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End Wall Dose Equivalent Estimates at 6 O'clock

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I. Introduction

At the 6 o'clock intersection region, the end walls of the experimental hall has a lateral extent which exceeds that of the berm cover on the outside of those walls. Fig. 1 shows the cross section of the end wall of the 6 o'clock hall together with the ground elevation prior to the construction of the accelerator service building for this region. The dashed line on the outside of this figure is the outline of the *inside* of the end wall; the roof is above this line and the lateral side wall (in the direction opposite ring-center) is to the right of this line. A person standing on the berm close to this end wall is exposed to faults at reasonably forward angles shielded by only the wall thickness which is 3 ft. of concrete. As an example, the DX magnet on the opposite side of the hall is 20m upstream of the end of the concrete wall. At a 12 ft. lateral distance in Fig. 1, the berm ends 7.6m from the beam line, which defines an angle of about 21° with respect to the beam line.

The purpose of this note is to report the result of CASIM[1] calculations of the dose equivalent on the outside of an end wall such as shown in Fig. 1. Some combination of access restrictions (fencing) and additional shielding must be employed to reduce the potential dose equivalent from a design basis fault to a radiation worker to either 1 rem or 0.5 rem depending on local occupancy requirements. More details concerning these criteria and the definitions of design basis fault and occupancy requirements are given elsewhere.[2]

II. Description of CASIM Calculations

The geometry of the magnets in the beam line upstream of the hall is that described in a recent note.[3] The approximation is made that only one ring of magnets exists whose axis coincides with the tunnel axis. The beam pipe is exaggerated in thickness (but reduced in density) to minimize "stepping over" the pipe during transport.. The magnetic fields are taken into account within the apertures of the magnets but ignored in the coil/yoke regions.

Within the hall two possible geometries were calculated. In one of these, an approximation of the STAR magnet is made,[4] and in the other only a beam pipe is assumed to exist. The latter geometry is necessary because the STAR detector can be withdrawn to an assembly building while the collider runs for physics at other IR's.

Only 250 GeV/c protons faulting on the DX magnet as described in Ref [4] were considered. Many calculations have shown that the difference between protons and the CASIM approximation of heavy ions is negligible for shielding calculations, and the proton version is much faster. For faults on magnets upstream of DX, DX itself acts as a shield, so that a fault on this magnet represents the worse case for illuminating the hall. For this magnet the design basis fault is 1.14×10^{13} interacting protons.[5] Star densities were calculated in the concrete wall (and beyond as indicated below) for transverse distances between 7m (the top of the berm shown in

Fig. 1) and 12m. The star density to dose equivalent in light concrete is assumed to be 1.8×10^{-5} rem per star per cc.[6]

III. Results

Fig. 2 shown the star density as a function of distance along the beam direction in the 91 cm. (~3 ft.) concrete end wall for 7 different transverse radii in the geometry of an empty hall. Fig. 3 shows the same quantity for the geometry where the STAR magnet is present. In the latter figure note the "peculiar" behavior that the star density gets higher as the transverse radius increases until very nearly 12m is reached. This is because, as the transverse radius increases, the STAR magnet acts less and less as a shield.

Fig. 4 shows the dose equivalent per proton at the exit of the concrete wall for both geometries. For completeness, the dose equivalent for muons is also shown to a transverse distance of 9m which is clearly negligible. The dose equivalent is quite high; at the top of the berm shown in Fig. 1, for example, ($R_t = 7.1$m), the fault dose in the empty hall geometry is $1.3\times10^{-12}\times1.14\times10^{13} = 14.8$ rem.

As mentioned above, this high dose must be reduced by some combination of access restrictions and additional shielding outside the end wall. To explore the length required for a fence, a calculation was made of star density in air as a function of distance downstream of the end wall. The results, expressed in rem/p, are shown in Fig. 5. The fact that the dose equivalent gets somewhat worse at the larger transverse distances is simply a reflection of the outward-going directionality of particles emerging from the end wall. To reduce the fault dose to 1 rem, a rem/p of 9×10^{-14} is required. From this figure, access restrictions for a distance of about 45m or 150 ft. is required. For 0.5 rem, the distance is about 200 ft.

