GEM TN-92-217

Neutron Task Force Meeting - SSCL

October 21, 1992

Abstract:

Agenda, attendees, and presentations of the first GEM Neutron Task Force Meeting held at the SSC Laboratory on October 21, 1992. Agenda items are: Status of Simulations and Neutron Fluences; Verification of Simulations; Discussion of Neutrons Sources and Mitigation; Shielding Strategies; Chamber Sensitivity and Lifetime; And What About Gammas?; and Plans for Work and Next Meeting.

AGENDA FOR FIRST NEUTRON TASK FORCE MEETING
SSCL 10/21/92 AT 10AM

1 STATUS OF SIMULATIONS AND NEUTRON FLUENCES
Talks by :Waters,Fissiak,Morgunov
Other work by Mokhov,Wuest..

2 VERIFICATION OF SIMULATIONS
McDonough, Johns

3 DISCUSSION OF NEUTRON SOURCES AND MITIGATION
Forward Calorimeter (Rutherfoord)
Beam Pipe (Morgan, Chapman)
FFS (Stroynowski)

Press RETURN for more...

MAIL>

#6 22-OCT-1992 10:00:21.45 NEWMAIL
IR Quads (Morgan)

4 SHIELDING STRATEGIES
B/Poly (Wuest)

5 CHAMBER SENSITIVITY AND LIFETIME
Whitaker,Fissiak

6 AND WHAT ABOUT GAMMAS?

7 PLANS FOR WORK AND NEXT MEETING

MAIL>

PRESENT

J. Rutherfoord	Arizona
K. Morgan	SSC
G. Chapman	SSC
M. Marx	SSC
A. Golutvin	SSC
Yu. Fisyak	SSC
V. Morgunov	SSC
K. McFarlane	SSC
L. Waters	LANL
J. McDonough	UT Austin
Yu. Kamyshkov	ORNL
C. Wuest	LLNL

Presentation by:

Yu. Fisyak

Aging of GEM muon chambers

Y.Fisyak, A.Golutvin, Y.Kiryushin, A.Korytov,
G.Mitselmakher, L.Waters

The goal of this document is to estimate a confidence level for hit rates and muon system lifetime in the GEM muon barrel based on the following list of assumptions. Our estimations are presented for discussion only. The point is the confidence levels for parameters which used in this calculations. The list of our assumptions is the following:

- Design luminosity: $10^{33} cm^{-2} s^{-1}$.
- Modified luminosity: $10^{34} cm^{-2} s^{-1}$.
- Neutron flux in GEM muon barrel in the Base 1 design:

  $10^{12.0\pm0.5}$ n/cm^2/SSCy[1].
- Neutron flux reduction factor in the Base line "X" design respect to the Base line 1: $10^{2.5\pm0.5}$.
- Efficiency for neutron registration by the muon chambers[2]:
  $10^{-2.4\pm0.1}$ hit/n/2.2 cm $= 10^{-2.74\pm0.10}$ hit/n/cm.
- Total no. of hits $\equiv$ no. of hits from neutrons:

  $$10^{12.0\pm0.5} n/cm^2/SSCy \times 10^{-7} SSCy/s \times 10^{-2.74\pm0.1} \text{ hit/n/cm}$$
  $$= 10^{2.26\pm0.51} \text{ hit } / \ cm^3/\text{s} = 182 \ {}^{+406}_{-126} \ \text{Hz/cm}^3.$$
- Wire lifetime[4]: $0.1 \div 1$ C/cm $= 10^{-0.5\pm0.5}$ C/cm.
- Collected charge per hit in proportional mode[4]:
  $0.1 \div 1$ pC/hit $= 10^{-12.5\pm0.5}$ C/hit.

- Collected charge per hit in streamer mode[4]:
  100 ± 50 pC/hits $\approx 10^{-10\pm0.24}$ C/hit.

- **PDT**

  - volume[3]: $\pi 4^2/4\times400cm^3 \simeq 5000cm^3$
  - Hit/channel: $10^{5.95\pm0.51}$ Hz/channel $= 10^{-.05\pm0.51}$ MHz/channel;
  - Hit/1cm of wires: $10^{3.36\pm0.51}$ Hz/cm
  - Collected charge in proportional mode:
    $10^{3.36\pm0.51}$ Hz/cm $\times$ $10^{-12.5\pm0.5}$ C/hit $= 10^{-9.14\pm0.71}$ C/cm/s
    $= 10^{-2.14\pm0.71}$ C/cm/SSCy $= 7.2\ ^{+29.2}_{-5.8}$ mC/cm/SSCy.
  - Lifetime in proportional mode:
  - Collected charge in streamer mode:
    $10^{3.36\pm0.51}$ Hz/cm $\times$ $10^{-10\pm0.24}$ C/hit $= 10^{-6.64\pm0.56}$ C/cm/s $=$
    $10^{0.36\pm0.56}$ C/cm/SSCy.

    * at design luminosity in Base line 1:
      $(10^{-0.5\pm0.5}$ C/cm$)$ / $(10^{-2.14\pm0.71}$ C/cm/SSCy$) = 10^{1.64\pm0.87}$ SSCy
      $= 44\ ^{+280}_{-38}$ SSCy
      i.e. 5% of wires (below 1.64 s.d.) will have some aging problem after 1.63 years of running.
    * at design luminosity in Base line "X":
      $(10^{1.64\pm0.87})$ SSCy $\times10^{2.5\pm0.5} = 10^{4.14\pm1.00}$
      $= 13.8\ ^{+124}_{-12.4} \times10^3$ SSCy
      i.e. 5% of wires will have some aging problem after 316 years of running.
    * at modified luminosity in Base line "X":
      $10^{1.64\pm0.87}$ SSCy $\times10^{2.5\pm0.5} \times 10^{-1} = 10^{3.14\pm1.00}$
      $= 1.38\ ^{+12.4}_{-1.24} \times10^3$ SSCy
      i.e. 5% of wires will have some aging problem after 31.6 years of running.

  - Lifetime in streamer mode:

* at design luminosity in Base line 1:
  $(10^{-0.5\pm0.5}$ C/cm) / $(10^{0.36\pm0.56}$ C/cm/SSCy)
  $= 10^{-0.86\pm0.75}$ SSCy $= 0.14 \begin{smallmatrix}+0.64\\-0.11\end{smallmatrix}$ SSCy
  i.e. 5% of wires will have some aging problem after 1 day of running.
* at design luminosity in Base line "X":
  $10^{1.64\pm0.9}$ SSCy $= 43.6 \begin{smallmatrix}+303\\-38.2\end{smallmatrix}$ SSCy
  i.e. 5% of wires will have some aging problem after 1.5 years of running.
* at modified luminosity in Base line "X":
  $4.36 \begin{smallmatrix}+30.3\\-3.82\end{smallmatrix}$ SSCy
  i.e. 5% of wires will have some aging problem after 15 days of running.

- **LSDT**
  - Volume: $2.5^2 \times 700$ cm^3 = 4375 cm^3.
  - Hit/channel: $10^{5.90\pm0.51}$ Hz/channel
  - Hit/cm: $10^{3.06\pm0.51}$ Hz/cm
  - Collected charge in streamer mode (Base line 1 at design luminosity):
    $10^{-6.94\pm0.56}$ C/s/cm $= 10^{0.06\pm0.56}$ C/cm/SSCy
  - Lifetime:
    * the Base line 1 design:
      $10^{-.56\pm0.75}$ SSCy $= 0.26 \begin{smallmatrix}+1.2\\-0.23\end{smallmatrix}$ SSCy
      i.e. 5% of wires will have some aging problem after 1.6 days of running.
    * at design luminosity in Base line "X":
      $10^{1.94\pm0.90}$ SSCy $= 87.1 \begin{smallmatrix}+605\\-76.1\end{smallmatrix}$ SSCy
      i.e. 5% of wires will have some aging problem after 1.64 years of running.

* at modified luminosity in Base line "X":

$10^{0.94\pm0.90}$ SSCy $= 8.71 \begin{array}{c}+60.5\\-7.61\end{array}$ SSCy

i.e. 5% of wires will have some aging problem after 29 days of running.

References

[1] D.M.Lee et al., "Progress Report: Neutron Flux in the GEM detector", GEM TN-92-91. In the tabl.7 of this report it is presented esimated neutron fluence at Z= 5.75m and R = 2.45m equaled to 1.18×10^{12} n/cm^2/SSCy for neutron with $E_{kin} > 100keV$. Number $3 \div 4\times10^{12}$ in the GEM muon barrel is obtained as the private communication from L.Waters after her accounting the structures of the Low Beta Quadrupoles.

[2] A.Korytov et al., "Neutron Sensitivity of LSDT chambers", GEM TN-92-122.

[3] " GEM Baseline 1 " , GEM TN-92-76 REV C

[4] Proceenings of the Workshop on Radiation Damage to wire chambers, LBL, Berkeley, Califormia, Jan. 16-17, 1986.
J.A.Kadyk, NIM, A300 (1991) 436-479.

gem

γeμ

Presentation by:

L. Waters

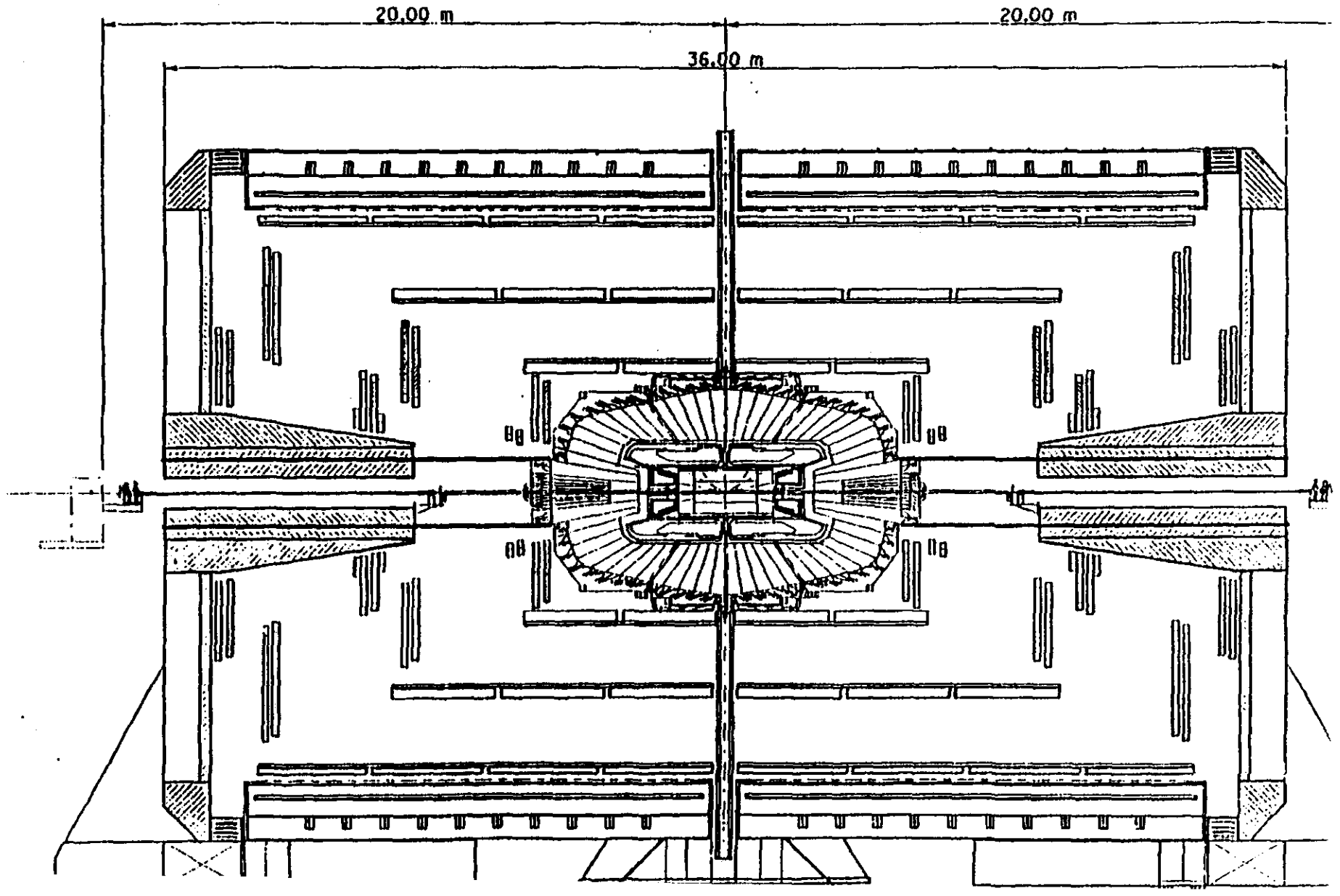
Lahet / MCNP
Laurie Waters

10-21-92

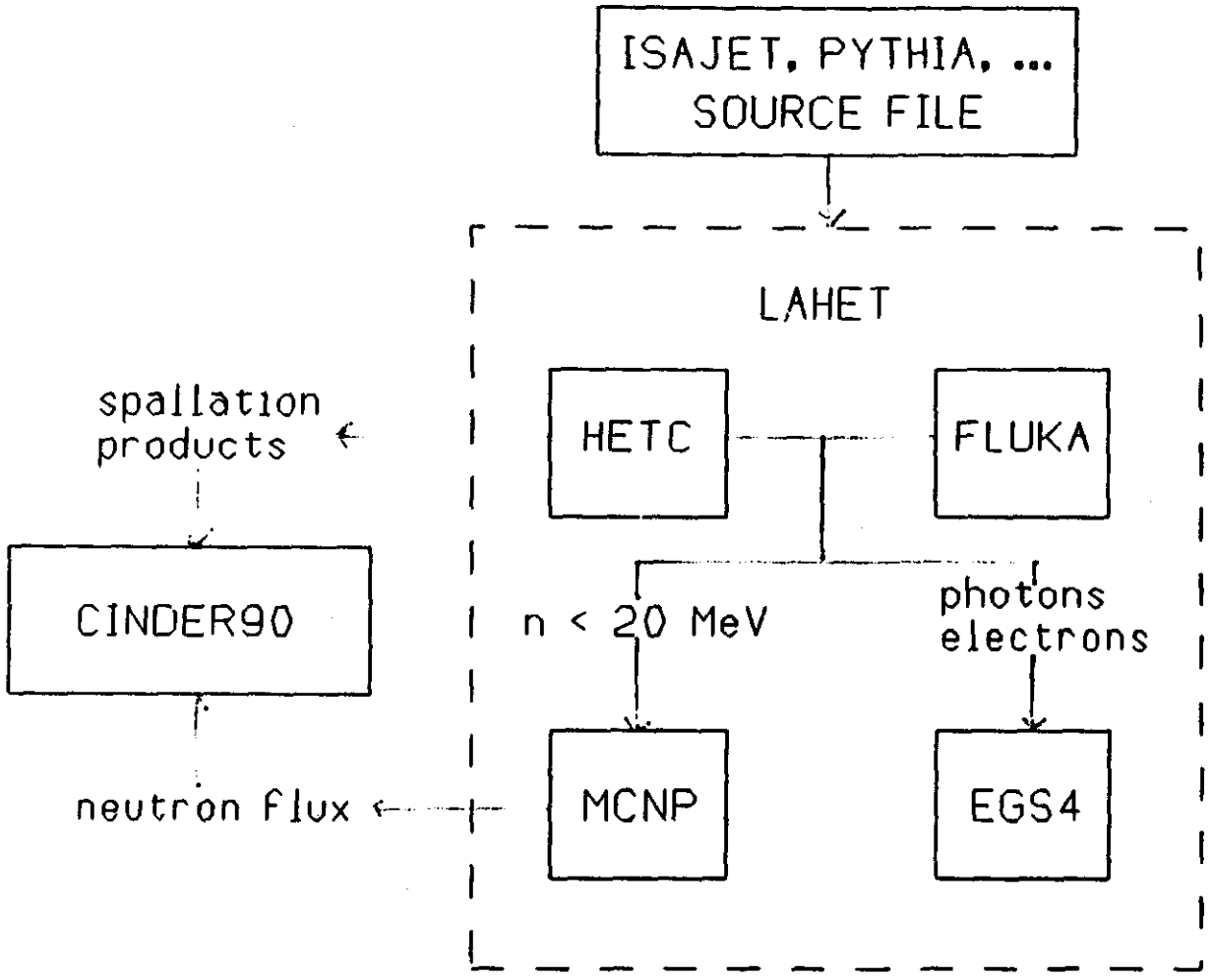
GEM DETECTOR D.C

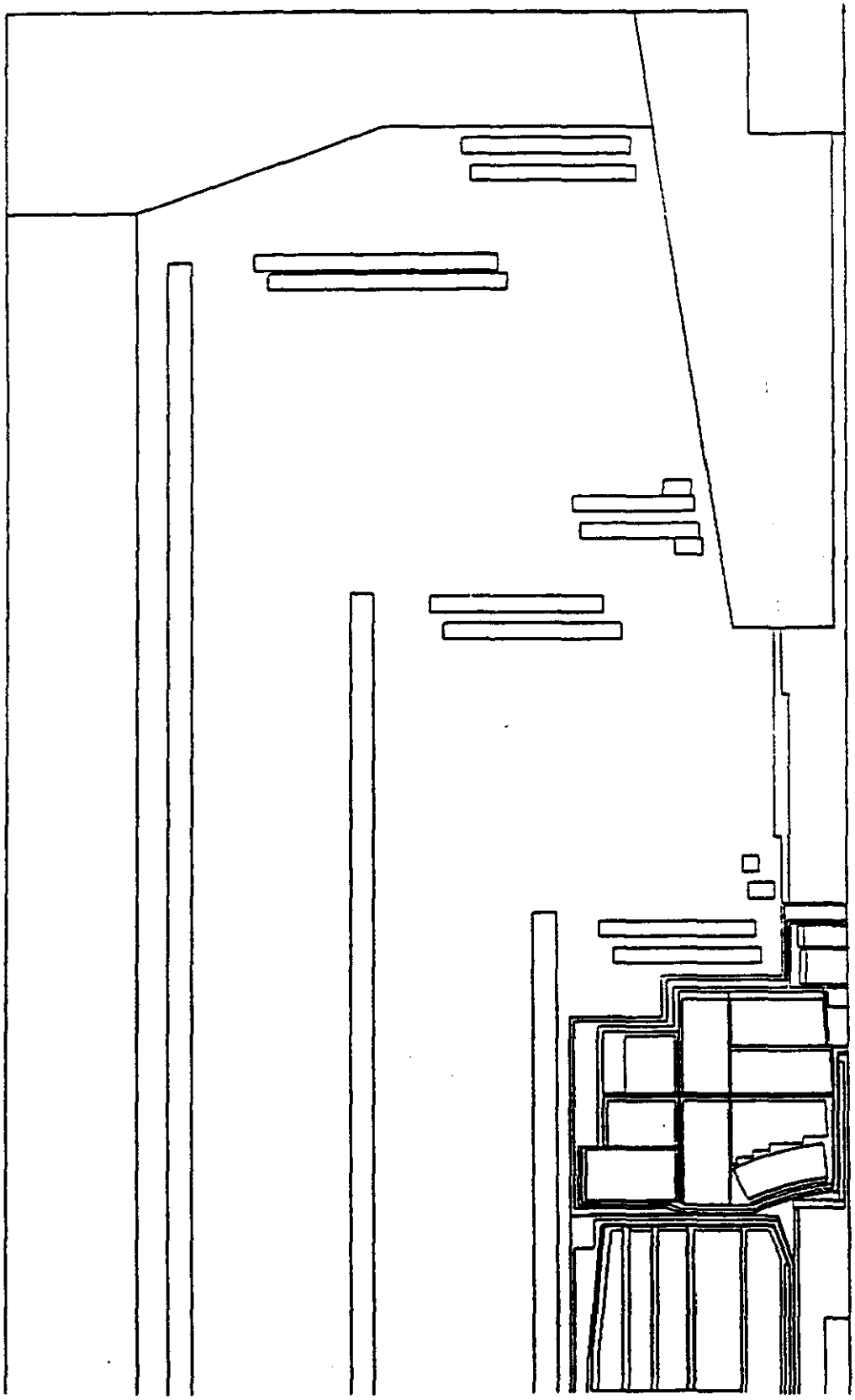
E.M. CALORIMETER : Liq Kr CALORIMETER : FIBER

VACUUM SYSTEM : OPTION 1 or 3

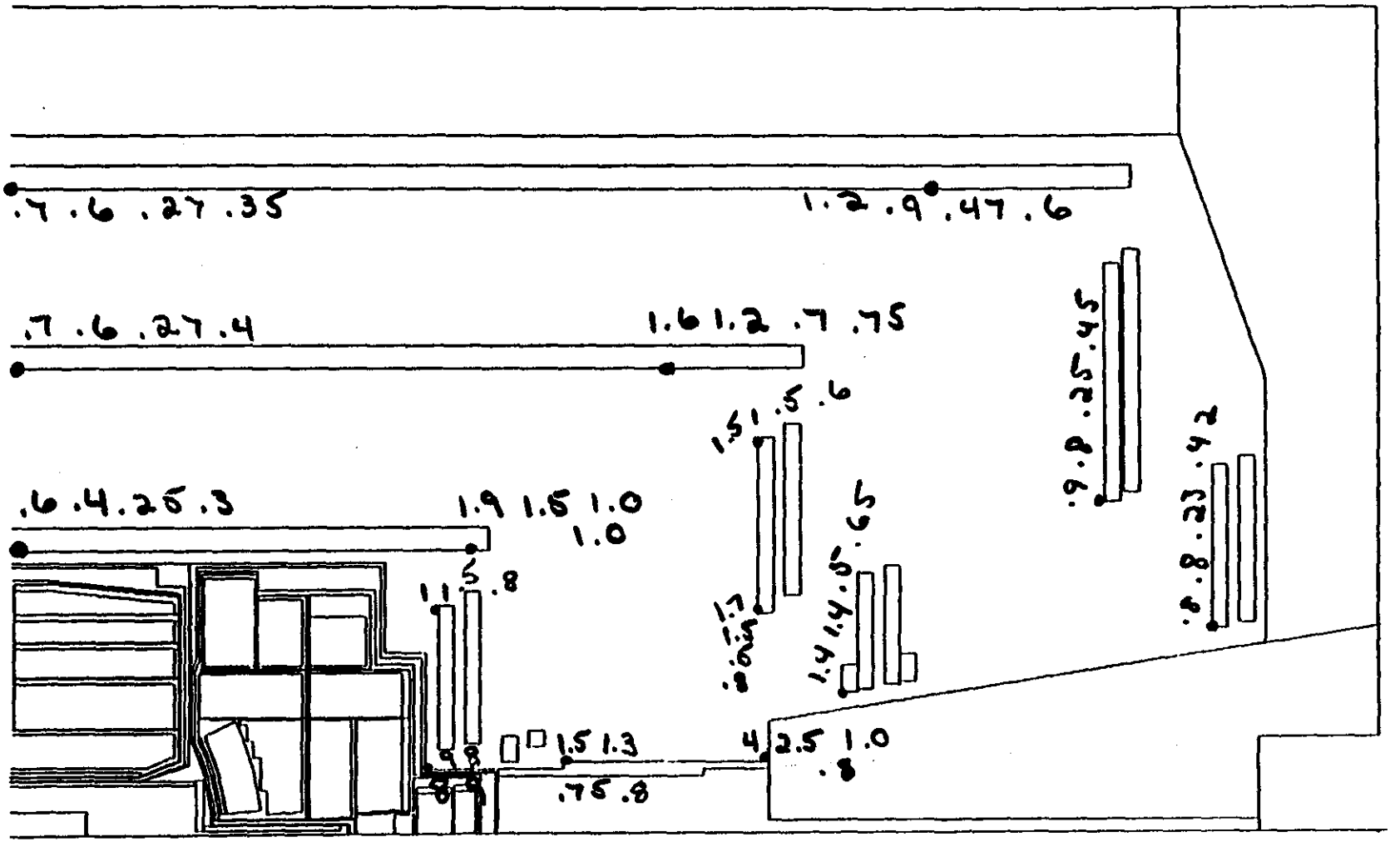


ORNL I&C
10 15 92 14:33 ☎6155762513
003


ISAJET, PYTHIA, ...
SOURCE FILE
LAHET
HETC
FLUKA
spallation
products
CINDER90
n < 20 MeV
photons
electrons
neutron flux
MCNP
EGS4



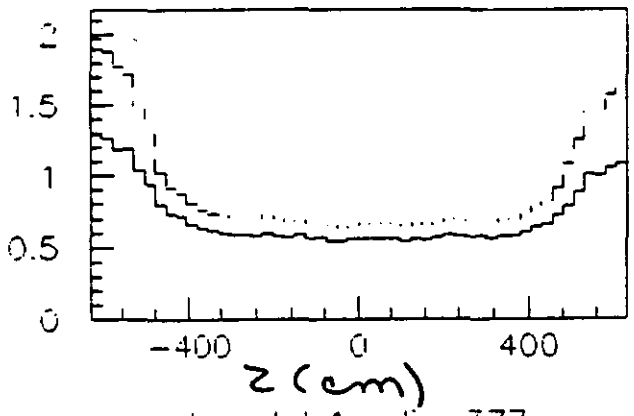
MODIFIED FIELD SHAPER
NO FIELD SHAPER SUPPORT
NO BEAMPIPE



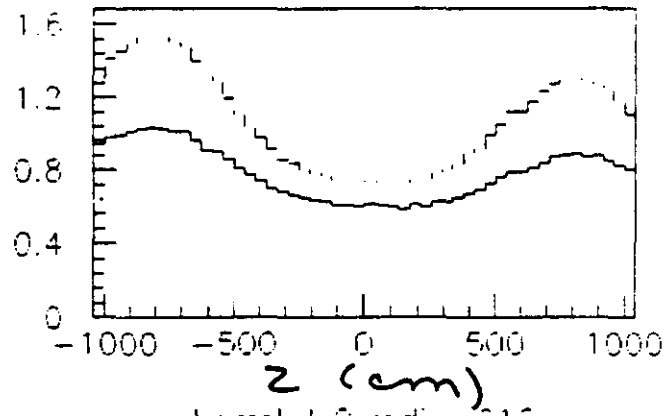
ORIGINAL

— — — — ALL

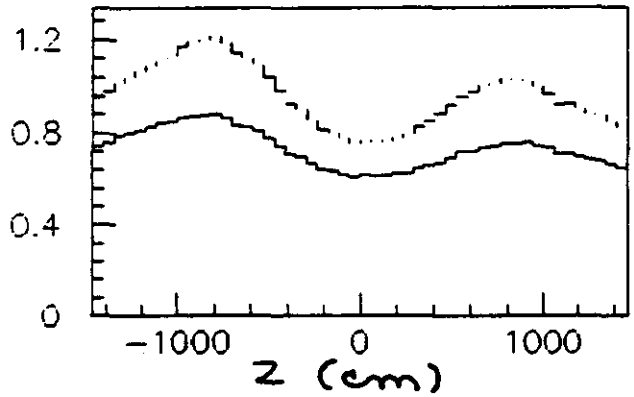
——— NEUTRONS WITH KE < 100 keV



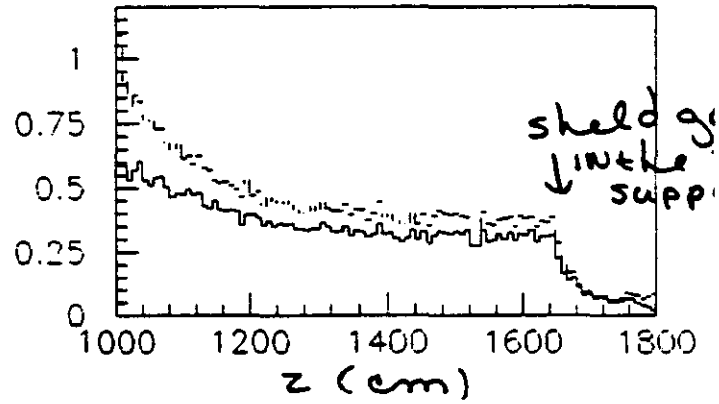
barrel dc1 radius 377



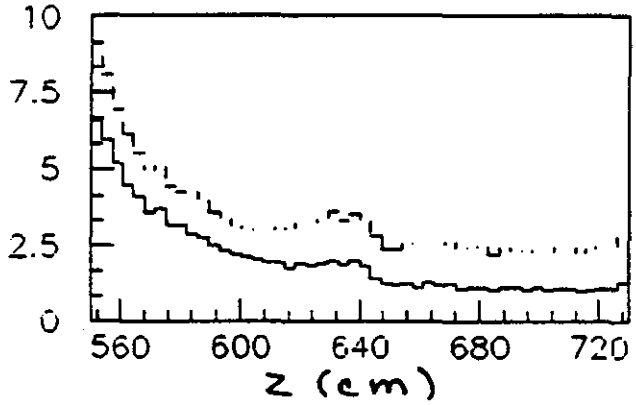
barrel dc2 radius 616



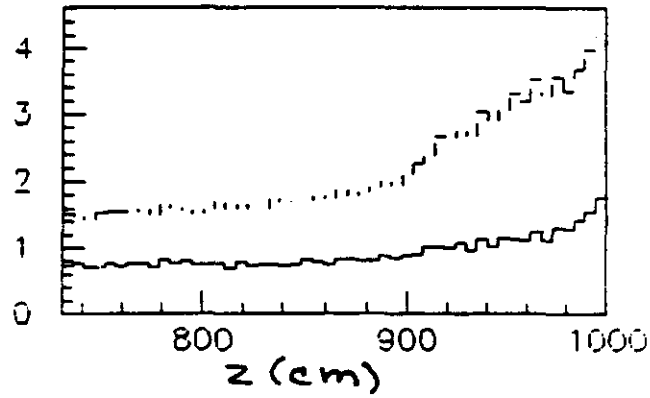
barrel dc3 radius 855



field shaper theta 3.7 deg



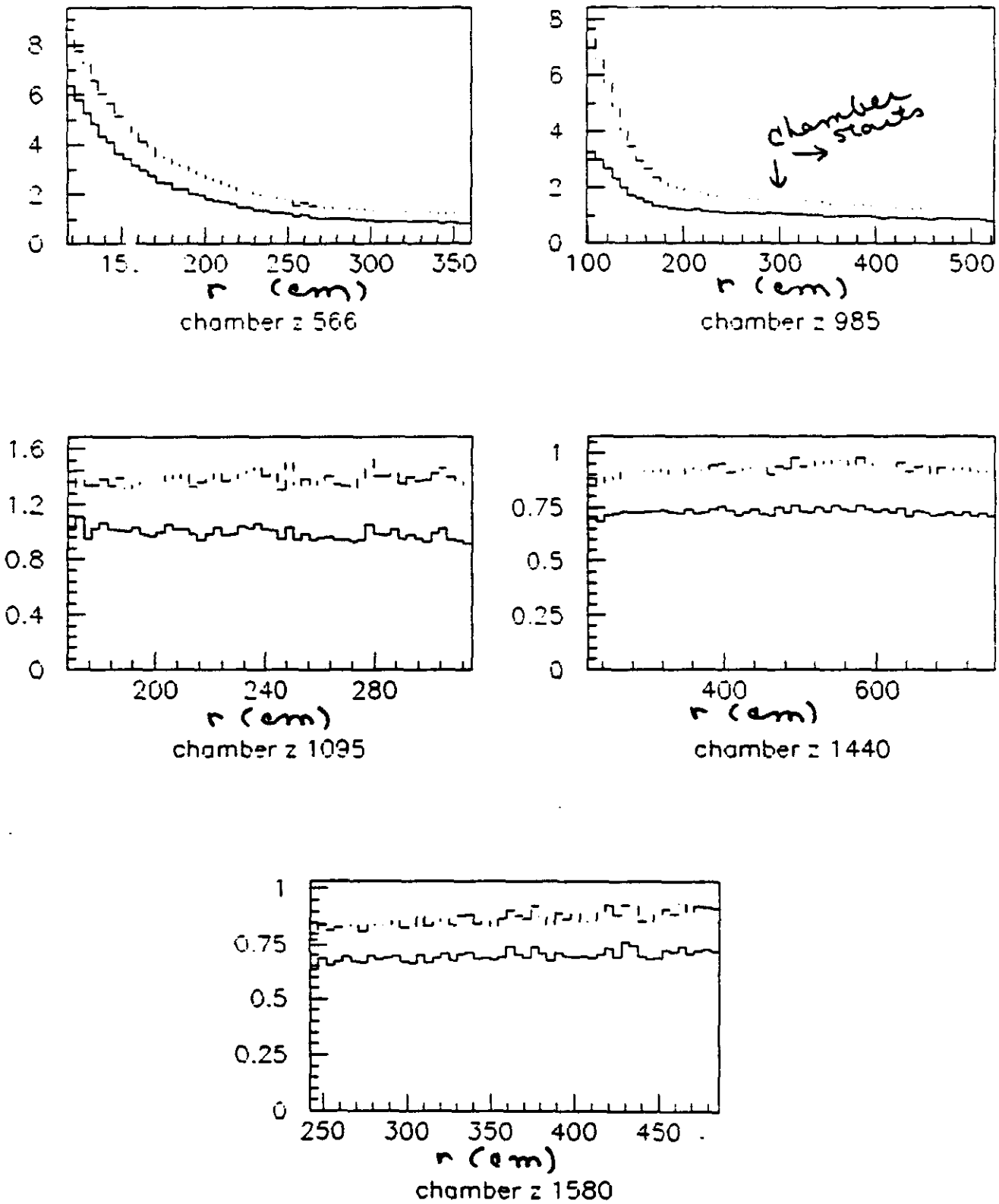
shield radius 89



shield radius 99

UNITS = #/cm²/ssc yr × 10¹² (L = 10³³)

