Collider-Accelerator Department

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Memo

date: *June 3, 2010*

to: *RSC*

from: *D. Beavis* DB

subject: *ATF Modifications*

A very simple set of modifications for the ATF transport has been proposed. The ATF requested that people experienced with shielding modifications examine the modifications.

The proposed modification was to move a Pb shield 6 inches downstream of its present location and to move a sextapole from downstream of the Pb shield to upstream of the Pb shield. In addition, borated poly blocks had been used to support a portion of the PB shield. ATF wanted confirmation that this was not shielding but just mechanical support. I have requested that P.K. Job, E. Lessard, and R. Karol serve with me as a small subcommittee to review the issues. The Pb shield is about one meter downstream of D2 which is the first dipole in the experimental hall. Downstream iof the beam line are two bends for two experimental beam areas as well as distributed beam optics, instrumentation and Pb shields.

I am in total agreement with the ATF personnel's assessment that the poly blocks under the Pb shield is for support and does not serve a shielding function. This conclusion does not require justification.

I concur that the moving of the Pb shield by six inches does not comprise the present shielding design. Justification is given below.

There appears to be some errors in the radiation analysis in the appendix of the SAD. It is suggested that the analysis be check in the near future and any errors or misconceptions corrected.

Justification and Details

The Pb shield is comprised of two PB bricks with dimensions 4-inch by 2-inch by 8-inch . A rectangular notch has been made in each brick and the are clam-shelled around the beam pipe. To simplest order this creates a cyclinder of 1 inch diameter hole with 1 inch wall thickness of pb and 8 inches long. The beam line starts with a dipole and then has a plunging beam profile (BPM)monitor which scatters the electron beam when inserted for measurements. This is followed by a quadrupole and in the present configuration the PB shield. No documentation on the specific location for the Pb shield has been provided. The dipole could cause scrapping anywhere along the beam pipe including downstream of the Pb shield. It is reasonable to assume

the shield primary purpose of the Pb shield is reduce radiation from the BPM and any scrapping of the beam in the quadrupole.

The Pb shield covers an angular region of 2.3 to 7.1 degrees for the present configuration. Larger angles are shielded by the quadrupole. In the new configuration the angles covered by the Pb shield are 1.9 degrees to 5.2 degrees. Larger angles are covered by the sextapole and the quadrupole. Smaller angles in both cases are covered by downstream optics components and additional Pb shields. This move of the shield is not expected to impact the shielding design based on these simple observations.

The Accelerator Safety Envelope (ASE) for ATF has an upper energy of 120 MeV for the electrons. The present equipment has an upper energy limit of 85 MeV. For 85 MeV on a thick target the forward radiation[1] at 3.5 degrees is 20% of the zero degree value. Thus a fair percentage of the forward bremsstrahlung radiation strike either design.

We can look at the over scale of the radiation issues by using the thick target radiation formulas, the Tenth-Valued Layer (TVL) numbers for the various shielding, and the dimensions.

We will consider 85 MeV as the electron primary energy. The ASE has a maximum beam current of 600 nano-amps but the SAD mentions that the experimental areas are only approved for 60 nano-amps. Thus we will examine the 60 nano-amps and the numbers can always be scaled. The beam power is therefore approved for a maximum of 5.1 Watts in the experimental area. Lower beam energy can be operated and the shielding issues will be determined by the highest energy.

Radiation from Gammas

The dose rate for forward and transverse gamma radiation is given in reference 1 figure 3.5 for thick targets. The following are the dose rates for gammas for 5.1 watts at 1 meter:

Angle (degrees)	Dose rate at 1 meter (rad/hr)
0	20,400
90	25.5

The layout drawing ATF-410.002-001 has the ouside of the shield wall as 15.2 meters from the plunging BPM. The distance through the concrete is 3.8 meters for the zero degree gamma rays. The TVL for light concrete[2] for 85 MeV is 46 cm. A dose rate outside the shield of 0.5 microrads per hour is obtained in the forward direction for a continuous full beam fault at the BPM. In the transverse direction the distance to the outside is 2.8 meters and there is 150 cm of concrete so that the results full beam fault would produce 1.8 mrem/hr.

