Fermilab

$\bar{p}$ Note #363

Muon Dose Rates Downstream of $\bar{p}$ Target Hall Due to Losses in the Main Ring and Saver

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Introduction

The muon dose rates in the area downstream of the $\bar{p}$ target vault due to accidental Main Ring or Saver losses are estimated in this note. Such estimates are useful in determining the personnel access conditions to the Tevatron I beam transport tunnels during operation of the Main Ring or Saver.

The geometry of the area, as shown in Figure 1, is of particular concern in that the pre-target hall is nearly tangent to the Main Ring. Muons from accidental beam losses could be directed along this hall, with a consequent reduction in the shielding between the loss point and the transport tunnels downstream of the target vault. The remaining soil and vault steel, while sufficient for the attenuation of hadrons has limited effectiveness for shielding muons.

Because of the complicated geometry, scaling is made of muon measurements, for a similar situation, within switchyard conducted on 1/12/84.[1]

Estimate of Doses

During the switchyard measurement a beam of 400 GeV and 1×10^{12} protons was intentionally lost (by turning off VH94) at a small angle (3.58 mr) on the Proton Lambertsons in ENCL B. Loss monitors were utilized to determine that the beam was lost on the first Lambertson. Four hundred and thirty feet along the tunnel there was 160′ of soil shielding between ENCL B and ENCL C. An ion chamber (Scarecrow) detector was placed on the downstream side of this soil, approximately one meter off axis, to measure the effective attenuation of the

magnets, tunnel and soil. The result was 1.5 mrem/3E13p.

Figure 1 compares the switchyard and pre-target Tevatron I geometries. The distance from the loss point to the detector in the switchyard measurement was 590′. For Tevatron I the distance from the magnet location EB4, downstream of the $\bar{p}$ dump, to its tangential loss point in the Main Ring is 630′. The small difference in distances will be scaled by a $1/r^2$ dependence. The Tevatron I tangential loss point in Main Ring, is 25′ upstream of the 120 GeV extraction Lambertsons for $\bar{p}$ production. Note that we are dealing with a loss at small angle into a magnet, as in the case of the switchyard measurement.

In the switchyard case the beam direction goes through 70′ (21 m) of magnets before it is clear of any steel shielding. For the Tevatron I case the beam passes through 47′ (14 m) of magnet and Lambertson steel before it is clear of the Main Ring arc. In either situation we have a significant amount of steel absorber close to the interaction point of the protons. We will compensate for the absorber length difference by scaling according to TM 630.[2] At 400 GeV the difference in attenuation of absorbers with 14 m and 21 m of steel is a factor of 3.3 determined from figure 3b. At 1000 GeV the difference in attenuation is a factor of 2.5 (figure 4b). To determine the difference at 150 GeV we first assume a power law dependence on energy so that;

$$\left(\frac{400}{1000}\right)^{\beta} = \left(\frac{3.3}{2.5}\right)$$

$$\beta = -.3030$$

Then

$$\left(\frac{150}{400}\right)^{-.3030} = \left(\frac{\chi}{3.3}\right)$$

$$\chi = 4.4$$

Hence the difference in the absorbers between the switchyard case and Tevatron I case is a factor of 4.4.

Downstream of the absorber we have as backstop shielding 160′ of earth in the switchyard case, and 70′ of earth plus 35′ steel in the target vault (for an equivalent of 190′ earth) in the $\bar{p}$ case. These are essentially equivalent for muon shielding.

In order to scale with the energy of the primary protons we will also utilize the results of TM 630.[2] From the switchyard measurement [(1.5 mrem/3E13)(28080 μ/cm^2/mrem) = 1.4E-9 μ/cm^2/p] and TM630 figure 5b we find an effective shield thickness of 120 meters of soil at 400 GeV and one meter off axis. From figure 6b for 120 meter of soil but 1000 GeV and one meter off axis we get 1.0E-8μ/cm^2/p. Assuming a power laws relationship we determine

$$\left(\frac{1000}{400}\right)^{\alpha} = \left(\frac{1.0E-8}{1.4E-9}\right)$$

$$\alpha = 2.2$$

Combining all of these factors we find

$$\left(\frac{3E13p}{pulse}\right)\left(\frac{1.5\ mrem}{3E13p}\right)\left(\frac{590}{630}\right)^2 (4.4)\left(\frac{150}{400}\right)^{2.2} = .67\ \frac{mrem}{pulse}$$

at 150 GeV and 3E13p/pulse. We note that the Main Ring has been altered such that 400 GeV Main Ring only is no longer an operating mode.

For the case of doubler operation at 400 GeV and 1000 GeV the absorber length is now 30′ (9 m). We then scale these to the switchyard case of 70′ (21 m) by figures 3b and 4b of TM 630 for factors of 6.7 and 5.0 rspectively. Then for a loss at 400 GeV we have:

$$\left(\frac{3E13p}{pulse}\right)\left(\frac{1.5\ mrem}{3E13p}\right)\left(\frac{590}{630}\right)^2 (6.7)\left(\frac{400}{400}\right)^{2.2} = 8.8\ \frac{mrem}{pulse}$$

and 1000 GeV

$$\left(\frac{3E13p}{pulse}\right)\left(\frac{1.5\ mrem}{3E13p}\right)\left(\frac{590}{630}\right)^2 (5.0)\left(\frac{1000}{400}\right)^{2.2} = 49\ \frac{mrem}{pulse}$$

Conclusion

We list the dose rates under various assumed intensity energy, and repetition rates in table I. For the doubler, a point loss would terminate further operation and we assume that an accident would consist of one pulse. For accident conditions restricted access is permitted for up to 500 mrem/hour and normal access to a radiation area is permitted for up to 100 mrem/hour.

