GEM TN-92-84

GEM Calorimeter Group Meeting - Tuscon

March 8, 1992

Abstract:

Agenda and transparencies of the GEM Calorimeter Meeting held on March 8, 1992, at the GEM Collaboration Meeting in Tuscon.

Sunday P.M.

AGENDA OF SUNDAY MARCH 8 CALORIMETER MEETING AT TUCSON

2:00 PM	Discussion on base line design (Liquid Argon Option) and other calorimeter options for Monday March 9 presentation (60′)
3:00	GEM Exec.Committee Review of e-m Calorimetry (information). Requirements to BaF2 and LAr e-m systems. (Yu.Kamyshkov 20′)
+10′	
3:20	Response from BaF2 group to exec. committee requirements (20′) H. Newman
+ 20′	
3:40	Response from LAr group to exec. committee requirements (20′) D. Lissauer
4:00	Status and R&D plans for SSCintCal (15′) W. Worstell
4:15	New option of scintillating calorimetry (Eagle tiles idea) (15′) L. Sulak
4:30	Status and R&D plans for Forward System (15′) J. Rutherfoord
4:45	Test beam at SLAC available? (Paul Mockett 5′)
4:50	Status and R&D plans for parallel plate LAr option (Paul Mockett 10′)
	Yu. Kamyshkov
5:00	LAr Calorimeter. BNL'91 experimental data and simulations. (Jim Brau 15′)
5:15	Results from Fermilab Beam Test of BaF2 (J.Branson, 45′)
6:00	BaF2 crystal quality : requirements, status and near term plans (R-Y Zhu, 20′)
6:20	Simulations on BaF2 response uniformity (K.Shmakov 20′)
6:40	Discussion
7:00	Adjourn

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

SUNDAY MARCH 8

Informal meetings all day

MONDAY MARCH 9 PLENARY MEETING

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

BASELINE DISCUSSIONS

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

BASELINE CONTINUED

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

3:15 Forward Calorimeter J Rutherfoord

3:45 BREAK

4:15 GEM Triggering Shaevitz/Marlow

4:45 Discussion of the Baseline
and Working Group Formation

5:30 Physics Talk: Ian Hinchliffe

6:30 Adjourn

TUESDAY MARCH 10 WORKING GROUPS

8:30 - 2:30

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

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

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

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

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

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

10:00-10:20 BREAK

2:30- 3:00 BREAK

3PM Cross Disciplinary Group

Integration (Marx,Harris)

Simulation (McFarlan,Lane)

Triggering (Marlow,Shaevitz)

7:30 BANQUET

WEDNESDAY MARCH 11 PLENARY SESSIONS

8:00 REPORT ON LHC EVIAN MEETING (Marx)

8:30 REPORTS OF WORKING GROUPS AND ISSUES FOR FUTURE

10:00 BREAK

10:30 INITIATION OF DETECTOR COSTING G SANDERS

11:00 WHAT'S NEXT? W. WILLIS

11:30 FINAL DISCUSSION OF BASELINE

12:00 ADJOURN

12:15 EXECUTIVE COMMITTEE

gem

γeμ

Presentation by:

Yuri Kamyshkov
(2)

Y. Kamyshkov

BNL Beams — May, June, 1992

Peter Yamin - coordinator for BNL

A2 $P \lesssim 9$ GeV — low flux

e – 2 Č's

Equality

GEM Si preradiator

A3 $P < 20$ GeV — high flux

e – 2 Č's

(funded by LAr subsystem)

E878 $pA \to h$

E852 $\pi^- p \to \eta$, $\eta \to \gamma\gamma$ ← priority by Associate Director

GEM LAr, LKr { 2mm, 1mm, parallel plates

C5 $P \lesssim 20$ GeV — high flux

OR with E850 (problem with superconducting magnet – fraction of electronics)

GEM – Scintillating fibers?

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Yu.

Kamyshkov

DRAFT 2/13/92

56 *Calibration Hall*

Introduction

A Calibration hall will be provided for calibration beam users. The hall will provide floor space prototype detector modules and R&D setups in three beam lines. Each beam-line will have seventy linear feet of space available. The overall dimensions of the hall are 100 by 250 feet , and include space for counting rooms, a storage and staging area, an office and tool area and a truck access bay.

FY92 Program

4. For the Calibration Hall, FY92 will be the year in which design requirements are written, and the design is carried through into the start of Title II. This design work will involve about $300K for A/E work and SSC support. An evaluation of the adequacy of the Calibration hall design for the SDC and GEM collaborations will take place as part of the process of establishing design requirements.

FY93 Program

4. For the Calibration Hall, FY93 will be the year in which Title II design is completed, and construction begins. This will represent a need for $400K in design costs and $1M in initial construction costs. This program will rely heavily on timely completion of infrastructure on the West Complex in the area around the MEB and IR1.

FY94 Program

4. For the Calibration Hall, FY94 will be the year in which construction is taking place. About $3M in construction should be completed on the Calibration Hall in this year. The Physics Division will be in a planning stage for taking BOD in FY95. However, early occupancy of the staging area would be most valuable for the physics program.

Future beam tests at SSCL

Request from George Yost :

test beam area;
cranes;
beam equipment;
type of beams, resolution , beam size etc.
any other relevant parameters

should be defined week ago !

Quality Requirements to the BaF_2 Crystals

Ren-yuan Zhu
Caltech

GEM Meeting, Tucson

March 8, 1992

- **Crystal Quality Control:**
  - Mechanical Dimension ⇒ Good Light Uniformity;
  - Understanding Radiation Damage of BaF_2: No permanent damage, Saturation, No self recovery at r.t., No dose rate dependence.
  - Transmittance Specification ⇒ Good Light Yield and Uniformity.
- **Main Issues of FY92 R&D on Crystal Quality Control:**
  - Mechanical Dimension;
  - Radiation Resistance ⇒ 70% at 220 nm;
  - Light Uniformity after Saturated Radiation Damage.

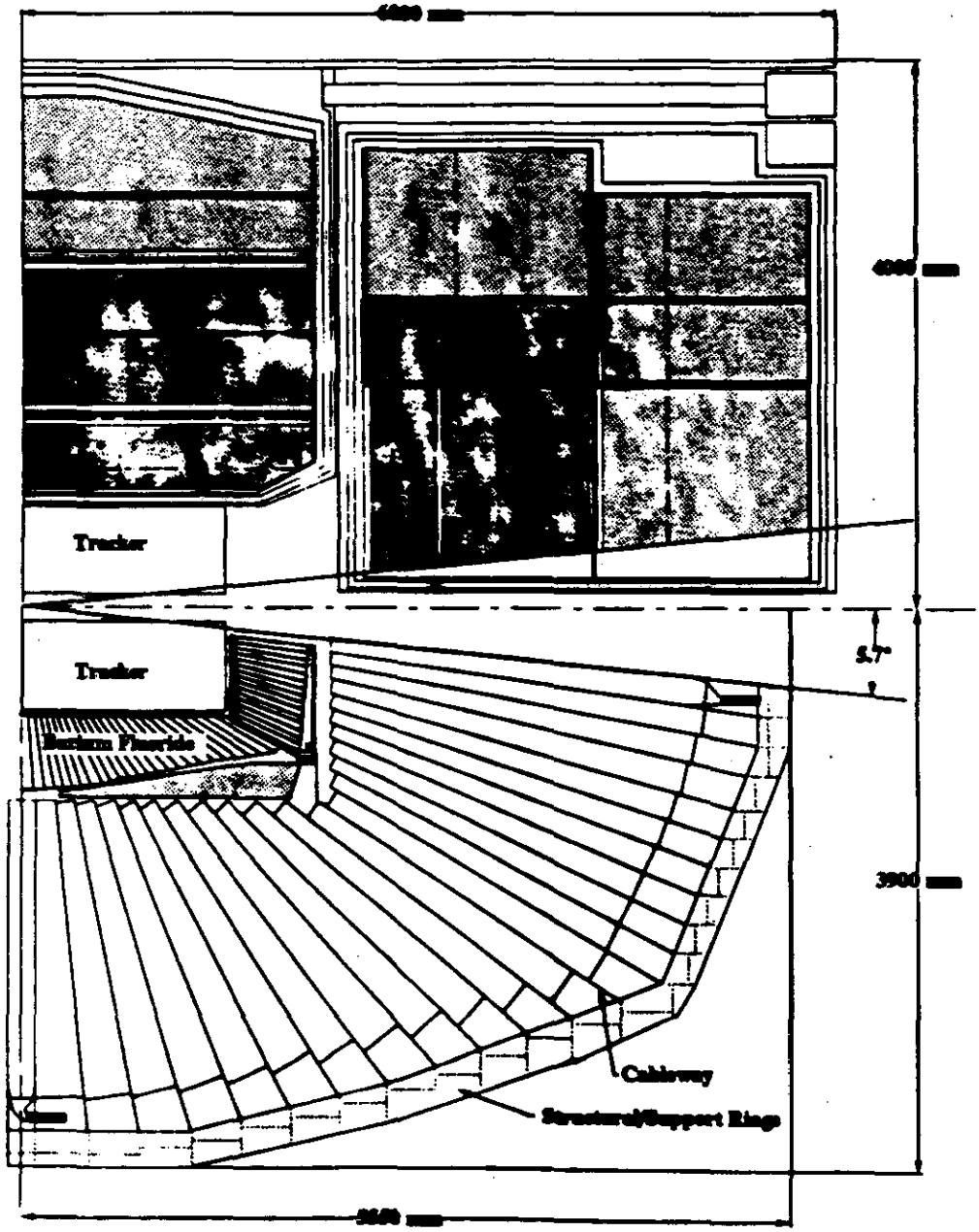
GEM Calorimeter { L. Ar. / BaF_2 + Scint.

Liquid Argon Calorimeter

L. Ar.

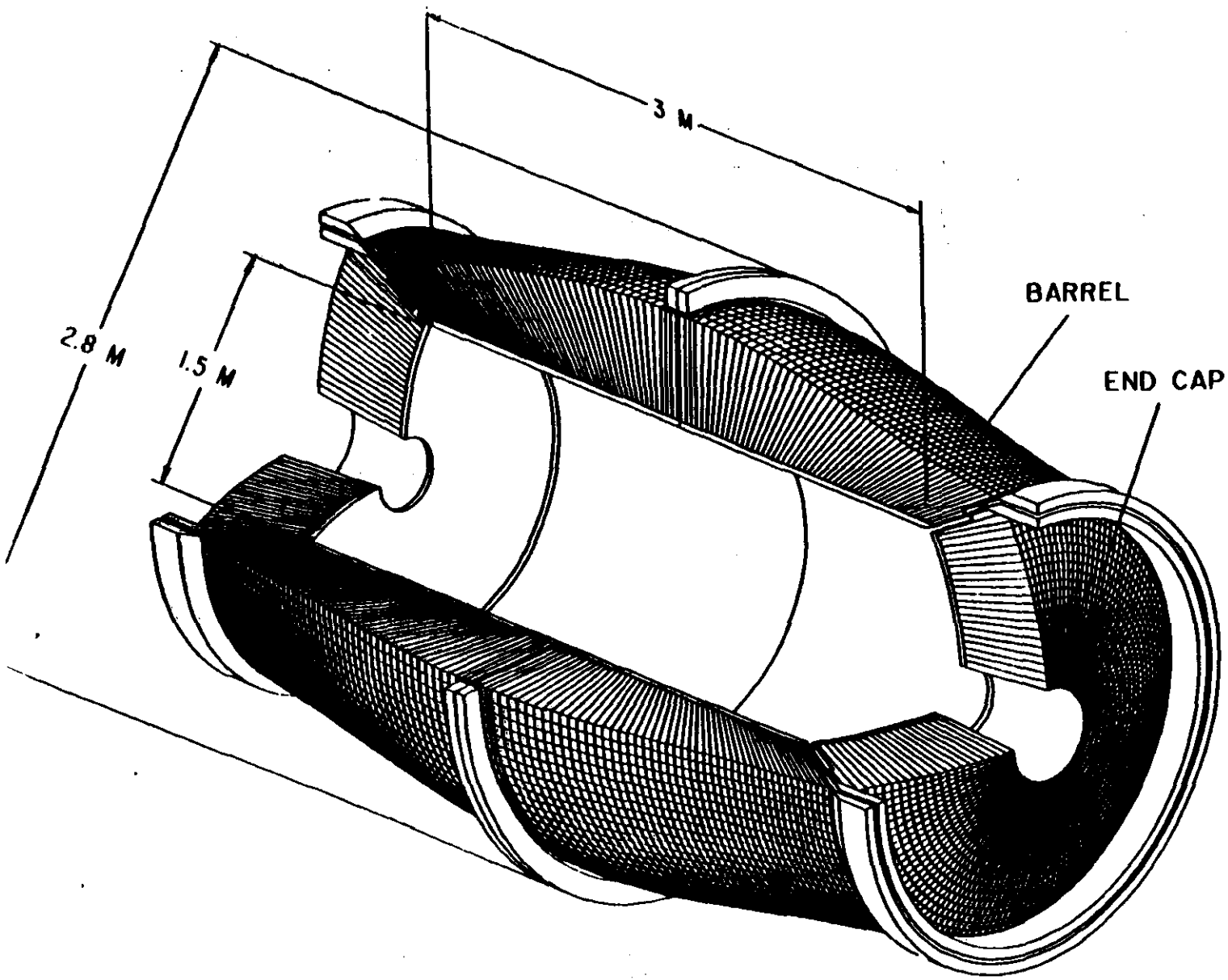
BaF_2

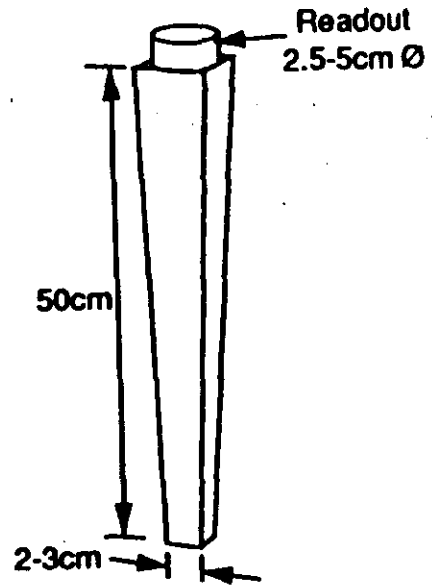
Scint.



BaF2 EM with Scintillating Fiber Hadron Calorimeter

GEM BaF_2 Calorimeter





Ba F2 EM CALORIMETER

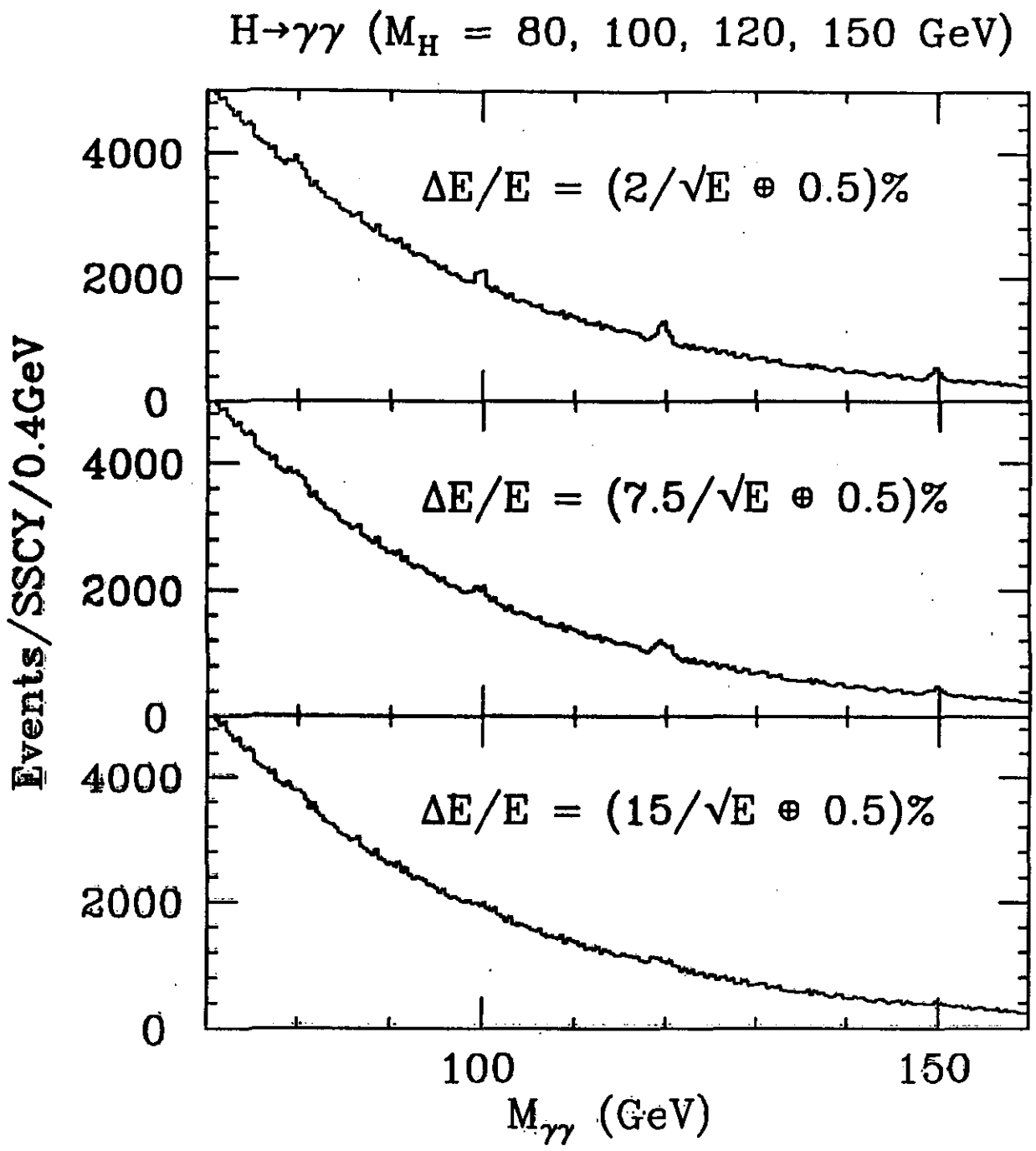
Features of the BaF_2 Calorimeter

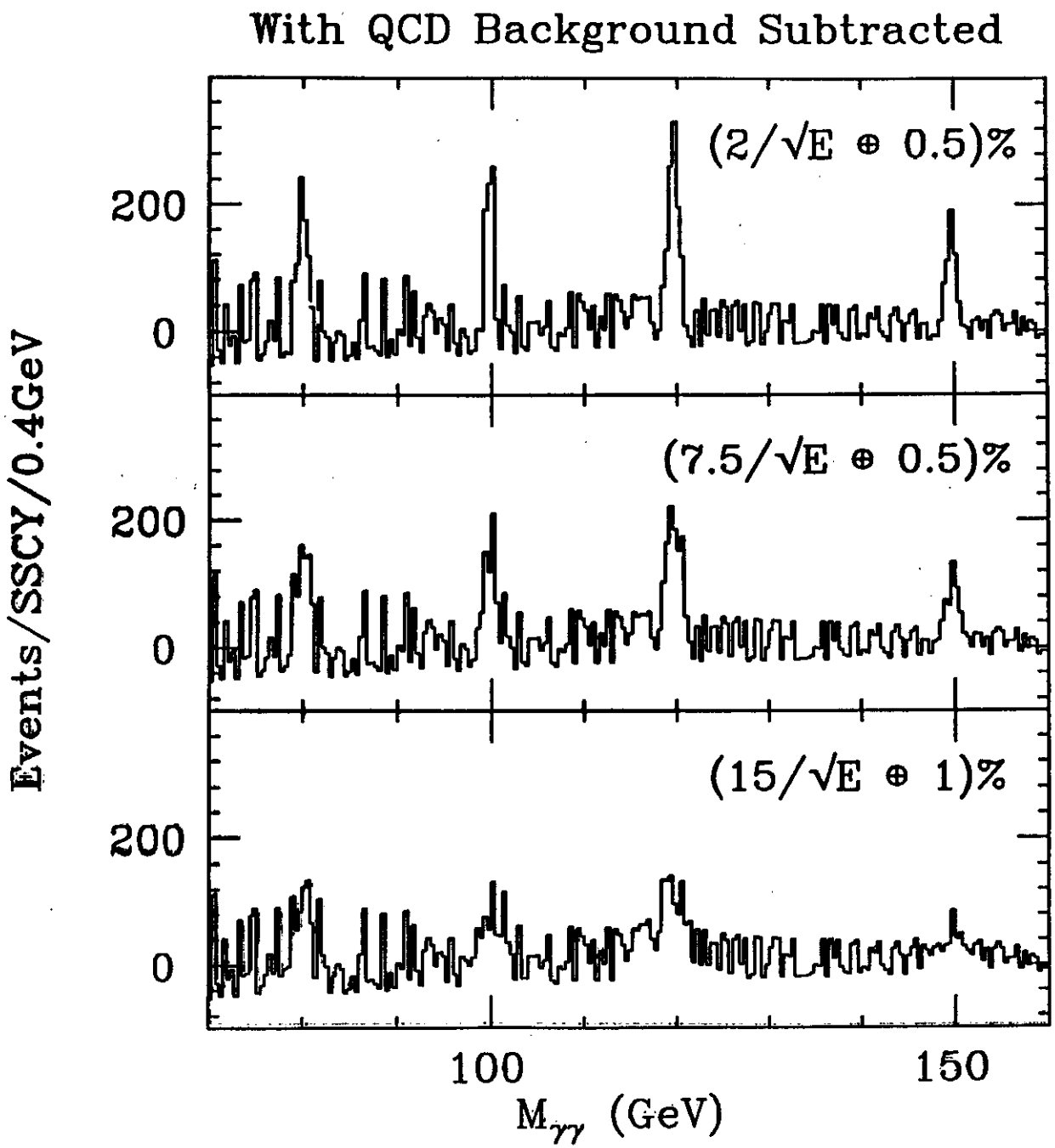
Detector	Barrel	Two Endcaps
Rapidity Coverage	$\|\eta\| \leq 1.32$	$1.32 \leq \|\eta\| \leq 2.5$
Crystal Front Face (cm^2)	3.1 × 3.1	2.3 × 2.3
Crystal Rear Face (cm^2)	5.1 × 5.1	3.1 × 3.1
Crystal Length (cm)	50	50
Crystal Number	10,880	4,144
Total Crystal Volume (m^3)	8.4	2.2
Total Crystal Weight (t)	41.1	10.7

Total: 15 K Crystals

10.6 m^3 & 52 Tons

Cost: \$80 M


H→γγ (M_H = 80, 100, 120, 150 GeV)
ΔE/E = (2/√E ⊕ 0.5)%
ΔE/E = (7.5/√E ⊕ 0.5)%
ΔE/E = (15/√E ⊕ 0.5)%
Events/SSCY/0.4GeV
4000
2000
0
100
150
M_γγ (GeV)


With QCD Background Subtracted
(2/√E ⊕ 0.5)%
(7.5/√E ⊕ 0.5)%
(15/√E ⊕ 1)%
200
0
200
0
200
0
Events/SSCY/0.4GeV
100
150
$M_{\gamma\gamma}$ (GeV)

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-PPE/92-001
8 January 1992

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PRECISE MEASUREMENT OF THE TOPONIUM MASS FROM THE OBSERVATION OF ITS TWO-PHOTON DECAY AT THE LHC

G. Pancheri
INFN, Laboratori Nazionali di Frascati
P.O. Box 13, 00044 Frascati, Italy

J.-P. Revol, C. Rubbia
CERN
1211 Geneva 23, Switzerland

Abstract

We propose to measure the toponium mass using an electromagnetic calorimeter of the "Crystal Ball" type at the LHC to detect $t\bar{t}$ bound states (toponium). If such a heavy system exists, the $J^{PC} = 0^{-+}$ state will dominate production at the LHC and could be observed above a relatively low background in the two-photon decay channel. The toponium mass could be measured for instance with a precision of 3×10^{-4} for $m_{t\bar{t}} = 200$ GeV/c^2. This method provides an accuracy comparable with what will ultimately be obtained with future dedicated e^+e^- top-quark factories.

(Submitted to Physics Letters B)

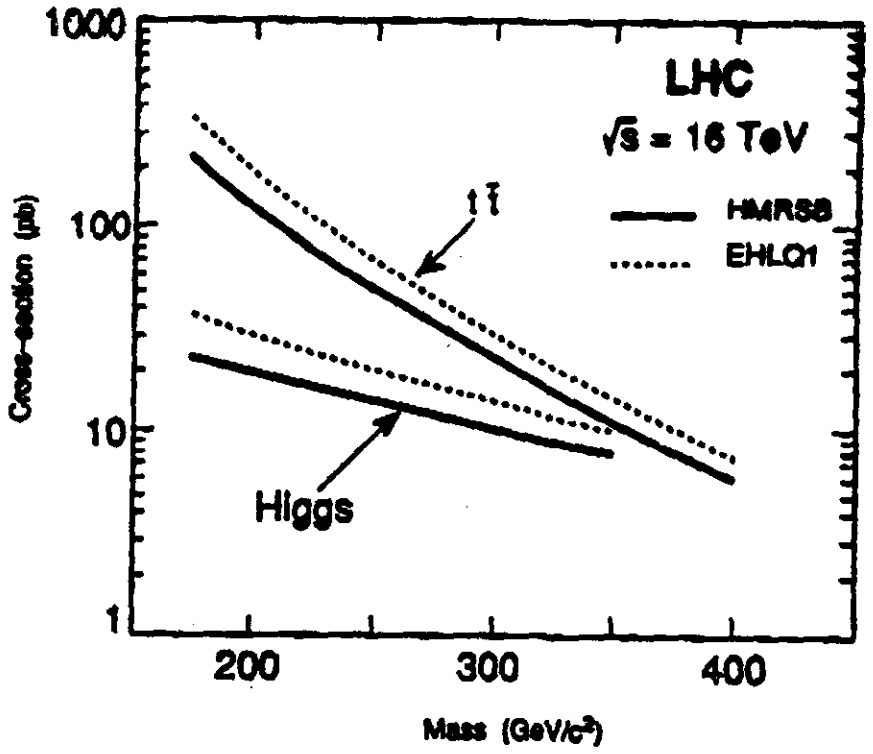


Fig. 3

Table 1. The effective toponium half-width, given in terms of the equivalent Gaussian σ, is shown with its contributions from experimental resolution [σ (exp)] and from the natural width [σ(nat)] of the bound state, for four toponium masses.

$m_{t\bar{t}}$	σ (exp)	σ (nat)	Effective σ
(GeV/c^2)	(MeV/c^2)	(MeV/c^2)	(MeV/c^2)
200	760	80	765
260	975	415	1060
300	1120	755	1350
400	1470	2080	2550

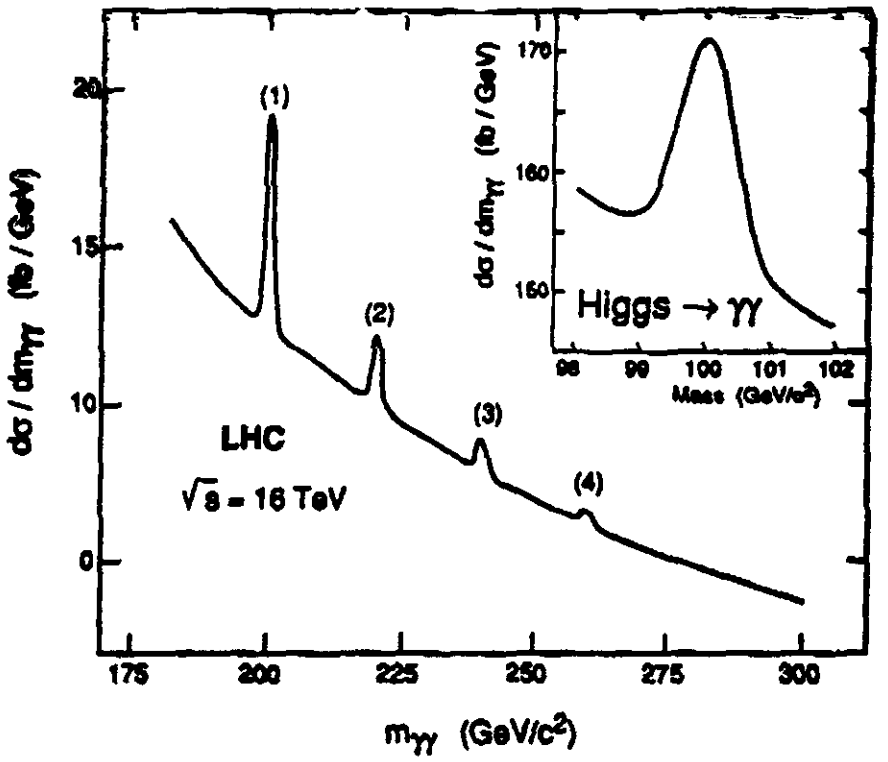

(1)
(2)
(3)
(4)
LHC
√s = 16 TeV
dσ / dm_γγ (fb / GeV)
m_γγ (GeV/c²)
Higgs → γγ
Mass (GeV/c²)

Fig. 5

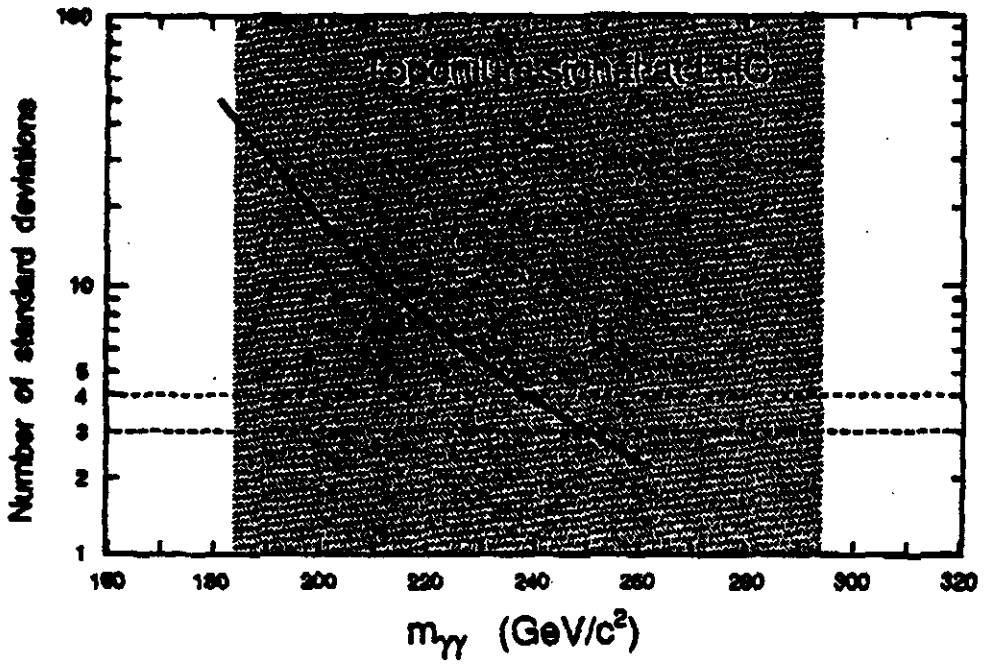

Number of standard deviations
m_γγ (GeV/c²)

Fig. 6

Energy Resolution of Electromagnetic Calorimeter

$$(\frac{\sigma}{E})^2 = (\frac{a_0}{E})^2 + (\frac{a_1}{\sqrt{E}})^2 + b^2$$

- a_0: Electrical noise, sum over few Moliere radii.
- a_1: Photon statistics.
- b: Constant term: $b^2 = b_G^2 + b_n^2 + b_C^2$
  - b_G (Geometry effect): shower leak (front, side and rear) and inactive material between cells.
  - b_n (Physics noise): light collection uniformity etc.
  - b_C (Intercalibration error): 0.4% is the best for a large system?

L3 Experience and GEM Design:

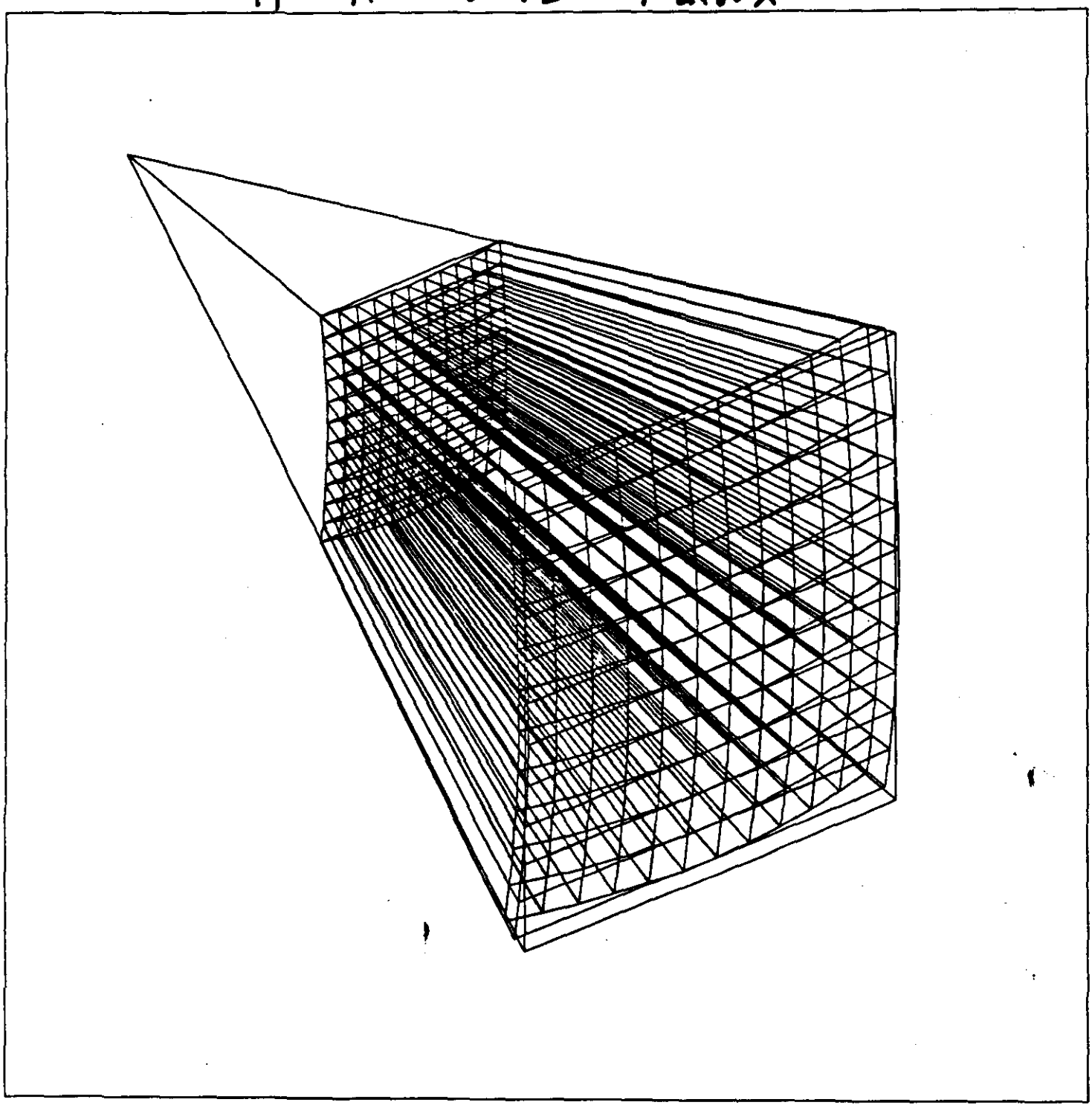
$$\frac{2\%}{\sqrt{E}} \oplus 0.5\%$$

GEANT SIMULATION
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

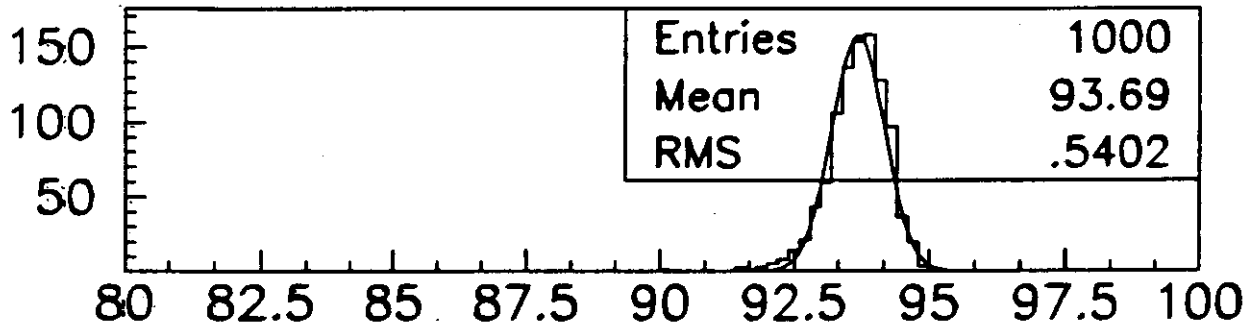
- Number of BaF_2 crystals: 11 x 11
- BaF_2 Crystal length: 50 cm
- Front (rear) face of BaF_2 :
  3 cm x 3 cm (5 cm x 5 cm)
- Carbon fiber wall thickness between any two crystal faces: 0.025 cm
- Particle is hitting over the front face of central BaF_2 crystal.
- One centimeter Aluminium placed just before the crystals and two 0.5 cm Aluminium placed between track origin and midway point to crystals (i.e., total 2 cm Al, whose $X_0 = 9$ cm)
- No magnetic field.
- Light yield response (Y) is parametrized with deviation (δ):

$$Y = Y_{25}[1 + \delta(Z/25 - 1)]$$

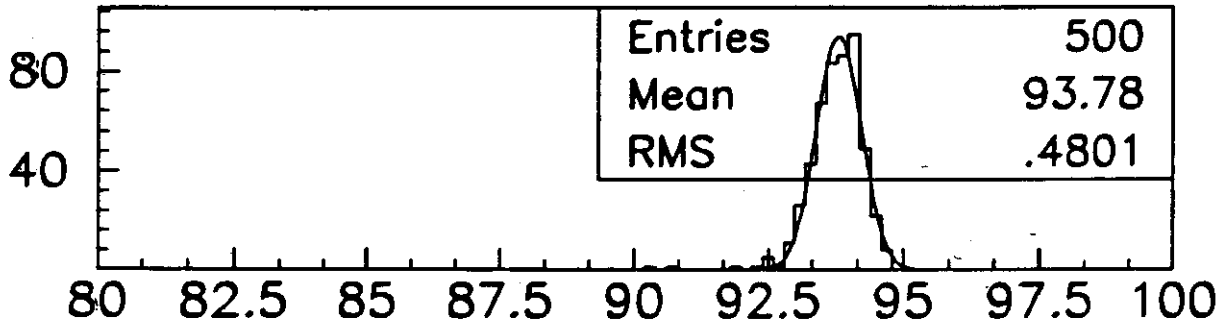
11 × 11 BaF_2 Matrix



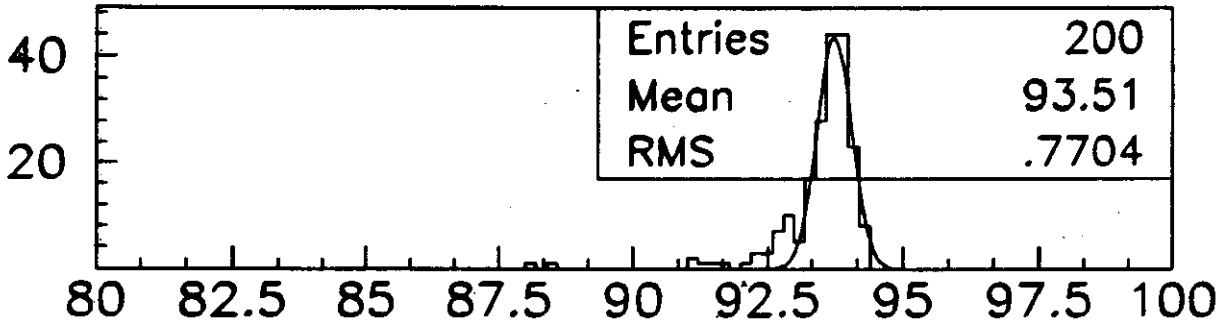
Energy Fraction in 3x3 Crystals



EFRAC 3(1ST Layer) 20 GeV Electron



EFRAC 3(1ST Layer) 50 GeV Electron



EFRAC 3(1ST Layer) 500 GeV Electron

Energy Resolution (%)

of BaF_2 Calorimeter

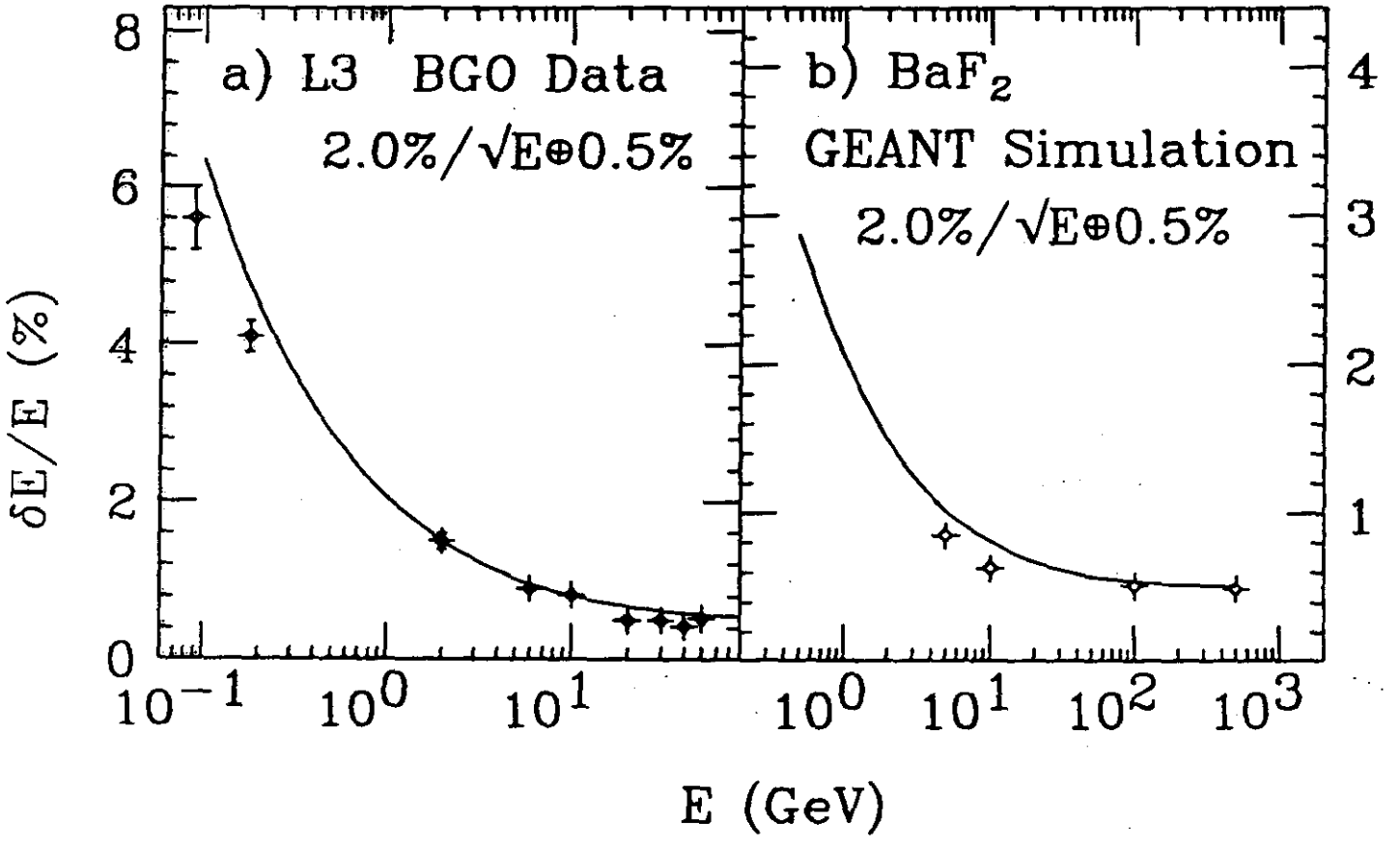
GEANT Simulation

E (GeV)	5	10	100	500
Electrical Noise	0.4	0.20	0.02	0.004
Photoelectrons	0.2	0.1	0.04	0.02
GEANT	0.60	0.43	0.31	0.29
Calibration	0.40	0.40	0.40	0.40
Total	0.85	0.63	0.51	0.49

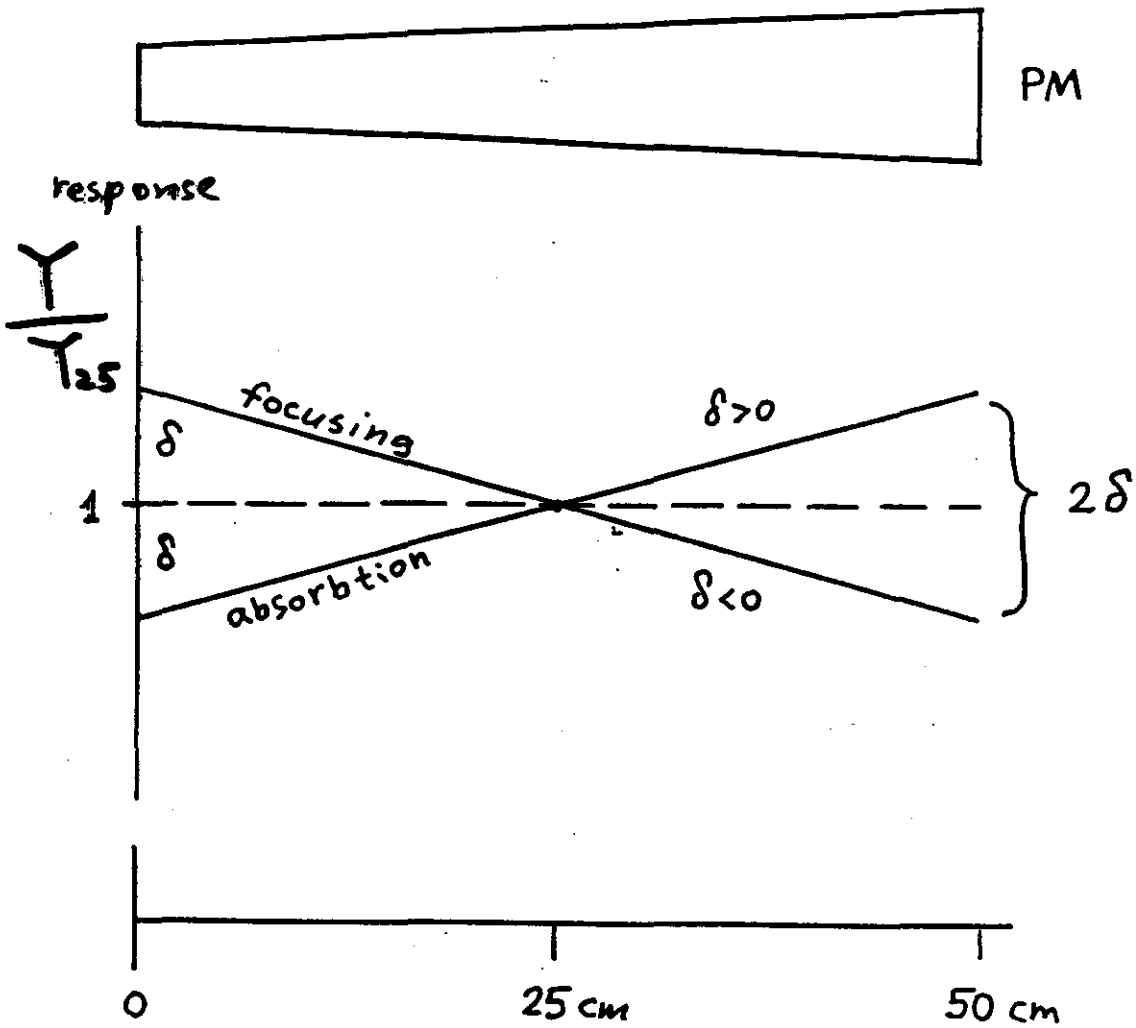
Energy Resolution (%)

of BaF_2 Calorimeter

GEANT Simulation

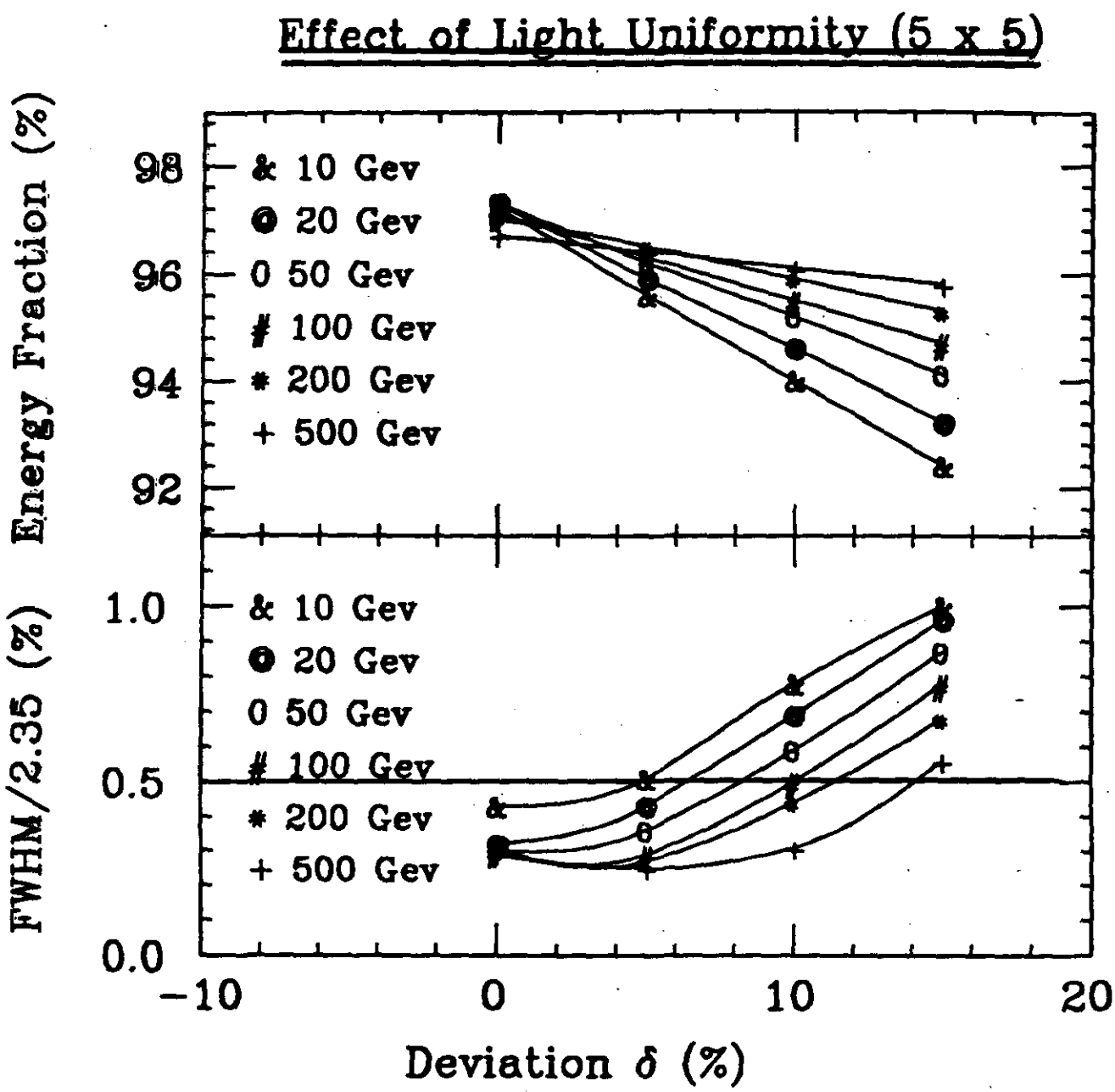


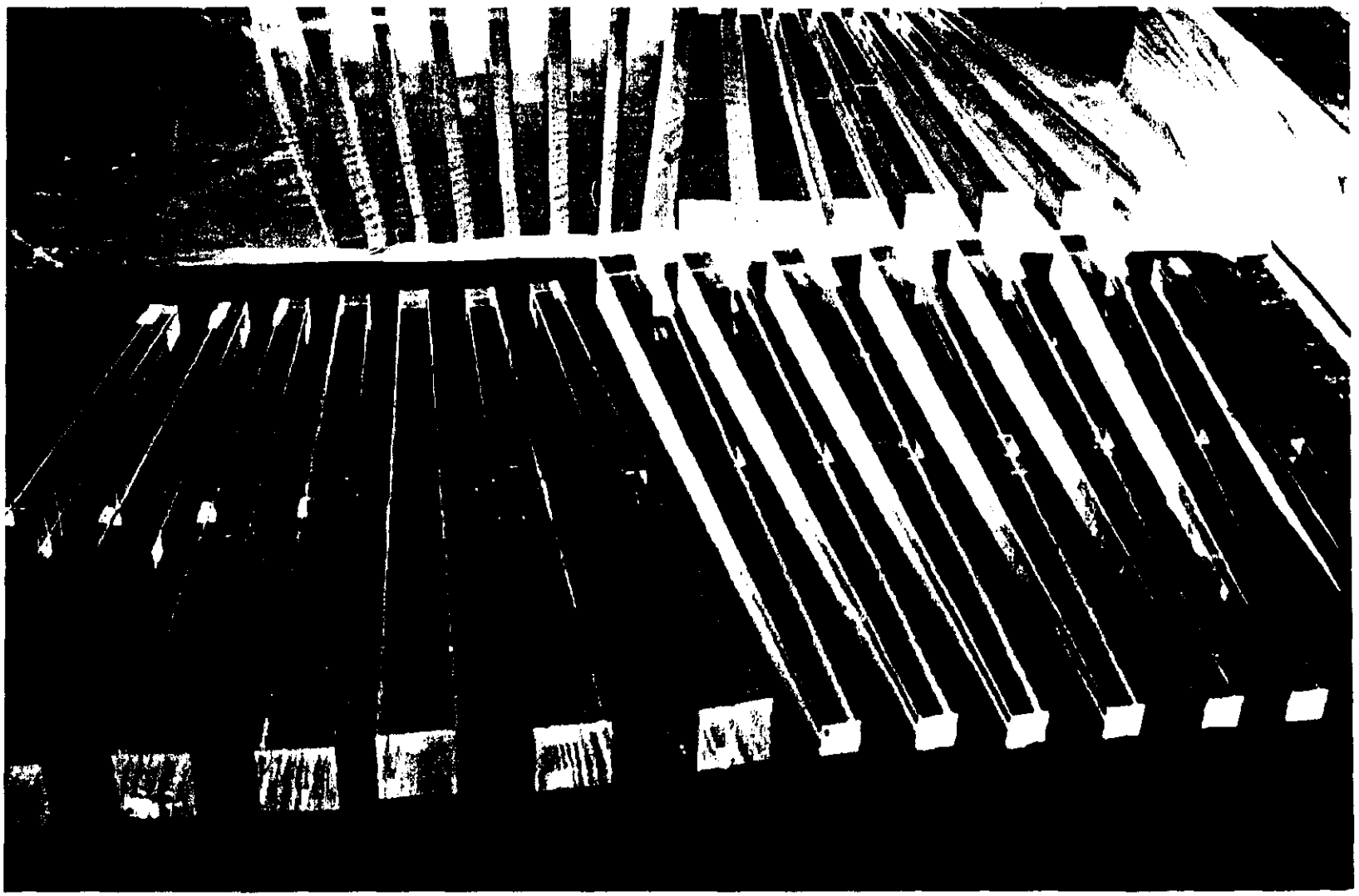
$$Y = Y_{25}\left[1 + \delta\left(\frac{z}{25} - 1\right)\right]$$

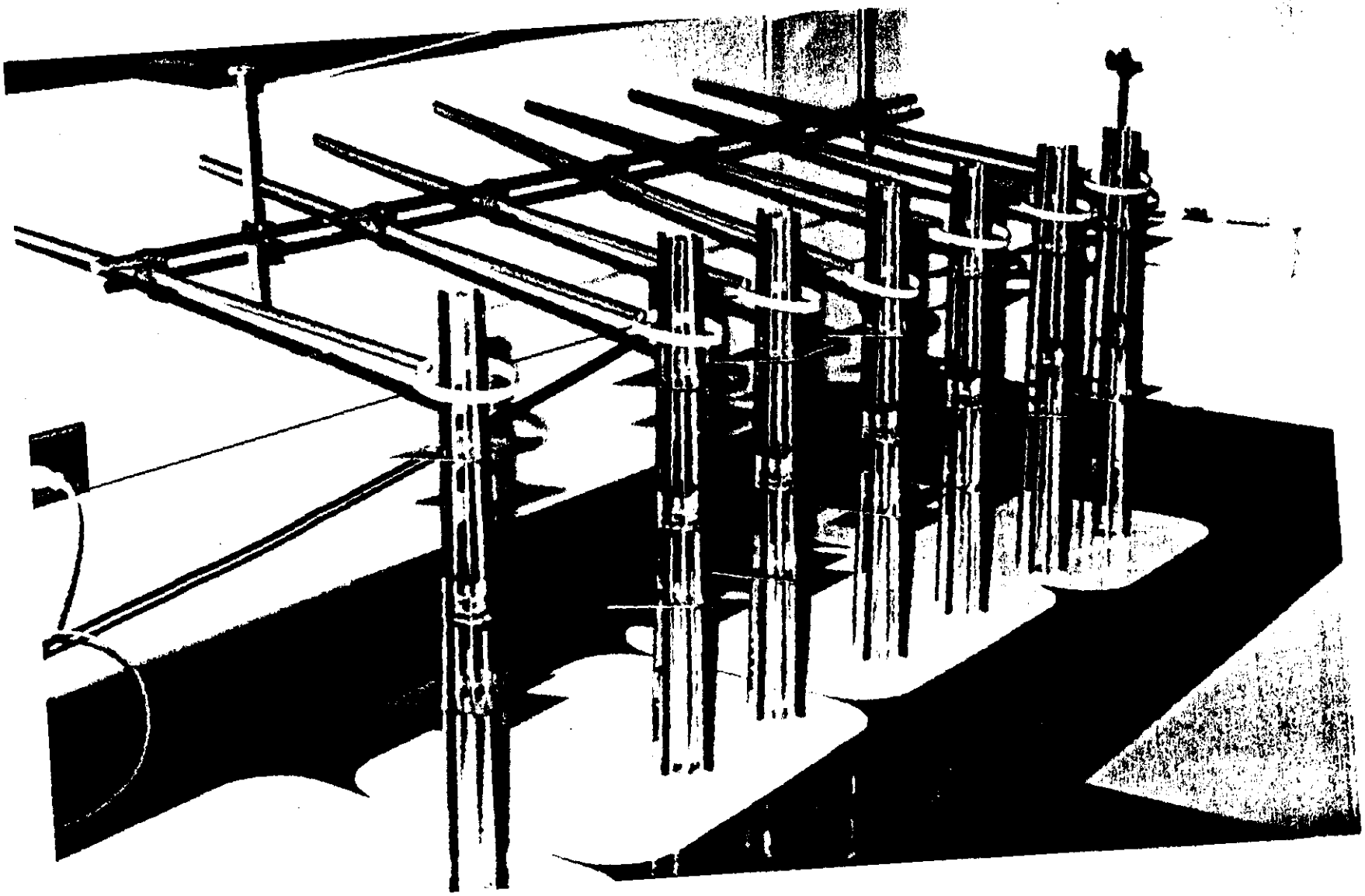


Linear parametrization of non-uniformity

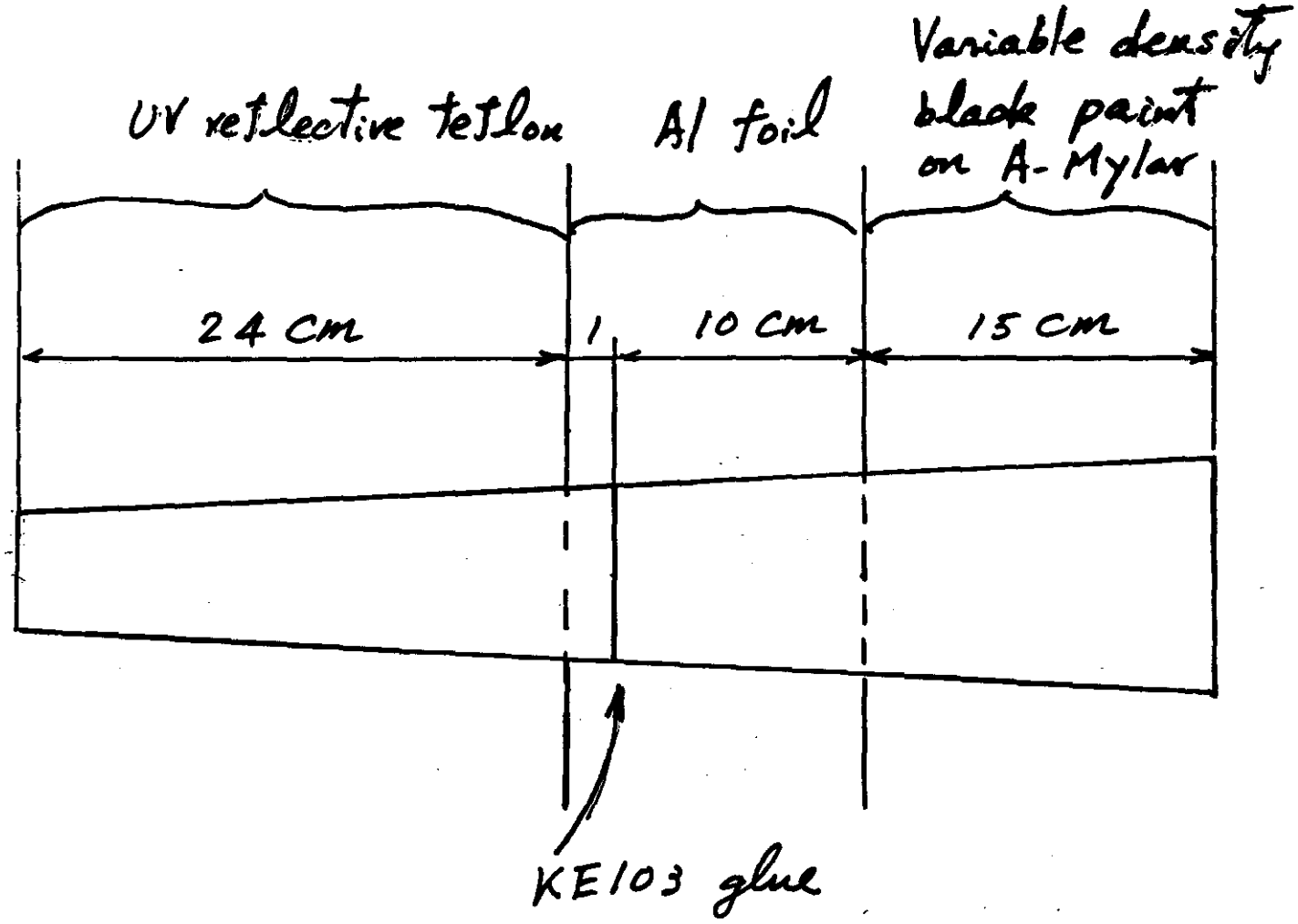
(definition of δ)


Effect of Light Uniformity (5 x 5)
Energy Fraction (%)
98
96
94
92
& 10 Gev
20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
FWHM/2.35 (%)
1.0
0.5
0.0
& 10 Gev
20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
−10
0
10
20
Deviation δ (%)

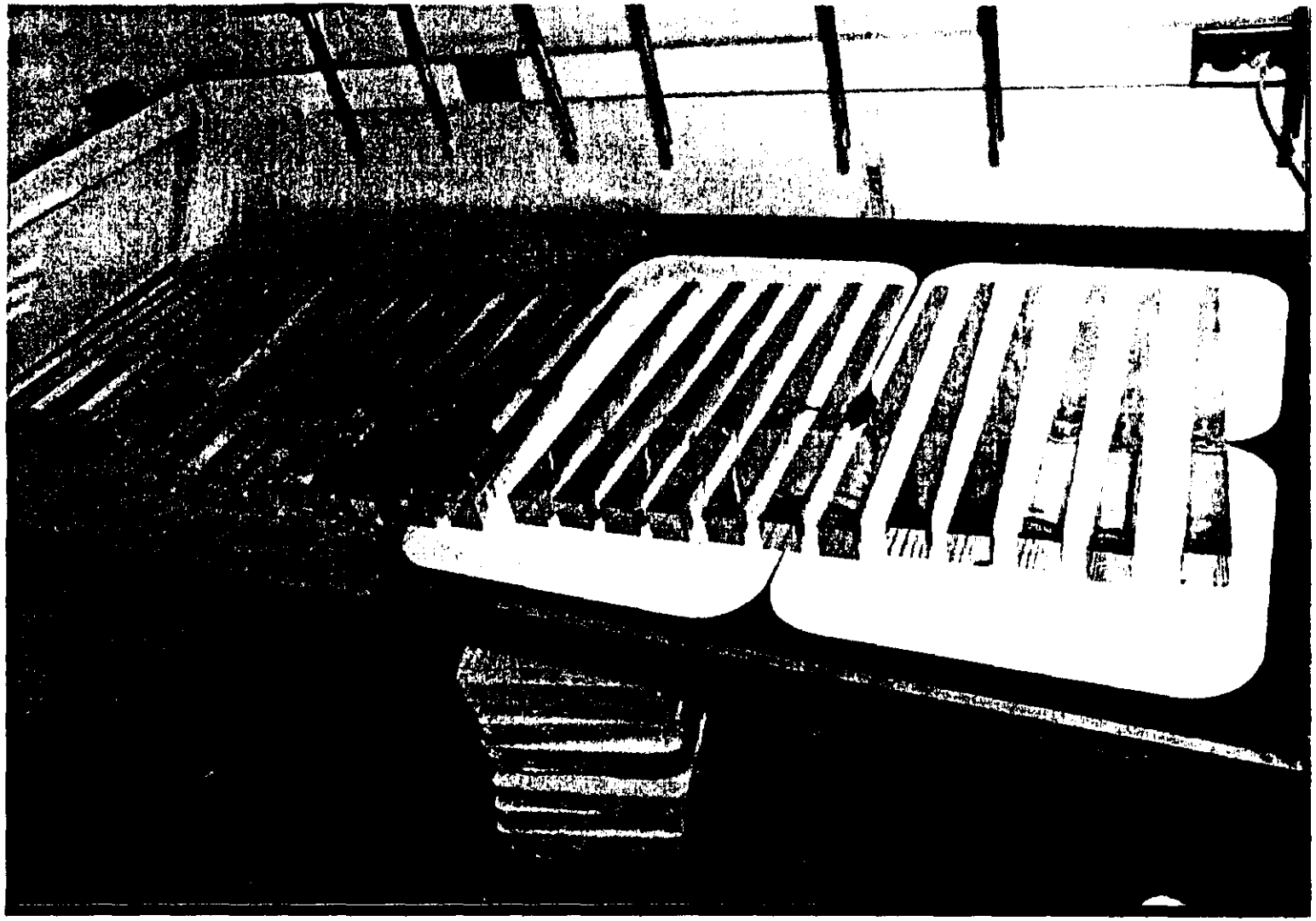




BaF₂ Wrapping for FNAL Test

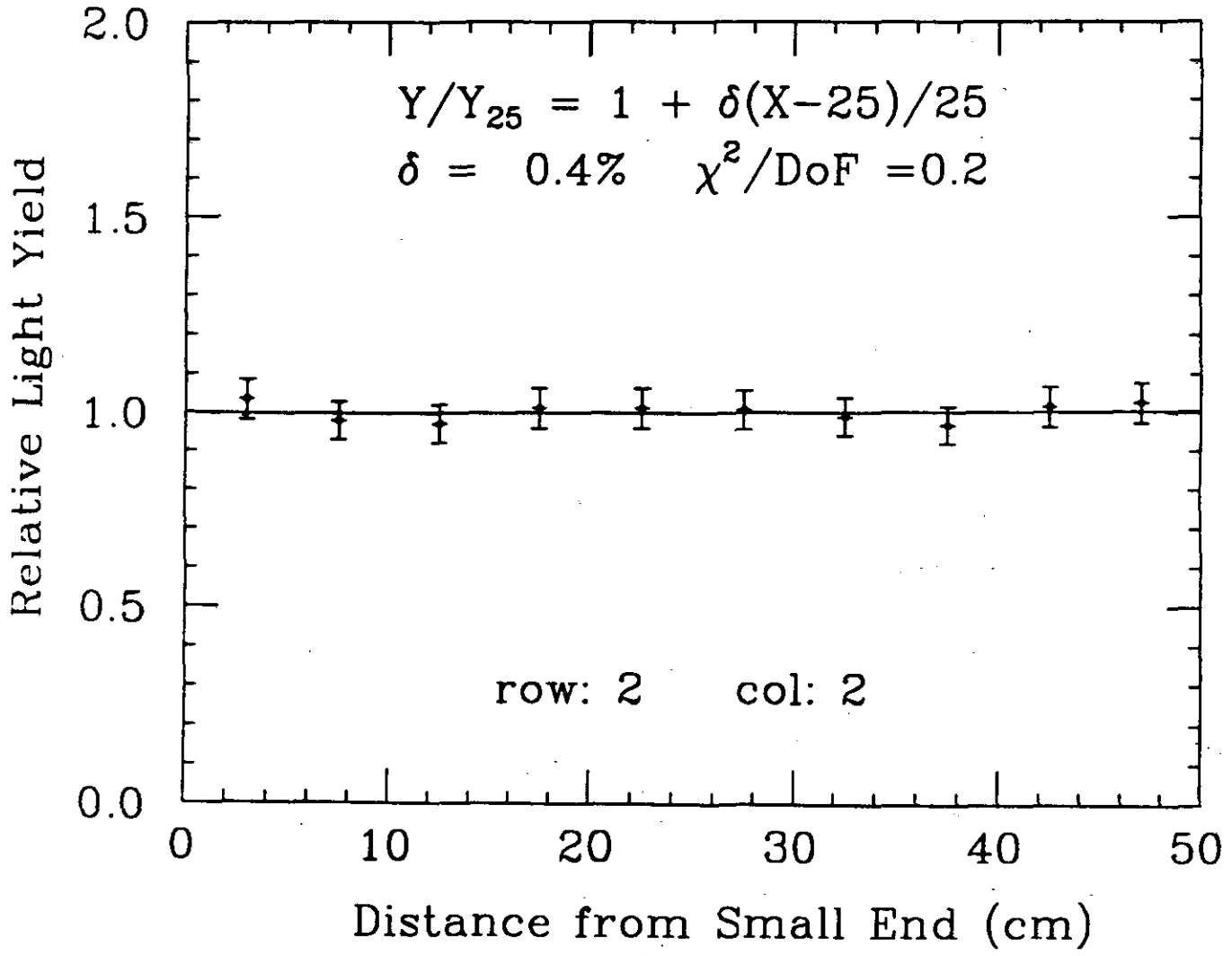


The best unprofessional Coating



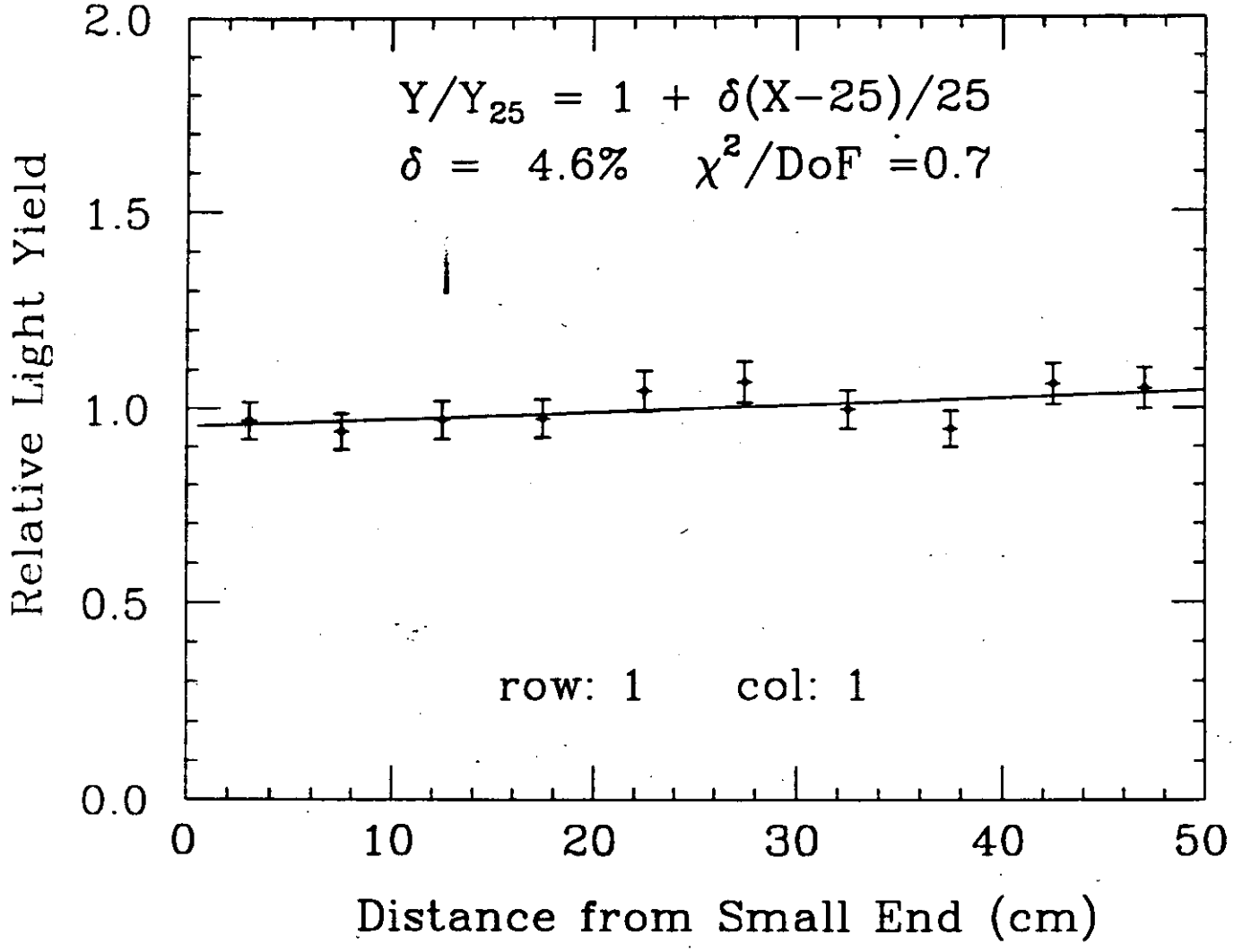
BaF₂ Test Matrix Data

from Fermi Lab Test Beam

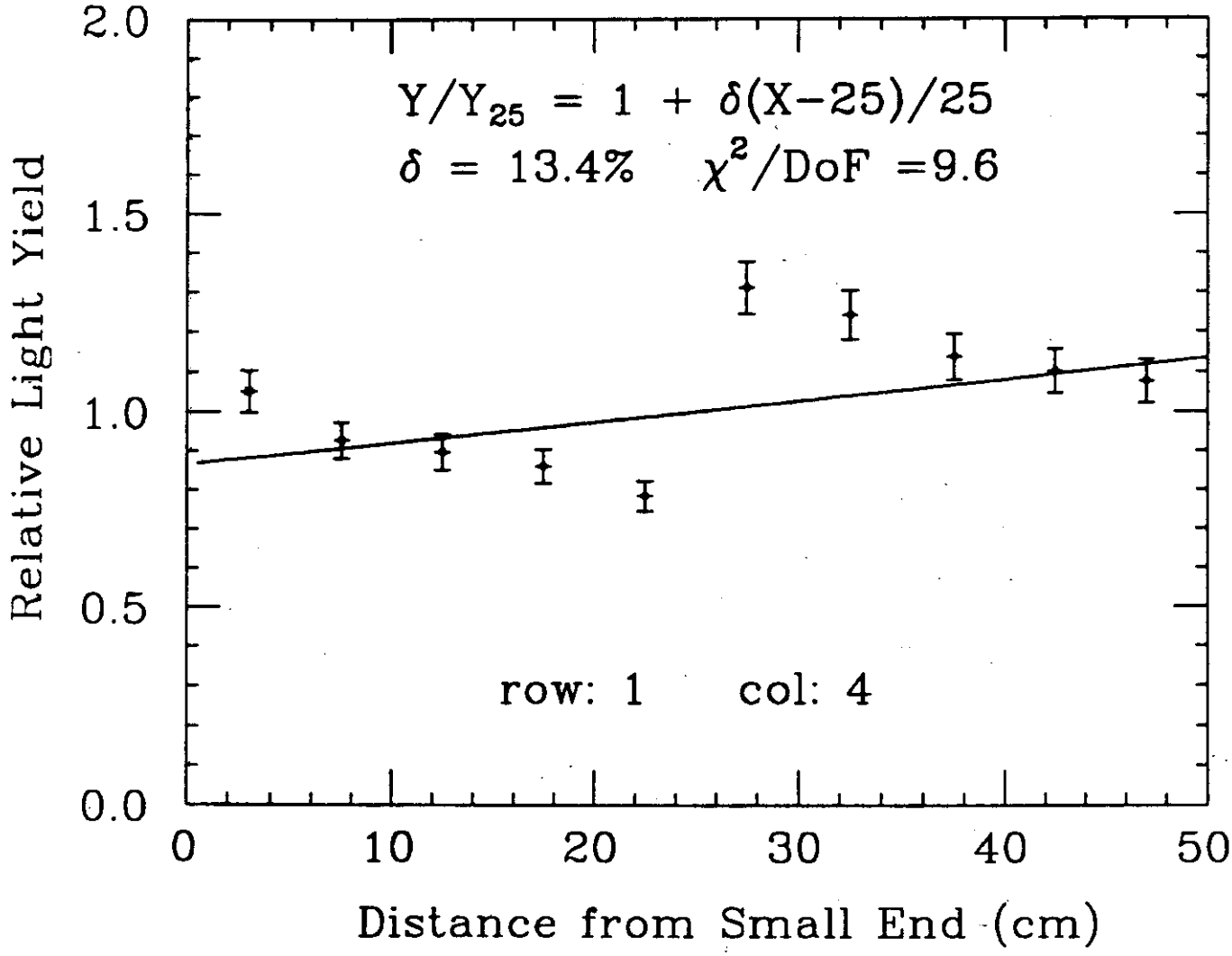


BaF_2 Test Matrix data

Measured with μ at Fermi



A broken BaF_2 Glue Joint
Fermi Test Beam Data



Major Lesons & R&D Issues (FY92)

from First BaF_2 Matrix (1991)

- Mechanical Specification:

  fens fens u XE103 joint

  ⇒ Good Light Uniformity

- Good UV Reflective coating:

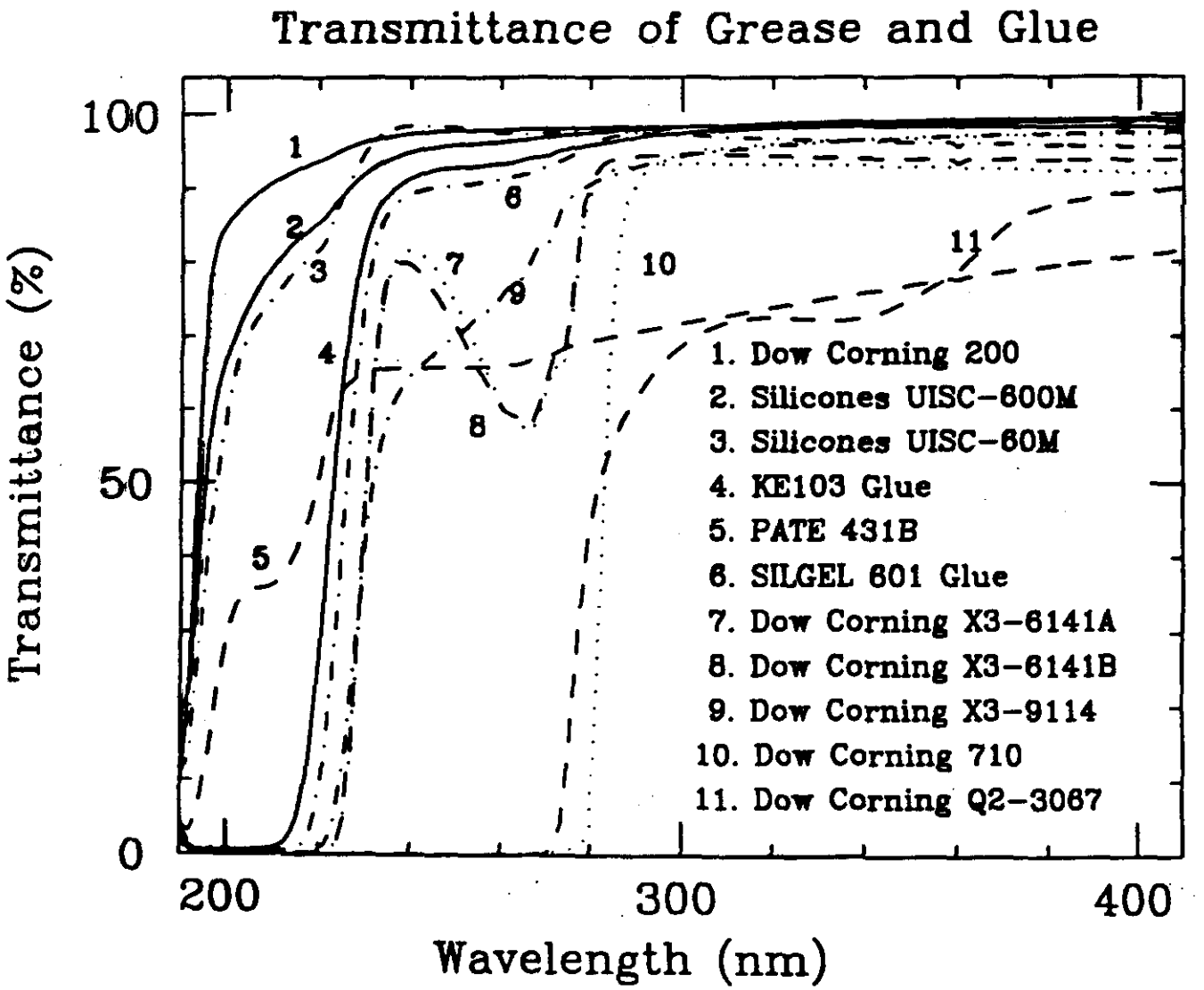
  MgF_2 + Aluminum overlayer

  85% reflectance @ 180 nm

  ⇒ Good Light Uniformity

- Radiation Resistance of Large size BaF_2 crystals

  ⇒ Good Light Uniformity



Tickness : 500μ ⇒ Not allowed

KE103 Glue is very good if few tens μ tick.

DD

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SLAC-PUB-5199
April 1990
(E)

PRODUCTION OF 400 MIRRORS WITH HIGH VUV REFLECTIVITY FOR USE IN THE SLD ČERENKOV RING IMAGING DETECTOR*

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THE SLD CRID COLLABORATION

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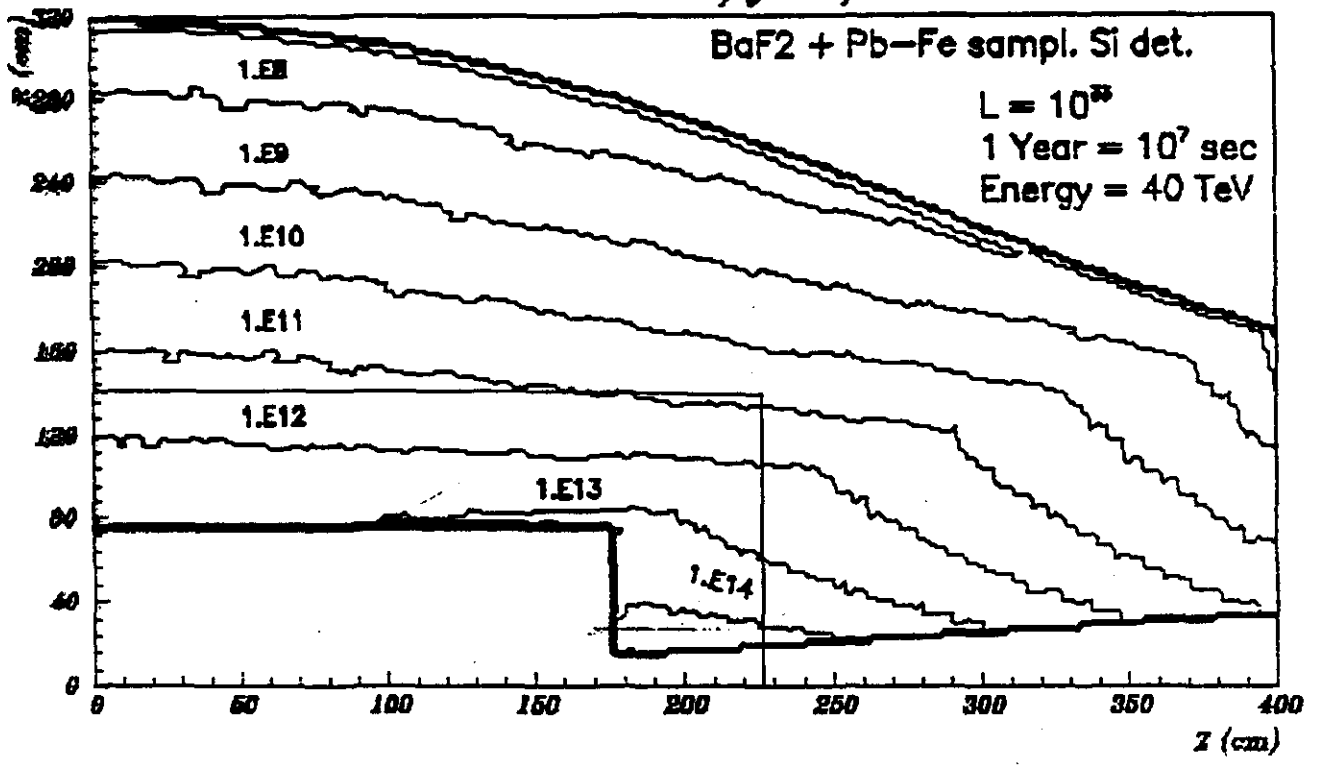
SLAC-PUB 5199
C.

ABSTRACT

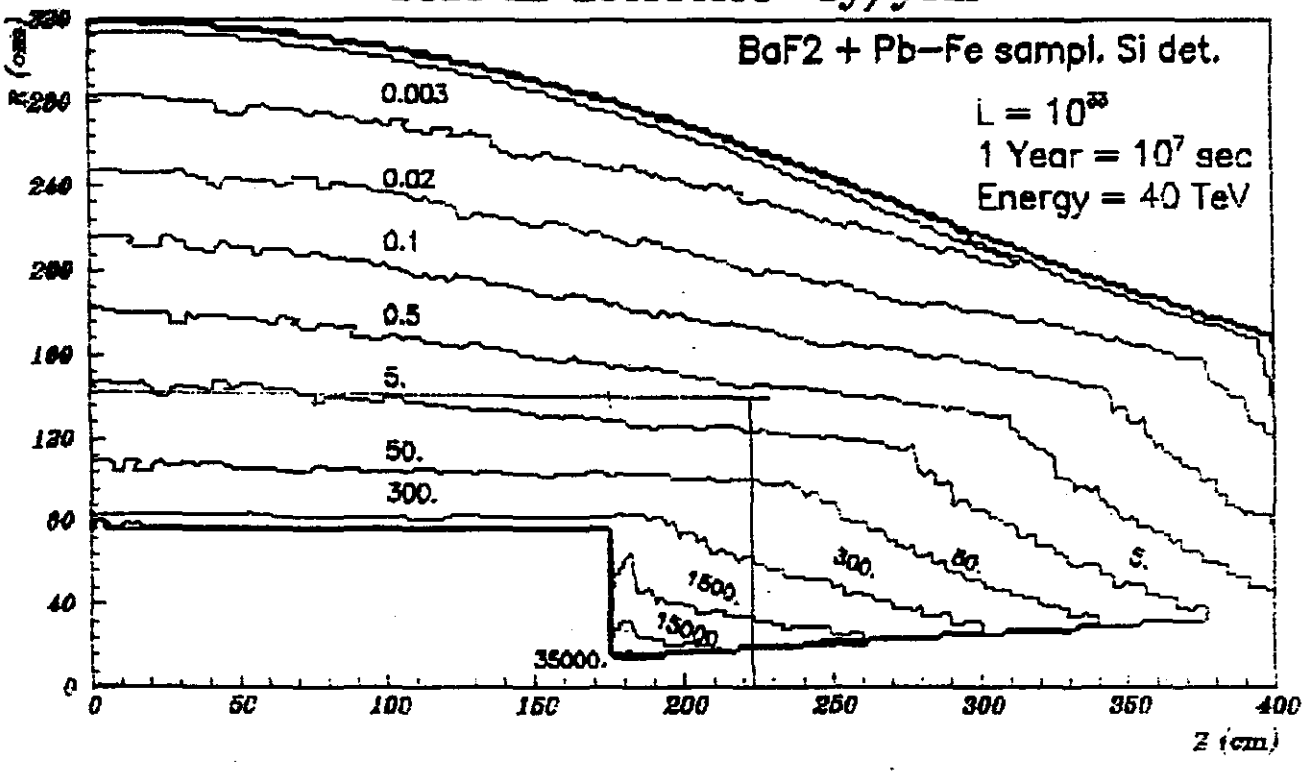
The Stanford Large Detector for experimental particle physics detection at the SLAC Linear Collider contains a Čerenkov Ring Imaging Detector (CRID). The barrel CRID mirrors have been successfully produced and installed. The industrial mirror production process, the quality control of the mirrors produced, and the results of the vacuum ultraviolet (VUV) reflectivity and mirror-shape accuracy are described. An average reflectivity of at least 80% for light at 160 nm and 85% for light in the 180–230 nm wavelength range has been achieved in the production of over 400 mirrors of a typical size of 30 by 30 cm. The surface roughness and optical distortion measurements imply that the light loss due to scattering is a few percent of the incident light and the angular error due to shape distortion is less than 1 mrad.

Reflectivity of 85% @ 220 nm has been achieved.

Neutron flux /year/cm2



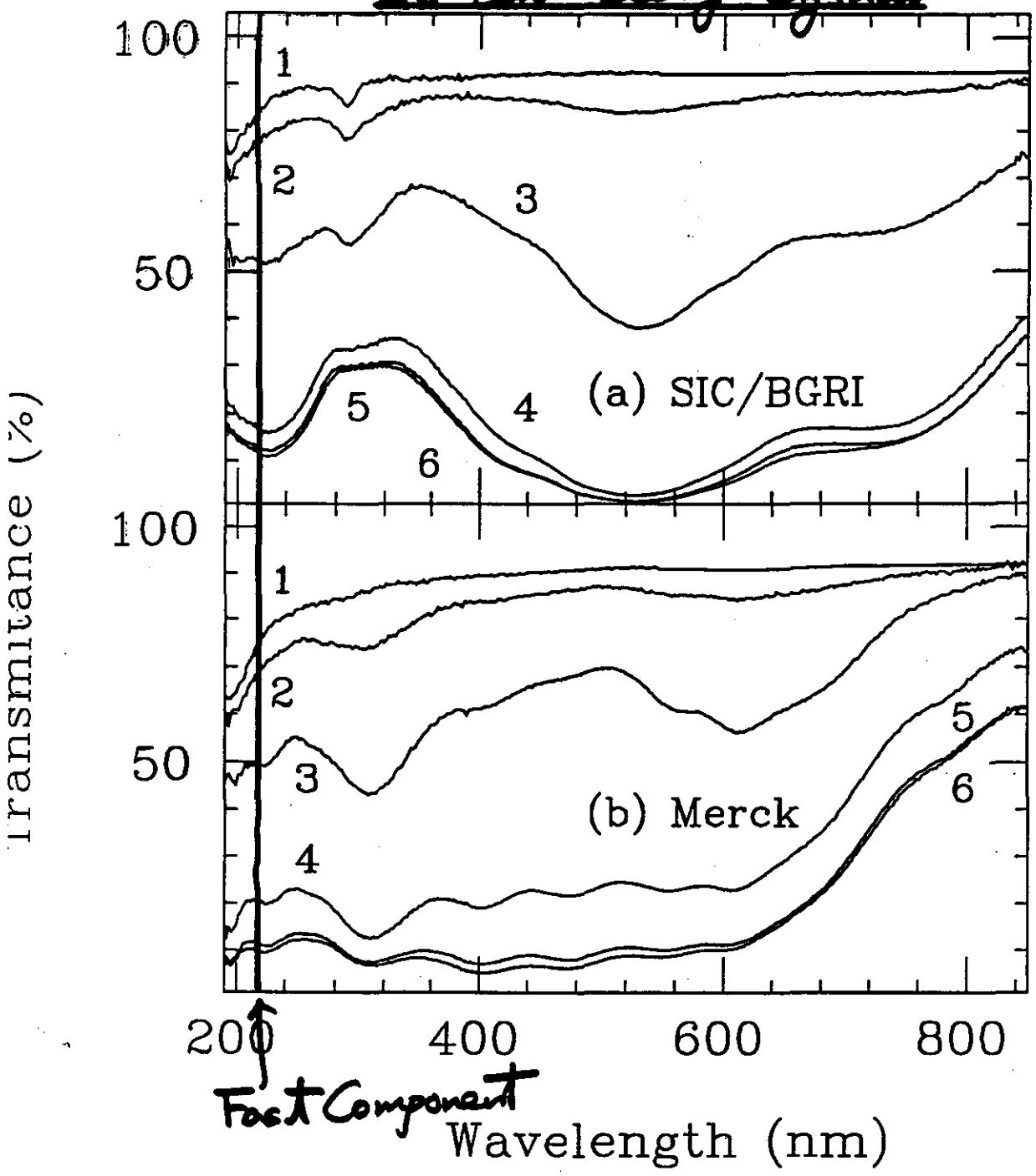
Doze in detectors Gy/year



13.04.90 V.Morgunov

Radiation Damage of BaF_2 (I)

2.5 Cm long Crystal



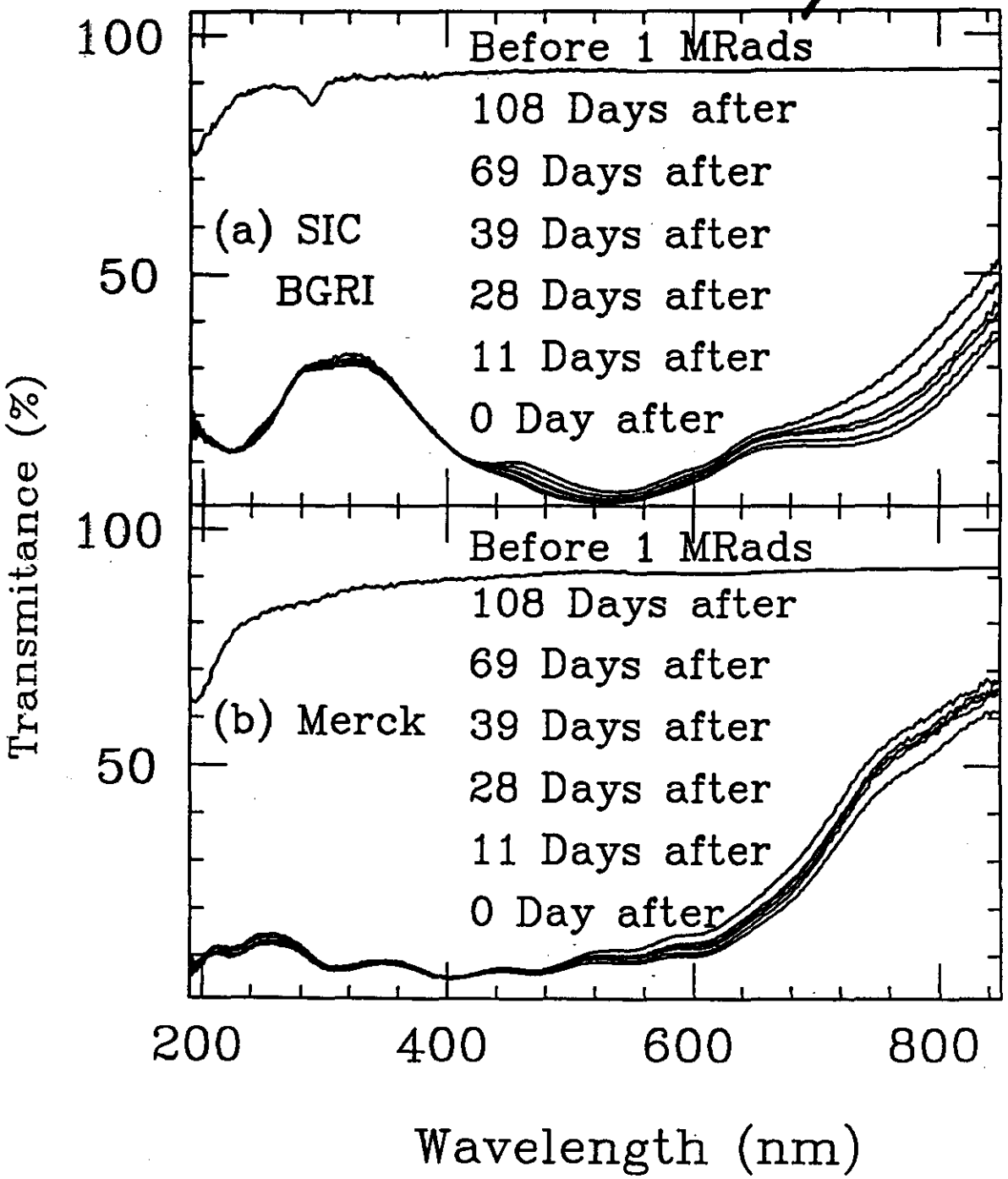
2: 100 Rads; 5. 100 kRads

3: 1kRads; 6. 1 MRads.

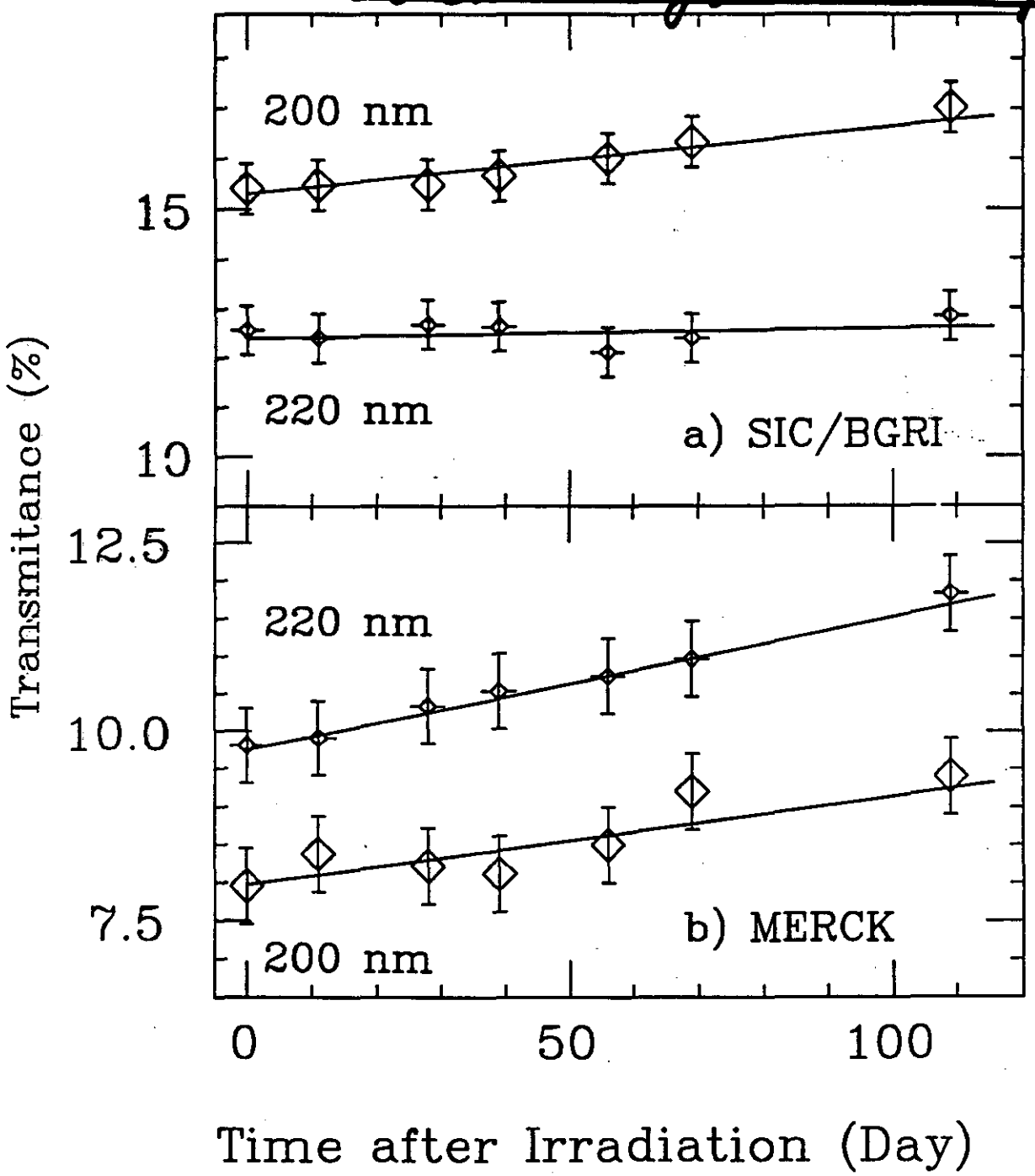
4: 10kRads;

Recovery of Radiation Damage

2.5 cm BaF₂ Crystals

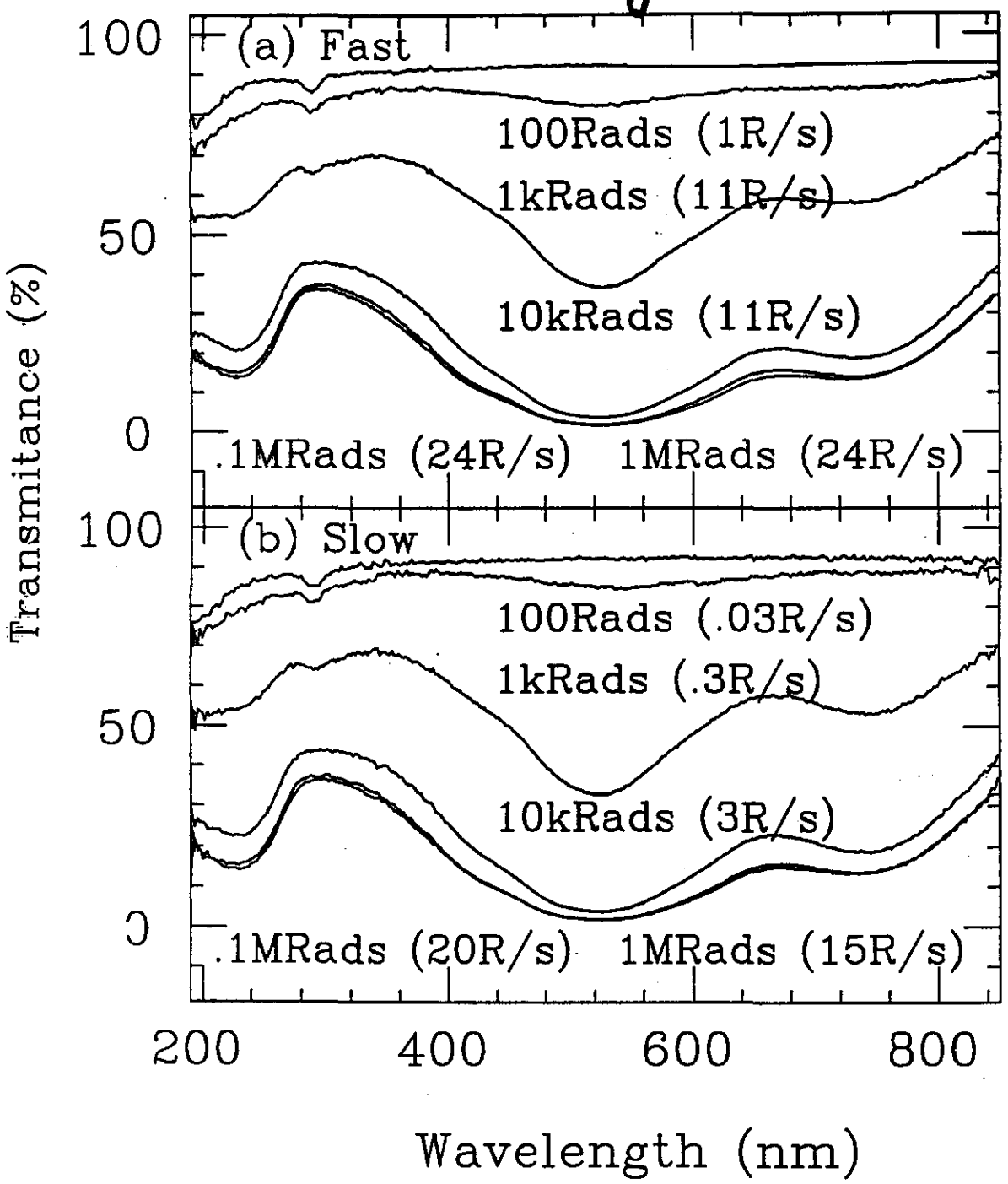


Recovery of BaF_2 Radiation Damage
25 cm long, room Temperature



Dose Rate Dependence Study

25 cm long BaF_2



Specification on Radiation Resistance

- The light attenuation length (ℓ) in BaF_2 affect light response uniformity, and thus energy resolution;

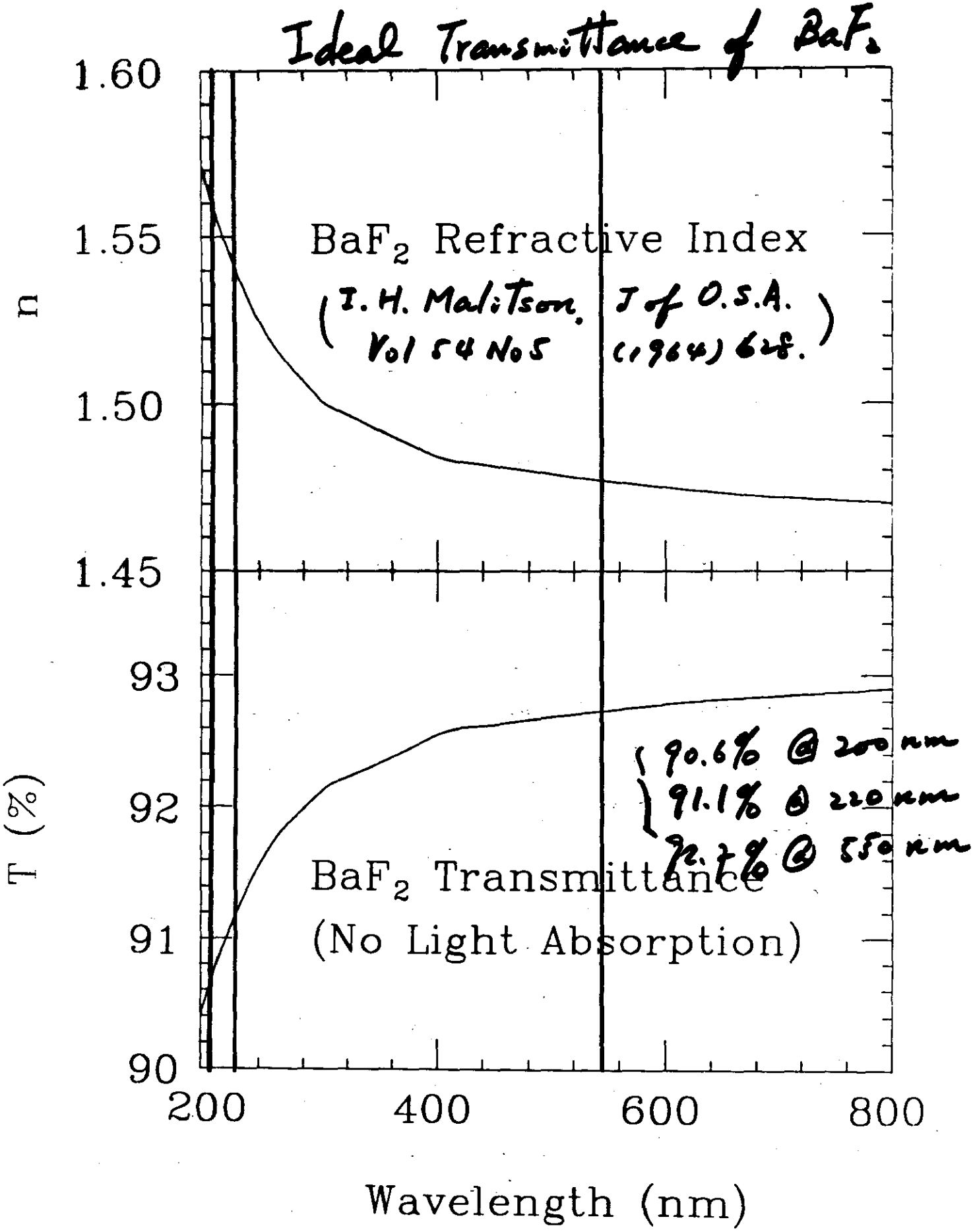
- Light attenuation length obtained from Transmittance (T) data:

$$\ell = \frac{25}{\ln \frac{T_{suf}}{T_{meas}}}$$

- Assuming light uniformity requires light attenuation length at 220 nm longer than 100 cm ⇒ allow 10% less than GEM specification.

- To be studied: proper coating to obtain the light uniformity for crystals with $\ell = 100$ cm.

λ(nm)	T_{suf} (%)	T_{spe0} (%)	ℓ_{spe0} (cm)	T_{spe1}	ℓ_{spe1}
200	90.6	75	130	66	79
220	91.1	80	<u>190</u>	70	<u>95</u>
550	92.7	85	290	77	135


Ideal Transmittance of BaF2
1.60
1.55
1.50
1.45
n
BaF2 Refractive Index
(I. H. Malitson, J of O.S.A. Vol 54 No 5 (1964) 628.)
93
92
91
90
T (%)
90.6% @ 200 nm
91.1% @ 220 nm
92.7% @ 550 nm
BaF2 Transmittance
(No Light Absorption)
200
400
600
800
Wavelength (nm)

CONCLUSIONS

Y. Kamyshkov

1. Assuming saturation with radiation and very slow self-recovery (response trimmed to uniform after preradiation) light absorbtion length at 220 nm should be > 53 cm (6 side polished crystal).

   Conservatively one can specify (as in R-Y Zhu specs) :

   Abs. length for irradiated crystals > 100 cm (> 200 cm fresh crystals)

   Response of the crystals with such absorbtion length can be trimmed to uniform by optical coating, wraping etc. Accuracy of such trimming should be at the level Delta < 3%.

2. Once crystals are coated and installed one can admit that global or local non-uniformity can be developed for 5 years of SSC operation at the level of no more than Delta=6% or change absorbtion length from > 100 cm to > 80 cm.

3. Change of global light yield of the crystal (with or without development of non-uniformity) should not exceed 1% per month of steady SSC operation (assume calibration once per month).

MEMORANDUM OF UNDERSTANDING

BETWEEN

THE GEM COLLABORATION
SSC, U.S.A.

AND

THE SHANGHAI INSTITUTE OF CERAMICS
SHANGHAI, CHINA

A PROGRAM OF COLLABORATION ON THE GEM EXPERIMENT AT THE SSC

Dec 14, 1991

Abstract

The Spokesmen of GEM experiment, B. Barish and W. Willis, visited the Shanghai Institute of Ceramics (SIC) of Chinese Academy of Sciences, Shanghai, China, during Dec 13—14, 1991. In this visit extensive discussions with Director Emeritus, Prof. D.S. Yan, and Prof. Z.W. Yin and H.R. Tan of SIC, were carried out to review present status of barium fluoride project and multichannel optical modulator project. This memorandum of understanding between the GEM Collaboration and the Shanghai Institute of Ceramics records the essential issues discussed, and is intended solely for the purpose of providing basic principles and necessary means for a fruitful collaboration between SIC and GEM.

