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Brookhaven National Laboratory

Estimates of Dose Equivalent Through the Wide Angle Hall End Wall

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I. Introduction

This note represents a follow-up (and correction) to a previous CASIM[1] estimate through the end wall of the Wide Angle (6 o'clock) hall.[2] One of the results reported in Ref. [2] was an estimate of dose equivalent in air downstream of the end wall caused by an assumed Design Basis Accident (DBA) fault on a magnet on the opposite side of the interaction region from the end wall being considered. Specifically, from Fig. 5 of Ref. [2], one would deduce that the dose equivalent at the nearest fence boundary, which is 41.5m downstream of the end wall, would be approximately 1 rem for a DBA fault at 4 times design intensity and the normal CASIM star density to dose conversion multiplied by 2. Because this result would exceed the 160 mrem RHIC design criteria for such a fault, this topic was flagged for a more detailed (and careful!) study.

In this note, additional CASIM calculations, as well as MCNPX[3] calculations, are presented addressing this subject. However, it was noted early in re-visiting this subject that **Fig. 5 of Ref. [2] is simply in error.** A blunder was made in converting star density to rem in this figure by one of us (AJS). If one extrapolates Fig. 5 of Ref. [2] to the wall, the result is 10 times higher than the results (dose at the exit of the end wall) given in Fig. 4 (or deduced from Fig. 2 or 3) in the same note. The points plotted in Fig. 5 of Ref. [2] should be an order of magnitude lower than shown.

II. CASIM Calculations

The most extensive CASIM calculations were done in a fully three-dimensional geometry.[4] which includes the roof of the hall. Fig. 1 is adapted from Fig. 1 of Ref. [2], which is an "end-on" view of the end wall. The dashed lines in this figure indicate some boundaries of the end wall itself. The parallelograms represent CASIM bins in air outside the end wall. Each of the 10 X,Y bins shown is associated with 40 bins in Z, with $\Delta Z = 1$m.

Fig. 2 shows the dose in the second bin from the left in Fig. 1 (the worst case at the fence line) as a function of distance downstream of the end wall for a 250 GeV/c proton beam interacting on the DX beampipe. The DBA fault in this case is 1.14×10^{13} protons, so the 3×10^{-15} rem/p at the 40m distance corresponds to about 34 mrem. As has been done to date in RHIC estimates, the CASIM star density to dose conversion has been multiplied by 2.[5]

Runs were also made with a source on D0 and Q2. D0 turned out to give a slightly higher result, so that the CASIM estimate with X2 QF at the fence line for a DBA fault is about 50 mrem with a 30% statistical error.

III. MCNPX Calculations

The MCNPX estimates reported here were made in a simplified cylindrically symmetric representation of the 6 o'clock area shown in Fig. 3. Based on previous comparisons between CASIM and MCNPX, a significantly lower result was anticipated at this relatively forward (~20°) angle.[6]

In the MCNPX runs, the source was 100 GeV protons interacting in the middle of the DX magnet. The magnetic field in DX was not taken into account, as this is not possible in MCNPX. After a series of runs with the geometry shown in Fig. 1, a 3 ft. cylindrical "roof" was added to include some approximation of hadrons "reflected" from the roof to the end wall.

Dose equivalent was estimated from particle (neutron, proton, and pion) fluxes across planes perpendicular to the beam axis, segmented in radius above the berm shown in Fig. 1. Table 1 shows the maximum (in R) total dose in the geometry which includes the roof as a function of location in the beam direction (Z) coordinate. Also shown is the same result scaled to 250 GeV and multiplied by 2^7 so that comparison can be made to the CASIM result.

Table 1 MCNPX Results & CASIM Comparison

Location	**MCNPX dose(*) (rem/100 GeV proton)**	**MCNX dose Scaled**	**CASIM dose(+) (rem/250Gev proton)**
Downstream end of end wall	2.67×10^{-14}	1.11×10^{-13}	5.8×10^{-13}
2m downstream of end wall	1.56×10^{-14}	6.49×10^{-14}	4.3×10^{-13}
7m downstream of end wall	5.22×10^{-15}	2.17×10^{-14}	7.9×10^{-14}
12m downstream of end wall	1.83×10^{-15}	7.62×10^{-15}	2.8×10^{-14}

(*) Statistical error < 5%
(+) From Fig. 2

Although these two estimates were made in different geometries, a few CASIM runs in the simplified geometry indicated that the geometric difference was not larger than a factor of 1.5, so that the primary difference in Table 2 is likely due to the physics differences.[6] Although it is quite possible that the MCNPX dose calculation underestimates the low energy neutrons created in the soil, we believe this is a small effect compared to the direct end wall punch-through that the calculation was optimized to evaluate. Given the fact that the FLUKA code is highly regarded in the physics community, the 50 mrem at the fence boundary for a DBA fault and X2 QF quoted in the preceding section should be regarded as an upper limit.

