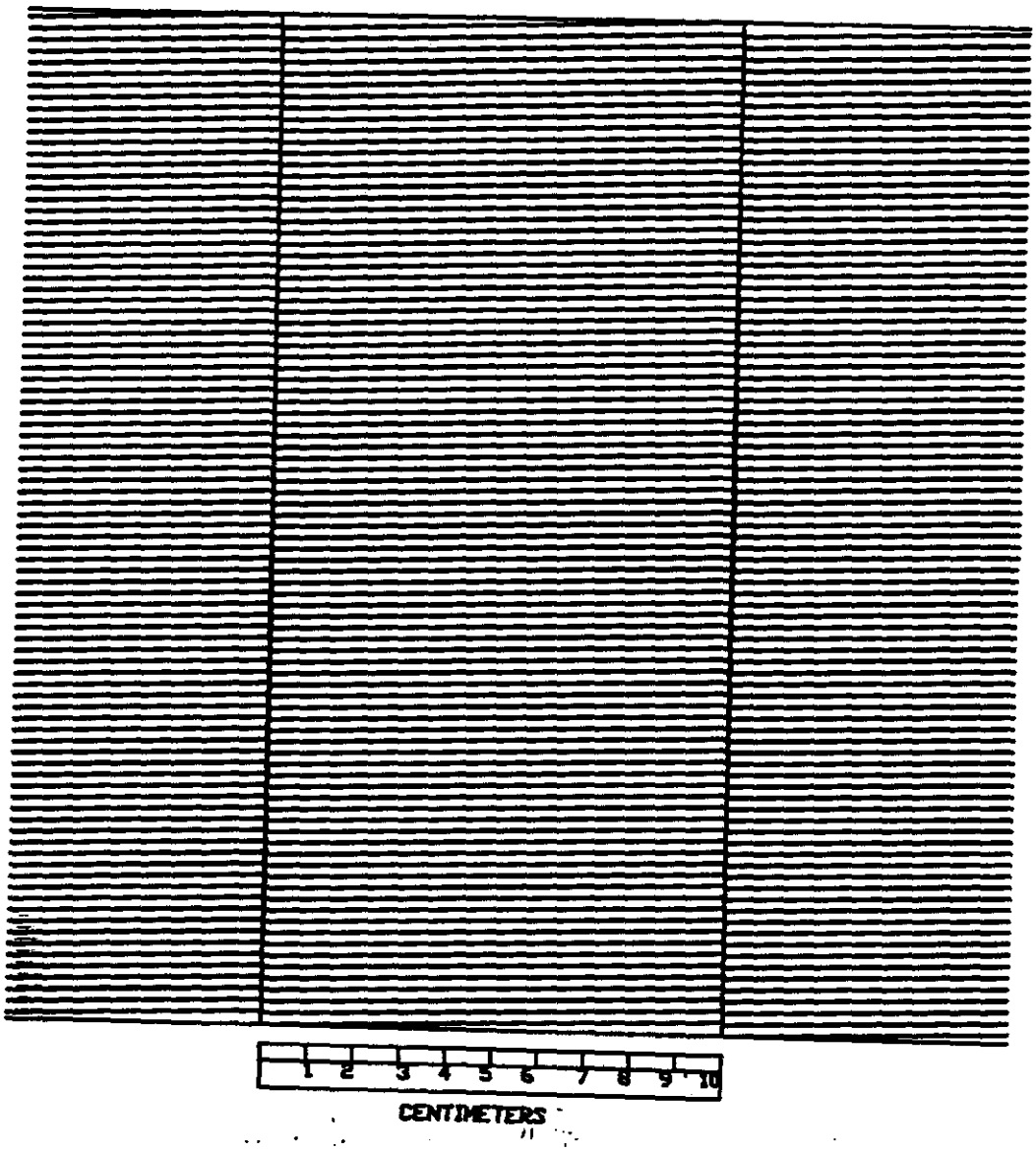



12 cm LADDER
ASSEMBLED BACK TO BACK
STRIP
SIGNAL
STRIP
SIGNAL
+5 milliradians
TOP SIDE
STEREO ANGLE
PARTICLE PATH
-5 milliradians
BOTTOM SIDE
STEREO ANGLE
10 milliradian
ENLARGED PLAN VIEW
PARTICLE PENETRATION
(STEREO ANGLE SHOWN EXAGERATED)


MECHANICAL BOND 2 PLACES
TAB BOND
ALUMINUM GUARD RING
100 MICRONS X 1 MICRON THK
2X 4.00
0.30
GRAPHITE RIB
2X 0.30
MECHANICAL BOND
2X 60.00
2X 60.00
TAB BOND
TAB BOND
F.O. READOUT
33.4
640 STRIPS/LADDER
(AT 50 MICRON PITCH AND
5 m rad STEREO ANGLE)
33.4 X 60 SI WAFER
2 LAYERS EACH
300 MICRON THICK
SIGNAL AND POWER LEADS
ELECTRONICS MCM ASSEMBLY
A SEE SH-2
PRELIMINARY
NOT TO BE USED FOR FABRICATION
METRIC
THIRD ANGLE PROJECTION
SILICON
LADDER ASSEMBLY
A1
SK-GEM12-005E
1


1 2 3 4 5 6 7 8 9 10
CENTIMETERS


1 2 3 4 5 6 7 8 9 10
CENTIMETERS

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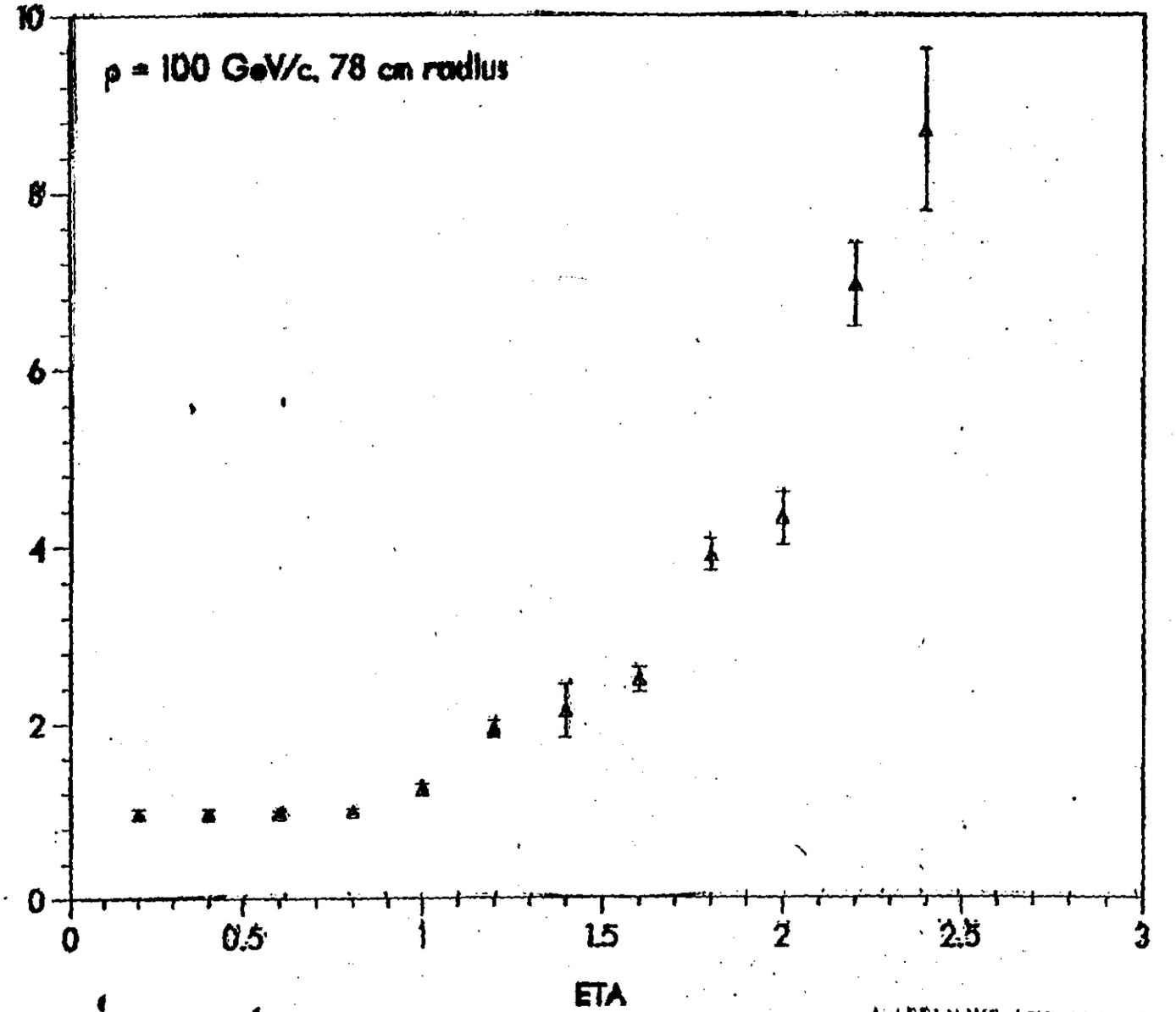
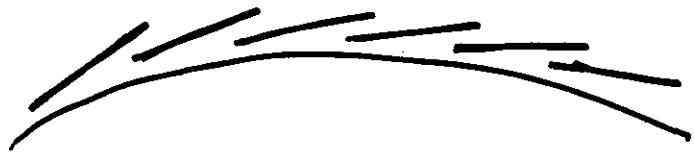


M. BROOKS, LOS ALAMOS

Silicon Geometry

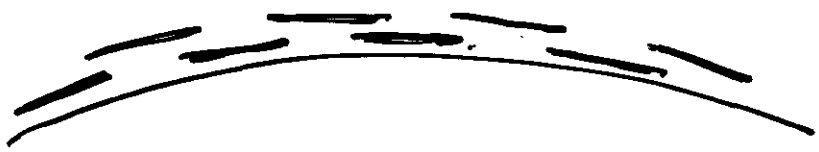
1. Present Design
   9° tilt angle, pinwheel geometry



looking along beam

2. Relevant Lorentz angle in Silicon Microstrips is ~ 1½°

3. New design with 1½° tilt angle and staggered geometry



looking along beam

1½° tilt angle reduces charge spreading to neighbouring strips

∴ improves signal to noise

Silicon Detector Strip Length

1. Present Design

   Barrel – 48 cm long i.e. 4 × 12 cm

   Forward – 16 cm radially 12 cm + 4 cm

2. Modified Design under consideration

   Barrel – 36 cm long 2 × 18 cm

   Forward – 18 cm radially 18 cm

3. Advantages of 18 cm strip length Design

   a) Mechanically much simpler

   b) All Electronics on end of barrel, outer edge of Forward discs

      - No buried cooling rings
      - Easier and reduced cable plant
      - Easier access to electronics
      - Reduced Radiation Length

