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RADIATION DAMAGES on MAGNET COILS of the 350 GeV/c DICHROMATIC TRAIN

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I. Introduction

In the recent TM report[1] we analyzed thermal stress problems caused by the beam in the magnet absorbers of the 350 GeV/c Dichromatic Train. In this report various aspects of radiation damage on magnet coil insulator caused by beam dumping in the magnet beam absorbers will be discussed.

II. Radiation Dose

The most vulnerable components of a magnet in which the primary proton beam is dumped are insulator layers between copper conductors and the aluminum absorber.[2] The energy density distribution of cascade showers in the copper conductor decreases rapidly in the radial direction. Therefore, inner layers between the copper conductors absorb less radiation. Since the back scattering from the copper conductor is negligible and also since the insulator layer is thin compared to the size of the cascade showers, the radiation absorbed in the coil insulator adjacent to the aluminum absorber can be approximated by the radiation absorbed in aluminum located at the same radial distance from the shower center as the insulator.

The CASIM program by Van Ginneken[3] was used to calculate the radiation doses absorbed in aluminum for two cases. In the first case, the primary beam strikes an aluminum absorber directly. In the second case, an aluminum target of one interaction length precedes an aluminum absorber at the distance of

600 cm. The second case corresponds to the Q2 absorber which is the closest magnet beam dump to the target in the present plan. Figures 1 and 2 show computed equi-dose curves as functions of the absorber depth, Z, and the radial distance from the primary beam direction, R. The incident proton energy is 400 GeV and the integrated number of protons is 10^{18}. The maximum radiation dose as a function of the radial distance is shown in Figure 3 for the two cases under the same conditions as in the previous figures.

We assume that the absorber is in the magnetic field free space and that there is no magnet between the target and the absorber in the second case. Contrary to the case of the quasi-static thermal stress, the radiation damage of interest takes place outside the shower peak area. Therefore, the effect due to the target is small and is about 30%. It is not obvious how the magnetic field changes the present estimate, but it would not seem to be significant.

From the curves shown in Figure 3, we can estimate how many protons can be dumped in the magnet absorber before the magnet fails due to the radiation damage <u>if</u> we know the level of radiation that would cause magnet failures. As expected, the radial distance is the most critical parameter.

Table I summarizes beam dump magnets, coils nearest to the dump spots, minimum radial distances to the coils from the shower center, and other parameters for various tunes of the Dichromatic Train at 400 GeV.[4] ε is the ratio of the tune momentum to the momentum of the primary proton. The dump magnets, coils nearest to the dump spot and minimum radial distances to the coils are dependent only on ε and independent of the primary proton energy. Radiation doses absorbed by the coils nearest to the dump spots per proton and numbers of incident protons corresponding to the radiation dose of 10^{11} Rads are given in columns 6 and 7, respectively, at 400 GeV. Tunes for $\varepsilon>0.7$ cannot be run in the present dump arrangement.

III. Strength of Coil Insulator Against Radiation Damage

An extensive radiation damage test on epoxies for coil insulation was performed and reported by E.Laukant[5] to determine radiation resistent epoxy systems for the Main Ring magnets. The epoxy formulation for Main Ring-type magnets consists mainly of DER 332 resin, MNA(Methyl Nadic Anhydride), alumina and glass beads.[6] The test results for the DER 332-MNA combination are shown in Figure 4.[5] Magnets for the 350 GeV/c Dichromatic Train were made of Main Ring type. Although it is difficult to determine at what radiation dose level a magnet fails due to radiation damage on the epoxy, substantial strength seems to be still maintained after absorbing a dose of 10^{11}Rads. No adequate data are available about magnet failures due to radiation damages.

We estimate the integrated radiation dose absorbed in the upstream coil end of the OWT magnet (EPB dipole) of the Sign Selected Bare Target(SSBT) train as a function of the distance from the beam center line. The CASIM program was used. The total number of protons used in the last run was 3.7×10^{18}at 400 GeV. The epoxy formulation for the EPB dipole magnets is essentially the same as for the Main Ring magnets.[7] Figure 5 shows the schematic diagram of the upstream end of the SSBT train and the computed radiation dose. An aluminum target of one interaction length and a cylindrical iron collimator with a 1.4 cm radius hole were used for simplicity of computation. This result should be applied only for the upstream end of the coils which follow directly after the collimator. The crude scraping test indicated the insulator material is still solid.[8] The distance from the beam to the top and bottom coils is 1.8 cm. Therefore, some sections of the coils absorbed radiation at the level of 10^{11}Rads.

