GEM TN-92-233

Neutron Task Force Meeting - SSCL

November 17, 1992

Abstract:

Attendees and presentations of the GEM Neutron Task Force Meeting held at the SSC Laboratory on November 17, 1992.

NEUTRON TASK FORCE / SSCL Nov 17, 1992

Michael Marx	SSCL	x 6188	SSCVX1::MARX
Yuri Kamyshkov	ORNL		SSCVX1::KAMYSHKOV
Nicolai Martovetsky	SSCL	6324	SSCVX1::MARTOVETSKY
Vladimir Glebov	SSCL	6321	SSCVX1::GLEBOV
Kate Morgan	SSCL	6027	SSCVX1::MORGAN
Craig Wuest	LLNL	(510) 423-2909	WUEST@LLNL.GOV
Yaman Guo	SSCL	X4457	SSCVX1::GUO
Yuri Fisyak	— " —	x6322	SSCVX1::FISYAK
Valery Kubarovsky	SSCL	x 3088	SSCVX1::KUBAROVSKY
Nikolay Mokhov	SSCL	x 4548	SSCVX1::MOKHOV
Frank Taylor	MIT	617-253-7249	MITLNS::FET
Roger McNeil	LSU	504-388-6857	LSUHEP::McNEIL
Christian Zeitnitz	Arizona	602-621-6804	UAZHEP::ZEITNITZ
John Rutherfoord	Arizona	602-621-2657	UAZHEP::RUTHERFO
DAVID M. LEE	LANL	505-667-8888	LEE@LAMPF

Presentation by:

Nikolai Mokhov

Nikolai Mokhov

SOURCE TERM IN INTERACTION REGIONS

- 20×20 TeV pp collisions at 10^8 Hz (10^{33} $cm^{-2}s^{-1}$)

  Three components: $x_F < 0.8$ secondaries

  $x_F > 0.8$ charge particles (protons)

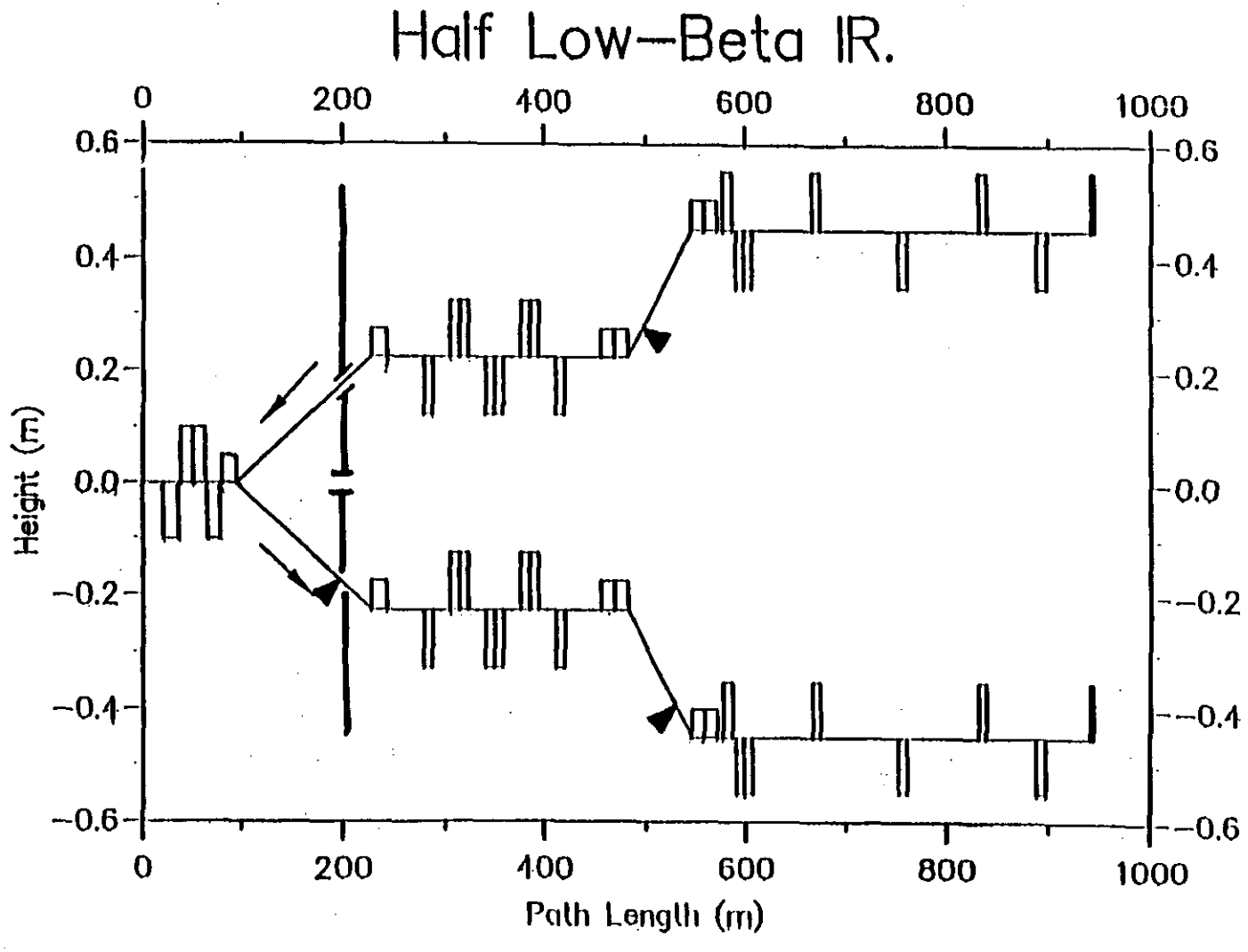
  $x_F > 0.8$ neutrals

- Beam Halo - Low-beta quads are a bottleneck for halo particles, so even with scrapers and collimators in the system on, they will experience increased beam loss, being a source of background to detector

  At $\beta^* = 0.5$ m $\beta_{peak} = 9180$ m. For 50 mm bore quadrupoles with 42mm beam pipe, LBQ aperture is +/- 30 σ. So, at maximum one can expect ~ 10^7 Hz beam loss rate at these locations

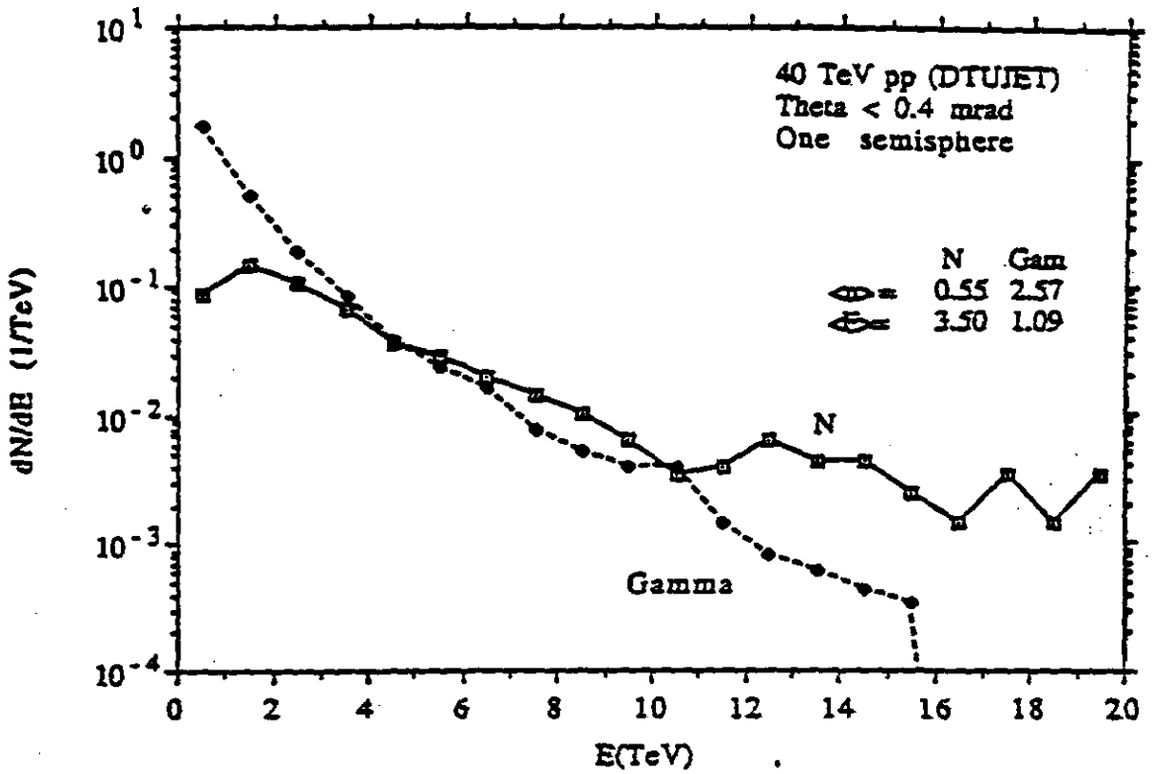
- Accidental Beam Loss $(1.3 - 4) \times 10^{14}$ ppp

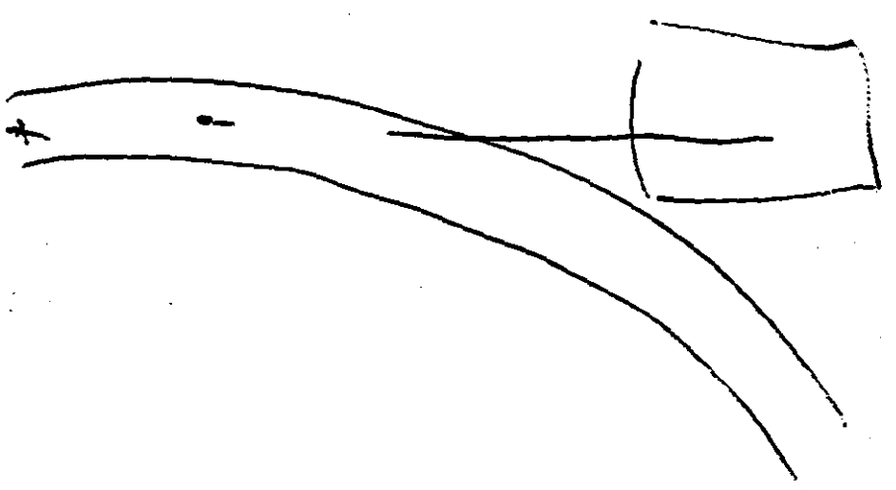
Nikolai Mokhov
Nov 17, 1992



20x20 TEV EVENT IN THE SSC LOW-BETA IR

Component	Length (m)	Energy (%)	γ / tot (E)	γ / tot (No)
Detector	0 - 18	1.6	0.3	0.5
Collimator	18 - 20	4.2		
Q1 - Q2	20 - 45	18.0	0.5	0.4
Q3 - Q4	45 - 81	13.7		
$BV1^-$ - $BV1^+$	81 - 244	15.0		
Leak(Protons)	> 244	24.0		
Leak(Neutral)	> 81	23.5	0.6	0.8


40 TeV pp (DTUJET)
Theta < 0.4 mrad
One semisphere
N Gam
0.55 2.57
3.50 1.09
N
Gamma
dN/dE (1/TeV)
E(TeV)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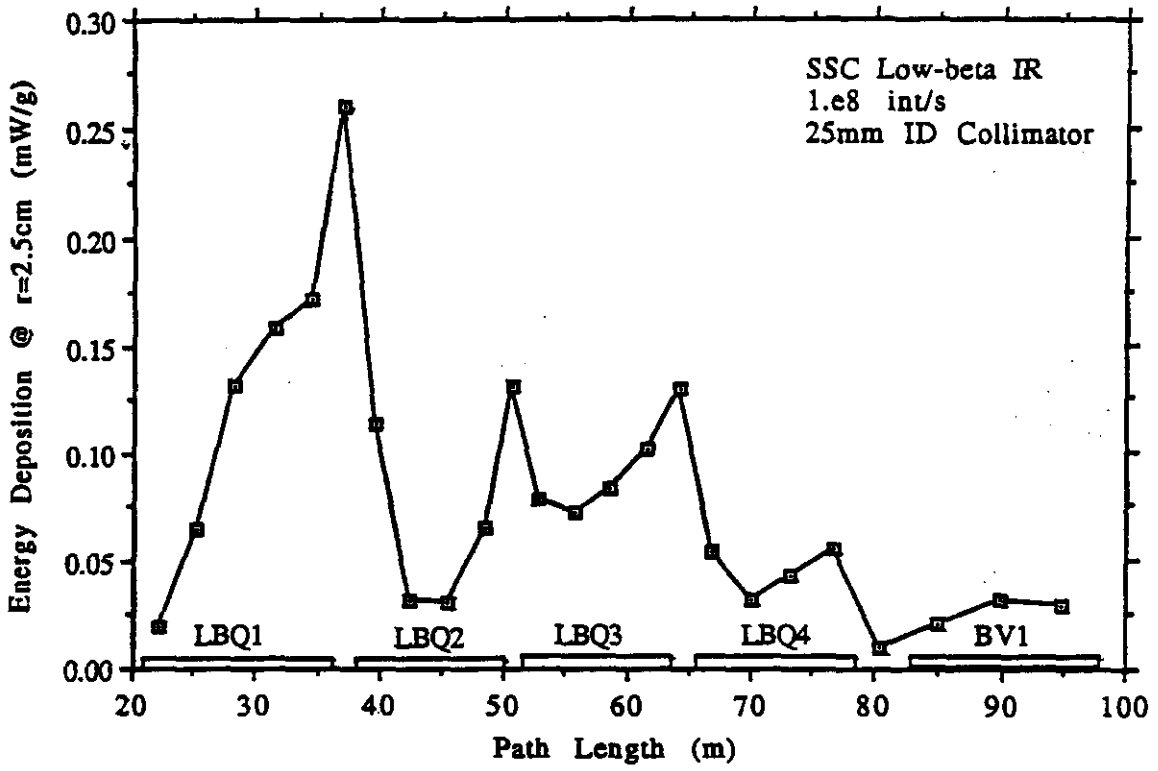
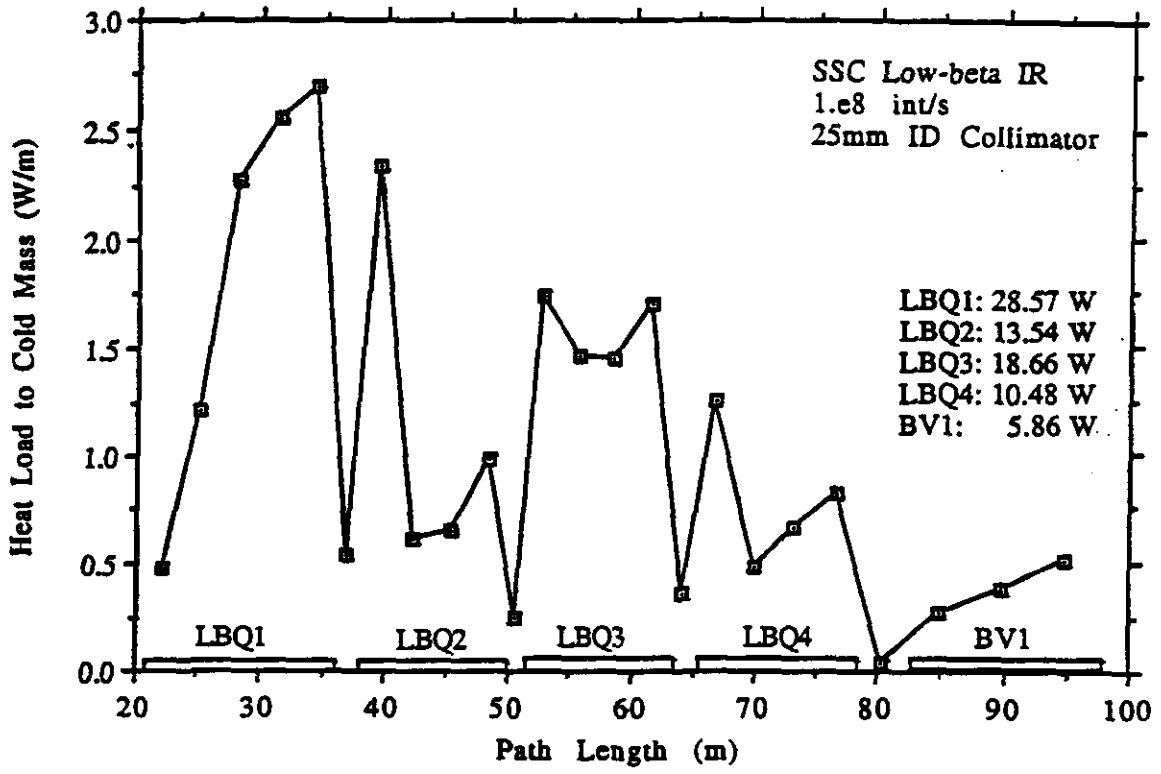
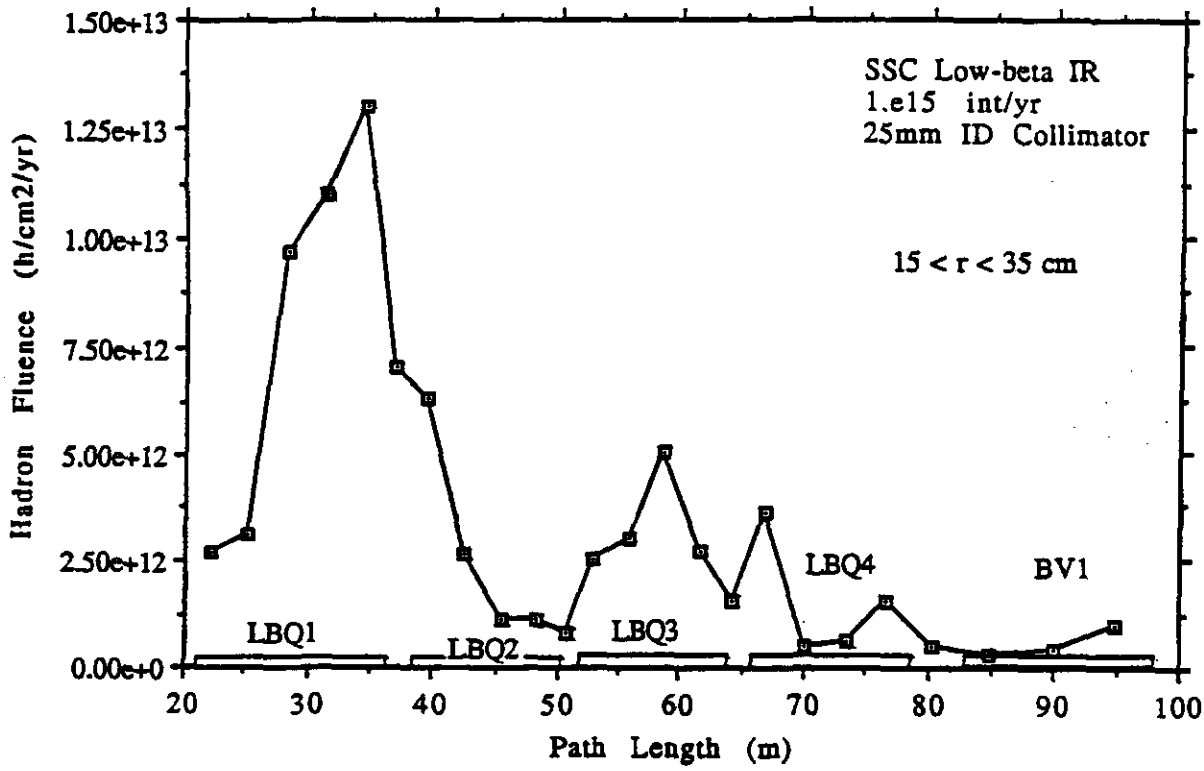
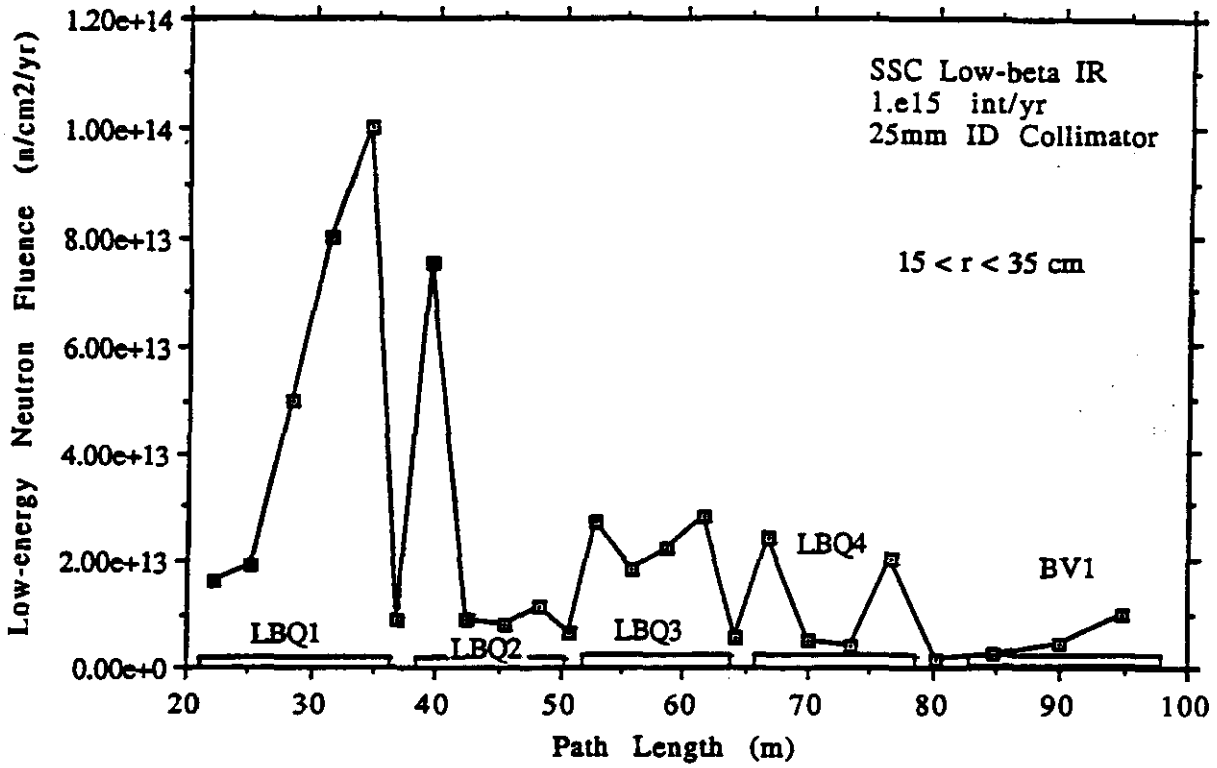
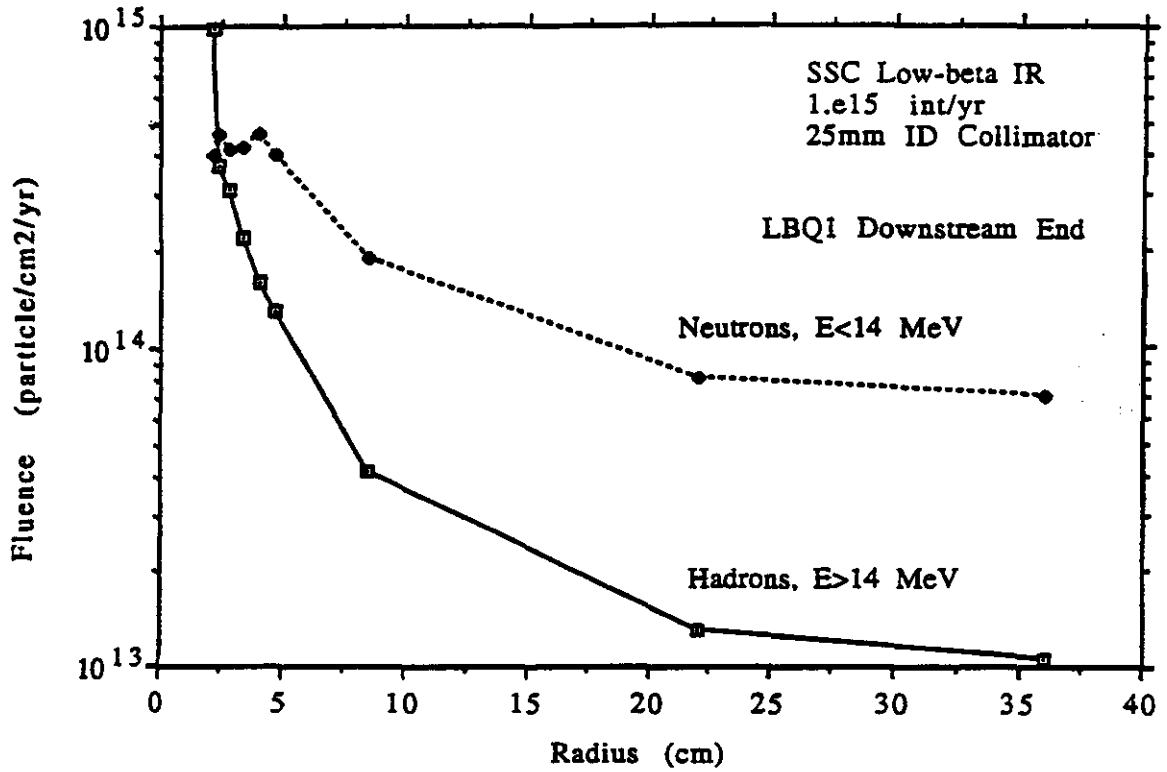

SSC Low-beta IR
1.e8 int/s
25mm ID Collimator
Energy Deposition @ r=2.5cm (mW/g)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
LBQ1
LBQ2
LBQ3
LBQ4
BV1
20
30
40
50
60
70
80
90
100
Path Length (m)


SSC Low-beta IR
1.e8 int/s
25mm ID Collimator
LBQ1: 28.57 W
LBQ2: 13.54 W
LBQ3: 18.66 W
LBQ4: 10.48 W
BV1: 5.86 W
LBQ1
LBQ2
LBQ3
LBQ4
BV1
Heat Load to Cold Mass (W/m)
Path Length (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
20
30
40
50
60
70
80
90
100


SSC Low-beta IR
1.e15 int/yr
25mm ID Collimator
15 < r < 35 cm
Hadron Fluence (h/cm2/yr)
1.50e+13
1.25e+13
1.00e+13
7.50e+12
5.00e+12
2.50e+12
0.00e+0
LBQ1
LBQ2
LBQ3
LBQ4
BV1
20
30
40
50
60
70
80
90
100
Path Length (m)

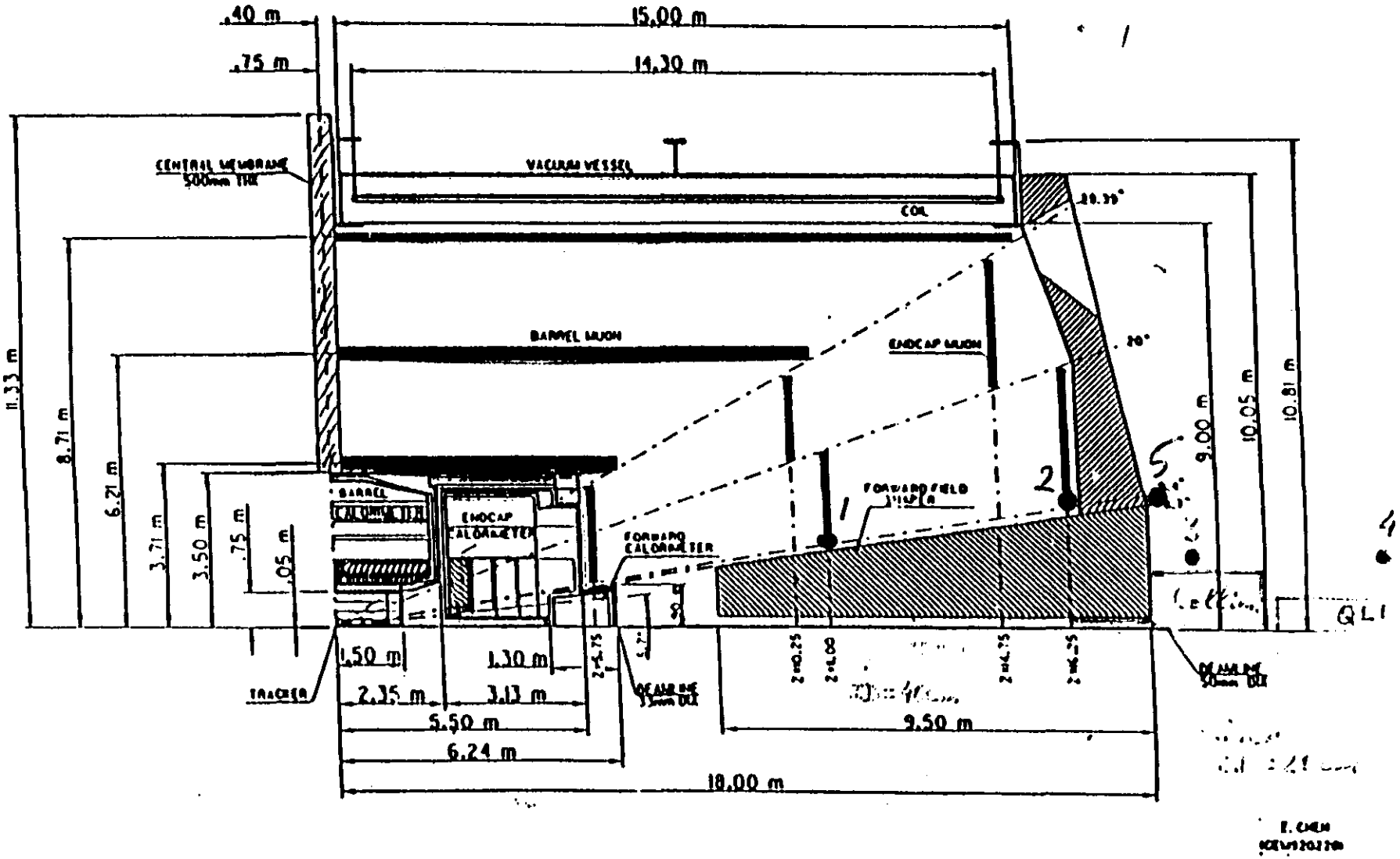

SSC Low-beta IR
1.e15 int/yr
25mm ID Collimator
15 < r < 35 cm
LBQ1
LBQ2
LBQ3
LBQ4
BV1
Low-energy Neutron Fluence (n/cm2/yr)
Path Length (m)
1.20e+14
1.00e+14
8.00e+13
6.00e+13
4.00e+13
2.00e+13
0.00e+0
20
30
40
50
60
70
80
90
100

$E_{th} = 0.5\ eV$


SSC Low-beta IR
1.e15 int/yr
25mm ID Collimator
LBQ1 Downstream End
Neutrons, E<14 MeV
Hadrons, E>14 MeV
Fluence (particle/cm2/yr)
Radius (cm)
10^{15}
10^{14}
10^{13}
0
5
10
15
20
25
30
35
40

$E_{th} = 0.5 eV$

GEM DETECTOR ELEVATION

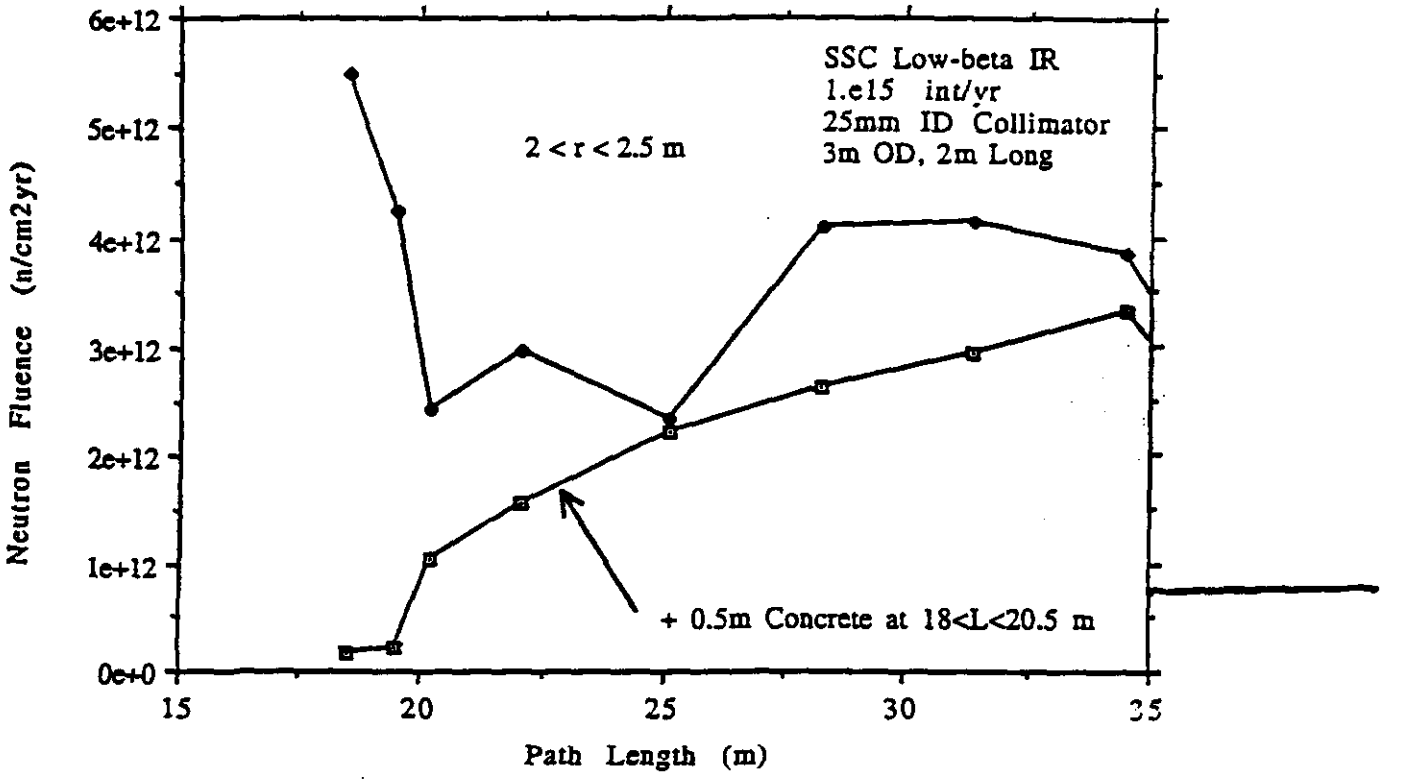


GEM Detector Layout Showing Top Right Quadrant

PARTICLE BACKGROUND

Annual Particle Fluence in GEM Detector (ptcl per cm^2)

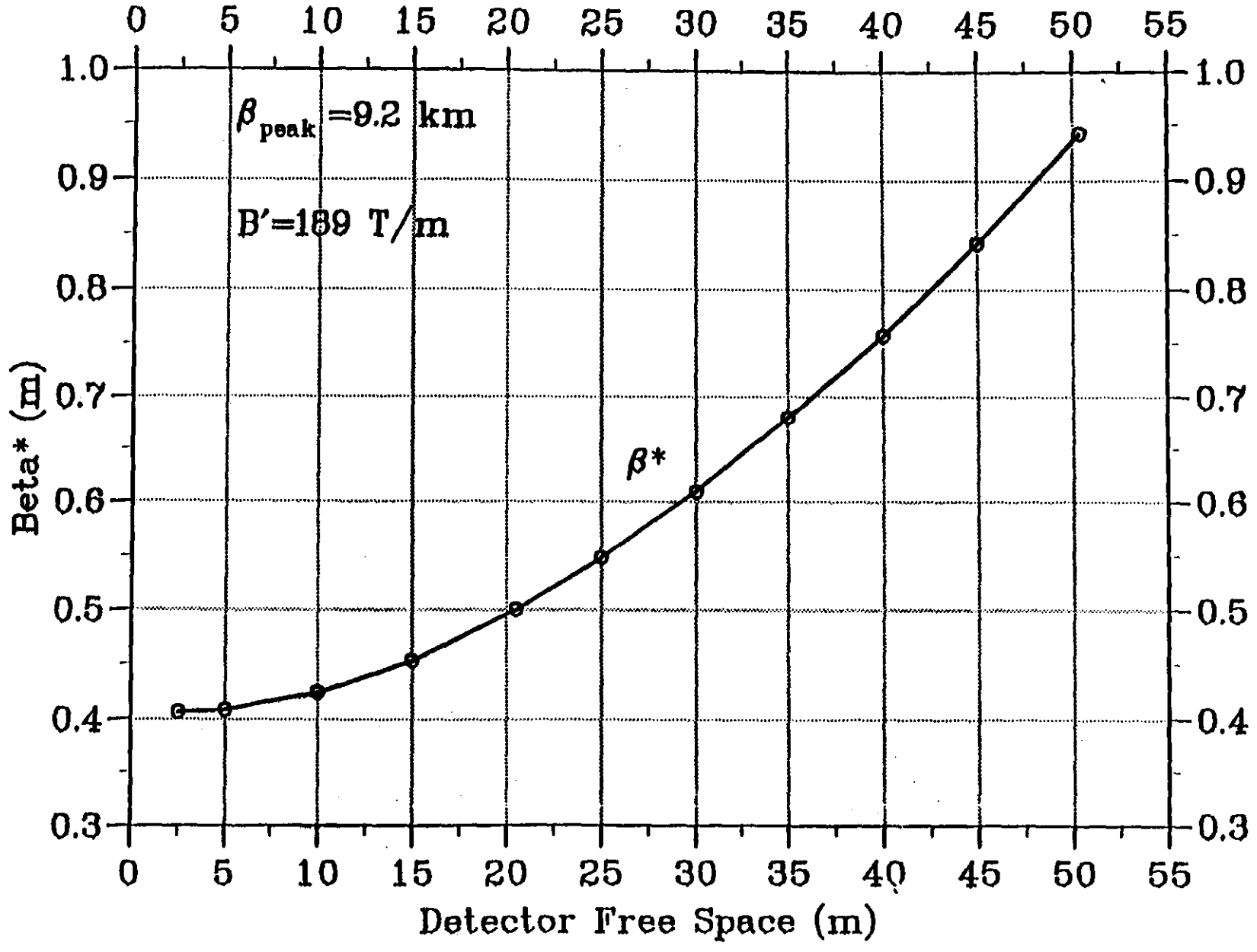
Particle	Point 1	Point 2	Point 3	Point 4
h_{tot}(>14MeV)	7.7×10^{9}	4.4×10^{8}	4.7×10^{10}	2.7×10^{11}
h_{ch} (>14MeV)	3.6×10^{9}	3.9×10^{6}	2.8×10^{7}	3.7×10^{10}
e (>1MeV)	1.9×10^{11}	6.8×10^{5}	5.0×10^{6}	7.9×10^{10}
n (<14MeV)	7.1×10^{10}	6.0×10^{11}	8.6×10^{12}	2.9×10^{12}



$E_{th} = 0.5\,eV$

$\Phi_n(r) \sim 1/\sqrt{r}$

Beta* vs Detector Free Space.



LBQ BACKGROUND REDUCTION

GEM: Point 5

MEASURE	FACTOR
• Collimator ID: 25mm --> 42mm	1.7
• Optimal collimator/LBQ shielding with 20m detector space	20
• Increasing of detector space: 20m to 35m ($0.76\mathcal{L}$)	

- Access to detector
- Rad. hot components → $P_\gamma \sim 0.1-5$ R/hr
- Background down factor of 10 (?)

Presentation by:

L. Waters

L. Waters
presented by D. Lee

Hi Mike,
I am now faxing you 18 figures along with this note on the studies for the program outlined in the minutes of the neutron task force meeting of 10-21. Vassily Morgunov has implemented the geometry for the hybrid option of Kamyshkov.

Figures 1-4 give details of the geometry. Just some comments.
Although there is a beampipe shown all the way through, it is actually present only up to and including the pump boxes just before the FCAL. The rest of the structure is a void. Therefore, you can consider the data for the drift chambers as having been simulated without beampipe.
In figure 1, you can see how the concrete halls are positioned.
The inner taper of the FCAL is eta=5.2. The inner taper of the ffs is eta=5.0.
On figures 2 and 3 I shaded in black the areas filled with borared poly. The 'shield' after the FCAL is composed of two cylinders; the inner has 20 cm of poly with a layer of 10 cm lead on the outside.
On figure 3 I have shown how the inner tracker region has been subdivided into cylinders of 9 cm and 20 cm radius, so some fluxes can be taken there.
Figure 4 is a cross section of the ffs shaper. This, along with the positioning of the halls, makes the simulation quite asymmetric.
There are 3 versions of the setup.

1. Tungsten+10% scintillator in FCAL with magnets at 20 meters
2. Copper+10% scint in FCAL with magnets at 20 meters
3. Tungsten+10% scintillator in FCAL with magnets at 35 meters

Figure 5-8 are two-d plots showing the pattern of various types of neutrons along the plan Z=15.84 meters (forward wire chamber#5 - fw5). These show some interesting behavior. Please note that the actual chamber has a radius of 275 cm to 488 cm in this plane.

plot 5: neutrons with kinetic energies greater than 20 Mev. Also require that they be 'outward' directed (w=cos(angle between particle direction and surface normal)
plot 6: neutrons with ke> 20 Mev, inward directed. Note the striking shadow pattern caused by the support of the field shaper.
plot 7: same as plot 5 but for neutrons with ke<100 keV
plot 8: same as plot 6 but for neutrons with ke<100 keV. No evidence of the shadowing is seen for the lower energy neutrons. The effect phases in between 100 kev and 20 Mev.

The rest of the plots show then neutrons along various surfaces for the 3 versions of the setup. As ususal, the top curve represents all neutrons, the bottom one neutrons with ke< 100 kev. The units on the y axis are #/cm^2/SSCyr x 10^12 (1=10^33). I am just counting neutrons, NOTE THESE ARE NOT FLUENCES.
Have fun studying them. Maybe you can give me a call before the meeting and we can discuss things. Just a few comments more:

plot 9: No I don't know what this spike is for the 'vertex barrel radius 36 cm' histograms. The peak in the 9 cm plot also shows up in the SDC simulations. We think it might be a numerical abberation; if you start with an event generator flat in eta, it would translate into a peak when plotted in Z.
plot 10: The dip seen in dc2 and dc3 seems to be a pure shielding effect of the central part of the calorimeter.

plot 11: The shielding efect of the ffs support does not seem to be very important for chambres 1-3. In these plots I have indicated where the chambers start and end in the simulation.

Plot 18 is the simulation which I did for Kate some months ago, which I think forshadows the probable design now being circulated. I will be easy to adapt this. It has lkr in the EM sections, a hadronic cu/scint barrell and lar in the hadronic endcaps. I just need some details from GEM.

