GEM TN-92-57

GEM Calorimeter Meeting
SSCL

January 22 and 24, 1992

Abstract:

Transparencies and agenda of the GEM Calorimeter Meeting on Preradiator and Forward Systems held at the SSCL on January 22 and 24, 1992.

Agenda for GEM Calorimeter meetings

Jan. 22 and Jan. 24, 1992 at SSCL

Wednesday January 22 (Discussions on Preradiator and Forward Systems)

Directorate Room #2

9:00 am	Introduction	Yuri Kamyshkov	5'
9:05	Integrated LAr accordion preradiator	Misha Leltchouk	30'
9:35	Parallel plate LAr preradiator	Paul Mockett	30'
10:05	Silicon strip preradiator	Jim Brau	30'
10:35	Break		
10:50	Preradiators with BaF2	Renyuan Zhu	30'
11:20	Discussion		
11:45	New ideas in sci.fiber calorimetry	Richard Wigmans	15'
12:00	Lunch		
	Forward calorimeter system :		
1:30 pm	Overview and present status	John Rutherfoord	30'
2:00	Physics of forward calorimetry	Frank Paige	45'
2:45	Report from recent Magnet meeting and implications for forward calorimetry	Bob Webb	30'
3:15	Break		
3:30	Gas calorimetry tests at FNAL	George Fanourakis	45'
4:15	LAr FCal integrated into end cap calorimeter	John Rutherfoord	30'
4:45	Review of liquid scintillator option for FCal	Bob Webb	30'
5:15	Discussions		

Calorimeter Meeting Jan 24

Bill Bugg	U. Tennessee
Leltchouk M.	Columbia
Konstantin Shmakov	~~Tennessee~~ ORNL
Paul M Mockett	Univ. of Washington
Howard Gordon	BNL
Jim Brau	Oregon
David Lissauer	BNL
Odette Benary	~~Tel Aviv Univ.~~, BNL
George Fanourakis	U. of Rochester
Kathy Young	ORNL
Hong Ma	BNL
Bill Worstell	Boston
L. Sulak	Boston
HANS COHN	ORNL
Fedyakin N.	~~IHEP, Protvino, USSR~~, MIT
Kamyshkov Yuri	ORNL ← (2 copies)
Harvey Newman	CALTECH
Bill Willis	Colombia
Carl Bromberg	MSU

Please send a copy to each one on the list. Send 2 to KAMYSHKOV.

Y. Kamyshkov

Preradiator

Physics: a) π^0 rejection (vs E_π an θ)
b) $\gamma\gamma$ vertex pointing (σz of reconstructed γ direction with beam line vs E_γ, θ)
c) e identification (end caps, high lumi)

Performance: a) for above processes
b) how much e-m resolution is degraded by preradiator.
Optimum π^0 rejection – resolution

Integration with e-m design

Cost idea

M. Leltchouk
M. Seman

Jan. 22, 92

Integrated LAr accordion preradiator

Preradiator: separate events with isolated γ from events with 2γ from isolated π^0.

Main motivation: $H \to 2\gamma$, $80\,\text{GeV} < M_H < 180\,\text{GeV}$

E_γ $20 \div 100$ GeV
↳ up to 160 GeV

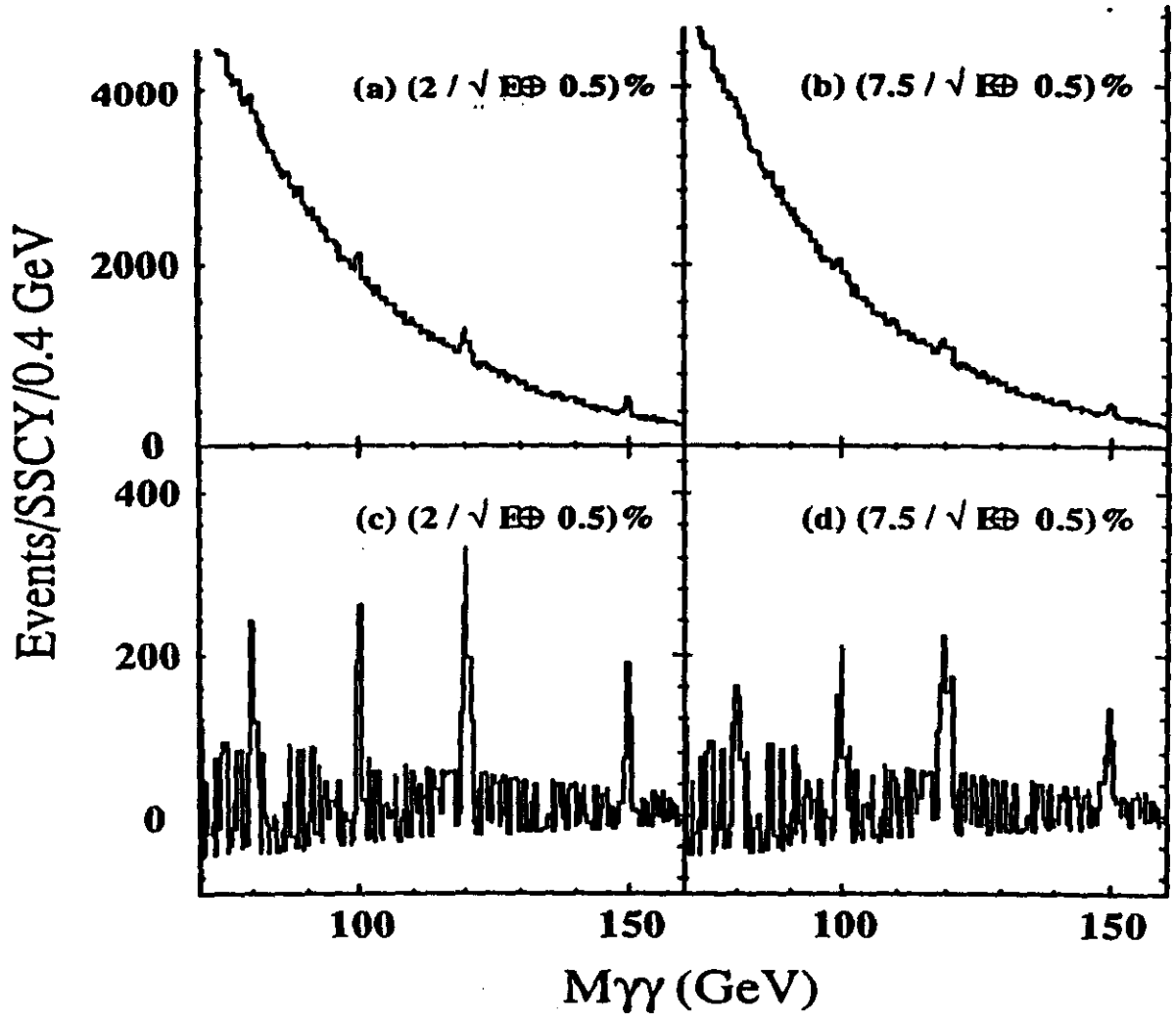
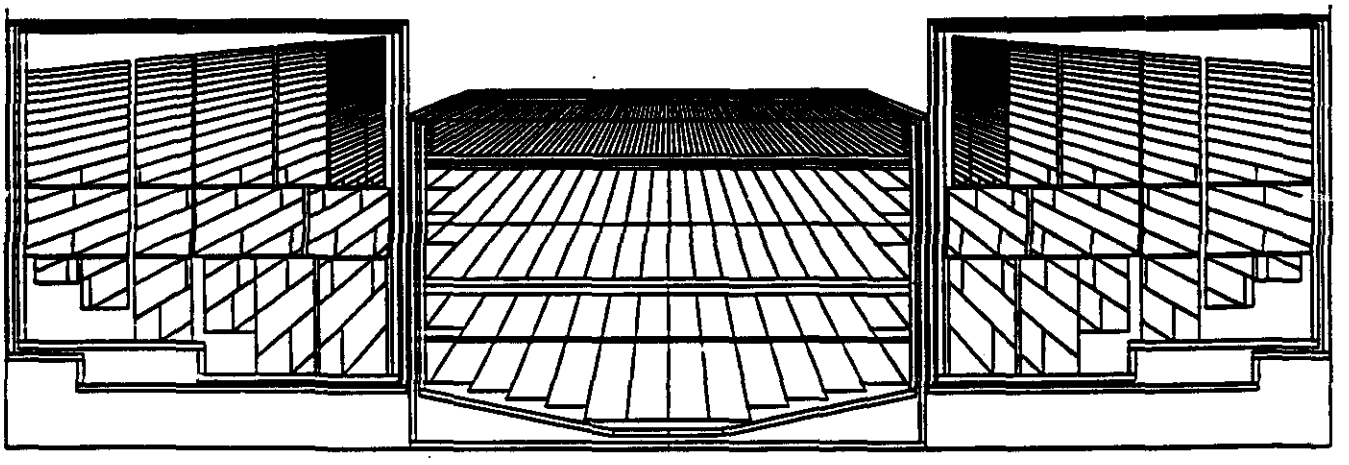
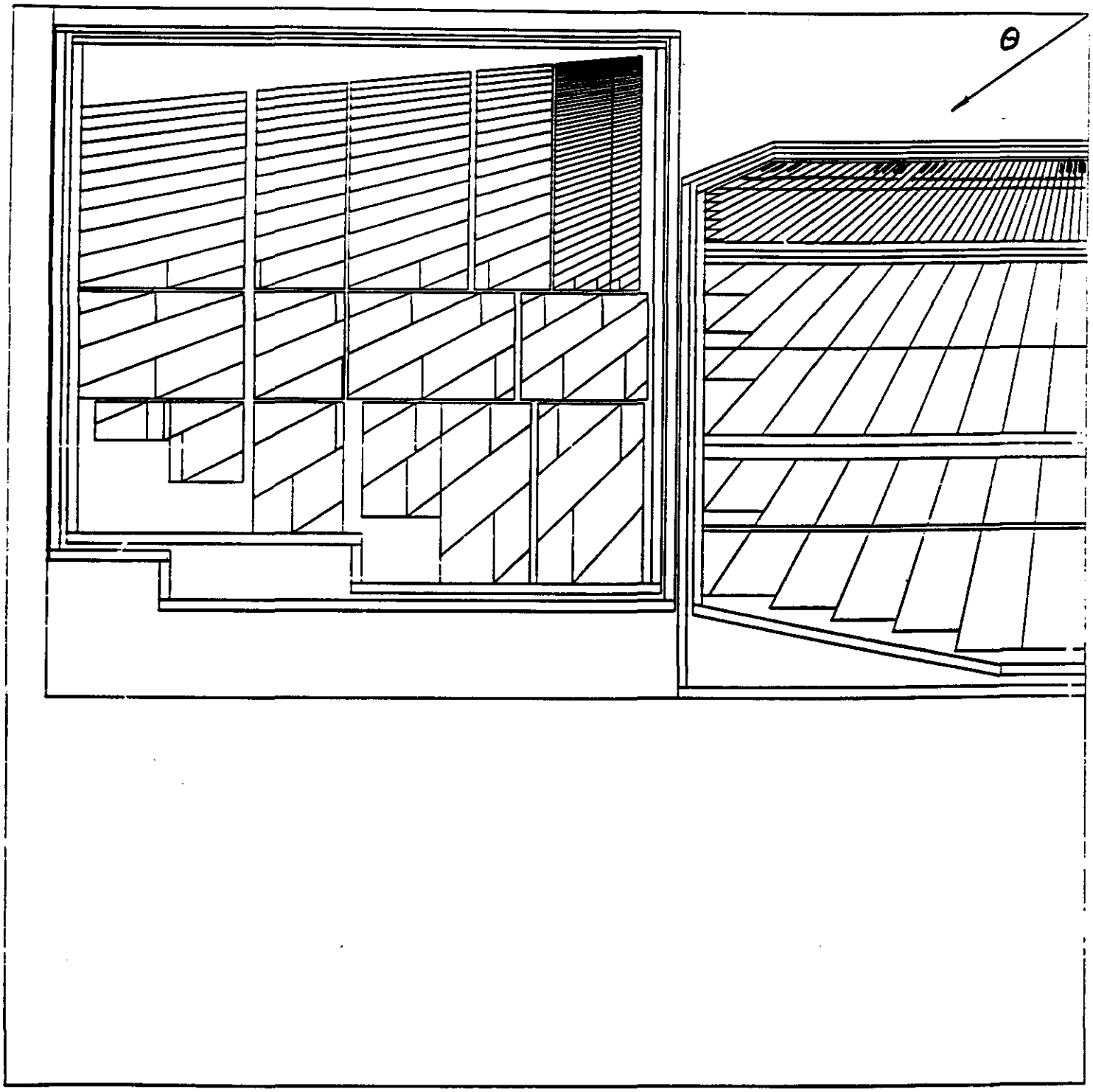
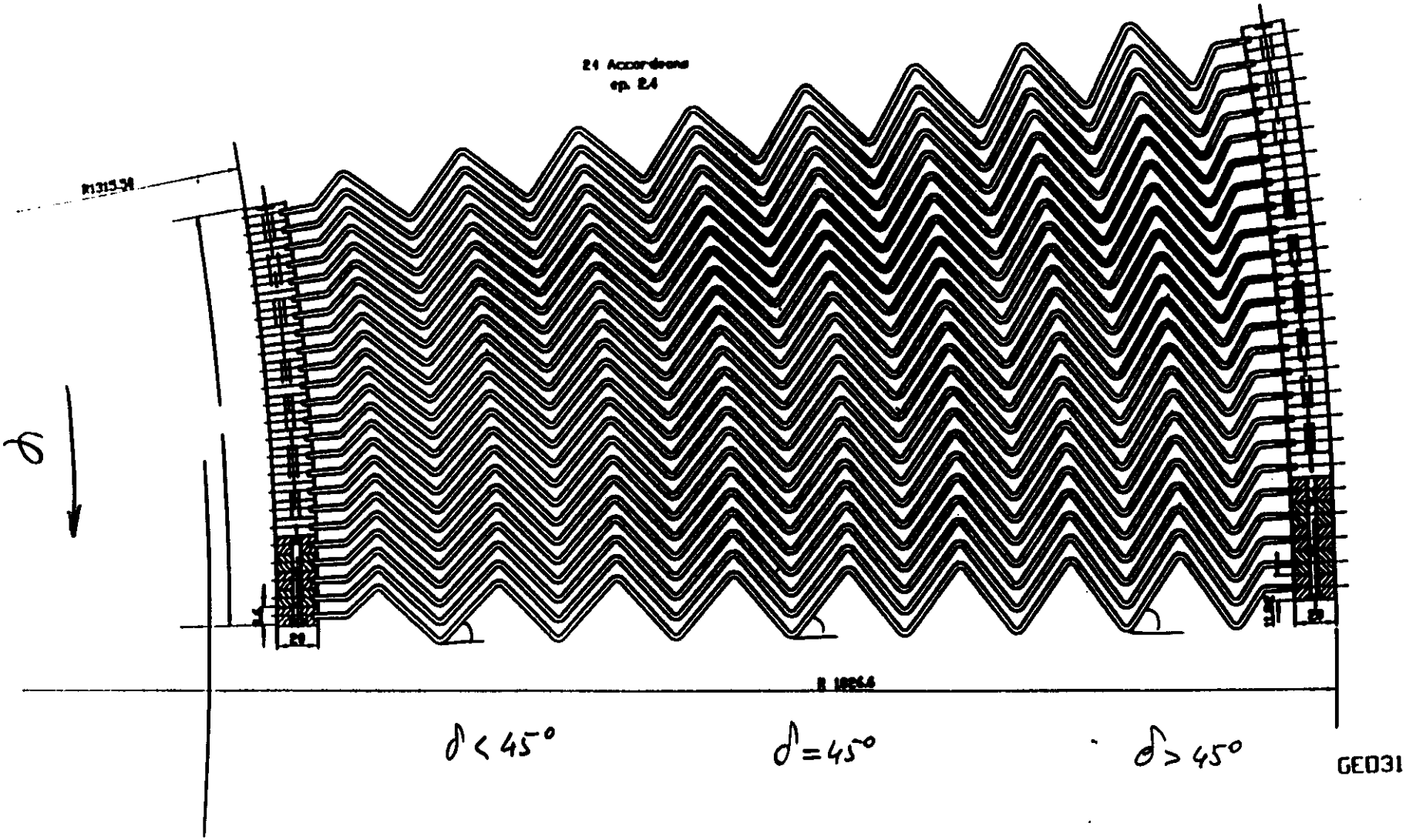
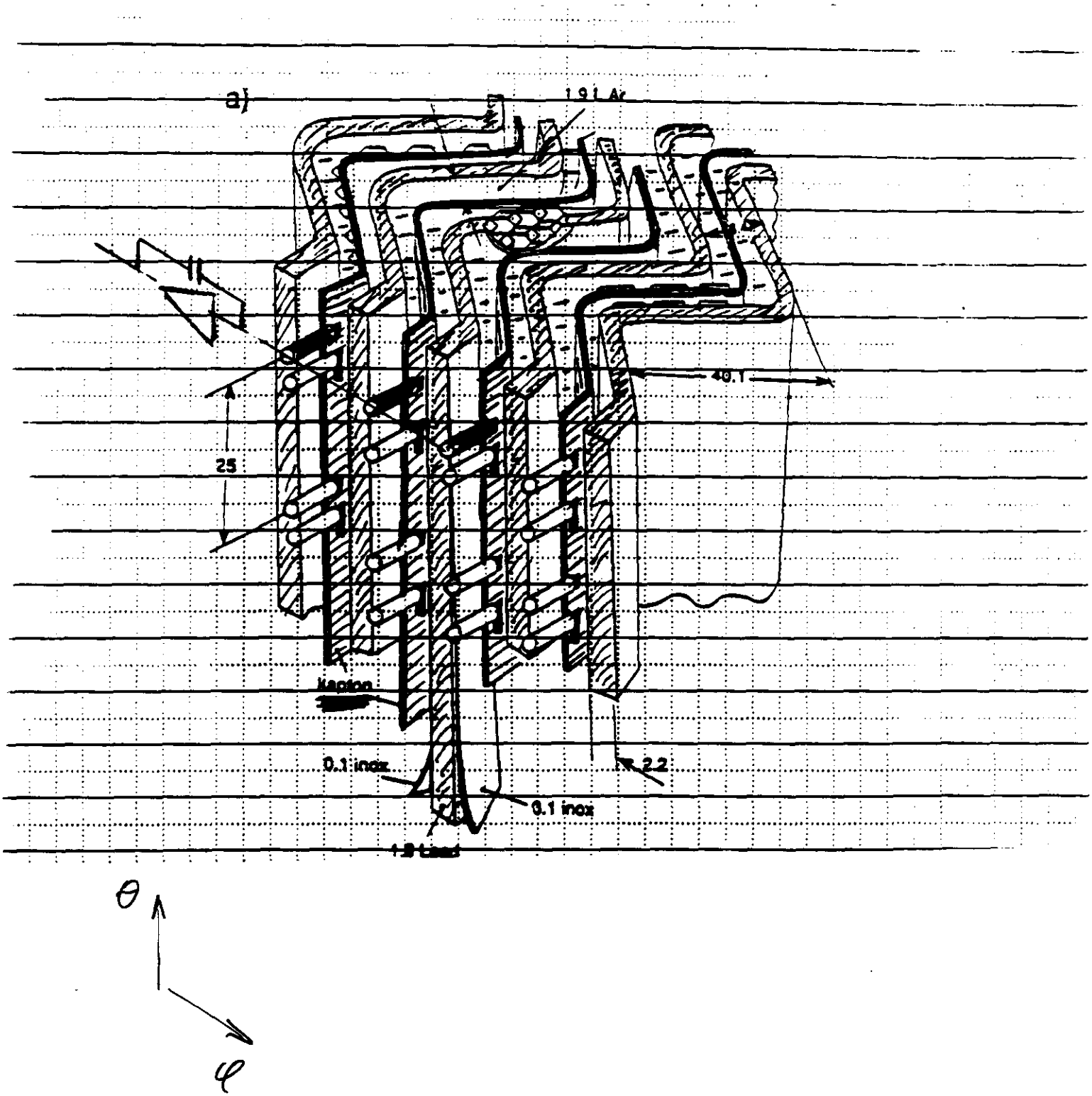


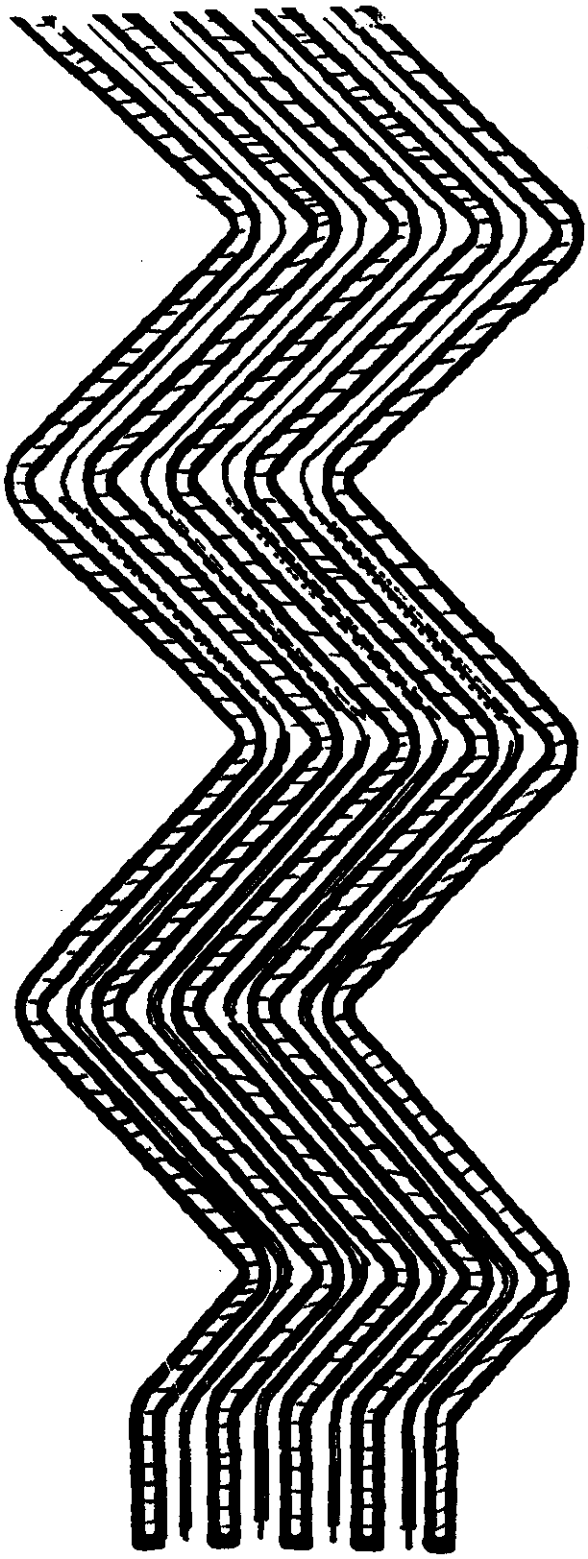
Figure 2-1 $H^0 \rightarrow \gamma\gamma$ signal and irreducible background for the two EM resolutions and four Higgs boson masses

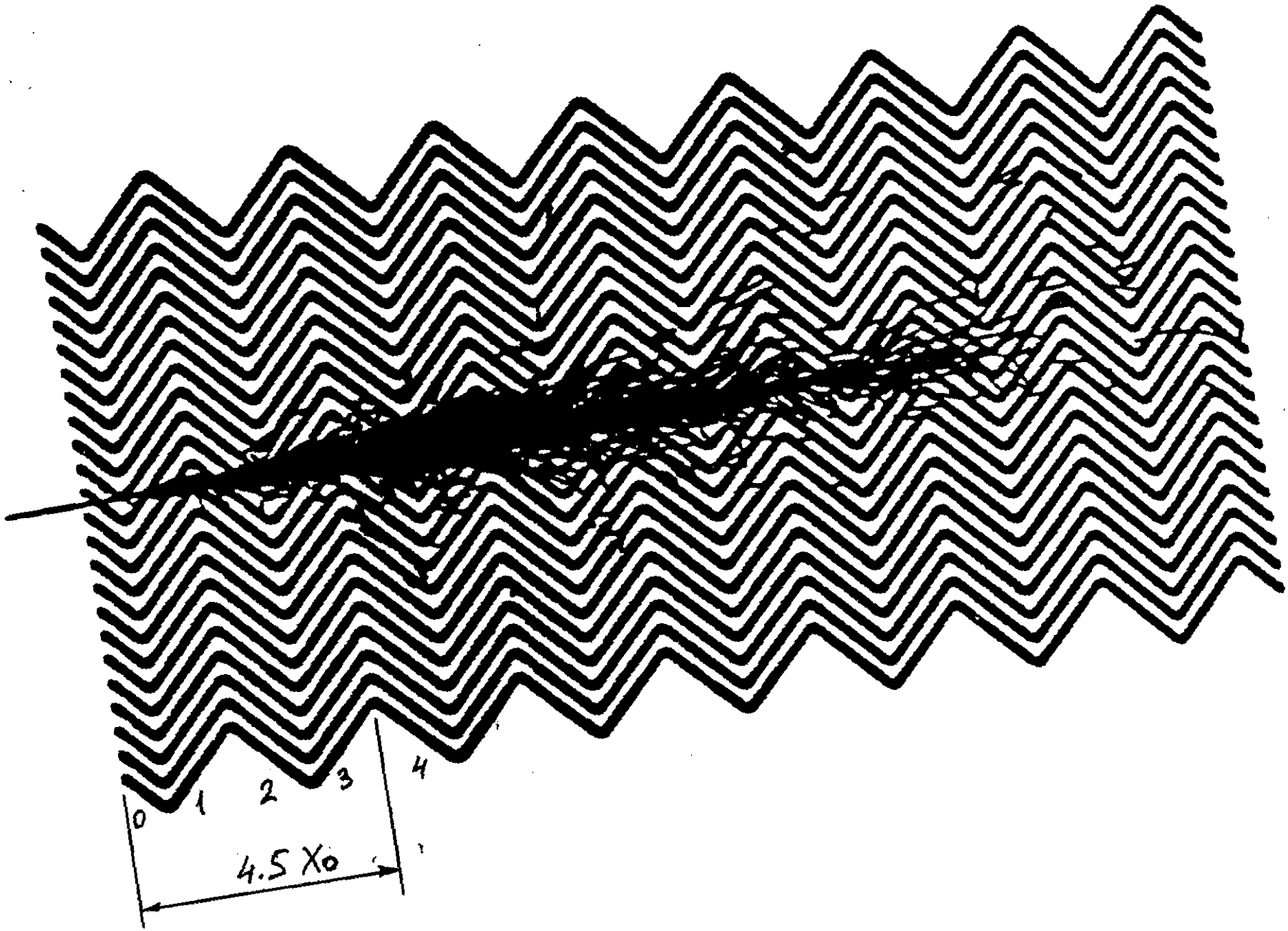



θ


24 Accordéons
ep. 2,4
R1313,38
R 1064,4
δ
δ < 45°
δ = 45°
δ > 45°
GE031


a)
19 l Ar
40.1
25
Kapton
0.1 inox
2.2
0.1 inox
θ
φ




0
1
2
3
4
4.5 Xo

θ - strips

width $\Delta\eta = 0.0012 \sim 1\,mm$ at $\theta = 90°$

length 15 cm, if 0+1+2+3 stacks

11 cm, if 0+1+2 stacks

φ - strips

width ~ 2.1 mm along the cell

1.5 mm in x-projection

length ~ 100 cm

2 strips on both sides of readout electrode are connected

strips from 2 adjacent cells are connected with shift of 6 to form stack φ-strip

$\frac{1}{2} \cdot 630$ cells $\cdot$ 12 strips $\approx$ 3800 stack φ-strips

$\times$ 4 parts along z

15 200 channels

Occupancy of φ-strip

$S = 0.2 \times 100\ cm^2$ single particle

or $R_{shower} \times 100\ cm^2$

$\sim S^{0.7}$

$t_p \approx 40\ ns$

EM tower occupancy at threshold $\underset{200}{100}\ \mu eV$

0.04×0.04

$\sim 3 \cdot 10^{-3}$

$\sim 1 \cdot 10^{-3}$

per min bias event

number of interactions occuring within the integration time $1.6 \cdot \frac{40\ ns}{16\ ns} = 4$

Probabity of a random overlap $\sim 1.2 \cdot 10^{-2}$

for tower

$\sim 4 \cdot 10^{-3}$

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for φ-strip with equivalent threshold

$\Rightarrow$ factor $S^{0.7} \sim 2 \div 4$

Probability of a random overlap $\sim 1\%$

at reasonable threshold

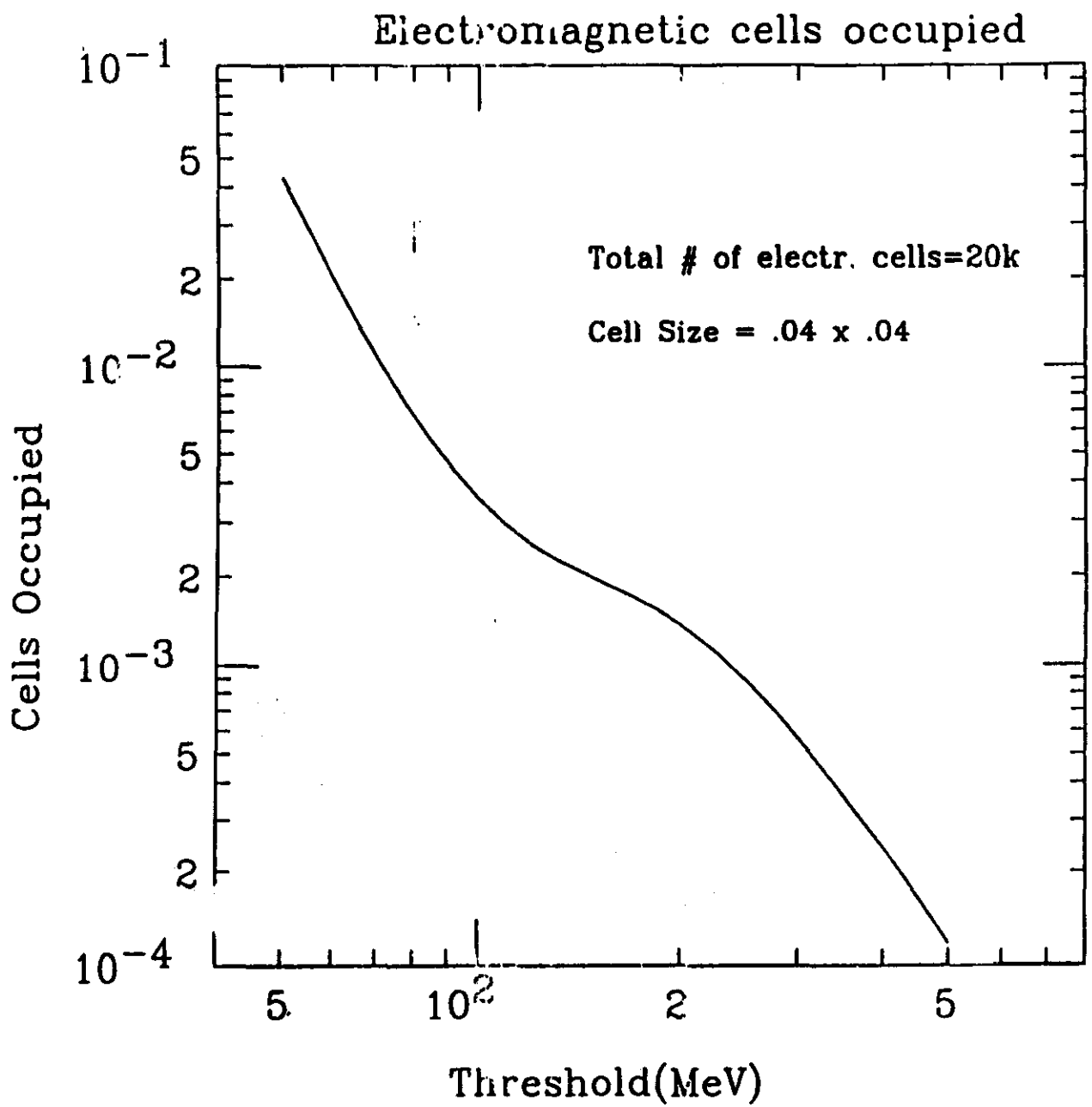
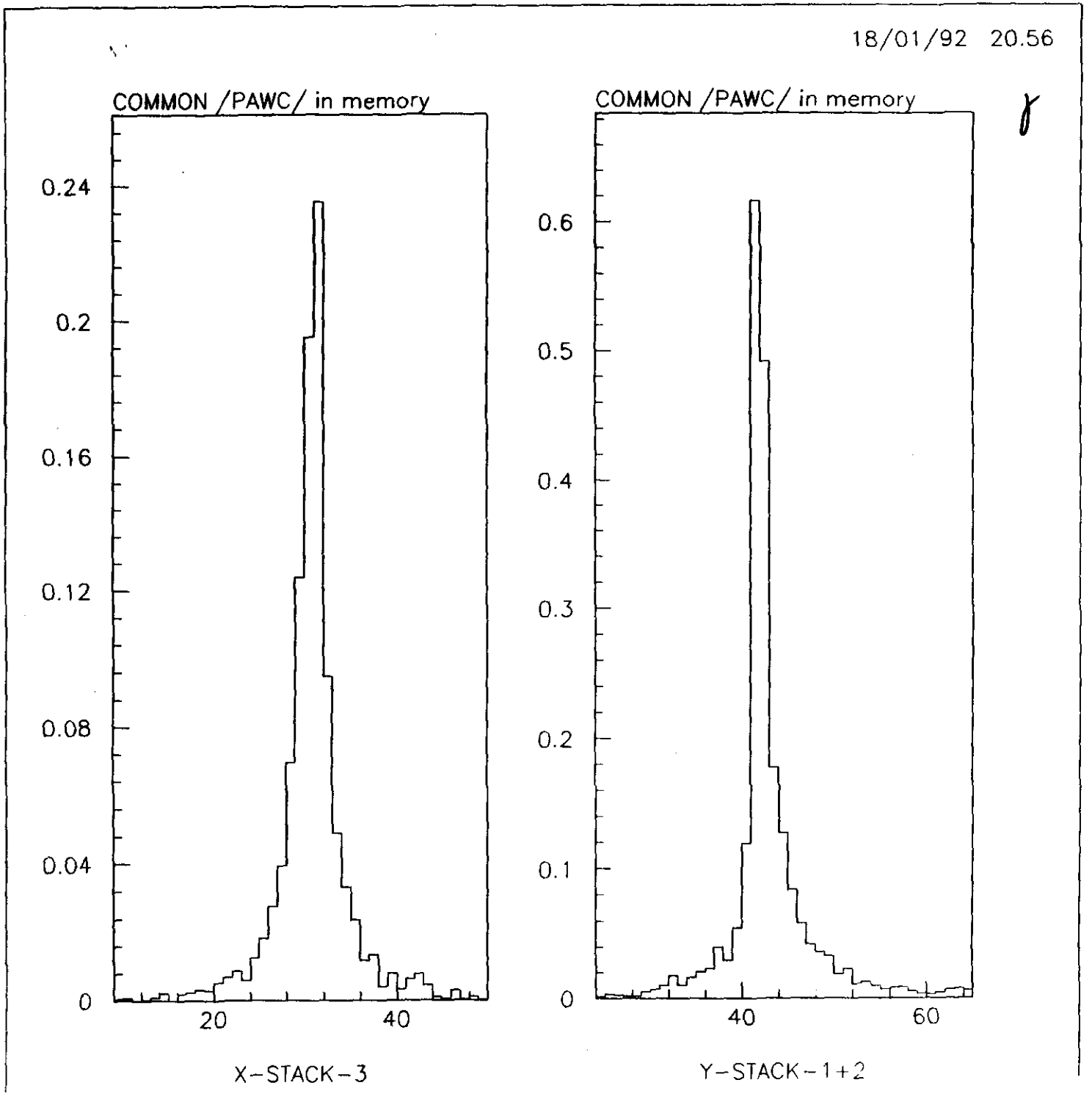
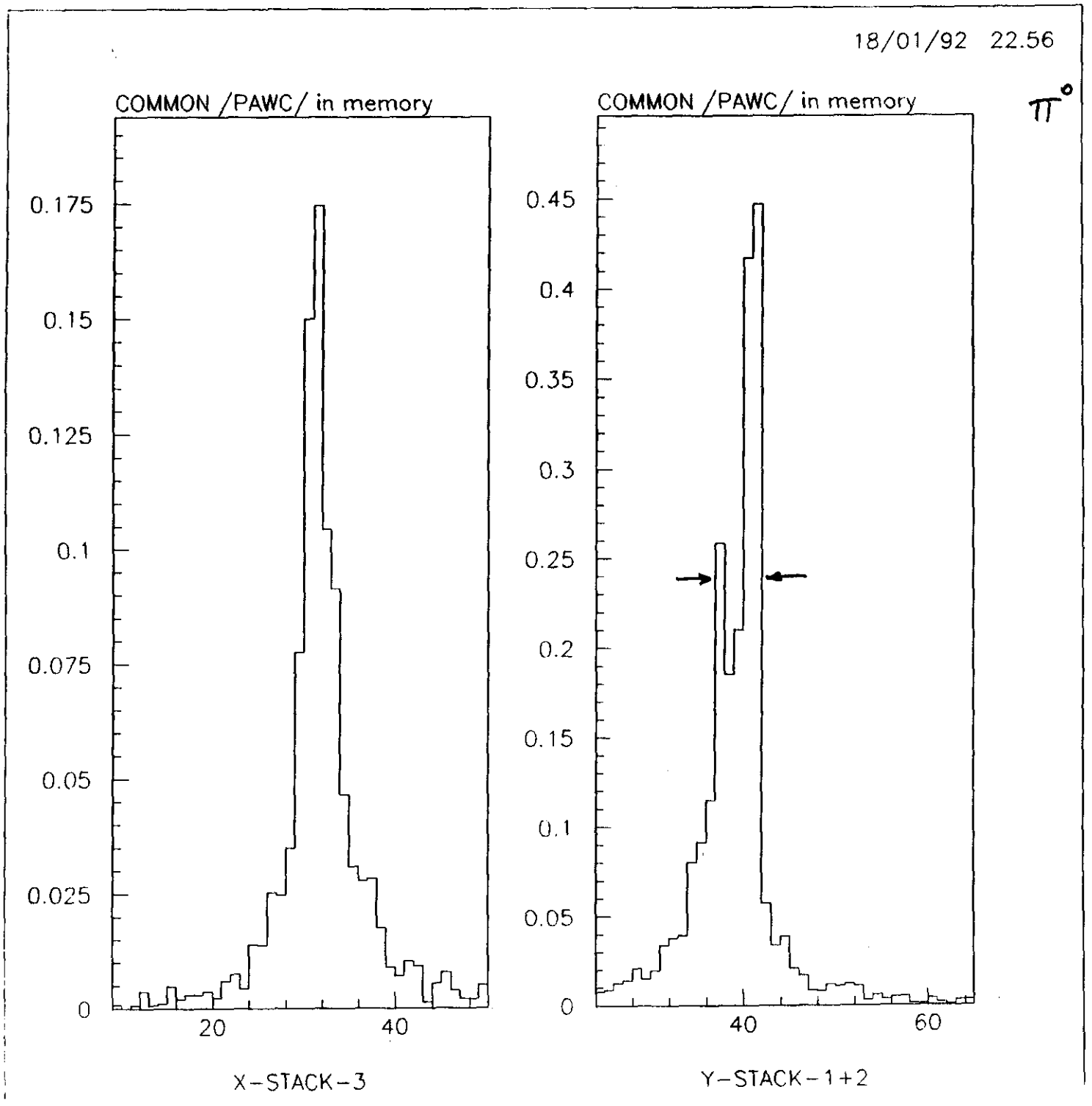


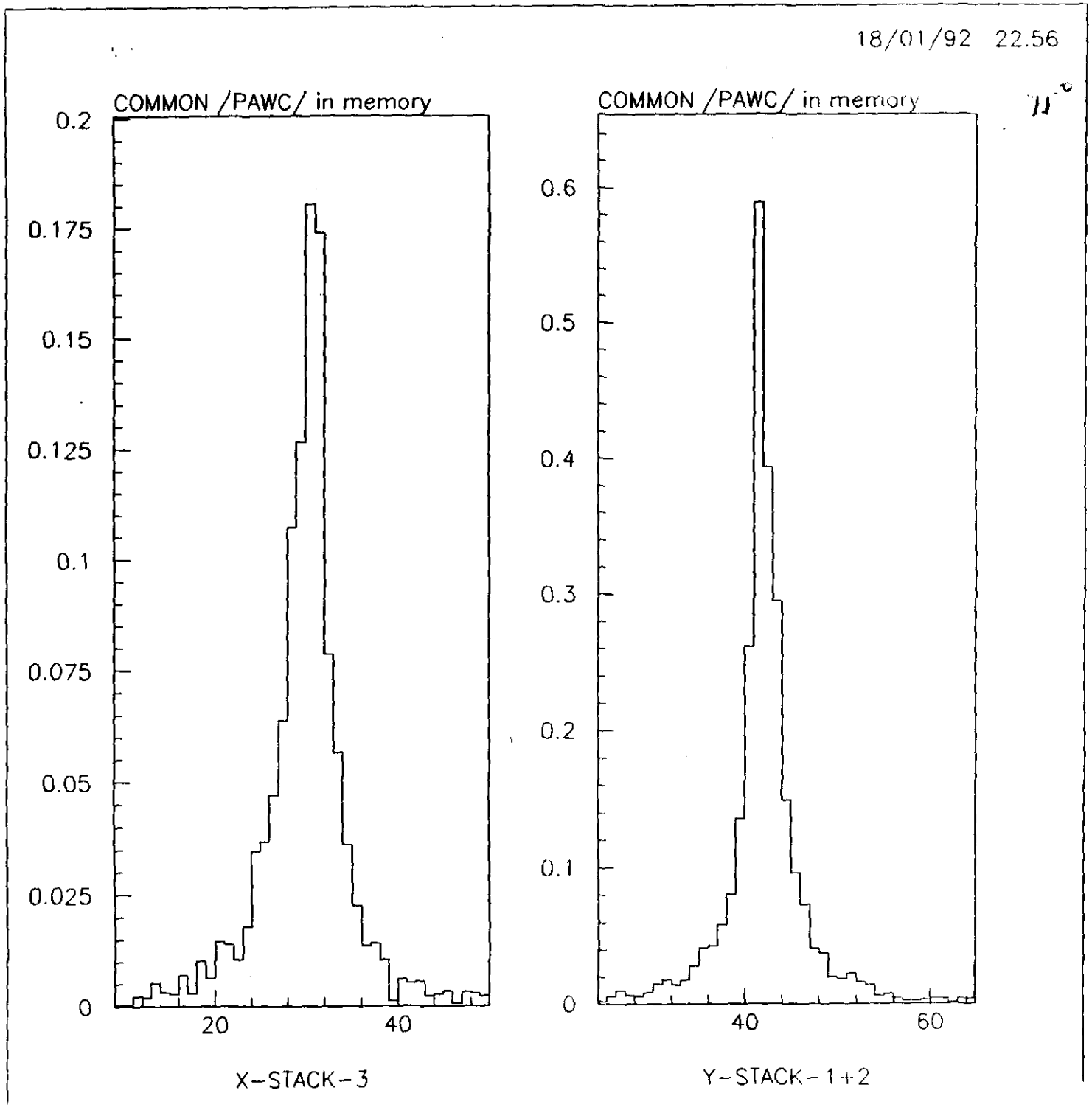
Figure 2: Occupancy in a LAr EM calorimeter cell for $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1}.


18/01/92 20.56
COMMON /PAWC/ in memory
0.24
0.2
0.16
0.12
0.08
0.04
0
20
40
X-STACK-3
COMMON /PAWC/ in memory
0.6
0.5
0.4
0.3
0.2
0.1
0
40
60
Y-STACK-1+2

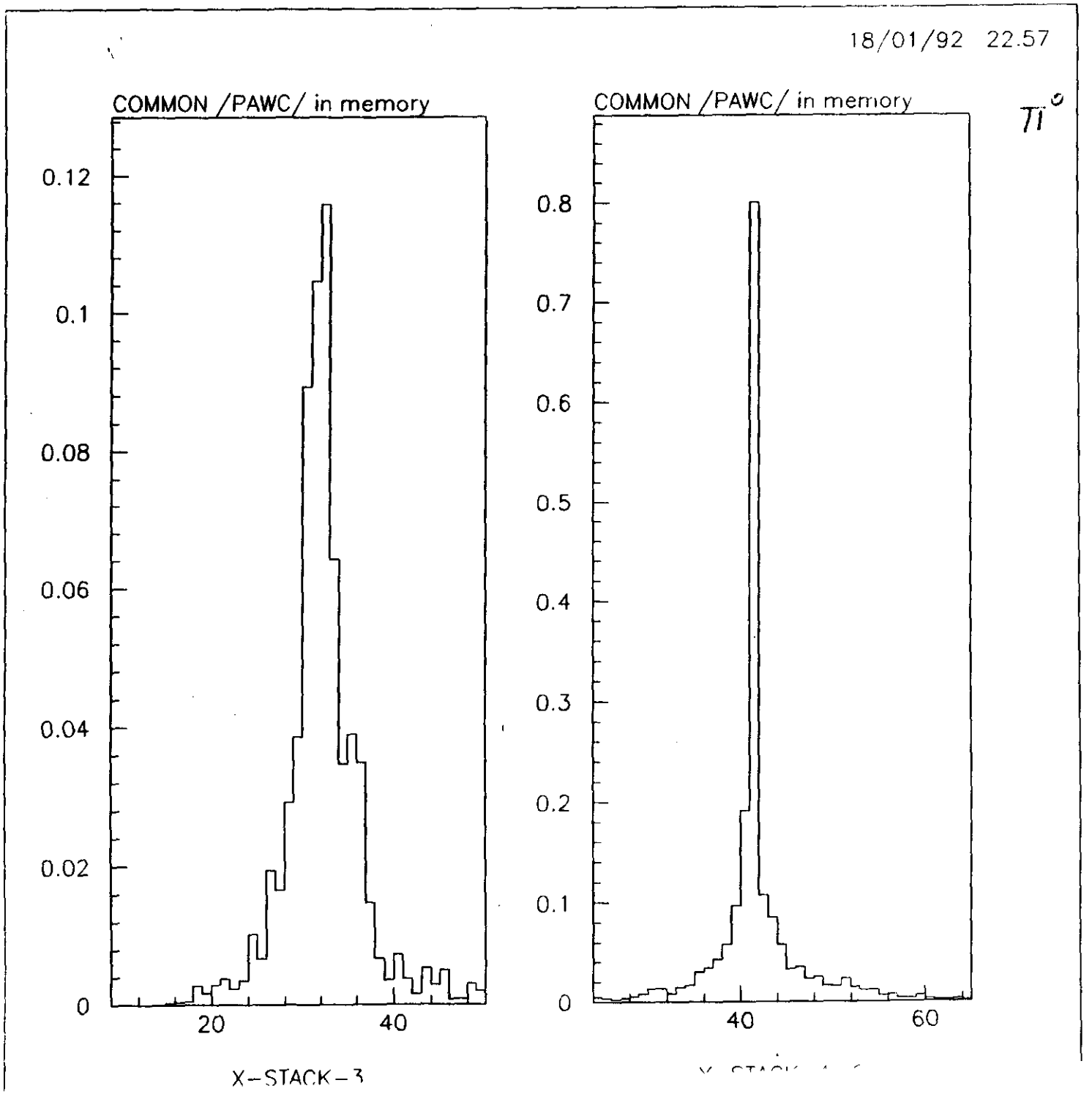
γ 50 GeV


18/01/92 22.56
COMMON /PAWC/ in memory
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
20
40
X-STACK-3
COMMON /PAWC/ in memory
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
40
60
Y-STACK-1+2

π^0 50 GeV


18/01/92 22.56
COMMON /PAWC/ in memory
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
20
40
X-STACK-3
COMMON /PAWC/ in memory
0.6
0.5
0.4
0.3
0.2
0.1
0
40
60
Y-STACK-1+2

π^0 50 GeV


18/01/92 22.57
COMMON /PAWC/ in memory
0.12
0.1
0.08
0.06
0.04
0.02
0
20
40
X-STACK-3
COMMON /PAWC/ in memory
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
40
60

π^0 50 GeV

First results

with θ strips and very simple simulation of 1 mm φ strip

Parameters:

1) width at equal relative threshold
2) "far amplitude"
   ↓ more than 10 strips from peak
   or $n < 10$
3) width of 2 "highest energy" strips
   3
   4
   5
   ⋮
n) "global" $P = \sum_i \ln P_i$

E dependence
θ dependence
magnetic field

low statistics
100 ÷ 200 events

50 GeV

$\varepsilon_\gamma = 100\%$

90° $R_\pi = 93\%$

45° $R_\pi = 89\%$

magnetic field 0.8T

$\varepsilon_\gamma = 100\%, 95\%, 85\%, 60\%$

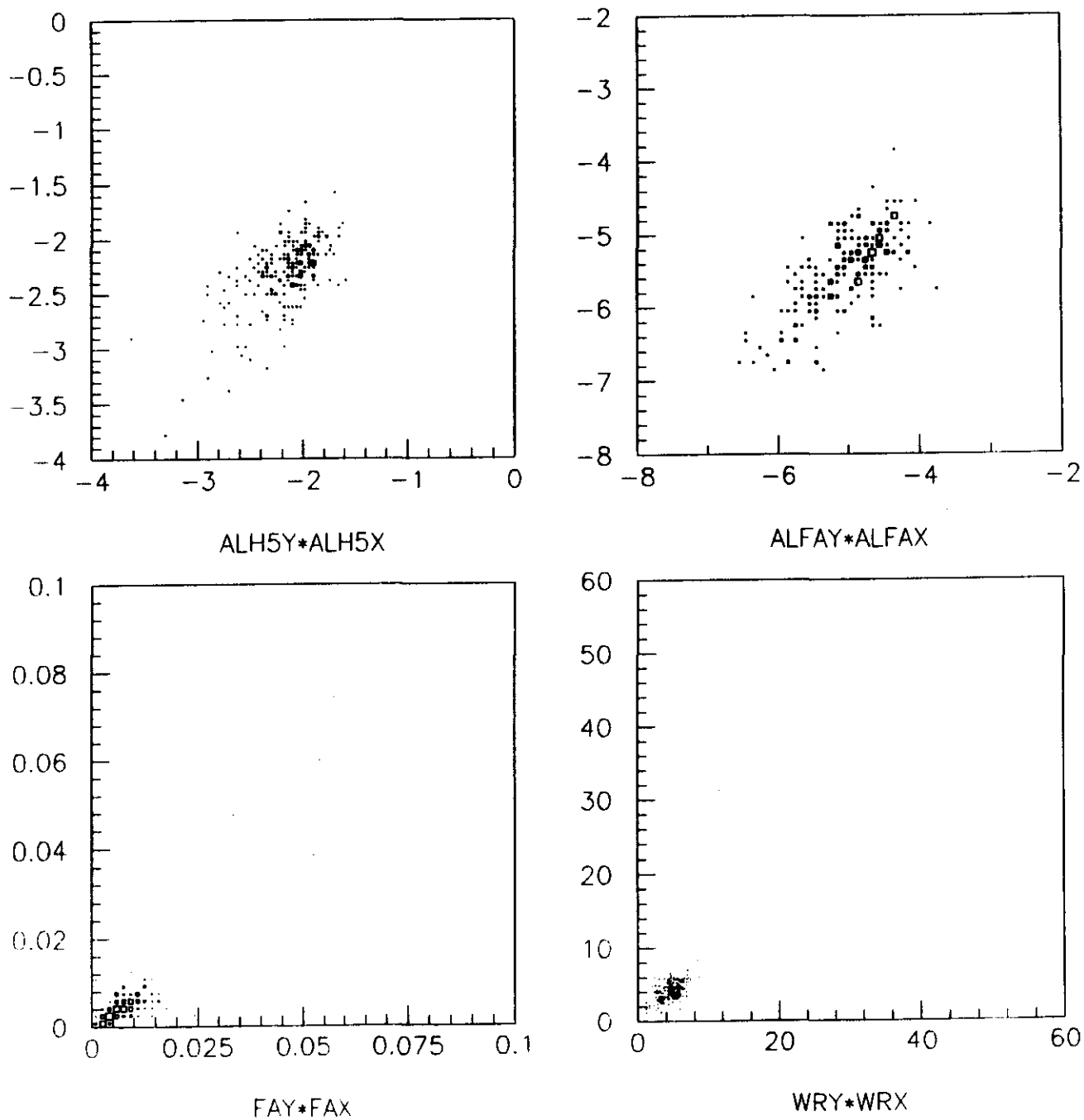
$R_\pi = 91\%$ 91% 93%, 95%

M. Seman – code with simulation of charge collection to realistic φ strips ~1.5 mm

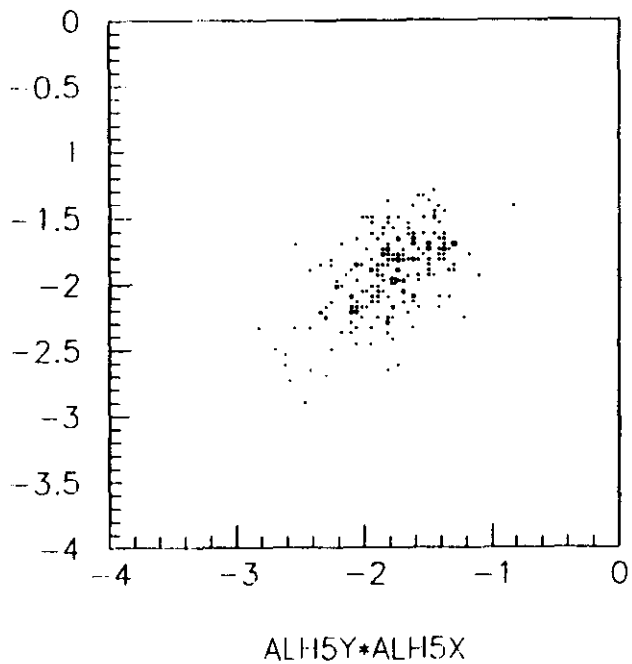
Parameters: 1) asymmetry
2) 2nd momentum

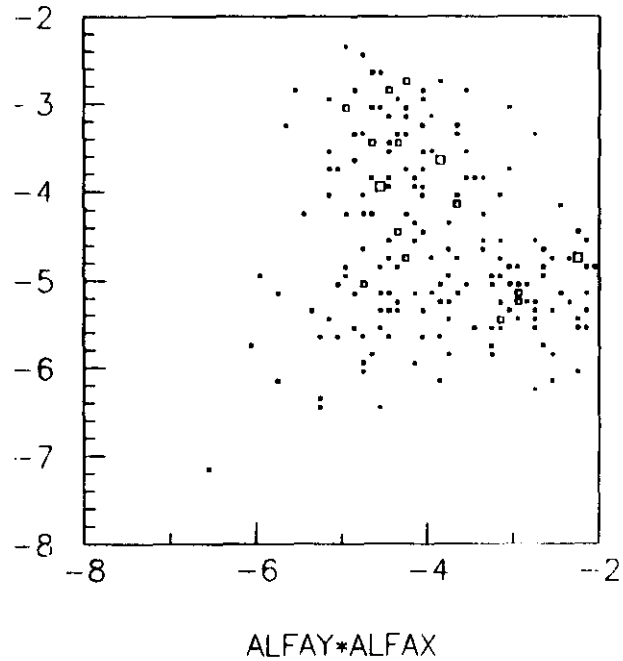
50 GeV $\varepsilon_\gamma = 94\%$ $R_\pi = 84\%$ – first result

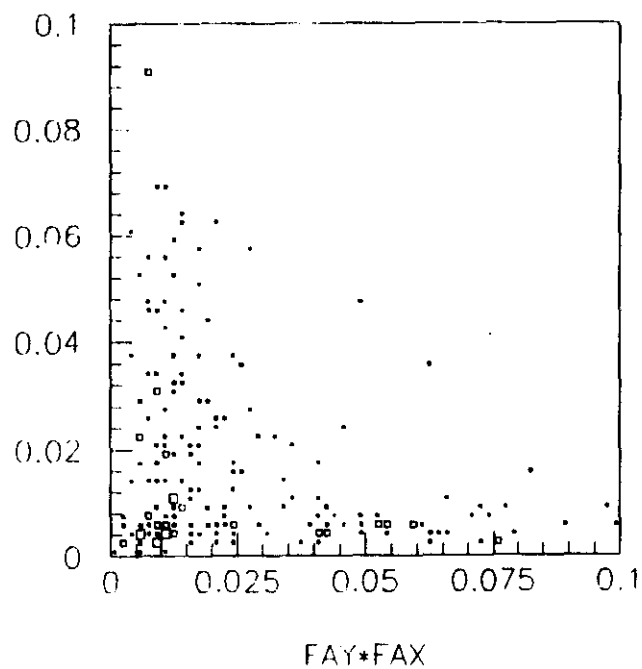
γ 25 GeV

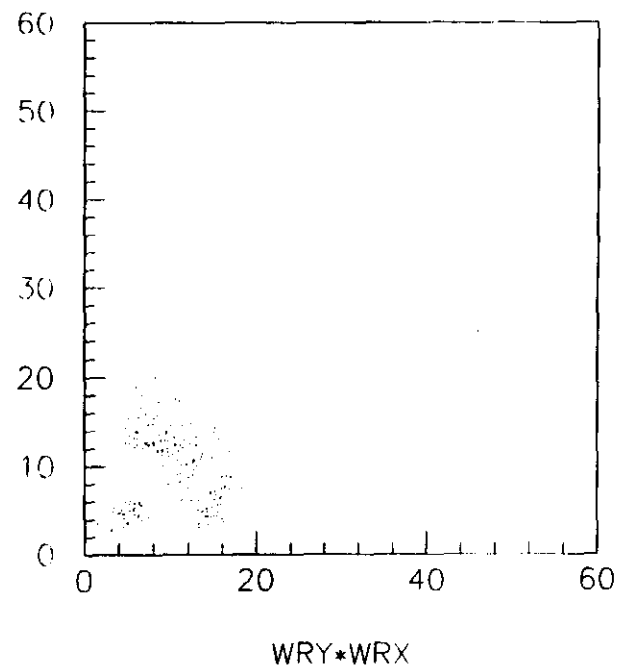


π 25 GeV

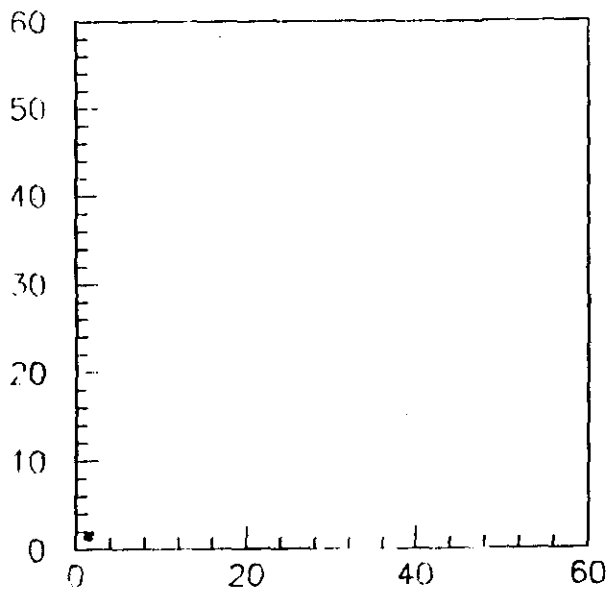

0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4
-3
-2
-1
0
ALH5Y*ALH5X


-2
-3
-4
-5
-6
-7
-8
-8
-6
-4
-2
ALFAY*ALFAX

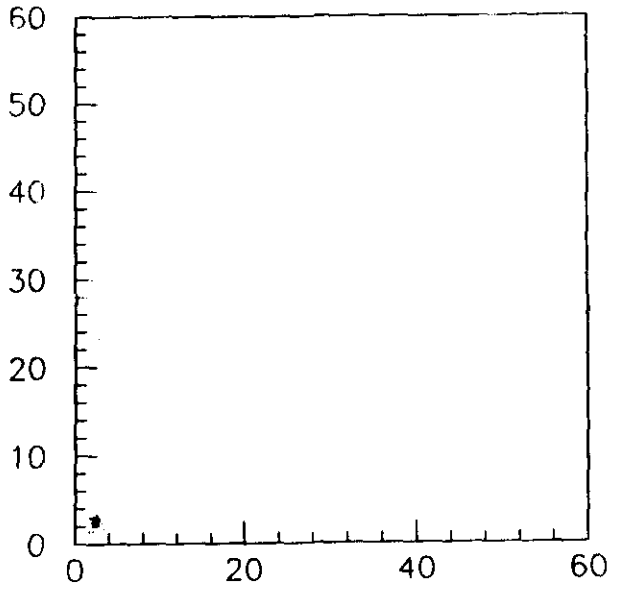

0.1
0.08
0.06
0.04
0.02
0
0
0.025
0.05
0.075
0.1
FAY*FAX


60
50
40
30
20
10
0
0
20
40
60
WRY*WRX

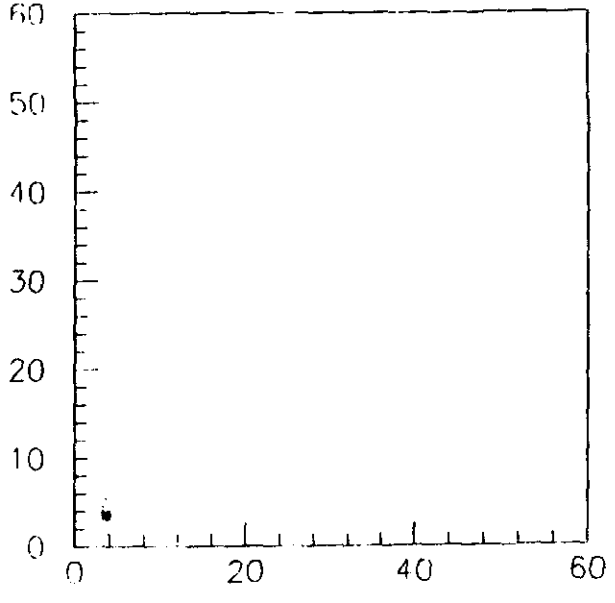
γ 25 GeV



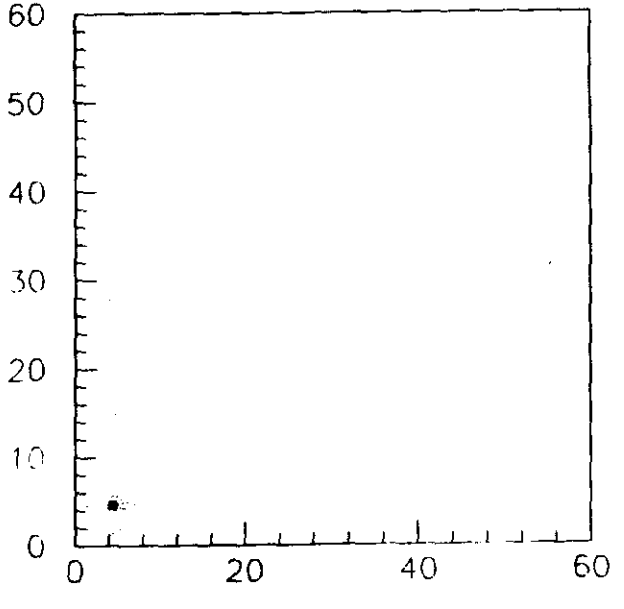
W2Y*W2X



W3Y*W3X

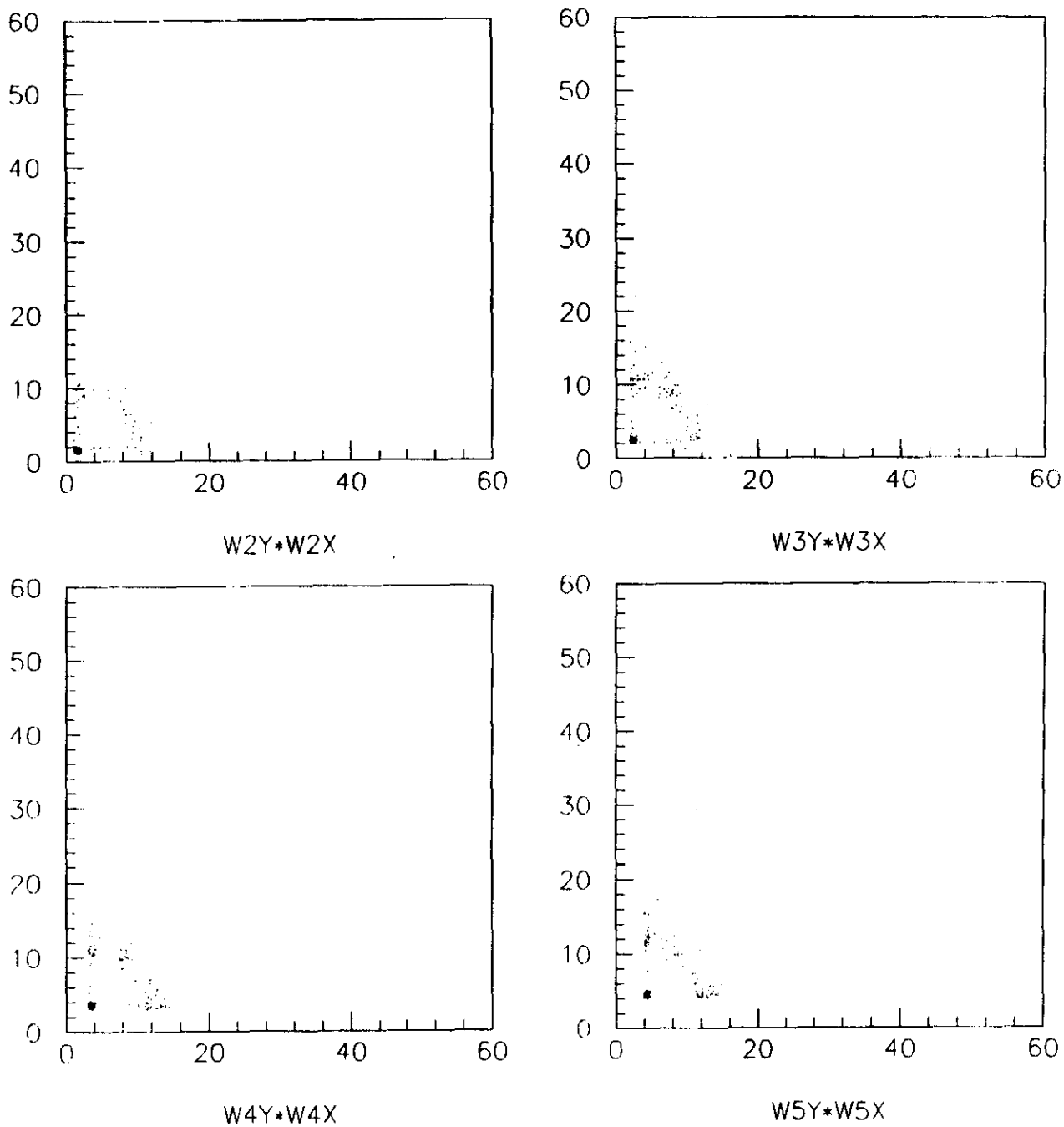


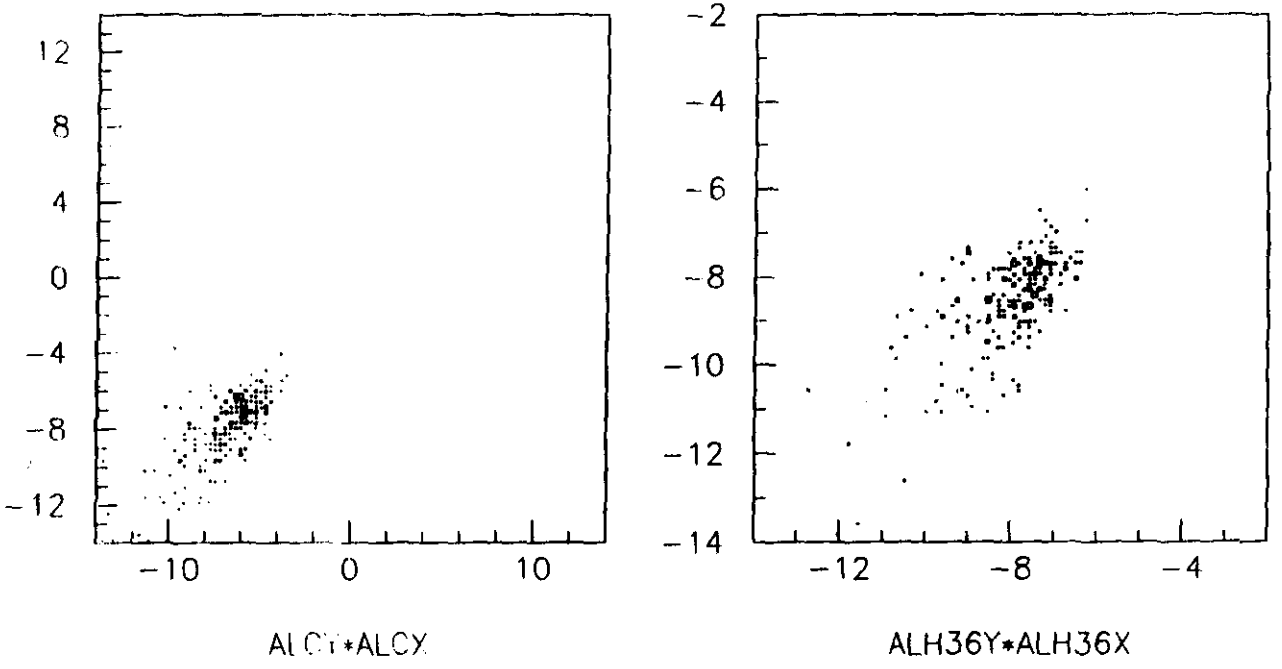
W4Y*W4X



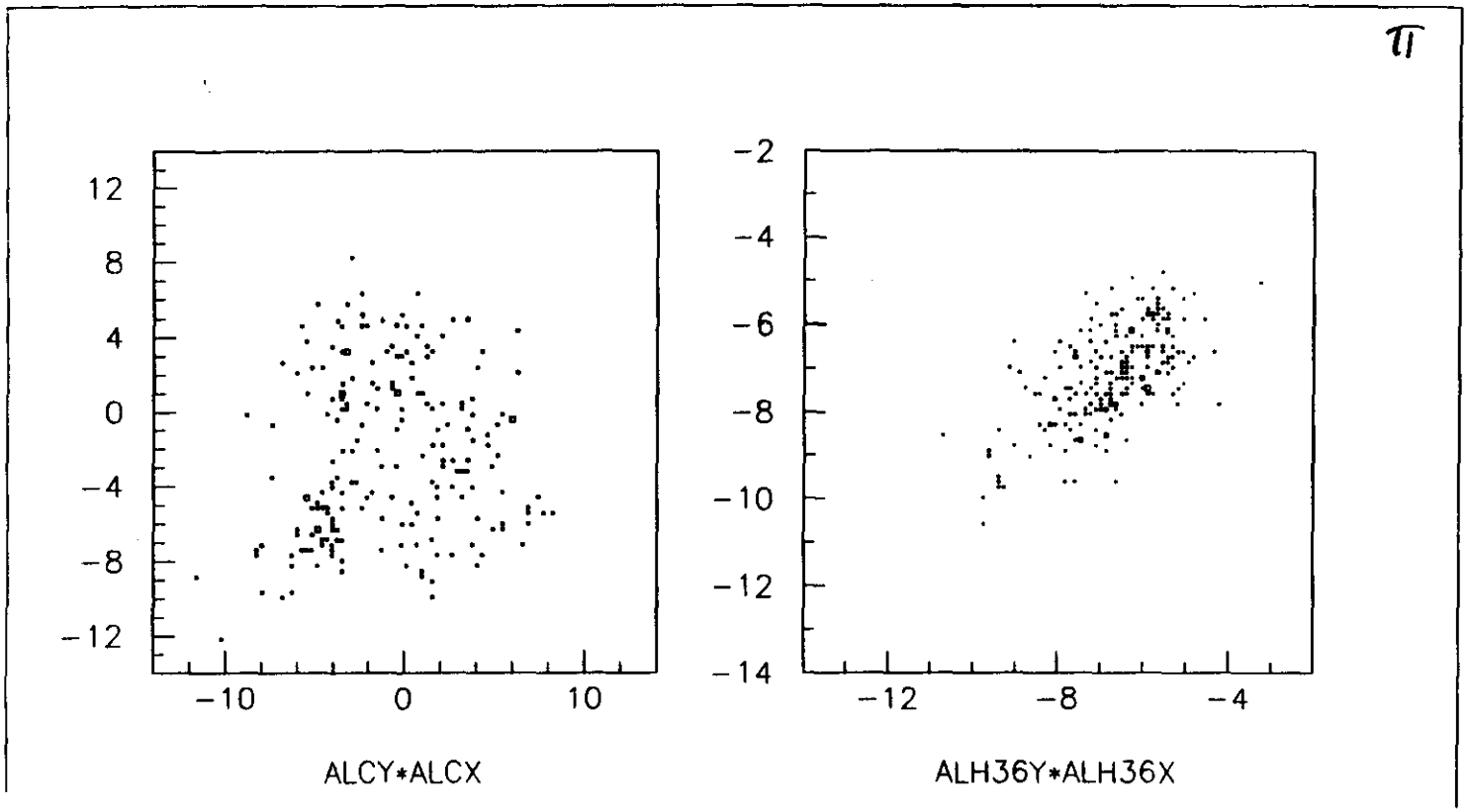
W5Y*W5X

π 25 GeV





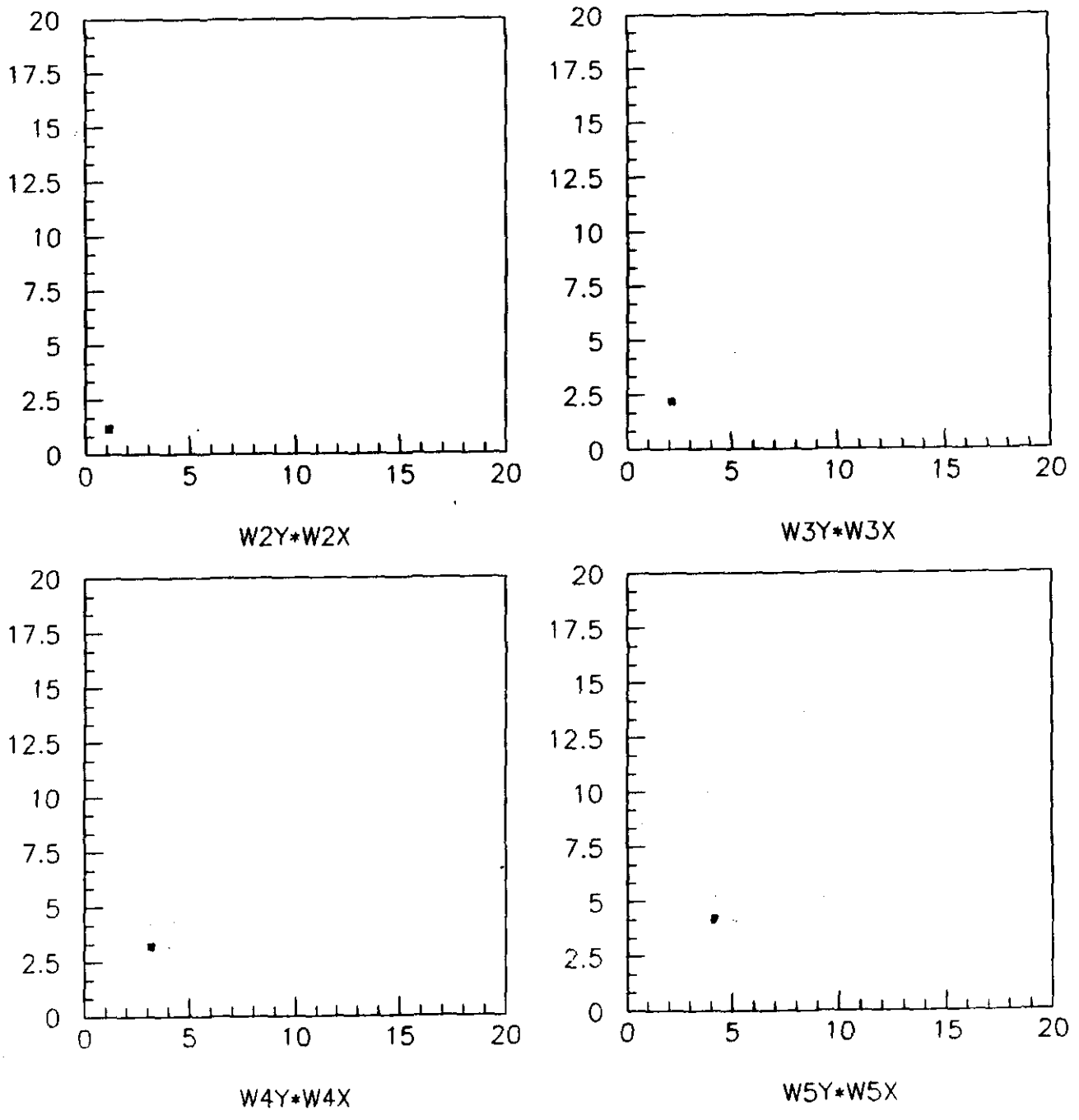
γ 25 GeV



25 GeV

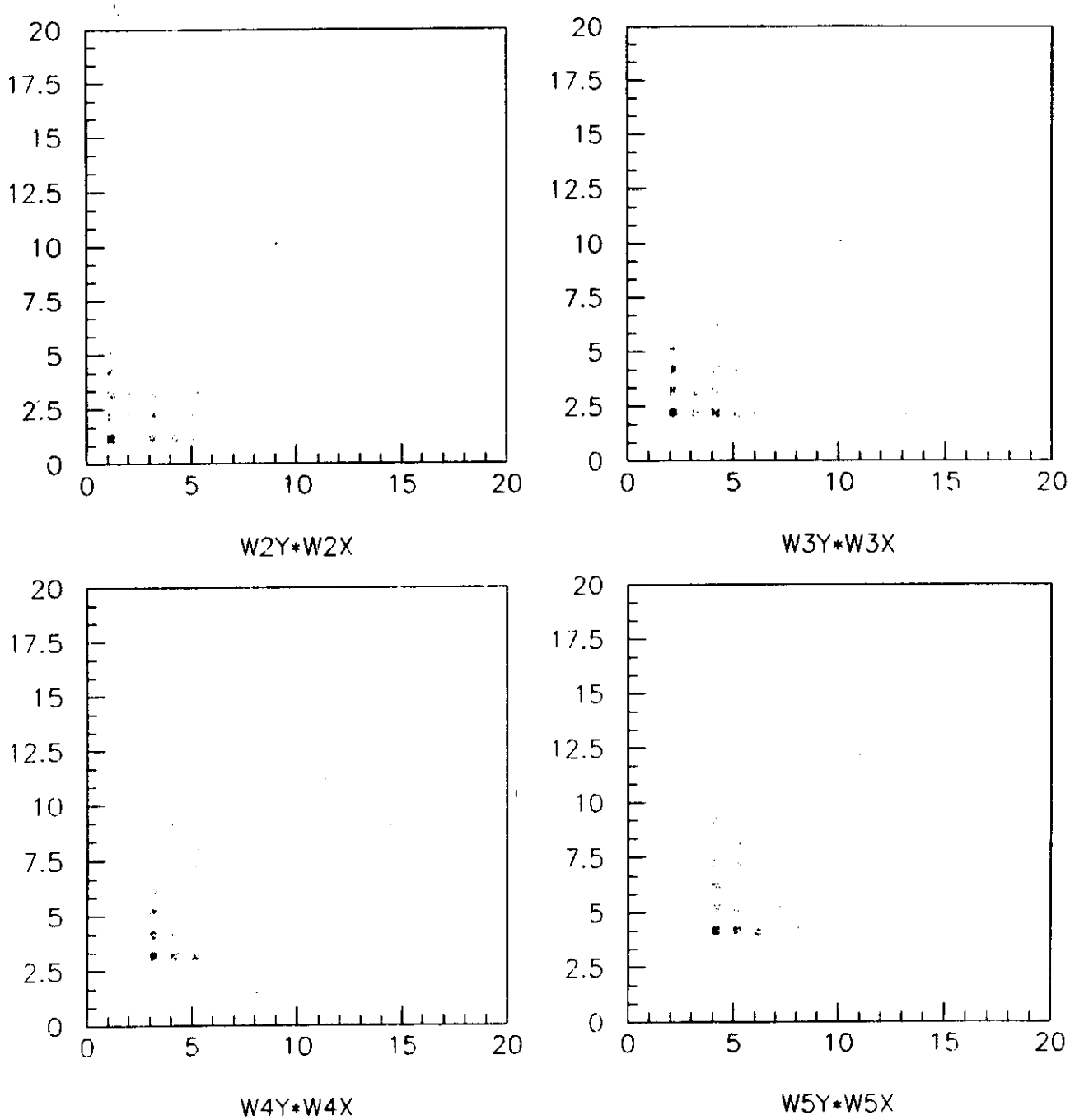
at $\varepsilon_\gamma = 99\%$

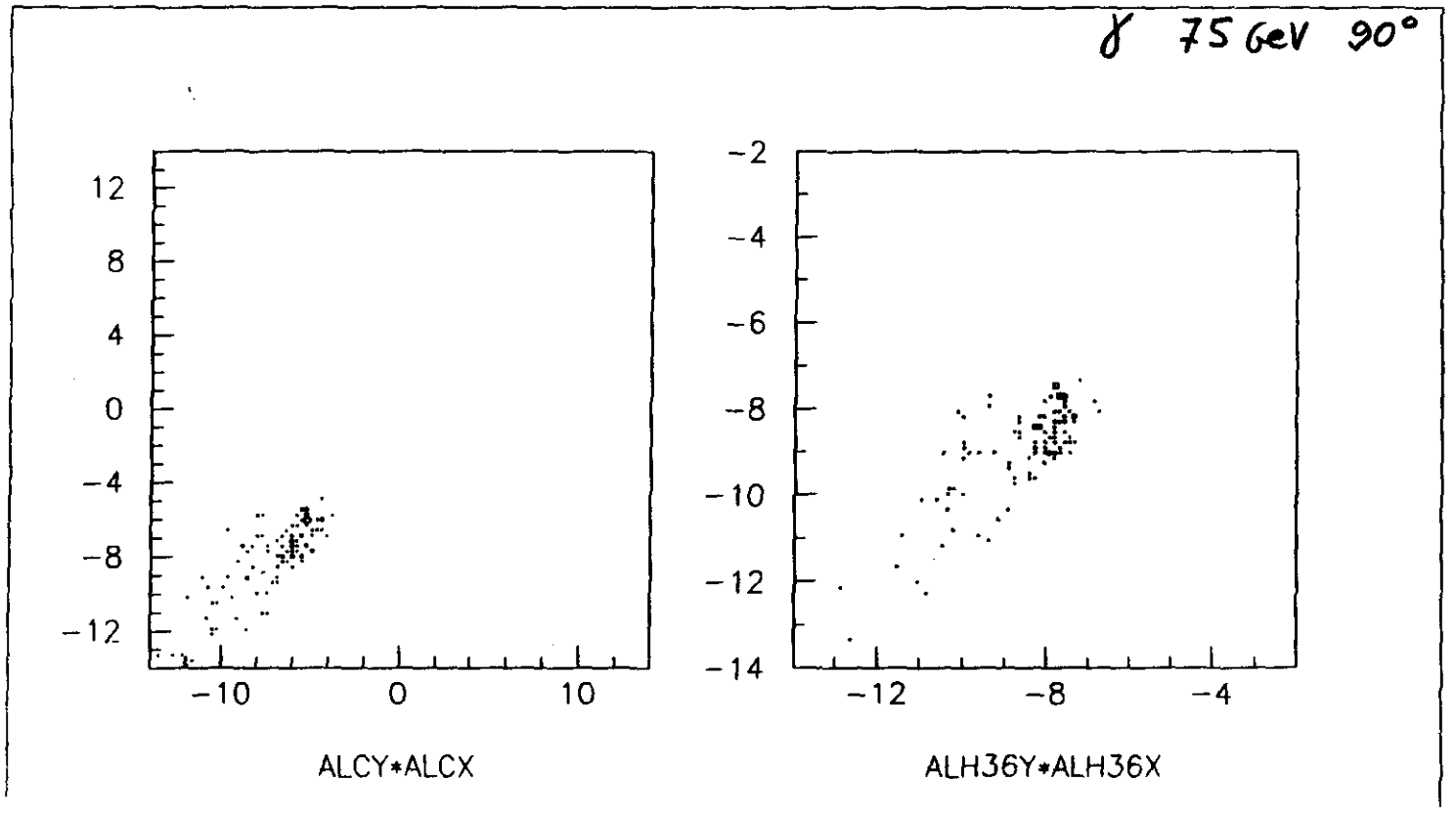
$R_\pi = 86\%$

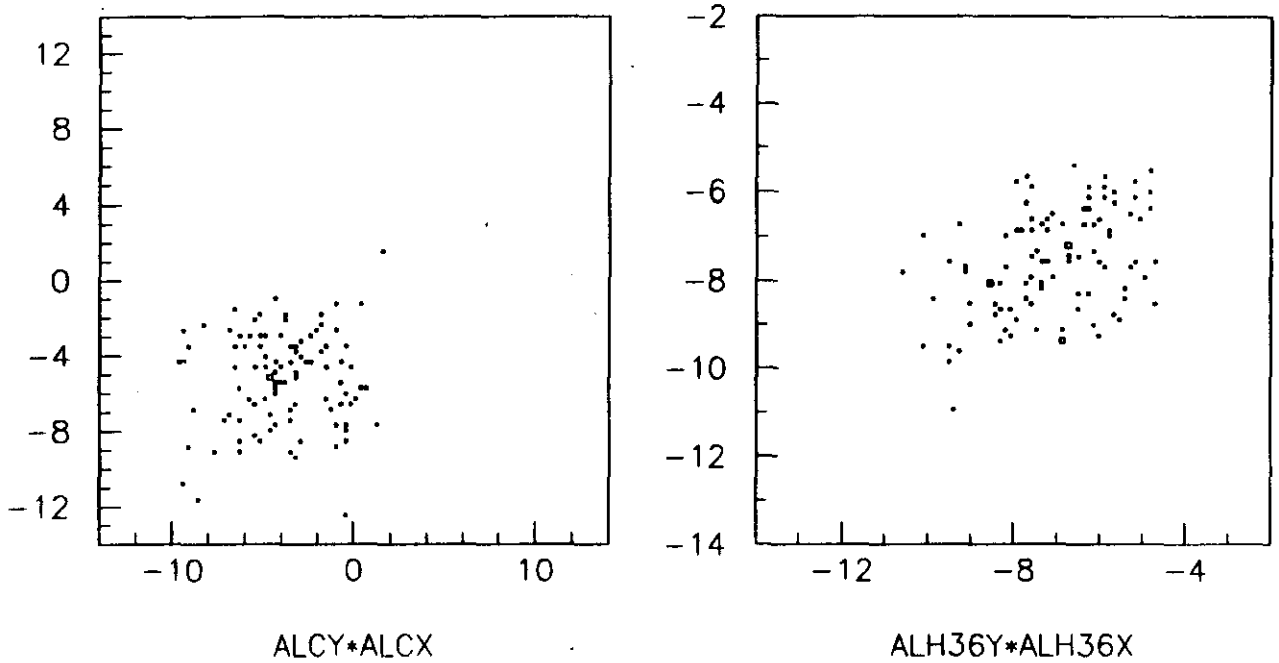


γ 75 GeV 90°

π 75 GeV 90°




γ 75 GeV 90°
12
8
4
0
−4
−8
−12
−10
0
10
ALCY*ALCX
−2
−4
−6
−8
−10
−12
−14
−12
−8
−4
ALH36Y*ALH36X

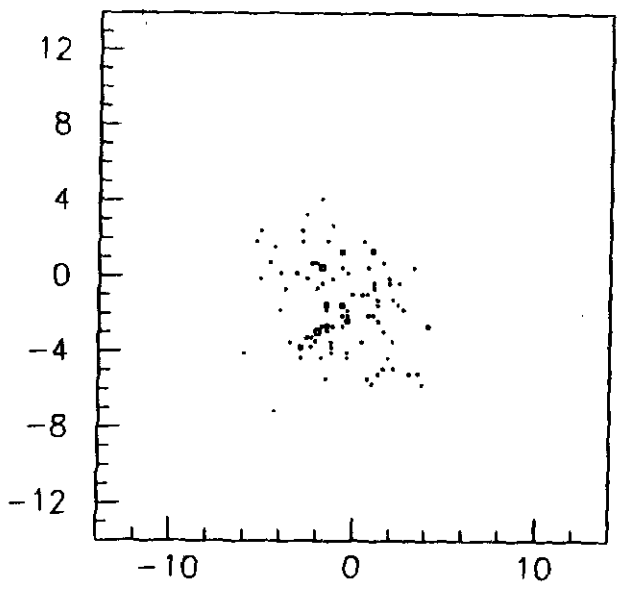


π^- 75 GeV 90°

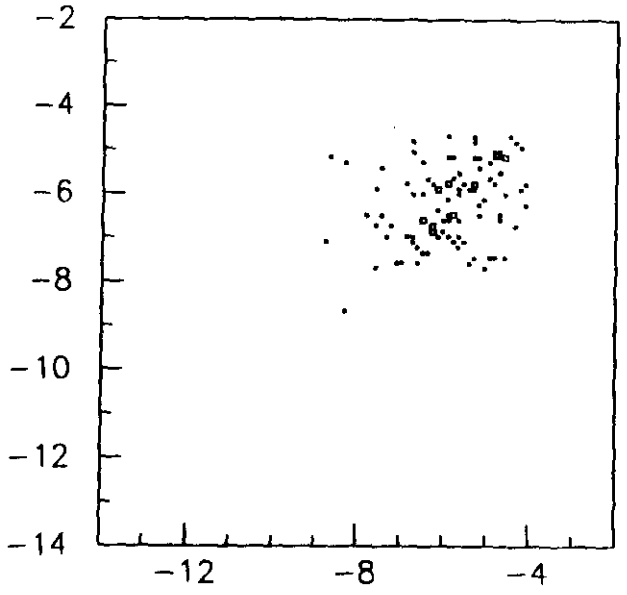
$\varepsilon_\gamma = 99\%$

$R_\pi = 88\%$

π 75 GeV 45°



ALCY*ALCX

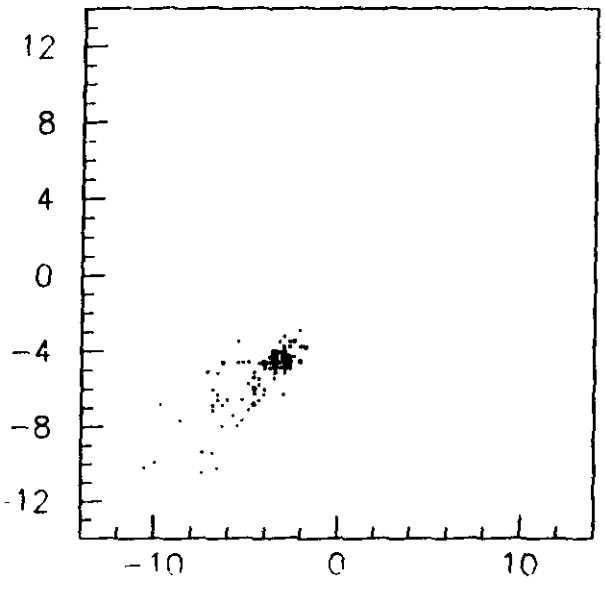


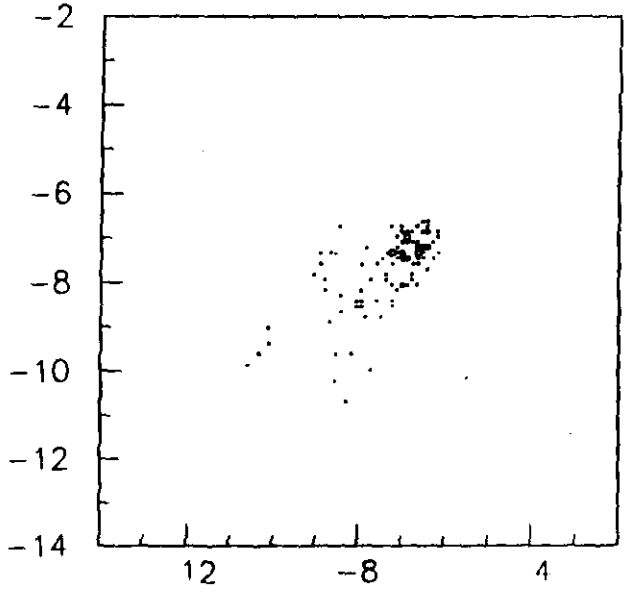
ALH36Y*ALH36X

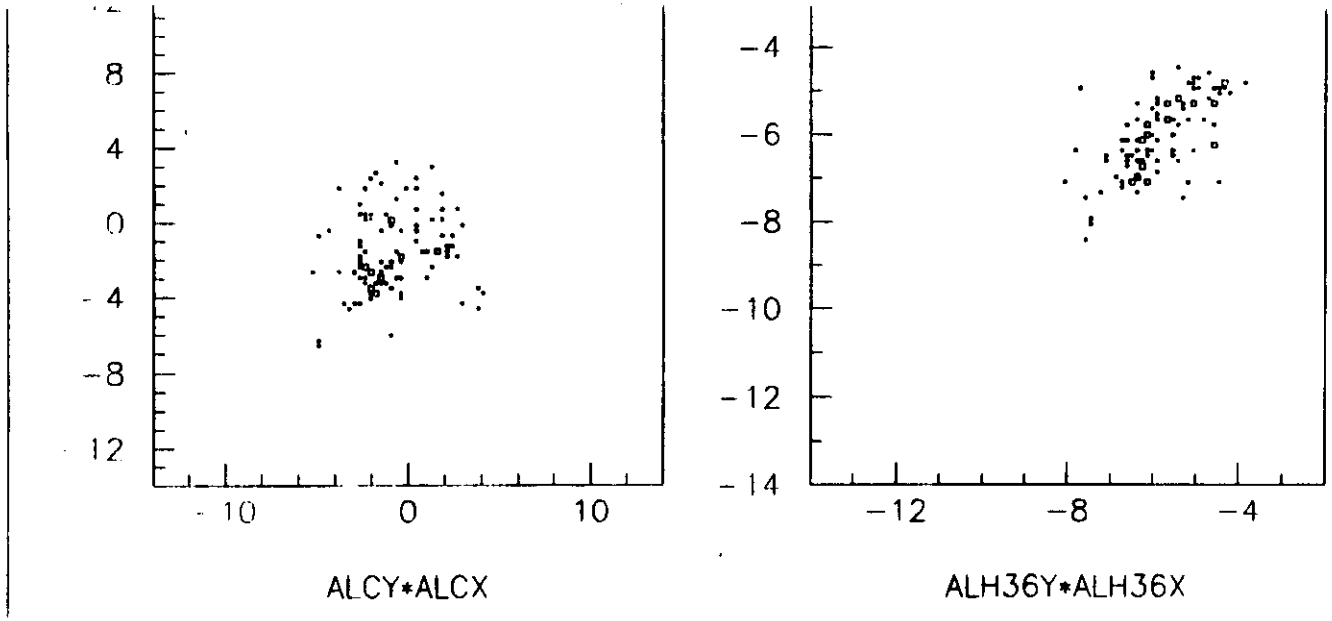
$\varepsilon_\gamma = 98\%$

$R_\pi = 94\%$

γ



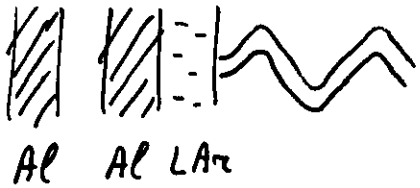




π

75 GeV 45° deviation

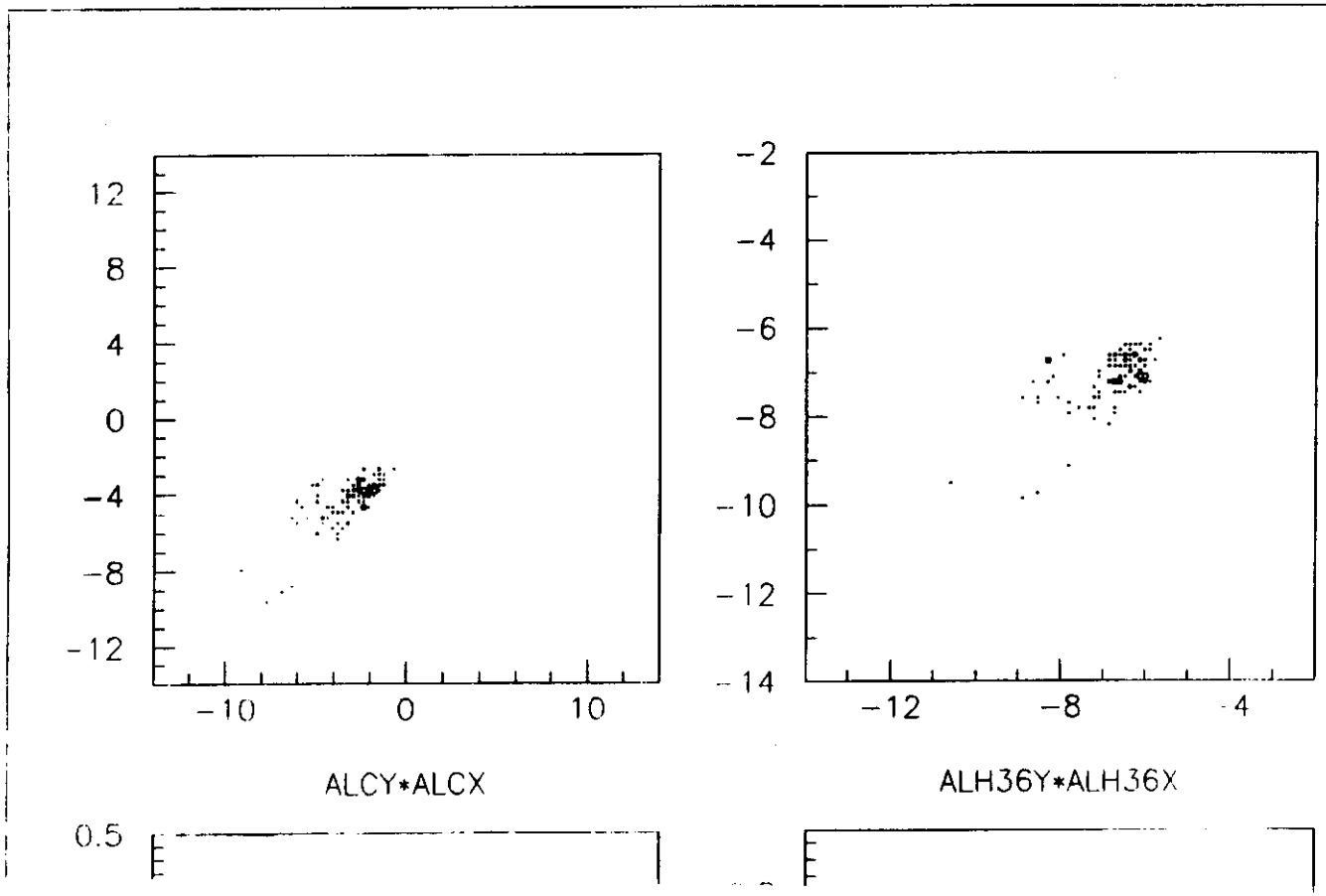
3 3 3 3 cm ⇒ $0.9 X_0$



$\varepsilon_\gamma = 99\%$

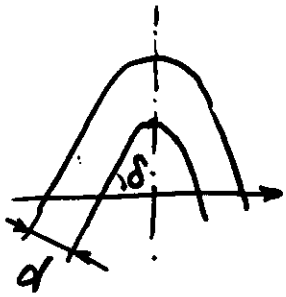
$R_\pi = 89\%$

γ



θ-strips

1) at $\theta \neq 90°$ smearing due to charge collection



<u>Max</u> shift from track $b = d \sin\delta \cos\theta$

$\delta = 45°$

$d = 2\,mm$

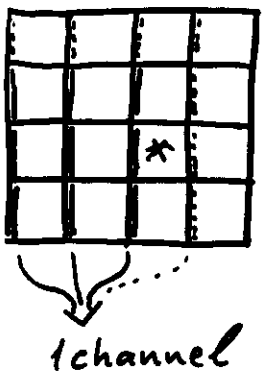
for $\theta = 45°$

$b = 1\,mm$

- when smearing increases the distance between γ's increases too.