A GEM Specifications on BaF_2 Crystals

The specifications of the BaF_2 crystals finally will be accepted for GEM BaF_2 calorimeter are summarized below:

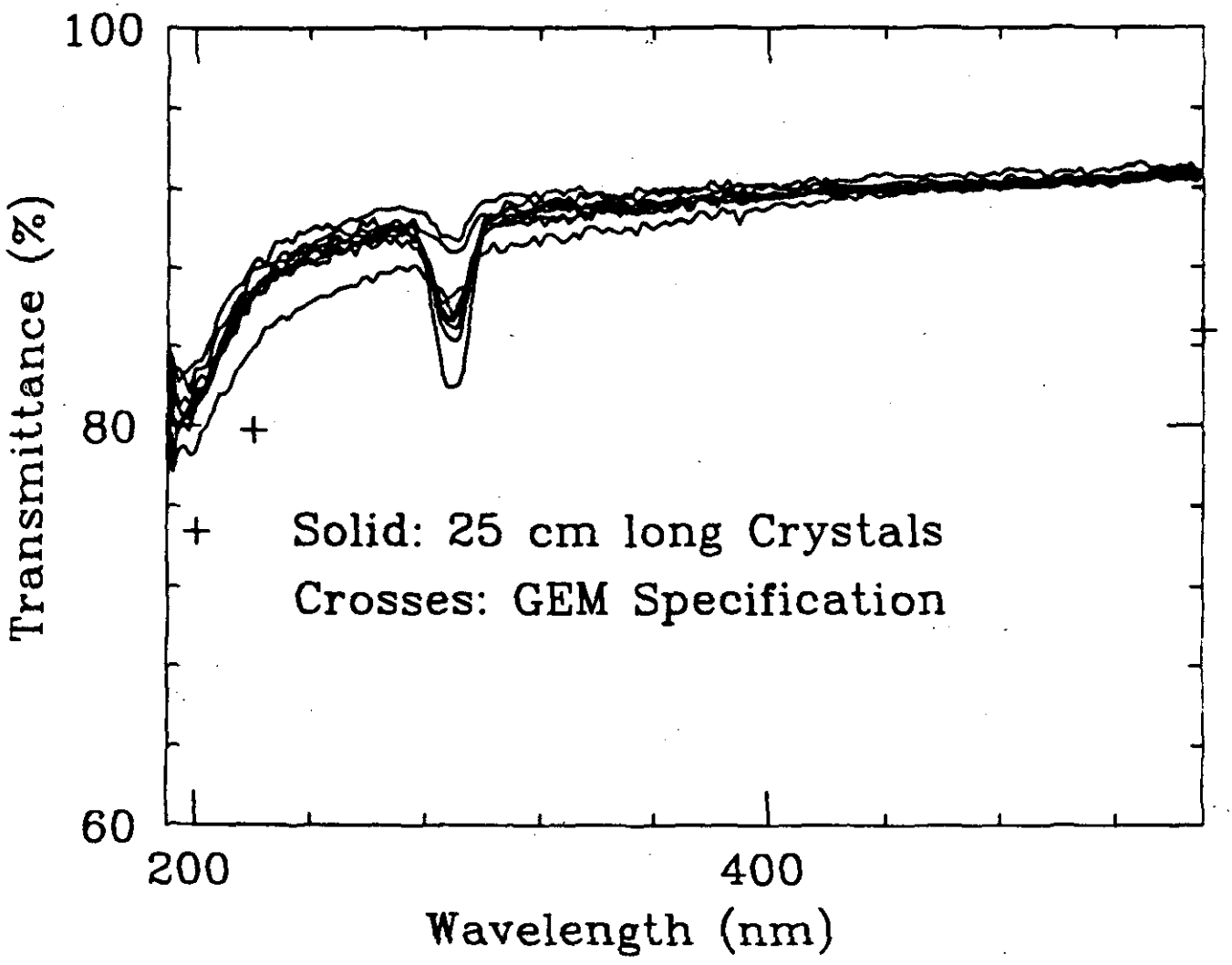
- **Dimensional tolerances** are dictated by the need to mount the crystals safely in the support structure, with a minimum of dead space between the crystals:
  - from -300 μm to 0 μm in the transverse dimensions (typical deviations from nominal 100μm)
  - from -400 μm to 0 μm in length
  - less than 50μm in planarity of all faces after coupling two 25 cm long half crystals.
- **Transparency before irradiation**, specified in terms of the minimum fraction of the light at specified wavelengths which passes through 25 cm of crystal length:
  - $\geq 75\%$ at $\lambda = 200$ nm
  - $\geq 80\%$ at $\lambda = 220$ nm
  - $\geq 88\%$ at $\lambda = 550$ nm
- **Transparency after 1 MRads irradiation**, specified in terms of the minimum fraction of the light at specified wavelengths which passes through 25 cm of crystal length:
  - $\geq 66\%$ at $\lambda = 200$ nm
  - $\geq 70\%$ at $\lambda = 220$ nm
  - $\geq 77\%$ at $\lambda = 550$ nm

Note: the saturation of both light yield loss and transmittance loss is assumed, given the data obtained. The corresponding light attenuation length of the fast component (220 nm) of BaF_2 crystal after saturated irradiation is about 100 cm.

C GEM Specification on 49 BaF_2 crystals

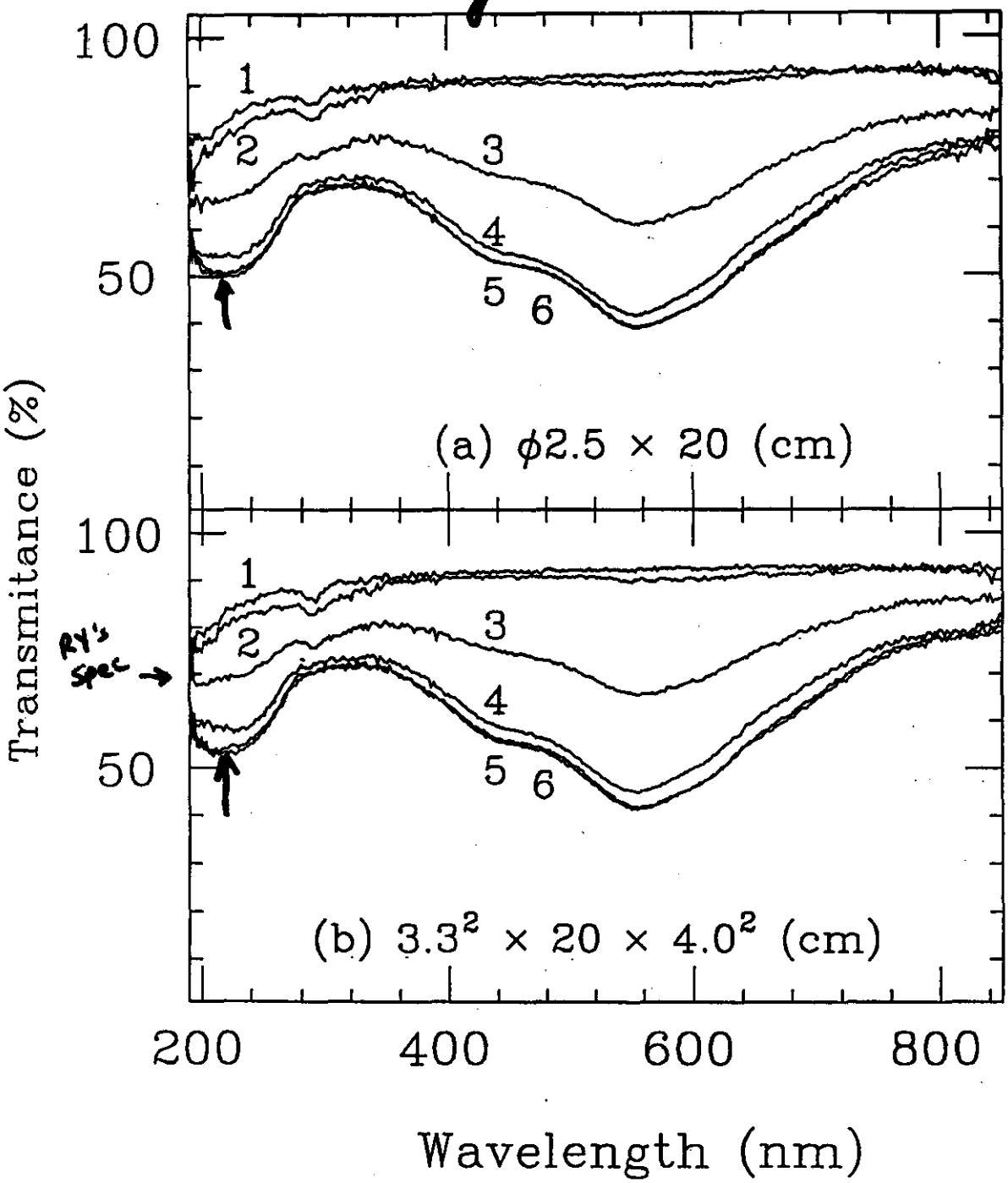
The specifications of the BaF_2 crystals will be accepted for GEM BaF_2 test matrix are summarized below:

- **Dimensional tolerances** are dictated by the need to mount the crystals safely in the support structure, with a minimum of dead space between the crystals:
  - from –300 μm to 0 μm in the transverse dimensions (typical deviations from nominal 100μm)
  - from –400 μm to 0 μm in length
  - less than 50μm in planarity of all faces after coupling two 25 cm long half crystals.
- **Transparency before irradiation**, specified in terms of the minimum fraction of the light at specified wavelengths which passes through 25 cm of crystal length:
  - $\geq$ 75% at $\lambda = 200$ nm
  - $\geq$ 80% at $\lambda = 220$ nm
  - $\geq$ 88% at $\lambda = 550$ nm
- **Transparency after 1 MRads irradiation**, specified in terms of the minimum fraction of the light at specified wavelengths which passes through 25 cm of crystal length:
  - $\geq$ 45% at $\lambda = 200$ nm
  - $\geq$ 50% at $\lambda = 220$ nm
  - $\geq$ 60% at $\lambda = 550$ nm

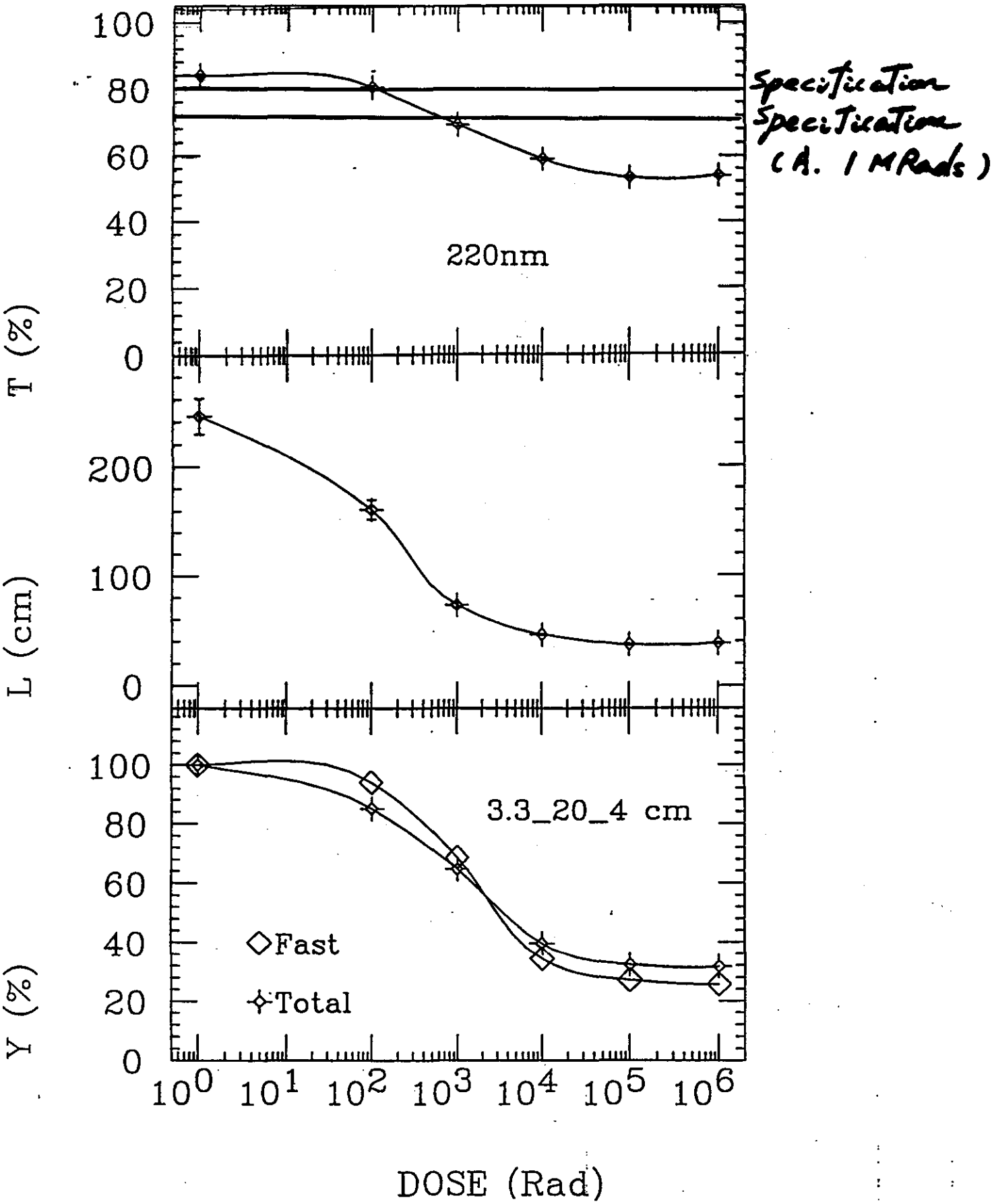

100
80
60
Transmittance (%)
200
400
Wavelength (nm)
Solid: 25 cm long Crystals
Crosses: GEM Specification

Radiation Damage of BaF_2 (II)

New Crystals from SIC 20 cm long



1: before irradiation;
2: 100 Rads;
3. 1 kRads;
4. 10 kRads;
5. 100 kRads;
6. 1 MRads.



Performance of a new BaF_2 (20 cm) from SIC

SIMS Oxygen Bulk Analysis of BaF2

Sample	Relative Concentration
K14417D	3.2
K458484A	6.22
SIC2x2.5	3.1
SICCube	6.5
SICXTL Tip	1.9
SICXTL Base	3.4

BaF_2 R&D Program in FY92

- Further improve BaF_2 quality to reach specifications:
  - mechanical specification;
  - radiation resistance.

    SIC/BGBI, ORNL, CALTECH, BNL
- Work on UV-reflective coating to achieve light uniformity of 5% for crystals after irradiation.

  LLNL, CALTECH, UCSD, CMU
- Side-line work on small pure crystal (Oxygen free) in U.S.

  OPTOVAC, CALTECH, BNL

BAF2 PROJECT

RADIATION DAMAGE STUDY

COORDINATORS

Peijun Li	• SIC, China
Zhezong Dai	• BGRI, China
H. Newman	• Caltech
R. Zhu	• Caltech

PANEL EXPERTS: SUB-COORDINATORS

C. Woody (BNL)	• Rad. Damage Measurements
M. Strathman (Charles Evans and Associates)	• Impurity and Defect Analysis
R. Sparrow (OPTOVAC)	• Crystal Processing Improvements
R. Craig (Battelle Pacific NW Lab)	• Analysis and Simulations

PLUS EXPERT SUPPORT PROPOSED:

Naval Research Lab

ORNL Solid State Division

BaF_2 EM CALORIMETER
1992 R&D PROGRAM
RADIATION DAMAGE STUDY

- BaF2 Group/U.S. Expert/China Coordination
- Extensive Testing on New Full Size Crystals, Small Crystals, and Raw Materials
- Correlate Trace Element, Structural and Surface Analyses With Rad Damage Tests
- PRIMARY ROLE: O_2 and OH^- (50 ppm Level)
- Improve Processing Technology: Raw Material Treatment, Oven Vacuum, Crucible, Growth Cycle
- Test Residual Effects of Rare Earths, Other Traces After Oxygen Level Reduced
- Test Saturation With Protons: at BNL (30 GeV) or LNPI (1 GeV)

#	Name	Size (mm)	Comment
B1	Powder	20g	raw material
B2	Powder	20g	raw material with different vendor
B3	Powder	20g	pure raw material
B4	Powder	20g	PbF_2 raw material
B5	Sintered	20g	polycrystal
B6	Sintered	20g	polycrystal with different processing
B7	Crystal	ϕ15×20	Cut from 6 cm crystal
B8	Crystal	ϕ15×20	Cut from 6 cm crystal
B9	Crystal	small pieces	residual from 6 cm crystal
S1	Powder	20g	raw material ⇒ Steve King
S2	Sintered	20g	polycrystal made with S1
S3	Powder	20g	pure raw material
S4	Sintered	20g	polycrystal made with S3
S5	Sintered	20g	polycrystal
S6	Crystal	45×43×18	from JB1-91-13/1
S7	Crystal	ϕ25.4×25.4	from JB1-91-13/0
S8	Crystal	ϕ25.4×25.4	from JB1-91-13/0
S9	Crystal	ϕ25.4×25.4	from JB1-91-13/0
S10	Crystal	ϕ25.4×25.4	from JB1-91-13/0
S11	Crystal	ϕ25.4×25.4	from JB1-91-13/0
S12	Crystal	5×5×8	from JB1-91-13/1
S13	Crystal	12×12×5	from JB1-91-13/1
S14	Crystal	small pieces	from JB1-91-13/4

Samples from BGRI and SIC

BaF2 ENGINEERING TASKS

M. Rennich and Staff (ORNL)

- Design and Develop Crystal Mounting Support Structure
- Improve Chinese Oven: $10^{-6} - 10^{-7}$ Torr
  - Western Diffusion Pump
  - Cold Trap, Ion Gauges
  - Commission and Test
- Recompute Crystal Dimensions:
  - Critical Surfaces Flat and Parallel to 10 Microns
  - Perpendicular To Two Long Crystal Faces
- PROJECT ENGINEERING:
  - Define Project Plan and Schedule, Including All Production Steps (8/92)
  - Specify Standard Operating Procedures: Growth, Machining, Surface Treatment
  - Define Tracking + Quality Control Steps: Tests and Specifications

BaF_2 R&D PROGRAM for 1992

LIGHT UNIFORMITY STUDY

C. Wuest (LLNL), R. Zhu (Caltech),
A. Engler (CMU)

- UV Reflective Coating, Optimized for BaF_2 Fast Component (190 - 240 nm)
- MgF_2 - Al_2O_3 Electron Beam Coating Tests Underway at LLNL:
  - Stress-Free Ion Beam Milling and X-Ray Diffraction Analysis (2/20 - 3/6)
  - Optical Polishing; X-Ray and Trace Analysis of Surface (2/20 - 3/6)
  - Wet and Dry Diamond Turning, With Surface Analysis (2/24 - 3/13)
  - Optical Characterization Before and After Coatings (3/13 - 3/27)
  - Precompute Graded Coating, Coat (and Seal) Crystals (3/20 - 4/24)
  - Verify Recovery of Uniformity After Radiation Effect (3/20 - 4/24)
- Correlate Improved Surface Processing and Sealing With Rad Damage (3/92 - 4/92)
- Process 20 New Crystal Pairs (5/92)

Barium Fluoride Crystal Surface Preparation and UV Coating R&D at Lawrence Livermore National Laboratory

Dr. Craig R. Wuest
Physicist
High Energy Physics Group
Physics Department

Theodore T. Saito
Group Leader, Optical Science and Engineering Group
Materials Fabrication Division

Dr. Daniel M. Makowiecki
Chemical Engineer
Chemistry and Materials Science Division

Lawrence Livermore National Laboratory

February 14, 1992

An Update on the LLNL Electro-optics Effort in Support of the GEM Detector

Kent McCammon, Electronics Engineer
Mark Lowry, NTES Photonics Project Leader
L-Division
Phone: 510/423-2924; email:Mlowry@LLNL.Gov

Lawrence Livermore National Laboratory

presented to

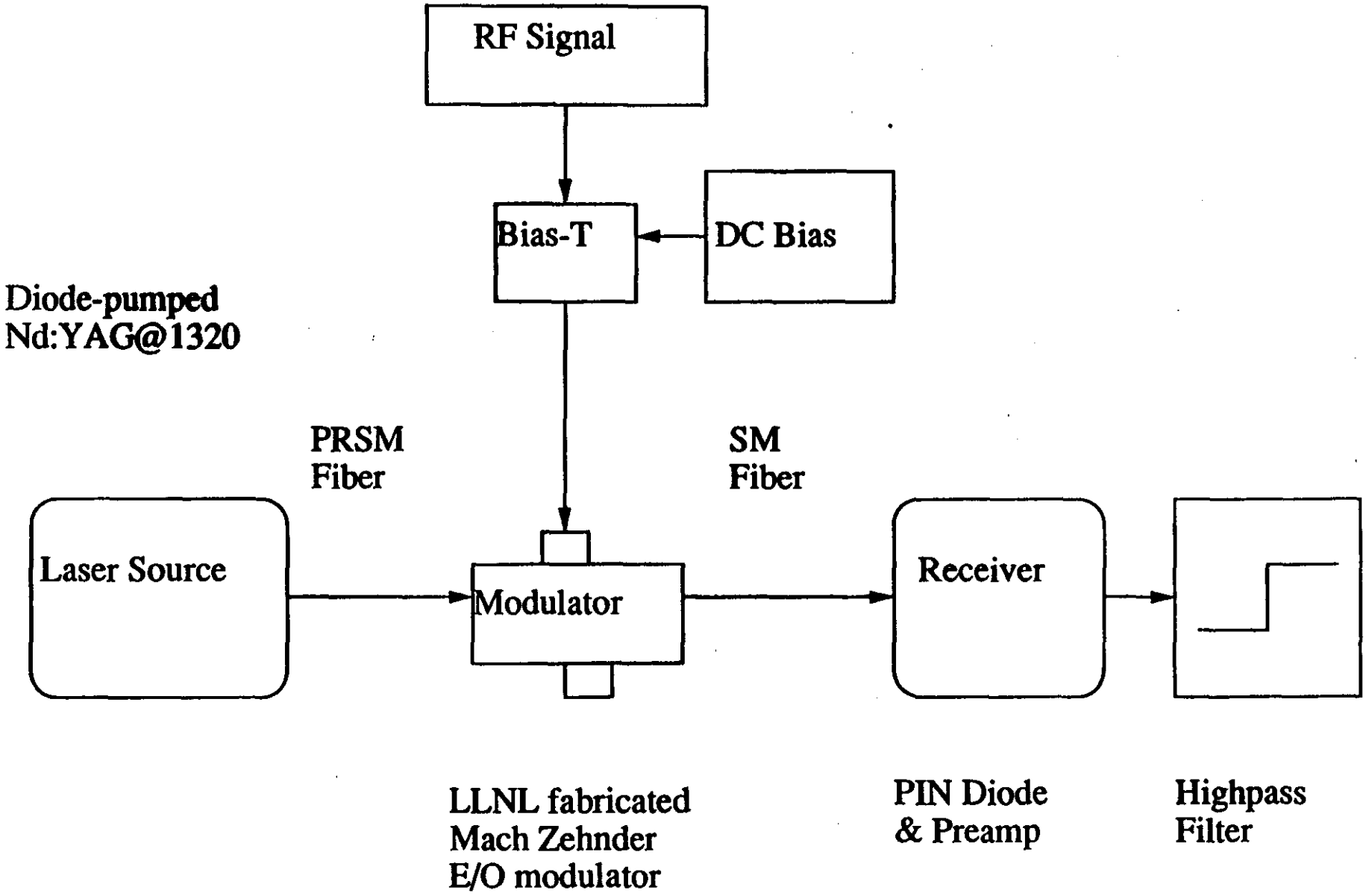
GEM collaboration
Detector Electronics Group
3/8/92
Tucson, AZ

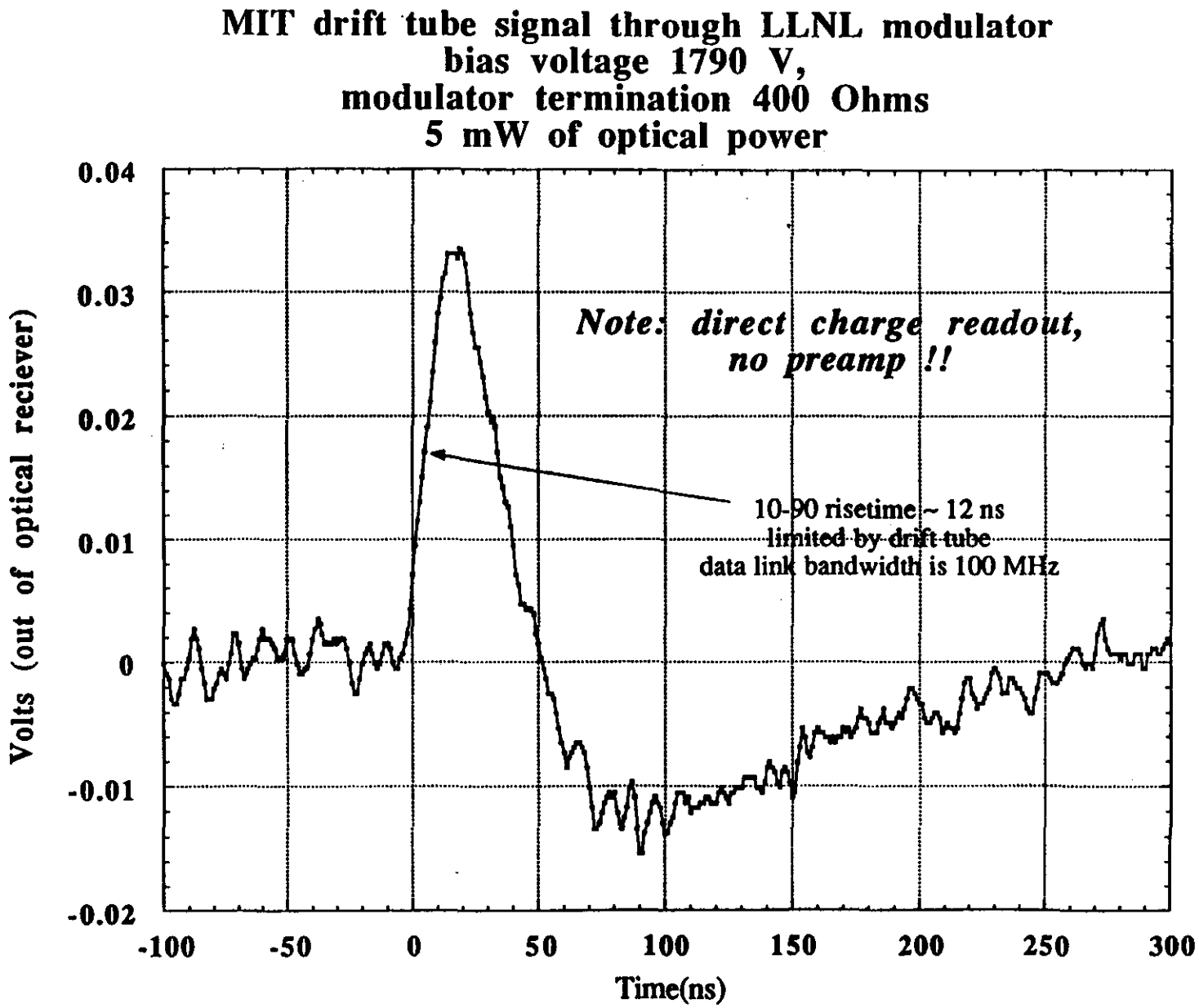
Outline for LLNL E/O update

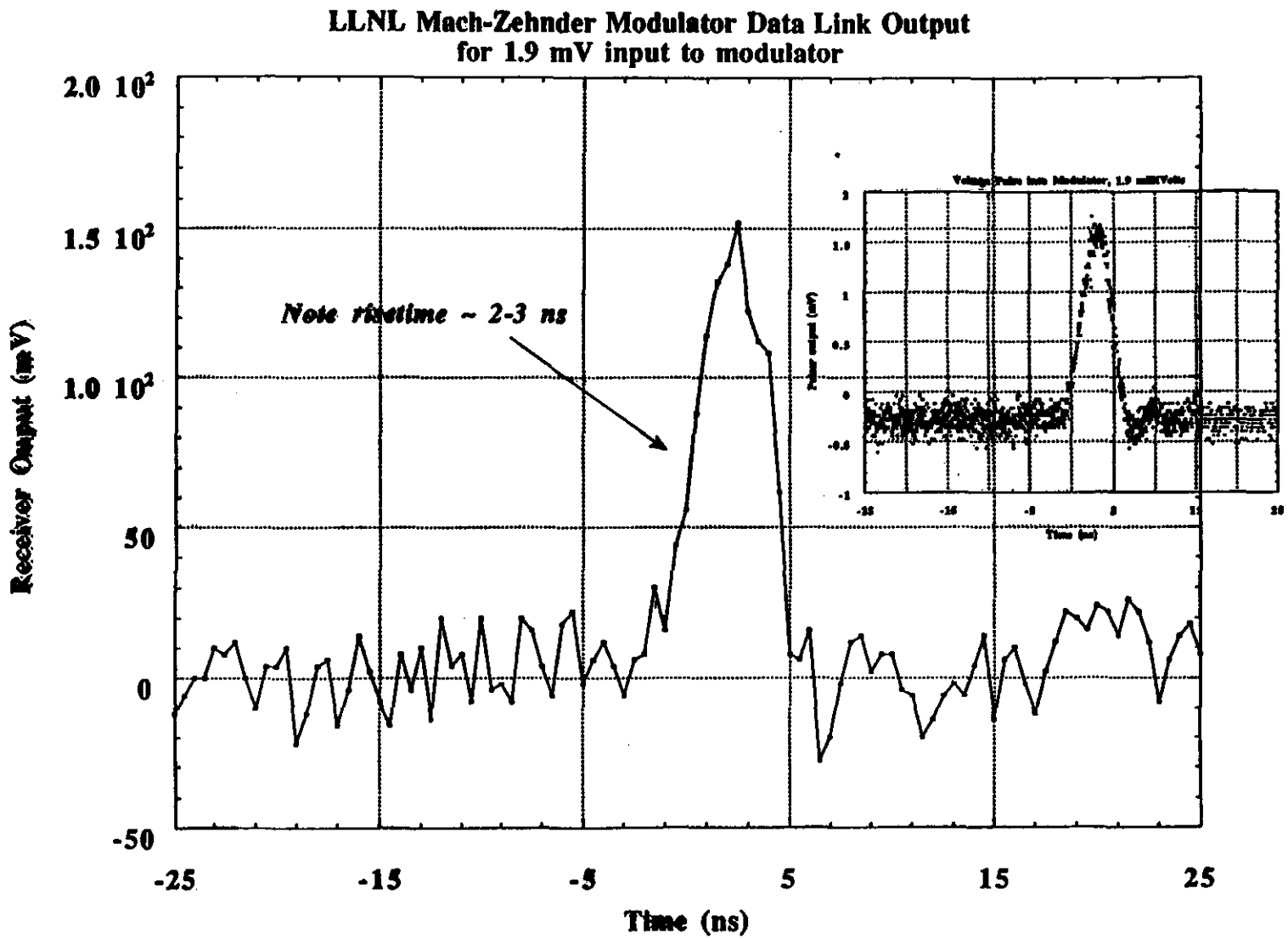
- Our latest direct charge-readout data link results using the MIT drift tube (now better fidelity than the conventional)
  - link output scope data
    - s/n, voltage and charge sensitivity
    - system bandwidth and signal risetime
    - implications for muon chamber timing data, from drift tube data
  - Pulse-height spectrum from Fe^{55}

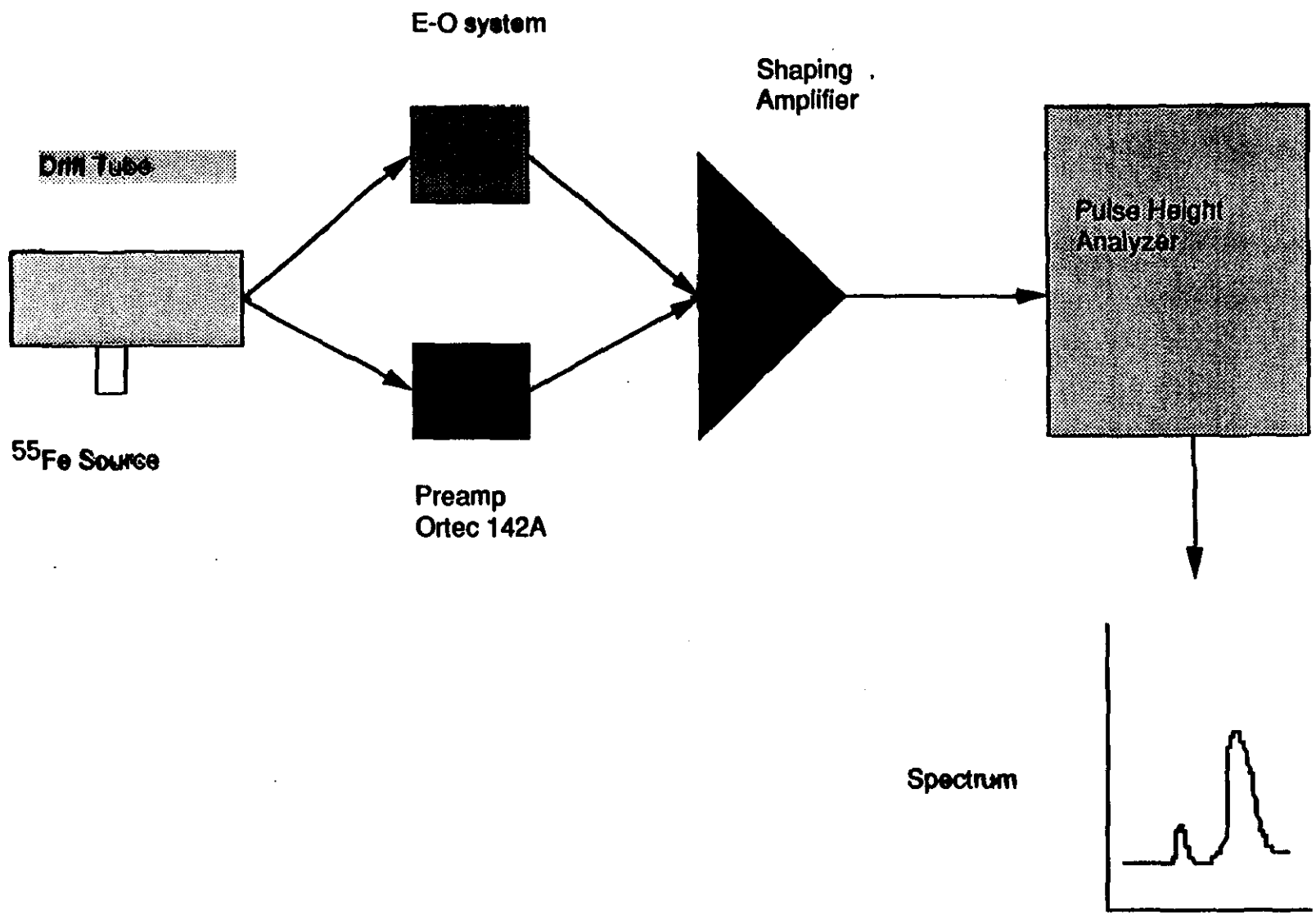
- Update on IOCC's flip-chip multi-channel modulator packaging work (R. Becker, et.al.)

- Some E/O system architecture proposals (extrapolating from M. Seman's proposals)
  - Pr (or Nd) fiber amplifiers (at 1300 nm)
  - unpolarized optical sources (at 1300 nm)


RF Signal
Bias-T
DC Bias
Diode-pumped
Nd:YAG@1320
PRSM
Fiber
SM
Fiber
Laser Source
Modulator
Receiver
LLNL fabricated
Mach Zehnder
E/O modulator
PIN Diode
& Preamp
Highpass
Filter


MIT drift tube signal through LLNL modulator
bias voltage 1790 V,
modulator termination 400 Ohms
5 mW of optical power
Note: direct charge readout,
no preamp !!
10-90 risetime ~ 12 ns
limited by drift tube
data link bandwidth is 100 MHz
Volts (out of optical reciever)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-100
-50
0
50
100
150
200
250
300
Time(ns)

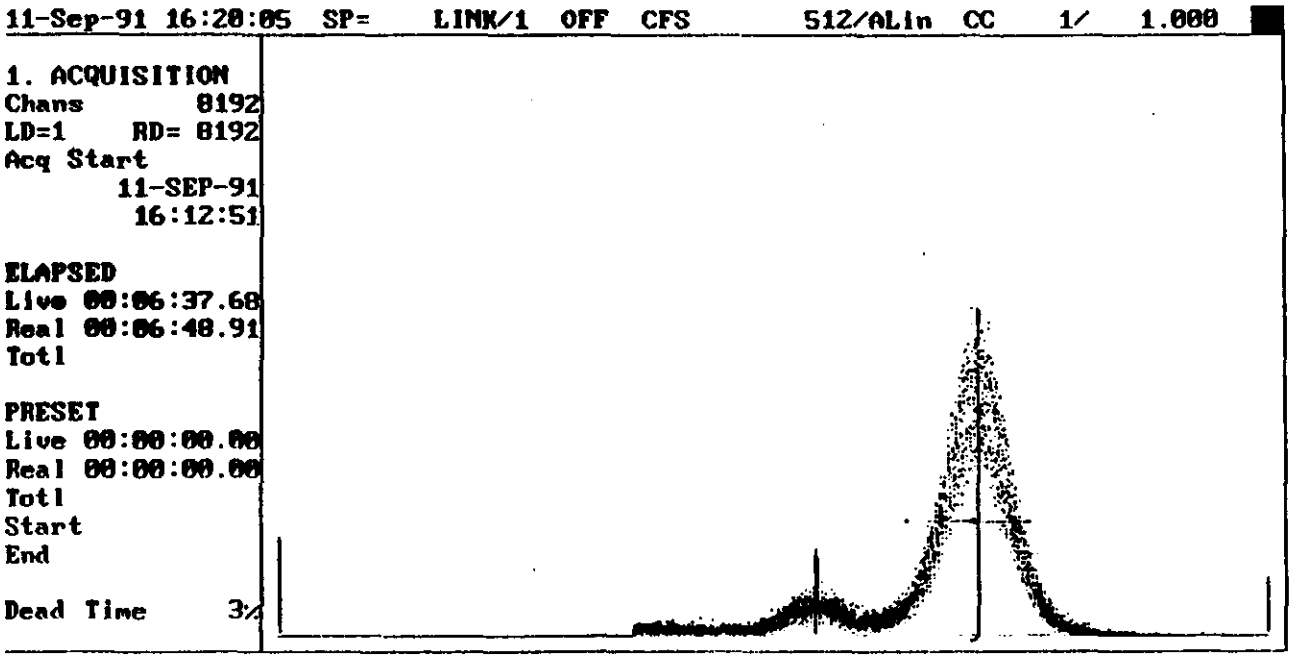

LLNL Mach-Zehnder Modulator Data Link Output
for 1.9 mV input to modulator
Note risetime ~ 2-3 ns
Receiver Output (mV)
2.0 10²
1.5 10²
1.0 10²
50
0
-50
-25
-15
-5
5
15
25
Time (ns)


E-O system
Shaping
Amplifier
Drift Tube
Pulse Height
Analyzer
55Fe Source
Preamp
Ortec 142A
Spectrum

Tube Voltage 1790

Link

Fe^{55} Spectrum using LLNL Modulator Link.



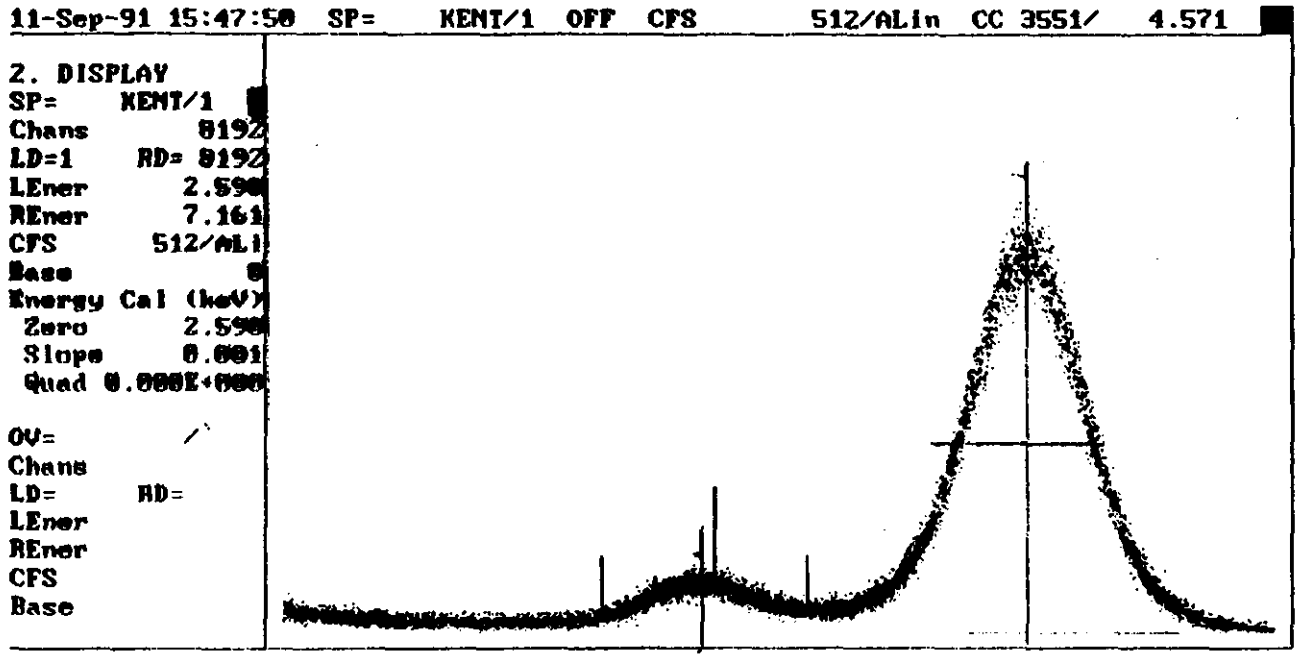
2.18cm

FWHM = 0.98cm (3keV / 2.18keV) = 1.35 keV

Tube Voltage 1790

Fe^{55} Spectrum using preamp.

Ortec 142 preamp

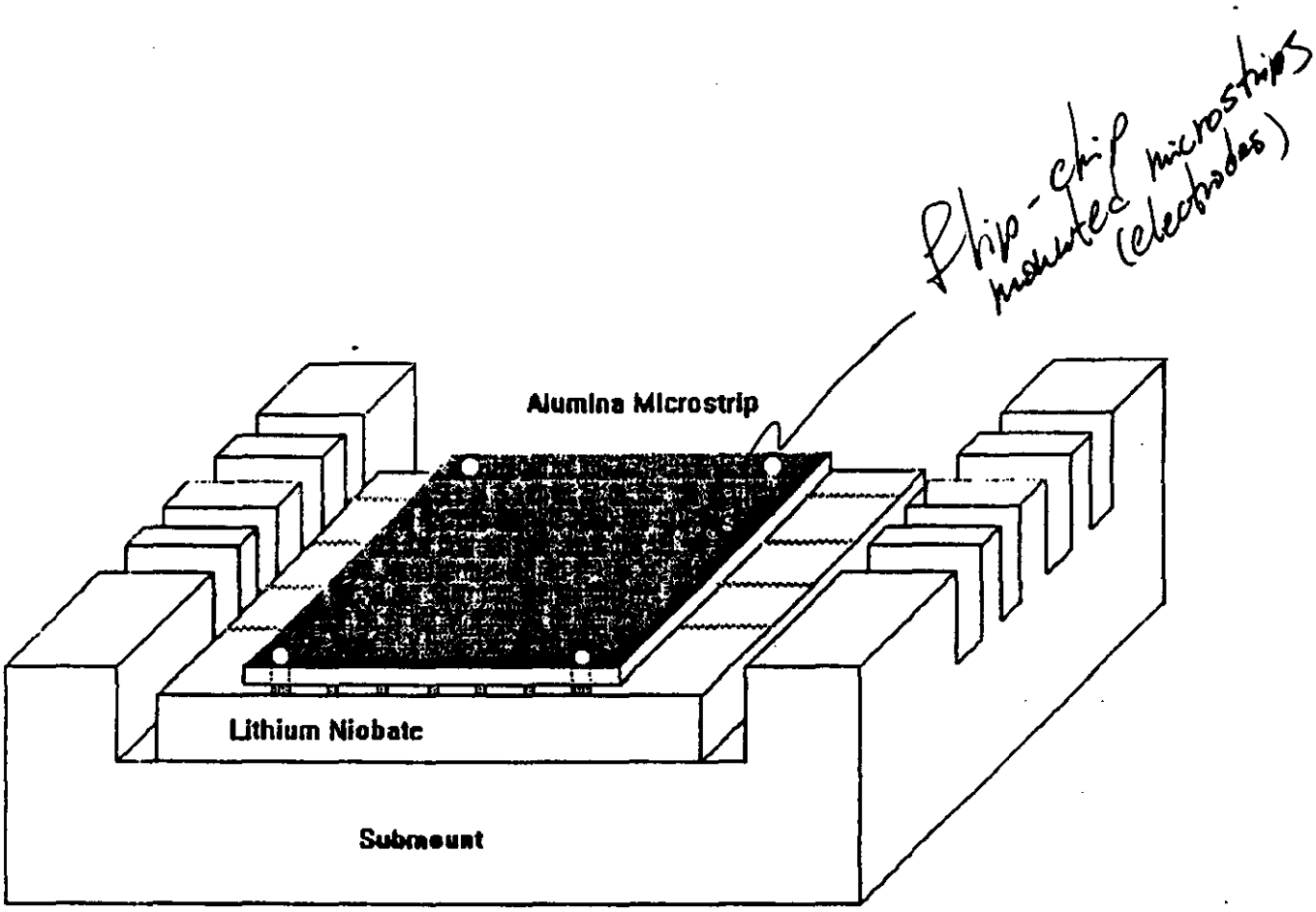


← 4.31 cm →

FWHM = 1.85 cm

$$\text{FWHM} = 1.85 \times \left(\frac{3\,\text{KeV}}{4.31}\right) = \underline{\underline{1.28\,\text{KeV}}}$$

IOCC's Multi-channel Modulator Package Approach (Courtesy of Rich Becker)

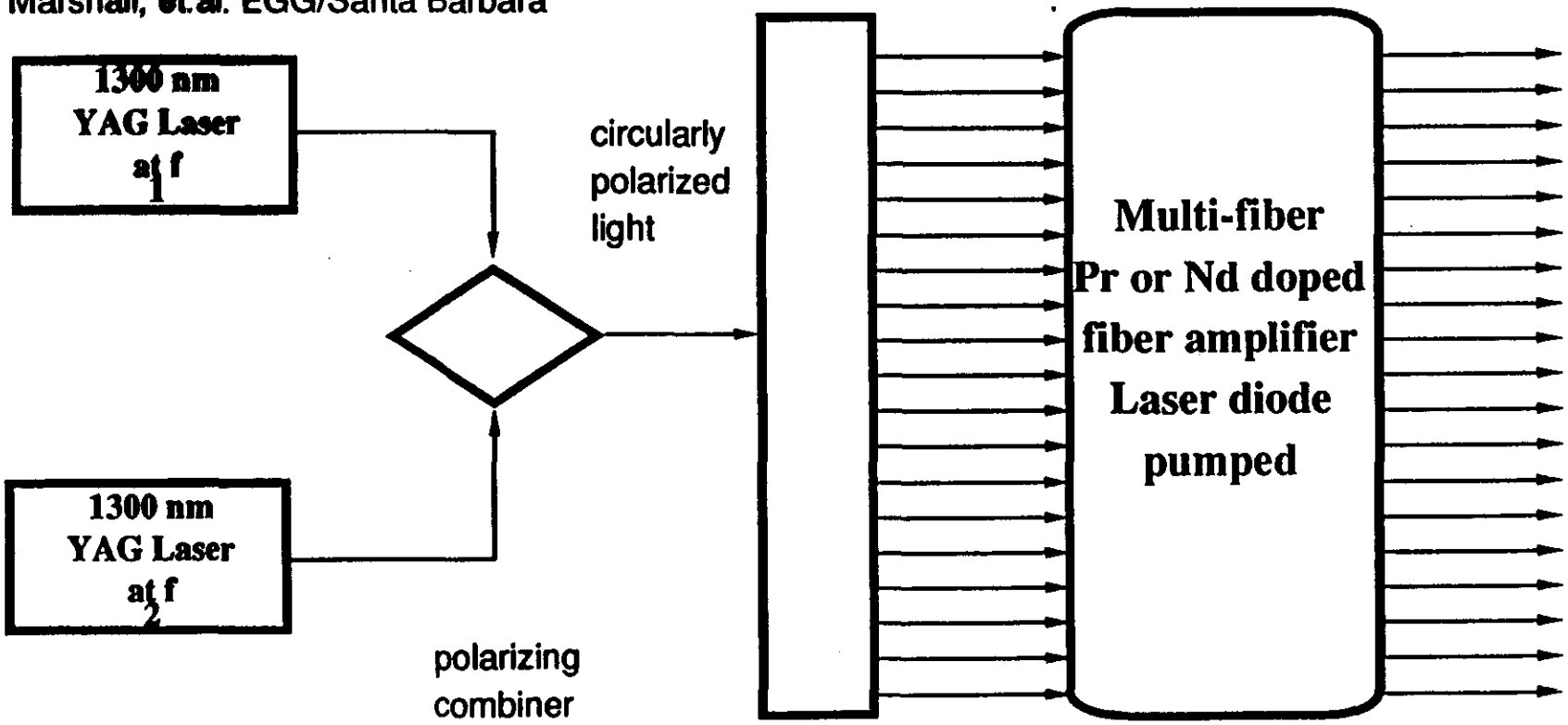


Sketch of Prototype (Fibers Not Shown).

A Proposal for Optical Power Distribution for E/O Modulators, extrapolating from the ideas of M. Seman, Columbia

Already done by Burns et. al NRL
and
Marshall, et.al. EGG/Santa Barbara

see proceedings of OFC '92,
San Jose



Acknowledgements

Yann-Hann Chang, MIT
Boleh Wyslouch, MIT
U. Becher, MIT

Rich Becher, IOCC

Funded by LLNL, LDRD

gem

γeμ

Presentation by:

Harvey Newman

BaF_2 EM CALORIMETER REQUIREMENTS FOR 8/92 (Cont'd):

CALIBRATION IN SITU: Detailed Calibration Strategy

(1) RFQ: Layout; Calibration Time Per Run; Frequency of Runs

(2) MIPs Calibration: Demonstrate With Muons; Specify Time to Obtain Required Accuracy.

(3) Physics Calibrations (e.g. $\Upsilon, Z^0 \rightarrow e^+e^-$): Time For Accuracy. Trigger Strategy.

Harvey Newman

BaF_2 EM CALORIMETER REQUIREMENTS FOR 8/92 GEM DECISION:

DEMONSTRATE CAPABILITY TO MAINTAIN THE HIGH RESOLUTION IN SITU

RADIATION HARD CRYSTALS

(1) **Demonstrate Substantial Improvement in 20 - 25 cm Crystals. $\lambda > 60$ cm After 1 MRad By 8/92.**

(2) **Produce Small Rad Hard Crystals: $\lambda \geq 95$ cm After 1 MRad. Show There are No Fundamental Limitations. (Recommended By Expert Panel).**

LIGHT COLLECTION UNIFORMITY

(1) **Develop Detailed Plan for Obtaining Uniform Crystals After Wrapping Or Coating.**

(2) **Demonstrate Stability, Or Specify Max. Non-Uniformity (and Time Dependence) Induced By Irradiation.**

(3) **Pre-Irradiation Question: Method; Time Dependence Due To Incomplete Saturation, or Annealing In Situ.**

(4) **Cosmic Ray Measurements With Transverse Muons**

BARIUM FLUORIDE EM CALORIMETER R&D FOR 1992

By Carrying Out Our R&D Program, We Expect To Have The Following Information By August 1992:

- Improved Understanding and Control of Radiation Damage In BaF_2
- Small Rad Hard Crystals
- Large Crystals Approaching the Final Specifications for Rad Hardness
- Realistic Evaluation of the Prospects for Rad Hard Crystal Mass Production
  - -- At $ 2.5/cc Fixed Price
- Demonstration of the Ability To Maintain The High Resolution In Situ
  - -- Uniformity, Stability and Calibration
  - -- Constant Term of 0.5%

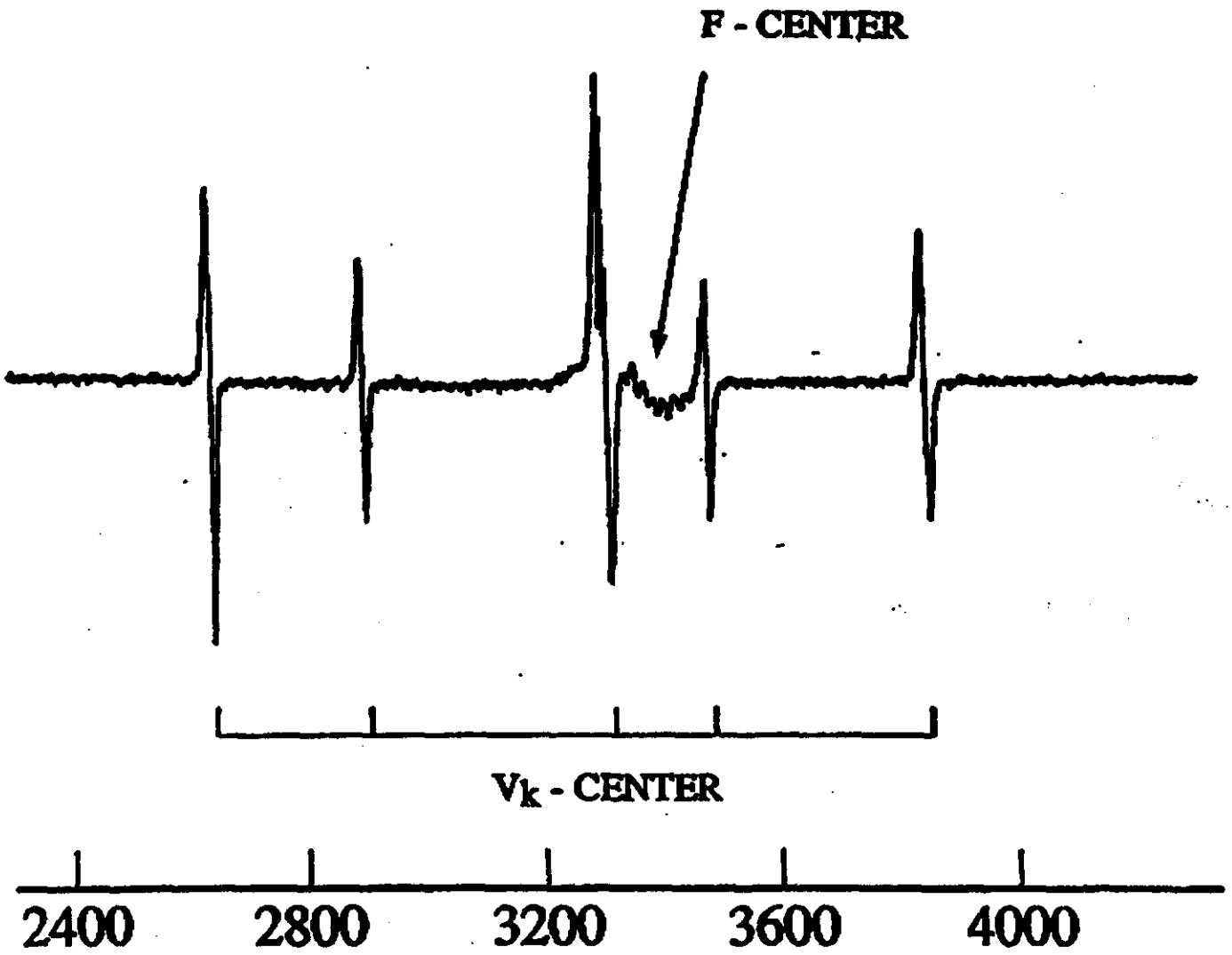
A Sufficient Demonstration of the Promise of the BaF2/Scintillating HCAL System in Time for the GEM Calorimetry Choice

BaF_2 R&D MILESTONES for 1992 (II)

Dates	MILESTONES
	Prototype Electronics Readout (ORNL, Princeton)
4/92	First preamp/shaper or gated integrator circuits for low gain photodevices developed and tested
5/92	Complete design of front end (surface mounted) circuit series
5/92	Verify noise and pickup-immunity at a test beam area
5/92	Deliver final circuit series for high gain photodevices; mount and test on prototype matrix at UCSD
7/92	Test low gain photodevice electronics readout on prototype matrix at UCSD CR test
	Cosmic Ray and RFQ Tests (UCSD, CIT)
3/92 - 5/92	Set up Cosmic Ray Tower at UCSD
5/92	Start stability and longitudinal uniformity tests with (partial) 1991 matrix
6/92	Start CR tests with some improved full sized crystals
6/92	Start MIP CR calibration tests with vertically mounted new crystals
7/92	Start CR testing full sized 25-pair matrix in cosmic ray tower
7/92	Start uniformity and stability tests of pre-irradiated crystals
8/92	Start tests of further-improved large crystals
9/92 - 12/92	Long term cosmic tests with 25-pair matrix; crystals with near-final specifications at the center
6/92	RFQ test at AccSys Technology
	BaF_2 Assembly (CIT, UCSD)
4/92 - 5/92	Reassemble 1991 matrix (with most crystals) at UCSD
5/92	Test and mount new UV photodevices (Hamamatsu)
4/92 - 6/92	Acceptance-test UV transmission, light output, rad hardness of improved full sized crystals for 1992 matrix
5/92 - 6/92	Test UV light collection uniformity of new crystals with sources
6/92	Final preparation, mounting of the crystals in 1992 prototype box
7/92	Final bench tests of prototype, before mounting in UCSD CR tower
7/92	Acceptance-test UV transmission, light output, rad hardness of improved full sized crystals for 1992 matrix

BaF_2 R&D MILESTONES for 1992 (I)

Dates	MILESTONES
	Crystal Mass Production (SHANGHAI, BEIJING)
2/92 - 3/92	Correlate trace impurities levels with damage levels (first matrix)
2/92 - 3/92	Demonstrate improved vacuum; effect on crystal quality
2/92 - 4/92	Correlate trace impurities levels with damage levels (new crystals)
6/92	Complete 25 full-size crystal pairs for 2nd prototype matrix
2/92 - 7/92	Determine nature of principal color centers
1/92 - 9/92	Demonstrate continued, systematic improved rad hardness
9/92	Complete production plan for final rad-hard crystals by mid-1993
	UV Performance Monitoring (CMU, LLNL, CIT,UCSD)
2/92- 5/92	Develop UV laser or flash lamp and quartz fiber monitor
2/92 - 6/92	Develop surface treatment and UV-reflective coating method for uniform UV response
5/92 - 7/92	Coat and test full size, improved 25 crystal-pair set
8/92	Coat and test full size, further-improved 5 crystal-pairs
	Analog and Digital Readout Testing (Princeton)
2/92 - 7/92	Test and develop fast front-end analog readout circuits
4/92 - 7/92	Test and debug front end circuits and connections on the BaF_2 prototype array
	Radiation Damage Tests (BNL, CIT, SIC, LNPI)
1/92 - 10/92	Test crystals with γ's to 10 MRad, neutrons to $> 10^{13} n/cm^2$, protons to Several Megarads
5/92 - 7/92	Verify rad hardness spec. for improved full size 25-pair crystal set
8/92	Verify rad hardness of further-improved 5-pair crystal set (near-final specifications)
1/92 - 12/92	Tests for continued improvement in rad hardness of large crystals
	Prototype Engineering Design (ORNL, CIT)
3/92 - 5/92	Engineer and verify precise crystal dimensions, and specifications for final crystal prototype
3/92 - 4/92	Engineer and install improved vacuum oven at SIC
3/92 - 8/92	Improve and specify mechanical processing of crystals at SIC, BGRI
3/92 - 5/92	Engineer support and housing for 1992 prototype
3/92 - 7/92	Specify the calorimeter production, control and verification


F - CENTER
Vk - CENTER
2400
2800
3200
3600
4000

ROOM TEMPERATURE RADIATION DAMAGE MECHANISM

Oxygen and hydrogen are present in the crystal as OH^- ions substituting for fluorine ions.

Radiation does two things:

1) Radiation creates F centers and clusters of H centers (i.e., fluorine vacancies and fluorine interstitials).

2) Radiation also dissociates the OH^- ions into O^- and H_i^0 centers.

A portion of the H_i^0 centers will recombine with F centers to form H_s^- centers.

The 220-nm UV absorption is due to these H_s^- centers.

TWO WAYS TO MINIMIZE RADIATION DAMAGE IN BaF_2

1) Prevent OH^- from entering the crystal during growth.

2) Prevent the formation of F centers by removing impurities that stabilize the fluorine interstitials (H centers).

ASPECTS OF THE RADIATION DAMAGE PROBLEM IN BaF_2

L. E. Halliburton, M. P. Scripsick, and G. J. Edwards
Optoelectronic Research Group
Department of Physics
West Virginia University
Morgantown, WV 26506

Telephone: (304) 293-3422
FAX: (304) 293-5732

SIMS Oxygen Bulk Analysis of BaF2

Sample	Relative Concentration
K14417D	3.2
K458484A	6.22
SIC2x2.5	3.1
SICCube	6.5
SICXTL Tip	1.9
SICXTL Base	3.4

BaF_2 RADIATION DAMAGE PROGRAM STATUS (Cont'd)

- FIRST RESULTS from CEA
  - Bulk Impurities: High Levels of O_2, S, Cl in Both Optovac and Chinese Crystals
  - Surface Damage Established: Improve Polishing (LLNL)
  - Subsurface Inclusions Observed: Depth Profiling; Microanalysis
- SMALL RAD HARD CRYSTAL PROGRAM At OPTOVAC
  - Study Raw Material Purity Effect, Crucible Effect, Oven Variables
  - Residual Gas Analysis
  - Small Crystals and 15-20 cm Rods
  - First Crystals By 5/92
  - Rad Hard Crystals By 8/92
- COLOR CENTER STUDY At UNIV. WEST VA: Paramagnetic and Low Temperature Spectroscopy
  - EPR: Energy Levels of Two Predominant Color Centers Determined
  - Correlated With Absorption Bands at Liquid Nitrogen Temperature
  - Further Paramagnetic Studies (ENDOR):
    - Color Center Hyperfine Splitting
    - Test Role of Interstitial Ions: Hydrogen, Oxygen

SPNPI, 19.02.1992

Dear Mike,

Here is our program for radiation tests of the BaF2 crystals. Please transfer it to H.Newman, C.Woody, Yu.Kamishkov and B.C.Barrish. It can be considered as an Appendix to the Report to the GEM EC from GEM BaF2 collaboration.

Best regards, Alexei.

PROGRAM
of irradiation tests of BaF2 crystals in 1 GeV proton beam in Gatchina

The method of irradiation tests of BaF2 crystals in 1 GeV proton beam has been developed recently in Gatchina and applyed to study the radiation properties of about 10 crystals produced in the Optical Institute in St.Petersburg. Some of the results are published (LNPI 1990-1991 Report).

The dose of radiation can be varied up to 5 Mrad. The transmission spectra are measured in the range of 200-400 nm. Also, the fast component of the light output is measured from the scintillations produced by 140 MeV protons.

Using this method we can perform detailed studies of the crystals considered as candidates for application in GEM. We can allocate 200 hours of the beam time in the next running period of the Gatchina synchrocyclotron from the mid of April till the end of June 1992. During this period we plan to investigate 8 crystals produced in St.Petersburg and about 10 crystals supplied by GeM BaF2 collaboration. For these studies we need 20 K$ (the cost of the beam time, crystals, and some equipment). For information: at present we have 50 crystals of 40x40x250 mm3 size designed to use in an EM calorimeter at E781 FNAL experiment and also some smaller size crystals for radiation tests. Some of these crystals can be sent to the GEM collaboration for independent studies.

BAF2 PROJECT

RADIATION DAMAGE STUDY

COORDINATORS

Peijun Li	• SIC, China
Zhezong Dai	• BGRI, China
H. Newman	• Caltech
R. Zhu	• Caltech

PANEL EXPERTS: SUB-COORDINATORS

C. Woody (BNL)	• Rad. Damage Measurements
M. Strathman (Charles Evans and Associates)	• Impurity and Defect Analysis
R. Sparrow (OPTOVAC)	• Crystal Processing Improvements
R. Craig (Battelle Pacific NW Lab)	• Analysis and Simulations

PLUS EXPERT SUPPORT PROPOSED:

Naval Research Lab

ORNL Solid State Division

BaF_2 EM CALORIMETER
1992 R&D PROGRAM
RADIATION DAMAGE STUDY

- BaF2 Group/U.S. Expert/China Coordination
- Extensive Testing on New Full Size Crystals, Small Crystals, and Raw Materials
- Correlate Trace Element, Structural and Surface Analyses With Rad Damage Tests
- PRIMARY ROLE: O_2 and OH^- (50 ppm Level)
- Improve Processing Technology:
  Raw Material Treatment, Oven Vacuum, Crucible, Growth Cycle
  - Large Crystals At SIC and BGRI
  - Small and Medium Size Crystals: Optovac
- Test Residual Effects of Rare Earths, Other Traces After Oxygen Level Reduced
- Identify Color Center With Paramagnetic Analysis, Low Temp. Spectroscopy: W. Va.
- Test Saturation With Protons:
  at BNL (30 GeV) or LNPI (1 GeV)

BaF_2 EXPERT PANEL RECOMMENDED R&D PROGRAM (II)

- RADIATION DAMAGE MEASUREMENTS: Correlate With Impurities and Defects
  - Longitudinal Profile
  - Particle Type Dependence: Photons, Neutrons, Hadrons
  - Non-Uniform Dose Distribution
  - Surface Effects
- SIMULATIONS and ANALYSIS: Radiation Effect On Resolution
  - Time and Position Dependence of Uniformity In Situ
  - Crystal To Crystal Variations
  - Accuracy of Calibration and Monitoring

BaF_2 EXPERT PANEL

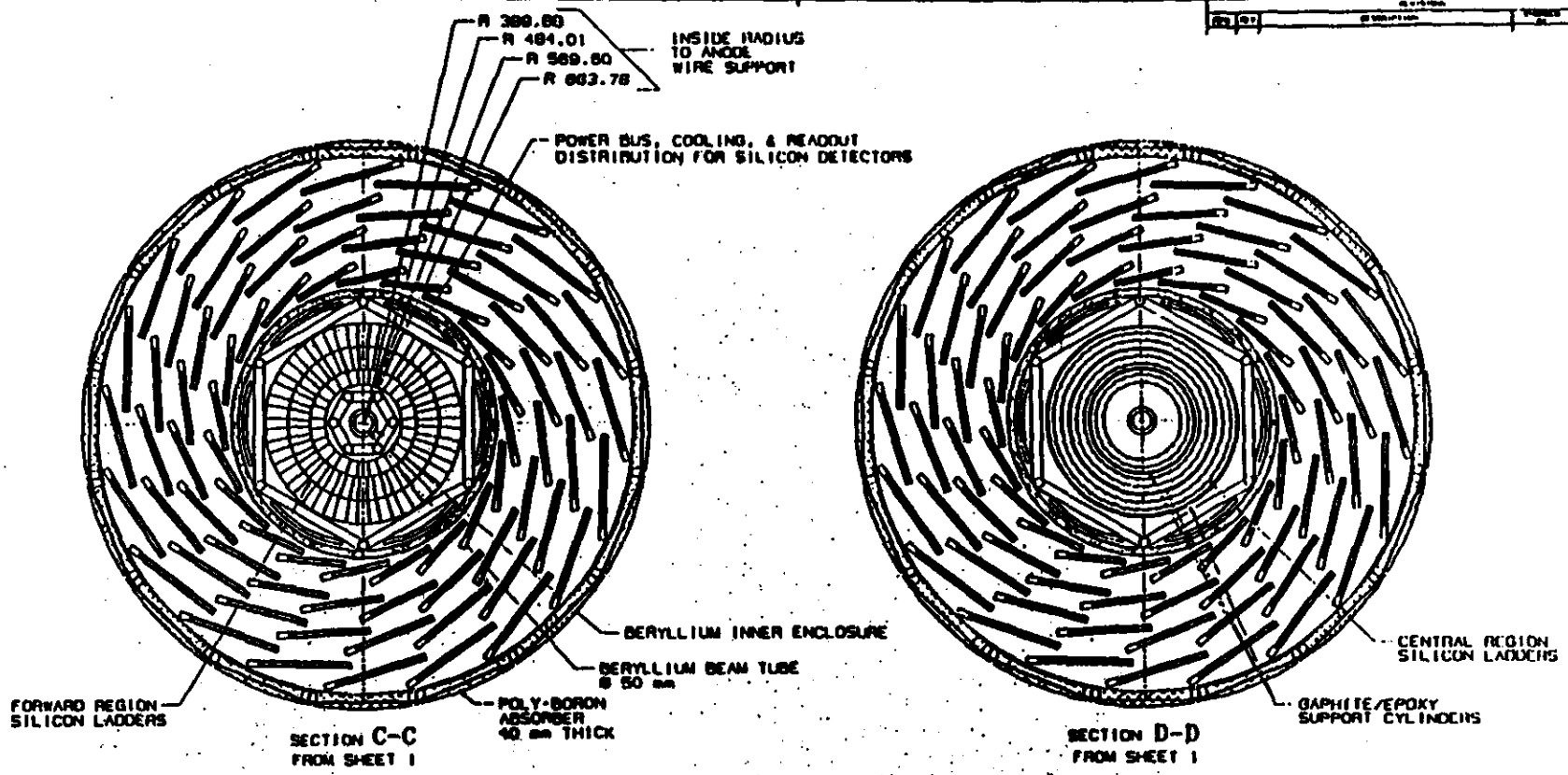
RECOMMENDED R&D PROGRAM IN ADDITION TO R&D IN CHINA

- CRYSTAL PROCESSING STUDY:
  Grow, Characterize and Measure
  - Small Specially Pure Crystals
  - Compare Crystals From Common Raw Material: China, Optovac
  - Improve Growth Process: Crucible, Residual Gas Analysis, Control of Atmosphere
- IMPURITY and DEFECT ANALYSIS
  - Experimental and Theoretical Study of Impurity Effects
  - Trace and Defect Analysis of:
    - Raw and Preprocessed Materials
    - Finished Crystals
    - Longitudinal Profile
    - Surface Damage
    - Subsurface Defects

BaF_2 EXPERT PANEL On RADIATION DAMAGE: FEBRUARY 1992 REPORT

SUMMARY OF FACTS

- Significant Progress On Rad Hardness
- Rad Damage Starts At Low Doses
  - Strong Evidence of Saturation
  - Needs Confirmation for Hadrons
- A Decrease In Light Transmission;
  No Evidence for Intrinsic Scintillation Loss
- Recovery With 500° C; UV Light.
  Room Temperature Annealing Very Slow.
- Oxygen May Be a Key Factor; Effect of
  Other Impurities: To Be Determined.



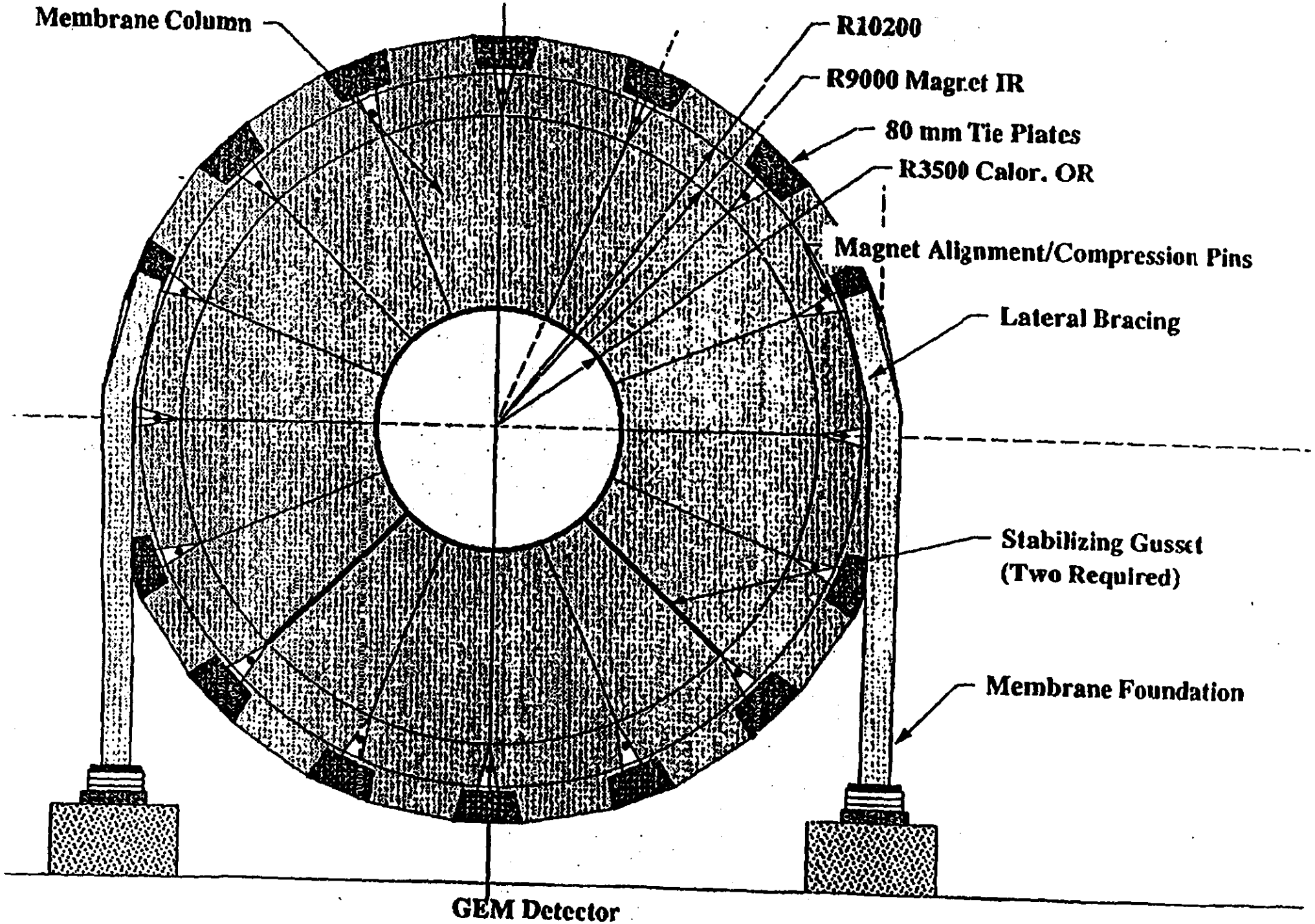
METRIC

THIRD ANGLE PROJECTION

Los Alamos

GEM CENTRAL TRACKER WORKING LAYOUT

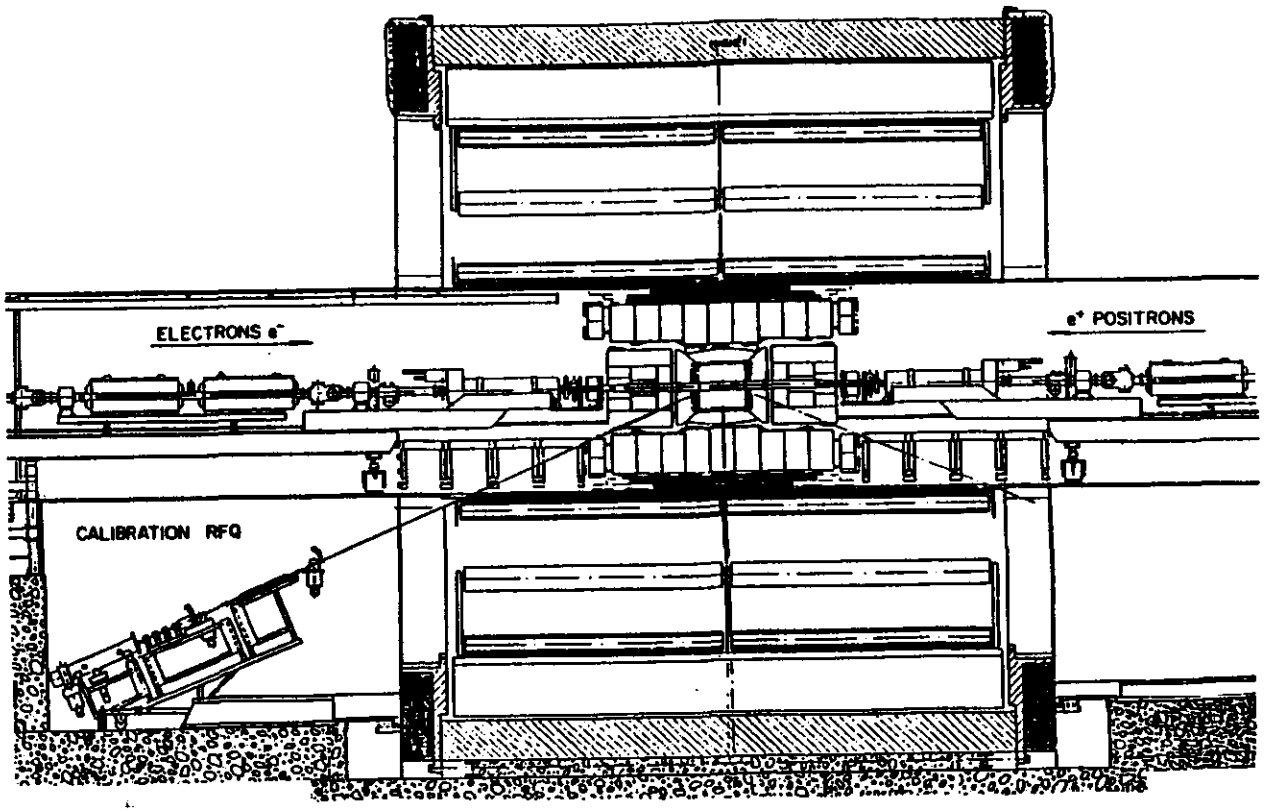
A1 | SK-GEM12-009A | 3



GEM Detector
Integral Calorimeter Support
Central Membrane

Rennich

HIGH ENERGY PHYSICS DETECTOR CALIBRATION SYSTEM



L3 DETECTOR

ACCSYS
TECHNOLOGY, INC

BaF_2 R&D PROGRAM for 1992

PHOTOSENSITIVE DEVICE STUDY

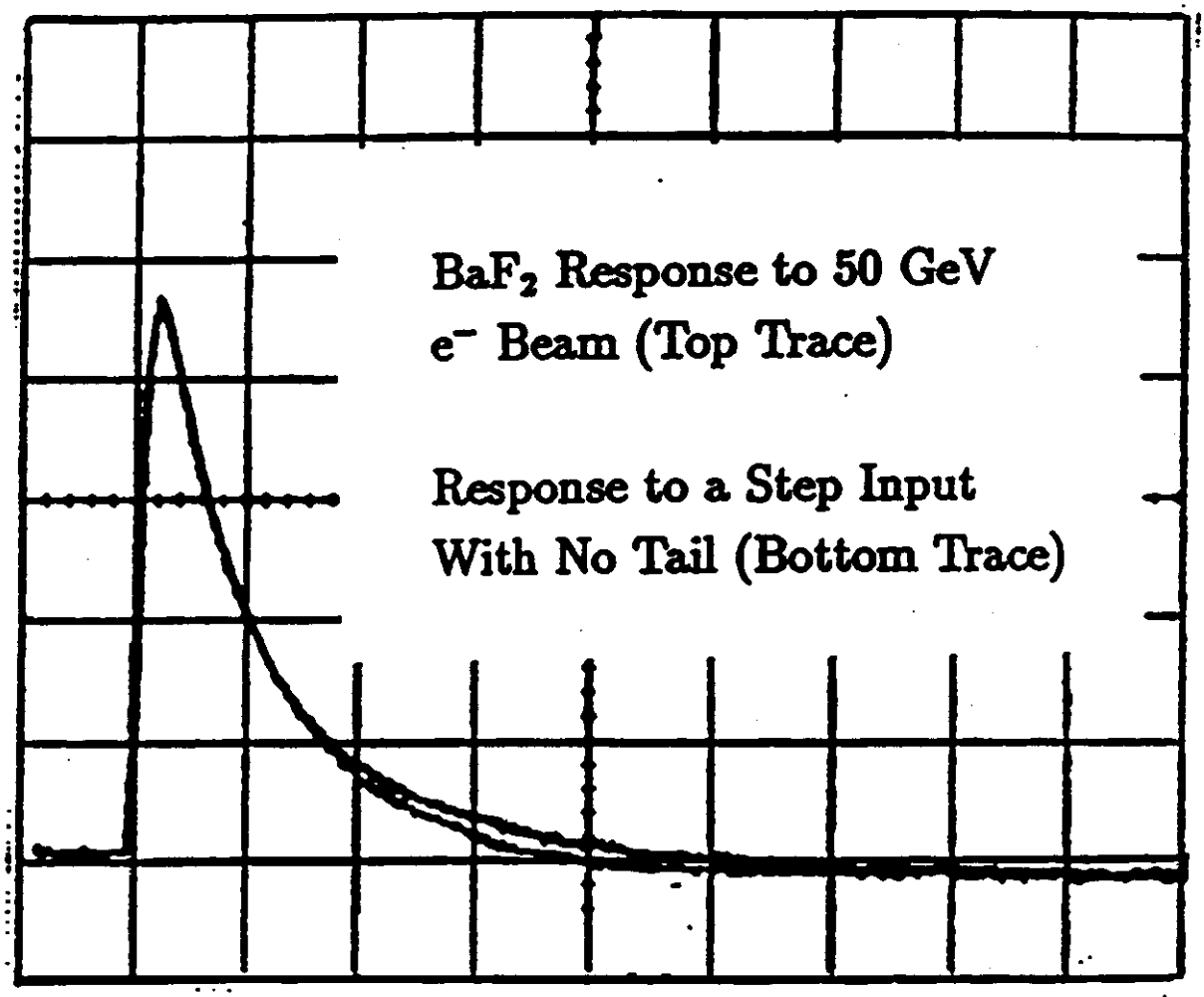
R. Zhu, X. Shi (Caltech),
Y. Kamyshkov, K. Read (ORNL)

- Proximity-Focused, Higher Gain
  5 to 7 Stage Grid Mesh Tube
- Solar Blind: K-Cs-Te Cathode
- Remote Processed: Near-Final Gain
- Compact: 25 mm Long

TESTS

- Short Term Stability:
  At A Test Beam
- Long Term Stability, Temperature
  Dependence: UCSD Cosmic Ray Stand
- Magnetic Field Immunity
- Dynamic Range, Linearity: With
  UV Laser Pulses; RFQ Pulses

Response of a 25 cm BaF_2 Crystal, Vacuum Phototriode and GaAs Preamp



Gallium Arsenide Preamp (Princeton):

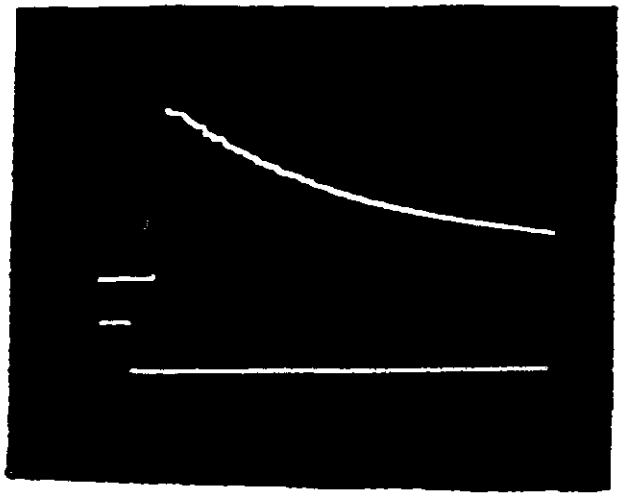
(a) Response to Step Input

(b) Leading Edge < 2 nsec Risetime

OUT

IN

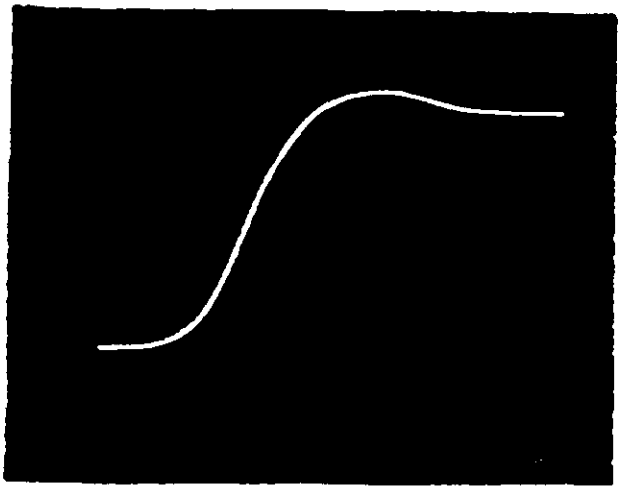
(a)



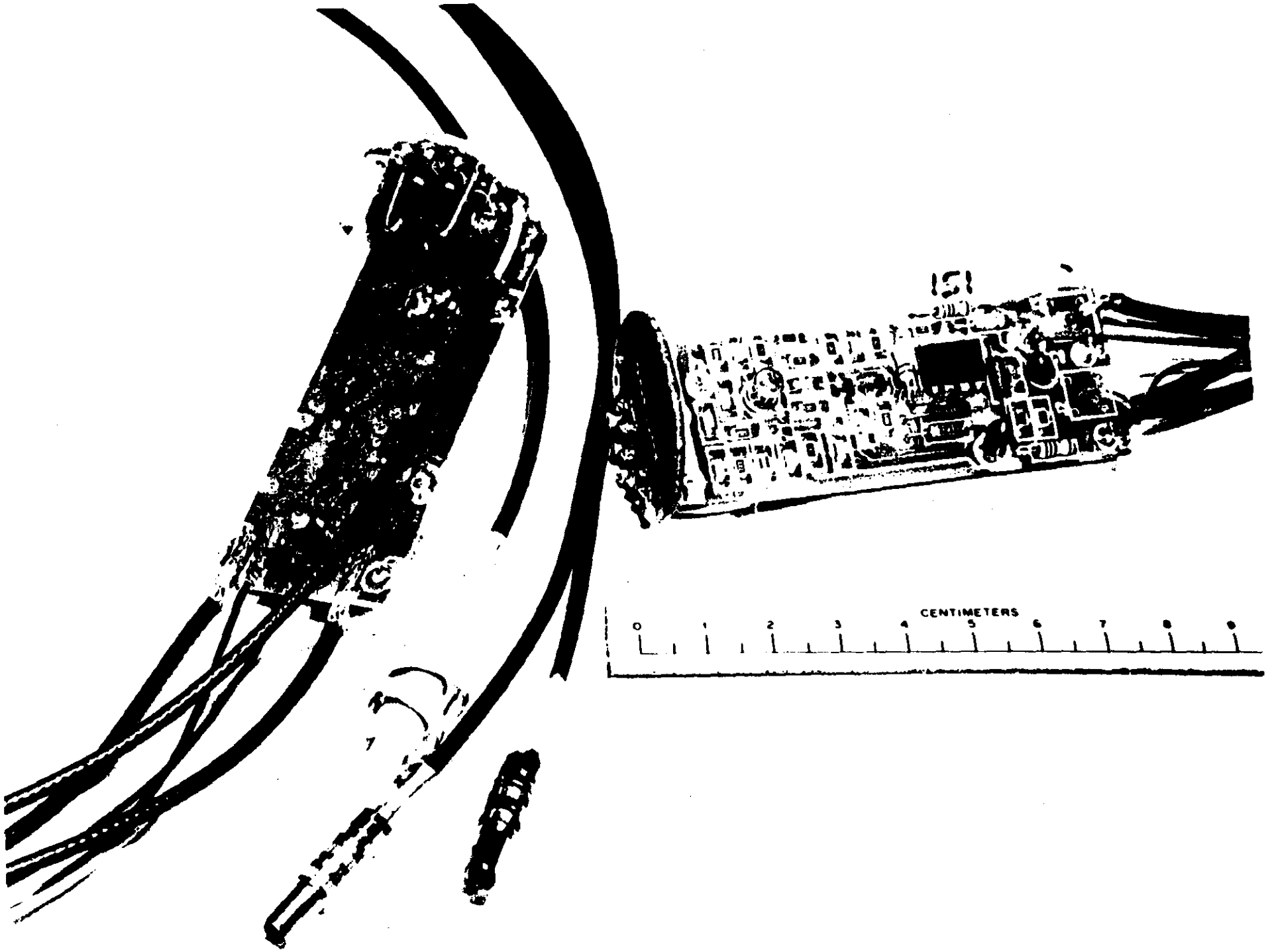
20 nsec/DIV

(b)

OUT



1 nsec/DIV


151
CENTIMETERS
0 1 2 3 4 5 6 7 8 9

- DYNAMIC RANGE
- NOISE REJECTION
- SPEED + OCCUPANCY
- MATCHING TO ADC
- GAIN of PHOTO DEVICE

BaF_2 ENGINEERING TASKS

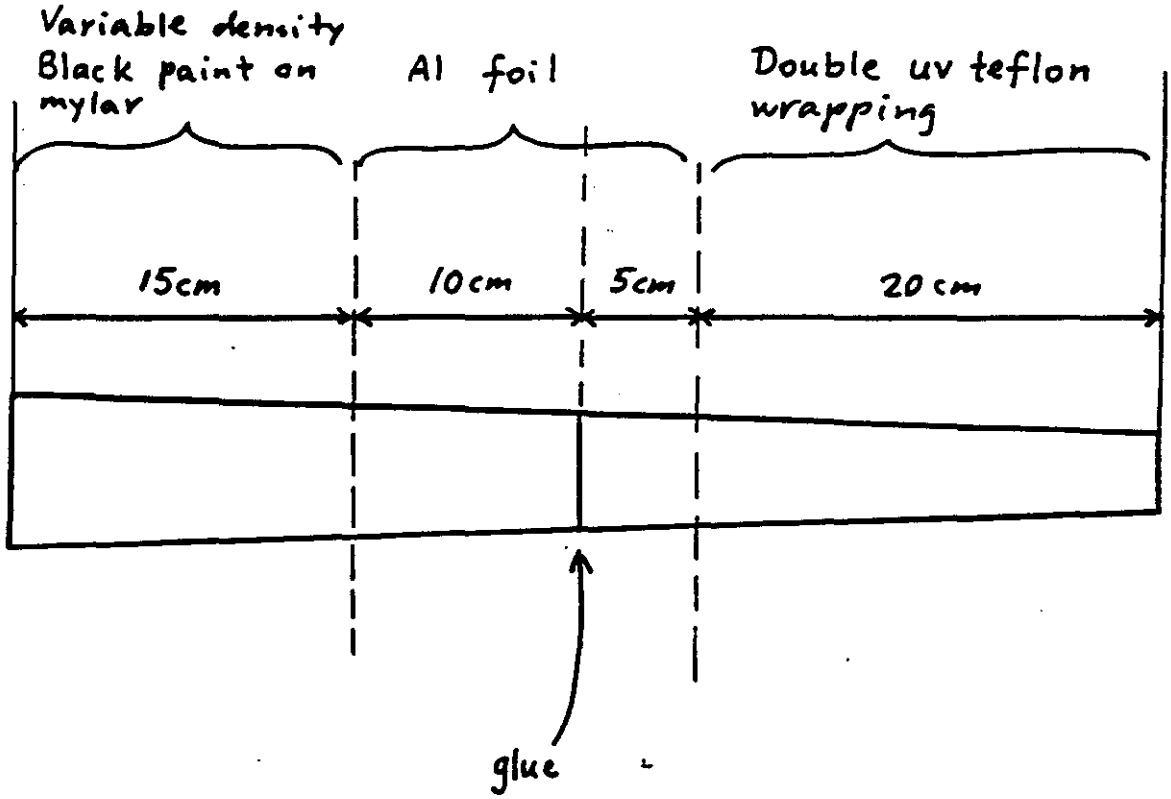
M. Rennich and Staff (ORNL)

- Design and Develop Crystal Mounting Support Structure
- Improve Chinese Oven To $10^{-6} - 10^{-7}$ Torr With M. LeBeau (By 4/92)
  - Western Diffusion Pump
  - Cold Trap, Ion Gauges
  - Commission and Test
- Redesign Crystal Dimensions, Crystal Pair Bonding Procedure
  - Critical Surfaces Flat and Parallel to 10 Microns
  - Design Bonding Jigs and Process With LLNL
- PROJECT ENGINEERING:
  - Define Project Plan and Schedule, Including All Production Steps (8/92)
  - Specify Standard Operating Procedures: Growth, Machining, Surface Treatment
  - Define Tracking + Quality Control Steps: Tests and Specifications

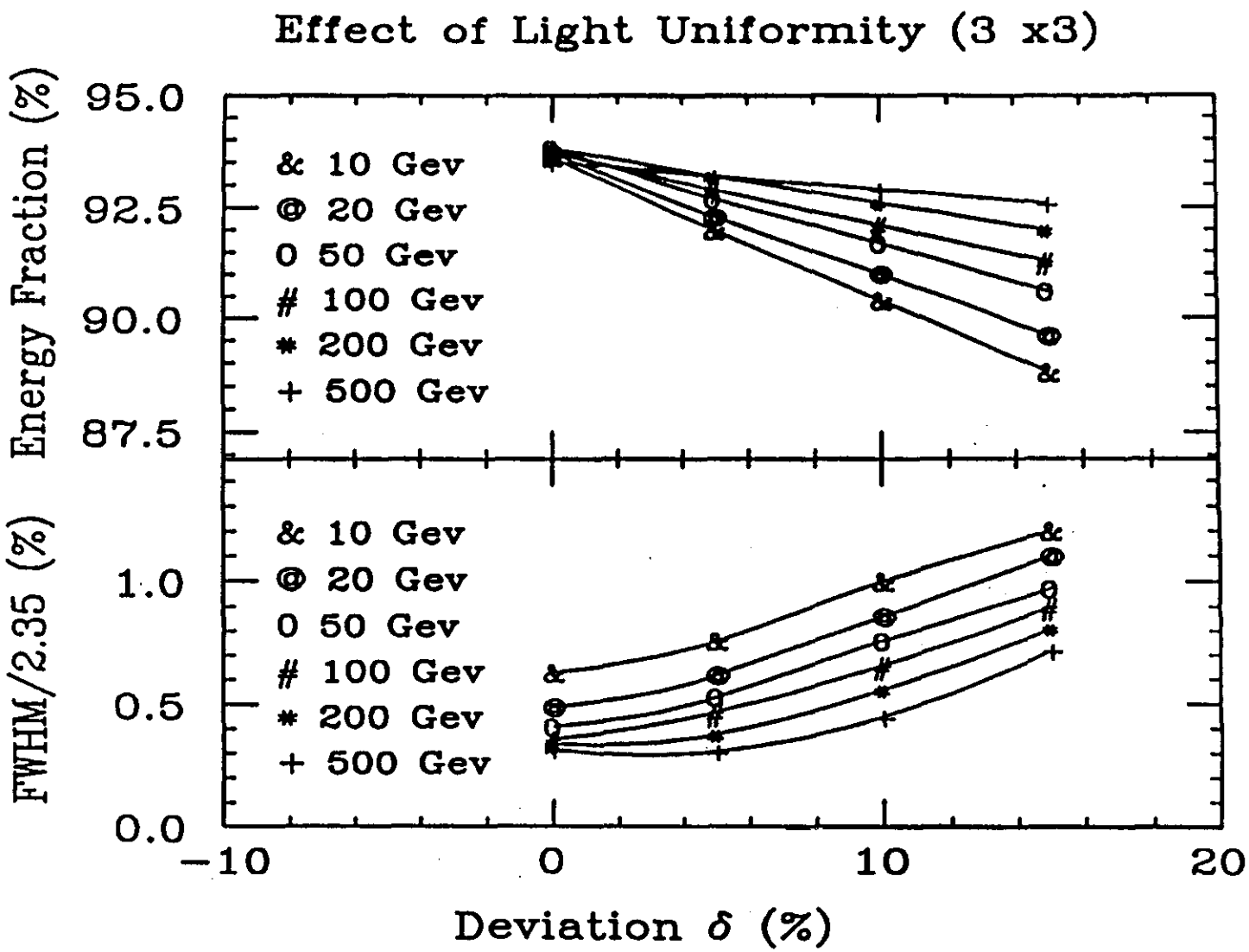
BaF_2 R&D PROGRAM for 1992
LIGHT UNIFORMITY STUDY

C. Wuest (LLNL), R. Zhu (Caltech),
A. Engler (CMU)

- UV Reflective Coating, Optimized for BaF_2 Fast Component (190 - 240 nm)
- MgF_2 - Al_2O_3 Electron Beam Coating Tests Underway at LLNL:
  - Stress-Free Ion Beam Milling and X-Ray Diffraction Analysis (2/20 - 3/6)
  - Optical Polishing; X-Ray and Trace Analysis of Surface (2/20 - 3/6)
  - Wet and Dry Diamond Turning, With Surface Analysis (2/24 - 3/13)
  - Optical Characterization Before and After Coatings (3/13 - 3/27)
  - Precompute Graded Coating, Coat (and Seal) Crystals (3/20 - 4/24)
  - Verify Recovery of Uniformity After Radiation Effect (3/20 - 4/24)
- Correlate Improved Surface Processing and Sealing With Rad Damage (3/92 - 4/92)
- Process $25+5$ Full Size Crystal Pairs (5/92 - 8/92)



BaF_2 crystal coating for FNAL tests



Effect of light uniformity predicted with GEANT simulation.

BaF_2 BEAM TEST: 7×7 ARRAY (Summer 1993)

- ELECTRON RESOLUTION
  Demonstrate $\sigma_E/E = (2.0/\sqrt{E} \oplus 0.5)\%$
  With Electrons from 10 GeV to > 100 GeV
  - Calibrate the gain for each crystal + phototube.
  - Scan the beam across the central crystal to establish the (position corrected) uniformity of response, with the carbon fiber prototype structure, and full-size crystals.
  - Check the stability of a period of weeks.
  - Check the resolution, and the absolute response, as a function of the rate.
  - Compare to GEANT predictions for resolution, energy sharing distributions, and position reconstruction accuracy as a function of the impact point.
- PION RESPONSE From 10 GeV to > 100 GeV
  - Using data taken at the same time as for the electrons above.
- ELECTRON-PION SEPARATION
  - Test (Sum of 9)/(Sum of 25): Transverse shower shape.
  - E (electromagnetic energy) versus p (Momentum), using the wire chamber spectrometer.
  - Veto using an HCAL module from our Collaboration, placed behind the crystal array.
- ELECTRONICS DEVELOPMENT
  - Run with Hammamatsu phototriodes, or new few-stage tubes. Cross check against a separate run with higher gain tubes.
  - Use preamp + shaper (or gated integrator) circuits, with lower noise than in 1991 tests; speed compatible with separation of signals from one SSC beam crossing.
  - Develop mounting, shielding and grounding techniques to reach an acceptable noise level for the full-scale calorimeter.
- COMPENSATION
  - Measure the constant term in the resolution.
  - Develop optimized weighting methods, to minimize the constant term.
  - Check results on the energy distributions in the crystals and the HCAL, and their correlations, against GEANT (GHEISHA) simulations. Check against other simulations (e.g. HETC) if necessary.

BaF_2 EM CALORIMETER CRYSTAL PRODUCTION at SIC and BGRI

- PRE-PRODUCTION ARRAY
  $(2\times2)\times(4\times4)\times50\ cm^3$
  - 49 CRYSTAL PAIRS DELIVERED By 5/91
  - TESTED AT FNAL By 12/91
- PRODUCTION ARRAY:
  $(3\times3)\times(5\times5)\times50\ cm^3$
  - 25 CRYSTAL PAIRS: 6/92
  - IMPROVED RAD HARDNESS
- NEAR-FINAL QUALITY PAIRS:
  $(3\times3)\times(5\times5)\times50\ cm^3$
  - 5 CRYSTAL PAIRS: 7/92
  - RAD HARDNESS NEAR SPECS

MASS PRODUCTION for SSC:
8/93 - 8/97. RAMP UP
TO 800 PIECES PER MONTH.

UCSD Cosmic Ray

STAND

SCHEDULE:

MECHANICAL	1 APRIL
COUNTERS	15 APRIL
CHAMBERS	1 MAY
TRIGGER	15 APRIL
DAQ	1 MAY
SOFTWARE	15 MAY

UCSD COSMIC RAY STAND

HARDWARE

2 [X,Y] PWC, 2mm SPACING

768mm x 1152 mm

1 m (high) x 1m x .75m
TEST SPACE

2 [X,Y] PWC, 2 mm SPACING

1152mm x 1536 mm

3 TRIGGER PLANES

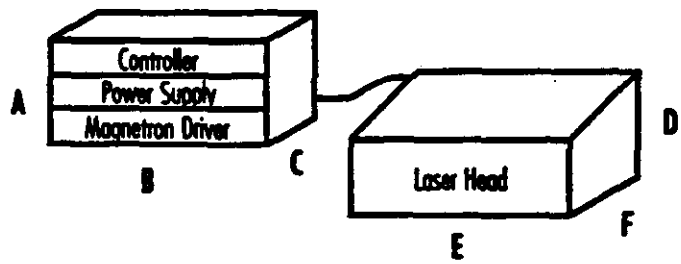
160 G/cm² STEEL HARDNER

Ultraviolet Waveguide Lasers

Models GX-500 and GX-1000

	Specification
KrF	Laser Medium
248 nm	Wavelength
10 μJ	Pulse Energy [1]
2000 Hz	Maximum Pulse Repetition Rate
50 ns	Pulse Duration [2]
200 Watts	Peak Power
12 mW	Specified Average Power
18 mW	Typical Average Power
0.5 mm dia.	Beam Dimensions (at exit)
$He/Kr/F_2$	Gas Composition
10 std cc/min	Minimum Gas Flow Rate

Configuration/Dimensions (Inches)



GX-500	Dimension	GX - 1000
12.5	Stack, Height A	12.5
19.0	Width B	19.0
17.0	Depth C	17.0
8.0	Laser Head, Height D	8.1
9.0	Width E	18.0
13.5	Depth F	13.8

Controller, power supply, and magnetron are configured for 19" rack mounting and are connected to the laser head by a 72" umbilical.

