Radiation Level in the Intersection Region of AP2 and 8GeV Beam-line due to Beam loss in the AP2 Beam-line

C.M. Bhat and P. Martin

Fermi National Accelerator Laboratory

P.O. Box 500, Batavia, Illinois 60510*

August 23, 1995

Recently a question has been raised regarding the access to the 8 GeV beam-line tunnel (beam-line from the Fermilab Booster to the FMI which is under construction) near the intersection of the 8 GeV and the AP2 beam-line tunnels during the stacking of pbars or when the AP3 beam-line is in use for the Accumulator or Debuncher studies. In this note we address this question and suggest possible solutions.

During the next fixed target run at Fermilab, the 120 GeV proton beam from the Main Ring will be used to produce pbars for E868 experiment. At the same time the installation of the 8 GeV proton beam-line instrumentation and/or the installation of the FMI will take place. But the 8 GeV pbar beam-line (AP2 beam-line) and the 8 GeV beam-line tunnel will intersect one above the other. The soil thickness between these two beam lines in the region of intersection is only about 1.37 m. Hence any accidental beam loss in AP2/AP3 beam line will increase the radiation dose level in the 8 GeV proton beam-line tunnel. During the installation of the instrumentations for the 8 GeV beam-line, there will be the FMI-construction/accelerator personnel working in the tunnel. Hence it is essential to estimate the radiation dose level in the 8 GeV beam-line and to ensure that the total radiation dose received by these personnel is within the safety limits.

A schematic view of the region of the AP2 beam-line and the 8 GeV beam-line is shown in Fig. 1. In the AP2 beam-line tunnel there are two beam lines viz., AP2 and AP3 beam-lines. Both of these beam lines are at about 1.8 m (6 ft) from the tunnel floor. The tunnel floor of the 8 GeV proton beam-line is at an elevation of 217.4748 m (713.5 ft) at the location where it intersects the AP2 beam line. They cross at an angle of about 49°. The floor of AP2 beam line tunnel is at 221.2848 m (726 ft) elevation with 1.3716 m soil in between the two beam line tunnels. Previously we have decided to replace 0.3048 m (1 ft) of this soil with shielding steel to provide the required shielding between the 8 GeV line and the surface. However, this steel is placed in a manner which does not provide full coverage for the conditions being addressed here, and is therefore neglected in this discussion.

To estimate the radiation levels in and around the 8GeV beam-line tunnel we make the following assumptions:

- The maximum number of protons @120GeV on the pbar target is 4E12/2.5 sec.

All negatively charged particles produced in the target, lying in a 4% momentum acceptance at 8GeV will be transported through the AP2 beam line.

- The maximum number of protons @8GeV in the AP3 beam-line is 3.6E13/hour.

The normal operational beam loss in AP2/AP3 beam lines is assumed to be negligible while the accidental beam losses are responsible for high radiation level in the 8 GeV beam line tunnel. We define an 'accidental beam loss' as continuous loss of all beam particles at one point for one hour. Our goal is to have radiation dose level for accidental losses smaller than 1.0 mrem/accident in the region where accelerator personnel can have access. The guide-lines to determine the acceptable radiation levels are taken from the FERMILAB RADIOLOGICAL CONTROL MANUAL.

Beam Loss in the AP2 and AP3 Beam-lines

Beam in the AP2 beam-line is mixture of 8GeV pbars, π^- and K^-. A schematic diagram of the pbar beam collection system is shown in Fig. 2. The total angular acceptance of the Li- lens is about 2.6^o. Using the calculated data from Ref. 1 for copper target and extrapolating to 120GeV we found,

the total number of π^- per 120GeV proton = 0.021.

The K^- production cross section is about 10% of π^- production cross section (Private communication with A. Ginneken). Hence we expect,

the total number of K^- per 120GeV proton = 0.0021.

From pbar production cross-section (C.Hojvat and A. Ginneken, Nucl.Inst. Methods Vol. 206(1983) 67) we expect,

the total number of pbar per 120GeV proton = 4.9E-5.

The π^- flux is therefore the dominant one in the AP2 beam-line. The total transported beam in the AP2 beam-line during the pbar stacking will be about 8E10/pulse. Hence during an accidental condition we can expect up to 1.2E14 π^-/accident in the vicinity of the intersection.

Occasionally 8GeV beam from the Main Ring will be transported through the AP3 beam-line for Accumulator and Debuncher studies. Depending upon the mode of operation of the Debuncher and Accumulator rings, different beam intensities are used. The operational modes and the corresponding beam intensities are shown in Table I. The maximum beam transported during these studies can be about 3.6E13p/hour. Any accidental beam loss during this period implies 3.6E13p/accident.