2) Isolated π^0 or γ: it is possible to connect several (non adjacent) strips to one preamp.

Example: 33 θ strips per tower 0.04×0.04



		Total
1) 33 channels for 9 towers		70,000
2) — " —	16	40,000

The 2-nd section of EM calorimeter points to the shower center, then one may use a information from strip channels.

Further investigation

1) noise (and pile up), crosstalk

2) simulation of charge collection

3) variant with θ-strips $0+1+2+3$ stacks
φ-strips 4 stack.
and others

4) EM energy resolution

5) LKr

π^0 Detector for GEM

LAr Option

P. MOCKETT, U. Washington

Jan 22, 1992

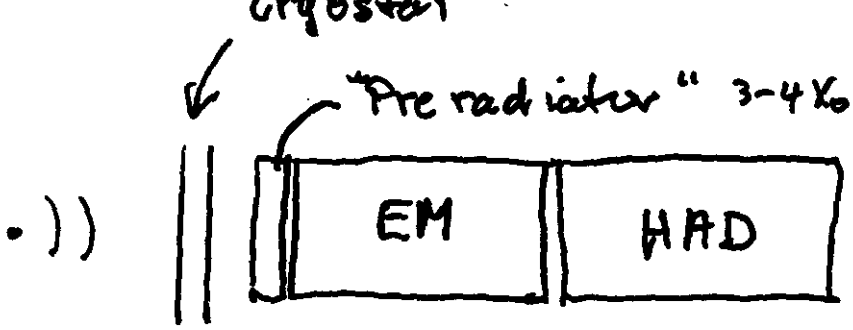
SSCL

γ/π^0 Separation: Higgs $\rightarrow \gamma\gamma$ searches

γ Isolation Cuts

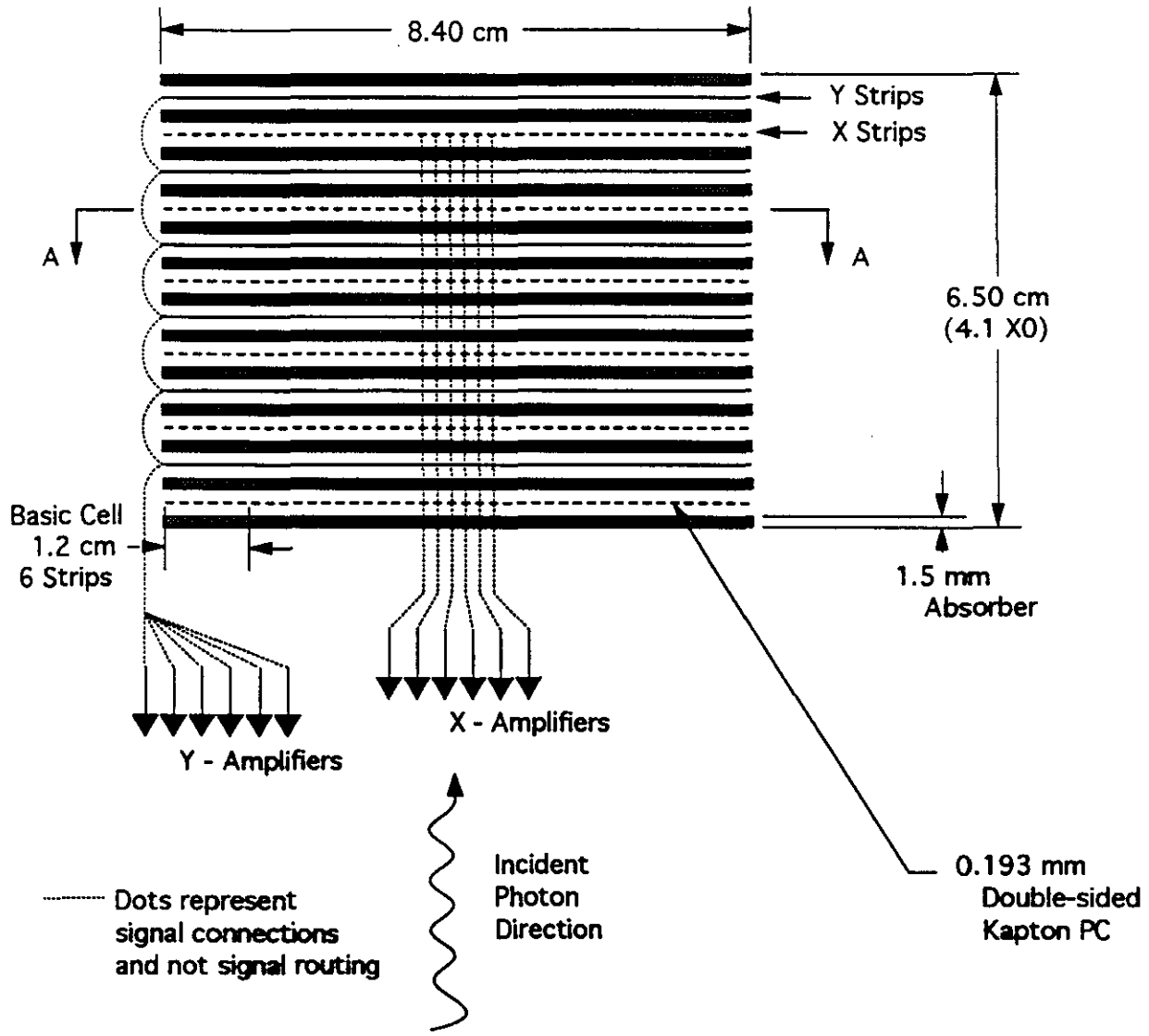
e/π Separation

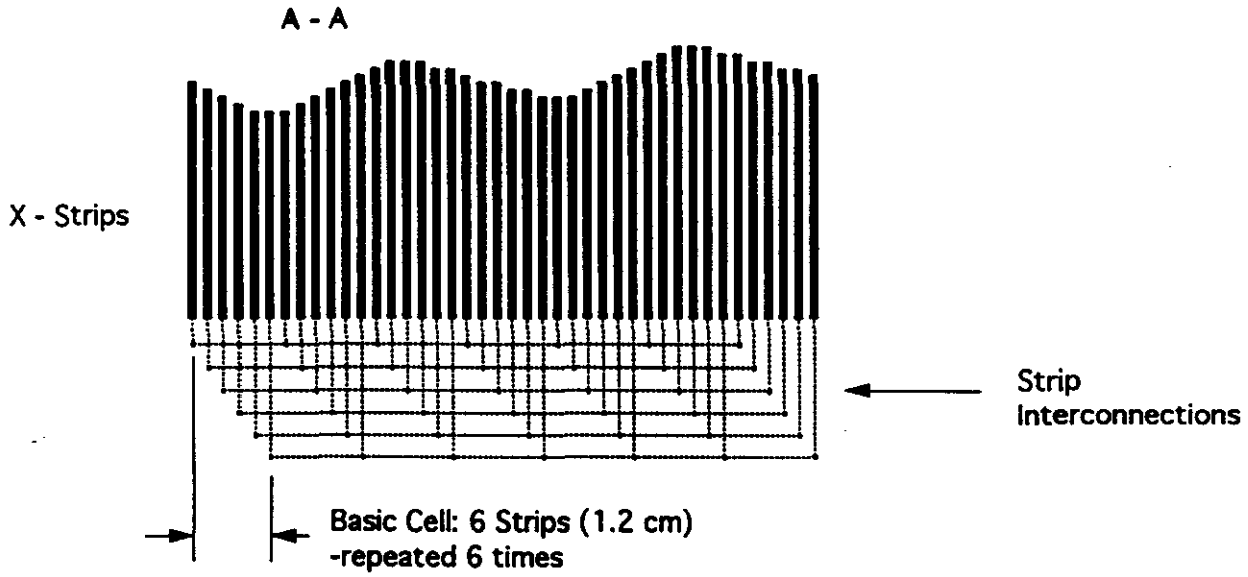
Vtx Pointing



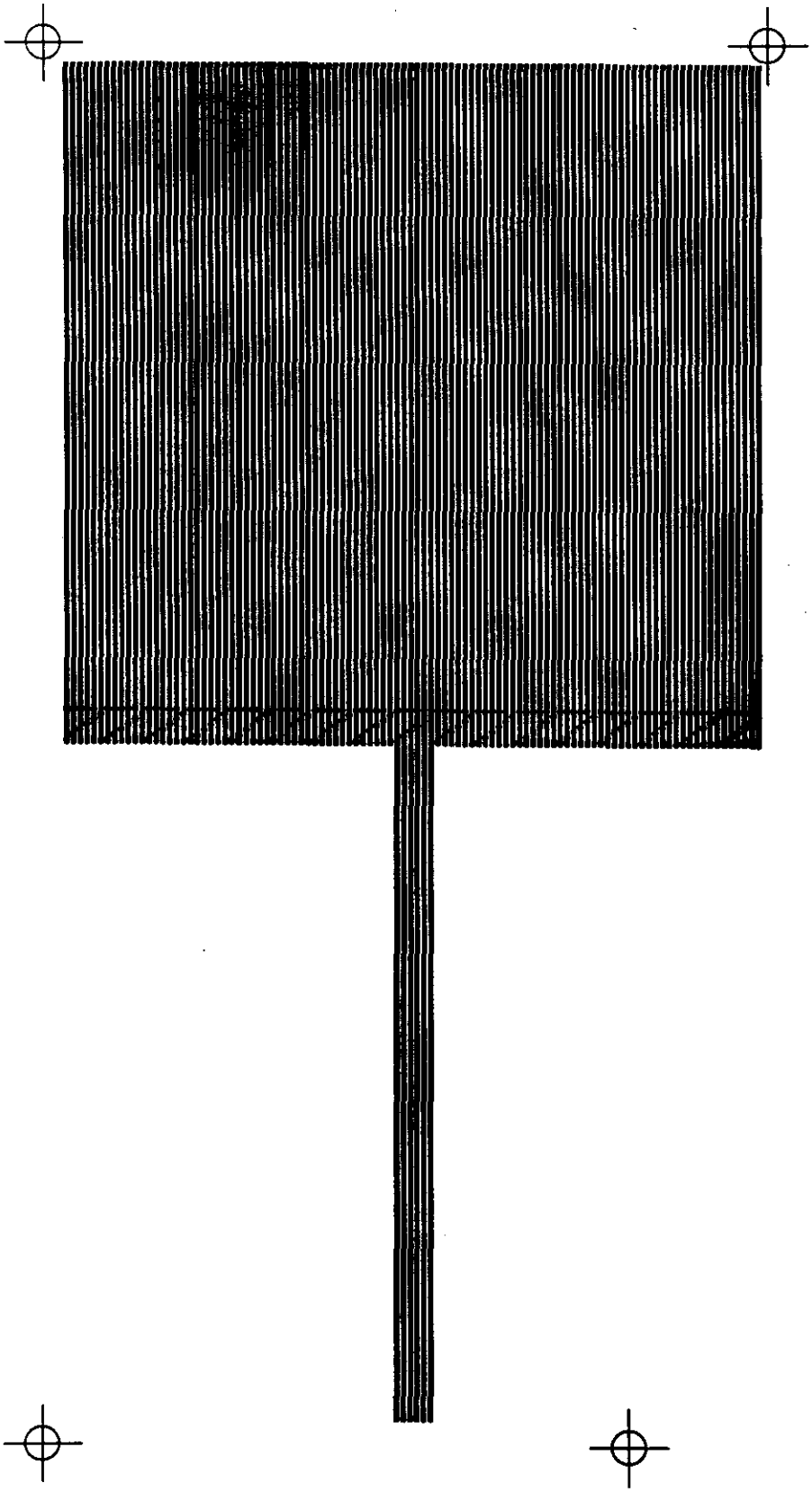
π^0 IDENTIFIER SCHEMATIC

(Parallel plate geometry)

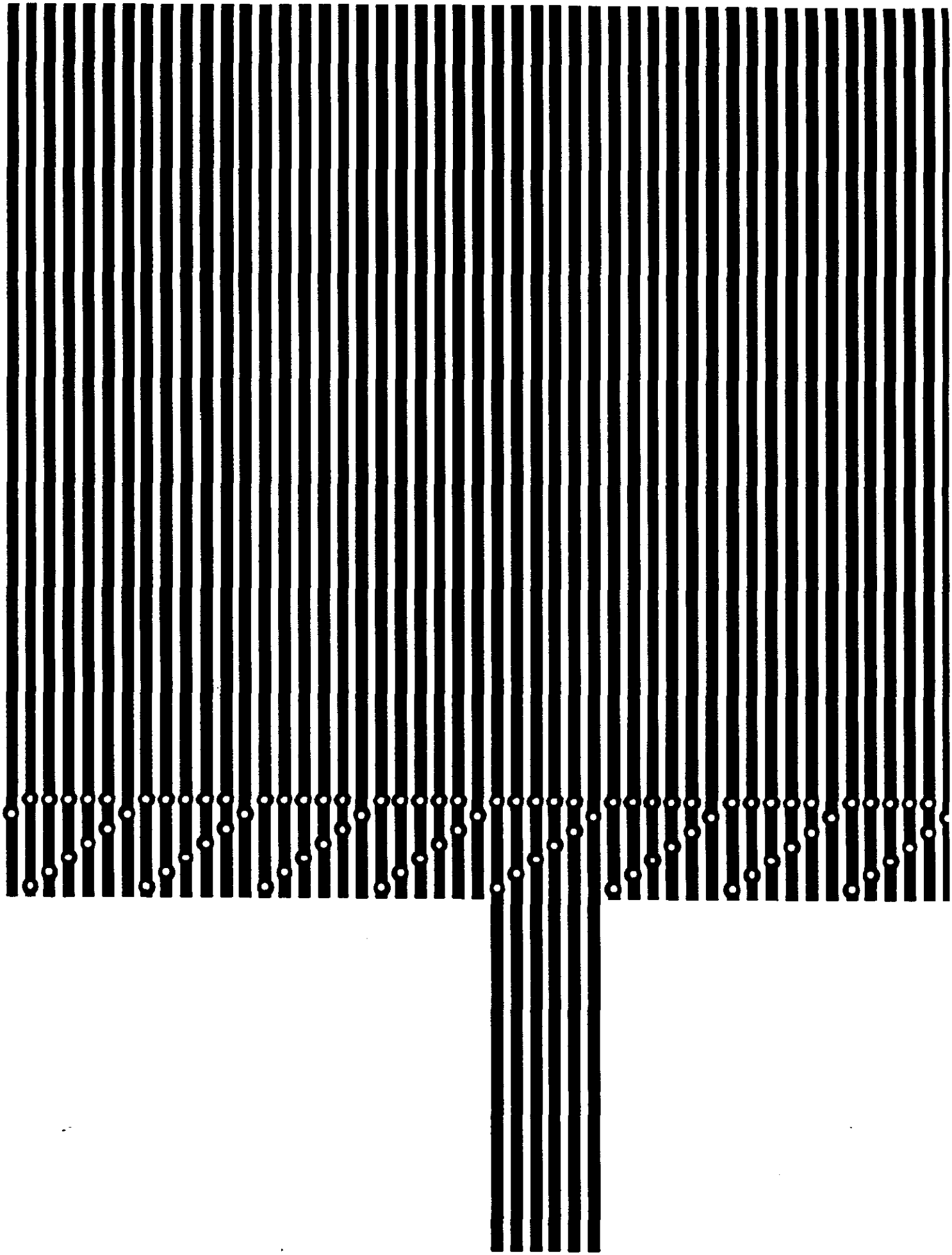


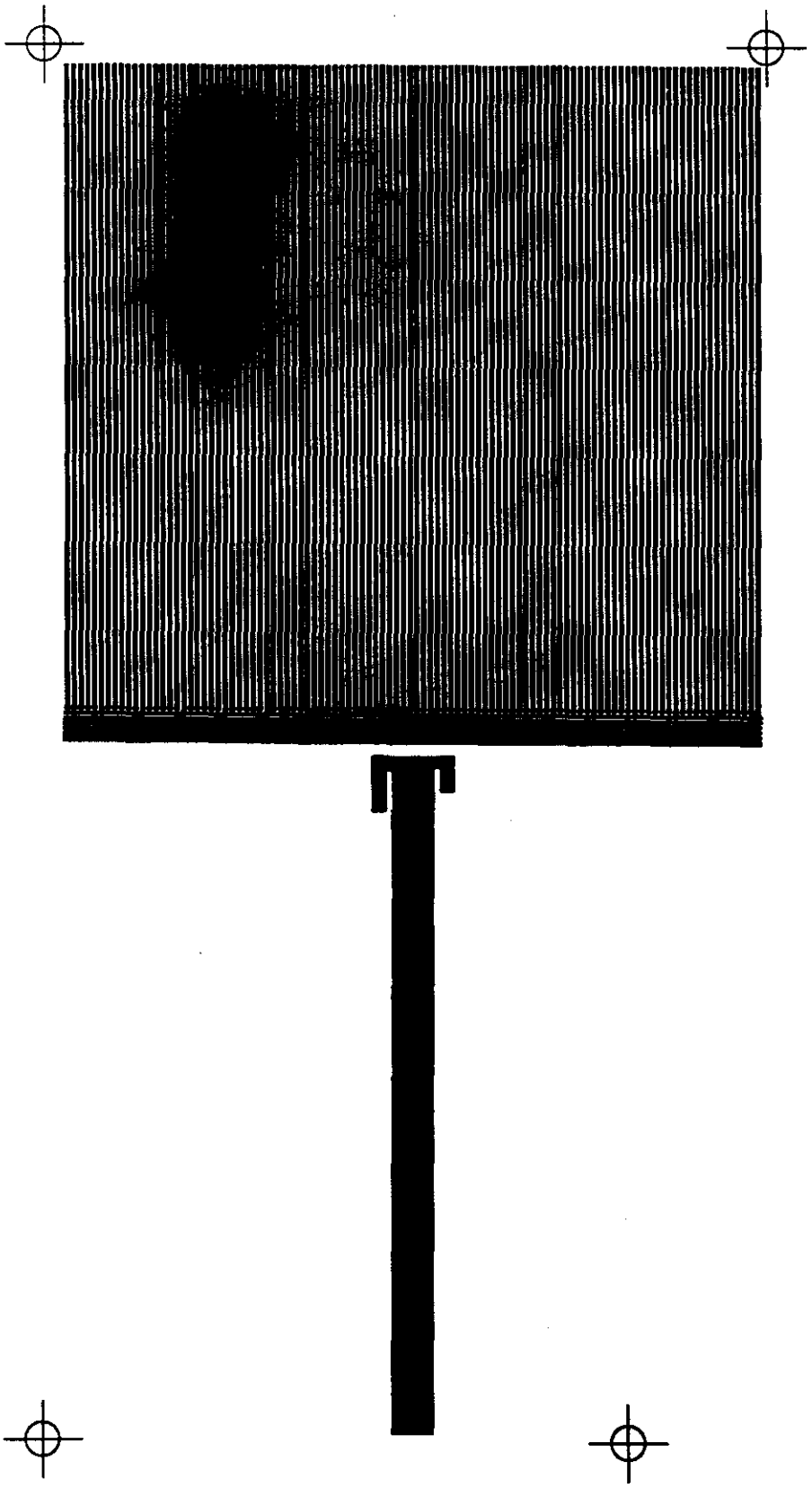


1/21/92



stripline side





π0 id JKE U of W 1/15/92

connection and ground plane

Signal & Noise Characteristics

Signal >30,000e

Noise ~ 3,000e

Cross talk

Maximum Fast X-talk < 20%

[CATT, IEEE('67)]

Can be unfolded to level of noise

We are continuing our study of this both in simulation & measurement

IVOR CATT, IEEE EC-16, 743 (67)

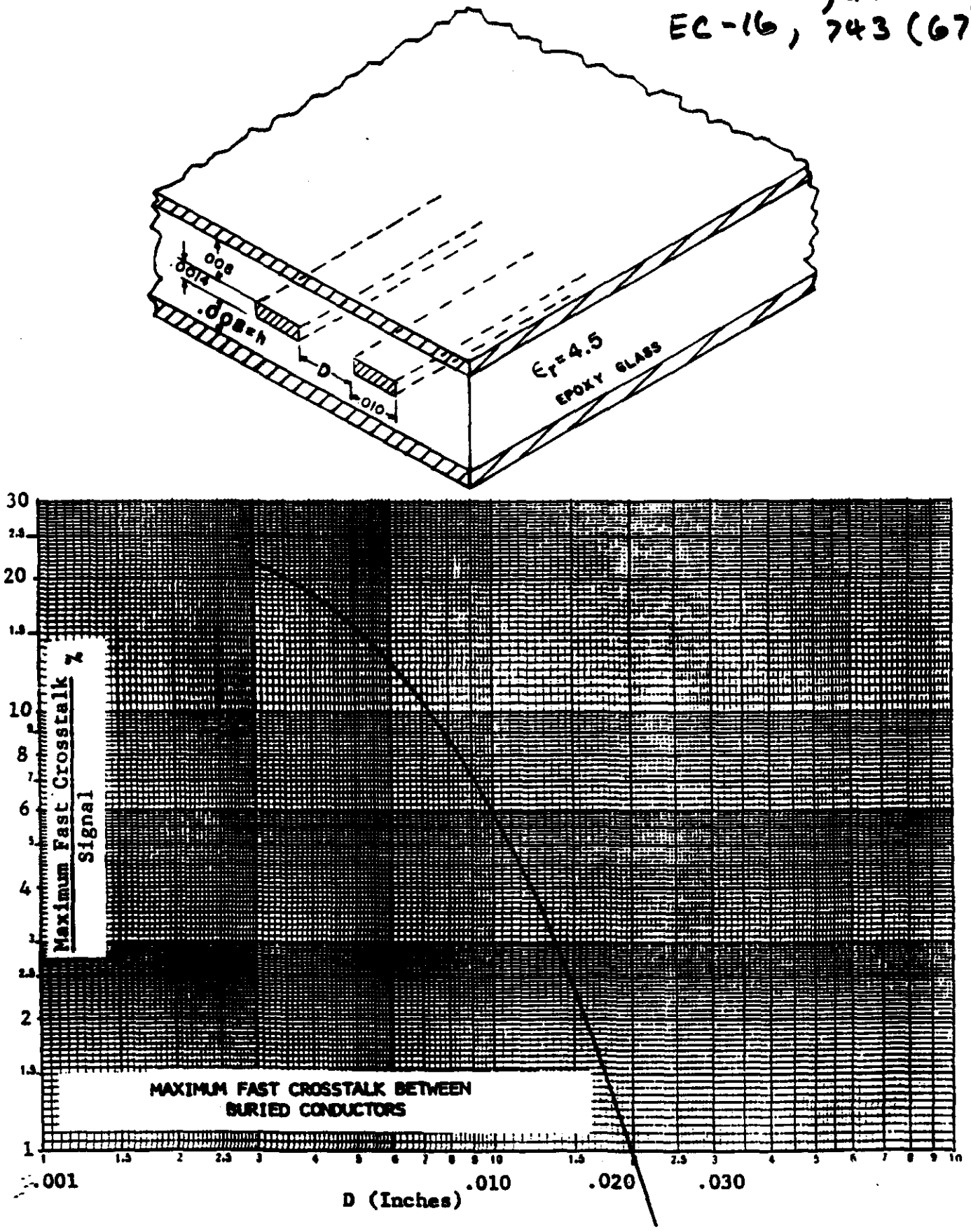
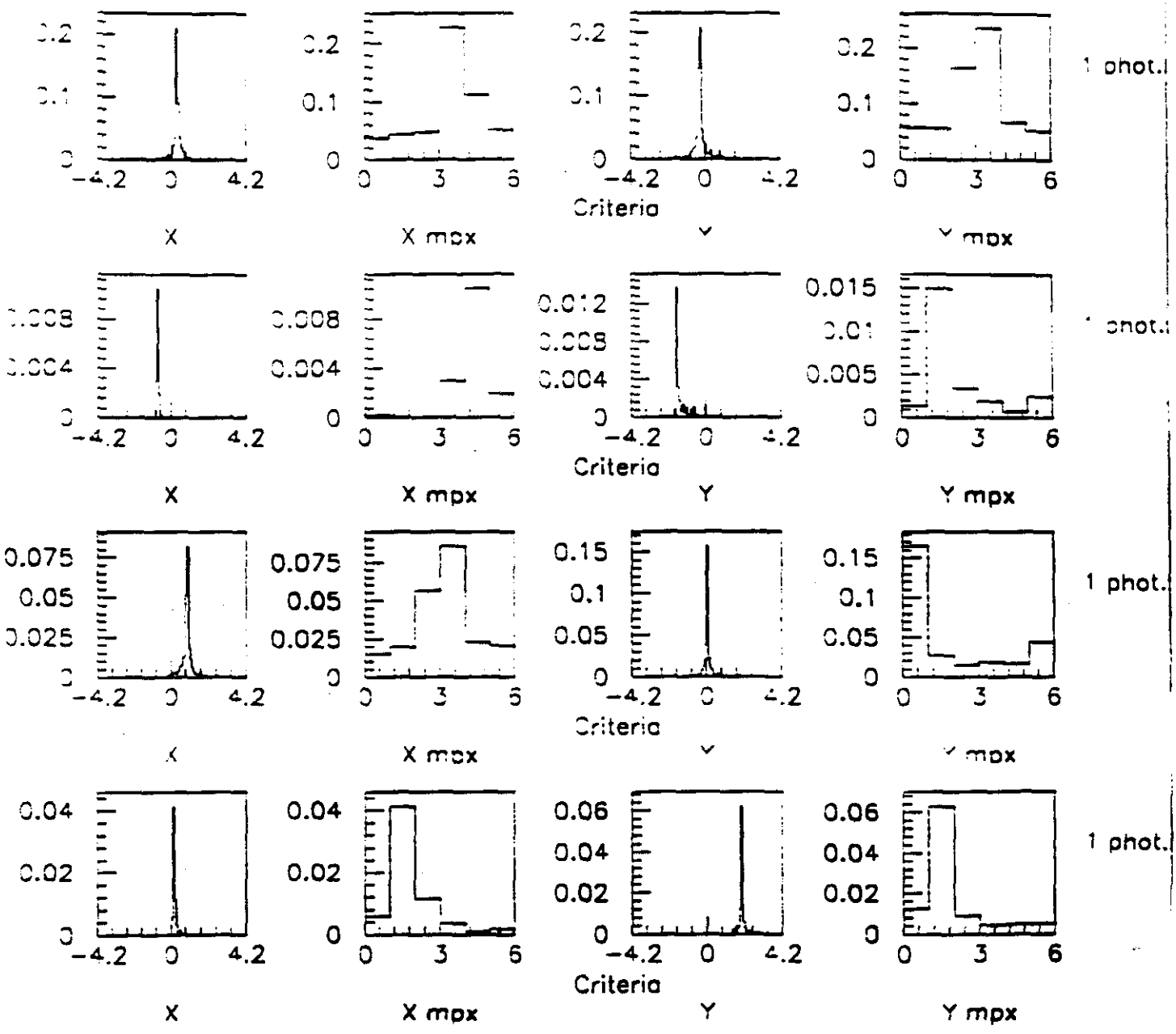
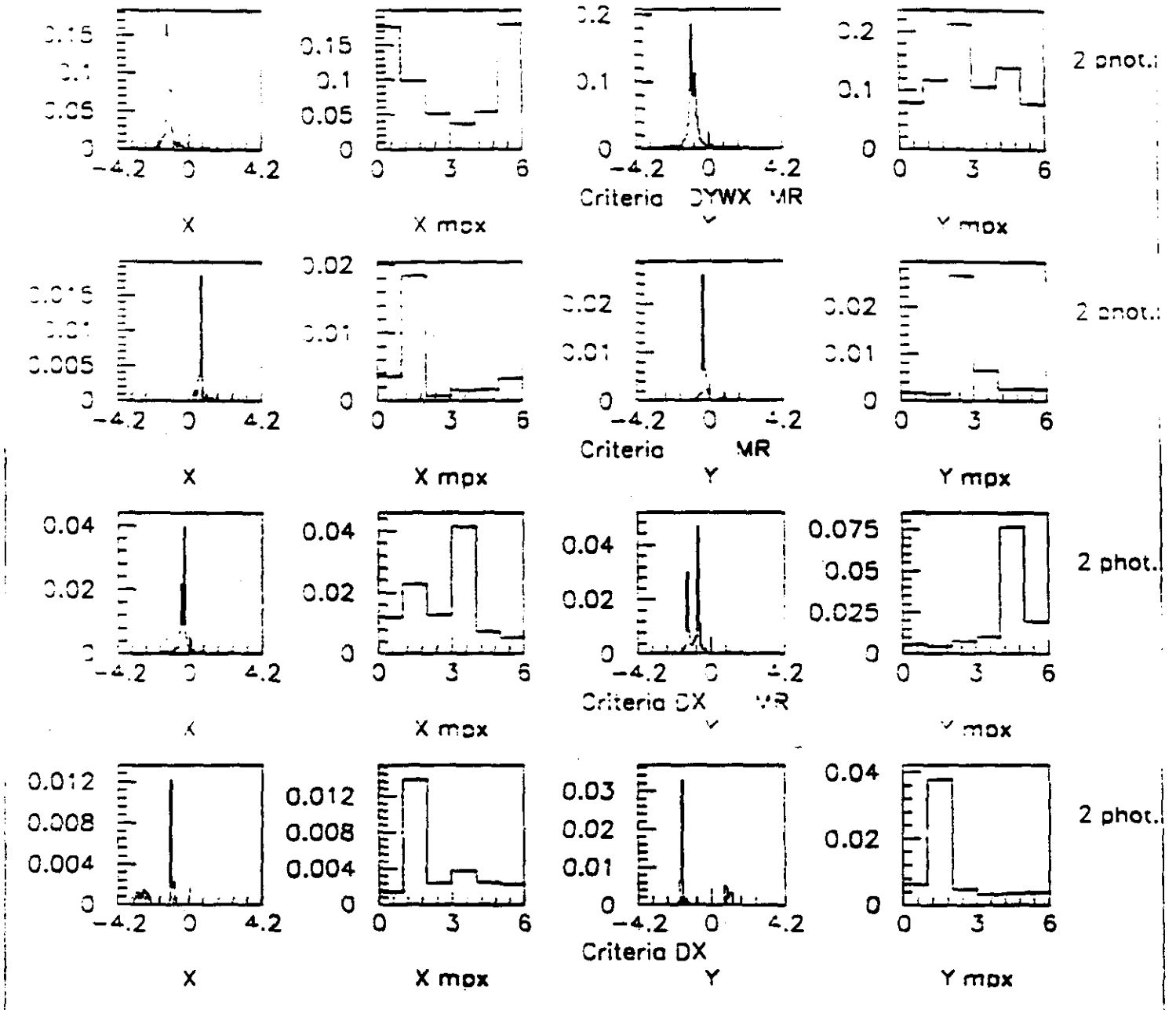


Fig. 24. Cross section of buried active transmission line and passive transmission line, and graph of resulting crosstalk (D/h may be scaled).

Strip width = 1.0mm multiplexing = 6 E=100.0 PHOT



Strip width = 1.0mm multiplexing = 6 E=100.0 PiO

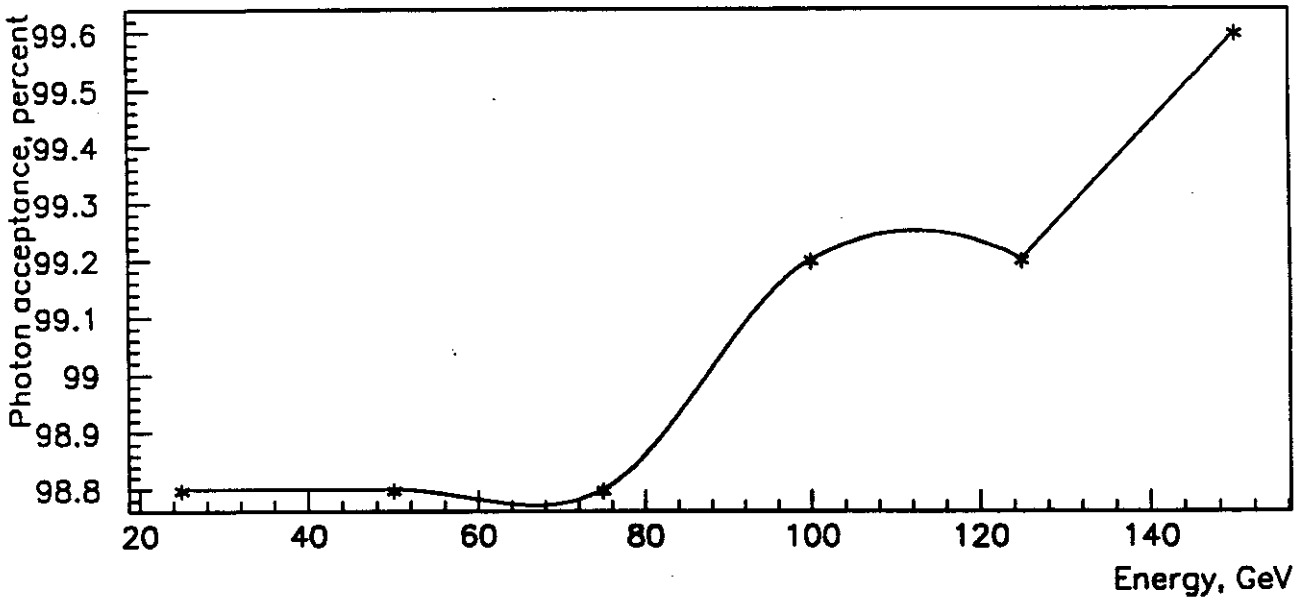


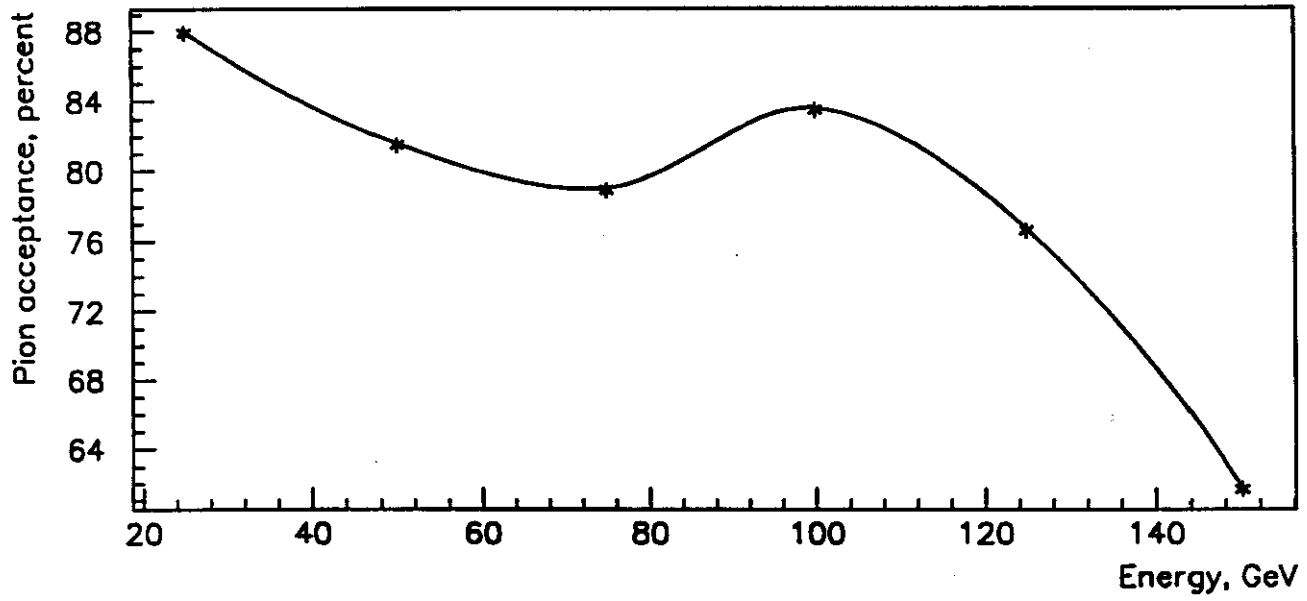
```
==========================================
Runs in: /usr/users/jke/gem/pi0/geant/bp/v3/1mm_all_vlong
Cut    : 2012
==========================================
```

E,GeV		accep	%0	%1	%2	%mean	only	%dip	only	%wid	only	run
25.0	1	99.2	14.0	85.2	0.8	0.8	0.8	0.0	0.0	0.0	0.0	3531
25.0	7	88.0	3.2	8.8	88.0	87.0	75.6	0.0	0.0	13.0	1.0	3532
50.0	1	99.2	8.4	90.8	0.8	0.8	0.8	0.0	0.0	0.0	0.0	3534
50.0	7	81.6	3.0	15.4	81.6	80.8	75.0	0.0	0.0	7.0	0.8	3535
75.0	1	98.8	13.4	85.4	1.2	1.2	1.2	0.0	0.0	0.0	0.0	3537
75.0	7	79.0	2.6	18.4	79.0	76.4	63.4	0.0	0.0	16.6	2.6	3540
100.0	1	98.8	11.6	87.2	1.2	1.0	0.8	0.4	0.2	0.0	0.0	3557
100.0	7	83.6	2.2	14.2	83.6	69.8	29.6	54.6	9.2	21.0	2.8	3564
125.0	1	98.8	14.2	84.6	1.2	1.2	1.0	0.2	0.0	0.0	0.0	3591
125.0	1	99.6	12.6	87.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	3566
125.0	7	76.7	2.2	21.1	76.7	56.0	24.2	39.9	13.5	24.2	7.2	3569
150.0	1	99.2	10.6	88.6	0.8	0.8	0.6	0.2	0.0	0.0	0.0	3572
150.0	7	61.8	2.4	35.8	61.8	44.4	18.6	28.2	6.0	23.4	11.2	3574

```
=========================================
Multiplexing factor                          [NMPX]= 6
Number of events processed (0=all)           [NEND]= 0
Energy required for peak                     [ECUT]= .015
Max. frac. of biggest peak for dip         [DIPMAX]= 0.5
Energy to start dip cut at                   [EDIP]= 75.
Number of bins wide considered pi0        [NCUTWID]= 3
Energy thresh. where ncutwid->NWCLOWER   [WCTHRESH]= 75.
Higher energy width cut                  [NWCLOWER]= 2
Min. frac. of biggest peak for width      [EWIDCUT]= 0.5
Min. frac. of biggest peak for second     [PEAKCUT]= 0.25
Mean offset for pi0 (in mm)               [CUTMEAN]= 2.83              bins, not cm!
Power of energy for mean offset scaling   [CUTPOWR]= -0.369
Tot. energy above which CUTMEAN->HEMEAN    [CUTOFF]= 75.
Mean difference cut above CUTOFF           [HEMEAN]= 0.5
dist. at which mean is to be extrapolated   [DMEAN]= 0.
        (mean offset cut = CUTMEAN * E^CUTPOWR)
=========================================
```

Cut 2012 in /usr/users/jke/gem/pi0/geant/bp/v3/1mmzallzvlong



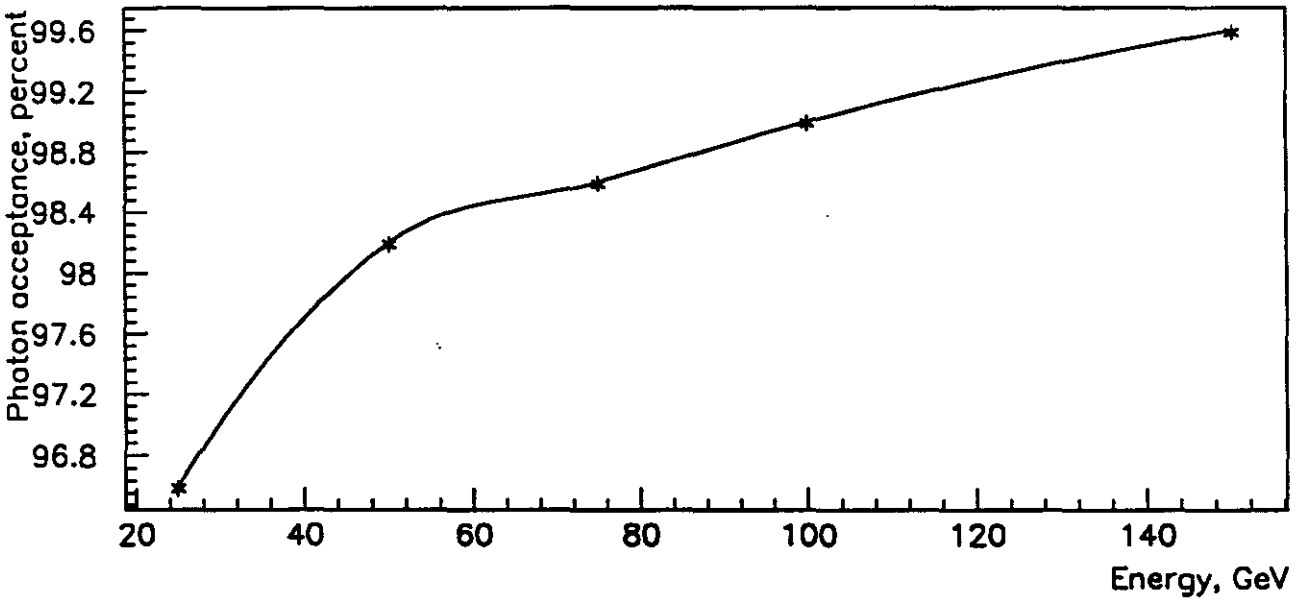


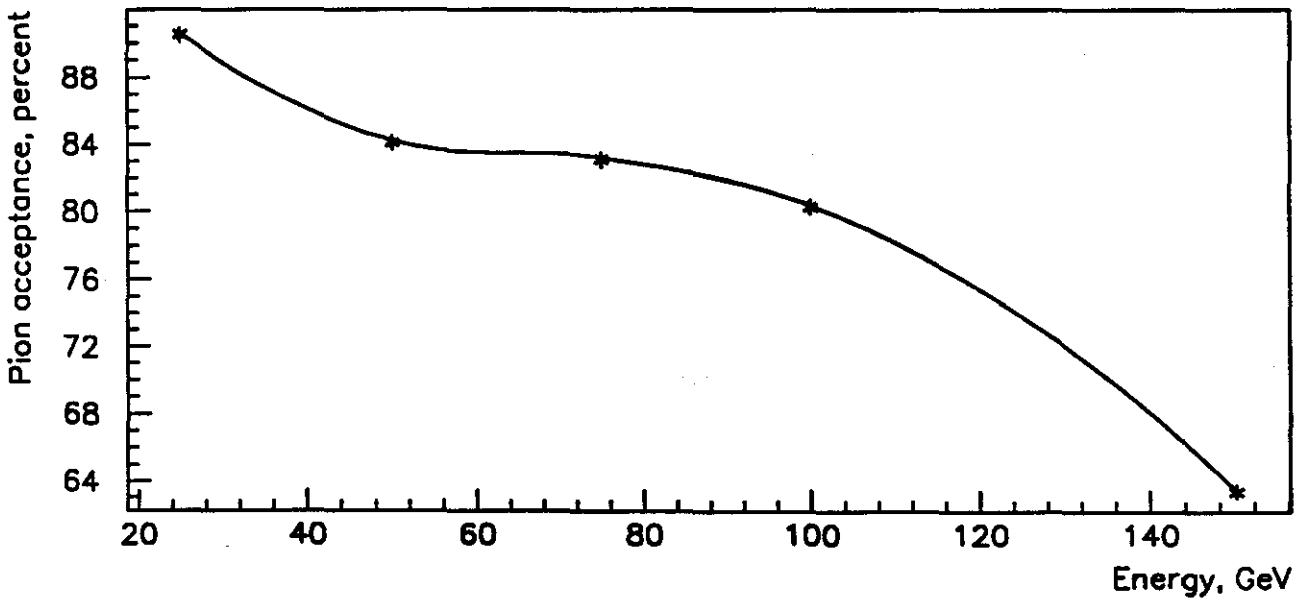
```
==========================================
Runs in: /usr/users/jke/gem/pi0/geant/bp/v3/1mm_last3_vlong
Cut     : 2103
==========================================
```

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

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

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



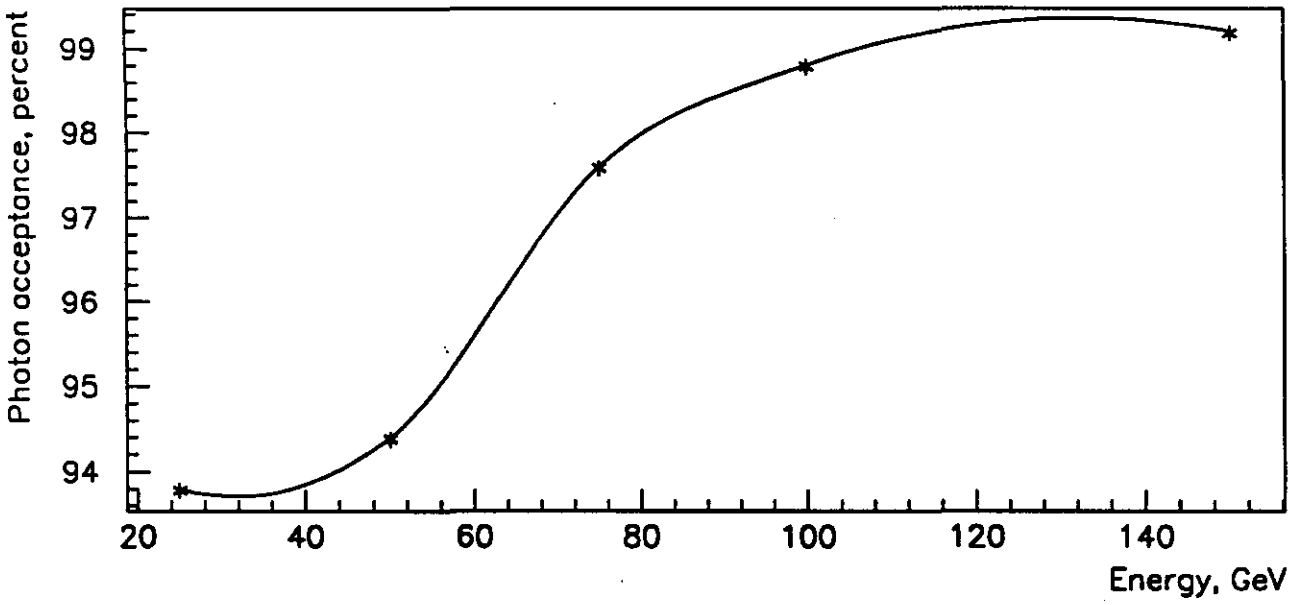


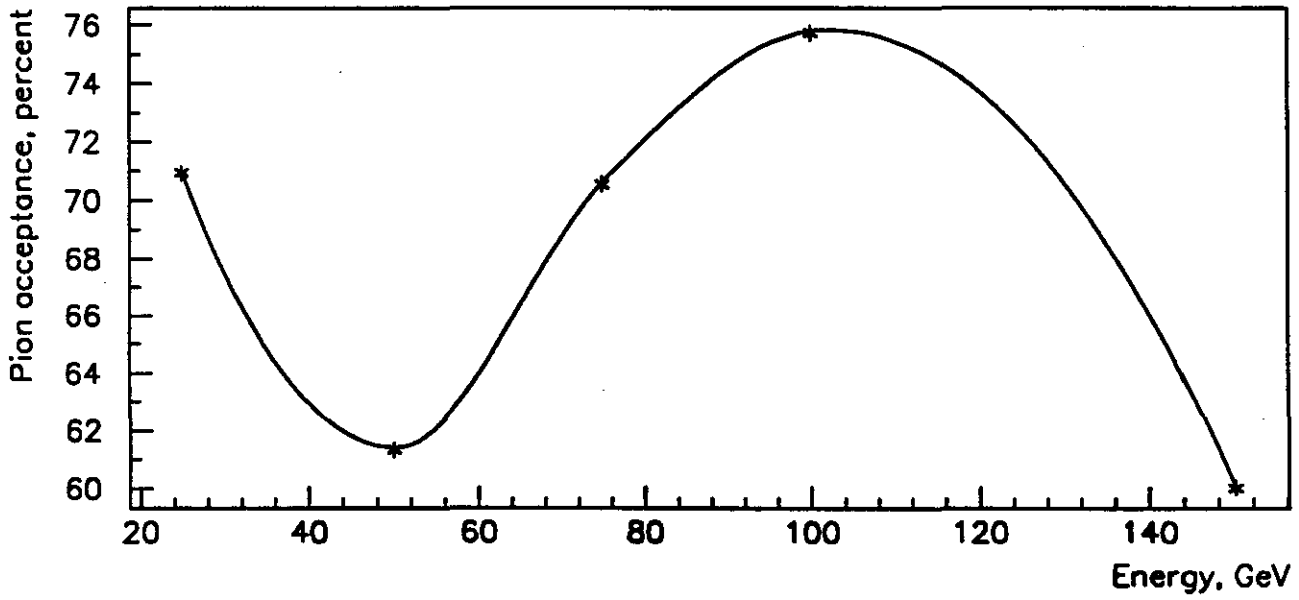
```
=============================================
Runs in: /usr/users/jke/gem/pi0/geant/bp/v3/1mm_last1_vlong
Cut    : 2104
=============================================
```

E,GeV		accep	%0	%1	%2	%mean	only	%dip	only	%wid	only	run
25.0	1	99.2	18.2	81.0	0.8	0.2	0.0	0.0	0.0	0.8	0.6	3523
25.0	7	71.0	7.8	21.2	71.0	69.2	60.2	0.0	0.0	12.2	1.8	3527
50.0	1	98.8	16.4	82.4	1.2	1.0	1.0	0.0	0.0	0.2	0.2	3585
50.0	7	61.4	3.8	34.8	61.4	60.6	55.2	0.0	0.0	6.6	0.8	3586
75.0	1	94.4	16.6	77.8	5.6	0.6	0.2	1.2	0.8	4.4	4.2	3530
75.0	7	70.6	3.8	25.6	70.6	50.8	19.0	33.6	7.0	38.2	8.6	3533
100.0	1	93.8	13.0	80.8	6.2	3.4	2.2	1.6	0.6	2.4	2.2	3536
100.0	7	75.8	2.6	21.6	75.8	55.6	23.6	31.2	5.0	40.4	13.2	3563
150.0	1	97.6	11.6	86.0	2.4	1.4	0.6	1.0	0.2	1.2	0.8	3545
150.0	7	60.1	2.0	37.9	60.1	35.2	15.2	18.6	4.6	36.4	19.8	3562

```
=========================================
Multiplexing factor                          [NMPX]= 6
Number of events processed (0=all)           [NEND]= 0
Energy required for peak                     [ECUT]= .015
Max. frac. of biggest peak for dip         [DIPMAX]= 0.4
Energy to start dip cut at                   [EDIP]= 50.
Number of bins wide considered pi0        [NCUTWID]= 4
Energy thresh. where ncutwid->NWCLOWER   [WCTHRESH]= 75.
Higher energy width cut                  [NWCLOWER]= 2
Min. frac. of biggest peak for width      [EWIDCUT]= 0.5
Min. frac. of biggest peak for second     [PEAKCUT]= 0.33
Mean offset for pi0 (in mm)               [CUTMEAN]= 8.25            bins, not cm!
Power of energy for mean offset scaling   [CUTPOWR]= -0.50
Tot. energy above which CUTMEAN->HEMEAN    [CUTOFF]= 100.
Mean difference cut above CUTOFF           [HEMEAN]= 0.6
dist. at which mean is to be extrapolated   [DMEAN]= 0.
        (mean offset cut = CUTMEAN * E^CUTPOWR)
=========================================
```

Cut 2104 in /usr/users/jke/gem/pi0/geant/bp/v3/1mmzlast1zvlong





SILICON STRIP PRERADIATOR FOR GEM

-J. Brau

JAN 22, 1992
SSCL

SIMULATION
PROTOTYPE
GEM ELECTRONICS

(MOST THOUGHT, SO FAR, BASED ON LIQUID ARGON CALORIMETER)

Simulation of a Silicon Preradiator for GEM

K. Furuno, X. Yang, J. Brau, D. Strom

I Motivation

II π^0 identification

III Energy Resolution

VI Effect of magnetic field

Motivation

Discovery of a Higgs with

$$80 < m_h < 160 \text{ GeV}$$

is difficult!

$H \to b\bar{b}$ looks like background

$H \to \gamma\gamma$ is possible

cut	$\sigma_{H\to\gamma\gamma}$	σ_{jj}	$\sigma_{j\gamma}$	$\sigma_{\gamma\gamma}$
$P_t > 20$	50-200fb	2mb	235nb	275pb
$\left.\begin{array}{l} \lvert\eta\rvert<2.5,\ E_t^\gamma > 20\text{GeV} \\ \lvert\cos^*\theta_\gamma\rvert<0.9,\ \lvert\eta_{\gamma\gamma}\rvert<3.0 \\ \text{isolation},\ M_{\gamma\gamma} > 70\text{GeV} \end{array}\right\}$	25-100fb	220pb	90pb	34pb
Shower Shape	25-100fb	120pb	50pb	34pb
Preradiator	25-100fb	20pb	24pb	34pb

highly uncertain

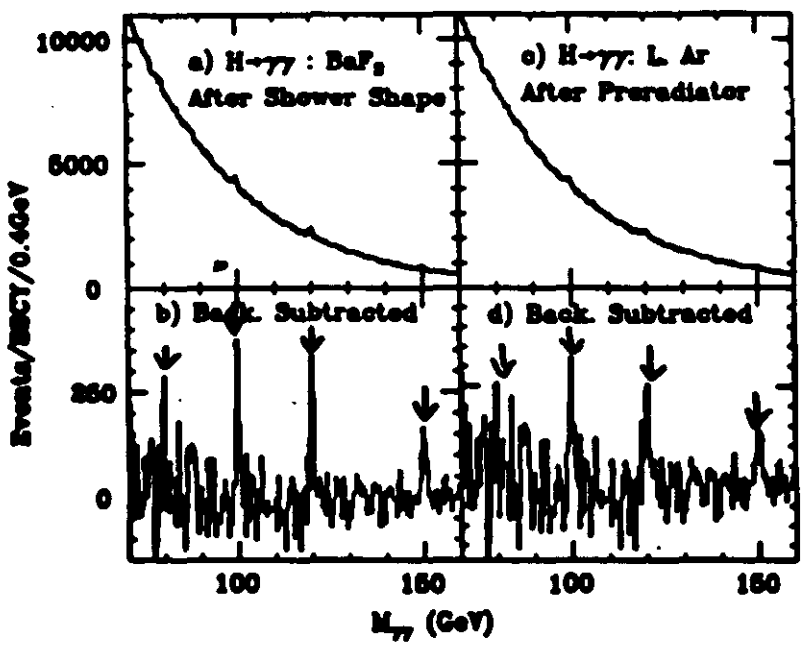
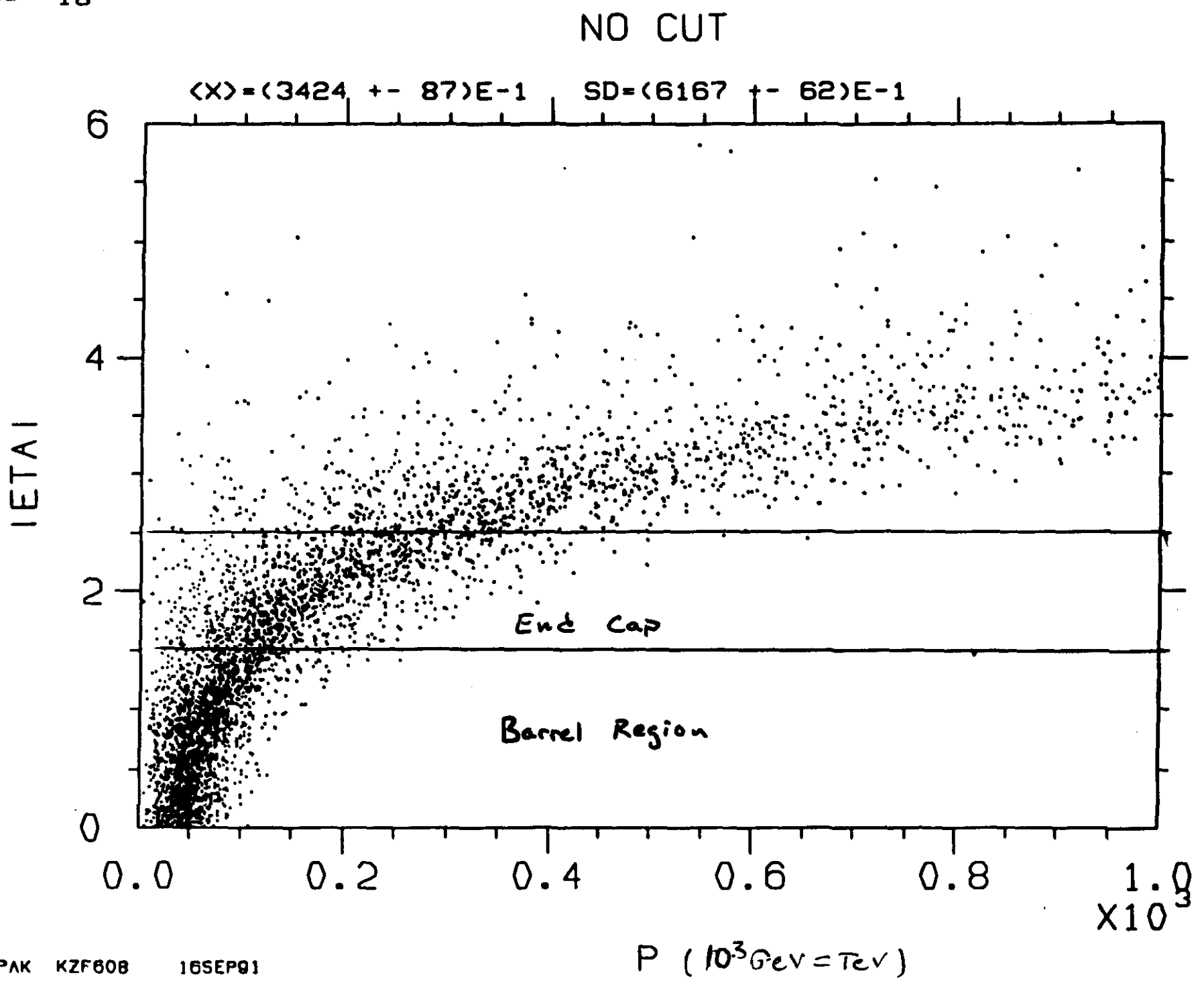


Figure 3.2-1 $H \rightarrow \gamma\gamma$ mass distributions and background-subtracted mass distributions for various Higgs masses. Left: BaF_2 calorimeter. Right: LAr calorimeter

ID= 18



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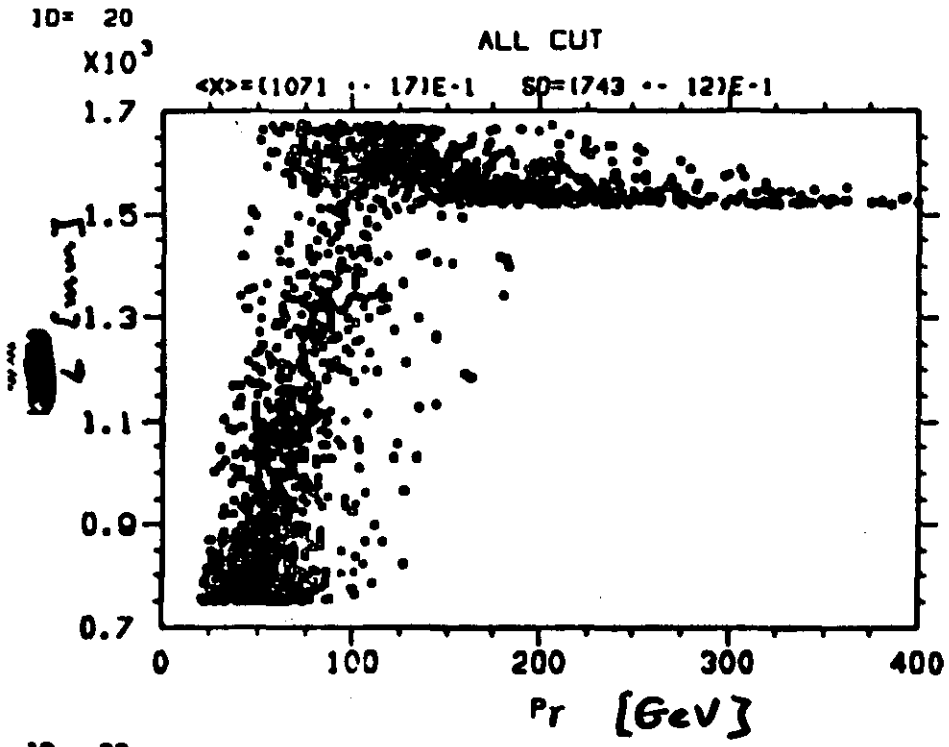
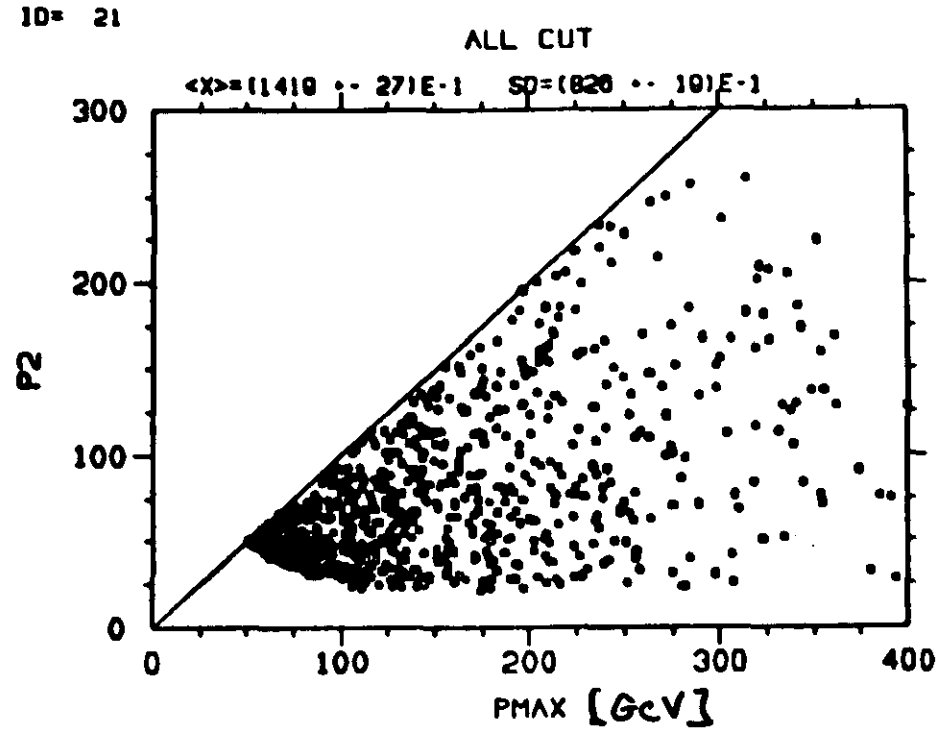
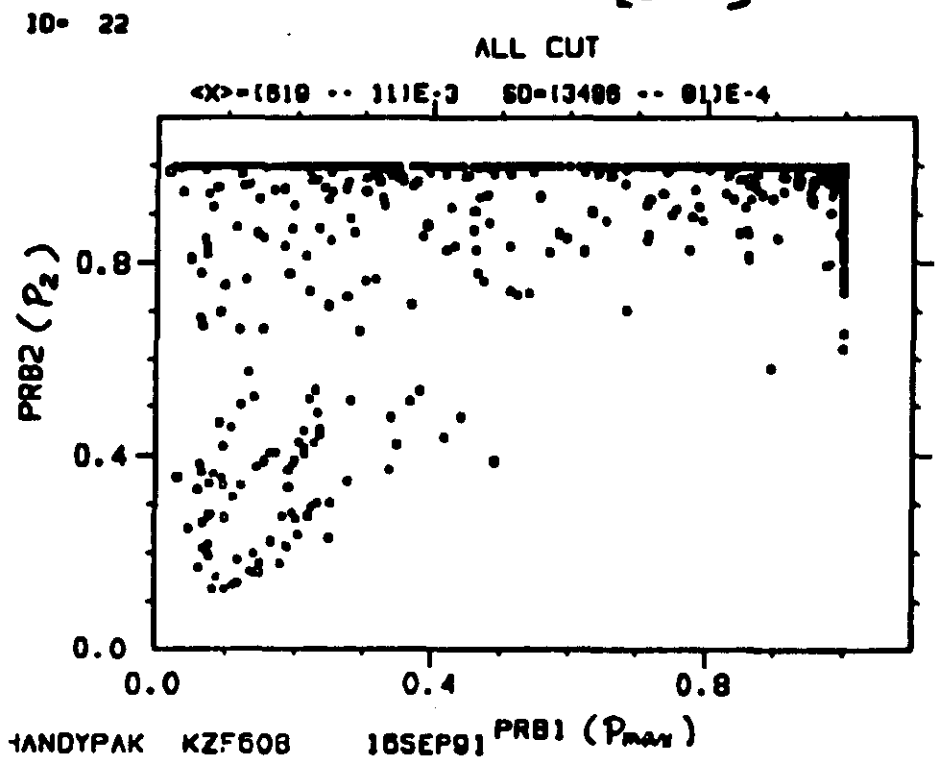
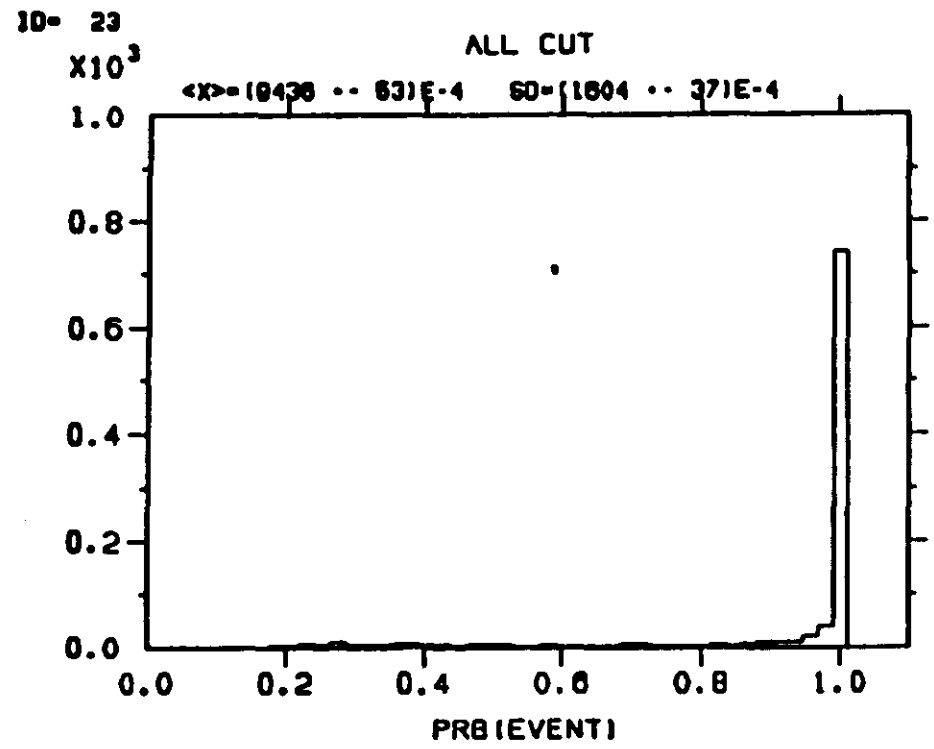

ID= 20
ALL CUT
X10^3
<X>=(1071 +- 17)E-1 SD=(743 +- 12)E-1
1.7
1.5
1.3
1.1
0.9
0.7
0
100
200
300
400
Pr [GeV]

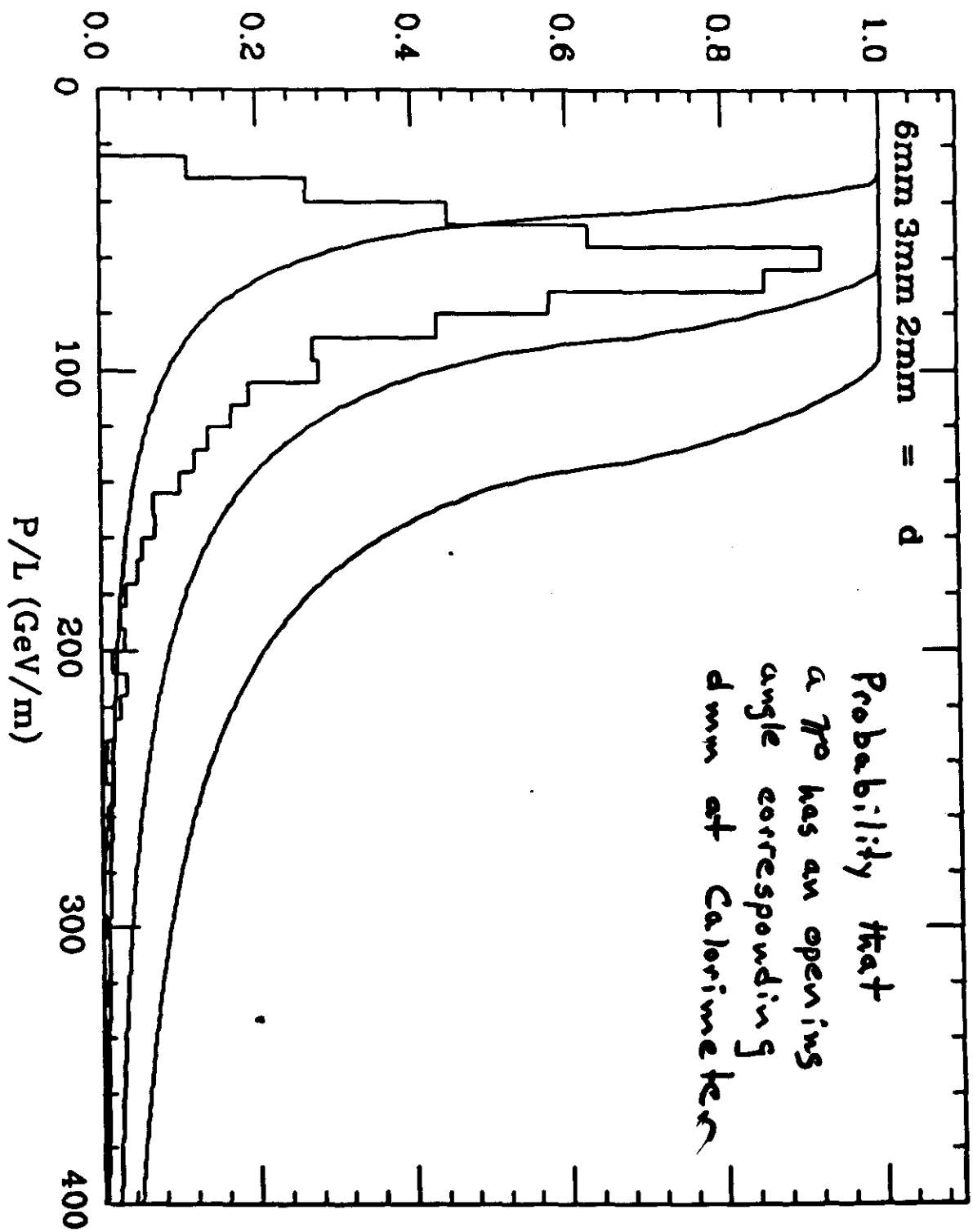

ID= 21
ALL CUT
<X>=(1410 +- 27)E-1 SD=(820 +- 19)E-1
300
200
100
0
P2
0
100
200
300
400
PMAX [GeV]

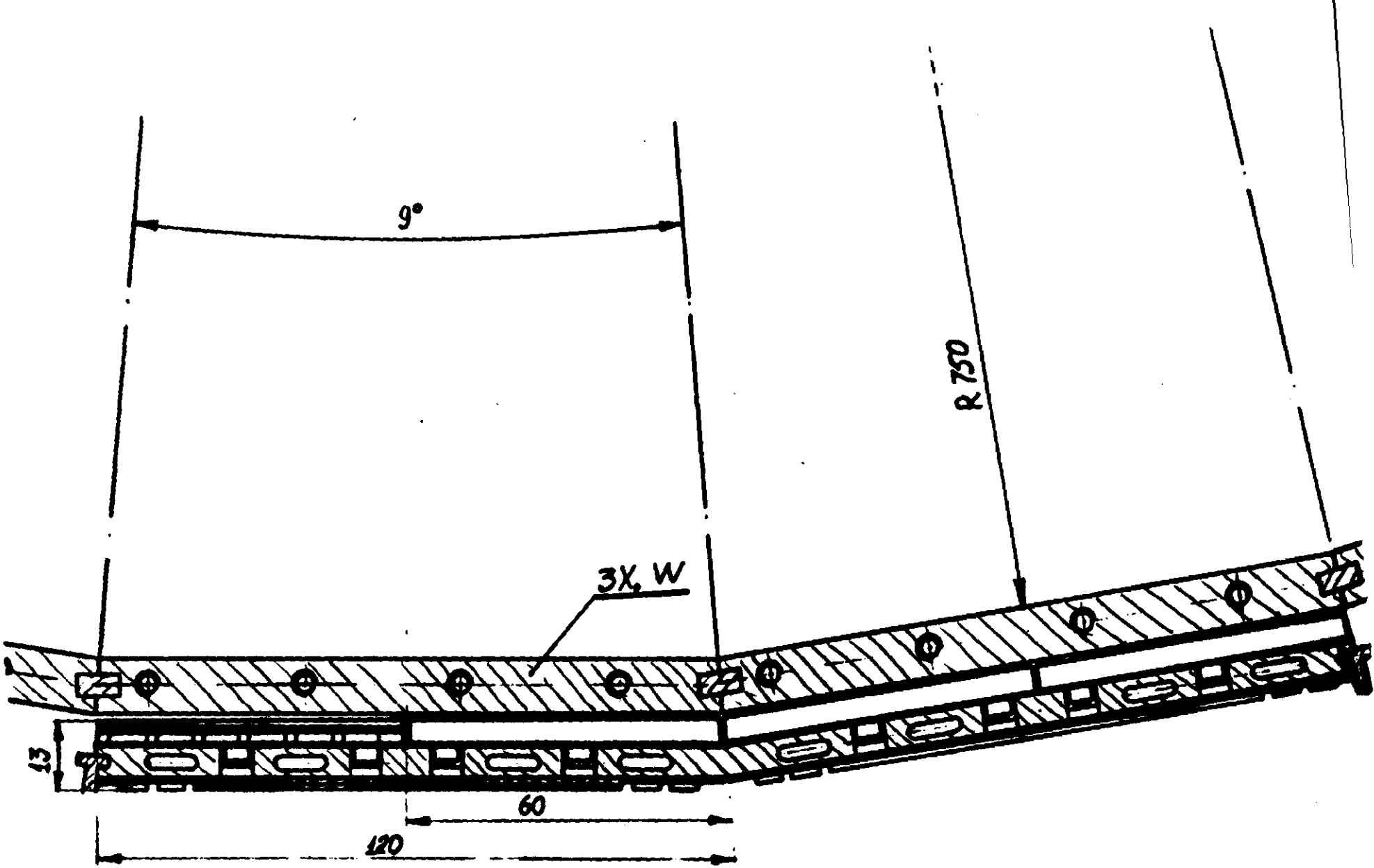

ID= 22
ALL CUT
<X>=(619 +- 11)E-3 SD=(3486 +- 81)E-4
PRB2 (P2)
0.8
0.4
0.0
0.0
0.4
0.8
PRB1 (Pmax)
HANDYPAK KZF608 16SEP91

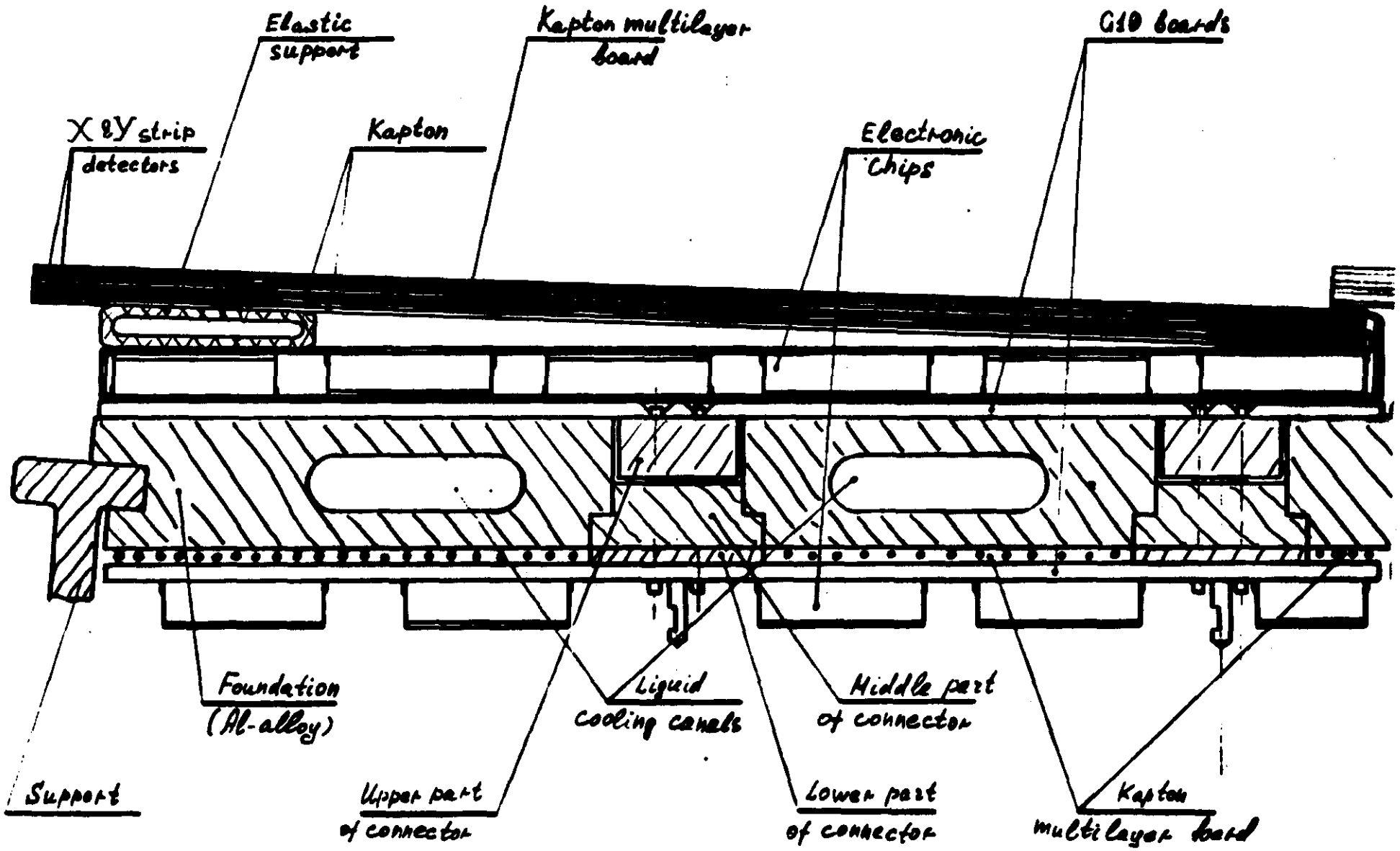

ID= 23
ALL CUT
X10^3
<X>=(9436 +- 63)E-4 SD=(1604 +- 37)E-4
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
PRB(EVENT)

π^0 rejection probability (curve)

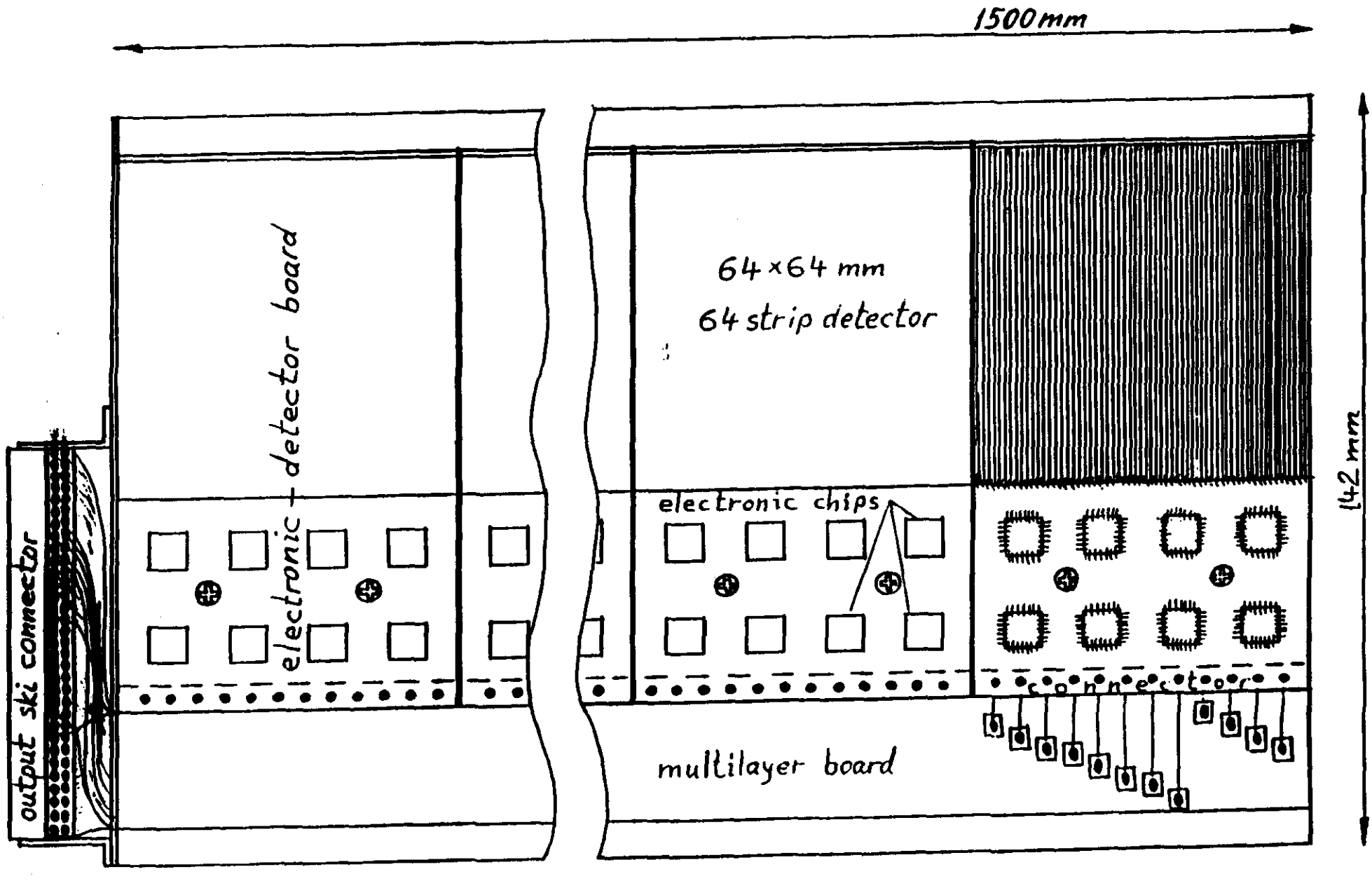
Number of γ from Higgs(100GeV) (hist arbitrary u)