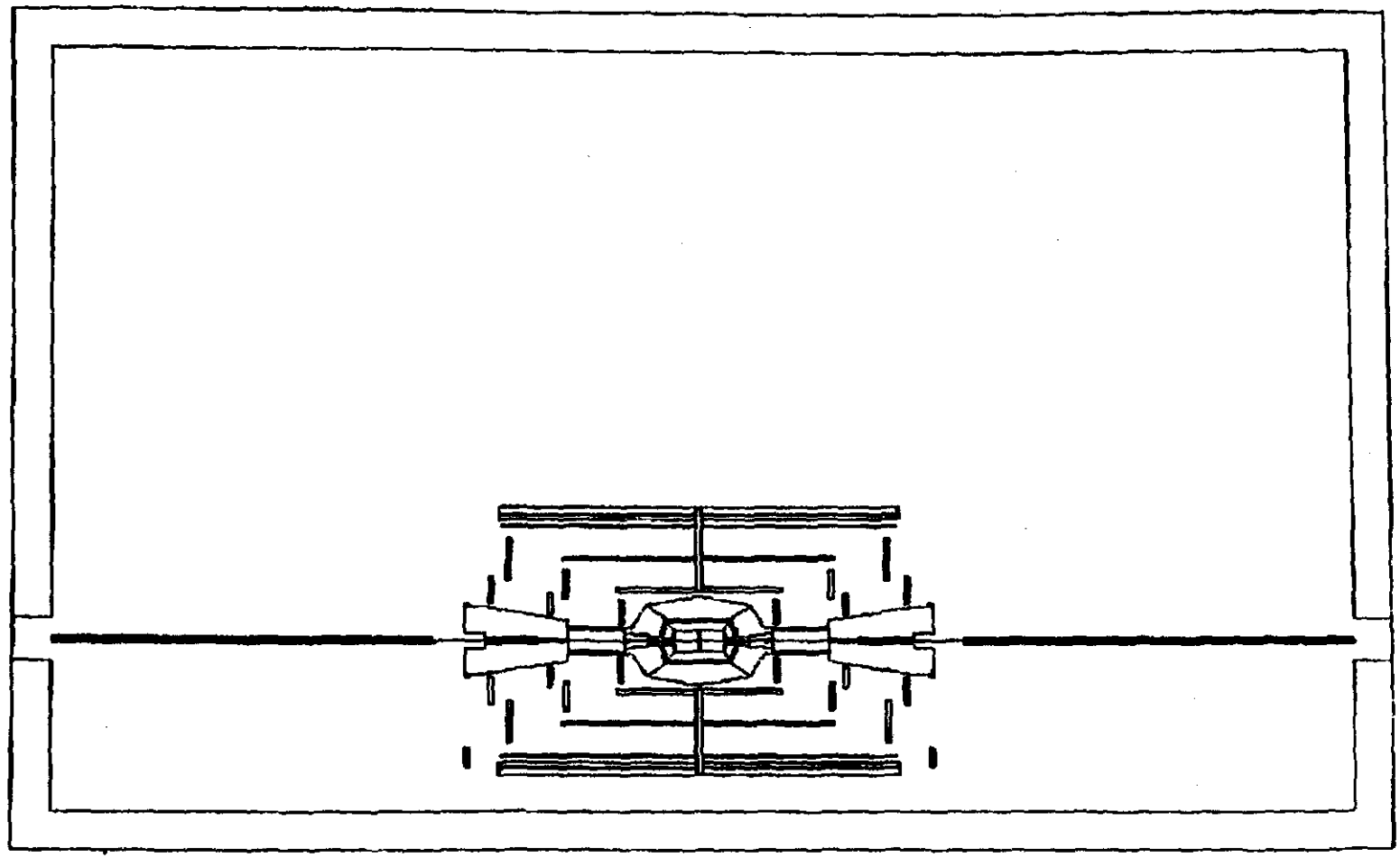
Look this over and call me. Now I am going back and try to finish off this leftover stuff from the BASELINE1 simulation, and will send you some more in a little while.
Laurie
505-665-4127

X TO CENTER
THE NORTH

18 08 00

', 1.000000)
', 0.000000)

', 0.00)
5400.00)

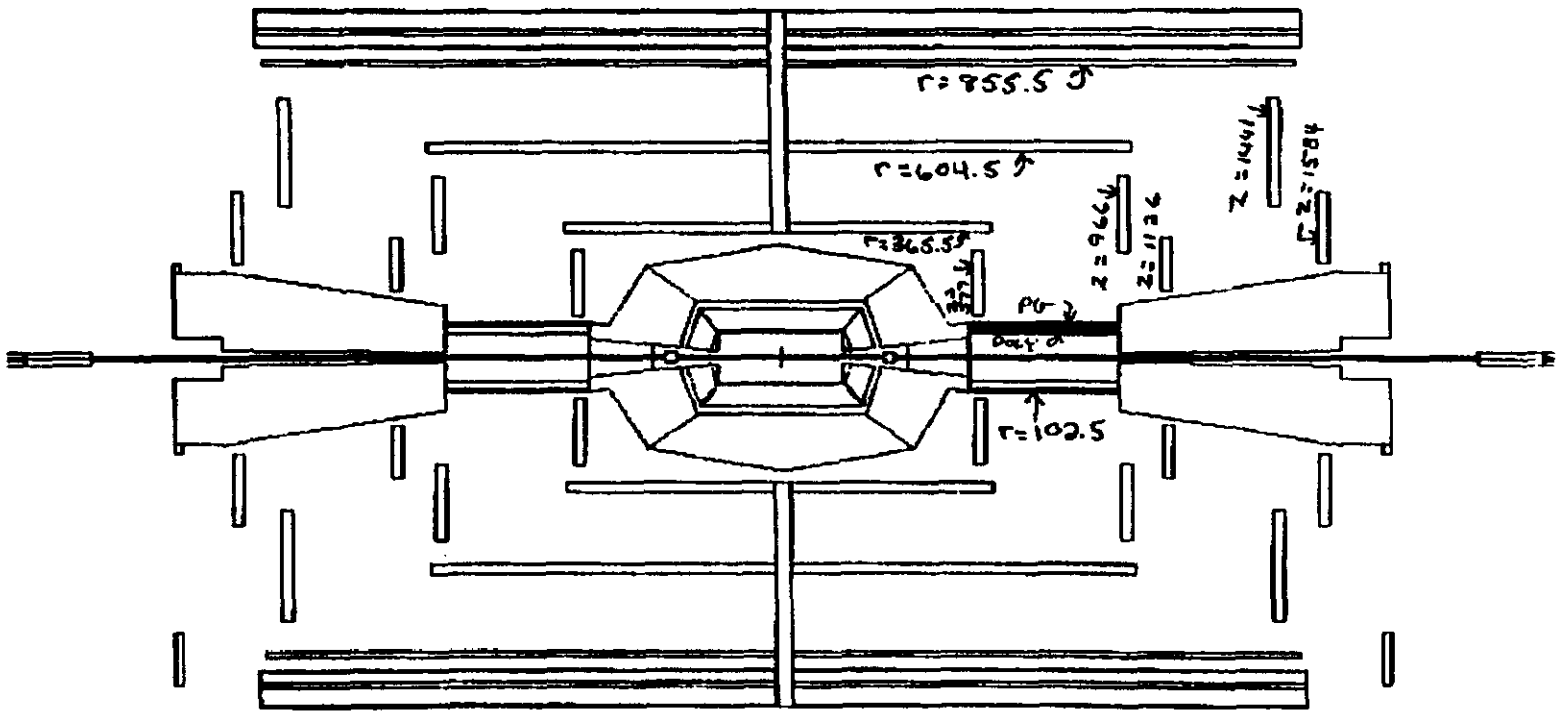


)3 55 04
(ERSION +X TO CENTER
+Z TO THE NORTH
:LD DIRE
1/17/92 03 48 41

0.000000, 1.000000)
1.000000, 0.000000)

0.00, 0.00)
2300.00, 2300.00)

(2)



(3)