Radiation Dose in The 8 GeV Beam-line Tunnel

High energy interactions of beam particles with beam-line elements results in a hadronic shower peaking in the forward direction. Therefore, to evaluate the radiation dose at a location near the beam-line one has to assume the radiation source point to be sufficiently up-stream of the point of interest. In the present case we assume that the beam is lost at about 7 - 8 m up-stream of the intersection of the two beam-lines. We have looked into two scenarios for beam loss : 1) point beam loss and 2) beam loss due to scraping. The latter acts as an extended source and gives rise to about an order of magnitude less radiation than the point source. Hence, only the results from the point source loss are presented here.

The 8 GeV beam-line is fairly straight in this region. There are two exits on both sides of the intersection; one is at about 36 m up-stream of the intersection and another is at about 57 m down-stream of the intersection (MI-8 Service Building with an alcove and labyrinth). We have estimated the radiation dose at the exits by carrying out Monte Carlo calculations using the code CASPEN (Ref. 2). The geometry of the whole problem is treated as a culvert. A schematic view of the geometry used in the Monte Carlo calculations is shown in Fig.3. By extrapolating the calculated results we have estimated the radiation levels in the tunnel near these exits to be far less than 1.0 mrem/accident. However, right under the intersection point we expect radiation levels over 5.0 rem/accident. The estimated radiation levels near the exits for different beam conditions are listed in Table I

Suggestions:

To avoid any accidental exposure of personnel to high radiation doses we suggest the following:

Temporary interlock gates can be installed near the exits. These gates will be secured when there is beam in the AP2/AP3 beam line. With this we can bring down the accidental radiation exposure to less than 1.0 mrem/accident.

Reference

1. H. Grote, R. Hagedorn and J. Ranft, 'Atlas of Particle Production Spectra'

2. V. A. Ginneken, Monte Carlo Code CASPEN

Table I. The maximum beam loss in AP2/AP3 beam line and the radiation dose in the 8GeV beam-line tunnel. The radiation doses presented here are obtained from Monte Carlo calculations with CASPEN2. (A continuous beam loss for one hour at a point in the beam line is taken to be an accidental beam loss).

Beam-line and Type of Beam	Max. Beam-loss /accident	Max. Rad. Dose near exits(mr/acc.)
AP2 beam-line, $\pi^- + K^- +$ anti-proton (Beam injection to Debuncher)	1.2E14	0.17 (A) 0.01 (B)
AP2 beam-line, forward protons (Beam injection to Debuncher)	3.6E13	0.085 (A) 0.001 (B)
AP3 beam-line, reverse proton (Beam injection to Accumularor)	3.6E13	0.085 (A) 0.001 (B)
AP2 beam-line, $\pi^+ + K^+ +$ protons(secondary) (Beam injection to Debuncher and proton staking)	1.2E14 *	0.17 (A) 0.01 (B)
AP2 beam-line,reverse proton (Beam from Debuncher towards pbar) Target	1E11	$\ll$ 0.001 (A) $\ll$ 0.001 (B)

A - Near the EXIT STAIRS, B - Near the Alcoves and Labyrinth, * - In this case the 8 GeV π^+ dominates over the K^+ or the secondary protons. The the number of secondary 8 GeV protons/120 GeV proton is about 3.5E-5. The maximum beam intensity on the pbar target is 4E12p/pulse @120 GeV (private communication with E. Harms Aug-1995).