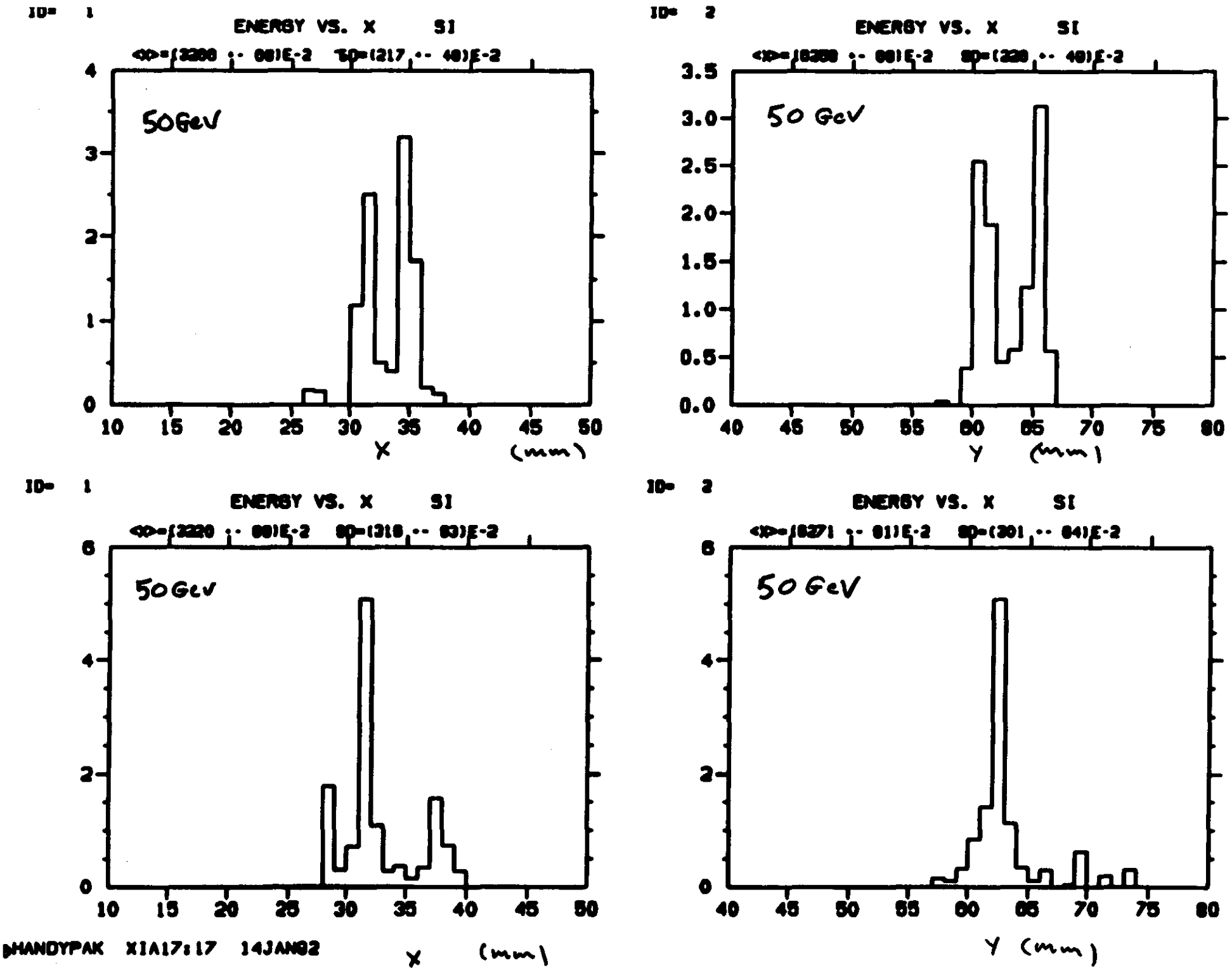



9°
R 750
3X, W
43
60
120

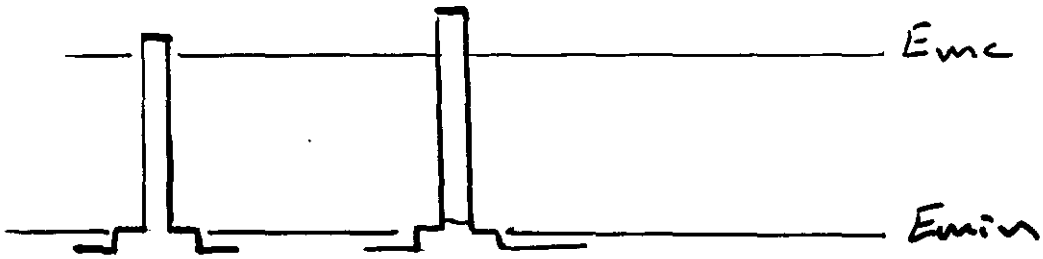

Elastic support
Kapton multilayer board
G10 boards
X & Y strip detectors
Kapton
Electronic Chips
Foundation (Al-alloy)
Liquid cooling canals
Middle part of connector
Support
Upper part of connector
Lower part of connector
Kapton multilayer board

ALUMINUM SKI top view




ID= 1
ENERGY VS. X SI
50GeV
X (mm)
ID= 2
ENERGY VS. X SI
50 GeV
Y (mm)
ID= 1
ENERGY VS. X SI
50GeV
X (mm)
ID= 2
ENERGY VS. X SI
50 GeV
Y (mm)
HANDYPAK XIA17:17 14JAN92

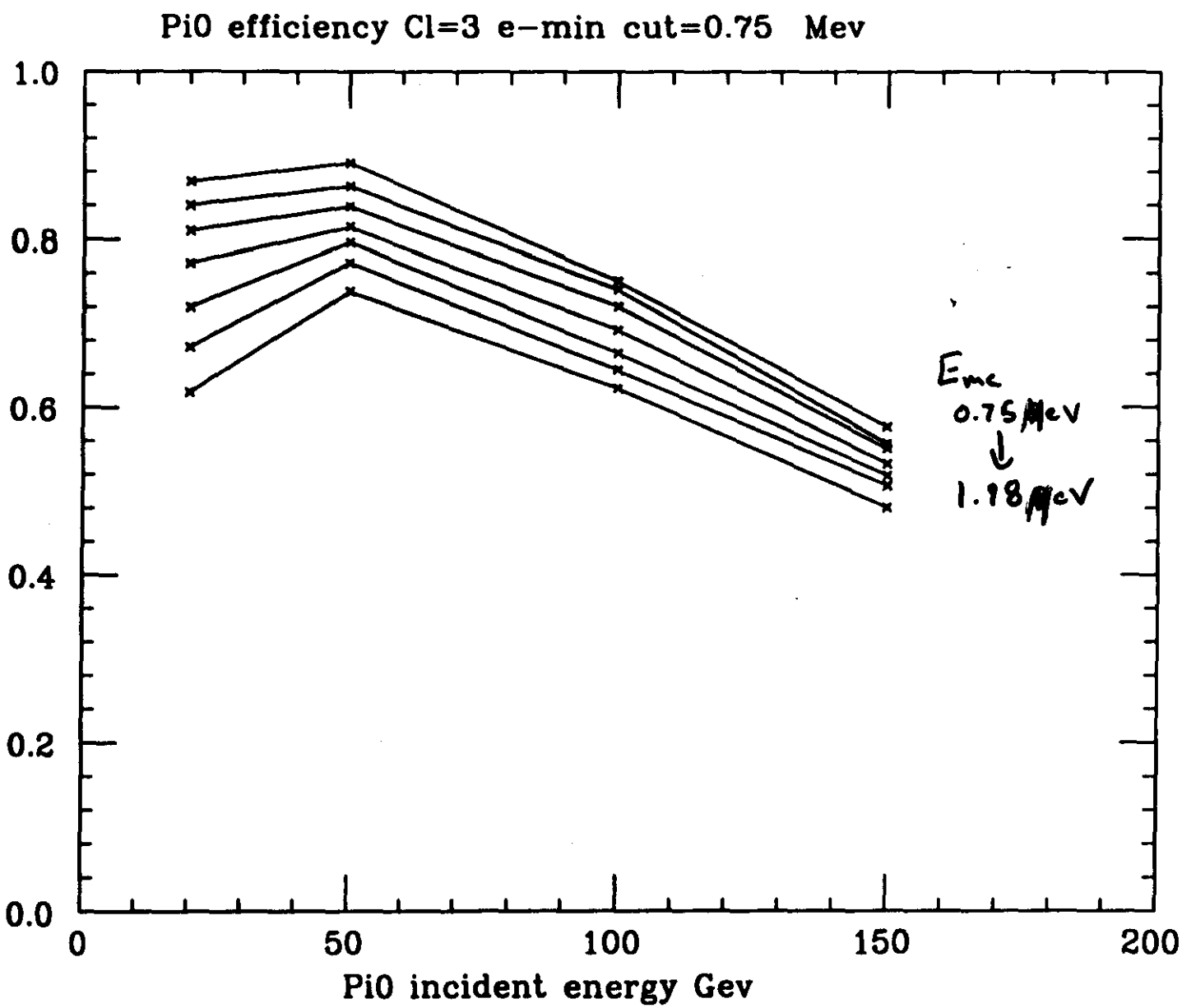
Cluster Finding Algorithm

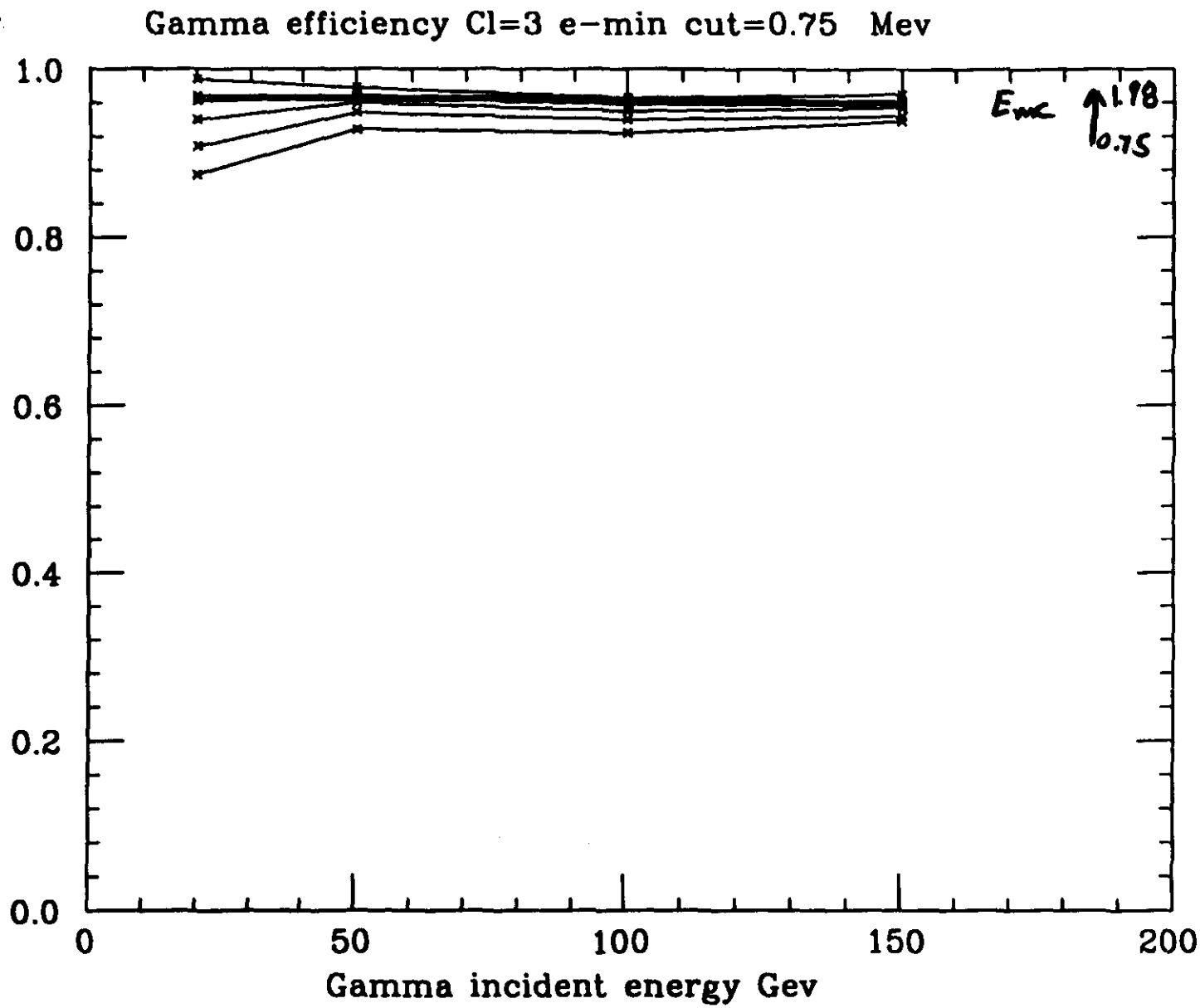


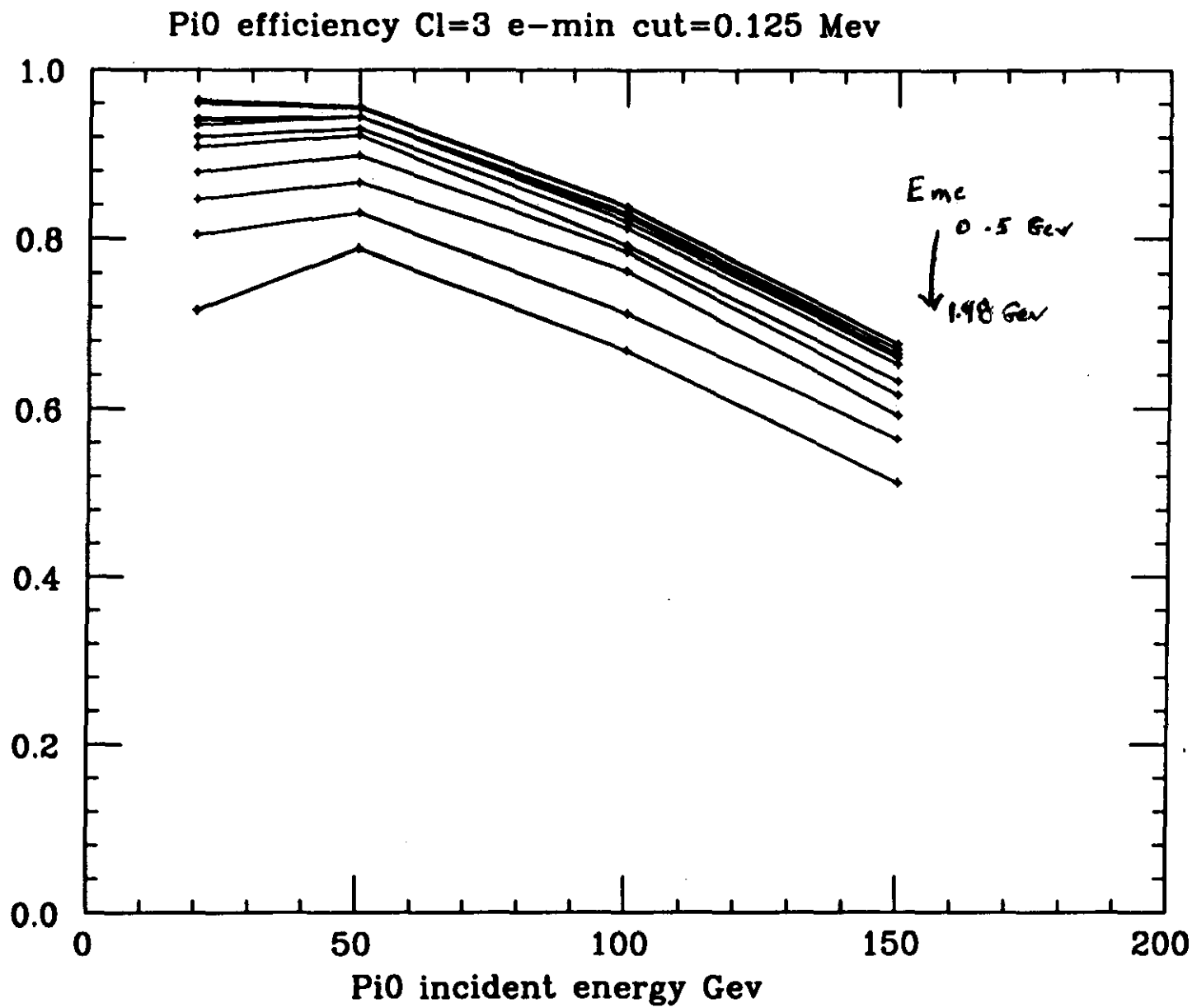
- Find all strips with $E > E_{min}$
- Find all peaks with $E > E_{mc}$
- If more than 2 peaks exist

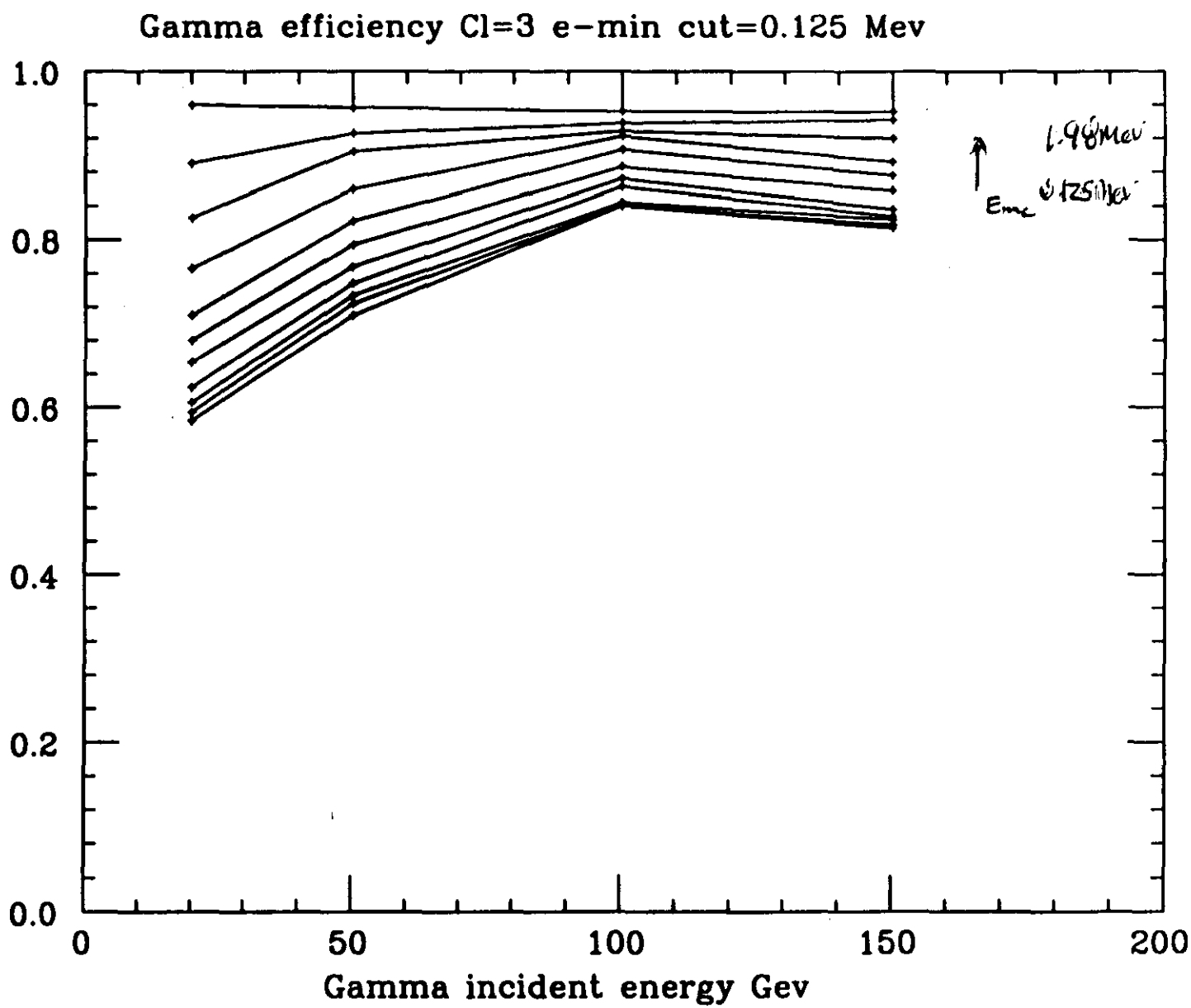
  require $E_2 > E_1 \cdot 0.4$

- If only one peak, require match to shower within 1.5 mm


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
Emc
0.75 MeV
1.98 MeV

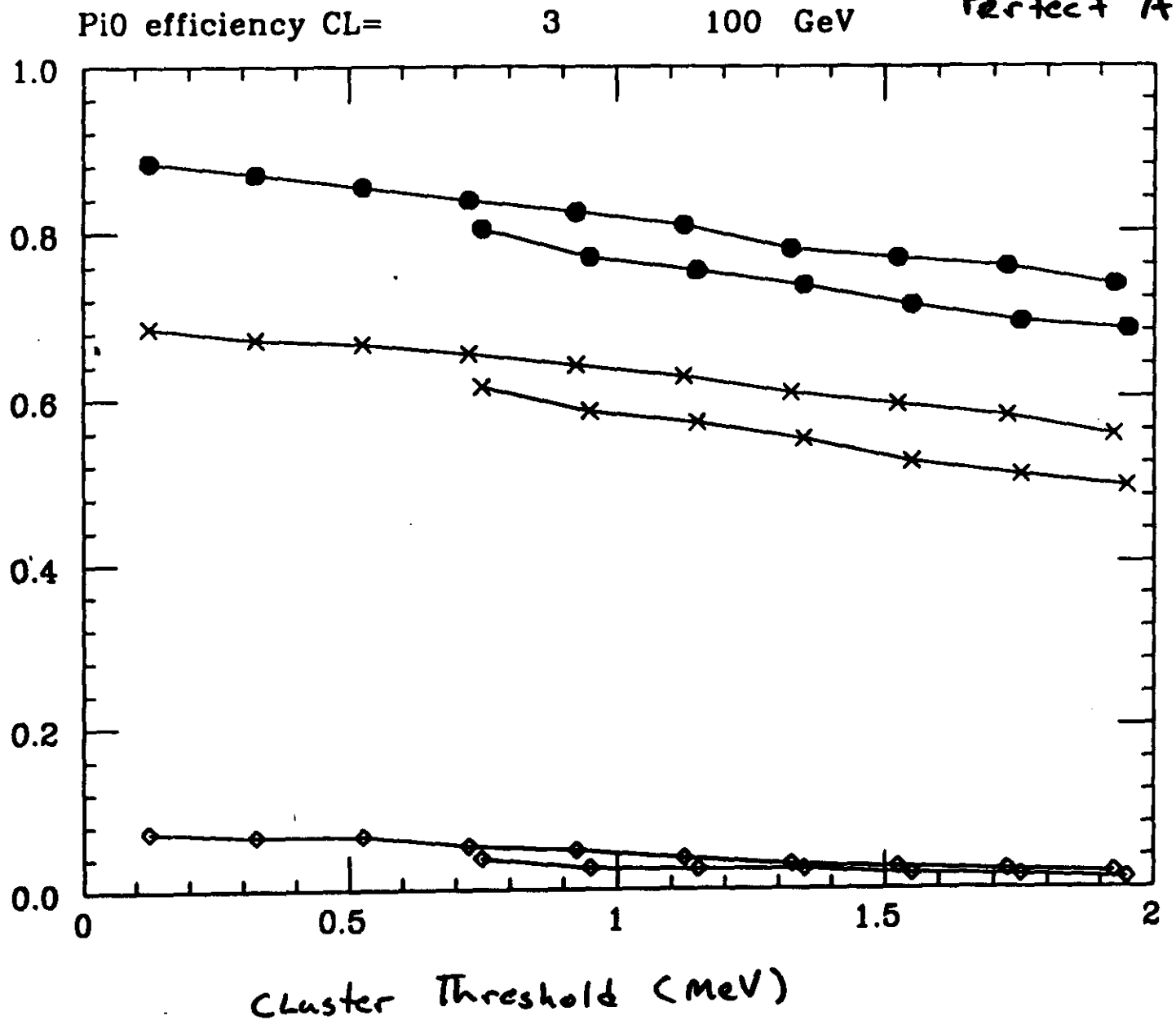

Gamma efficiency Cl=3 e-min cut=0.75 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Gamma incident energy Gev
Emc
1.98
0.75


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
Emc
0.5 Gev
1.98 Gev

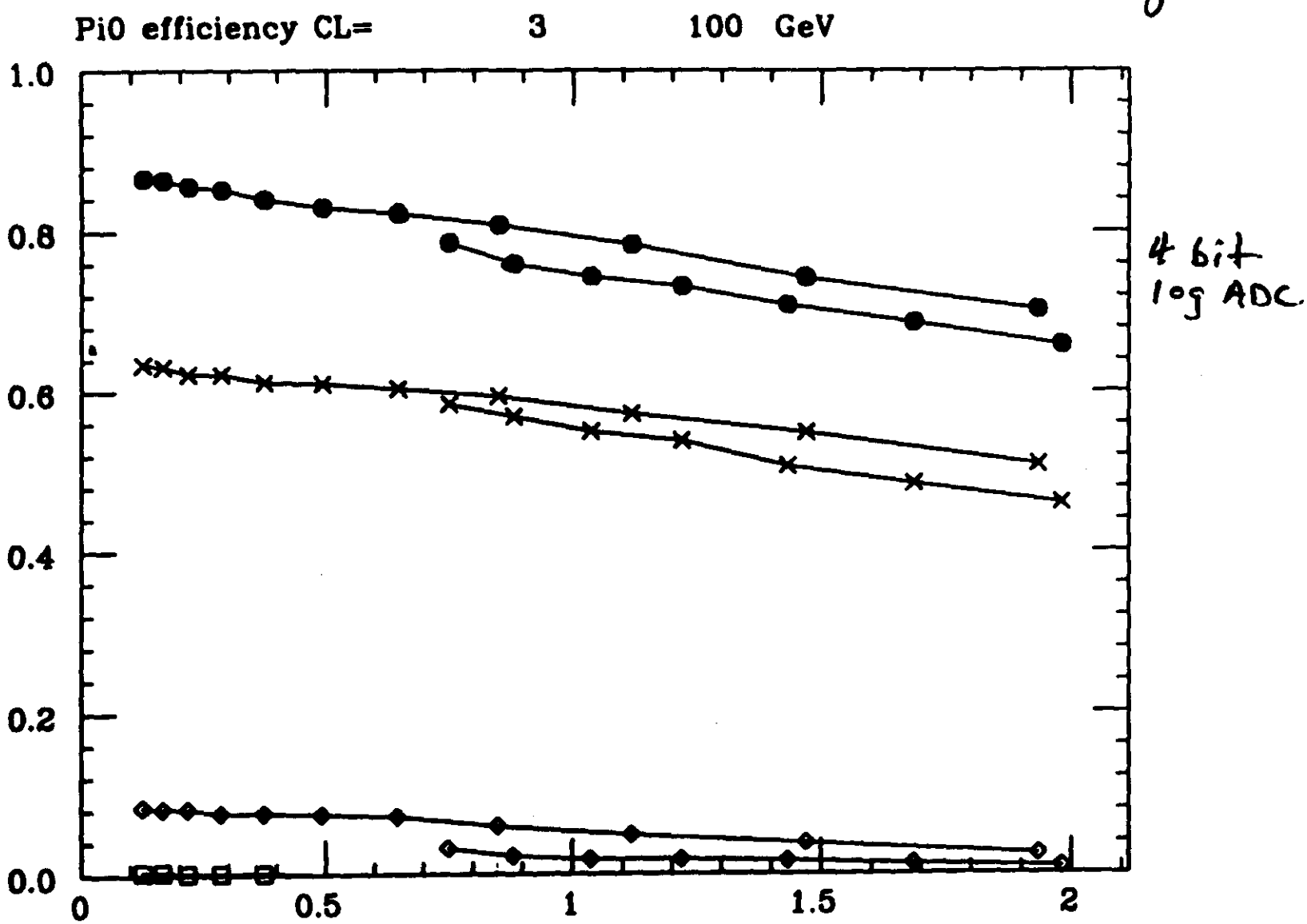

Gamma efficiency Cl=3 e-min cut=0.125 Mev
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Gamma incident energy Gev
1.98Mev
Emc
0.125Mev

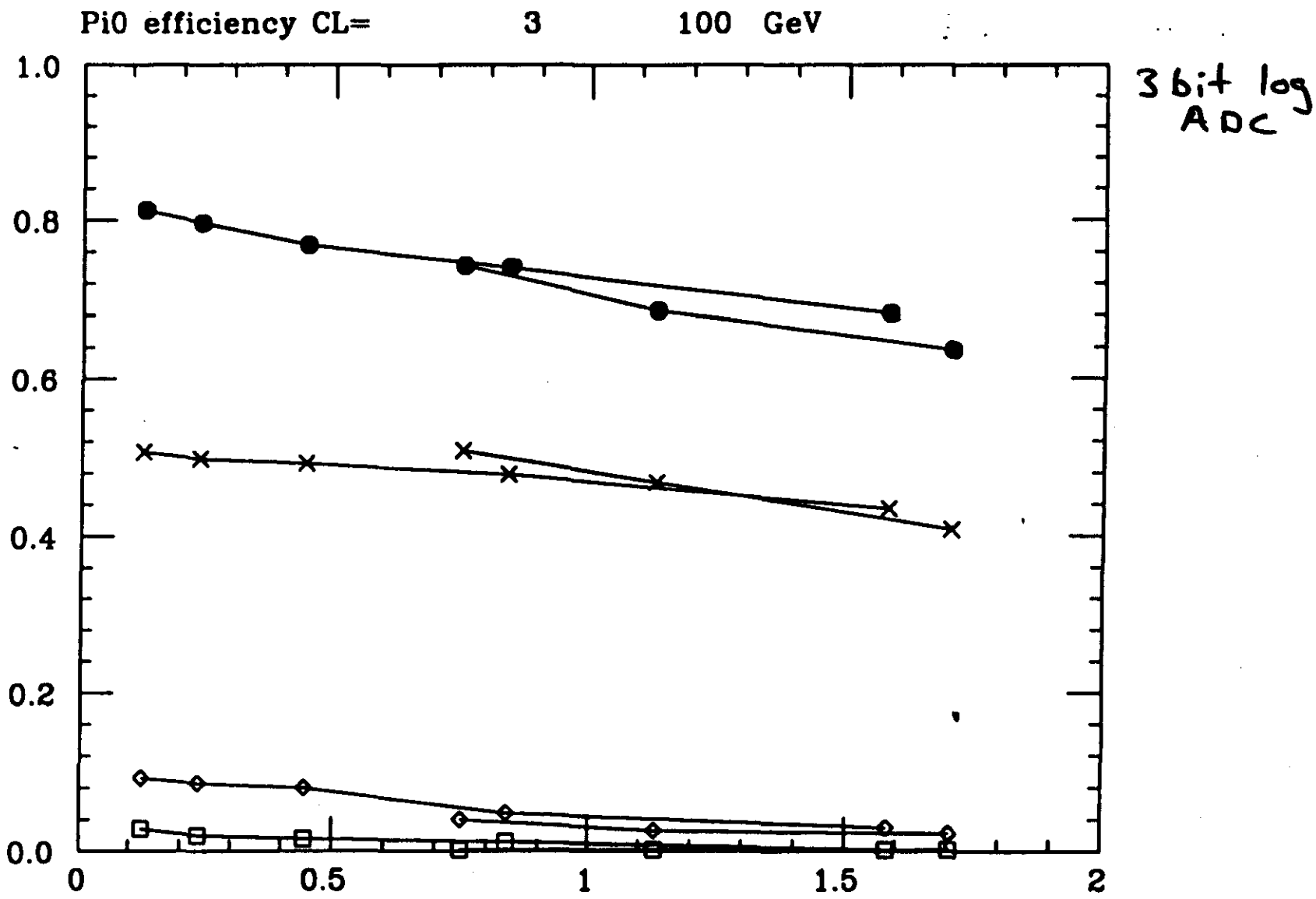
infinite bits

Perfect ADC



4bits log <10Me




Pi0 efficiency CL= 3 100 GeV
1.0
0.8
0.6
0.4
0.2
0.0
0
0.5
1
1.5
2
3 bit log ADC

Significance of Higgs signal

$$S = \frac{\varepsilon_\gamma^2 N}{\sqrt{\varepsilon_\gamma^2 B_{\gamma\gamma} + \varepsilon_\gamma \bar{\varepsilon}_j B_{\gamma j} + \bar{\varepsilon}_j^2 B_{jj}}}$$

ε_γ = photon finding efficiency

$\bar{\varepsilon}_\gamma$ = inefficiency of π^0 removal

Two scenarios:

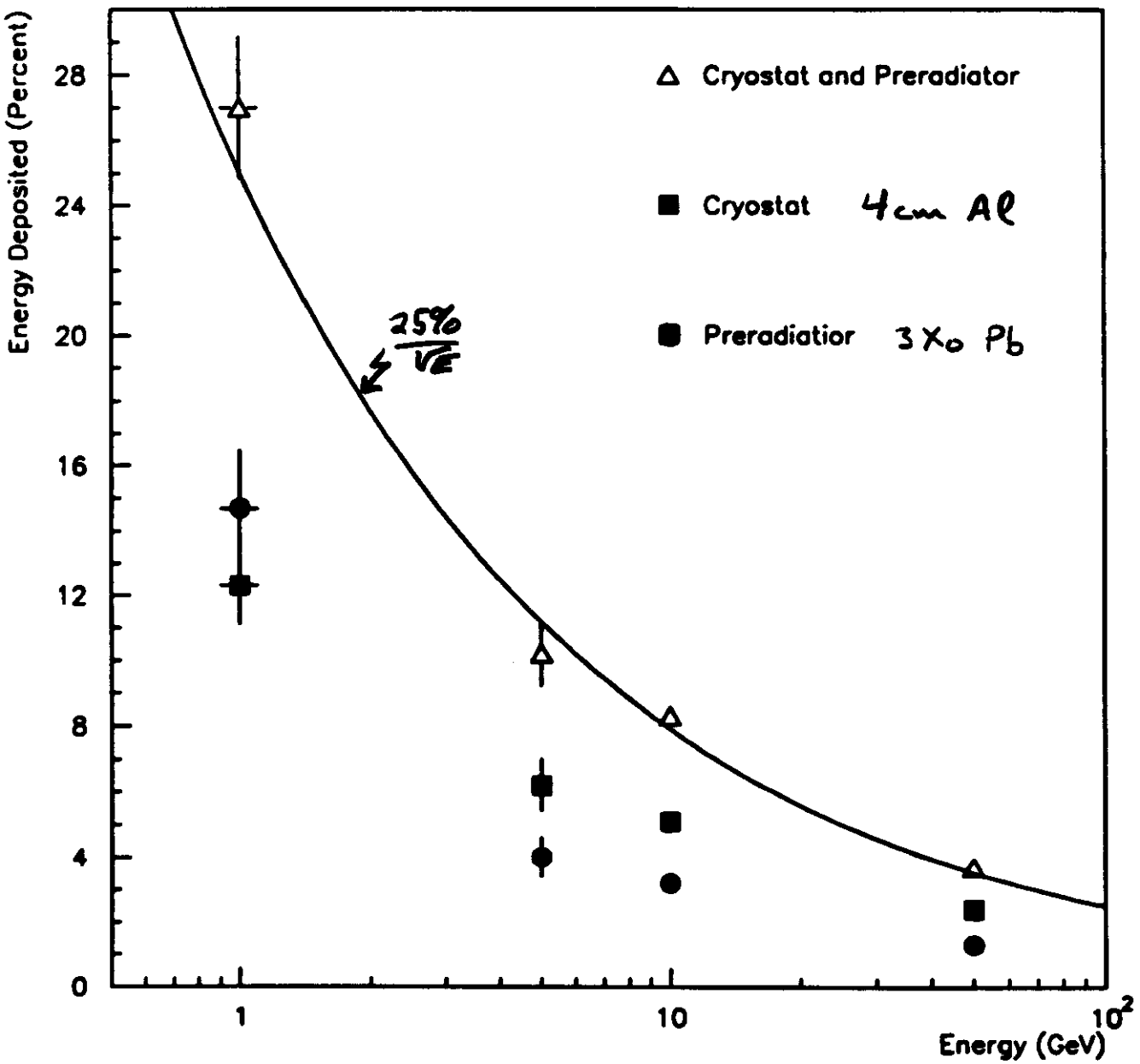
$$B_{\gamma\gamma} = B_{\gamma j} = B_{jj}$$

	ε_γ	$\bar{\varepsilon}_j$	
50 GeV	.96	.2	$S = 1.49$
100 GeV	.96	.3	$S = 1.40$

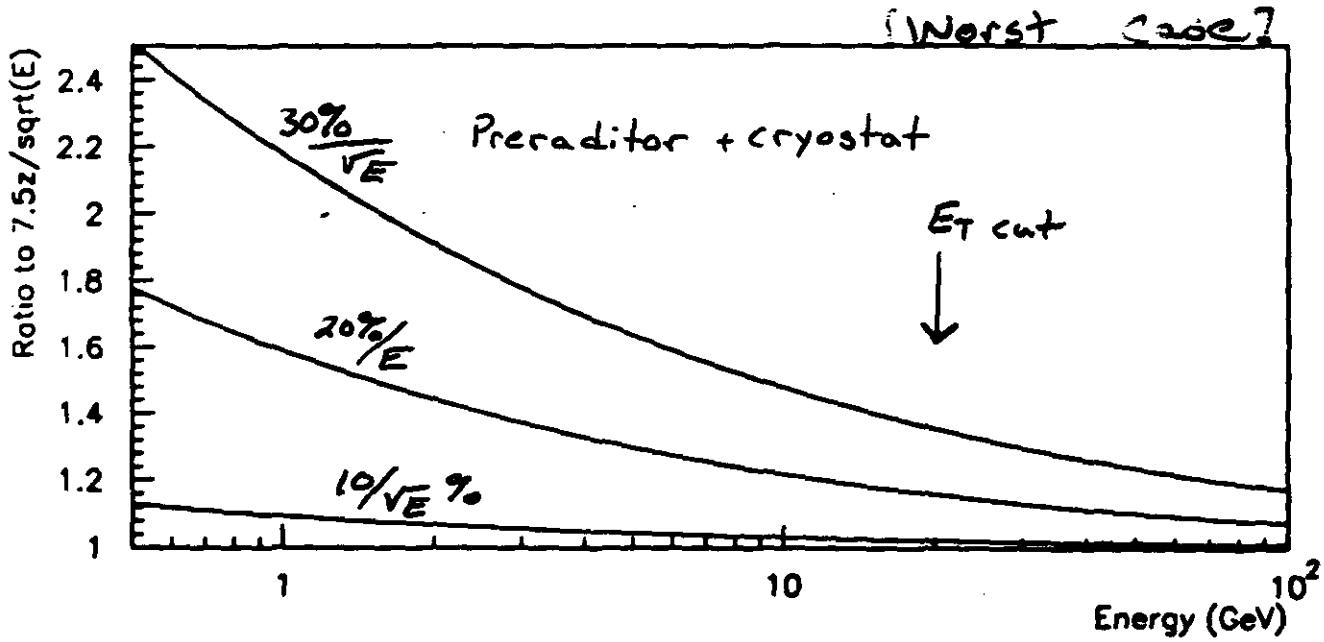
$$10 B_{\gamma\gamma} = B_{\gamma j} = B_{jj}$$

	ε_γ	$\bar{\varepsilon}_j$	
50 GeV	.96	.2	$S = 2.7$
100 GeV	.96	.3	$S = 2.1$

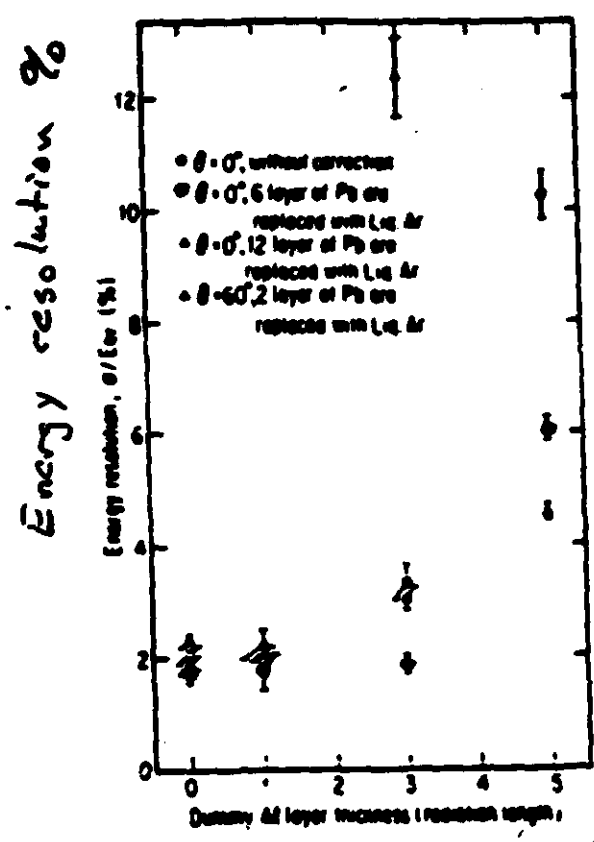
Fraction of Energy Deposited in Preradiator & cryostat



cryostat wall of ~2cm Al may be possible!



Effect of material on Energy resolution assuming energy in dead material measured to $x\%/\sqrt{E}$.



H. Hirayama, NIM A302 (1991) 427

Fig. 4. Recovery of the energy resolution in case 1 as function of the Al dummy layer thickness.

From "The Effect of a Preradiator on the EMPACT/TEXAS Liquid Argon Calorimeter" Pitts, Braun

Conclusion: compensation possible!

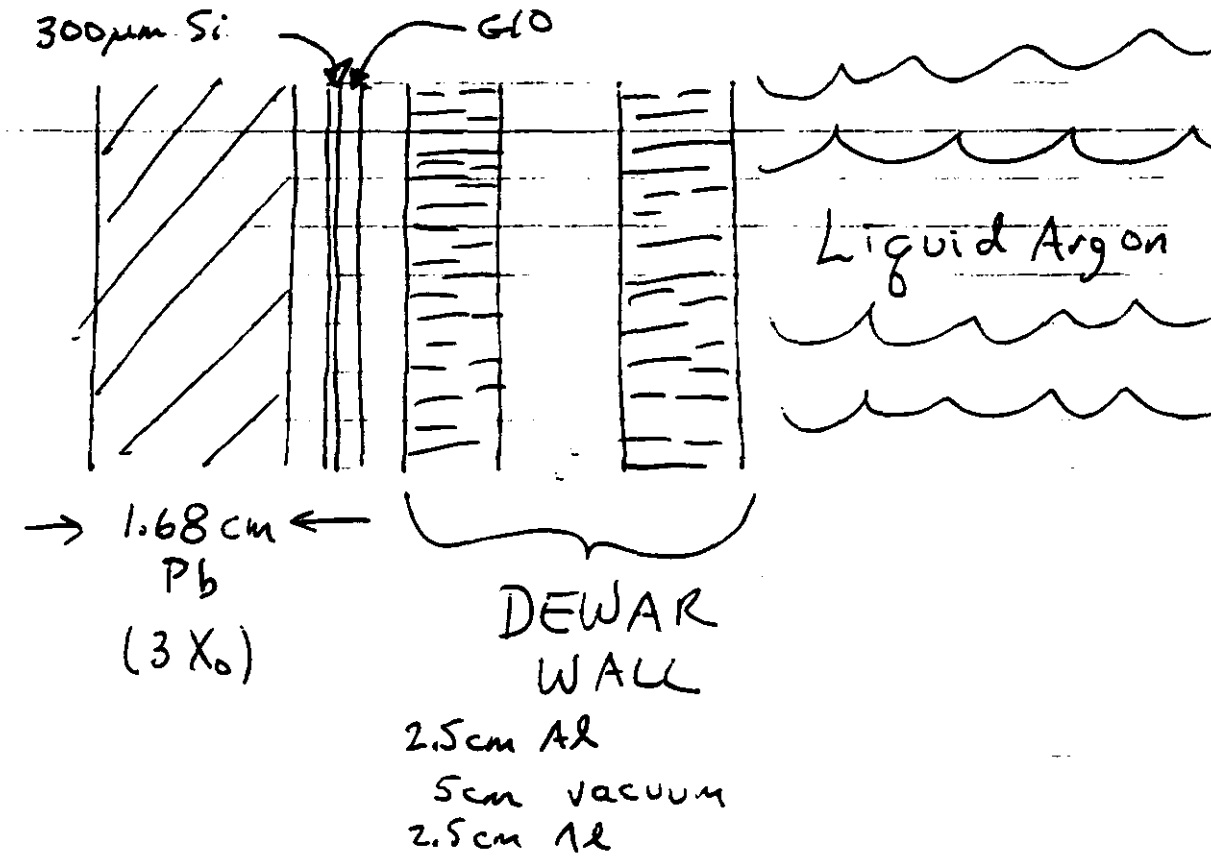
Table 3.

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

particle type	incident energy (GeV)	η	number of events	$\frac{e}{\pi}$	$\frac{\sigma_E}{E} \times \sqrt{E_{in}}$ (%)	$k_2 =$	comments
e^-	10	0	366	2.9	9.1± 0.5	$2.3k_1$	optimal
				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
				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
				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
				1.2	8.5± 0.6	k_1	k_2 fixed
γ	50	2	192	1.5	10.5± 0.8	$0.82k_1$	optimal
				1.6	11.2± 0.8	k_1	k_2 fixed

STUDIES OF ENERGY CORRECTION WITH PRE-RADIATOR IN PRESENCE OF MAGNETIC FIELD

X. Yang + J.B.



$$E = k_1 E_1 + k_2 E_2 + k_3 E_3$$

E_1 = energy in silicon

E_2 = energy in 1ST liquid argon gap ('massless gap?')

E_3 = energy in rest of liq argon calorimeter

EGS RESULTS

e/γ	E (GeV)	∡	Pterad (X₀)	k2/k3	B field (T)	σ/√E | unc.	σ/√E | cor	Deionr Al-Air-Al	# of event
e	50	90°	3X.	1	0	21.67 %	9.09 %	2.5-5-2.5	200
e	50	90°	3X.	1	.8	19.56 %	8.30 %	2.5-5-2.5	200
γ	50	90°	3X.	1	0	24.3 %	9.17 %	2.5-5-2.5	200
γ	50	90°	3X.	1	.8	26.6 %	8.39 %	2.5-5-2.5	200
e	50	90°	3X.	1.8	0	22.2 %	8.54 %	2.5-5-2.5	98
e	50	90°	3X.	2.24	.8	19.09 %	9.09 %	2.5-5-2.5	78

EFFECT OF MATERIAL IN FRONT OF CALORIMETER

2 General Rules

1.) The farther in front of the calorimeter, the more harmful it is.

2) For a given number of radiation lengths, low Z material is more harmful.

$$\left(E_c^{low\ Z} > E_c^{hi\ Z} \right)$$

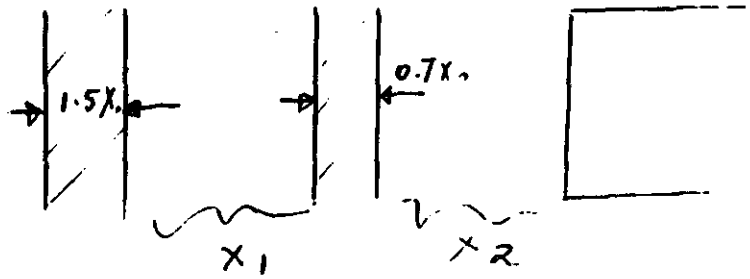
$$\left(\frac{dE}{dx} X_0^{low\ Z} > \frac{dE}{dx} X_0^{hi\ Z} \right)$$

study motivated by simulation results of M. Nessi and F. Nessi

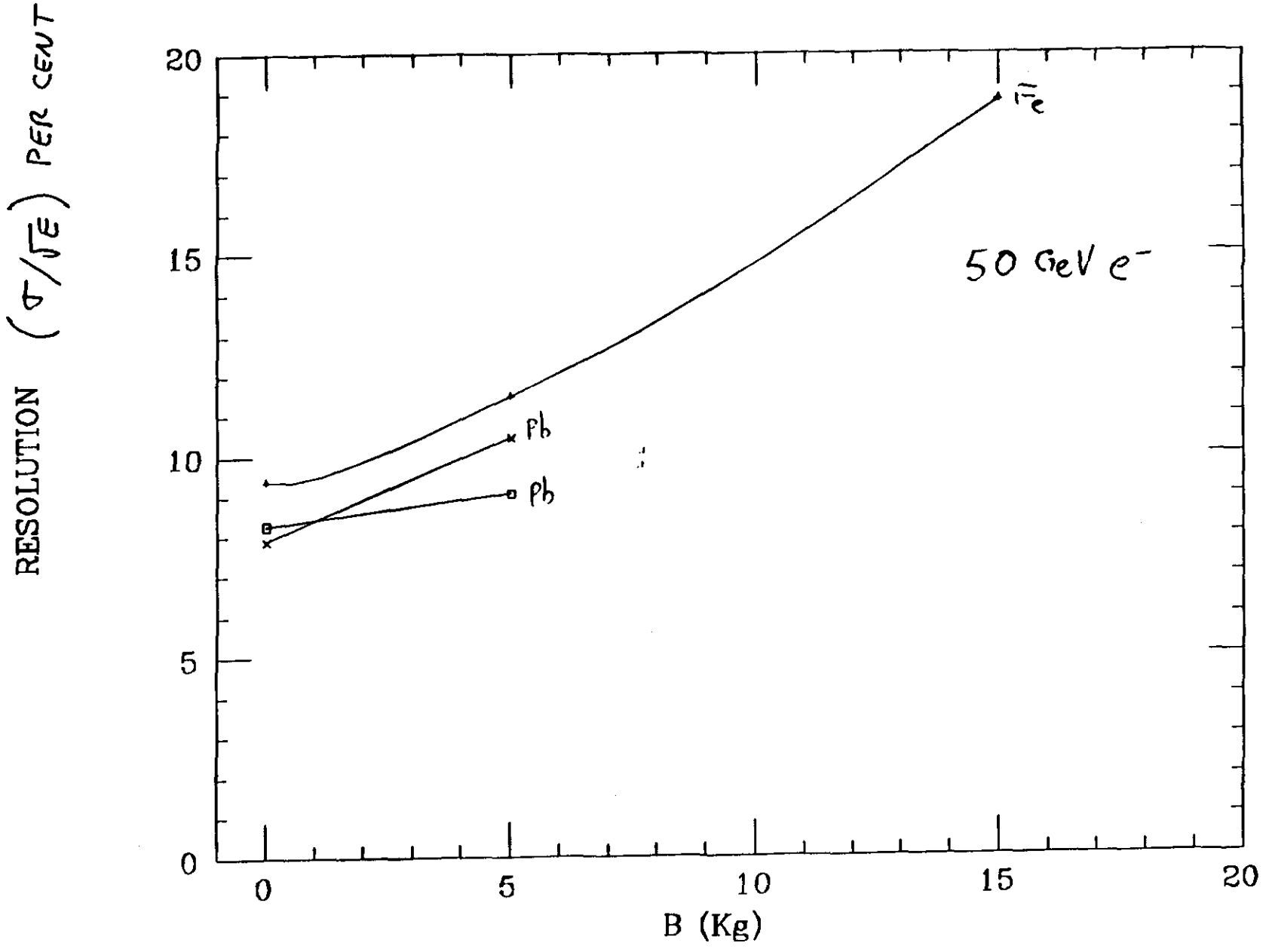
- low Z
- large distance
- w/ B field

} beware!

50 GeV
e^-



MED-1	MED-2	X_1	X_2	B (T)	σ_{fe}	# of event
Fe	Fe	40	10	0	9.37	84
Fe	Fe	40	10	0.5	11.5	100
Fe	Fe	40	10	1.5	18.8	100
Pb	pb	40	10	0	7.89	63
pb	pb	40	10	0.5	10.45	42
pb	pb	10	10	0	8.25	100
pb	pb	10	10	0.5	9.06	42


RESOLUTION $(\sigma/\sqrt{E})$ PER CENT
20
15
10
5
0
0
5
10
15
20
B (Kg)
Fe
Pb
Pb
50 GeV e^-

Silicon Preradiator Prototype for GEM

(SECC → GEM)

Anatoli Arodzero, Moscow State / UO

George Beshindzhagyan, Moscow State

Jim Brau, U.O.

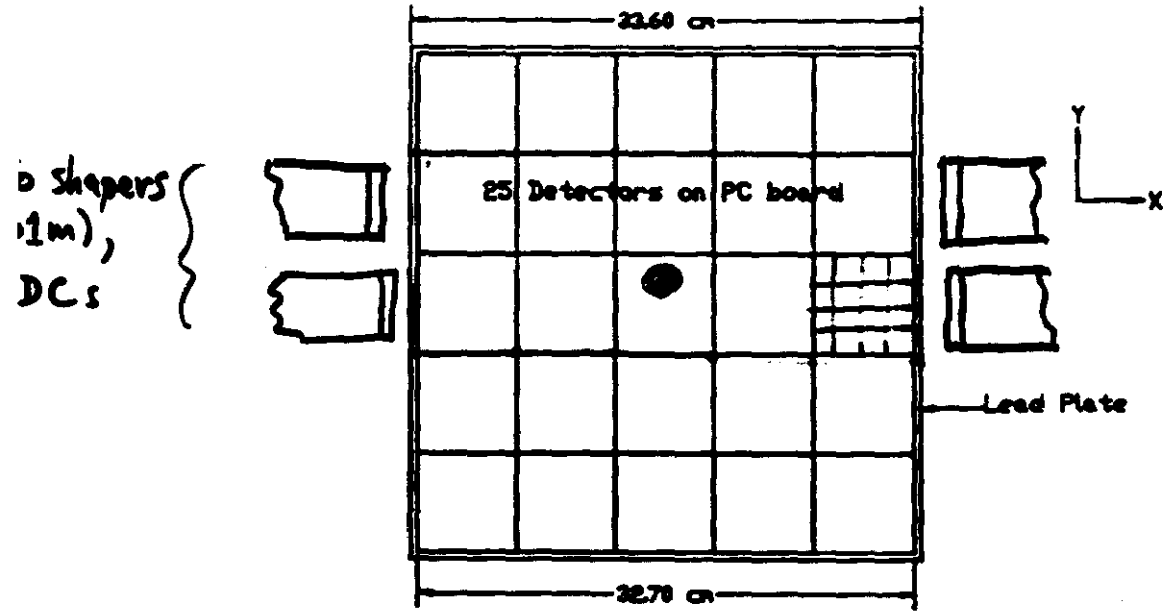
Ray Frey, UO

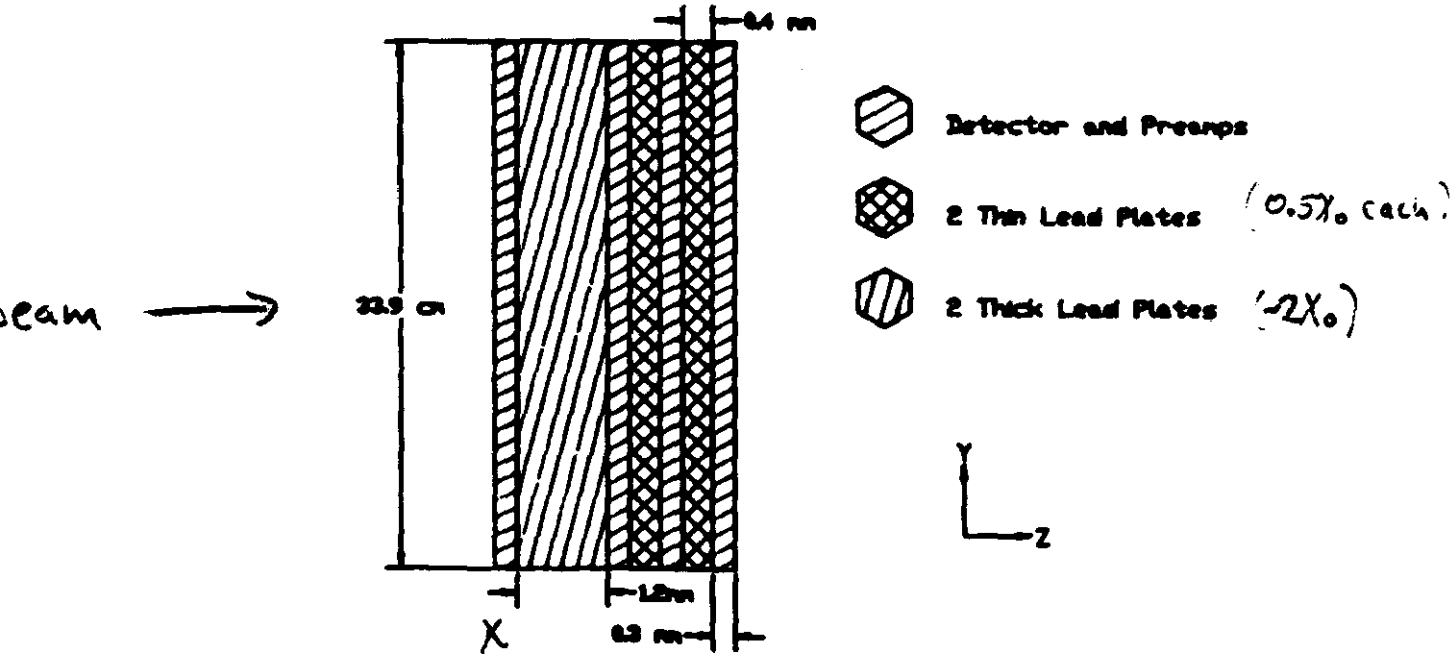
David Mason, UO undergraduate

David Strom, UO

Electronics: Dick Todd, Martin Bauer, ORNL

Test module


23.60 cm
25 Detectors on PC board
Lead Plate
32.70 cm
Y
X
o shapers
1m),
DCs


0.4 mm
Detector and Preamps
2 Thin Lead Plates (0.5X₀ each)
2 Thick Lead Plates (~2X₀)
beam
23.9 cm
1.2mm
0.3 mm
X
Y
Z

1st Prototype

Will be completed at UO 2/92

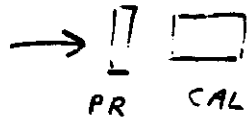
- 1.6 cm × 1.6 cm Si pad detector elements
- Pb-alloy radiator plates
- custom preamps (ORNL) + shapers
- readout circuits

↳ DAQ system

↳ FNAL test

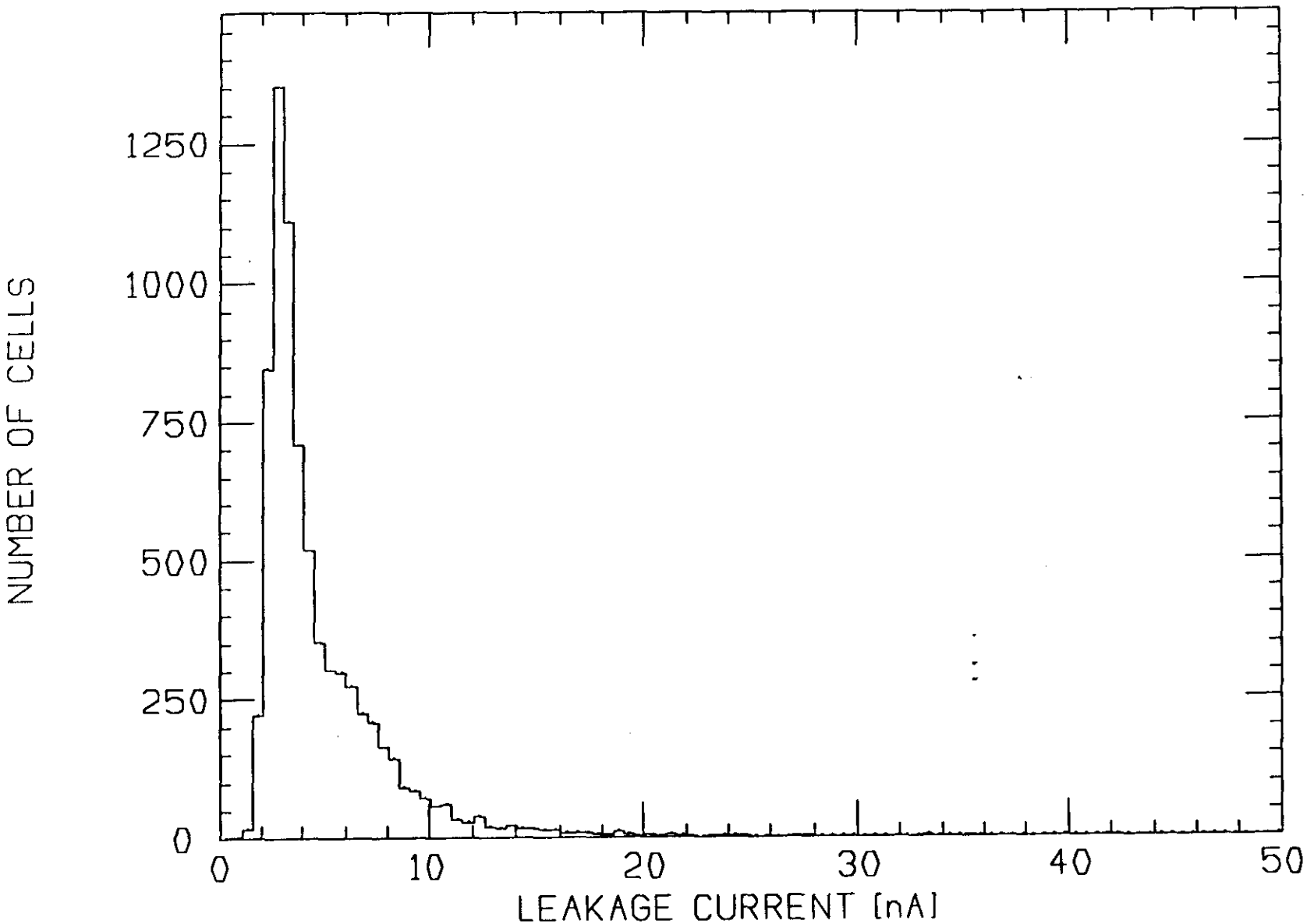
↳ BNL test

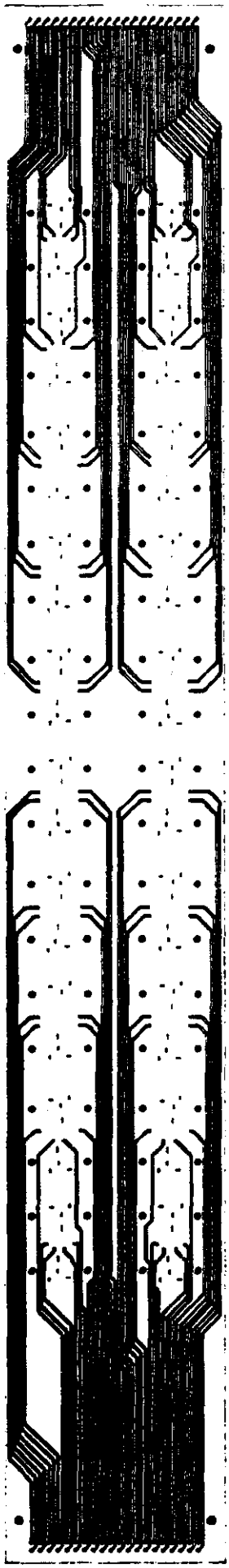
Goals:
- Technical experience
- test MC calculations for deposited energy, profiles, etc.
- Energy resummation → effect on em. cal. resolution

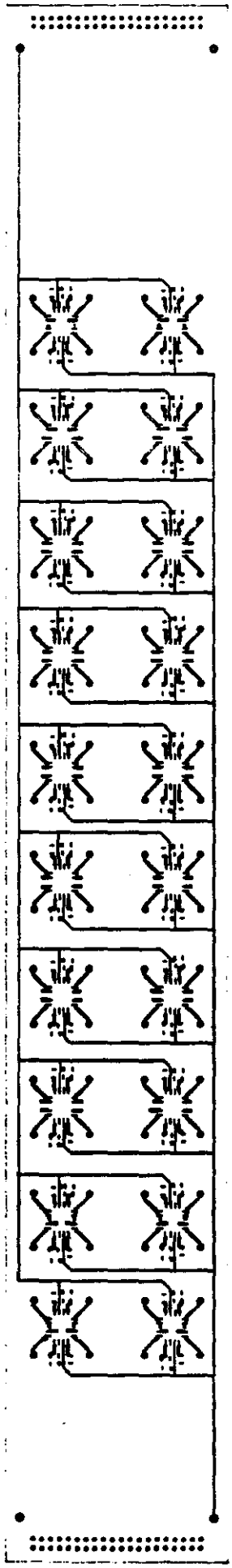
→ 

1.6x1.6cm²

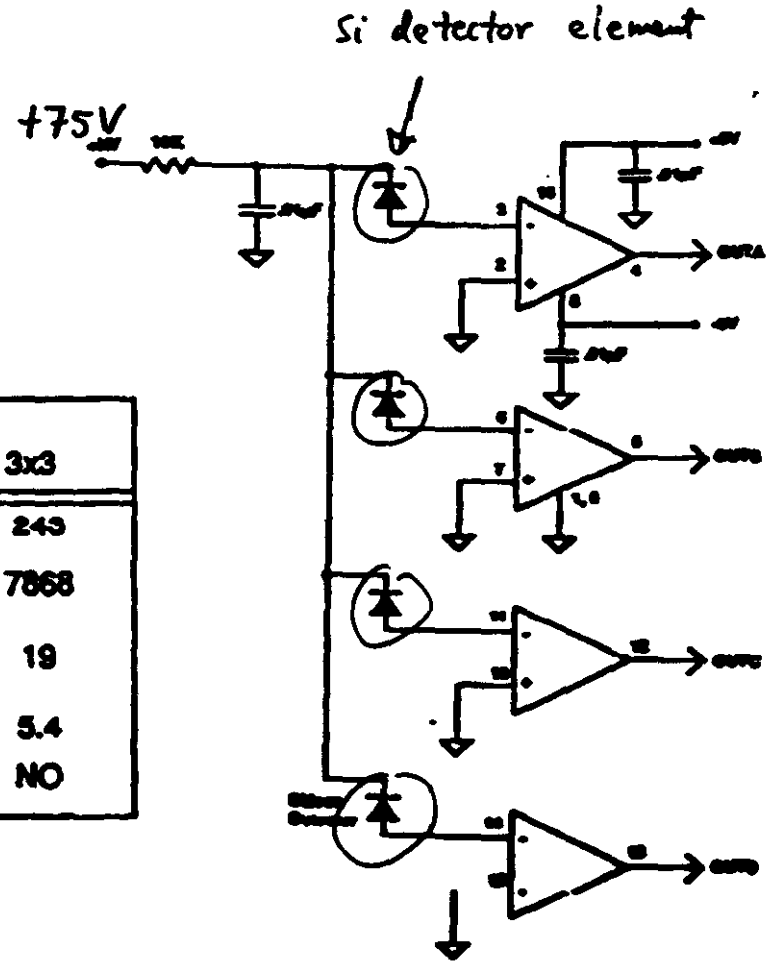
SECC 4*4 DETECTOR AT 75 V





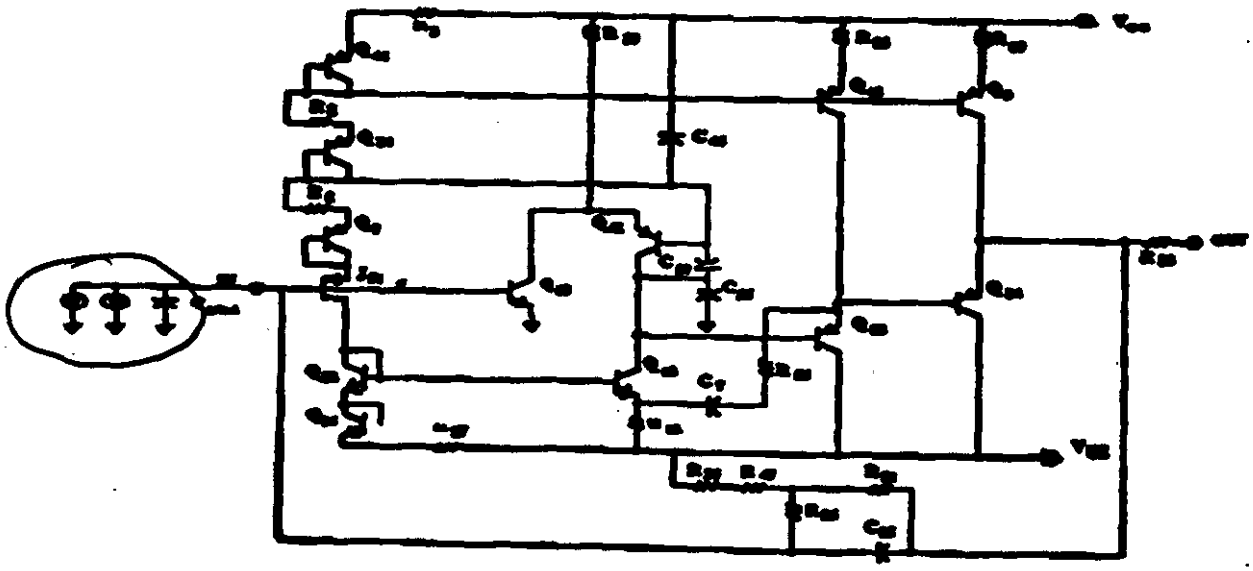


ORNL Preamp

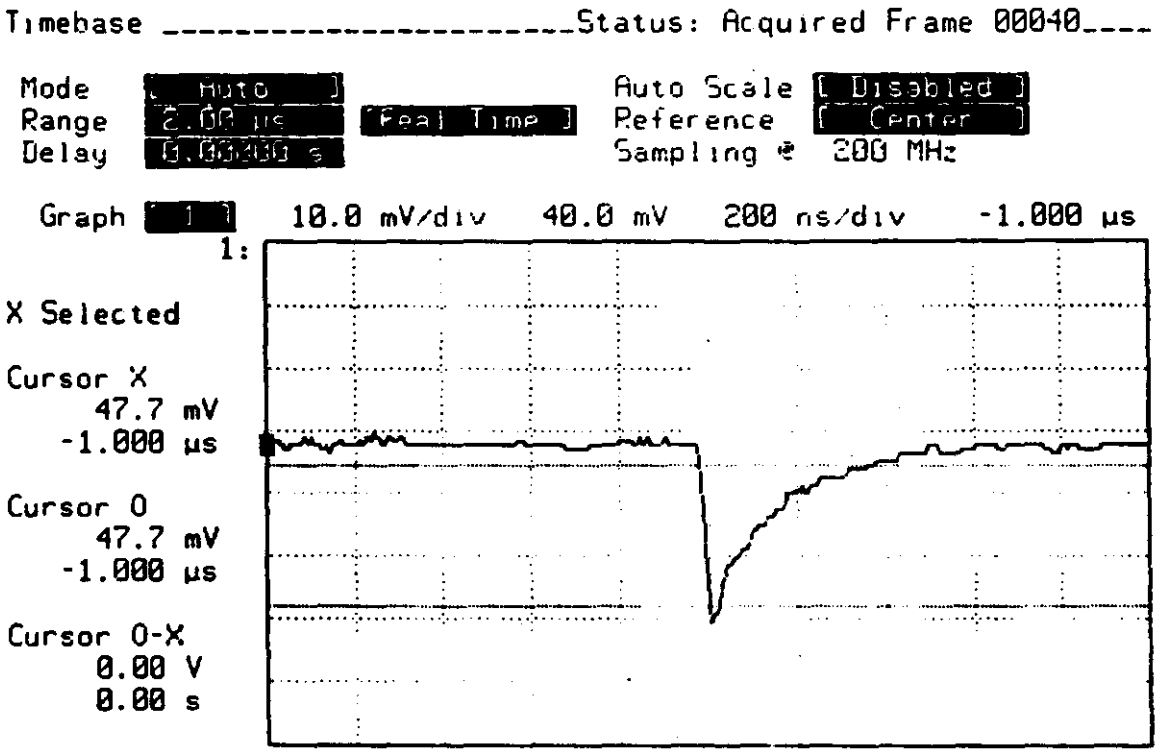


Preamp Type Detector Size	Folded Cascode 1x1	2x2	3x3
C_d (pF)	27	106	243
ENC_n	4152	5001	7868
P_d (mW)	18.2	19.5	19
t_r (ns)	3.5	3.3	5.4
Ext. Cap. ?	NO	NO	NO

HARRIS VHF BIPOLAR PROCESS CE CHARGE - SENSITIVE PREAMP

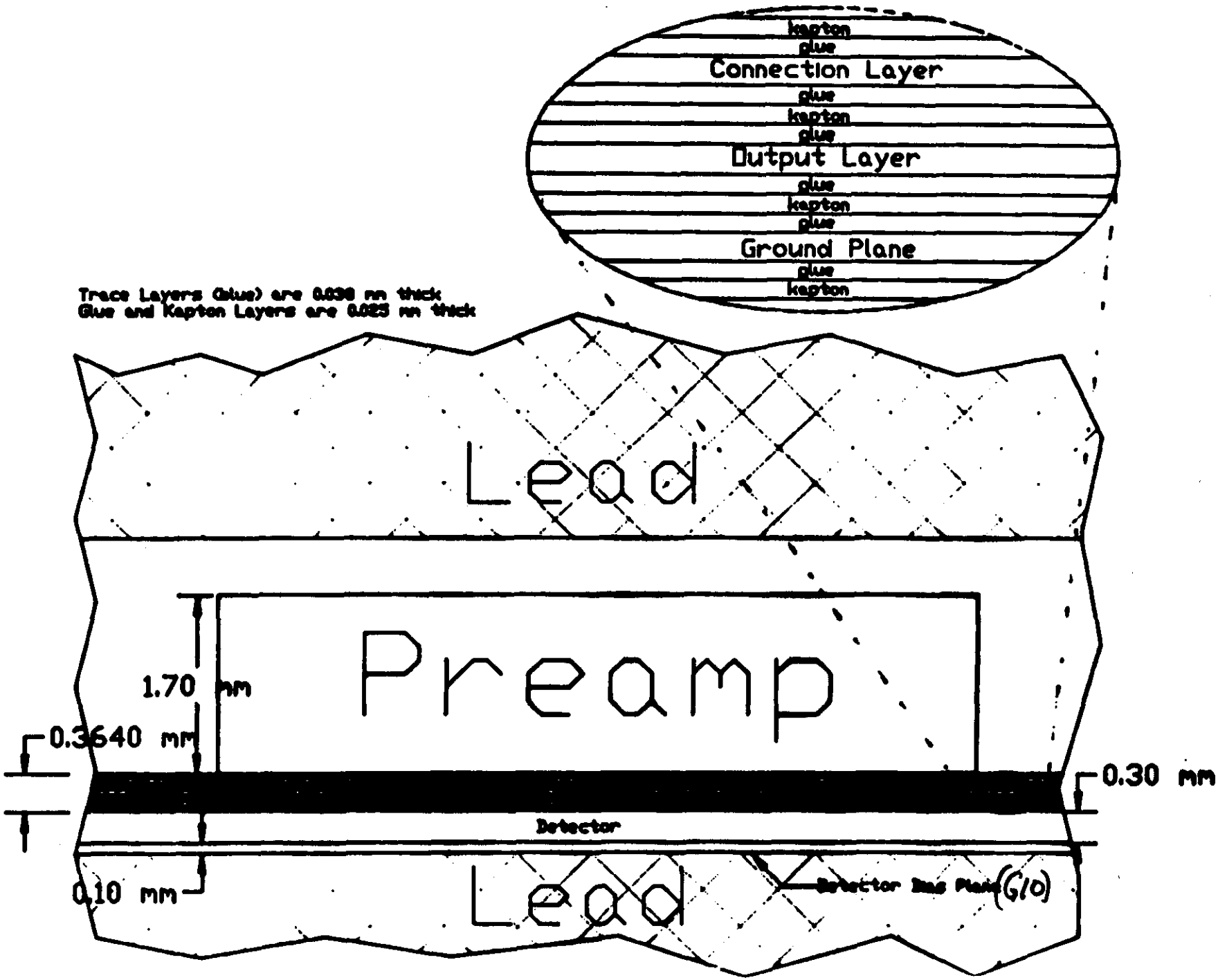


Detector board prototyping



α source 1 cm x 1 cm detector

CF1X1 preamp

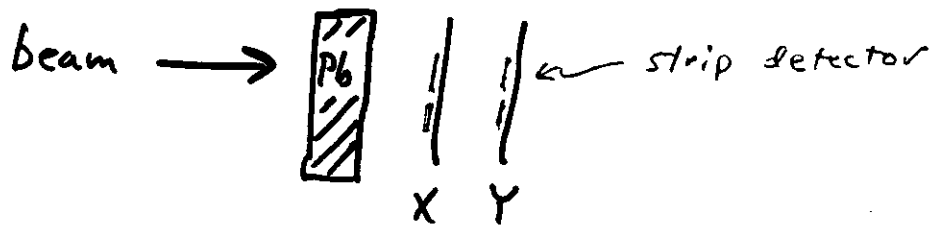

kapton
glue
Connection Layer
glue
kapton
glue
Output Layer
glue
kapton
glue
Ground Plane
glue
kapton
Trace Layers (Glue) are 0.038 mm thick
Glue and Kapton Layers are 0.025 mm thick
Lead
Preamp
1.70 mm
0.3640 mm
0.30 mm
Detector
0.10 mm
Lead
Detector Bias Plane (G10)

Next Step

Include Si "strip" layers, pitch ≈ 1mm required for $\pi^0 \to \gamma\gamma$ rejection for $M(H^0) \sim 100 - 150$ GeV

5 strip detectors in hand: (Hamamatsu)

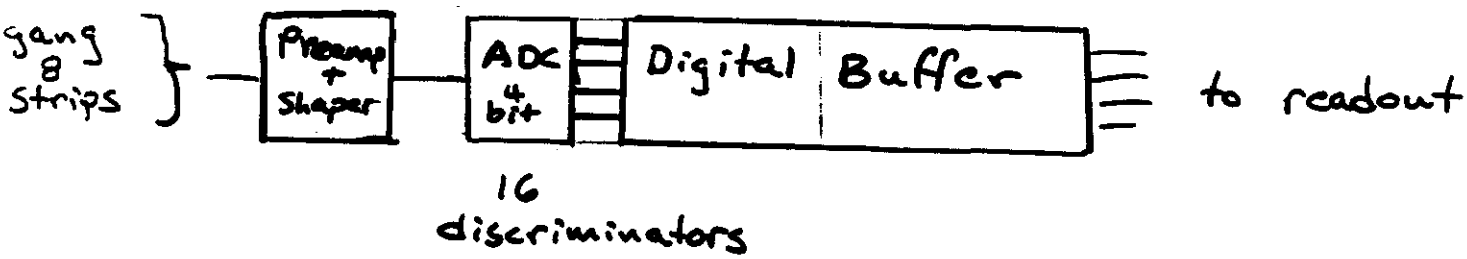
48 x (48mm x 1mm elements)



Goals:
- 2-shower resolving power
- resolution; energy resummation
- e^- id.
- technical — Need to use wire bonding of detector strips to readout PC.

Electronics for the Preradiator

- Total number of strips is ~ 500,000 need to minimize electronics costs.



- Prohibitively expensive to readout each strip individually

- Still have ~ 62,000 electronics channels

- Main cost is ADC & on-board electronics.

On Preradiator for BaF_2

Ren-yuan Zhu
CALTECH

Jan 22. 1992

- Physics of preradiator

  $H \to \gamma\gamma$

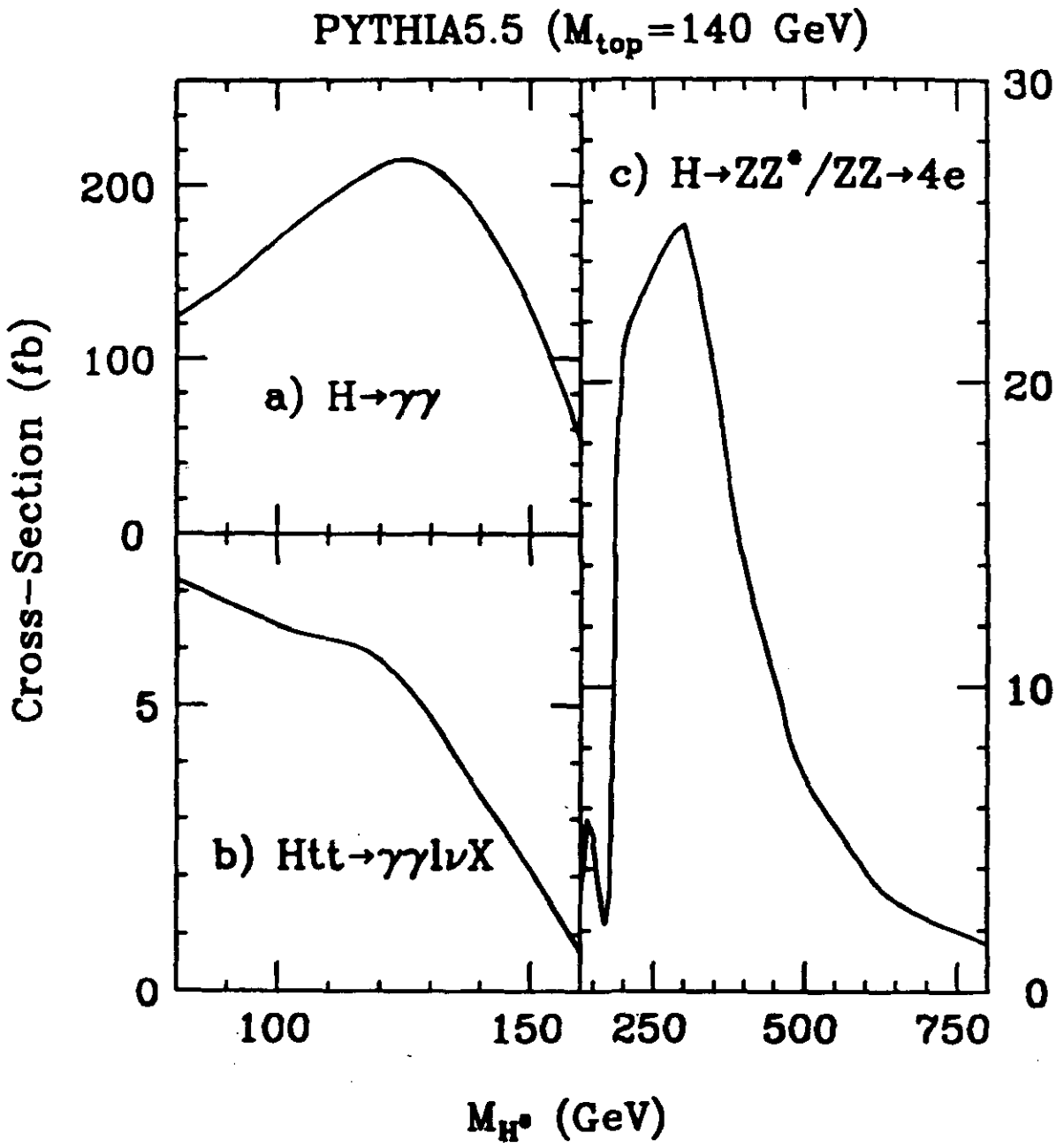
  $H\tau\tau \to l\gamma\gamma$

  10^{34} ?

- A possible senario of preradiat. for BaF_2 detector.

- Issues not considered:

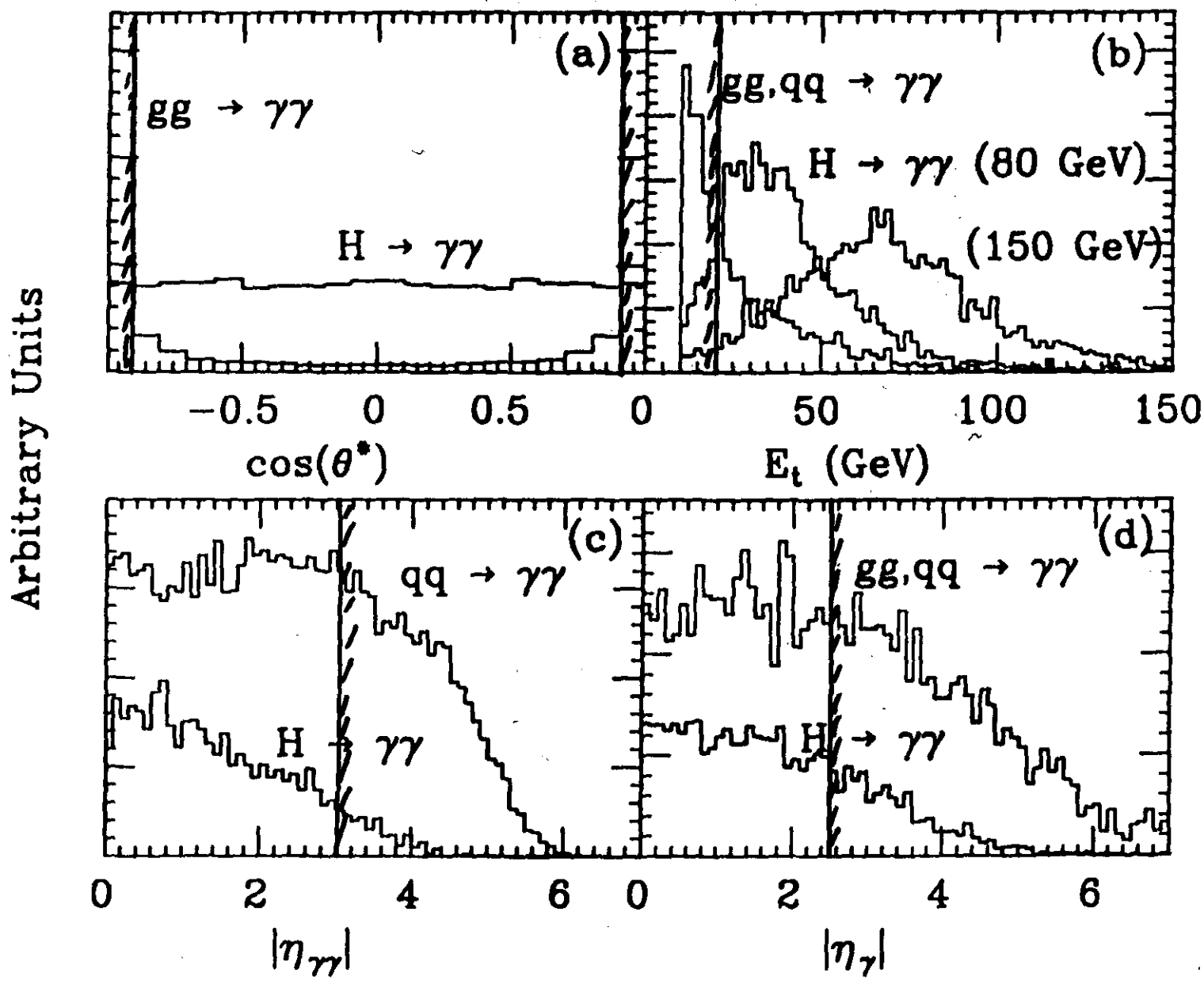
  COST.


PYTHIA5.5 (M_{top}=140 GeV)
Cross-Section (fb)
200
100
0
5
0
30
20
10
0
a) H→γγ
b) Htt→γγlνX
c) H→ZZ*/ZZ→4e
100
150
250
500
750
M_{H^0} (GeV)

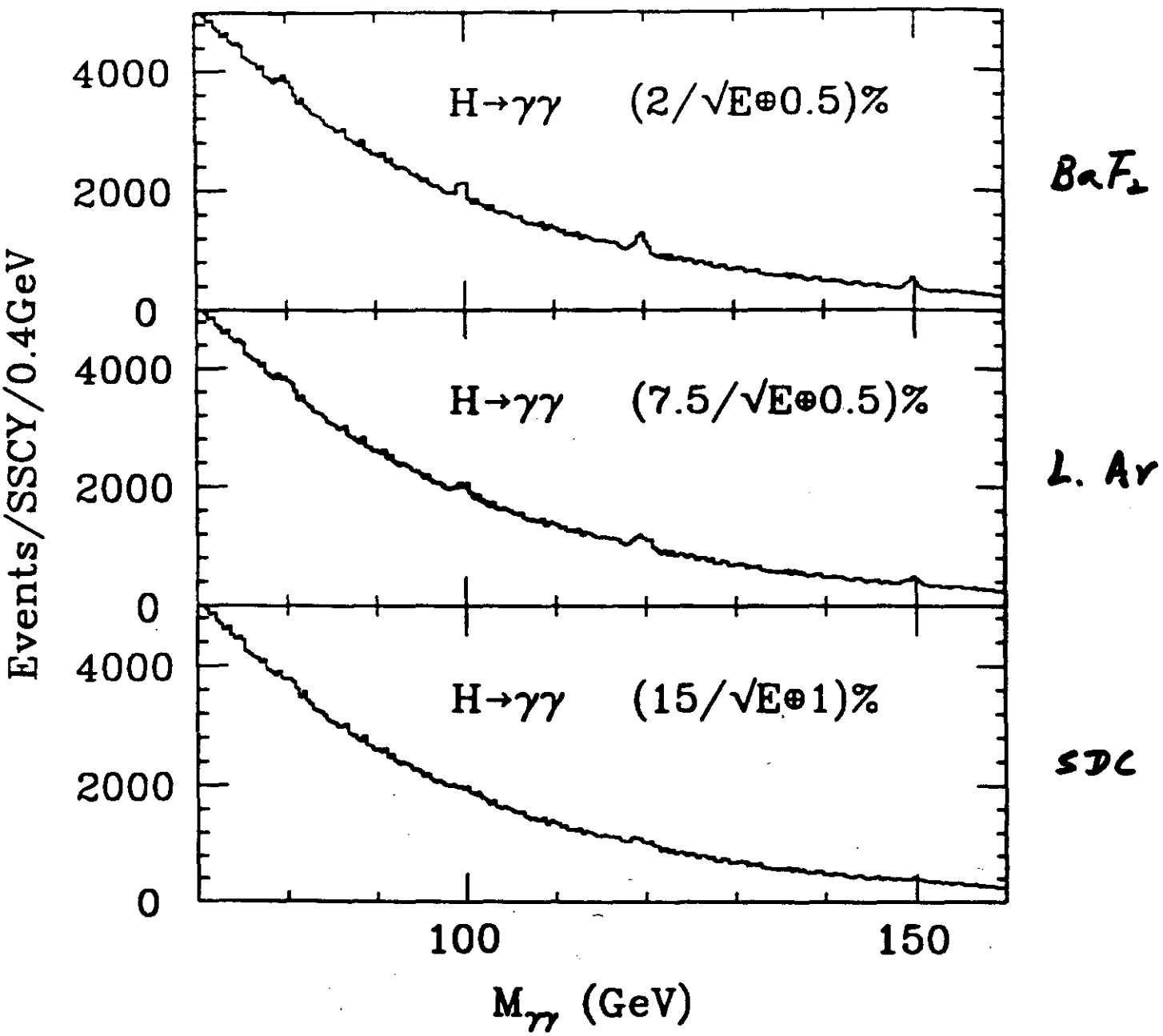
$H^0 \rightarrow \gamma\gamma$ Signal/Background

- Signal: 0.05–0.2 pb for $M_H \in (80,160)$GeV:
  - $|\eta_\gamma| < 2.5$;
  - $E_T > 20$ GeV;
  - $|cos\theta^*_\gamma| < 0.9 \Rightarrow$ reduce gg $\rightarrow \gamma\gamma$;
  - $|\eta_{\gamma\gamma}| < 3 \Rightarrow$ reduce qq $\rightarrow \gamma\gamma$.
- Direct Photon Background:
  - 276 pb (gg$\rightarrow \gamma\gamma$: 198 and qq $\rightarrow \gamma\gamma$ 78);
  - After selection and isolation (5 GeV, 0.75): 32 pb for $M_{\gamma\gamma} \in$ (75, 165) GeV.
- QCD Background:
  - 2jets: 2 mb;
  - γ-jet: 237nb ($qg \rightarrow \gamma q$: 226 and $qq \rightarrow \gamma g$: 11);
  - After isolation: 23 and 20 pb (50/73);
  - After shower shape analysis (5 mrad): 21 and 16 pb (28/29);
  - After preradiator (2 mrad): 19 and 16 pb (21/16);
  - Irreduciable (single γ): 14 and 10 pb (14/10).