The BPM after D2[3] is ¼ inch of Al with a phosphor on the surface. Others have an additional ¼ inch of glass\. The BPM is 45 degrees to the beam and typically placed into the beam for 1 minutes to make profile measurements. The average energy loss[4] in the ¼ inch of Al is 8 MeV for the 85 MeV electron beam. Much of this beam will aperture in D4. Thus it is useful to examine a full beam fault in D4. Using the same method as described above the dose rate outside

the shielding for a full beam fault on D4 would be 2 microrad/hr at 0 degrees and 6.2 mrem/hr at 90 degrees. The gap in D4 is packed with PB and no credit has been taken for the shielding it would provide.

The gamma dose rate out the roof can also be estimated. The distance to the outside of the shield is estimated to be 5.5 ft or 1.6 meters. The SAD reports the roof to be 1.25 feet of concrete. Thus for a full beam fault of 85 MeV electrons at 60 nano-amps a dose rate or 1500 mrad/hr is estimated. A one minute fault could provide a dose of 25 mrad to someone on the concrete roof. This is not affected by the modifications presented here. Most thick targets along the beam line have steel and Pb to help provide shielding. To obtain a more realistic dose rate for the roof the details of the potential thick targets would need to be examined more carefully. The TVLs for steel and Pb are 11 cm and 4.3 cm respectively. Thus one quickly reduces the gamma rays with a few inches of either material.

Radiation from Neutrons

The potential dose from neutrons can be estimated in a similar fashion. The yield of neutrons[5] from 85 MeV electrons hitting an Fe target is $7*10^{11}$ neutrons/(s-kW). For 5.1 Watts the neutron dose[6] rate at 1 meter is $8.3*10^{3}$ mrem/hr. The estimated dose rate out the side wall near D4 is estimated[7] to be 1 mrem/hr for a full beam fault. The roof is estimated to have a dose[7] rate of 660 mrem/hr.

Comments

The Appendix of the SAD should be revisited on a short time scale and corrected for any errors or misconceptions. More detailed analysis could be done as needed to examine the issues. There may be a few weak locations to the shielding, which I am not sure are addressed in the SAD. For example, the building structure represents a weak spot in the shield at several locations and I do not recall it being discussed. There appears to be a weak location in the side wall shielding upstream of D2 although it is small in area.

No specific radiological issue was identified for the configuration change that has been proposed. The roof appears to have high levels when there are large faults but I do not know the access requirements for the shielding roof. There were no cross-sectional views to examine the experimental area for weaknesses in 3-dimensions. The side walls were assumed to be uniform thickness in height.

The administrative controls to limit beam were not clearly depicted in the SAD. This analysis assumed 60 nano-amps at 85 MeV. The numbers can be scaled as needed.

References

1. Radiation Protection for Particle Accelerators Facilities, NCRP Report No. 144, National Council on Radiation protection, 2003. See figure 3.6.

2. Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerators Facilities, NCRP Report No. 51, National Council on Radiation protection, 1977. See figure E.12 The equilibrium number has been assumed.
3. Inspected on June 3, 2010 to determine which type. Also see the description in the ATF SAD dated March 1, 2010.
4. See the electron stopping power tables at the NIST web site. At 85 MeV the stopping power is 4.96 MeV/(gm/cm^2) in Al. The numbers given in the ATF SAD are not correct.
5. See figure 3.12 of reference 1.
6. A flux to dose rate conversion of 1n/cm^2-s=0.295 mrem/hr.
7. Figure 4.8 of reference 1 has been used to estimate the attenuation of the shielding.

CC: M. Zarcone
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RSC ATF file