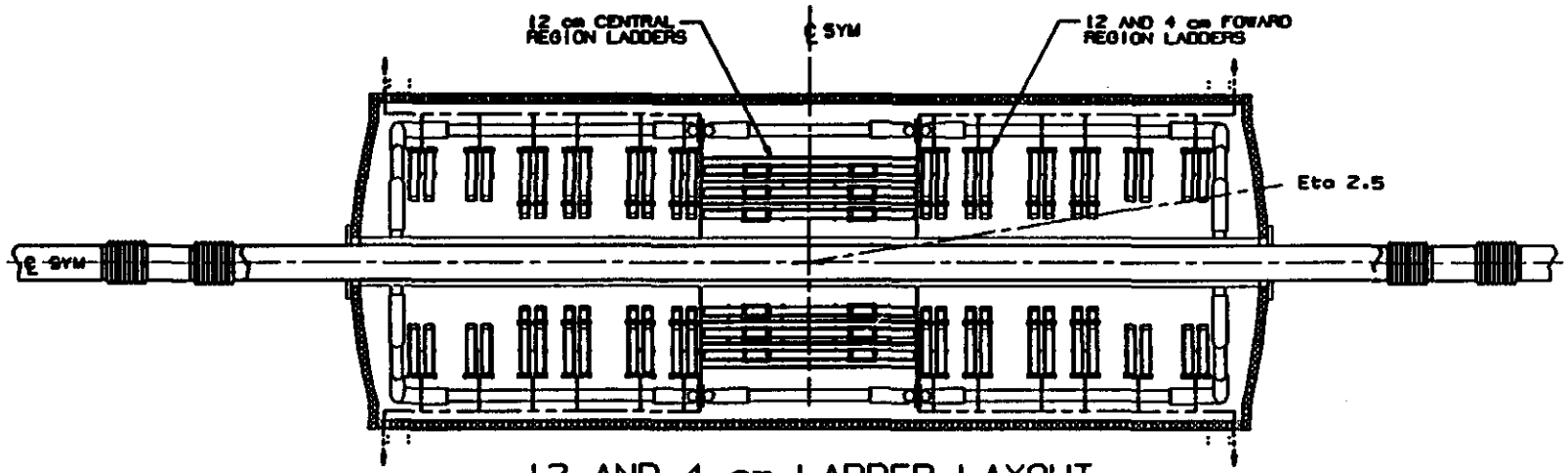
   c) Channel count reduced by ~ 25%

      - Cost saving
      - Less total power dissipated

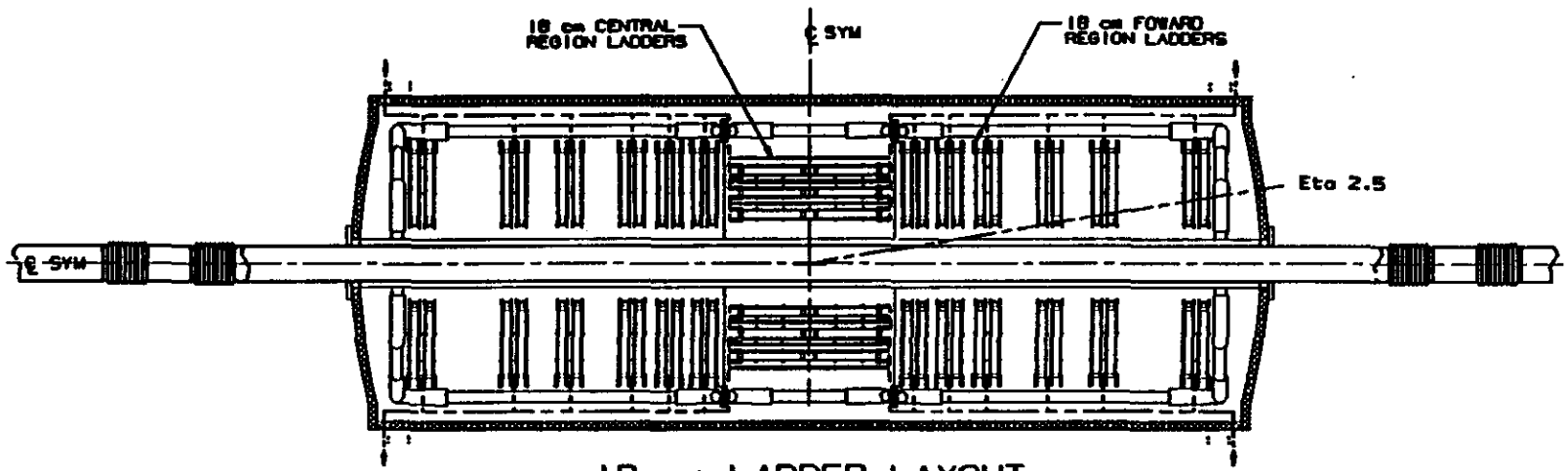
4. Concerns about 18 cm long strips

   Signal to Noise

   Will make decision after actual measurements on prototypes



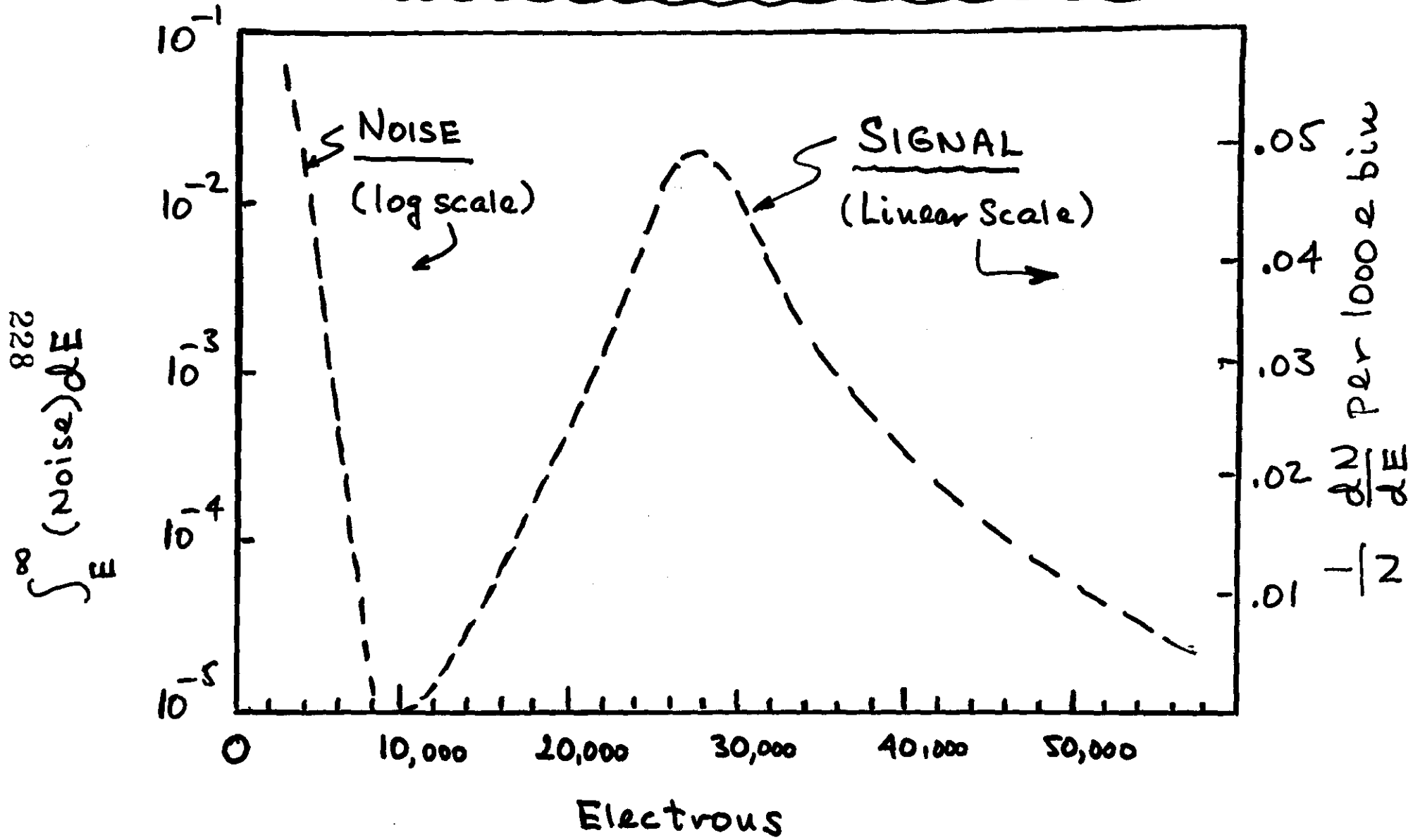
12 AND 4 cm LADDER LAYOUT

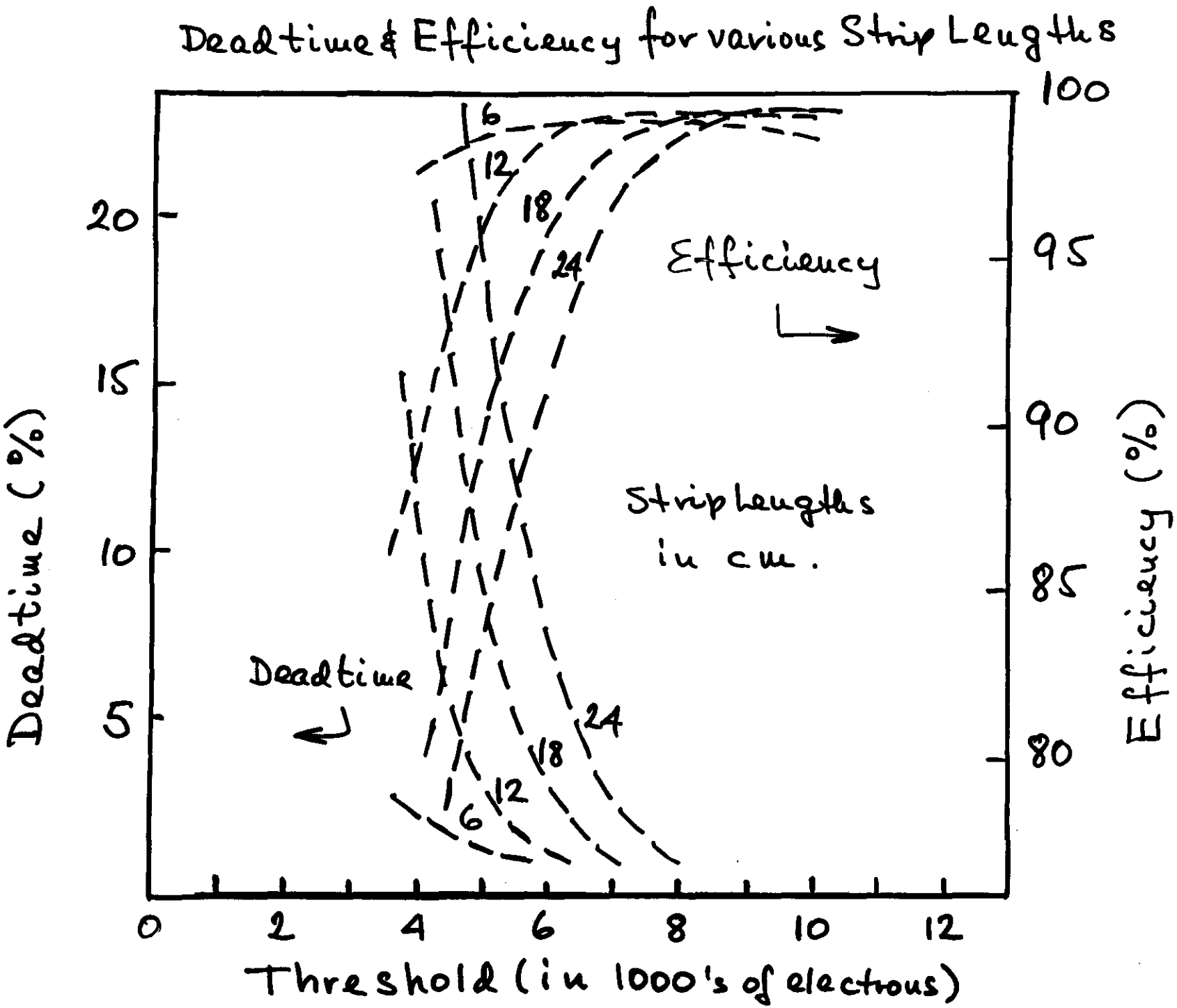


18 cm LADDER LAYOUT

JIM DRHU, Univ. of Oregon

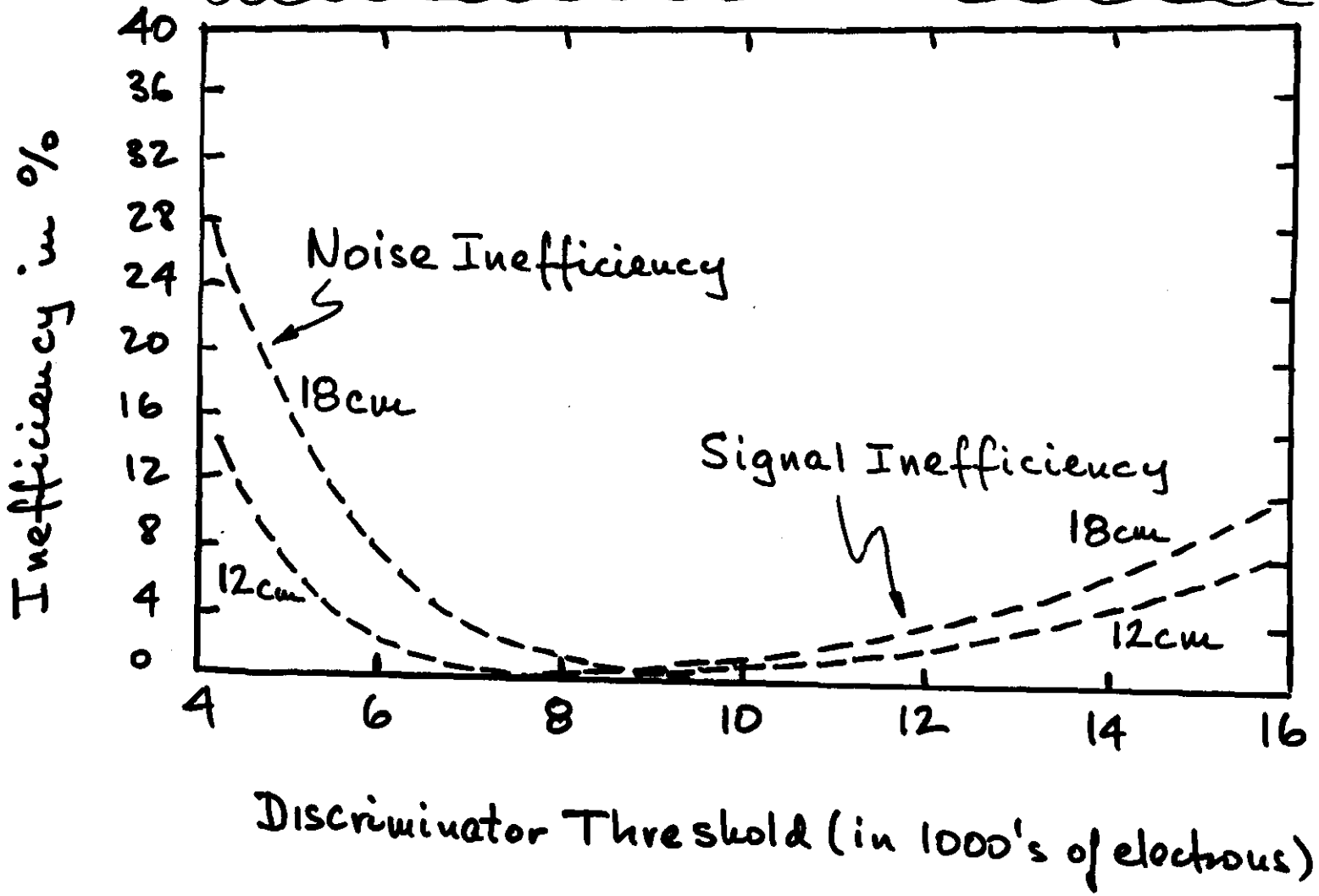
Signal to Noise in Silicon Microstrips




Deadtime & Efficiency for various Strip Lengths
Deadtime (%)
Efficiency (%)
Threshold (in 1000's of electrons)
Efficiency
Deadtime
Striplengths in cm.
6
12
18
24
0
2
4
6
8
10
12
5
10
15
20
80
85
90
95
100

G. Mills & S. Hahn, Los Alamos

Inefficiencies for 12 and 18 cm long strips



R & D Prototype Program

1. Silicon Tracker

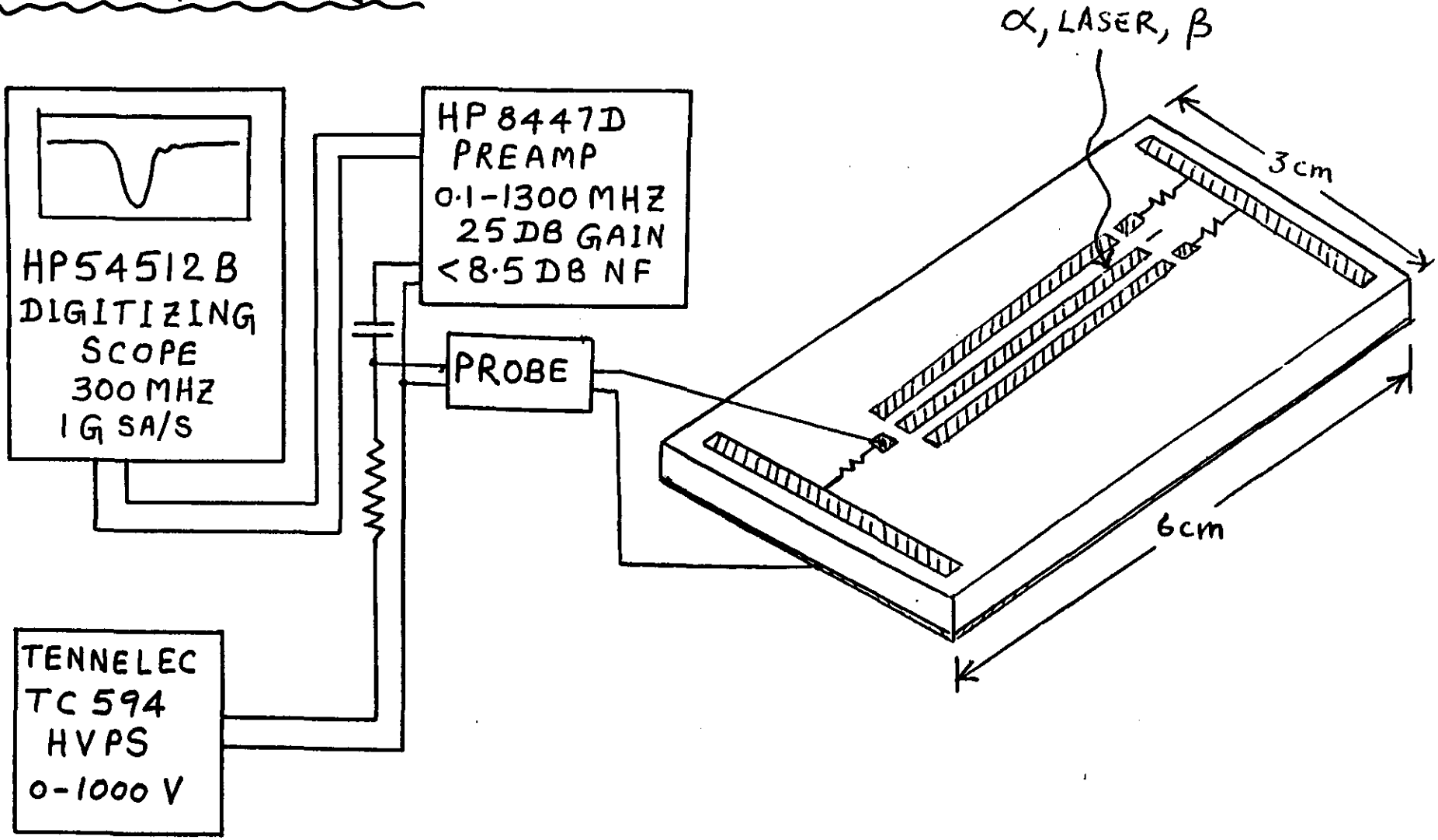
a) 18 cm Barrel Ladder	J. Brau	U. of Oregon
b) Forward Disc	D. Lee	Los Alamos

2. IPC Tracker

a) Reduced size prototype with final working parameters	C. Bowers	Indiana U.
b) Fullsize Barrel Chamber	C. Baltay	Yale U.
c) Fullsize Endcap Chamber		Taiwan

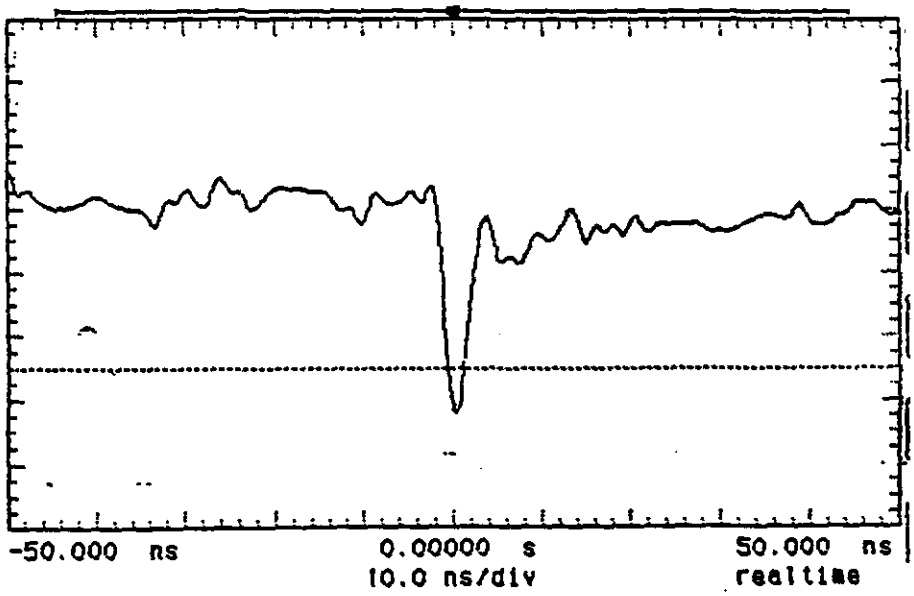
3. Test Beam Setups

a) Silicon Ladders	G. Mills, R. Frey	Los Alamos, U. of Oregon
b) IPC Chambers	K. Morgan	SSCL

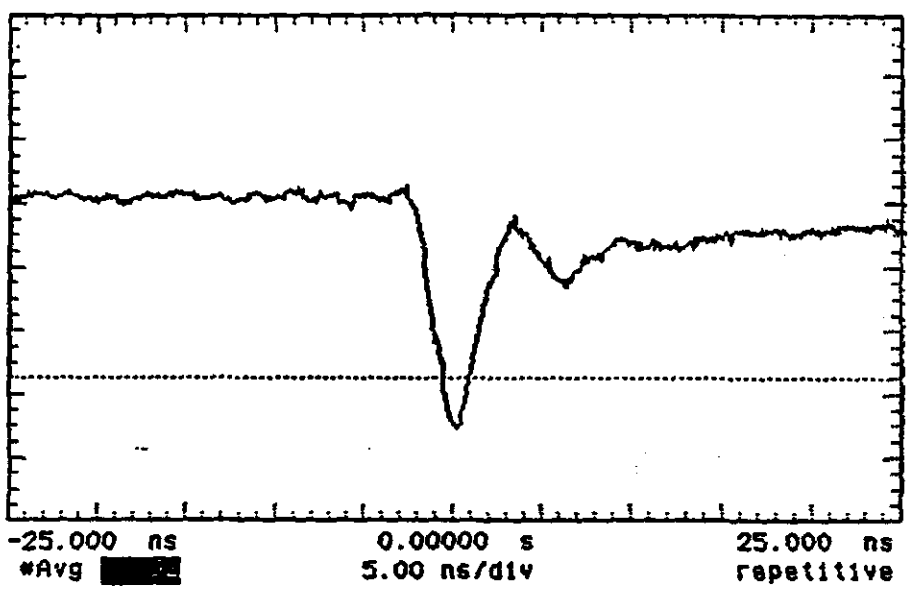


MOSCOW DETECTORS

PITCH	50 μm	COUPLING	AC
P^+ STRIP WIDTH	8 μm	OXIDE THICKNESS	225 nm
Al STRIP WIDTH	16 μm	POLY SI RESISTOR	2±.2 MΩ
Al THICKNESS	1 μm	ρ_{SUB}	8 KΩ-cm

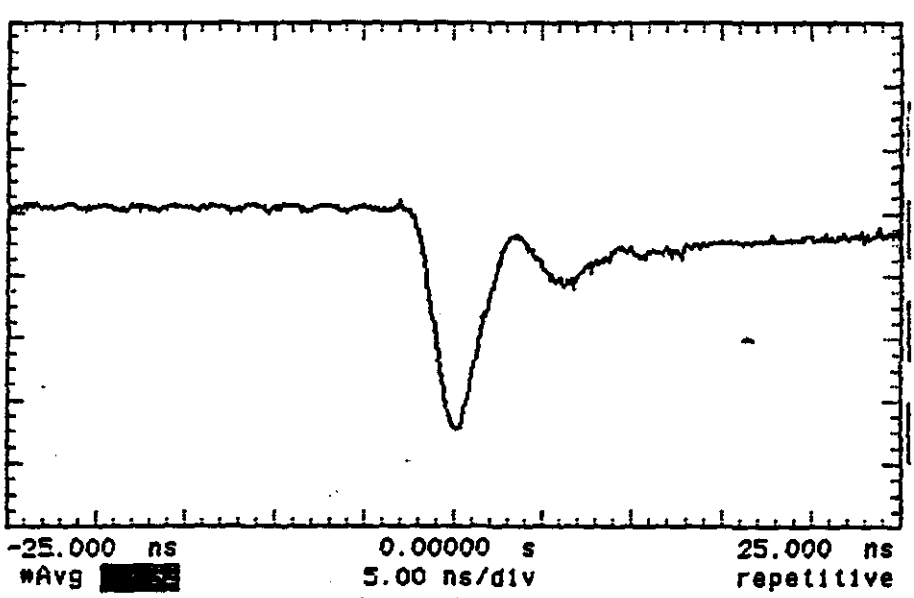


2 mV/div



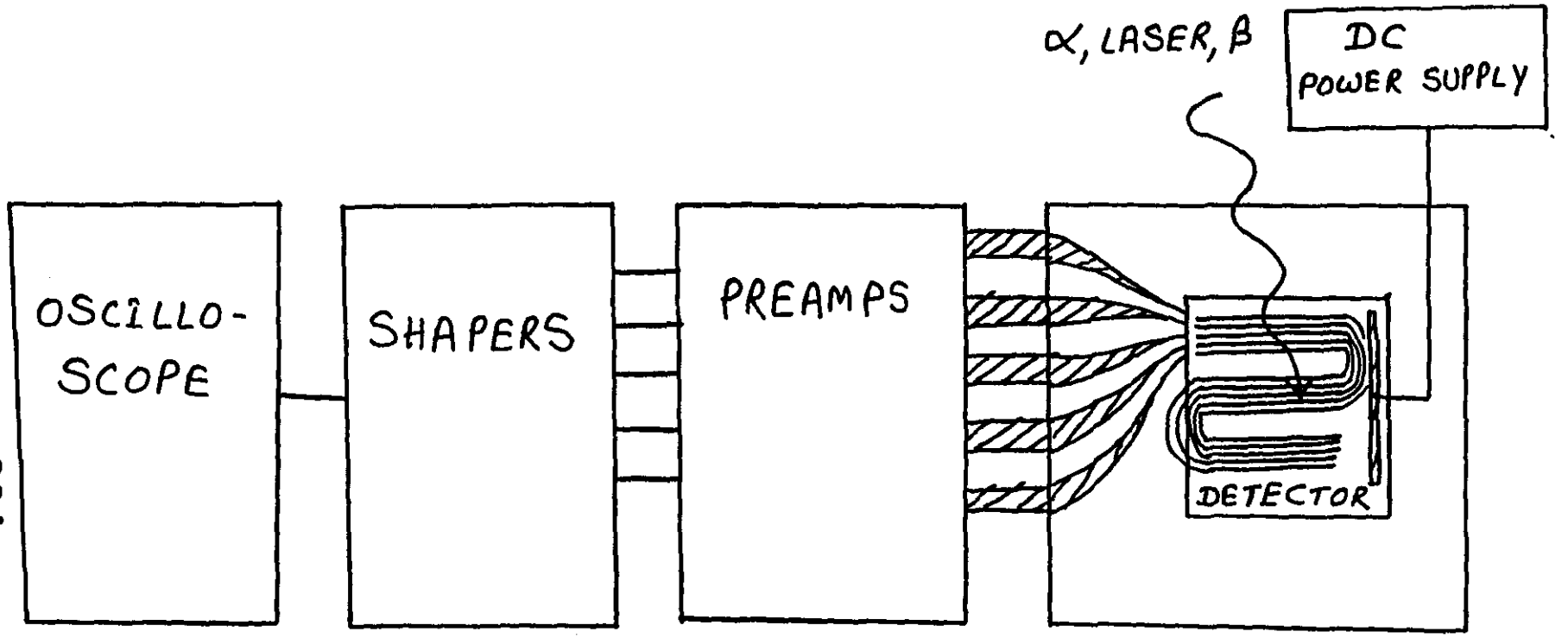
2 mV/div

α-SOURCE CLOSE TO THE PROBE TIP



2 mV/DIV

α-SOURCE AT 6CM AWAY FROM THE PROBE TIP


OSCILLO-
SCOPE
SHAPERS
PREAMPS
α, LASER, β
DC
POWER SUPPLY
DETECTOR

Letter of Understanding

We, the National Science Council on behalf of the Academia Sinica, the Universities and the Industrial Technology Research Institute, and the Superconducting Super Collider, express definite intention to proceed in accordance with the Cooperative Agreement (as attached).

1. Upon the signing of this letter, the following will start immediately (with all terms defined in the attached document).

a) A start of the scientific exchange program

b) The startup of the strengthening of the research groups and their infrastructure in Taiwan

c) A start of the R&D (Research and Development) program and the collaboration on the engineering design of the GEM Central Tracker

2. Formal agreement will be signed upon the completion of due review process and approval from the relevant agencies of both parties. We expect this completion should not be later than February 1993.

Executed by the parties this 6TH day of NOVEMBER, 1992.

For Superconducting Super Collider Laboratory

R. Schwitters

For National Science Council

Yii Der Chuang

gem

γeμ

Presentation by:

K. Lane

TRIVIALITY – A BOUND ON M_H

THE HIGGS BOSON POTENTIAL IN THE MINIMAL, ONE-DOUBLET STANDARD MODEL —

$$V(\varphi, \varphi^\dagger) = \lambda \left(\varphi^\dagger \varphi - \frac{v^2}{2}\right)^2$$

HIGGS VEV

λ: DIM'LESS HIGGS SELF-COUPLING, ≥ 0!

- $\frac{G_F}{\sqrt{2}} = \frac{1}{2v^2} \rightarrow \underline{v = 246 \text{ GeV}}$

- $M_H^2 = 2\lambda v^2$

  HOW BIG CAN λ BE ?

λ IS ENERGY SCALE (M) - DEPENDENT —
A RUNNING COUPLING SATISFYING THE RGE

$$M \frac{d\lambda(M)}{dM} = \frac{24}{16\pi^2}\lambda^2(M) + \text{SMALL TERMS INVOLVING } g, g', g_t = \frac{\sqrt{2}\, m_t}{v} + O(\lambda^3)$$

$$\rightarrow \frac{1}{\lambda(M)} = \frac{1}{\lambda(\Lambda)} + \frac{24}{16\pi^2} \ln\left(\frac{\Lambda}{M}\right)$$

UV MOMENTUM CUTOFF

- $\lambda(M) \rightarrow 0$ $(\forall M!)$ AS $\Lambda \rightarrow \infty$

  THE ELEMENTARY HIGGS THEORY IS <u>FREE</u>
  - TRIVIAL - AS CUTOFF Λ IS REMOVED!

ALTERNATIVELY —

- DEFINE $\Lambda_\infty = M_0\, e^{16\pi^2/24\lambda(M_0)}$, SO ...

$$\boxed{\lambda(M) = \frac{16\pi^2}{24 \ln \frac{\Lambda_\infty}{M}}}$$

THEORY CANNOT BE DEFINED FOR $M \geq \Lambda_\infty$;
i.e., <u>EFFECTIVE FIELD THEORY FOR $M < \Lambda_\infty$</u>!

$$M_H = \sqrt{2\lambda(M_H)}\, v = \frac{2\pi v}{\sqrt{3 \ln \frac{\Lambda_\infty}{M_H}}}$$

How big is $\lambda(M_H)$? → How big is Λ_∞?

