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M4 Beam Line Cable Penetration Evaluation

The purpose of this document is to evaluate the efficacy of the thirty, 6 inch diameter penetrations to be installed between the M4 beam line and the Detector Hall Power Supply Room. The basis for this evaluation is the penetration layouts given in the Mu2e Conventional Facilities drawing set [1].

Three penetration layouts are given in Sheet S-6, S-7, and S-8 of Reference 1. Two possible layouts are given in each of the drawings, one with two 90 degree bends and one with one 90 degree bend. The preferred configuration [2] is the layout with just one 90 degree bend. Only the one bend configuration is considered in this document. It will be necessary to make a slight bend in leg 1 in order for the penetration axis to be normal to the enclosure wall surface on each end [2]. No credit is taken for the curvature of the first leg. The dimensions of penetrations from the preferred configuration at the three locations are listed in Table 1. If the penetration layout from drawing S-6 is found to be adequate, no further consideration of the penetrations on drawings S-7 and S-8 would be required.

Drawing	# of bends	Diameter	Leg 1 length	Leg 2 length	Angle of Leg 1 axis wrt wall surface [2][1]	Angle of bend
S-6	1	0.5	23.375	10.5	90	90
S-7	1	0.5	29.729	10.5	90	90
S-8	1	0.5	29.729	10.5	90	90

Table 1: Penetration dimensions for M4 beam line 6 inch diameter penetrations. All dimensions are in feet or degrees.

The source term for the beam loss at the entrance to the penetrations must be determined. The Mu2e experiment beam power transported through the M4 line is to be 8 kW. In the preliminary design, Total Loss Monitors (TLMs) are planned to be used in the M4 beam line [4]. The protection level is to be based upon limiting residual radioactivity levels to 1 W/m. The total length of the M4 beam line is approximately 276 meters. Since 2 TLMs are planned to be used, the trip level will be based upon a total loss of 138 Watts. The TLM does not distinguish single point losses from distributed losses, so the worst case beam loss permitted by the TLM system would be 138 Watts at a single location. At 8 GeV, this is equivalent to a beam loss of 1.08E11 protons per second.

The method for the dose attenuation calculation is taken from Reference 3. A spreadsheet based upon Reference 3, included as an attachment to this document, requires a description of

[1] While the angle the penetration makes with the surface of the enclosure wall is listed at 90 degrees, the angle to be entered on the penetration dose attenuation worksheet is the angle of the penetration opening with respect to the penetration axis. In this case, the value is 0 degrees.

the source term as depicted in Figure 1. Required parameters for the source term description are listed in Table 2. The radius R is determined from the beam enclosure layout shown in the Conventional Construction Drawing, S-6. The distance d, is derived by determining the location of the worst case beam loss relative to the penetration. In the 1998 MI shielding assessment [5], it was determined that the peak of the shower resulting from a beam loss occurs at a horizontal angle of 70 degrees relative to the incident beam direction. Thus, the Sullivan angle is set to 70 degrees and one can solve for d:

$$d = \frac{R}{\tan(70^o)}$$

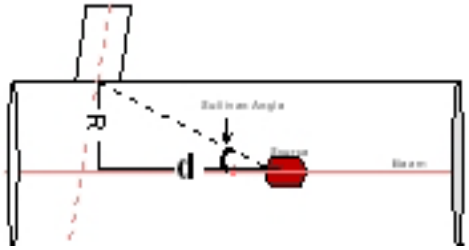

Figure 1: Generic source term input parameters

Proton Energy	8 GeV
Protons per second	1.08E11
Pulses per hour	3600
R	6.25
d	2.27
Sullivan angle	70 degrees

Table 2: Source term parameters for spreadsheet input

The resulting dose rate at the exit of leg 2 of the penetration illustrated on S-6 is 1.56E-3 mrem/hr, indicating the penetration design is acceptable. The calculation assumes the penetration is empty. No additional treatment of the penetration (e.g., poly beads) is required. Penetrations illustrated in sheets S-7 and S-8 are acceptable as well.

References

1. Conventional Construction Drawings, Mu2E Document 472-v8, T. Lackowski, November 2, 2012
2. Private conversation, Jim Budlong, November 20, 2012
3. RP NOTE 140, Dose Attenuation Methodology for NuMI Labyrinth, Penetrations, and Tunnels, K. Vaziri, May 2003

4. Mu2e Conceptual Design Report, Mu2e Document 1169-v19, R. Ray, et. al., November 16, 2012
5. Shielding Assessment of the MI Complex, Beams Document 336-v1, C. Bhat, et. al., September 1998