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Radiation Safety Review of Enclosure G2 North Addition

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A north addition is being designed for Enclosure G2 as a part of the upgrade of the switchyard for Tevatron era beam transport to the Neutrino Laboratory. The principal features of this enclosure, as far as radiation safety considerations are concerned, are shown on Figs 1 and 2. Figure 1 is a plan view which shows the NØ and muon beam lines. The N7 beam also passes through this enclosure just to the east of the NØ beam but is not shown for reasons of clarity. An important feature is the large hatch at the downstream end which will be used for occasionally dropping magnets into the enclosure and which will contain removable shielding blocks. The principal access is provided by the standard type labyrinth shown in Fig 1. A road (not shown on the simplified drawings given here) will be built from road A across the Meson Laboratory beam just upstream of the F1 manhole to near the top of the new labyrinth. This paper will now review several aspects of the new Enclosure.

First consider the shielding over the top of the enclosure. As one can see, there is planned to be approximately 17 feet of soil shield plus 1 foot of concrete. Using a value of 2.24 g/cm^2 for the soil density in a compacted berm and 2.4 g/cm^2 for the density of concrete one calculates a total shielding thickness of 16.9' (514 cm) of concrete equivalent shielding. Note that the NØ beam is the closest beam line to the hatch, the surface, and the labyrinth and also handles the highest intensity under the usual operating conditions. Because of some uncertainty in exact locations of beam line elements a specific Monte Carlo calculation was not made. For these reasons, a "standard" case shown in Chapter 12 of the Fermilab Radiation Guide was used. This case results from a CASIM calculation[1] and a contour plot of equal star density as a function of depth and radius is shown as Fig 3. This is a case of 300 GeV protons hitting a steel object roughly the same dimensions as an EPB dipole and represents a reasonable case for the present situation. Obviously an extrapolation from R=400 cm shown in Fig 3 to the real berm top will have to be made. At R=400 cm (200 cm of concrete) we have a star density of 8×10^{-9} stars/cm^3·proton. From the Particle properties Data Booklet the absorption length of concrete is about 38 cm. Thus after 314 cm of additional concrete and correcting to 400 GeV operation (scaling by the ratio of energies) we get a star density of:

$$2.8 \times 10^{-12} \text{ stars/cm}^3\cdot\text{proton}$$

At 2.5×10^{13} proton/pulse (neglecting recent intensity records!) and using the factor of 9×10^{-6} rem/star·cm^3 this becomes a one pulse dose equivalent of 0.63 mrem. Of course, because of the replacement of soil with concrete, a $1/r^2$ correction needs to be made. Also the NØ center line is actually 30 cm from the ceiling instead of 200 cm. Putting both of these in we have: $\left(\frac{514 + 200}{549 + 30}\right)^2 0.63 = 0.96 \frac{\text{mrem}}{2.5 \times 10^{13}}$ @400 GeV

A 1 per cent continuous loss would be 3 mrem/hr (300 pulses). Both of these comply with the Fermilab Radiation Guide (Chapter 6) for areas with minimal occupancy since the calculation is conservative in that a direct hit (as opposed to a scraping loss) was considered. The area above the berm would have to be posted as a radiation area. At 10^{14} protons/

pulse at 1000 GeV one then has a 10 mrem/pulse area over the enclosure. A one per cent loss under the above 1000 GeV conditions would represent a dose equivalent of 6 mrem/hr (60 pulses). Fences or interlocked detectors would be advisable under such conditions. The hatch poses no special problem if built as designed. The cracks between the blocks and the walls will act as small labyrinths if the blocks are properly staggered.

The third major item needing evaluation is the labyrinth. Labyrinth calculations are done following Ref 2. In this case the aperture is 8' x 3.5' so that the unit length $\sqrt{A}$ is 5.3'. If the source is considered to be a point on the NØ beam line, it is then 4' from the mouth of the labyrinth. Using the "one neutron/GeV rule" and 3×10^7 n/cm$^2\cdot$rem, the source term at the mouth is (for various conditions):

S(400 GeV, full loss) = 1.83×10^3 rem/pulse
S(400 GeV, 1%) = 5.52×10^3 rem/300 pulse
S(1000 GeV, full loss) = 1.83×10^4 rem/pulse
S(1000 GeV, 1%) = 1.1×10^4 rem/60 pulse

From Fig 7 and 8 of Ref 3 we get the following reduction factor for each leg (the interlocked gate is assumed to be at the top of the stairs):

1st leg:	0.14
2nd leg	2.5×10^{-3}
3rd leg	1×10^{-3}
Total	3.5×10^{-7}

The change in elevation is neglected above but worth perhaps a factor of five so that we have for each operating condition at the top of the stairs:

400 GeV; full: 0.13 mrem/2.5 x 10^{13}
400 GeV; 1% loss: 0.4 mrem/hr
1000 GeV; full: 1.3 mrem/10^{14}
1000 GeV; 1% loss: 0.8 mrem/hr

All of these are acceptable in an area with minimal occupancy.