$\Lambda_\infty = M_{PL.} \cong 10^{19}$ GeV $\Rightarrow M_H = 143$ GeV

$\Lambda_\infty = M_{GUT} \simeq 10^{16}$ GeV $\Rightarrow M_H = 158$ GeV

⋮

Minimum $\Lambda_\infty \cong 2\pi M_H$ (LATTICE)

→ Maximum $M_H \cong \frac{2\pi v}{\sqrt{3 \ln 2\pi}} = 660$ GeV

THE TRIVIALITY BOUND –

~ 660 GeV !

DOES THIS MEAN THAT M_H CANNOT EXCEED ~ 700 GeV ?

NO !

BUT, IF IT DOES ...

NEW PHYSICS MUST COME IN AT

$$\lesssim \Lambda \cong M_H \, e^{4\pi^2 v^2/3M_H^2}$$

$\sim$ 2-3 TeV FOR $M_H < 1$ TeV

SO – BE PREPARED !

gem

γeμ

Presentation by:

C. Bower

Test Results of the Indiana University IPC Prototype

Chuck Bower

10 Dec 1992

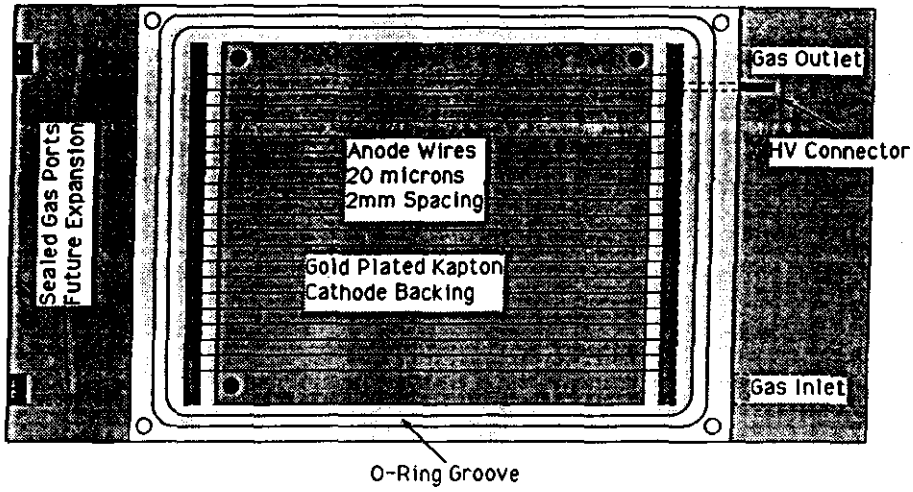
GOAL:

Determine the position resolution for a prototype interpolating pad chamber (IPC) which has been configured with the characteristic geometry, baseline gas mixture, and front end electronics of the proposed GEM Central Tracker.

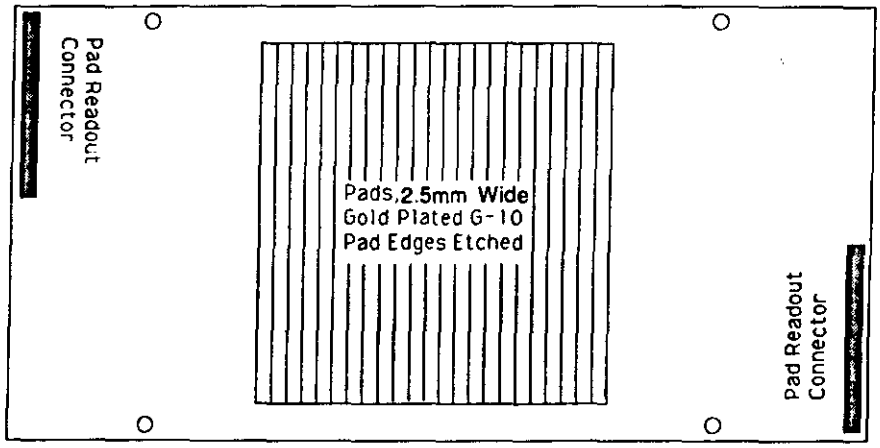
PRIMARY CONTRIBUTORS TO THE STUDY:

Chuck Bower
Mark Gebhard
Jim Musser
Jim Pitts

Anode Board

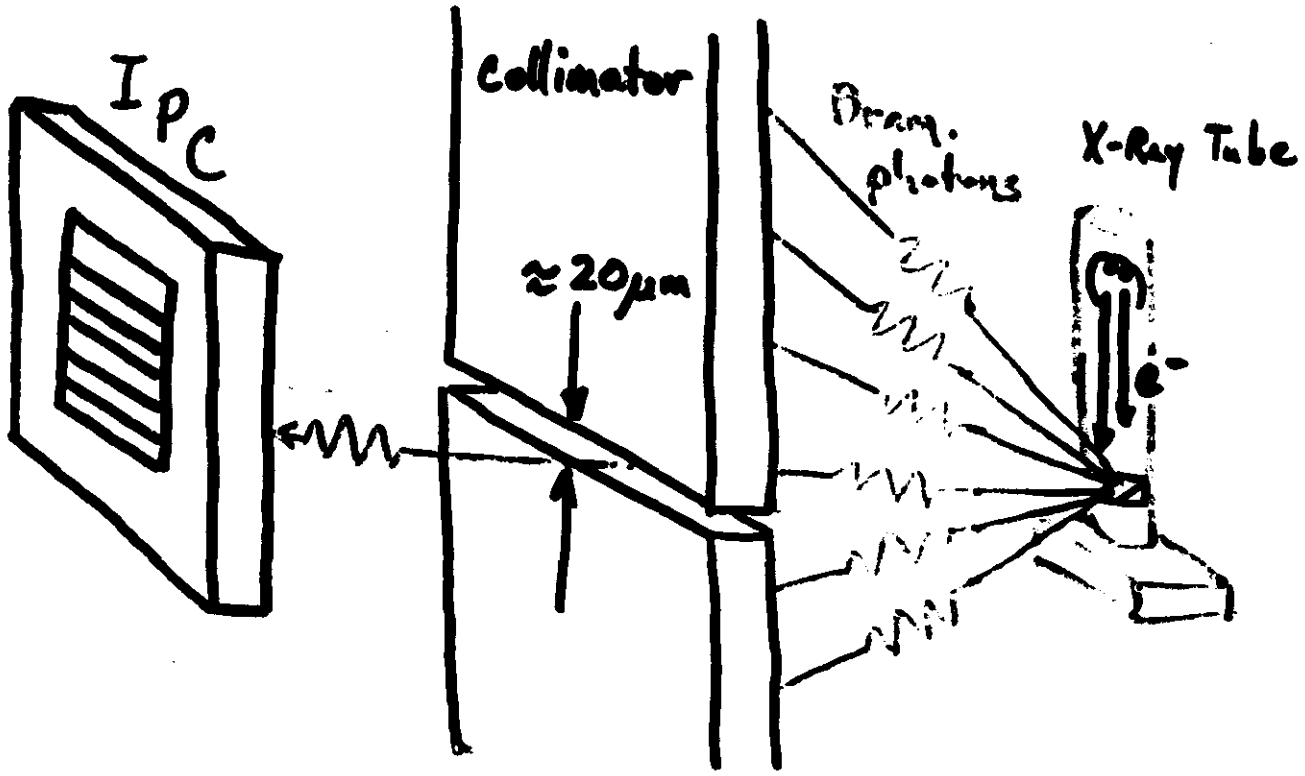


Pad Board



Chamber Vital Statisics

Sensitive area	60 mm X 60 mm
Chamber thickness	4 mm
Anode wire pitch	2 mm
Anode-cathode separation	2 mm
Cathode inter-strip separation	75 μm
Cathode strip size	2.5 mm X 60 mm
Number of cathode pads	24
Anode wire	20 μm dia. Gold/Tungsten
Top (non-readout) cathode composition	70 nm Gold / 50 μm Kapton
Bottom (readout) cathode composition	Au / 18 μm Cu / 0.5 mm G10
Chamber wall composition	G10



Position Resolution with X-Rays

Advantages of X-Rays:

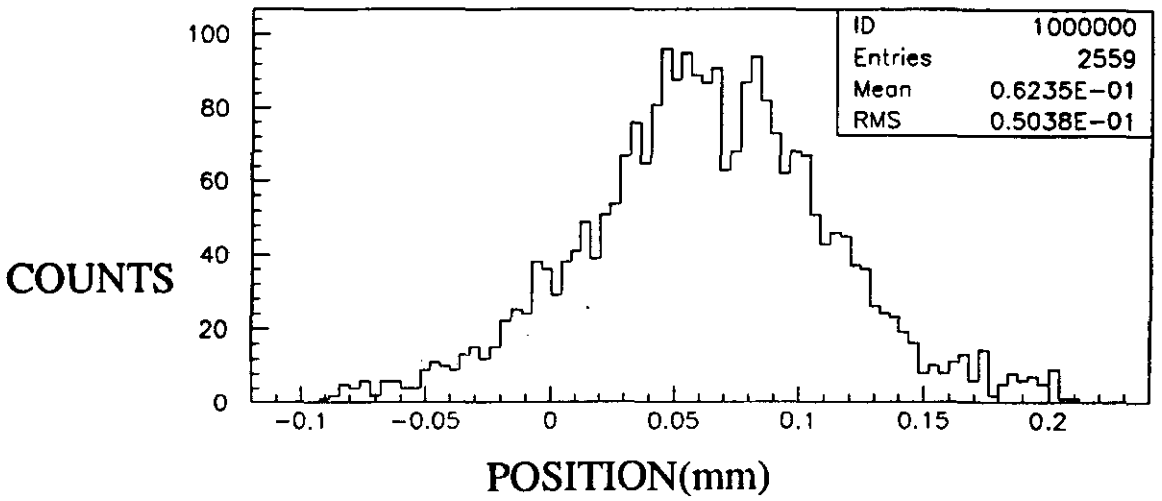
1. High Flux.
2. Continuum and Line sources.
3. Easily Collimated.
4. Tests can be performed in a Laboratory (i.e. don't need accelerator).

Disadvantages of X-Rays:

1. Localized ionization, unlike long trail left by MIP.
2. Photoelectron & Auger electron paths can be long and are in random directions.

Choice of X-Rays for our tests:

1. Vanadium K line (4.95 keV) for P10 gas.
2. Tungsten Continuum, with software energy cuts at $1.5<E/keV<2.5$.
3. Rectangular Collimator (20μm × 75μm approximate size) all tests.



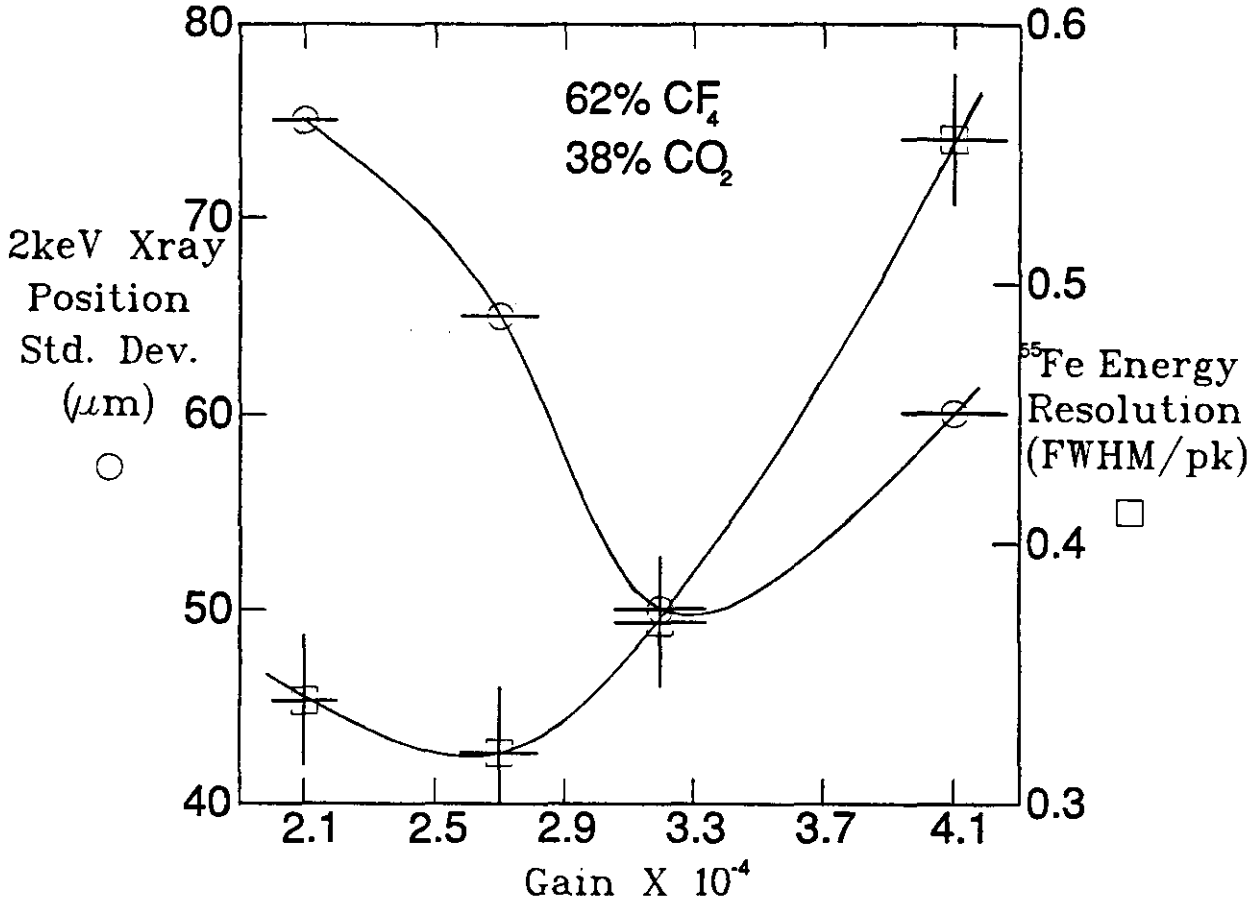
Test Conditions:

1. Bremstrahlung X-rays from Tungsten tube.
2. 20 μm wide slit collimator.
3. Prototype fast front end electronics.
4. LeCroy 2249W ADC.
5. Pulse height for 3 cathode pads and summed anode recorded.

Analysis Procedures:

1. Cut on event anode energy 1.5<E/(keV)<2.5 to simulate MIP. (Energy calibration from Fe-55).
2. Cut events with very low or very high ADC values.
3. Use 3 parameter fit to Mathieson Distribution to determine individual event locations.

NOTE: <u>No</u> corrections made for: collimator width, Photoelectron Range (25-80 μm), or electronics noise.



Resolution vs. Gas Gain

Gain Determination:

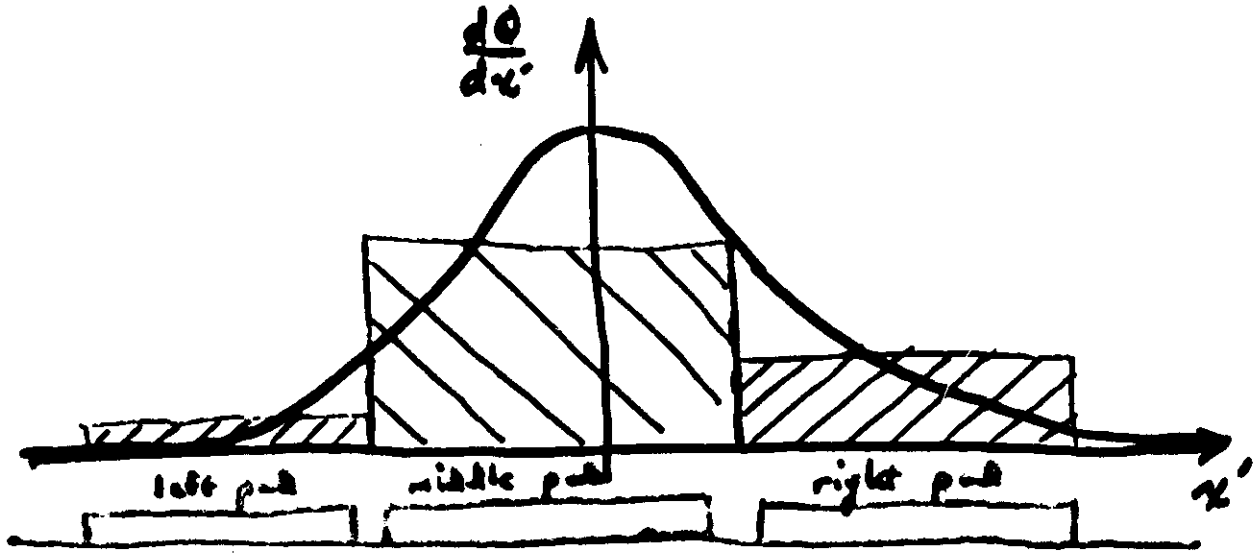
1. Assume Q(in) = E(X-ray) / 34eV
2. Q(out) is found from Oscilloscope Pulse in 2 ways:
   a. Q(out) = Pulse Ht (V) / Capacitance
   b. Q(out) = Pulse Area (V-s) / Resistance Load (Ω)

Energy Resolution determined from MCA pulse height spectrum.

Position Resolution determined from RMS of distribution for single point (collimated) X-rays with 1.5<E/(keV)<2.5 cut.

Cathode Charge Distribution

(from Mathieson, Gordon, Thompson + NIM articles)



$$\frac{dQ}{dx'} \propto \frac{1-\tanh^2(Kx')}{1+K'\tanh^2(Kx')}$$ "Mathieson Distribution"

TRADITIONAL ANALYSIS TECHNIQUE

$$x' = \frac{\sum_{\text{pads}} Q_i x_i'}{\sum_{\text{pads}} Q_i}$$

x_i': ith pad center

Q_i: charge on ith pad

x': event position

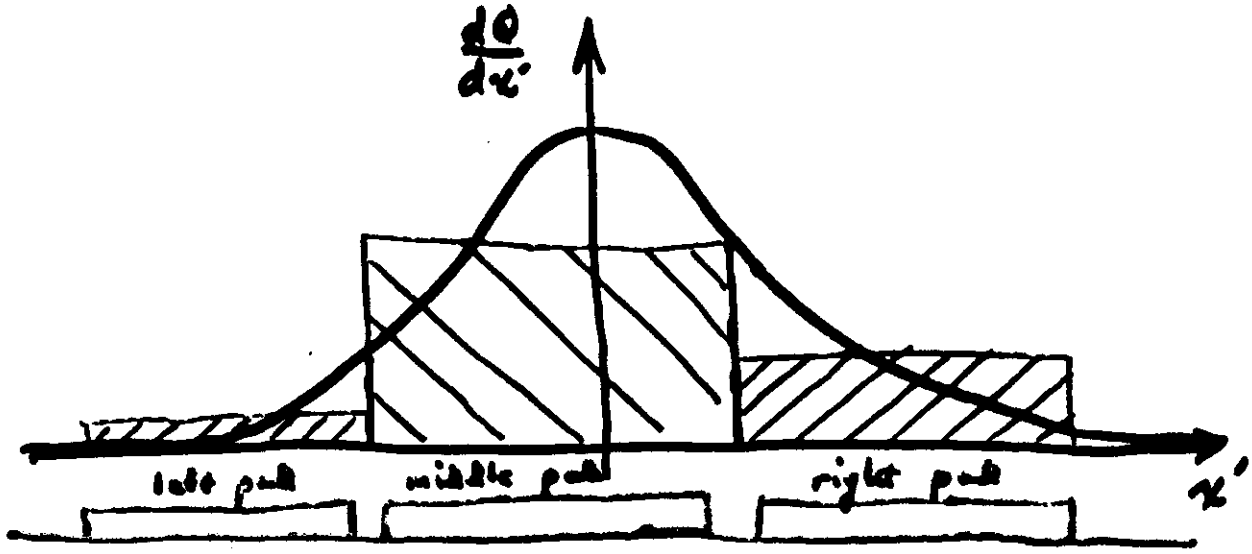
"Center of Mass" or "Weighted Average"

inaccurate because:

1. Missing Charge (strong effect)
2. Finite Sampling Size (weak effect - offsetting)

Cathode Charge Distribution

(from Mathieson, Gordon, Thompson 4 NIM articles)



$$\frac{dQ}{dx'} \propto \frac{1-\tanh^2(Kx')}{1+K'\tanh^2(Kx')}$$ "Mathieson Distribution"

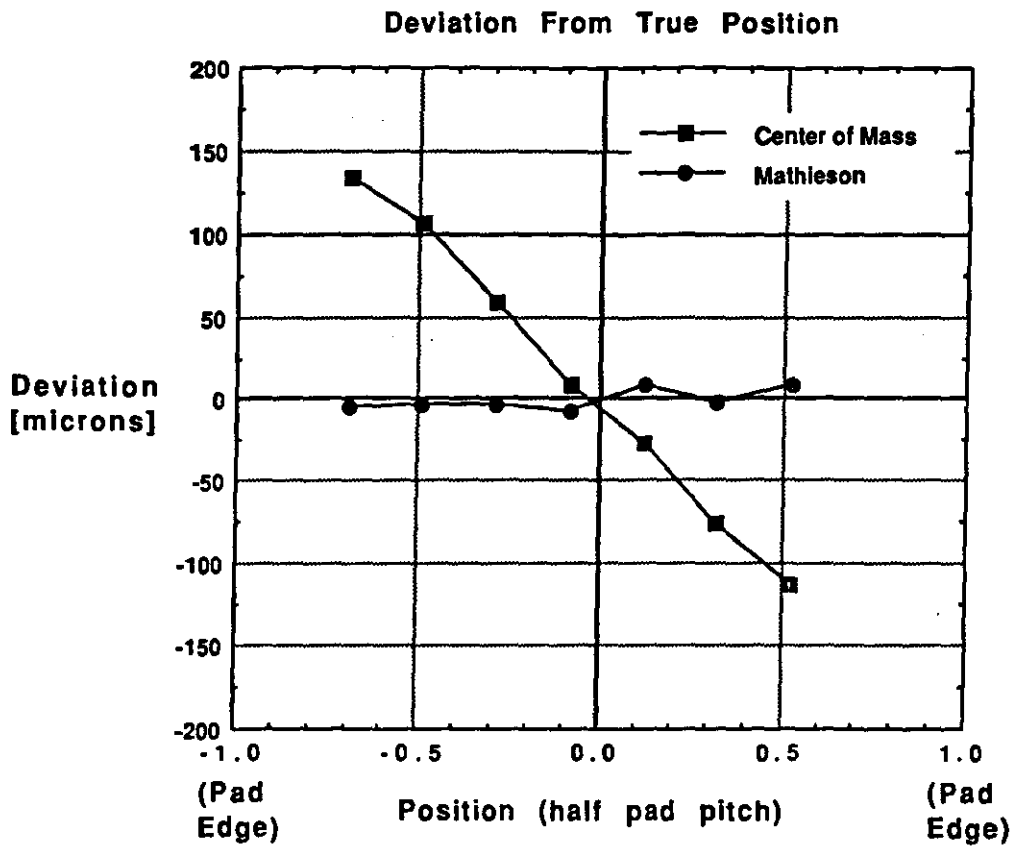
ALTERNATE ANALYSIS TECHNIQUE

3 parameter (iterative) fit to Mathieson Distr.

parameters:

1. Distribution height $\propto Q_{total}$ (anode)
2. Distribution width $\propto K$
3. Distribution centroid = position of event

"paydirt"



Linearity Tests

Test Conditions:

1) True position measured with micrometer (0.010 in. steps).
2) Pad pitch = 2.5 mm (= 2.425 mm pad + 0.075 mm gap).
3) Three pads (only) used to determine event position.
4) Random RMS uncertainty in measured positions = 3 μm.
5) RMS deviation of Mathieson fit points from true = 6 μm.
6) P10 gas, 5keV x-rays, and slow electronics used.