IV. Conclusions

The severest radiation damage appears downstream about 1 m from the upstream end of the dump magnet and is essentially localized within 50 cm. The mechanical stress on the coil due to current excitation of the magnet should be modest in this area. The electrical potential between the coils and the ground will be less than 100 volts for all the magnets. Some of the critical magnets can be operated near the ground level by power supply arrangements.

Many questions concerning the radiation damage and magnet failure still remain unanswered. However, if the magnet coil can stand a radiation dose of 10^{11}Rads, the 350 GeV/c Dichromatic Train can run at least for 3×10^{18} protons at 400 GeV for each dump magnet as was originally designed. The bottom coil of the Q2 magnet will be used for all the tunes of $\varepsilon<-0.3$ and will be the most critical magnet with regard to the radiation damage.

Finally, it should be reemphasized that the radiation damage on magnet coils is one of the most limiting factors to the Train. A rational and carefully planned run is most desirable for success of the Train.

References

1. S. Mori and H. Stredde, Magnet Beam Absorbers of the 350 GeV/c Dichromatic Train, TM-761, January 1978.
2. The arrangement of the aluminum beam absorbers are briefly described in Ref. 1.
3. The CASIM program has been modified for the present application by Van Ginneken.
4. The final dump configurations were optimized by D. Edwards.
5. E. Laukant, Radiation Damage Test on Epoxies for Coil Insulator, EN-110, July 1969.
6. F. Kleber, private communication.
7. J. O'Meara, private communication.
8. The test was made by F. Gardener and S. Mori.

Tunes for 400 GeV Protons (GeV/c)	ε	Dump Magnet	Coil Nearest to Dump Spot	Minimum Radial Distance (cm)	Radiation Dose per Proton (Rads)	Number of Protons Corresponding to 10^{11} Rads
80	0.2	D2	West	5.8	7.4×10^{-9}	1.4×10^{19}
120	0.3	D2	West	6.1	6.1×10^{-9}	1.6×10^{19}
160	0.4	D2	East	6.3	5.4×10^{-9}	1.9×10^{19}
200	0.5	D2	East	6.0	6.5×10^{-9}	1.5×10^{19}
240	0.6	Q4	Bottom	3.7	2.6×10^{-8}	3.8×10^{18}
280	0.7	Q4	Bottom	4.0	2.2×10^{-8}	4.6×10^{18}
-80	-0.2	D2	West	4.4	1.7×10^{-8}	5.8×10^{18}
-120	-0.3	Q2	Bottom	3.7	2.6×10^{-8}	3.8×10^{18}
-160	-0.4	Q2	Bottom	3.6	2.8×10^{-8}	3.6×10^{18}
-200	-0.5	Q2	Bottom	3.5	2.9×10^{-8}	3.4×10^{18}
-240	-0.6	Q2	Bottom	3.4	3.1×10^{-8}	3.2×10^{18}
-280	-0.7	Q2	Bottom	3.3	3.3×10^{-8}	3.0×10^{18}

Table I. Tunes for 400 GeV proton beam, the ratio of the tune momentum to the momentum of the primary proton, ε, beam dump magnets, coils nearest to the dump spots, minimum radial distances to the coils from the shower centers, radiation doses per proton, and numbers of protons corresponding to 10^{11} Rads.

