DOSE RESPONSE OF SCR'S

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The purpose of this paper is to present data from a controlled experiment which exposes SCR's to the CTF neutron beam and to relate this data to the expected radiation environment in the Main Ring.

The general question that one wishes to answer is how long SCR's will survive in the Main Ring. Previous measurements used TLD's to monitor the dose received by SCR's in the tunnel. This paper will discuss a more controlled experiment using the CTF neutron beam and a more appropriate and accurate radiation monitor, a metallic foil threshold detector.

Figure 1 shows the energy dependence of the cross sections of interest[1] and in the discussion that follows the energy dependence has been approximated by a rectangular distribution which starts at the energy indicated by arrows on the graphs (n.b. we have assumed the spallation cross sections for copper are the same for neutrons as for protons). It has been noted in the literature[2] that only neutrons above 1 MeV significantly damage semiconductor materials and, hence, all of the cross correlation calculations have used a lower limit of 1 MeV. Since the foils respond to a threshold and the SCR's respond to a threshold, it is our belief that we have an intrinsically better way to monitor the expected radiation damage using foils than with TLD's which respond to thermal neutrons.

EXPERIMENTAL SET-UP

A schematic of the experimental area is shown in Fig. 2. The SCR's were mounted in a polystyrene holder and the radiation monitors were placed immediately upstream (foil packages) and downstream (TLD's) of the SCR's. The absolute dose was known to better than 5%, the spatial uniformity was better than 5%, and the relative uniformity from trial to trial was better than 1%.[3] The expected neutron energy spectrum is indicated in Fig. 3. The experiment consisted of irradiating the SCR's, measuring the forward voltage drop, and removing one of the four radiation monitoring packets. The exposures were 100R, 100R, 300R and 300R resulting in a cumulative dose to the SCR's of 100R, 200R, 500R and 800R.

RESULTS

The TLD results are shown in Fig. 4 and indicate the scatter that made interpretation of the earlier results difficult. Figure 5 indicates the procedure used to extrapolate the total neutron flux, along with the equations used. From a knowledge of the dose and an estimate of the fluence dose conversion factors (Fig. 6) one can calculate the neutron fluence and compare it to the foil activation results. The fluence dose result is 1.4E10 N/CM2 and the foil result using an average sigma of 45 MB and a spectrum correction factor of .776 is 1.15E10 N/CM2. From Fig. 1 one can see that the 45 MB number is somewhat of a guess and, in fact, one could use the dose results to get a better value for the cross section. However, we prefer to use this calculation as a good indication that our results are reasonable.

The dose to fluence plot is shown in Fig. 7 and the important point to note is the linearity of the plot especially as compared to Fig. 4.

The SCR forward voltage drops as a function of dose are shown in Fig. 8. Two of the SCR's are shown in more detail in Figs. 9 and 10. Table I gives a summary of the data including a slope using the first three points along with a slope using all five points. These two slopes are given since Fig. 8 indicates somewhat of a break in slope around 200R. For the remainder of the paper, however, we shall use the average of the five point slopes to estimate the SCR response to radiation.

SCR DOSE RESPONSE IN TUNNEL ESTIMATION

We have presented a description of the SCR response to a known radiation source, and we wish to tie this known response to an estimated tunnel radiation environment in order to have some knowledge of the lifetime of the SCR's in the tunnel.

Figure 3 shows the relative CTF fluxes along with the spectrum inside the tunnel wall[4] (where the SCR's will reside). Figure 11 shows more detail of the tunnel fluxes. We have indicated on Fig. 12 the schematic way in which the total flux (En>1 MeV) passing through an SCR can be estimated from the measured flux using the foil activation technique. Note that the threshold for the foils in the tunnel will be different than for the CTF irradiation foils since we have to use a longer lived isotope for the tunnel monitoring. A very important consideration is that the scaling factor for 400 GeV is 3.405 and for 8 GeV the factor is 3.18. Hence a detailed knowledge of the energy dependence of the losses is not necessary; i.e., at 400 GeV more neutrons are produced but the fraction seen by the foils is roughly the same as at 8 GeV. The tunnel fluxes have been estimated from the tabulated calculations[4] and with the particular assumptions given in Table II. The spectrum and, hence, the predictions given below can easily be scaled for differing assumptions about the nature of the losses. Using the CTF results and various assumed loss patterns, we have the predicted SCR forward voltage changes given in Table III; of course, the total voltage change would be a summation of losses at all energies. A voltage change of 1 volt is the deterioration level at which one would consider replacing SCR's (Tables II and III).

As indicated on Fig. 11, the dose rate on the inside of the tunnel is expected to be less than the outside by a factor of two. Since Table III indicates that we are in the situation where we could lose SCR's, thought should be given to placing the SCR's on the inside of the tunnel

ACKNOWLEDGEMENT

We wish to thank the CTF staff for their assistance in performing the irradiations.

REFERENCES

1. H.R.Heydesser, C.K.Garret and A.VanGinneken, Thin Target Cross Sections, Physical Review 6, 1235 (1972).

2. S. Battisti, et al., Radiation Damage to Electronic Components, Nuclear Instrument & Methods 136, 451 (1976).

3. R.Ten Haken, private communication.

4. Keran O'Brien, Neutron Spectra in the Side-Shielding of a Large Particle Accelerator, HASL 240, January 1971.

TABLE I

						$\frac{\Delta(\text{Vf [volts]})}{\Delta(\text{FLUENCE } [10^{10}/\text{cm}^2])}$	
Fluence (10^{10} n/cm^2) E_n>1 MeV	0	1.15	2.30	5.73	9.33	3 pts	5 pts
Dose (Rads)	0	100	200	500	800		
				Vf @ 2 kV			
SCR Number							
1202	1.373	1.417	1.475	1.680	1.901	.0445	.0578
1203	1.208	1.235	1.262	1.368	1.482	.0233	.0299
1207	1.477	1.559	1.642	1.918	2.214	.0715	.0794
1234	1.428	1.571	1.606	1.755	1.936	.0773	.0503