Potomac Photonics, Inc.
The Washington Business Park
4720E Boston Way
Lanham, MD 20706

UCSD Cosmic Ray Stand

HARDWARE

2 [X, Y] PWC, 2mm SPACING

768mm x 1152 mm

1 m (high) x 1m x .75m
TEST SPACE

2 [X, Y] PWC, 2 mm SPACING

1152mm x 1536 mm

3 TRIGGER PLANES

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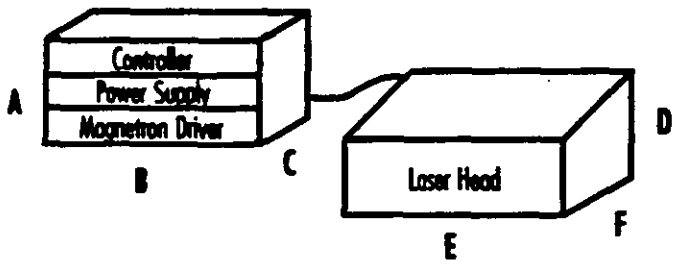

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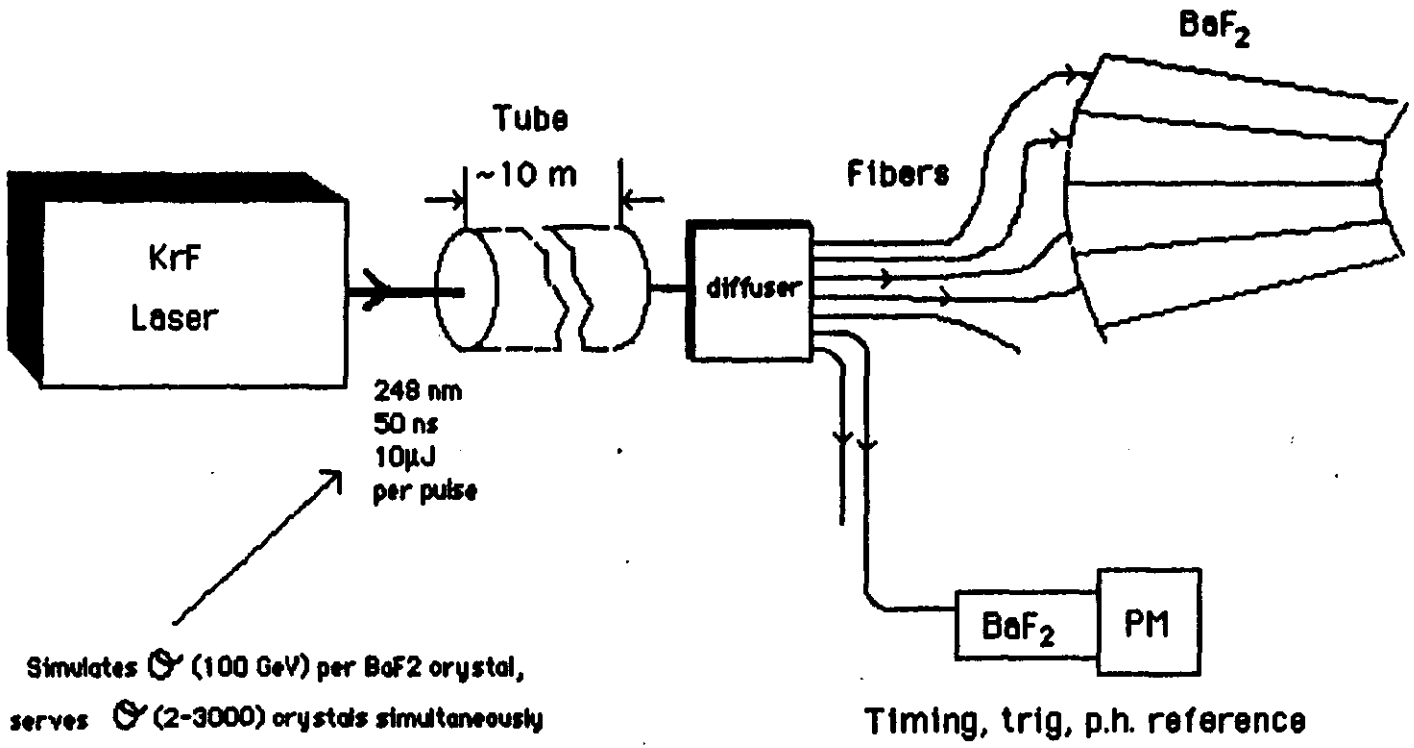

BaF2
Tube
~10 m
Fibers
KrF
Laser
diffuser
248 nm
50 ns
10μJ
per pulse
BaF2
PM
Simulates γ (100 GeV) per BaF2 crystal,
serves γ (2-3000) crystals simultaneously
Timing, trig, p.h. reference

BaF_2 EM CALORIMETER

1992 R&D PROGRAM

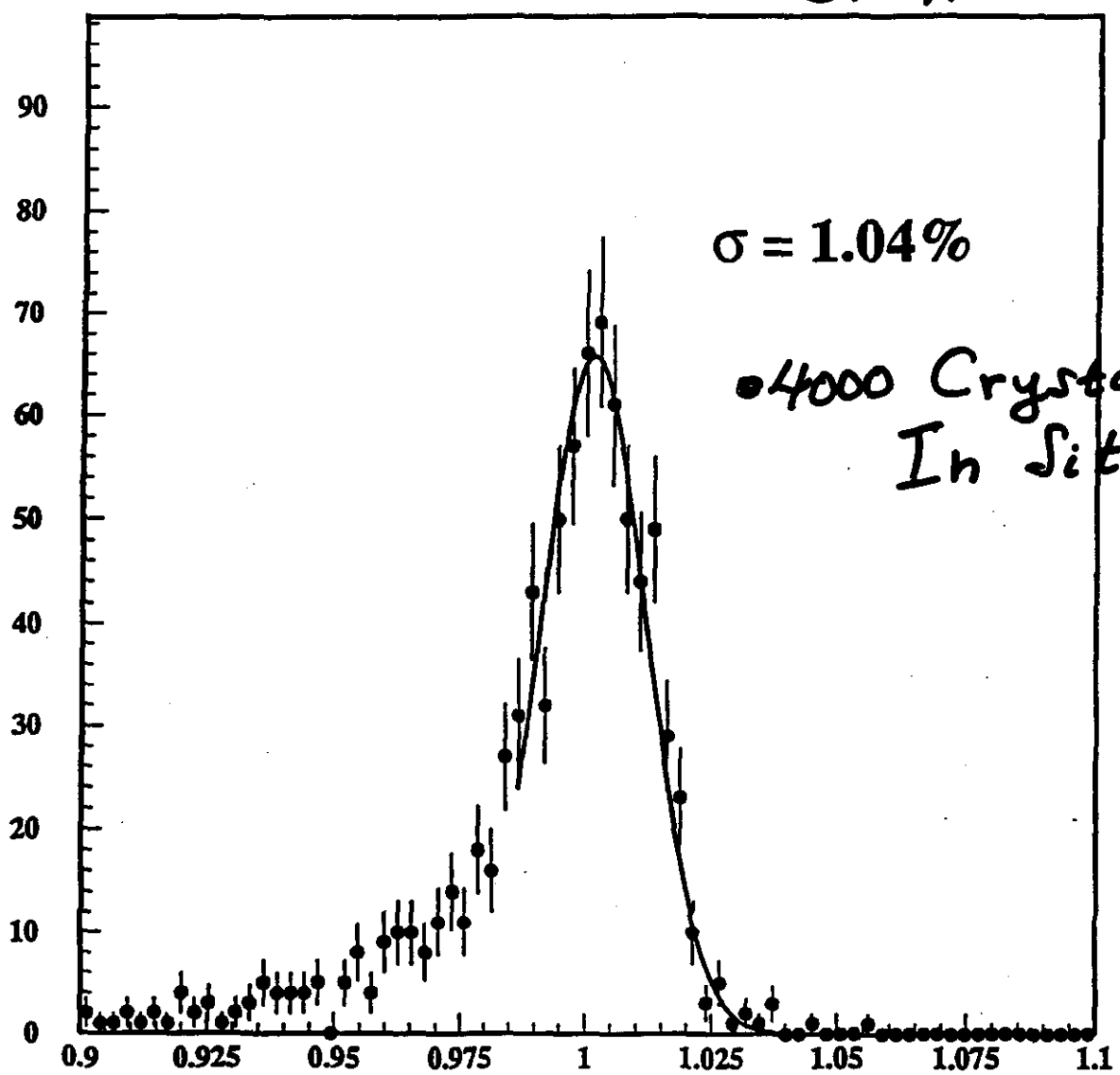
DEMONSTRATE ABILITY TO MAINTAIN HIGH RESOLUTION IN SITU

- CALIBRATION, STABILITY, UNIFORMITY TESTS
  - COSMIC RAY TEST Tower at UCSD (By 5/92):
    - New Matrix and Specially Treated Crystals
    - Uniformity Tests: Before and After Irradiation With Transverse Muons
    - Long Term Stability, and Short Term Tests
    - Post-Saturation Annealing Test
    - MIP Calibration Tests With Longitudinal Muons
    - Electronic Noise Tests
  - RFQ TESTS:
    - AccSys Test With 3.85 MeV RFQ (6/92)
    - L3 RFQ Experience (Start 4/92)
- SIMULATION STUDY: RESOLUTION IN SITU
  - Residual Non-Uniformity
  - Time Dependence
  - Calibration Accuracy
  - Calibration Strategy

BaF_2 EM CALORIMETER 1992 R&D PROGRAM

- BaF_2 CRYSTAL PRODUCTION:
  (SIC, BGRI)
- RADIATION DAMAGE STUDY:
  (SIC, BGRI, CALTECH, BNL, TIFR, LNPI; CEA, OPTOVAC; NRL, UWV)
- UV MONITORING SYSTEM:
  (CMU,UCSD)
- SURFACE PREPARATION, UV COATING:
  (LLNL; CEA, CIT, BNL)
- PROTOTYPE ENGINEERING DESIGN; DESIGN MANUFACTURING PROCESS:
  (ORNL; CALTECH, UCSD, LLNL)
- PROTOTYPE ELECTRONIC READOUT
  (ORNL, PRINCETON)
- CALIBRATION, UNIFORMITY, STABILITY: COSMIC RAY STAND; RFQ SYSTEM:
  (UCSD, CALTECH)
- BaF_2 CRYSTAL ACCEPTANCE TEST; MATRIX ASSEMBLY:
  (CALTECH, UCSD)
- SIMULATION and ANALYSIS:
  (CALTECH, ORNL; UCSD, CMU)

L3 at LEP DATA



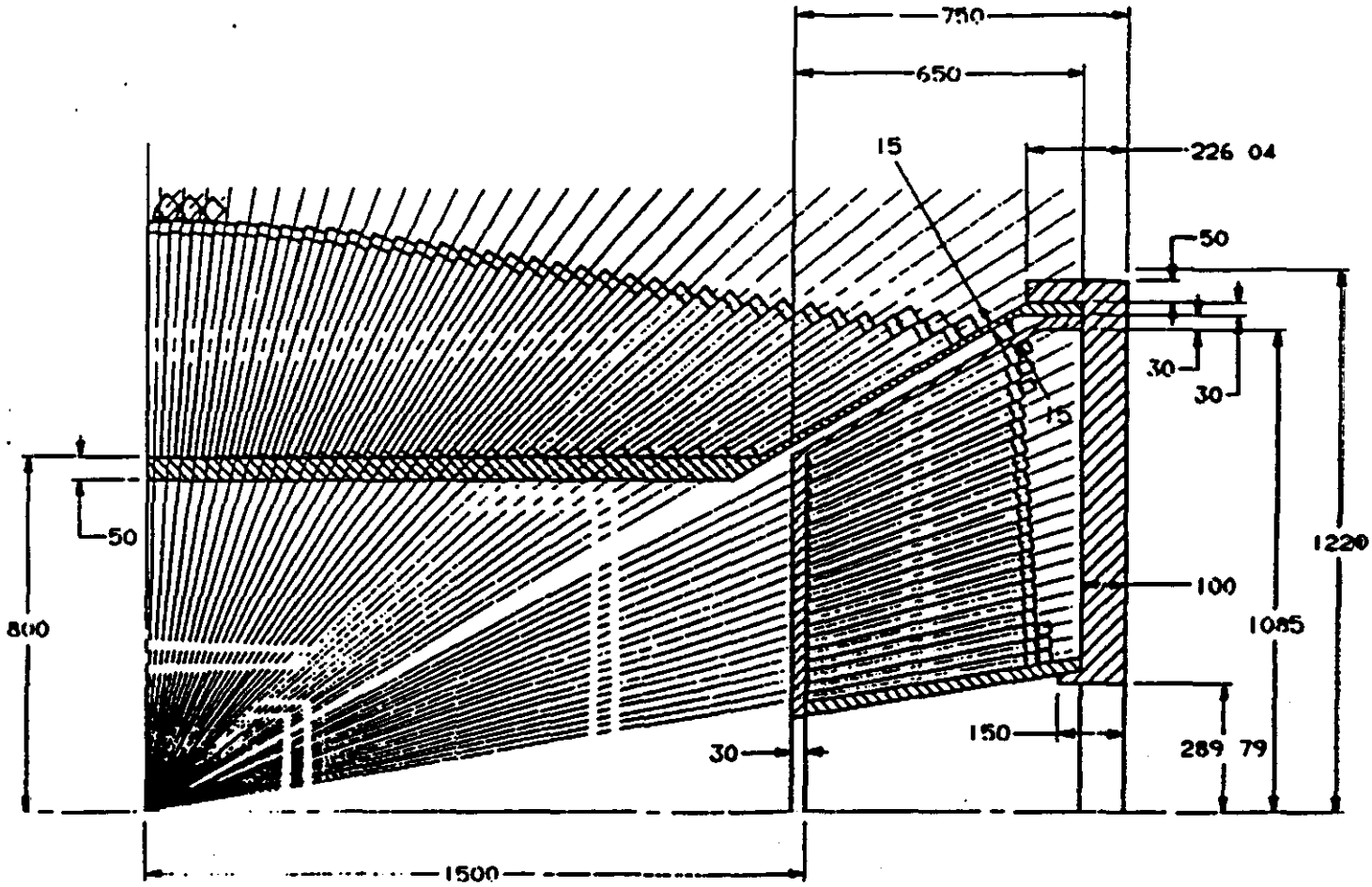
• 4000 Crystals In Situ

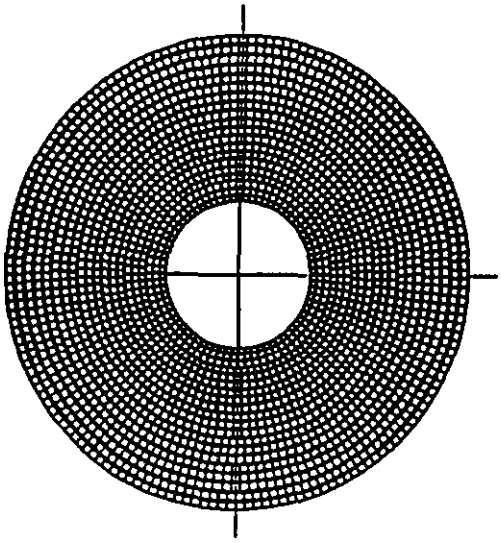
$e^+e^- \to e^+e^-(\gamma)$

$\sqrt{s} = M_{Z^0}$

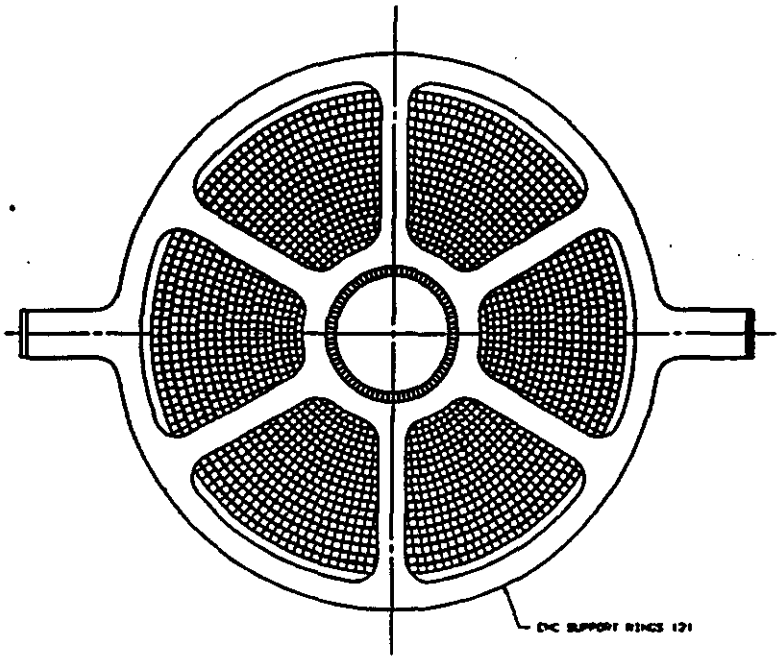
Unfold Radiate Bhabha Distribution

$\Rightarrow$ CONSTANT TERM = 0.7%


750
650
226 04
15
50
30
30
15
50
1220
100
800
1085
150
289 79
30
1500



SECTION A-A


DIC SUPPORT RINGS (2)

A PRECISION BaF_2 CRYSTAL CALORIMETER FOR GEM AT THE SSC

California Institute of Technology
University of California, San Diego
Princeton University
Carnegie Mellon University
Brookhaven National Laboratory
Oak Ridge National Laboratory
Lawrence Livermore National Laboratory
Shanghai Institute of Ceramics
Beijing Glass Research Institute
Institute of HEP, Beijing
University of Science and Technology, Hefei
Tongji University, Shanghai
Tata Institute of Fundamental Research, Bombay
LNPI, St. Petersberg

GEM Tucson Meeting
March, 1992

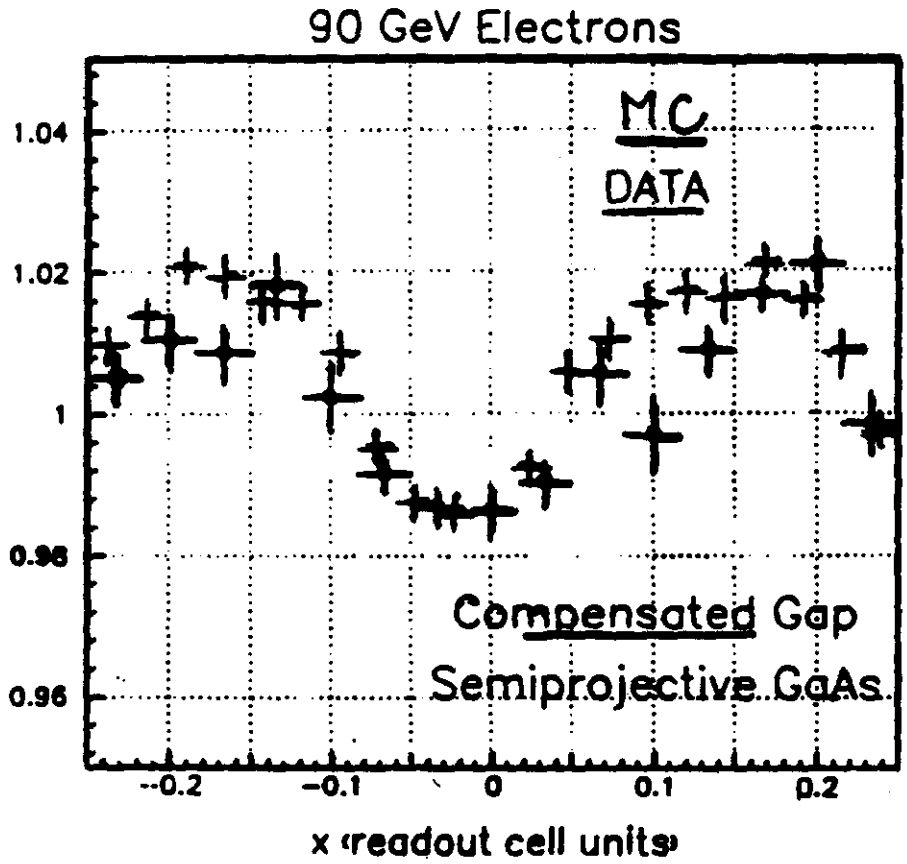
gem

γeμ

Presentation by:

D. Lissauer

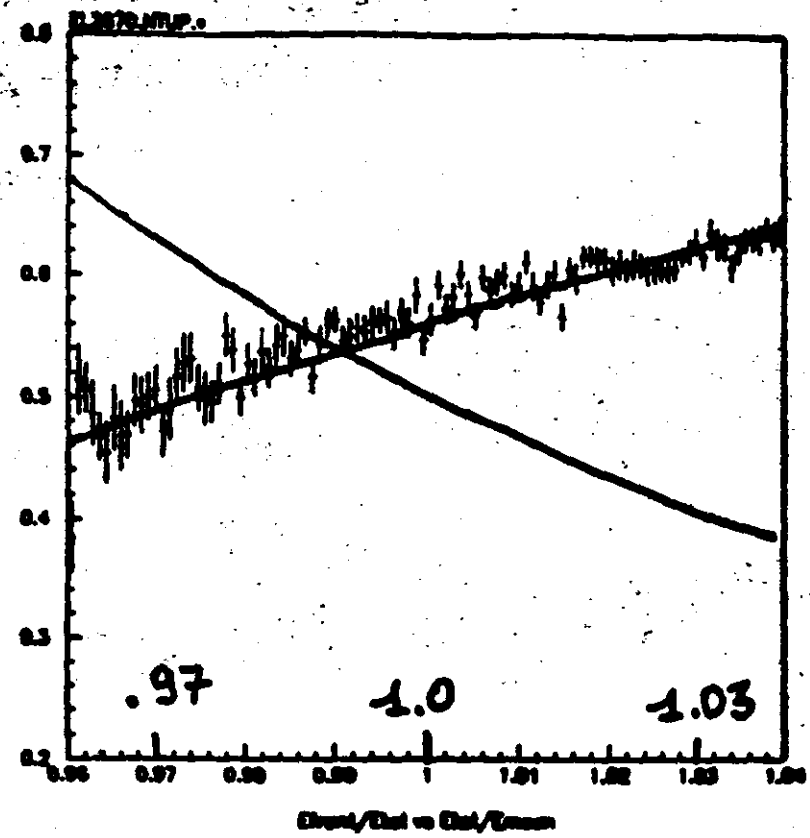
Semipointing



x modulation : ≈ facteur 2 larger : //

"OPENING GAP"

$\frac{E_{front}}{E_{tot}}$

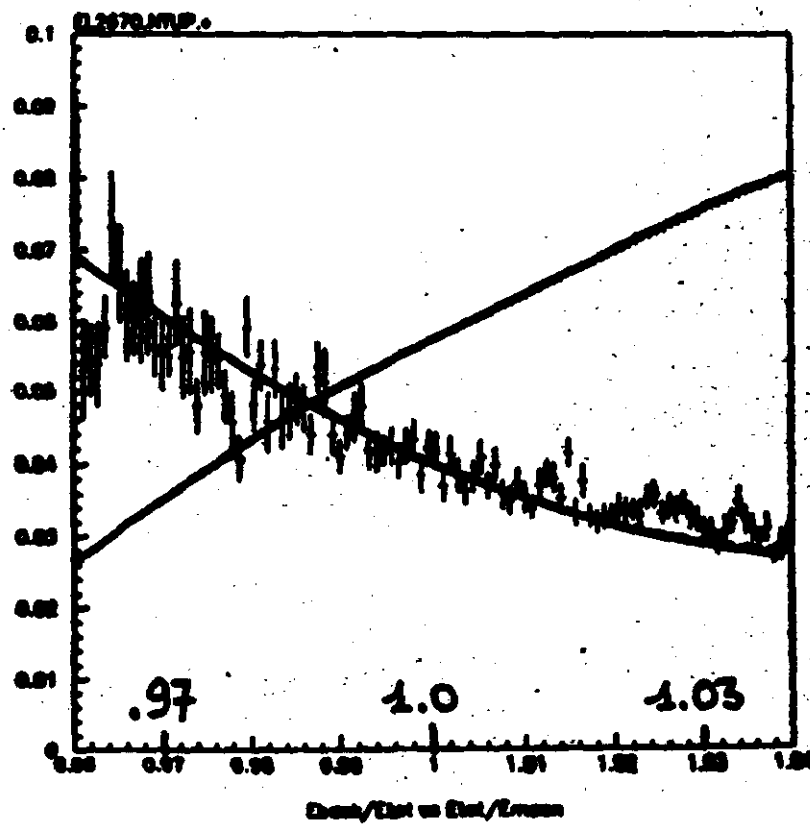


— all Q integrated

— including channel light and shaping.

$\frac{E_{tot}}{\langle E_{tot} \rangle}$

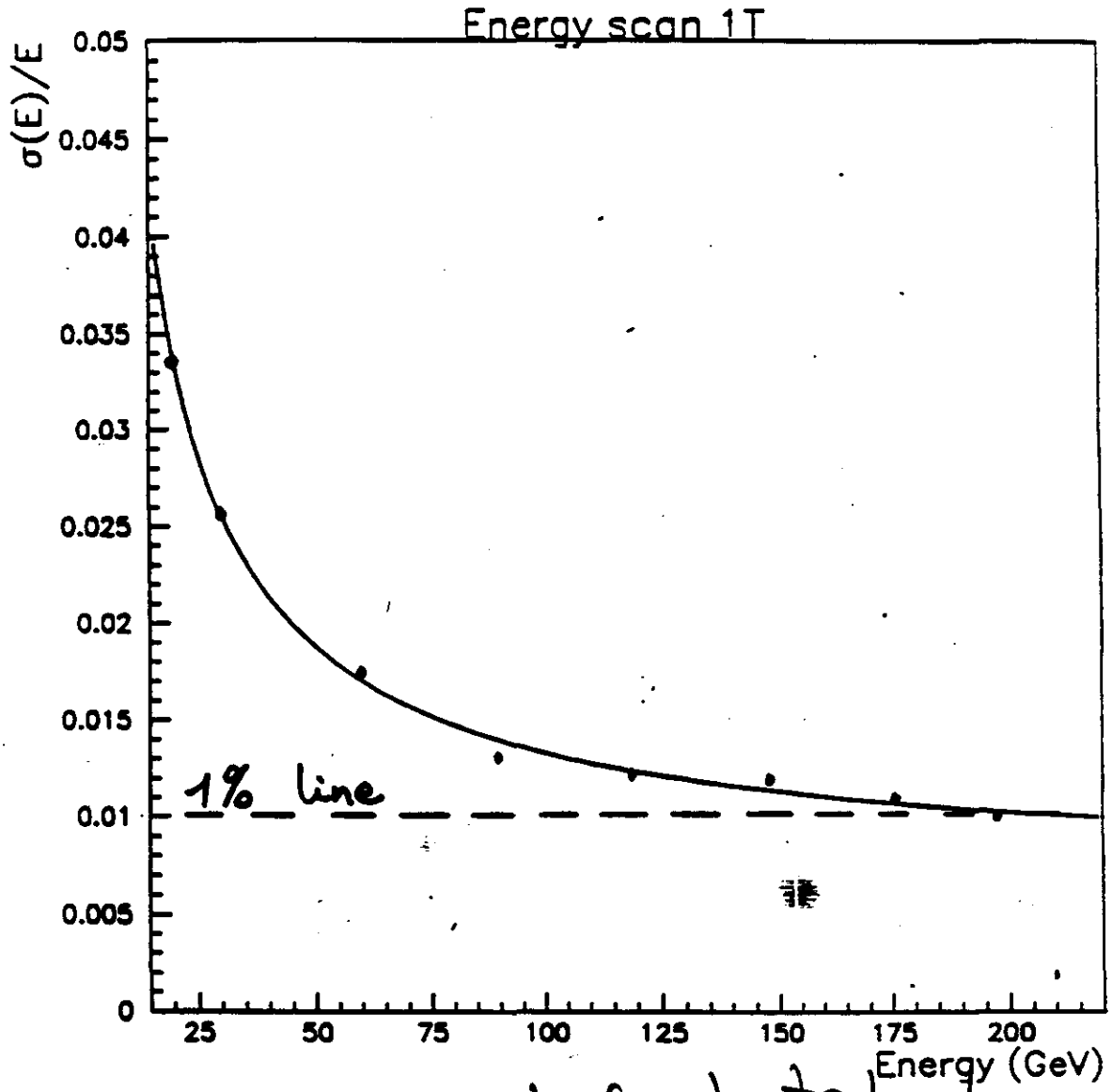
$\frac{E_{back}}{E_{tot}}$



$\frac{E_{tot}}{\langle E_{tot} \rangle}$

OPENING GAP:

$E_{tot} = E_{front}$



After energy independent front to back weighting.

$$\frac{\Delta E}{E} = \frac{10\% \pm 0.5\%}{\sqrt{E}} \oplus 0.6 \pm 0.2$$

1992' : RD3:

- Fully projective 2 meter long e.m Accordion.

  Oct. 92'. - Dec 92'.

- EST Hadronic Accordion.

The Liquid Argon Test.

Objectives:

1) EM energy resolution of 7.5% / $\sqrt{E}$ + 0.5%

→ 1.3mm Pb Solution. Liquid Krypton. (Sampling fraction)

→ .8 mm Pb in both absorber & readout electrode. (sampling frequency)

2) Position Resolution & e/π separation.

Chevron Design

→ 3) Trigger.

Sum energy front and back... Time resolution
Isolation cuts..... overlapping sums.

→ 4) Calibration.

Test new calibration system. 0.1-0.2 %

→ 5) Electronic readout.

AMU – ZEUS electronics.
Track and hold.

→ 6) Simulations.

Non projective geometry
Quasi projective
Projective geometry

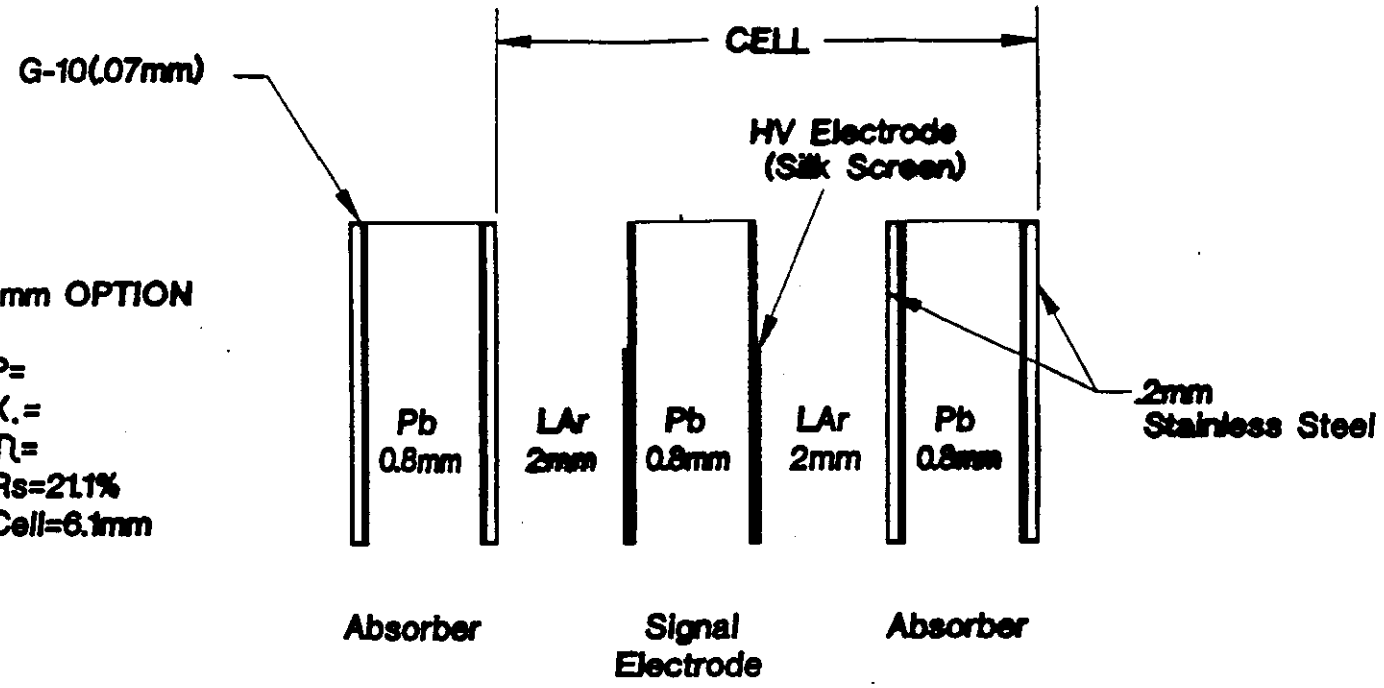
7) Bending machine

Bending machin for Projective Geometry.

EM Configuration

1mm OPTION

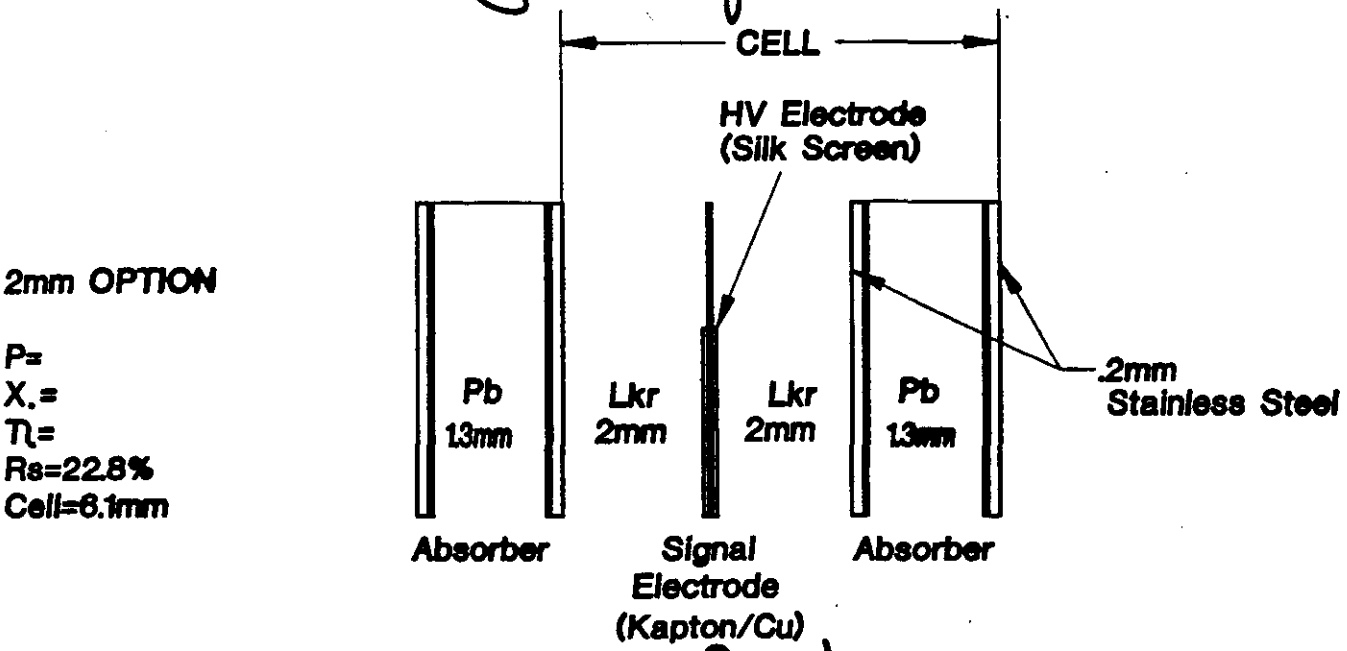
P=
X.=
η=
Rs=21.1%
Cell=6.1mm



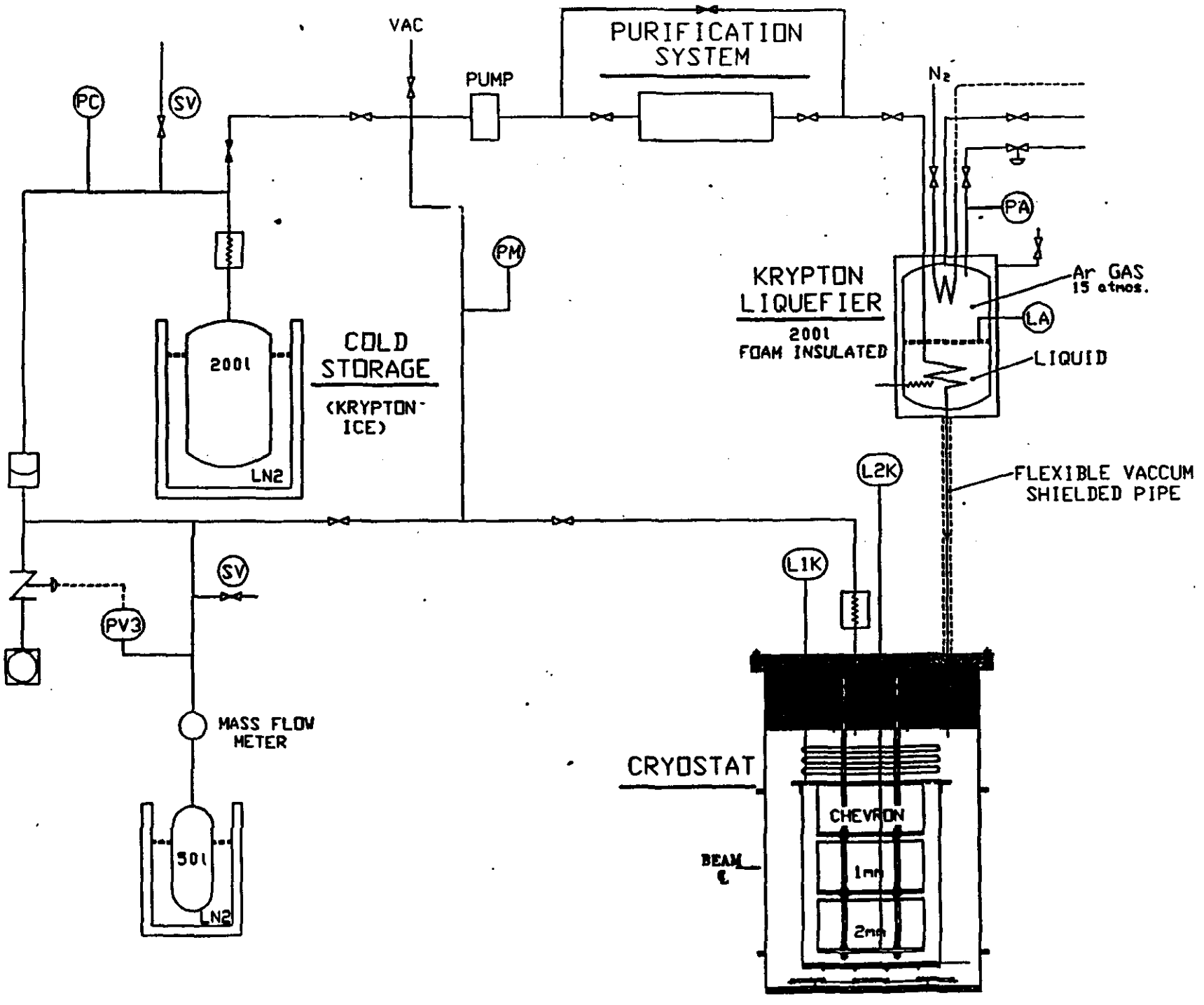
Sampling frequency.

2mm OPTION

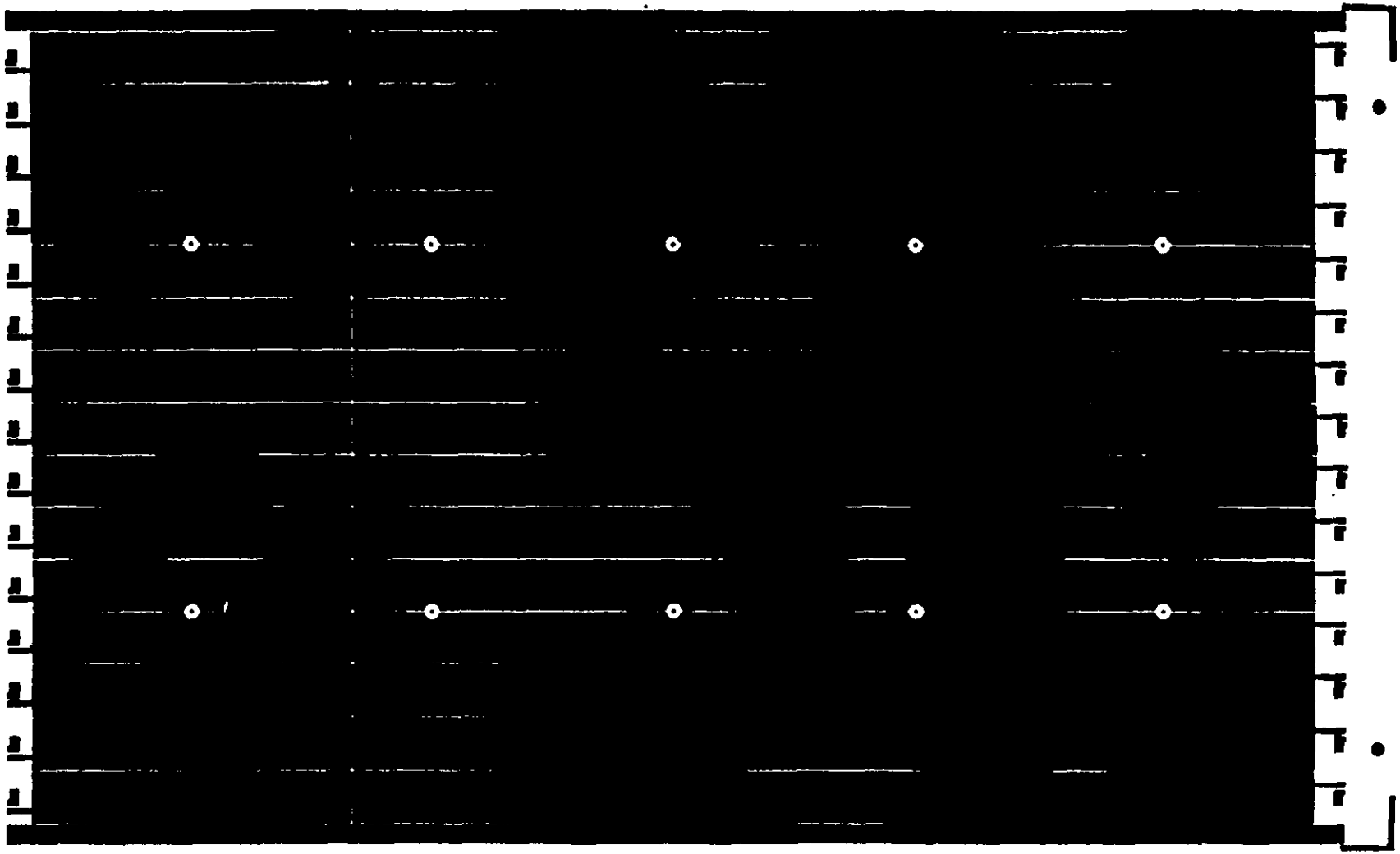
P=
X.=
η=
Rs=22.8%
Cell=6.1mm



Sampling fraction.

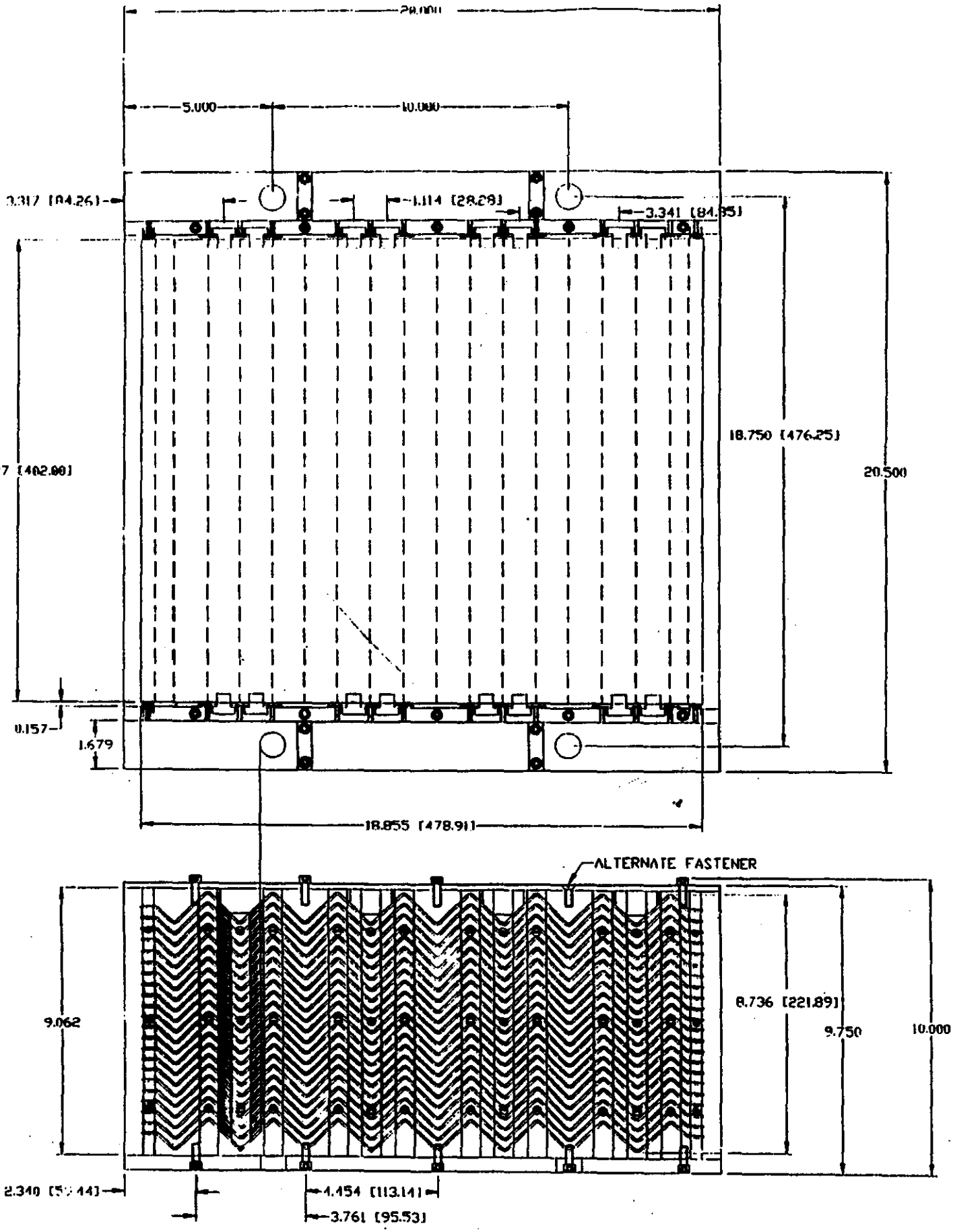

VAC
PUMP
PURIFICATION SYSTEM
N2
PC
SV
PM
PA
KRYPTON LIQUEFIER
200l
FOAM INSULATED
Ar GAS
15 atmos.
LA
LIQUID
COLD STORAGE
(KRYPTON ICE)
200l
LN2
L2K
FLEXIBLE VACCUM SHIELDED PIPE
L1K
SV
PV3
MASS FLOW METER
CRYOSTAT
CHEVRON
BEAM ℄
1mm
2mm
50l
LN2

Chevron: Readout electrode



BROOKHAVEN NATIONAL LAB, P/N 10634 LEVEL 2.

2/20/92
RON RYAN
ACAD FILE: 10634_L2.DWG


5.000
10.000
3.317 [84.26]
1.114 [28.29]
3.341 [84.85]
18.750 [476.25]
15.827 [402.00]
20.500
0.157
1.679
18.855 [478.91]
ALTERNATE FASTENER
9.062
8.736 [221.89]
9.750
10.000
2.340 [59.44]
4.454 [113.14]
3.761 [95.53]

1/7/92

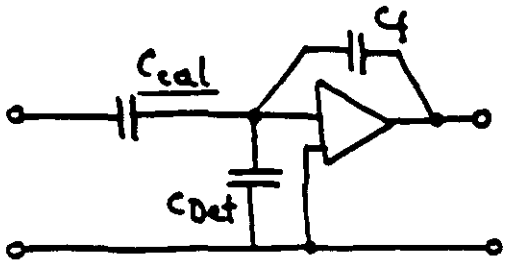
ELECTRONICS, CABLES and FEEDTHROUGHS

- Calibration
- Preamplifier Board
- Hybrids
  preamplifiers
  calibration
- Signal/Calibration Cables
- Feedthrough
- Power/ HV Cables
- Intermediate Amplifiers
- Blue Cable
- Variable Gain Amplifiers
- Track and Hold
- ADC'S

February 12, 1992

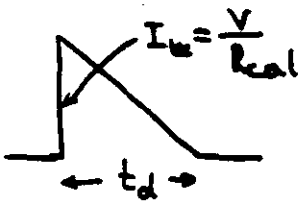
Charge Calibration

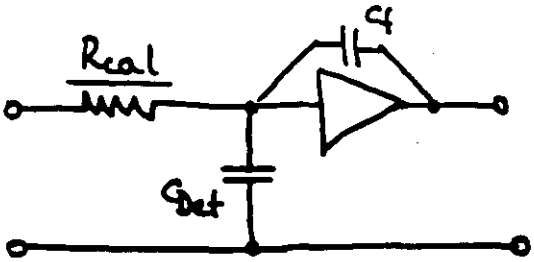
1) $Q = CV$



$$\frac{\delta C_{cal}}{C_{cal}} \approx 2\%$$

2)

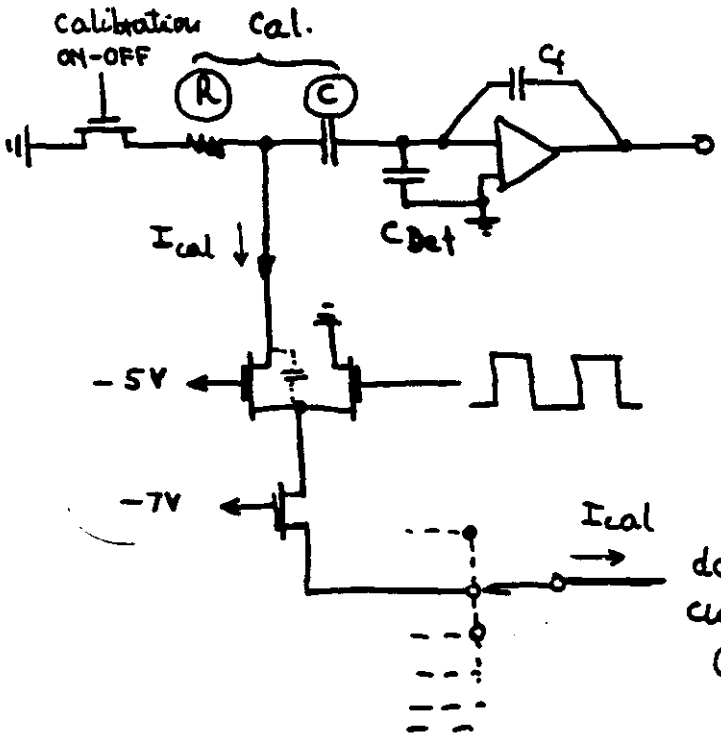




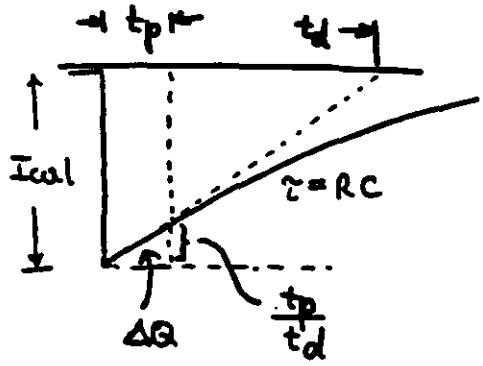
$$\frac{\delta R_{cal}}{R_{cal}} \approx 0.1\%$$

Problems:
1. Low R needed
2. Distribution of precisely controlled pulses.

3)



1. R can be low
2. dc current distributed
3. 10% R's and C's result in 0.5% calibration.



$$Q_{cal} = I_{cal} \cdot t_p \left(1 - \frac{1}{2}\frac{t_p}{t_d}\right)$$

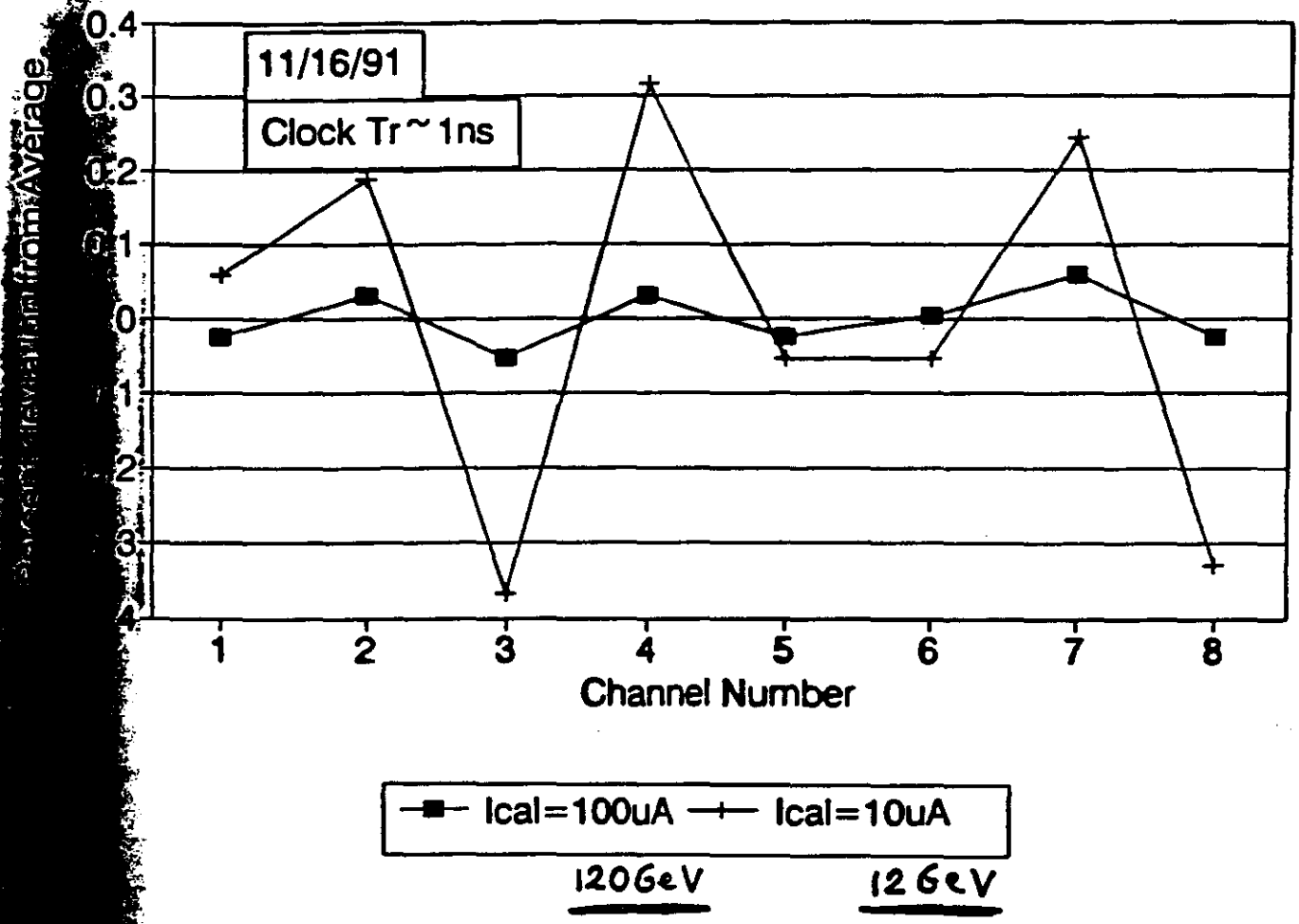
$$\frac{\Delta Q}{Q_{cal}} = \frac{1}{2}\frac{t_p}{t_d} \approx \frac{1}{20} \text{ for } \quad t_p = 40\ \mu sec, \quad t_d = 400\ \mu sec$$

$$\boxed{\frac{\delta I_{cal}}{I_{cal}} \approx \frac{1}{20}\left(\frac{\delta R}{R}, \frac{\delta C}{C}\right)} \quad \therefore$$

switch parameters (V_t and noise) do not influence calibration.

25ns Shaper Output Uniformity vs Ical

PJ32 FET



120GeV 12GeV

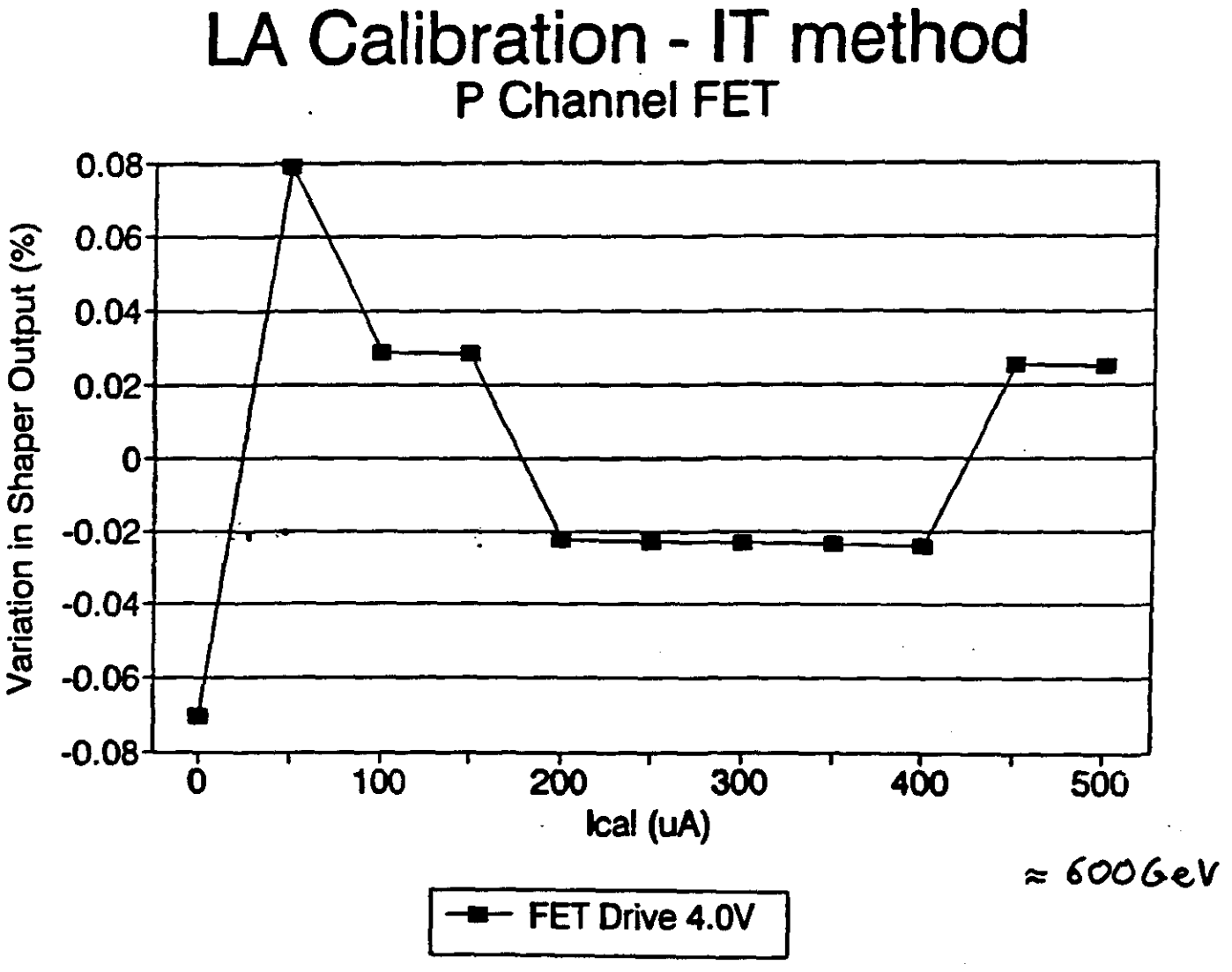
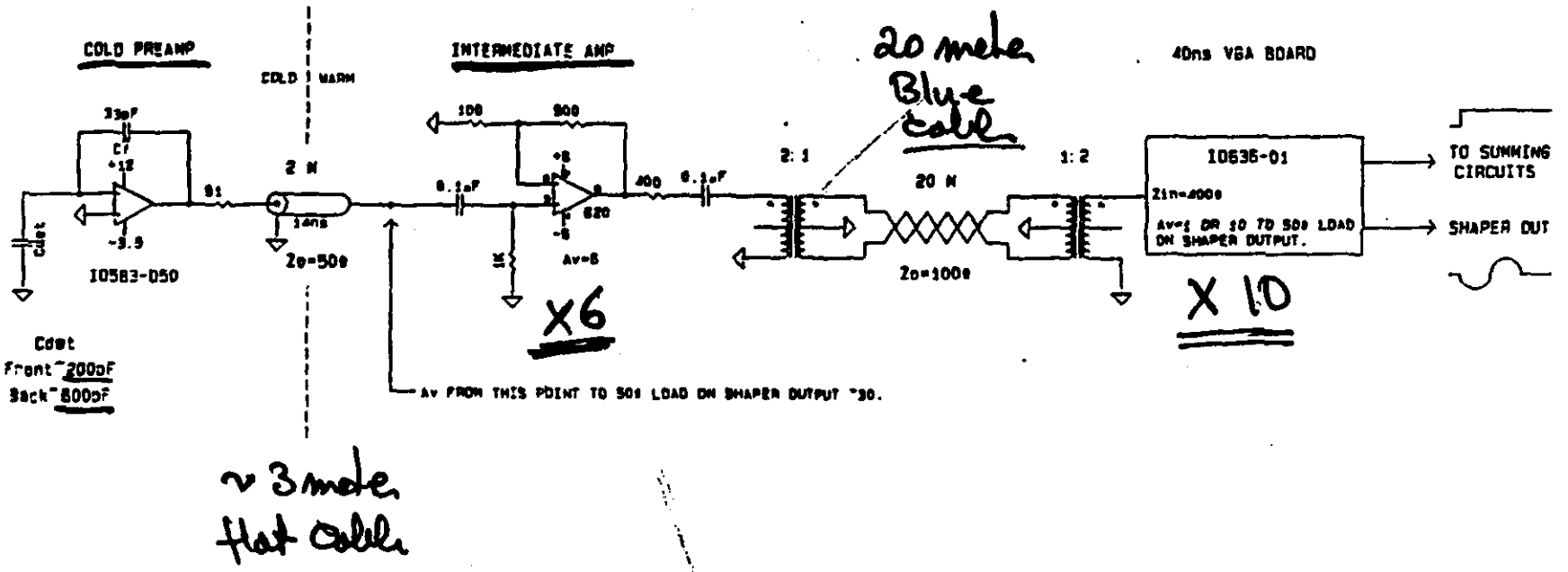

LA Calibration - IT method
P Channel FET
Variation in Shaper Output (%)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
100
200
300
400
500
Ical (uA)
≈ 600GeV
FET Drive 4.0V

Fig. 5



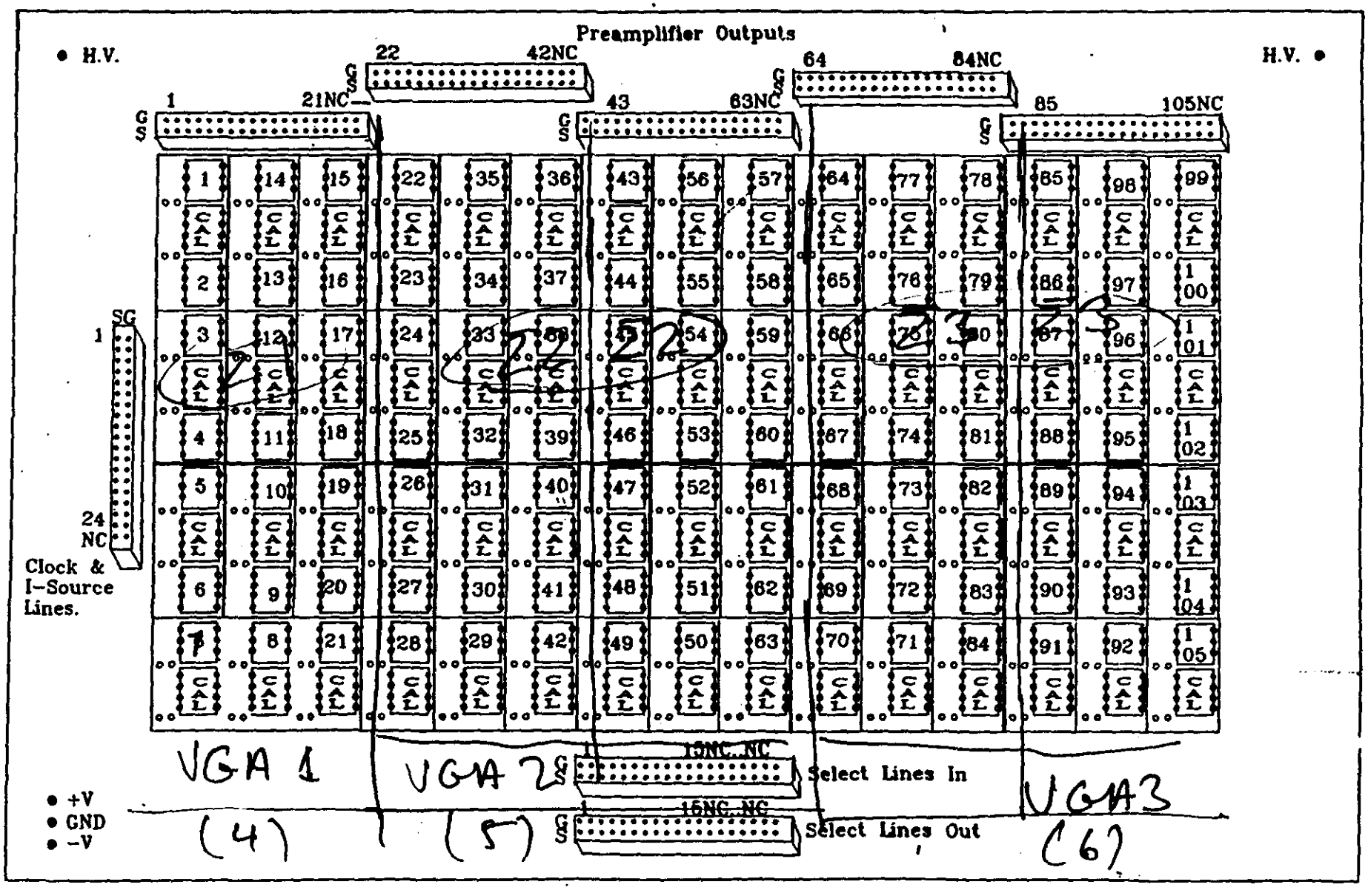
INSTRUMENTATION DIVISION
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

TITLE: GEN BLOCK DIAGRAM

SIZE	DRAWING NUMBER	REV.
B	IOXXX-XX	A - 00

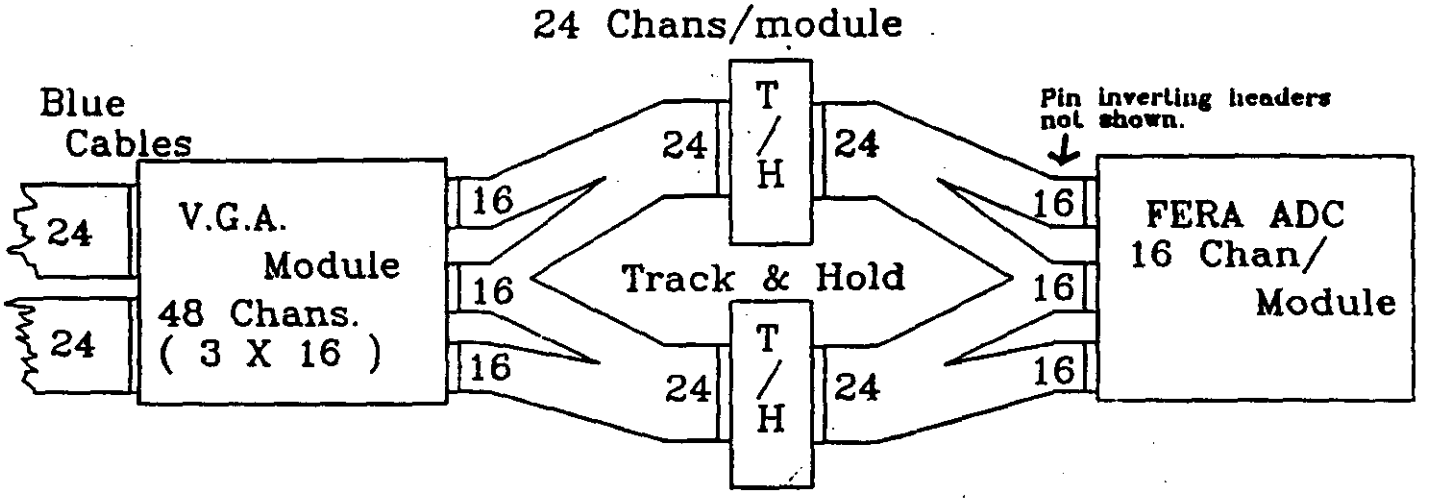
DATE 1/27/88 BY LCR | SHEET 1 OF 1

Accordion Calorimeter Preamplifier Board



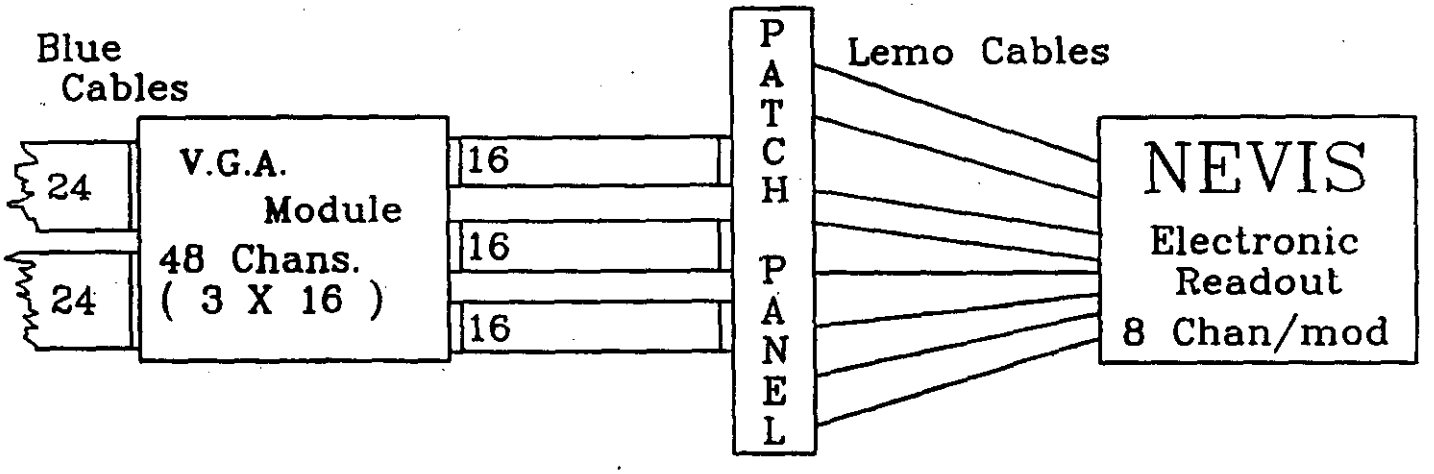
Accordion Calorimeter
Cable Multiplicity Scheme

B.N.L. Readout

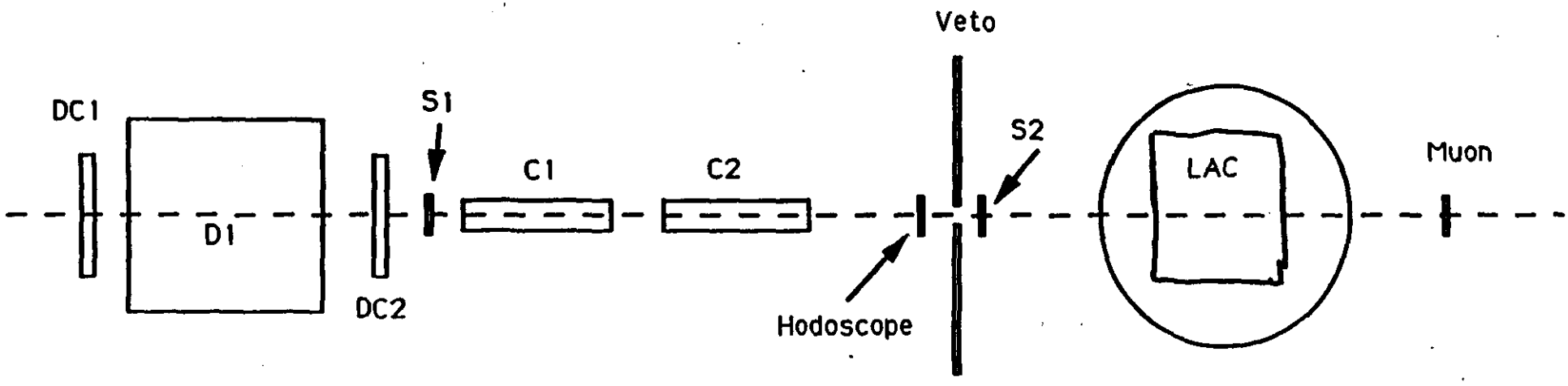


The Cables are split 25 Channel 100 OHM Twist & Flat.

NEVIS Readout



Test. Beam Set up.
A3 Line BNL



0.5 – 20 Gev $e/\pi/\mu/\bar{p}$.

Run Plans:

AGS: March 14th – April 15th Si

April 15th – April 30th Au MD.

May 1st – May 7th Open / P-setup

May 7th – June 30th Proton.

Instalation:

March 14th : - Set up a Fake 2 ch. Cal.
- DAQ set up.
- Trigger

March 14th – April 15th : - Debug online
- Calibration Prog.
- Tape / Disk.

April 15th – May 7th : - Instalatic
- Cryogenic check

May 7th – May 31st – Debug
- Data Taking

Liquid Argon Baseline Design.

1) Calorimeter Design (Mechanical): (Martin Marietta Astronautics)

e.m Section : Accordion Design, Bend angles
depth, barrel length. endcap design.

Hadronic Section : Parallel plate Geometry
Uranium tiles (High density, μ problem.
Electrostatic transformer

Forward Calorimeter: Tungsten Integrated in L.A. endcap.

2) Electronics Development

Pre-amps (Inst. Division) – Tested Rad hard, J-FET

Shapers (Inst. Division) – hybrid ✓ ,

Pipeline Electronics (Nevis) – APU + ADC

Cables, Feedthrough

3) Calorimeter Trigger.

Architecture: Physics def., Technology

Trigger Sums: Size, overlapping

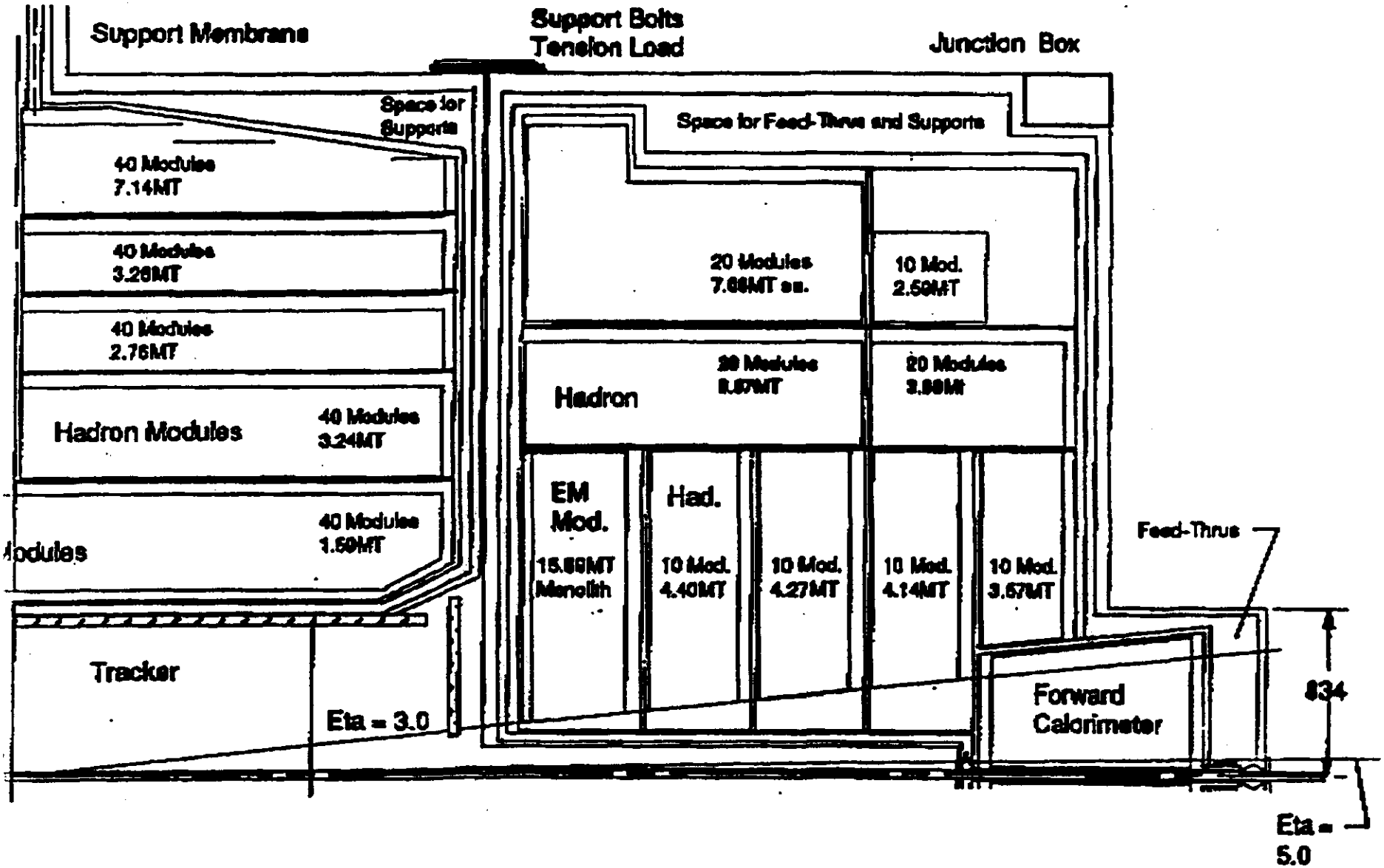
Calibration & pulsing system

Parallel system to the individaul towers

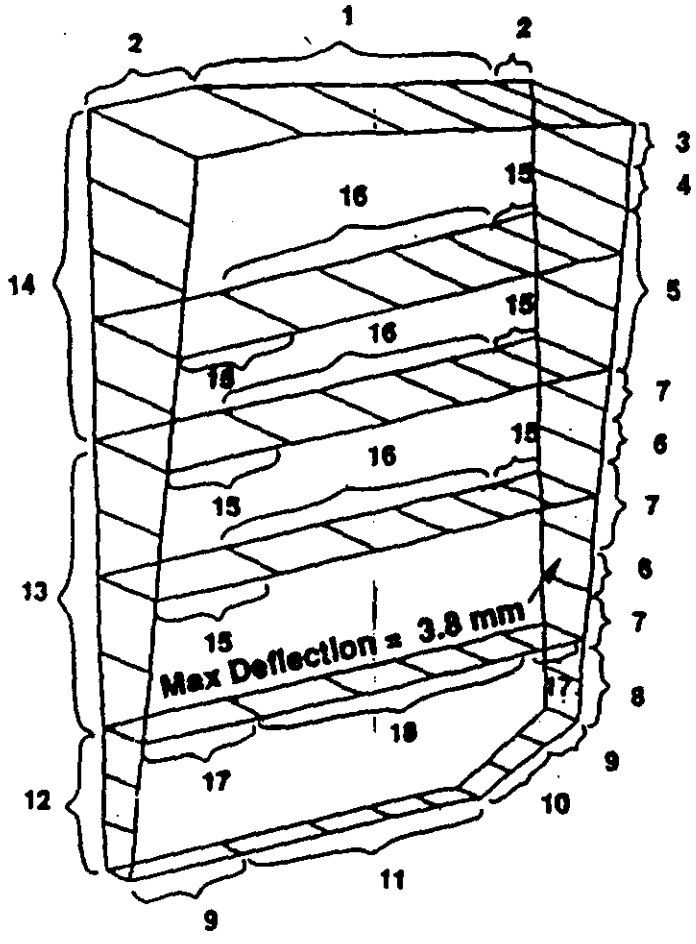
4) Calibration monitoring.

5) Simulation.

6) Integration questions:
Services
Access Liquid argon electronics.


Support Membrane
Support Bolts
Tension Load
Junction Box
Space for
Supports
Space for Feed-Thrus and Supports
40 Modules
7.14MT
40 Modules
3.26MT
40 Modules
2.76MT
Hadron Modules
40 Modules
3.24MT
40 Modules
1.59MT
Modules
20 Modules
10 Mod.
2.59MT
Hadron
20 Modules
20 Modules
EM
Mod.
15.69MT
Monolith
Had.
10 Mod.
4.40MT
10 Mod.
4.27MT
10 Mod.
4.14MT
10 Mod.
3.57MT
Feed-Thrus
Tracker
Eta = 3.0
Forward
Calorimeter
834
Eta =
5.0

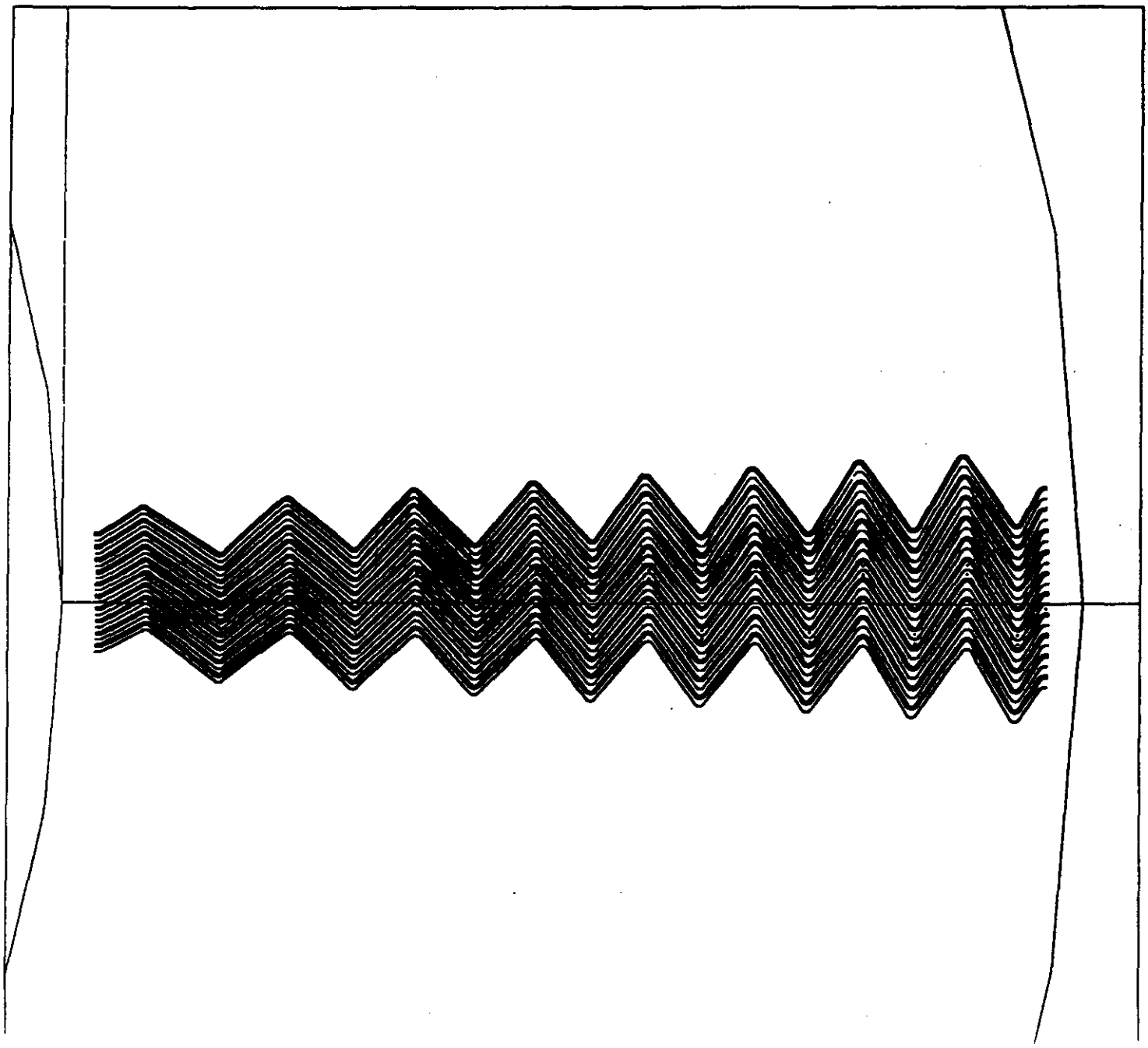
Gem3 Central Calorimeter Argon Vessel Wall Thickness

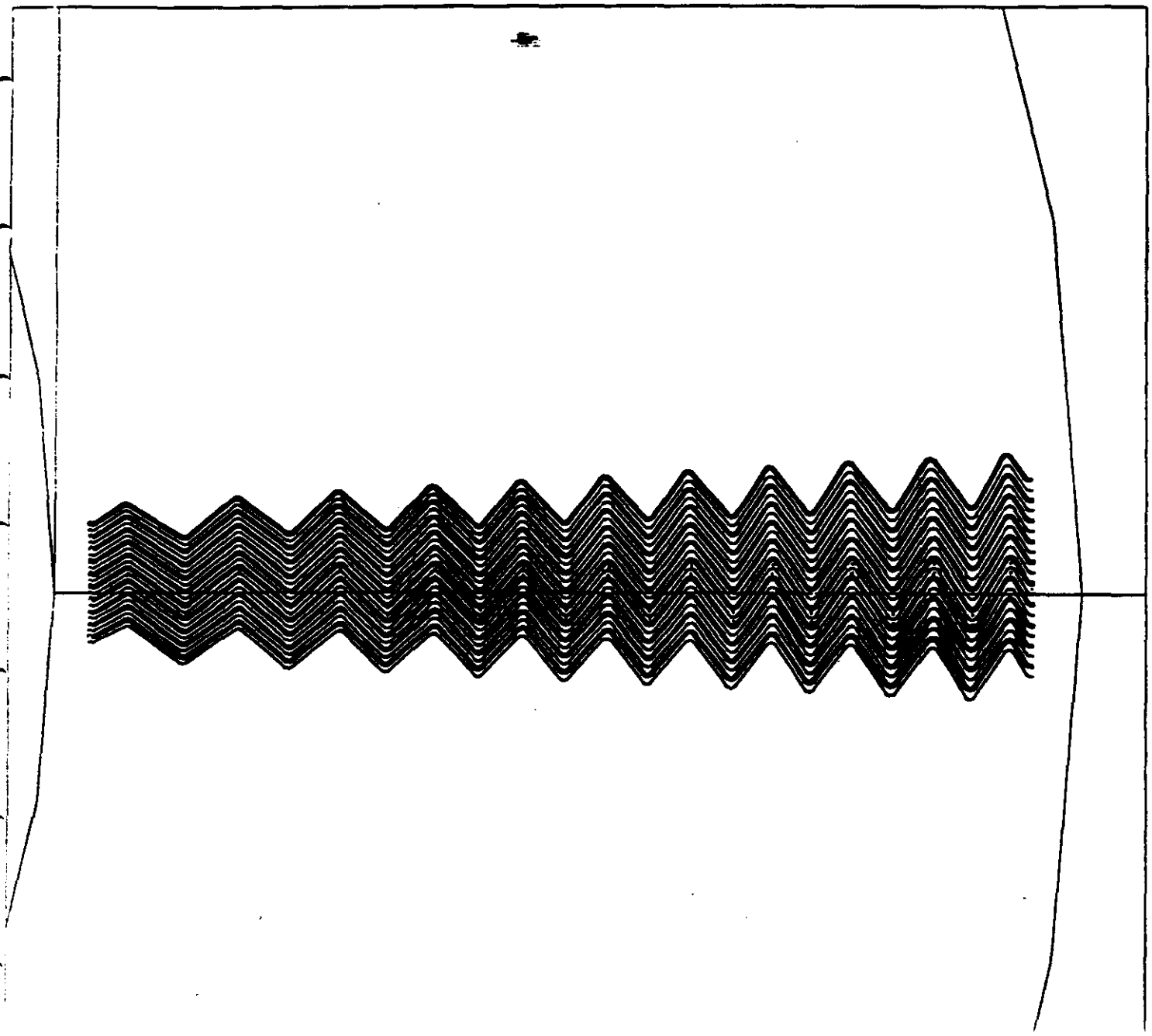


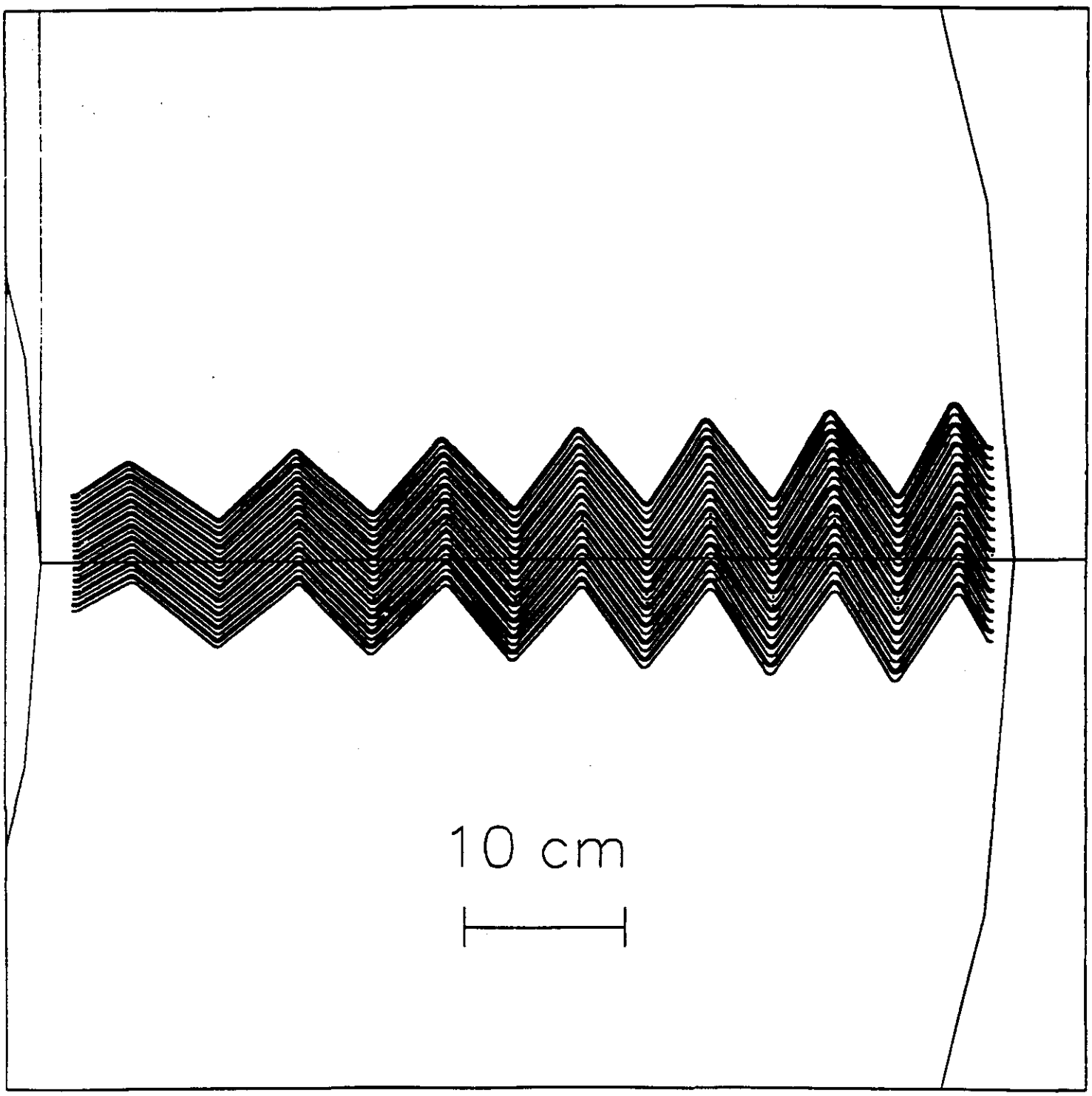
Group	[2]Wall (mm)	[1]ASME Sizing	Pressure (psi)	Von Mises (ksi)
1	(L)22.9	H	-14.7	N/A
2	(L)22.9	H	-14.7	N/A
3	20.2	3.0 Sm	50.0	32.4
4	29.3	1.5 Sm	50.0	17.4
5	18.6	3.0 Sm	50.0	25.4
6	13.7	1.5 Sm	50.0	16.8
7	68.7	3.0 Sm	50.0	4.9
8	8.4	3.0 Sm	50.0	34.2
9	(L)15.5	H	50.0	N/A
10	(L)15.5	H	50.0	N/A
11	(L)15.5	H	50.0	N/A
12	1.00	1.0 Sm	50.0	10.8
13	1.02	1.0 Sm	50.0	13.3
14*	1.57	1.0 Sm	50.0	11.4
15*	2.90	1.0 Sm	50.0	16.7
16*	3.28	1.0 Sm	50.0	14.1
17	9.13	1.0 Sm	50.0	10.6
18	2.73	1.0 Sm	50.0	11.6

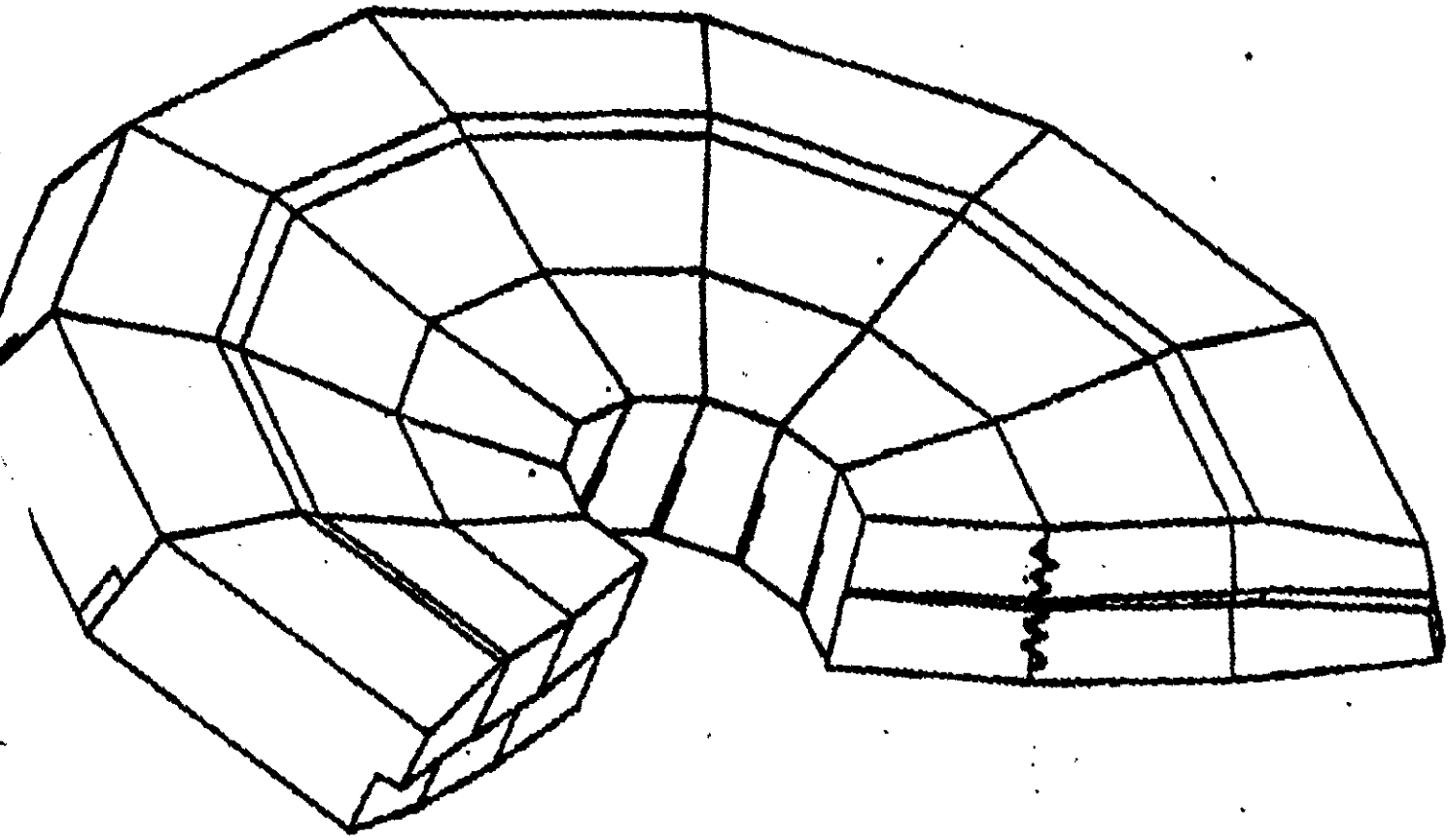
[1]ASME Section VIII Division 2
Sm (5083 AL) = 12000 psi for $1.3 \le t \le 38.1$ mm
H = Hoop Buckling
[2](L) = Optimizer reached lower limit
* = Half Thickness

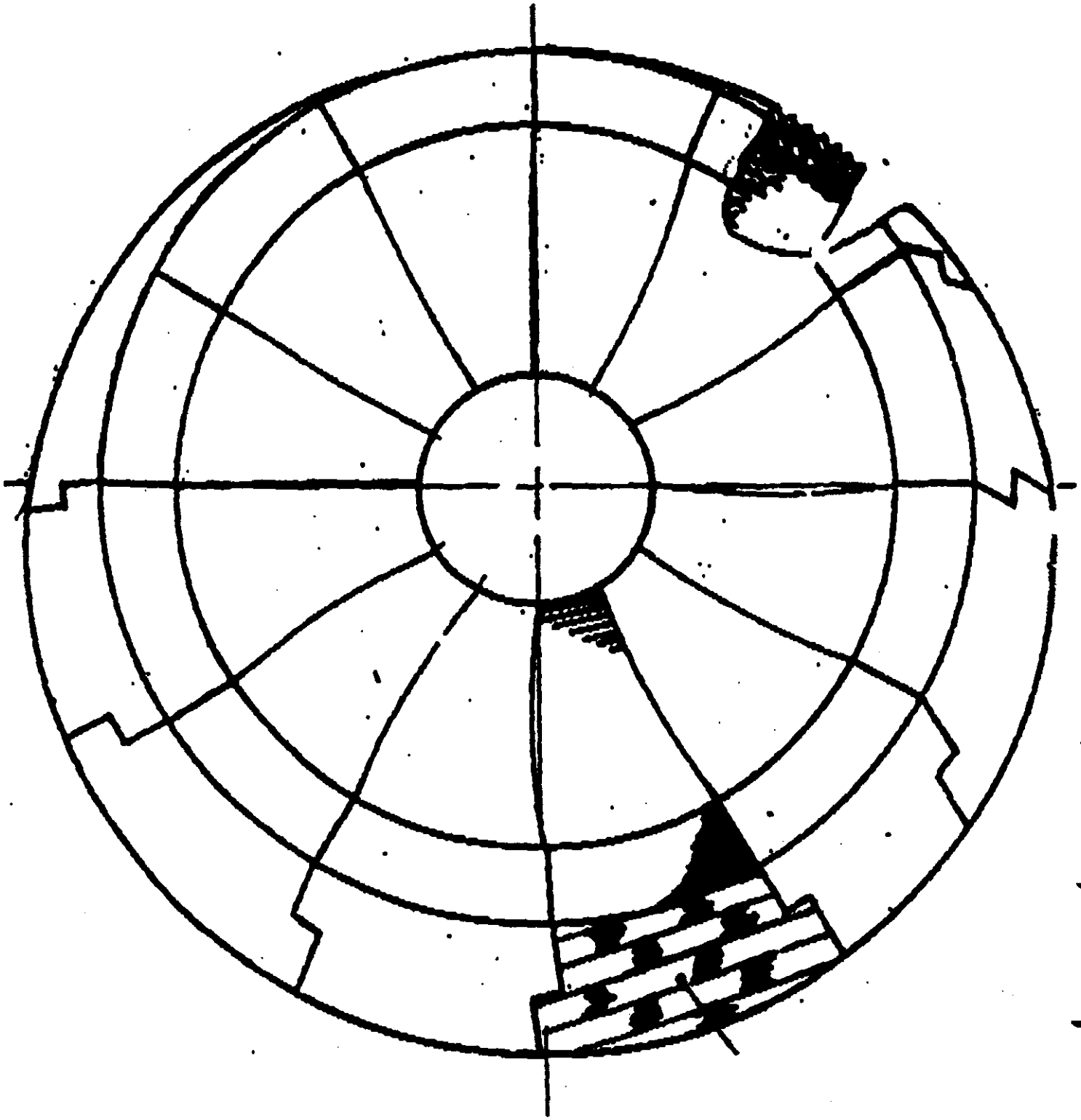
1

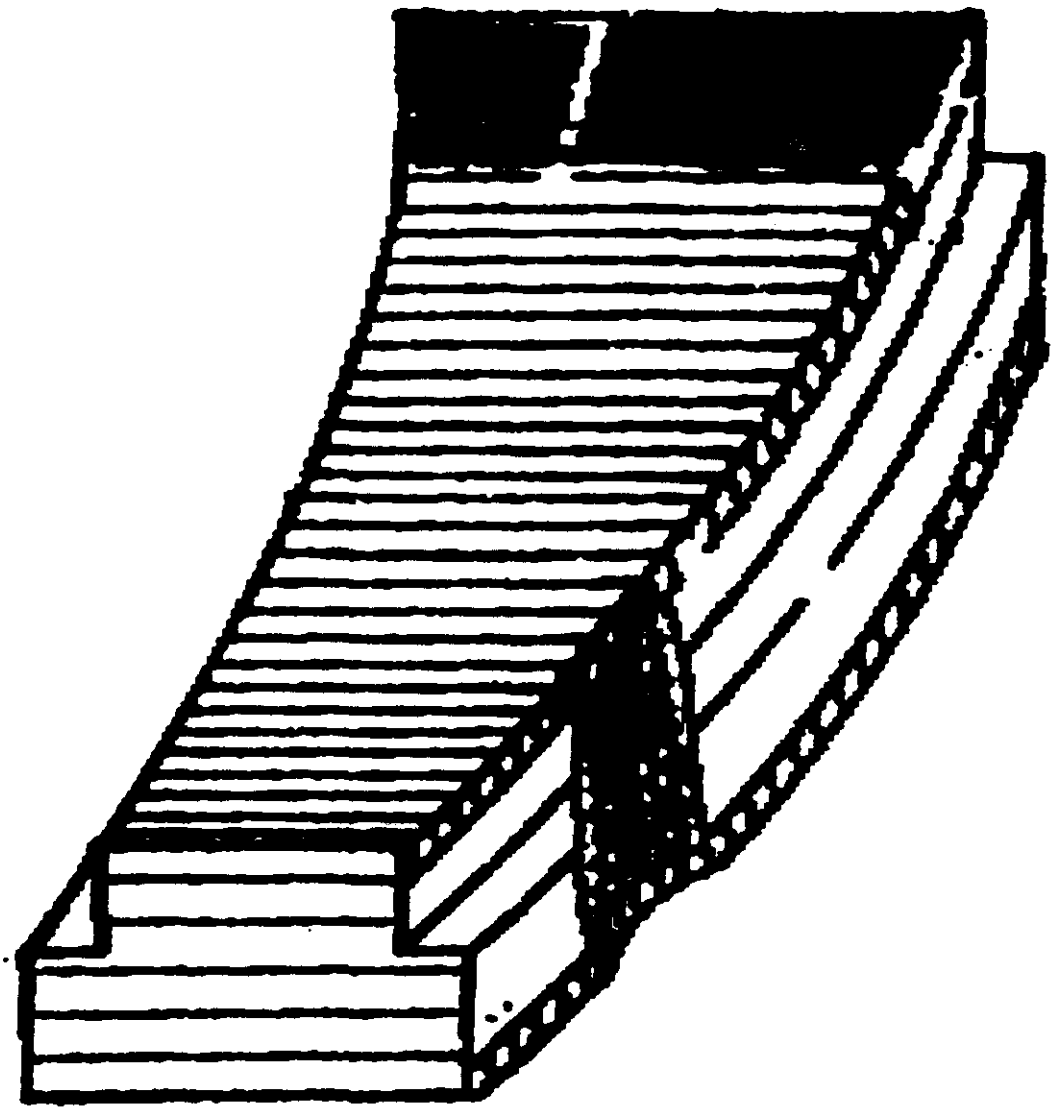




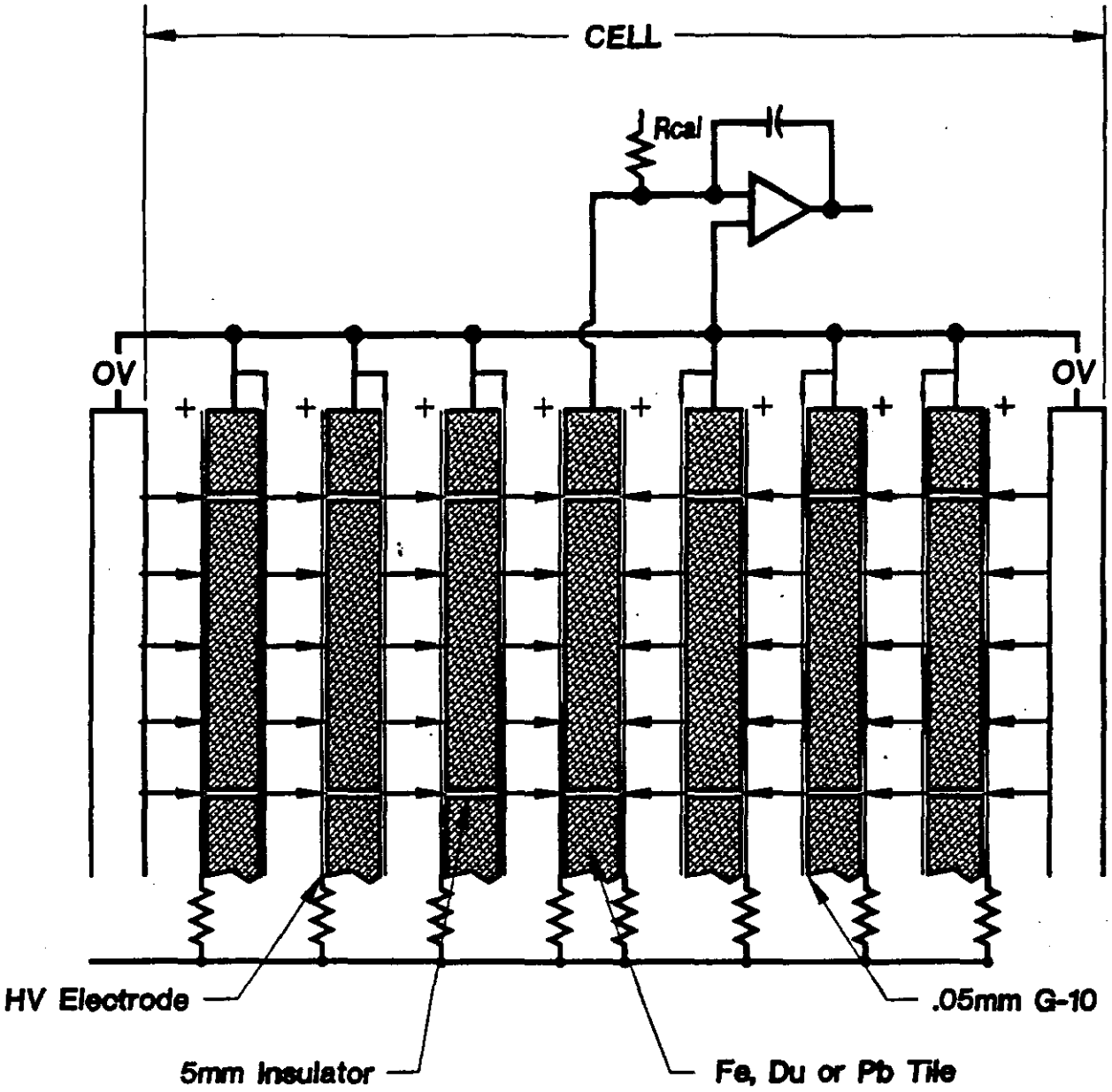

10 cm



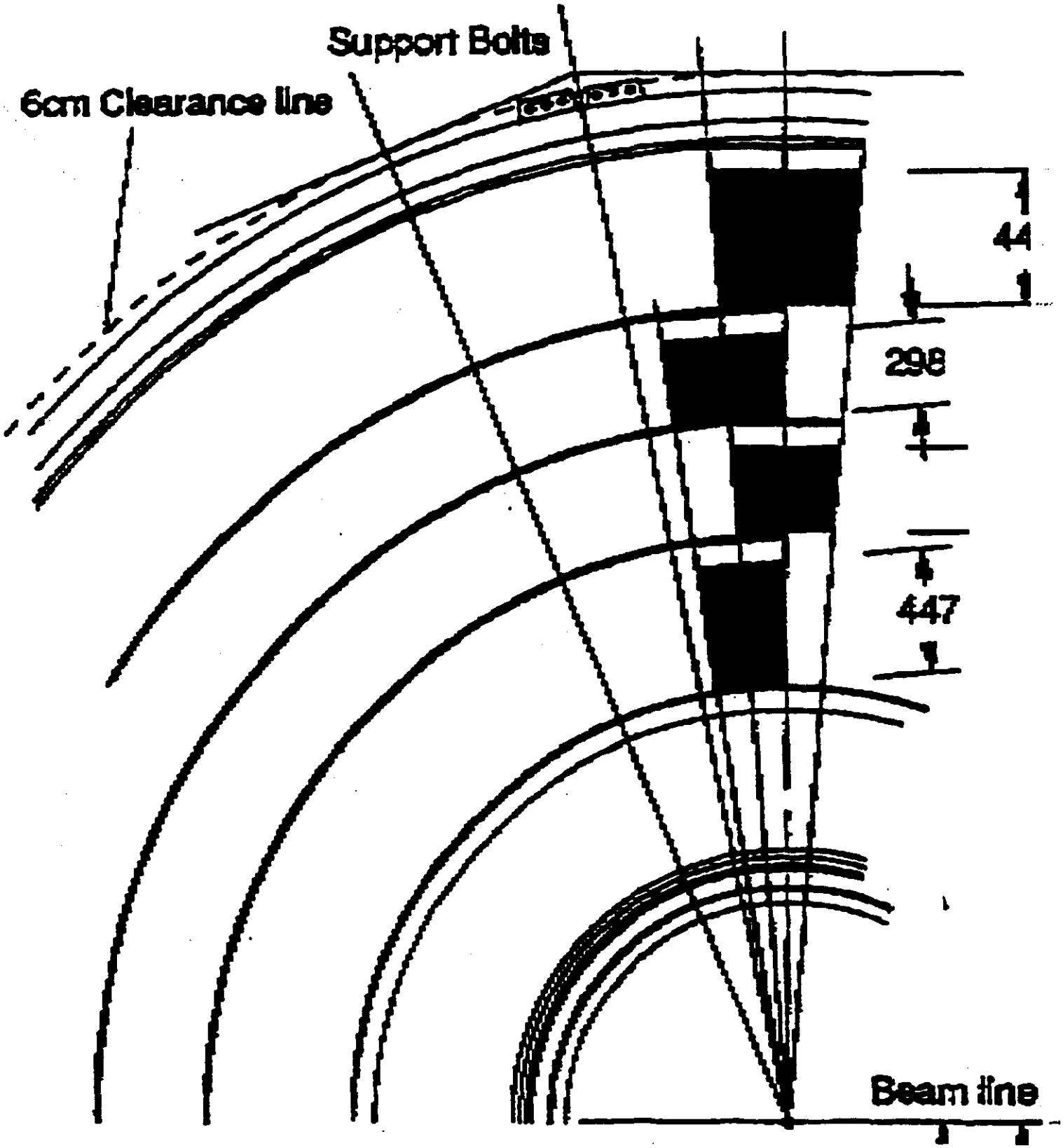


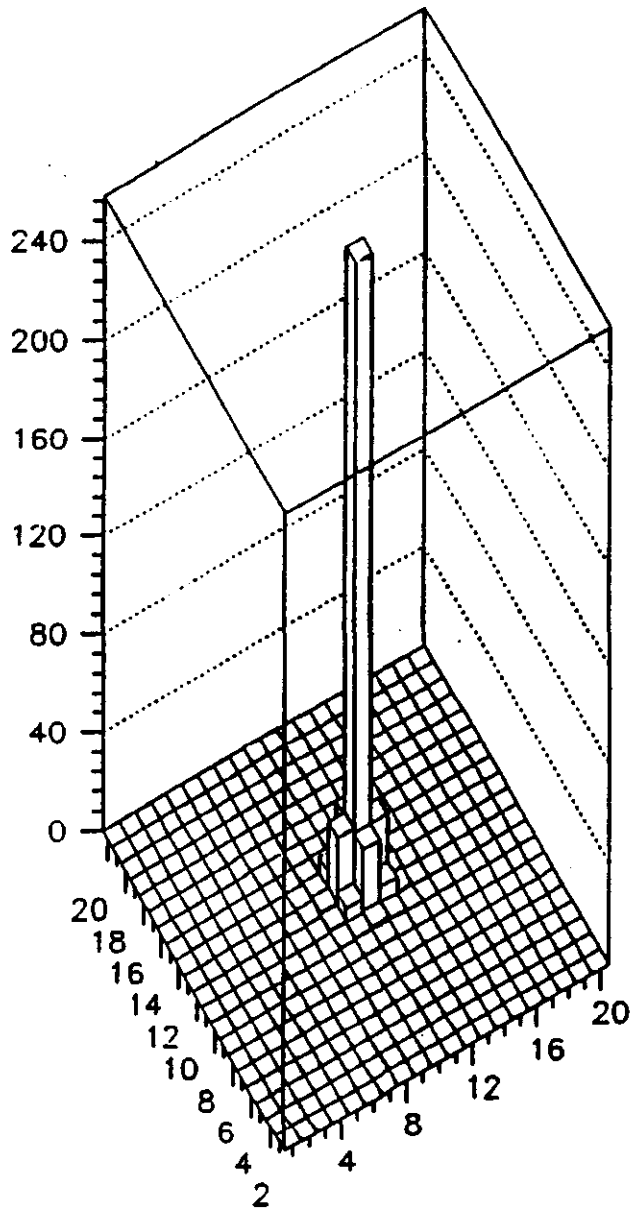


Hadronic Configuration with Electrostatic Transformer

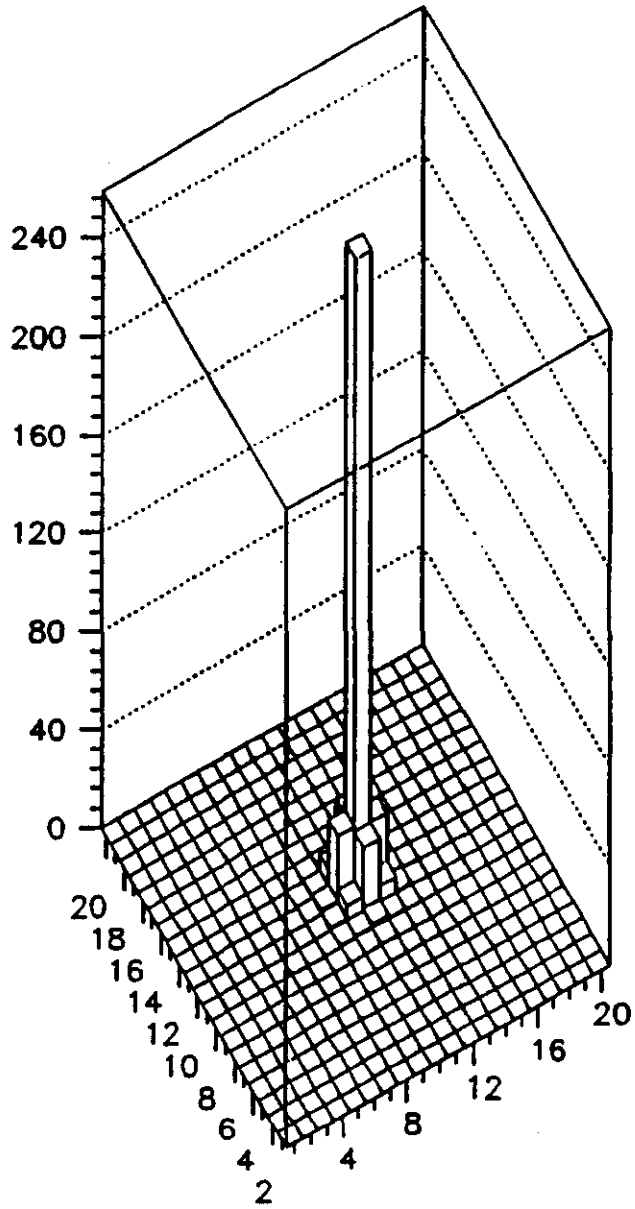


	Barrel		End Cap	
	Fine	Course	Fine	Course
P				
TL				
Rs				
Cell				


Support Bolts
6cm Clearance line
44
298
447
Beam line



energy flow in the calorimeter



energy flow in the EST calorimeter

Conclusions:

1. Constant term has been measured for non projective geometry. $< 0.4\%$
2. Sampling term has been measured for non projective geometry $\frac{9.7\%}{\sqrt{E}}$
3. Semi pointing - "Opening Gap" geometry has been tested. $9.6\%/\sqrt{E} + 0.6\%$ } Not projective sol'n.

1992:

BNL: Improve Resolution.

- Increase Sampling fraction
- Increase Sampling frequency
- New Calibration System.

(No Const. term, max energy 20 GeV)

CERN:

2 meter projective prototype

- Aug Mechanical assembly
- Dec. Test Beam.

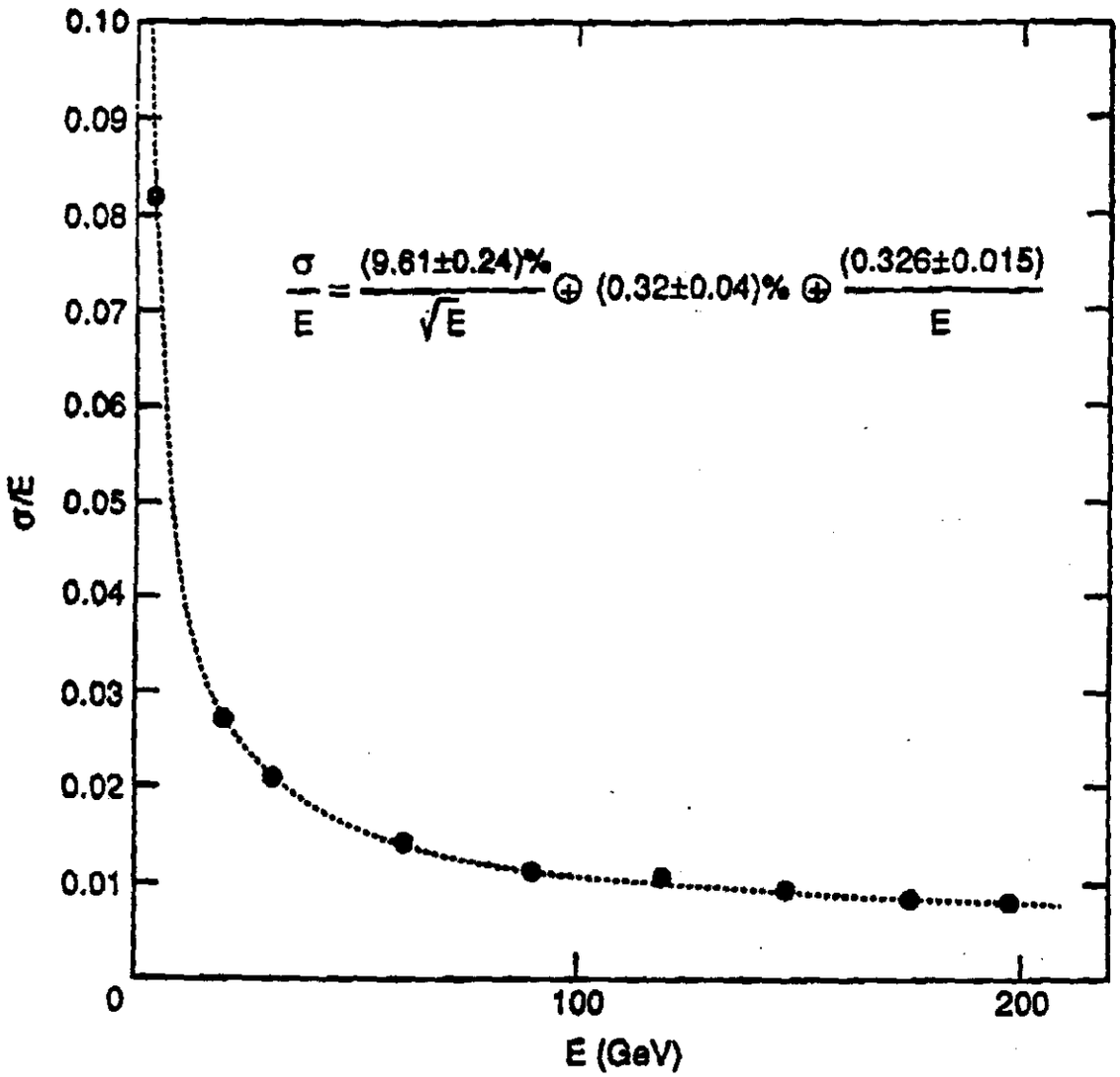


Fig. 9

1991 Data: Non Projective Geometry.

$t_p = 20$ n-sec.