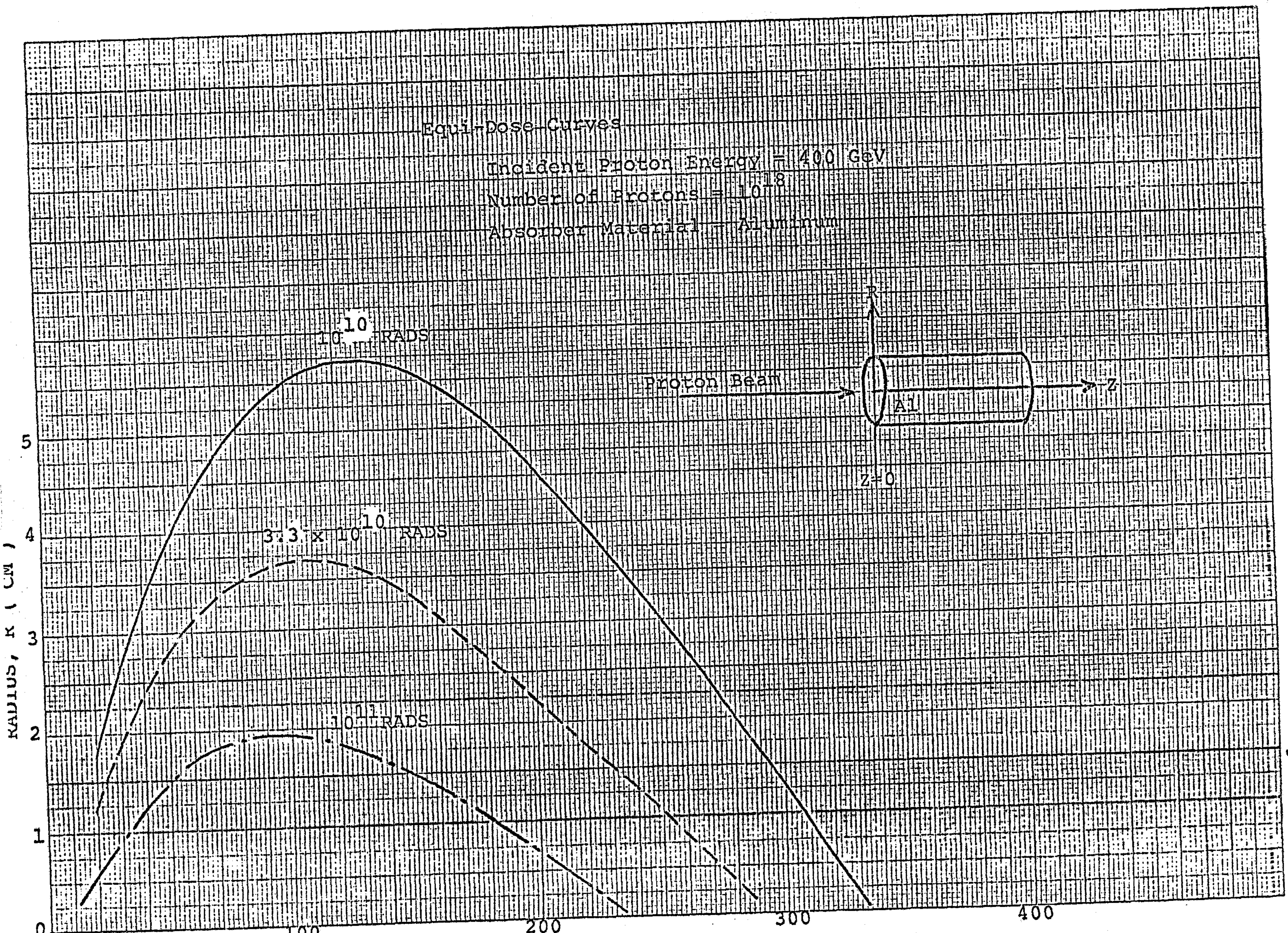