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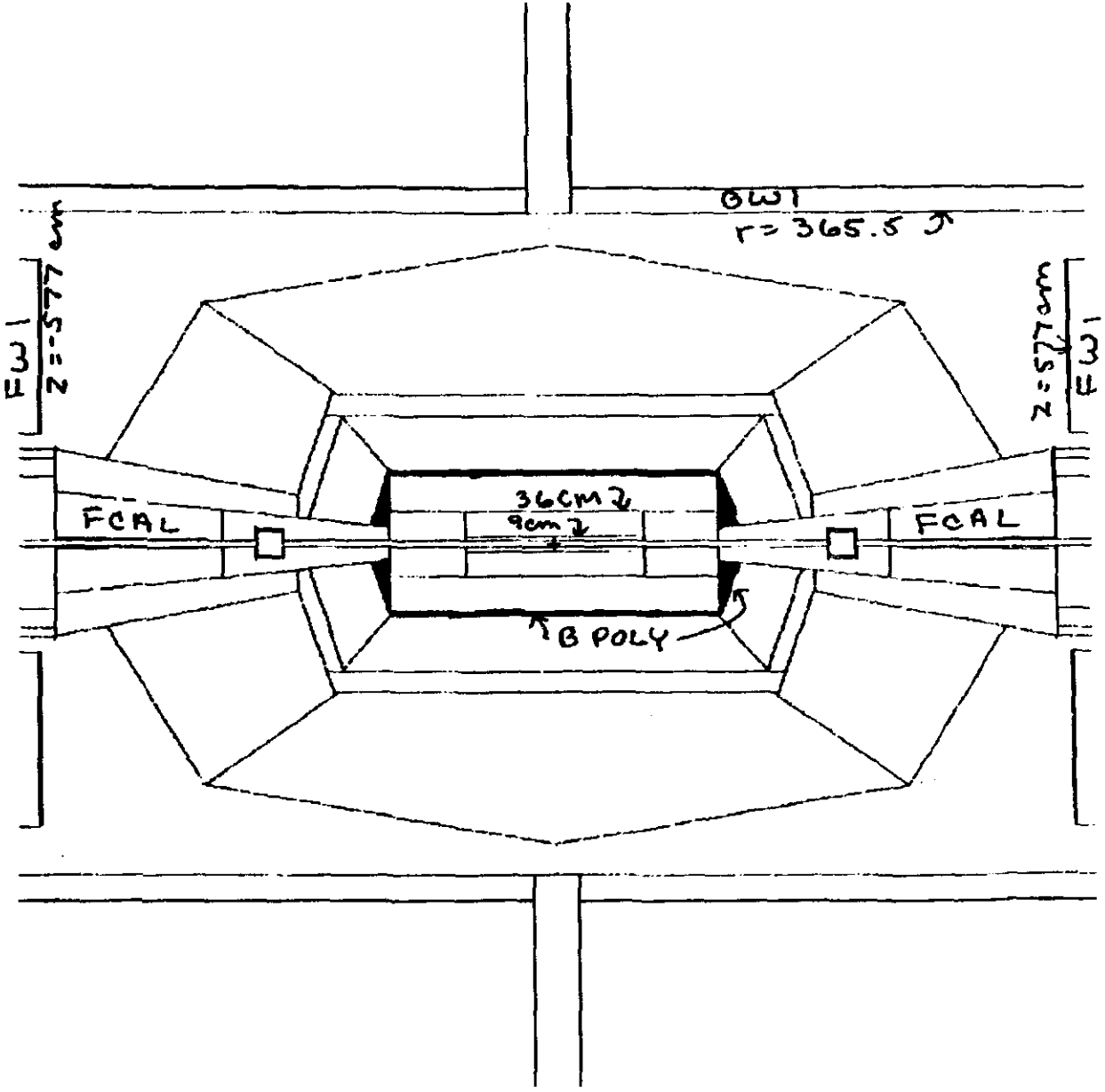
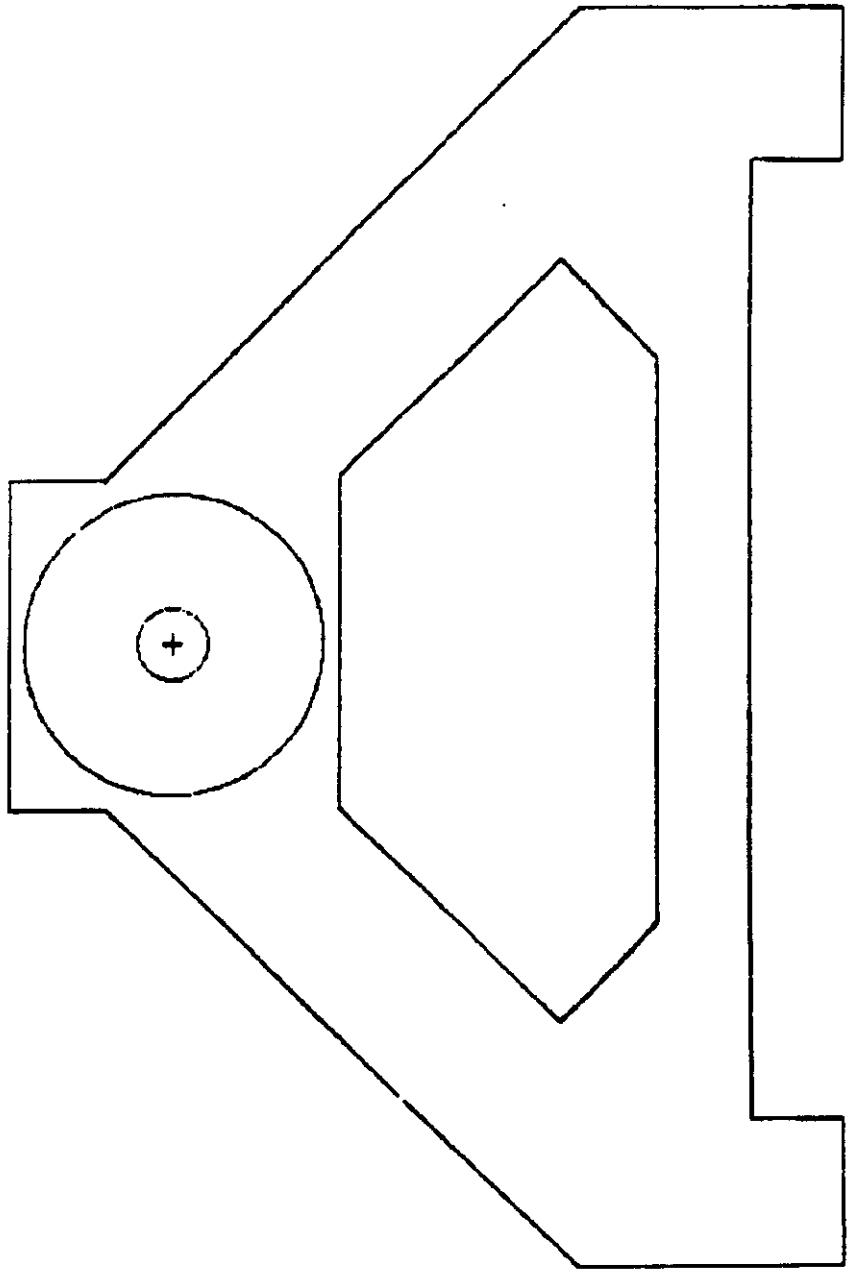
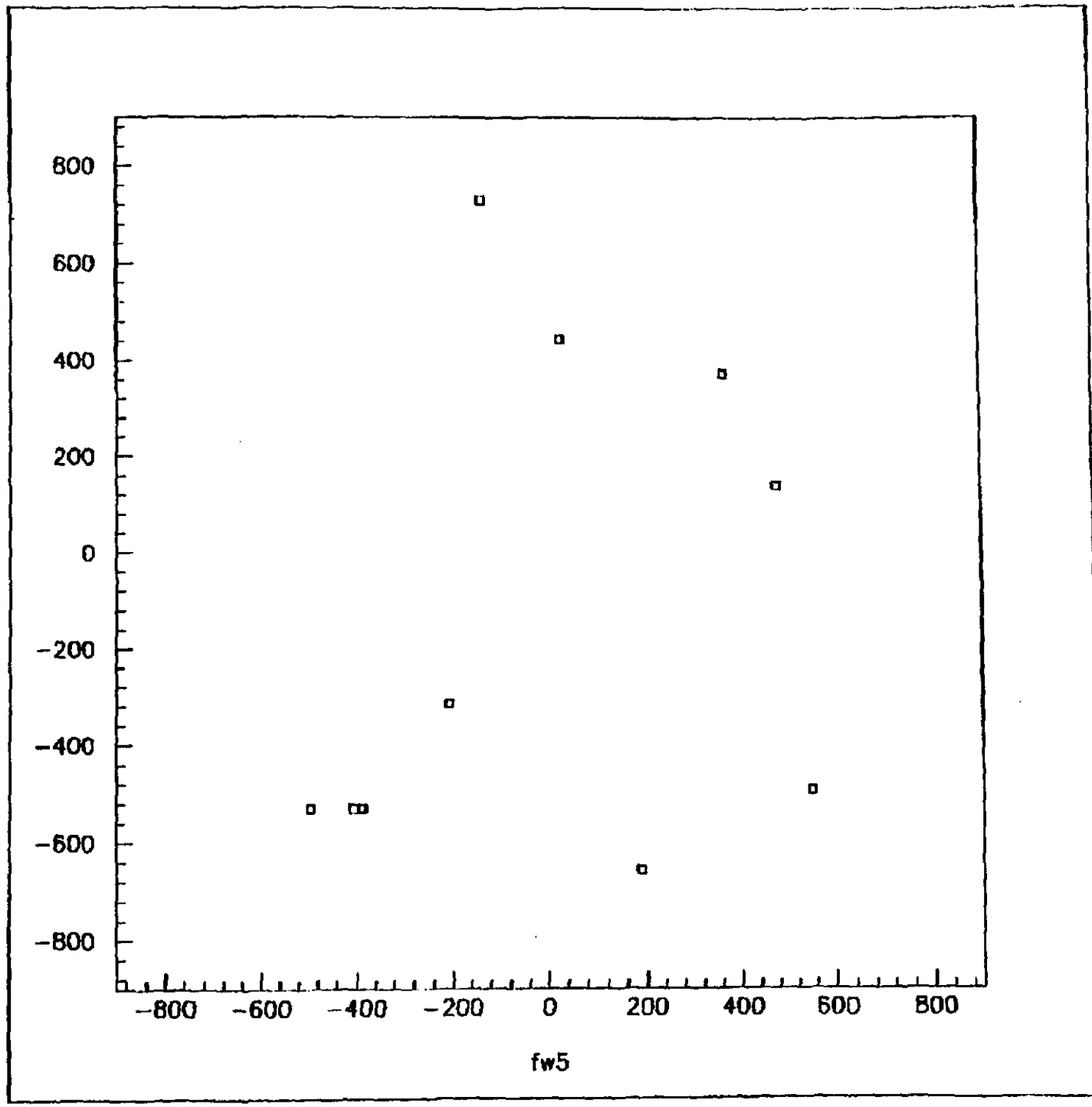
  11/17/92 05 19 02
GEM HYBRID VERSION +X TO CENTER
 +Y TO ZENIT  +Z TO THE NORTH
 AND MAG.FIELD DIRE
PROBID -   11/17/92 05 18 29
BASIS
( 0.000000, 0.000000, 1.000000)
( 0.000000, 1.000000, 0.000000)
ORIGIN
(      0.00,      0.00,      0.00)
EXTENT = (   600.00,   600.00)
```

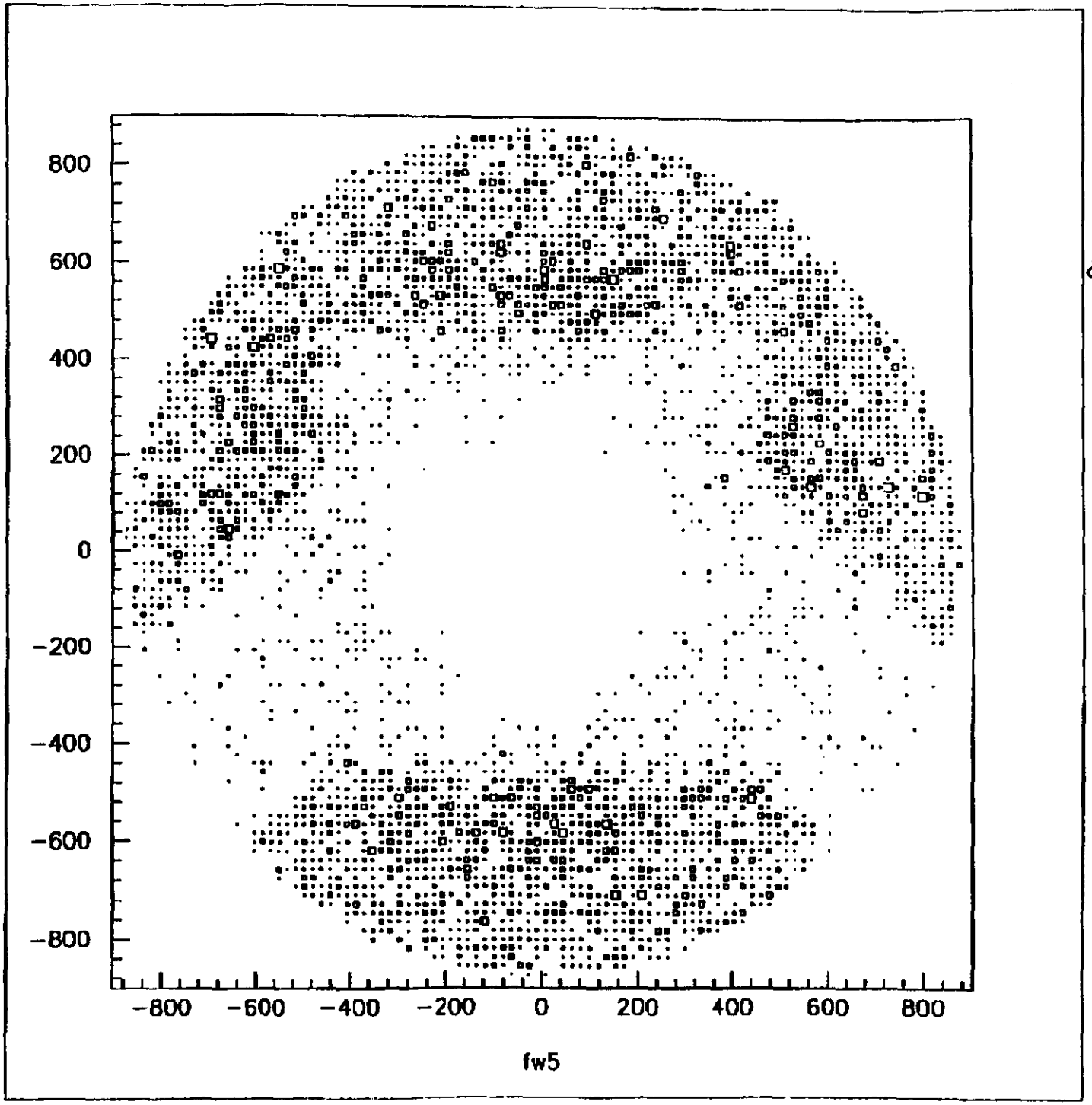






(5)

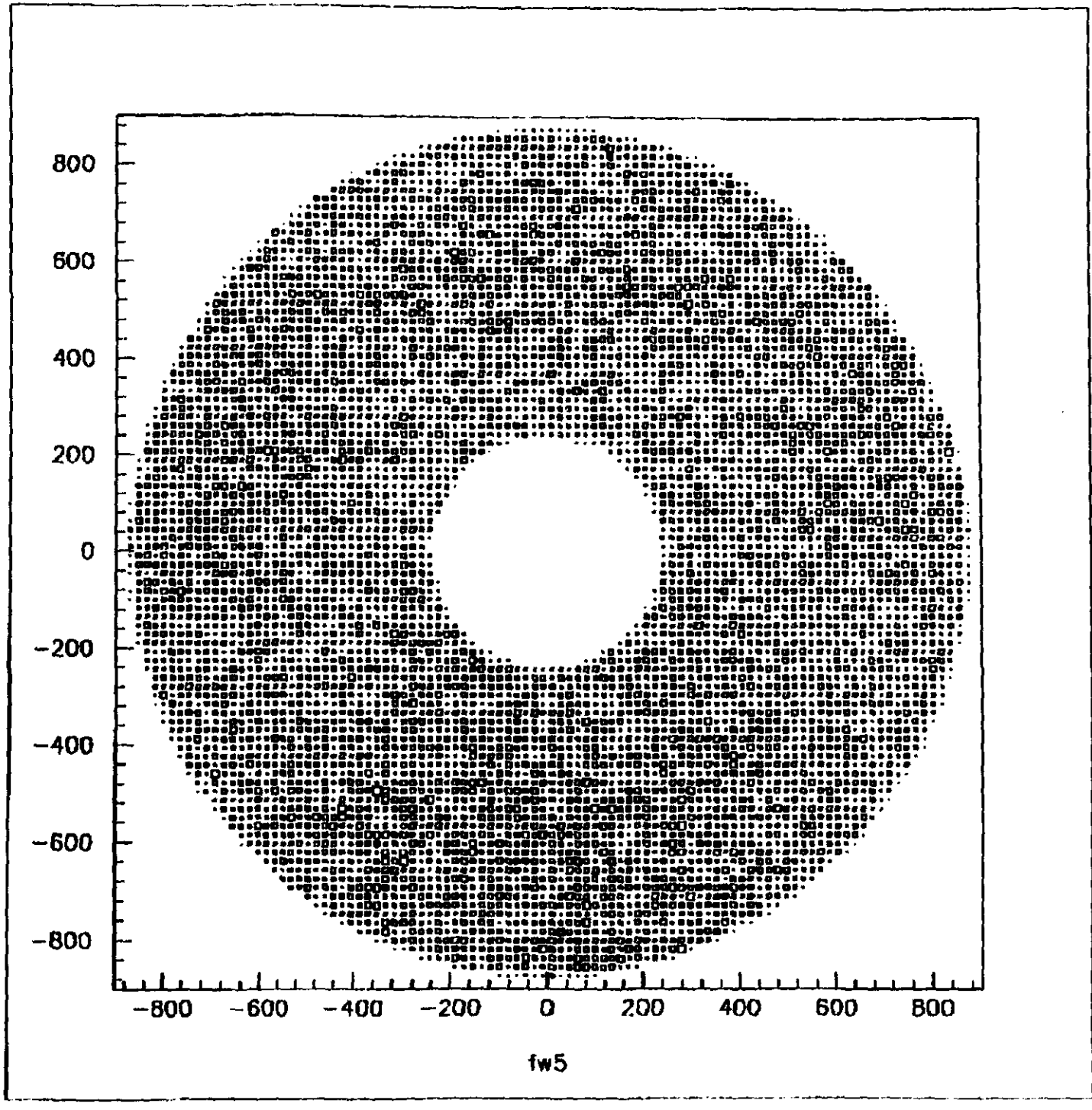
NEUTRONS
$E_{kin} > 20$ MeV
$\omega > \phi$



(6)

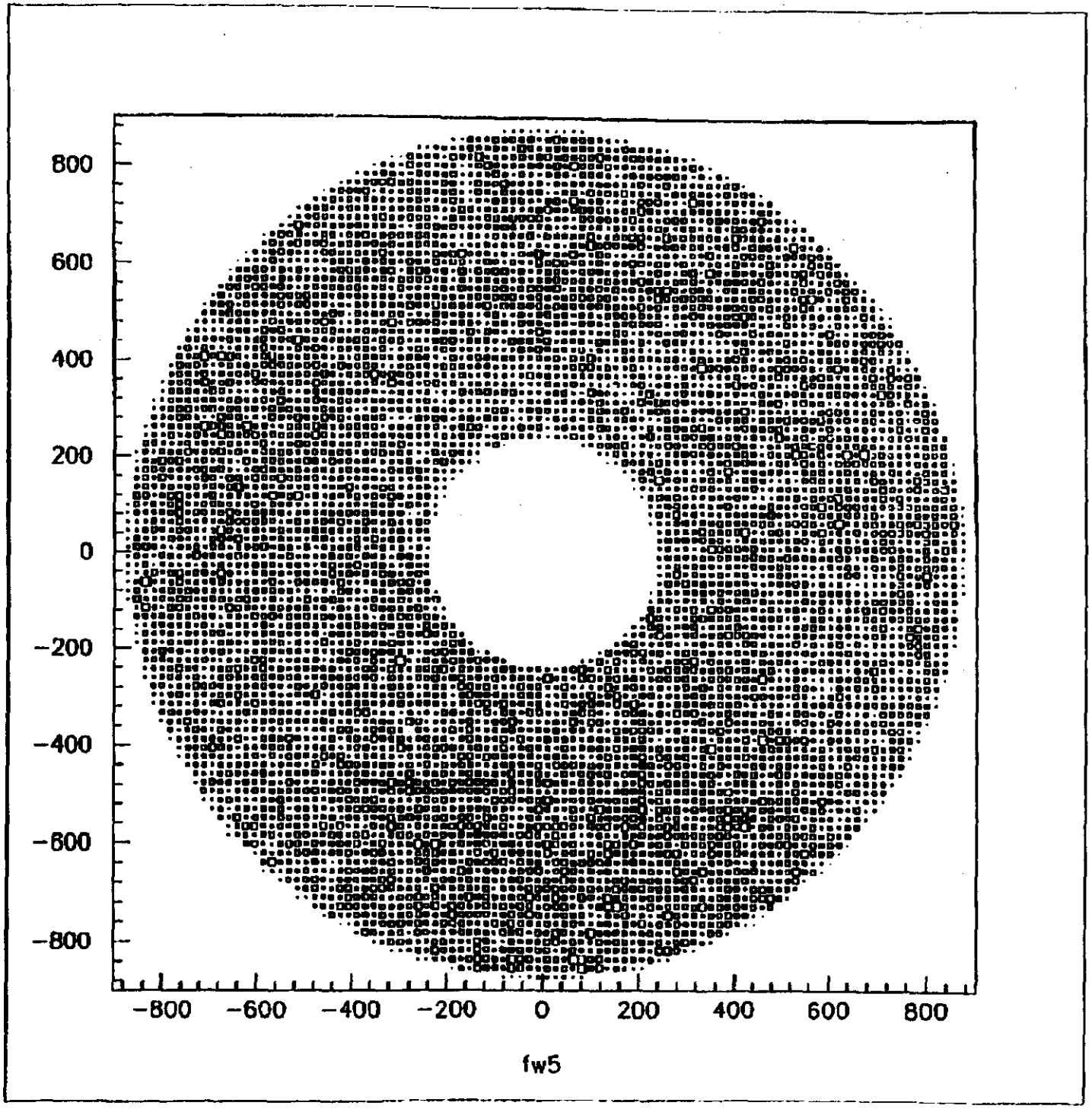
NEUTRONS
$\mathcal{E}_{kin} > 20$ MeV
$\omega < \phi$

NOV-17-94 TUE 9:18



7

NEUTRONS
$E_{KIN} < 100$ keV
$\omega > 0$

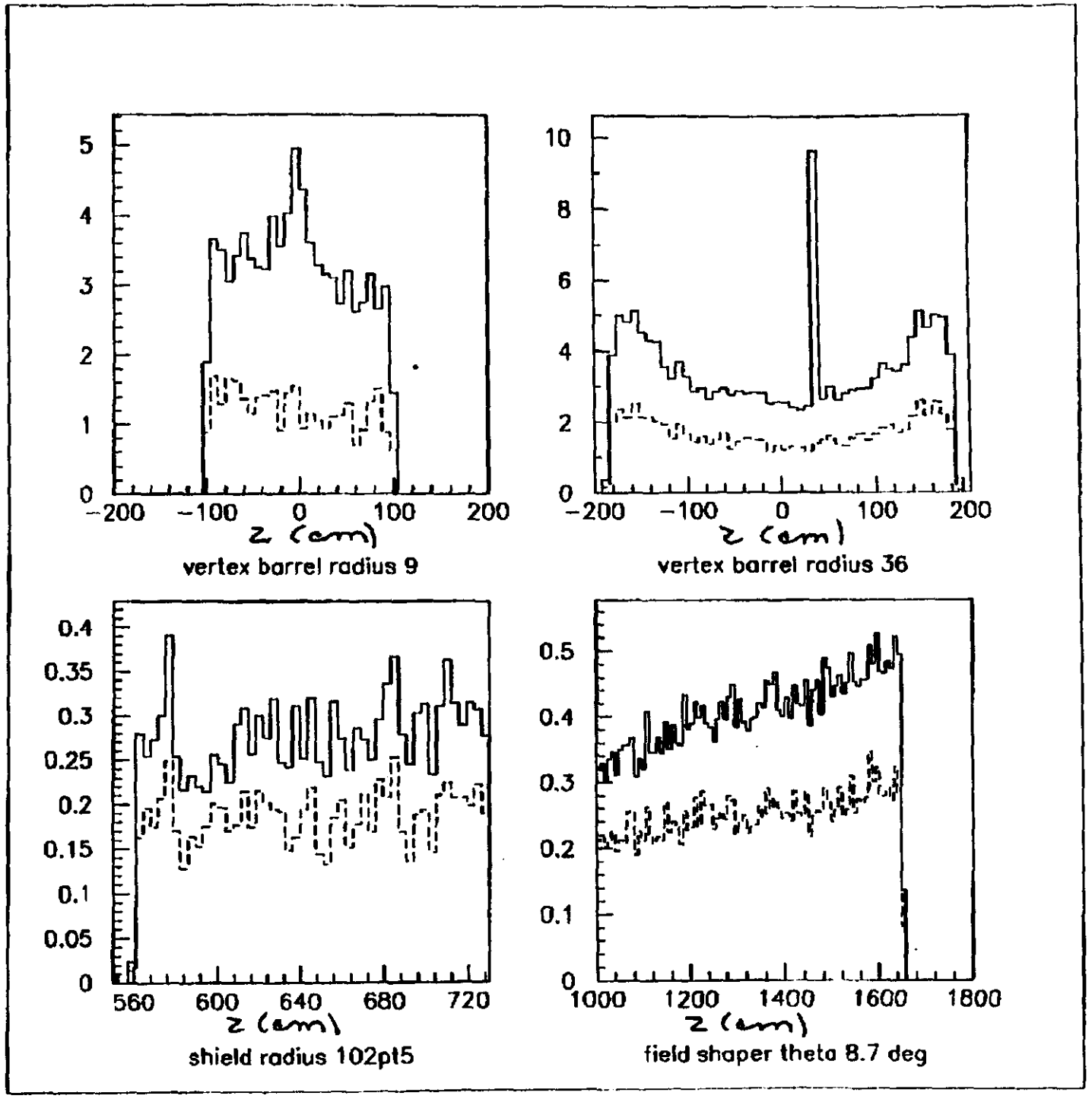


(8)

NEUTRONS
$E_{KIN} < 100$ keV
$\omega < \phi$

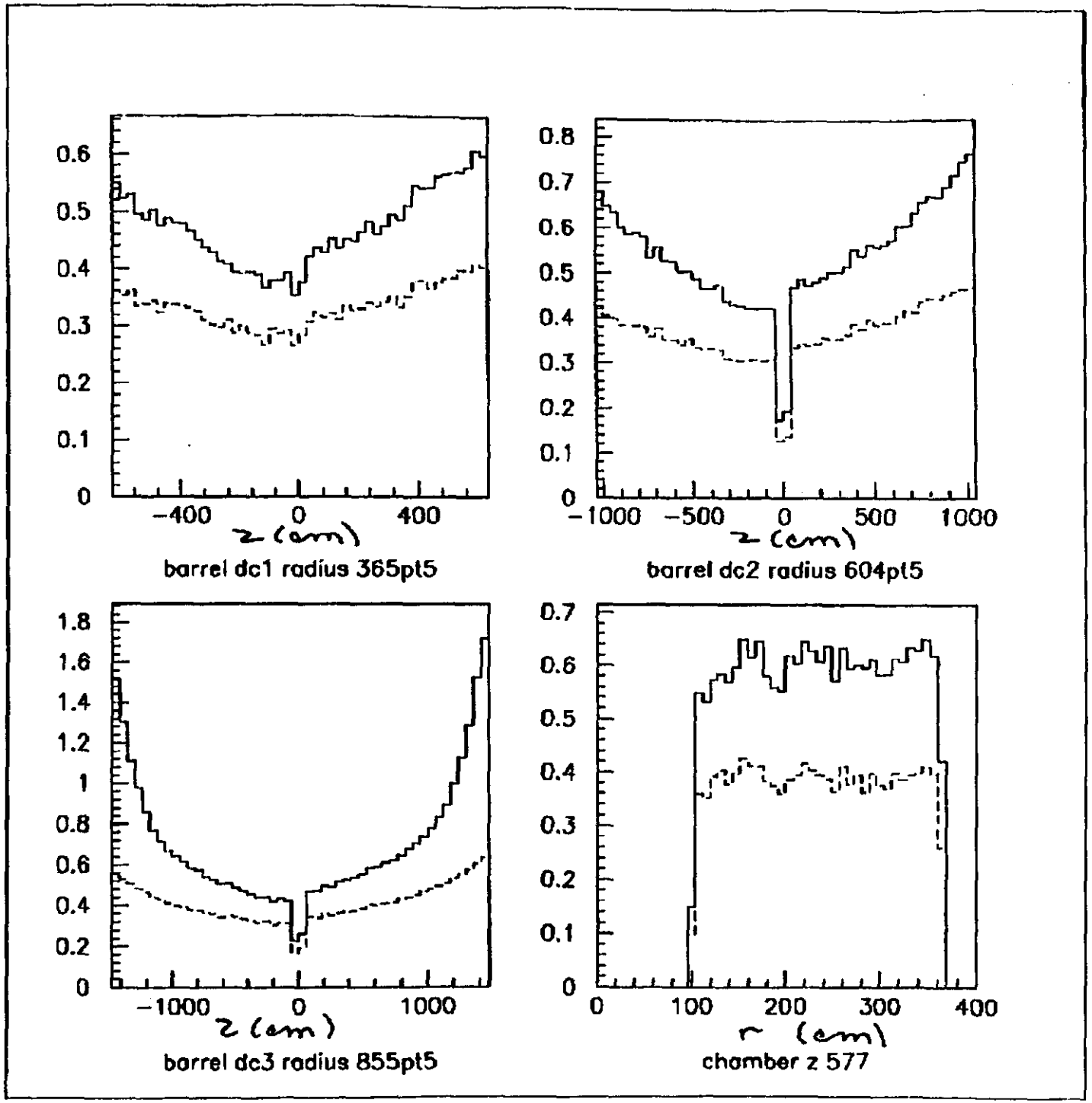
(9)

w FCAL
20 m


z (cm)
vertex barrel radius 9
z (cm)
vertex barrel radius 36
z (cm)
shield radius 102pt5
z (cm)
field shaper theta 8.7 deg

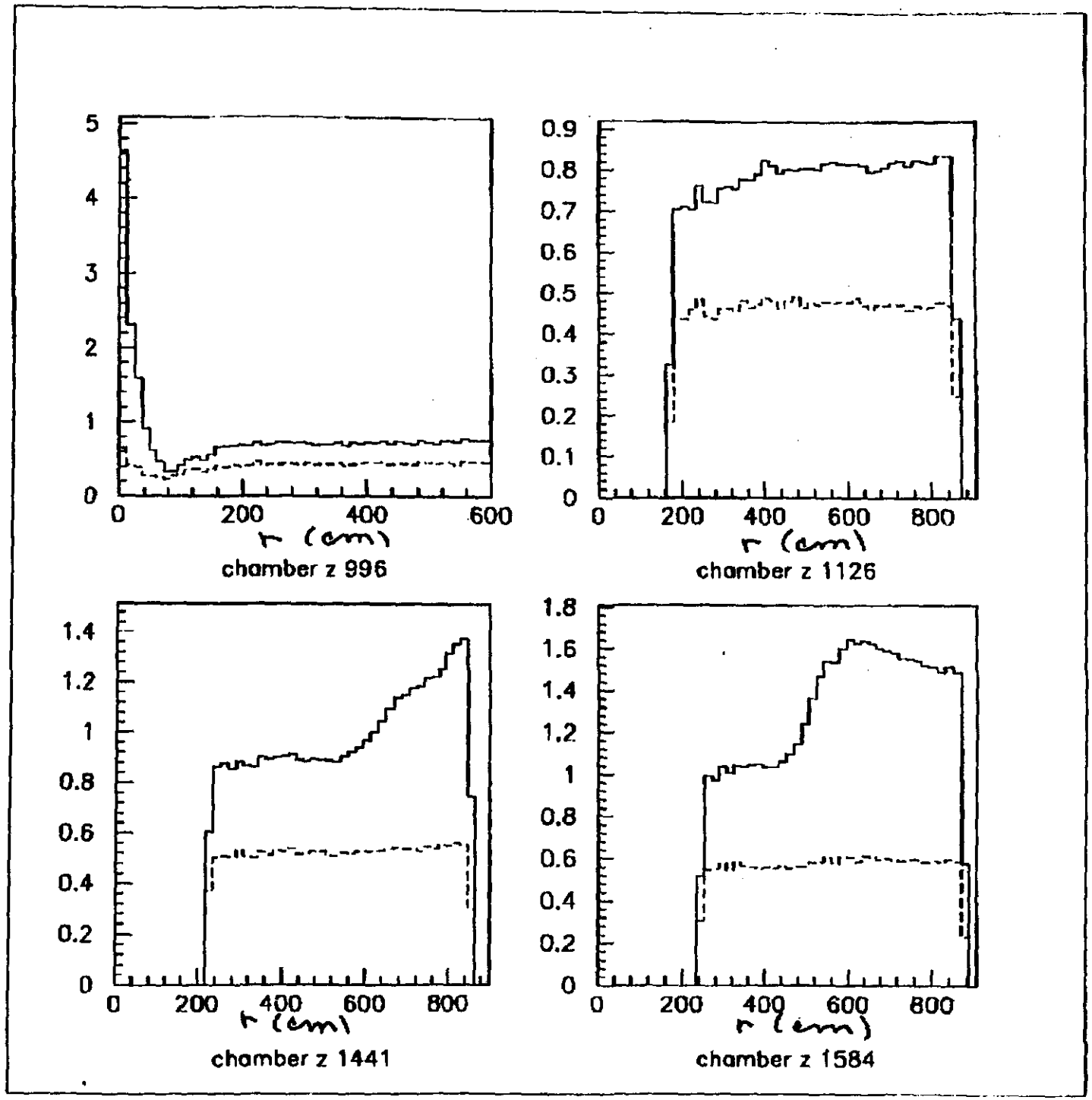
(10)

W FCAL
20 m


0.6
0.5
0.4
0.3
0.2
0.1
0
-400
0
400
z (cm)
barrel dc1 radius 365pt5
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1000
-500
0
500
1000
z (cm)
barrel dc2 radius 604pt5
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1000
0
1000
z (cm)
barrel dc3 radius 855pt5
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
r (cm)
chamber z 577

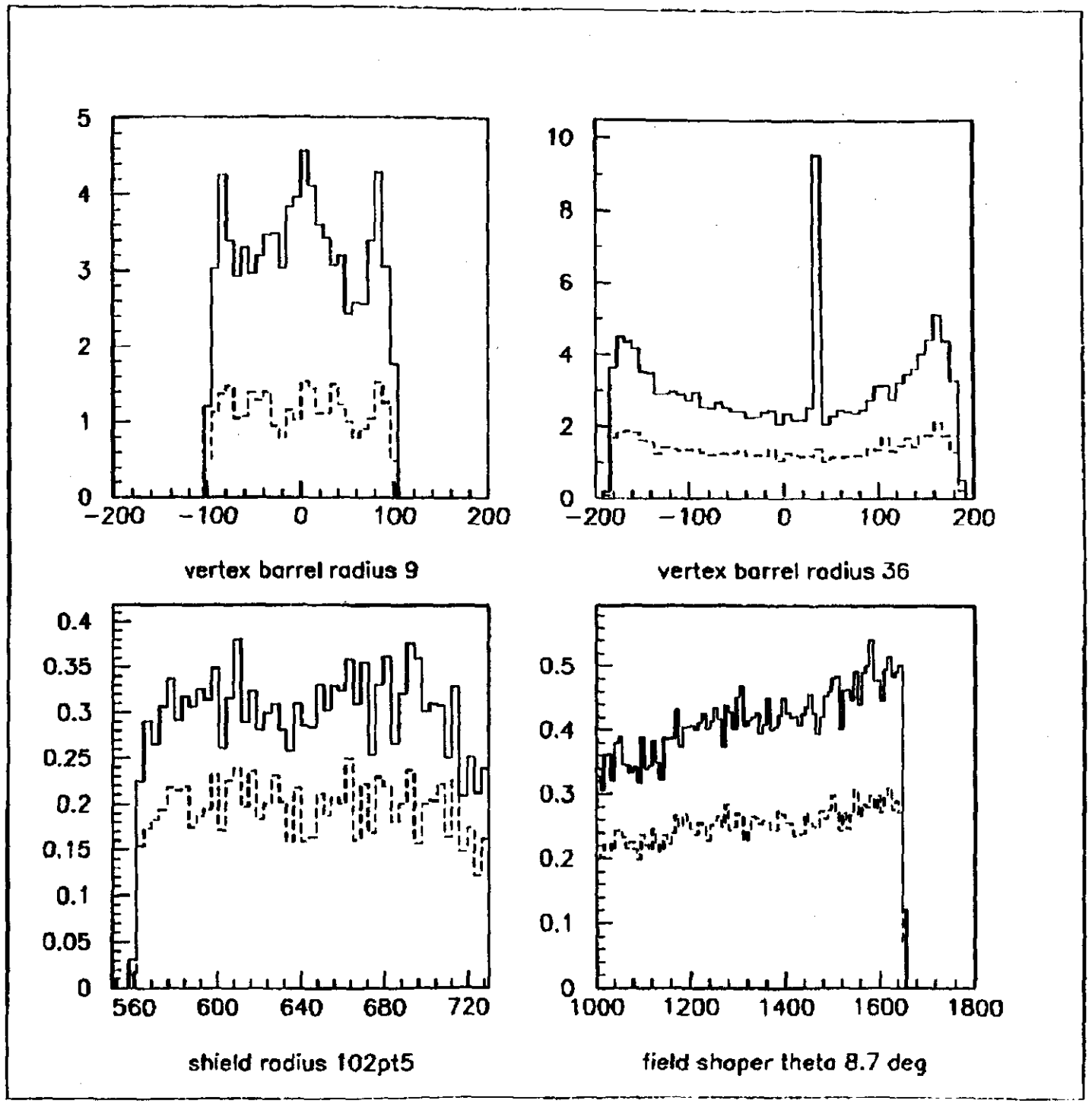
(11)

W FCAL
20 m


r (cm)
chamber z 996
r (cm)
chamber z 1126
r (cm)
chamber z 1441
r (cm)
chamber z 1584

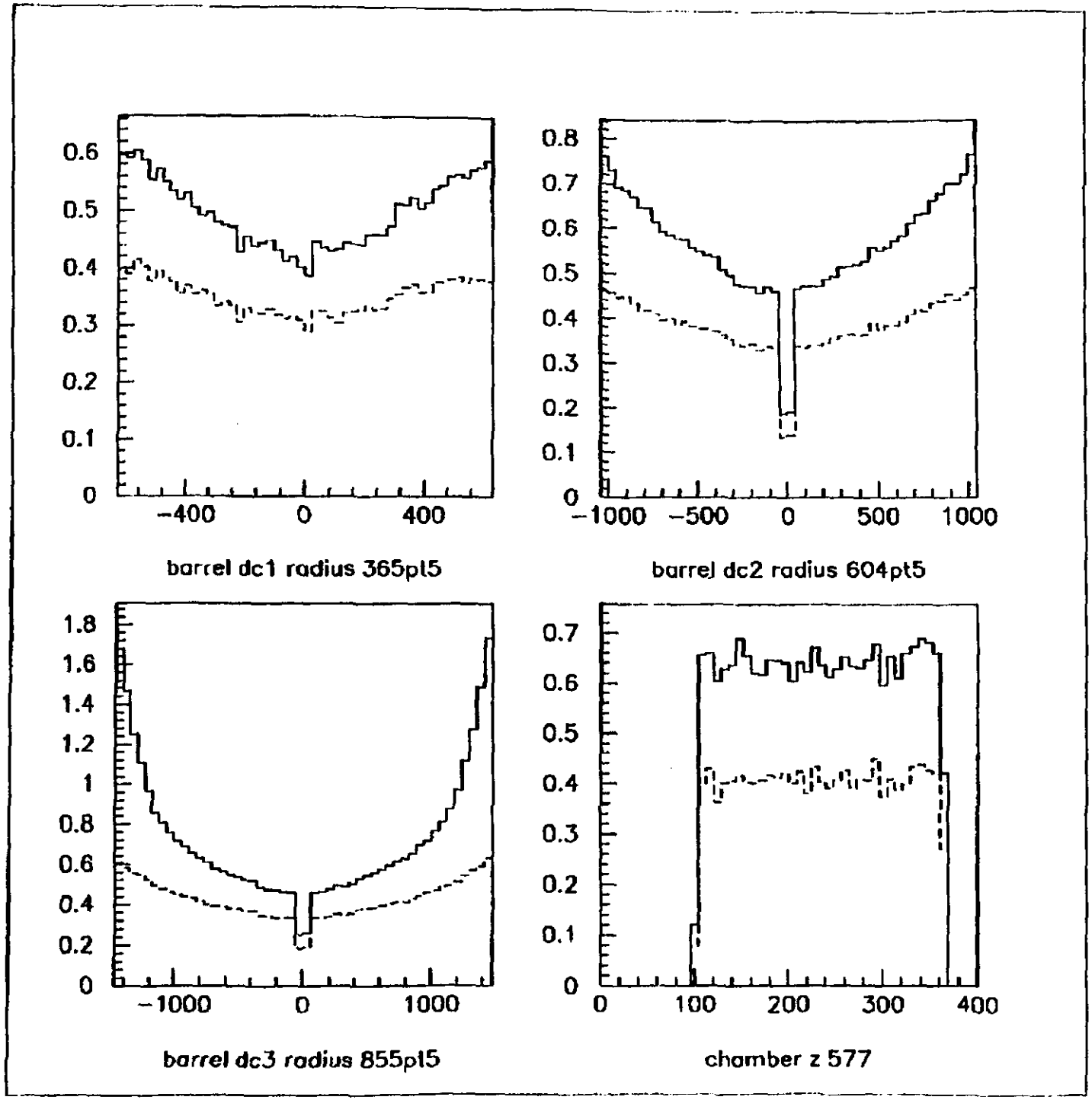
(12)

Cu FCAL
20 m



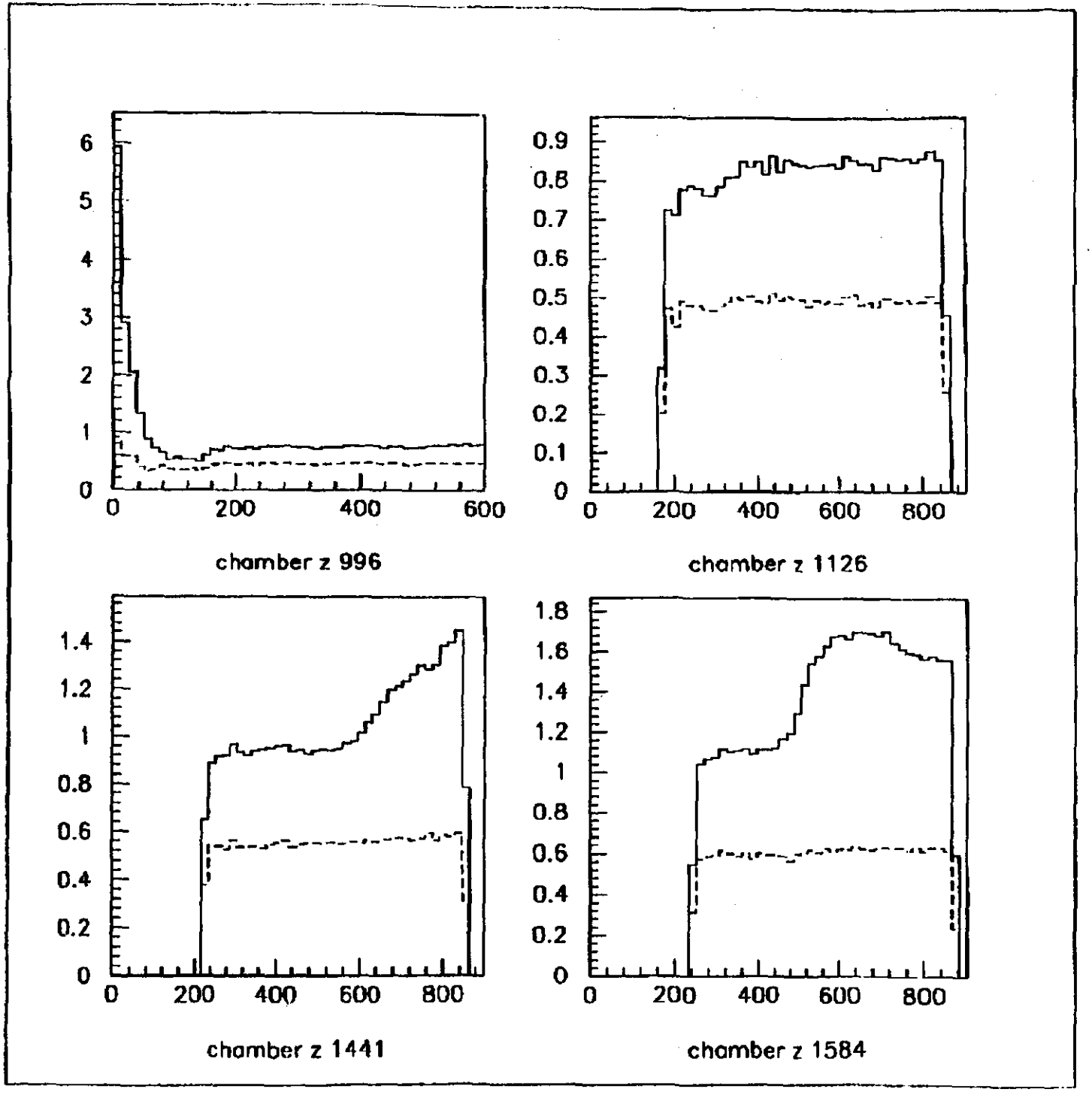
(13)

Cu FCAL
20 m



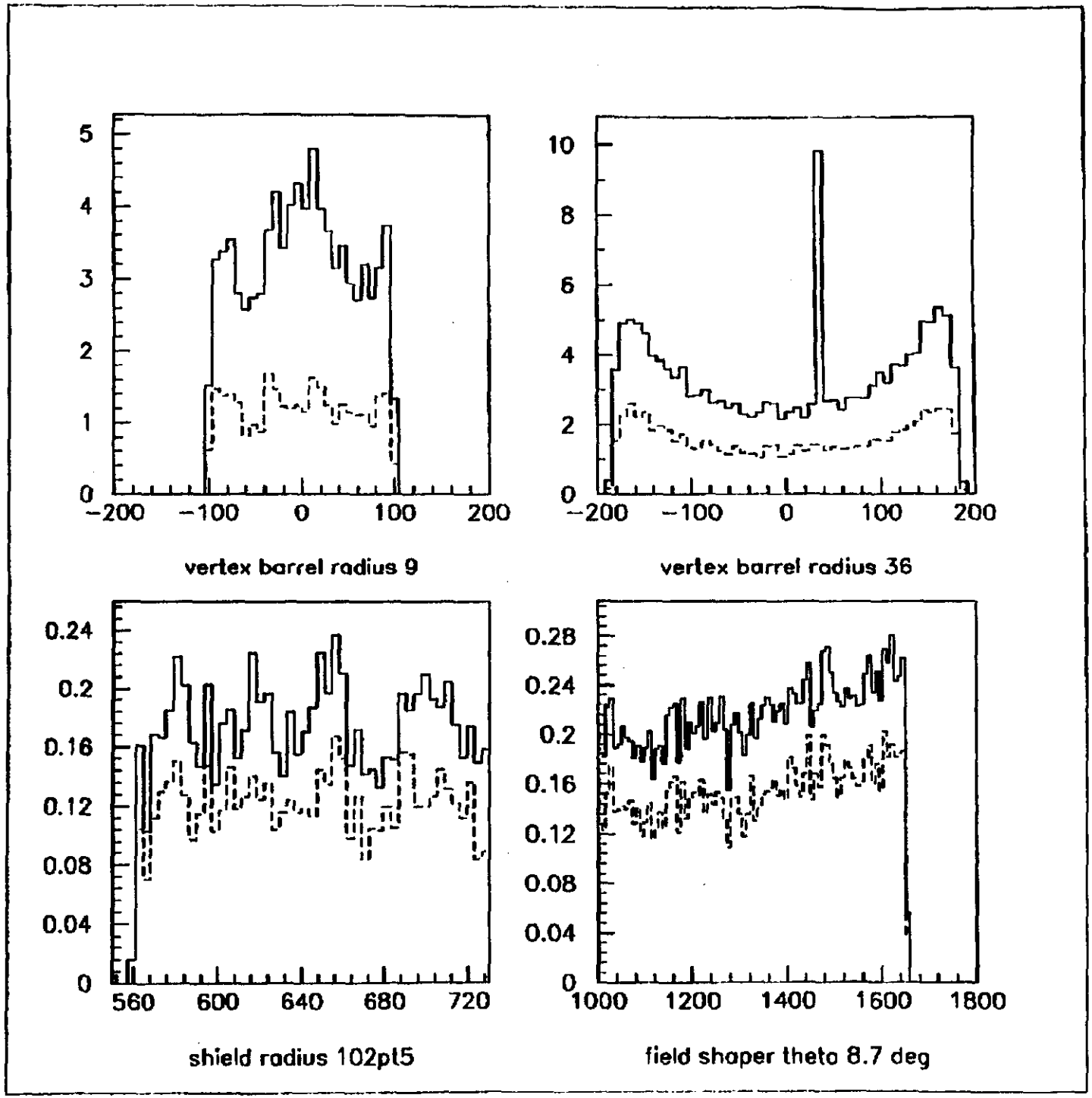
(14)

Cu FCAL
20 m



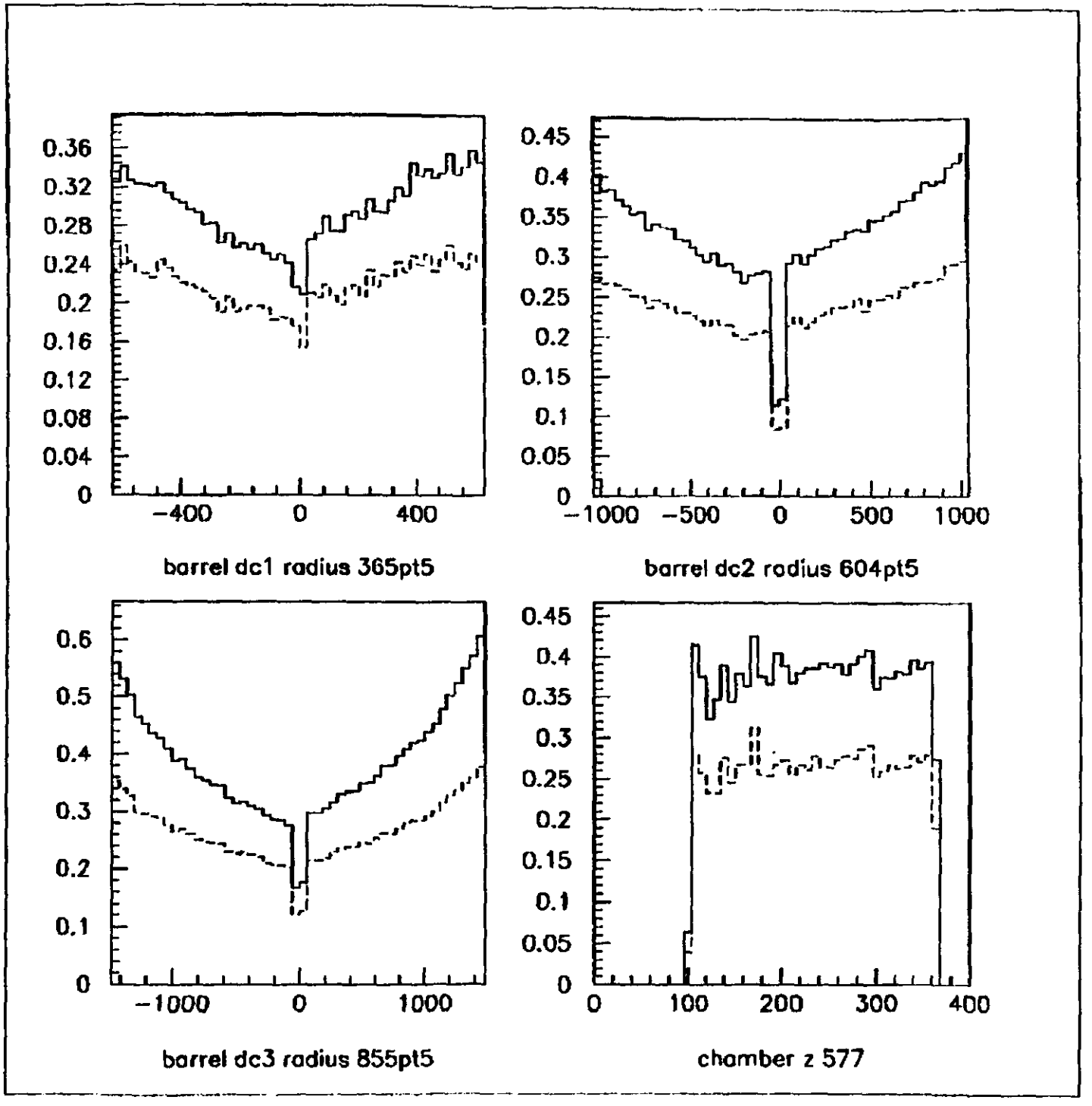
(15)

W FCAL
35 m


vertex barrel radius 9
vertex barrel radius 36
shield radius 102pt5
field shaper theta 8.7 deg

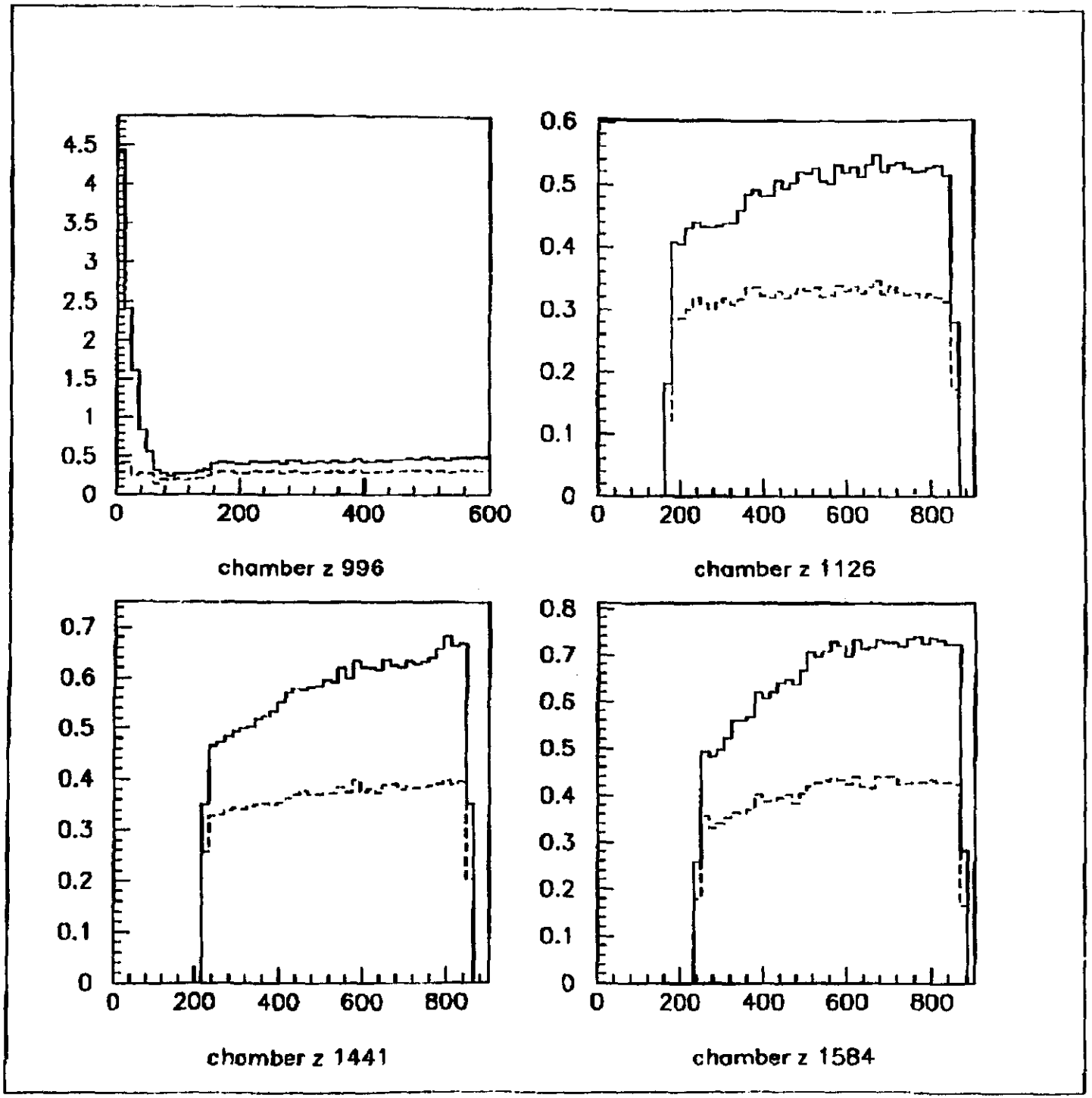
(16)

W FCAL
35 m

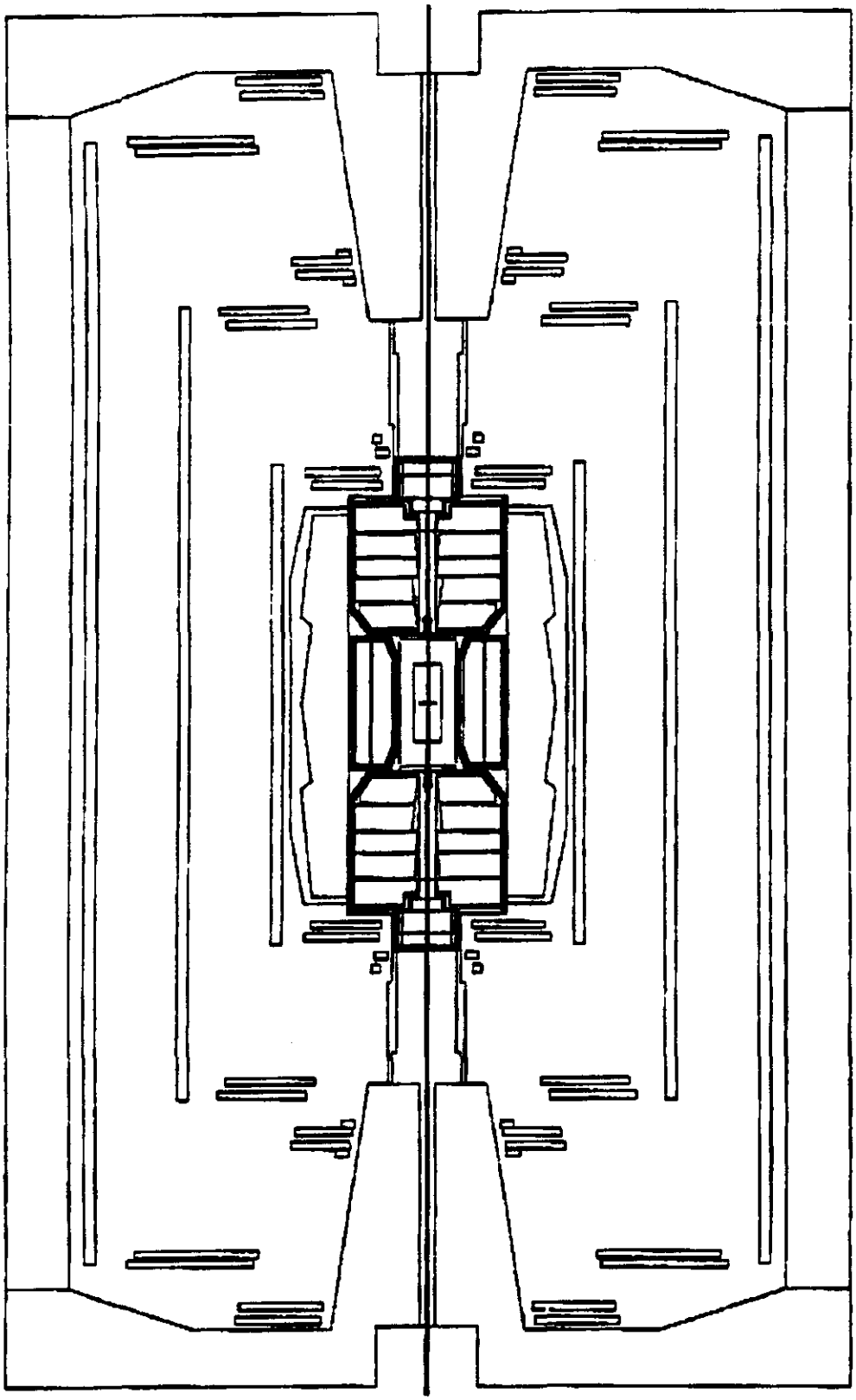

0.36
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0
−400
0
400
barrel dc1 radius 365pt5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
−1000
−500
0
500
1000
barrel dc2 radius 604pt5
0.6
0.5
0.4
0.3
0.2
0.1
0
−1000
0
1000
barrel dc3 radius 855pt5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
100
200
300
400
chamber z 577

(17)

W FCAL
35 m



18



gem

γeμ

Presentation by:

K. Morgan

Short Report on the

Radiation Workshop on the Design

of the LHC Forward Detectors.

November 9 - 10

CERN

K Morgan

can they help?

- The ultimate challenge: a reliable (a factor of 2) calculation of the residual nuclei over the full mass range.
- Present status: useful informations can be obtained only for $A_T < A_{res} < A_T$ (spallation region)

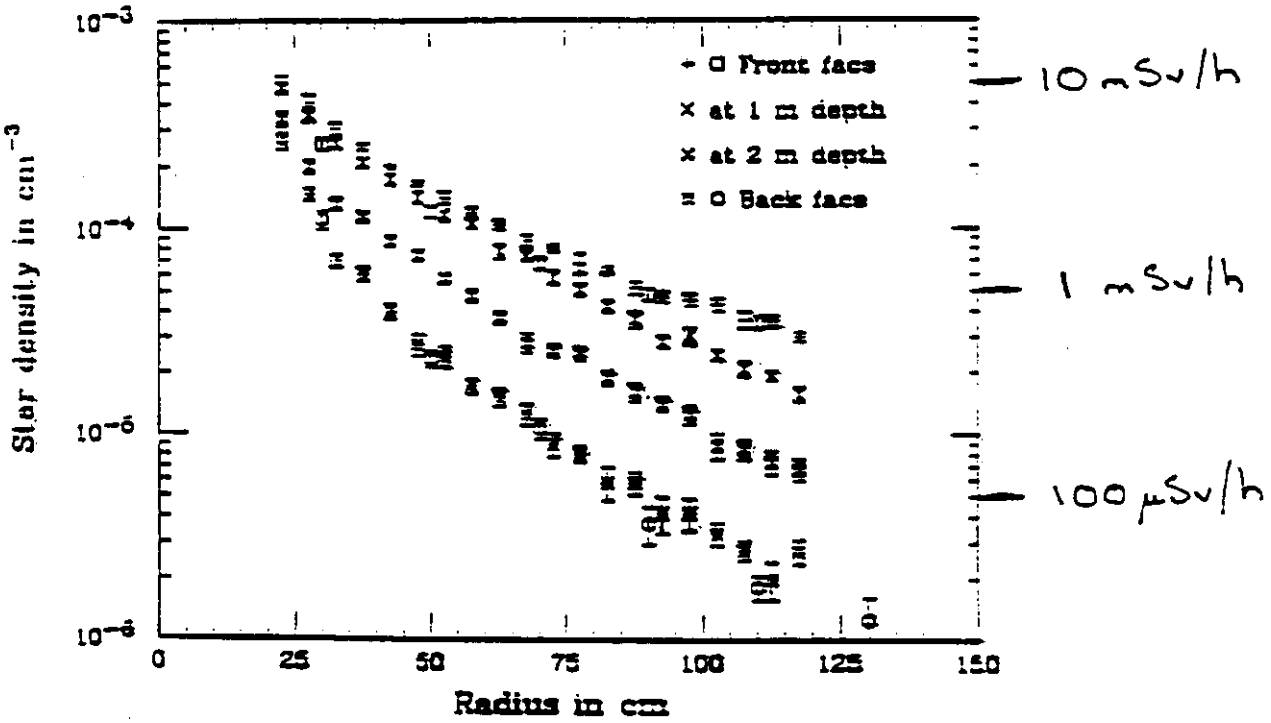
but:

- Particle fluxes are computed within a 20-30% error over the full energy range

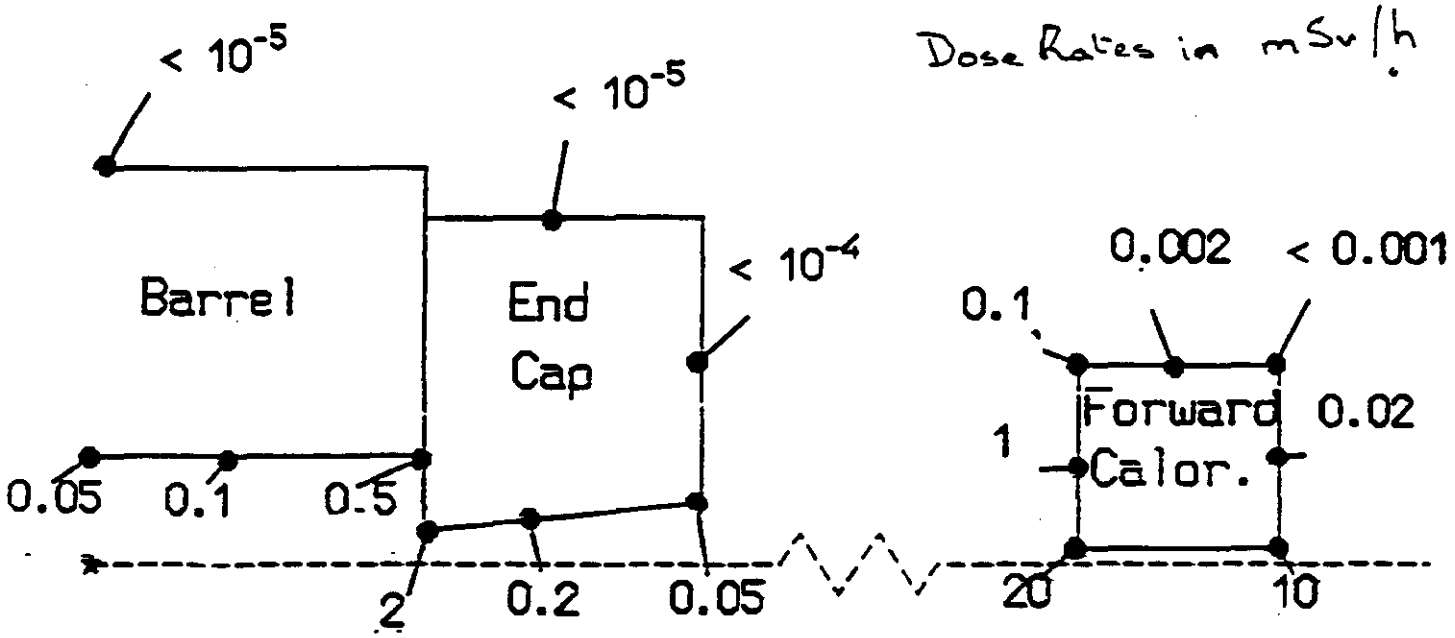
↓

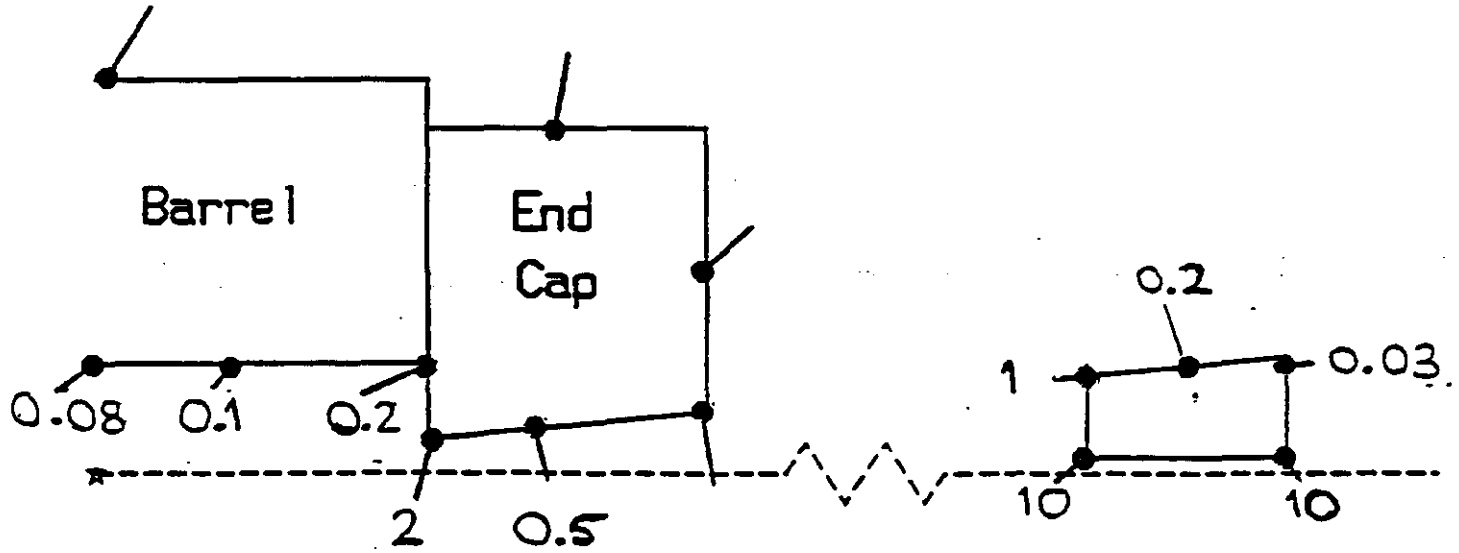
For those isotopes for which cross sections are known reasonable predictions can be made.

Very Forward Detector



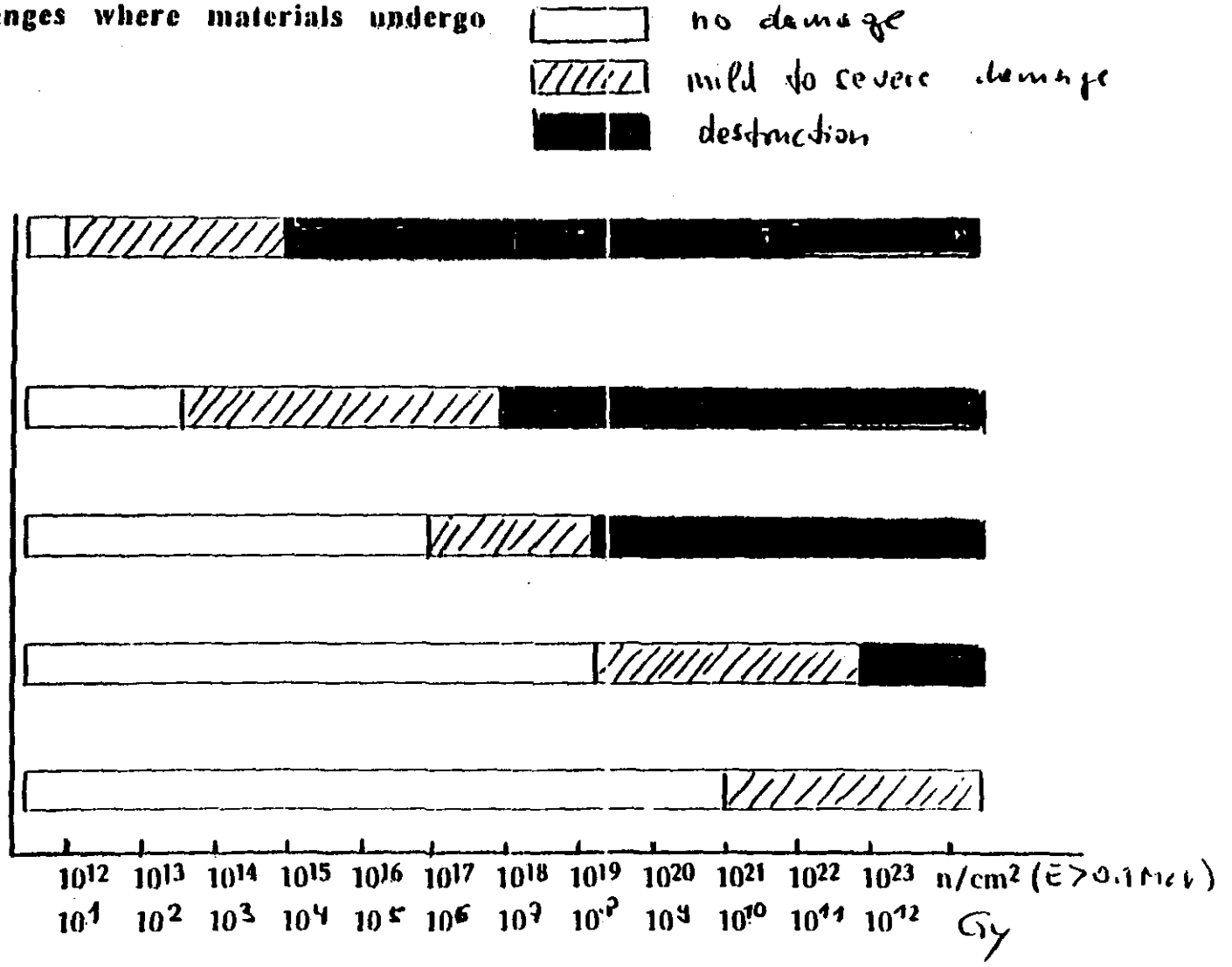
Atlas LOI Comparison



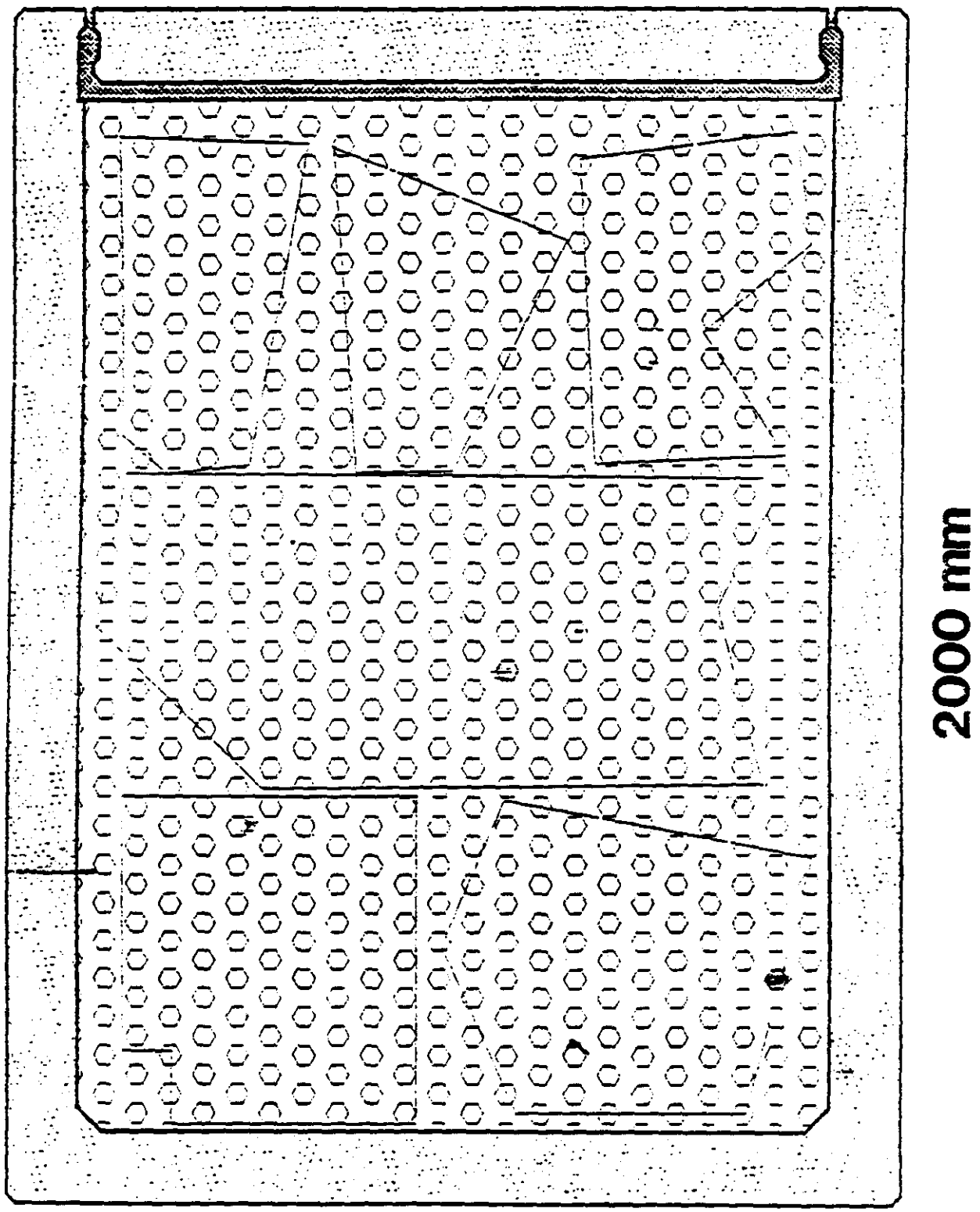


GENERAL APPRECIATION OF RADIATION DAMAGE TO MATERIALS

Shown are dose ranges where materials undergo



TYP: KC-T12



48

1500 mm

new legislation (ICRP)

20 mSv/a

2 – 3 mSv/a

0.03 – 0.05 mSv

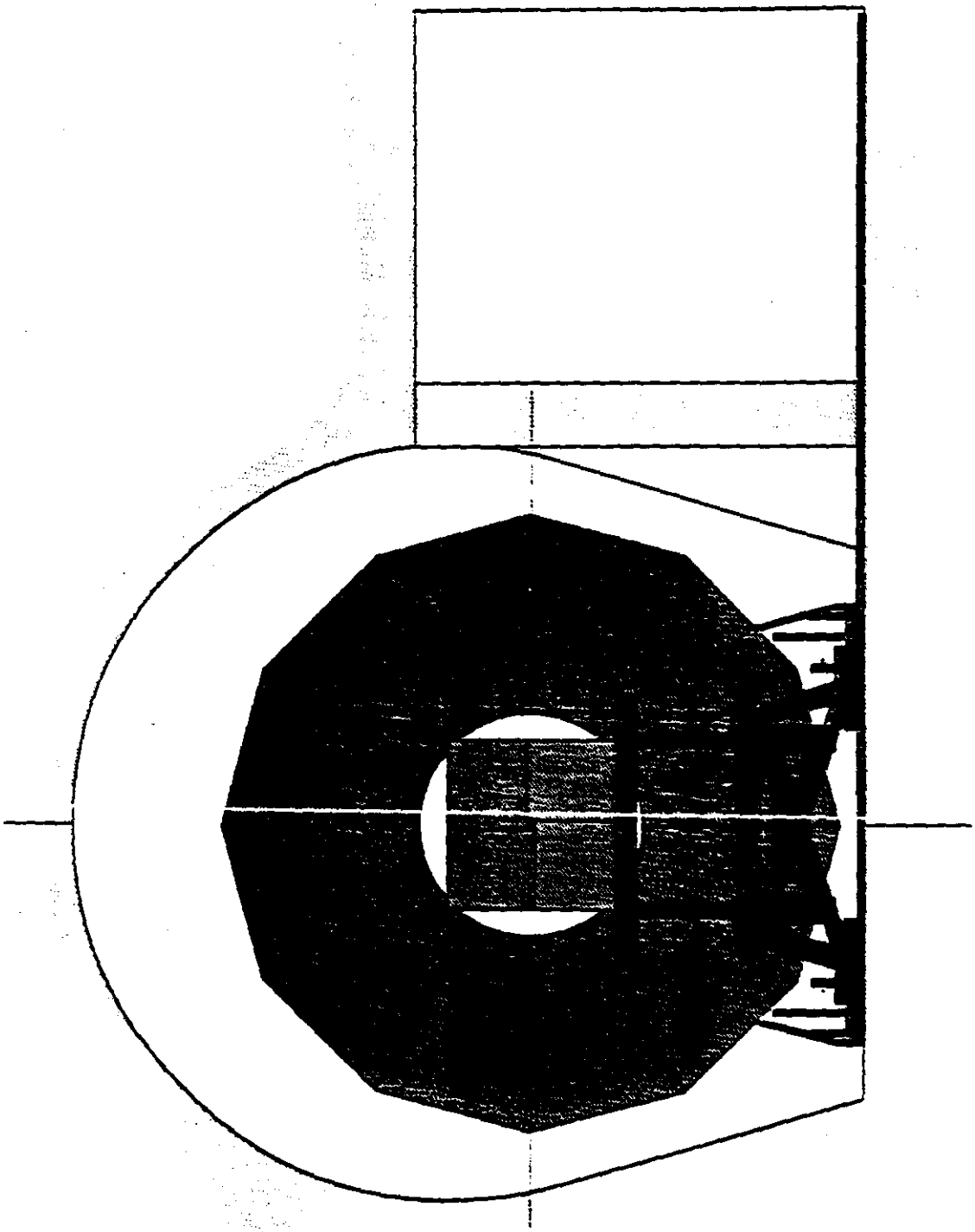
⇒ though rad. prot. is well done additional efforts are necessary

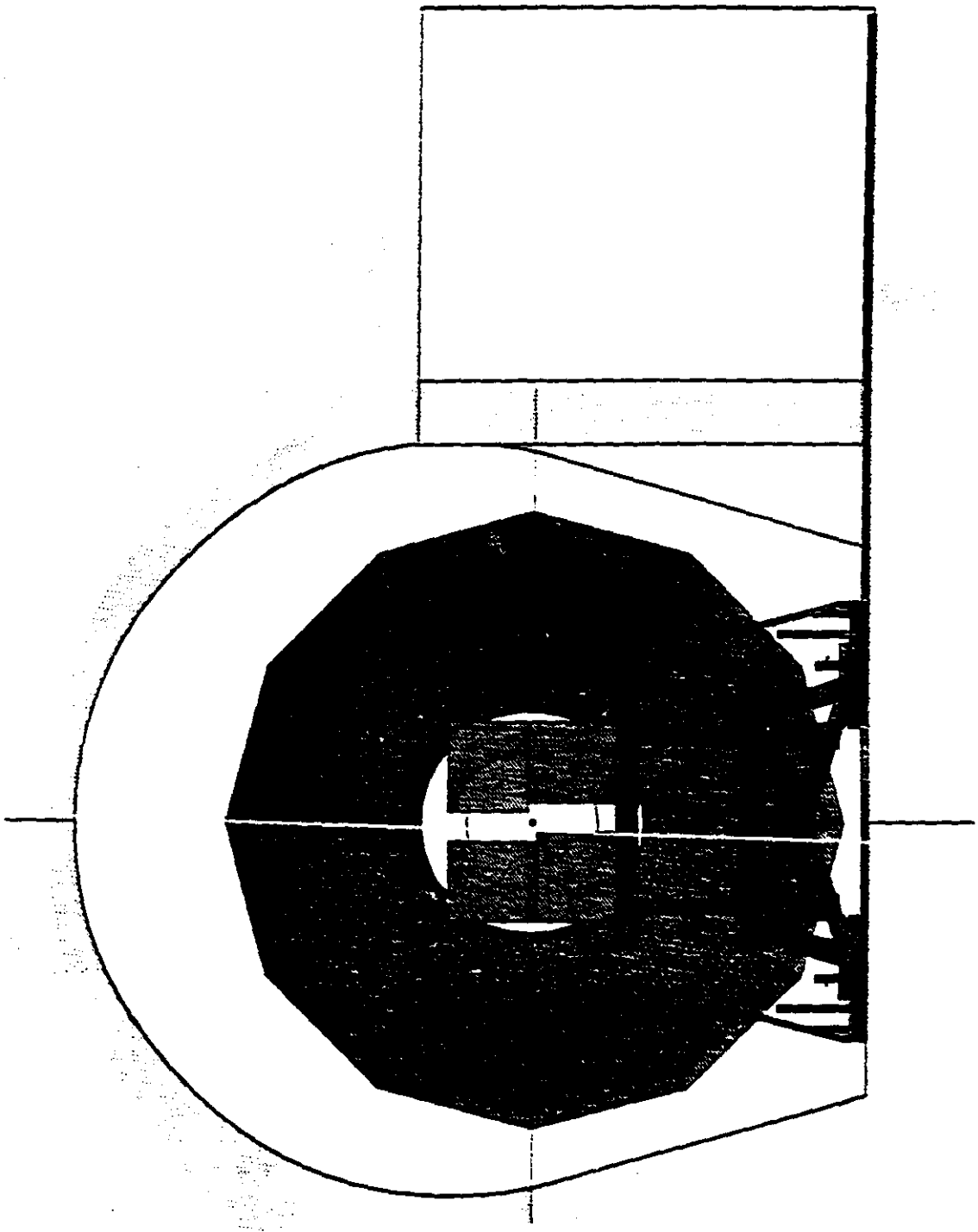
!?

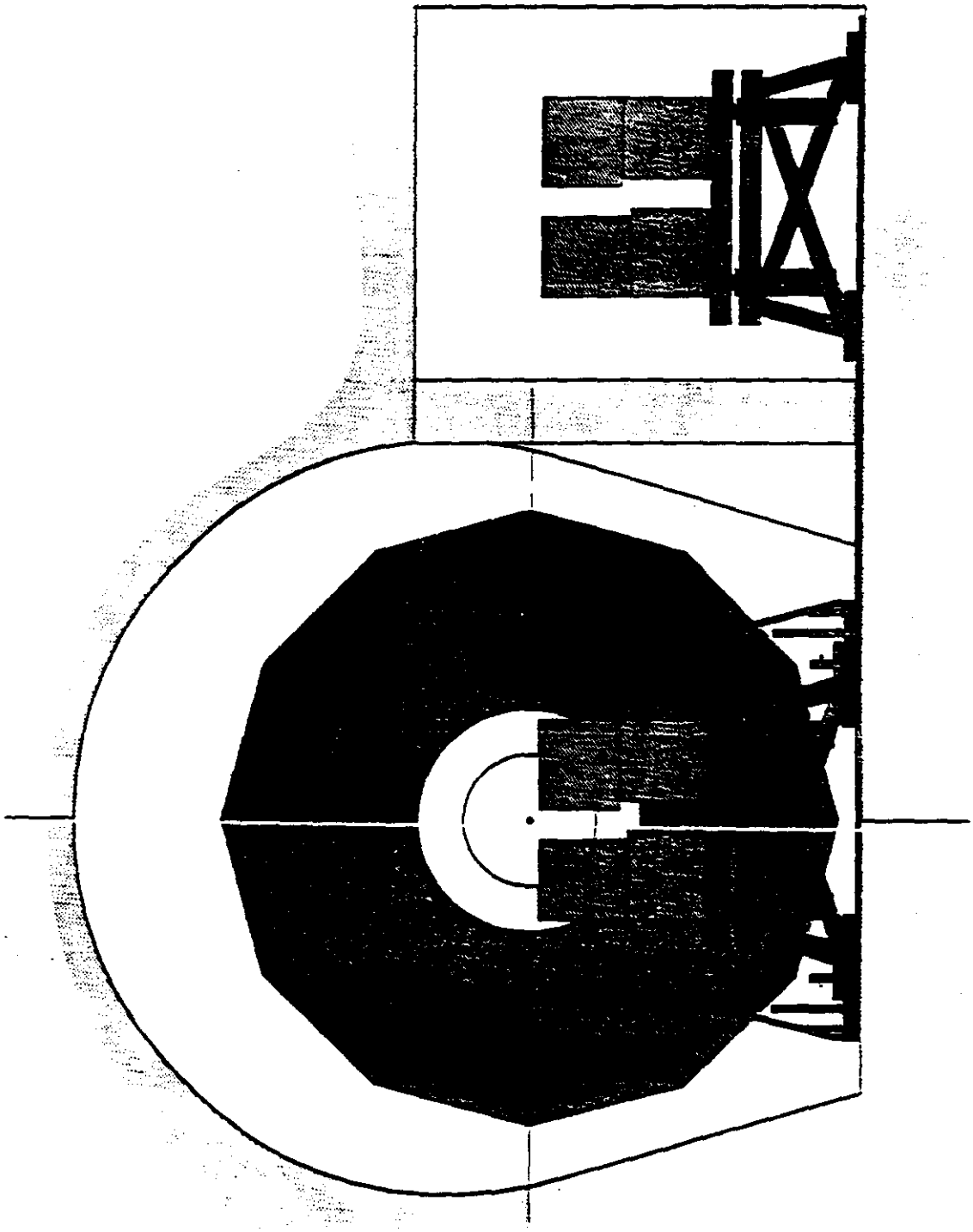
F. Cartier, HSK

REFERENCE MONETARY VALUE OF THE MAN-SIEVERT AT EDF

0-1	mSv/year	=	0,1 MF/h.Sv
1-5	mSv/year	=	0,5 MF/h.Sv
5-15	mSv/year	=	2,3 MF/h.Sv
15-30	mSv/year	=	6,7 MF/h.Sv
30-50	mSv/year	=	15 MF/h.Sv







gem

γeμ

Presentation by:

C. Wuest

Reactor Experiments, Inc. R/X 1275 HAMMERWOOD AVE., SUNNYVALE, CA 94089-2231
(408) 745-6770 • FAX: (408) 745-7013 • TELEX: 34 5505

Bulletin S-87N
June, 1991

TECHNICAL DATA SHEET
POLYETHYLENE-BASE SHIELDING

Polyethylene is an excellent base material for neutron shielding materials because of its exceptionally high hydrogen content. Of all practical materials, it contains more hydrogen atoms in a given volume than any other substance, is chemically inert, and has excellent machining and fabricating characteristics.

This bulletin presents selected tests and data on the different available types of shielding that use polyethylene as a base material for a variety of additives.

Cat. No.	Description	Typical Applications
201	5% Boron-Polyethylene	Research, training and power reactors.
202	1% Boron, 80% Lead-Polyethylene	Where it is necessary to shield against combined thermal neutrons, fast neutrons and gamma rays.
206	76.5% Lead-Polyethylene	LIGHT-LEAD® gamma shielding for radioisotope and nuclear medicine fabrications.
207	Self-Extinguishing Borated Polyethylene	Power reactors or where flame-resistant material is important.
210	30% Boron-Polyethylene	Reduction of very high thermal neutron flux levels.
213	Pure Polyethylene	Moderator for neutrons.
215	7.5% Lithium-Polyethylene	Shielding gamma sensitive detectors or experiments against neutrons without producing capture-gamma rays.

MISCELLANEOUS DATA

Catalog No. 201

Effect of Heating: 9 days @ 200°F: Material lost 2.5% of its original hydrogen.

Calculated Heat of Combustion: 15,300 BTU/lb - 8425 cal/g.

Exposure to 100% Relative Humidity for 3 Years: No effect.

Catalog No. 207

ASTM Test D-635 (Flammability of Self-Supporting Plastics) shows Catalog No. 207 to be completely self-extinguishing. No flame results after removal of a torch held to the material for 30 seconds. ASTM Test D-2863 gives a Limiting Oxygen Index of 30.2.

Reactor Experiments, Inc. R/X 1275 HAMMERWOOD AVE., SUNNYVALE, CA 94089-2231
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EA-277
May, 1991

TYPICAL ELEMENTAL ANALYSIS

HEAT RESISTANT SHIELDING
(Catalog No. 277)

Element	Weight Percent
O	58.65%
Al	23.91
Ca	8.83
H	3.37
Si	2.13
B	1.56 *
Na	0.59
Mg	0.50
Fe	0.27
S	0.19
Total	100.00%

Density = 1.68 g/cc (105 lbs/cu ft)

Hydrogen Atoms per cc = 3.4×10^{22}

Boron Atoms per cc = 1.43×10^{21} *

* Type 277 contains a boron additive which has a natural isotope distribution. The weight-percent ^{10}B in the material is therefore about 0.29% and the ^{10}B atoms/cc is about 2.7×10^{20}.

PROPRIETARY INFORMATION

Reactor Experiments, Inc. R/X 1275 HAMMERWOOD AVE., SUNNYVALE, CA 94089-2231
(408) 745-6770 • FAX: (408) 745-7013 • TELEX: 34 5505

EA-202
May, 1991

TYPICAL ELEMENTAL ANALYSIS

BORON-LEAD-POLYETHYLENE
(Catalog No. 202)

Element	Weight Percent
Pb	81.33%
C	10.28
O	3.60
H	1.70
Ca	1.06
B	1.04 *
Si	0.41
Na	0.34
Mg	0.19
Al	0.05
Total	100.00%

Density = 4.2 g/cc (262 lbs/cu ft)

Hydrogen Atoms per cc = 4.3×10^{22}

Boron Atoms per cc = 2.40×10^{21} *

Lead Atoms per cc = 10.00×10^{21}

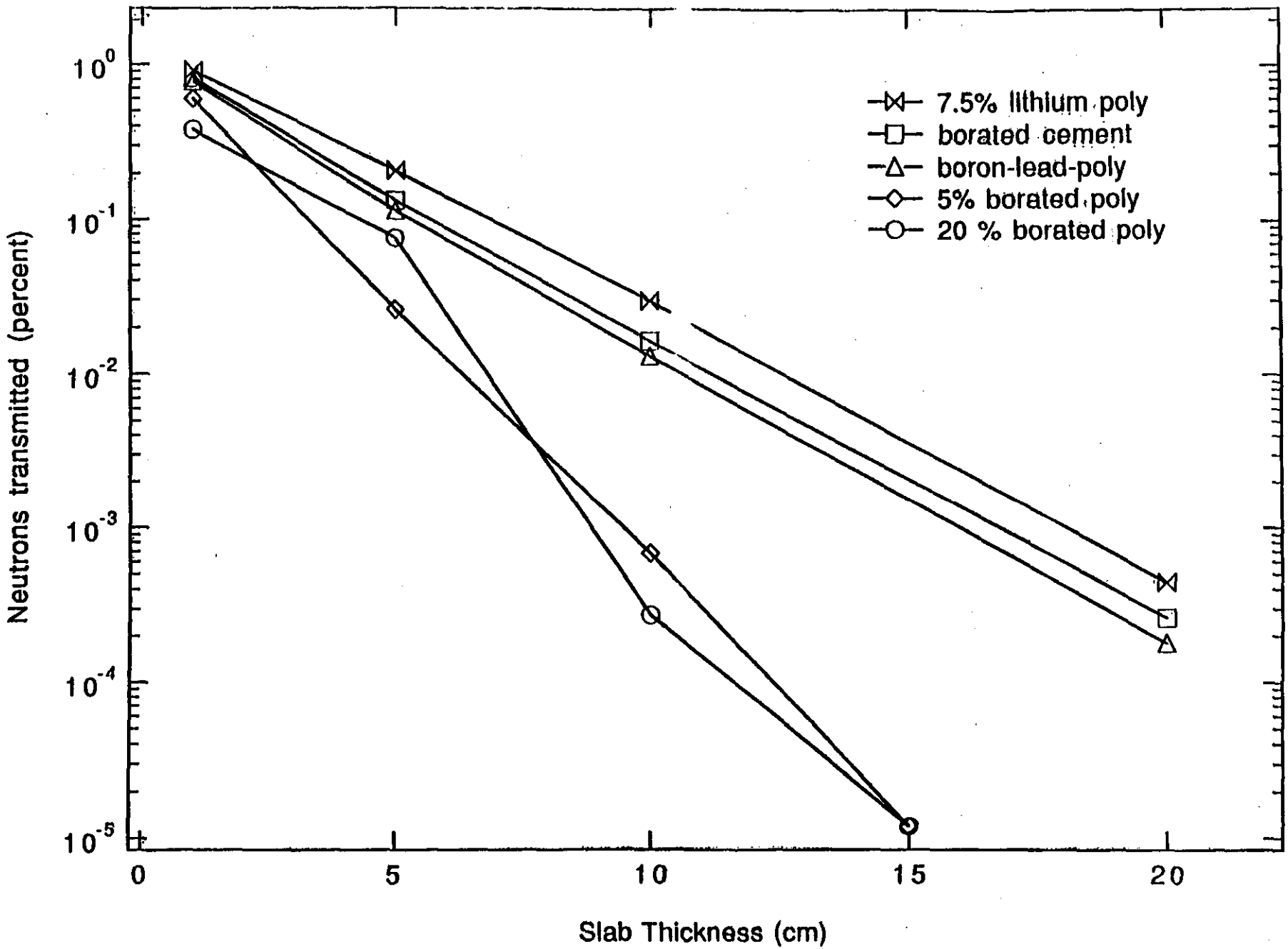
* Type 202 contains a boron additive which has a natural isotope distribution. The weight-percent ^{10}B in the material is therefore about 0.19% and the ^{10}B atoms/cc is about 4.6×10^{20}.

PROPRIETARY INFORMATION

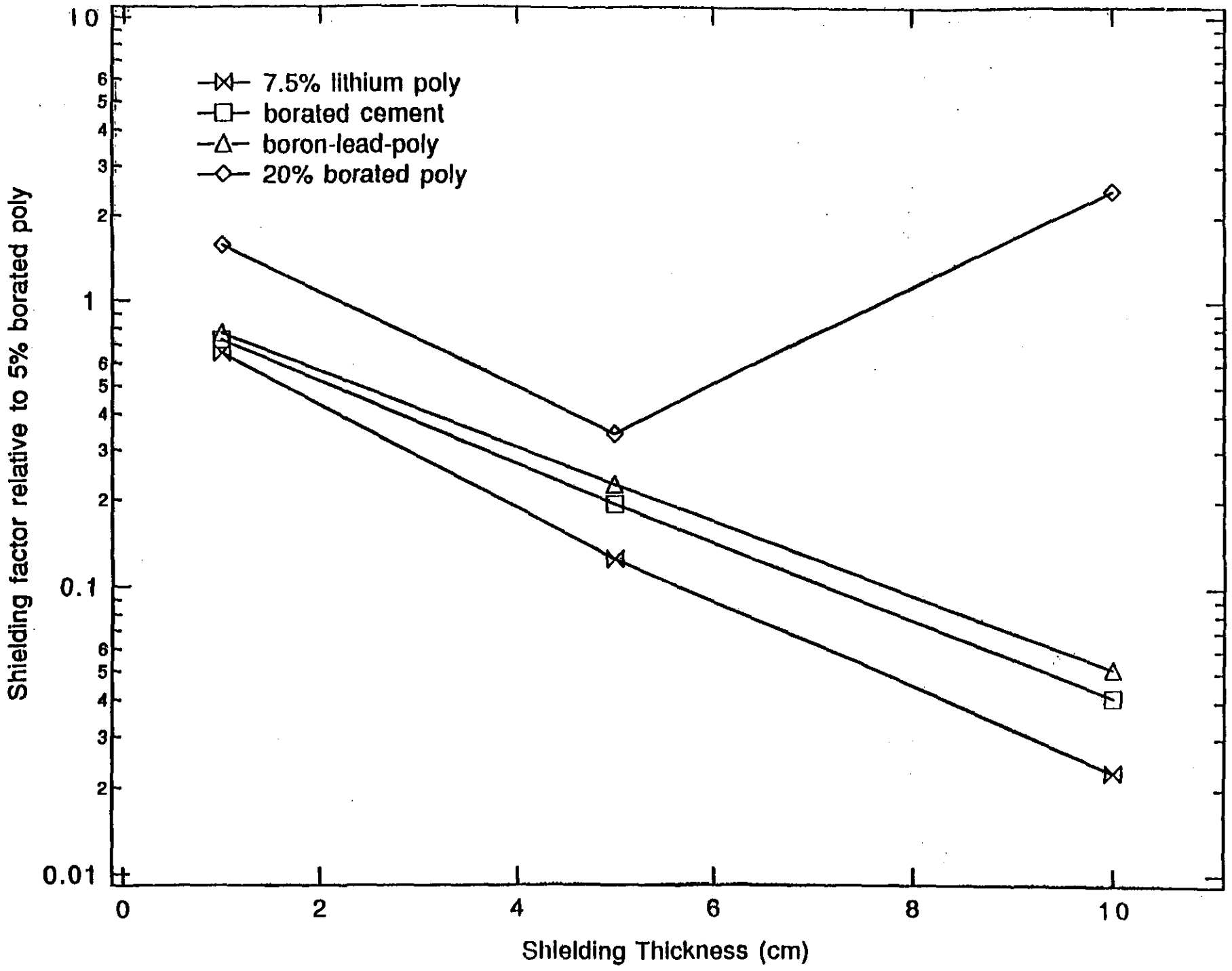
Total Neutron Flux as a function of shielding material and thickness for a cylindrical slab.