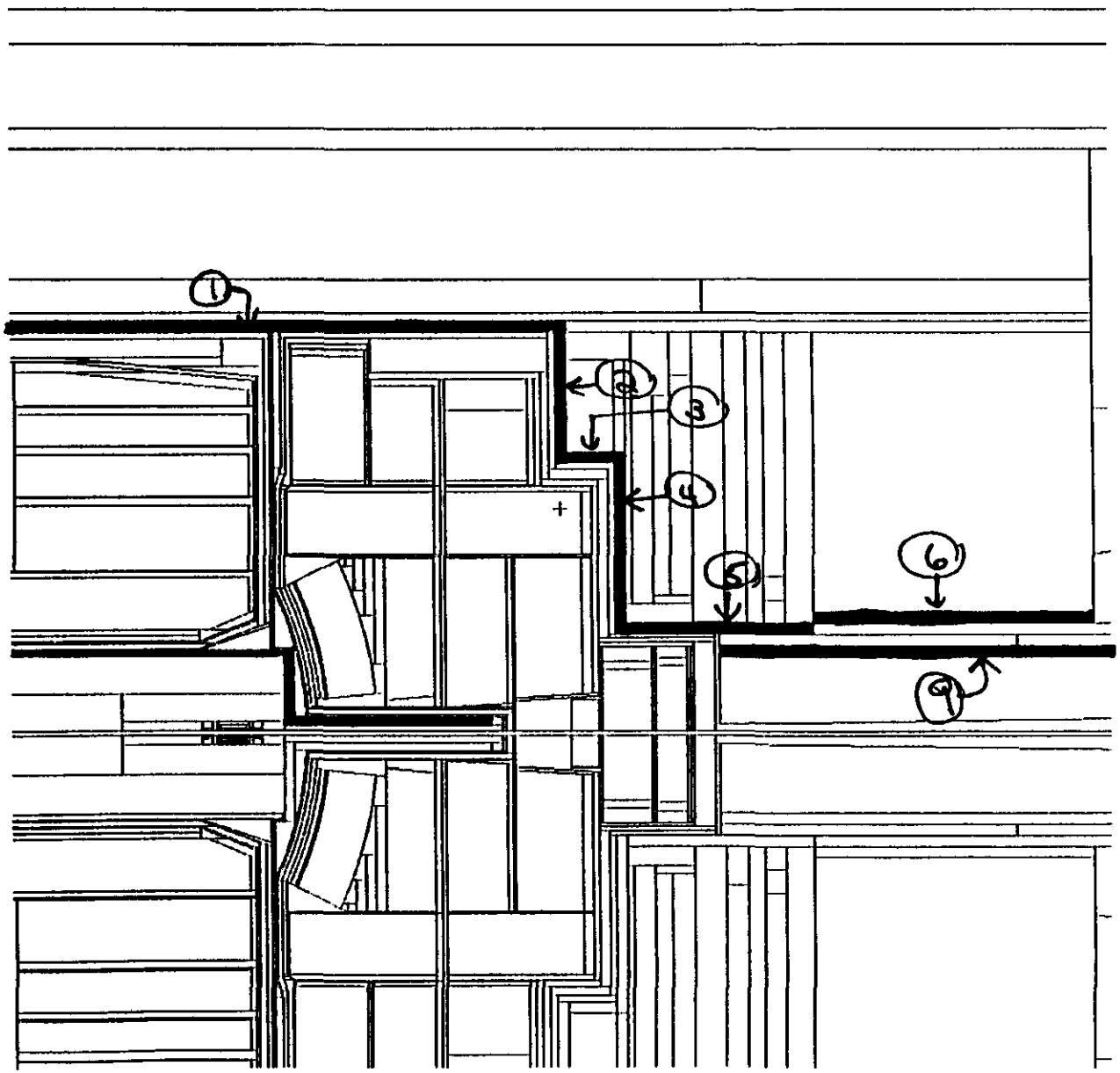
ORIGINAL


r (cm)
chamber z 566
chamber starts
r (cm)
chamber z 985
r (cm)
chamber z 1095
r (cm)
chamber z 1440
r (cm)
chamber z 1580

10/16/92 14 50 20
GEM SIMULATION FINE
SEGMENTATION

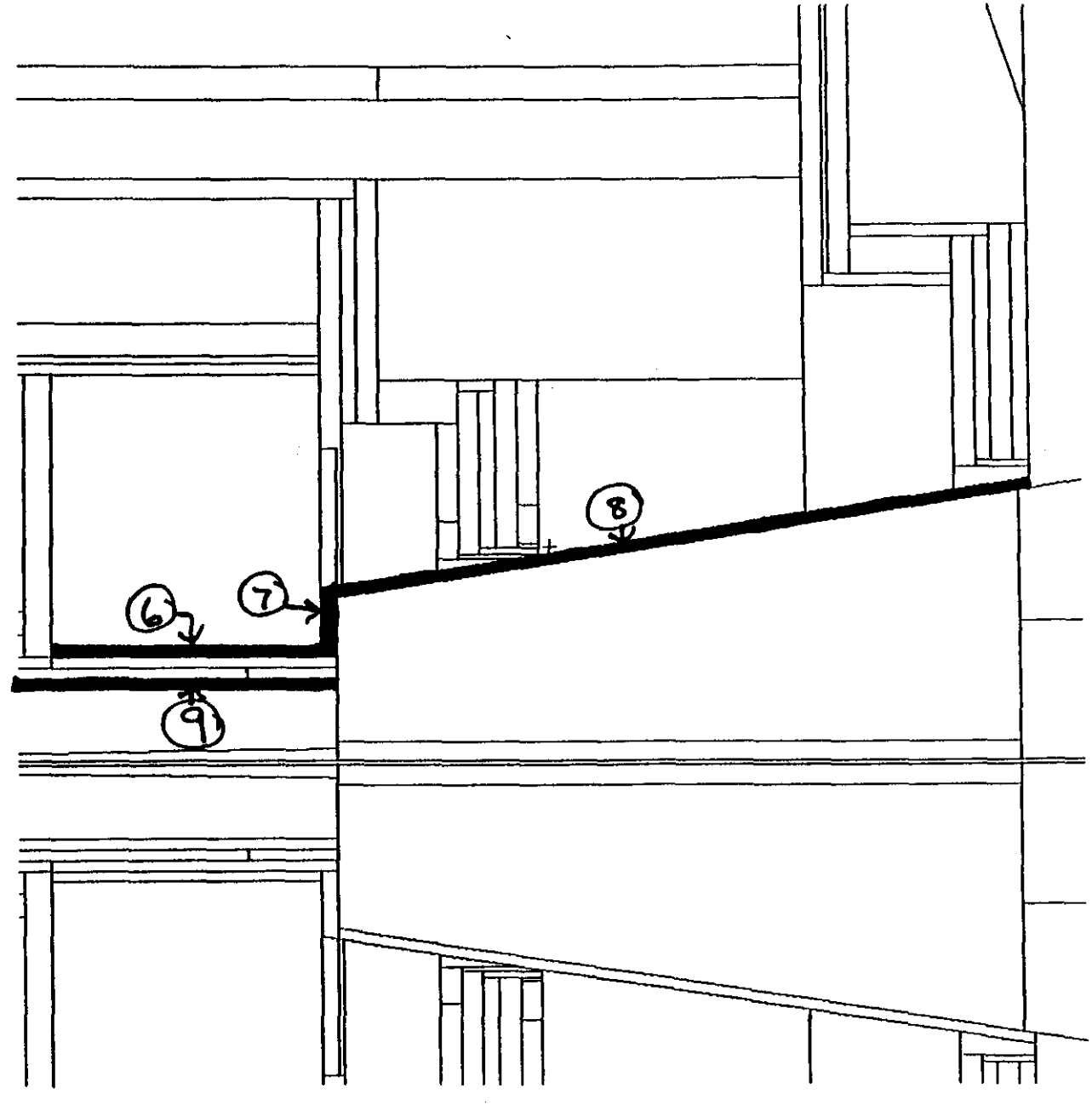
PROBID = 10/16/92 14 49 41
BASIS
(0.000000, 0.000000, 1.000000)
(0.000000, 1.000000, 0.000000)
ORIGIN
(0.00, 200.00, 500.00)
EXTENT = (500.00, 500.00)

1 10 cm
2 10 cm
3 10 cm
4 10 cm
5 9.97 cm
6 10 cm
7 15 cm
8 10 cm
9 10 cm



10/16/92 14 52 52
GEM SIMULATION FINE
SEGMENTATION

PROBID = 10/16/92 14 52 22
BASIS
(0.000000, 0.000000, 1.000000)
(0.000000, 1.000000, 0.000000)
ORIGIN
(0.00, 200.00, 1200.00)
EXTENT = (500.00, 500.00)



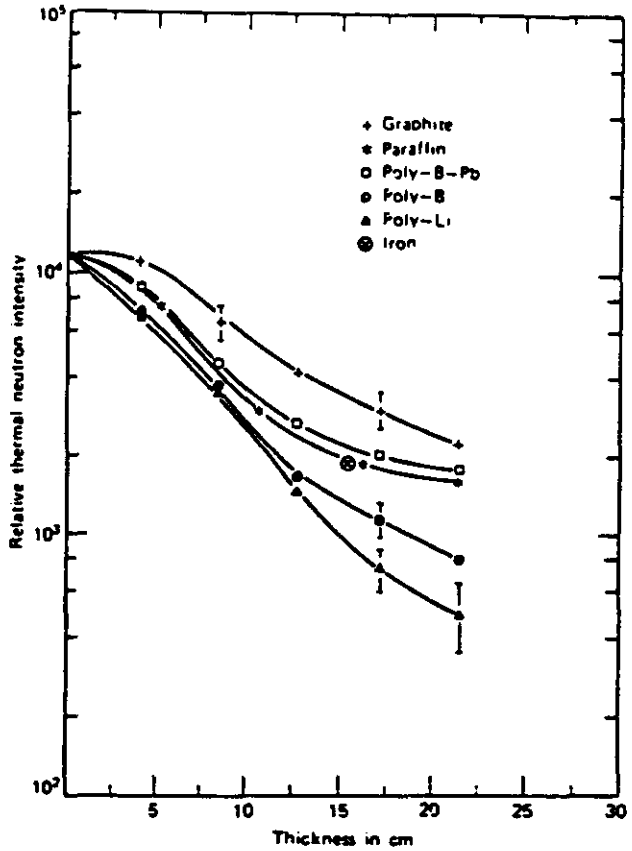


FIGURE 20-7. The relative effectiveness of different shielding materials for 2.6 MeV neutrons as indicated by the thermal neutron flux for various thickness. (From Gujrathi and D'Auria[12].)

Boron-Polyethelyne 201

by weight: C 61.2%

H 11.6%

O 22.2%

B_{nat} 5%

B_{nat} = 20% ^{10}B, 80% ^{11}B

kb cross section for neutron absorption (thermal)

$^{10}B(n,\alpha)$

.48 MeV gamma ray

6 EM. DESIGN!

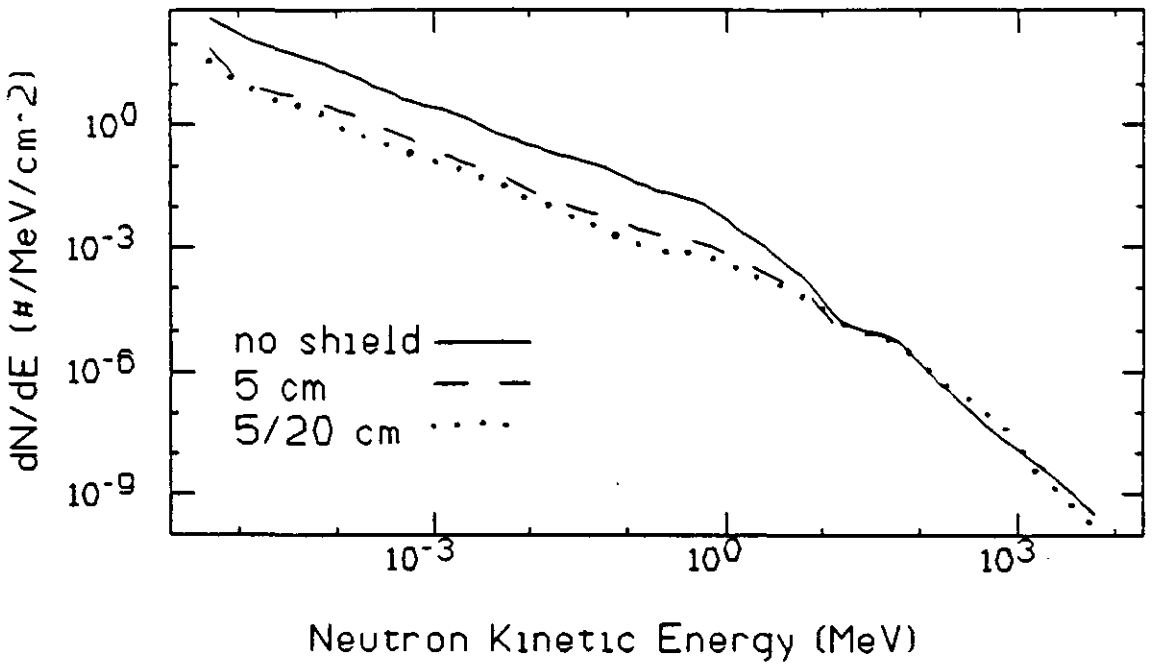


Figure 5: Differential neutron fluence is compared for the no shield, 5 cm and 5/20 cm cases. Results are per SSC minimum bias event. waters/4-4-92

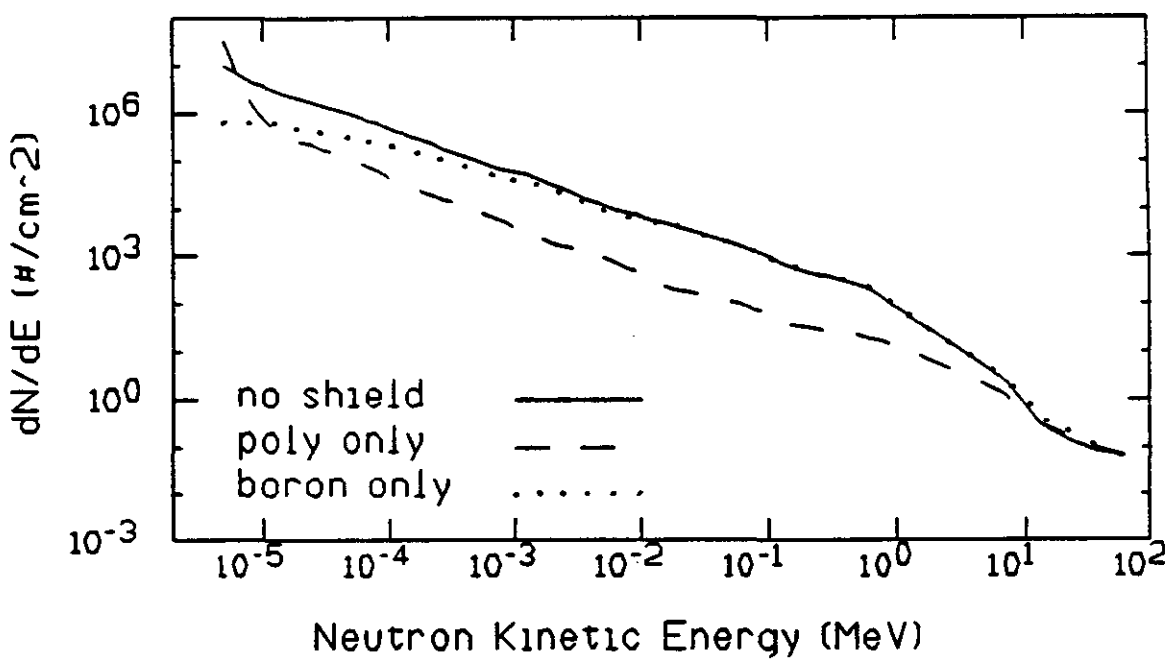
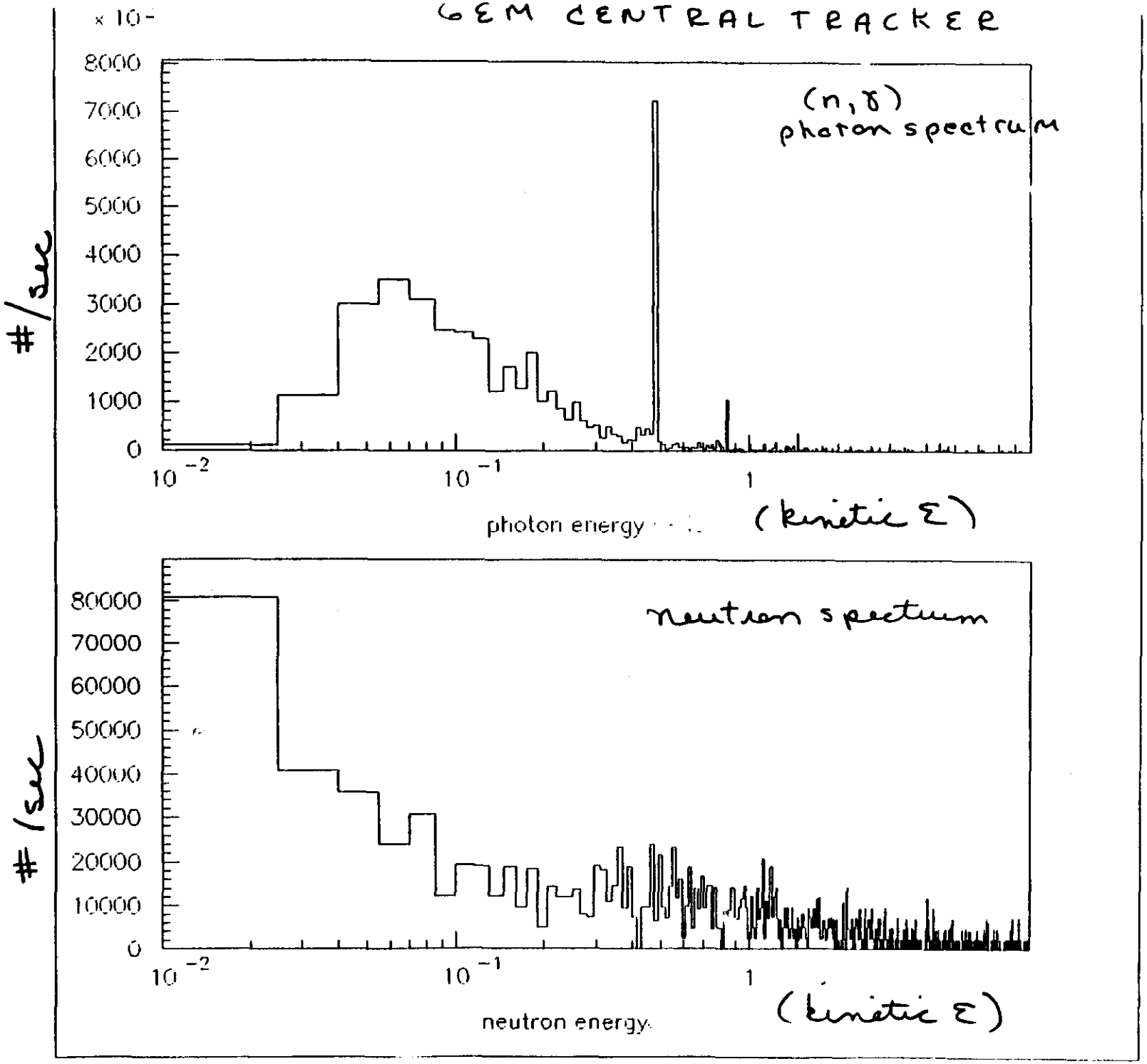
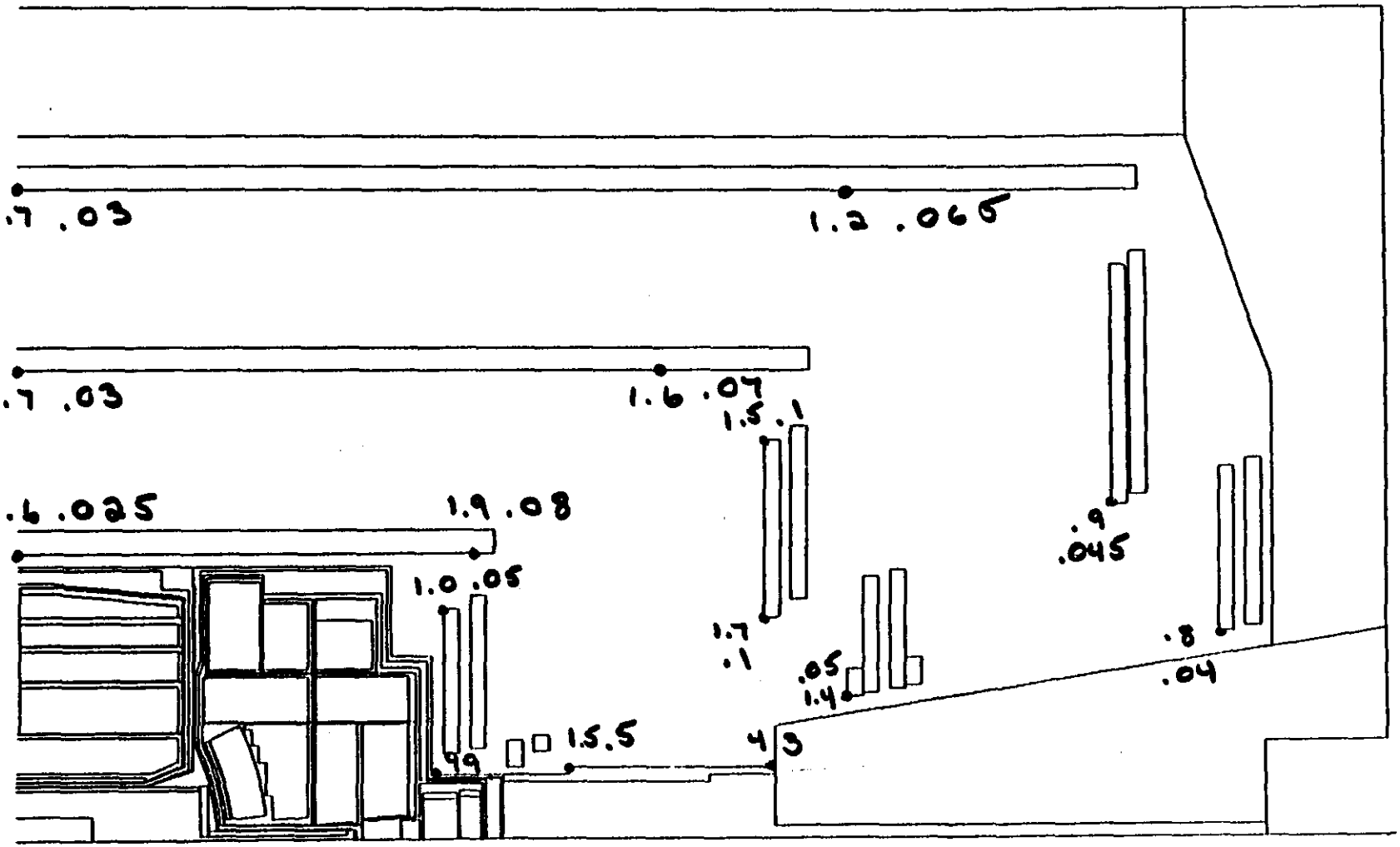


Figure 6: The thermalization effects of shielding composed of just polyethylene, and the supression of the thermal neutrons with a shield composed of just boron are compared to the no shield case. Results are per SSC minimum bias event. waters/4-4-92

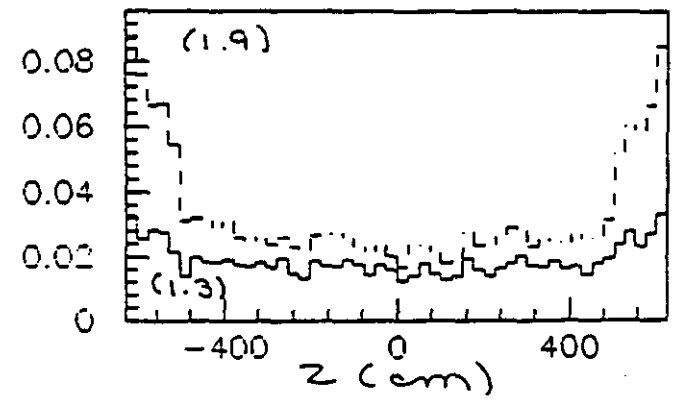
GEM CENTRAL TRACKER



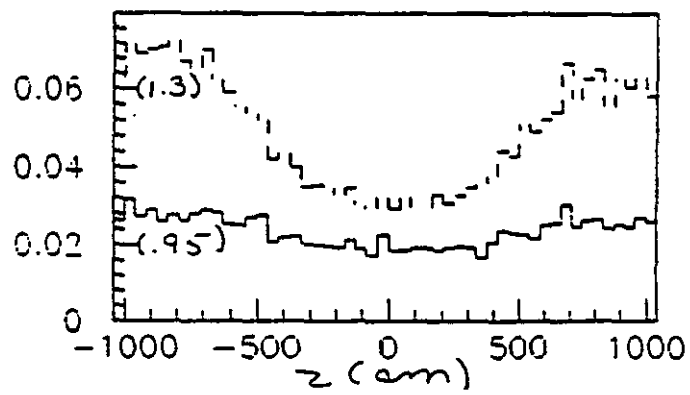
ORIGINAL x 10[illegible] n/cm²/SSCYZ
10 cm B-Poly



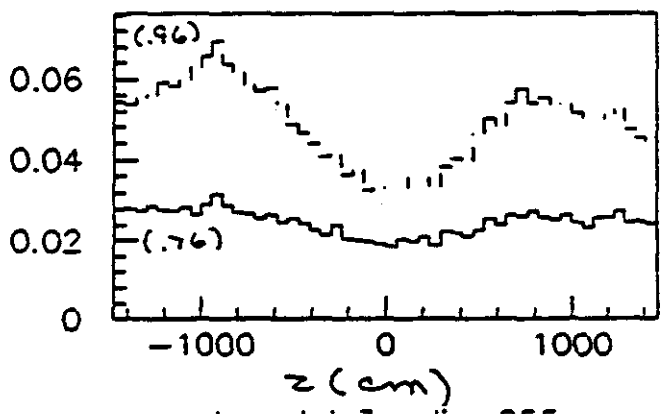
1-9 (10 cm) case 3



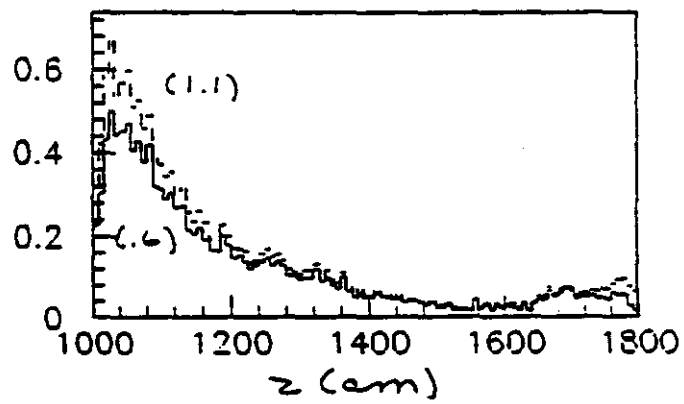
barrel dc1 radius 377



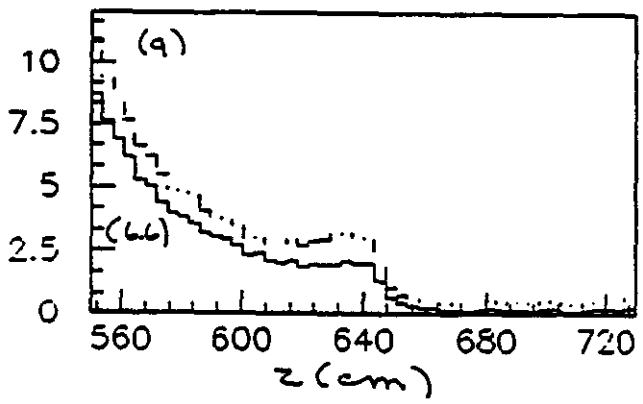
barrel dc2 radius 616



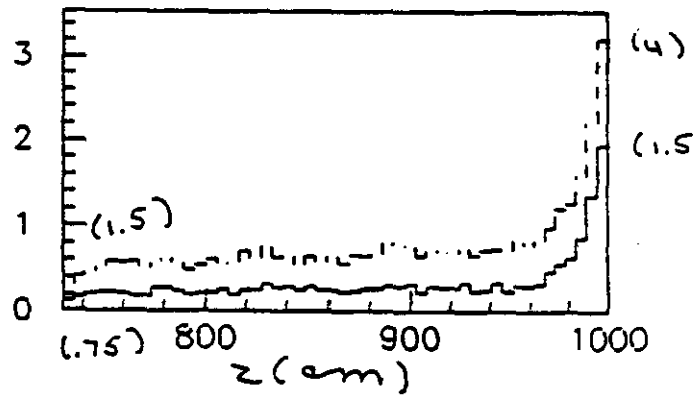
barrel dc3 radius 855



field shaper theta 8.7 deg

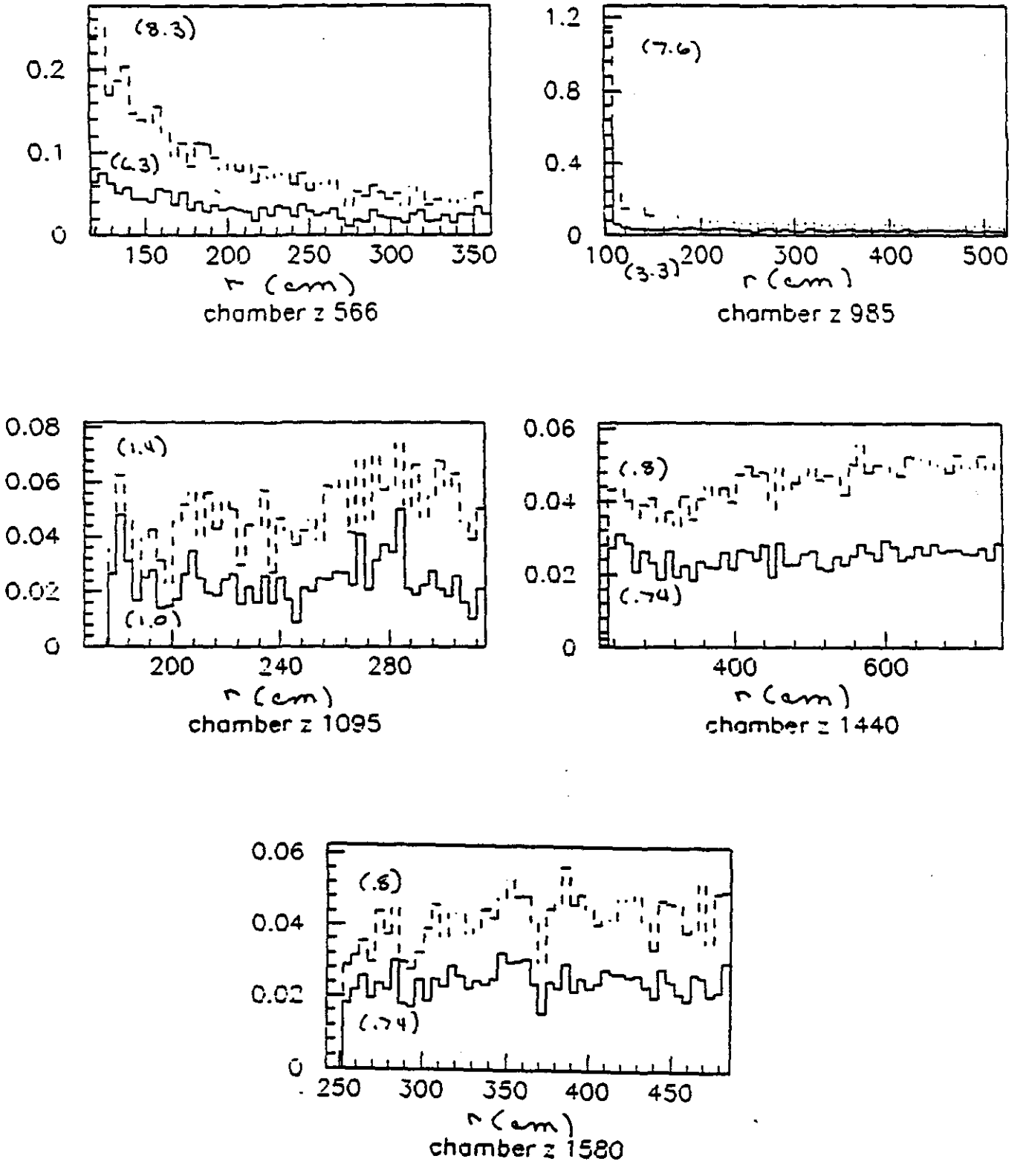


shield radius 89



shield radius 99

1-9 (10 cm)


