GEM TN-93-275

Neutron Task Force Meeting - SSCL

January 27, 1993

Abstract:

Agenda, attendees, and presentations of the Neutron Task Force Meeting held at the SSC Laboratory on January 27, 1993.

Neutron Task Force Meeting

1/27/93

M. Diwan

M. Harris

I. Azhgiriey

A. Vzunian

L. Waters

M. Marx

B. Barish

W. Wisniewski

J. Lawler

G. Sanders

K. Morgan

N. Mokhov

Y. Kamyshkov

I. Fissiak

#1 25-JAN-1993 16:12:32.90 NEWMAI

From: SSCVX1::DIWAN "Milind V. Diwan at the SSC 214-708-4477"
To: @NEUTRON.LST
CC:
Subj: agenda

Agenda for the neutron task force meeting on Jan. 27.

Meeting will be at 1 pm in the GEM conference room

1300	SDC calculations	Azhigirey/Uzunian
1400	New results	Waters
1440	Organization	Diwan
	Shielding	
1520	Discussion	
	Next meeting	

MAIL>

gem

γeμ

Presentation by:

I. Azhigirey

CALCULATIONS OF BACKGROUNDS FOR THE SDC FMS

I. AZHGIREY & A. UZUNIAN
IHEP, RUSSIA

GOAL: TRY TO DETERMINE PRINCIPAL SOURCE OF BACKGROUND COUNTS FOR FMS CHAMBERS

SOFTWARE:

(a) pp-GENERATOR:

ISAJET TWOJET, $p_t^{min} = 5$ GeV/c

(b) PARTICLES TRANSPORT:

MARS92C = COMBINATION OF: { MARS12, MARSMU, MARS11 }

NEUTRONS: 28 GROUP MONTE-CARLO
BNAB-MICRO DATA LIBRARY

PHOTONS LEVEL ESTIMATIONS:
49-GROUP N + 15-GROUP γ
DISCRETE ORDINATES METHOD CODE ROZ-6

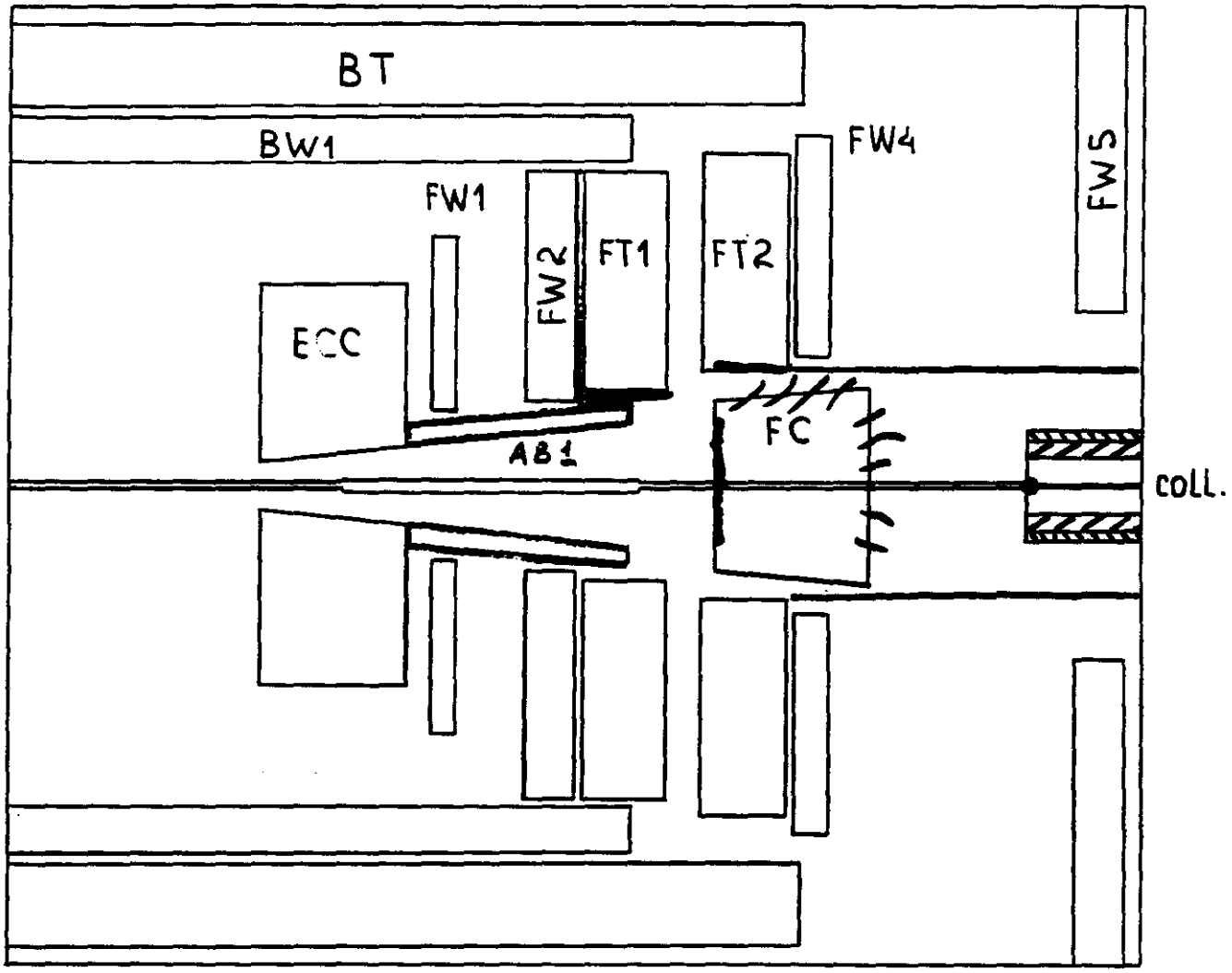
GEOMETRY OF CALCULATIONS :

A : AB1 only

B : FCAL - Albedo shield reinforced

C : Collimator shield added

SERIOUS SPACE PROBLEM - TO ORGANIZE EFFECTIVE ALBEDO/SIDE LEAKAGE SHIELD OF FCAL



COLLIMATOR : 18.0 M , r = 1.25 CM

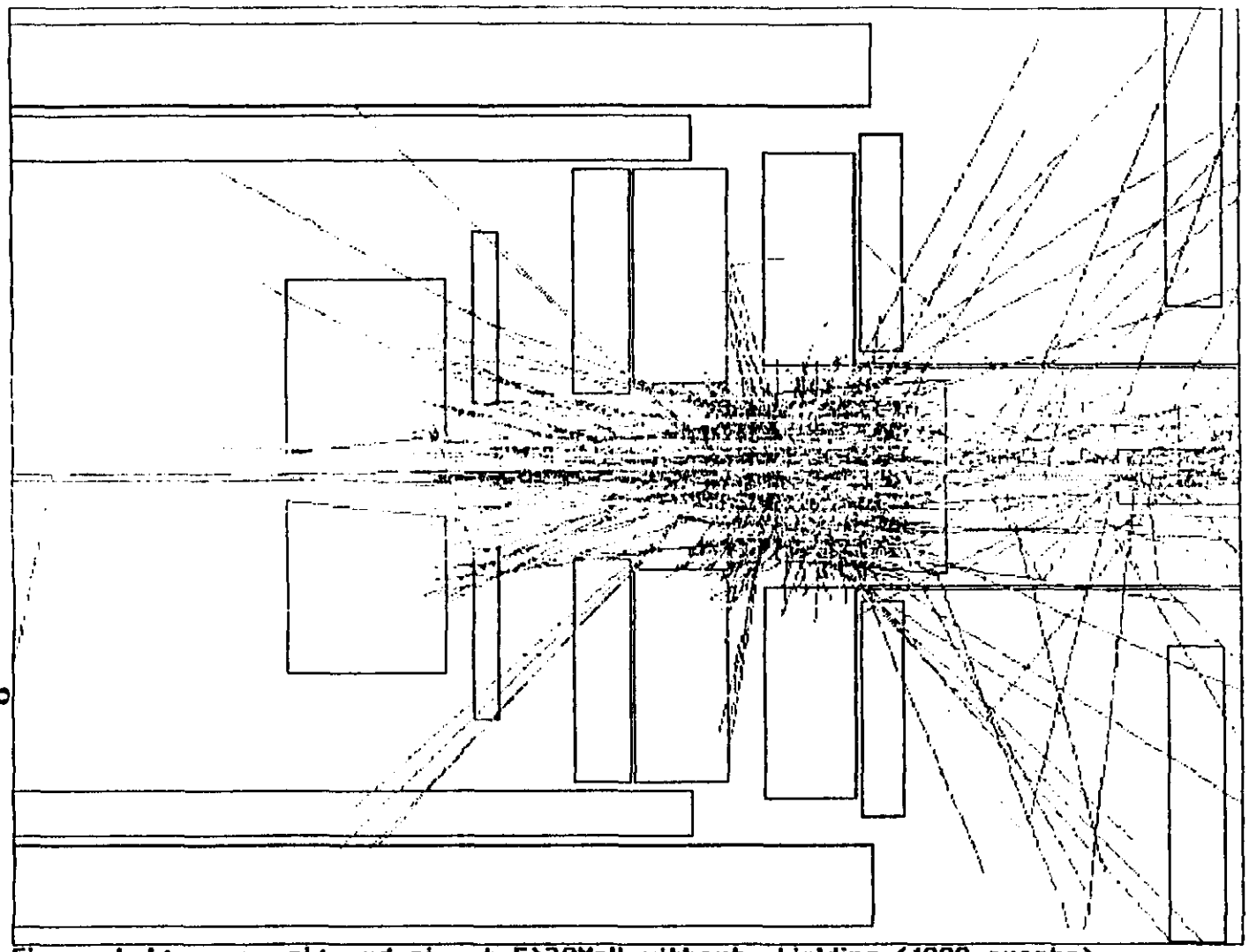


Figure 1.1: p, n, pi+ and pi- at E>20MeV without shielding (1000 events).

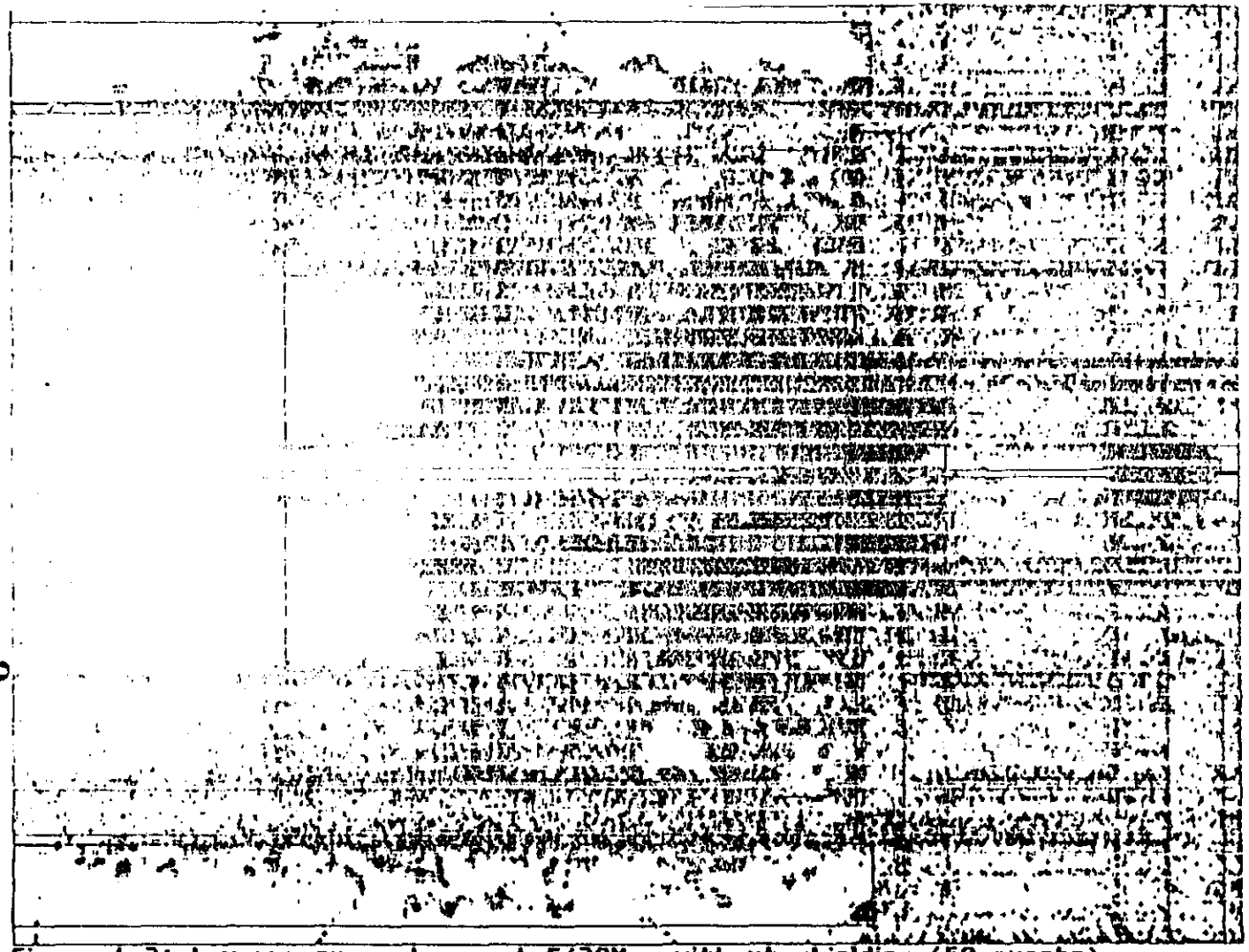
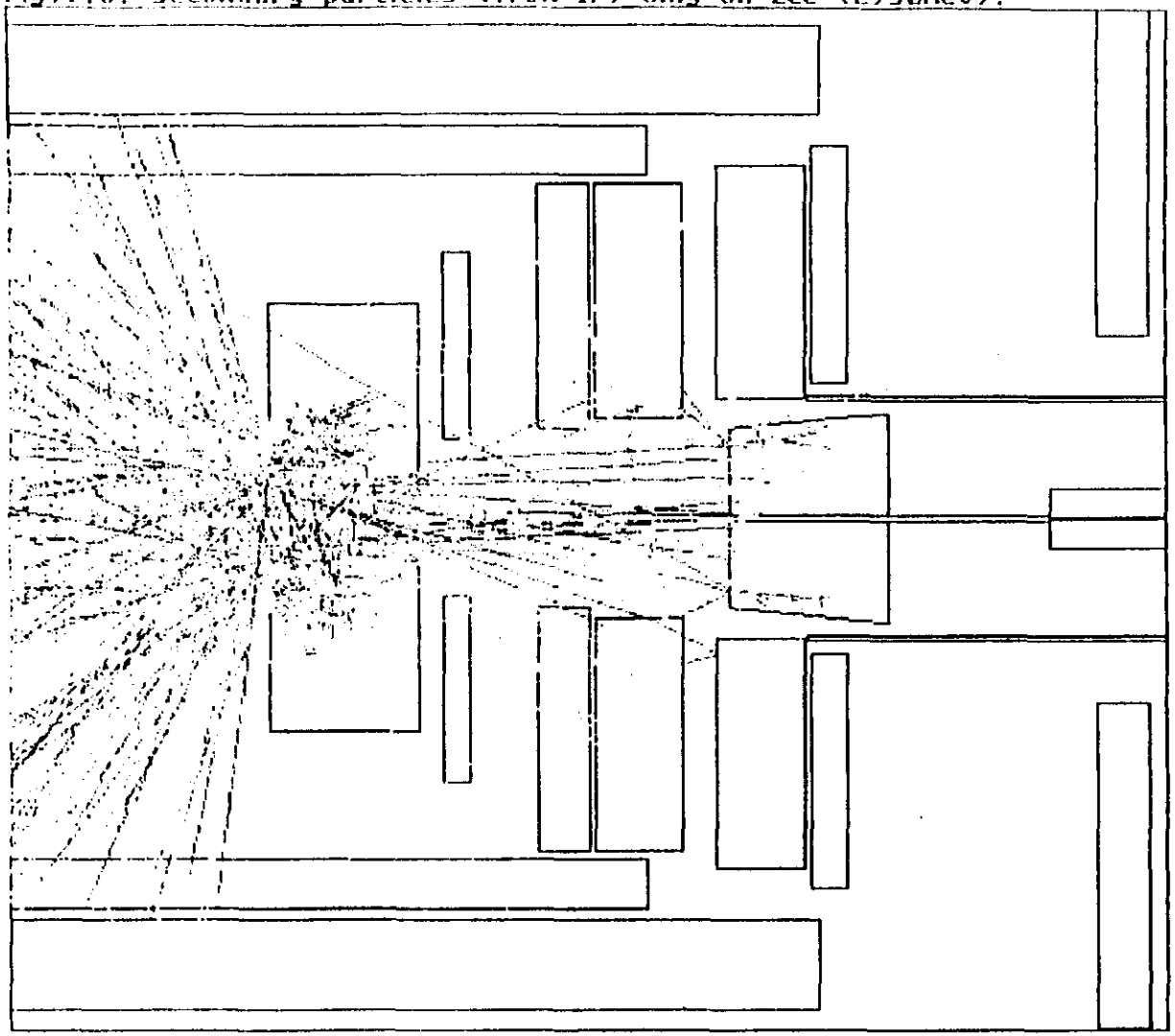


Figure 1.2: Low energy neutrons at E<20Mev without shielding (50 events).

Fig.1.6: Secondary particles (from IP) only on ECC (E>50MeV).



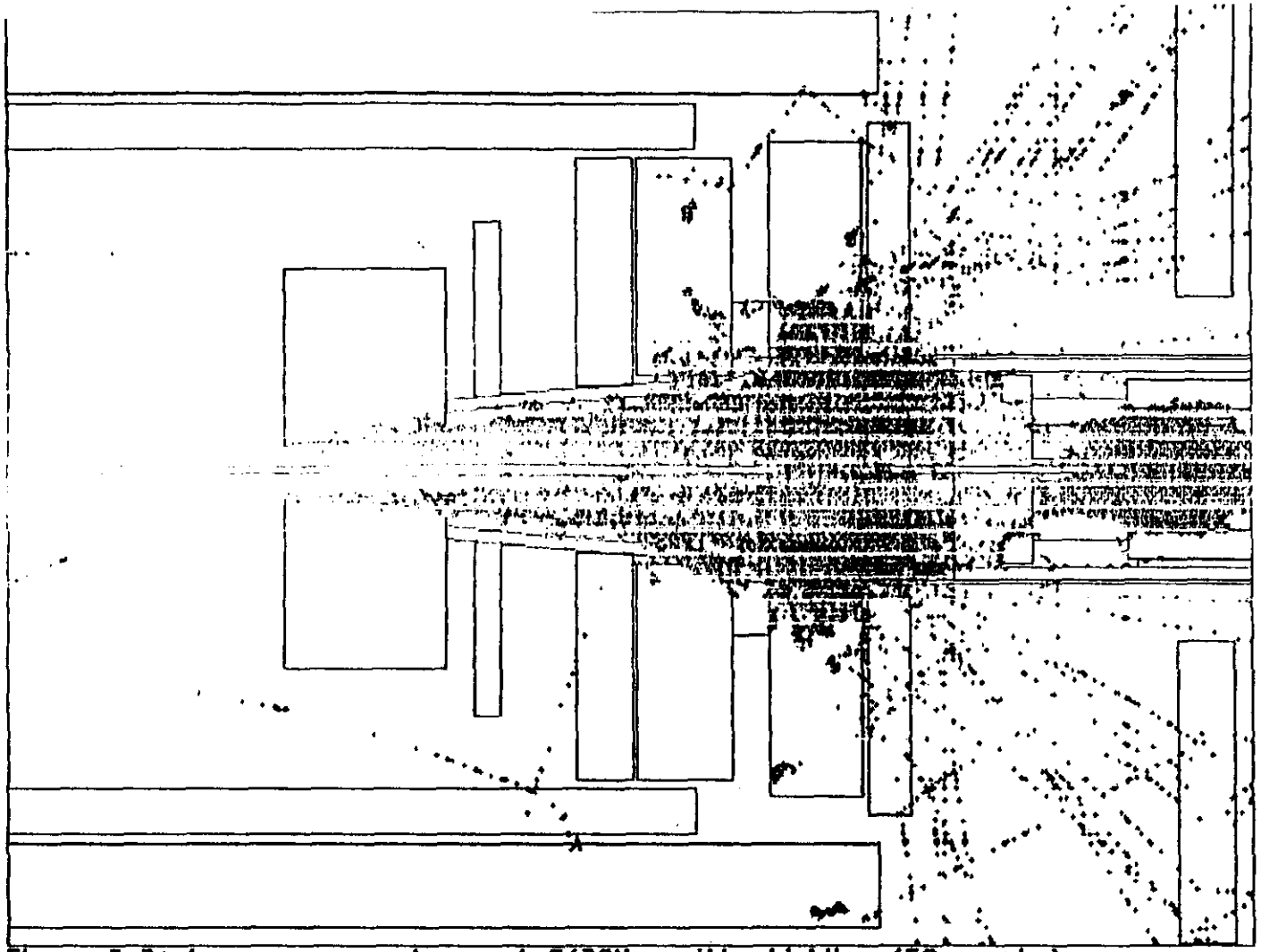
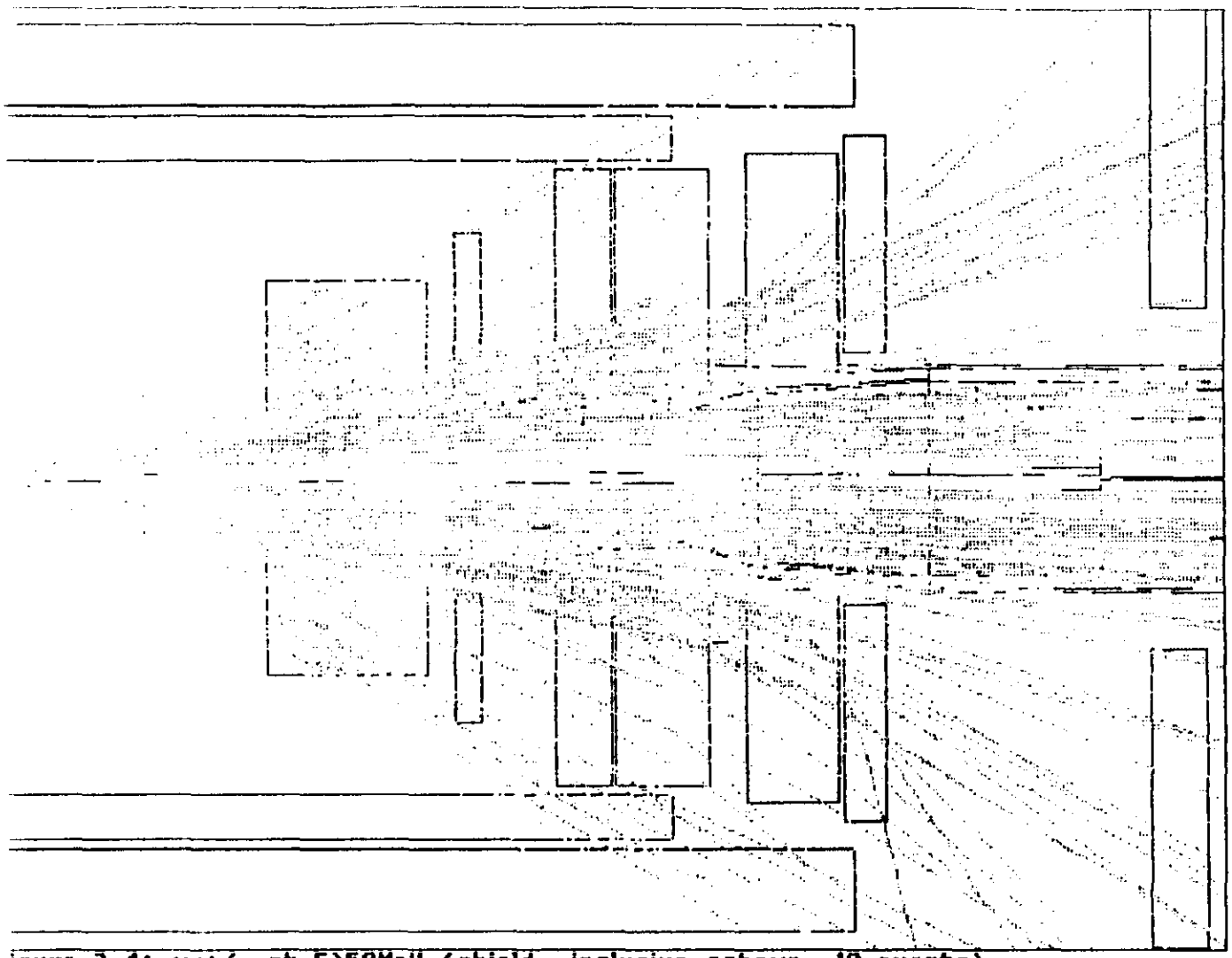
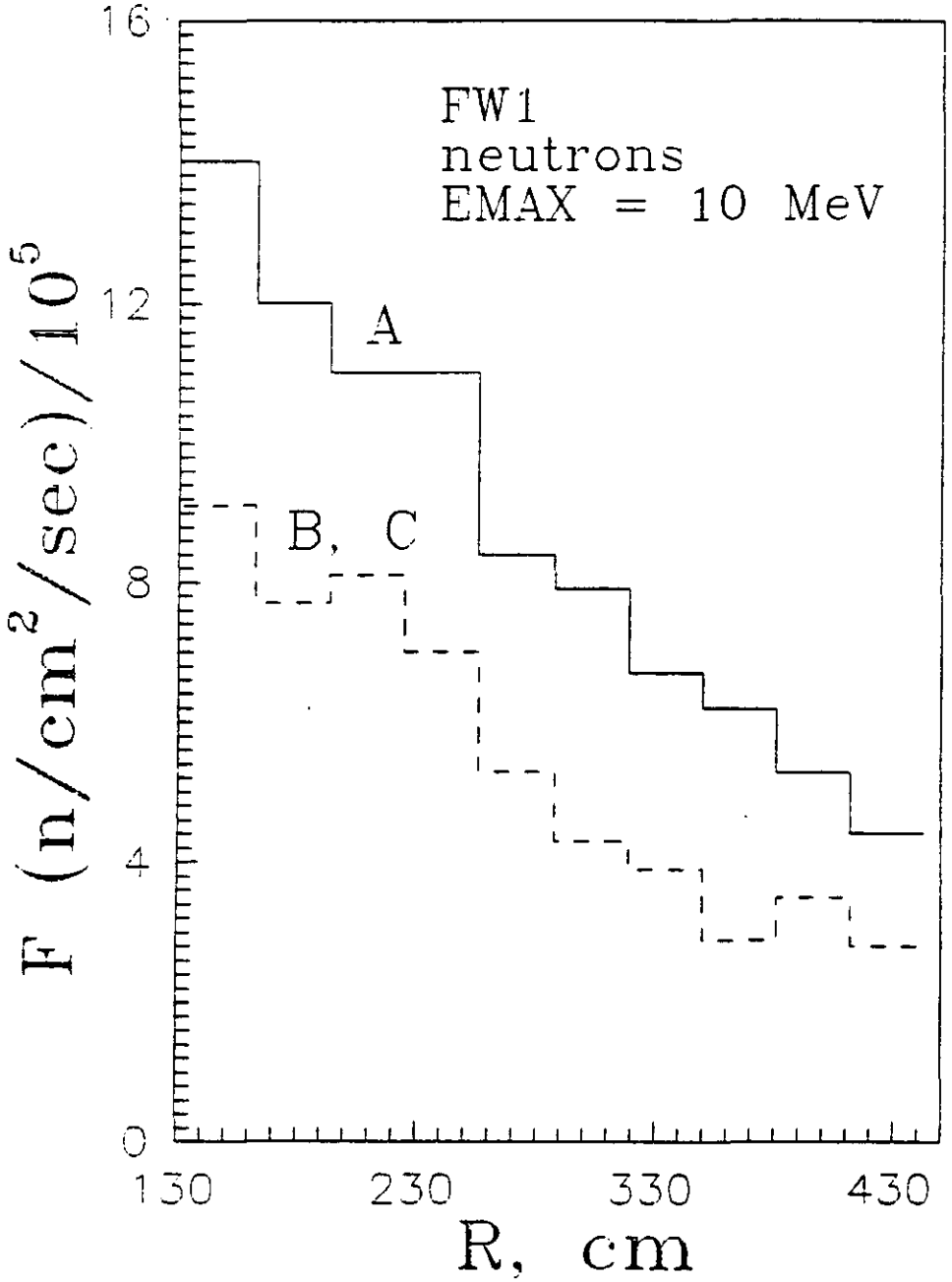
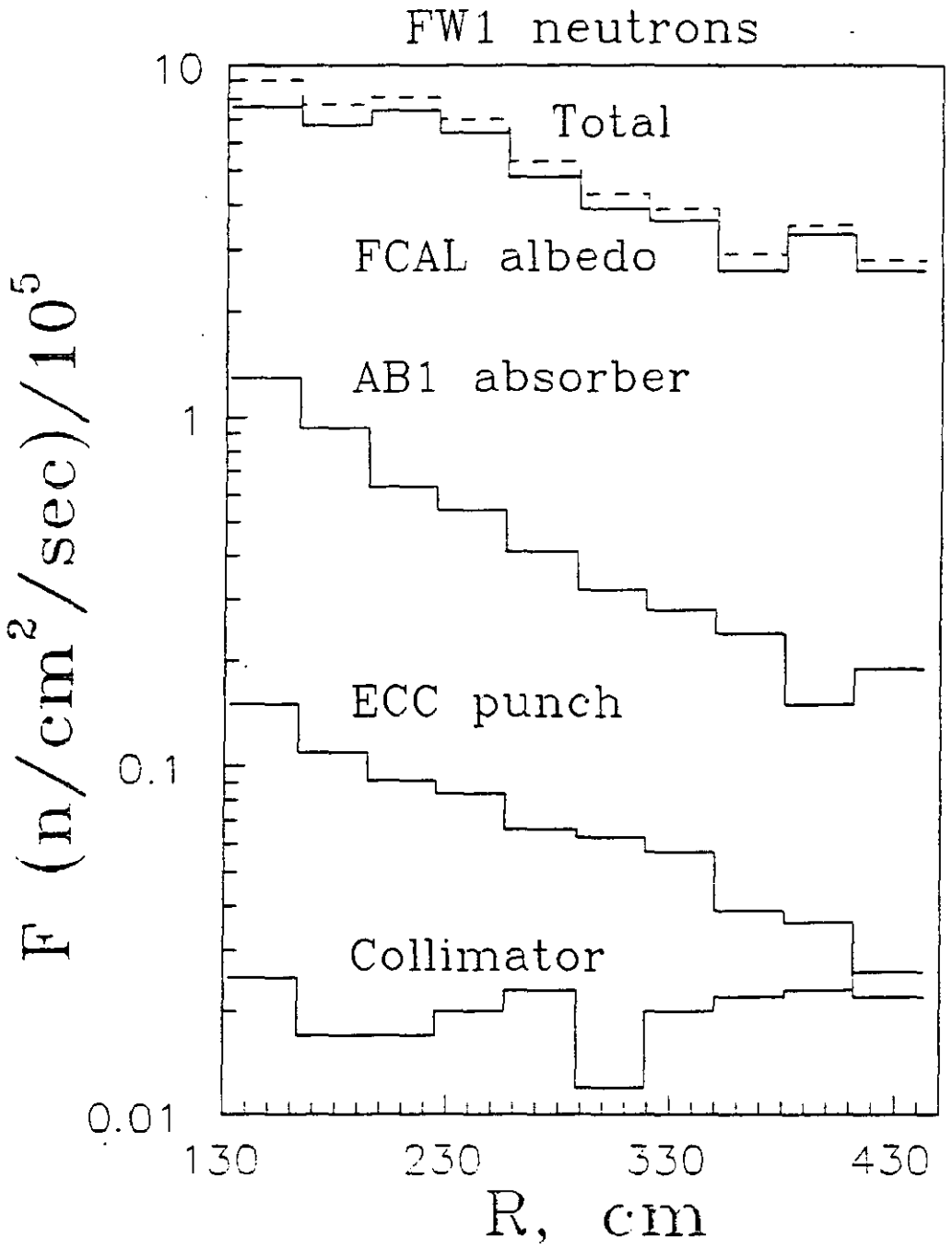