Linearity:

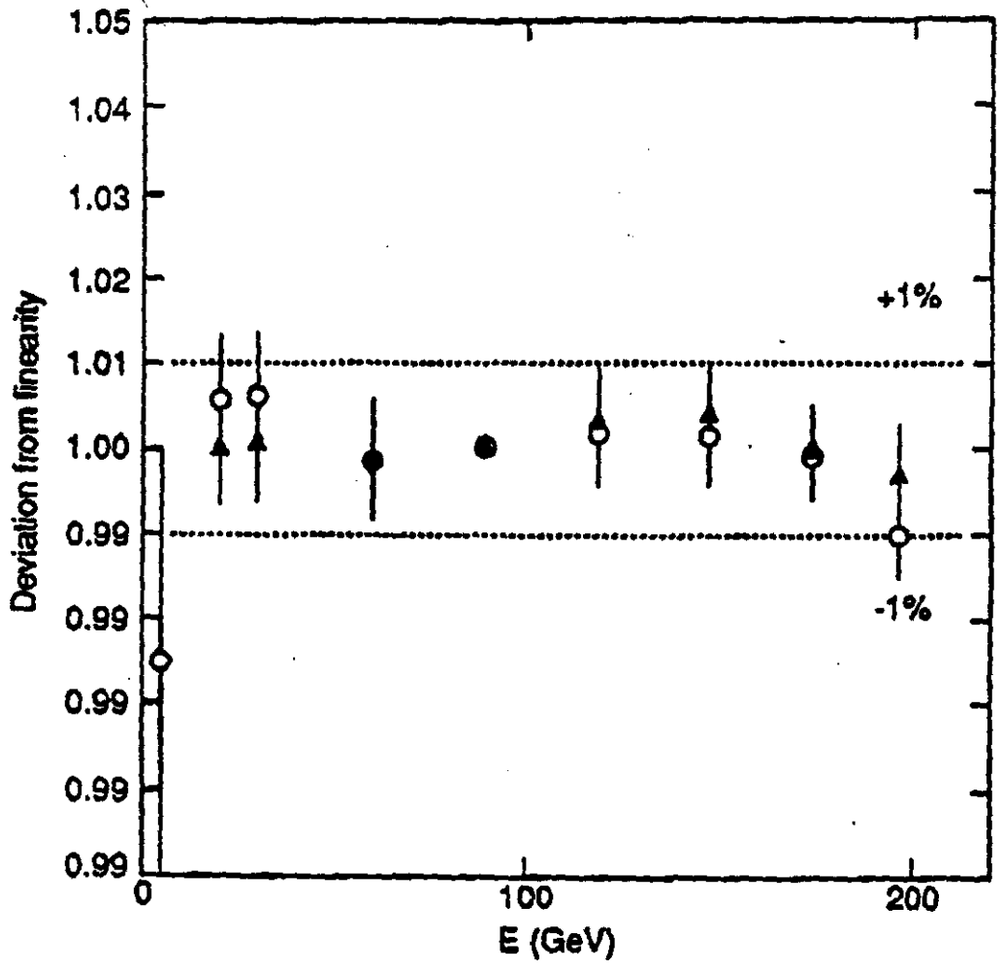
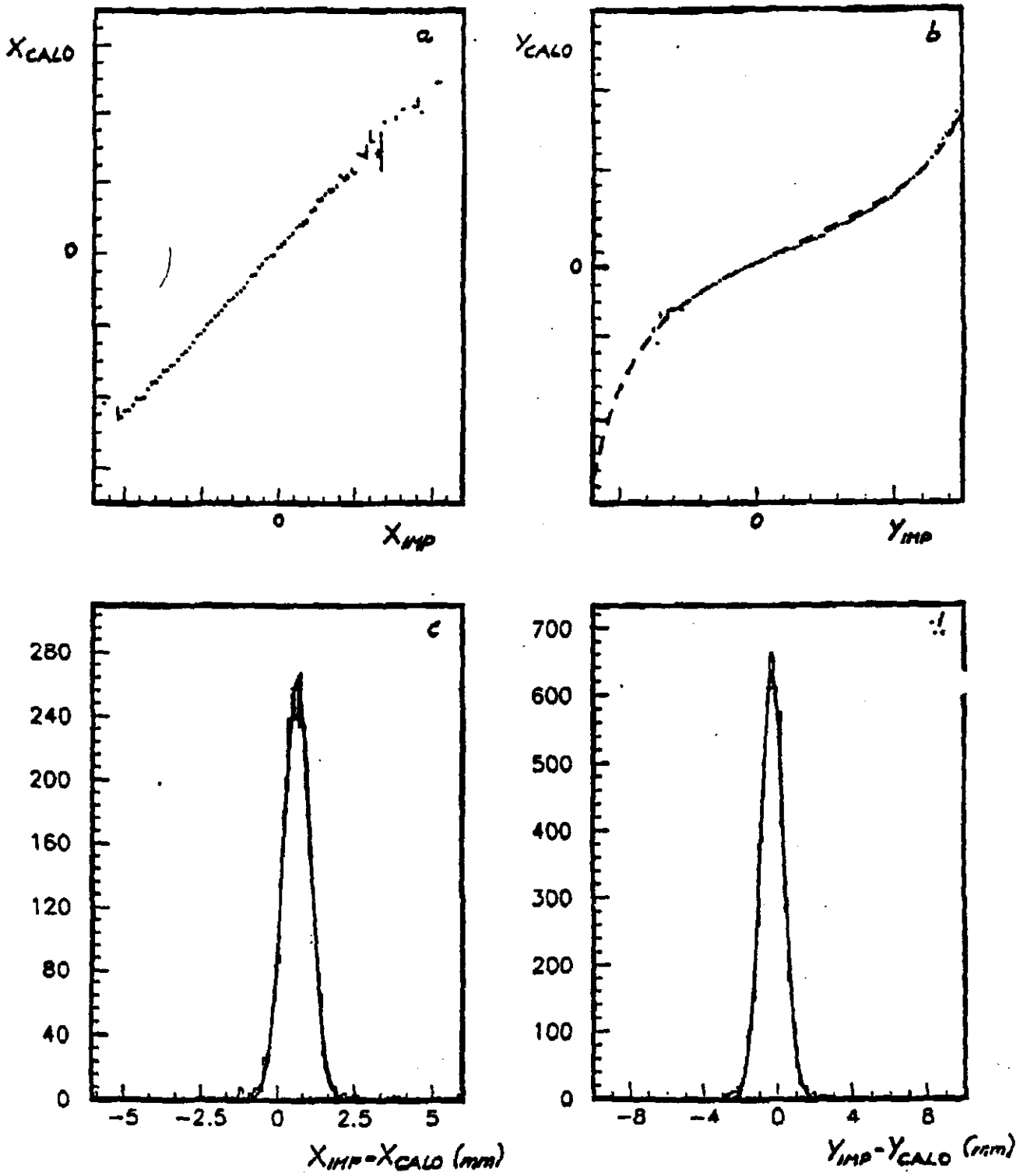


Fig. 10



position Resolution:

$$\Delta X_F \simeq \frac{3.6\,mm}{\sqrt{E}}$$

Figure 11

(Still to be drawn)

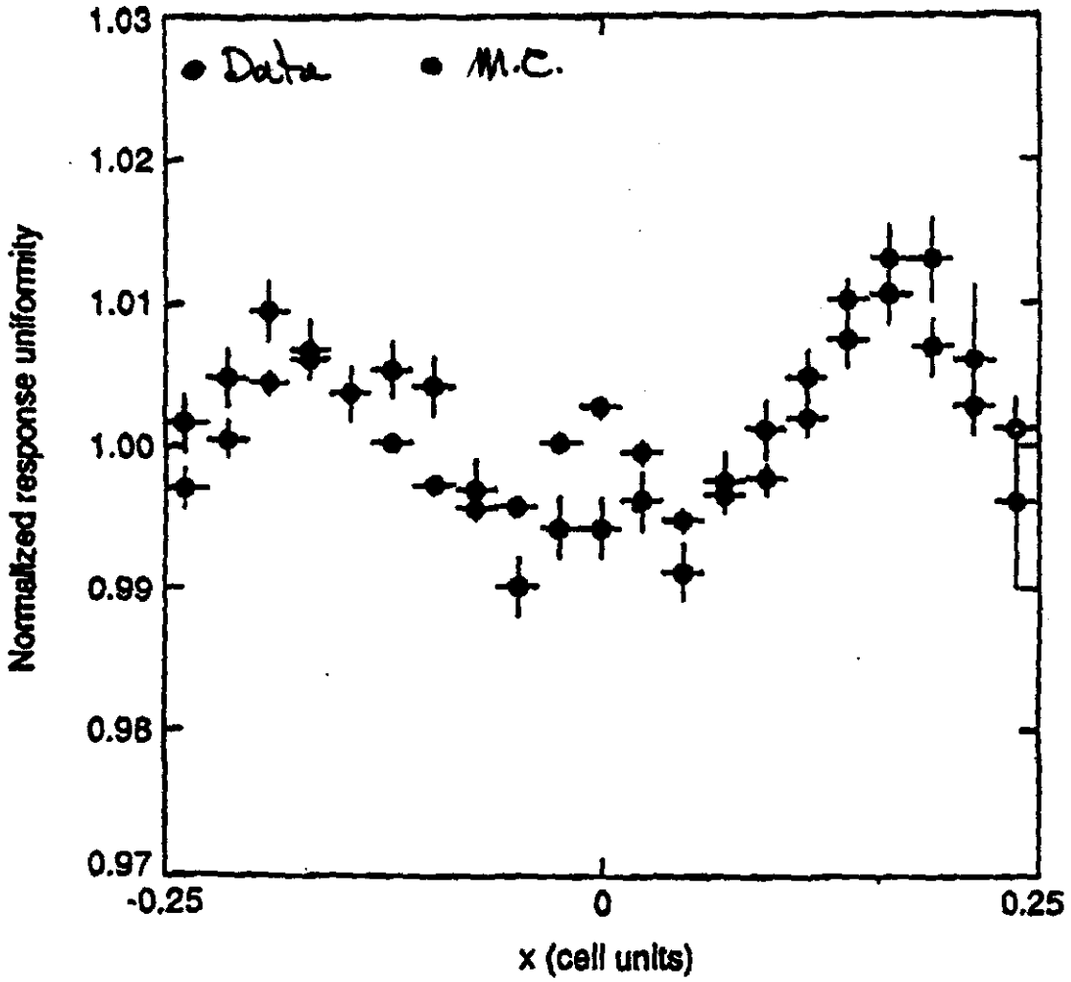


Fig. 6

Response Uniformity. ±1%

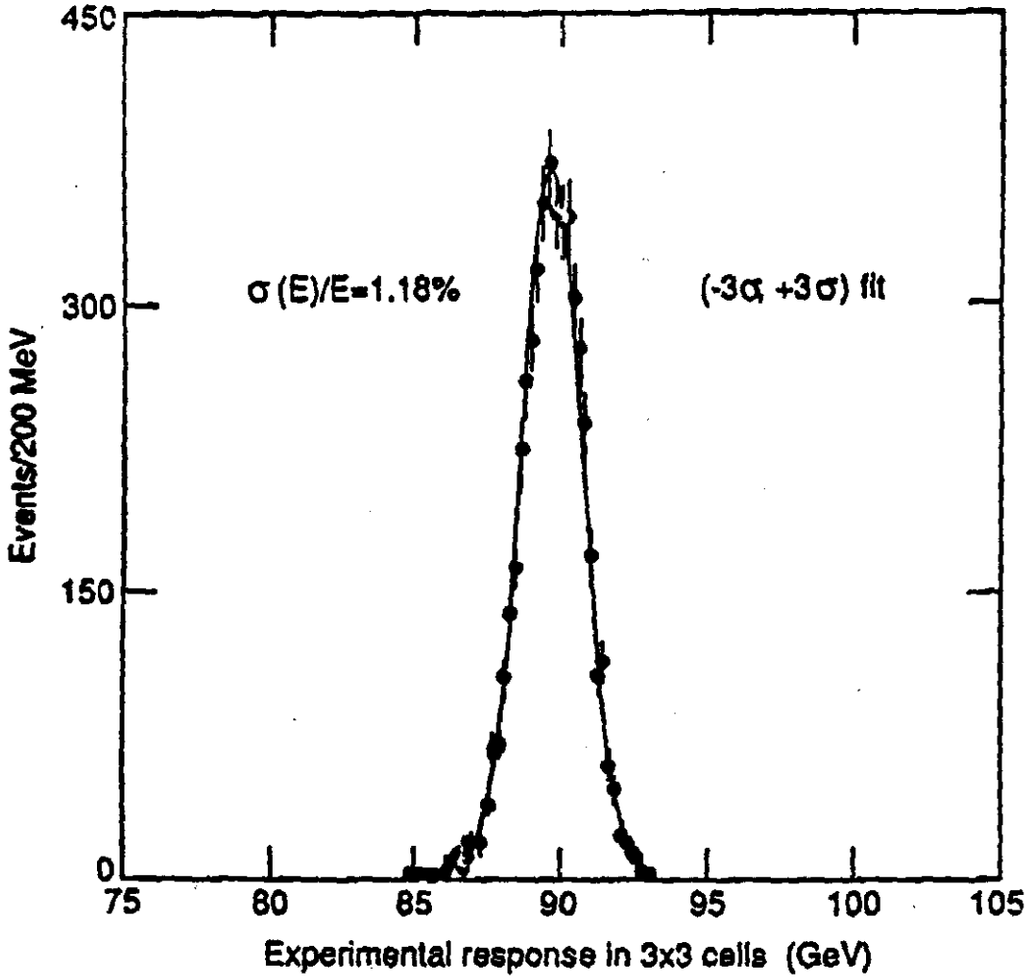


Fig. 8

1991 Test. 90 Gev e^-

20 n-sec

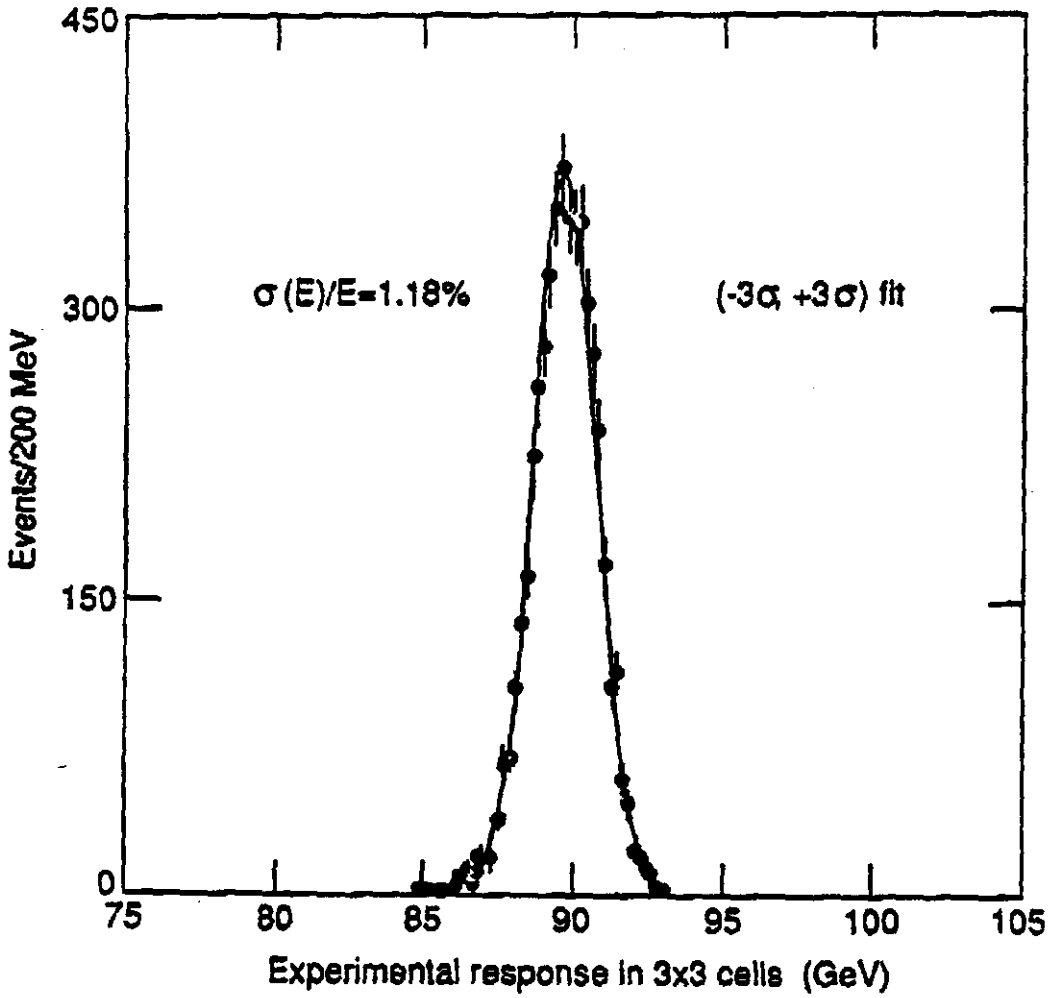

450
300
150
0
Events/200 MeV
σ(E)/E=1.18%
(-3σ, +3σ) fit
75
80
85
90
95
100
105
Experimental response in 3x3 cells (GeV)

Fig. 8

(RD3)

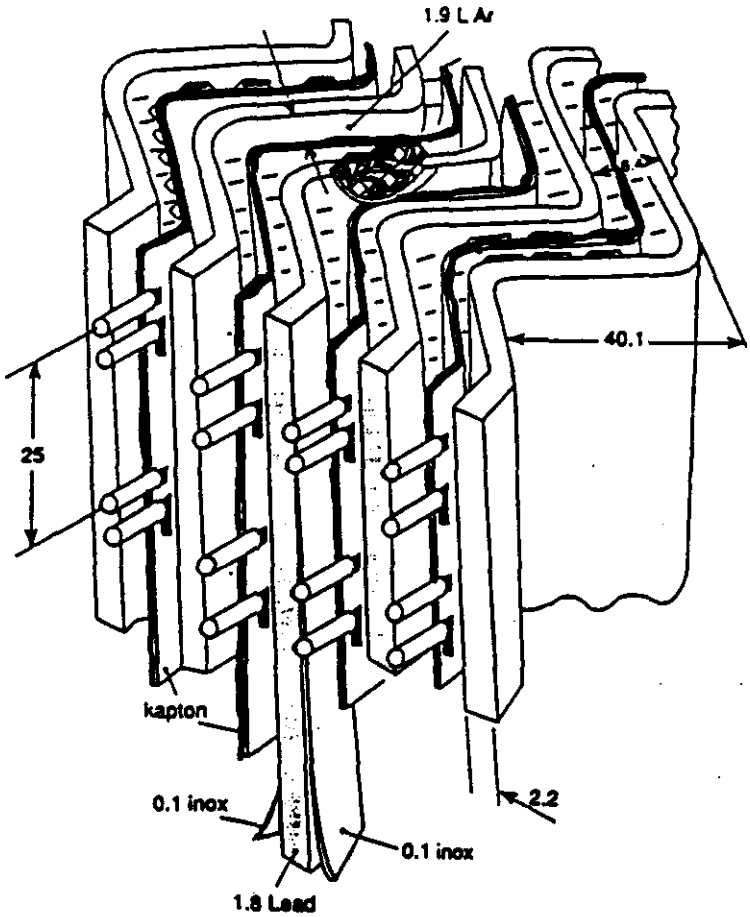
Annecy - Brookhaven - CERN - Milano - Orsay - Saclay - Stockholm

optimized for:

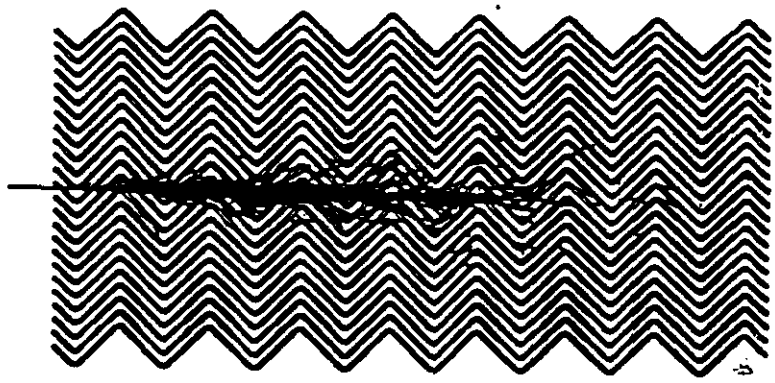
speed

hermeticity

granularity



40 GeV e^-



1990: $\frac{10.0 \pm 0.6}{\sqrt{E}} \oplus (0.1 \pm 0.1)\%$

B. Aubert et al Nuclear Inst. & Meth. A 305 (1991) 438

RD3 - Collaboration:

Annecy, BNL, CERN, Saclay, Milano, Orsay, Stockholm, Grenoble

1990': Non projective Geometry (100 n-sec)
(published. NIM A309 (1991) 438.

1991': Non Projective Geometry (20 n-sec)

"Semi pointing" Geometry.

1992': LARGE Fully projective Geometry
(2 meters)
Oct. '92
Prelim Results Dec '92.

Liquid Argon Calorimeter.
R&D Status.

1. RD3 – 1990': Results 1992': Plans.
   1991': Prelim Results.

2. Test at BNL –

3. Base line Design –
   - Eng.
   - Simulations.

D. Lissauer

gem

γeμ

Presentation by:

Bill Worstell

Bill Worstell

Key Issues Addressed During Current Prototype Construction

1) Engineering information:

   a) Manufacture requirements/techniques
   b) Mechanical tolerances
   c) Fiber positioning/uniformity
   d) Mechanical stability/strength

2) Performance information:

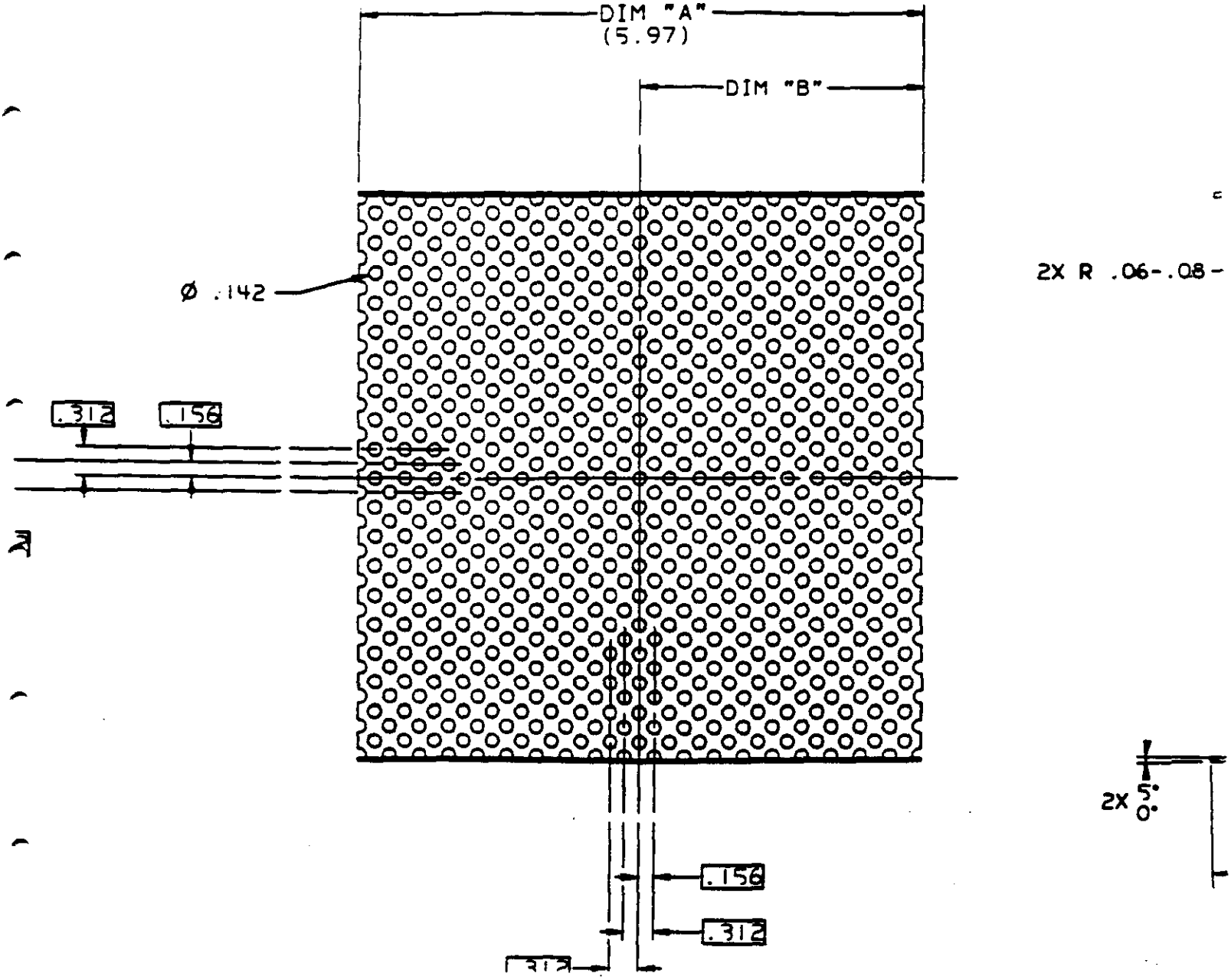
   a) Resolution + Uniformity
   b) Light Yield
   c) Calibration System Performance

3) Critical technologies:

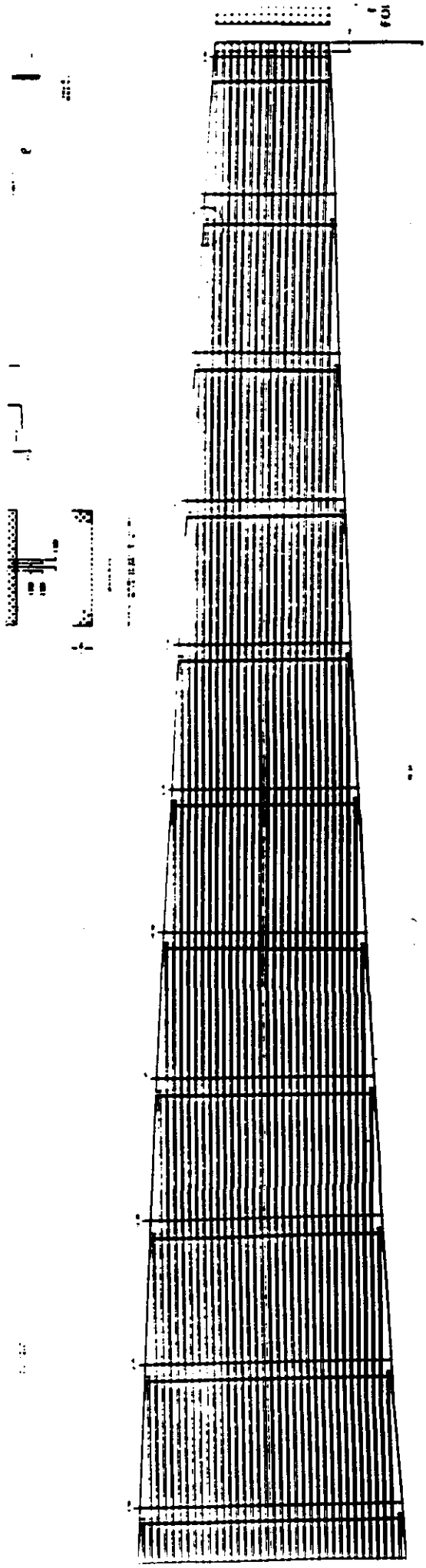
   ✓ a) Lead shot fill -- full-size supertower w/ shot — Done
   ✗ ~~b) Fiber splice readout -- full scale tests~~
   ✓ c) SS sheaths -- after casting for now

GEM 1992 SSCintCAL Towers
Bids Received from vendors

Item	Bid
1.5mm 3HF fibers cut to length	$2,000 / tower
3mm O.D. nylon tubing cut, "headed", sealed	$1,000 / tower + 1-time tooling
Spacer plates and supports cut, bent, ready for preform threading	$1,500 / tower in small quantities (less with tooling)
1mm diameter lead shot	$1,000 / tower
Eutectic alloy	$3,500 / tower
Total raw materials for 1.5 Ton tower:	$9,000 / tower



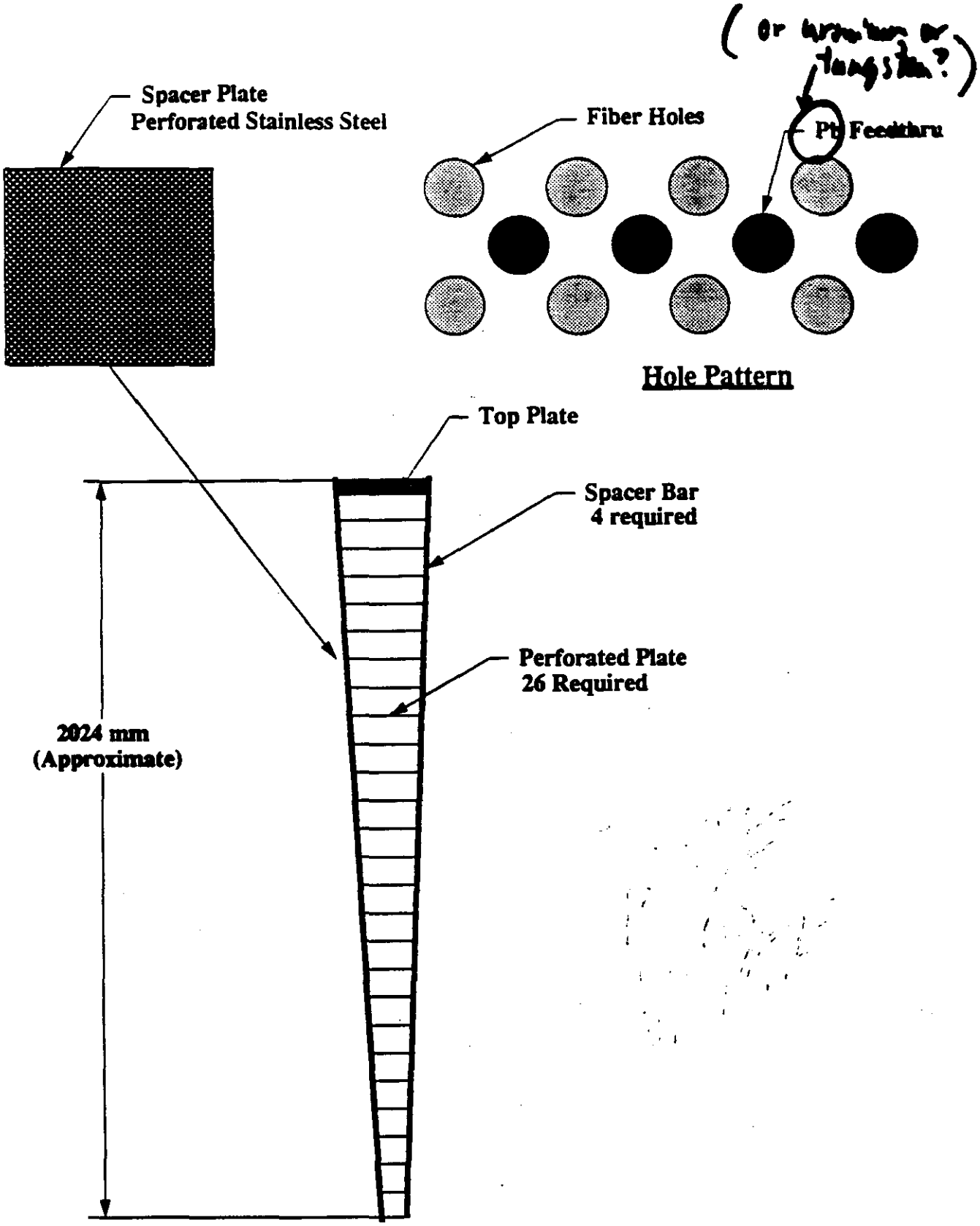
Spacer Plate
for
SSCintcal
preform



Fiber Preform for SSC intCal Tower

Modifications of GEM 1992 SSCintCAL Towers from 1991 SSCintCAL Design

1991	1992
2mm diameter fibers	1.5mm diameter fibers within 3mm diameter plastic tubes
11% fiber filling fraction	11% filling with tubes 3% fiber filling
100% eutectic absorber	65% lead shot / 35% eutectic absorber
No longitudinal segmentation	Physical and electronic depth segmentation



GEM Detector
Spaghetti Hadron Calorimeter
Spacer Assembly

G.03.SC.00065

Rennich

Key Issues for
Scintillating Fiber
GEM Hadron Calorimeter

Performance of prototype :	Stochastic resolution and high-energy resolution limit Feasibility, segmentation
System cost:	Based on prototype construction costs + realistic projections
Engineering Design for complete system:	Integrated into overall GEM detector design, Structural stability
Impact on other systems:	Compactness, coordination with muon system and EM calorimeter system
Long-term stability	Radiation hardness, Ageing effects

gem

γeμ

Presentation by:

Larry Sulak

Preliminary Costing of one of 5 manufacturing strategies...

TOTAL COST OF CU TOWER MODULES

WBS	ITEM	MAT'L K$	LABOR HRS	LABOR K$	TOTAL K$	EDIA K$	CONT K$	TOTAL K$
3.3.1	Tower Module							
3.3.1.1	Laminates	5423			5423	1356	407	7185
3.3.1.1.1	Receive & Inspect		1564	70	70	18	5	93
3.3.1.1.2	Stress relieve				526	132	39	697
3.3.1.1.3	Machine Grooves		3680	166	166	41	12	219
3.3.1.1.4	Shear		7038	211	211	53	16	280
3.3.1.1.5	Deburr		6256	282	282	70	21	373
3.3.1.1.6	Inspect & Kit		1564	78	78	20	6	104
3.3.1.2	Tubes	2190			2190	548	164	2902
3.3.1.2.3	Assemble Tower Kits		782	35	35	9	3	47
3.3.1.3	Clean, Stack & Reflow Sold	1390			1390	348	104	1842
3.3.1.4	Finish Tower							
3.3.1.4.1	Machine Taper Faces		9384	338	338	84	25	448
3.3.1.4.2	Final Inspect		1564	70	70	18	5	93
3.3.1.5	Assemble Fibers							
3.3.1.5.1	Fibers	3225			3225	806	242	4273
3.3.1.5.2	Insert		8602	258	258	65	19	342
3.3.1.5.3	Bundle/Bond/Polish		2346					
3.3.1.5.4	Light Mixer	190			190	48	14	252
3.3.1.5.5	Assembly	219	1564	47	266	66	20	352
3.3.1.6	Tooling	3500			3500	875	263	4638
	TOTAL				18218			24139

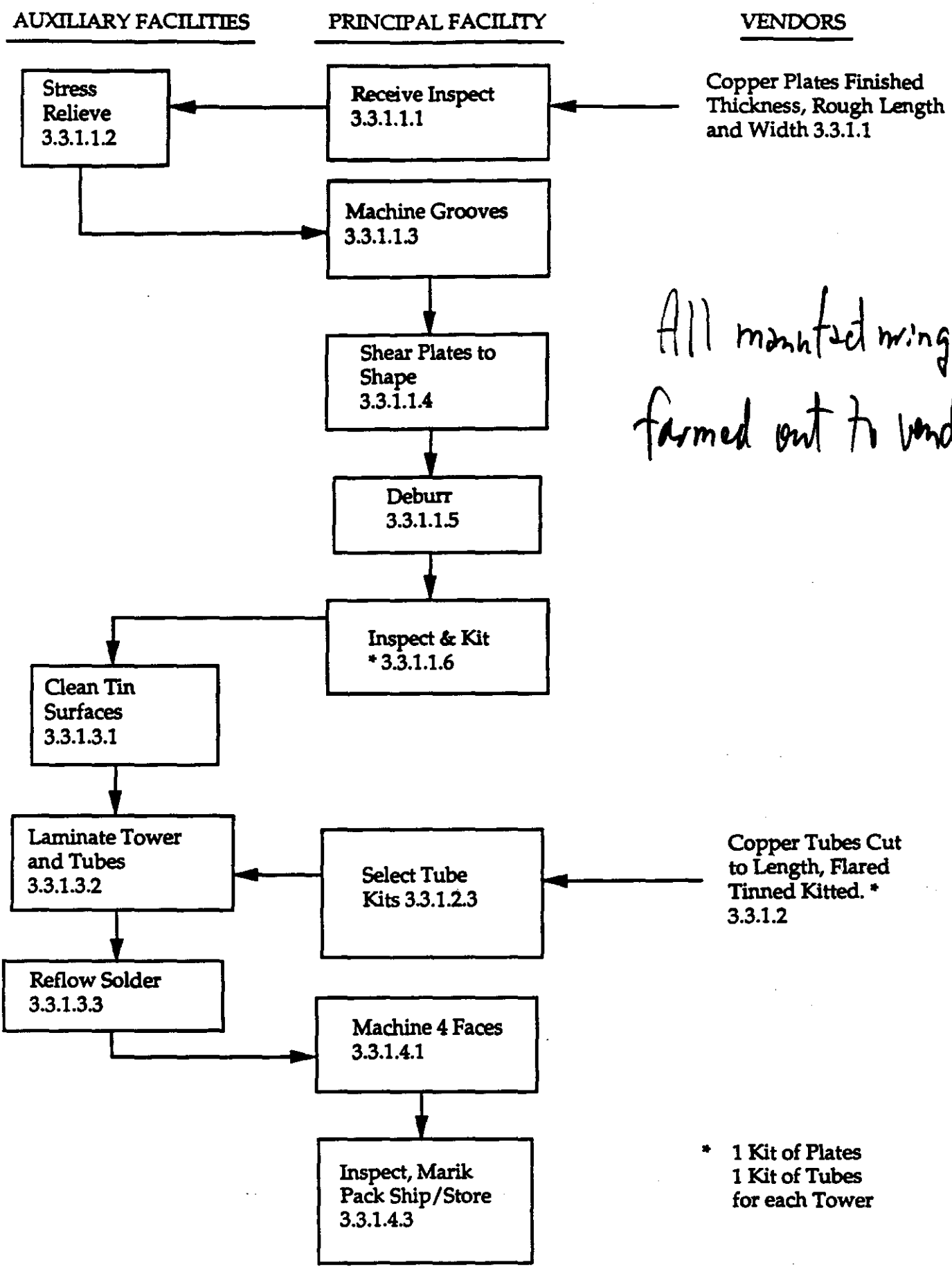
3% fiber

$\frac{e}{h} \sim 1$

potential saving of $\lesssim$ \$15M

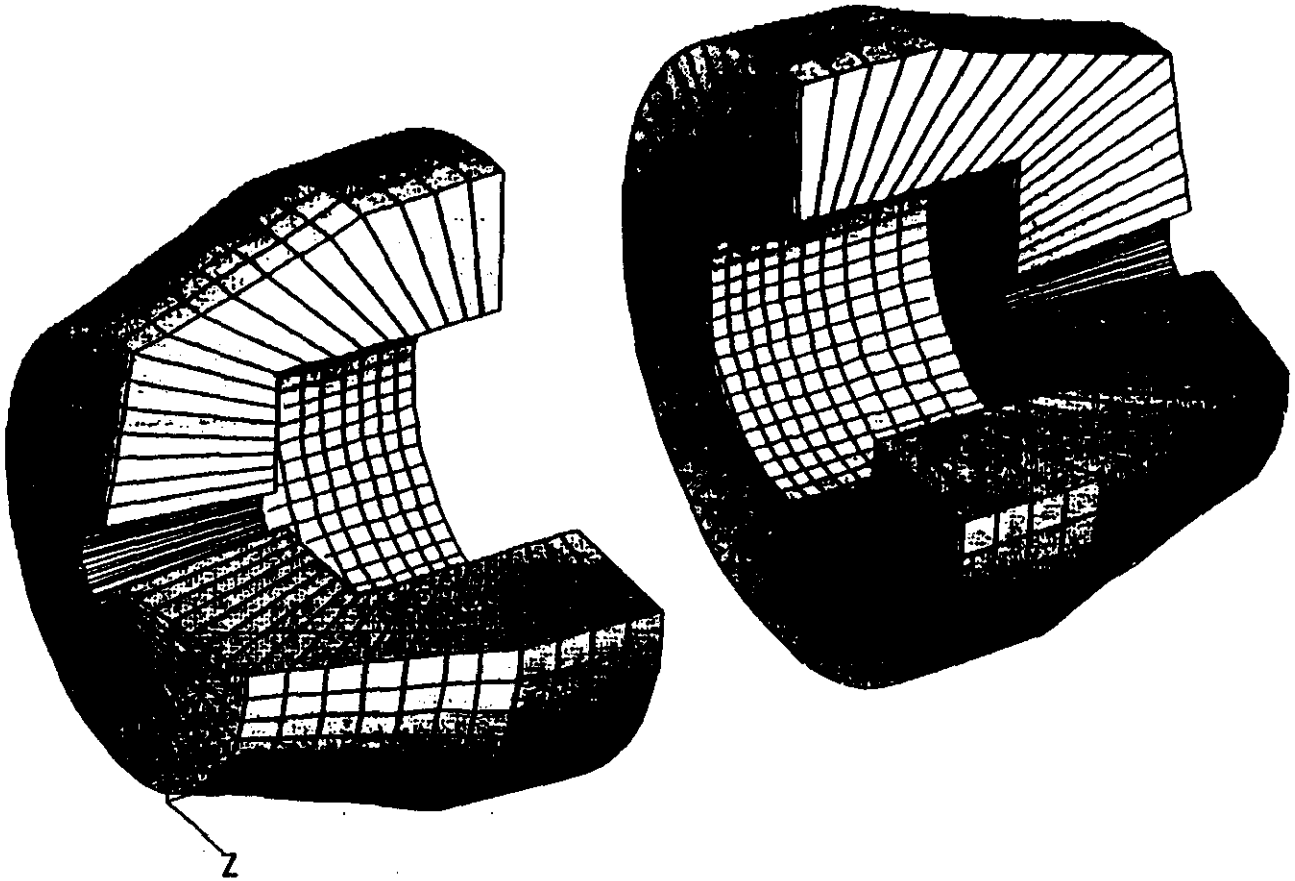
... but will take ~ 2 months of engineering study to verify

Larry Sulak



All manufacturing farmed out to vendors

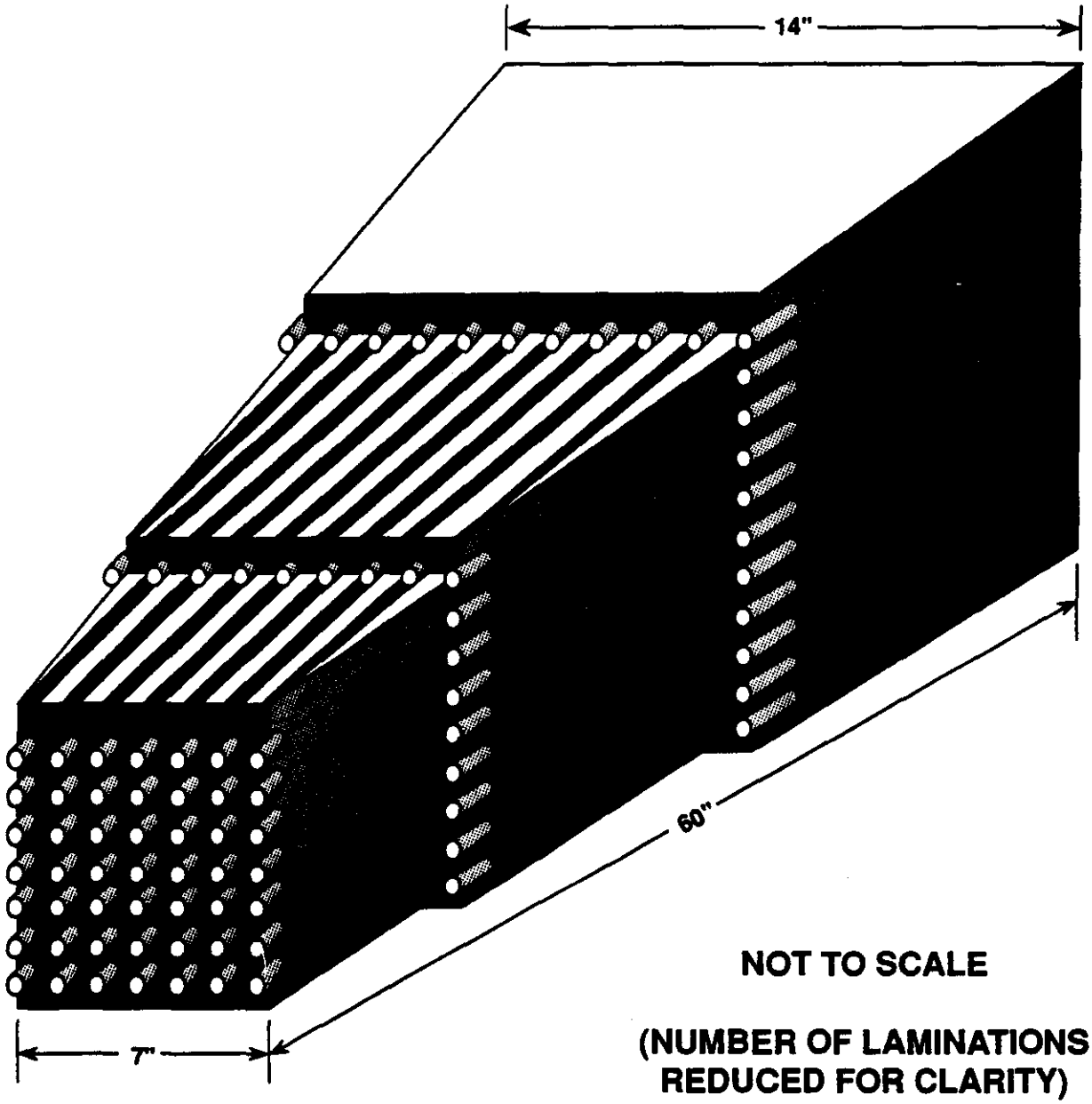
Cu indistinguishable from Pb realization



machine braised block to pyramidal shape...

TYPICAL COPPER LAMINATED TUBE AND PLATE TOWER

AS ASSEMBLED, BEFORE FINAL MACHINING



NOT TO SCALE

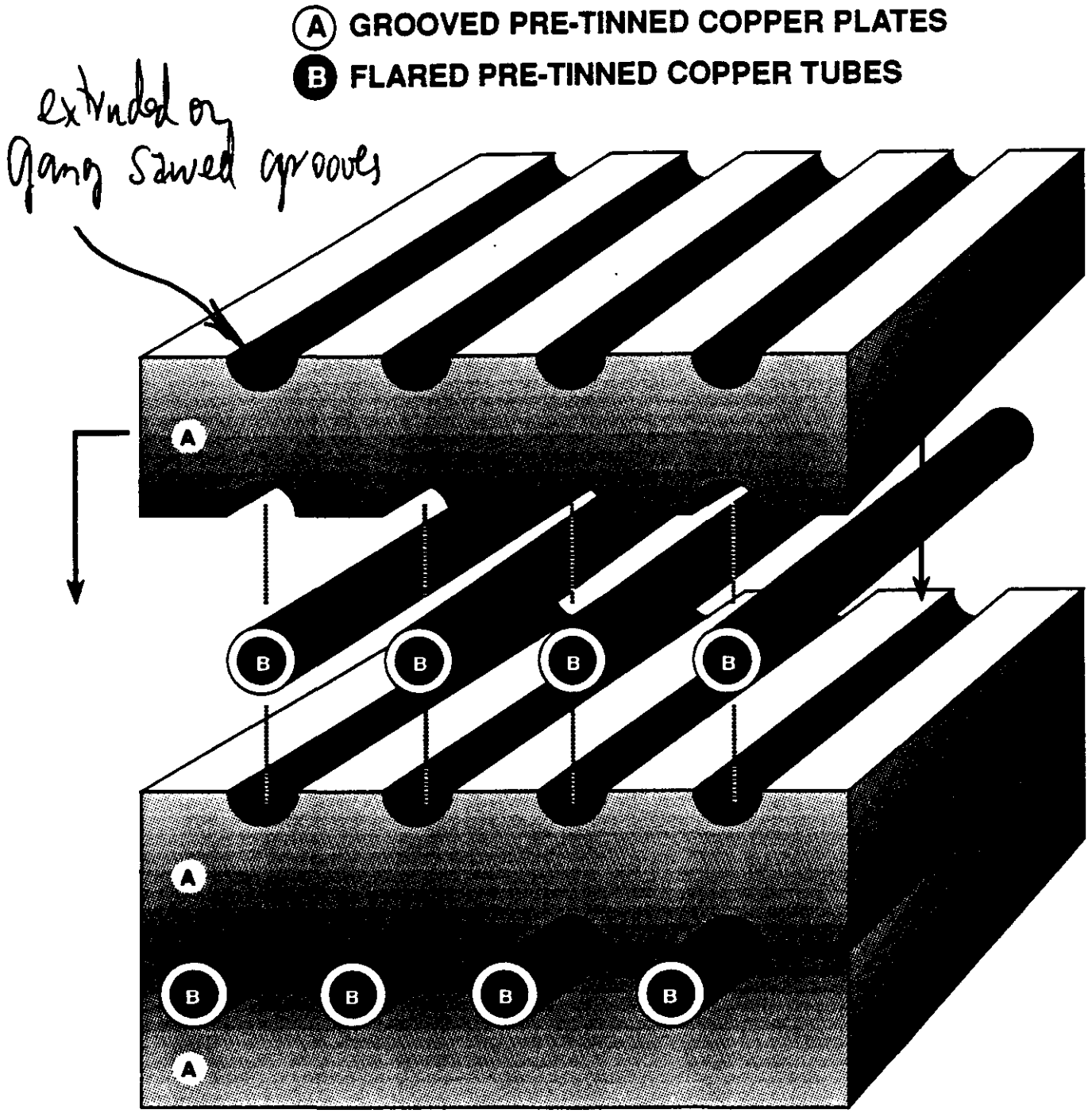
(NUMBER OF LAMINATIONS REDUCED FOR CLARITY)

9203B219-9

Simple fly cut

Braise together pretinned copper plates sheared to shape...

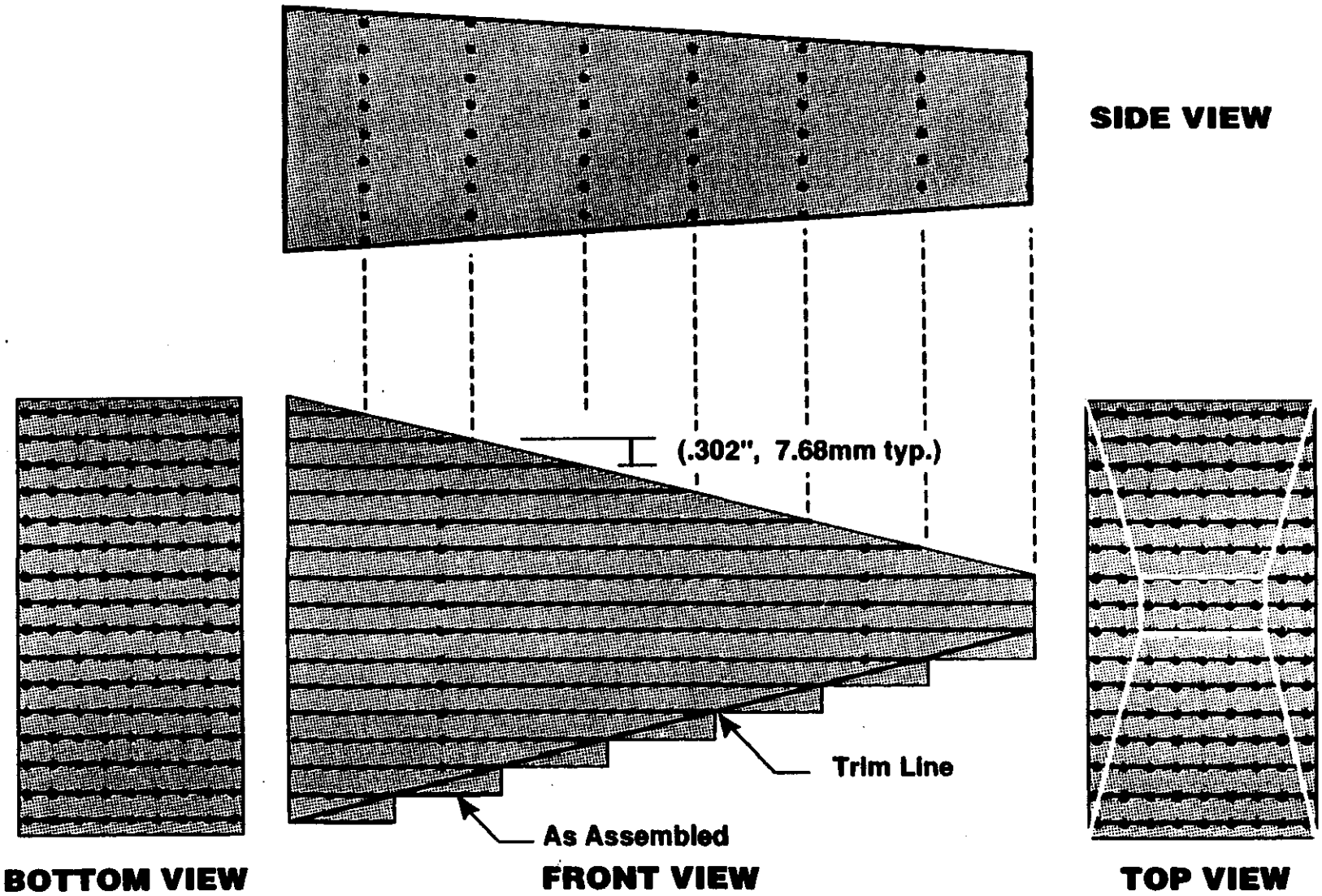
TOWER ASSEMBLY



9203B219-8

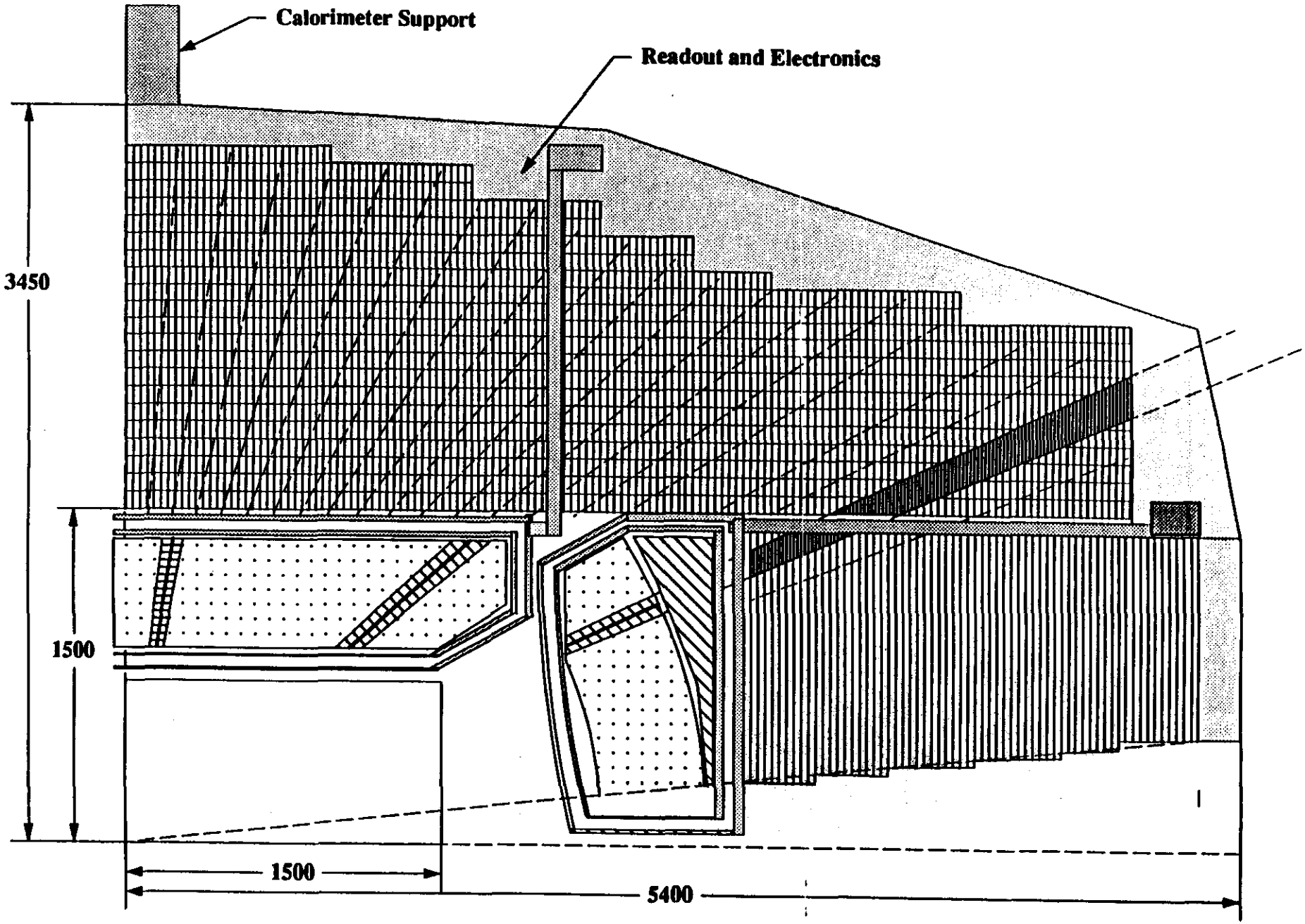
... Copper tubes insure registration & channel scintillating fibers upon insertion

SIMPLIFIED VIEW OF GEM CALORIMETER TOWER



R & D issues for Scint. Tiles

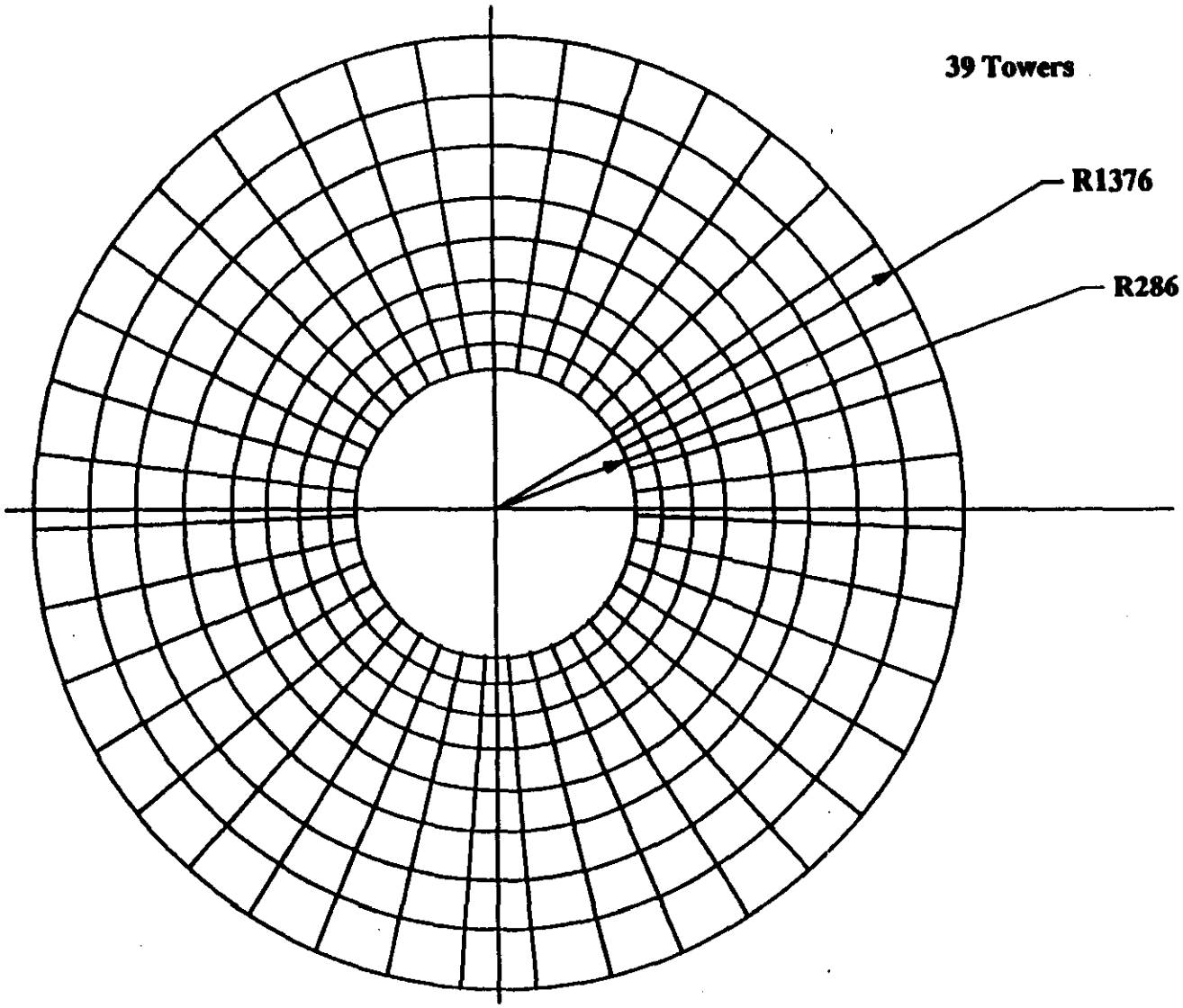
- ✓ Non projectivity — solved
- Radiation degradation ... ± ~ fiber
- Light collection uniformity — scan of plate to be done
- Performance monitoring — sources on each plate
- Hadronic resolution for unusual orientation of tiles — GEANT as a function of incident angle



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
W/LKr EM Calorimeter

G.03.T.023

Rennich

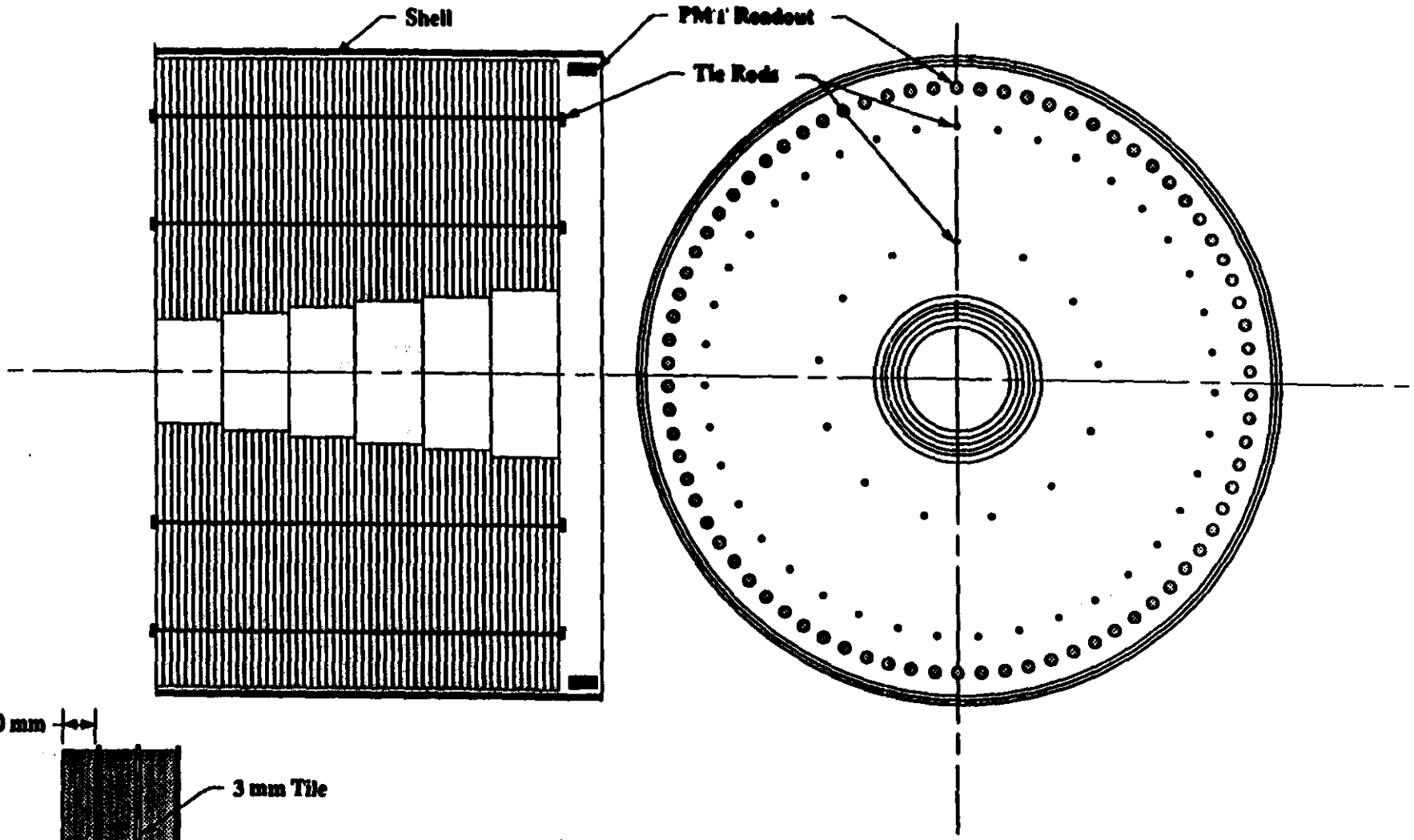


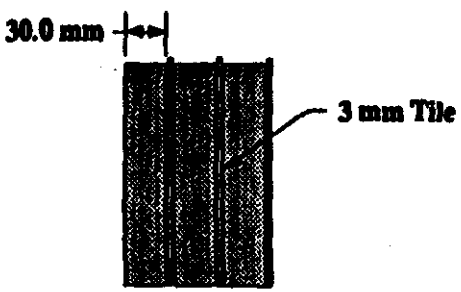
GEM Detector
Plastic Tile Calorimeter
End Cap Segmentation
Layer 3

G.03.T.007

Rennich

Rennick's endcap





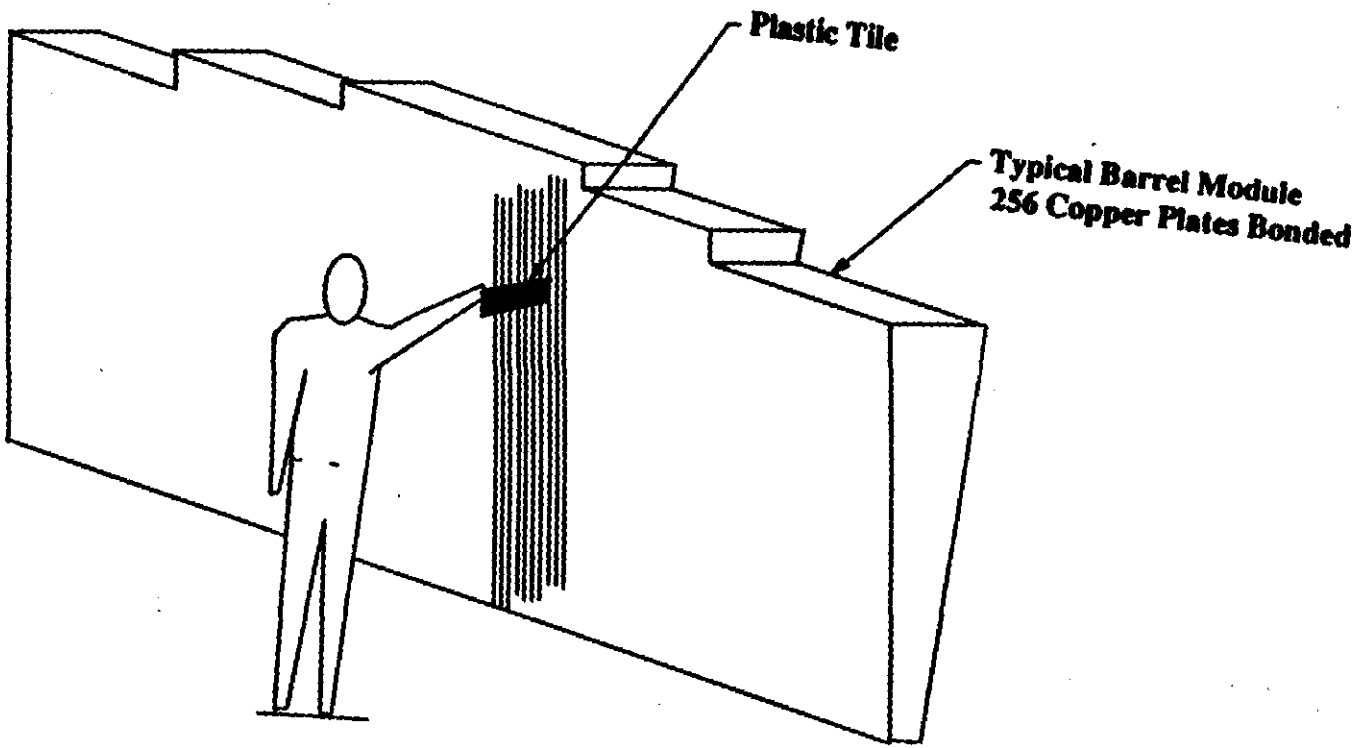
Detail of Plate Configuration

GEM Detector
Plastic Tile Calorimeter
End Cap Structure

G.03.T.008

Rennich

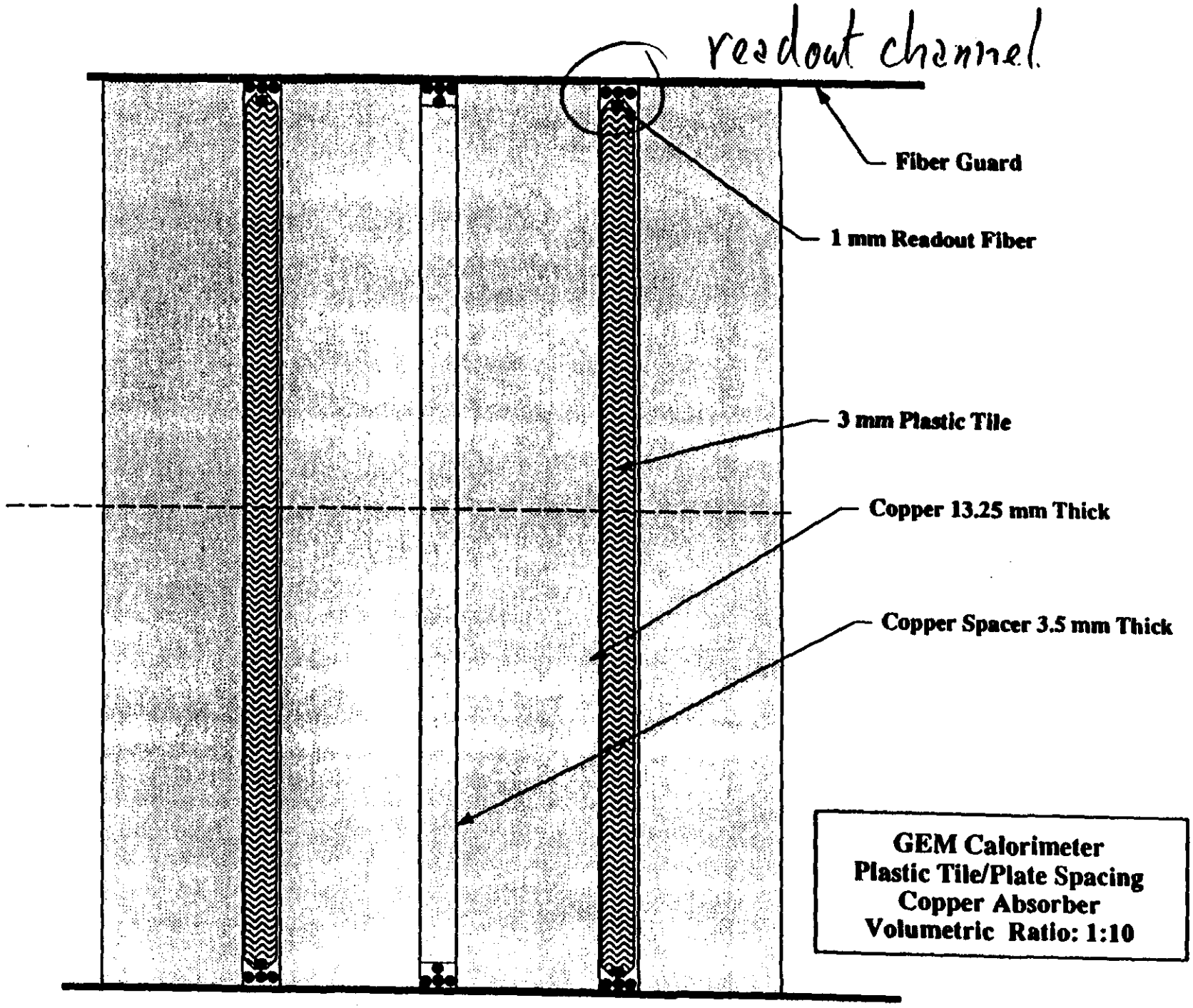
assembly...



G.03.T.013

GEM Detector
Plastic Tile Hadron Calorimeter
Copper Barrel Module
Tile Assembly Configuration

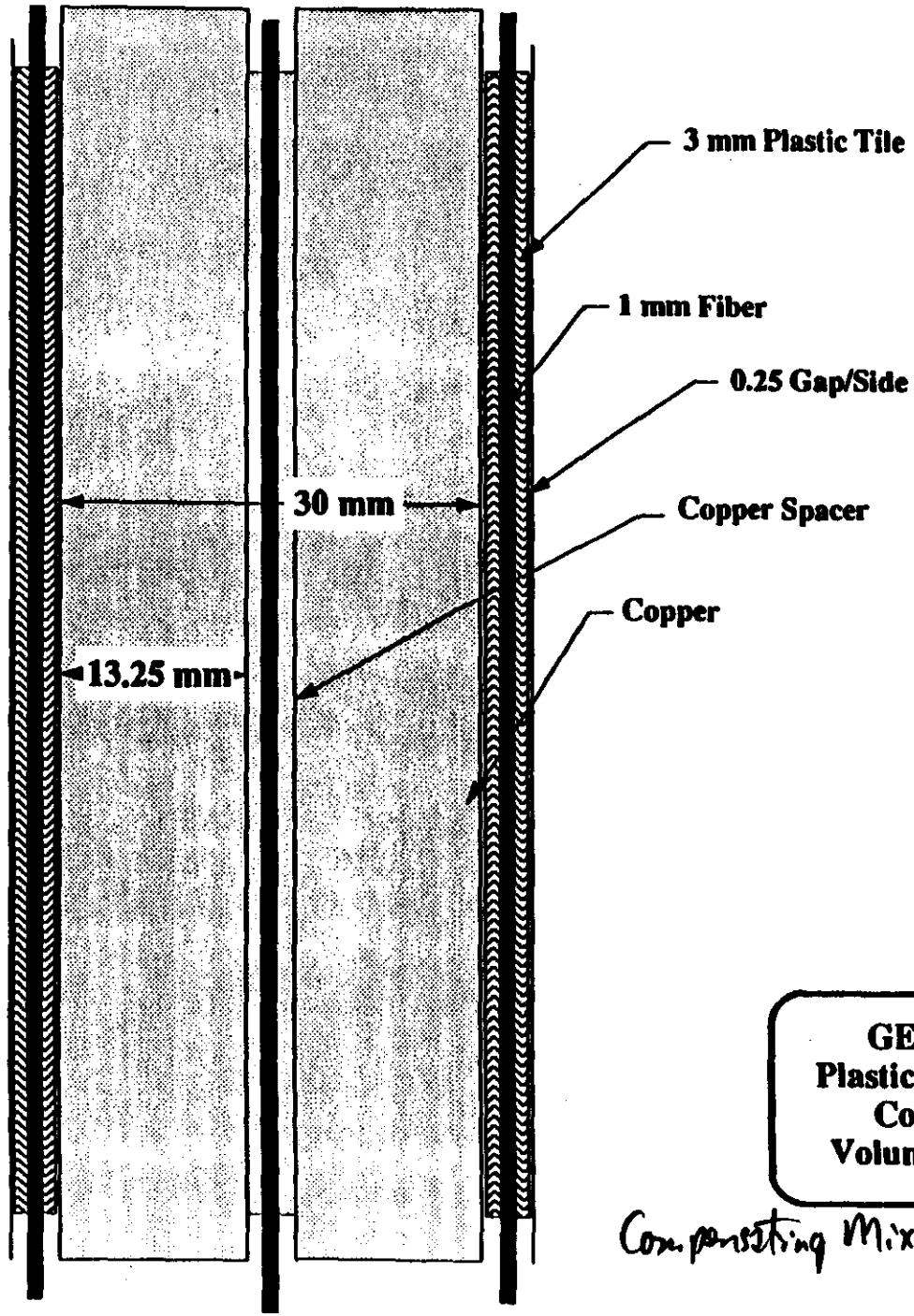
Renaich



G.03.T.005

Top View of One Phi Segment

Rennich



GEM Calorimeter
Plastic Tile Plate Spacing
Copper Absorber
Volumetric Ratio: 1:10

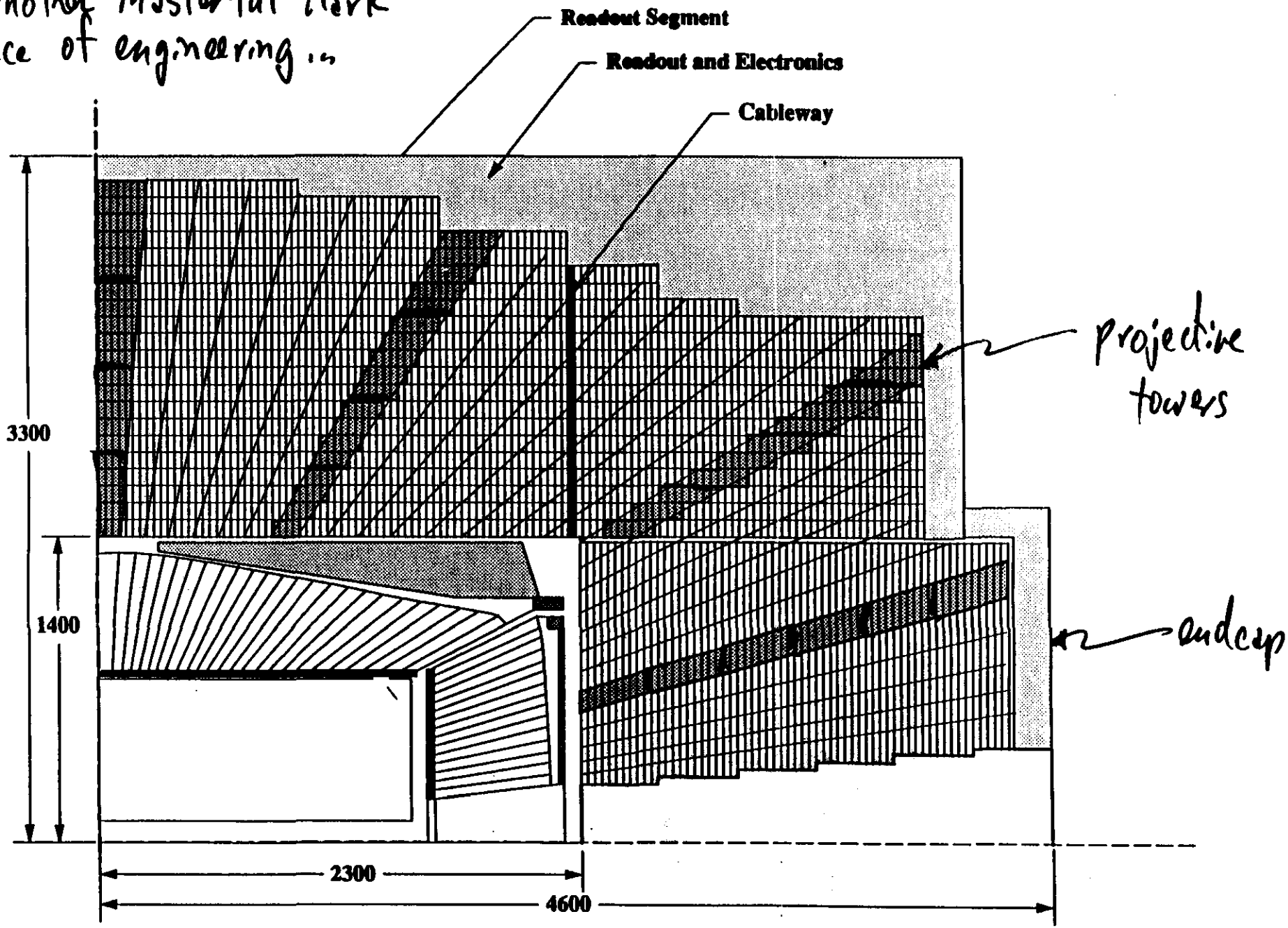
Same as Gildemeister

Compensating Mixture = 1:30

G.03.T.004

RENNICH

... another masterful Mark piece of engineering ...



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

G.03.T.001

Rennich

COST ESTIMATE (barrel)

	MSFR	MSFR
12300 PM-channels		
à 1 kSFR	12.3	12.3
1630 t punched iron plates:		
plate material:		
0.8 kSFR/t + 20% scrap	1.6	
punching: 0.5 kSFR/t	0.8	
	2.4	2.4
15400 m² Scintillator:		
plate material:		
0.2 kSFR/m² + 20% scrap	3.7	
cutting: 0.1 kSFR/m²	1.5	
	5.2	5.2
700 km WLS-fibers:		
0.5 kSFR/km	0.4	0.4
mounting of modules:		
600 man-h/module à 40 SFR		
64 × 24 kSFR	1.5	1.5
support structure + tooling	1.0	1.0
overheads (10%)	2.2	2.2
TOTAL		25.0

"European" Costed Barrel ≃ $18M

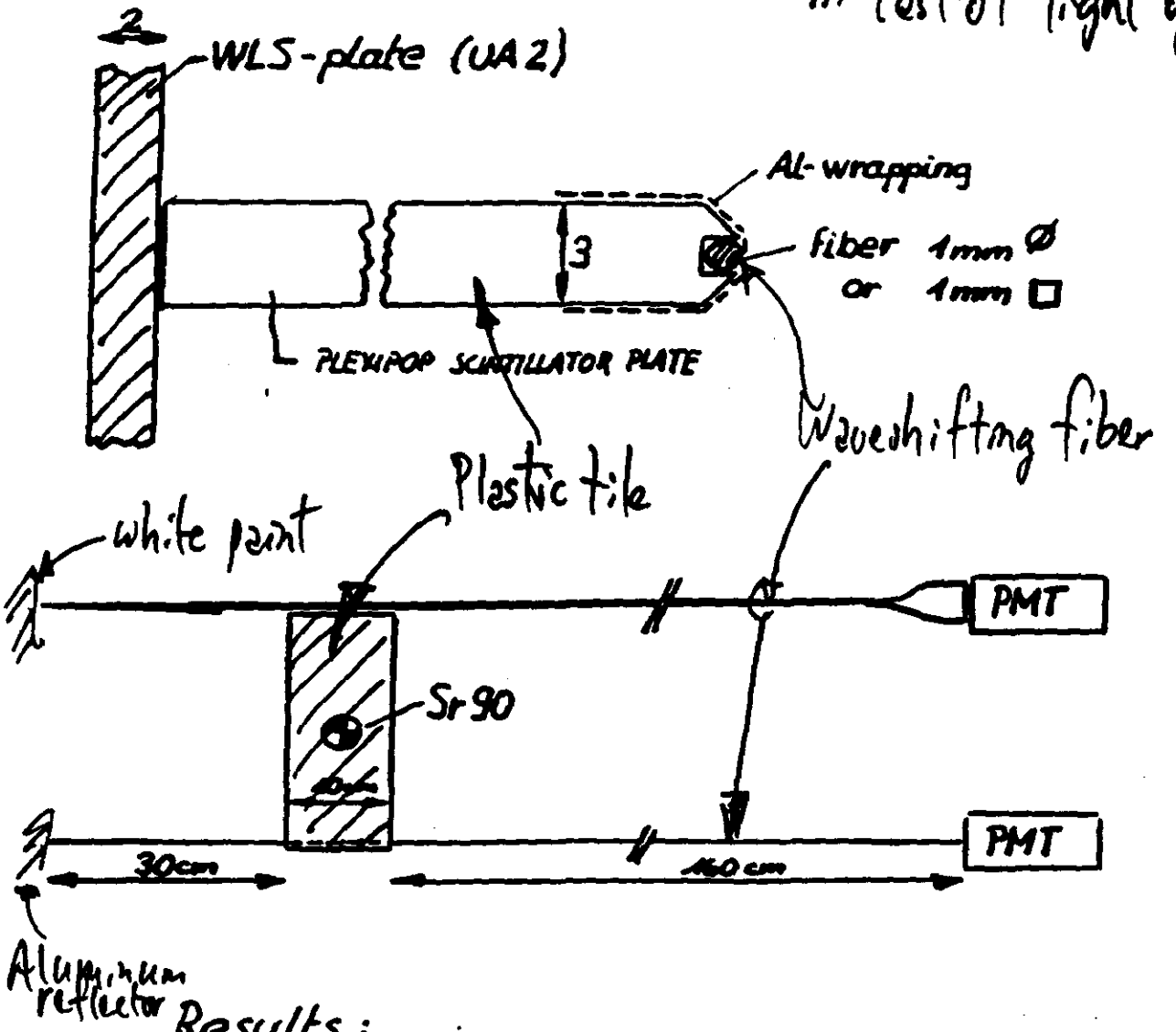
~Labor X2

$35M

End Caps ~$50 M

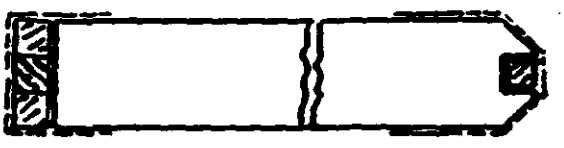
LIGHT COLLECTION MEASUREMENTS

... test of light yield



Results:

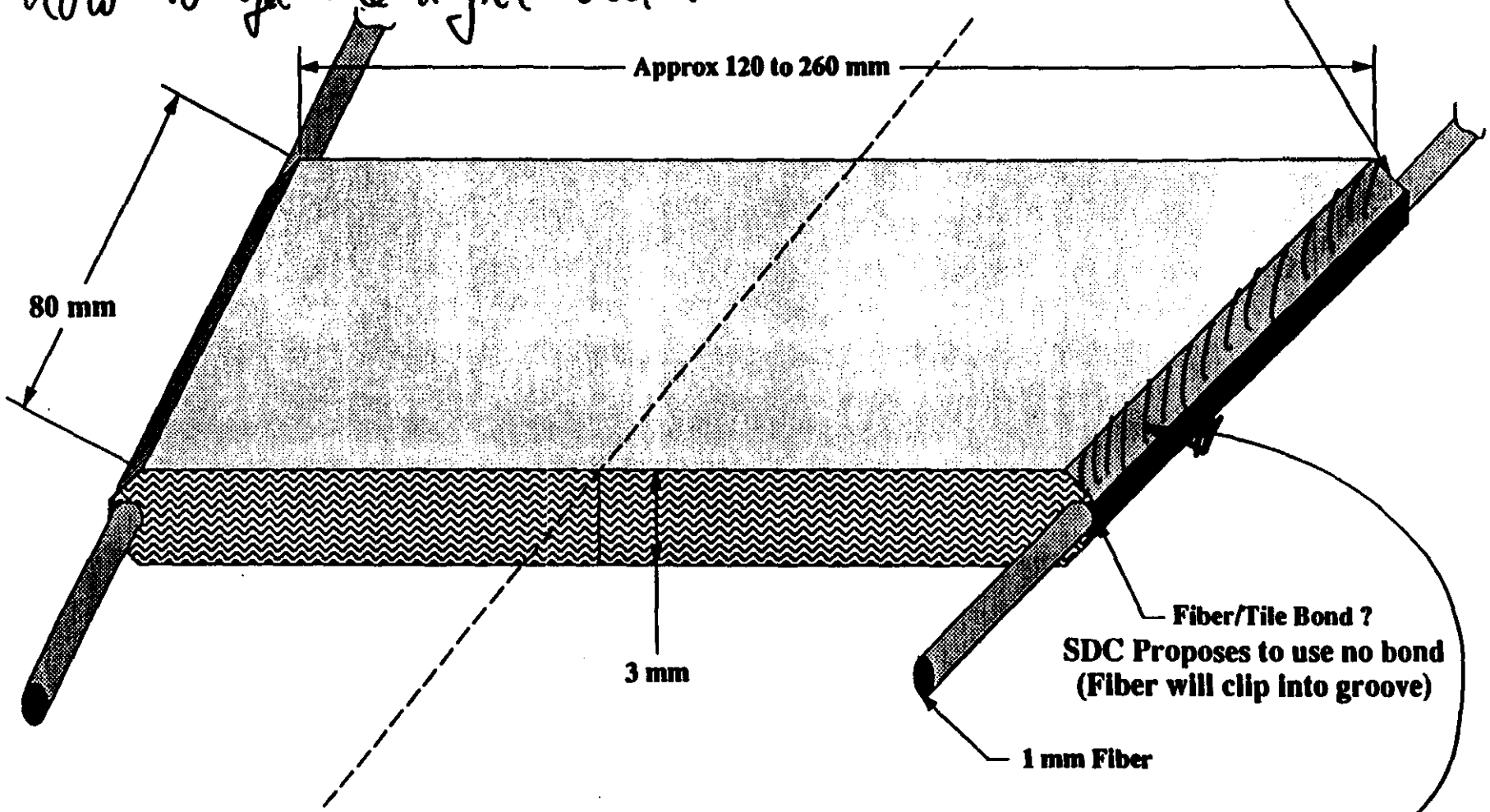
* yield of WLS-fiber relative to WLS-plate ≈ 70 %
  (fiber aluminized on rear end)
  (gain ≈ 1.74)
* no significant difference between O and □ - fibers
* light collection from 3mm scintillator to 1mm□ fiber



yield of 1 fiber relative to 3 fibers:

≈ 80 ± 8 %

how to get the light out?



important "reflector"

GEM Detector
Plastic Tile Calorimeter
Tile Configuration

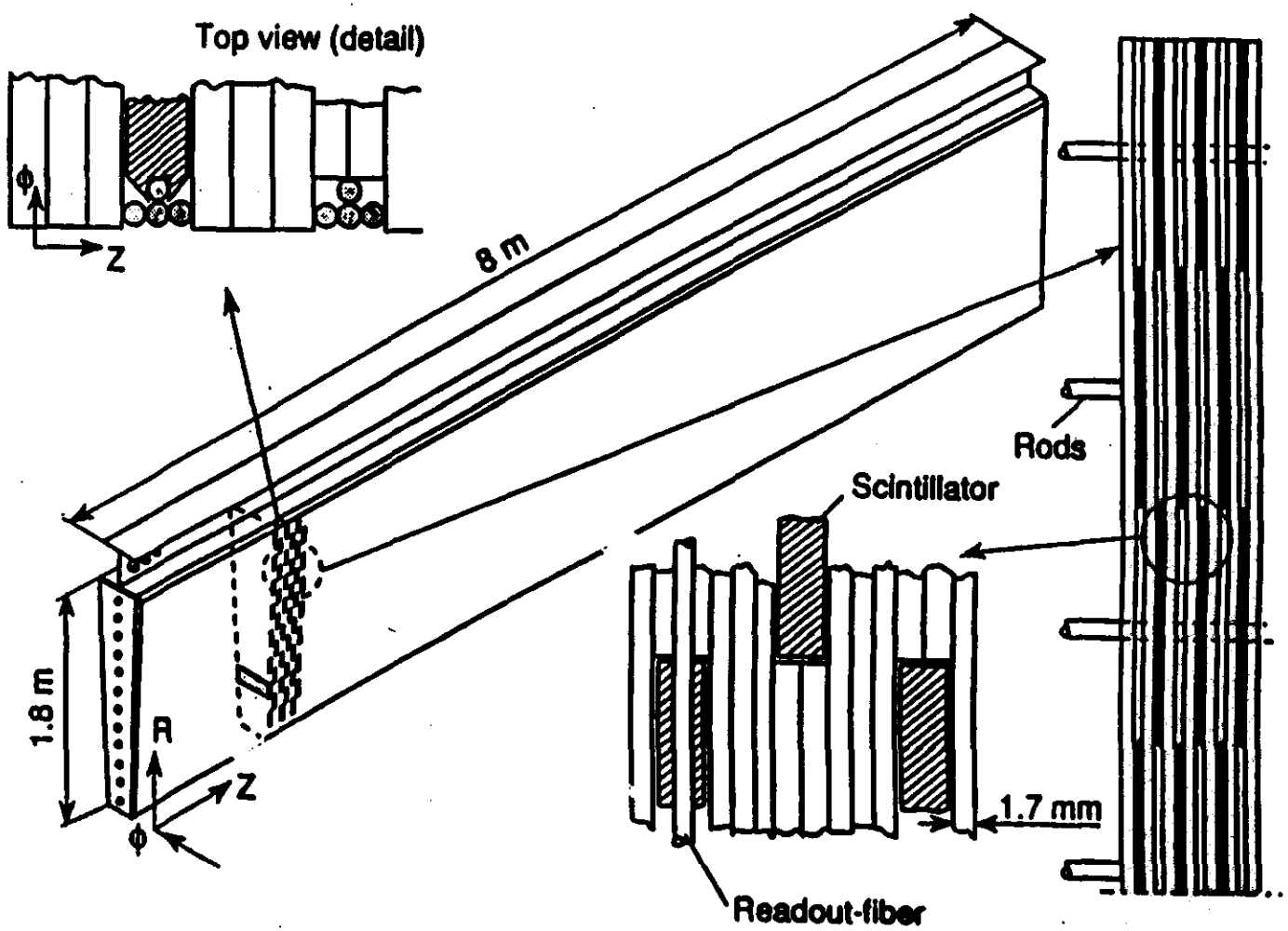


Fig. 4 Conceptual design

how to realize in a barrel geometry?

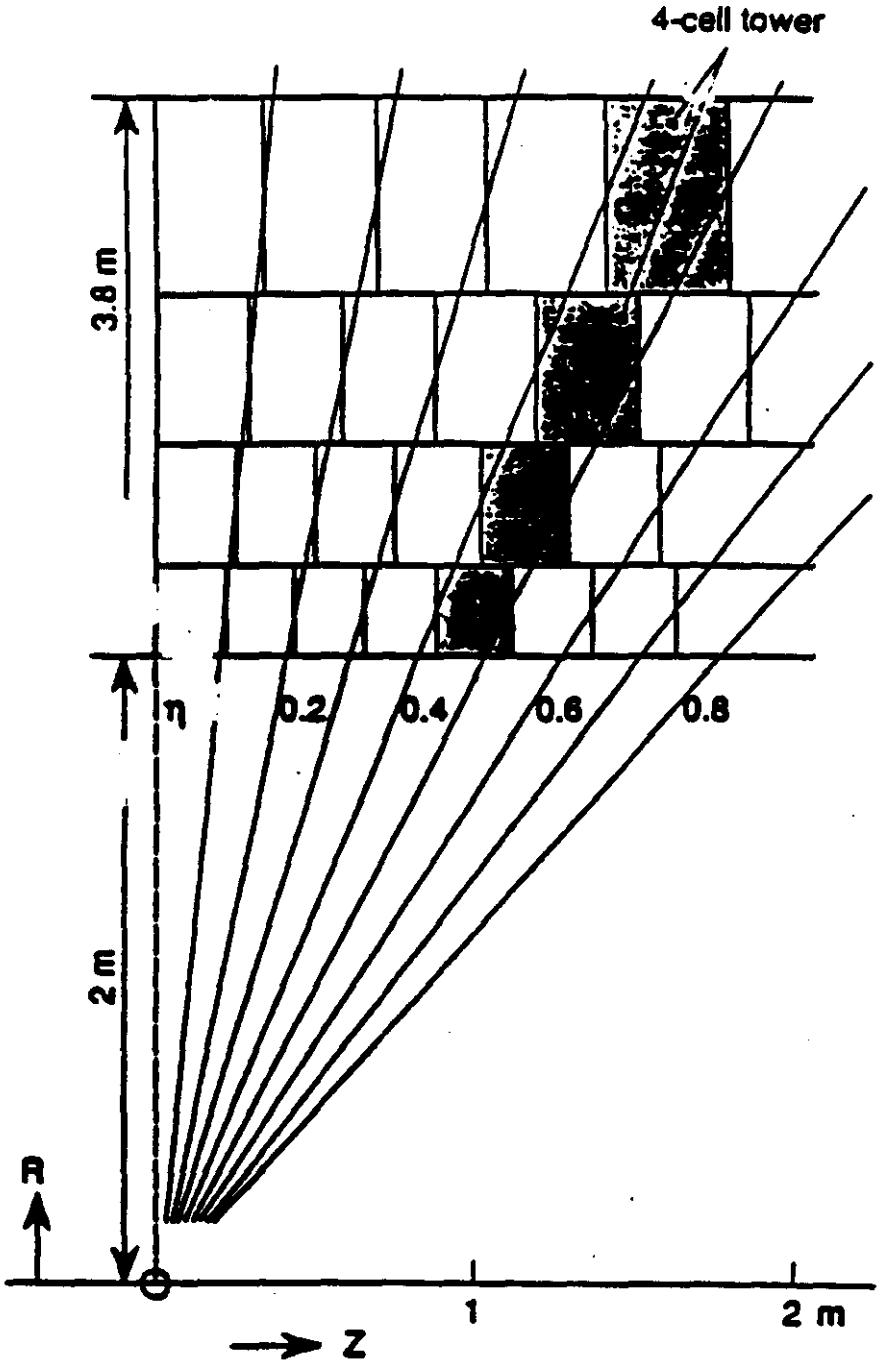


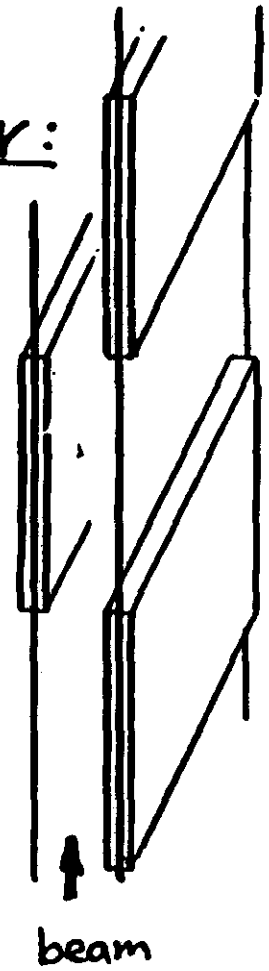
Fig. 3 Cell structure within a module

how to get the light out?

PROPOSED GEOMETRY:

(3) radial tiles

WLS-fibers



* straight fibers
* selfsupporting absorber

angular distribution of particles in a cascade is rapidly becoming ~ isotropic!

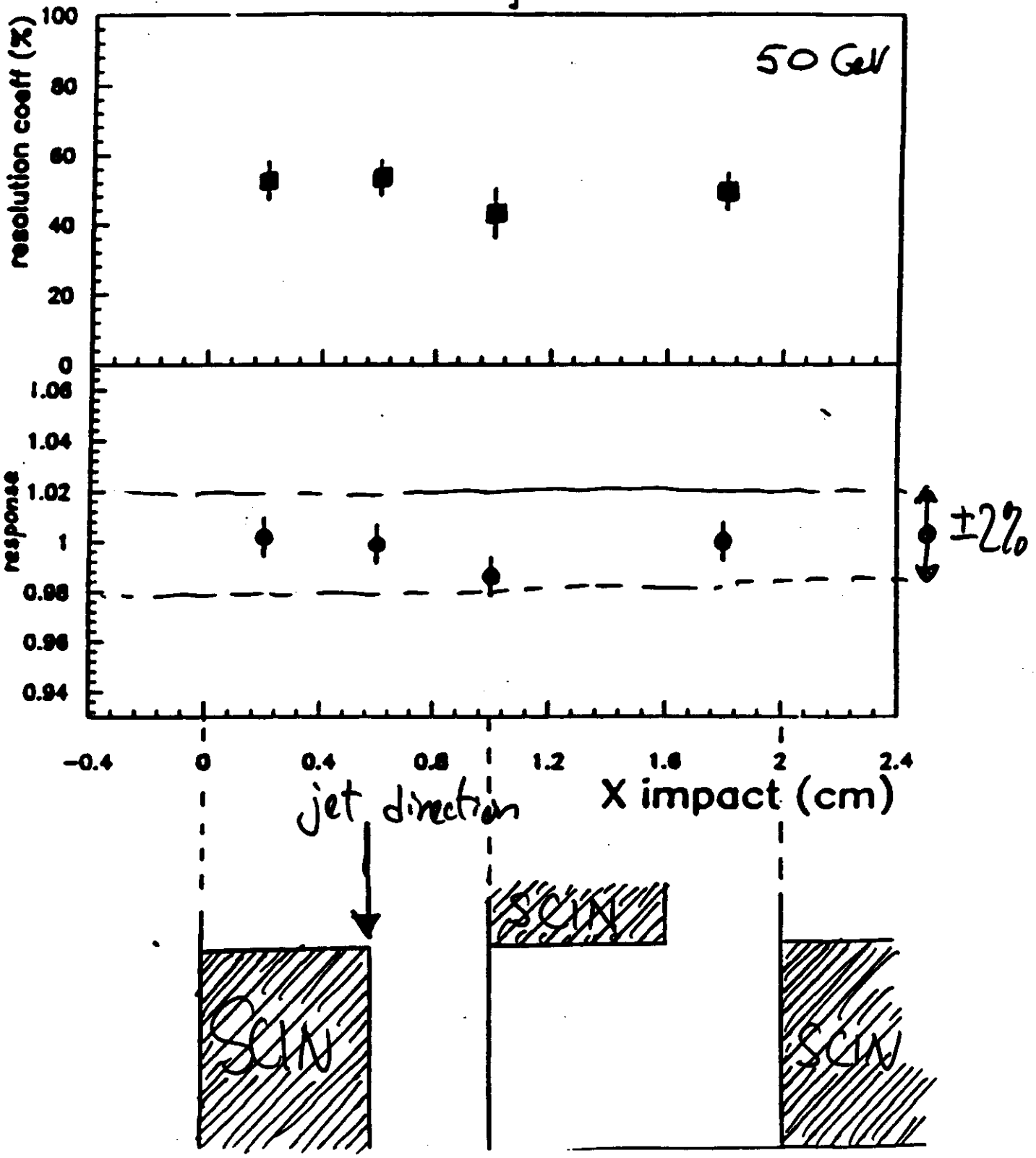
~ 1λ in front of hadr. calorimeter

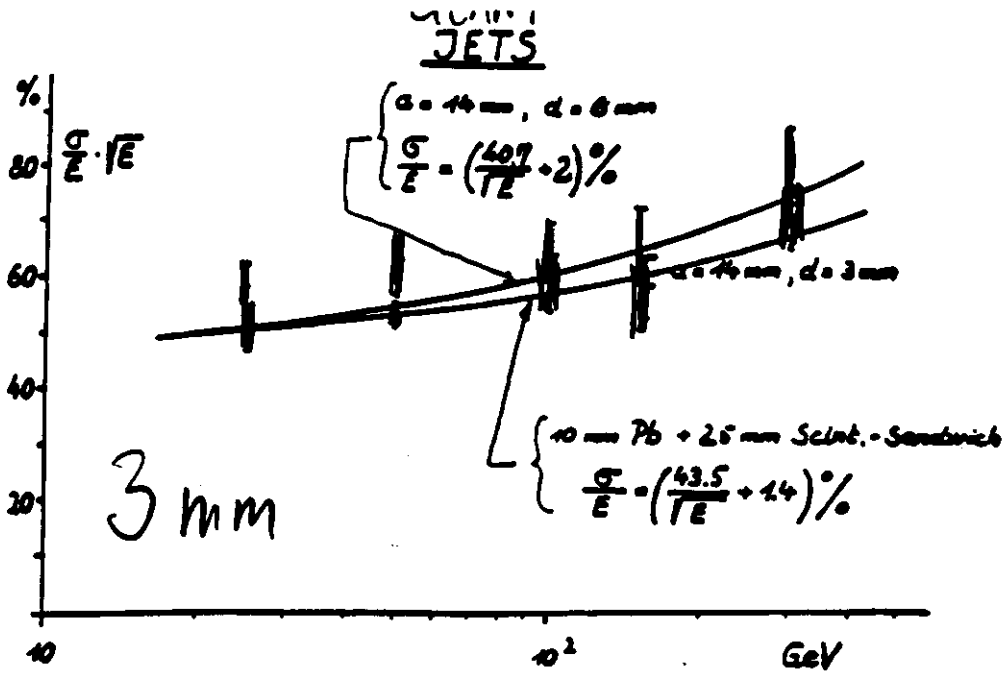
Fe $a = 1.4$ cm

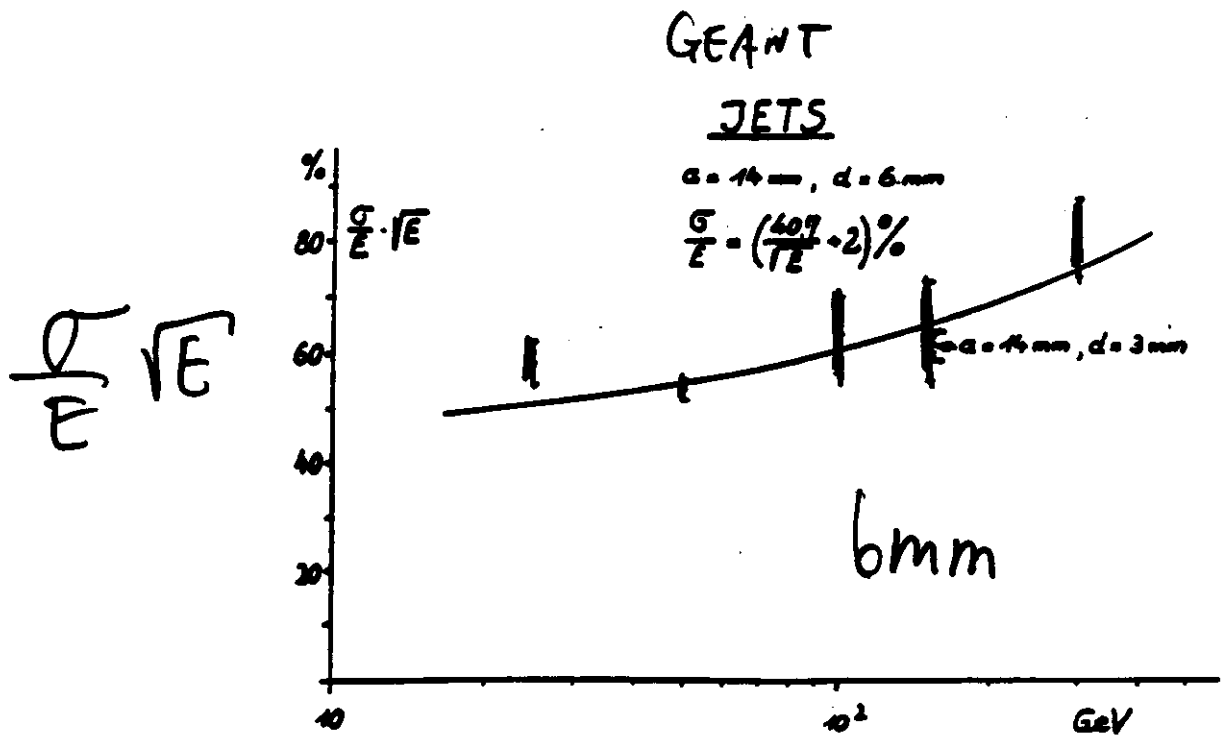
Sci $d = 0.6$ cm

GEANT

jets







(... volume % change X2, no change in resolution)

sandwich structure :

3 mm Pb + 4 mm Liq. Ar

<u>Hadr.-CAL</u> : 9.5 λ — Bill suggests Cu

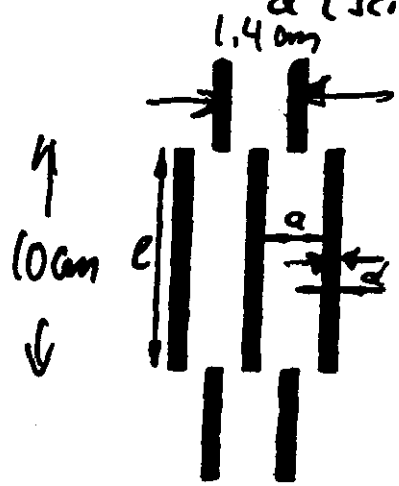
① Fe - Scintillator ,

<u>longitudinal staggered</u> scint. plates

ℓ = 10 cm

a (absorber thickness) = 14 mm

d (scintill. ") = 6(3) mm



$d = \begin{cases} 6\,mm, & 30\% \\ 3\,mm, & 18\% \end{cases}$ volume of plastic

<u>RESULTS</u> : $\frac{\sigma}{E}$ [%] <u>(JETS 25–300 GeV)</u>

$\boxed{\frac{40.7}{\sqrt{E}} + 2}$

$\frac{\ell}{h} \sim 1.4$

as comparison :

② <u>Pb - Scintillator</u>

<u>normal sandwich</u> structure $\frac{43.5}{\sqrt{E}} + 1.4$

10 mm Pb + 2.5 mm Scintillator

③ <u>Pb - Liq. Argon</u> ,

<u>normal sandwich</u> structure $\frac{41.3}{\sqrt{E}} + 2.2$

10 mm Pb + 4 mm Ar

Ignore :

> 1 D geometry

nonuniformities

light coupling fluctuations

$\boxed{\text{Simulations}}$ EAGLE

CAL-NO-006
22 November 1991

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

O. GILDEMEISTER, F. NESSI-TEDALDI, M. NESSI + P. Jenni
CERN, Geneva

ABSTRACT

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

1. Introduction

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

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

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

2. GEANT simulations

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

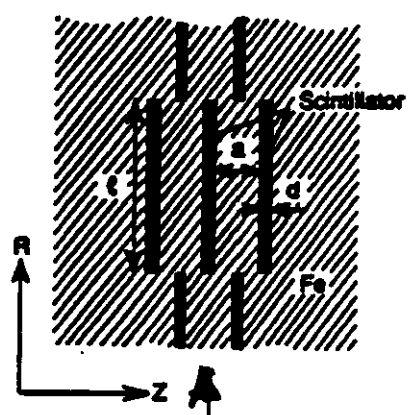


Fig. 1 Basic structure

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

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

jet

New SSCint Option for GEM

Scintillating tiles+copper (& maybe tungsten) hadron calorimeter

an idea of O.Gildemeister EAGLE / CERN

Why Scintillating Tiles ?