Comments:

1) Events close to pad edge not plotted due to a pad near pedestal.
2) Center of Mass analysis better if 4 pads used.
3) Electronics calibration is critical.

Resolution Summary

A. Results:

1. Single position repeatability tests: $< 50\ \mu m$ RMS.

2. Linearity tests (deviation of average position from true position): $< 10\ \mu m$ (approx. 800 evts).

B. Weakness of study:

1. Used X-rays, not MIPs.
2. No magnetic field.

C. Future work:

1. Cosmic Ray Muons (in progress).
2. Magnetic field (setup complete).
3. High energy beam (in planning stage).

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Presentation by:

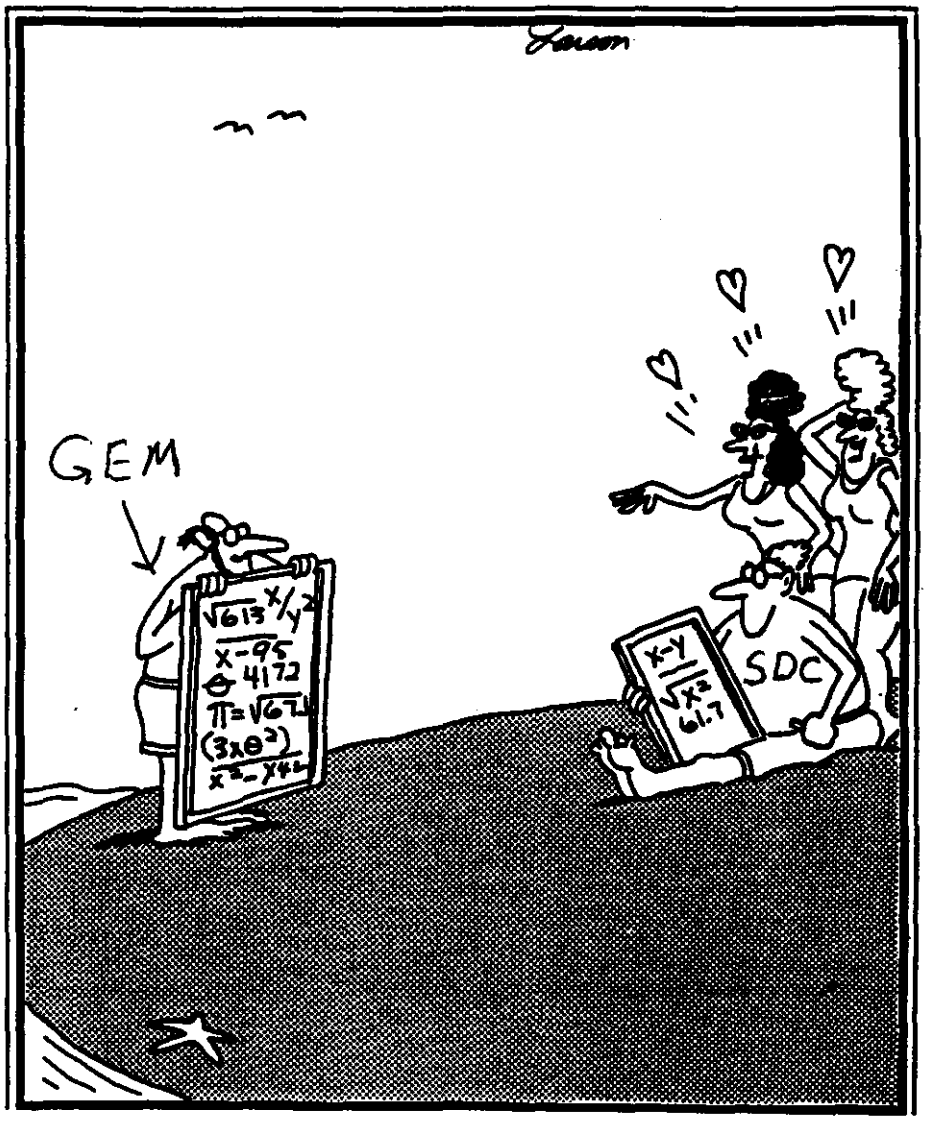
E. Prebys

Dynamic Range and Zero Suppression Studies for the GEM Liquid Argon/Krypton Calorimeter

Eric Prebys, Princeton University

December 10, 1992

GEM Council Meeting, Dallas, TX



Dynamic Range Studies

- Goal: To determine the dynamic range needed by both the electromagnetic and the hadronic calorimeters

- Low End of Dynamic Range: Total thermal and pileup noise $/\sqrt{2}$[1]
  - $\approx$ 25 MeV for the Electromagnetic Calorimeter
  - $\approx$ 140 MeV for the Hadronic Calorimeter

[1] To take into account the longitudinal segmentation.

What about minimum ionizing particles?

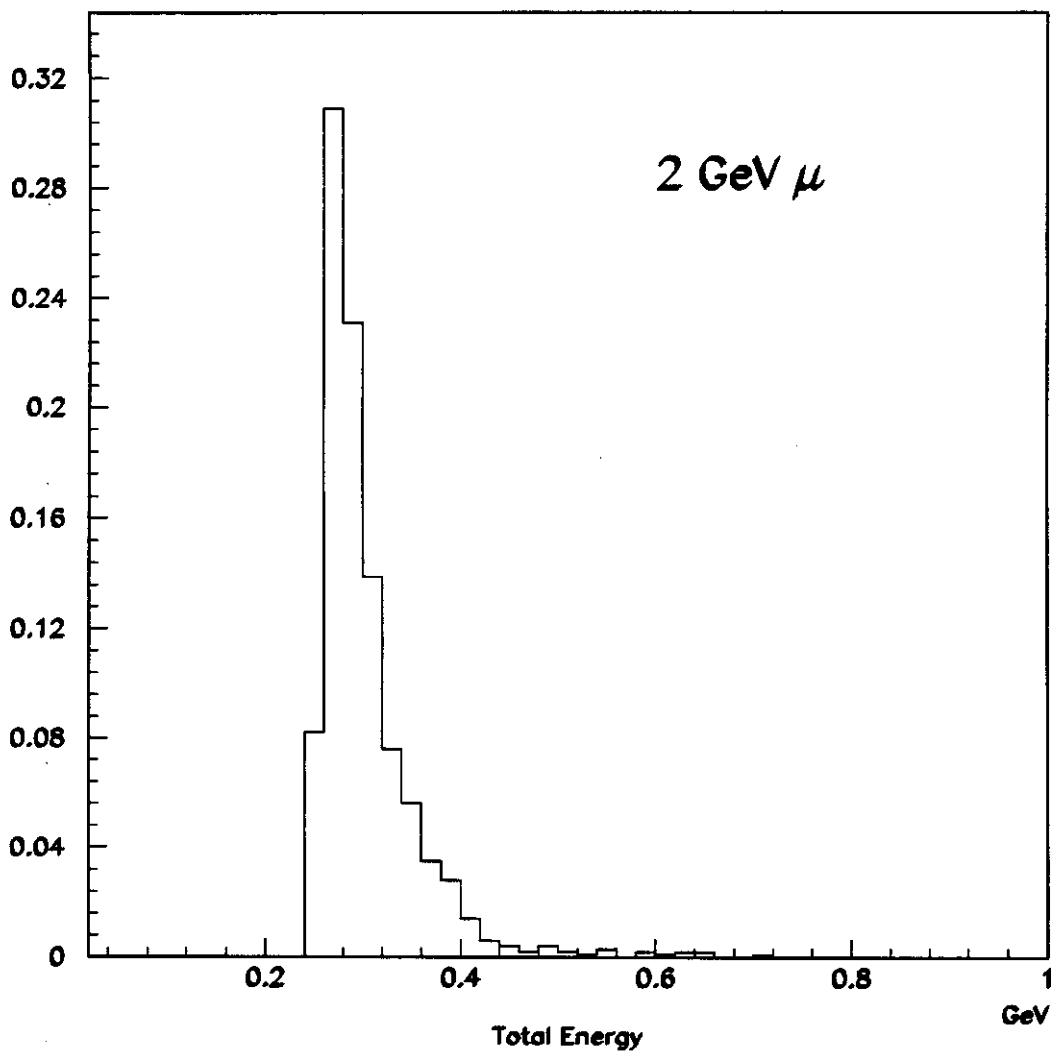


Figure 1: Total energy deposited by muons in the electromagnetic calorimeter.

High End of Dynamic Range for EM Calorimeter

Use decays of the form

$$Z' \to e^+e^-$$

Choose

$$M(Z') = 12 \text{ TeV}$$

because, assuming "standard" couplings, this gives 10 events in one year at $10^{34}\text{s}^{-1}\text{cm}^{-2}$ luminosity.

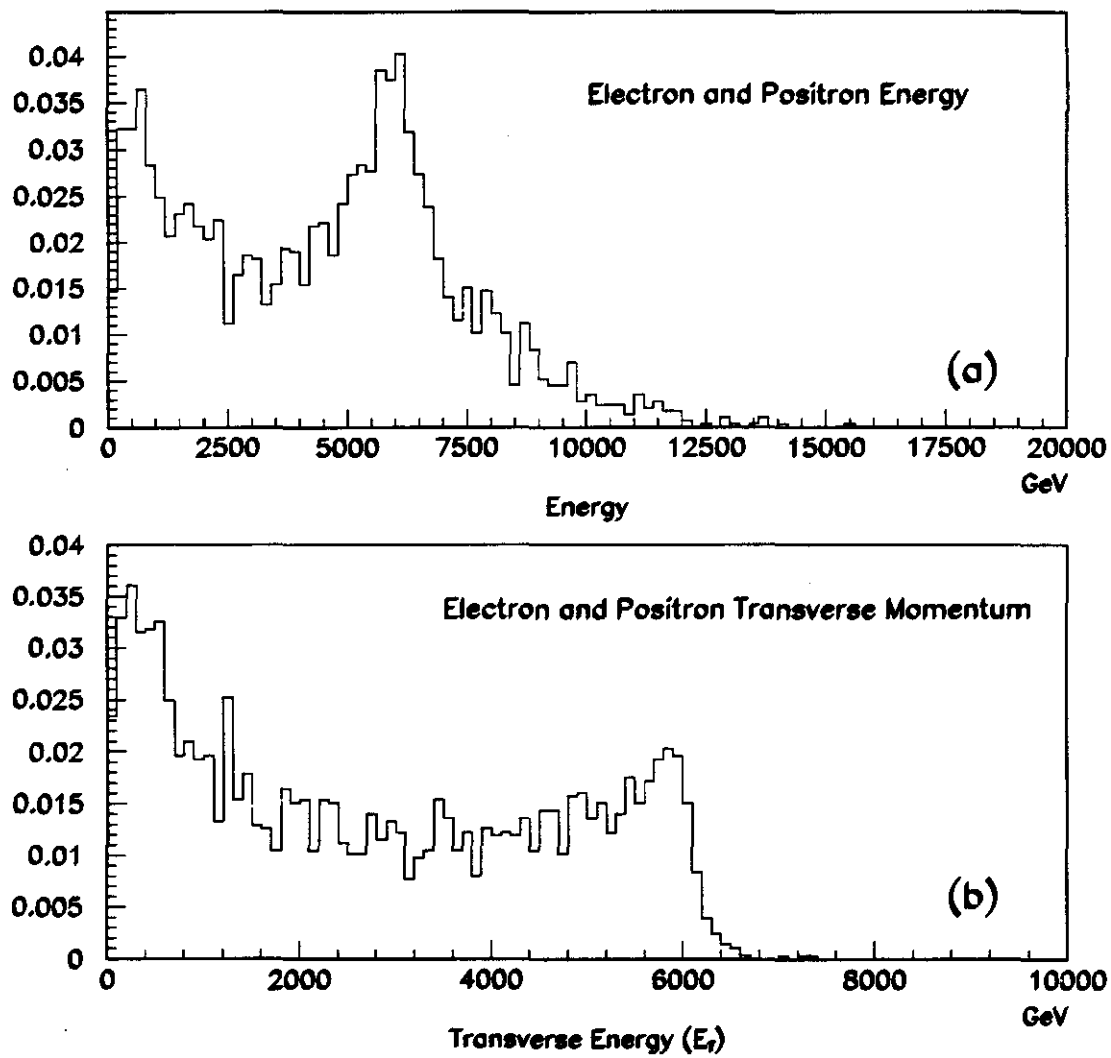


Figure 2: (a) Total energy and (b) transverse momentum of electrons and positrons originating from the decay of a 12 TeV Z'.

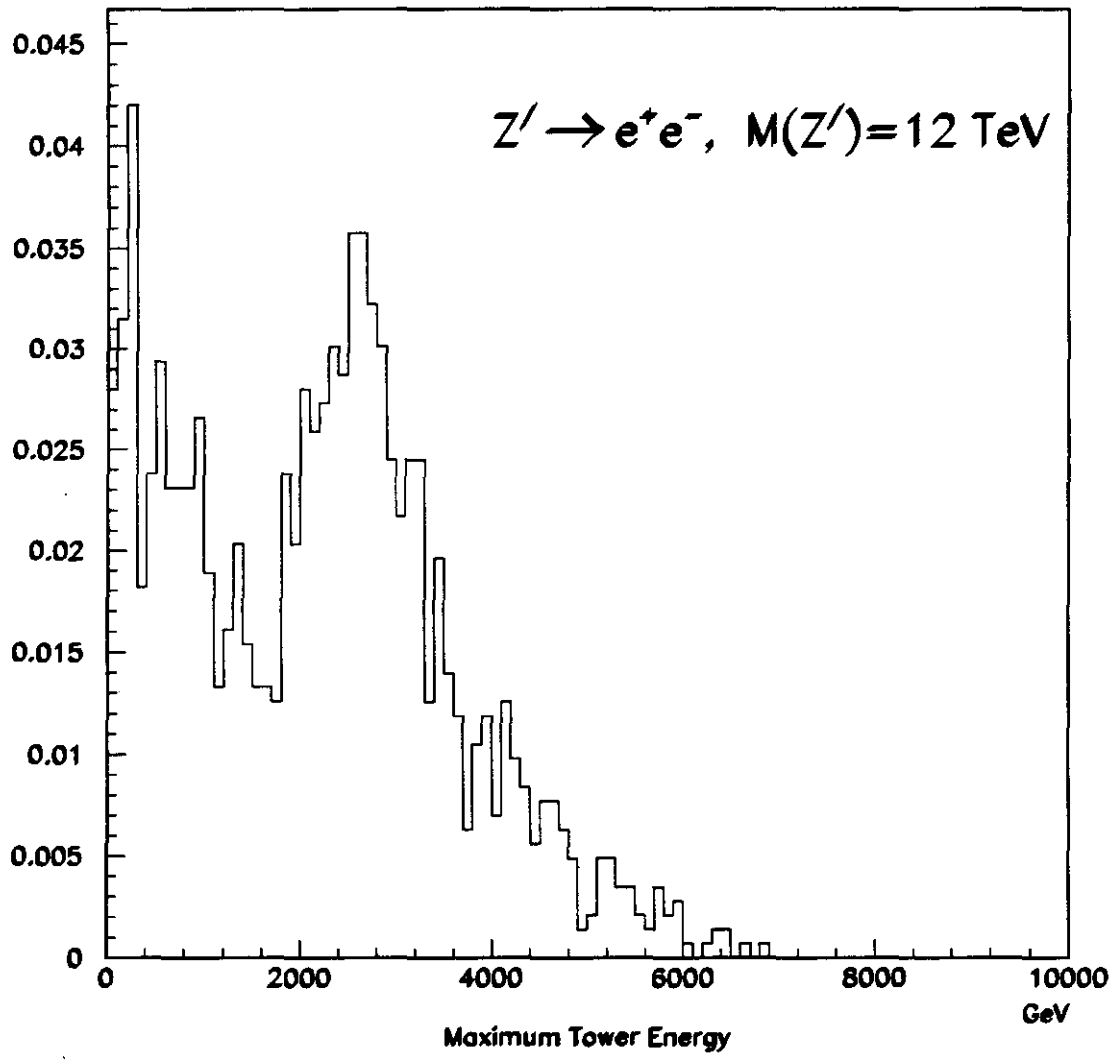


Figure 3: Highest energy in any electromagnetic tower for massive $Z' \rightarrow e^+e^-$ decays.

High End of Dynamic Range for Hadronic Calorimeter

Use high-p_T two jet events

Choose

$$p_T > 8 \text{ TeV}$$

because the standard model predicts roughly 100 events in this range in one year at $10^{34}\text{s}^{-1}\text{cm}^{-2}$ luminosity $\rightarrow$ enough to detect discrepancies (eg. compositeness).

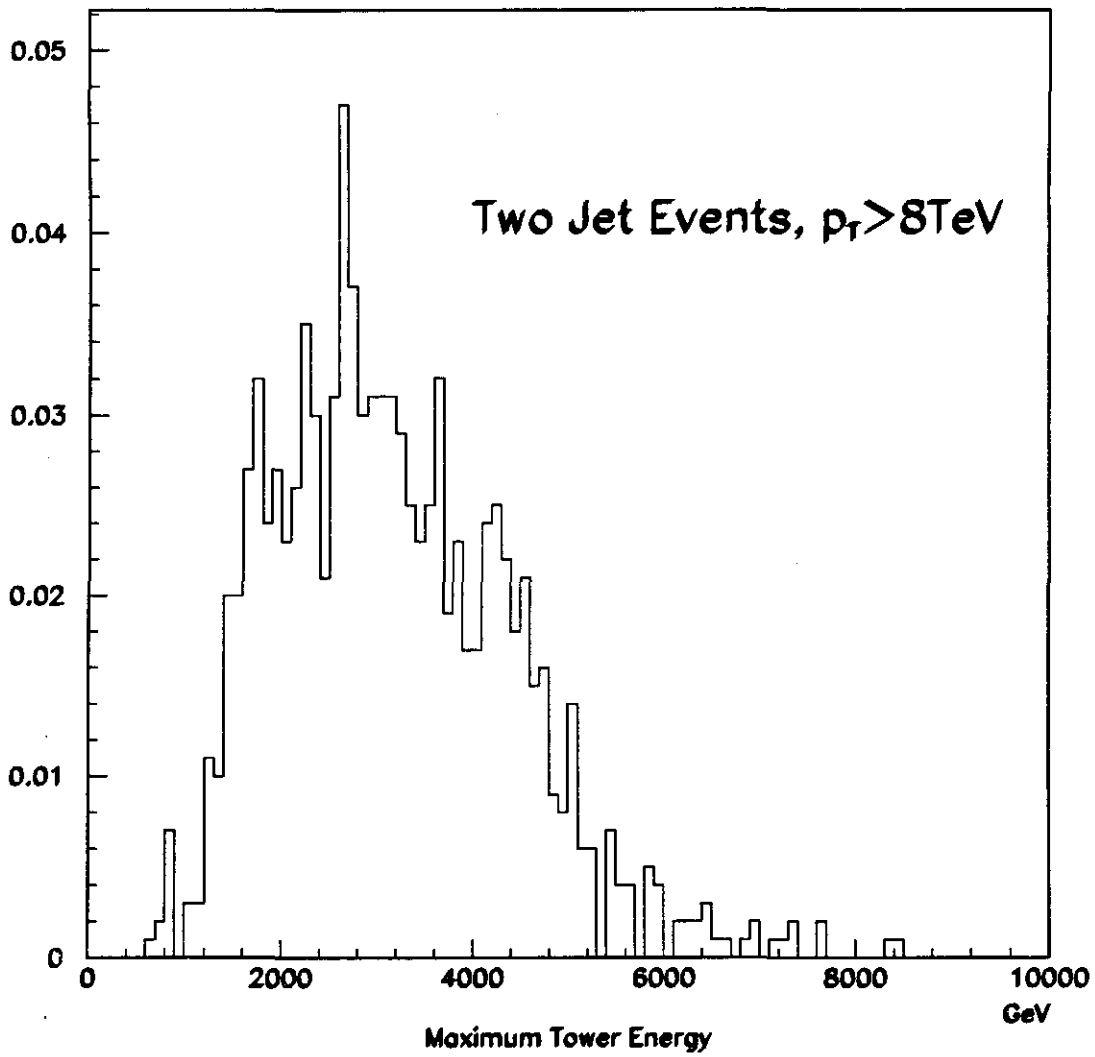


Figure 4: Highest energy in any hadronic tower for high-$p_T$two jet events.