<>=.0543

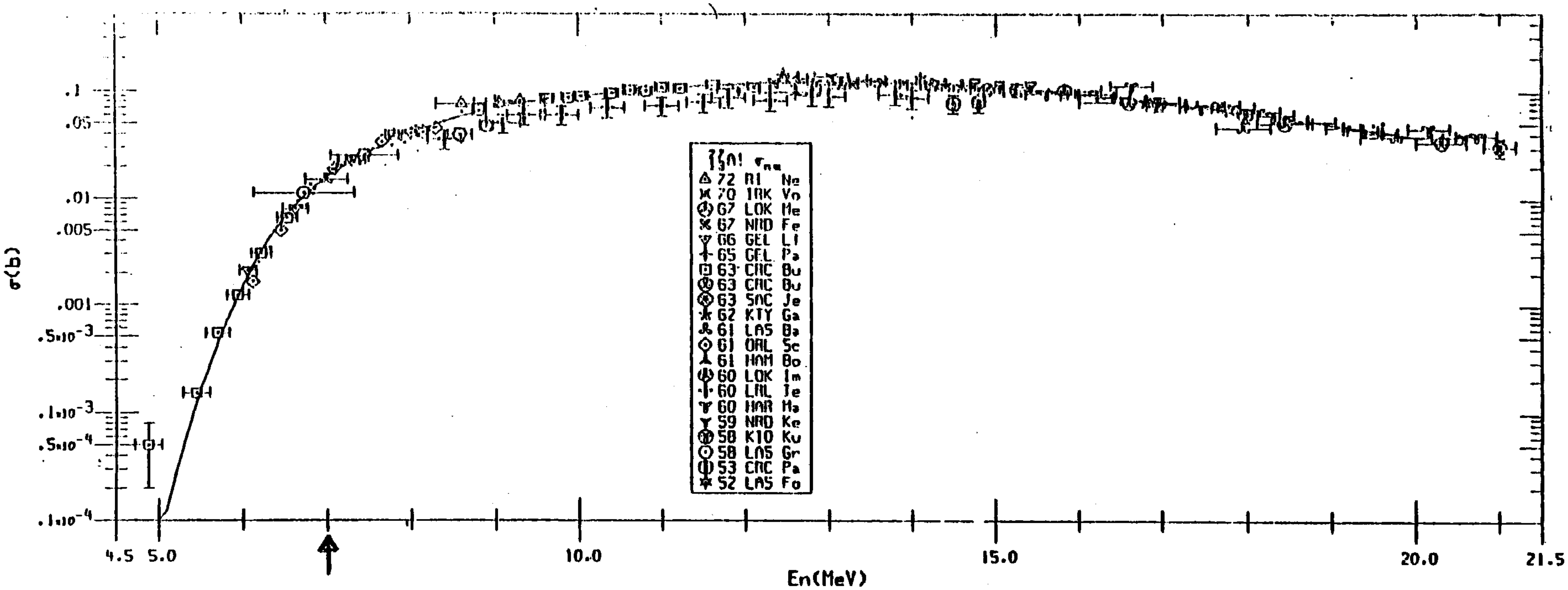
TABLE II

TUNNEL LOSS PARAMETERS FOR FIGURE 12

Energy of lost protons	8 GeV, 400 GeV
Distance into wall	200 g/cm^2
Cycle time	10 sec
Loss (assumed uniform)	1%
Intensity	2.5×10^{13}
Main Ring Radius	1000m

TABLE III

Time in Tunnel	Condition	Change in Forward Voltage Drop
1 year	10% loss of 8 GeV beam	.2V
1 year	1% loss of 400 GeV beam	1.0V


σ(b)
En(MeV)
4.5 5.0 10.0 15.0 20.0 21.5
.1 .05 .01 .005 .001 .5x10^-3 .1x10^-3 .5x10^-4 .1x10^-4
72 RI Ne
70 IRK Vo
67 LOK Me
67 NRD Fe
66 GEL Li
65 GEL Pa
63 CRC Bu
63 CRC Bu
63 SAC Je
62 KTY Ga
61 LAS Ba
61 ORL Sc
61 HAM Bo
60 LOK Im
60 LRL Te
60 HAR Ma
59 NRD Ke
58 KIO Ku
58 LAS Gr
53 CRC Pa
52 LAS Fo

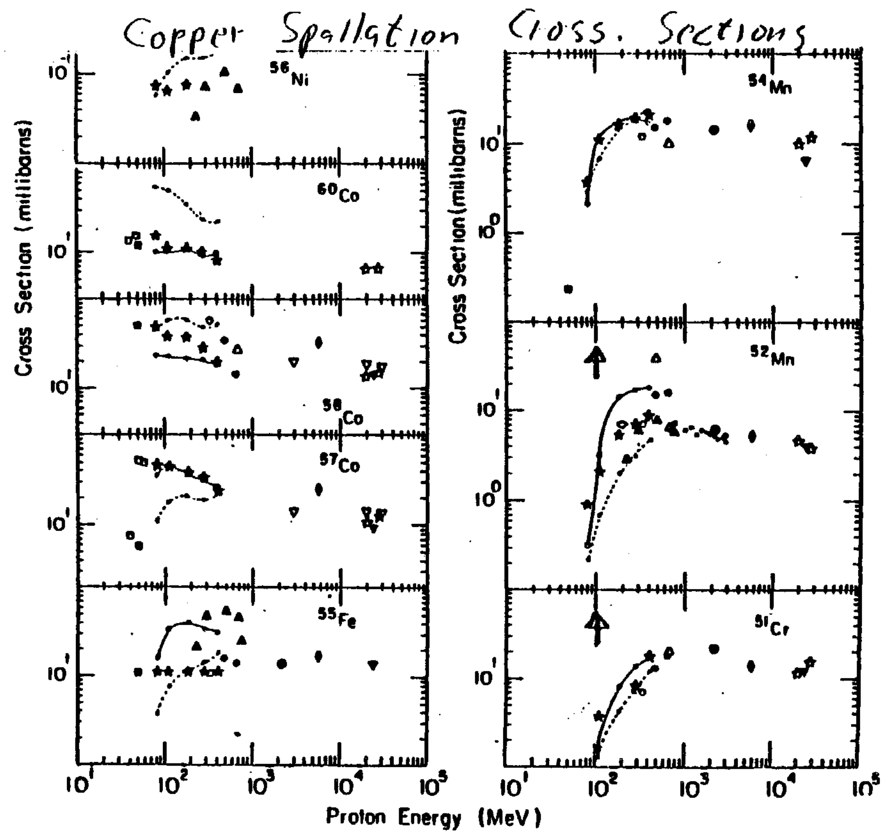

Copper Spallation Cross Sections
Cross Section (millibarns)
Proton Energy (MeV)
56Ni
60Co
58Co
57Co
55Fe
54Mn
52Mn
51Cr