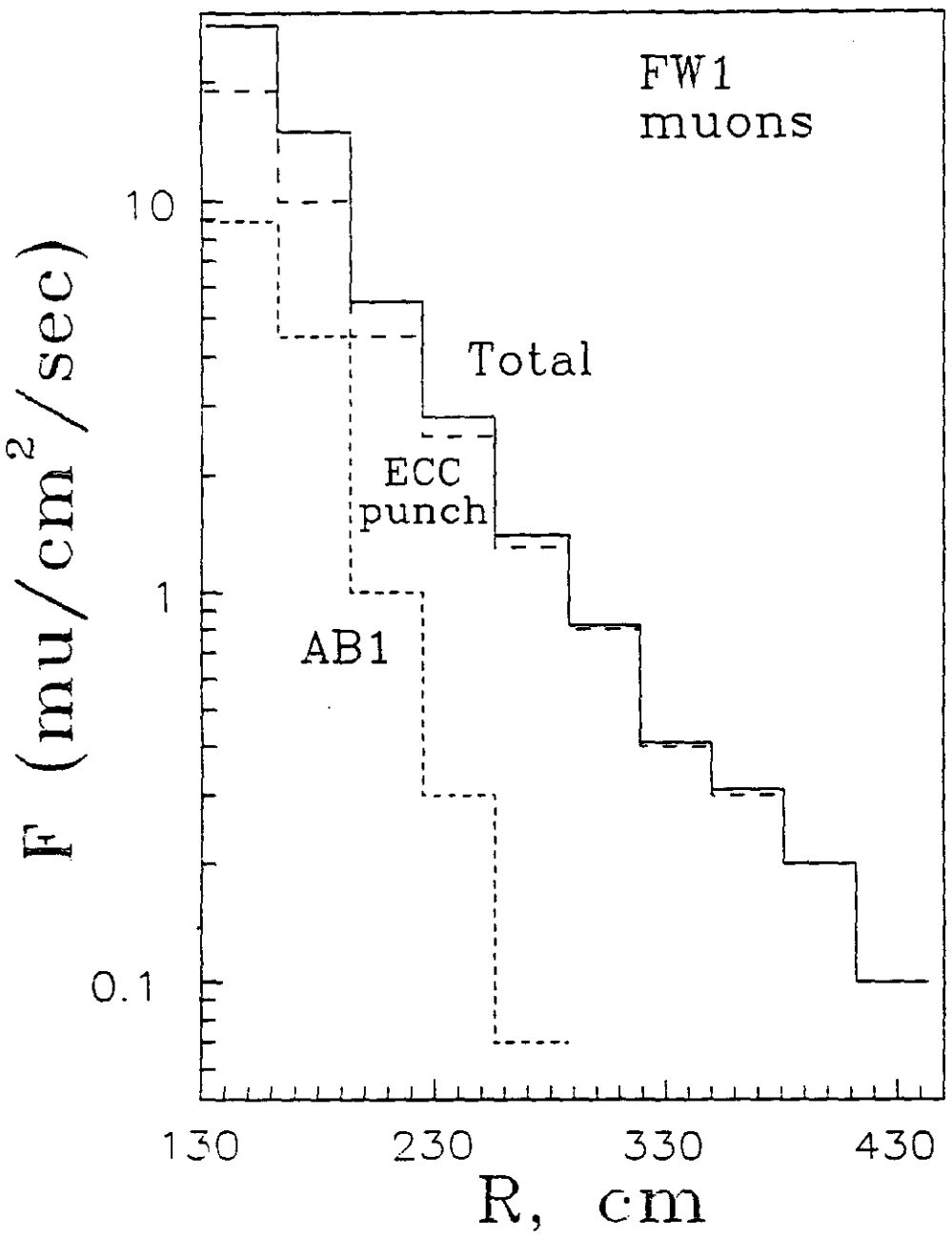
Figure 2.2: Low energy neutrons at E<20Mev with shielding (50 events).

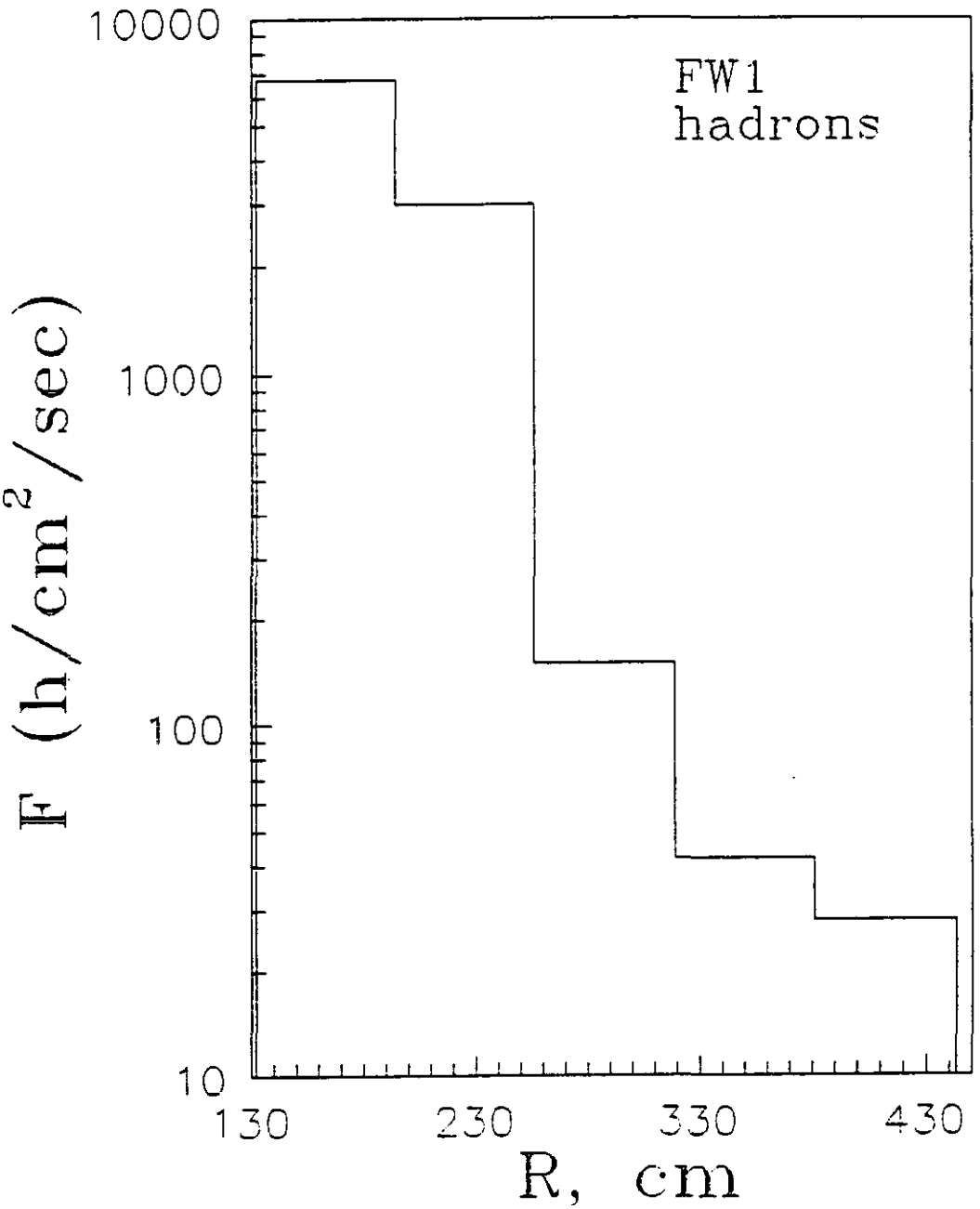


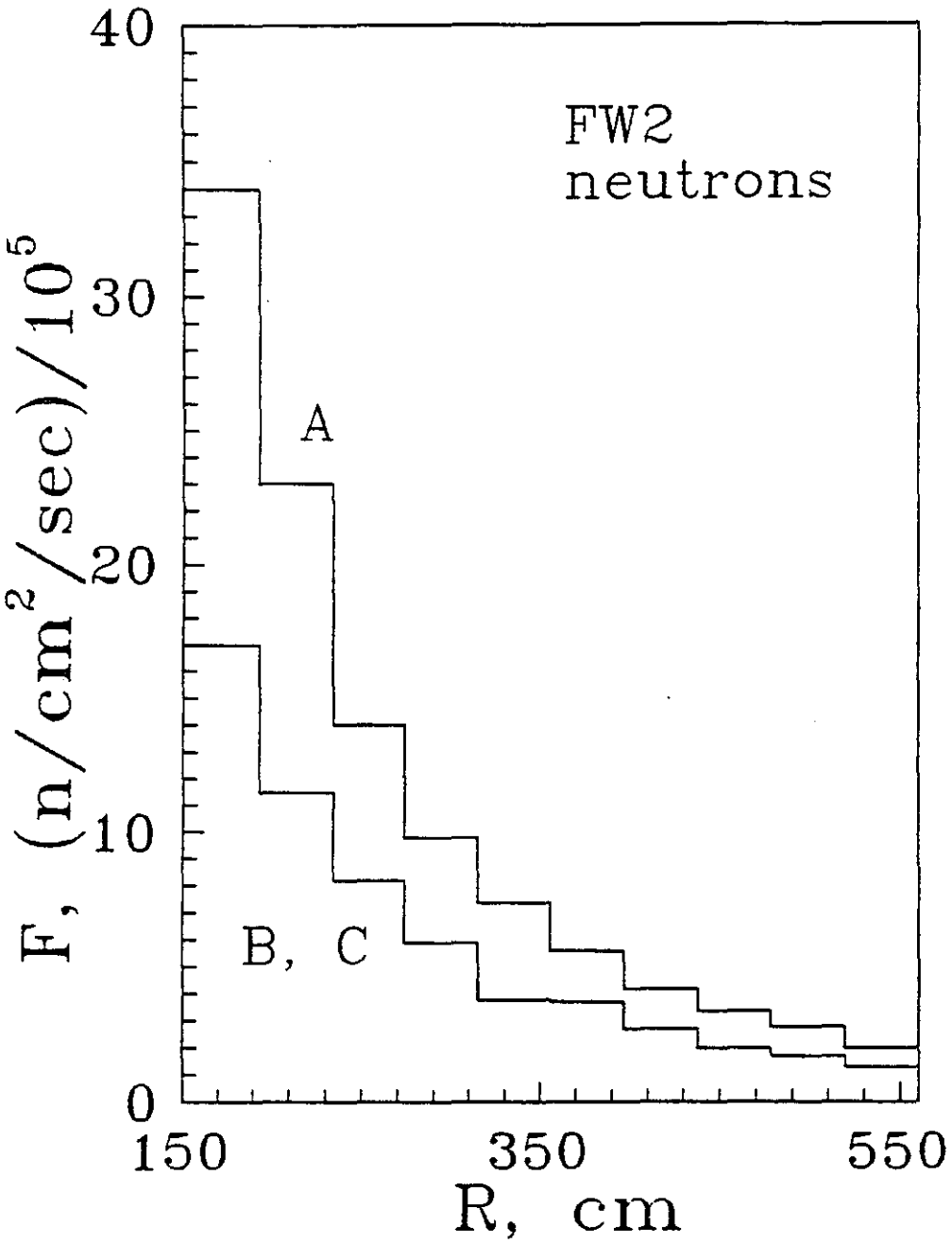
igure 2.4: mu+/- at E>50MeV (shield, inclusive scheme, 10 events).

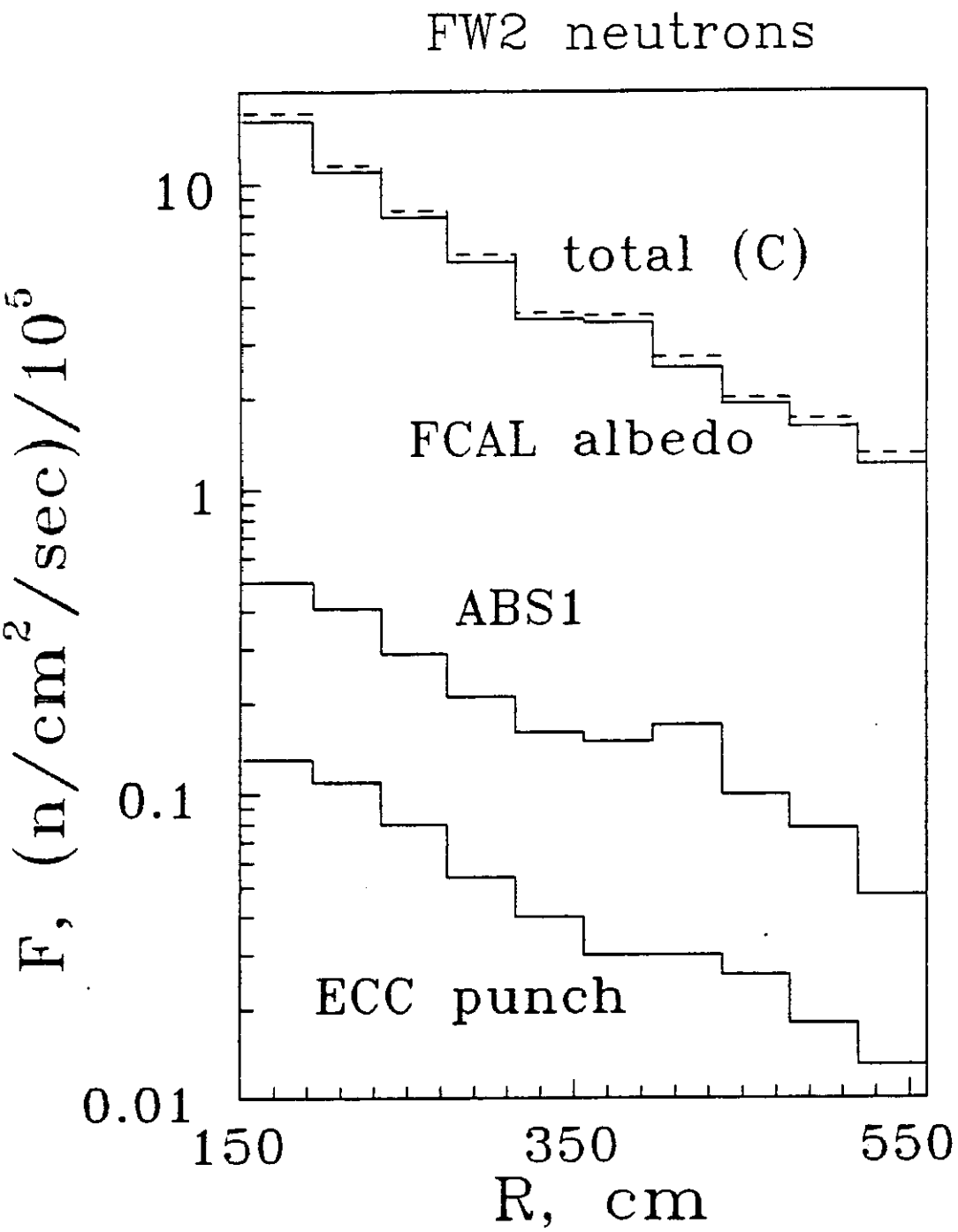

FW1
neutrons
EMAX = 10 MeV
A
B, C
F (n/cm²/sec)/10⁵
0
4
8
12
16
130
230
330
430
R, cm

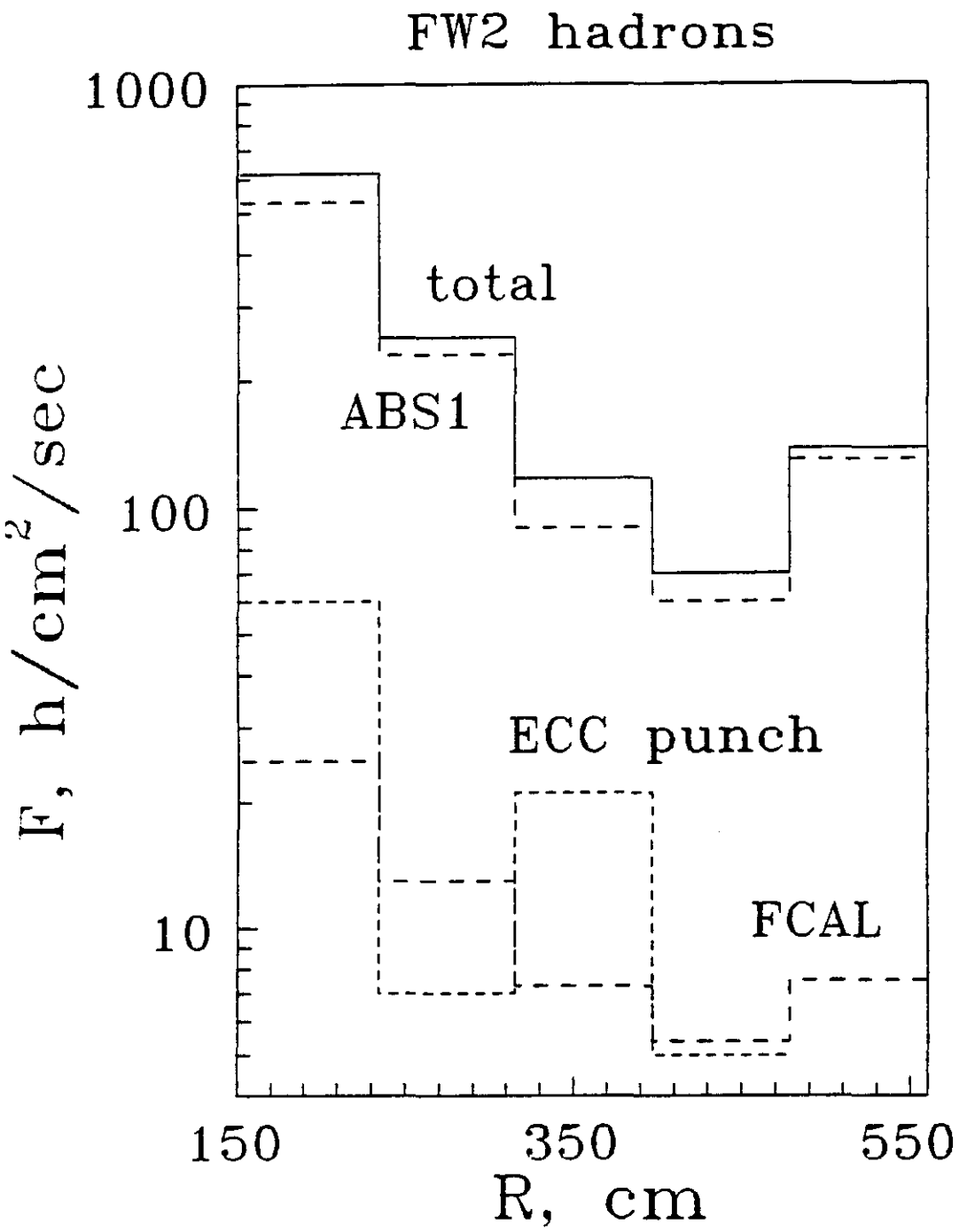

FW1 neutrons
Total
FCAL albedo
AB1 absorber
ECC punch
Collimator
10
1
0.1
0.01
130
230
330
430
R, cm
F (n/cm²/sec)/10⁵