Summary of Dynamic Range Studies

Electromagnetic Calorimeter

$$\textbf{range} = \frac{6000}{.025} \times \frac{6}{5} \approx 288000 \approx \textbf{18bits}$$

Hadronic Calorimeter

$$\textbf{range} = \frac{6000}{.140} \times \frac{6}{5} \approx 51400 \approx \textbf{16bits}$$

Implementation of 18-bit Dynamic Range

Probably will use a preamp with a non-linear (dual-linear) response in conjunction with a dual range ADC. If so, the worst effect on the relative resolution will come at two points

1. At then end of the lower range, where the resolution will effectively be given by the "overlap bits"

$$N^{bits}_{overlap} = 2N^{bits}_{ADC} - N^{bits}_{range}$$

   e.g. two 12 bit ADCs covering a 16 bit dynamic range have 8 bits of resolution at the cross-over.

2. At the break in the linearity, where the resolution will be

$$\frac{\Delta E}{E}\Big|_{E_{BREAK}} = \left(\frac{1}{E_{BREAK}}\right)\left(\frac{E_{MAX} - E_{BREAK}}{2^{N_{BIT}} - E_{BREAK}/E_{LSB}}\right)$$

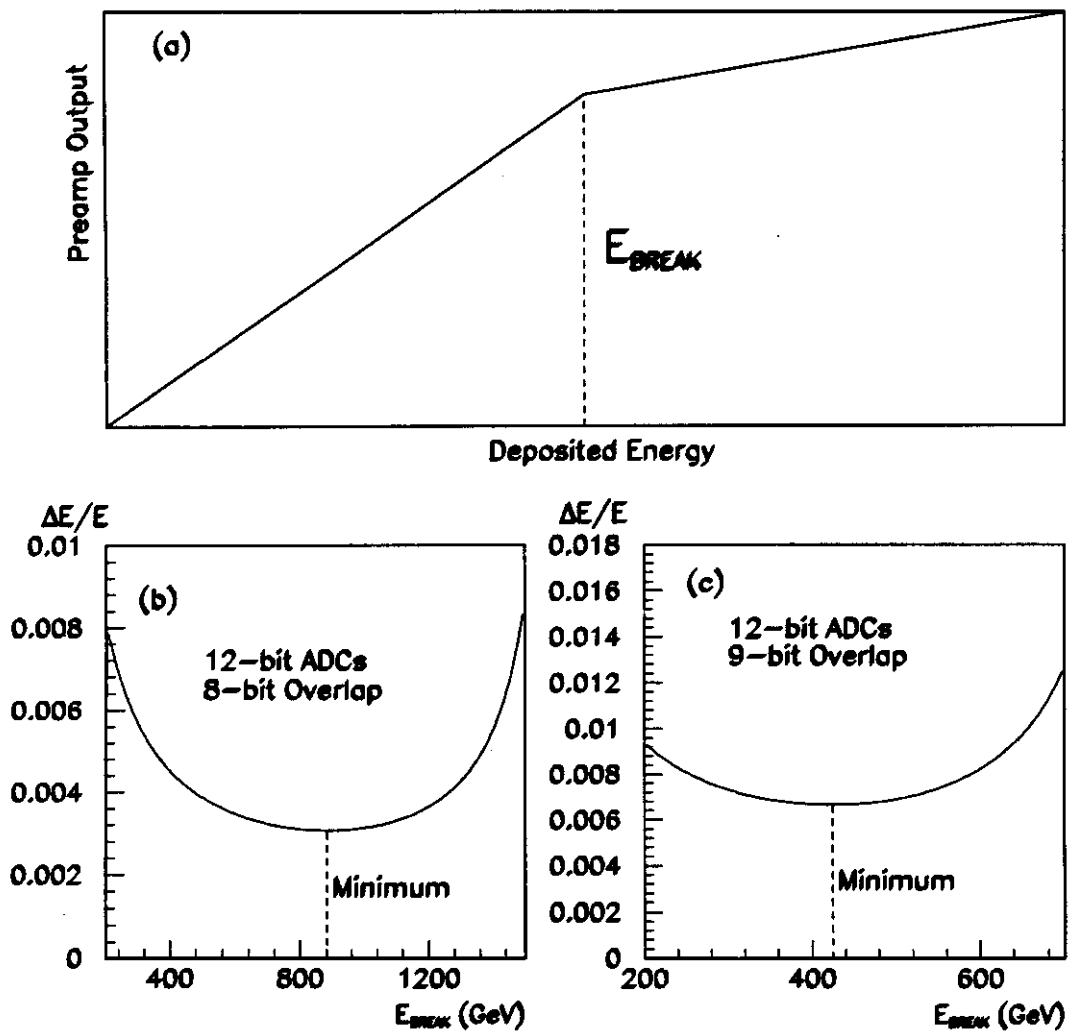


Figure 5: Effect of preamp nonlinearity on quantization error. The nonlinear preamp curve envisioned for GEM is shown in (a). The relative quantization error at the "break" is shown as a function of the break energy for the case of dual range 12-bit ADCs with (a) 8-bit and (b) 9-bit overlap.

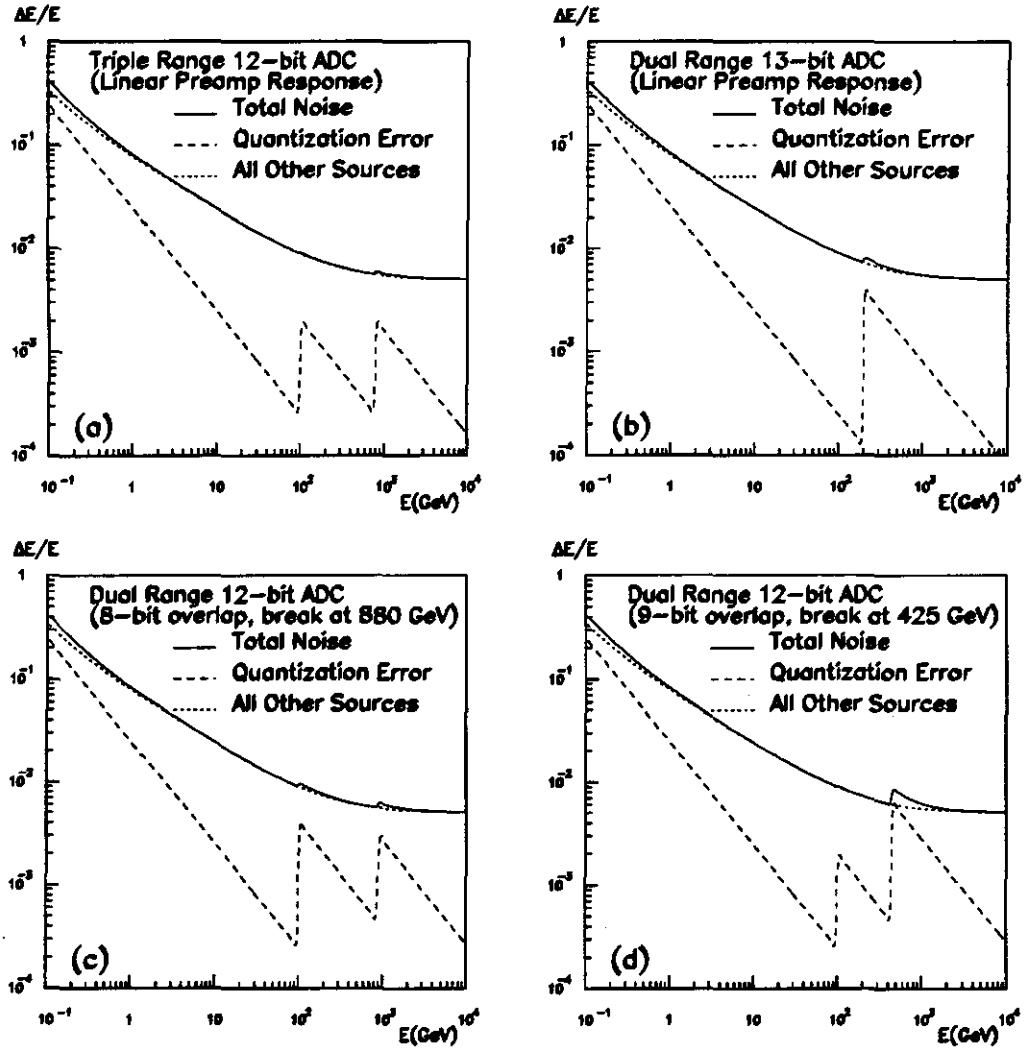


Figure 6: Conribution to the total energy uncertainty from quantization errors for: (a) triple-range 12-bit ADCs with linear preamp response; (b) dual-range 13-bit ADCs with linear preamp response; (c) dual range 12-bit ADCs with 8-bit overlap and a break in the preamp response at 880 GeV; and (d) dual range 12-bit ADCs with 9-bit overlap and a break in the preamp response at 425 GeV.

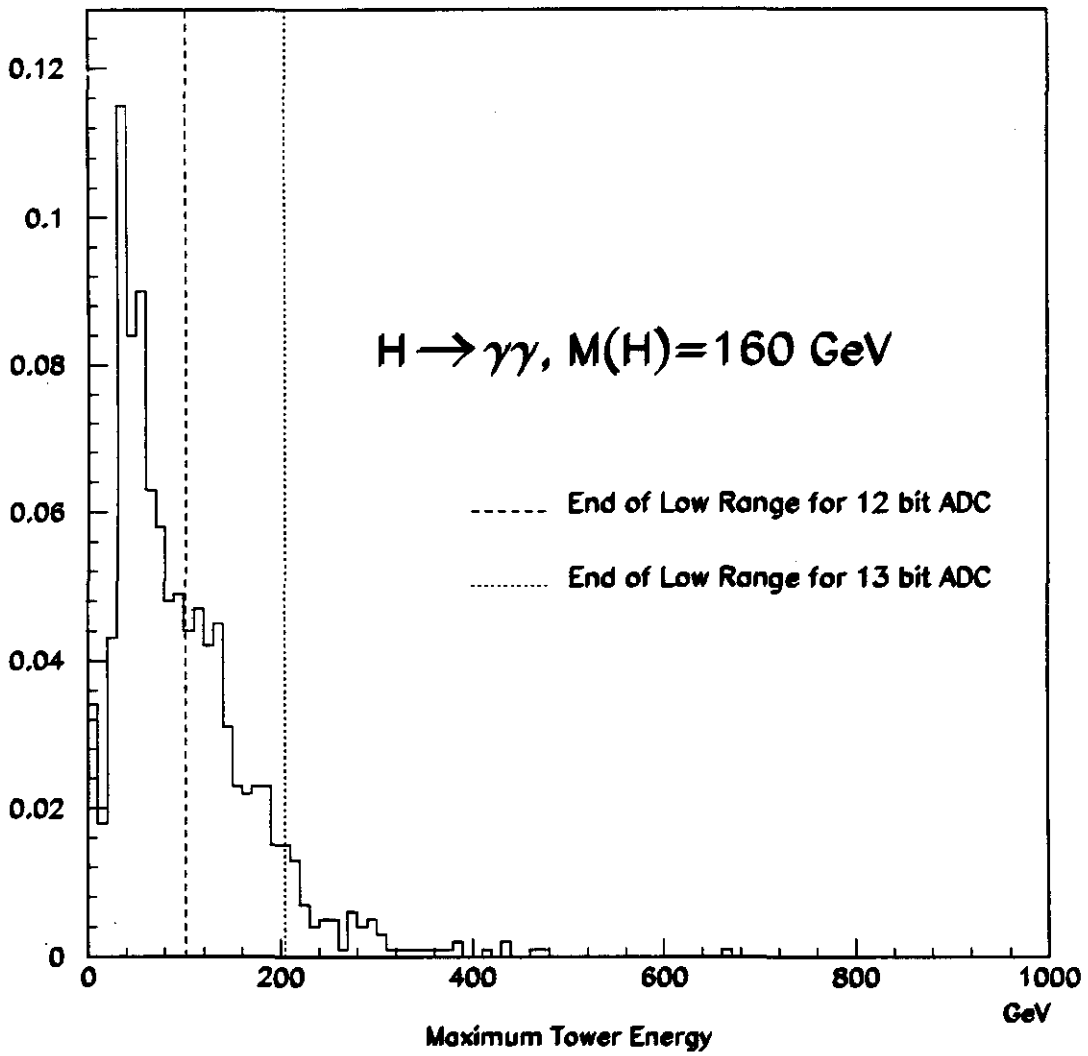


Figure 7: Highest energy in any electromagnetic tower for $H \rightarrow \gamma\gamma$ decays.

Zero Suppression Studies

It is unlikely that the entire calorimeter can be read out at the level one trigger rate, so some sort of zero suppression will have to be done. The two questions to be answered are

1. What is the best zero suppression scheme to reduce data volume while still maintaining data quality?
2. Are the zero-suppressed data adequate for the final analysis?

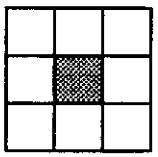
Several zero-suppression schemes are evaluated in the following areas

- Effect on the total data volume
- Effect on the energy resolution and linearity
- Effect on the position resolution
- Effect on the missing E_T
- Effect on $E_{3\times3}/E_{5\times5}$ (still in progress)

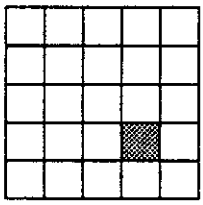
Zero Suppression Schemes

- *Scheme 1-* The simplest zero-suppression. Read out only those channels for which the absolute value of the signal is above a certain threshold.

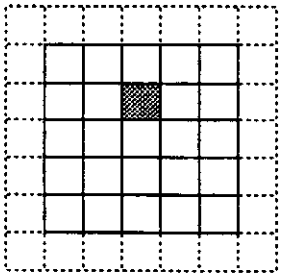
- *Scheme 2-* If a given channel is above threshold, all neighboring channels (front and back) are read out. Perhaps difficult to implement in practice, particularly at the boundaries between readout modules.



- *Scheme 3-* If any channel is above a given threshold, all the channels in its 5×5 readout module are read out, front and back.



- *Scheme 4-* This is somewhat like the last scheme, except that in addition to the readout cell containing the above-threshold channel, the bordering rows from the adjacent cells are read out.



Monte Carlo Simulation

Zero suppression schemes are evaluated in the following way

1. A sample of minimum bias events is used to determine the data suppression factor as a function of some appropriate threshold.

2. Photons are generated at discreet energies (1, 5, 10, and 50 GeV) to study the effect of a given scheme on data quality (resolution, linearity, etc.) as a function of the data suppression. Photon position is varied to uniformly illuminate a tower.

In all cases, full GEANT simulations are used, with thermal noise added in as a gaussian and pileup noise is added in using a sample of minimum bias events convolved with the event of interest based on 1.6 interactions/crossing.

Photon energies are taken to be the 5×5 sum around the peak and position is calculated from a corrected center of gravity.

Effect on Data Volume

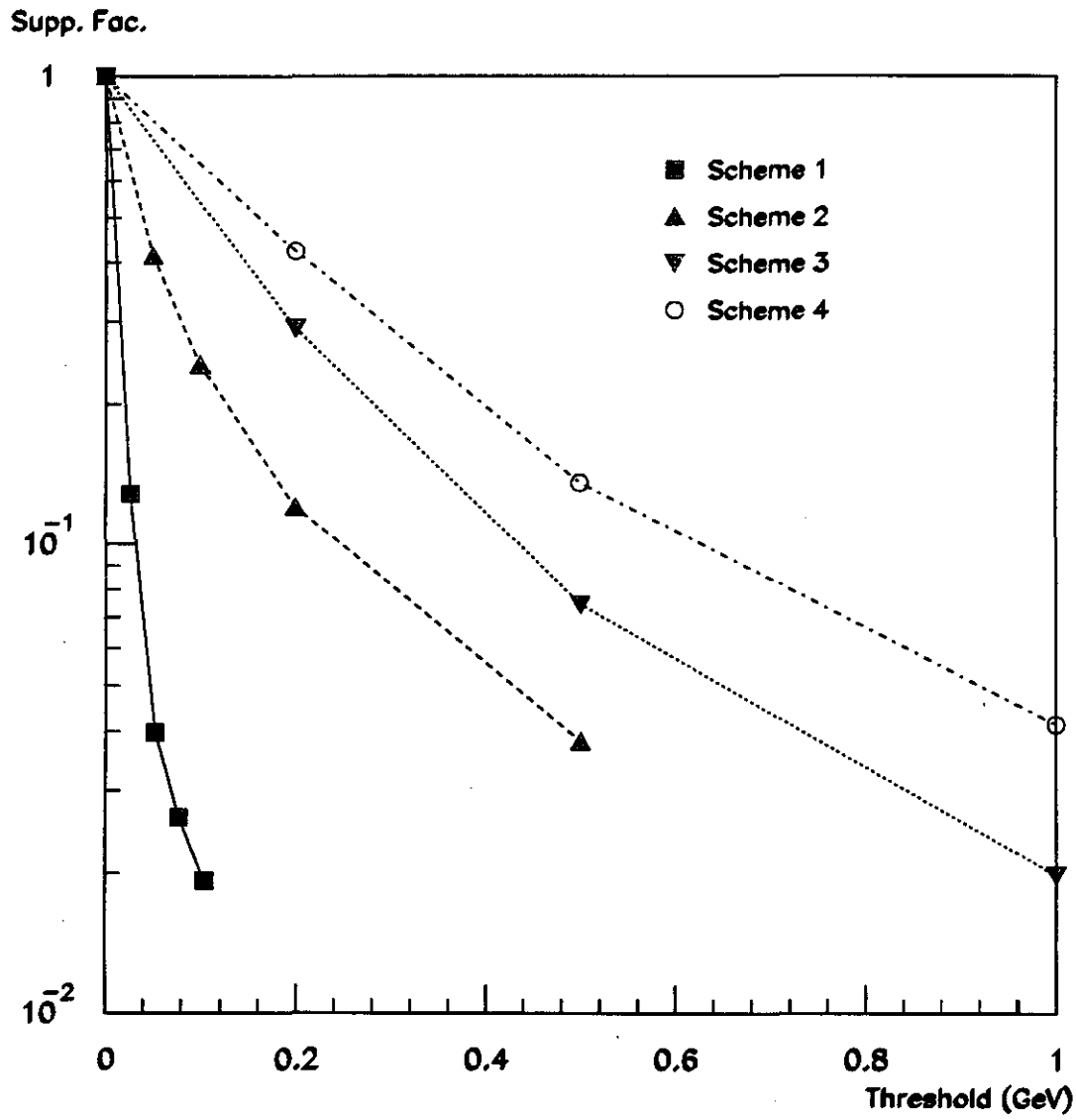


Figure 8: Zero suppression factor vs. zero suppression threshold for the various schemes discussed.

Effect on Energy Resolution

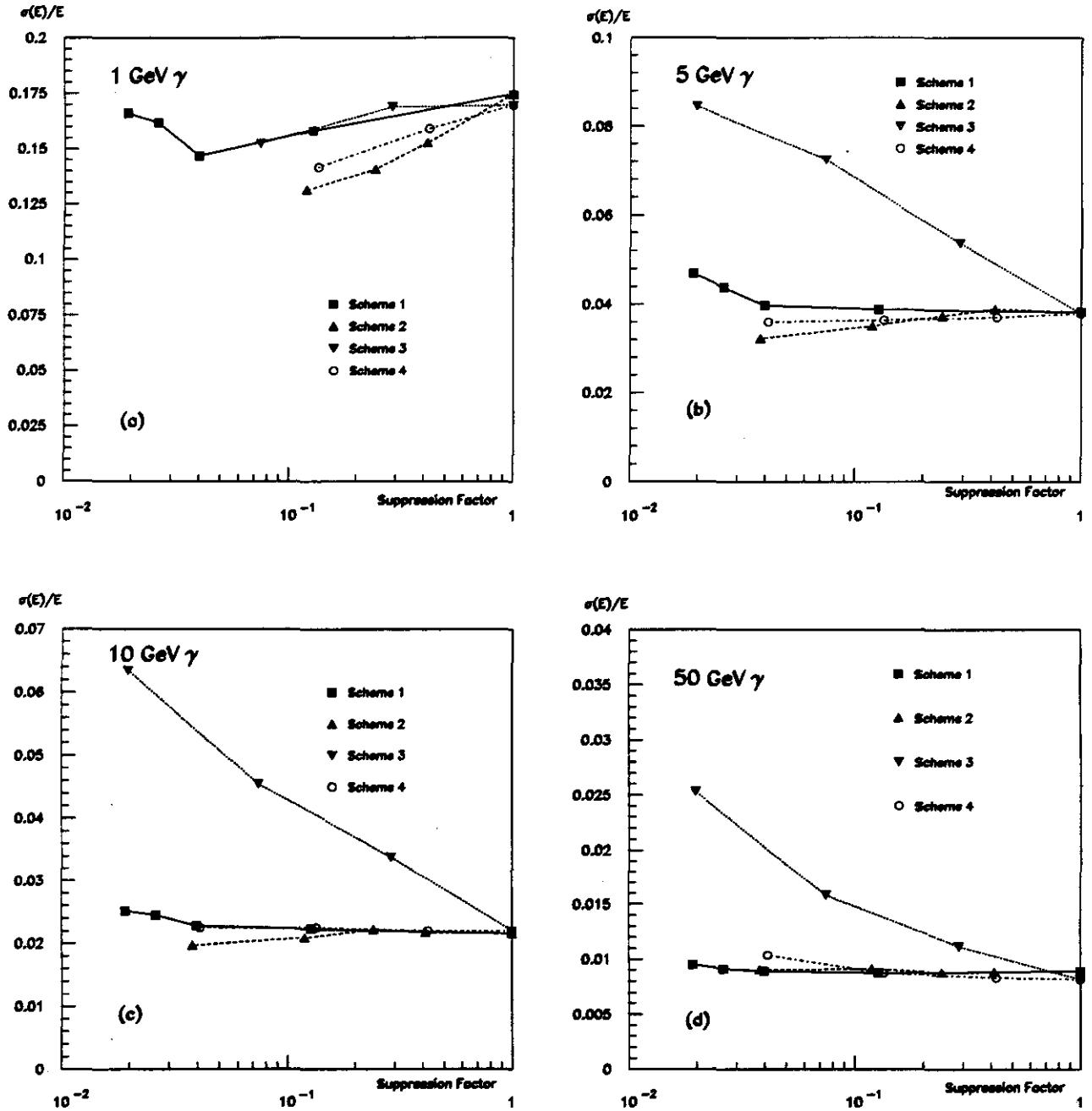


Figure 9: Energy resolution vs. zero suppression factor for various suppression schemes with (a) 1 GeV; (b) 5 GeV; (c) 10 GeV; and (d) 50 GeV photons.