FIGURE 1

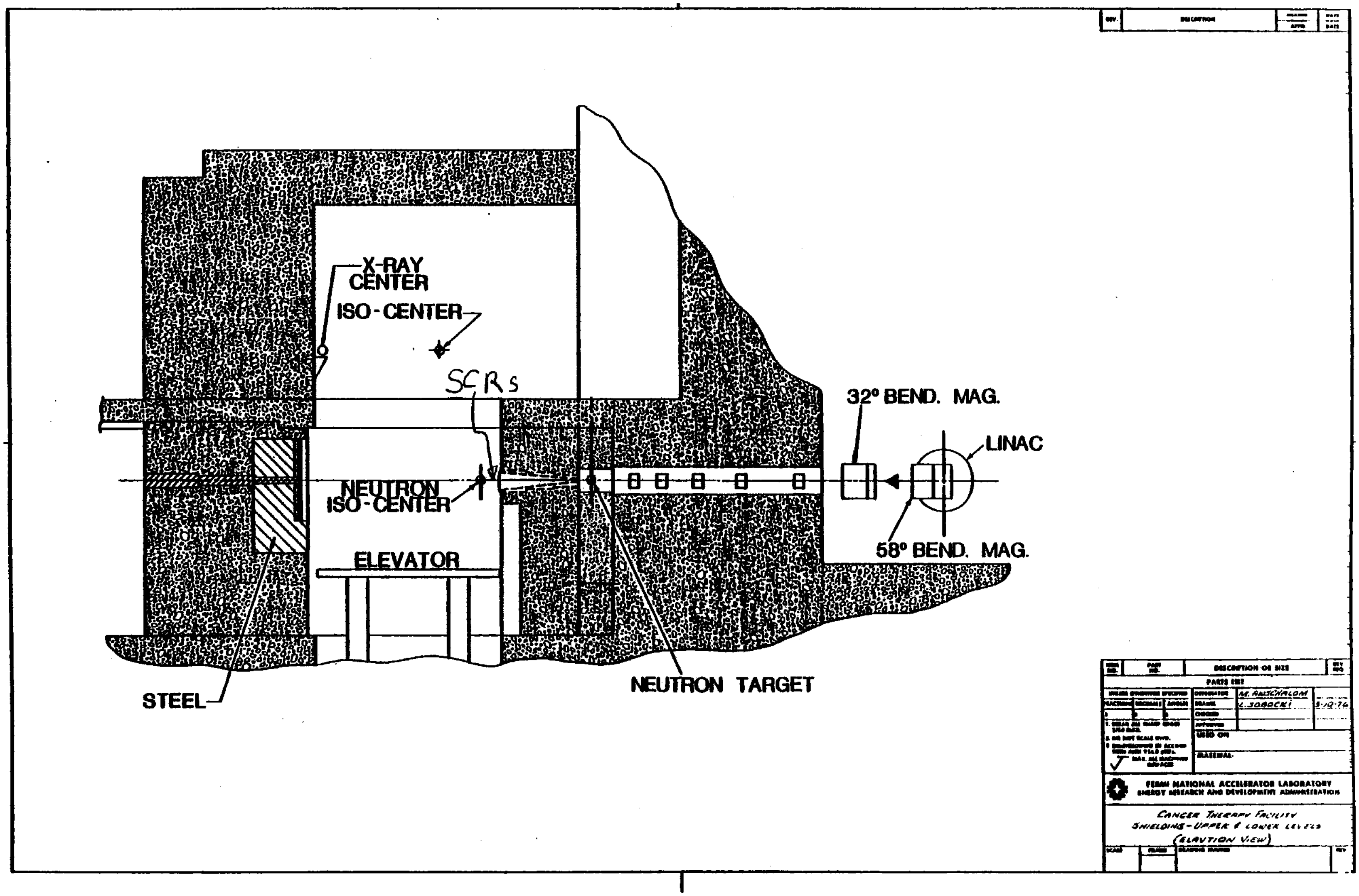
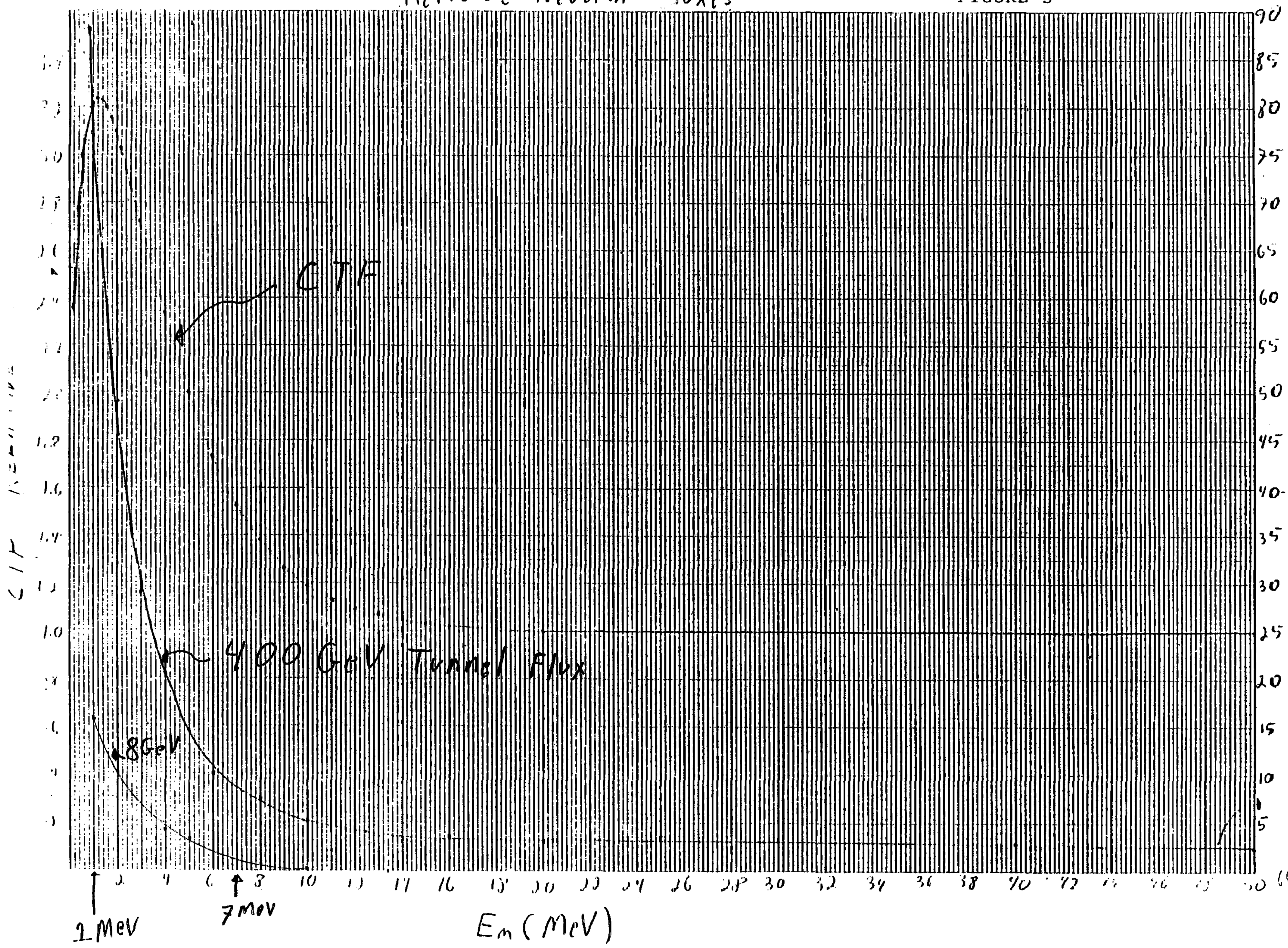

