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COMPARISON OF CASIM PREDICTIONS WITH RECENT MEASUREMENTS

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DECEMBER 1, 1979

The Monte-Carlo code CASIM[1] is used at Fermilab to predict dose equivalent rates to be expected outside of relatively thick concrete, or soil, shields. Since shielding is expensive it is imperative for the Laboratory to be able to accurately predict shielding requirements. This note represents an attempt to compare such predictions with some recent measurements of dose equivalent rates.

In the spring of 1979 protons at 200 GeV and negative pions at 200 and 300 GeV were transported to the Experiment #258 target and dumped on a dump roughly centered in the PW 5 hall. This target and dump were studied in TM 877[2] and it was determined that area above the dump constituted the most serious loss point of these two. Another loss point is presented by the string of bending magnets (EPB dipoles) then installed in the part of PW 5 upstream of the target. Both of these cases lend themselves to comparison with CASIM calculations and will be discussed in succession below.

First consider the area above the dump. As actually operated, the dump (33" x 33" x 8') was shielded on all sides by 90 cm of concrete extending the length of the dump in addition to soil equivalent to 150 cm of concrete above PW 5. The dump modeled in the calculation of Ref.2 was given a radius of 50 cm as compared with the 42 cm represented by the actual dump. Hence, all star densities taken from Ref. 2 for radii greater than 50 cm need to be increased by a factor of approximately $\exp(8/\lambda_1) \cdot \exp(-8/\lambda_2)$ where $\lambda_1 = 10.2$ cm and $\lambda_2 = 26.2$ cm (the collision lengths of Fe and concrete). This factor has the value of 1.6.

In Ref. 2 neglecting the distance between the top of the dump and the ceiling it may be seen that a total of 240 cm of concrete above the dump results in a star density of 2×10^{-9} stars/ (cm^3 · incident proton) for 400 GeV protons which scales 1.5×10^{-9} at 300 GeV. In Ref. 2 the calculation was done with the shielding placed directly on top of the dump so that 240 cm of such shielding implied a radial distance from the loss point of 280 cm. In practice, because of the large gap between the top of the dump and the ceiling of the PW 5 pit, the top of the berm is 746 cm radially from the loss point. The dump is, at large radii, almost a point source so the star density scales to $1.5 \times 10^{-9} \times (280/746)^2 = 2.1 \times 10^{-10}$ stars/ (cm^3 · proton). Applying the correction on p 1, the star density becomes 3.4×10^{-10} stars/ (cm^3 · proton). Applying the appropriate dose equivalent conversion (9×10^{-6} rem·cm^3/star), at an intensity of 10^{12} protons per pulse one obtains a predicted dose equivalent rate ($\dot{H}_{calc}$) of:

$\dot{H}_{calc} = 10^{12}$ proton/pulse $\times 9 \times 10^{-6}$ rem cm^3/star $\times 3.4 \times 10^{-10}$ star cm^{-3}/proton

$$\dot{H}_{calc} = 3.1 \text{ mrem/pulse (point source)}$$

If the source is considered instead to be a line source, then;

$$\dot{H}_{calc} = 8.2 \text{ mrem/pulse}$$

so that between these limiting cases:

$$3.1 < \dot{H}_{calc} < 8.2 \text{ mrem/pulse}$$

A beam on survey was performed on 6/6/79 by the author during which approximately 3×10^8 π^-/pulse were incident on this target and dump[3]. At this intensity and energy a reading with a tissue equivalent ion chamber (Health Physics Instruments, Model #1010) of 0.0005 mrad/pulse was obtained in the area directly over the dump. Applying a quality factor of 5 and scaling by the intensity one obtains at 10^{12} hadrens/pulse:

$$\dot{H}_{measured} = 8.3 \text{ mrem/pulse}$$

so that the agreement is reasonable given the uncertainties in the "as built" geometry and the approximations made to simplify the geometry for use in the Monte-Carlo calculation. The difference between π^- and protons in the incident beam has been neglected here. The reasonableness of this has been verified in other calculations. It is also not surprising that $\dot{H}_{measured} > \dot{H}_{calc}$ since $\dot{H}_{calc}$ assumes somewhat more shielding of components upstream of the dump than existed in practice.

Now consider the case of a scraping loss on the upstream dipoles. This case is comparable to that discussed on p 12.1-6 of the Fermilab Radiation Guide. The star density outside of 160 cm of concrete shielding (equivalent to the berm over PW 5) was calculated at 300 GeV bombarding energy to be 2.3×10^{-8} stars cm $^{-3}$/proton. This value is obtained at a radial distance of 360 cm from the loss point. This loss point at the large distance to the top of the berm will also be almost a point source so at the location of interest the star density becomes: 5.4×10^{-9} stars cm $^{-3}$/hadron so that at 10^{12} hadrons/pulse: $\dot{H}_{calc}$ (300 GeV) = $1 \times 10^{12} \times 9 \times 10^{-6} \times 5.4 \times 10^{-9}$ = 49 mrem/pulse. We also have $\dot{H}_{calc}$ (200 GeV) = 32 mrem/pulse.

If instead the extra distance to the location of measurement is taken into account by considering the loss to be a line source, then:

$$\dot{H}_{calc} \text{ (300 GeV)} = 101 \text{ mrem/pulse}$$
$$\dot{H}_{calc} \text{ (200 GeV)} = 70 \text{ mrem/pulse}$$

so that between these limiting cases

$$49 < \dot{H}_{calc} \text{ (300 GeV)} < 101 \text{ mrem/pulse}$$

$$32 < \dot{H}_{calc} \text{ (200 GeV)} < 70 \text{ mrem/pulse}$$

In May of 1979 D. Grobe measured 200 mrem/hr while losing beam on these dipoles at an intensity of 5×10^{10} 200 GeV protons per pulse. At 10 sec cycle time this implies at 10^{12} protons per pulse:

$$\dot{H}_{measured} \text{ (200 GeV)} = 11 \text{ mrem/pulse}$$

This survey was done with a remote detector set up before the beam was tuned so that it was likely that it was not located in the hottest spot and would thus be likely to give a low reading.

On June 4, D. Grobe repeated the measurement with π^- beam (200 GeV on target) using the same portable ion chamber mentioned above. In this case it was possible to locate the worst spot relative to a particular loss point. In the region of interest 24 mrem/hr per 2.5 x 10^9 π^- was measured at an 11 sec cycle time.

This, of course, implies at 10^{12} hadrons/pulse,

$$\dot{H}_{measured}\ (200\ \text{GeV}) = 29\ \text{mrem/pulse}$$

which is quite consistent with the Monte-Carlo Prediction.

The conclusion is that CASIM predictions of dose equivalent rates are in good agreement with these measurements.

References:
1. A. Van Ginneken, FN - 272
2. J. D. Cossairt, TM - 877
3. Memo from J. D. Cossairt to D. Grobe, June 8, 1979
4. Memo from D. Grobe to K. Stanfield, June 11, 1979