References/Footnotes

1. A. Van Ginneken, "CASIM; Program to Simulate Hadron Cascades in Bulk Mater," Fermilab FN-272 (1975).

2. A.J. Stevens, "End Wall Dose Equivalent Estimates at 6 O'clock," AD/RHIC/RD-91, June, 1995.

3. H.G. Hughes, R.E. Prael, R.C. Little, "MCNPX – The LAHET/MCNP Code Merger," X-Division Research Note, 4/22/97. The version number of the code used here is 2.1.5. This is a beta-test version of the code released by Los Alamos National Laboratory for testing and validation purposes. The authors of this note are aware of the current limitations of the code, and have performed their own validation procedures for the present application. MCNPX has various physics options; only the default options were used.

4. In all calculations reported here, the STAR magnet is not present in the simulations. As indicated in Ref. [2], this is the worst case, as the magnet steel represents some amount of shielding.

5. The (doubled) conversion can be expressed as 4.5×10^{-7}*L, where L is the high energy neutron interaction length in cm. For the approximation of air made here, L is 7.08×10^{4} cm., which give 3.19×10^{-2} rem per star/cc.

6. One of the defaults in MCNPX (See Note [3]) is use of the FLUKA code for particle production at high energy. FLUKA is well known to have far less particle flux than CASIM in the forward direction. See, for example, K. Tesch and H. Dinter, "Estimation of Radiation Fields at High Energy Proton Accelerators," Radiation Protection Dosimetry, Vol. 15 pp. 89-107, 1986.

7. The energy spectrum in the MCNPX results is much harder than the equilibrium spectrum assumed by CASIM. If this result is correct, multiplying the result by 2 would "over-compensate" for the possibility of an increased low energy neutron quality factor, both in CASIM and MCNPX.