X-RAY CENTER
ISO-CENTER
SCRs
32° BEND. MAG.
LINAC
NEUTRON ISO-CENTER
58° BEND. MAG.
ELEVATOR
STEEL
NEUTRON TARGET
L. SOBOCKI
5-10-74
CANCER THERAPY FACILITY
SHIELDING - UPPER & LOWER LEVELS
(ELAVTION VIEW)

FIGURE 2

Relative Neutron Fluxes FIGURE 3



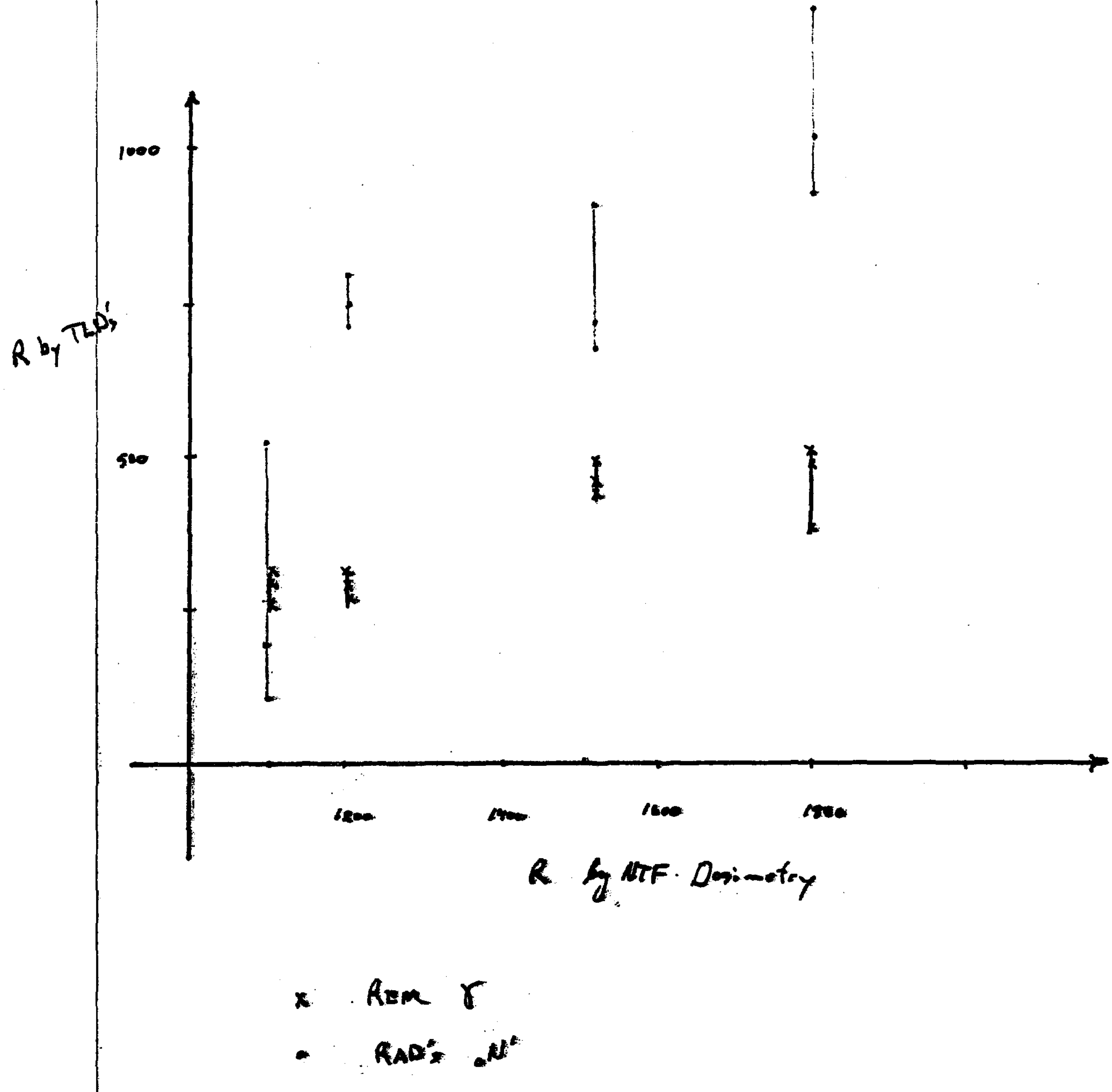
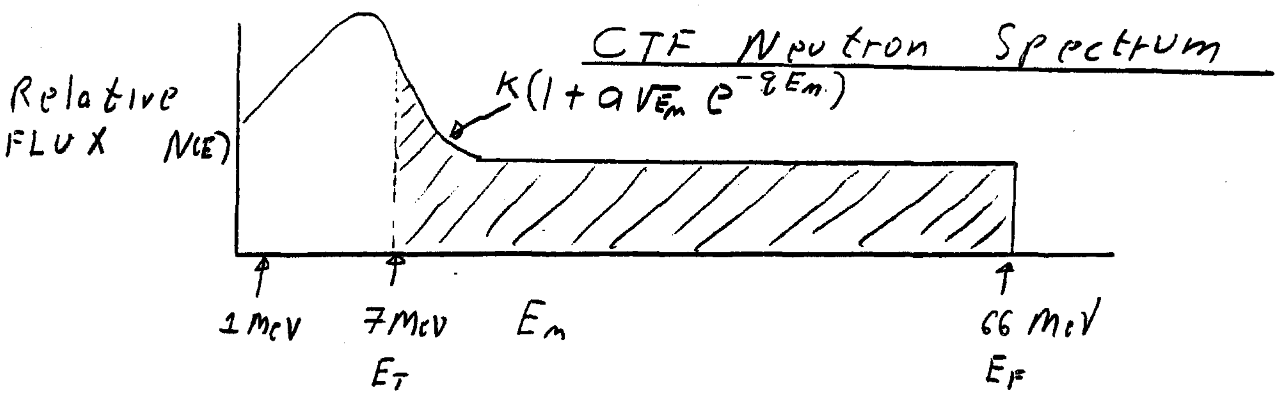


