GEM TN-91-45

GEM CALORIMETRY MEETING

December 4, 1991

Abstract:

Agenda and transparencies contributed to the GEM Calorimetry Meeting held on December 4, 1991.

CALORIMETRY MEETING

Wednesday, December 4, 1991

(Location to be posted at the User's Office)

Revised Tentative Agenda (12/3/91)

8:30	Meeting opens, General Business	(Brau)
9:00	Progress Report on Noble Liquids	(Gordon)
9:30	The Parallel Plate Liquid Argon Option	(Mockett)
10:00	Progress Report on Forward Calorimetry	(Rutherford)
10:30	Progress Report on Silicon Strip Pre-Radiator	(Brau)
11:00	Pre-Radiator and Isolation Studies	(Zhu or Yamamoto)
11:30	Electronics	(Marlow?)
12:00	LUNCH	
1:00	Progress Report on Barium Fluoride, Panel	(Newman)
1:30	Progress Report on Scintillating Fiber	(Worstell)
2:00	Effective Compensation	(Paar)
2:30	Progress Report on Engineering	(Rennich)
3:00	Adjourn (SubGroups may meet separately)	

CALORIMETRY MEETING 12/9

LOI - completed 11/25

R+D Request
submitted 11/27

R+D committee meeting now

Status of funding:

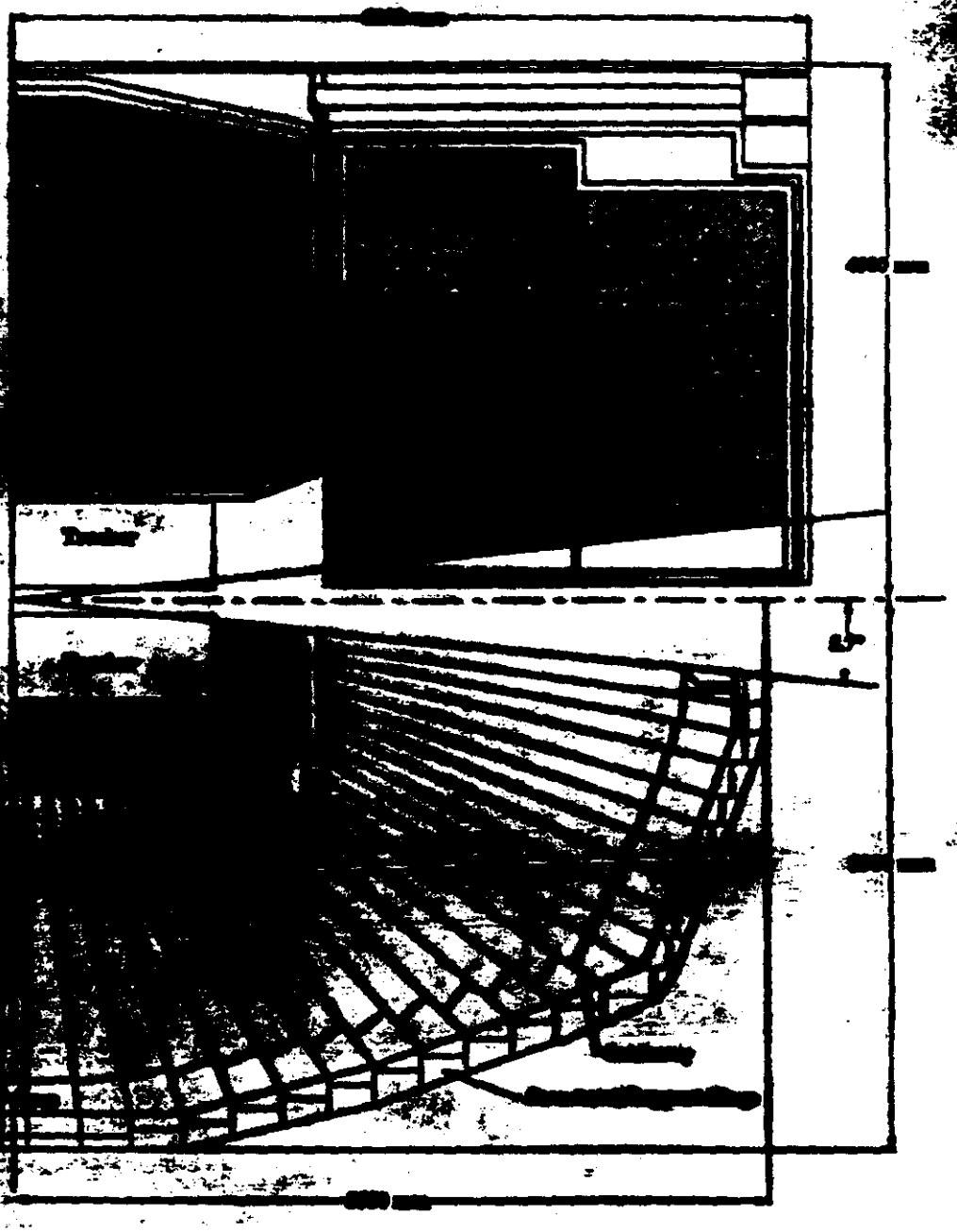
No decision from Siskin to
Gilman's request for increase

TNRLC meets 13-14 Dec

Still 'hope' for
10M$ SSCL
5M$ TNRLC

Engineering
Kunitch will discuss

Liquid Argon Calorimeter



November 26, 1991

Part IV

GEM Calorimetry R+D Request

1 Introduction

The GEM detector has been designed to discover and study in detail the physics of electroweak symmetry breaking and to search for the origin of the meaning of flavor and other new physics. High-precision measurements of photons, electrons, and muons provide the route to this physics goal. For calorimetry this translates into the best attainable electromagnetic calorimetry, which is augmented by forward calorimetry to provide missing transverse energy ($\not{E}_T$) and limited forward jet measurements.

These basic goals of GEM are supported by the on-going research and development program which explores the most promising techniques for giving the highest energy resolution in the energy range of interest to GEM. Two strong candidates have emerged from a study of many alternatives. A choice of one of these promises to yield the best and most cost effective performance. They are noble-liquid ionization detectors and barium fluoride crystal scintillators. The research and development plan for FY92 is designed to generate a choice of these two within one year. The barium fluoride electromagnetic calorimeter is backed up by a hadron calorimeter constructed from scintillating fiber-lead modules.

Following a series of reviews of the needs of the various subgroups within the GEM Calorimetry Group, a plan for research, development, and engineering for FY92 has been established. This has resulted from a number of very hard decisions to limit or eliminate the work on various (sometimes important) aspects of this program. Having made these choices, the total

Table 1: Calorimetry Budget Summary

	R & D (k$)	Engineering (k$)
Liquid Argon/Kr	1 170	798
BaF_2	1 209	
Scin. Fiber	610	250
Forward	75	10
Sil. St. Prerad	140	10
Post decision		350
Totals	3 204	1 418

Table 2: Liquid Argon/krypton R&D

	k$
2 mm Pb Accordian (RD3) BNL	150
Improve EM accordian (2 mm Kr + 1 mm Ar)	520
Hadronic module EST	50
Parallel plate EM + preradiator (UW)	205
Test beam support (Arizona)	20
Precision calibration	75
Operation of test beam	50
Cryogenics, purification, for test beam	100
Liquid Argon/krypton total	1 170

Table 3: BaF_2 R&D

	k$
UV Performance Monitoring	47
Analog and Digital Readout Testing	50
Radiation Damage Tests	310
Prototype Electronics Readout	117
Rad Hard Electronics Readout	30
Beam and Cosmic Ray Tests	241
BaF_2 Crystal Matrix Assembly	414
BaF_2 total	1 209

Table 4: Scintillating fiber hadron R&D

	k$
Engineering and design	140
Shop time	20
M & S Hardware	200
Tooling	50
SPACAL work	150
Test Beam support	50
Scintillating fiber total	610

Table 5: Forward calorimetry R&D

	k$
Liquid scintillator	50
High pressure gas tubes	25
Forward calorimetry total	75

Table 6: Silicon strip preradiator R&D

	k$
Electronics development	80
Beamtest hardware and support	60
Silicon strip prerad total	140

Cost Review -

Next week @ SSCL (11-12 Dec)

Main emphasis on L.A.

Electronics

Monthly meetings in the N.E.
have been announced by
John Persons
(1st meeting - Dec 18 @ Nevis)

BaF_2 Panel

Meeting now
Harvey will report

Simulation

Need to move toward coherent
and coordinated effort

~~Next meeting - Wed, Jan 22~~

Date: Sun, 1 Dec 1991 21:12 MST
From: <SANDERS@LAMPF>
Subject: Cost Review Meeting
To: jimbrau@slacvm
Original_To: BITNET%"jimbrau@slacvm",BITNET%"adair@yalehep",
BITNET%"ahlen@buphyc",BITNET%"fet@mitlns",
BITNET%"ryszard@sscvxl",BITNET%"maschke@sscvxl",
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BITNET%"sulak@buphyc",SMTP%"deis@troy.llnl.gov"

From: DAC::SANDERS 1-DEC-1991 21:01:08.93
To: SANDERS
CC: SANDERS
Subj:

To: Distribution
November 27, 1991

From: Gary Sanders, Rick Sawicki

Subject: GEM Cost Review, December 11-12, 1991, SSC Laboratory

We will hold the next GEM Cost Review at the SSC Laboratory on December 11 and 12. The meetings will be held in the upstairs Directorate Conference Room over the entrance to the main administrative building at the SSC Laboratory.

The goals for this review are:

1. Preparation for the PAC presentation the following week.
2. Identification of design and estimate status, estimate strengths, weaknesses and methodology, remedial actions, near term priorities.
3. Finalize GEM Cost Estimate Report to be delivered to PAC in lieu of estimate presentation in LOI.
4. Establish work plan for next two months.
5. Educate new members of design/estimating team.
6. Expose subsystem physicists, design engineers and estimators to the entire estimating process.

This review should be attended for both days by the lead subsystem physicists, lead design engineers (mechanical and electronic), and lead cost estimators. In addition, any others required to defend or establish the basis of the estimates are invited, as are the integration team members. A deficiency, which was intentional, at our last review was that the lead physicists and design engineers were not generally present. This made it impossible to discuss and review the design basis of the estimate. That review, however, was intended to upgrade the definition of our methodology. We must now insure that we are generating costs for the desired systems, and we must be able to question the

I. Cryogenic

II. a) 1.3 mm Pb stack

b) Chevron Design.

c) 1mm Pb electrod readout.

III. Bending Machine –

IV. Electronic Read out.

V. Cal. Design

D. Lissauer
BNL.

I. Cryogenic.

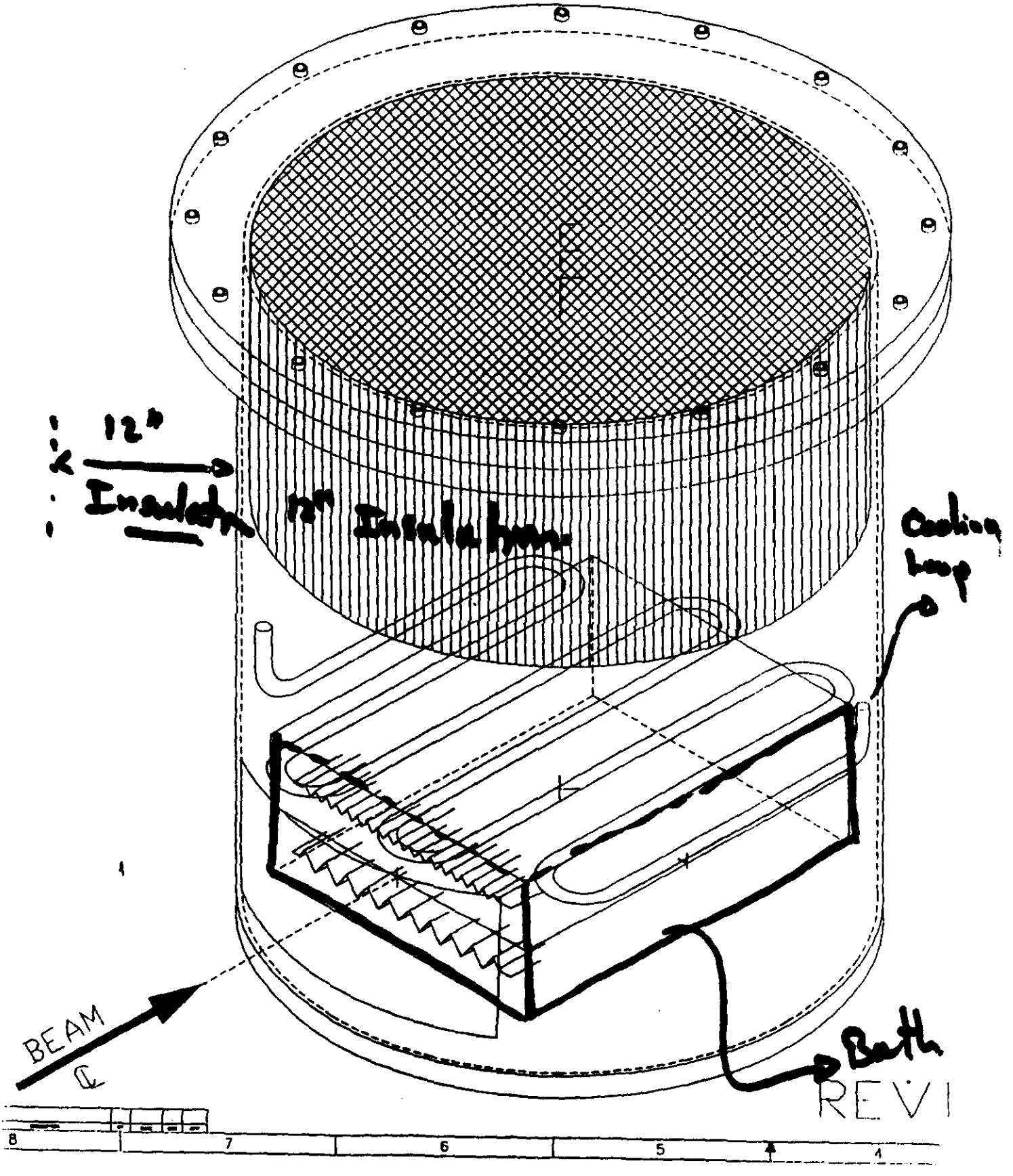
Vessel: Design is under way.

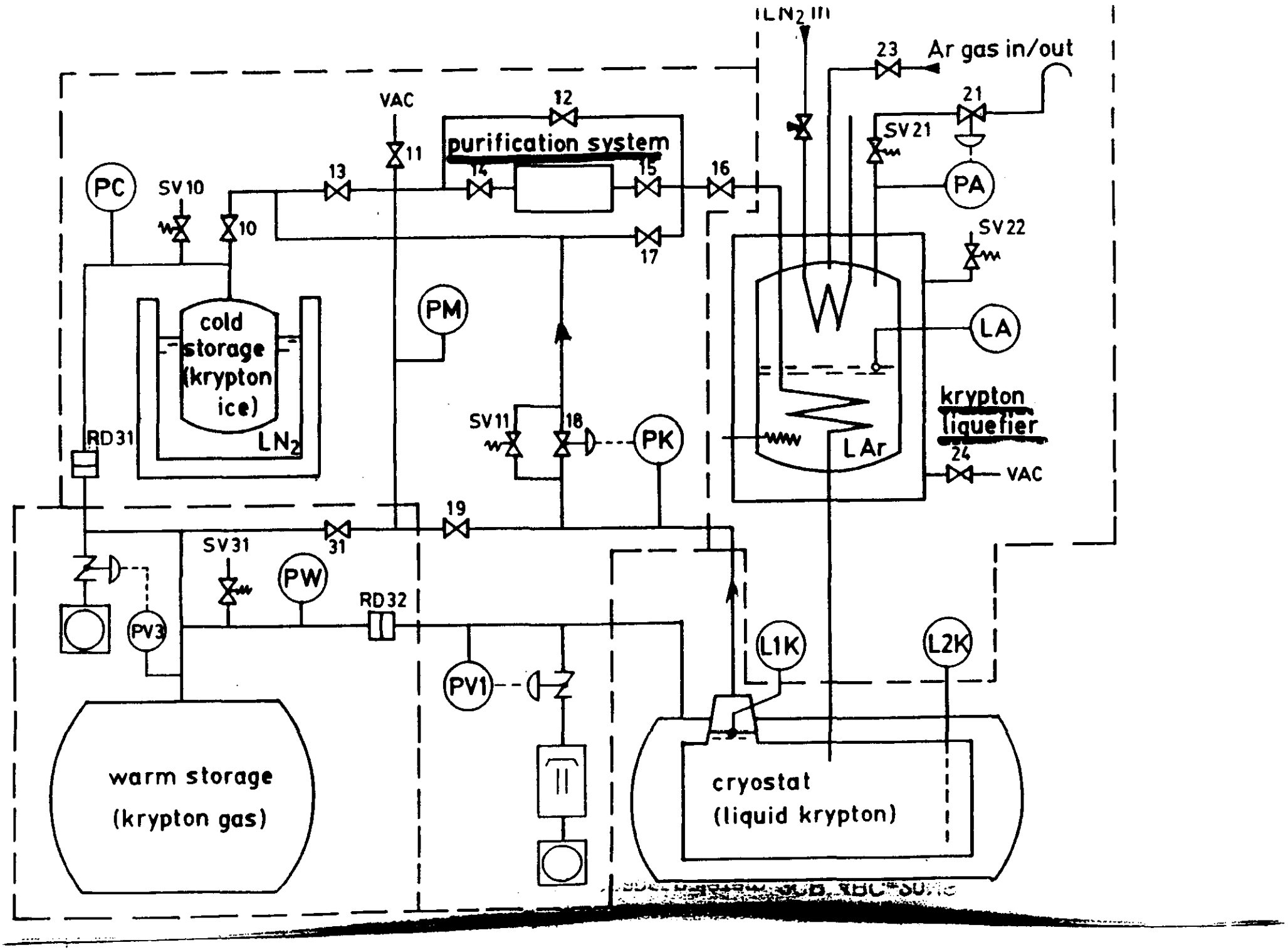
- New Vessel
  - Single Wall + Insulation.
  - Stainless Steel. ($\sim 1/8\ X_0$)
  - 1 meter Diameter
  - enough space for 3-ministrels.
  - Cooling loop inside for Liq. Argon
  - bathtub arrangement
  - Feedthrough (NA 34 Design.

Krypton -

- purification System. (NA 48)

design under way (MIT, Colourmbia, BNL


12"
Insulation
12" Insulation
Cooling loop
Bath
BEAM
℄
REV
8
7
6
5
4



L N2 COLDTRAP

1.3 mm Pb

Cell structure:

	1.3 mm Pb .2 mm steel .05 mm Prepreg	Absorber
	2 mm Liq. Argon / Liq. Krypton.	
Readout ←	H.V. Cu + Res Kapton Cu. Kapton H.V. Cu + Res.	Readout Electrode.

Design of stack – 2 weeks.

Pb, steel, Prepreg – Ordered.

Bending tests – Start this week

Read out Board – Send out to P.C. Shop
~3 weeks.

1.8 mm Pb.

Cell structure:

1.3 mm Pb — .05 mm Prepreg.
.2 mm steel

2 mm L.A or L. K.

readout board:

Cu + Kapton. } Design complete this week.

weeks

R = 10K between section I & II. effective

Cook/plum

R discharge 60 K/section/fold.

Rate effect:

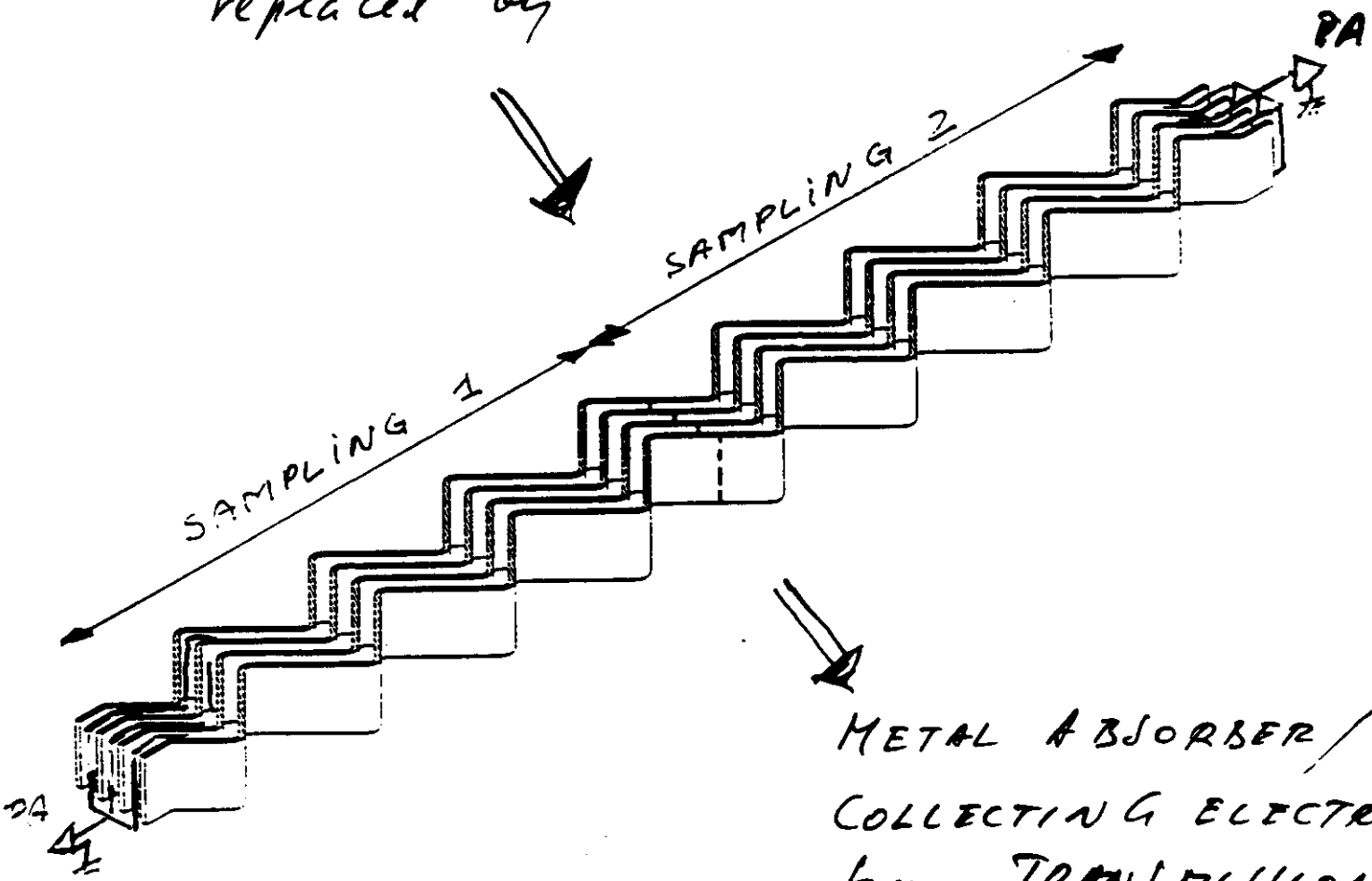
voltage drope. 1-2 meg/sq total.

Pb has been order:
steel - ordered:
pre.preg - ordered.

BASIC IDEA:

Parallel Plate Geometry

replaced by



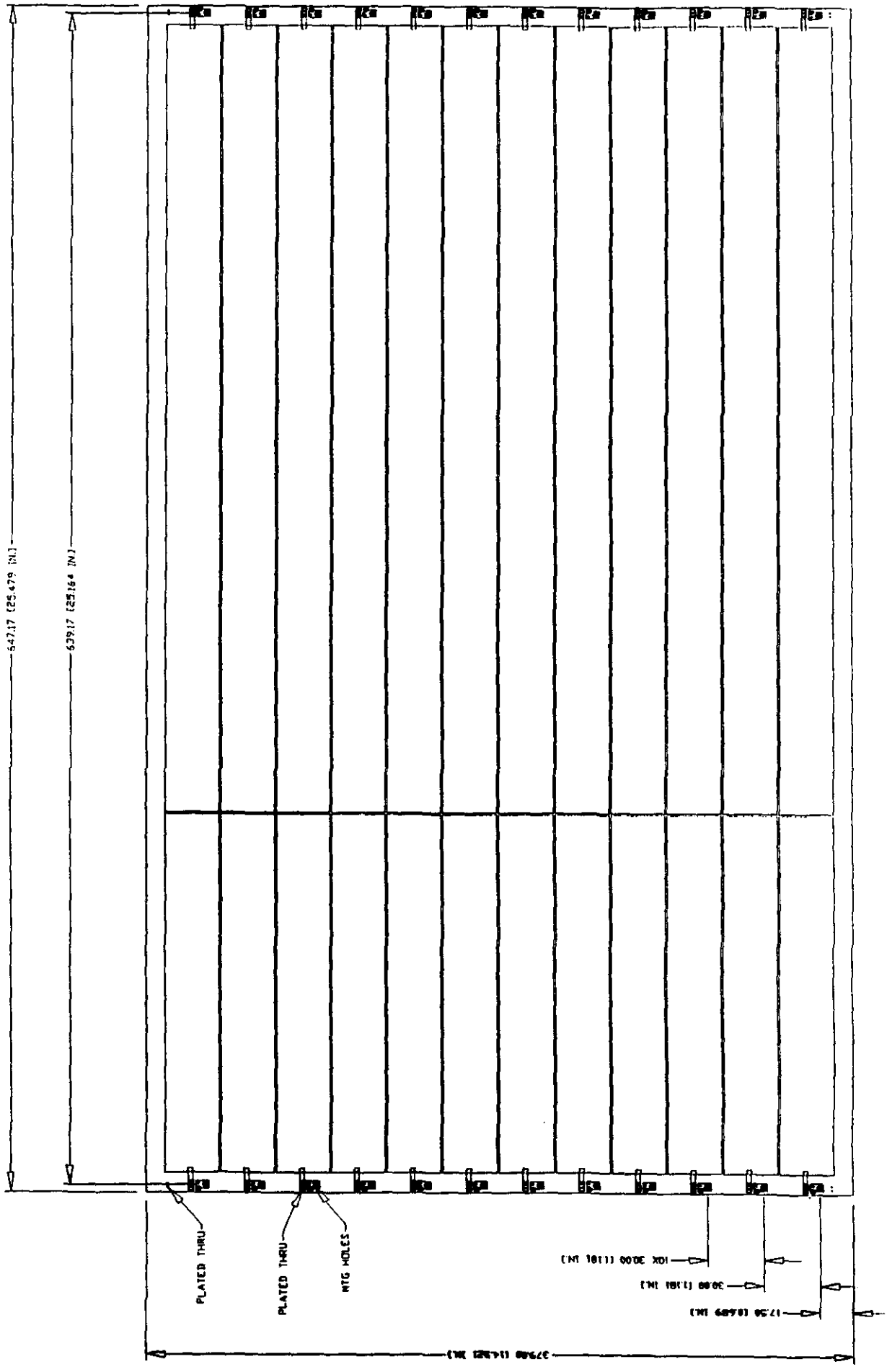
METAL ABSORBER/
COLLECTING ELECTROD.
form TRANSMISSION
LINE; EASE of PREAMP
LOCATION

Electromagnetic Calorimeter

with

"accordion" structure

Signal Board for 1.3 mm Pb stack.



~~Projective~~

Chevron structure: (Under study)

1. Improve position resolution.
2. M.C. Simulation to understand shower shape analysis for π^0 rejection.

What is a chevron readout structure??

Chevron Readout: (Under Study)

1. Improve position Resolution.

2. M.C. studies optimal π^0, γ separation from shower slope.

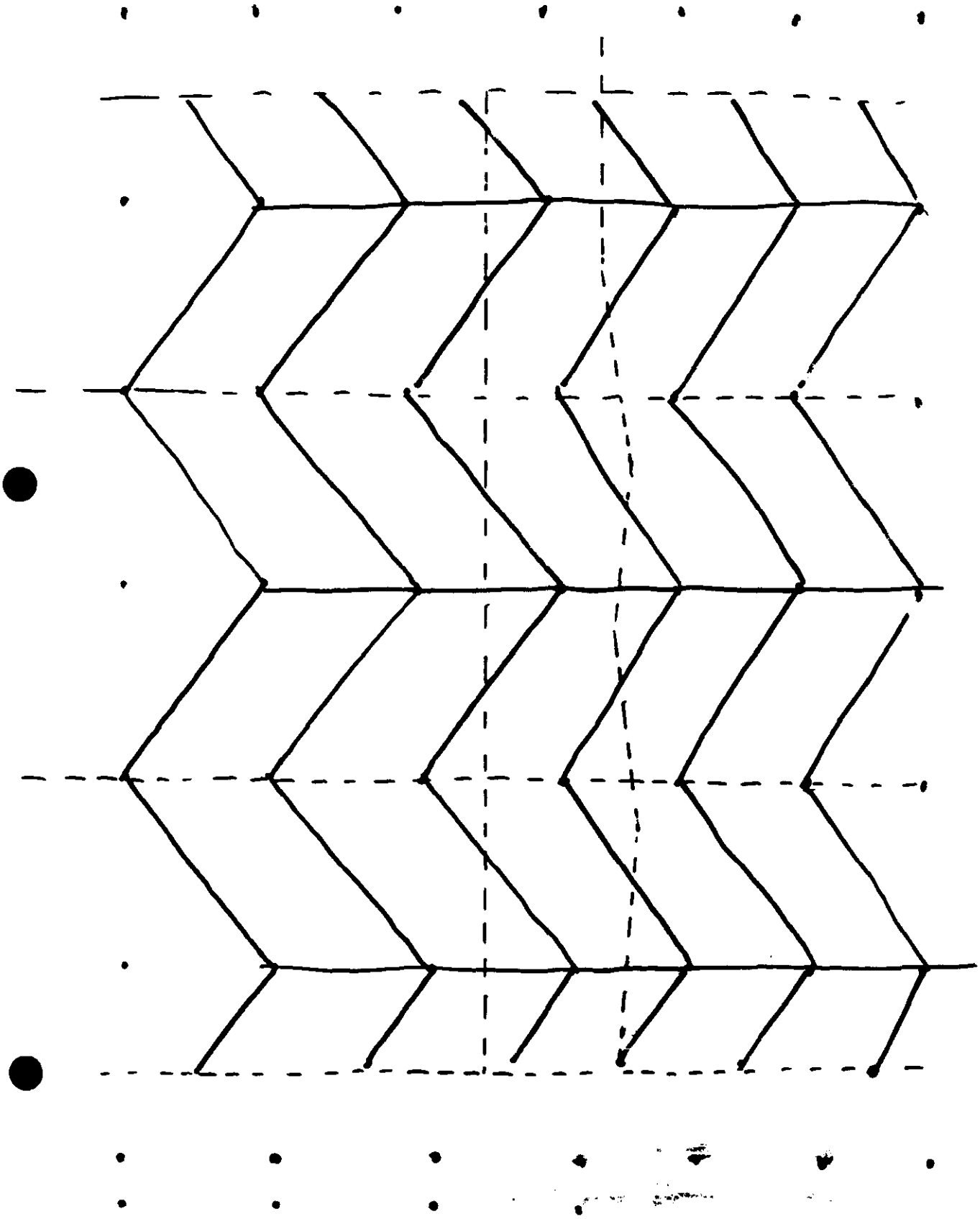
- What is a chevron Readout?

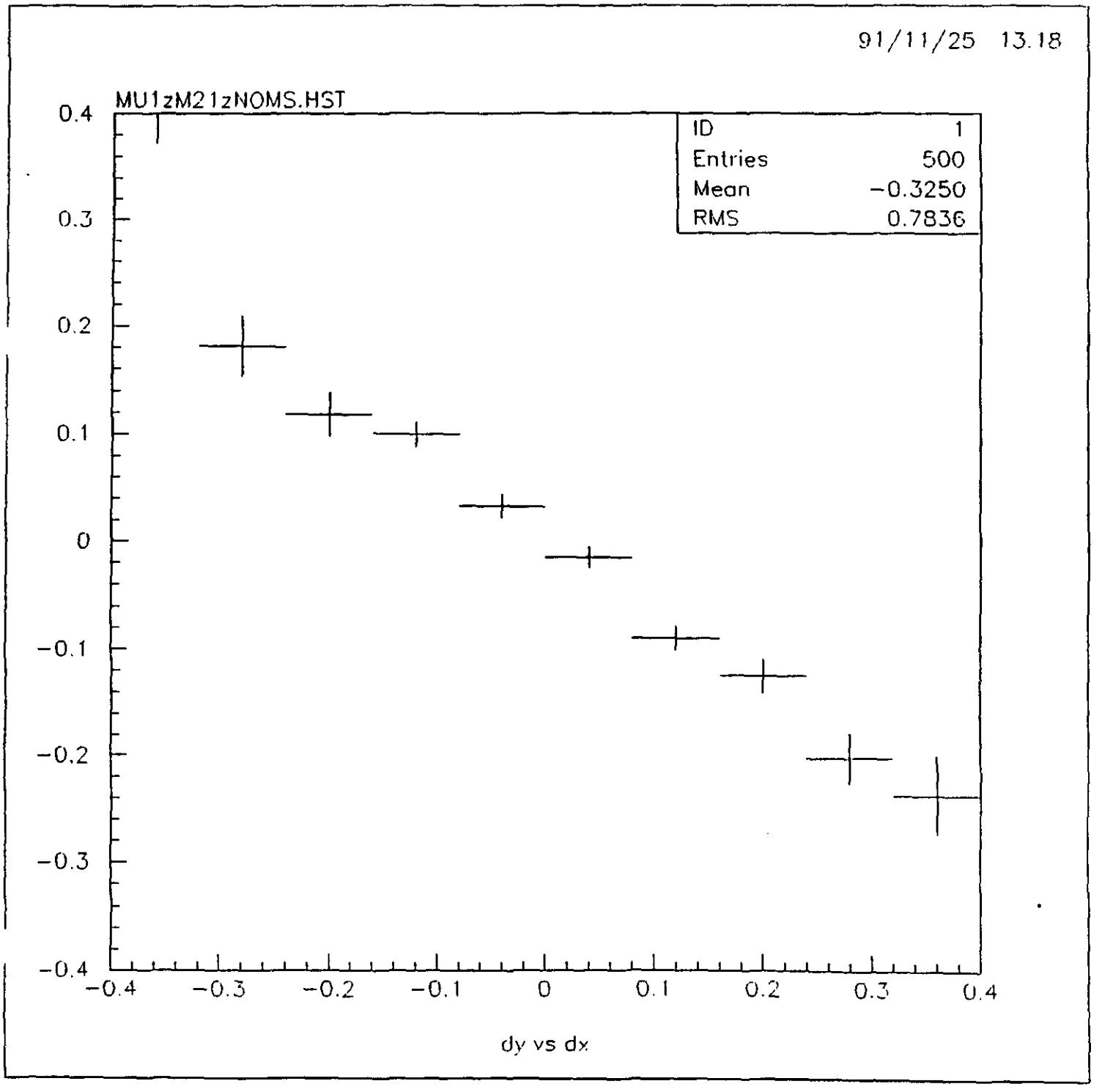
(Fig.).

M.C. Studies:

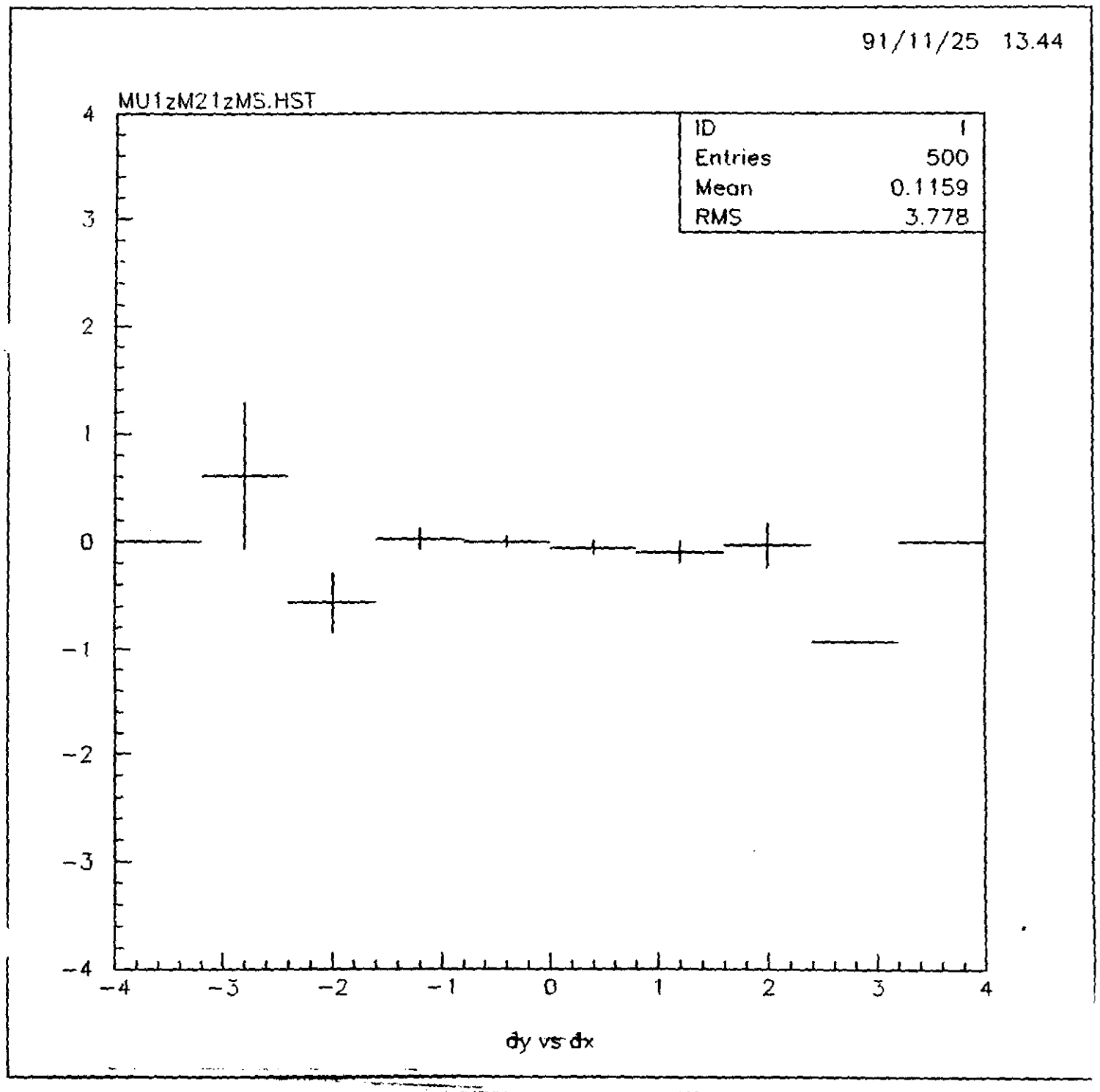
- frequency of chevron.
- Relation to Accordion frequency.

(Corr.).




91/11/25 13.18
MU1zM21zNOMS.HST
ID 1
Entries 500
Mean −0.3250
RMS 0.7836
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4
dy vs dx

Mt Mult Scott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MU1zM21zMS.HST
ID 1
Entries 500
Mean 0.1159
RMS 3.778
4
3
2
1
0
−1
−2
−3
−4
−4
−3
−2
−1
0
1
2
3
4
dy vs dx

We need art

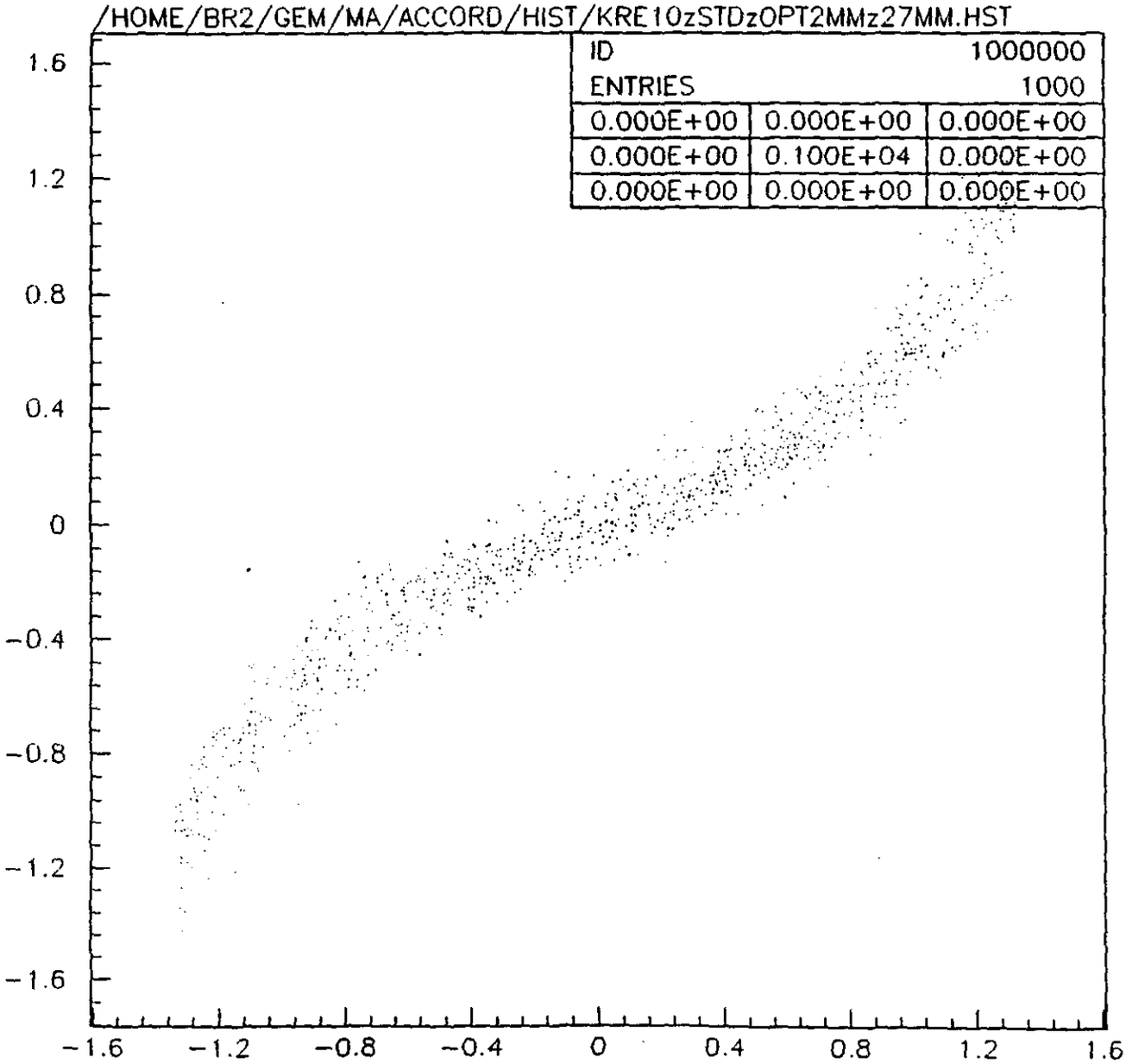
in the Acc. bend direction

1 mr at 10 GeV

imp. $\sim \frac{1}{\sqrt{E}}$

91/11/25 13.04

/HOME/BR2/GEM/MA/ACCORD/HIST/KRE10zSTDzOPT2MMz27MM.HST



XSUM.F(2022) VS YCFSET*X602.F(8)

91/11/25 13.04

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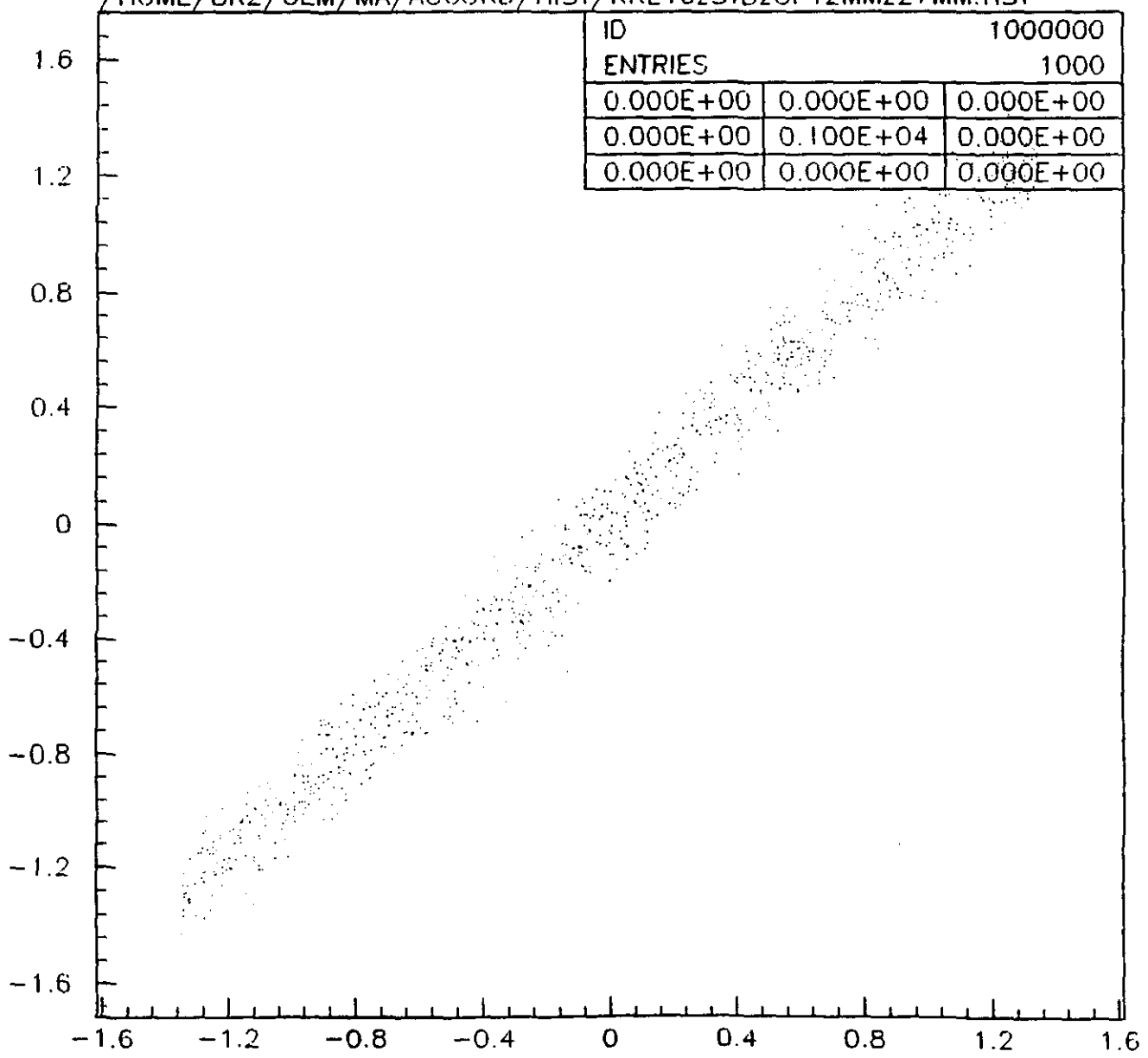

XSUM.F(1022) VS XCESET*X602.F(80)

91/11/25 13.15

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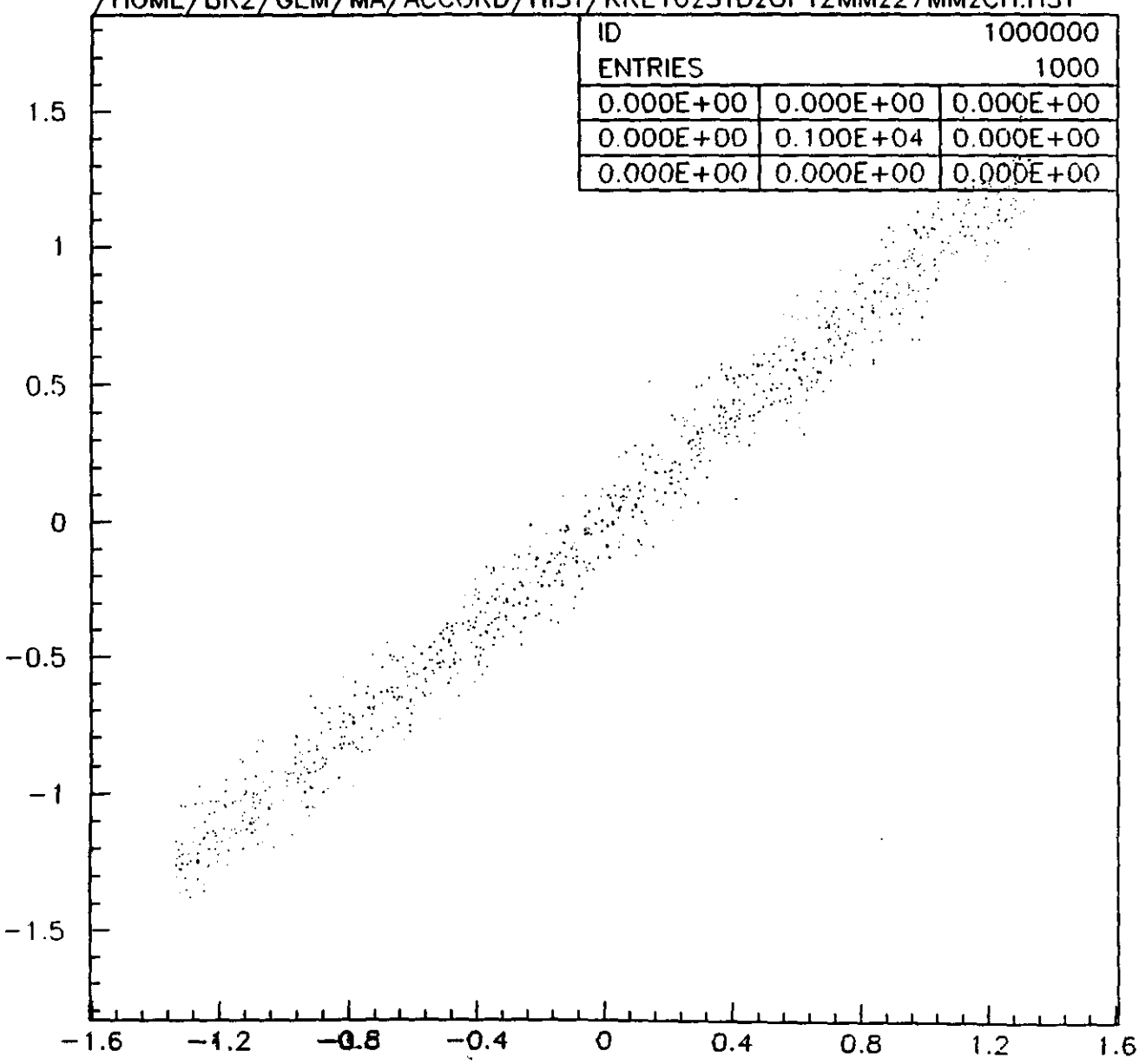
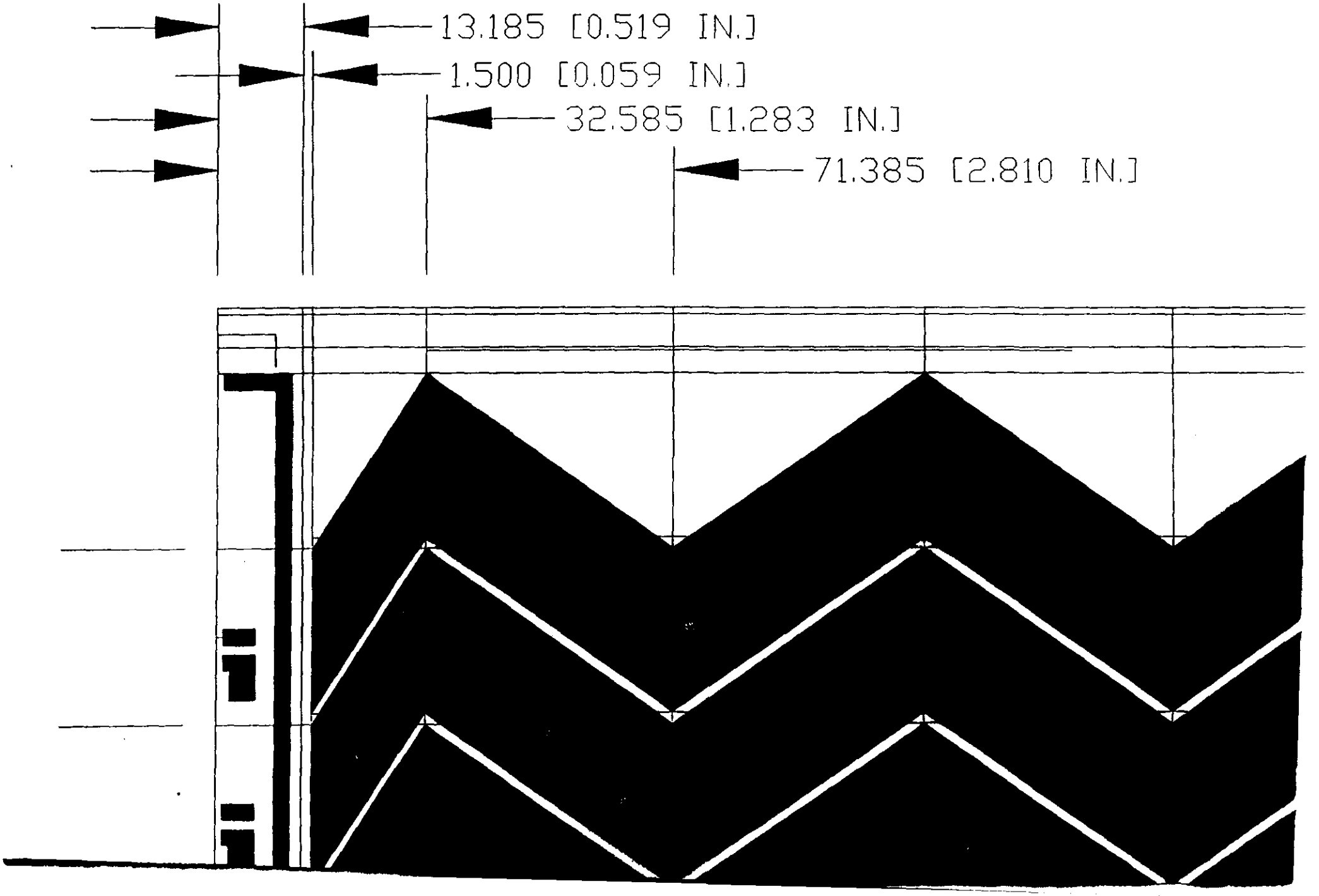


XSUM.F(2022) VS YCESET*X602.F(8)


13.185 [0.519 IN.]
1.500 [0.059 IN.]
32.585 [1.283 IN.]
71.385 [2.810 IN.]

1 mm - Electrode structure

i) studies are underway to
[illegible]

.8 mm Pb
(.2 mm steel)*2 + Prepreg (.05)*2. } Absorber.

.8 mm Pb
Prepreg *.1 mm
H.V. Resistive + Cu } Readout Elect.

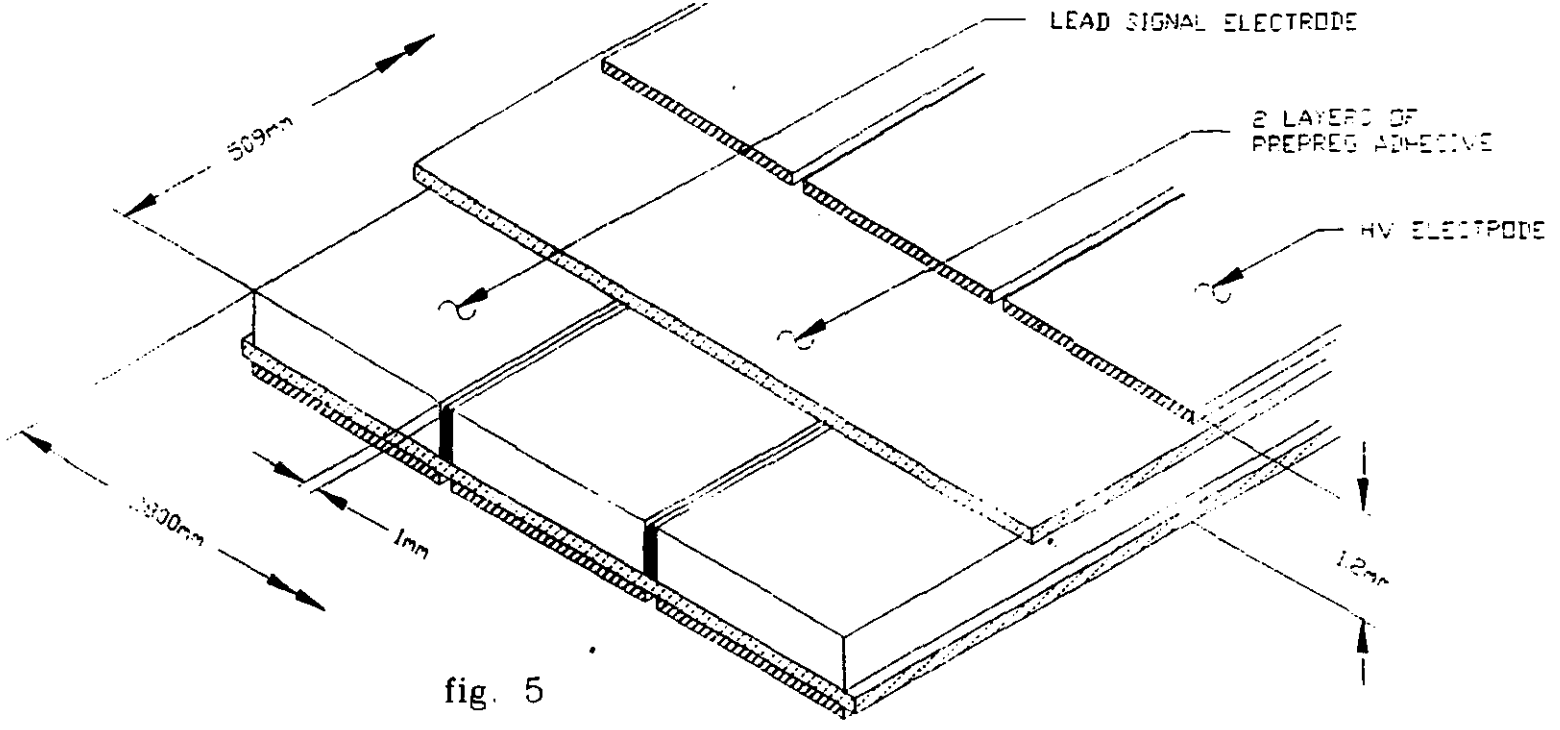


fig. 5

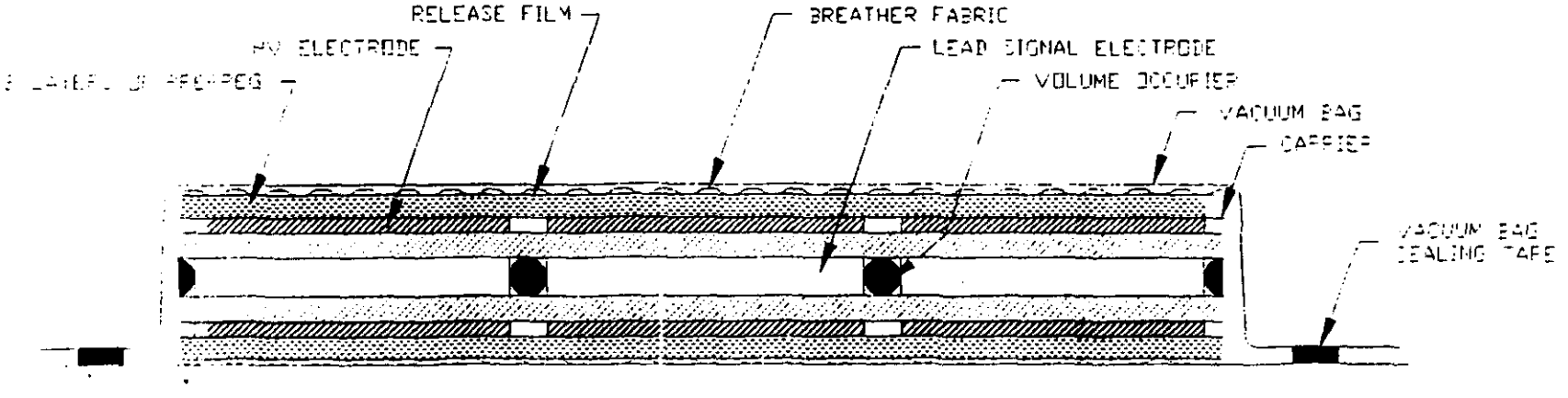
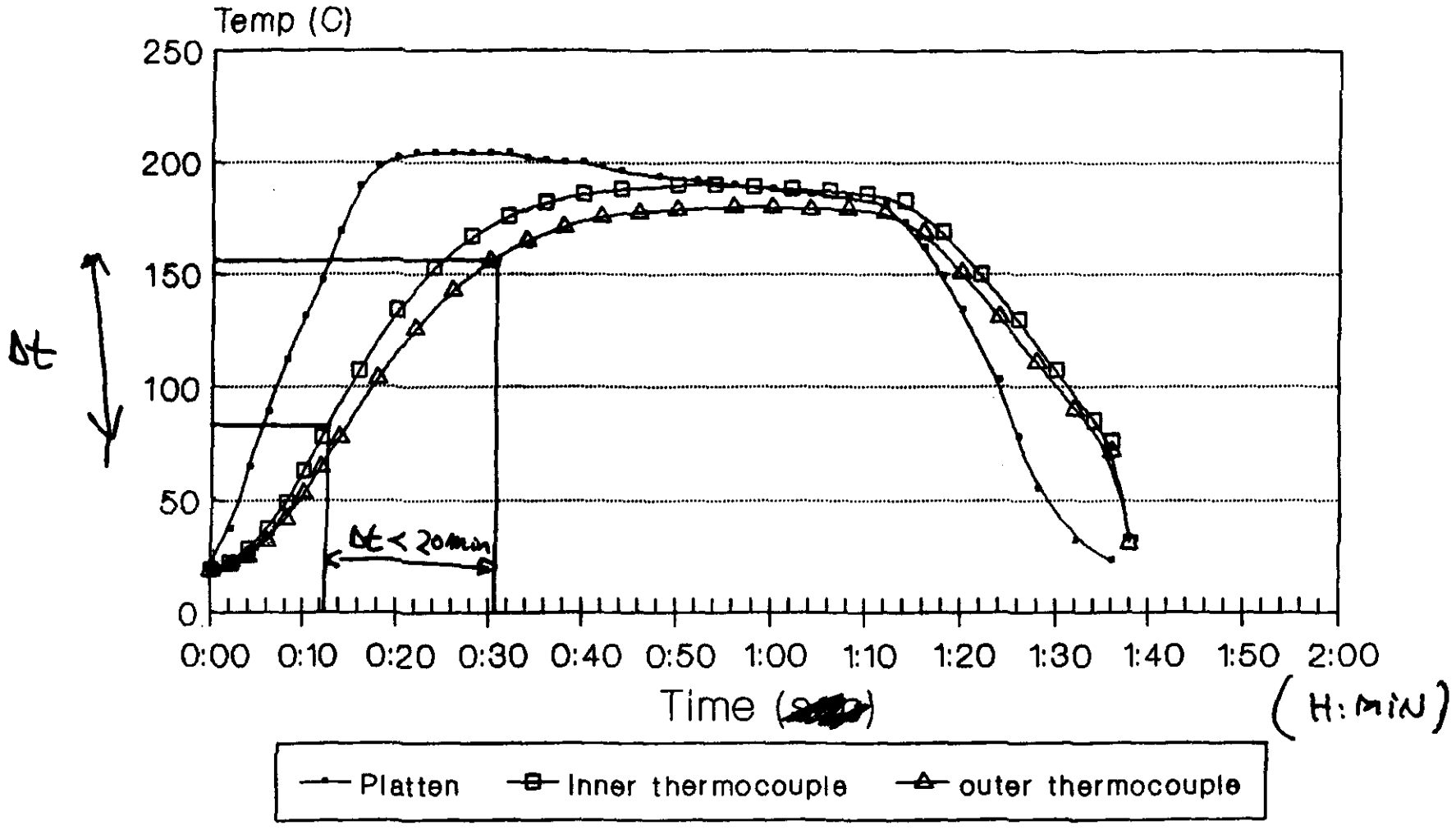


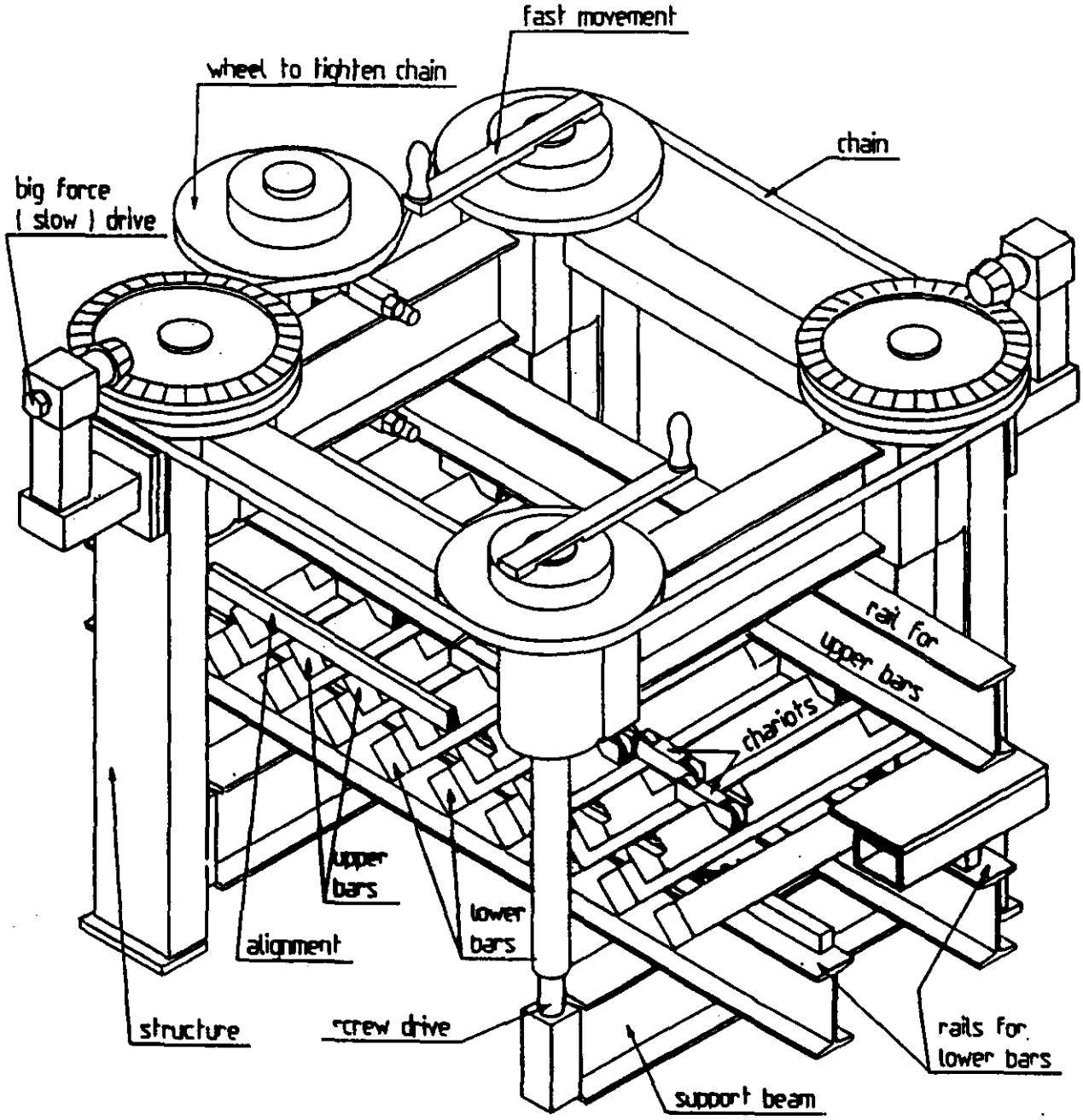
fig. 6

P78-13-013-3A

Curing Cycle Lead Electrodes



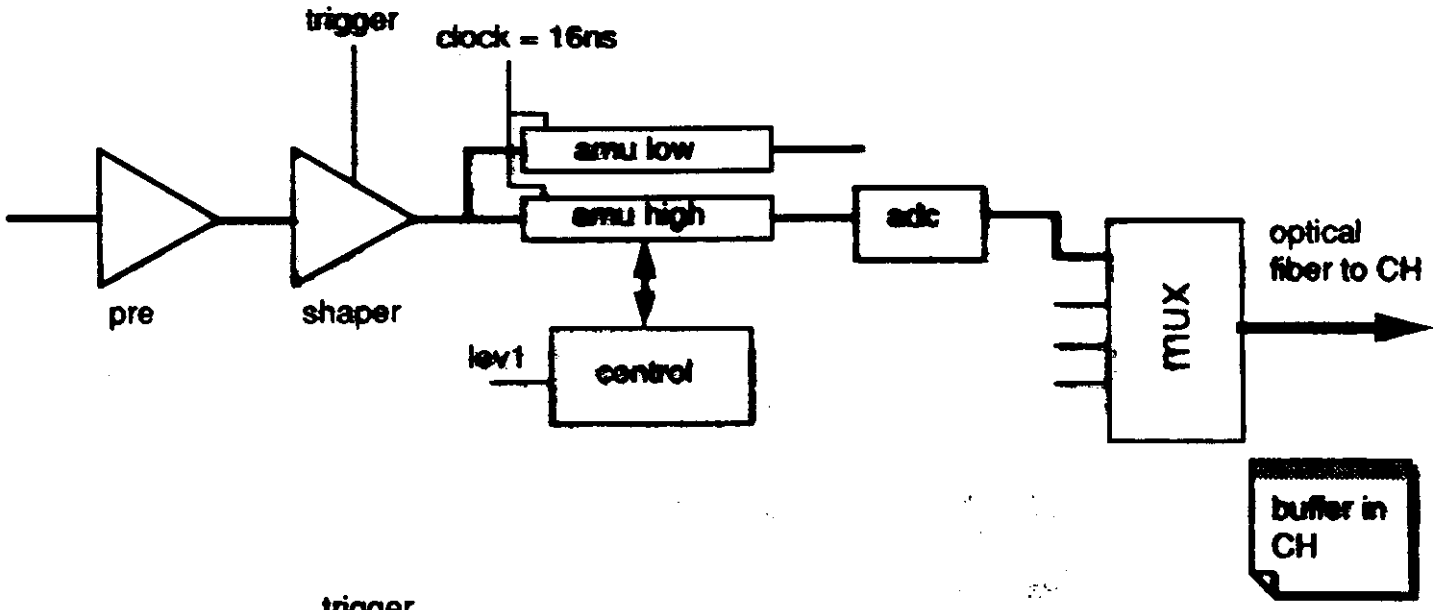
Thermocouple Imbeded In lead

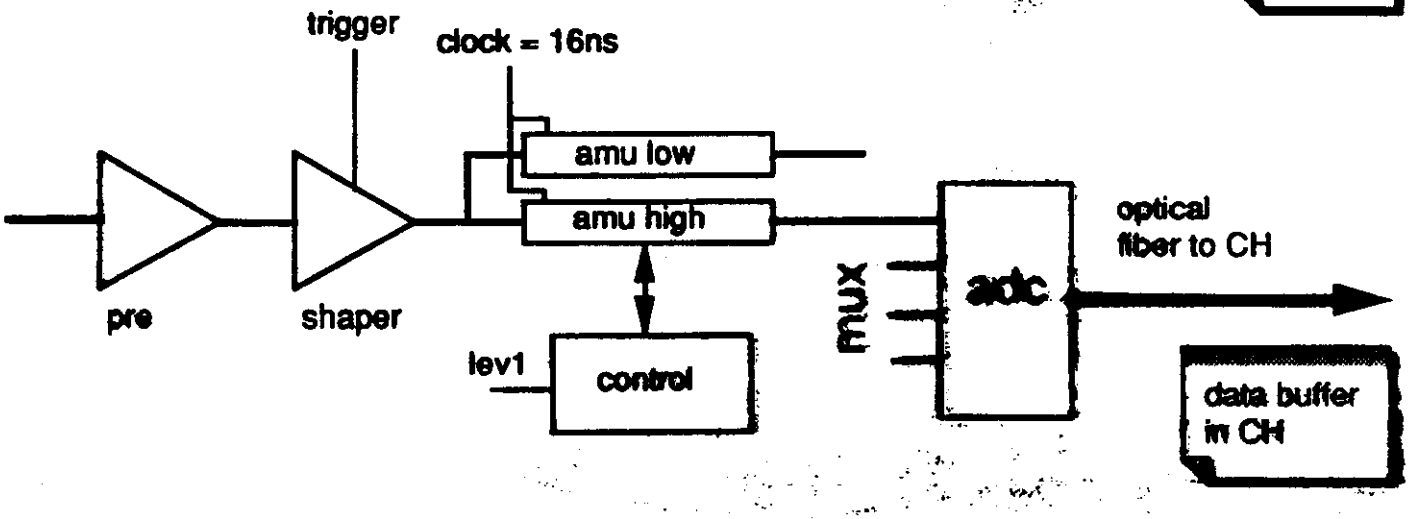

fast movement
wheel to tighten chain
chain
big force
(slow) drive
rail for
upper bars
chariots
upper
bars
lower
bars
alignment
structure
screw drive
rails for
lower bars
support beam

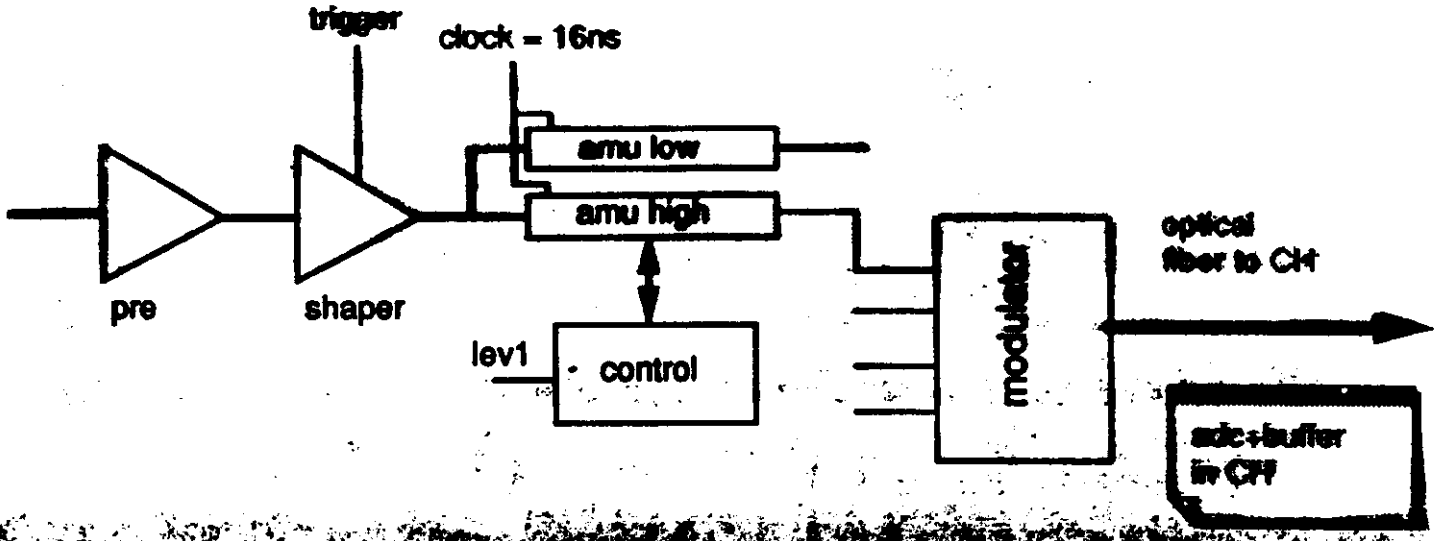
CERN

Bending Machine – has arrived and is installed at BNL.