(8.3)
(6.3)
0.2
0.1
0
150
200
250
300
350
r (cm)
chamber z 566
(7.6)
(3.3)
1.2
0.8
0.4
0
100
200
300
400
500
r (cm)
chamber z 985
(1.4)
(1.0)
0.08
0.06
0.04
0.02
0
200
240
280
r (cm)
chamber z 1095
(.8)
(.74)
0.06
0.04
0.02
0
400
600
r (cm)
chamber z 1440
(.8)
(.74)
0.06
0.04
0.02
0
250
300
350
400
450
r (cm)
chamber z 1580

```
   9/19/92 13 46 13
SDC SIMULATION

PROBID =    9/19/92 13 29 16
BASIS
( 0.000000, 0.000000, 1.000000)
( 0.000000, 1.000000, 0.000000)
ORIGIN
(      0.00,      0.00,      0.00)
EXTENT = (  6000.00,  6000.00)
POSSIBLE CAUSES OF DOTTED LINES
 ERRORS IN THE GEOMETRY.
 COOKIE-CUTTER CELL IN THE SOURCE.
 A PROBLEM PLANE COINCIDENT WITH
  THE PLOT PLANE.
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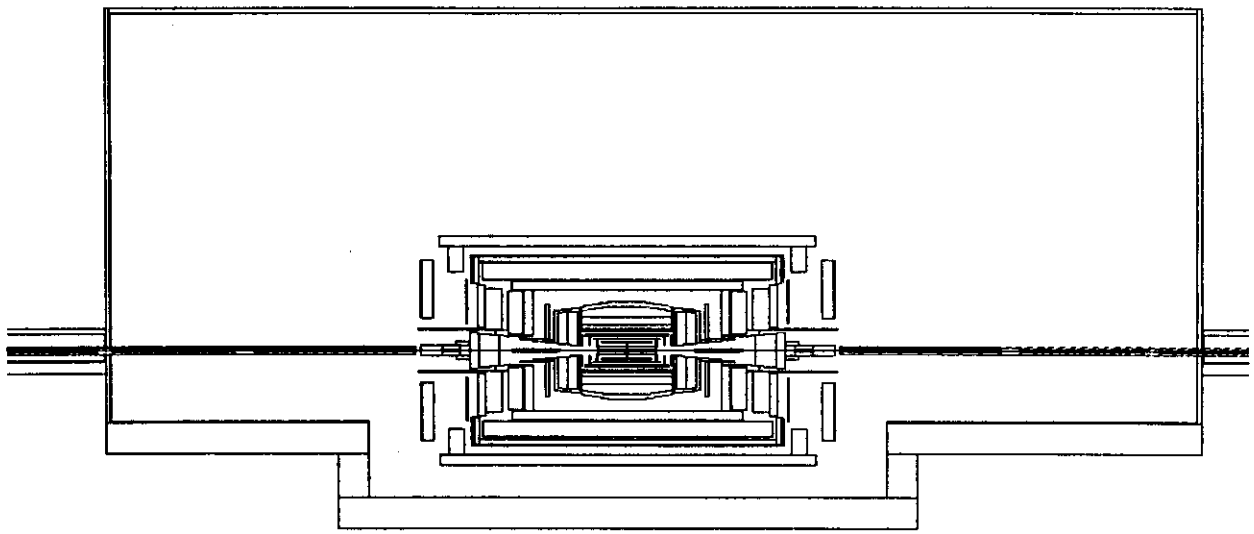
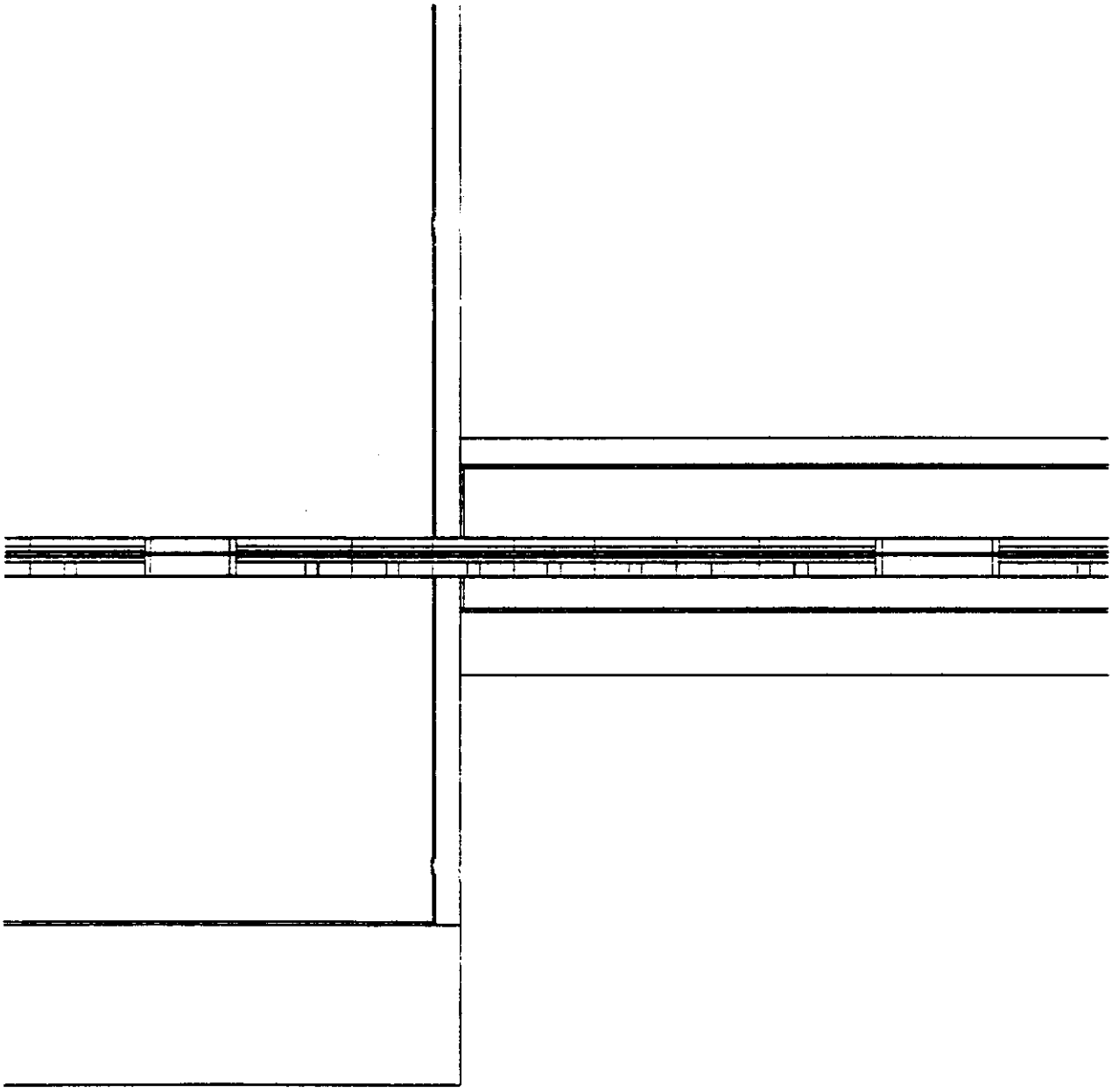
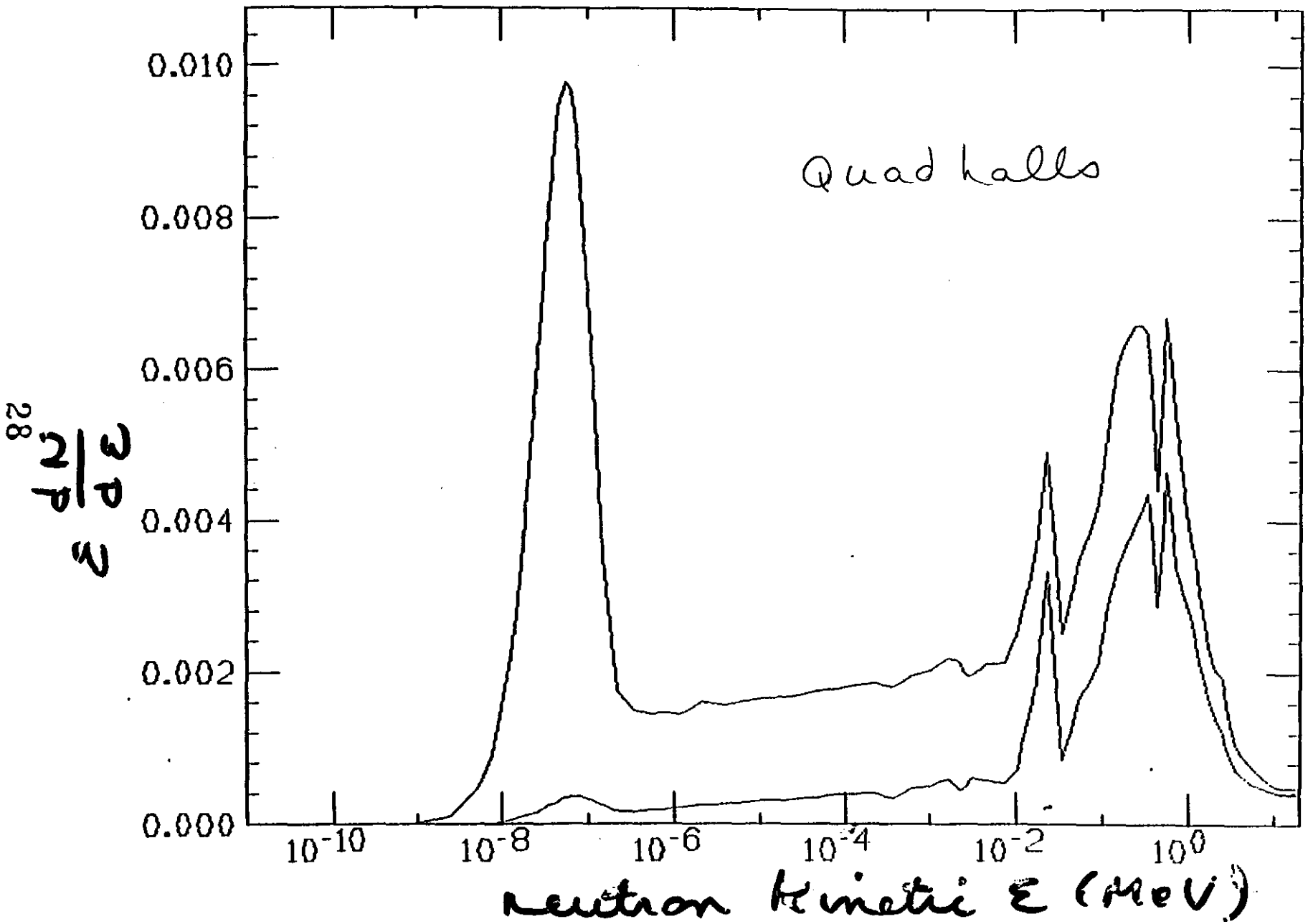
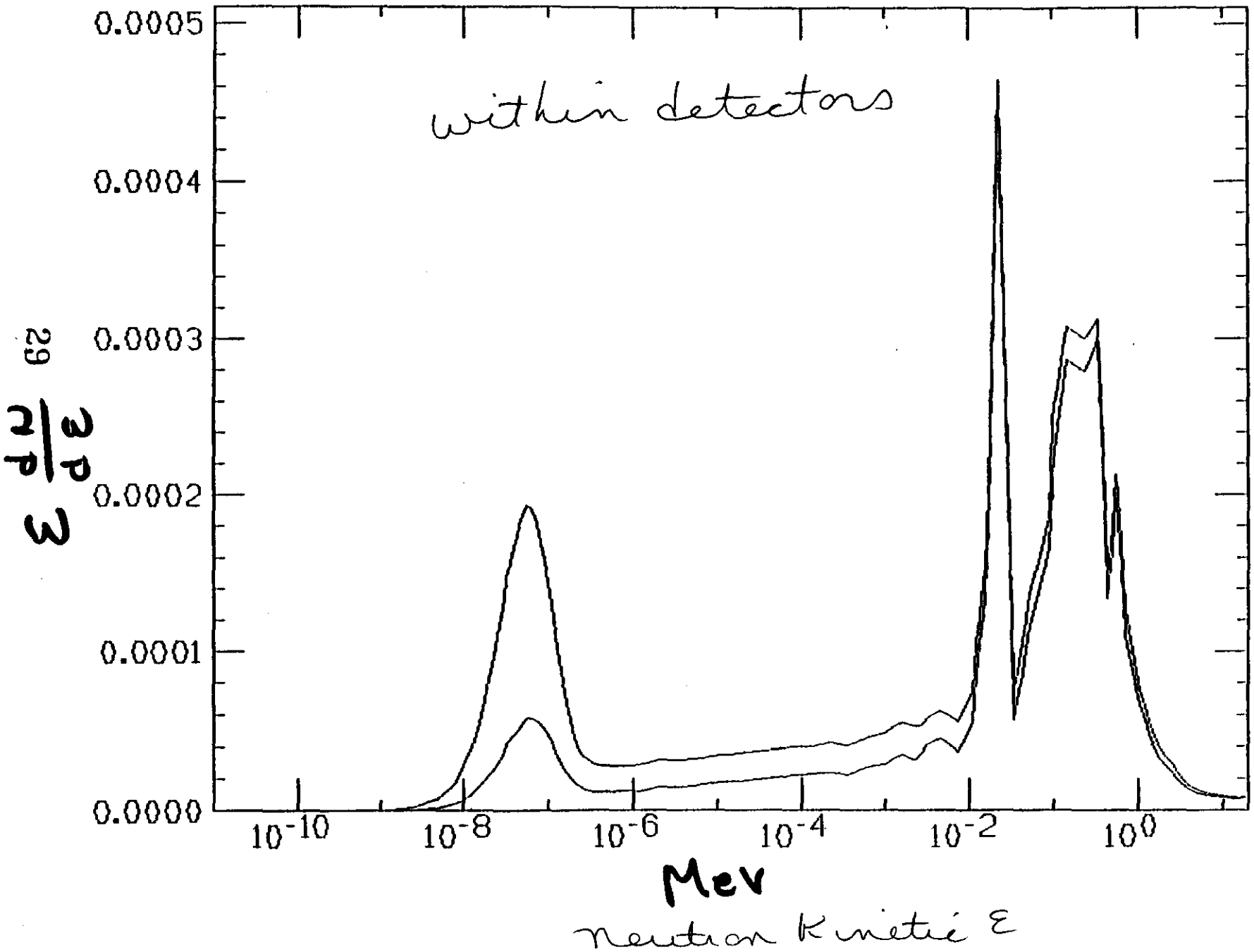
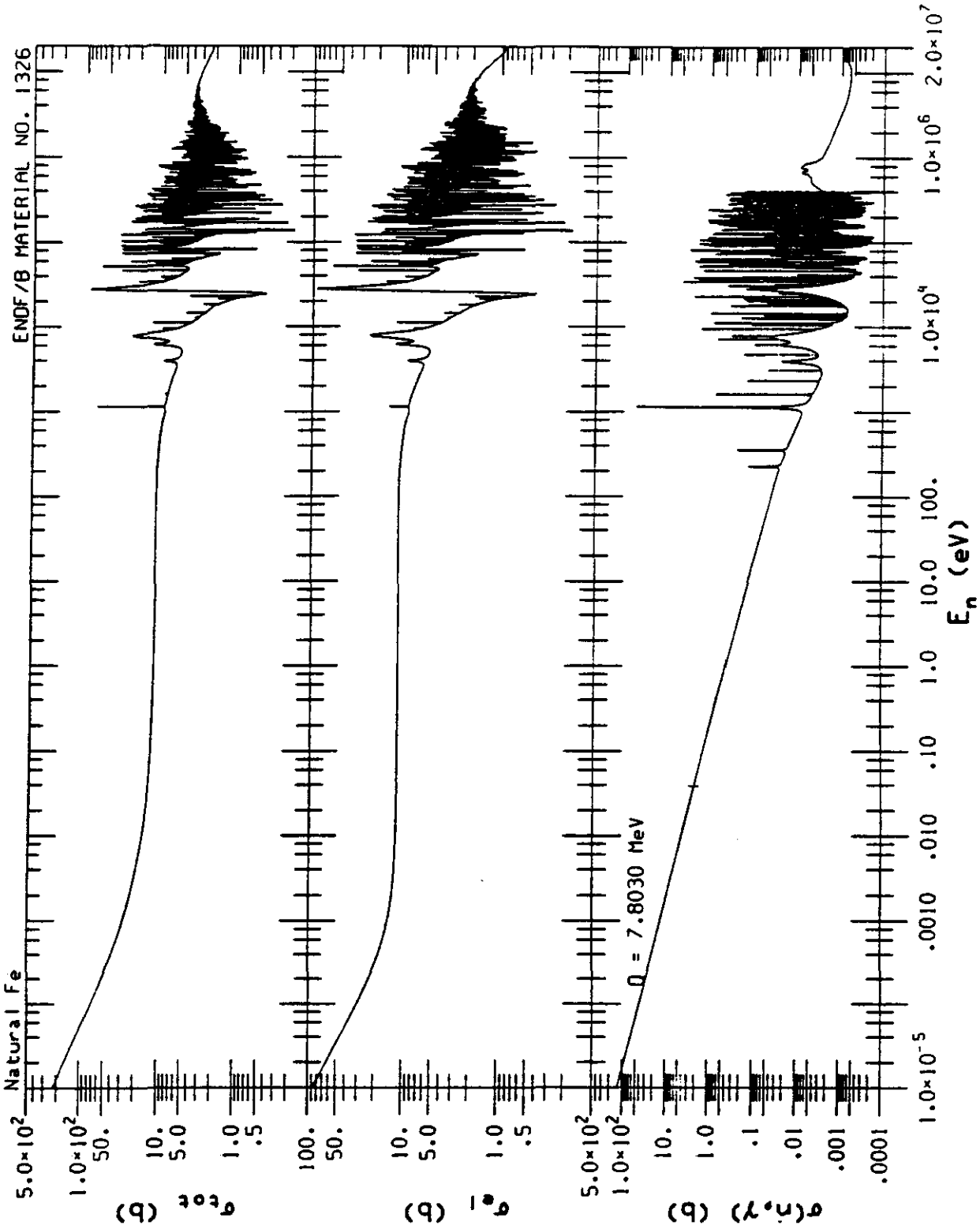





Quad halls
0.010
0.008
0.006
0.004
0.002
0.000
$\varepsilon \frac{dN}{d\varepsilon}$
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
neutron kinetic ε (MeV)



within detectors
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
Mev
neutron Kinetic ε


ENDF/B MATERIAL NO. 1326
Natural Fe
Q = 7.8030 MeV
E_n (eV)
σ_{tot} (b)
σ_{el} (b)
$\sigma(n,\gamma)$ (b)

26-0-1

Proposals

1. Low-Betta Quads $\Longrightarrow$ $35m$. Factor 5 - 10.
2. Borated Poliethylene shield ($10cm$). Factor 30.
   - Lead to supression gammas.
3. Reactor concrete shields. Factor ?.
4. FCAL
   - Make from concrete. Factor ?.
   - Push FCAL further into endcap. Factor ?.
   - "Redesign FCAL". Factor ?.
5. Hall.
   - Borated Poliethylene shield at the walls? Factor ~ 3.
6. Beam pipe. Factor 3.

gem

γeμ

Presentation by:

V. Morgunov

V. Morgunov

Neutron sources in GEM setup

All calculations are made by program GEANT.
Only hadrons component of events was used.
Parameters for calculation:

1. Mini-bias events from DTUGET (N.Mokhov) - 900
2. Luminosity - $10^{34} cm^{-2} sec^{-1}$
3. SSC year - $10^{7} sec$
4. Total cross section - $100 mbarn$
5. Interactions per year - 10^{16}
6. Forward calorimeter :
   - material - Tungsten + Quartz
   - inner radius - $2.5 cm$
   - face distance from interaction point - $3.5 m$
   - length - $1463 cm$
7. Field shaper :
   - material - Iron
   - inner radius - $21 cm$
   - face distance from interaction point - $10 m$
8. Collimator:
   - material - Iron

- inner radius - $2.5cm$
- face distance from interaction point - $33m$
- length - $200cm$

9. LBQ:

- material - Iron
- inner radius - $2.5cm$
- face distance from interaction point - $35m$

Space distributions of hadron stars density in different parts of GEM setup are shown in fig. 1,2,3.

In fig. 4 are shown linear stars density in Forward calorimeter, Field shaper, Collimator and in First Low-betta quadrupole. Linear density is an integral of histograms along radius.

The whole integral for this curve (fig. 4) is neutrons yelded during year - $6.45 \cdot 10^{20}$ neutrons. The fractions are FCAL - 32%, FLSH - 14%, Collimator + LBQ - 52%, 2% from the beam tube. One can see the stars density has the same order in FCAL and Collimator but for the neutron fluxes it will be a big difference becaurse the sources in FCAL are shilded by the calorimeter (endcup) body in oposit the sources in Collimator and LBQ arn't shilded by it's body.

Another interesting point is factor 2 difference between neutron yield in Tungsten and in Iron which is given by GEANT.

At the fig. 5 are shown difference in neutron yield from LBQ with and without magnetic field in it. There is difference in neutron yield from LBQ $\sim$ factor 2.

Next step of calculations will be to calculate fluxes from this neutron sources in muon chambers and tracker by LAHET code.

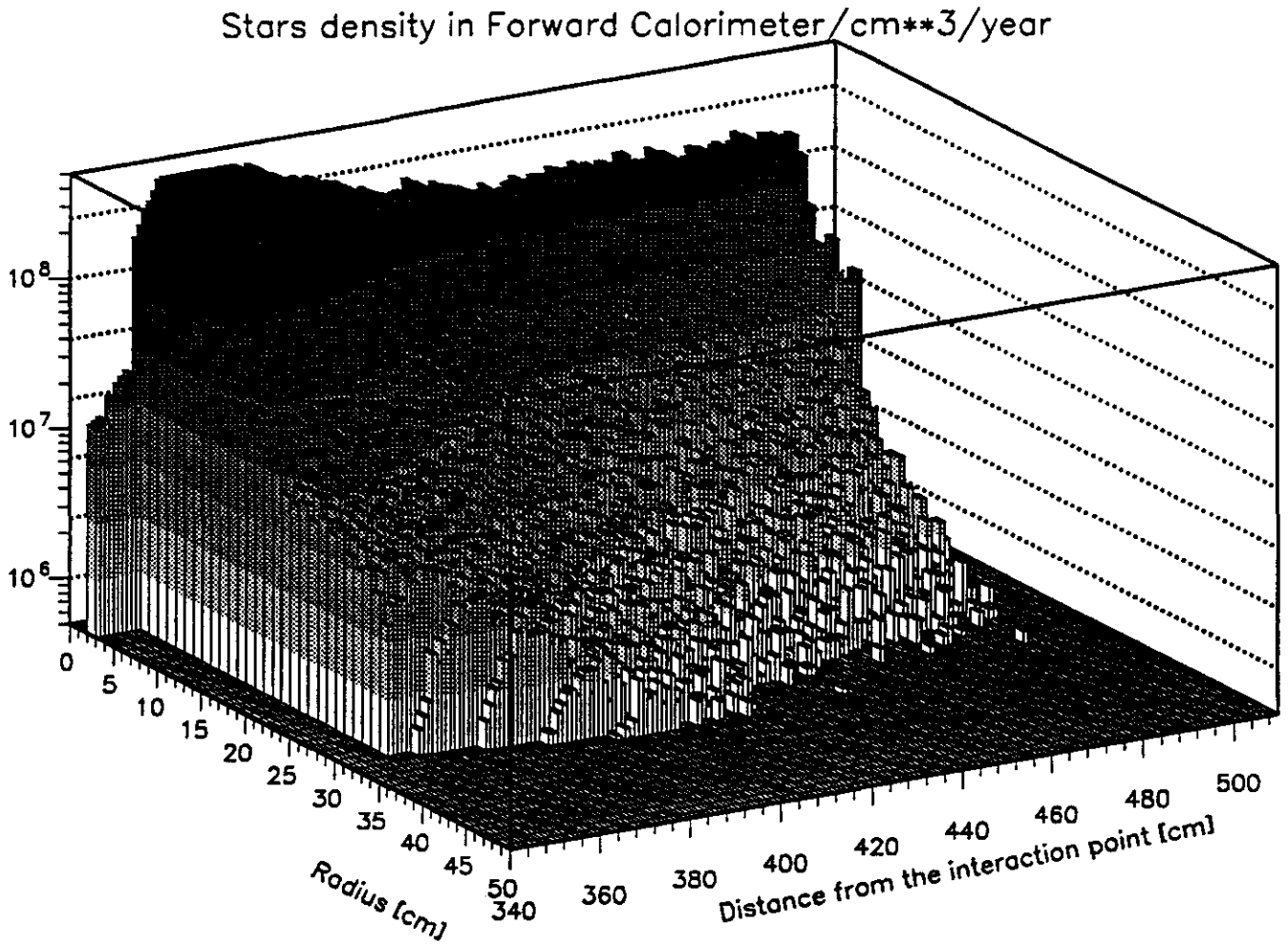

Stars density in Forward Calorimeter/cm**3/year
10^8
10^7
10^6
0
5
10
15
20
25
30
35
40
45
50
Radius [cm]
340
360
380
400
420
440
460
480
500
Distance from the interaction point [cm]

Fig. 1

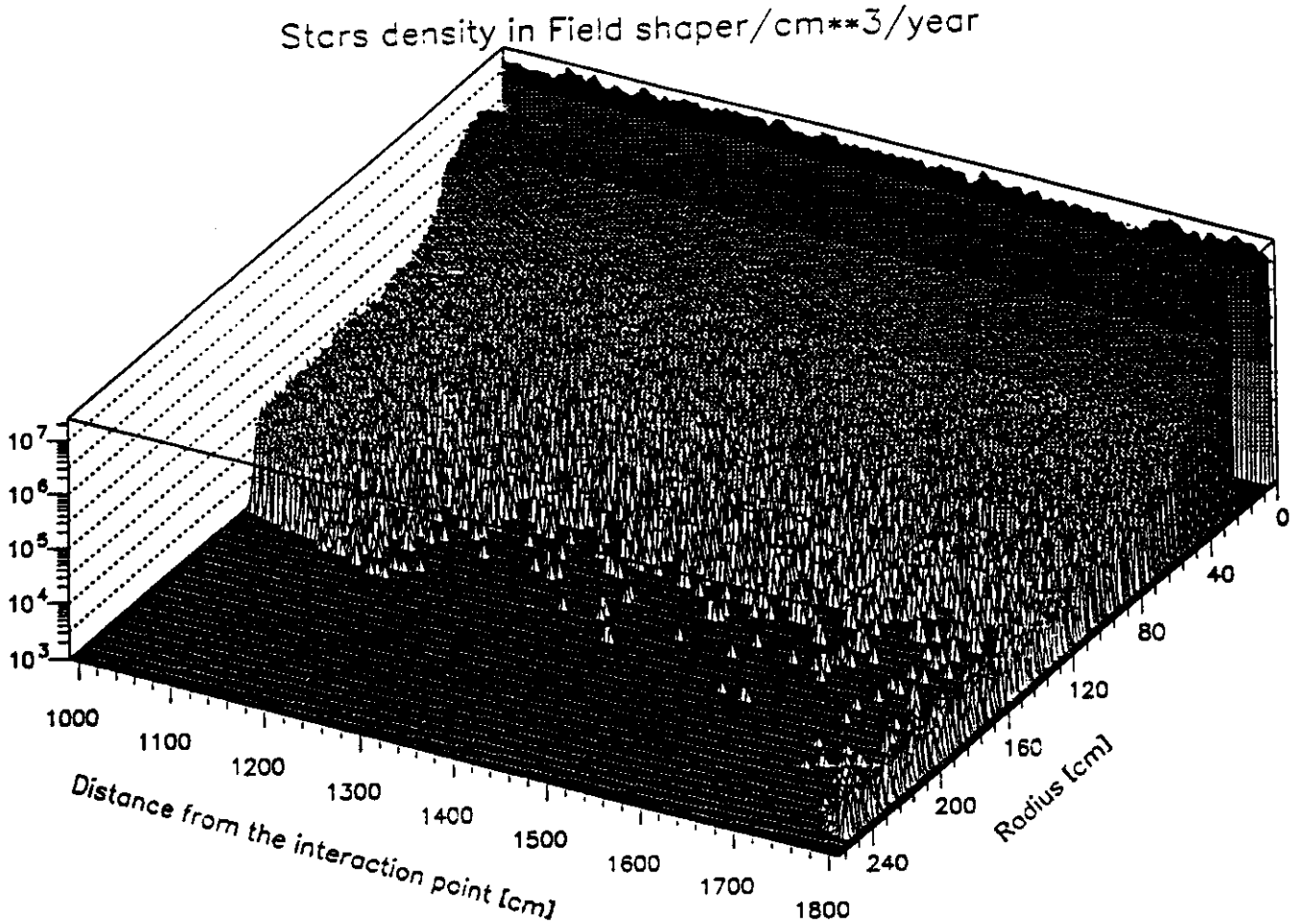