FIG. 4

Fig 5



$$\text{CROSS HATCHED AREA} = \int_{E_T}^{E_F} K(1. + a\sqrt{E}\, e^{-qE})\, dE$$

$$= K\,[E_F - E_T)$$

$$+ \frac{Ka}{q}\left[\sqrt{E_T}\, e^{-qE_T} - \sqrt{E_F}\, e^{-qE_F}\right]$$

$$+ Ka\left[\frac{\sqrt{\pi}}{2q^{3/2}}\right]\left[\Phi(\sqrt{qE_F}) - \Phi(\sqrt{qE_T})\right]$$

$$\Phi(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}\, dt$$

$E_T = 7$
$E_F = 66$
$a = 3.3$
$q = .4$

$$\int_{E_T}^{E_F} N(E)\, dE = 61.4\, K$$

Correction factor for neutrons from 1 MeV

is $$R = \frac{\int_{E_T}^{E_F} N(E)\, dE}{\int_{E=1}^{E_F} N(E)\, dE} = \frac{61.4\,K}{79.2\,K} = .776$$

$$.776^{-1} = 1.29$$

For the dose estimate in the paper we have assumed $\int_{E=1}^{E_F} N(E)\, dE = \int_{E=0}^{E_F} N(E)\, dE$

RADIATION FIELDS

Table 2.IX. Conversion and modifying factors for neutrons.
(The number of significant digits given facilitates convenient numerical interpolation, and does not indicate the accuracy of the recommended factors.)

Neutron energy (MeV)	Conversion factor (n/cm^2 sec/mrem/h)	Modifying factor
2.5×10^{-8}	265	2.3
5×10^{-8}	254	2.2
1×10^{-7}	242	2.0
2×10^{-7}	234	2.0
5×10^{-7}	226	2.0
1×10^{-6}	222	2.0
2×10^{-6}	224	2.0
5×10^{-6}	228	2.0
1×10^{-5}	231	2.0
2×10^{-5}	233	2.0
5×10^{-5}	237	2.0
1×10^{-4}	239	2.0
2×10^{-4}	248	2.0
5×10^{-4}	261	2.0
1×10^{-3}	272	2.0
2×10^{-3}	278	2.0
5×10^{-3}	281	2.0
1×10^{-2}	283	2.0
2×10^{-2}	170	3.3
5×10^{-2}	82	5.7
1×10^{-1}	48	7.4
2×10^{-1}	28	9.2
5×10^{-1}	14	11.0
1×10^{0}	8.5	10.6
2×10^{0}	7.0	9.3
5×10^{0} 5	6.8	7.8
1×10^{1}	6.8	6.8
2×10^{1}	6.5	6.0
5×10^{1} 50	6.1	5.0
1×10^{2}	5.55	4.4
2×10^{2}	5.10	3.8
5×10^{2}	3.60	3.2
1×10^{3}	2.25	2.8
2×10^{3}	1.55	2.6

FIGURE 6.

