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RADIATION PROTECTION IMPLICATIONS OF THE TRANSPORT OF PRIMARY BEAM TO PW5

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Presently there is a proposal to transport a primary proton beam to the E258 target located in the PW5 experimental hall. The initial proposal is to transport 200 GeV protons from "front porch extraction" with an intensity as large as 1×10^{11} protons per pulse possibly to be increased to 1×10^{12} protons per pulse. As the Proton High Intensity Area is scheduled to be upgraded to 400 GeV, it is quite possible that a 400 GeV proton beam might eventually be transported to PW5. This memo reports on a CASIM[1] calculation designed to establish shielding requirements.

The calculation was done for 400 GeV proton beam incident on the E258 PW5 target, choosing a one interaction length iron target. Because of the scaling with energy, the star density for 200 GeV protons at a given point in space will be approximately one-half that for 400 GeV protons. Figure 1 shows a contour plot of star density superimposed on a schematic drawing of the apparatus. The target is located at coordinates depth = 400 and radius = 0 in the figure. Since the purpose of the calculation was to determine shielding requirements, concrete of density 2.4 gm/cm^3 was placed outside the envelope of the apparatus in a manner which approximates a possible geometry for stacking large concrete blocks. The amount of concrete necessary to shield down to a desired star density can then be determined. As one can see from Fig. 1, the target and dump areas need to be shielded relatively heavy compared to the region near the 5 toroids.

It is important to be able to convert from star density to dose equivalent. From Ref. 1, outside of several feet of concrete there are 9×10^{-6} $rem/star/cm^3$. If one has a 10 sec cycle time, there are then 3.6×10^{12} protons incident per hour at 10^{10} protons per pulse. At this intensity the dose equivalent rate is then 3.2 mrem/hr at a star density of 10^{-10} $stars/cm^3 \cdot proton$.

A location of considerable concern under conditions of high intensity running is the outdoor area on top of the berm. There is only 5 feet of soil plus 1 foot of concrete (approximately equivalent to 5.2 feet of concrete). From Fig. 1 it is seen that approximately 310 cm of concrete (10.2 feet) are required to shield to a star density of 10^{-10}. Thus, if 152 cm (approximately 5 feet) of shielding is installed around the dump in addition to the shielding provided by the berm, dose equivalent rates of 32 mrem/hr would be estimated on top of the berm at 10^{11} protons per pulse. However, the top of the berm is actually 24.5 feet above the center of the dump instead of the 12 feet represented by the concrete. From Fig. 1, it is conservative to consider the source as a line source so that the extra distance reduces the dose equivalent rate to approximately 16 mrem/hr at 10^{11} protons/pulse. To obtain the same dose rate at 10^{12} protons per pulse approximately 2.3 additional feet of concrete would be required. The situation around the target is similar although in practice complicated greatly by the apparatus associated with the hydrogen target. In the geometry which would probably result in practice, the contours in Fig. 1 will spread as a function of depth in any air space between the outer surface of the shielding and the walls or between the iron elements and the shielding.

A possible trouble spot is the penetration from the P4 service building into PW5 which is aligned with the center of the dump. A recent radiation survey on 3/7/79 indicated a dose equivalent rate of about 6 mrem/hr in the P4 service building as the top of this pipe at approximately 10^{9} 200 GeV

π^- per pulse incident on the bare iron beam dump.[2] Five feet of shielding and 10^{11} 400 GeV protons per pulse on target would make the dose equivalent rate in the P4 service building as the top of the penetration became

$$\frac{400}{200} \times 6 \text{ mrem/hr} \times \frac{10^{11}}{10^{9}} \times 10^{-5} \times 30.48/70 = 8.0 \text{ mrem/hr}$$

So that if the 5 feet of shielding is installed around the dump, the penetration can easily be locally shielded for intensities 10^{11} protons per pulse.

Residual dose rates in PW5 outside of the shielding are also of interest. For 30 days of continuous running followed by one day of cooldown, Chapter 12 of the Fermilab Radiation Guide gives the conversion factor for residual dose rate of 2.5×10^{-6} rad $hr^{-1}/(\text{star } cm^{-1} \text{ } sec^{-1})$. Assuming this time structure of beam off and beam on periods to be accurate, outside of 150 cm of concrete the star density per proton is about 2×10^{-8} in the worst place. At 10^{11} protons/pulse, 10 sec cycle time the above conversion gives a residual dose rate of 0.50 mrem/hr. However, in practice, cracks in the shielding may increase such a residual dose rate by large factors.

Soil activation constitutes another possible complication of high intensity primary beam operations in PW5. If the volume between the target and dump and the floor were filled with concrete, and the sides shielded by 5 feet of concrete, the rms distance from the beam line center to the unprotected soil is 170 cm for depths in Fig. 1 less than 900 cm and 253 cm for depths in Fig. 1 greater than 900 cm. The total number of stars produced in the unprotected soil was calculated to be 0.24 stars per incident proton for depth less than 900 cm and 0.15 stars per incident proton for depth greater than 900 cm giving total of 0.39 stars per incident proton. Following the recent calculation of soil activation for the antiproton target,[3] 30 days continuous running at 10^{12} protons per pulse, 10 sec cycle time will produce 1.01×10^{17} stars in the unprotected soil. This implies the production of 7.6×10^{15} atoms (0.38 mCi) of leachable ^{3}H and 2.1×10^{15} atoms (0.47 mCi) of ^{22}Na, the principal radionuclides of interest. These values are approximately 70 per cent of those calculated to be produced annually by the antiproton target (Table 4 of Ref. 3). The result of TM-816 was that the antiproton target annually would produce approximately 61 per cent of the Environmental Protection Administration limits of 20 pCi/mℓ for ^{3}H and 0.2 pCi/mℓ for ^{22}Na based upon the entire radionuclide production entering a well. These concentration limits are based upon a yearly exposure of 4 mrem to an individual user of such a well who drinks 2 liters per day.