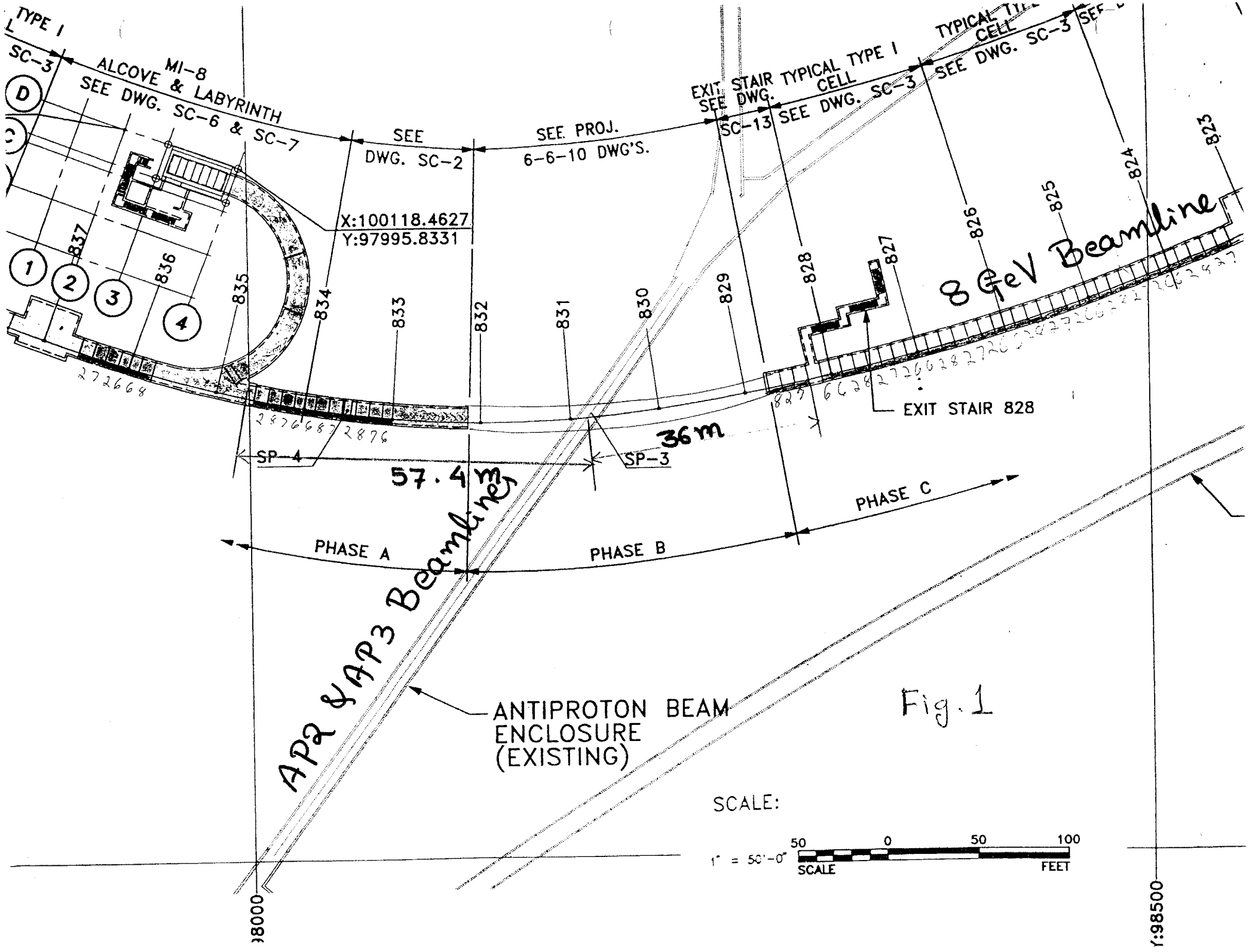
TYPE I
SC-3
MI-8
ALCOVE & LABYRINTH
SEE DWG. SC-6 & SC-7
SEE
DWG. SC-2
SEE PROJ.
6-6-10 DWG'S.
EXIT STAIR TYPICAL TYPE I
SEE DWG. SC-13
CELL
SEE DWG. SC-3
TYPICAL TYPE I
CELL
SEE DWG. SC-3
X:100118.4627
Y:97995.8331
D
C
1
2
3
4
837
836
835
834
833
832
831
830
829
828
827
826
825
824
823
8 GeV Beamline
EXIT STAIR 828
SP-4
SP-3
36m
57.4m
PHASE A
PHASE B
PHASE C
AP2 & AP3 Beamlines
ANTIPROTON BEAM
ENCLOSURE
(EXISTING)
SCALE:
1" = 50'-0"
50
0
50
100
SCALE
FEET
98000
Y:98500