Although additional shielding behind the wall is possible, the requirements have a sharp dependence — at least for the empty hall geometry — on the transverse distance at which occupancy is required. Note in Fig. 2 that the attenuation in concrete (after the buildup) depends on the radius. Fig. 6 shows points from an "eyeball" fit to the attenuation lengths in Fig. 2 together with a parameterization that fits the R_t dependence reasonably well. If low occupancy is required at an R_t value that is $\geq$ 12m, then a reduction from 3×10^{-13} (Fig. 4) to 9×10^{-14} (0.30) is required. From Fig. 6, $\lambda = 62$ cm. is appropriate which gives 75 cm (2.5 ft.) of light concrete or the equivalent. However, if high occupancy would be required at a transverse distance of 7.5m., then a reduction of $(4.5\times10^{-14})/(1.15\times10^{-12}) = 0.039$ would be needed with a λ of 105.4 cm. This requires 342 cm. or 11.2 ft. of concrete!

IV. Existing Structure

The accelerator service building mentioned in the Introduction overlaps the 6 o'clock hall endwall. An examination of this building shows that the nearest point that a person inside the building can come the beam line is an R_t value of 9.9m. This value occurs when a person is at the extreme rear of the building. In the coordinates of Fig. 1, the point is at 29.5 ft. transverse distance and 91 ft. elevation. Note that this is only 4 ft. below the beginning of the roof. For high occupancy an R_t of 9.9m implies about 6.1 ft. of concrete, or 8.2 ft. of dirt is needed as additional shield. The earth is needed for a vertical extent of 5-6 ft. from existing grade since this will overlap the 6 o'clock roof. The remaining exposed sections of the end walls at 6 o'clock must also receive attention. As indicated in the last section, one solution is to fence off the berm to a distance of about 150 ft. from the hall.

The 8 o'clock region was also examined. Here the berm covers almost the entire end wall for a length of about 20 ft. past the end wall before it begins to slope downward. A person standing on the beam line at 94 ft. elevation (R_t=7.6m) is about 45 ft. from the end of the end wall and has about 30 ft. of earth shield. This would reduce a fault dose to below 2 mrem, even without taking account of the PHENIX detector which, unlike STAR, is not intended to be moved to an assembly area. Thus no fence is required at this location due to end wall problems.[7]

References/Footnotes

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

2. A. Stevens, S. Musolino, and M. Harrision, "Design Criteria for Prompt Radiation Limits on the Relativistic Heavy Ion Collider Site," Health Physics Vol. **66**, pp. 300-304 (1994).

3. A.J. Stevens, "Estimated Shielding Requirements for the PHENIX Detector," RHIC/DET. Note 13, (1994).

4. A. Stevens, "Local Shielding Requirements for the STAR Detector," RHIC/DET Note 5 (1992). The shield wall which separates the hall from the assembly area described in this note is outdated. The more current wall was not simulated in these calculations, but is not relevant.

5. This is twice the design beam intensity which corresponds to half of 4 times the design intensity interacting on DX.

6. This is **twice** the normal CASIM star density to rem conversion constant which follows the recommendation of the "RADCON Manual" to assume an increased quality factor for neutrons for design purposes.

7. In general, at least roofs themselves must be fenced. Although detailed consideration of interior detectors might in principle remove this restriction, for the PHENIX detector the roof must be fenced.