Test will start later this week.

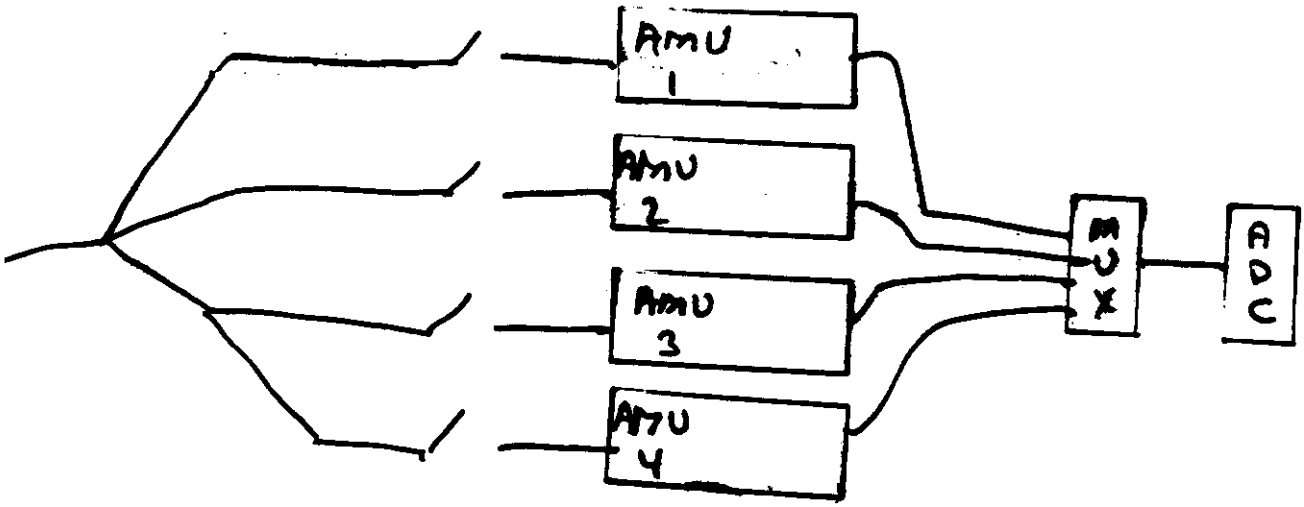

trigger
clock = 16ns
amu low
amu high
adc
pre
shaper
lev1
control
mux
optical
fiber to CH
buffer in
CH


trigger
clock = 16ns
amu low
amu high
pre
shaper
lev1
control
mux
adc
optical
fiber to CH
data buffer
in CH


trigger
clock = 16ns
amu low
amu high
pre
shaper
lev1
control
modulator
optical
fiber to CH
adc+buffer
in CH

Pre-Amp : Cold pre Amps.

Shaper : 40 n-sec.



"ZEUS" AMU 58 buckets.

Design for 96 n-sec. clock (HERA)

Multiplex input into 4 diff AMU.

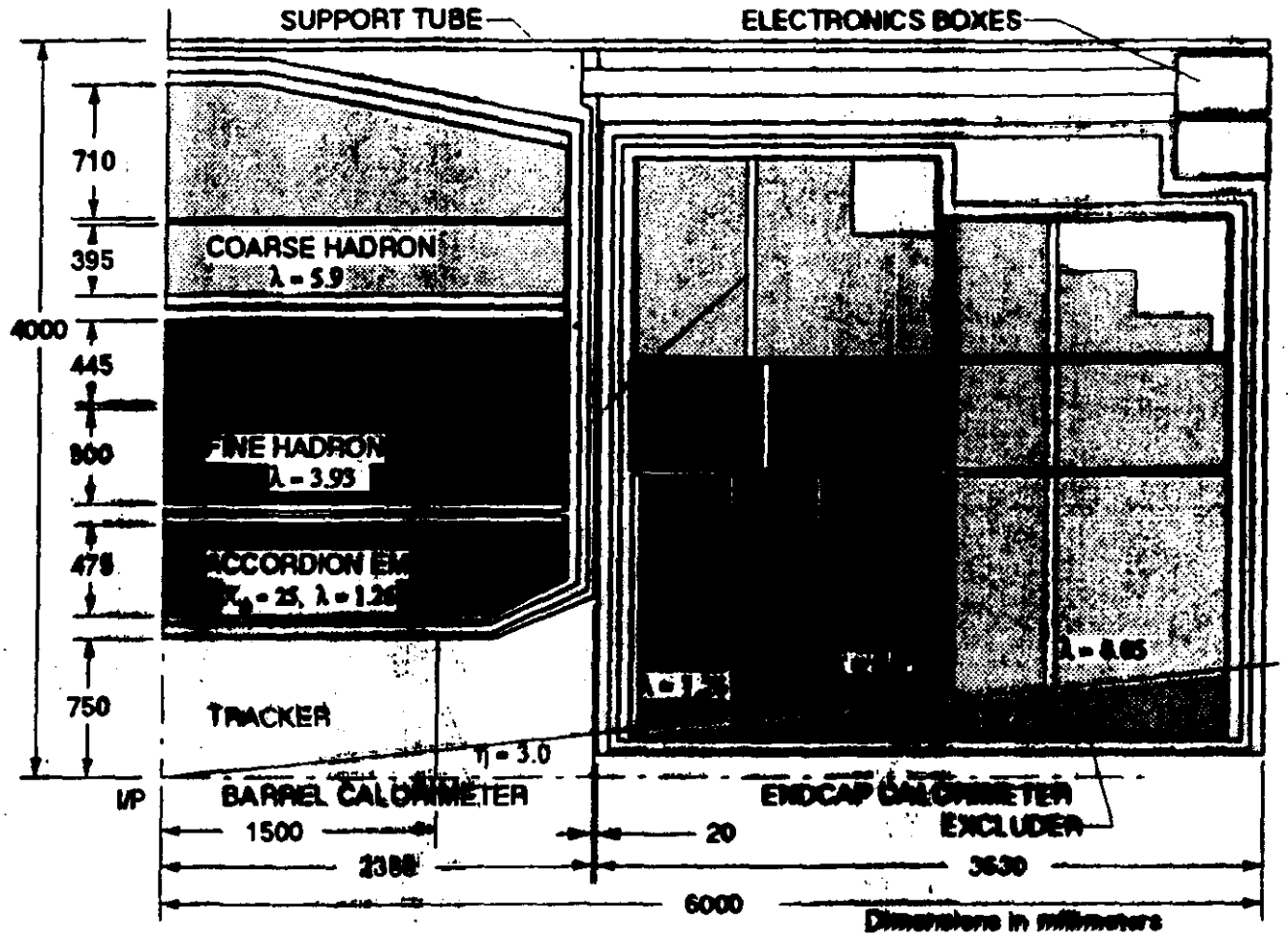
18 n-sec.

Tested last year at FNAL

J. PARSONE et Al. (NEVIS)

Electronic Readout –

Pre-Amp – } Have been defined
Shaper – 40-n-sec


SUPPORT TUBE
ELECTRONICS BOXES
710
395
4000
445
900
475
750
COARSE HADRON
λ = 5.9
FINE HADRON
λ = 3.93
ACCORDION EM
TRACKER
η = 3.0
I/P
BARREL CALORIMETER
ENDCAP CALORIMETER
EXCLUDER
1500
20
2380
3630
6000
Dimensions in millimeters

optim. Head stack

#λ's S.M.

#λ's total

λ's tail Cutoler

- Sampl. Ratio
- plate thick. (freq.)
- # λ's fine head
  # λ's coarse head.

IIC plate — Electrostatic transformer

Accordion — ?

Base line Design Completed for LOI.

- ~~[illegible]~~ Baseline Configuration.

11- 14 λ's $\eta = 0 \rightarrow 3.5$.

- Optimization of Had. stack.

* λ's 1st, 2nd, 3rd & 4th.

Pb plate with Electrostatic transformers.

- <u>RD3</u> -

- 2 m bending machine
- 1st hadronic Accordion Looks good.

1 cm. s steel.

Review

Calorimeter Group Goal for Resolution

$\leq 7.5\%/\sqrt{E}$ stochastic

$\leq .5\%$ constant

BaF_2 Clearly has the best stochastic

Much experience with LAr calorimeters

Accordion has shown fast operations

$\tau_p \sim 20\,ns$

Best $\frac{\sigma}{E} \sim 10\%/\sqrt{E}$

NA31 slow

$\sigma/E \sim 7.5\%/\sqrt{E}$

$\sigma = 25\%\sqrt{E}$

Can we make the NA31 design (parallel plates) fast and return $7.5\%/\sqrt{E} = \sigma/E$

?

Review

Dallas SSCL 12/4/91
P Hackett

Calorimeter Group Goal for Resolution

$\leq 7.5\% \sqrt{E}$ stochastic

$\leq .5\% E$ constant

BaF_2 clearly has potentially the best stochastic term

Much experience with LAr calorimeters

Accordion has demonstrated fast operation

$\tau_p \sim 20ns$ but $\sigma \sim 10\% \sqrt{E}$

NA31 demonstrated $\sigma = 7.5\% \sqrt{E}$

but slow

Can the NA31 design (parallel plates) be made Fast & retain $\sigma \leq 7.5\% \sqrt{E}$

?

Parallel Plate EM Options (PEM)

Meeting MIT Oct 23-24

Copy list p 116 bk II

~~Discussion of speed~~ Stripline Design Review

a) Fast loaded stripline signal line

$$v = \frac{c}{\sqrt{K(1+\eta)}}$$

b) < 1% of area non uniform

c) 1.5mm Pb + Cu (brass) cladding ⇒ 2.5%/$\sqrt{E}$ in LAr

Discussion of Speed

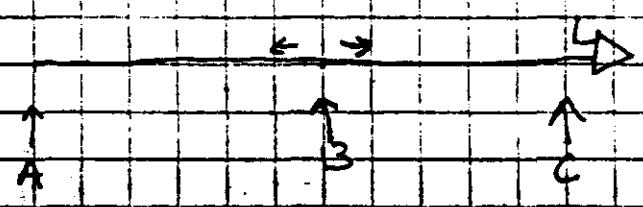
Loaded Stripline

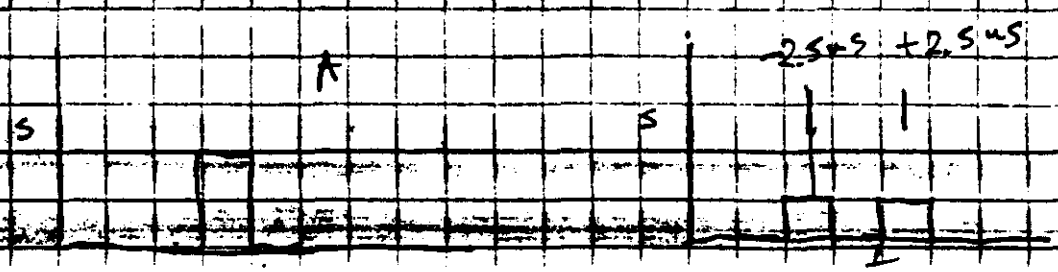
$$v = \frac{c}{\sqrt{K(1+\eta)}} \quad \text{where } \eta = C_L/C_S; \text{ for } K=3.5 \ \eta = 3$$

$$\Rightarrow v_p = \frac{c}{\sqrt{3.5 \times 4}} =$$

Accordion $v_p = \frac{c}{\sqrt{1.5 \times 2}} \times$

so ×2 faster





PARALLEL PLATE OPTICS
(PPEMCAL)

Meeting @ MIT Oct 23-24
UA MIT & UW

Stripline Design Review

a) 1.5 mm Pb plates with Cu cladding
$< 7\%/\sqrt{E}$ in LAr

b) <1% of area non uniform

c) $v = c/\sqrt{K(1+\eta)}$: Fast loaded Stripline Readout

Discussion of Speed

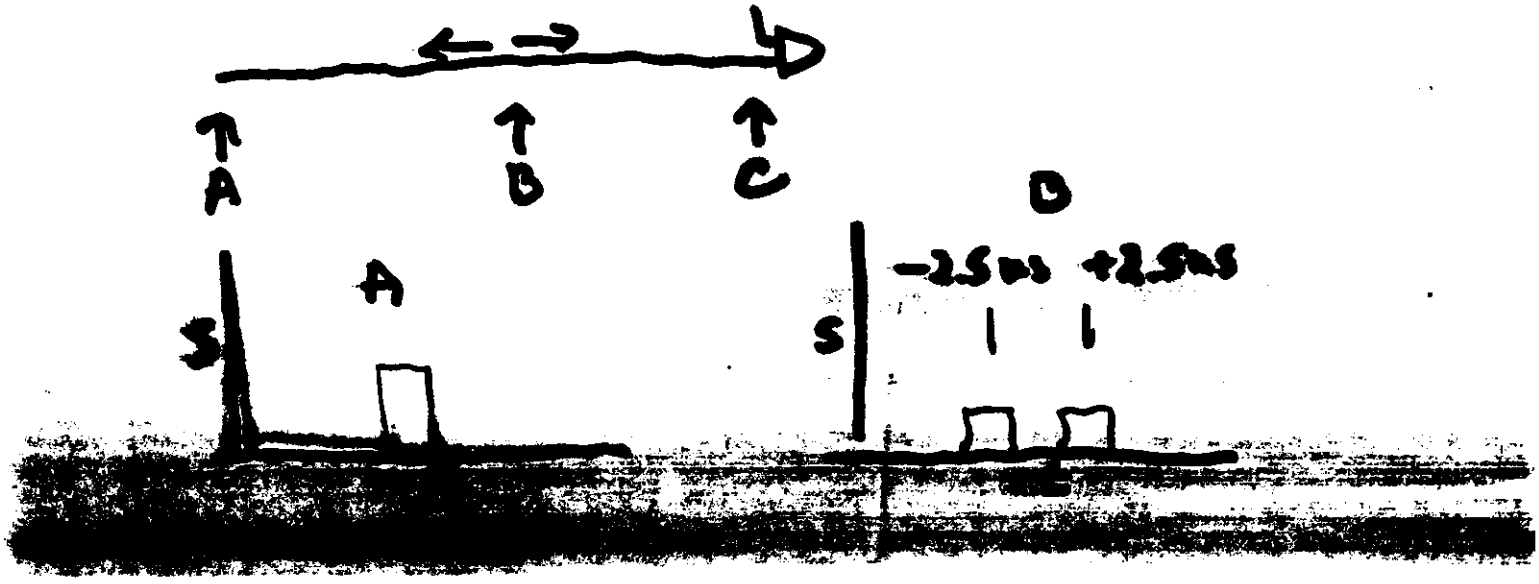
Loaded Stripline

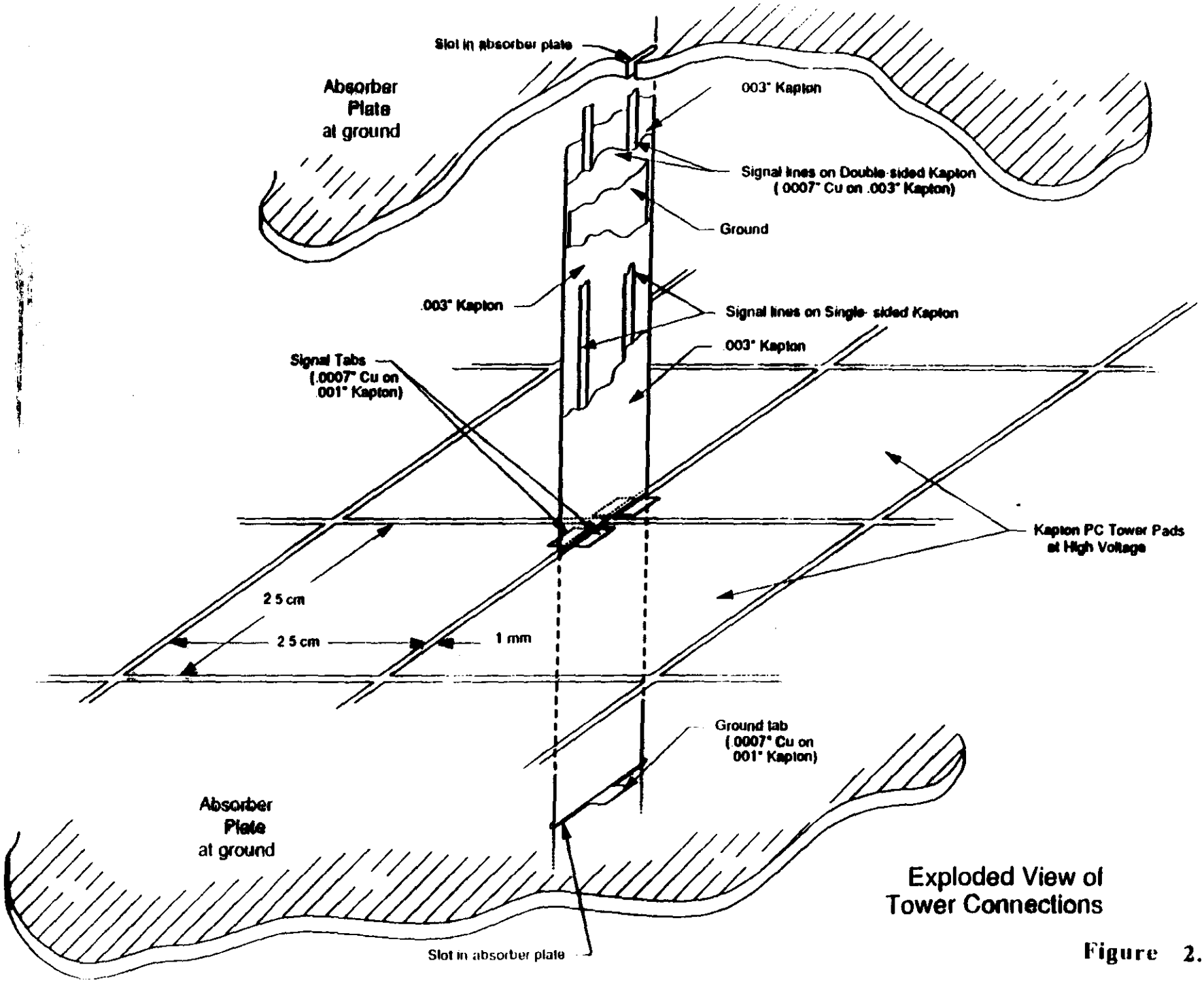
$$v = \frac{c}{\sqrt{K(1+\eta)}} \quad \text{where } \eta = C_L/C_S$$

for $K = 3.5$ (Kapton) & $\eta = 3$

$$v = c/\sqrt{3.5 \times 4}$$

[Accordion $v = c/\sqrt{1.5 \times 2}$
so Accordion $\times 2$ faster]





Exploded View of Tower Connections

Figure 2.

Four - Channel Stripline

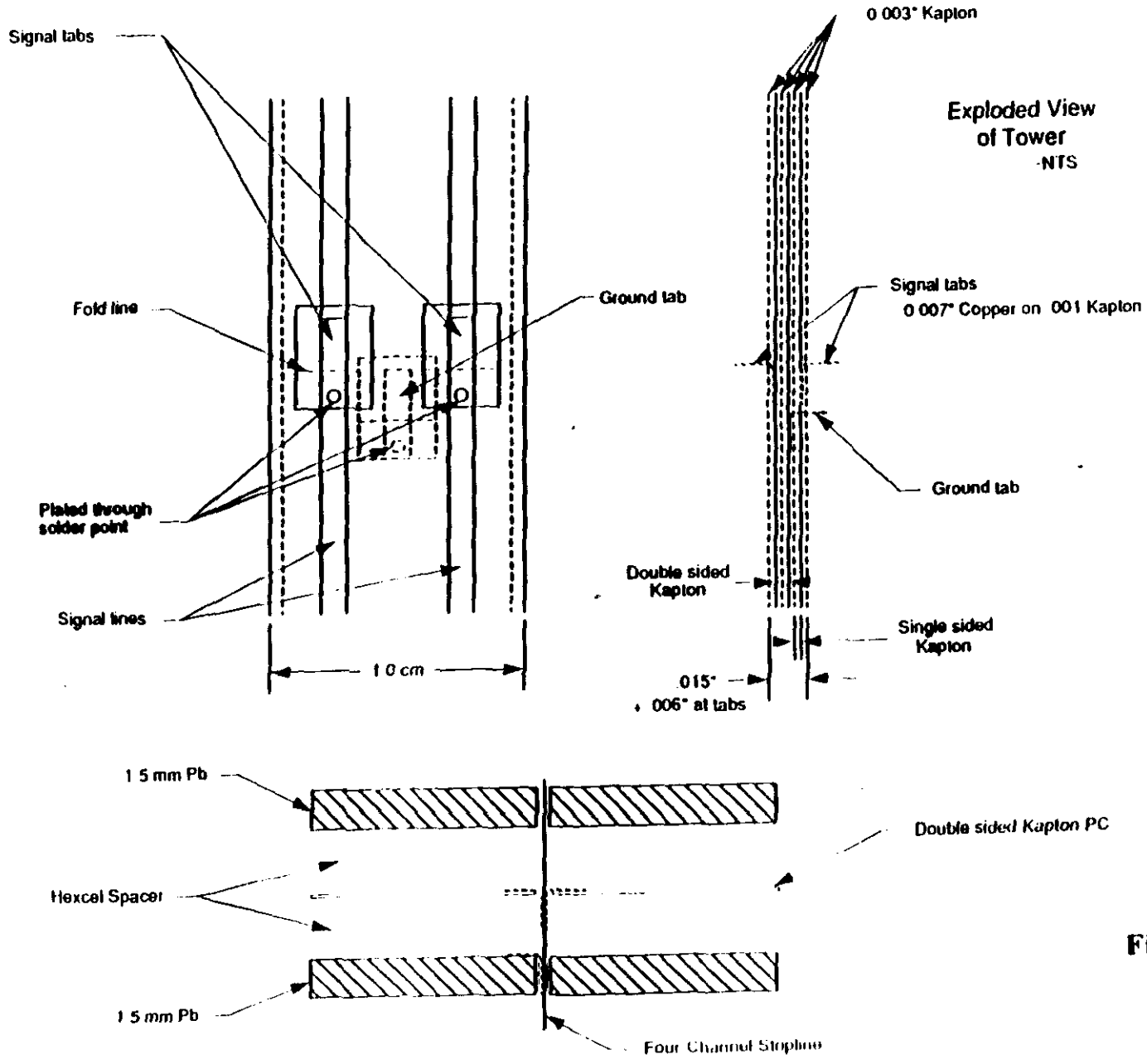


Figure 1.

Decoupling Capacitor Schematic

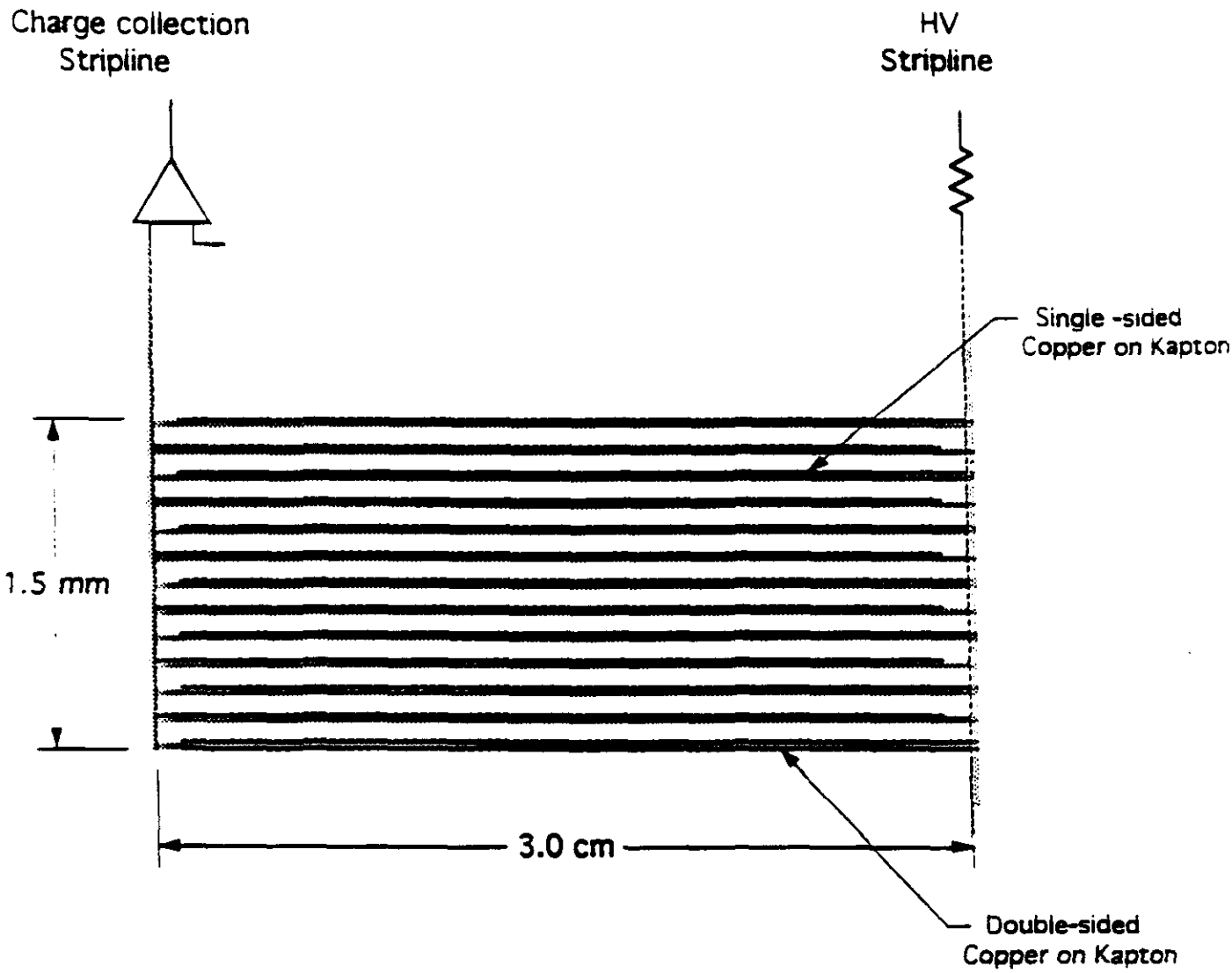


Figure 3.

V. Radeka simulation of Loaded Stripline

12.5 ns delay (vs 5 ns for parallel plate EM)

τ_p = 50 ns (vs 40 ns PEM)
Stu input 2.1 Ω line 1.5 Ω amp (vs 10 Ω PEM
δt = 2 ns
$\frac{\delta E}{\langle E \rangle}$ = 3%

Conclusion: Speed & uniformity not a problem for PEM

PLATE THICKNESS

(A) 1.5 mm Pb 4 mm LAr vs (B) 1 mm Pb 2 mm LAr
M. Shupe QVA

(A) σ = % ~~σ~~ VE LAr L = % VE LKr

(B) σ = LAr

Inclusion of tile cracks would certainly degrade B further

Conclusion: Use 1.5 mm Pb (+ cladding)

Practical Considerations

Slots for SL

inefficiency < 1% (= 2/3% @ z = 0)

σ → (σ + .4)% VE GEANT *

← Pb cladding σ →

* May go away with pre radiator

V. Radeka Simulation of [redacted]

12.5ns delay (vs 5ns for PPEHCAL)

$\tau_p = 50ns$ (vs 40ns PPEHCAL)

Sin input 21Ω line, 1.5Ω amp (vs 10Ω PPEH

$\delta t = 2$ ns

$\delta E = 3\%$

Conclusion: Speed & Uniformity not a problem for PPEHCAL

PLATE THICKNESS

(A) 1.5mm Pb 4mm LAr vs (B) 1mm Pb 2mm LAr
M. Shupe U of A

(A) ⇒ $\sigma = 6.3\% \sqrt{E}$

(B) $\sigma = 6.5\% \sqrt{E}$

Inclusion of tile cracks would certainly degrade B further

Conclusion: Use 1.5mm Pb plates

Practical Considerations

Slots for 5λ's

inefficiency < 1% (= 2/3% @ z = 0)

$\sigma \rightarrow (\sigma \oplus .4)\% \sqrt{E}$ GEANT

[redacted]

Test Specifications (1992)

Projective vs non Projective

Ideally projective
a) cost
b) time
c) easily adaptable to projective

Conclude: make test cal non projective
cell = $(2.5)^2$ cm^2

Preamps inside or outside Cryostat
Ideally inside
a) Inside preamps tested with accordion
b) Run at LAr & LKr temperatures
c) FT's or $\in$ 50 Ω much too large!

Conclude: Preamps must be inside
$Z \sim 10\Omega$s
taper @ 88K & 150K

HV Distribution
A) Resistive coat
1) Harder to hook up to SL's
2) Loss of plate near shower max affect resolution of many towers
3) Maintains hermeticity
B) Capacitor Decoupling
1) Easy to hook up
2) HV shorts out tower lost - some loss in hermeticity - no loss in resolution

Conclude: use Capacitive decoupling

Calibration

A) Type

1) C	SLD	$.25\%/\sqrt{3}$	stray C
2) R	DØ	$.1\%/\sqrt{3}$	"
3) I	DEW		

B) After HV decoupling Capacitor

$$q \rightarrow \frac{q_0}{1+\frac{C_L}{C_C}} \Rightarrow C_C \sim 10\, C_L$$

precision required

$$\frac{\delta q}{q} = \frac{1}{1.2} \times .1 \frac{\delta C_C}{C_C} \sim .08 \frac{\delta C_C}{C_C}$$

$$\Rightarrow \frac{\delta q}{q} \leq .1\% \Rightarrow \frac{\delta C_C}{C_C} \leq 1.2\%$$

C) Use mean shower profile in calibration pulse shape (direct + reflected pulse)

Stack Depth

A) need 25 X_0 for high energy (not for BNL energ

21 X_0 PPEMCAL = 39 cm
3 X_0 Homogeneous LKr 3 14 cm

Total	53 cm
Dewar	54 cm
	+ 1 cm

Not enough for preamps

25 X_0 (LAr) $\rightarrow$ 20 X_0 $\Rightarrow$ remove 4 X_0
$\Rightarrow$ 56 plates / 32 cm
$\Rightarrow$ 8 cm for preamps

Conclude: No extension required of ITEF D

Current Responsibilities

UA
- MC Simulation
- Calibration
- Striplines
- Tests: bench & cosmic ray with brass model
- DAQ

MIT
- LKr, LAr
  - Supply, Purity monitoring
  - Materials certification

- Homogeneous preradiator (LKr, LXe) (incl. amplifier for Photo Diode)
- Dewar (ITEP?)
- Investigate W for Pb

UW
- Plate & electrode structure including decoupling C
- HV distribution
- Amplifiers
- Strip Pre radiator
- Overall coordination

Stack Parameters

Plate 1.5 mm Pb + 2x .05 mm Cu
2 x 2 mm LAr

σ = 1.5 mm Pb (E&S) = 6.33 [illegible]
.05 mm cladding Cu → [illegible]
$\Rightarrow \sigma = 6.3 \times \frac{[illegible]}{1.5}$ = [illegible] % [illegible]

$\sigma^2 = 6.5^2 + 2.1^2 = 6.8^2$ *

[* Note sight effects may disappear with preamplifier]

Conclusion: σ's 7% $\sqrt{E}$ in LAr possible

→ 6% $\sqrt{E}$ in LKr

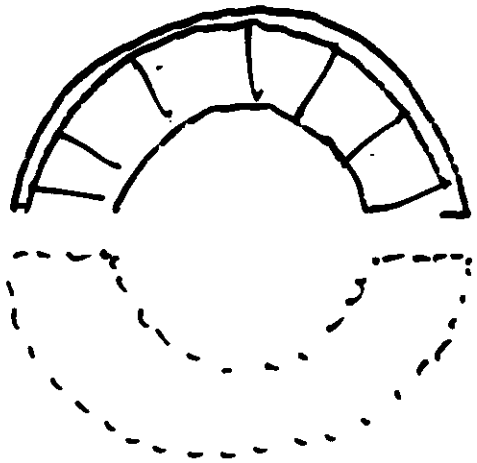
Fast parallel plate EM CAL with $\sigma \leq 7\% \sqrt{E}$ can be designed

Challenges

A Many connections (x2 SLD wire connections)

B Precision & uniformity of parts

Engineering



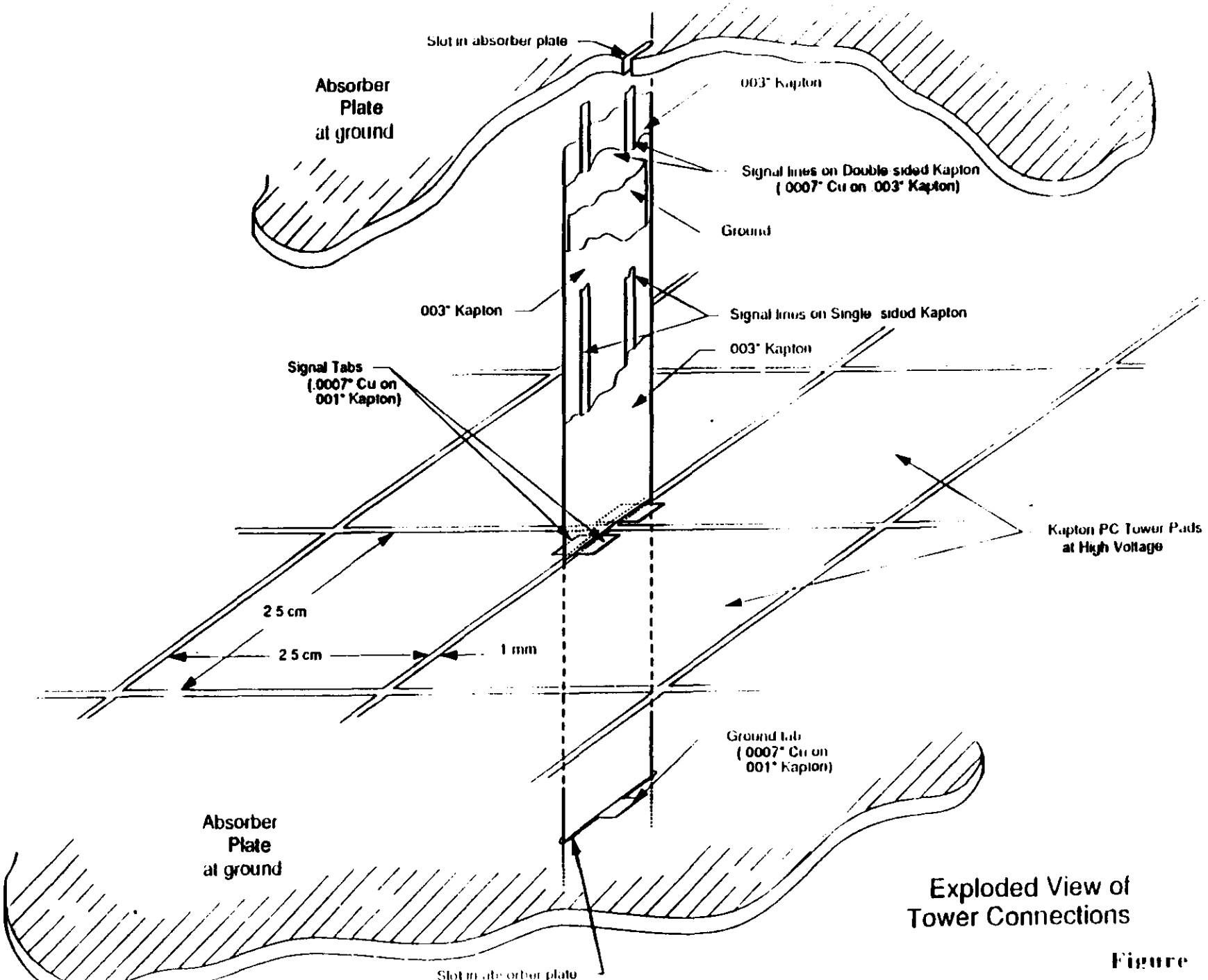
tie rods < .2% of area

2-3 very small ⊥ cracks

Ideal for End Caps

Costs

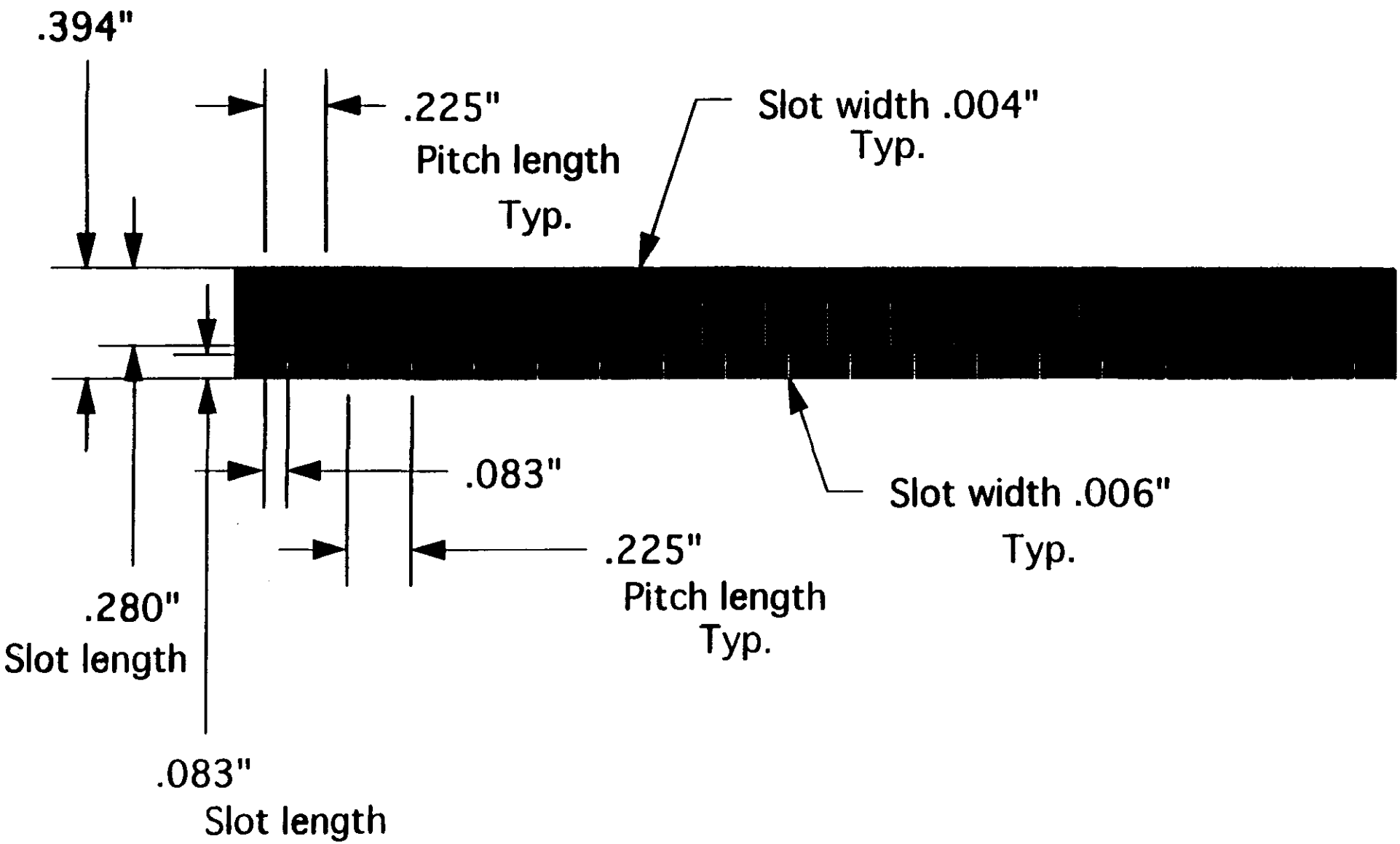
All SLD (~ connections >> mass) cost 65M$!