- Compact $\lambda_{eff} \sim 16.8$ cm
- Simple mechanical modular construction
- Low cost
- Longitudinal segmentation
- Fast response
- Low Z , < 140 X_0 for 12 λ_{int}
- Good sampling for muon rad. losses ~ 2 X_0
- Low noise

Most of these features are in common with Scintillating Fibers (Spaghetti) technique

SSCintCAL not wedded to $\begin{cases} \text{lead} \\ \text{fiber} \end{cases}$

GEM Annual Meeting Tucson 5/8/92 L.R. Sulak

HADRON CALORIMETRY CONCERNS

Bill Willis Boston SSC int CAL Meeting 2/5/92

0) Muon lever arm
⇒ compactify hadronic calorimeter
had already gone from 3.9 to 3.3mC

1) BaF_2 EM (and Liq Ar) 25 X_0 ... but need 31 X

⇒ investigate specs & capabilities of EM tail catcher = front end of HAD CAL

2) a) Correcting for catastrophic μ dE/dx

b) Using vertex constraint for low energy muons

⇒ investigate a low Z absorber

3) Muon chamber confusion due to late showers

⇒ { hadronic tail catcher/veto
{ low Z absorber for last λ_{abs}'s

his idea: ... check out Copper calorimetry & Guildemeister

gem

γeμ

Presentation by:

Paul Mockett
(1 & 2)

Paul Mockett (talk 1&2)

TEST BEAMS @ SLAC

I Contacted D. Leith 3/2/92

First Interest shown to date

II R. Gearhart 3/4/92

III SLAC Possibilities

A BEAM LINE 19

1 1yr; $250K ; e+ only

2 $E_{max} \sim 25$ GeV; 10-20 pps ; $\frac{\Delta P}{P} = .2\%$

3 π's ~1 M$

4 Parasitic with ESA

B END STATION A

1 Prime user

2 $E_{max} \sim 25$ GeV ; 3 wks/yr

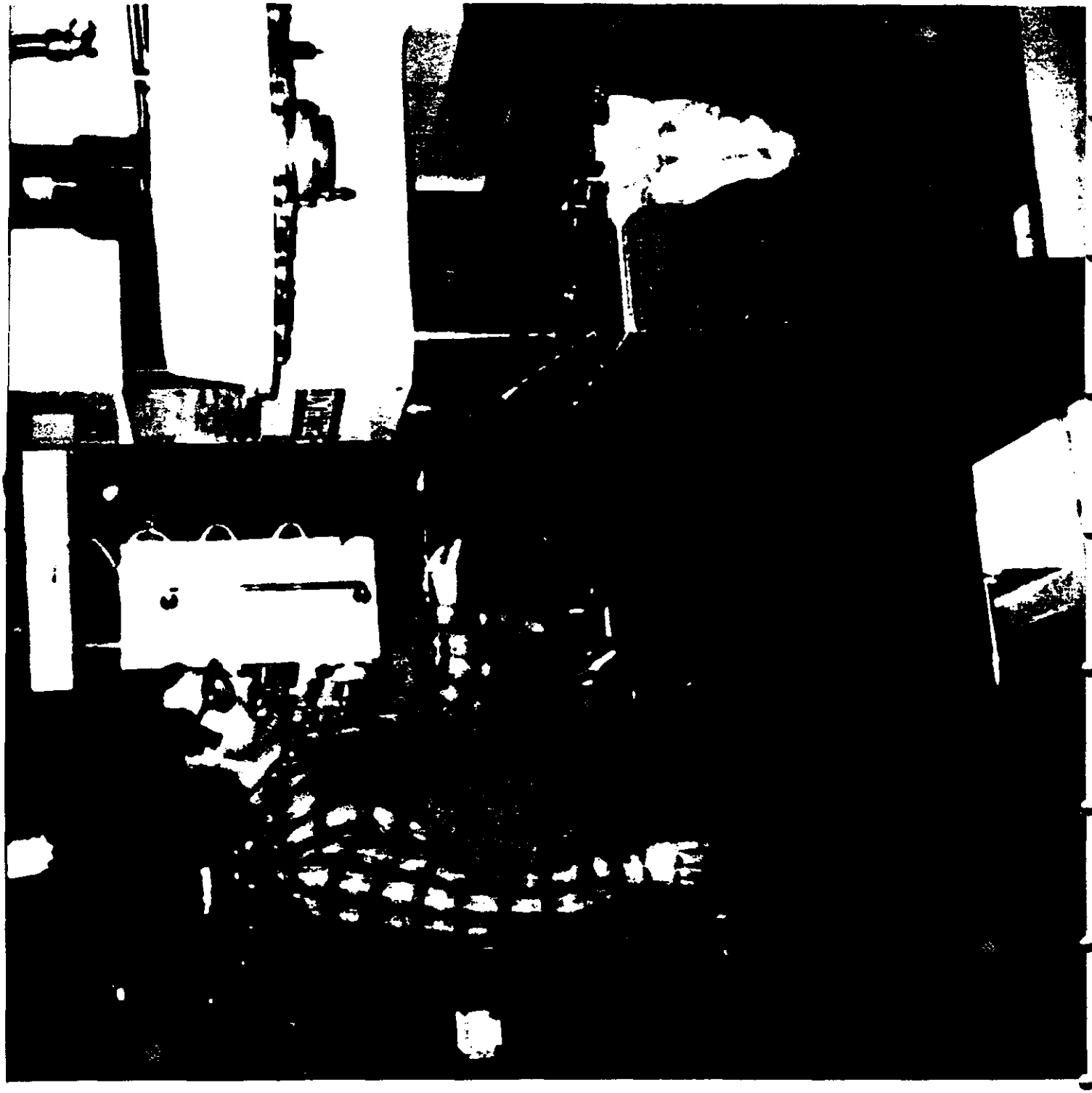
3 e+ only (with some additions)

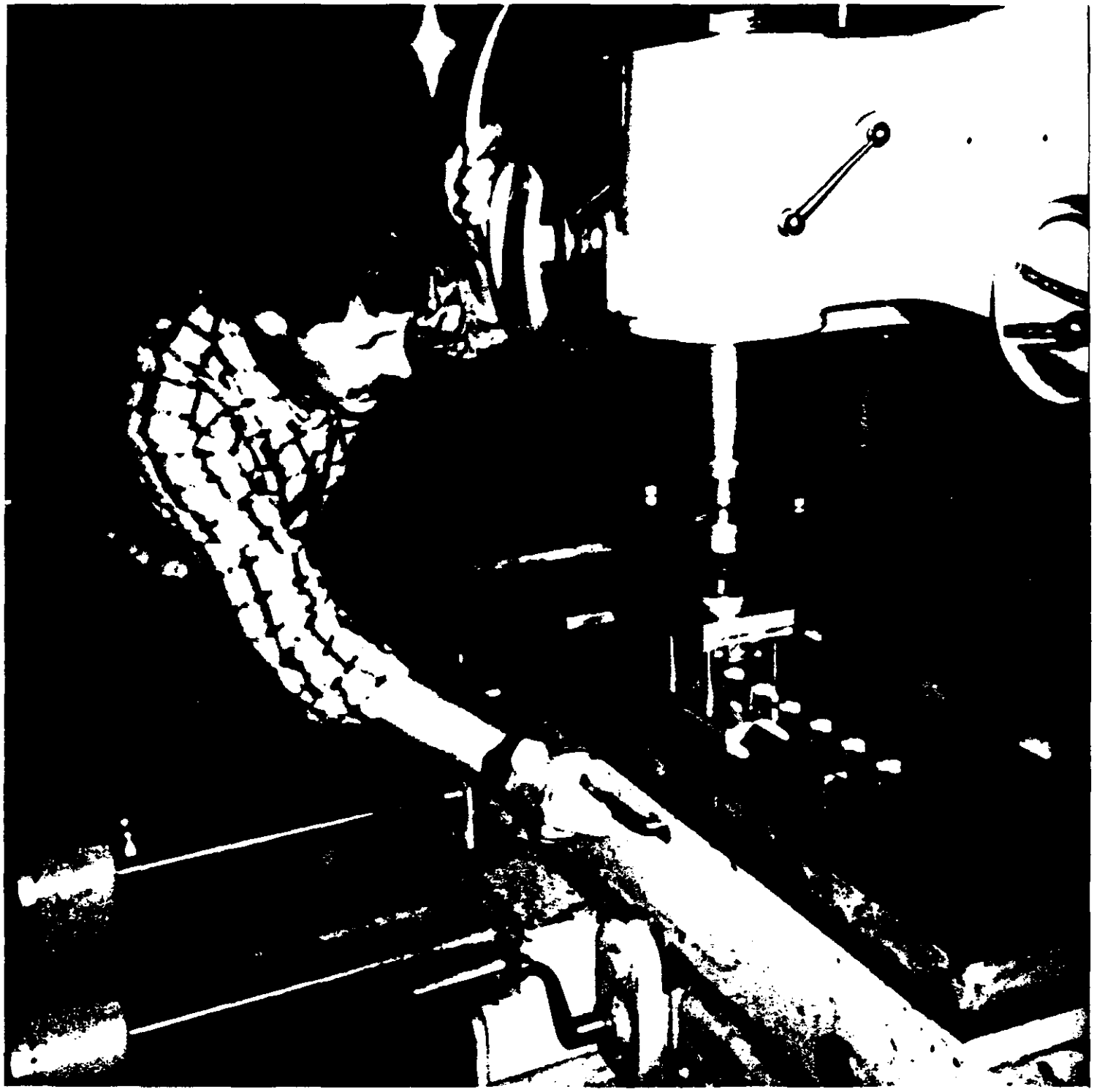
4 Nov - Dec '92 Physics Run

5 To be upgraded to 50 GeV in ~1yr
might get e+ @ ~40 GeV

C FINAL FOCUS TEST BEAM

1. Spring of '93
2. Not parasitic
3. How to get a few e^+pp?





Monte Carlo Results

1 mm Pb & 4mm LKr

	cutoffs, KeV	res., %/√E	error
EGS4		4.4	0.2
GEANT 3.14	10	4.51	0.09
GEANT 3.14	100	4.92	0.09

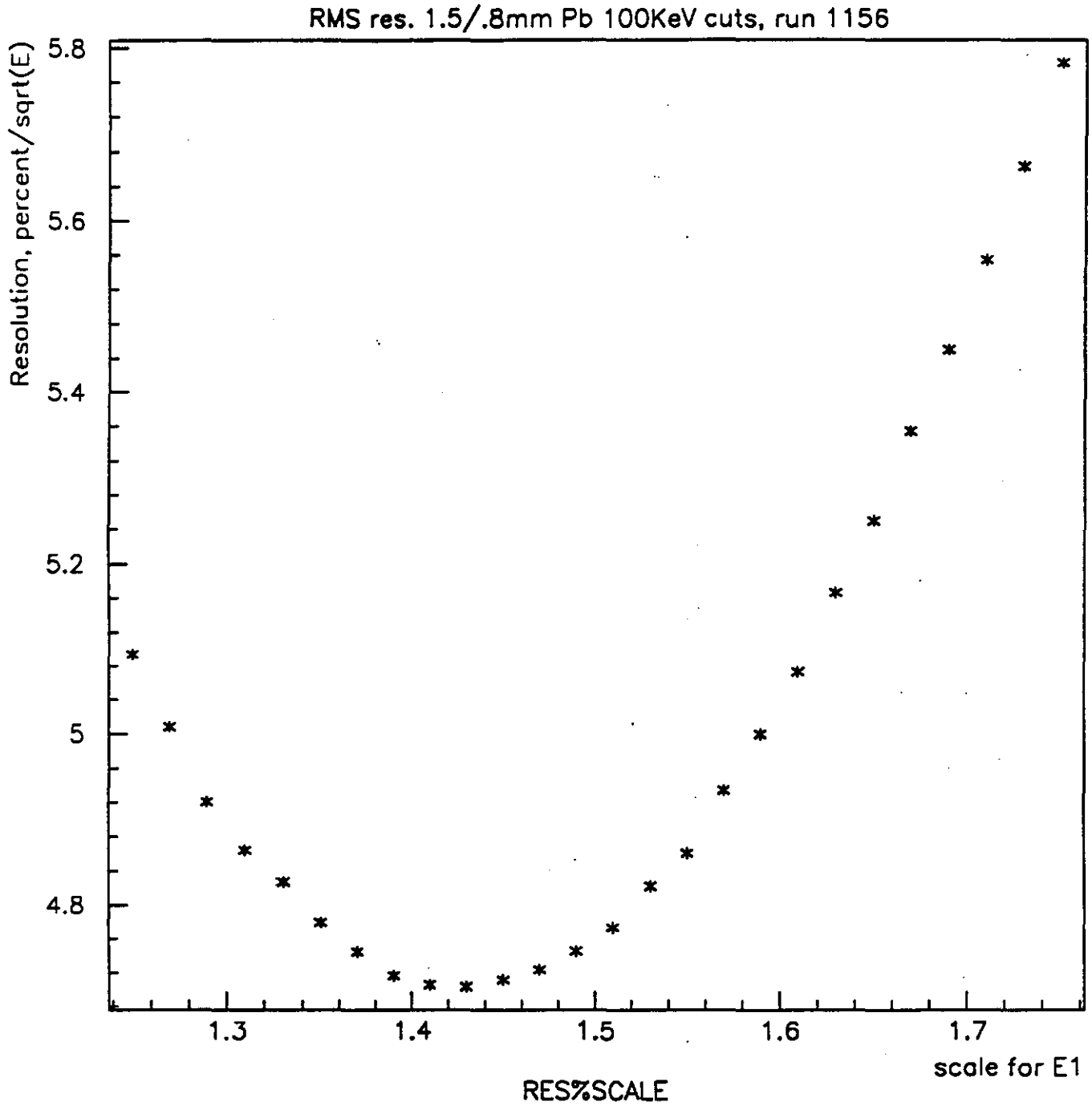
0.8 mm Pb & 4.915 mm LKr

	cutoffs, KeV	res., %/√E	error
GEANT 3.14	10	4.02	.09
GEANT 3.14	100	4.28	.09

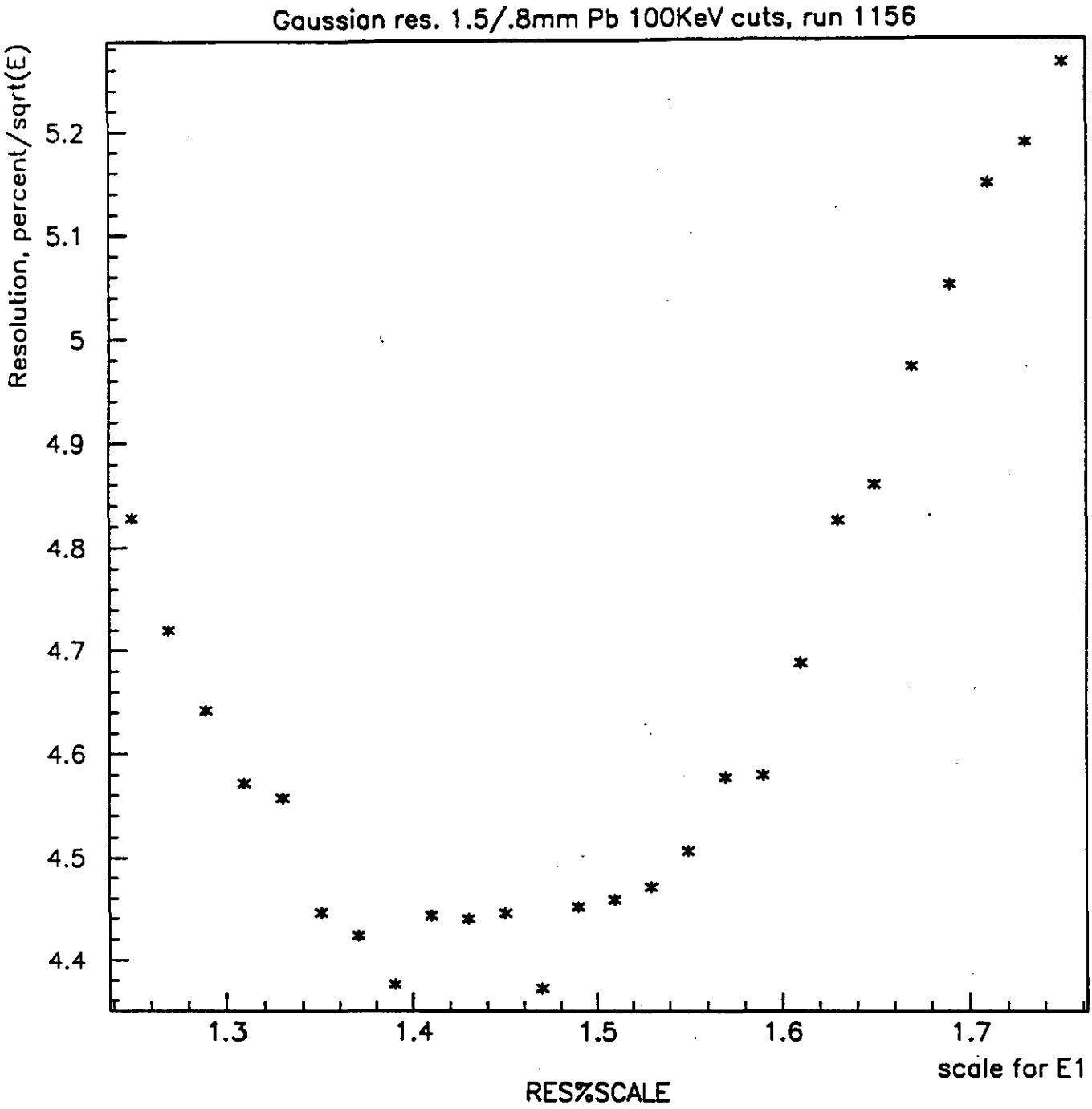
11 x 1.5 mm Pb & 71 x 0.8 mm Pb on 5.715 mm pitch in LKr

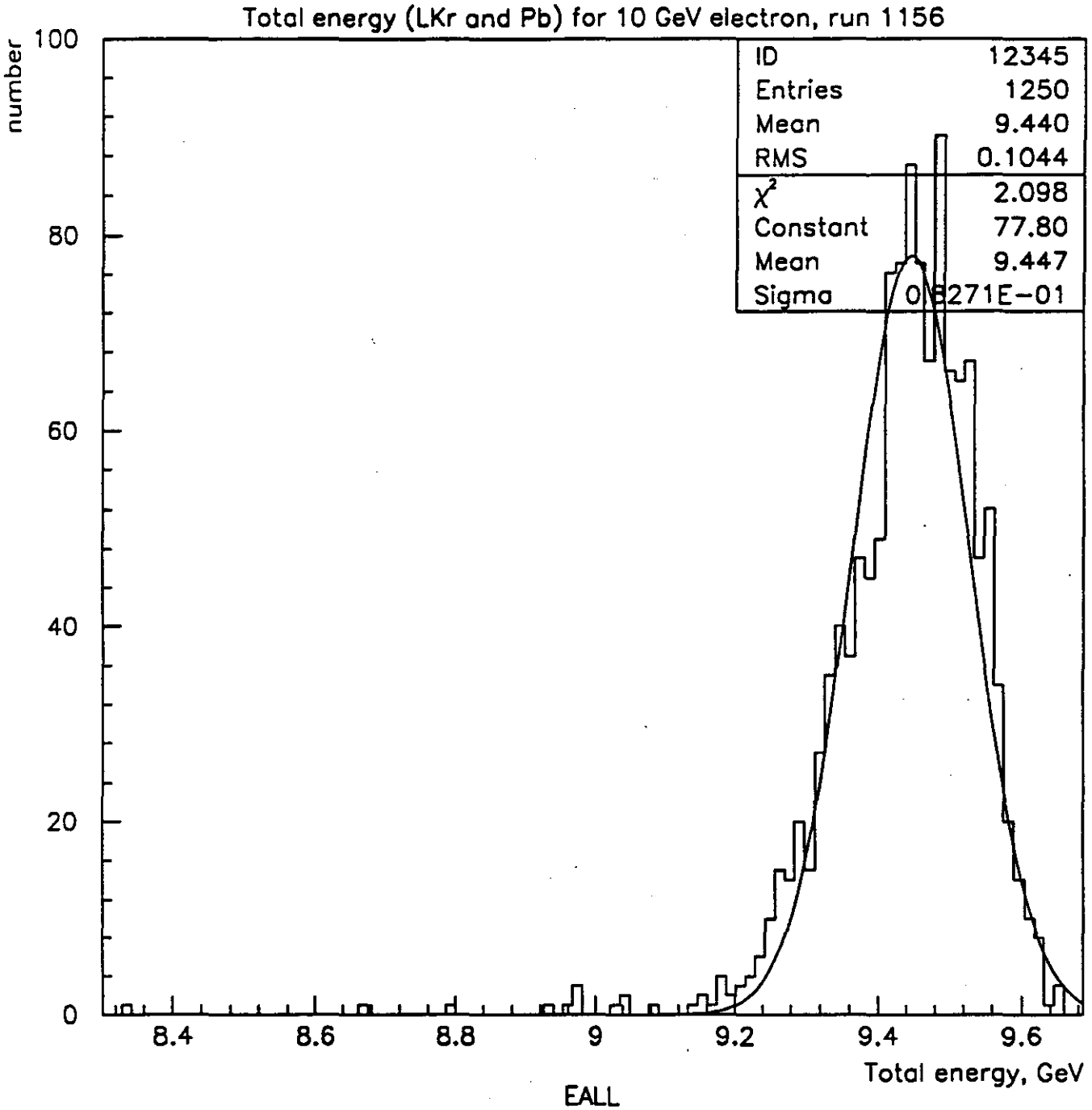
	cutoffs, KeV	res., %/√E	error
GEANT 3.14	10	4.15	0.1
GEANT 3.14	100	4.4	0.1

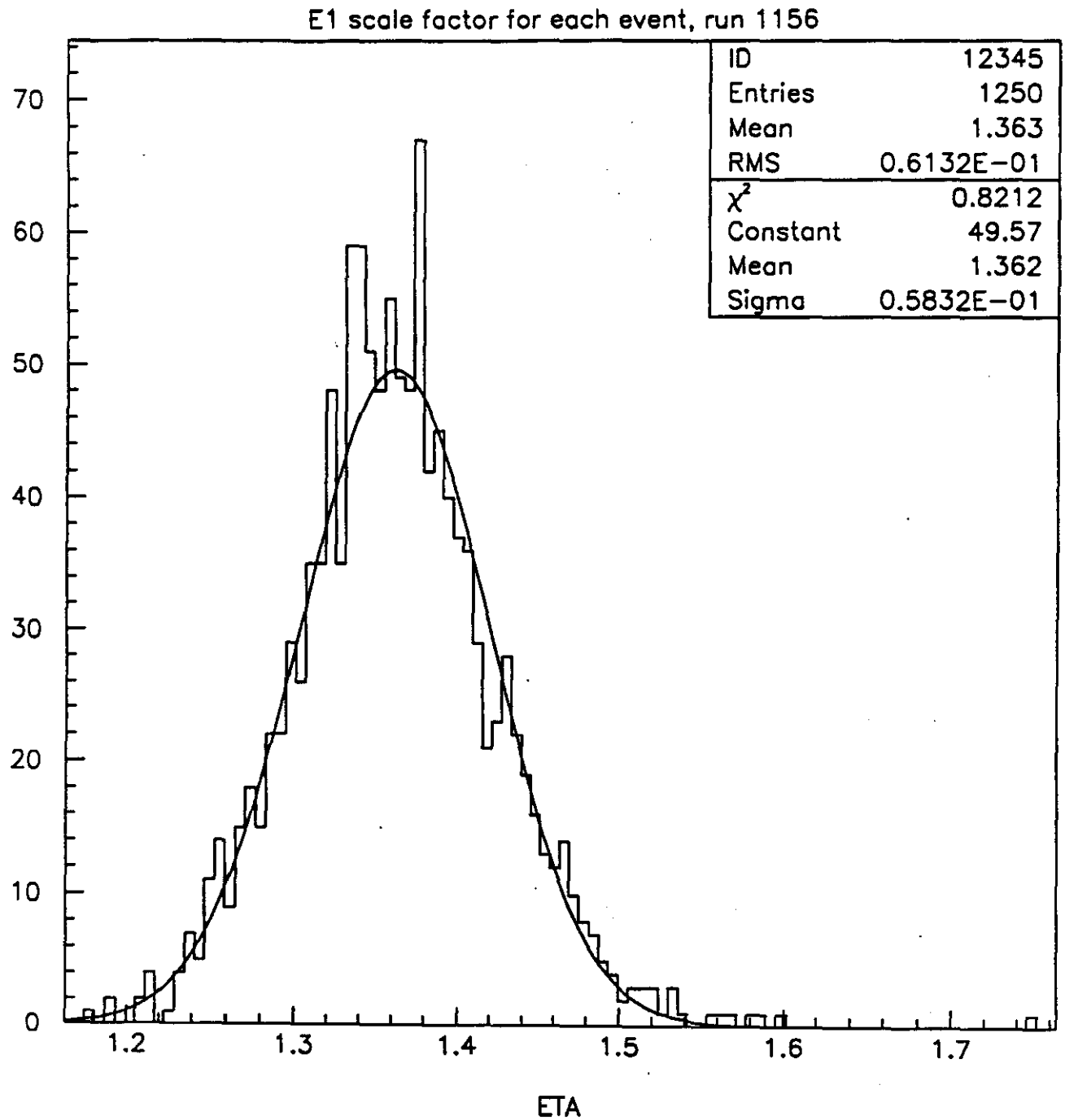
100 KeV cuts

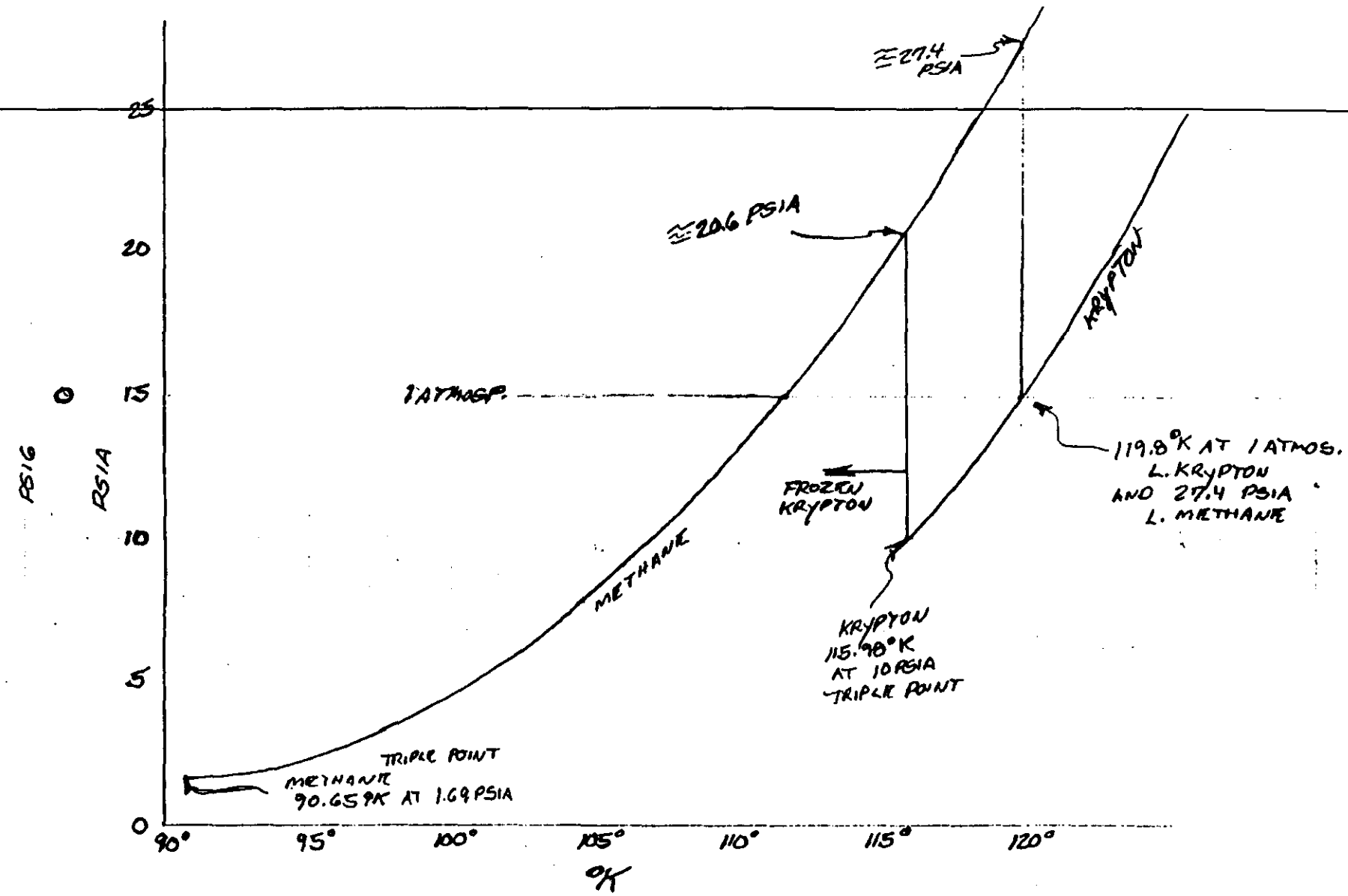

RMS res. 1.5/.8mm Pb 100KeV cuts, run 1156
Resolution, percent/sqrt(E)
5.8
5.6
5.4
5.2
5
4.8
1.3
1.4
1.5
1.6
1.7
scale for E1
RES%SCALE

100 KeV cuts!

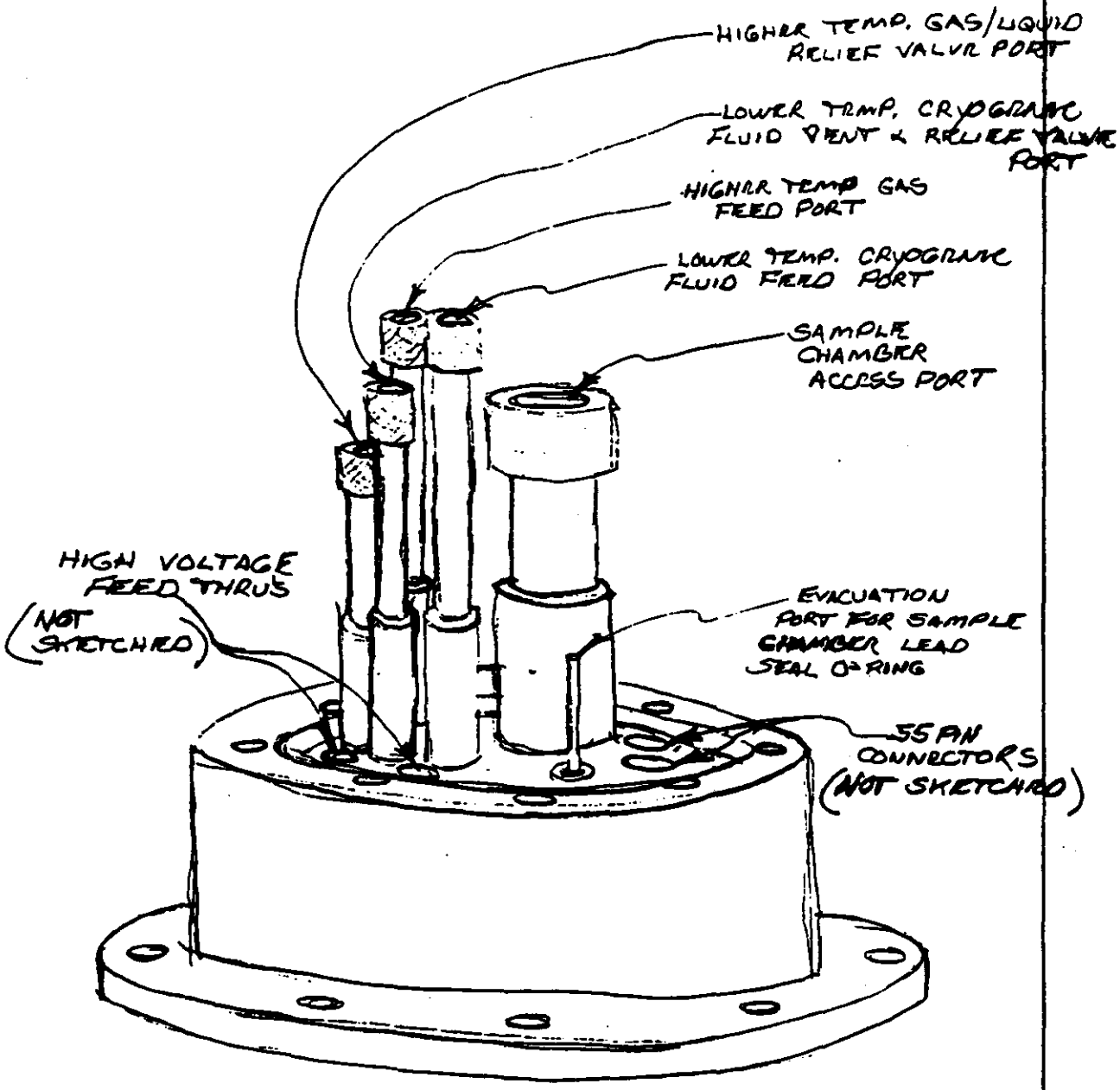

Gaussian res. 1.5/.8mm Pb 100KeV cuts, run 1156
Resolution, percent/sqrt(E)
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
1.3
1.4
1.5
1.6
1.7
scale for E1
RES%SCALE

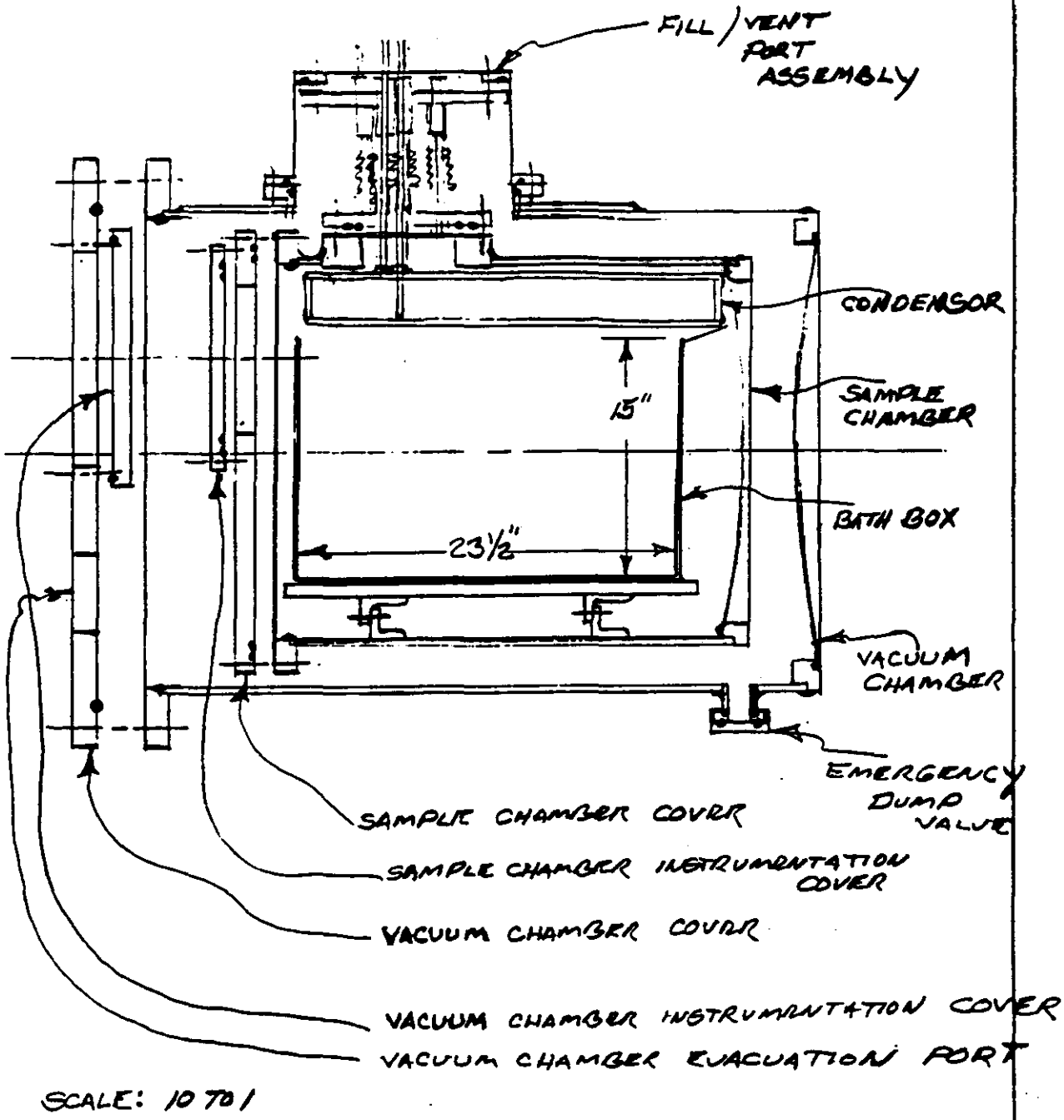

Total energy (LKr and Pb) for 10 GeV electron, run 1156
number
100
80
60
40
20
0
ID 12345
Entries 1250
Mean 9.440
RMS 0.1044
χ² 2.098
Constant 77.80
Mean 9.447
Sigma 0.8271E-01
8.4
8.6
8.8
9
9.2
9.4
9.6
Total energy, GeV
EALL


E1 scale factor for each event, run 1156
ID 12345
Entries 1250
Mean 1.363
RMS 0.6132E−01
χ² 0.8212
Constant 49.57
Mean 1.362
Sigma 0.5832E−01
70
60
50
40
30
20
10
0
1.2
1.3
1.4
1.5
1.6
1.7
ETA


≅27.4 PSIA
≅20.6 PSIA
1 ATMOSP.
KRYPTON
FROZEN KRYPTON
119.8°K AT 1 ATMOS. L. KRYPTON AND 27.4 PSIA L. METHANE
METHANE
KRYPTON 115.90°K AT 10 PSIA TRIPLE POINT
TRIPLE POINT METHANE 90.65°K AT 1.69 PSIA
PSIG
PSIA
25
20
15
10
5
0
90°
95°
100°
105°
110°
115°
120°
°K

SKETCH OF
FILL/VENT PORT ASSEMBLY
OF TEST DEWAR





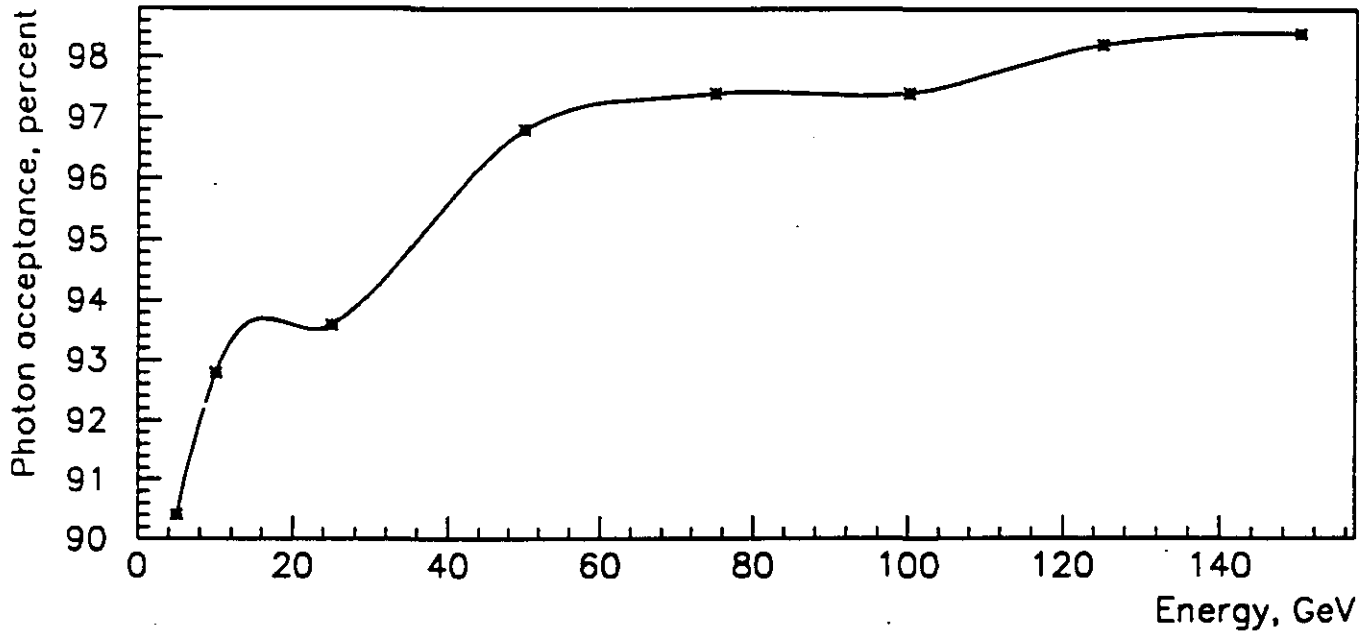
SKETCH OF TEST DEWAR

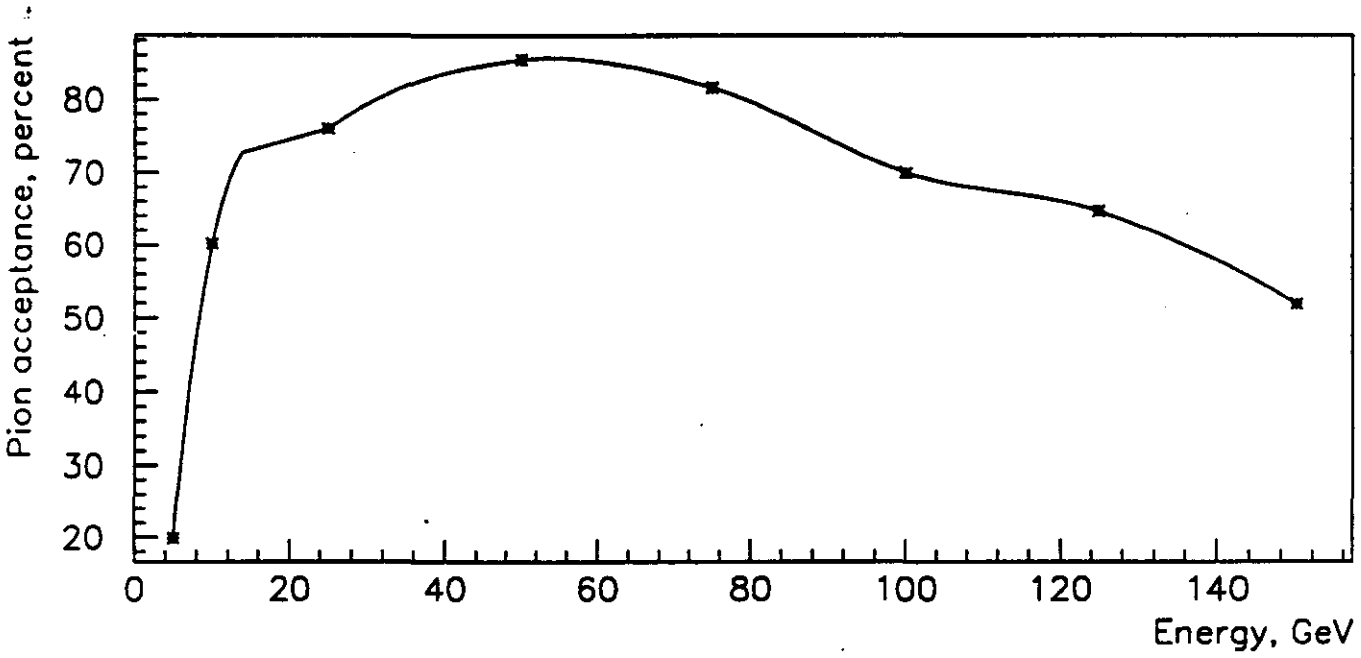
==========
Runs in: /usr/users/jke/gem/pi0/geant/bp/v3/1mm_last1_Kr
Cut : 3100
==========

E,GeV		accep	%0	%1	%2	%mean	only	%dip	only	%wid	only	run
5.0	1	92.8	25.4	67.4	7.2	0.2	0.2	0.0	0.0	7.0	7.0	3689
5.0	7	19.8	20.6	59.6	19.8	9.8	7.8	0.0	0.0	12.0	10.0	3690
10.0	1	90.4	18.8	71.6	9.6	0.6	0.4	0.0	0.0	9.2	9.0	3691
10.0	7	60.2	9.8	30.0	60.2	48.4	33.6	0.0	0.0	26.6	11.8	3692
25.0	1	97.4	13.6	83.8	2.6	1.4	1.0	0.0	0.0	1.6	1.2	3693
25.0	7	76.0	4.6	19.4	76.0	72.4	56.4	0.0	0.0	19.6	3.6	3694
50.0	1	93.6	11.0	82.6	6.4	2.8	2.0	1.8	1.2	2.6	2.4	3695
50.0	7	85.4	2.0	12.6	85.4	83.0	44.0	20.4	1.6	27.2	0.6	3696
75.0	1	96.8	12.2	84.6	3.2	1.8	1.0	1.0	0.4	1.2	1.0	3697
75.0	7	81.6	1.4	17.0	81.6	69.8	31.4	31.6	6.4	27.0	4.2	3698
100.0	1	97.4	10.8	86.6	2.6	1.8	1.0	1.2	0.4	0.4	0.4	3699
100.0	7	70.0	2.0	28.0	70.0	53.2	21.6	34.2	8.0	21.8	8.0	3700
125.0	1	98.2	8.2	90.0	1.8	0.8	0.2	1.2	0.8	0.4	0.2	3701
125.0	7	64.6	2.0	33.4	64.6	41.6	17.8	26.4	8.2	26.8	14.4	3702
150.0	1	98.4	10.0	88.4	1.6	0.8	0.4	0.8	0.4	0.4	0.4	3703
150.0	7	52.0	1.2	46.8	52.0	28.4	12.4	14.8	4.6	27.8	18.8	3704

1 LAYER LKr (1x & 1y) 3.9 X_0

Cut 3100 in /usr/users/jke/gem/pi0/geant/bp/v3/1mmzlast1zKr





PRELIMINARY

```
==================================================================
Cut    : 3100
==================================================================

Multiplexing:
-------------
Multiplexing factor                          [NMPX]= 6

Peak definition:
----------------
Energy required for peak (GeV)               [ECUT]= .015
Min. frac. of biggest peak for second     [PEAKCUT]= 0.25

Dip cut:
--------
const for max frac. of biggest peak      [DICONST]= 1.11
const for max frac. of biggest peak        [DIPMAX]= -.013
Energy power for max frac. of biggest peak[DIPPOWR]= 1.
HEnergy to set fraction to HEDIP              [EDIP]= 0.5
Energy to set fraction to HEDIP              [EDIP]= 50.
Dip fraction above EDIP                     [HEDIP]= 0.5

dip fraction    = DIPCONST + DIPMAX * E^DIPPOWR : EDLOW<=E<EDIP
                = HEDIP                         : E>= EDIP
                = cut turned off                : E<EDLOW

Width cut:
----------
Multiplier for width cut below WCTHRESH    [CUTWID]= 6.96
Power of energy for width cut             [WIDPOWR]= -.25
Energy thresh where widthcut->NWCLOWER   [WCTHRESH]= 50.
Higher energy width cut                  [NWCLOWER]= 2
Min. frac. of biggest peak for width      [EWIDCUT]= 0.6

width bin height cut    = INT(CUTWID * E^WIDPOWR)       : E < WCTHESH
                              = NWCLOWER                        : E>= EDIP

Mean position cut:
------------------
Mean offset for pi0 (in mm)               [CUTMEAN]= 6.75            bins, not cm!
Power of energy for mean offset scaling   [CUTPOWR]= -0.5
Tot. energy above which CUTMEAN->HEMEAN    [CUTOFF]= 50.
Mean difference cut above CUTOFF           [HEMEAN]= 0.65

mean offset cut = CUTMEAN*E^CUTPOWR     : E<CUTOFF
                = HEMEAN                      : E>= HEMEAN
```

Paul,
Here's the latest on the pi0 identifier cuts. This is for LKr, last 2 layers (1 X and 1 Y) of 11 1.5mm Pb layers.

I've parameterized the higher energy behavior in a sensible fashion, yielding pretty good results. The low energy stuff suffers from having to make the width cut quite open in order to preserve some semblance of good efficiency. I will look at this some more and e-mail/fax you with any updates.

Note that all the cuts have a parameterization.

The cut procedure goes like this:

1) find the two biggest peaks

   The sum of the two biggest peaks must be at least **ECUT.**
   To be considered a second peak, the second highest channel must be at least **PEAKCUT** * the highest channel

2) Dip cut:

   If there are two peaks which are not adjacent, or at the two ends, then look for a channel between the two highest peaks which have heights less than the dip fraction which is given by

DIPCONST + DIPMAX * E^DIPPOWR	for EDLOW<=E>EDIP
HEDIP	for E>= EDIP
dip cut turned off	for E < EDLOW

3) Width cut

   Look for adjacent channels with heights greater than the width bin height cut (with wrap-around) where the height cut is given by:

INT(CUTWID*E^WIDPOWR)	for E< WCTHESH
NWCLOWER	for E >= EDIP

4) Mean position cut

   Find the discrepancy between the true mean position and the mean position given by the mean of the two highest peaks. The mean difference, in radius is said to be off when greater than the mean offset cut, given by:

CUTMEAN *E^CUTPOWR	for E<CUTOFF
HEMEAN	for E>=HEMEAN

Have a good trip
--Jon

```
==========================================
Runs in: /usr/users/jke/gem/pi0/geant/bp/v3/1mm_last3_vlong
Cut    : 2103
==========================================
```

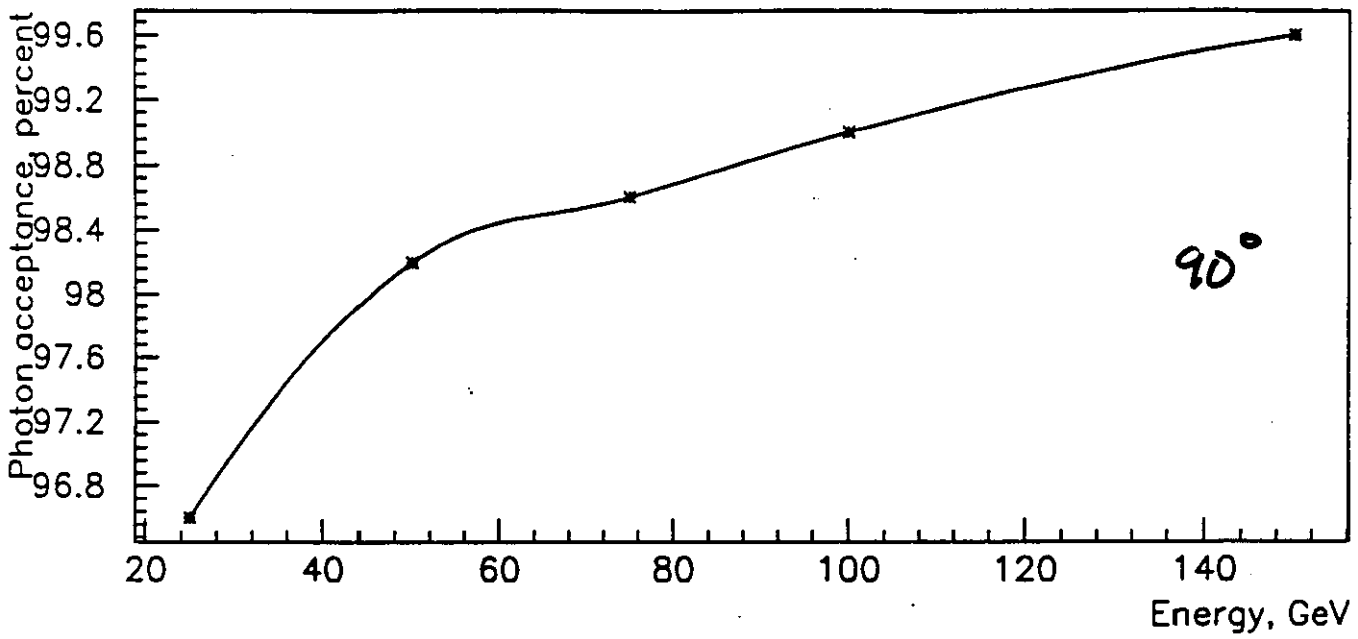
3X & 3Y layers

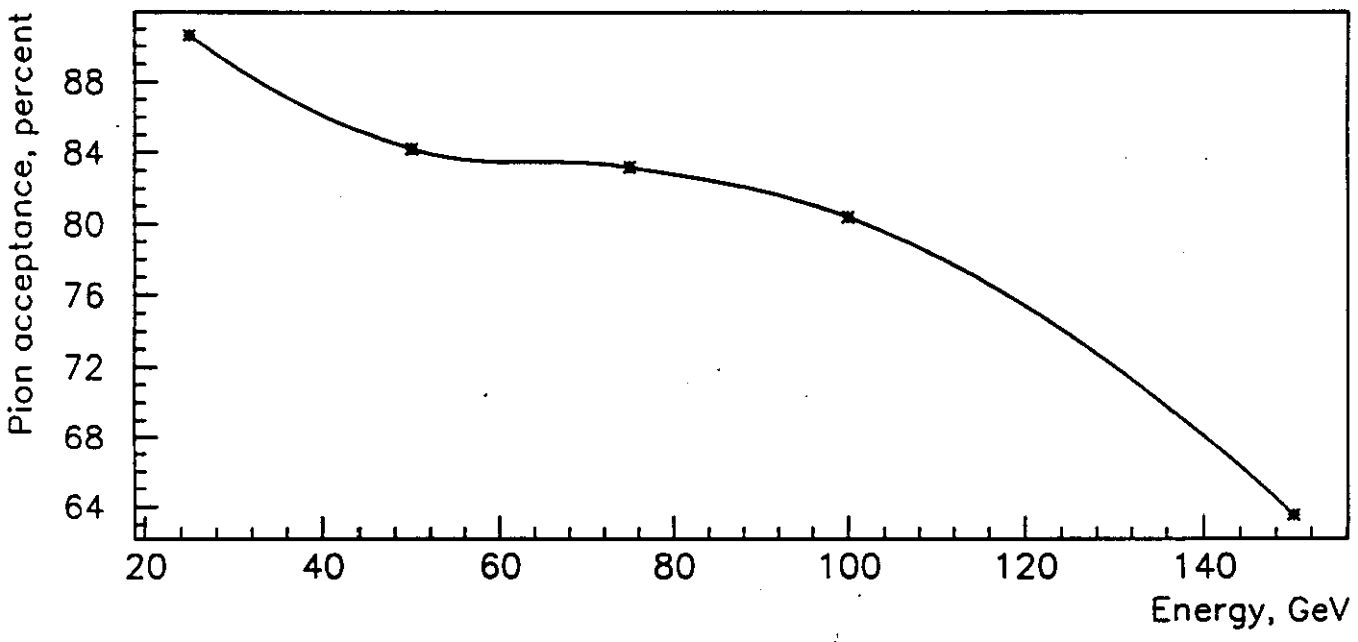
E,GeV		accep	%0	%1	%2	%mean	only	%dip	only	%wid	only	run
25.0	1	96.6	14.2	82.4	3.4	3.4	3.4	0.0	0.0	0.0	0.0	3577
25.0	7	90.6	3.2	6.2	90.6	90.0	85.2	0.0	0.0	5.8	0.6	3578
50.0	1	99.0	12.8	86.2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	3589
50.0	7	84.2	2.4	13.4	84.2	84.2	81.6	0.0	0.0	2.6	0.0	3590
75.0	1	98.6	13.0	85.6	1.4	0.8	0.6	0.8	0.6	0.0	0.0	3579
75.0	7	83.2	2.8	14.0	83.2	69.2	26.4	55.6	8.2	28.0	1.4	3580
100.0	1	98.2	12.2	86.0	1.8	1.0	0.8	0.6	0.4	0.4	0.4	3581
100.0	7	80.4	2.8	16.8	80.4	60.0	26.2	52.4	13.6	25.8	4.0	3582
150.0	1	99.6	10.8	88.8	0.4	0.2	0.0	0.4	0.2	0.0	0.0	3583
150.0	7	63.5	1.5	35.0	63.5	37.0	13.6	26.5	7.7	32.1	18.8	3584

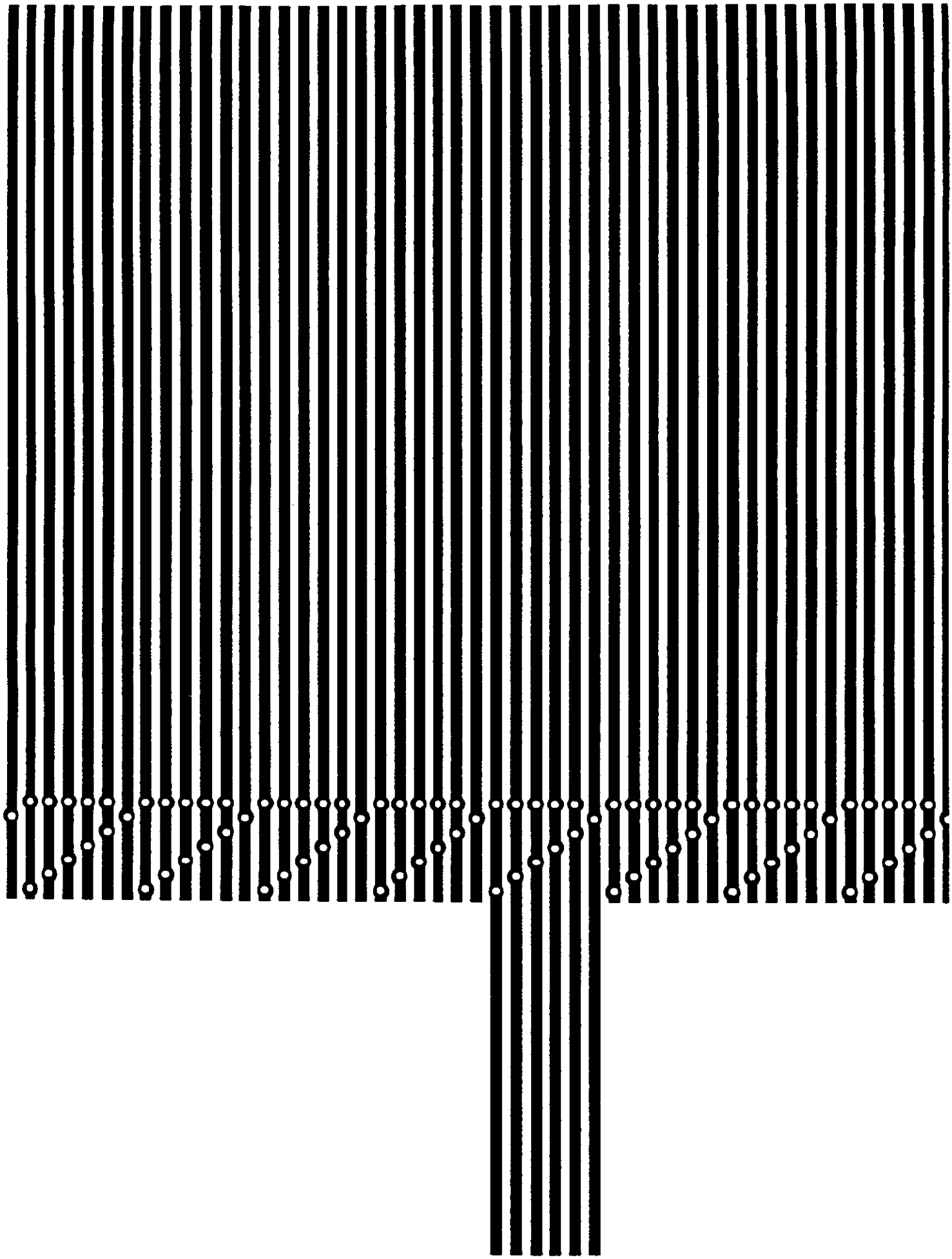
```
=========================================
Multiplexing factor                          [NMPX]= 6
Number of events processed (0=all)           [NEND]= 0
Energy required for peak                     [ECUT]= .015
Max. frac. of biggest peak for dip         [DIPMAX]= 0.5
Energy to start dip cut at                   [EDIP]= 50.
Number of bins wide considered pi0        [NCUTWID]= 4
Energy thresh. where ncutwid->NWCLOWER   [WCTHRESH]= 75.
Higher energy width cut                  [NWCLOWER]= 2
Min. frac. of biggest peak for width      [EWIDCUT]= 0.5
Min. frac. of biggest peak for second     [PEAKCUT]= 0.25
Mean offset for pi0 (in mm)               [CUTMEAN]= 8.0              bins, not cm!
Power of energy for mean offset scaling   [CUTPOWR]= -0.50
Tot. energy above which CUTMEAN->HEMEAN    [CUTOFF]= 25.
Mean difference cut above CUTOFF           [HEMEAN]= 0.6
dist. at which mean is to be extrapolated   [DMEAN]= 0.
        (mean offset cut = CUTMEAN * E^CUTPOWR)
=========================================
```

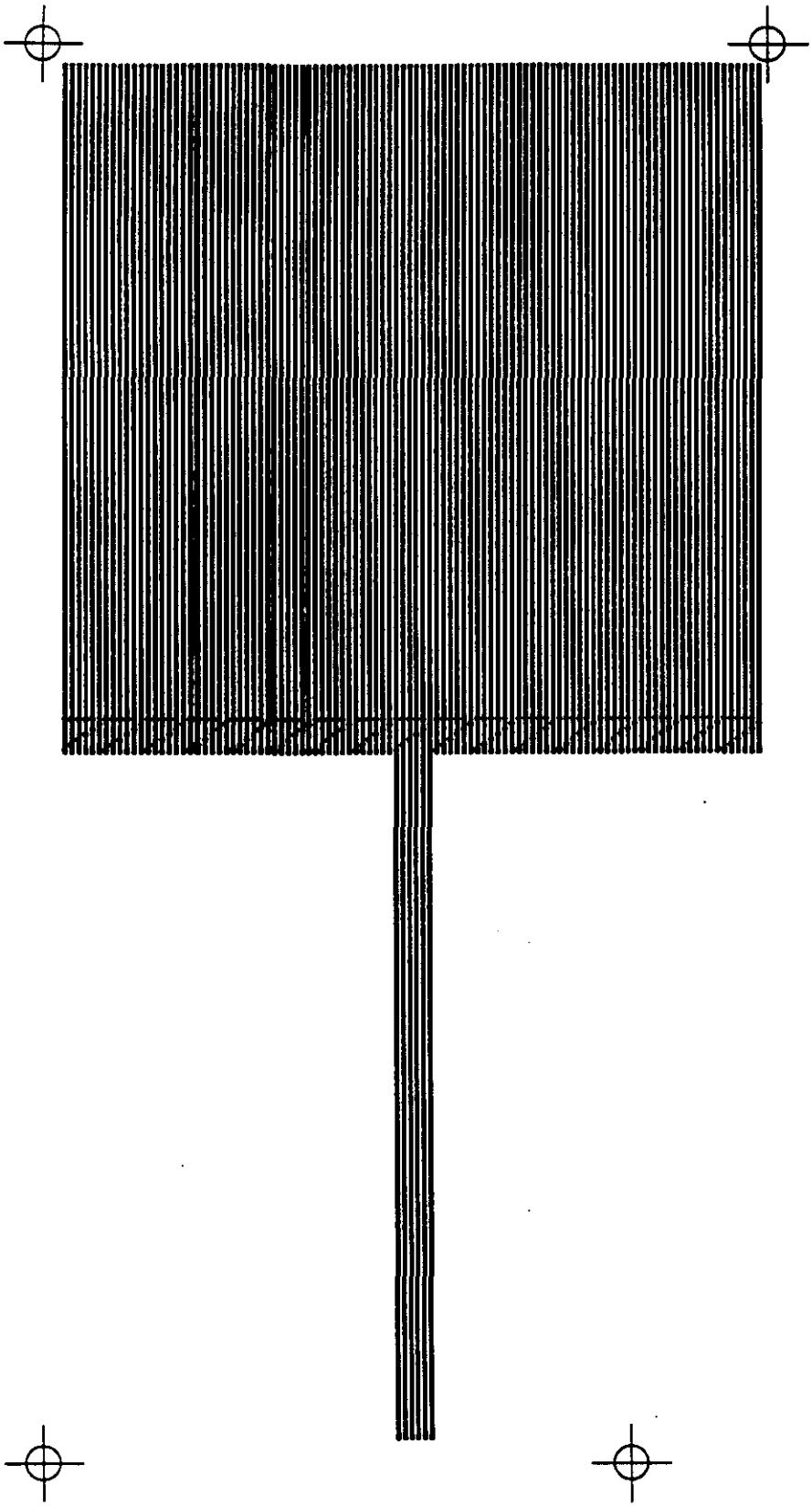
3 LAYERS LAr (3-x & 3-y) 3.9 X0 Premodiator

Cut 2103 in /usr/users/jke/gem/pi0/geant/bp/v3/1mmzlast3zvlong





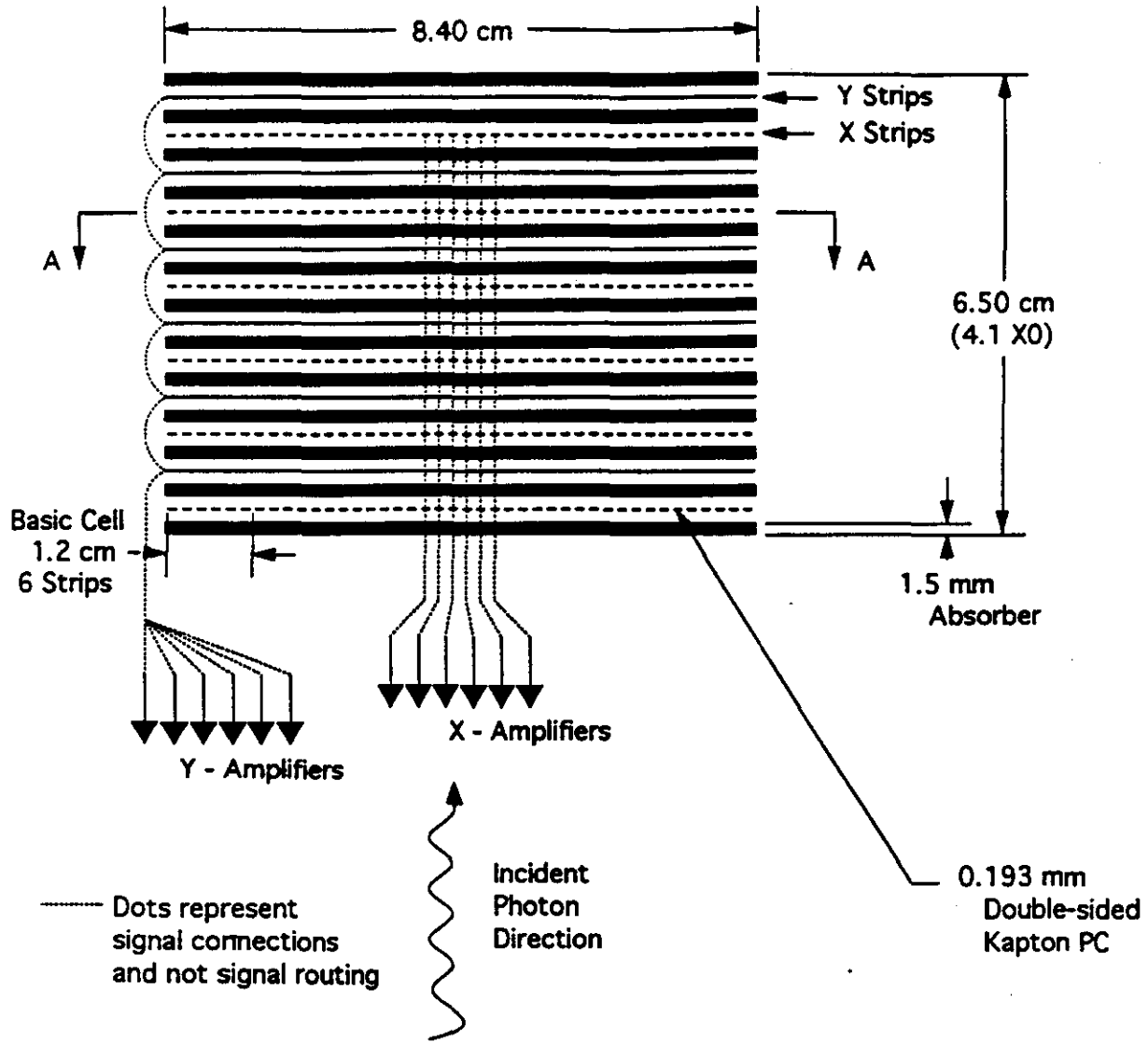


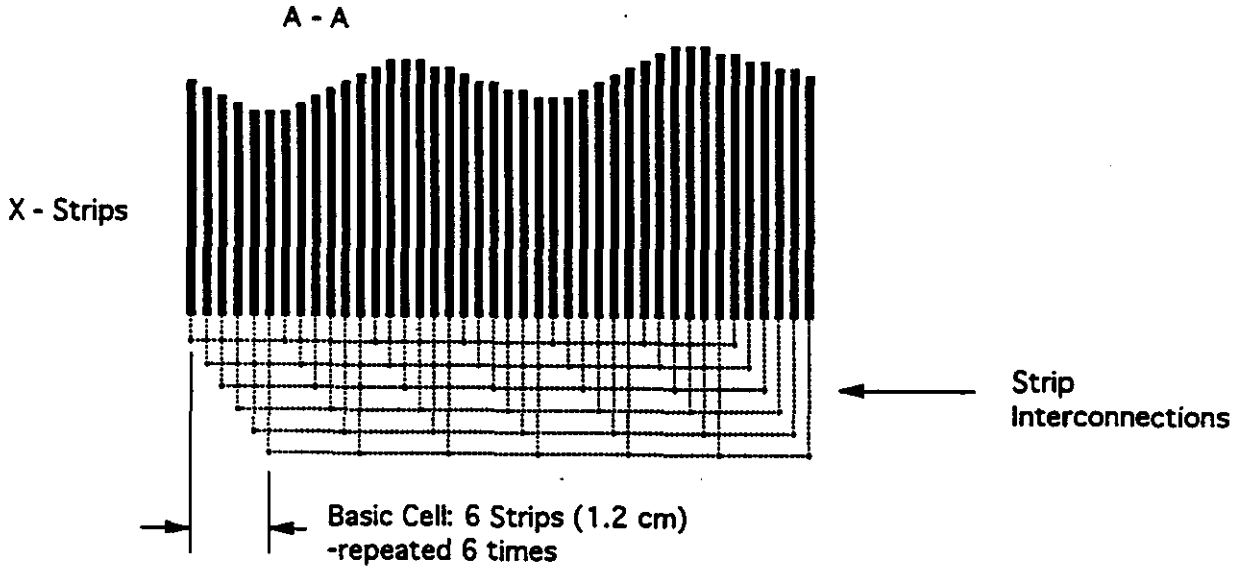


stripline side

π^0 IDENTIFIER SCHEMATIC

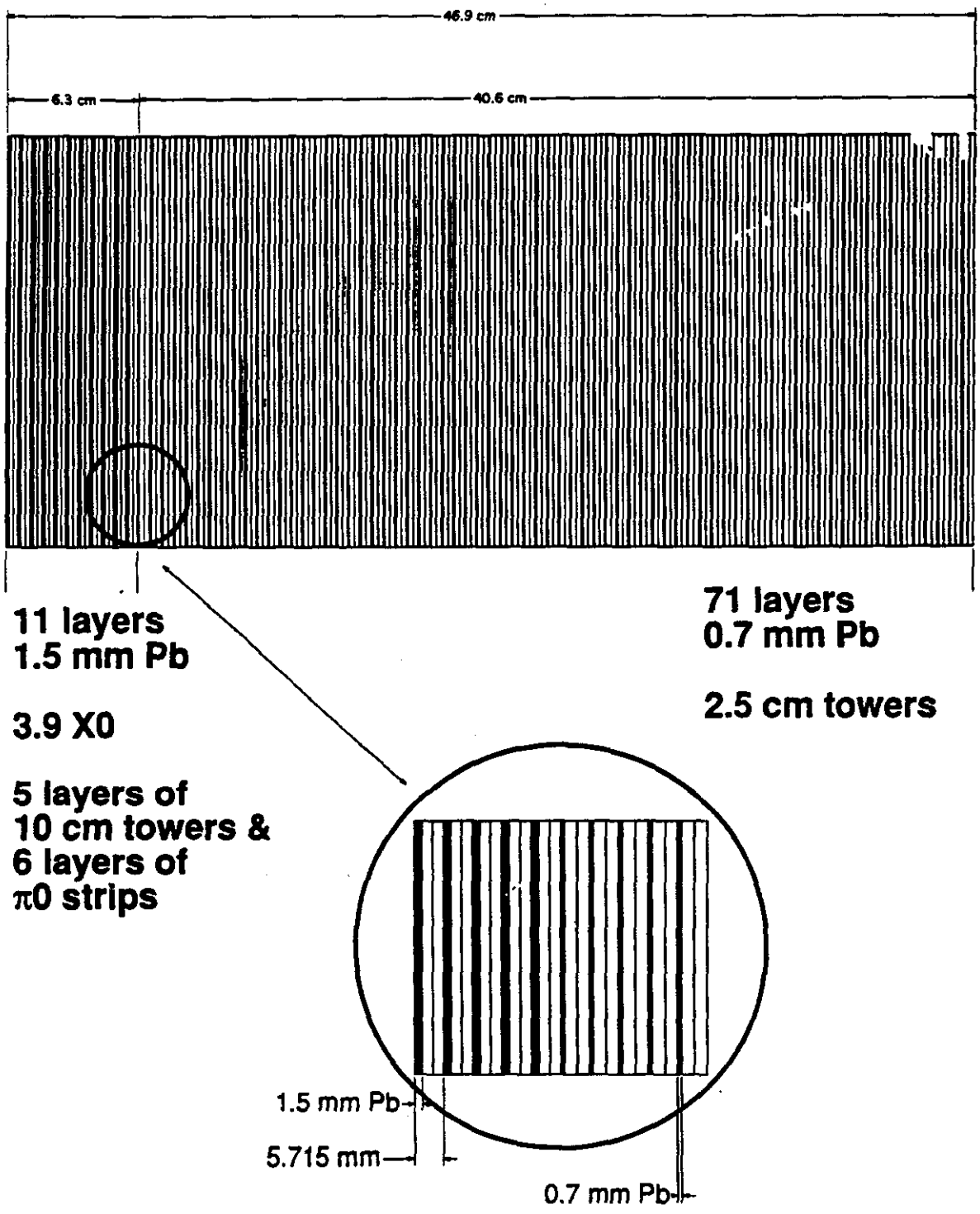
(Parallel plate geometry)



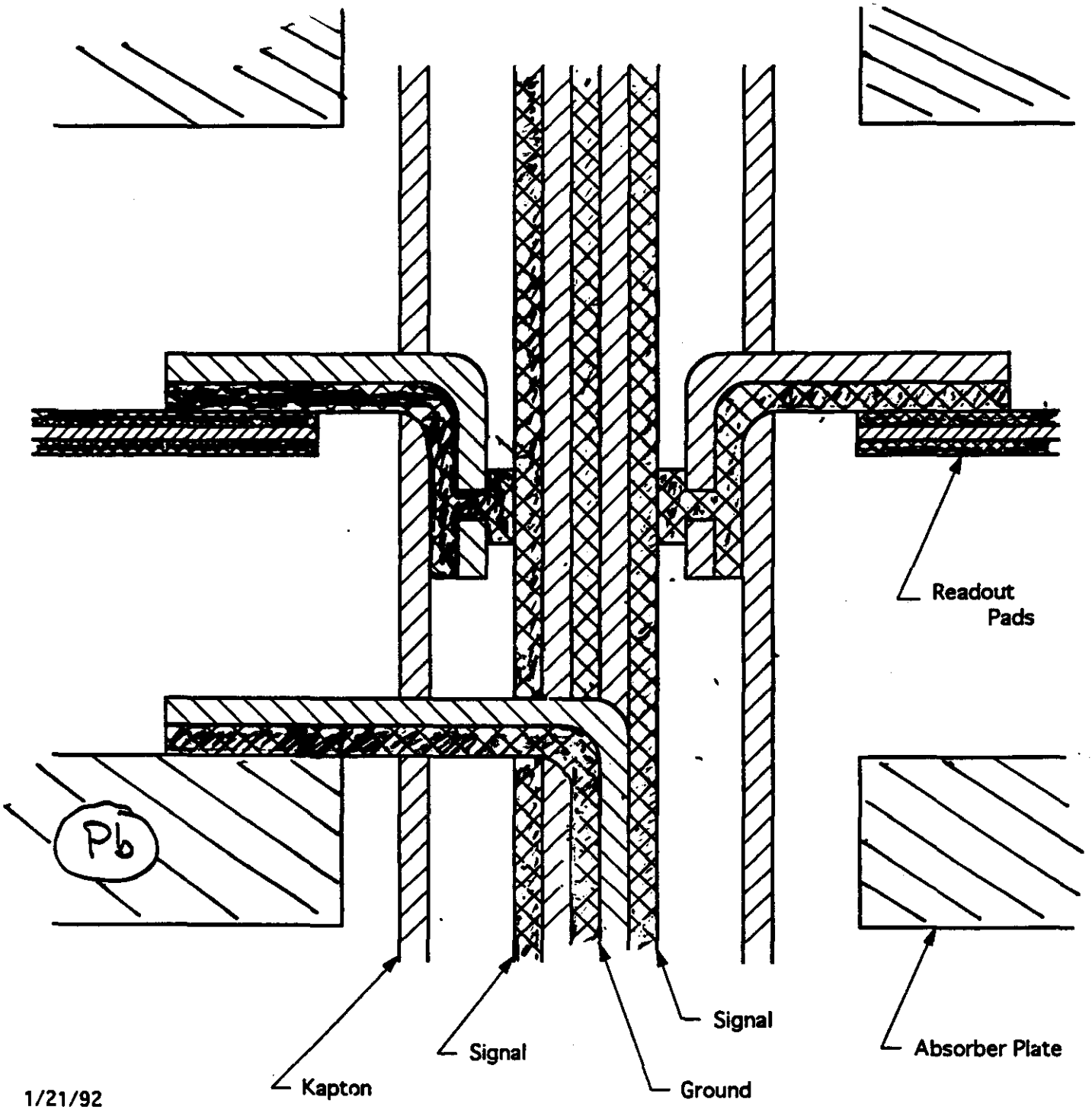


1/21/92

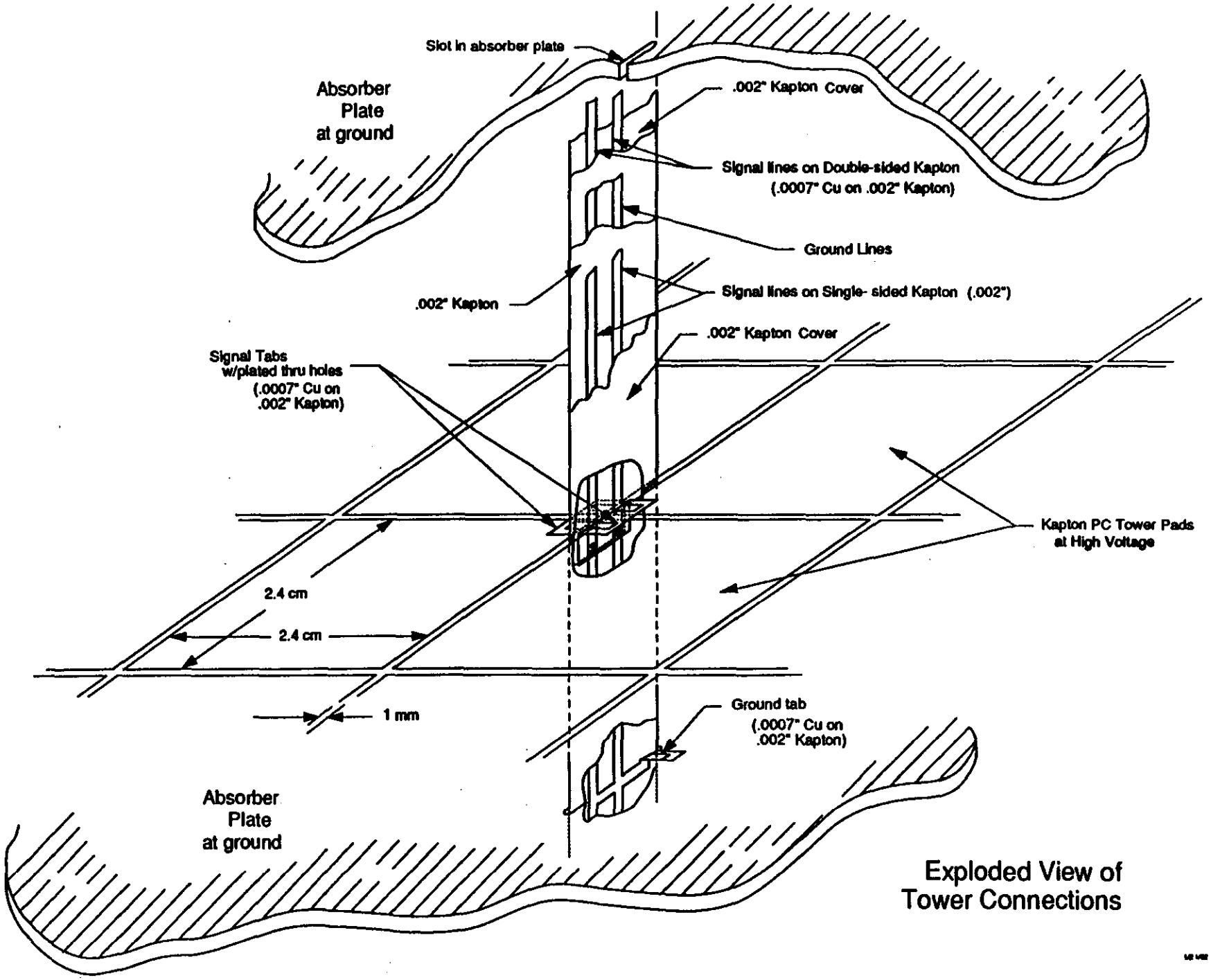
Parallel Plate EM Calorimeter with pre-radiator



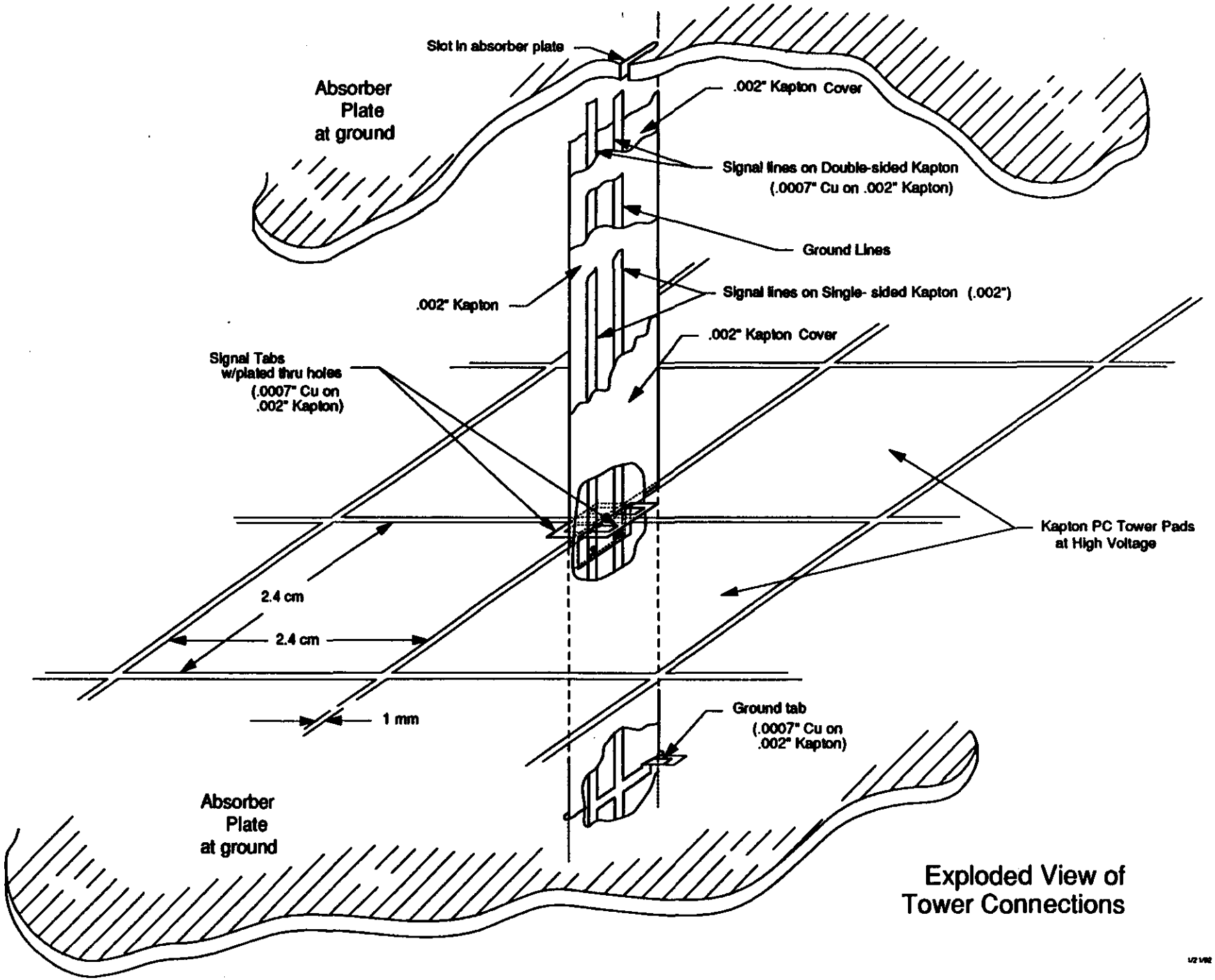
Microstrips for GEM Parallel Plate EM LAC



1/21/92
DAF



Exploded View of Tower Connections



Exploded View of Tower Connections

π^0 Detector Status

Monte Carlo

Optimized for 3 layers in LAr
1 layer in progress in LKr

Electrode

Protype made

Mother Board

BN2

Adaptor Board

Concept

Dewar Status

Design

Complete

Fabrication

In progress
< 4 wks

π^0 Detector

MC
optimized for 3 layer
working on 1 layer

Electrode
prototype made

Mother board
BNL

Adaptor board
concept complete

Parallel Plate Calorimeter
Status Report

Striplines

Tabs made

Artwork completed
Test Samples etched
Materials in hand
Four Prototypes made / Tested to 4KV in LAr

Electrodes

Contract let - 3 wks delivery

Decoupling Capacitors

Contract let 3 wks delivery

HV distribution

Artwork complete
Materials in hand

Absorber Plates

1 Prototype made - Tested in LN

Mother Board

BNL

Adapter Board

Concept

PP CAL

Strip liner
Tabs made
Artwork completed for lines Test samples etched Material in Hand
Prototypes (4) Test to 4KV in LAr

Electrodes
Bid let 3wks delivery

Decoupling Cap
Bid let 2wks delivery

HV distribution
Artwork complete

Dewar
~1 month more work

Phales Absorber
1 prototype made - Tested in LN

Motherboard
BNL

Adapter Board
Concept

gem

γeμ

Presentation by:

Yuri Kamyshkov
(1)

SIMULATIONS AND LAB TESTS:
Demonstrate High Resolution
Maintainable In Situ
Max. Constant Term 0.6%

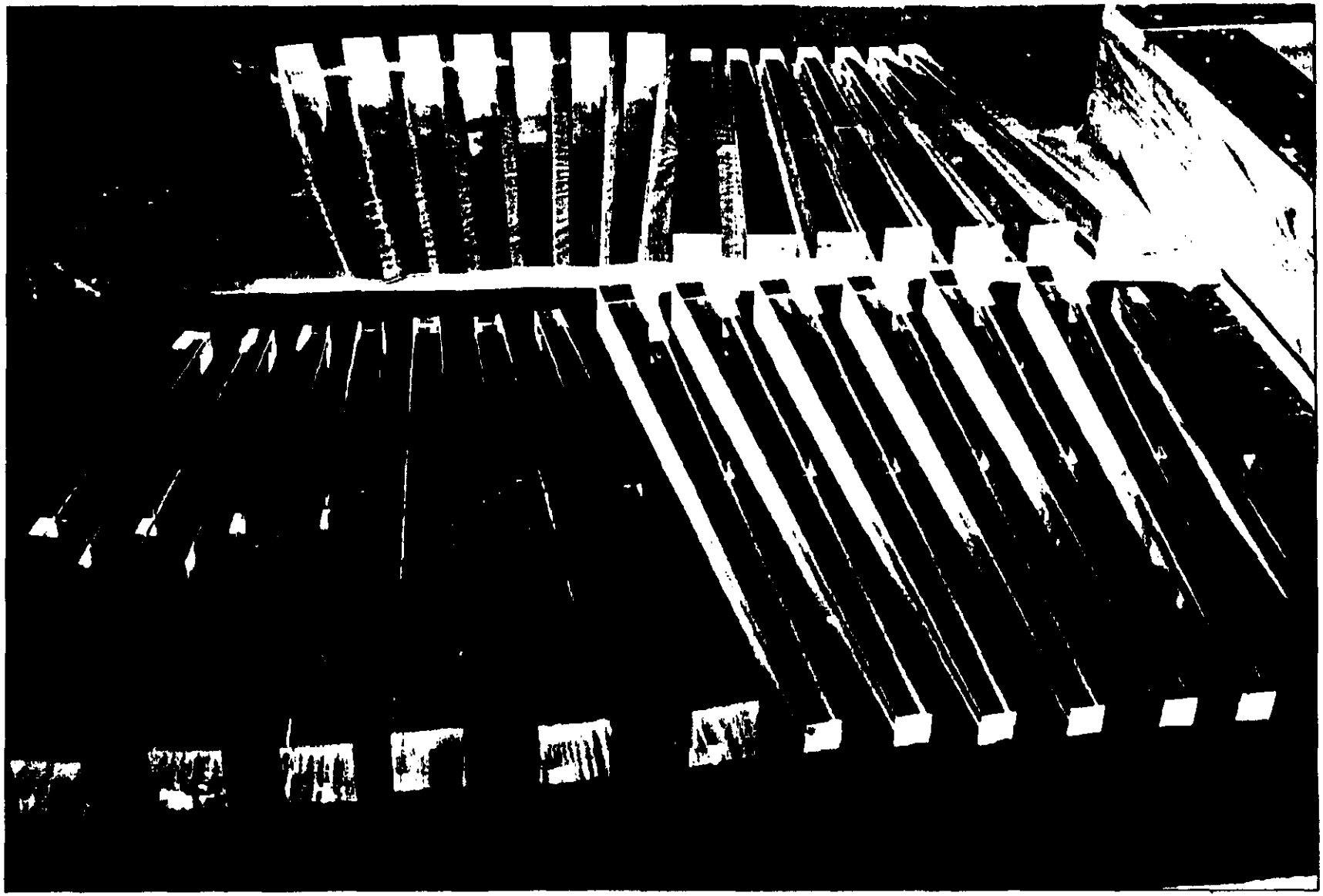
EFFECTS TO BE INCLUDED

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

Y. Kamyshkov

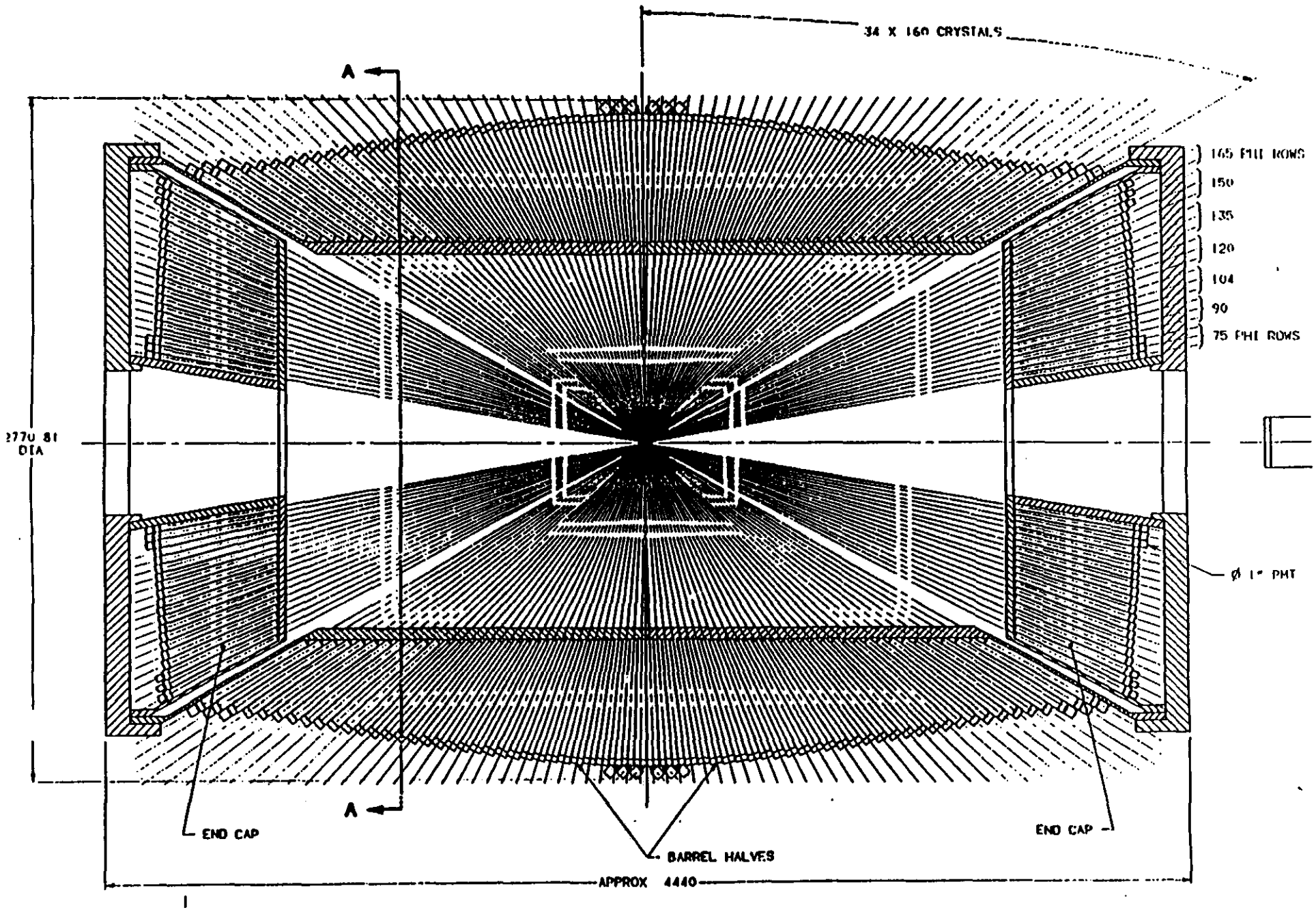
BaF_2 CALIBRATION

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



BaF_2 EM CALORIMETER
12/91 BEAM TEST

- CALORIMETER RESOLUTION: BaF_2-SPECTROMETER DIFFERENCE
  - Resolution 20×20 mm^2: 1.0%
  - Instrumental Contributions
    - * Spectrometer Resol'n: $0.5 \pm 0.2\%$
    - * Pedestal Diff. Linearity: 0.4%
  - BaF_2 Matrix Resolution (at 68 GeV): $0.77\ (+0.12 - 0.18)\%$
  - Further Contribution (Not Subtracted): Crystal Non-Uniformity: $0.5 \pm 0.1\%$
  - Possible Calorimeter Resolution: $0.6 \pm 0.2\%$


34 X 160 CRYSTALS
A
A
165 PHI ROWS
150
135
120
104
90
75 PHI ROWS
2770.81
DIA
Ø 1" PMT
END CAP
END CAP
BARREL HALVES
APPROX 4440

GEM Executive Committee requirements to BaF2 and LAr-Kr technologies

The Executive Committee at the meeting Feb. 20th has reviewed the status of e-m calorimetry R&D Programs and has formulated the list of requirements for each technology which should be met before the management of the Collaboration will proceed with the choice of one of the options. Our plan is to make the choice before the end of August 92, and preferably earlier.
Response to the requirements must be reported to Collaboration management by the specified date or earlier, in order to allow proper consideration.
It was noted by the Executive Committee that the BaF2 technology has a lower probability of success in its R&D Program, because of possible radiation damage and other effects which can destroy the small constant term in energy resolution.

A. Requirements for BaF2 technology :

1. Demonstrate substantial improvement in radiation resistance of large BaF2 crystals (20-25 cm long) towards the GEM specifications - reach absorbtion length of at least >60 cm at 220 nm after 1MRad irradiation with photons, and if possible high energy hadrons. Present a detailed plan to obtain final GEM quality crystals, along with evidence of manufacturability and cost, including work required to prepare crystals after delivery.

   by August 1, 1992

2. As proposed by the expert panel, produce small radiation-hard crystals to demonstrate there are no fundamental limitations in making rad hard BaF2 crystals. (eg. absorbtion length >= 95 cm at 220 nm after 1 MRad)

   by August 1, 1992

3. Address in detail questions of preradiation, wrapping, residual non-uniformity, etc in crystals we can practicably expect to manufacture. Cosmic ray transverse measurements in produced crystals could provide useful data. Provide detailed practical plan for calibration of BaF2 system in-situ :describe calibration strategy, RFQ layout, required calibration time for each proposed technique to achieve necessary accuracy.

   by July 1, 1992

4. Show by MC and by lab.tests that the following effects do not destroy the resolution of the BaF2 system (maximum tolerable constant term is 0.6%) :

   - residual non-uniformity (as installed);
   - non-uniformity developed by possible further radiation damage of "saturated" crystals and/or by possible annealing;
     (note - the expert panel and executive committee are not convinced of the proposal to preradiate the crystals)
   - accuracy of intercalibration (see point 3);
   - short term instabilities of readout system;
   - linearity, linearity calibration and dynamic range of readout system.

   by July 1,1992

B. Requirements for LAr-Kr technology :

1. Demonstrate by beam tests stochastic term in resolution for non-projective geometry <= 7%/sqrt(E). Determine angular dependence of this resolution.
   by August 1,1992

2. Produce detailed mechanical design/analysis of e-m barrel and end caps with optimization of gap between barrel and end cap, wall thicknesses, etc.
   by July 1,1992

3. Demonstrate by MC simulations for realistic projective geometry and full angular range (between 90 and 5.7 degrees) the resolution
   <= 7%/sqrt(E) + 0.4%
   and physics consequences of the gap between barrel and end cap, wall thicknesses, etc.
   by July 1, 1992

DECISION:

In August, a decision will be made between the two technologies based on our best judgement of the expected performance of each technology, balanced against the cost and risk involved in each. A primary choice will be made for our e-m calorimeter for the TDR. Depending on the status of open questions at the time of making the decision, a strategy will be developed for continuing the development of the second technology at a considerably lower level, while these outstanding issues are resolved for the primary option and to allow the proponents to smoothly finish their R&D program.

The final decision will be made by the spokesmen, after considering the evidence presented for each technology and receiving the advice of the Executive Committee.

Additional requirements for LAr-Kr technology :

(proposed by individual members of exec. committee and members of calorimeter group)

by the time of e-m decision

1. Show Higgs -> 2 gamma spectra (mass range 80-150 GeV) for realistic e-m LAr-Kr detector and background simulations.

2. Provide detailed practical plan for calibration of LAr-Kr detector in situ. Provide an evidence that electronic calibration is equivalent to the detector calibration with the required accuracy.

3. Provide experimental proof of radiation stability of LAr-Kr e-m system (for actually used materials).

4. Provide the results of the benchmark tests of LAr-Kr electronics which demonstarate required linearity, dynamic range, white and coherent noise in the real accordion system, cross talks and means of linearity calibration.

gem

γeμ

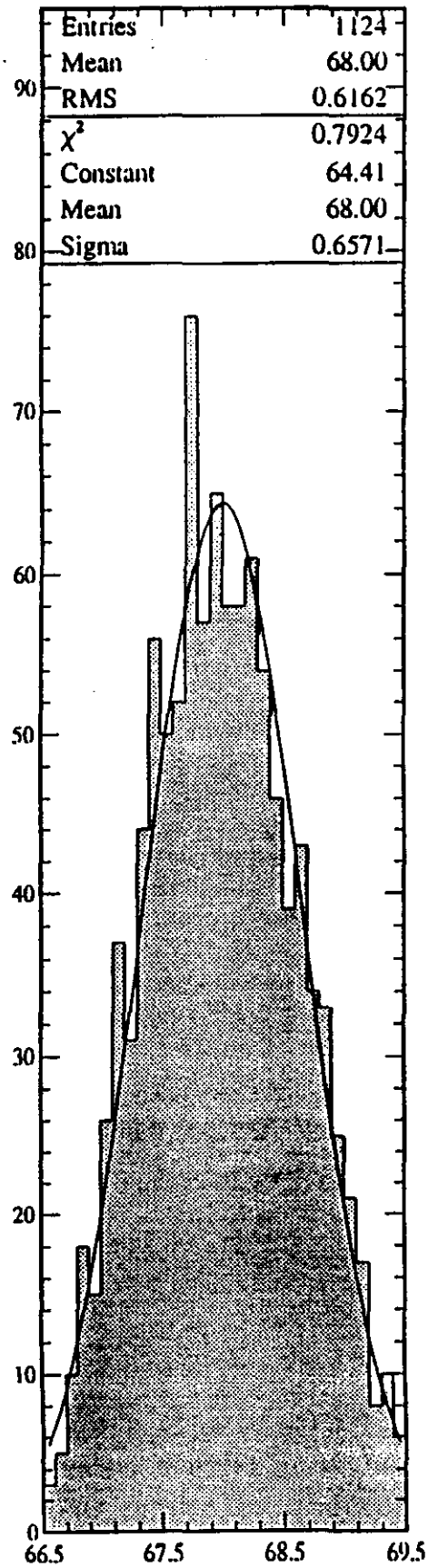
Presentation By:

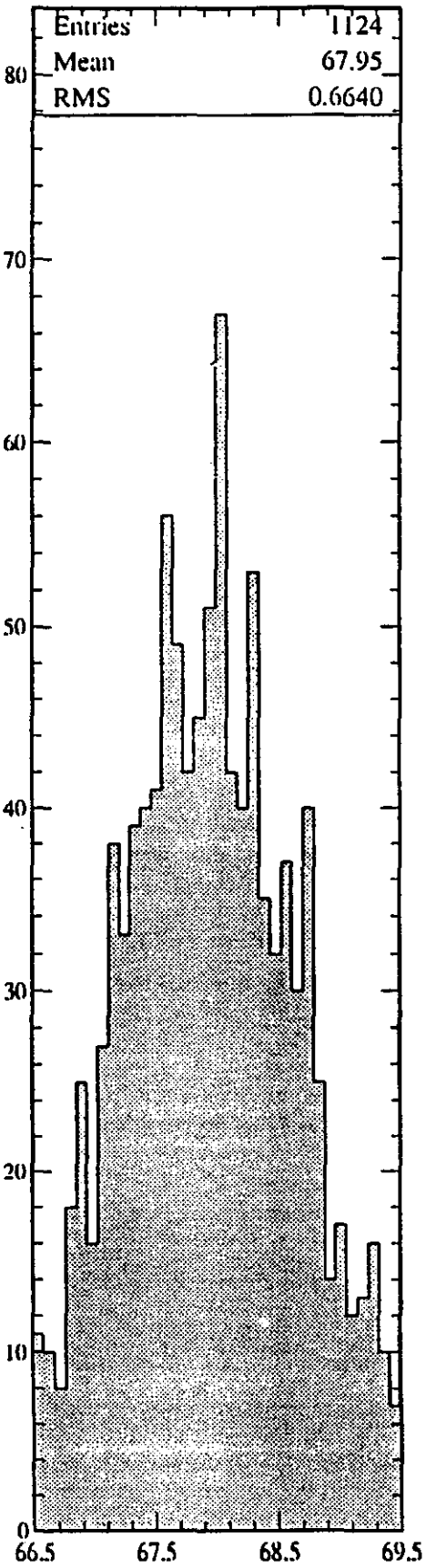
Jim Branson

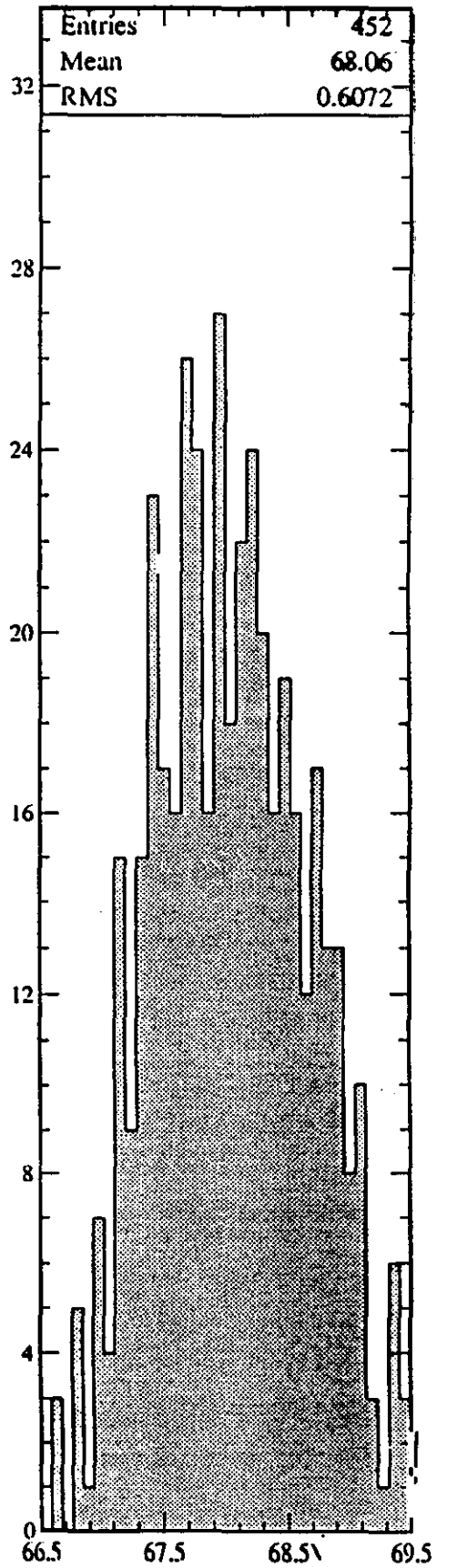
Jim Branson

Sumary

- First BaF_2 test beam was quite successful.
- Carried out entirely by GEM physicists at FNAL.
- We know how to improve things substantially.
- We will tune up a new matrix in cosmic ray stand and be fully ready for the next test.