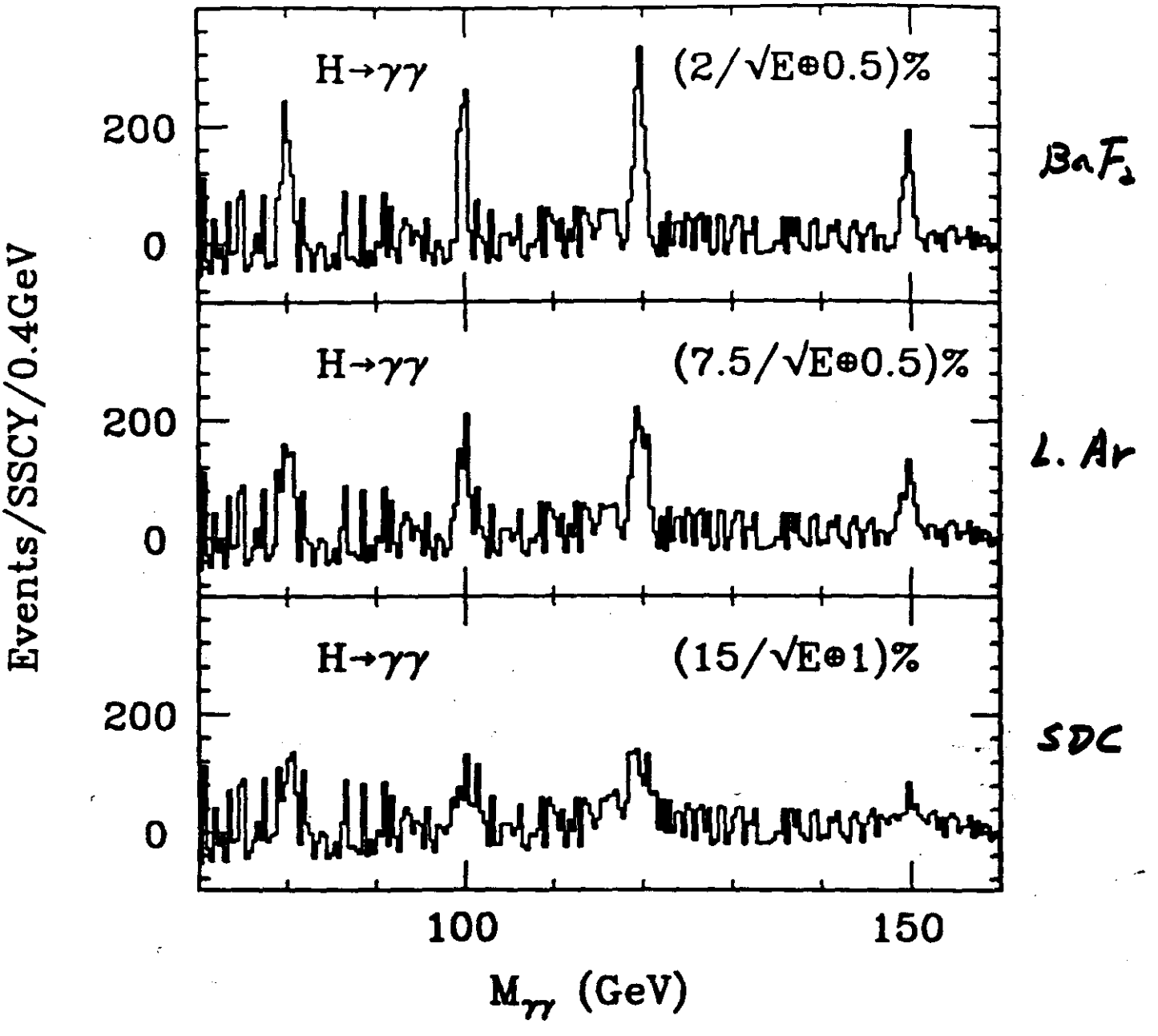
Events Selection ($H \to \gamma\gamma$)



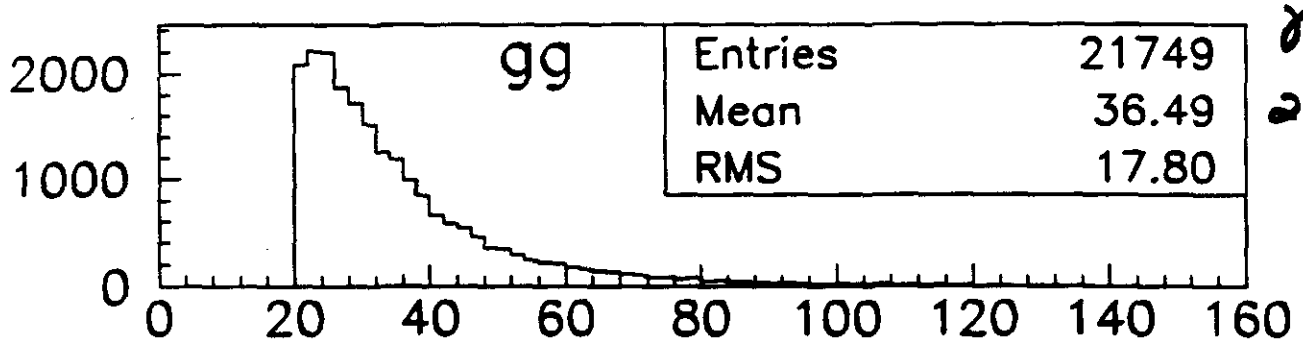
$H \to 2\gamma$ with Direct Photon Background



$H \to 2\gamma$ with Direct Photon Background

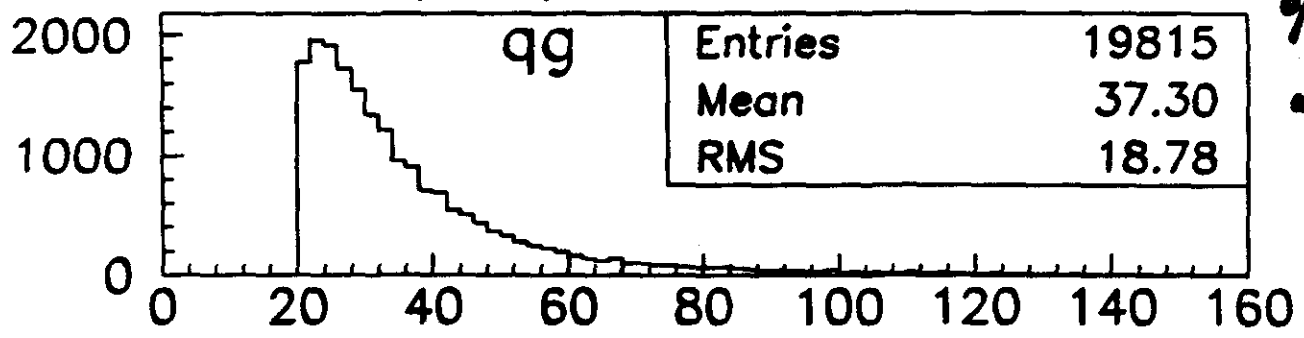


2 Gamma Background (20k)



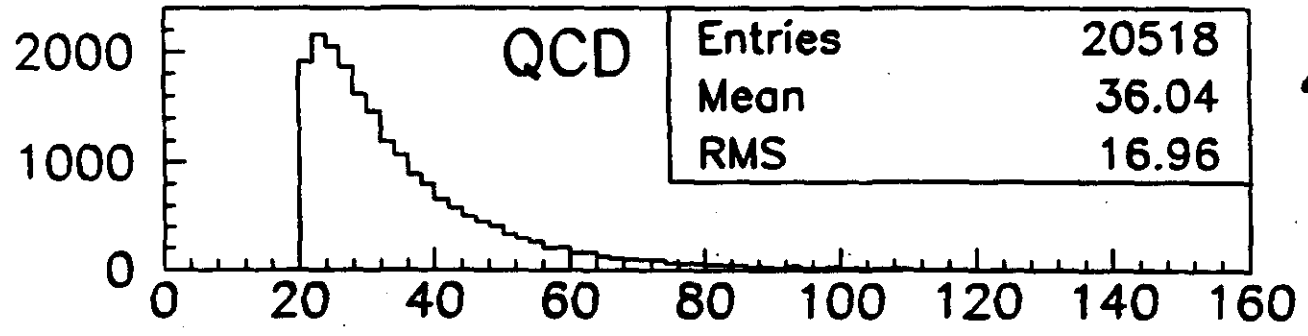
γγ
276pb

pt of parton eta less 2.5



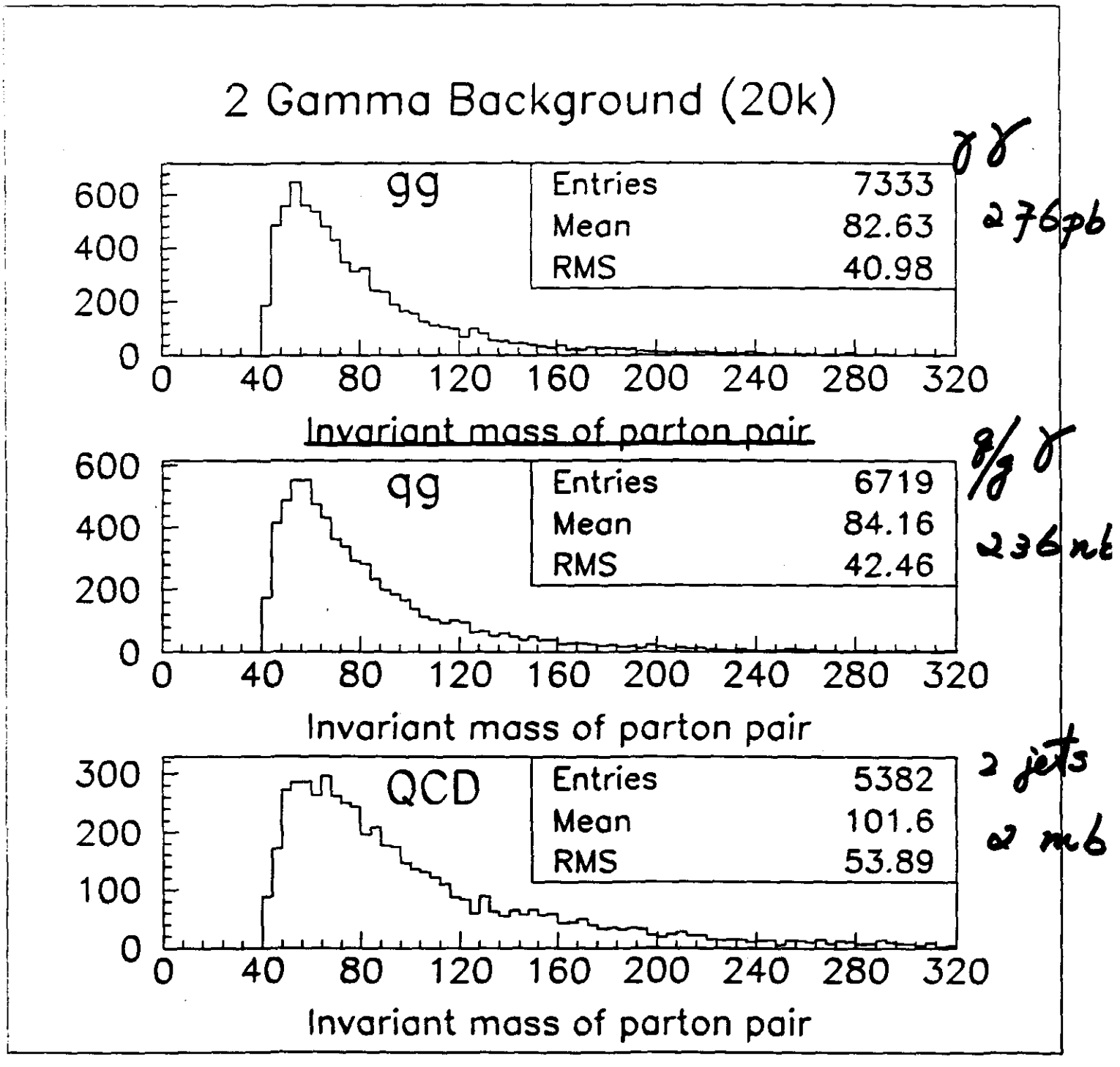
q/g γ
236nb

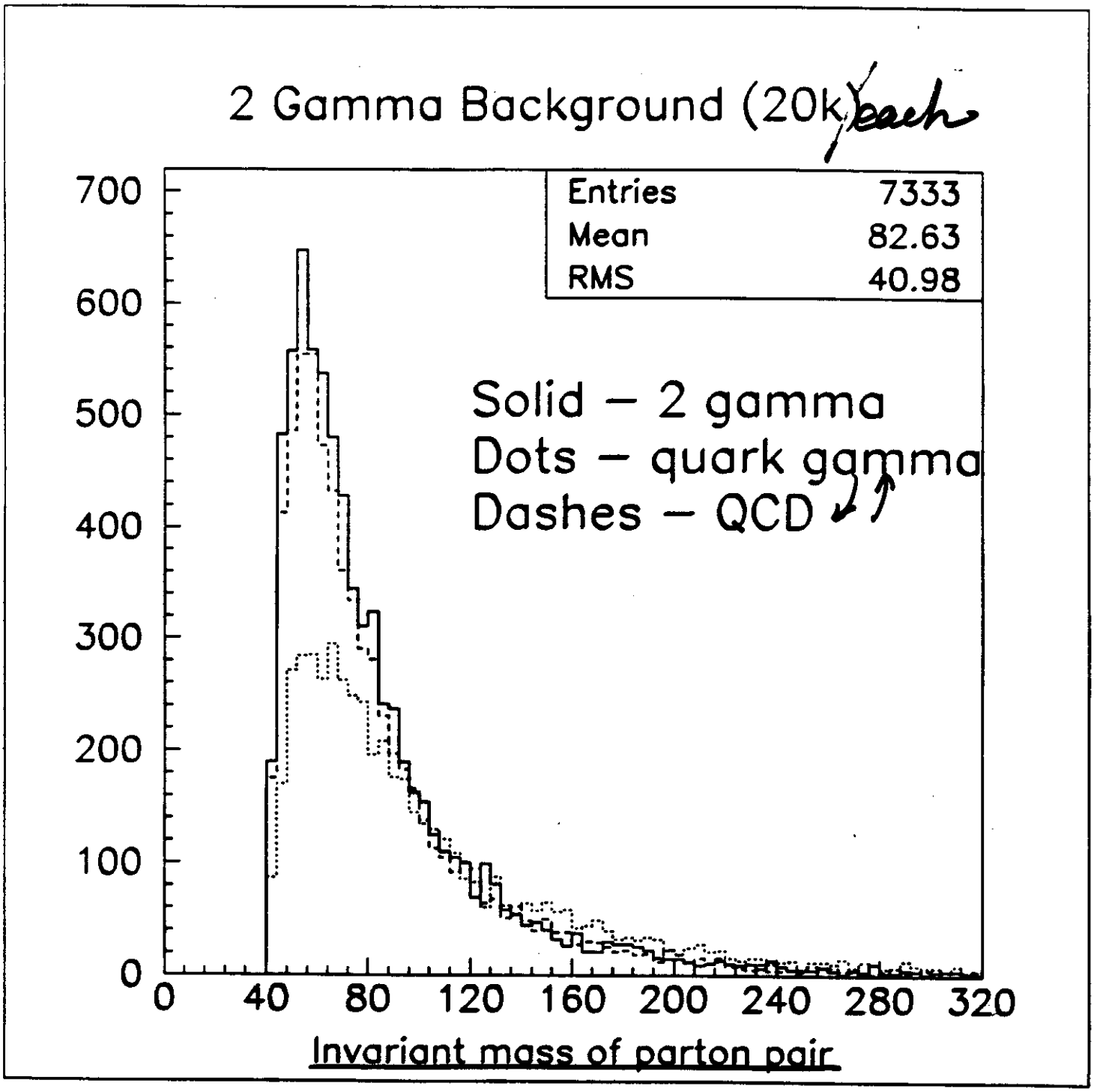
pt of parton eta less 2.5

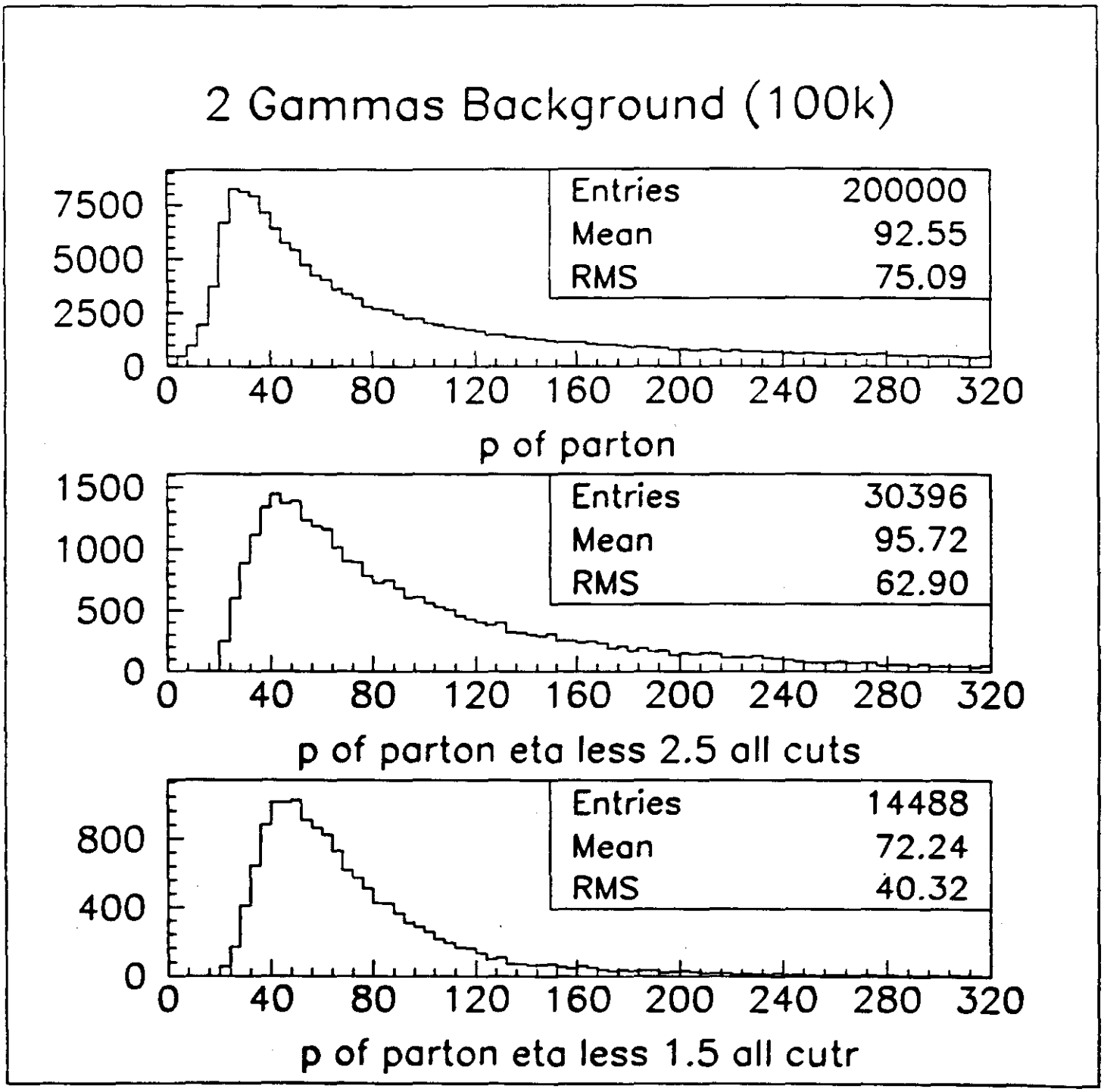


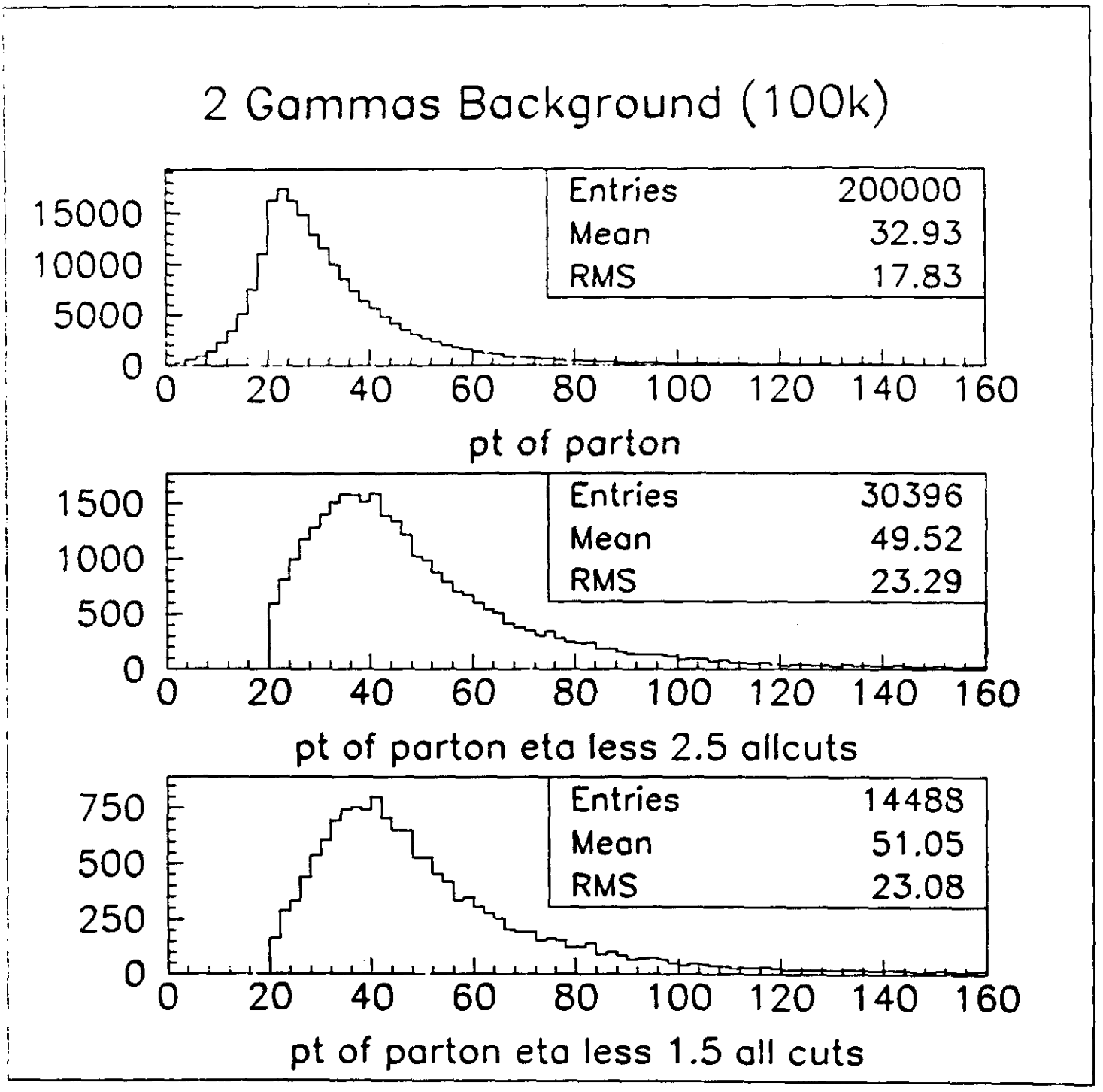
2 jets
2 mb

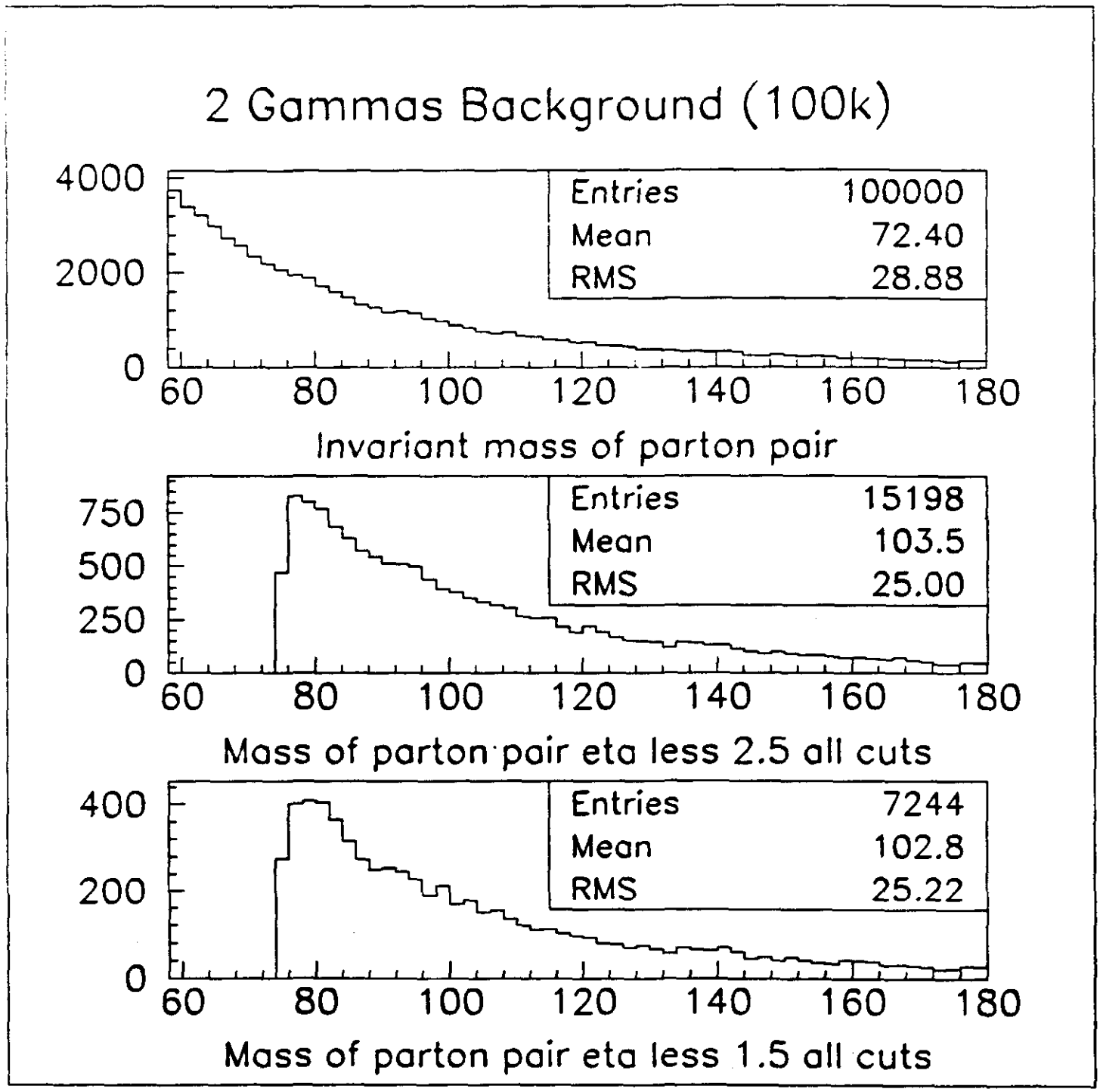
pt of parton eta less 2.5

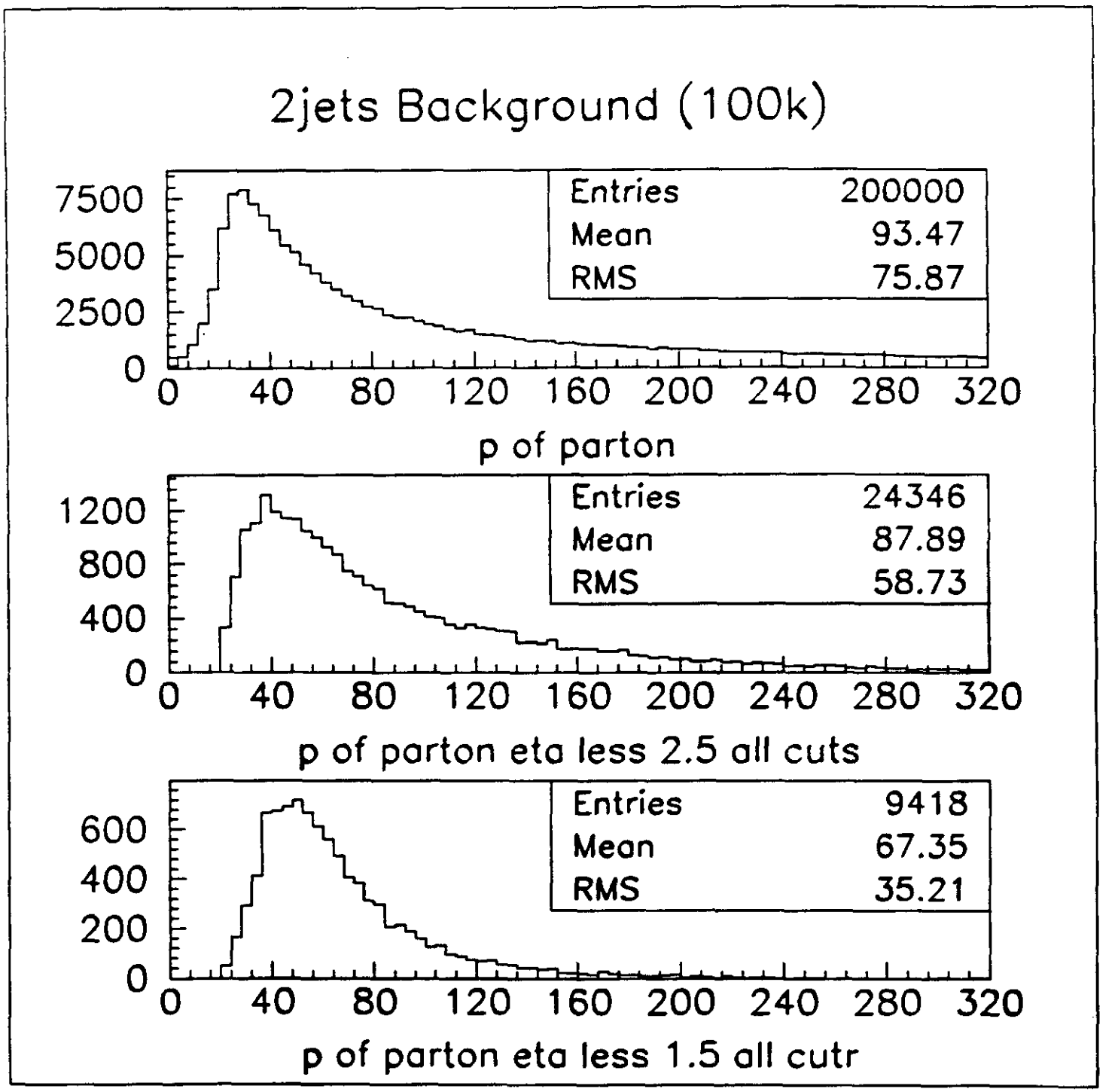

2 Gamma Background (20k)
gg
Entries 7333
Mean 82.63
RMS 40.98
Invariant mass of parton pair
qg
Entries 6719
Mean 84.16
RMS 42.46
Invariant mass of parton pair
QCD
Entries 5382
Mean 101.6
RMS 53.89
Invariant mass of parton pair
γγ
276pb
q/g γ
236nb
2 jets
2 mb

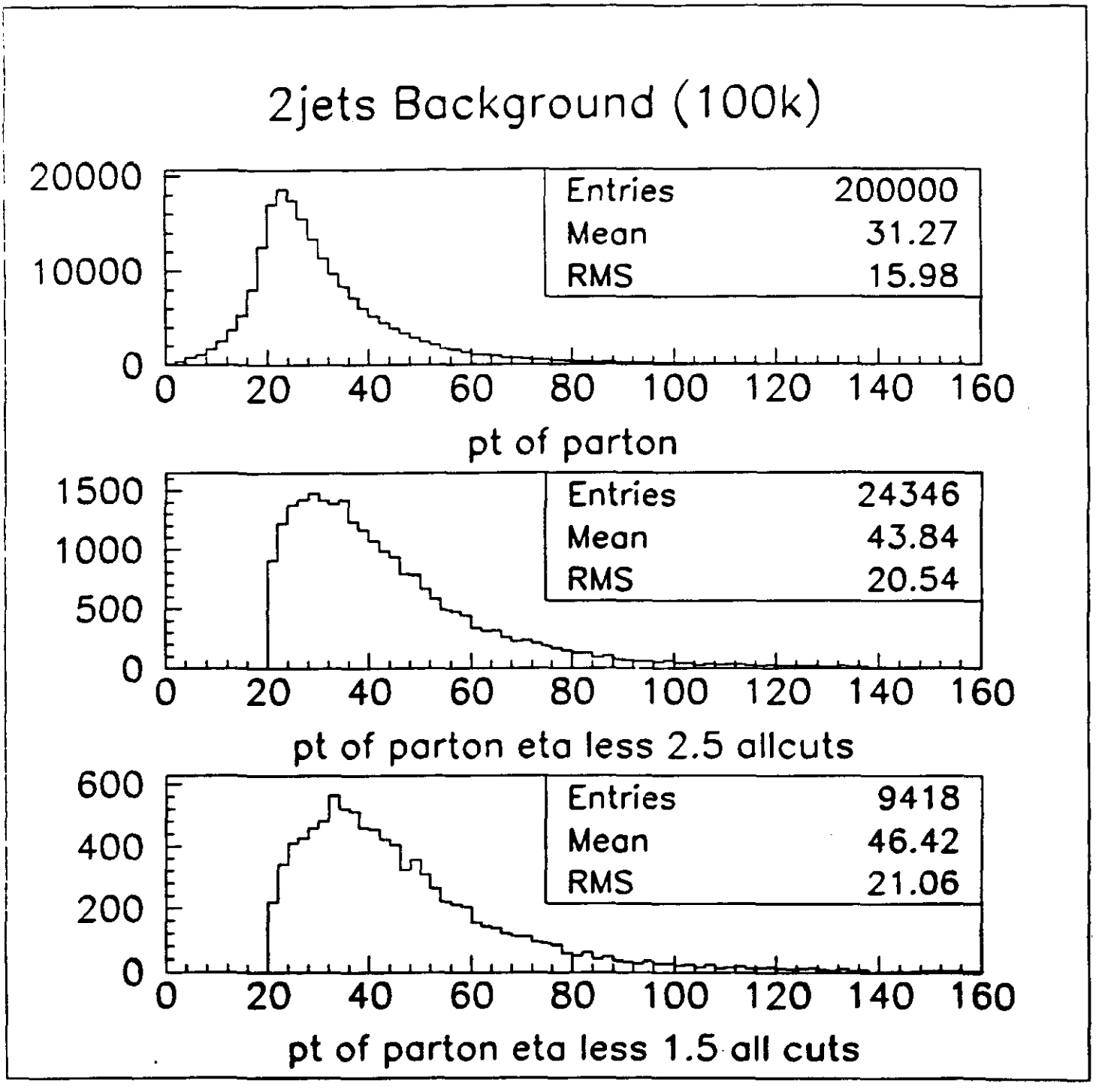

2 Gamma Background (20k each)
Entries 7333
Mean 82.63
RMS 40.98
Solid – 2 gamma
Dots – quark gamma
Dashes – QCD
700
600
500
400
300
200
100
0
0
40
80
120
160
200
240
280
320
Invariant mass of parton pair

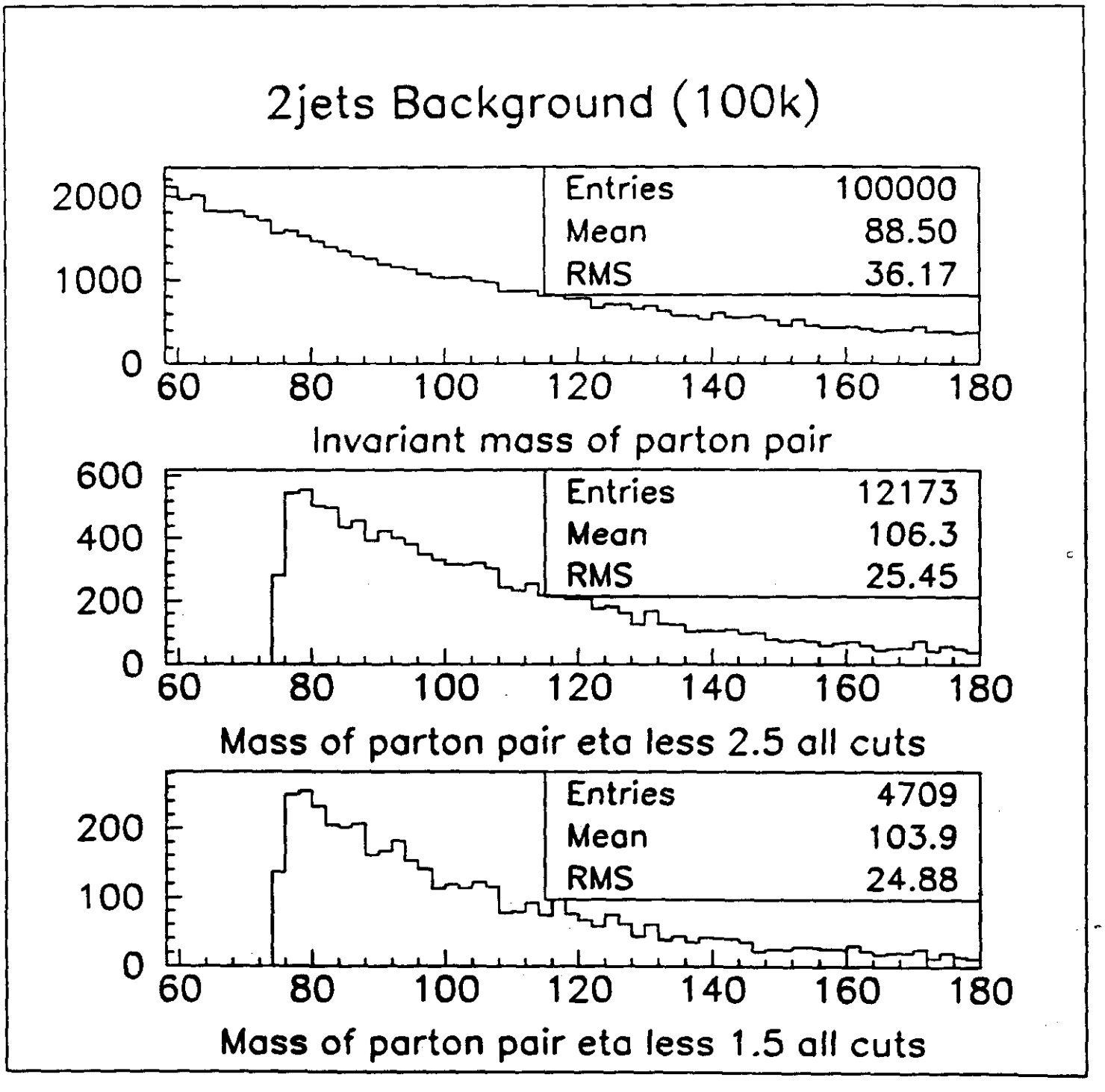

2 Gammas Background (100k)
Entries 200000
Mean 92.55
RMS 75.09
7500
5000
2500
0
0 40 80 120 160 200 240 280 320
p of parton
Entries 30396
Mean 95.72
RMS 62.90
1500
1000
500
0
0 40 80 120 160 200 240 280 320
p of parton eta less 2.5 all cuts
Entries 14488
Mean 72.24
RMS 40.32
800
400
0
0 40 80 120 160 200 240 280 320
p of parton eta less 1.5 all cutr

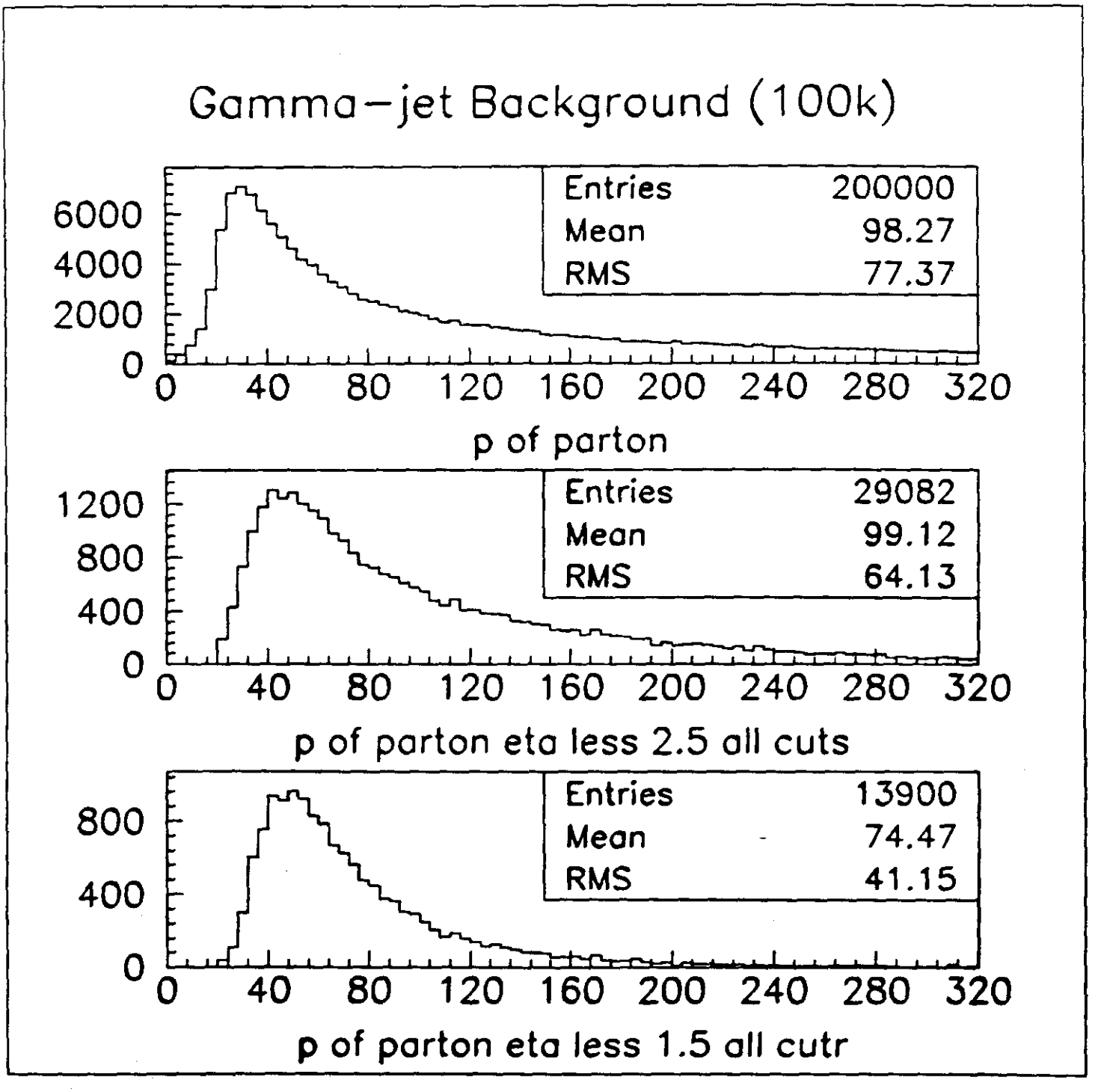

2 Gammas Background (100k)
Entries 200000
Mean 32.93
RMS 17.83
15000
10000
5000
0
0 20 40 60 80 100 120 140 160
pt of parton
Entries 30396
Mean 49.52
RMS 23.29
1500
1000
500
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5 allcuts
Entries 14488
Mean 51.05
RMS 23.08
750
500
250
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 1.5 all cuts

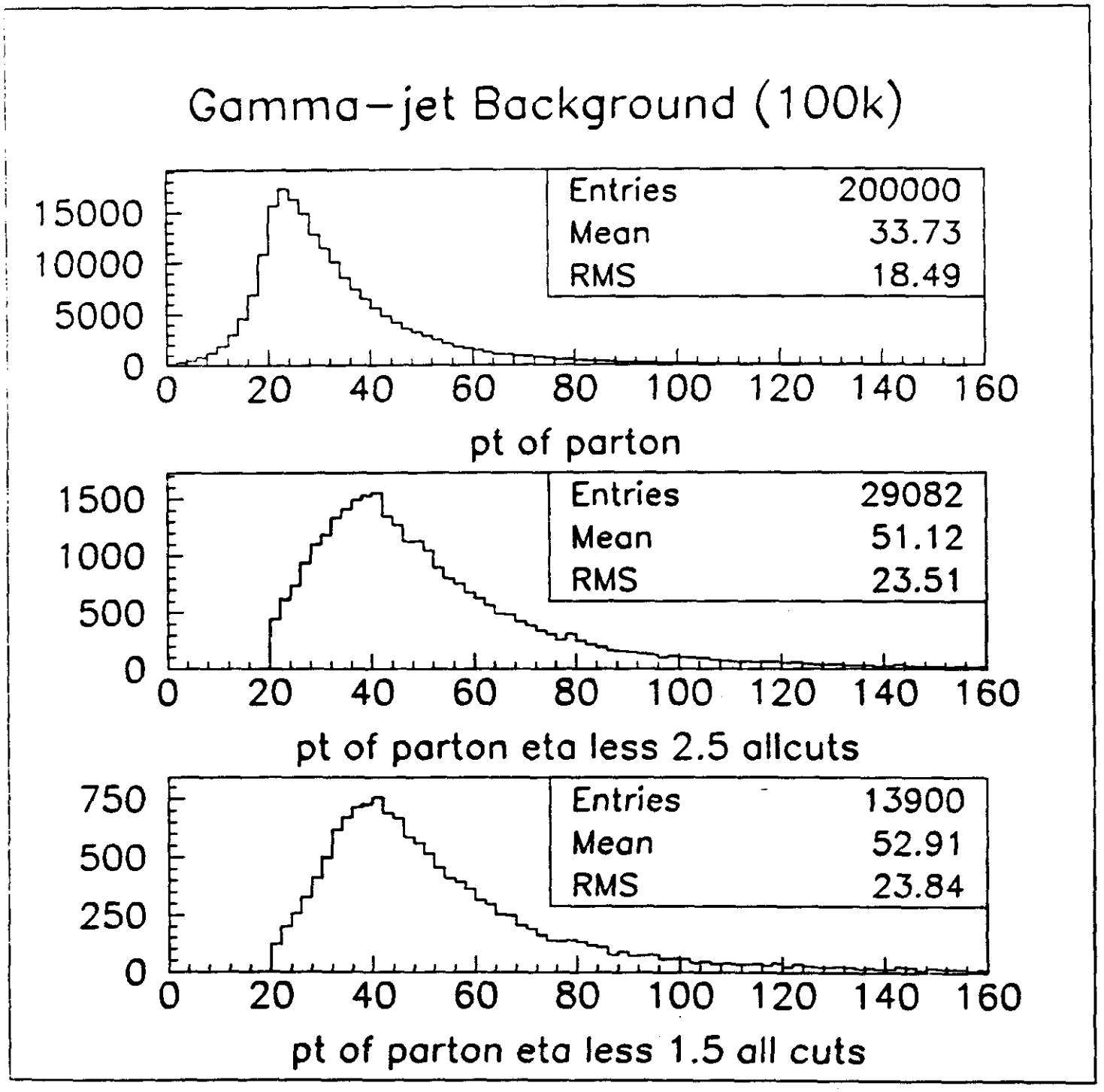

2 Gammas Background (100k)
4000
2000
0
Entries 100000
Mean 72.40
RMS 28.88
60 80 100 120 140 160 180
Invariant mass of parton pair
750
500
250
0
Entries 15198
Mean 103.5
RMS 25.00
60 80 100 120 140 160 180
Mass of parton pair eta less 2.5 all cuts
400
200
0
Entries 7244
Mean 102.8
RMS 25.22
60 80 100 120 140 160 180
Mass of parton pair eta less 1.5 all cuts

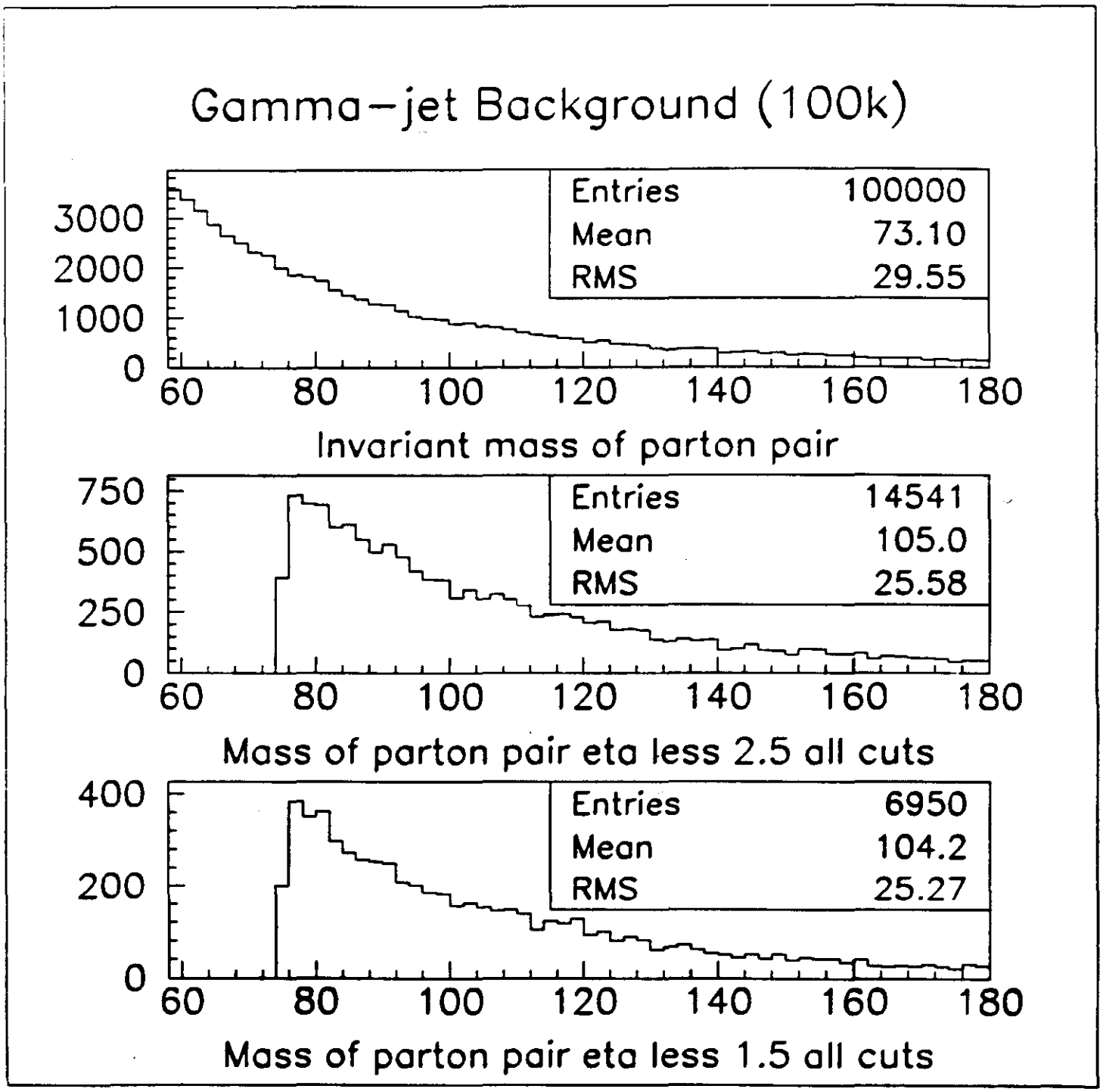

2jets Background (100k)
Entries 200000
Mean 93.47
RMS 75.87
7500
5000
2500
0
0 40 80 120 160 200 240 280 320
p of parton
Entries 24346
Mean 87.89
RMS 58.73
1200
800
400
0
0 40 80 120 160 200 240 280 320
p of parton eta less 2.5 all cuts
Entries 9418
Mean 67.35
RMS 35.21
600
400
200
0
0 40 80 120 160 200 240 280 320
p of parton eta less 1.5 all cutr


2jets Background (100k)
Entries 200000
Mean 31.27
RMS 15.98
20000
10000
0
0 20 40 60 80 100 120 140 160
pt of parton
Entries 24346
Mean 43.84
RMS 20.54
1500
1000
500
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5 allcuts
Entries 9418
Mean 46.42
RMS 21.06
600
400
200
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 1.5 all cuts


2jets Background (100k)
Entries 100000
Mean 88.50
RMS 36.17
2000
1000
0
60 80 100 120 140 160 180
Invariant mass of parton pair
Entries 12173
Mean 106.3
RMS 25.45
600
400
200
0
60 80 100 120 140 160 180
Mass of parton pair eta less 2.5 all cuts
Entries 4709
Mean 103.9
RMS 24.88
200
100
0
60 80 100 120 140 160 180
Mass of parton pair eta less 1.5 all cuts


Gamma-jet Background (100k)
Entries 200000
Mean 98.27
RMS 77.37
6000
4000
2000
0
0 40 80 120 160 200 240 280 320
p of parton
Entries 29082
Mean 99.12
RMS 64.13
1200
800
400
0
0 40 80 120 160 200 240 280 320
p of parton eta less 2.5 all cuts
Entries 13900
Mean 74.47
RMS 41.15
800
400
0
0 40 80 120 160 200 240 280 320
p of parton eta less 1.5 all cutr


Gamma-jet Background (100k)
Entries 200000
Mean 33.73
RMS 18.49
15000
10000
5000
0
0 20 40 60 80 100 120 140 160
pt of parton
Entries 29082
Mean 51.12
RMS 23.51
1500
1000
500
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 2.5 allcuts
Entries 13900
Mean 52.91
RMS 23.84
750
500
250
0
0 20 40 60 80 100 120 140 160
pt of parton eta less 1.5 all cuts


Gamma−jet Background (100k)
Entries 100000
Mean 73.10
RMS 29.55
3000
2000
1000
0
60 80 100 120 140 160 180
Invariant mass of parton pair
Entries 14541
Mean 105.0
RMS 25.58
750
500
250
0
60 80 100 120 140 160 180
Mass of parton pair eta less 2.5 all cuts
Entries 6950
Mean 104.2
RMS 25.27
400
200
0
60 80 100 120 140 160 180
Mass of parton pair eta less 1.5 all cuts

Isolation Cut

- Generate 2jets or γ-jet with PYTHIA5.5, deposit all EM energy and part of hadron energy (from GEANT) in calorimeter cells with parametrized shower spread. Record cell numbers hitted by charged track with 8 kG field.

- Search through all cells ($\Delta\eta \times \Delta\phi$=0.04 $\times$ 0.04) to identify all cells hit by photons only, find E_T^{cell}.

- Charge Veto: if there is a charged track hitting neighboring 8 cells $\Rightarrow$ **Reject**;

- Define the sum of E_T^{cell}'s of these 9 cells ($\sum_{9cells} E_T^{cell}$) as the E_T^{photon};

- Isolation Veto: if the sum of the transverse energies in a cone of radius R (R=$\sqrt{\Delta\eta^2 + \Delta\phi^2}$), excluding the E_T^{photon}, is larger than 10% of the E_T^{photon} plus an isolation energy cut (E_T^{cut}).

$$\sum_{r<R} E_T - E_T^{photon} > (E_T^{cut} + 0.1 E_T^{photon}) \Rightarrow \textbf{Reject};$$

- Option: use only cells with transverse energy larger than 3 standard deviations of combined thermal and pile-up noise:
150 MeV for BaF_2 + Spaghetti, and 250 MeV for L.Ar.

Isolation Rejection Factor (10^{-4})

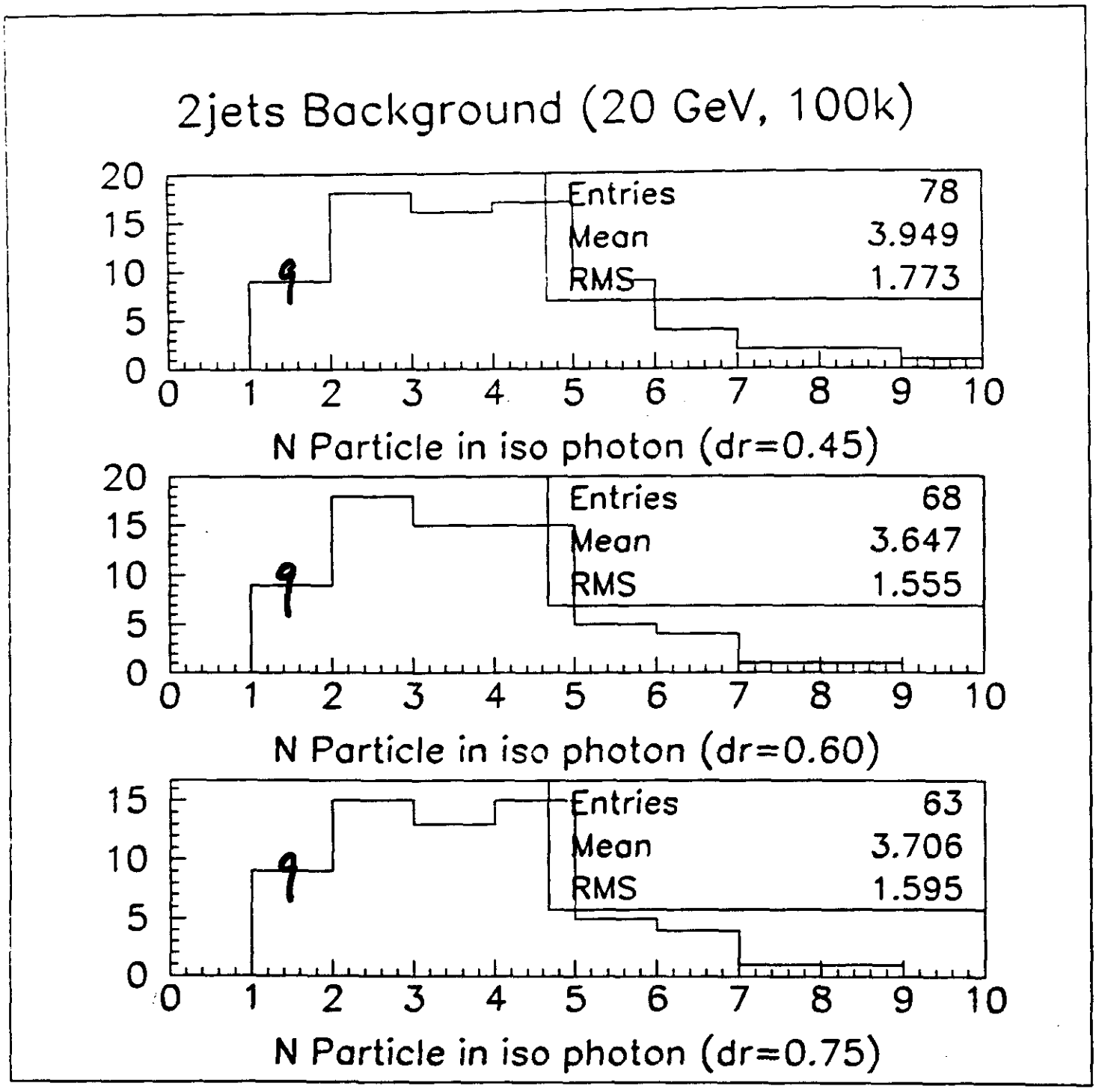
- 2jets: 2 mb (gg: 1.54; gq: 0.44 and qq: 0.043), 12% quark jets and 88% gluon jets.

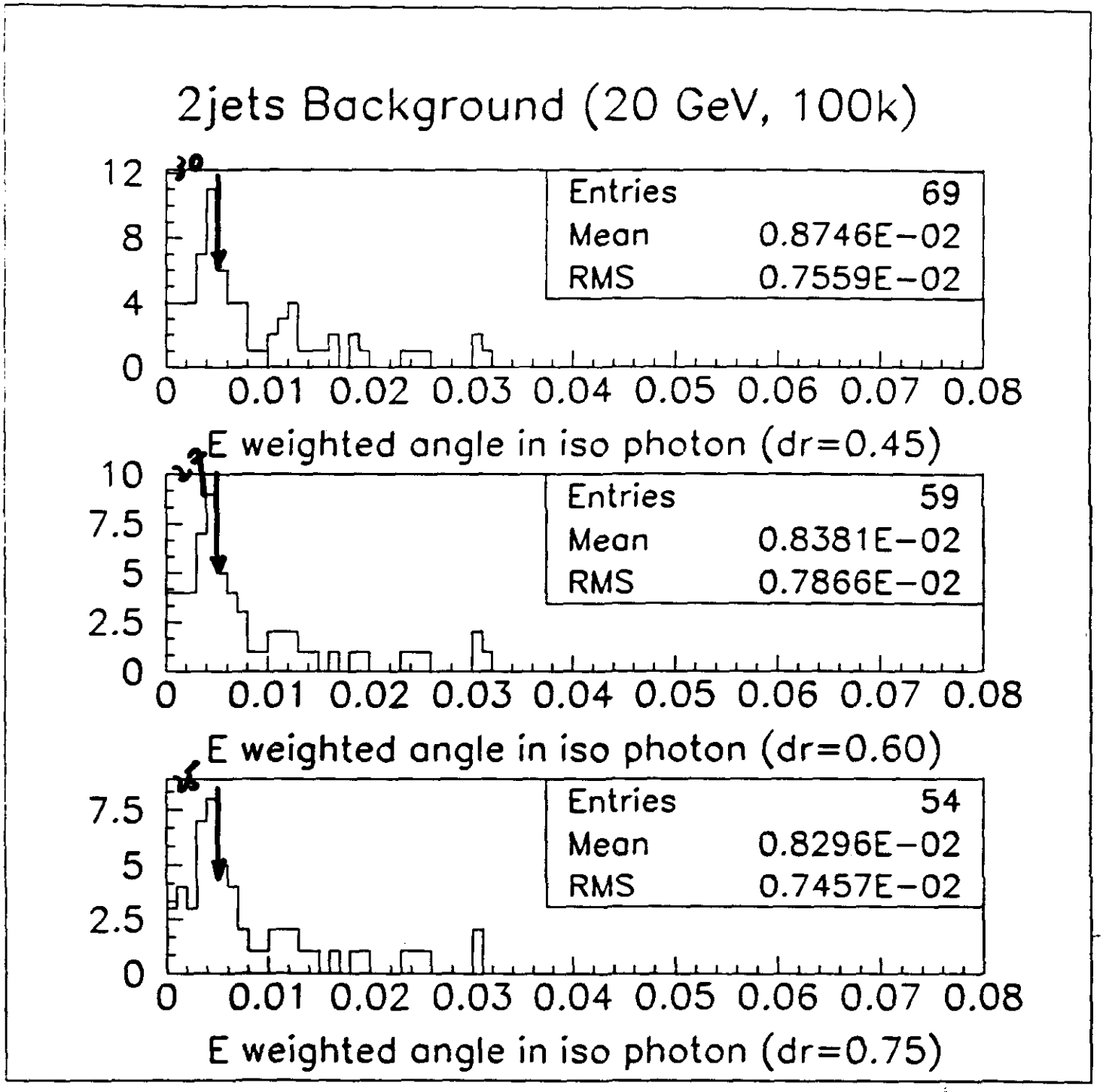
E_T^{cut}	R=0.45	R=0.60	R=0.75
5 GeV	5.3	4.1	3.1
10 GeV	8.8	6.8	6.2
15 GeV	13	10	8.6
20 GeV	16	14	13

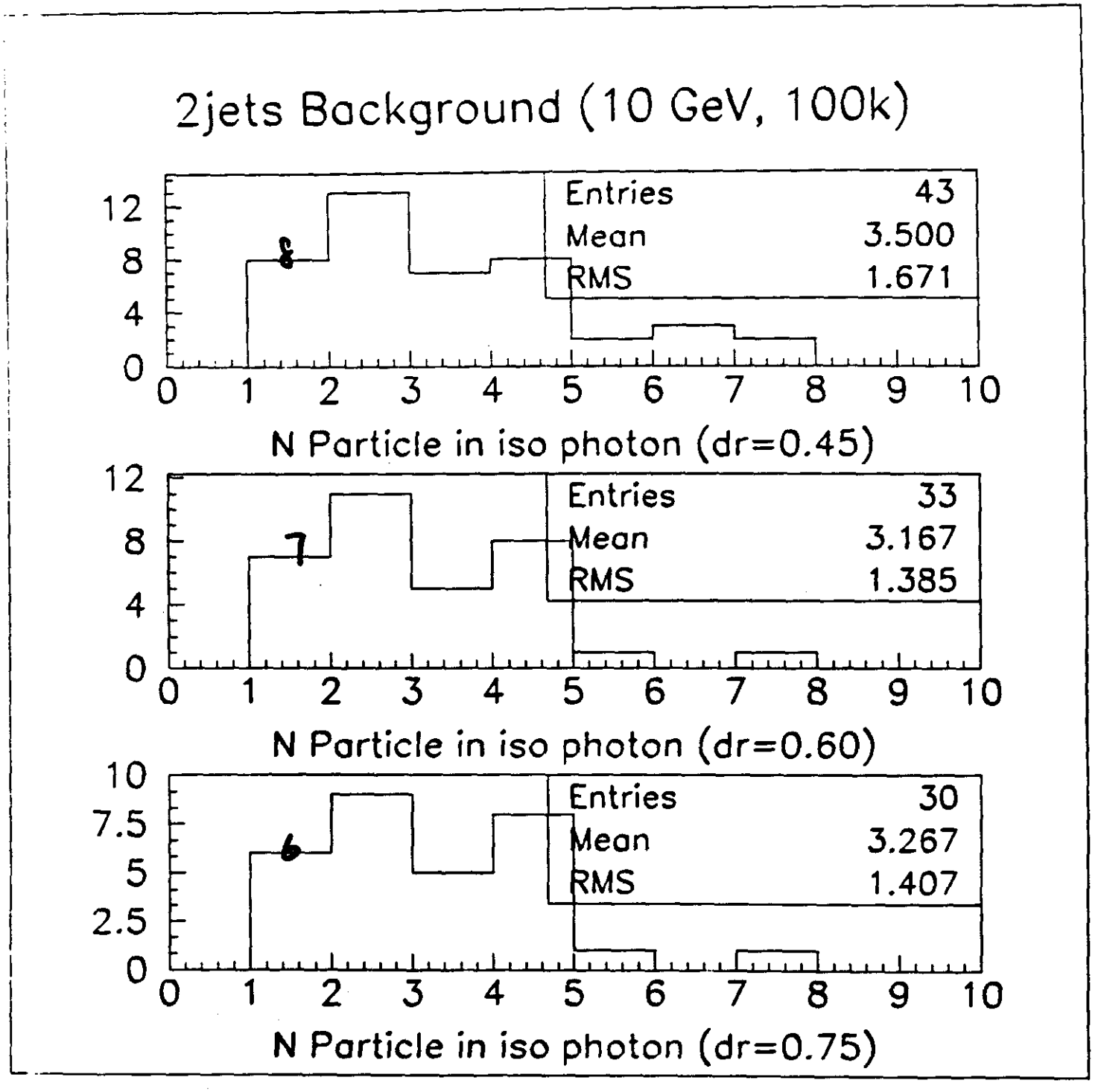
- γ-jet: 237nb (γq: 226 and γg: 11), 95% quark jets and 5% gluon jets.

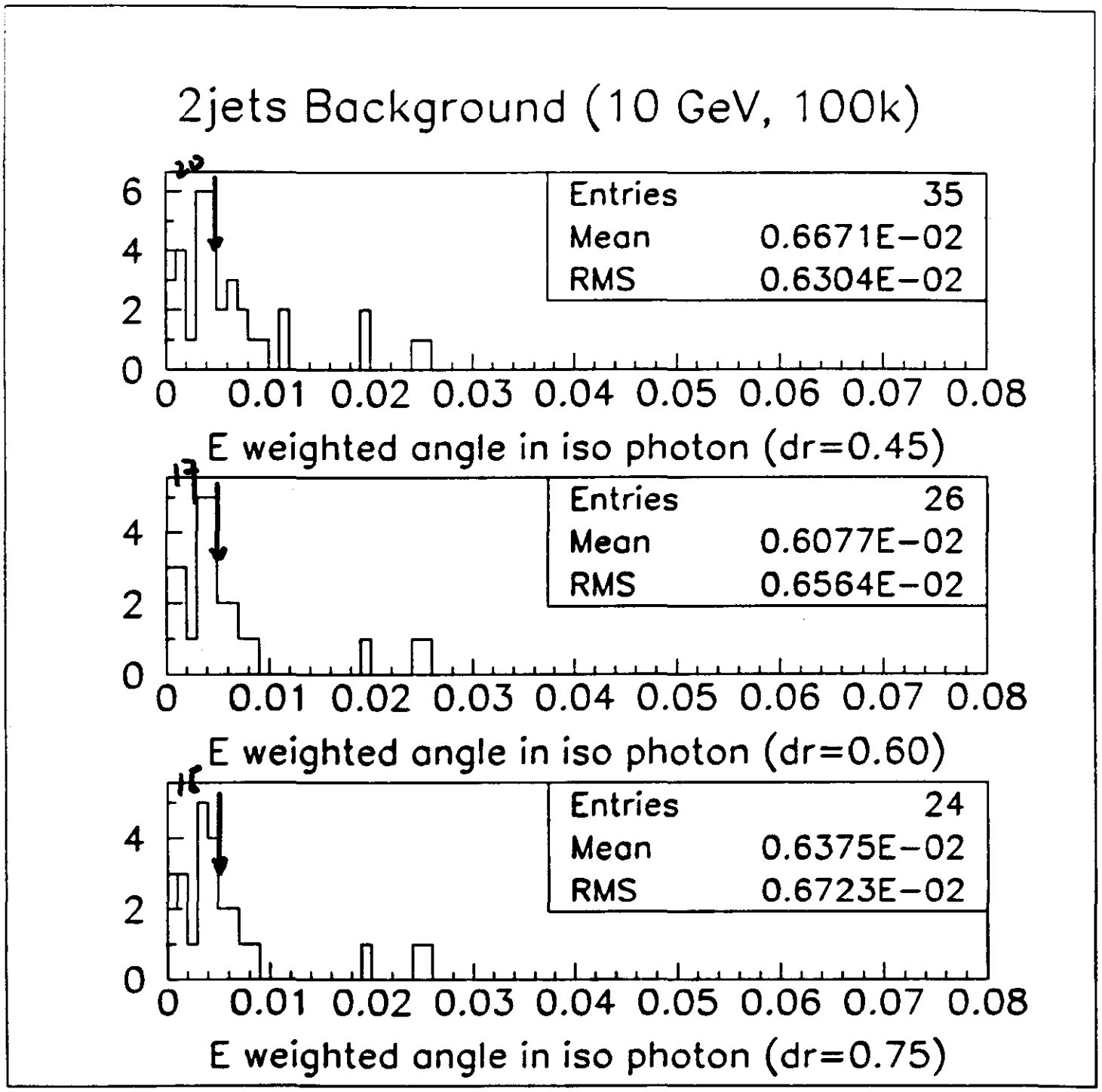
E_T^{cut}	R=0.45	R=0.60	R=0.75
5 GeV	16	13	9.6
10 GeV	30	26	22
15 GeV	40	34	32
20 GeV	54	47	43

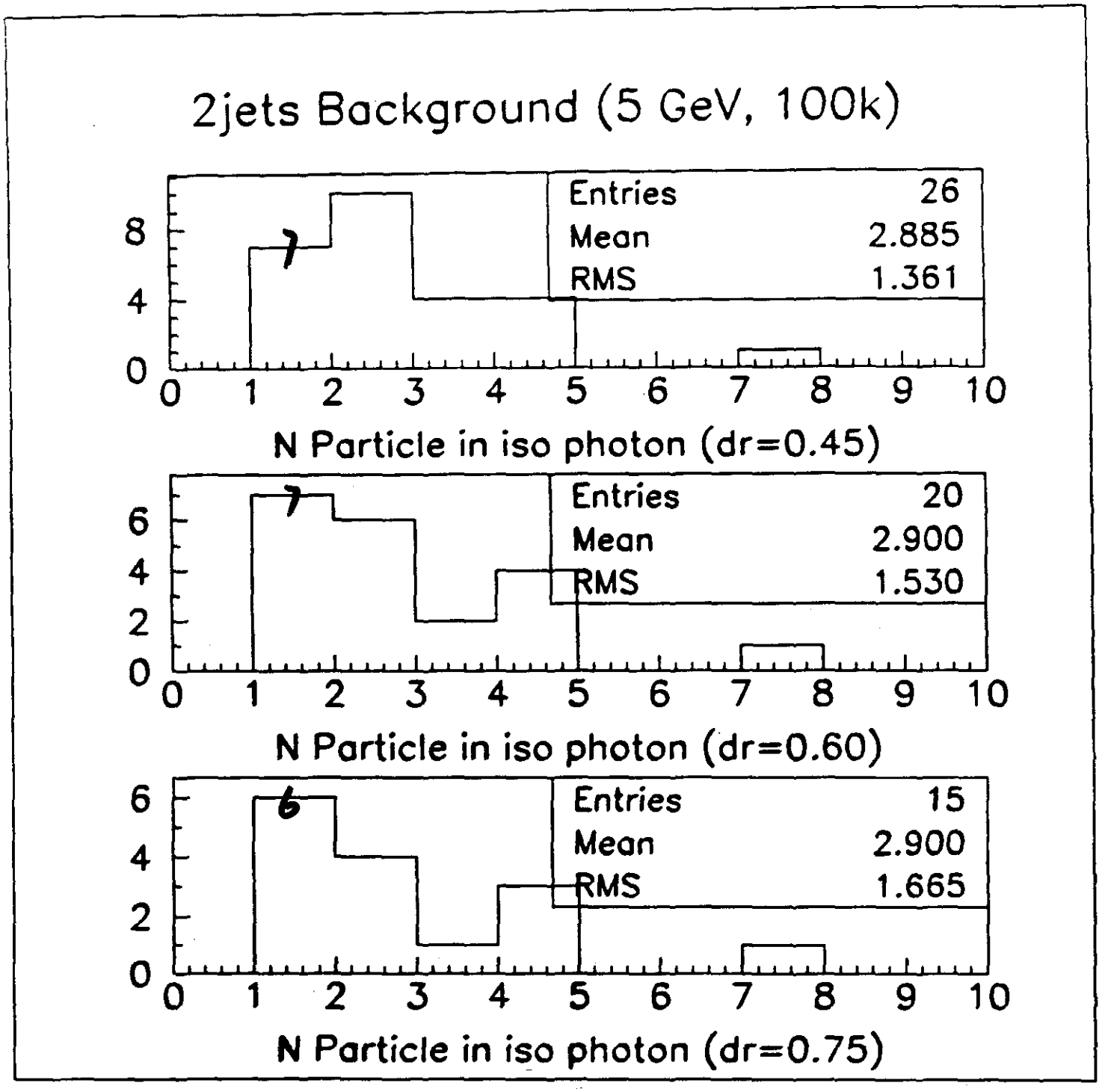
- Result:
  10^{-3} for quark jets and 2.2×10^{-4} for gluon jets.

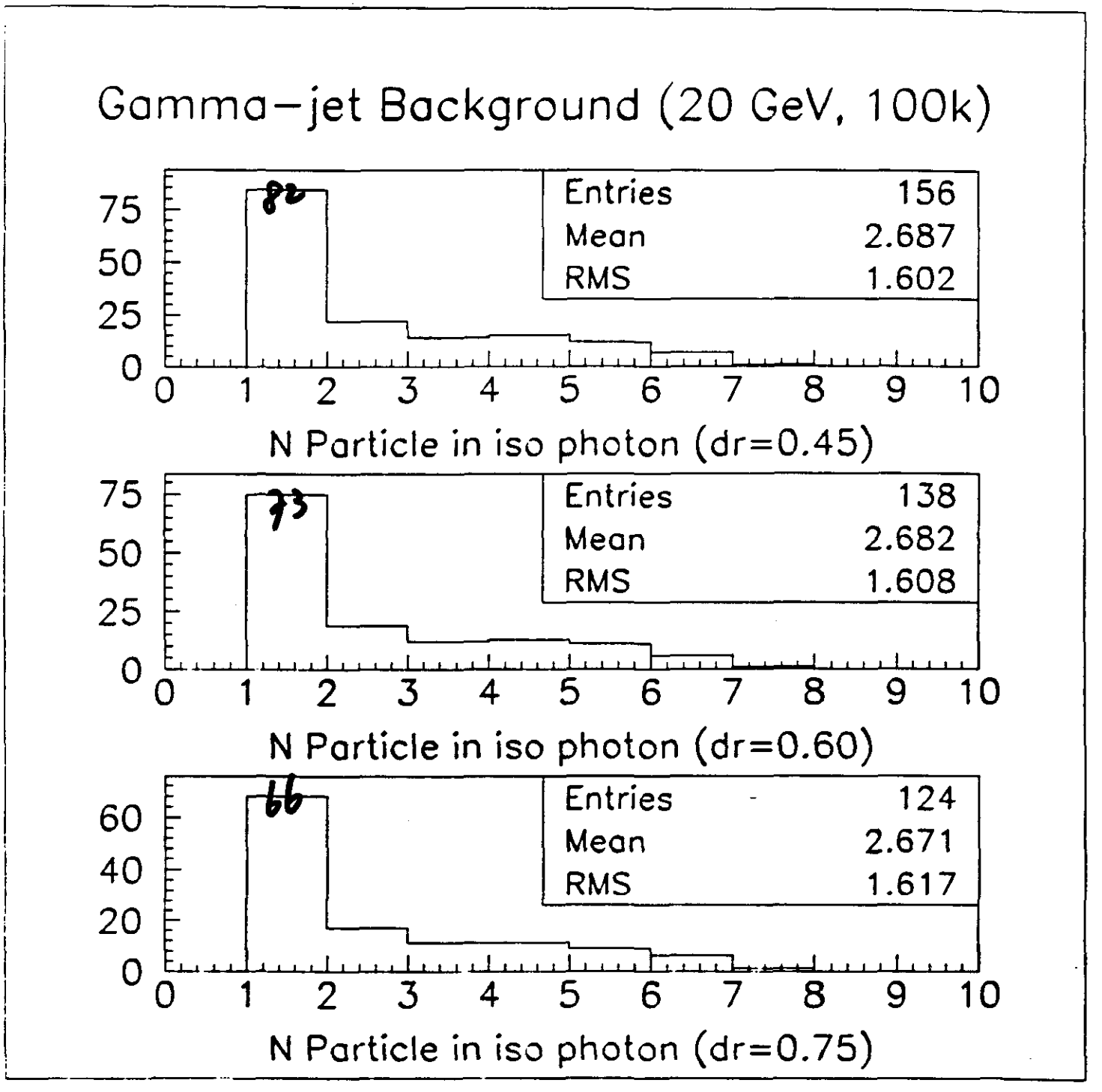

2jets Background (20 GeV, 100k)
Entries 78
Mean 3.949
RMS 1.773
N Particle in iso photon (dr=0.45)
Entries 68
Mean 3.647
RMS 1.555
N Particle in iso photon (dr=0.60)
Entries 63
Mean 3.706
RMS 1.595
N Particle in iso photon (dr=0.75)

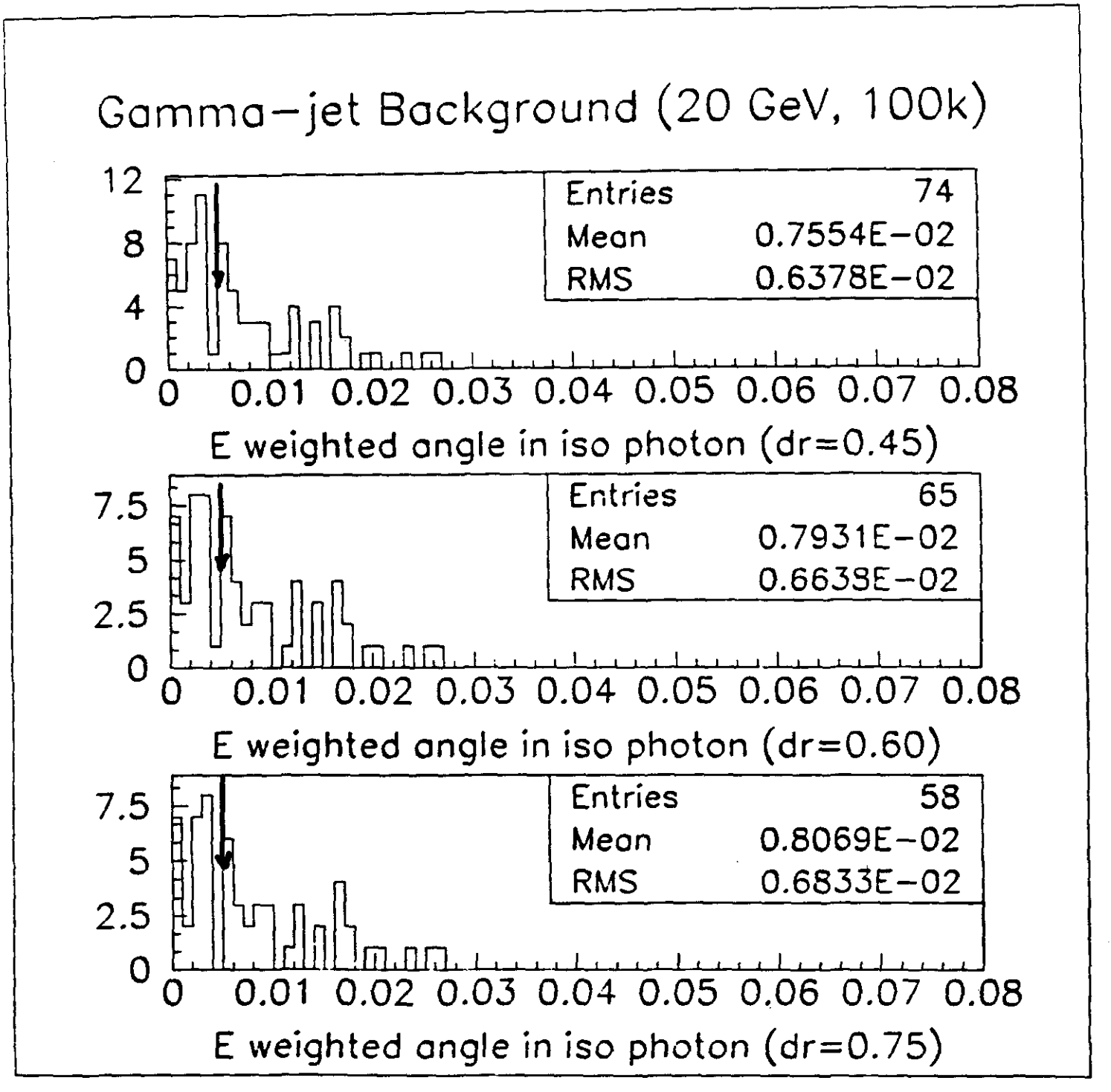

2jets Background (20 GeV, 100k)
Entries 69
Mean 0.8746E−02
RMS 0.7559E−02
E weighted angle in iso photon (dr=0.45)
Entries 59
Mean 0.8381E−02
RMS 0.7866E−02
E weighted angle in iso photon (dr=0.60)
Entries 54
Mean 0.8296E−02
RMS 0.7457E−02
E weighted angle in iso photon (dr=0.75)

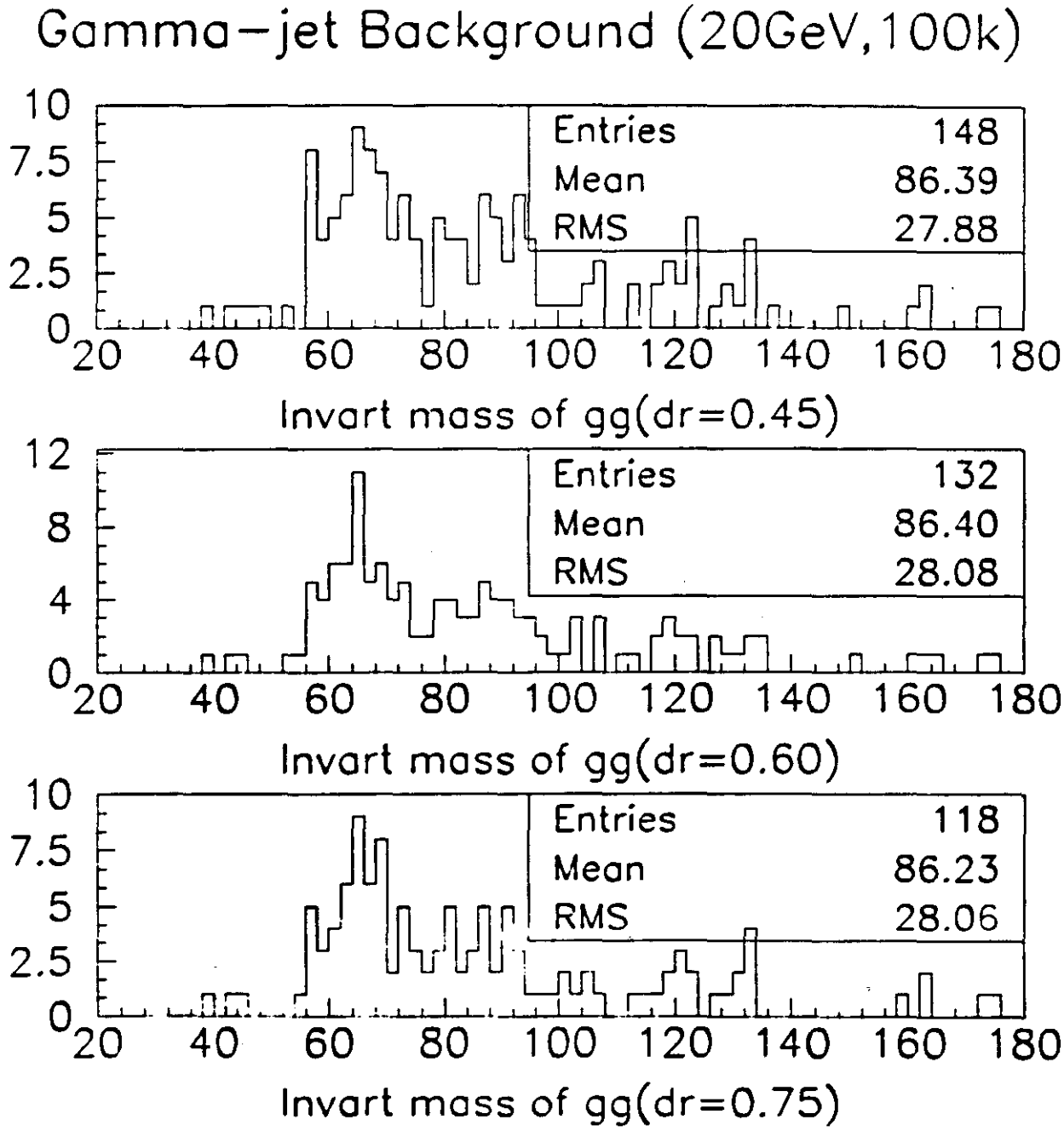

2jets Background (10 GeV, 100k)
Entries 43
Mean 3.500
RMS 1.671
N Particle in iso photon (dr=0.45)
Entries 33
Mean 3.167
RMS 1.385
N Particle in iso photon (dr=0.60)
Entries 30
Mean 3.267
RMS 1.407
N Particle in iso photon (dr=0.75)


2jets Background (10 GeV, 100k)
Entries 35
Mean 0.6671E−02
RMS 0.6304E−02
E weighted angle in iso photon (dr=0.45)
Entries 26
Mean 0.6077E−02
RMS 0.6564E−02
E weighted angle in iso photon (dr=0.60)
Entries 24
Mean 0.6375E−02
RMS 0.6723E−02
E weighted angle in iso photon (dr=0.75)

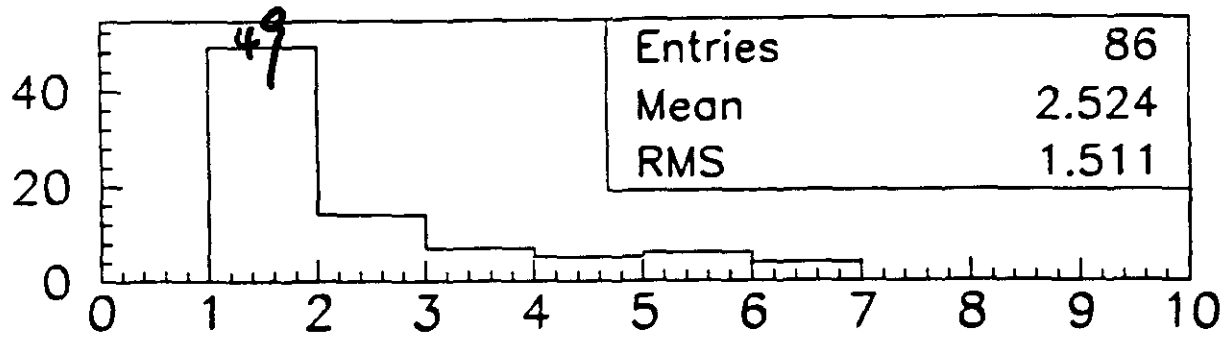

2jets Background (5 GeV, 100k)
Entries 26
Mean 2.885
RMS 1.361
N Particle in iso photon (dr=0.45)
Entries 20
Mean 2.900
RMS 1.530
N Particle in iso photon (dr=0.60)
Entries 15
Mean 2.900
RMS 1.665
N Particle in iso photon (dr=0.75)


Gamma−jet Background (20 GeV, 100k)
Entries 156
Mean 2.687
RMS 1.602
82
N Particle in iso photon (dr=0.45)
Entries 138
Mean 2.682
RMS 1.608
73
N Particle in iso photon (dr=0.60)
Entries 124
Mean 2.671
RMS 1.617
66
N Particle in iso photon (dr=0.75)

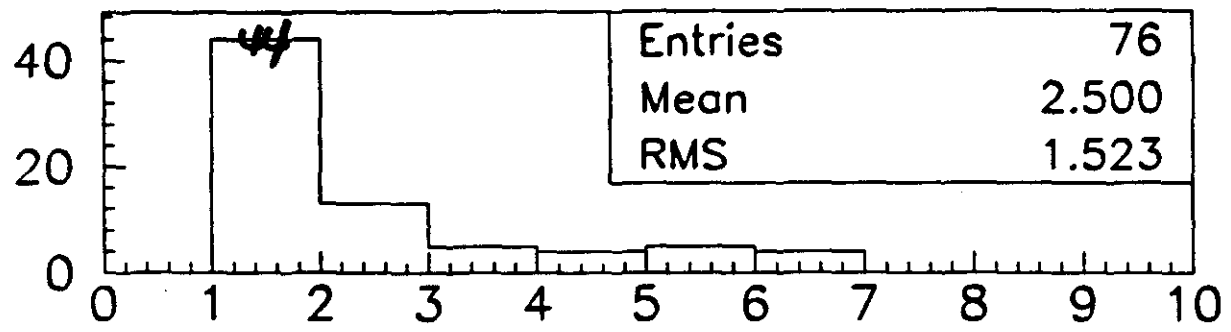

Gamma-jet Background (20 GeV, 100k)
Entries 74
Mean 0.7554E-02
RMS 0.6378E-02
E weighted angle in iso photon (dr=0.45)
Entries 65
Mean 0.7931E-02
RMS 0.6638E-02
E weighted angle in iso photon (dr=0.60)
Entries 58
Mean 0.8069E-02
RMS 0.6833E-02
E weighted angle in iso photon (dr=0.75)