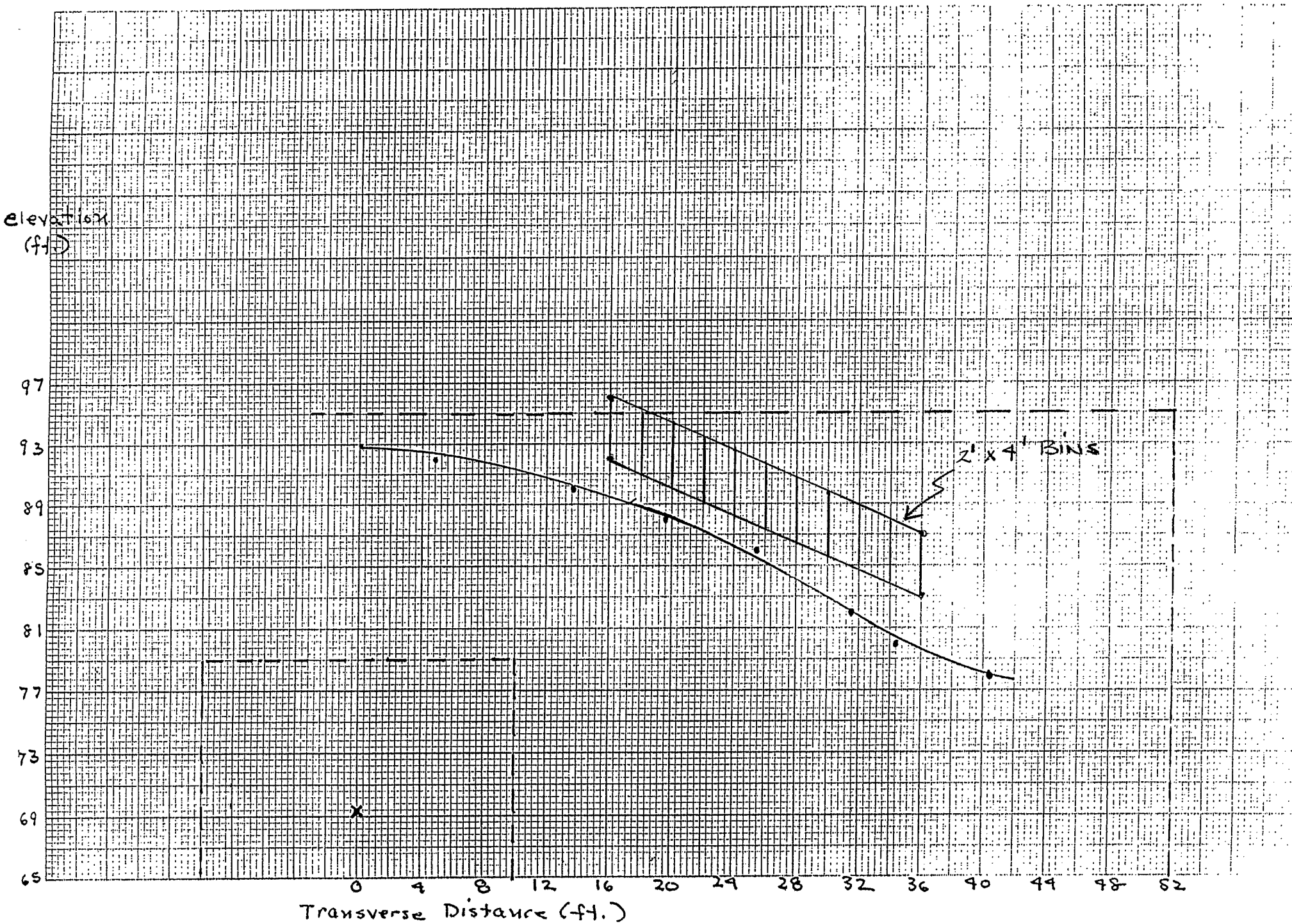


Fig. 1 Adapted from Fig. 1 of Ref. [2] See Text.