FIGURE 7

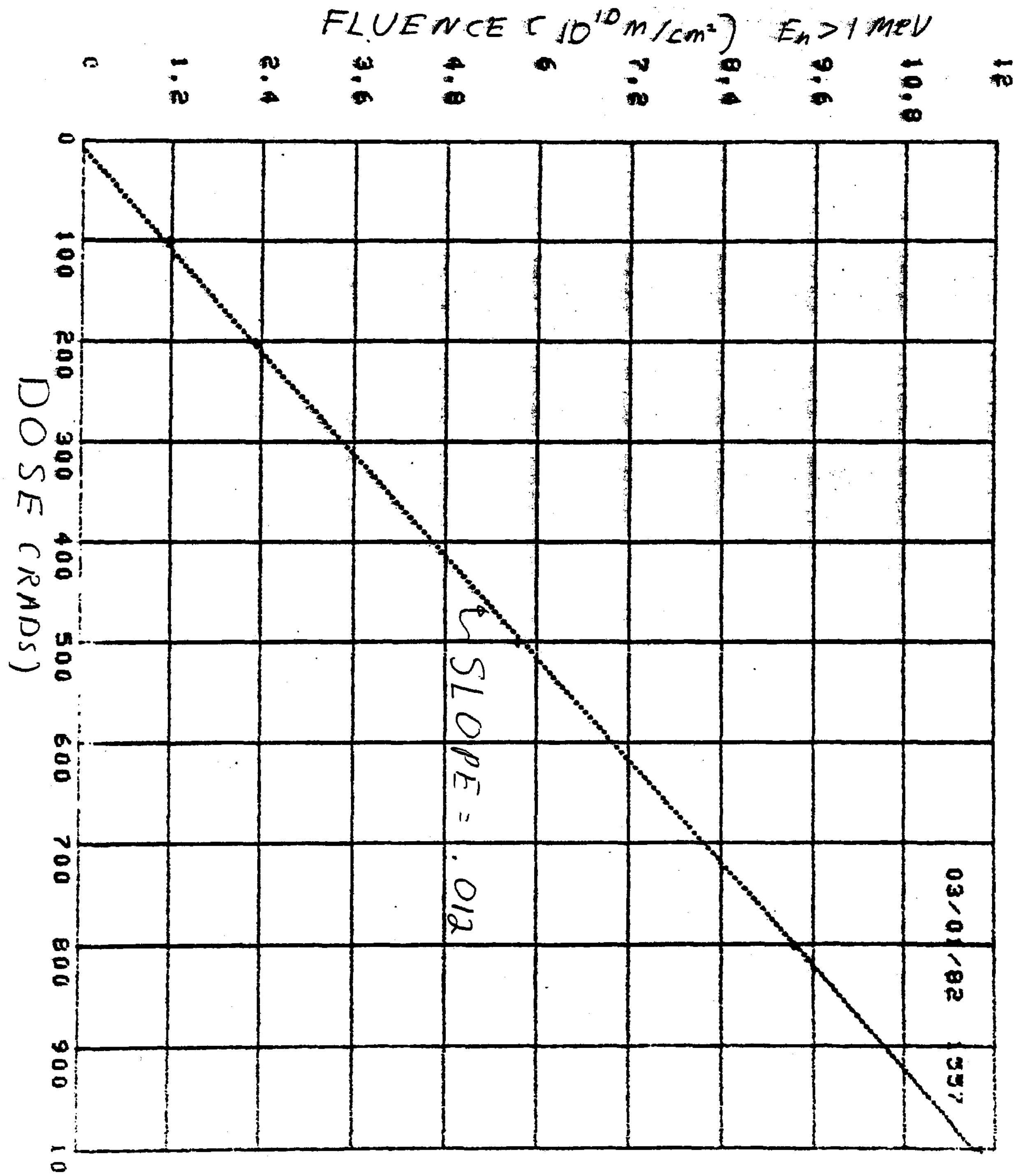
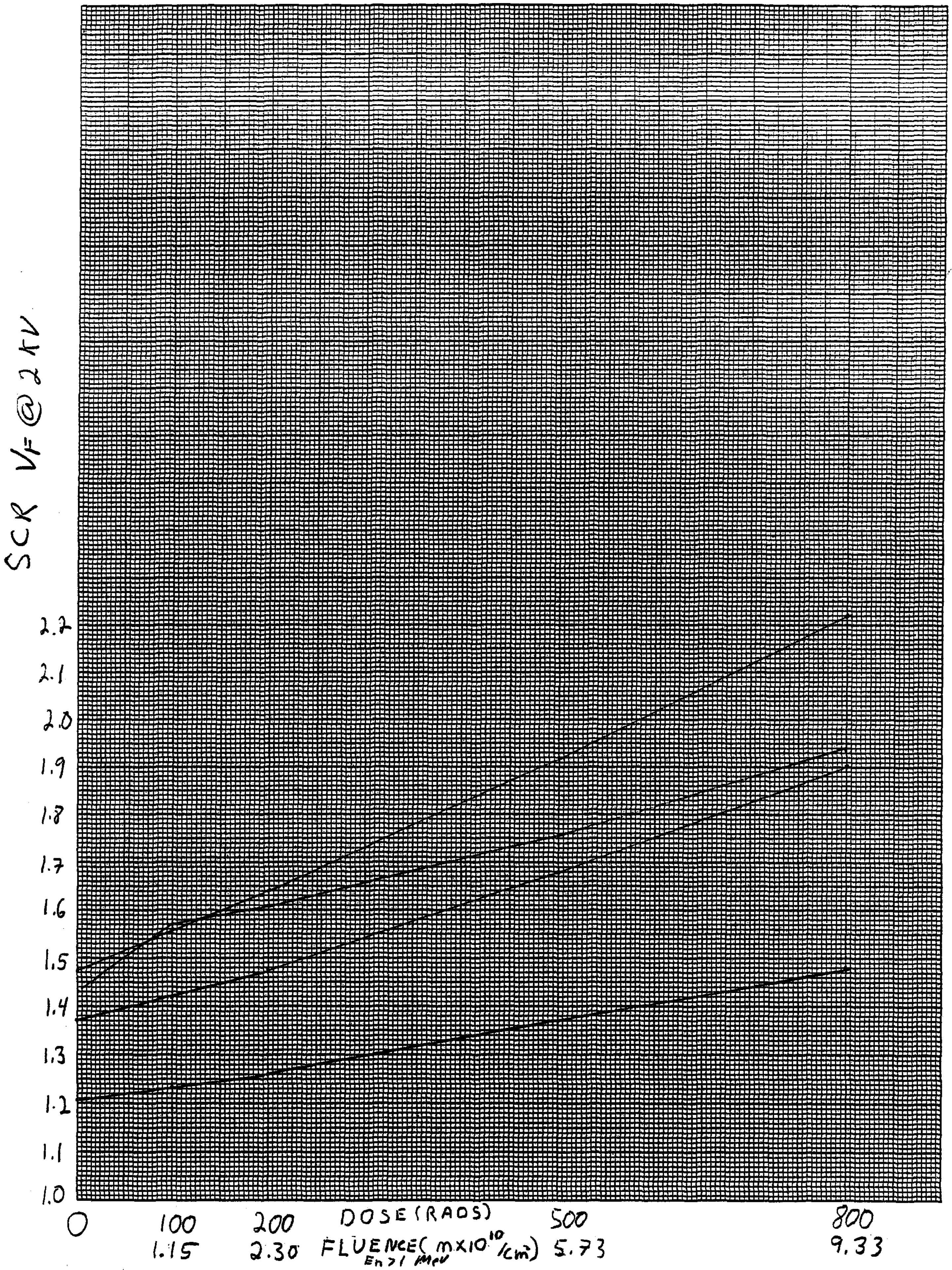

FLUENCE (10^10 n/cm²) En > 1 MeV
0
1.2
2.4
3.6
4.8
6
7.2
8.4
9.6
10.8
12
DOSE (RADS)
0
100
200
300
400
500
600
700
800
900
10
SLOPE = .012
03/01/82
357

FIGURE 8


SCR V_F @ 2 kV
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
100
200
DOSE (RADS)
500
800
1.15
2.30
FLUENCE (n x 10^{10}/cm²) E_n > 1 MeV
5.73
9.33