Fig. 1

Standard Fermilab Geometry for the pbar Target and pbar Collection System

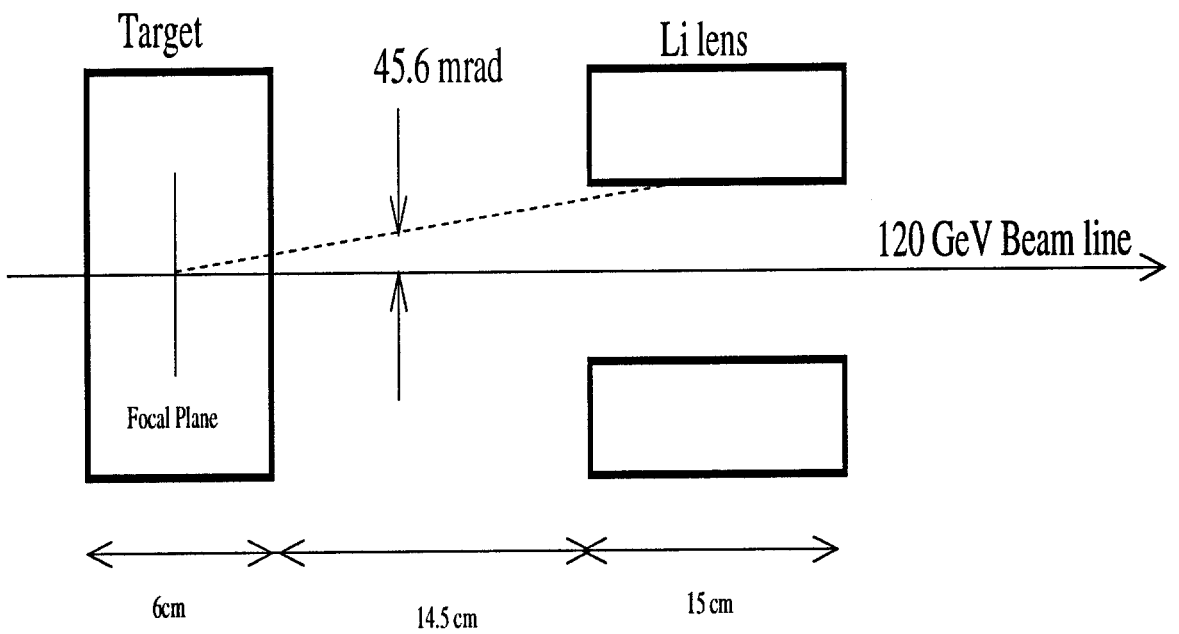

Figure 2: A schematic view of the pbar collection system. The 8 GeV pbar bending magnet is not shown.

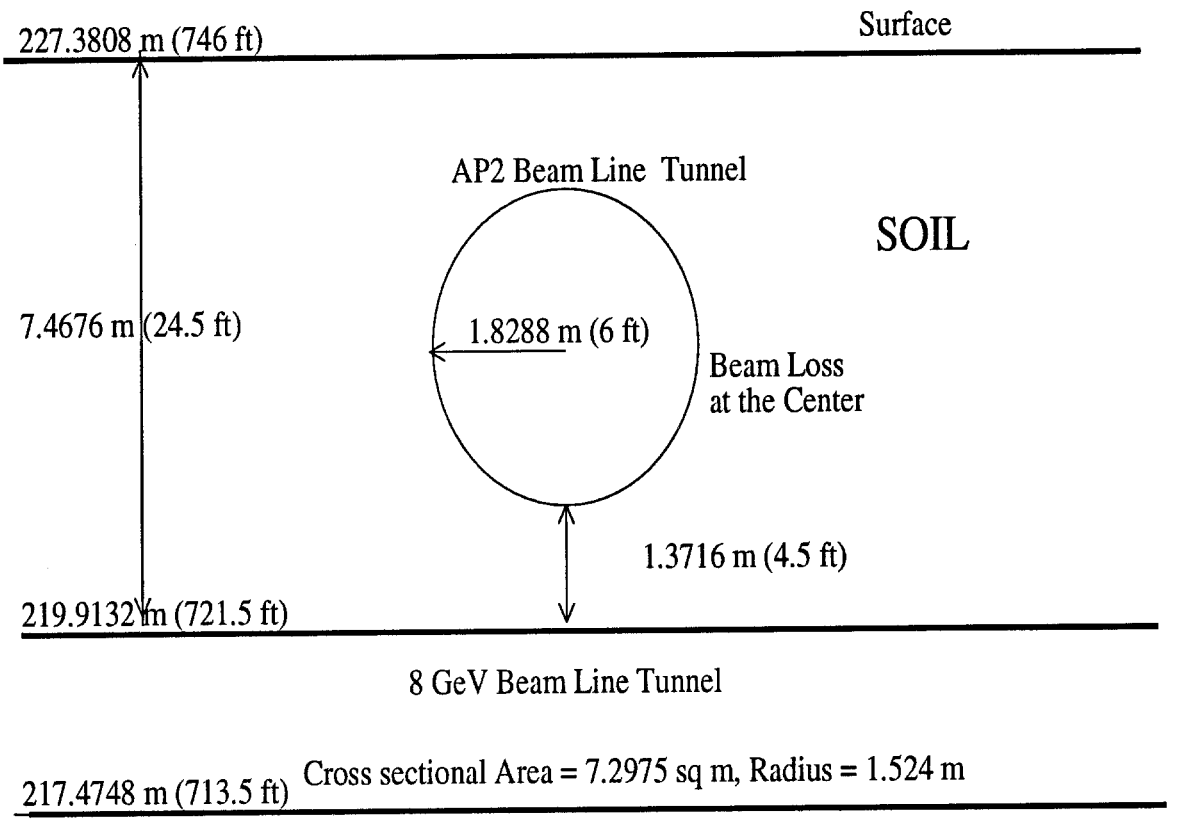

Figure 3: Geometry used in the Monte Carlo calculations to estimate the radiation dose in 8 GeV beam line tunnel due to an accidental beam loss in the AP2/AP3 beam line.