Effect on Linearity

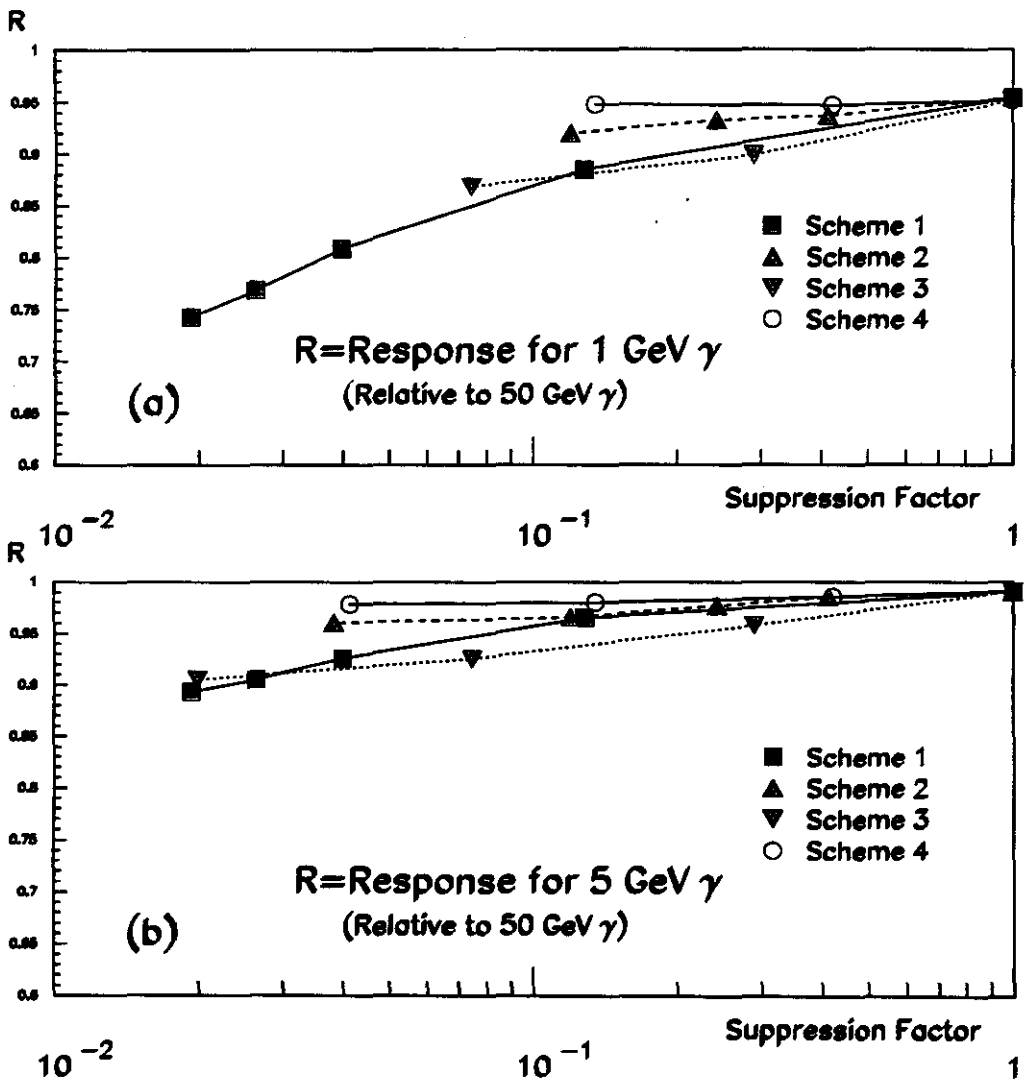


Figure 10: The effect of zero suppression on the linearity of (a) 1 GeV and (b) 5 GeV photons, relative to 50 GeV photons. See text for details.

Position Resolution Optimization

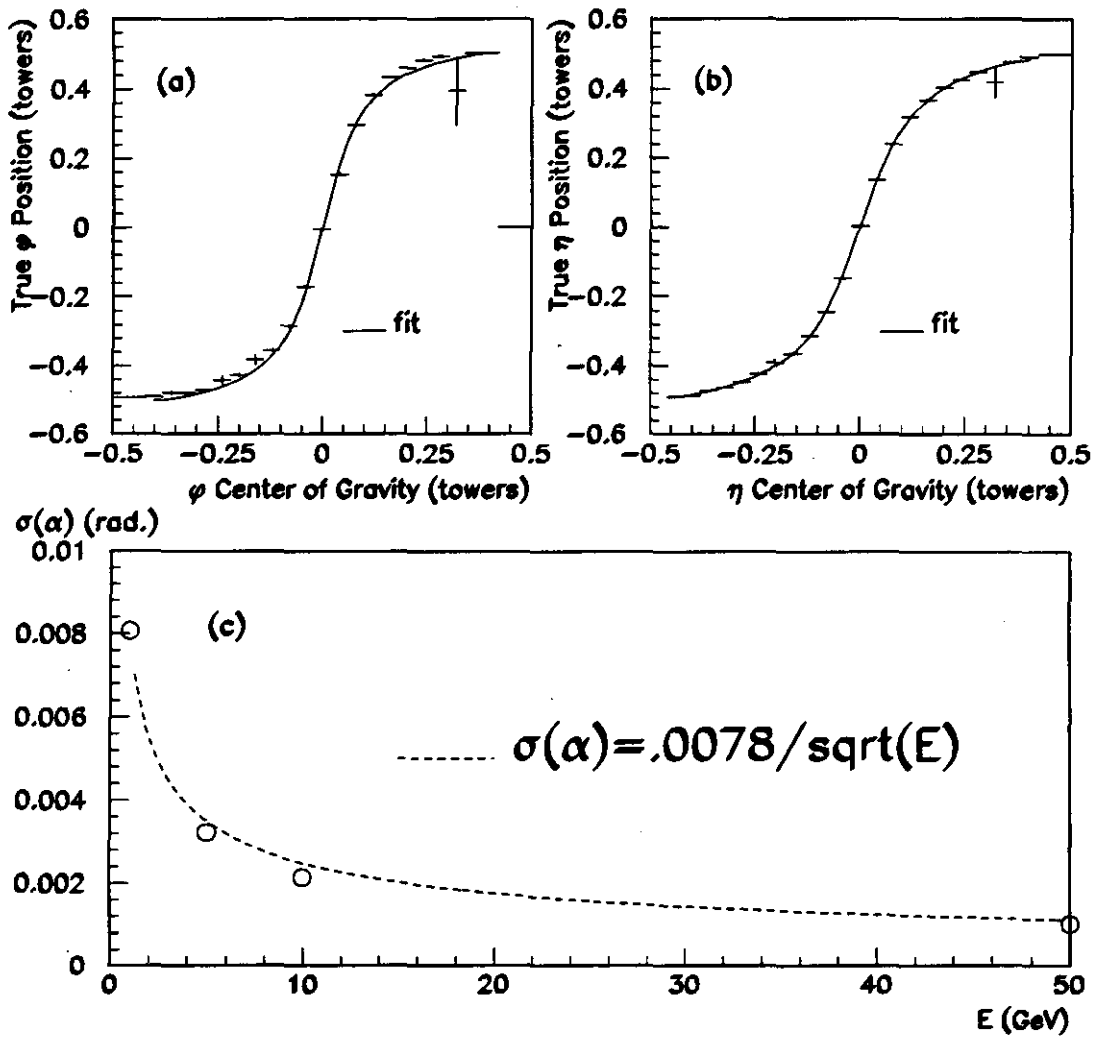


Figure 11: Corrected position resolution. The true position versus the center of gravity position for (a) ϕ and (b) η. These fits are used to obtain the true position from the weighted mean. The plot (c) of $\sigma(\alpha)$ ($\alpha^2 = (\Delta\phi)^2 + (\Delta\theta)^2$) versus E is also shown.

Effect on Position Resolution

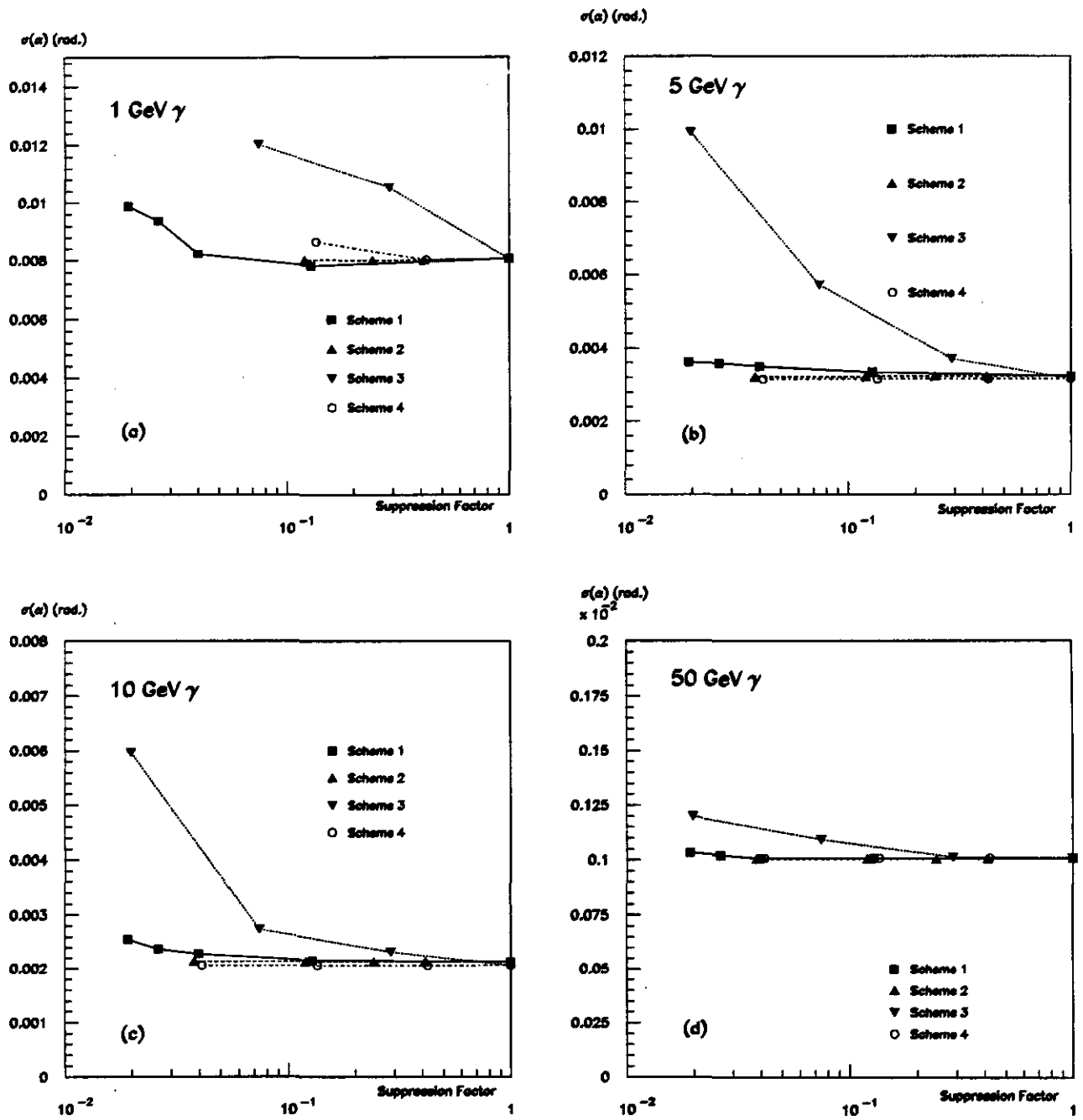


Figure 12: Effect of zero suppression on the position resolution for photons. Results are shown for (a) 1 GeV; (b) 5 GeV; (c) 10 GeV; and (d) 50 GeV photons.

Effect on Missing E_T

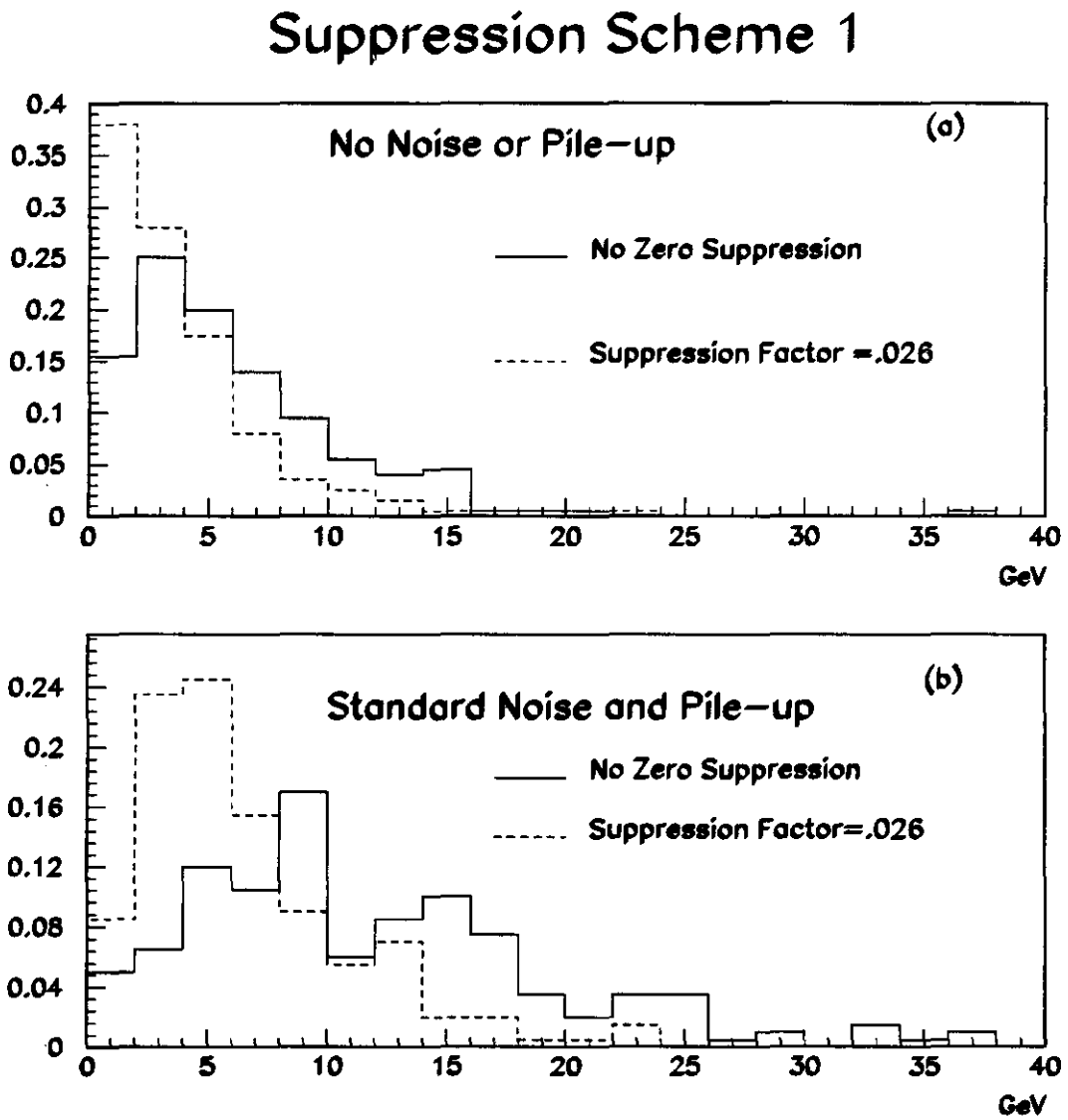


Figure 13: Effect of zero suppression on the total missing E_T spectrum (a) without and (b) with thermal and pileup noise simulated. The effects of scheme 1 zero suppression are shown by the superimposed histograms.

Zero Suppression Conclusions

Based on these studies, it is clear that one can achieve a reduction factor of greater than 10 with several zero suppression schemes without greatly sacrificing resolution or linearity. It also appears that the missing E_T resolution is not drastically compromised. Of the schemes studied, it appears that the most attractive is the most basic - namely the scheme in which one simply reads out channels satisfying a certain threshold. This scheme allows one to achieve reduction factors of up to 50 without greatly impacting the quality of the data. At lower reduction factors, the simple scheme shows similar or superior behavior to the other schemes. A threshold equivalent to about 2σ, which gives a reduction of about 20, appears to be optimal.

gem

γeμ

Presentation by:

H. Takai

Precision Timing with Liquid Ionization Calorimeters

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], J. Rabel[7], 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 11530
2. University of Arizona, Tucson, AZ 85721
3. Brookhaven National Laboratory, Upton, NY 11973
4. Budker Institute for Nuclear Physics, Novosibirsk, Russia
5. Columbia University, New York, NY 15633
6. Oak Ridge National Laboratory, Oak Ridge, TN 37831
7. University of Pittsburgh, Pittsburgh, PA 15260
8. SUNY at Stony Brook, Stony Brook, NY 11794
9. Tel-Aviv University, Tel-Aviv, Israel

OUTLINE

1. Introduction
2. Discriminator
3. Data Collection
4. Offline Corrections
5. Results and Conclusions

- Good timing from calorimeters:

  ⟶ unique assignment of an event to a particular beam crossing at SSC or LHC (bunch spacing ~ 10ns)

- Conventional Wisdom :

  "Scintillators are *fast*; PMT have sharp signal"
  therefore : Good Timing!

- However,

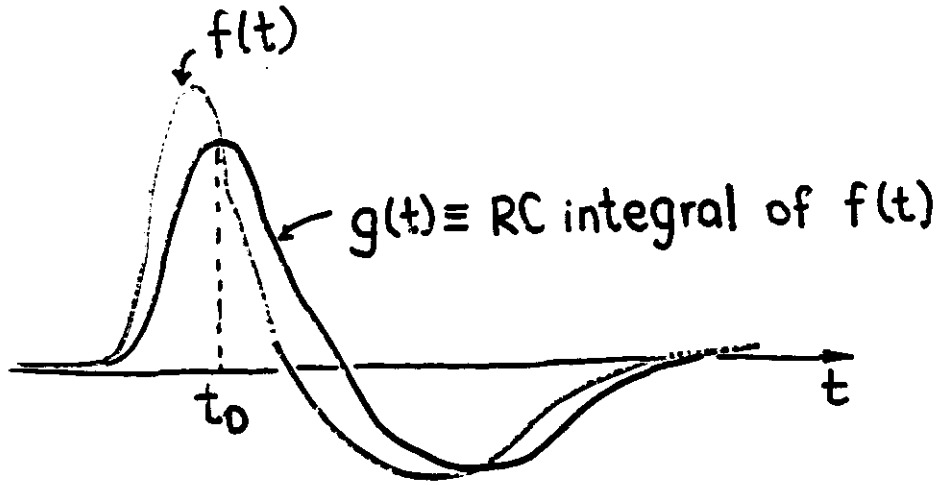
  Liquid ionization calorimeters have:

  - very uniform waveform
  - very low fluctuations (3×10^6 e^-/GeV)

  ⇒ good timing is possible!