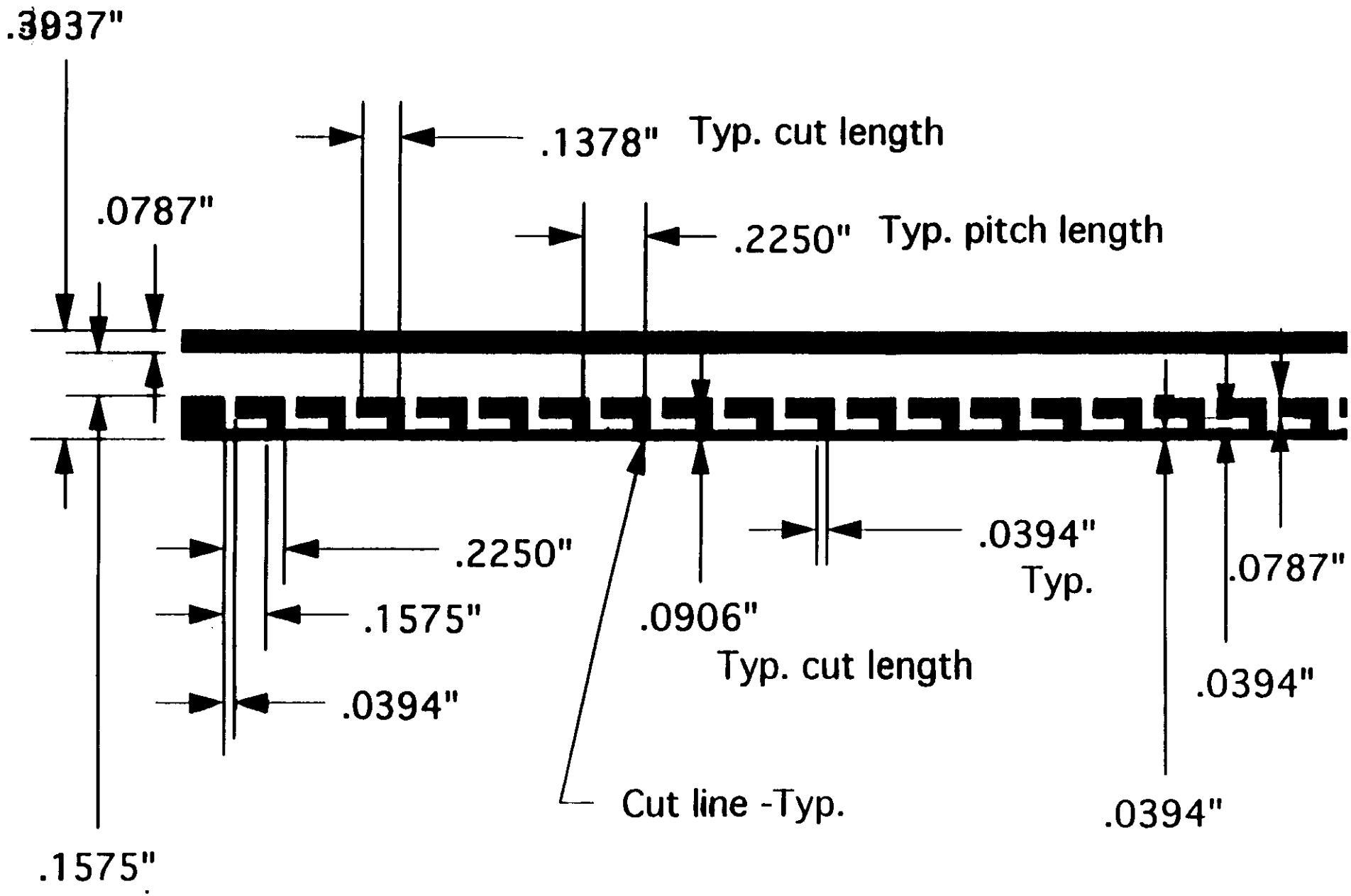
Exploded View of Tower Connections

Figure 2

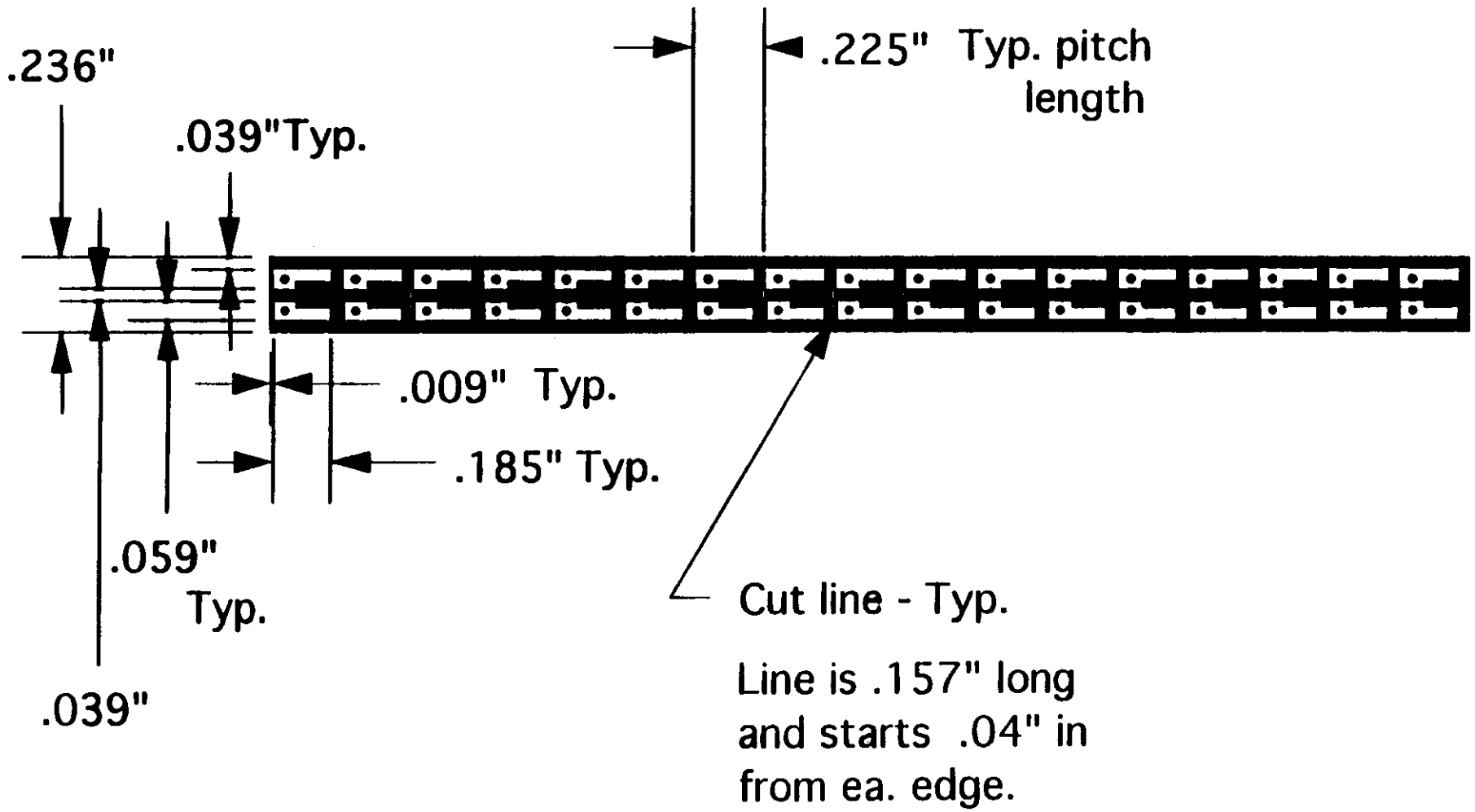
Kapton Slit Pattern



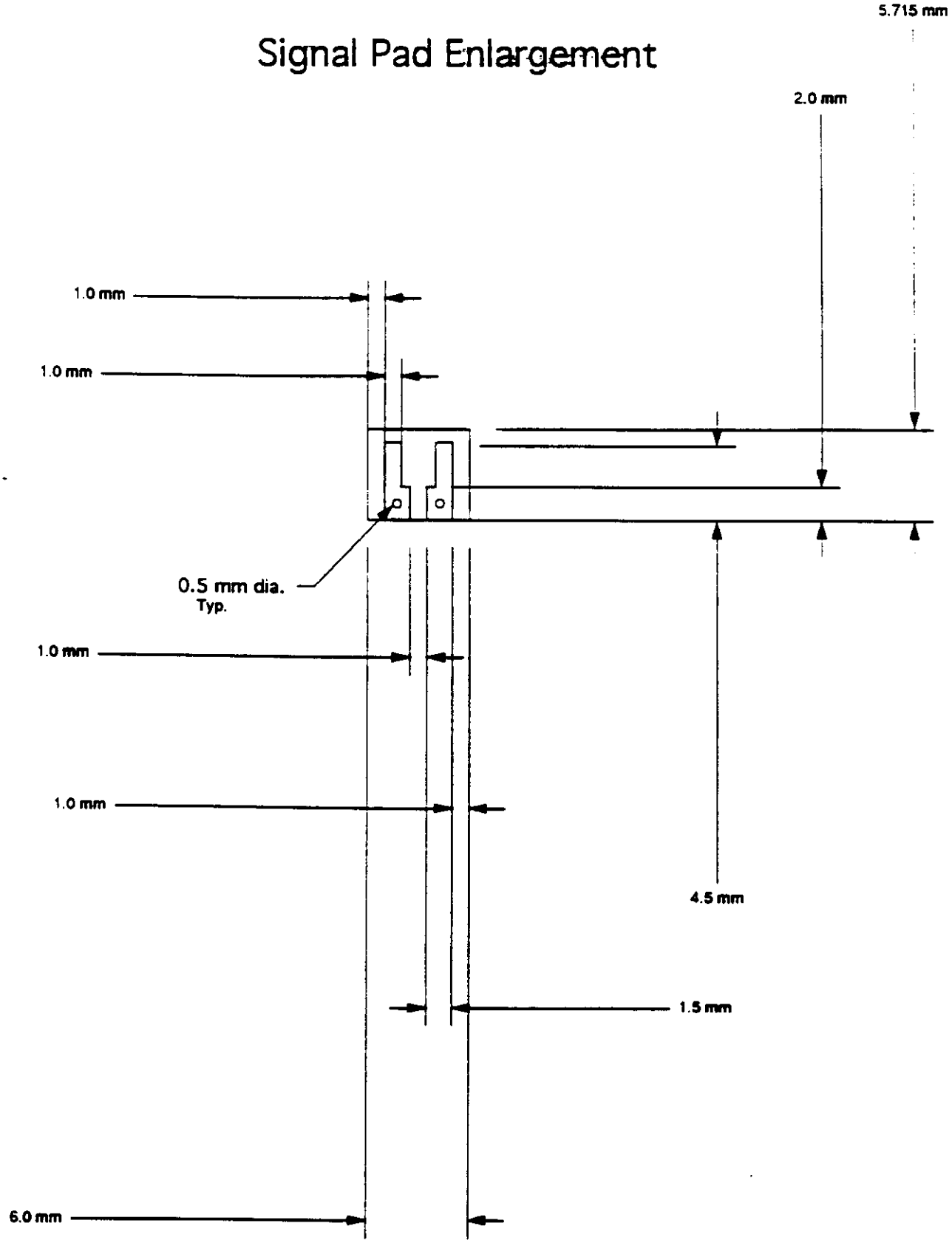
Ground Tab Enlargement



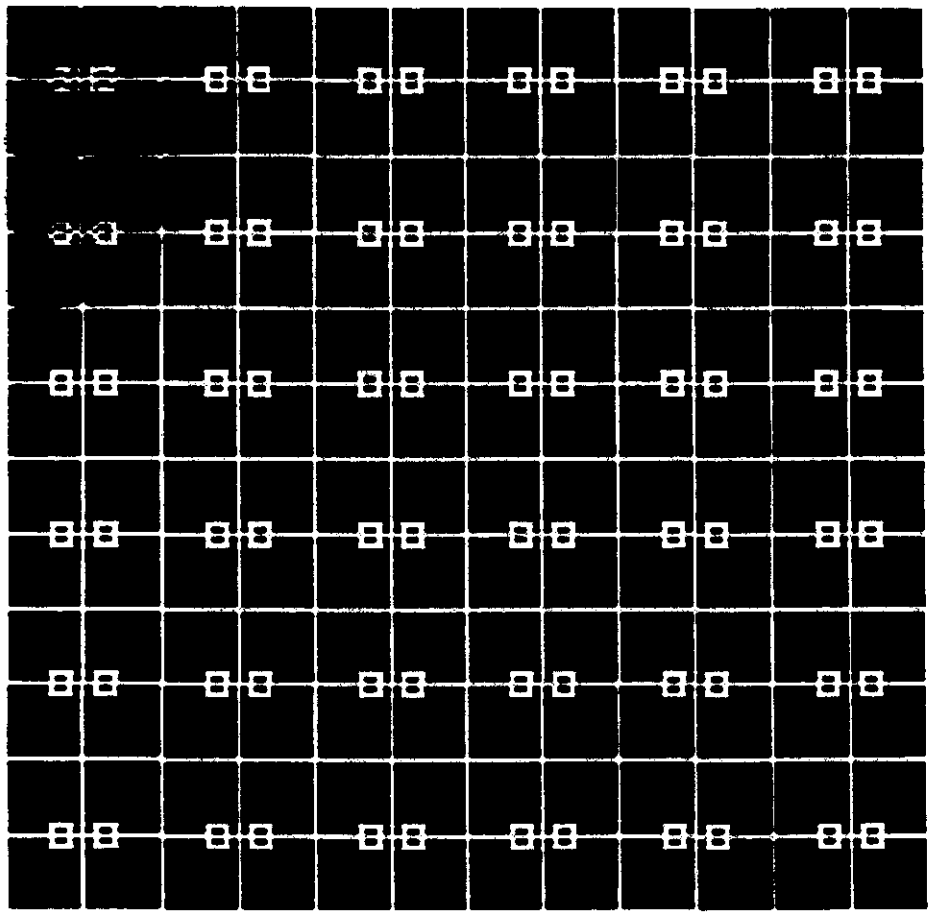
Signal Tab Enlargement

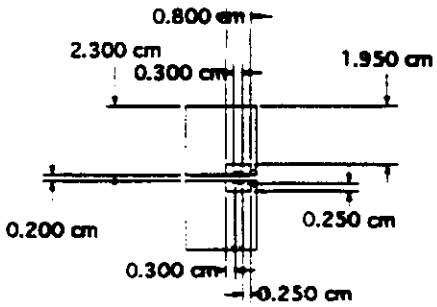


Signal Pad Enlargement

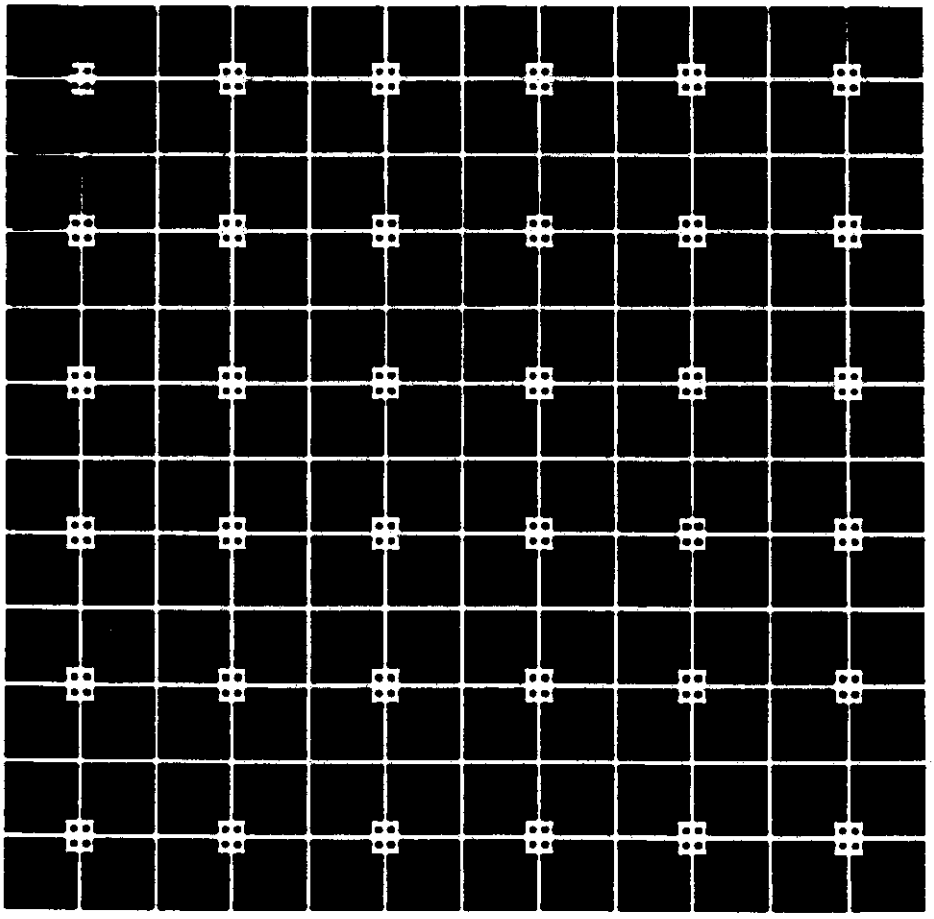


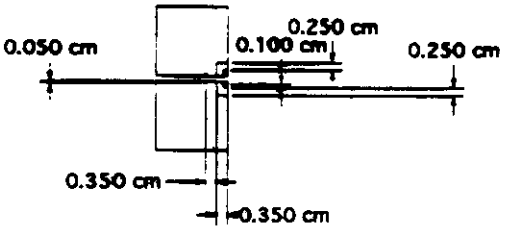
High Voltage Capacitor plate



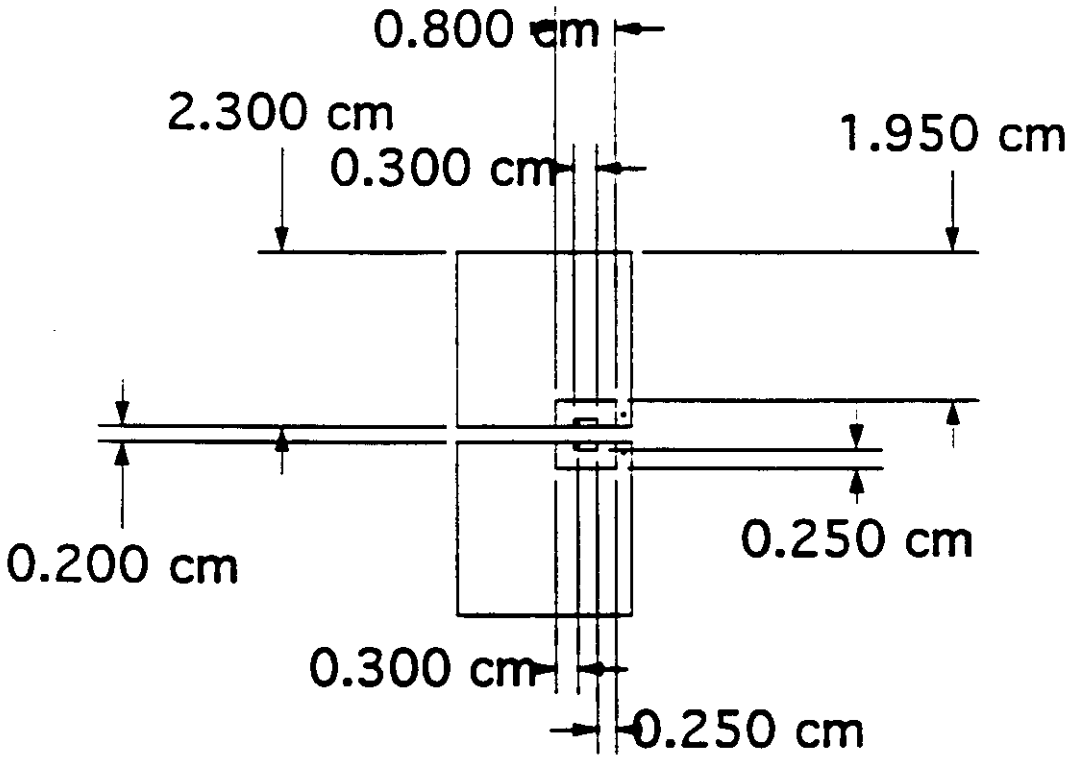


Low Voltage Capacitor plate

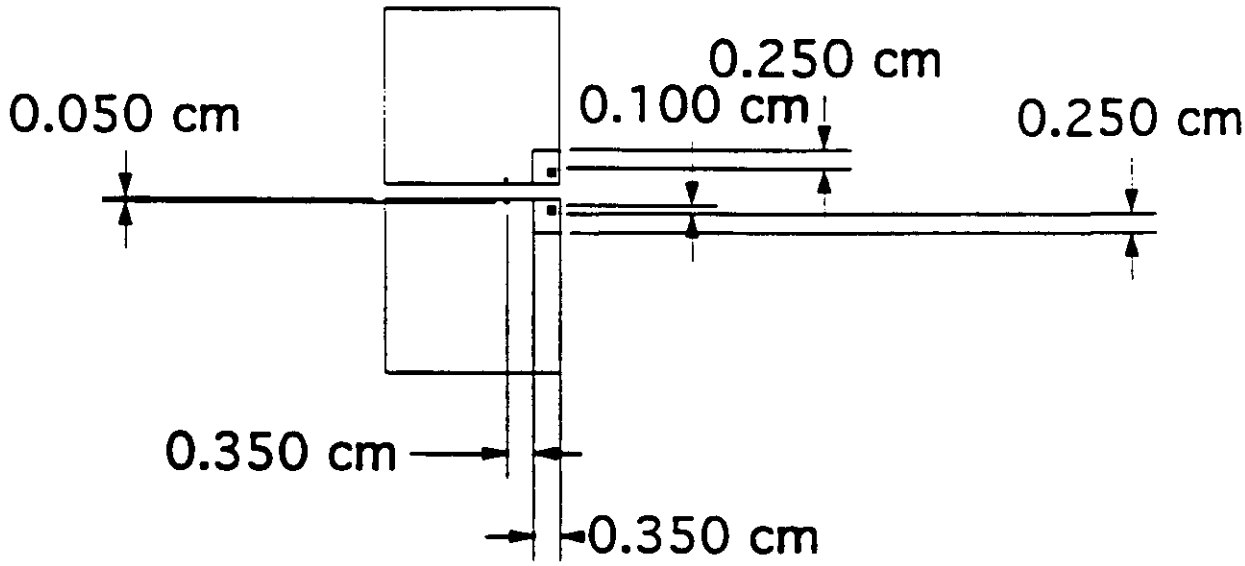




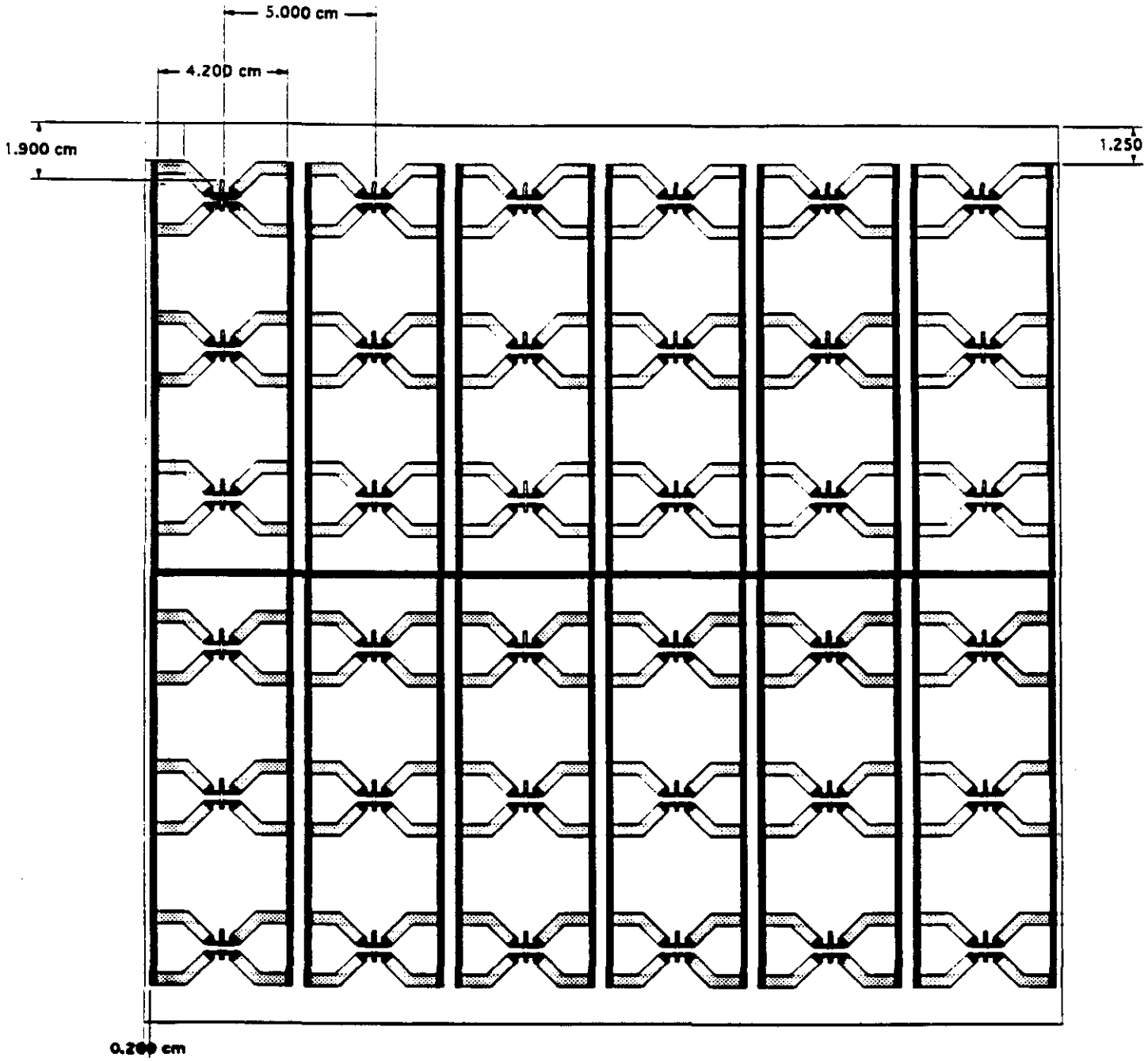
High voltage
capacitor plate
detail



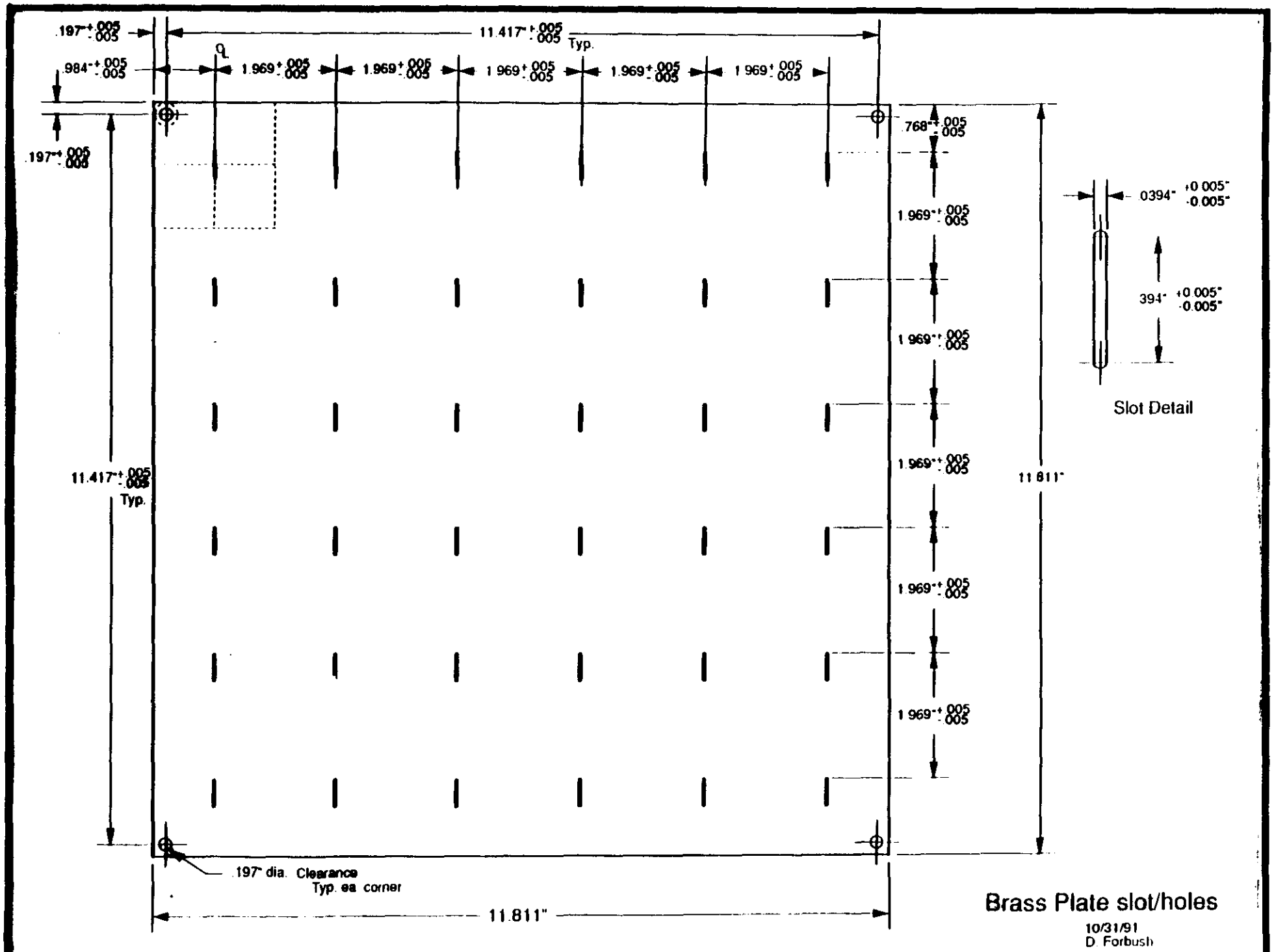
Low voltage
capacitor plate
detail

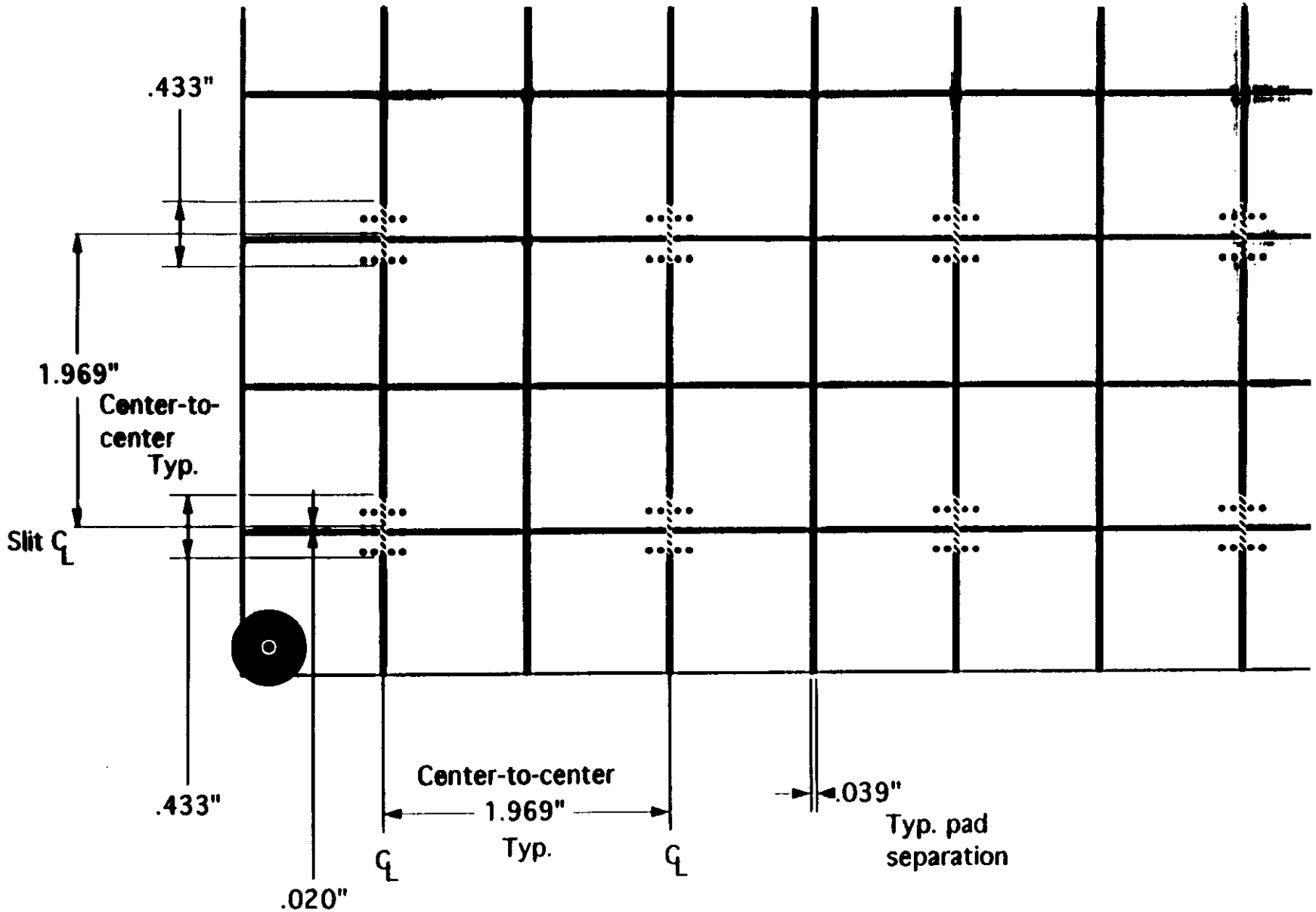


High Voltage Distribution



Solid = Cu
dotted = resistive coating


.197" +.005 -.005
11.417" +.005 -.005 Typ.
.984" +.005 -.005
1.969" +.005 -.005
.768" +.005 -.005
.197" +.005 -.005
.0394" +0.005" -0.005"
.394" +0.005" -0.005"
Slot Detail
11.417" +.005 -.005 Typ.
11.811"
.197" dia. Clearance Typ. ea corner
11.811"
Brass Plate slot/holes
10/31/91
D. Forbush



Note:
Slit has a total length of .433" and .039" width.

Pad Slit Pattern

11/14/91

P. Mockett, University of Washington, Seattle, WA

Budgets for LAr(LKr) projects for GEM

Here are my refined estimates of costs associated with our proposed GEM LAr projects.

There are three projects:

A Parallel plate calorimeter(goal to reach better than 7%/rtE in LAr).

B Pizero strip preradiator module for test with Parallel plate EM.

C 36 person weeks at BNL to help with tests.

Details of budgets:

A Parallel plate calorimeter			
E&D (7 mm)	$ 33K		
Tech (7 mm)	13K		
Hourly	10K		
M & S	20K		
Shop	3K		
Clean Room	5K		
Signal Feed Thrus	6K		
HV Feed Thrus	1K		
Travel	4K		
Subtotal	95K		
15% Contingency		14K	
Total			$109K
B Pizero Strips			
E & D (3 mm)	$ 14K		
Tech (3 mm)	6K		
Hourly	3K		
M & S	5K		
Shop	1K		
Travel	1K		
Subtotal	$ 30K		
15% contingency	$ 4K		
Total			$ 34K

C BNL Test support		
36 mw at BNL	$ 16K	
20 Trips	20K	
Subtotal	$ 36K	
Indirect costs(30%)	$ 11K	
Total		$ 47K
Total of A, B & C		$ 205K
University of Arizona		20K
Program total		$ 225K

11/19/91
P. M. Mockett

M&S LAr Parts Budget for GEM

Pb plates	$ 500	
Washers	500	
Rods	50	
Nuts	400	
HEXCEL	795	
Copper Sheet	500	
SnPb Solder	1000	
Heaters	500	
Fluxes Etc.	250	
Msc'l 500		
Total	$4995	$ 4995
Printed circuits		
PC Tabs	$ 11700	
Electrodes	12200	
Decoupling Cap	1500	
HV Distrib.	250	
Amp. Board	250	
Total	25900	$25900
Total		$30895
less U of A		(10400)
Net to U of W		$20495

UW Budget request incl. Contingency is $23000.

P. Mockett
MET Meeting
Oct 23 & 24 1991

Parallel Plate EM

I Motivation
- A Better σ_E
  1) @ 90°
  2) @ forward angles
  3) lower noise at shower max with preconvertor
  4) Incorporate uniform gaps readily
     cryostat compensation
- B End Cap EM
  1) Fewer ϕ cracks
  2) Shorter z
- C Costs
  1) Design/manufacture
  2) Thermal expansion
  3) support
  4) wiring

II Sampling frequency
- A No tiles
  1) plate thickness
- B Tiles
  1) ~~costs~~ thickness, construction
  2) costs
- C LAr (LKr) gap
- D ∥ to z to ⊥ to z transition point
  1) Barrel @ 45°?
  2) EC only

III Segmentation
- A Preradiator at 4 X₀ implications
  1) 3×3 (.04) 800 pF @ 90° (too large?)
  2) 2×2 (.03) 600 pF @ 90°
  3) [illegible] 3×3 to keep C @ ~500 pF
  4) [illegible] 3×3

P. Mockett
MIT Meeting
Oct 23 & 24 1991

Parallel Plate EM

I Motivation
- A Better σ_e
  1) @ 90°
  2) @ forward angles
  3) lower mass at shower max with preconverter
  4) Incorporate massless gaps readily
     cryostat compensation
- B End Cap EM
  1) Fewer ϕ cracks
  2) Shorter z
- C Costs
  1) Design/manufacture
  2) Thermal expansion
  3) support
  4) wiring

II Sampling frequency
- A No tiles
  1) plate thickness — No Tiles
- B Tiles
  1) ~~costs~~ thickness, construction — 1.5 mm Pb
  2) costs — + Brass
- C LAr (LKr) gap
- D ∥ to Z to ⊥ to Z transition point
  1) Barrel @ 45°?
  2) EC only

III Segmentation
- Pre Rd A Preradiator at 4X0 implications
- 1) 3x3 (.04) [illegible] pF @ 90° (too large?)
- ~~2) 2x2 (.03)~~ [illegible] pF @ 90°
- B How to segment 3x3 to keep C @ ~500 pF
- C Dumor near shower max for 3x3

D Signal lines
1) Internal (to cryostat) preamps ←
a) two operating temperatures
2) External preamps
a) noise penality, speed penality?
i) Feed thru design
ii) availability - time constraints
3) Optimize stripline (loaded) speed vs noise

E Shaping
1) Variable ~~timing~~ τ_p
a) Individual
b) Σ only
2) Fixed timing, 40 ns τ_p? ← τ_p = 40 ns
a) Downside?

F ADC's
1) Precision
2) speed
3) style
} BNL

G DAQ
1) stand alone [CERN connection]
2) BNL system ← choose M.E. check

IV Purity
1) acceptance
2) Monitoring Wide Gap Ionization
3) purification
4) Materials testing

V Preradiator
A LKr/diode (LXe only?) not for
B LAr sampling vs Diode
C LKr " Diode
D π^0 Detector For LAr Tess
a) Tests
i) e
ii) π^0 π^- target CEX
trigger & Veto req.
~~[illegible] evaluation~~

BNL Drift
Millistrip
Si
~~Si Simulation~~

Base Line
Pre Rad
of ll Plan

Conceptual Design for a Parallel Plate LAr and LKr Electromagnetic Calorimeter for GEM

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University of Washington, Seattle, WA

J. Rutherfoord, L. Shaver, M. Shupe
University of Arizona, Tucson, AZ

The GEM calorimeter group has endorsed the goal of achieving the very best electromagnetic energy resolution possible in the 100 GeV energy range.They have advised that we pursue a two prong attack on this goal supporting both the development of a BaF_2 calorimeter and a LAr(LKr) calorimeter.The group has emphasized that beam test results are by far the preferred method of demonstrating the resolution that can be achieved. Modeling of the full system incorporating these beam tests is needed for overall comparison.

With the LAr effort there are different paths that might be followed. The 1.8 mm Pb plate accordion technique pioneered by the RD3 group has demonstrated a $10\%/\sqrt{E}$ stochastic term while the 1.5 mm Pb parallel plate calorimeter of NA31 has demonstrated a $7.5\%/\sqrt{E}$ stochastic term. In the latter case a long shaping time was used to process the signals so that it remains to be shown that the same resolution can be obtained with the fast shaping required for GEM. Although it has not been tested, it is believed that substituting LKr for the LAr will further improve the resolution in both cases.

We propose to follow the NA31 path and develop a parallel plate calorimeter with fast signals. To achieve this the signals must be collected and brought to the amplifiers on nearly projective striplines. In this case the thermal noise will be increased by approximately 25% but when added in quadrature to the pileup noise this produces a negligible increase in the total noise.

The striplines must pass through slots in the absorber plates. To minimize the affected area, a four-channel stripline will pass through 1 mm by 10 mm slots. This affects much less than 1% of the total area. A simulation of the effects of these slots on resolution is being carried out at the University of Arizona. Current results show the

effect of the slots on the resolution is less than 0.5%. A schematic of how such a stripline might look is shown in Fig. 1 and an exploded view of the arrangement is shown in Fig. 2. Four towers are serviced by on stripline so that the number of penetrations is minimized. The amplifiers will be placed at the inner and outer radii of the detector to service the inner and outer sections of the calorimeter respectively.

The absorber plates will be constructed of 1.5 mm Pb clad on each side with 0.003" yellow brass sheets. Brass is easier to solder than stainless steel and is a better match to the thermal expansion of Pb. For the GEM detector these plates would be formed in arcs of the appropriate radii. The number of degrees subtended by these arcs depends upon a detailed engineering study and the results of construction tests. Ideally they would subtend 180 degrees. This would result in only two minor phi cracks. More realistically we imagine 120 degree sections could be produced. The plates would be supported off of a strongback that could also serve as the first plate of the hadron section. The brass cladding not only supplies substantial strength to the plates but it should greatly reduce the likelihood of lead chips leading to shorts being found in the gaps. The end caps would be composed of flat plate sections having a similar structure.

The electrodes would be etched from copper clad Kapton. These could be strips two towers wide with notches at the appropriate points to allow the striplines to pass. This structure is indicated in Figs. 1 and 2. For the most part. Hexcel could serve as the spacer material and support of the Kapton electrodes. Additional spacers and tie rods from the strong back would be used to give added support as necessary. There would also be support structure at the ends of the plates. It is important that the towers be precisely aligned so that precision position measurements of the showers can be obtained.

The high voltage can be supplied in a couple of ways. It can be produced on a resistive coating separated from the tower electrodes by a dielectric or it can be applied directly to the tower electrodes. In the latter case the amplifiers must be capacitively decoupled from the stripline. The capacitors must have very low inductance and take up little room. We could achieve this by using capacitors formed by layers of copper clad Kapton printed circuits in the outer gap(or gaps). About six such layers would be required to give 90% charge

transfer. A schematic of this concept is shown in Fig. 3. We must be sure that such devices don't distort the wave form on the stripline.

We have looked at fast pulses on a printed circuit model of the proposed structure. The model is shown in Fig. 4. This loaded stripline model is about 20% slower than we expect for the actual EM calorimeter because the dielectric is G10 (k=5) and not Kapton(k=3.5). The loading is also somewhat higher. The total load is expected to come to about 600 pF much less than the 1.2 nF for the model line. We look at these pulses with a high impedance scope probe across the 5 ohm termination. The transmission of these pulses from different places corresponding to different depths in the calorimeter look as expected and encourage us to believe that the electrical challenge can be met. We expect two pulses, one arriving directly at the amplifier and the second arriving at the amplifier after reflection at the far end of the structure. The average time of arrival of the charge is independent of where it is injected. If we designate t=0 as the time of arrival of the charge from the far end of the structure, then when we inject charge at 20 cm from the end two equal pulses are observed. One arrives at -2.5 ns and the other +2.5 ns . The accordion calorimeter being faster would provide two pulses, one being -1.25 ns and one +1.25 ns. But with 40 ns shaping time these small numbers do not present a problem for uniformity of charge collection. We find upon integrating the pulse out to 30 ns, the same amplitude independent of where the charge is introduced. The pulse traces and integrals are shown in Fig. 5-a,b,c,d,e,f. 5-f repeats 5-c which appeared to be 1% low. We attribute the difference to poor probe contact for the 5-c measurement. Such uniformity is substantially greater than is required to prevent the depth fluctuations from degrading the resolution.

We also have reviewed pulse measurements made for our BRITE PAD bench calorimeter. Here charge was injected using a laser, fiber optic link and photodiode in the gap of the plates. The pulses were viewed with a 50 ns RCCR filter. Again the amplitude was independent of the position of the photodiode. Hence, we have good reason to believe that we can bring out fast signals in a uniform way and achieve the resolution goals set for this calorimeter design.

The stack would be constructed in the following fashion. The striplines would be soldered to the absorber serving as the ground plate and a layer of Hexcel placed on the plate. The Kapton PC's providing the tower structure would be added and checked for high

voltage breakdown. If none is found the signal tabs on the strip lines would be soldered to the towers. After continuity checks on the strip lines and towers are performed, another layer of Hexcel is placed over the Kapton PC's. Another absorber plate is moved into place as the striplines are drawn through the slots. Again the system is tested for shorts before the ground tabs on the striplines are soldered to the plate. As each layer is added care must be taken that no foreign material can get into the gaps already assembled. Very clean assembly techniques must be used to prevent fibers and such from adhering to the plates, Hexcel and Kapton. This program is carried out repeatedly to complete the stack. We expect that the brass sheets on the lead absorber will greatly reduce the likelihood of lead chips leading to shorts, during and after construction. In the past we have been successful in burning off shorts that appear in the gap using high voltage discharges to burn the object away. This technique should be used as a last resort since there is always a chance of forming a carbon path between the towers and ground.

We have estimated the construction costs of the 7 by 7 test module to be as follows.

Engineering	65K$
Stack	45K
Electronics	50K
Operations	40K
Total	200K$

The University of Arizona will contribute 1/2 an FTE electrical engineer and the University of Washington will be able to utilize its skilled instrument shop.

We also need to begin the required systems engineering to ascertain the feasibility and cost of the proposed technology. We request 50K$ to investigate the construction and cost of the parallel plate calorimeter.

Four - Channel Stripline

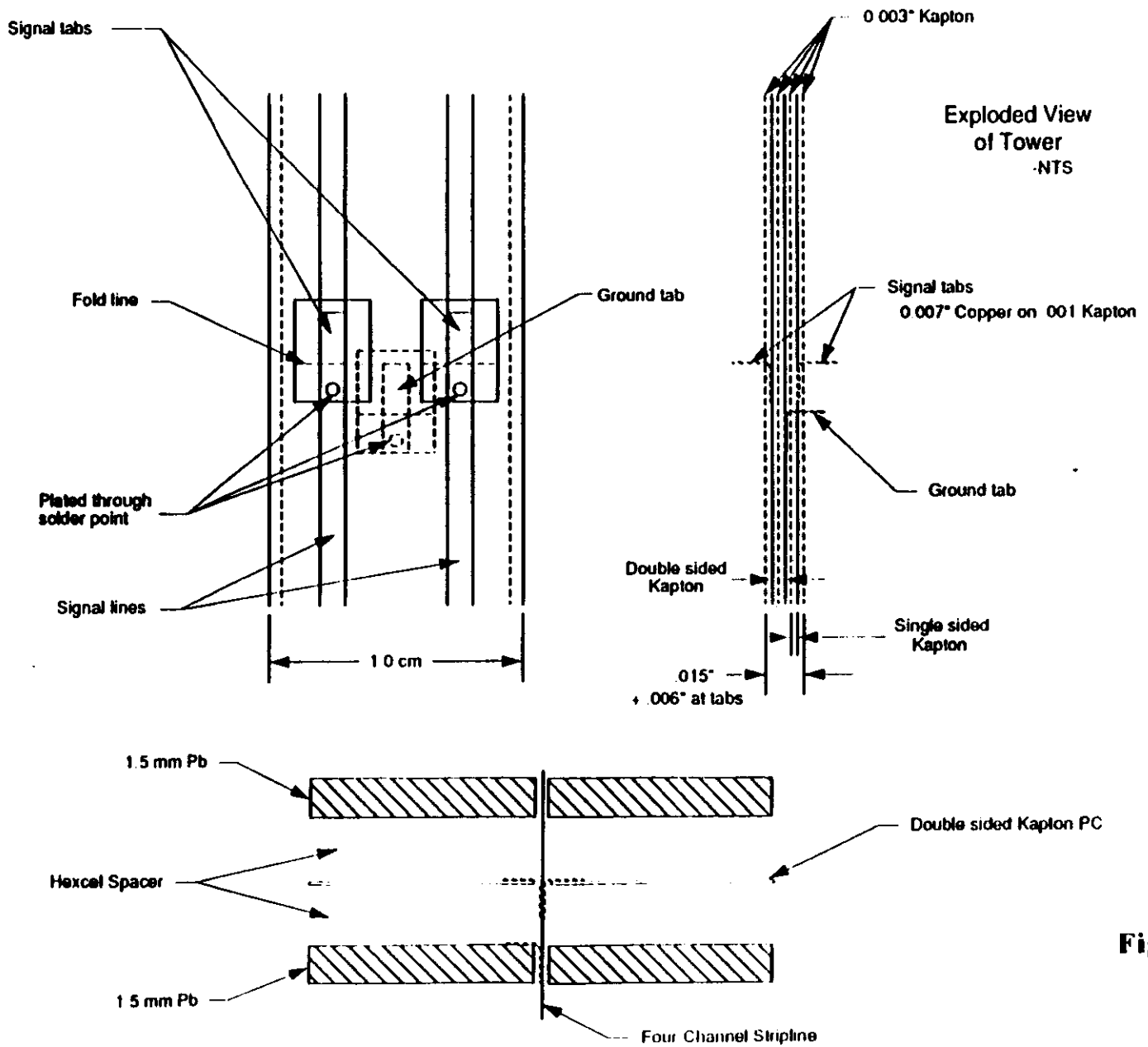
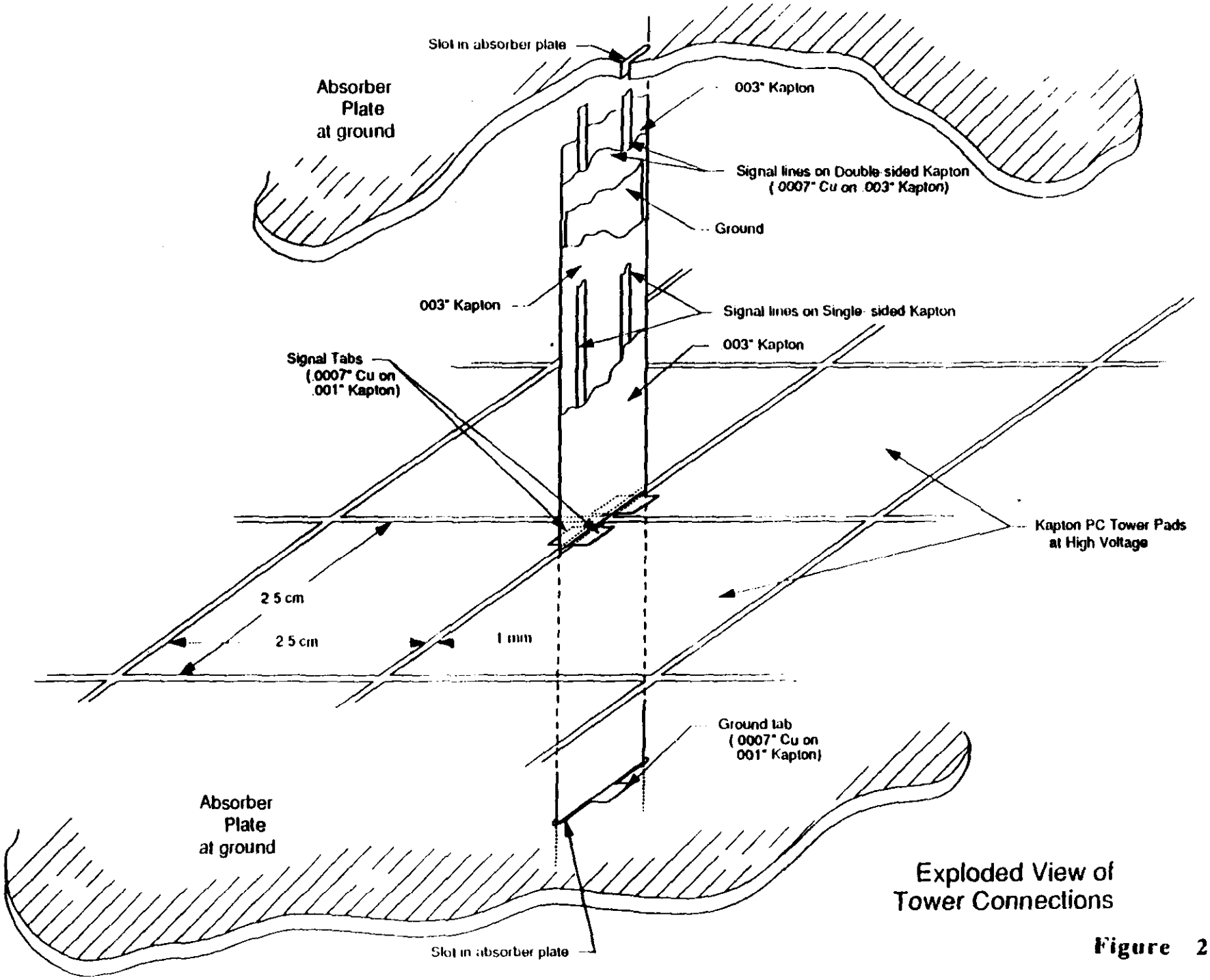


Figure 1.



Exploded View of Tower Connections

Figure 2.

Decoupling Capacitor Schematic

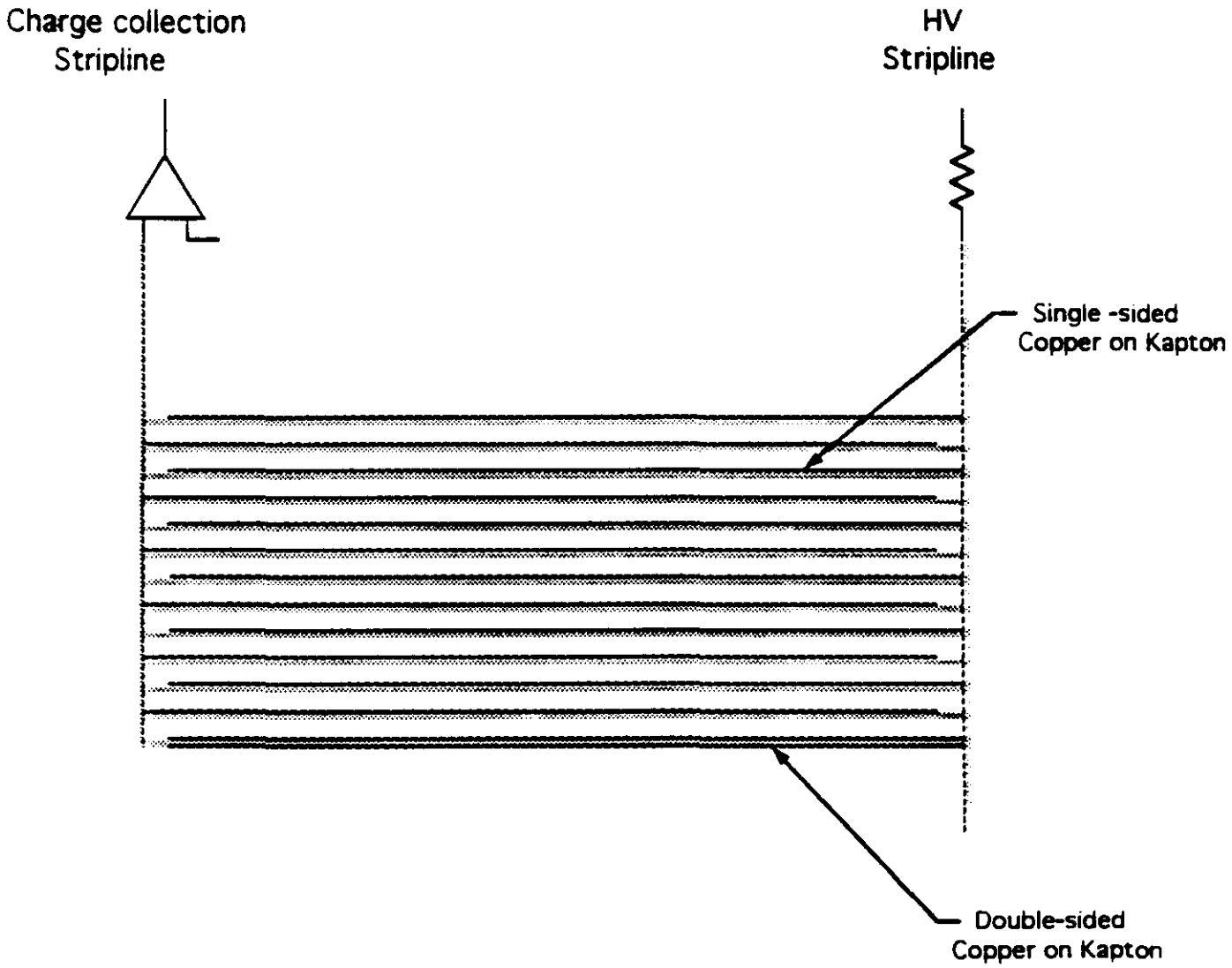
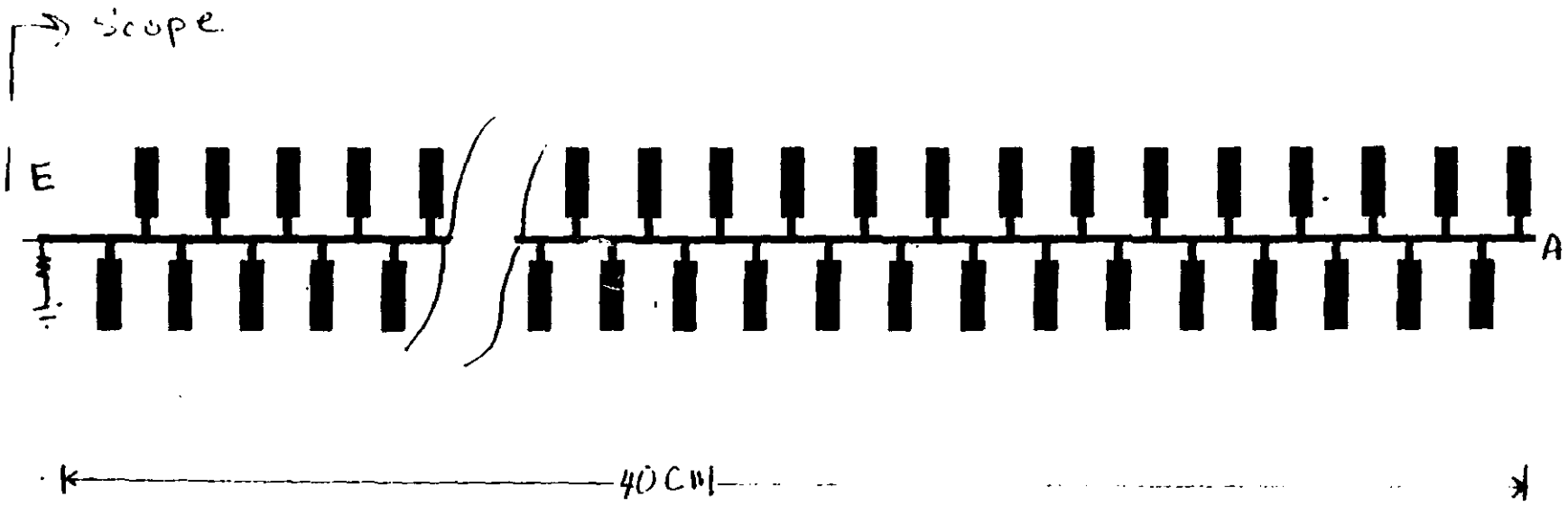


Figure 3.

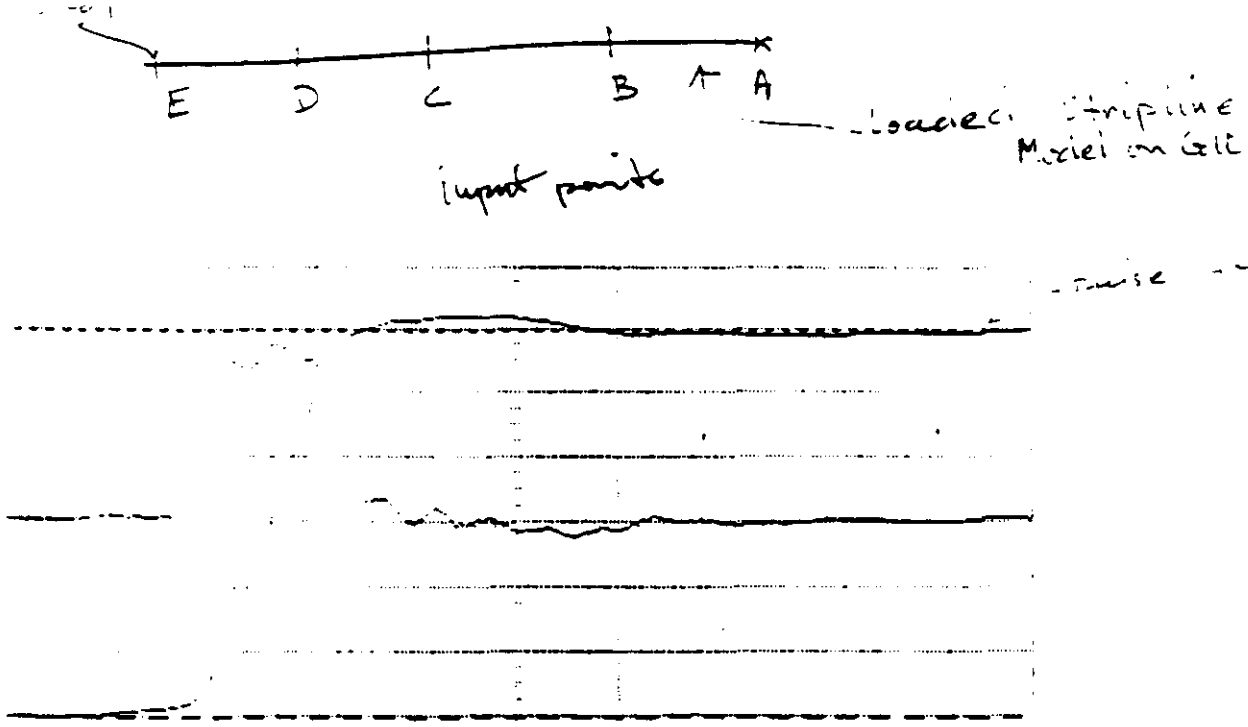


0.005" [illegible] h = 5

1.161 nF

termination 5.1 Ω

Figure 4.

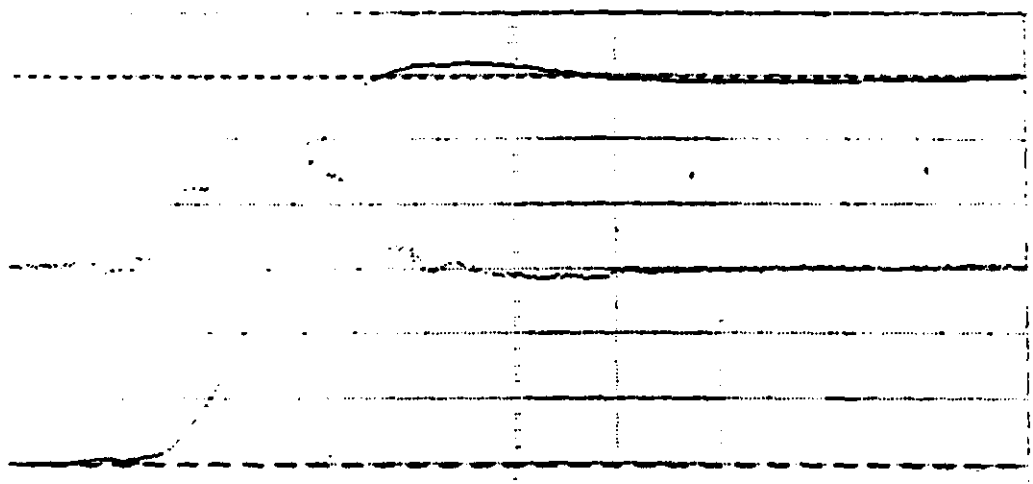


Ch.	= 100.0 mvolts/div	Offset	= 0.000 Volts
Function2	= 200 pVolts/div	Offset	= 300 pVolts
Timebase	= 5.00 ns/div	Delay	= 216.200 ns
Function 2 Parameters		P-P Volts	= 1.850 nVolts
Rise Time	= 5.850 ns	Overshoot	= 20 pVolts
Freshoot	= 0.000 Volts	Avg Volts	= 1.330 nVolts
Delta V	= 1.780 nVolts		
Vmarker1	= 0.000 Volts	Vmarker2	= 1.780 nVolts
Delta T	= 0.00000 s		
Start	= 591.200 ns	Stop	= 591.200 ns

Trigger mode : Edge
Ch Pos. Edge on Trig3
Trigger Levels
Trig3 = 0.000 Volts
Holdoff = 70.000 ns

Input at A

Figure 5-a.



[illegible] ns 215.200 ns [illegible] ns

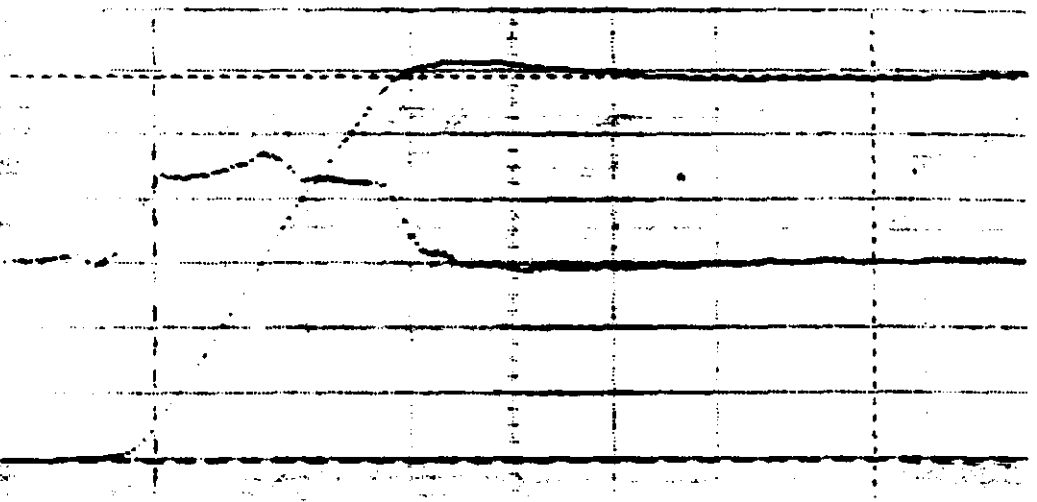
[illegible]	=	100.0 mVolts div	Offset	=	0.000 Volts
Function2	=	300 pVolts/div	Offset	=	300 pVolts
Timebase	=	5.00 ns/div	Delay	=	216.200 ns
Delta V	=	1.780 nVolts			
Vmarker1	=	0.000 Volts	Vmarker2	=	1.780 nVolts
Delta T	=	0.00000 s			
Start	=	691.200 ns	Stop	=	691.200 ns

Trigger Mode : Edge
[illegible] Pos. Edge on Trig3
Trigger Levels
Trig3 = 0.000 Volts
Holdoff = 72.000 ns

2

I pmt ad B

Figure 5-b.



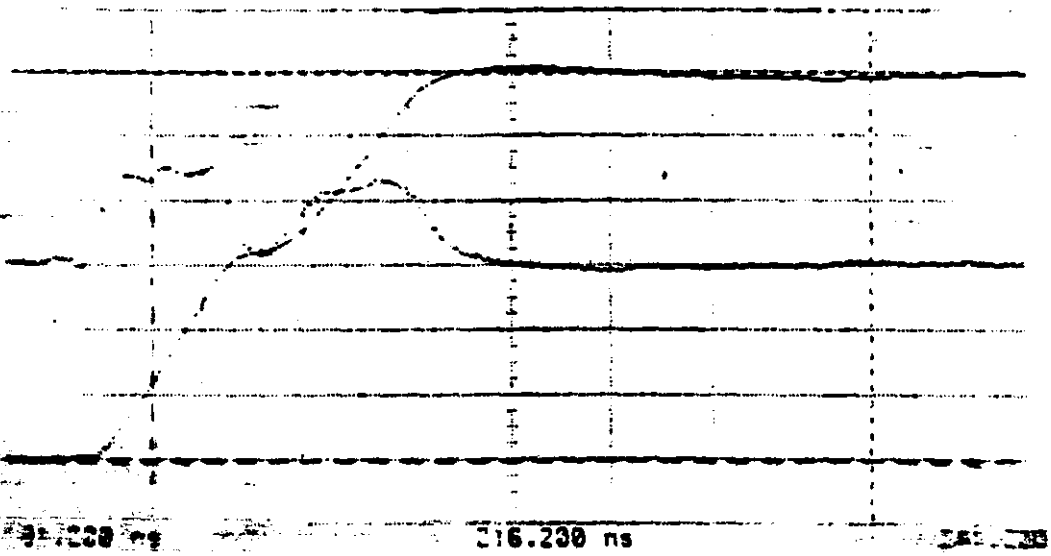
[illegible] ns [illegible] 216.200 ns

[illegible]	=	100.0 mVolts/div	Offset	=	0.000 Volts
Function2	=	300 μVolts/div	Offset	=	900 μVolts
Timebase	=	5.00 ns/div	Delay	=	216.200 ns
Delta V	=	1.760 nVolts			
Vmarker1	=	2.000 Volts	Vmarker2	=	1.760 nVolts
Delta T	=	35.000 ns			
Start	=	198.700 ns	Stop	=	233.700 ns

Trigger mode : Edge
[illegible] Pos. Edge on Trig3
Trigger Levels
Trig3 = 2.000 Volts
[illegible] = 20.000 ns

Input at °C

Figure 5-c.



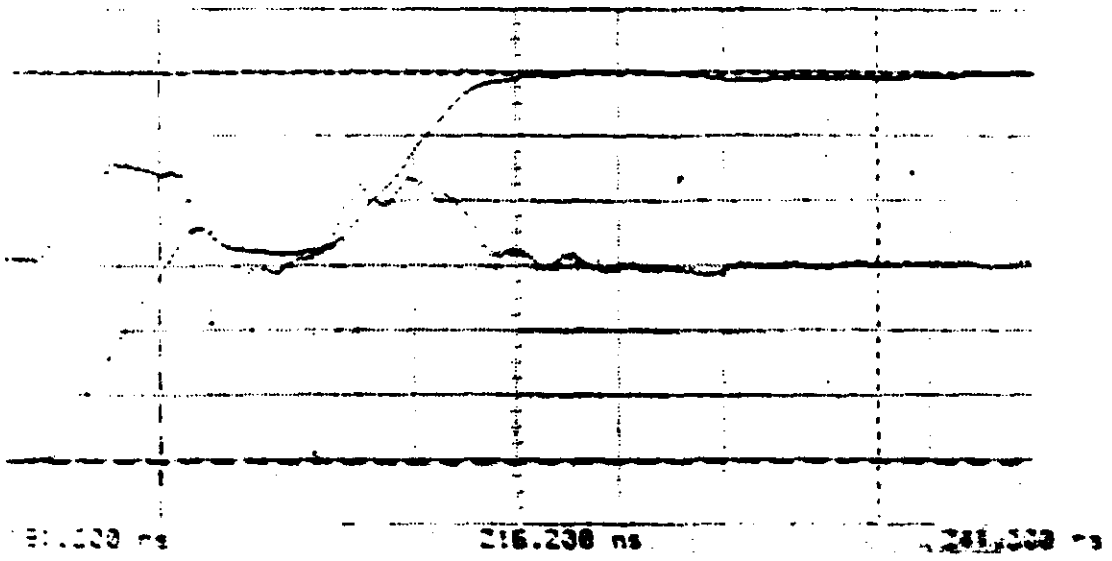
In. 1	=	100.0 mVolts/div	Offset	=	0.000 Volts
Function2	=	300 mVolts/div	Offset	=	900 mVolts
Timebase	=	5.00 ns/div	Delay	=	216.200 ns
Delta V	=	1.780 mVolts			
Vmarker1	=	0.000 Volts	Vmarker2	=	1.780 mVolts
Delta T	=	35.000 ns			
Start	=	198.700 ns	Stop	=	233.730 ns

Trigger mode : Edge
In Pos. Edge on Trig3
Trigger Levels
Trig1 = 0.000 Volts
Delay = 70.000 ns

4

D

Figure 5-d.

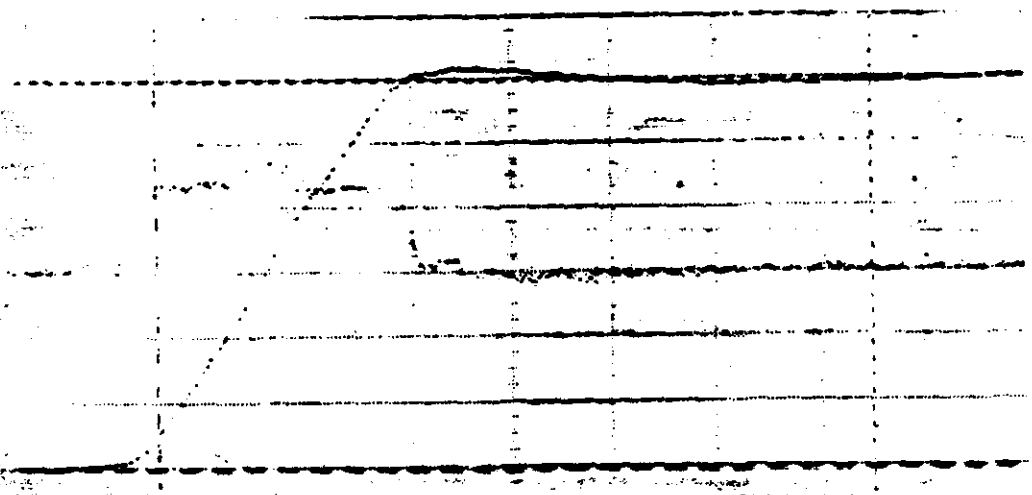


[illegible]	=	100.0 mVolts/div	Offset	=	0.000 Volts
Function2	=	300 pVolts/div	Offset	=	300 pVolts
Timebase	=	5.00 ns/div	Delay	=	216.200 ns
Delta V	=	1.780 nVolts			
Vmarker1	=	0.000 Volts	Vmarker2	=	1.780 nVolts
Delta T	=	35.000 ns			
Start	=	198.700 ns	Stop	=	233.700 ns

Trigger mode : Edge
In Pos. Edge on Trig3
Trigger Levels
Trig3 = 3.000 Volts
Holdoff = 70.000 ns

E

Figure 5-e.



[illegible]	=	30.0 mVolts/div	Offset	=	2.000 Volts
[illegible]	=	320 pVolts/div	Offset	=	800 pVolts
Timebase	=	5.00 ns/div	Delay	=	216.200 ns
Delta V	=	1.780 nVolts			
Vmarker1	=	2.000 Volts	Vmarker2	=	1.780 nVolts
Delta T	=	35.000 ns			
Start	=	198.700 ns	Stop	=	233.700 ns

Trigger mode : Edge
In Pos. Edge on Trig3
Trigger Levels
[illegible] = 0.000 Volts
[illegible] = 20.000 ns

Figure 5-1.

P. Mockett
U. of Washington
October 7, 1991

UW PUB 91-30

A Pizero Identifier for GEM

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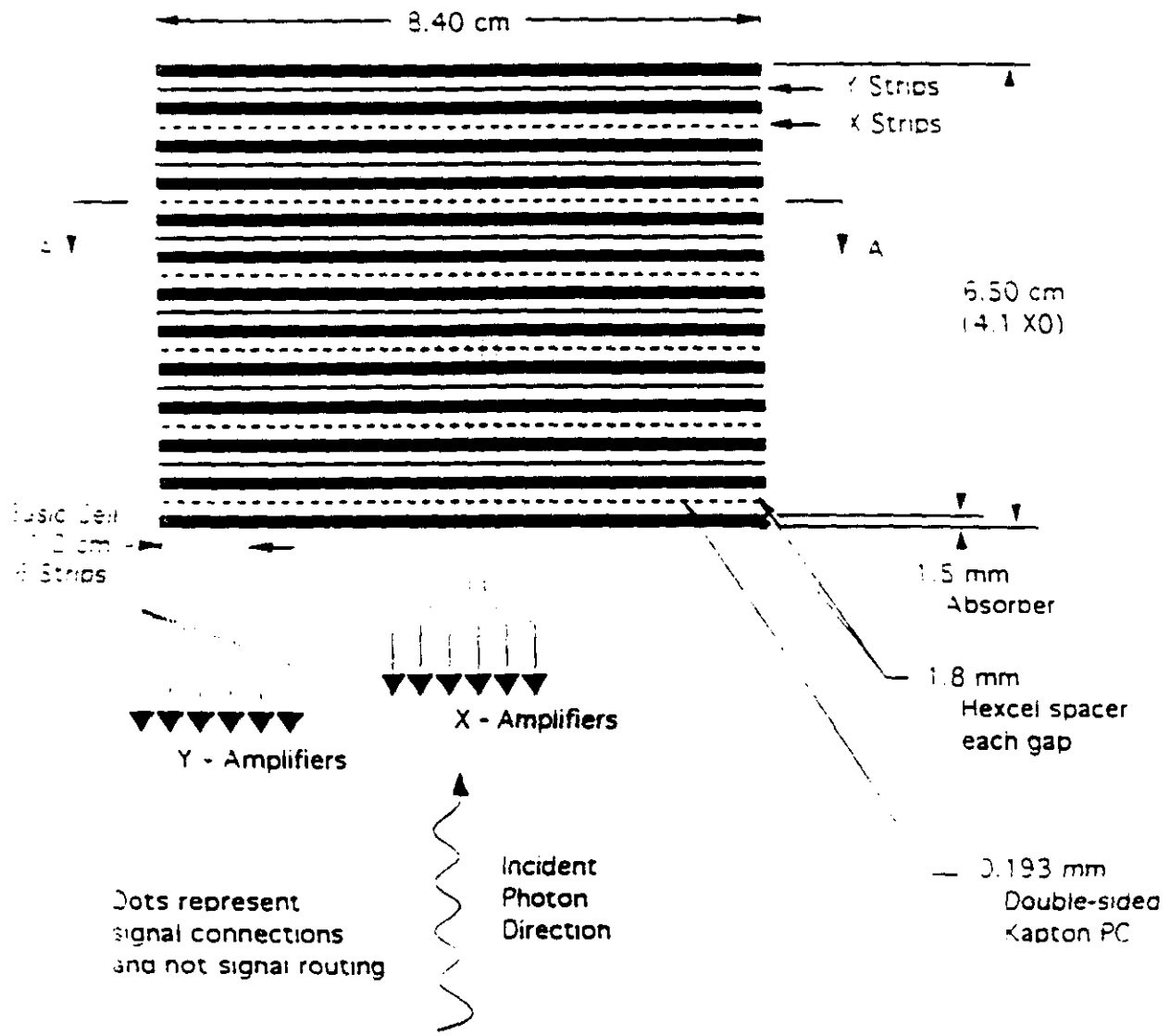
The pizero detector serves as a front end of the EM stack. There is of course flexibility in the details but we are considering a system about 8 cm by 8 cm(covering 16 towers). A schematic is shown in Fig. 1. It would be about 4 X0 thick with the same plate thickness as the remainder of the stack. Alternate gaps would be viewed by x and y strips. The strips would have a 1 to 2 mm pitch and every sixth strip connected together. The x strips would be read by 6 channels and the y strips would be read by 6 channels. Hence the signals from different sub regions would be folded on top of each other. Using the GEANT Monte Carlo we have been testing an algorithm devised to separate one gamma from the two gammas from pizeros. The first tests look encouraging. We are getting nearly 100% acceptance of one gamma and a good rejection of pizeros. We are still in the process of optimizing the cuts and expect further improvements Table I gives the cuts used in the algorithm and Table II gives the results for a series of photon and pizero energies. The results of these cuts are plotted in Fig. 2. Fig. 3 provides a series of x and y energy profiles for 100 GeV photons and pizeros both in absolute and folded coordinates. These pictures are for photons and pizeros originating 85 cm from the calorimeter. Accompanying each picture are mnemonics showing which if any cut the event fails to pass. The pizero rejection is still about 85% which can substantially reduce the background under the Higgs to gamma gamma signal.

On the simulation side we plan to continue to optimize the algorithm by adding energy dependence to the cuts. On the hardware side we will also construct a test module for bench testing and beam testing. With these hardware tests we plan to verify the simulations as well as demonstrate the feasibility of the construction of such a device. Preliminary investigations of noise and cross talk indicate they are quite manageable.

π^0 IDENTIFIER SCHEMATIC

(Parallel plate geometry)



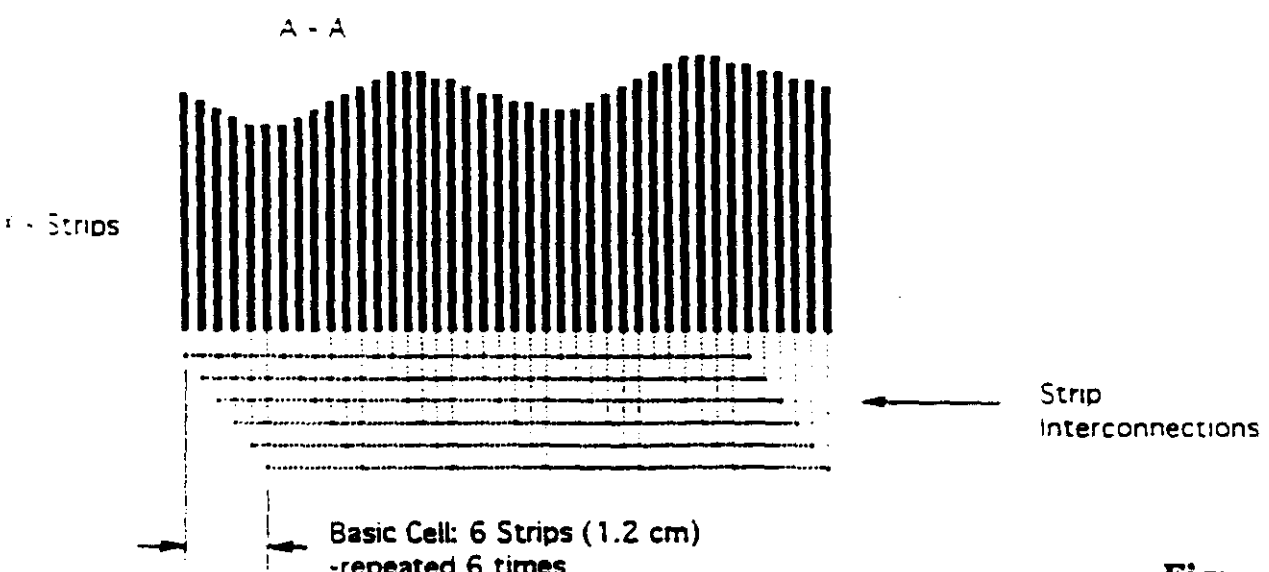


Figure 1.

Cut Values
1mm strips

Category	Description	Name	Value
Peak definition	Energy required for sum of two highest strips to be considered peaks	ECUT	.015 GeV
	Minimum fraction of highest energy strip that second highest strip must have to be considered a second peak	PEAKCUT	25 %
Width cut	Largest number of adjacent strips not considered a π^0	NCUTWID	3 strips
	Fraction of highest energy strip which NCUTWID+1 adjacent strips must exceed to be considered a π^0	EWIDCUT	50 %
	Total energy above which NCUTWID is replaced by NWCLOWER	WCTHRESH	75. GeV
	Higher energy width cut	NWCLOWER	2 strips
Mean off cut	Mean off constant for π^0 rejection	CUTMEAN	2.83 mm
	Power of energy for mean offset scaling	CUTPOWR	-0.37
	Total energy above which CUTMEAN becomes half the strip width	CUTOFF	75. GeV
Dip cut	Maximum fraction of strip between peaks considered π^0 dip	DIPMAX	50 %

Table I

1mm Strips
Acceptances and Cut Performances

incident particle		accept.	number of photons			number selected by cuts					
E (GeV)		(%)	0 (%)	1 (%)	2 (%)	mean (%)	mean only	dip (%)	dip only	width (%)	width only
5	γ	86.0	6.4	69.6	14.0	2.8	1.6	9.2	8.0	3.6	3.2
5	π^0	77.6	11.6	10.8	77.6	71.2	46.4	17.2	2.8	22.8	3.2
10	γ	94.0	20.4	73.6	6.0	2.0	1.2	4.0	3.2	0.8	0.8
10	π^0	88.4	6.0	5.6	88.4	84.4	51.2	25.6	2.4	20.0	1.6
25	γ	96.8	14.4	82.4	3.2	1.2	0.4	2.8	2.0	0.0	0.0
25	π^0	94.0	4.0	2.0	94.0	89.2	46.0	53.2	4.0	13.2	0.4
50	γ	99.2	15.2	84.0	0.8	0.0	0.0	0.8	0.8	0.0	0.0
50	π^0	92.0	0.4	7.6	92.0	87.6	54.0	40.8	4.0	9.2	0.0
75	γ	98.4	12.8	85.6	1.6	1.6	1.2	0.8	0.0	0.0	0.0
75	π^0	90.0	3.2	6.8	90.0	80.0	34.0	62.4	8.8	15.2	0.4
100	γ	98.0	14.0	84.0	2.0	1.2	1.2	0.8	0.8	0.0	0.0
100	π^0	85.6	2.8	11.6	85.6	68.8	30.8	53.6	12.0	21.2	3.6
125	γ	99.2	12.8	86.4	0.8	0.4	0.4	0.4	0.4	0.0	0.0
125	π^0	81.6	2.0	16.4	81.6	62.4	26.8	46.8	13.2	22.4	4.8
150	γ	97.2	8.8	88.4	2.8	2.8	2.0	0.8	0.0	0.0	0.0
150	π^0	70.0	3.2	26.8	70.0	49.2	24.0	28.4	8.4	23.6	12.4

Table II

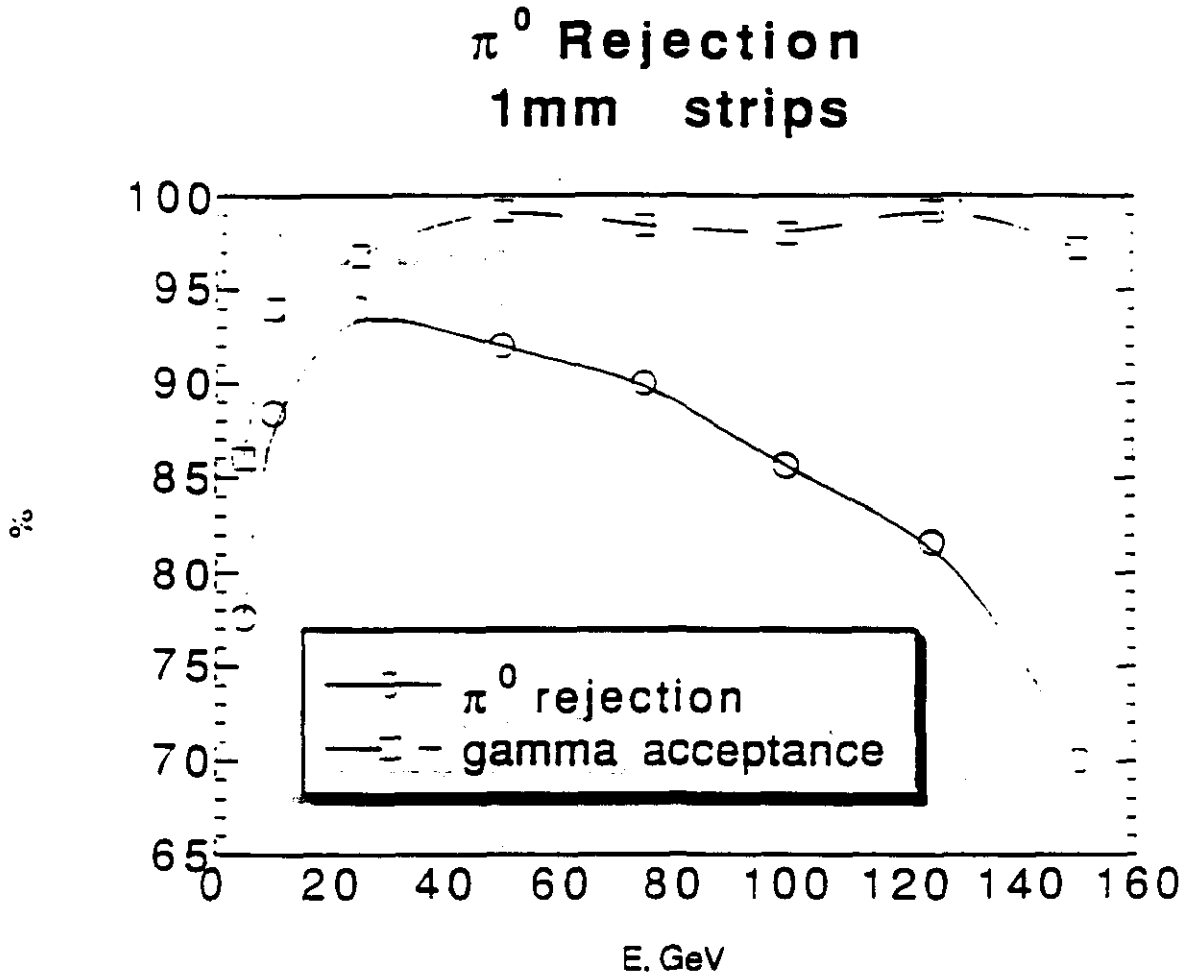

π⁰ Rejection
1mm strips
100
95
90
85
80
75
70
65
%
0
20
40
60
80
100
120
140
160
E. GeV
π⁰ rejection
gamma acceptance

Figure 2.