Entries 1124
Mean 68.00
RMS 0.6162
χ^2 0.7924
Constant 64.41
Mean 68.00
Sigma 0.6571
Enerc (cog in 44)


Entries 1124
Mean 67.95
RMS 0.6640
Energ (cog in 44)

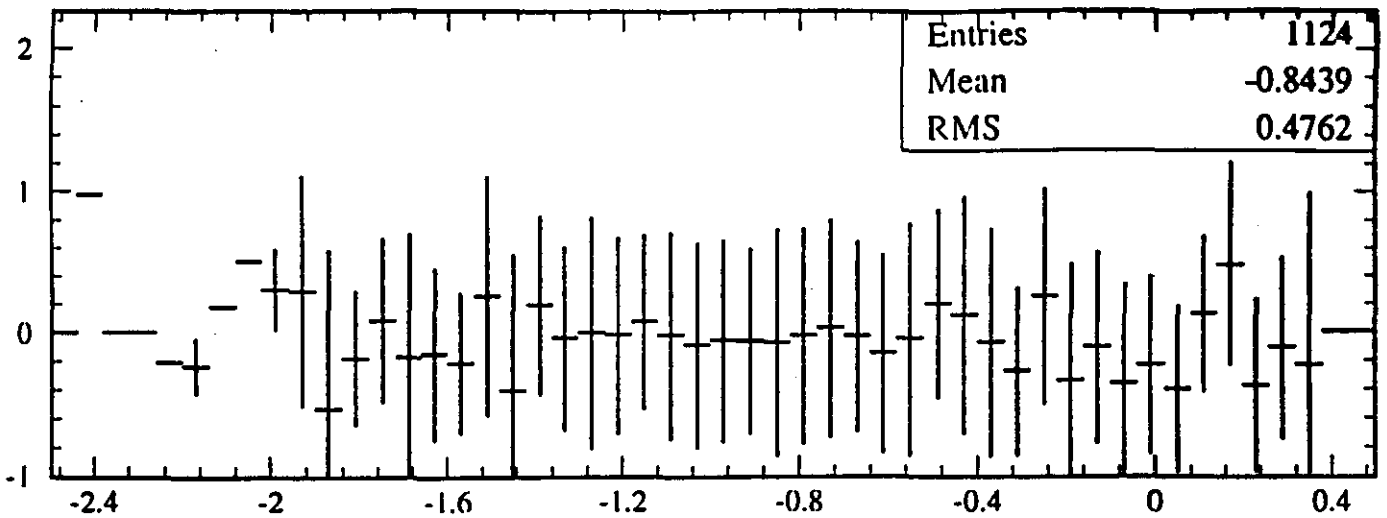

Entries 452
Mean 68.06
RMS 0.6072
corrected energy good yseg (cog in 44)

Subroutine ... to center computed energy distribution width = Sigma

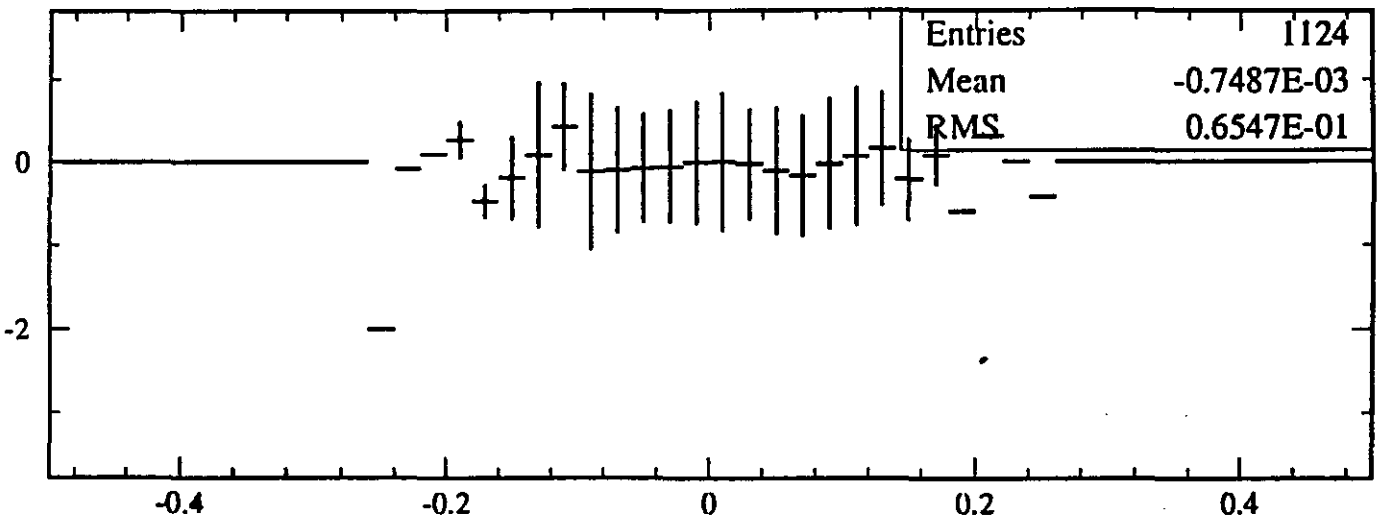
```
1
    ******************************************
    *                                        *
    * Function minimization by SUBROUTINE MFITGA *
    * Variable-metric method                 *
    * ID =        976  CHOPT = T             *
    *                                        *
    ******************************************
Convergence when estimated distance to minimum (EDM) .LT.   .10E-03

FCN=   9.217442     FROM MIGRAD    STATUS=FAILED       100 CALLS      101 TOTAL
                    EDM=   .72E+01    STRATEGY= 1      ERR MATRIX NOT POS-DEF

 EXT PARAMETER                 APPROXIMATE        STEP         FIRST
 NO.   NAME        VALUE          ERROR           SIZE       DERIVATIVE
  1   Constant     87.406         4.0317        .00000E+00    .59140E-01
  2   Mean         67.989         .57685E-02    .00000E+00    208.01
  3   Sigma        .25811         .85843E-02    .00000E+00   -16.806

CHISQUARE =  .7681E+00  NFFIT =   25

histogram average and rms    67.999      .252
1Enerc    (cog in 44)

NBOOK     ID =       976                                    DATE  29/02/92            NO =   2

     102.5
     100                    -
      97.5                  I
      95                    I
      92.5                  I
      90                    I
      87.5                 *I
      85                    *
      82.5                  I
      80                   - I
      77.5                 * I
      75                   I-I
      72.5                 I I*
      70                   I  I
      67.5                 I  I
      65                   I  I
      62.5                 I  I
      60                  -I  I
      57.5                 *  I
      55                  I   I
      52.5                I   I*
      50                  I   I-
      47.5                I    I
      45                  I    I
      42.5                I    I
      40                 -I    I
      37.5               *     I
      35                 I     I*
      32.5               I     I
      30                 I     I-
      27.5               I      I
      25                 I      I-
      22.5              *I       I
      20                 I       *
      17.5              -I       I
      15                I        I
      12.5              I        I
      10               *I        I*
       7.5             I          I
       5              *I          I*
       2.5     ******** I          I********

CHANNELS  10   0        1         2         3
           1   1234567890123456789012345678 90

CONTENTS 100                 1
          10            114587074321
           1.         2 06080301904031

LOW-EDGE  10   66666666666666666666666666666
           1.  66666777777777788888888899999
           0   56789012345678901234567890123 4

* ENTRIES =        568      * ALL CHANNELS =  .5670E+03      * UNDERFLOW =  .0000E+00      * OVERFLOW =  .1000E+01
* BIN WID =  .1000E+00      * MEAN VALUE   =  .6800E+02      * R . M . S =  .2519E+00      * NEQUIVAL =  .5670E+03
* CHISQUAR  =   .9218E+01
```

0.4%

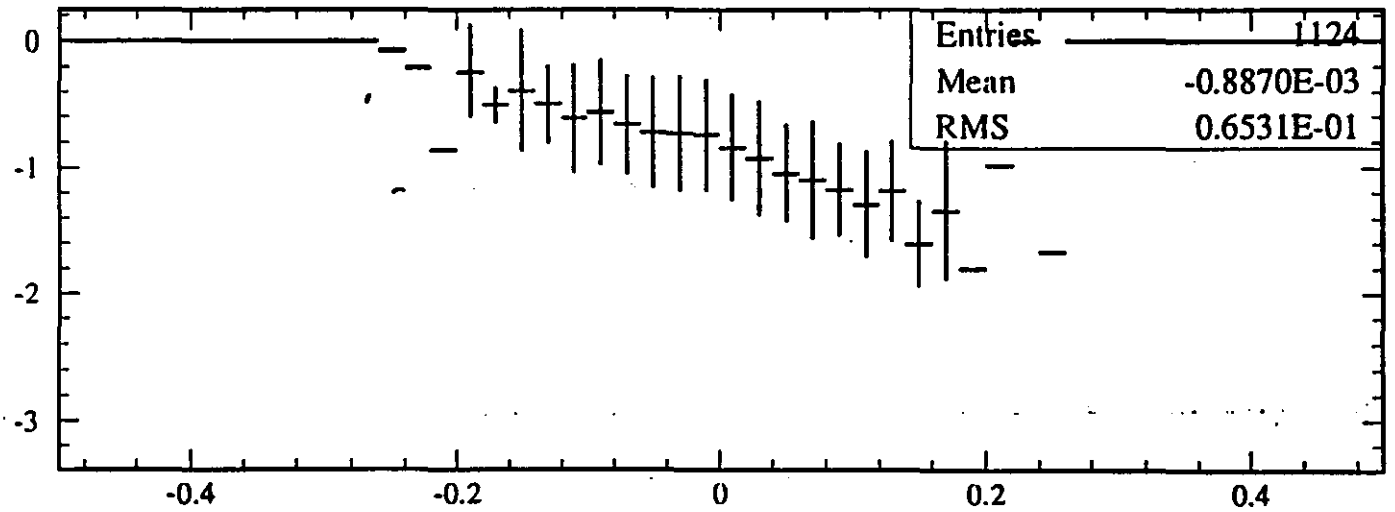
Pedestal events treated like data. (68 GeV shift)



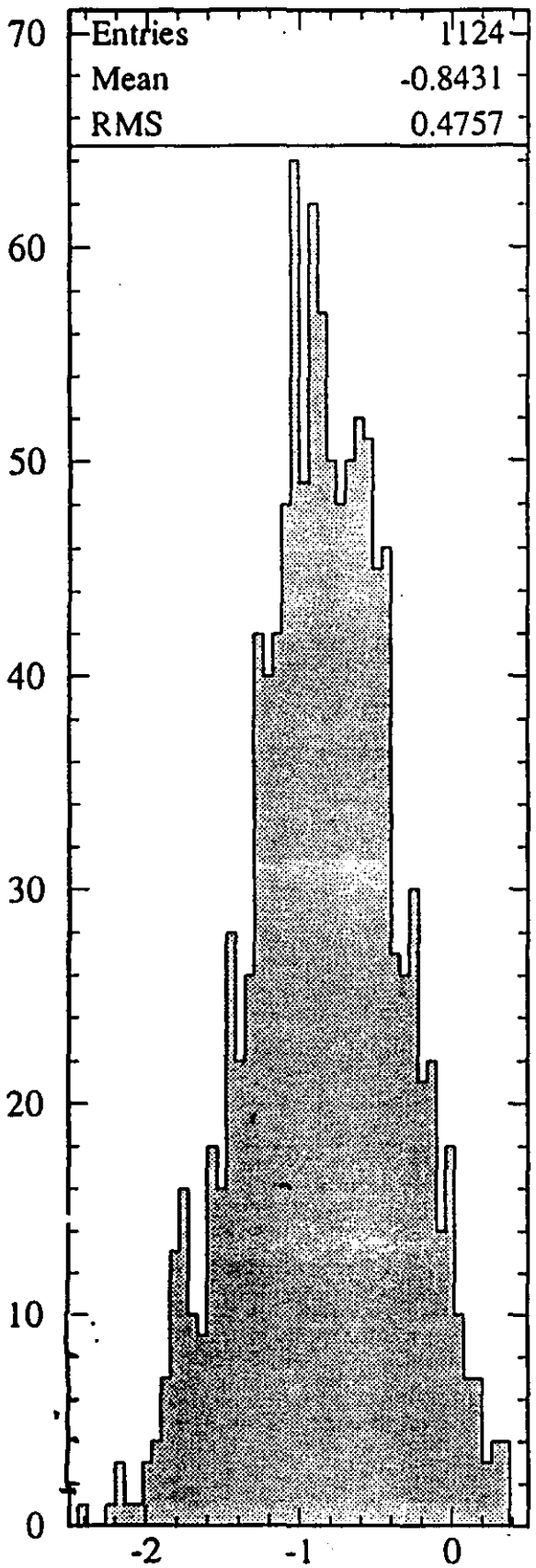
ave cor energy error (cog in 44) vs. Eouter



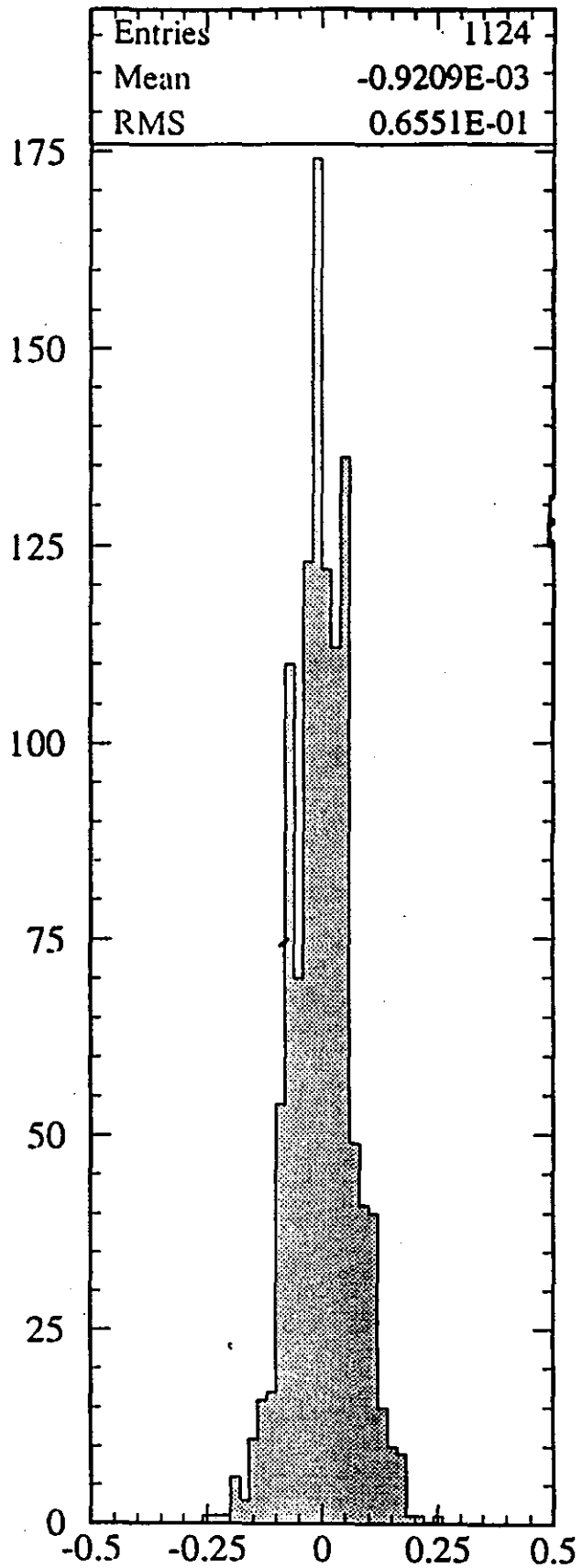
ave cor energy error (cog in 44) vs. sumdum



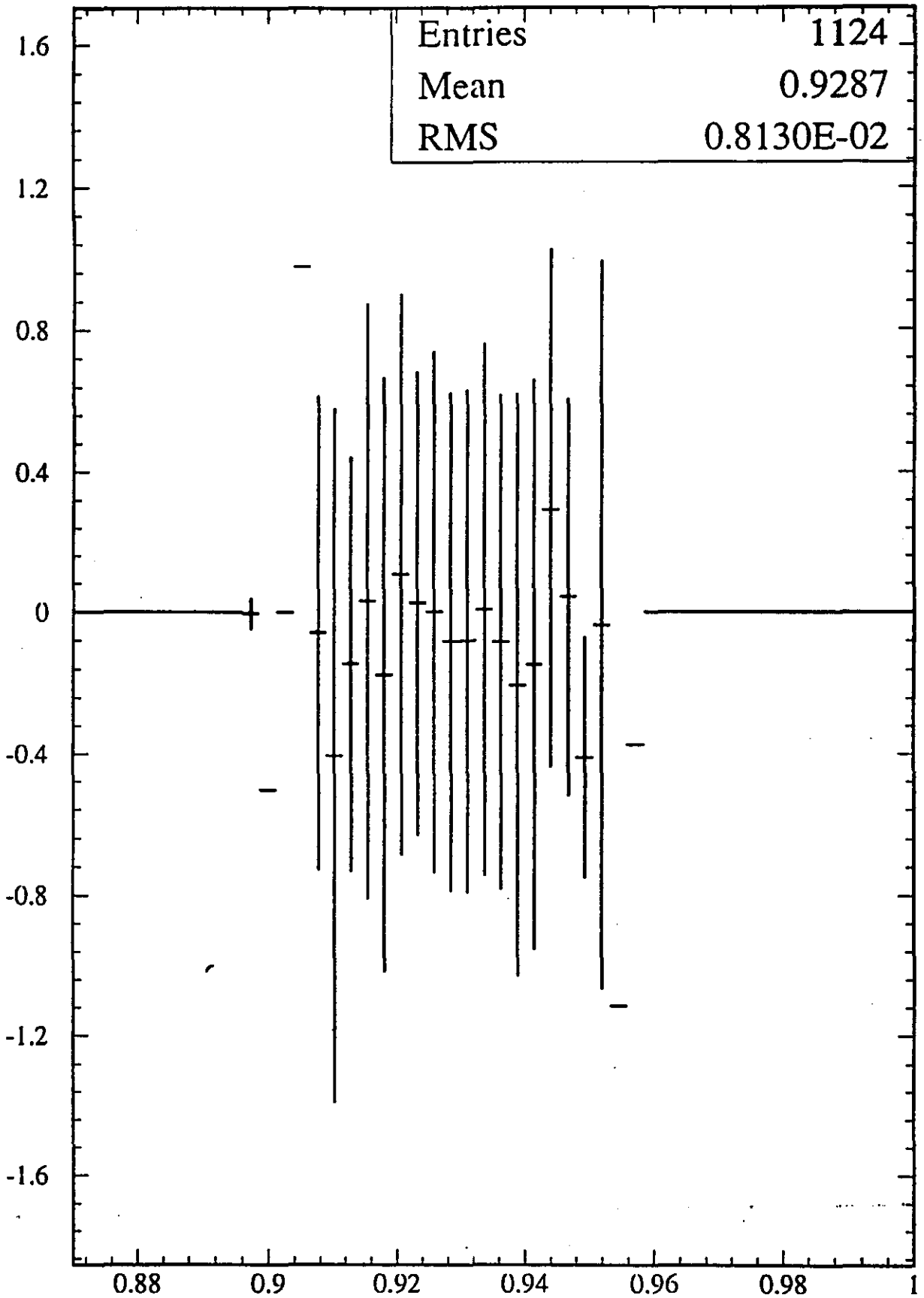
ave Eouter (cog in 44) vs. sumdum



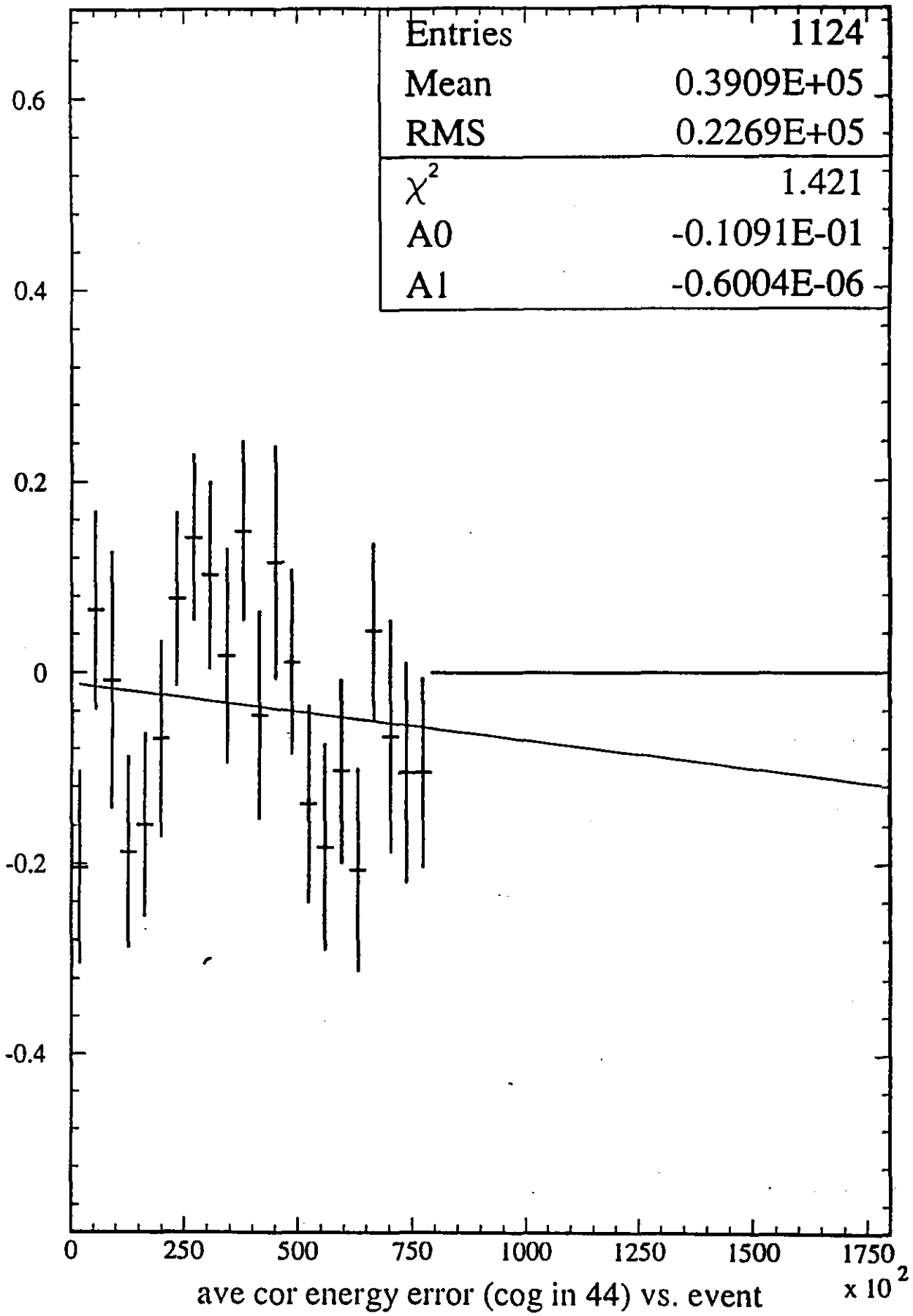
outer row

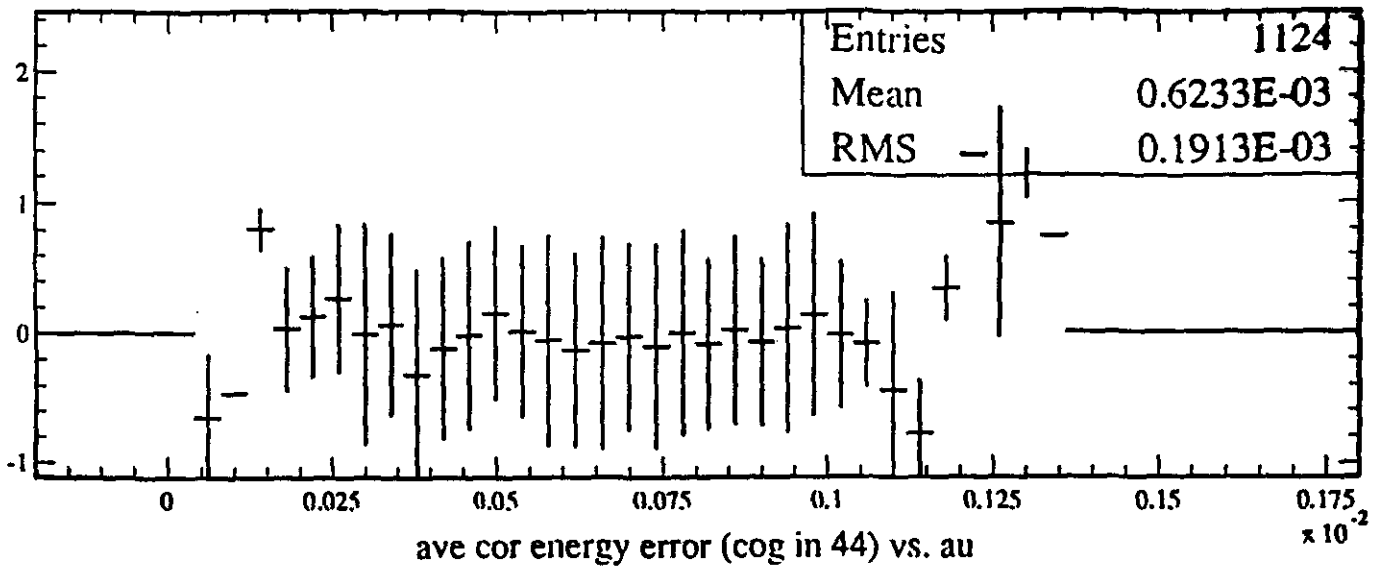


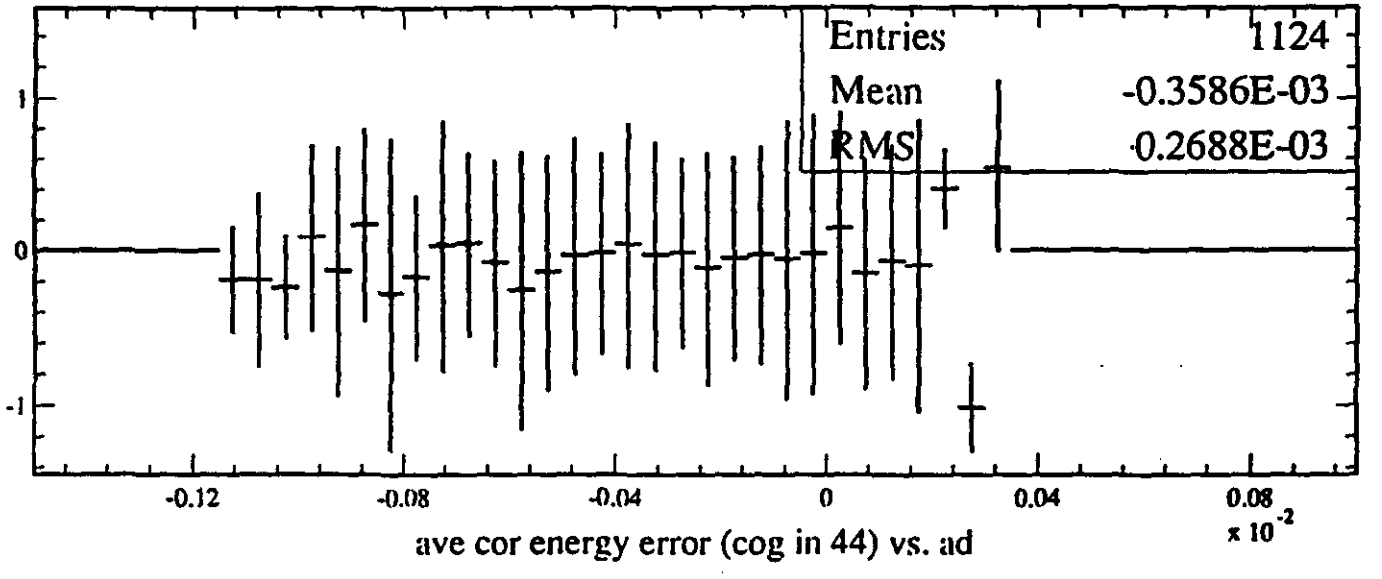
3 dummy counters

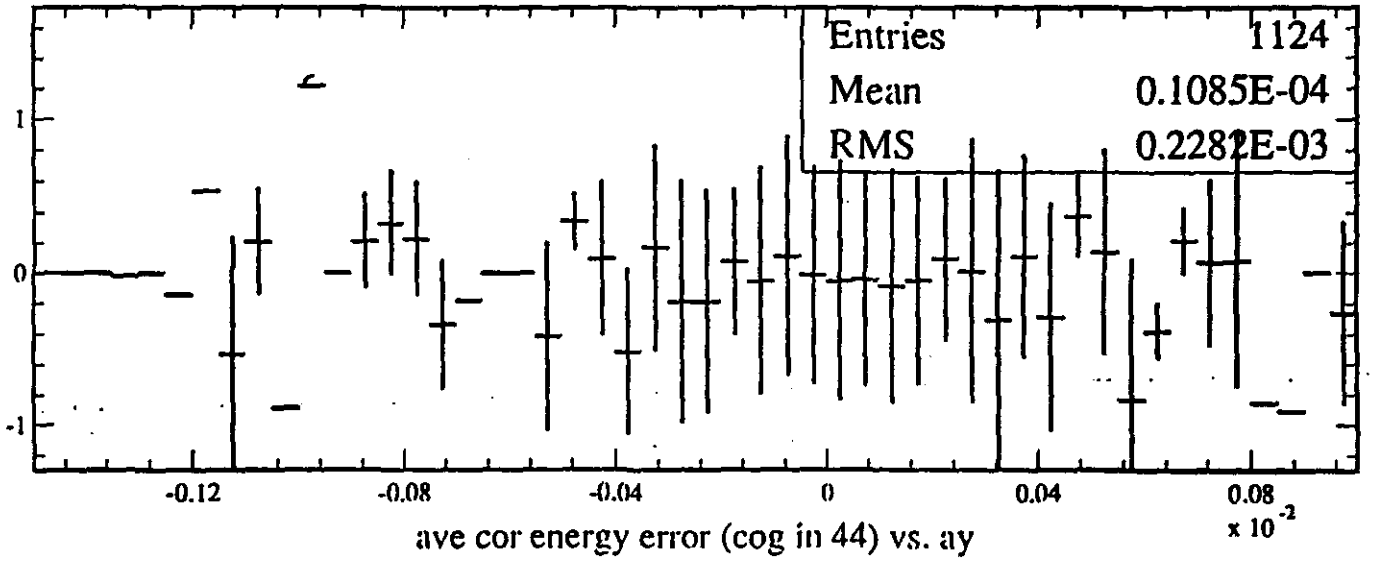


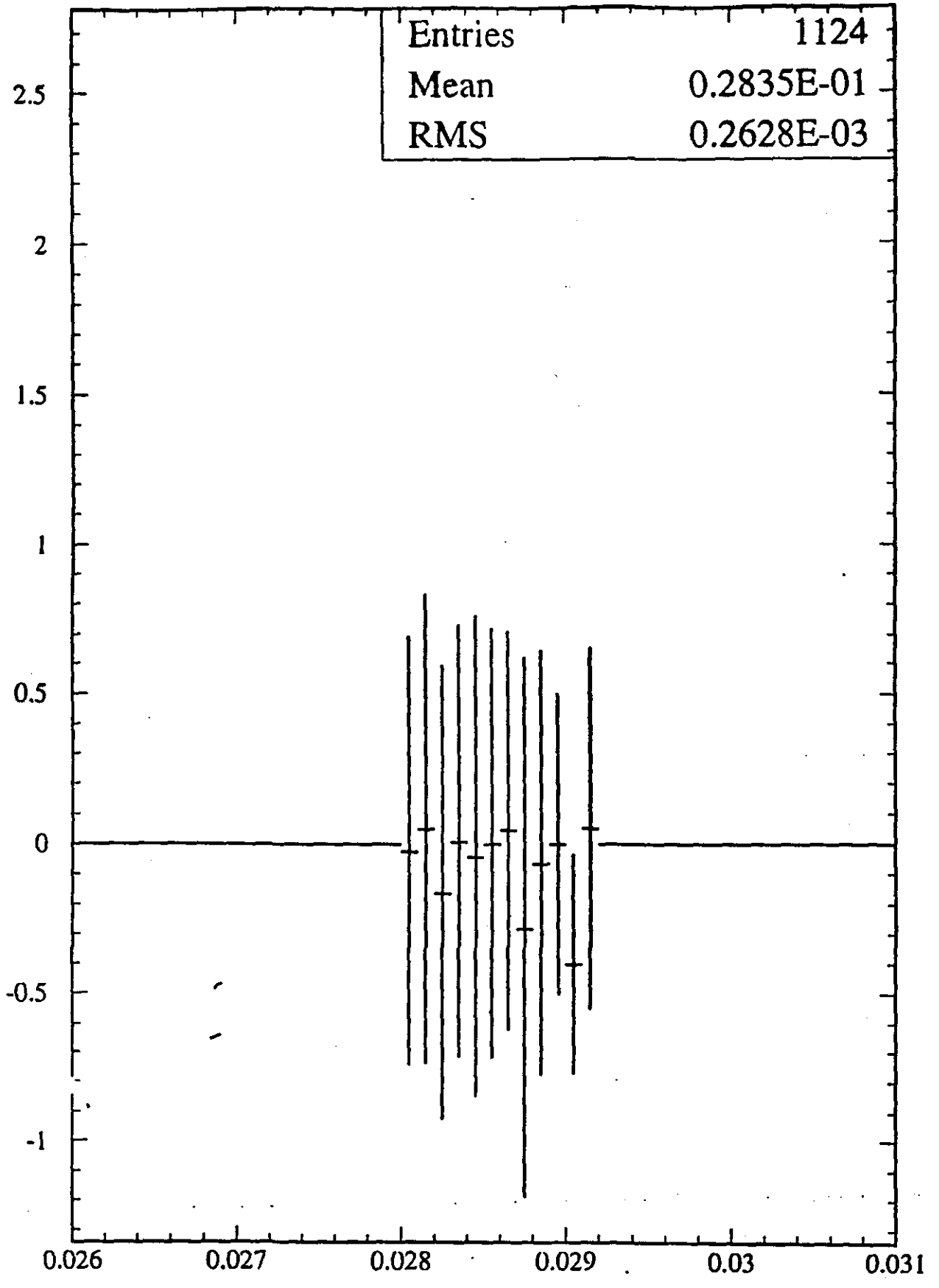
ave cor energy error (cog in 44) vs. s33/s55


Entries 1124
Mean 0.3909E+05
RMS 0.2269E+05
χ² 1.421
A0 -0.1091E-01
A1 -0.6004E-06
0.6
0.4
0.2
0
-0.2
-0.4
0
250
500
750
1000
1250
1500
1750
x 10²
ave cor energy error (cog in 44) vs. event


Entries 1124
Mean 0.6233E-03
RMS 0.1913E-03
2
1
0
-1
0
0.025
0.05
0.075
0.1
0.125
0.15
0.175
x 10^-2
ave cor energy error (cog in 44) vs. au

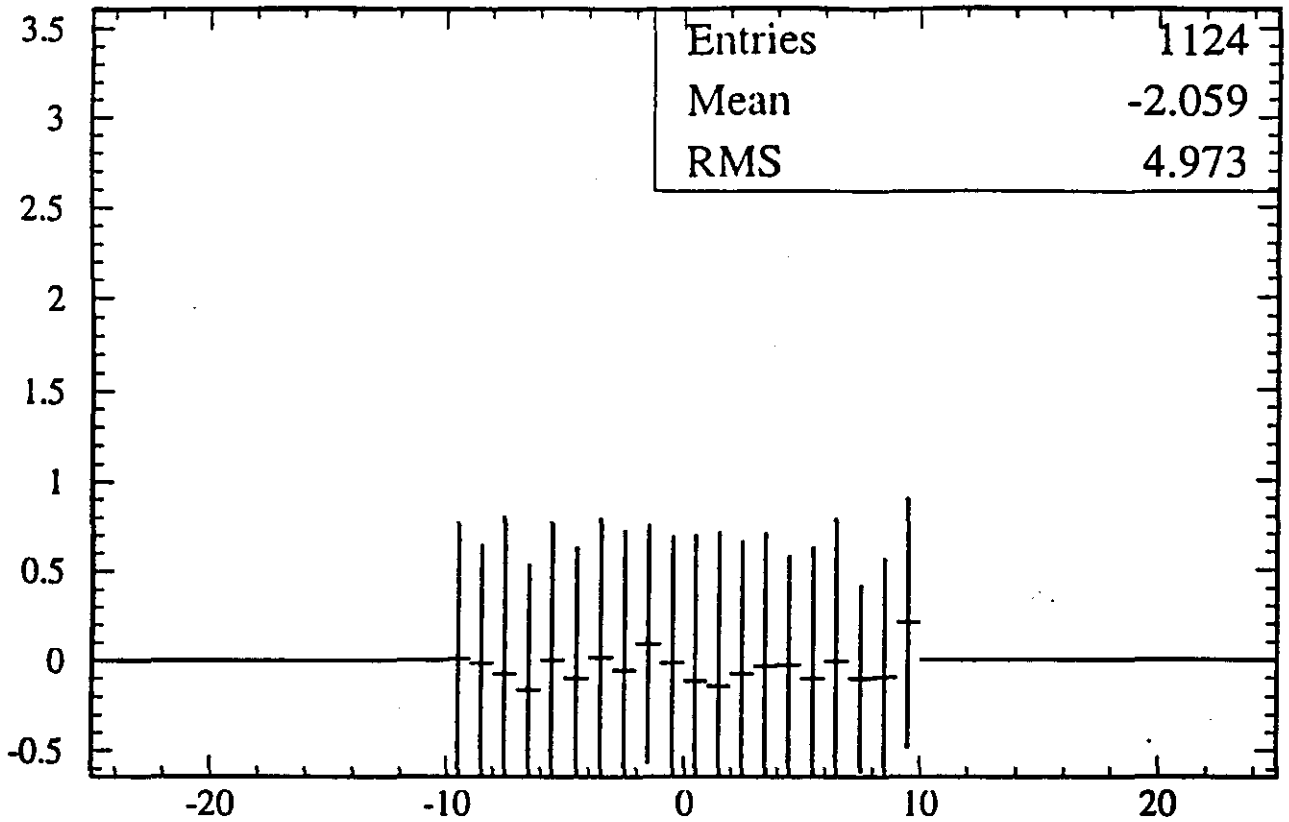

Entries 1124
Mean -0.3586E-03
RMS 0.2688E-03
1
0
-1
-0.12
-0.08
-0.04
0
0.04
0.08
x 10^-2
ave cor energy error (cog in 44) vs. ad


Entries 1124
Mean 0.1085E-04
RMS 0.2282E-03
1
0
-1
-0.12
-0.08
-0.04
0
0.04
0.08
x 10^-2
ave cor energy error (cog in 44) vs. ay

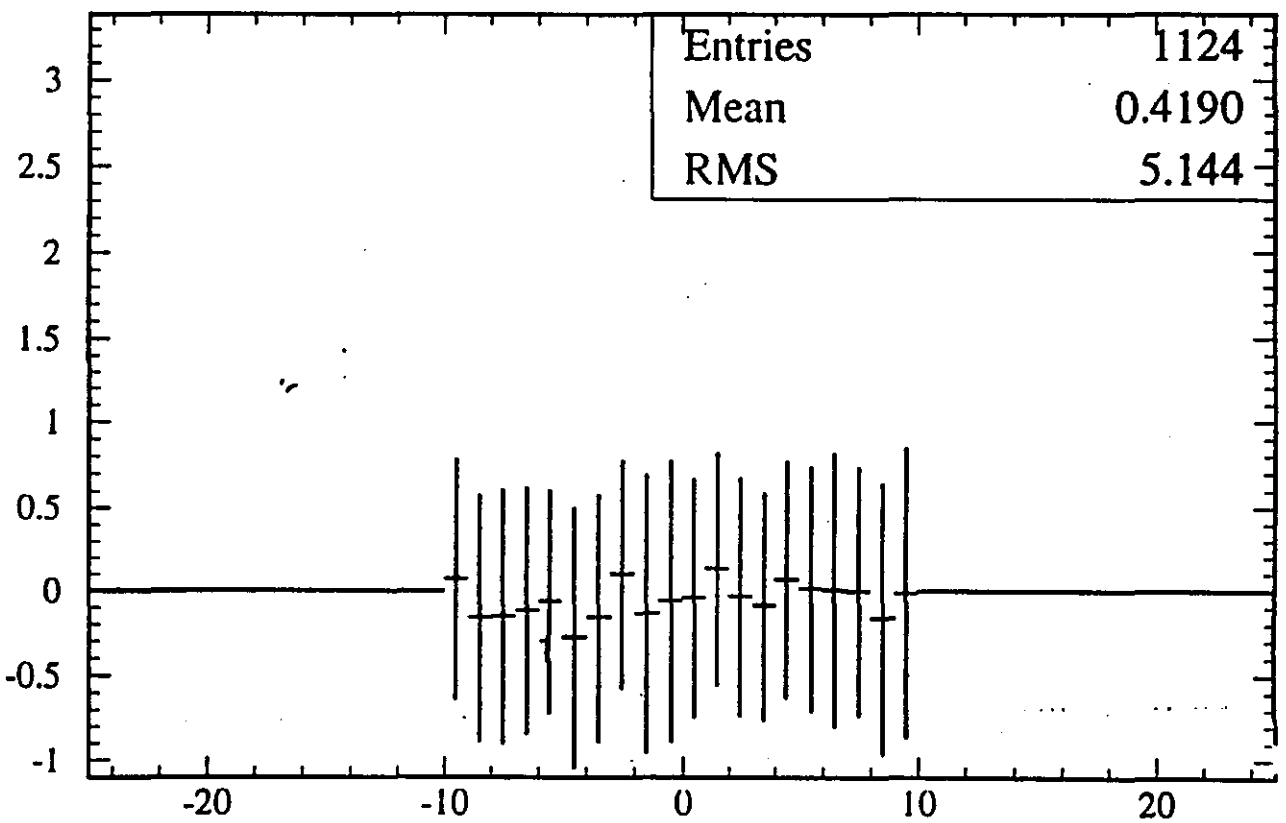


ave cor energy error (cog in 44) vs. bend

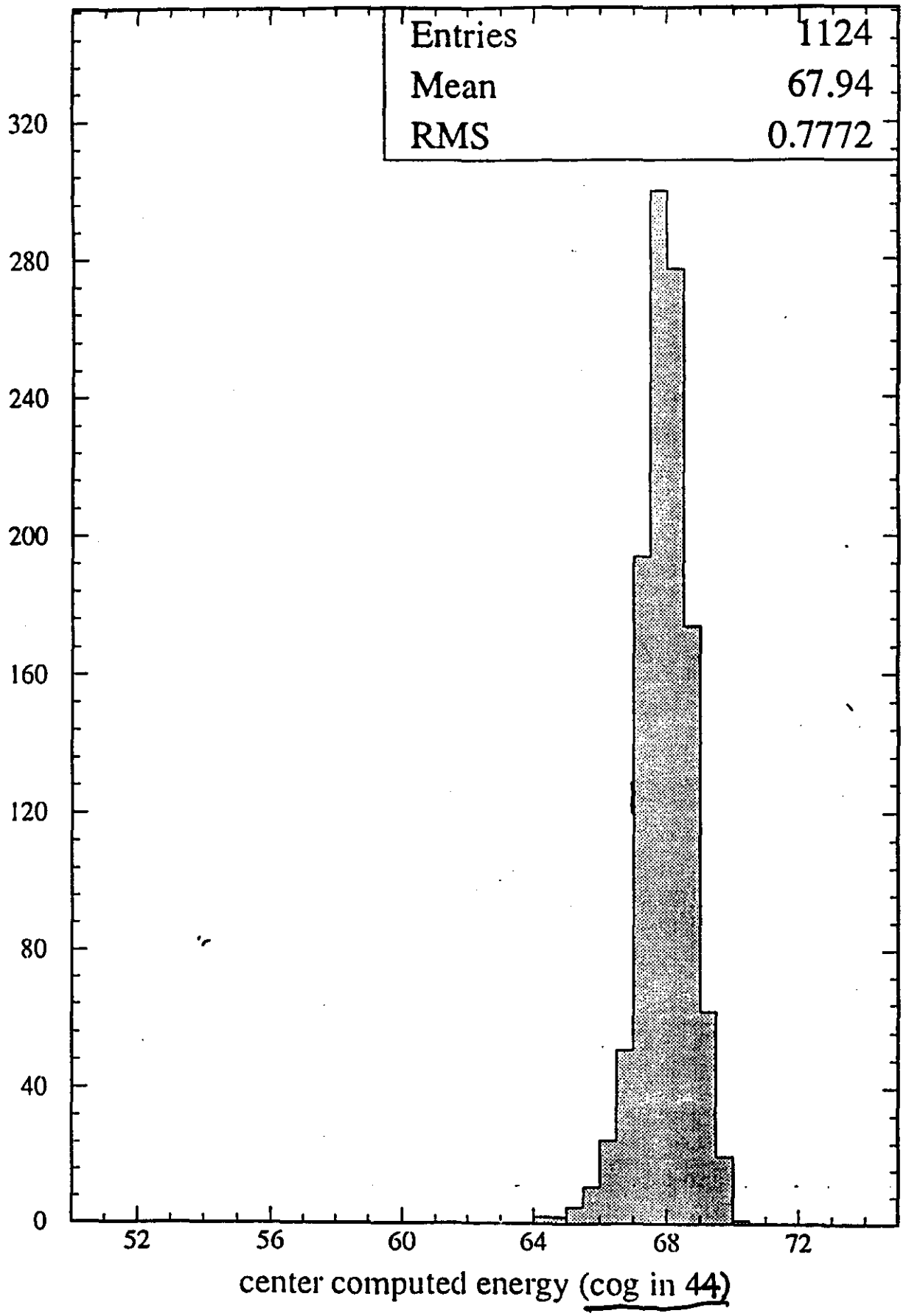
no (sum1x1/sum3x3) correction
no position correction

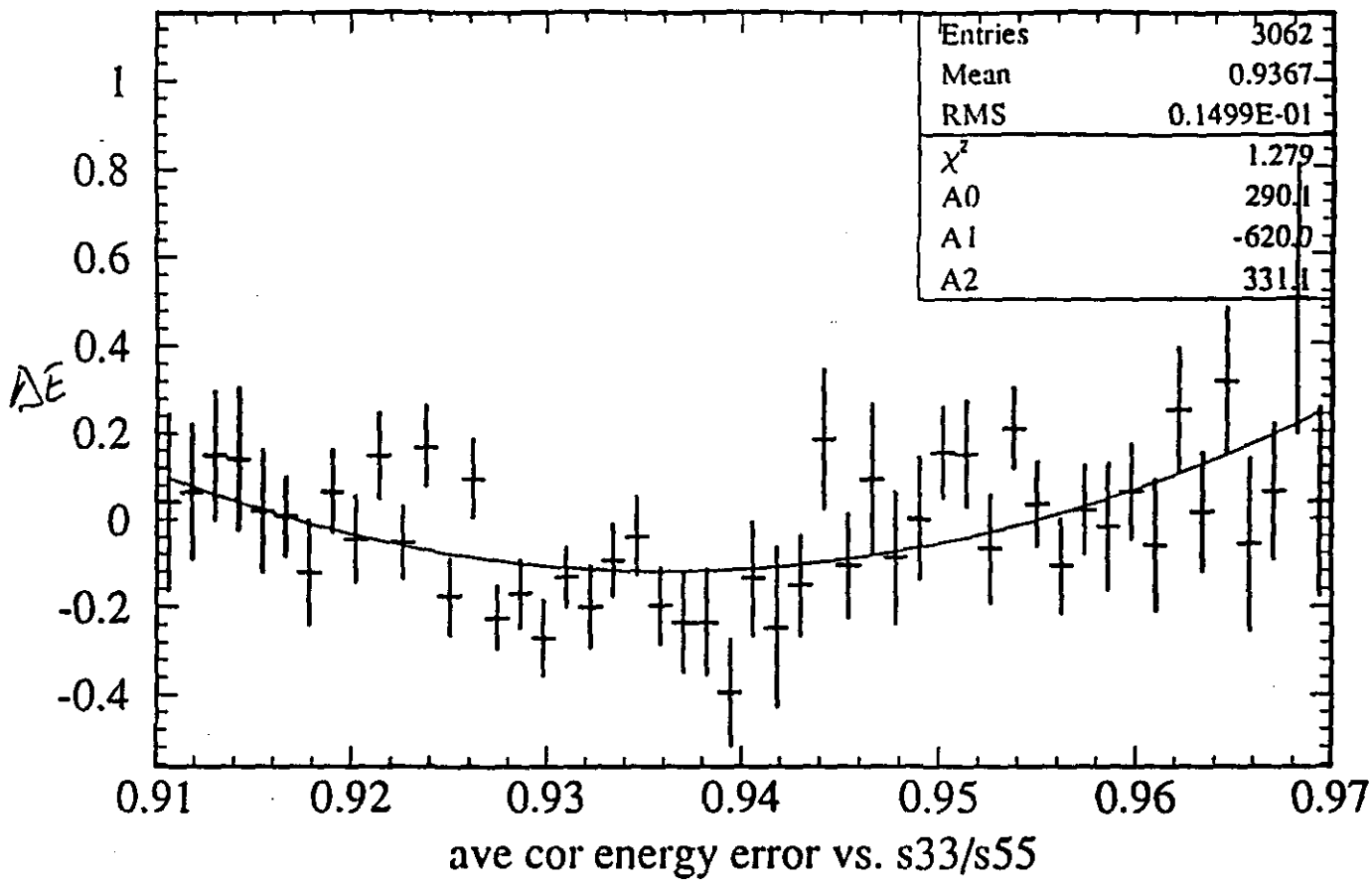


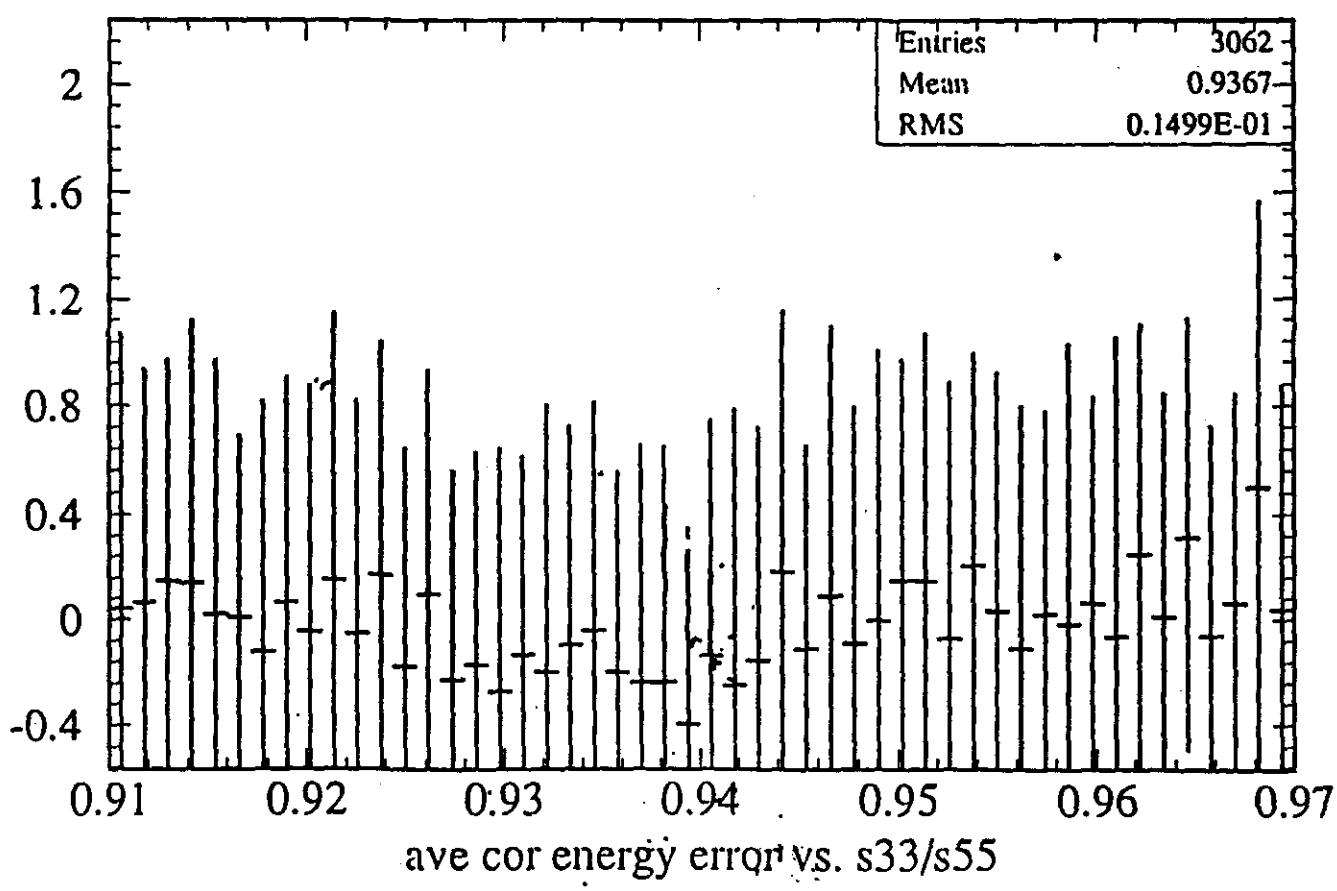
ave cor energy error (cog in 44) vs. cogx

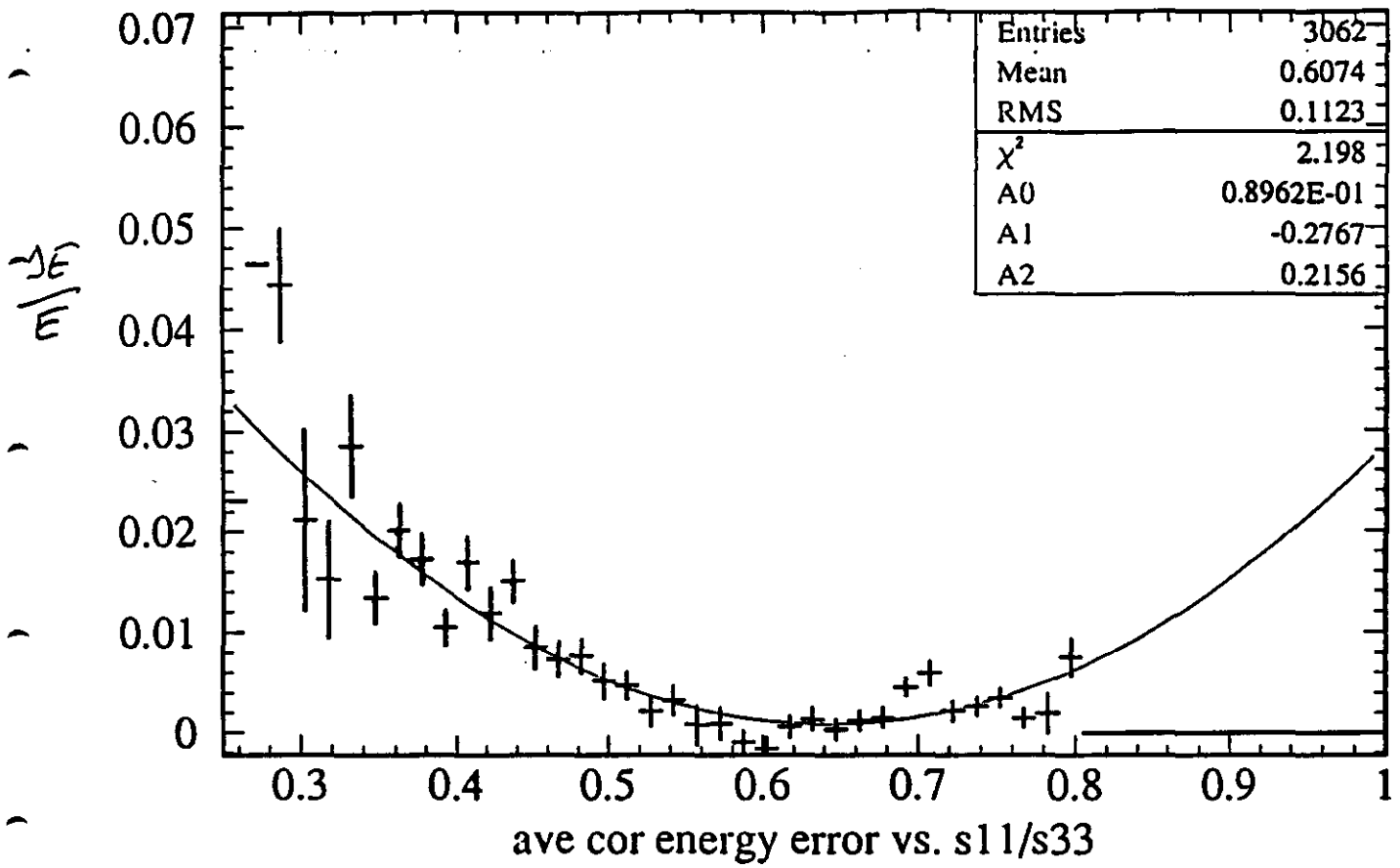


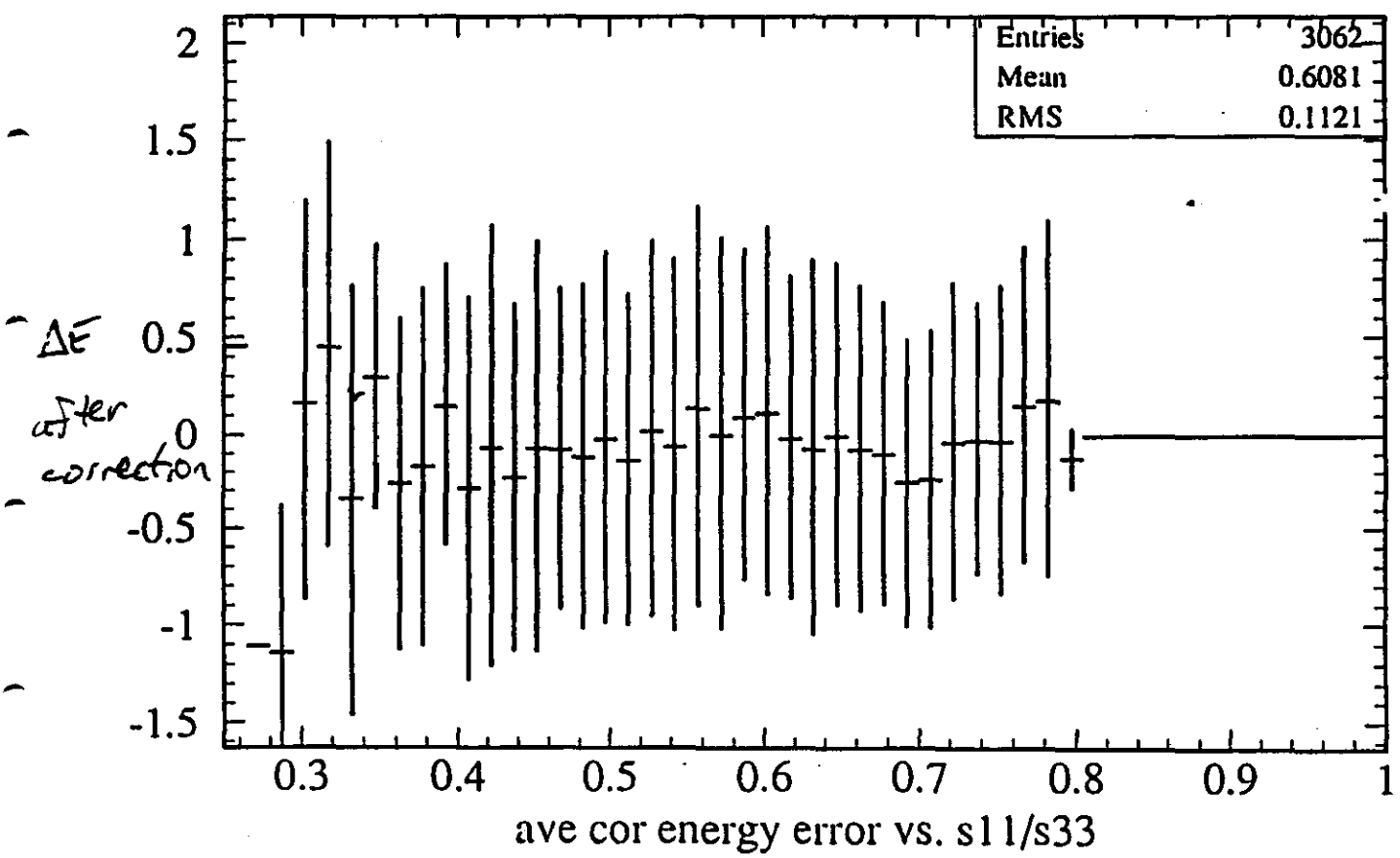
ave cor energy error (cog in 44) vs. cogy

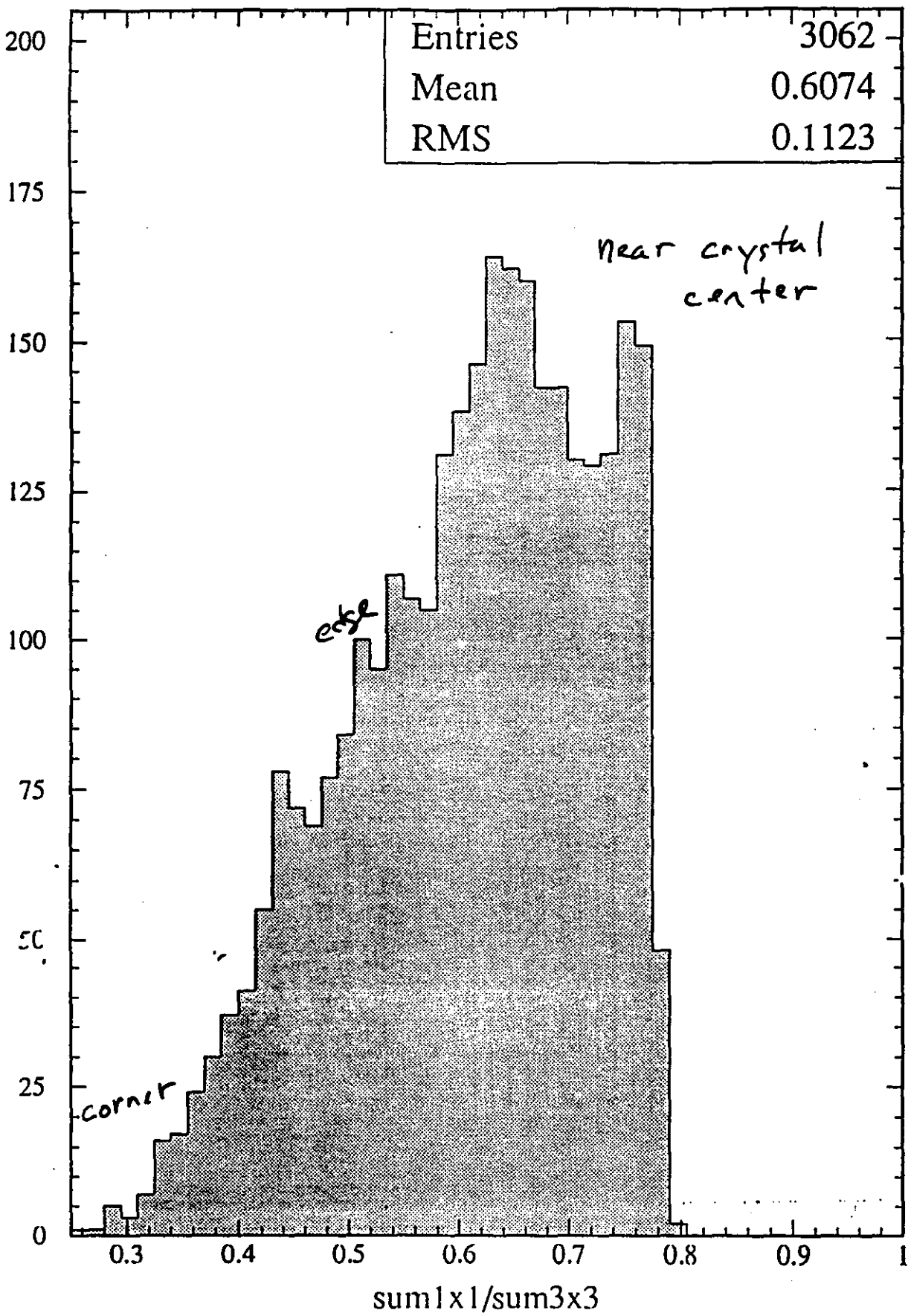

Entries 1124
Mean 67.94
RMS 0.7772
320
280
240
200
160
120
80
40
0
52
56
60
64
68
72
center computed energy (cog in 44)

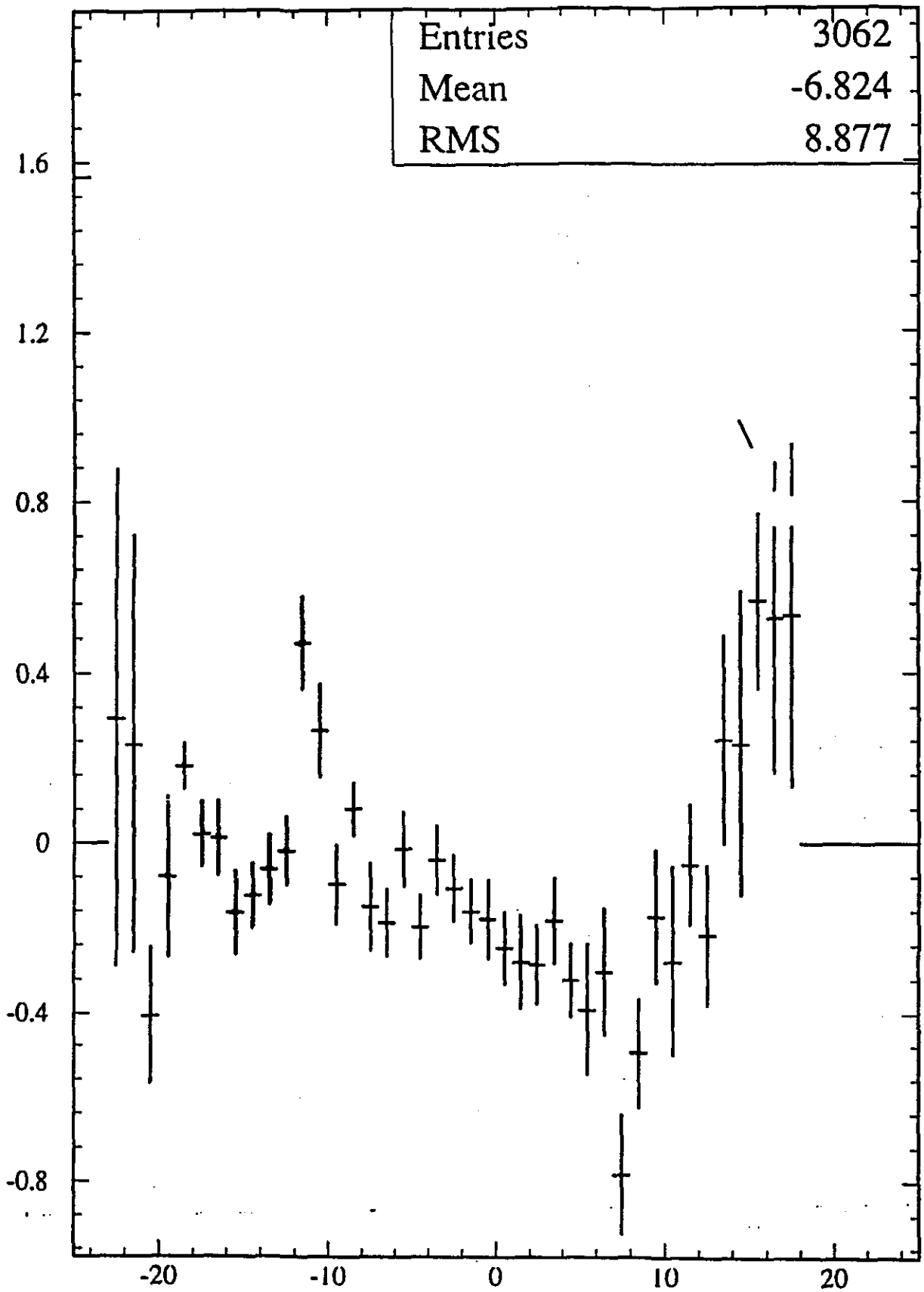

Entries 3062
Mean 0.9367
RMS 0.1499E-01
χ^2 1.279
A0 290.1
A1 -620.0
A2 331.1
ΔE
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0.91
0.92
0.93
0.94
0.95
0.96
0.97
ave cor energy error vs. s33/s55


Entries 3062
Mean 0.9367
RMS 0.1499E-01
2
1.6
1.2
0.8
0.4
0
-0.4
0.91
0.92
0.93
0.94
0.95
0.96
0.97
ave cor energy error vs. s33/s55

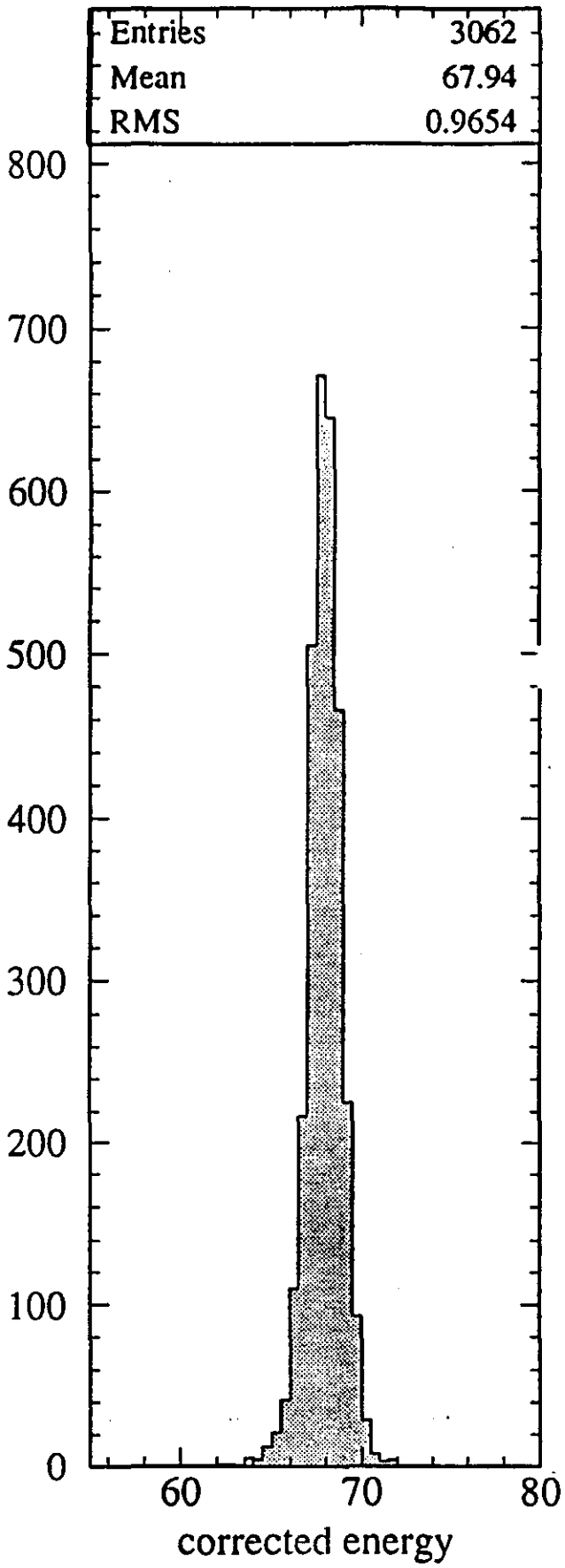

Entries 3062
Mean 0.6074
RMS 0.1123
χ^2 2.198
A0 0.8962E-01
A1 -0.2767
A2 0.2156
$\frac{\Delta E}{E}$
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ave cor energy error vs. s11/s33

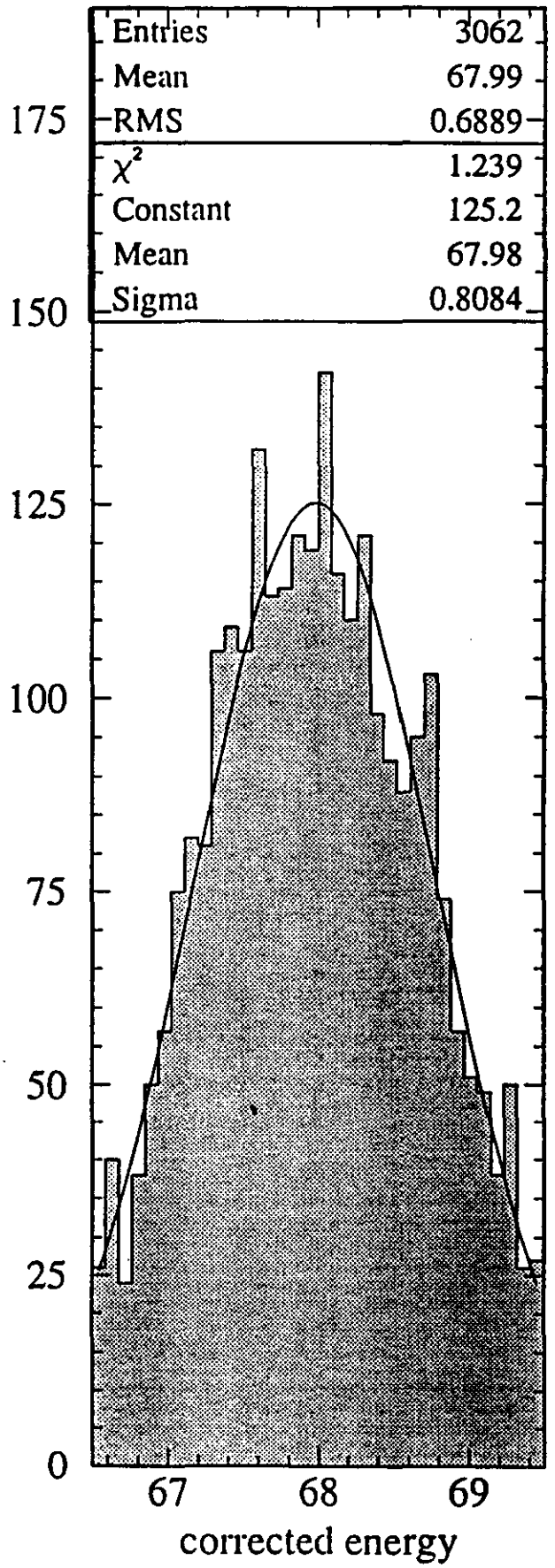

Entries 3062
Mean 0.6081
RMS 0.1121
ΔE after correction
2
1.5
1
0.5
0
-0.5
-1
-1.5
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ave cor energy error vs. s11/s33


Entries 3062
Mean 0.6074
RMS 0.1123
near crystal center
edge
corner
200
175
150
125
100
75
50
25
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
sum1x1/sum3x3



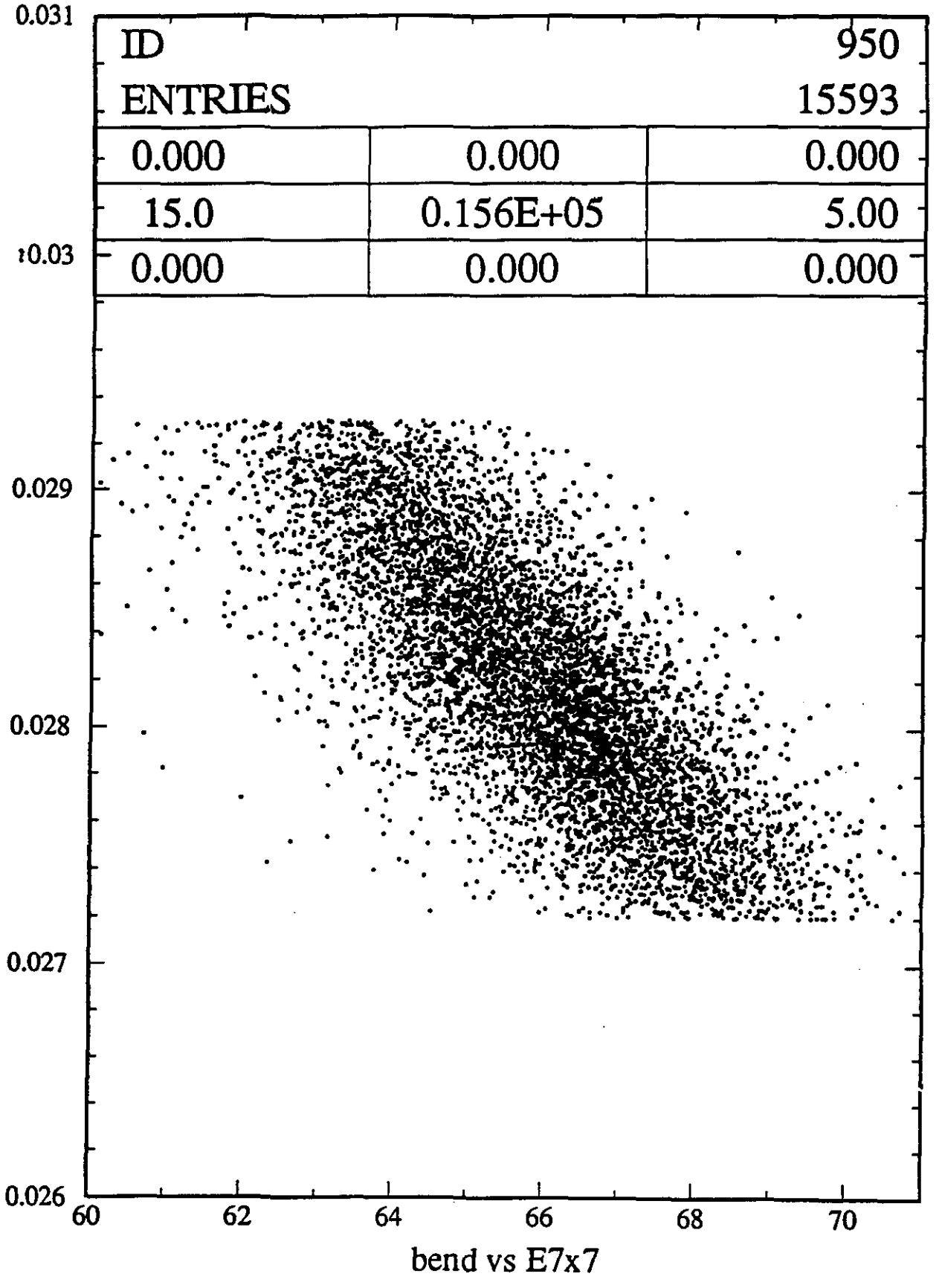
ave uncor. energy error vs. cogx

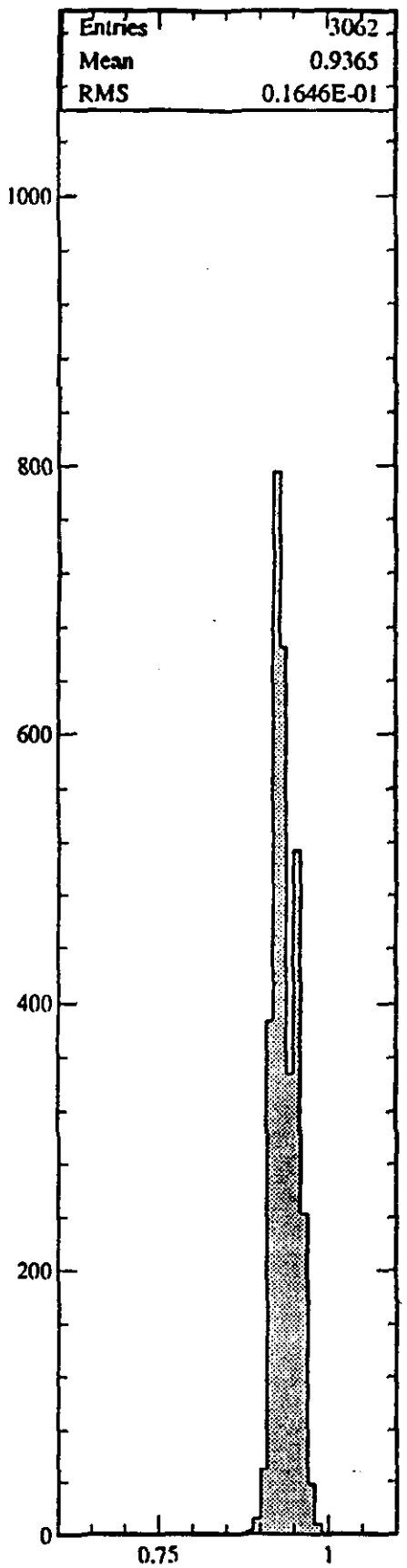




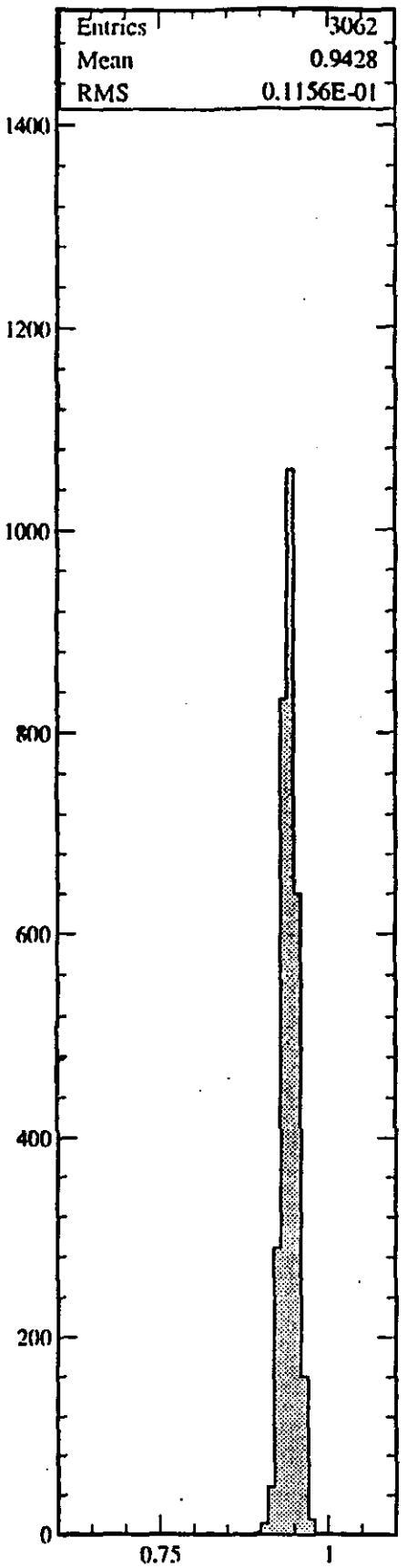
1.2% in full beam spot.

(we can improve)

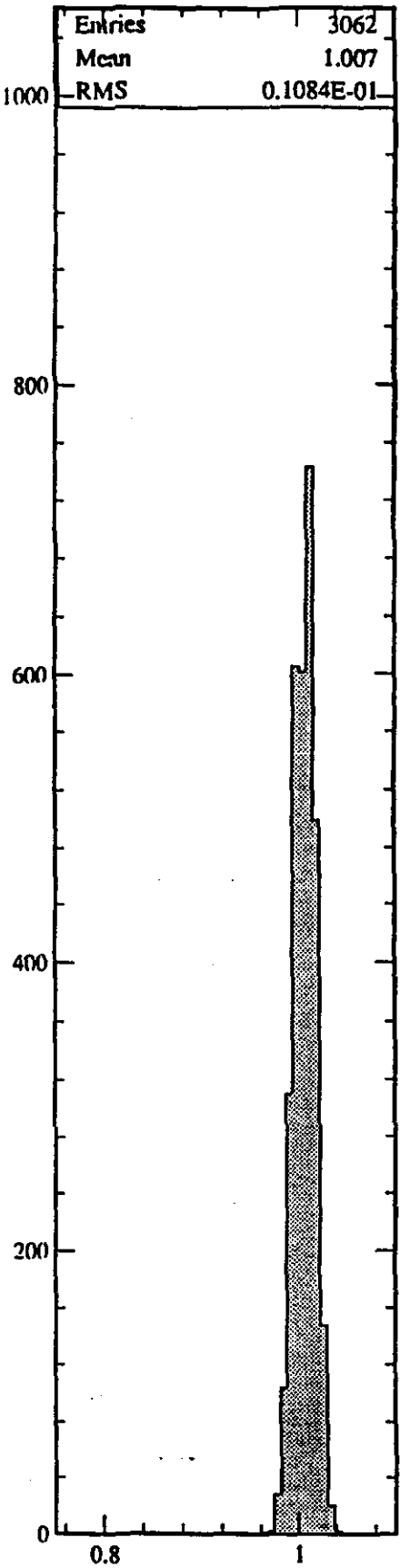

ID 950
ENTRIES 15593
0.000 0.000 0.000
15.0 0.156E+05 5.00
0.000 0.000 0.000
0.031
0.03
0.029
0.028
0.027
0.026
60
62
64
66
68
70
bend vs E7x7



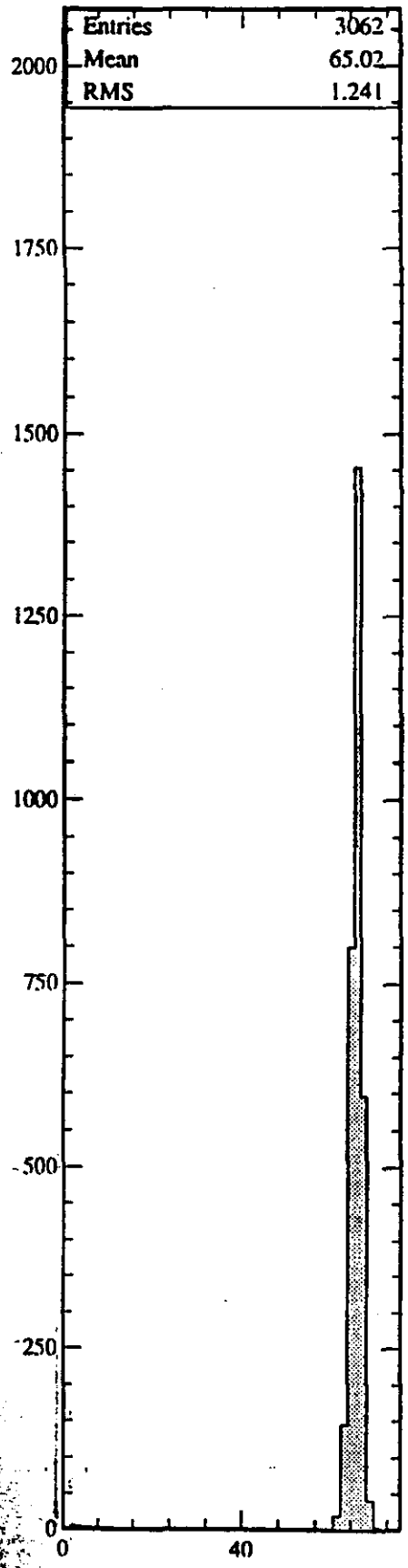
E3x3 / E5x5



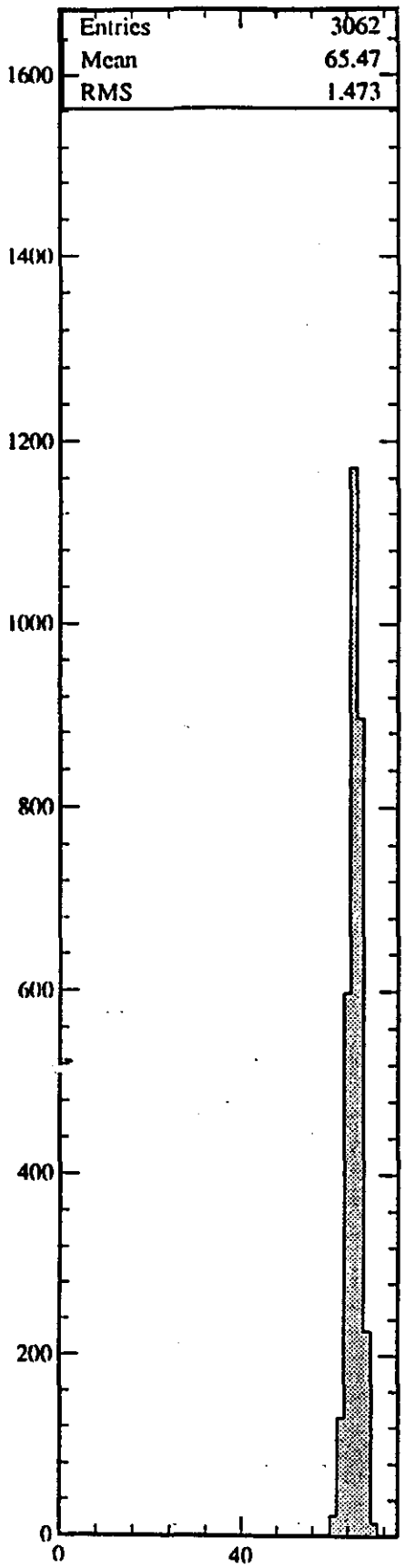
E3x3 / E7x7



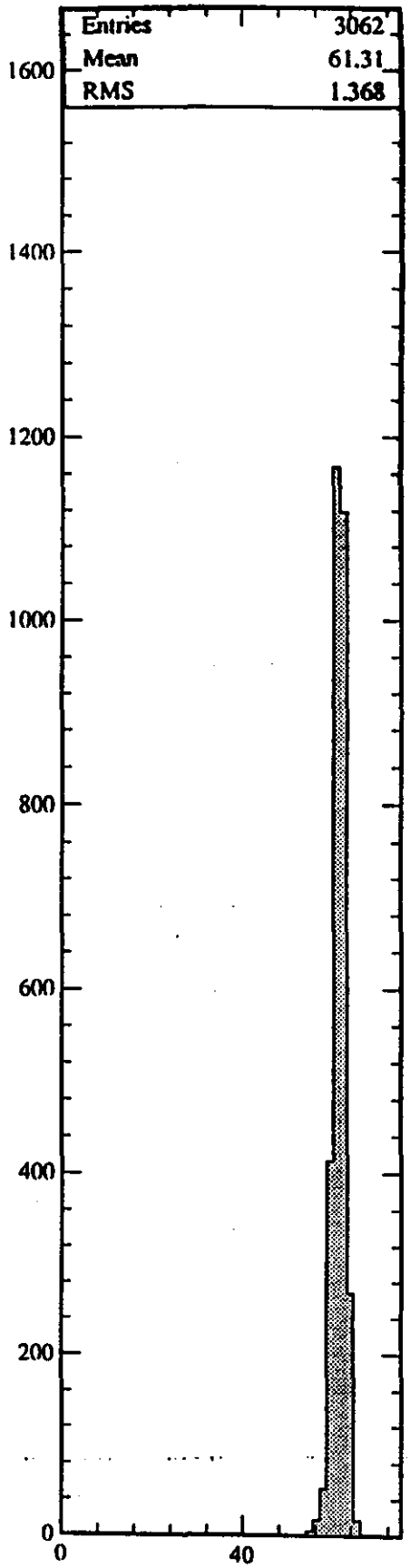
E5x5 / E7x7



E 7x7



E5x5

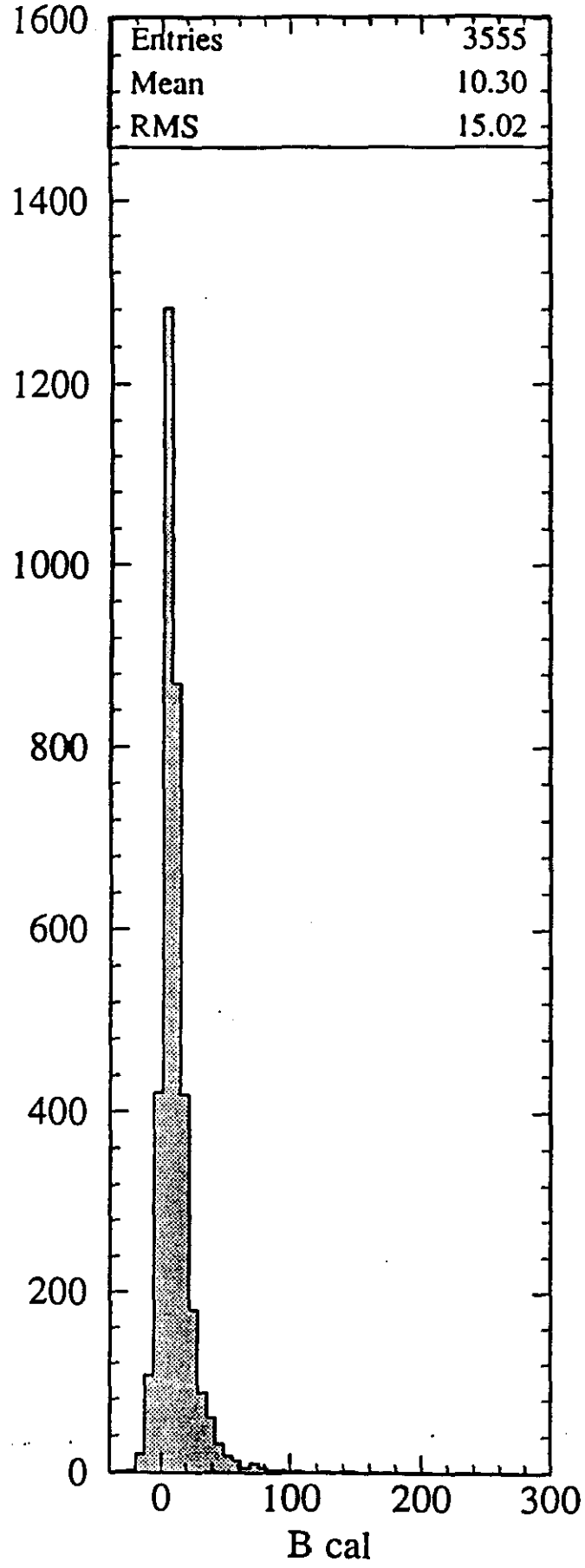


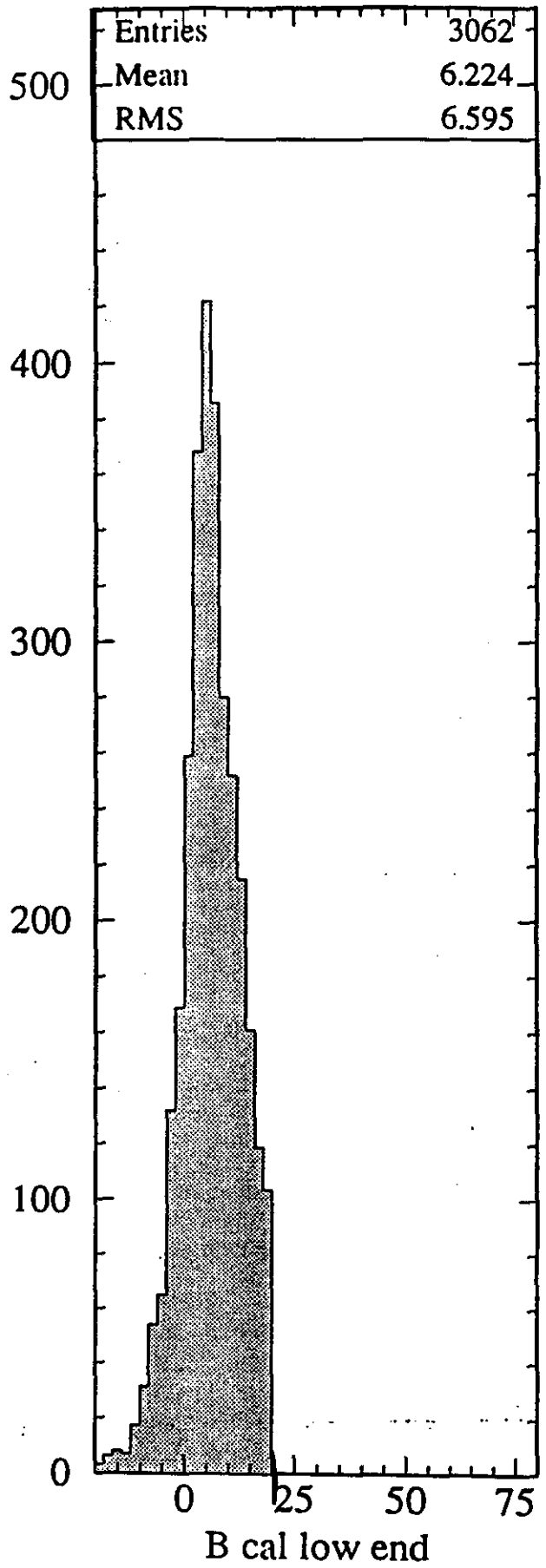
E3x3

Cuts

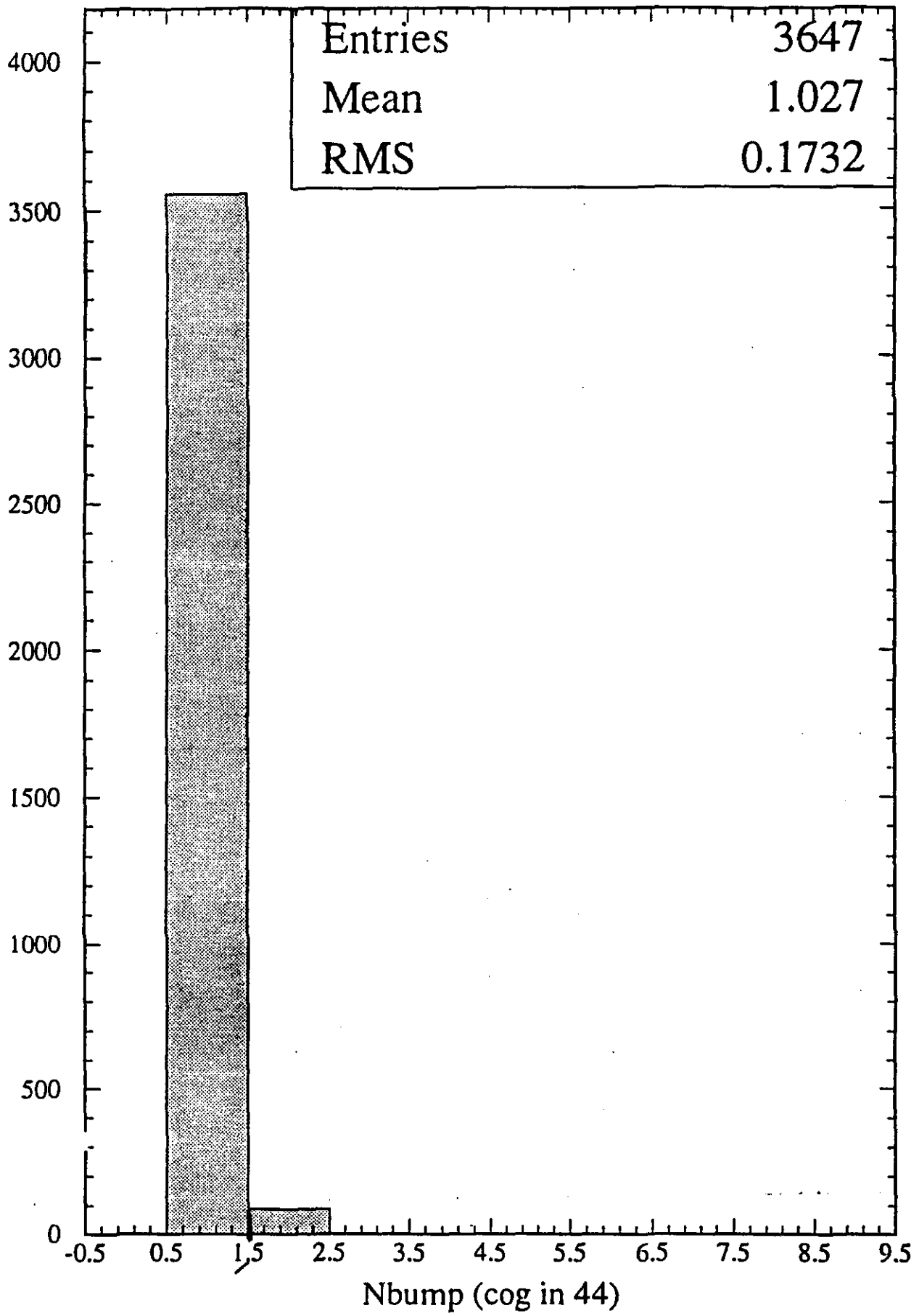
	79205
$n_u \geq 5$ + $n_d \geq 5$	15764
-0.2 mrad $< a_u < 1.4$ mrad -1.6 mrad $< a_d < 1.2$ mrad	14028
$-18 < X^u_{mag} < 21$ $-19 < X^d_{mag} < 22$	13621
$-22 < X_{ctr} < 20$	13016
$-2.6 < \Delta X_{mag} < 2.4$	10530
* 28.0 mrad $<$ bend $<$ 29.3 mrad	4684
$\Delta P_{beam} < 0.17$	4571
$\lvert cog_x - X_{baf} \rvert < 1.8$ mm	3647
$n_{bump} < 2$	3555
$E_{cal} <$ "20"	3062
$\lvert cog_x \rvert < 20$ mm	
$\lvert cog_y \rvert < 20$ mm	1124

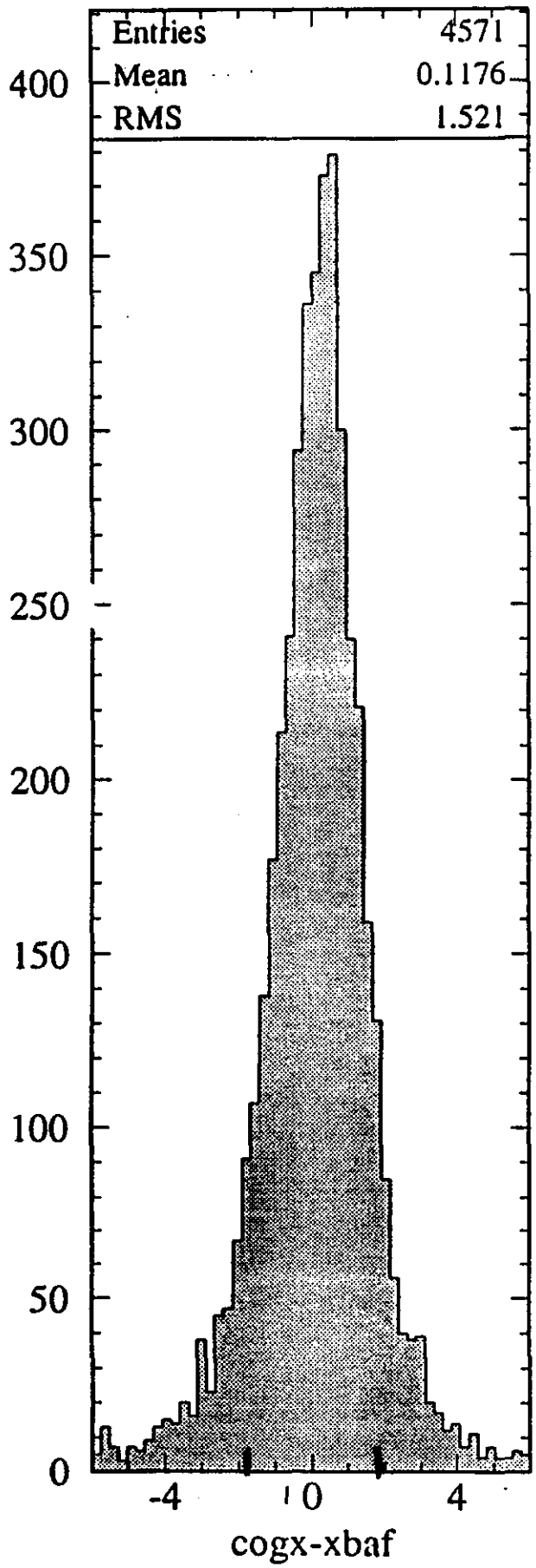
Energy in backing calorimeter.

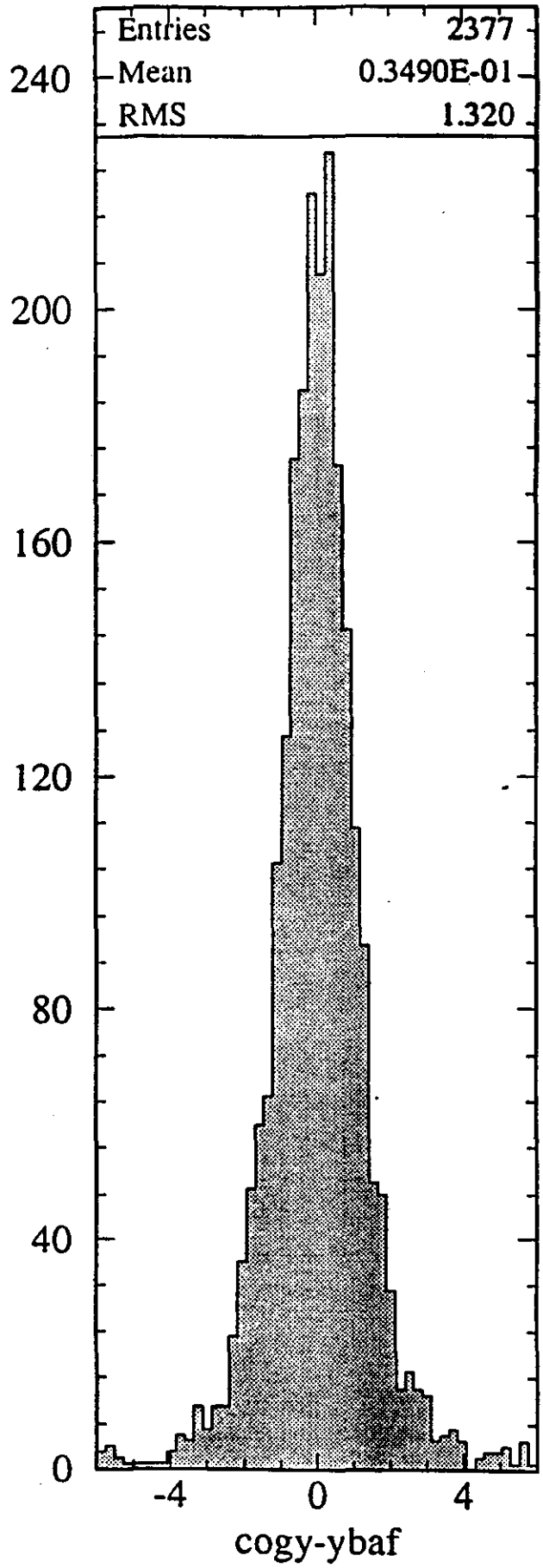




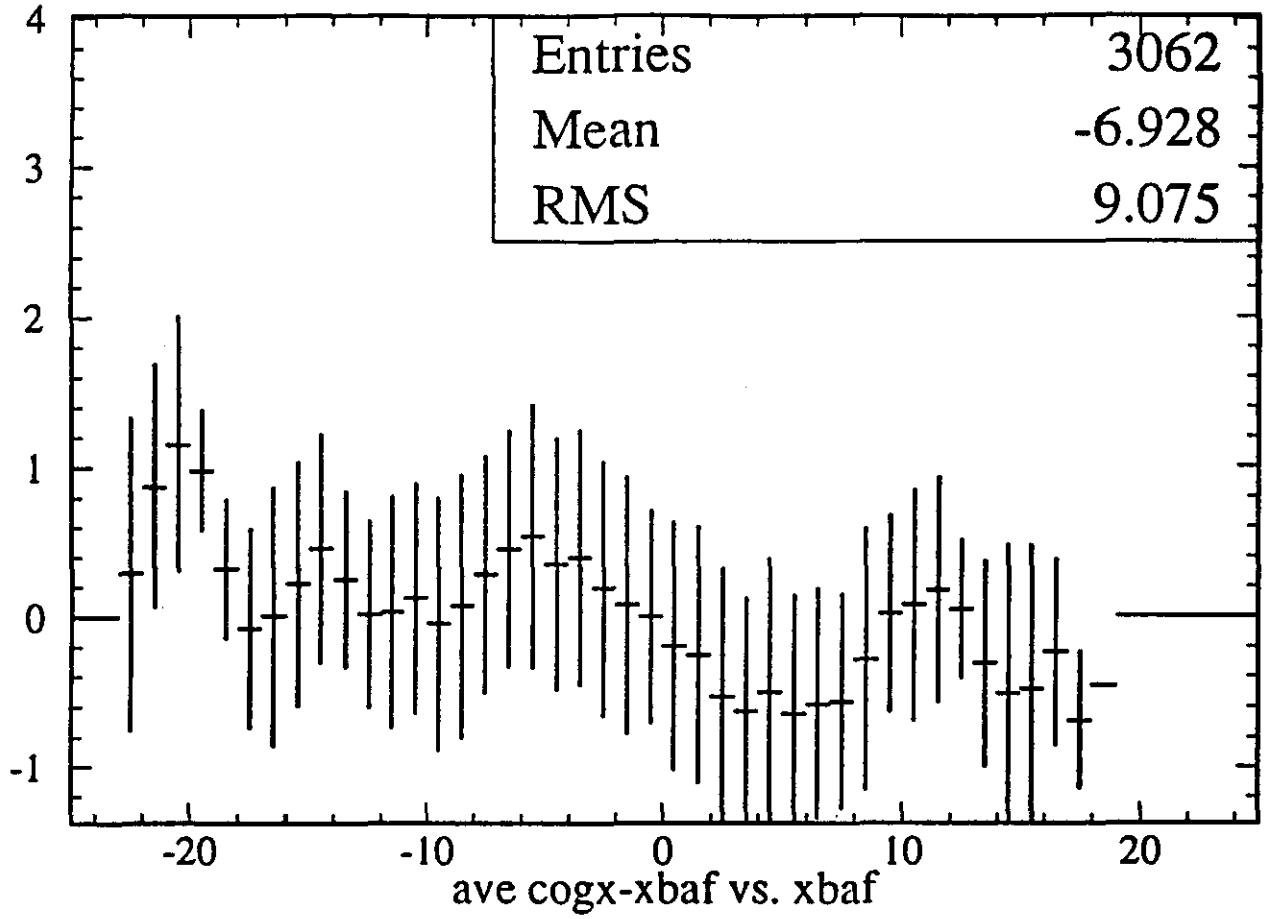
Number of local maxima with E > 300 MeV

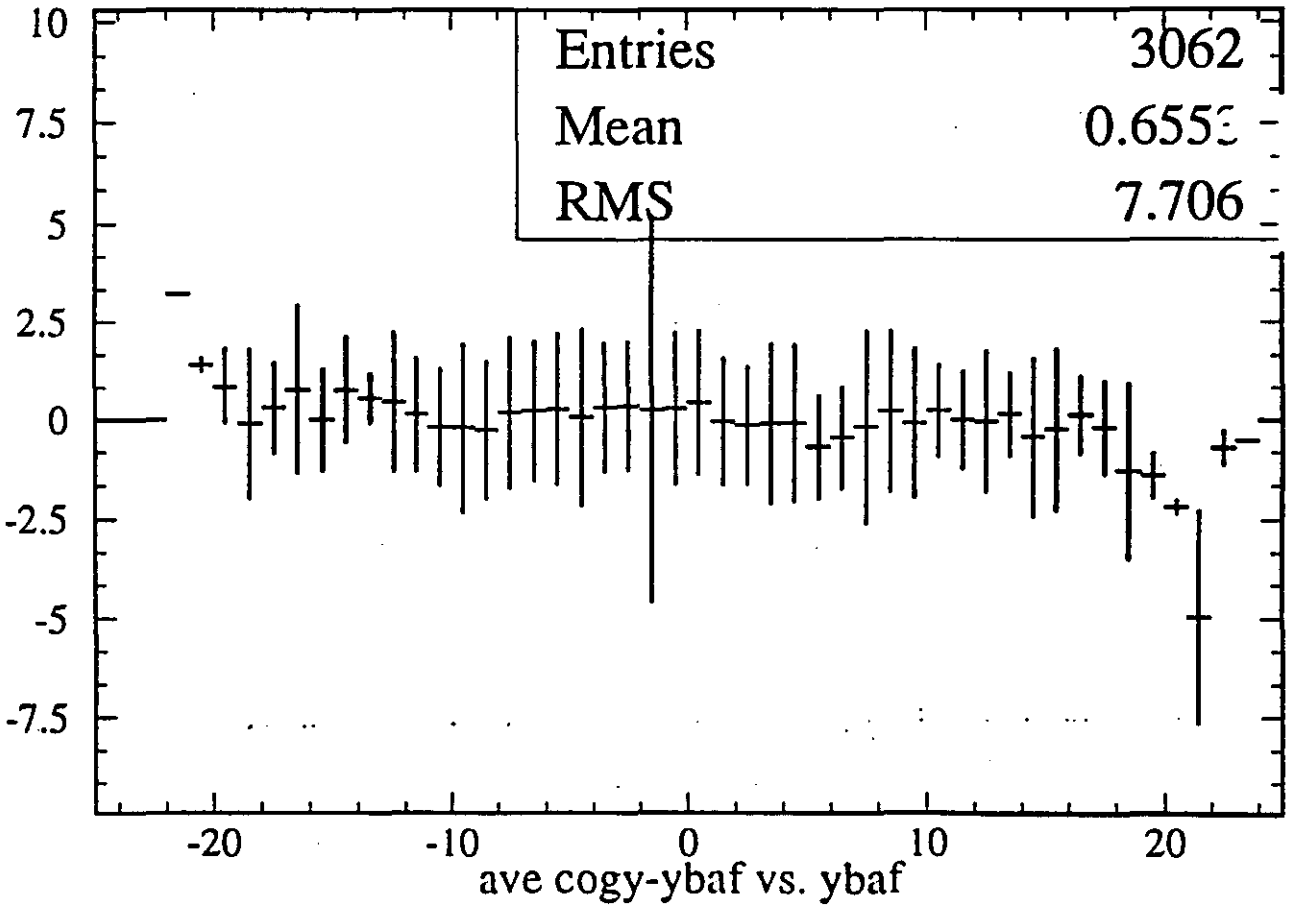



Entries 4571
Mean 0.1176
RMS 1.521
400
350
300
250
200
150
100
50
0
-4
0
4
cogx-xbaf

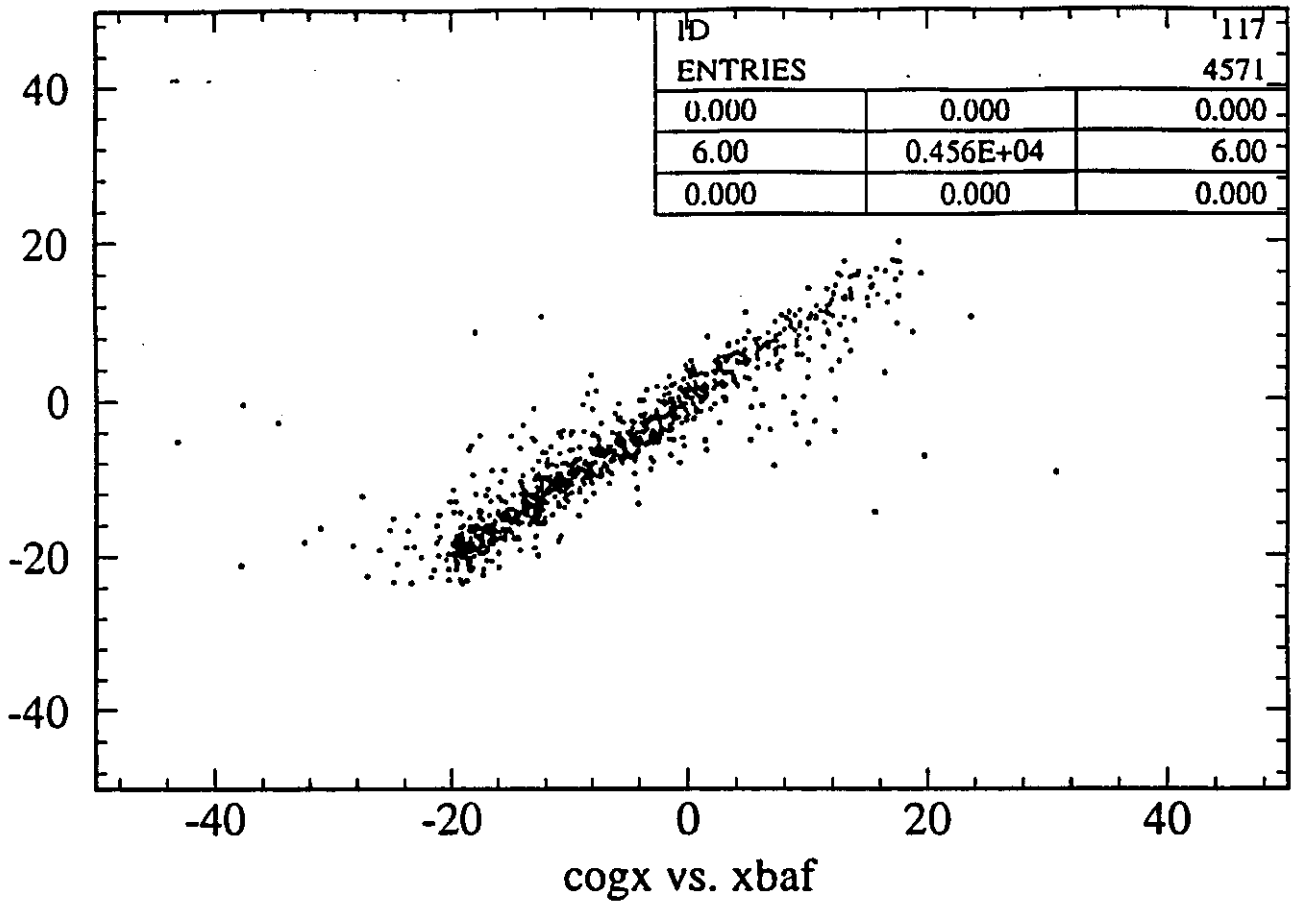

Entries 2377
Mean 0.3490E-01
RMS 1.320
240
200
160
120
80
40
0
-4
0
4
cogy-ybaf

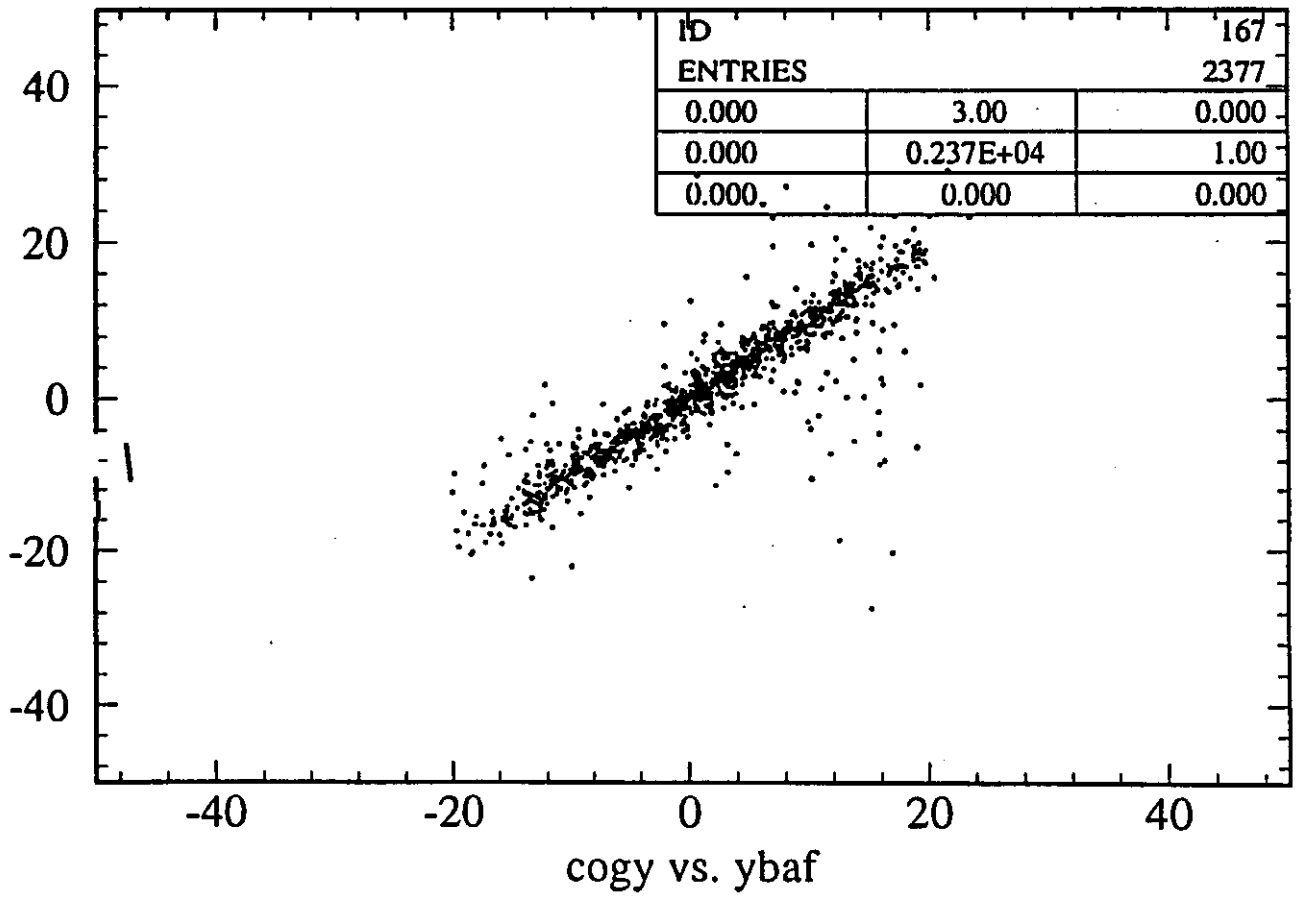
corrected cog position



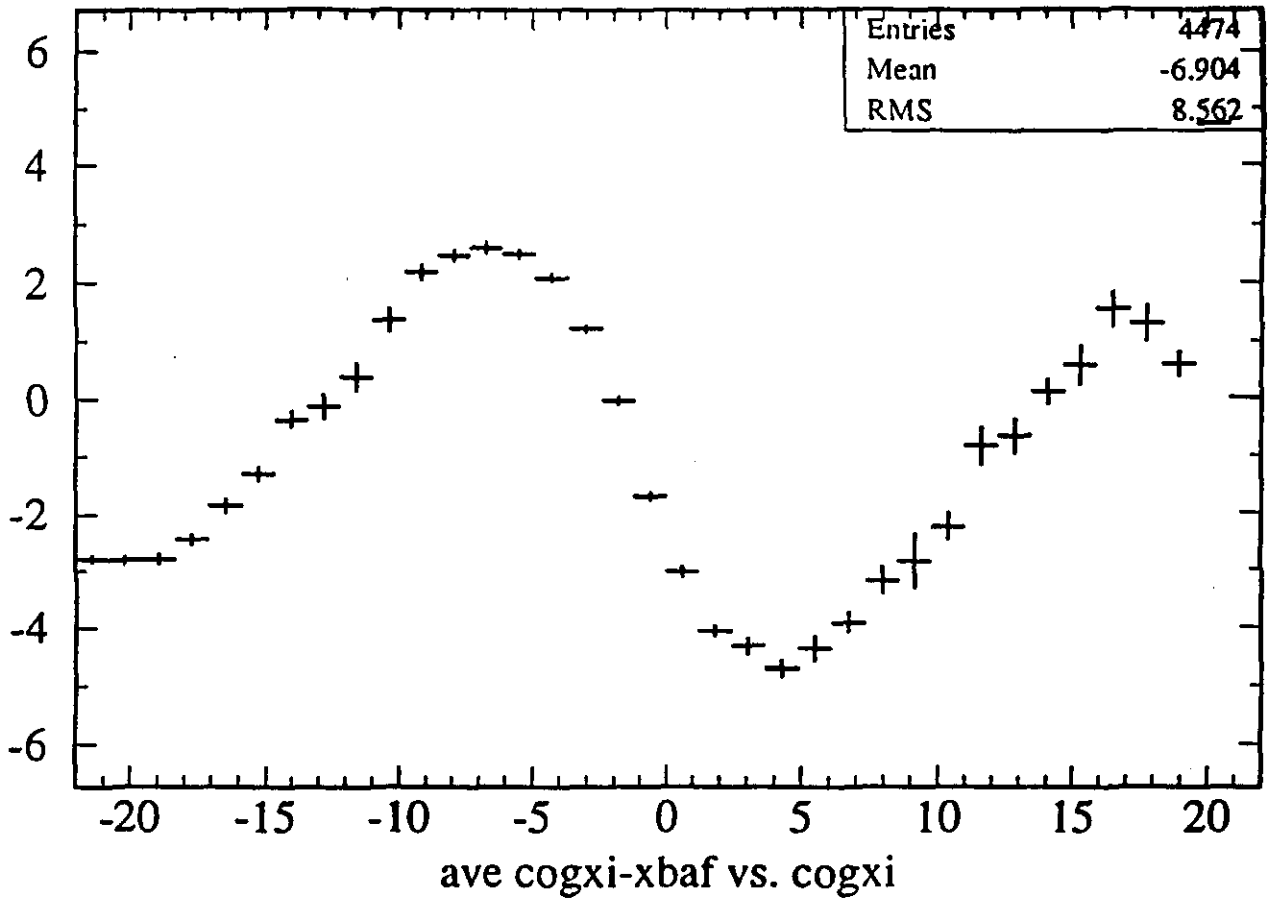


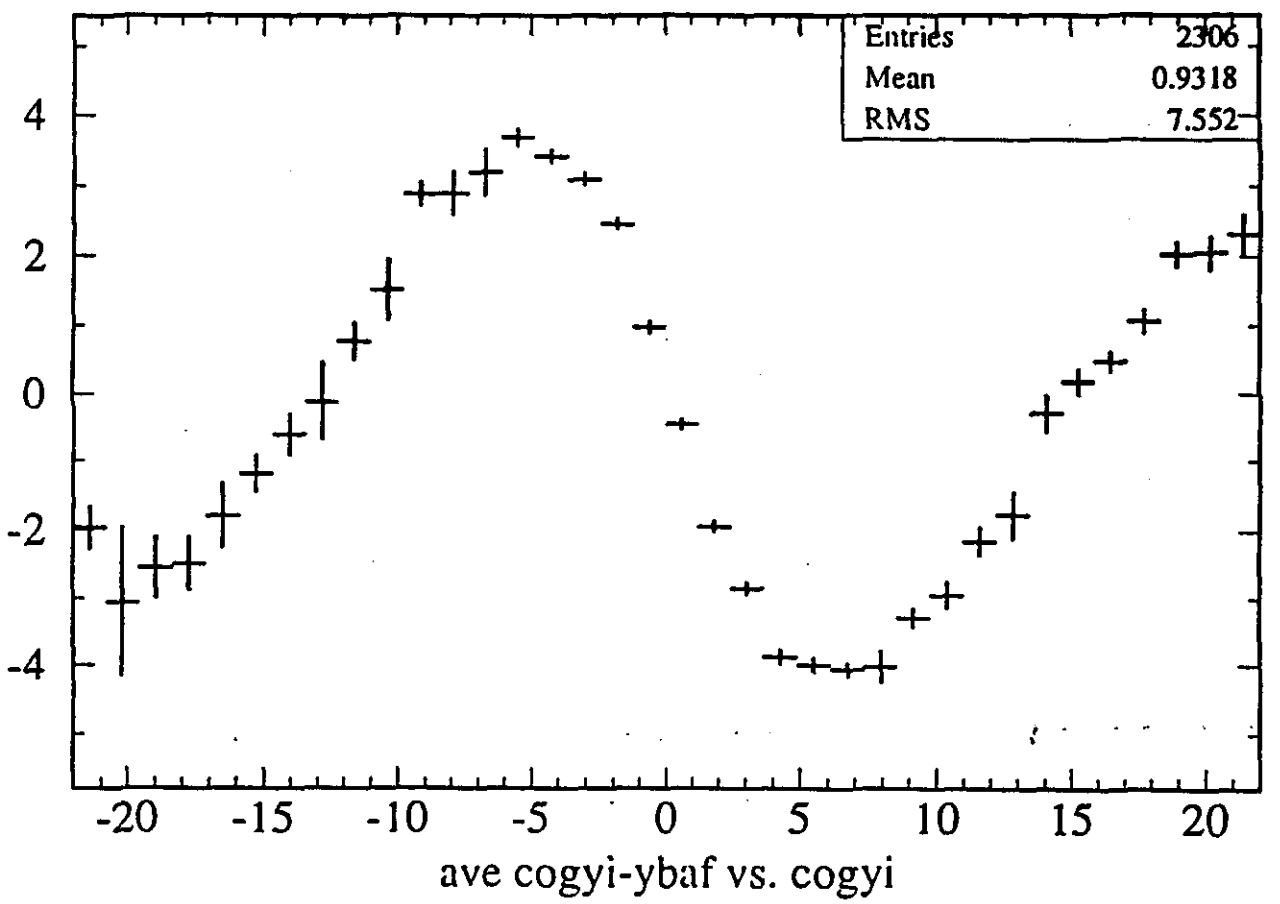
some bad tracks even after all the cuts.