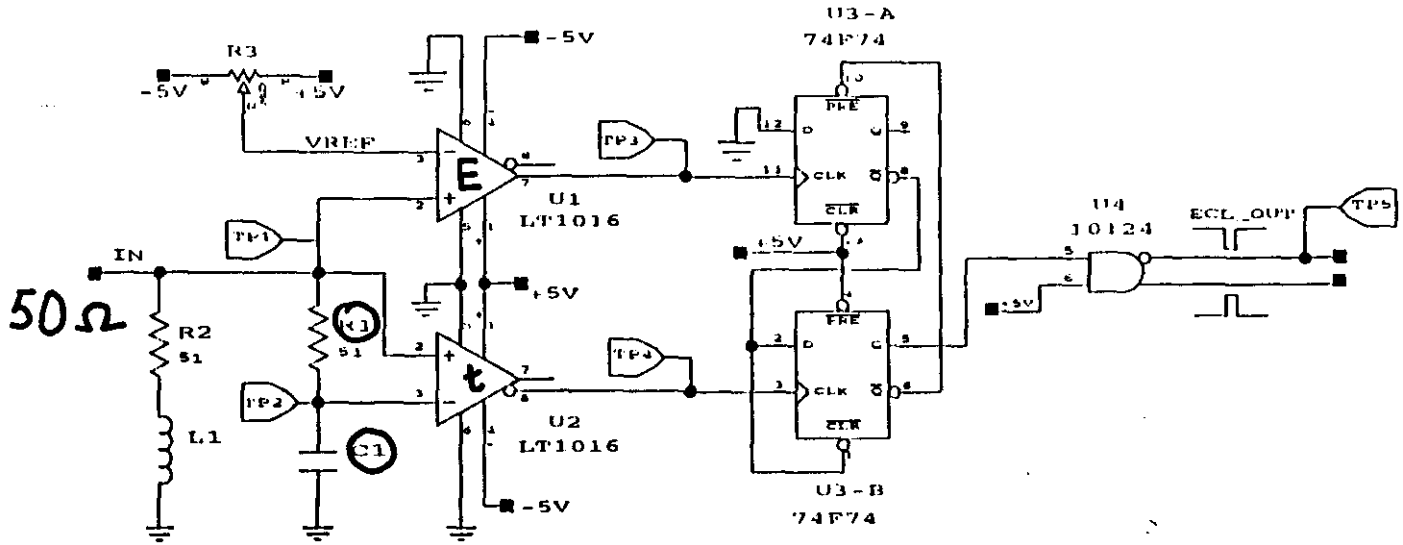
Principle of Operation

(*Turko & Smith*)

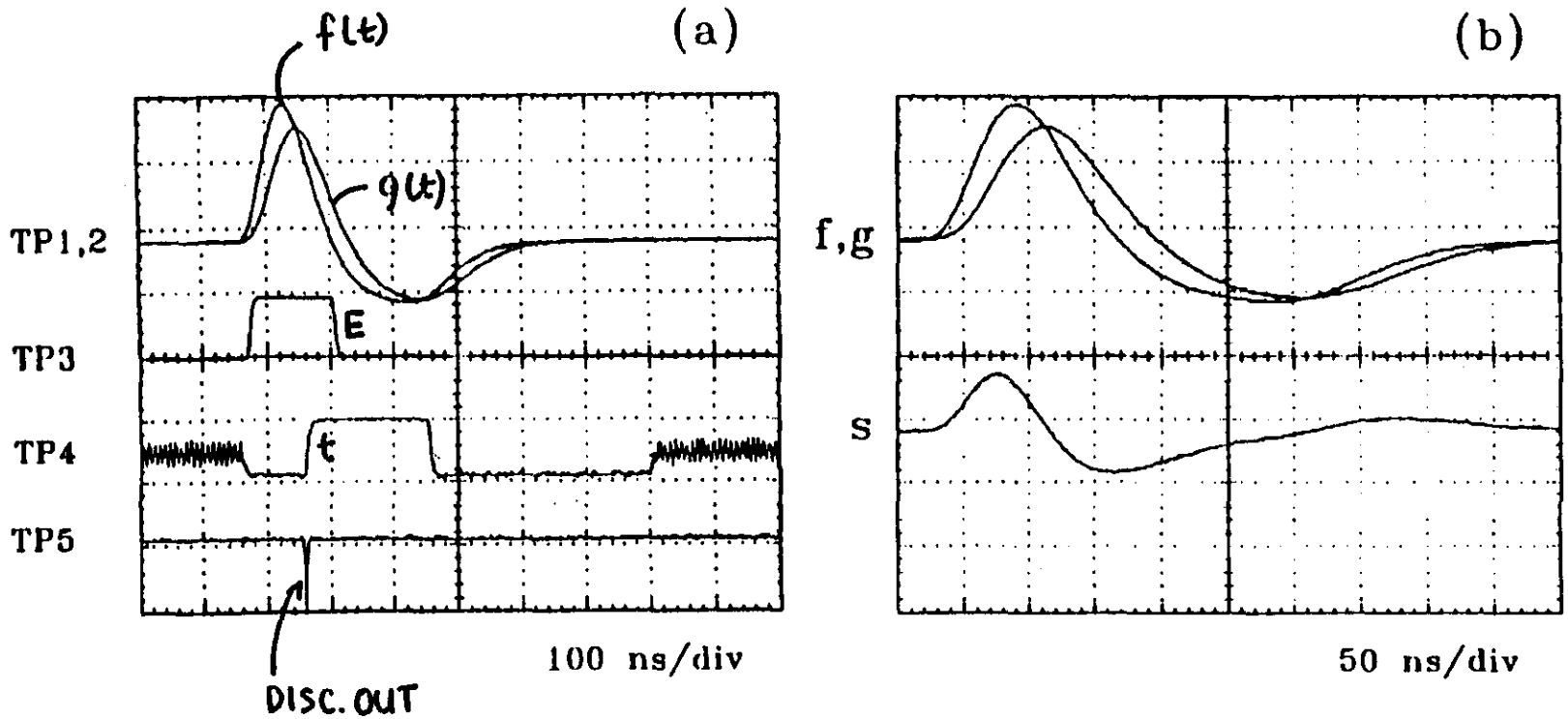


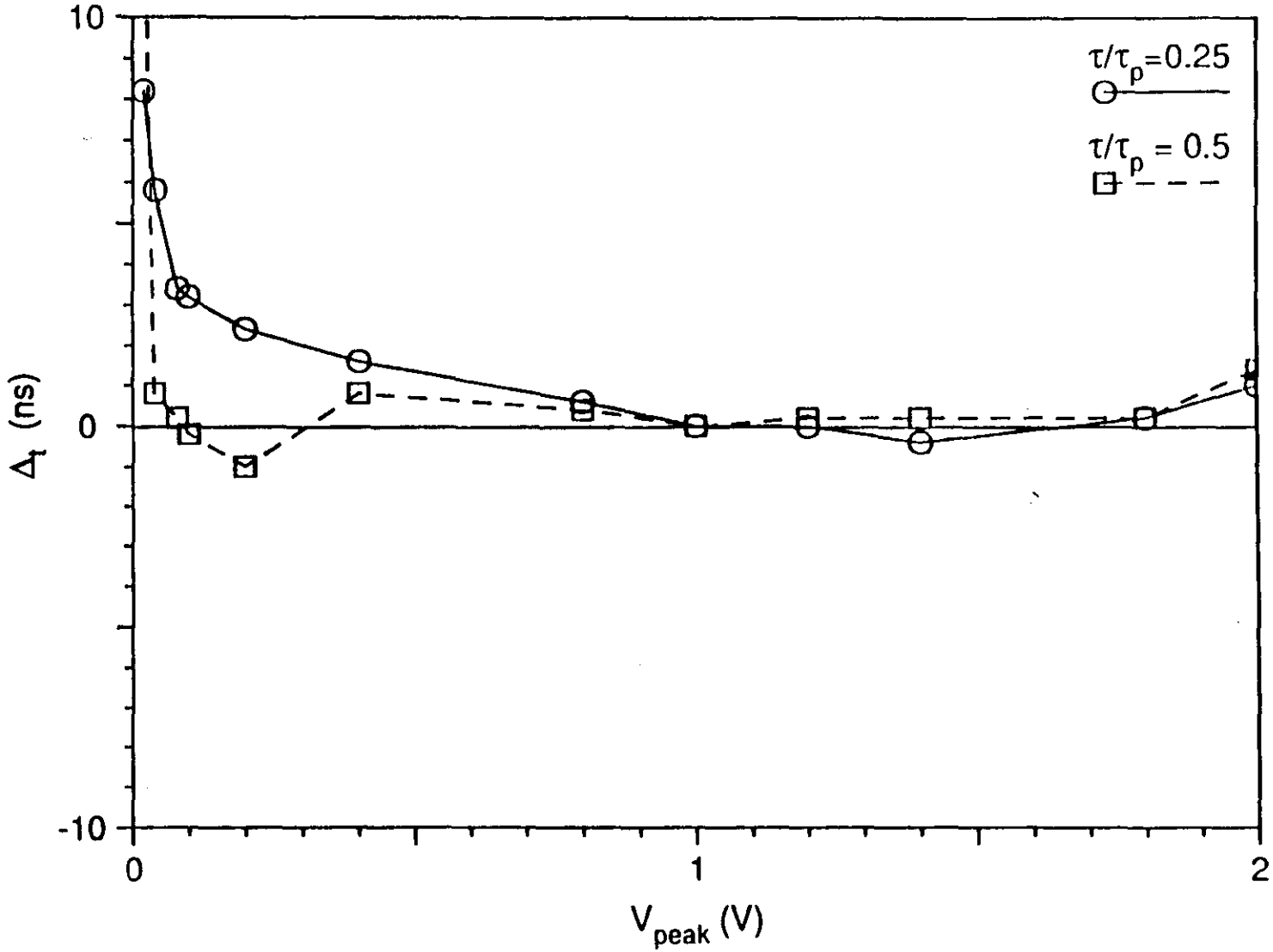
☞ t_0 is generated when $S(t) = f(t) - g(t) = 0$

"t_0 is independent of amplitude"



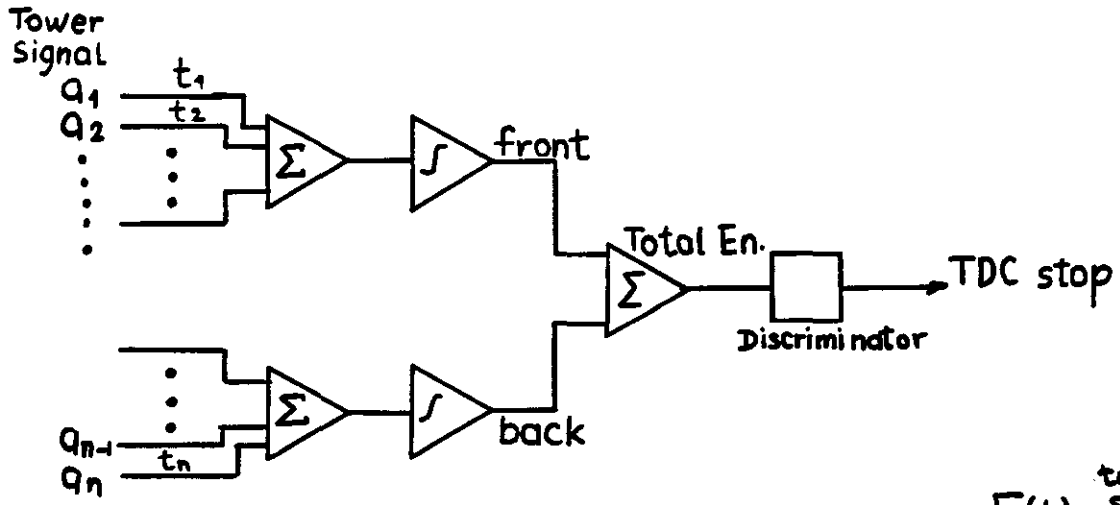
Pitts Burgh MADE in USA


(a)
f(t)
g(t)
TP1,2
E
TP3
TP4
t
TP5
DISC. OUT
100 ns/div
(b)
f,g
s
50 ns/div

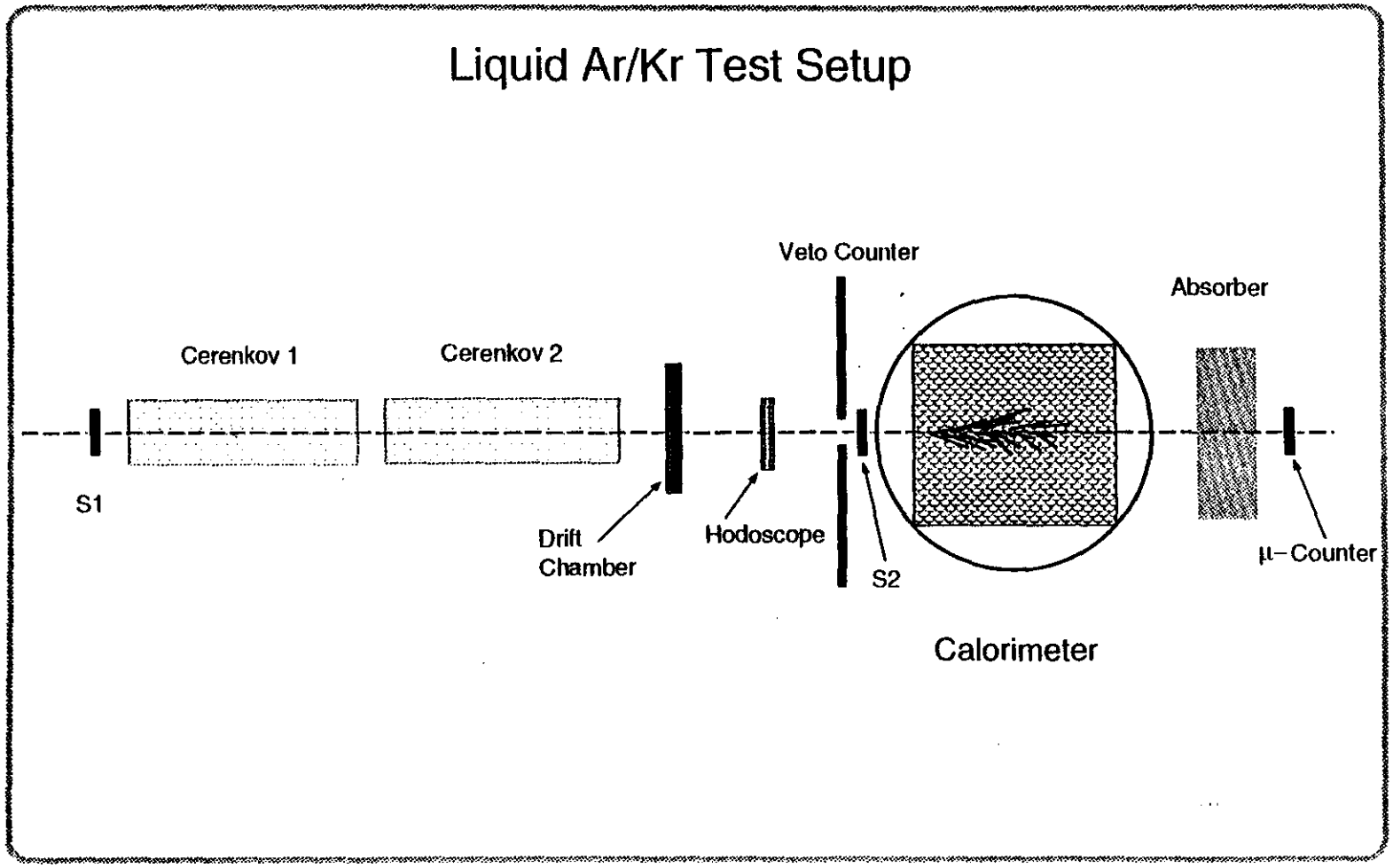

10
0
-10
0
1
2
Δ_t (ns)
V_{peak} (V)
τ/τ_p=0.25
τ/τ_p = 0.5

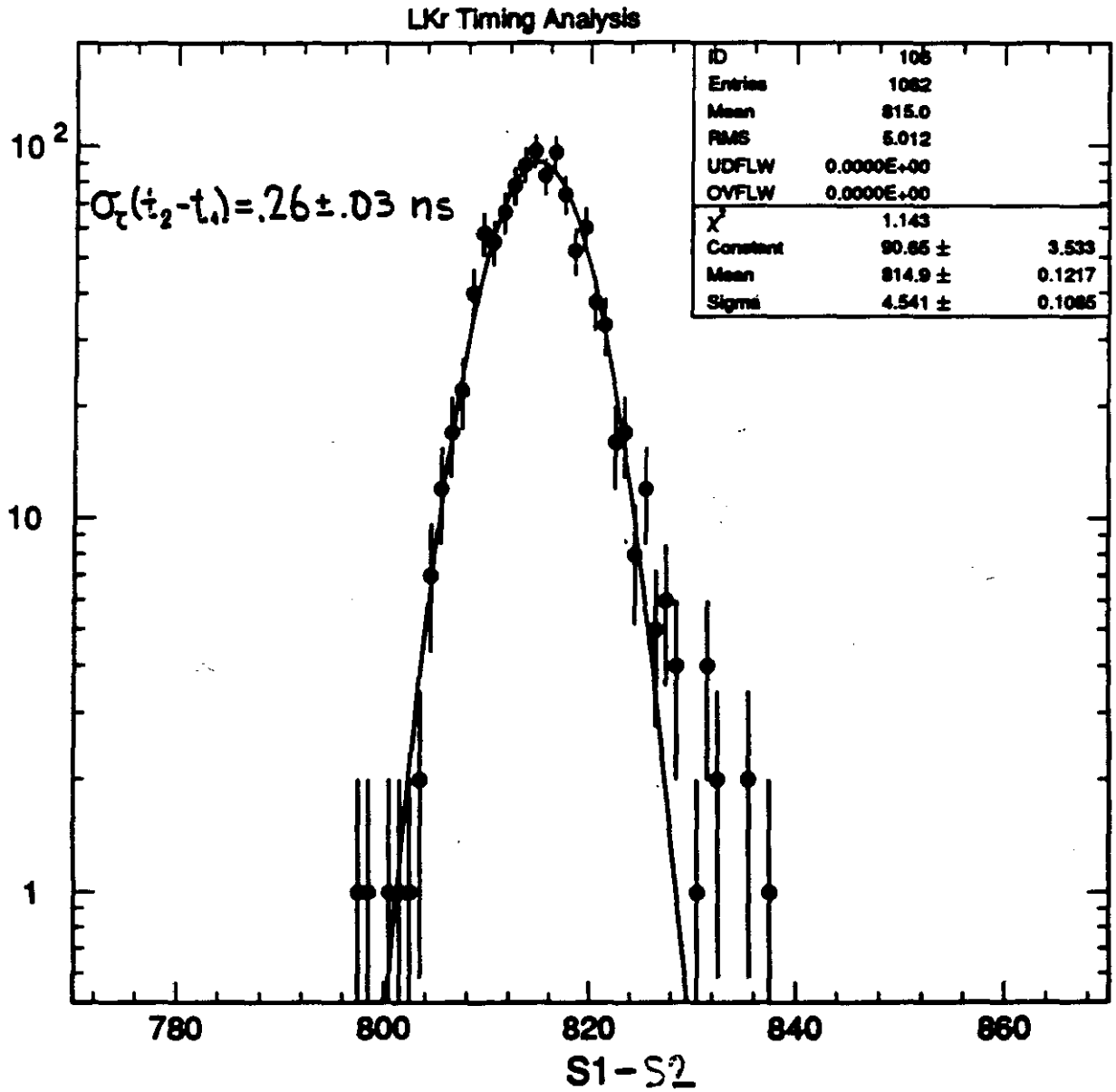
Test Setup

- Calorimeter : • Accordion geometry + Liquid Krypton.
  - • Active region (5×5 towers)
    tower = 2.5×2.7 cm²
  - • Longitudinal Segmentation $6X_0+18X_0$
- e^- beam momentum : 5, 10, 15 and 20
- Discriminator connected to Total Energy signal :



- o Total Energy pulse shape : $F(t) = \sum_{i=1}^{towers} a_i \cdot f(t-t_i)$
- o a_i , Energy deposited in tower i
- o t_i , time offset for channel i (cables, mostly)


Liquid Ar/Kr Test Setup
Veto Counter
Absorber
Cerenkov 1
Cerenkov 2
S1
Drift
Chamber
Hodoscope
S2
μ−Counter
Calorimeter

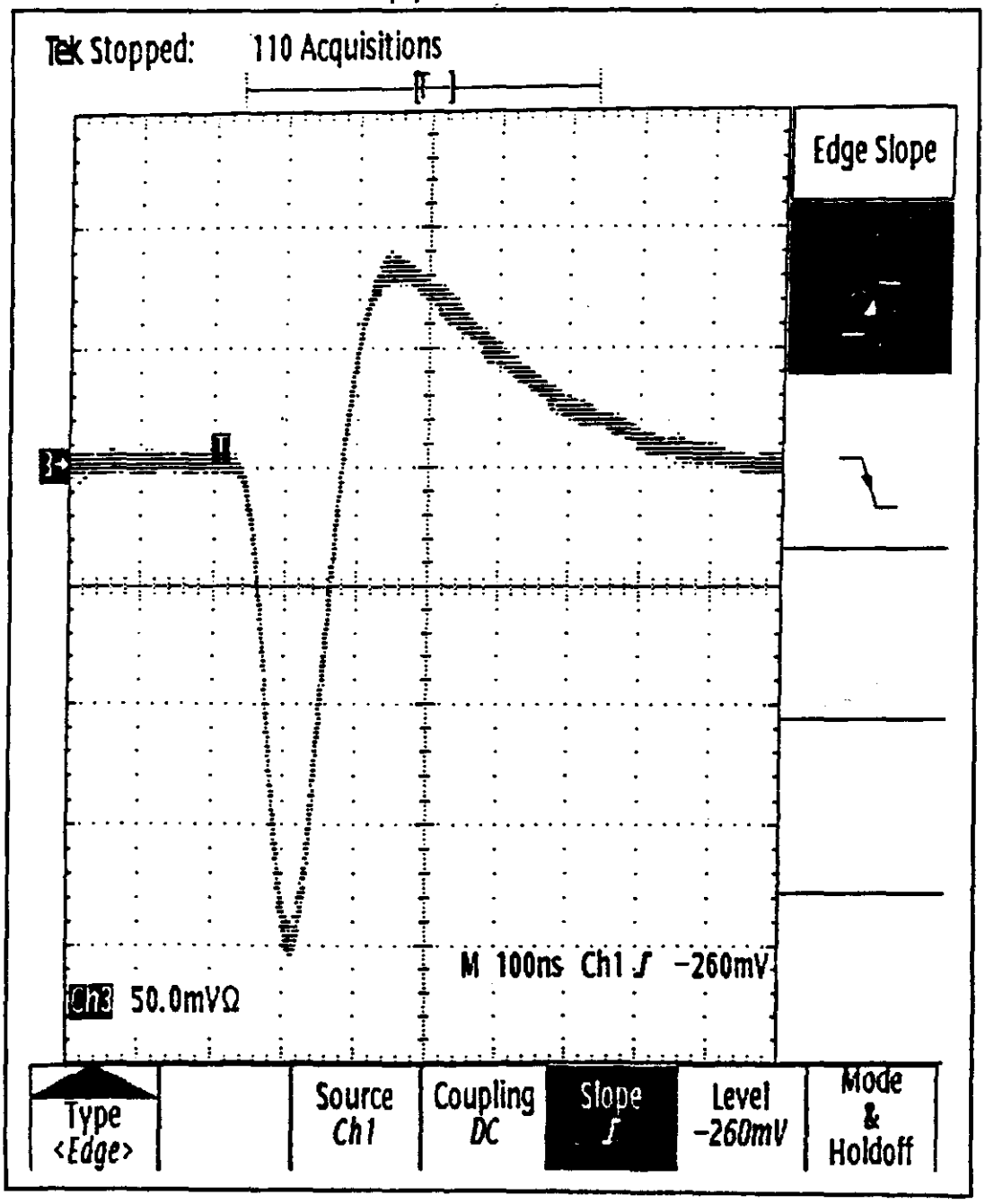

LKr Timing Analysis
ID 106
Entries 1082
Mean 815.0
RMS 5.012
UDFLW 0.0000E+00
OVFLW 0.0000E+00
χ² 1.143
Constant 90.65 ± 3.533
Mean 814.9 ± 0.1217
Sigma 4.541 ± 0.1085
σ_τ(t_2-t_1)=.26±.03 ns
10²
10
1
780
800
820
840
860
S1-S2

