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Memo

date: *November 15, 2011*

to: *RSC, L. Syndstrup*

from: *D. Beavis*

subject: *Shielding for 10 MeV Electron Beam Dumps*

Simple estimates are provided for the radiation shielding for 10 MeV beam dumps for eRHIC. I will use figures and tables for this guidance from well established references. I will be a bit sloppy in this first pass and typically not worry about rounding numbers. If more details are needed we can make a second pass and refine the estimates. I assume that these estimates will be sufficient for cost estimates for the conceptual design. Finally, we can run Monte Carlo simulations if more details are required.

Radiation Source

The beam parameters provided where a beam power of 500kW and a maximum electron energy of 10 MeV. The absorbed dose from Figure 3.5 of reference 1 is used to estimate the transverse and forward radiation. I estimate:

Angle degrees	Dose (rads/hr per kW at 1 meter)
0	$3*10^5$
90	10^4

I will now scale to 1 foot and use the 500 kW of power to arrive at the dose from a thick high Z target:

Angle degrees	Dose (rads/hr) at 1 foot
0	$1.5*10^9$
90	$5.*10^7$

Using a high Z material makes the numbers conservative if a lighter material such as copper or steel is used for the beam dump.

Shielding and Area Requirements

The source term requires that the area that contains the dump must be excluded of personnel and have dual interlocks. The amount of shielding that encloses the area with the source must have sufficient shielding to meet the access requirements for the adjacent area outside the shielding. It is reasonable to assume that the area outside the shielding will be a Controlled Area with 10% expected occupancy. An upper limit of 0.5 mrem/hr for the dose rate would then be allowed. Higher dose rates could be allowed if a TLD was required.

This establishes the desired attenuation in the forward direction and in the transverse direction. This attenuation is achieved from a combination of shielding and distance. For the adjacent area discussed we are looking for a total reduction in radiation of:

Angle degrees	Total attenuation
0	$3.3*10^{-13}$
90	10^{-11}

The source is a "point" source and $1/R^2$ scaling can be used for distance. The material used for shielding can be described by broad beam attenuation factors[2] often expressed in tenth value layer (TLV). The total attenuation, att, is then approximated by :

$$Att = 10^{-(D/Mtvl)}/(R^2) ,$$

where D is the thickness of the material, M_{tvl} is the tenth value layer for the material in the same units as D, and R is the distance to the outside of the shielding from the source in feet. When several shielding materials are used then D and M_{tvl} are used for each layer and a product of the factors is formed.

Shielding

The TVLs for common materials can be found in many references. For the purposes of this note the values from Figure 4.1 of reference 1 are used. A crude estimate for soil can be obtained by scaling the light concrete value by the ratio of the densities[3].

Material	**Density (g/cc)**	**TVL (gm/cm^2)**	**TVL (cm)**
Pb	11.35	65	5.7
Fe	7.87	81	10.3
Concrete	2.35	95	40.4
Soil	1.8	95	52.8

A soil shield 16.5 feet thick would be required to shield the beam dump in the transverse direction. A shield of 2 feet of Pb would provide the same protection. In both cases an extra

distance of three feet was assumed. Using the formulas and numbers given above it is easy to estimate the shielding for any desired configuration. The most likely configuration is a dense shielding material used as part of the dump (local shielding) and the remainder of the shielding would be part of the enclosure (tunnel) shielding.

The amount of local shielding is established by reducing the dose from the beam dump into adjacent machine equipment and addressing potential activation issues. Therefore, one needs to establish the minimum thickness of the local shielding to protect local accelerator components and instrumentation. The beam transport will have routine beam losses and potential beam faults that determine the minimum thickness of the perimeter shield, which will also serve as shielding for the beam dump.

Other considerations that go into the design of the beam dump shield design are cooling water activation, air activation, soil activation, ozone generation, and the residual activation of the dump, which workers may have to work near during maintenance periods. All of these considerations are reduced if the quantity of local shielding is increased.

It is recommended that the impact of the potential x-rays be considered on local equipment to the first estimate of the desired minimum local shield thickness. The choice of local materials should be done to provide the best performance of dump cooling. At 10 MeV activation by photo-production and neutrons is low. As an example the neutron thresholds from photo-production in Cu are 10.84 MeV for ^{63}Cu and 9.91 MeV for ^{65}Cu. Figure 23 of reference 4 demonstrates that the neutron yields are very low at 10 MeV. It is therefore expected that activation is not an issue for air, water or soil.

The x-rays can result in substantial ozone production around the beam dump. This can be estimated once the local requirement for protecting equipment from the x-rays is determined.

References

1. Radiation Protection for Particle Accelerator Facilities, NCRP Report No. 144, National Council on radiation protection and Measurements (2003).
2. The broad beam attenuation factor used in this manner should provide a conservative estimate for the shielding when used in the fashion described. When the source is close to the shielding the estimate will be more conservative then when far away.
3. The density used for BNL soil will be 1.8 g/cc and the density of light concrete will be 2.35 g/cc.
4. Radiological Safety Aspects of the Operation of Electron Linear Accelerators, IEAE Technical Report No. 188, International Atomic Energy Agency Vienne, 1979

CC:

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eRHIC file
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