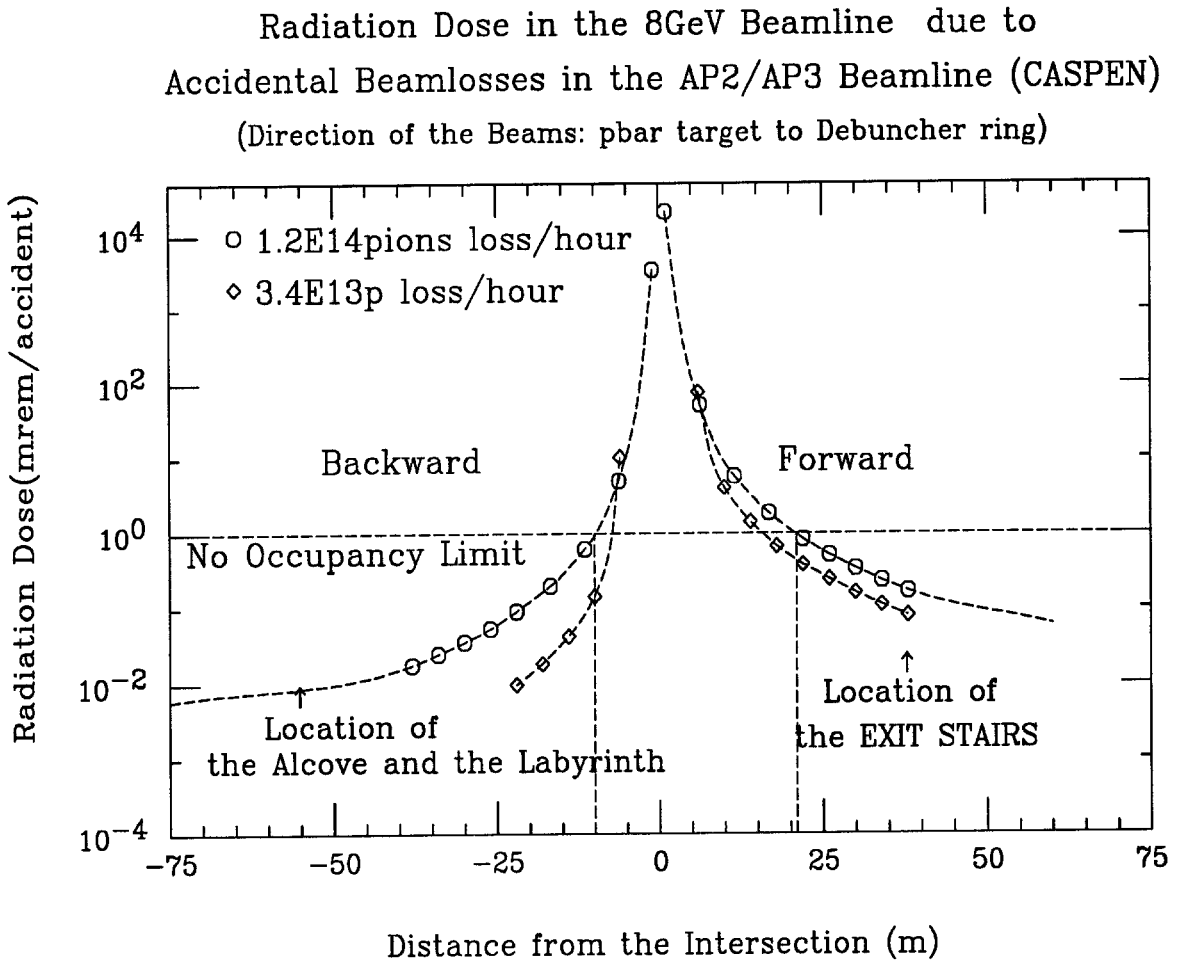

Figure 4: Results of the Monte Carlo calculations with computer code CASPEN for protons and pions. The locations of the EXITs (from the 8 GeV beam-line) which are on the both sides of the intersections are indicated by arrows. The origin is the point of intersection of two beam lines.