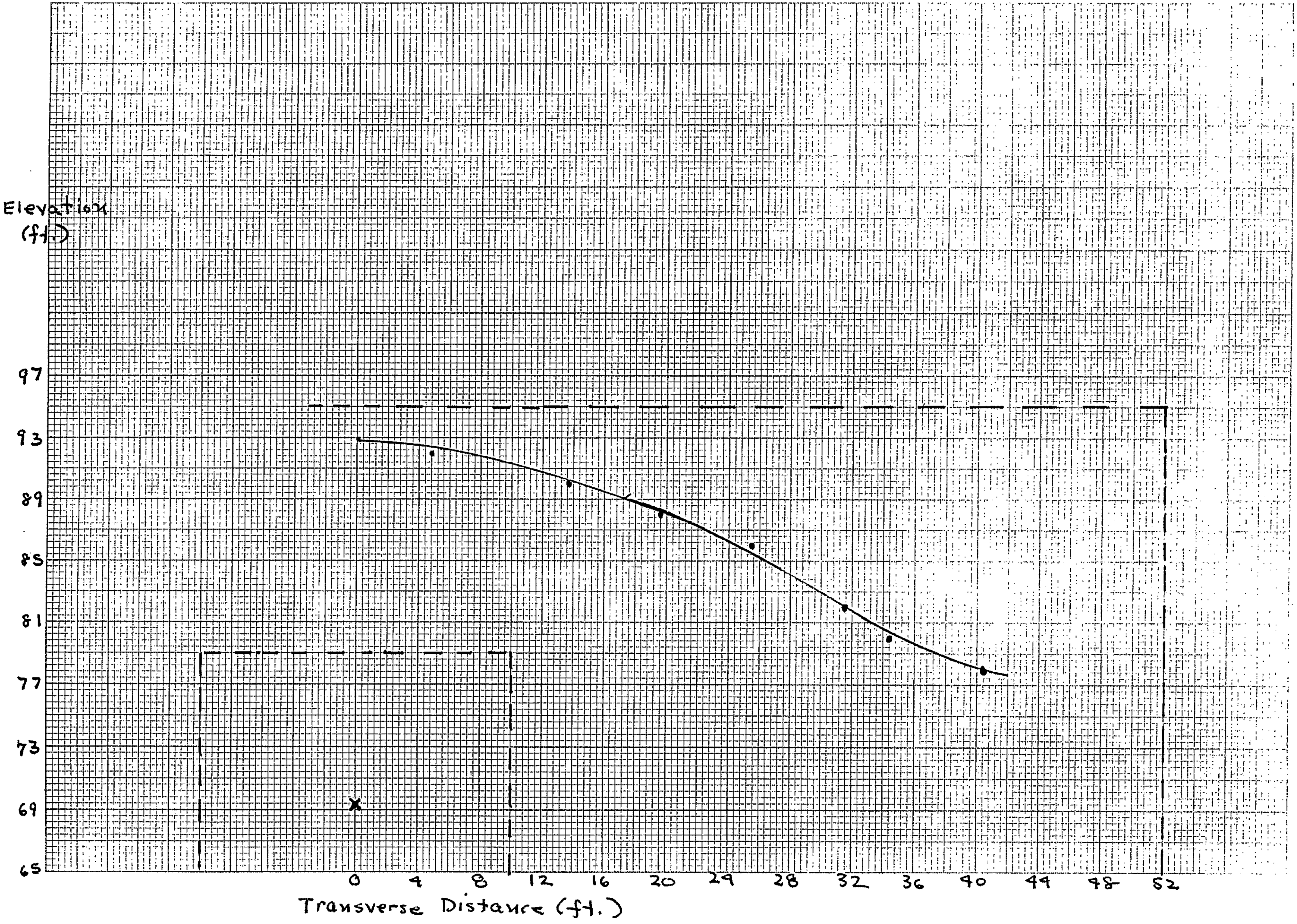

Fig. 1. Half Cross Section of the 6 O'clock End Wall. The Berm Contour does not Reflect Recent Construction