Gamma−jet Background (20GeV,100k)
Entries 148
Mean 86.39
RMS 27.88
Invart mass of gg(dr=0.45)
Entries 132
Mean 86.40
RMS 28.08
Invart mass of gg(dr=0.60)
Entries 118
Mean 86.23
RMS 28.06
Invart mass of gg(dr=0.75)

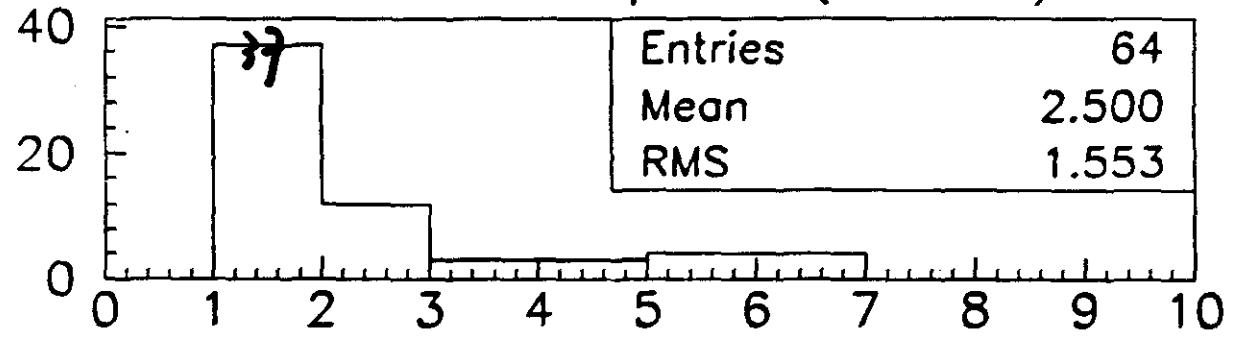
Gamma–jet Background (10 GeV, 100k)



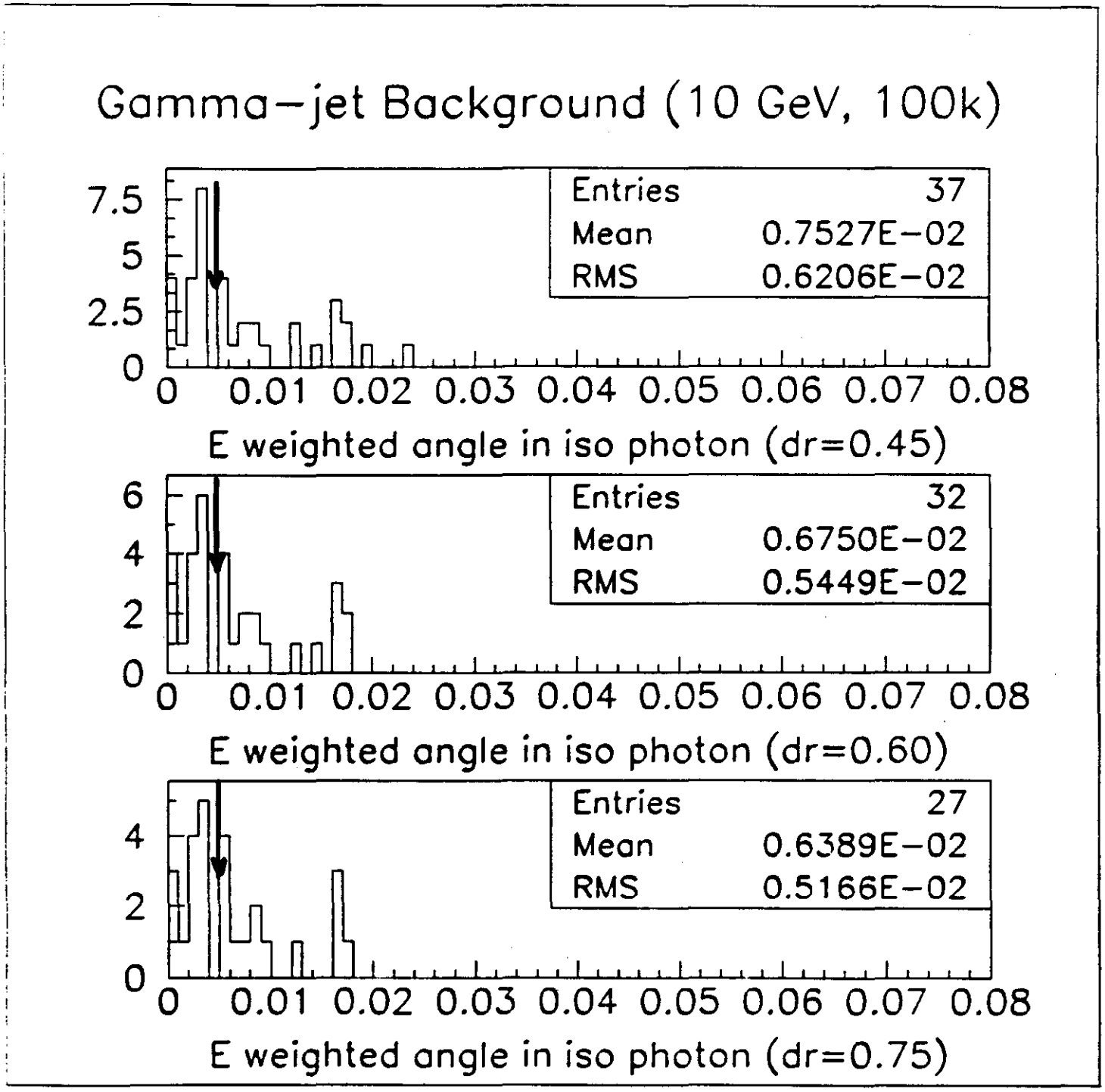
N Particle in iso photon (dr=0.45)

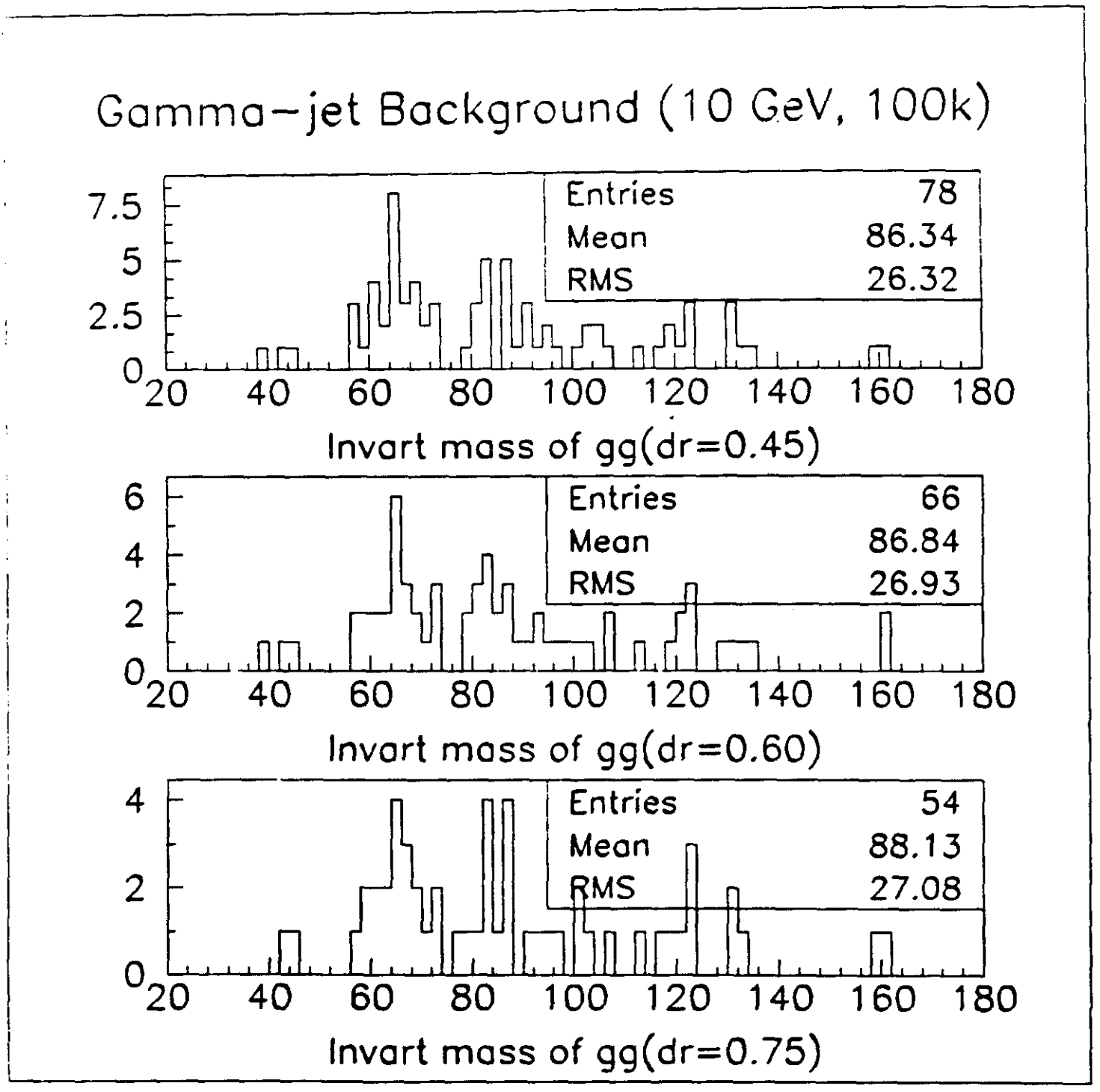


N Particle in iso photon (dr=0.60)

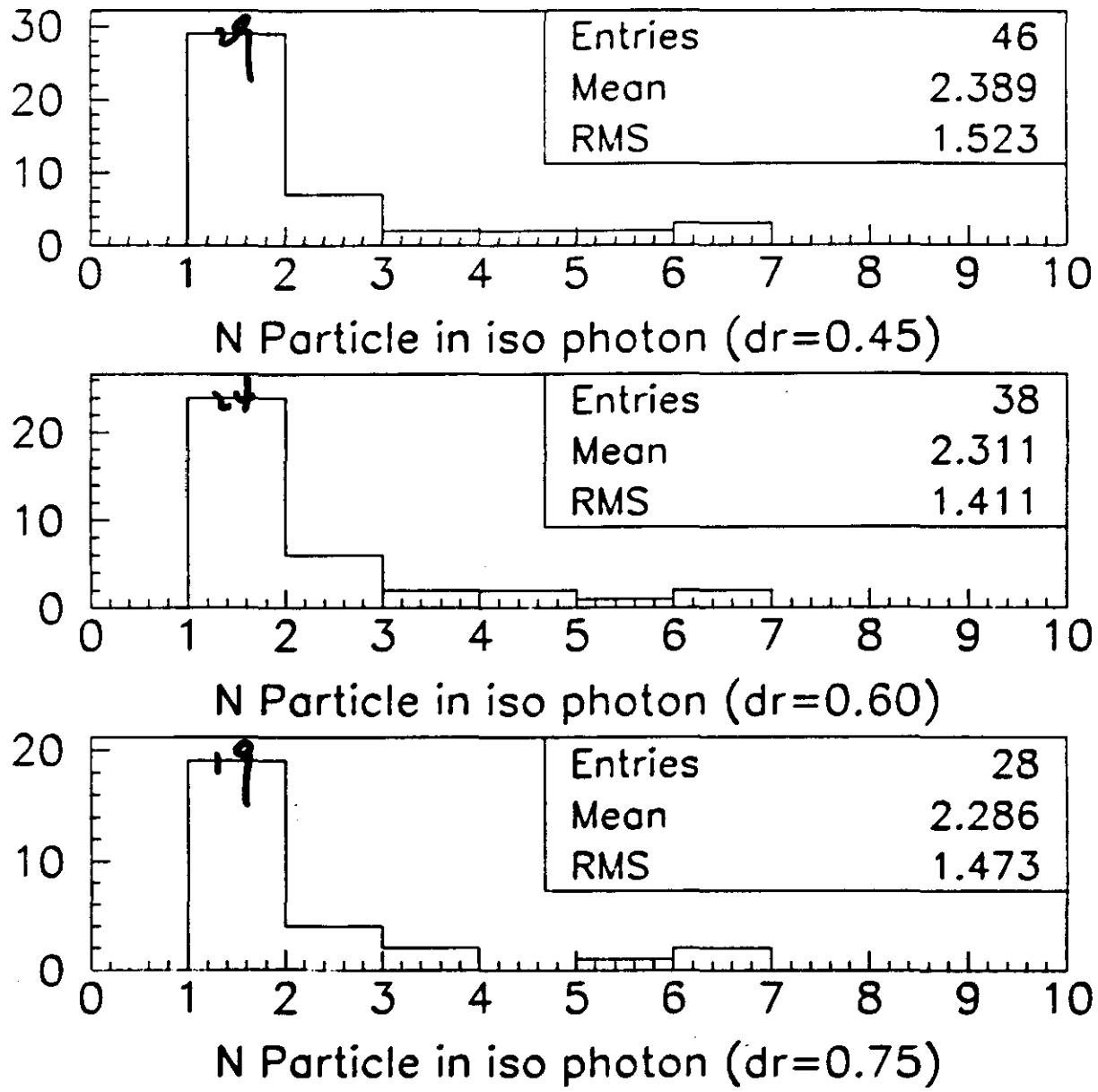


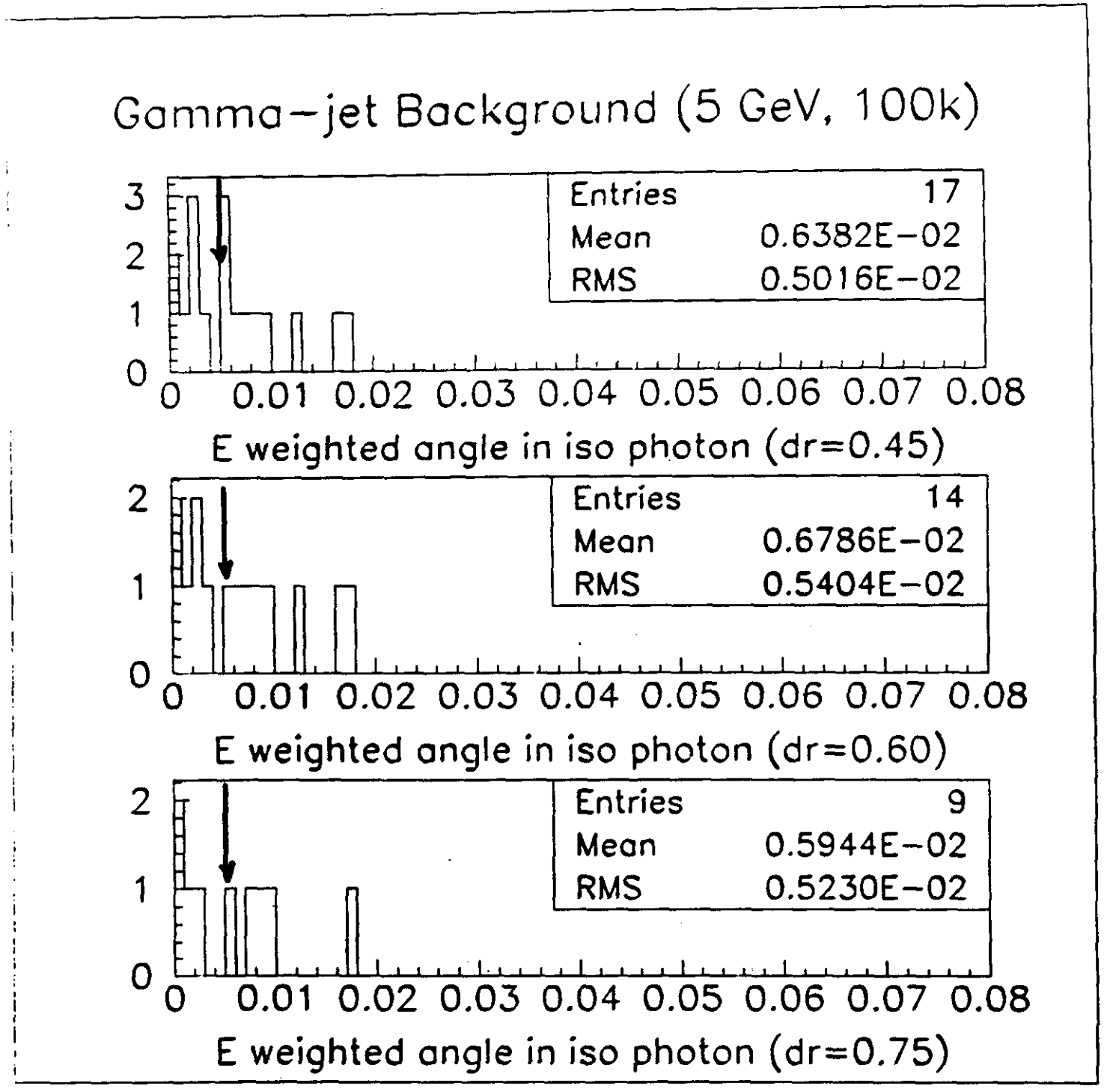
N Particle in iso photon (dr=0.75)

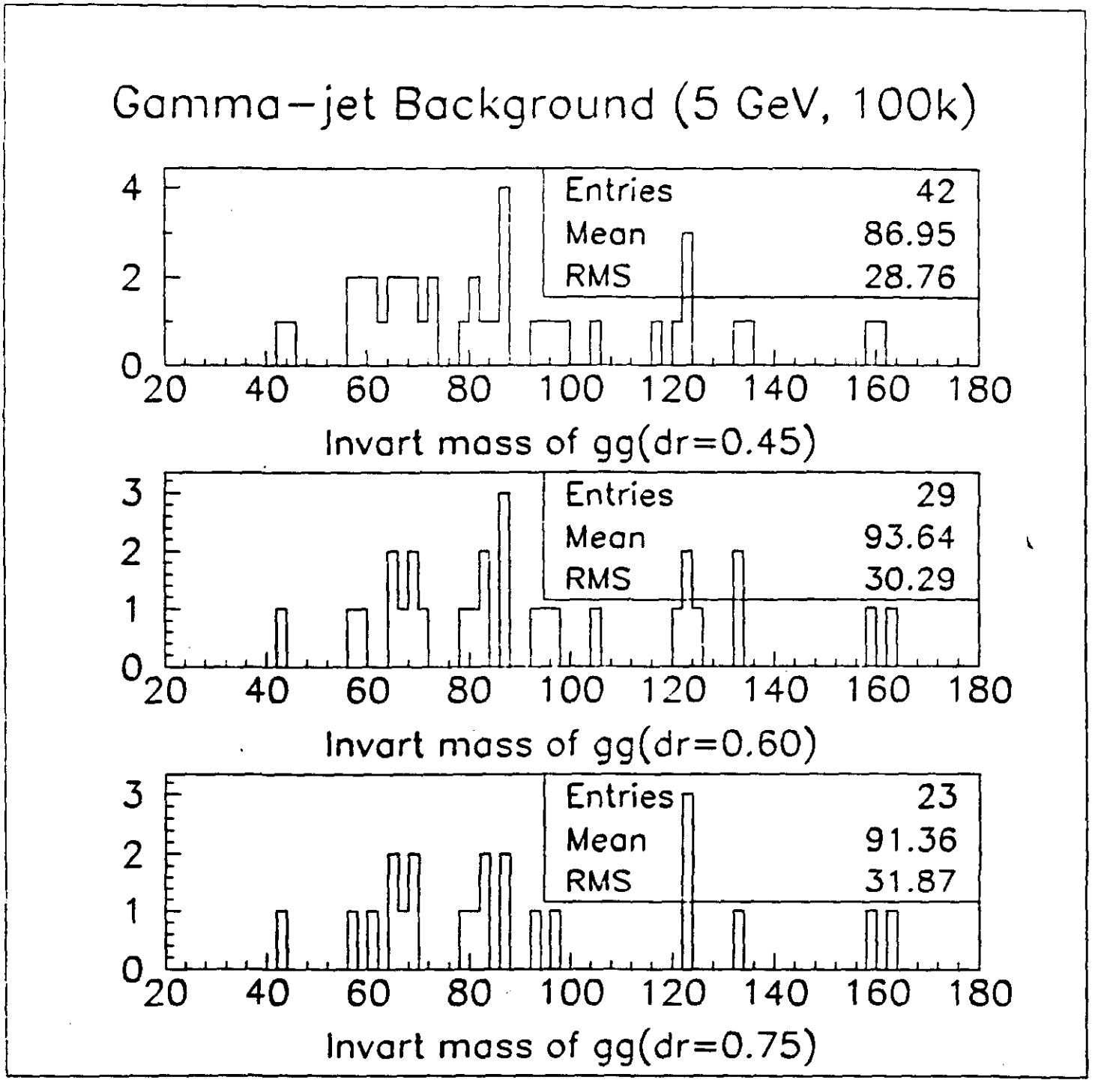

Gamma−jet Background (10 GeV, 100k)
Entries 37
Mean 0.7527E−02
RMS 0.6206E−02
E weighted angle in iso photon (dr=0.45)
Entries 32
Mean 0.6750E−02
RMS 0.5449E−02
E weighted angle in iso photon (dr=0.60)
Entries 27
Mean 0.6389E−02
RMS 0.5166E−02
E weighted angle in iso photon (dr=0.75)


Gamma-jet Background (10 GeV, 100k)
Entries 78
Mean 86.34
RMS 26.32
Invart mass of gg(dr=0.45)
Entries 66
Mean 86.84
RMS 26.93
Invart mass of gg(dr=0.60)
Entries 54
Mean 88.13
RMS 27.08
Invart mass of gg(dr=0.75)

Gamma–jet Background (5 GeV, 100k)




Gamma-jet Background (5 GeV, 100k)
Entries 17
Mean 0.6382E-02
RMS 0.5016E-02
E weighted angle in iso photon (dr=0.45)
Entries 14
Mean 0.6786E-02
RMS 0.5404E-02
E weighted angle in iso photon (dr=0.60)
Entries 9
Mean 0.5944E-02
RMS 0.5230E-02
E weighted angle in iso photon (dr=0.75)


Gamma-jet Background (5 GeV, 100k)
Entries 42
Mean 86.95
RMS 28.76
Invart mass of gg(dr=0.45)
Entries 29
Mean 93.64
RMS 30.29
Invart mass of gg(dr=0.60)
Entries 23
Mean 91.36
RMS 31.87
Invart mass of gg(dr=0.75)

QCD Background Rejection

Shower Shape Analysis and Preradiator

- Calculate Background x-section by analyzing **isolated photon candidates** passing isolation cuts.

- Calculate $\bar{\theta}$ for each **isolated photon candidate**:

$$\bar{\theta} = \frac{\sum_i E_i \times \theta_i}{\sum_i E_i}$$

where

$$\cos\theta_i = \frac{\vec{E}_i \cdot \vec{n}}{E_i}, \quad \vec{n} = \frac{\sum_i \vec{E}_i}{|\sum_i \vec{E}_i|},$$

and $\vec{E}_1$ is the energy vector of the ith photon in the **isolated photon candidate**.

- A detailed GEANT study by **H. Yamamoto** shows that isolated photon candidates with $\bar{\theta} > 5$ mrad can be effectively rejected by using shower shape analysis.

- Assuming isolated photon candidates with $\theta_M > 2$ mrad may be rejected by using an effective preradiator.

Table 2: QCD Background Cross-Sections (pb)

After Isolation						
Process	2jets			γ-jet		
E_T^{cut}	R=0.45	R=0.60	R=0.75	R=0.45	R=0.60	R=0.75
5 GeV	140	81	46	55	45	33
10 GeV	370	220	180	100	90	76
15 GeV	780	510	360	140	120	110
20 GeV	1200	940	800	190	160	150
After Showe Shape Analysis						
Process	2jets			γ-jet		
E_T^{cut}	R=0.45	R=0.60	R=0.75	R=0.45	R=0.60	R=0.75
5 GeV	73	34	20	31	26	21
10 GeV	160	120	89	54	50	42
15 GeV	250	210	140	68	59	57
20 GeV	310	260	230	83	73	66
After Preradiator						
Process	2jets			γ-jet		
E_T^{cut}	R=0.45	R=0.60	R=0.75	R=0.45	R=0.60	R=0.75
5 GeV	20	16	13	19	17	17
10 GeV	25	20	13	24	24	19
15 GeV	34	29	20	24	24	24
20 GeV	34	34	29	26	26	26
Irreducible QCD Background						
Process	2jets			γ-jet		
E_T^{cut}	R=0.45	R=0.60	R=0.75	R=0.45	R=0.60	R=0.75
5 GeV	10	10	7.3	17	14	14
10 GeV	13	10	7.3	19	14	14
15 GeV	16	16	13	21	17	17
20 GeV	16	16	16	21	19	17

Total Background (pb) for H→ $\gamma\gamma$

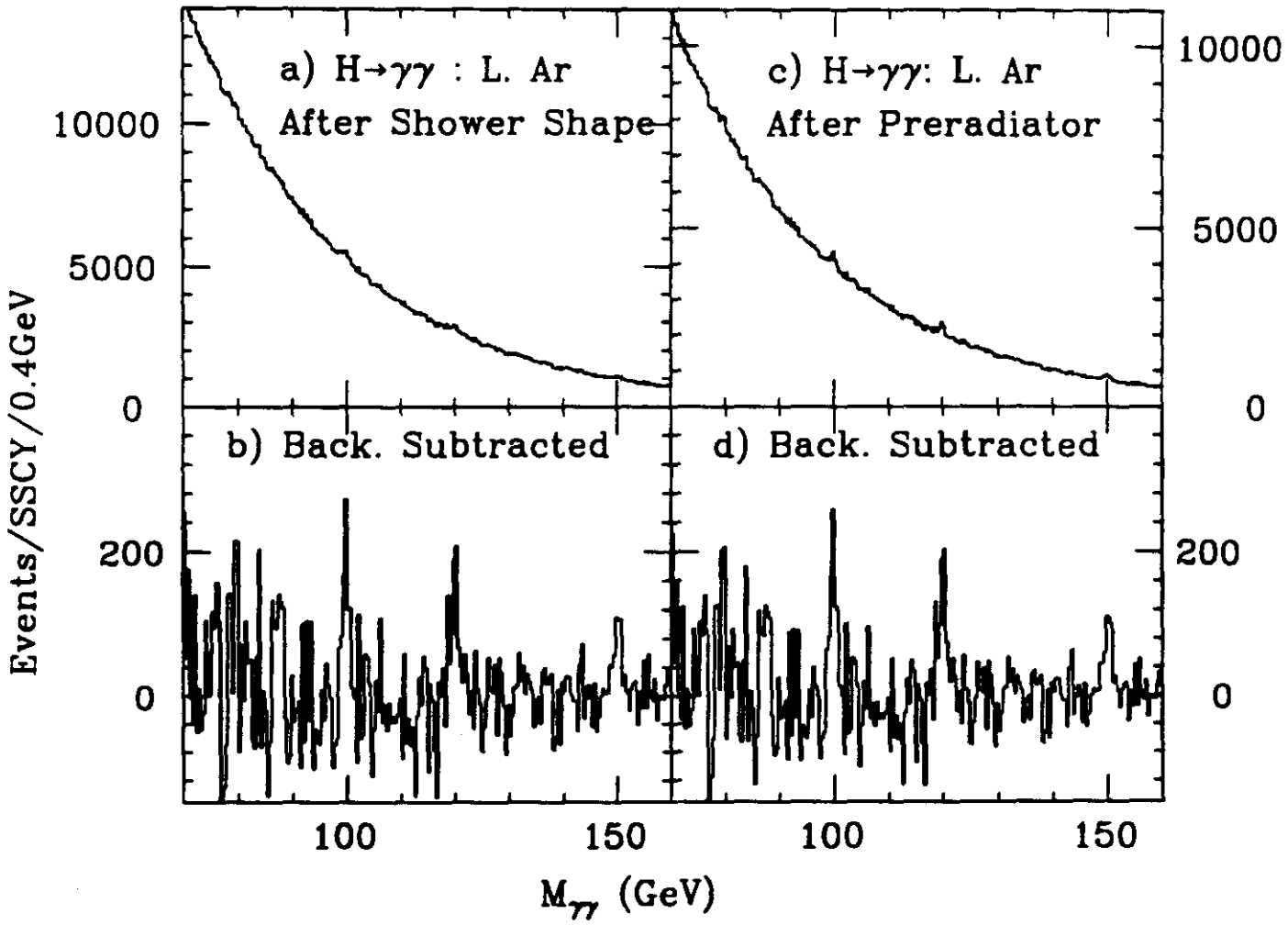
- **BaF_2** followed by a fast scintillation calorimeter:
  $E_T^{cell} > 150$ MeV, R = 0.6, $E_T^{cut} = 2.5$ GeV.

Process	$\gamma\gamma$	γ-jet	2jets	Total	B Factor
Isolation	32	23	20	75	2.3
Shower Shape	32	21	16	69	2.2
Preradiator	32	19	16	67	2.1
Irreducible	32	14	10	56	1.8

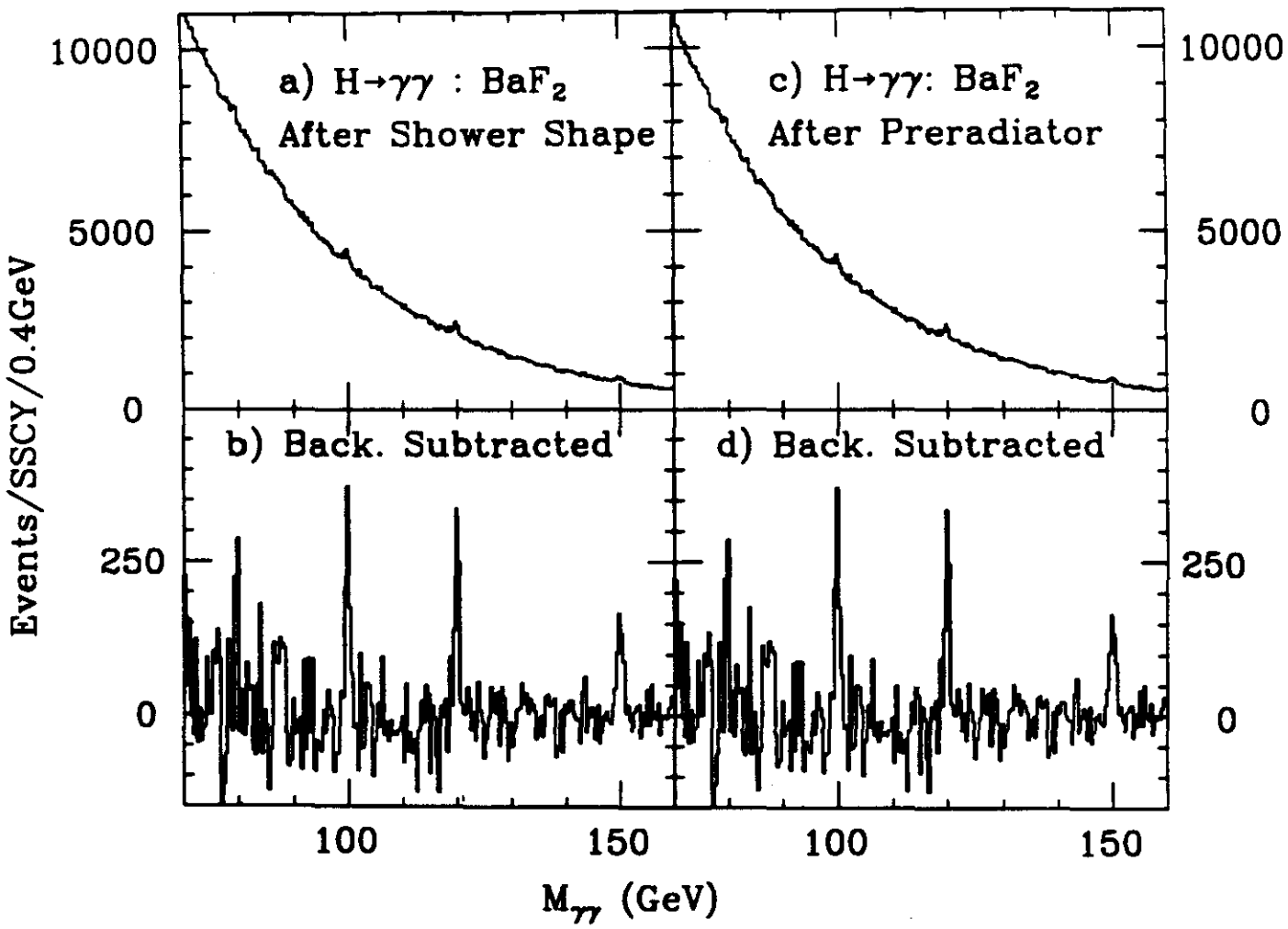
- **Liquid Argon** calorimeter:
  $E_T^{cell} > 250$ MeV, R = 0.6, $E_T^{cut} = 3.6$ GeV.

Process	$\gamma\gamma$	γ-jet	2jets	Total	B Factor
Isolation	32	50	73	155	4.8
Shower Shape	32	28	29	89	2.8
Preradiator	32	21	16	69	2.2
Irreducible	32	14	10	56	1.8

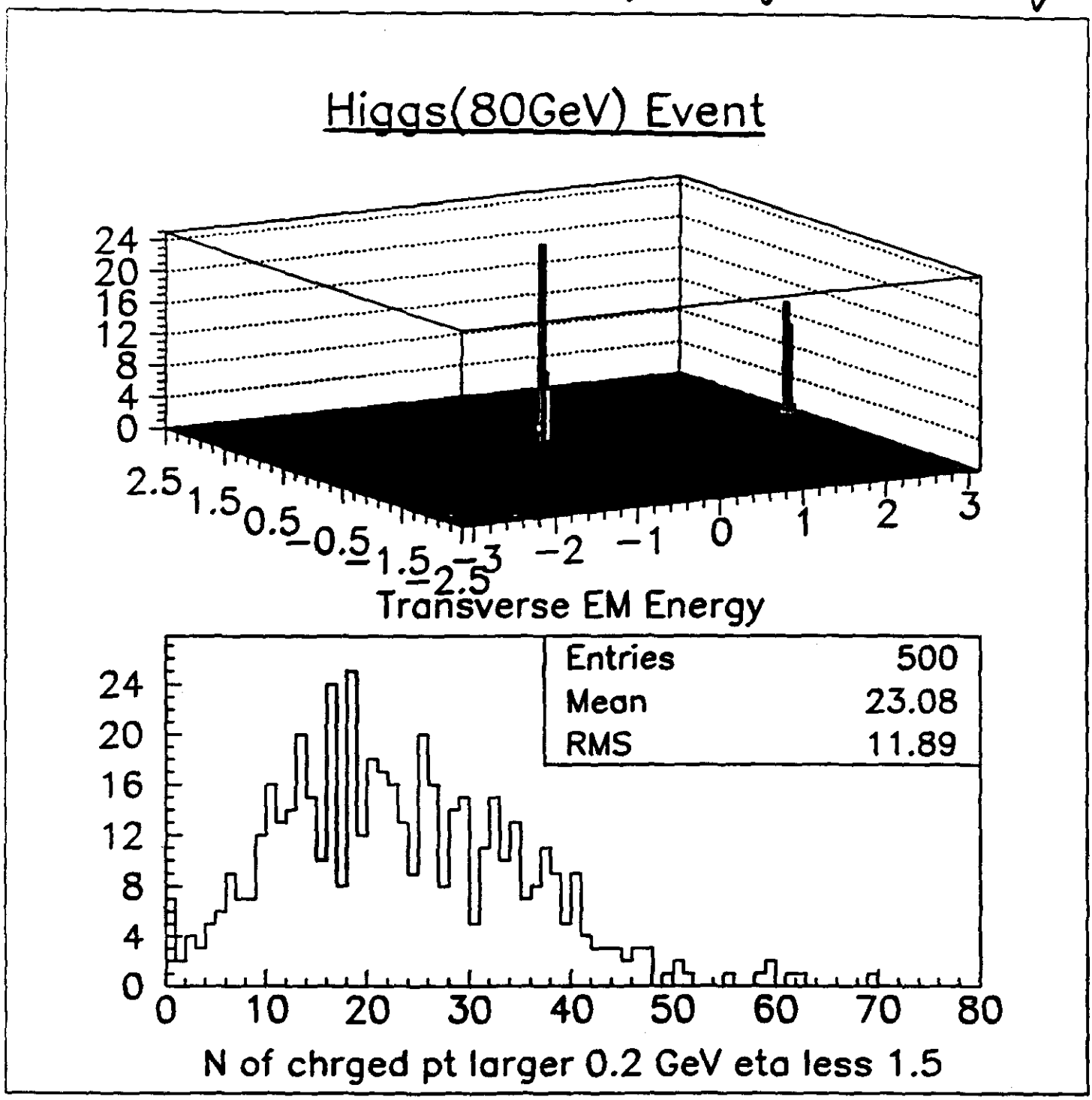
80, 100, 120 & 150 GeV Higgs



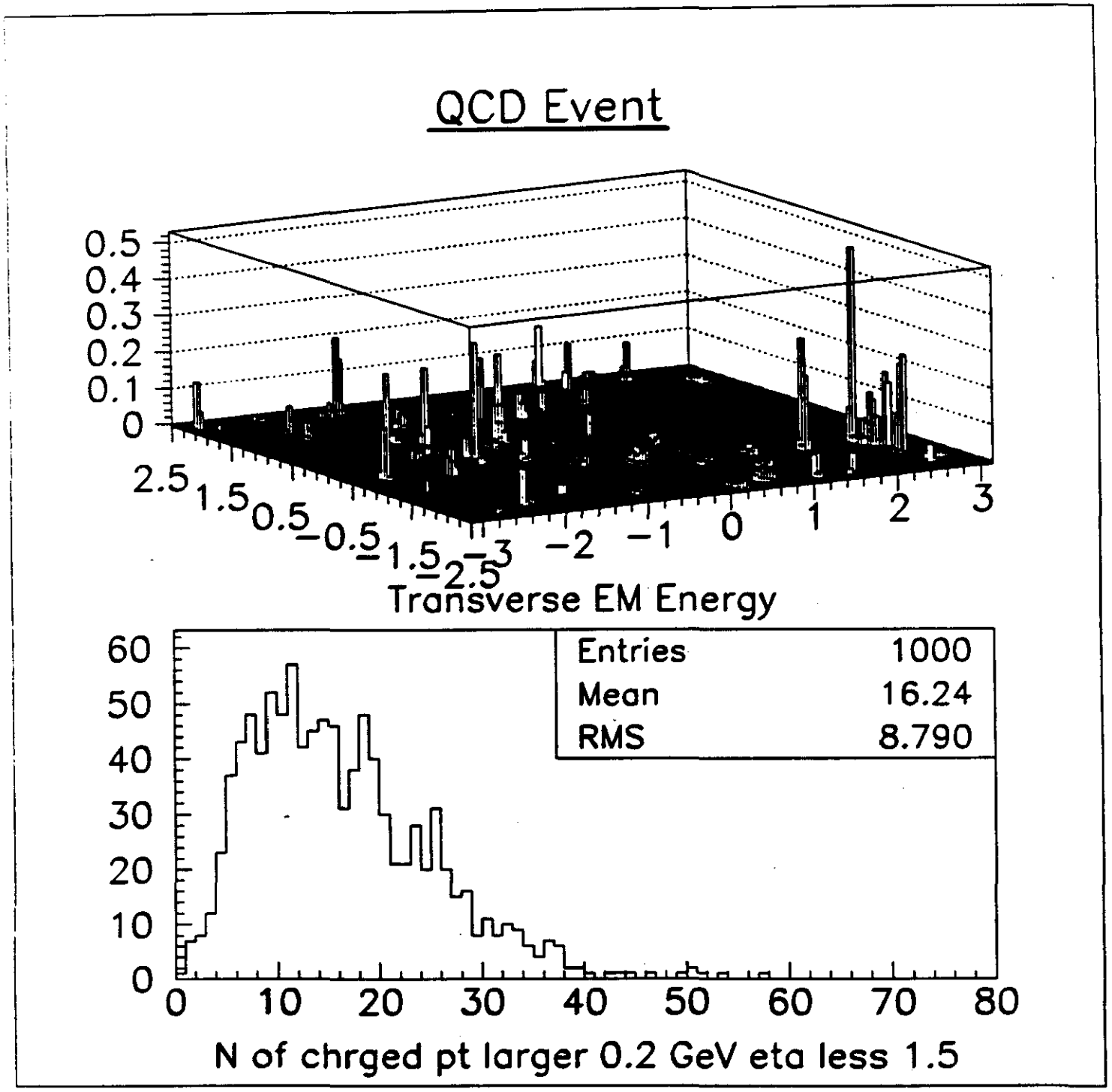
80, 100, 120 and 150 GeV Higgs



Vertex with high charge multiplicity



Vertex' with low charge multiplicity

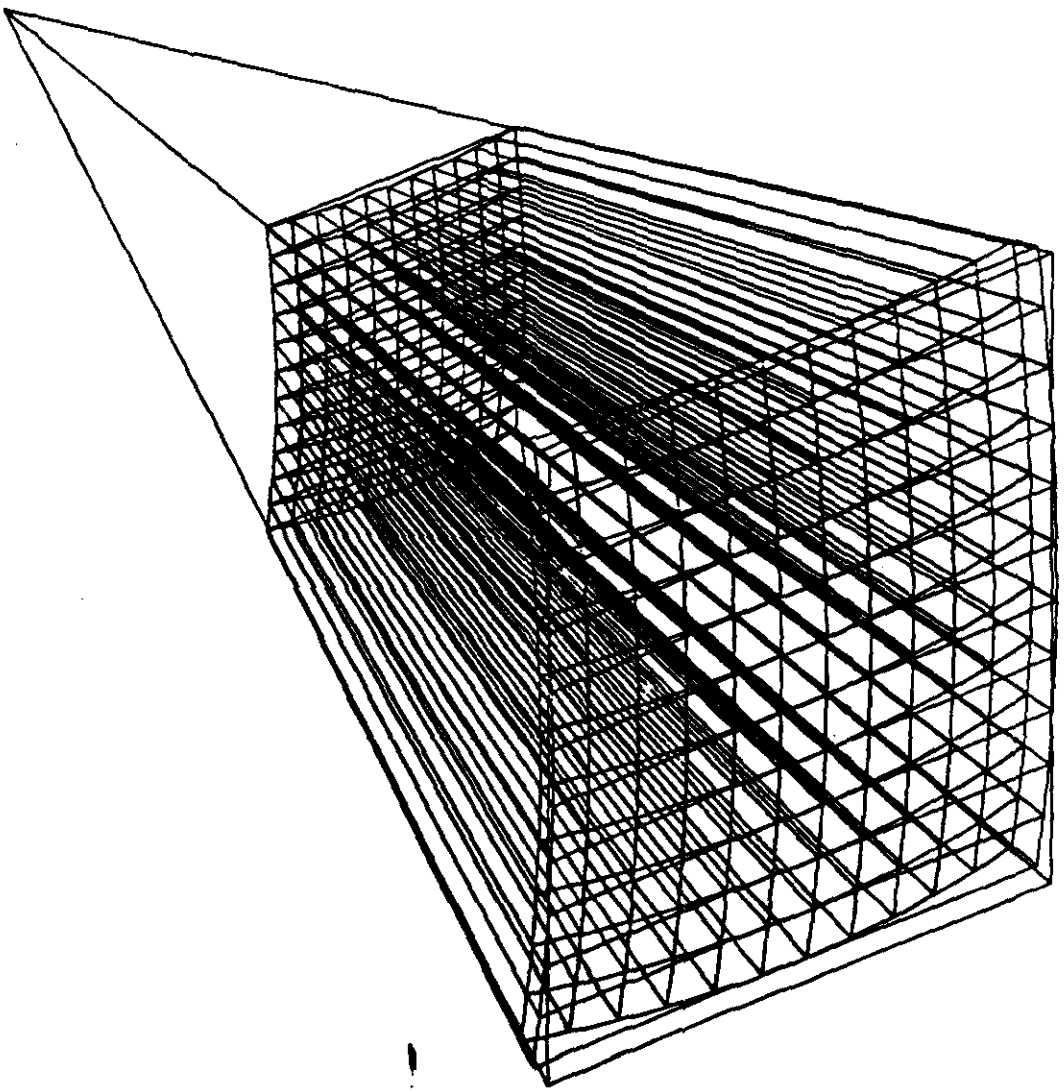


GEANT SIMULATION
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

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

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

11 × 11 BaF_2 Matrix



Shower Shape Analysis

H. Yamamoto

1. The center of the 5x5 crystals is the one which has the largest energy deposit.

2. If the 2nd or 3rd cells (cells which have the 2nd and 3rd largest energy deposits) is not in 3x3 cells around the center, this candidate is rejected.

3. Fit the projection of the $e_{i,j}$ to each axis by Gaussian to find the center and σ. These 4 values are used as the initial values for the following fit.

4. Fit the 5x5 energy deposits using the following oval shape, with 6 parameters.

   $$f(x,y) = A * exp(-\frac{X^2}{2*\sigma_{min}} - \frac{Y^2}{2*\sigma_{max}})$$

   $$X^2 = cos(\theta)^2 * (x - x0)^2 + sin(\theta)^2 * (y - y0)^2$$
   $$Y^2 = sin(\theta)^2 * (x - x0)^2 + cos(\theta)^2 * (y - y0)^2$$

   where
   A : overall normalization
   σ_{min} and σ_{max} : standard deviations of the oval shape ($\sigma_{min} < \sigma_{max}$)
   θ : angle between the original xy axis and the principal axis of the oval.
   x0, y0 : center of the oval

5. Reject if $\sigma_{min} < 0.0165$ to keep 95% of the real single γ Reject if $\sigma_{min} < 0.0160$ to keep 90% of the real single γ These 2 values are determined by 40 and 80 GeV γs simulated by GEANT. The efficiency for the lower energy γ is slightly lower. For example, the efficiencies for the 20 GeV γ are a few % less in both cases. See Fig. 2 for more details, which is explained below.

Fig 1 σ_{min} distribution

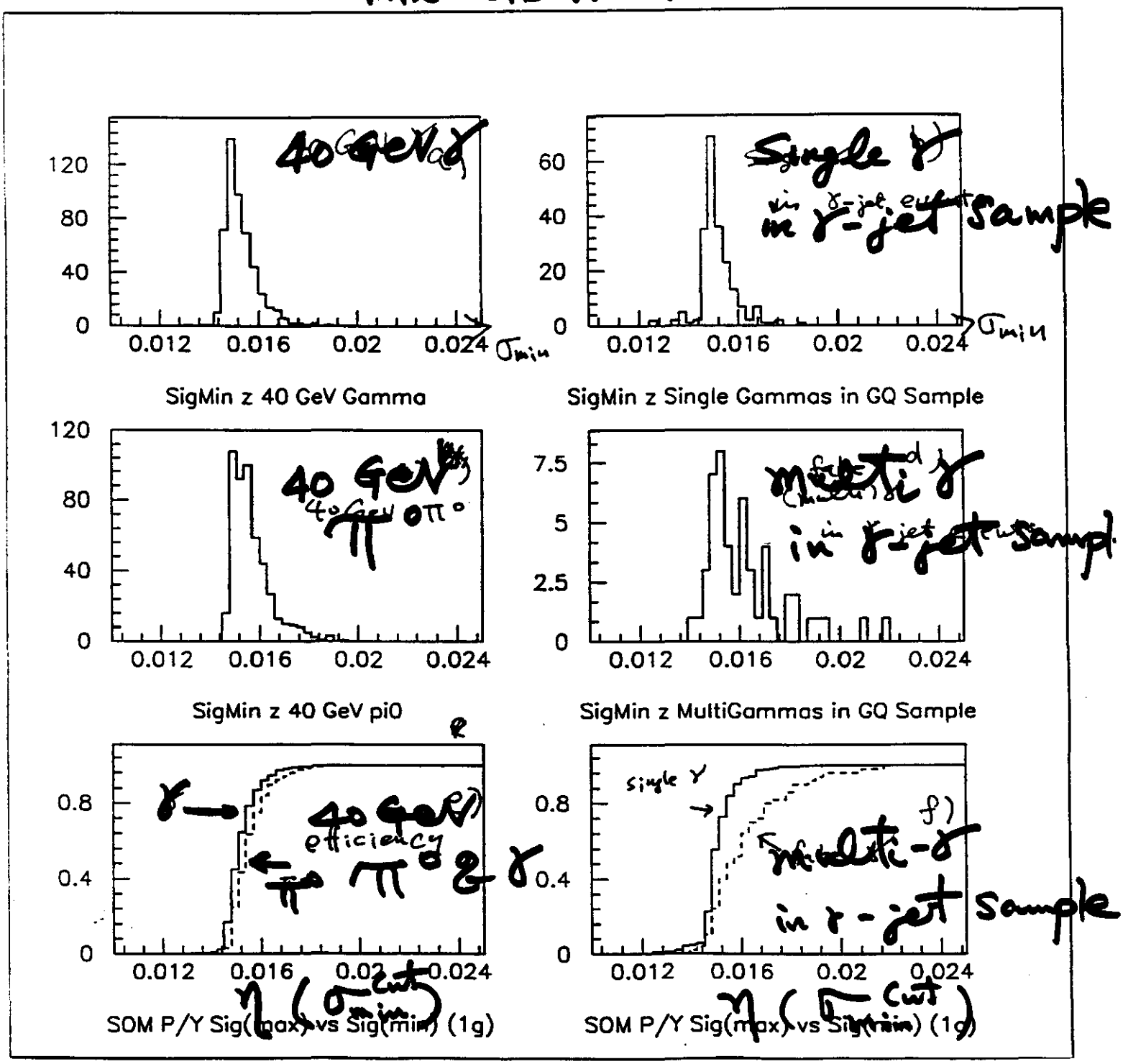
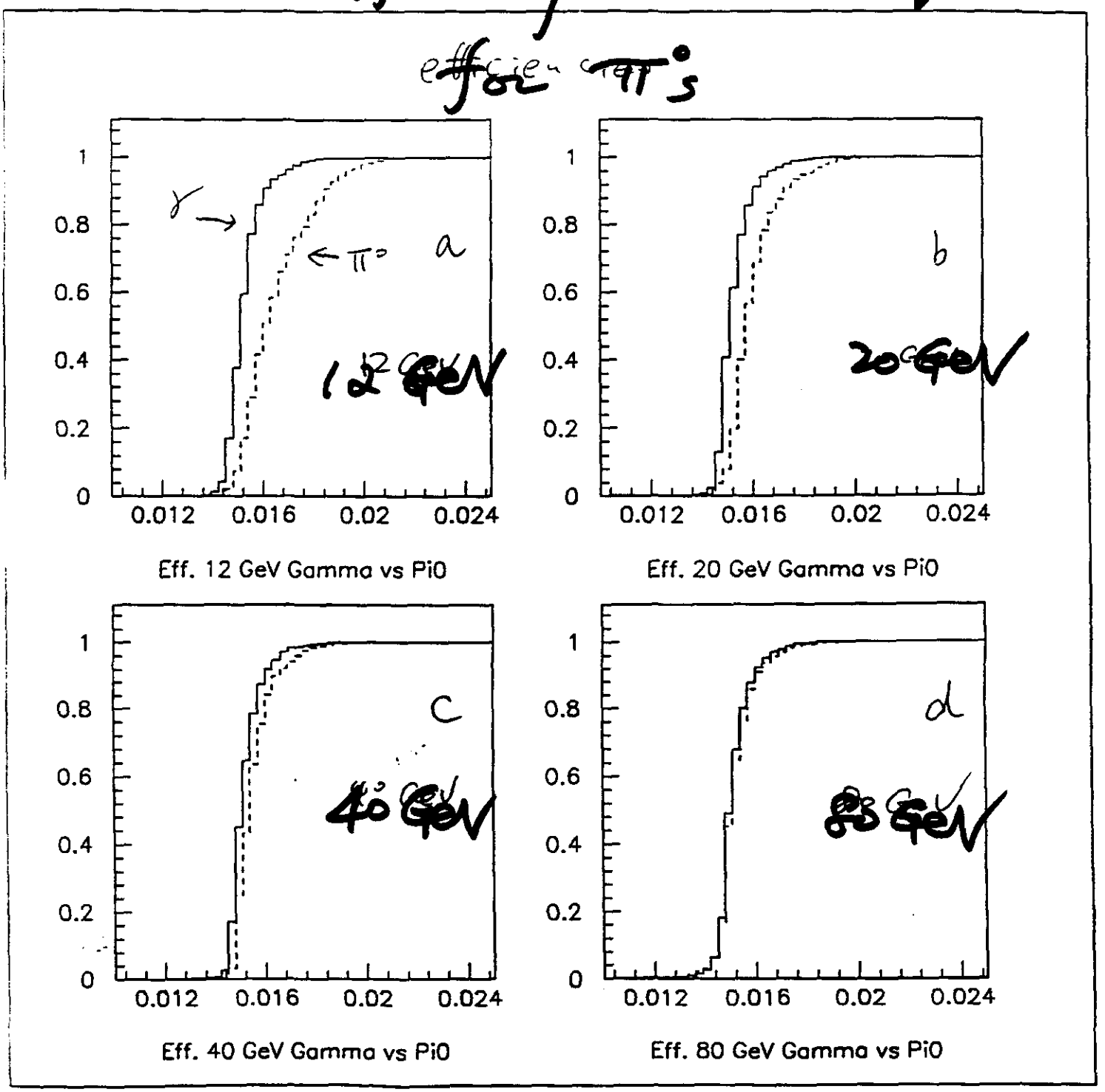
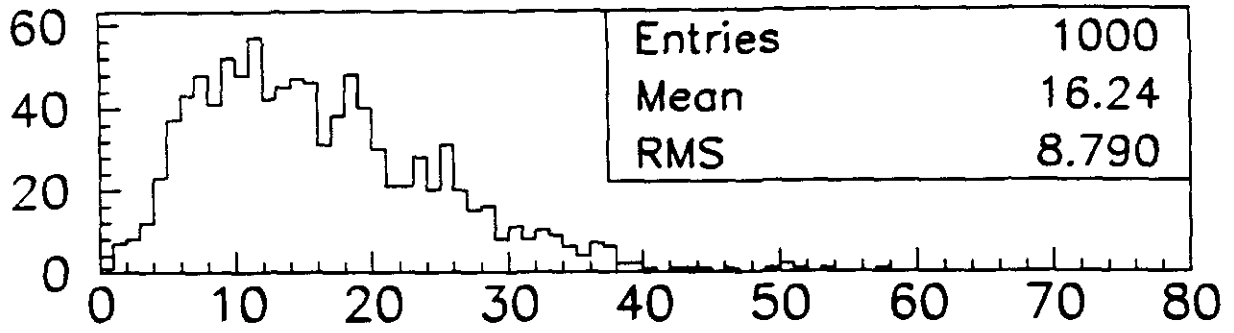


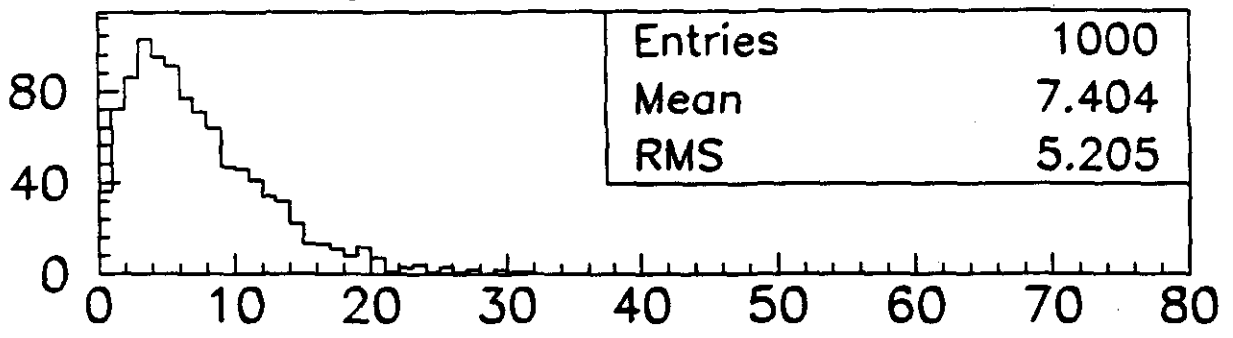
Fig 2 Efficiency as function of σ_{min} for π^0's



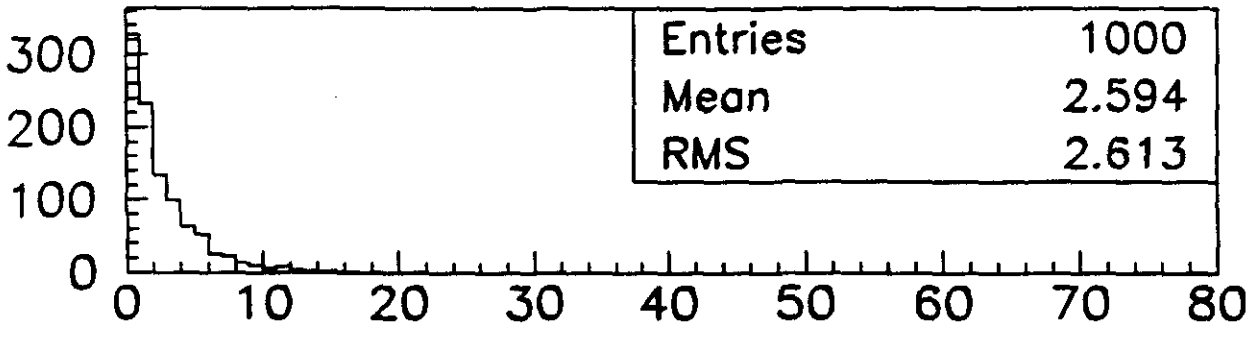
QCD Events



N of chrged pt larger 0.2 GeV eta less 1.5

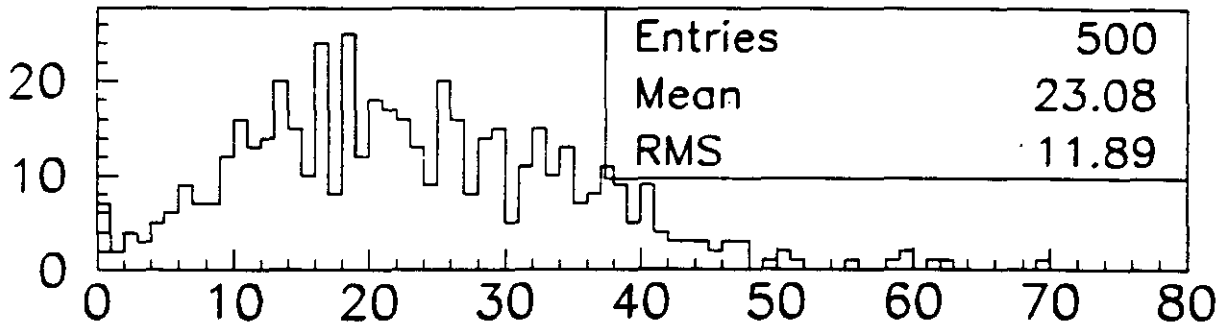


N of chrged pt larger 0.5 GeV eta less 1.5

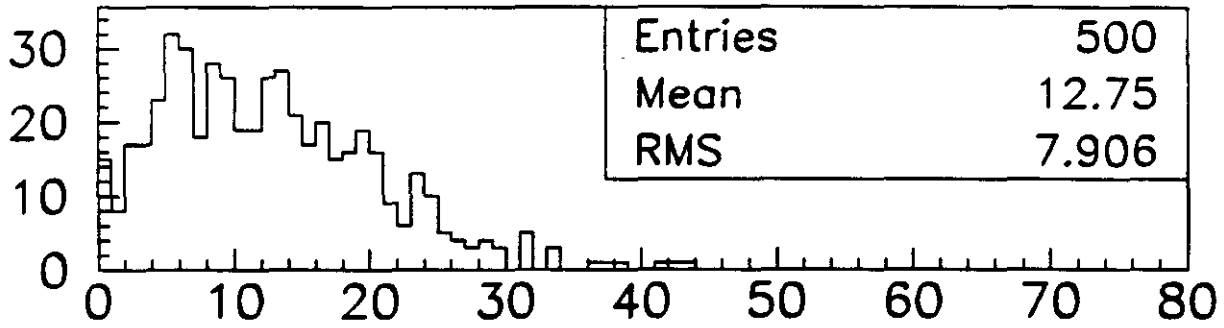


N of chrged pt larger 1 GeV eta less 1.5

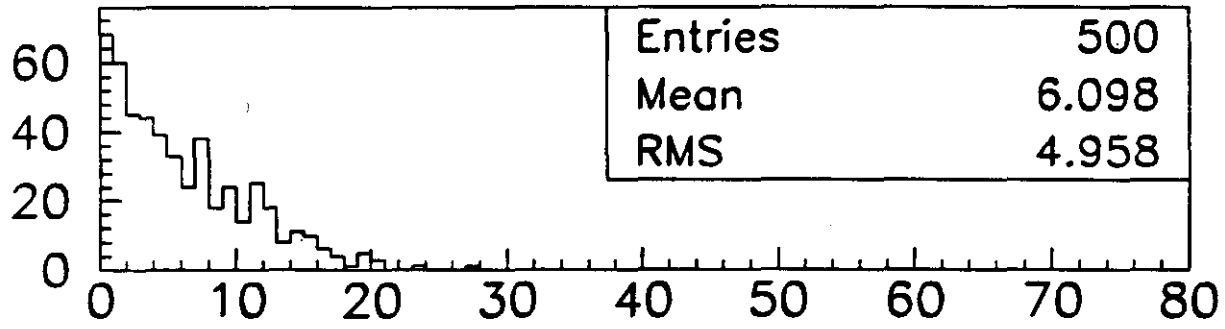
Higgs(80GeV) to 2 Photons



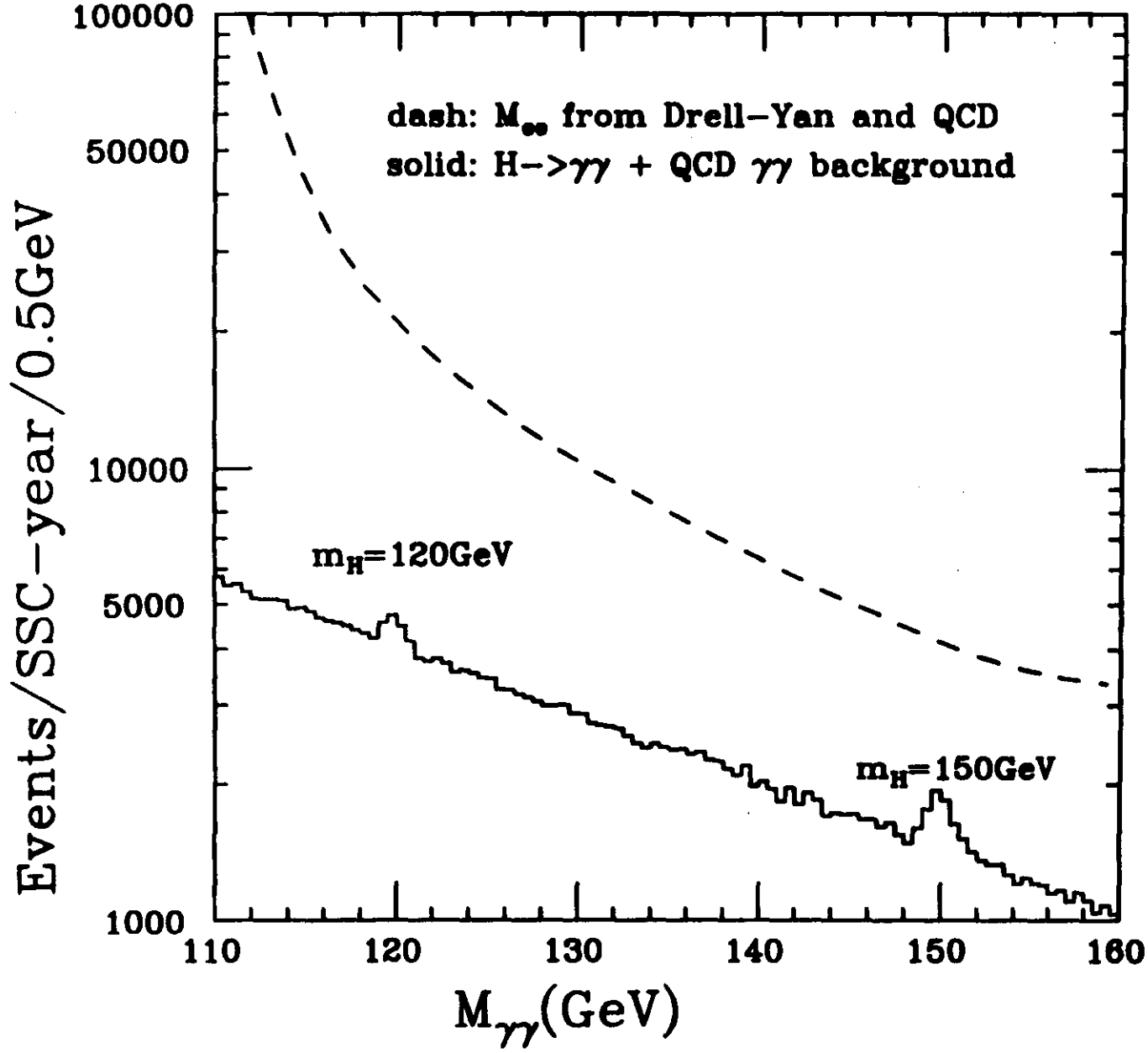
N of chrged pt larger 0.2 GeV eta less 1.5



N of chrged pt larger 0.5 GeV eta less 1.5



N of chrged pt larger 1 GeV eta less 1.5


dash: $M_{\gamma\gamma}$ from Drell–Yan and QCD
solid: H–>$\gamma\gamma$ + QCD $\gamma\gamma$ background
m_H=120GeV
m_H=150GeV
100000
50000
10000
5000
1000
110
120
130
140
150
160
Events/SSC–year/0.5GeV
$M_{\gamma\gamma}$(GeV)

DD $\rightarrow Ht\bar{t}X \rightarrow \gamma\gamma l\nu X$

Production Cross-Section and Events/SSCY
PYTHIA 5.5 (M_{top}=140 GeV)

M_H(GeV)	$\sigma_{\gamma\gamma t\bar{t}X}$(fb)	$N_{\ell\gamma\gamma}(0.3)$	$N_{\ell\gamma\gamma}(0.45)$	$N_{\ell\gamma\gamma}(0.6)$
80	18	17	16	14
90	17	25	22	16
100	16	19	16	16
120	14.5	20	16	14
140	8.5	15	12	10
150	5.2	15	7	5

- $|\eta_\ell| < 2.5$, $P_T^\ell > 20$ GeV, R = 0.3.
- $|\eta_\gamma| < 2.5$, $P_T^\gamma > 20$ GeV, R = 0.3, 0.45, 0.6
- isolation cut $\Rightarrow$ reject $t\bar{t}$

$$\sum_{r<R} E_T - E_T^{photon} < 5GeV + 0.1E_T^{photon}$$

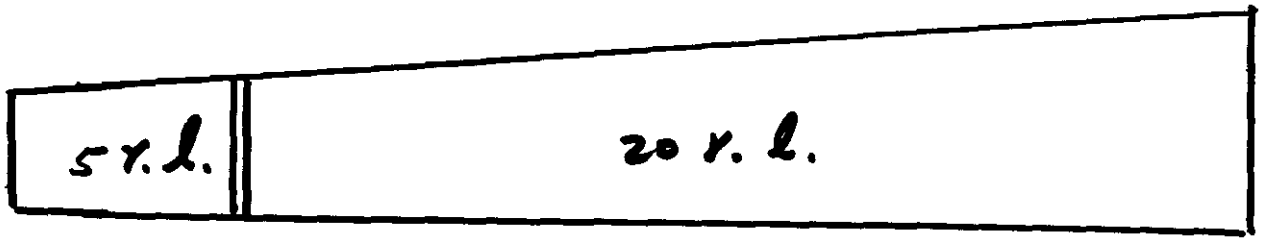
- P_T of di-photon > 50 GeV $\Rightarrow$ reject $t\bar{t}$
- Shower Shape Analysis: $\bar{\theta} < 5$ mrad
- Preradiator: $\theta_M < 2$ mrad

pp $\rightarrow Ht\bar{t}X \rightarrow \gamma\gamma\ell\nu X$ (Cont.)

2.6 M $t\bar{t}$ Background

R_{cut}	0.3	0.45	0.6
Isolation	45	26	11
$R_{\gamma/q-jet}$ (10^{-3})	3.5	2.6	1.7
75 GeV< $M_{\gamma\gamma}$ <165 GeV	11	7	4
$p_T(2\gamma) > 50$ GeV	5	3	1
Shower Shape	2	1	0
$R_{\ell\gamma\gamma}$ (10^{-6})	0.8	0.4	<0.4
X-Section (fb)	12.8	6.4	<6.4
Events/SSCY	128	64	<64
Preradiator	2	1	0
$R_{\ell\gamma\gamma}$ (10^{-6})	0.8	0.4	<0.4
X-Section (fb)	12.8	6.4	<6.4
Events/SSCY	128	64	<64

A possible senario of P.R. (BaT



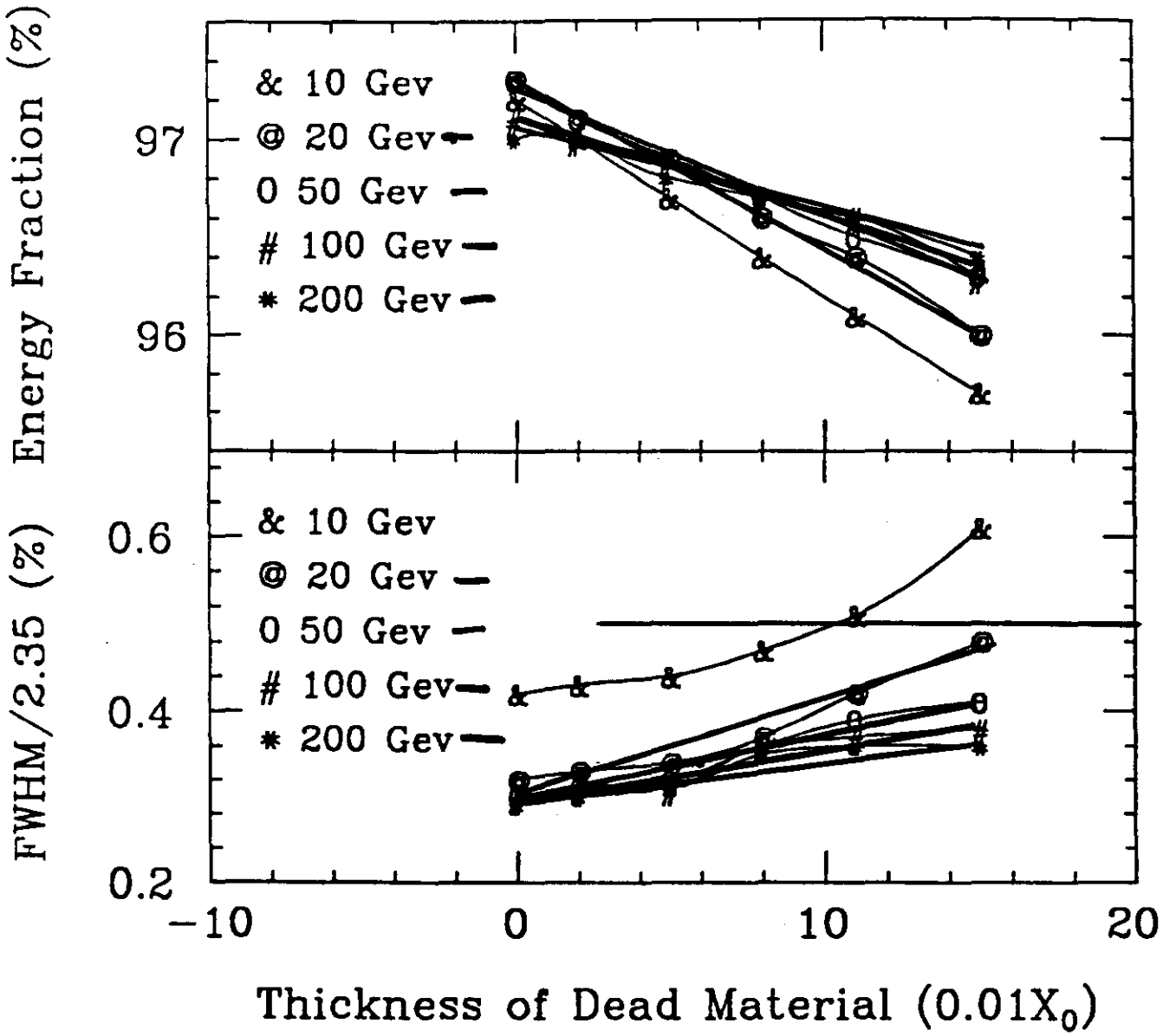
position detector at 5. r.l.

- if presition is 150μ in x and y, the γ direction can be determined to 7 mrad for 50 GeV γ
- if position detector is 1mm strip or cell in x and y. the γ/π° rejection is improved for low energy γ/π°.

Analysis uses only information of Yes or No for either cell or strip with threshould of 4 and 8 for cell & strip

preradiator

Effect of Dead Material at $5X_0$ (5 x 5)



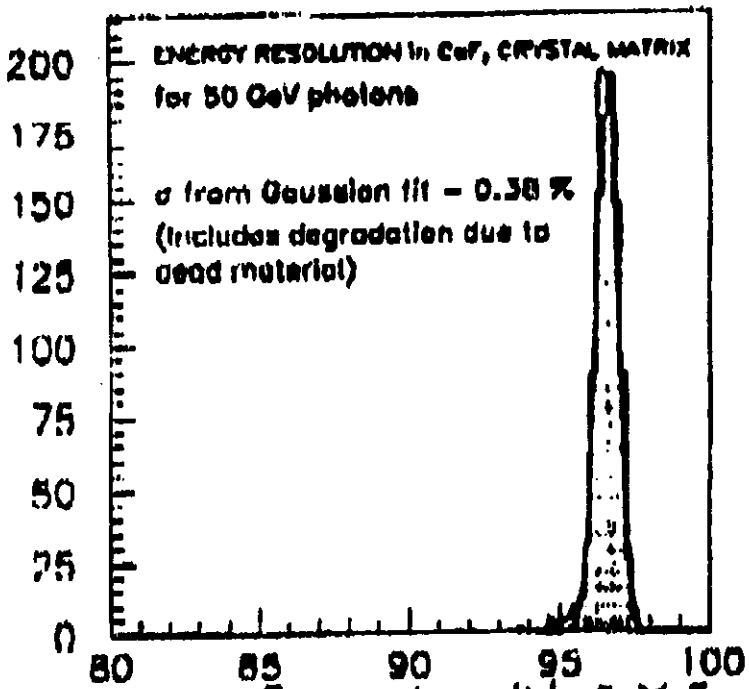


Fig. 1 Energy deposit in 5 × 5 Crystal Array (in %)

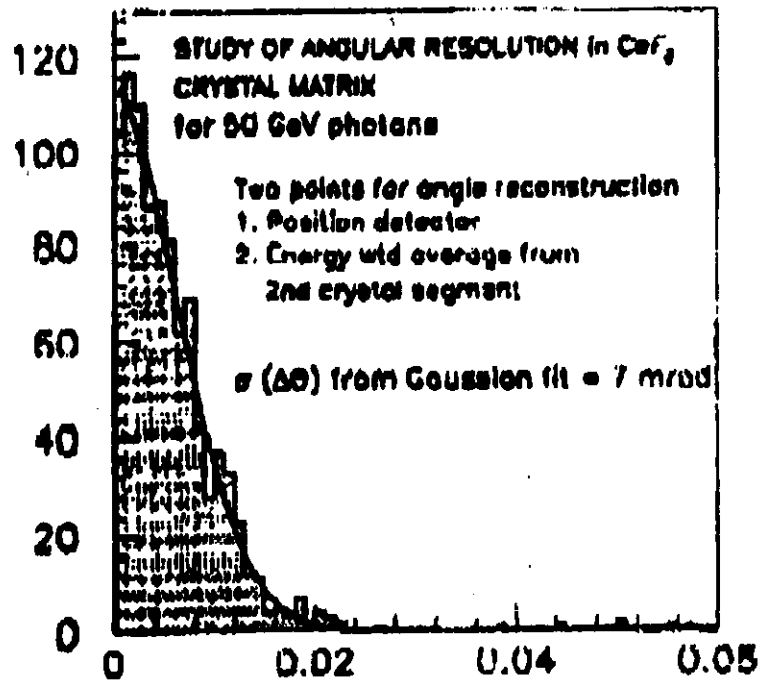
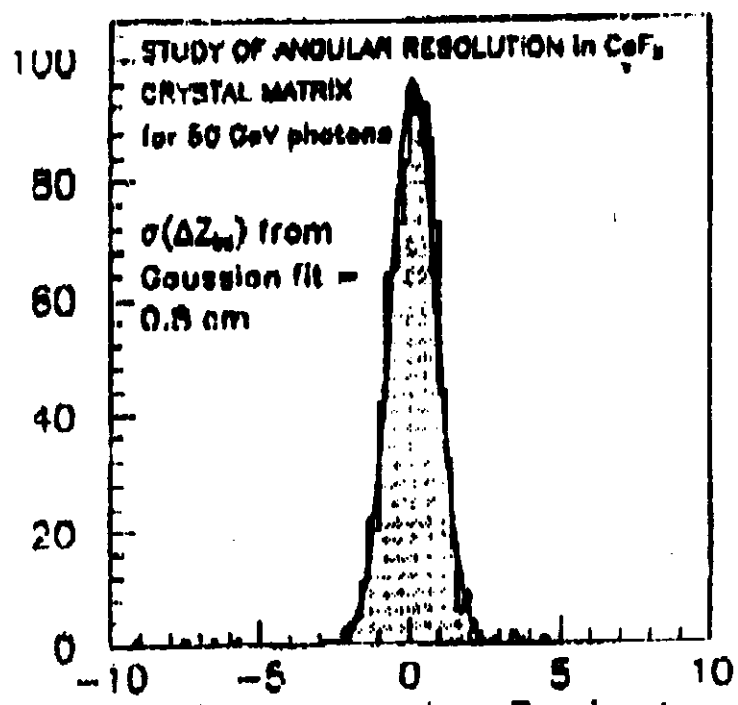


Fig. 2 $|\Theta_{rec} - \Theta_{true}|$ (rad)



Angular precision

$\sigma = 7$ mrad.

A. Gurtu

Preradiator Study H. Yamamoto

Table 1: Acceptance for single gamma and multi-gamma particles
(%)

Energy (GeV)	γ	π^0	η	K^0_s
20	90/93	33 / 67		
40	92 / 93	36 / 50		
80	92 / 99	53 / 74	22 / 26	12 / 16
120	98 / 94	64 / 86		
160	95 / 96	70 / 90	30 / 44	16 / 43

New Ideas in Scintillating Fiber Calorimetry

R. Wigmans, SSC 1/22/92

SPACAL (CERN) active since 1987

20 ton detector constructed (1990)

- Monolythic (no e.m./had. sections)
- Non-projective
- Pb : fiber = 4 : 1 $\rightarrow f_{samp} = 2.3\%$

En. res.:

electrons: $\sigma/E = 12.9\%/\sqrt{E} + c(\theta_z)$

$\theta = 3^\circ \rightarrow c = 1.2\%$

pions: $\sigma/E = 30.6\%/\sqrt{E} + 1.0\%$

$e/h = 1.15 \pm 0.02$

($e/\pi = 1.02 - 1.09$ depending on E)

1991:

- Projective structure (2 ton)
- Longitudinal segmentation

e.m. section:

- use 0.5 mm fibers
- same sampling fraction
  $\longrightarrow$ # fibers * 4

$$\sigma/E = 9.3\%/\sqrt{E} + c(\theta), \qquad \theta = 2^\circ \longrightarrow c = 0.6\%$$

improves by $\sqrt{2}$ — improves by 2

Photon statistics <u>NOT</u> a limiting factor
(500 p.e./GeV)

$$\sigma/E = \frac{\sqrt{\sigma^2_{samp} + \sigma^2_{p.e.} + (\sigma^2_{intr})}}{\sqrt{E}} + \cdots$$

$$\boxed{\sigma_{samp}/\sqrt{E} \sim \sqrt{\phi_{fib}}.}$$

Hadronic section:

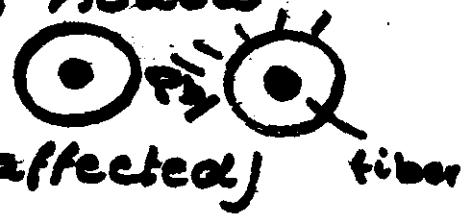
Go to 3 mm fibers

→ expect $\sigma/E \approx \frac{45\%}{\sqrt{E}}$ (pions)

<u>New idea</u>:

Major cost item: Photocathode surface (~18%)

→ use 1 mm fibers in 3 mm hollow plastic tube.
(shower development <u>not</u> affected)



- fiber surface reduced by factor q (photocathode surface)
- light yield reduced by factor q
  (→ 15%/$\sqrt{E}$ from photon statistics, no problem)

In practice:

What happens to e/h?

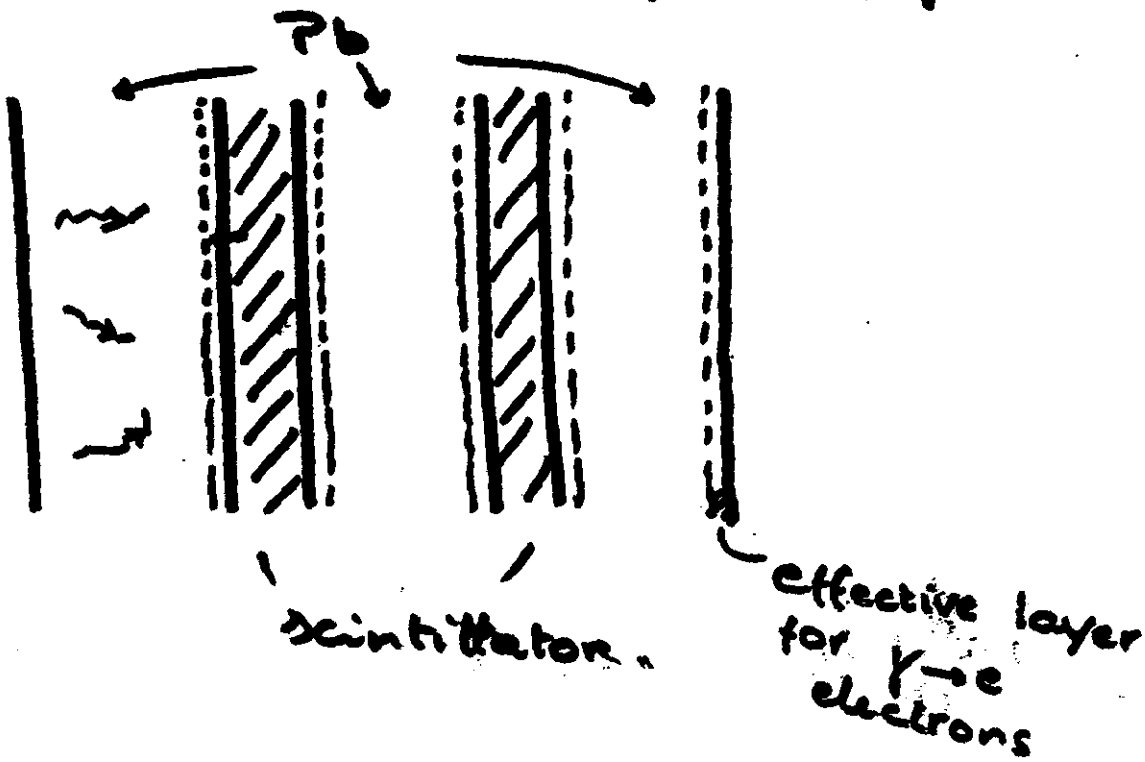
Expected to drop w.r.t. original SPACAL results (due to e.m. response)

<u>Two effects</u> on e/mip

e.m. shower in Pb: → ~40% of E deposited by particles softer than 1 MeV.

→ e/mip < 1.

Photo electric effect important process:



- e/mip depends on sampling frequency
- low-Z passive material between Pb and active material reduces e/mip

<u>GEANT</u>: Combined effect ~10% on e/mip, e/h

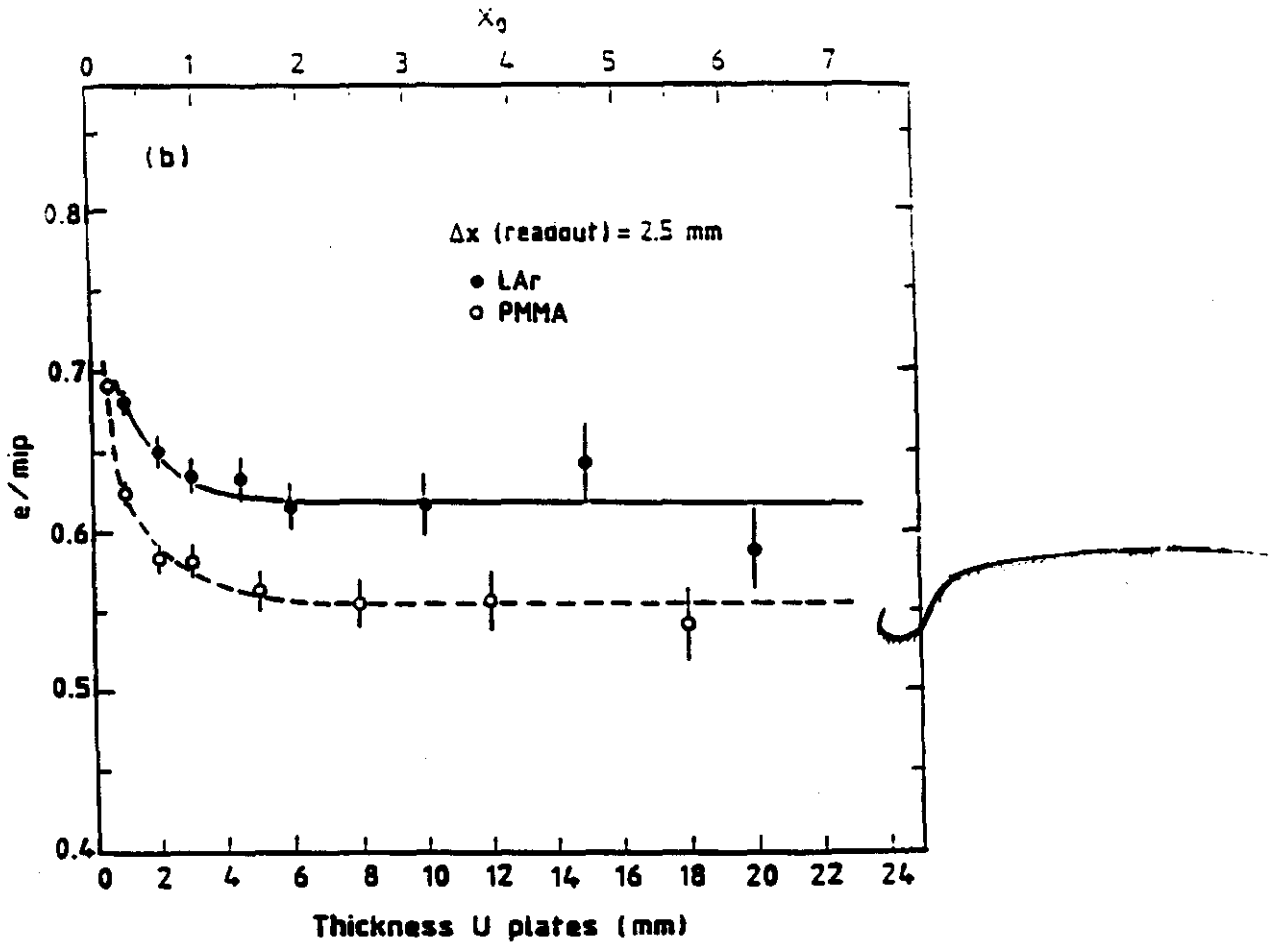


Figure 7 **The e/mip ratio as a function of the thickness of the passive layers, for uranium/LAr and uranium/plastic-scintillator calorimeters. The thickness of the active layers is 2.5 mm. Results from EGS4 Monte Carlo calculations[18].**

Other new idea

SPACAL with Quartz fibers for forward calorimetry.

These fibers were not (measurably) affected after exposure to 100 GRad.

e.m. prototype built & tested:

Light yield ~ 5 p.e./GeV

First sampling cal. based on Č. light.