Stcrs density in Field shaper/cm**3/year
10^7
10^6
10^5
10^4
10^3
1000
1100
1200
1300
1400
1500
1600
1700
1800
Distance from the interaction point [cm]
0
40
80
120
160
200
240
Radius [cm]

Fig. 2

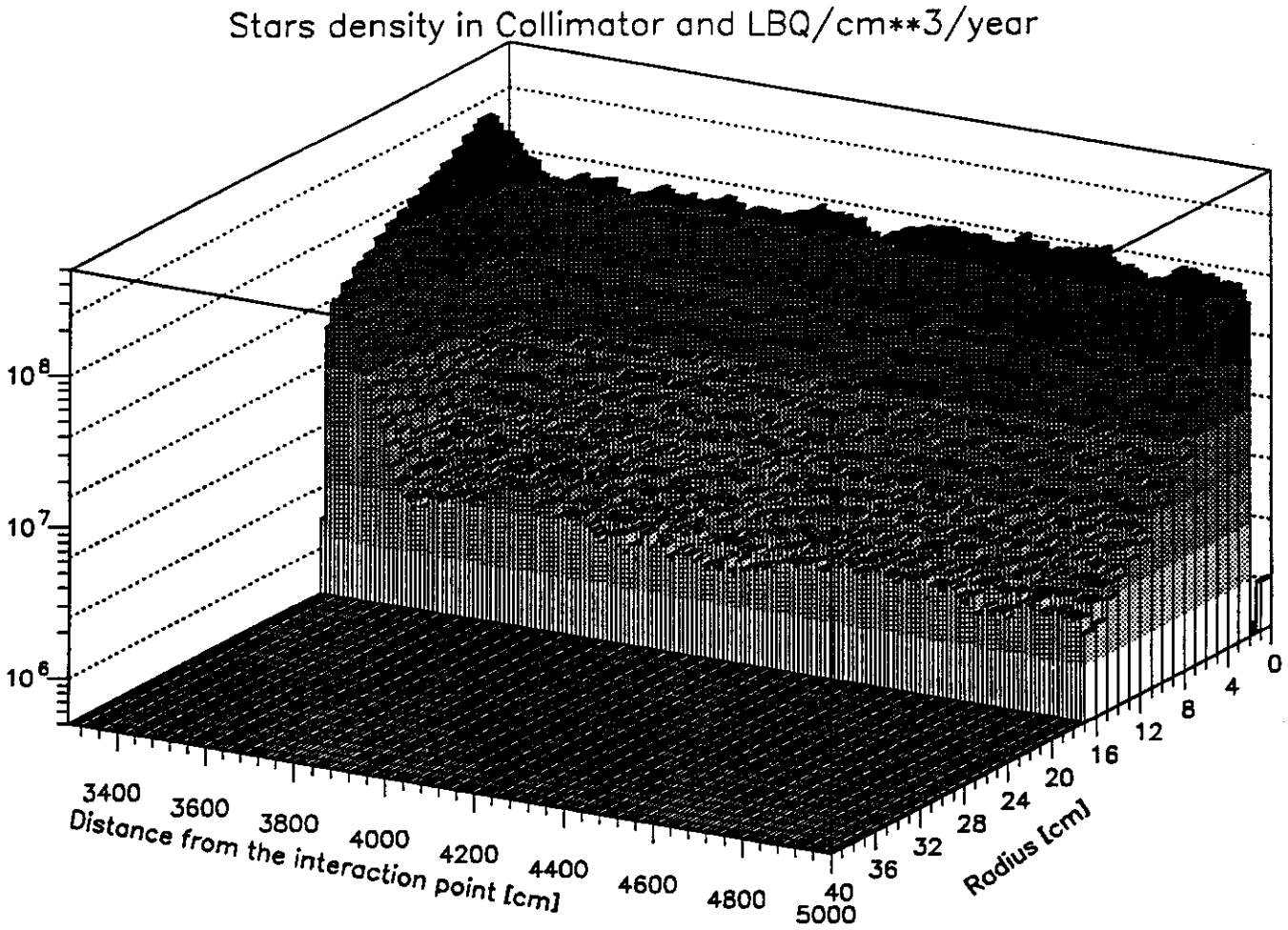
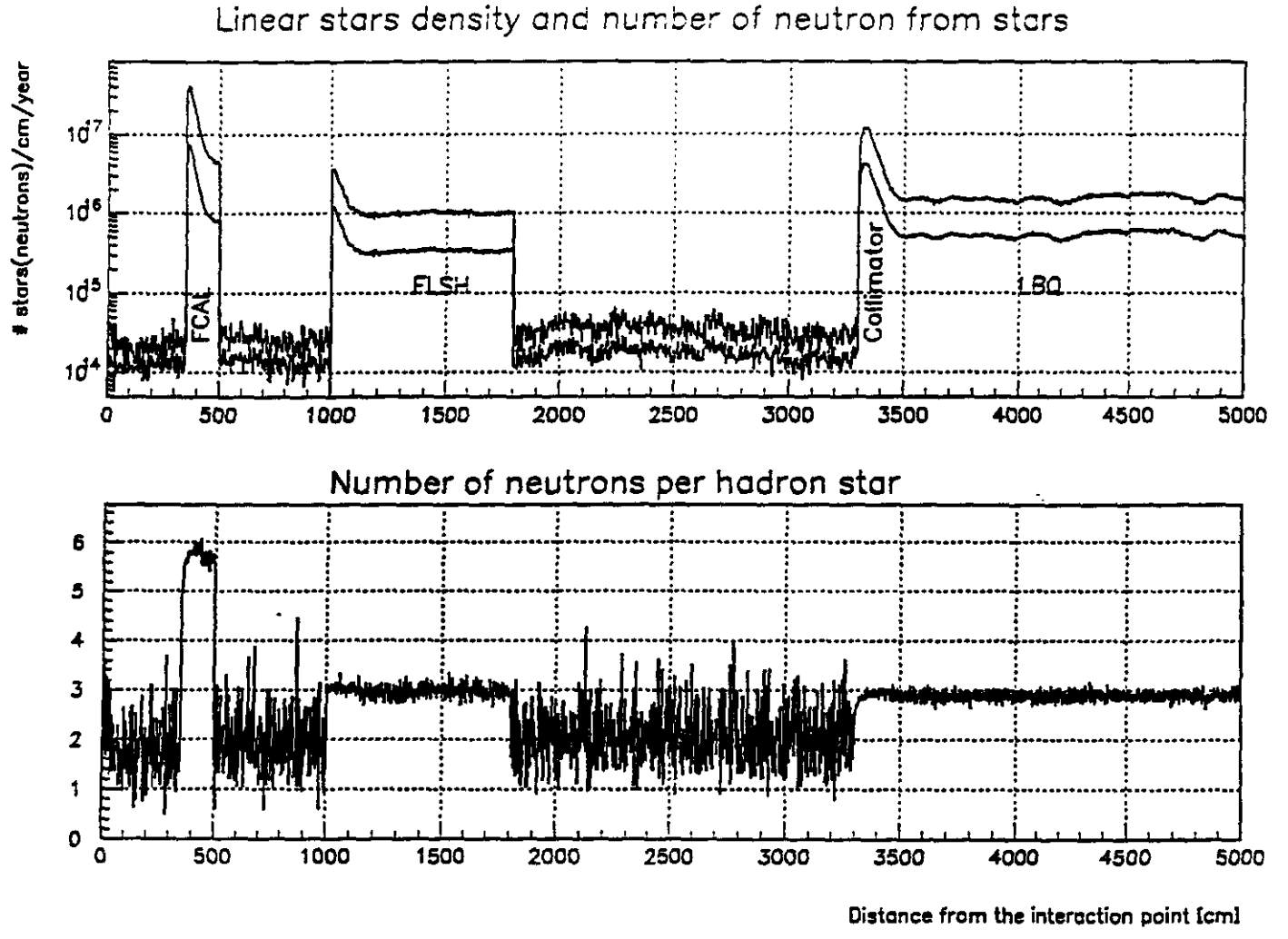

Stars density in Collimator and LBQ/cm**3/year
10^8
10^7
10^6
3400
3600
3800
4000
4200
4400
4600
4800
5000
Distance from the interaction point [cm]
0
4
8
12
16
20
24
28
32
36
40
Radius [cm]

Fig. 3


Linear stars density and number of neutron from stars
stars(neutrons)/cm/year
FCAL
FLSH
Collimator
LBQ
Number of neutrons per hadron star
Distance from the interaction point [cm]

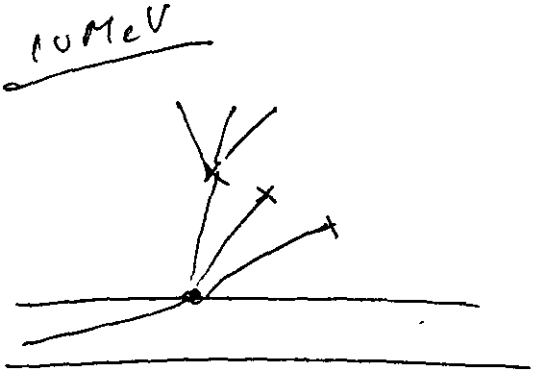

10MeV

Fig.4

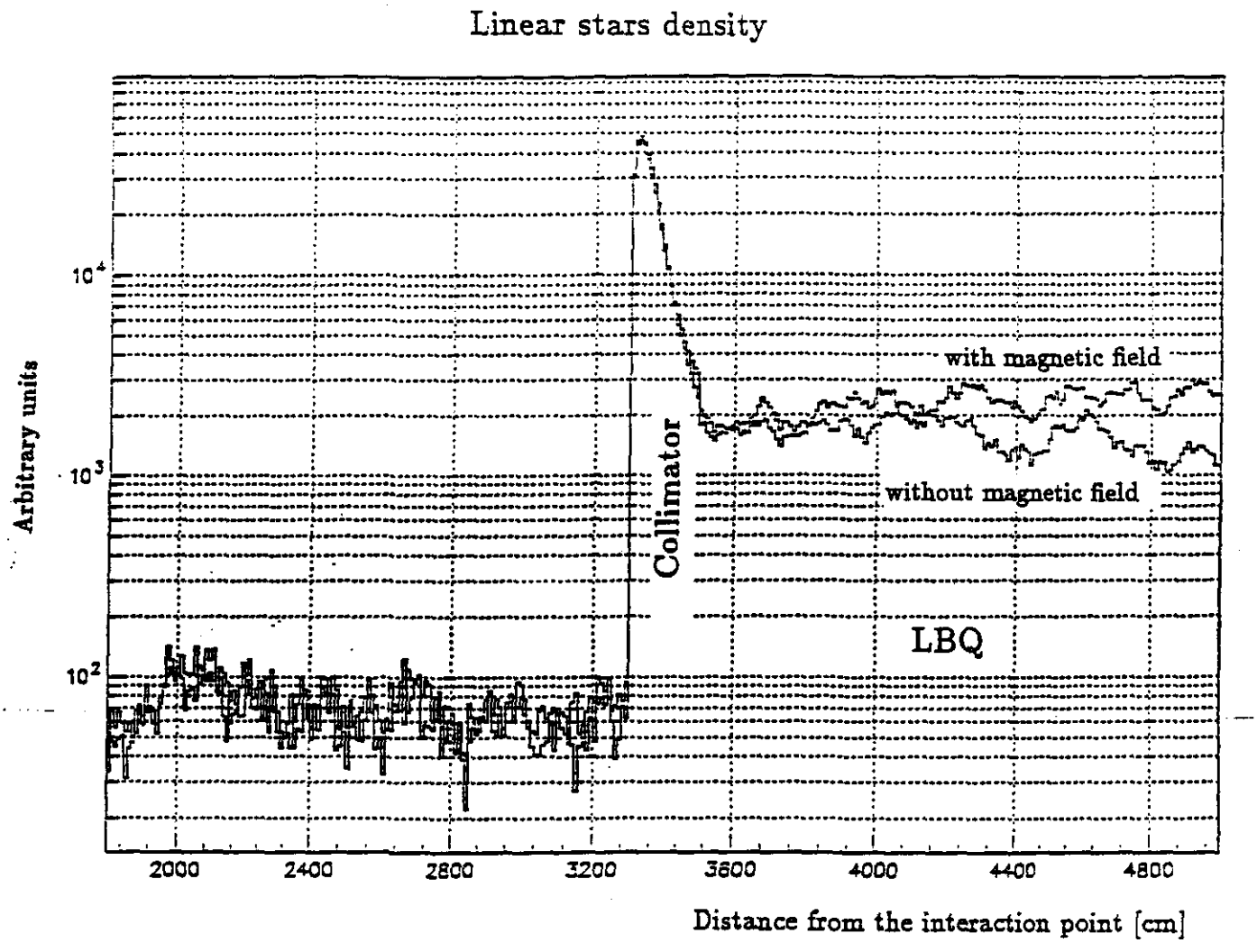

Linear stars density
Arbitrary units
10^4
10^3
10^2
with magnetic field
without magnetic field
Collimator
LBQ
2000
2400
2800
3200
3600
4000
4400
4800
Distance from the interaction point [cm]

Fig. 5

gem

γeμ

Presentation by:

J. McDonough

Beam-Plug Design for BNL's E871

- Description of E871 at Brookhaven
- Beam-plug design and CALOR89
- Neutron and photon detectors
- Comparison of data to Monte Carlo
- Comparison of data and Monte Carlo to actual drift chamber rates
- Conclusions

Jim McDonough
21 October 1992

AGS PROPOSAL
A NEW SEARCH FOR VERY RARE K_L DECAYS

September 25, 1990

$K_L \to \mu e, ee, \gamma$

FROM: A. Heinson, W. R. Molzon - *University of California, Irvine*

M. Diwan, G. M. Irwin, K. Lang, D. A. Ouimette,
A. Schwartz, S. G. Wojcicki - *Stanford University*

J. Belz, C. Guss, V. L. Highland, S. Kettell,
W. K. McFarlane - *Temple University*

G. W. Hoffmann, J. McDonough, P. J. Riley, J. L. Ritchie,
A. Yamashita - *University of Texas at Austin*

M. Eckhause, A. D. Hancock, J. R. Kane, Y. Kuang,
W. F. Vulcan, R. E. Welsh, R. G. Winter, M. Witkowski
- *College of William and Mary*

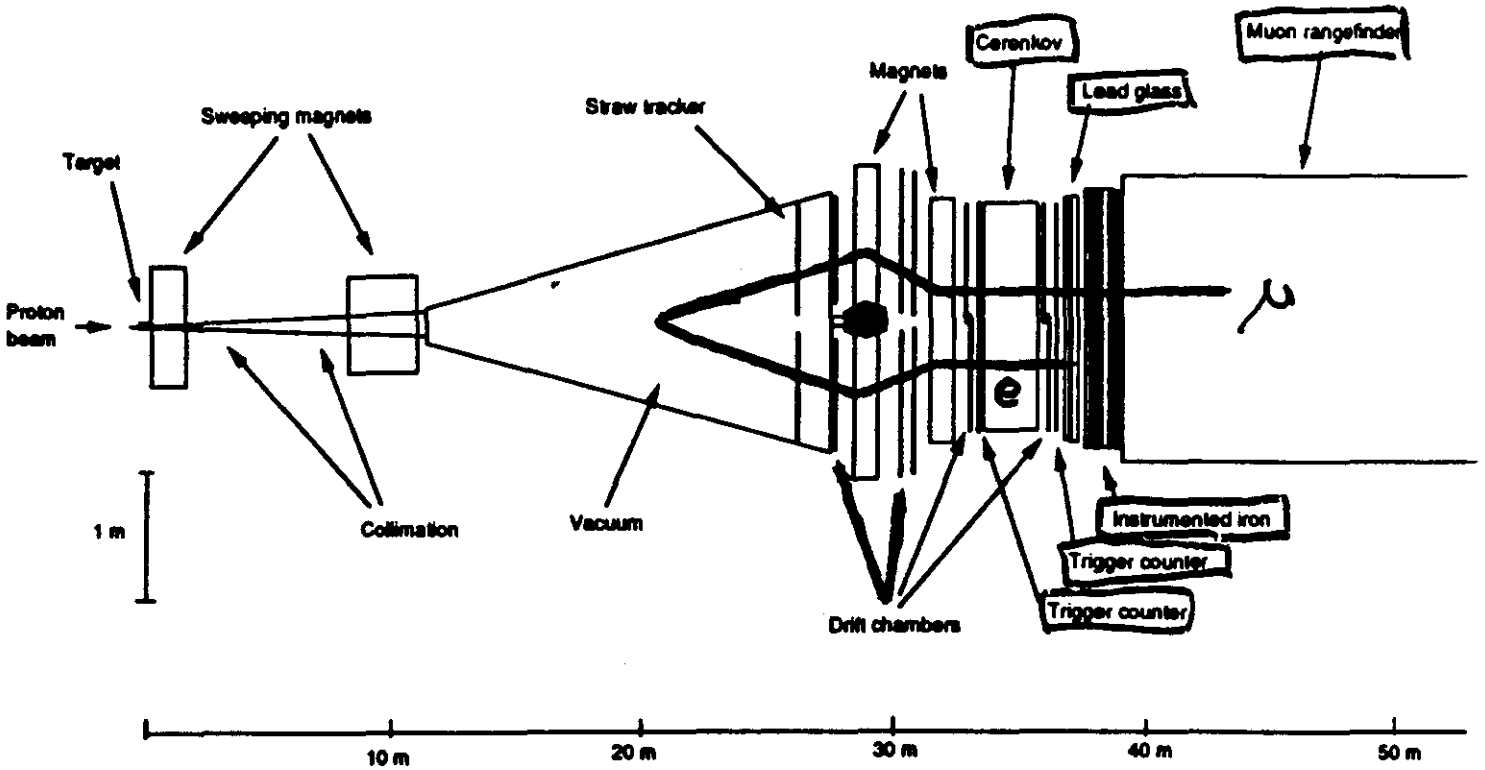
BEAM: B5 beamline, upgraded for 2×10^{13} protons/pulse
Target moved, new longer vacuum decay volume, thin window.
Beam stop in spectrometer magnet

DETECTOR: Two dipoles, scintillating fiber trackers, drift chambers, gas Cerenkov counter, scintillation counters, lead glass, muon rangefinder

OLDF: Link requested

TIME REQUEST: Beam test in B5 - Spring 1991, 5×10^{12} protons/pulse, 800 hours
Test run - 1992, 5×10^{12} protons/pulse, 800 hours
Engineering run - 1993, 1×10^{13} protons/pulse, 800 hours
Physics data - 1994 and 1995, 2×10^{13} protons/pulse, 4000 hours

$\sim 2 \times 10^7$ K_L decays/spill in sensitive region



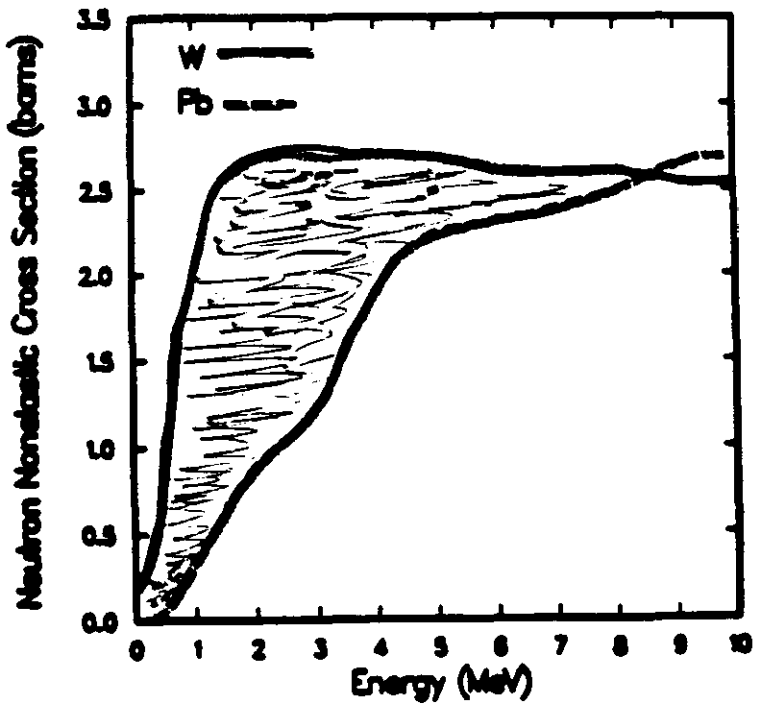
Plan view of the E871 spectrometer.

- Lower particle ID rates
- Low trigger rate with magnets set so tracks are parallel in the downstream detector elements.
- Must stop 3×10^9 $\frac{\text{neutrons}}{\text{spill}}$
  $(E_n)_{AVE} \sim 12$ GeV

Hadronic interaction length (cm)	W	Pb	Cu
	9.6	17	15

Neutron interaction length

Energy (MeV)	(n,p) in CH_2 (cm)	W (cm)	Pb (cm)	Cu (cm)
0.01	0.7	------	------	------
0.1	1.2	------	------	------
1.0	3.9	5.9	120	60
5.0	10.3	6.3	14	7.4



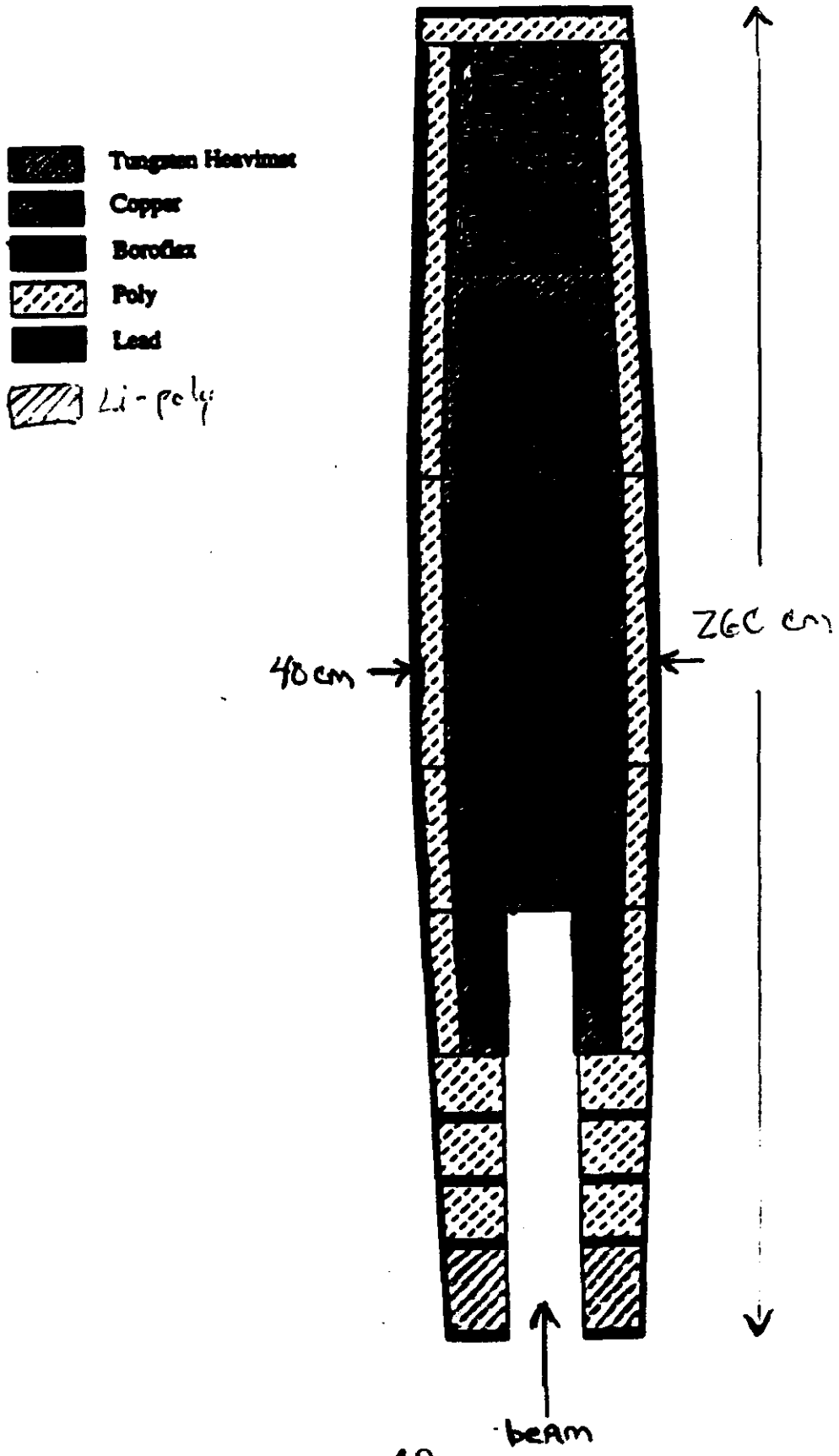
Use CH_2 with ^{10}B to capture thermals. $^{10}B(n\,\alpha)\,^{7}Li^{*}$

$\hookrightarrow\, ^{7}Li + \gamma$ (480 keV)

$\sigma_{n\alpha} = 3900$ barns

$\lambda \approx \frac{1}{2}$ cm for 5% Borated polyethylene

Use Pb to attenuate γ's


Tungsten Heavimet
Copper
Borofax
Poly
Lead
Li-poly
40 cm
beam

CALOR89 Monte Carlo

- HETC/FLUKA
  Uses Bertini intranuclear-cascade-evaporation model for nonelastic NN, πN collisions up to 5 GeV. Uses an extrapolation for higher energies. Also calls FLUKA for particle production.
  Transports protons, $\pi^{\pm}$, $\mu^{\pm}$ down to 1 MeV; stores π^{0} for transport by EGS4; neutrons below 20 MeV are stored for MORSE.

- MORSE
  Transports neutrons from 20 MeV to thermal. Includes elastic, inelastic, and capture cross-sections. Photons are produced but are transported by EGS4.

- EGS4
  Transports the photons produced by HETC and MORSE. Low-energy limits are 0.1 MeV for photons and 0.5 MeV for electrons. (Monte Carlo does not include magnetic field which would trap almost all electrons).