SHIELDING MATERIAL	1 [cm]	5 [cm]	10 [cm]	15 [cm]	20 [cm]
Li-Poly.	7.60 ± .003	1.73 ± .005	0.249 ± .014		0.0037*
Cement	6.804 ± .003	1.115 ± .007	0.138 ± .019		0.0022
B-Pb-Poly	6.456 ± .003	0.951 ± .007	0.110 ± .021		0.0015
5% B-Poly	4.963 ± .003	0.217 ± .015	0.0057	0.0001	0.0000
20%B-Poly	3.168 ± .005	0.631 ± .0270	0.0023	0.0001	0.0000

* The errors have not been given because are larger than the value reported. If needed, we will run a larger number of particles than the 20000 used in these calculations

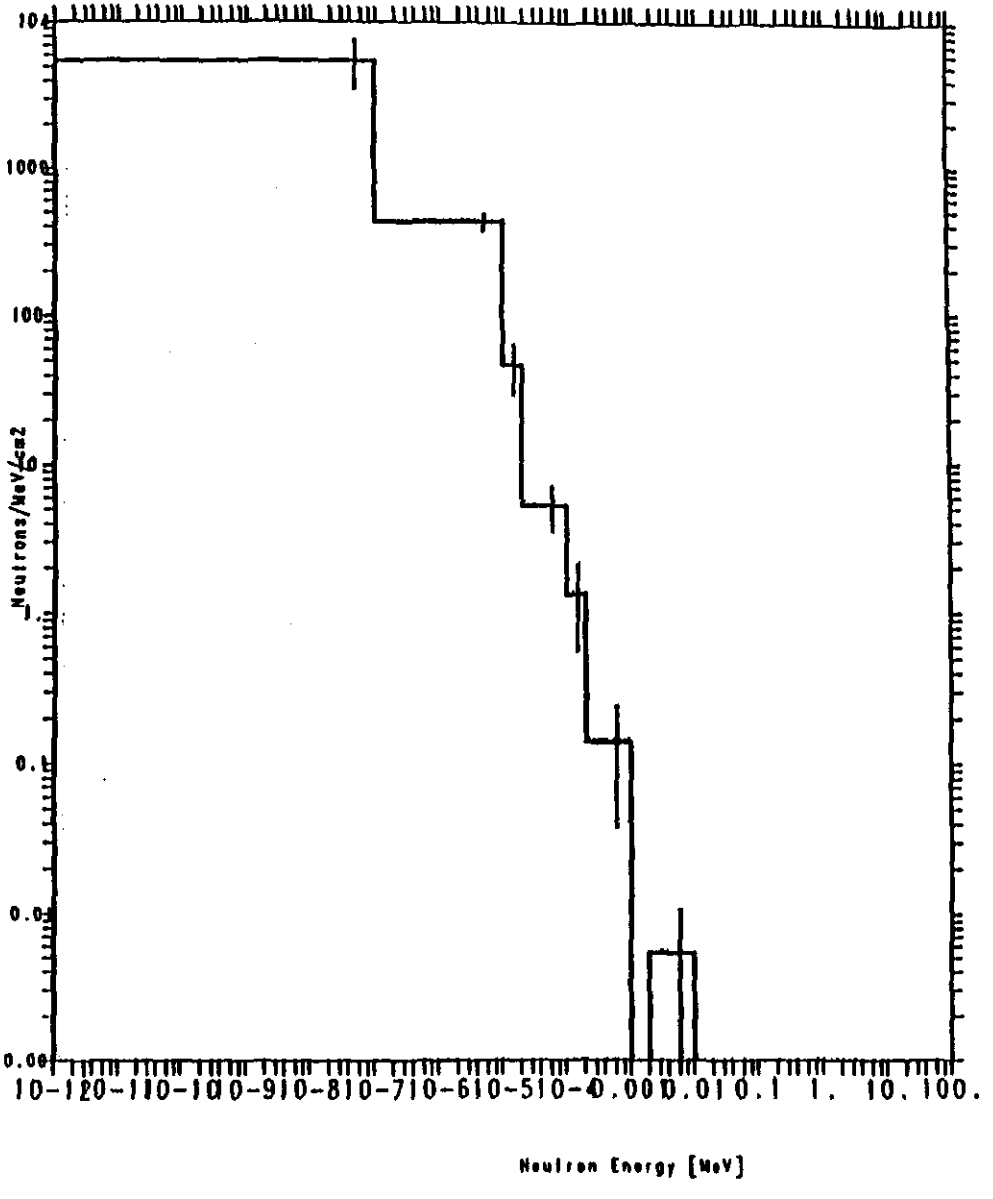


Total neutron flux a function of shielding material and thickness for a cylindrical slab (MCNP)


7.5% lithium poly
borated cement
boron-lead-poly
20% borated poly
Shielding factor relative to 5% borated poly
Shielding Thickness (cm)
10
1
0.1
0.01
0
2
4
6
8
10

5% Boraled Polythylene (10 cm)

file runlp101 --- tally 2

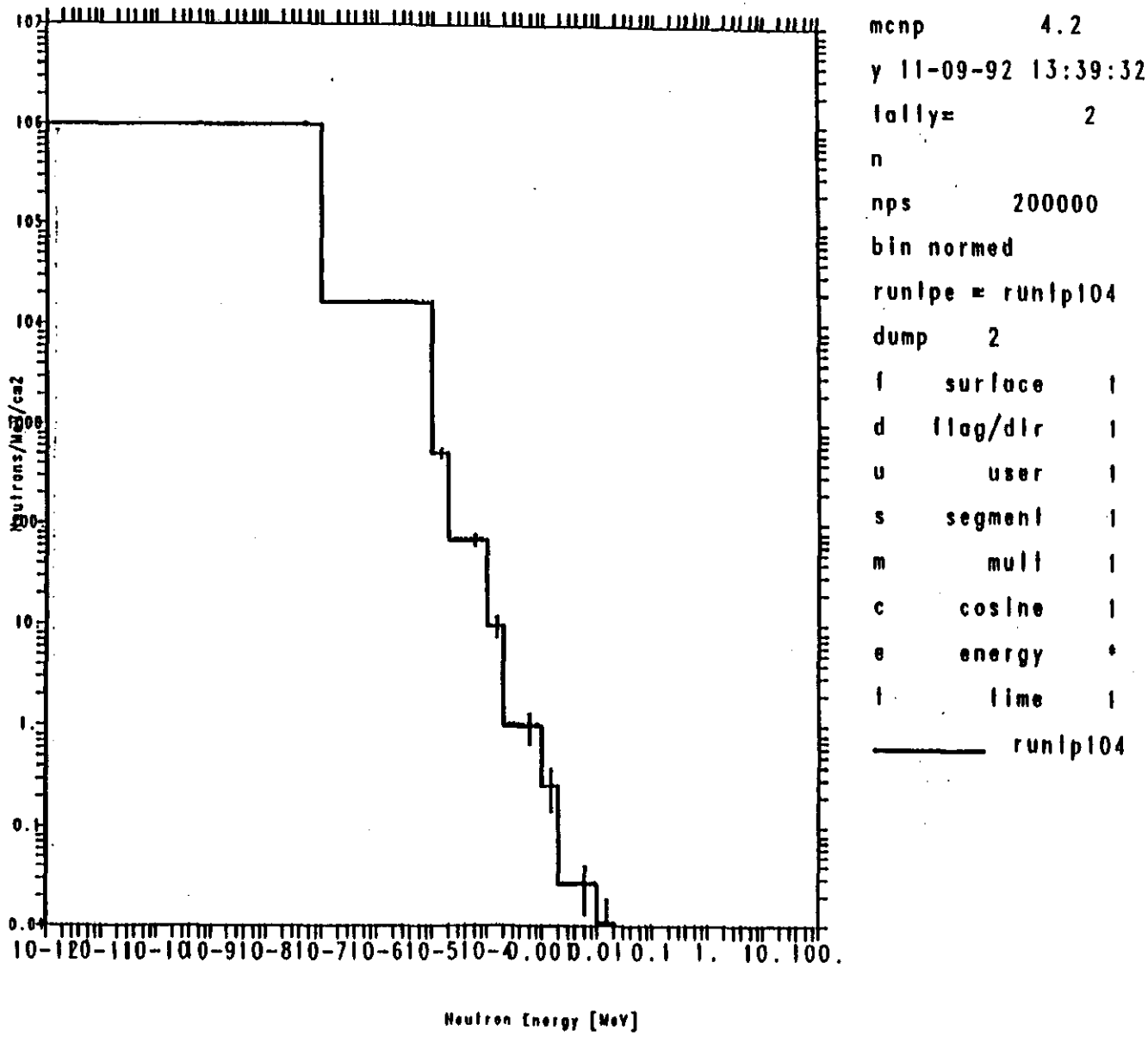


mcnp 4.2
y 11-09-92 13:47:37
tally= 2
n
nps 200000
bin normed
runlpe = runlp101
dump 2

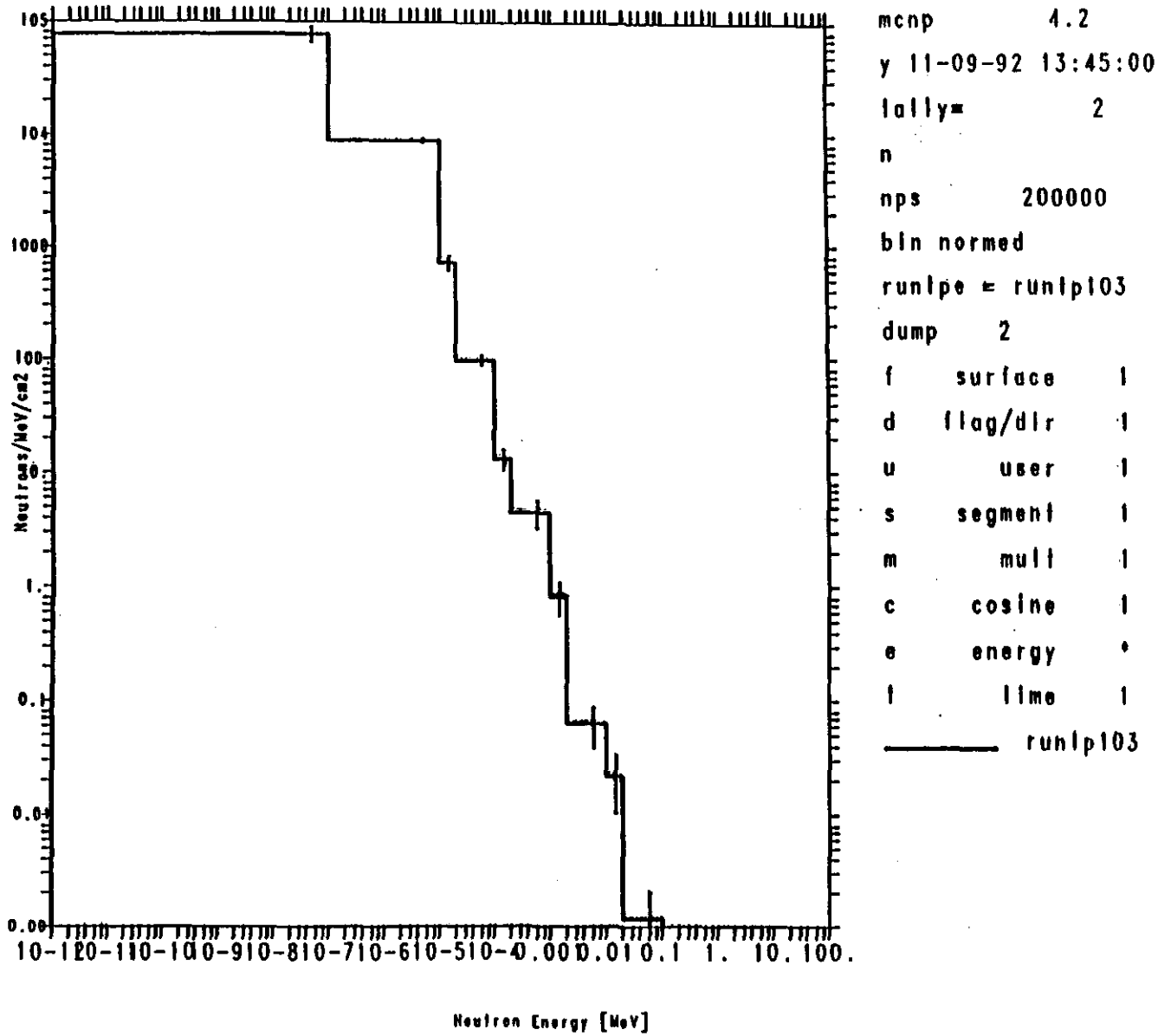
f	surface	1
d	flag/dir	1
u	user	1
s	segment	1
m	mult	1
c	cosine	1
e	energy	*
t	time	1

runlp101

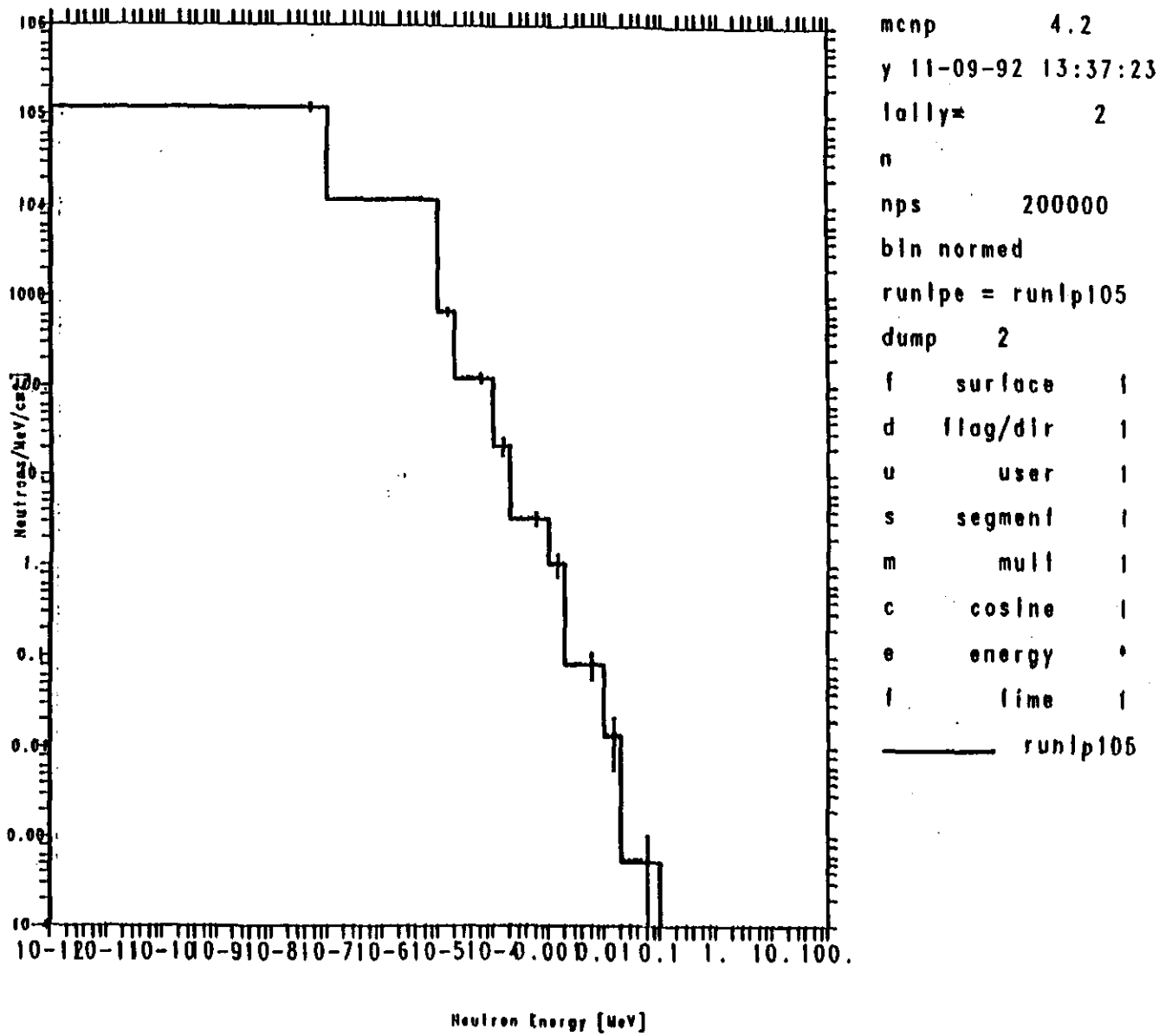
Li-Polyethylene (10 cm)



Boron-Lead-Polyethelene (10cm)

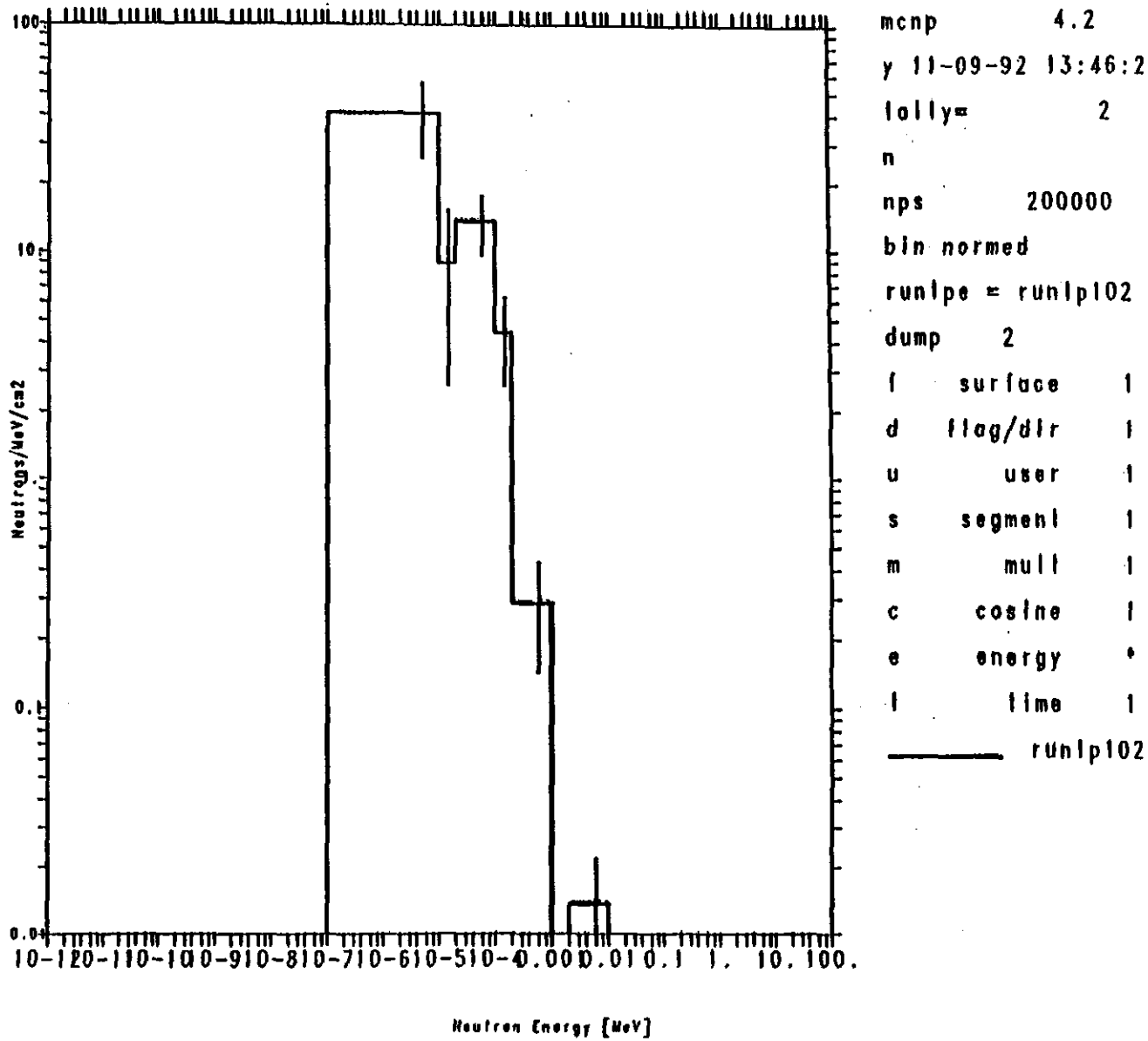


Cement Shielding (10 cm)



20% Boraled Polythyelene (10cm)

file runlp102 --- tally 2



mcnp 4.2

y 11-09-92 13:46:29

tally= 2

n

nps 200000

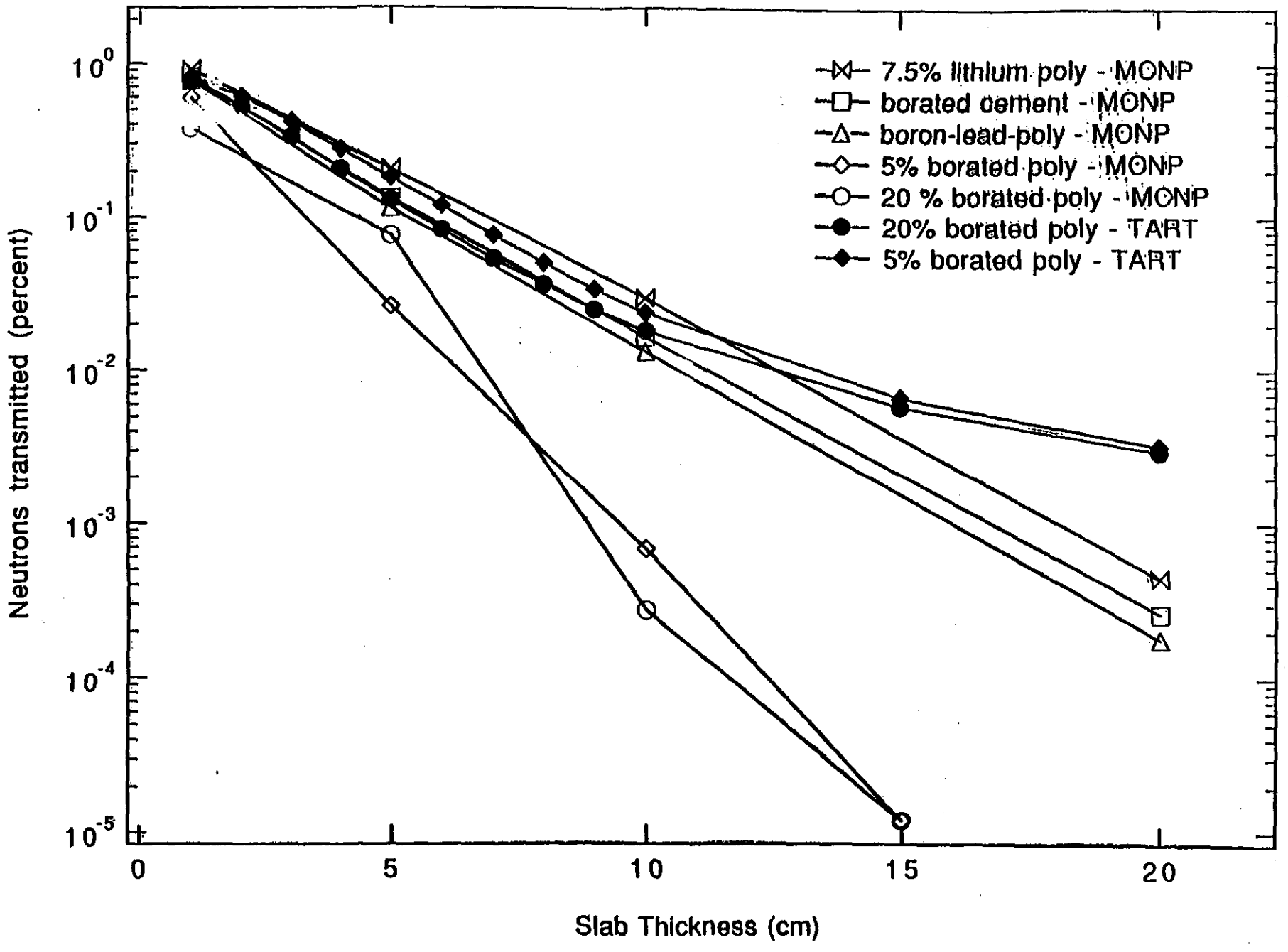
bin normed

runlpe = runlp102

dump 2

f	surface	1
d	flag/dir	1
u	user	1
s	segment	1
m	mult	1
c	cosine	1
e	energy	*
t	time	1

runlp102



Total neutron flux a function of shielding material and thickness for a cylindrical slab (MCNP)

gem

γeμ

Presentation by:

R. McNeil

McNEIL

GEM Barrel Muon "Fake" Trigger rate in the presence of a High neutron hit rate.

Neutron Rate in barrel expected to be $10^3 - 10^6$ Hz/cm^2

optimistic 10^{33} rate — pessimistic 10^{34} rate

Define parameter $R = \dfrac{\text{Neutron Flux}}{10^4 \text{ Hz/cm}^2}$

Want to determine CSC, RPC trigger rate vs R

- Limiting 1ST Level Muon trigger rate is 10^4 Hz (Barrel + Endcap)
- Rate of $P_T > 50$ GeV/c muons @ 10^{34} cm^{-2}s^{-1} is ~ few x 100 Hz in barrel

Primary Goal: Robust triggering @ 10^{34} cm^{-2}s^{-1} ⇒ Rate < 10^4 Hz

Common Assumptions:

- Neutron flux uniform in time and space in Barrel region Expressed in units of R.
- Neutron response probability is 0.5 % independent of technology

RPC Trigger: SL1 * SL2 * SL3 + Bend * non Bend Plane

- Each SL has 2 RPC layers which are ORed
  SL Bend-plane strips are ORed along Z

  SL1 Trigger element size: 1.3cm x 330 cm x 2 = 858 cm^2
  SL2 " " " " 360 cm x 3 = 1404 cm^2
  SL3 " " " " 380 cm x 4 = 1976 cm^2

- RPC signals are fast; with mean timing $\Delta t < 20ns$

- Rate of n hits in SL3 element: $R \times 10^4 \frac{Hz}{cm^2} \times .005 \times 2 \times 1976 cm^2 = R \times 2.0 \times 10^5 \frac{Hz}{el}$

- 50 GeV/c P_t trigger => ±2 strip widths in SL2, ±6 widths in SL1

- Probalility of coincidence (area, $2\times\Delta t$)

  SL1: $R \times .0205$ SL2: $R \times .0112$ Total: $2 \times R^2 \times .0205 \times .0112$ ← ± sign of charge.
  $= R^2 \times 4.6 \times 10^{-4}$

- Rate of Bend-Plane trigger per barrel sector:

  $253 \text{ elem/sector} \times R \times 2.0 \times 10^5 \frac{Hz}{elem} \times R^2 \times 4.6 \times 10^{-4} = R^3 \times 2.3 \times 10^4 \text{ Hz/sector}$

- Projective non Bend Plane requirement:

  $3 \times \frac{1}{166 \text{ strips}} \times \frac{1}{166 \text{ strips}} = 1.1 \times 10^{-4}$

- Total Rate of neutron conspiracy triggers:

  $R^3 \times 2.3 \times 10^4 \frac{Hz}{sector} \times 1.1 \times 10^{-4} \times 2 \times 16 \text{ sectors} = \underline{R^3 \times 82 \text{ Hz}}$

CSC: SL2 × SL3 Bend-Plane strips only considered

- Each SL(2,3) has 4 layers of CSC : 3 out of 4 required for trigger
- 4 Strips ganged ⇒ Trigger element size : $2\,cm \times 300\,cm = 600\,cm^2$
- Time window for coincidence : $2 \times \Delta t_{drift} = 2 \times 50\,ns$
- Rate of n per element : $R \times 10^4 \frac{Hz}{cm^2} \times 600 \frac{cm^2}{elem} = R \times 6 \times 10^6 \frac{Hz}{elem}$
- Rate of 3 out 4 per element (within $2 \times \Delta t$)

$$4 \times R \times 6.0 \times 10^6 \frac{Hz}{elem} \times .005 \times \left(R \times 6 \times 10^6 \frac{Hz}{elem} \times .005 \times 2 \times 5 \times 10^{-8} s \right)^2 = R^3 \times 1.1 \frac{Hz}{elem}$$

- Rate of 3 out 4 per sector

$$SL2: \quad 60 \frac{elem}{sector} \times R^3 \times 1.1\,Hz/elem = R^3 \times 64 \frac{Hz}{sector}$$

$$SL3: \quad 80 \frac{elem}{sector} \times R^3 \times 1.1\,Hz/elem = R^3 \times 85 \frac{Hz}{sector}$$

- 50 GeV/c $P_\perp$ trigger ⇒ ±2 element widths in SL2 out of 60 per sector
- Bend-Plane neutron conspiracy trigger rate per sector

$$R^3 \times 85\,Hz/sect \times R^3 \times 64 \frac{Hz}{sect} \times 2 \times 5 \times 10^{-8} s \times \frac{4\,elem}{60\,elem/sector} \times 2^{\pm sign} = R^6 \times 7.3 \times 10^{-5} \frac{Hz}{sector}$$

- Total Bend-Plane neutron conspiracy trigger rate in barrel

$$4 \times 2 \times 16 \text{ sector-chambers} \times R^6 \times 7.3 \times 10^{-5} \frac{Hz}{sector\ chamber}$$

$$= R^6 \times 0.0093\,Hz \quad \text{neutrons only.}$$

We aren't finished yet...

- Charged particle rate in SL2, SL3 is about .1 Hz/cm², .05 Hz/cm² @ $10^{33}\,cm^{-2}s^{-1}$

$$\text{Define} \quad H \equiv \frac{\text{Luminosity}}{10^{33}\,cm^{-2}s^{-1}}$$

Requiring charged tracks to be radial in SL $\Rightarrow P_T \gtrsim 2$ GeV/c

$\Rightarrow$ factor ~10 reduction in rate

Rate of "stiff" charged tracks per trigger element

$$\left.\begin{array}{ll} \text{SL2:} & 6\,\text{Hz/elem} \times H \\ \text{SL3:} & 3\,\text{Hz/elem} \times H \end{array}\right\} \text{3 out 4 always}$$

Rate of "fake" triggers caused by stiff charged track/secto

$$H \times 6\,\frac{\text{Hz}}{\text{elem}} \times H\,\frac{3\,\text{Hz}}{\text{elem}} \times \frac{80\,\text{elem}}{\text{sector}} \times \frac{2\times 4\,\text{elem}}{60\,\text{elem/sector}} \times 2\times 5\times 10^{-8}\,s$$

$$= H^2 \times 1.1\times 10^{-3}\ \text{Hz/sector-cham in SL3}$$

- Total CSC fake trigger rate in barrel

$$\underbrace{R^6 \times .0093\,\text{Hz}}_{\text{neutrons only}} + \underbrace{R^3 \times H \times .078\,\text{Hz}}_{\text{1 charged part + neutrons}} + \underbrace{H^2 \times .15\,\text{Hz}}_{\text{2 charged particles}}$$

Fake Trigger Rates in GEM Barrel Muon System satisfying 50GeV/c P_T Threshold

RPC: Bend-* non Bend-Plane info used

CSC: Only Bend-Plane info used

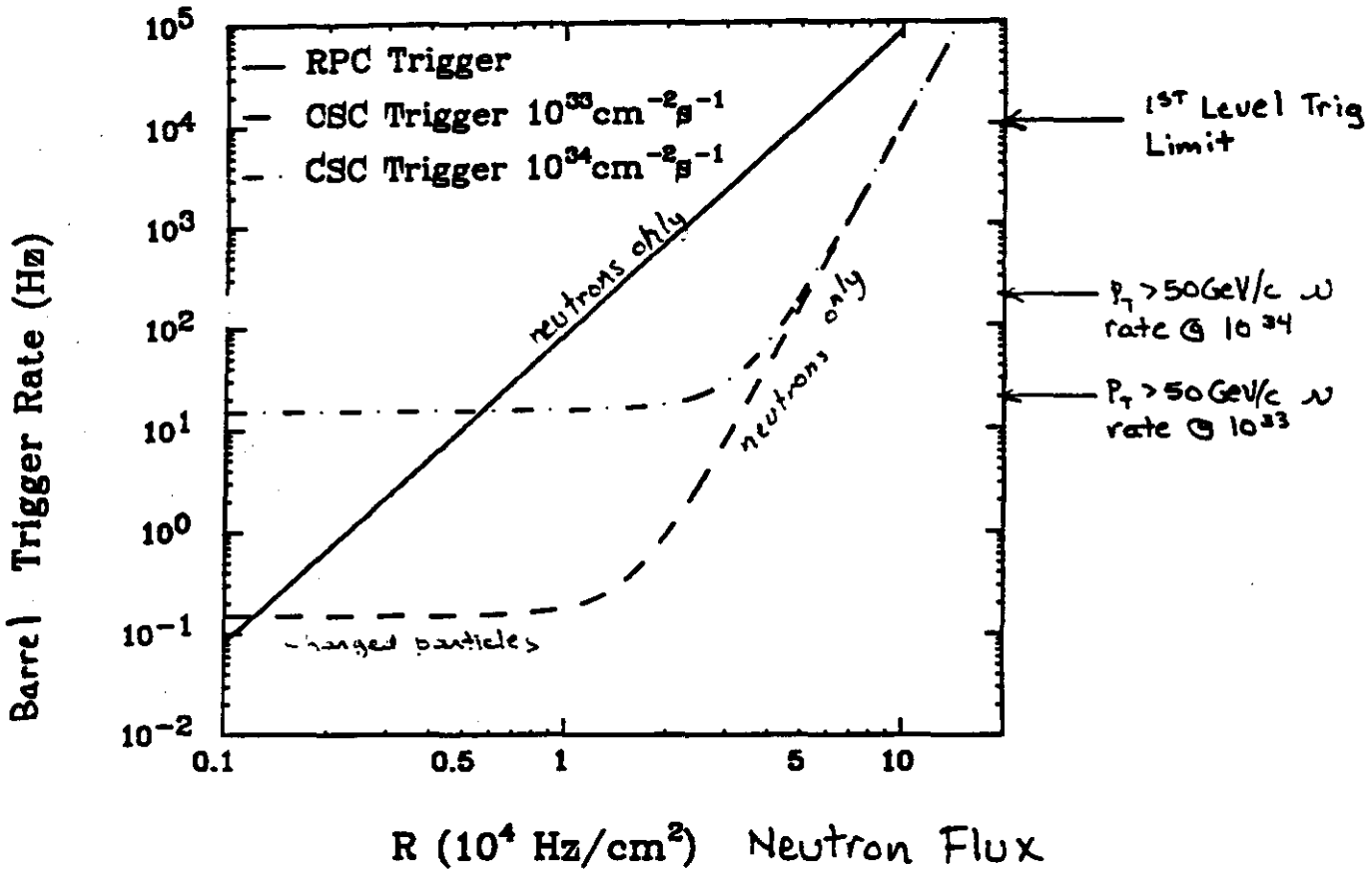


Figure 1. Comparison of fake-trigger rates from RPC (solid) and CSC (dashed and dot-dashed) as a function of neutron flux R X 10^4Hz/cm^2

gem

γeμ

Presentation by:

J. Rutherfoord

J. Rutherfoord
UAZ 11/17/92

GEM Beam Pipe Issues

1) Vacuum Requirements
   - In tracker region
   - Between tracker and FCal
   - Between FCal and FFQ collimator
2) Beam tube diameter and material for optimal pumping
3) Vacuum pump failure scenarios
4) Surveying requirements on beam pipe
5) Beam pipe as a source of secondaries (neutrons).
6) Physics coverage of FCal - impact on missing E_T measurement.
7) Temperature requirements on the beampipe

Vacuum Requirements

1) 10^{-7} in IP region gives $\lesssim 10^{6}$ Hz beam gas, i.e. $\lesssim 1\%$ of min bias events in tracker region at $\mathcal{L} = 10^{33}\ cm^{-2}\ sec^{-1}$