An additional concern is that the soil cover at the intermediate landing is only 3.3' soil + concrete cover. However, at this location this is adequate because of the softening of the neutron spectrum at this location.

A third item of concern is the road over the Meson line. This road will be at elevation 747' while the Meson beam is at 730' implying 17' of soil shield over a beam pipe capable of only scraping type losses. Such scraping losses result in dose equivalents roughly 1/25 of those obtained from direct targeting on magnets (Ref 3) so that, in view of the conclusions above, the shielding is adequate. Soil actuation problems with G2 should be minimal since no deliberate targeting will be done here.

It will be advisable to cover the existing G2 enclosure with any available soil since in view of the results here, its shielding is too thin. The authors would like to thank L. Coulson for his reading of this paper.

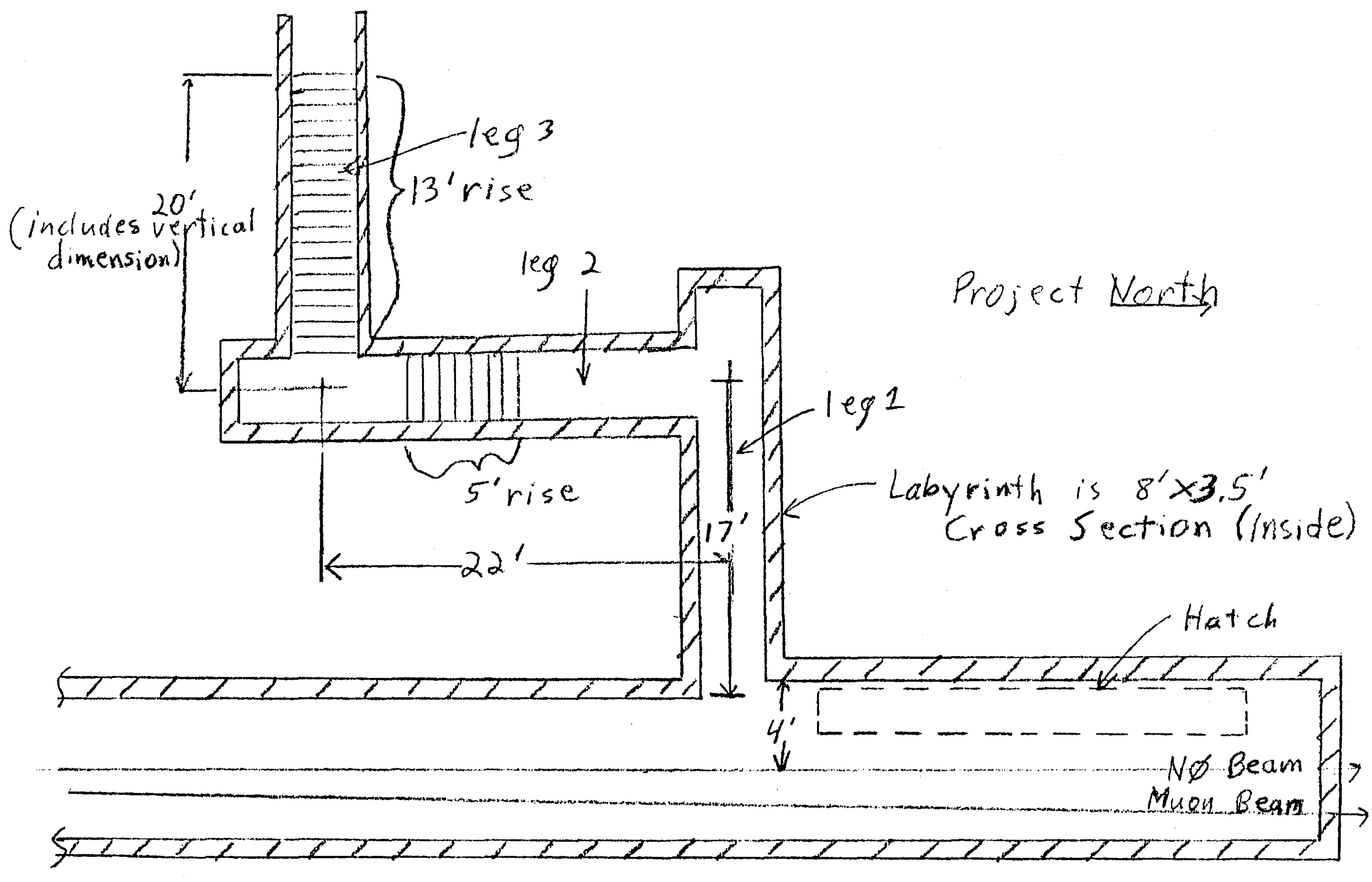
References

1. A. Van Ginneken and M. Awschalom, _High Energy Particle Interactions in Large Targets_, Fermilab, 1975.

2. P. J. Gollon and M. Awschalom, "Design of Penetrations in Hadron Shields", in CERN 71-16, Vol 2 p 697.

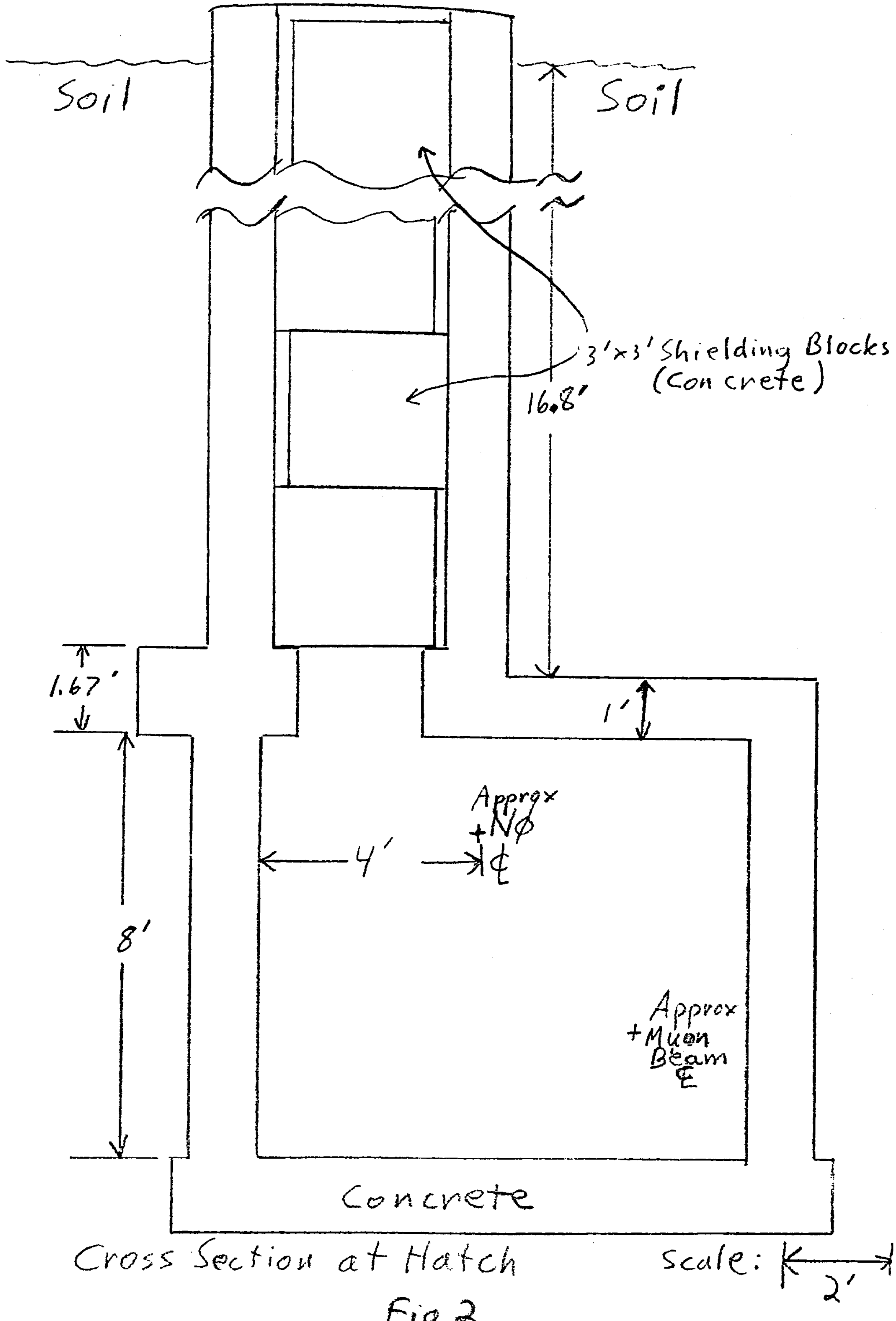
3. P. J. Gollon, Memo to F. Turkot, January 20, 1978.