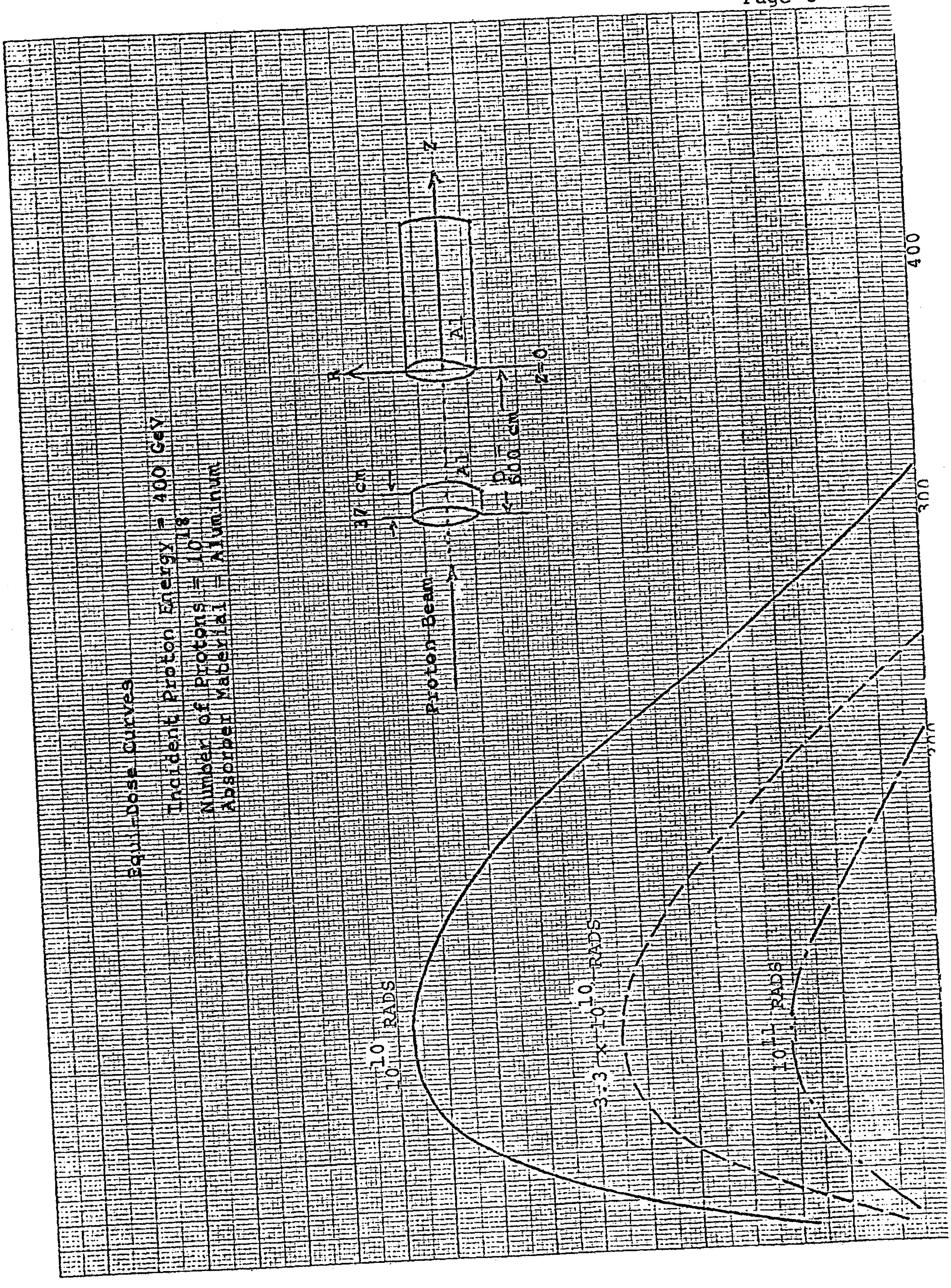