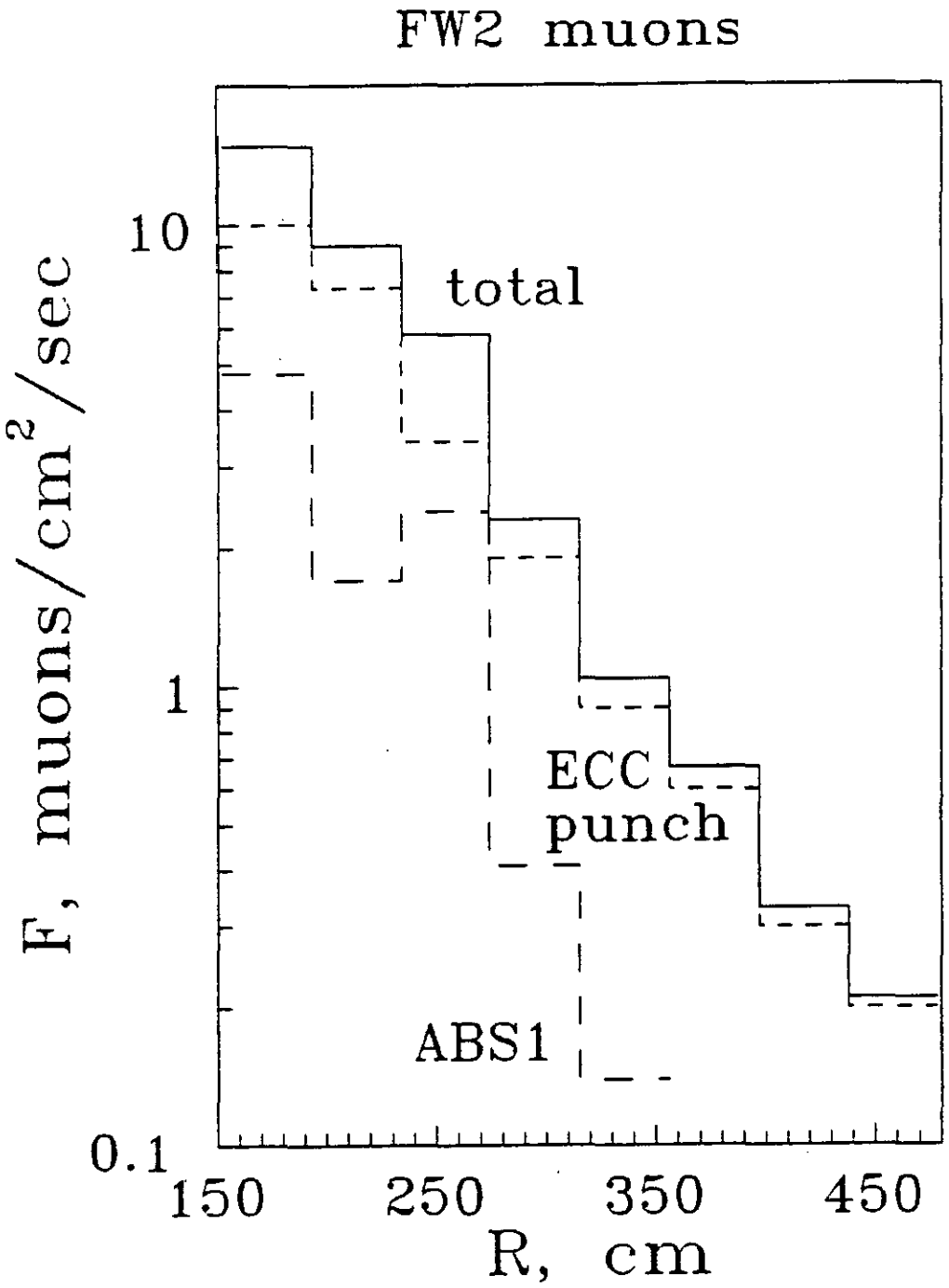

FW1
muons
Total
ECC
punch
AB1
10
1
0.1
F (mu/cm^2/sec)
130
230
330
430
R, cm

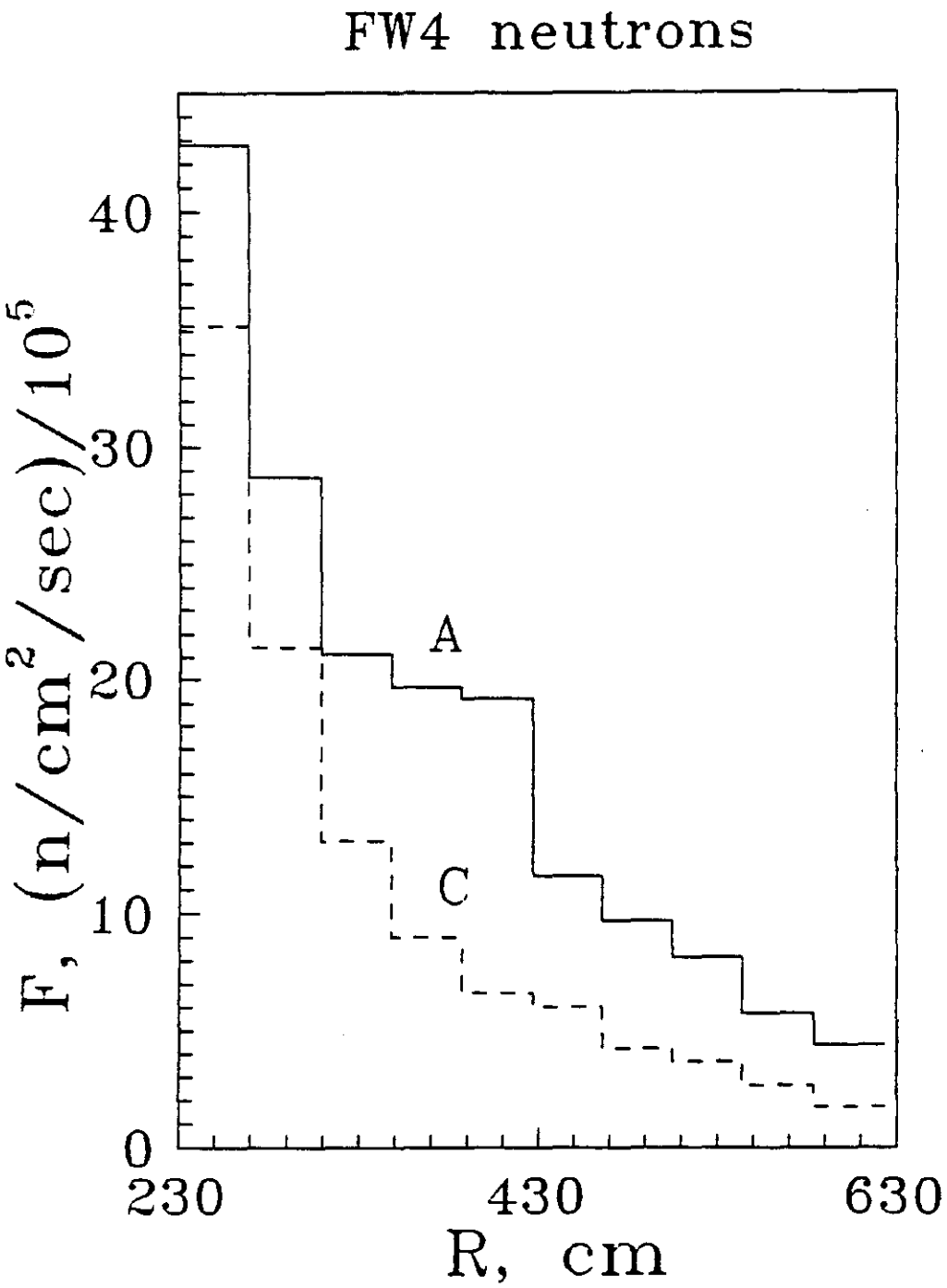

FW1
hadrons
10000
1000
100
10
F (h/cm^2/sec)
130
230
330
430
R, cm

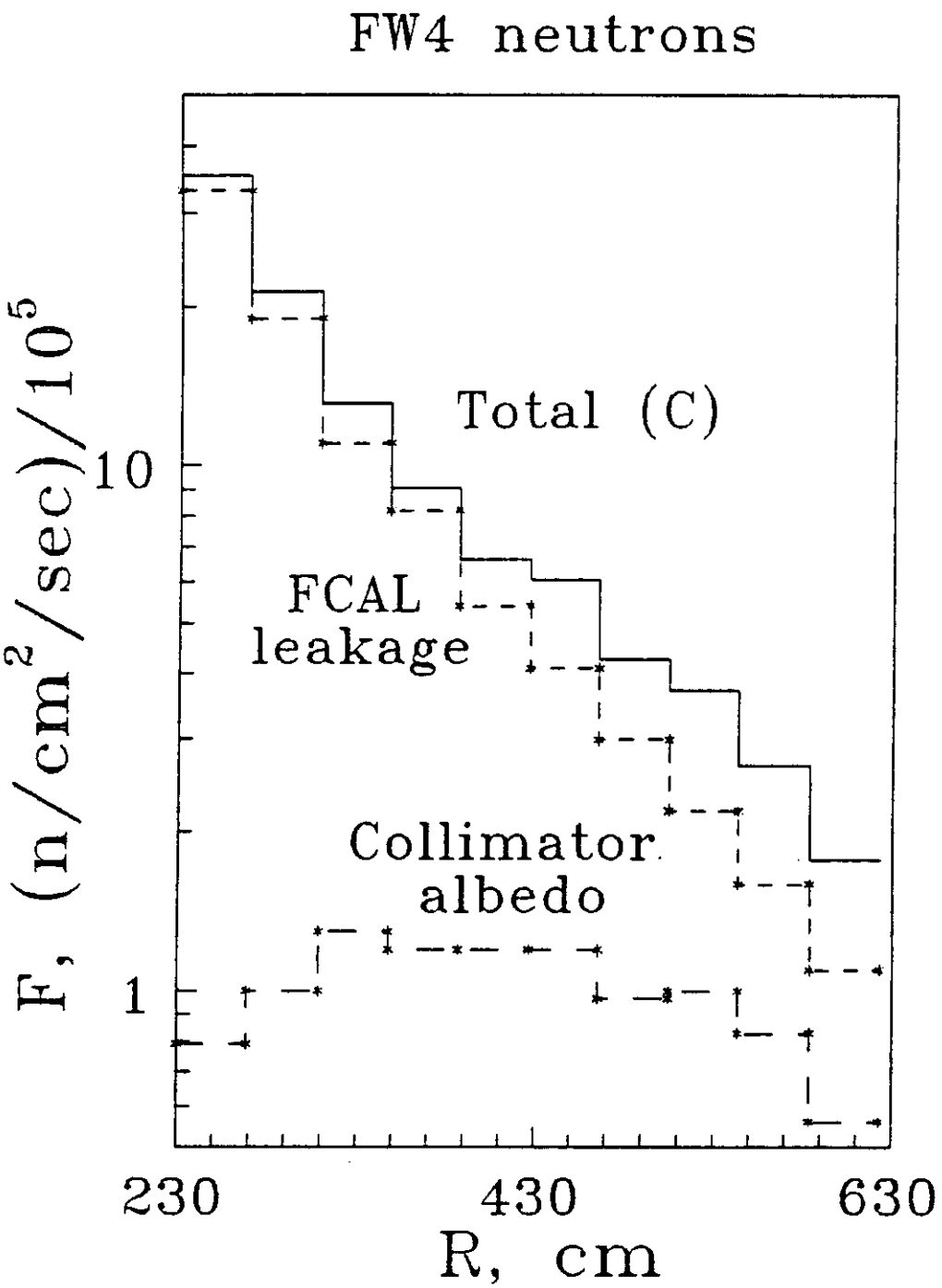

FW2
neutrons
A
B, C
40
30
20
10
0
150
350
550
R, cm
F, (n/cm^2/sec)/10^5

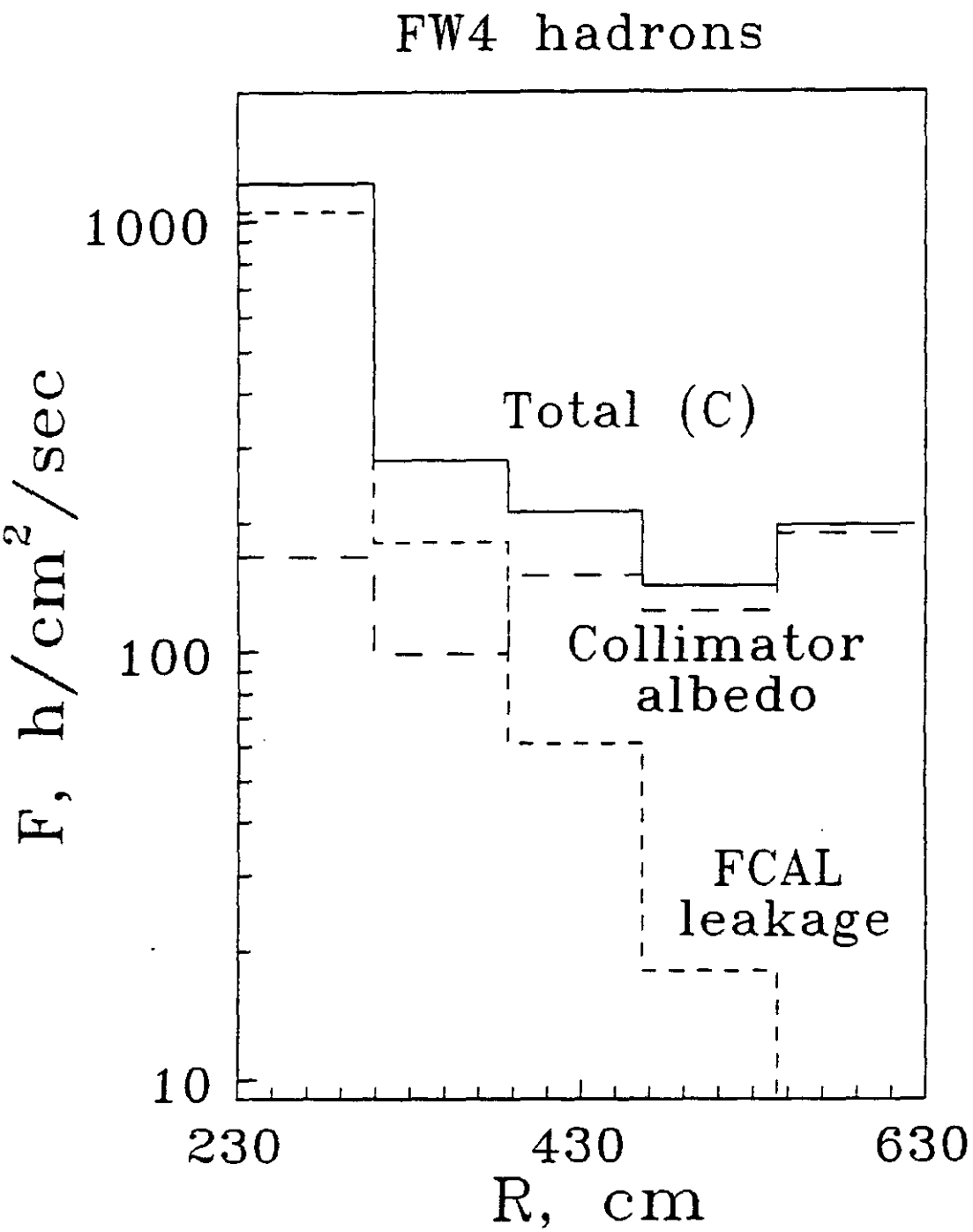

FW2 neutrons
10
1
0.1
0.01
F, (n/cm^2/sec)/10^5
total (C)
FCAL albedo
ABS1
ECC punch
150
350
550
R, cm

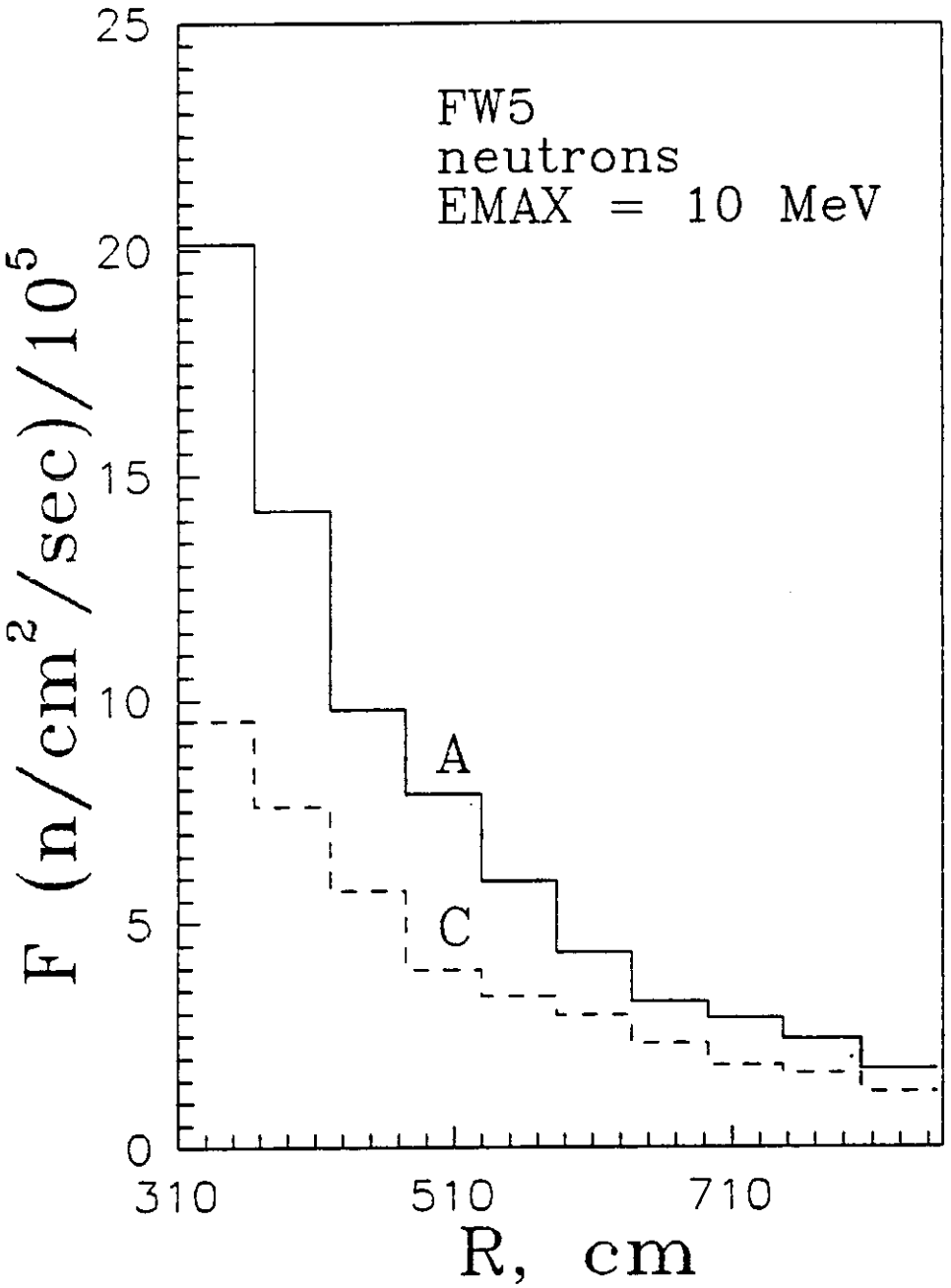

FW2 hadrons
1000
100
10
F, h/cm^2/sec
total
ABS1
ECC punch
FCAL
150
350
550
R, cm

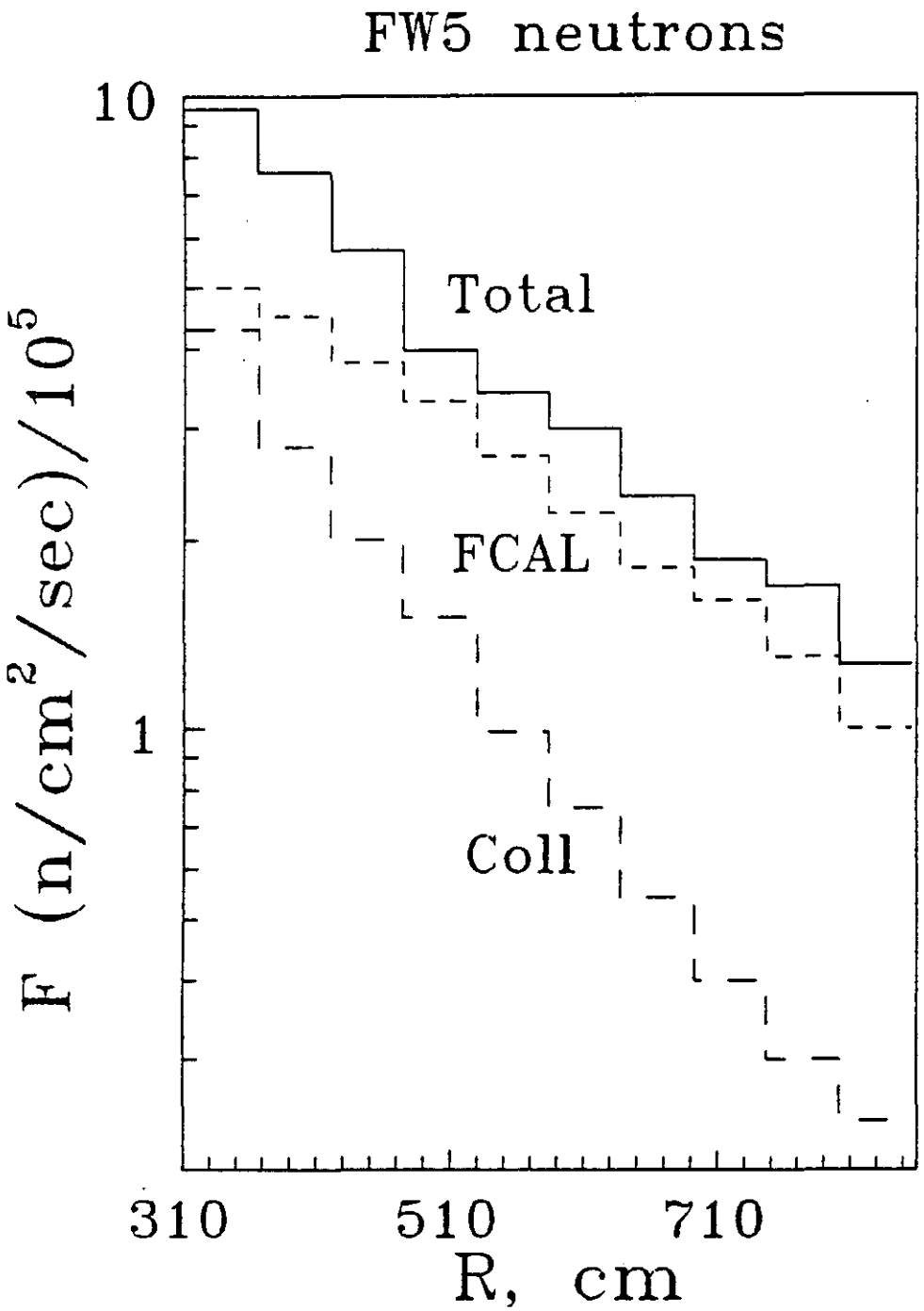

FW2 muons
10
1
0.1
F, muons/cm^2/sec
total
ECC
punch
ABS1
150
250
350
450
R, cm

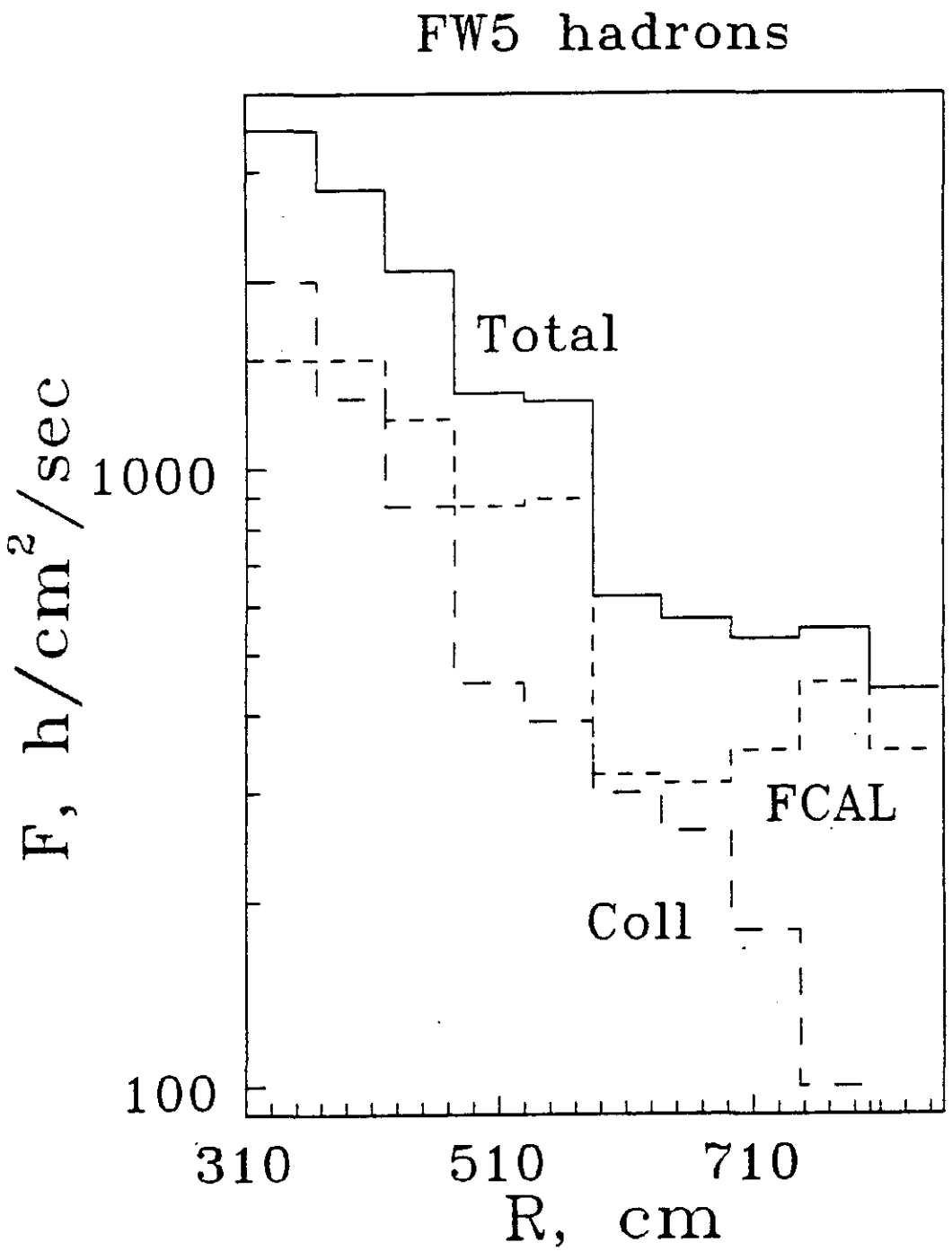

FW4 neutrons
F, (n/cm²/sec)/10⁵
40
30
20
10
0
A
C
230
430
630
R, cm

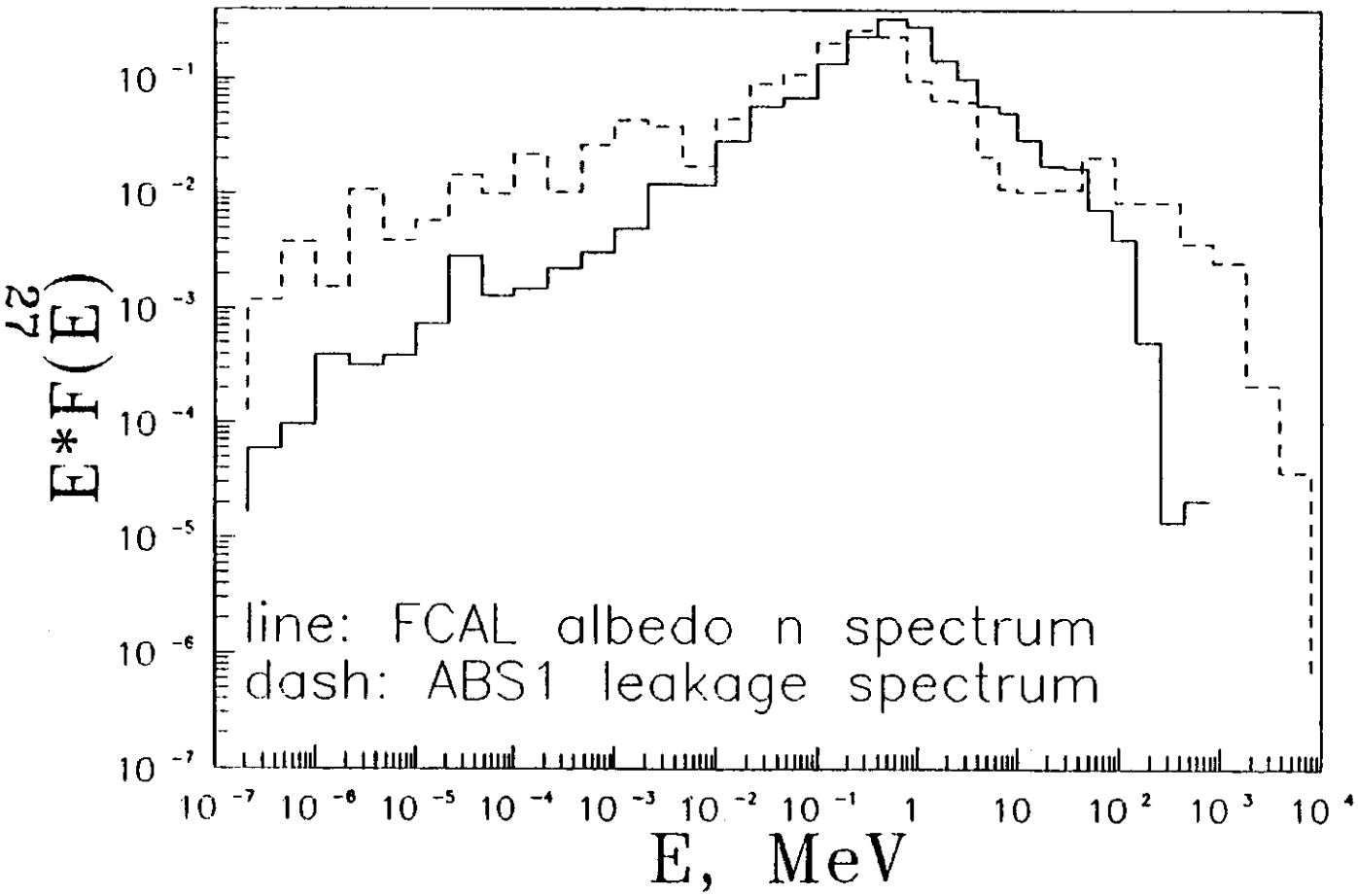

FW4 neutrons
Total (C)
FCAL
leakage
Collimator
albedo
10
1
F, (n/cm^2/sec)/10^5
230
430
630
R, cm

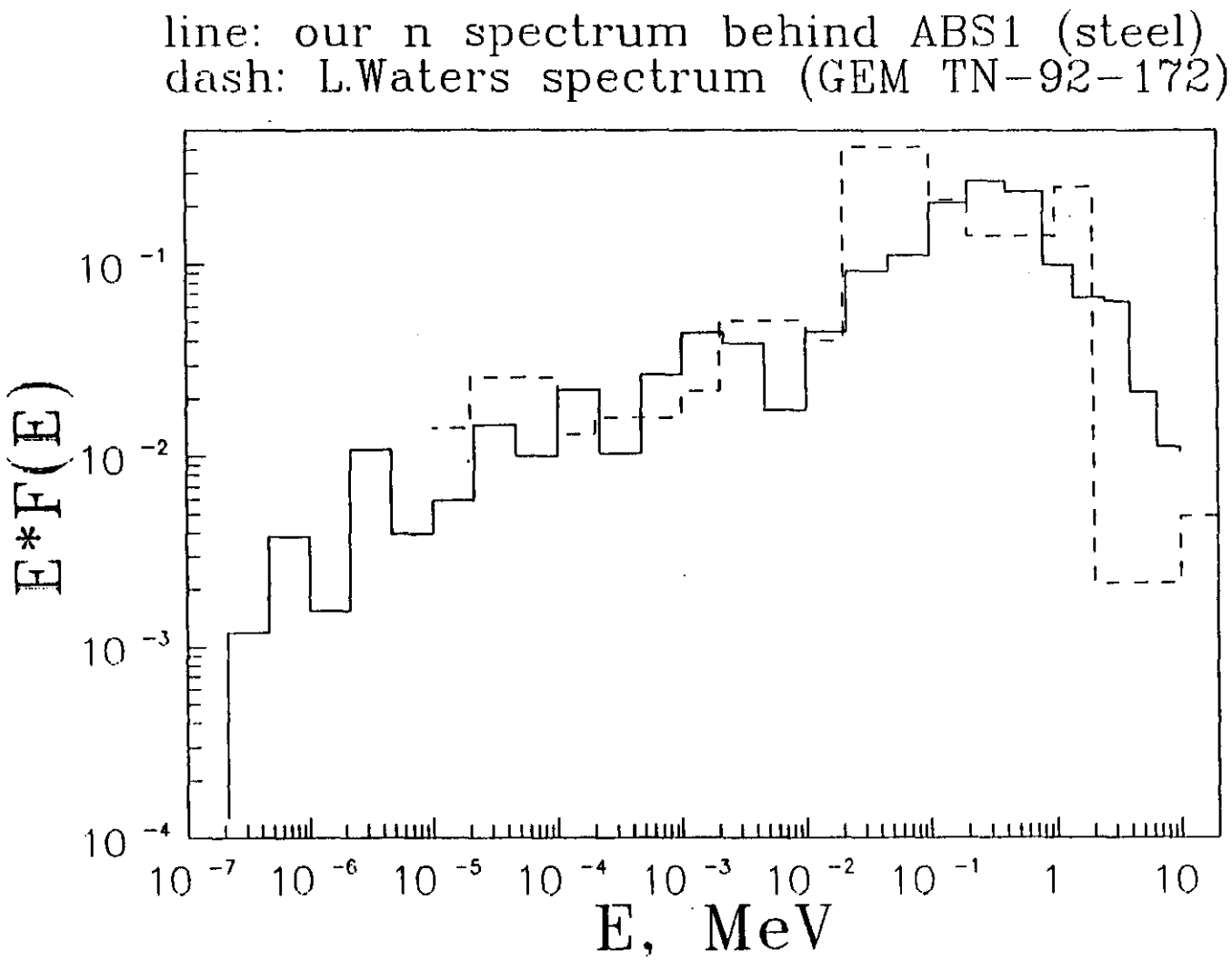

FW4 hadrons
1000
100
10
F, h/cm^2/sec
Total (C)
Collimator
albedo
FCAL
leakage
230
430
630
R, cm