P. Mockett
U. of Washington
October 7, 1991

UW PUB 91-30

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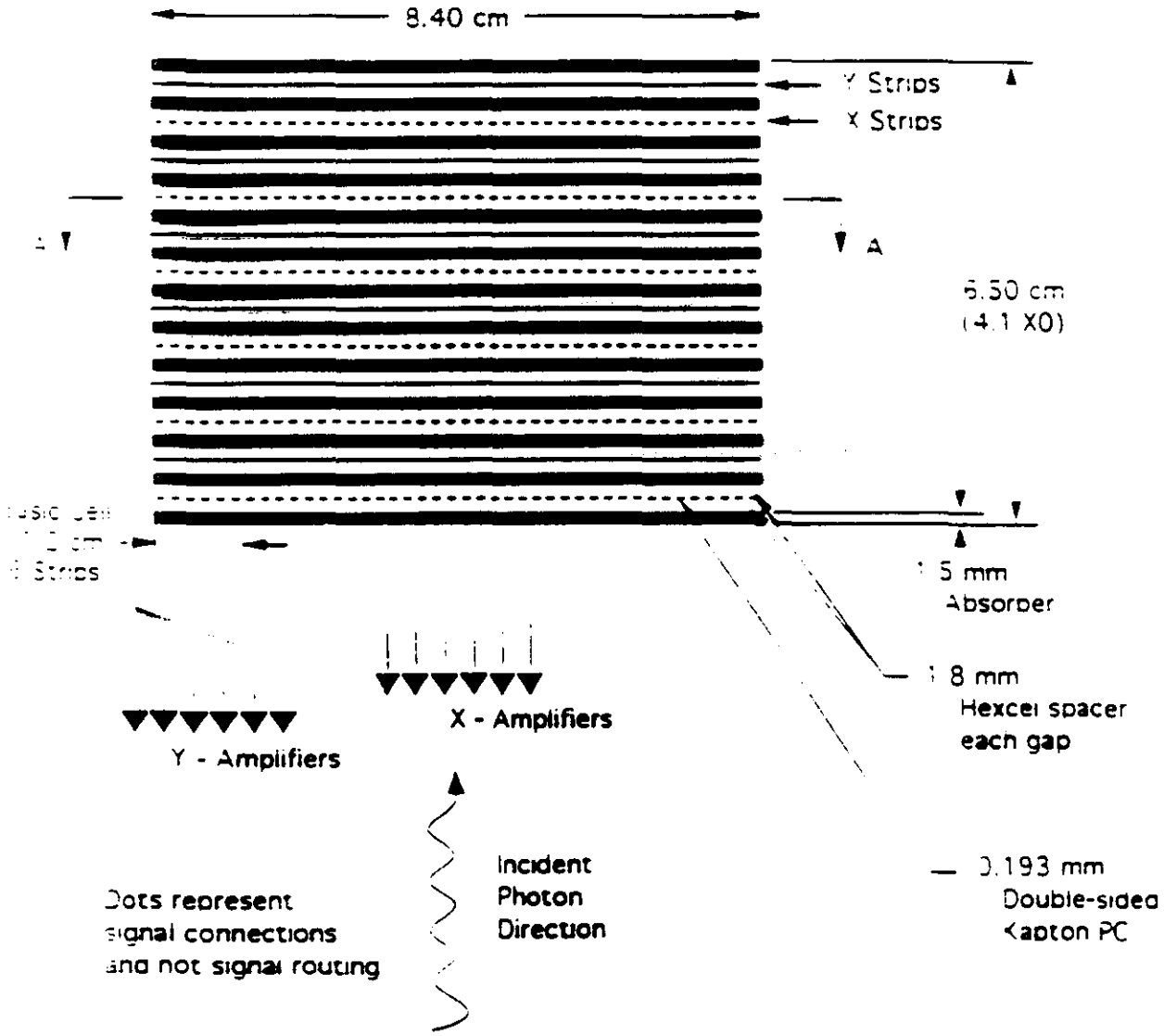

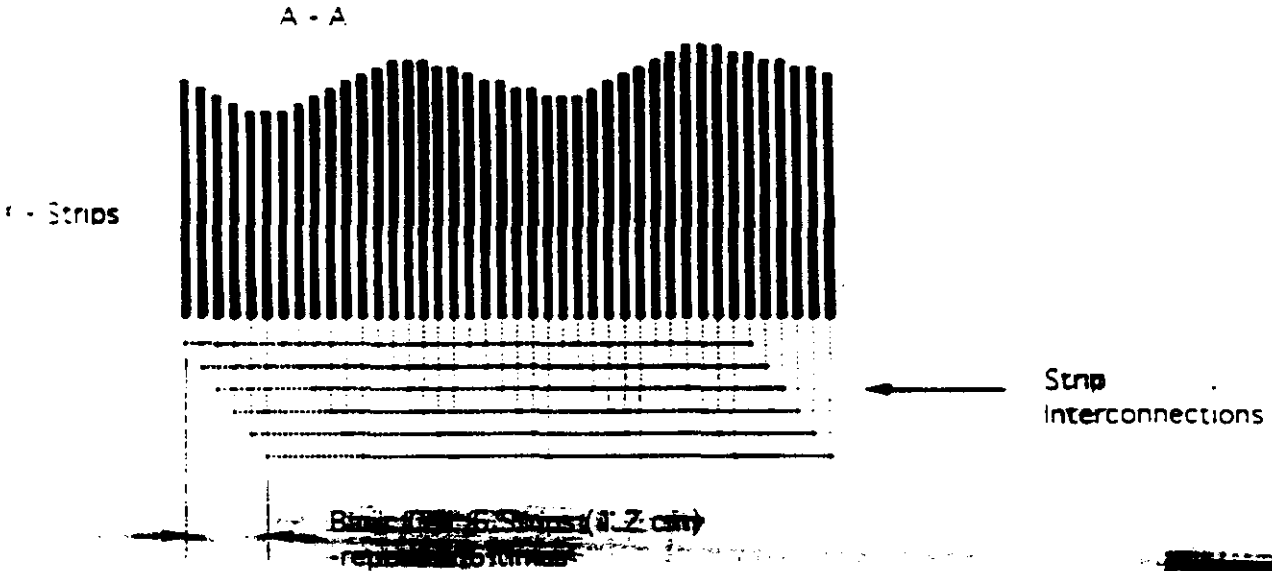

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	Total energy above which CUTMEAN becomes half the strip width	CUTOFF	75. GeV
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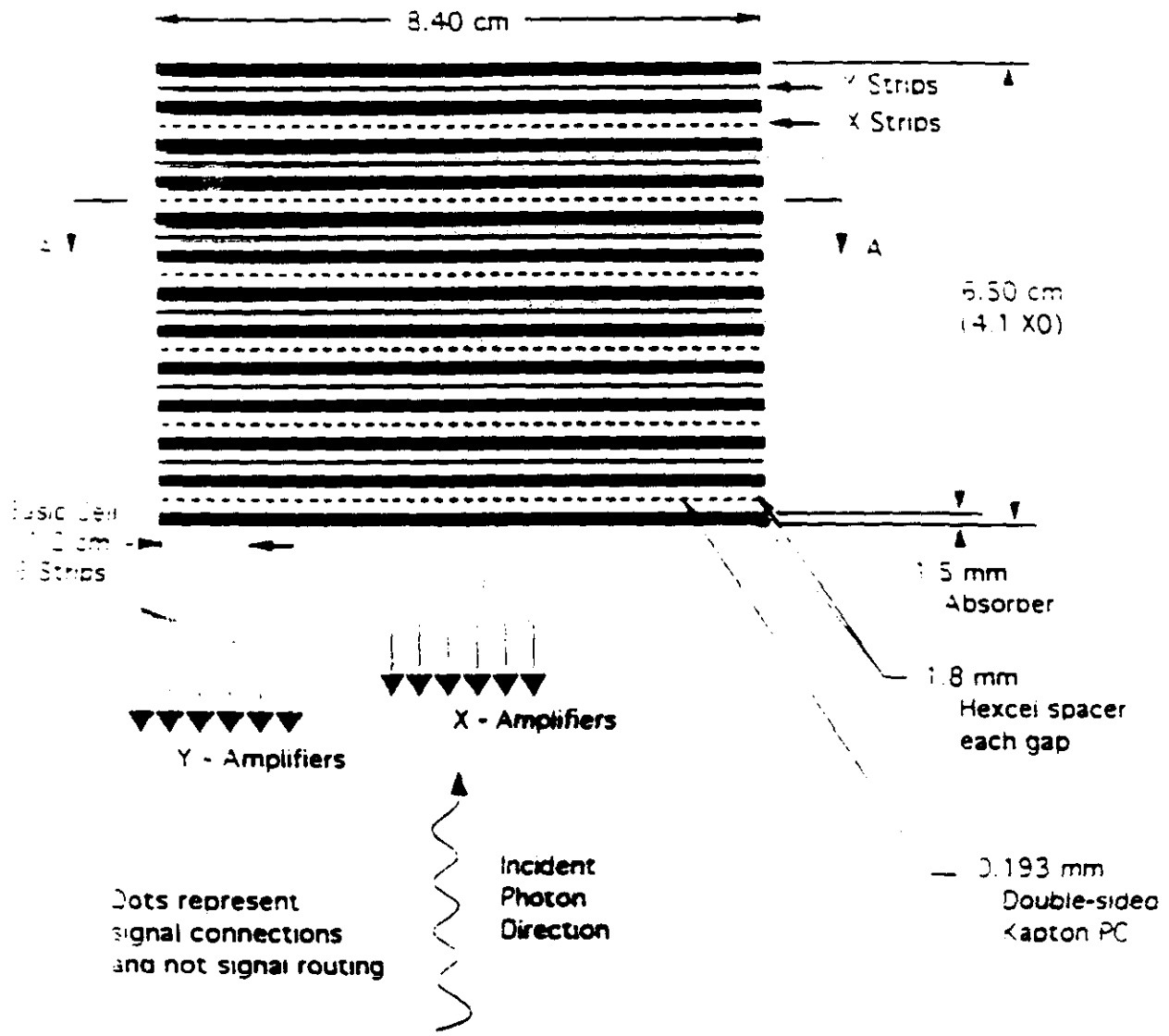
10	γ	94.0	20.4	73.6	6.0	2.0	1.2	4.0	3.2	0.8	0.8
10	π^0	88.4	6.0	5.6	88.4	84.4	51.2	25.6	2.4	20.0	1.6
25	γ	96.8	14.4	82.4	3.2	1.2	0.4	2.8	2.0	0.0	0.0
25	π^0	94.0	4.0	2.0	94.0	89.2	46.0	53.2	4.0	13.2	0.4
50	γ	99.2	15.2	84.0	0.8	0.0	0.0	0.8	0.8	0.0	0.0
50	π^0	92.0	0.4	7.6	92.0	87.6	54.0	40.8	4.0	9.2	0.0
75	γ	98.4	12.8	85.6	1.6	1.6	1.2	0.8	0.0	0.0	0.0
75	π^0	90.0	3.2	6.8	90.0	80.0	34.0	62.4	8.8	15.2	0.4
100	γ	98.0	14.0	84.0	2.0	1.2	1.2	0.8	0.8	0.0	0.0
100	π^0	85.6	2.8	11.6	85.6	68.8	30.8	53.6	12.0	21.2	3.6
125	γ	99.2	12.8	86.4	0.8	0.4	0.4	0.4	0.4	0.0	0.0
125	π^0	81.6	2.0	16.4	81.6	62.4	26.8	46.8	13.2	22.4	4.8
150	γ	97.2	8.8	88.4	2.8	2.8	2.0	0.8	0.0	0.0	0.0
150	π^0	70.0	3.2	26.8	70.0	49.2	24.0	28.4	8.4	23.6	12.4

Table II

π^0 IDENTIFIER SCHEMATIC

(Parallel plate geometry)



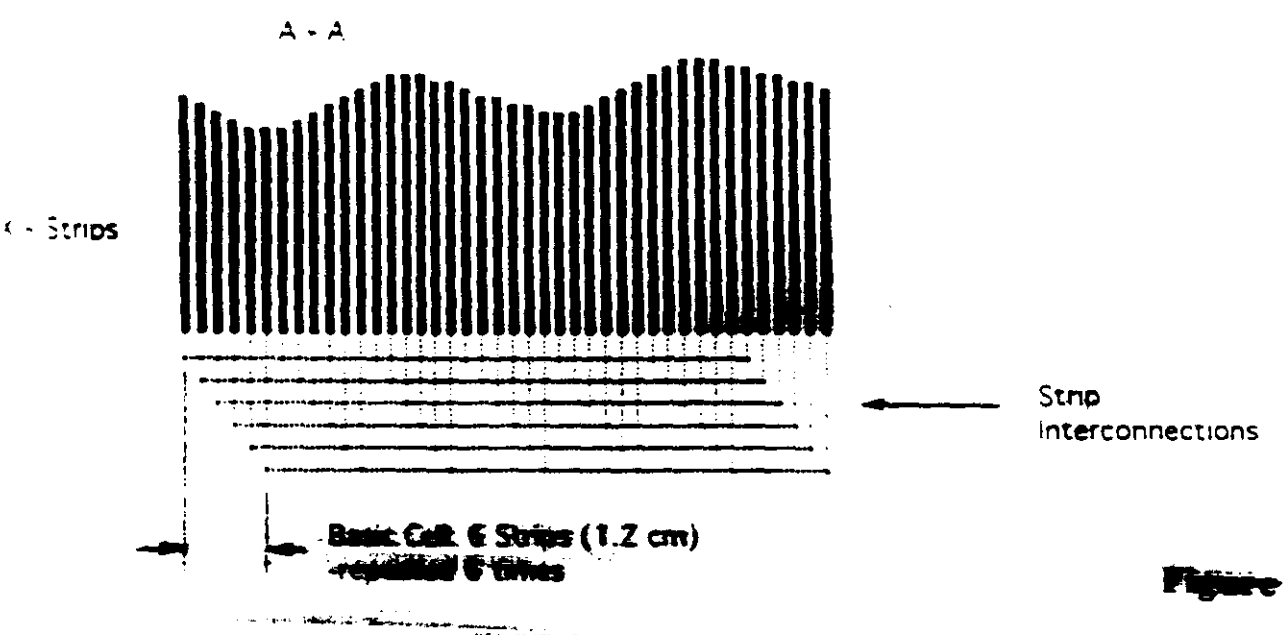


Figure 1:

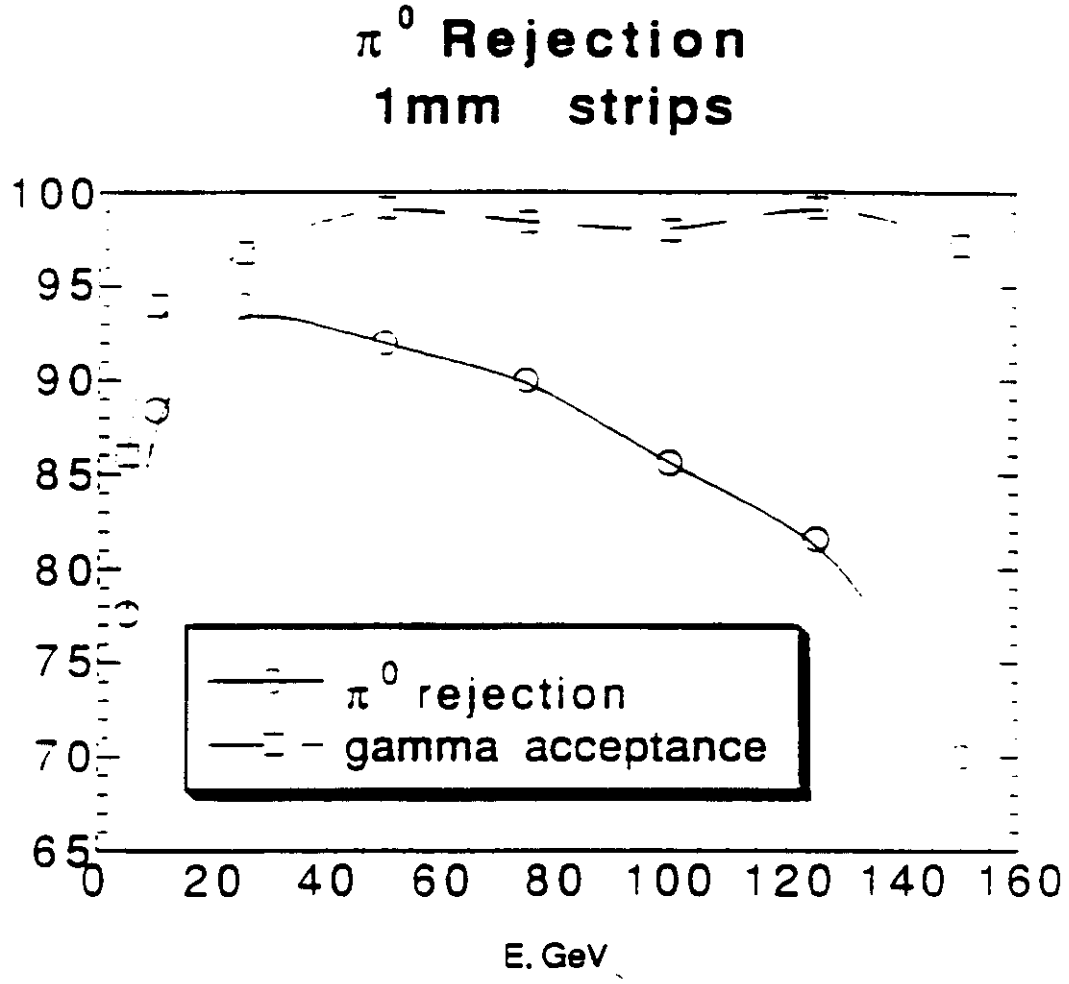

π⁰ Rejection
1mm strips
100
95
90
85
80
75
70
65
0
20
40
60
80
100
120
140
160
E. GeV
π⁰ rejection
gamma acceptance

Figure 2.

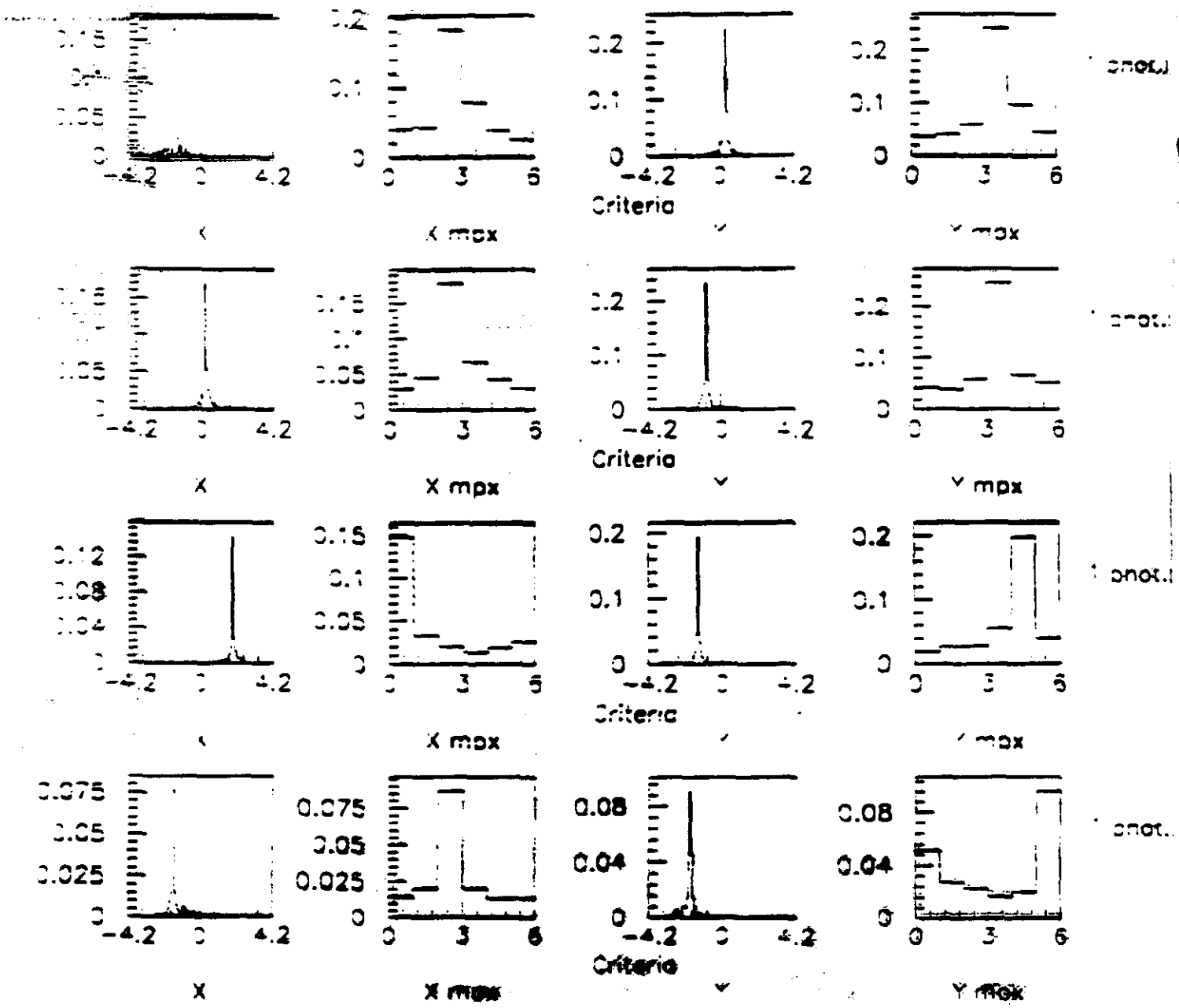
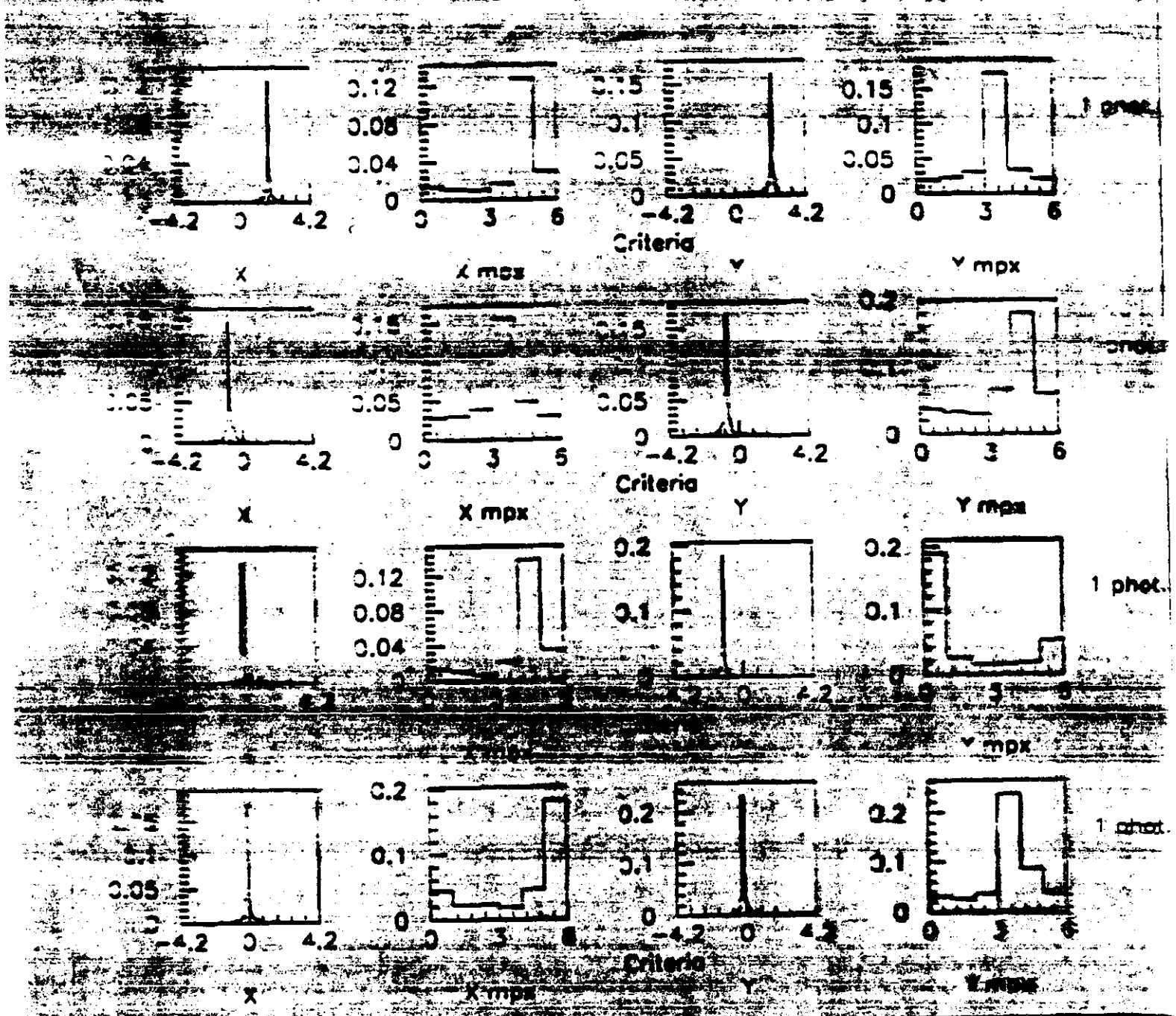
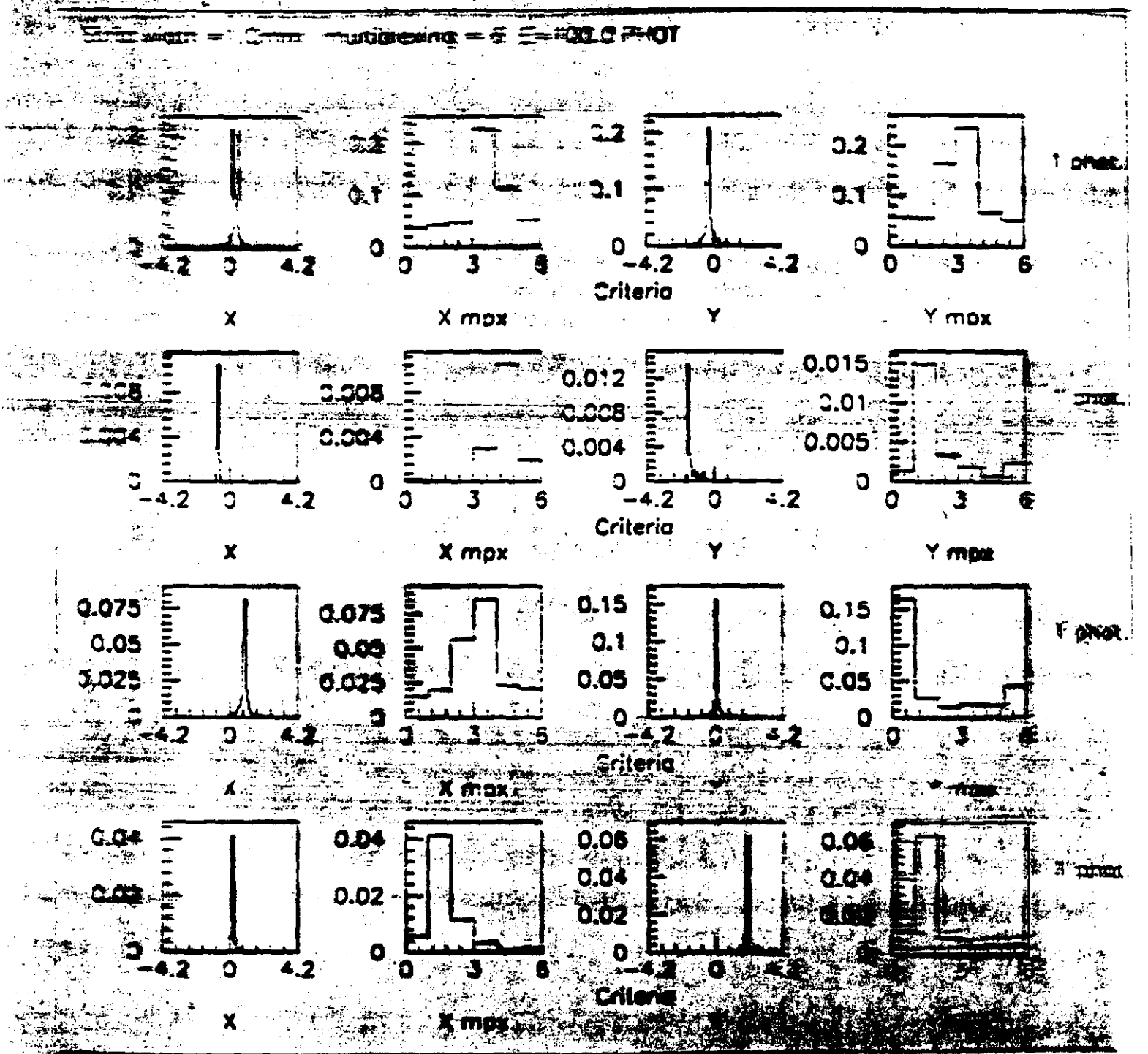
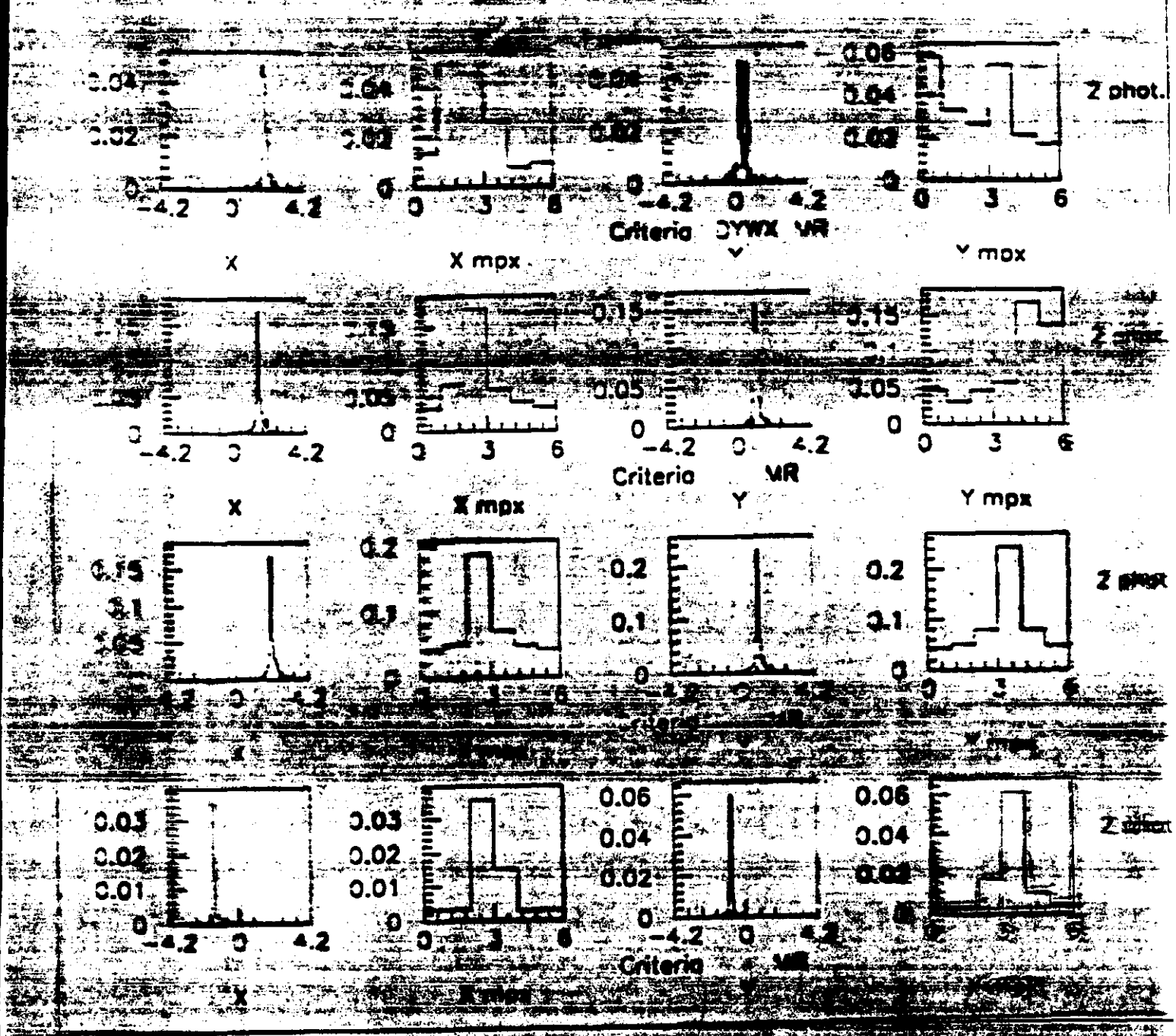
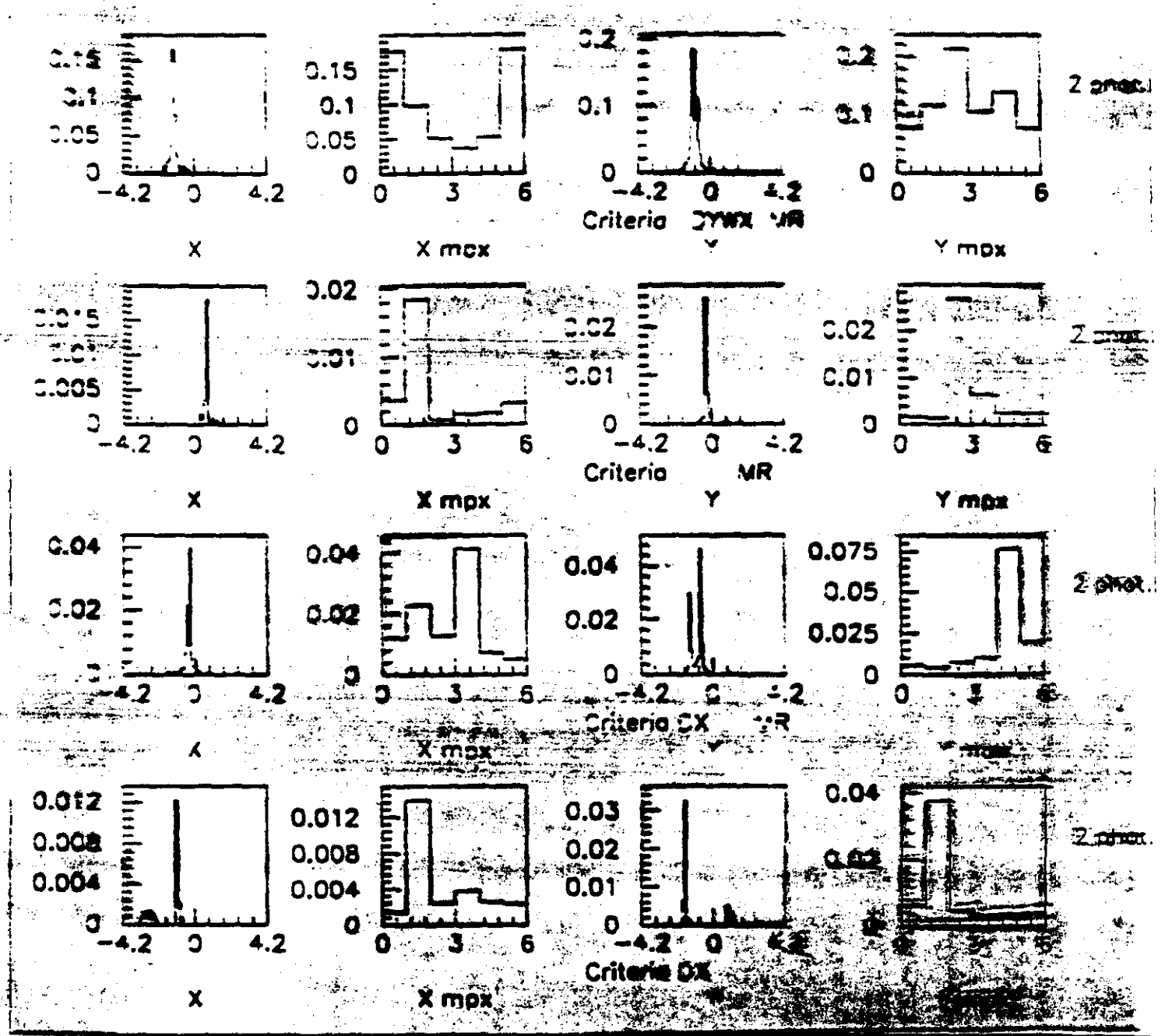

Criteria
X
X max
Y max
Criteria
X
X max
Y max
Criteria
X
X max
Y max
Criteria
X
X max
Y max

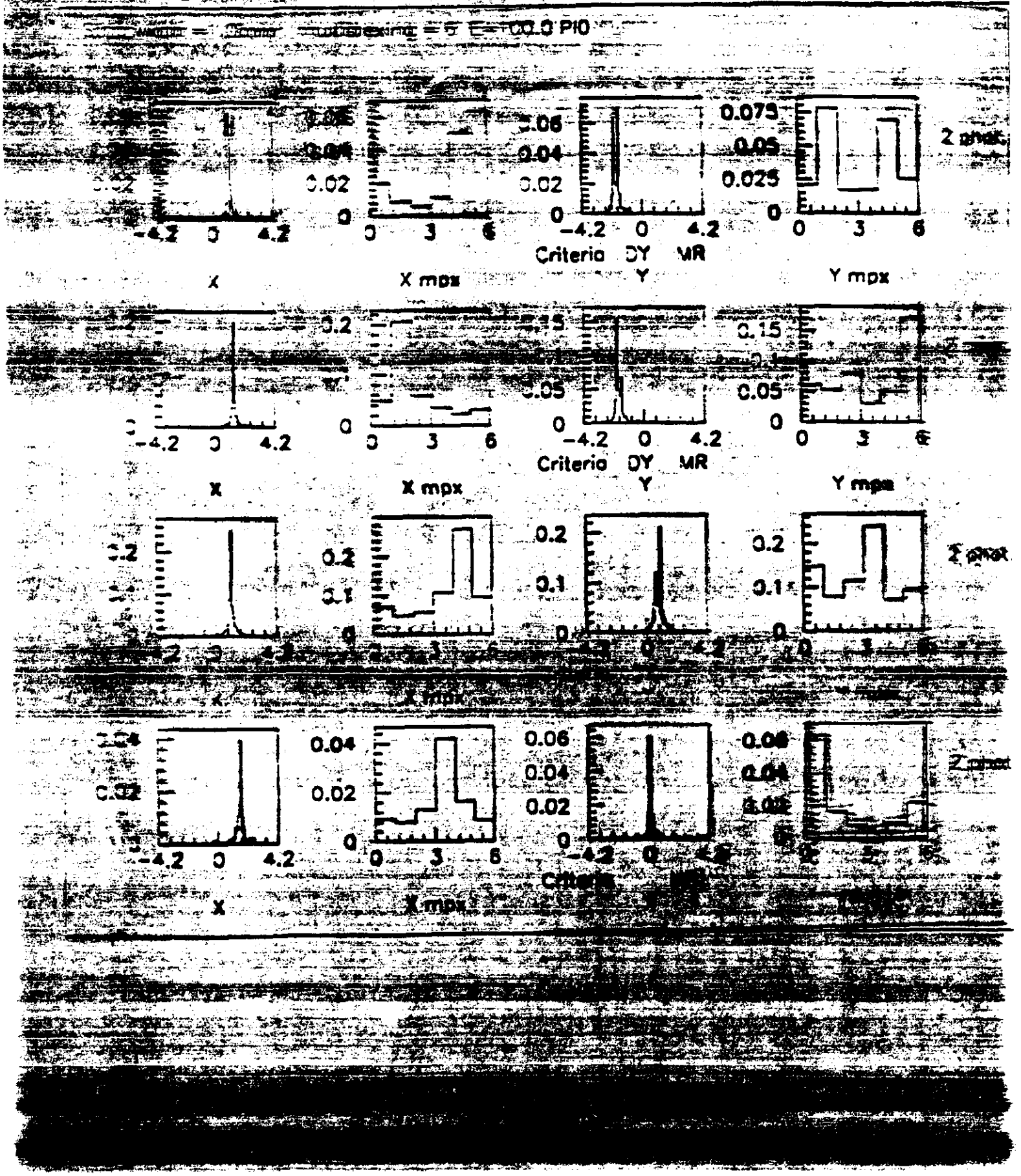
Figure 3.


X
X mpx
Y
Y mpx
Criteria
1 phot.


1 photon
X
X max
Y
Y max
Criteria
2 photon
X
X max
Y
Y max
Criteria
4 photon
X
X max
Y max
Criteria
3 photon
X
X max
Criteria


Slit width = 1.0mm multiplexing = 6
Z phot.
Criteria
X
X mpx
Y mpx
Criteria
X
X mpx
Y
Y mpx
Criteria
X
X mpx
Criteria

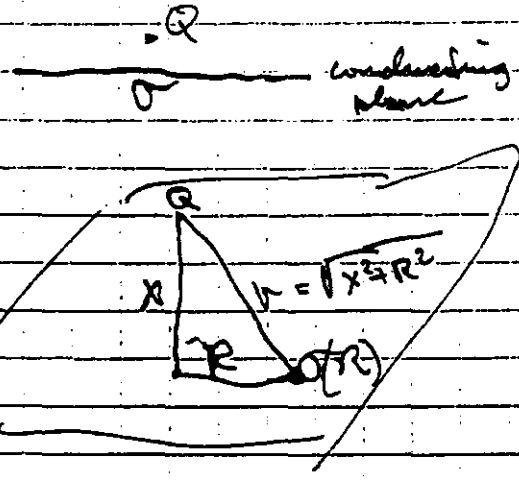

X
X max
Criteria
Y
Y max
Z max
Criteria DX
Criteria DX


Criteria DY MR
X
X mpx
Y
Y mpx
Z pixel

π^0 Detector

P. Mockett
NIT Meeting
10/23-24/91

Image charge techniques give



$$V(R) = \frac{Q}{2\pi} \frac{1}{x^2(1+R^2/x^2)^{3/2}}$$

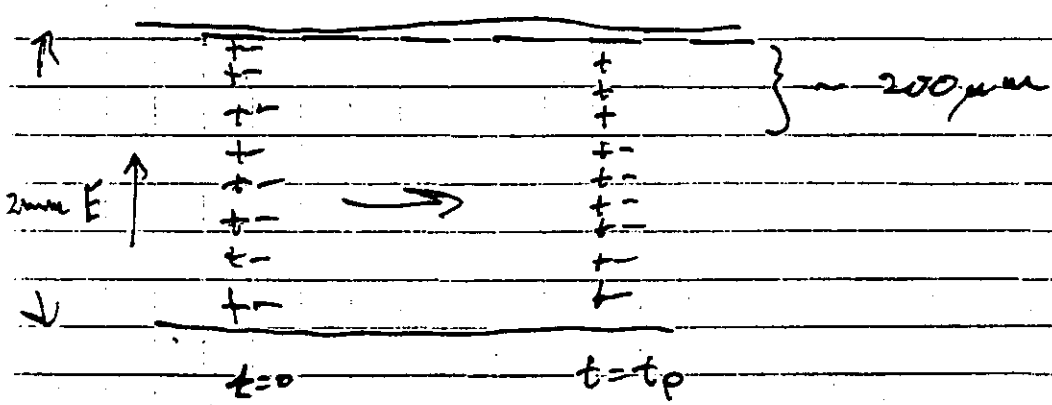
for a line charge of density γ

$$V(R) = \frac{\gamma}{2\pi} \int_{x_b}^{x_e} \frac{dx}{x^2(1+R^2/x^2)^{3/2}}$$

when $R \gg \geq x$ the charge density damps like $\frac{1}{R^3}$ so the field of a rather sharp degree a few x lengths.

for 2 conducting plane we must sum an infinite series of image charges (cross & feedback).

Consider the strip case and approximate with single conducting plane distribution



200 μm << Strip Pitch so we expect little charge sharing

Some Issues to Consider

* What happens if E is reversed?

* How does the second conducting plane modify the above approximation?

* What happens when the drift is not along the charge column?
  a) Wide angle ionization
  b) Tilted plates wrt γ direction

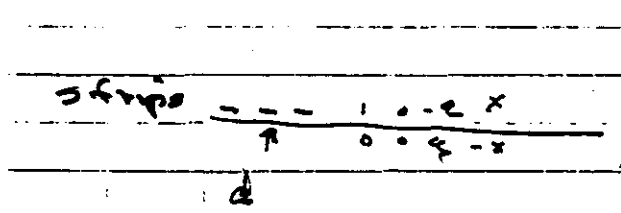
Partial answer to a) We are mainly interested in the dense core which is ⊥ to the plates and hence ∥ to E (at 2σ)
b) When γ angle is large then 2σ separation is also larger.

* What second order effects are there on the induced charge
  a) Non uniformity in charge column
  b) Diffusion of e away from I^+

* To what degree can ~~charge~~ induced beyond the strip inhomogeneities be corrected?

* To what degree can the charge induced on the strips be quickly removed? Must we worry about antisymmetric/symmetric wave x talk between strips?

$3 \cdot -q \quad (d+d+x)$
$3 \cdot +q \quad (d+d-x)$



$1 \cdot -q \quad -(d+d-x)$
$2 \cdot +q \quad -(d+d+x)$

so we have dipoles spaced ~ 2d away

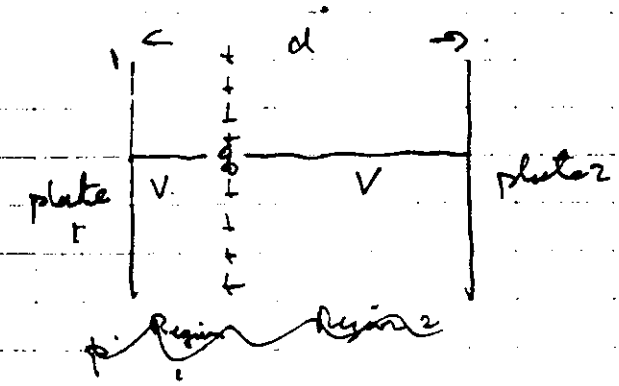
dipole fields go like $x/2d^3 \cdot 2 = \frac{x}{d^3}$ (there are 2 mol

$\Rightarrow \frac{E'}{E} = \frac{x^3}{2d^3} \sim 10^{-3}$ so should not be a problem

since E' induces charges $\sim 10^{-3}$ of E. Hence angle plate approximation is good.

charges must be at same voltage w.r.t each plate &

hence



superposition allows us to consider only ⊥ field lines

so $E_1 x = E_2 (d-x)$

$E_1 + E_2 = \sigma$ G.L.

$E_1 x = (\sigma - E_1)(d-x)$

$= \sigma(d-x) - E_1 d + E_1 x$

$E_1 = \dfrac{\sigma(d-x)}{d}$

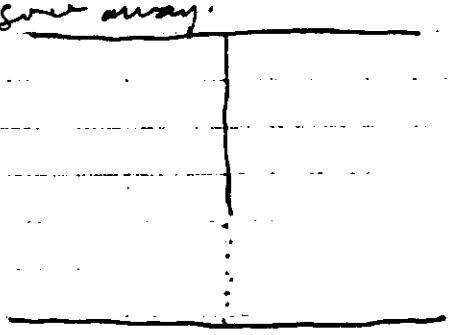
$E_2 = \dfrac{\sigma x}{d}$

hence the charge induced in each plate by a single charge q_0 is given by (using superposition arguments).

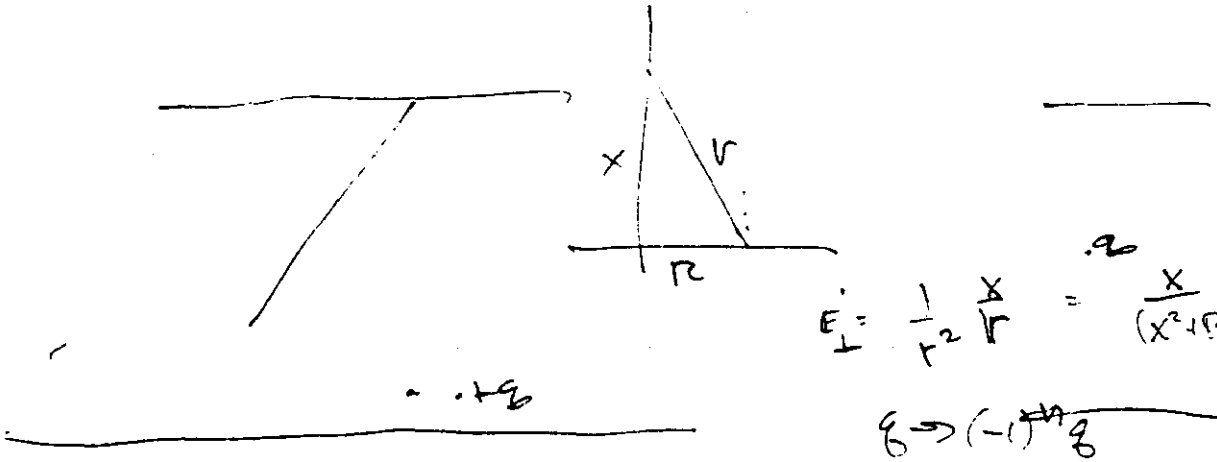
$$q_1 = \frac{q_0(d-x)}{d} \qquad q_2 = \frac{q_0 x}{d}$$

So indeed a single charge moving along at v has a constant rate of charge induction independent of its position x.

However in the case of a column of charge field lines only change when the column changes and hence the induced charge comes only from the region of moving charge where the field lines have gone away.



The ~~strength of the~~ amount of charge induced on the strips is varies as distance from the opposite plate. Some charge ~~[illegible]~~ near the electrode opposite the strips induce little charge on the strips and their movement produces little change in the charge distribution

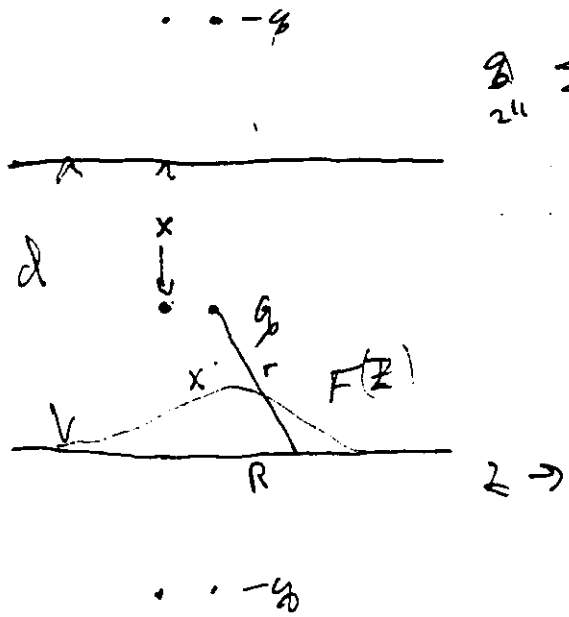


$$E_\perp = \frac{1}{r^2}\frac{x}{r} = \frac{x}{(x^2+R^2)^{3/2}} = \frac{1}{x^2(1+R^2/x^2)^{3/2}}$$

$$q \to (-1)^n q$$

$$x \to x + nd$$

$-q$



$$\frac{q}{2\pi}\sum \frac{1}{x^2(1+R^2/x^2)^{3/2}} + \frac{1}{}$$

$F(z, R)$

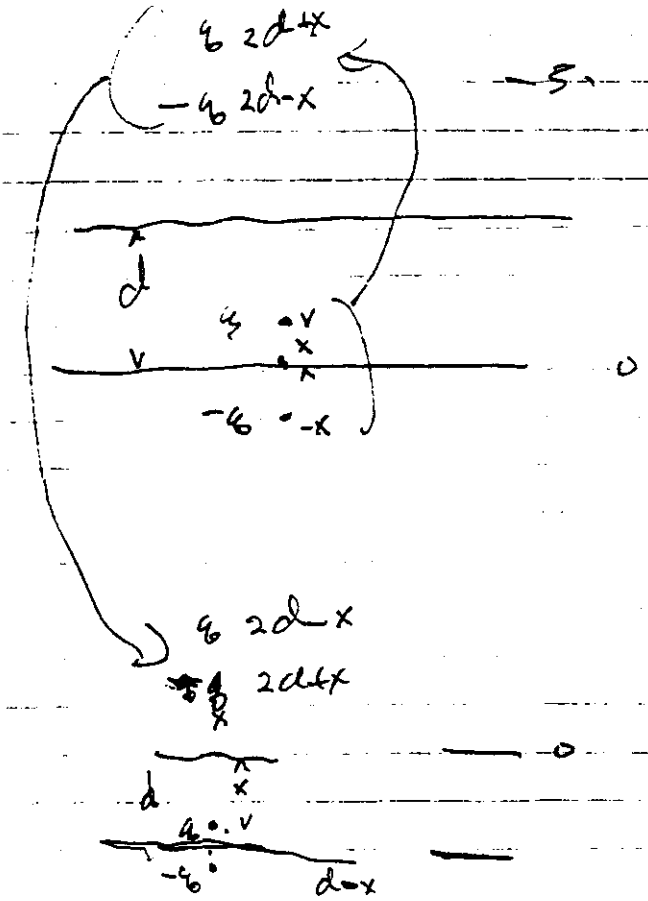
$F'(z, R)\,\Delta z$

· symmetric about $z = 0$

$$F(z) = \sum_{i=0}^{\infty} F_i z^{2i}$$

$$F'(z) = \sum_{i=0}^{\infty} 2i F_i z^{2i-1}$$

$-q$


q 2d+x
-q 2d-x
d
q
v
x
-q
-x
q 2d-x
q 2d+x
d
x
q
v
-q
d-x

J. Rutherfoord
SSC Lab

GEM Forward Calorimetry

Physics Goals:

- Hermetic measurement of global $\vec{p}_T$
- Forward tagging jets

Critical Parameters

- Mean density of calorimeter
- Diameter of beam hole

Tucson ForCal Mtg. Monday Nov. 18th Summary

- Three proposed technologies
  - High Pressure Gas
  - Liquid scintillator capillaries
  - Liquid Argon
- General simulation
- Integration issues

Preliminary Cost Estimates

(Preliminary)

Liquid scintillator spillover

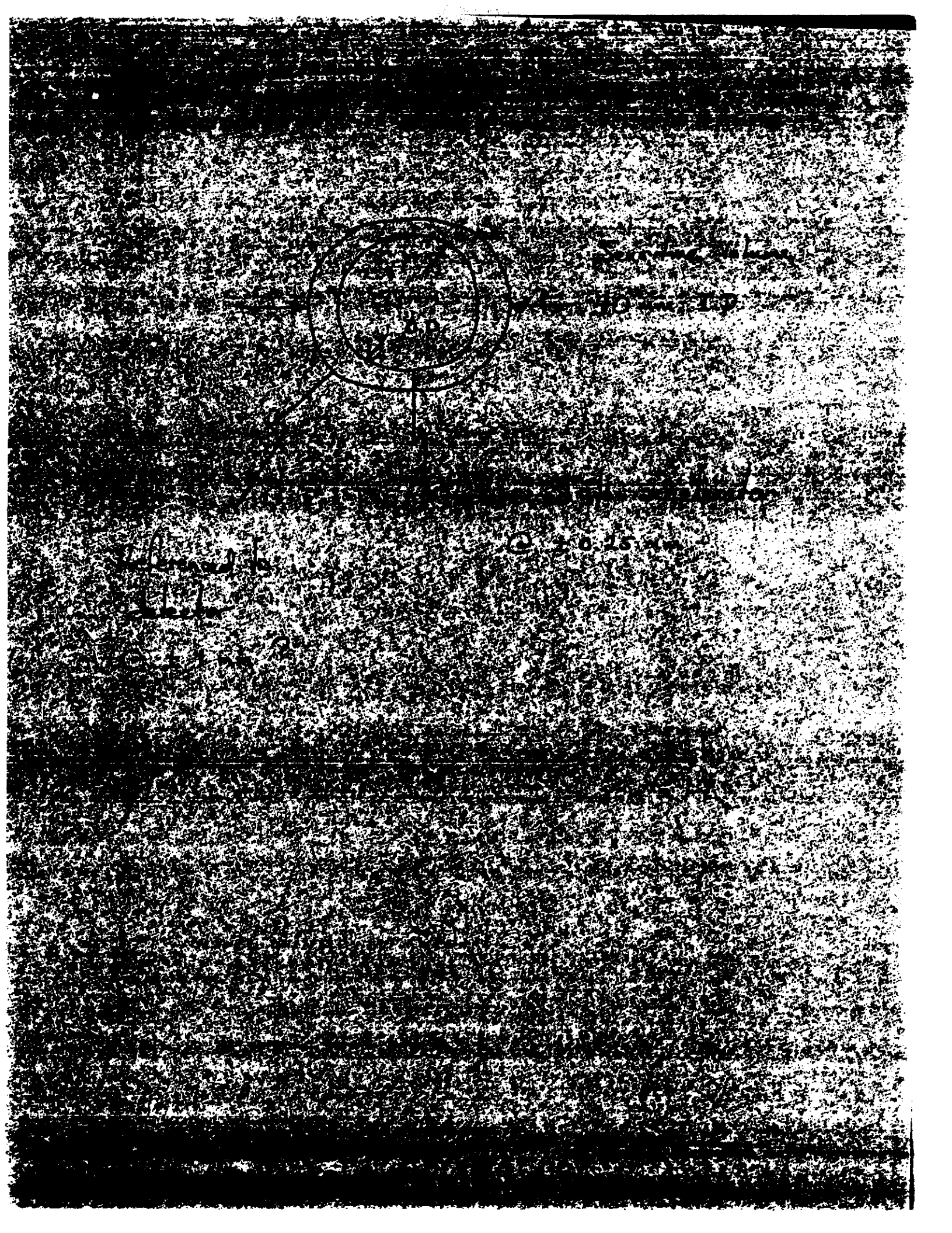
[illegible] M → [illegible] M Mark Lamb Oak Ridge

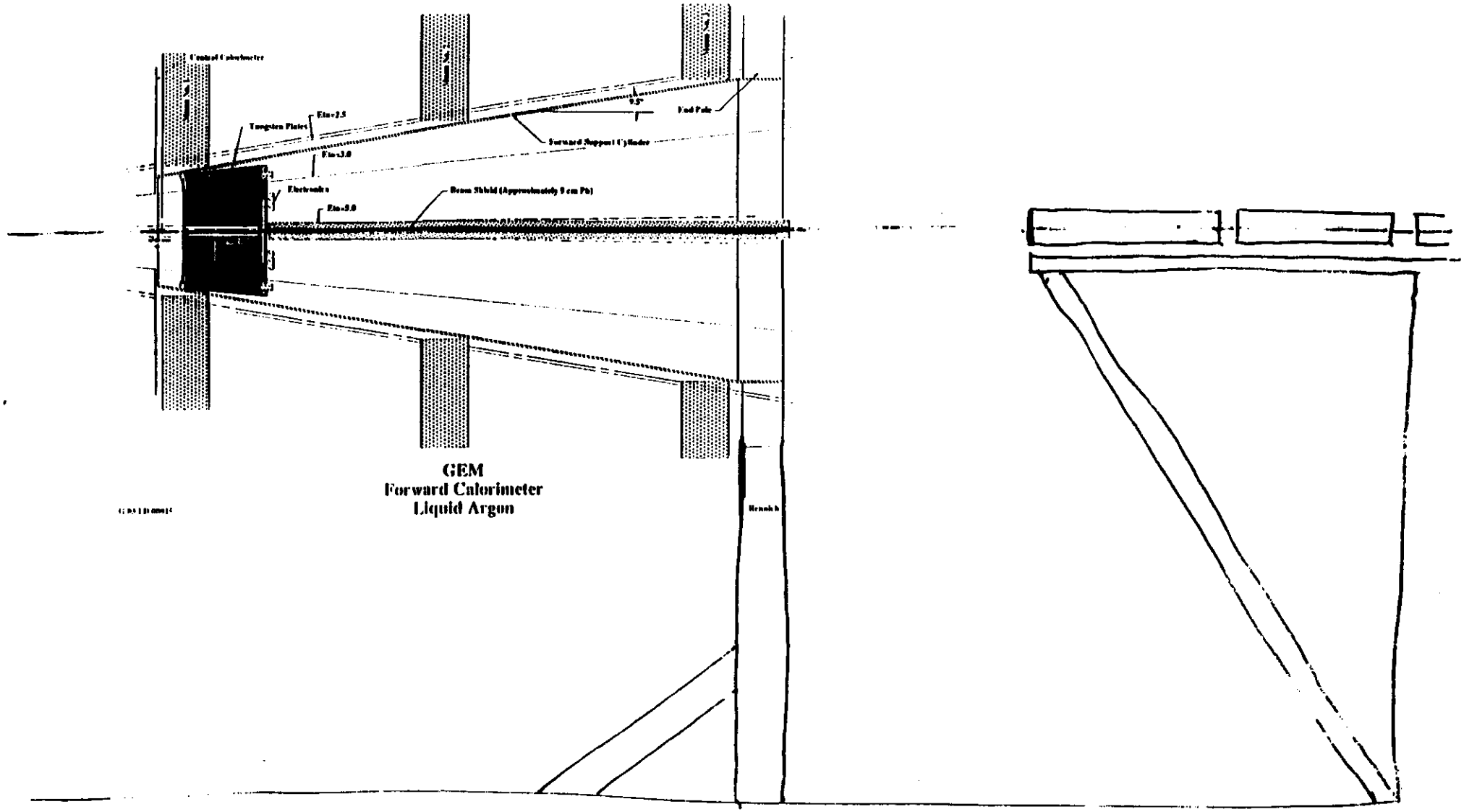
[illegible] Lamb AGM

[illegible]

[illegible] 20 M Slim Cheer Oak Ridge

Jody Cable Monday Marietta




Tungsten Plates
Forward Support Cylinder
Beam Shield (Approximately 9 cm Pb)
GEM
Forward Calorimeter
Liquid Argon

Integration Issues

Beam Pipe

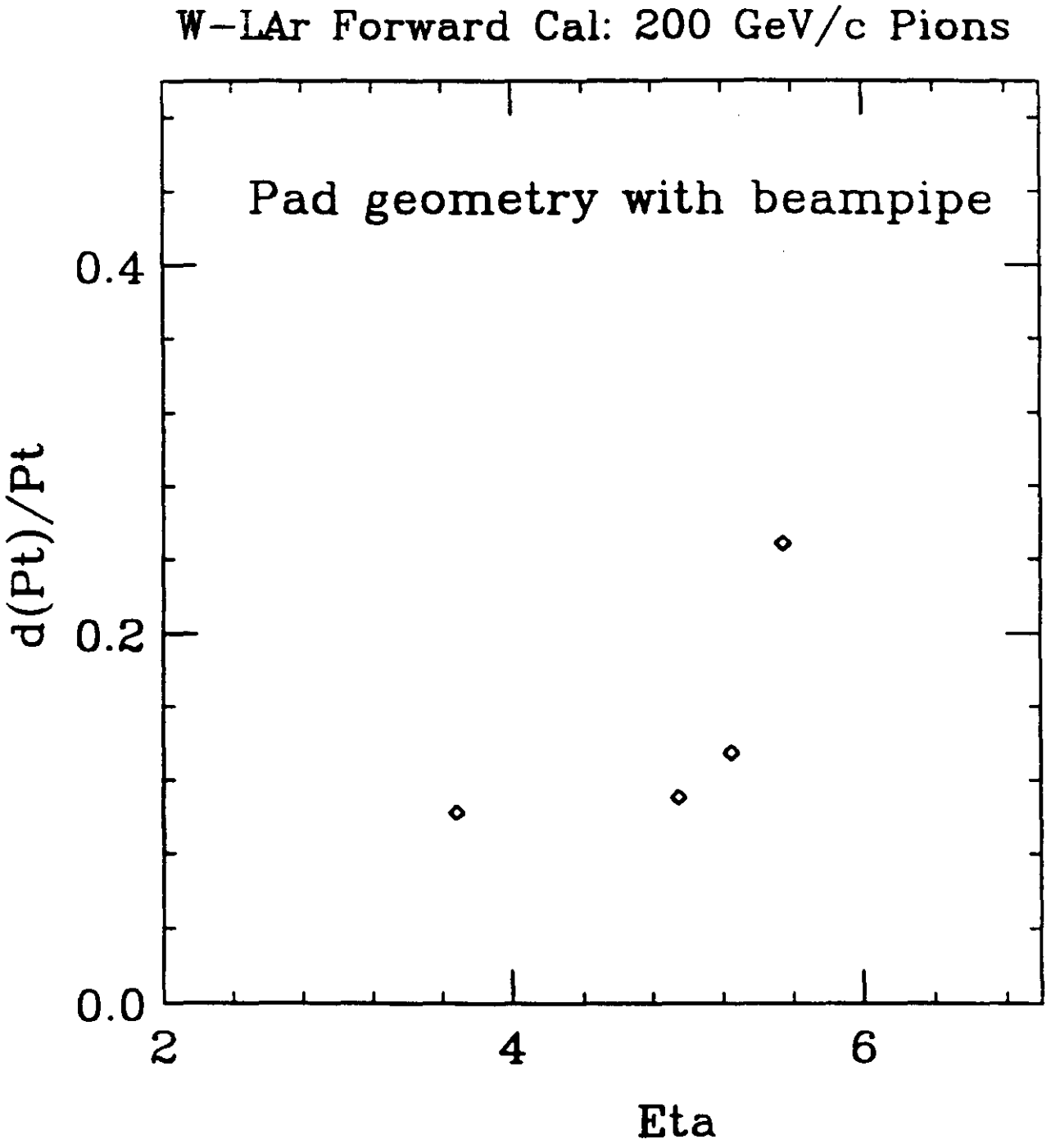
Support

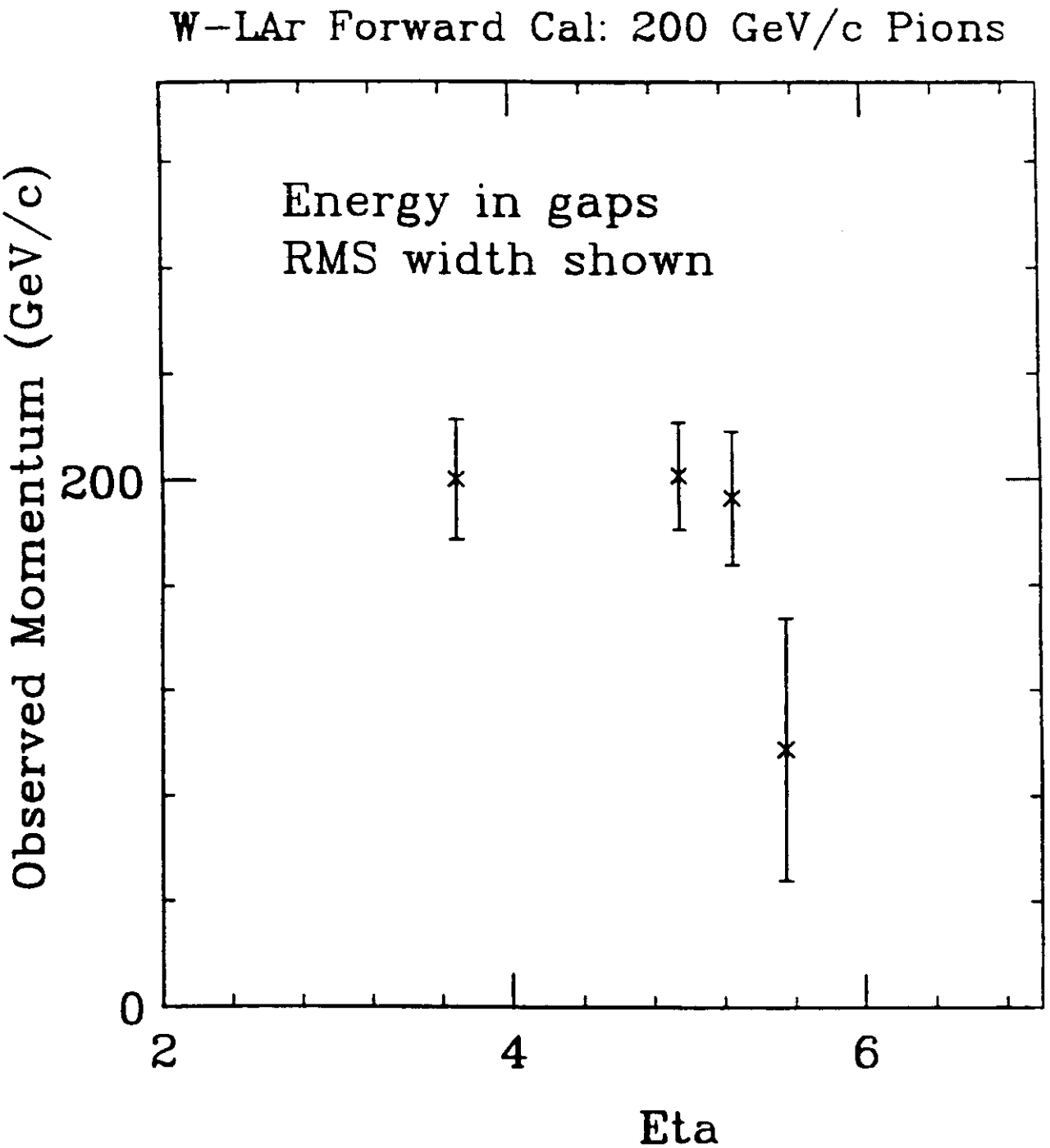
Spray into muon system

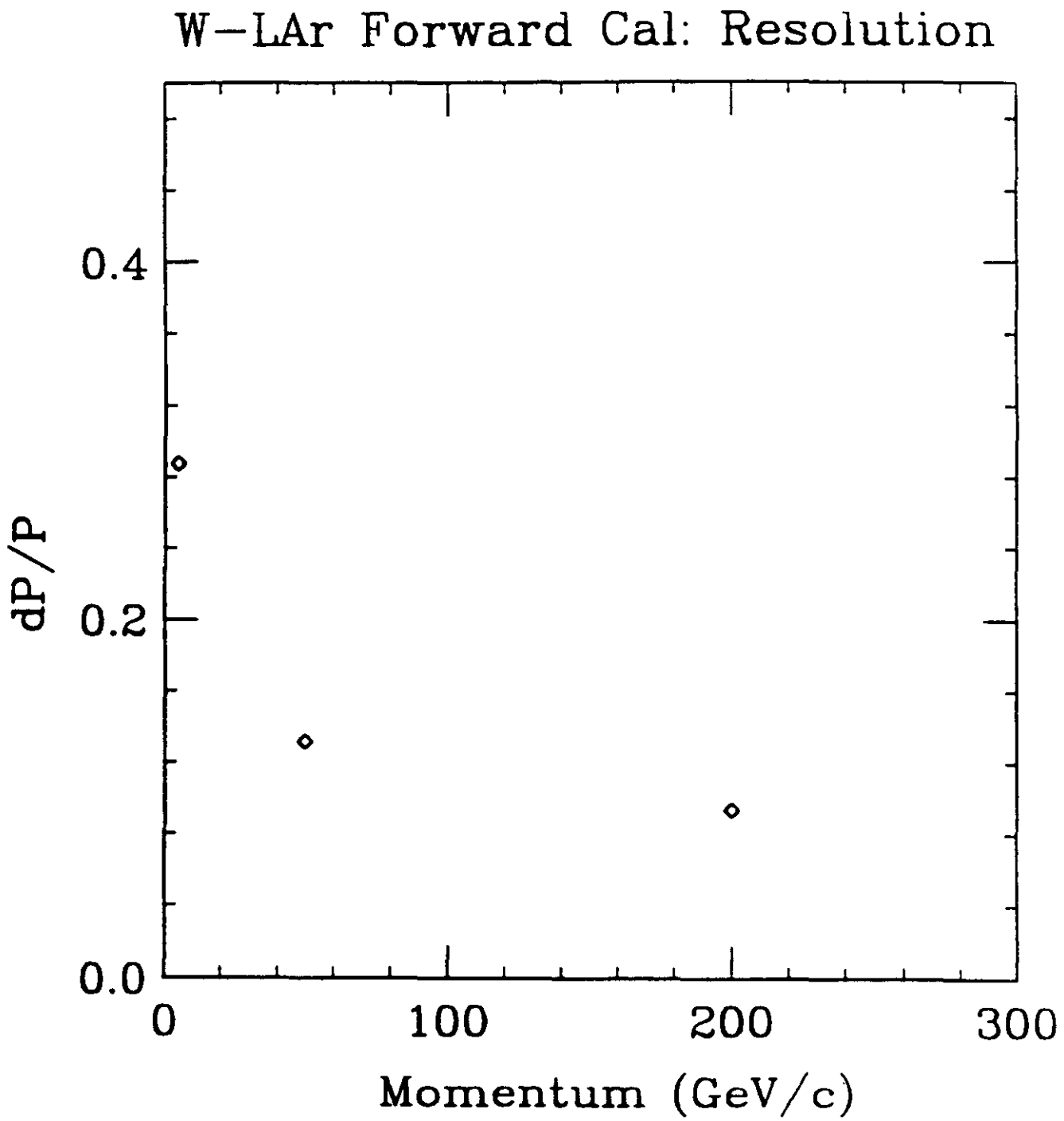
Neutron albedo into tracking volume

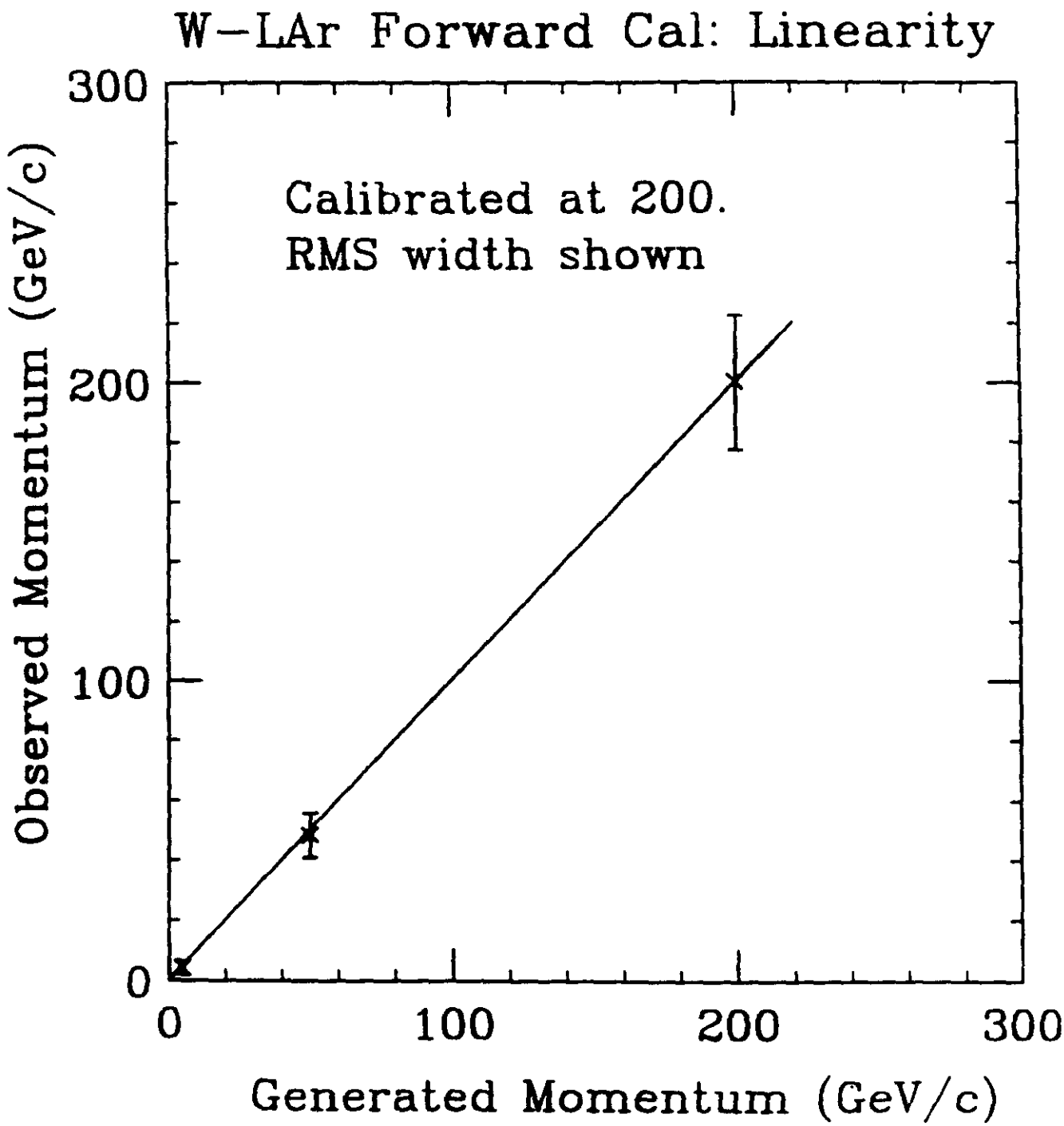
Readout electronics, cables, tuning, etc.

