

## SHIELDING OF THE CBETA ELECTRON DUMP

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### 1. INTRODUCTION

The initial shielding of the ERL dump was described in a note "Notes on CBETA Dump Shield" dated March 5th, 2019. In that note the primary concern was to minimize the radiation downstream from the dump as the electron beam entered the FFAG arc on the East side of LOE. Accordingly, the entrance into the dump in LOE was not shielded. In retrospect this was a mistake as it was found that radiation emitted by the dump in the "upstream" direction into LOE causes gamma radiation monitors to set off at electron currents  $> 10\mu A$ . Also, the actual shielding configuration in the previous note does not reflect the actual shielding as implemented and the calculations described below take this into account and include addition shielding at the entrance to the dump that was not present in the previous note.

### 2. SHIELDED ERL DUMP

The MCNP6 input geometry for the shielded dump is shown in figure 1. The

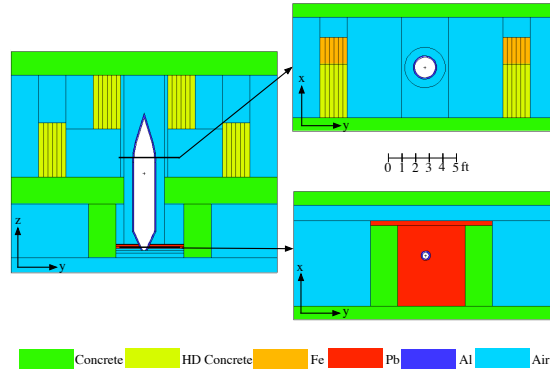


FIGURE 1. MCNP6 input geometry for the shielded dump. The cross sections at two positions are shown.

shielding consists of a labyrinth made from high density concrete ( $244 \text{ lbs}/\text{ft}^3$  or

3.91  $gm/cm^3$ ) 4' x 4' x 2' blocks on top of which are stacked two rows of 1' x 1' x 1' steel blocks. 32" wide entrance and exit openings provide access to the dump. Additional lead shielding at the entrance to the dump is shown in red. The Pb shielding consists of standard 8" x 4" x 2" lead bricks, stacked so that the long (8") direction is along the beam direction. (If the volume to be shielded is 67" x 72" x 8" or 34,560  $in^3$ , and the volume of a lead brick 64  $in^3$ , then 540 bricks are needed.)

The gamma dose rate contours are shown in figure 2. Figure 3 shows a more

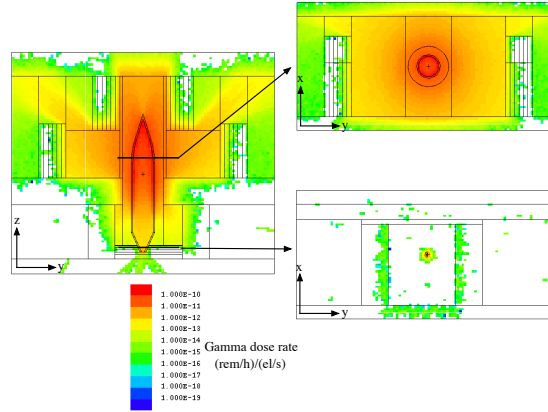


FIGURE 2. Gamma dose rate contours in the planes shown in figure 1.

detailed view of the gamma dose rate in the plane of the electron beam and outside the lead shield shown in figures 1 and 2. As can be seen, eight inches of lead block the radiation completely except in the vicinity of the dump entrance. Figure 4 (provided by Dave Burke) shows the entrance to the beam dump with a row of lead shielding blocks inserted. (The space around the dump cone in the red rectangle in figure 4 will have to be filled with smaller bricks and/or lead shot.)

### 3. CONCLUSION

The 6 MeV electron energy bremsstrahlung end point is well below the 13.06 MeV threshold for the  $^{27}Al + \gamma \rightarrow ^{26}Al + n$  reaction so that neutrons are not generated in the dump. (For 6061 aluminum, none of the listed impurities <sup>1</sup> have Q values less than 6 MeV <sup>2</sup> ) Figure 5 shows bremsstrahlung spectra produced by 6 MeV electrons incident on 2.5 and 10 mm thick sheets of aluminum. The radiation emitted in the

<sup>1</sup><https://www.aluminum.org/sites/default/files/Teal%20Sheets.pdf> "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys", Teal Sheets, 200815

<sup>2</sup><https://www.nndc.bnl.gov/qcalc/>

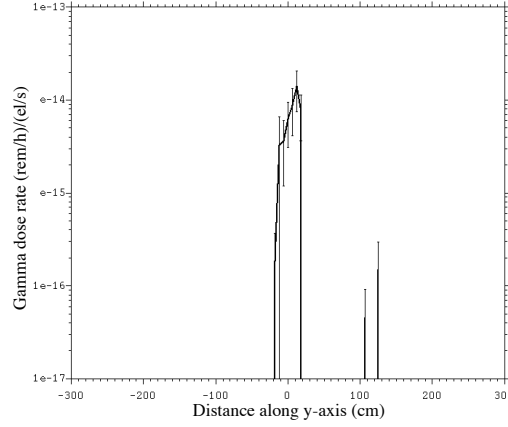


FIGURE 3. Gamma dose rate just outside the lead shield shown in figures 1 and 2.