Equi-Dose Curves
Incident Proton Energy = 400 GeV
Number of Protons = 10^{18}
Absorber Material = Aluminum
10^{10} RADS
3.3×10^{10} RADS
10^{11} RADS
Proton Beam
R
Z
Z=0
Al
RADIUS, R (CM)
0
1
2
3
4
5
100
200
300
400

Figure 1


Equi-Dose Curves
Incident Proton Energy = 400 GeV
Number of Protons = 10^{18}
Absorber Material = Aluminum
37 cm
Al
D = 600 cm
Al
Z=0
R
Z
Proton Beam
10^{10} RADS
3.3×10^{10} RADS
10^{11} RADS
400
300
200

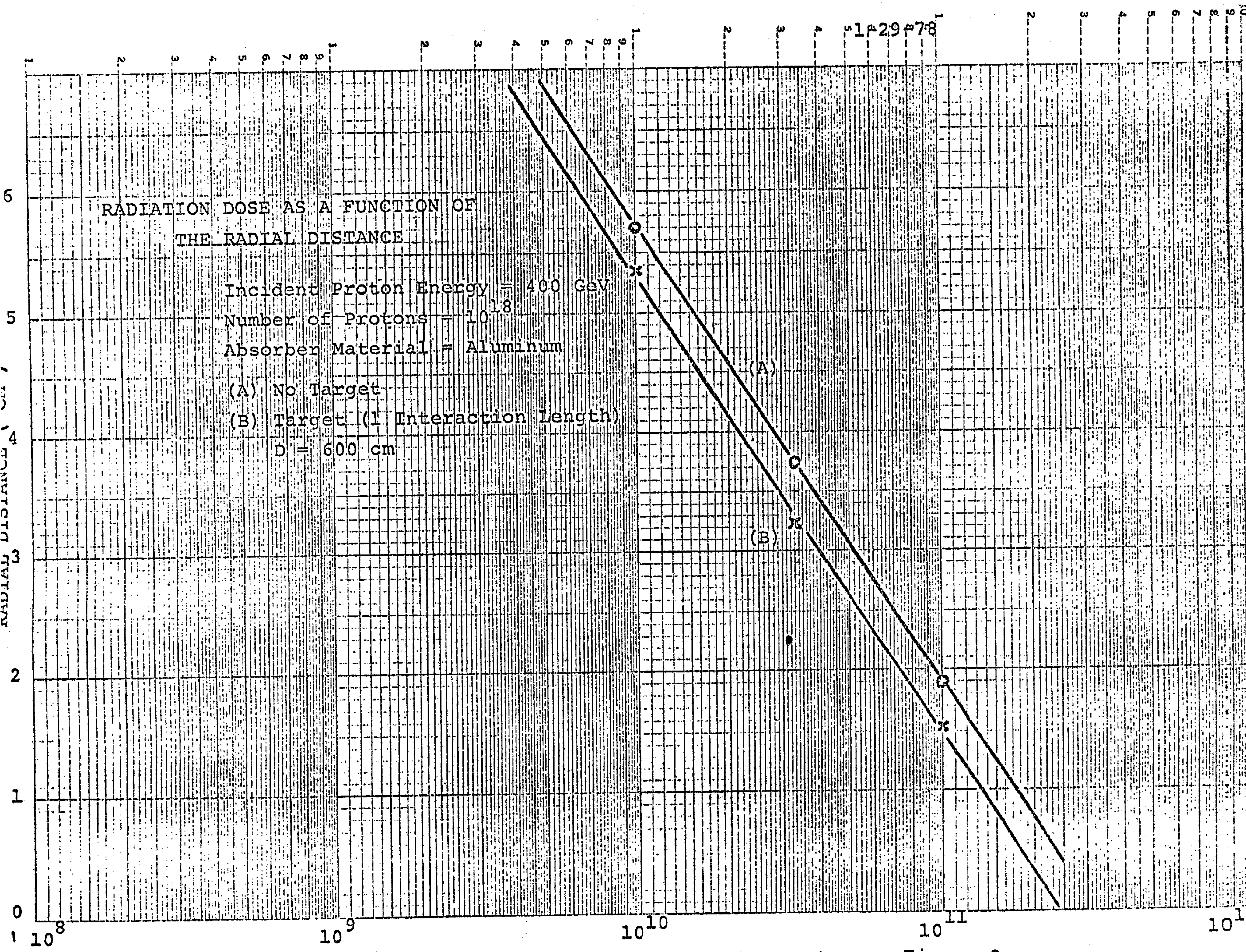

RADIATION DOSE AS A FUNCTION OF
THE RADIAL DISTANCE
Incident Proton Energy = 400 GeV
Number of Protons = 10^{18}
Absorber Material = Aluminum
(A) No Target
(B) Target (1 Interaction Length)
D = 600 cm
(A)
(B)
RADIAL DISTANCE (CM)
RADIATION DOSE (RADS)
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
0
1
2
3
4
5
6
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Figure 3.