HETC	1	CPU sec/event on SLACVI
MORSE	8	CPU sec
EGS4	10	CPU sec

Neutron Detectors

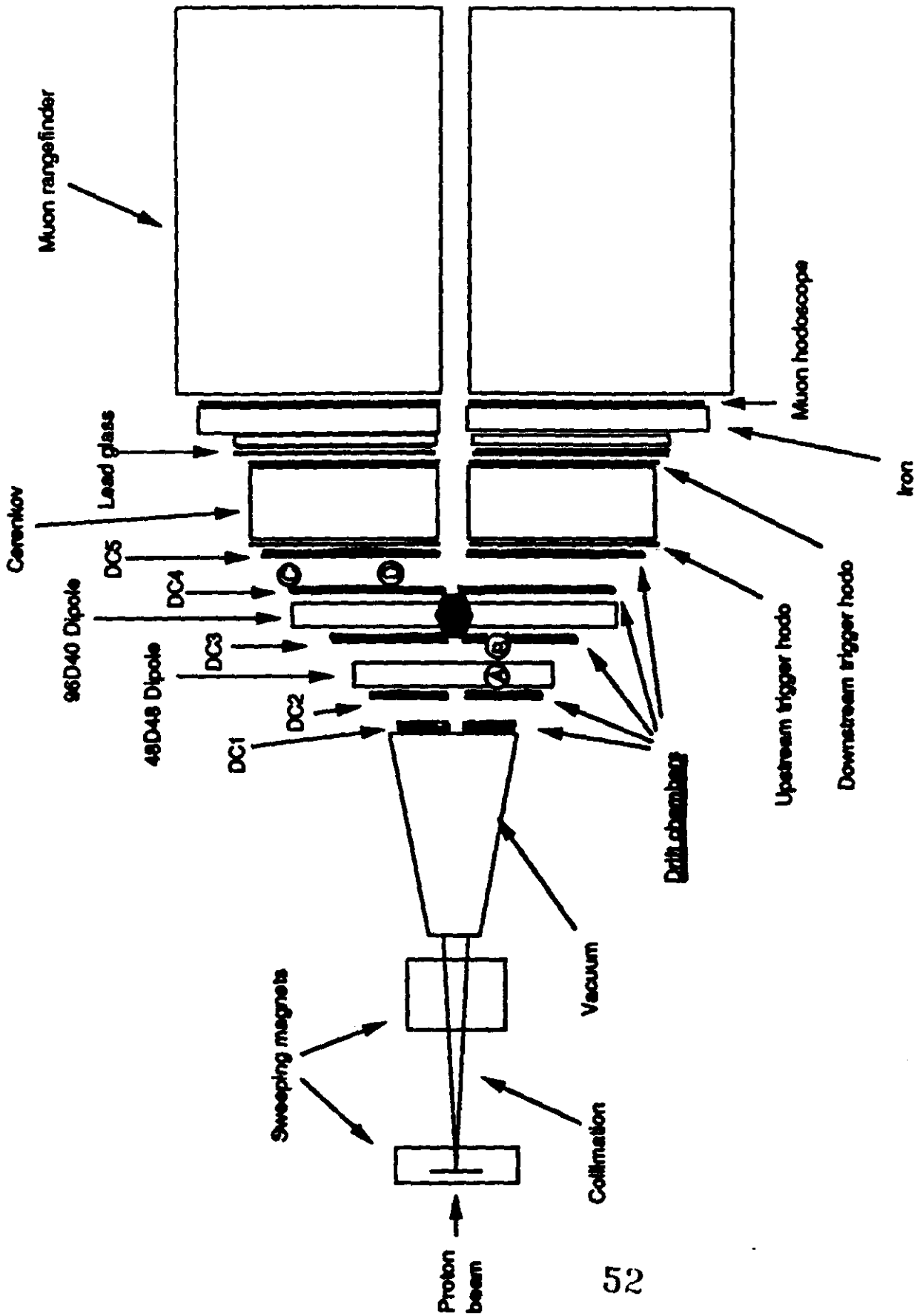
- Bonner spheres
- liquid scintillator
- ^3He counters
- Germanium

Photon Detectors

- liquid scintillator
- Germanium

Charged particle Detector

- liquid scintillator in coincidence with plastic scintillators



The upstream dipo

BONNER Spheres

- LiI(Eu) scintillator inserted into a CH_2 ball.

- Sensitive to thermalized neutrons
  $^6Li(n\alpha)^3H$ $\sigma_{n\alpha}(.025eV) \approx 930b$

- Program exist to convert count rate from 7 spheres to incident neutron energy spectrum and flux in range thermal $< E_n < 20$ MeV

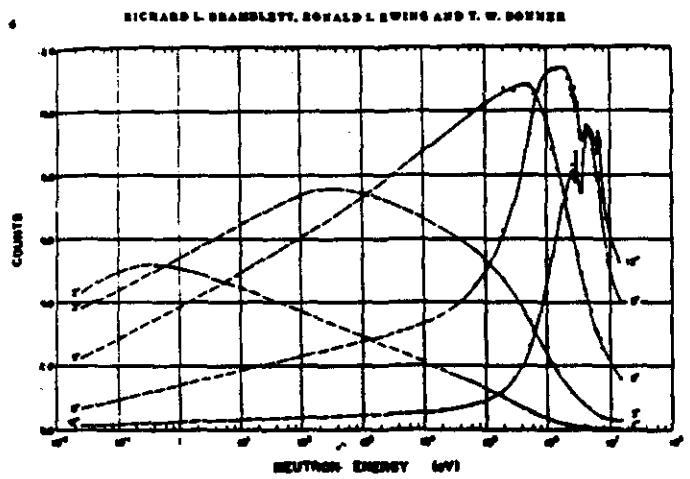


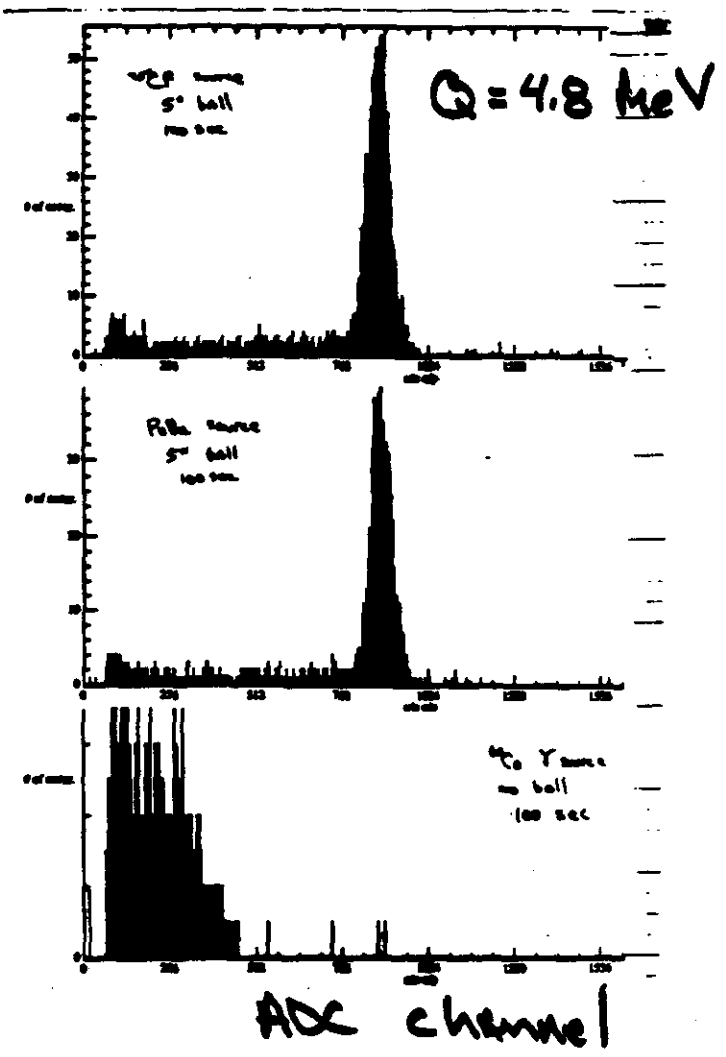
Fig. 8. Results with all counters giving the counts per 10^6 neutrons emitted from an isotropic point source 40 cm away.

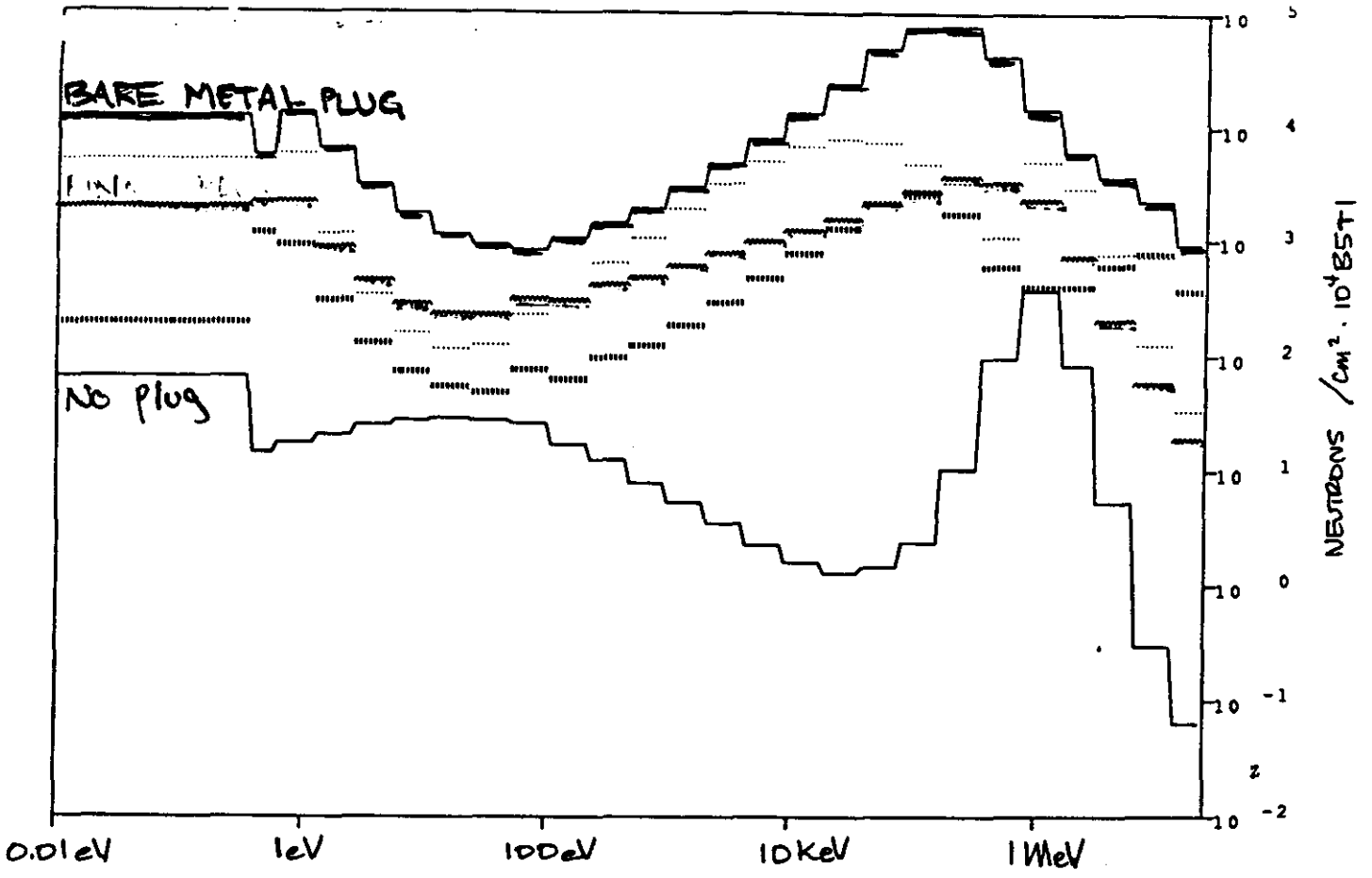
Maxima of the counting rate curves

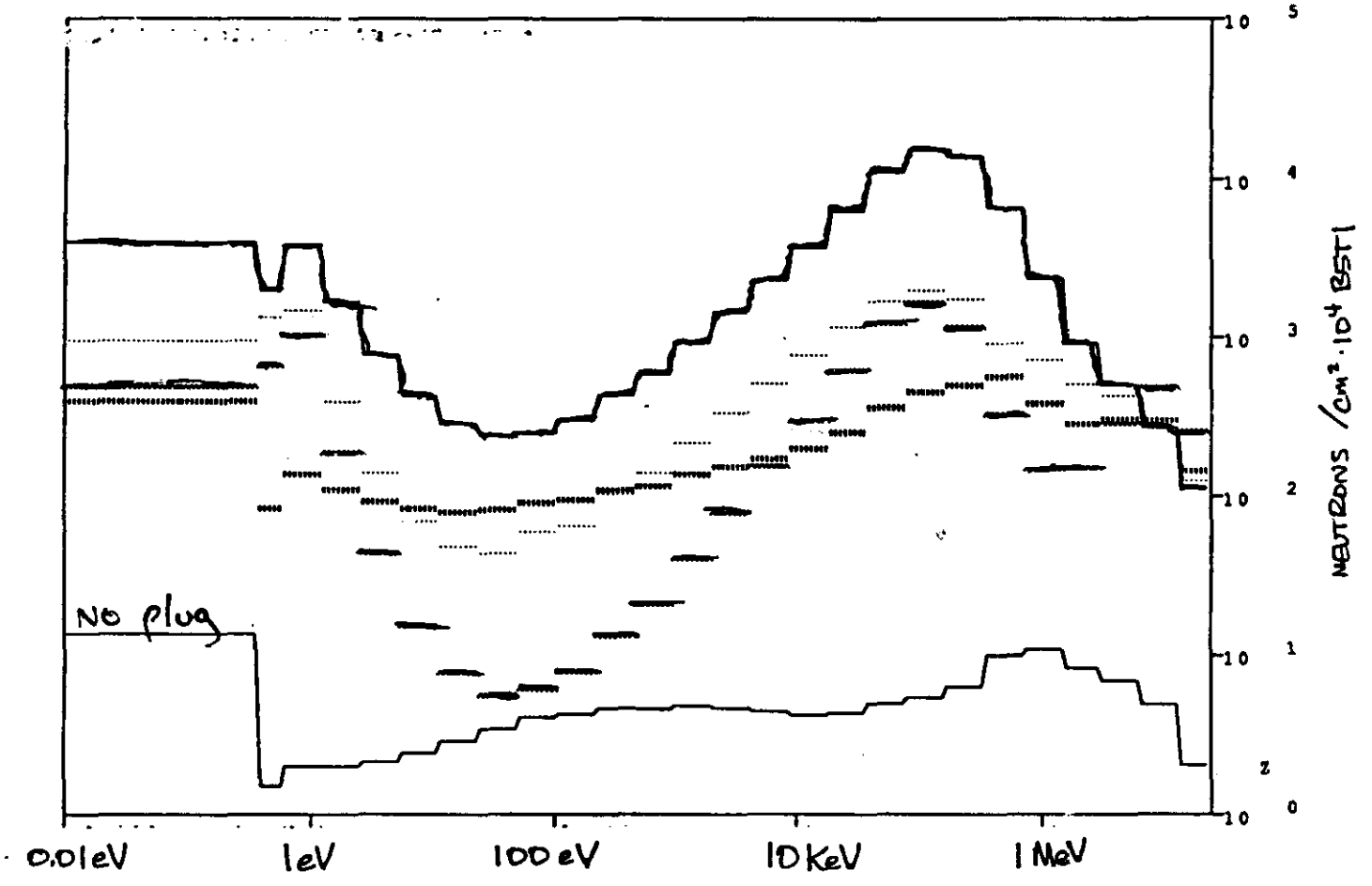
Counter diameter (inches)	Position of maximum (eV)	Counts per 10^6 neutrons*	Absolute efficiency†† in per cent
2	0.3	5	0.5
3	3.0×10^3	8	0.3
5	4.5×10^3	10.8	0.172
8	1.7×10^3	11.3	0.080
12	3.0×10^3	9.4	0.025

* Counts per 10^6 neutrons emitted from an isotropic source 40 cm away.

†† The percentage of the neutrons which strike the surface of the counter which result in a count.




BARE METAL PLUG
No plug
0.01eV
1eV
100eV
10KeV
1MeV
NEUTRONS /cm².10⁴BSTI


No plug
0.01eV
1eV
100eV
10KeV
1MeV
NEUTRONS /cm².10⁴BSTI

Liquid Scintillator (BC510A)

NUCLEAR INSTRUMENTS AND METHODS 137 (1976) 397–398; © NORTH-HOLLAND PUBLISHING CO.

A DIGITAL TECHNIQUE FOR NEUTRON-GAMMA PULSE SHAPE DISCRIMINATION*

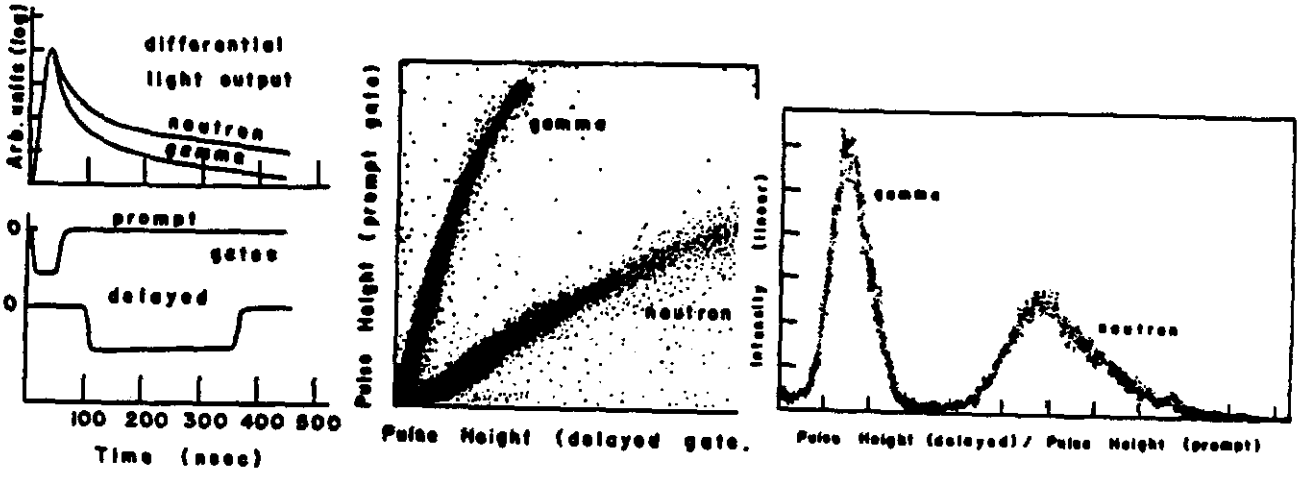
CHRISTOPHER L. MORRIS

University of Virginia, Charlottesville, VA, U.S.A. and
University of California, Los Alamos Scientific Laboratory, Los Alamos, NM, U.S.A.

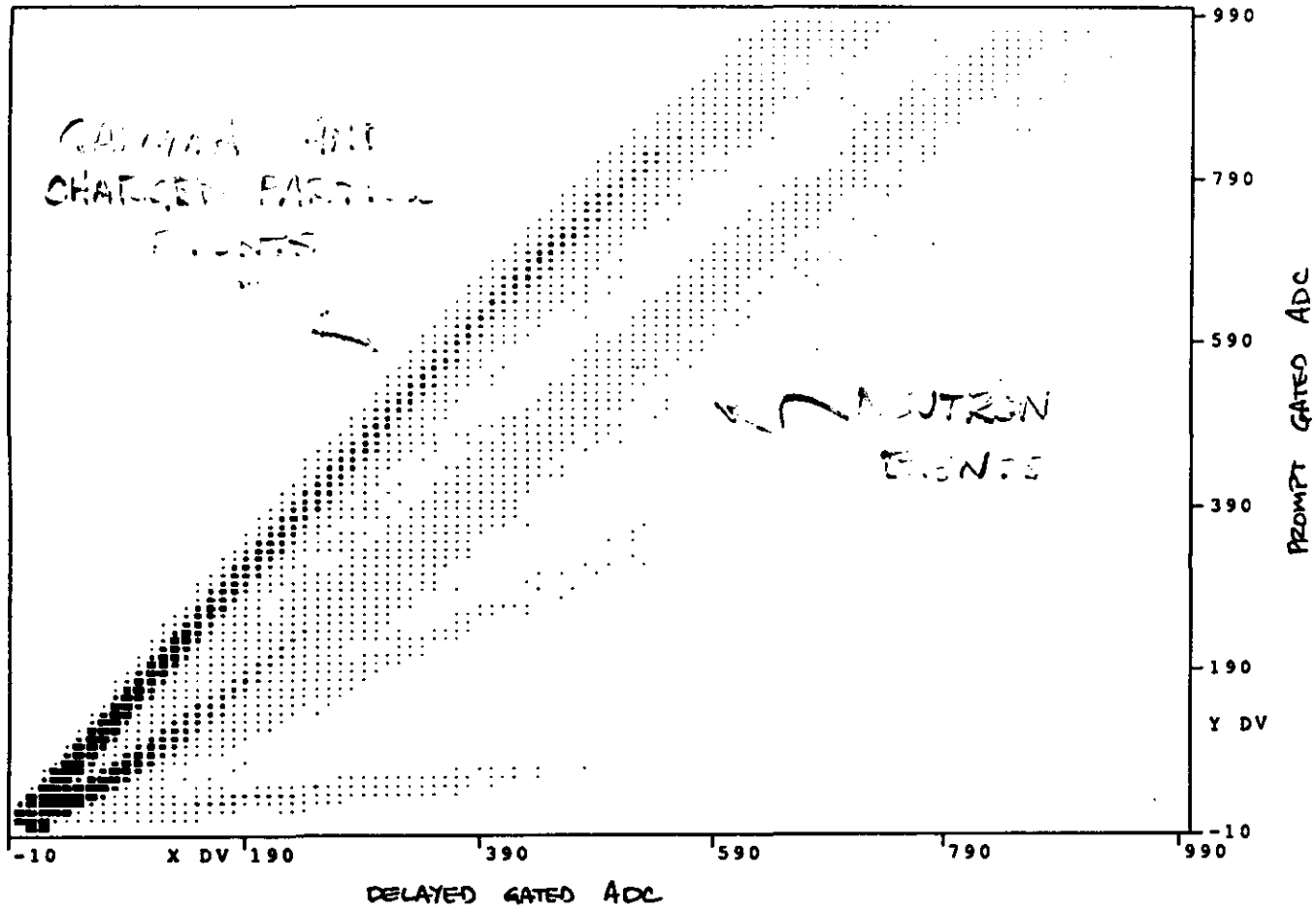
JOSEPH E. BOLGER, GERALD W. HOFFMANN, C. FRED MOORE, L. EUGENE SMITH

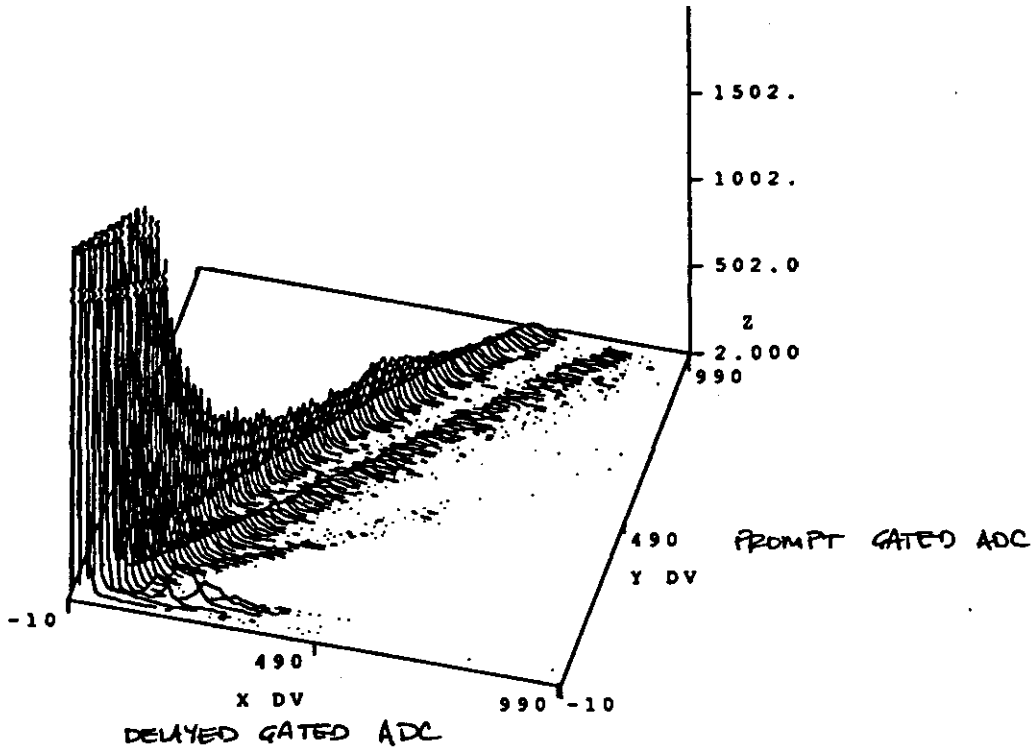
University of Texas, Austin, TX, U.S.A.
and
HENRY A. THIESSEN

University of California, Los Alamos Scientific Laboratory, Los Alamos, NM, U.S.A.



- allows us to separate γ's from neutrons
- programs exist that will allow us to unfold data to give the incident neutron energy spectrum
- Works for E_n from $\sim \frac{1}{2}$ MeV to ~ 20 MeV


990
790
590
390
190
Y DV
-10
PROMPT GATED ADC
-10
X DV
190
390
590
790
990
DELAYED GATED ADC

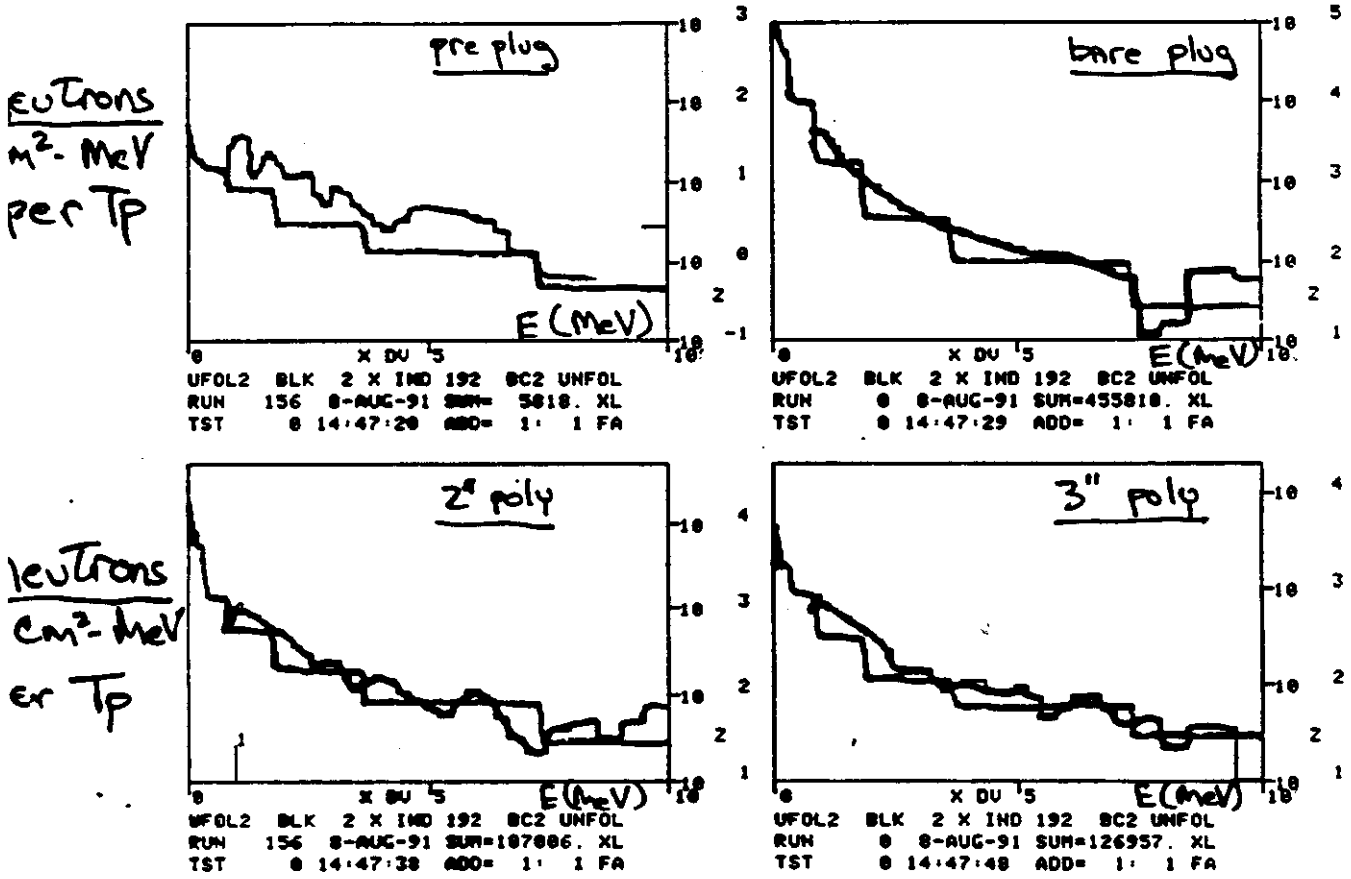

1502.
1002.
502.0
Z
2.000
990
490
PROMPT GATED ADC
Y DV
-10
490
X DV
990
-10
DELAYED GATED ADC

Calculated Neutron Energy

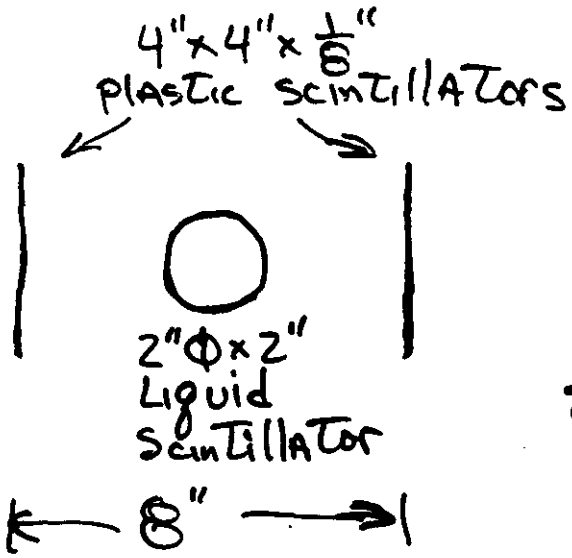
— From Liquid Scintillator measurements

— From Bonner sphere measurements

DOWNSTREAM POSITION



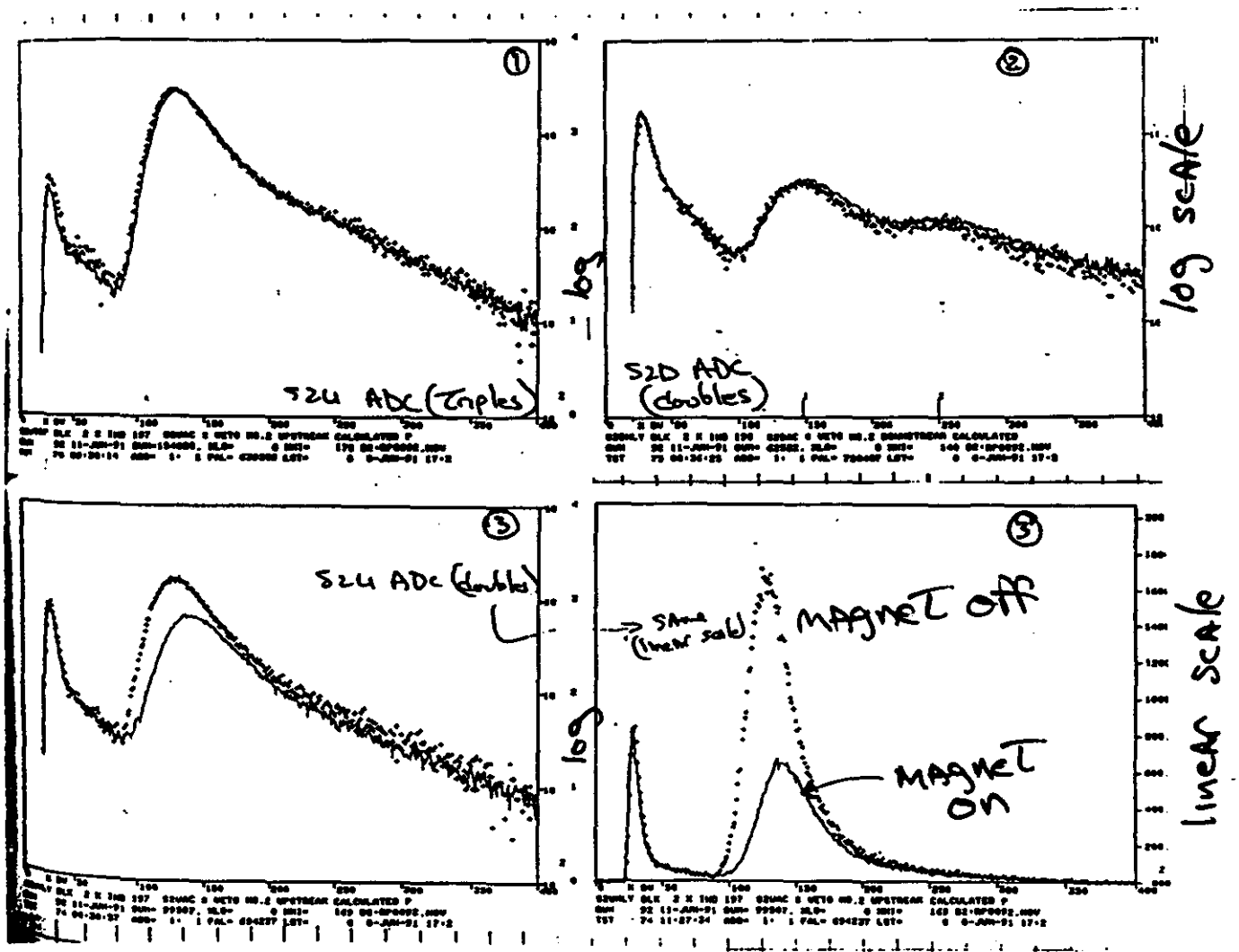
Charged Particle Definition



Require either:

1- both plastic in time, OR

2- one plastic in time with an ADC measure consistent with a charged particle

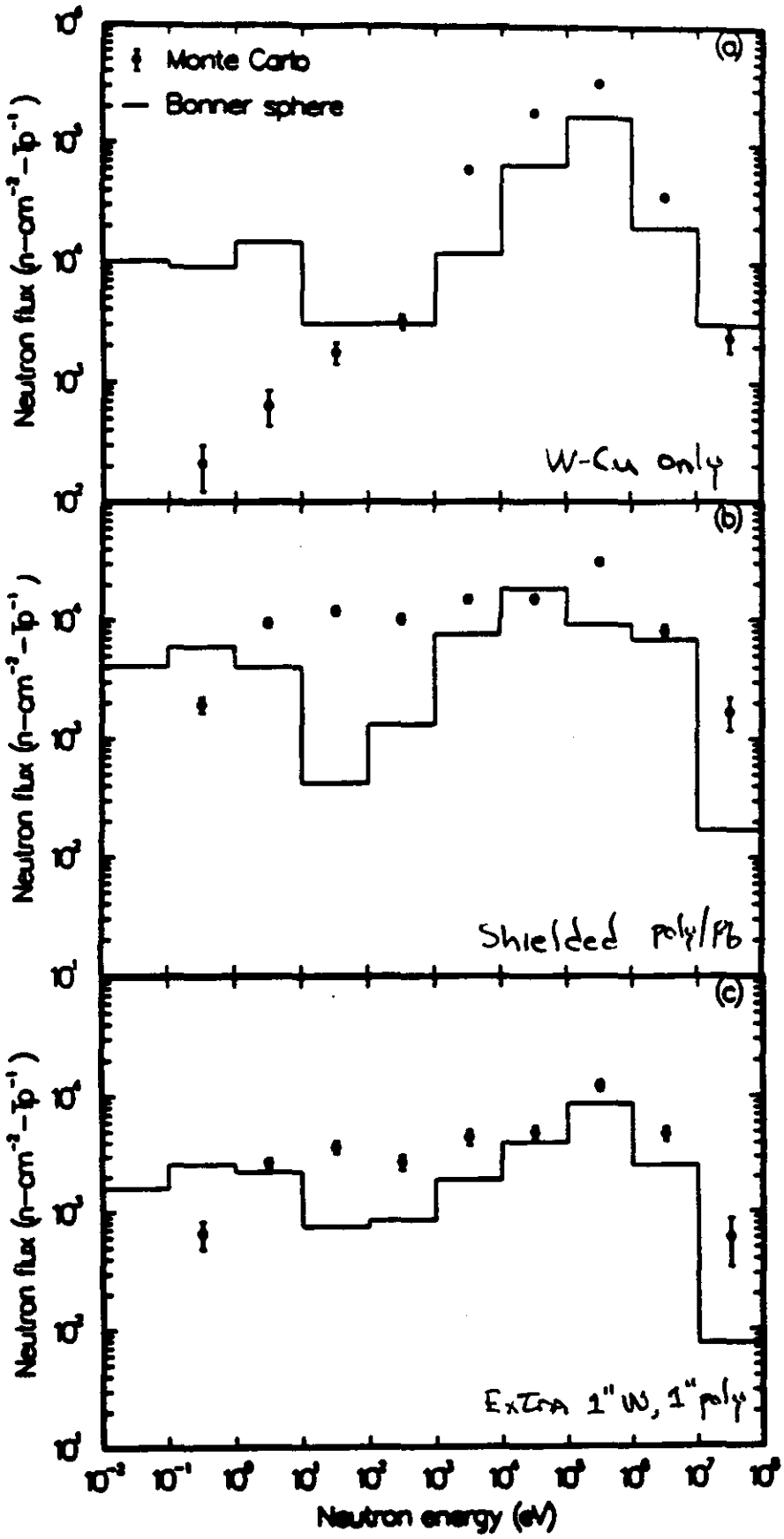


Plastic scintillator ADC

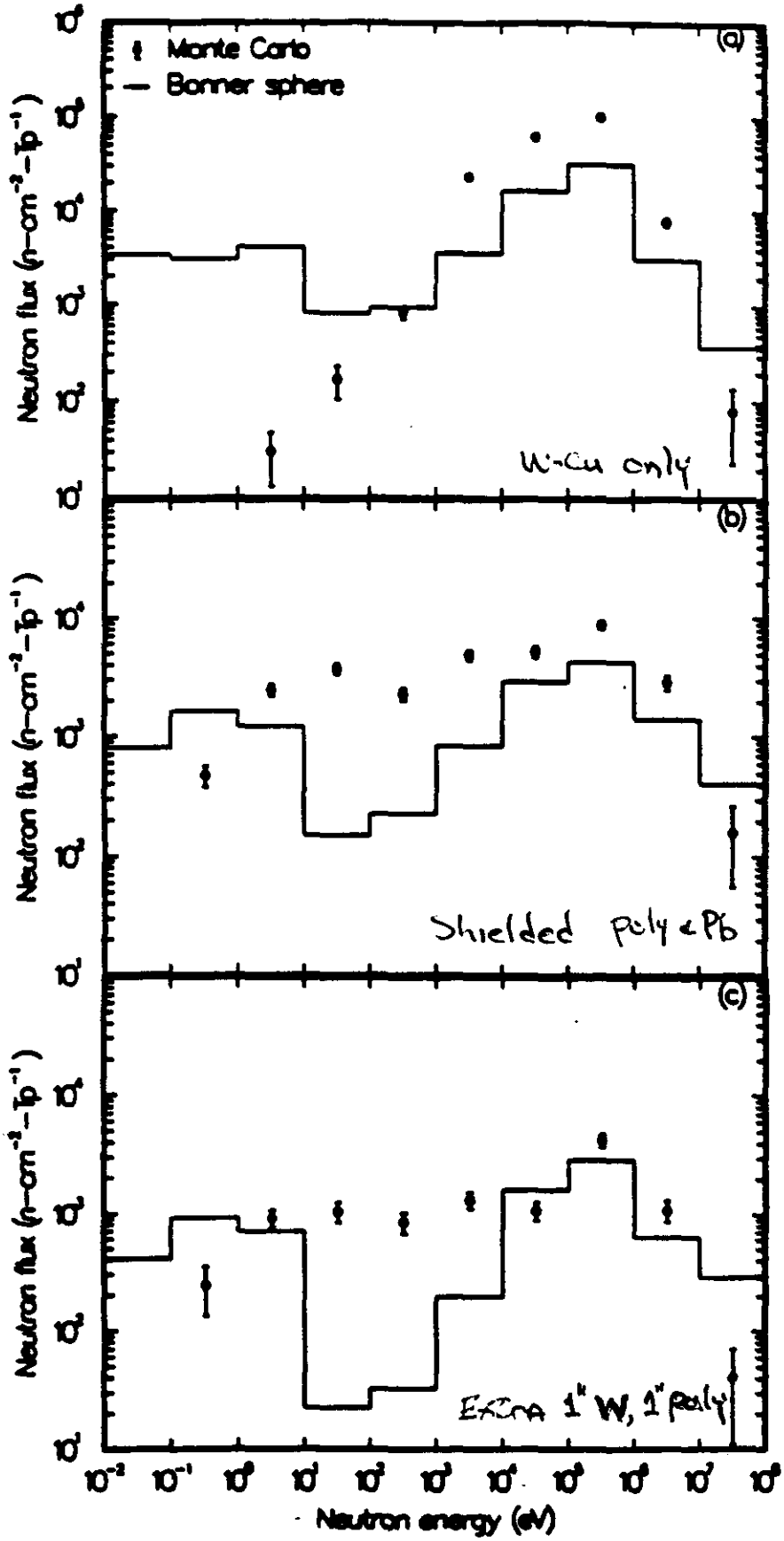
The neutron flux calculated from the Bonner sphere measurements "predicts" the result from the liquid scintillator measurement

plug configuration	UPSTREAM predicted	UPSTREAM measured	DOWNSTREAM predicted	DOWNSTREAM measured
pre plug	0.045	0.017	0.003	0.005
bare W/Cu	2.4	1.2	0.38	0.35
2" poly + Pb	0.90	0.56	0.17	0.16
3" poly + Pb	0.14	0.27	0.10	0.10
1" extra W	0.32	0.17	0.06	0.12

- Units are n/cm^2 per BST)
- Energy range is 0.9 - 7.4 MeV



Upstream of beamplug



Downstream of beamplug

Neutron and γ Interactions in our drift chambers and Trigger counters

<u>DC</u>:

$$\sigma_{np} \approx \frac{4.4 \text{ barns}}{\sqrt{E(\text{MeV})}} \quad E_n > 50 \text{ MeV}$$

$$\approx 20 \text{ barns} \quad E_n < 50 \text{ MeV}$$

$$N_H \approx 8.4 \times 10^{19} \text{ cm}^{-3}$$

$$\tau \approx 1.35 \text{ cm}$$

$$P_I^n \approx N\tau\sigma = \frac{4.4 \times 10^{-4}}{\sqrt{E}} \quad E_n > 50$$