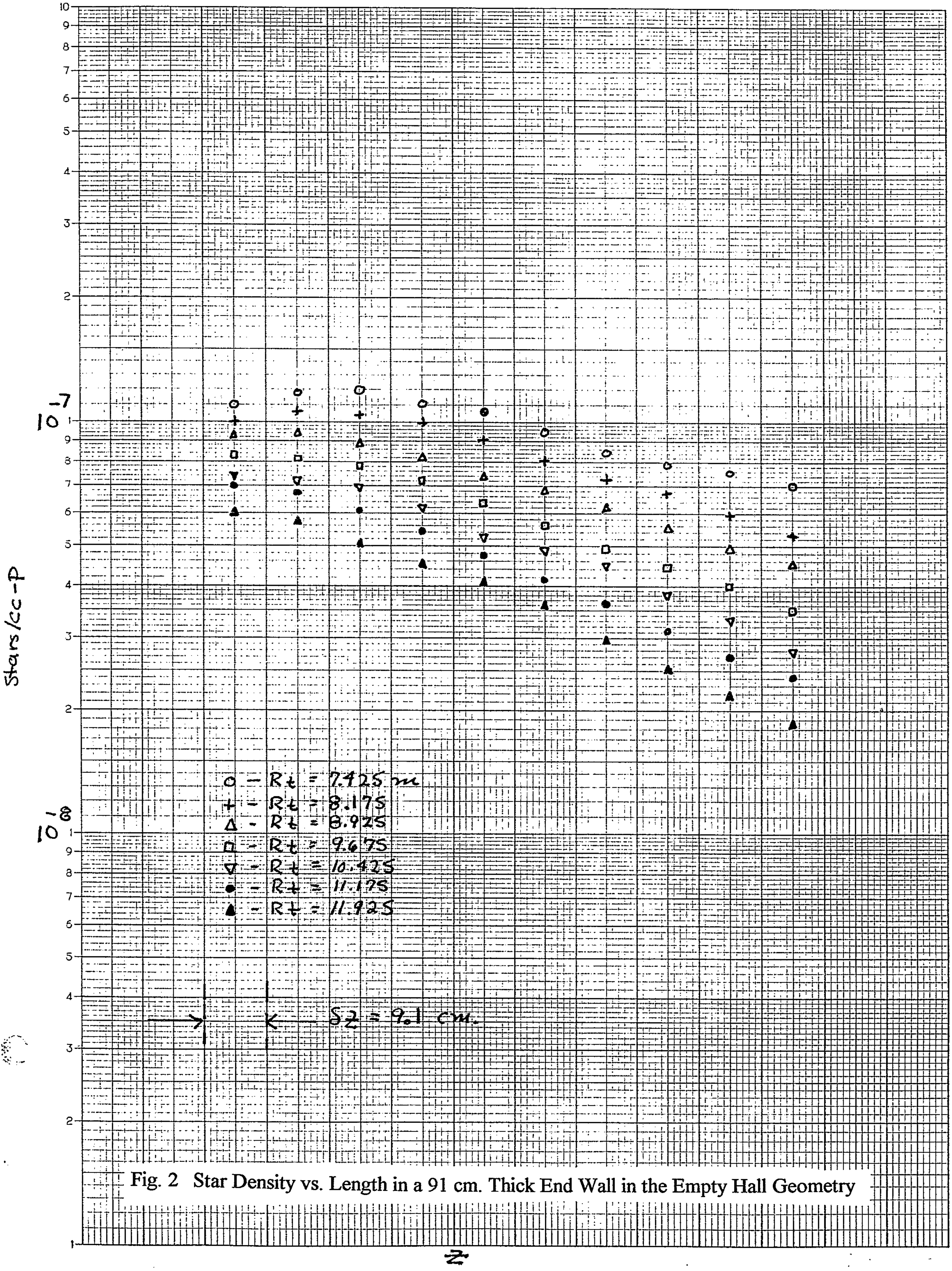

Fig. 2 Star Density vs. Length in a 91 cm. Thick End Wall in the Empty Hall Geometry