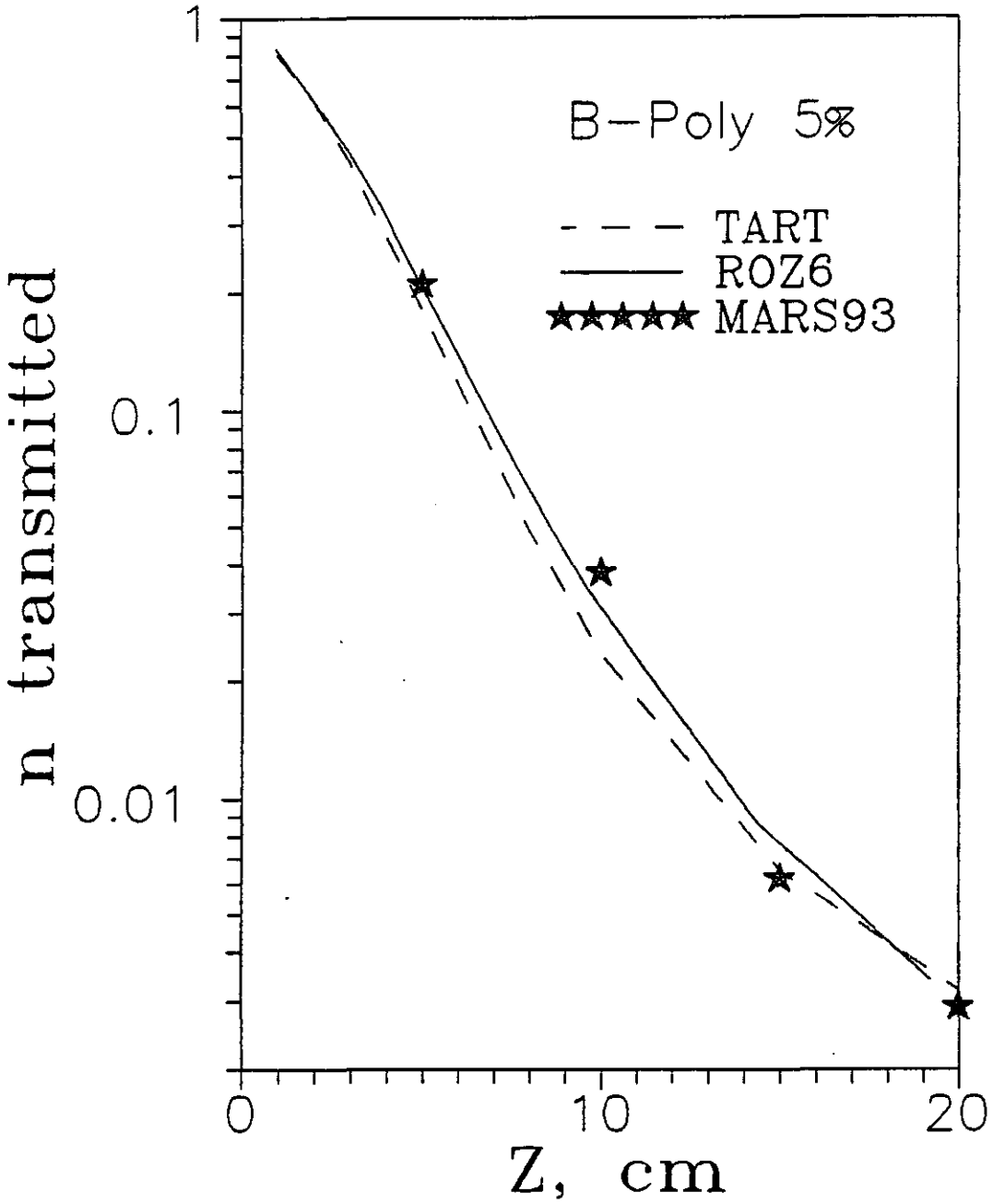

FW5
neutrons
EMAX = 10 MeV
A
C
F (n/cm²/sec)/10⁵
R, cm
0
5
10
15
20
25
310
510
710


FW5 neutrons
10
1
Total
FCAL
Coll
F (n/cm²/sec)/10⁵
310
510
710
R, cm


FW5 hadrons
Total
FCAL
Coll
1000
100
F, h/cm²/sec
310
510
710
R, cm


E*F(E)
E, MeV
line: FCAL albedo n spectrum
dash: ABS1 leakage spectrum
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10 -7 10 -6 10 -5 10 -4 10 -3 10 -2 10 -1 1 10 10 2 10 3 10 4


line: our n spectrum behind ABS1 (steel)
dash: L.Waters spectrum (GEM TN-92-172)
E*F(E)
10 -1
10 -2
10 -3
10 -4
10 -7
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
10
E, MeV


B-Poly 5%
TART
ROZ6
MARS93
n transmitted
1
0.1
0.01
0
10
20
Z, cm

SDC FMS n-spectrum

20 cm barrier

	T	A	K_T	K_A
Fe	0.40	0.55	0.015	0.06
Pb	0.28	0.71	0.003	0.007
C	0.25	0.79	0.006	0.002
Concrete	0.23	0.67	0.25	0.09
B-Conc #1 (2.5%)	0.17	0.53	0.04	0.017
B-Poly (5%)	0.01	0.26	0.32	0.019
B-Poly (20%)	0.01	0.22	0.14	0.010

T - probability to pass through barrier

A - probability "to be reflected"

$K_T = T_\gamma / T_n$

$K_A = A_\gamma / A_n$

γ-convoy estimation: $\Phi_\gamma \simeq 0.05 \cdot \Phi_n$

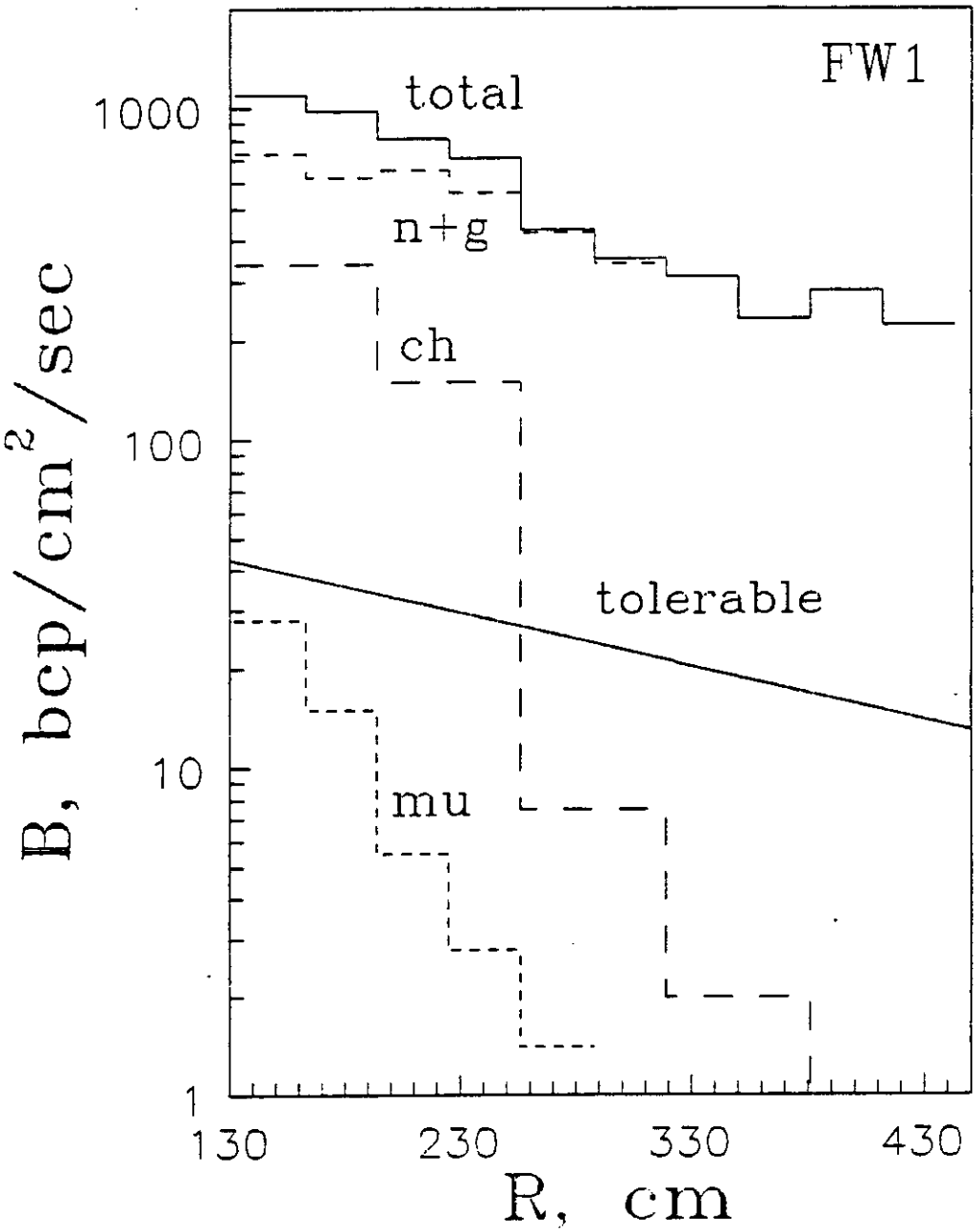
'Tolerable levels'

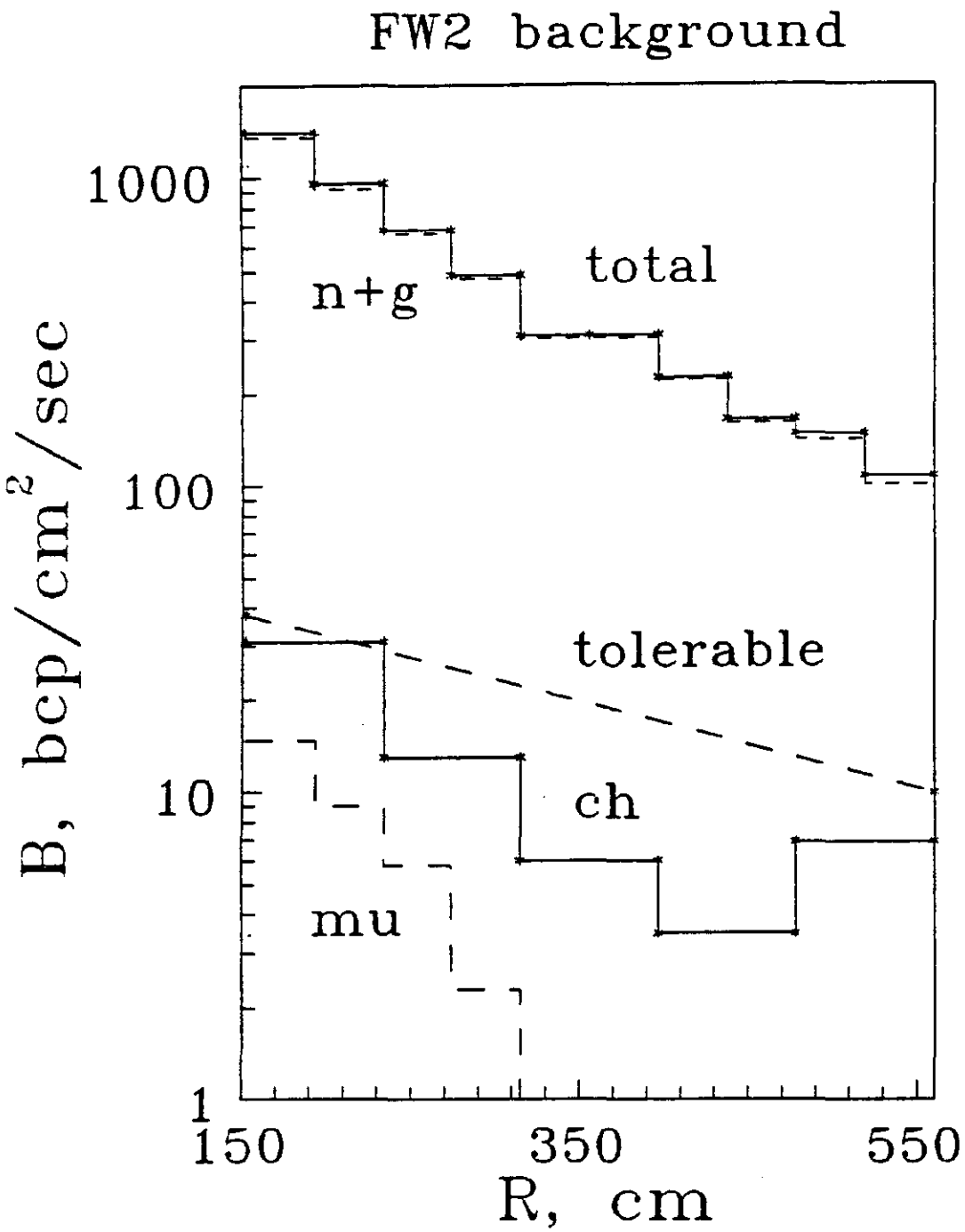
10^4 background counts per tube per sec.
Normalization to the tube volume at different R

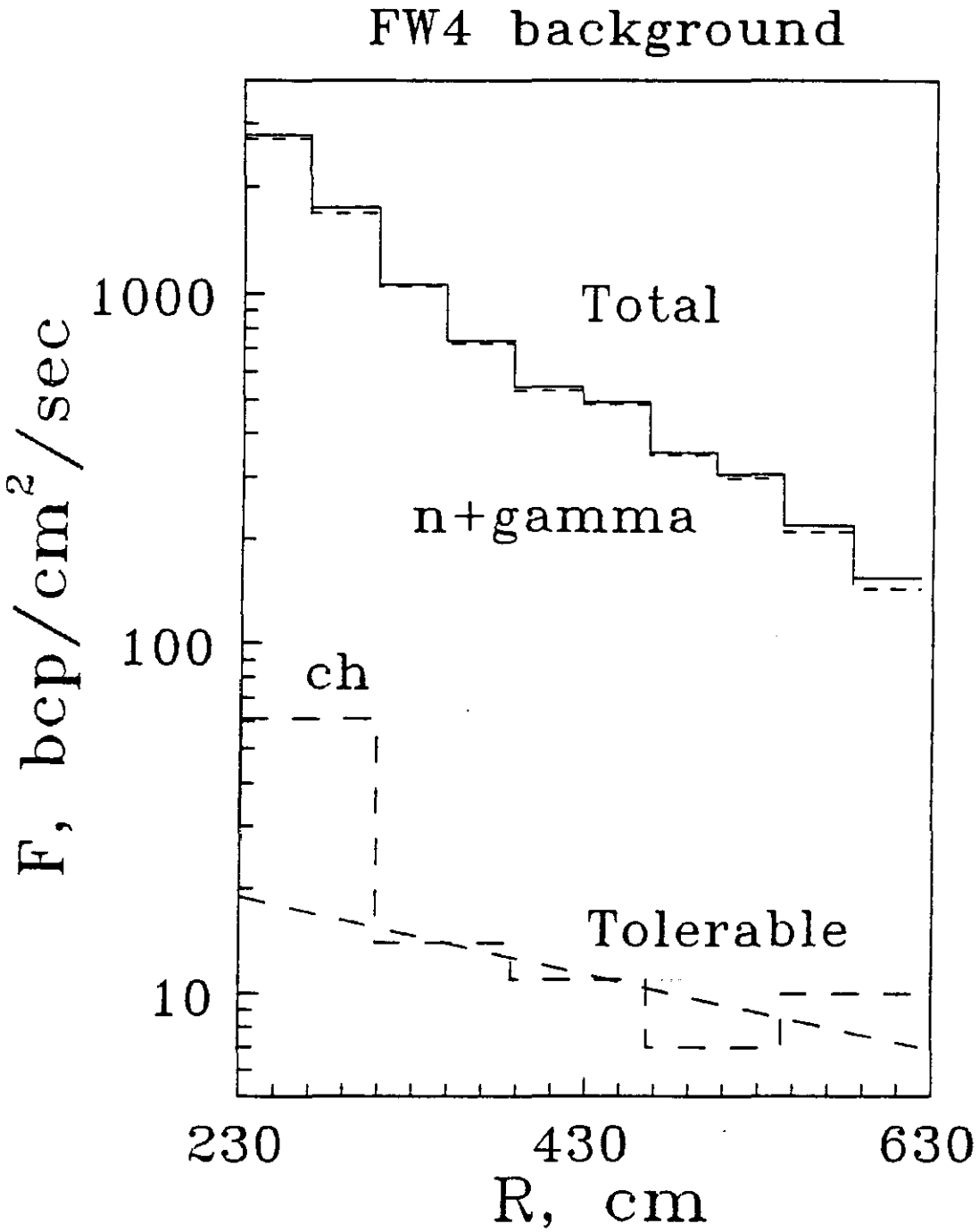
Current $\simeq$ 0.5 × Fluence (Isotropy)

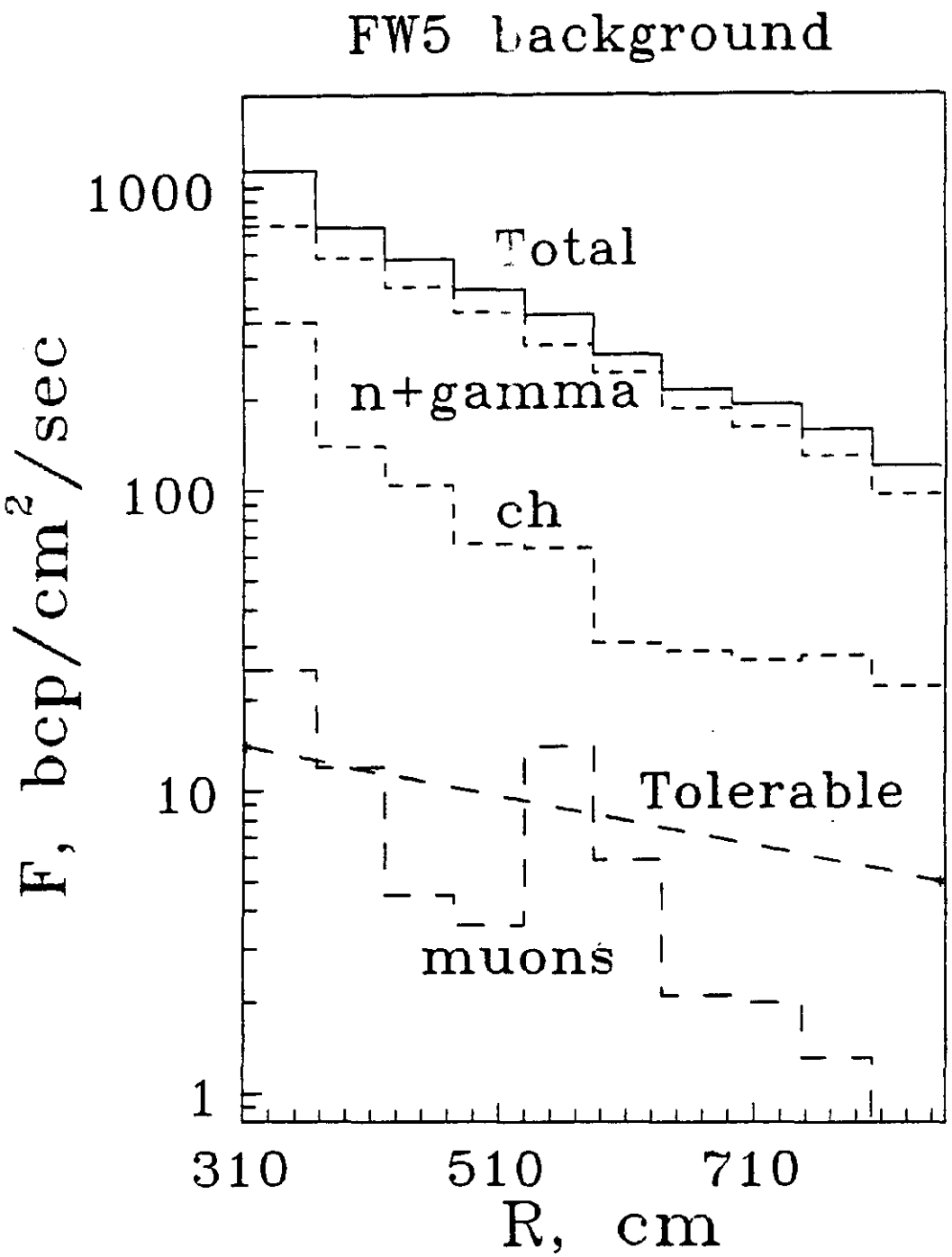
Background Count Particles

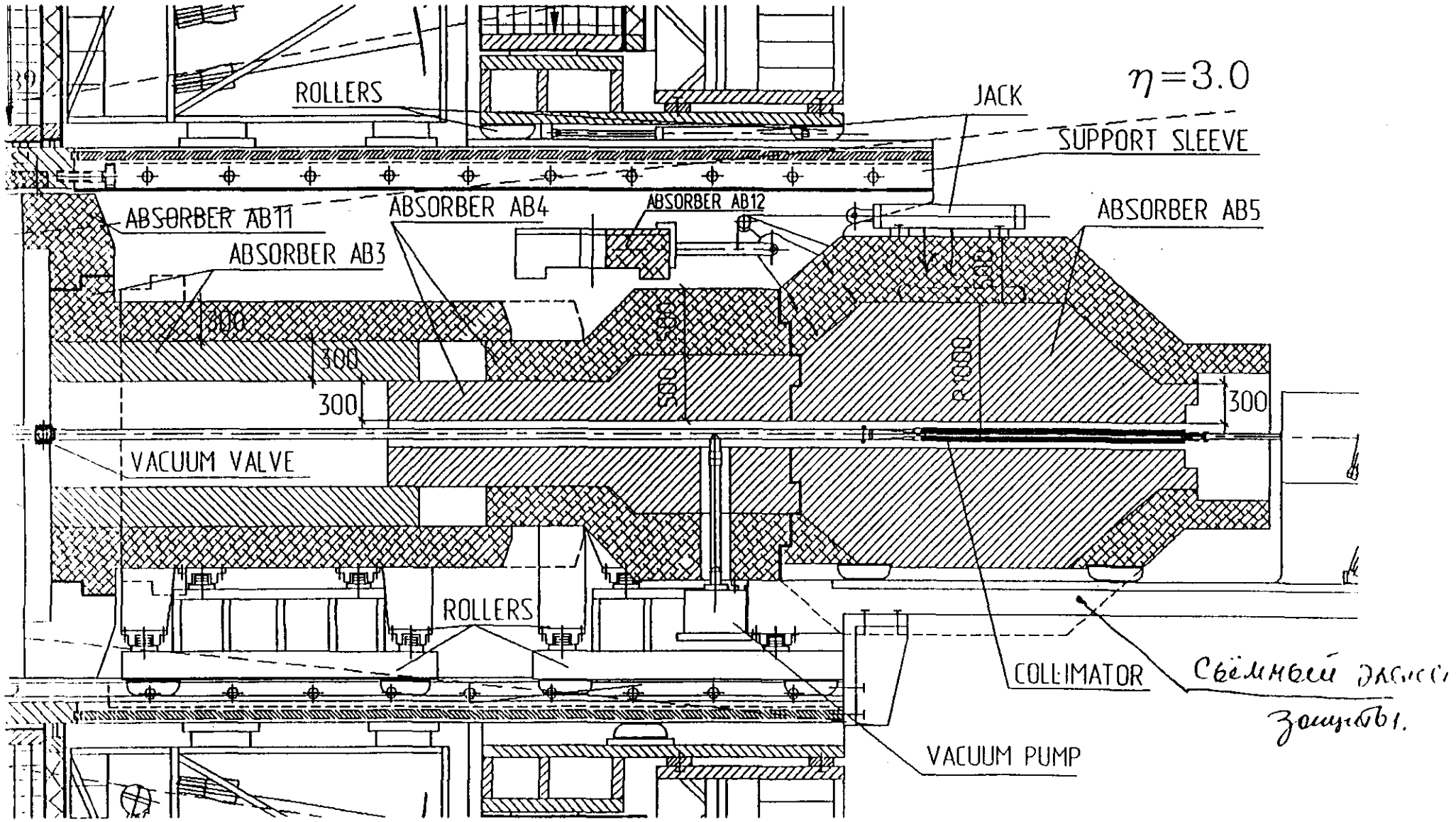
1 muon = 1 ch. hadron = 1 e = 1 b.c.p.
1 neutron has 0.05 γ-convoy
1 γ = 0.01 b.c.p.
$\Rightarrow$ 1 n = $3 \cdot 10^{-4} + 0.05 \cdot 0.01 = 8 \cdot 10^{-4}$


FW1
total
n+g
ch
tolerable
mu
1000
100
10
1
130
230
330
430
B, bcp/cm^2/sec
R, cm


FW2 background
1000
100
10
1
150
350
550
R, cm
B, bcp/cm^2/sec
total
n+g
tolerable
ch
mu


FW4 background
1000
100
10
F, bcp/cm^2/sec
Total
n+gamma
ch
Tolerable
230
430
630
R, cm

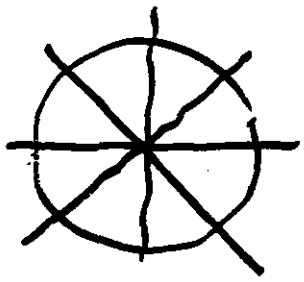

FW5 background
1000
100
10
1
F, bcp/cm^2/sec
Total
n+gamma
ch
Tolerable
muons
310
510
710
R, cm


η=3.0
ROLLERS
JACK
SUPPORT SLEEVE
ABSORBER AB11
ABSORBER AB4
ABSORBER AB12
ABSORBER AB5
ABSORBER AB3
300
300
300
300
300
300
VACUUM VALVE
ROLLERS
COLLIMATOR
Съёмный экран
защиты.
VACUUM PUMP

CONCLUSIONS

1) FCAL position & design are extremely important

2) Additional shield:
   - anti-albedo covering
   - local shield
   - chamber design (16-sectors)



gem

γeμ

Presentation by:

V. Uzunian

The shield of SDC elements from low energy n, γ Background.

(The main physical processes and experimental results)

I. Azhgirey, G. Krupny, A. Kuznetzov, V. Peleshko,
A. Uzunian, I. Kurochkin
(Institute for High Energy Physics) Protvino

L. Trykov, Ju. Kolevatov, V. Volkov
(Institute for Power Energy Physics) Obninsk

contents

* problems
* n, γ radiation
* n, γ calculations for different materials
* experimental device and exp. results of n, γ attenuation. Comparison with calculations
* conclusions

The SDC experimental facility with point of view radiation problems represents a bulk of the heterogeneous mass of iron and organic materials. In this conditions during hadronic and electromagnetic cascades initiated by particles from IP a lot of low energy secondary neutrons and gammas are generated.

It was shown by our calculation results, that low energy neutrons and gammas (via (n,γ)-reactions) give considerable contribution to background at SDC detector elements.

For 10^{33} SSC luminosity we have expected in to the SDC forward muon system (without using a special shielding design):

<u>average flux</u>

<u>neutrons</u> with energy less than 20 MeV up to the thermal energy $\sim 5\cdot 10^{5}\ n\cdot cm^{-2}\cdot s^{-1}$

<u>gammas</u>

$0.1\ MeV < E_\gamma \leq 8\ MeV$

$\bar{E}_\gamma \approx 3\ MeV$ $\qquad \sim 10^{4}\ \gamma\cdot cm^{-2}\cdot c^{-1}$

Our estimations give us:

registration efficiency (ε) of muon tube

- to neutrons $\varepsilon_n \sim 2\cdot 10^{-5} \div 2\cdot 10^{-4}$
  (for different types of neutron spectra)
- to gammas $\varepsilon_\gamma \sim 1\cdot 10^{-2}$

Tolerable counting level of muon-tube is ~ 10 counts per cm^2 per second. Like that we shall have problems with neutrons and gammas.

It is well know that the main processes of photons production are the following:
(in energy range of neutrons below ~ 10 MeV)

- radiation capture

$$ {}_{Z}F^{A} + {}_{0}n^{1} \longrightarrow {}_{Z}F^{A+1} + \gamma $$

- inelastic scattering

$$ {}_{Z}F^{A} + {}_{0}n^{1} \longrightarrow ({}_{Z}F^{A})^{*} + ({}_{0}n^{1})^{1} $$

excited nucleus

$$ ({}_{Z}F^{A})^{*} \longrightarrow {}_{Z}F^{A} + \gamma $$

The effectiveness of neutron attenuation and photon generation is a function of the amount of Boron and hydrogen in the shielding material.
Hydrogen moderates neutrons (due to elastic scattering) and Boron is povided neutron capture.
The effectiveness of photon attenuation is provided by heavy nuclei presence.

For neutron/photon transport we used one-dimensional transport code ROZ6, using 49×15 constants system and Monte Carlo code MARS93, using 28 groups constants system for neutron transport and gamma production.