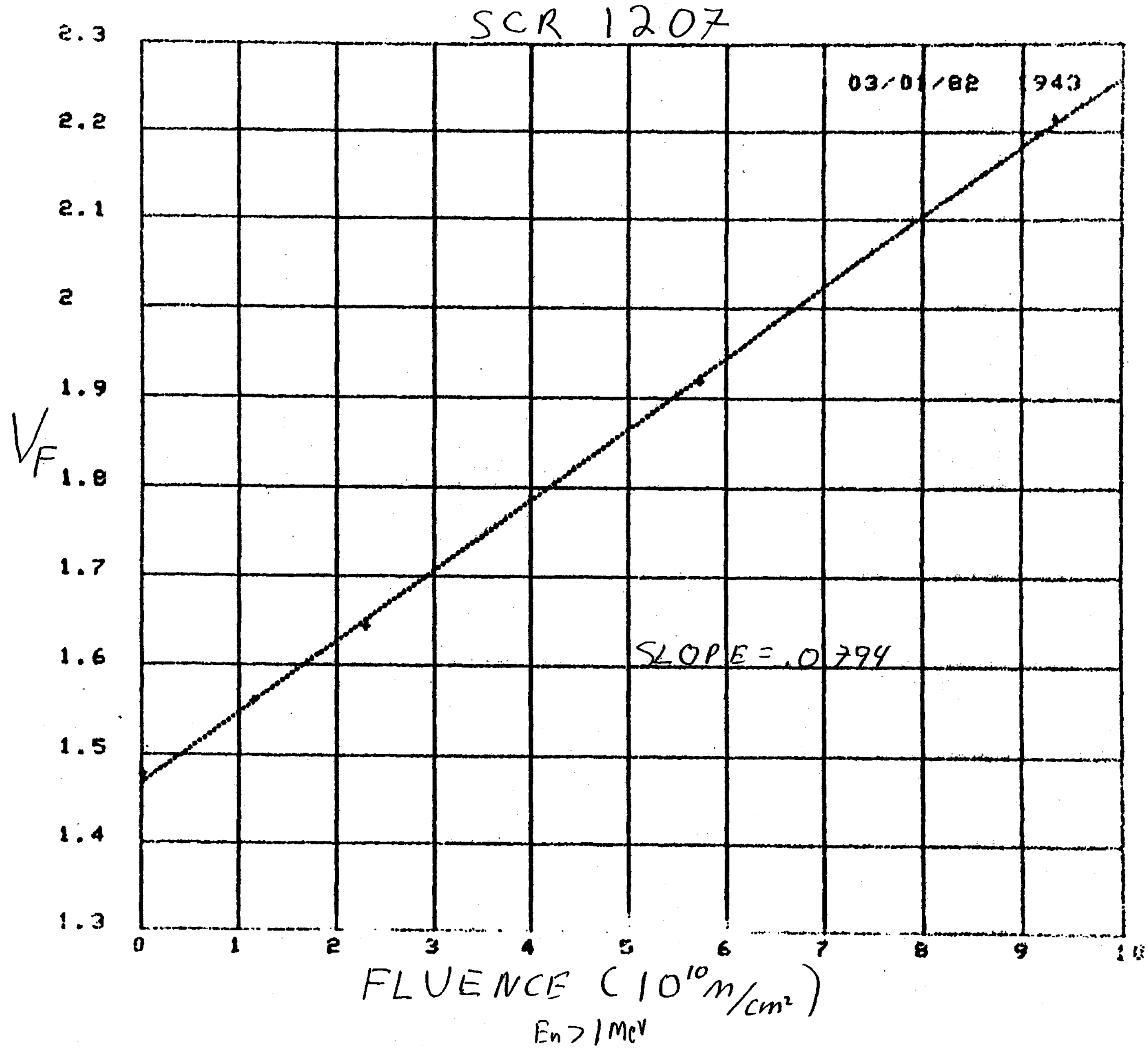

SCR 1207
03/01/82 1943
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
V_F
SLOPE = .0794
0
1
2
3
4
5
6
7
8
9
10
FLUENCE (10^{10} n/cm²)
En > 1 MeV

FIGURE 9

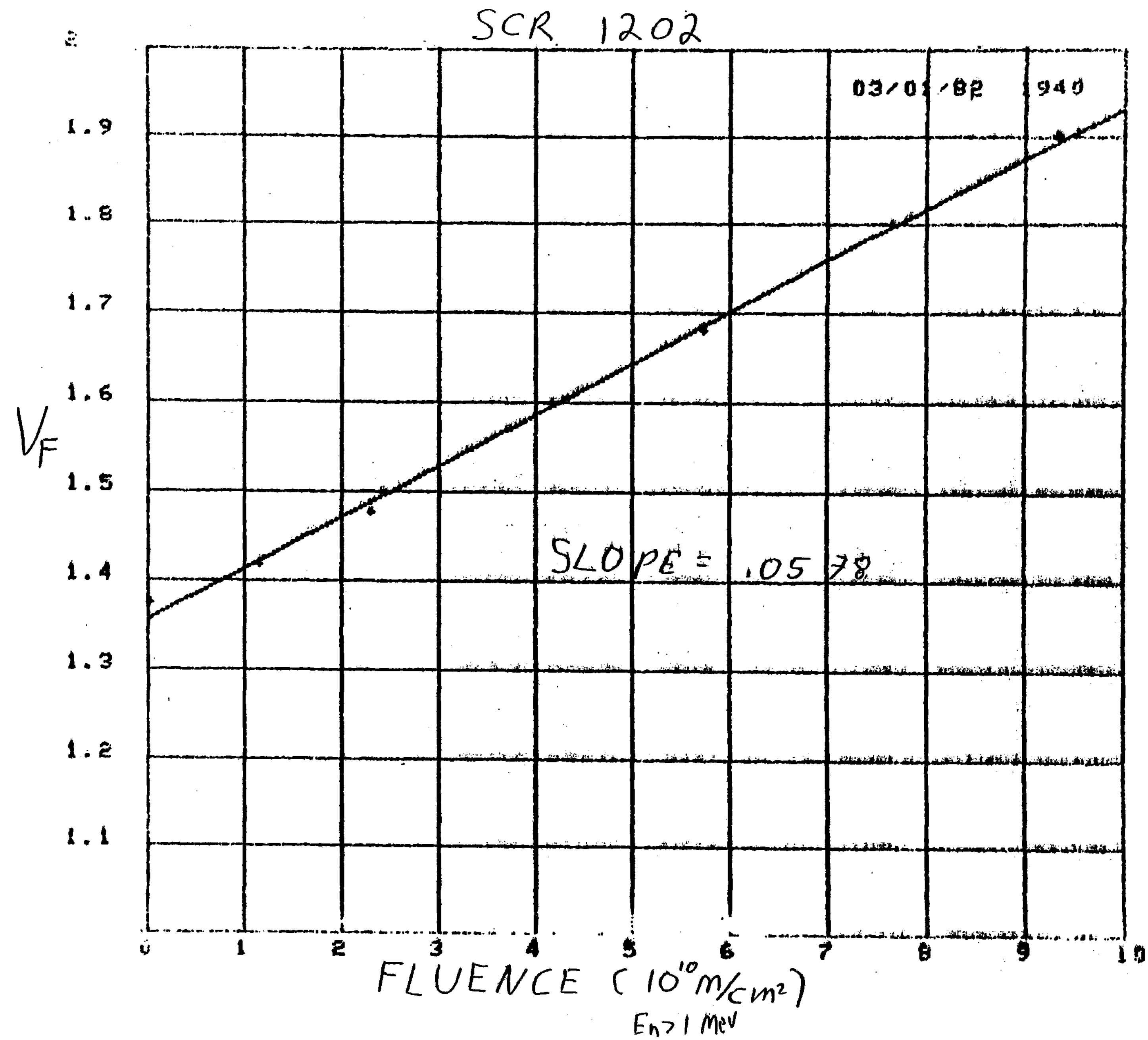

SCR 1202
1940
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
VF
SLOPE = .0578
0
1
2
3
4
5
6
7
8
9
10
FLUENCE (10¹⁰ n/cm²)
En>1 MeV

FIGURE 10

ESTIMATED ₀N' FLUX @ 200 gm/cm² into Shielding for 8 GEV + 400 GEV in Radially outward or Radially inward walls.