Photon attenuation length

$$\lambda \approx 15\sqrt{E} \text{ g/cm}^2 \quad .1 < E_\gamma < 5 \text{ MeV}$$

$\tau\rho$:

22.5	mg/cm^2	gas (15 cm)
8.3	mg/cm^2	Al-mylar window
2.6	mg/cm^2	wires
33.4	mg/cm^2	

$$P_I^\gamma \approx \tau\rho/\lambda = \frac{2.2 \times 10^{-3}}{\sqrt{E}}$$

$$\frac{P_I^\gamma}{P_I^n} \approx 5 \quad \text{for the same energy}$$

SAN4 SPUN 0.00,0.00 1.0000 0.0000 1.9062 [illegible]

Spheres	Measured Counts	Scale Factor	Scaled Counts	Calculated Counts	Per Cent Difference
bare	31056.0	109.0	284.8	282.5	-0.8
bare+Cd	15368.0	93.0	165.2	163.5	-1.0
2 inch	89547.0	100.0	895.1	935.9	4.6
2 inch+Cd	80446.0	104.0	773.2	767.2	-0.8
3 inch	187064.0	117.0	1598.2	1561.5	-2.3
5 inch	584531.0	286.0	2043.0	2025.6	-0.9
8 inch	98136.0	88.0	1114.7	1139.3	2.2
10 inch	45871.0	68.0	674.3	667.7	-1.0
12 inch	30219.0	72.0	419.5	419.4	0.0

Total fluence =	1.007E+04	Neutrons/cm^2
Ave energy(less th) =	6.445E+00	MeV
Dose =	2.254E-05	Rad
Dose equivalent =	1.337E-04	rem
Quality factor =	5.933	rem/rad
Bonner scale factor =	68.000	
Run scale factor =	0.015	

bin no.	energy max (MeV)	fluence n/cm^2	fluence n/cm^2/MeV	helium hits/cm^2	drift chamber hits/m^2
1	4.140E-07	4.893E+02	7.605E+09	9.618E+03	5.250E+01
2	6.826E-07	6.704E+02	1.261E+09	5.688E+03	0.000E+00
3	1.445E-06	1.044E+03	1.051E+09	6.691E+03	0.000E+00
4	3.059E-06	1.890E+02	8.992E+07	8.565E+02	0.000E+00
5	6.476E-06	4.386E+01	9.853E+06	1.392E+02	0.000E+00
6	1.371E-05	1.522E+01	1.615E+06	3.364E+01	0.000E+00
7	2.902E-05	7.656E+00	3.838E+05	1.174E+01	1.652E+02
8	6.144E-05	5.632E+00	1.334E+05	5.975E+00	1.215E+02
9	1.301E-04	6.093E+00	6.815E+04	4.462E+00	1.315E+02
10	2.754E-04	7.792E+00	4.117E+04	3.934E+00	1.681E+02
11	5.929E-04	1.327E+01	3.285E+04	4.596E+00	2.864E+02
12	1.234E-03	2.103E+01	2.458E+04	5.011E+00	4.537E+02
13	2.613E-03	3.993E+01	2.224E+04	6.574E+00	8.616E+02
14	5.531E-03	7.788E+01	2.049E+04	8.818E+00	1.680E+03
15	1.171E-02	1.551E+02	1.927E+04	1.208E+01	3.347E+03
16	2.479E-02	3.080E+02	1.808E+04	1.649E+01	5.318E+03
17	5.247E-02	6.203E+02	1.720E+04	2.282E+01	9.371E+03
18	1.111E-01	1.226E+03	1.605E+04	3.100E+01	1.587E+04
19	2.237E-01	1.684E+03	1.068E+04	2.965E+01	1.636E+04
20	4.508E-01	1.171E+03	3.687E+03	1.453E+01	8.849E+03
21	9.072E-01	3.324E+02	5.197E+02	8.108E+00	1.436E+03
22	1.872E+00	1.481E+02	1.136E+02	3.835E+00	4.797E+02
23	3.679E+00	1.501E+02	5.718E+01	3.368E+00	3.241E+02
24	7.408E+00	2.900E+02	5.555E+01	8.871E-01	3.132E+02
25	1.492E+01	4.806E+02	4.572E+01	1.037E+00	3.633E+02
26	2.581E+01	2.570E+02	1.310E+01	4.057E-01	1.110E+02
27	4.465E+01	2.148E+02	6.328E+00	2.576E-01	4.635E+01
28	7.725E+01	1.733E+02	2.951E+00	1.580E-01	3.739E+01
29	1.336E+02	1.337E+02	1.316E+00	9.284E-02	1.442E+01
30	2.312E+02	9.992E+01	5.685E-01	5.273E-02	5.420E+00

64% of DC rate due to neutrons is from 100keV < E_n < 2MeV

He =	2.321E+04	HeCd =	1.001E+04
Counts in He peak =	2.316E+04	Counts in HeCd peak =	9.958E+03
Thermals =	1.320E+04	Counts above peak =	5.612E+01

Total number of hits/m^2 in a DC = 6.617E+04
Total number of n/cm^2 in a BC (FERD) = 5.881E+02
Total number of hits in straw gas = 1.245E+02
Total number of hits in straw wall = 6.023E+00

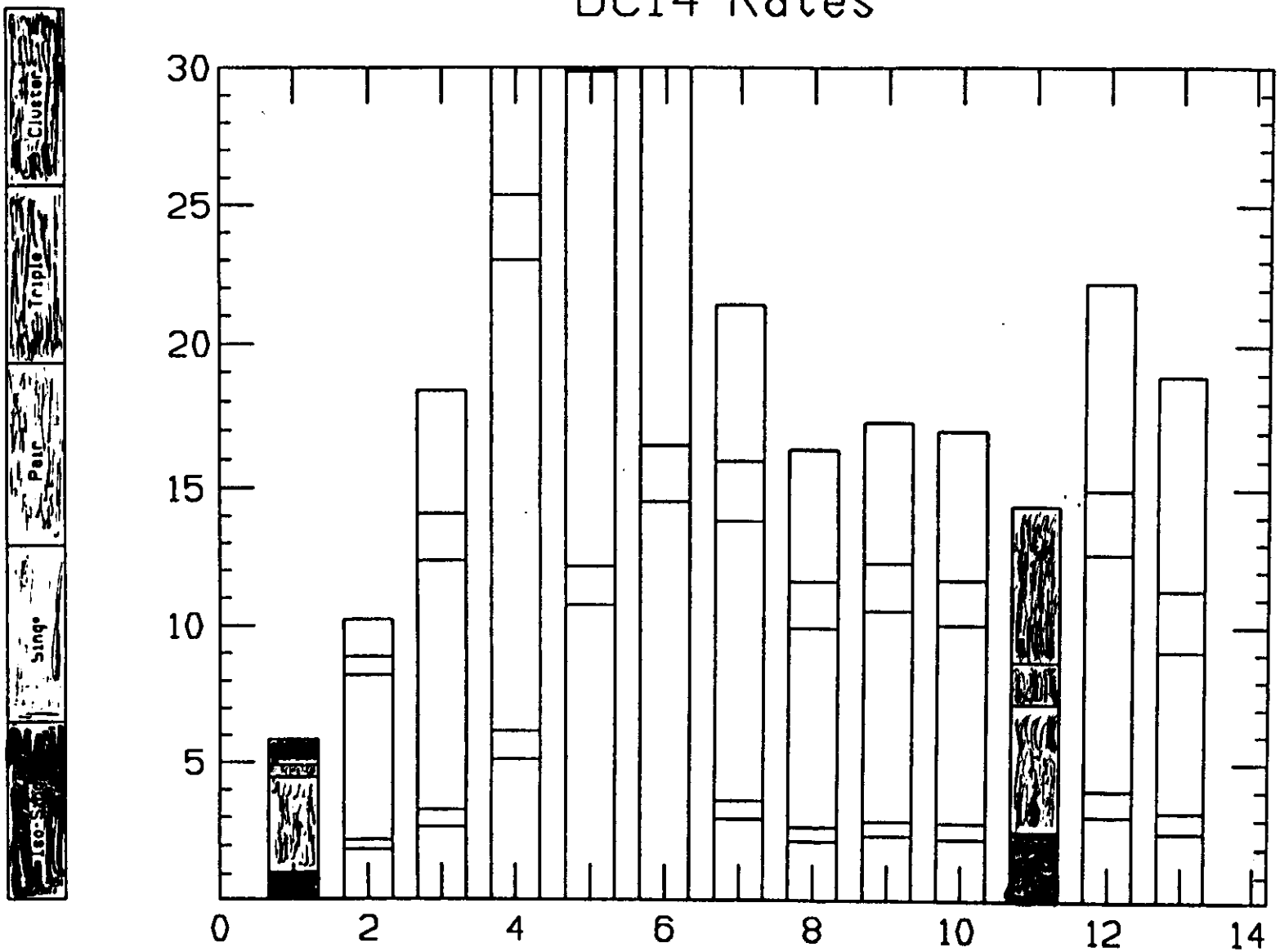
Table 1. Typical BUNKI output. All data in this table are per 10 000

Definition of a cluster

– A set of drift chamber hits that has no more than one contiguous "miss" between "hit" wires.

These 5 hit wires are considered to be a single cluster

from Dunn/Eckhart
VI. 757



Drift chamber rates (clusters / BST1)

Upstream of plug	Metal only plug	Shielded plug	Extra 1" W and poly
DC3 rate – pre-plug	**3315**	**772** (÷4)	**545** (÷1.4)
<u>Monte Carlo</u>			
from charged particles	987 ± 61	339 (÷3)	242 (÷1.4)
from neutrons	1125 ± 16	247 (÷4.5)	70 (÷3.5)
from photons	235 ± 10	137 (÷1.7)	94 (÷1.5)
Sum	**2347**	**783** (÷3)	**406** (÷1.8)
Liquid scintillator and <u>Bonner spheres minus pre-plug</u>			
charged particles	401	158 (÷2.5)	195 (×1.2)
neutrons	432	99 (÷4.4)	31 (÷3.2)
photons	205	100 (÷2)	53 (÷2)
Sum	**1038**	**357** (÷3)	**279** (÷1.3)