Our calculations for neutrons attenuation and photon generation in Borated polyethylene is in a good agreement with calculations By Craig R. Wuest (transport code TART, GEM TN-92-172)

We developed the technology for production of radiation shielding material on the Basis of concrete with Boron coutamination and different Boron/hydrogen ratio. These materials have same advantages (as compared with polyethylene):

- it's cheap;
- it's easy used to make any shielding unit configuration;
- it's non-flammabel.

The experimental testing of neutron attenuation efficiency was performed on Cf-252-neutron source.

Experimental Layout

We chose the following parameters on the Basis of our calculations:

- neutron sourse - Cf-252 with intensyty - 10^9 n/s;
- heterogeniouds filter for Cf-252 to form the test neutron field. The filter composition are steel lead, carbon.

The geometry of experiment is shown in figure.

Detectors

For the measurements of neutron and gamma fluxes and spectra we are used two kinds of spectrometers:

1. Multysphere Bonner spectrometer with scintillation detector of thermal neutrons (cristal $^{6}LiJ(Eu)$ φ $10\times10 mm^3$). The set of polyethylene spheres was: 2, 3, 5, 8, 10 and 12 inches in diameter. Each sphere was covered by 1mm thick cadmium.
2. Scintillation neutron/gamma spectrometer (cristal of stylbene, φ $40\times20 mm^3$) with the n/γ separation on the shape of output signals.
   (L. Trykov, Ju. Kolevatov, V. Volkov, preprint IPEP-1730, 1985, Obninsk)

Results of measurement

The measured and calculated spectra of neutrons that incidented on testing shielding material is shown in fig.

The attenuation curves of neutrons for the Boron and standard concrete are shown in fig.
The curves are normalized to total incident flux.

It is necessary to note that starting from depth ~ 15cm of experimental layer we noticed the influence of scattered neutrons. In this case we had the neutrons leakege from surrourding concrete in to the detection point. Unfortunately, we could not remove the neutron background when we have tested the borated concrete. Therefore the discrepancy between experimental and calculational results is present.

Conclusions

We got the attenuation curves, using the expected neutron spectra on the forward muon system (behind the steel shield), for following materials:

- Bet1 : Boron (B) - 2.5%, H - 0.4%
- Bet2A : B - 2%, H - 1.8%
- Bet2B : B - 1.4%, H - 3.7%
- polyethylene 1 : B - 5% H - 11.6%

} weight percent

material	neutron attenuation length, cm		neutron/gamma ratio behind 30cm depth of material	density g/cm³
	5<Z<15	Z>20cm		
„Bet1"	10.5	10	15	2.14
„Bet2A"	7.5	8	5	1.7
„Bet2B"	5.5	7.5	2.3	1.35
polyethylene1	3.5	7	1	0.94

By this means the borated polyethylene has the best capacity to attenuate the low energy neutrons and gives the little output of photons. But Bet2B material is competitive with polyethylene, and has some advantages:

- it is cheap;
- it is easy used to make any shielding configuration;
- it is non-flammabel.

At present time we are ready to poduce this material and to provide the lowering low energy neutrons and gammas background on the forward muon system.

! show the crazy concrete !

The problem of muon system shield from neutron/photon background, in our opinion, may be done completely by three stages.

First stage: - the experimental and calculational determination of real detector (muon tube, scintillator, ...) efficiency to low energy neutrons and gammas separatly.
The experimental measurements may be perfomed on radionuclide neutron and gamma sources.
There is only problem to create neutron fields with negligible gamma contribution (the ratio n/γ should be $\gtrsim 100$).
We have some ideas how to do this.

Second stage: - the choice of convenient shielding materials (effective, cheap, non-flammable, durable etc.) using the experimental and calculational methods. This stage includes also the experimental testing of attenuation efficiency of shielding materials on radionuclide neutron source.

Third stage: - the performance of the model experiment in similar to SDC conditions. This study may be done at IHEP accelerator at ~ 50 GeV hadron energies.

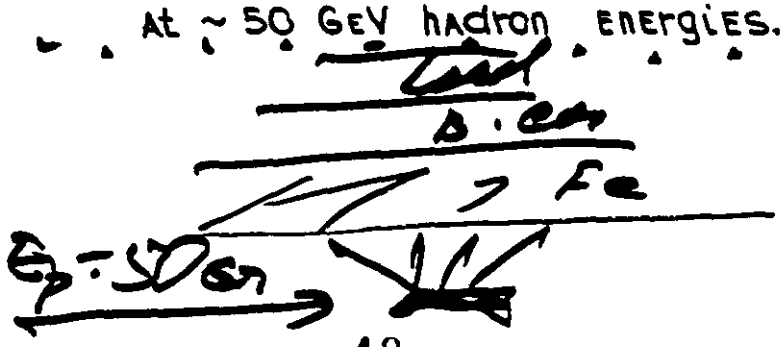
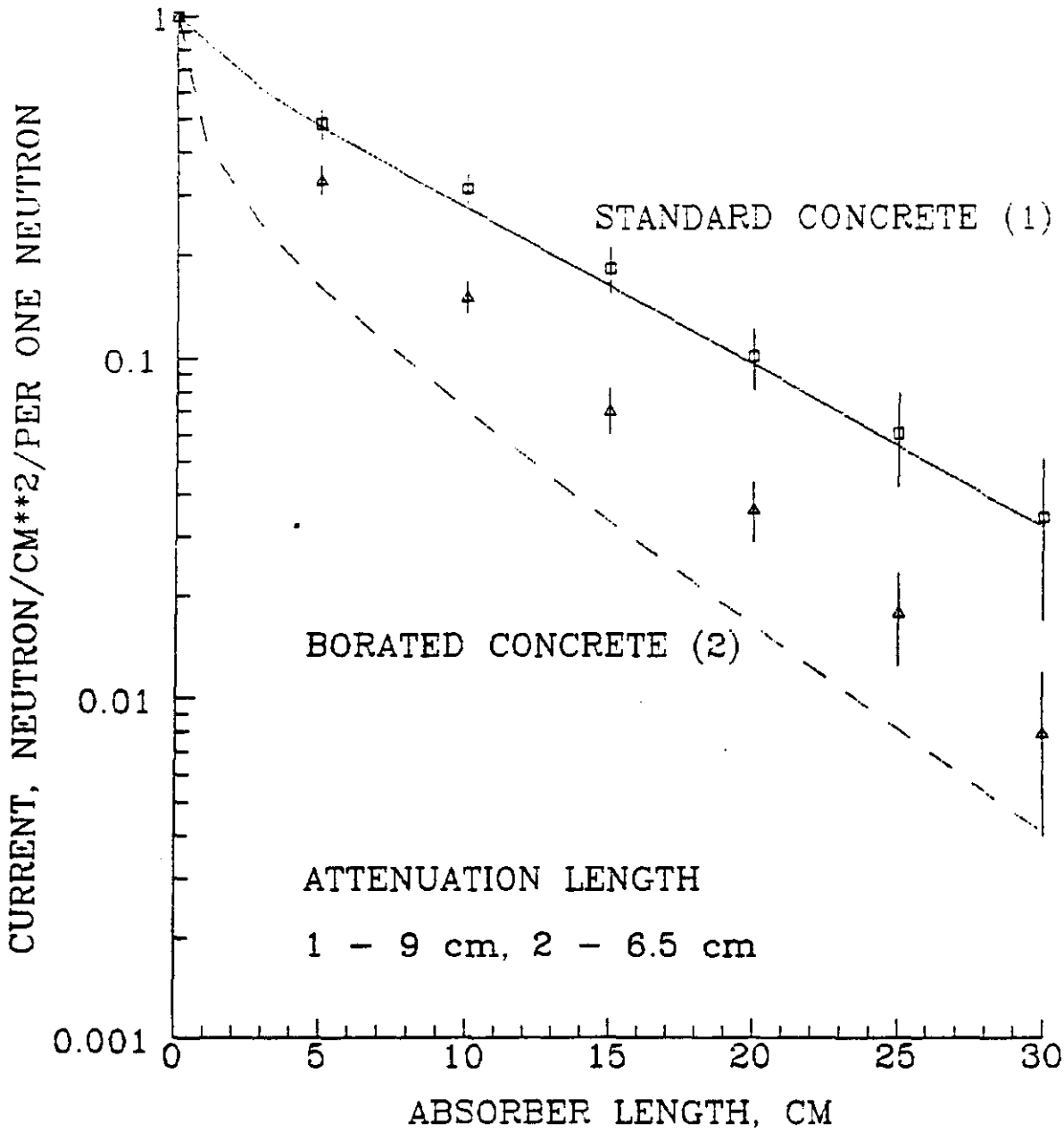
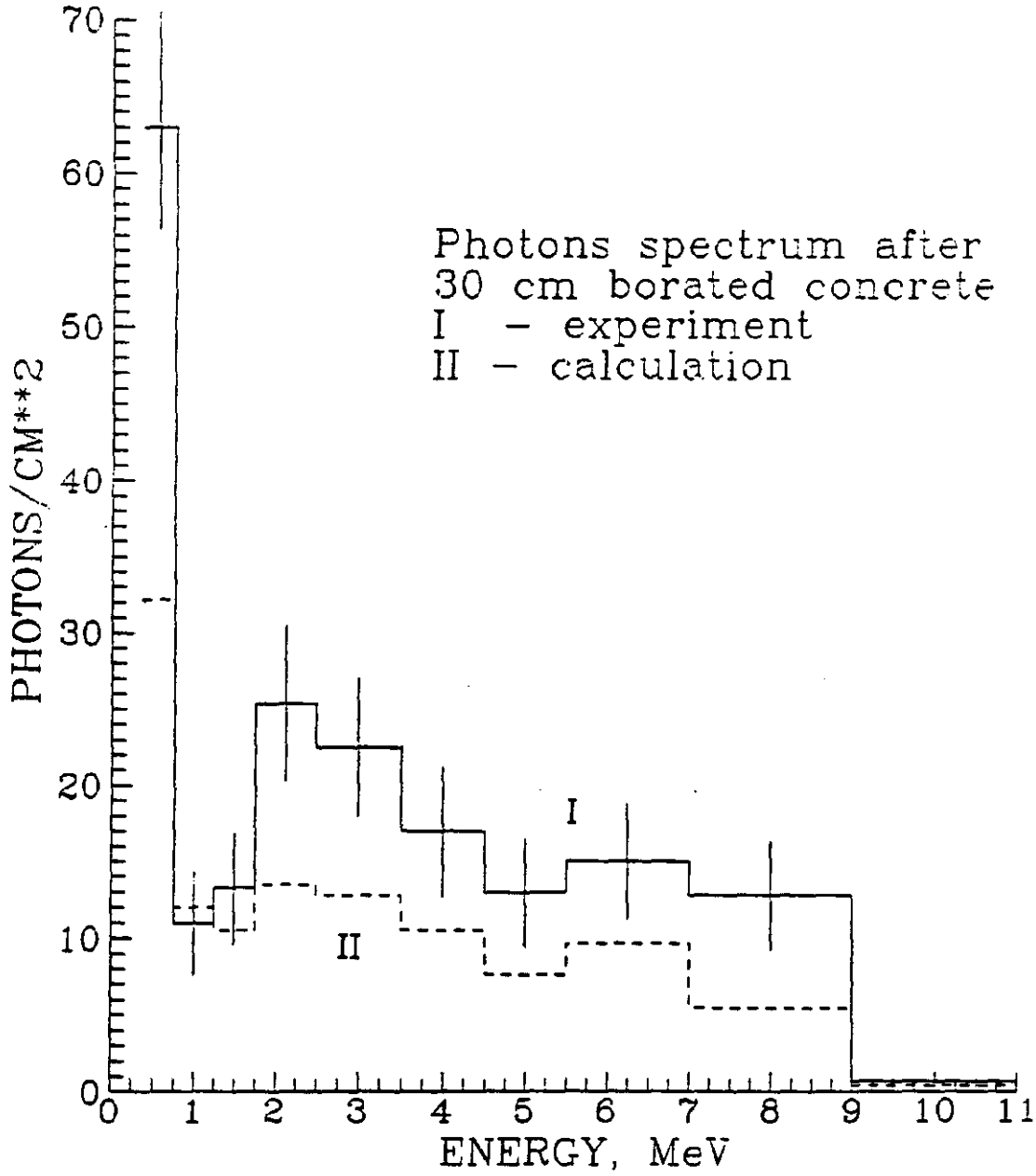
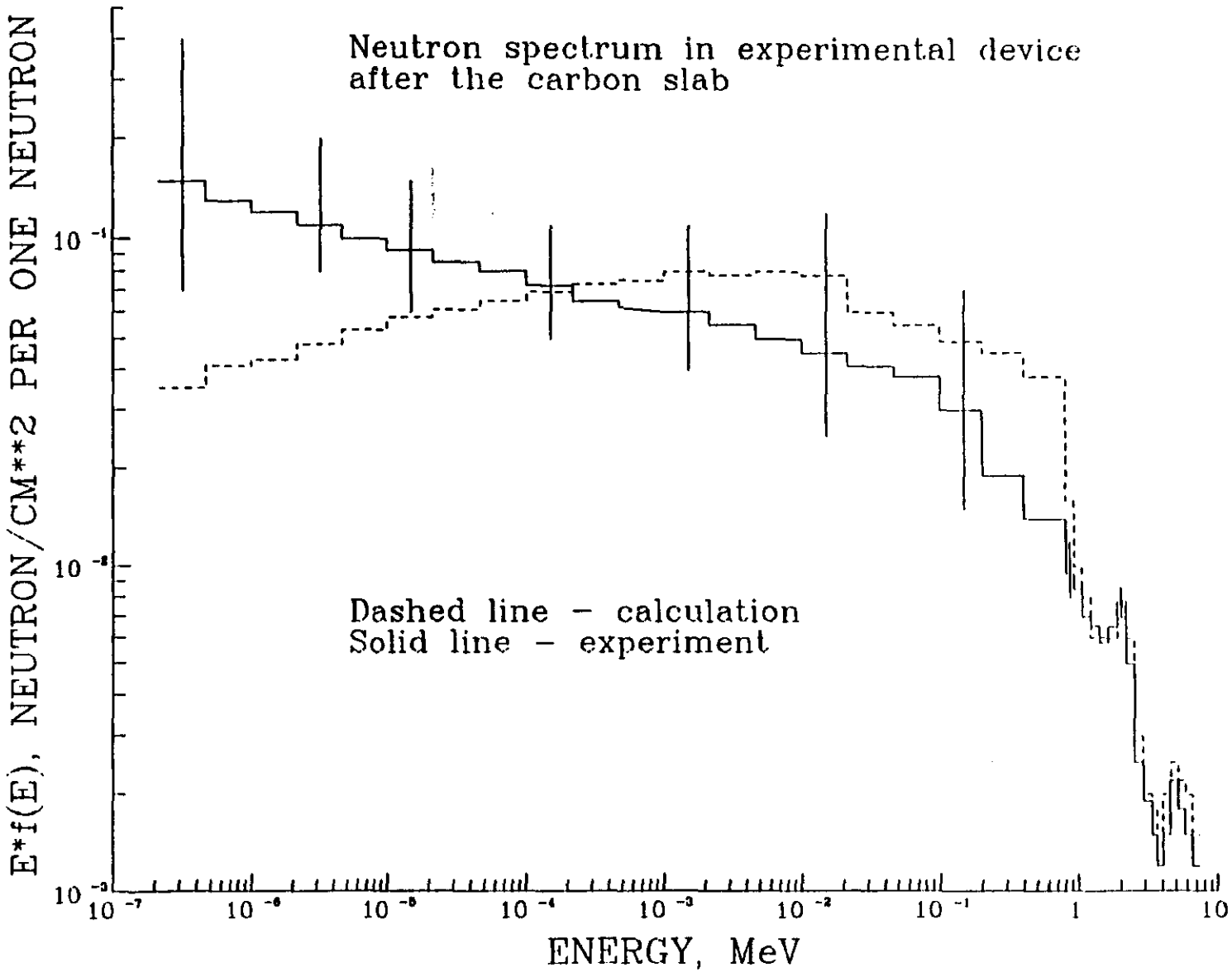


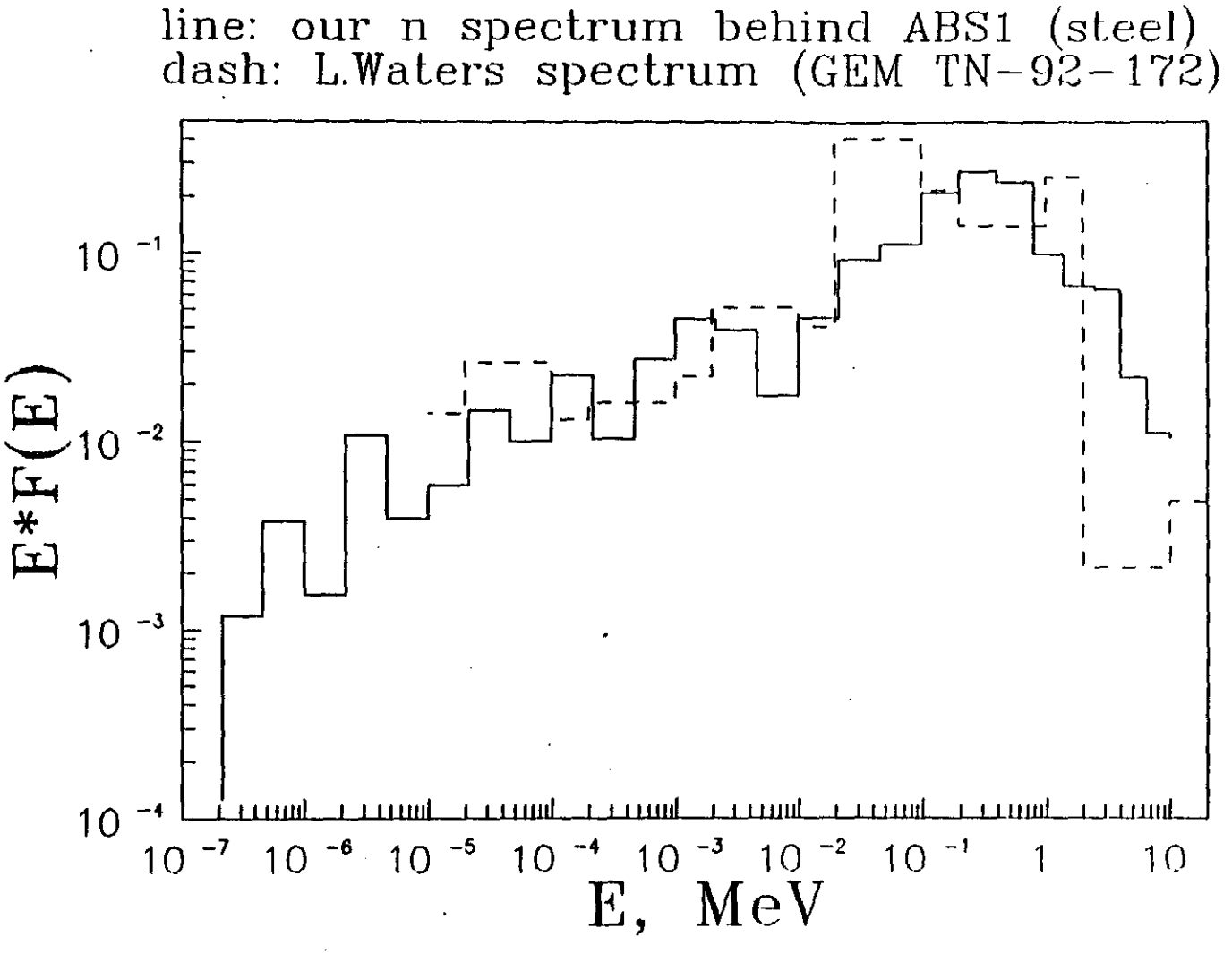
Table 1: Radiation capture crossection for thermal neutrons $\sigma_{\gamma th}$ and photons yield per one capture S_γ(E) for different nucleuses.

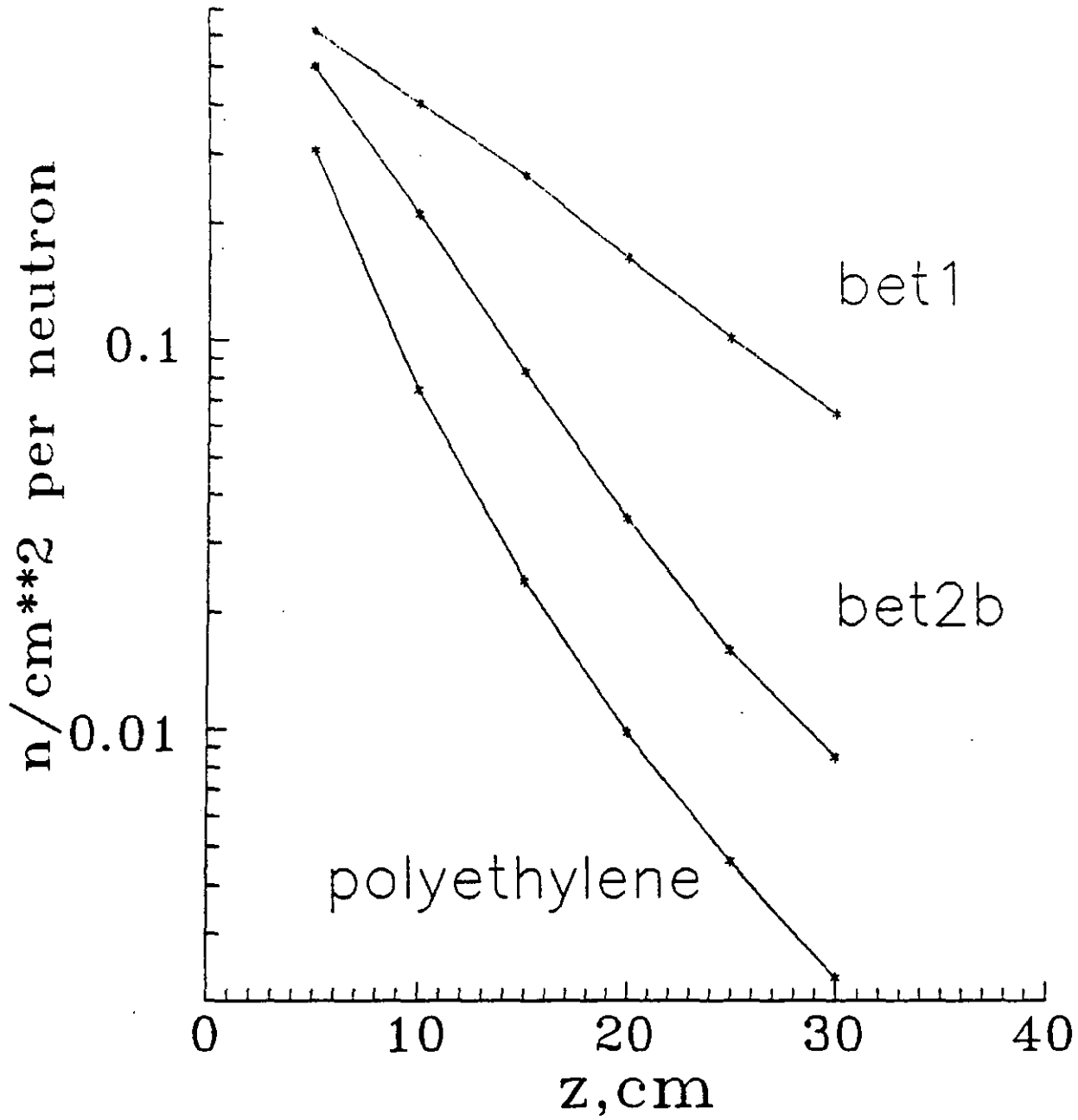
Nucleus	$\sigma_{\gamma th}$, barn	S_γ(E) in energy intervals, MeV						
		0-1	1-2	2-3	3-5	5-7	7-9	> 9
H'	0.33	0	0	1	0	0	0	0
Be	0.009	0.03	0	0.02	0.46	0.73	0	0
$B^{10}(n,\gamma)B^{11}$	0.5	0	0	0.02	0.9	0.18	0.7	0.008
$B^{10}(n,\alpha)Li^7$	3830	0.94	0	0	0	0	0	0
O^{16}	$2 \cdot 10^{-4}$	1.0	0.8	0.14	0	0	0	0
Al	0.23	0.3	0.12	0.1	0.7	0.12	0.35	0
Fe	2.55	0.3	0.4	0.17	0.45	0.5	0.7	0.05
W	18.5	0.85	0.25	0.68	0.53	0.25	0.01	0
Pb	0.17	0.02	0.015	0	0.020	0.07	0.9	0
C	0.0034	0	0.33	0	0.96	0	0.003	0


CURRENT, NEUTRON/CM**2/PER ONE NEUTRON
1
0.1
0.01
0.001
0
5
10
15
20
25
30
ABSORBER LENGTH, CM
STANDARD CONCRETE (1)
BORATED CONCRETE (2)
ATTENUATION LENGTH
1 - 9 cm, 2 - 6.5 cm

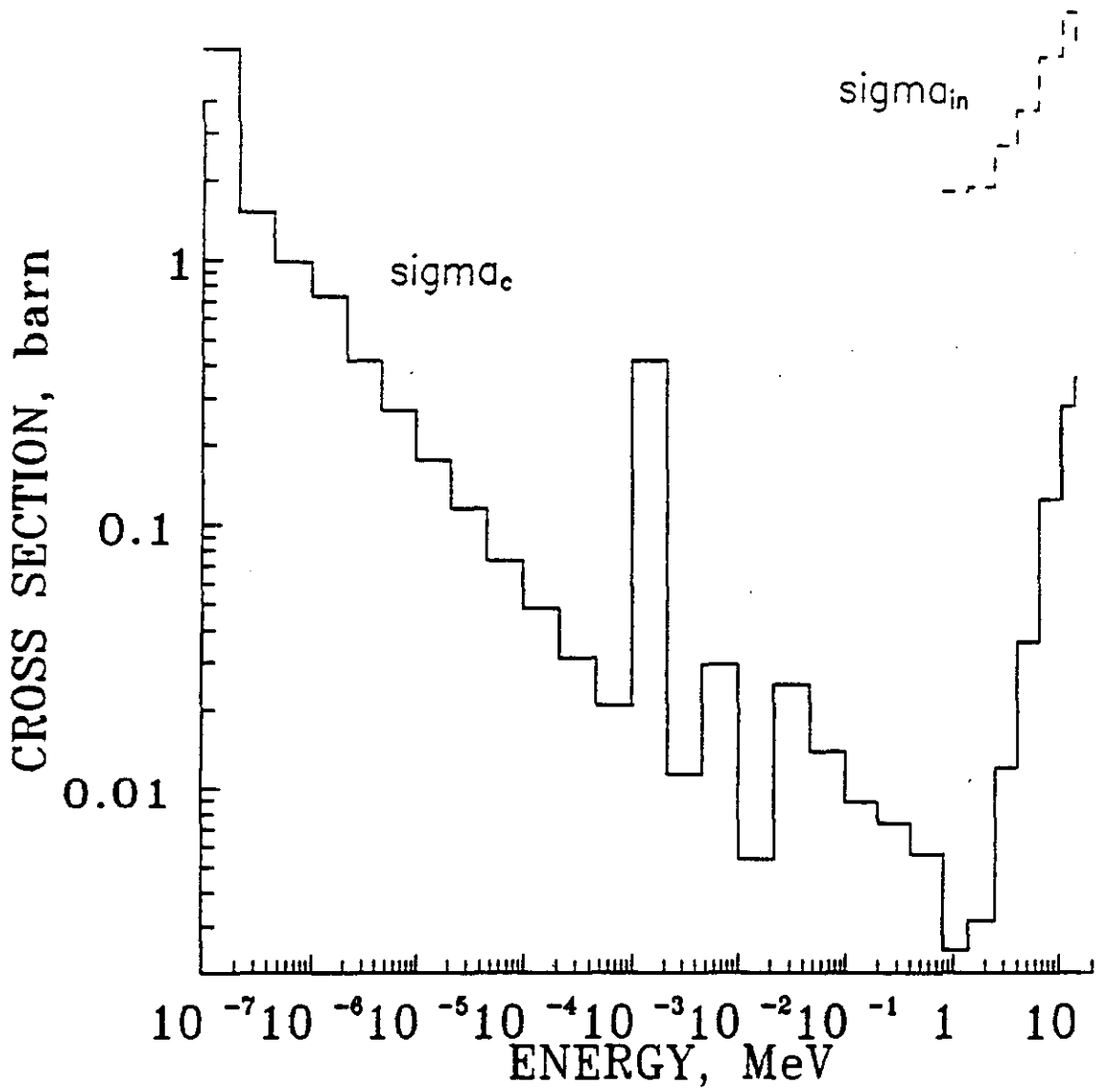

Photons spectrum after
30 cm borated concrete
I - experiment
II - calculation
PHOTONS/CM**2
ENERGY, MeV
I
II
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6
7
8
9
10
11