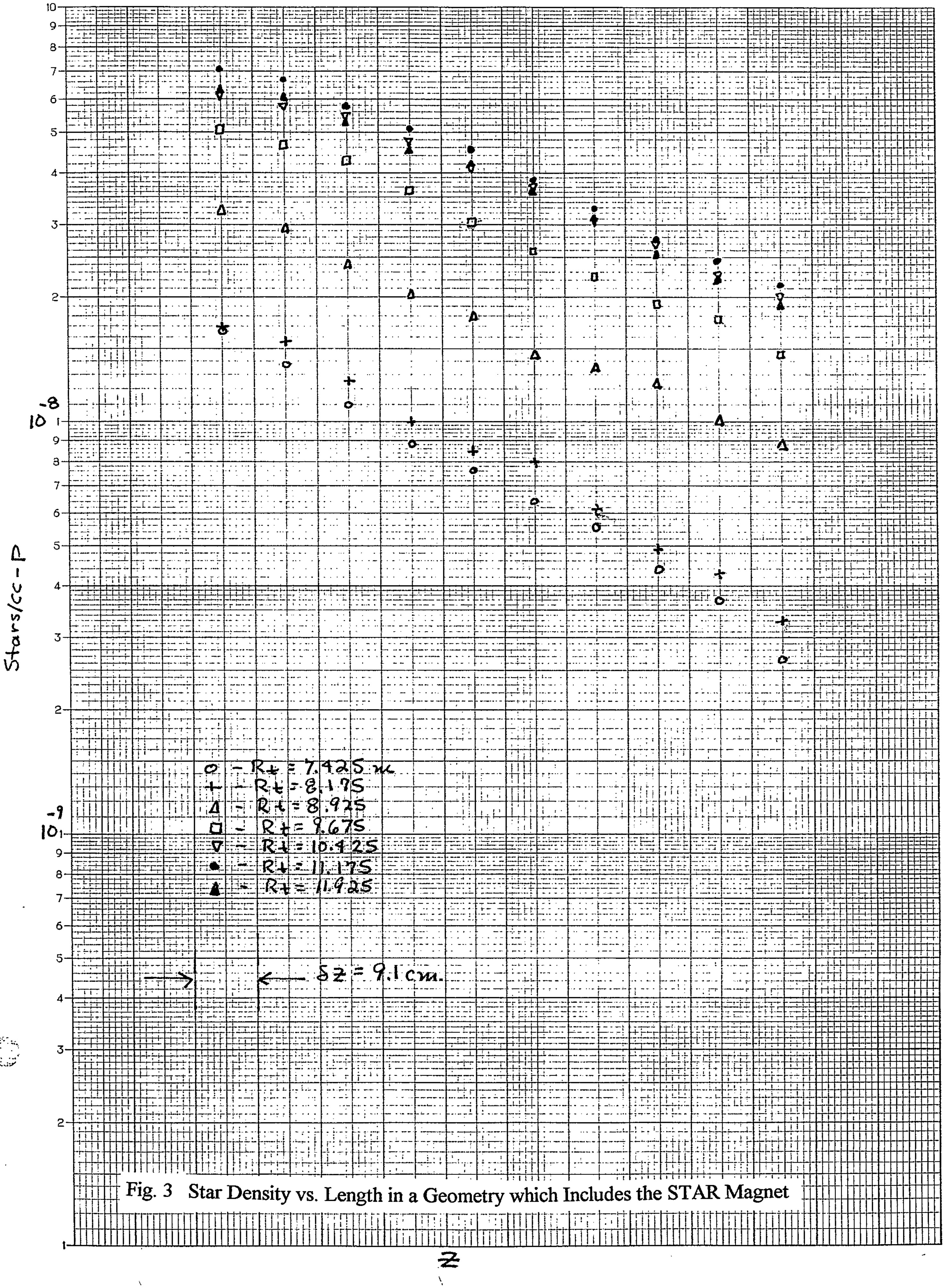

Fig. 3 Star Density vs. Length in a Geometry which Includes the STAR Magnet