GEM FCal

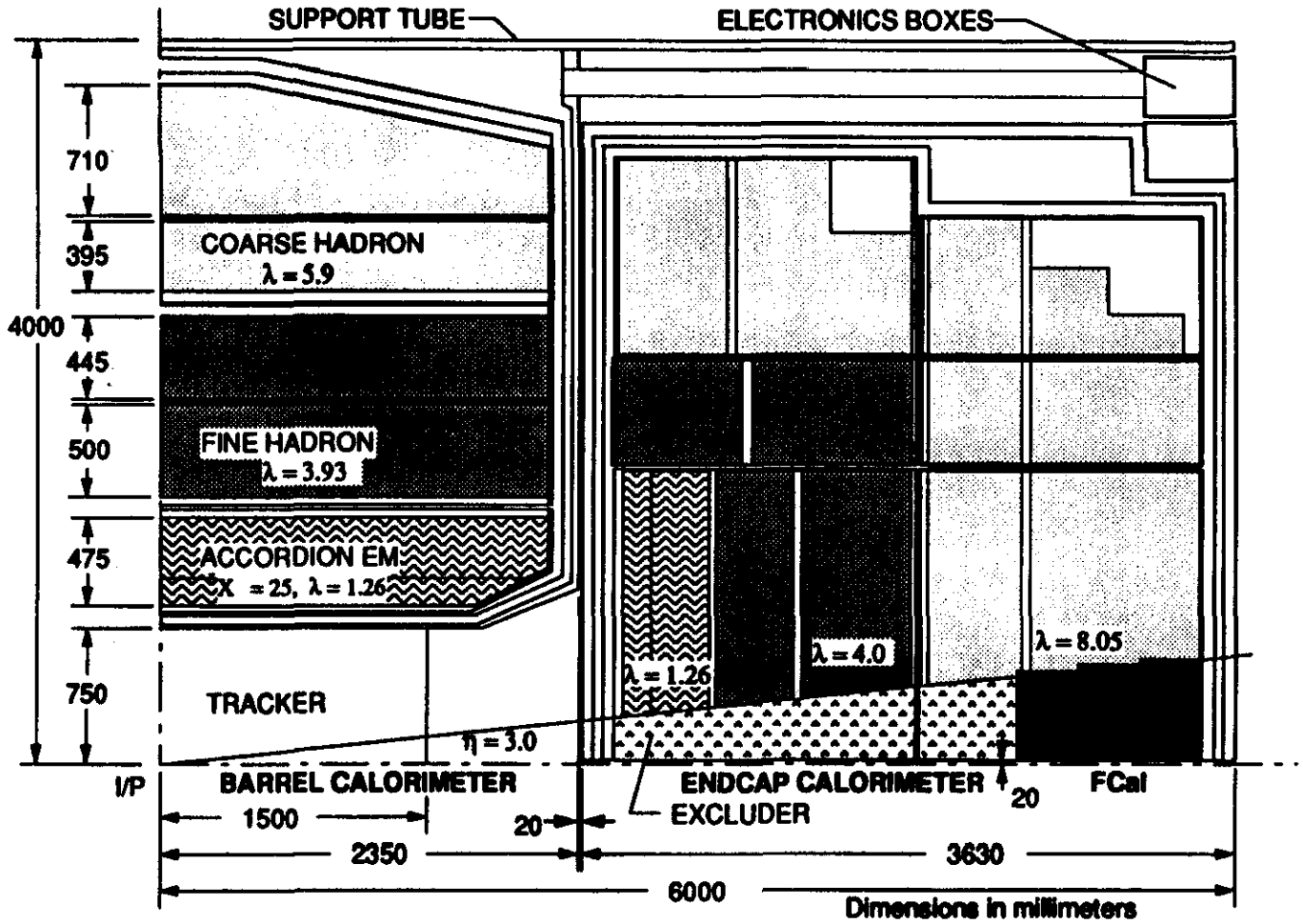
"Integrated" Liquid Ar Option

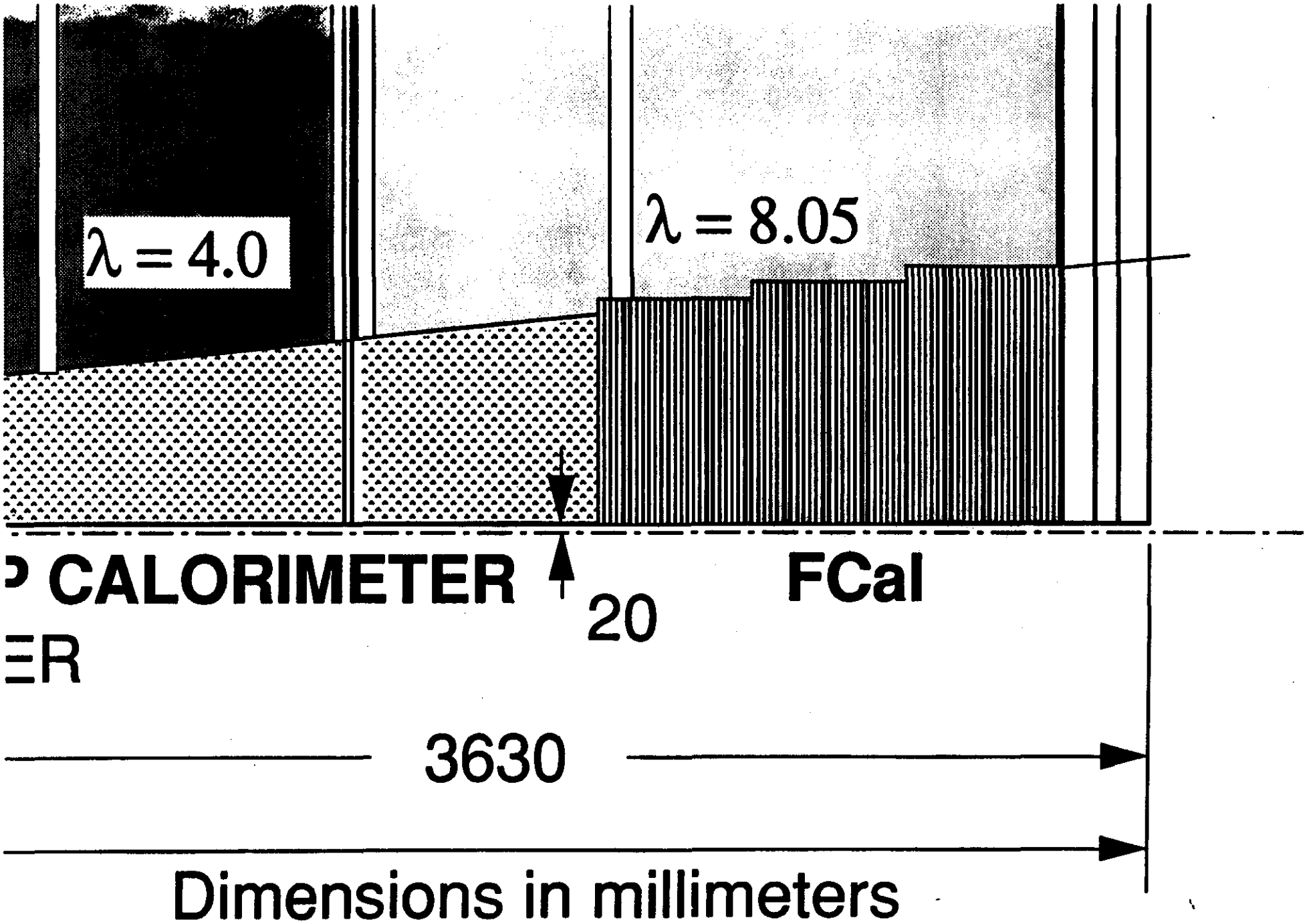
J. Rutherfoord 1/22/92 SSCL

Mechanical Concept

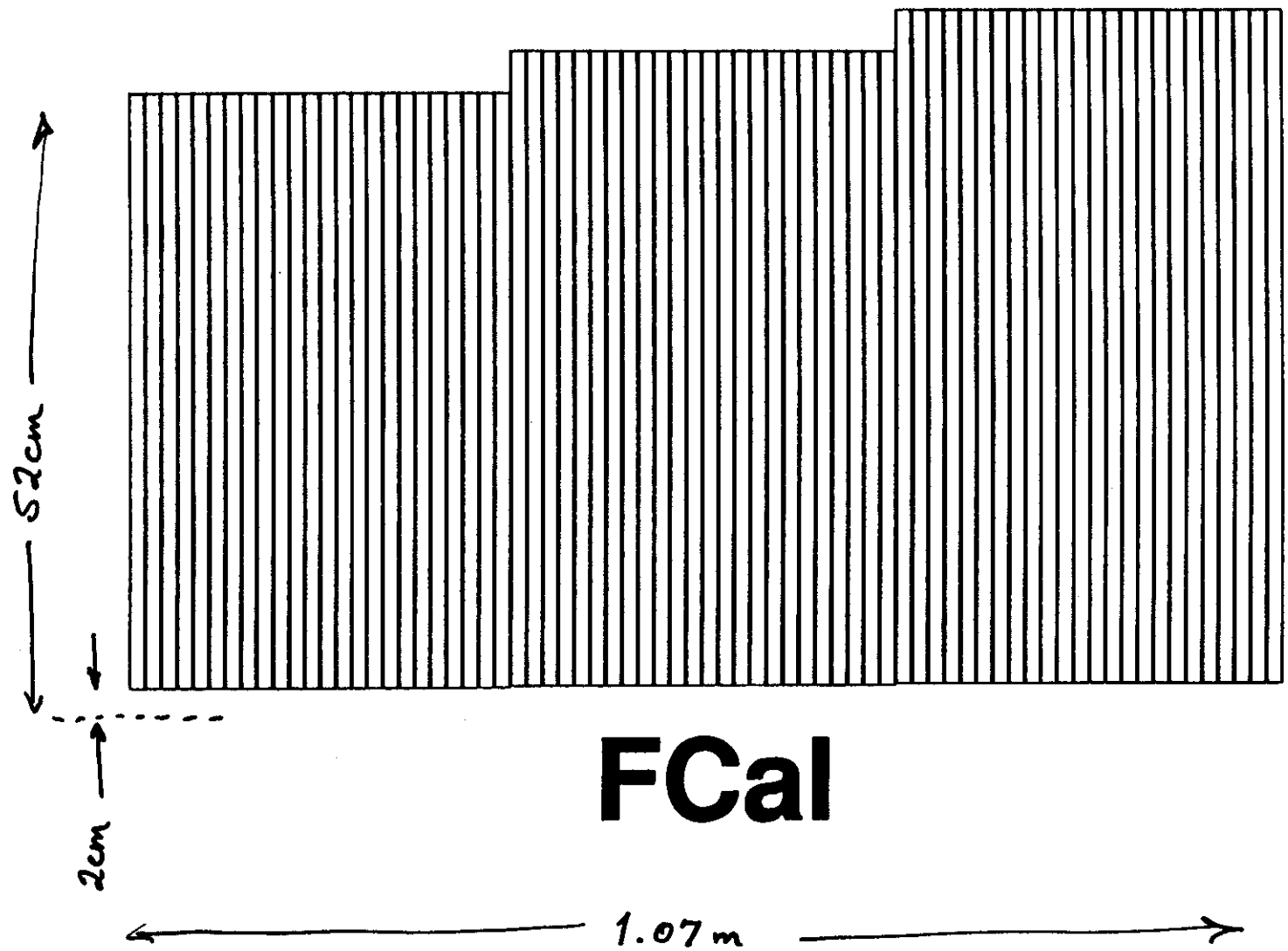
Simulation

Ion Loading

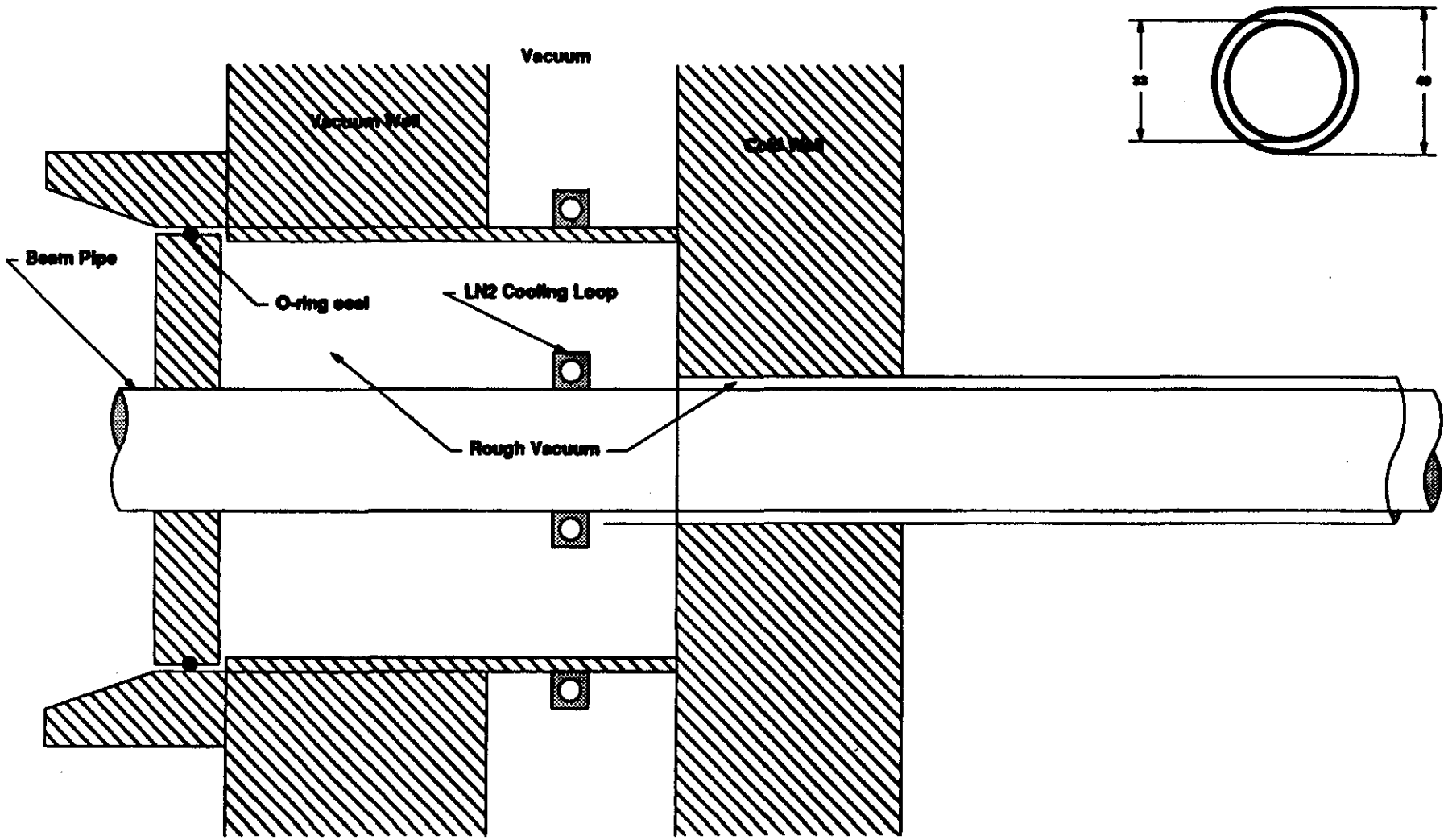

SUPPORT TUBE
ELECTRONICS BOXES
710
395
4000
445
500
475
750
COARSE HADRON
λ = 5.9
FINE HADRON
λ = 3.93
ACCORDION EM
X = 25, λ = 1.26
TRACKER
η = 3.0
λ = 1.26
λ = 4.0
λ = 8.05
I/P
BARREL CALORIMETER
ENDCAP CALORIMETER
FCal
EXCLUDER
20
20
1500
2350
3630
6000
Dimensions in millimeters

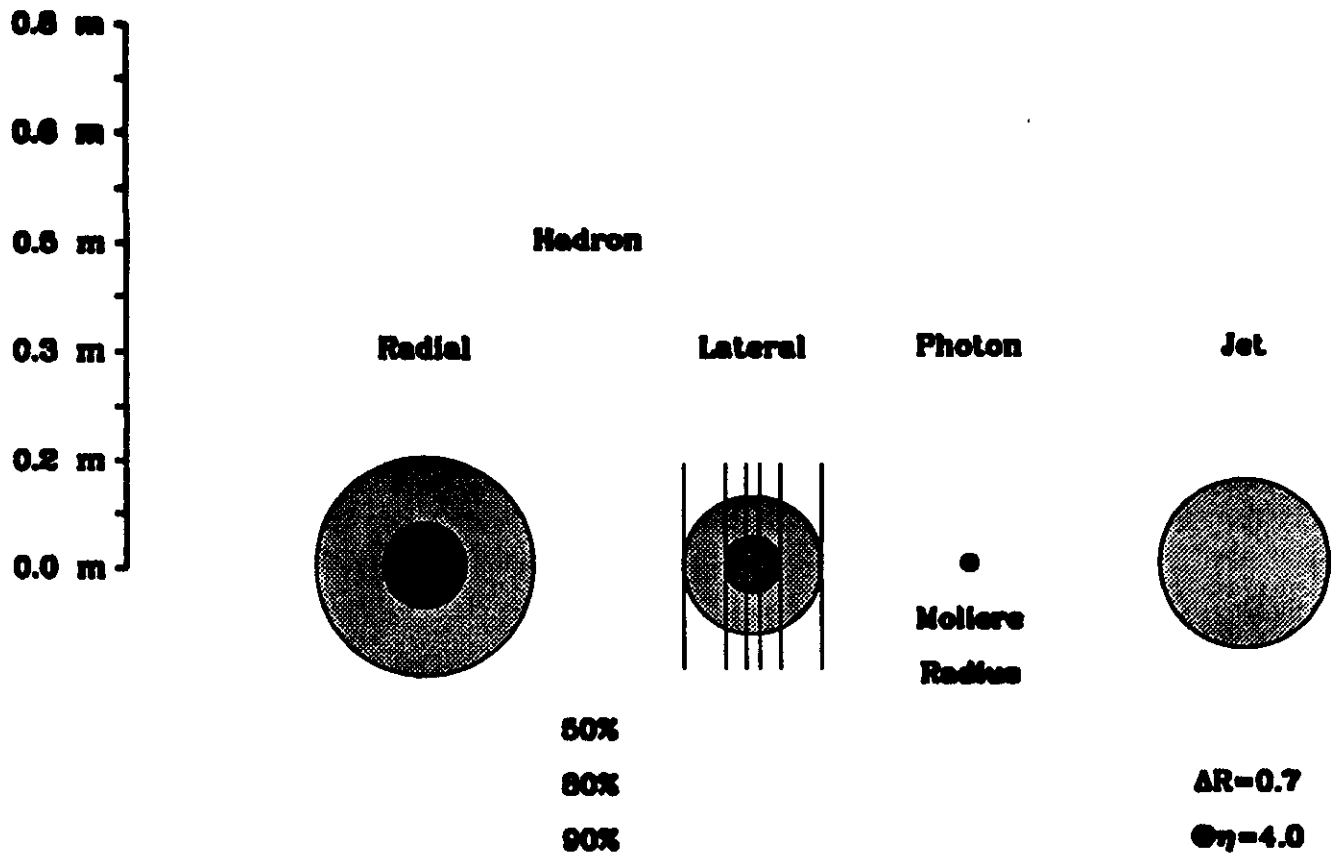

λ = 4.0
λ = 8.05
CALORIMETER
FCal
20
3630
Dimensions in millimeters

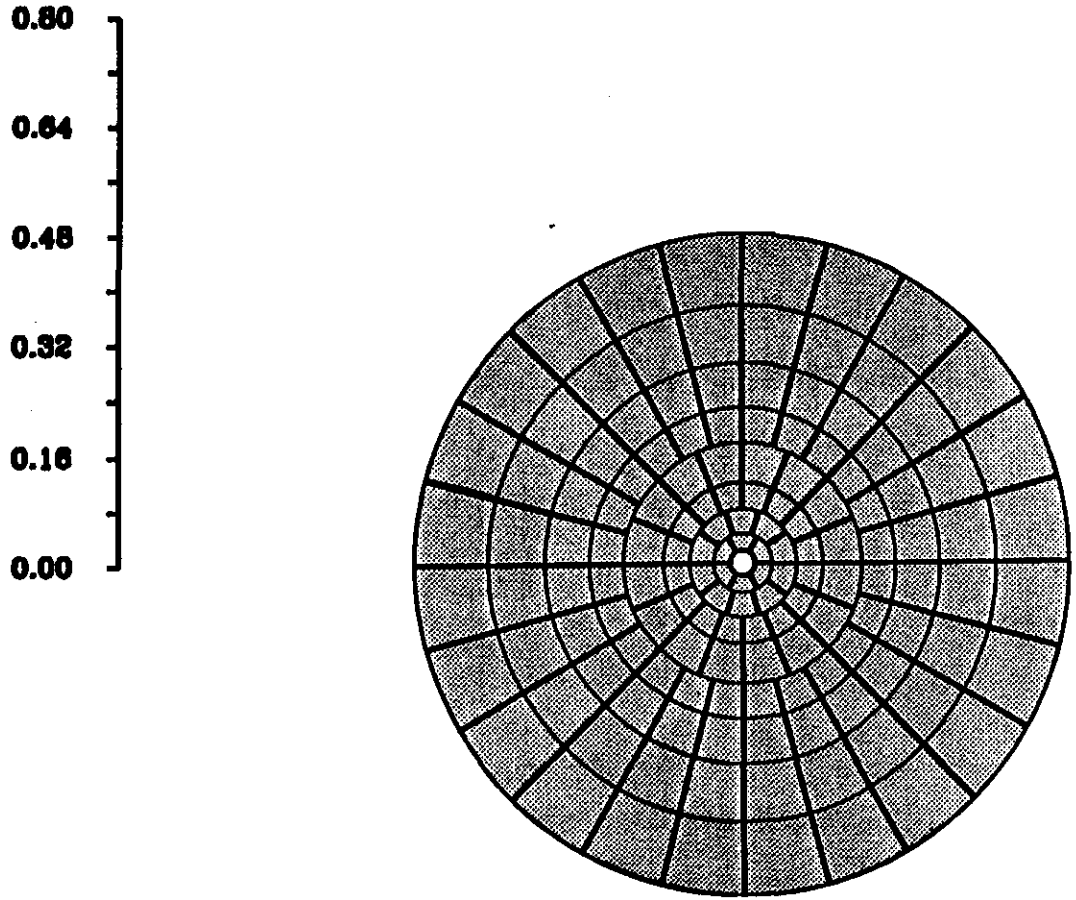
15.5 Tonnes each

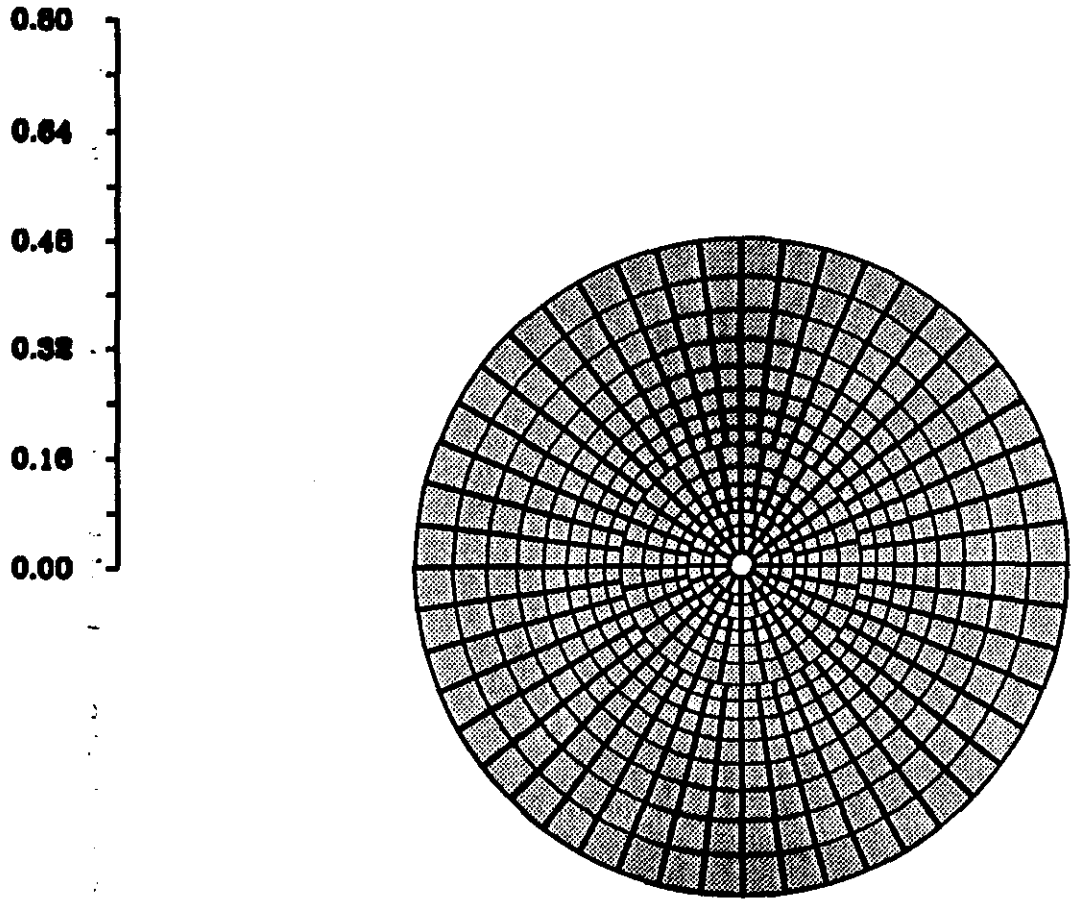


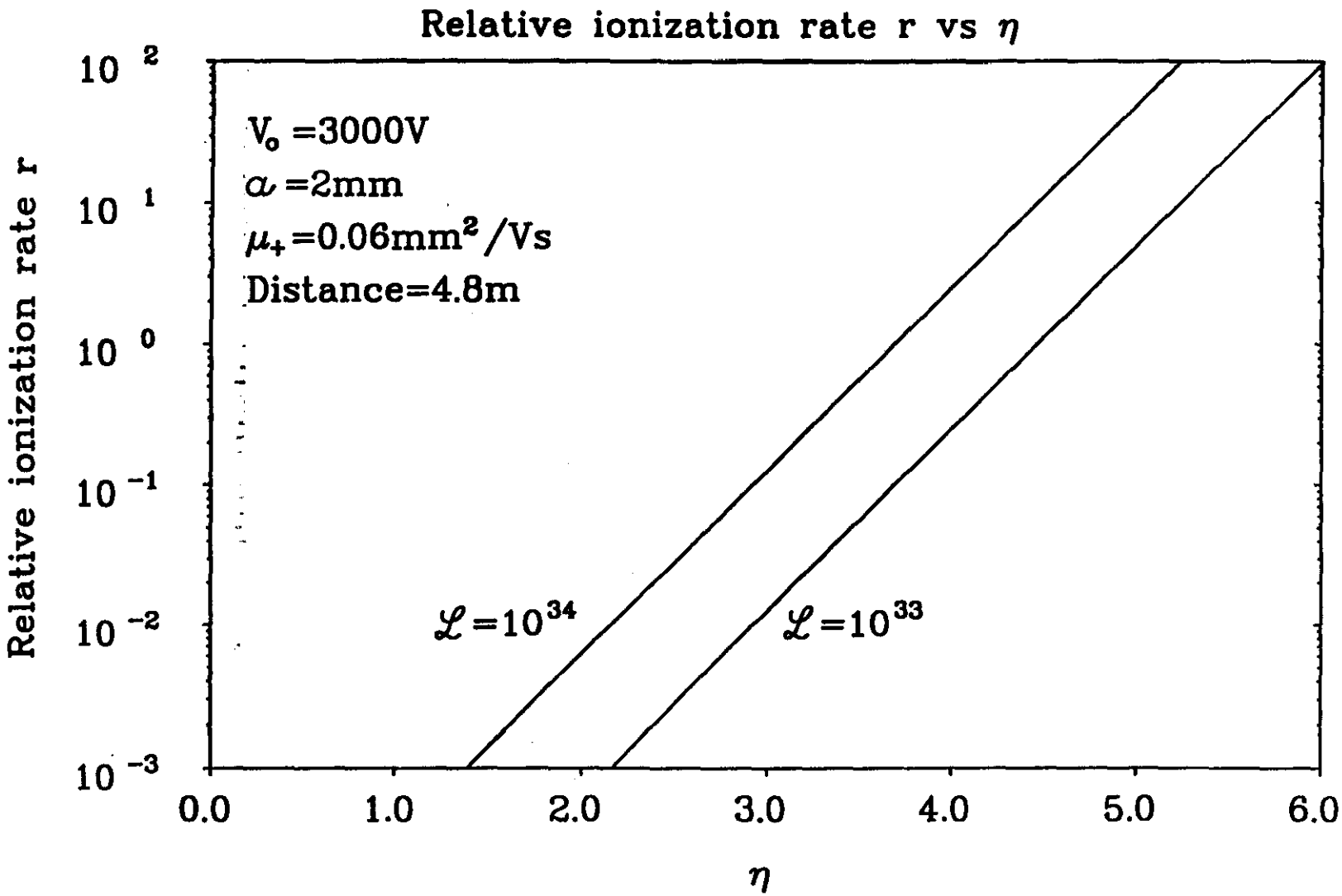
FCal

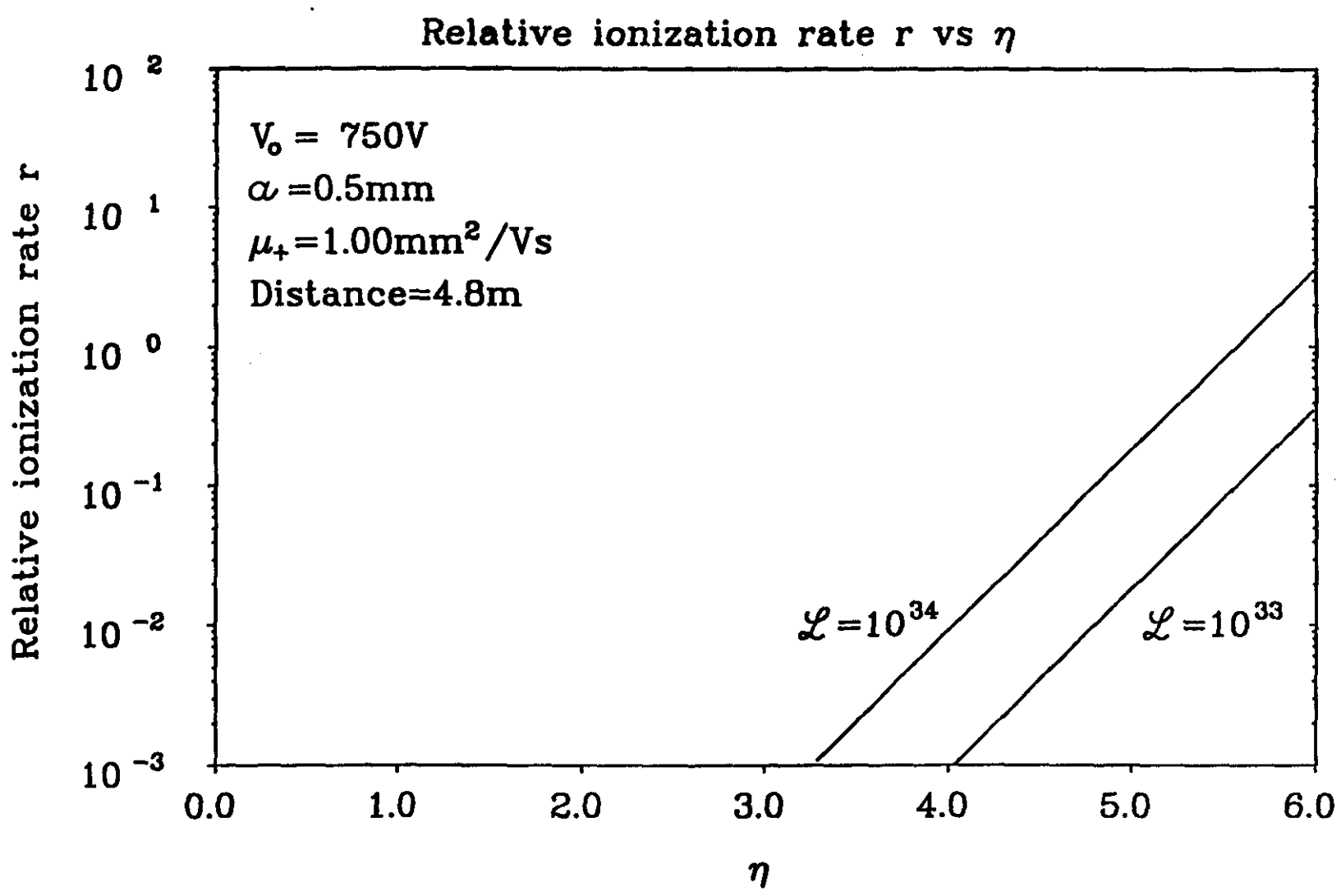

Vacuum
Vacuum Wall
Cold Wall
Beam Pipe
O-ring seal
LN2 Cooling Loop
Rough Vacuum
33
40


0.8 m
0.6 m
0.5 m
0.3 m
0.2 m
0.0 m
Hadron
Radial
Lateral
Photon
Jet
Moliere
Radius
50%
80%
90%
ΔR=0.7
@η=4.0


0.80
0.64
0.48
0.32
0.16
0.00


0.80
0.64
0.48
0.32
0.16
0.00


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


Relative ionization rate r vs η
V_o = 750V
α =0.5mm
μ_+=1.00mm²/Vs
Distance=4.8m
$\mathcal{L}=10^{34}$
$\mathcal{L}=10^{33}$
Relative ionization rate r
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
0.0
1.0
2.0
3.0
4.0
5.0
6.0
η

Missing-E_T Signatures at SSC

Frank E. Paige

Any new heavy particle must decay into quanta of the standard model,

- Leptons (e, μ, τ)
- Photons
- Jets (g, u, ..., t)
- Neutrinos

or into new stable particles.

SSC physics may involve any combination of these.

New stable particles are typically neutral and weakly interacting.

Need $\not{E}_T$ to detect them and ν's.

$\not{E}_T$ needed to reconstruct neutrinos from many standard model sources:

$$W^{\pm} \to \ell^{\pm}\nu$$

$$Z^0 \to \nu\bar{\nu}$$

$$\tau \to \nu_\tau X$$

$$c,\ b,\ t \to \ell\nu X$$

Useful as signatures for new physics.

Lightest SUSY particle $\widetilde{\chi}_1^0$ is typical example of new weakly interacting particle.

Absolutely stable in MSSM.

Coupling is $\mathcal{O}(e)$, so cross section is

$$\sigma \sim \frac{\alpha^2}{m_{\widetilde{q}}^2} \sim \sigma_\nu$$

Physics Signatures

$\not{E}_T$ is at least useful for many possible physics channels:

Standard Higgs: Heavy Higgs is not very likely, but it is important benchmark. Cleanest mode is

$$H \to Z^0 Z^0 \to \ell^+\ell^-\ell^+\ell^-,$$

Very small rate. Can double it using

$$H \to Z^0 Z^0 \to \ell^+\ell^-\tau^+\tau^-$$

Can be fully reconstructed using $\not{E}_T$ plus Z^0 mass constraint.

Needs background study!

$\ell^+\ell^-\ell^+\ell^-$ rate increased by factor of six with

$$H \to Z^0 Z^0 \to \ell^+\ell^-\nu\bar{\nu}.$$

Large background from Z^0 + jets. Can eliminate with hard cuts, but remaining signal small.

WW Interactions: If no new physics, then strong WW interactions for $M_{WW} \sim 1\,\mathrm{TeV}$. Interesting in any case.

Can use $\not{E}_T$ to reconstruct

$$W^{\pm}Z^0 \to \ell^{\pm}\nu\ell^{+}\ell^{-}$$

with quadratic ambiguity.

Like-sign channel

$$W^{\pm}W^{\pm} \to \ell^{\pm}\nu\ell^{\pm}\nu$$

has no $q\bar{q}$-induced continuum, although there are other standard-model backgrounds. Cannot reconstruct even with $\not{E}_T$, but knowing $\not{E}_T$ helps to estimate the WW mass.

Similarly for W^+W^- channel if it can be separated from $t\bar{t}$ background.

Jet Tagging: Forward calorimetry useful for detecting the forward jets from WW fusion. Reduces the QCD backgrounds, albeit not by large factors.

SUSY: LEP data are consistent with SUSY GUTS for masses in the 100 GeV–1 TeV range. Meaningful *only* because masses are sensible. But sensitive to details.

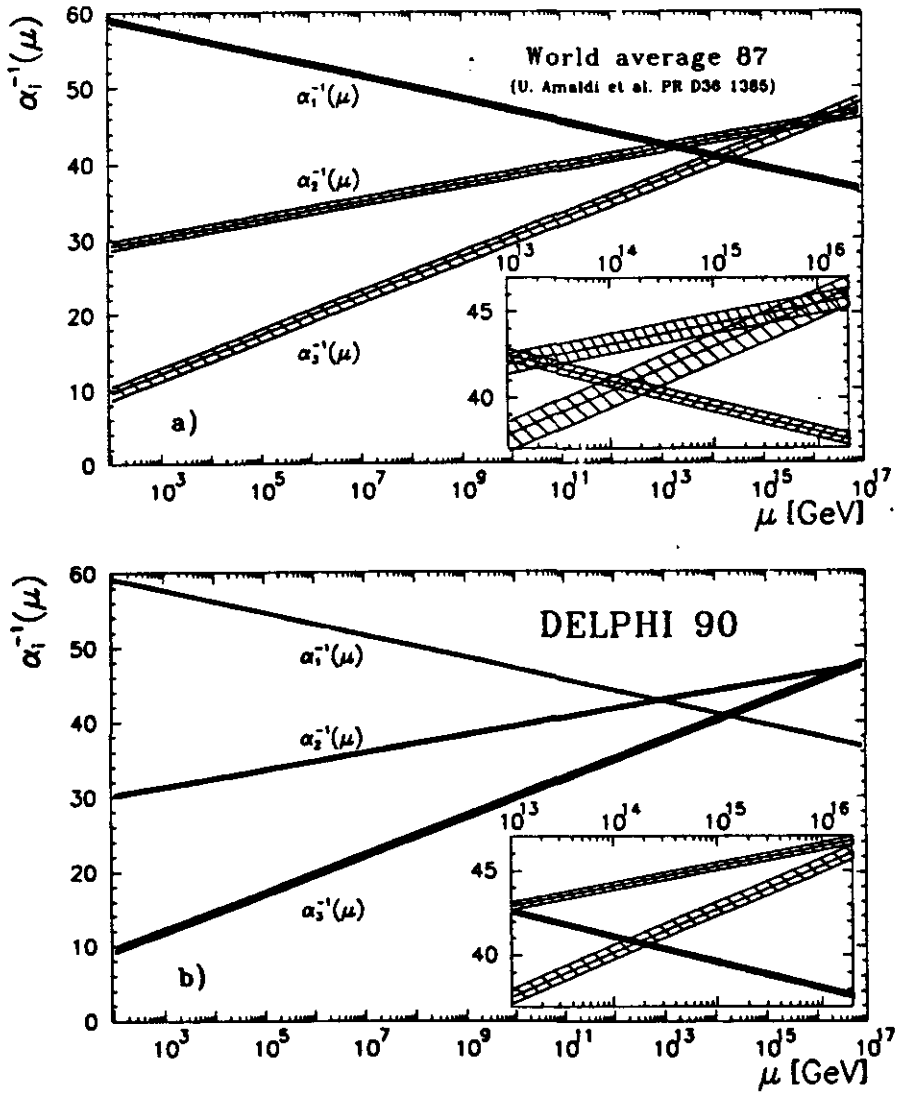


Fig. 1. (a) First order evolution of the three coupling constants in the minimal standard model (world average values in 1987 from ref. [1]). The small figure is a blow-up of the crossing area). (b) As above but using M_Z and $\alpha_s(M_Z)$ from DELPHI data. The three coupling constants disagree with a single unification point by more than 7 standard deviations.

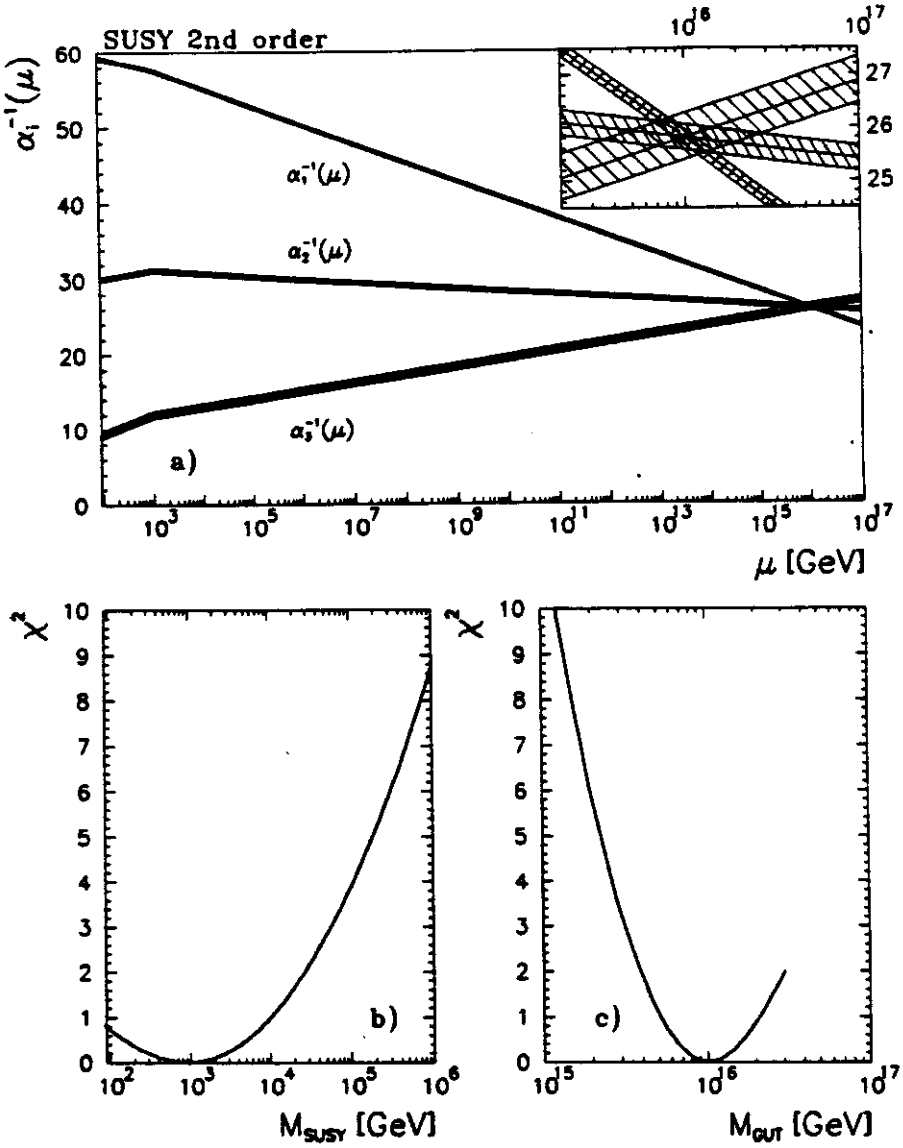


Fig. 2. (a) Second order evolution of the three coupling constants in the minimal SUSY model. M_{SUSY} has been fitted by requiring crossing of the couplings in a single point. The two lower plots show the χ^2 distribution for the SUSY scale M_{SUSY} (b) and for the unification scale M_{GUT} (c) taking into account their correlation.

SUSY particles are pair produced, decay into LSP $\widetilde{\chi}_1^0$, producing $\not{E}_T$ plus multiple jets and leptons.

$\not{E}_T$ signature for $\widetilde{g}\widetilde{g}$ is observable if detector covers $\eta \lesssim 5.5$. More work needed to reconstruct full decay scheme and separation of $\widetilde{q}$ and $\widetilde{g}$.

Technicolor: Dynamical model for Higgs bosons. All models predict

$$\rho_{TC}^{\pm} \to W^{\pm} Z^0 \to \ell^{\pm} \nu \ell^+ \ell^-.$$

Typical $m \sim$ 1–2 TeV, so small rates. Maybe can assume

$$p_{T,W} \approx p_{T,Z}$$

Technicolor generally gives pseudo-Goldstone bosons, e.g. a spin-0, color-3

leptoquark P_3:

$$gg \to P_3 P_3 \to b\tau\bar{b}\bar{\tau}.$$

Reconstruct using components of $\not{E}_T$; need good resolution for moderate $\not{E}_T$.

New Gauge Bosons: Might observe

$$W'^{\pm} \to \ell^{\pm}\nu,$$

for $m \lesssim 6$–$8\,\mathrm{TeV}$. Very large $\not{E}_T$, so hermetic detector may not be important.

Experimental Requirements

Want background from detector not large compared to SM ν cross section. Issues:

- η coverage
- Resolution in E, p_T
- Cracks, non-Gaussian tails

Can examine first two using toy calorimeter. Need real design and full simulation for cracks.

To improve statistics, examine total $\not{E}_T$ cross section. Should redo this with cuts appropriate to specific signals, say gluinos.

Generate 4000 events/bin with ISAJET:

$$25\,\mathrm{GeV} < p_T < 50\,\mathrm{GeV}$$

$$50\,\mathrm{GeV} < p_T < 100\,\mathrm{GeV}$$

$$100\,\mathrm{GeV} < p_T < 200\,\mathrm{GeV}$$

$$200\,\mathrm{GeV} < p_T < 400\,\mathrm{GeV}$$

$$400\,\mathrm{GeV} < p_T < 800\,\mathrm{GeV}$$

Includes c, b, and t quarks, and hence (most of) real $\not{E}_T$ cross section. No $\not{E}_T$ cuts.

Simulate toy calorimeter using CALSIM:

$$\Delta\eta = \Delta\phi = 0.1, \quad \eta < 6$$

Find jets with $E_T > 10\,\mathrm{GeV}$ in $R < 0.7$ with GETJET.

Sum of minijets reproduces $\not{E}_T$ from whole detector. Hence can use jet resolutions to model detector effects.

Signal for 300 GeV gluino has $\not{E}_T \sim$ 100 GeV. Want detected $\not{E}_T$ cross section in this region comparable to true $\not{E}_T$ background.

Case I: Perfect E resolution. Compare sum of calorimeter with that of jets with various η cuts.

$\eta < 6$: Jet sum similar to true $\not{E}_T$ distribution.

$\eta < 5$: Substantial extra background for $\not{E}_T \sim 50$ GeV.

$\eta < 4$: Detector dominates for $\not{E}_T \lesssim$ 500 GeV.

$\eta < 3$: Hopeless.

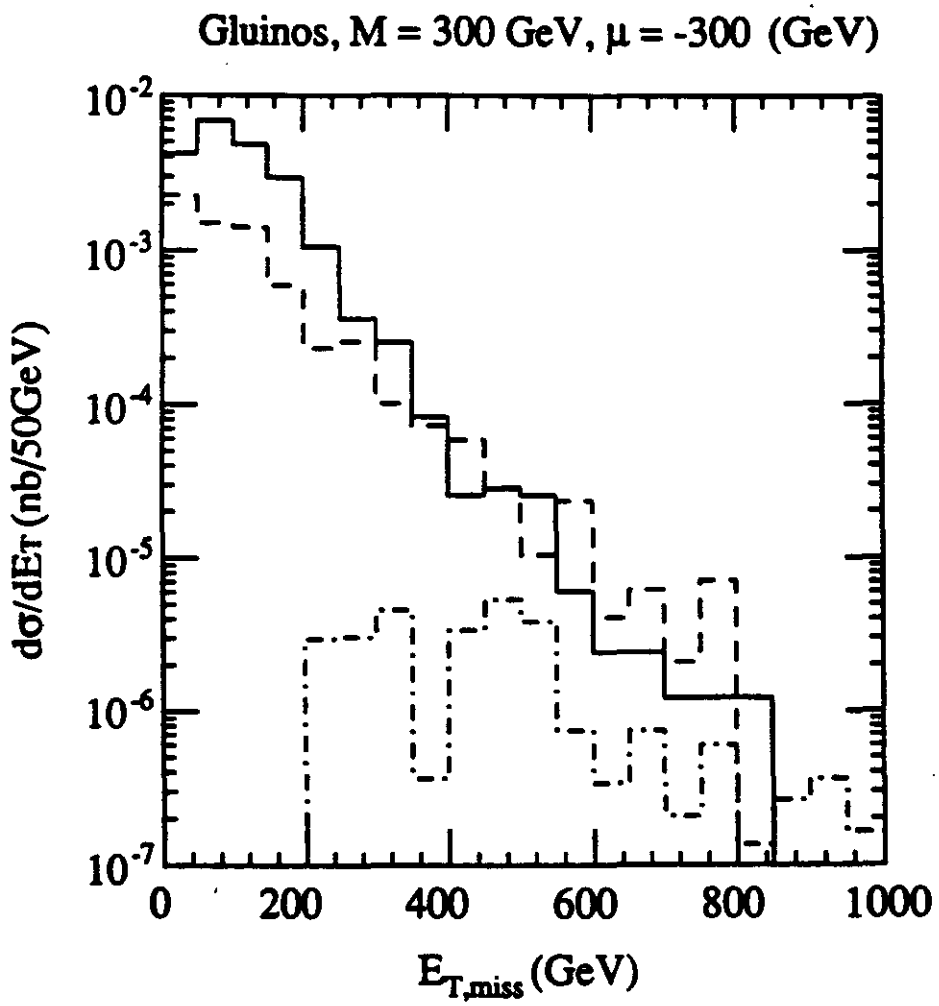


Figure 3.4-4 $\not{E}_T$ signal after cuts for 300 GeV gluino and backgrounds. Solid: gluinos. Dashed: heavy quarks. Dotted: $Z^0 \rightarrow \nu\bar{\nu}$

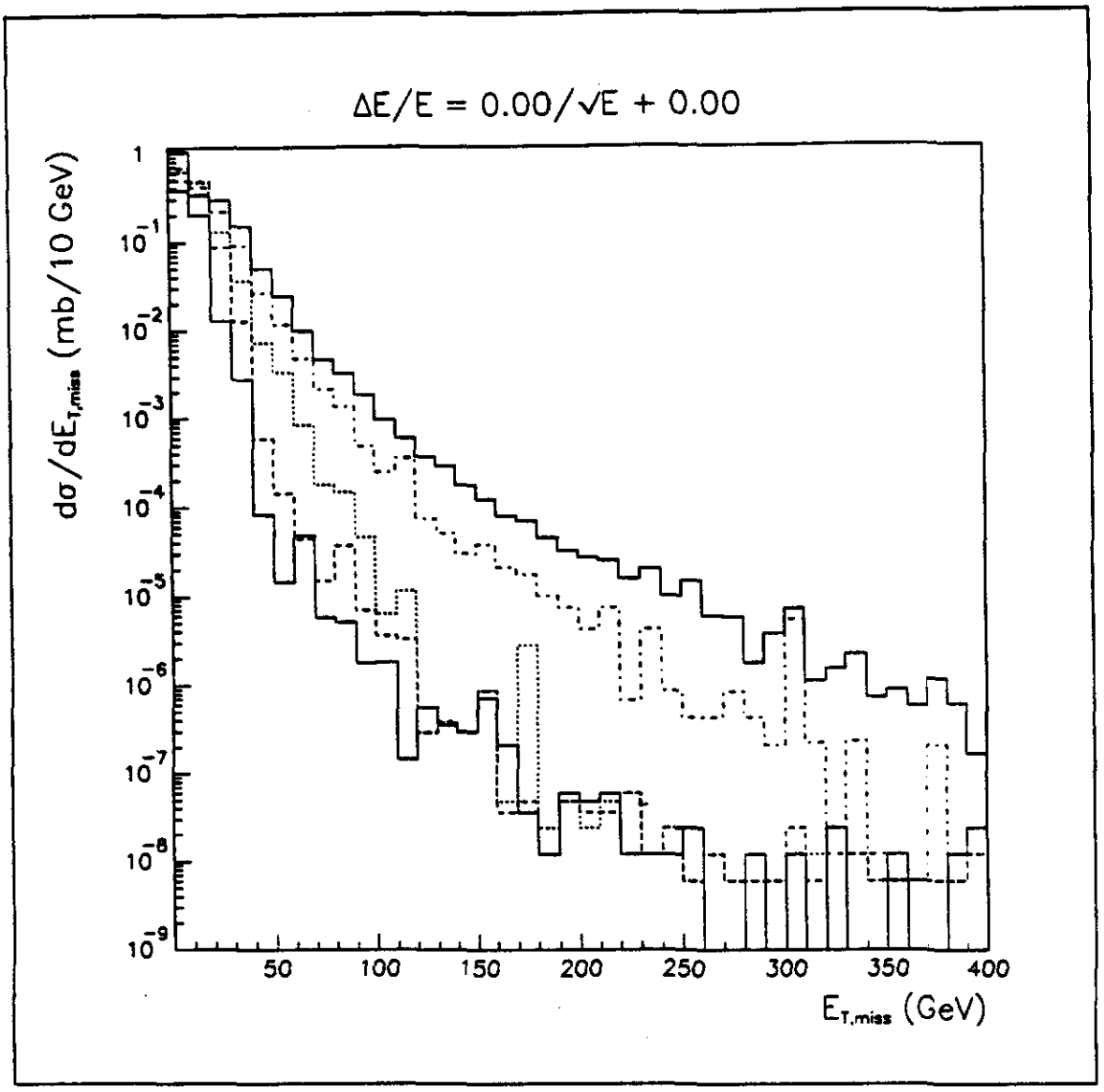
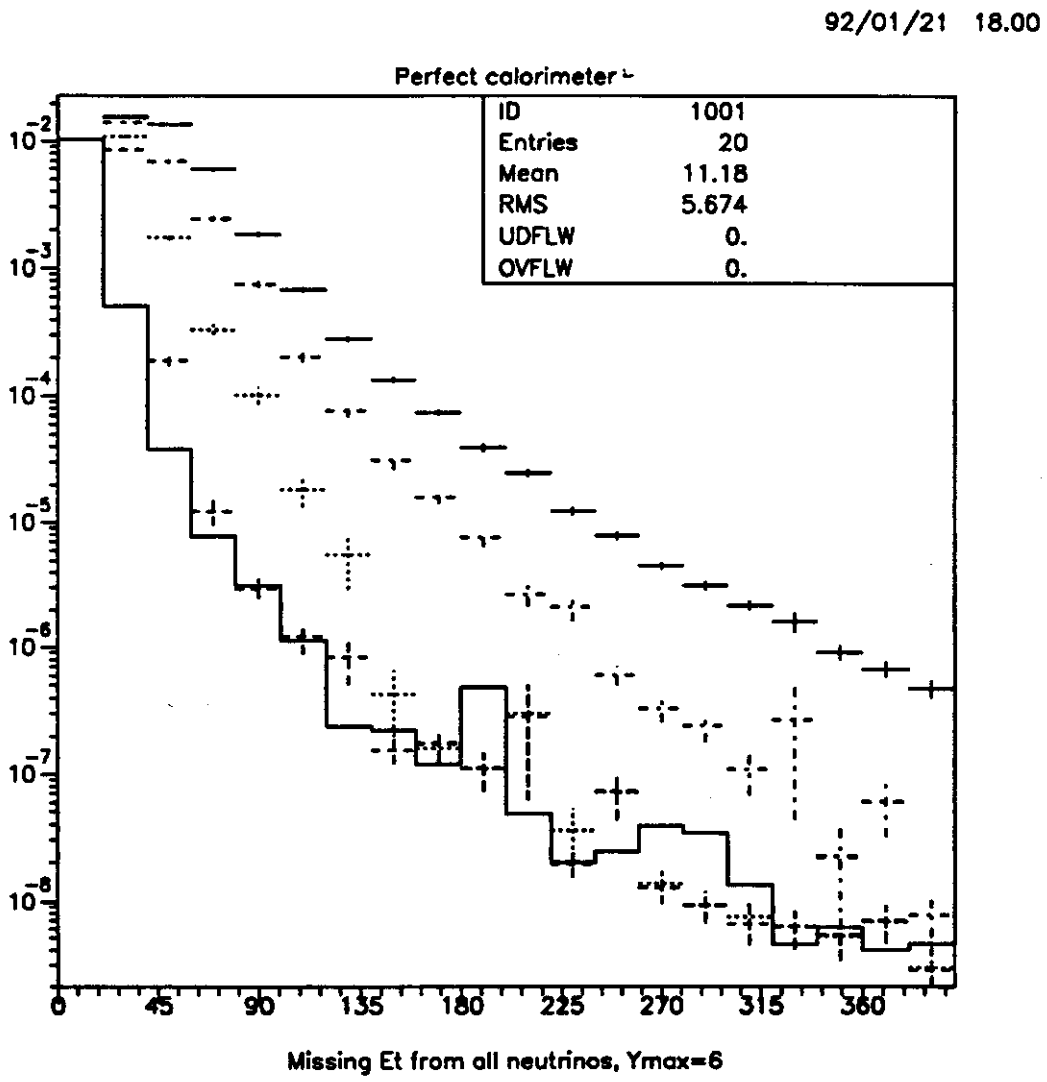


Figure 1: $\not{E}_T$ cross section for perfect energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

New calculation using better calorimeter simulation and analysis and 25 K events/bin (Vanyashin).



Case II: Add Gaussian energy resolution

$$\Delta E/E = 0.50/\sqrt{E} \oplus 0.02$$

Similar results.

Case III: Add Gaussian energy resolution

$$\Delta E/E = 0.70/\sqrt{E} \oplus 0.05$$

Similar results.

Case IV: Perfect energy resolution but with a cut pT, jet $> 20\,\mathrm{GeV}$. Some effect at small $\not{E}_T$.

Case V: Smear jets with $\eta > 3$ with a Gaussian p_T resolution of 10% or 20% (c.f. Arizona group).

Some degredation for 20%.

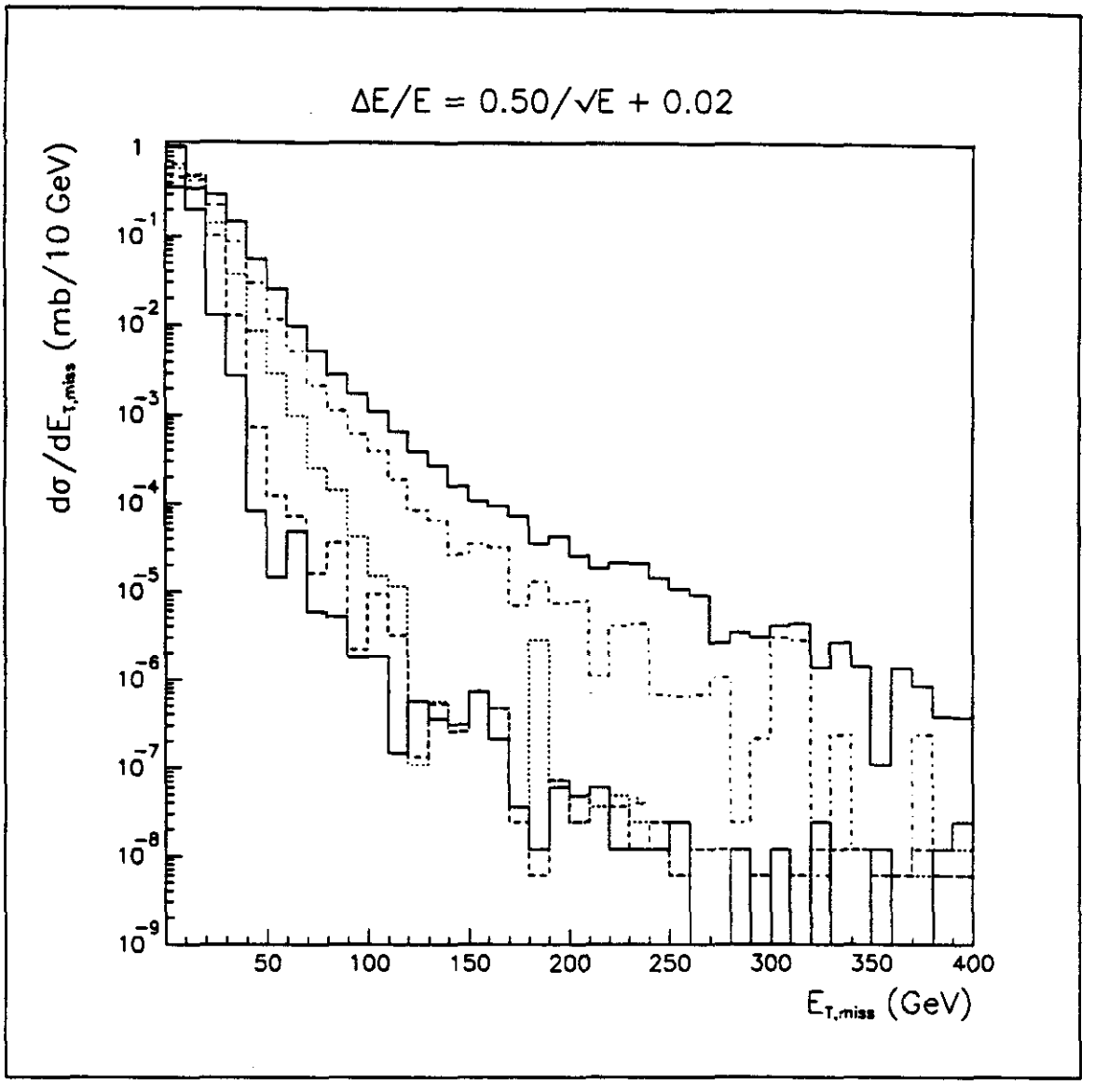


Figure 2: $\not{E}_T$ cross section for good energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

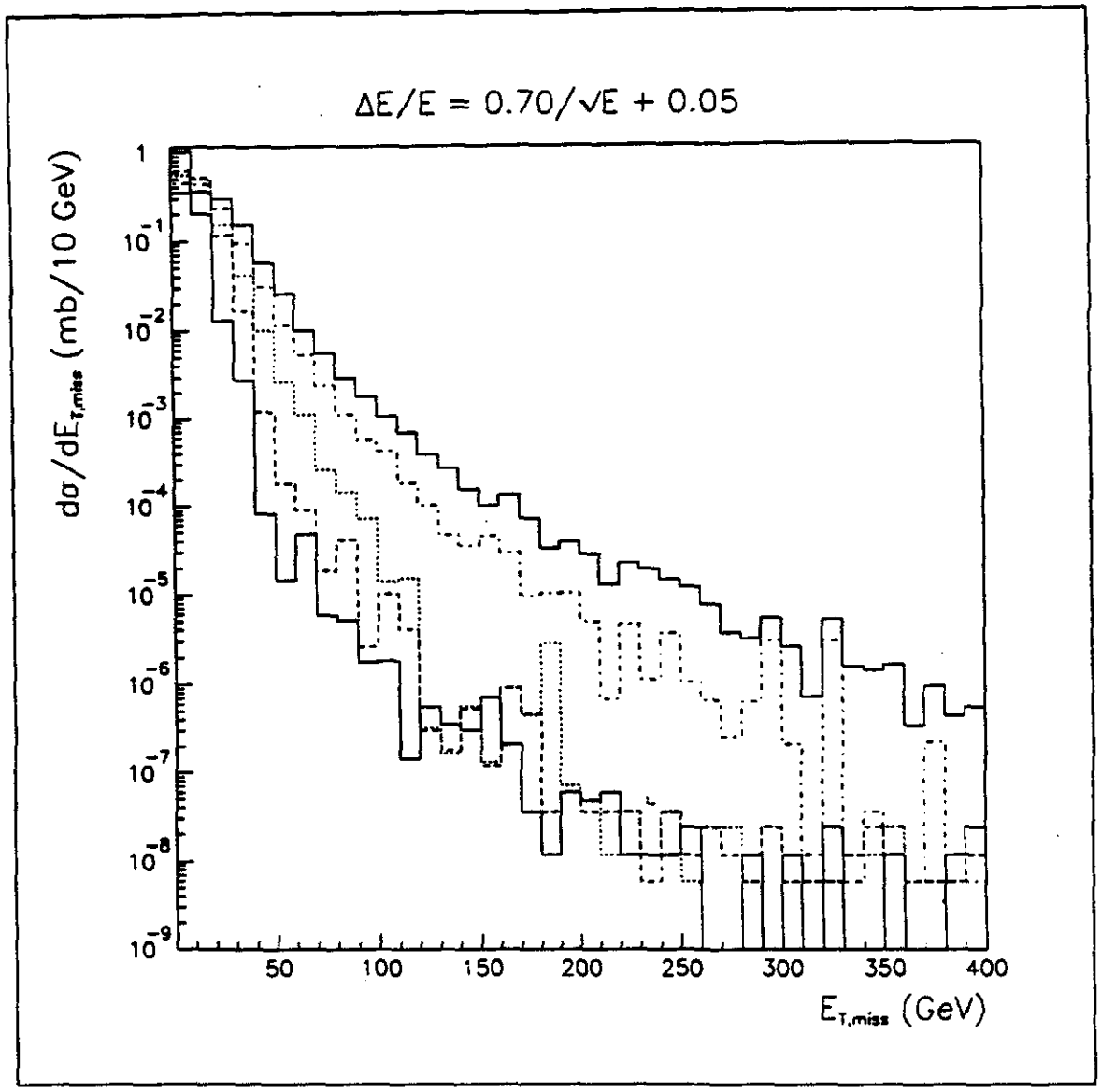


Figure 3: $\not{E}_T$ cross section for mediocre energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

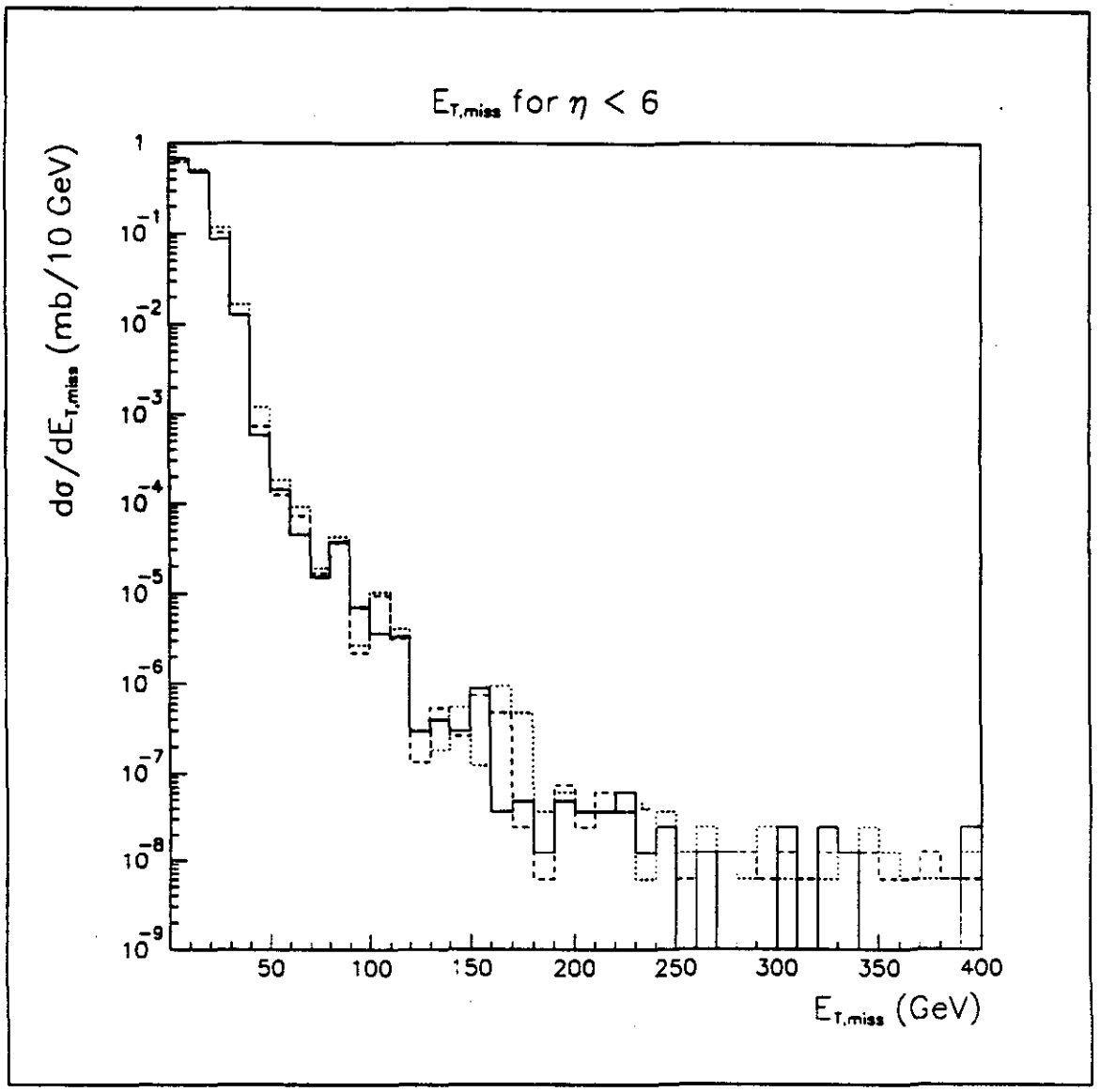


Figure 4: $\not{E}_T$ cross section for perfect resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

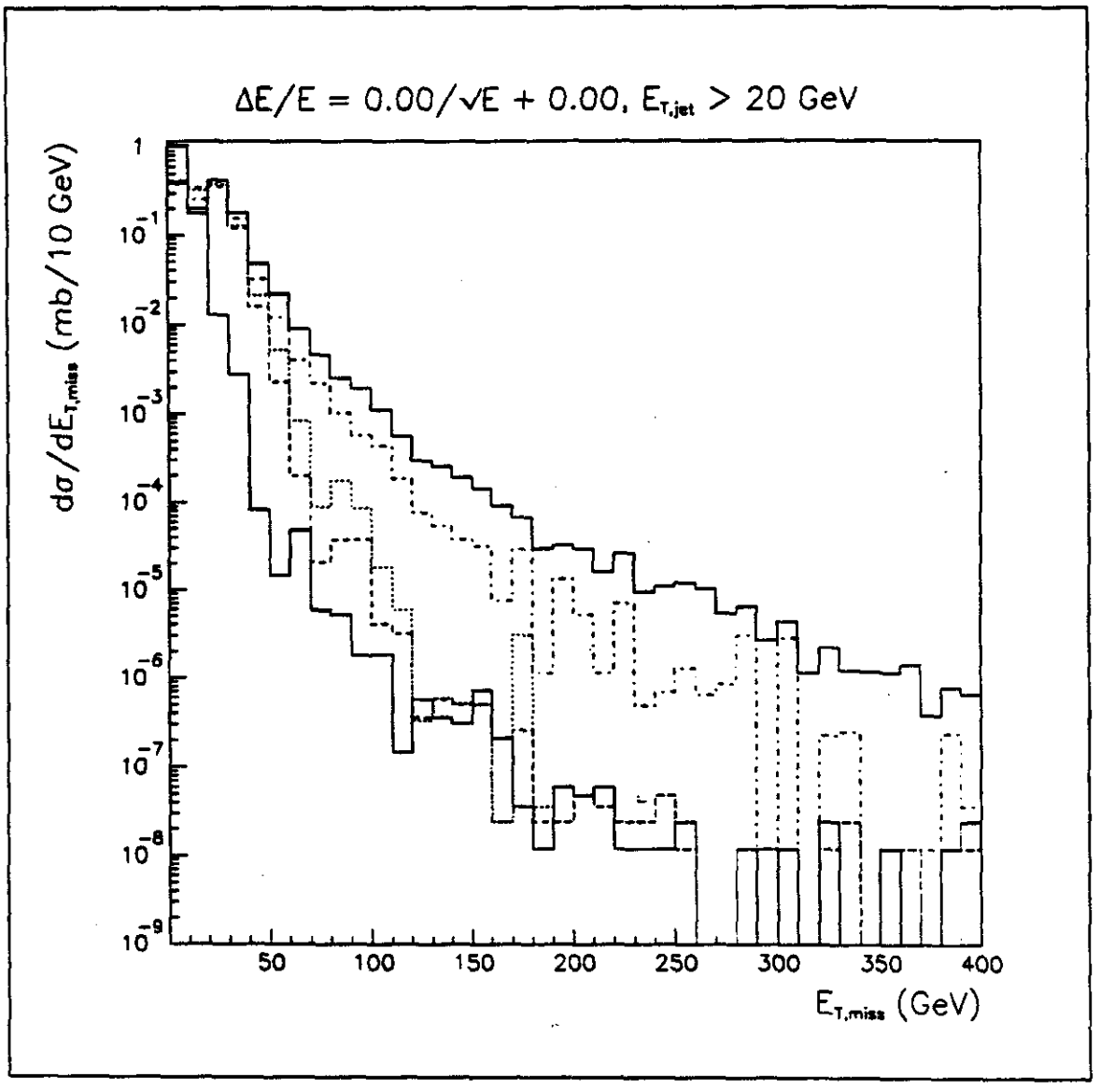


Figure 5: The same as Fig. 1 for $p_{T,\mathrm{jet}} > 20\,\mathrm{GeV}$.

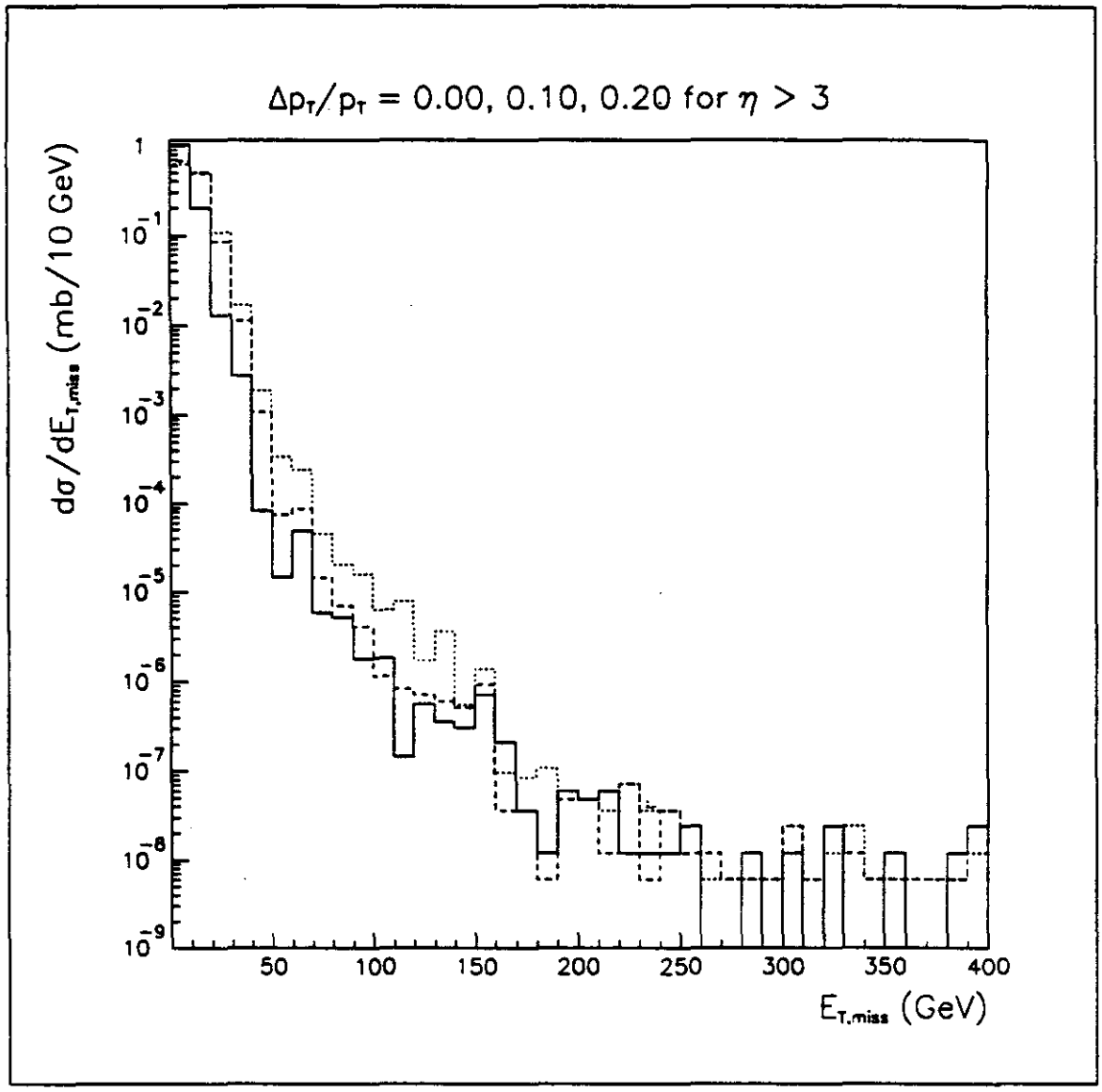


Figure 6: Solid: $\not{E}_T$ cross section for full calorimeter. Dashed: $\not{E}_T$ cross section with $\Delta p_T/p_T = 0.10$ for $\eta > 3$. Dotted: Same, for $\Delta p_T/p_T = 0.20$.

Within approximations used here, most important thing is to cover

$$\eta \leq 5\text{–}6$$

E and p_T resolution effects are much smaller.

Implications

Hadron shower has size $R \sim \lambda_I$. Hence estimate effective cutoff is

$$\eta_{\text{max}} \approx -\ln \tan \left(\frac{\lambda_I + R_{\text{pipe}}}{2L} \right)$$

Calorimeter must be dense and/or far away.

Effective η limit from real simulation? Should calculate resolution including leakage vs. η.

EM core of jet is much smaller.

Use EM core to determine jet direction, taking energy from hadron shower?

Use EM core at large η as veto? Signal efficiency?

Plans for Future Cavity
and its
Interaction with the "Flux Sucker"

An Update of work carried out
within the Integration and Magnet Groups
over the last few weeks...

Reported by

R. Webb
Texas A&M University
1/22/92

It has long been realized that the long solenoid configuration of L* and GEM required additional field shaping to provide "Good" muon momentum resolution for $|\eta| \sim 2.5$.

The Problem in GEM

$$\frac{\Delta p_T}{p_T} \sim 100\% \quad \text{for } p_T = 500\,\text{GeV} \quad @\ \eta = 2.5\,!!$$

So what are the possibilities for improving this muon momentum resolution at a "modest" cost ??

Possible Solutions

[1] Shaped pole piece

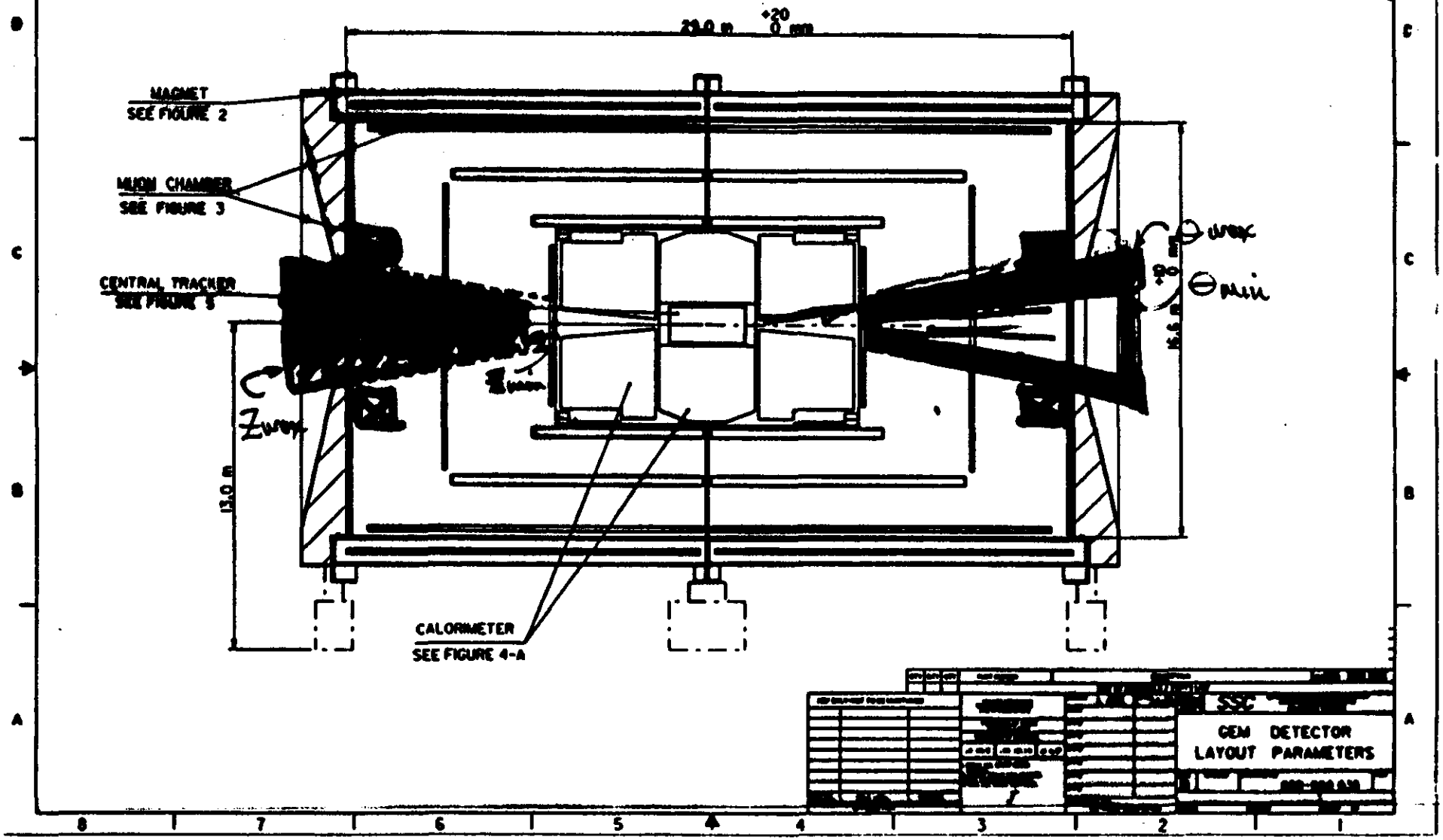
[2] Active Flux Termination

[3] Forward Toroids

[4] Field shaping plug ("Flux Sucker")

Supply final dimensions and tolerance on the drawing subsequently by the next meeting.

FIGURE 1



Since the presentation to the PAC of our LOI (and perhaps even before this time) work has progressed within the Magnet Design Team to evaluate possibilities [1], [2] & [4].

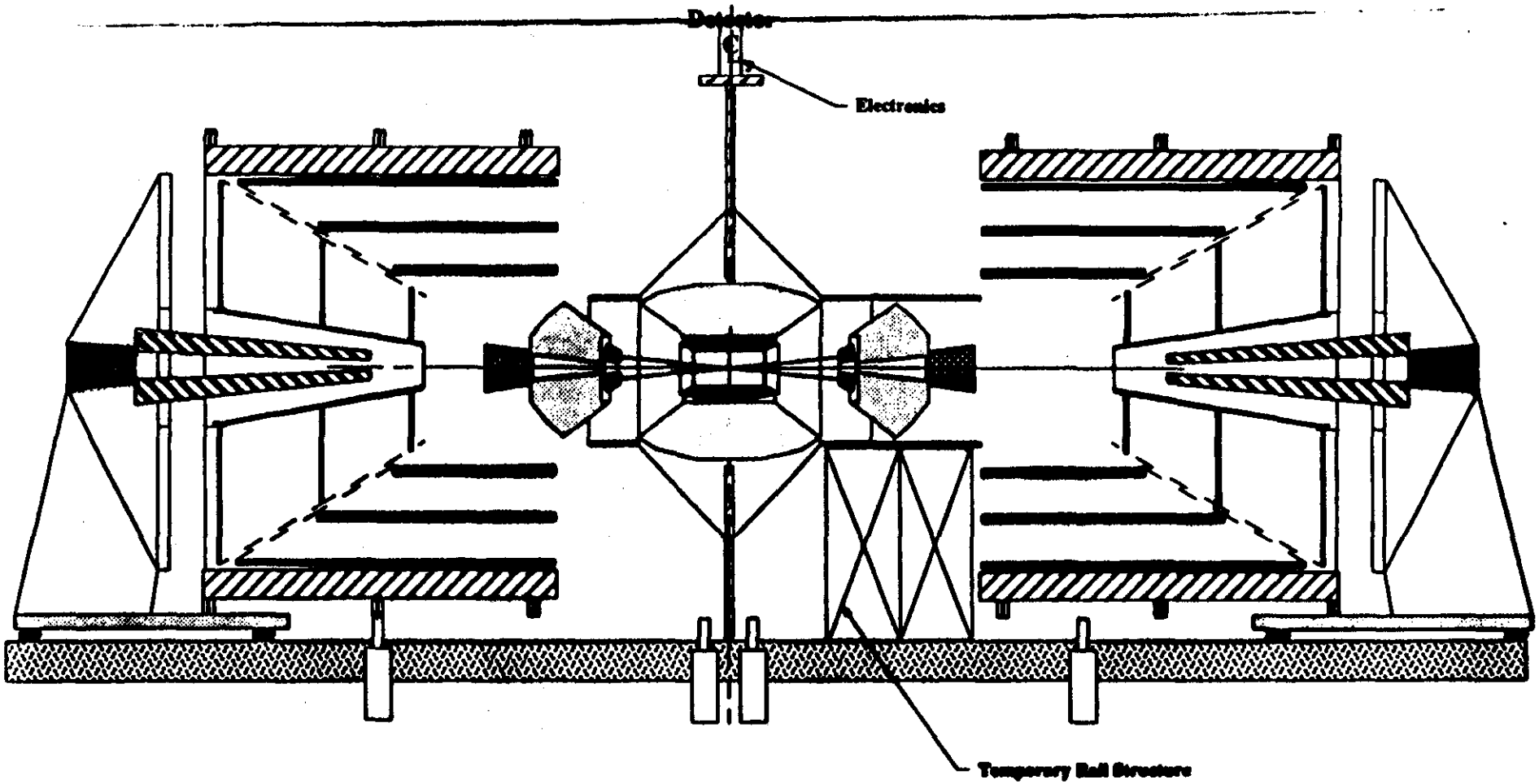
At a special Magnet Design Group meeting 2wks ago a detailed set of presentations of work along this line were made.

Jim Sullivan discussed progress mainly on designs which included options [1], [2] and [4].

To summarize the results presented at this meeting. It was found that a very simple conical shaped forward/backward plug could provide substantial resolution improvements at $\eta = 2.5$ (factor ~6) at a modest cost.

In the comparison of the flux sucker with actual forms of flux diversion it appeared that the flux sucker idea looked very promising.

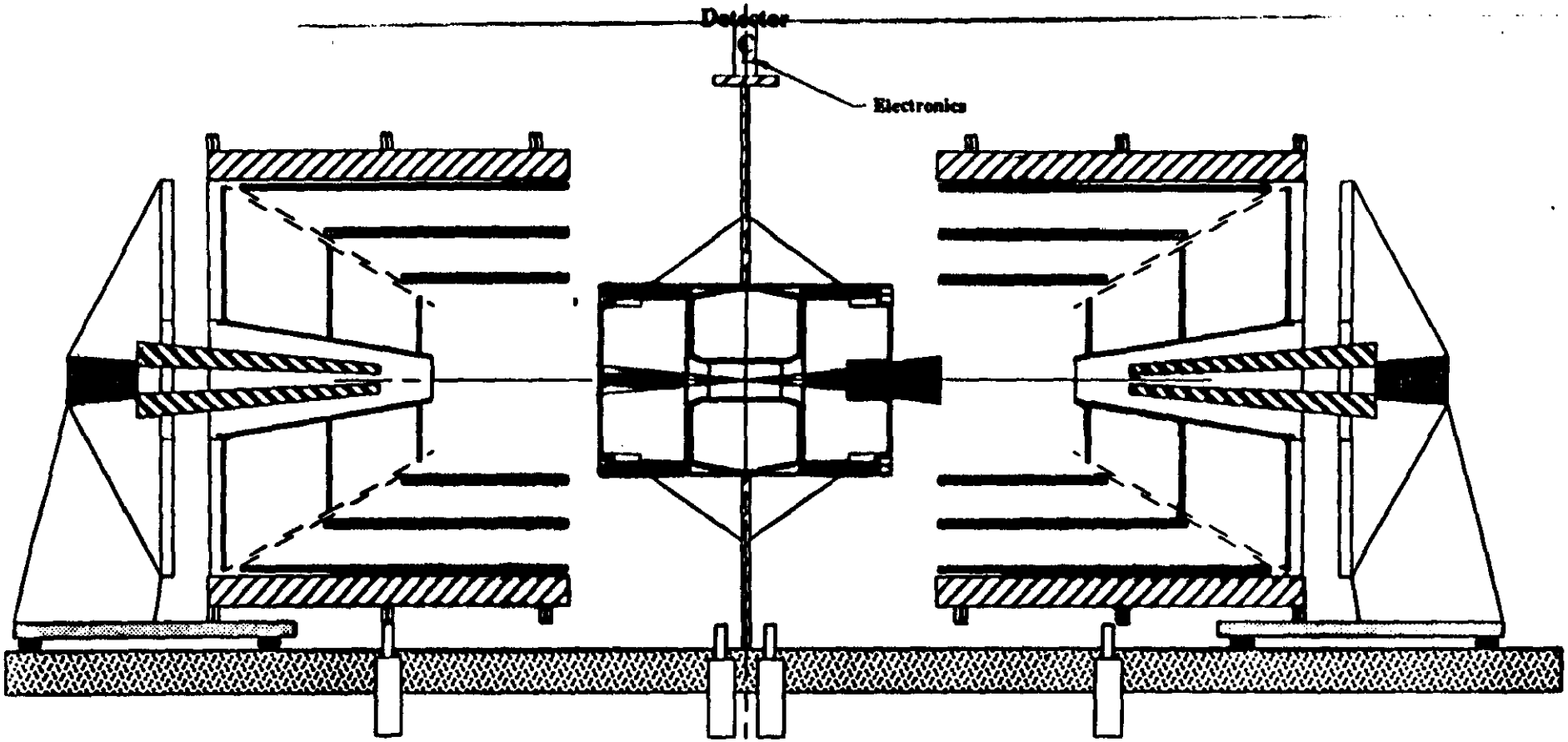
At this magnet meeting a long list of study parameters were outlined in order to see what the optimum shape of the iron pole piece would have with a response date of last week for the results.



GEM Configuration Option Study
Scintillating Calorimeter
Integral Calorimeter Version

G.03.AS.00010

EDERLE/RENNICH



GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version

G.83.AS.0003

BBBRLE/RENNICH

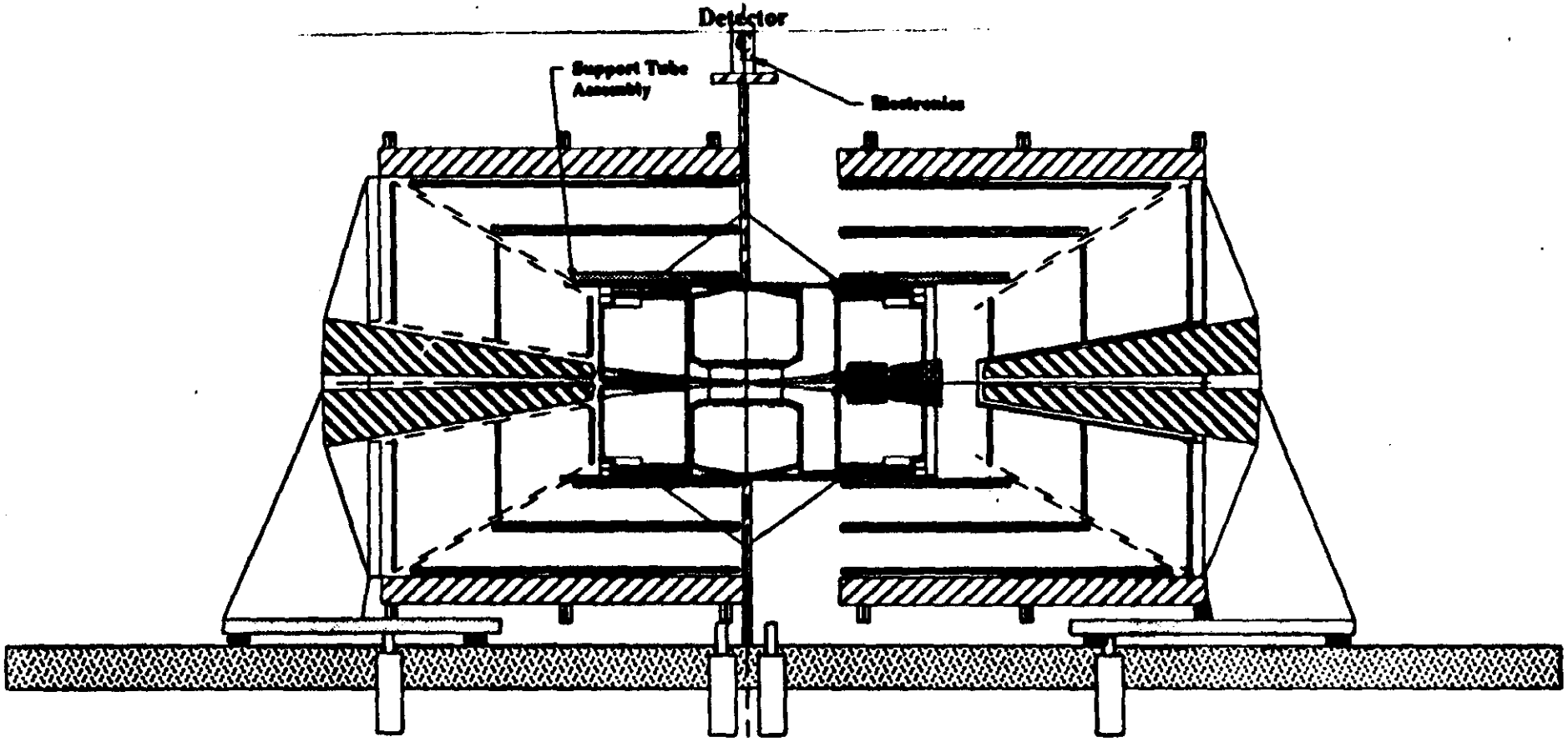
Results of Studies (The good news first)

(1) Iron pole piece appears to do little to shape field without flux sucker and with flux sucker doesn't contribute to field shaping. (Is a convenient support).

(2) Iron is saturated in the flux sucker so the larger the volume of iron the better.

a) can start at $z_{min} = 7\text{-}8$ m
b) needs to stick out of the pole $z_{max} = 16\text{-}17$ m
c) $\theta_{max} \sim 8°$
d) $\theta_{min} \sim 1°$

(3) $\frac{\delta p_T}{p_T} \sim 13\%$ for 500 GeV p_T @ $\eta = 2.5$!!