Downstream of plug	Metal only plug	Shielded plug	Extra 1" W and poly
DC4 rate – pre-plug/2	**2542**	**654** (÷4)	**624** (same) ?
<u>Monte Carlo</u>			
from charged particles	215 ± 22	202 same	114 (÷1.8)
from neutrons	1025 ± 15	195 (÷5)	55 (÷3.5)
from photons	187 ± 12	110 (÷1.7)	59 (÷1.9)
Sum	**1427**	**507** (÷3)	**228** (÷2)
Liquid scintillator and Bonner <u>spheres minus pre-plug/2</u>			
charged particles	409	504 (×1.2)	263 (÷1.4)
neutrons	263	48 (÷5.5)	21 (÷2.3)
photons	240	78 (÷3.1)	38 (÷2.1)
Sum	**912**	**630** (÷1.5)	**322** (÷2)

Conclusions

- The expected drift chamber rates from CALOR89 calculations and measurements using Bonner spheres and liquid scintillators generally agree to better than a factor of two.

- The Monte Carlo tends to predict 3-4 times as many neutrons compared to the neutron measurements but the spectral shapes are similar.

- The Monte Carlo accounts for the actual drift chamber rates to within a factor of two for three very different plug configurations.

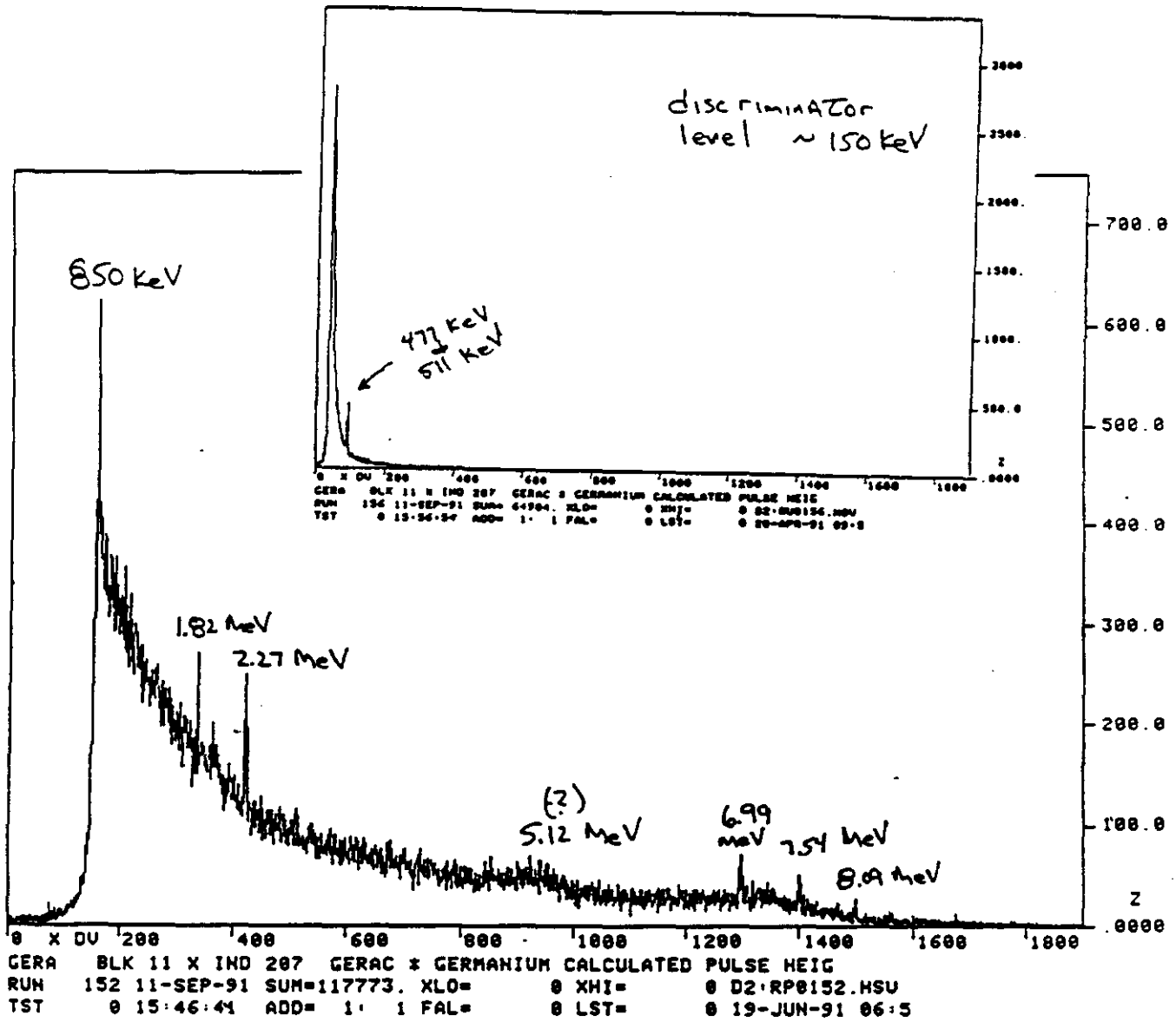
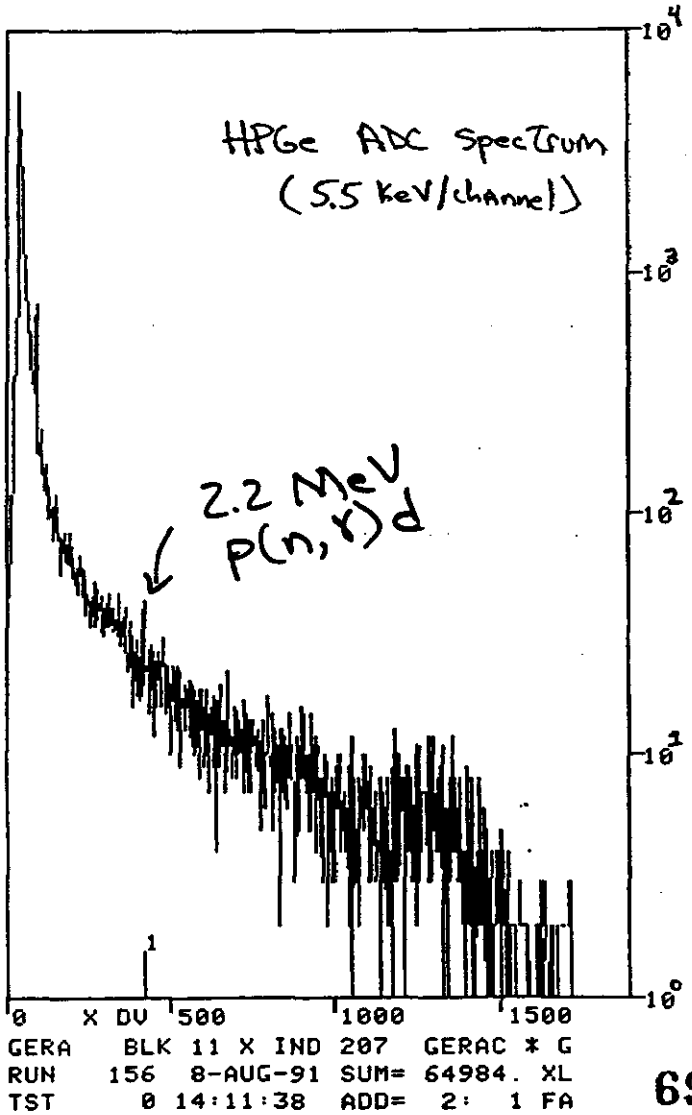
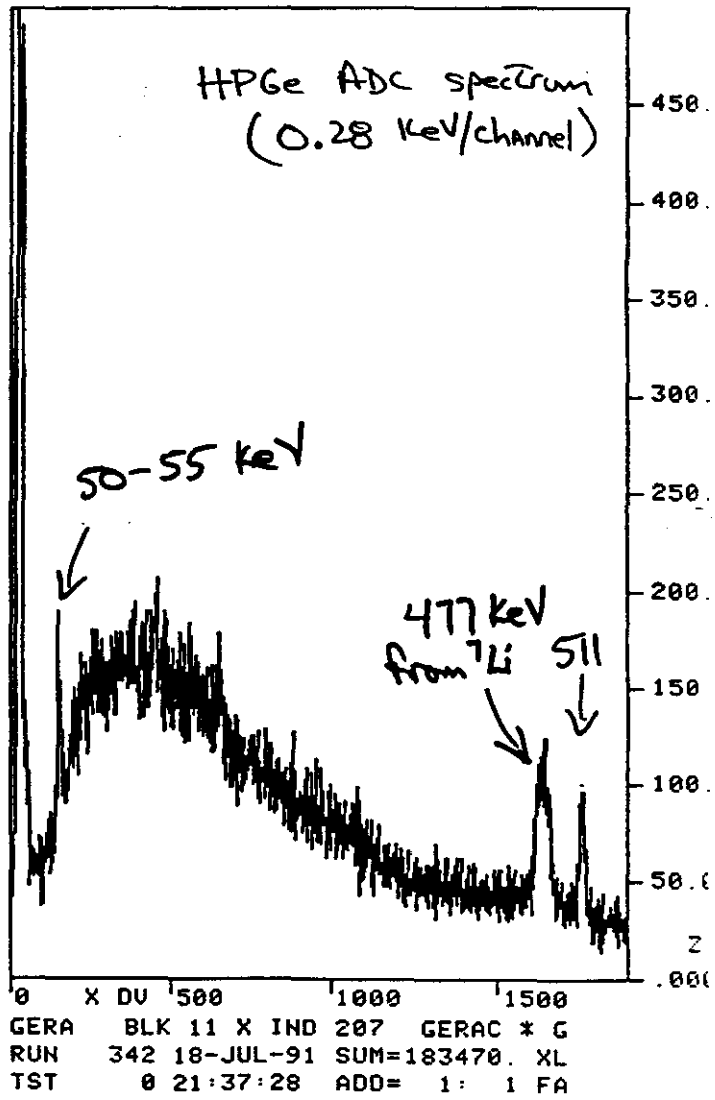


Figure 2. ADC spectrum from the Germanium detector from the early part of the experiment when the detector was operated with low gain. With a high discriminator level several lines are visible and tentatively identified; 847 keV ^{56}Co, 2.22 MeV from neutron capture on hydrogen, 7.65 MeV neutron capture on ^{56}Fe, 7.1 MeV neutron capture on Pb. Several lines are not identified. The inset shows that when the discriminator level is lowered there appear to be a large number of low-energy events.

Germanium Detector

Spectrum is mostly continuous with few neutron induced lines.



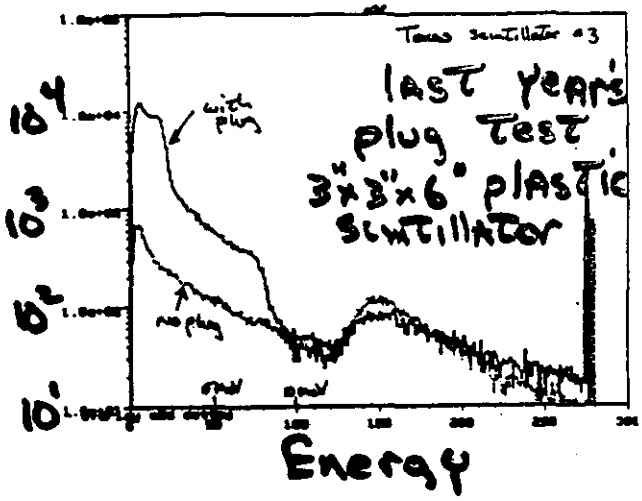


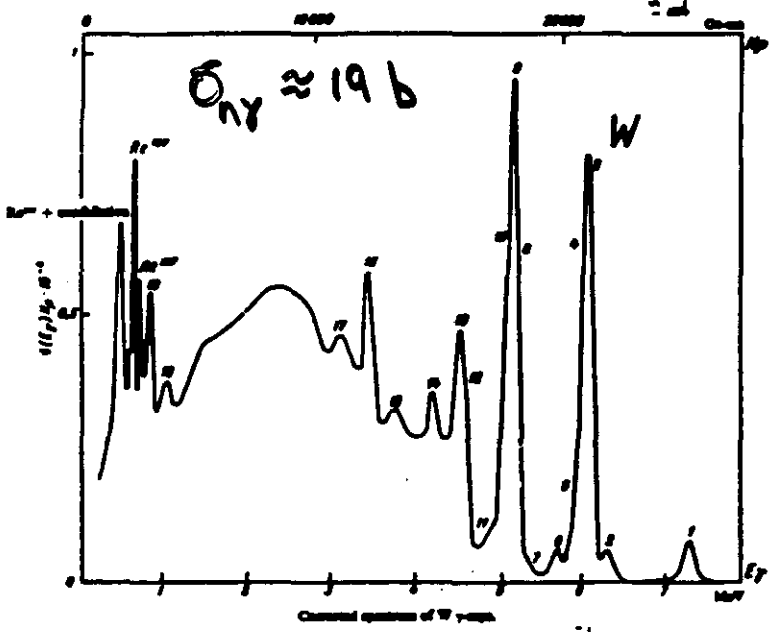
HPGe detector
- identify source of some γ's

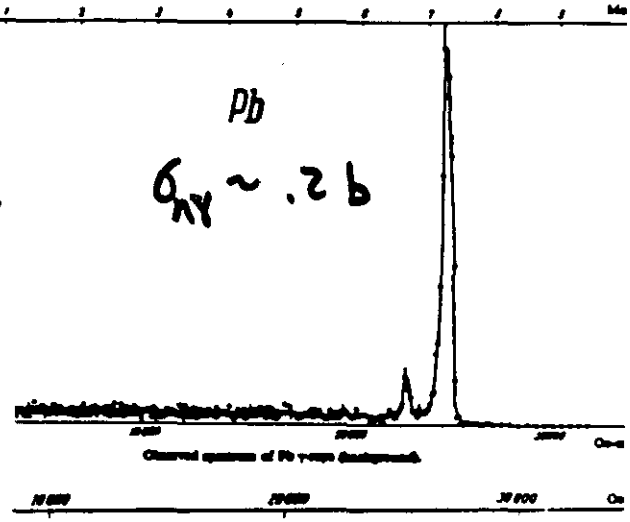
such as W, Fe and Pb (below)

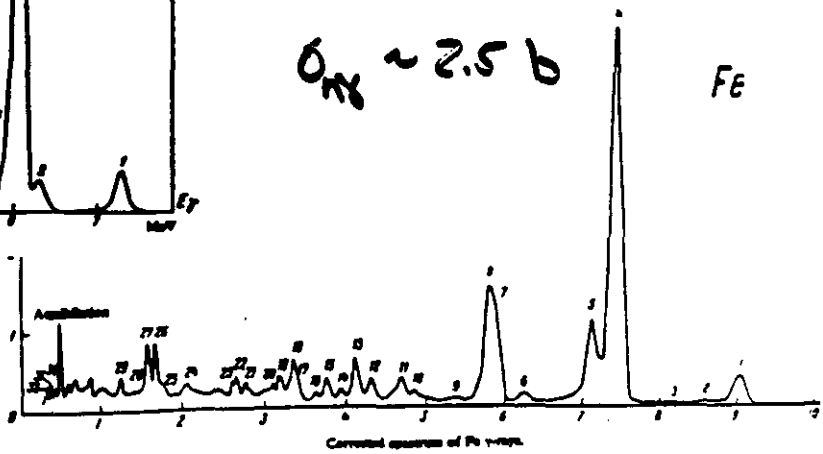
or the .48 MeV γ
from $^{10}B(n\alpha)^7Li^*$
$\hookrightarrow {}^7Li + \gamma$

or the 2.2 MeV γ
from
$p(n\gamma)d$







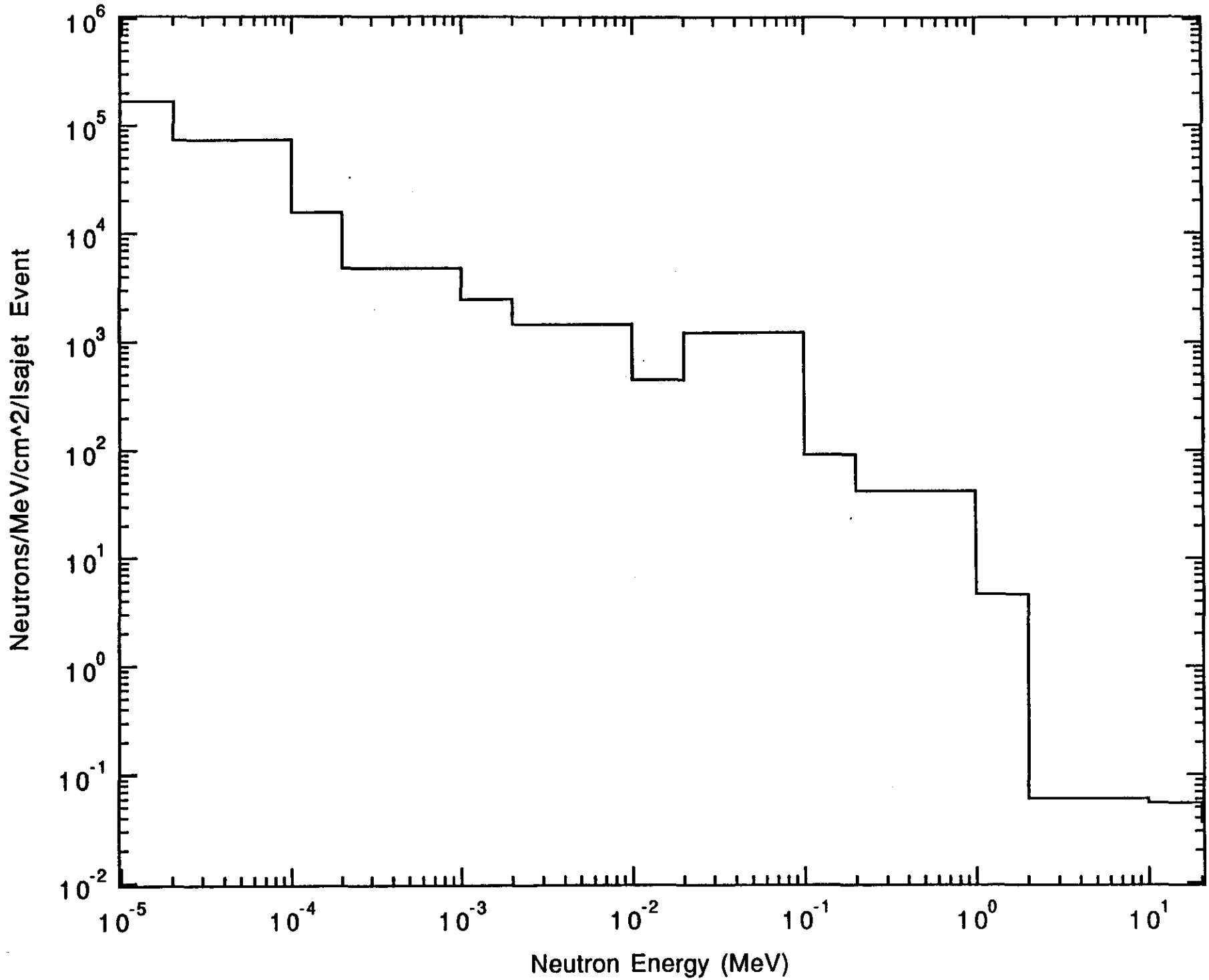


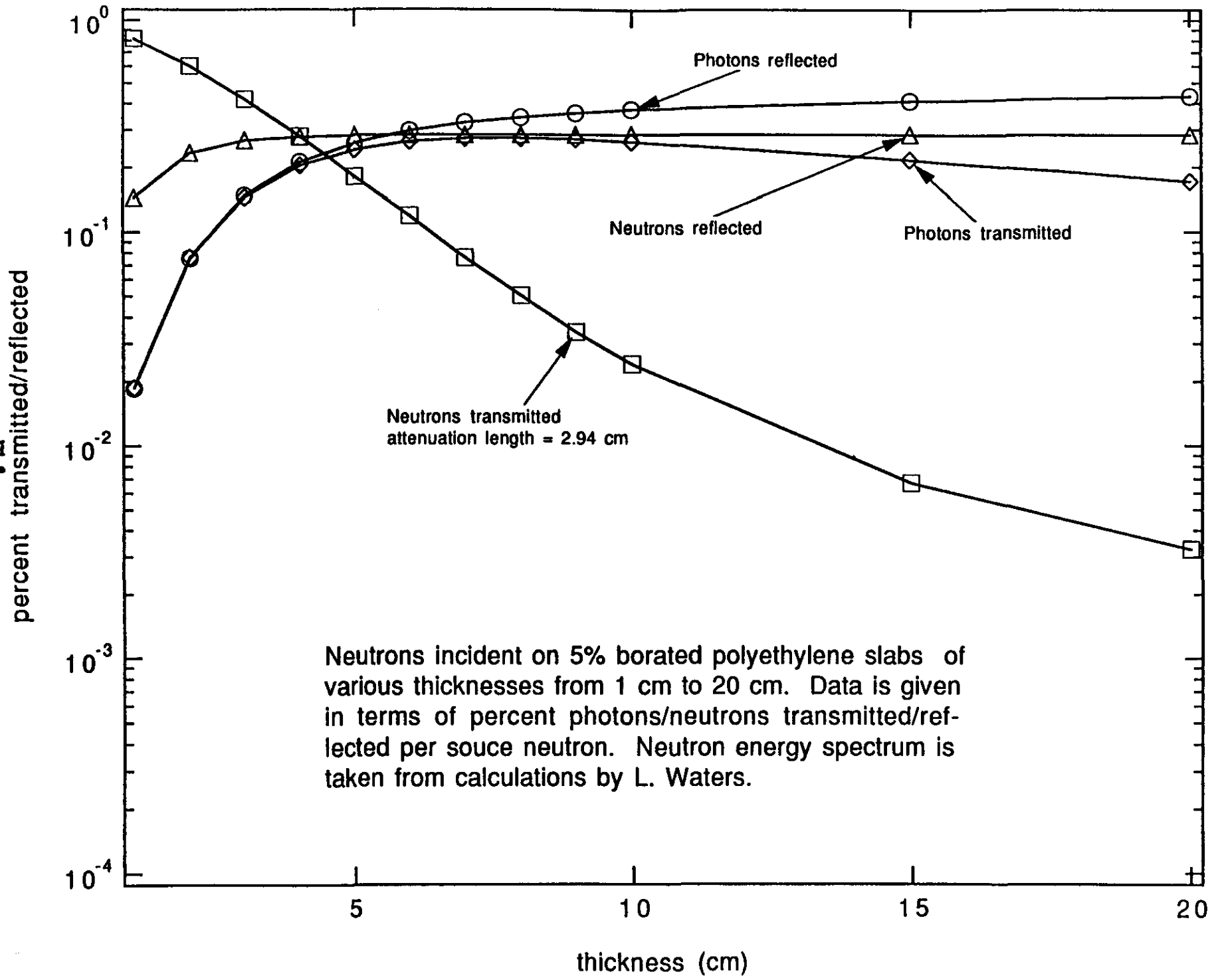
gem

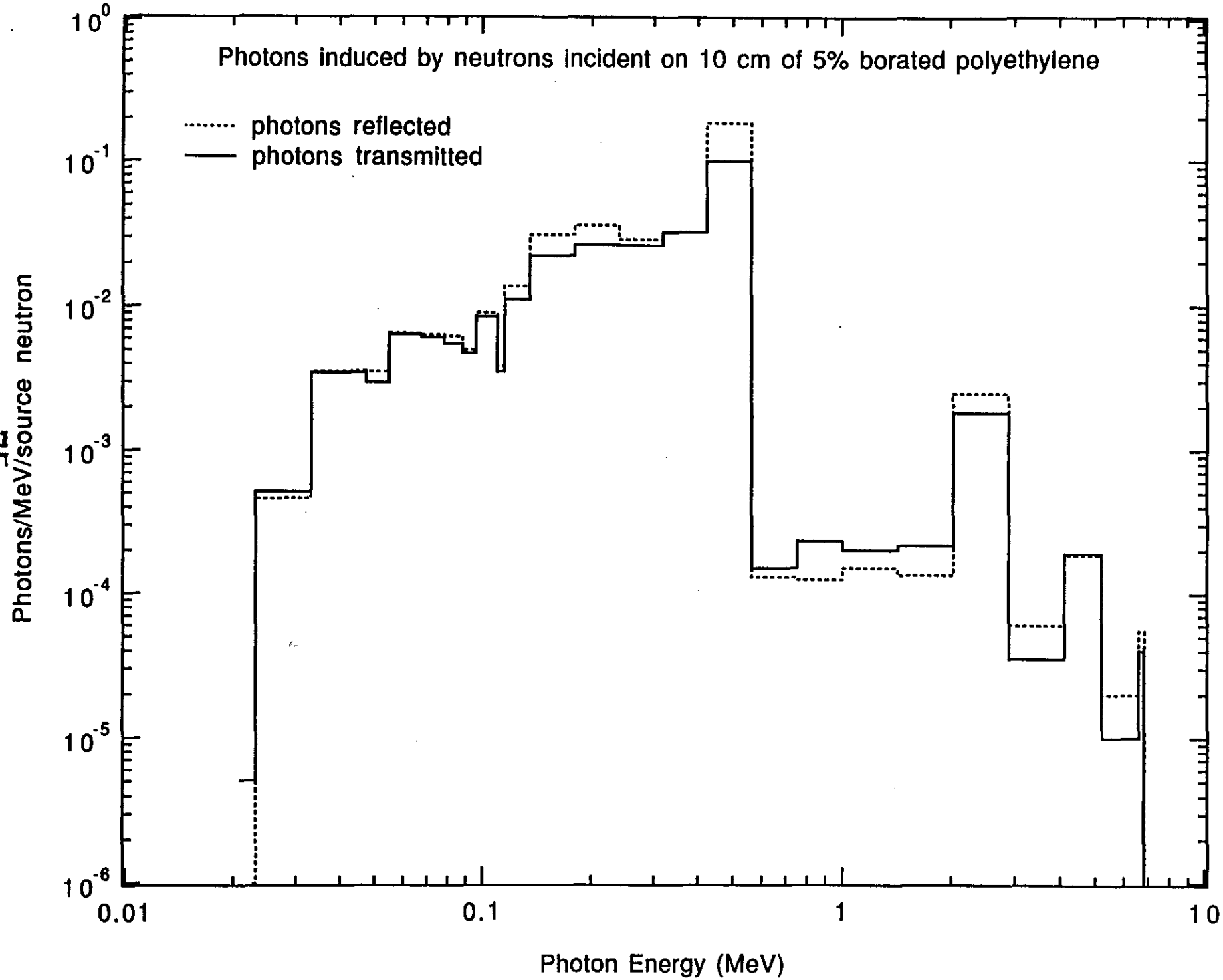
γeμ

Presentation by:

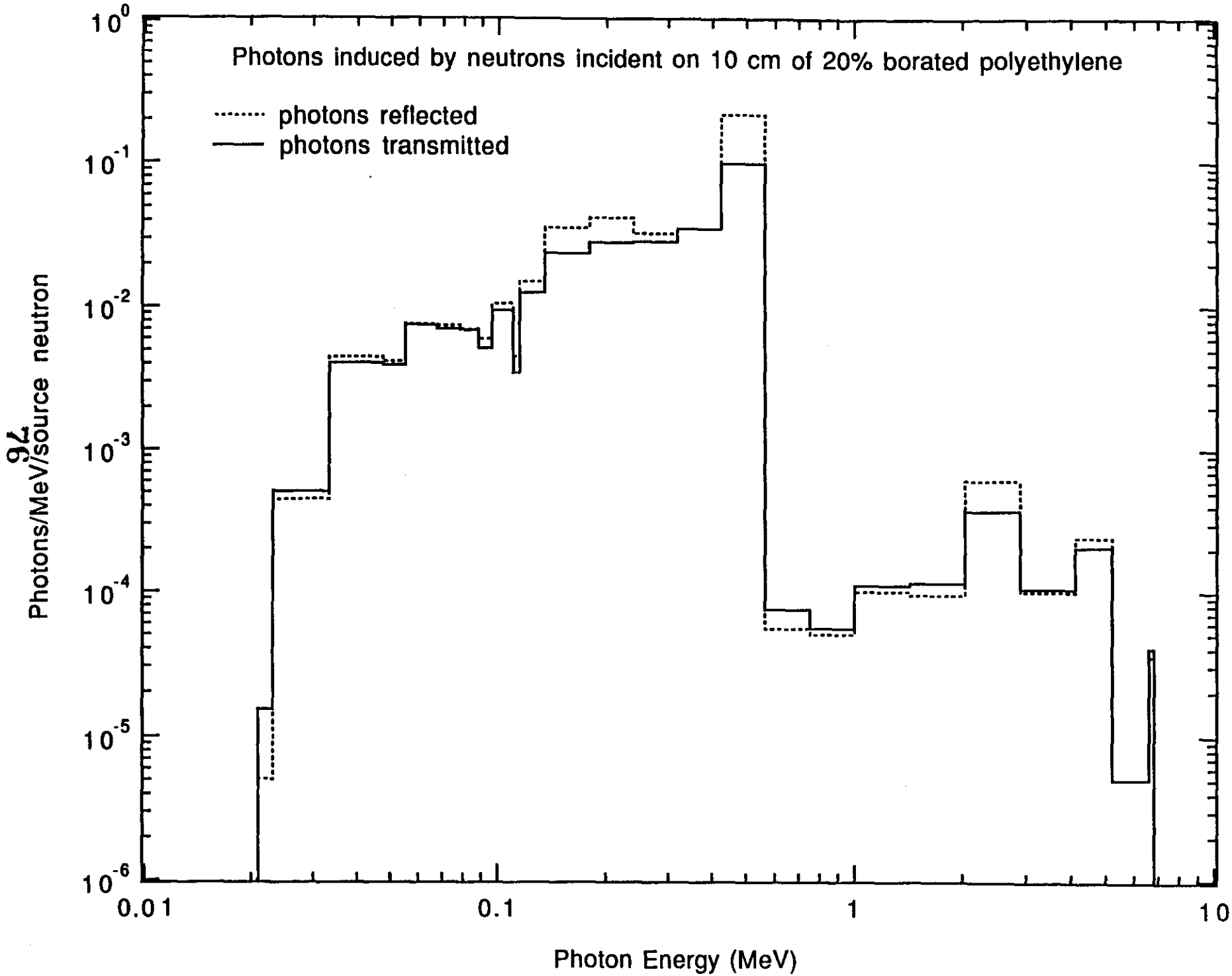
C. Wuest

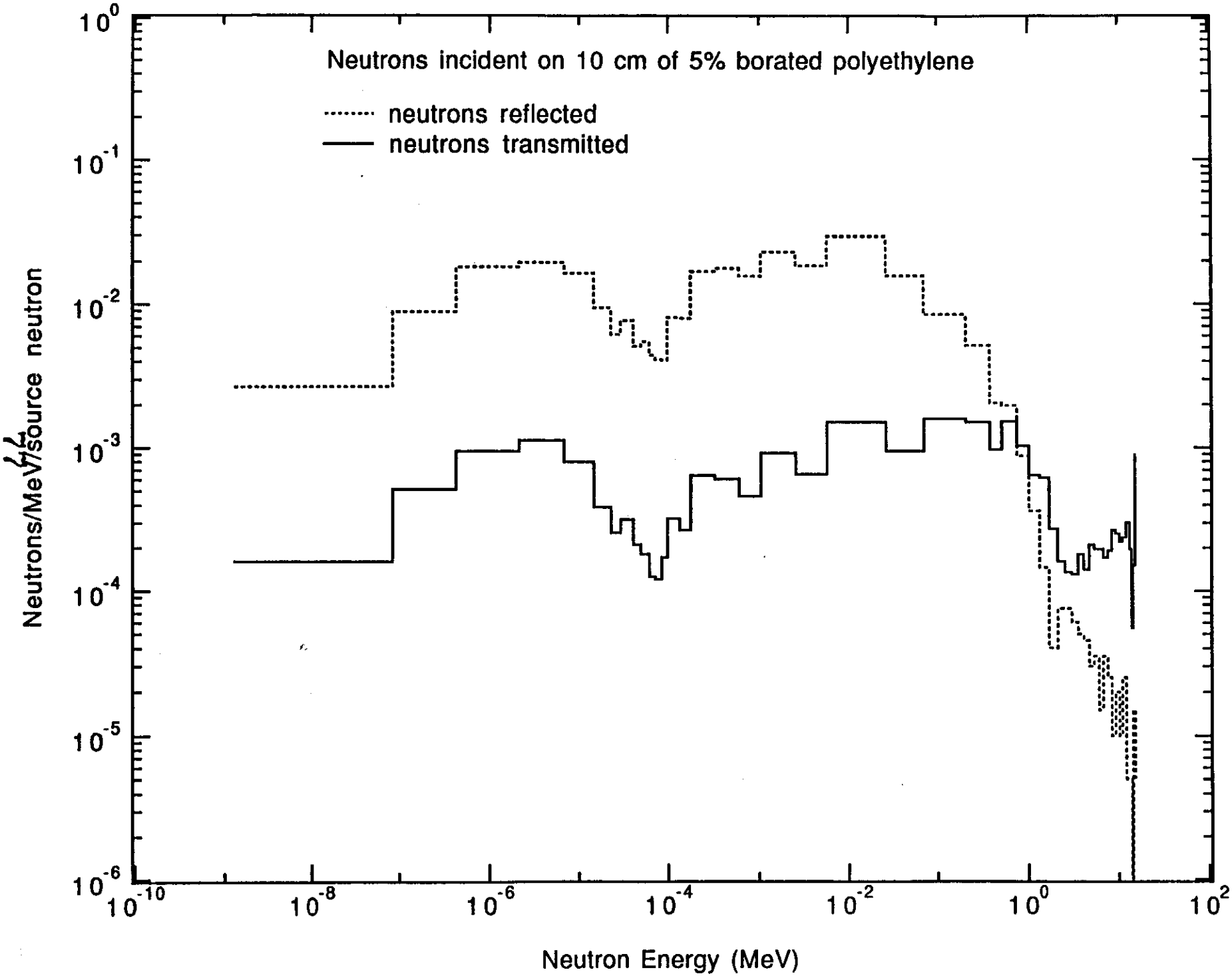

Neutrons/MeV/cm^2/Isajet Event
Neutron Energy (MeV)
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}


Photons reflected
Neutrons reflected
Photons transmitted
Neutrons transmitted
attenuation length = 2.94 cm
Neutrons incident on 5% borated polyethylene slabs of various thicknesses from 1 cm to 20 cm. Data is given in terms of percent photons/neutrons transmitted/reflected per souce neutron. Neutron energy spectrum is taken from calculations by L. Waters.
percent transmitted/reflected
thickness (cm)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
5
10
15
20

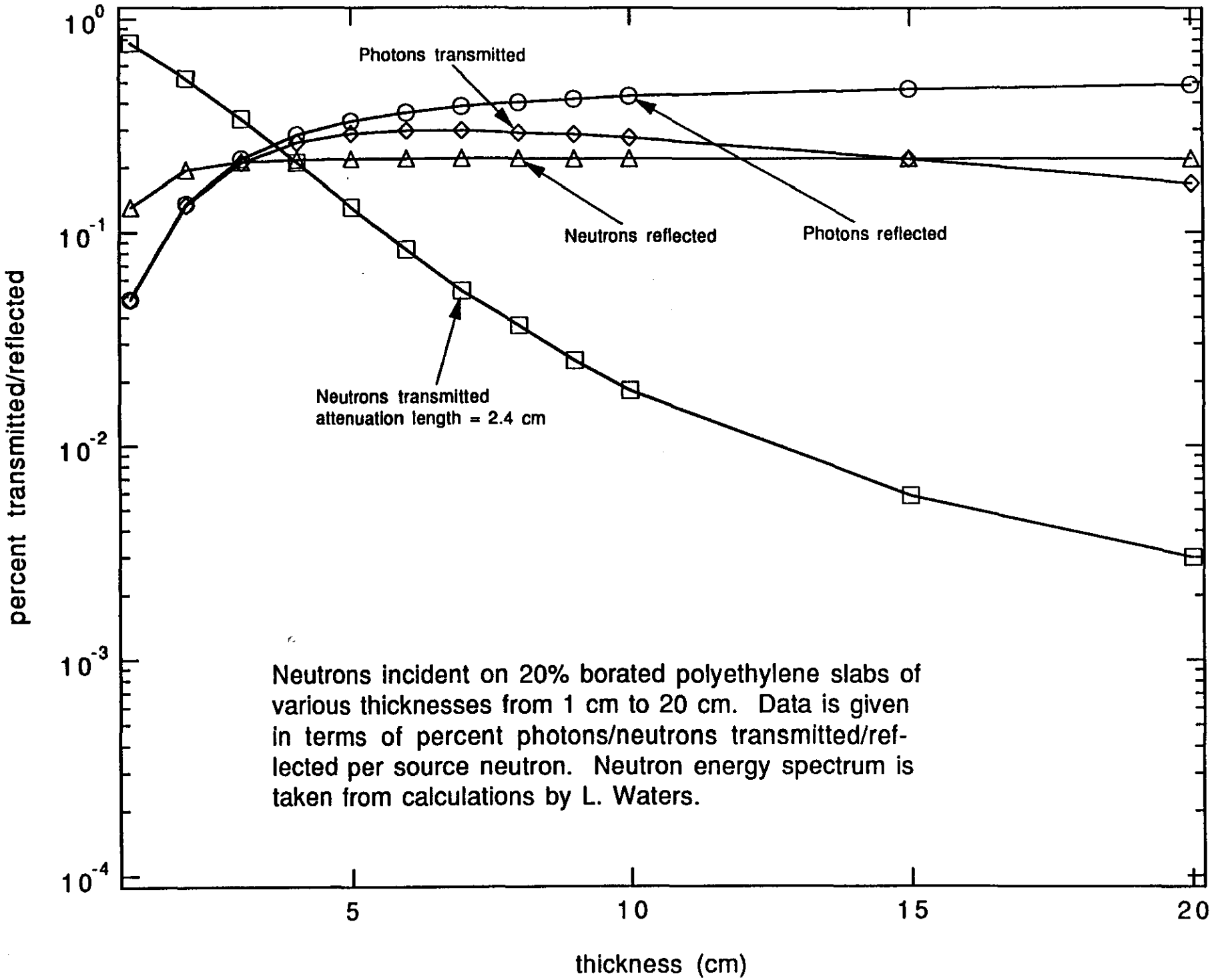

Photons induced by neutrons incident on 10 cm of 5% borated polyethylene
photons reflected
photons transmitted
Photons/MeV/source neutron
Photon Energy (MeV)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.1
1
10

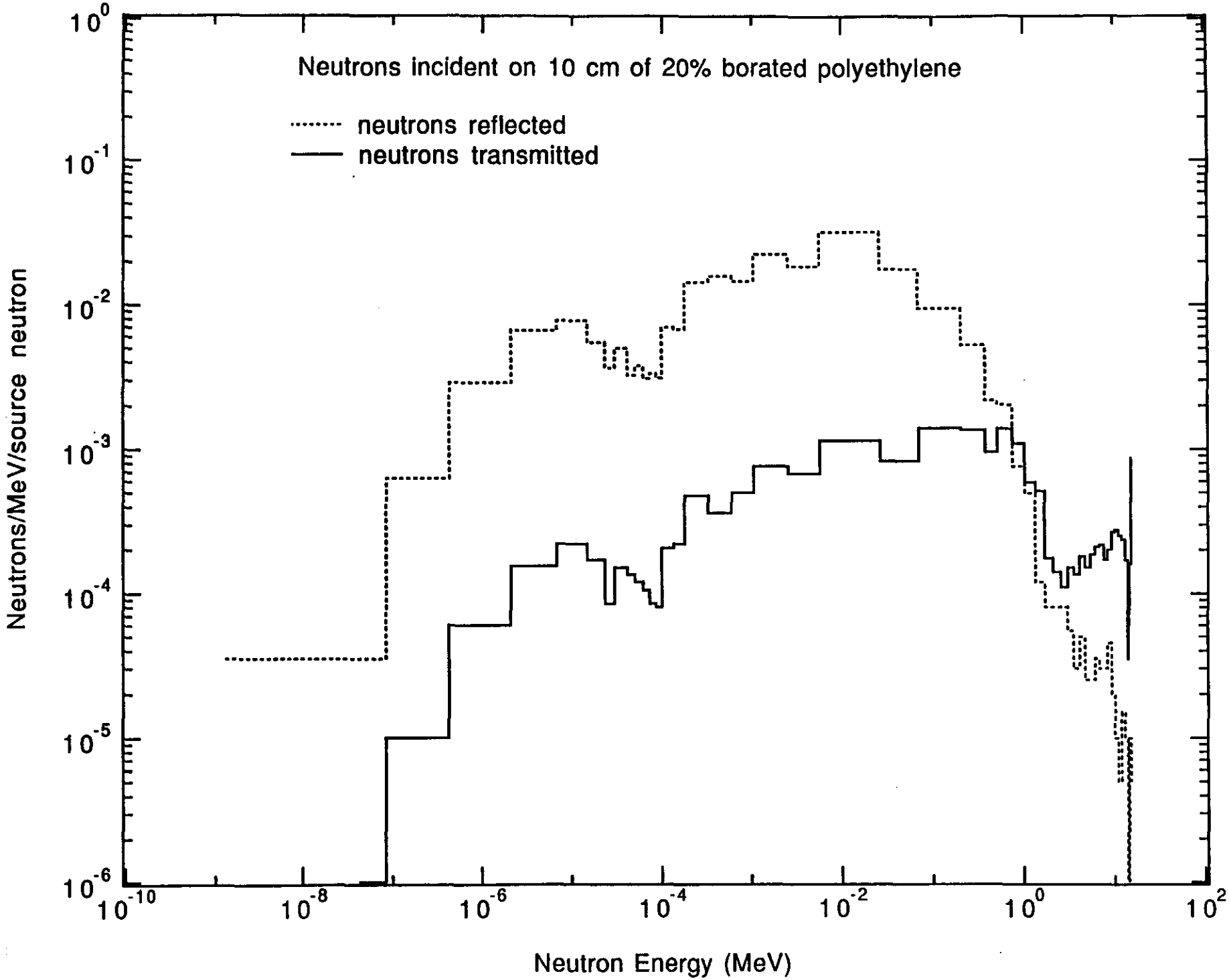
GEM TN-92-172

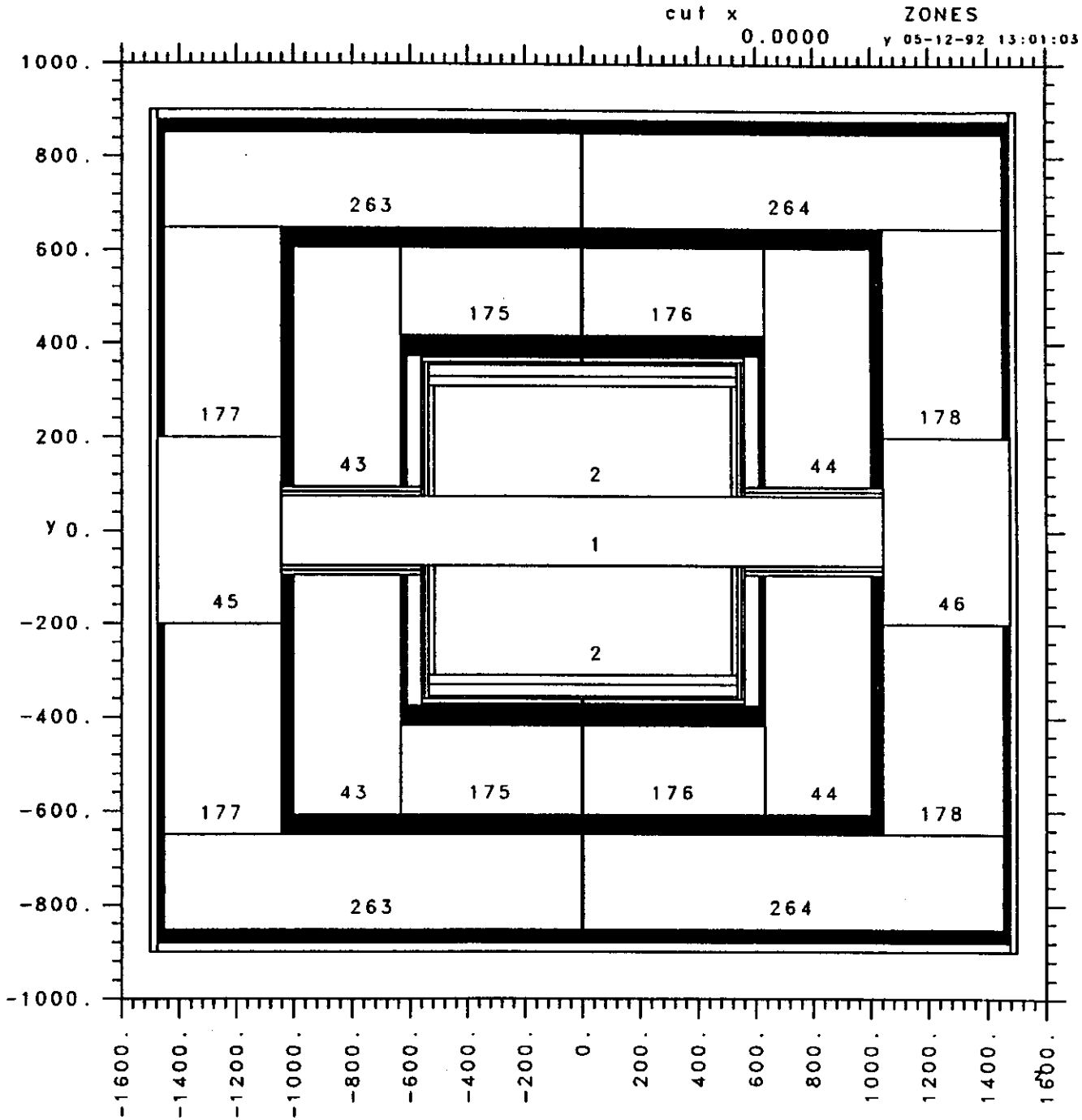

Photons induced by neutrons incident on 10 cm of 20% borated polyethylene
photons reflected
photons transmitted
Photons/MeV/source neutron
Photon Energy (MeV)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.1
1
10

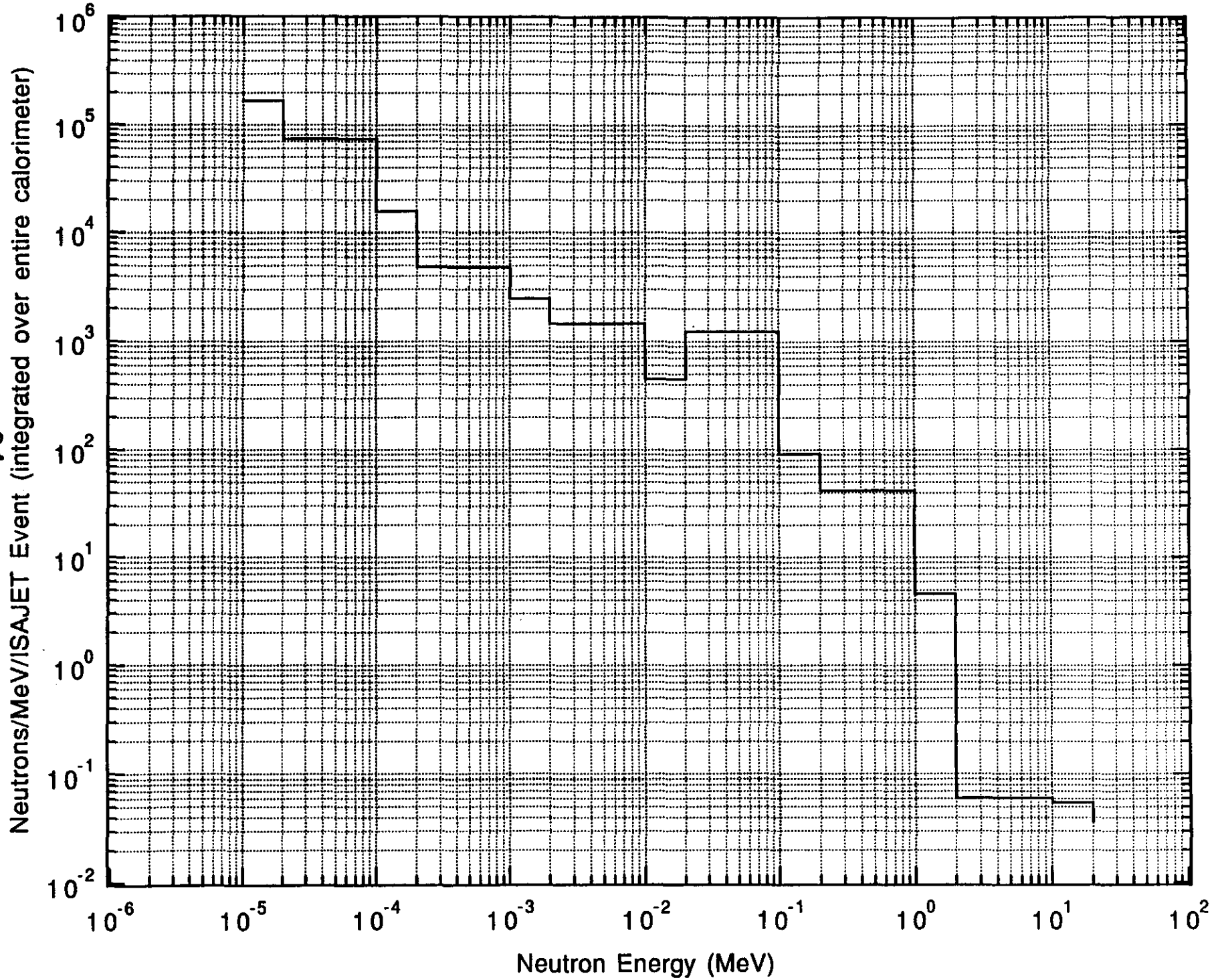

Neutrons incident on 10 cm of 5% borated polyethylene
neutrons reflected
neutrons transmitted
Neutrons/MeV/source neutron
Neutron Energy (MeV)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}

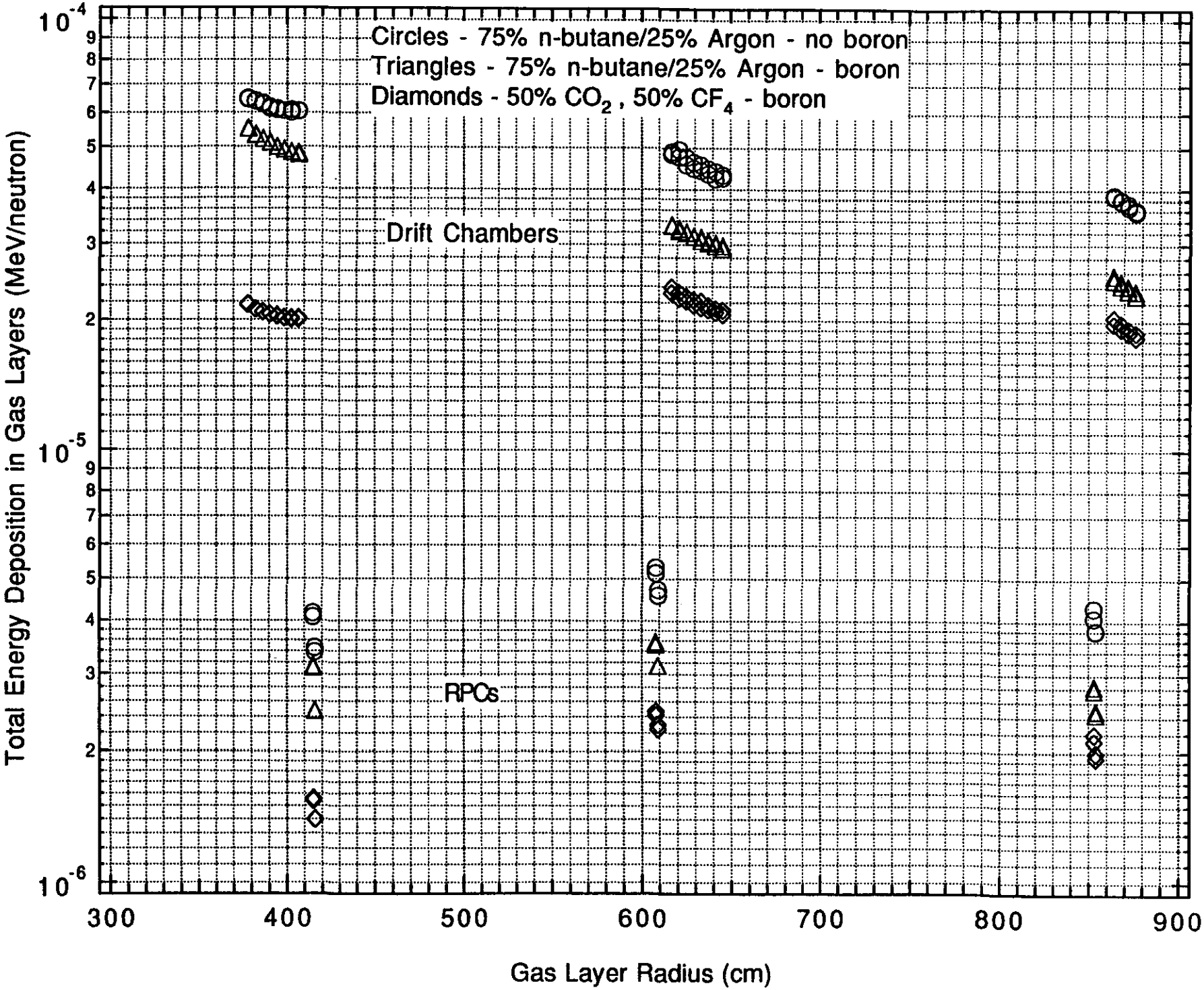
GEM TN-92-172

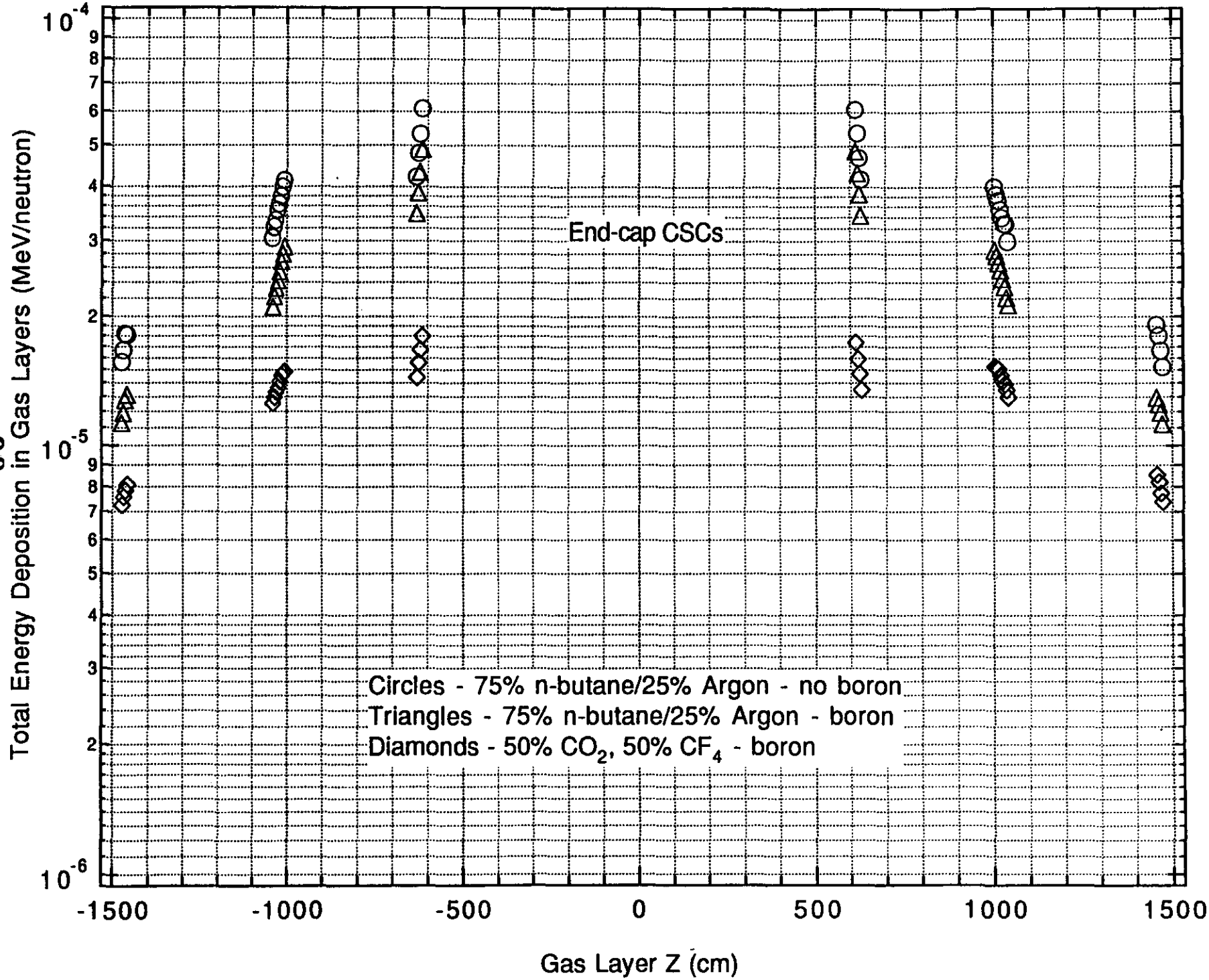

Photons transmitted
Neutrons reflected
Photons reflected
Neutrons transmitted
attenuation length = 2.4 cm
Neutrons incident on 20% borated polyethylene slabs of various thicknesses from 1 cm to 20 cm. Data is given in terms of percent photons/neutrons transmitted/reflected per source neutron. Neutron energy spectrum is taken from calculations by L. Waters.