2) 2×10^{-6} Torr in region ± 35 m gives 10^{8} Hz beam-gas interactions – same as beam-beam loss.

3) Beam-gas interactions outside FCal yield secondaries which strike FCal and create neutrons. Also strike beam pipe etc.

J. Kuthertoord
GEM Collaboration Mtg.
BNL 11/5/92

Mitigating the Neutrons in the Muon Chambers

Neutron task force – chaired by M. Marx
SSCL 10/21/92

First attempt to reduce the sources of neutrons

Plan of Attack

For hadrons from IP with

$|\eta| < 6$?

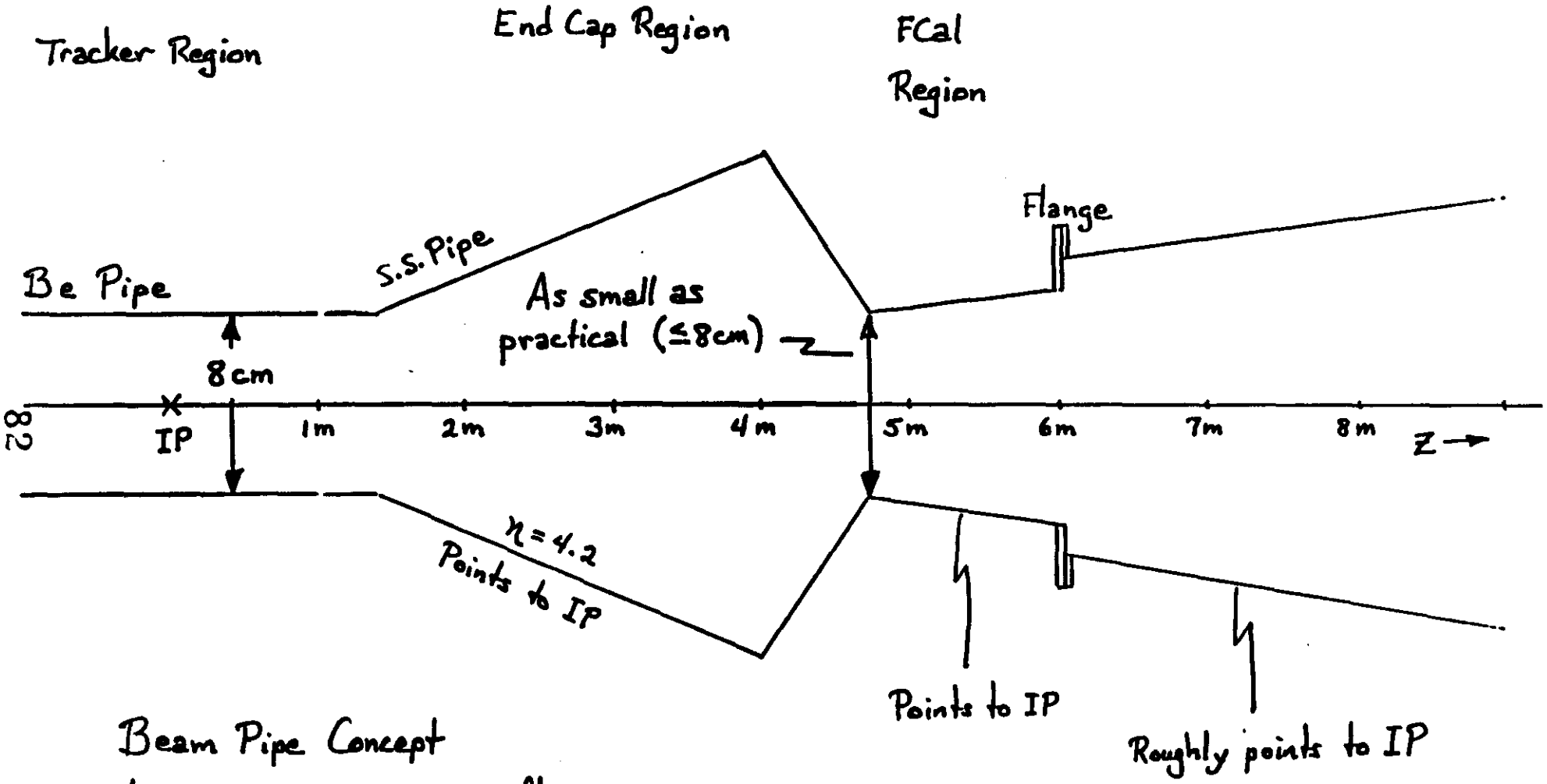
Bury them in calorimeters
(Must make end-cap and FCal deeper)

$|\eta| > 6$?

Let them go cleanly to end of hall
(Strategies to deal with them there.)

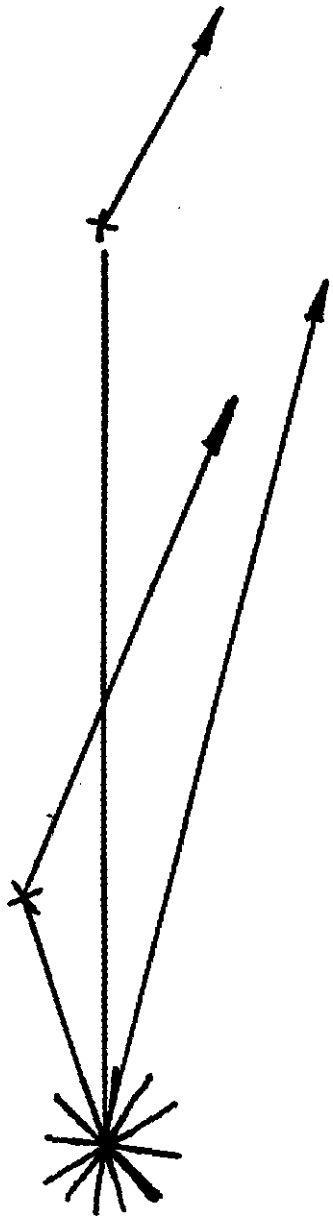
Reduce secondary sources * key concept *

Use FCal as collimator – Calorimeter system acts as bottle with small holes.

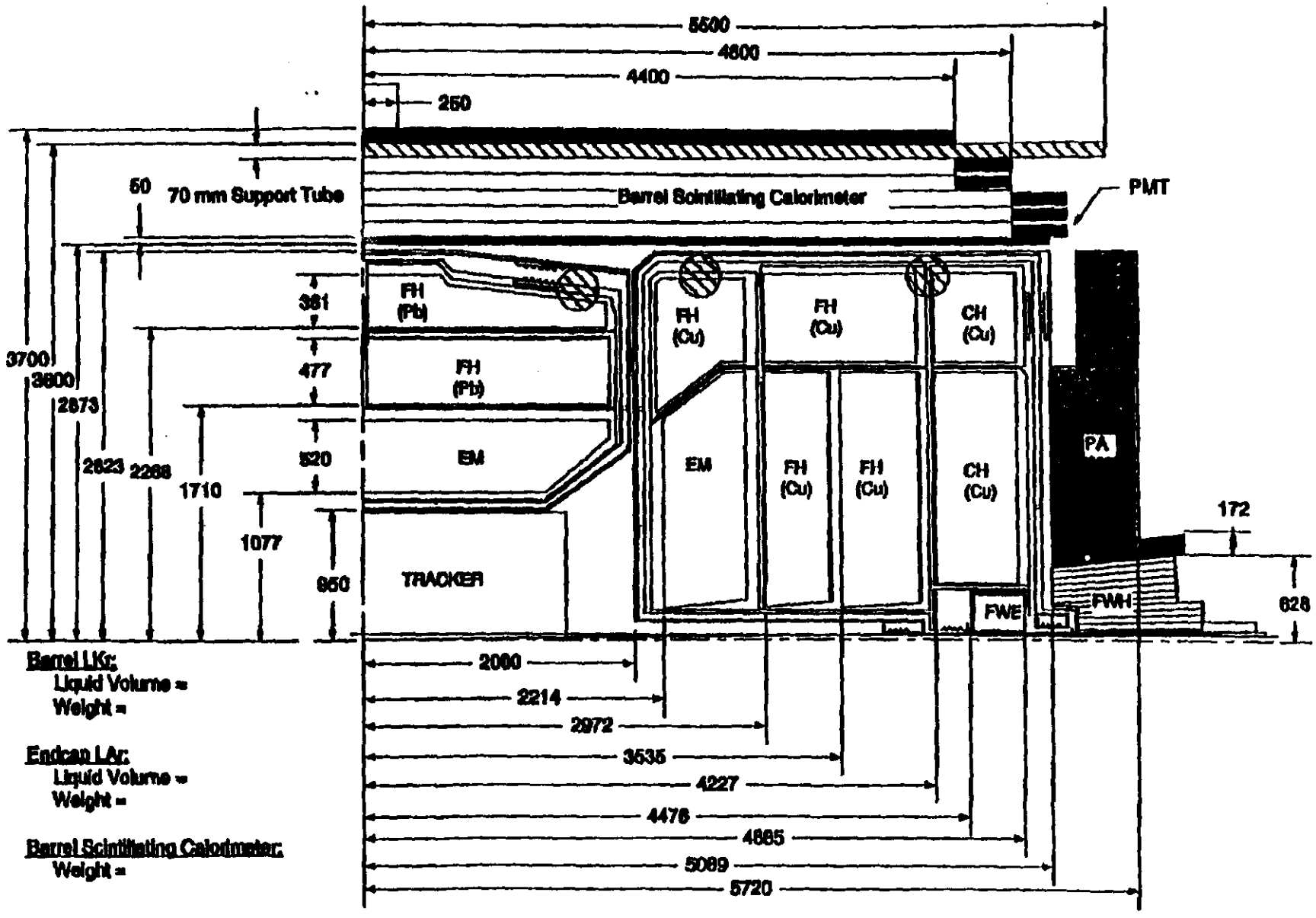


Beam Pipe Concept
to minimize neutron fluence
in muon chambers
11/4/92 J. Rutherfoord

Sources



GEM Calorimeter



Barrel LKr:
Liquid Volume =
Weight =

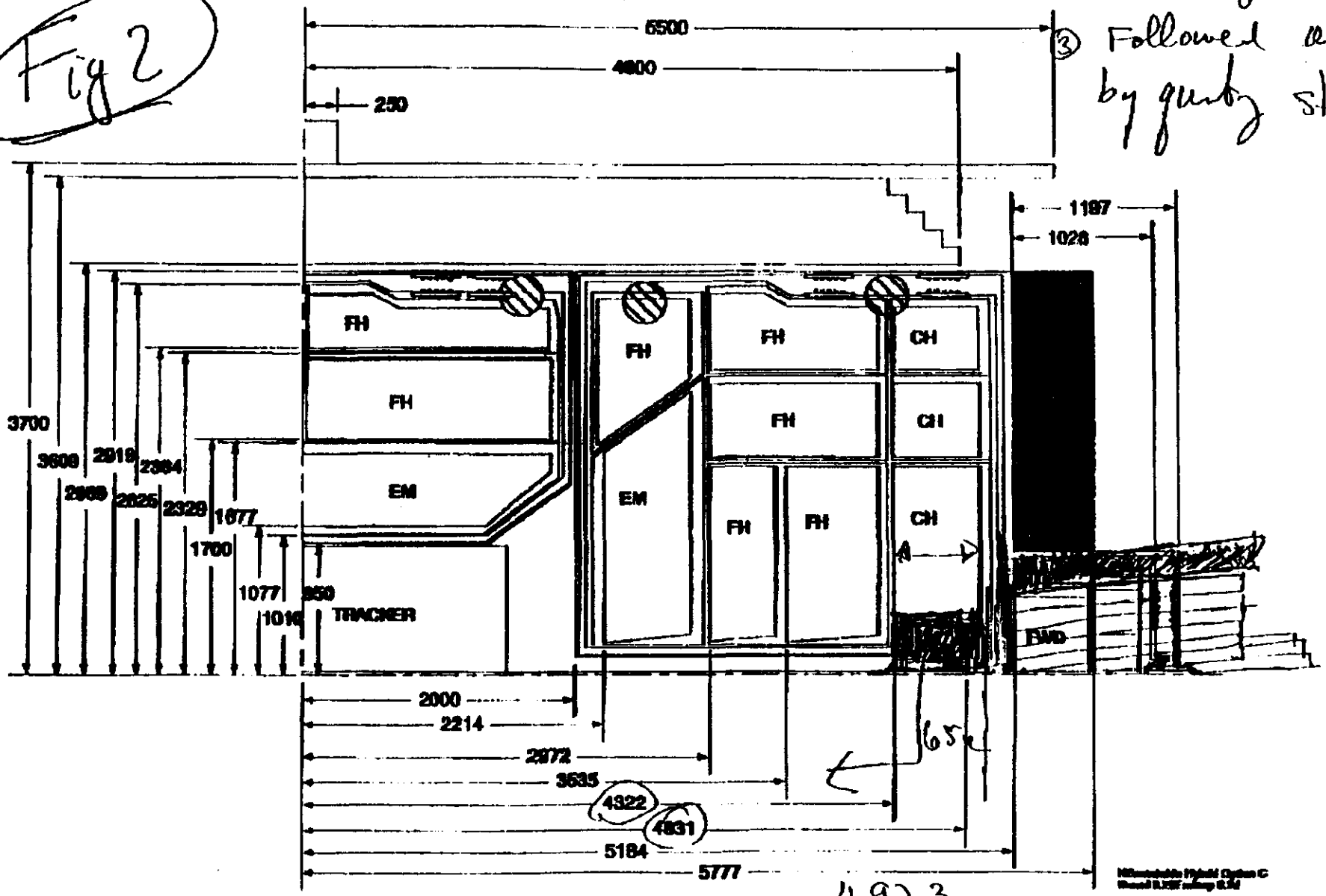
Endcap LAr:
Liquid Volume =
Weight =

Barrel Scintillating Calorimeter:
Weight =

Preliminary Hybrid Concept - Hybrid Option C

Fig 2

John: ① Wall's come down at end
② ~65 c.m of Forward.
③ Followed outside by gantry stepper

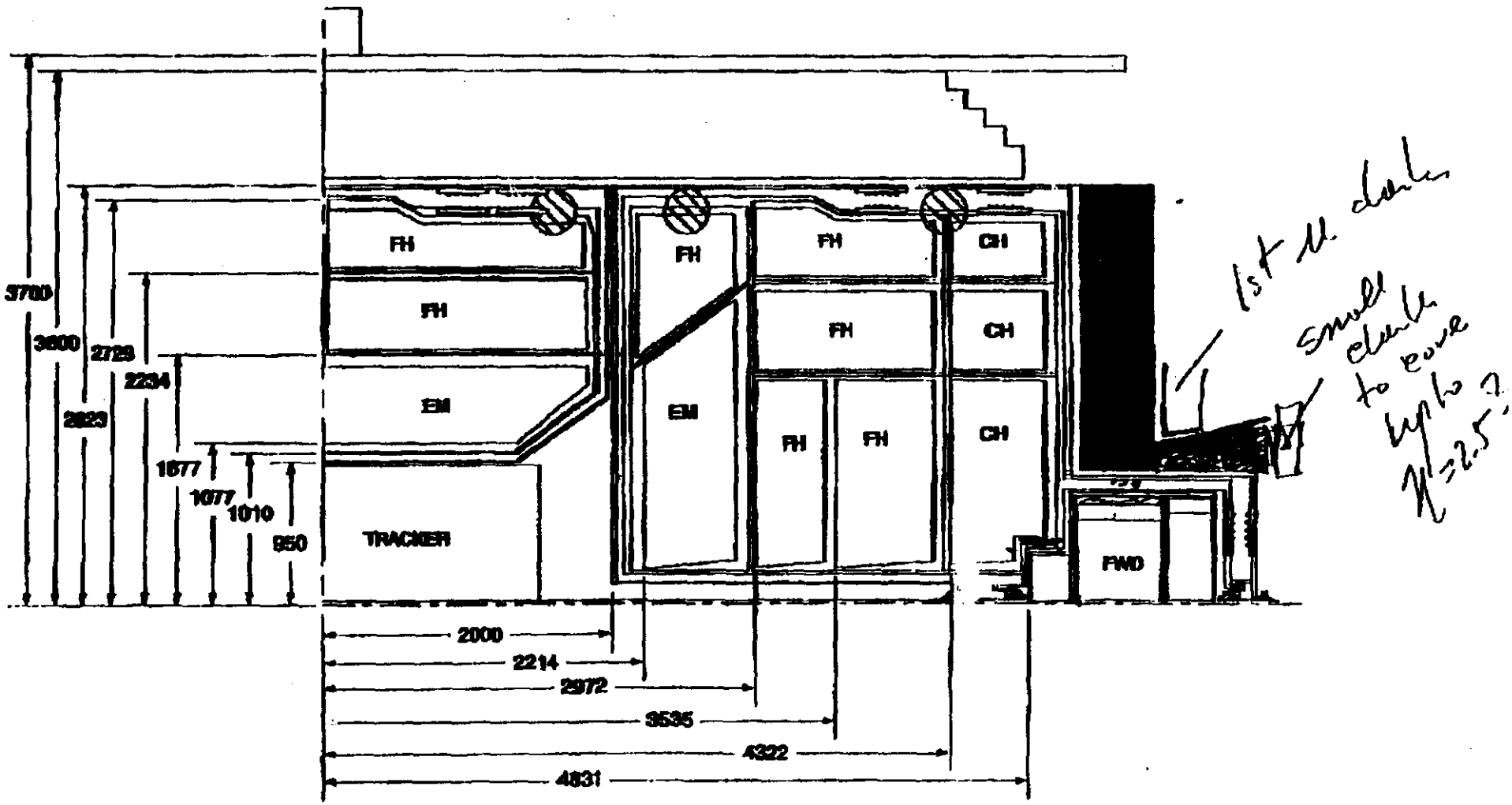


4973
~ 4322

Q: Forward μ's

Preliminary Hybrid Concept

Fig. 1



gem

γeμ

Presentation by:

C. Zeitnitz
T. A. Gabriel

The Geant-Calor Interface

C. Zeitnitz University of Arizona
T. A. Gabriel ORNL

- CALOR89
- CALOR in GEANT
- The Interface
- The low energy neutron code

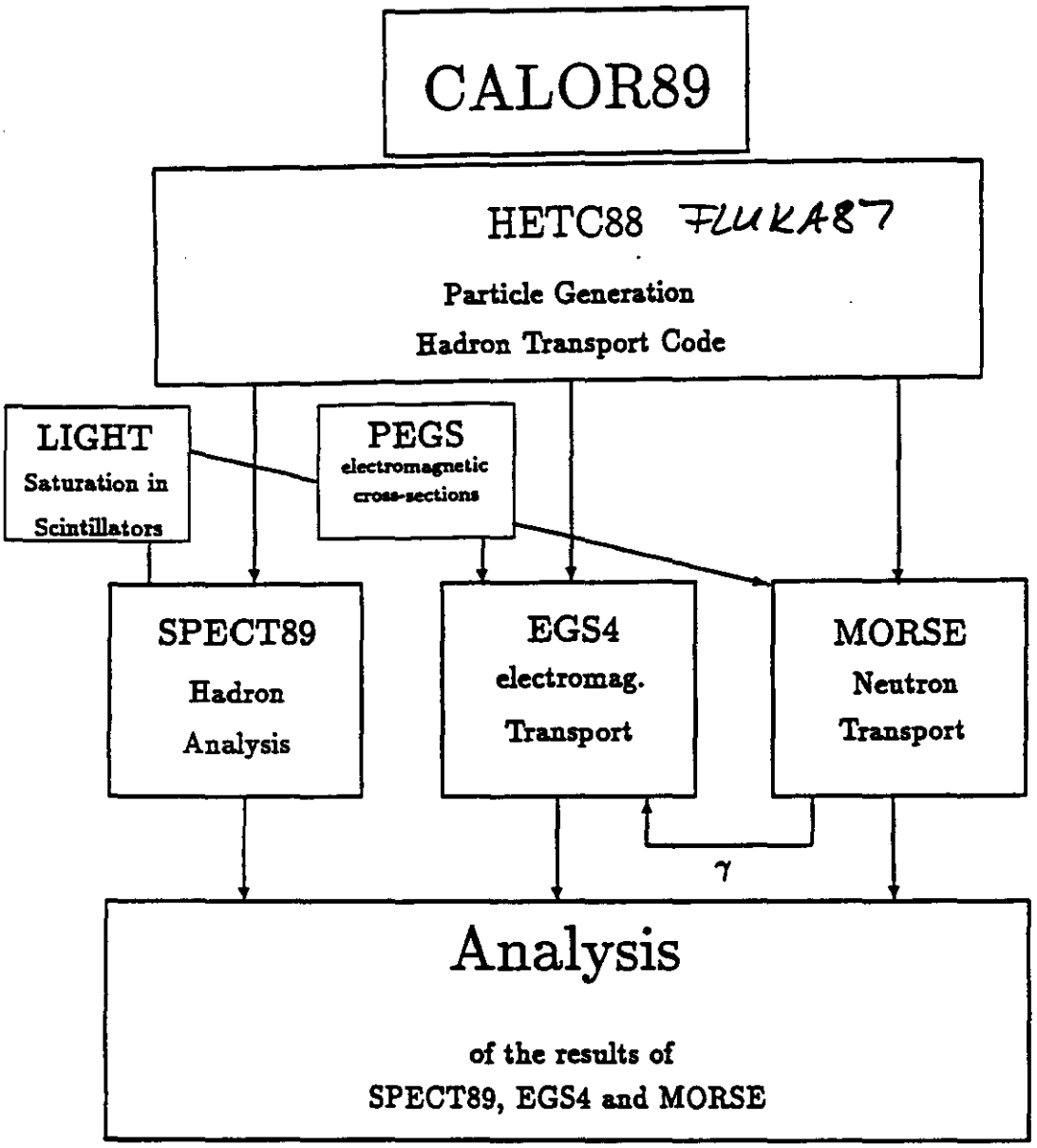
- Summary
- Future plans

CALOR 89

- HETC - High Energy Transport Code
  - NMTC - Nucleon Meson Transport Code
    nucleons $E_{kin} < 3.5$ GeV
    charged pions $E_{kin} < 2.5$ GeV

    based on intranuclear-cascade-evaporation-model
  - Scaling model
    nucleons $3.5 \leq E_{kin} < 10-15$ GeV
    charged pions $2.5 \leq E_{kin} < 10-15$ GeV

    smooth transition to FLUKA
- modified FLUKA 87
  nucleons $E_{kin} \geq 10-15$ GeV
  charged pions $E_{kin} \geq 10-15$ GeV
  other particles (hadrons)
- MORSE - Multigroup Oak Ridge Stochastic Experiment
  neutrons $E_{kin} < 25$ MeV
  125 energy bins
- EGS 4
  $e^{\pm}, \gamma$


CALOR89
HETC88 FLUKA87
Particle Generation
Hadron Transport Code
LIGHT
Saturation in
Scintillators
PEGS
electromagnetic
cross-sections
SPECT89
Hadron
Analysis
EGS4
electromag.
Transport
MORSE
Neutron
Transport
γ
Analysis
of the results of
SPECT89, EGS4 and MORSE

- difficult to use
  - geometry
  - setup of input files
  - analysis
- sequential processing of programs
  - huge amount of mass storage needed for history files

CALOR in GEANT

- FLUKA (already in GEANT 3.15)
  nucleons $E_{kin} > 3.5$ GeV
  $\pi^{\pm}$ $E_{kin} > 2.5$ GeV
  other hadrons all energies
  (calls GHEISHA below 50 MeV)
- NMTC
  n, p: $E_{kin} < 3.5$ GeV $\pi^{\pm}$: $E_{kin} < 2.5$ GeV
  modified in order to work with Geant material description and store secondaries in Geant common
- MICAP neutron code (similar to MORSE)
  neutron 10^{-5} eV $< E_{kin} < 20$ MeV
  - point cross-section code
  - No fixed number of bins like MORSE
  - reads in ENDF/B cross-section data (compressed)

  modified to work with Geant material description and get rid of particle weights

- Scaling Model NOT implemented
  - particle weights not useable in GEANT

MICAP Neutron Code

Monte carlo Ionization Chamber Analysis Package

- similar to MORSE
- advantages:
  - uses preprocessed ENDF/B cross-section data
  - no limited number of energy bins like MORSE → uses all informations from cross-section file
  - energy range: 10^{-5} eV – 20 MeV
  - secondary particle distributions (energy + multiplicity) from ENDF/B data
- changes:
  - no more particle weights are used all particles are explicitly generated (e.g. fission neutrons, deexcitation photons)
  - particle storage
  - material description taken from GEANT

- Reaction Types

Type of Reaction	final state particles
elastic scatt.	n
(nA,n'A)	n
(nA,2n'A')	2n
(nA,n'αA')	n, α
(nA,2n'αA')	2n, α
(nA,n'pA')	n,p
(nA,n'3αA')	n, 3α
(nA,γA')	γ
(nA,pA')	p
(nA,DA')	D
(nA,TA')	T
(nA,^3HeA')	^3He
absorption	-
(nA,αA')	α
(nA,2αA')	2α
(nA,3αA')	3α
(nA,2pA')	2p
(nA,pαA')	p,α
(nA,T2αA')	T, 2α
(nA,D2αA')	D, 2α
fission	n, p , α

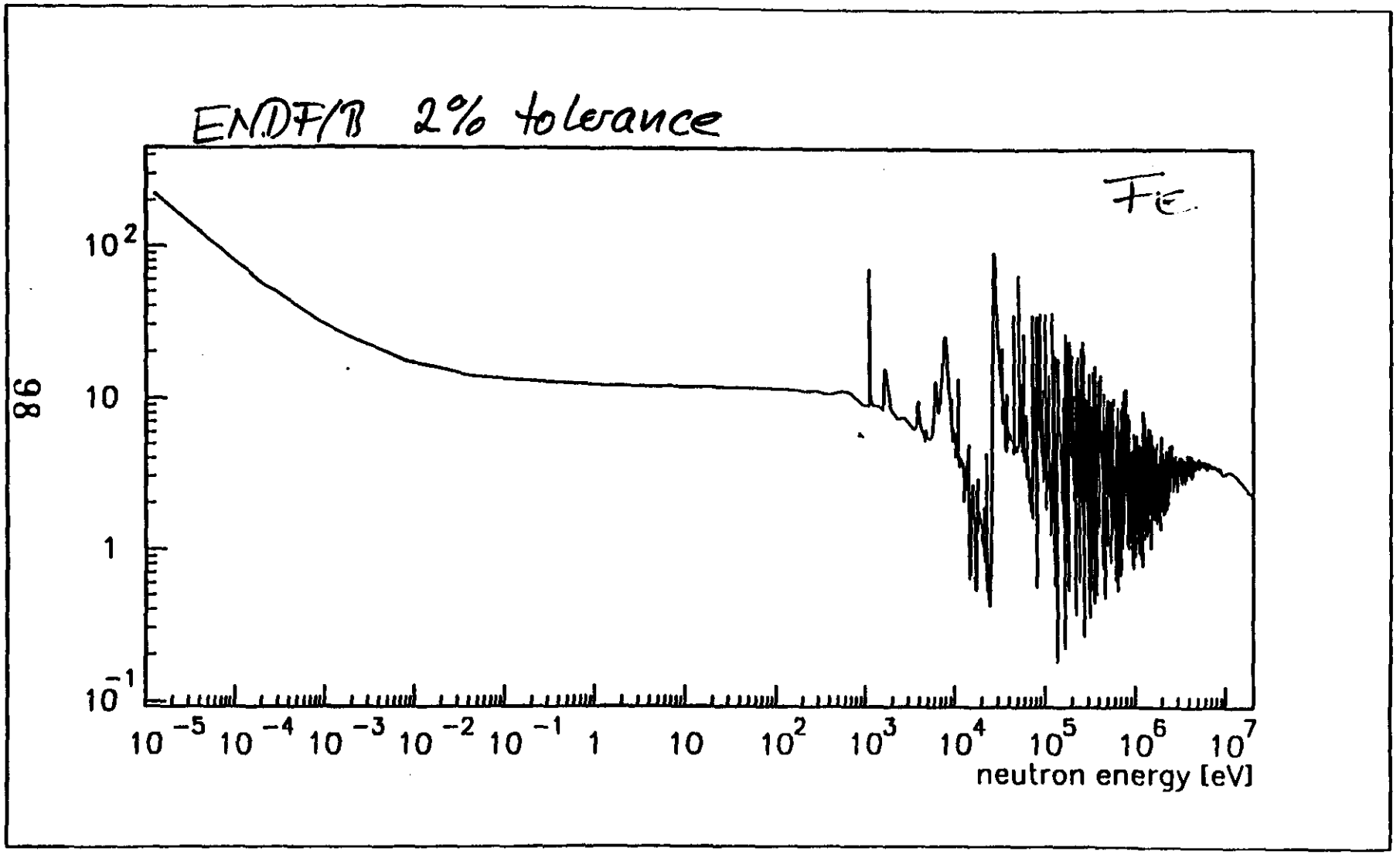
- deexcitation gammas generated, if nucleus after reaction in excitated state

• Isotopes in cross-section file

Isotope		charge number Z	kBytes
Hydrogen	H	1	6
Hydrogen	H_2O bound	1	6
Lithium	^{6}Li	3	29
Lithium	^{7}Li	3	31
Boron	^{10}B	5	47
Boron	^{11}B	5	11
Carbon	C	6	58
Nitrogen	N	7	126
Oxygen	O	8	122
Fluorine	F	9	96
Sodium	Na	11	492
Magnesium	Mg	12	73
Aluminum	Al	13	202
Silicon	Si	14	365
Chlorine	Cl	17	104
Argon	Ar	18	17
Calcium	Ca	20	156
Chromium	Cr	24	289
Iron	Fe	26	591
Nickel	Ni	28	237
Copper	Cu	29	129
Molybdenum	Mo	42	104
Cadmium	Cd	48	68
Barium	Ba	56	21
Tantalum	Ta	73	225
Tungsten	W	74	386
Lead	Pb	82	123
Uranium	^{235}U	92	173
Uranium	^{238}U	92	649

$\sum_{29}$ 4.8 MByte

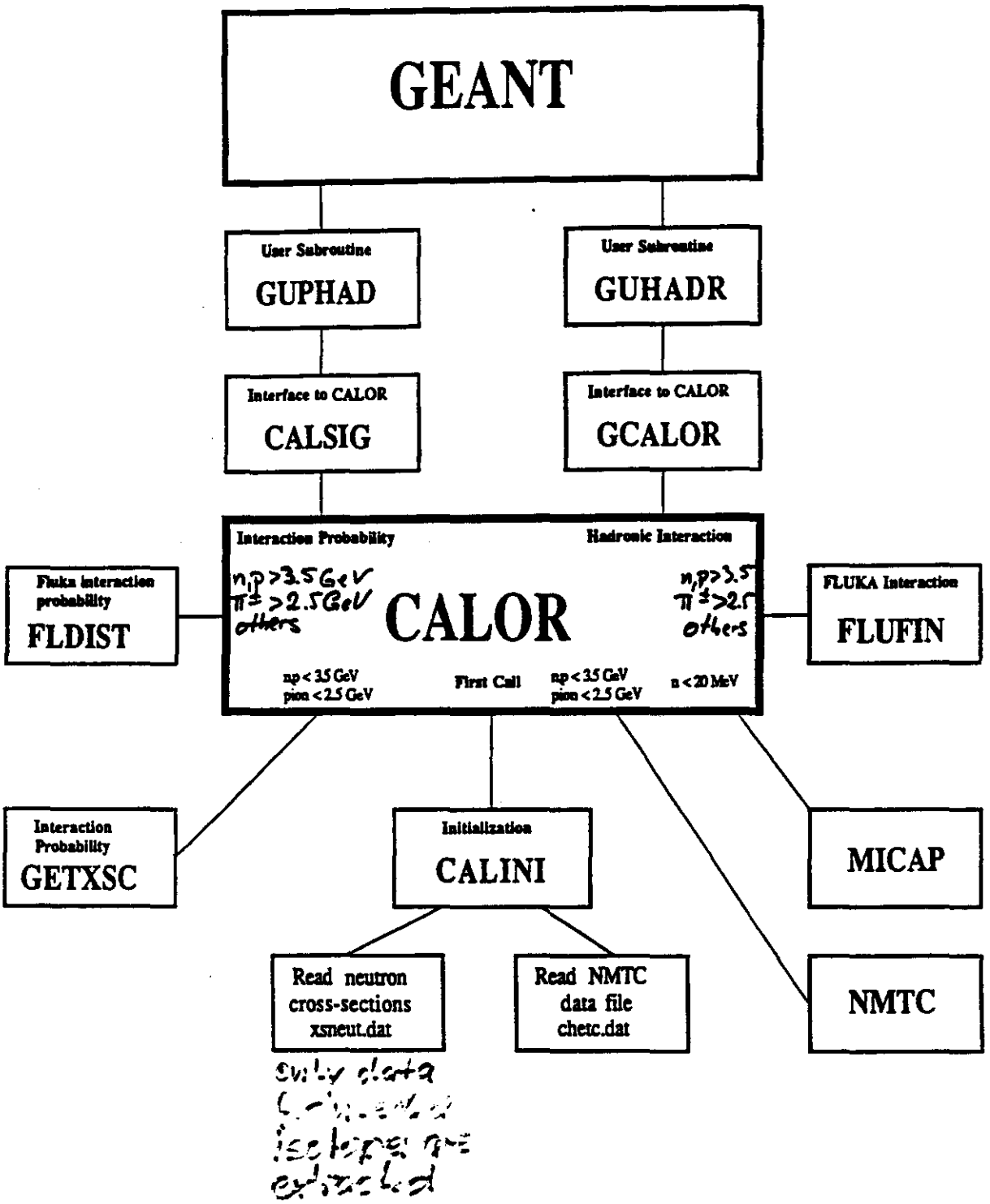
Fe


ENDF/B 2% tolerance
Fe
10^2
10
1
10^{-1}
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^2 10^3 10^4 10^5 10^6 10^7
neutron energy [eV]

The Interface

- 2 GEANT subroutines have to be changed
  - GUPHAD – get interaction probability
  - GUHADR – calculate inelastic hadron interaction
- tracking, particle storage done by GEANT
- NO difference for the user compared to the use of GHEISHA
- 2 sequential ASCII files are needed
  - chetc.dat – intranuclear cascade and evaporation data (MARS)
  - xsneut.dat – neutron cross-sections and secondary distributions (HILCAT)
    (~ 12 MByte)

- cutoff energies taken from GEANT
  - 10 keV is minimal cutoff energy in GEANT
  - SET CUTNEU to desired value ($> 10^{-5}$ eV)
    Not overwritten by GEANT 3.15/95
- neutron cross-sections and secondary distributions stored in ZEBRA common GCBANK


GEANT
User Subroutine
GUPHAD
User Subroutine
GUHADR
Interface to CALOR
CALSIG
Interface to CALOR
GCALOR
Interaction Probability
Hadronic Interaction
CALOR
np < 3.5 GeV
pion < 2.5 GeV
First Call
np < 3.5 GeV
pion < 2.5 GeV
n < 20 MeV
Fluka interaction probability
FLDIST
FLUKA Interaction
FLUFIN
Interaction Probability
GETXSC
Initialization
CALINI
MICAP
Read neutron cross-sections xsneut.dat
Read NMTC data file chetc.dat
NMTC

Summary

- GEANT-CALOR interface is easy to use
  - NO difference to the use of GHEISHA or FLUKA
- All material information taken from GEANT
- Low energy neutron code taken from MICAP (10^{-5}eV < E_{kin} < 20 MeV)
  - ENDF/B cross-section data
- CALOR89 "Scaling Model" not implemented
- tested on the following computers:
  - VAX - VMS 5.5
  - SGI - IRIX
  - IBM 3090 - MVS
- works with GEANT 3.15 and above
- Release of V 1.0 mid-end Nov. '92

Future plans

- benchmarks with
  - hanging file
  - DØ testbeam data
  - ZEUS testbeam data
- New model for transition from NMTC to FLUKA (E_{kin} = 3 – 10 GeV)
- installation on more computer types

THE GEANT-CALOR INTERFACE

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ABSTRACT