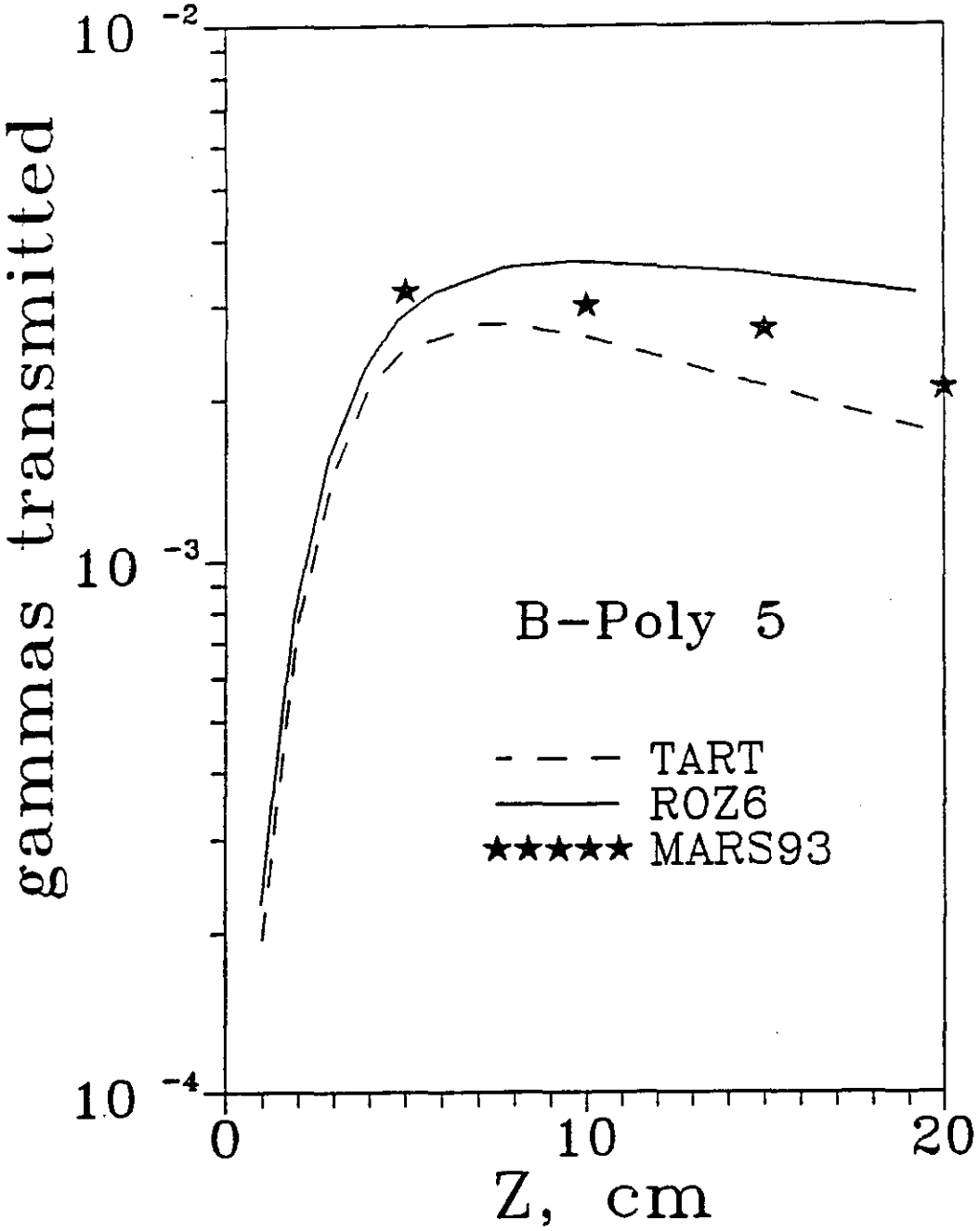

Neutron spectrum in experimental device
after the carbon slab
Dashed line – calculation
Solid line – experiment
E*f(E), NEUTRON/CM**2 PER ONE NEUTRON
ENERGY, MeV
10 -1
10 -2
10 -3
10 -7
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
10

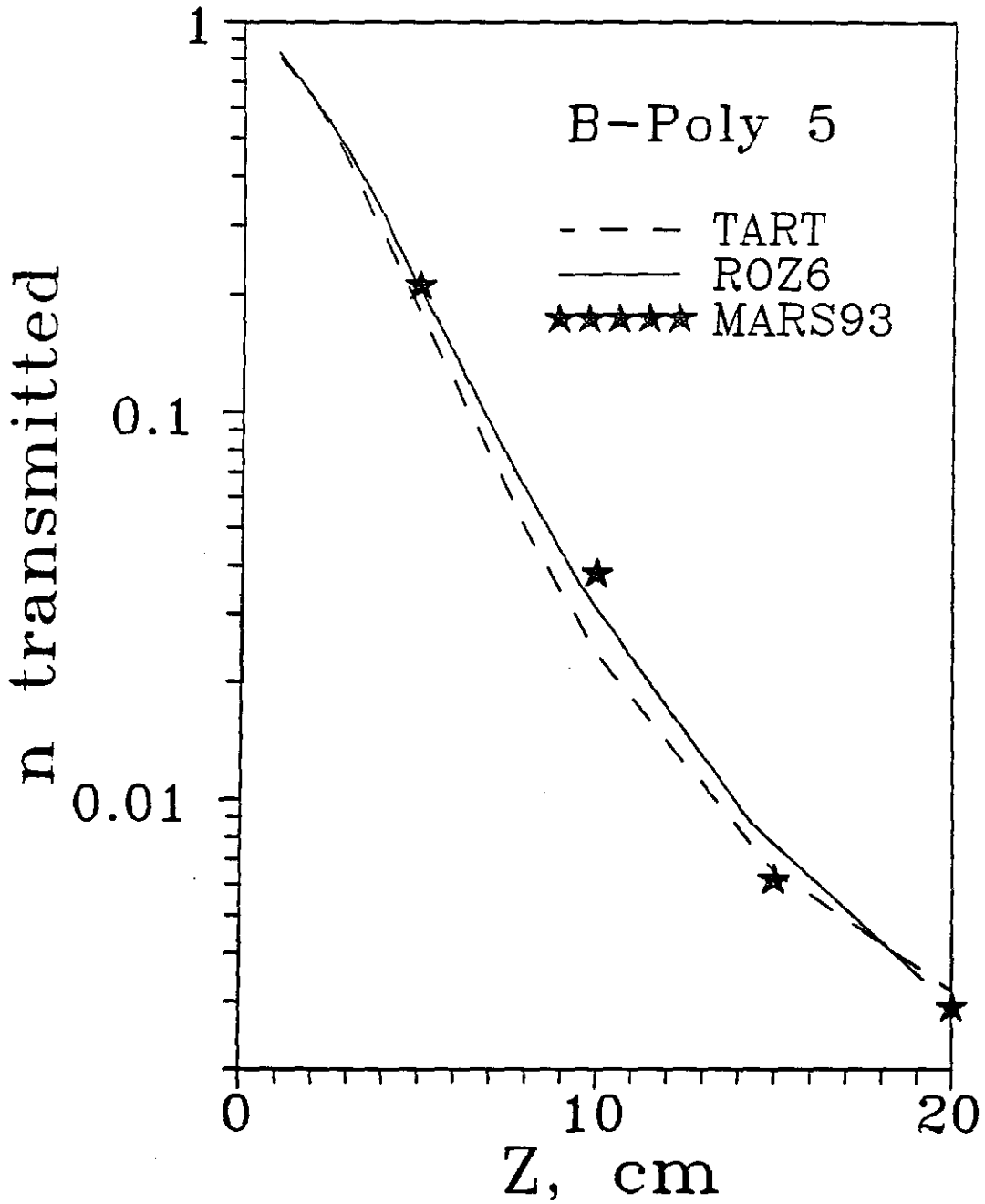

line: our n spectrum behind ABS1 (steel)
dash: L.Waters spectrum (GEM TN-92-172)
E*F(E)
10 -1
10 -2
10 -3
10 -4
10 -7
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
10
E, MeV

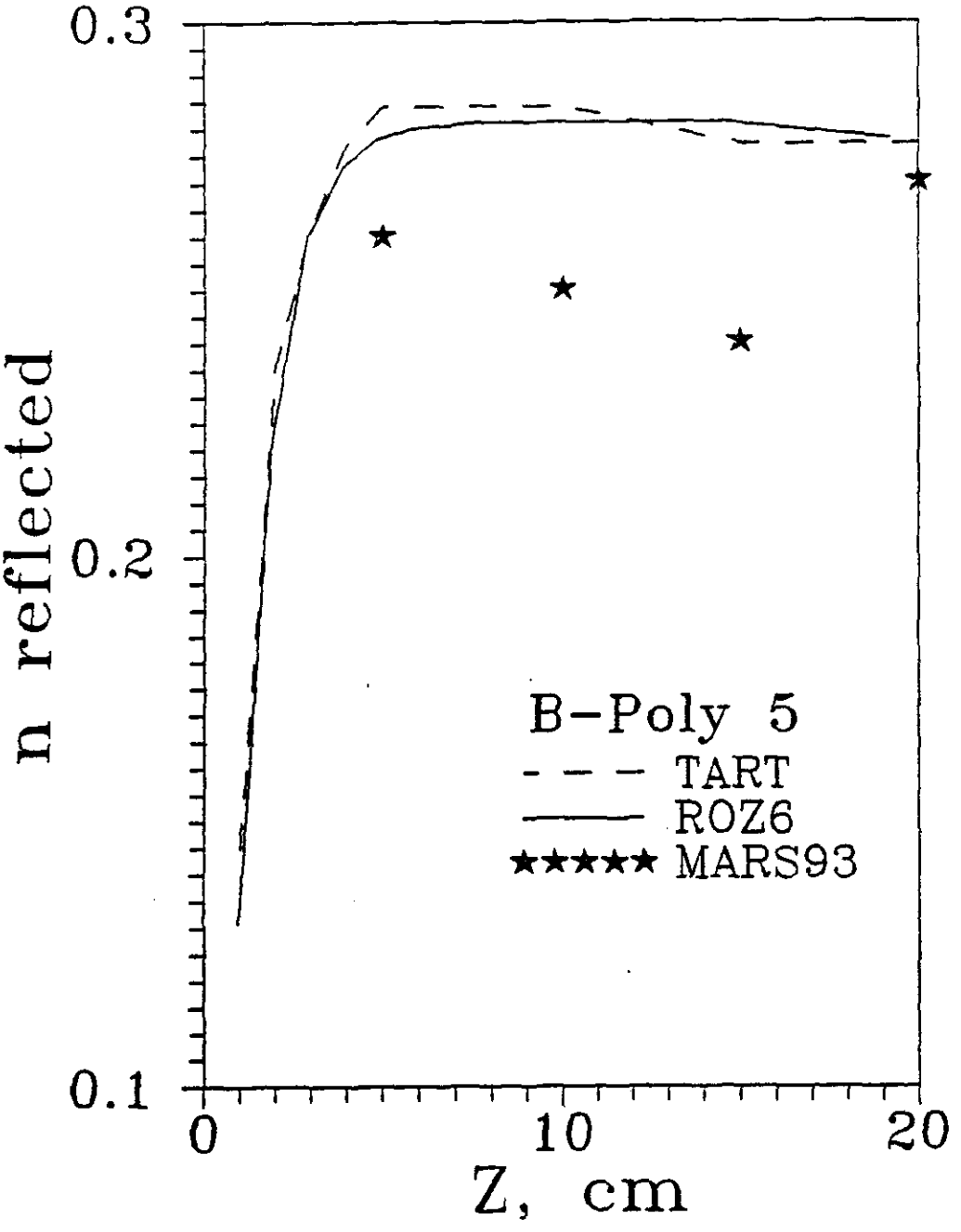

n/cm**2 per neutron
0.1
0.01
bet1
bet2b
polyethylene
0
10
20
30
40
z,cm

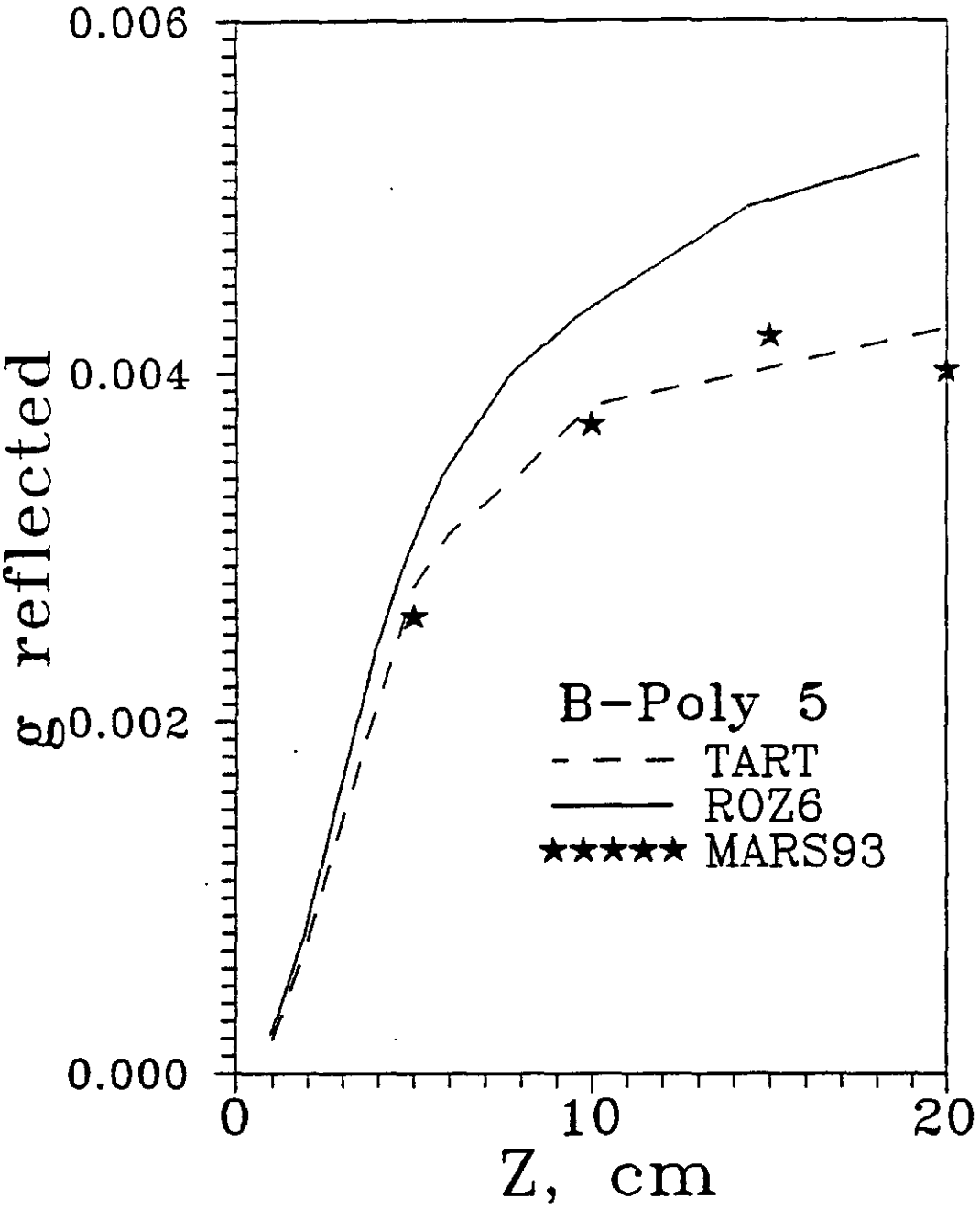
Averaged cross section of radiation capture($sigma_c$) and inelastic scattering ($sigma_{in}$)for iron

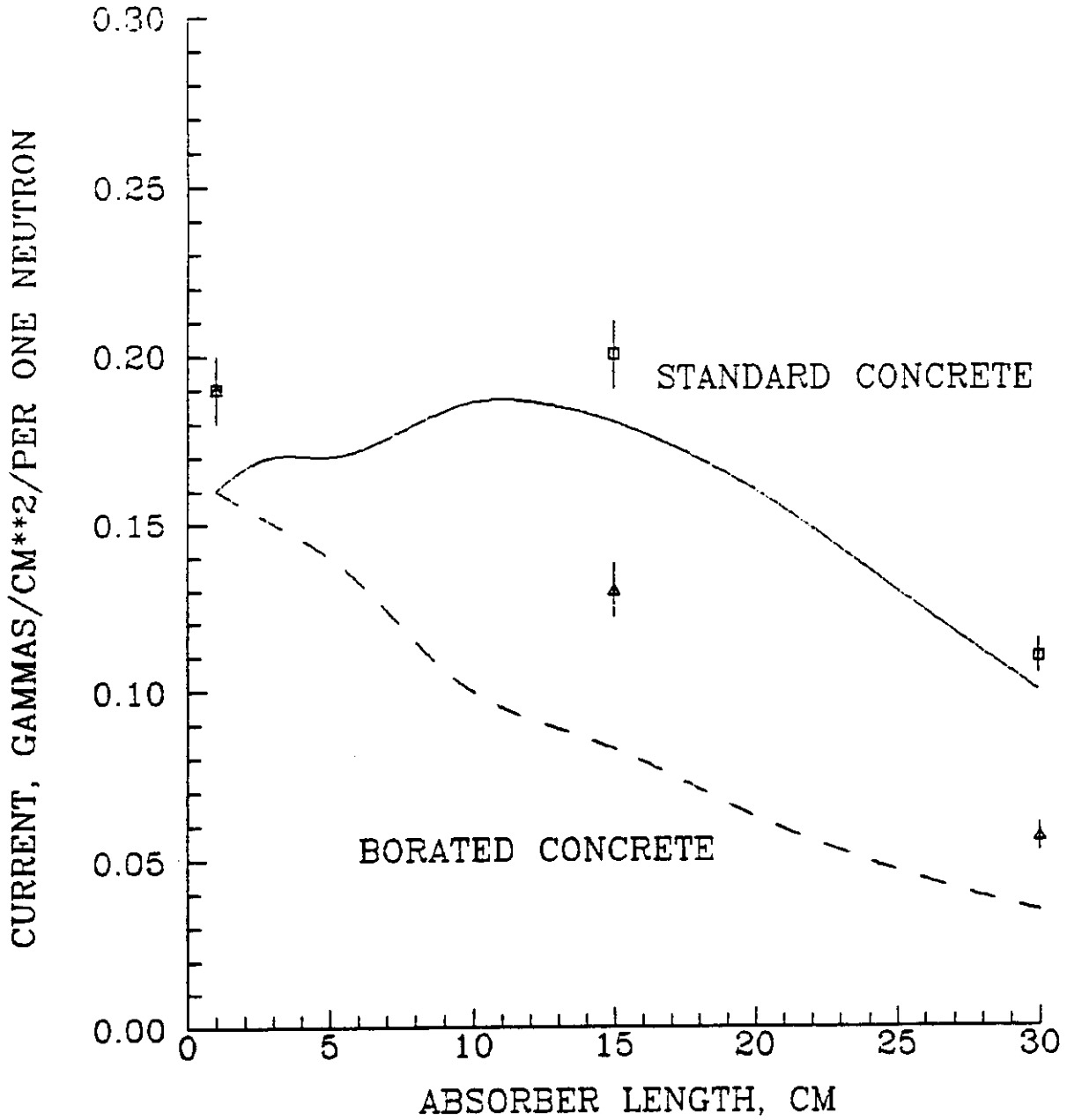


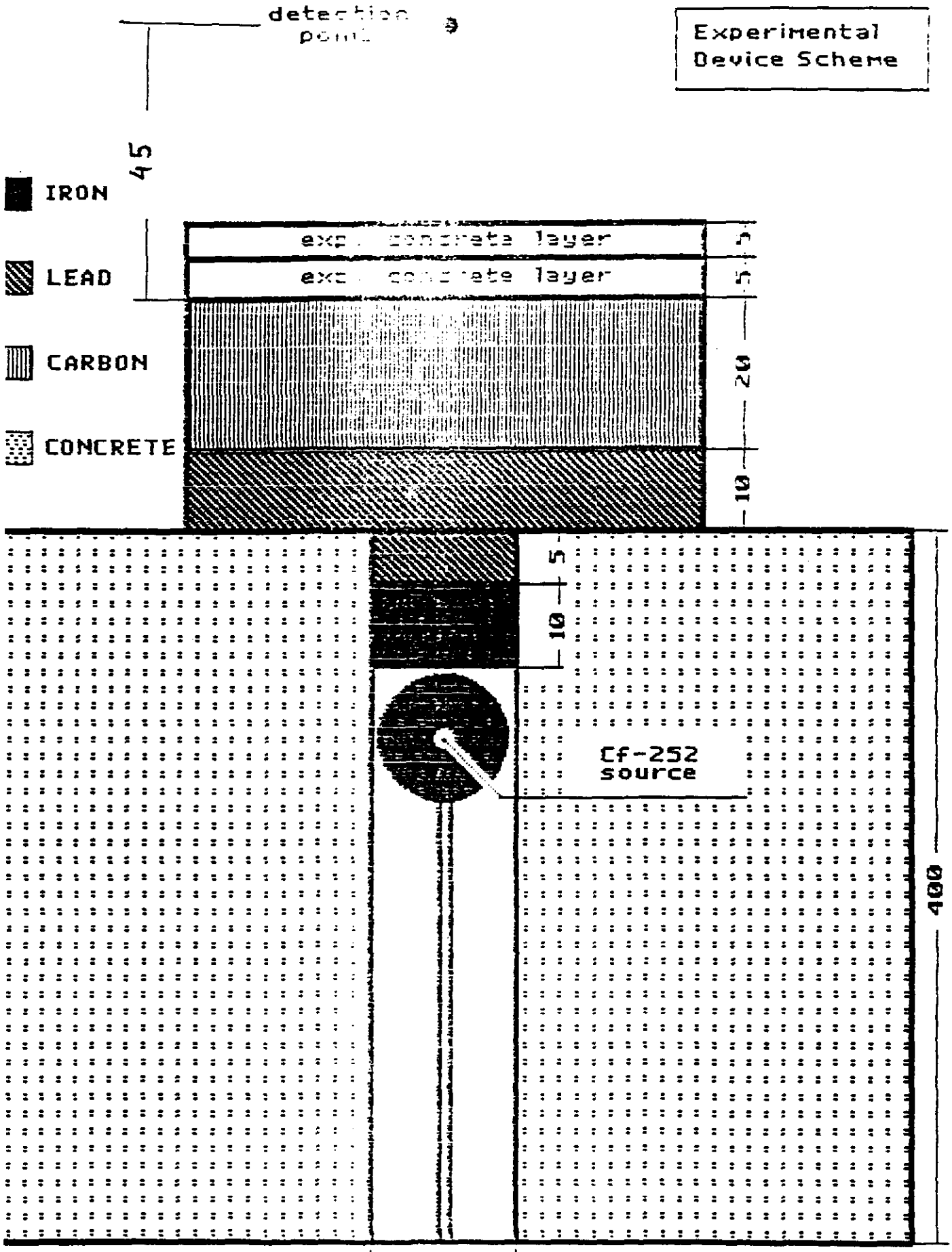

gammas transmitted
10 -2
10 -3
10 -4
0
10
20
Z, cm
B-Poly 5
TART
ROZ6
MARS93

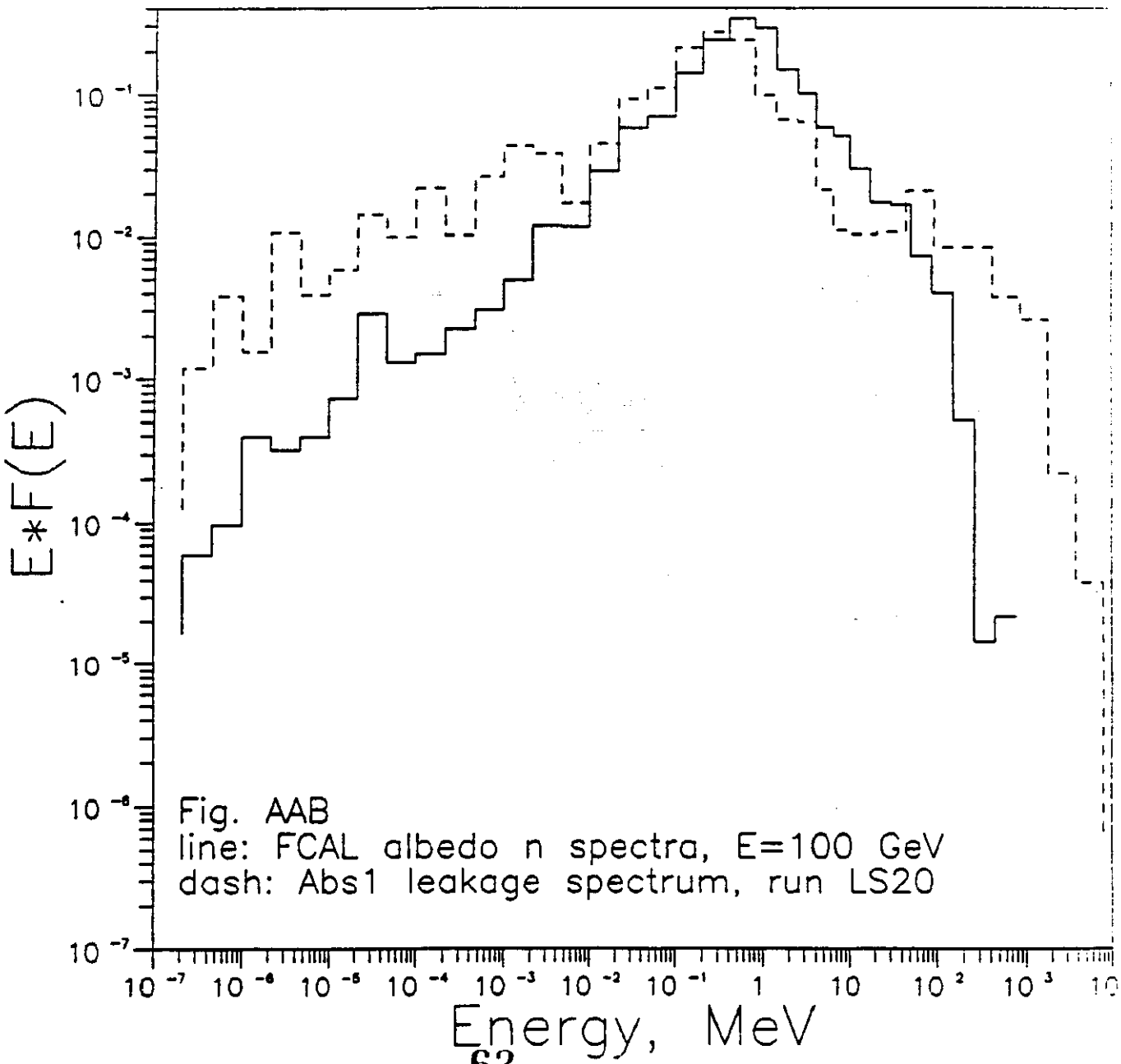

B-Poly 5
TART
ROZ6
MARS93
n transmitted
1
0.1
0.01
0
10
20
Z, cm


0.3
0.2
0.1
n reflected
0
10
20
Z, cm
B-Poly 5
TART
ROZ6
MARS93


0.006
0.004
0.002
0.000
g reflected
0
10
20
Z, cm
B-Poly 5
TART
ROZ6
MARS93


0.30
0.25
0.20
0.15
0.10
0.05
0.00
CURRENT, GAMMAS/CM**2/PER ONE NEUTRON
STANDARD CONCRETE
BORATED CONCRETE
0
5
10
15
20
25
30
ABSORBER LENGTH, CM


Experimental Device Scheme
detection point
45
IRON
LEAD
CARBON
CONCRETE
exp. concrete layer
exp. concrete layer
5
5
20
10
5
10
Cf-252 source
400
20