percent transmitted/reflected
thickness (cm)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
5
10
15
20

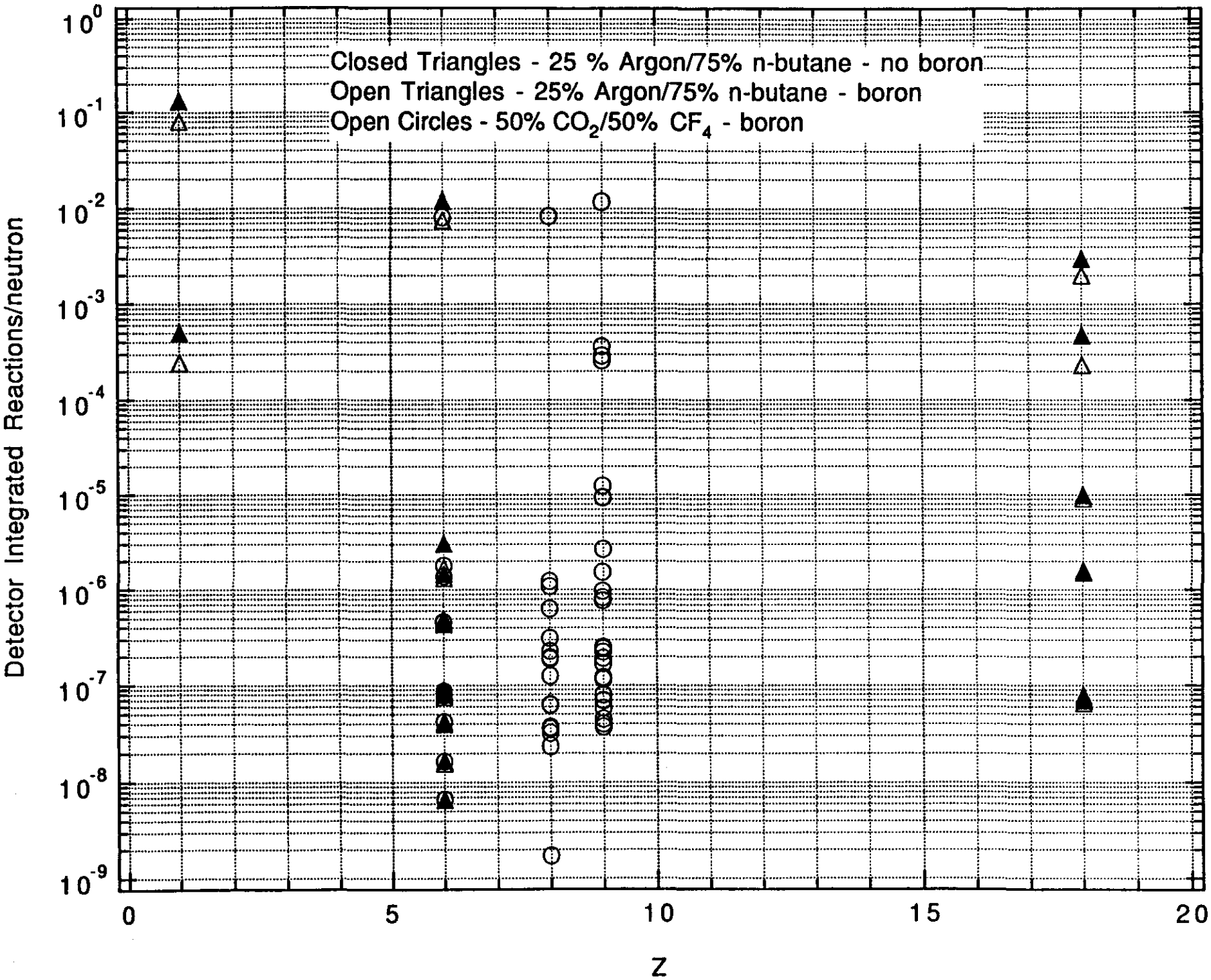

Neutrons incident on 10 cm of 20% borated polyethylene
neutrons reflected
neutrons transmitted
Neutrons/MeV/source neutron
Neutron Energy (MeV)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}

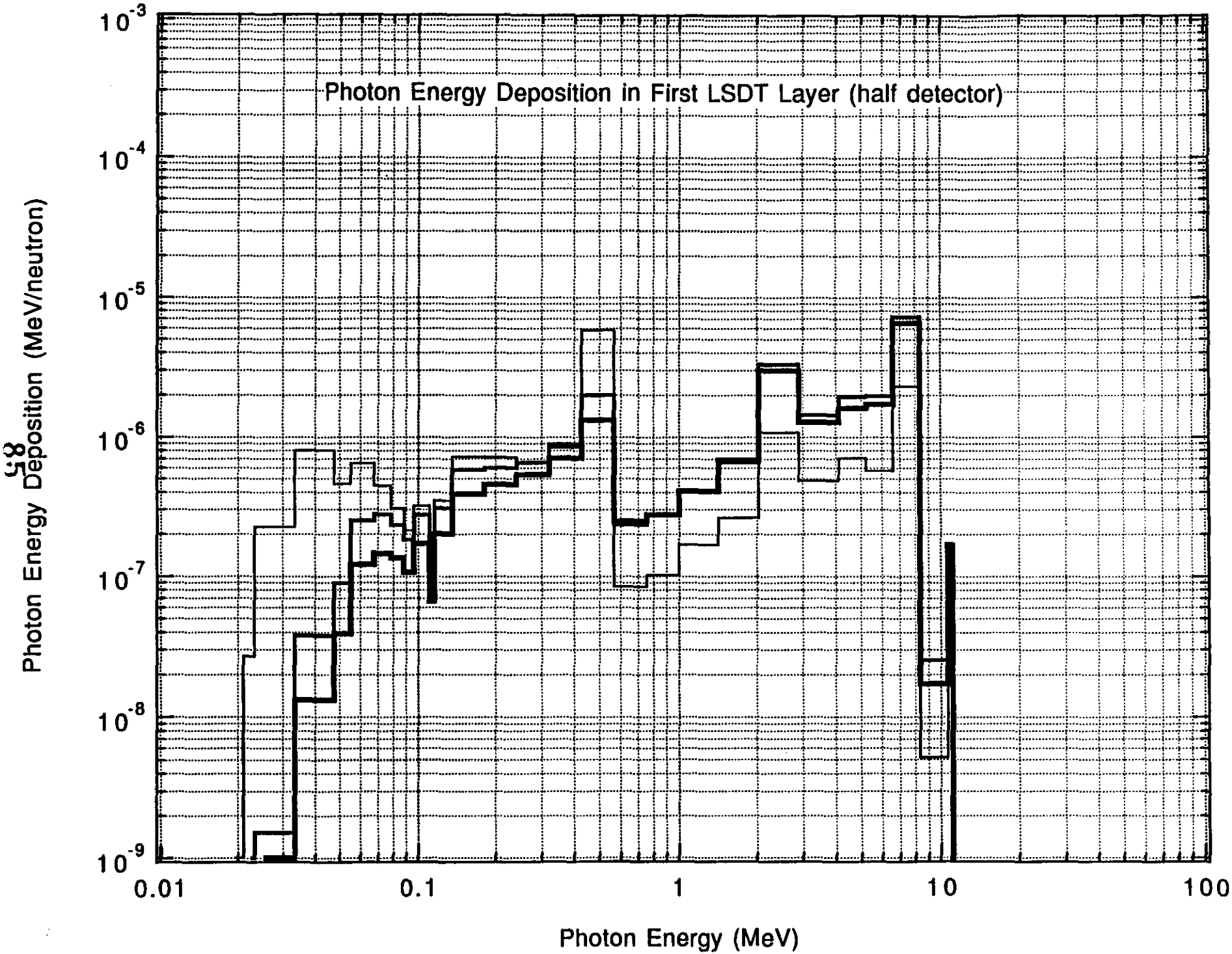

cut x
0.0000
ZONES
y 05-12-92 13:01:03
263
264
175
176
177
178
43
44
2
1
45
46
2
43
175
176
44
177
178
263
264
y
1000.
800.
600.
400.
200.
0.
-200.
-400.
-600.
-800.
-1000.
-1600.
-1400.
-1200.
-1000.
-800.
-600.
-400.
-200.
0.
200.
400.
600.
800.
1000.
1200.
1400.
1600.

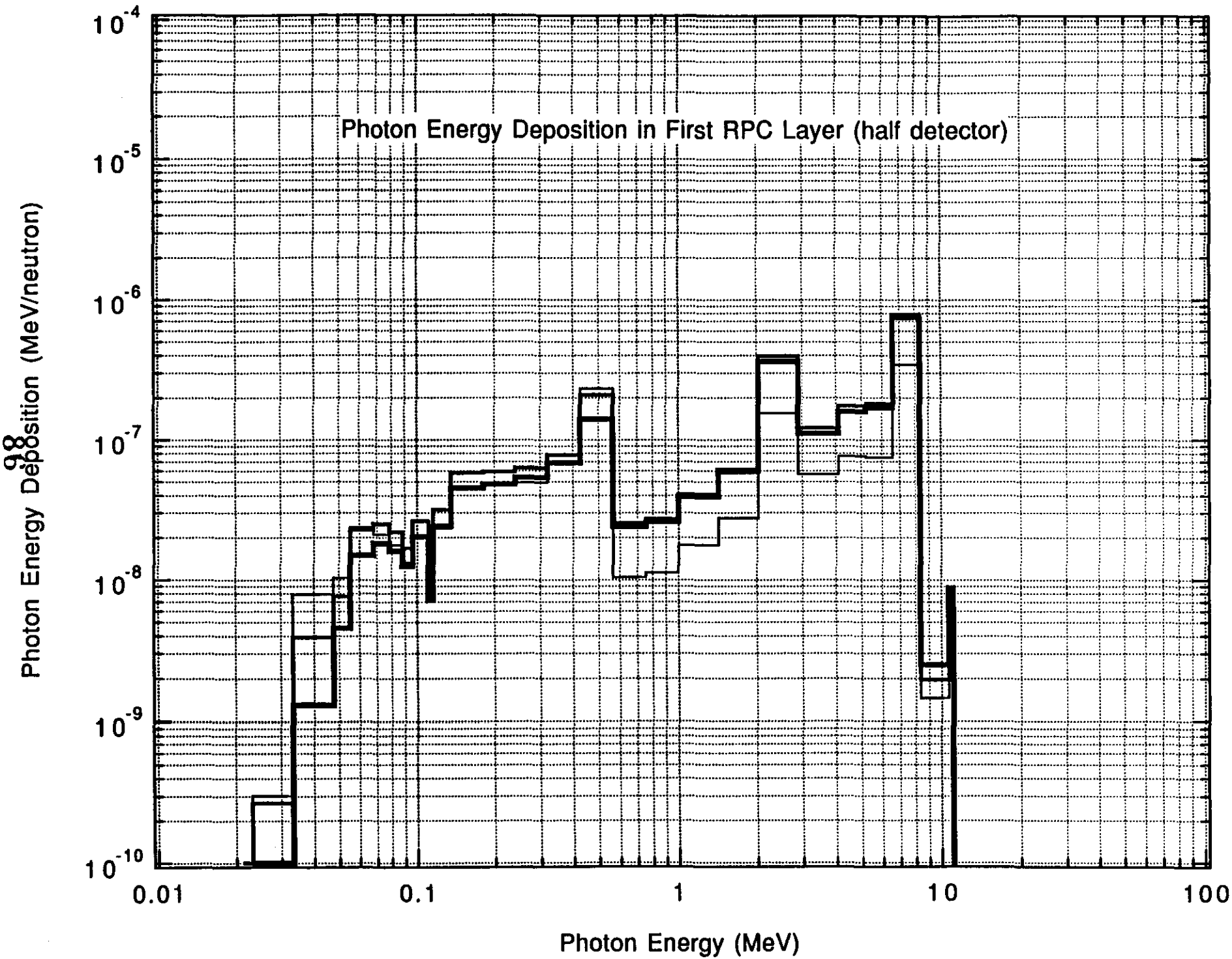

Neutrons/MeV/ISAJET Event (integrated over entire calorimeter)
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Neutron Energy (MeV)

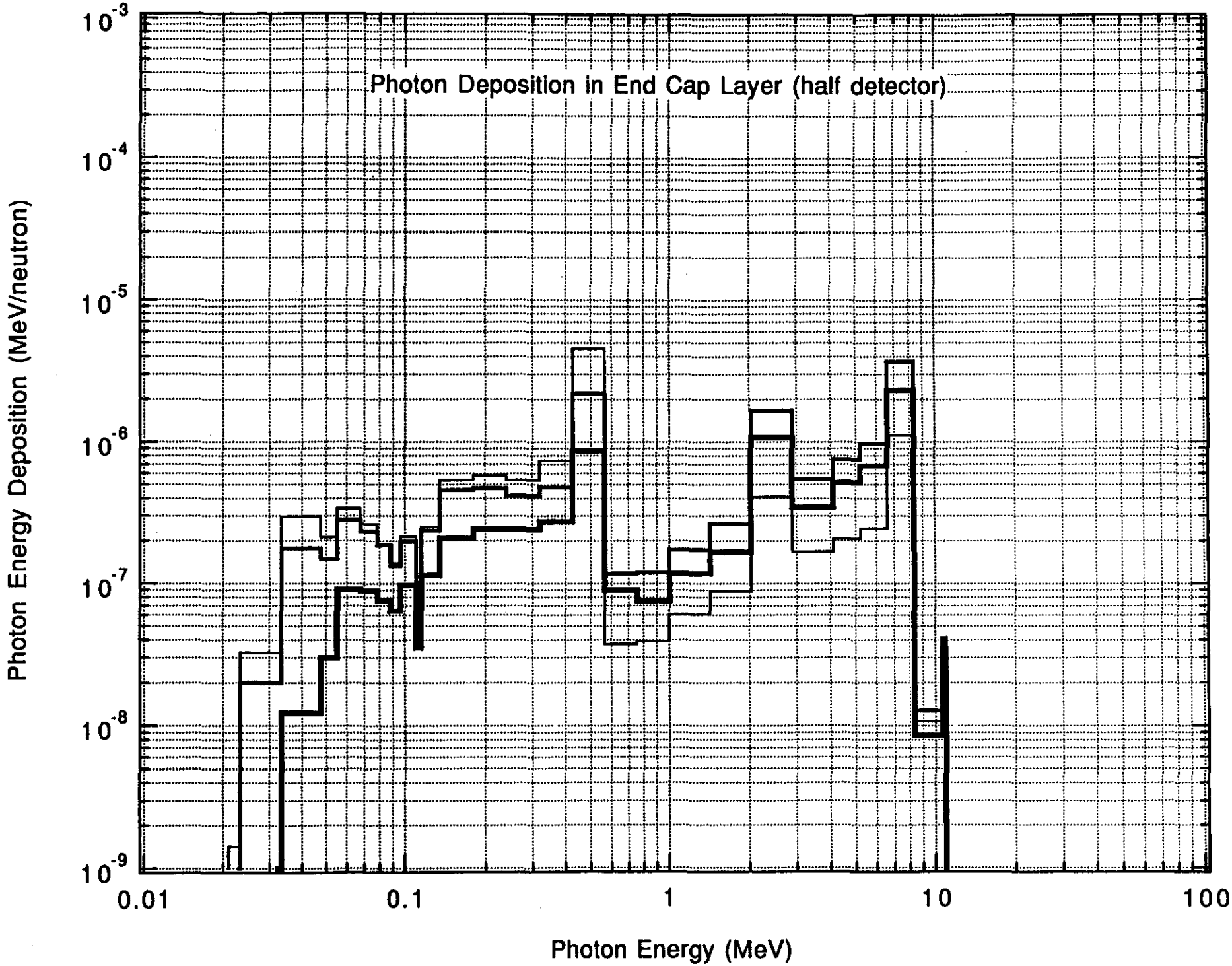

Circles - 75% n-butane/25% Argon - no boron
Triangles - 75% n-butane/25% Argon - boron
Diamonds - 50% CO_2 , 50% CF_4 - boron
Drift Chambers
RPCs
Total Energy Deposition in Gas Layers (MeV/neutron)
Gas Layer Radius (cm)
10^{-4}
10^{-5}
10^{-6}
300
400
500
600
700
800
900

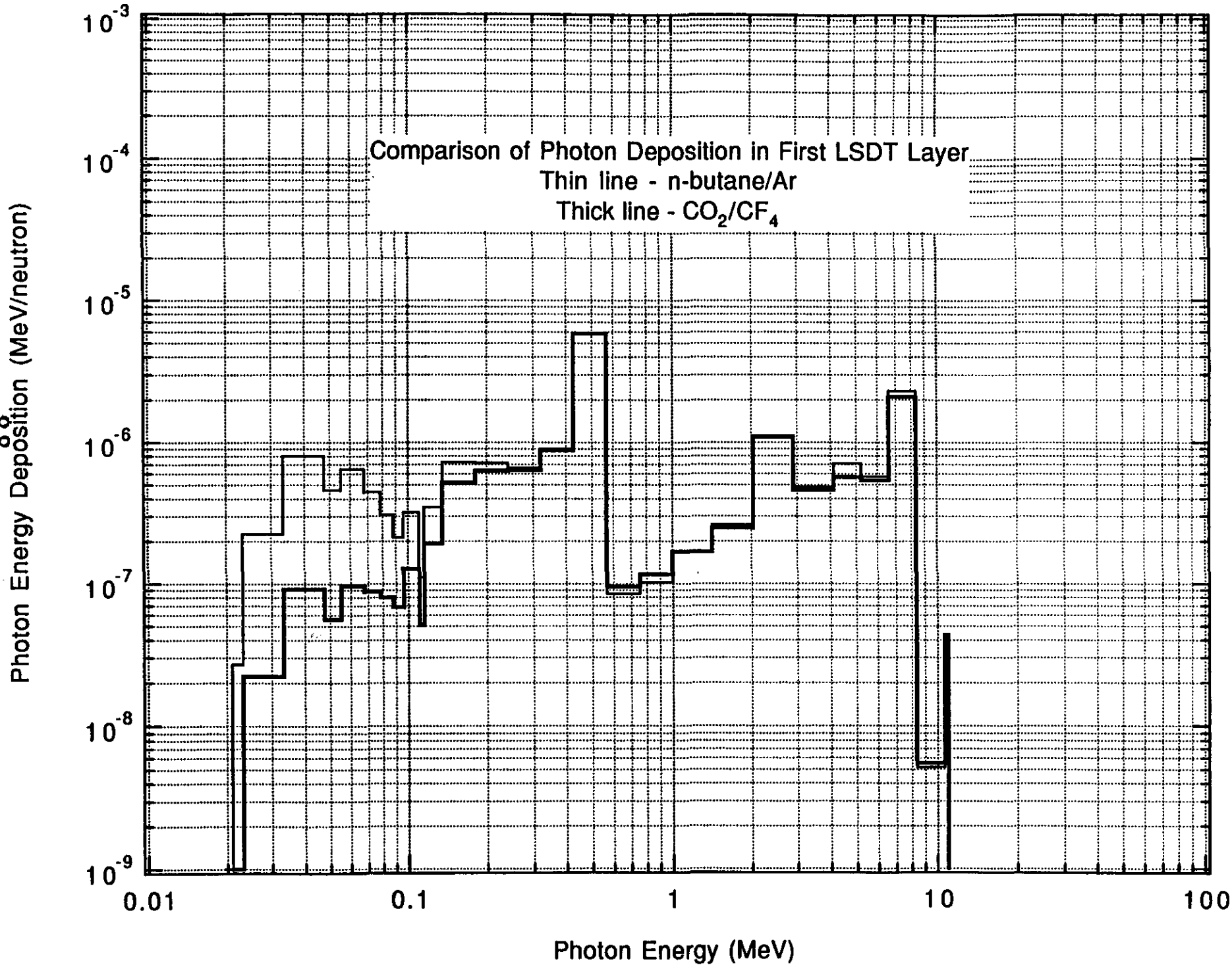

End-cap CSCs
Circles - 75% n-butane/25% Argon - no boron
Triangles - 75% n-butane/25% Argon - boron
Diamonds - 50% CO_2, 50% CF_4 - boron
Total Energy Deposition in Gas Layers (MeV/neutron)
Gas Layer Z (cm)
10^{-4}
10^{-5}
10^{-6}
-1500
-1000
-500
0
500
1000
1500

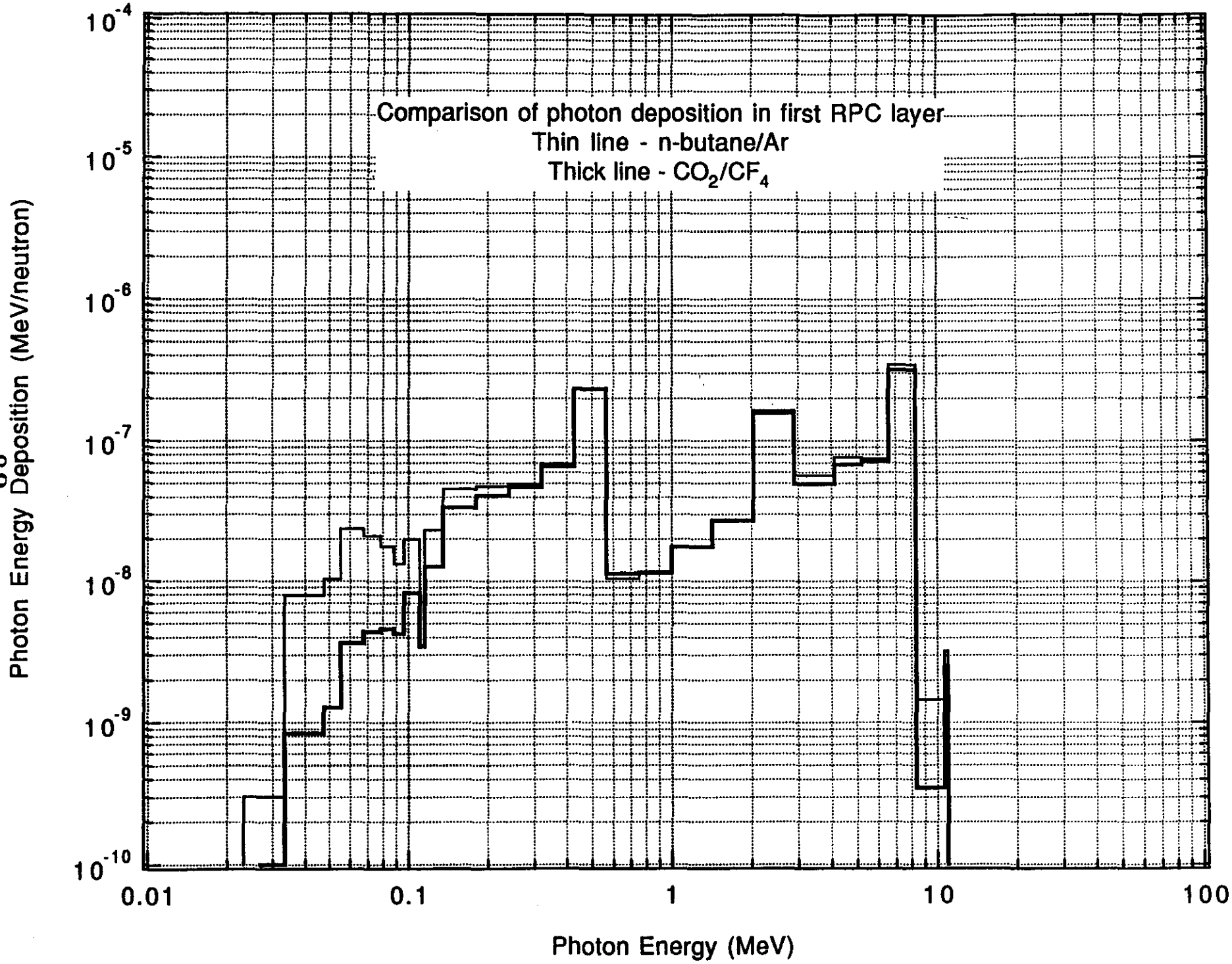

Closed Triangles - 25 % Argon/75% n-butane - no boron
Open Triangles - 25% Argon/75% n-butane - boron
Open Circles - 50% CO_2/50% CF_4 - boron
Detector Integrated Reactions/neutron
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
5
10
15
20
Z

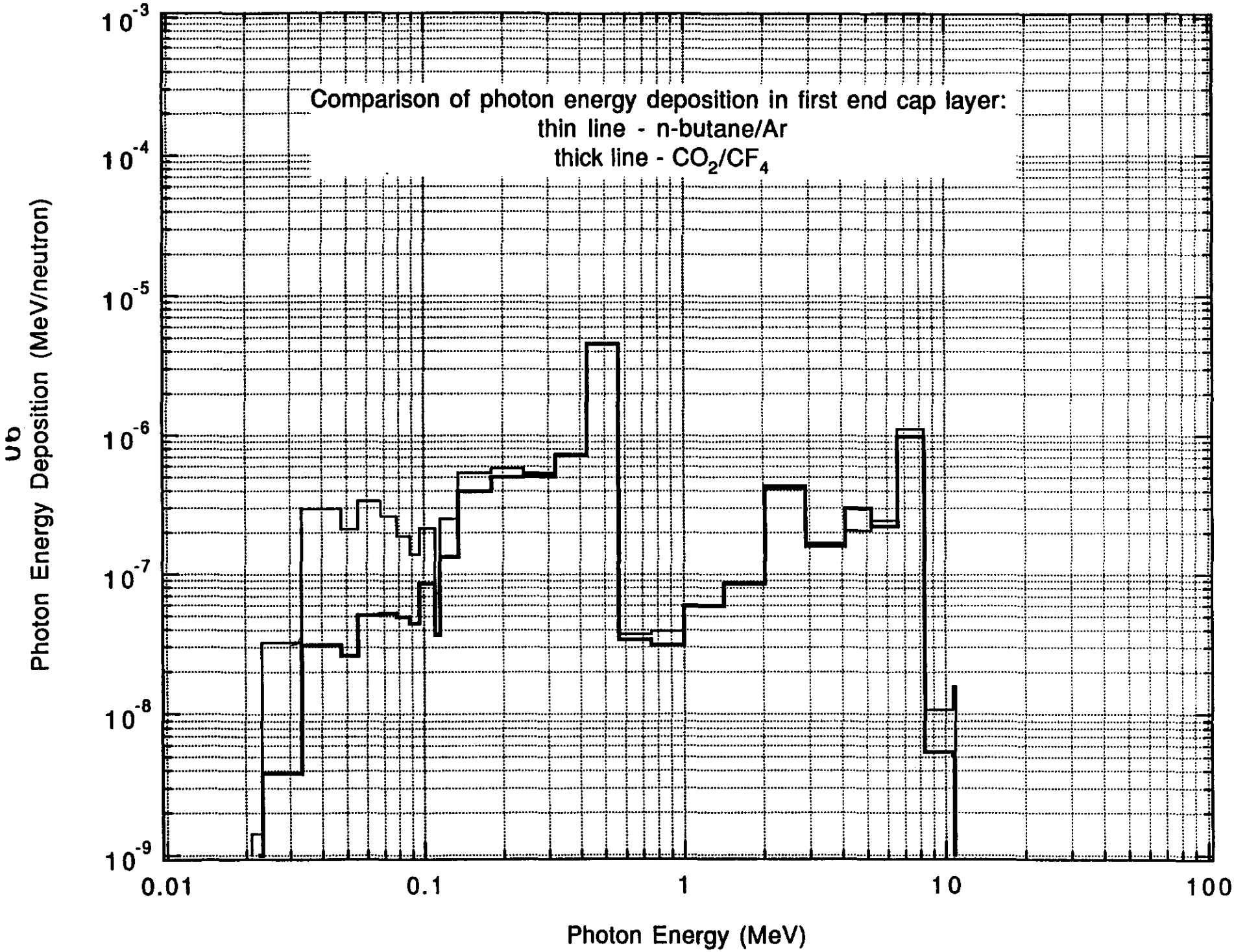

Photon Energy Deposition in First LSDT Layer (half detector)
Photon Energy Deposition (MeV/neutron)
Photon Energy (MeV)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.01
0.1
1
10
100


Photon Energy Deposition in First RPC Layer (half detector)
Photon Energy Deposition (MeV/neutron)
Photon Energy (MeV)
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
0.01
0.1
1
10
100


Photon Deposition in End Cap Layer (half detector)
Photon Energy Deposition (MeV/neutron)
Photon Energy (MeV)
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0.01
0.1
1
10
100


Comparison of Photon Deposition in First LSDT Layer
Thin line - n-butane/Ar
Thick line - CO_2/CF_4
Photon Energy Deposition (MeV/neutron)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.01
0.1
1
10
100
Photon Energy (MeV)


Comparison of photon deposition in first RPC layer
Thin line - n-butane/Ar
Thick line - CO_2/CF_4
Photon Energy Deposition (MeV/neutron)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01
0.1
1
10
100
Photon Energy (MeV)


Comparison of photon energy deposition in first end cap layer:
thin line - n-butane/Ar
thick line - CO_2/CF_4
Photon Energy Deposition (MeV/neutron)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.01
0.1
1
10
100
Photon Energy (MeV)

617-565-8316

McNEIL

RPC Conspiracy trigger

neutron rate 10^4 Hz/cm^2 @ 10^{34} @ 90°

Per RRC SL either layer fires .4% of n
so rate/cm^2 of hits in SL1 ~ 80 Hz/cm^2
in SL2 ~ 36 Hz/cm^2 in SL3 ~ 20 Hz/cm^2 } Either layer of 2-layer SL

Given a strip 1.3cm × 330cm in SL1
rate is 3×10^4 Hz @ 10^{34}

Consider 50GeV/c trigger:
Given a SL1 strip fires, look ±3 strips in SL2, SL3
rate is

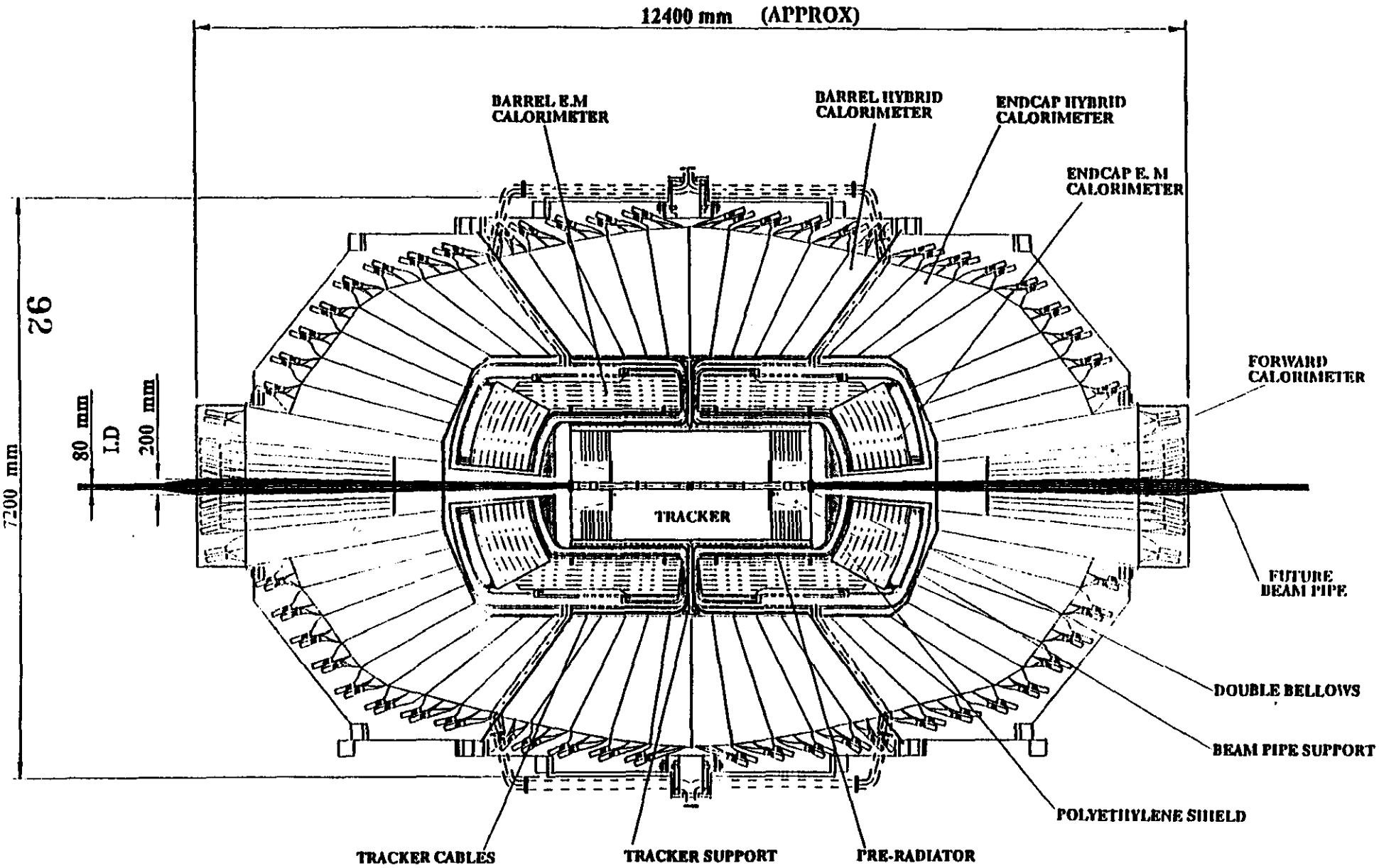
SL2 strips 360cm × 1.3cm SL3 strips 380cm × 1.3cm
Rate SL2 trigger window 10^5 Hz, SL3 ~ 6×10^4 Hz
Assume Gate: 200ns?

So Coincidence prob SL2 ~ 2% SL3 ~ 1.2%
What if 20ns gate .2% SL2, .12% SL3

Per Strip trigger rate: 7.2 Hz (200ns) .072 Hz (20ns)
How many strips: 7300

So, for 20ns Gate: 500 Hz; for 200 ns gate 50kHz

non bend trigger? strips 6% ea-h => 2 eff @ 200ns
SL1, 12% SL2, 13% 1.3×10^{-3}
→ 60 Hz @ 200ns
1×10^{-6} eff ... = 75×10^{-4} Hz @ 20ns

G. Chapman

HYBRID CALORIMETER