The simulation of large scale high energy physics experiments is based mainly on the GEANT package. In the current version 3.15 the simulation of hadronic interacting particles is based on GHEISHA or FLUKA. Both programs miss an accurate simulation of the interaction of low energetic neutrons ($E_{kin} < 20\,MeV$) with the materials of the detector. The CALOR89 program package contains a low energetic neutron code. An interface between the CALOR program parts and the GEANT package has been developed.

1. Introduction

The Monte Carlo package GEANT[1] is the most widely used program to study large scale detectors. In the current version 3.15 two different hadronic interaction models are implemented. The GHEISHA[2] program is well tuned to reproduce the average shower shape and energy resolution of standard calorimeters. The FLUKA[3] program calculates the single hadronic interaction in more detail (fragmentation model), but provides no information about particles with energies below 50 MeV. For these low energies GHEISHA is called.
The CALOR89[4] program package simulates hadronic interactions down to 1 MeV for nucleons and charged pions and into the thermal region for neutrons. For high energies (10-15 GeV) the FLUKA model is used.
The low energetic neutron code makes CALOR superior for studies, where neutrons play an important role for the detector response. One example is a lead- or uranium-scintillator calorimeter, where part of the *invisible* hadronic energy, carried by low energetic neutrons, is converted into a visible signal by collision with hydrogen in the plastic scintillator.
For future collider experiments like the SSC or the LHC, with very high luminosity and the resulting high particle fluxes, predictions of the charged particle and neutron flux in the area of muon chambers is an important issue. In order to carry out as accurately as possible such calculations and others, an interface of the CALOR

code to GEANT was the aim of the work reported here.

2. The Program CALOR89

The program CALOR89 consists of the following simulation programs:

- HETC - (High-Energy-Transport-Code) hadrons up to 10-15 GeV
- FLUKA - hadrons above the HETC limit
- MORSE - (Multigroup-Oak-Ridge-Stochastic-Experiment) neutrons below 20MeV
  or
- MICAP - (Monte carlo Ionization Chamber Analysis Package) a point cross-section neutron code. This program is similar to MORSE and will be implemented in the CALOR package in the next version
- EGS 4 - electrons,positrons and gammas

In addition some programs are analysing the results of the different simulation codes. The relation between the different program parts are shown in figure 1. The monte carlo code HETC[5] consists of two parts. The Nucleon-Meson-Transport-Code (NMTC), which is calculating the interaction of nucleons below 3.5GeV and charged pions below 2.5GeV, based on the intranuclear-cascade-evaporation-model as implemented by Bertini.[6,7] For Hadron-Hydrogen collisions a special model is used.
Above the NMTC limit a Scaling Model is used to get a smooth transition to the FLUKA model (particle multiplicities, types and energies).
The program MORSE[8] is using an energy binning for the neutron cross-sections. Neutrons are generated only with these discrete energies. MORSE does account for particle multiplicities by assigning a weight to the generated neutron or photon.
The MICAP program uses ENDF/B cross-section data and the number of energy points is not fixed, but depends on the isotope and the available cross-sections for this isotope. For details about the MICAP program see the user's guide.[11,12]
The program EGS Version 4[9,10] is called after HETC and MORSE to simulate the interaction of the generated photons with the material of the setup.

3. CALOR in the GEANT frame

Since the FLUKA system is already available in GEANT 3.15, only the HETC and the low energy neutron code had to be adapted to GEANT. Instead of the MORSE

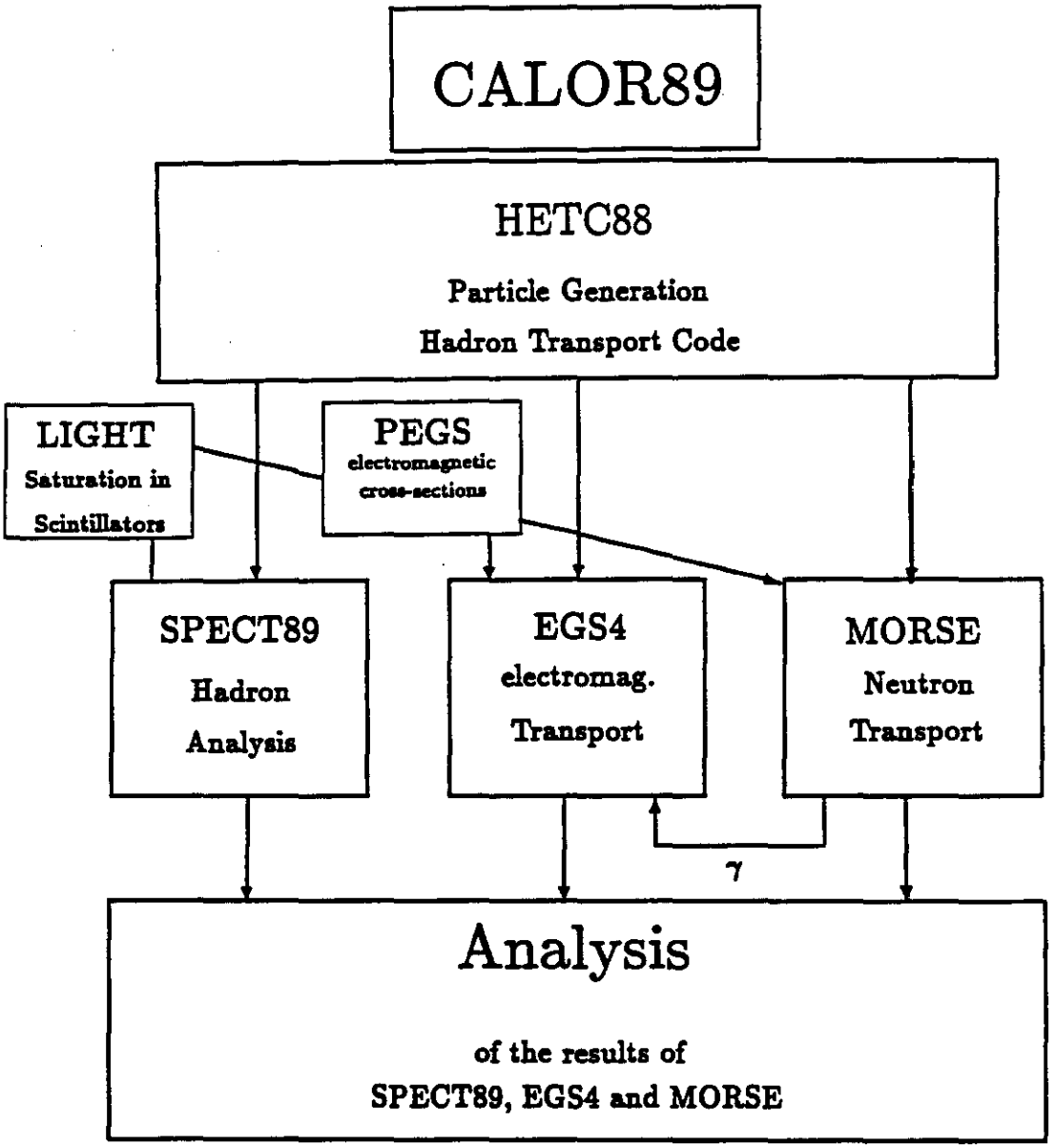

Figure 1: Flow diagram of CALOR89

program, the MICAP neutron program is used in the frame of GEANT.
CALOR in the frame of GEANT consists of:

- NMTC - nucleons below 3.5 GeV, charged pions below 2.5 GeV
- MICAP - neutrons below 20MeV
- FLUKA - nucleons above 3.5 GeV and charged pions above 2.5GeV, and for all energies for particle types not implemented in CALOR

The Scaling Model has not been implemented, because it works mainly with particle weights in order to get a smooth transition between NMTC and FLUKA. Particle weights are not usable in the GEANT frame.

3.1. The Nucleon-Meson-Transport-Code

A slightly modified NMTC version has been implemented into the GEANT frame for low energetic nucleons and charged pions. This part of the program needs some input data for the intranuclear cascade and evaporation model. These data are provided by an ASCII file. This file is read only once during initialization.

3.2. The low energy neutron code

Interactions of neutrons with an energy below 20 MeV down to the thermal energy range (down to $10^{-5}eV$) with a nucleus are calculated by the NEUTRON code taken from the MICAP program. The program works similar to the MORSE program implemented in CALOR, but has the advantage not to use particle weights in the main part of the interaction. Slight changes were necessary to get rid of weights in some special processes (for example fission neutron production). Another advantage of this program is, that it can read in preprocessed ENDF/B neutron cross-section data and is not restricted to a limited number of energy bins and thus uses all information given in the cross-section file (secondary neutron,photon energy and angular distributions). The cross-section data and secondary energy and angular distributions are thinned to an accuracy of 2%, which means that the original ENDF/B data are reproduced by an extrapolation with this precision. Figure 2 shows the used cross-section for iron.
The type of processes which are implemented into the MICAP neutron code are listed in table 1. If the residual nucleus A' is after the interaction in an excited state, deexcitation photons are generated. A specific process can only happen, if a partial cross-section for it is stored in the cross-section file.
The cross-sections are stored in an ASCII file. From this file, depending on the problem, the needed isotope data are extracted during initialization. The cross-section data are stored in the GEANT common GCBANK via ZEBRA. The needed amount of space in the ZEBRA common depends on the number of isotopes used.

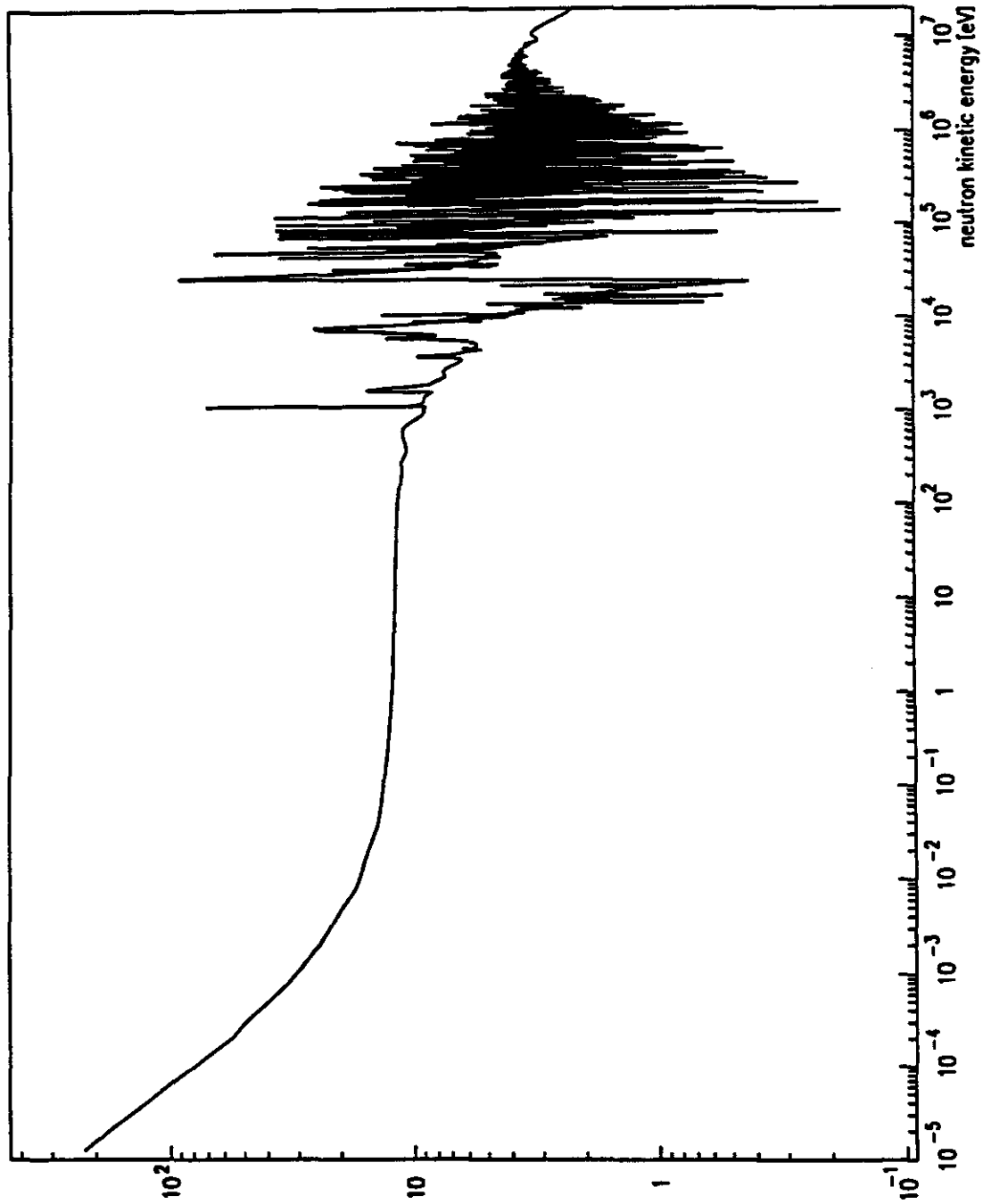

Figure 2: Microscopic neutron cross-section for iron

Table 1: Process types for neutron-nucleus reaction implemented in the MICAP neutron code

Type of Reaction	final state particles
elastic scatt.	n
(nA,n'A)	n
(nA,2n'A')	2n
(nA,n'αA')	n, α
(nA,2n'αA')	2n, α
(nA,n'pA')	n,p
(nA,n'3αA')	n, 3α
(nA,γA')	γ
(nA,pA')	p
(nA,DA')	D
(nA,TA')	T
(nA,^3HeA')	^3He
absorption	-
(nA,αA')	α
(nA,2αA')	2α
(nA,3αA')	3α
(nA,2pA')	2p
(nA,pαA')	p,α
(nA,T2αA')	T, 2α
(nA,D2αA')	D, 2α
fission	n, p , α

3.3. *How to use CALOR in GEANT ?*

The only changes in the GEANT code have to be done in the user subroutines GUPHAD and GUHADR. Here the CALOR subroutines CALSIG and GCALOR have to be called instead of the GHEISHA routines GPGHEI and GHEISH. In figure 3 the flow chart of the interface is shown. The following Fortran lines give an example how to call the GEANT-CALOR interface subroutines.