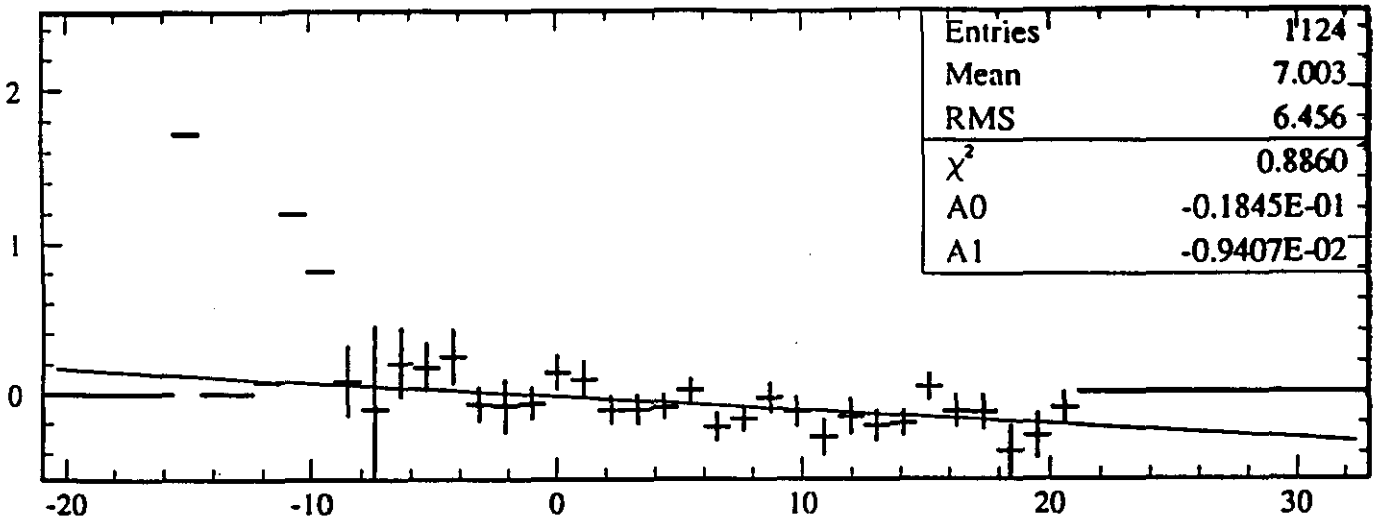




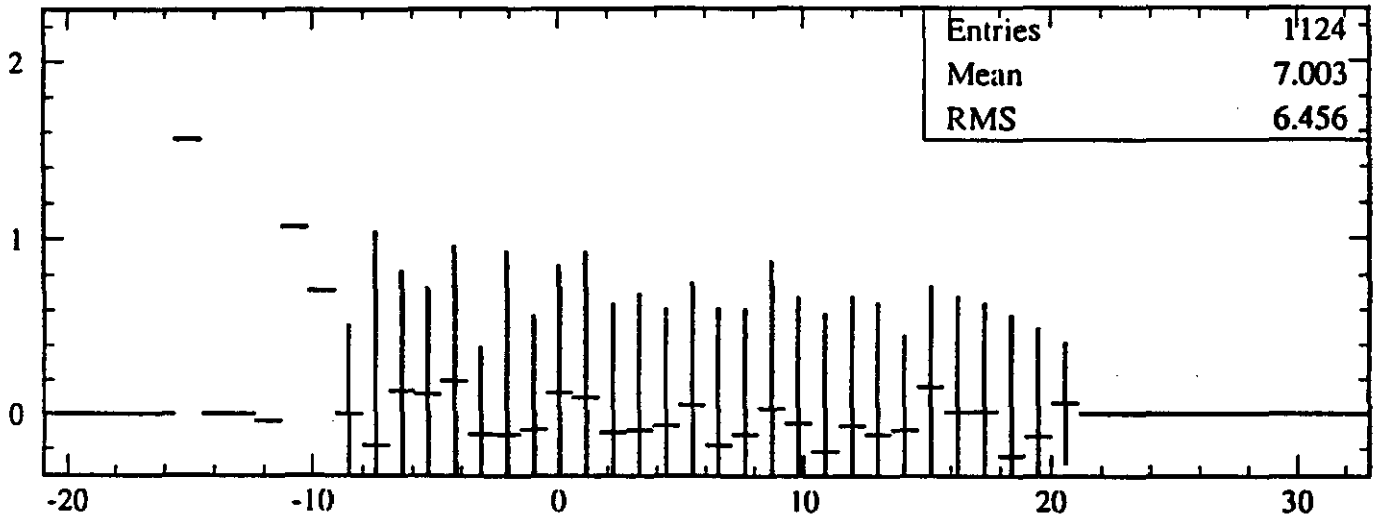
BaF2 center of gravity vs. chamber position



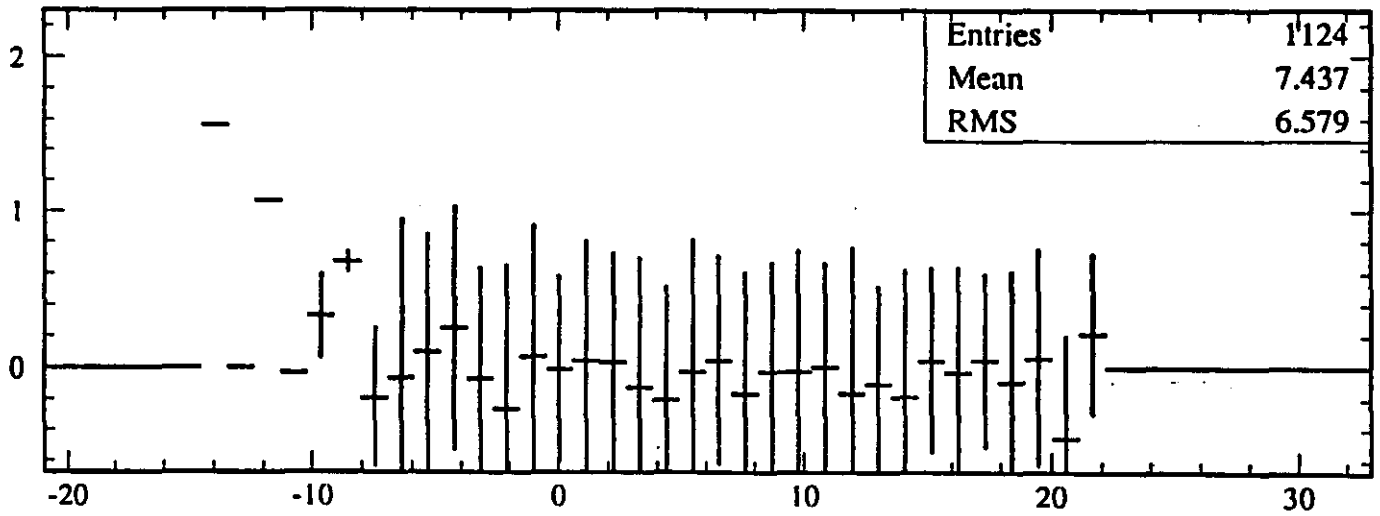




ave cor energy error (cog in 44) vs. xmagu

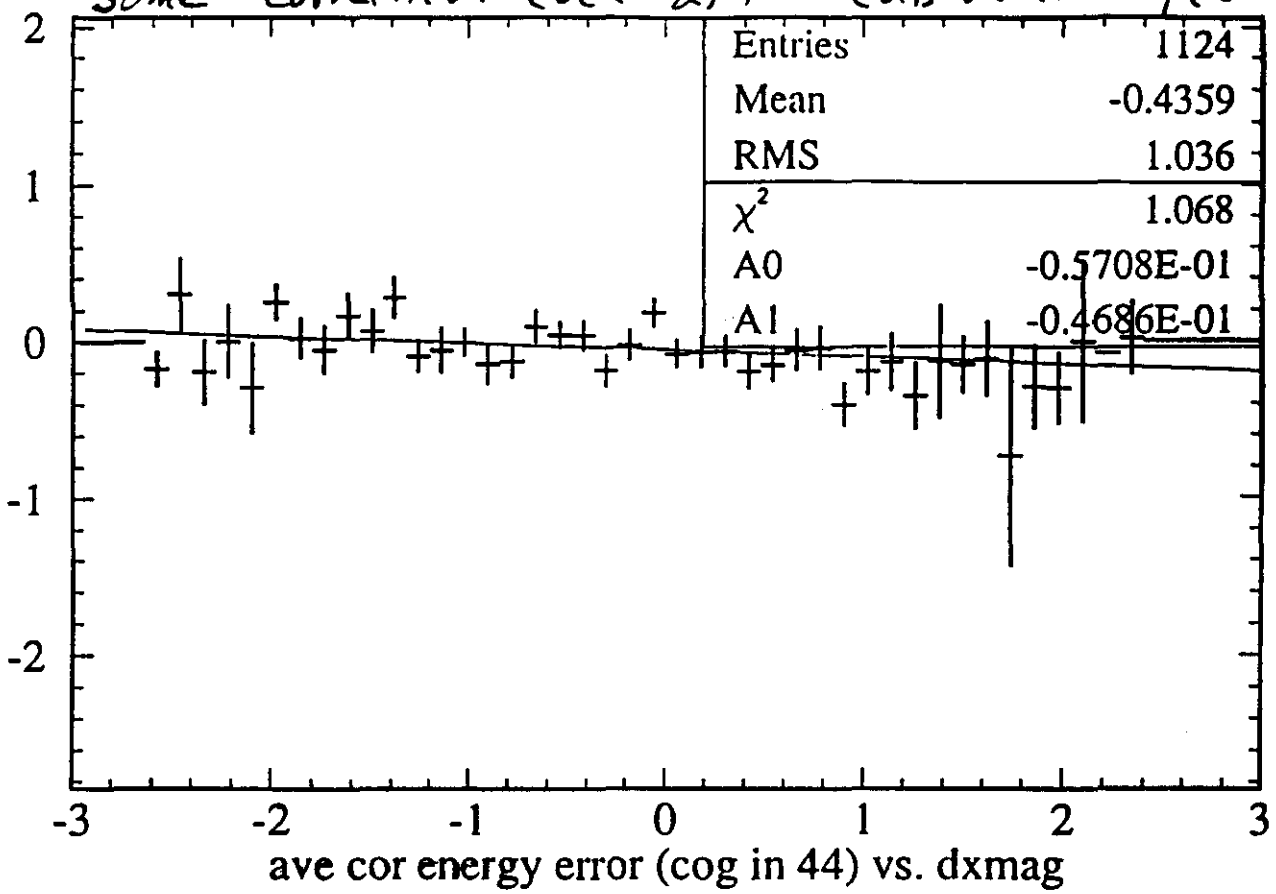


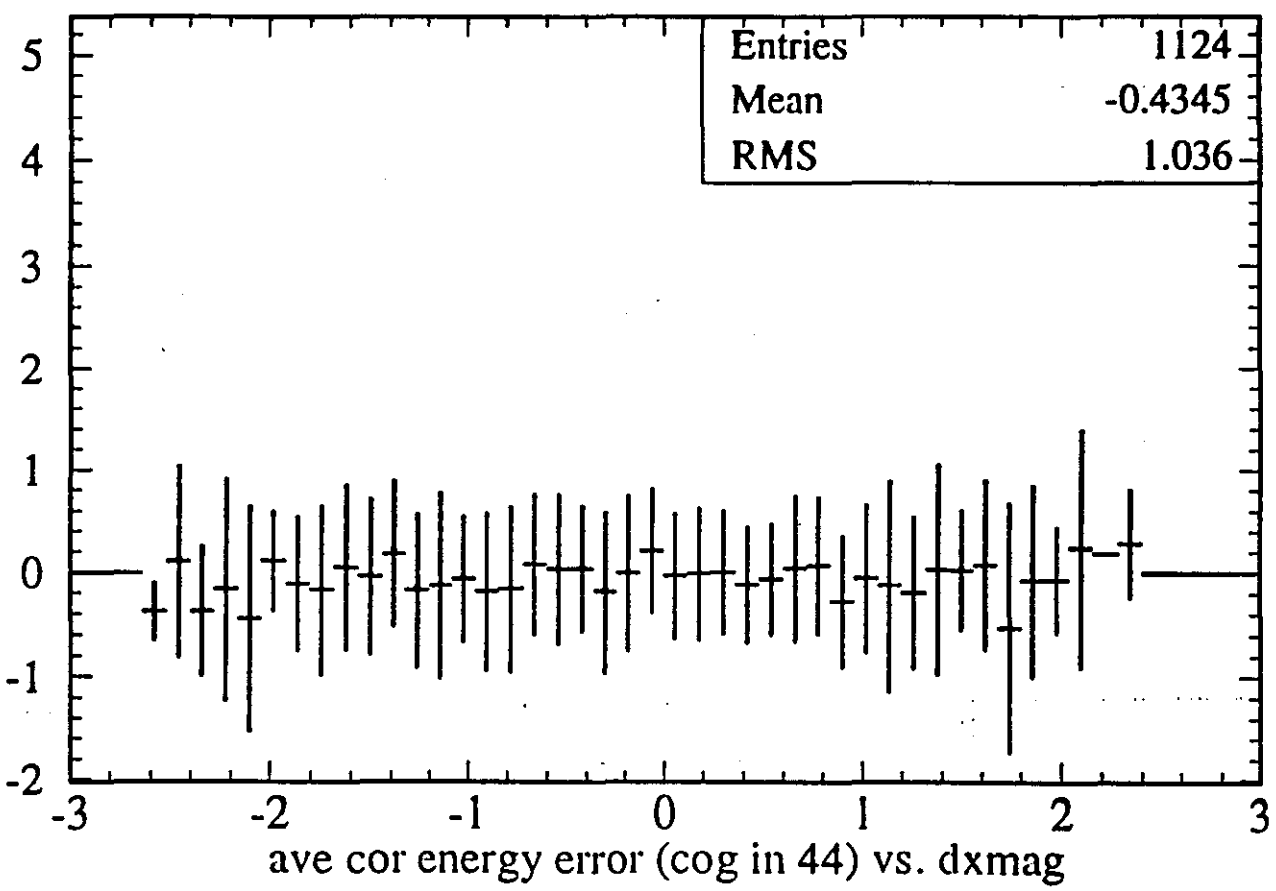
ave cor energy error (cog in 44) vs. xmagu

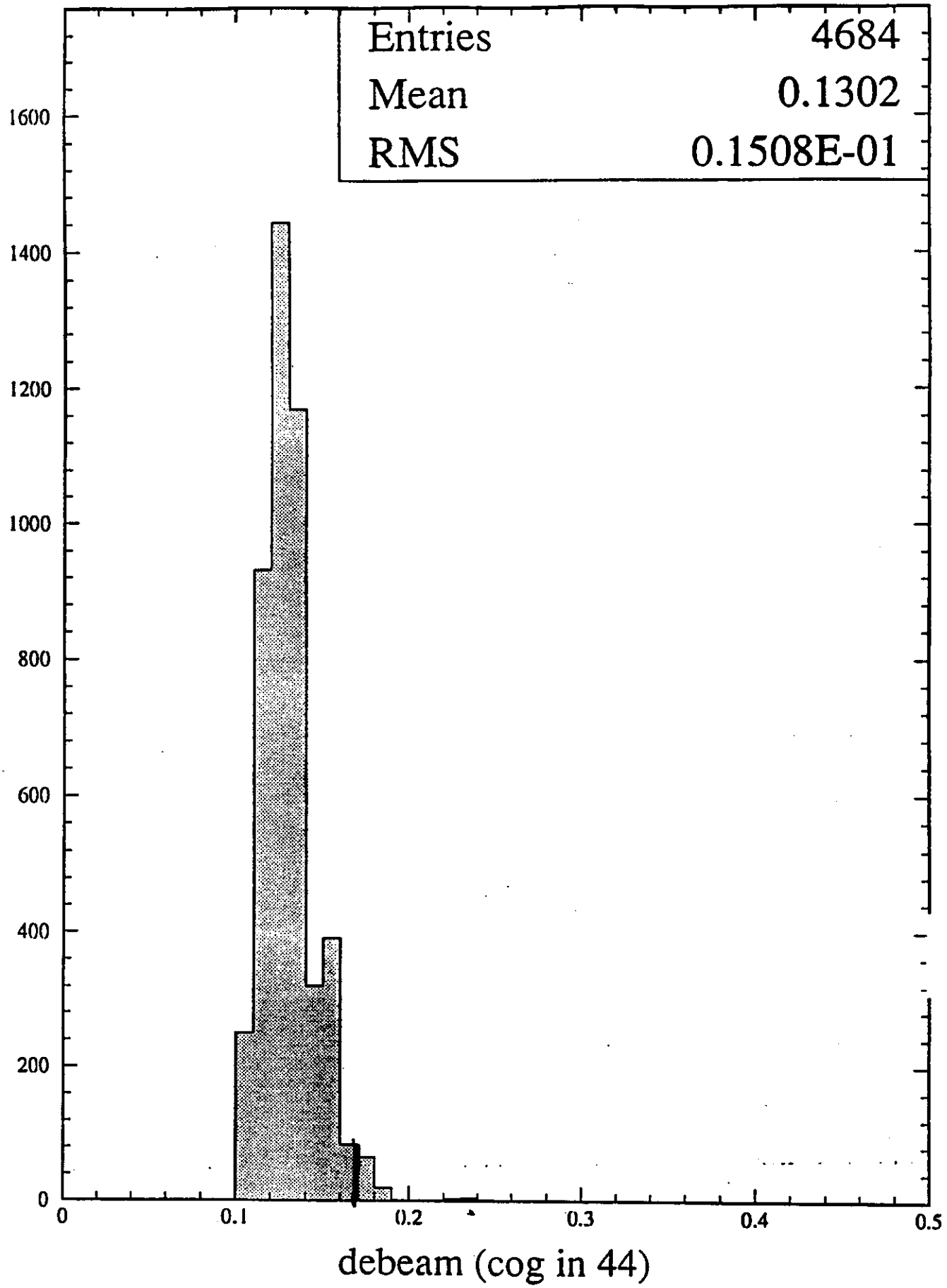


ave cor energy error (cog in 44) vs. xmagd

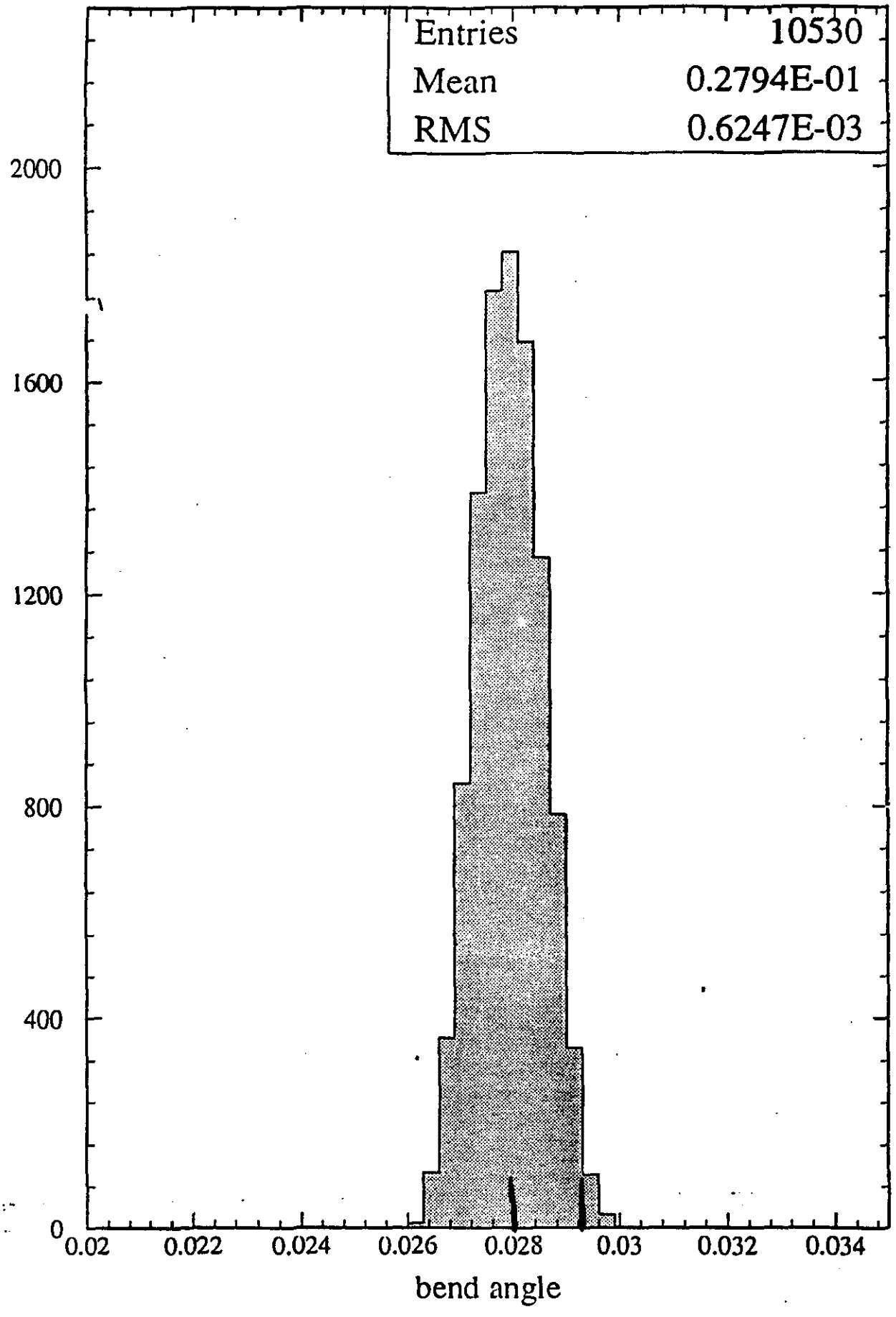
Some correlation even after constrained fit

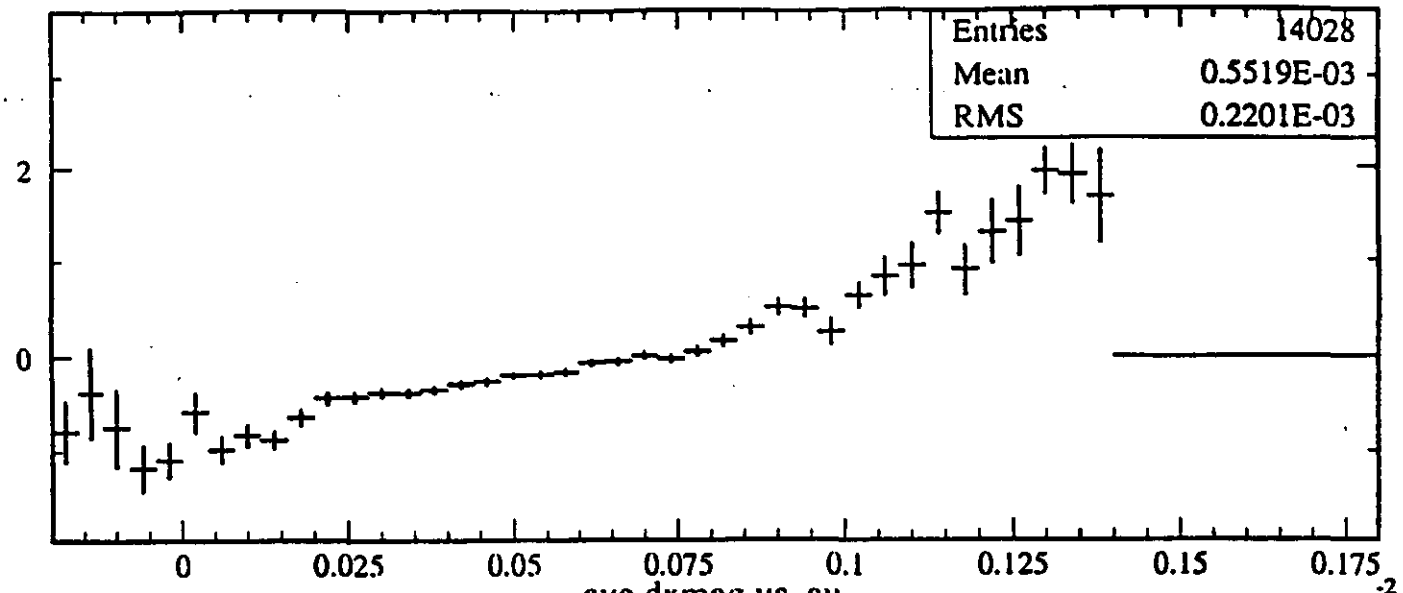


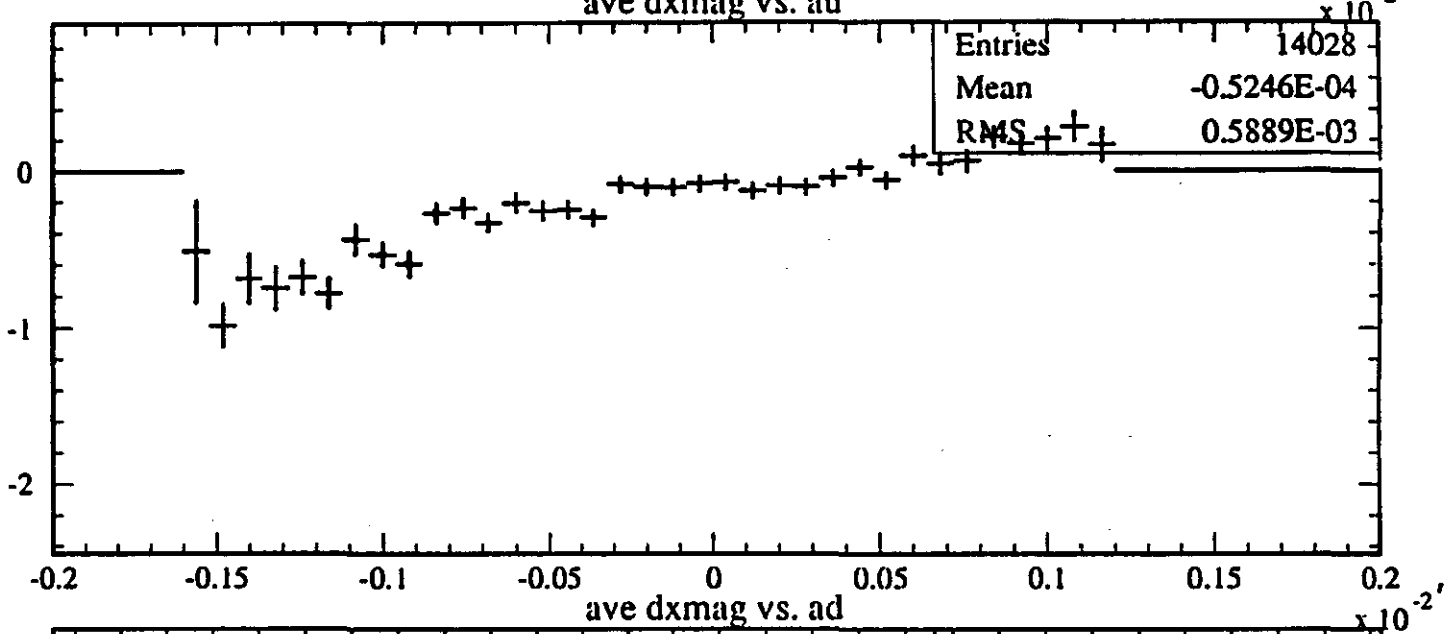


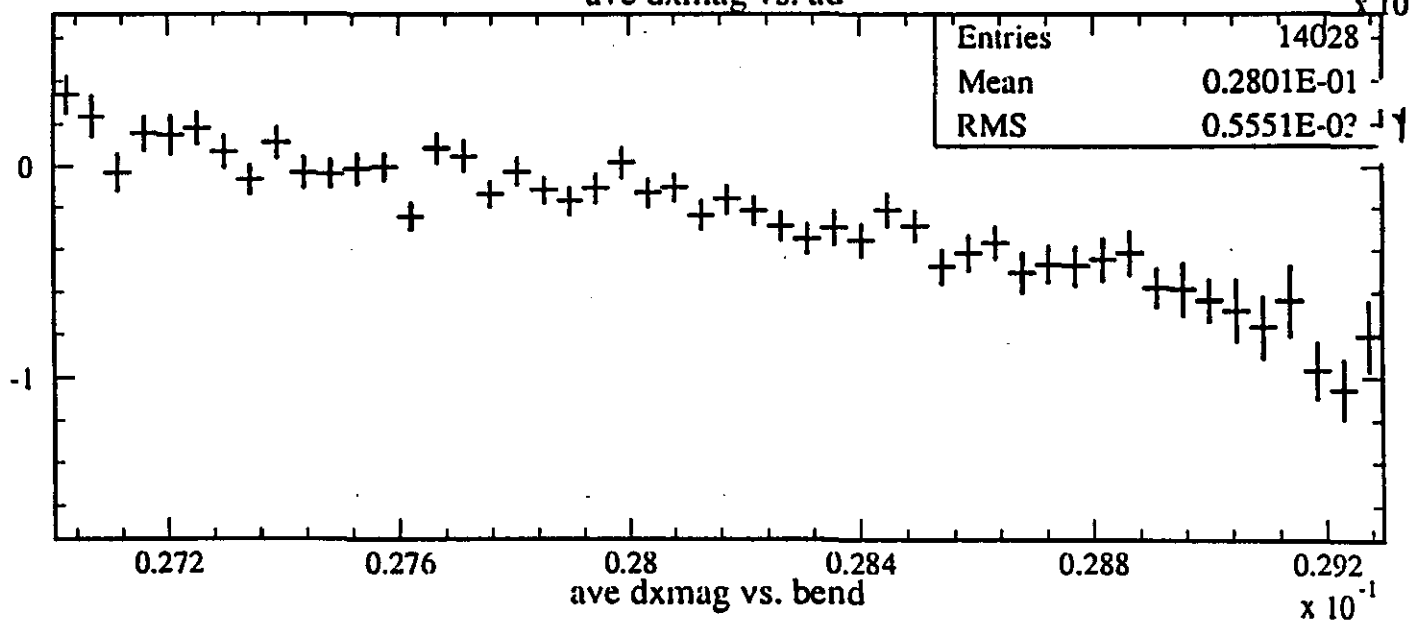

Entries 4684
Mean 0.1302
RMS 0.1508E-01
1600
1400
1200
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
debeam (cog in 44)

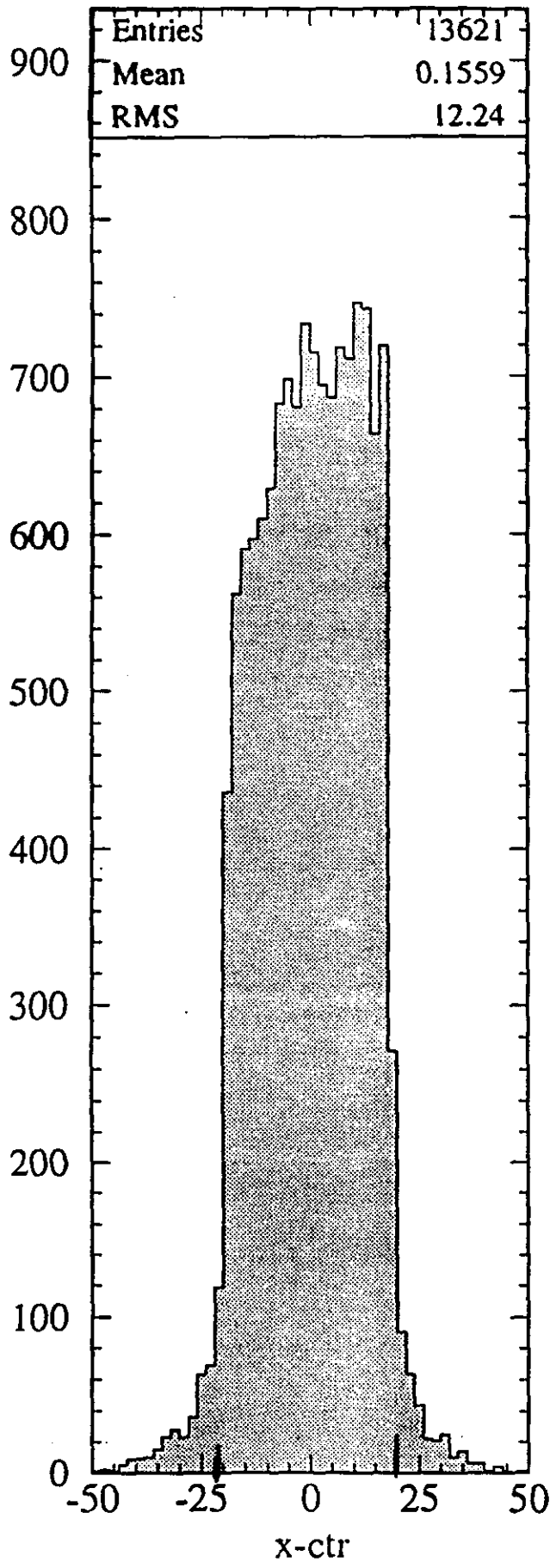
upstream & downstream tracks constrained to meet at center of magnet.

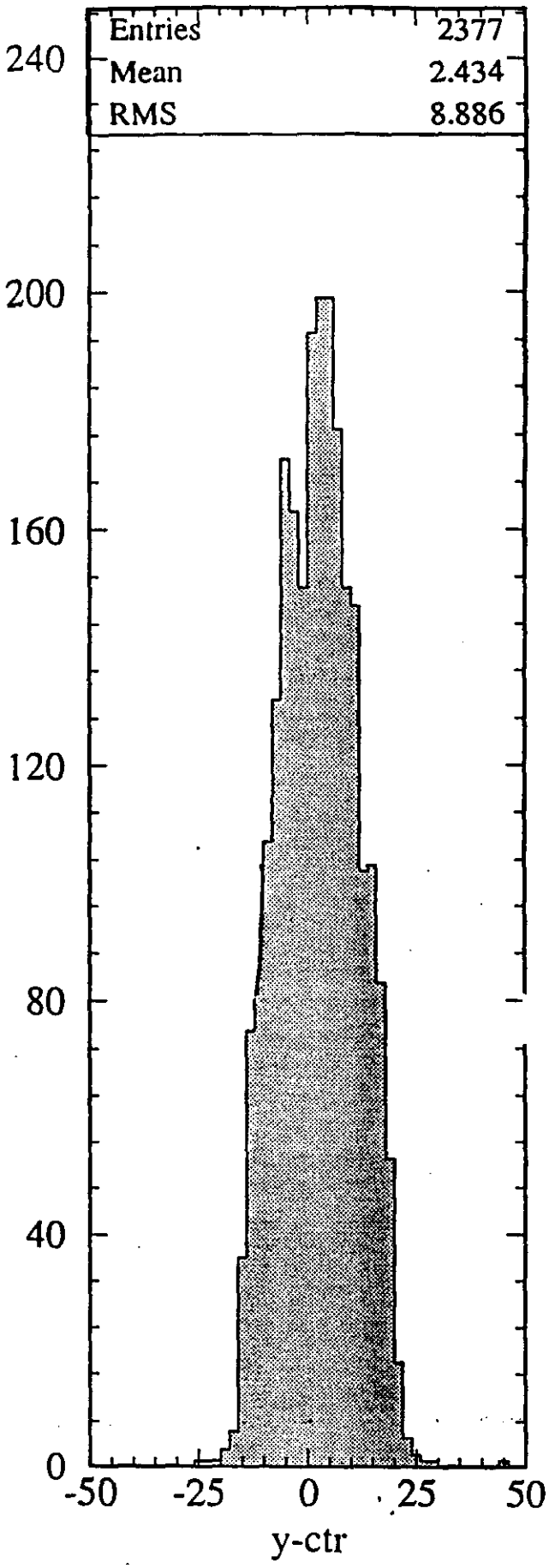


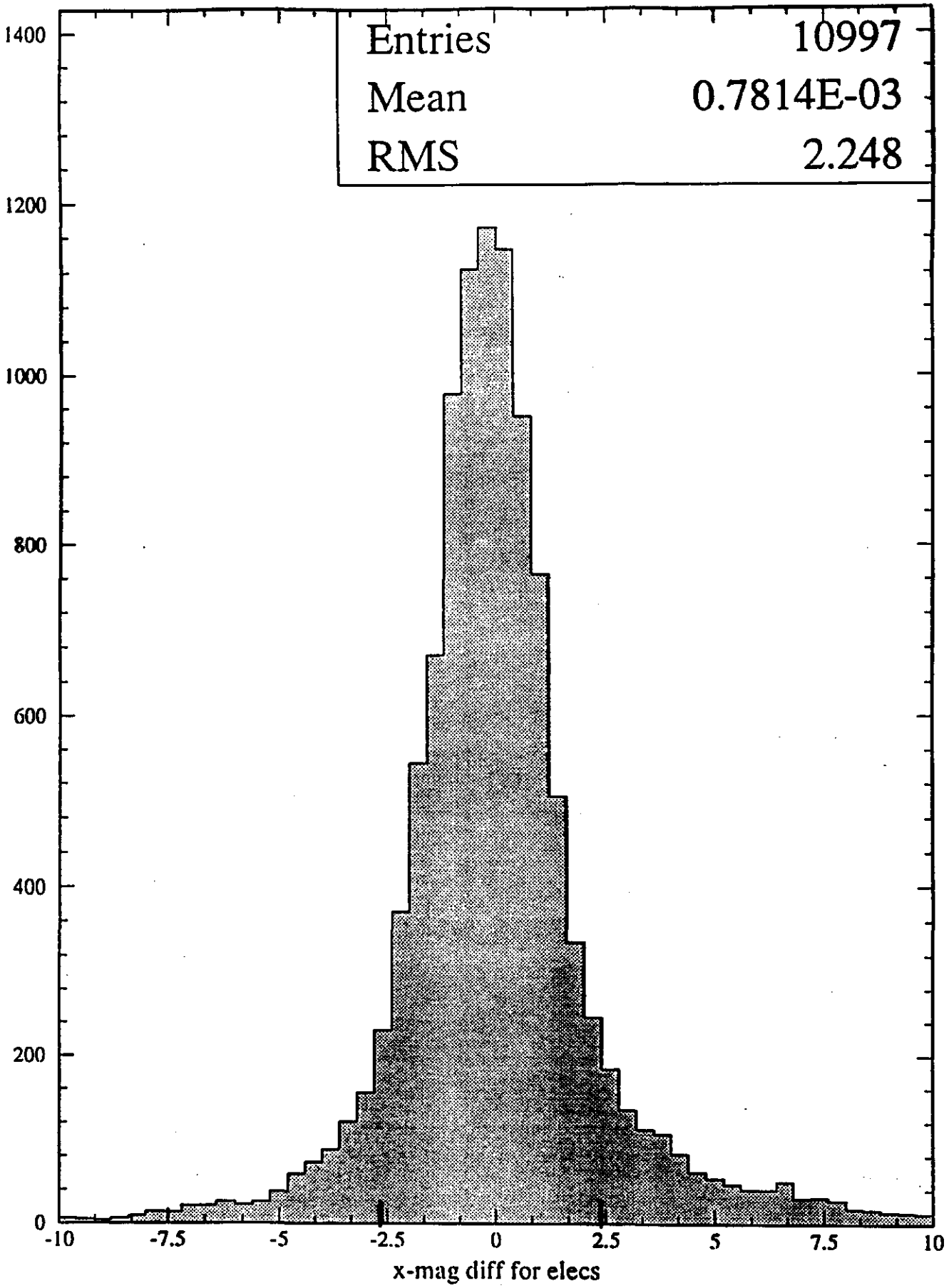

Entries 14028
Mean 0.5519E-03
RMS 0.2201E-03
2
0
0
0.025
0.05
0.075
0.1
0.125
0.15
0.175
ave dxmag vs. au
x 10^-2

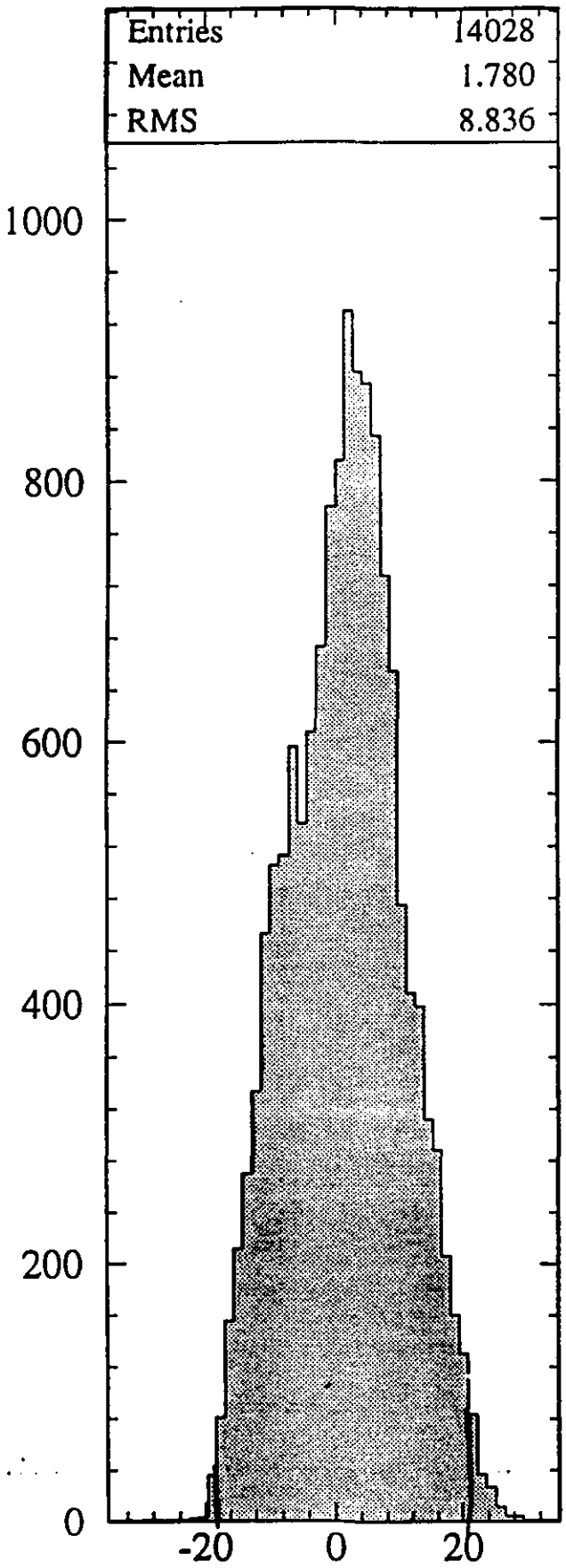

Entries 14028
Mean -0.5246E-04
RMS 0.5889E-03
0
-1
-2
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
ave dxmag vs. ad
x 10^-2


Entries 14028
Mean 0.2801E-01
RMS 0.5551E-02
0
-1
0.272
0.276
0.28
0.284
0.288
0.292
ave dxmag vs. bend
x 10^-1

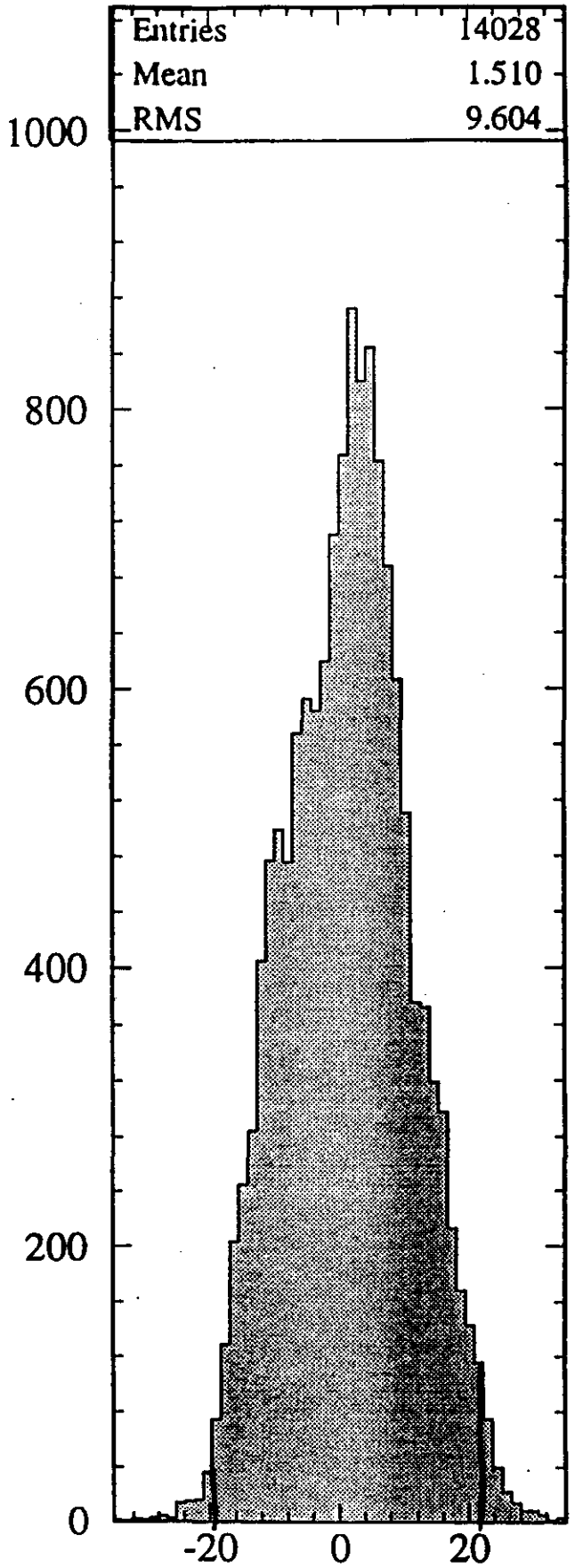

Entries 13621
Mean 0.1559
RMS 12.24
900
800
700
600
500
400
300
200
100
0
-50
-25
0
25
50
x-ctr


Entries 2377
Mean 2.434
RMS 8.886
240
200
160
120
80
40
0
-50
-25
0
25
50
y-ctr

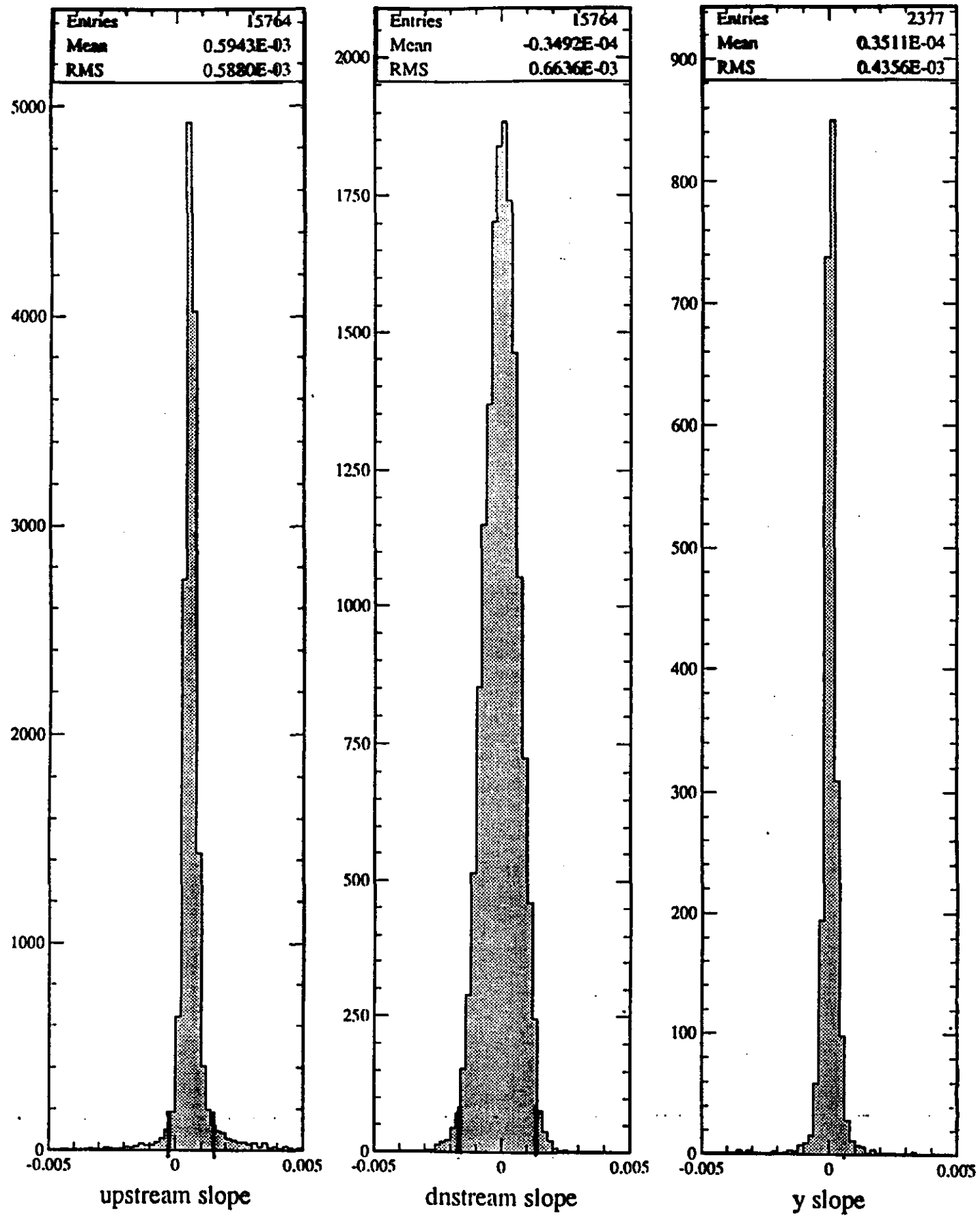

Entries 10997
Mean 0.7814E-03
RMS 2.248
1400
1200
1000
800
600
400
200
0
-10
-7.5
-5
-2.5
0
2.5
5
7.5
10
x-mag diff for elecs

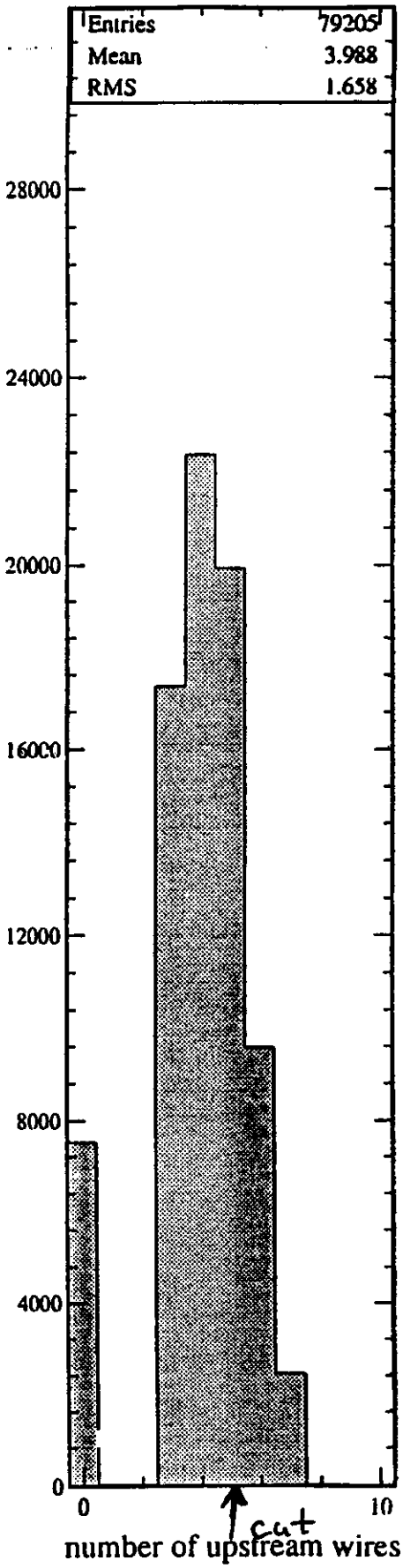


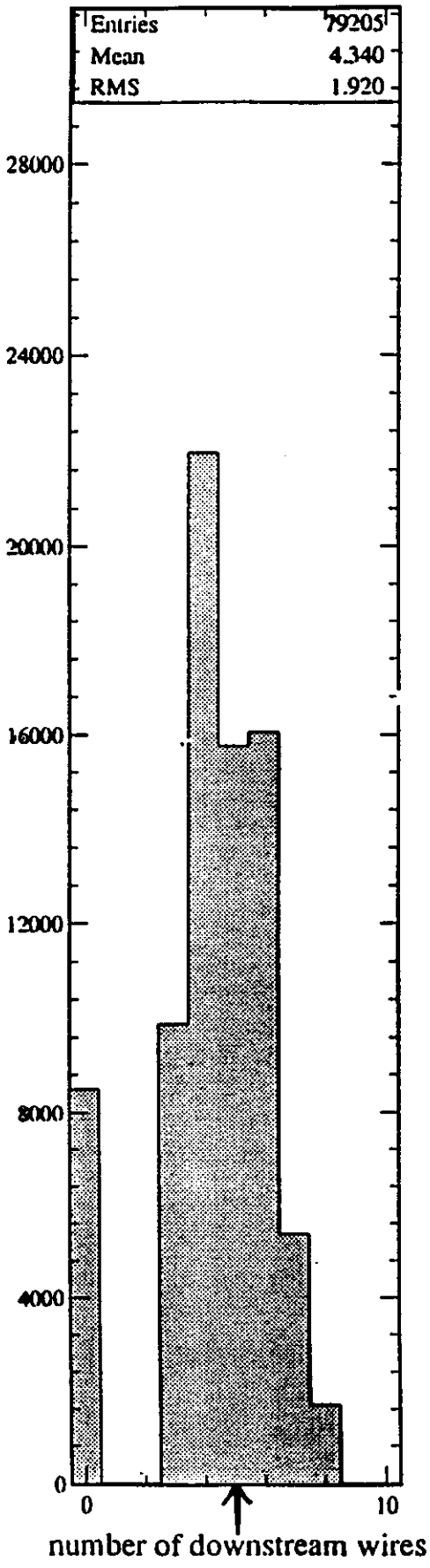
x-magnet from upstream track

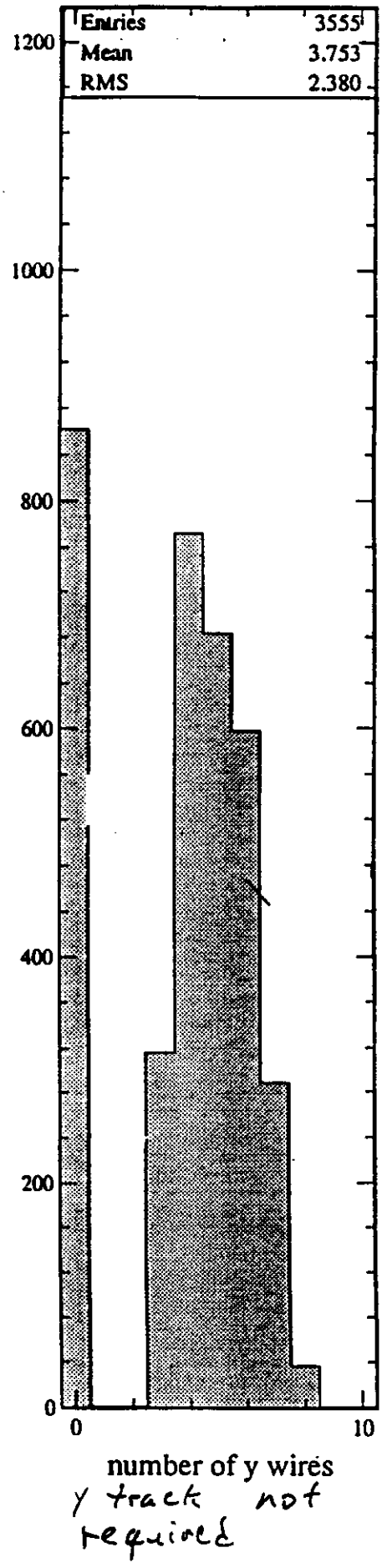


x-magnet from dnstream track


Entries 15764
Mean 0.5943E-03
RMS 0.5880E-03
5000
4000
3000
2000
1000
0
-0.005
0
0.005
upstream slope
Entries 15764
Mean -0.3492E-04
RMS 0.6636E-03
2000
1750
1500
1250
1000
750
500
250
0
-0.005
0
0.005
dnstream slope
Entries 2377
Mean 0.3511E-04
RMS 0.4356E-03
900
800
700
600
500
400
300
200
100
0
-0.005
0
0.005
y slope

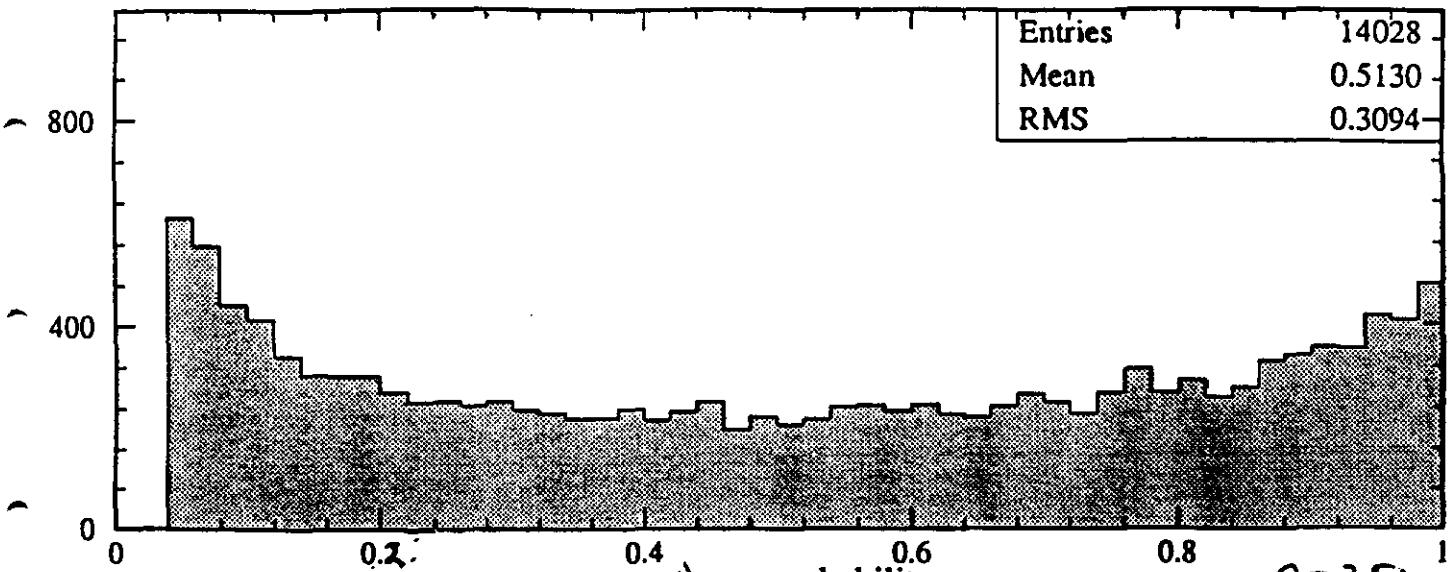

Entries 79205
Mean 3.988
RMS 1.658
28000
24000
20000
16000
12000
8000
4000
0
0
10
cut
number of upstream wires


Entries 79205
Mean 4.340
RMS 1.920
28000
24000
20000
16000
12000
8000
4000
0
0
10
number of downstream wires

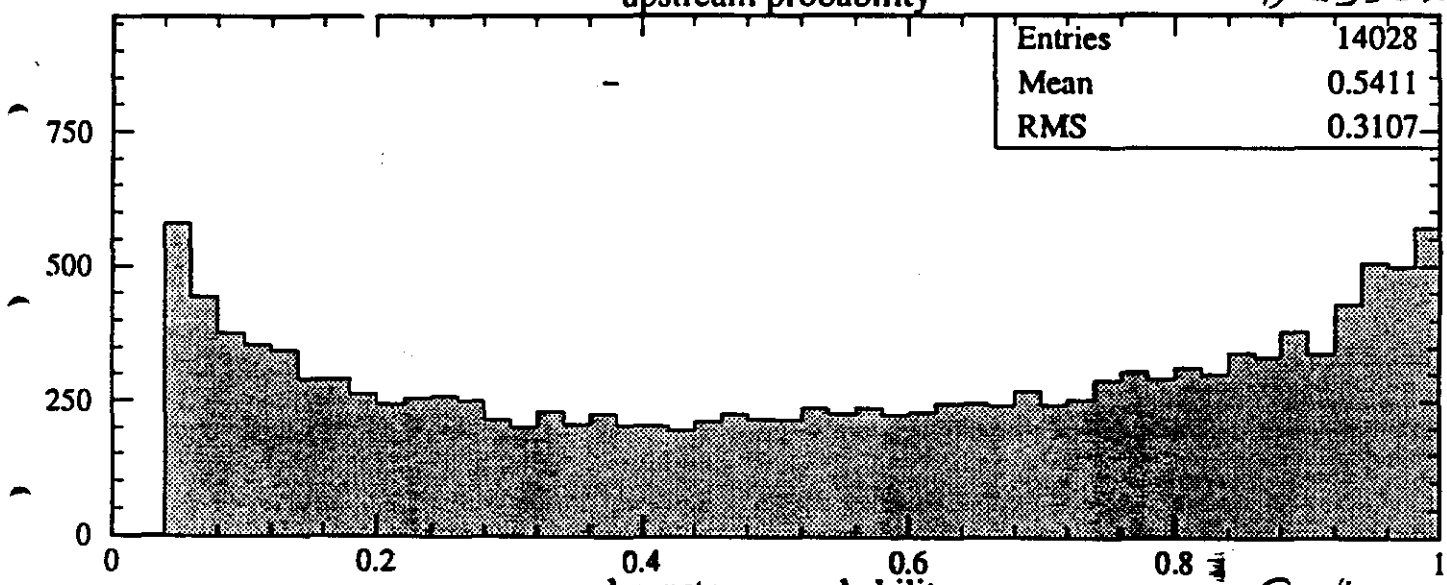

Entries 3555
Mean 3.753
RMS 2.380
1200
1000
800
600
400
200
0
0
10
number of y wires
y track not required

Drop hits until $P(\chi^2) > 0.04$

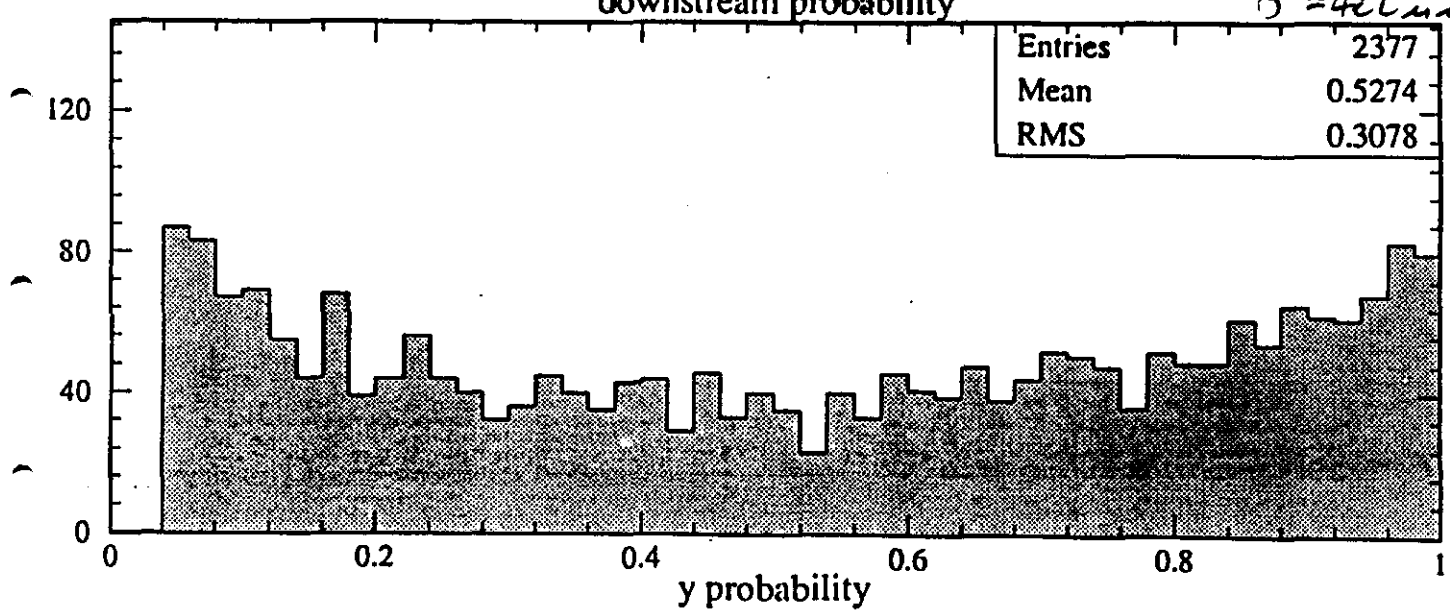
$\sigma = 341\ \mu m$



$\sigma = 352\ \mu m$



$\sigma = 421\ \mu m$



Outline

- cuts
- resolution + systematics in full beam spot.
- resolution + systematics in center crystal.

- **PRELIMINARY CALORIMETER RESOLUTION**
  - **Measured RMS($E_{BaF_2} - p_{beam}$)**
    - **1.0%**
  - **Instrumental Contributions**
    - **Spectrometer Resolution: 0.5±0.2%**
    - **Electronic Noise: 0.40%**
  - **Calorimeter Resolution (at 68 GeV)**
    - $\boxed{0.77^{+0.012}_{-0.018}\%}$ **(0.6% desired)**
  - **Further Contributions (not subtracted)**
    - **Crystal Non-Uniformity: 0.5-0.6%**

- **These are preliminary results. Some, particularly the estimate of beam momentum resolution, may change. We may be able to make improvements.**

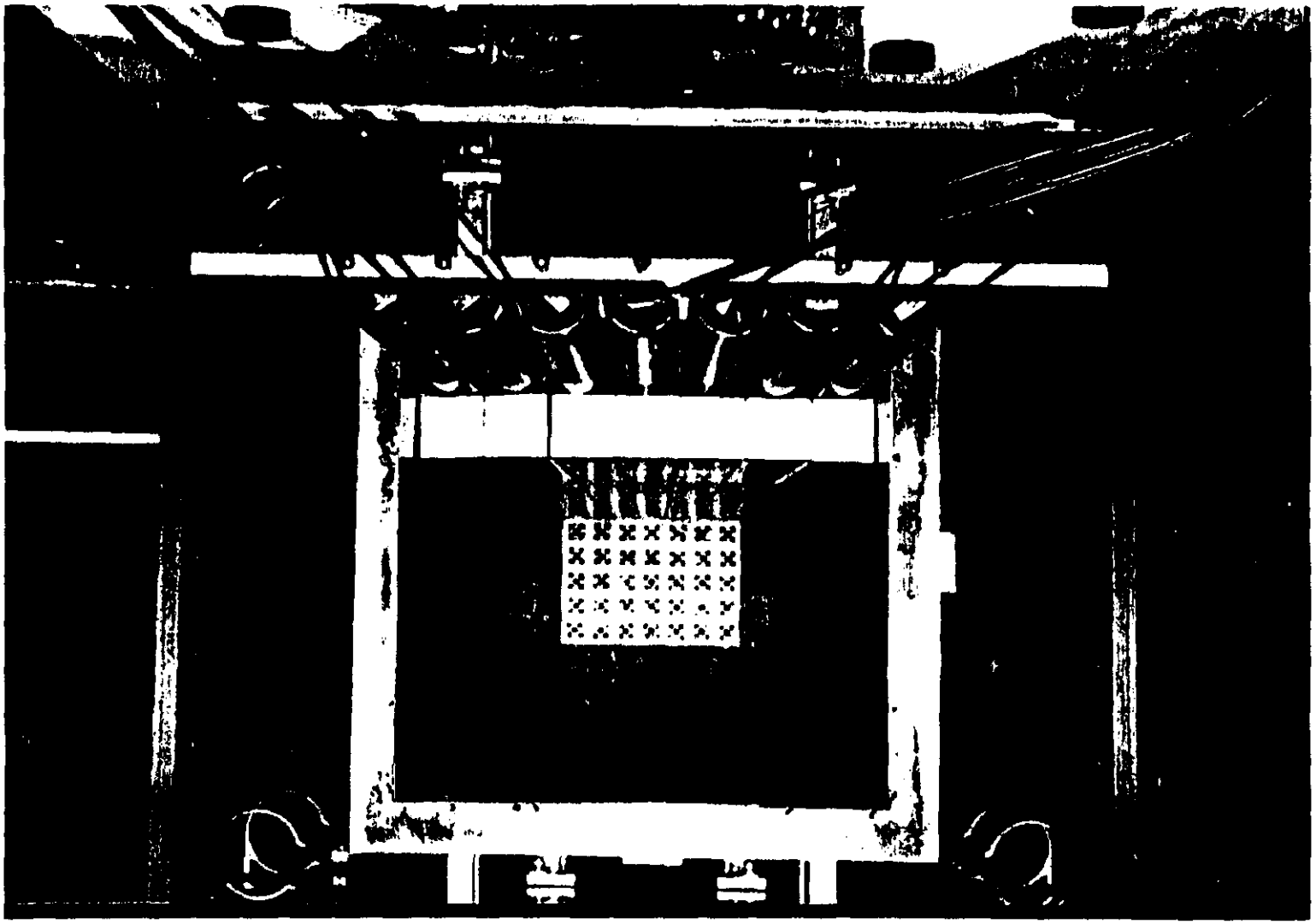
- **EVENT SELECTION**
  - **"Clean Beam" cuts in spectrometer**
  - **Spectrometer Impact matches Calorimeter Coordinate**
  - **One particle (local maximum) only in Calorimeter**
  - **Impact in center crystal 20 mm × 20 mm**

- **BaF_2 ENERGY CALCULATION**
  - $E = \sum_i G_i \, (ADC_i - PED_i)$
  - **no position or other corrections applied**
  - **G_i determined from electron data**

BaF_2 EM CALORIMETER
1991 BEAM TESTS
(FERMILAB T-849)
PRELIMINARY RESULTS

- **BEAM**
  - Spot Size: 40 mm × 40 mm
  - Momentum: 68 GeV/c
  - Momentum Spread : 3 GeV/c (FWHM)
  - Angular Spread: 1.7 mrad
  - Electron Tag: TRD
  - Previous Momentum Resolution ~ 1%
  - Rather Thick Chambers and Counters
  - Momentum Resolution (estimated) 0.5±0.2%

- **ELECTRONIC NOISE (trivial)**
  - 30 MeV / ADC channel
  - 1 channel RMS pedestal width
  - Measured "noise" contribution 0.4% (pedestal events)



1991 FNAL MATRIX

(why our first serious attempt to verify the small constant term was to be in 1992)

- crystals too small
- dimensions not accurate
- large bevels in corners
- no support structure for crystals
- grease joints to phototubes
- poor control of spring loading
- 30 MeV per ADC channel
- uniformity tuning done quickly (with source)
- uniformity sensitive to grease joint.
- no calibration system

o Uniformity not optimal

o matrix too small to study position dependence

o outer row needed for noise subtraction

o time dependence of detected signal.

gem

γeμ

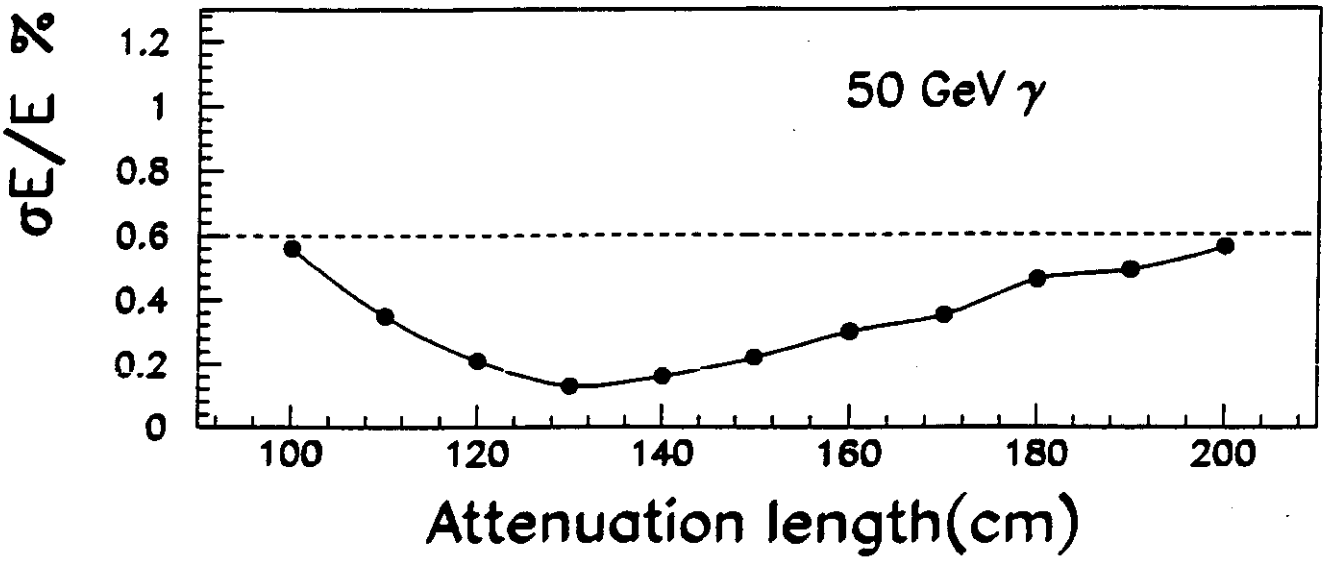
Presentation by:

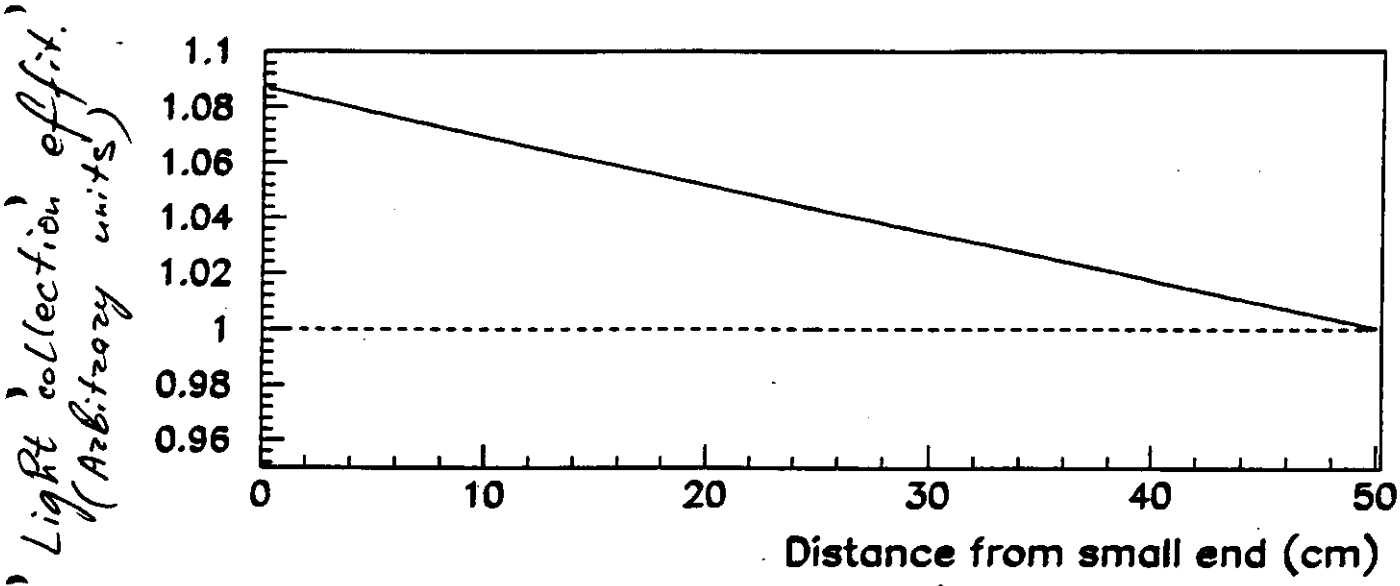
K. Shamakov

K. Shamakov

SCENARIO – all crystals were preradiated to λ=150cm

and were uniform with λ=150cm

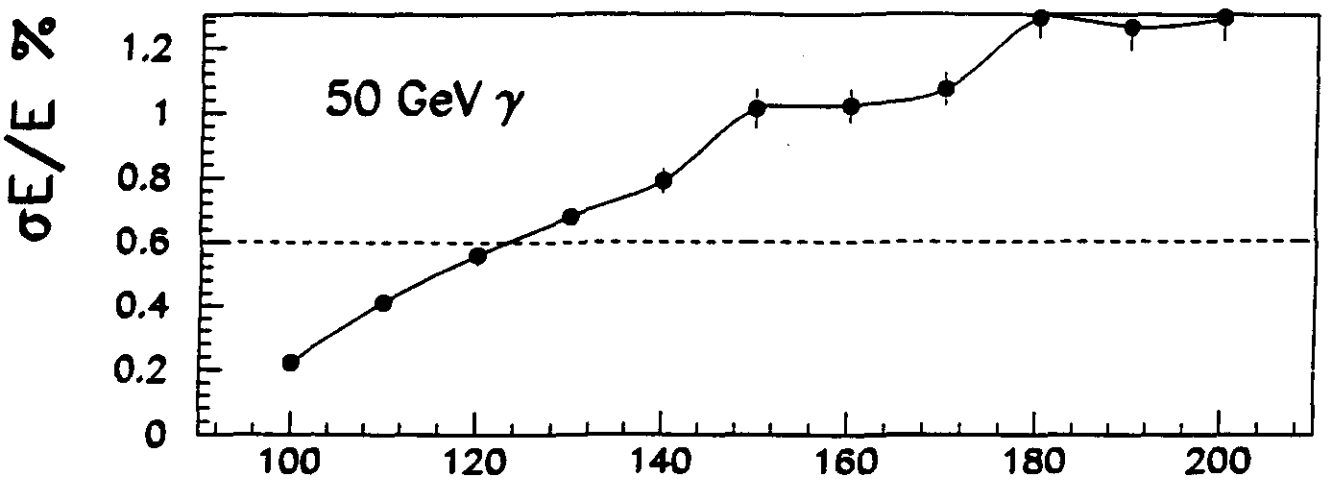




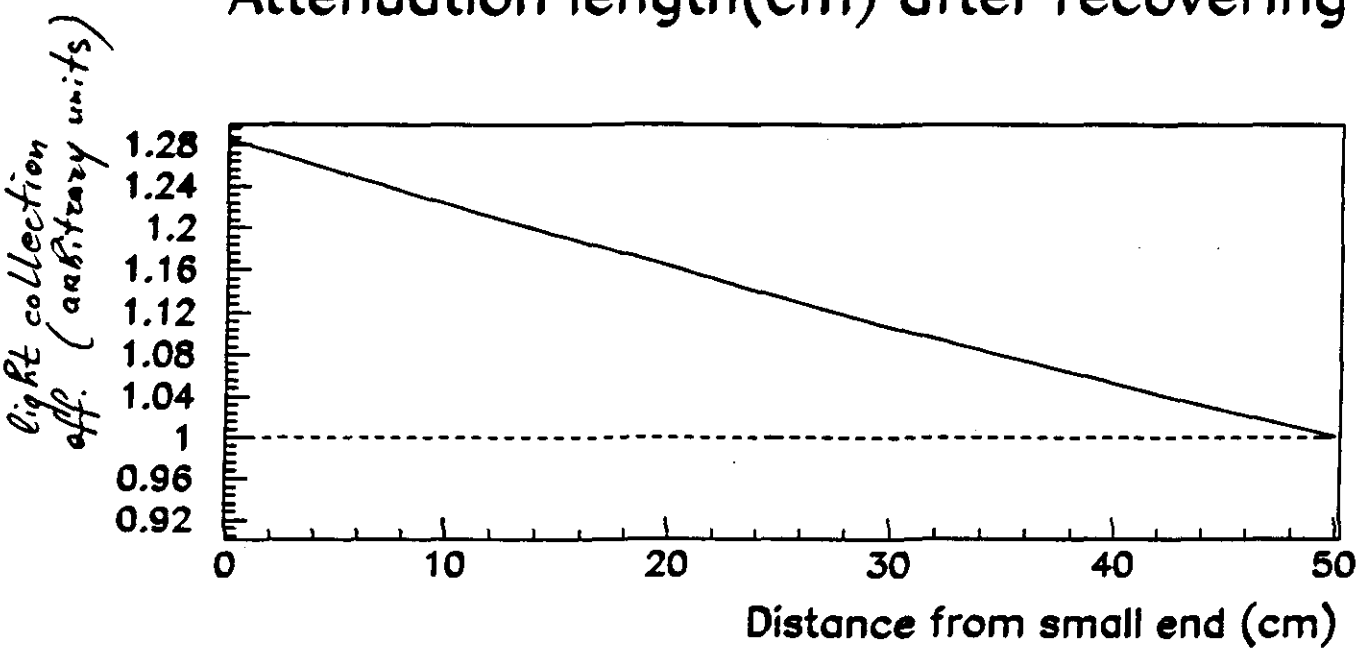
Nonuniformity for λ=200cm (after full recovering)

SCENARIO – all crystals were preradiated to saturation

and were uniform with λ=100cm



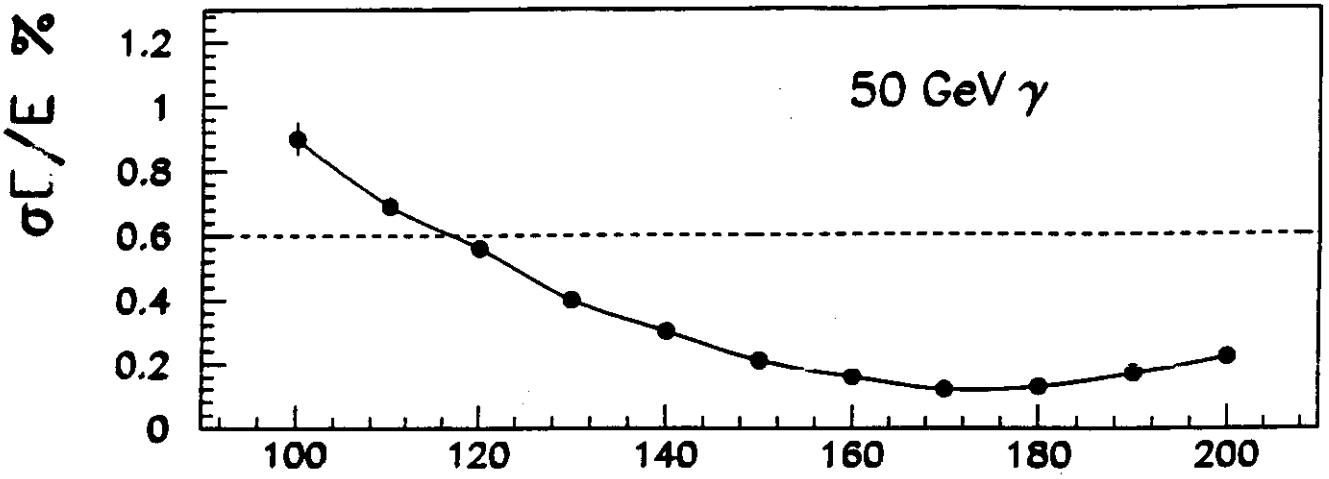
Attenuation length(cm) after recovering



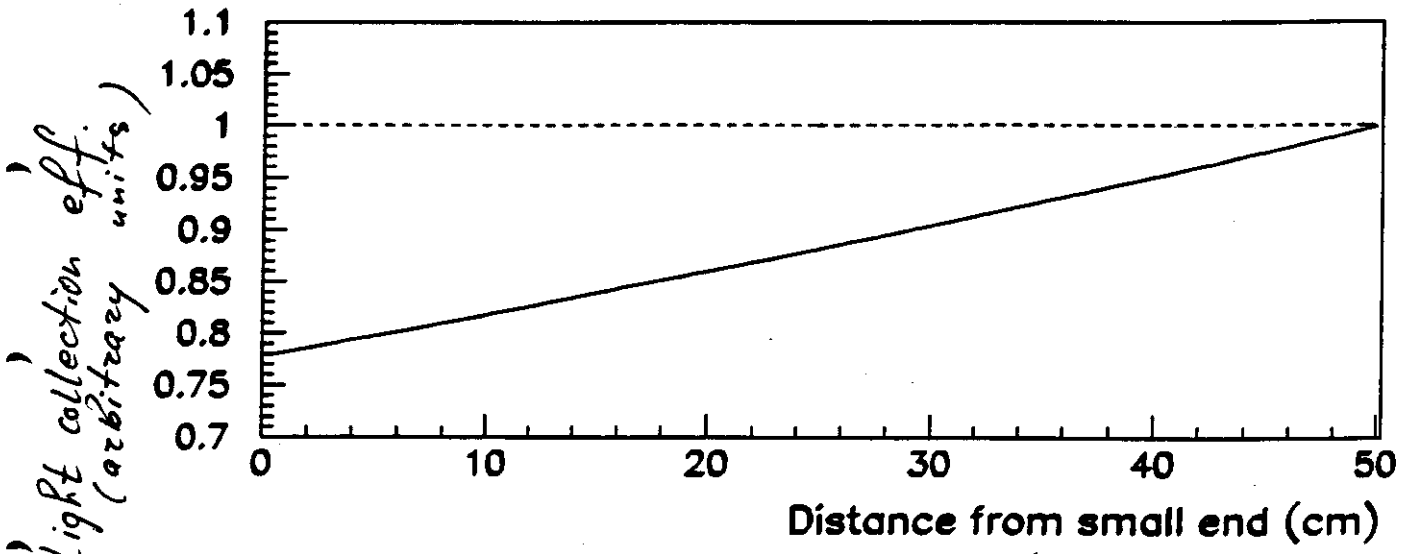
Nonuniformity for λ=200cm (after full recovering)

SCENARIO – all crystals were NOT preradiated

and were uniform with λ=200cm



Attenuation length(cm) after irradiation



Nonuniformity for λ=100cm (at saturation)

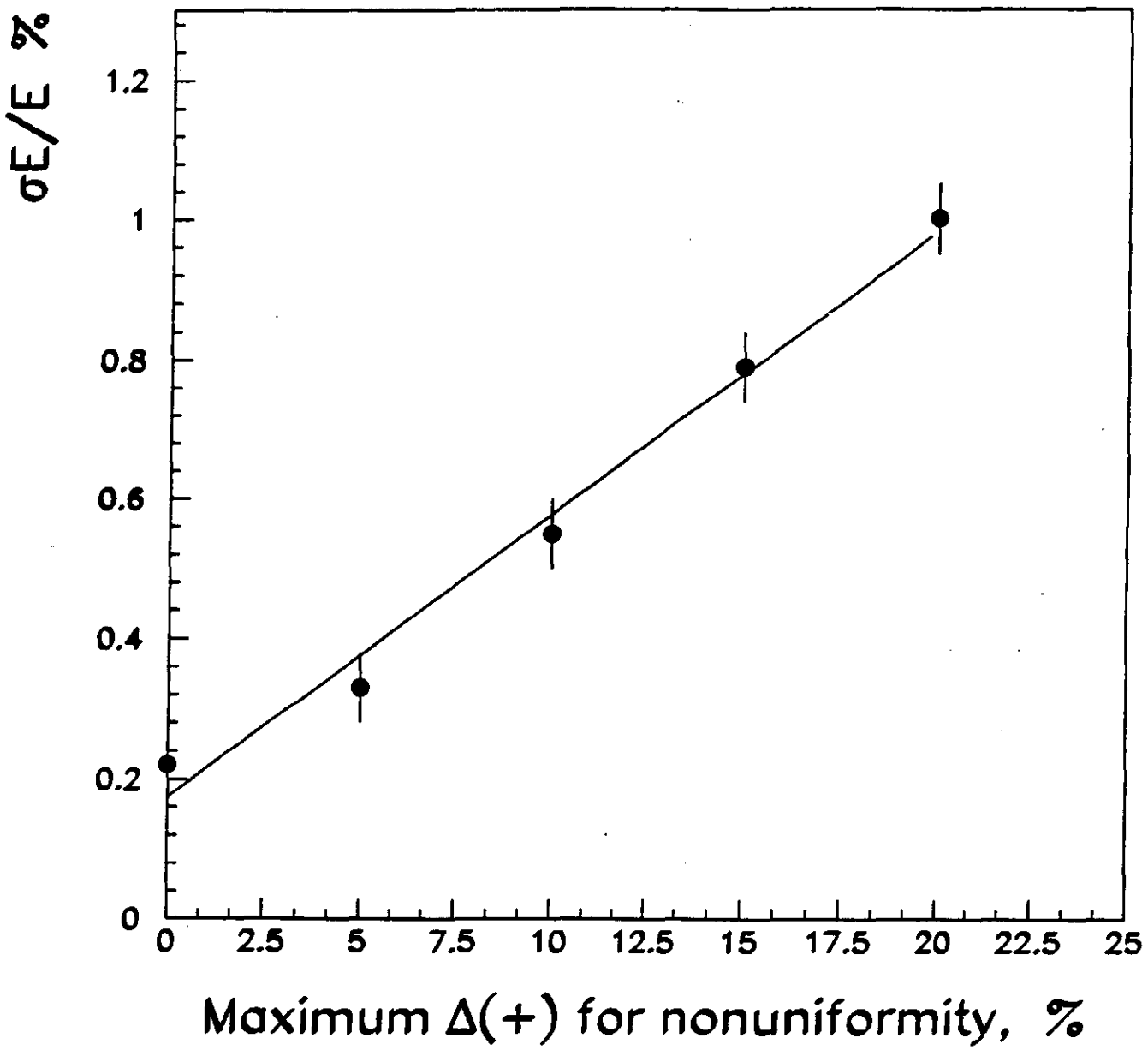
WHAT WILL BE IF PRERADIATION

OF ALL CRYSTALS IS ASSUMED?

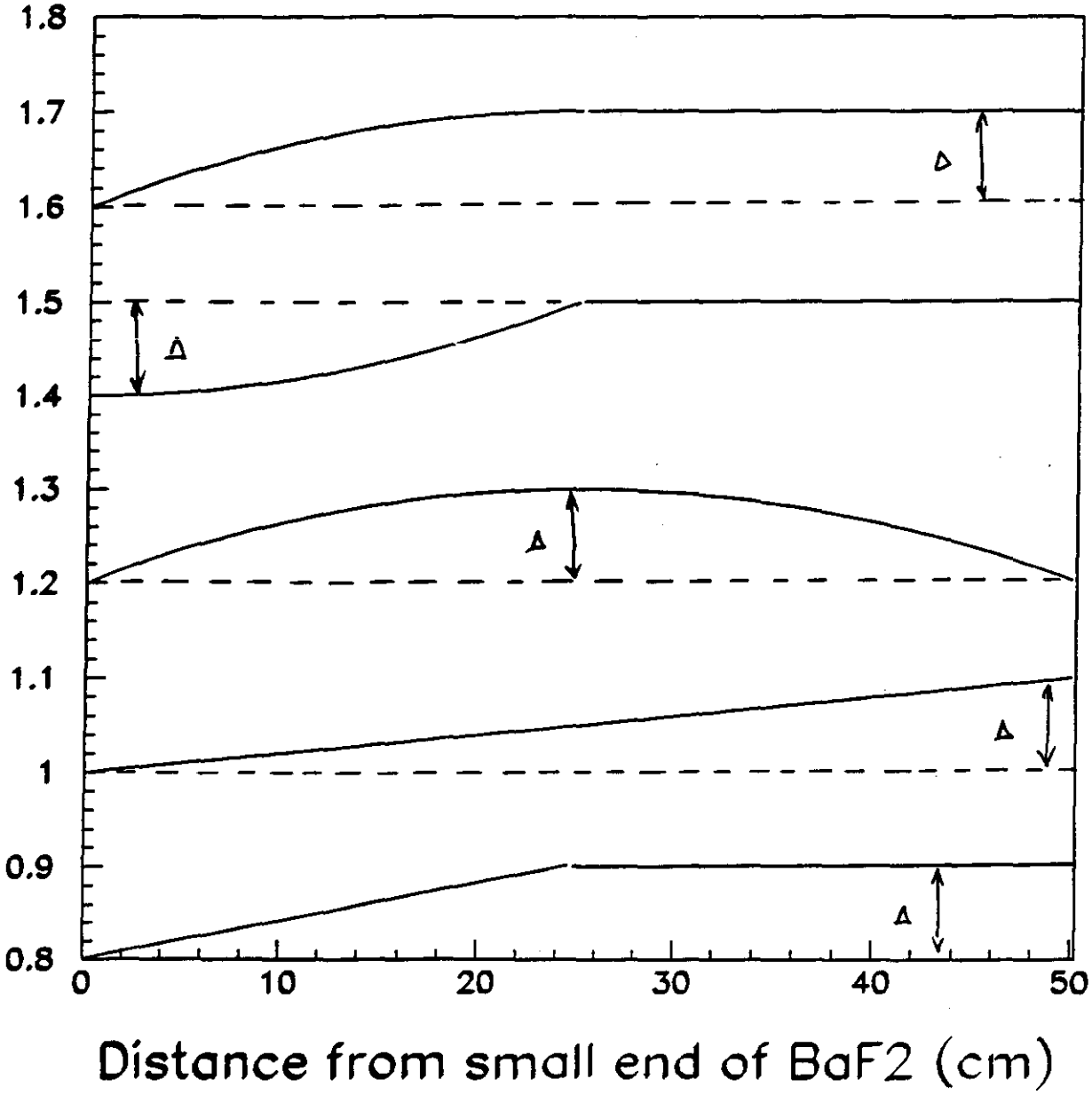
TO WHAT DOSE ALL CRYSTALS

SHOULD BE PRERADIATED?

ALL 5 TYPES of nonuniformities with positive slope



5 TYPES of nonuniformities



Simulation of matrix
5x5 crystals with
5 types of non-uniformities

For each crystal type and magnitude ($\delta\%$) of nonuniformity were picked up randomly

Response for 100 GeV γ was simulated with RFQ and *mip* calibration applied

CONCLUSION

Max magnitude of non-uniformities of types 1-5 should not exeed 5% (contribution to constant term 0.3%)

CONCLUSION

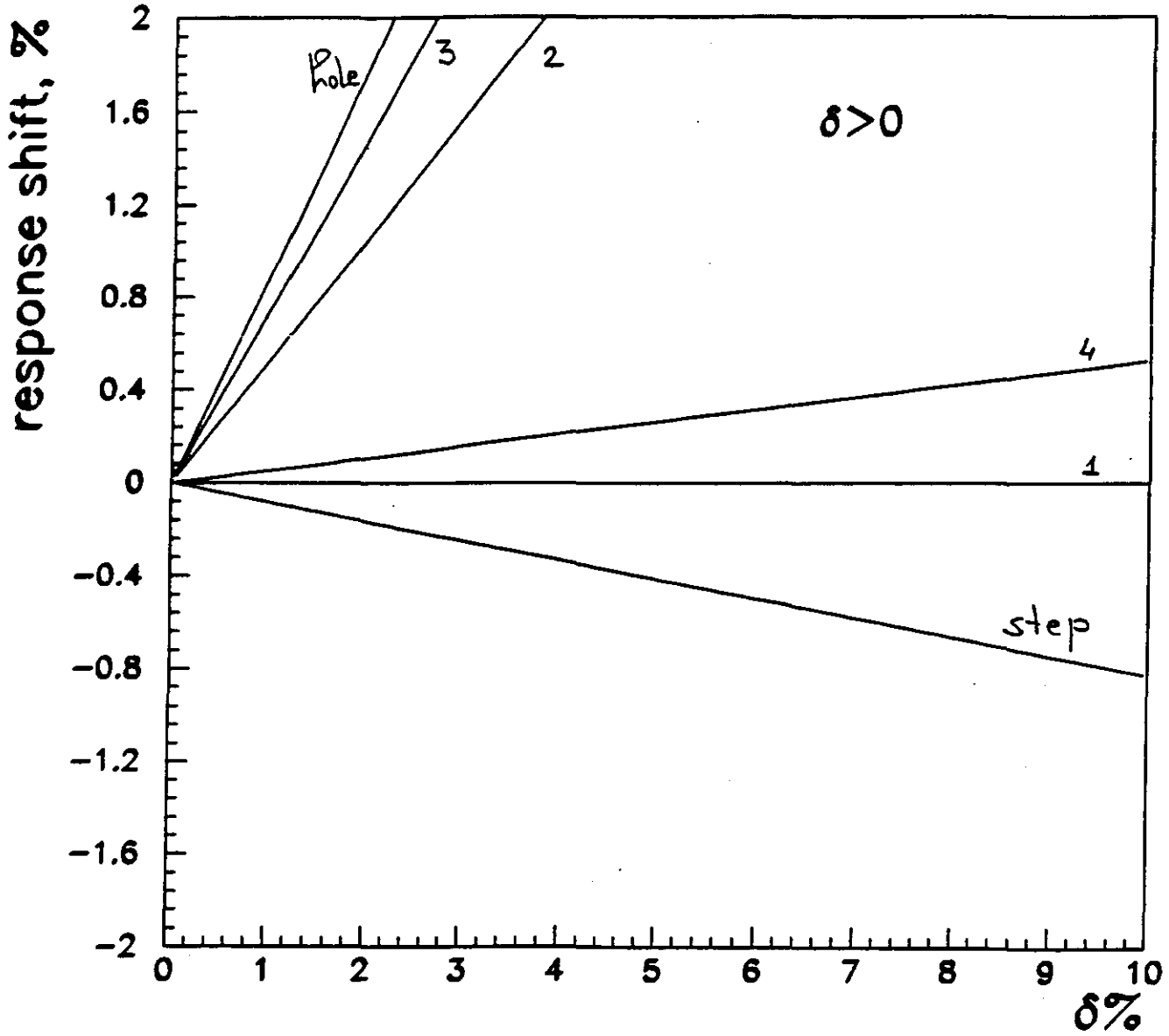
Not all the types of non-uniformities are allowed.

Crystals with bad type of non-uniformity should be rejected in the production.