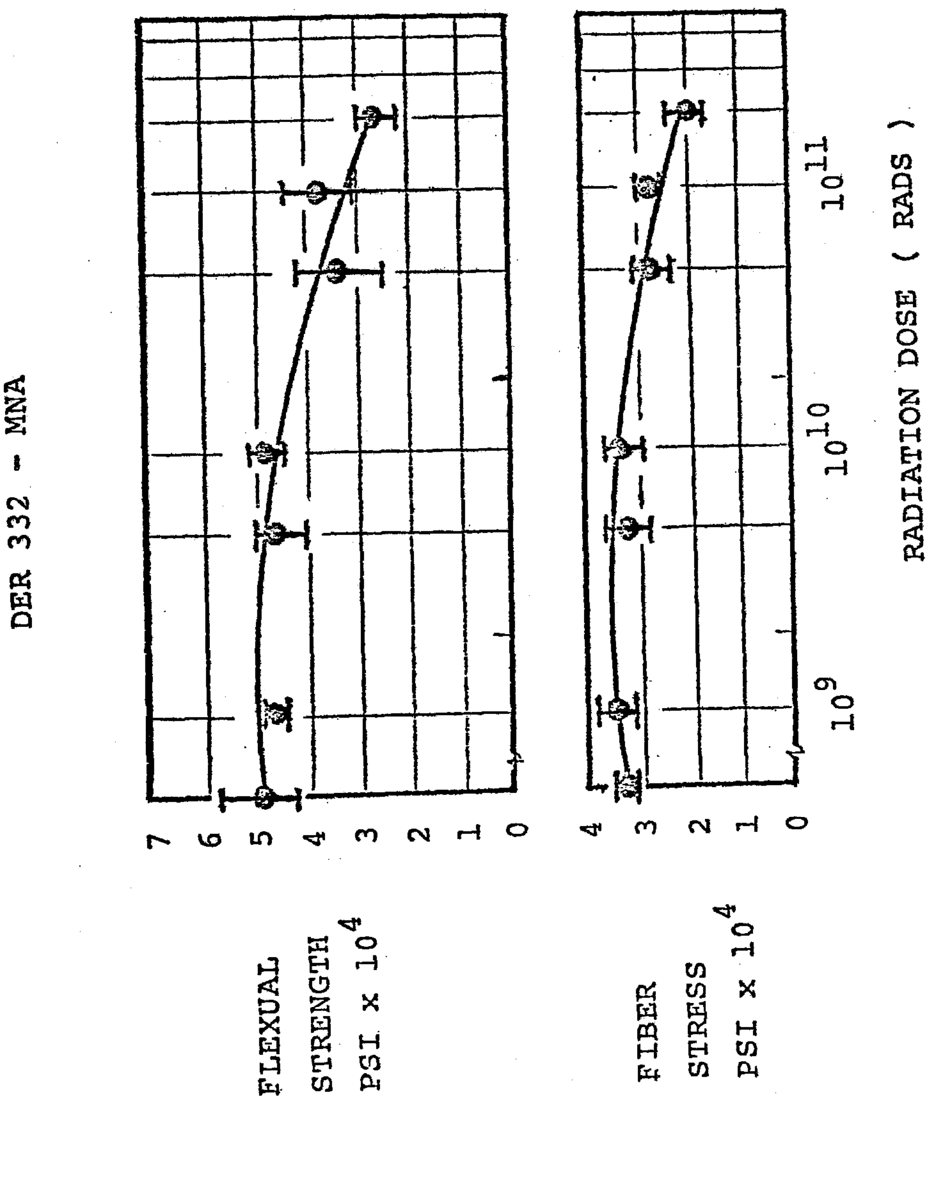
DER 332 - MNA
FLEXUAL
STRENGTH
PSI x 10^4
7
6
5
4
3
2
1
0
FIBER
STRESS
PSI x 10^4
4
3
2
1
0
10^9
10^10
10^11
RADIATION DOSE (RADS)

Figure 4.