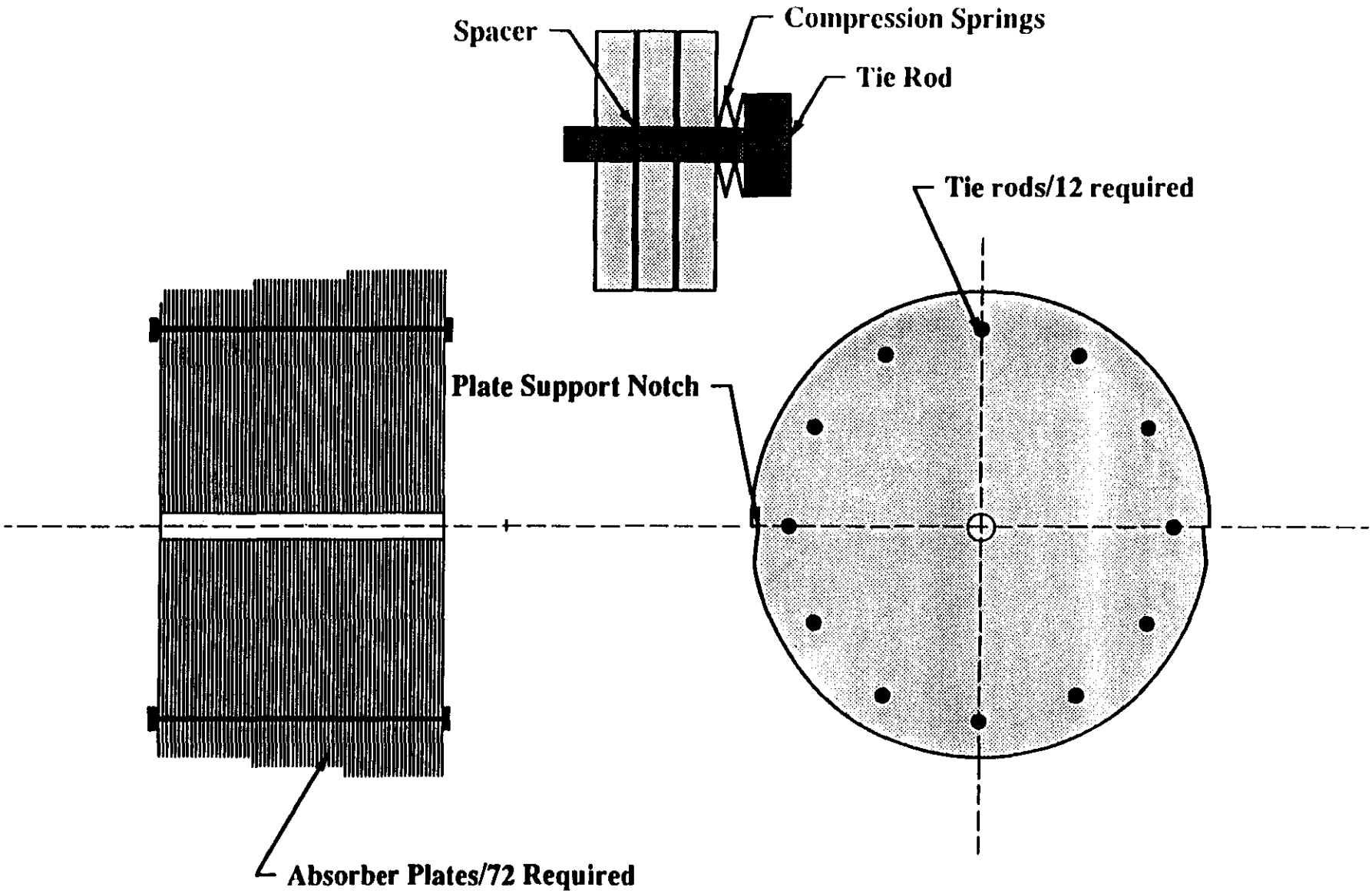
Mechanical, electrical interface/interference with other systems


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


W-LAr Forward Cal: 200 GeV/c Pions
Energy in gaps
RMS width shown
Observed Momentum (GeV/c)
200
0
2
4
6
Eta

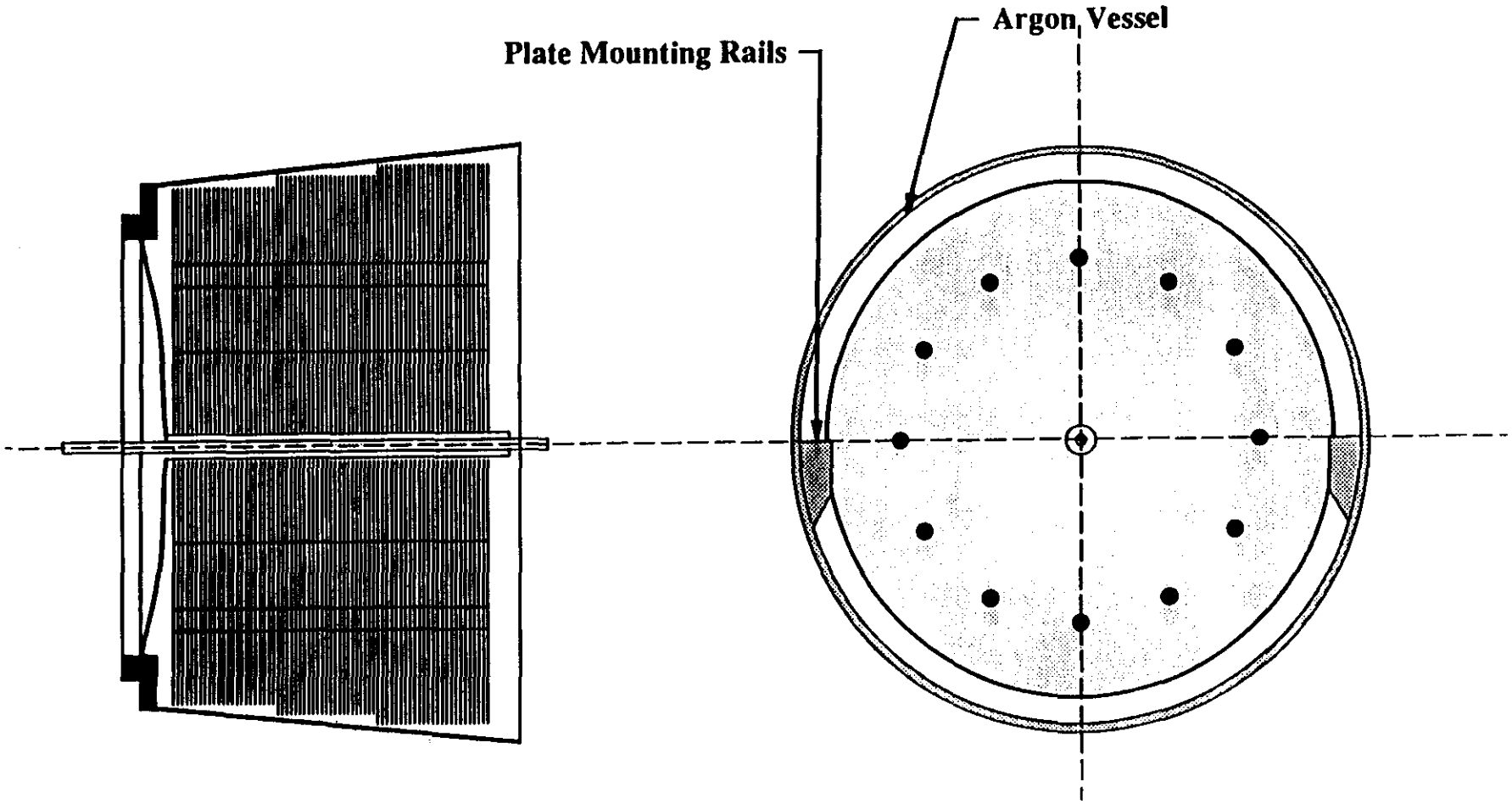

W−LAr Forward Cal: Resolution
0.4
0.2
0.0
dP/P
0
100
200
300
Momentum (GeV/c)


W−LAr Forward Cal: Linearity
Calibrated at 200.
RMS width shown
Observed Momentum (GeV/c)
Generated Momentum (GeV/c)
0
100
200
300
0
100
200
300



Liquid Argon Forward Calorimeter
Absorber Stack Assembly

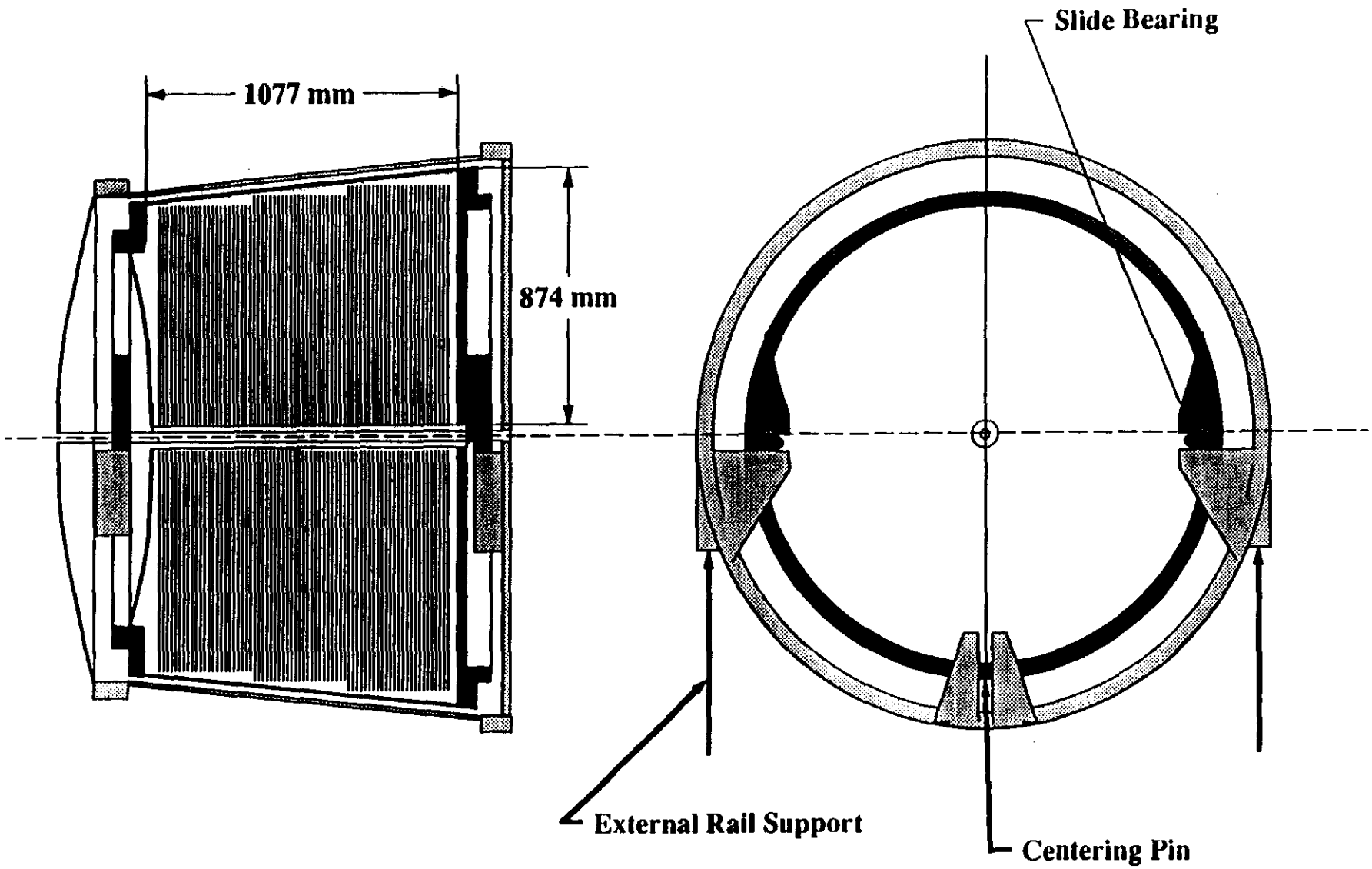
Rennich/Chae



Liquid Argon Forward Calorimeter
Tungsten Plate Support System

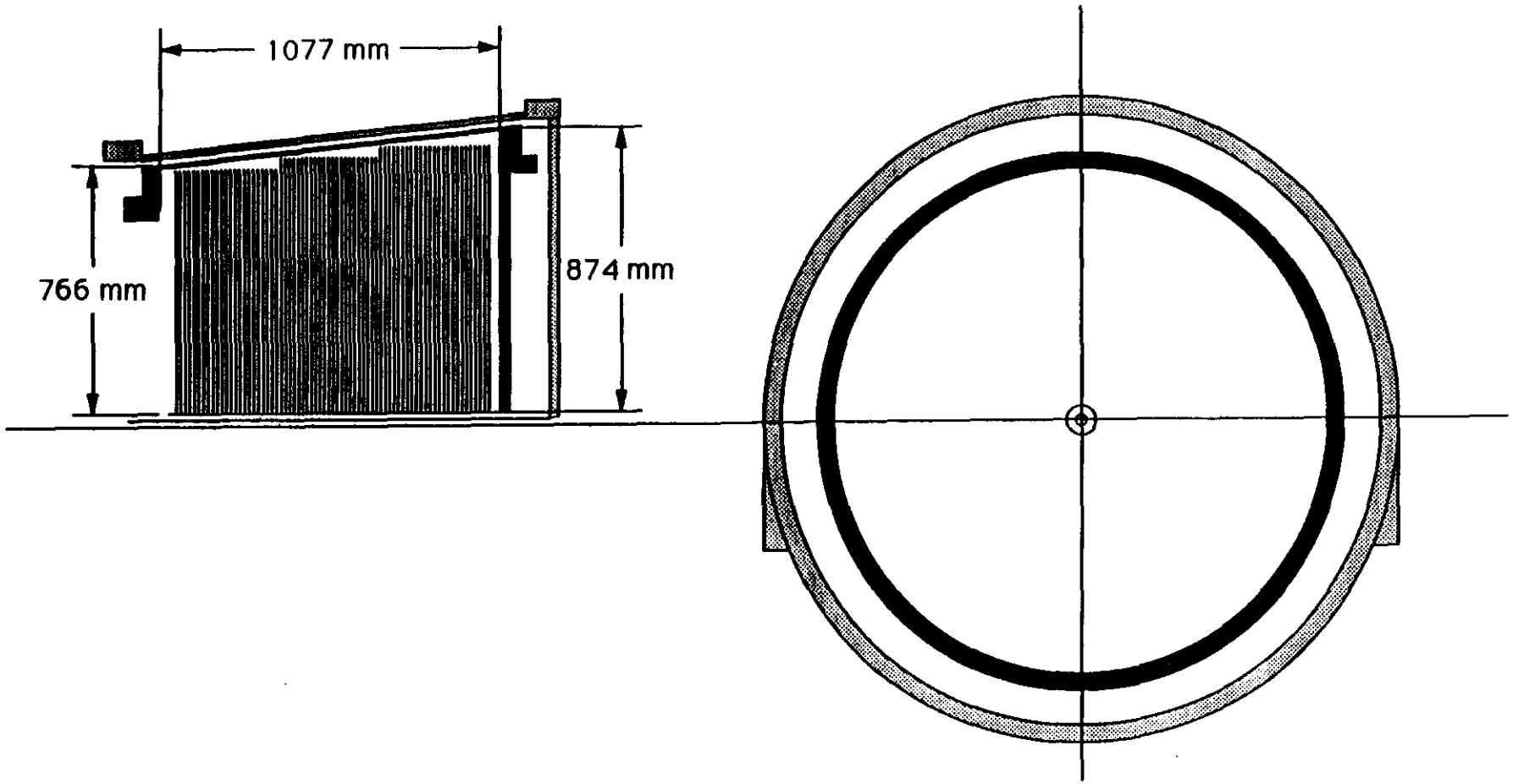
Rennich/Chae

Forward 4



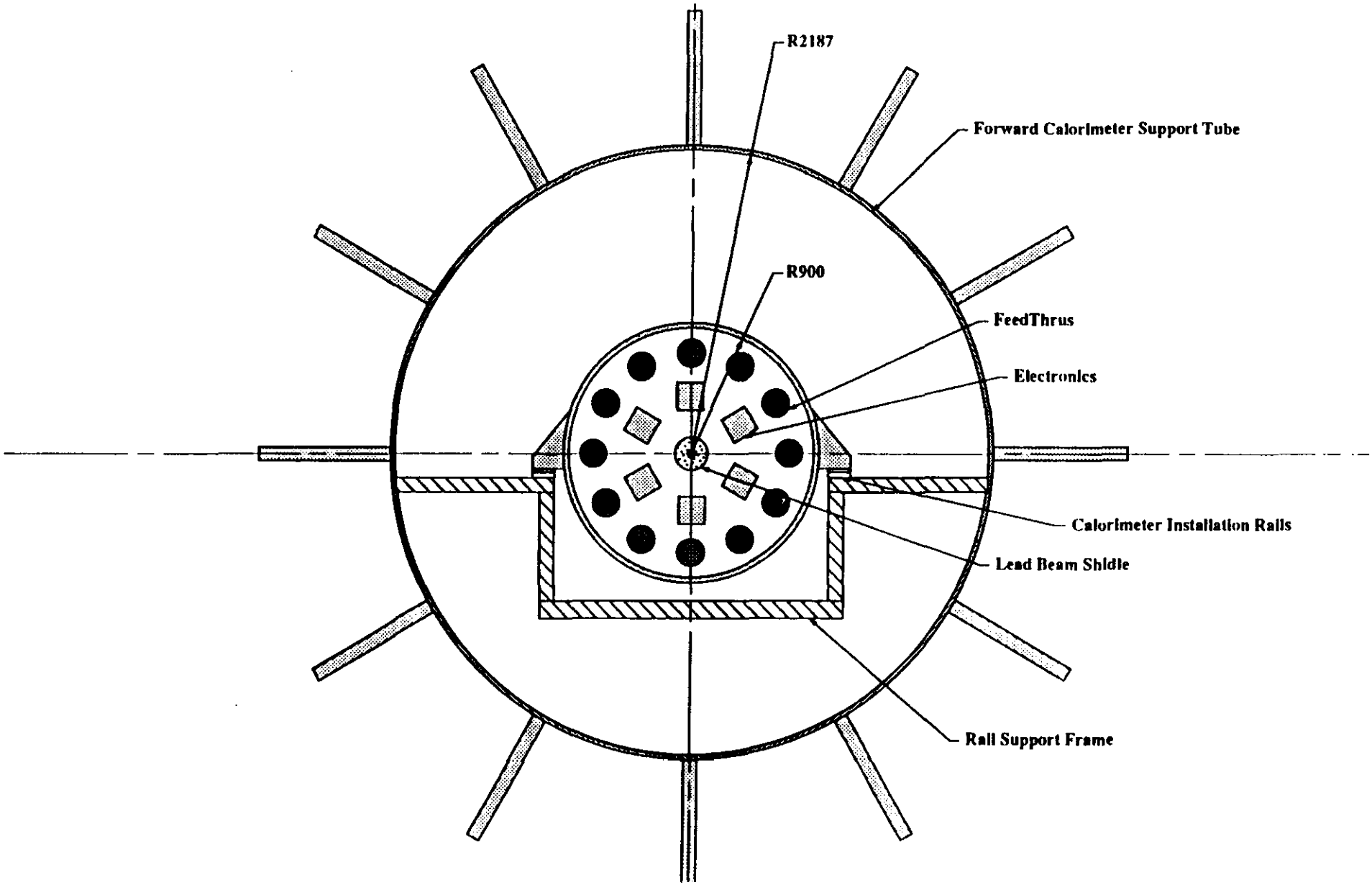
Liquid Argon Forward Calorimeter
Argon Vessel Support System

Rennich/Chac



Liquid Argon Forward Calorimeter

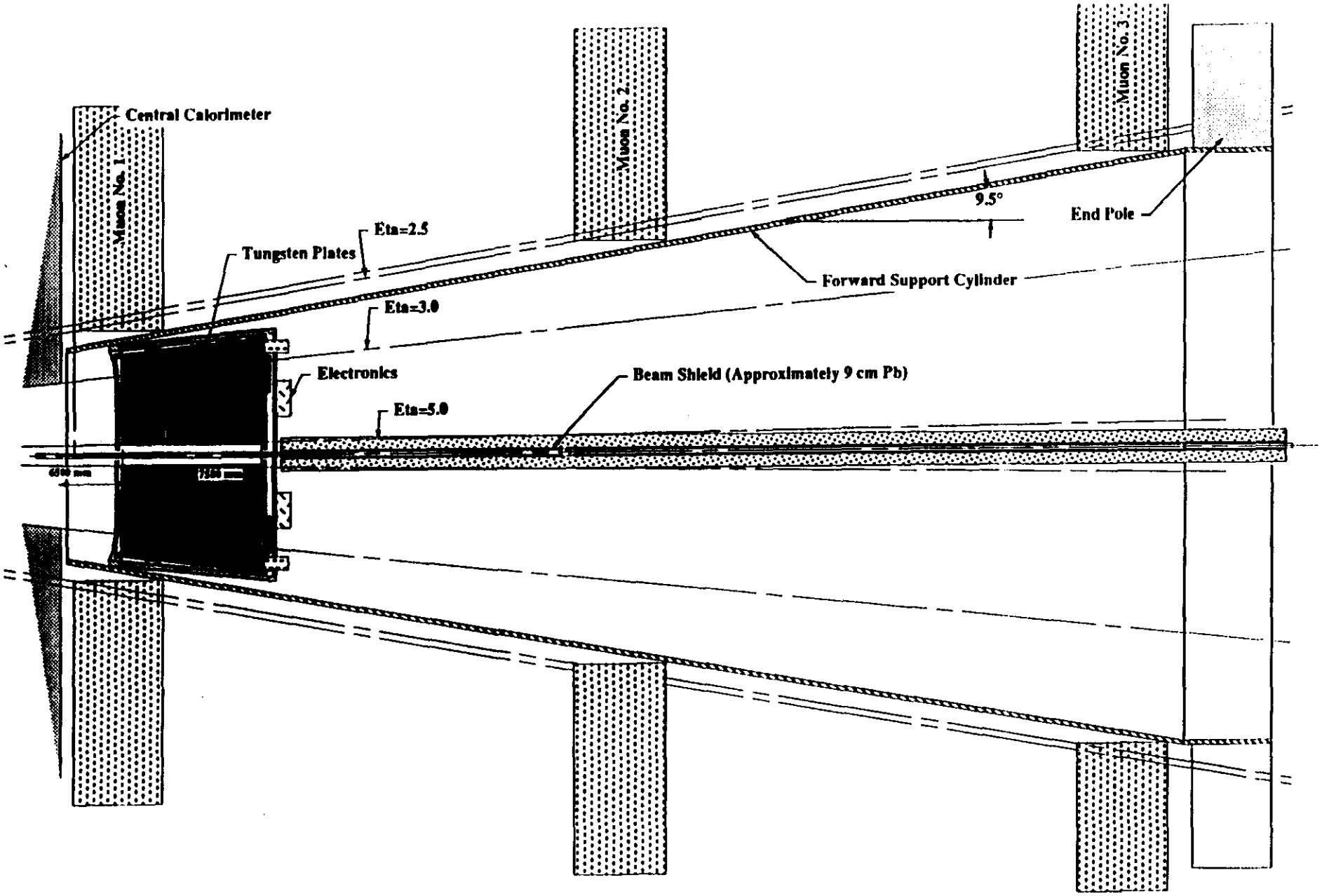
Rennich/Chae



GEM
Forward Calorimeter
End View
Liquid Argon

G.03.FD.00015

Rennich



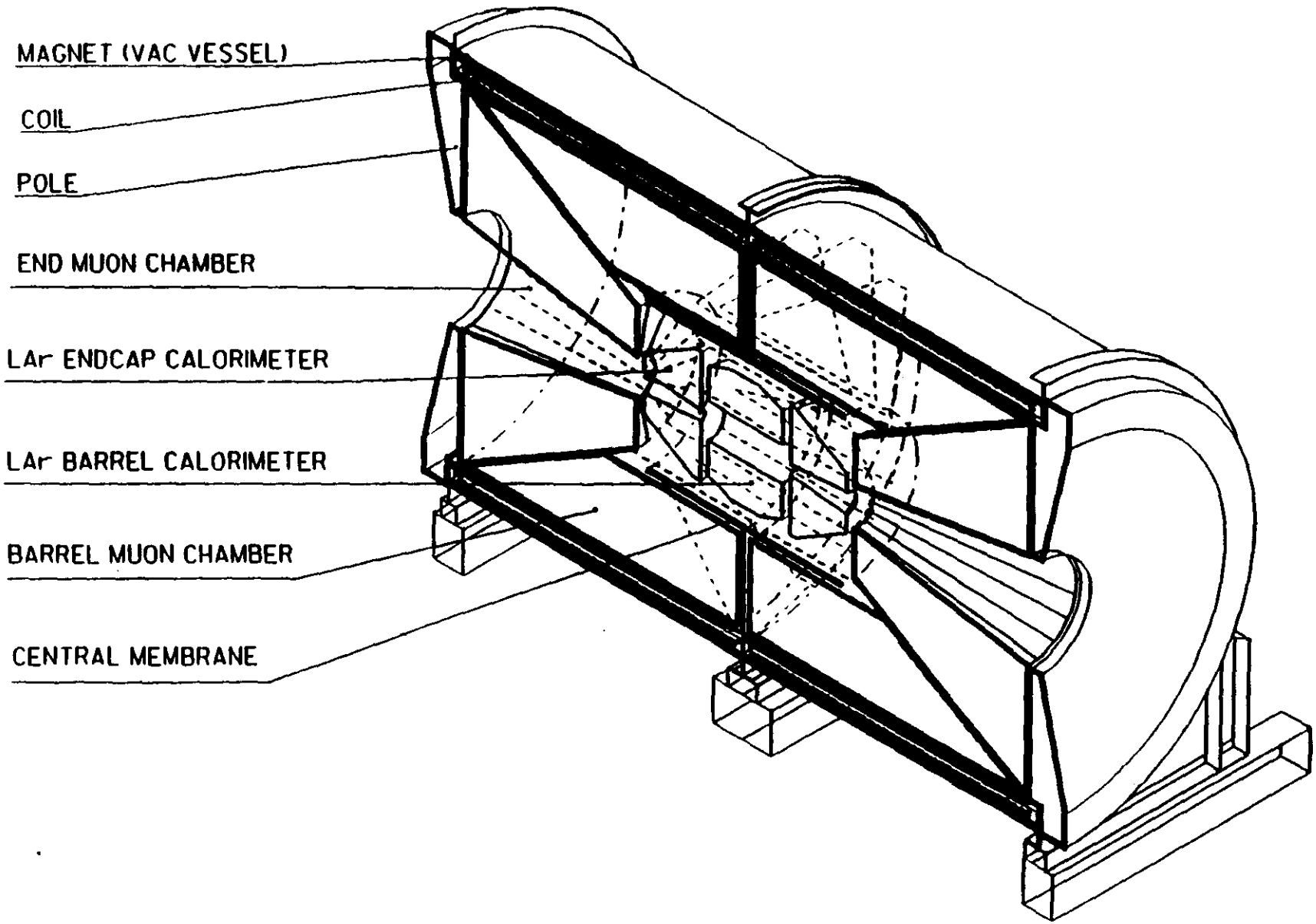
GEM
Forward Calorimeter
Liquid Argon

G.03.FD.00015

Rennich

GEM

DETECTOR ISO SECTION (LAr OPTION)



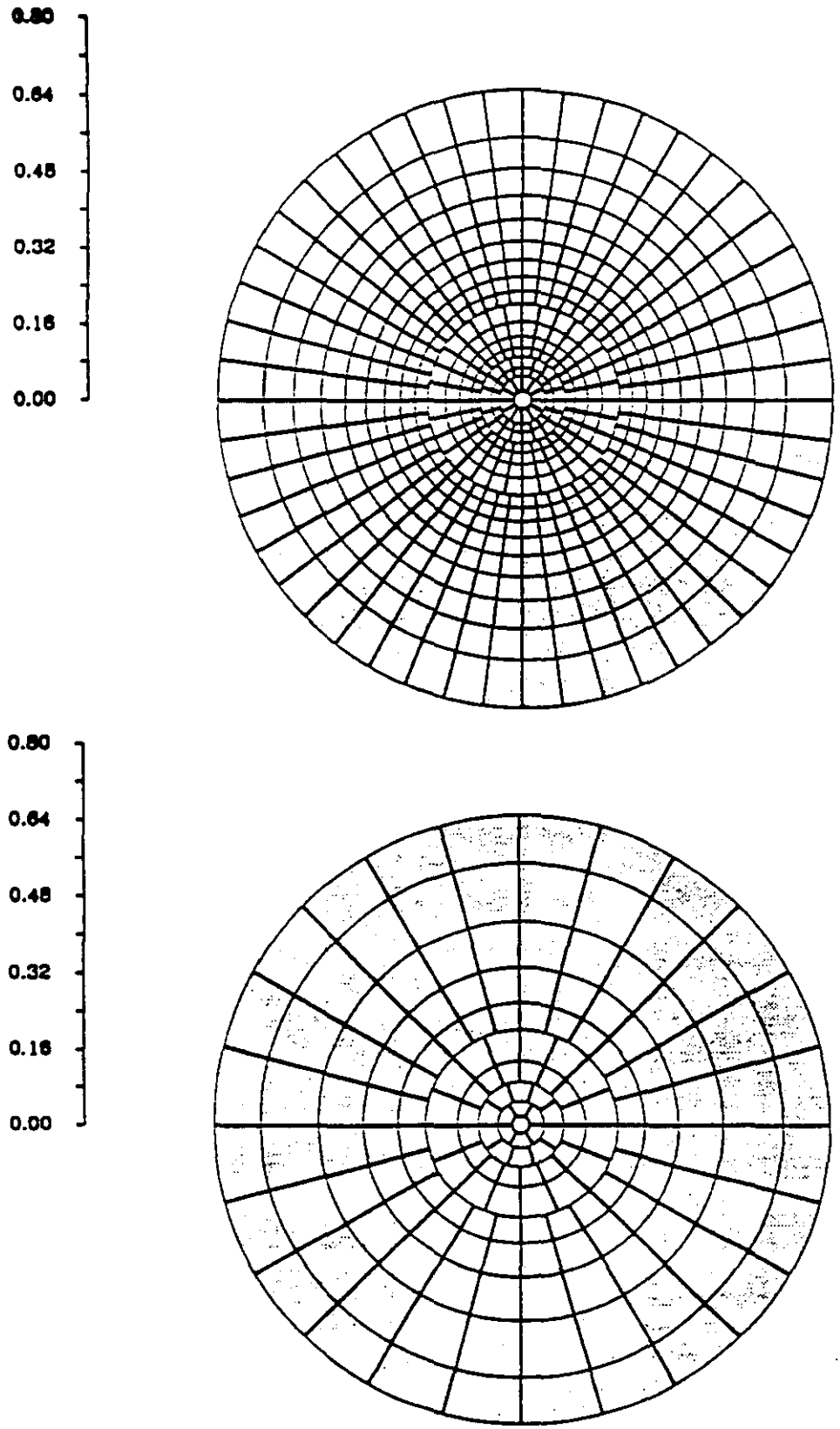


Figure 4

GEM FCal Simulation Parameters

	Photons	Hadrons
Energy Resolution $\frac{\Delta E}{E}$	$\frac{40\%}{\sqrt{E}} + 2\%$	$\frac{100\%}{\sqrt{E}} + 2\%$
Position Resolution $\frac{\Delta\theta}{\theta}$	$\leq \frac{0.17}{\sqrt{12}}$	$\leq \frac{0.17}{\sqrt{12}}$
Coverage w/ full containment	$3 < \eta < 5.8$	$3 < \eta < 5.2$

GEM FCal Parameters (Each of 2)

Distance from IP to front face	6.5 m
Mean outer radius	80 cm
Weight	40 T
Unit cell	
Heavymet plate	1.3125 cm
G10 sheet w/Cu pads	0.019 cm
Liquid Argon gap	0.10 cm
Electronic read-out channels	
At 1st depth segment	698
2nd	186
3rd	186
Total	1070 channels

GEM-Silicon Strip Preradiator

Simulation

π^0 rejection

Energy correction

GEM skis

Russian industrial interest

Prototype

Final system electronics—VERY little progress

12/4/91

J. Bra

Discussion at LeCroy

Nov 15, '91

R. Strom, M. Bayer, R. Todd, D. Marlow

D. Sumner et al.

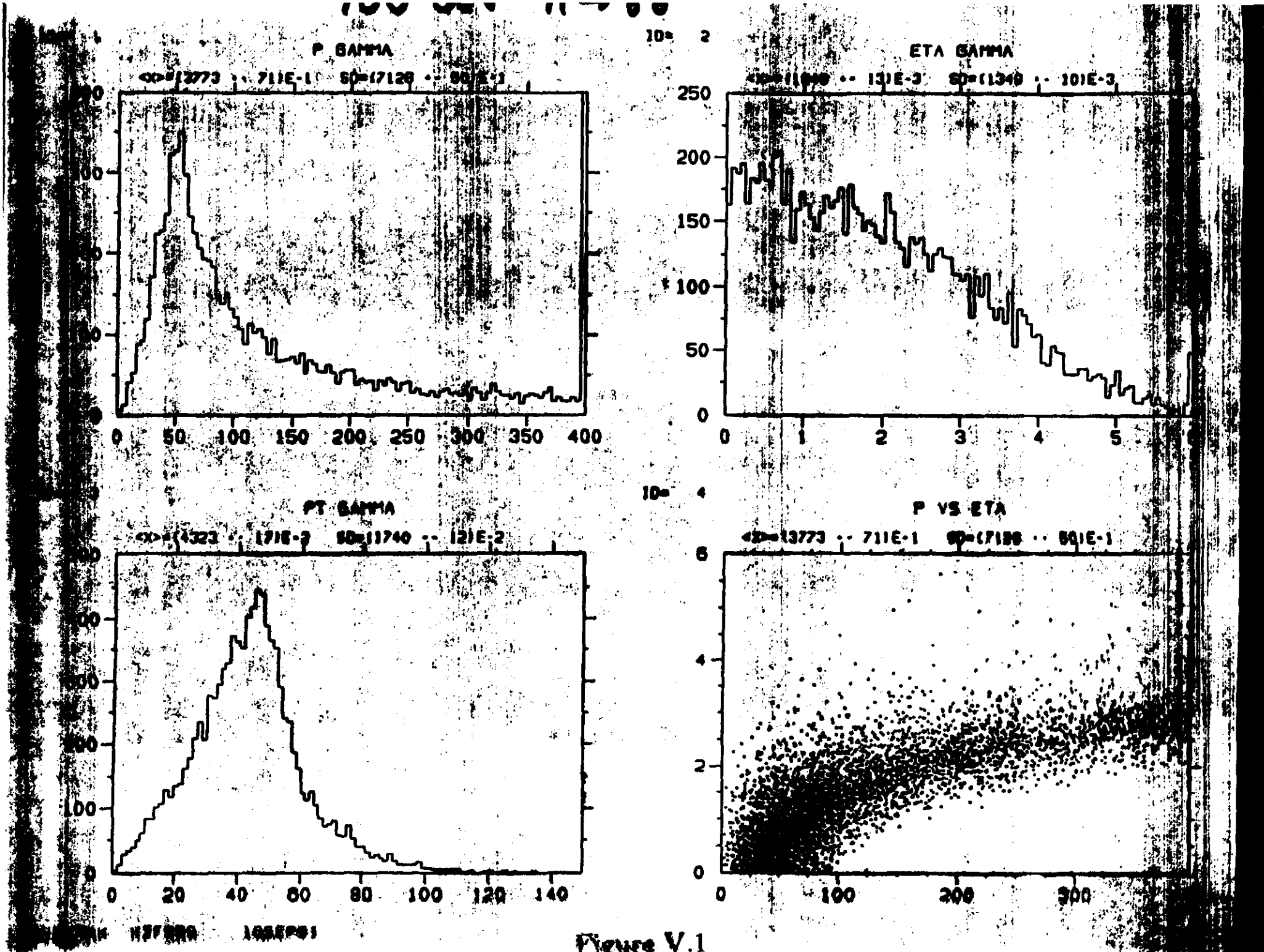


Figure V.1

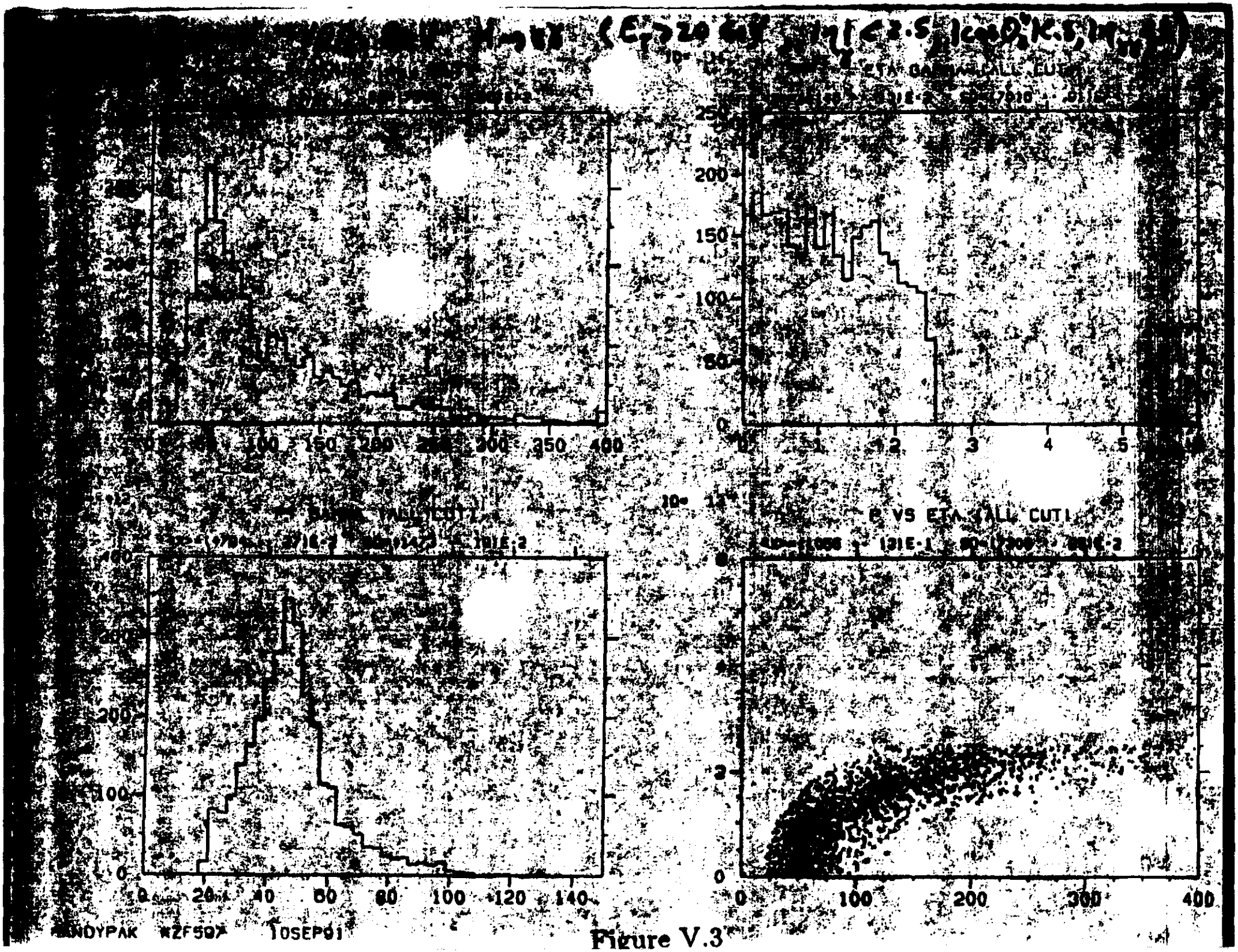
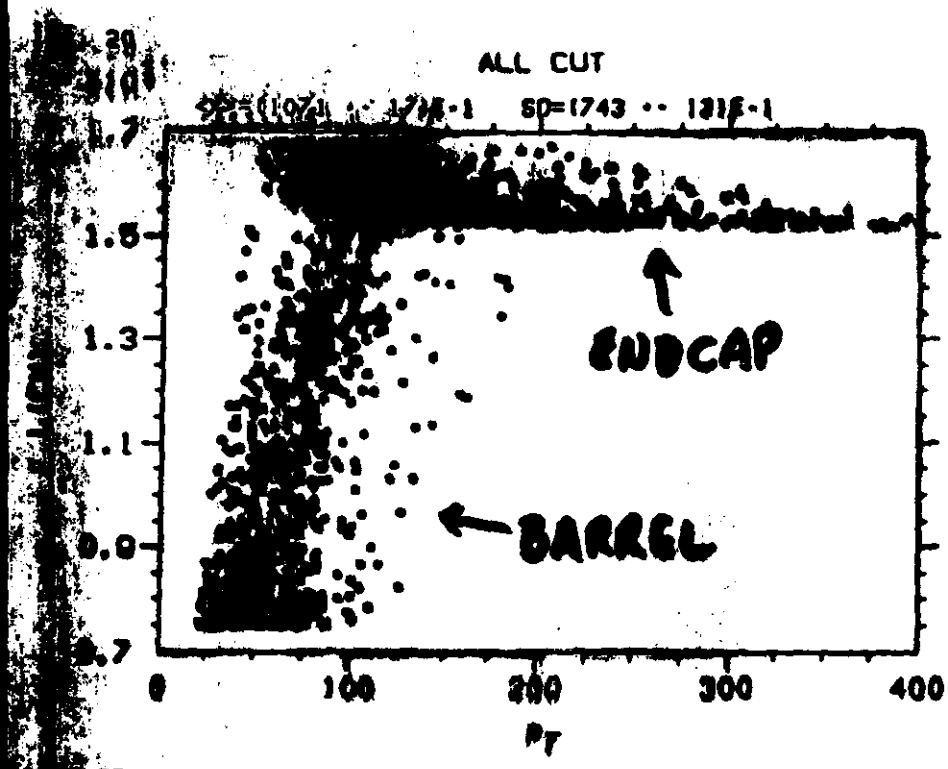
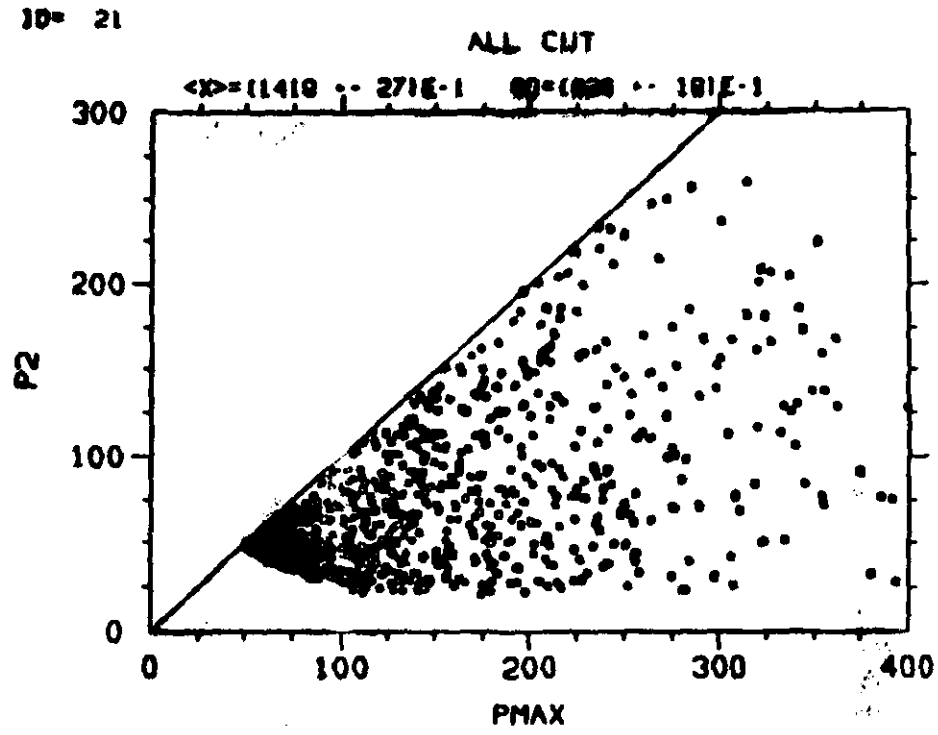
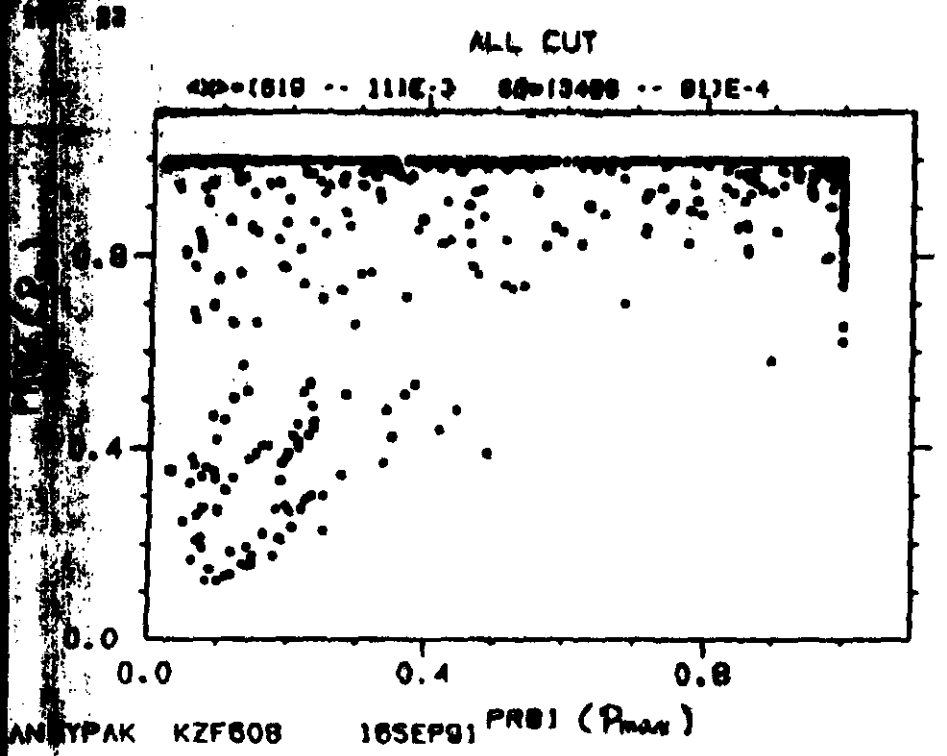
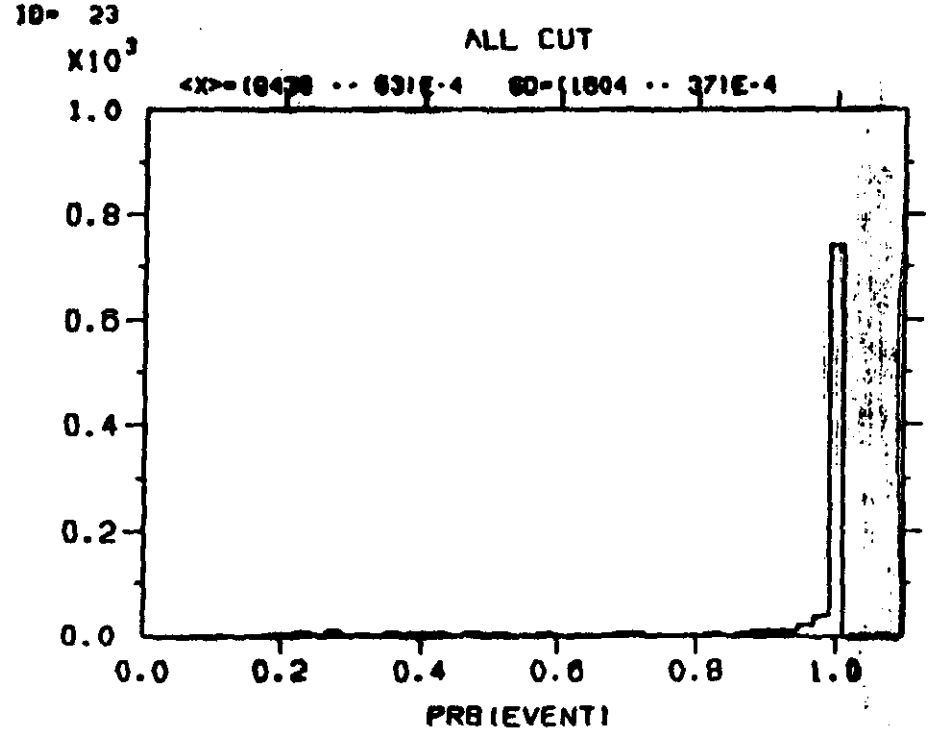


Figure V.3

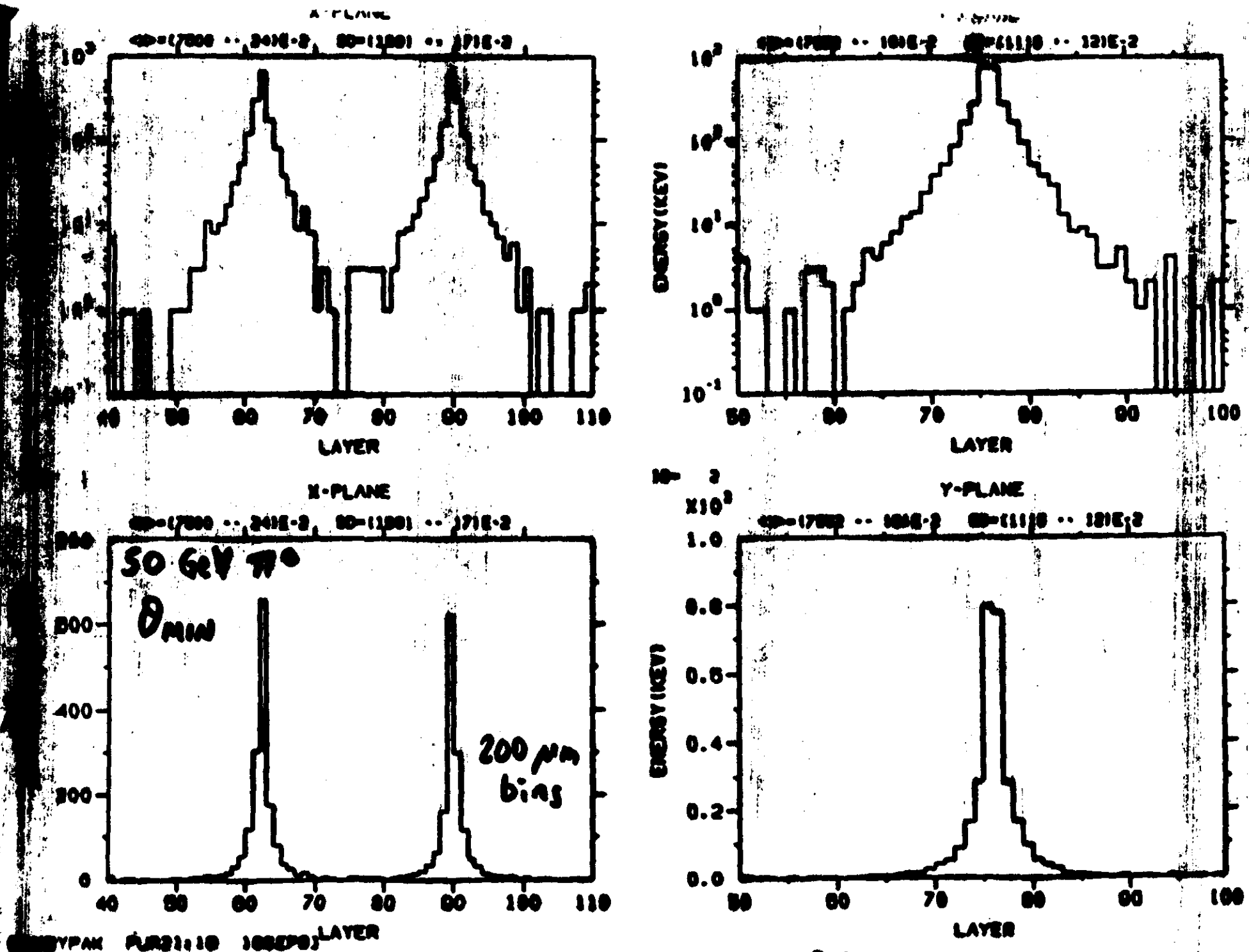








ANALYPAK KZF608 16SEP91


X-PLANE
LAYER
ENERGY (KEV)
Y-PLANE
50 GeV π⁰
θMIN
200 μm
bias

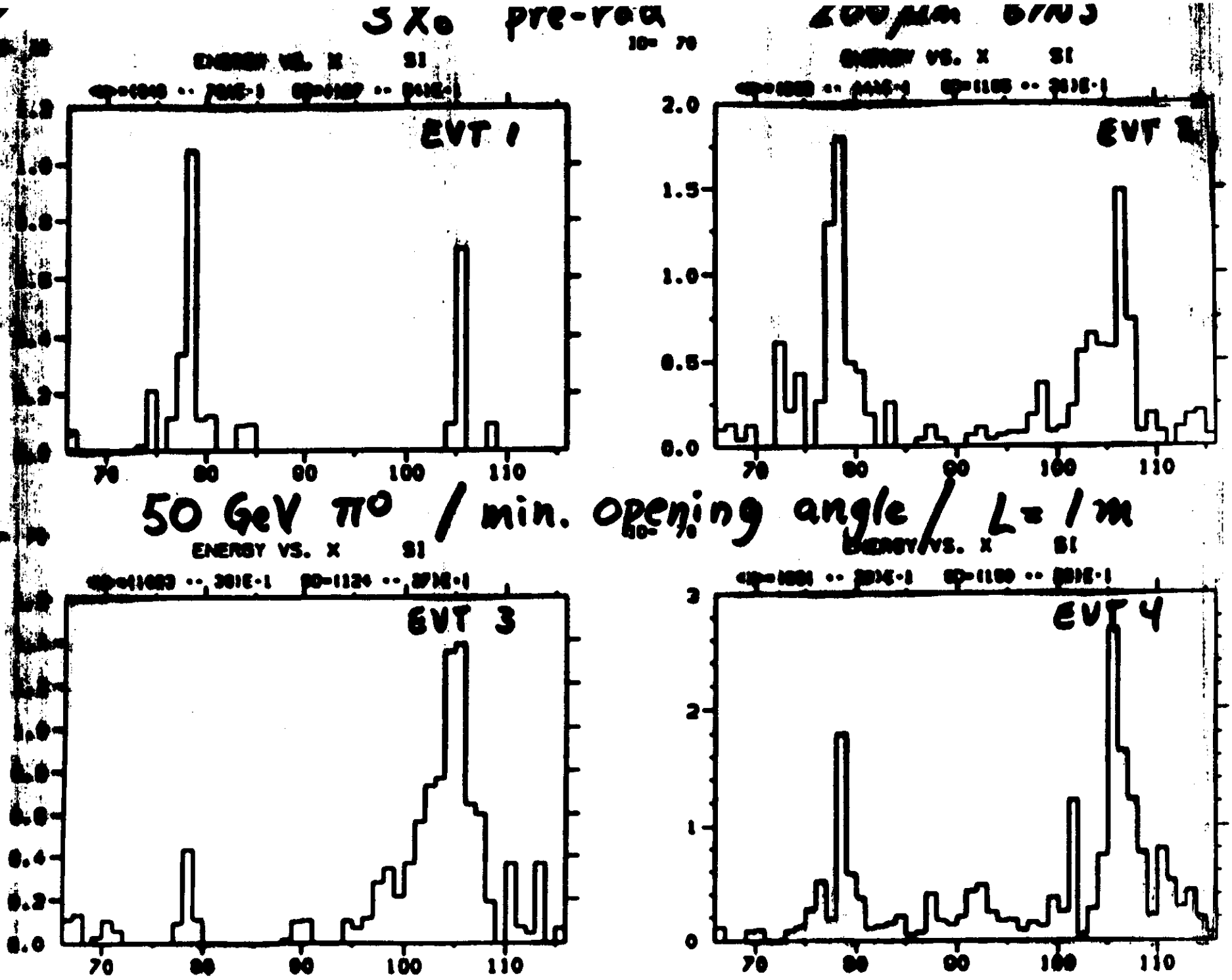

3 X0 pre-rea
ENERGY VS. X SI
EVT 1
EVT 2
50 GeV π0 / min. opening angle / L = 1 m
EVT 3
EVT 4
70
80
90
100
110
0.0
0.5
1.0
1.5
2.0
0
1
2
3