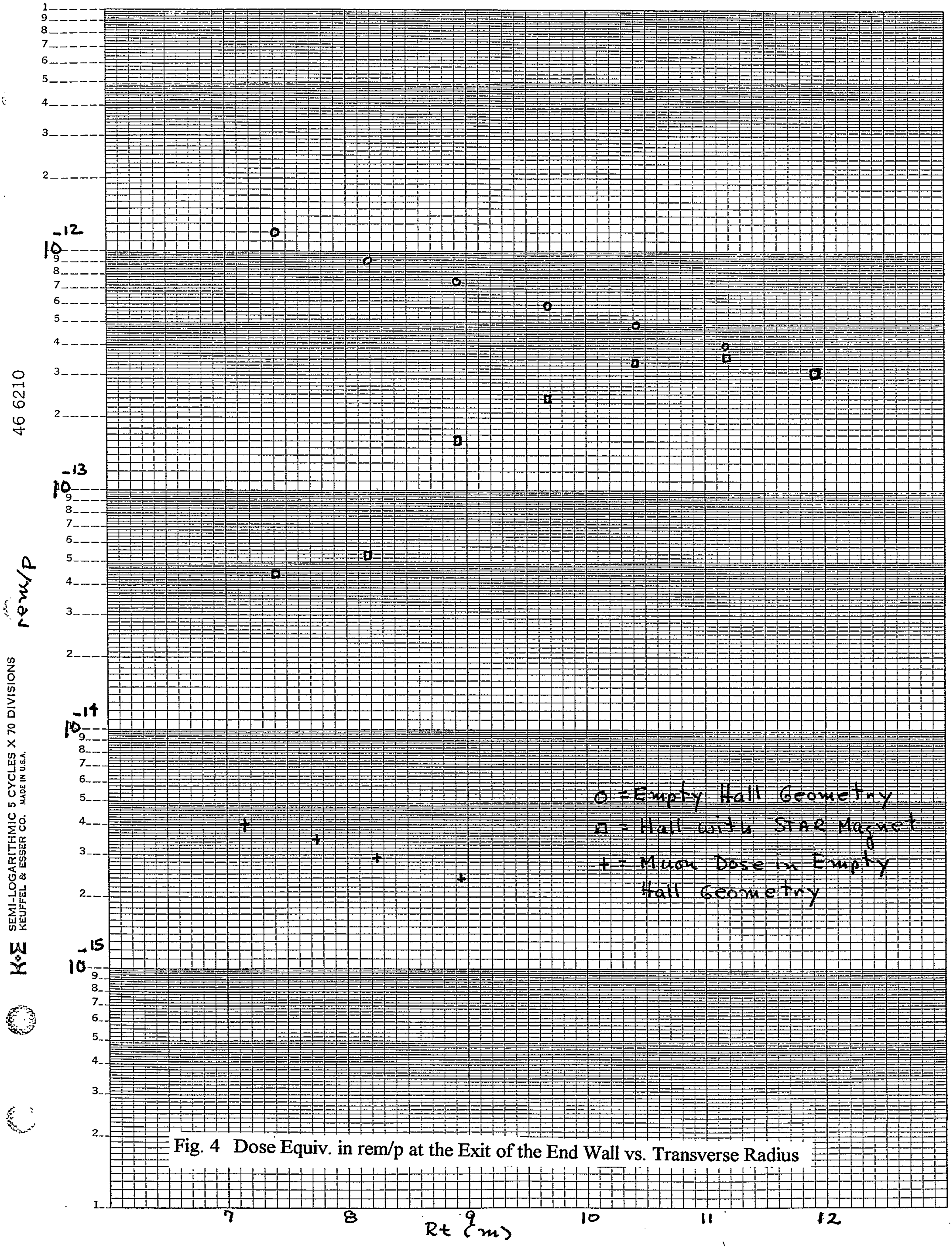

Fig. 4 Dose Equiv. in rem/p at the Exit of the End Wall vs. Transverse Radius