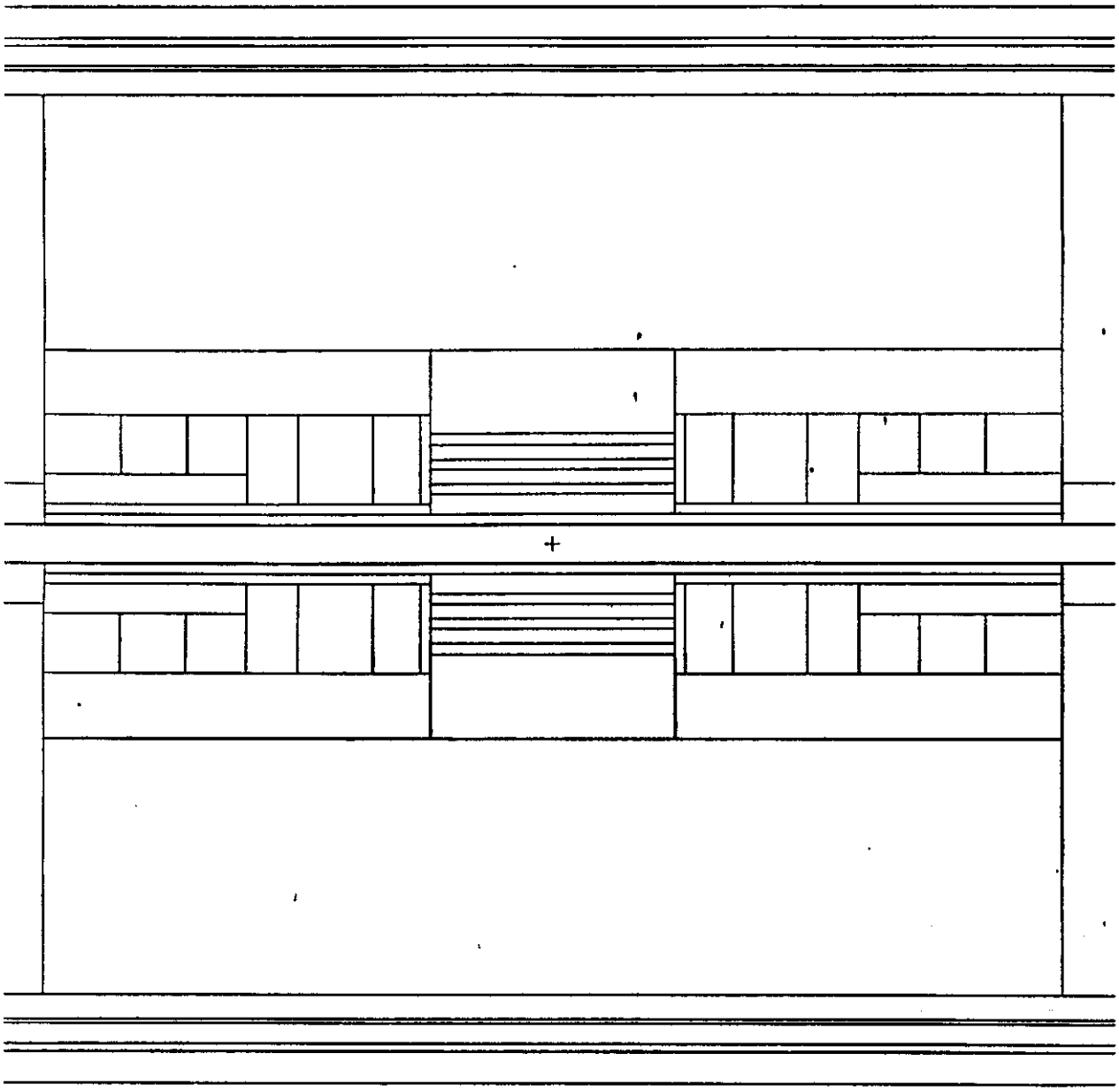

E*F(E)
Energy, MeV
Fig. AAB
line: FCAL albedo n spectra, E=100 GeV
dash: Abs1 leakage spectrum, run LS20

gem

γeμ

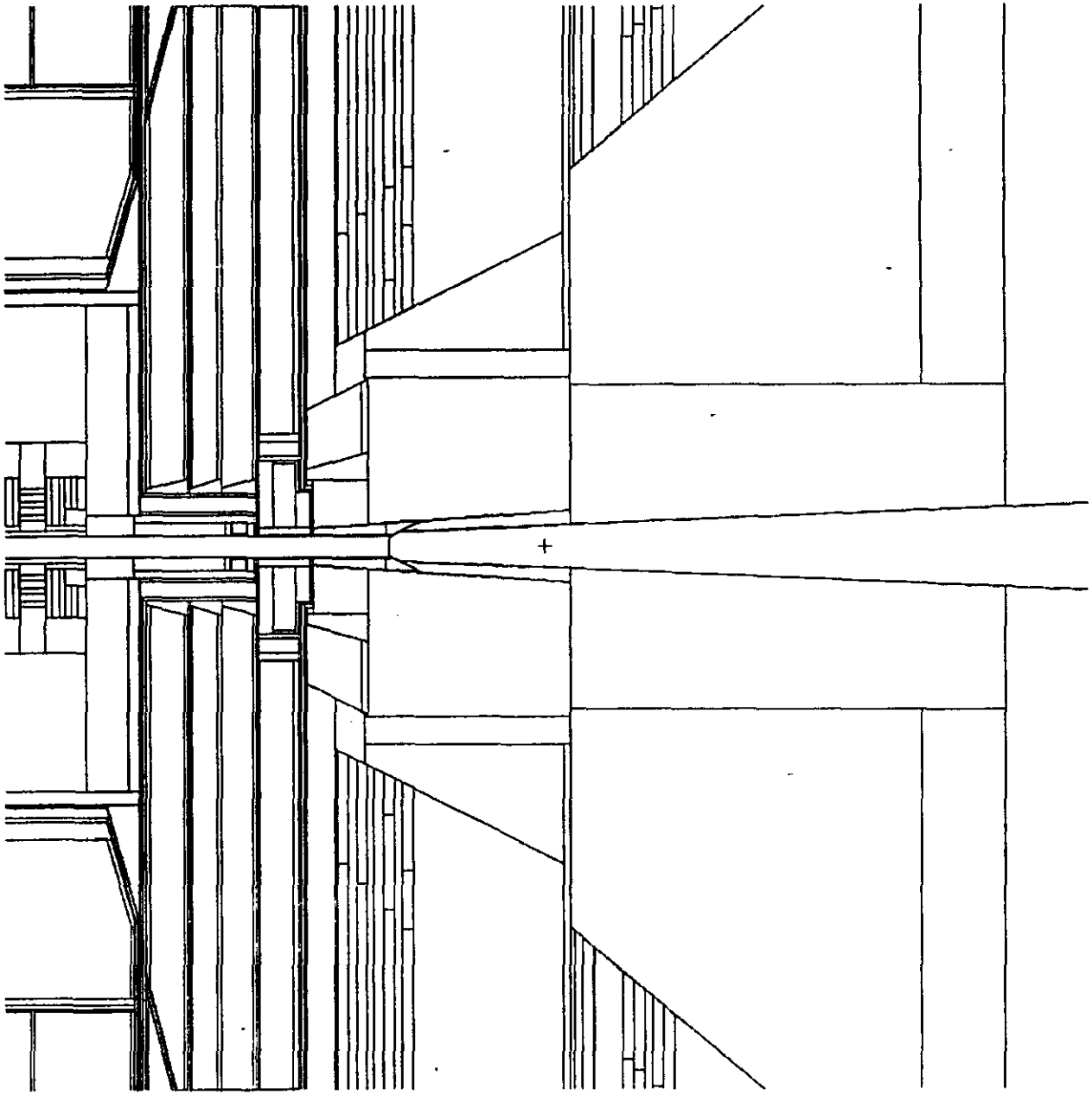
Presentation by:

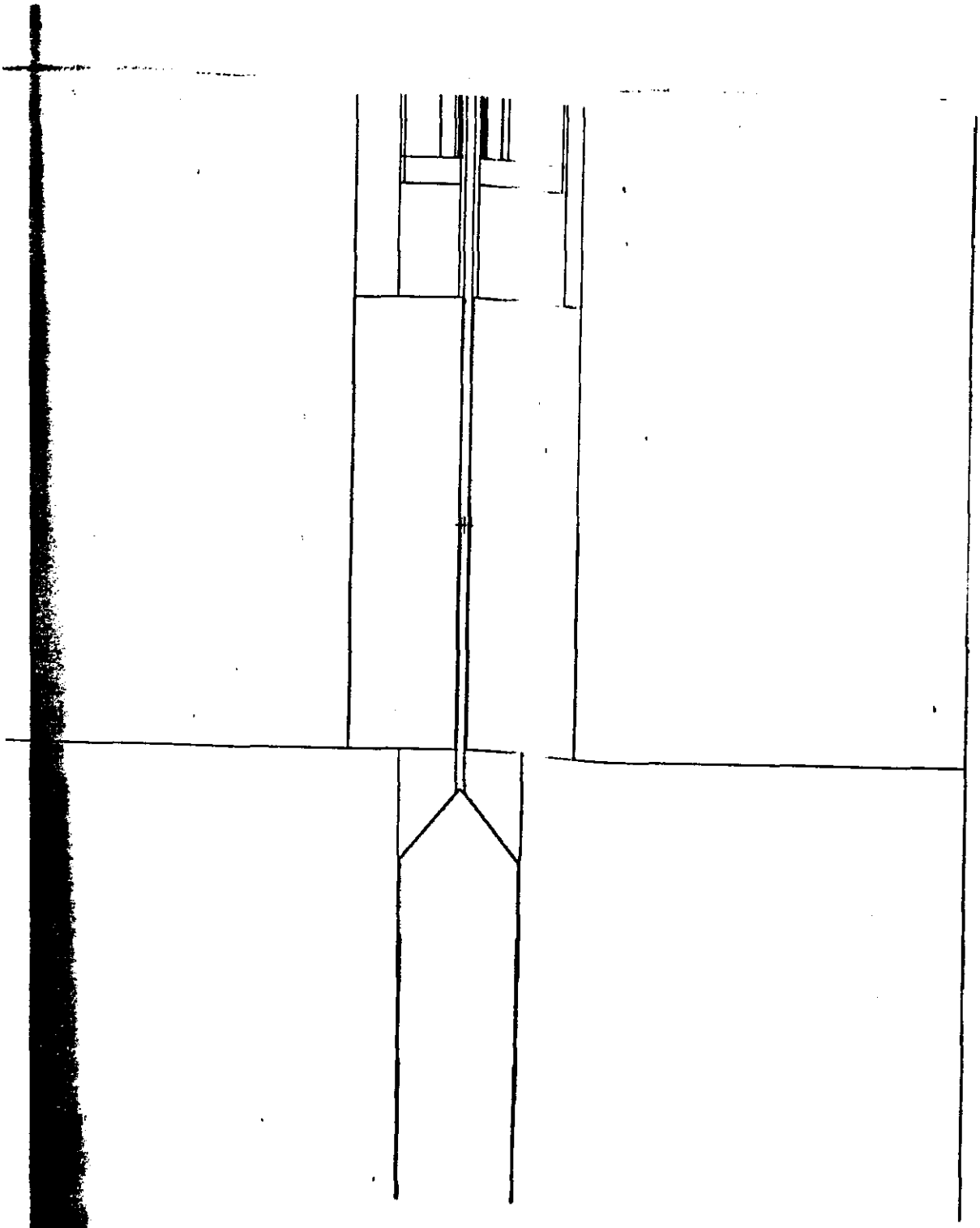
L. Waters



1/26/93 15 00 35
GEM SIMULATION FINE
SEGMENTATION

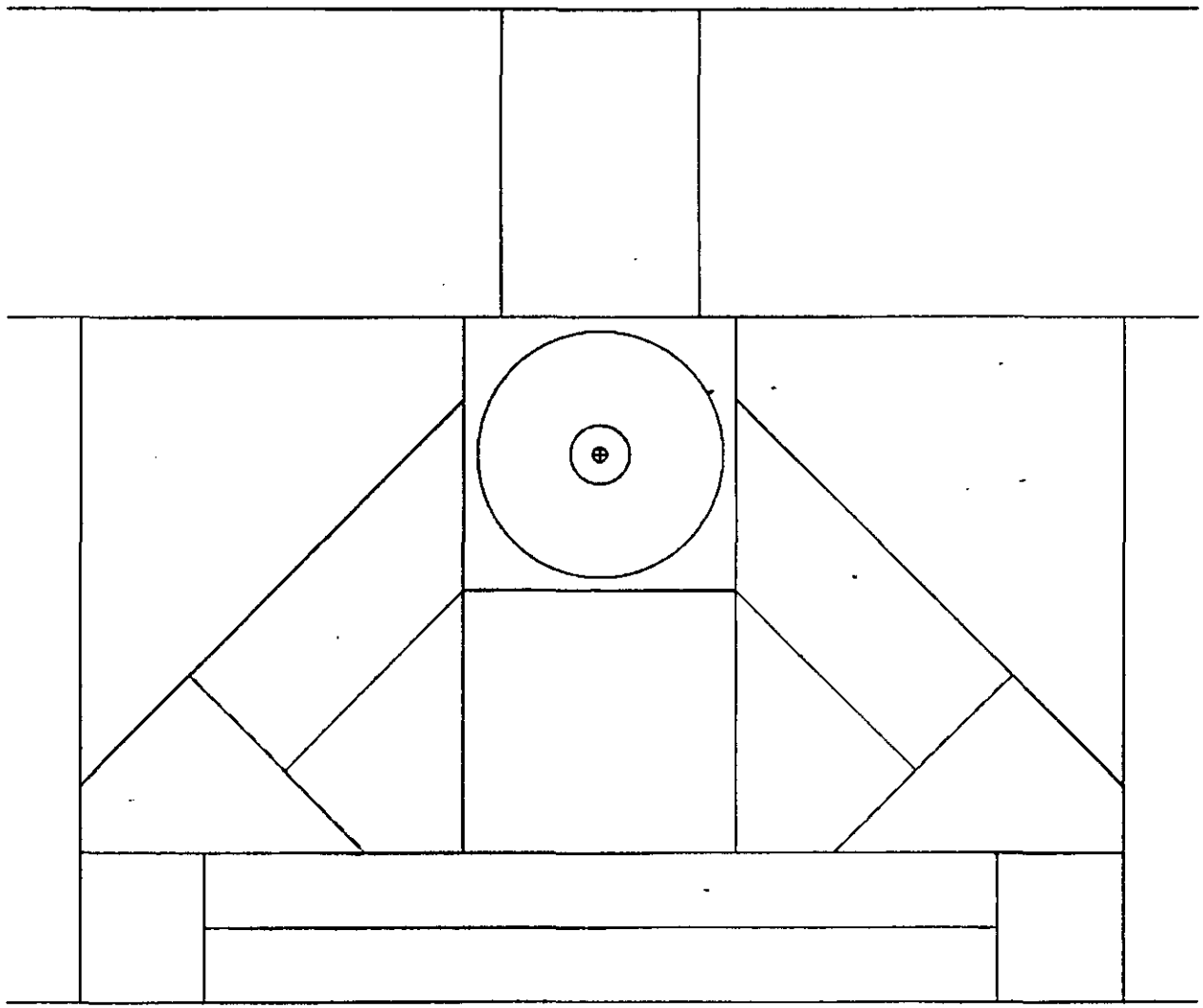
PROBID = 1/26/93 14 57 32
BASIS
(0.000000, 0.000000, 1.000000)
(0.000000, 1.000000, 0.000000)
ORIGIN
(0.00, 0.00, 950.00)
EXTENT = (1000.00, 200.00)

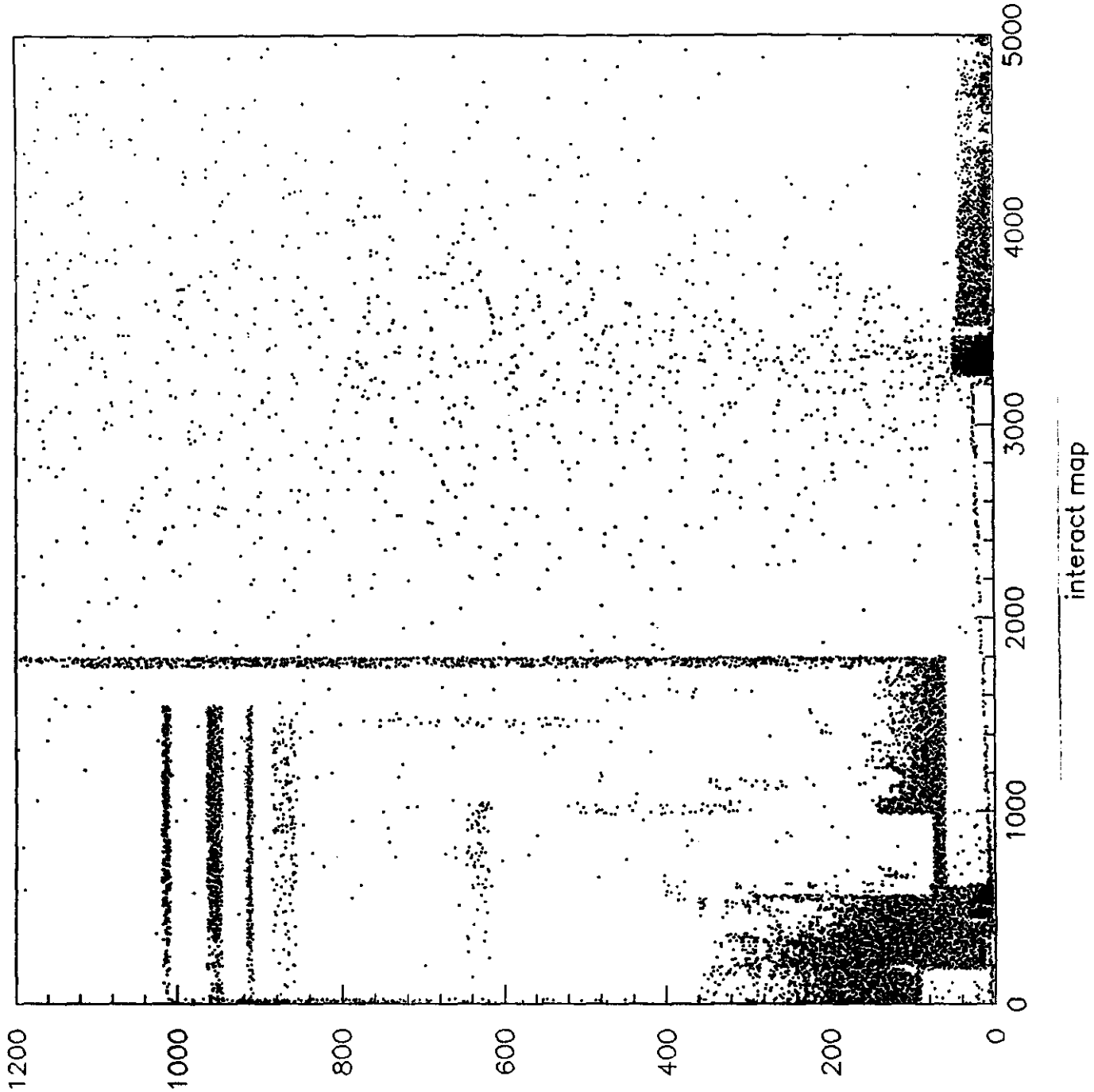


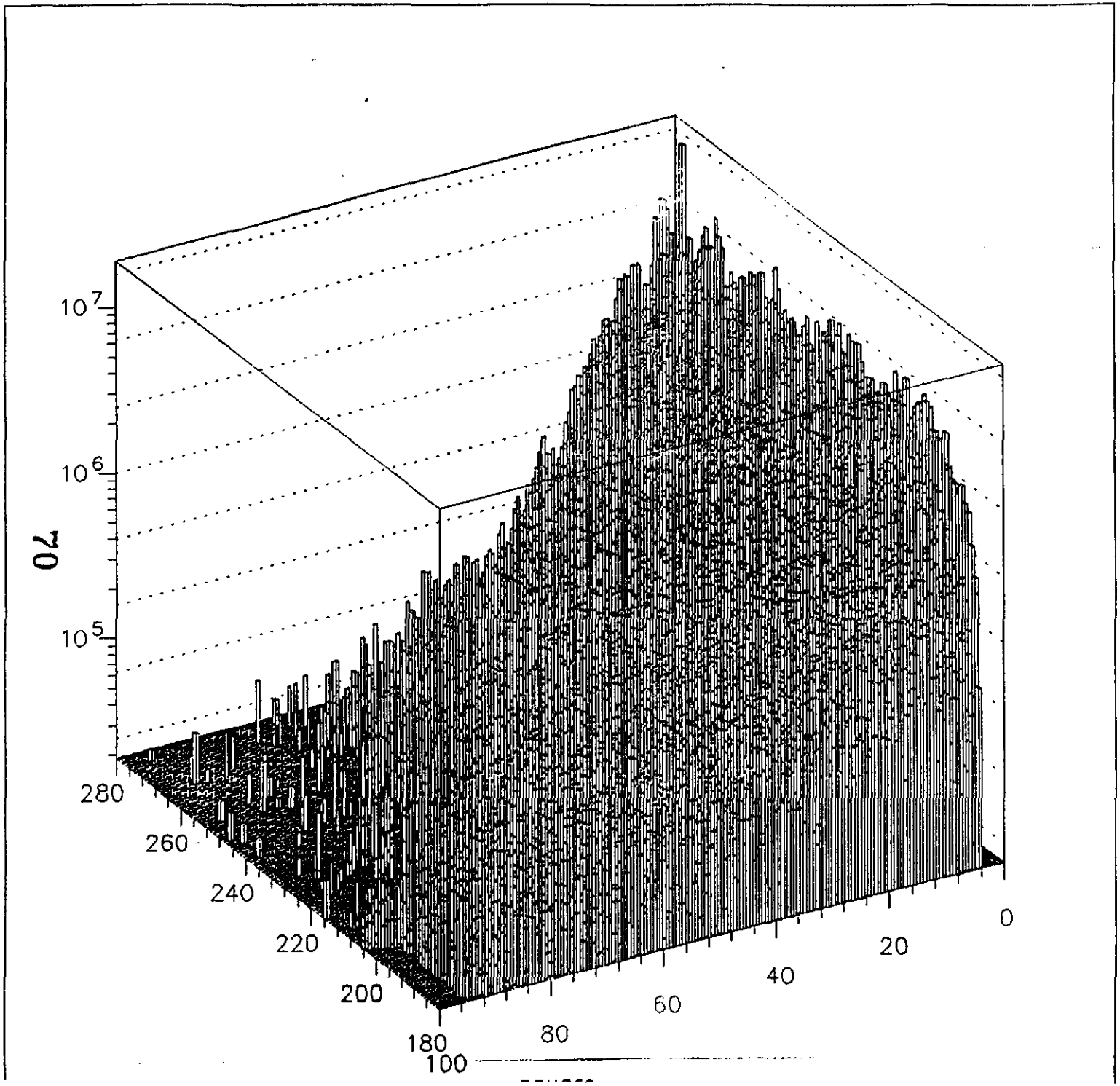


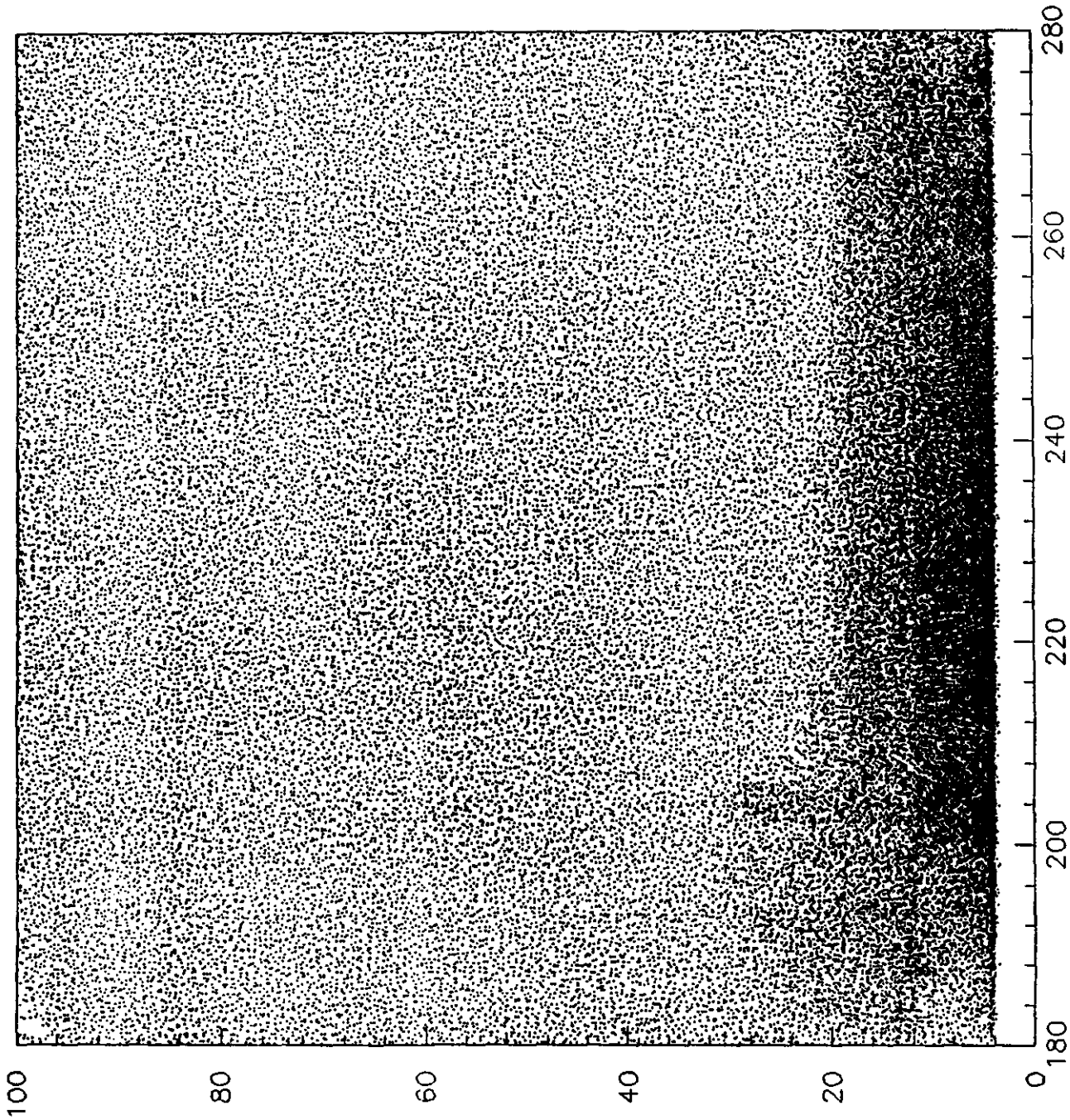
1/26/93 14 46 43
GEM SIMULATION FINE
SEGMENTATION

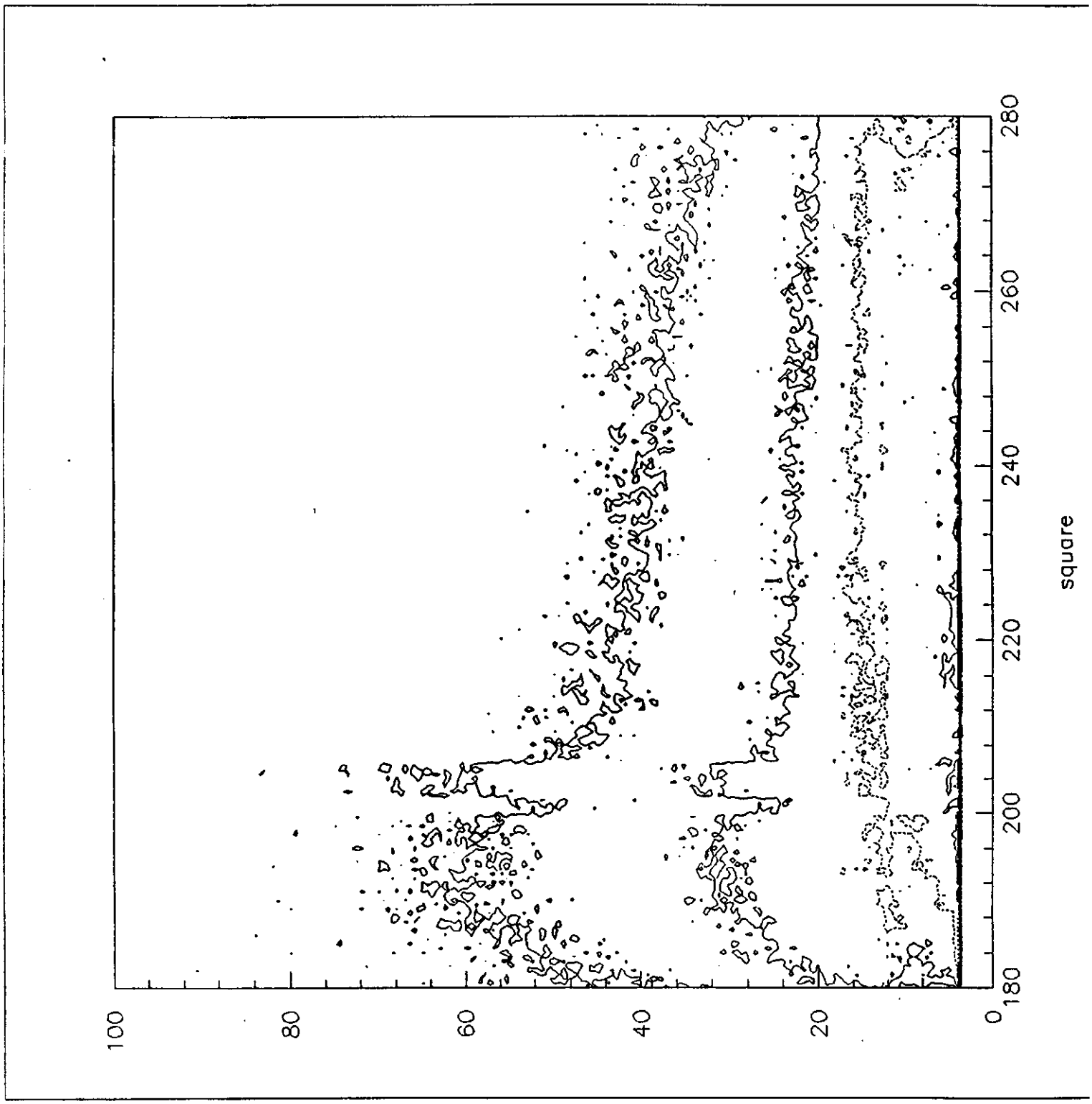
PROBID = 1/26/93 14 44 00
BASIS
(1.000000, 0.000000, 0.000000)
(0.000000, 1.000000, 0.000000)
ORIGIN
(0.00, 0.00, 1775.00)
EXTENT = (1200.00, 1200.00)