Figure V.5

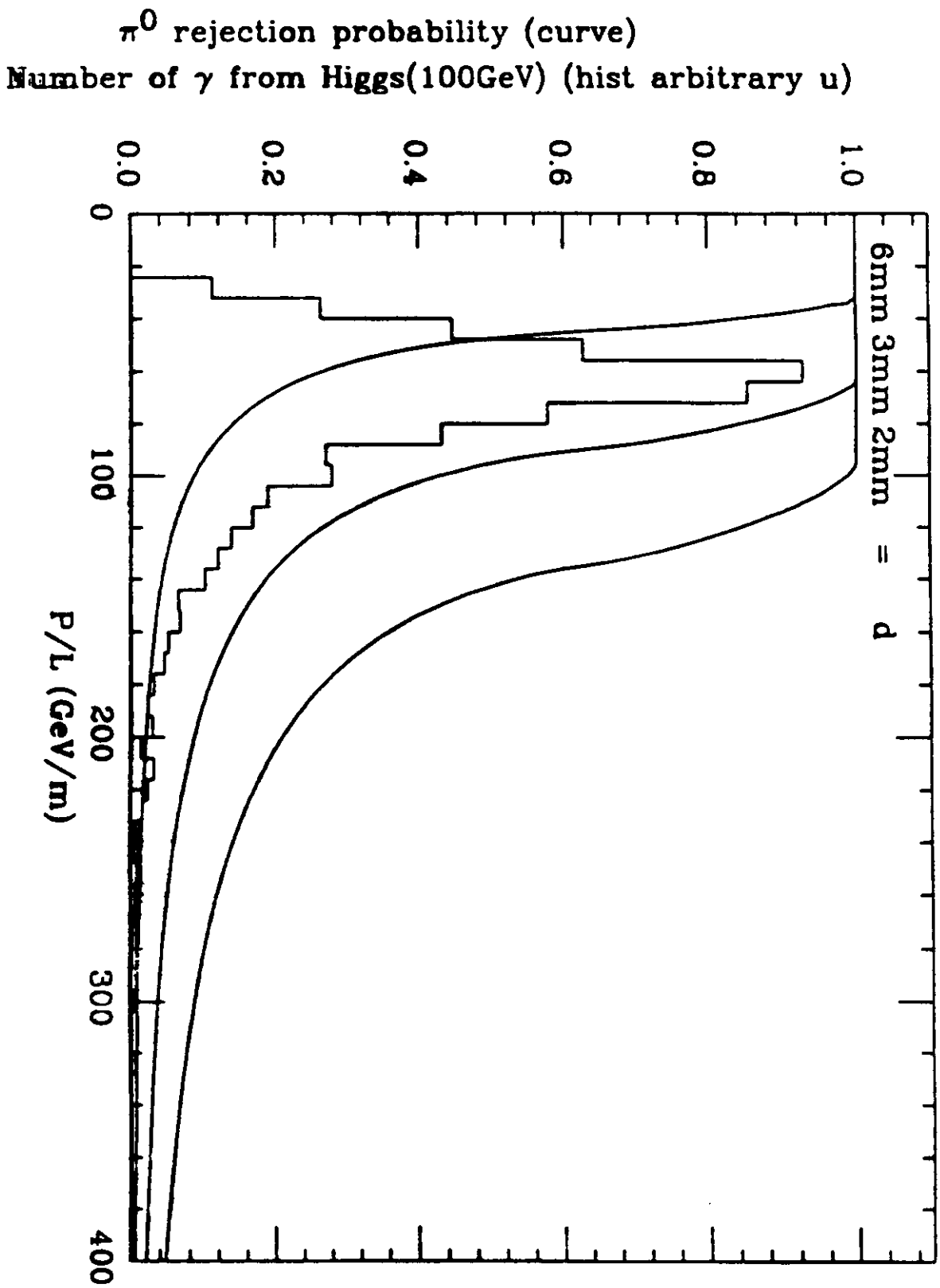
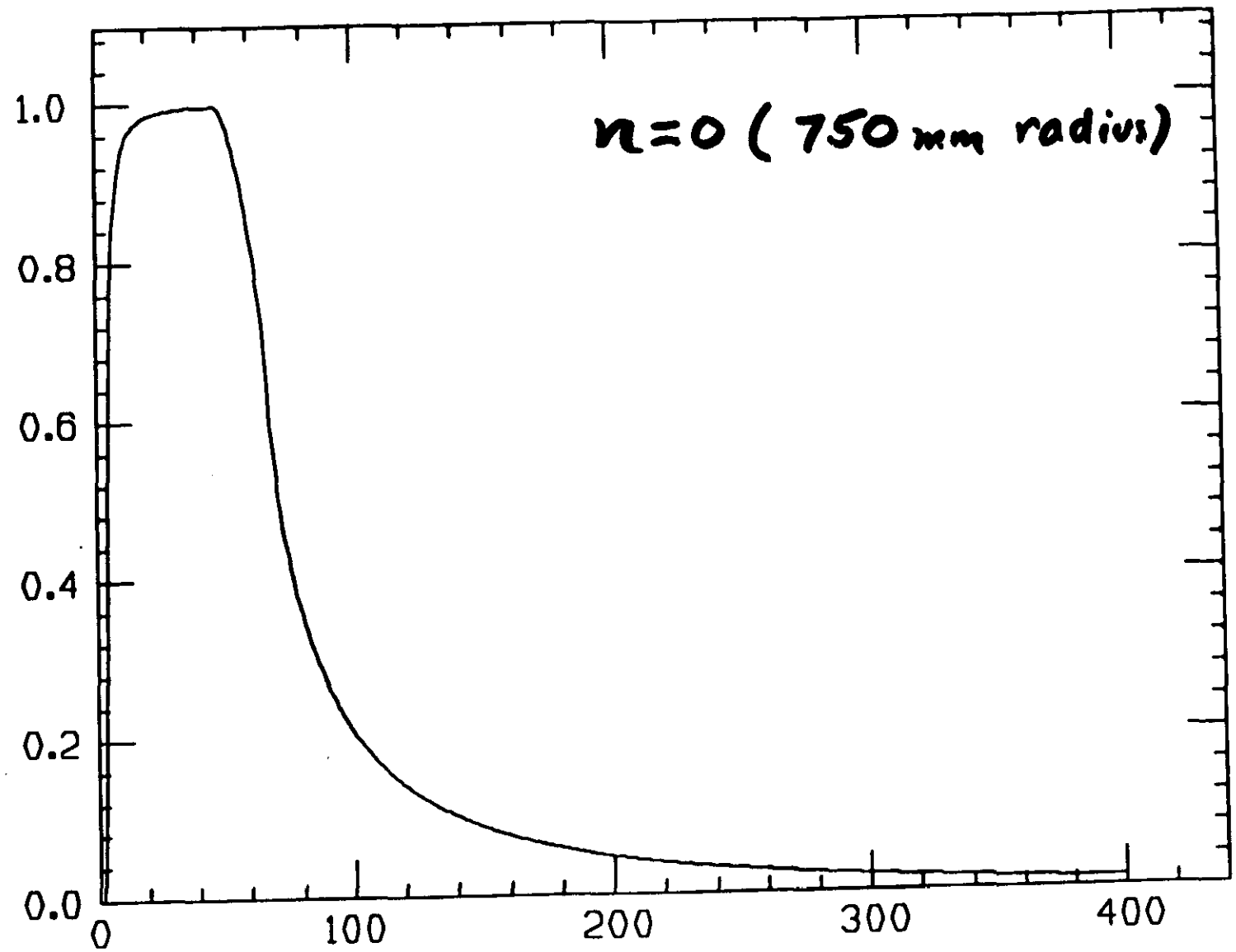
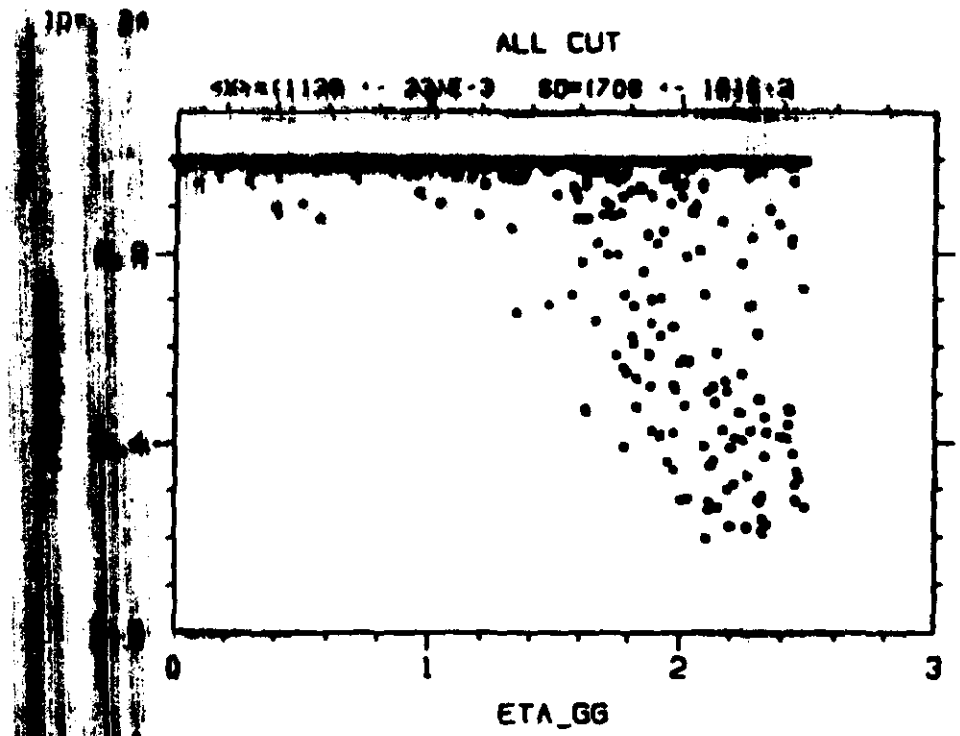
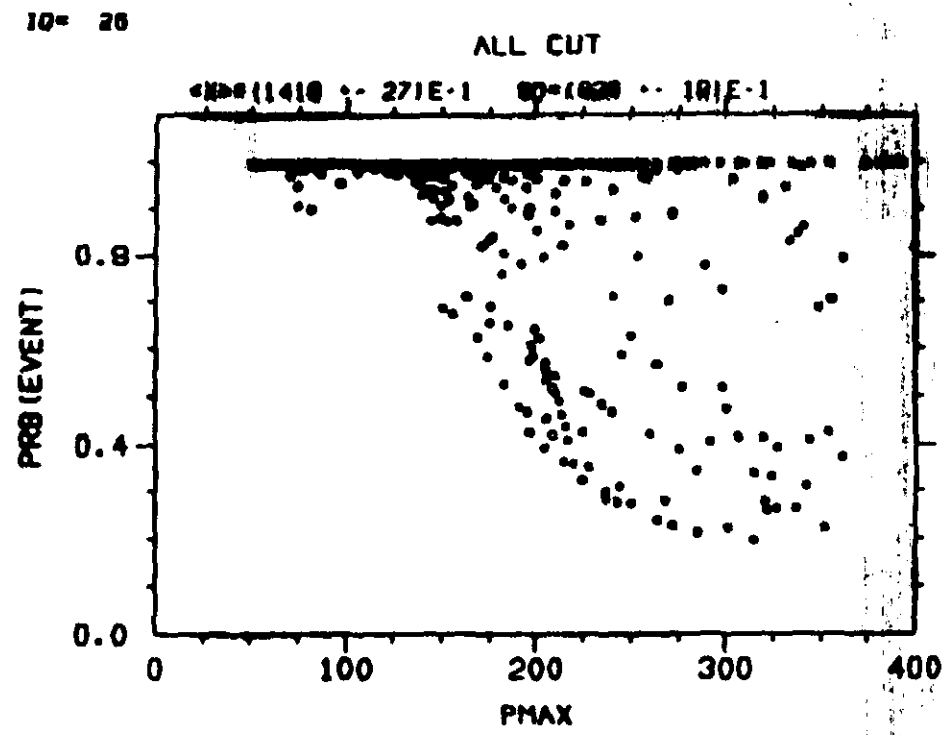
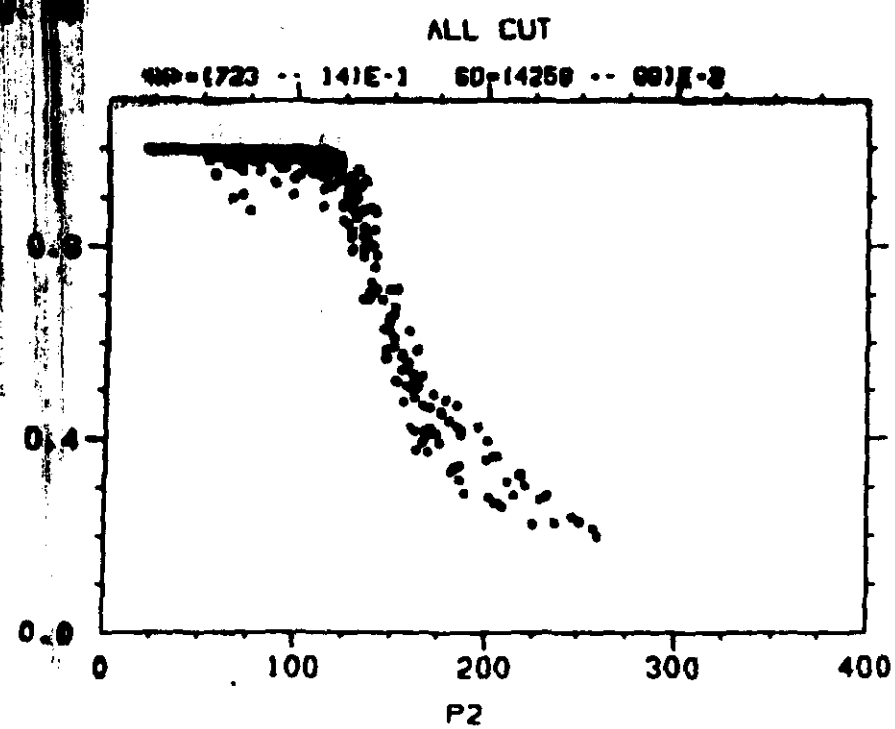

π^0 rejection probability (curve)
Number of γ from Higgs(100GeV) (hist arbitrary u)
6mm 3mm 2mm = d
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
P/L (GeV/m)

Figure V.2


n=0 (750 mm radius)
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400







$$\mathrm{Prob}(ev) = \mathrm{Prob}(\gamma_1) + \mathrm{Prob}(\gamma_2) - \mathrm{Prob}(\gamma_1)\cdot\mathrm{Prob}(\gamma_2)$$

all cut :

$$\begin{cases} |\eta_\gamma| < 2.5 \\ |\eta_{\gamma\gamma}| < 3 \\ |\cos\theta^*_\gamma| < 0.8 \\ E_{T_\gamma} < 20\ \mathrm{GeV}. \end{cases}$$

932 ev.

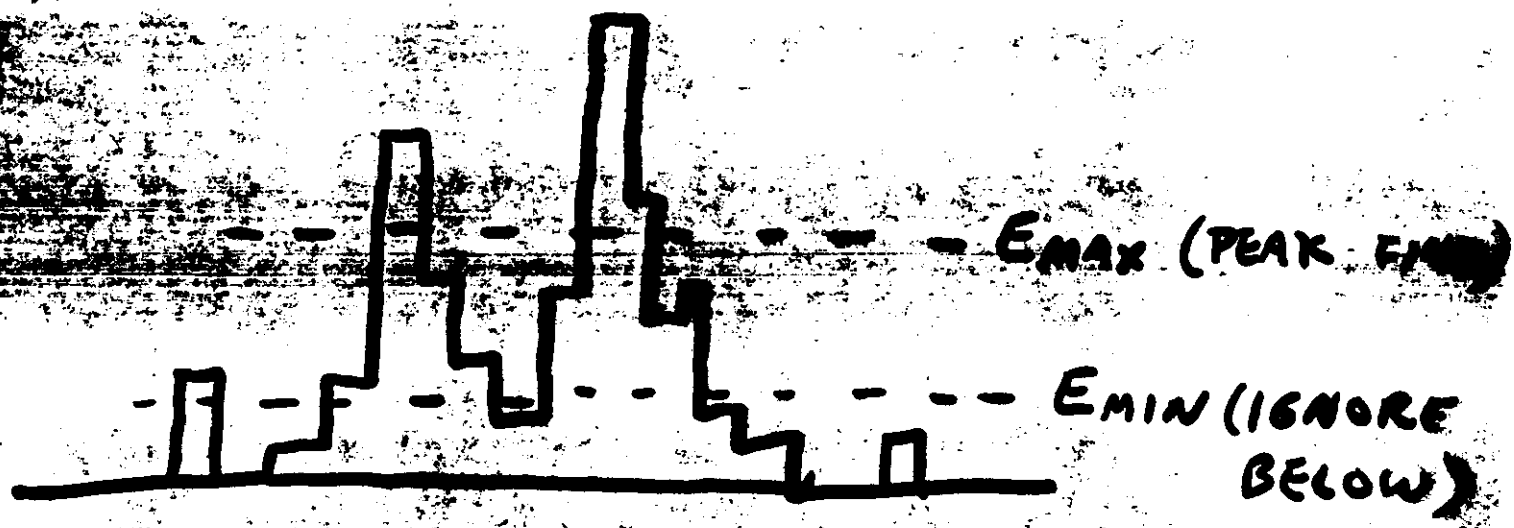
37%

production
H(100)
$P_t > 1$ GeV

no cut :
$|\cos\theta_\gamma| \neq 1$

2496 ev

621 ev/SSC year

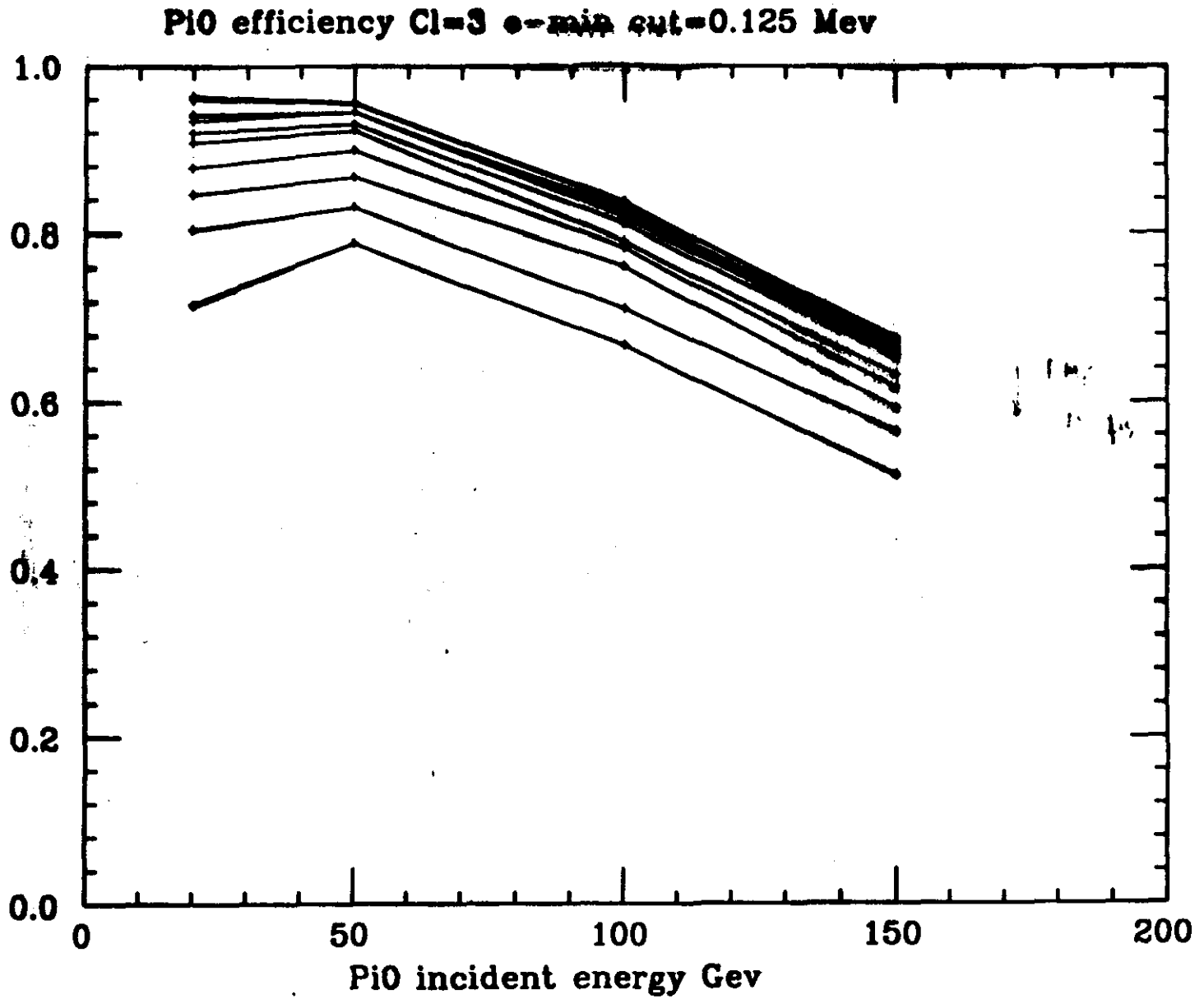

EMAX (PEAK
EMIN (IGNORE
BELOW)

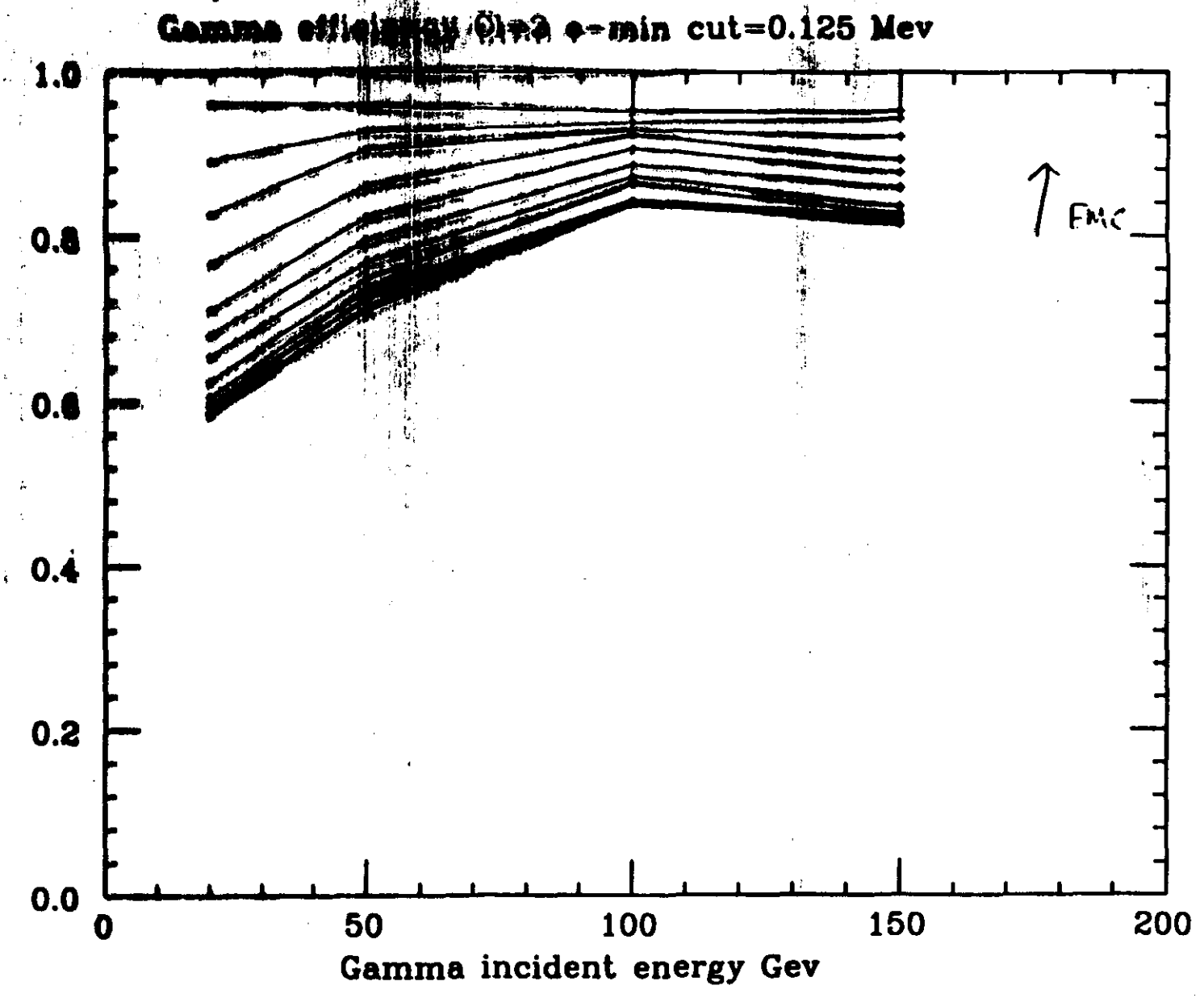
Search for all peaks (higher than neighbors)

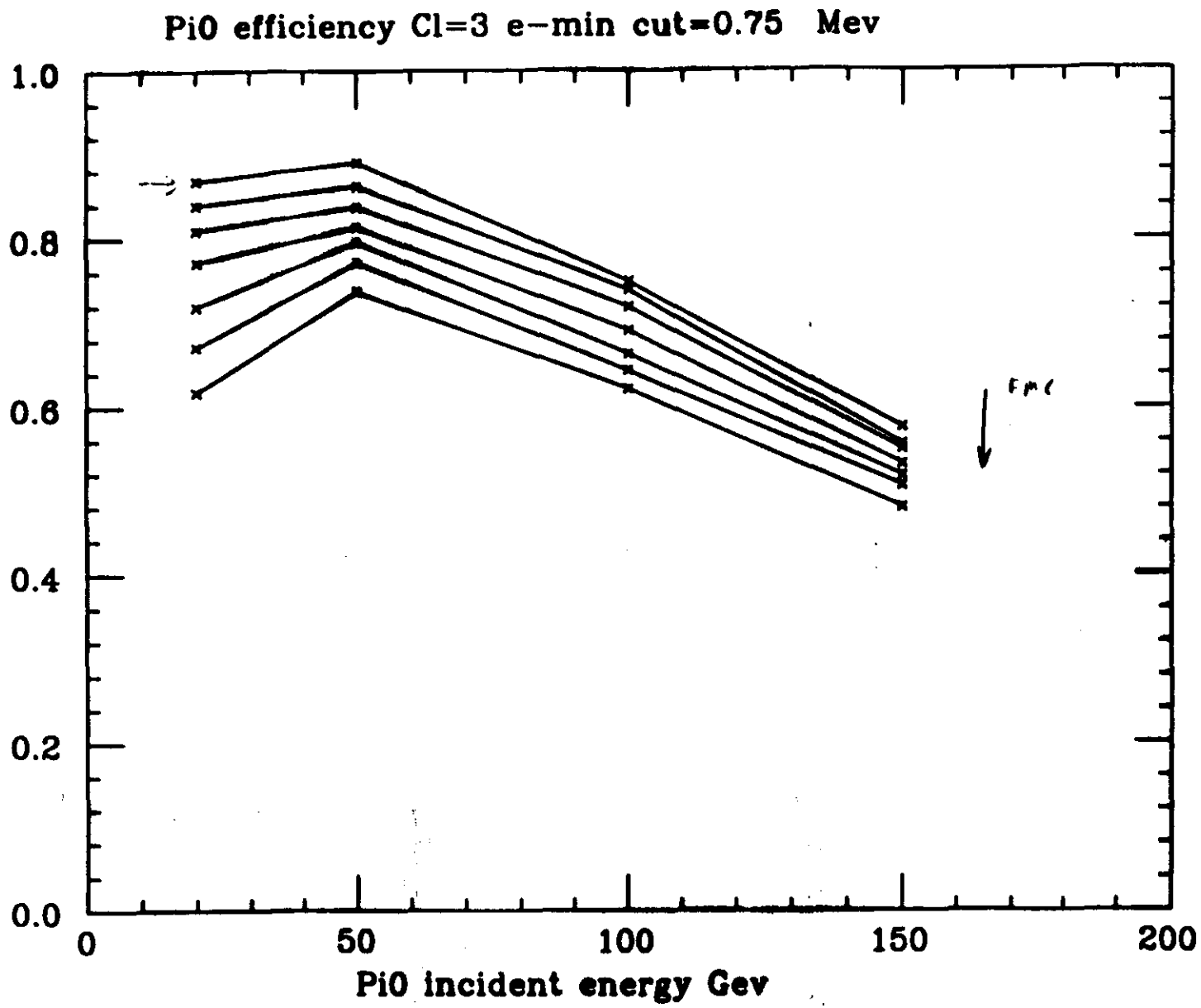
applying E_{min}, E_{max}

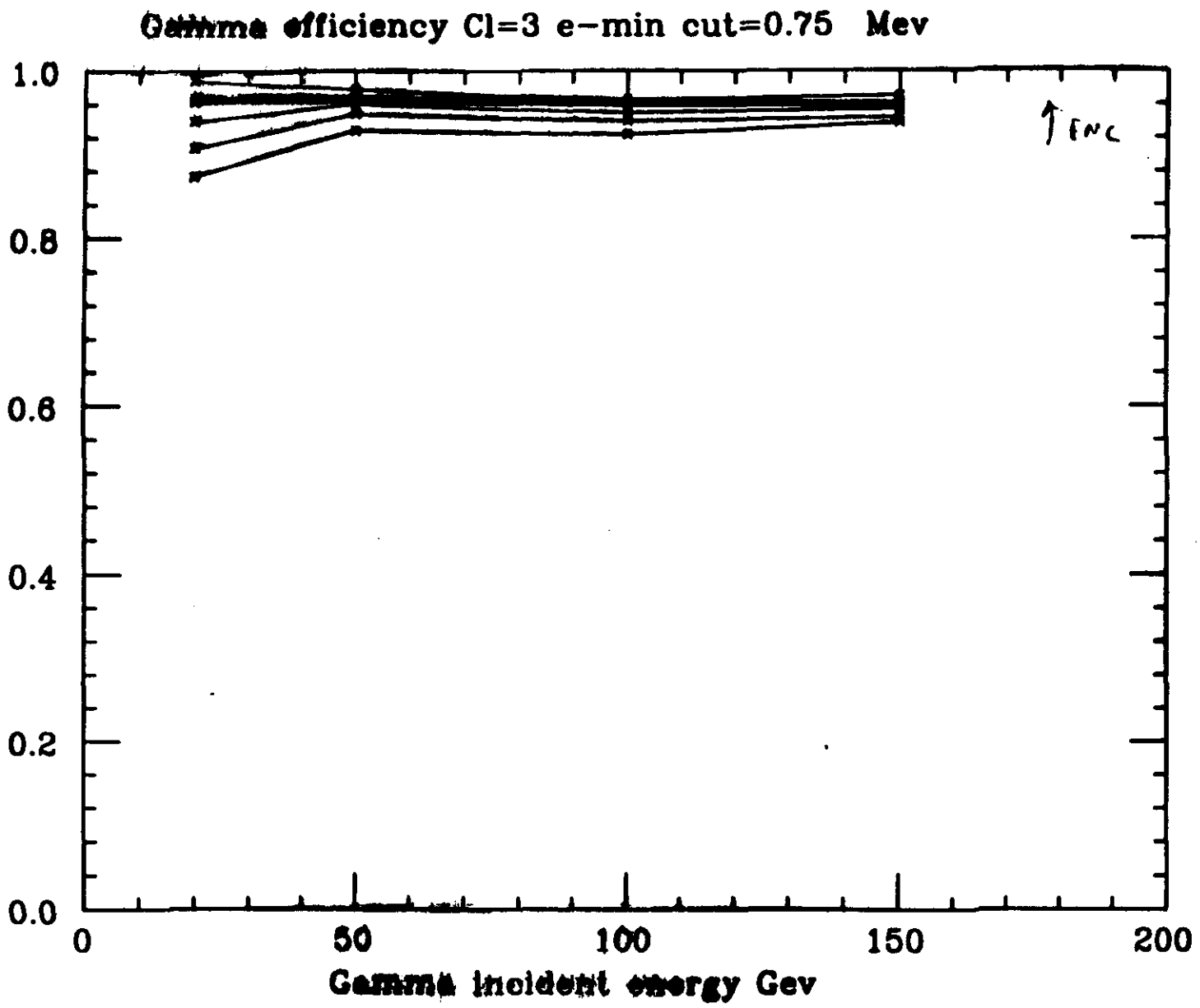
Require $E^{2nd\,pk} / E^{highest\,pk} > .4$

$|\langle x \rangle_{pk} - \langle x \rangle_{pol}| < 1.5\,mm$


Pi0 efficiency Cl=3 e-min cut=0.125 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Pi0 incident energy Gev


Gamma efficiency
e-min cut=0.125 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Gamma incident energy Gev
FMC

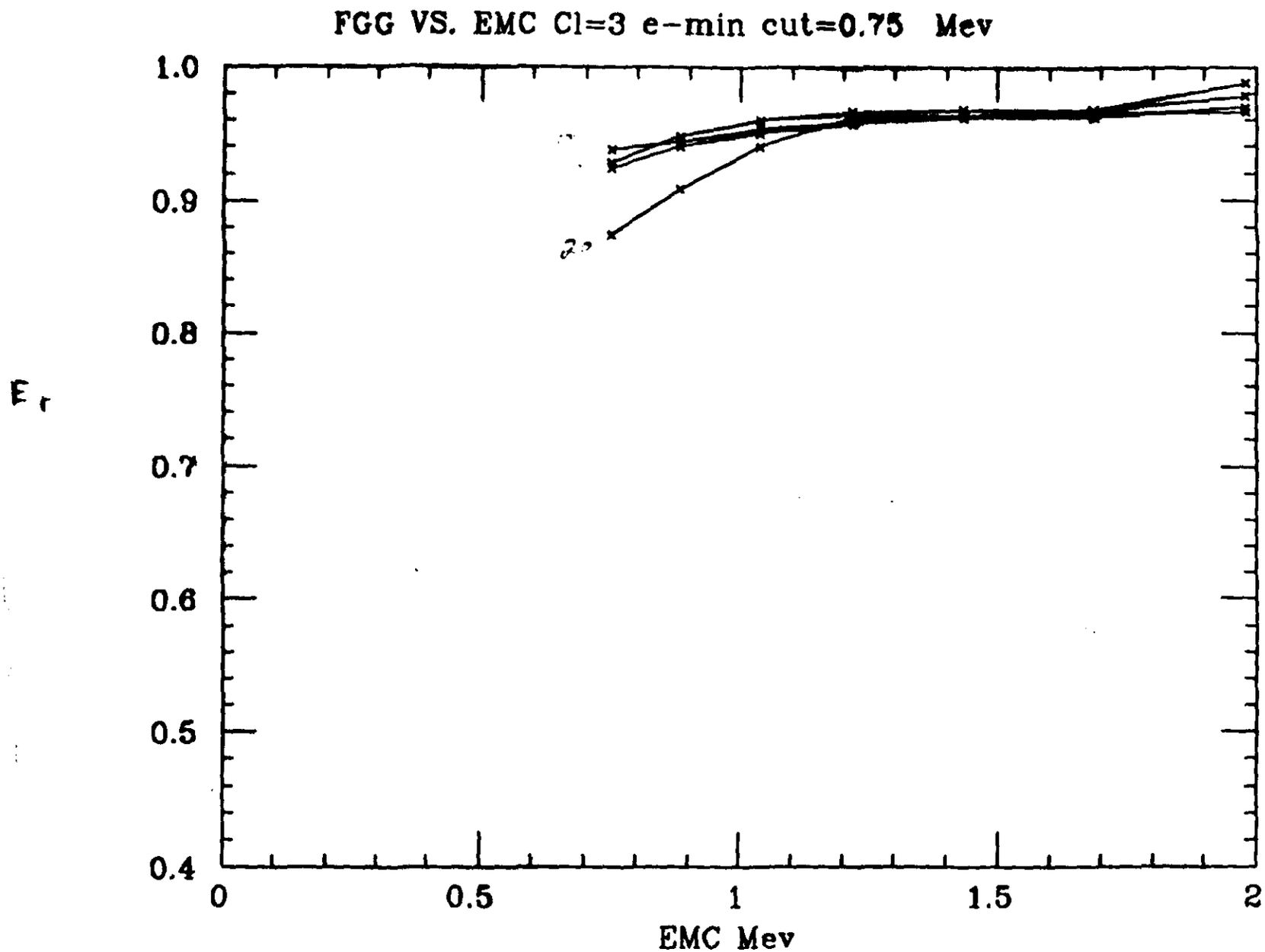

Pi0 efficiency Cl=3 e-min cut=0.75 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Pi0 incident energy Gev
Fmc

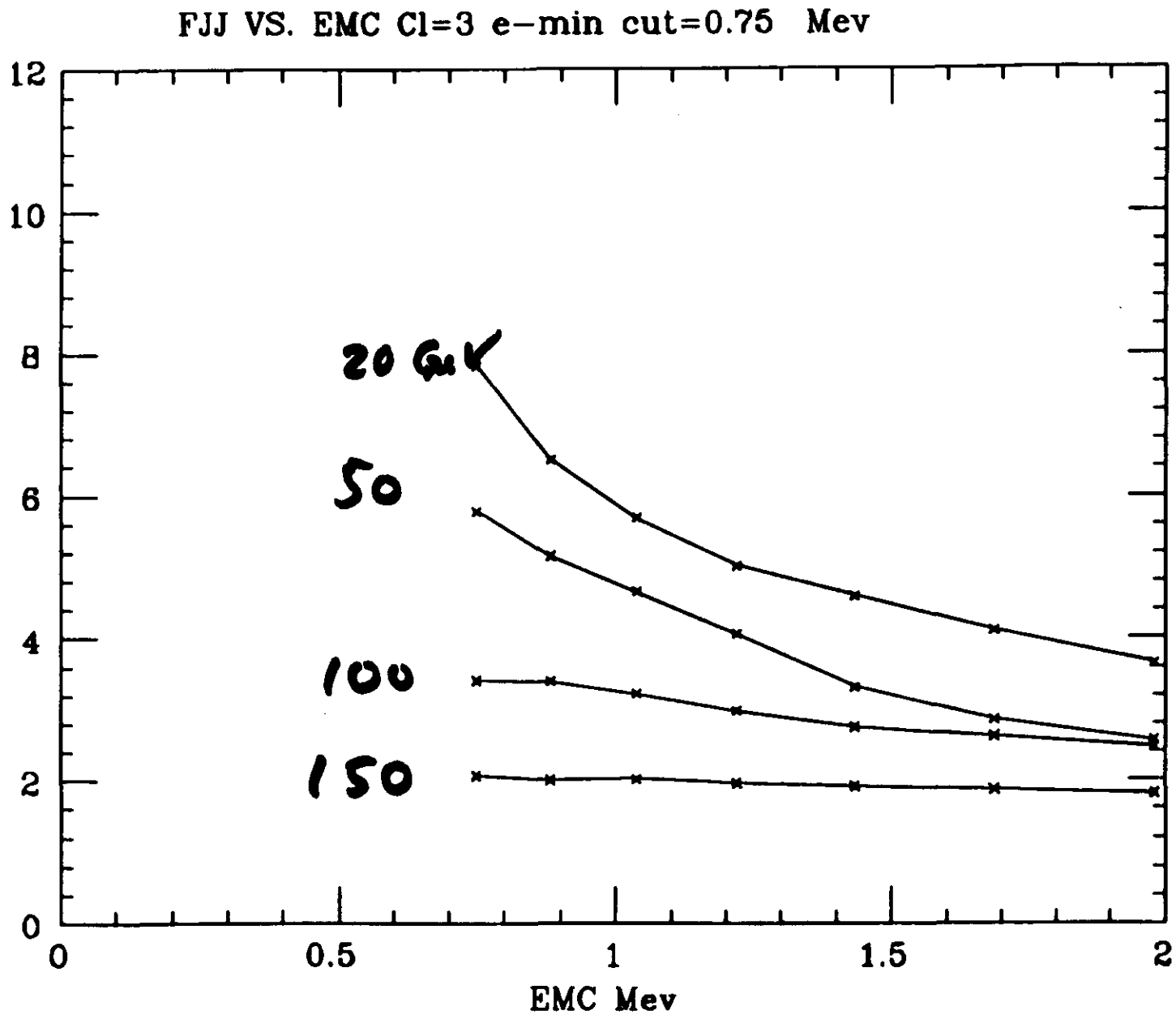

Gamma efficiency Cl=3 e-min cut=0.75 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Gamma incident energy Gev
FNC

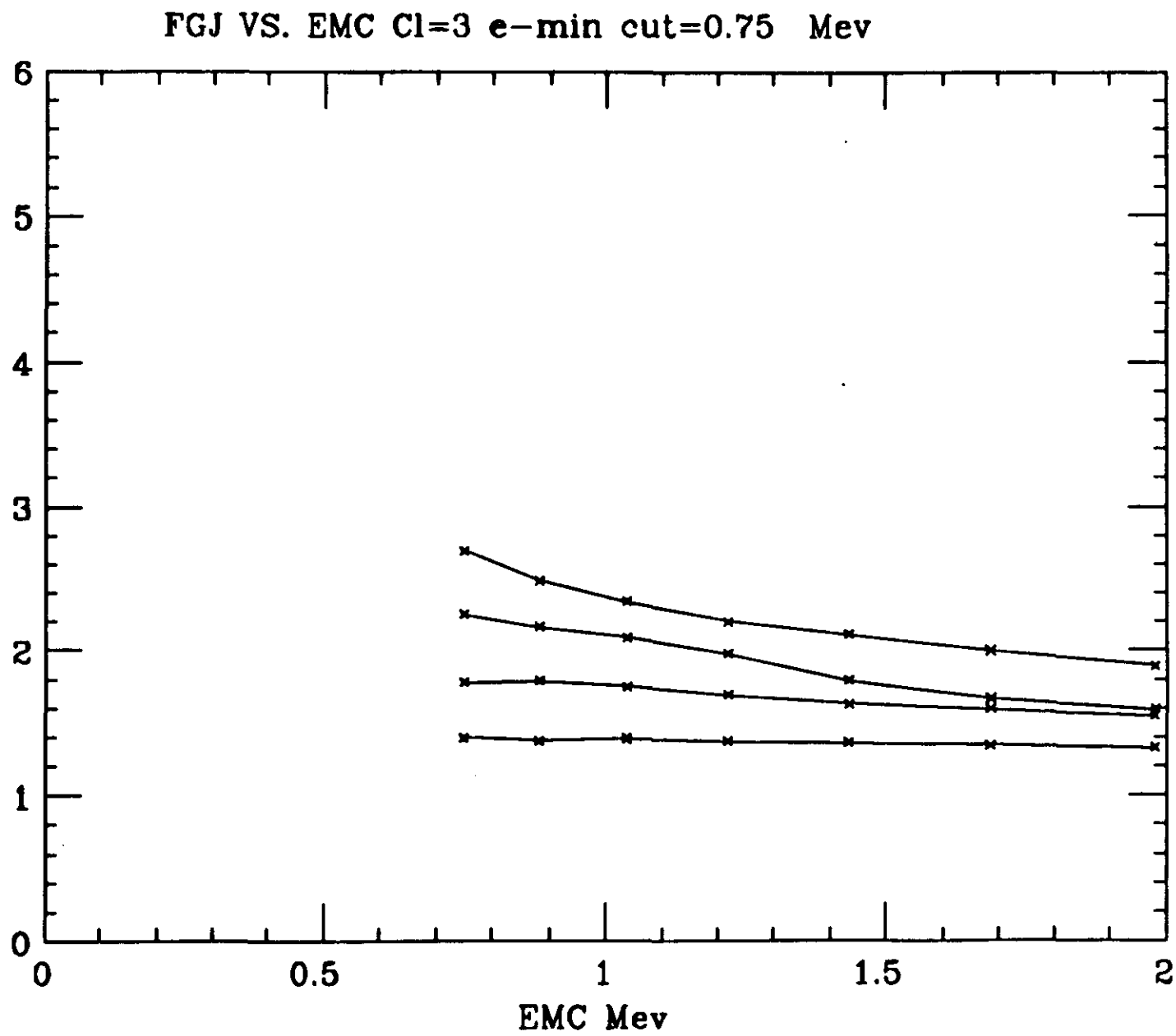
$$F_{ss} = \frac{\epsilon_\gamma^2}{1-\epsilon_{\pi^0}}$$

$$F_{\gamma s} = \frac{\epsilon_\gamma^2}{\sqrt{\epsilon_\gamma(1-\epsilon_{\pi^0})}}$$

$$F_{\gamma\gamma} = \epsilon_\gamma$$


FGG VS. EMC Cl=3 e-min cut=0.75 Mev
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
0.5
1
1.5
2
EMC Mev


FJJ VS. EMC Cl=3 e-min cut=0.75 Mev
12
10
8
6
4
2
0
0
0.5
1
1.5
2
EMC Mev
20 GeV
50
100
150


FGJ VS. EMC Cl=3 e-min cut=0.75 Mev
6
5
4
3
2
1
0
0
0.5
1
1.5
2
EMC Mev

SIGNIFICANCE ENHANCEMENT FACTOR (S_F)

APPROXIMATELY:

$$S_{IG} \sim \frac{N_{HIGGS \to \gamma\gamma}}{\sqrt{B_{\gamma j} + B_{jj} + B_{\gamma\gamma}}}$$

ASSUME $B_{\gamma j} \approx B_{jj} \approx B_{\gamma\gamma} \equiv B$

THEN

$$S_{IG} \longrightarrow \frac{\epsilon_\gamma^2 \, N_{HIGG \to \gamma\gamma}}{\sqrt{\epsilon_\gamma \bar{\epsilon}_j \, B_{\gamma j} + \bar{\epsilon}_j \bar{\epsilon}_j B_{jj} + \epsilon_\gamma^2 B_{\gamma\gamma}}} \equiv S_F(S_{IG})$$

$$\boxed{S_F = \frac{\epsilon_\gamma^2}{\sqrt{(\epsilon_\gamma \bar{\epsilon}_j + \bar{\epsilon}_j^2 + \epsilon_\gamma^2)/2}}}$$

$$\epsilon_j = 1 - \bar{\epsilon}_j$$

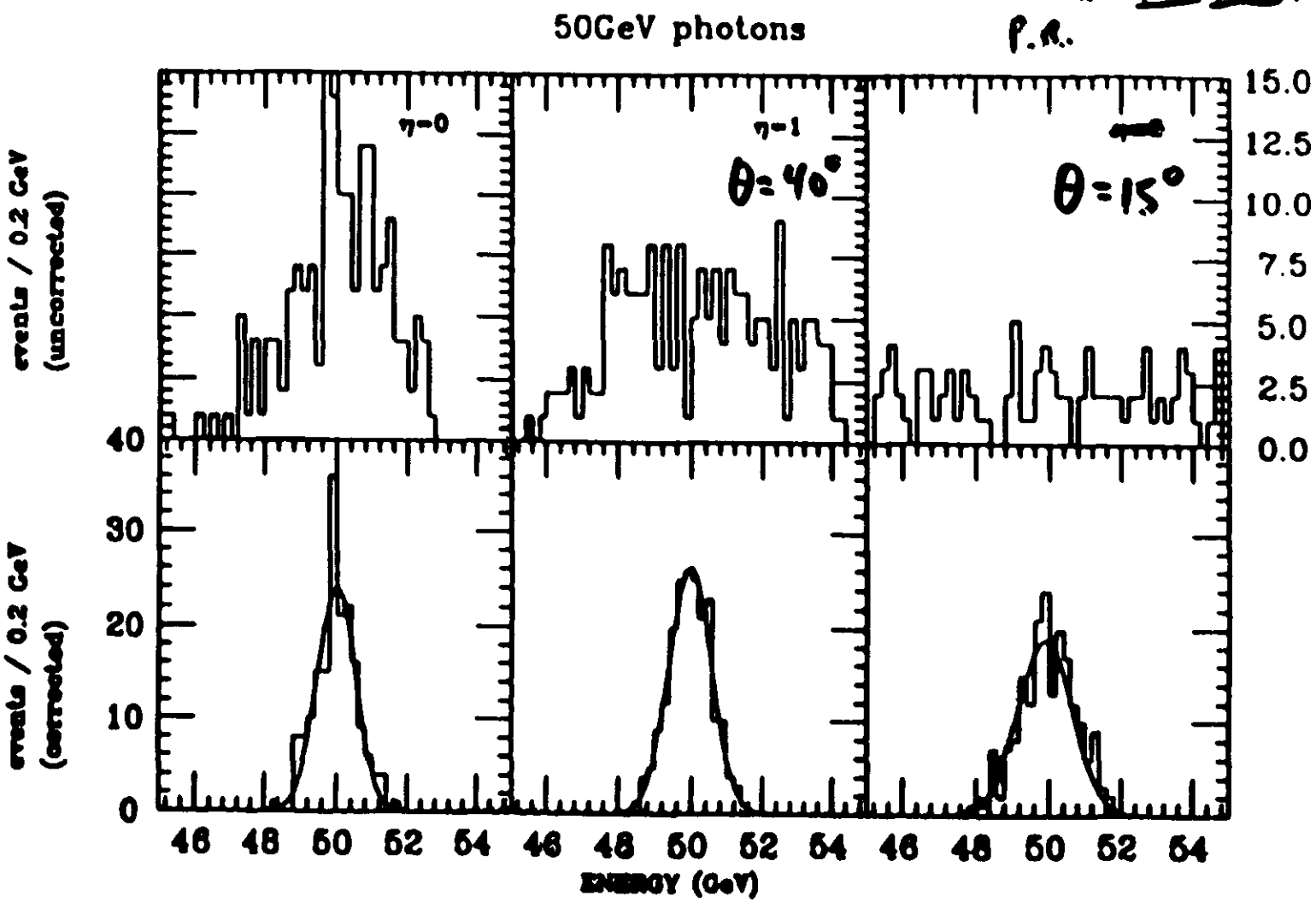


Figure 5. Uncorrected and corrected energy

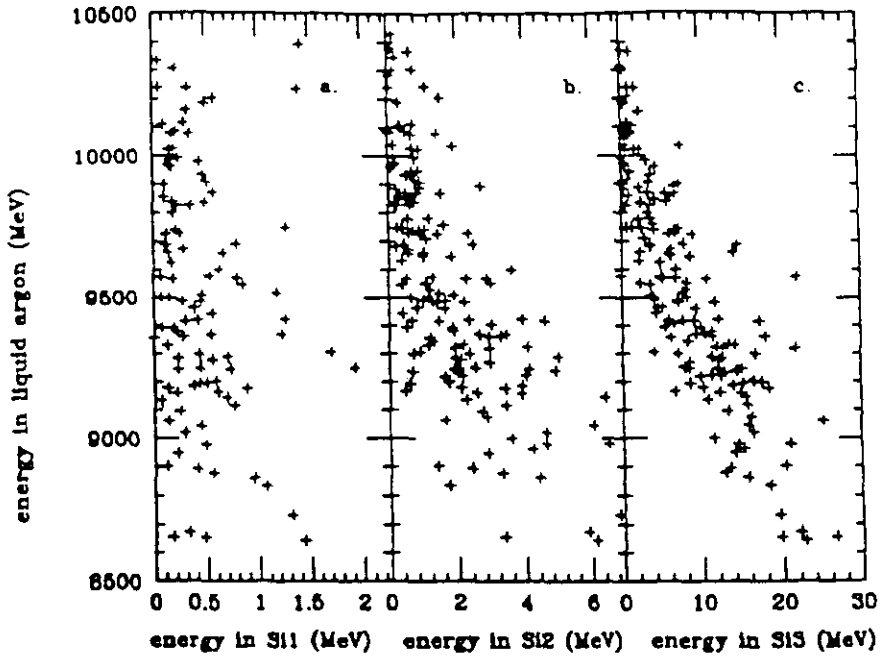


Figure 3. Preshower: $0, 1, 2X_0$ ($\eta = 1$)

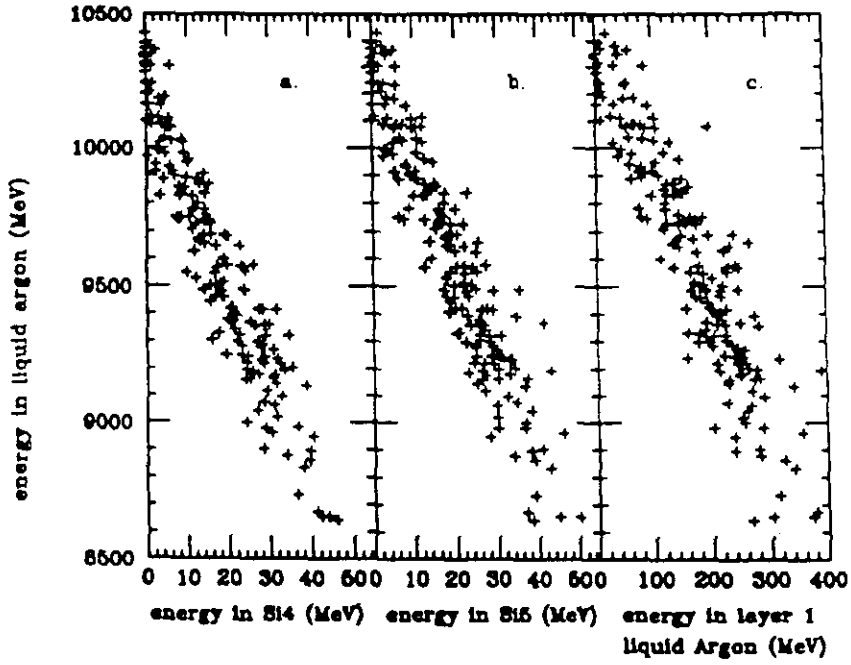


Figure 4. Preshower: $3, 3.7, 4.5X_0$ ($\eta = 1$)

Table 1.

Lead–Liquid Argon calorimeter (no pre–radiator)

particle type	incident energy (GeV)	η	number of events	energy in LAr (GeV)	σ_E (rms) (GeV)	$\frac{\sigma_E}{E} \times \sqrt{E_{in}}$ (%)	θ
e^-	10	0	400	2.04	0.047	7.3± 0.4	90°
e^-	50	0	206	10.2	0.105	7.3± 0.5	90°
γ	50	[illegible]	150	10.2	0.166	11.5± 0.9	15°

Table 2.

Pb/LAr calorimeter with $3X_0$ pre–radiator (uncorrected)

particle type	incident energy (GeV)	η	number of events	energy in LAr (GeV)	σ_E (rms) (GeV)	$\frac{\sigma_E}{E} \times \sqrt{E_{in}}$ (%)	
e^-	10	0	366	1.76	0.110	19.8± 1.0	90°
e^-	50	0	176	9.55	0.274	20.3± 1.5	90°
γ	50	0	120	9.81	0.302	21.8± 2.0	90°
γ	50	1	198	9.62	0.452	33.2± 2.3	40°
γ	50	[illegible]	192	8.57	1.05	86.6± 6.2	15°

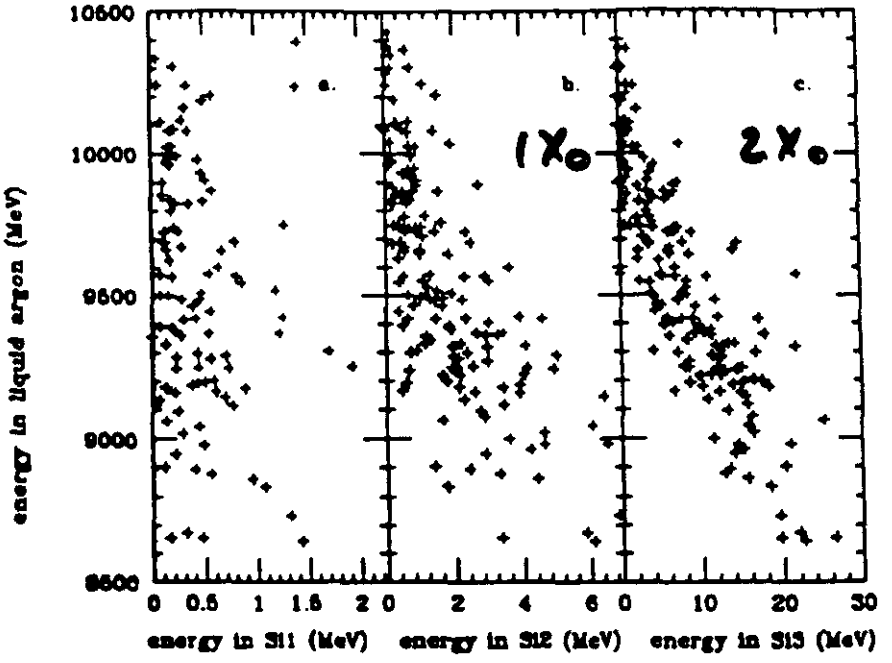
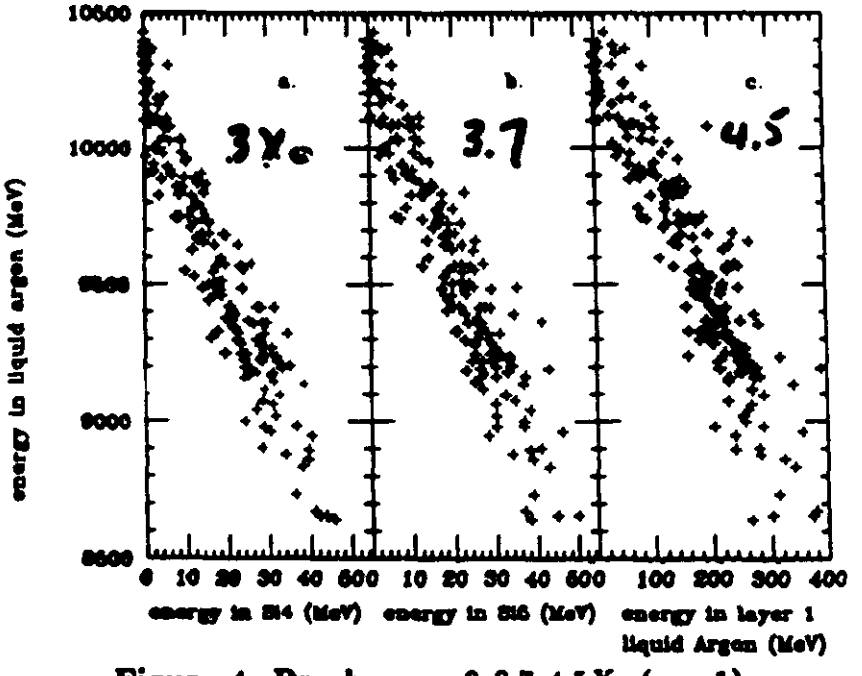


Figure 3. Preshower: $0, 1, 2X_0$ ($\eta = 1$)



$\theta = 40°$

Figure 4. Preshower: $3, 3.7, 4.5X_0$ ($\eta = 1$)

3.7 is behind 1st Dewar wall!!

4.5 is in LA cal

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Table 3.

Pb/LAr calorimeter with $3X_0$ preradiator (corrected)

particle type	incident energy (GeV)	η	number of events	$\frac{\sigma}{E}$	$\frac{\sigma_E}{E} \times \sqrt{E_{in}}$ (%)	$k_2 =$	comments	θ
e^-	10	0	366	2.9	9.1± 0.5	$2.3k_1$	optimal	90°
				3.0	9.4± 0.5	k_1	k_2 fixed	
e^-	50	0	176	1.1	7.5± 0.6	$2.3k_1$	optimal	90°
				1.1	7.8± 0.6	k_1	k_2 fixed	
γ	50	0	120	1.0	7.3± 0.7	$1.8k_1$	optimal	90°
				1.1	7.9± 0.7	k_1	k_2 fixed	
γ	50	1	198	1.2	8.3± 0.6	$0.69k_1$	optimal	40°
				1.2	8.5± 0.6	k_1	k_2 fixed	
γ	50	[illegible]	192	1.5	10.5± 0.8	$0.82k_1$	optimal	15°
				1.6	11.2± 0.8	k_1	k_2 fixed	

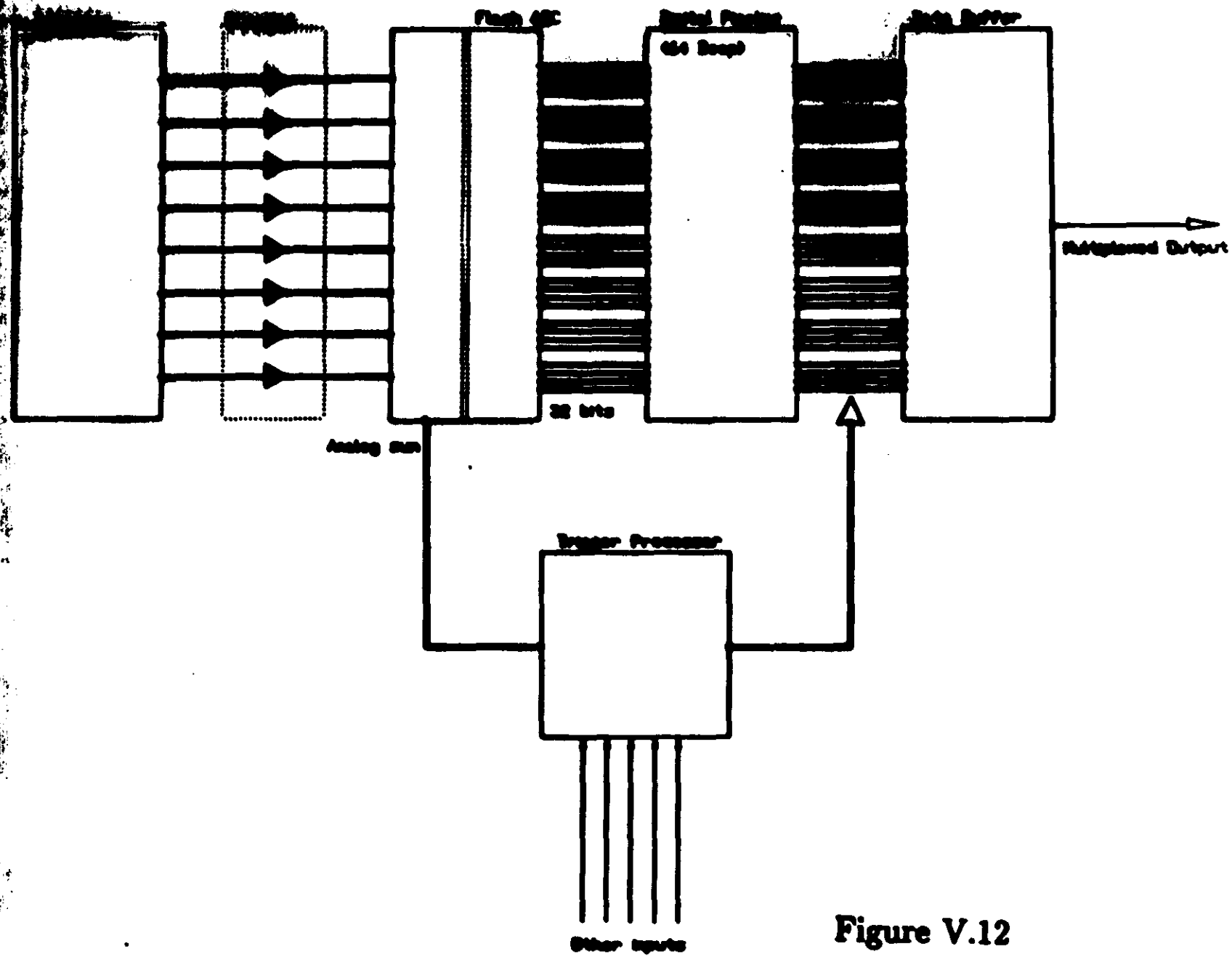
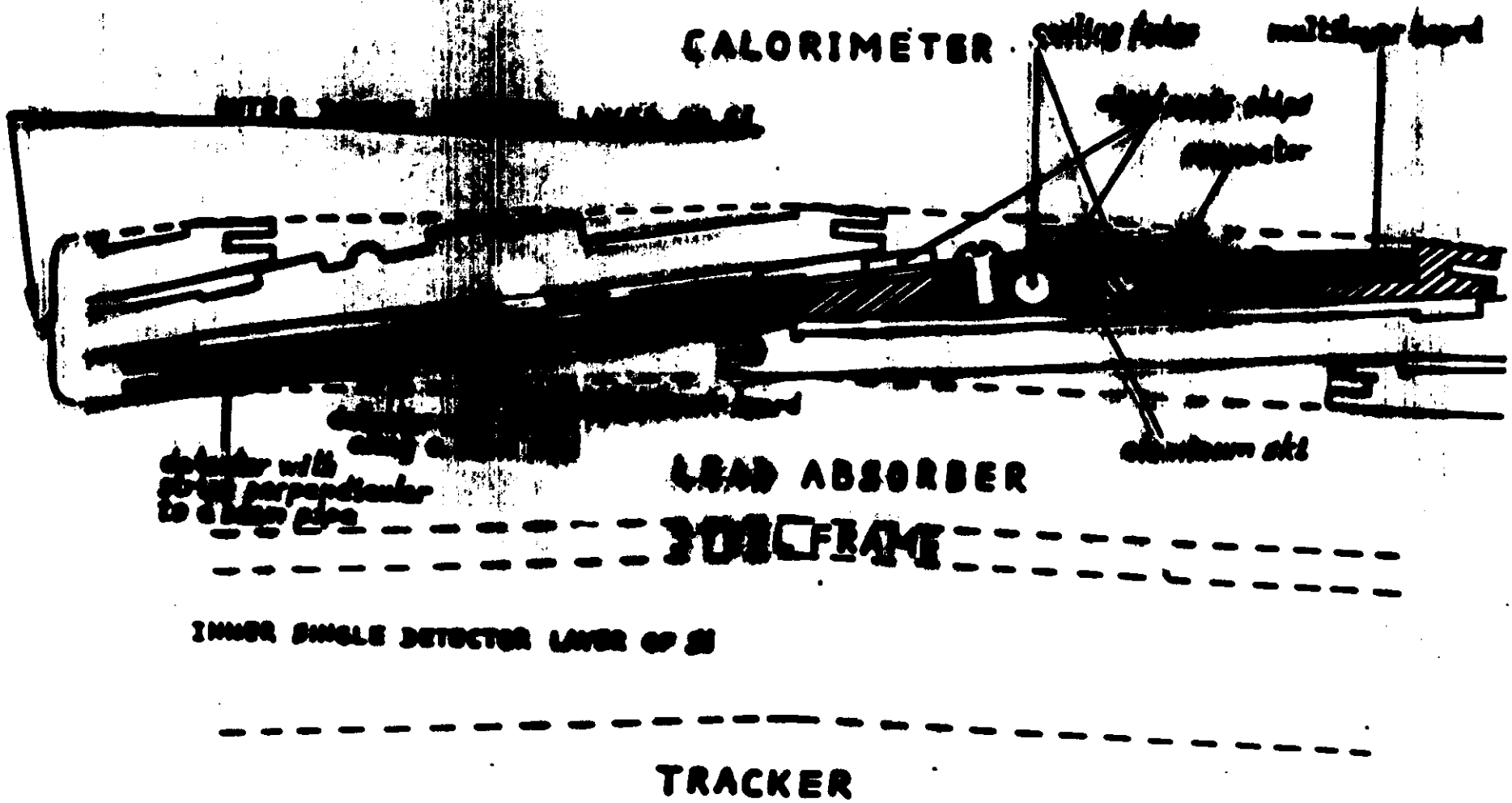
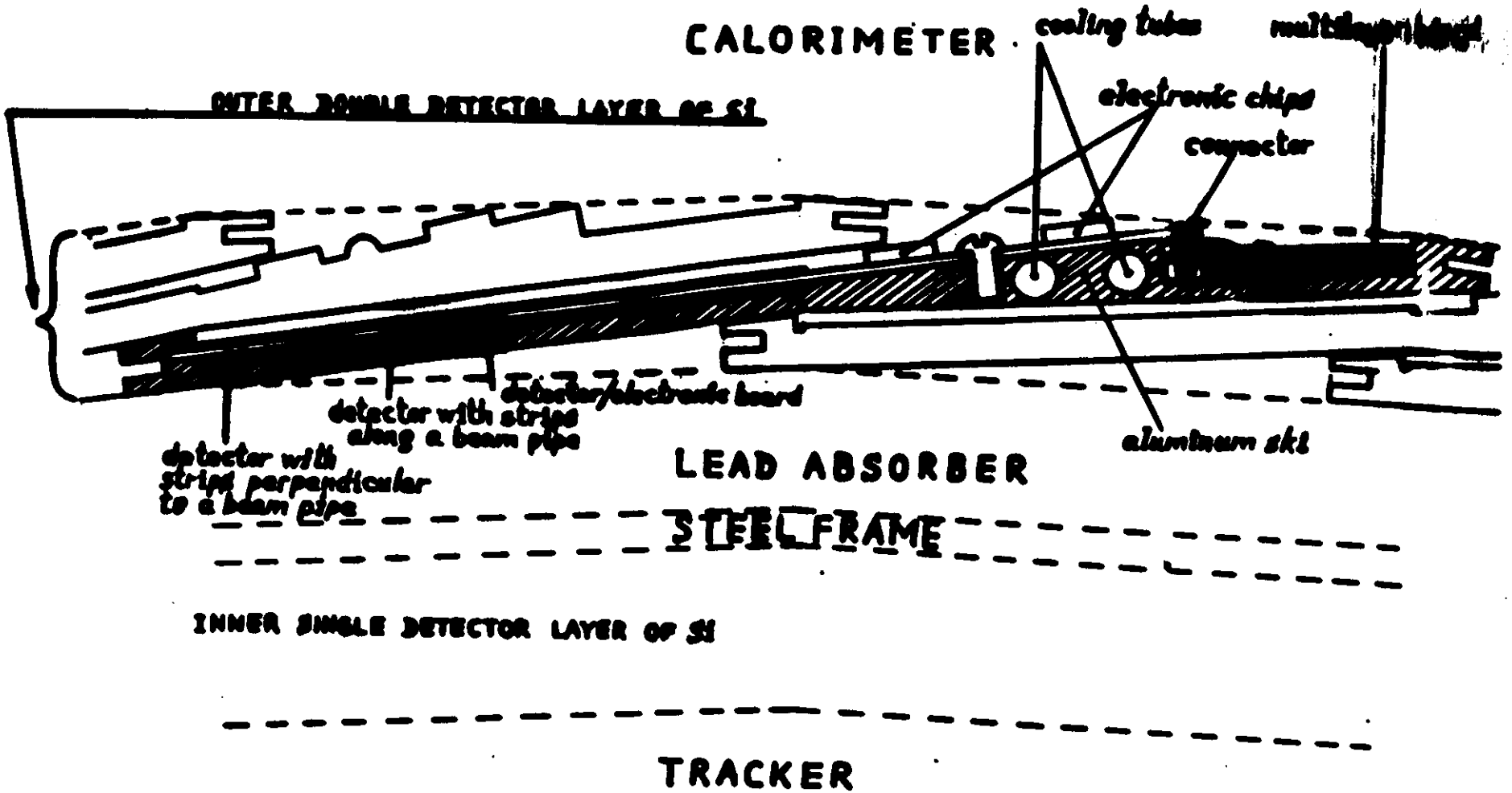

Flash ADC
64 Deep
32 bits
Analog sum
Trigger Processor
Other inputs

Figure V.12

PREFRAME DRAWING 1

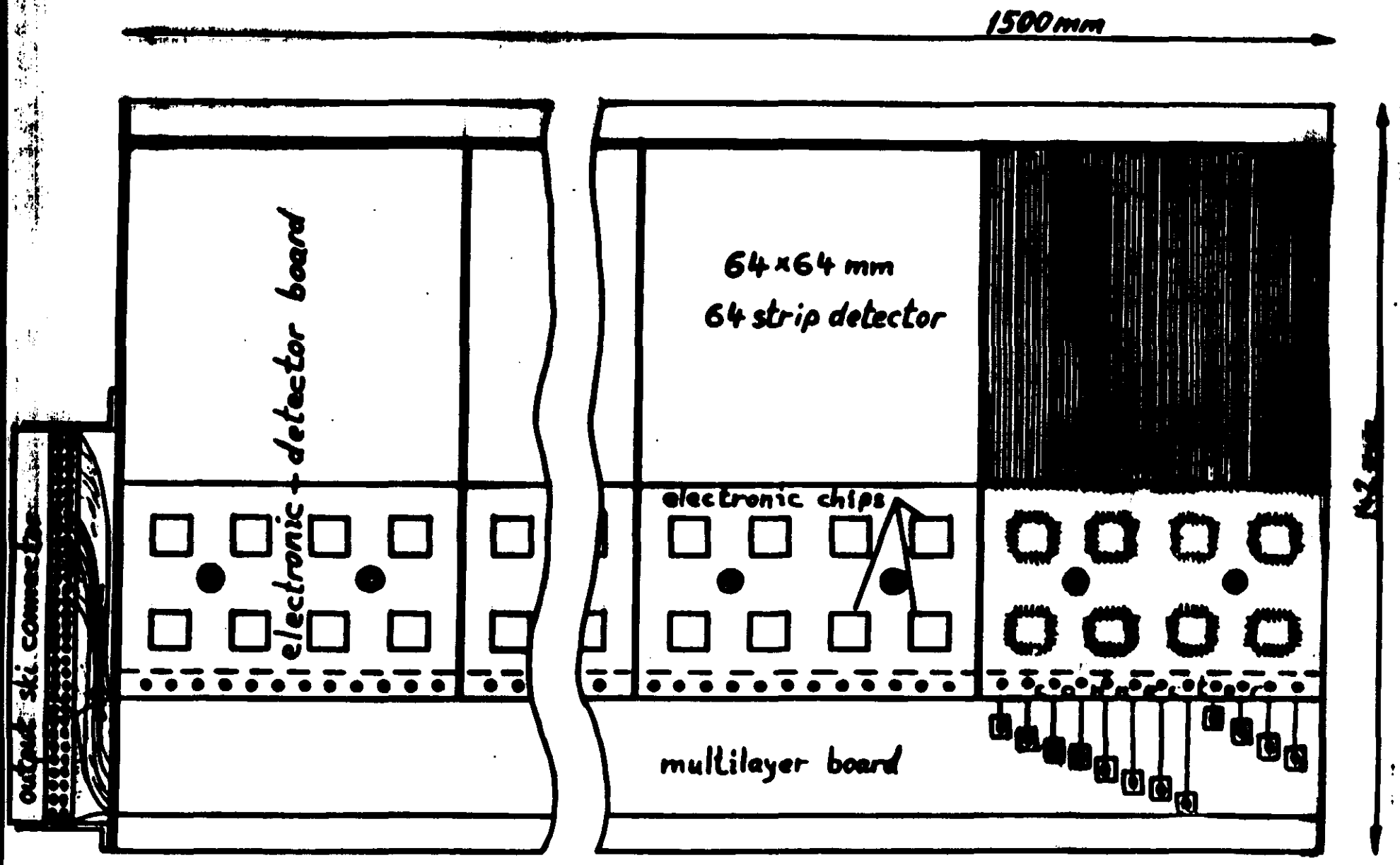


PRERAD DRAWING



PRERAD DRAWING

ALUMINUM SKI top view



SCIENTIFIC - INDUSTRIAL ASSOTIATION
E L M A
103460 Moscow Russia
Telephone: (7)(095)531-7651, Fax: (7)(095)531-0976

Prof. P.F.Ermolov
Dr. G.L.Bashindzhagyan
Moscow State University

According to your request we have investigated and calculated a cost estimation for a possible strip detector production at ELMA for GEM detector at SSC.