```
      SUBROUTINE GUPHAD
C
C get free path length to next hadronic interaction
C
C use CALOR interaction probability
      CALL CALSIG
      RETURN

      SUBROUTINE GUHADR
C
C hadronic interaction takes place
C
C call CALOR
      CALL GCALOR
      RETURN
```

The particles which are generated in an inelastic hadronic interaction are stored in the GEANT stack. For the user it makes no difference, if GHEISHA, FLUKA or CALOR is called for the interaction.
The NMTC code and the neutron code need input data provided in two files:

- **chetc.dat** : intranuclear cascade and evaporation data used in NMTC
- **xsneut.dat** : low energetic neutron cross-section, energy and angular distributions used in the MICAP code

The CALOR package is automatically initialized when either CALSIG or GCALOR is called the first time. The input files are read in only once. After selecting the isotopes needed for the problem, the neutron cross-sections are mixed corresponding to the material descriptions stored in the GEANT structure JMATE. The total neutron cross-sections of all elements and mixtures are calculated during initialization.
Here are some recommendations how to describe materials :

- Try to use only elements listed in the table 2. If the selected isotope is not available in the neutron cross-section file, the data of the isotope with the closest charge number Z will be used

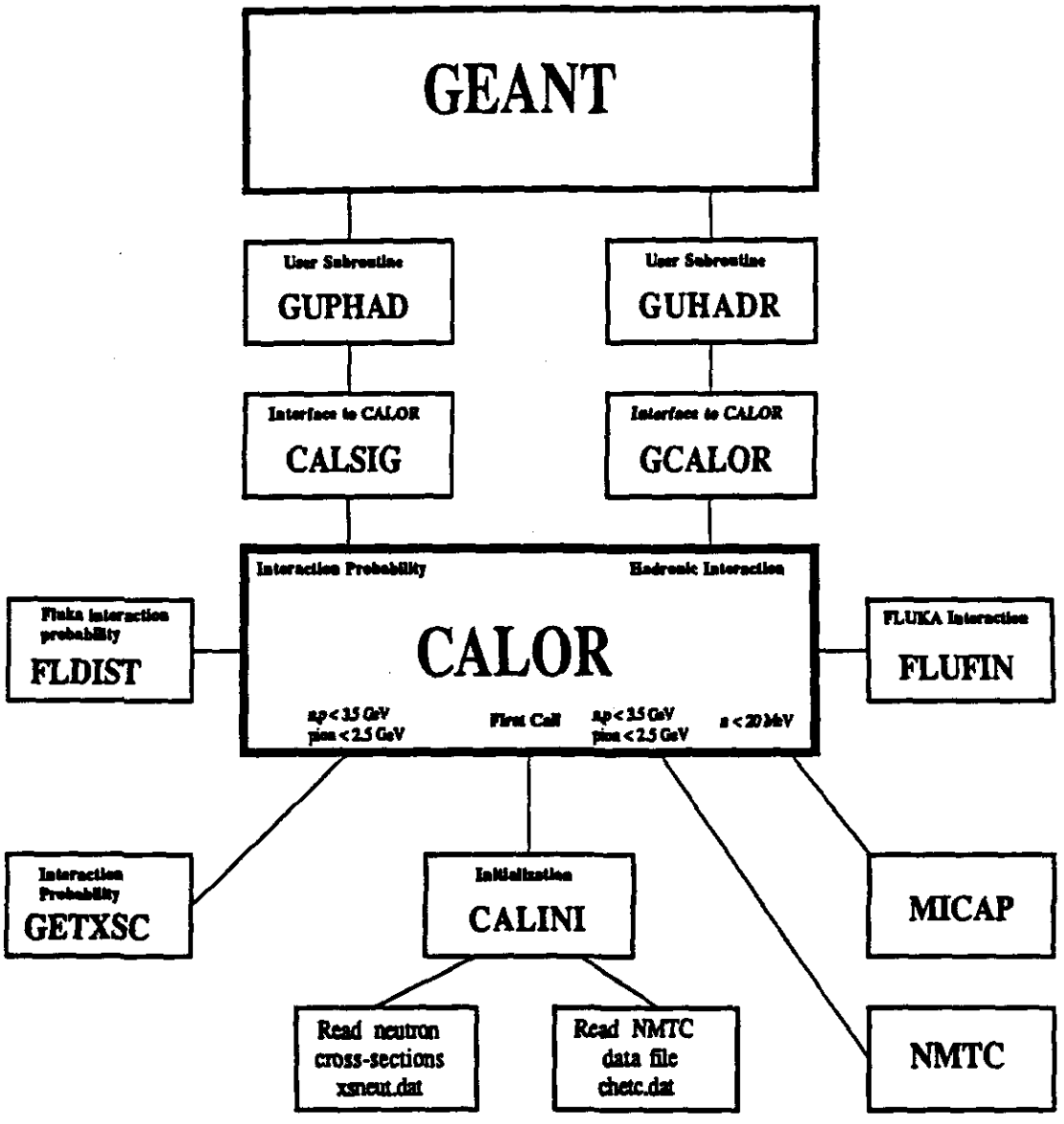

Figure 3: Flow diagram of the GEANT-CALOR interface

Table 2: Isotopes for which neutron cross-section data are available and the amount of memory needed to store them in the GEANT common GCBANK

Isotope		charge number Z	kBytes
Hydrogen	H	1	6
Hydrogen	H_2O bound	1	6
Lithium	^{6}Li	3	29
Lithium	^{7}Li	3	31
Boron	^{10}B	5	47
Boron	^{11}B	5	11
Carbon	C	6	58
Nitrogen	N	7	126
Oxygen	O	8	122
Fluorine	F	9	96
Sodium	Na	11	492
Magnesium	Mg	12	73
Aluminum	Al	13	202
Silicon	Si	14	365
Chlorine	Cl	17	104
Argon	Ar	18	17
Calcium	Ca	20	156
Chromium	Cr	24	289
Iron	Fe	26	591
Nickel	Ni	28	237
Copper	Cu	29	129
Molybdenum	Mo	42	104
Cadmium	Cd	48	68
Barium	Ba	56	21
Tantalum	Ta	73	225
Tungsten	W	74	386
Lead	Pb	82	123
Uranium	^{235}U	92	173
Uranium	^{238}U	92	649

- Don't use COMPOUNDS or MIXTURES of COMPOUNDS !!
- The results of simulations for isotopes not available in the neutron cross-section file might be wrong

For the isotopes listed in table 2, cross-section data are available. The number of kBytes needed to store the data are only estimates. If the isotopes are used in mixtures, more memory is needed in order to mix the partial cross-sections.

The interface is creating an output file named **calor.out**, which contains information about the material parameters used in the neutron code and how many locations were used for the cross-section tables in the ZEBRA division *constant*.
In the case of a runtime error a message is written to the output file. Only in case of program abortion due to an error, a message informs the user where the error occurred.
The standard GEANT (with GHEISHA or FLUKA) does not work with cutoff energies below 10 keV. In order to simulate neutrons down to thermal energies its possible to set CUTNEU to the desired value. GEANT will complain, that the cutoff energy must be greater than 10 keV, but does not overwrite CUTNEU with the default value.

4. Conclusion

The GEANT-CALOR Interface allows everyone familiar with the GEANT package to use the CALOR program without being an expert for it. Only two GEANT user subroutines have to be changed in order to get the interaction probability from CALOR and calculate the hadronic interaction with this program package. The CALOR code in the version 1.0 of the interface is missing only a single program part compared to the CALOR89 package; the *Scaling Model* is not implemented in the GEANT frame.

5. Acknowledgement

We like to thank J.O.Johnson from Oak Ridge National Laboratory for the help with MICAP.

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4. T.A.Gabriel et al., *CALOR89: A Monte Carlo program Package for the design and Analysis of Calorimeter Systems*, ORNL/TM-11185 in preparation
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12. J.O.Johnson, T.A.Gabriel, *Development and Evaluation of a Monte Carlo Code System for Analysis of Ionization Chamber Responses*, ORNL/TM-10196, July 1987

gem

γeμ

Presentation by:

Vladimir Glebov

11/17/92

VLADIMIR GLEBOV

SSCL

What can we learn from the DØ experiment?

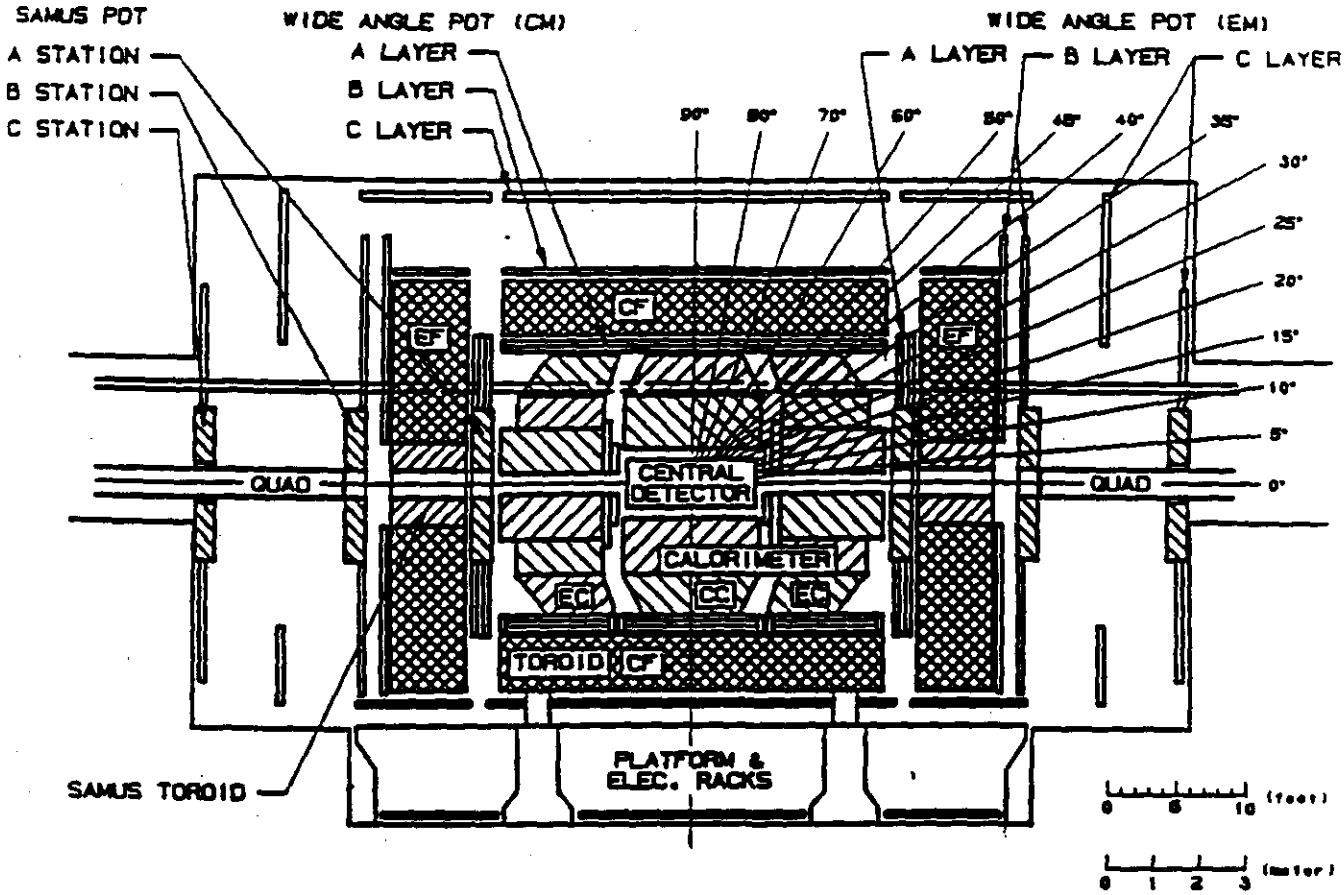


Fig. 1 Elevation of the DØ Detector

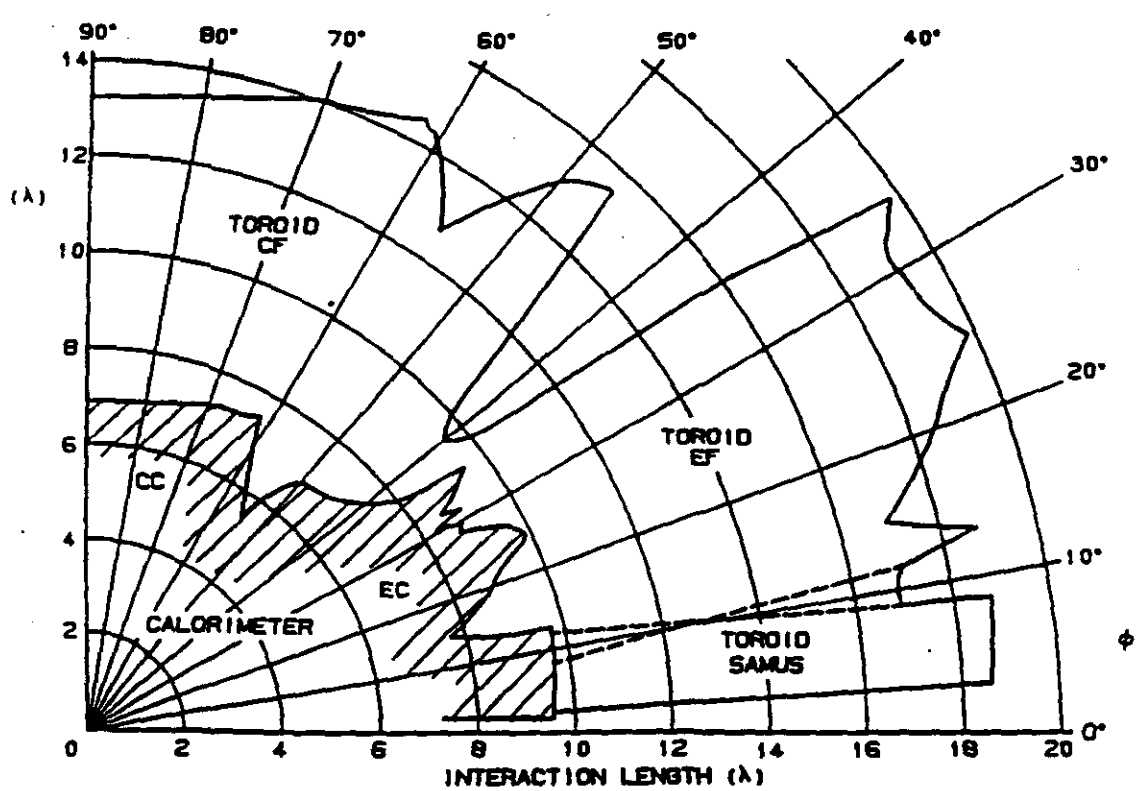