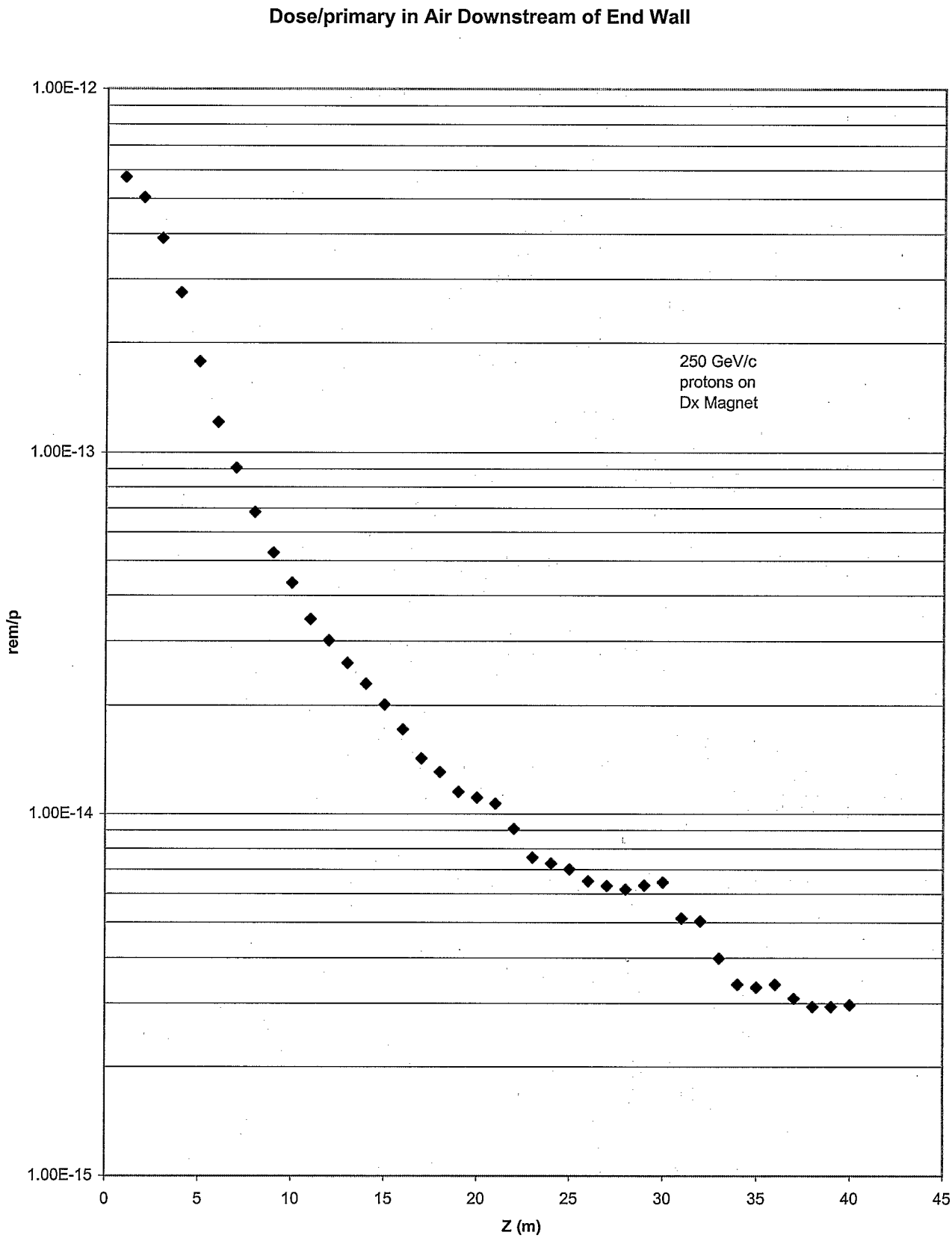
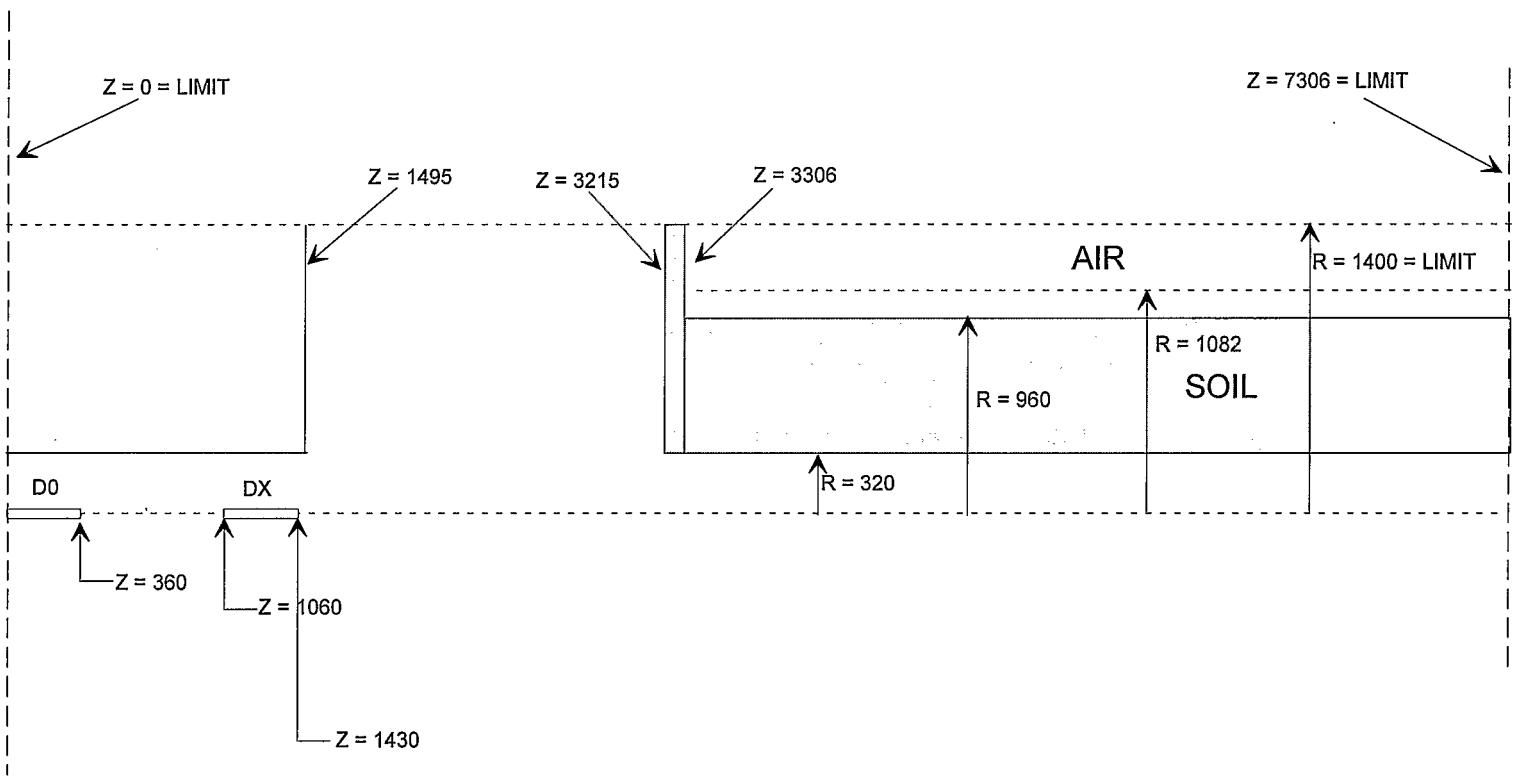

Dose/primary in Air Downstream of End Wall
1.00E-12
1.00E-13
1.00E-14
1.00E-15
rem/p
250 GeV/c
protons on
Dx Magnet
0
5
10
15
20
25
30
35
40
45
Z (m)

Fig. 2

8 inches on drawing = 7500 cm.



Detail near beam line: A "beam pipe" exists from R = 5.8 to R = 6.0 cm.
The magnets extend from the beam pipe to R = 19 cm.

Fig. 3 2D Representation