Table I

	Energy	Intensity	Cycle Time	Dose Rate
			MAIN RING	
1	150 GeV	3E12	2 sec	121 mrem/hr.
2		3E13	6 sec	402 mrem/hr.
3		3E 13	1 min	40 mrem/hr.
4		3E13	10 pulses	6.7 mrem/hr.
			TEVATRON	
5	400 GeV	3E13	1 pulse	8.8 mrem
6	1000 GeV	3E13	1 pulse	49 mrem

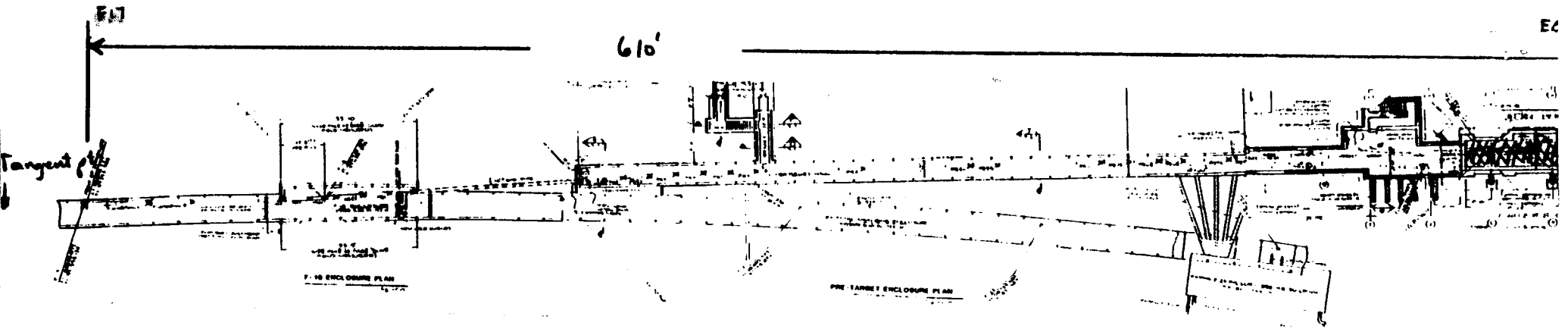
References

1) Memo to Interlock File from P. Yurista 1/12/84.

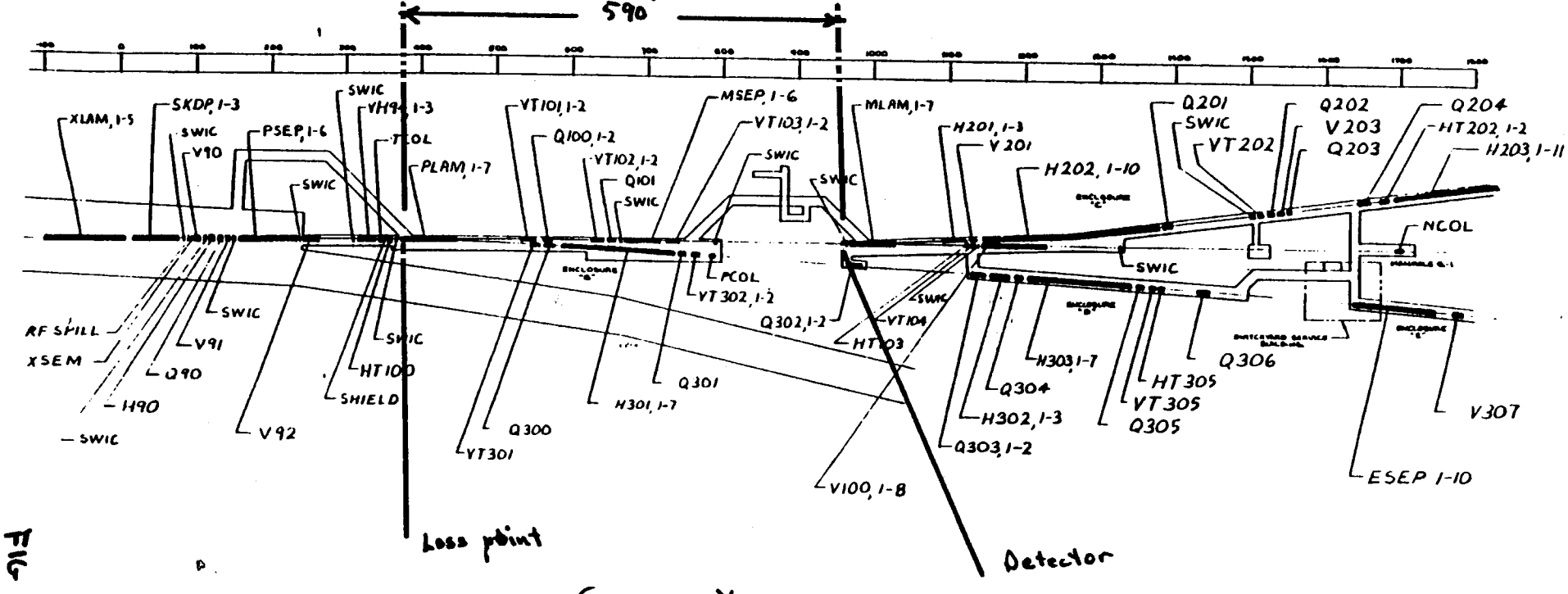
2) TM 630 "Penetration of Prompt and Decay Muon Components of Hardonic Cascades through Thick Shields", A. Van Ginneken 11/15/75.

Figures

1) Physical geometry's of Switchyard measurement case and Tevatron I loss case.



TEVATRON I CASE



SWITCHYARD CASE

FIG 1