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Memo

date: *October 9, 2008*

to: *RSC EBIS File*

from: *Dana Beavis*

subject: **Cable Penetrations into Booster for EBIS**

Three five-inch diameter penetrations are proposed for cabling to run from the Linac service building to the Booster enclosure (see fig. 1). The concrete that is in this location will be core drilled and the penetrations will be approximately two feet above the beam height in the booster.
The potential dose rates out these penetrations will be examined in this note.

Sources

There are two potential source of radiation for the penetrations. The injected Linac beam or the Booster beam can have losses in the vicinity of these proposed penetrations. The TTB injected beam energy is sufficiently low that the potential for radiation is well below the cases considered for the Linac and Booster energies.

The Maximum allowed Linac beam for injection to stay below the Booster ASE is $2.7*10^{18}$ protons per hour at 0.2 GeV. The maximum Booster beam operating at the ASE is $2.7*10^{17}$ protons per hour at 2 GeV. The potential dose rates out the penetrations will be examined for full beam loses with the Booster operating at the ASE.

The Booster typically operates well below the ASE with low intensity ion beams and polarized protons. C. Gardner has provided a list[1] of typical operating intensities for ions and polarized protons. An intensity of 10^{12} nucleons per second is a very conservative upper limit with values mostly a factor of 10 or more smaller.

Beam Dose to the Penetrations

The dose calculated by A. Stevens[2] for a proton beam striking an iron target at 200 MeV, 1 GeV and 5 GeV will be scaled to obtain the dose rates per lost proton at the penetration in the booster. For the Linac beam the dose rate is estimated to be $5*10^{-14}$ rem/p and for the booster beam at 2 GeV the dose rate is $1.6*10^{-12}$ rem/p. The Booster number needs to be multiplied by 0.39 to provide the dose per proton at the correct distance. Similar numbers can

be obtained using curves in Sullivan[3] and other sources. The dose rates are based on an optimum loss. Typically, the loss is distributed and there is self shielding. A factor of 0.1 will be used to account for the self shielding of the source and the distribution that occurs for more realistic beam losses.

Attenuation of Dose in the Penetration

The attenuation of the radiation after it transverses the length of the penetration reduces the dose rate into the Lianc building substantially. Figure 2.25 of Sullivan provides a simple estimate of the attenuation factor for penetrations with different length to transverse dimensions as a function of the angle of the radiation to the penetration axis. For Booster beam losses the angle is about 14 degrees and for Linac beam losses it would be 27 degrees. Using the length as 177 inches we obtain a ratio of the length to transverse size of 40. Using 15 degrees and adjusting for the smaller pipe diameter than used for the figure the attenuation of the penetration would be $6*10^{-4}$. This does not take into account any material inside the penetration, which would provide additional attenuation.

Another means to estimate the attenuation is to use the formulation of Goebel[4] for the first leg of a labyrinth. The Goebel formula would give an attenuation of $2*10^{-5}$. These two simple methods probably provide an upper and lower bounds on the attenuation for the penetration.

Dose Rate Estimates

Using the conservative estimate for routine operations of 10^{12} protons per second with all the lost near the EBIS penetrations at 2GeV the exit dose rate from the penetration is:

130 mrem/hr using the curves of reference 3 and
4 mrem/hr using the Goebel formula.

Normal losses at 2 GeV would be expected to be a factor of 10 to 1000 times lower.

The potential dose rates from the Linac injection line will be lower due to the lower energy with comparable intensity per cycle.

If the Booster operates at the ASE and the entire beam is lost in the vicinity of the penetrations the estimated dose rate out of the penetrations is 10 rem/hr using reference 3 and 300 mrem/hr using reference 4. The Linac could produce essentially the same levels due to the allowed higher beam per cycle, although this is not realistic.

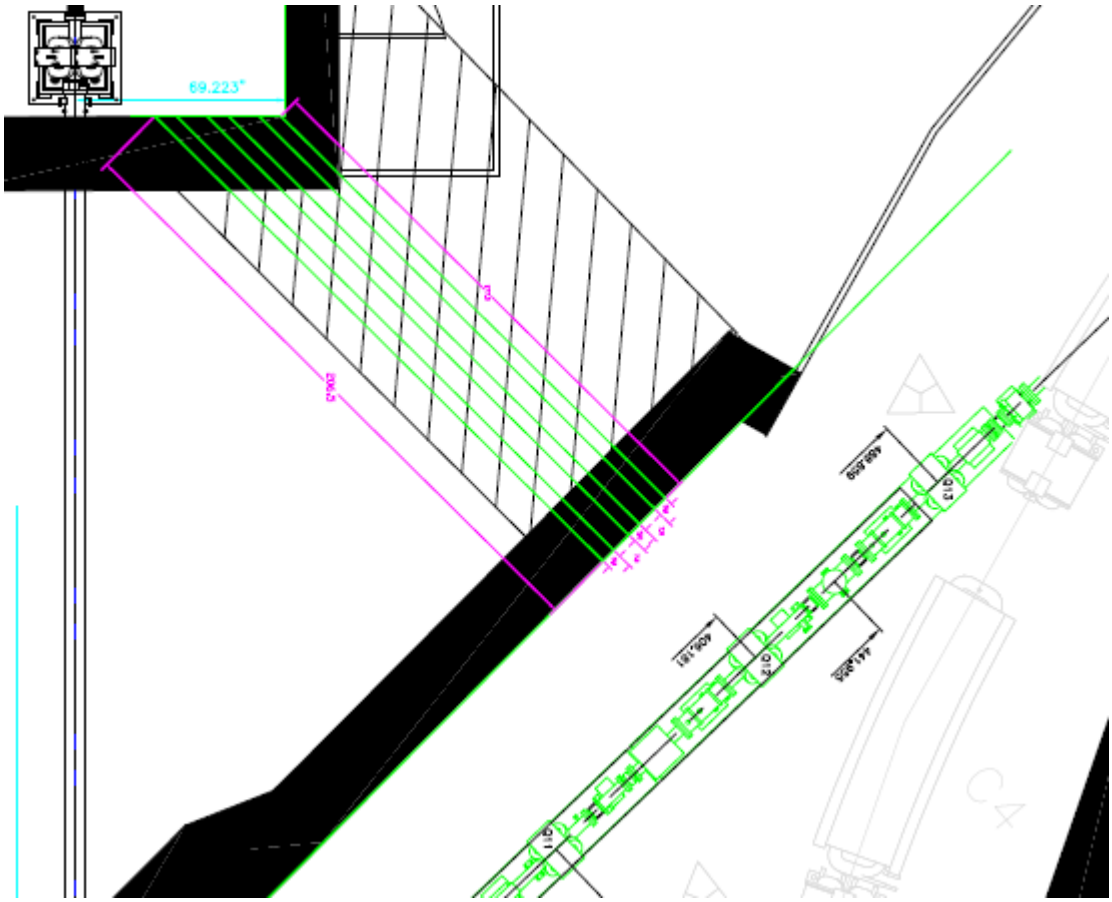

Figure 1: Proposed layout of penetrations for EBIS

References

1) C. Gardner to D Beavis e-mail of Oct. 3, 2008.

2) A. Stevens to D. Beavis (see RSC file).

3) A.H. Sullivan, A Guide to Radiation Protection and radioactivity Levels Near High Energy Accelerators, Nuclear technology Publishing, 1992.

4) K. Goebel et al., CERN LABII-RA/Note/75-10 (1975).