On-line Pulse Shape

LKr, 2mm stack, 1.5kV

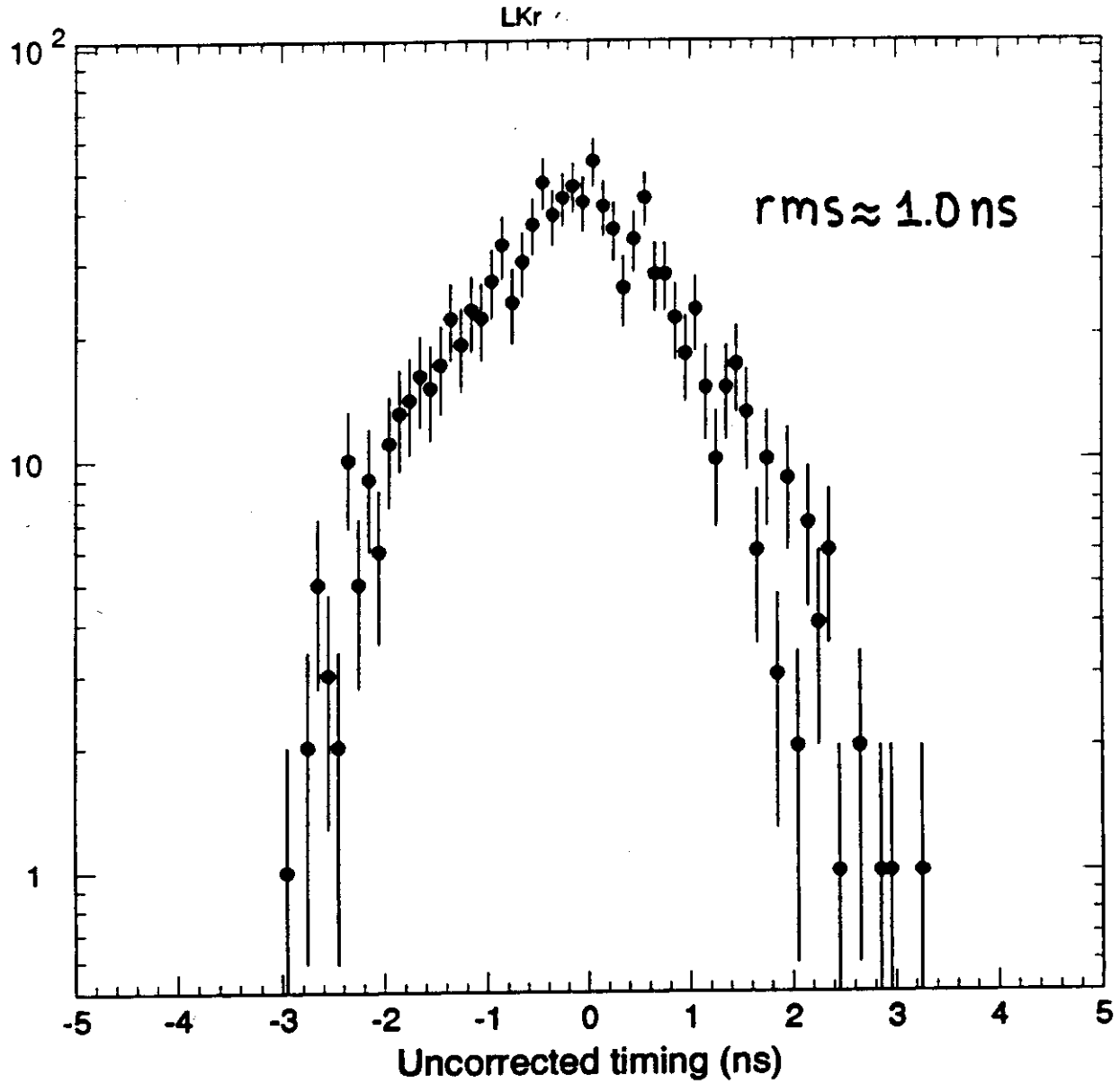
Beam Momentum = 20 GeV

Sum of approx. 150 channels



Multiple trace - variable persistence ! !

Raw Timing Distribution



Correction to raw distributions

- It can be shown that for $F(t) = \sum a_i f(t - t_i)$ a timing shift $\delta = \frac{\sum a_i t_i}{\sum a_i}$ will be introduced.

- Therefore t_i can be found offline by minimizing

$$\sum_{j=1}^{\text{events}} \epsilon_j^2 = \sum \left(t_j^0 - \sum \alpha_{ij} t_i \right)^2$$

where, $\boxed{t_j^0}$ is the on-line timing for event j

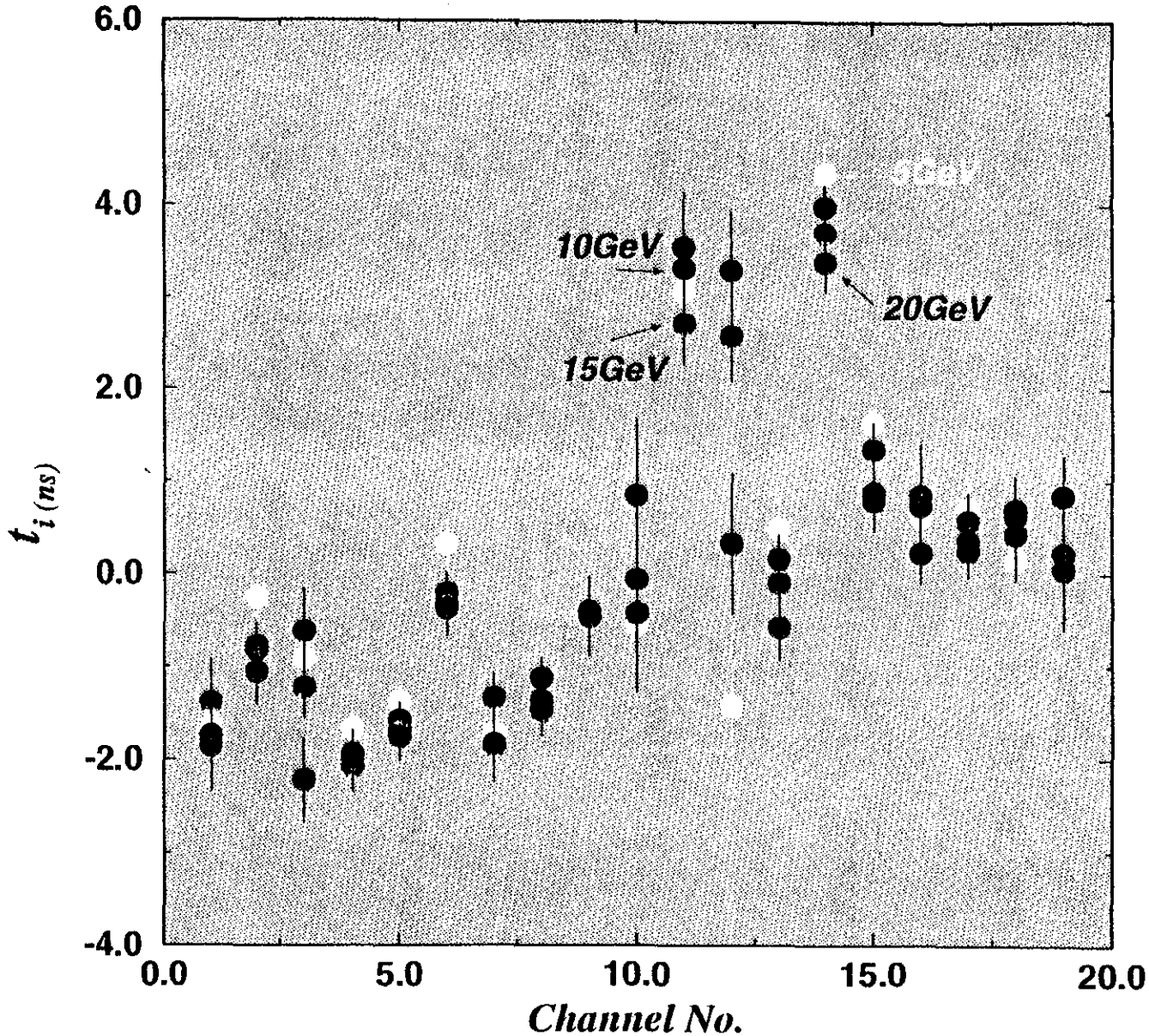
$\boxed{\alpha_i} = \frac{a_i}{\sum a_i}$, the normalized pulse height

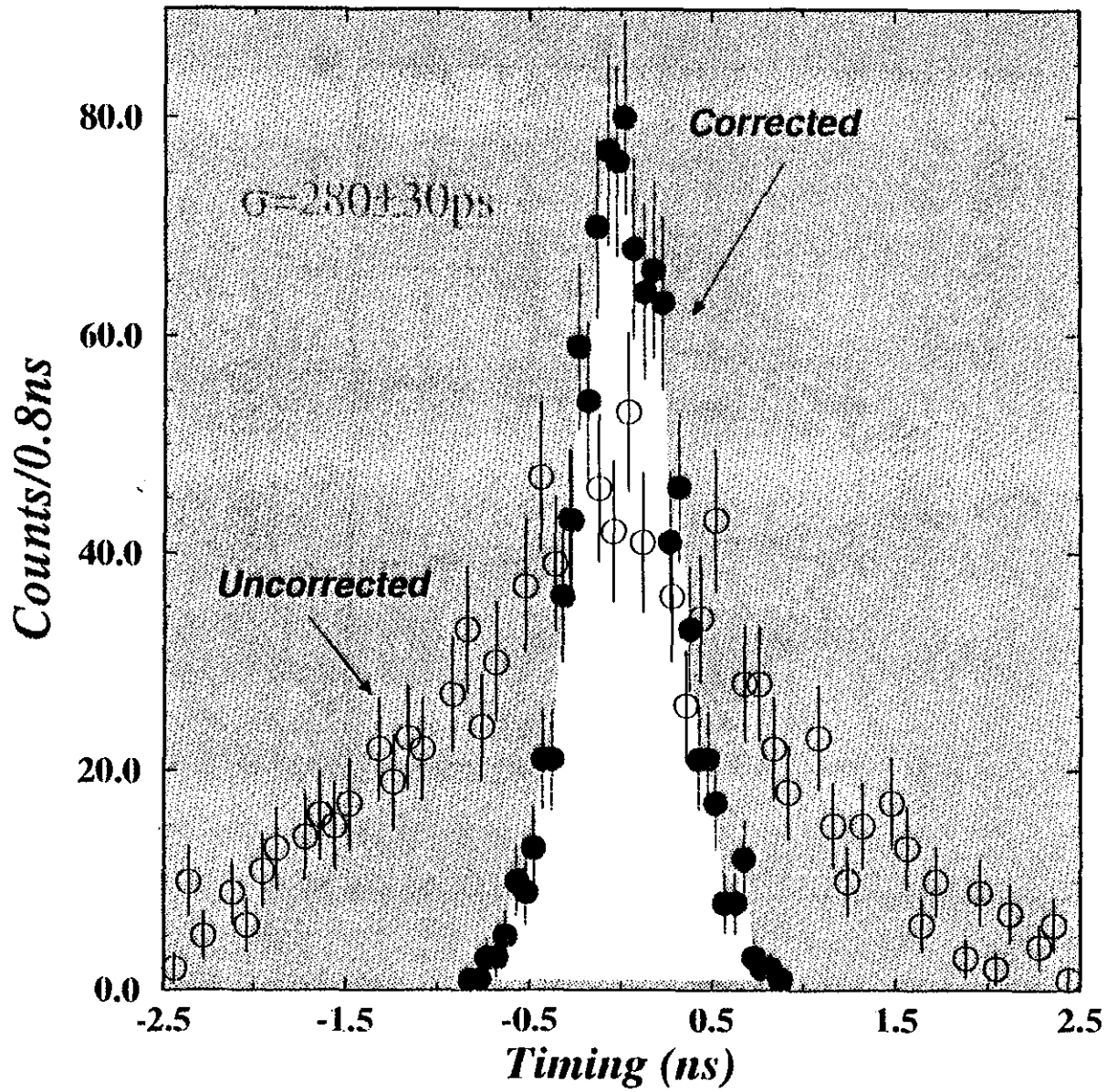
- Which leads to:

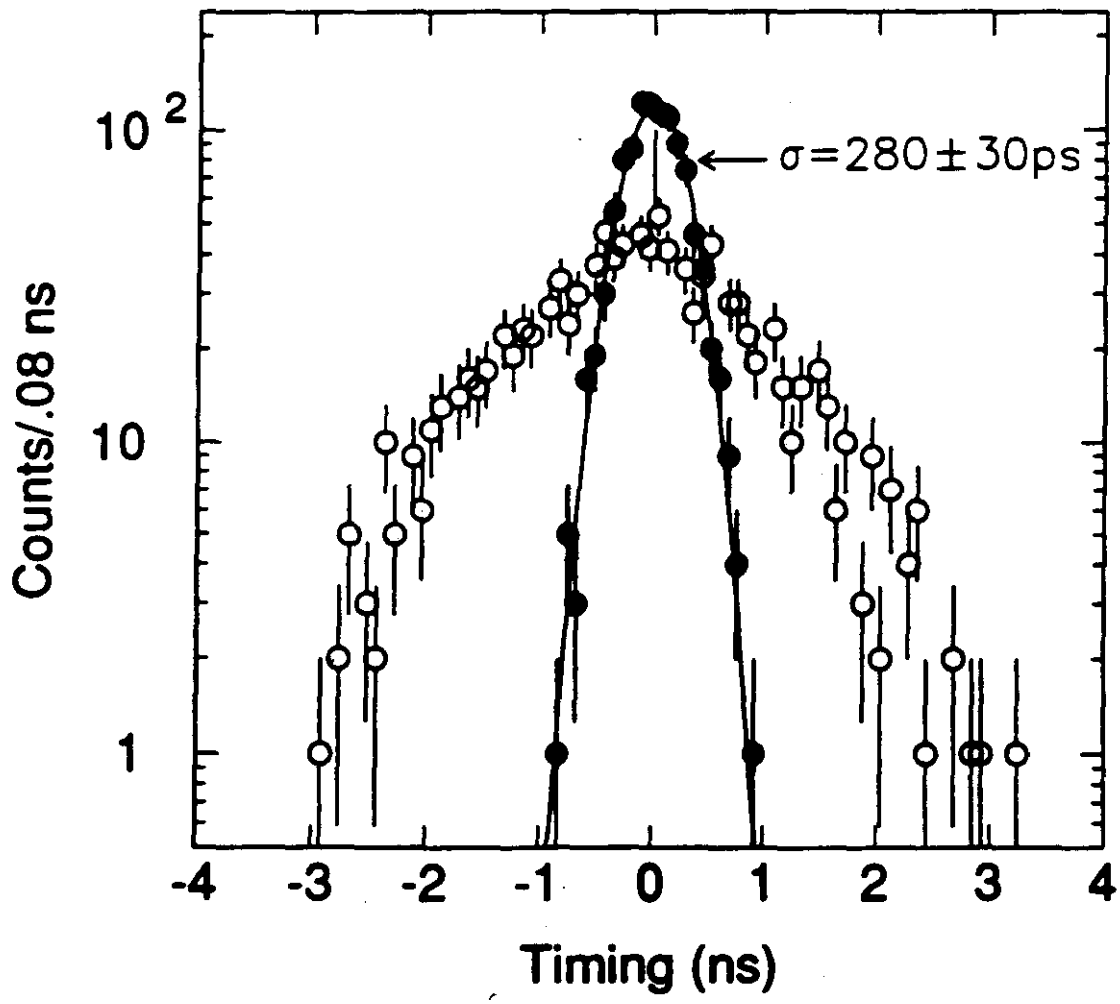
$$\vec{A} - \mathbb{R}\vec{t} = 0$$

$$A_k = \sum_{j=1}^{\text{events}} t_j^0 . \alpha_{kj} \quad \text{and} \quad R_{ki} = \sum_{j=1} (\alpha_{kj} . \alpha_{ij})$$

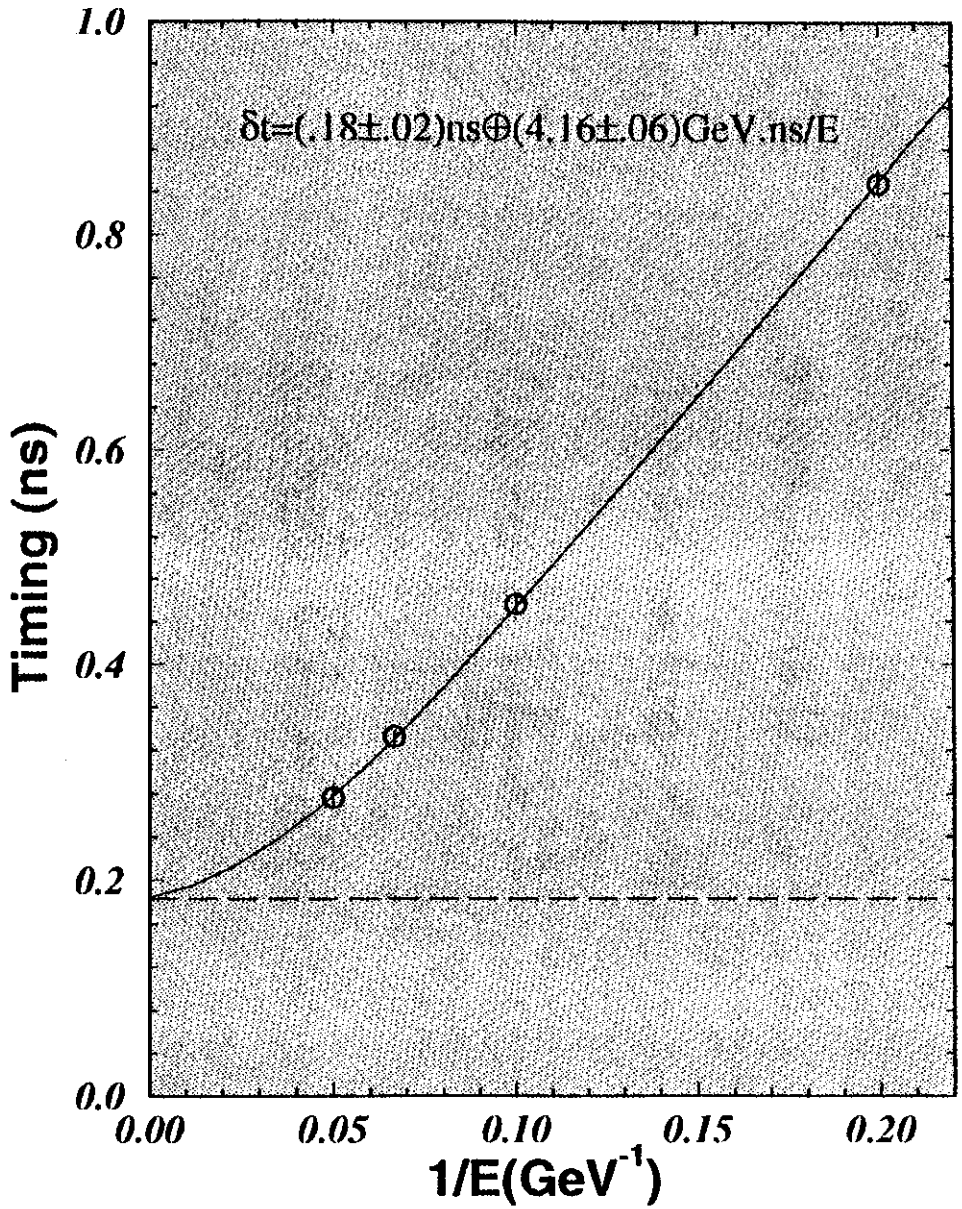
- With the determined t_i, correction is applied to measured t_j^0, event by event, on the basis of the energy distribution.


6.0
4.0
2.0
0.0
-2.0
-4.0
$t_{i\,(ns)}$
0.0
5.0
10.0
15.0
20.0
Channel No.
10GeV
15GeV
20GeV


σ=280±30ps
Corrected
Uncorrected
Counts/0.8ns
Timing (ns)
80.0
60.0
40.0
20.0
0.0
-2.5
-1.5
-0.5
0.5
1.5
2.5


σ=280±30ps
Counts/.08 ns
10 2
10
1
-4
-3
-2
-1
0
1
2
3
4
Timing (ns)

LKr Timing Resolution



Expected timing Resolution

$$\sigma_\tau(\text{thermal}) = \frac{\sigma_E}{E} \cdot \frac{1}{s'(t_0)}$$

$\sigma_E \equiv$ thermal noise

$E \equiv$ pulse height

$$s' = \frac{d}{dt}\left(f(t) - g(t)\right)$$

$$\Rightarrow \quad \sigma_\tau = 4.5 \, \frac{\text{GeV} \cdot \text{ns}}{E}$$

Conclusions

- Liquid Ionization Calorimeters have excellent timing properties.

- Energy Dependence: Calculable on the basis of thermal noise

  - we infer that the inherent timing resolution of one tower is $\sim 0.8 \frac{\text{GeV. ns}}{E}$

- $\sigma_\tau = (0.18 \pm 0.02)\text{ns} \oplus (4.16 \pm .06) \frac{\text{GeV. ns}}{E}$