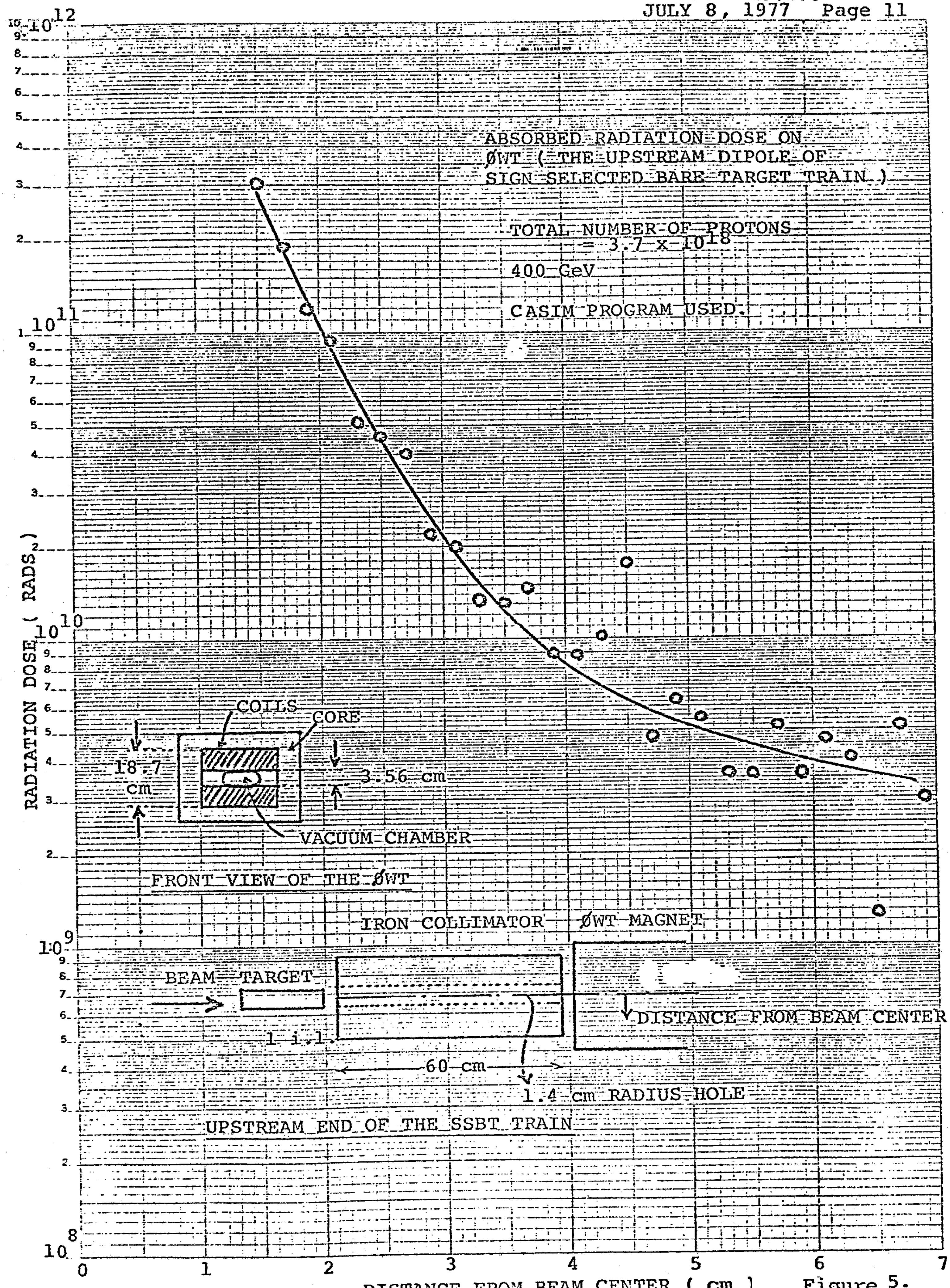
ABSORBED RADIATION DOSE ON ØWT (THE UPSTREAM DIPOLE OF SIGN SELECTED BARE TARGET TRAIN)
TOTAL NUMBER OF PROTONS = 3.7 x 10^18
400 GeV
CASIM PROGRAM USED.
RADIATION DOSE (RADS)
10^12
10^11
10^10
10^9
10^8
COILS
CORE
18.7 cm
3.56 cm
VACUUM CHAMBER
FRONT VIEW OF THE ØWT
IRON COLLIMATOR
ØWT MAGNET
BEAM
TARGET
1 i.l.
DISTANCE FROM BEAM CENTER
60 cm
1.4 cm RADIUS HOLE
UPSTREAM END OF THE SSBT TRAIN
0
1
2
3
4
5
6
7
DISTANCE FROM BEAM CENTER (cm)

Figure 5.