DOUBLE CALIBRATION RFQ + MIP

GEANT – response shift for 50 GeV γ (BaF_2)

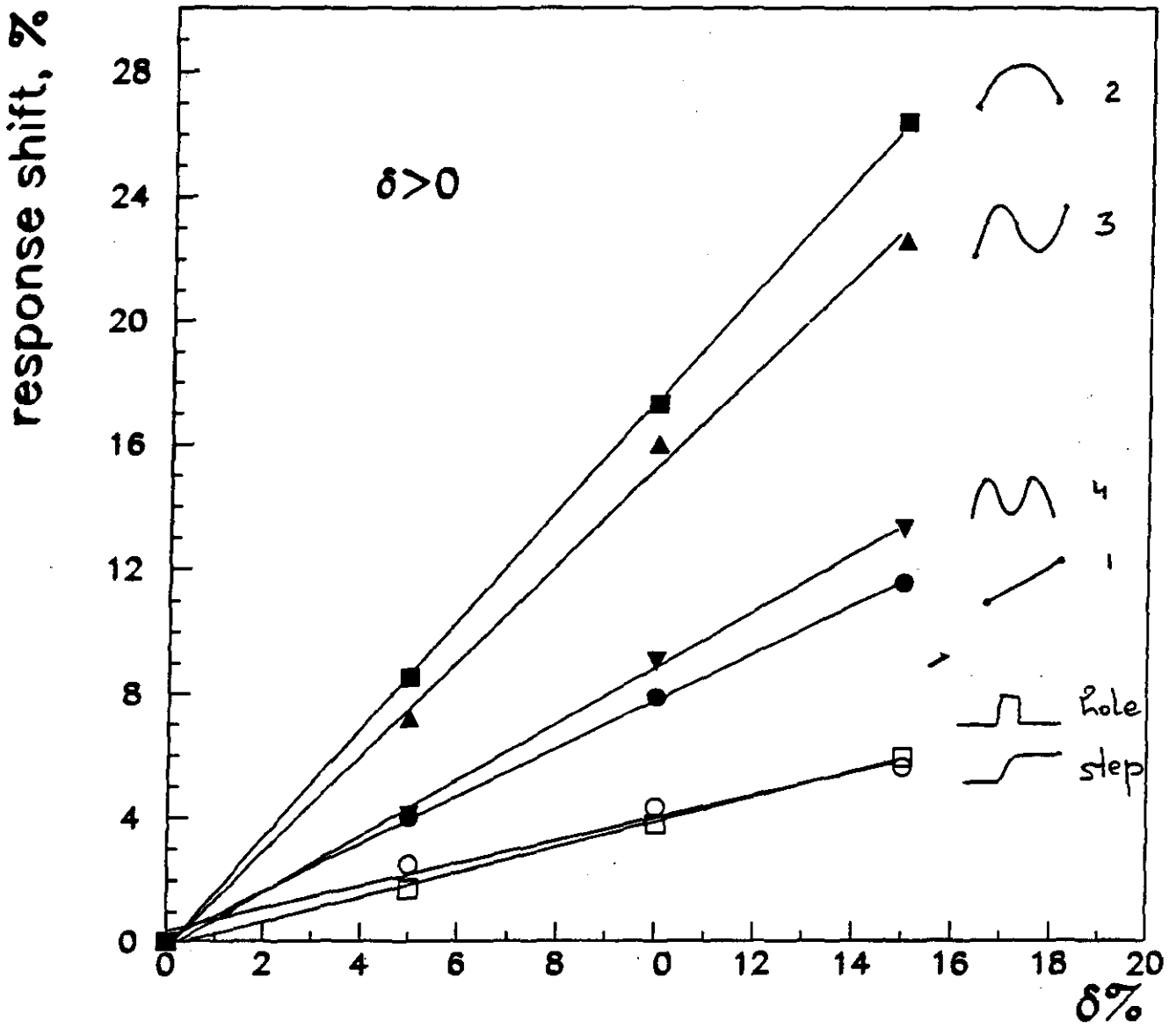
due to different nonuniformity shapes



RFQ calibration only is assumed

GEANT – response shift for 50 GeV γ (BaF_2)

due to different nonuniformity shapes



ARBITRARY NON-UNIFORMITY

Will affect resolution in the crystal

Will change the mean response

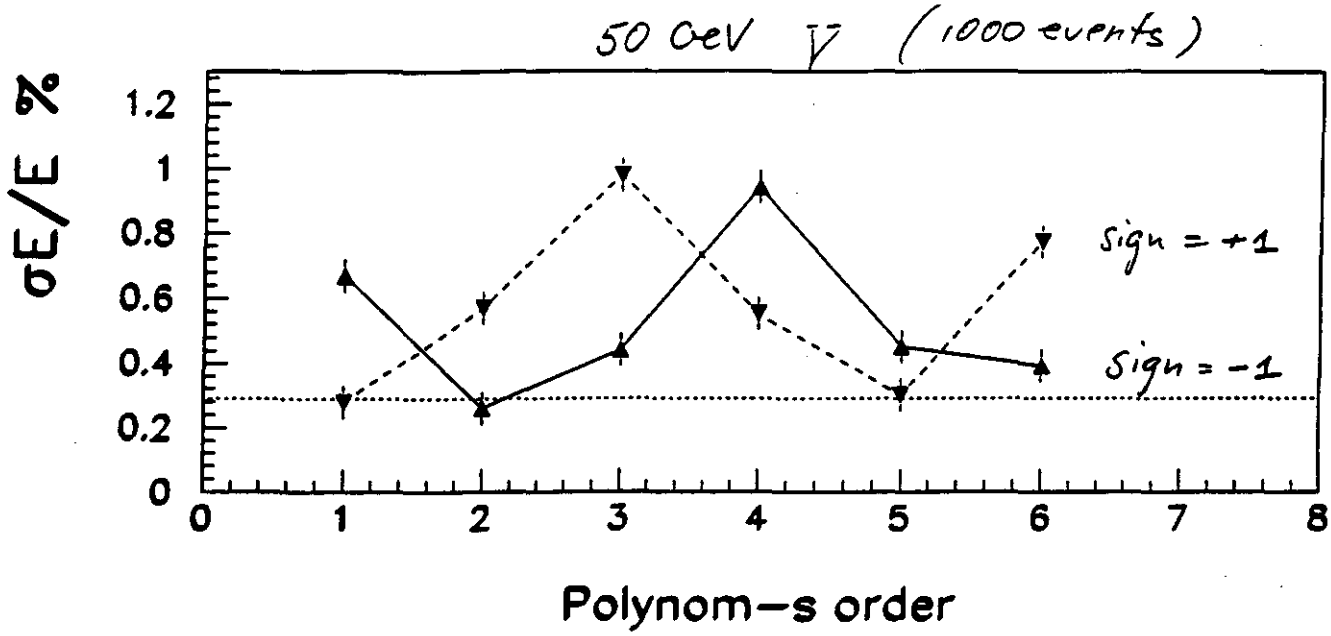
In situ calibration should restore the mean value

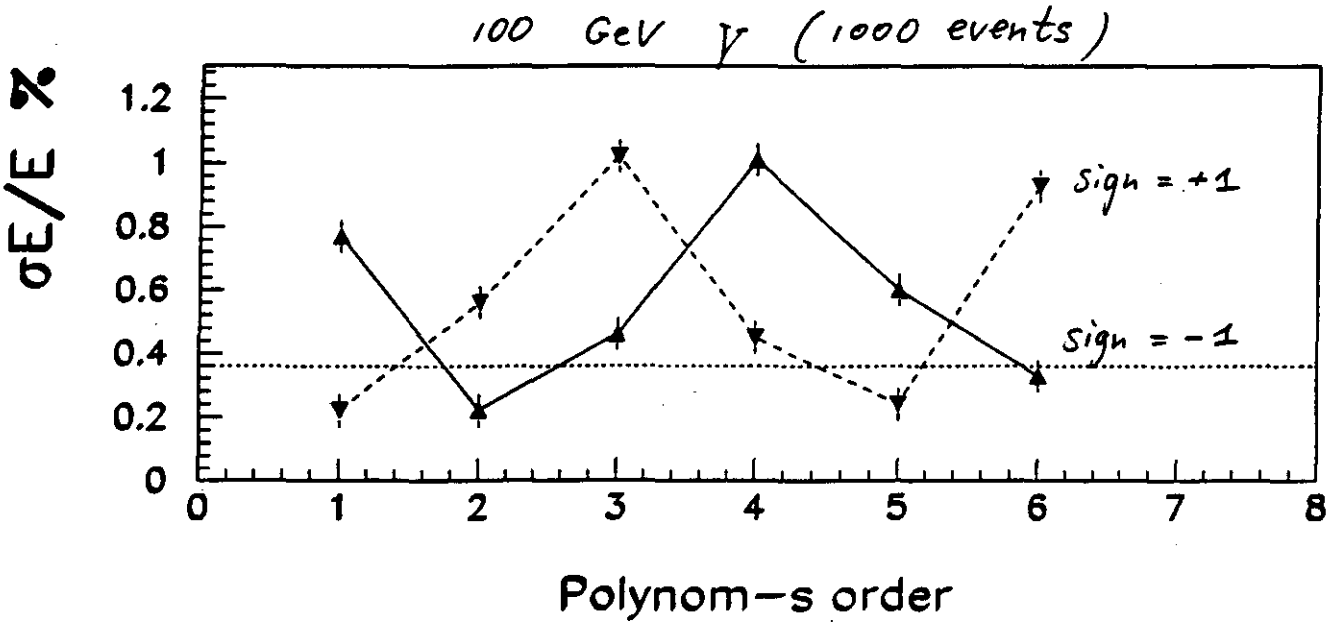
a) mip calibrates average value of longitudinal non-uniformity

b) RFQ calibrates response of the first 5-7cm of the crystal

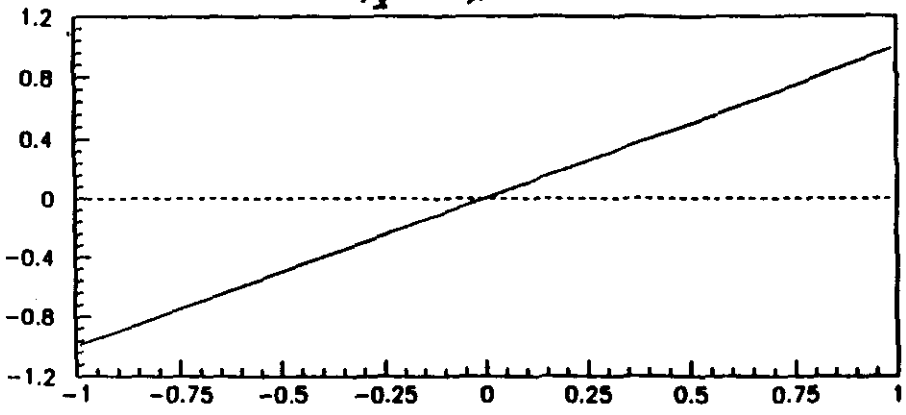
If only a) or b) applied the residial shift of average response will be large.

Chebyshev−s polynoms of +−5%, different orders

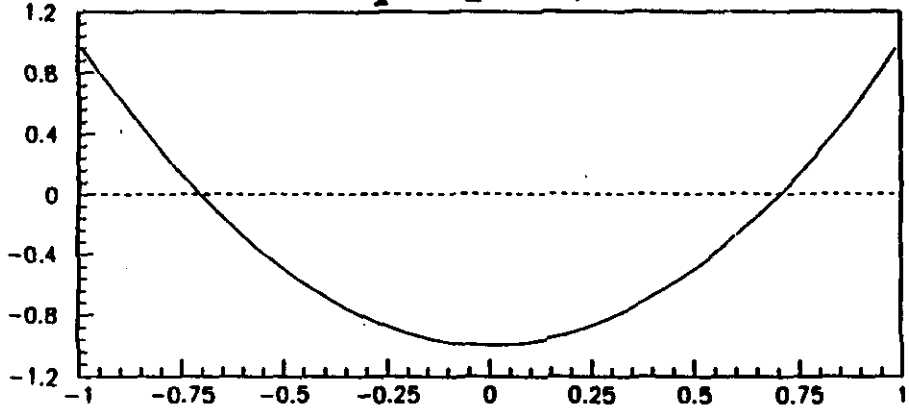




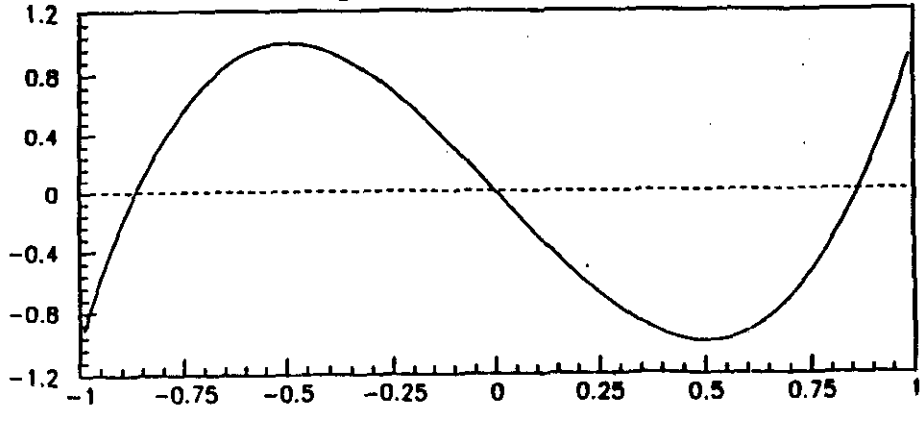
$T_1 = x$



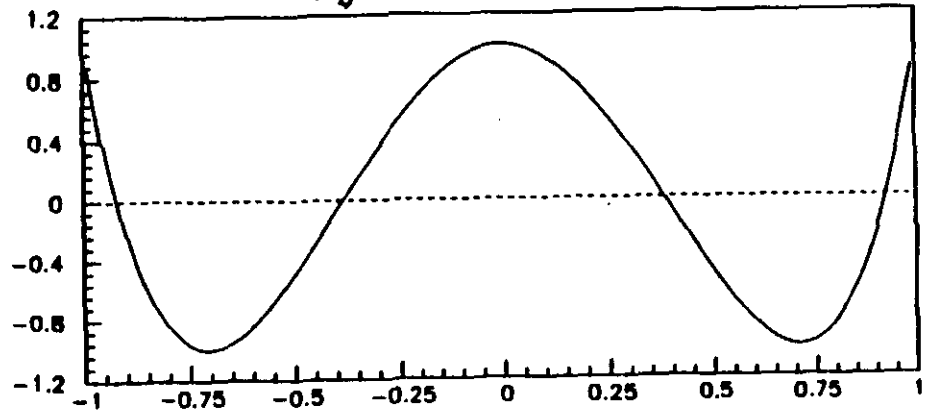
$T_2 = 2x^2 - 1$



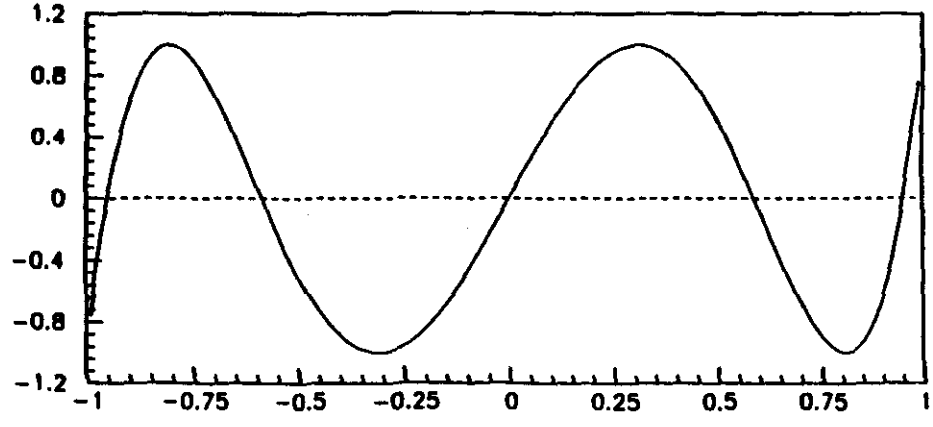
$T_3 = 4x^3 - 3x$



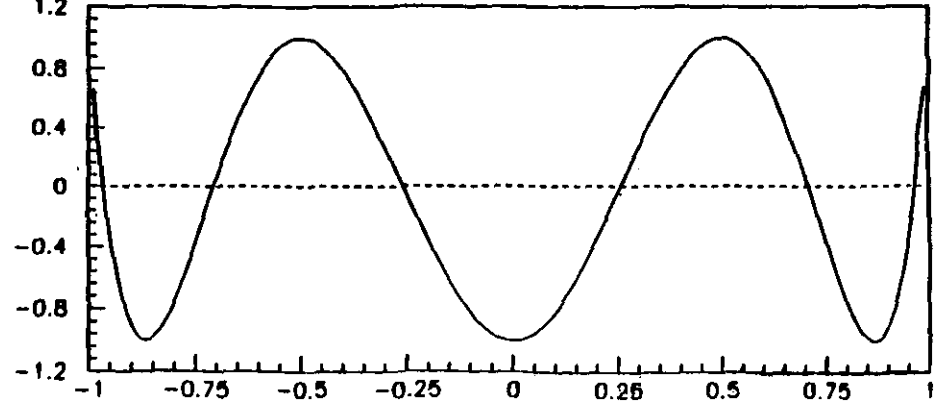
$T_4 = 8x^4 - 8x^2 + 1$



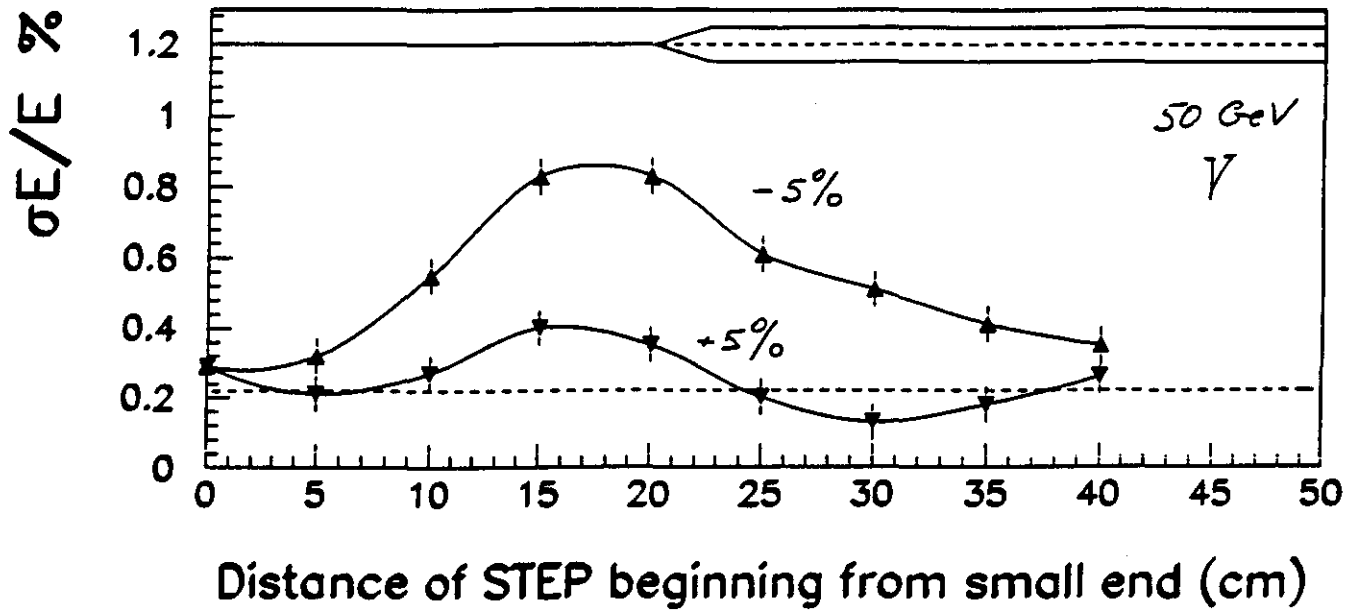
$T_5 = 16x^5 - 20x^3 + 5x$

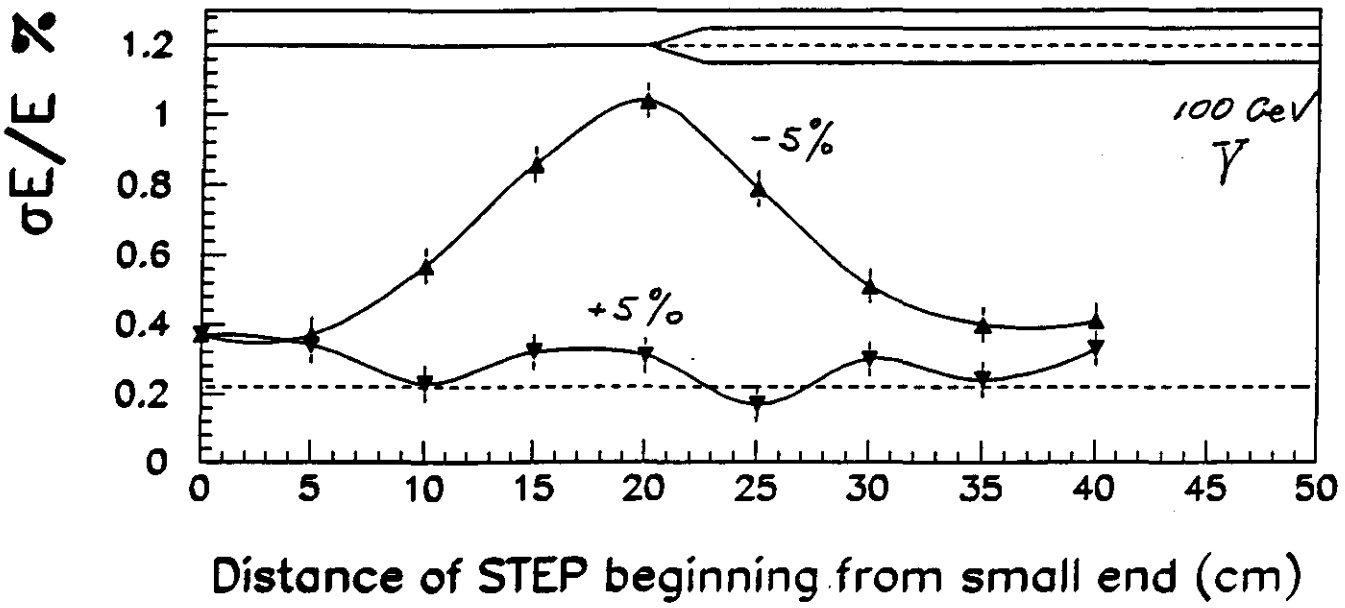


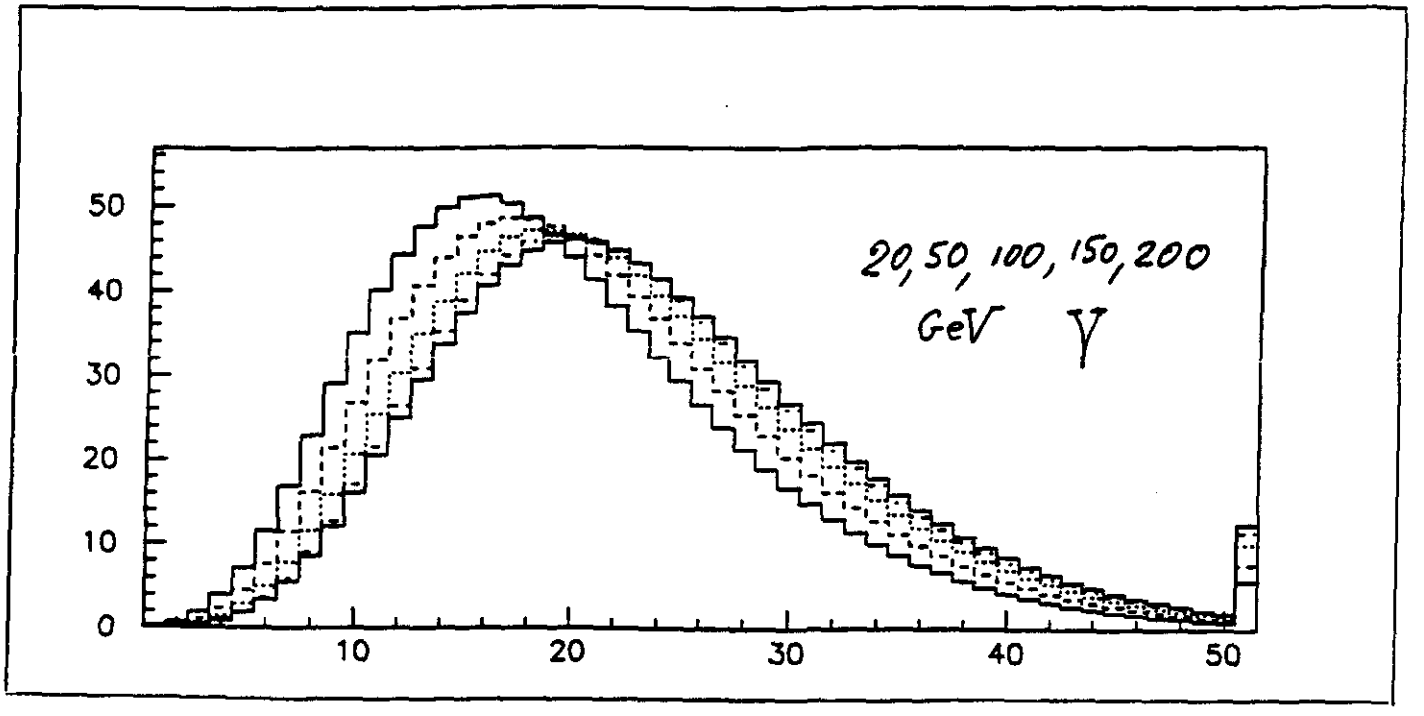
$T_6 = 32x^6 - 48x^4 + 18x^2 - 1$



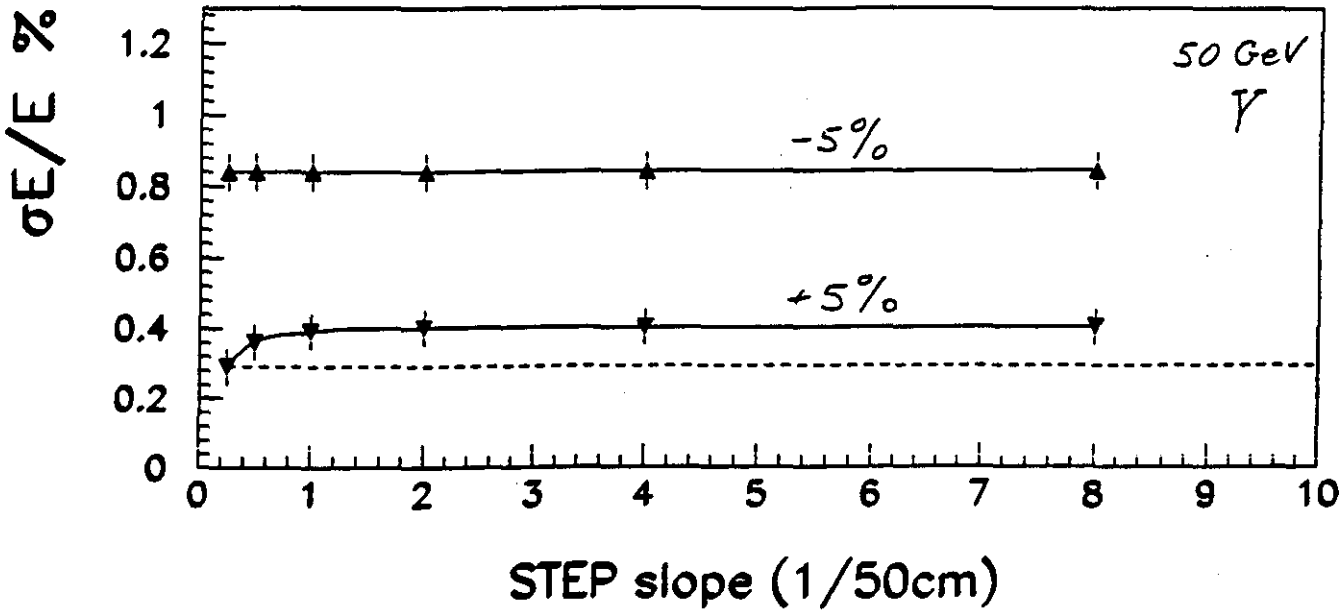
Nonuniformity like STEP of 5% starting at different depth

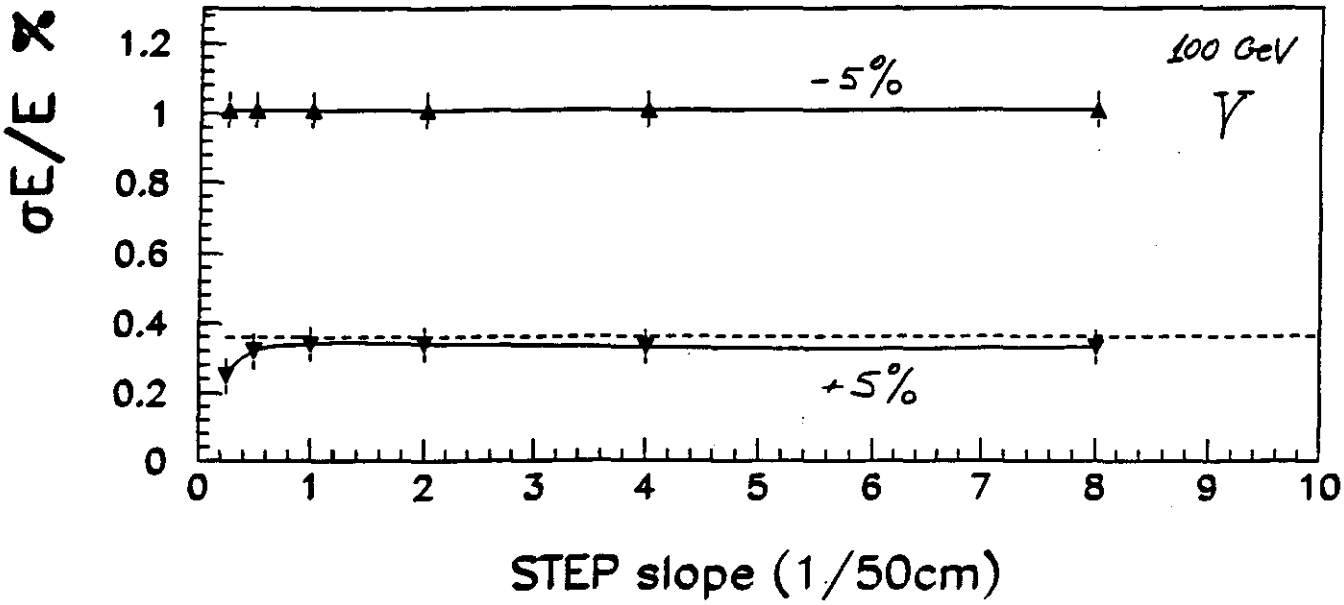




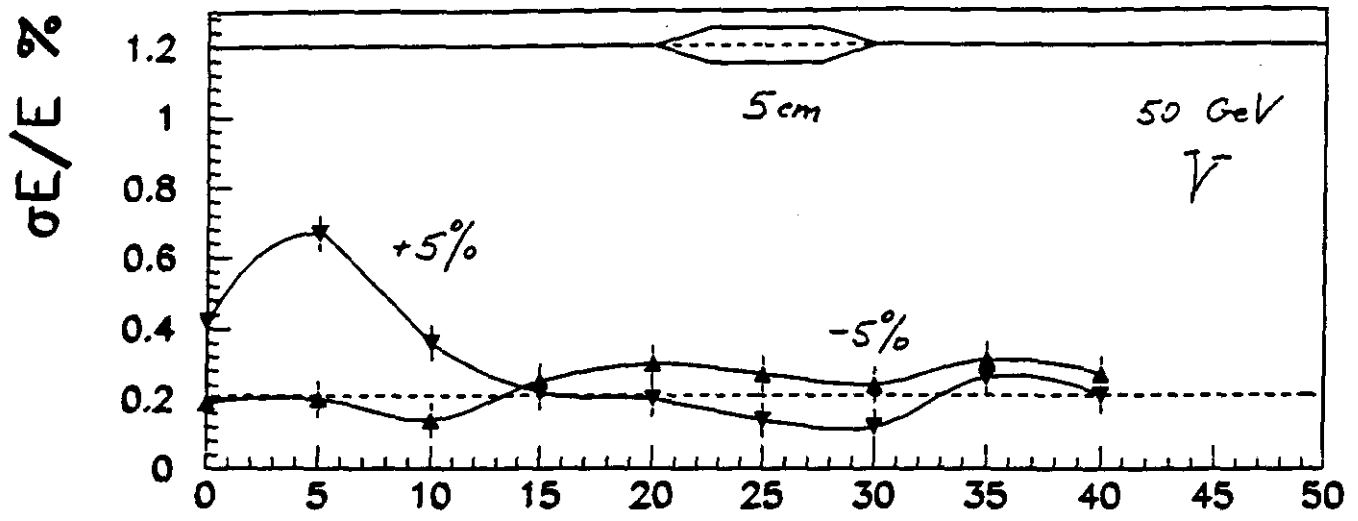

50
40
30
20
10
0
10
20
30
40
50
20, 50, 100, 150, 200
GeV γ

Nonuniformity like STEP of 5% at 18cm, different slopes

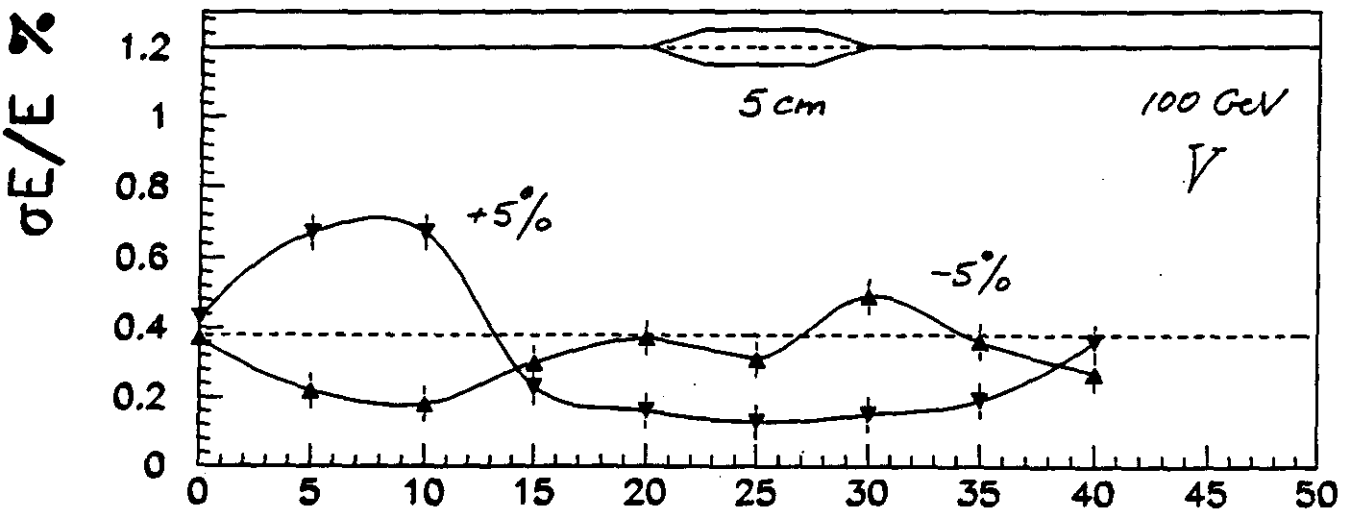




Nonuniformity like HOLE of 5% starting at different depth

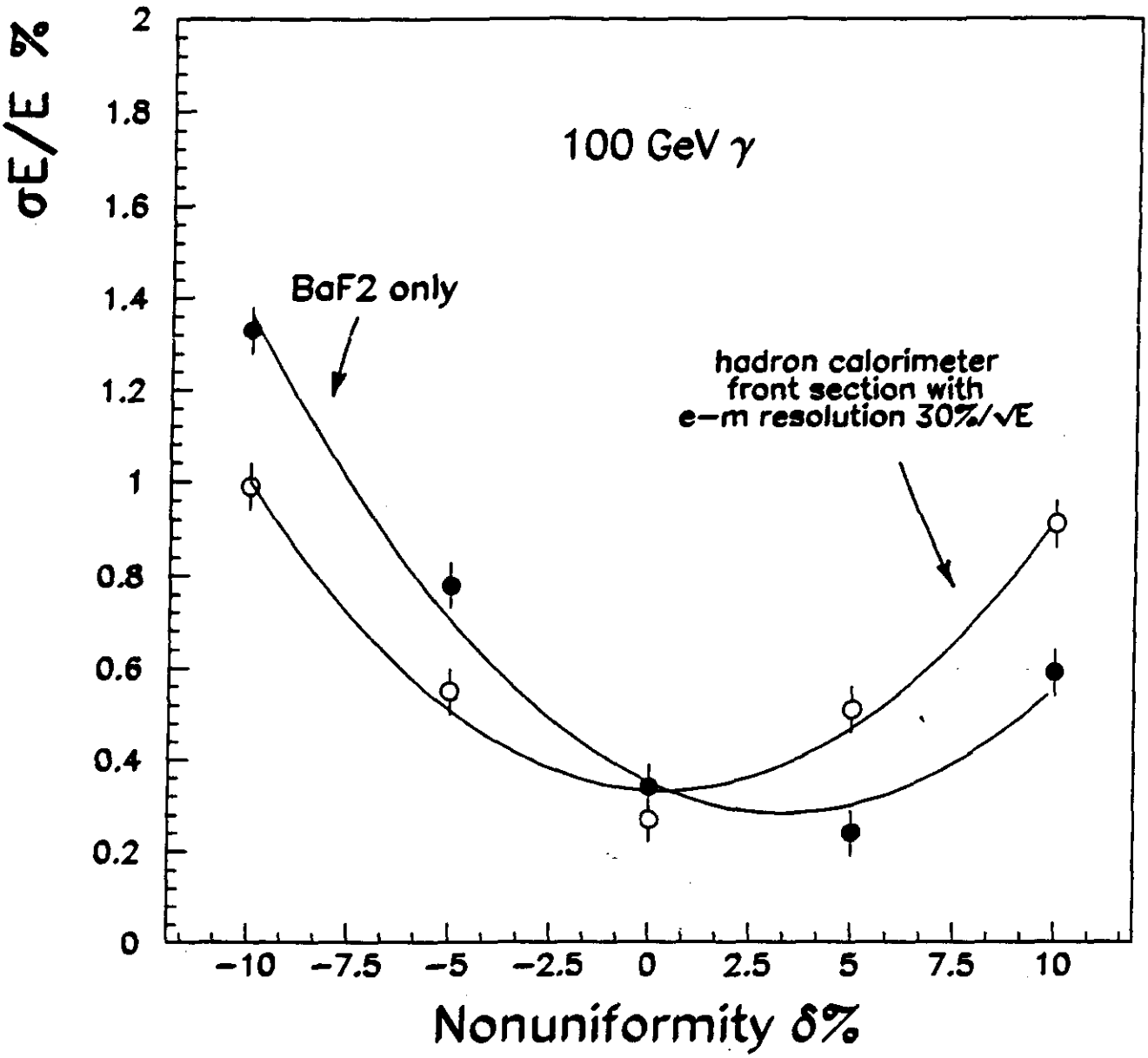


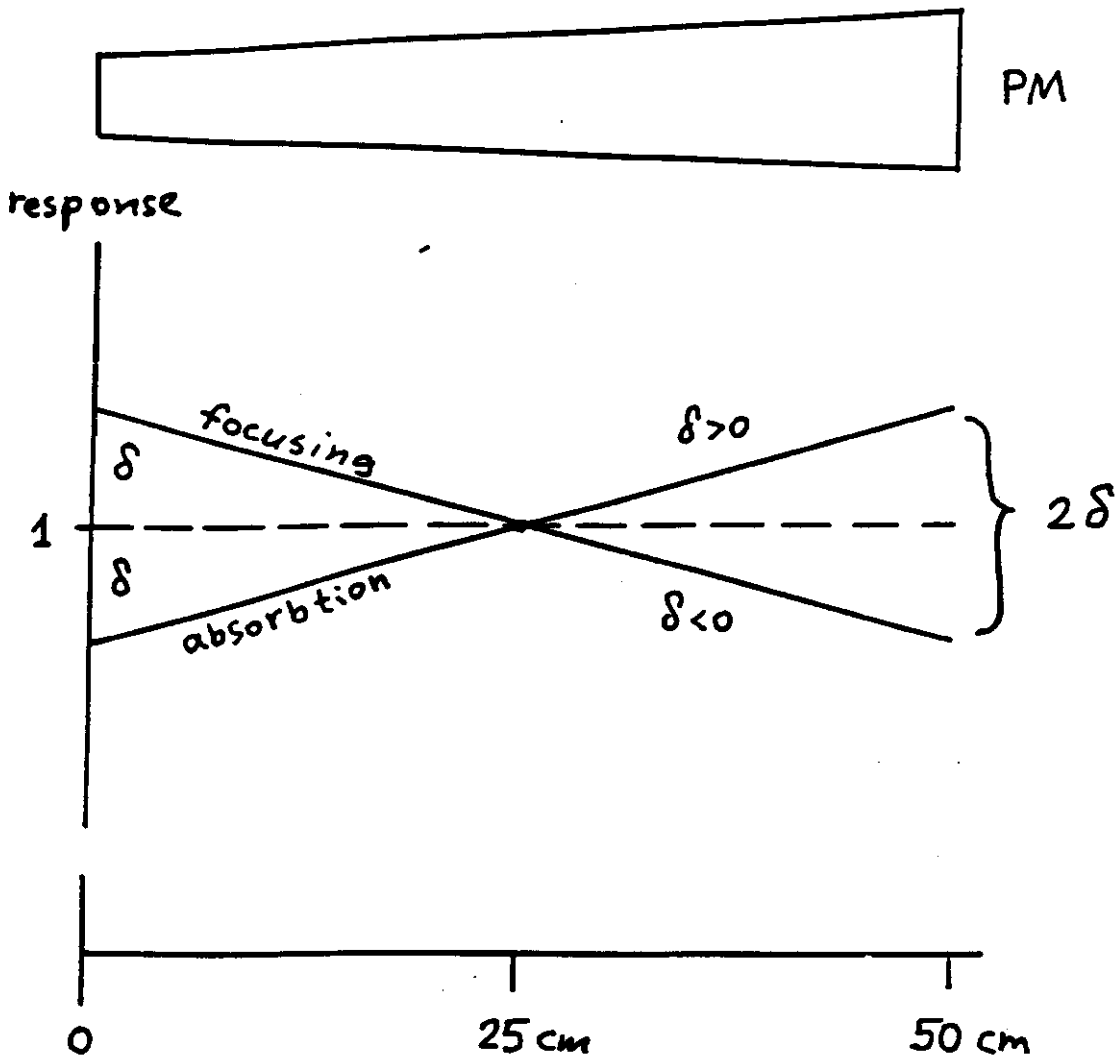
Distance of HOLE beginning from small end (cm)



Distance of HOLE beginning from small end (cm)

BaF2 resolution vs nonuniformity slope (δ)





Linear parametrization of non-uniformity
(definition of δ)

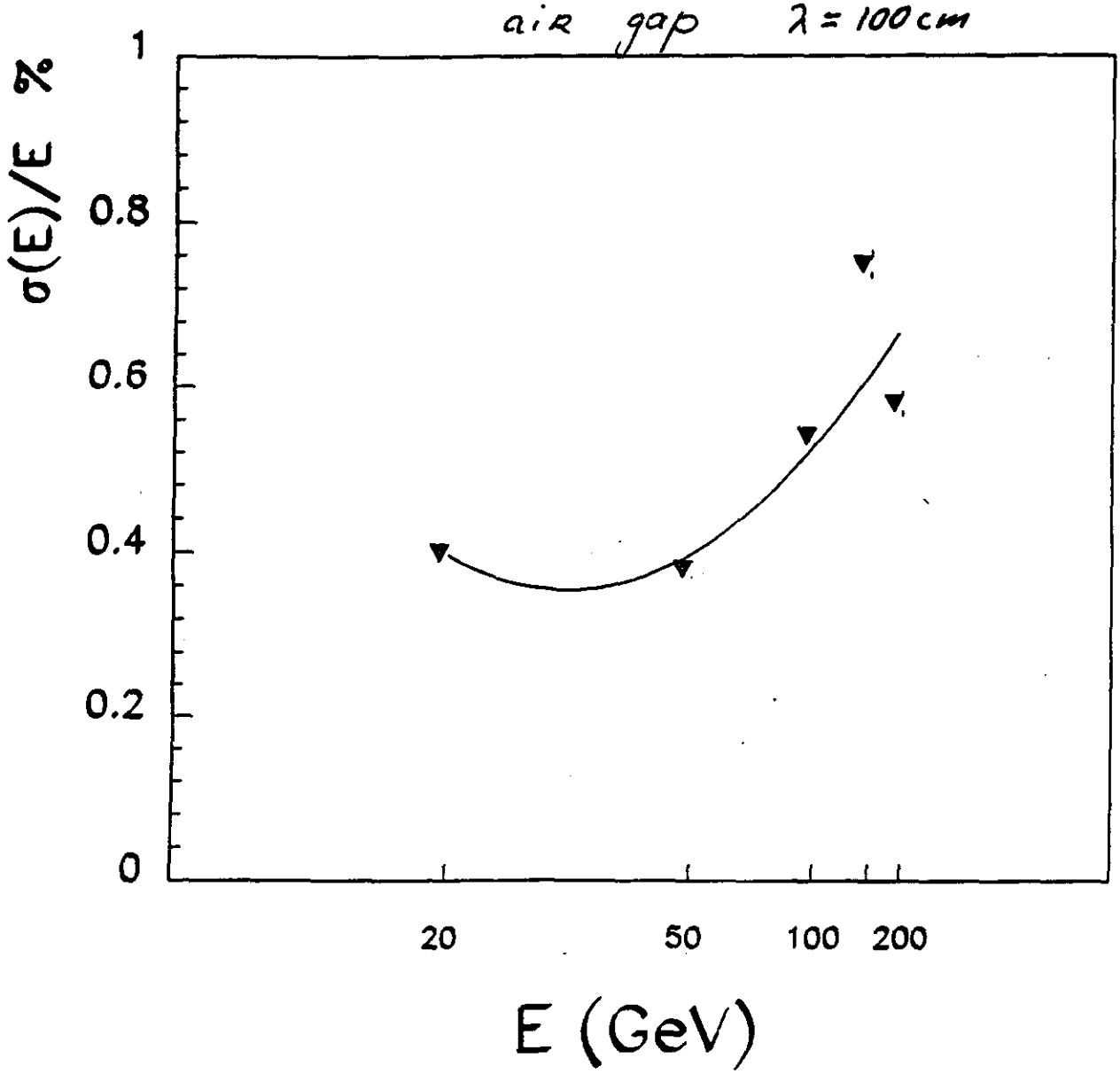
EFFECTS OF

LOCAL NONUNIFORMITIES

GAMMA RESOLUTION – GEANT3

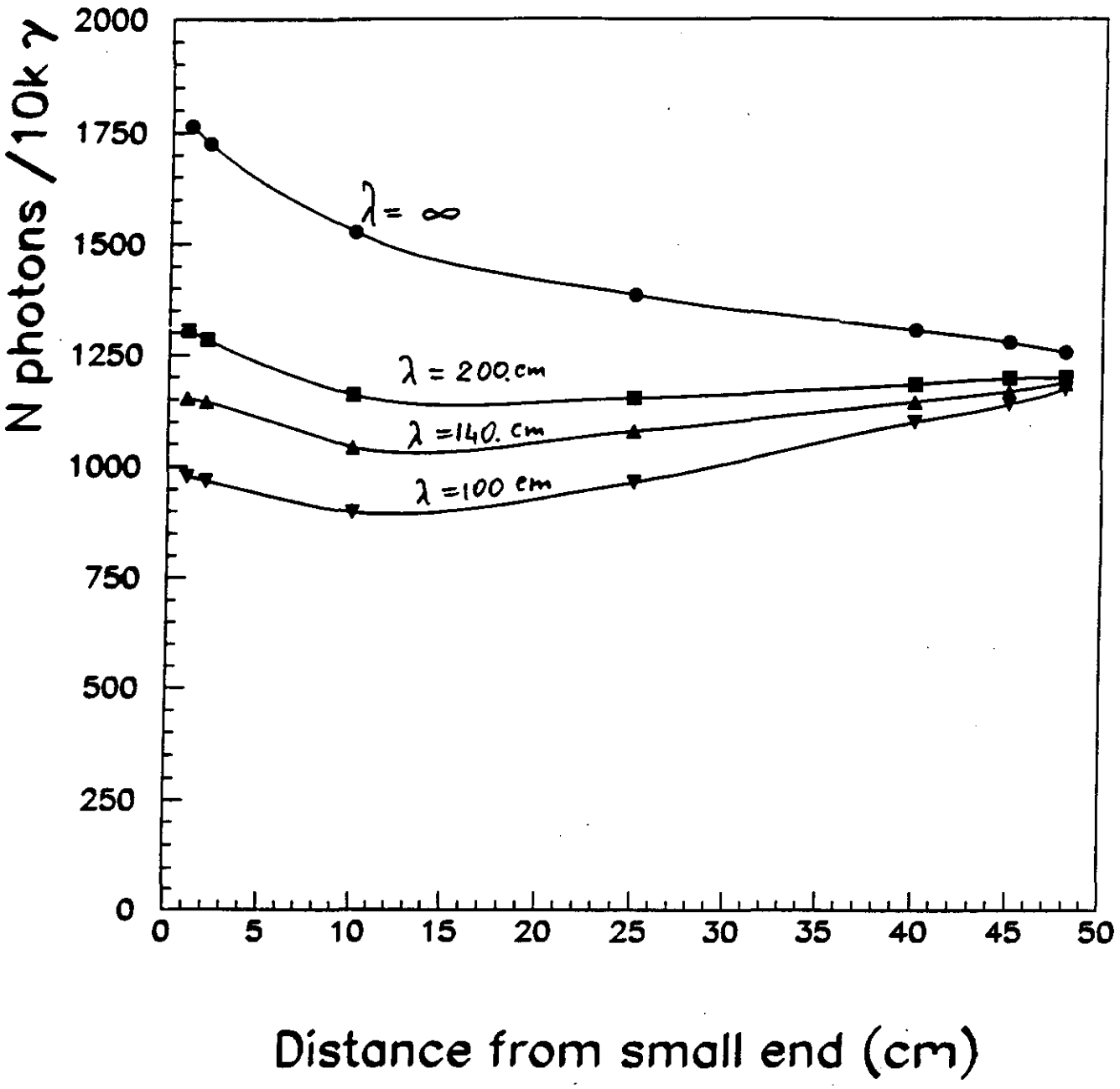
BaF2 (25 X0), MgF2 mirror

air gap $\lambda = 100$ cm



$K_{refL}(MgF_2) \equiv const = 0.88$
for all Q_{inc}

Spectrum – BaF2 x K–Cs–Te, MgF2 mirror, air gap



MgF_2 mirror on five surfaces

$$\theta_{\text{inc}} = \theta_{\text{refl}}$$

$$K_{\text{refl}} = \text{const} = 0.88$$

$$\text{for all } \theta_{\text{inc}}$$

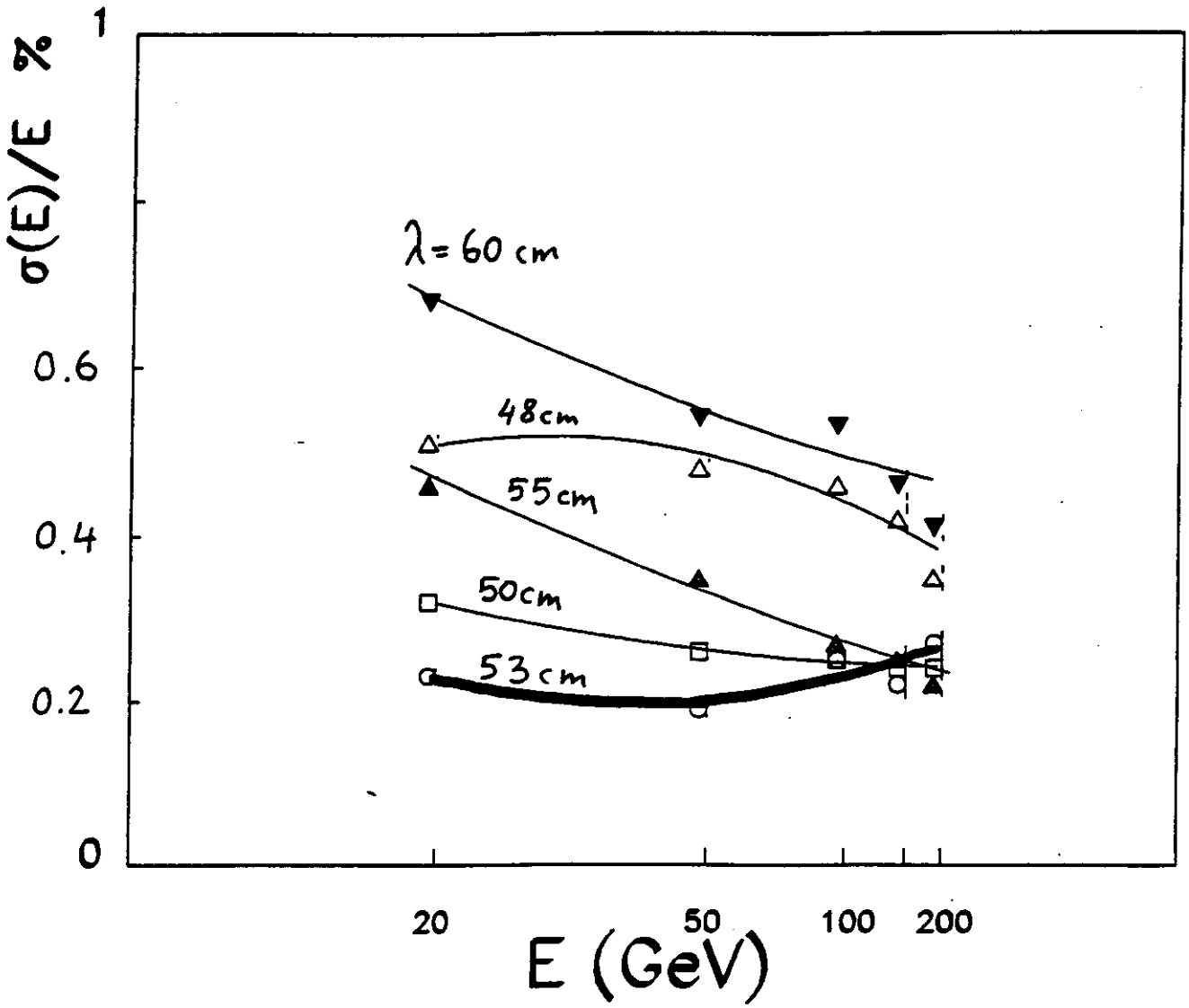
CONCLUSION

Detailed properties of MgF_2 mirror should be measured.

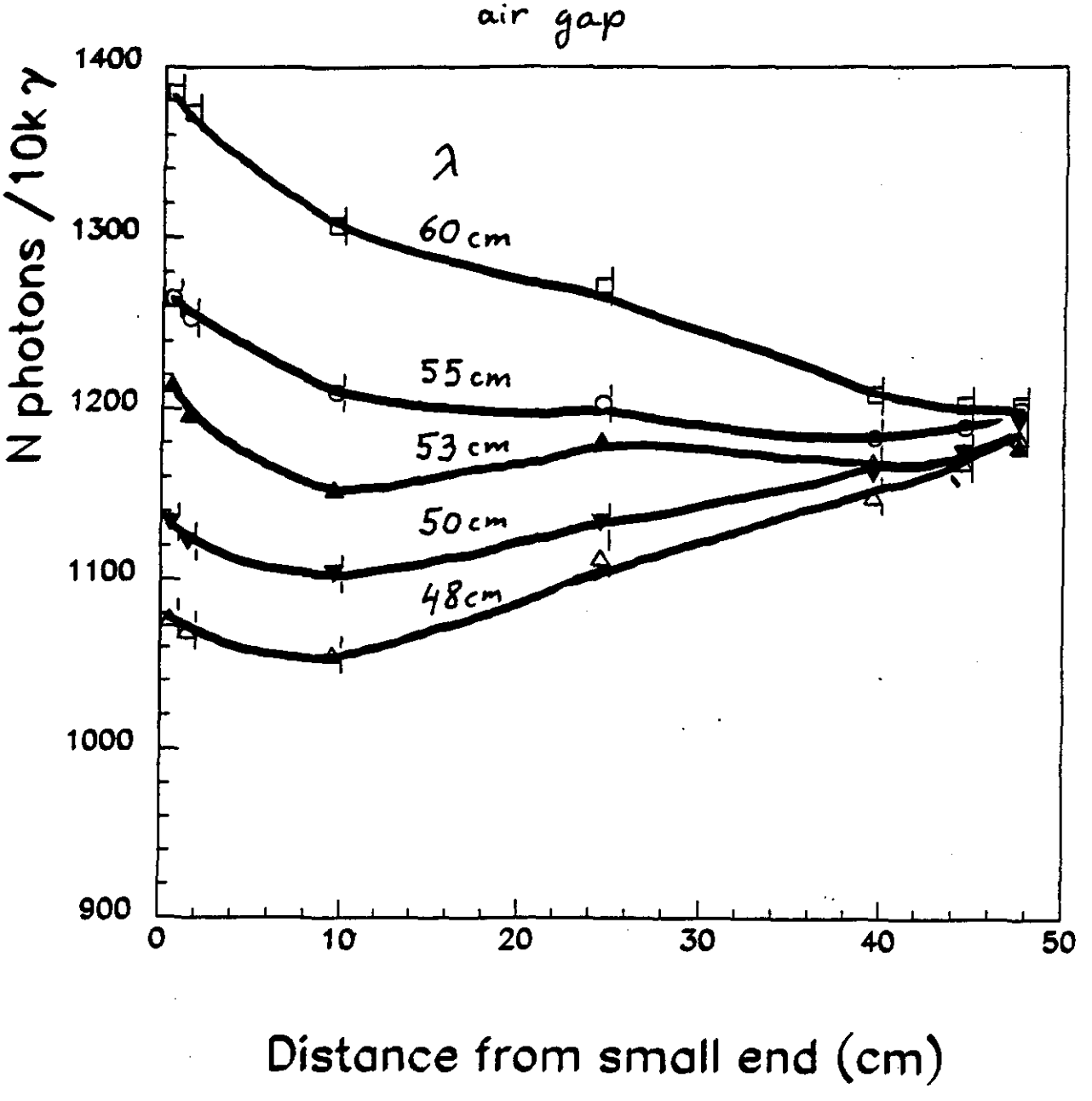
If assumptions about MgF_2 mirror are correct non-irradiated crystals ($\lambda_{\text{abs}} > 200$ cm) painted with MgF_2 will show non-uniformity

GAMMA RESOLUTION – GEANT3

BaF2 (25 X0)



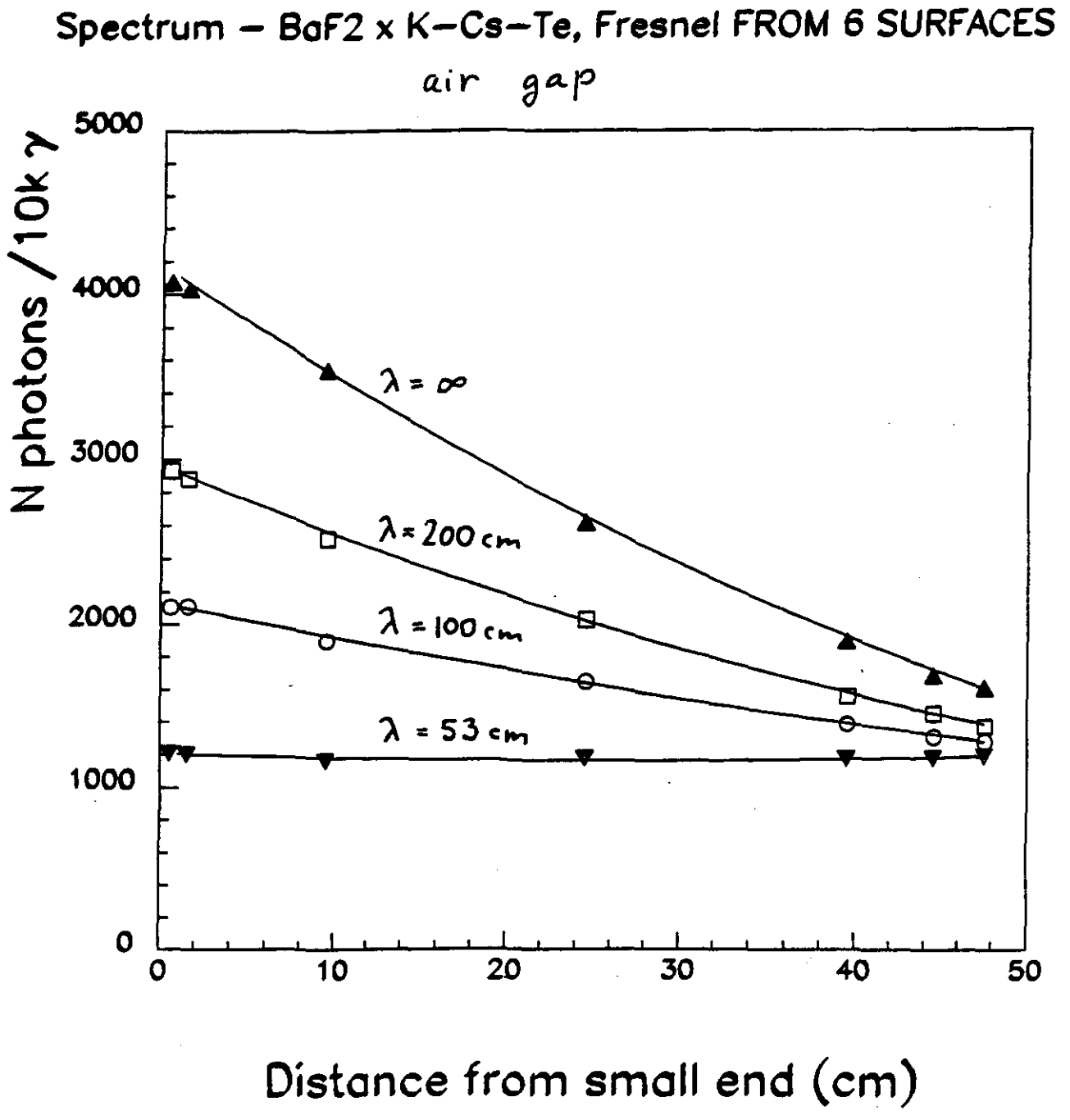
Spectrum – BaF2 x K–Cs–Te, Fresnel FROM 6 SURFACES

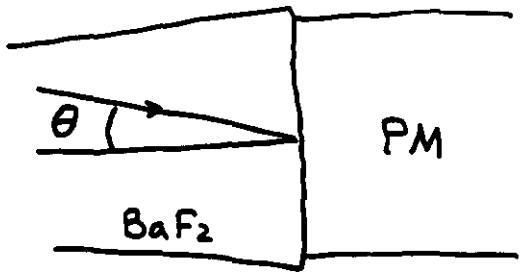


For all polished 50cm long crystals and air gap coupling to photodetector the uniform responce can be achieved for the absorbtion length as small as 53cm

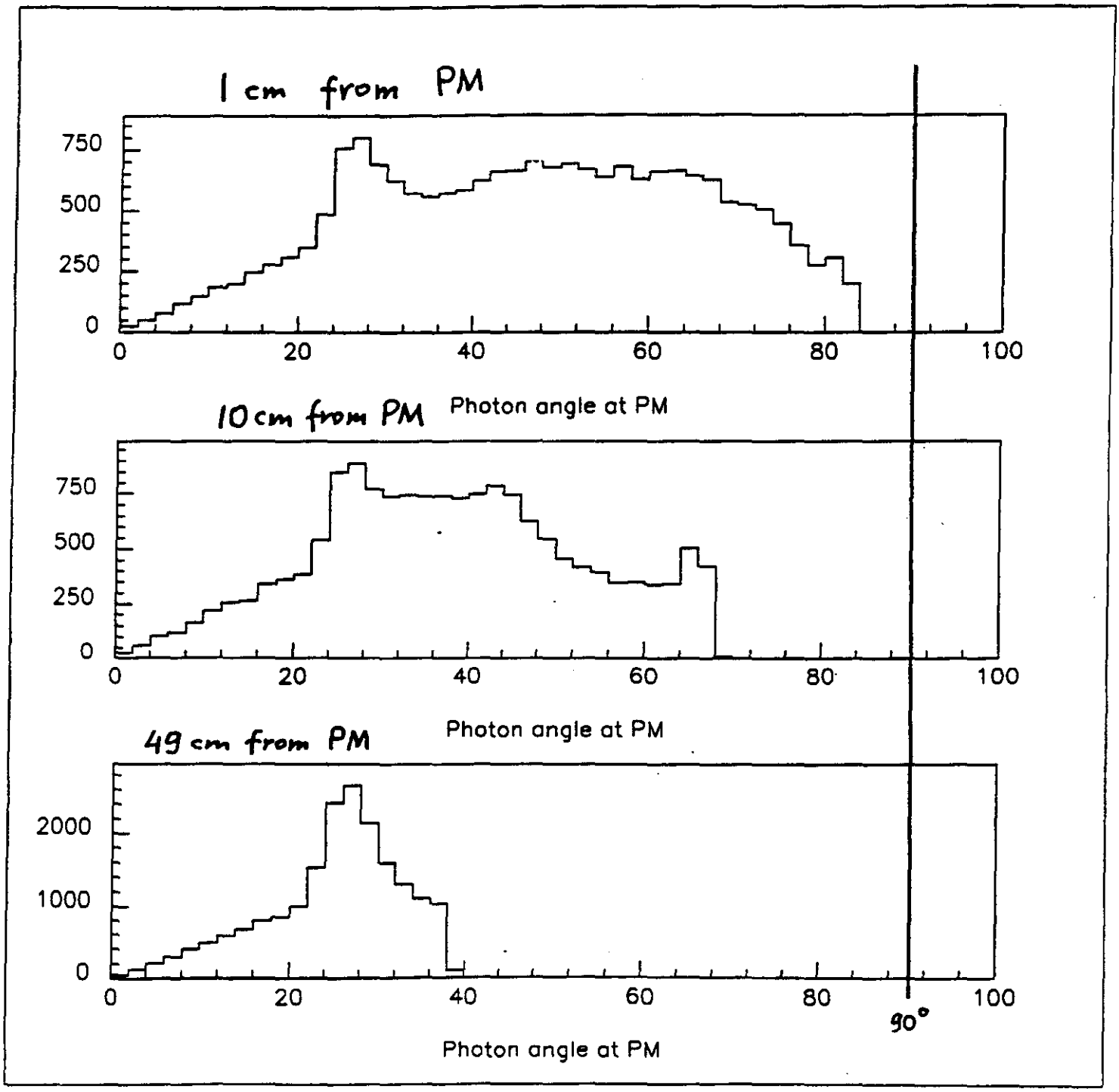
For $\lambda_{\text{abs}} > 53$cm uniformity probably can be achieved by wrapping, painting, reflecting etc.

In BaF_2 specification $\lambda_{\text{abs}} > 95$cm at 220nm is assumed for crystal saturated by irradiation.

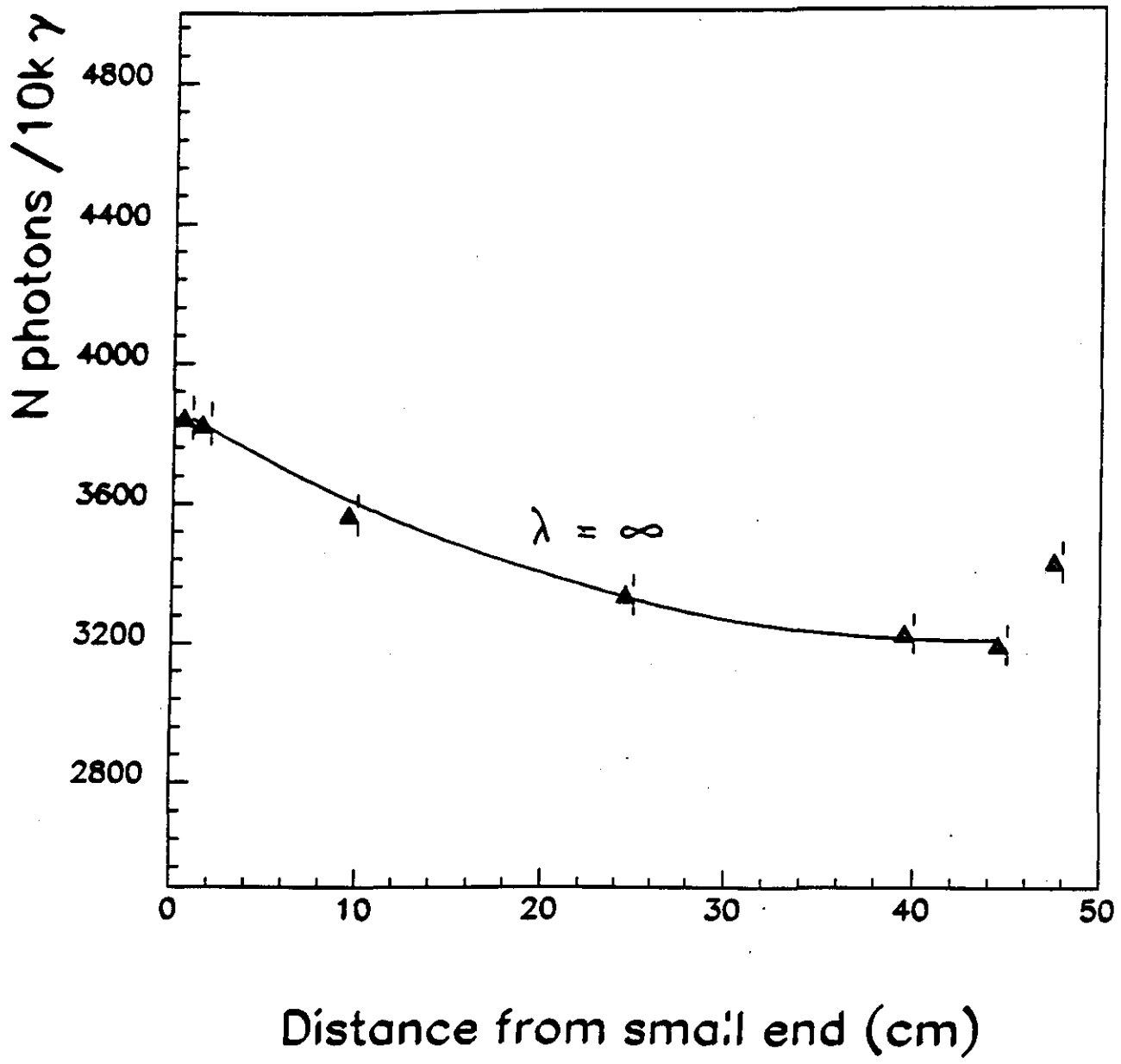

Spectrum – BaF2 x K–Cs–Te, Fresnel FROM 6 SURFACES
air gap
N photons /10k γ
5000
4000
3000
2000
1000
0
λ = ∞
λ = 200 cm
λ = 100 cm
λ = 53 cm
0
10
20
30
40
50
Distance from small end (cm)

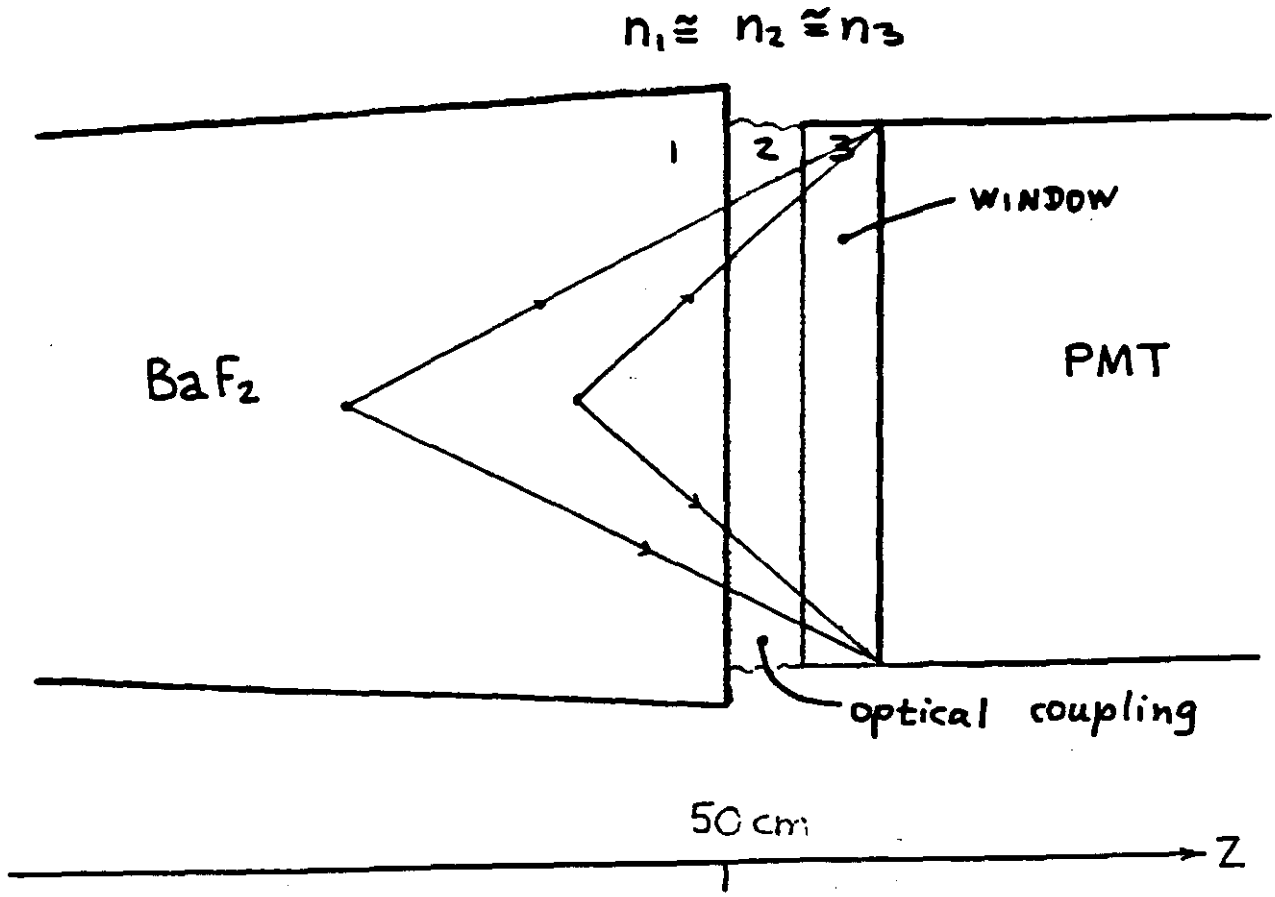


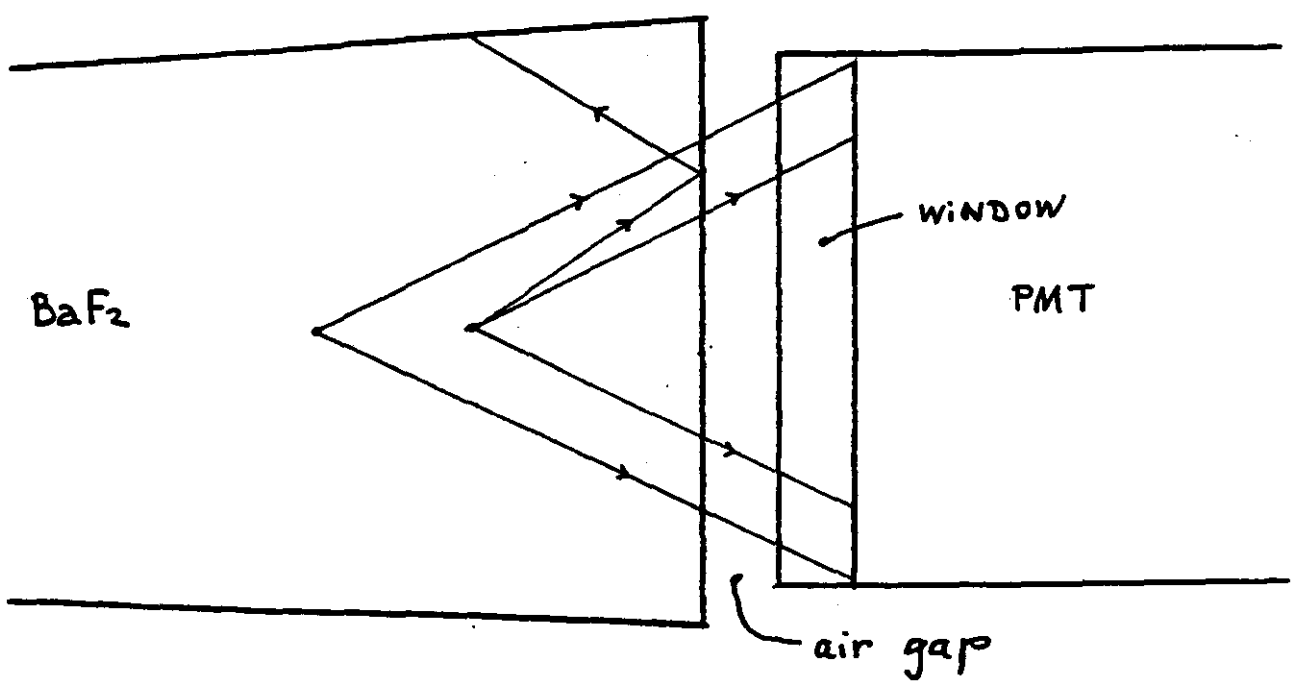
optical coupling



Natural BaF2 spectrum, Fresnel, optical coupling

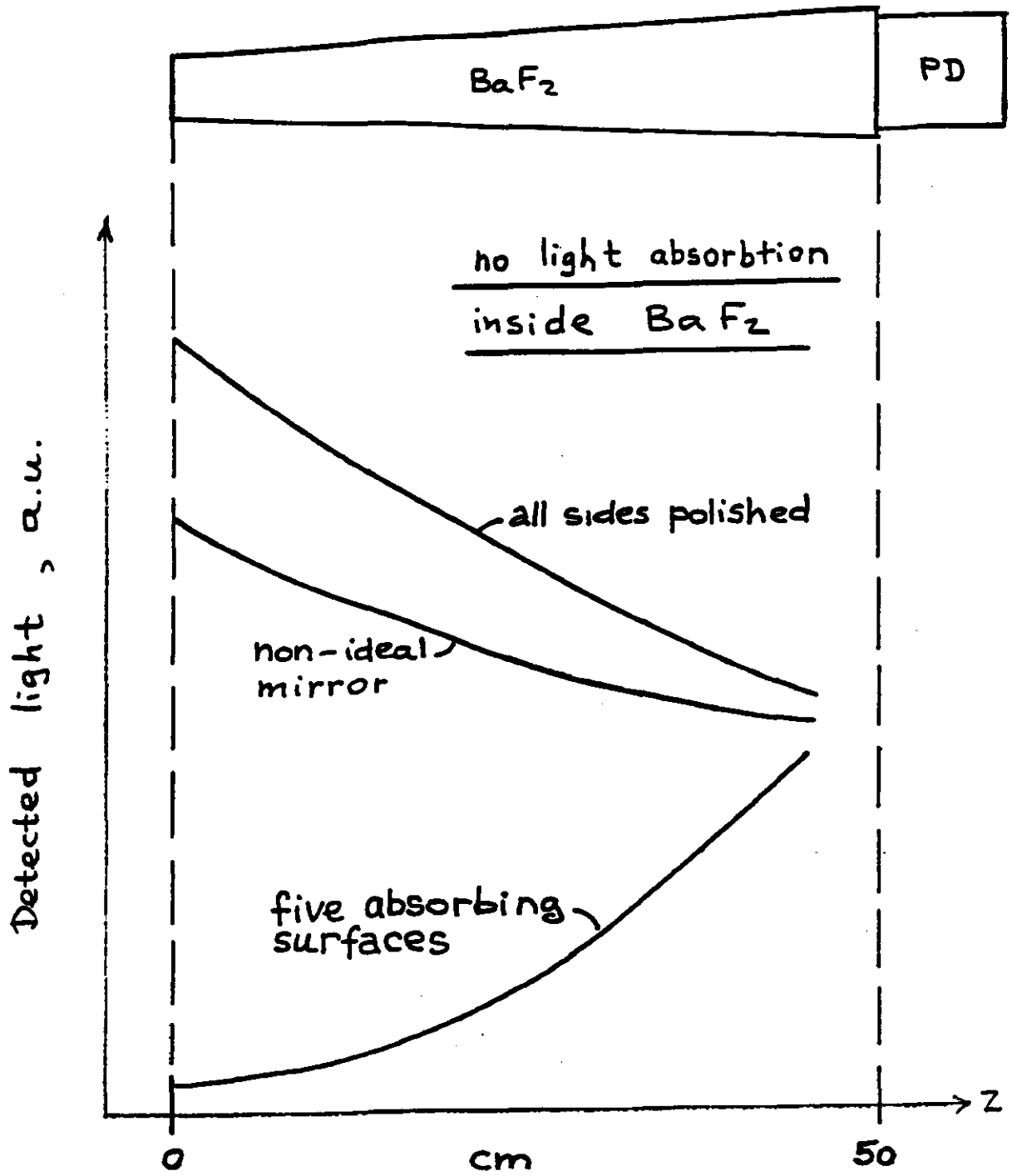






Region of BaF_2 close to photocathode

a) light collection



Qualitive effects in BaF_2 coating

Amount of light received by photodetector is a function of :

a) light collection (total internal reflection, mirrors, reflecting paints, absorbing paints). For polished crystals it is known to produce positive non-uniformity which can be improved by wraping, coating, painting etc. in the wide range.

b) Absorbtion in the bulk BaF_2 :

Definition of absorbtion length:

$$\lambda = \frac{25}{\ln(T_s / T_m)} \text{ [cm]}$$

for 25 cm long crystals

where T_s is theoretical transmission with infinite light attenuation length, T_m is measured transmittance.

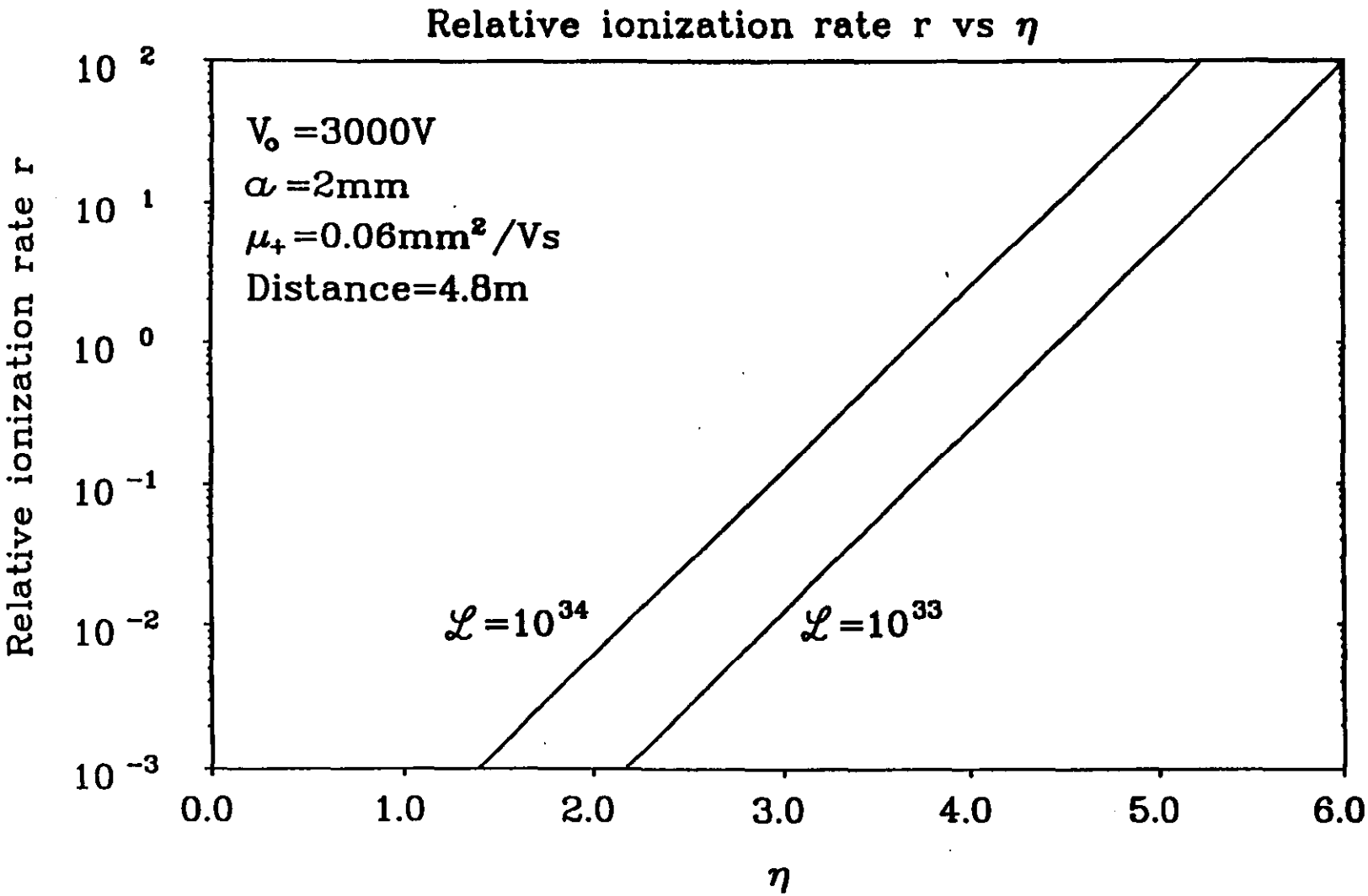
In a simple picture the total effect of both a) and b) or <u>global crystal non-uniformity</u> will affect the resolution

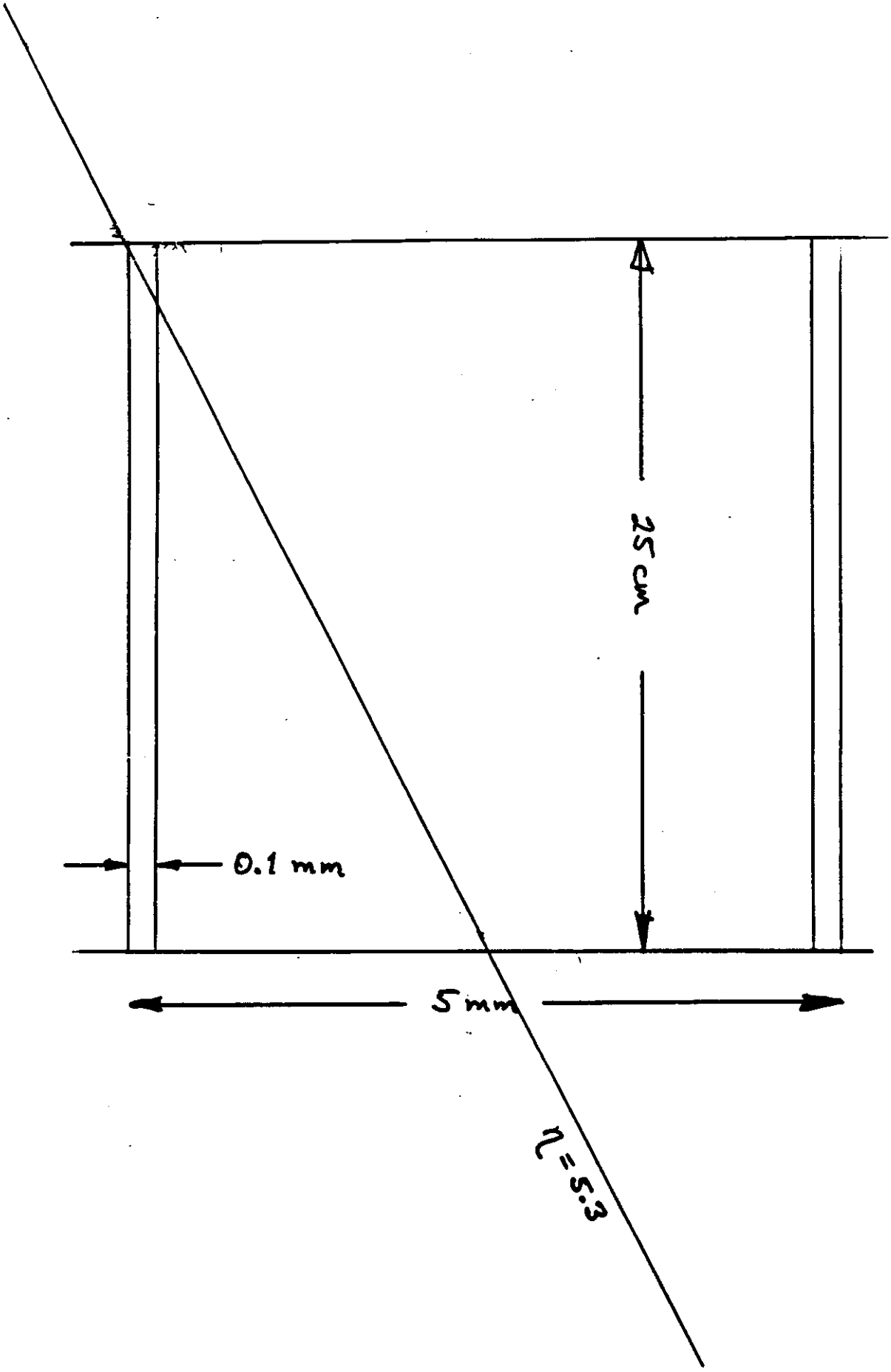
SIMULATIONS ON LIGHT COLLECTION AND ENERGY RESOLUTION FOR BAF2 CRYSTALS

K.Shmakov /ORNL

Tucson, March 92

John Rutherfoord

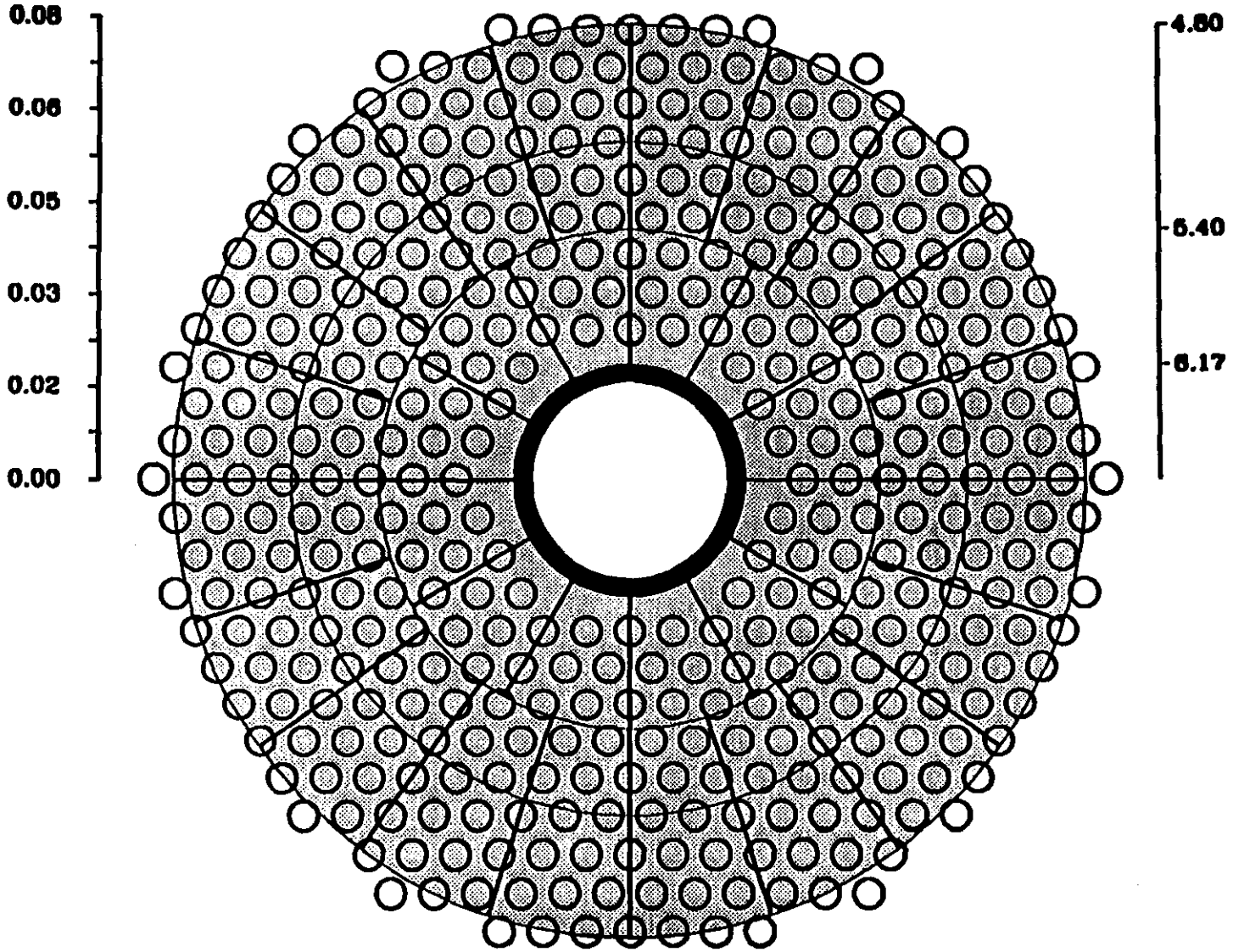


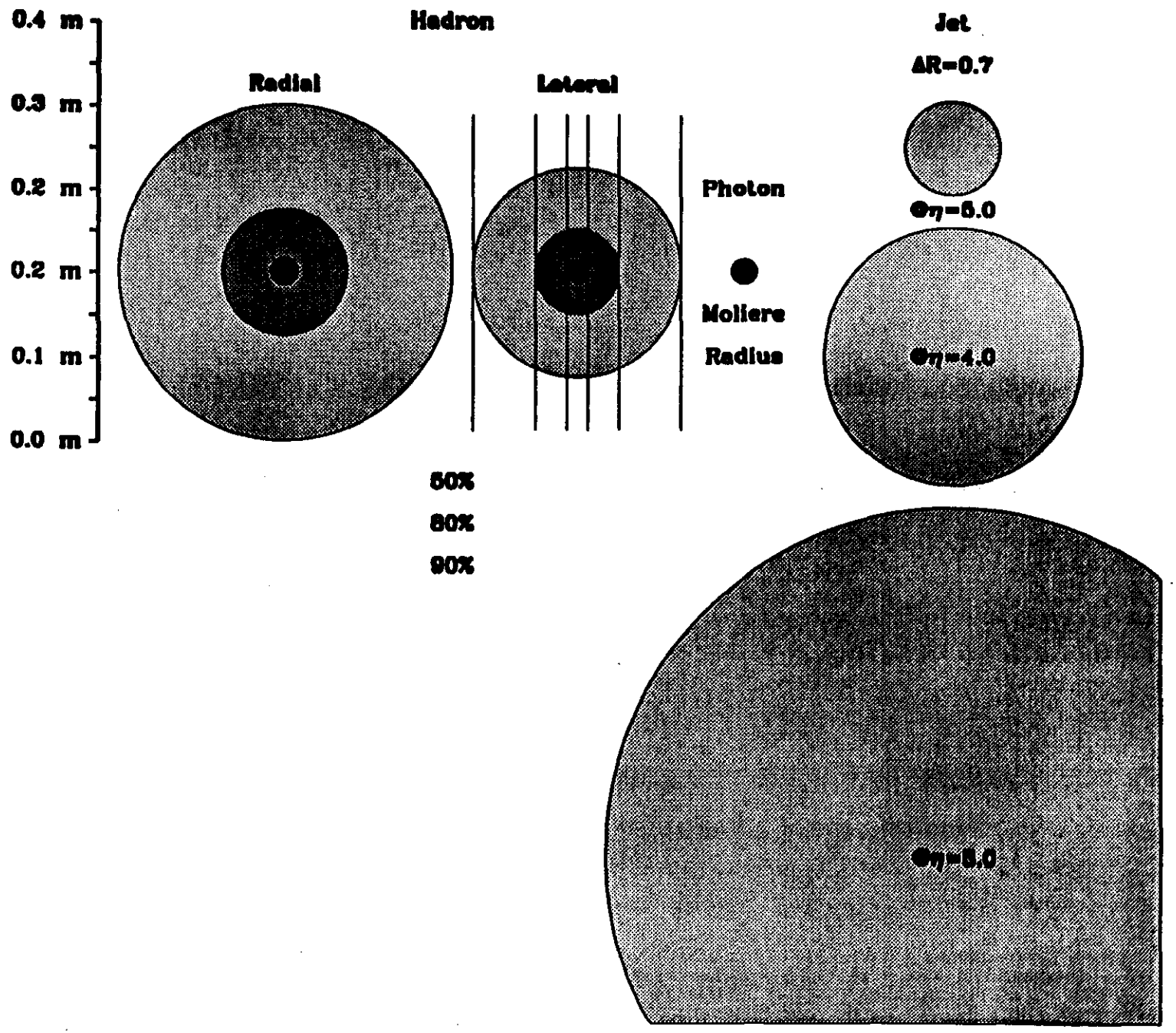

25 cm
0.1 mm
5 mm
η = 5.3

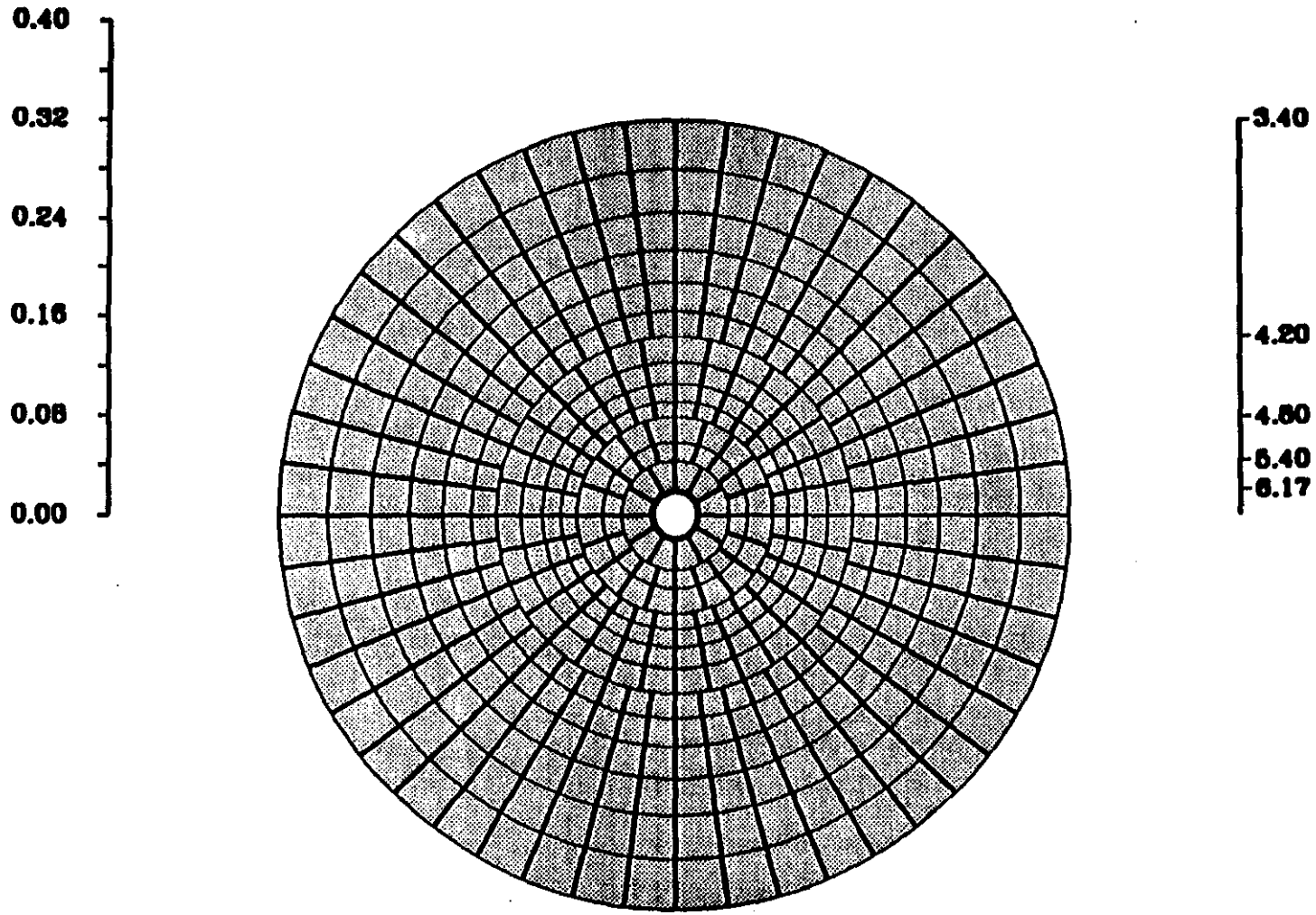
LAr Tube FCal

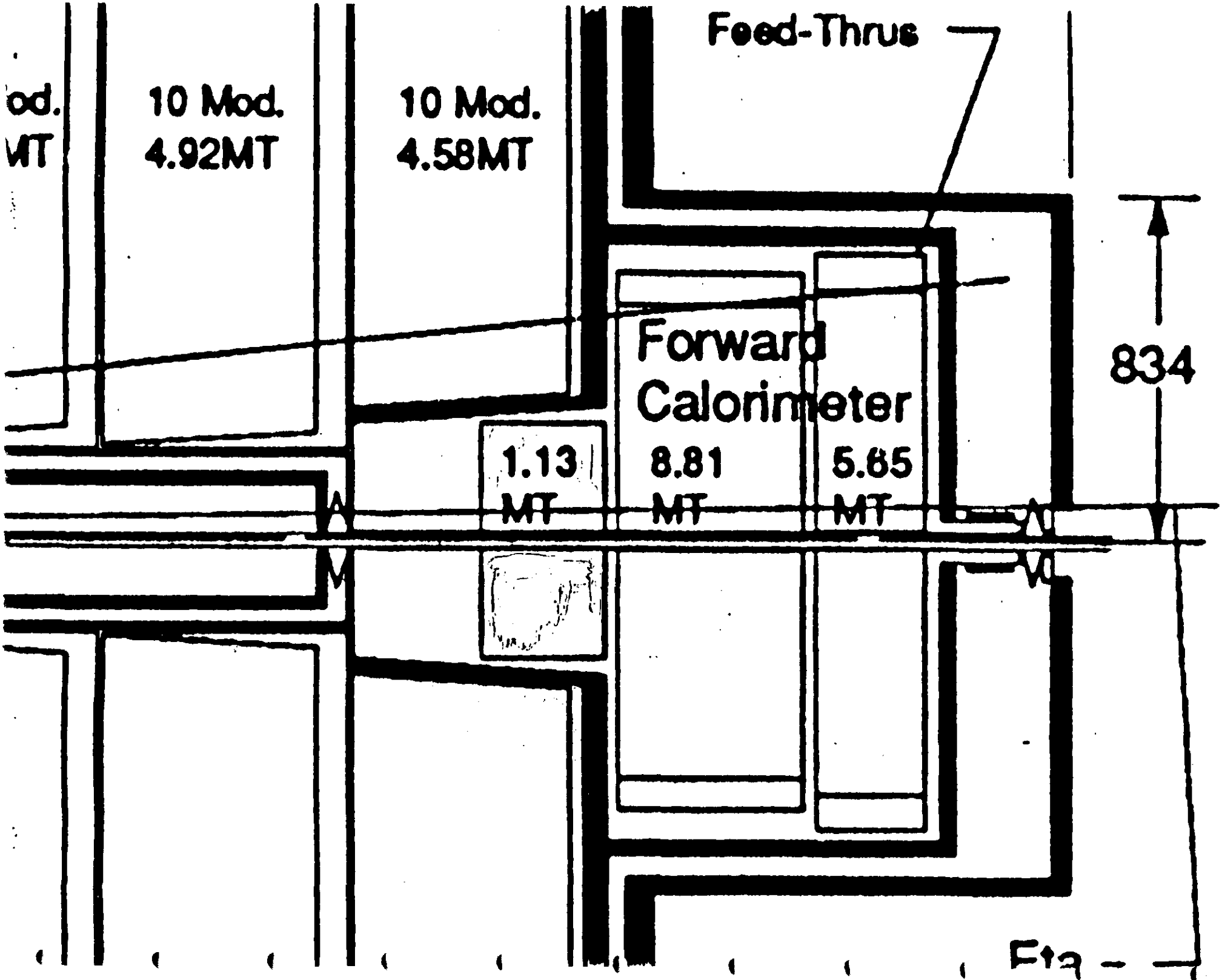
Parameters:

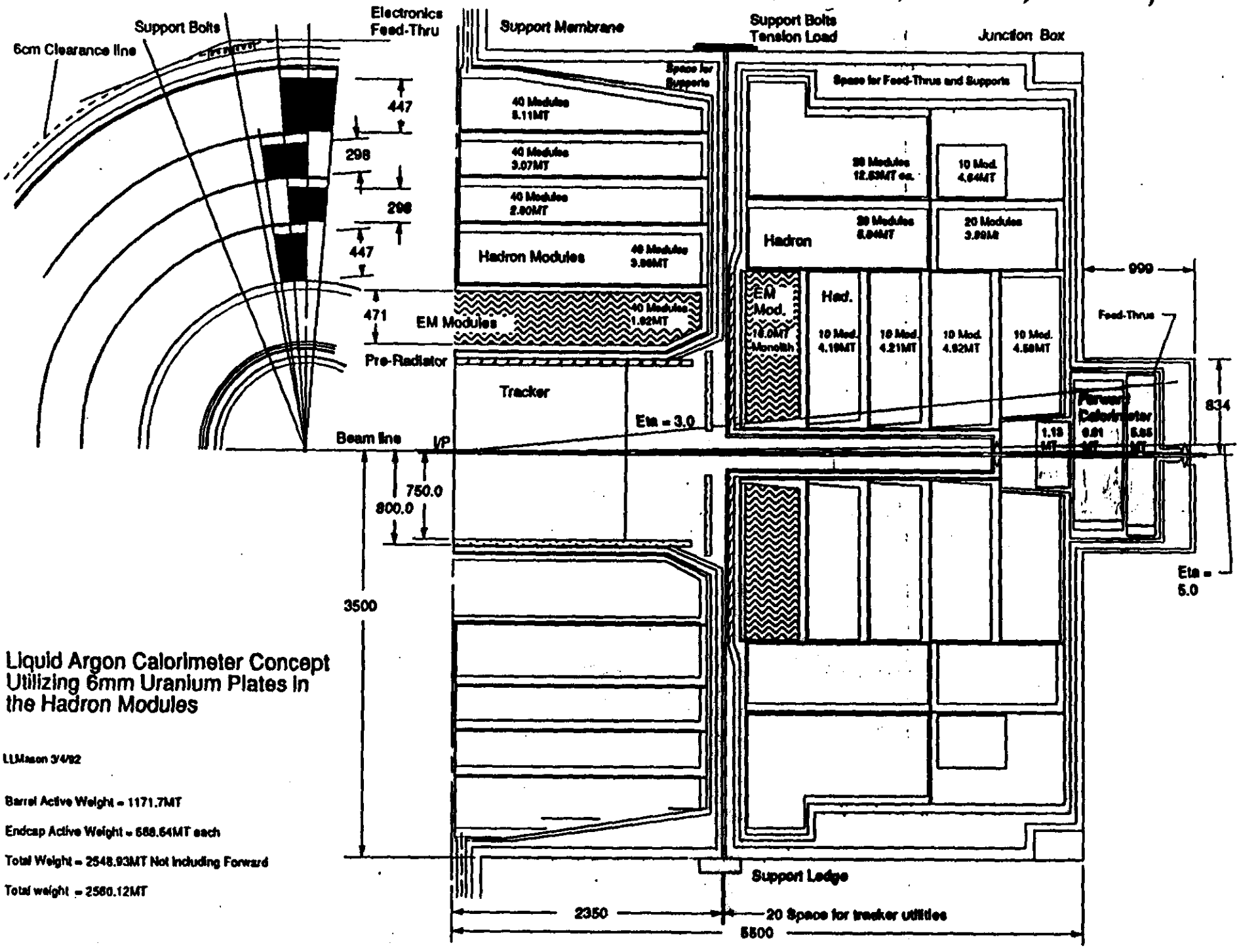
Tube radius	2.5 mm
Gap	0.1 mm
$\hat{C}$	2.2 nF/m
Z	2.0 Ω
t_D	20 ns
V_0	125 volts
Nearest neighbor center-to-center distance	7.5 mm
No. of holes in EM section	6600
Sampling fraction	0.5%


0.08
0.06
0.05
0.03
0.02
0.00
4.80
5.40
6.17


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


0.40
0.32
0.24
0.16
0.08
0.00
3.40
4.20
4.80
5.40
6.17


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



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

LLMason 3/4/92

Barrel Active Weight = 1171.7MT

Endcap Active Weight = 688.64MT each

Total Weight = 2548.93MT Not Including Forward

Total weight = 2560.12MT

Paige - Vanyashin

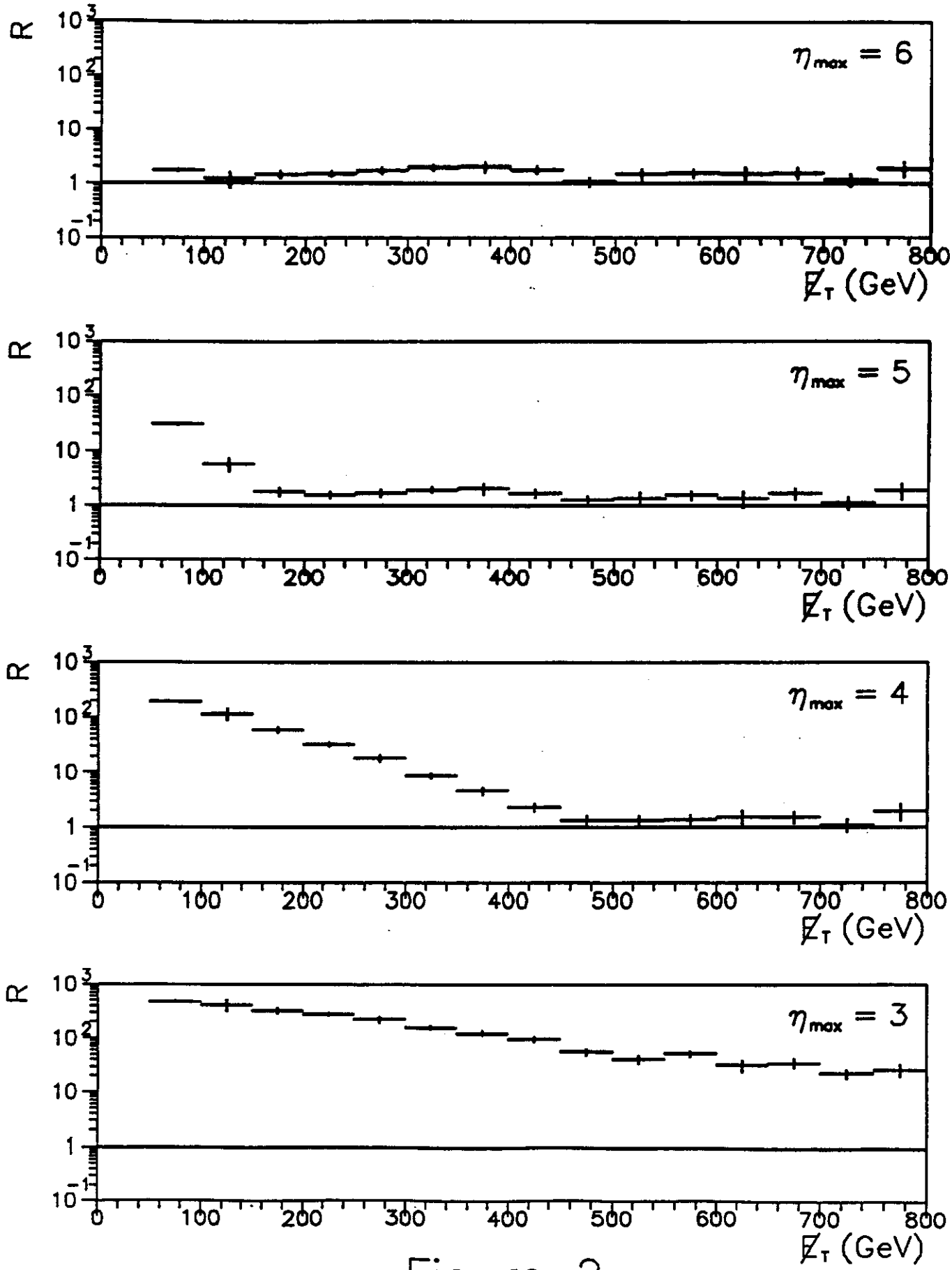


Figure 2

GEM Collab Mtg.
Tucson 2/8/92

GEM Forward Calorimetry

Physics Goals

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

Forward tagging jets

Critical Parameters

Mean density of calorimeter (As high as possible)

Diameter of beam hole (As small as possible)

Engineering Baseline

LAr tube - integrated

Studies

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

Positive ion build-up

Poisoning

Mechanical - construction

Electronics