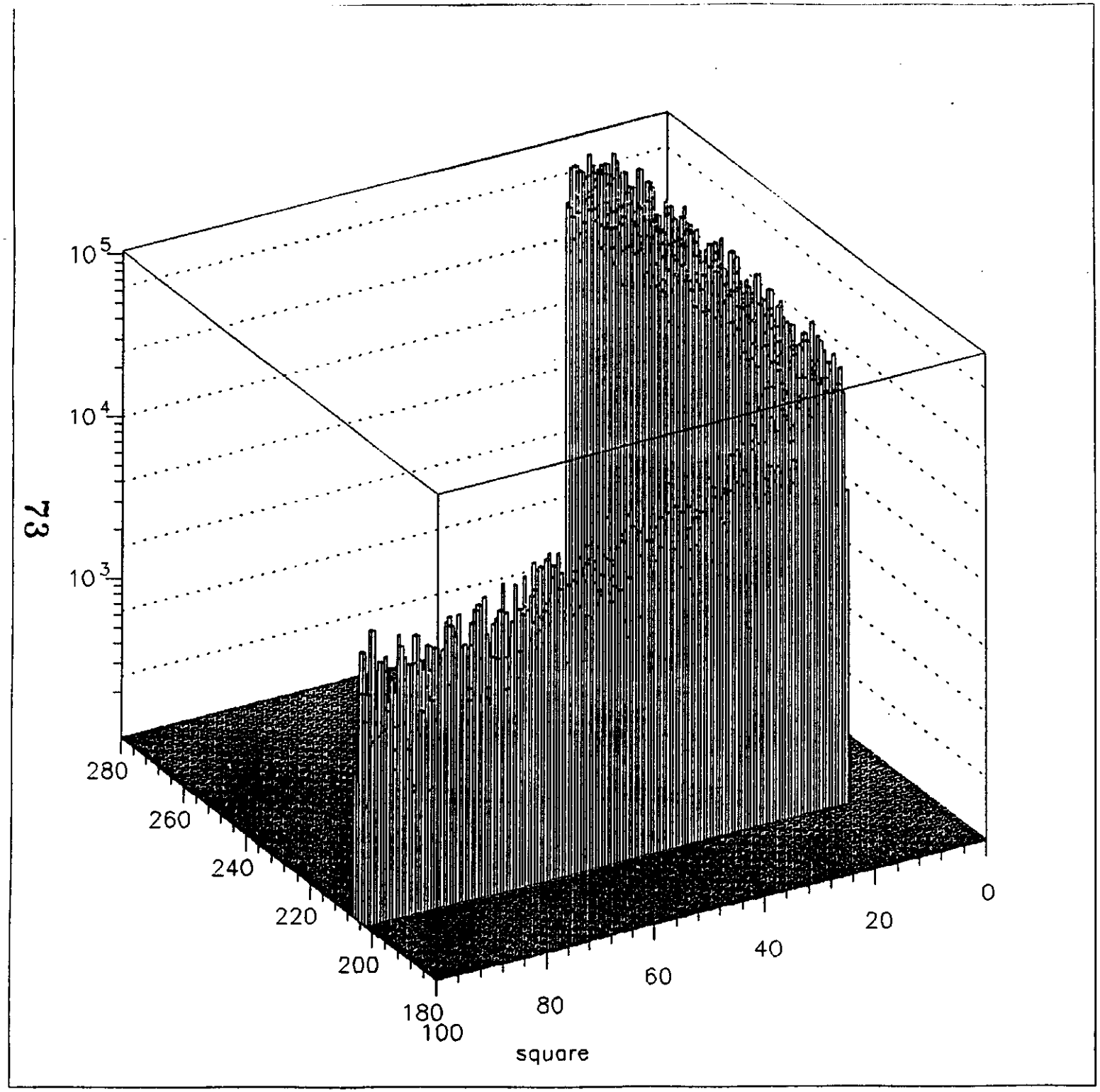


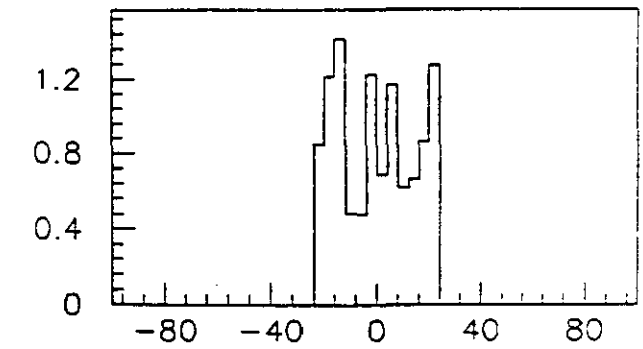

1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
interact map


10^7
10^6
10^5
280
260
240
220
200
180
100
80
60
40
20
0

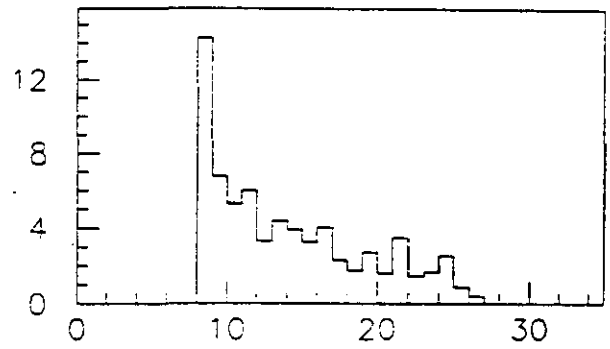

100
80
60
40
20
0
180
200
220
240
260
280
square


100
80
60
40
20
0
180
200
220
240
260
280
square

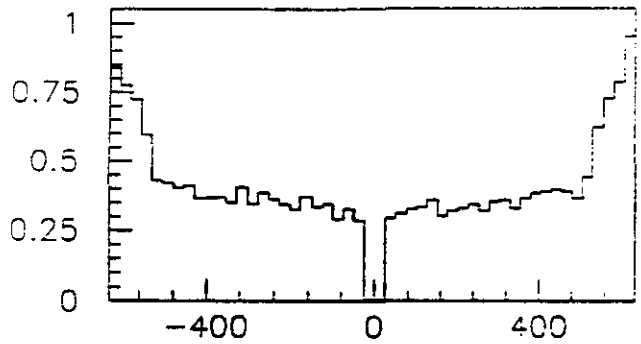

10^5
10^4
10^3
280
260
240
220
200
180
100
80
60
40
20
0
square



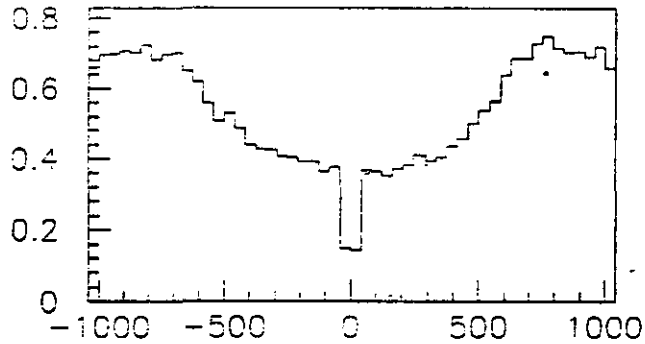
vertex barrel radius 17pt1



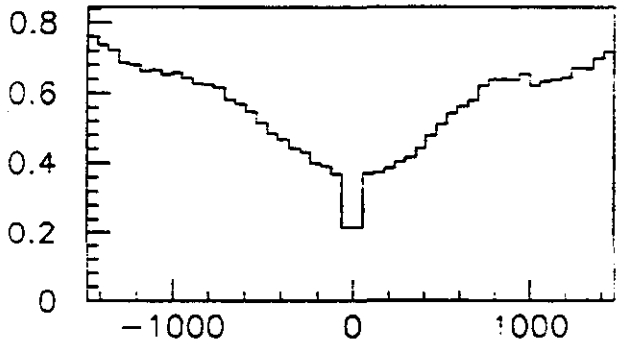
vertex slices z 50



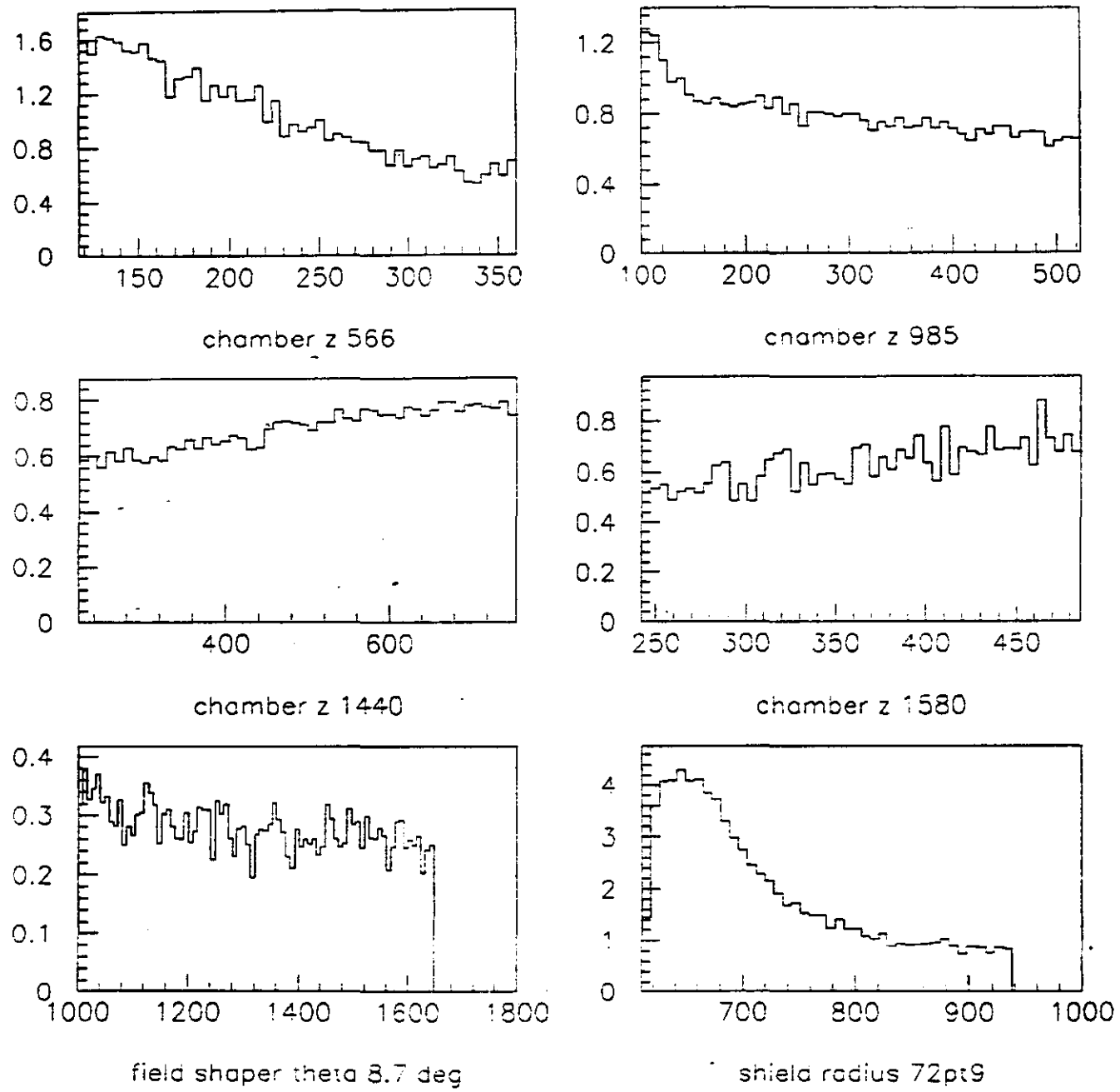
barrel dc1 radius 377



barrel dc2 radius 616



barrel dc3 radius 855


1.6
1.2
0.8
0.4
0
150
200
250
300
350
chamber z 566
1.2
0.8
0.4
0
100
200
300
400
500
chamber z 985
0.8
0.6
0.4
0.2
0
400
600
chamber z 1440
0.8
0.6
0.4
0.2
0
250
300
350
400
450
chamber z 1580
0.4
0.3
0.2
0.1
0
1000
1200
1400
1600
1800
field shaper theta 8.7 deg
4
3
2
1
0
700
800
900
1000
shield radius 72pt9

gem

γeμ

Presentation by:

M. Diwan

Plan of action

M. Diwan

1) Radiation damage

mainly dependent on accelerator conditions.

Normal operations charged particle dose $\frac{0.4\ \mathrm{MGy\ yr^{-1}}}{r^2 \sin^2\theta\ \mathrm{cm}^{-2}}$

neutron dose uncertain

2) Singles rate

will calculate n, γ, c fluxes at different locations

3) Health and Safety

Activation dose -
SSC lab safety office responsibility.

ECAL corner.

Charged dose

$3 \cdot 10^4$ Gy/sscy $\qquad 10^{33}\ cm^{-2}/sec$

↓

$\times 10$ full luminosity

↓

$\times 6$ neutral dose γ's, n's

↓

$2 \cdot 10^6$ Gy/sscy

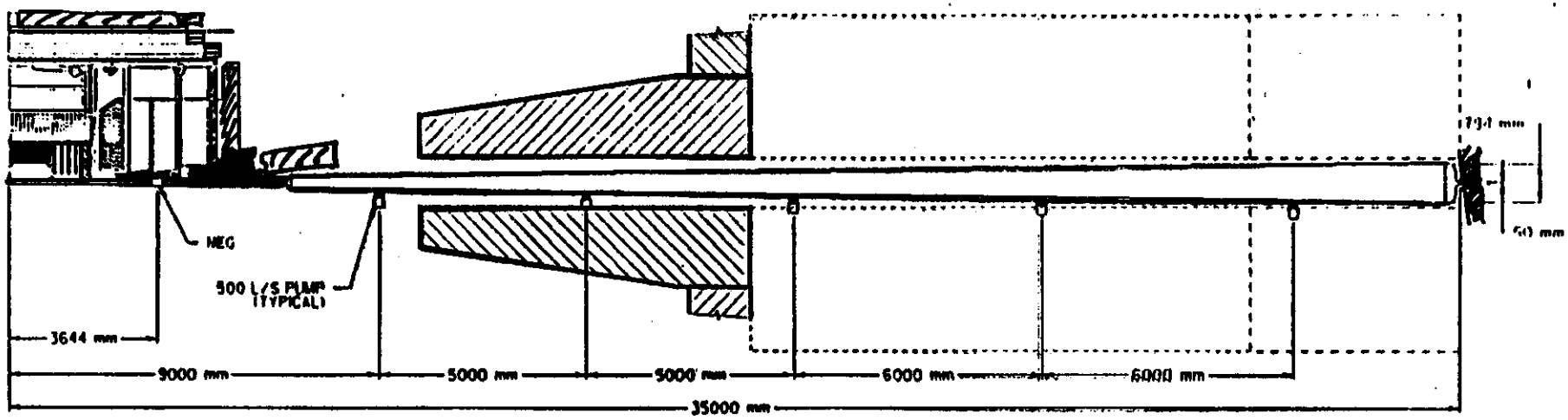
↓ 10 years

$\times 10$ for 10 years

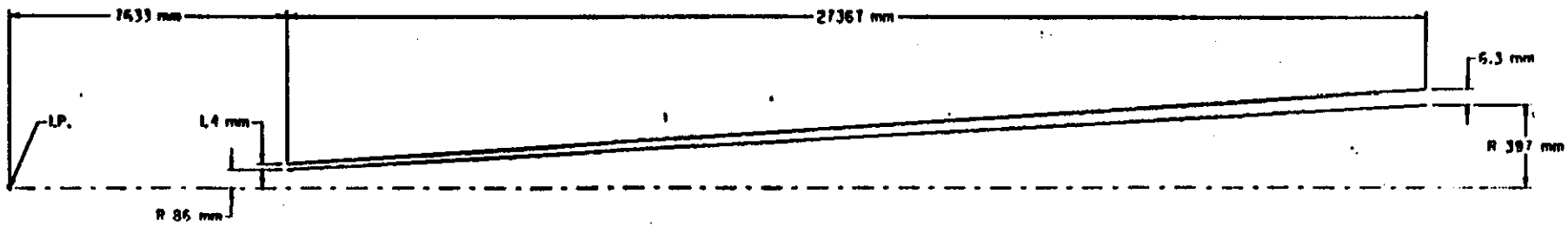
↓

$20 \cdot 10^6$ Gy ~~/sscy~~

$\boxed{20\,MGy}$



OPTION 4



CONICAL SECTION
WALL THICKNESS
SAFETY FACTOR 2

List of Calculations

1) New beam pipe, larger hole in FFS

2) Central Cavity

$10^{12} - 10^{13}$ n/cm²/s scy

~1/10 with 5cm poly + 20cm poly on end.

small dependence on FCAL position

Small dependence on CAL material

– mostly volume effect ?

3) Muon system

Collimator shielding

FCAL shielding

Barrel shielding

Passive absorber

Magnet aperture shielding

FFS shielding

4) Activation

collimator

Vacuum system

FCAL

FFS

ECAL including barrel

n kinematics

Average number of collisions to go from E_1 to E_2 is of

$$\frac{\ln(E_1) - \ln(E_2)}{\xi}$$

ξ = Average logarithmic energy decrement

= 1 for hydrogen

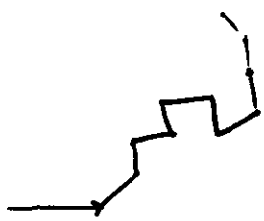
Average lab. scattering angle

$$\langle \cos\theta \rangle = \frac{2}{3A} \qquad A = \text{atomic number}$$

Estimate thickness required to thermalize

$$\sim \frac{\ln(E) - \ln(1/40)}{\xi} \cdot \langle \cos\theta \rangle$$

Overestimate by factor 2.



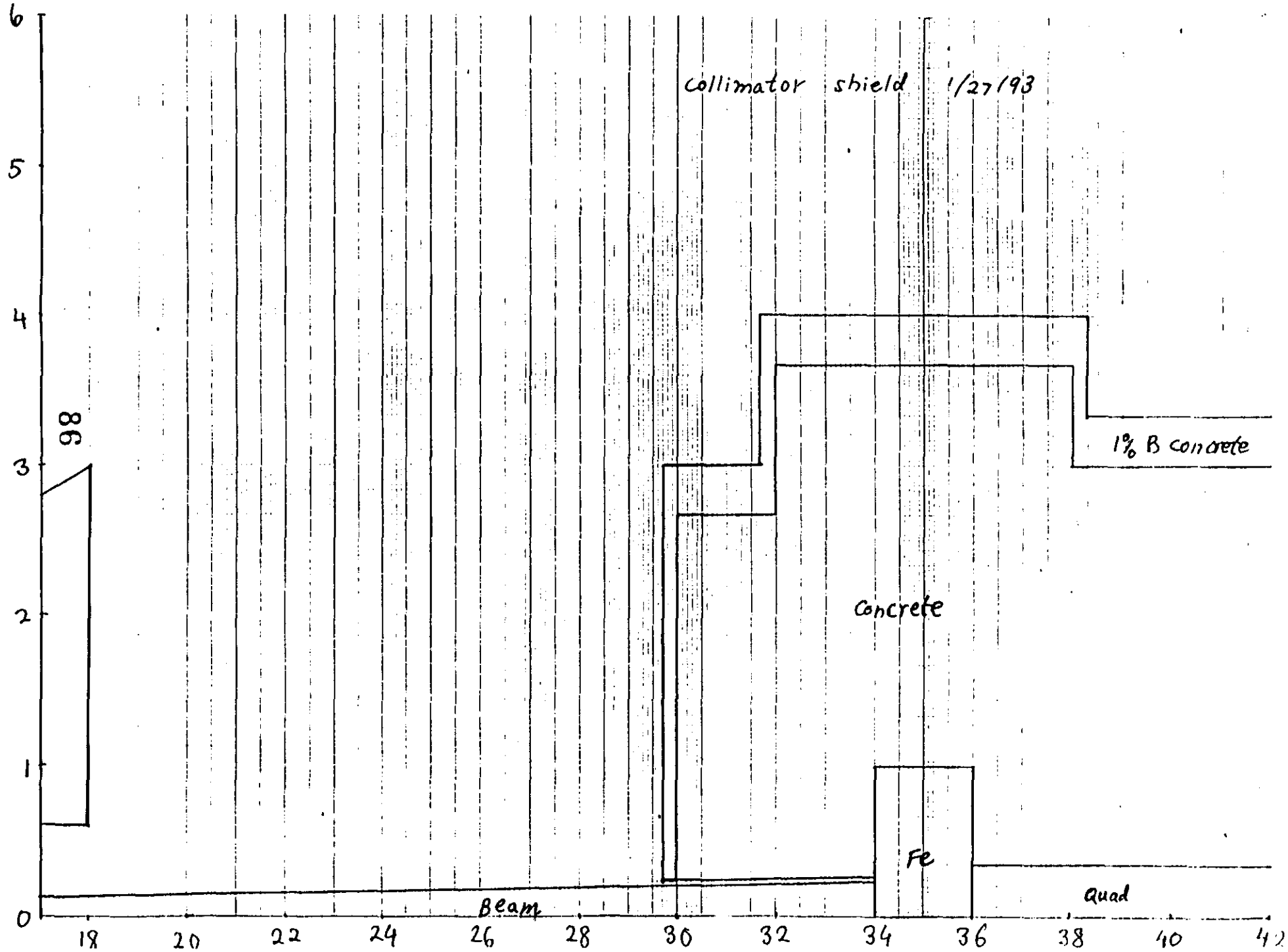
	A	Z	δ gm/cc	λ_T cm	X cm	$\lambda_{0.1\,MeV}$ (cm)	$\lambda_{1\,MeV}$ (cm)
[illegible]	183.8	74	(18.5) 19.3	5.96	0.37	0.30	1.08
Pb	207.2	82	11.4	10.2	0.56	0.44	1.75
Cu	63.5	29	8.96	9.6	1.43	0.98	2.23
Fe	55.8	26	16.8	10.5	1.76	1.27	1.19

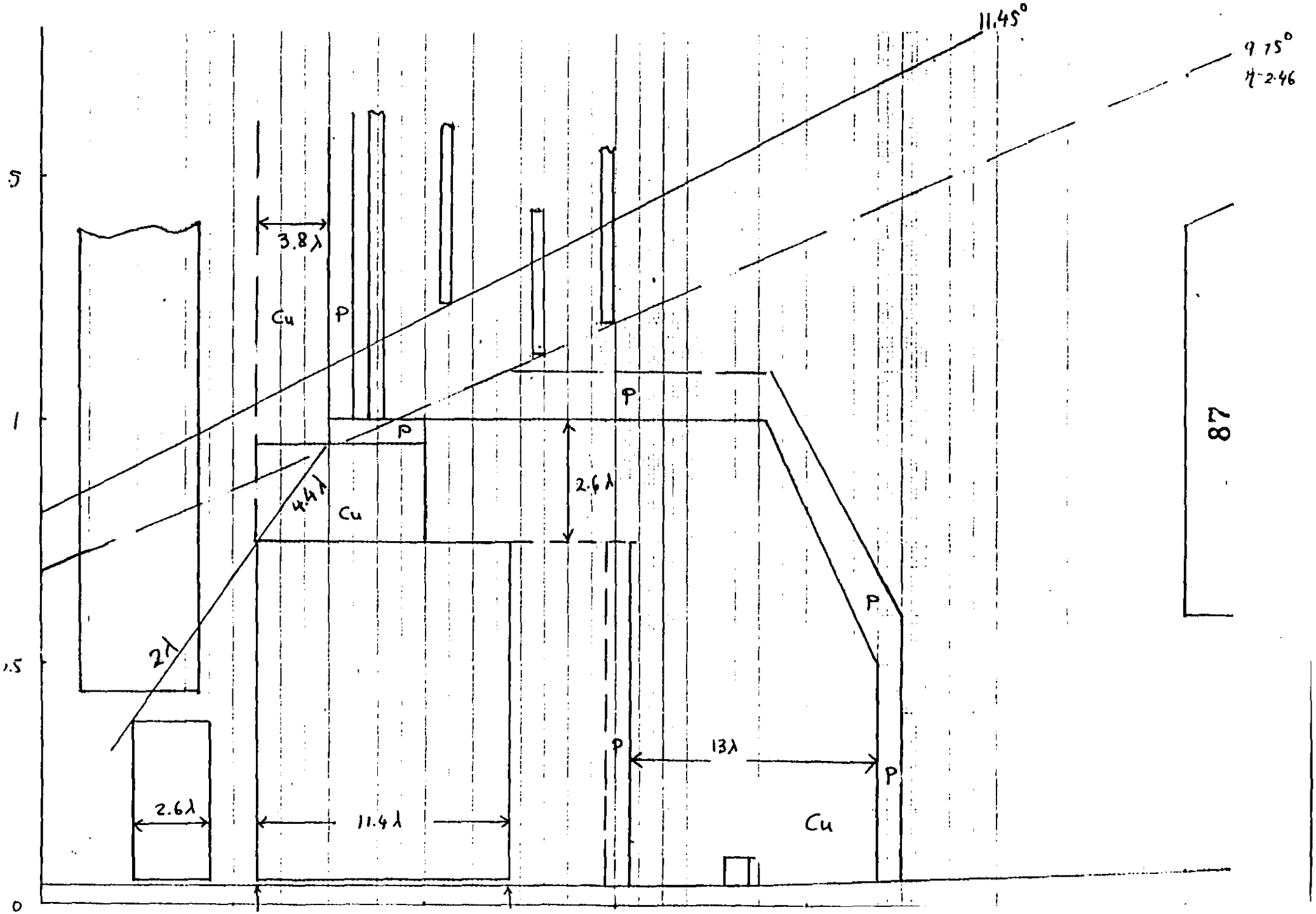
	gm/cc			0.1 MeV	1 MeV	thermal capture
CH_2	δ	δ_H	δ_B	λ_s	λ_s	λ_a
1% B	0.948	0.134	0.009	0.89	2.83	2.5 cm
2% B	0.958	0.134	0.019	0.89	2.83	1.25 cm
5% B	0.987	0.134	0.049	0.89	2.83	0.5 cm

Standard Concrete H 1% λ_T = 27.0 cm

andard Concrete	δ	δ_H	δ_B	0.1 MeV λ_s cm	1 MeV λ_s cm	λ_c (cm) on H	λ_c (cm) on B
0% B	2.30	0.023	0.0	5.2	16.5	219	—
1% B	2.30	0.023	0.023	5.2	16.5	219	0.98
2% B	2.30	0.023	0.046	5.2	16.5	219	0.49

METRIC
Fig. 9-1 GEN CENTRAL TRACKER ENVELOPE DRAWING
CENTRAL TRACKER LENGTH
3000.00
CENTRAL TRACKER WIDTH
1300.00
1134.00
300.00
MINIMUM TOTAL LENGTH
MINIMUM 20.00
END CAP CUT CONTOUR
1112 STRAVOE TO CONTOUR TO
500 LIN BOSCH BOFA
100 TO
INNER EXCEPTURE
100 OD X 3000 LONG
SIT 1000 TRACKER
INC TRACKER
50 TO
BEVM WIRE
POSITION 11 FOR MINIMUM TO V BRACKET CONTOURING
11-10-05
BOSCH-BOFA
20.00
MODELLING
CYCLE
50.00
BOSCH-BOFA OD
CYLINDRICAL TO
1000
N


collimator shield 1/27/93
98
1% B concrete
Concrete
Fe
Beam
Quad
0
1
2
3
4
5
6
18
20
22
24
26
28
30
32
34
36
38
40
42


11.45°
9.75°
η-2.46
3.8λ
Cu
P
P
P
4.4λ
Cu
2.6λ
2λ
P
P
13λ
P
2.6λ
11.4λ
Cu
87
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