GEM Configuration Option Study
Liquid Argon Calorimeter
Integral Calorimeter Version
Short Term Access

G.03.A2.00017

EDERLE/RENNICK

What problems does this device present to the forward systems, calorimetry in particular?

Spatial Constraints

non-uniform magnetic fields

10 M tons of forces need to be restrained!!

Pole piece weighs ~ 900 tons/end !!

May complicate installation plans and detector access.

Overall integration question of Forward [illegible] with the Central Calorimeter/Flux Sucker/ ??

G. FANOURAKIS
28-JAN-92

HIGH PRESSURE GAS CALORIMETRY

- MOTIVATION
- PARALLEL PLATE HIGH PRESSURE EM CALORIMETER TEST AT FNAL
- RADIATION HARDNESS TESTS
- A DESIGN FOR SSC (SDC)
- CONCLUSION

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*** Also INFN, Pisa, I-56010 Pisa.

Table 3.3-2 Calorimetry Techniques (cont)

TECHNIQUE	ATTRIBUTES	DISADVANTAGES	R&D EFFORTS	REF.
		FORWARD CALORIMETRY		
High Pressure Gas	Faster than liquid Argon	e/π not measured	Performance	12
	Rad hard	Leaks	Engineering design	
	Small Moliere radius	Not proven in a large experiment		
	Inexpensive	Untested technology		
	Robust	Safety		
		Long term gain stability		
Warm Liquid - TMS	Fast	Purity maintenance to ppb/materials compatibility	Test of a prototype	13
	Rad hard	Calibration unproven		
		Not proven in a large experiment	Electronics development	
	Large dynamic range		Complete engineering workup	
	Small Moliere radius - uranium/tungsten	Expensive		
		Electronics embedded in the detector - rad hard		
	Compensated	Safety-flammability		
		Radiolysis production of gas and long lived isotopes	R&D on radiolysis products	
Liquid scintillator capillaries	Fast	Circulate and filter for > 10 Mrad dosage	Rad hardness	10
	Hermetic	Not proven in a large experiment	Liquid monitoring and recycling	
	Good resolution			
	Inexpensive	Leaks	Engineering of leak-proof design	
	Uniform response	Readout dynamic range	Calibration	
	Compensating			
	Small Moliere radius in tungsten version			
	Safe			
Liquid Argon				11
	Small Moliere radius in tungsten version			
	Rad hard			
	Mature technology	Dewar walls, supports etc.- degrade hermeticity	Detailed design	4
	Experience with construction of large systems	Speed/noise tradeoff- isolation cuts		
	Uniform response	Integration time- ≥40ns; pileup	Fast shaping preamps	
	10^5 dynamic range	Preamps inside dewar- reliability/maintenance/ hardness	Under test	
	Gain = 1	Cryogenic system	Detailed design	
	Simple calibration	Large sampling fraction e/h ~ 1.5	1 mm Pb plate to be tested	
		Positive ion buildup at high luminosity		
EM only:	$7\%/\sqrt{E} \oplus 0.5\%$ resolution for plate geometry	"Accordion" mechanics nontrivial for projective geometry.	Needs detailed design	5
		Large sampling fraction- long Lrad		

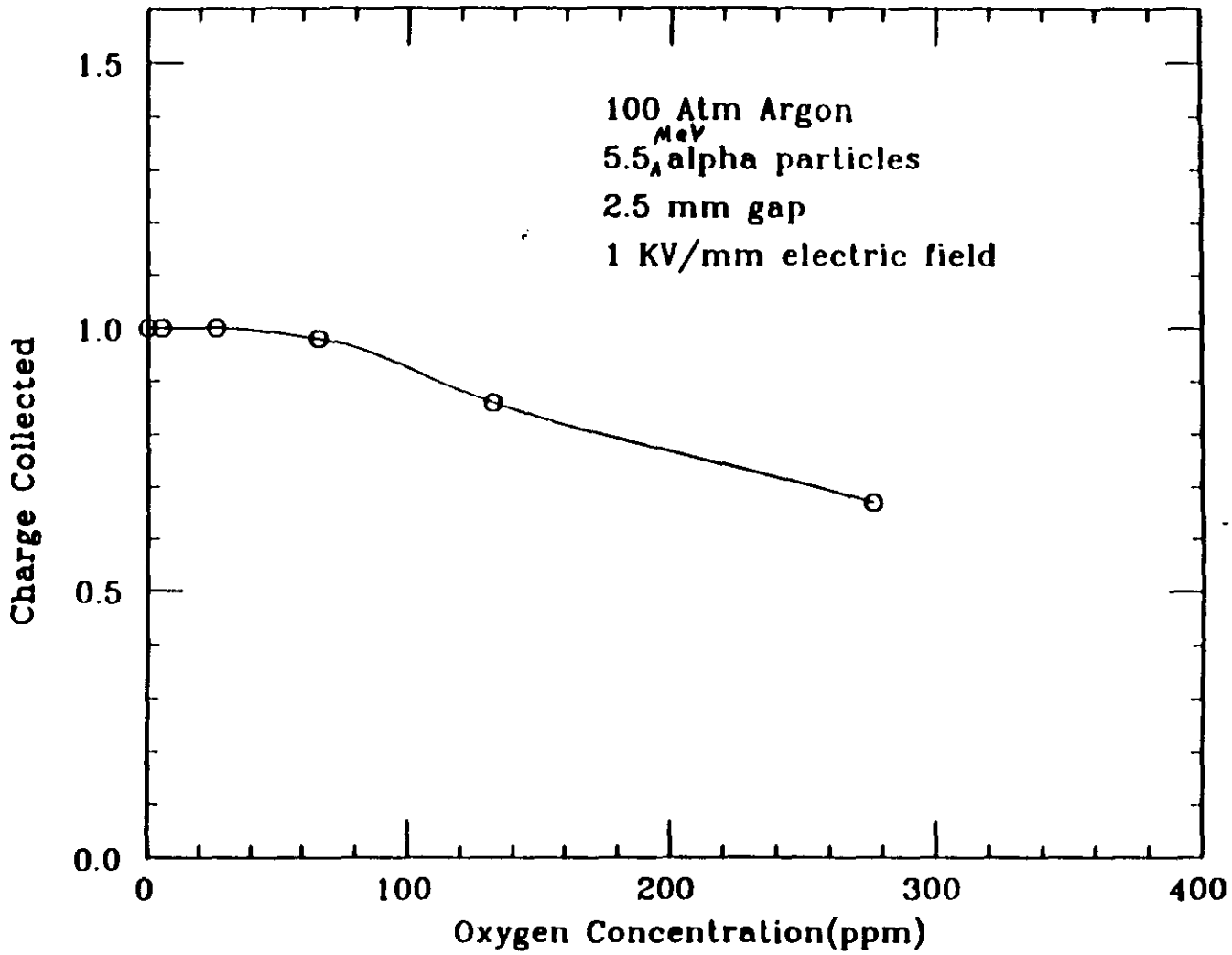
MOTIVATION FOR HPC

- The other options have complications and/or high costs
  - Liquid Argon : elaborate cryogenics, slow, dead regions, sensitive to impurities (ppm) space charge effects.
  - Warm liquids : Oversensitive to impurities (ppb), dangerous, dead regions, expensive, subject to radiolysis.
  - Liquid scintillator : no unity gain, needs filtering in high radiation environments.
  - Low pressure gas : Extremely low sampling, texas towers, glow mode problems.

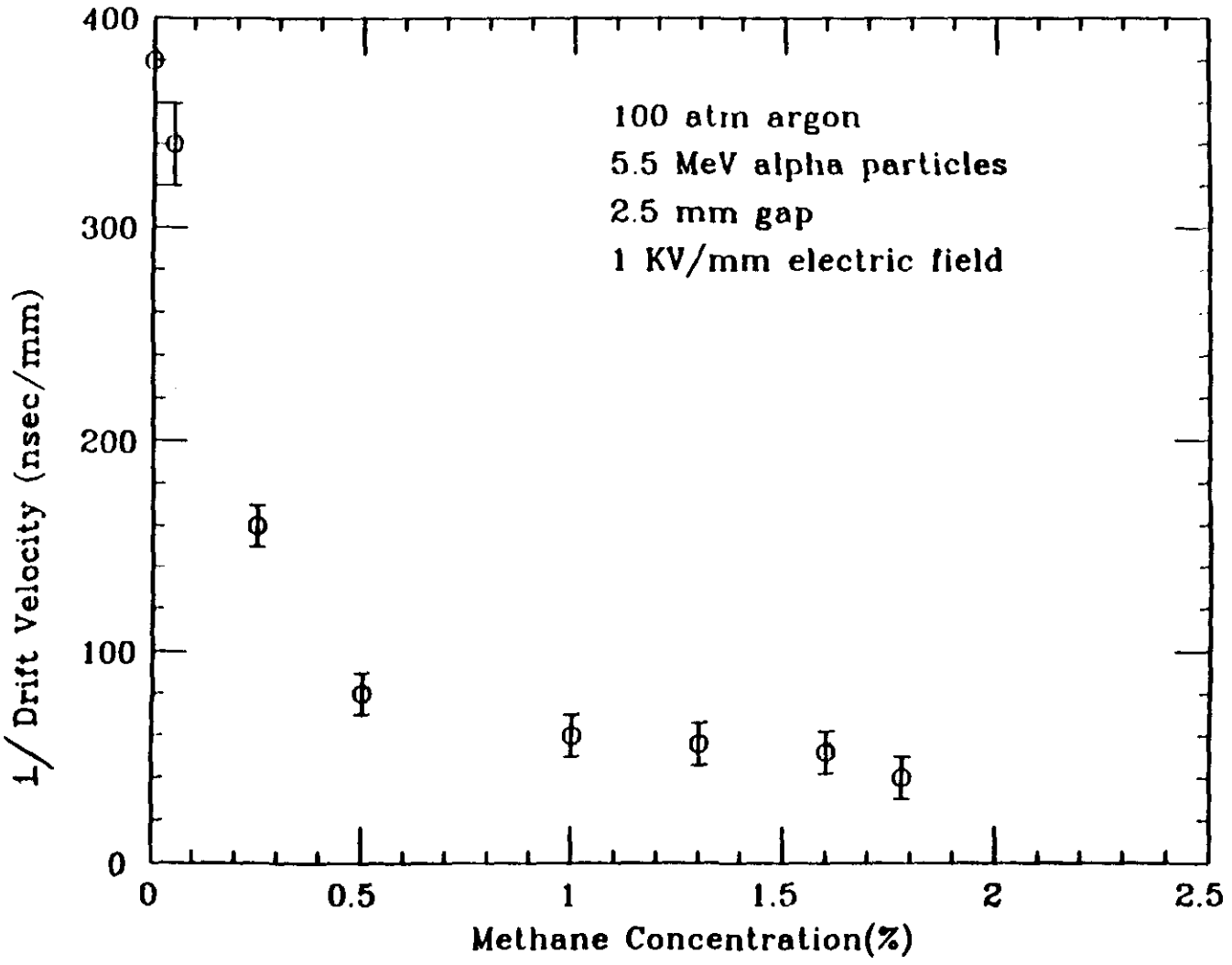
- It sounds like a good idea !
  - is it a bomb ?
  - 8 times lower sampling than LAr (only) for 100 at Ar
  - Unity gain
  - Some ground work has been done (20 atm max).
    1. V.I. Baskakov et al, NIM 159 (1979) 83.
    2. T.A. Amatuni et al, NIM 203 (1982) 179.
    3. D.M. Khazins et al, NIM A300 (1991) 281.

- Tests with an ^{241}Am α-source on the center of a 2 cm diameter cathode, an anode 2.5 mm away in a 1 lt vessel filled with 100 atm Ar.
  (N.D. Giokaris et al, NIM A291 (1990) 552

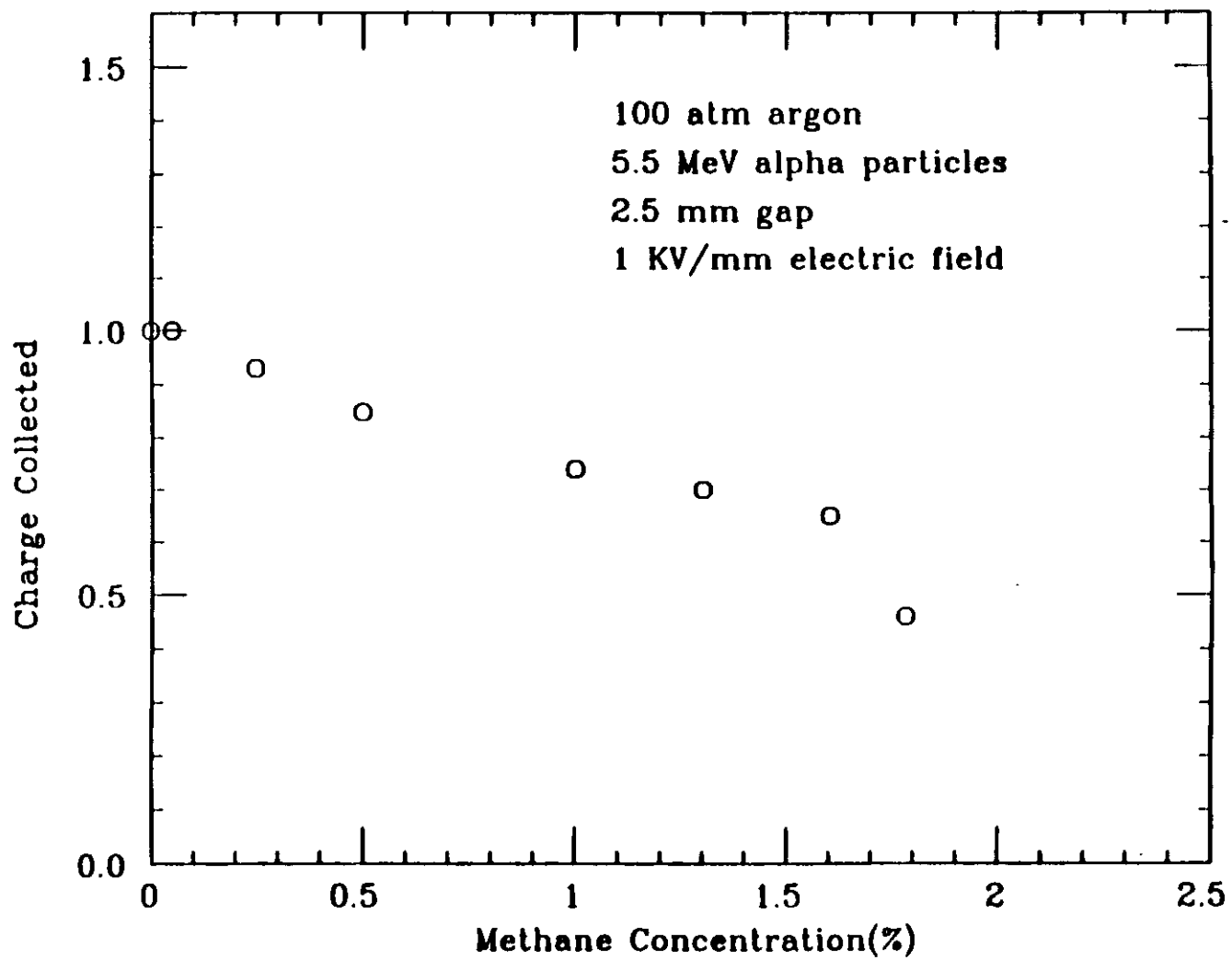
  - The signal loss due to 100 ppm O_2 is small (~9%)
  - The collection time of the electrons can be dramatically reduced by adding a few % CH_4.
    400 ns/mm → 60 ns/mm (with 1% CH_4)
    signal drops by 25%.
  - At 100 atm 70% of the total charge is collected



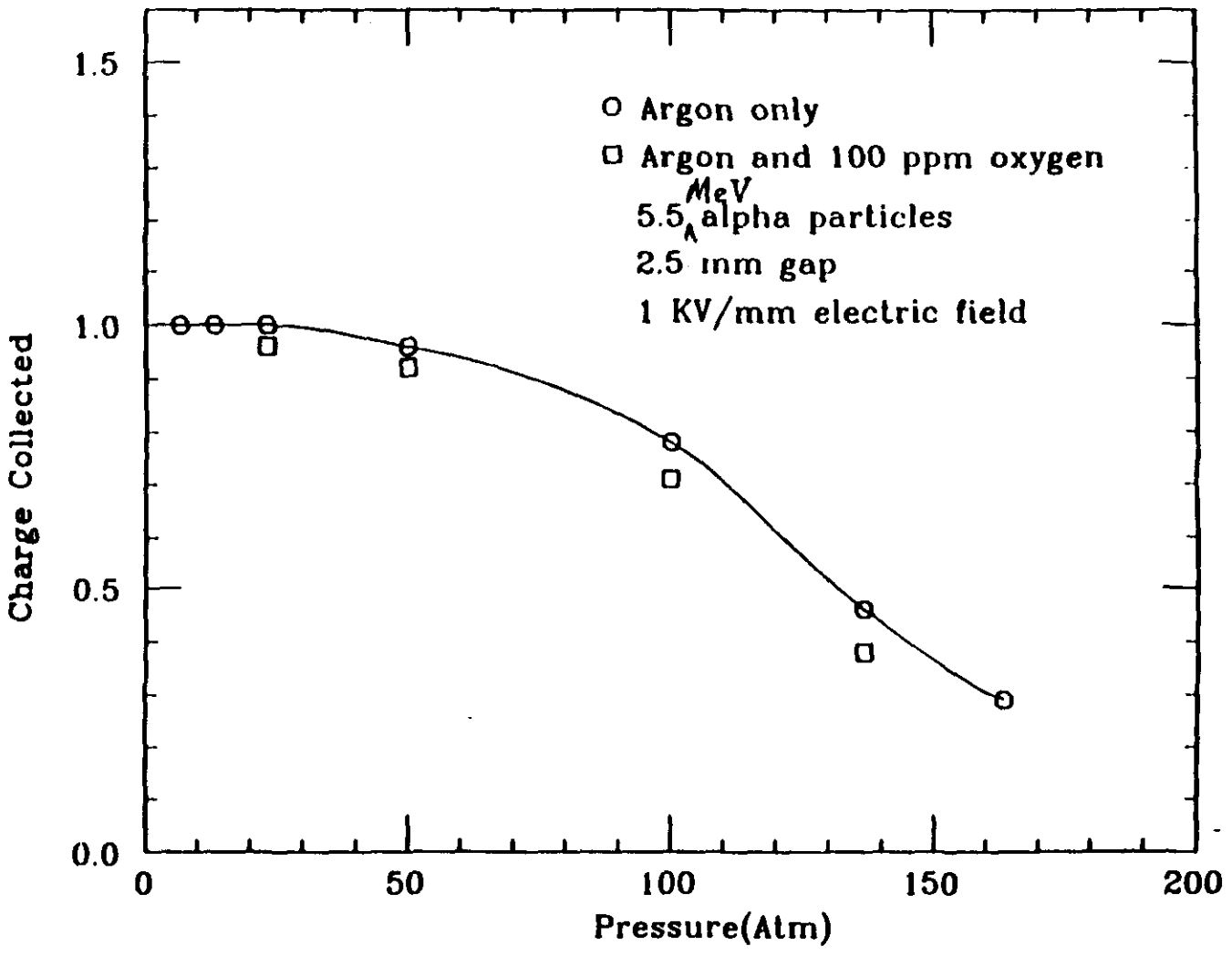
Charge collected as a function of oxygen concentration in 100 atm argon gas. The ordinate scale is normalized to the total charge liberated by 5.5 MeV alpha particles in pure argon gas.



Drift velocity of electrons as a function of methane concentration in 100 atm argon gas.



Charge collected as a function of methane concentration in 100 atm argon gas. The ordinate scale is normalized to the total charge liberated by 5.5 MeV alpha particles in pure argon gas.



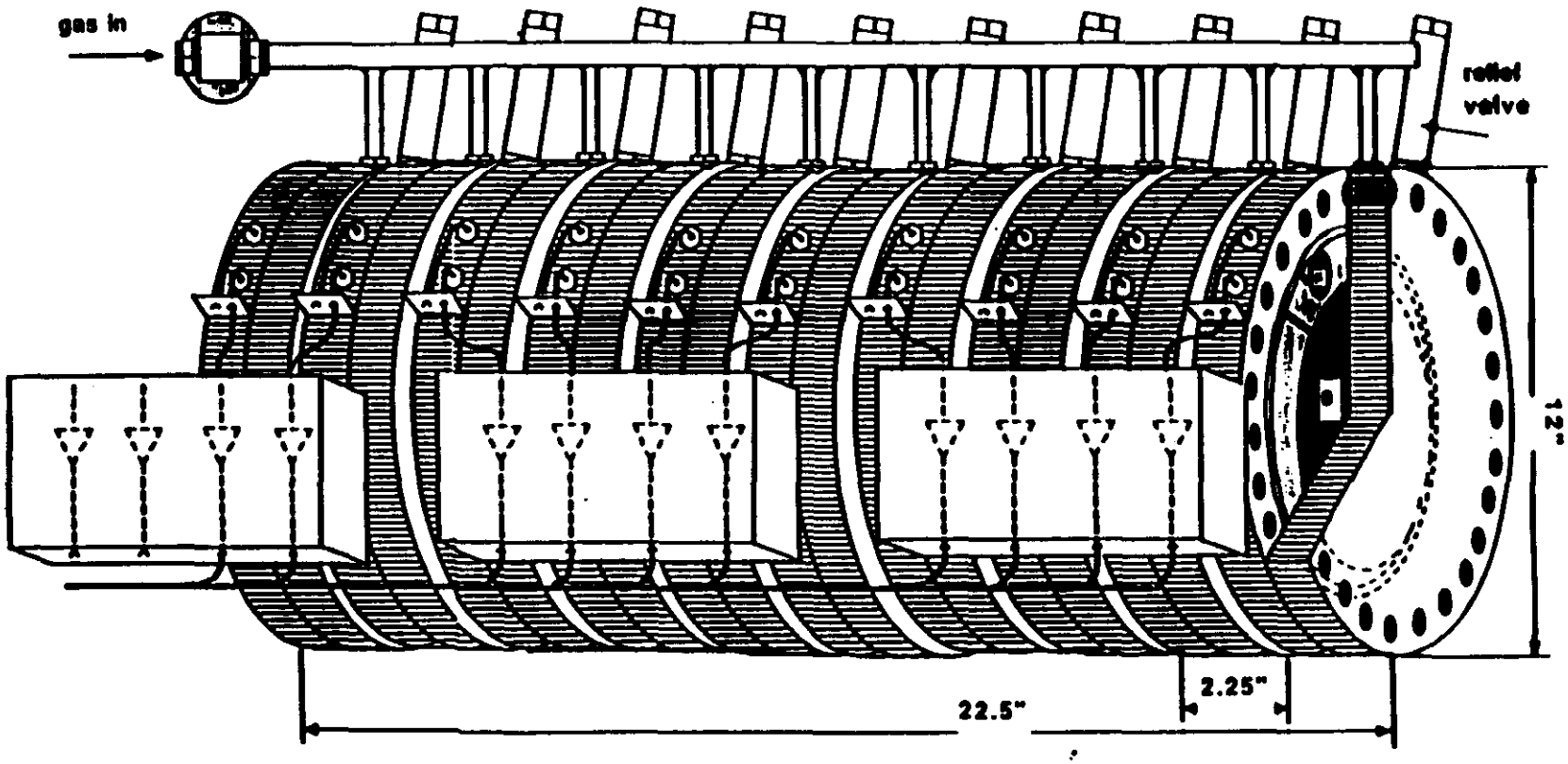
Charge collected as a function of pressure in argon gas and in argon plus 100 ppm oxygen mixture. The ordinate scale is normalized to the total charge liberated by 5.5 MeV alpha particles in pure argon gas.

PARALLEL PLATE HIGH PRESSURE EM CALORIMETER TEST

- A simple design cell-vessel
  - 2 steel plates, each 1.25" thick, bolted together
  - 12" diameter
  - 10" diameter, 5mm deep groove milled on one plate
  - A 1 mm thick copper clad G-10 readout board supported with ceramic spacers in the groove.
  - High pressure gas occupies a 2mm gap on both sides of the G-10 board
  - A 7" diameter electron pad and a 1.25" muon pad.
  - 2 high voltage/signal and a gas feedthroughs at the side of each vessel.
  - A relief valve

- A simple design test calorimeter
  - Put 10 vessels together
  - Mount preamps close to feedthroughs
  - Use ^{241}Am α-sources in 3 vessels read by muon pad

- A simple data acquisition system
  - Use a MAC II GI with a GP/IB interface to a table top CAMAC crate and a LeCroy 2280 ADC
  - Use LabView II software



. Schematic diagram of the prototype parallel plate electromagnetic calorimeter.

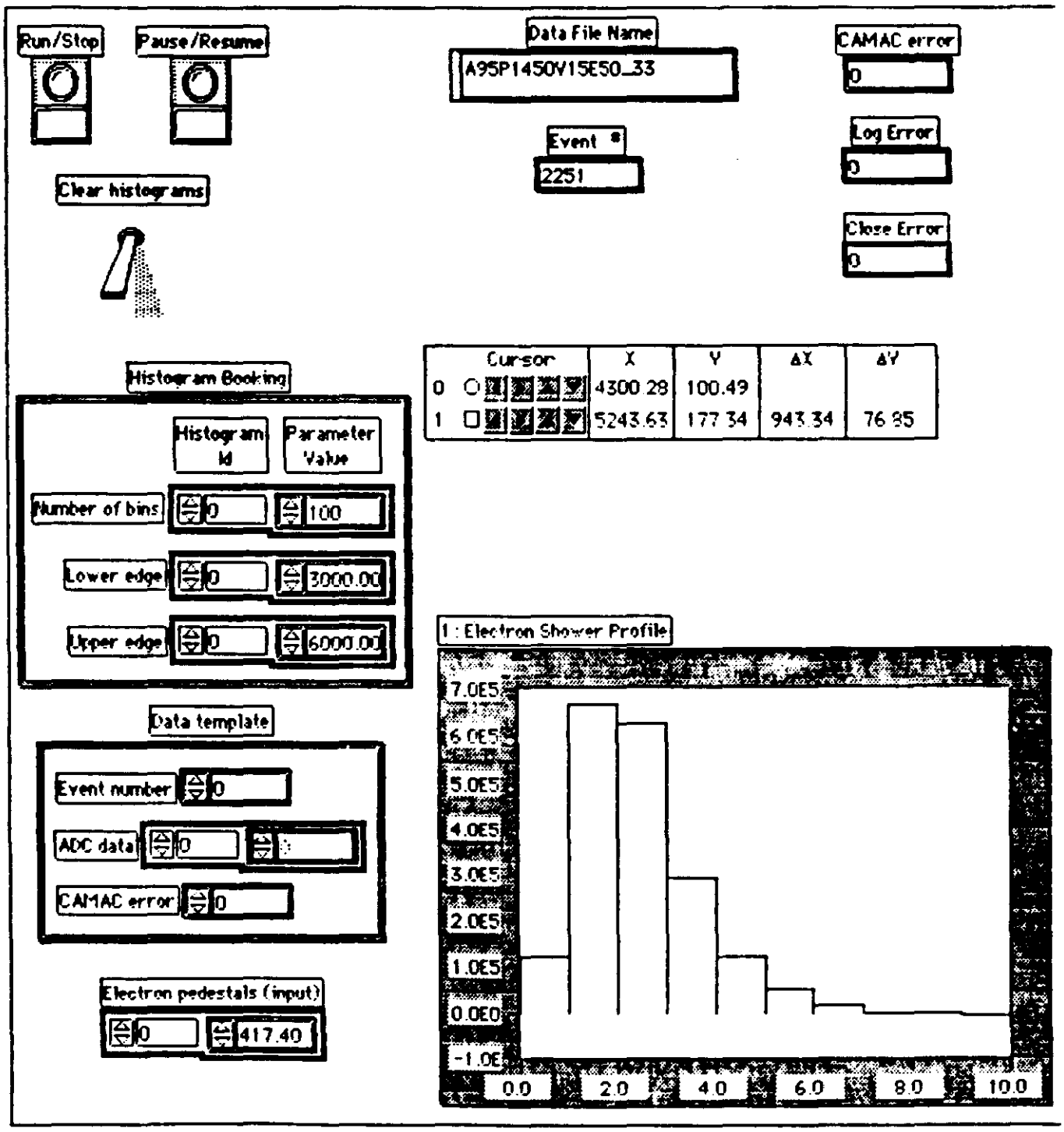
95% Ar + 5% CH4
P=1500 psig , HV=1500 V

50 GeV e's

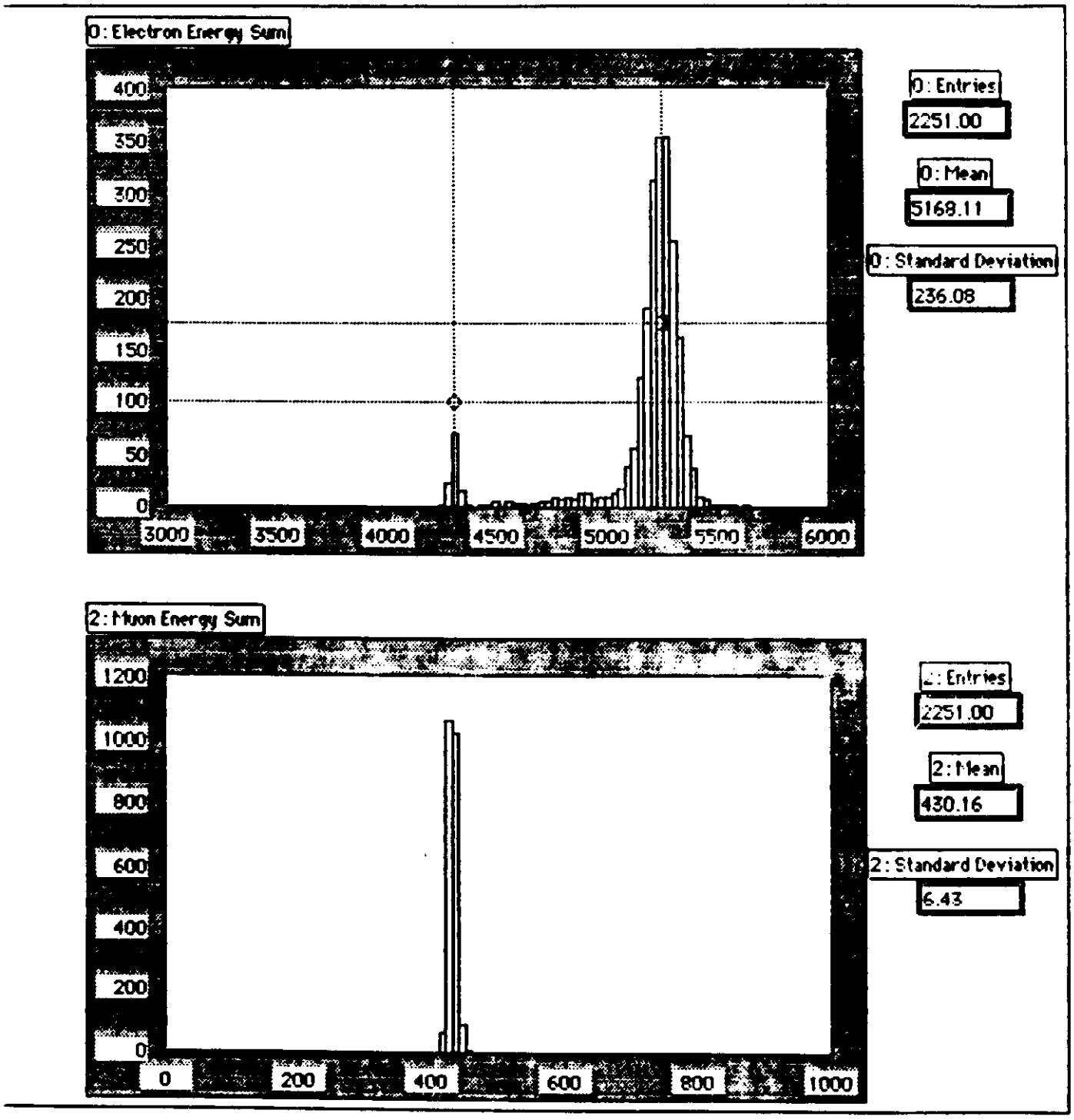
ON LINE

Run_Control
. ,day, December 13, 1991 12:51 PM

Front Panel



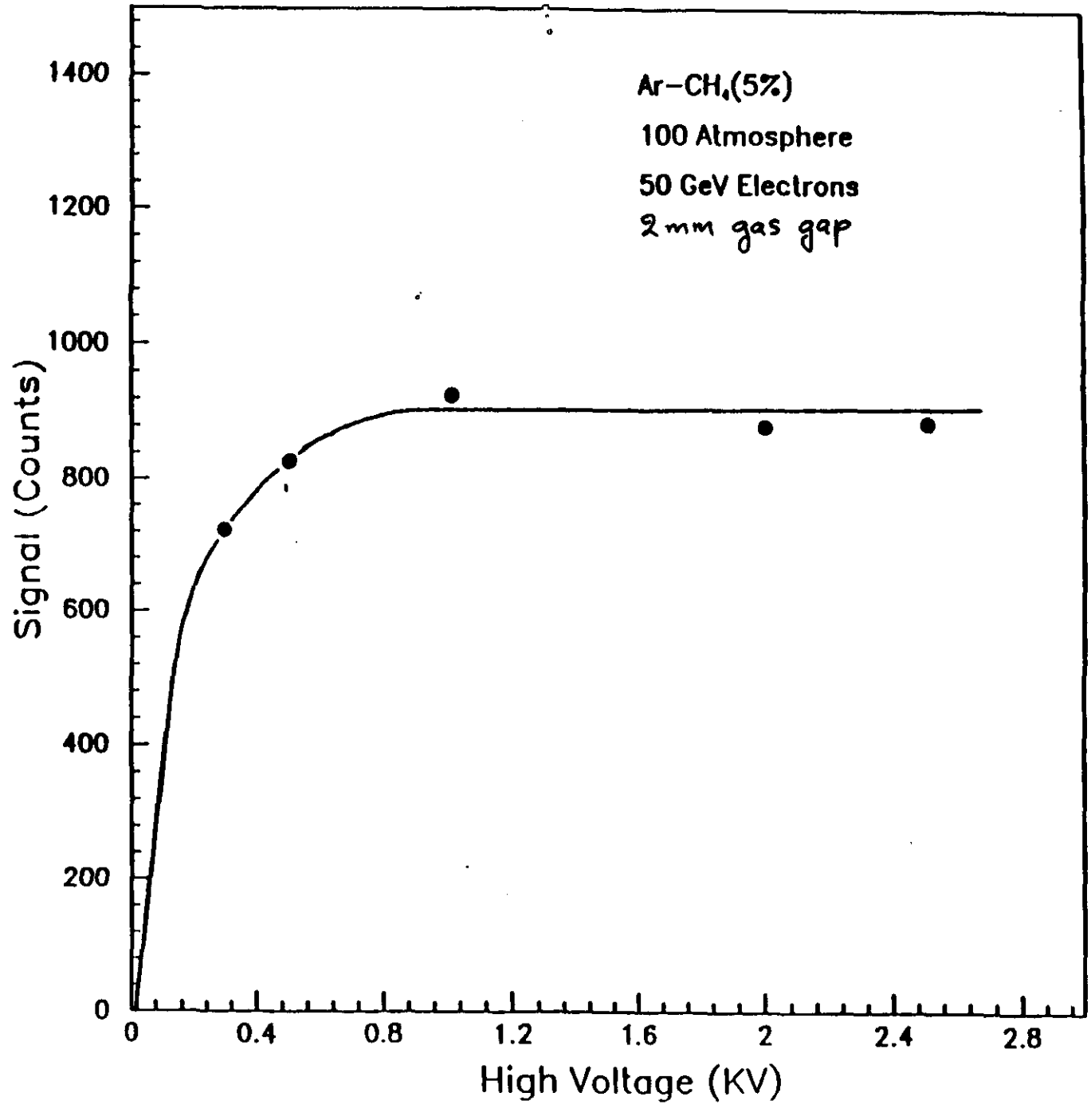
ON LINE


0: Electron Energy Sum
400
350
300
250
200
150
100
50
0
3000
3500
4000
4500
5000
5500
6000
0: Entries
2251.00
0: Mean
5168.11
0: Standard Deviation
236.08
2: Muon Energy Sum
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
2: Entries
2251.00
2: Mean
430.16
2: Standard Deviation
6.43

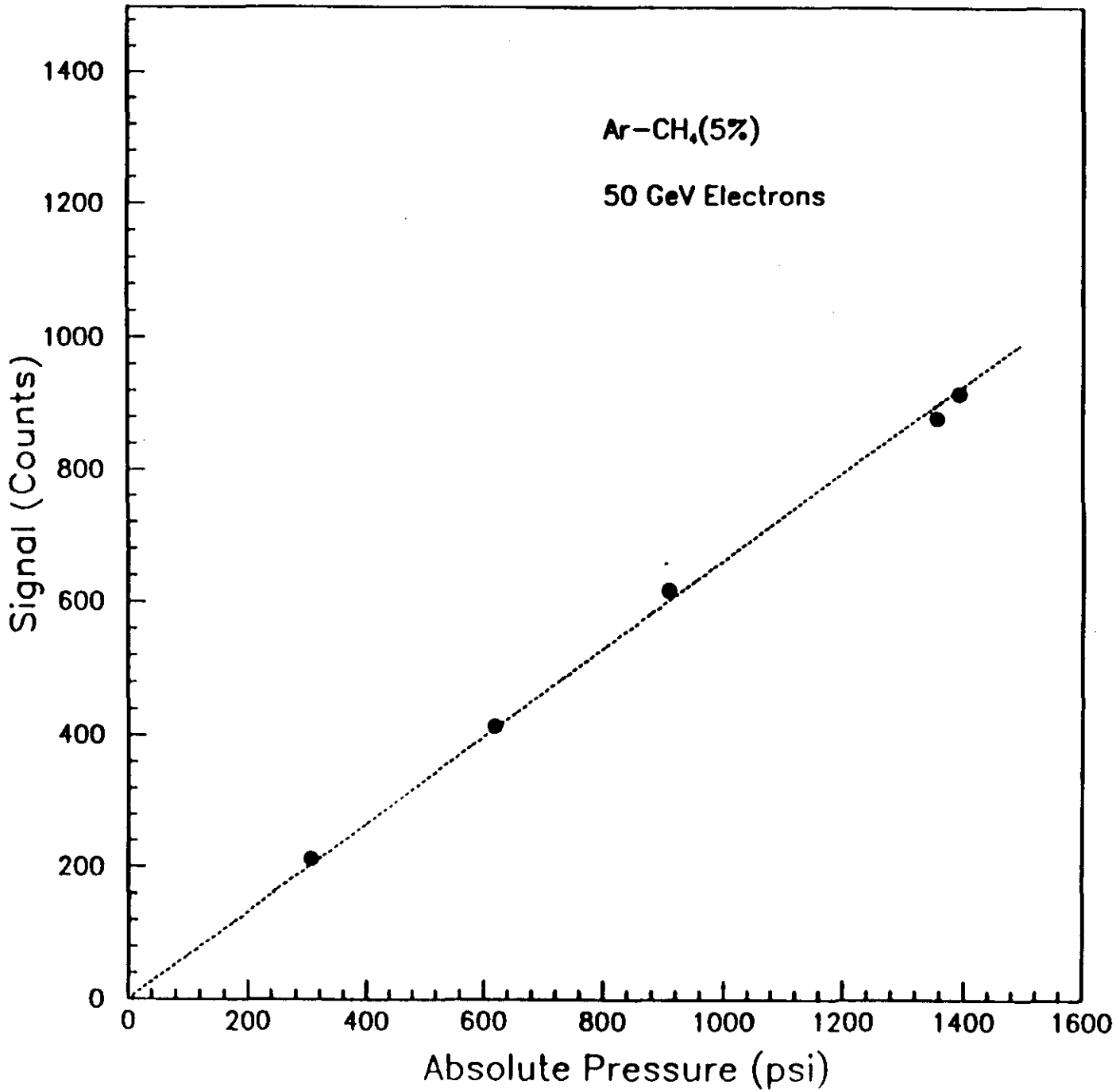
- Results - Conclusions

- The signal saturates at 1 kV (0.5 kV/mm)
- The energy responce is linear with pressure
- The energy responce is linear with energy
- The energy resolution agrees with MC.
- For 100 Atm Ar+5% CH_4: $1/v_d = 20$ ns/mm
- THE CALORIMETER IS VERY STABLE AND EASY TO OPERATE.

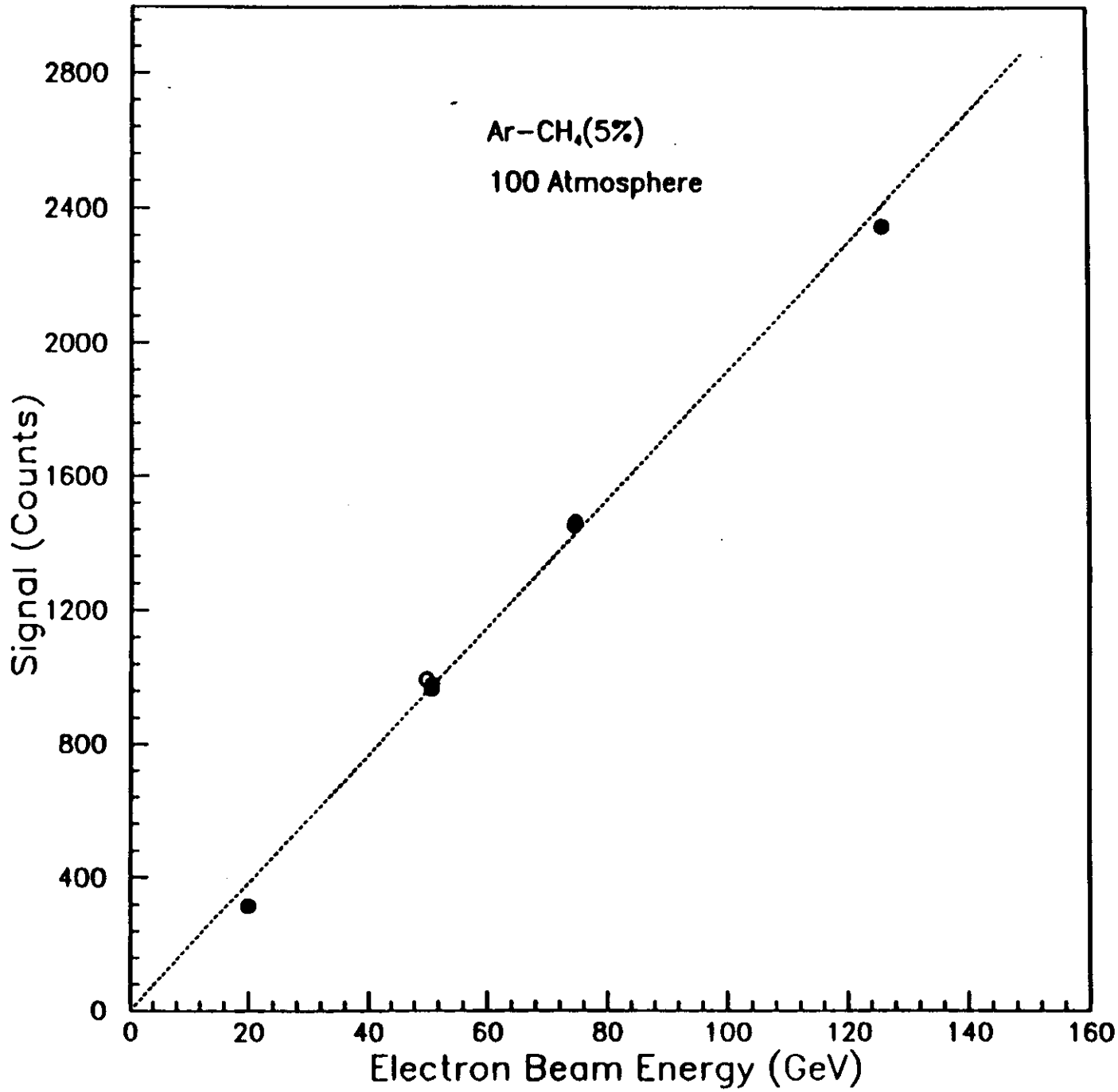
Preliminary

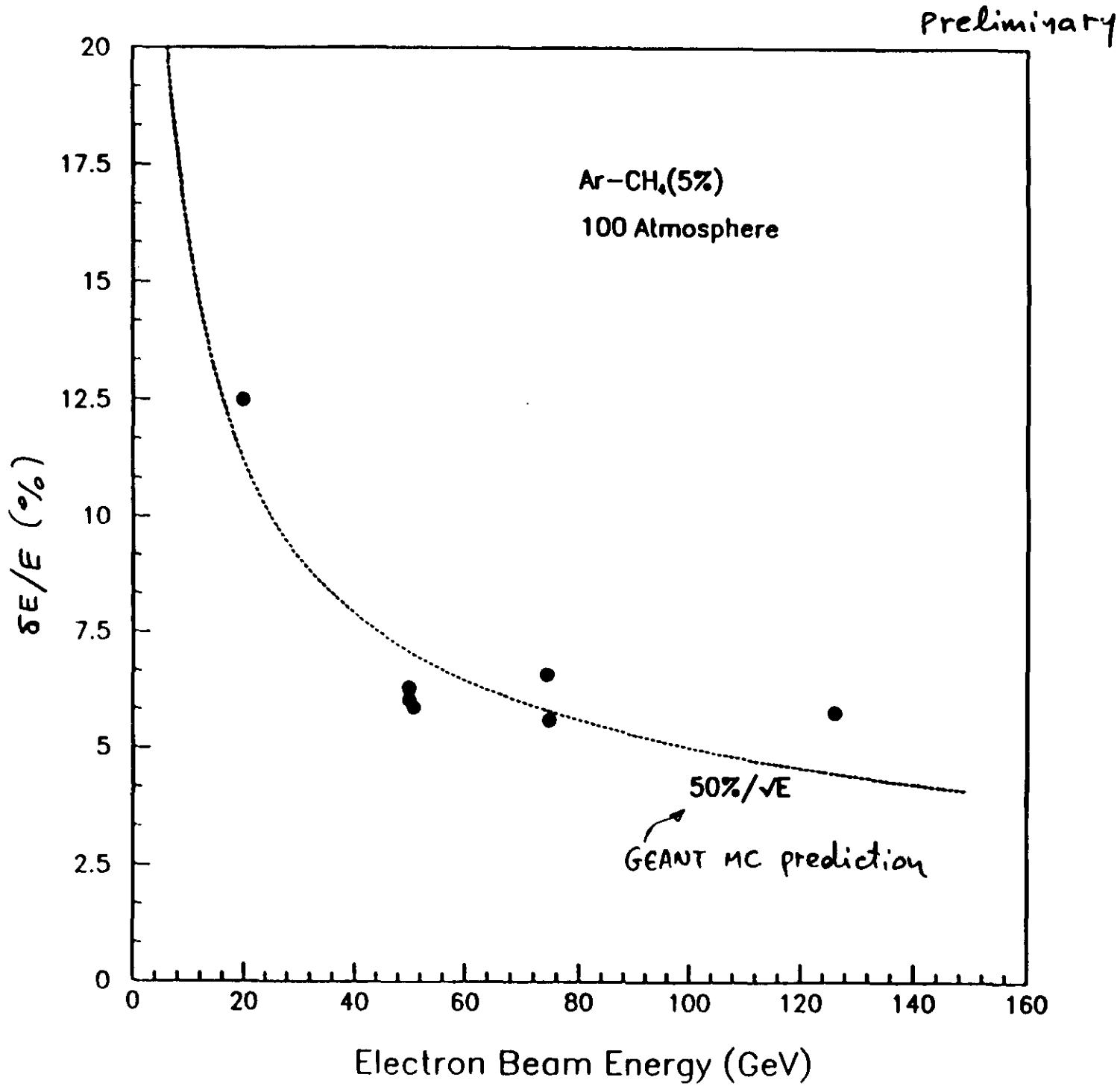


Preliminary



preliminary




Preliminary
Ar−CH₄(5%)
100 Atmosphere
50%/√E
GEANT MC prediction
δE/E (%)
Electron Beam Energy (GeV)
0
2.5
5
7.5
10
12.5
15
17.5
20
0
20
40
60
80
100
120
140
160

RADIATION HARDNESS TESTS

- Experimental setup
  - 1 lt high pressure vessel
  - 2 plates 2.5 mm gap, ^{241}Am α-source
  - 100 atm Ar
  - 100 atm Ar + 1% CH_4
  - Irradiated with a ^{60}Co γ source at the Phoenix Lab of University of Michigan.
  - ~ 16 Mrad of γ radiation

- Results

Ar
- At 1 kV/mm the signal after irradiation ~ 6% less
- The drift velocity larger by ~ 50% !
  vessel wall outgassing ...? systematics ?

Ar/CH_4
- At 1 kV/mm the signal after increased by 8% !
- No change in the drift velocity.
  Some CH_4 radiolysis ? systematics ?

- Conclusion

  This calorimeter can operate for a year in the high radiation environment of SSC forward region (1°, 12 m) without the need for gas circulation or refilling.

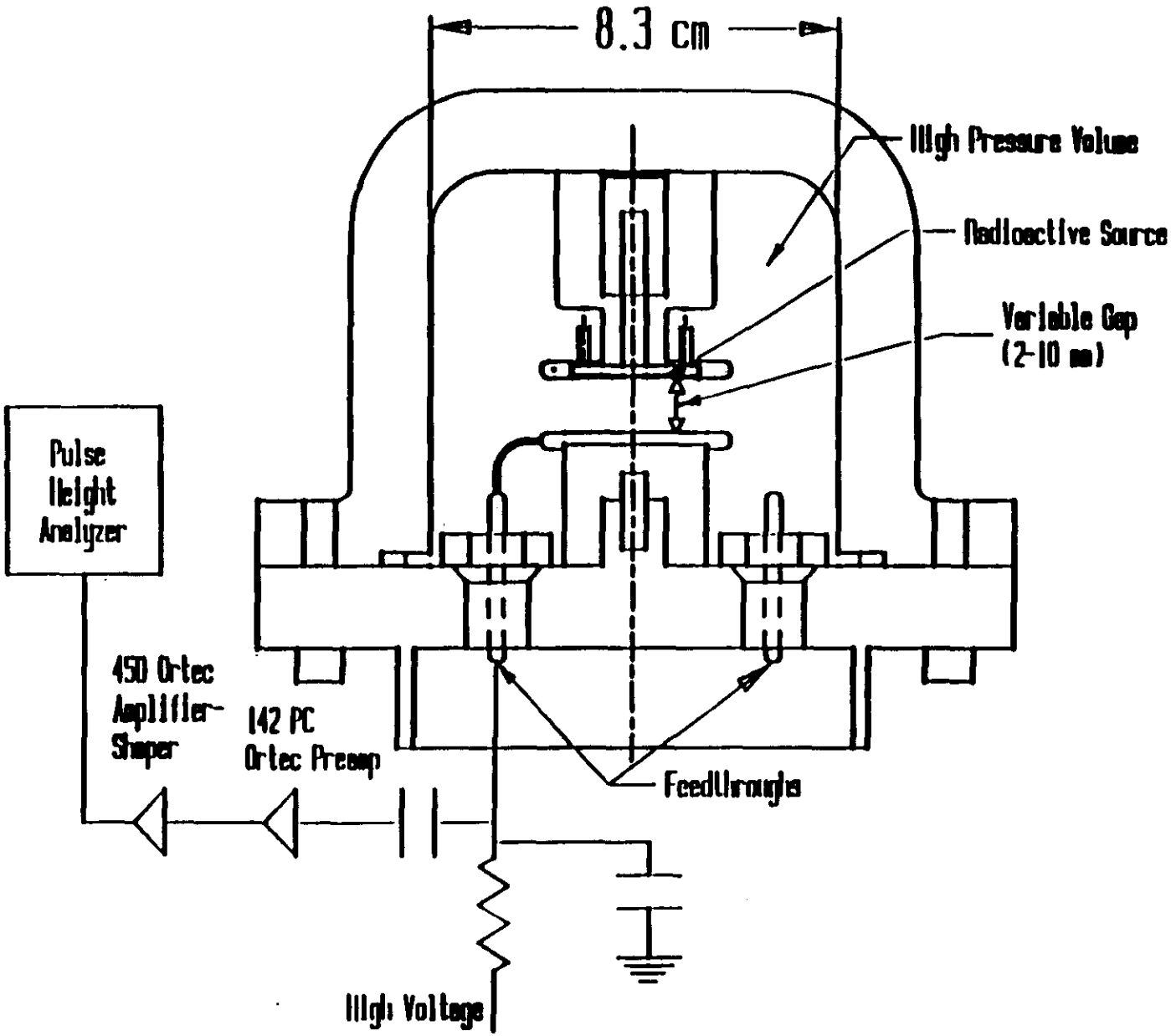
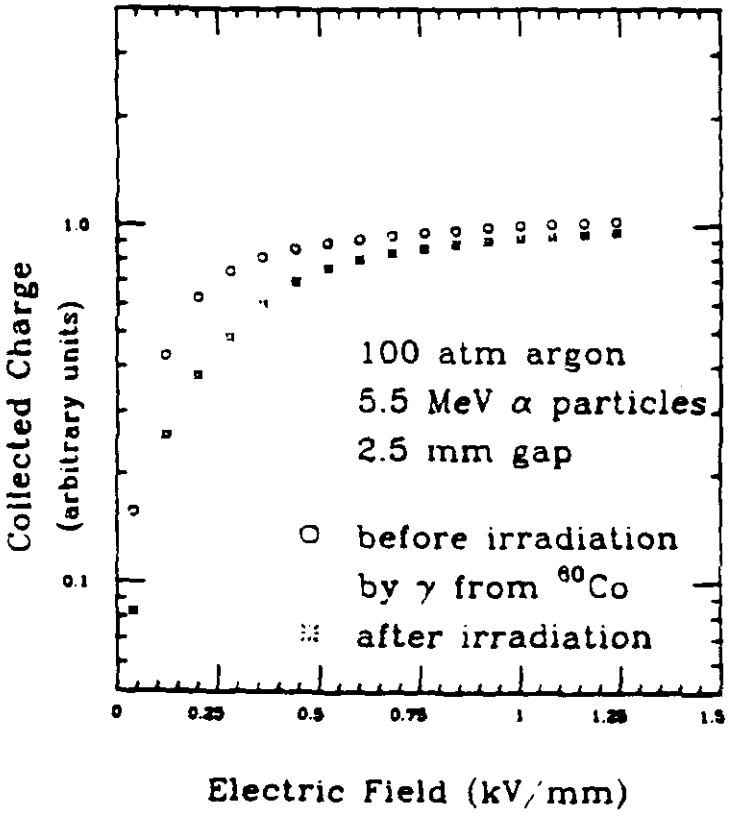
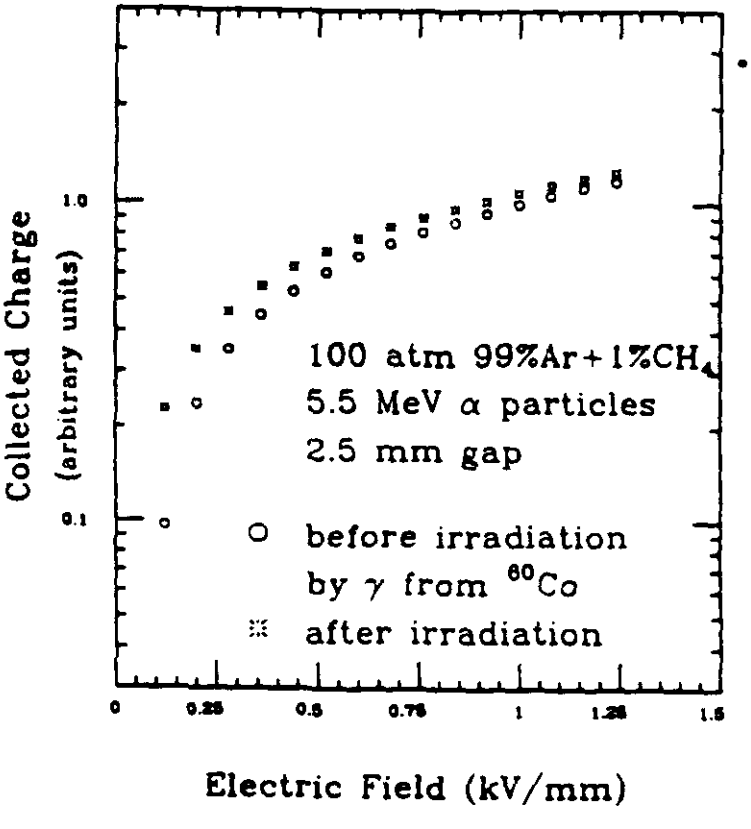


Diagram of the vessel used for radiation damage studies.


Collected Charge
(arbitrary units)
1.0
0.1
0
0.25
0.5
0.75
1
1.25
1.5
100 atm argon
5.5 MeV α particles
2.5 mm gap
before irradiation
by γ from 60Co
after irradiation
Electric Field (kV/mm)

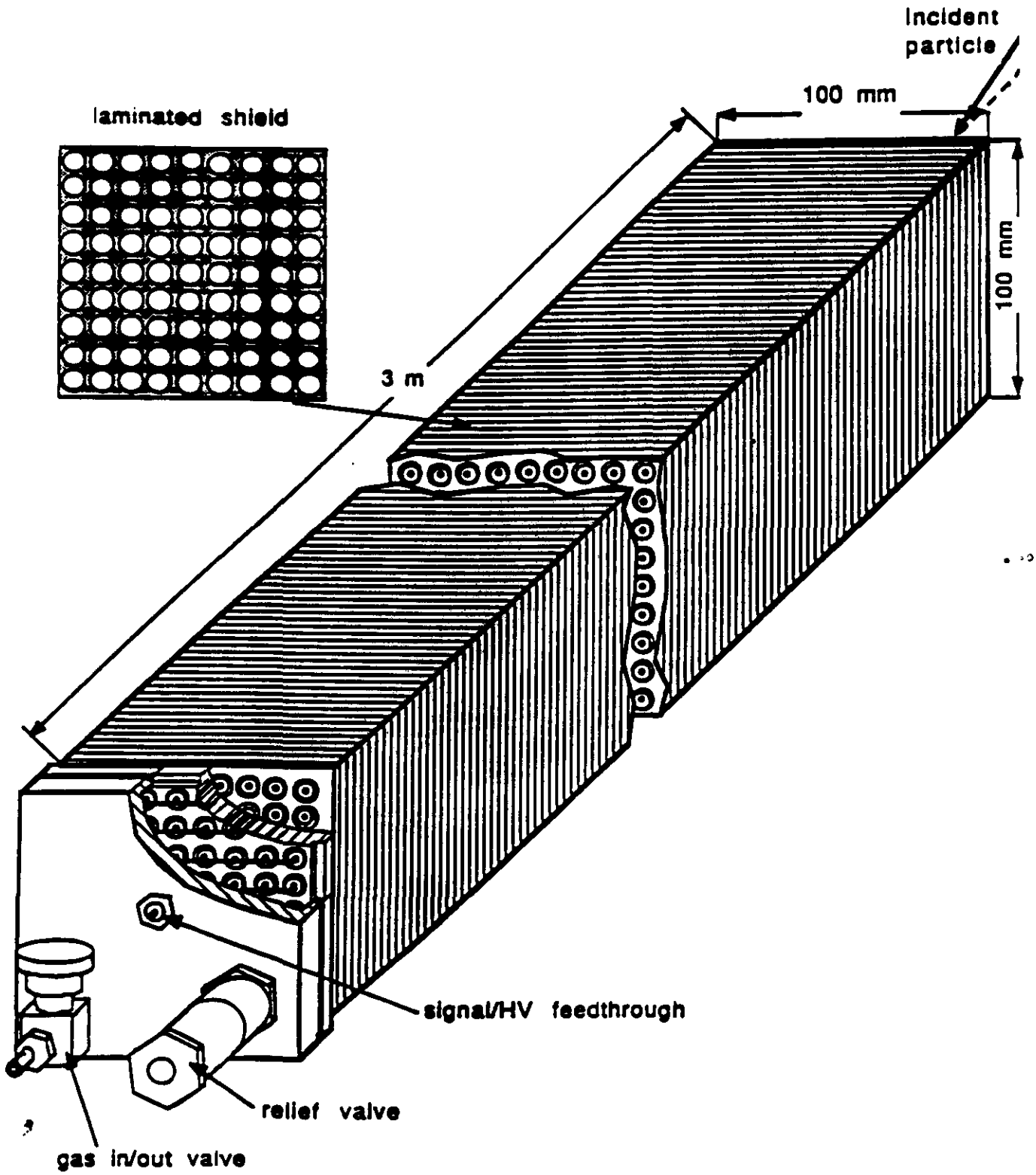

Collected Charge
(arbitrary units)
1.0
0.1
0
0.25
0.5
0.75
1
1.25
1.5
100 atm 99%Ar+1%CH4
5.5 MeV α particles
2.5 mm gap
before irradiation
by γ from 60Co
after irradiation
Electric Field (kV/mm)

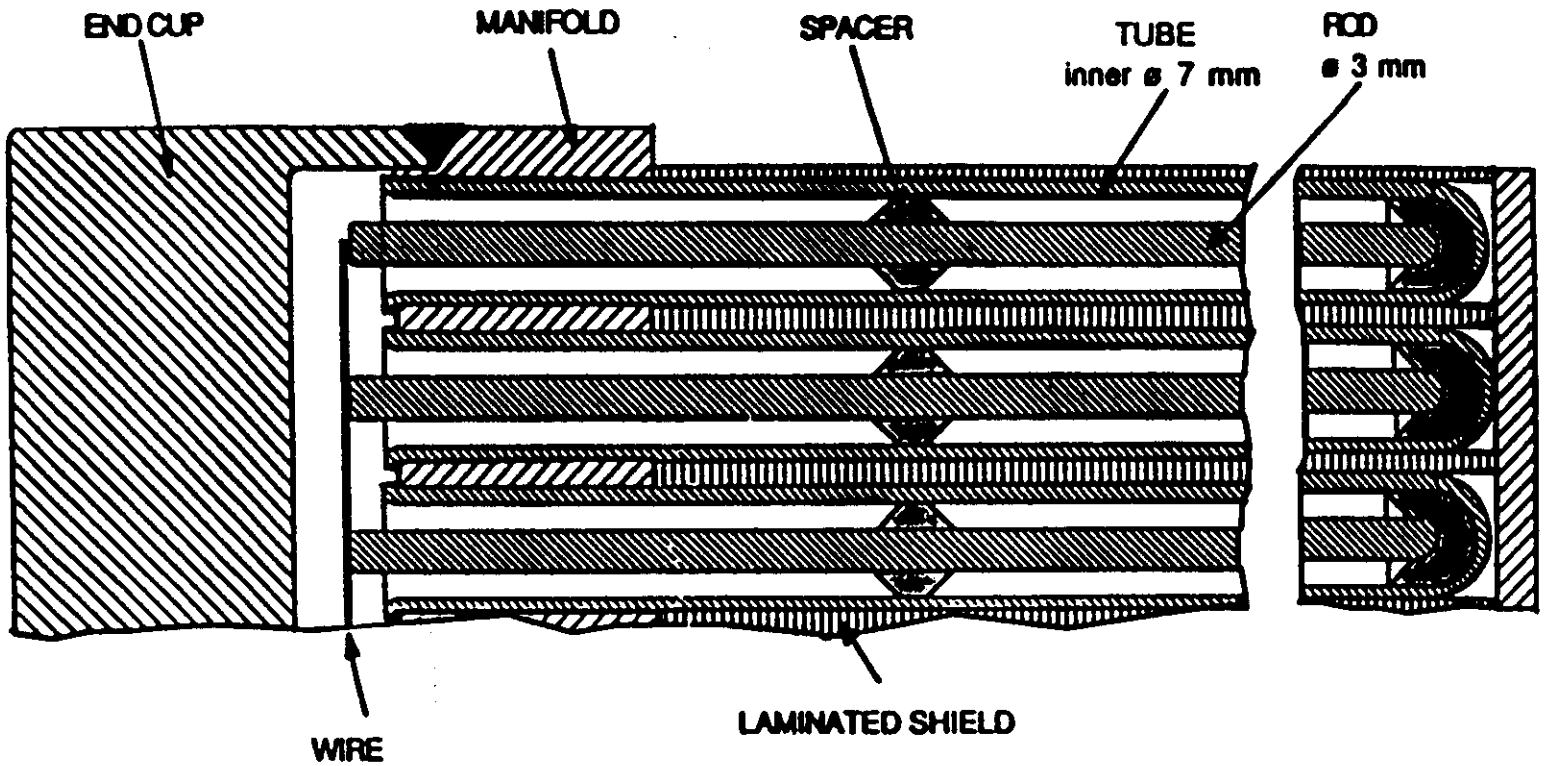
A DESIGN FOR SSC (SDC)

- A tube calorimeter
  - consists of $10 \times 10\ cm^2 \times 3m$ modules
  - each module: 81 tubes closed at one end and welded to 1" stainless steel at other.
    The absorber is steel laminations
    Charge collection rods in tubes
    Gas gap = 2 mm
    MC current best estimate 7 mm tube
    3 mm rod
    Ceramic spacers along rods (use Pb?
    Rods connected electrically on one end
    Another steel plate carrying feedthrough
    is welded at the end.
  - A prototype module half done (shorter length)
  - Pressure test done to 9,000 psi ! (100 atm ≈ 1500 psi)

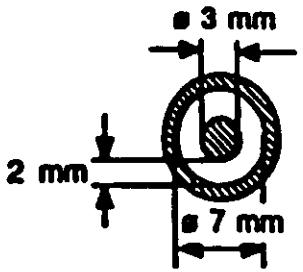
- The MC game
  - + GEANT Monte Carlo is being used to study the parameters of the tube calorimeter.
  - Energy resolution represented as:

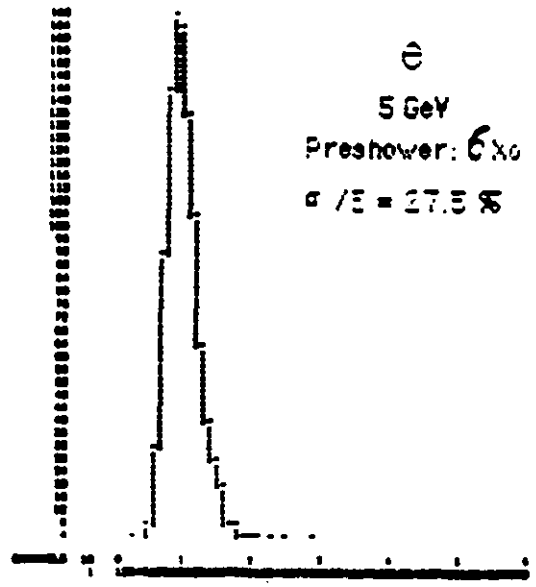
$$\sigma/E = \frac{A}{\sqrt{E}} \oplus B$$

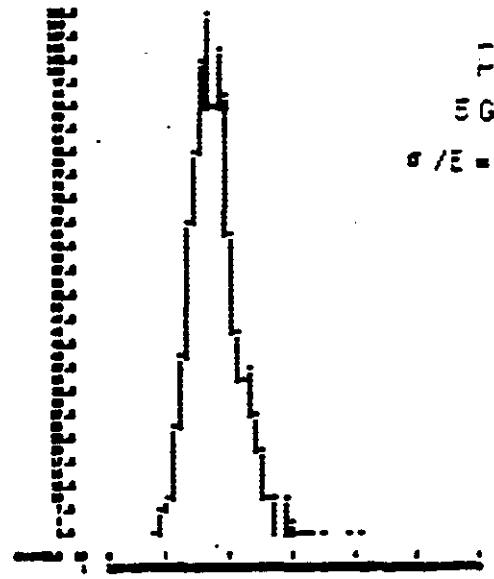

Incident particle
100 mm
laminated shield
100 mm
3 m
signal/HV feedthrough
relief valve
gas in/out valve

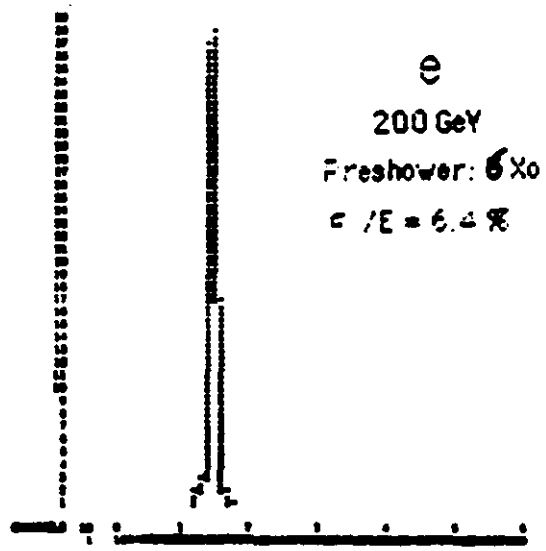


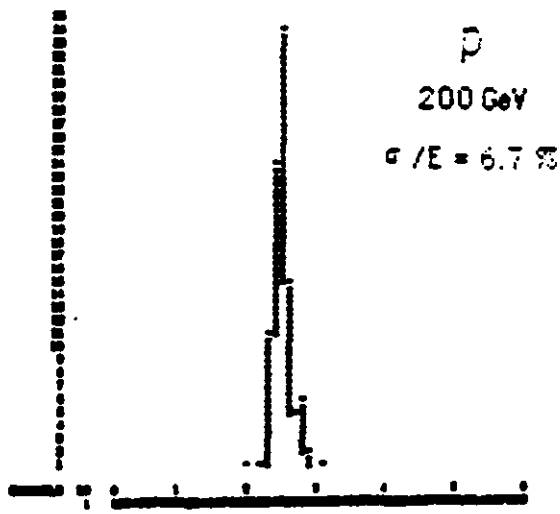
$$\frac{\text{steel volume}}{\text{gas volume}} = 3$$




e
5 GeV
Preshower: 6 Xo
σ /E = 27.5 %


π
5 GeV
σ /E = 24.5 %


e
200 GeV
Preshower: 6 Xo
σ /E = 6.4 %


p
200 GeV
σ /E = 6.7 %

CONCLUSIONS

TECHNIQUE	ATTRIBUTES	DISADVANTAGES	R+D EFFORTS
High pressure Ar gas (100 atm)	Fast (20 ns/mm) Rad hard Inexpensive Robust Unity gain Linear energy response Linear pressure " Very stable Easy to operate	C/M not measured not proven	In progress It's about time!

J. Rutherfoord
1/22/92 GEM Mtg SSCL

GEM Forward Calorimetry

Physics Goals (F. Paige)

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

Critical Parameters

- Mean density of calorimeter (High as possible)
- Diameter of beam hole (Small as possible)

Technologies

- High pressure gas (E. Kistenev, G. Fanourakis)
- Liquid Scintillator spaghetti (R. Webb)
- Liquid Argon (J. Rutherfoord)

General Simulation Results

Integration Issues

Preliminary Cost Estimates

GEM FCal Meeting Agenda

1/22/92 SSCLab

3:30	~~1:30PM~~	J. Rutherfoord	Overview and present status
	~~2:00 PM~~	R. Webb	Magnet field shaping and implications for forward calorimetry
:40	~~2:30 PM~~	G. Fanourakis	Gas calorimetry tests at FNAL
	~~3:15 PM~~	Break	
:00	~~3:30 PM~~	S. Chae	Engineering Gas Calorimetry
*	4:00 PM	F. Paige	Physics of Forward Calorimetry
:30	~~4:30 PM~~	J. Rutherfoord	LAr FCal integrated into end cap calorimeter
4:30	~~5:00PM~~	R. Webb	Review of liquid scintillator option
	~~5:30PM~~	Discussion	

Liquid Noble Calorimeters
as a

Forward Calorimeter Option

for

GEM

- Physics Motivation
- Difficulties in working in this region
- "Straw man" forward calorimeter
- Important short term issues
- Summary

} skip over these today and refer to previous speakers in this session

R.C. Wells
Texas A&M University
1/22/92

Revised 1/22/92
RCW 9/6/91

Difficulties in working

@ $|\eta| > 3$

- Radiation Doses for both neutrons and ionizing radiation High.
- Particles / area vs. Shower size
- Pileup effects are worse for this region

"Bad News"

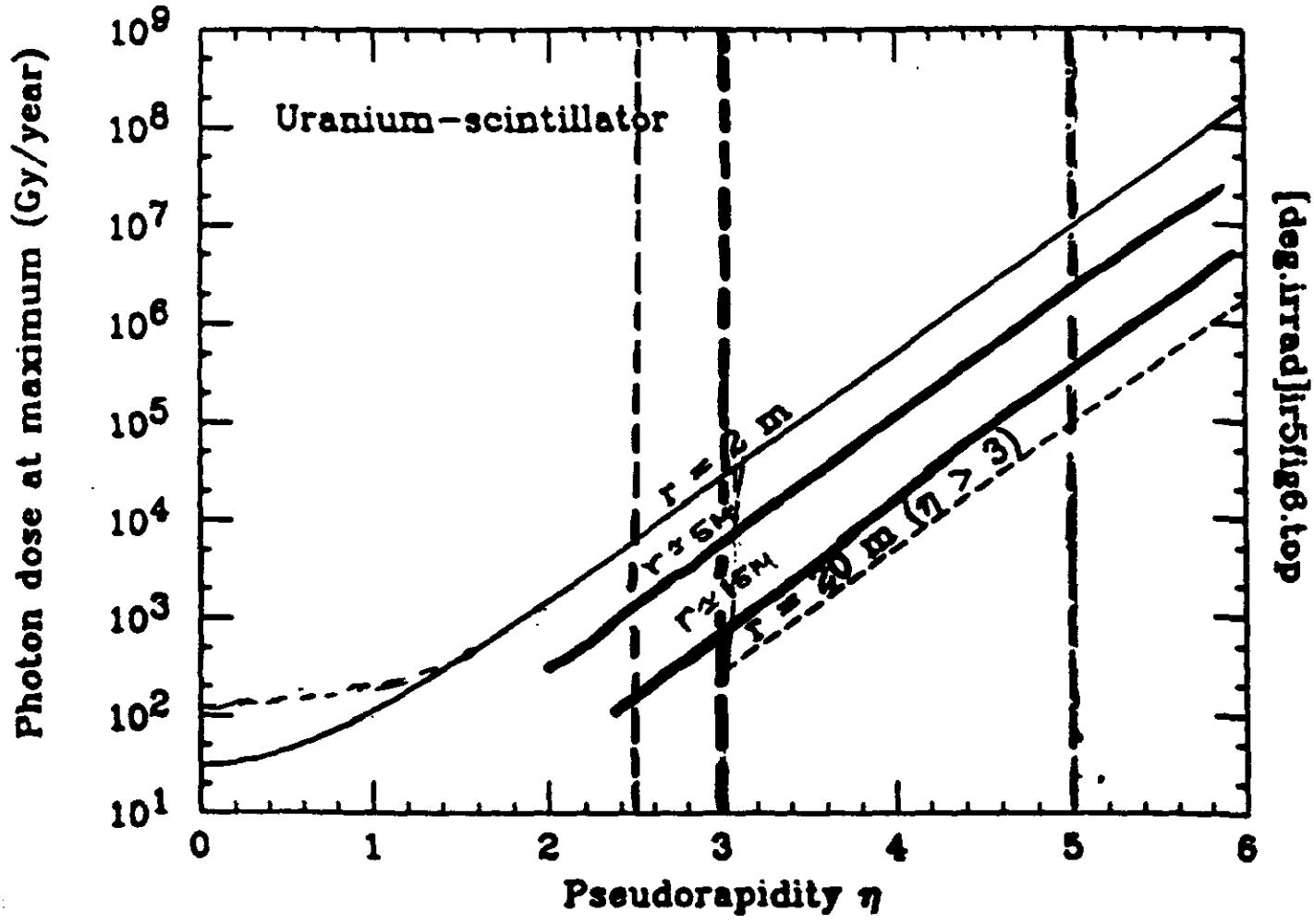


FIG. 5-6 *Revised*. The maximum dose from incident photons. The solid curve assumes the maximum occurs at 200 cm. The other curve is calculated for 20 m, typical of forward detectors.

FIG. 4. Revised Fig. 5-6 from SSC-SR-1033. Maximum dose is for lead (or uranium) plat the calorimeter, and may be somewhat higher in the lower-Z sensitive material.

Fig 18

But ....

there are some advantages to being in this region.

- Only modest energy resolution needed in stochastic term
- physical sizes of these objects is "manageable"
- not a critical path item, but provision must be made to include this element in the detector when design developed.
- costs within reach for some technology choices

Strawman Concept

Liquid filled capillaries 3mm ϕ ; MgF_2, polysiloxane

Lead Eutectic Technology 15λ thick (3m)
(100 Ton/each)

η range coverage $|\eta| \geq 2.5(3.0)^{*\#}$ $|\eta| \leq 5.0$

4 : 1 absorber to liquid ratio

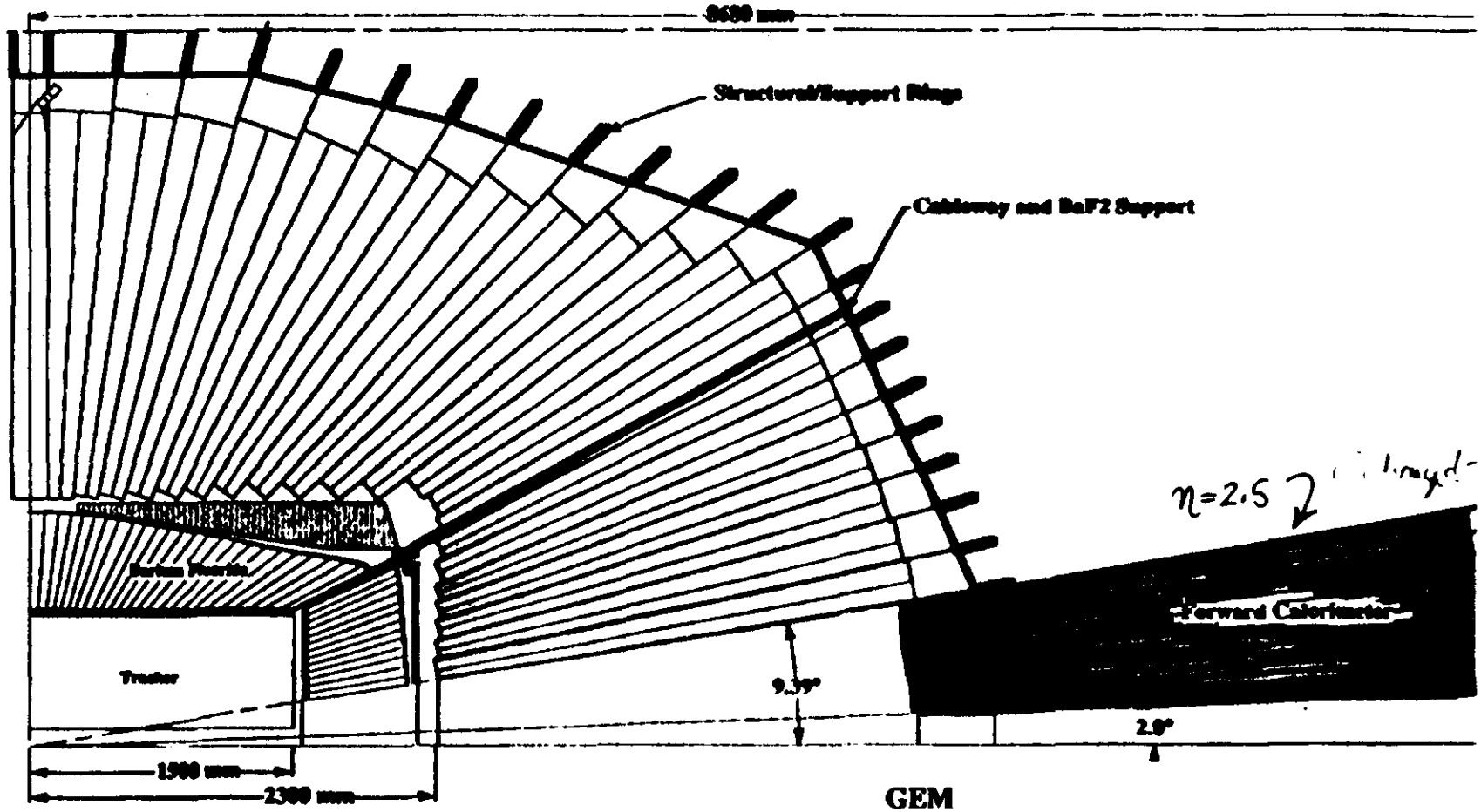
Tower sizes chosen to match shower size

Single longitudinal sampling w/ transverse sampling

located at $z \sim 5m$

liquid volume $\sim$ 5K liters

This exercise was carried in order to give the collaboration some feeling for the cost, physical limit of a forward system. This concept is quite RAW and clearly will benefit from detailed engineering work.



G.83.SC.00044

GEM
Spaghetti Hadron Calorimeter
Barium Fluoride EM Calorimeter

2	2.55000	.15585E+00	.70541E+02	.10440E+03	[redacted]	
3	2.60000	.14827E+00	.74686E+02	.10142E+03	[redacted]	
4	2.65000	.14107E+00	.71066E+02	.96426E+02	[redacted]	
5	2.70000	.13421E+00	.67510E+02	.91679E+02	[redacted]	
6	2.75000	.12768E+00	.64100E+02	.87170E+02	.10514E+03	
7	2.80000	.12147E+00	.61036E+02	.82887E+02	.99977E+02	
8	2.85000	.11556E+00	.58039E+02	.78816E+02	.95087E+02	
9	2.90000	.10994E+00	.55190E+02	.74948E+02	.90402E+02	
10	2.95000	.10458E+00	.52483E+02	.71273E+02	.85908E+02	
11	3.00000	.99492E-01	.49911E+02	.67779E+02	.81754E+02	
12	3.05000	.94647E-01	.47465E+02	.64458E+02	.77748E+02	
13	3.10000	.90038E-01	.45141E+02	.61301E+02	.73941E+02	
14	3.15000	.85652E-01	.42931E+02	.58300E+02	.70321E+02	
15	3.20000	.81479E-01	.40830E+02	.55447E+02	.66880E+02	
16	3.25000	.77510E-01	.38833E+02	.52735E+02	.63608E+02	
17	3.30000	.73733E-01	.36933E+02	.50156E+02	.60497E+02	32
18	3.35000	.70140E-01	.35128E+02	.47703E+02	.57539E+02	
19	3.40000	.66722E-01	.33410E+02	.45371E+02	.54726E+02	
20	3.45000	.63470E-01	.31778E+02	.43154E+02	.52052E+02	
21	3.50000	.60376E-01	.30225E+02	.41045E+02	.49508E+02	
22	3.55000	.57433E-01	.28748E+02	.39040E+02	.47090E+02	
23	3.60000	.54634E-01	.27344E+02	.37133E+02	.44790E+02	
24	3.65000	.51971E-01	.26009E+02	.35320E+02	.42602E+02	
25	3.70000	.49437E-01	.24739E+02	.33595E+02	.40522E+02	
26	3.75000	.47027E-01	.23531E+02	.31955E+02	.38543E+02	
27	3.80000	.44734E-01	.22382E+02	.30395E+02	.36662E+02	
28	3.85000	.42553E-01	.21289E+02	.28911E+02	.34872E+02	
29	3.90000	.40478E-01	.20250E+02	.27500E+02	.33170E+02	
30	3.95000	.38505E-01	.19262E+02	.26158E+02	.31551E+02	
31	4.00000	.36627E-01	.18322E+02	.24881E+02	.30011E+02	
32	4.05000	.34841E-01	.17428E+02	.23667E+02	.28547E+02	
33	4.10000	.33142E-01	.16577E+02	.22512E+02	.27154E+02	
34	4.15000	.31526E-01	.15768E+02	.21413E+02	.25829E+02	
35	4.20000	.29989E-01	.14999E+02	.20369E+02	.24568E+02	
36	4.25000	.28527E-01	.14267E+02	.19375E+02	.23370E+02	16
37	4.30000	.27135E-01	.13571E+02	.18429E+02	.22229E+02	
38	4.35000	.25812E-01	.12909E+02	.17530E+02	.21145E+02	
39	4.40000	.24553E-01	.12279E+02	.16675E+02	.20113E+02	
40	4.45000	.23356E-01	.11680E+02	.15862E+02	.19132E+02	
41	4.50000	.22217E-01	.11110E+02	.15088E+02	.18199E+02	
42	4.55000	.21134E-01	.10568E+02	.14352E+02	.17311E+02	
43	4.60000	.20103E-01	.10053E+02	.13652E+02	.16467E+02	
44	4.65000	.19123E-01	.95625E+01	.12986E+02	.15663E+02	
45	4.70000	.18190E-01	.90960E+01	.12352E+02	.14899E+02	
46	4.75000	.17303E-01	.86523E+01	.11750E+02	.14173E+02	
47	4.80000	.16459E-01	.82303E+01	.11177E+02	.13481E+02	
48	4.85000	.15656E-01	.78289E+01	.10632E+02	.12824E+02	
49	4.90000	.14893E-01	.74470E+01	.10113E+02	.12198E+02	
50	4.95000	.14167E-01	.70838E+01	.96197E+01	.11603E+02	

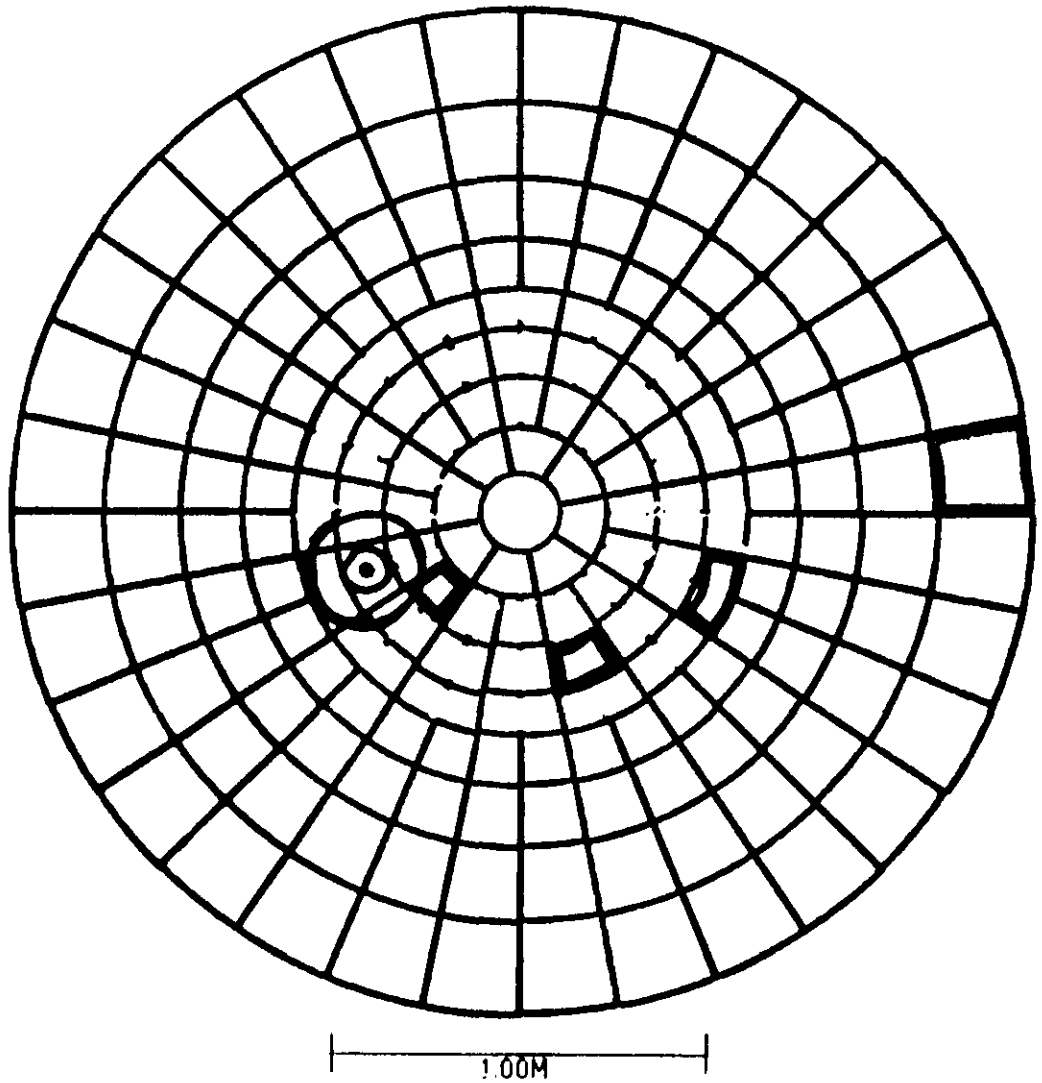
t--- Tower Boundaries

Lead Version

Tungsten Version

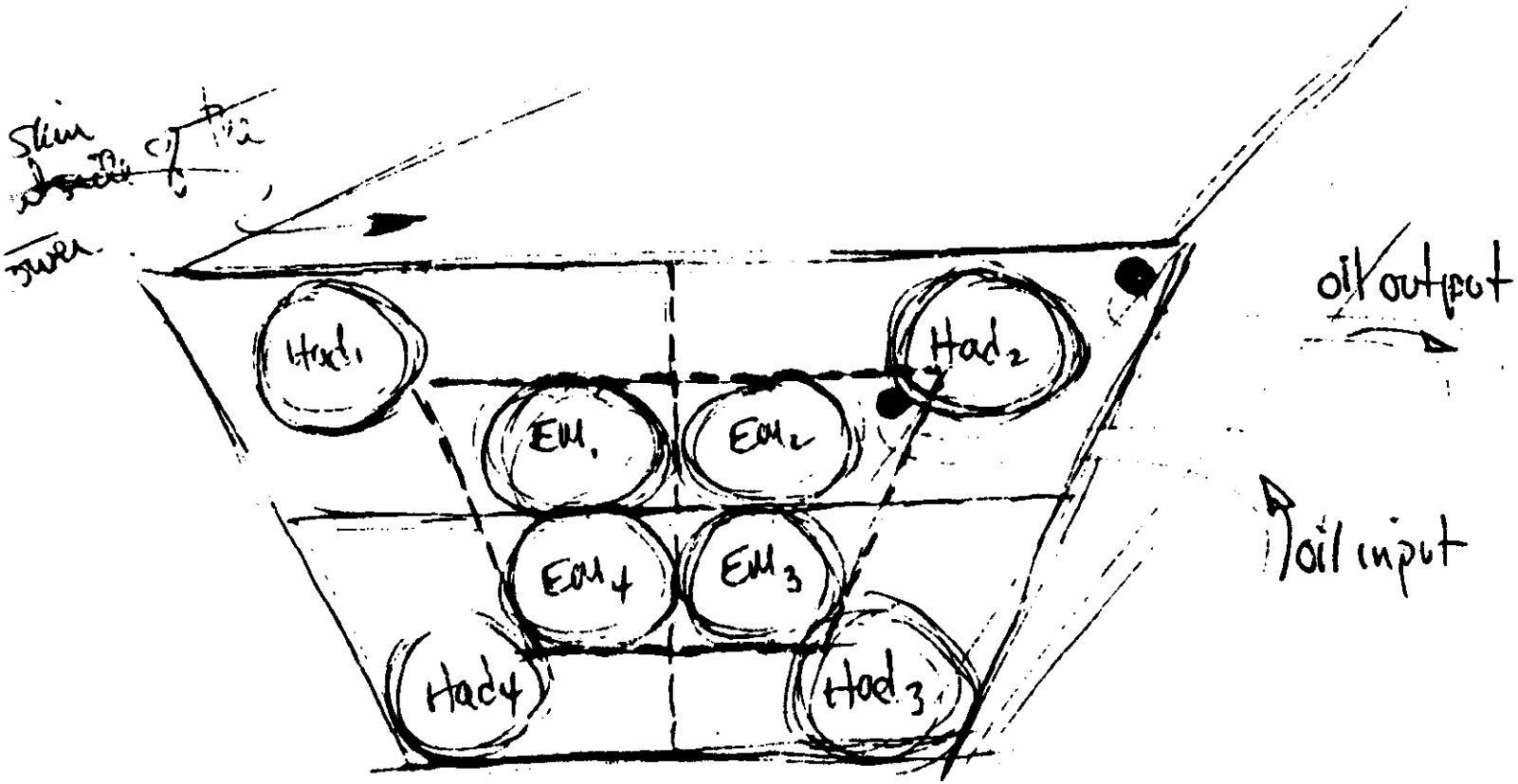
This calorimeter has a total of 704 Towers/end with each one being readout via a photodevice of the same type being developed for the central SPACAL calorimeter. Four of these towers are then grouped together to form a Super-Tower for construction and assembly purposes(176 super-towers/end). The eta-phi segmentation chosen has been strongly influenced by the fact that the smallest sensible unit of segmentation for the forward hadron calorimeter should be comparable to the size of a typical shower in this device.