Size	64 x 64 mm^2
Thickness	0.4 mm
Pitch	1 mm
Leakage current for 95% of strips	5 - 15 nA/strip
Leakage current	up to 200 nA is acceptable for 5% of strips
Bias voltage	less than 100 V

A cost estimation for a lot of 10,000 detector production is $ 400,000. 400 kg float zone n-type silicon ingots with resistivity 5-10 kOhm*cm and 100 mm diameter have to be supplied by customer.

General Director

L.A.Ivaniutin

S.A.LAVOCHKIN SCIENTIFIC - INDUSTRIAL UNION
24 Leningrad Rd., Himky 141400 Moscow USSR
Telex: 911721 IRBIS SU Fax: (7) (095) 573-3591

Prof. P.F.Ermolov
Dr. G.L.Bashindzhagyan
Moscow State University

A possibility to design and produce ski type mechanical units for GEM detector at SSC was discussed at Lavochkin Scientific-Industrial Union. As a result of the discussion and analysis of the ski structure the following cost estimation was calculated:

- for total order around 300 skis made from AMG-6 hard aluminum the price of one ski production is $ 250 - 300, including expences on mechanical ingeneering and special equipment.

Total price for all 300 ski order is around $ 75,000 - 90,000.

General Director

A.M.Baklunov

M I C R O T E C H
Scientific - Industrial Firm
91 Pervomaiskaya, Sverdlovsk, 620219, USSR
Telephone: (7)(095) 440019, Fax: (7)(095) 445040

Prof. P.F.Ermolov
Dr. G.L.Bashinzhagyan
Moscow State University

In according with your request MICROTECH Scientific-Technical Counsil examined a possibility of a multilayer cards production and assembling with silicon detectors and VLSI chips for GEM detector at SSC.

A cost estimation for order of 7,500 units is $45 per one fully assembled card (a price of detectors and VLSI chips is not included). The price for total order is $337,500. A multilayer card design could be done in cooperation with customer's electronic engineers.

General Director V.I.Alimov

Technical Director A.V.Vlasov

Preradiator Prototype

Version 1 – Si pads + ORNL preamps/shaper

will be completed this month

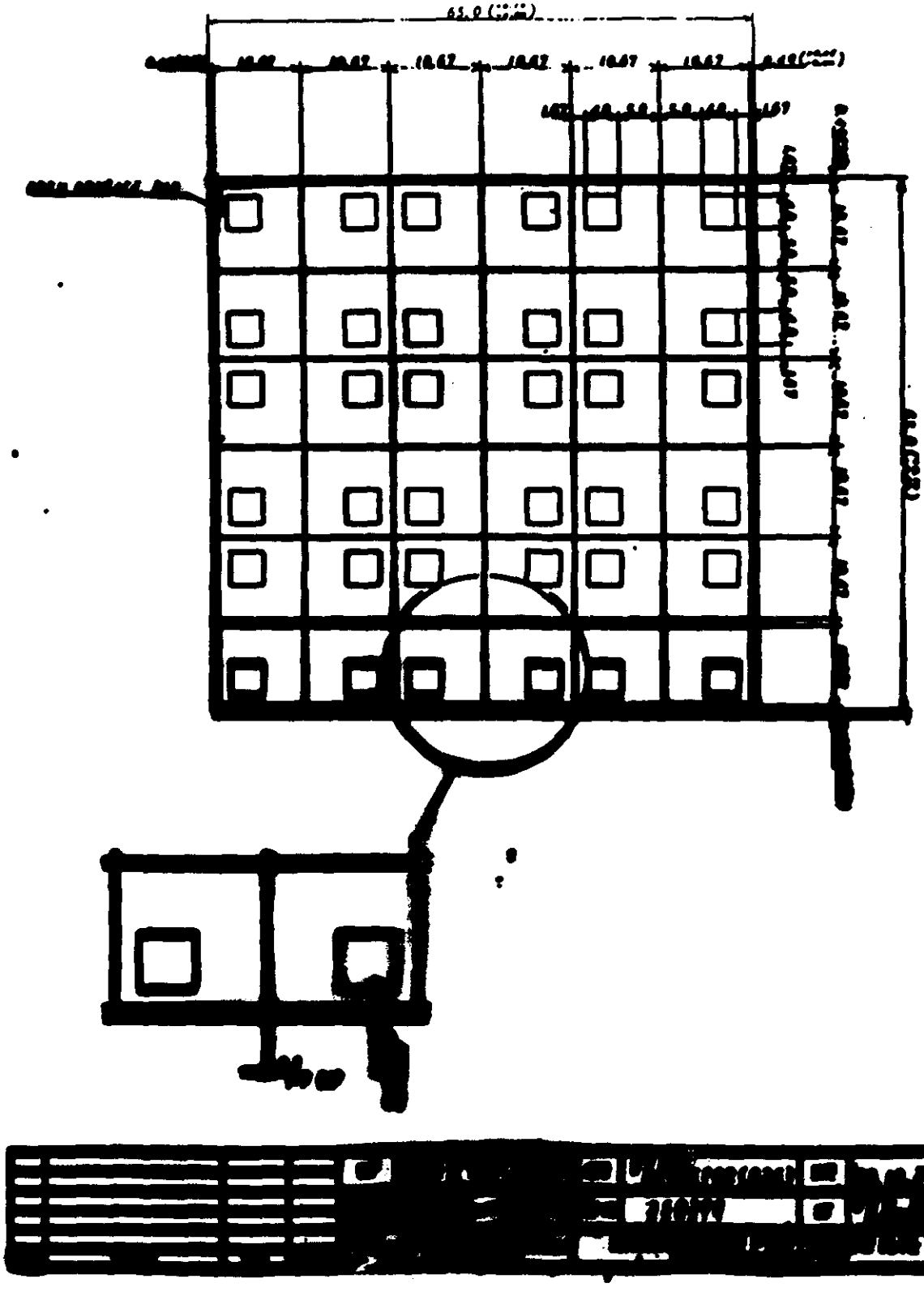
plan to test at FNAL w/

BaF_2 killed by Dec 23 shutdown

test in '98 @ BNL? CERN?

Version 2 – 1mm Si strips

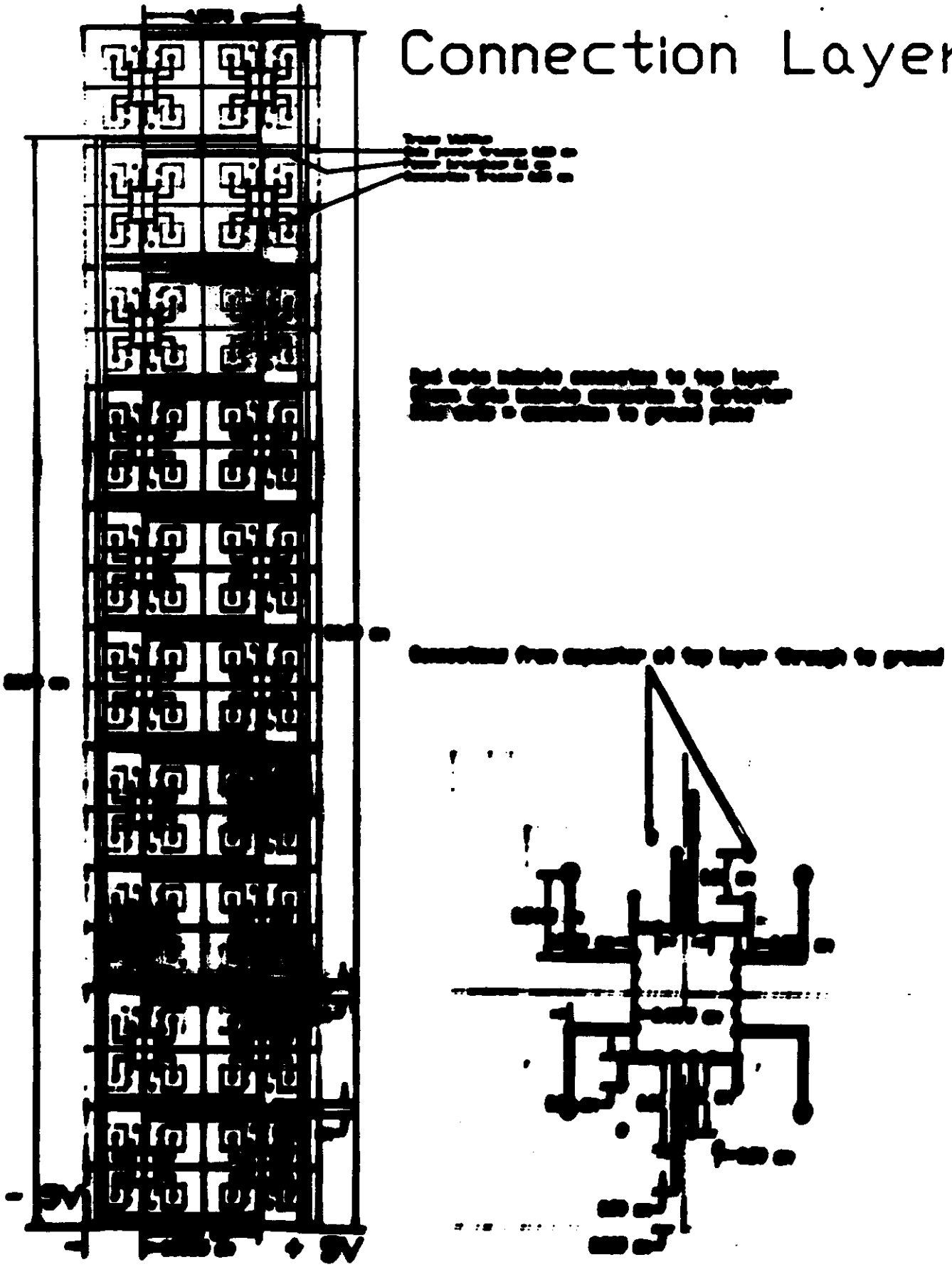
under construction



[redacted]

[redacted]

Connection Layer



Progress on GEM Scintillating Fiber Hadron Calorimeter

Bill Worstell

GEM Calorimeter
Working Group Meeting

December 4, 1991

SSCL

Collaboration & Mission

1) We have made progress in coordinating and synthesizing the capabilities and efforts of the former scintillating fiber and liquid scintillator groups.

2) We have expanded our research program to more directly address several key issues which were raised by the GEM calorimetry working group during our recent technology decision meeting:

   a) Longitudinal Segmentation
   b) Long-term Stability + Radiation Damage
   c) Calibration Systems
   d) Photomultiplier + Readout Systems

3) Our R & D Budget request has been modified to reflect the increase in scope of our mission and the strengthening of our team.

Table II

SSCintCal R & D Budget

before additional missions of long term stability and longitudinal segmentation

	TOTAL	BU	FAIRFIELD	MSU/LSU	UCSD
1. GEM PROTOTYPE	430	350		80	
1.1 Operations	120	70		50	
1.2 Equipment	310	280		30	
2. SPACAL/CERN	90				90
2.1 Operations	38				38
2.2 Equipment	52				52
3. TEST BEAM	25			25	
3.1 Operations	25			25	
4. CALIBRATION	49		49		
4.1 Operations	21		21		
4.2 Equipment	28		28		
5. PMTs + DAQ	16		16		
5.1 Equipment	16		16		
OPERATIONS	204*	70	21	75	38
EQUIPMENT	406	280	28	30	52
TOTAL	610*	350	49	105	90

*Overhead (33% x $204K=$70K) not included.

Table I

Proposed Total SSCintCal R & D Budget (SSC and TNRLC)

with new missions of long term stability and longitudinal segmentation

	TOTAL	BU	FAIRFIELD	IOWA	MSU/LSU	UCSD	UT/ORNL	UMISS	LLNL
1. GEM PROTOTYPE	430	350			80				
1.1 Operations	120	70			50				
1.2 Equipment	310	280			30				
2. SPACAL/CERN	90					90			
2.1 Operations	38					38			
2.2 Equipment	52					52			
3. TEST BEAM	70				25		15	30	
3.1 Operations	60				25		15	20	
3.2 Equipment	10							10	
4. LONG TERM STABILITY									
& RADIATION DAMAGE	90						60	30	
4.1 Operations	70						50	20	
4.2 Equipment	20						10	10	
5. CALIBRATION	79		49				30		
5.1 Operations	41		21				20		
5.2 Equipment	38		28				10		
6. PMTs + DAQ	360			95			115		150
6.1 Operations	260			45			75		140
6.2 Equipment	100			50			40		10
7. LONGITUDINAL									
SEGMENTATION	110	50				60			
7.1 Operations	50	20				30			
7.2 Equipment	60	30				30			
OPERATIONS	604*	90	21	45	75	68	160	40	105
EQUIPMENT	590	310	28	50	30	82	60	20	10
TOTAL	1194*	400	49	95	105	150	220	60	115

* Overhead (33% of $327K = $109K) on SSC/DOE (but not on TNRLC) operations not included.

Sixteen Tower Prototype

Segmentation:	0.1		RADIAL	
Total Towers:	16	Each	Location	
Types of Towers	2	"A" & "B"		
Inner Radius	141	cm	R1	
Bottom Cap Thickness	0.5	cm	R2	
Absorber Length	178.5	cm	R3	
Top Plate Thickness	2.5	cm	R4	
Readout Plate Thickness	1	cm	R5	
Readout Abs Thickness	12.5	cm	R6	
Total Tower Height	195	cm		
Sheath Wall Thickness	0.19	cm		
Gap Between Towers	0.19	cm		
WLS Fiber	3	mm		
Readout Fiber	1	mm		
Fiber Spacing	0.765	cm		
Percent Lead Shot:	61.40%			
Percent Fiber:	11.30%			

Tower Module Dimensions		Coverage		Centerline	R1	R2	R3	R4	R5	R6
		Deg.	Deg.	Deg.	cm	cm	cm	cm	cm	cm
Type A	Deg	0.00	5.72	2.86	141.28	141.78	320.63	323.13	324.13	336.66
	Radian	0.00	0.10	0.05						
Type B	Deg	5.72	11.38	8.55	141.82	142.33	321.87	324.38	325.39	337.96
	Radian	0.10	0.20	0.15						

Bill Of Materials

	Quantity	Surplus	Tot. Quant.	Units	Unit Price	Price	
Tower Sheaths	399.50	6.25%	424.47	Kg	$12.12	$5,145	
Top Plate	290.18	6.25%	308.31	Kg	$25.00	$7,708	
Bottom Plate	128.24	6.25%	136.25	Kg	$12.12	$1,651	
Readout Sheath	64.66	6.25%	68.70	Kg	$12.12	$833	
Eutectic	6195.65	20.00%	7434.78	Kg	$5.58	$41,486	
Lead Shot	11952.11	20.00%	14342.54	Kg	$0.99	$14,199	
3 mm Fiber	27049.55	20.00%	32459.46	Meters	$1.73	$56,155	
1 mm Fiber	8400.00	20.00%	10080.00	Meters	$0.35	$3,528	
Light Mixer	16.00	6.25%	17.00	Each	$45.00	$765	
PMT	64.00	6.25%	68.00	Each	$300.00	$20,400	EST
Readout Bracket	16.00	6.25%	17.00	Each	$100.00	$1,700	Est
Framing	1.00	0.00%	1.00	Each	$2,500.00	$2,500	Est
Spacers	160.00	10.00%	176.00	Each	$5.00	$880	Est
Molds	2.00	0.00%	2.00	Each	$10,000.00	$20,000	Est
Material Price						$176,950	

Weights			
Modular Assembly	19418.02	Kg	
Average Tower	1213.63	Kg	
Structure	1000.00	Kg	Estimate
Total	21631.65	Kg	

Volumes		
Modular Assembly	2,022,718	cc
Average Tower	126,419	cc

Status of 4-Ton Prototype

We are constructing a total of 6 1-Ton supertowers:

(4 physics towers each, each tower would be 0.05 eta x 0.05 phi at eta=0)

a) One cast tower with splice joints for fiber bundle readout is complete, machined and under bench test.

b) Four towers are under construction, a subset of which will be tested at FNAL subject to beam schedule (December 23 - January 8)

Characteristics:

No splice joints (scifi bundle readout)
89% eutectic/ 11% 2mm fibers

First ready to cast, second being threaded, fibers cut for third

Four towers at FNAL by Xmas.

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 -- 6th supertower w/ shot
   b) Fiber splice readout -- full-scale tests
   c) SS sheaths -- after casting for now

Key Questions to Resolve for 16-Ton Prototype

1) Supertower dimensions/segmentation:

   2.5-Ton Supertowers 0.16 eta x 0.16 phi may be optimal in long-term but may not be feasible short-term

   16 1-Ton 0.10 eta x 0.10 phi supertowers takes advantage of existing infrastructure

2) Degree of fidelity to long-term design which is feasible for short-term construction (August 1992 CERN Beamtest)

   a) Spherical vs. true GEM geometry
   b) Mesh dynode PMT readout ($)
   c) Specification of sheaths and mechanical support structure

3) Longitudinal Segmentation:

   a) Specifications for physical segmentation
   b) Off-shelf vs. dedicated electronic segmentation

Schedule & Deadlines

1) 4-Ton prototype:

   a) To FNAL by Xmas
   b) Lead shot supertower in January
   c) Fiber splice readout tested by January
   d) BNL spring run?

2) 16-Ton prototype

   a) Request for Quotations to Fiber Vendors
      Division of inside/outside preform preparation is key question

      Purchase order placed before Feb. 1

   b) Photomultipliers selected and ordered before Feb. 1

   c) Special order for splice/spacer plates by Feb. 1

3) We expect to begin construction of first new supertowers in March/April 1992.

GOAL: Total hadronic containing test, projectile, constant term, linearization
enough $ to do the job... by August '92?

SSCintCal Status Report
.. the R&D request

FY91 SSC R&D [illegible] 4 prototype towers [illegible]

FY92 GEM R&D Request – 13 towers, July '91 $ 923K
EM + Hadronic

→ remove EM section

[SSC R&D Request } no IDC Sept 15, '91 $ 738K
[TNRLC Request } Nov 1, '91 $ 738K
to be reviewed 12/12-13/91

→ remove forward calorimetry Nov 6 Meeting
GEM CALORIMETRY RECOMMENDATION

but GEM DECISION MEETING + SUBSYSTEM REVIEW
⇓
New Missions 1.) Longitudinal Segmentation
a.) tail catcher
b.) electronic depth of shower } Ele.
c.) transverse segmentation for "effective" longitudinal
2) Long Term Stability
a.) [illegible] b.) rad damage

... a merged collaboration ...

Progress Report and Renewal Request to DoE and the SSC Laboratory

The Engineering and Testing of a Fiber Calorimeter Prototype For the Second Detector

The SSCintCal Collaboration

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Y. Kamyshkov, R.A. Lillie, F. Plasil, K. Read, M.J. Reanich,
A. Savin, K. Shmakov, R.H. Singeltary, A. Smirnov, E. Turkovsky, R.A. Todd, K.G. Young
Oak Ridge National Laboratory, Oak Ridge, TN 37831

E. Atkins, F. Augustin, R. Bionta, H. Britt, O. Champ, C. Cochran,
G. Grabow, M. Lowry, D. Manquelier, K. Strahan, C. Wuest
Lawrence Livermore Laboratory, Livermore, CA 94551

November 27, 1991

[illegible]

New GEM SSC R&D Request
Nov. 27, '91

Target Institutions — 15 institutions, 6 PhDs

Enhanced Research Mission

detailed in Appendices and referenced to similar tasks in regular scintillator program

Look with Iowa for TNRLC?

Oak Ridge

Linked for WRL

Tennessee

Partial Pulse [illegible]

Chemical Stability

Light Beam & Electronics [illegible]

Light Beam

Engineering Support Request Justification

Oak Ridge [illegible]

Recommended Budget Request (GEM Specific) — $610k

Total Required (with new optronic missions) — $1303k*

= Total of new request to TNRLC to be made — $693k

FY91 400
"110" vs initial TNRLC Request: 50

SSC Int Cal	$738k
Iowa	$110k
Mississippi	$50k

$560k "expected" from TNRLC

* assuming 35% IDC

... budget decision before merged R&D groups ?

Table II

SSCintCal R & D Budget

before additional missions of long term stability and longitudinal segmentation

	TOTAL	BNL	FAIRFIELD	MSU/LSU	UCSD
1. GEM PROTOTYPE	430	350		80	
1.1 Operations	120	70		50	
1.2 Equipment	310	280		30	
2. SPACAL/CERN	90				90
2.1 Operations	38				38
2.2 Equipment	52				52
3. TEST BEAM	25			25	
3.1 Operations	25			25	
4. CALIBRATION	49		49		
4.1 Operations	21		21		
4.2 Equipment	28		28		
5. PMTs + DAQ	16		16		
5.1 Equipment	16		16		
OPERATIONS	204*	70	21	75	38
EQUIPMENT	406	280	28	30	52
TOTAL	610*	350	49	105	90

*Overhead (33% x $204K=$70K) not included

* In FY91 we succeeded in shifting from the 91 to 3 ...
... all equipment to Brookhaven ...
... all operations to TNRLC ... [illegible]
[illegible] WE ASSUME WE (?) AROUND THE [illegible] ??

Table I

Proposed Total SSCintCal R & D Budget (SSC and TNRLC)

with new missions of long term stability and longitudinal segmentation

	TOTAL	BU	FAIRFIELD	IOWA	MSU/LSU	UCSD	UT/ORNL	UMISS	LLNL
1. GEM PROTOTYPE	430	350			80				
1.1 Operations	120	70			50				
1.2 Equipment	310	280			30				
2. SPACAL/CERN	90					90			
2.1 Operations	38					38			
2.2 Equipment	52					52			
3. TEST BEAM	70				25		15	30	
3.1 Operations	60				25		15	20	
3.2 Equipment	10							10	
4. LONG TERM STABILITY & RADIATION DAMAGE	90						60	30	
4.1 Operations	70						50	20	
4.2 Equipment	20						10	10	
5. CALIBRATION	79		49				30		
5.1 Operations	41		21				20		
5.2 Equipment	38		28				10		
6. PMTs + DAQ	360			95			115		150
6.1 Operations	260			45			75		140
6.2 Equipment	100			50			40		10
7. LONGITUDINAL SEGMENTATION	110	50				60			
7.1 Operations	50	20				30			
7.2 Equipment	60	30				30			
OPERATIONS	604*	90	21	45	75	68	160	40	105
EQUIPMENT	590	310	28	50	30	82	60	20	10
TOTAL	1194*	400	49	95	105	150	220	60	115

* Overhead (33% of $327K = $109K) on SSC/DOE (but not on TNRLC) operations not included.

Reminders to GEM SSCintCal Group:

1.) "SSCintCal Meeting" Just after the Calorimeter session

2) Conference Call - 2:30 EST every Thursday

Call Lori @ 617-353-9365
or email Lori @ BUPHY to get on.

list to long to call everybody everytime

3) If you didn't get "draft" of GEM SSCintCal R&D request
(call after mailing)

See Lori in mailing list not perfect!

Jet-Energy Measurement with a Non-Compensating Cal'r

Hans Paar, Richard Wigmans

1. Goals
2. Method
3. Some general results
4. Corrected Jet-energy
   Resolution
   Linearity
5. Conclusions

Acknowledge discussions with
Jim Branson, Yuri Kamyshkov

Goals

Want to measure E_{jet} with non-comp. calorimeter

Maximum reliance on prototype in test beams (e, π, multi part.)

Minimal reliance on models:

EGS	best
e/h	↓
$f(\pi^0)$	
fragmentation	
hadronic shower dev	worst

Method: BOTEC

100 lines of Fortran
random number generator
GAUSS integration (CERNLIB)

— Generate jets (à la Green):

$$D(z) = (\alpha+1)\,\frac{(1-z)^{\alpha}}{z}$$

$\alpha = 3$ agrees with LEP

$= 6$ " " CDF

Pions only, generate charge at random (40% π^0 on average)

— All π^0 energy in em section

— All $\pi^{\pm}$ energy à la Böck etal

$$dE = k\Big[\underbrace{w\, s^{a-1} e^{-bs}}_{\text{"}\pi^0\text{"}} + \underbrace{(1-w)\, t^{c-1} e^{-dt}}_{\text{"}\pi^{\pm}\text{"}}\Big]\, dz$$

$s = z/L_R$ $\qquad$ $t = z/L_{int}$

a, b, c, d, w depend on E_{in}

k = normalisation const.

- Each $\pi^\pm$ starts had shower at z_0 from $\exp[-z_0/1.5 L_{int}]$
- Choose $\omega(E_{in})$ to have π^0 energy fraction

$$f_{\pi^0} = 1 - \left[\frac{1}{E_{in}}\right]^{0.15} \quad \text{(Groom)}$$

- Low energy $\pi^\pm$ range out ionisation loss only

Detected energy

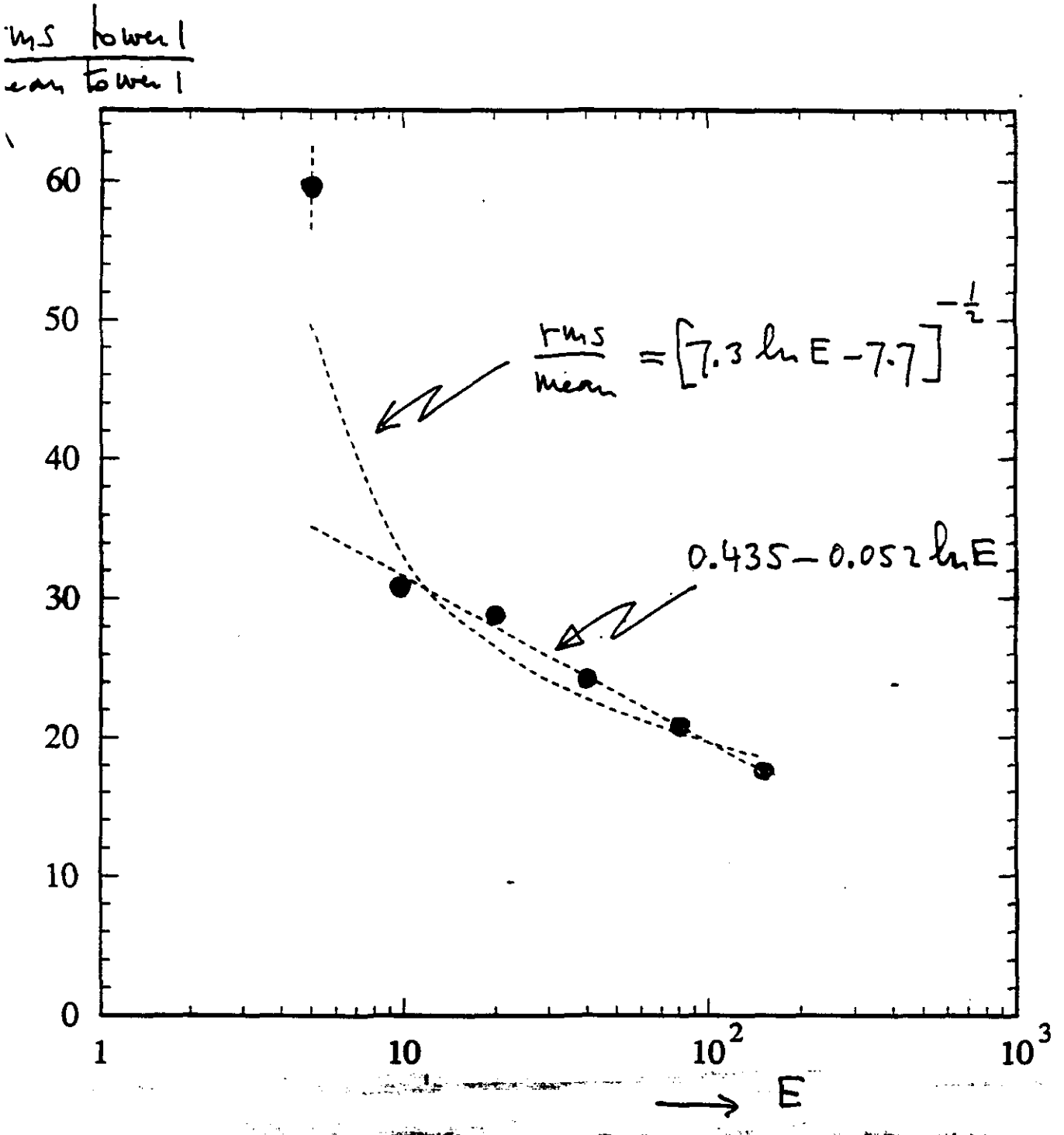
em, π^0: $E_{det} = \left(\frac{e}{h}\right) \times E_{dep}(\text{em}_{\pi^0})$

$\pi^\pm$: $1.00 \times E_{dep}(\pi^\pm)$

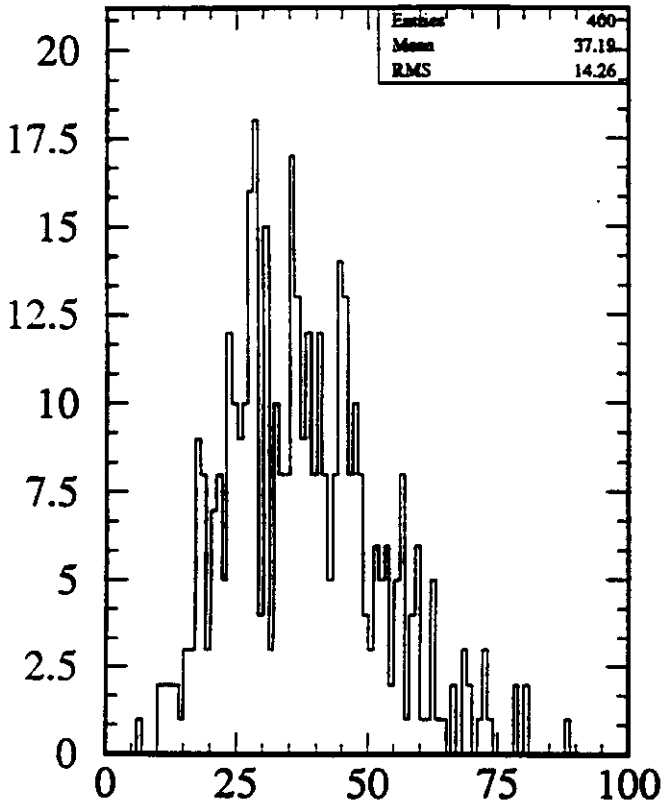
low E $\pi^\pm$: $\frac{mip}{h} \times E_{dep}(\text{ionis})$

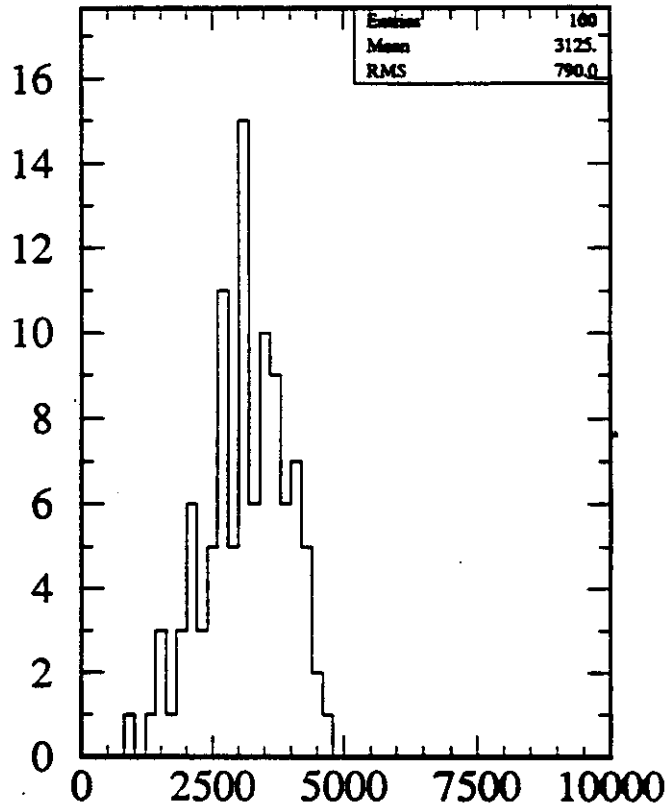
11/26/91

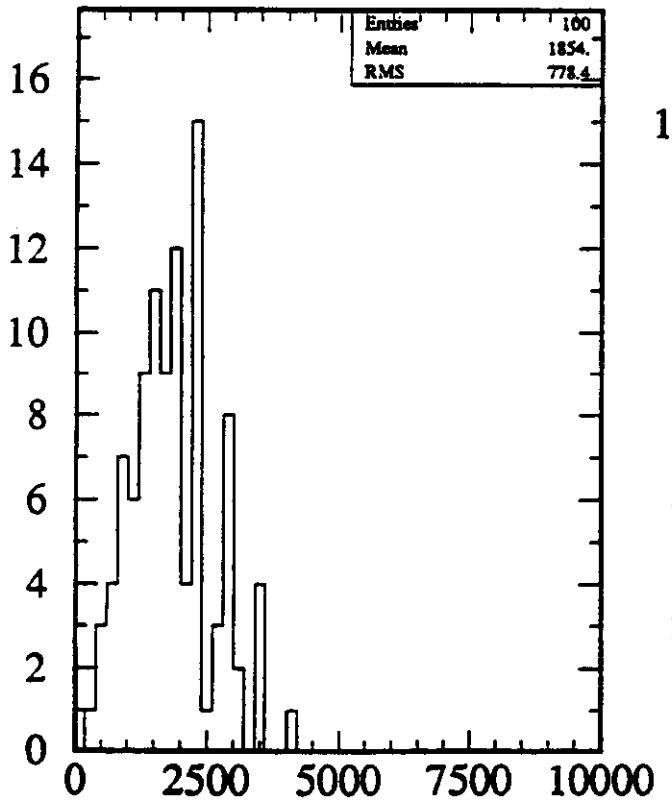
π^+ at 0 deg

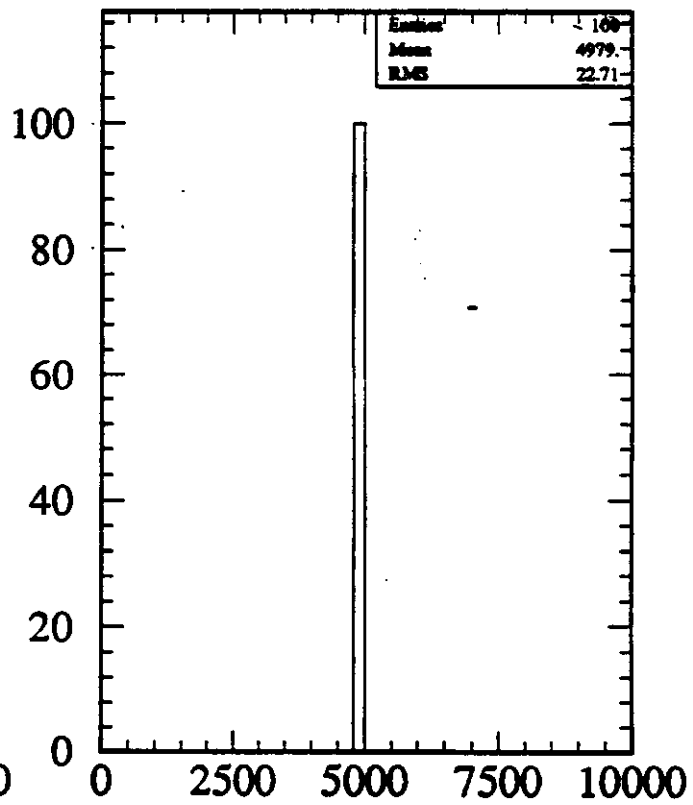


Dat / DC
$\alpha = 3$ 5 TeV

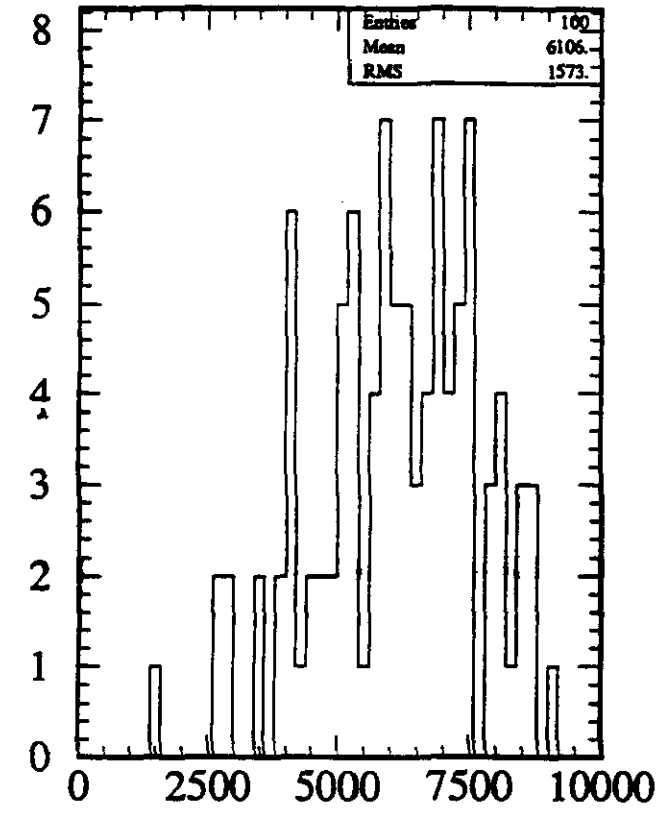




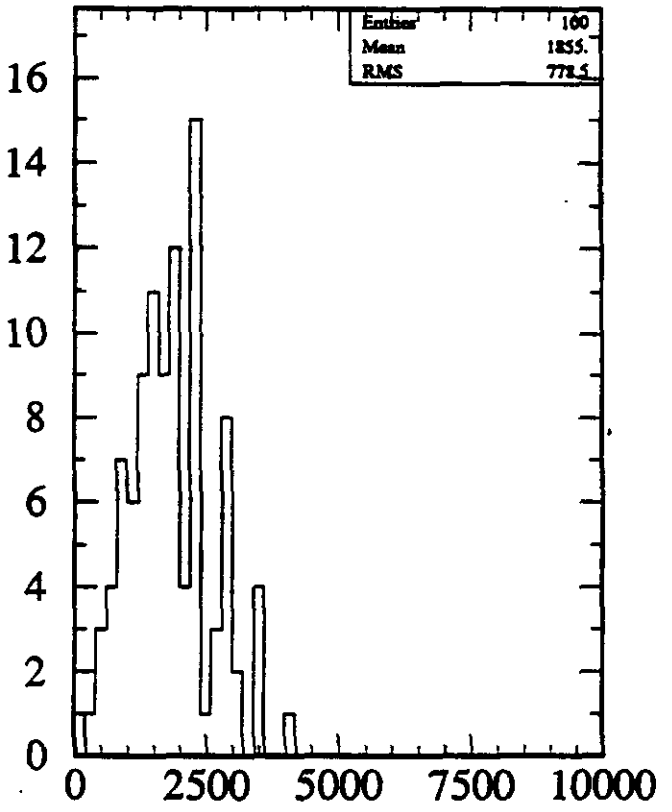




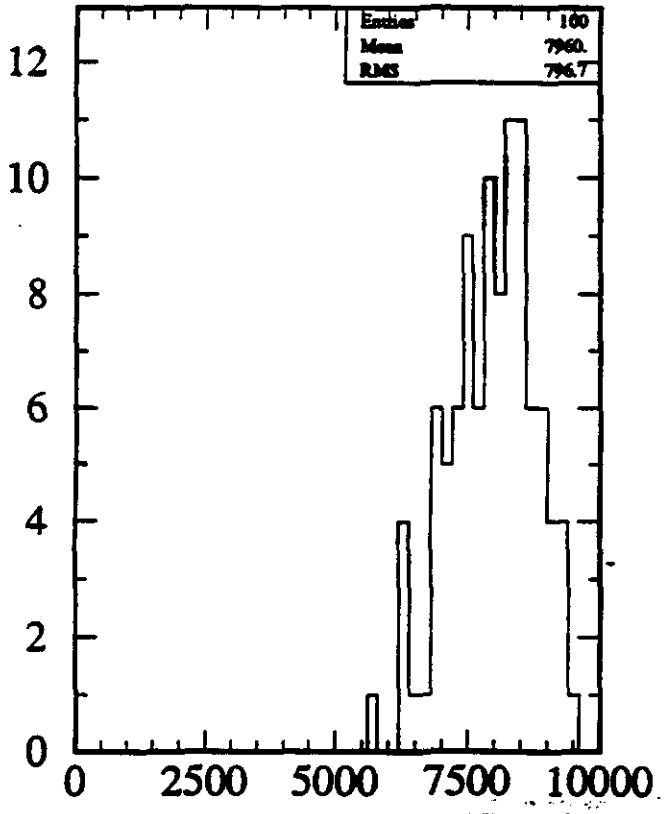
BaF/Sc
$\alpha = 3$ 5 TeV



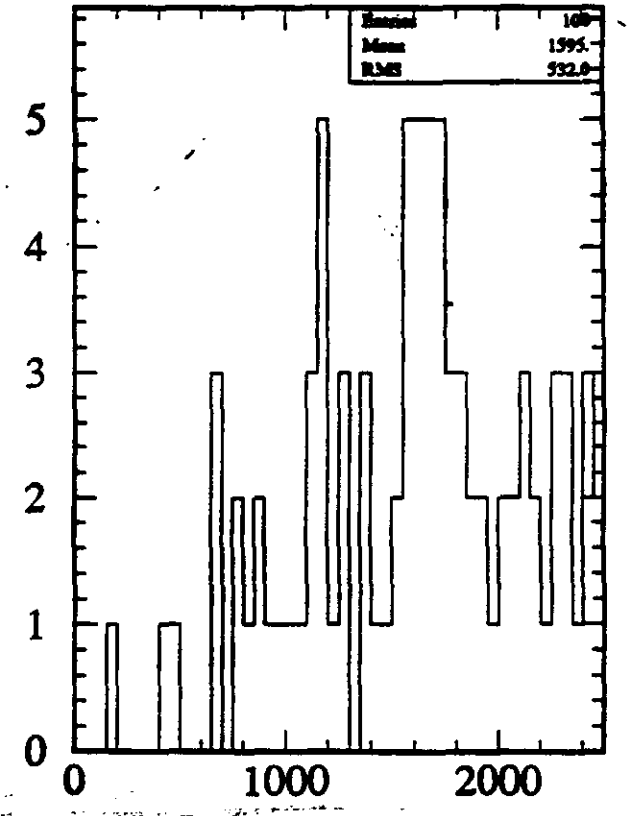
E1-Det



E2-Det

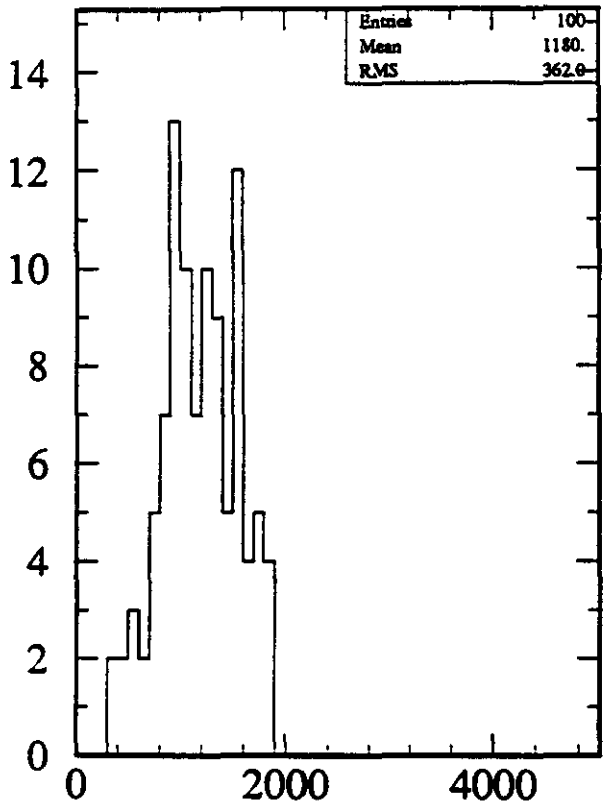


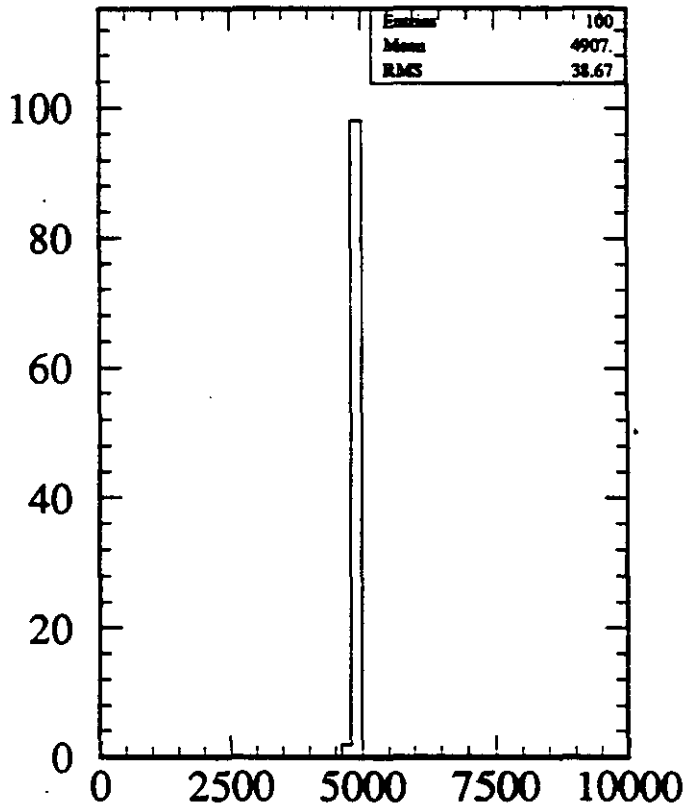
E-Det

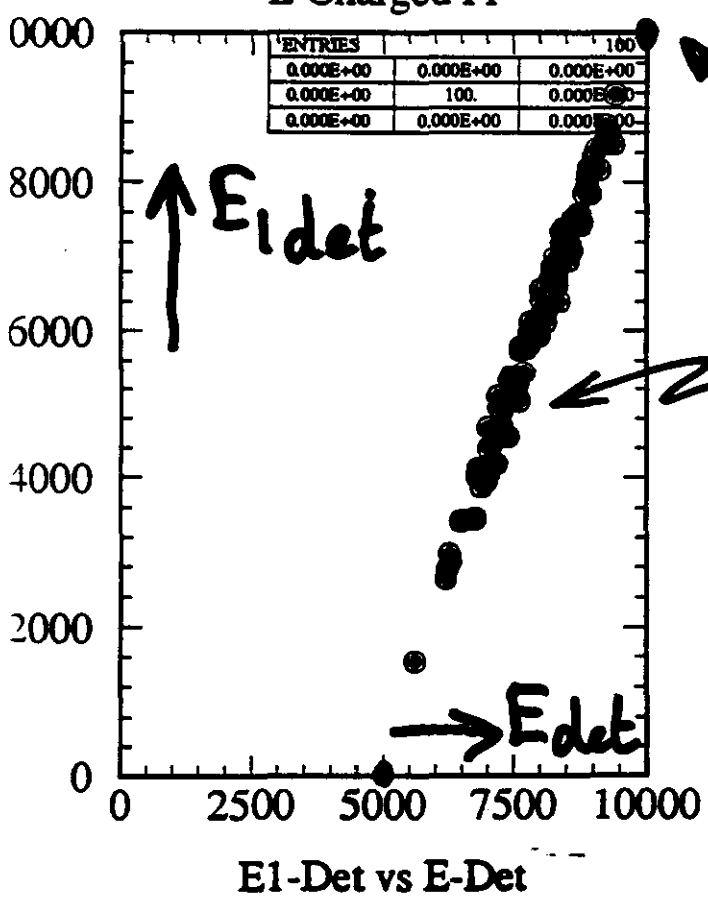


E-Pizero

Dat/JC
$\alpha = 3$ 5 TeV







only π^0's in jet

$E_{1det} = 2E_{det} - 2E_{jet}$

only $\pi^\pm$ in jet and not interactions in em section

E-dep (BaF / SPACAL)

E_{jet}	$\pi^{\pm}$ had showers		$\frac{E_1(had)}{E_{jet}}$
	$E_1(em)$	$E_1(had)$	
10	0.4	2.5	25%
20	1.2	5.0	25%
100	11	18	18%
500	77	58	12%
5000	1051	207	4%

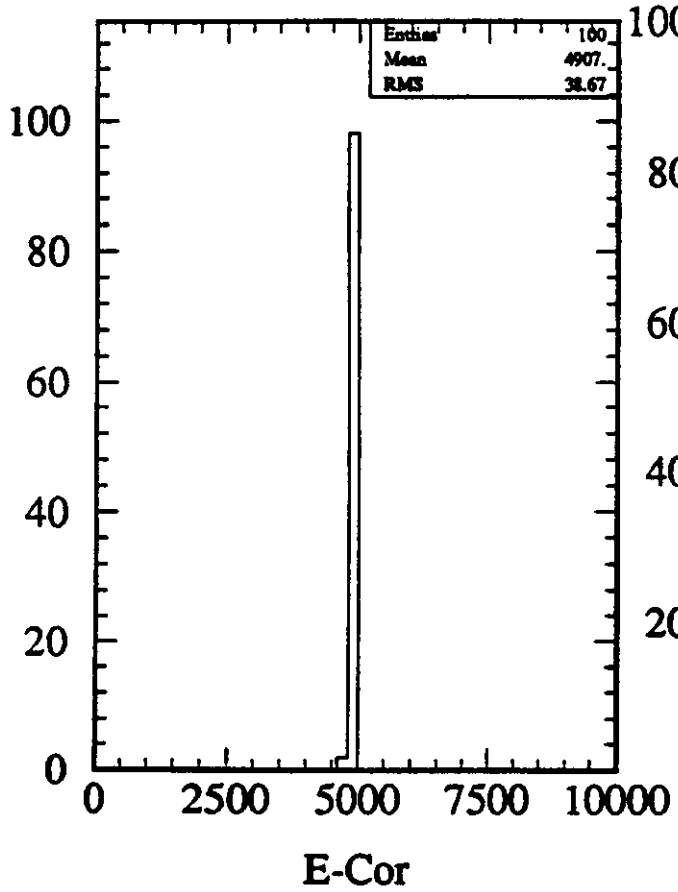
Equation of line for BaF / SPACAL:

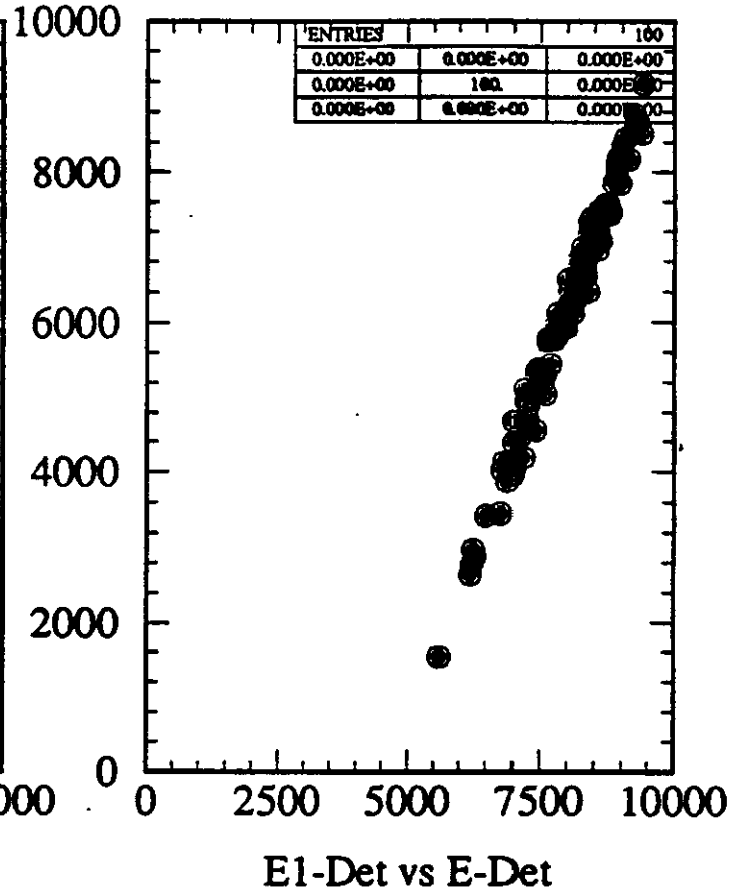
$$E_{jet} = \frac{E_{1\,det}}{\left(\frac{e}{h}\right)_1} + E_{2\,det}$$