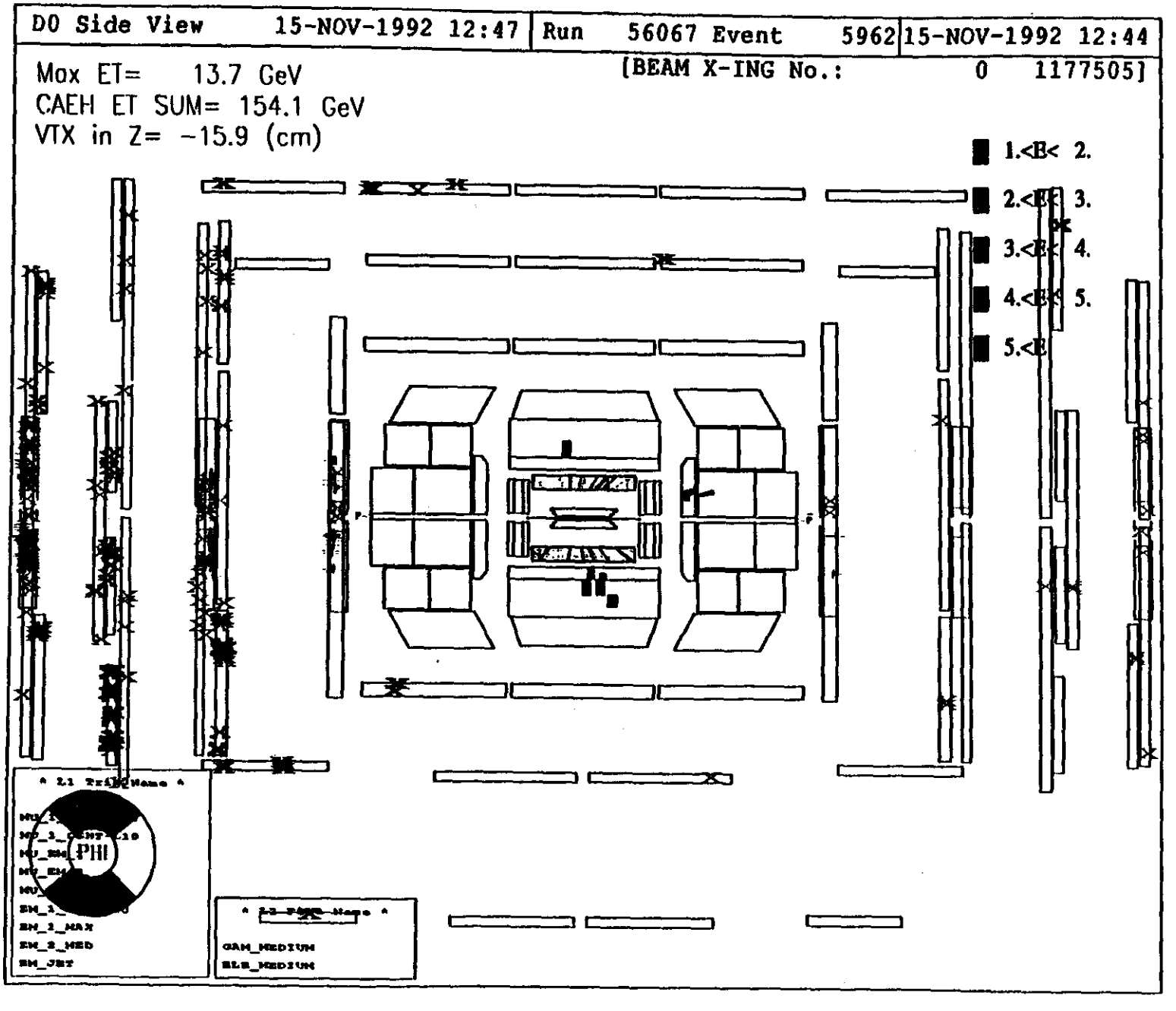
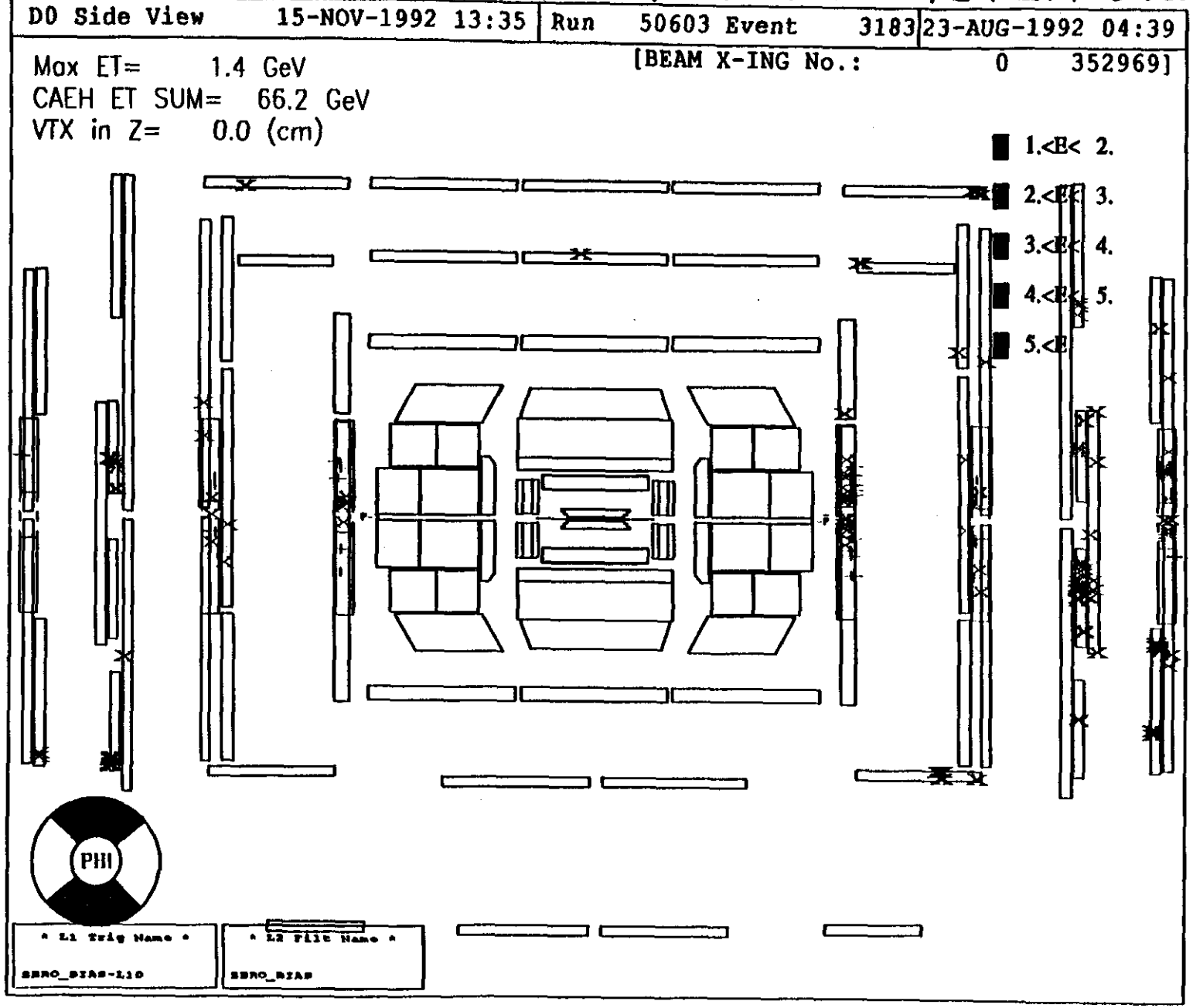


Fig. 2 Total interaction lengths of the calorimeters and iron toroids

„Typical" DØ event



MIN_BIAS DØ EVENT (MUON SYSTEM ONLY)



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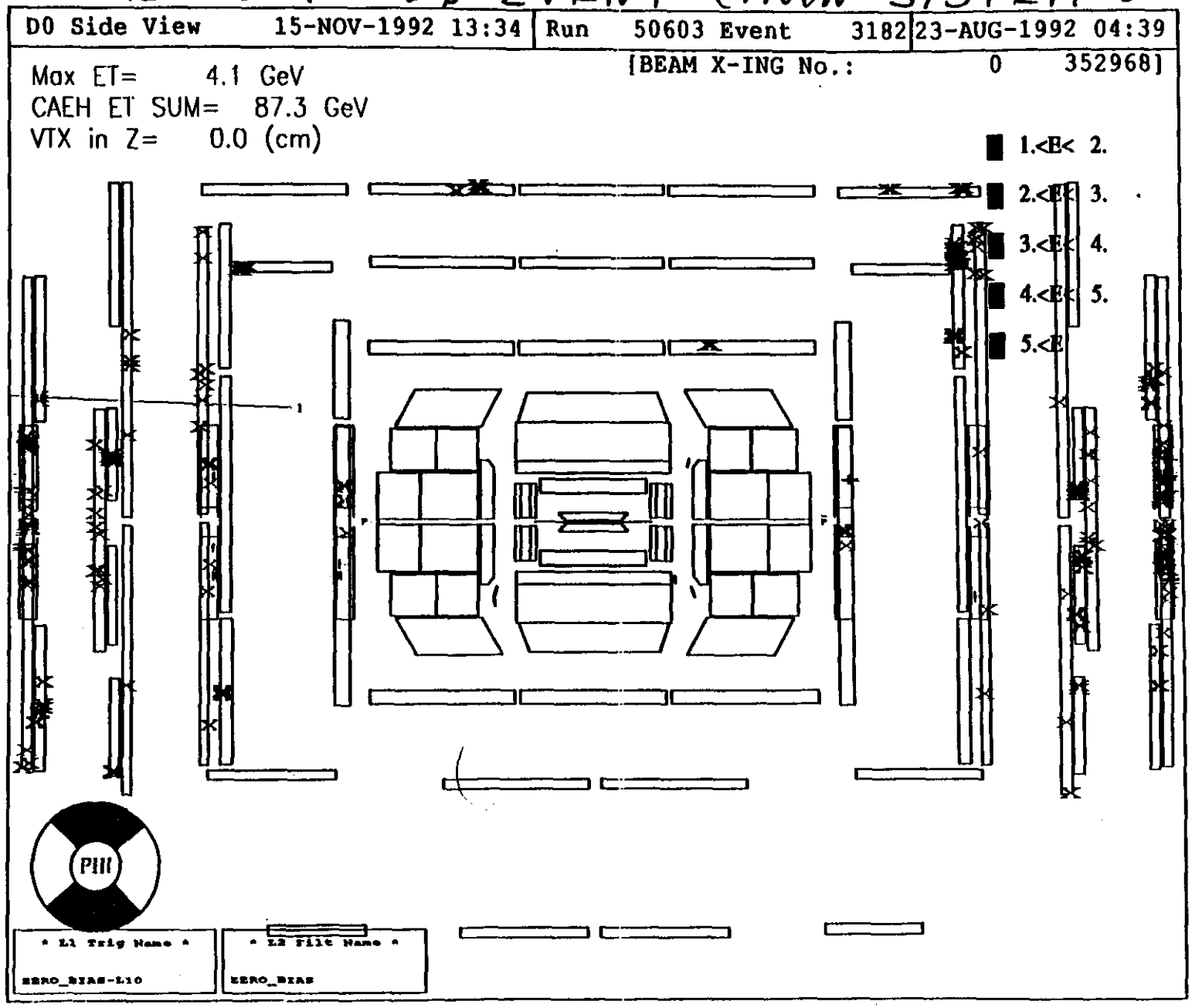

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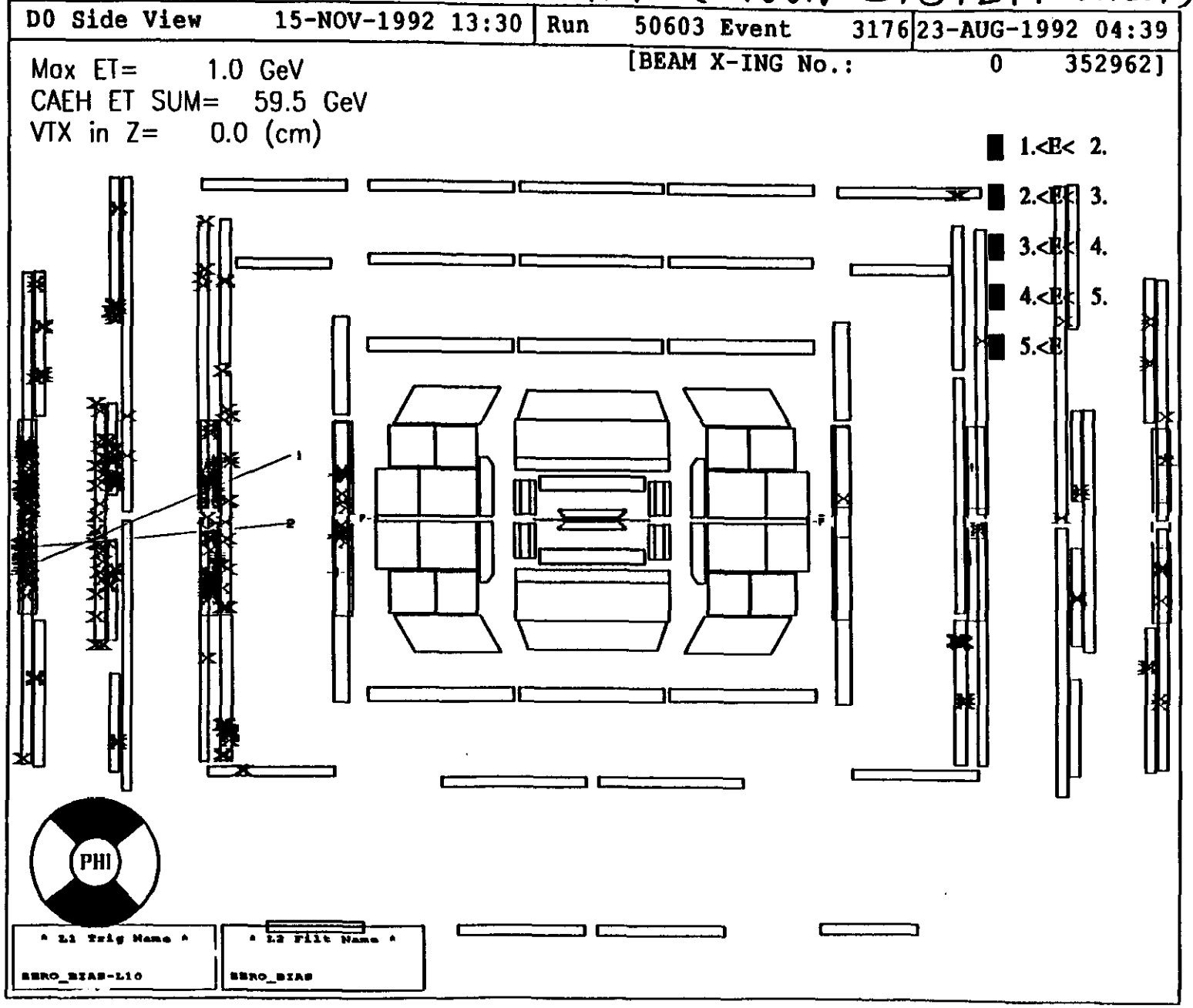
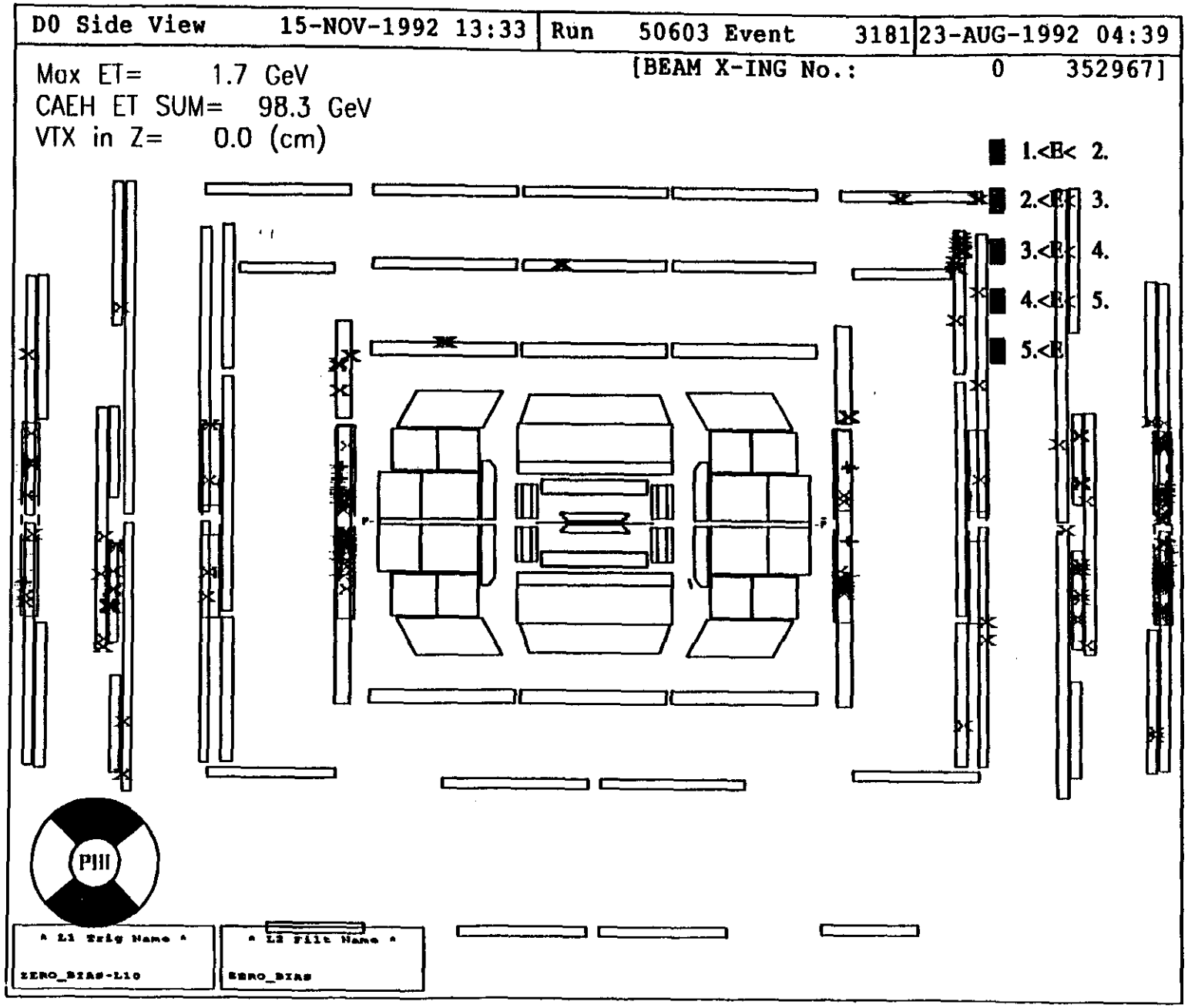


MIN_BIAS DØ EVENT (MUON SYSTEM ONLY)



GEM and DØ comparison

40 TeV	2 TeV
$10^{33}\,cm^{-2}s^{-1}$	$2\cdot10^{30}\,cm^{-2}s^{-1}$

factor 10^4

	GEM	DØ
n flux:	$10^5\,n/cm^2/s$	$10\,n/cm^2/s$

Efficiency for neutrons:

$4\cdot10^{-3}$

At DØ: $4\cdot10^{-3}\cdot10 = 4\cdot10^{-2}$ hits/cm²/s

Gate: $500\,ns = 5\cdot10^{-7}\,s$

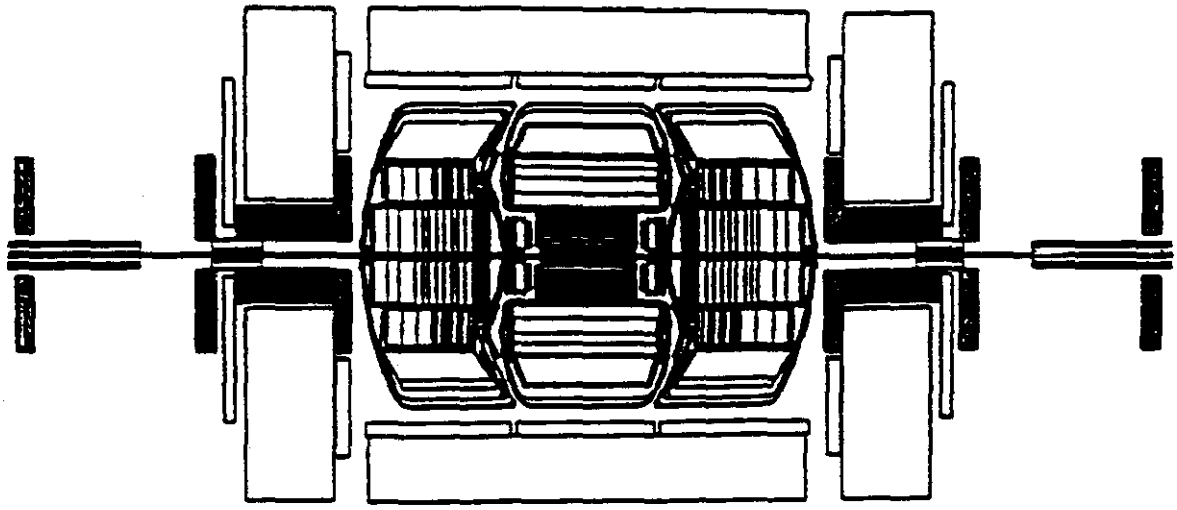
Area: $3\cdot500\,m^2 = 1500\cdot10^4\,cm^2 = 1.5\cdot10^7\,cm^2$

Number of hits in the DØ <u>barrel</u> from neutron per events:

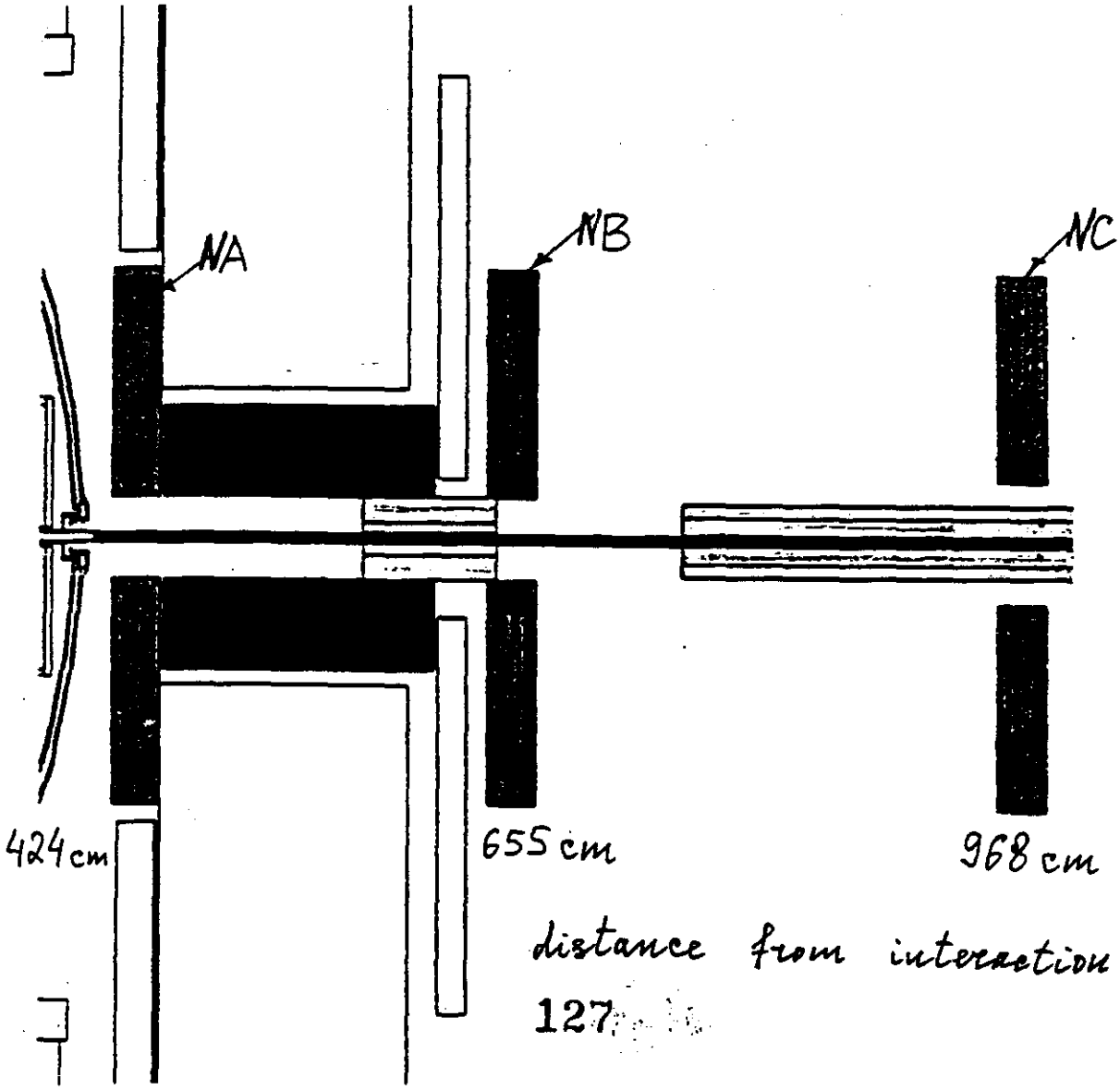
$$N\ hits = 4\cdot10^{-2}\cdot5\cdot10^{-7}\cdot1.5\cdot10^{7} = 3\cdot10^{-1}$$

$$\boxed{N\ hits/events\ @\ D\emptyset \simeq 0.3}$$

SAMUS – Small Angle MUon System



SAMUS GEOMETRY



distance from interaction point

DRIFT TUBE STATIONS

Each SAMUS station consists of 3 planes of tubes. Each plane consists of 2 layers for left-right ambiguity resolution:

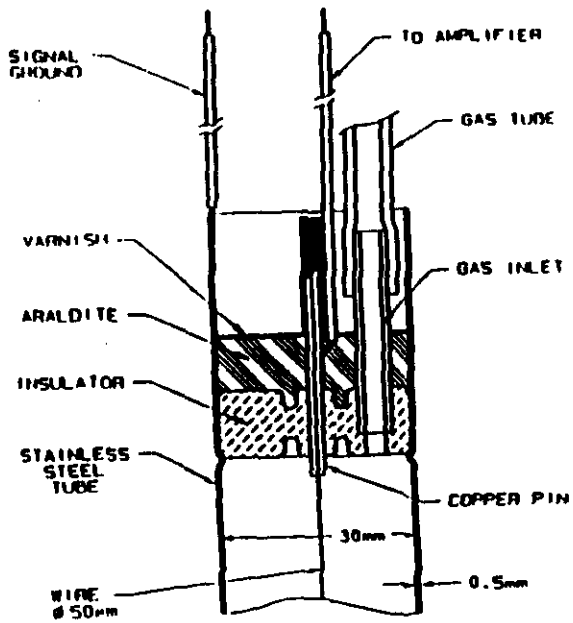
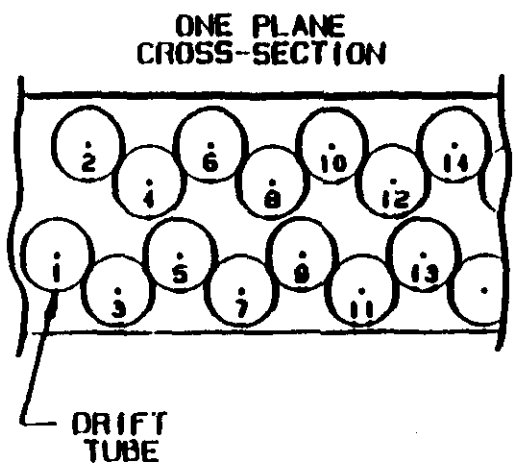
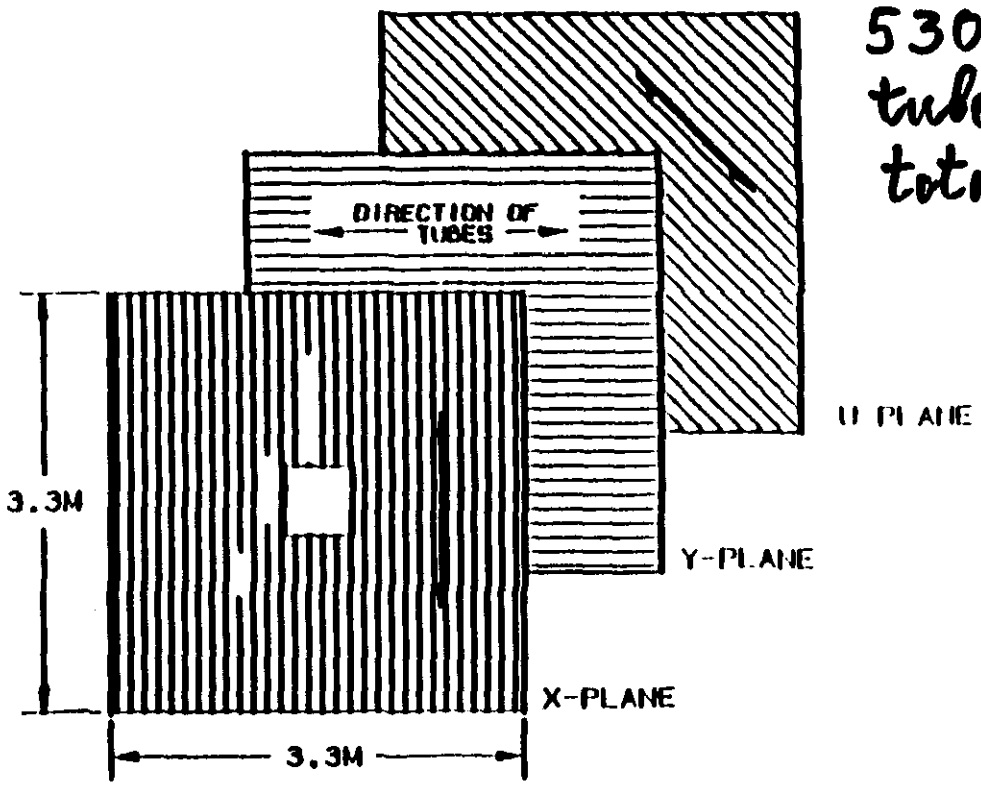


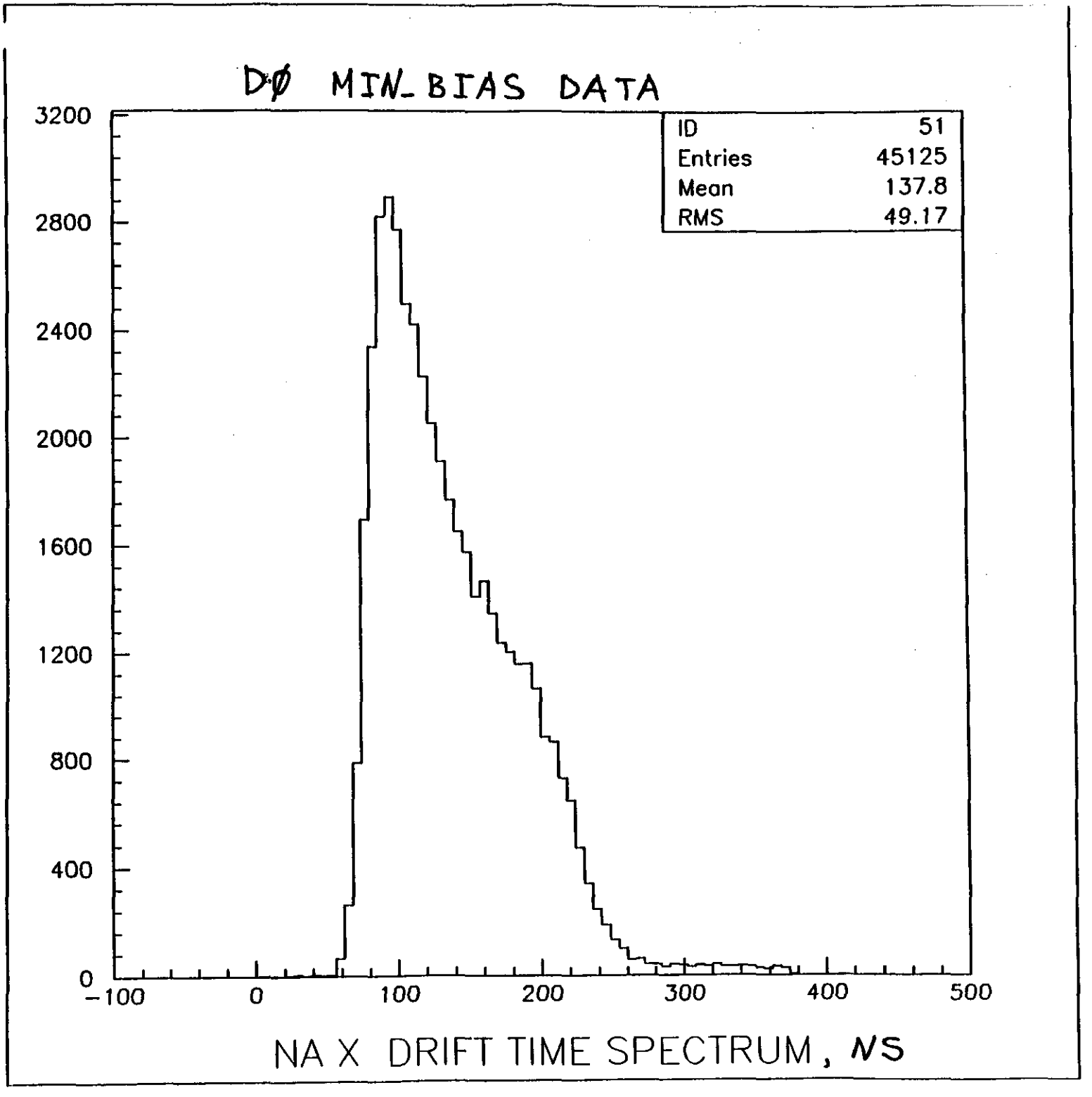
Fig. 9. SAMUS PDT tubes.

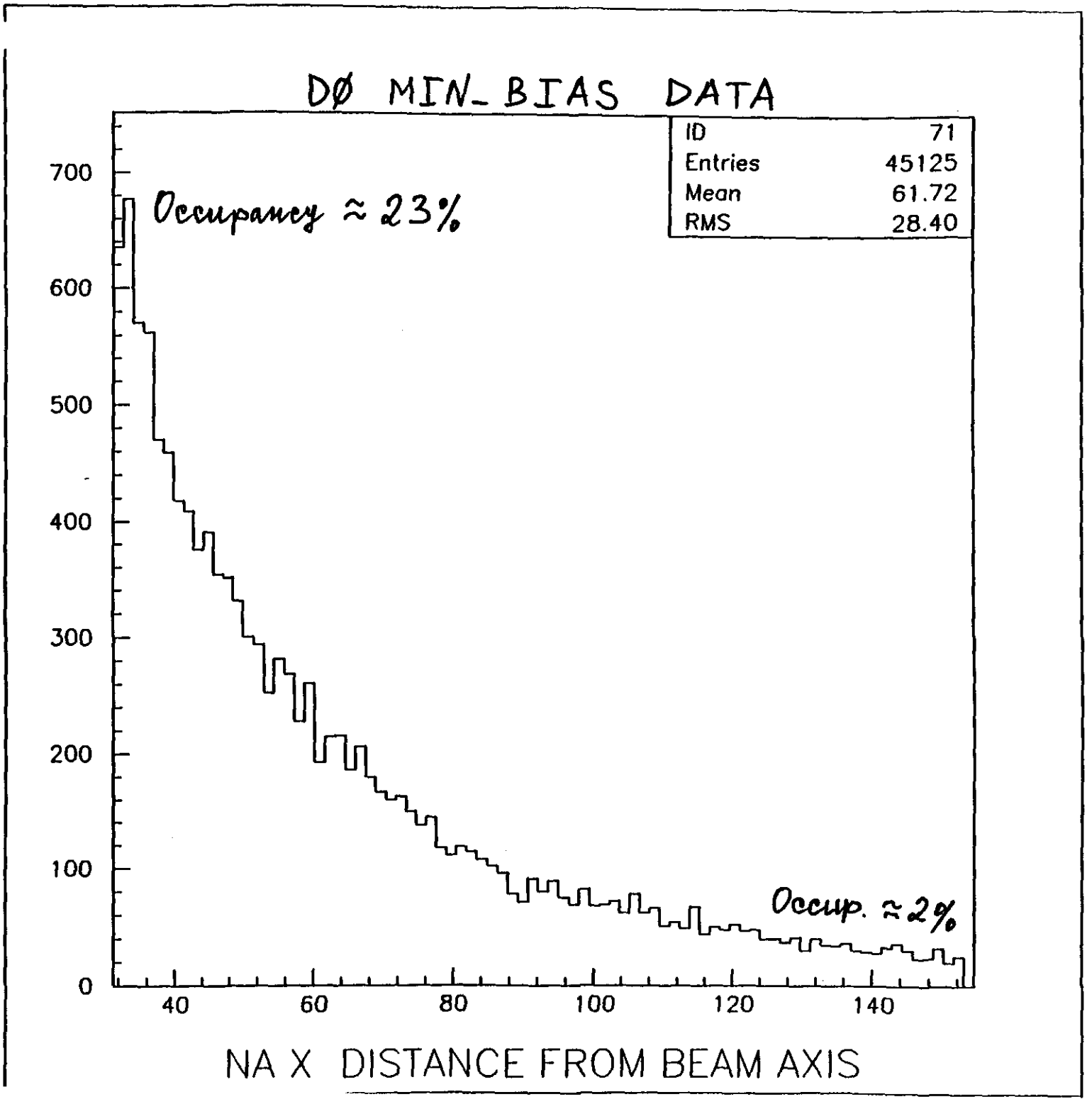


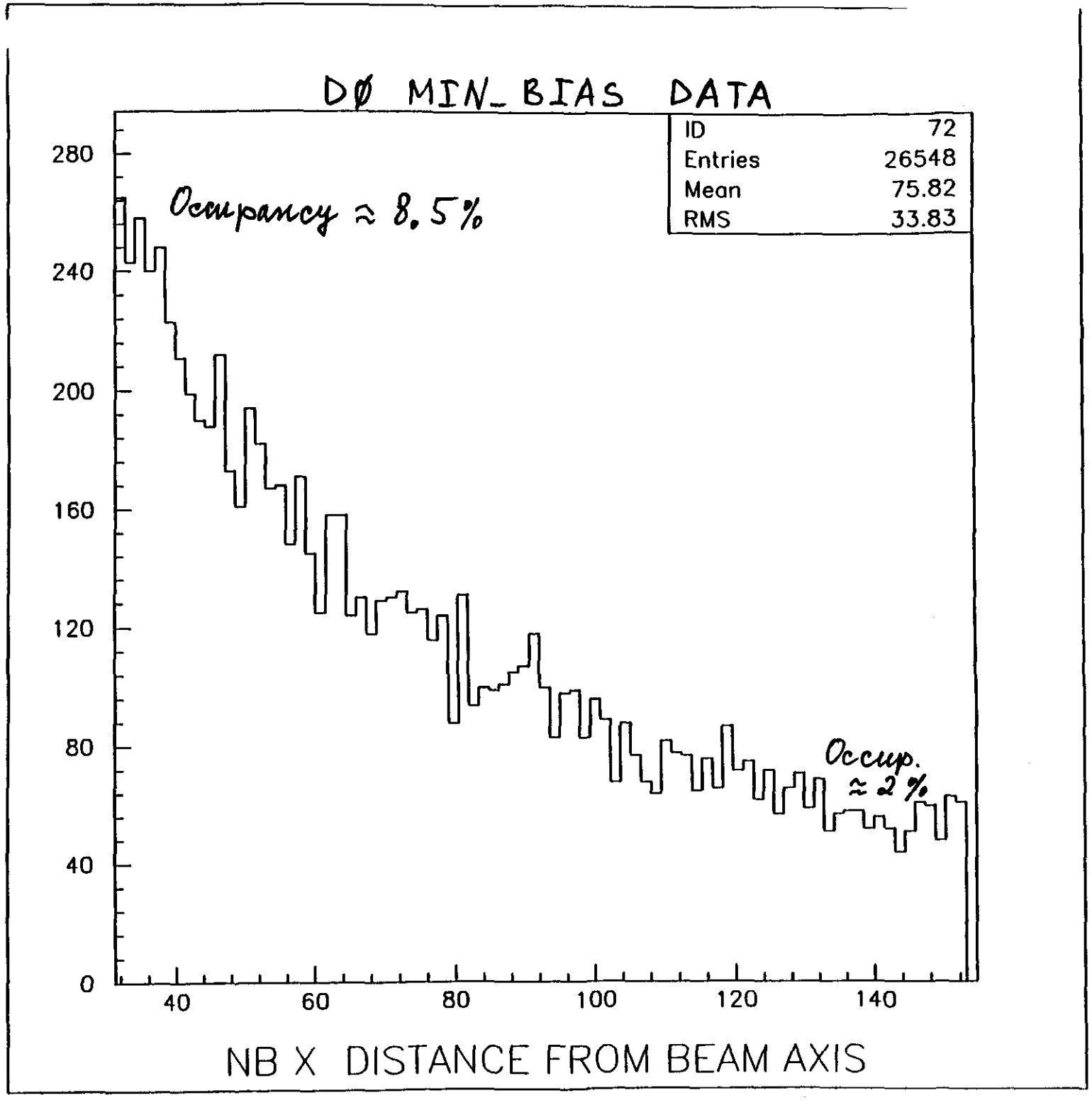


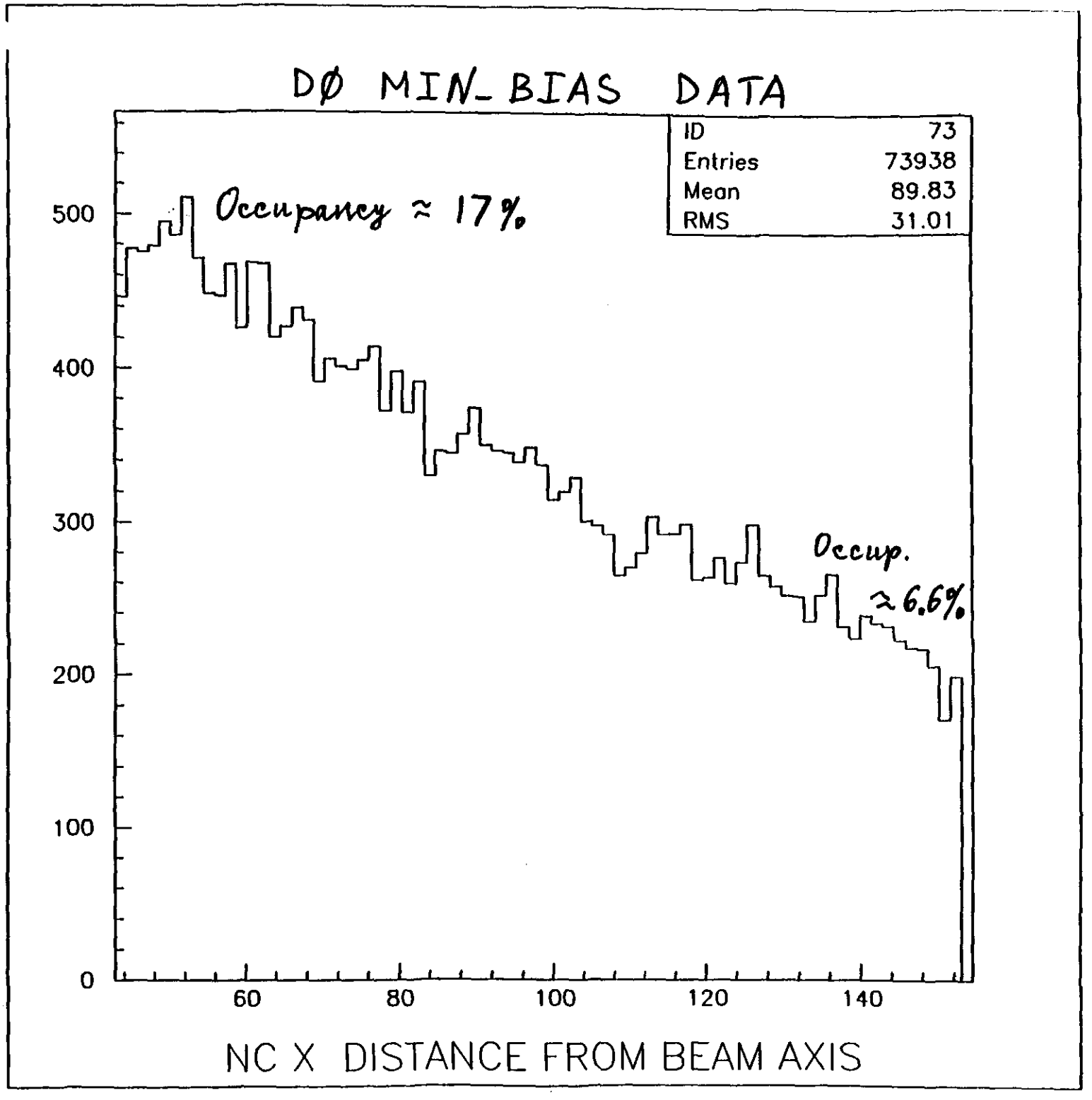
5308 tubes total

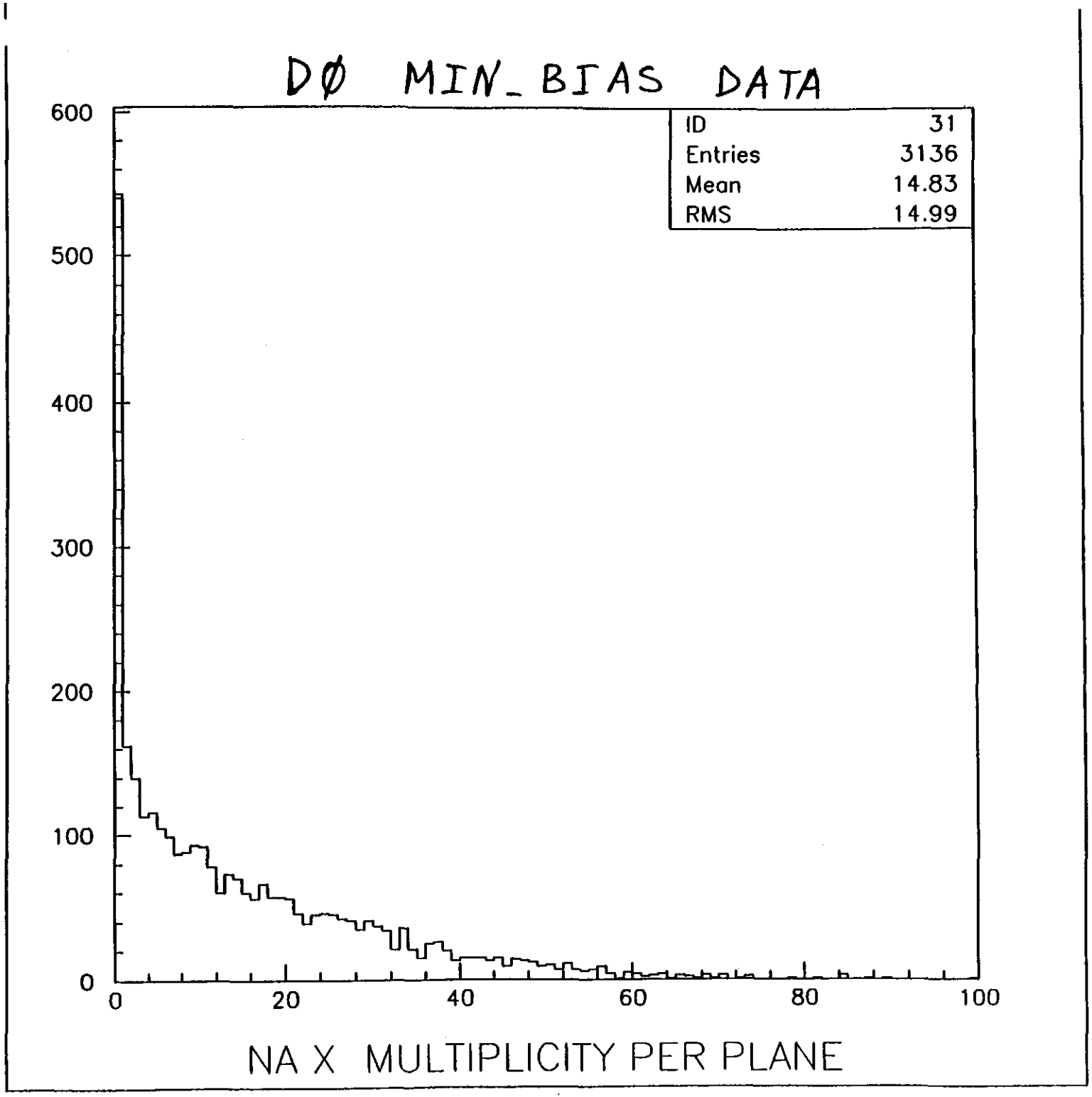
CROSS SECTION AND STRUCTURE OF SAMUS PDT STATION

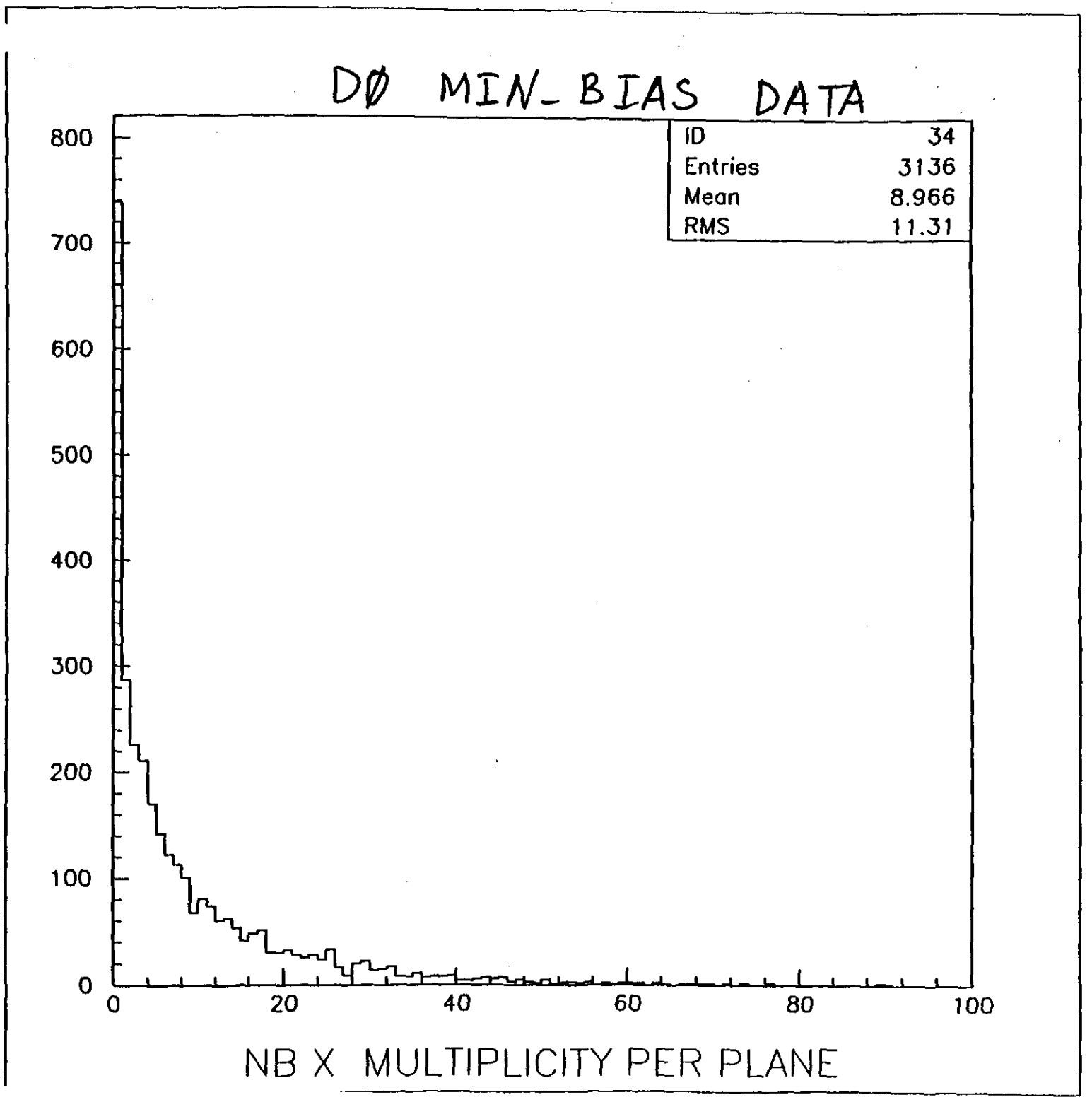

DØ MIN_BIAS DATA
ID 51
Entries 45125
Mean 137.8
RMS 49.17
3200
2800
2400
2000
1600
1200
800
400
0
-100
0
100
200
300
400
500
NA X DRIFT TIME SPECTRUM, NS

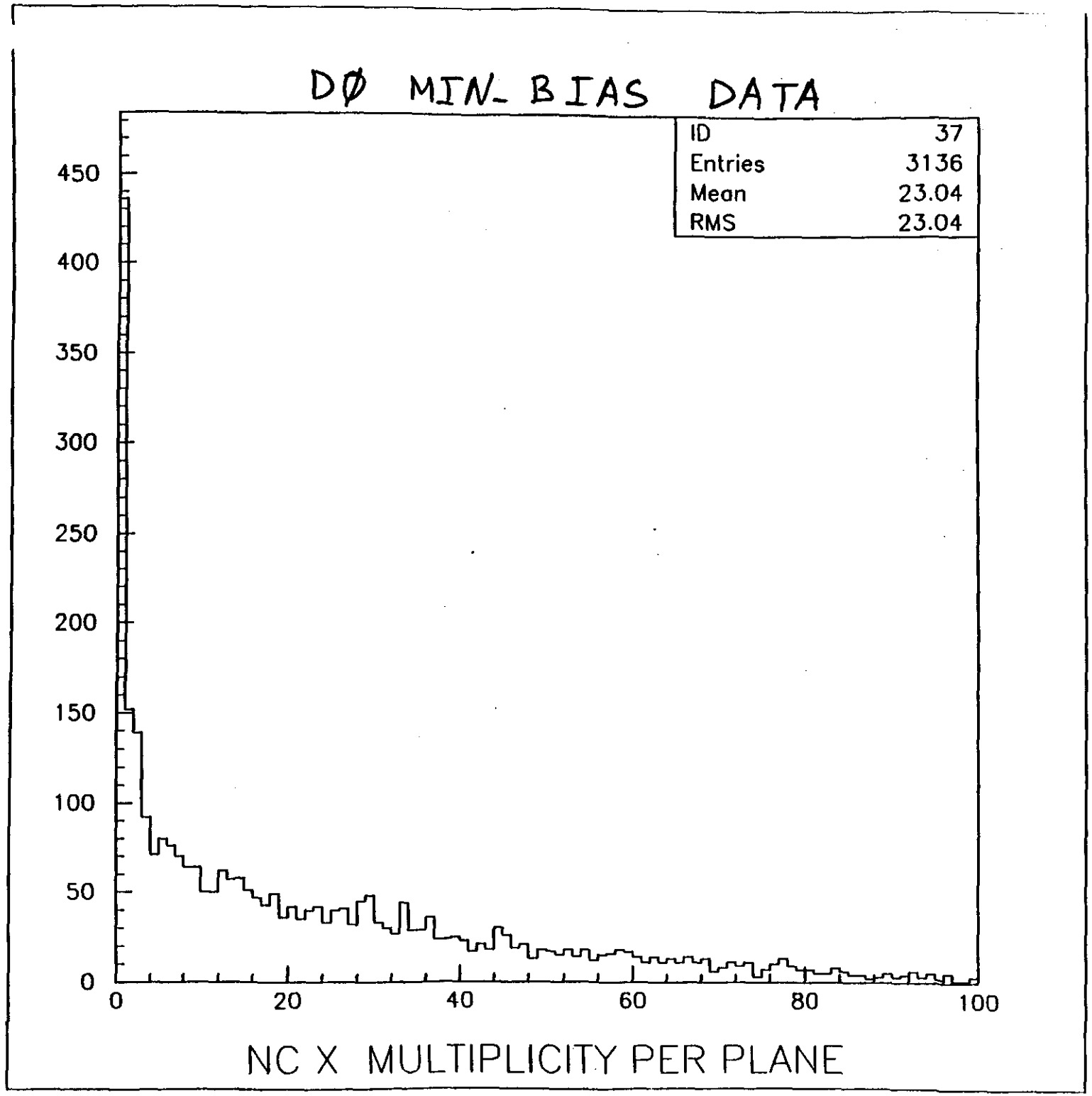

DØ MIN_BIAS DATA
ID 71
Entries 45125
Mean 61.72
RMS 28.40
Occupancy ≈ 23%
Occup. ≈ 2%
700
600
500
400
300
200
100
0
40
60
80
100
120
140
NA X DISTANCE FROM BEAM AXIS


DØ MIN_BIAS DATA
ID 72
Entries 26548
Mean 75.82
RMS 33.83
Occupancy ≈ 8.5%
Occup. ≈ 2%
280
240
200
160
120
80
40
0
40
60
80
100
120
140
NB X DISTANCE FROM BEAM AXIS

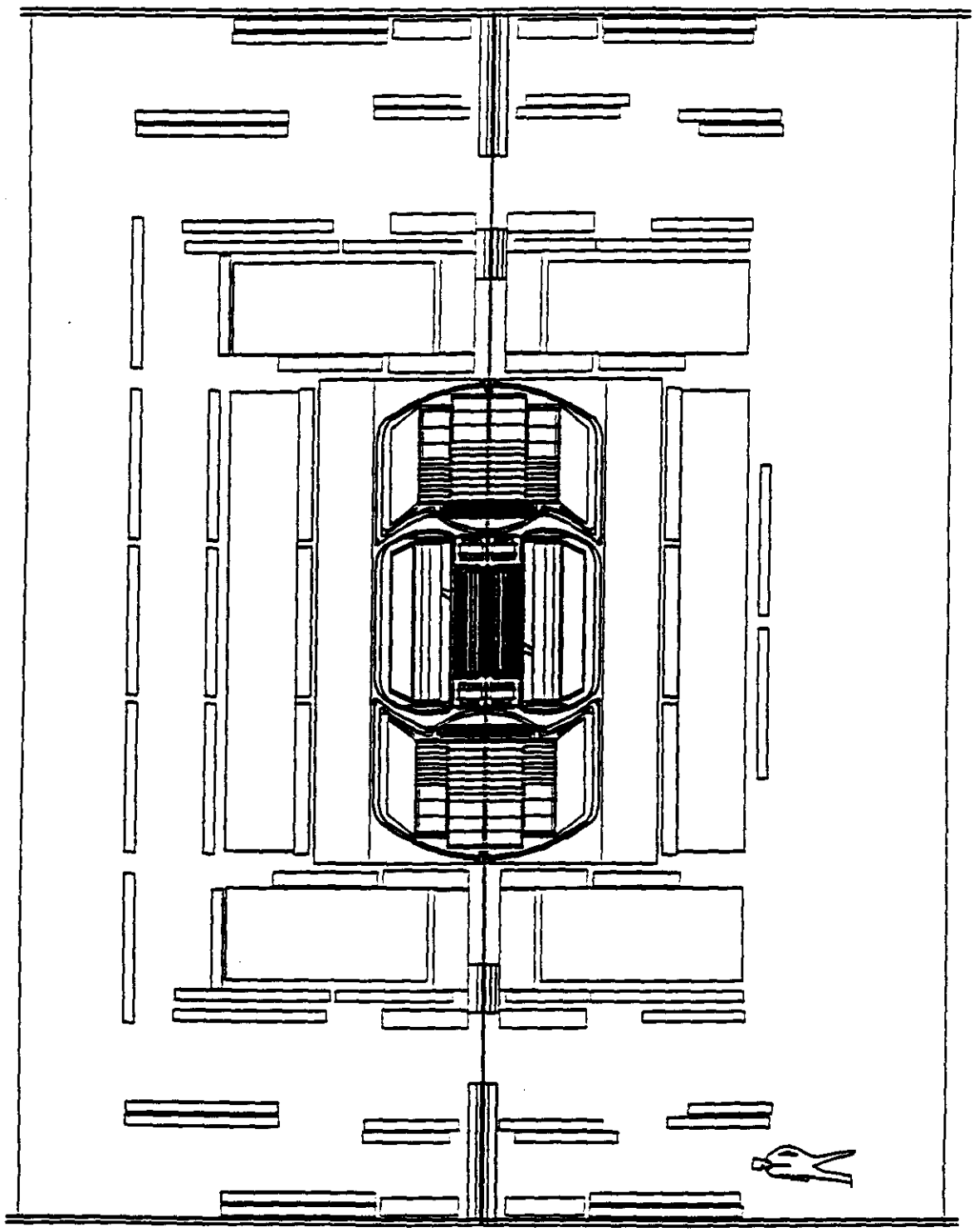

DØ MIN_BIAS DATA
ID 73
Entries 73938
Mean 89.83
RMS 31.01
Occupancy ≈ 17%
Occup. ≈ 6.6%
500
400
300
200
100
0
60
80
100
120
140
NC X DISTANCE FROM BEAM AXIS

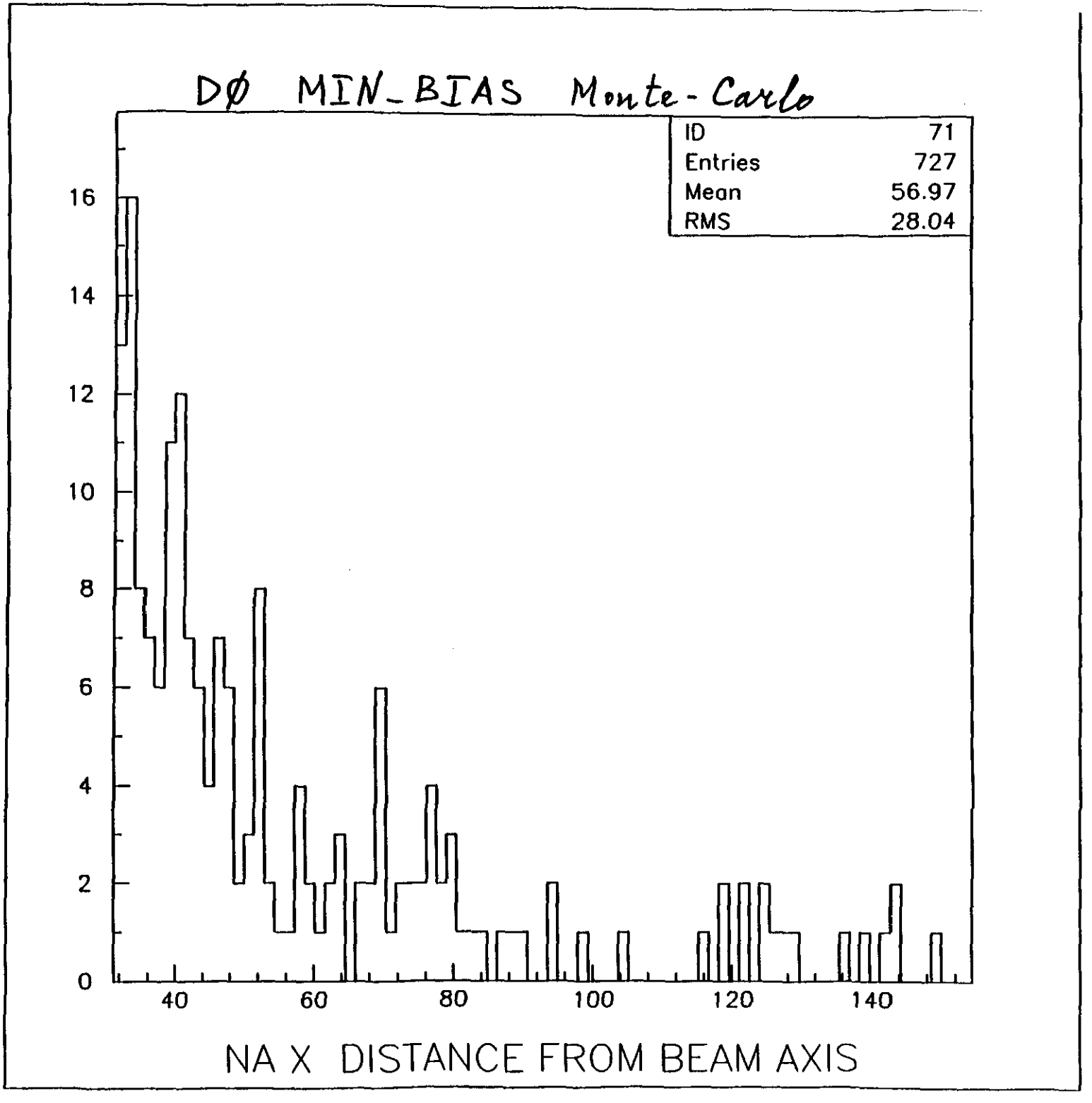

DØ MIN_BIAS DATA
ID 31
Entries 3136
Mean 14.83
RMS 14.99
600
500
400
300
200
100
0
0
20
40
60
80
100
NA X MULTIPLICITY PER PLANE

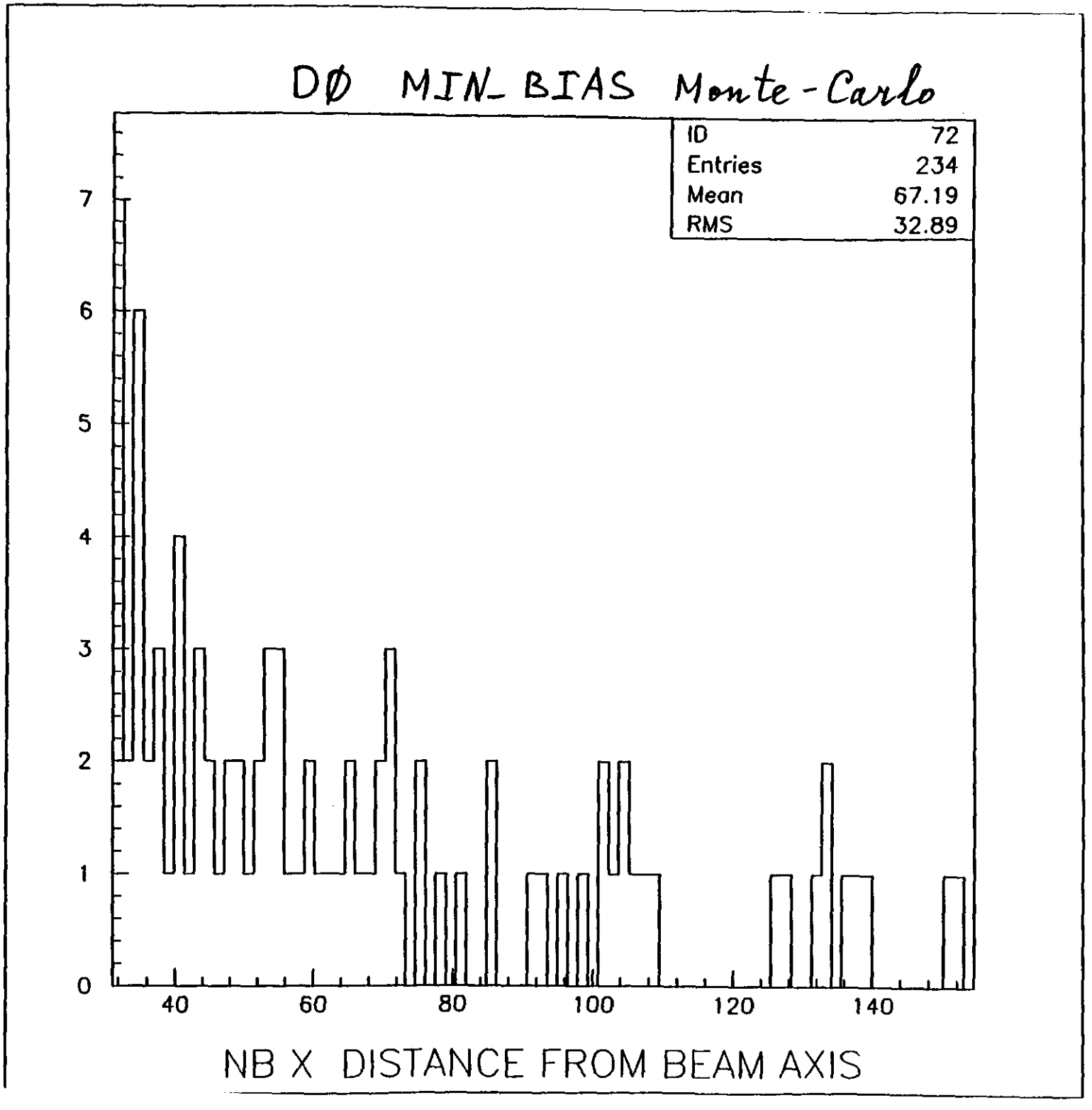

DØ MIN_BIAS DATA
ID 34
Entries 3136
Mean 8.966
RMS 11.31
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
NB X MULTIPLICITY PER PLANE

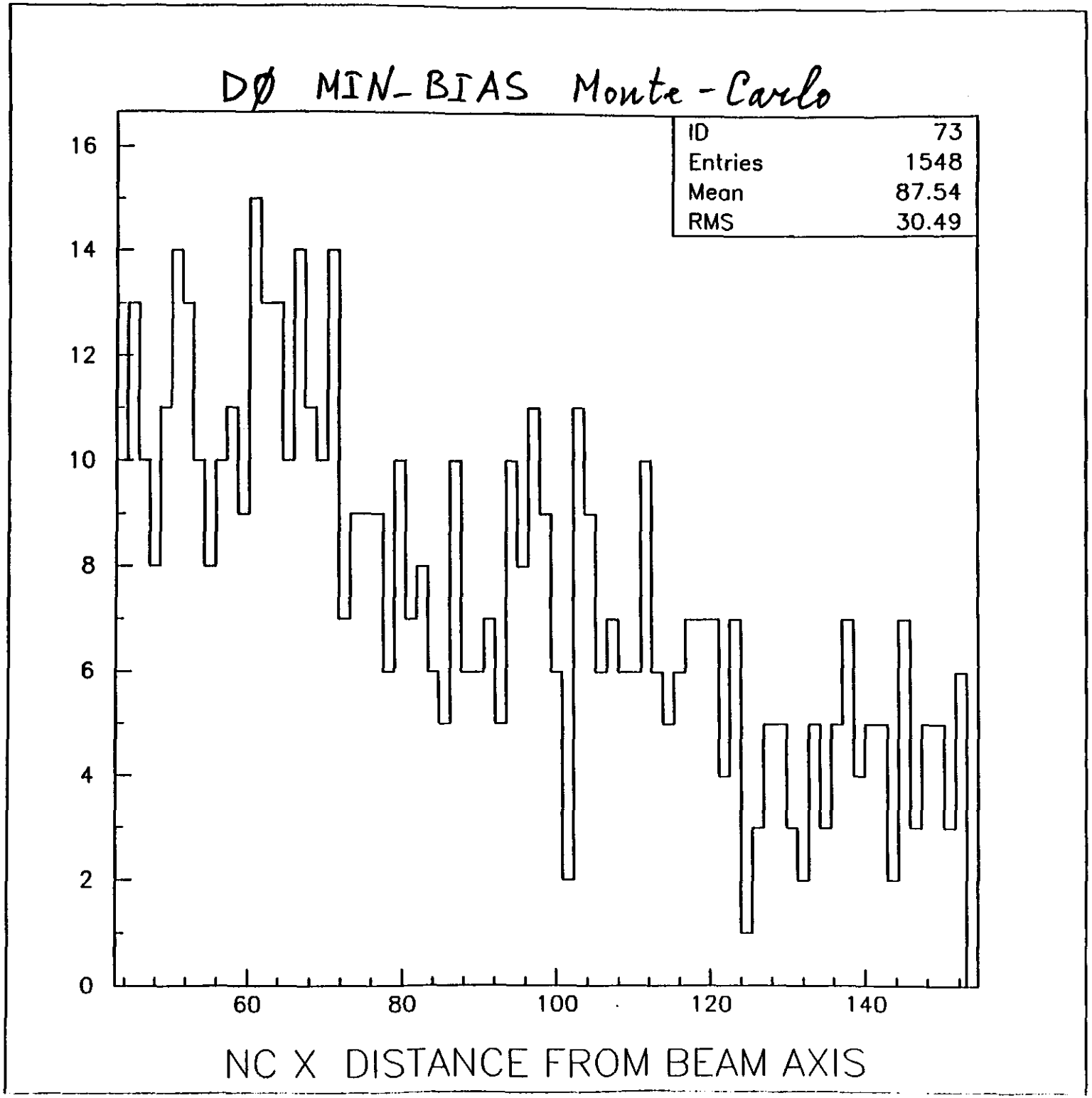

DØ MIN_BIAS DATA
ID 37
Entries 3136
Mean 23.04
RMS 23.04
450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
NC X MULTIPLICITY PER PLANE

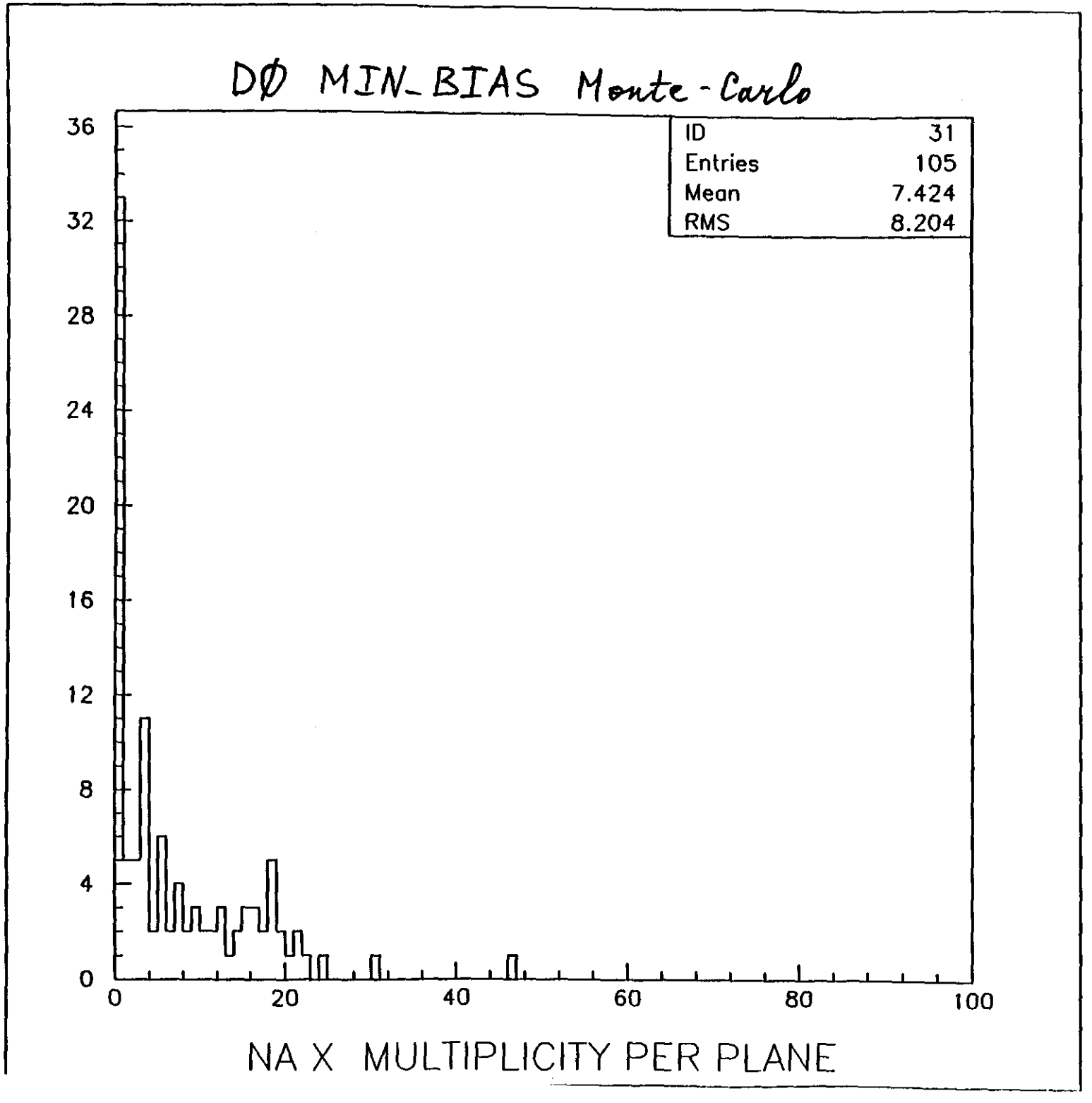
SAMUS in DOGEANT

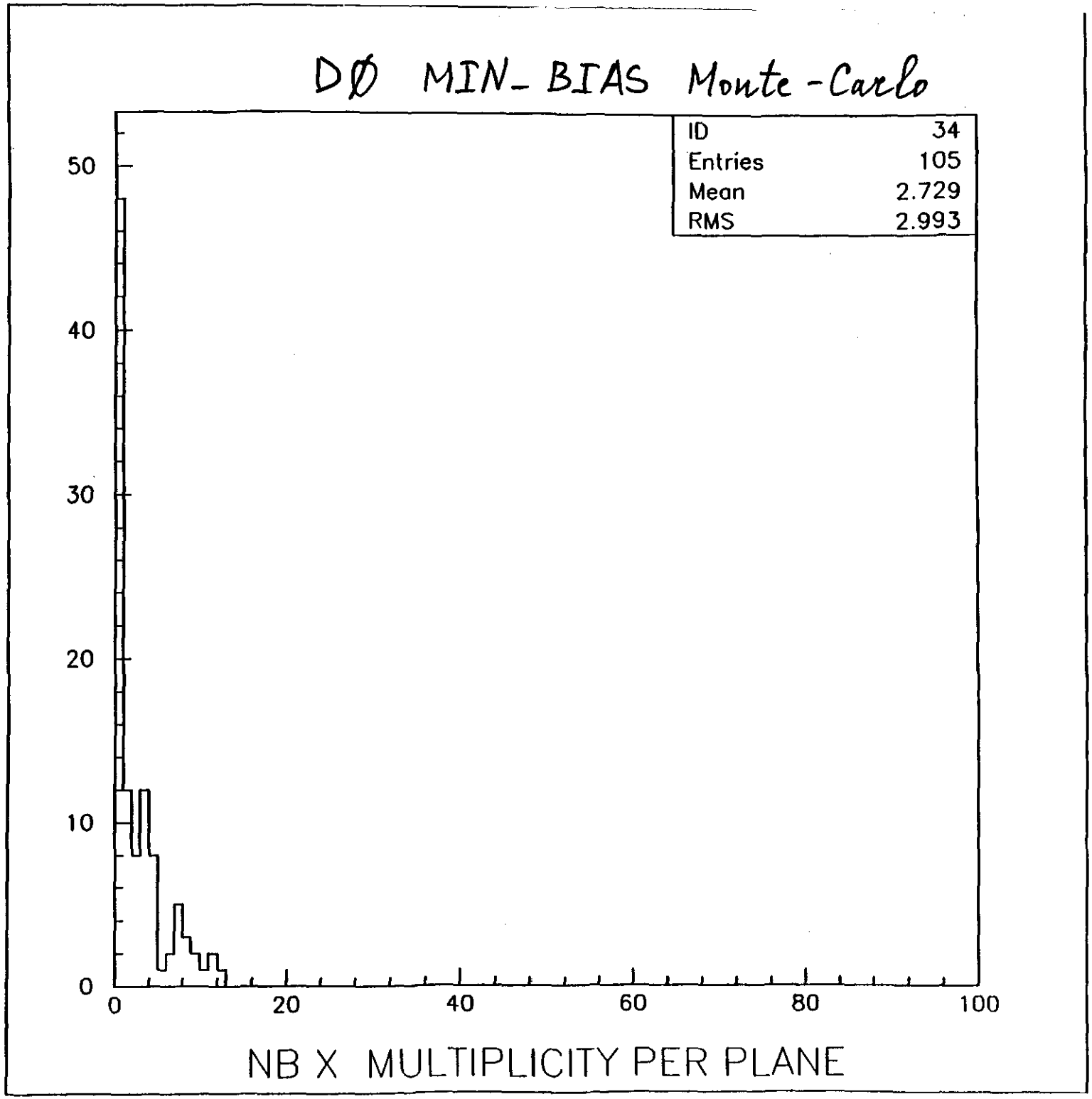


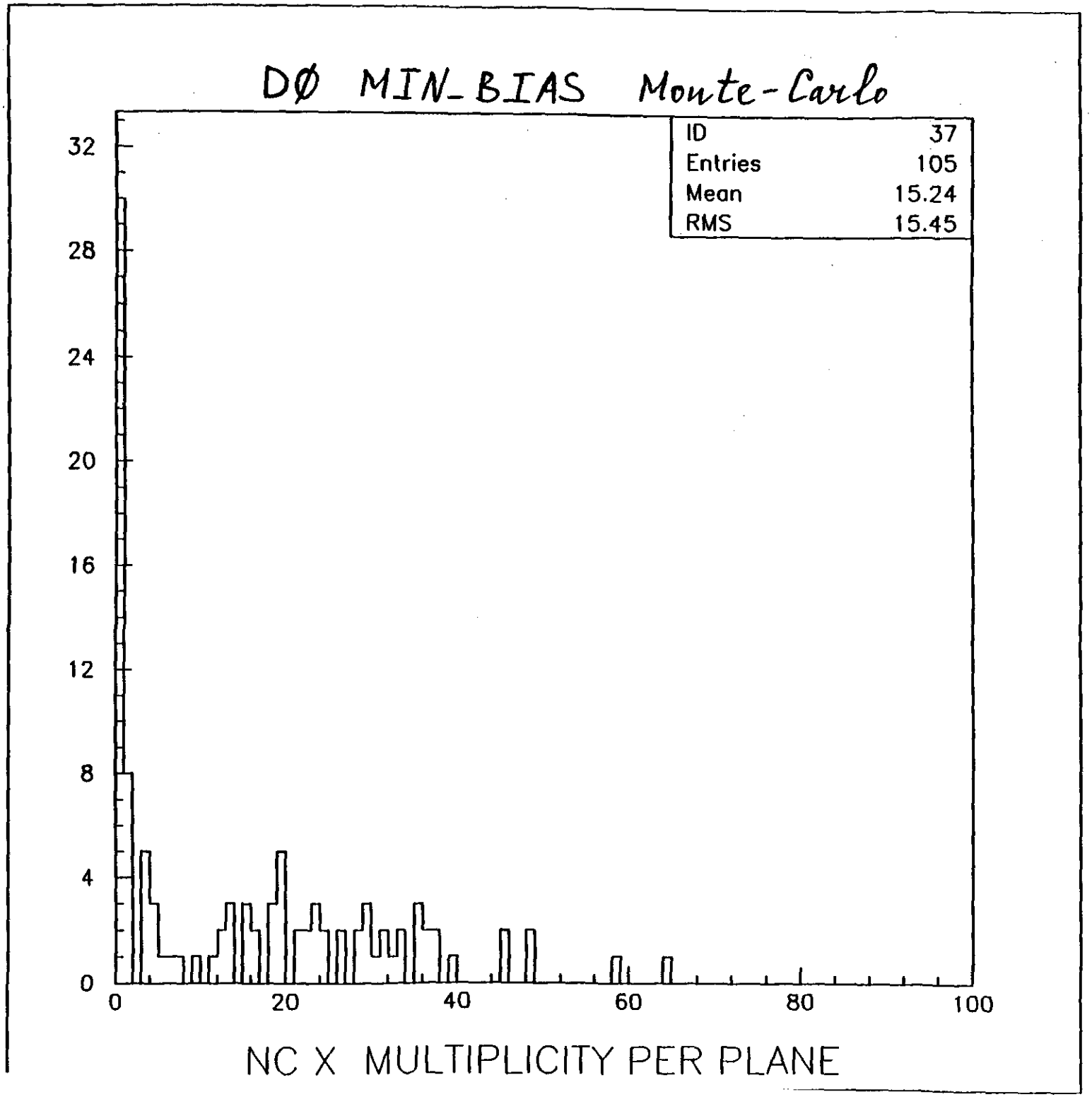

DØ MIN_BIAS Monte-Carlo
ID 71
Entries 727
Mean 56.97
RMS 28.04
0
2
4
6
8
10
12
14
16
40
60
80
100
120
140
NA X DISTANCE FROM BEAM AXIS


DØ MIN_BIAS Monte-Carlo
ID 72
Entries 234
Mean 67.19
RMS 32.89
0
1
2
3
4
5
6
7
40
60
80
100
120
140
NB X DISTANCE FROM BEAM AXIS

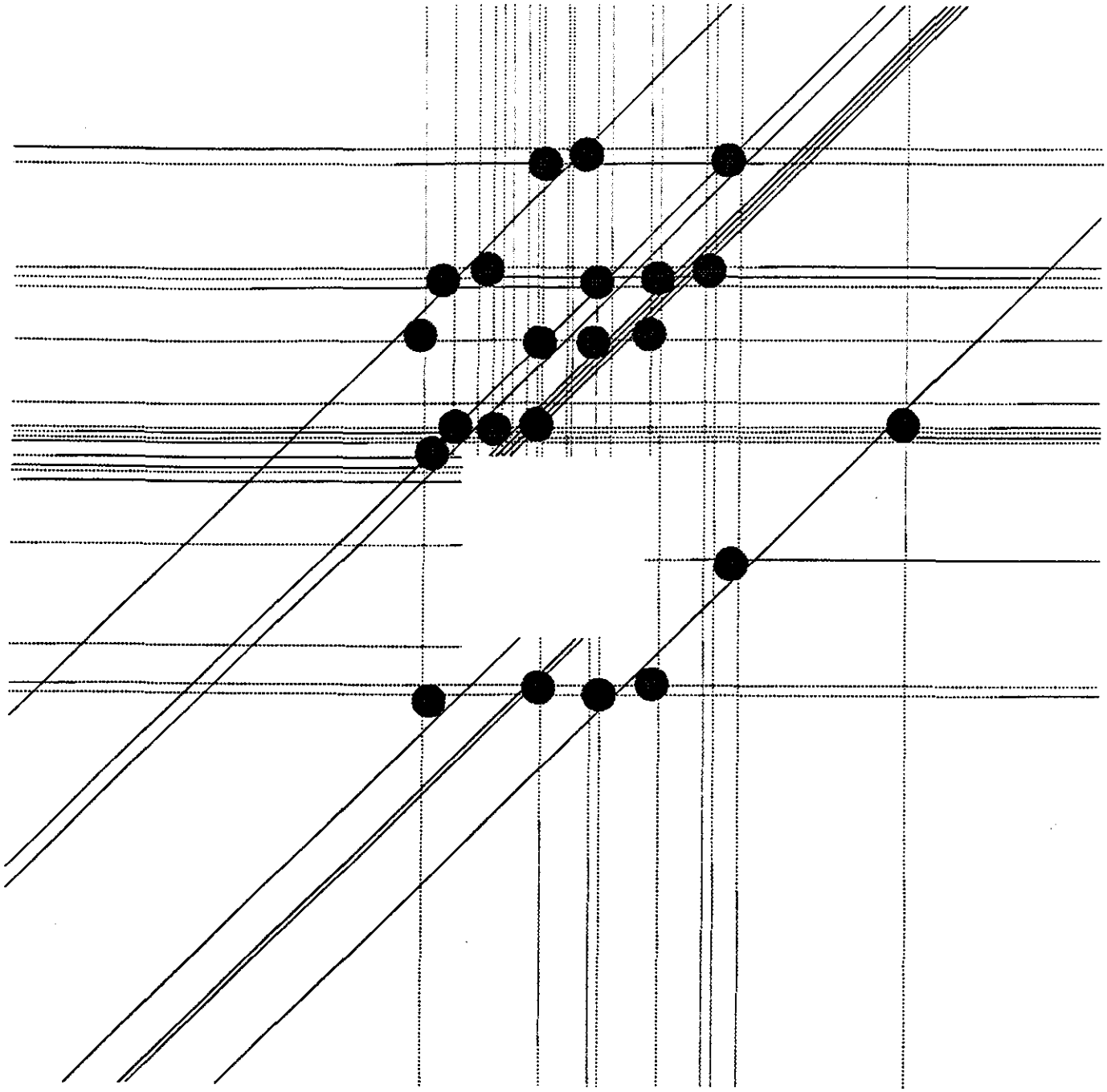

DØ MIN_BIAS Monte-Carlo
ID 73
Entries 1548
Mean 87.54
RMS 30.49
16
14
12
10
8
6
4
2
0
60
80
100
120
140
NC X DISTANCE FROM BEAM AXIS


DØ MIN_BIAS Monte-Carlo
ID 31
Entries 105
Mean 7.424
RMS 8.204
36
32
28
24
20
16
12
8
4
0
0
20
40
60
80
100
NA X MULTIPLICITY PER PLANE


DØ MIN_BIAS Monte-Carlo
ID 34
Entries 105
Mean 2.729
RMS 2.993
50
40
30
20
10
0
0
20
40
60
80
100
NB X MULTIPLICITY PER PLANE


DØ MIN_BIAS Monte-Carlo
ID 37
Entries 105
Mean 15.24
RMS 15.45
32
28
24
20
16
12
8
4
0
0
20
40
60
80
100
NC X MULTIPLICITY PER PLANE

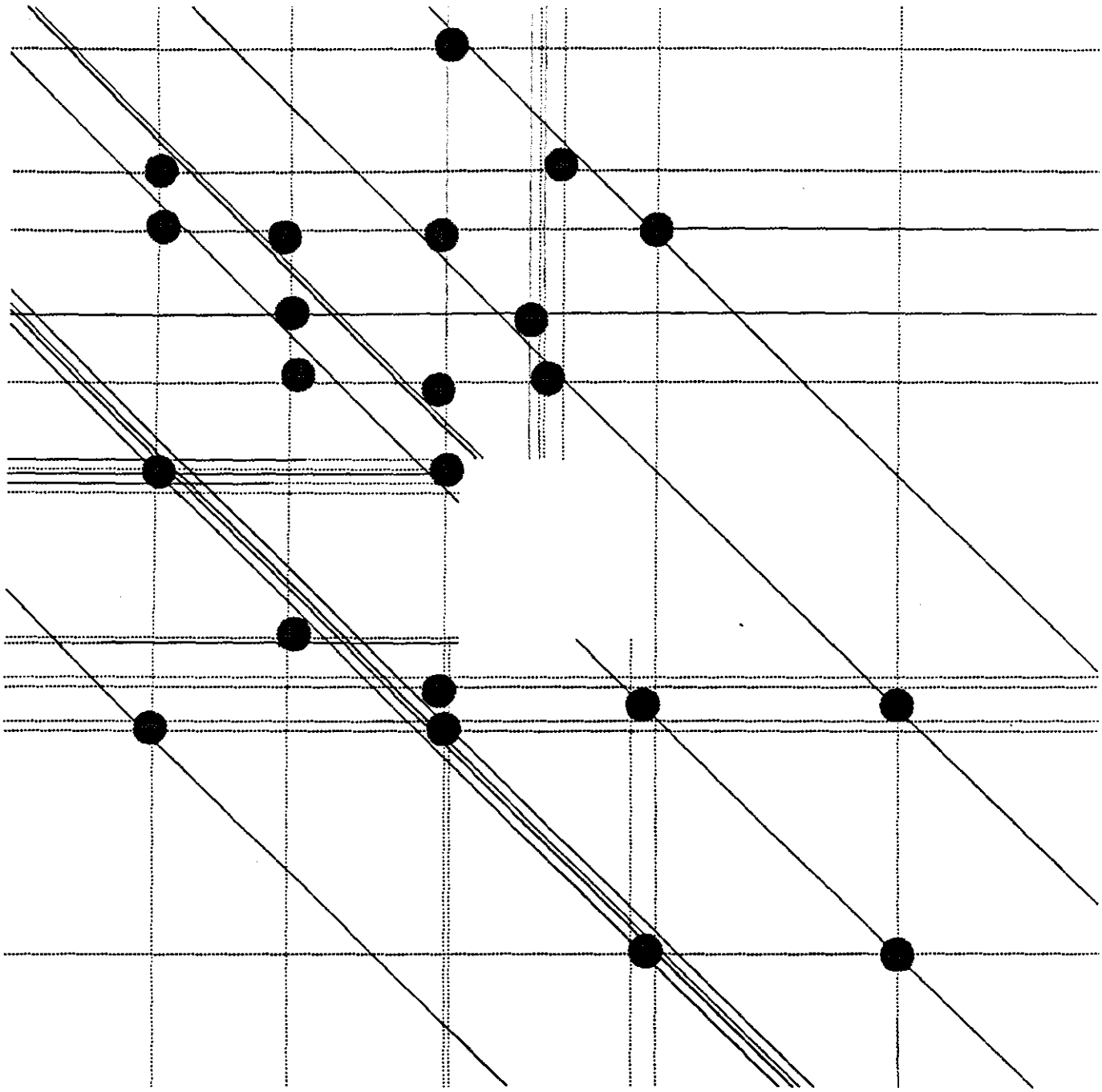
DØ MIN_BIAS DATA



SAMUS STATION A

LOW MULTIPLICITY EVENT

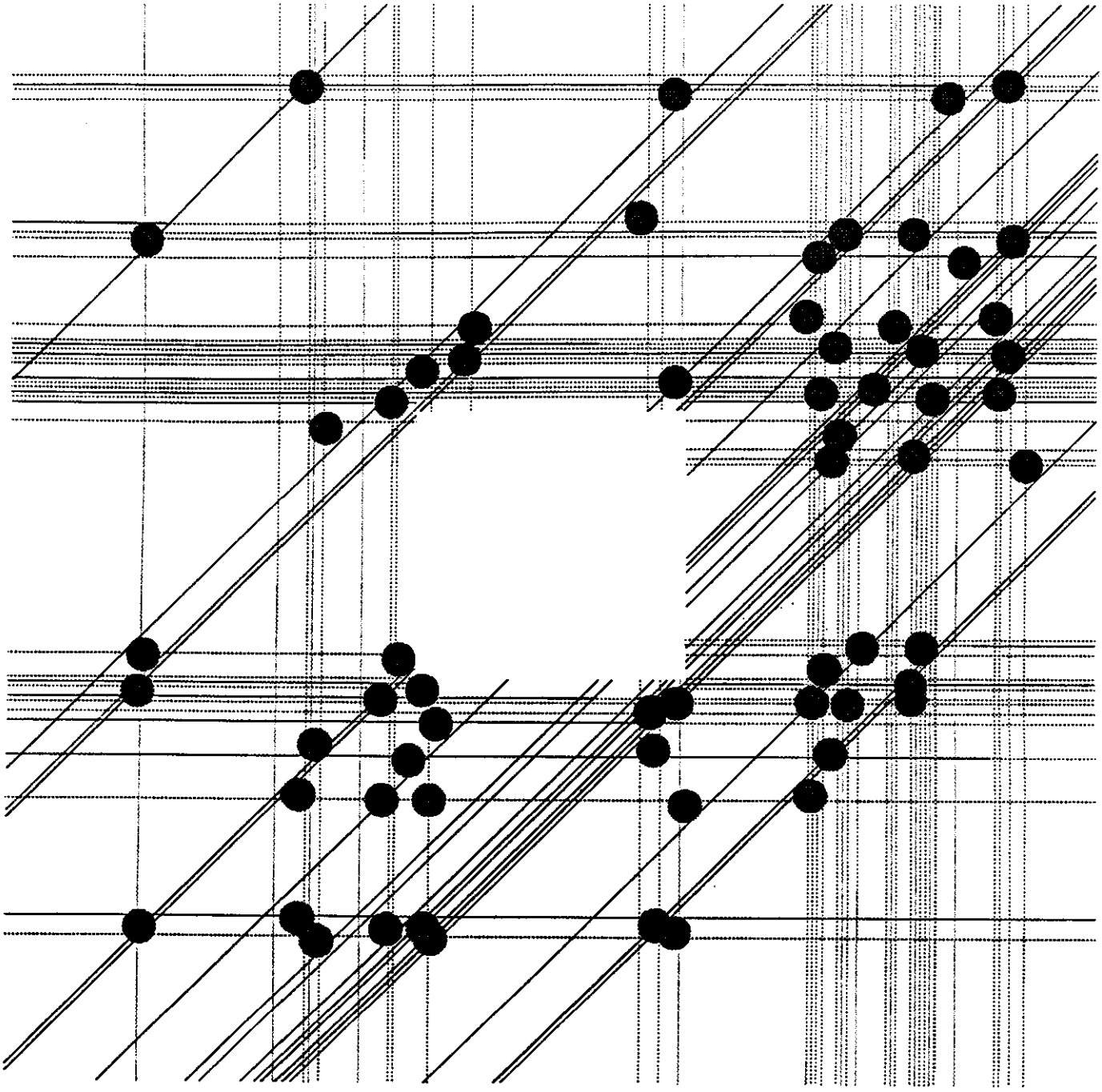
DØ MIN_BIAS DATA



SAMUS STATION B

LOW MULTIPLICITY EVENT

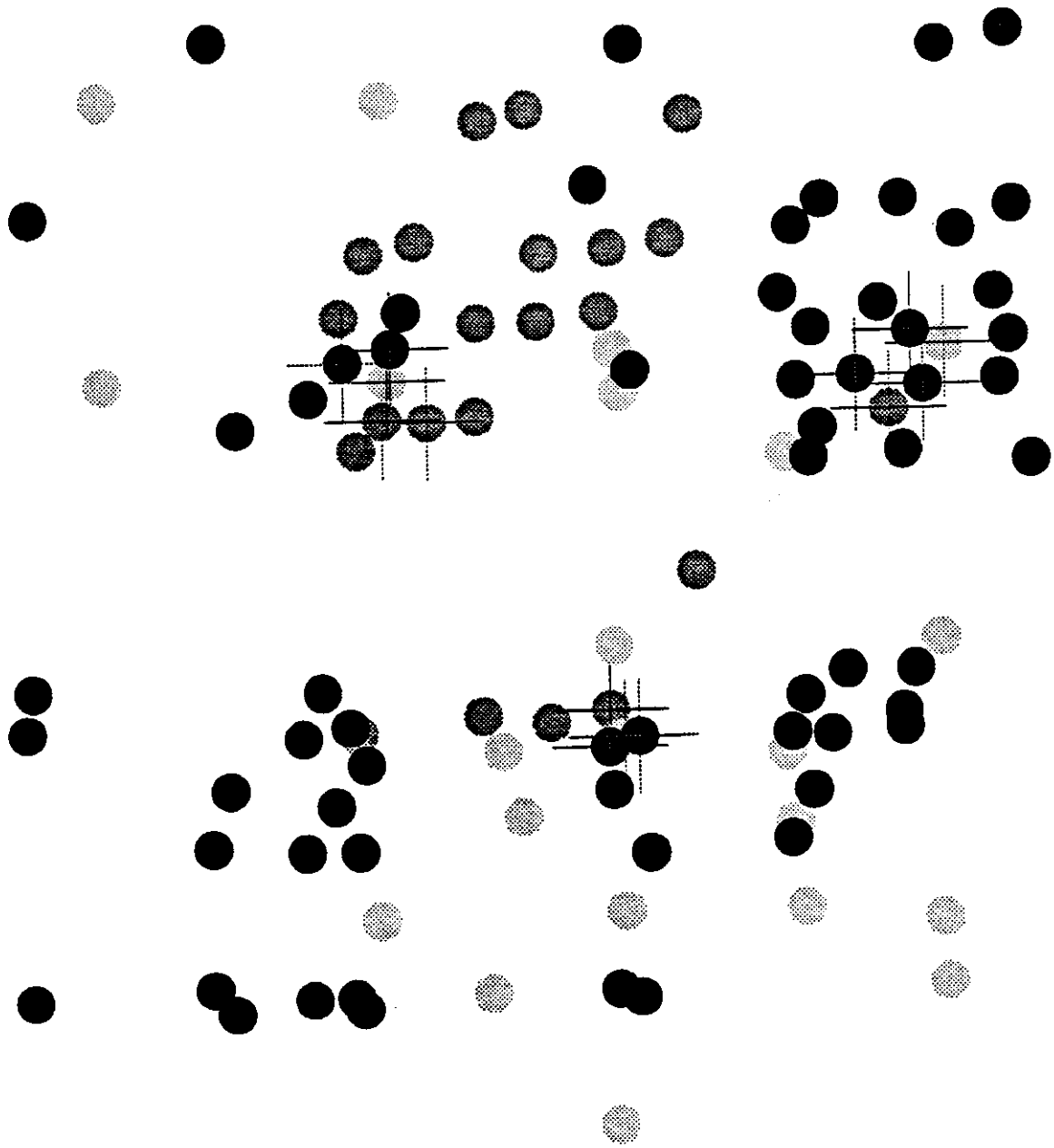
DØ MIN_BIAS DATA



SAMUS STATION C

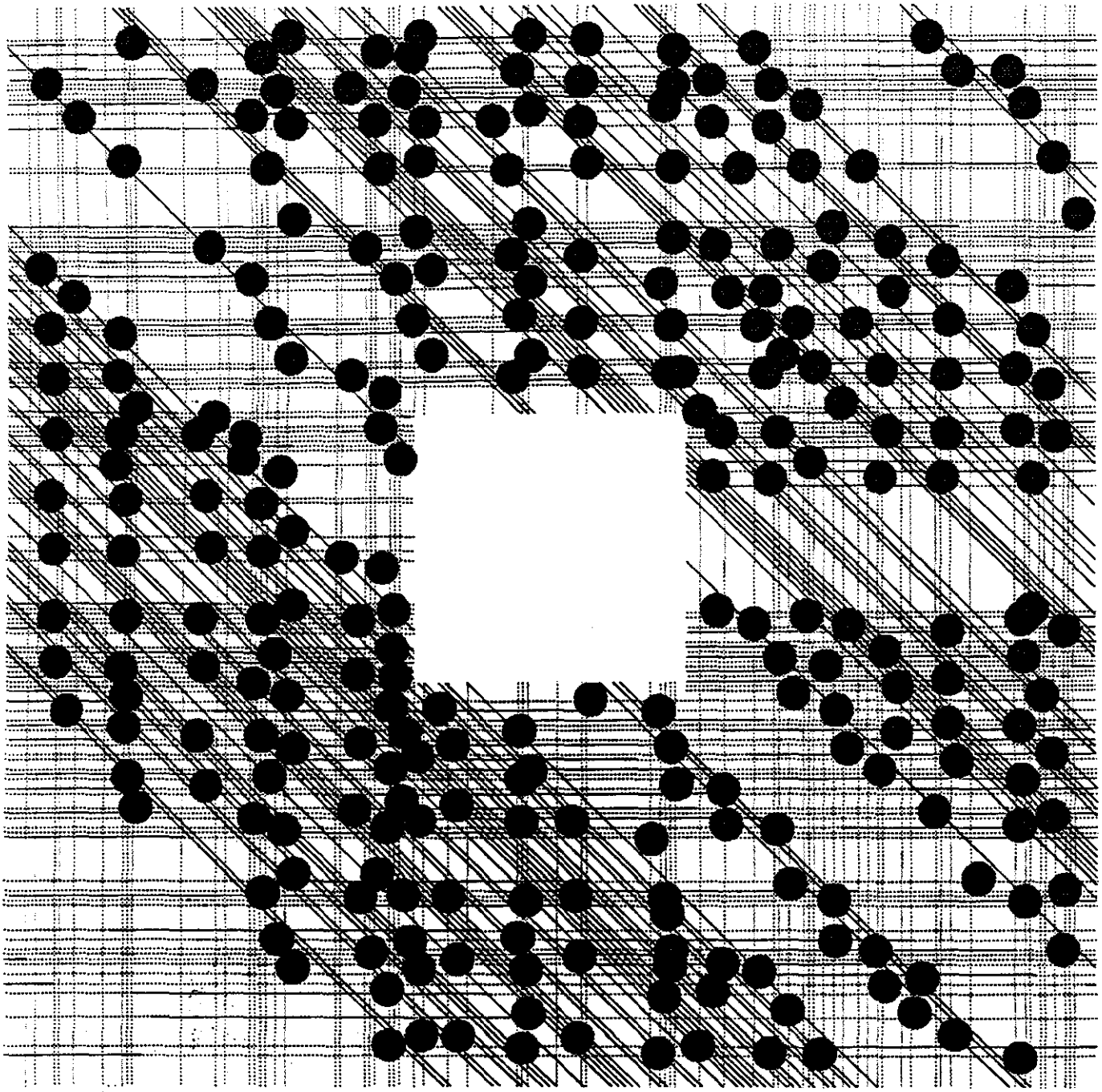
LOW MULTIPLICITY EVENT

DØ MIN_BIAS DATA



SAMUS Stations A, B and C
low multiplicity event

DØ MIN_BIAS DATA



„Typical" SAMUS event