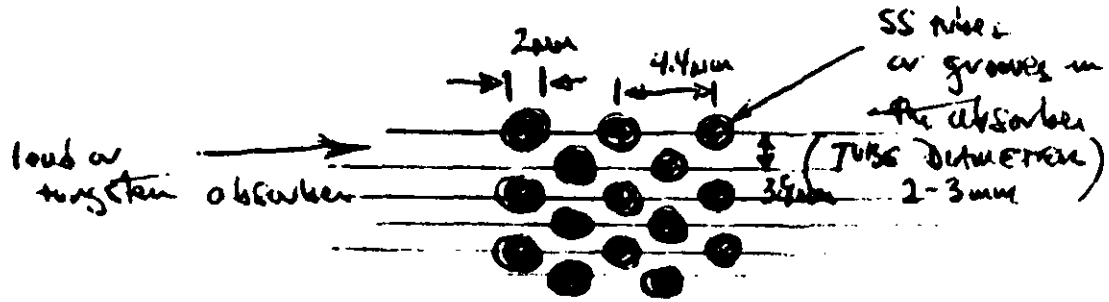
Super tower Outline at [illegible]
of inverted calorimeter
$z \doteq 8.19$ m from IR
$2.5 < \eta < 5.0$



Super tower (detail drawing [illegible])
Schematic

PMT END OF "SUPERTOWER"





TUBE : ABSORBER

1 : 4

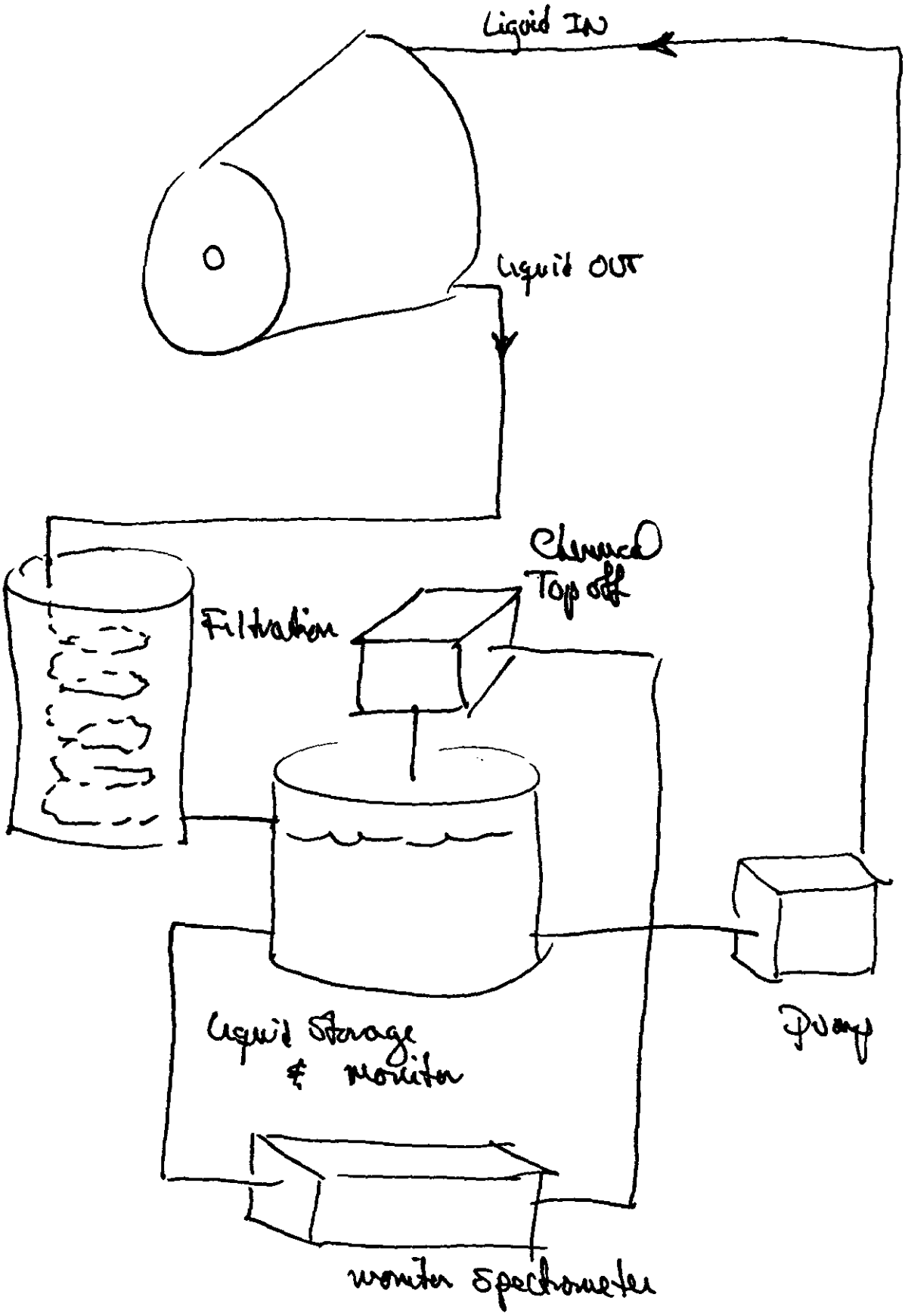
1. Lead w/ MgF_2 coated SS tubes in the
2. Lead w/ MgF_2 coated sheets.
3. Tungsten w/ MgF_2 coated SS tubes

(front face at 5 meters from IR)

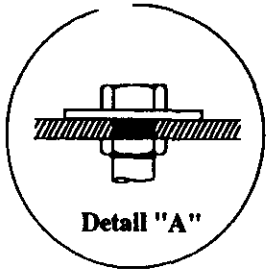
ITEM	CATEGORY	Total Units	$K/ Unit	Units	Cost	Cont
1.00	Material					
1.10	Lead	41.2	5.58	Mton	230	
1.20	SS Tubing(3mm)	$1.67X10^5$	0.001	Meters	167	
1.30	MgF_2 coating	$1.67X10^5$	0.001	Meters	167	
1.40	Sheaths	224	1.50	Each	336	
1.50	Light Guides/Mixers	1792	0.1	Each	179	
1.60	Spacers	224	0.2	Each	45	
1.70	Calib. Loops	30	2.00	Each	60	
1.80	Liquid Scintillator	1060	0.010	Liter	11	
2.00	Electronics					
2.10	PMT'S	1792	0.3	Each	538	
2.20	Electronics	1792	0.25	Channels	448	
3.00	Structure				500	
4.00	Thermal Control				90	
5.00	Liquid Handling	2	100	System	200	
6.00	Fab. & Assembly					
6.10	Fab. Ass. & Test	30	0.045	MH/tower	1210	
6.20	Tooling				1500	
7.00	Testing				750	
7.10	Test Beam					
7.20	Test Beam Equipment					
8.00	Transport				100	
9.00	Installation					
9.10	Install. Labor	5556	.045	Man Hour	250	
9.20	Install. Equip.				500	
	DIRECT COST				7281	
	EDIA	25%			1820	
	Base Cost				9101	
	Contingency	40%			3640	
	Subtotal				12741	
	R&D	11%			1402	
	TOTAL				14143	

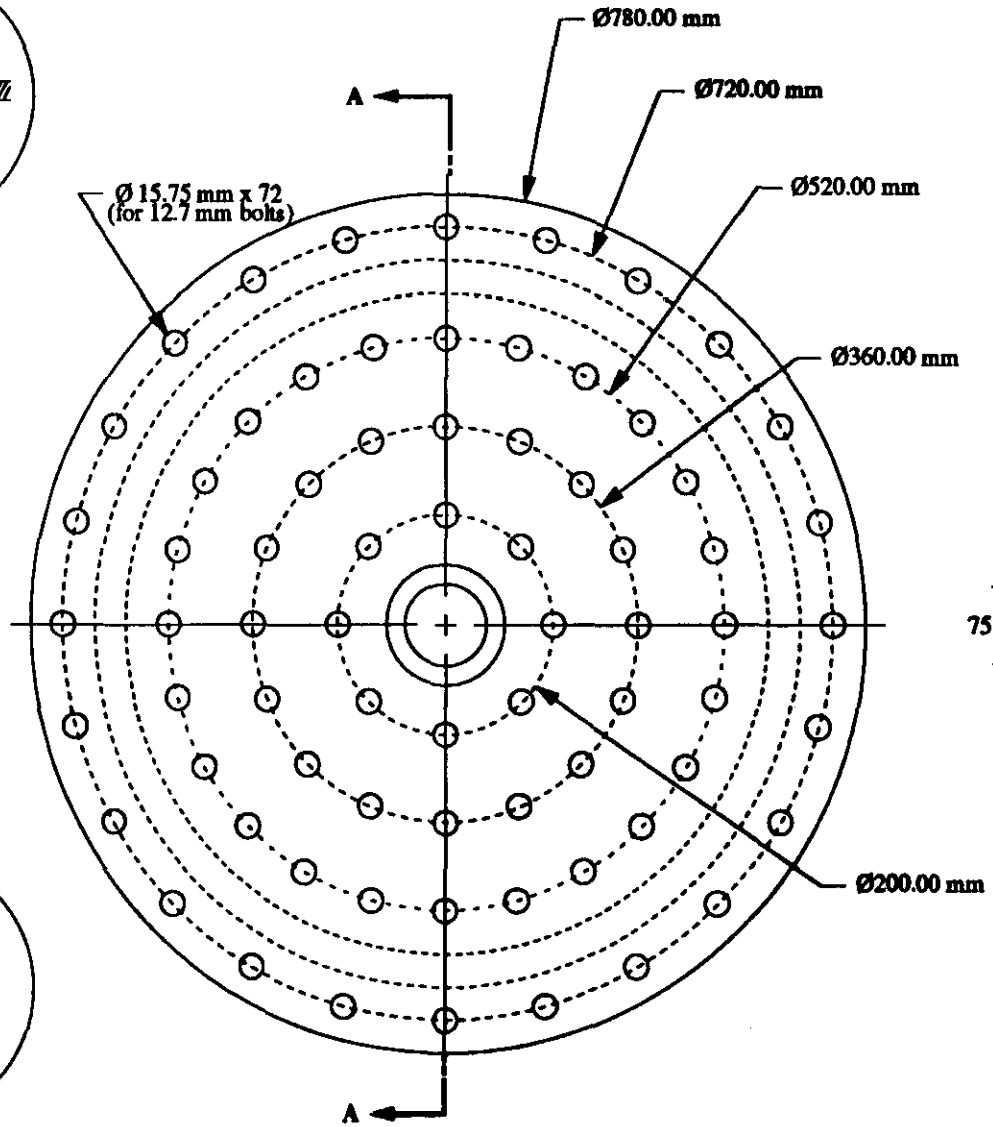
Short term Issues

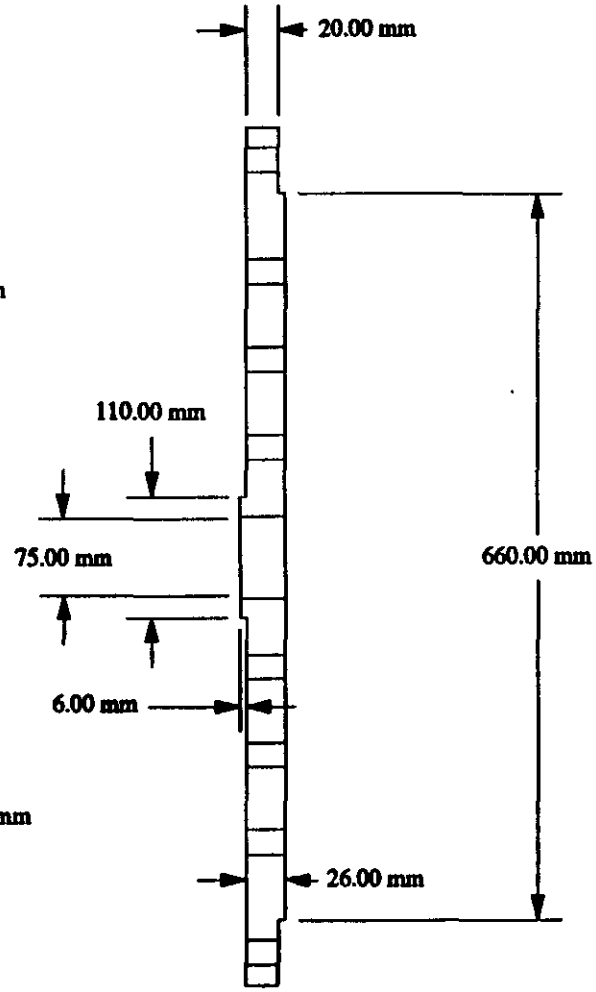
- R&D for material choice and ability to recycle and purify active material.
- Detailed engineering design needed! This will benefit both the R&D and ability to cost these GEM elements more reliably.
- Integration issue within the GEM Baseline detector design. (This impacts shielding of forward μ's, magnet iron, μ system supports etc.)
- Simulation of physics to optimize segmentation choices.
- Testing in a beam of prototype system to study performance, calibration, gain monitoring, radiation damage and liquid recycling.


Liquid IN
Liquid OUT
Chemical Top off
Filtration
Liquid Storage & monitor
Pump
monitor spectrometer

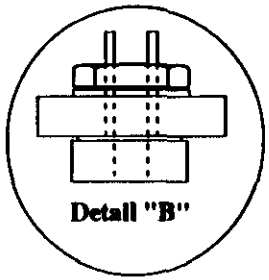
Steve Chae







VIEW "A-A"

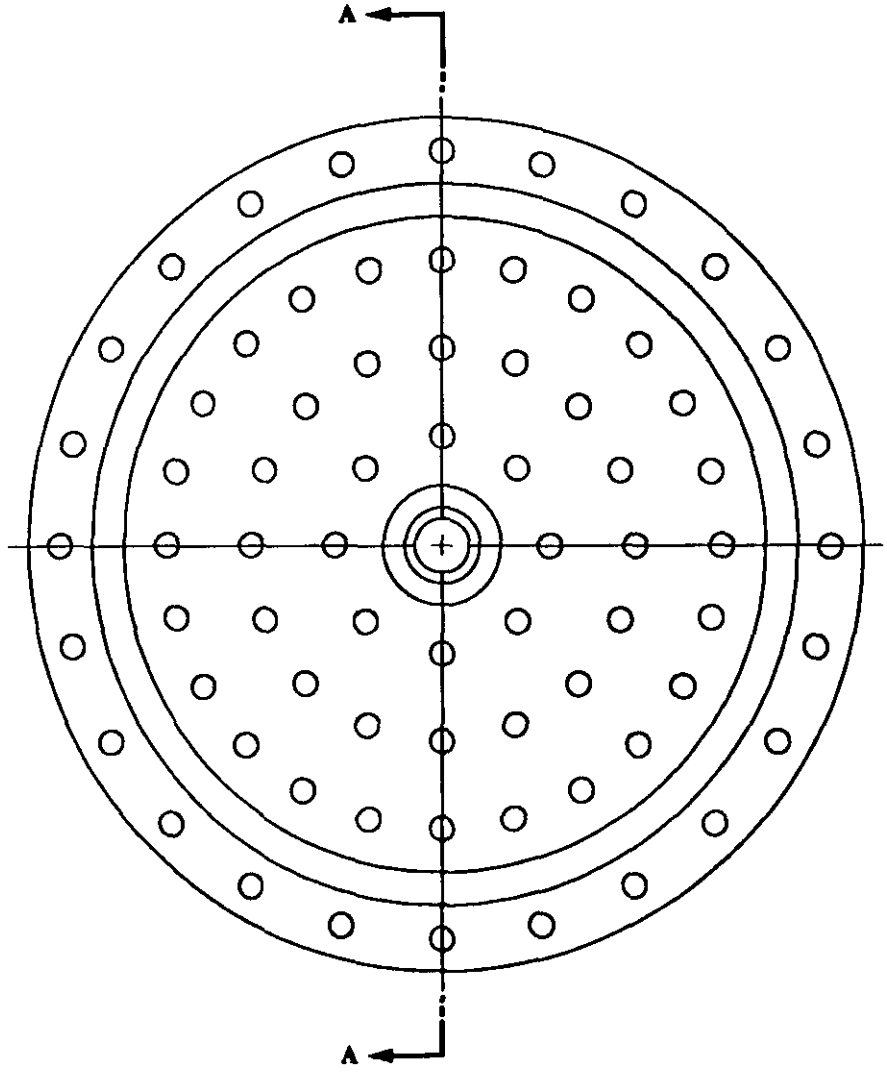


MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT

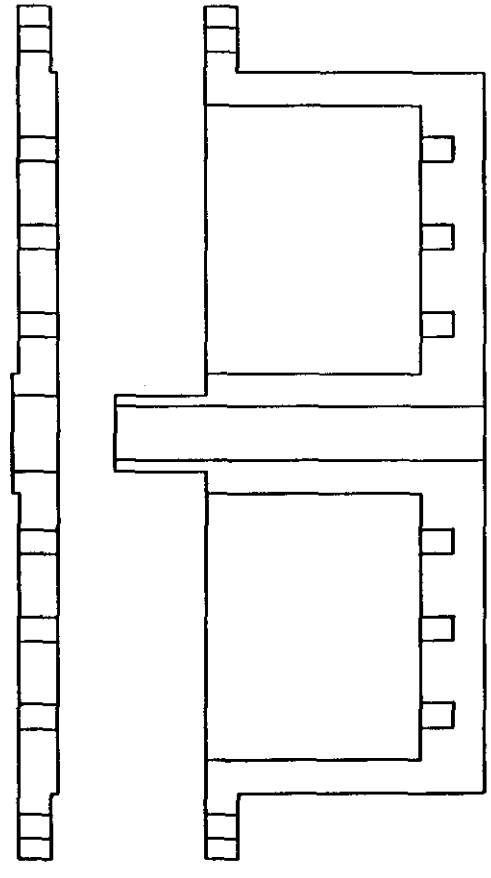
Notes: 1. Stays are screwed through plate and fitted with single nuts outside of plate, or with inside and outside nuts, omitting washers. (See detail "A".)

2. The center of the cover plate is bolted down by a method shown in detail "B".

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 2	
PRINT NO: D-FCHPG-GMD002sp	REV 0
DRAWN BY: S. M. CHAE	1/15/92
CHECKED & APPROVED BY:	

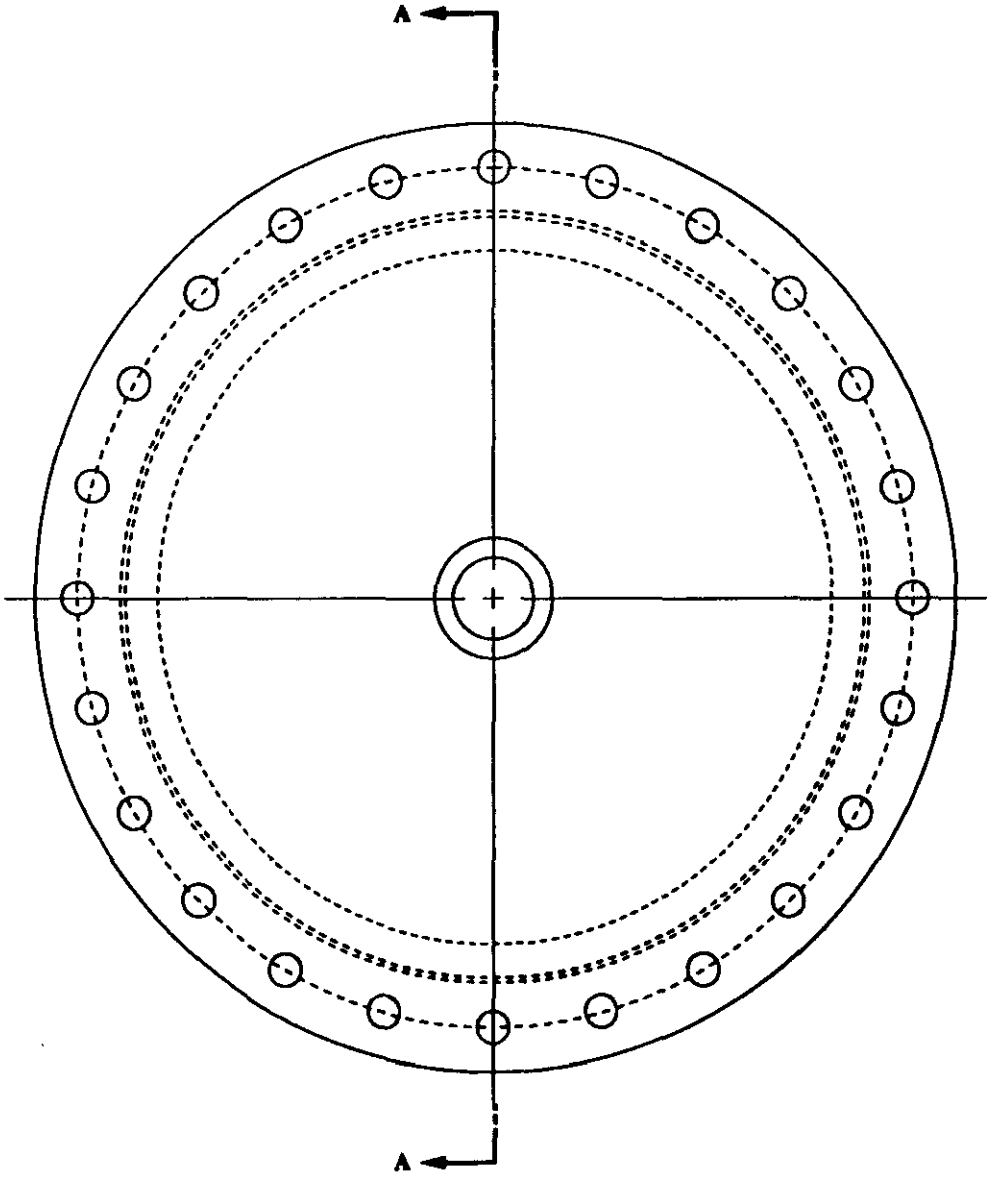


MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT

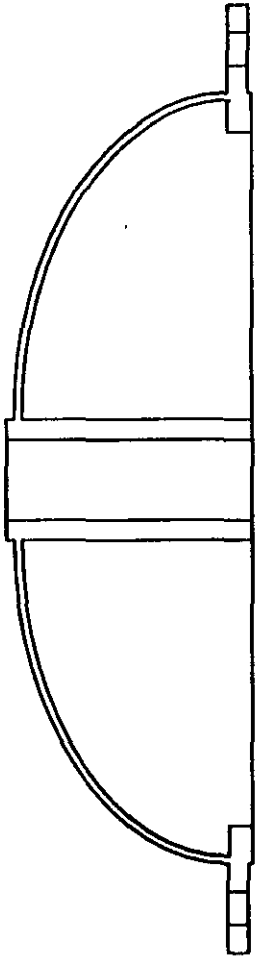


VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 2	
PRINT NO: D-FCHPG-GMD001sp	REV 0
DRAWN BY: S. M. CHAE	1/15/92
CHECKED & APPROVED BY:	

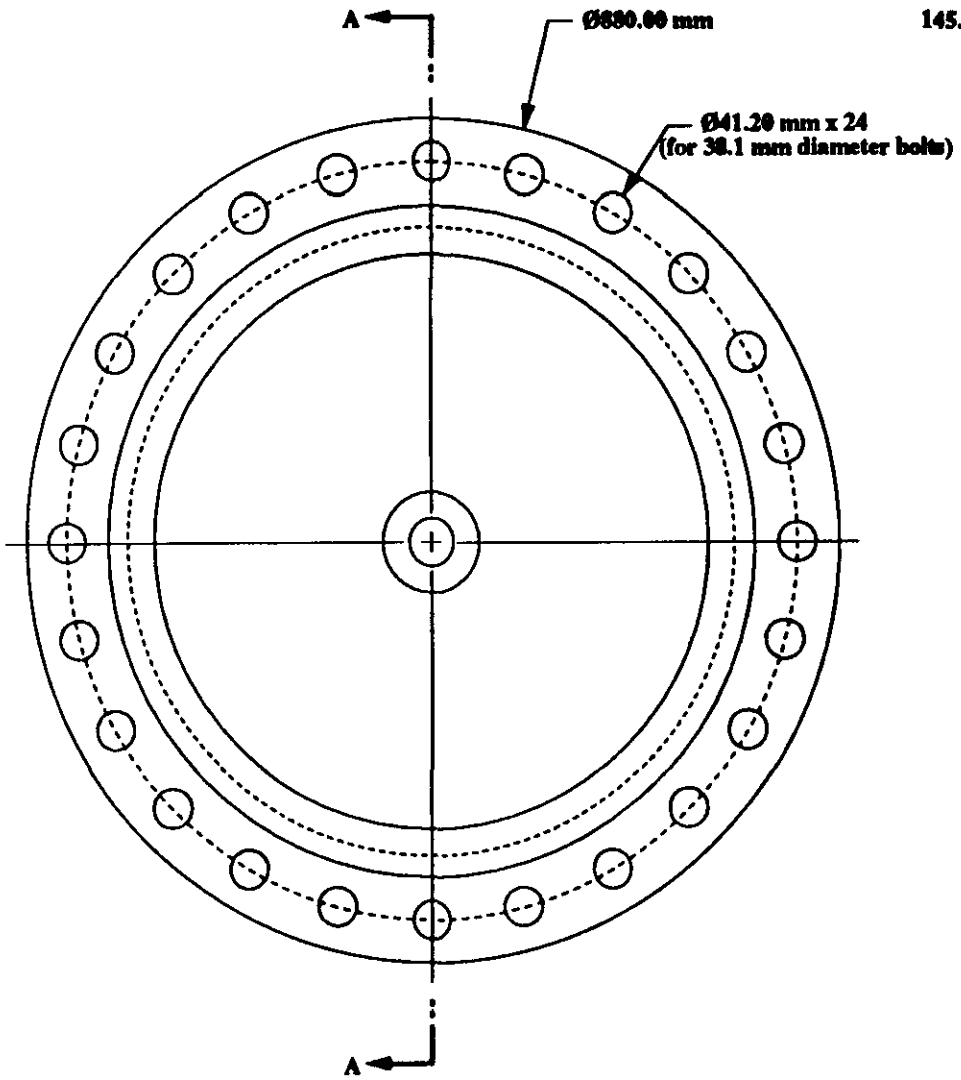


MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT

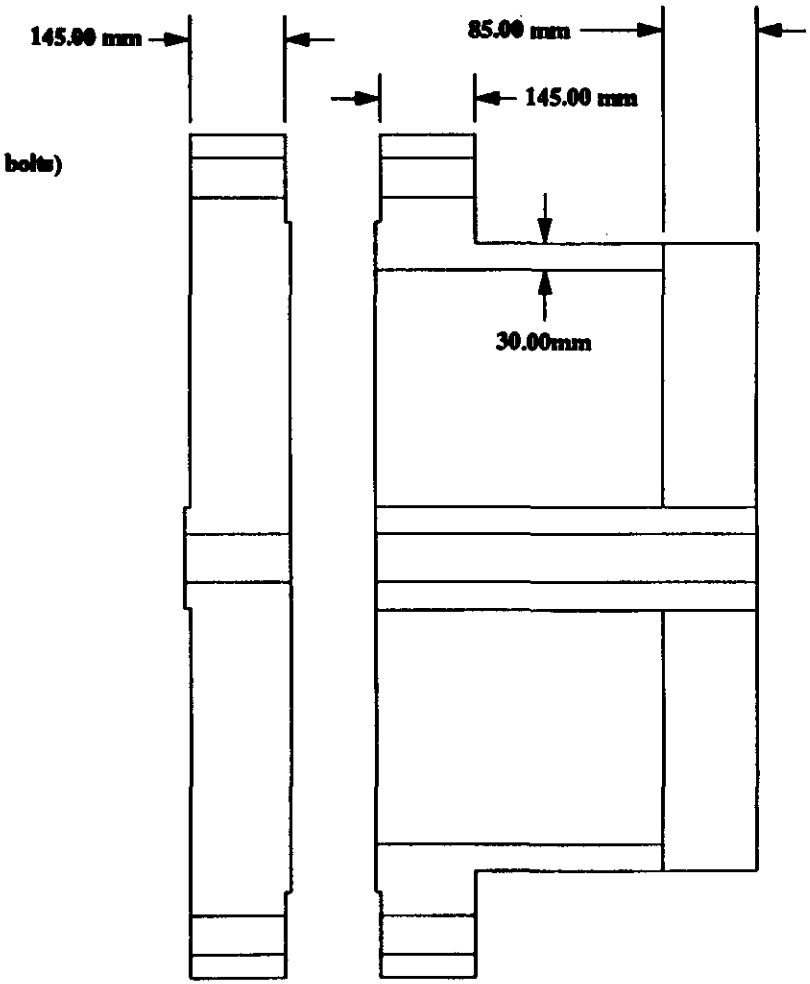


VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 1	
PRINT NO: D-FCHPG-GMD002eh	REV 0
DRAWN BY: S. M. CHAE	1/21/92
CHECKED & APPROVED BY:	

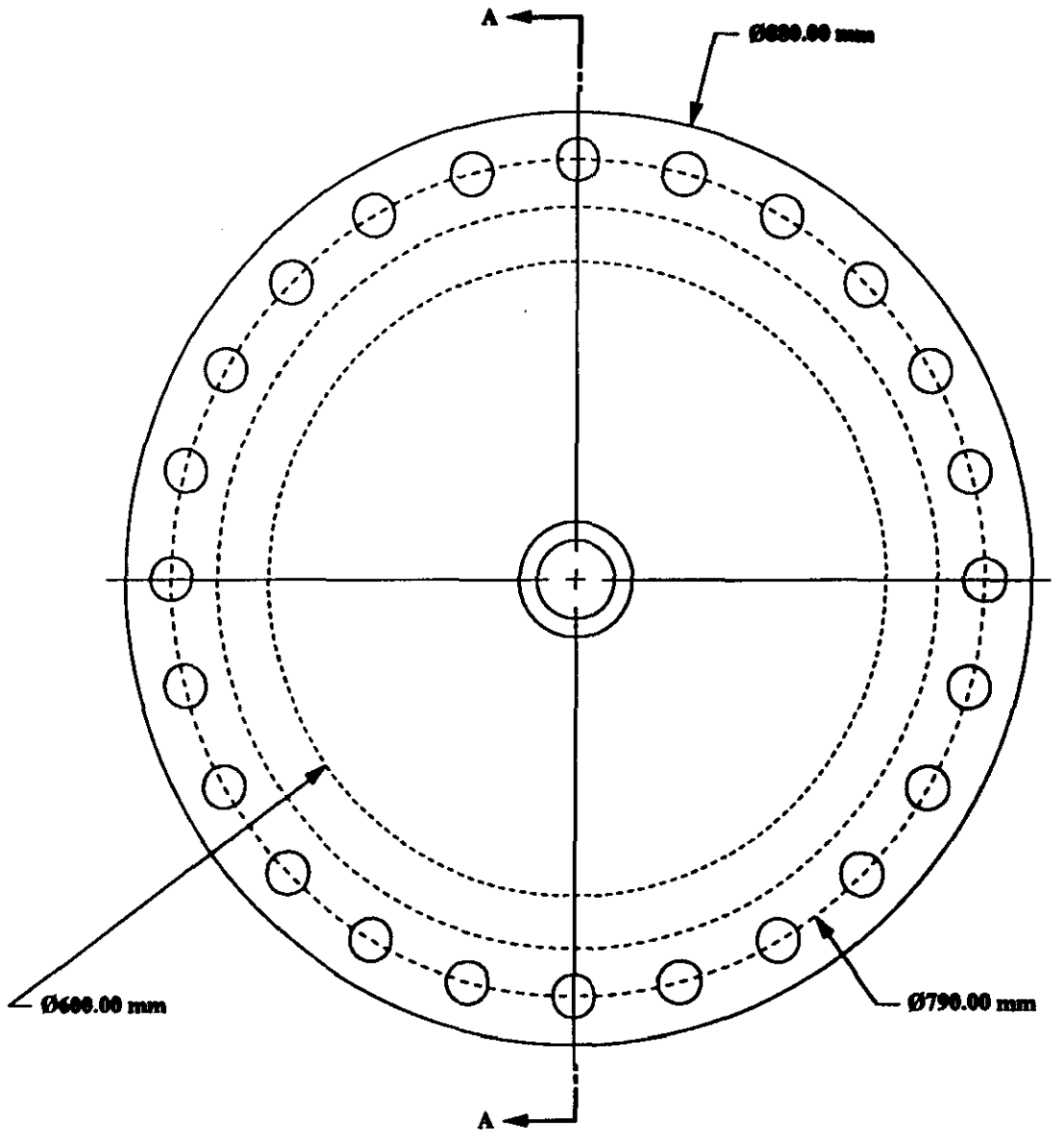


TOP VIEW OF THE PRESSURE MANIFOLD

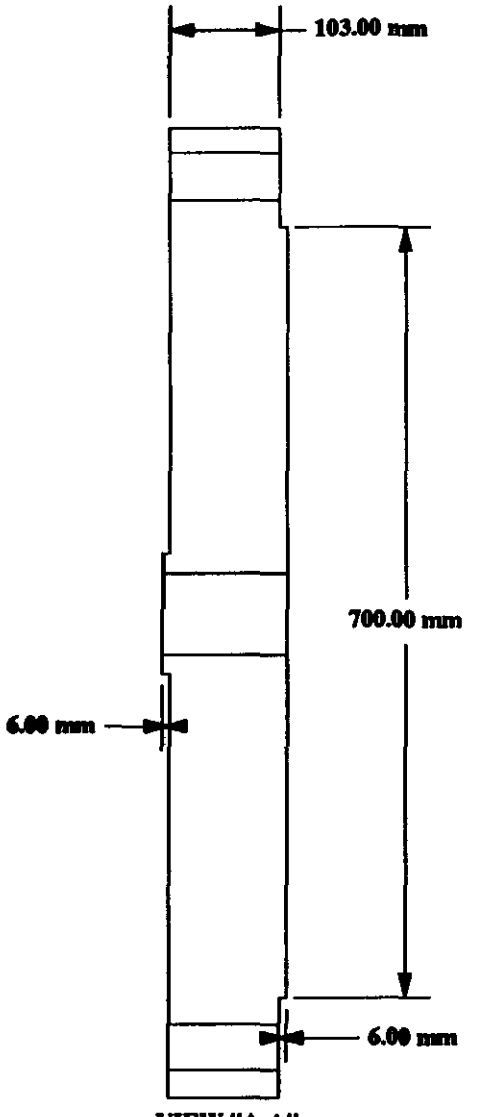


VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN BOLT ARRANGEMENT OPTION 1	
PRINT NO: D-FCHPG-GMD001	REV 0
DRAWN BY: S. M. CHAE	1/3/92
CHECKED & APPROVED BY:	

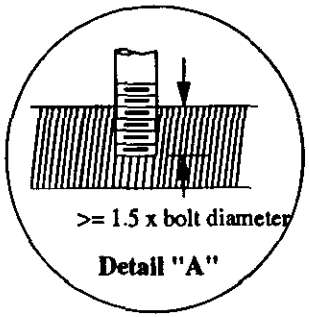


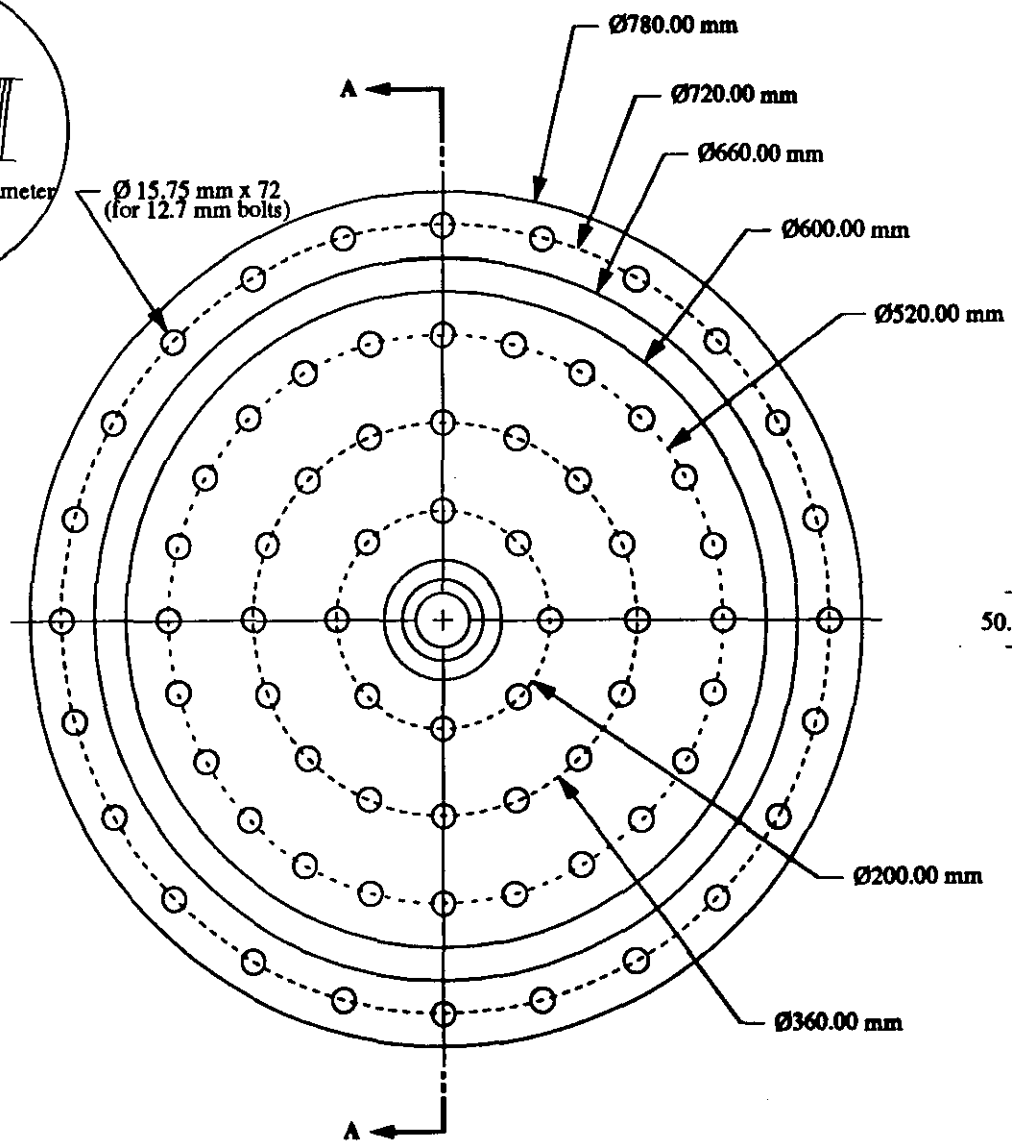
MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT

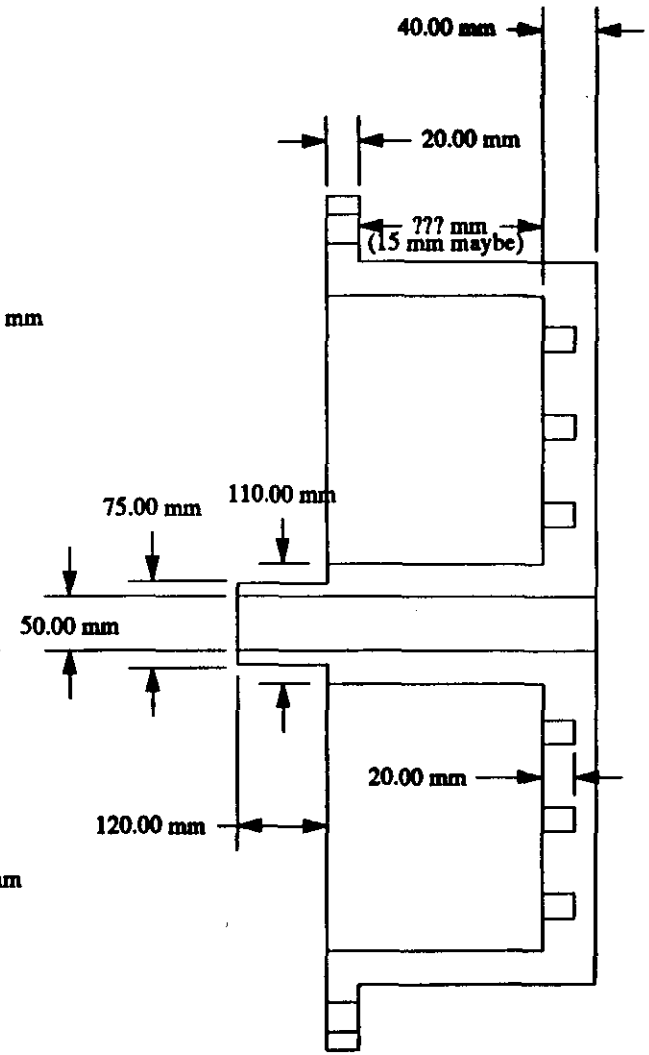


VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 1	
PRINT NO: D-FCHPG-GMD002	REV 0
DRAWN BY: S. M. CHAE	1/3/92
CHECKED & APPROVED BY:	







VIEW "A-A"

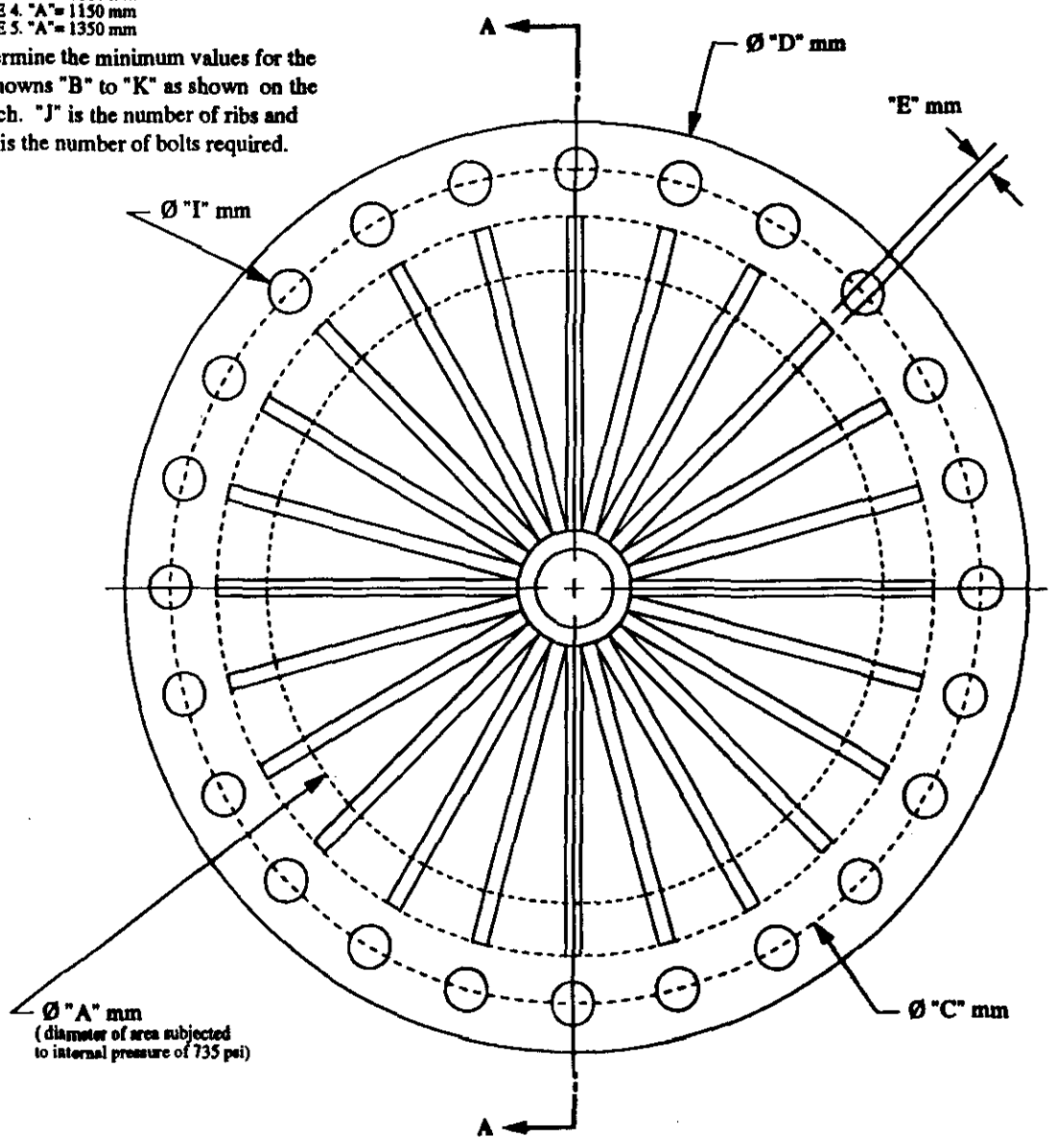
MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT

Notes: 1. Stays are screwed into the plate as shown in detail "A".

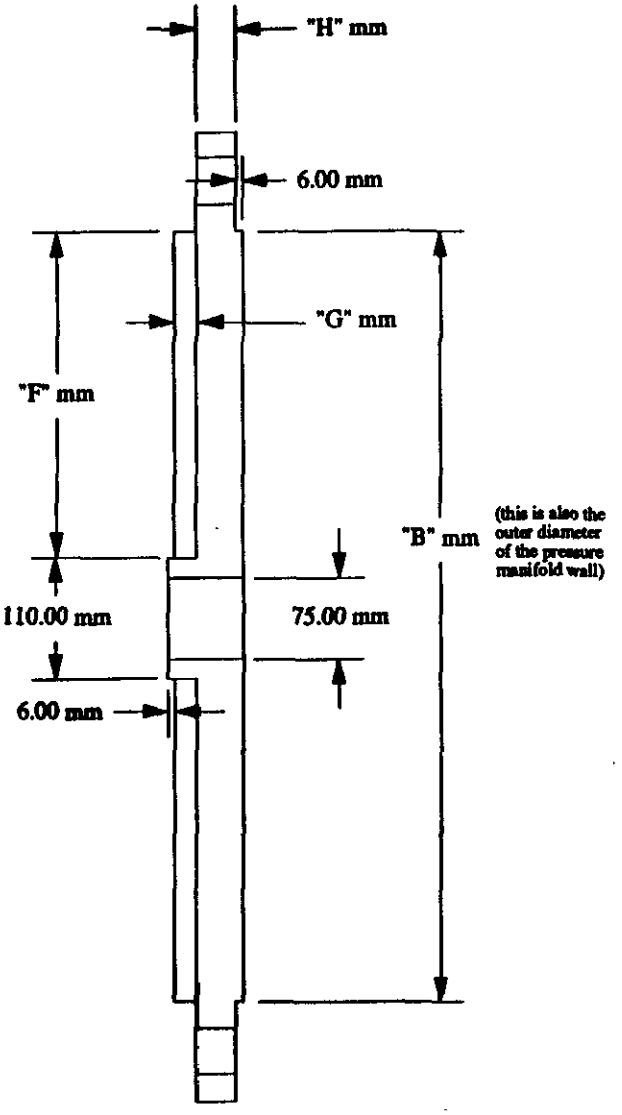
MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 2	
PRINT NO: D-FCHPG-GMD003	REV 0
DRAWN BY: S. M. CHAE	1/15/92
CHECKED & APPROVED BY:	

CASE 1. "A"= 600 mm
CASE 2. "A"= 800 mm
CASE 3. "A"= 1000 mm
CASE 4. "A"= 1150 mm
CASE 5. "A"= 1350 mm

Determine the minimum values for the unknowns "B" to "K" as shown on the sketch. "J" is the number of ribs and "K" is the number of bolts required.

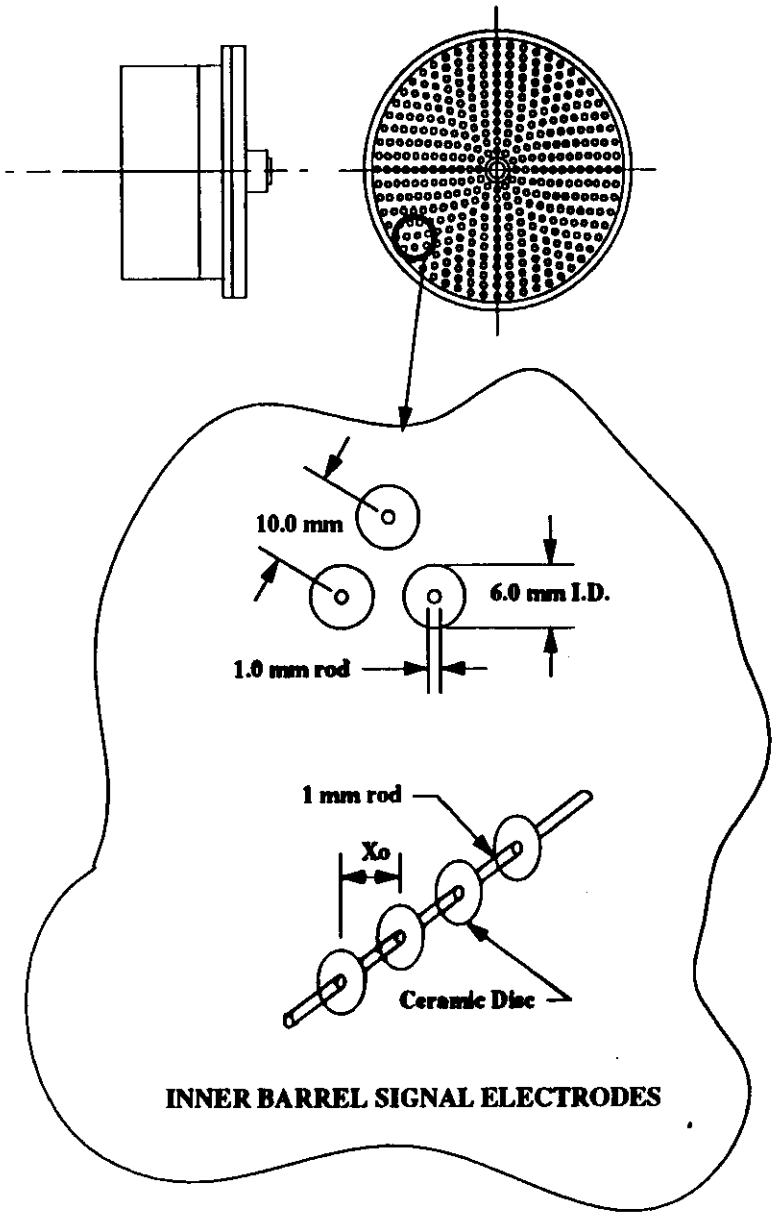


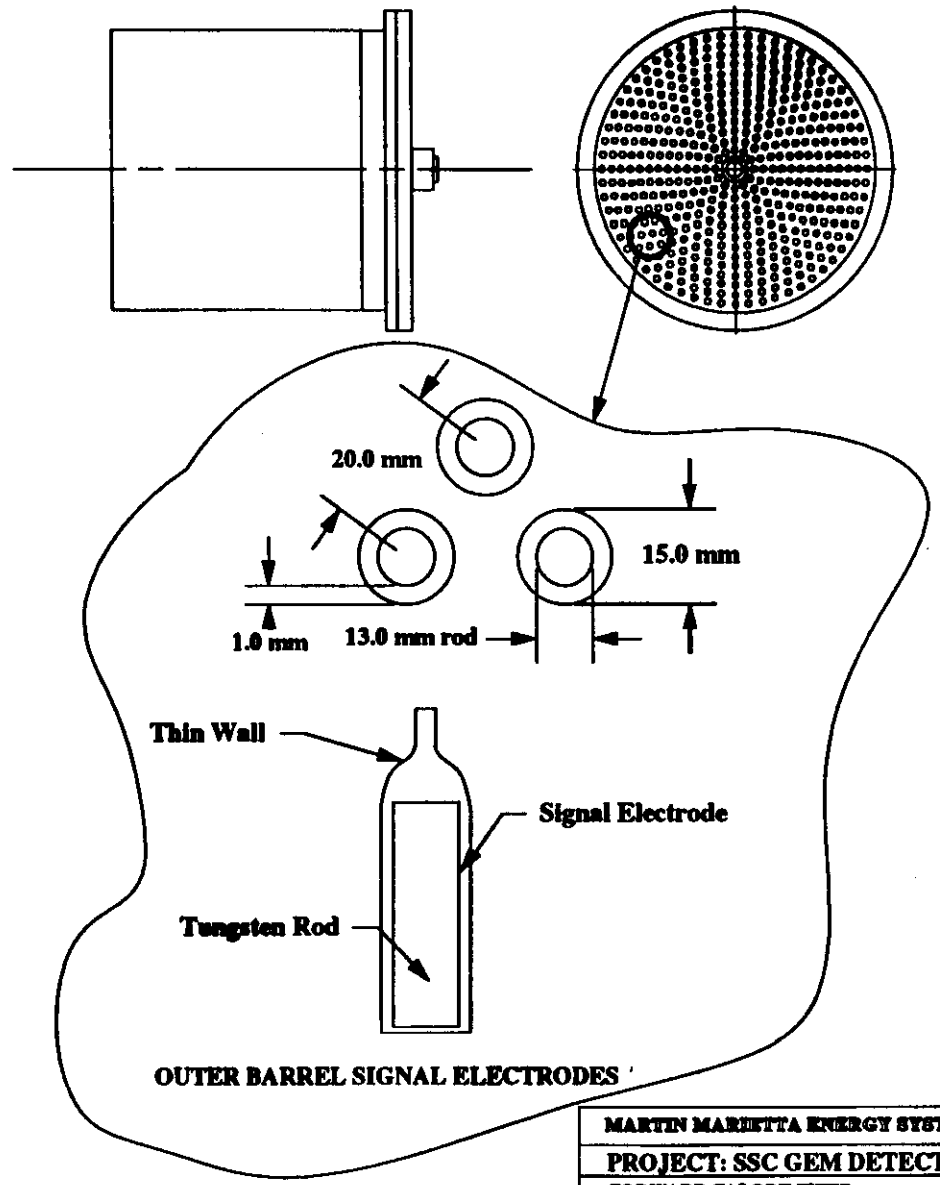
MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT



VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 3	
PRINT NO: D-FCHPG-GMD002rp	REV 0
DRAWN BY: S. M. CHAE	1/21/92
CHECKED & APPROVED BY:	

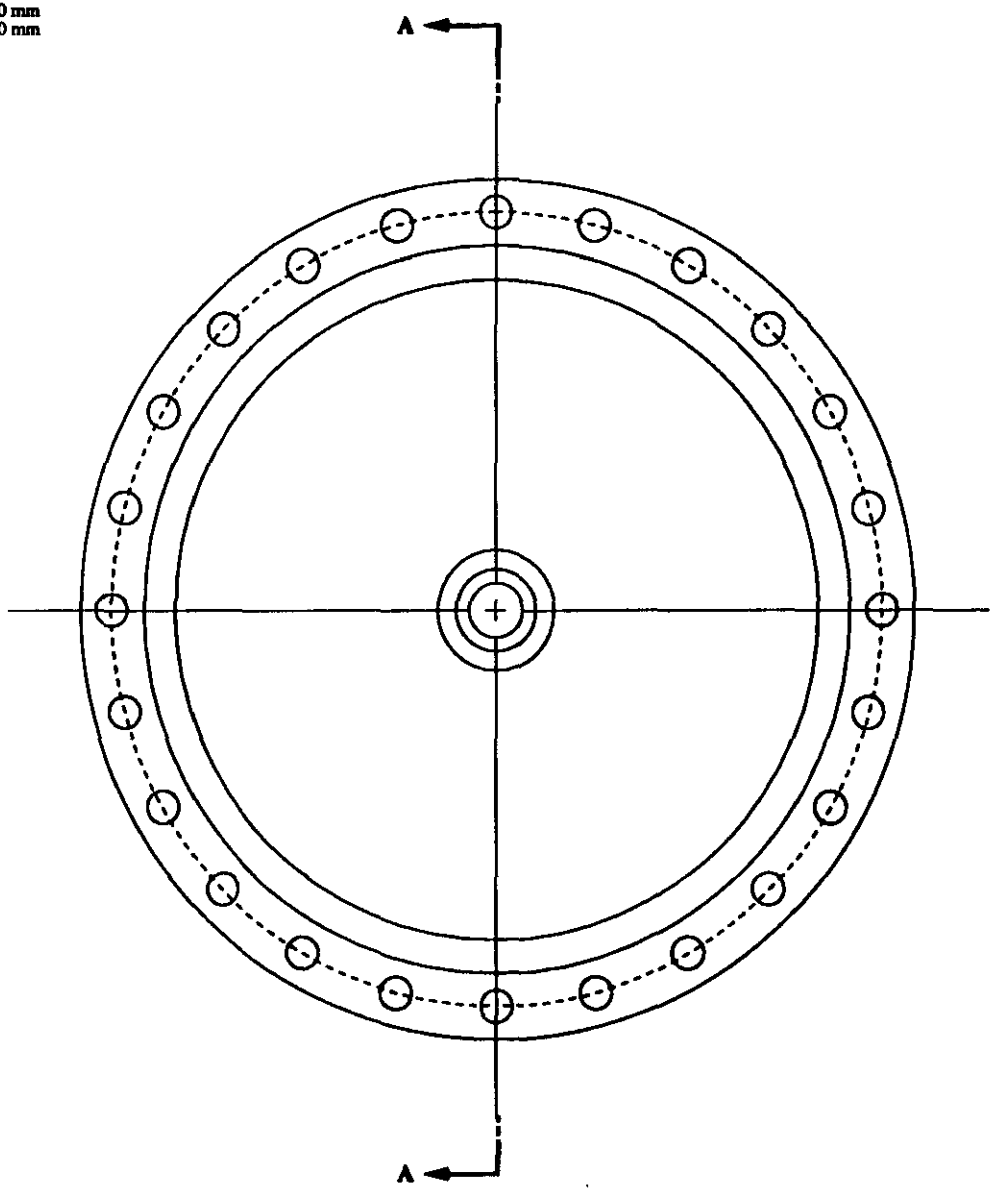




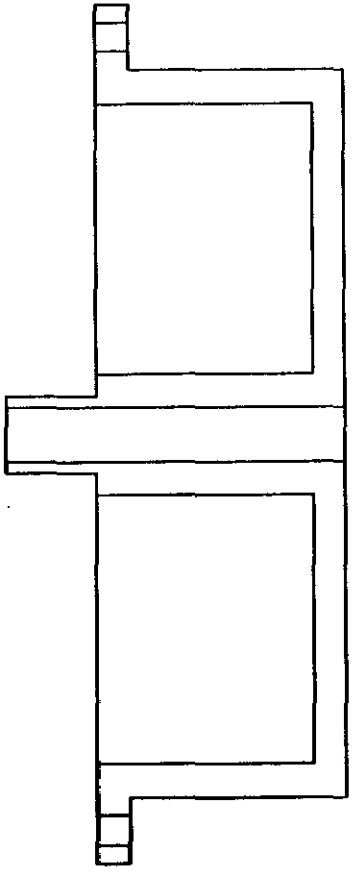
NOTES: 1. The tube locations are per the correct pattern.
2. All numers shown are approximate values.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION TUBE ARRANGEMENTS IN INNER & OUTER BARRELS	
PRINT NO: D-FCHPG-CTD003	REV 0
DRAWN BY: S. M. CHAE	1/17/92
CHECKED & APPROVED BY:	

CASE 1. "A" = 600 mm
CASE 2. "A" = 800 mm
CASE 3. "A" = 1000 mm
CASE 4. "A" = 1150 mm
CASE 5. "A" = 1350 mm

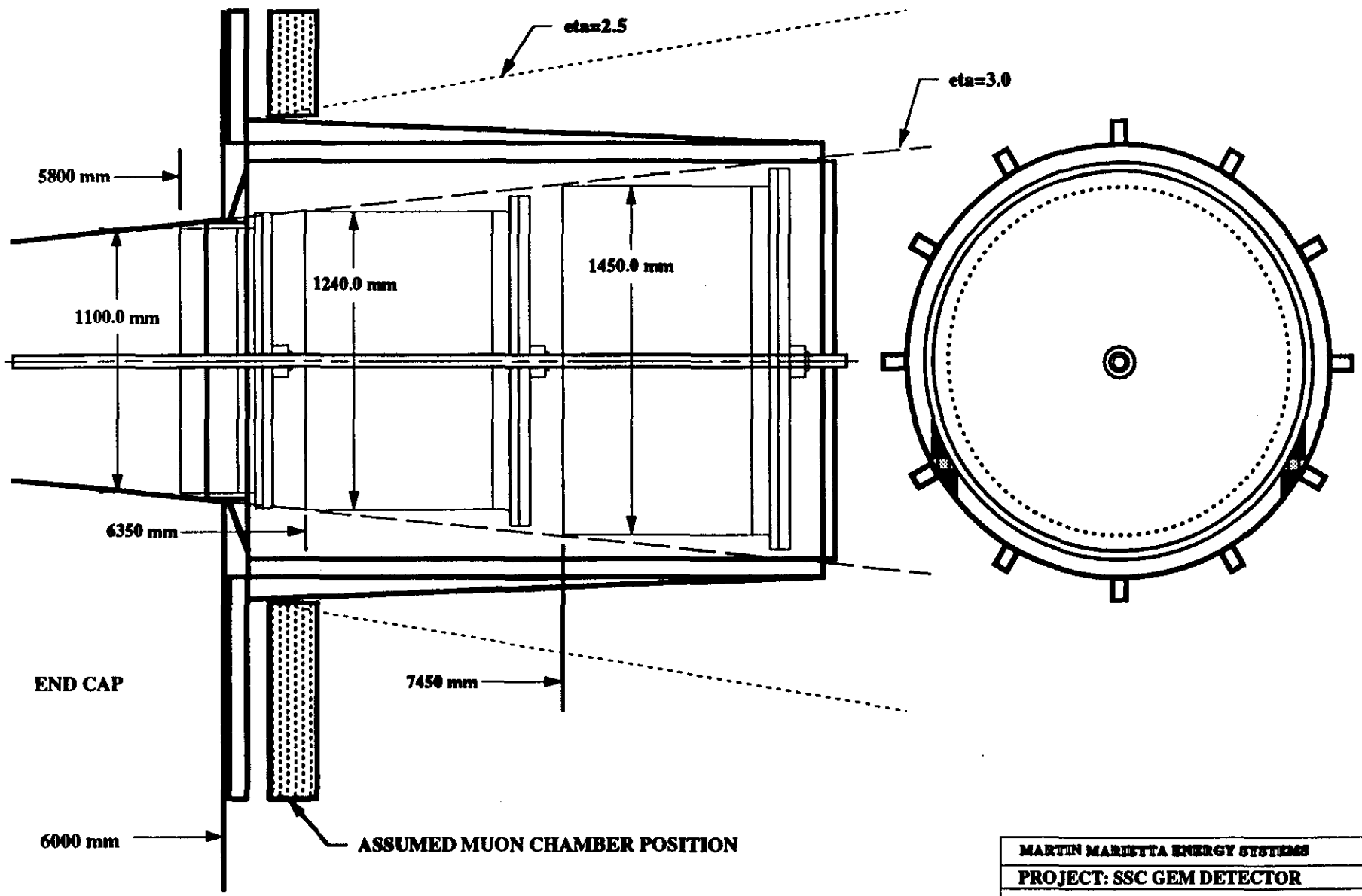


MANIFOLD COVER PLATE BOLT HOLE ARRANGEMENT



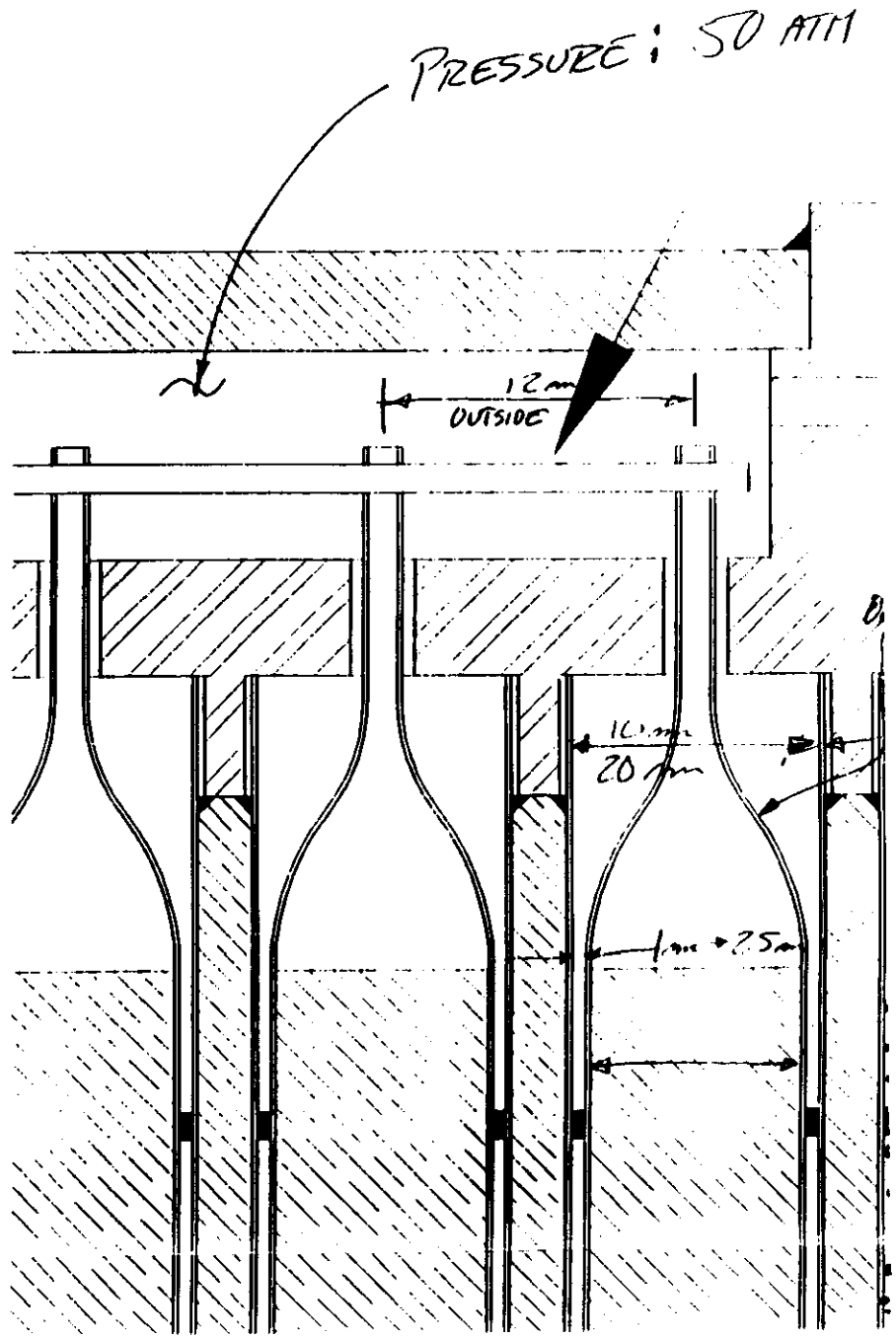
VIEW "A-A"

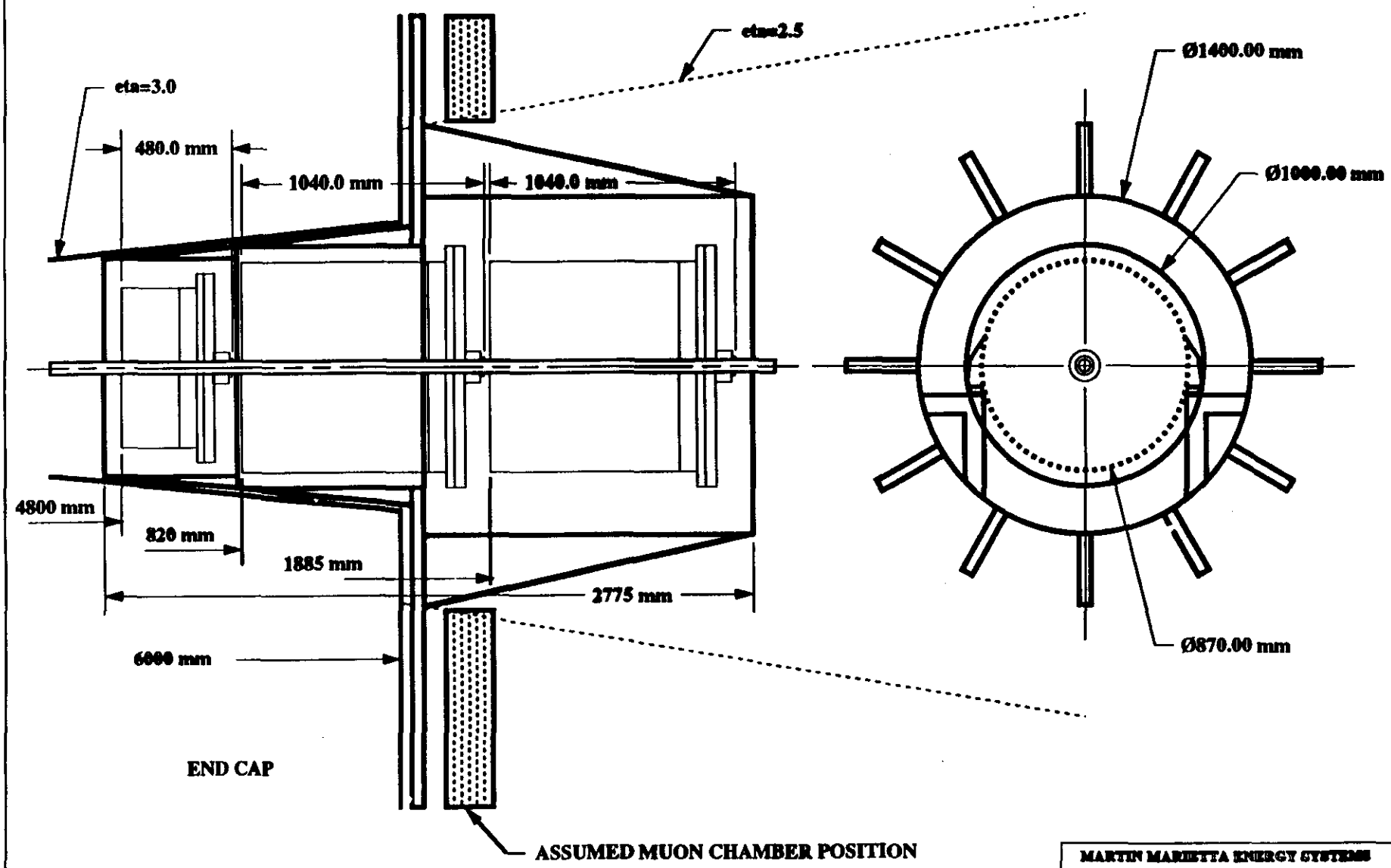
MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN GAS MANIFOLD PLATE DESIGN - OPTION 3	
PRINT NO: D-FCHPG-GMD003rp	REV 0
DRAWN BY: S. M. CHAE	1/21/92
CHECKED & APPROVED BY:	



NOTES: 1. Bolts, reinforcing ribs or the signal feed thru's are not shown on the manifold cover plates.
2. All numers shown are approximate values.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION BARREL MOUNTING CONCEPT 2	
PRINT NO: D-FCHPG-MC002	REV 0
DRAWN BY: S. M. CHAE	1/20/92
CHECKED & APPROVED BY:	


PRESSURE: 50 ATM
12 mm
OUTSIDE
10 mm
20 mm
1 mm
2.5 mm



NOTES: 1. Bolts, reinforcing ribs or the signal feed thru's are not shown on the manifold cover plates.
2. All numers shown are approximate values.

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION BARREL MOUNTING CONCEPTS	
PRINT NO: D-FCHPG-MC001	REV 0
DRAWN BY: S. M. CHAE	1/16/92
CHECKED & APPROVED BY:	

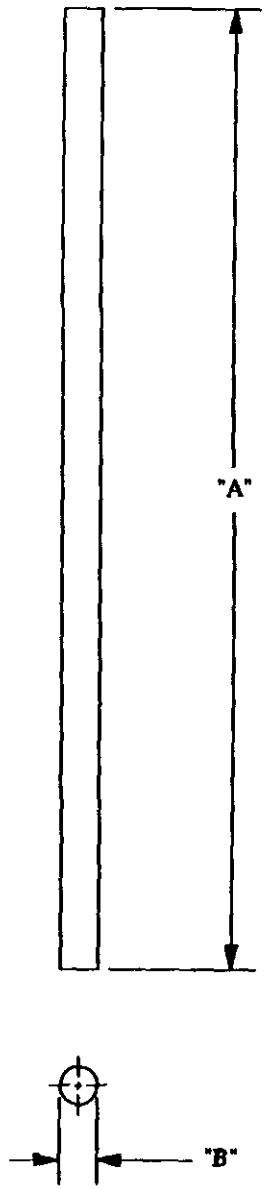
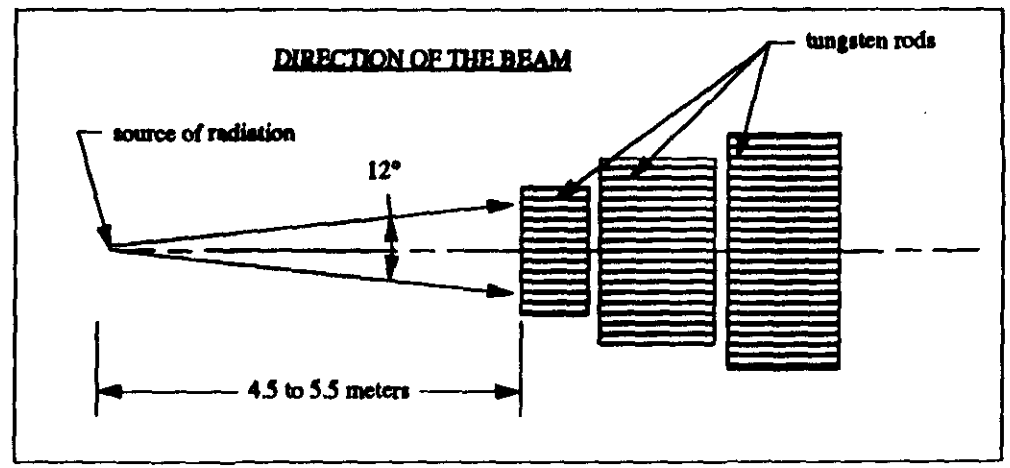


TABLE I. DIMENSIONS TUNGSTEN RODS

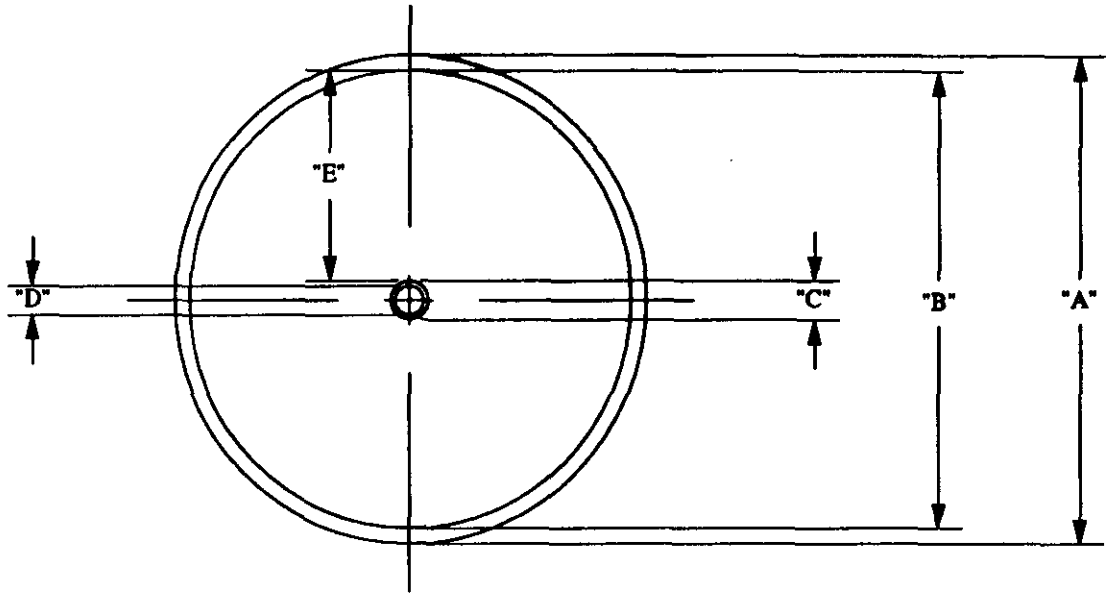
	SET 1	SET 2
Number of rods	500	1200
"A"	250.0	800.0
"B"	1.000	13.000

NOTES:

1. TUNGSTEN RODS ARE MADE OF 90% TUNGSTEN HEAVYMET.
2. ALL UNITS ARE IN MM, UNLESS SPECIFIED OTHERWISE.
3. PARTS SHOWN ARE NOT DRAWN TO SCALE.
4. THERE ARE 2 SETS OF TUNGSTEN RODS. EACH SET HAS DIFFERENT NUMBER OF PLATES WITH DIFFERENT DIMENSIONS AS SHOWN IN TABLE I. DIMENSION TOLERENCE FOR "A" IS ± 0.1mm AND FOR "B" IS ± 0.001mm.



MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION TUNGSTEN ROD DETAIL	
PRINT NO: D-FCHPG-ERD001	REV 0
DRAWN BY: S. M. CHAE	1/20/92
CHECKED & APPROVED BY:	



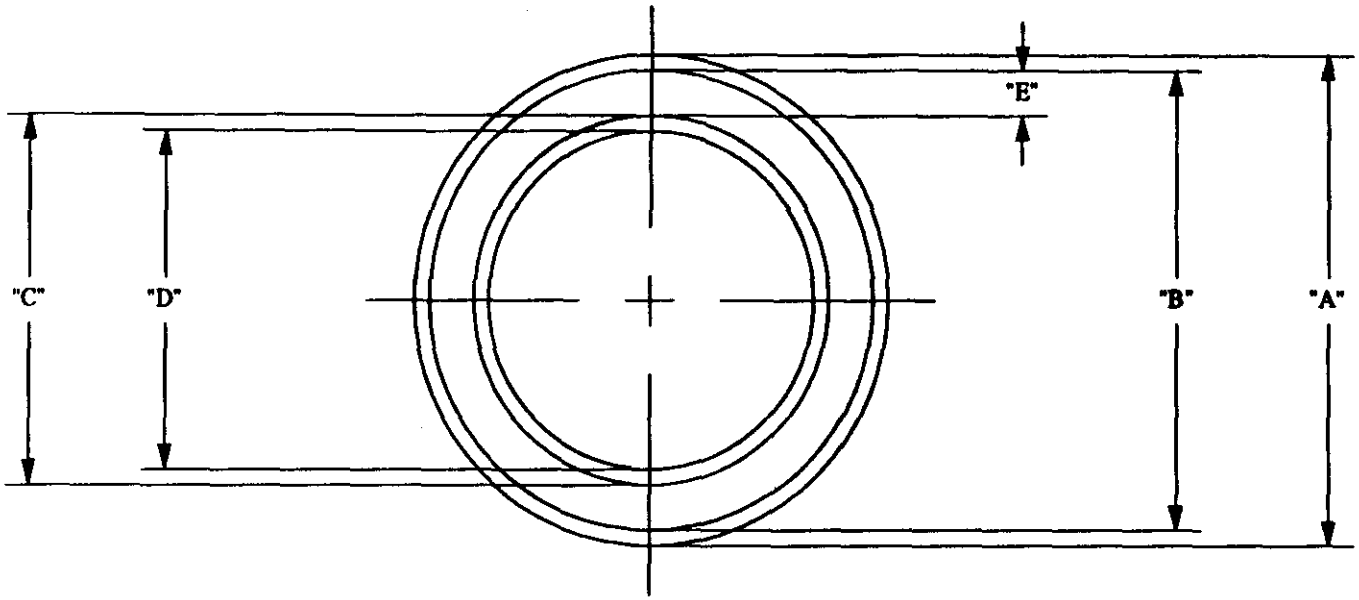
OPTIONS	WALL THICK, IN		A		B		C		D		E	
	REQ'D	AVAIL	mm	in	mm	in	mm	in	mm	in	mm	in
1	0.0091	0.0099	5.5563	0.2188	5.0546	0.1990	1.0160	0.0400	0.7620	0.0300	2.0193	0.0795
2	0.0105	0.0100	6.3500	0.2500	5.8420	0.2300	1.0160	0.0400	0.7620	0.0300	2.4130	0.0950
3	0.0103	0.0120	6.3500	0.2500	5.7404	0.2260	1.0160	0.0400	0.7620	0.0300	2.3622	0.0930
4	0.0107	0.0160	6.7310	0.2650	5.9182	0.2330	1.0160	0.0400	0.7620	0.0300	2.4511	0.0965
5	0.0128	0.0158	7.9375	0.3125	7.1374	0.2810	1.0160	0.0400	0.7620	0.0300	3.0607	0.1205
6	0.0144	0.0149	8.7313	0.3438	7.9756	0.3140	1.0160	0.0400	0.7620	0.0300	3.4798	0.1370
7	0.0157	0.0160	9.5250	0.3750	8.7122	0.3430	1.0160	0.0400	0.7620	0.0300	3.8481	0.1515
8	0.0203	0.0280	12.7000	0.5000	11.2776	0.4440	1.0160	0.0400	0.7620	0.0300	5.1308	0.2020
9	0.0232	0.0278	14.2875	0.5625	12.8778	0.5070	1.0160	0.0400	0.7620	0.0300	5.9309	0.2335
10	0.0260	0.0280	15.8750	0.6250	14.4526	0.5690	1.0160	0.0400	0.7620	0.0300	6.7183	0.2645
11	0.0285	0.0318	17.4625	0.6875	15.8496	0.6240	1.0160	0.0400	0.7620	0.0300	7.4168	0.2920

MARTIN MARIETTA ENERGY SYSTEMS

PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
HIGH PRESSURE GAS OPTION
CYLINDER TUBE SIZE DESIGN
OPTION 2: APPRX. 1 mmOD INNER TUBE

PRINT NO: D-FCHPG-CTD002	REV 1
DRAWN BY: S. M. CHAE	12/30/91
CHECKED & APPROVED BY:	



OPTIONS	WALL THICK, IN		A		B		C		D		E	
	REQ'D	AVAIL	mm	in	mm	in	mm	in	mm	in	mm	in
1	0.0157	0.0160	9.5250	0.375	8.7122	0.3430	6.5532	0.2580	6.3500	0.2500	1.0795	0.0425
2	0.0203	0.0200	12.7000	0.5000	11.2776	0.4440	9.5250	0.3750	9.1694	0.3610	0.8763	0.0345
3	0.0232	0.0270	14.2875	0.5625	12.8778	0.5070	11.1125	0.4375	10.8204	0.4260	0.8827	0.0348
4	0.0260	0.0280	15.8750	0.6250	14.4526	0.5690	12.7000	0.5000	12.4460	0.4900	0.8763	0.0345
5	0.0285	0.0318	17.4625	0.6875	15.8496	0.6240	14.2875	0.5625	13.4874	0.5310	0.7811	0.3080
6	0.0311	0.0350	19.0500	0.7500	17.2720	0.6800	15.8750	0.6250	15.3670	0.6050	0.6985	0.0275
7	0.0343	0.0060	19.3548	0.7620	19.0500	0.7500	15.8750	0.6250	15.0622	0.5930	1.5875	0.0625
8	0.0355	0.0490	22.2250	0.8750	19.7358	0.7770	17.4625	0.6875	16.4592	0.6480	1.1367	0.0448
9	0.0411	0.0200	23.8252	0.9380	22.8092	0.8980	19.3548	0.7620	19.0500	0.7500	1.7272	0.0680
10	0.0432	0.0200	24.9936	0.9840	23.9776	0.9440	19.3548	0.7620	19.0500	0.7500	2.3114	0.0910
11	0.0432	0.0200	24.9936	0.9840	23.9776	0.9440	22.2250	0.8750	21.4122	0.8430	0.8763	0.0345

MARTIN MARIETTA ENERGY SYSTEMS

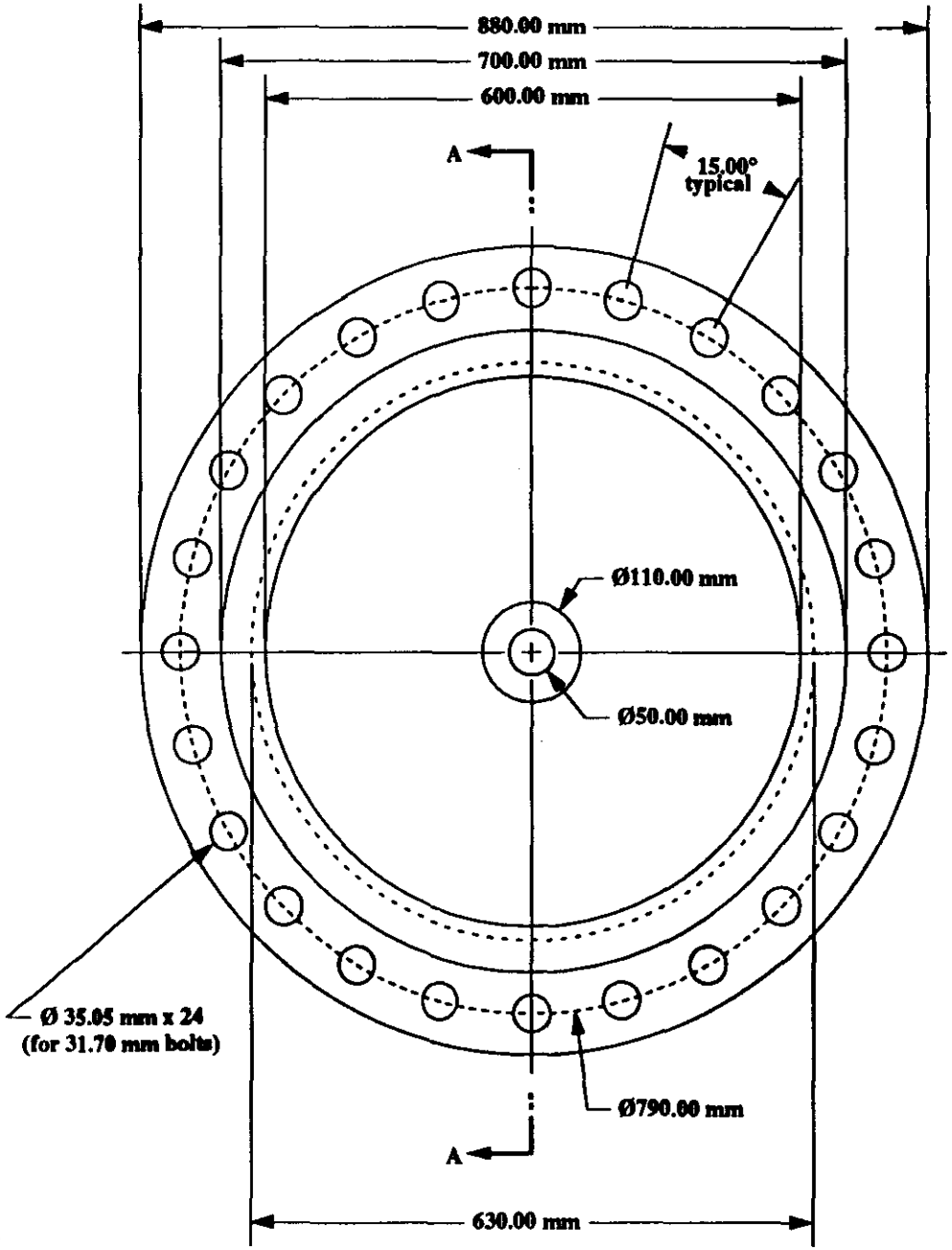
PROJECT: SSC GEM DETECTOR

FORWARD CALORIMETER
HIGH PRESSURE GAS OPTION
CYLINDER TUBE SIZE DESIGN
OPTION 1: APPROX. 1 mm GAS GAP

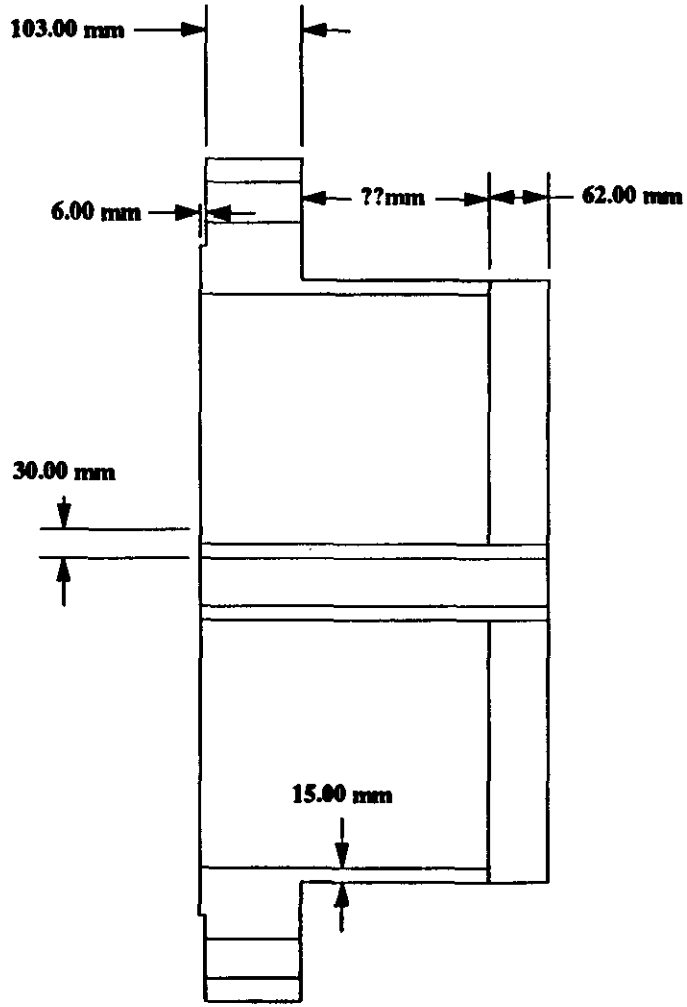
PRINT NO: D-FCHPG-CTD001 | REV 0

DRAWN BY: S. M. CHAE | 12/12/91

CHECKED & APPROVED BY:



MANIFOLD WALL BOLT HOLE ARRANGEMENT



VIEW "A-A"

MARTIN MARIETTA ENERGY SYSTEMS	
PROJECT: SSC GEM DETECTOR	
FORWARD CALORIMETER HIGH PRESSURE GAS OPTION GAS MANIFOLD DESIGN MANIFOLD DESIGN OPTION 1	
PRINT NO: D-FCHPG-GMD003	REV 0
DRAWN BY: S. M. CHAE	1/3/92
CHECKED & APPROVED BY:	