$$\left[\left(\frac{e}{h}\right)_1 = 2\right]$$

$\alpha = 3$

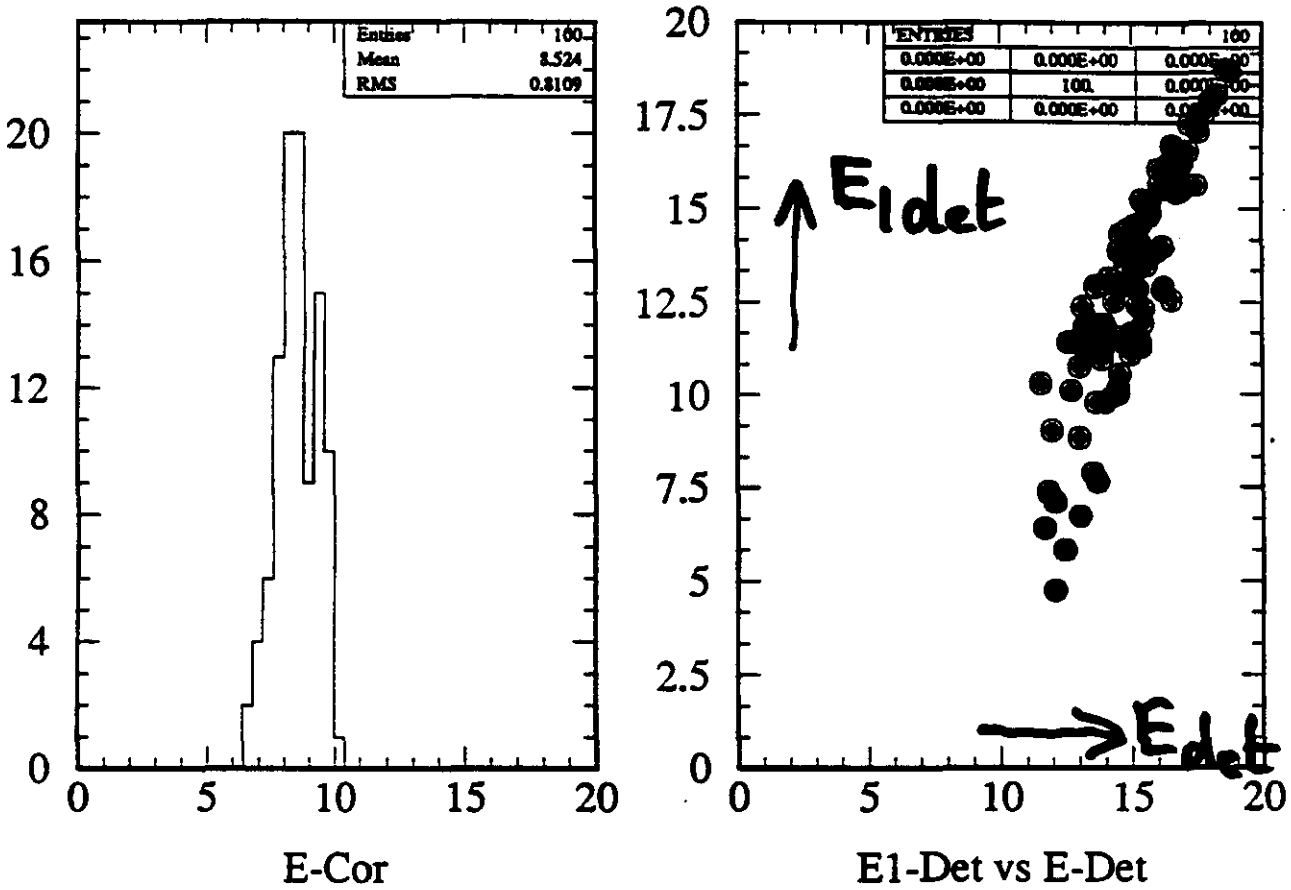
5000 GeV



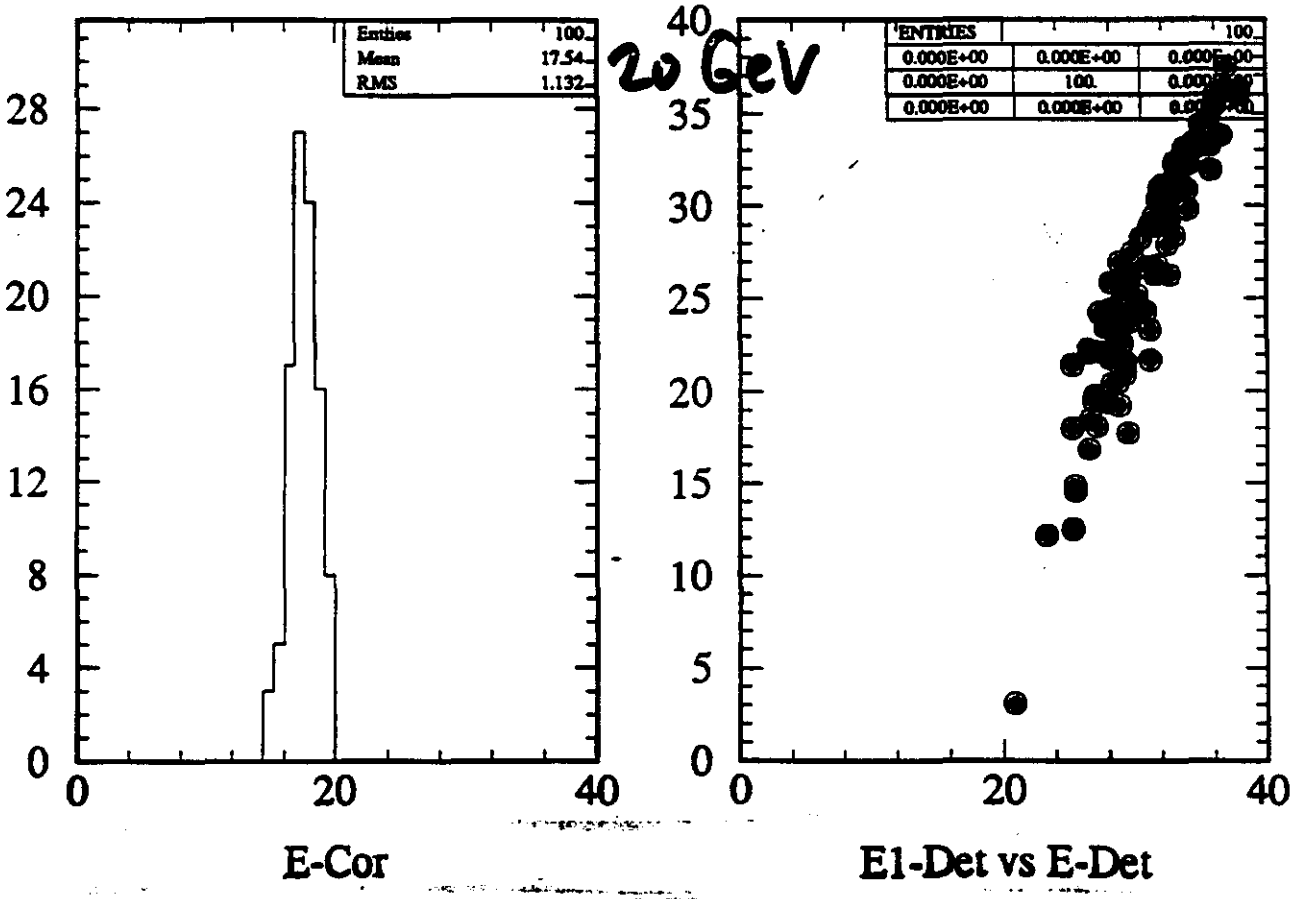


Dat / DC
$\alpha = 3$

10 GeV

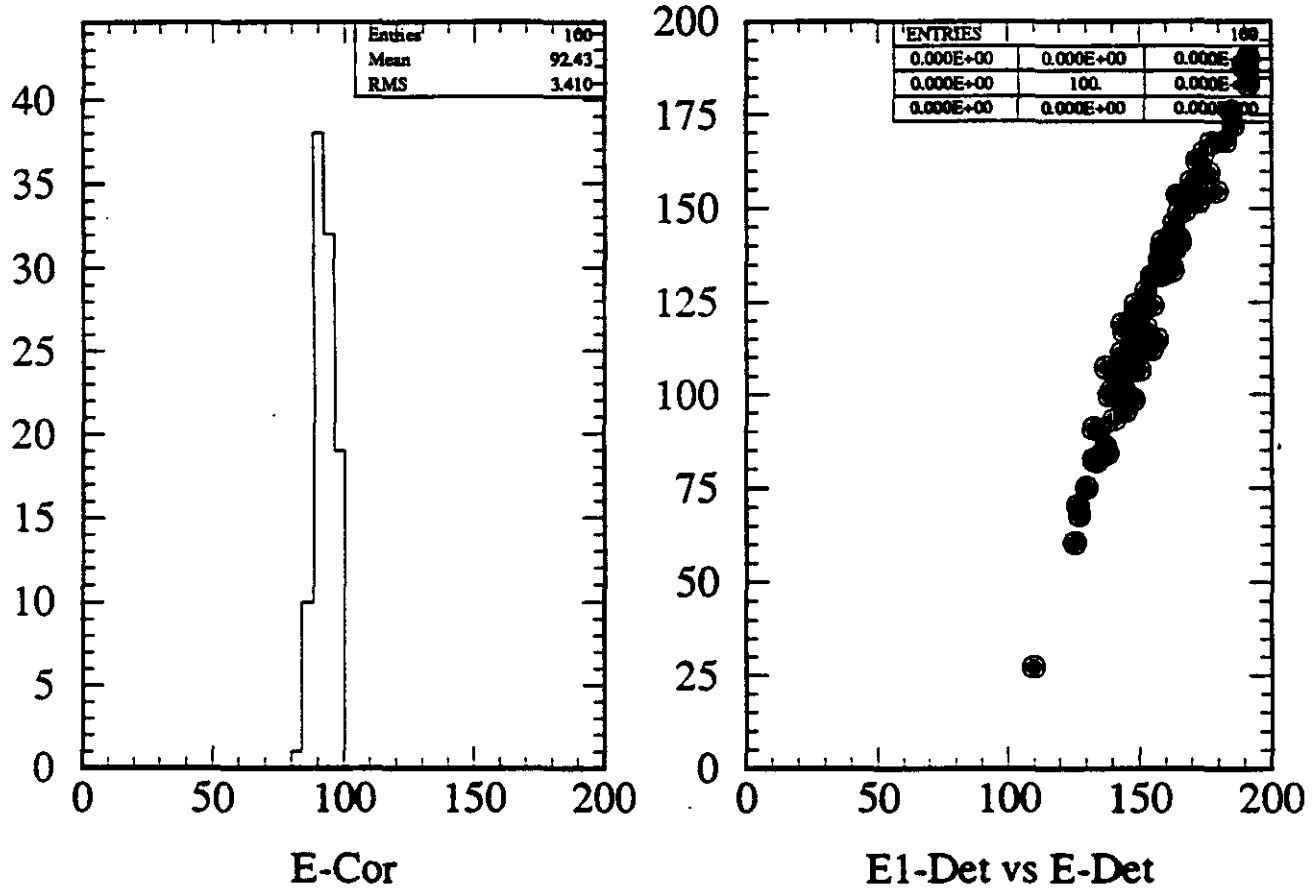


20 GeV

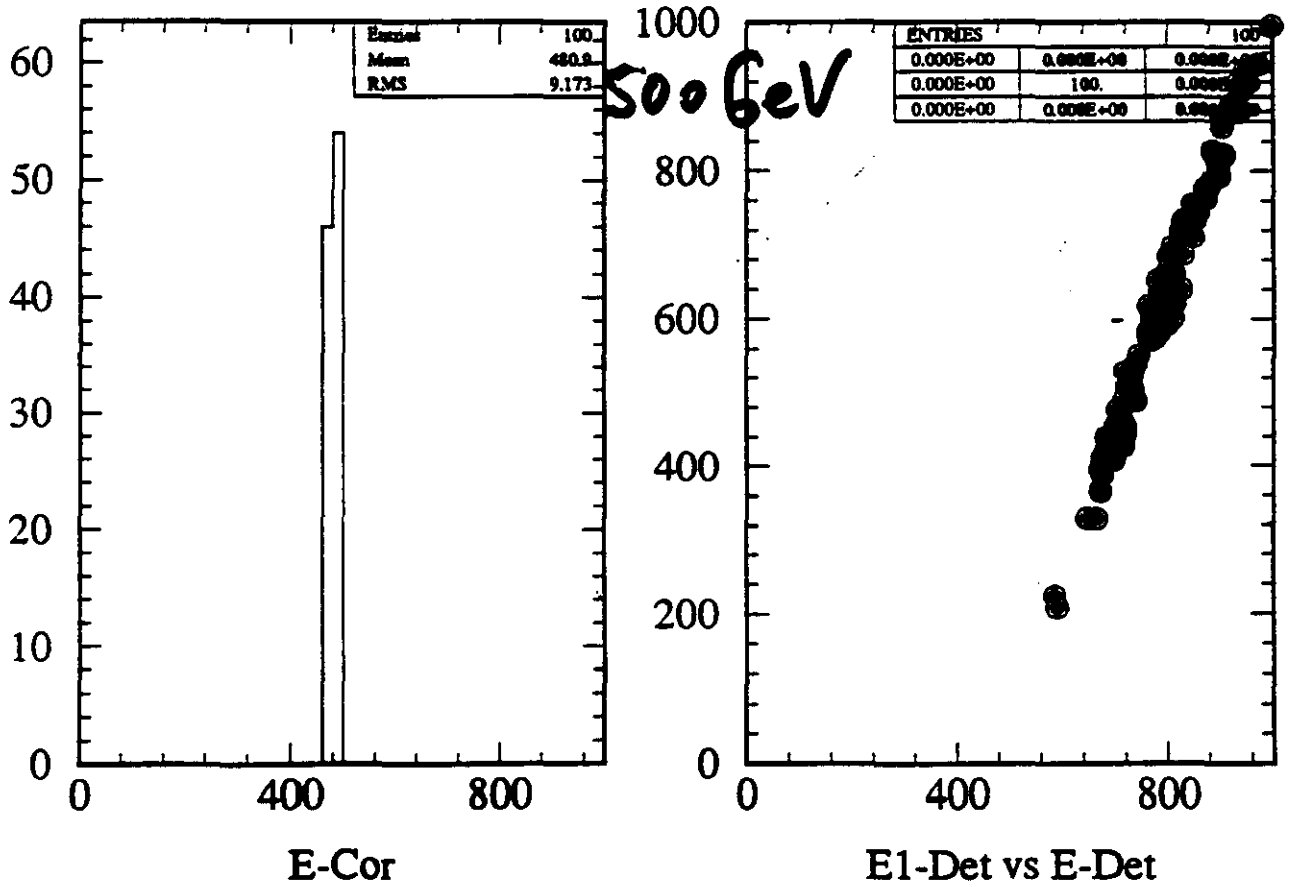


Bar / Sc
$\alpha = 3$

100 GeV

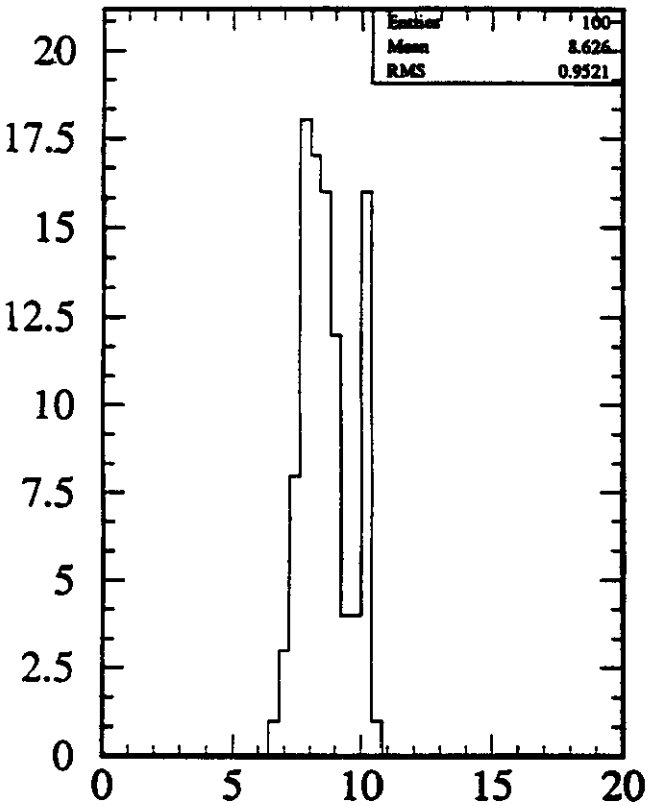


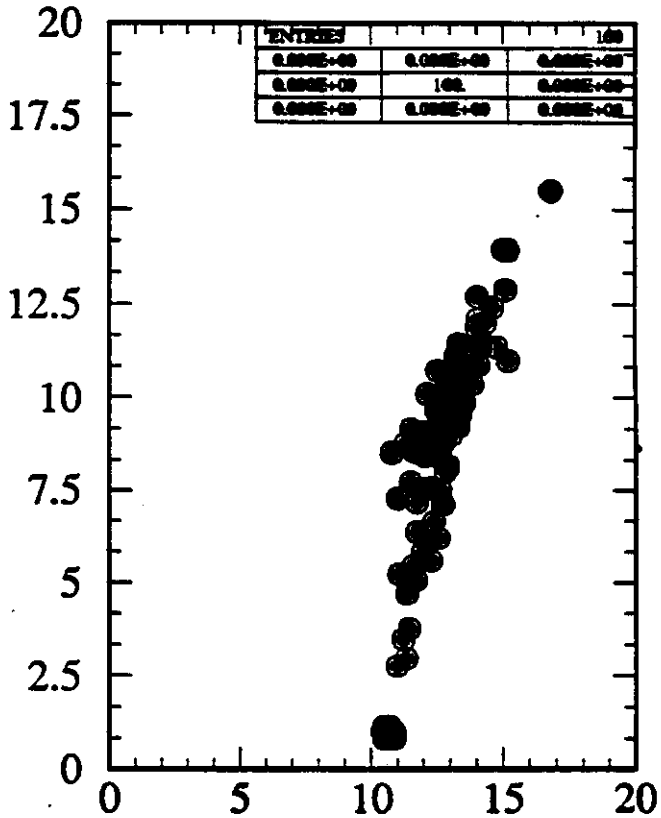
500 GeV



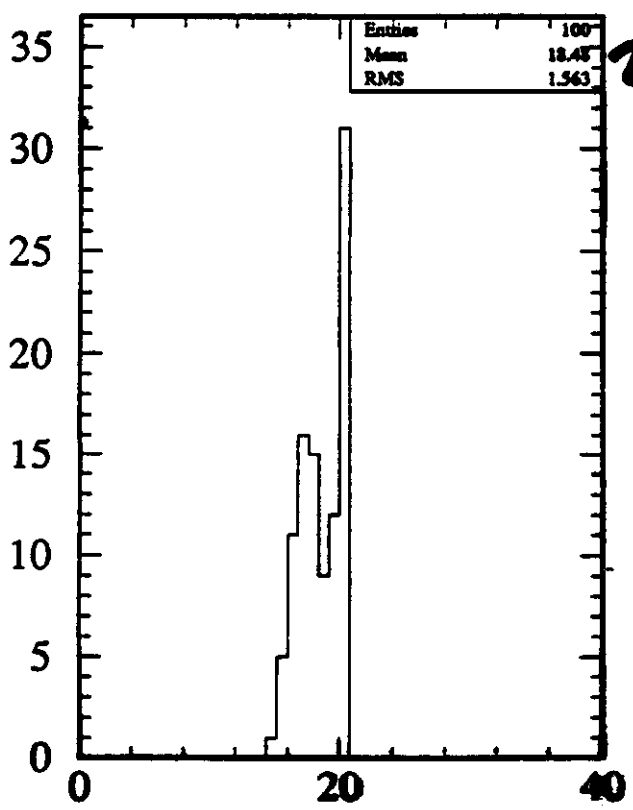
BaF/Sc
α = 9

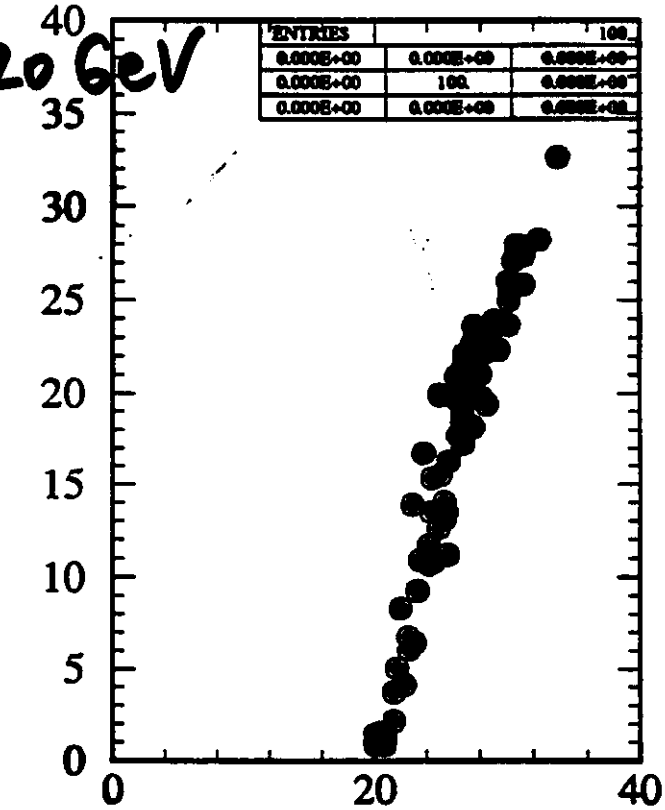
10 GeV





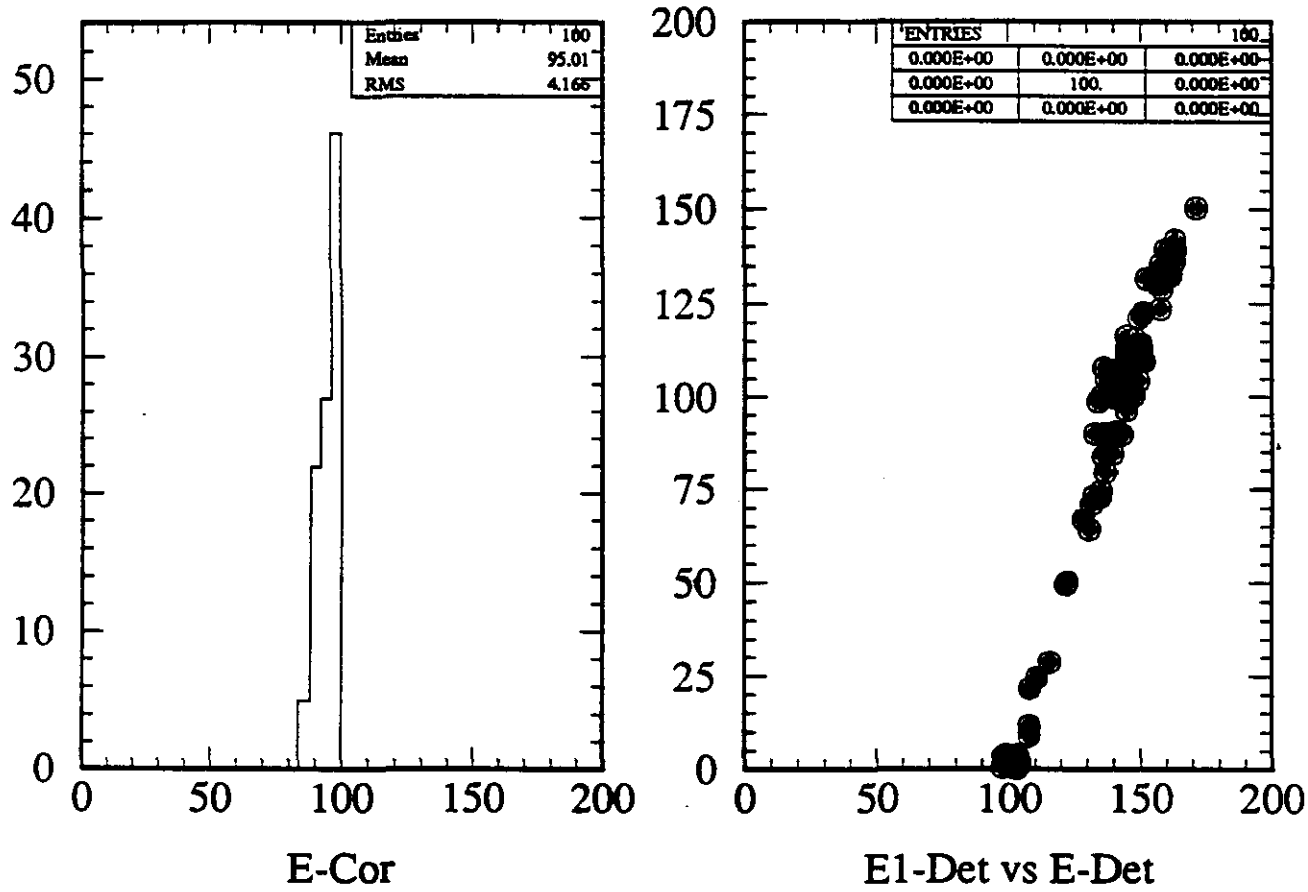
20 GeV



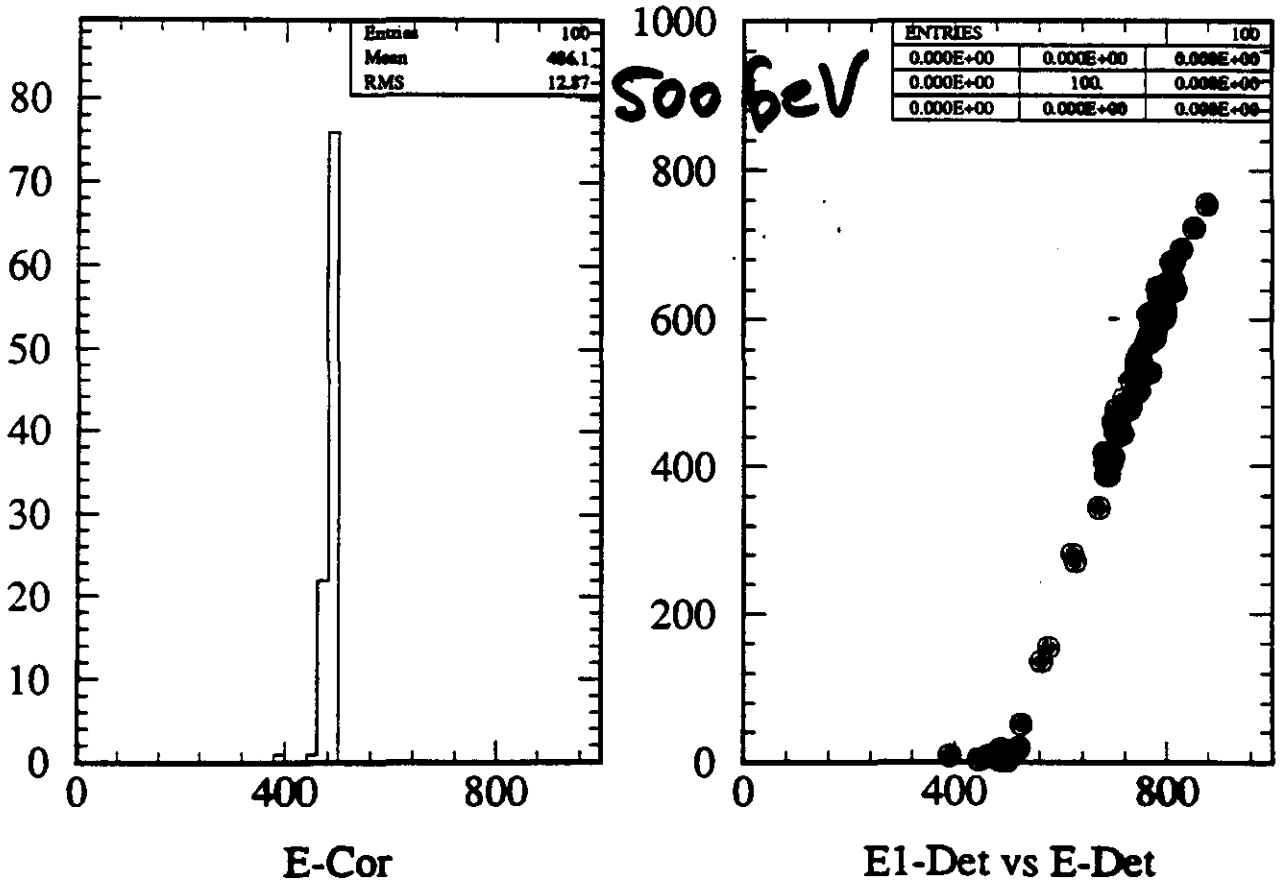


Dat / JC
K = 0

100 GeV

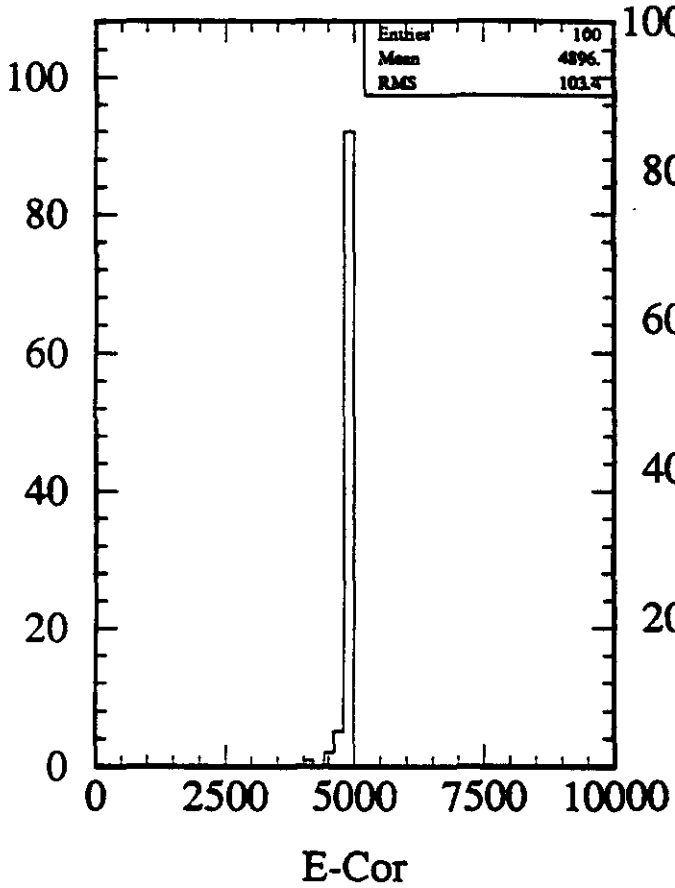


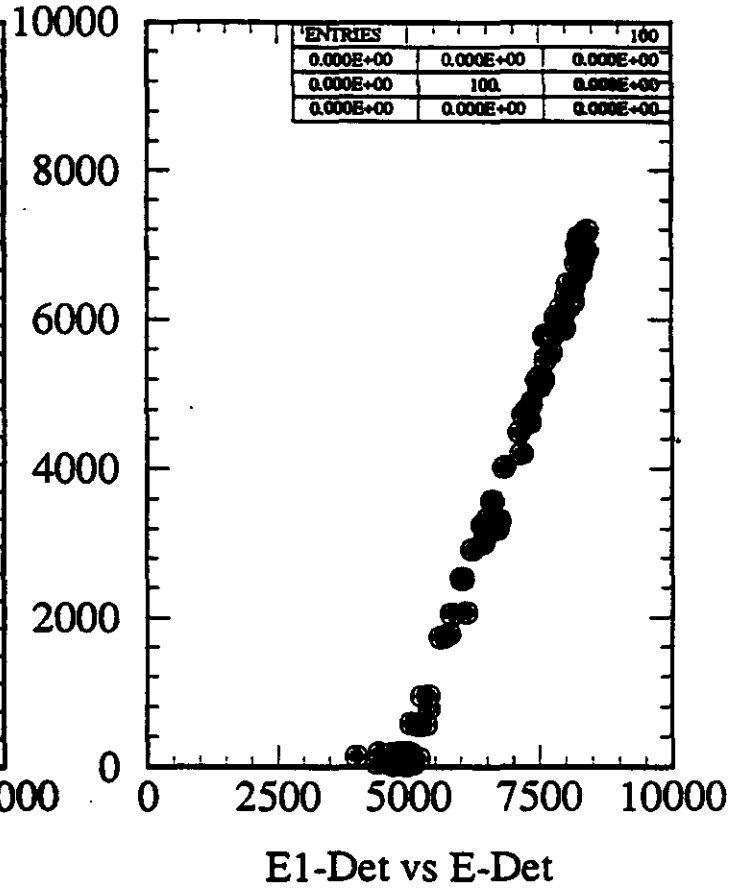
500 GeV



BaF / Jc
α = 0

5000 GeV





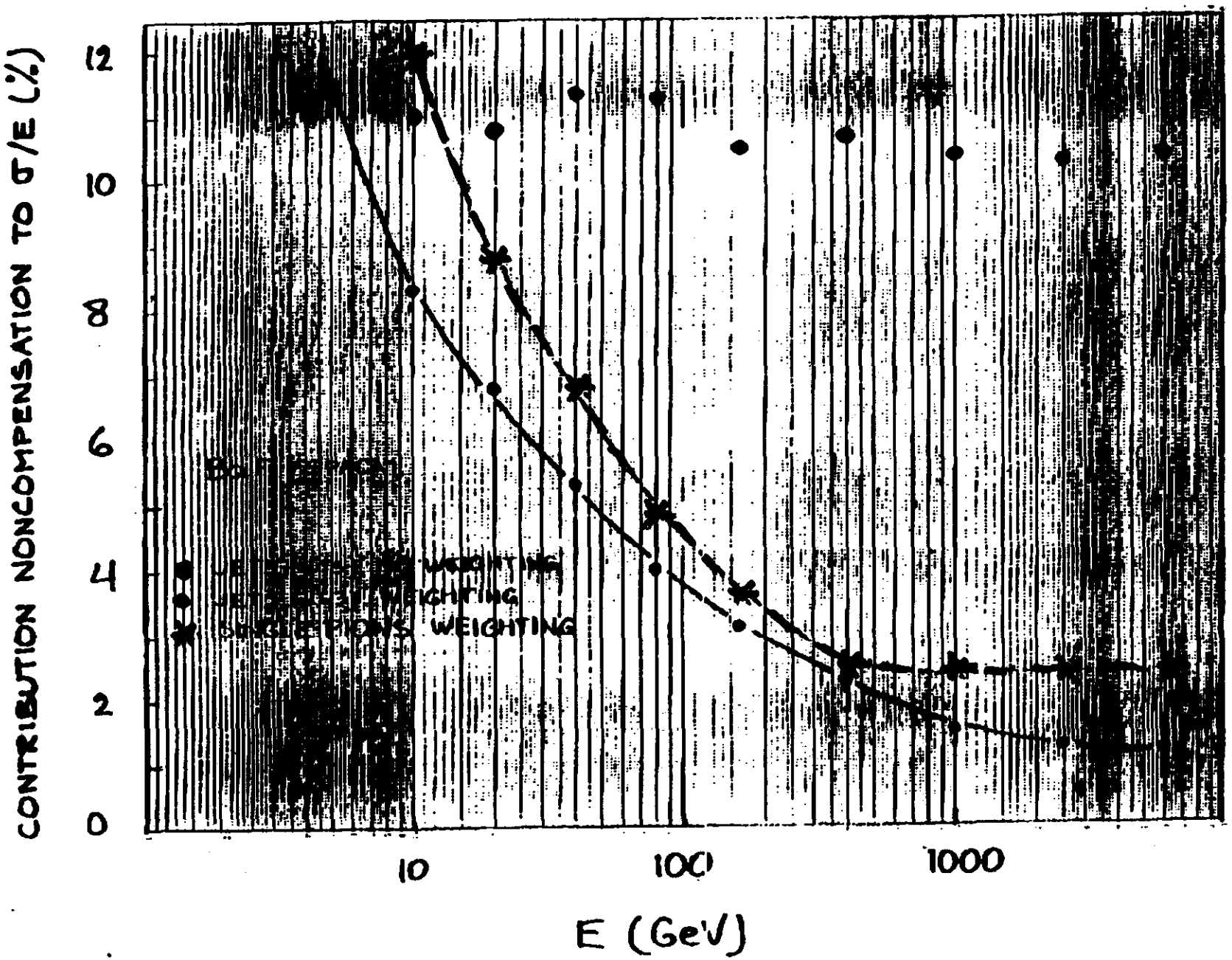

CONTRIBUTION NONCOMPENSATION TO σ/E (%)
0
2
4
6
8
10
12
10
100
1000
E (GeV)
WEIGHTING
WEIGHTING
WEIGHTING

fig. 1

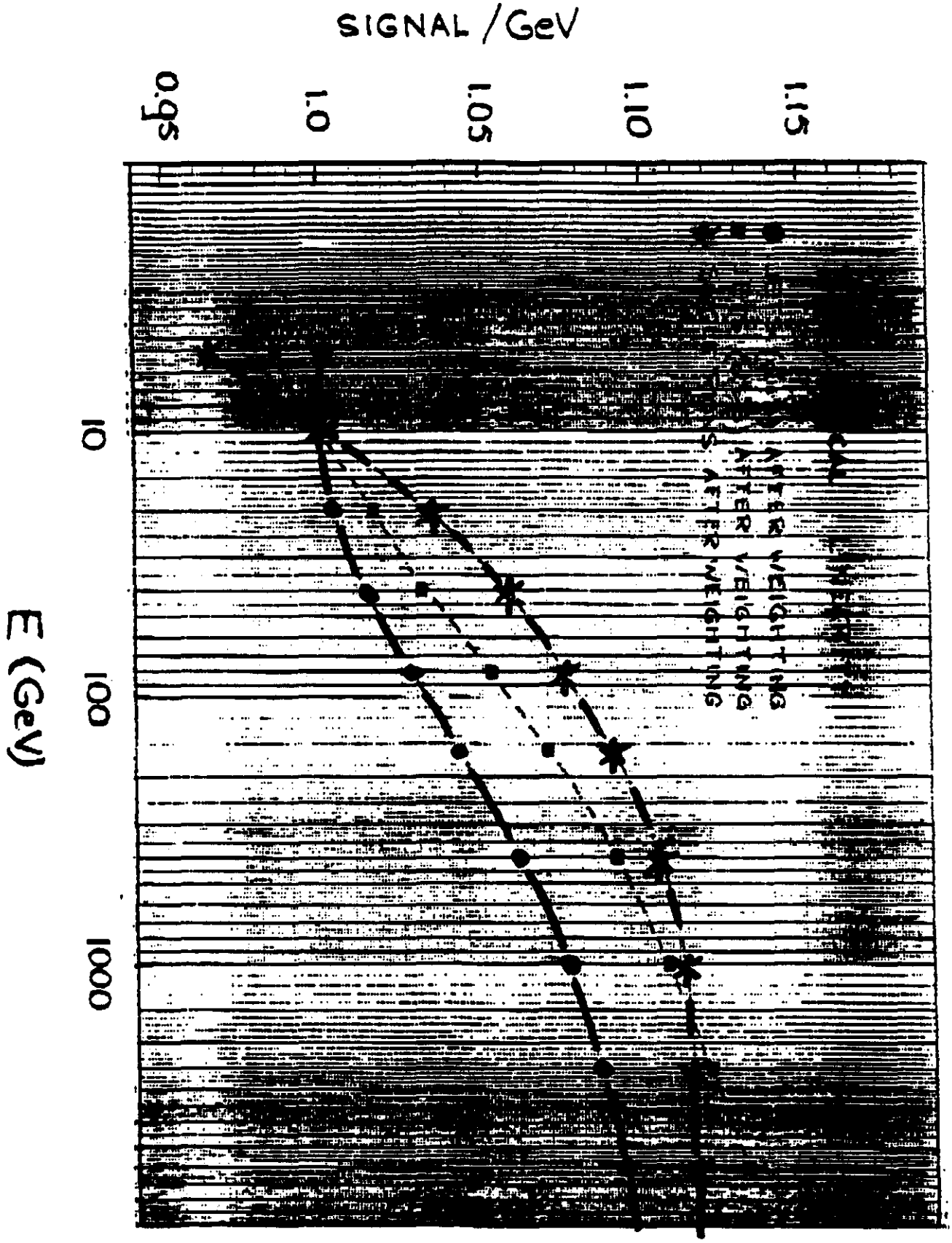

SIGNAL / GeV
0.95
1.0
1.05
1.10
1.15
E (GeV)
10
100
1000
CM
AFTER WEIGHTING
AFTER WEIGHTING
AFTER WEIGHTING

fig. 2

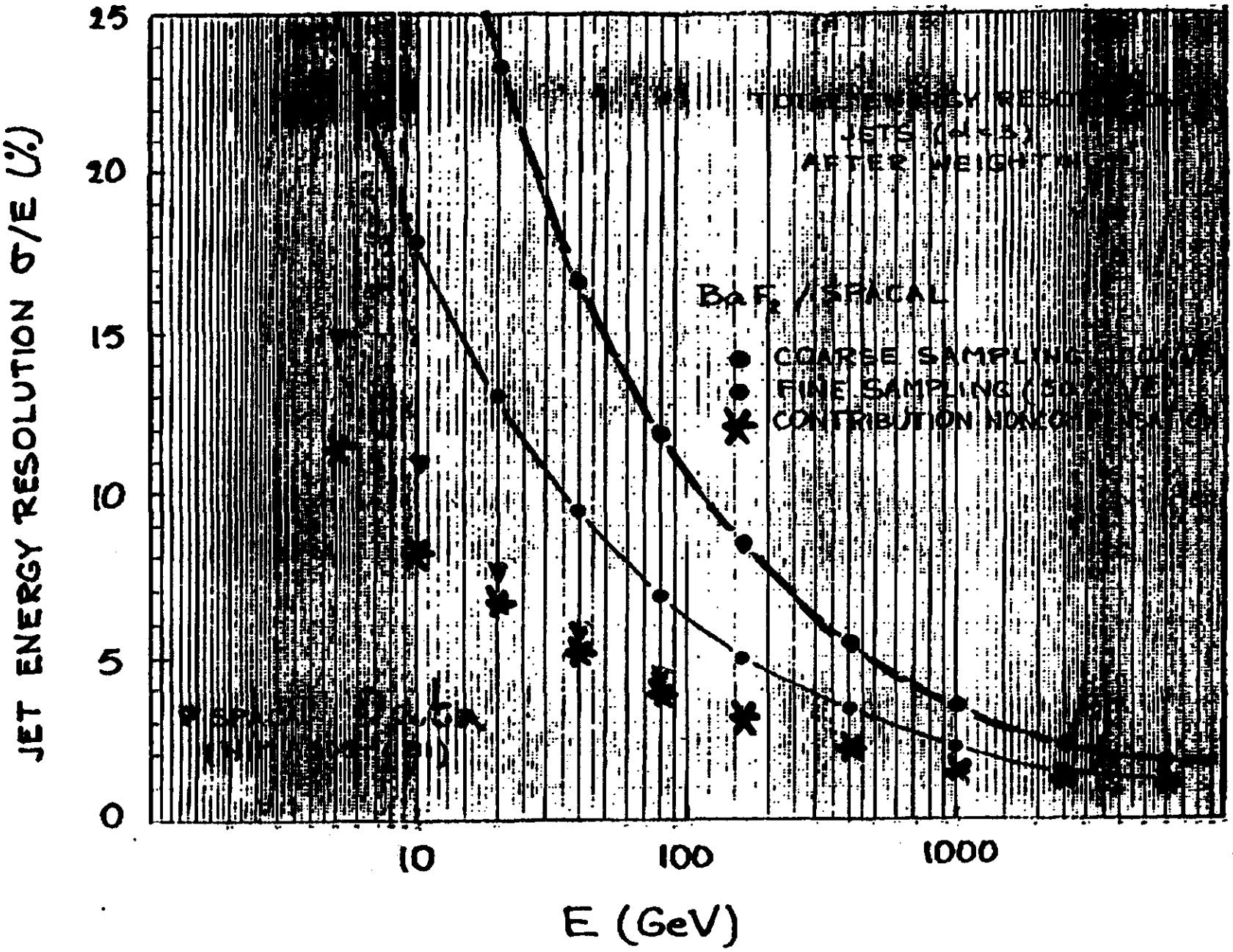
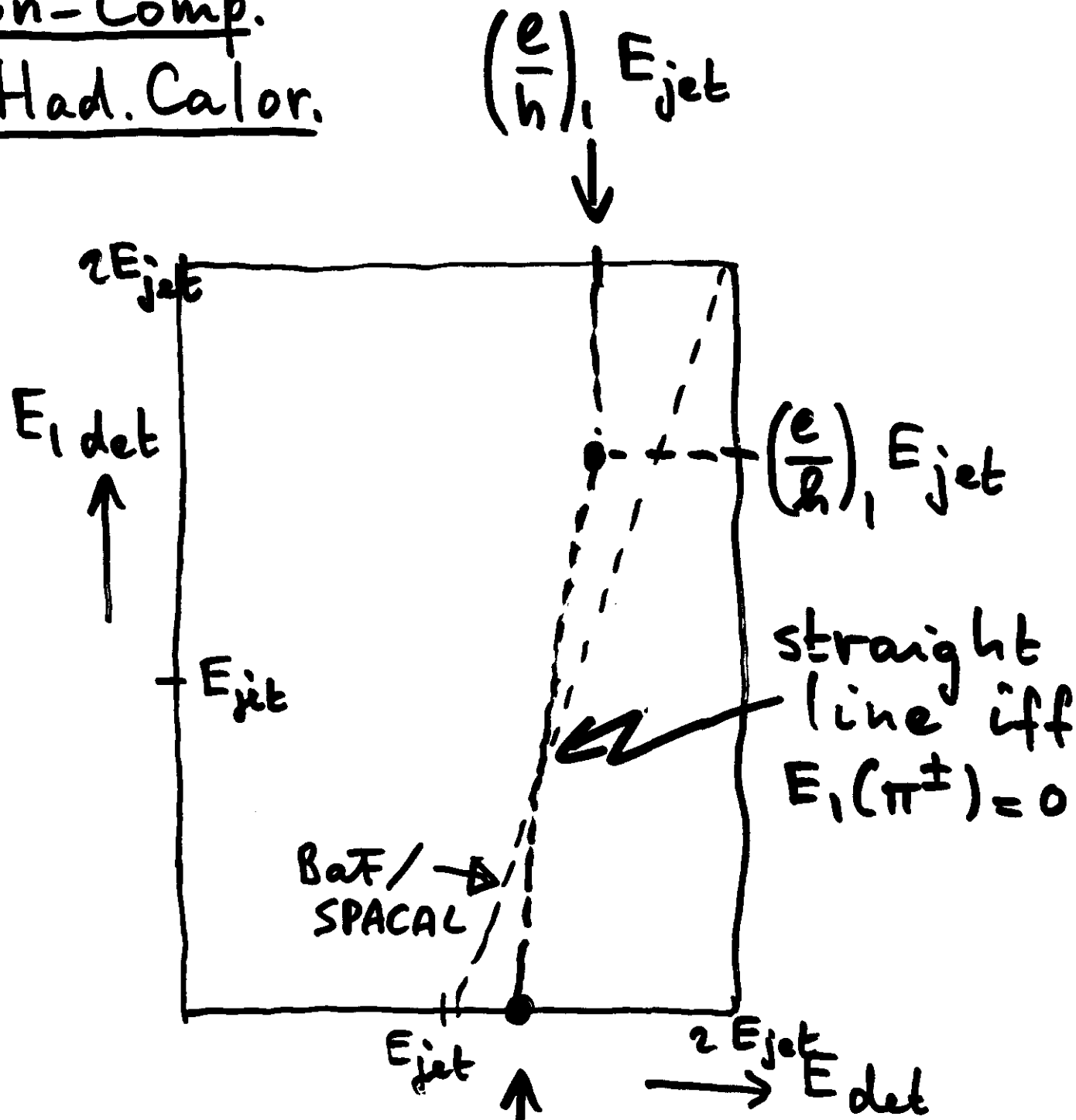

JET ENERGY RESOLUTION σ/E (%)
25
20
15
10
5
0
10
100
1000
E (GeV)
BaF₂/SPACAL
COARSE SAMPLING
FINE SAMPLING
CONTRIBUTION

fig. 4

Non-Comp. Had. Calor.



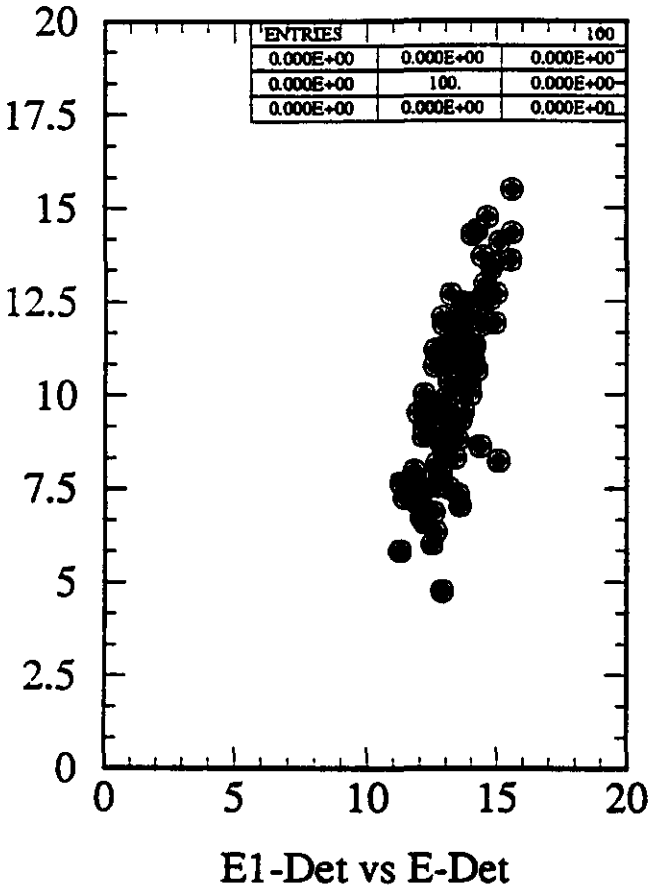
$$\left[1+\left\{\left(\frac{e}{h}\right)_2-1\right\}\langle f_{\pi^0}\rangle\right]E_{jet}$$

N.B. $\langle f_{\pi^0}\rangle$

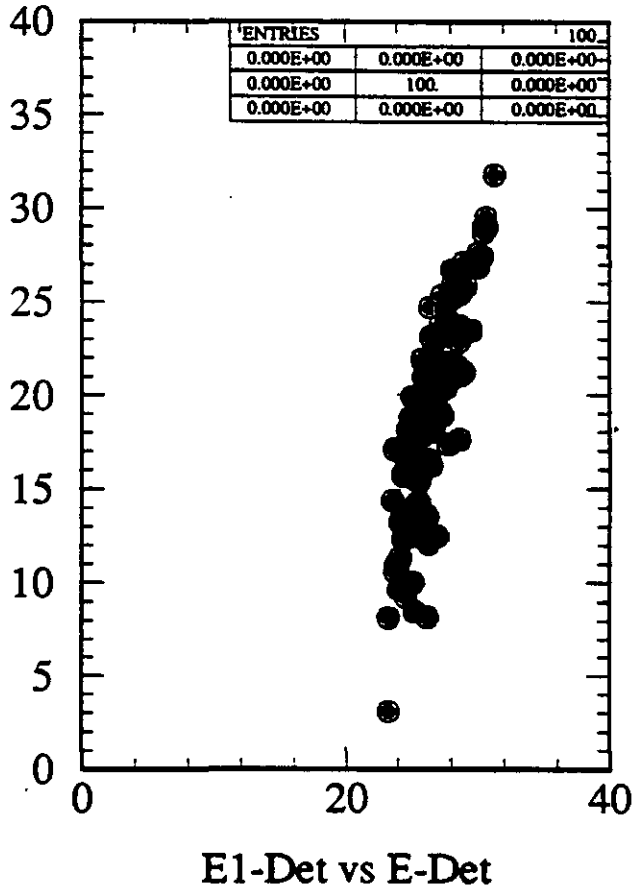
LHT/LHT

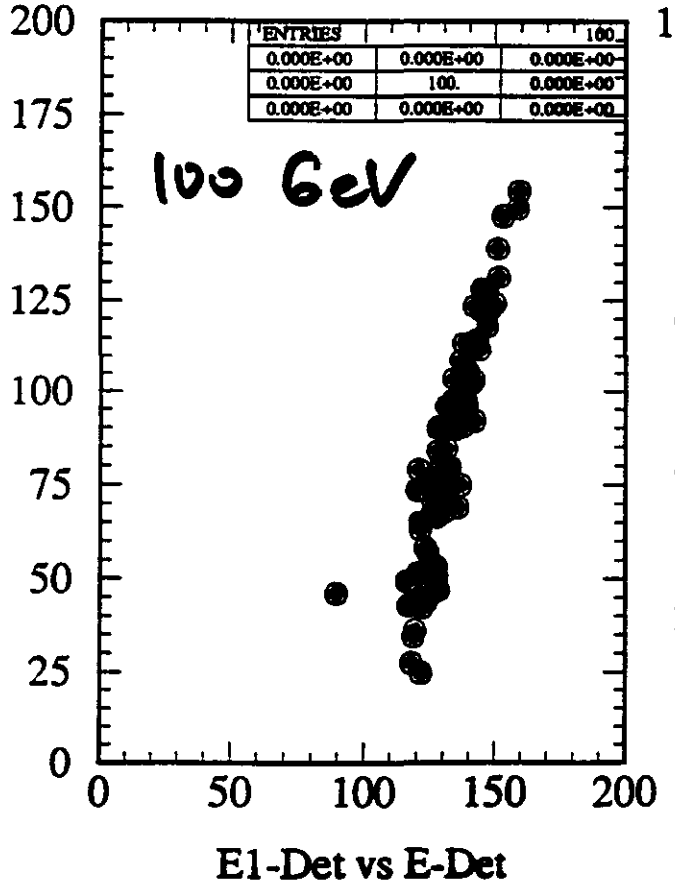
$\alpha = 3$

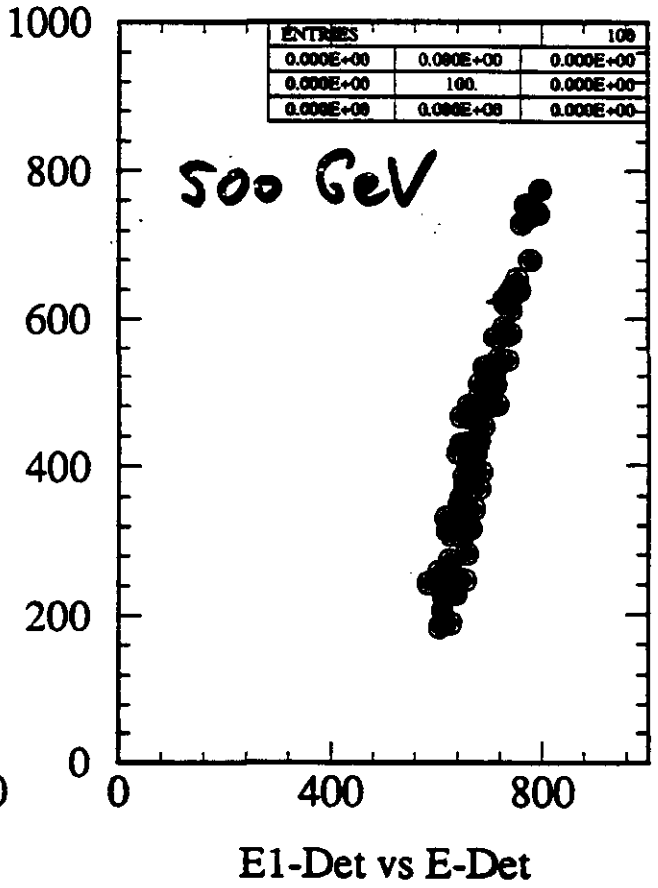
10 GeV



20



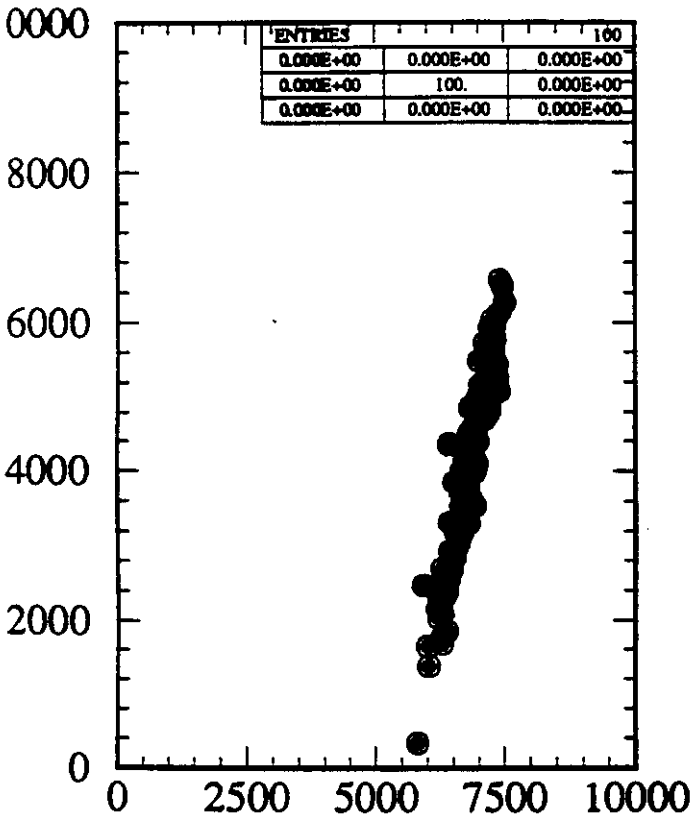




LHr/LAr

$\alpha = 3$

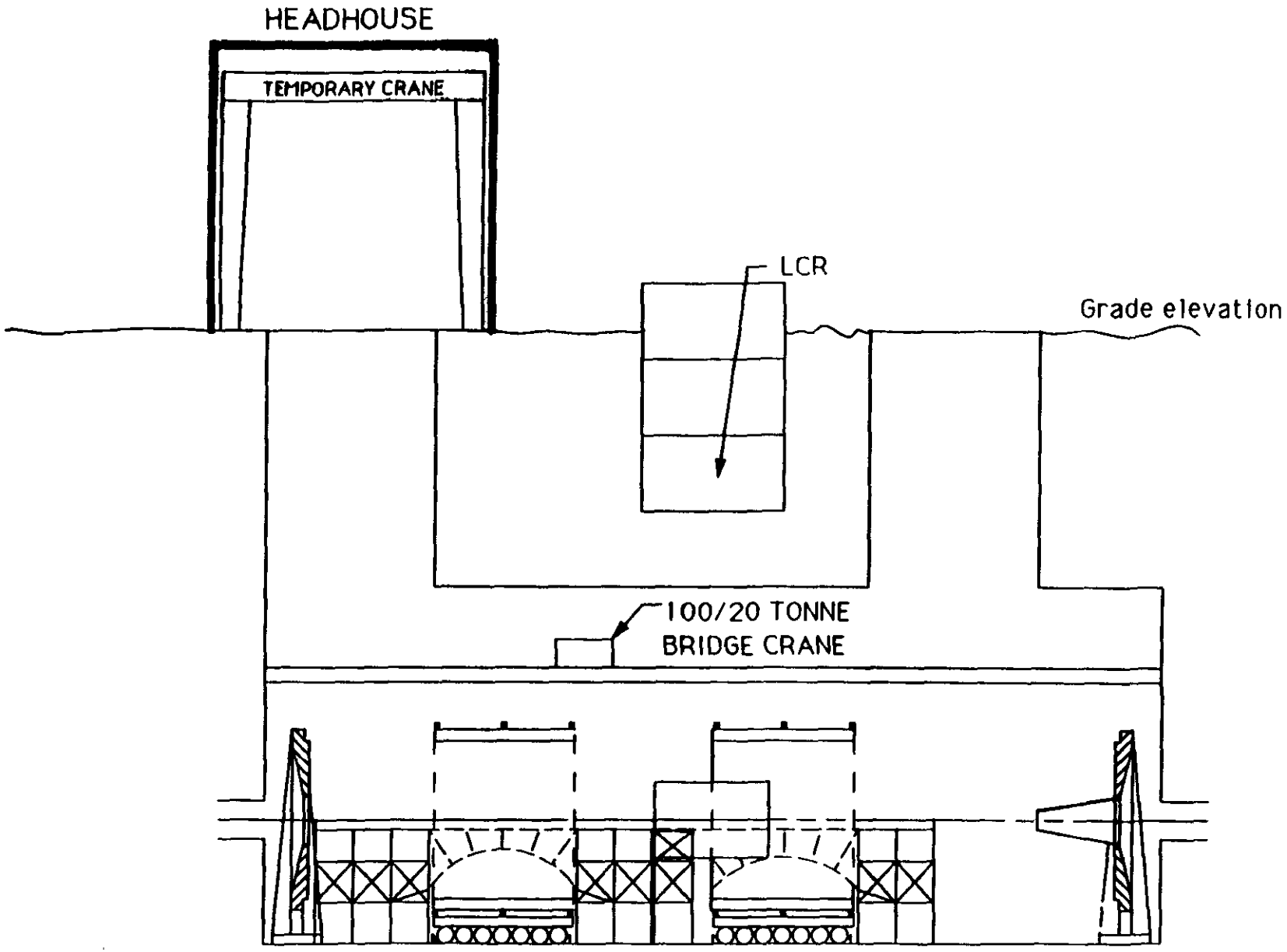
5000 GeV



E1-Det vs E-Det

Conclusions

- Can get good E_{jet} above 100 GeV if had. cal. is compensating
- Input data for method is measurable with prototypes in testbeams (e, π, multi-part.)
- No need for "black-box" MC, fragmentation, hadron shower dev.
- Non-comp. hadron calorimeter introduces model dependence (ex. $\langle f_{\pi^0} \rangle$)
- Problem at low E_{jet}?
  Missing E_T but linearity and resolution not so important?



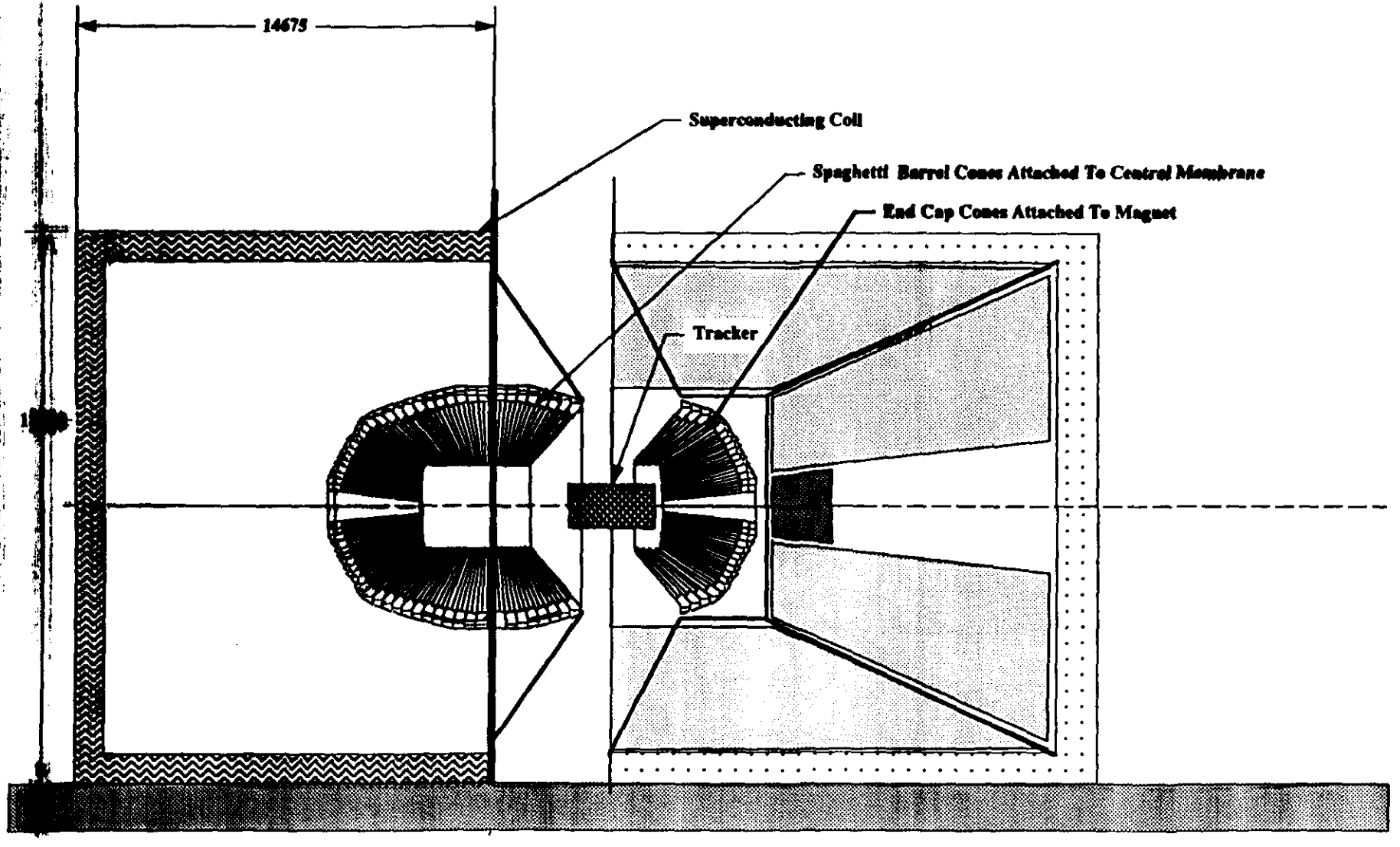
CONFIGURATION 1G

DRAFT

SCALE 400:1

Eberle 12/02/91

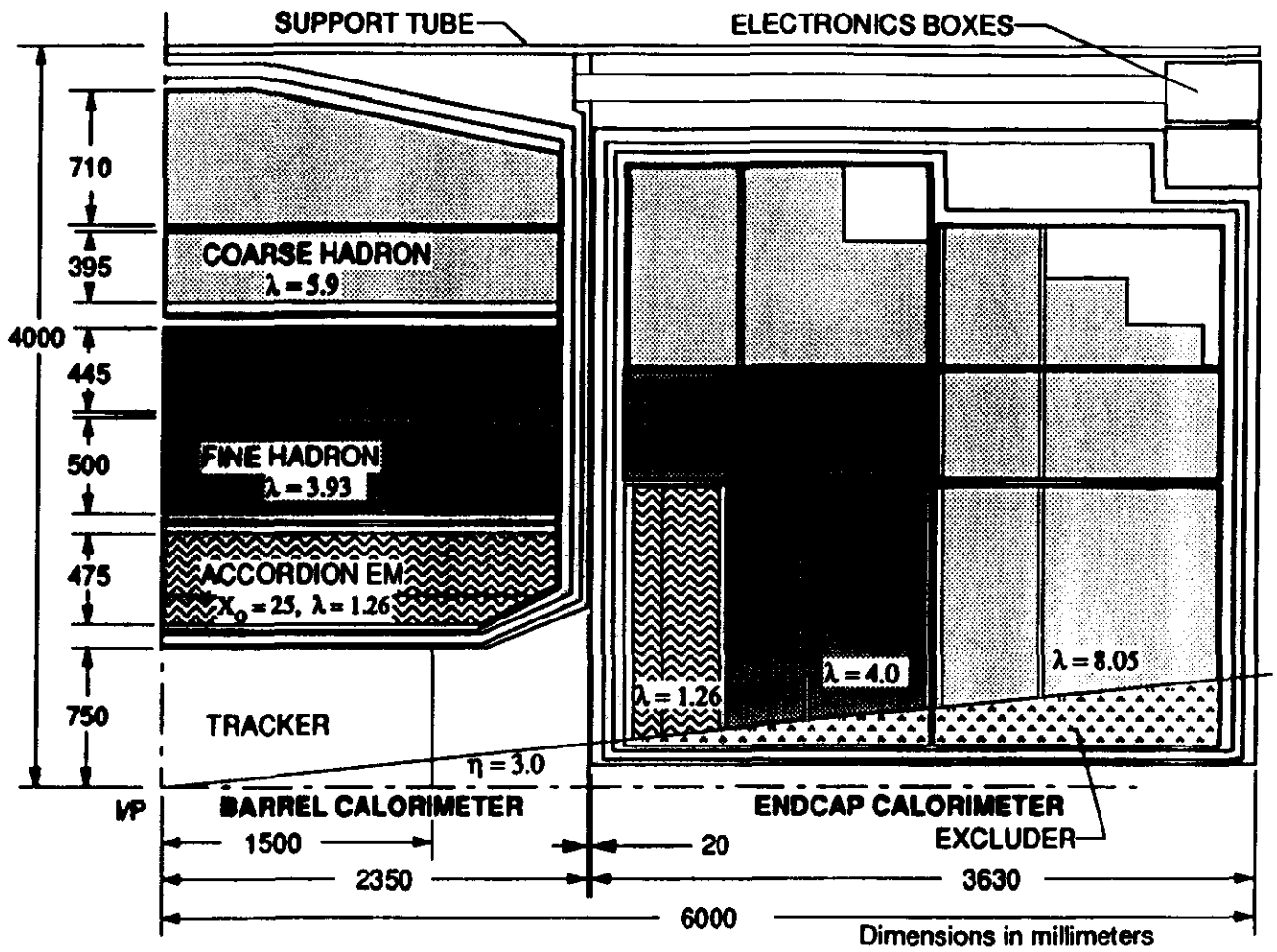
Note: The Central Membrane Will Require Temporary Bracing During The Installation Process

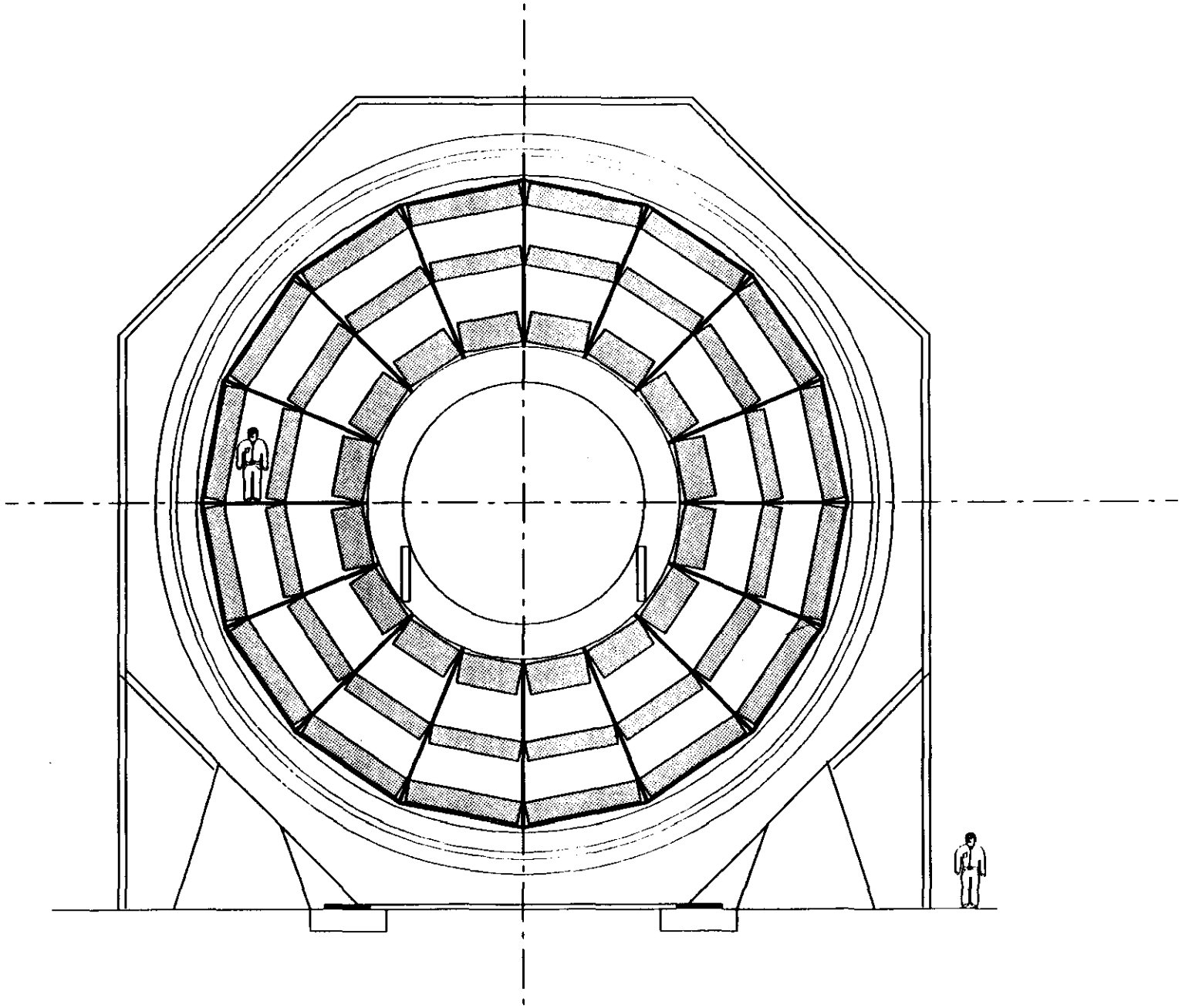


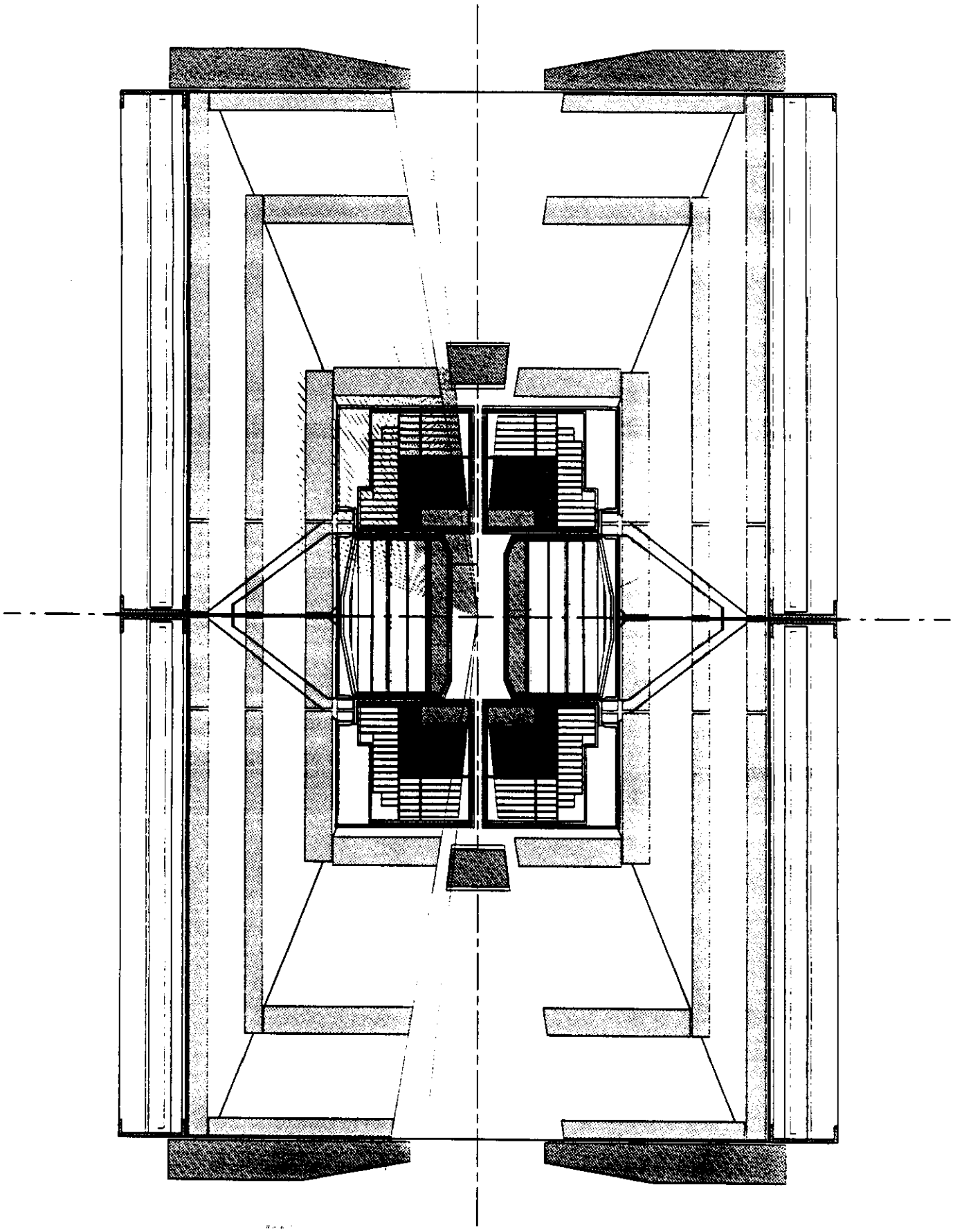
GEM Detector
Spaghetti Hadron
Maintenance Concept

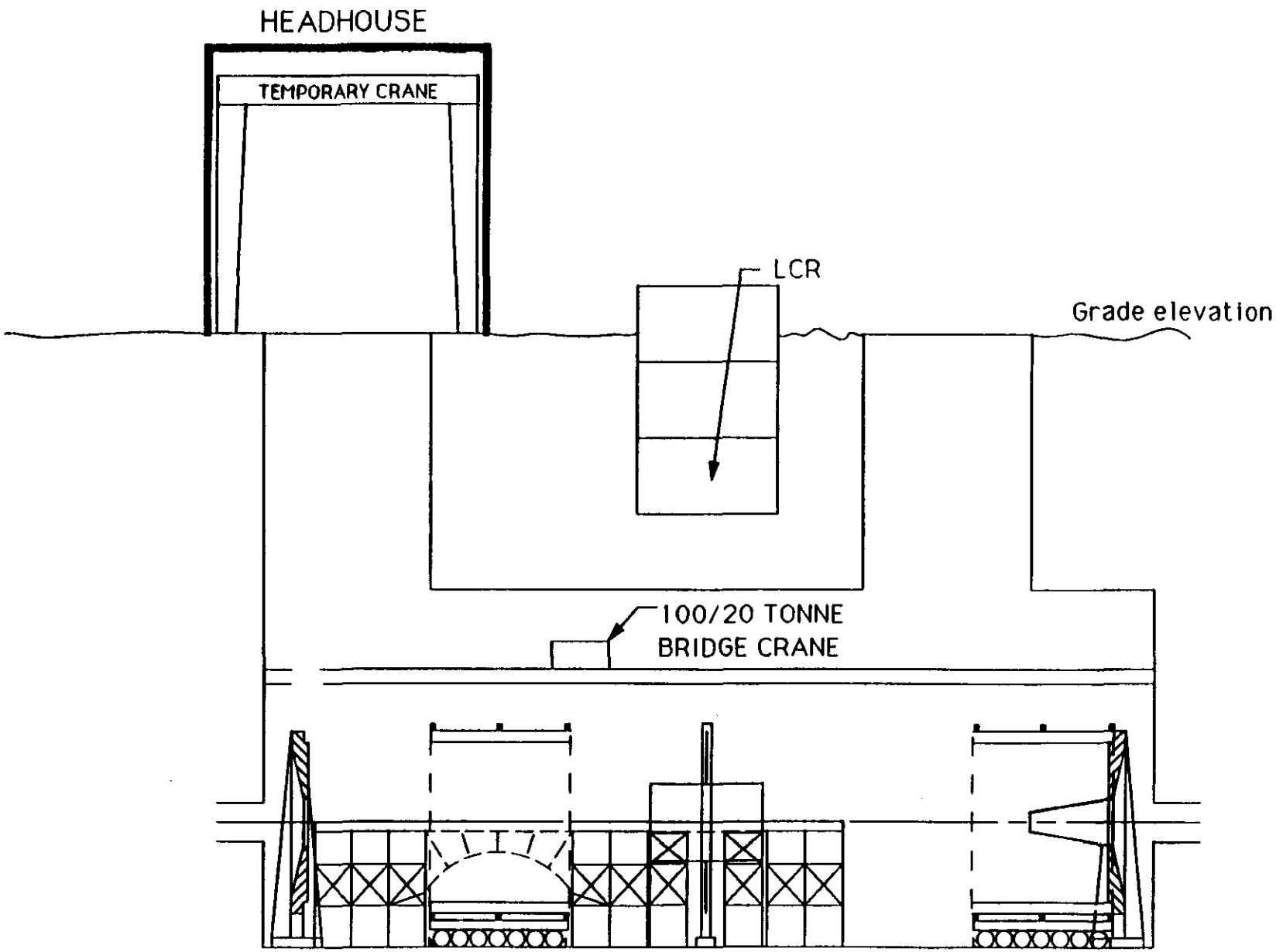
Q.82.SC.00077

Rennich


SUPPORT TUBE
ELECTRONICS BOXES
710
395
4000
445
500
475
750
COARSE HADRON
λ = 5.9
FINE HADRON
λ = 3.93
ACCORDION EM
X0 = 25, λ = 1.26
TRACKER
η = 3.0
λ = 1.26
λ = 4.0
λ = 8.05
I/P
BARREL CALORIMETER
ENDCAP CALORIMETER
EXCLUDER
1500
20
2350
3630
6000
Dimensions in millimeters







CONFIGURATION 1F

DRAFT

SCALE 400:1

Eberle 12/02/91