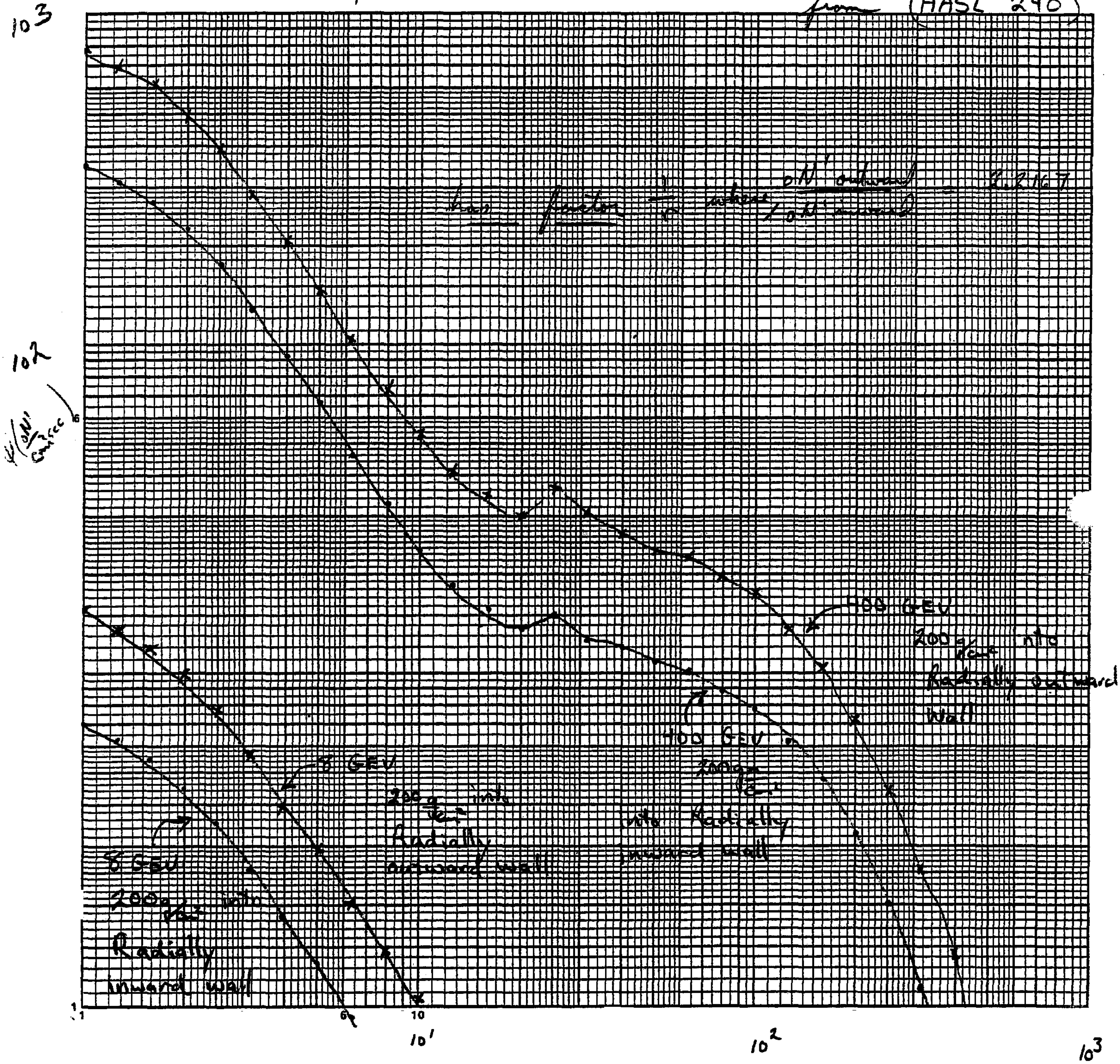
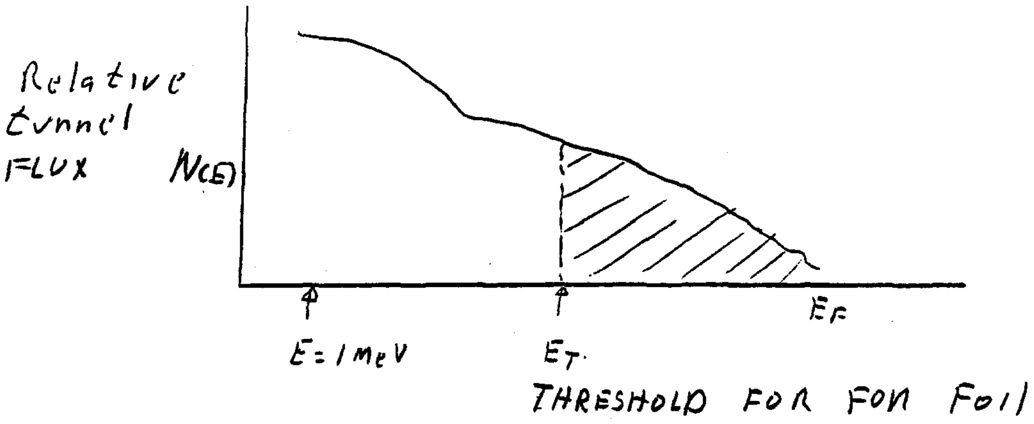


FIG 11

En (Mev)

assumed uniform losses of 1% of 2.5E13 around entire ring

Tunnel Foil Correction Factor Fig 12



Correction factor is obtained by numerically integrating the area under the curve.

$$R = \text{Correction factor} = \frac{\int_{E_T}^{E_F} N(E)\,dE}{\int_{E=1}^{E_F} N(E)\,dE}$$

$$R\Big|_{400G\ \text{losses}} = .294 \qquad .294^{-1} = 3.405$$

$$R\Big|_{8GeV\ \text{losses}} = .314 \qquad .314^{-1} = 3.18$$