List of Figure Captions



Enclosure G2 North Addition - Plan view - Downstream End

Fig 1



Cross Section at Hatch

Fig 2

From Fermilab Radiation Guid
Sept. 1978 Revision

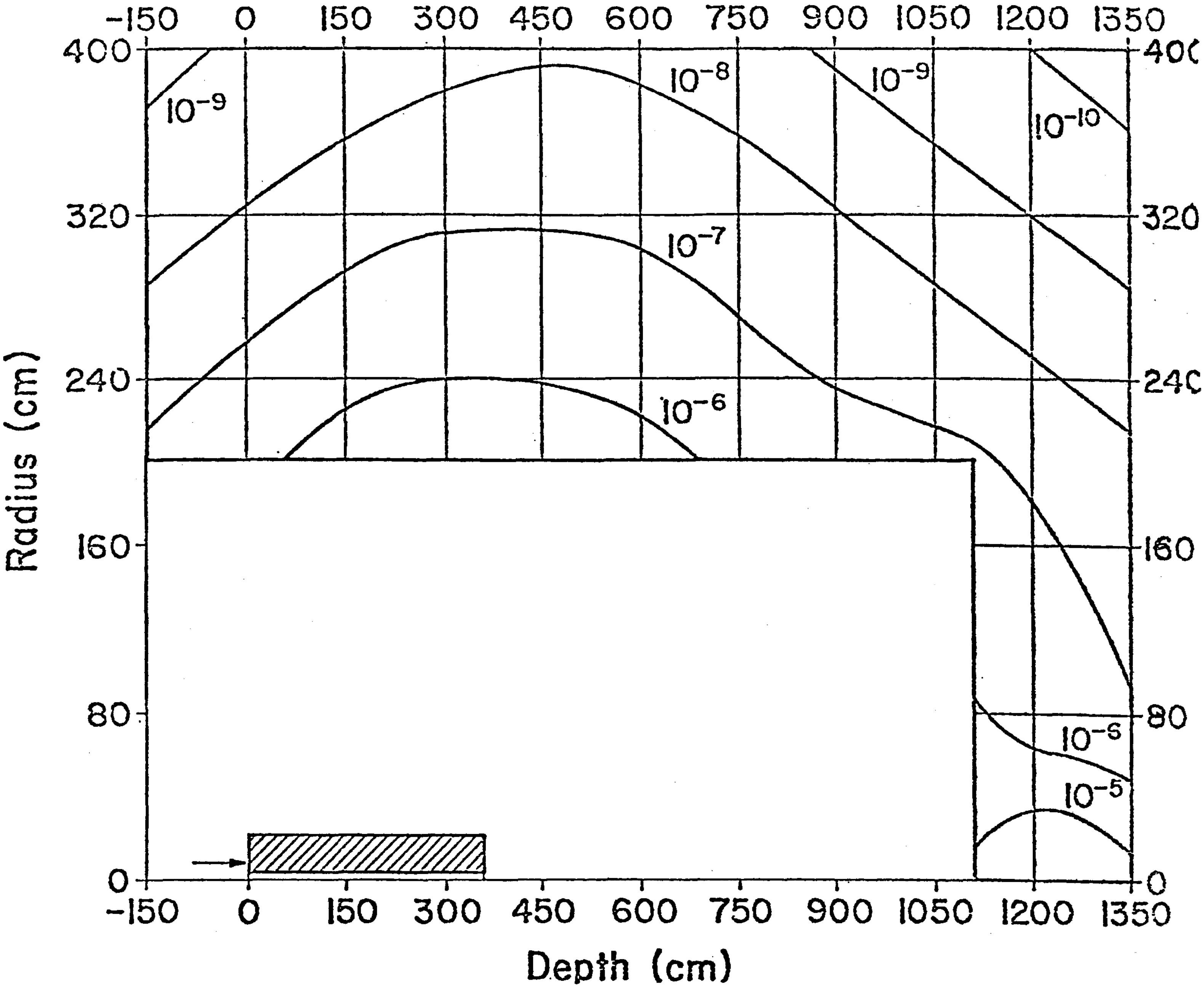


Figure 3. 300 GeV protons incident on a steel "collimator" (or magnet) placed in a concrete enclosure. Contours of equal star density (stars/cm^3·incident proton) of stars produced by hadrons above 0.3 GeV/c momentum. The collimator is a cylindrical shell, 360 cm long, with an outer radius of 20 cm and an inner radius of 3.75 cm. The beam has a square cross section of 0.1 x 0.1 cm and is centered at a radius of 4 cm. The contours show the star density averaged over azimuthal angle.