This is the exposure limit currently used by the Laboratory for new facilities [4]. The beam in PW-5 is 5 ft. higher in elevation than the antiproton target so that more time may be required for the water to reach the aquifer.

This may reduce the ^{3}H activity somewhat and the ^{22}Na activity substantially by decay if the hydrology is the same at the two locations. It thus appears that running the equivalent of 10^{12} protons for one month per year will not create a ground water problem off site.

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References:

1. A. Van Ginneken and M. Awschalom, High Energy Particle Interactions in Large Targets, Fermilab.

2. D. Grobe, memo to T. Murphy, March 7, 1979.

3. P. J. Gollon, Fermilab TM-816, Sep. 14, 1978.

4. A. L. Read, Memo to Division/Department Heads, April 5, 1979.

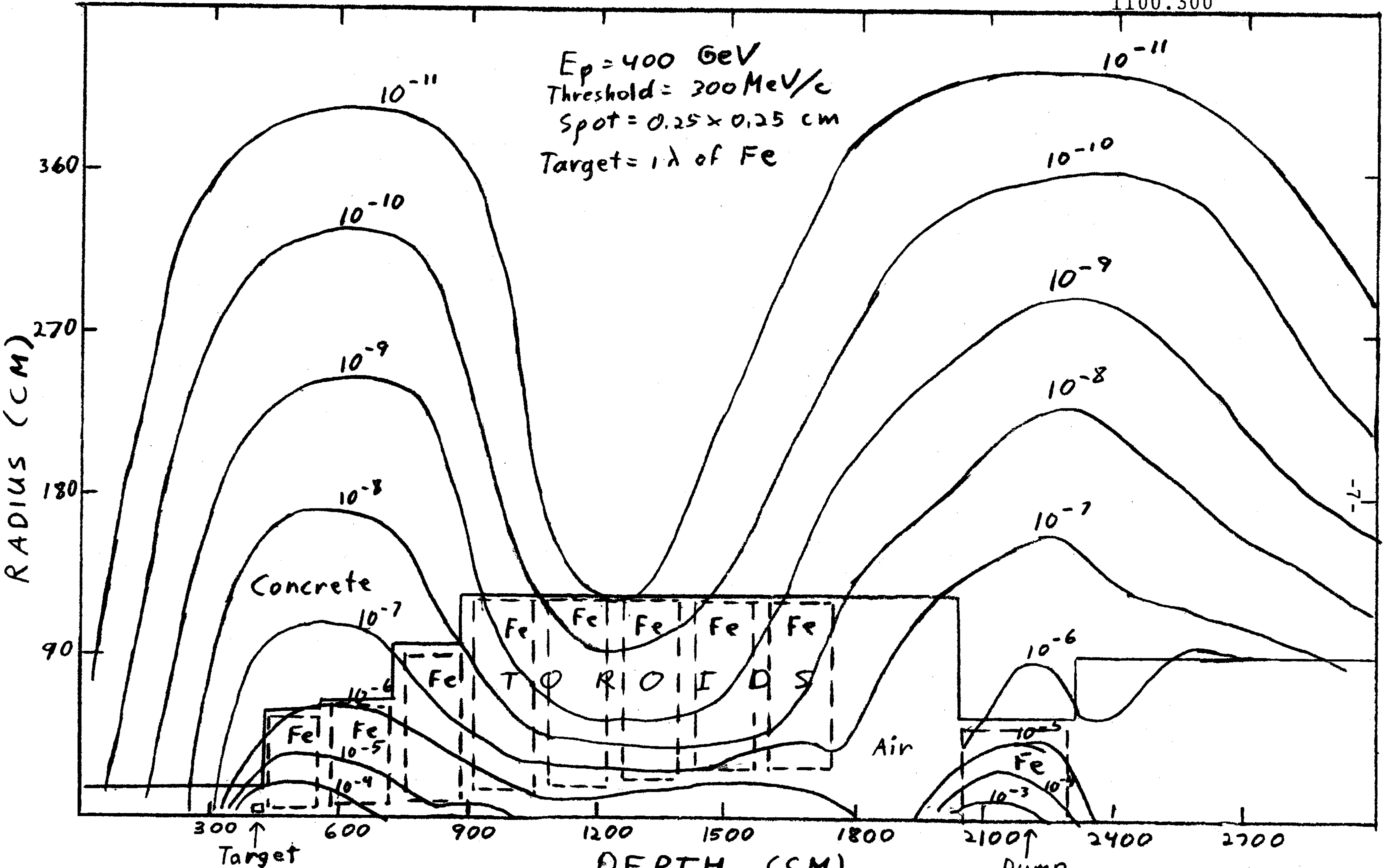

Fig.1 Contour Plot of Star Density (stars/cm³·proton). The blocks labeled Fe denote the configuration of equipment. Concrete is assumed present at radii greater than that indicated by the solid line.