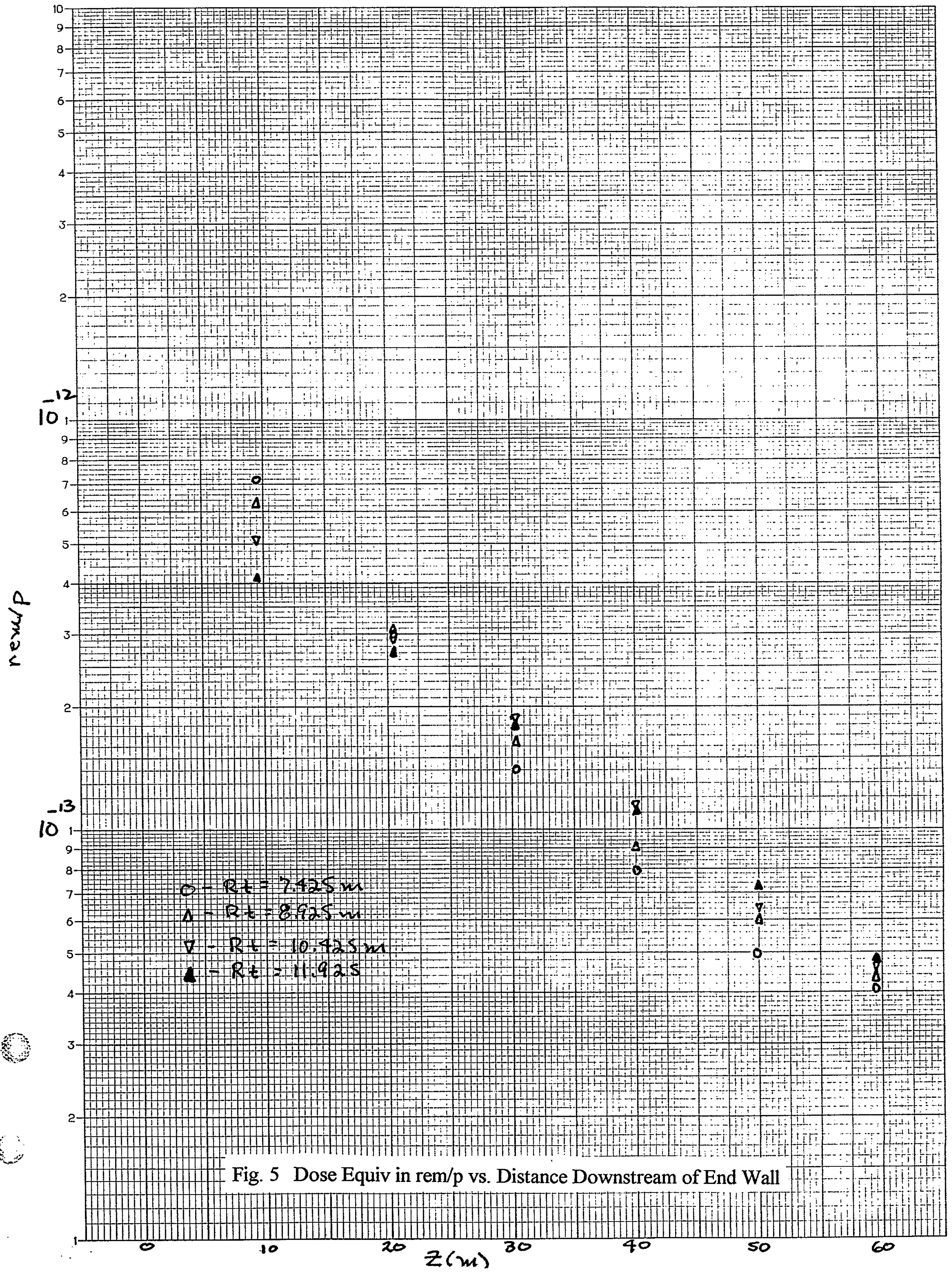

Fig. 5 Dose Equiv in rem/p vs. Distance Downstream of End Wall

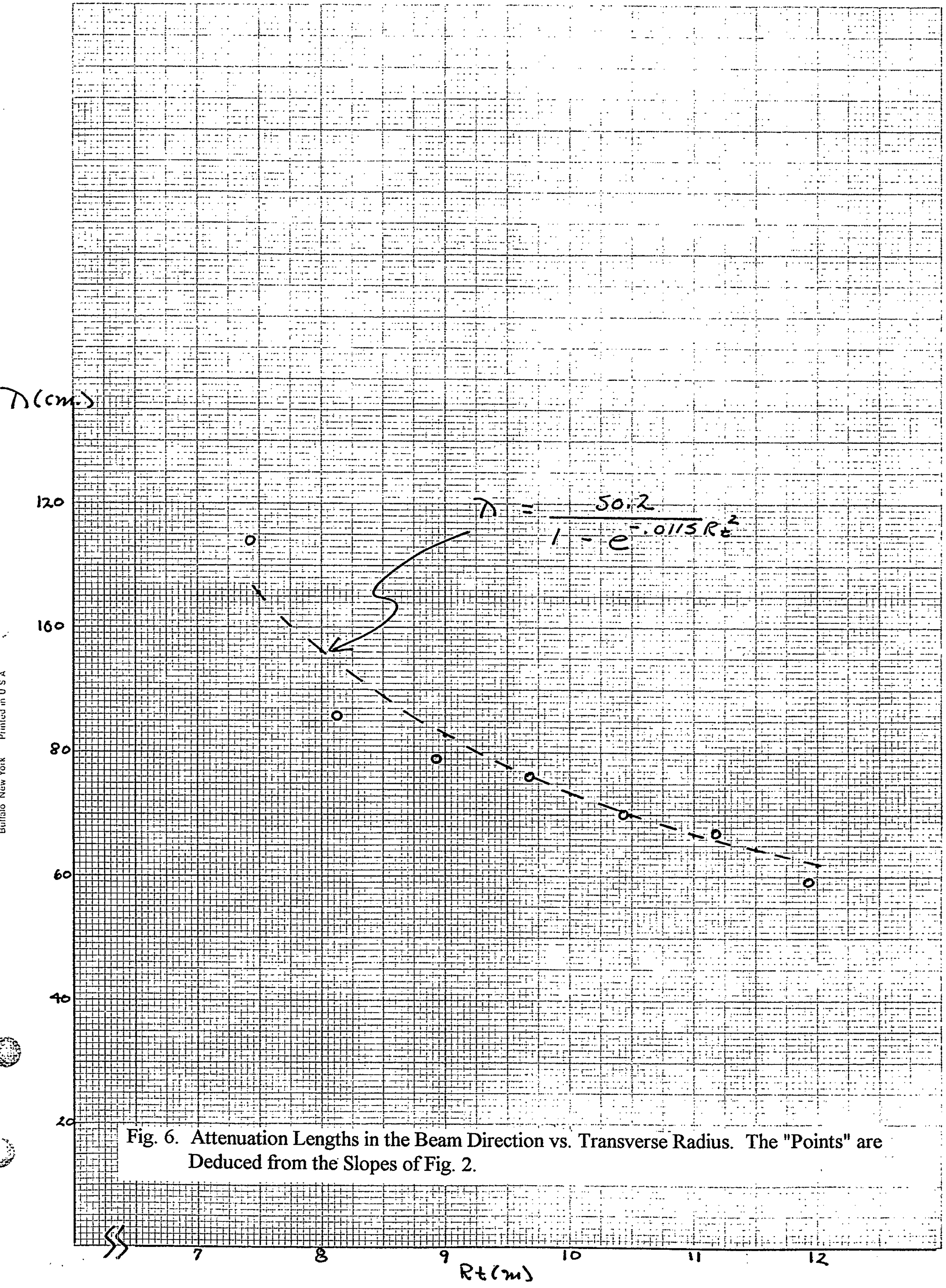

Fig. 6. Attenuation Lengths in the Beam Direction vs. Transverse Radius. The "Points" are Deduced from the Slopes of Fig. 2.