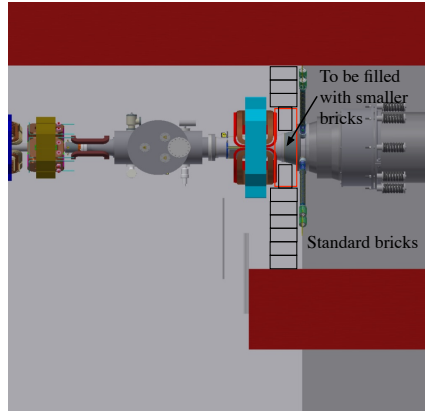


FIGURE 4. Entrance to the ERL beam dump with a suggested position of lead shielding blocks indicated.

forward direction is labeled "Front" while that in the backward direction is labeled "back". The bremsstrahlung emitted in the backward direction is due to the electrons hitting the collector as shown in figure 6. Accordingly, 8" of lead should be enough to shield the dump collecting 40 mA, 6 MeV electrons.

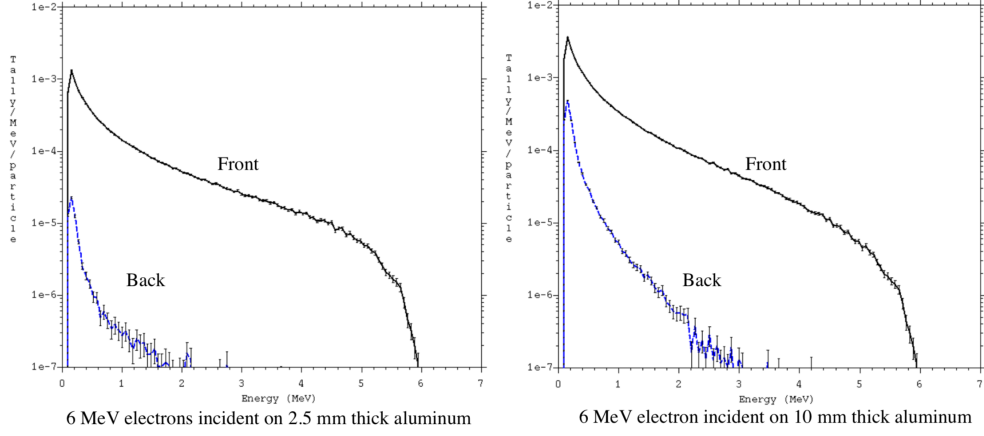


FIGURE 5

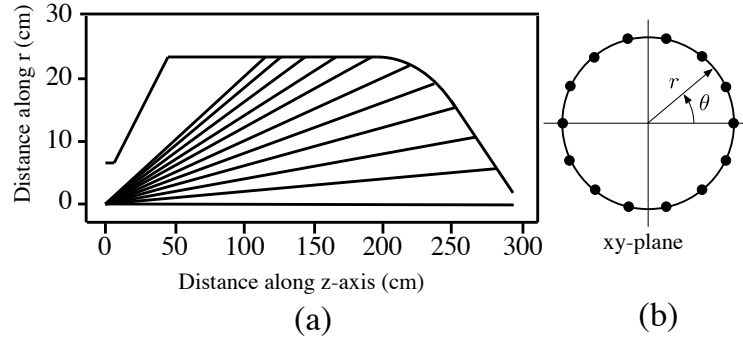


FIGURE 6. (a) Shows 11 different positions where the electron beam strikes the collector and (b) shows 14 different angular positions for each position shown in (a).

The attenuation coefficient of air between 0.4 and 6 MeV ranges from  $9.562 \times 10^{-2}$  to  $2.523 \times 10^{-2} \text{ cm}^2/\text{g}$ . <sup>3</sup>If the gamma detector located approximately 100 ft from

<sup>3</sup><https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html> and assuming that the composition of air is  $N_2$  78.09%,  $O_2$  20.95%,  $Ar$  0.93%,  $CO_2$  0.04% and  $H_2O$  1.00%.

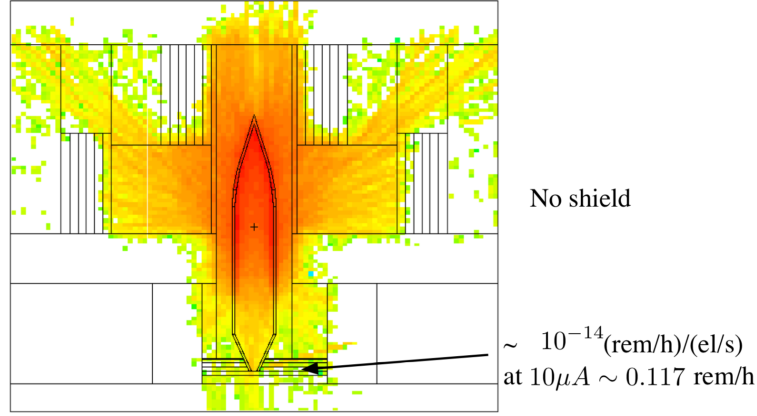


FIGURE 7

the dump was set off, then  $100 \text{ ft} = 3048 \text{ cm}$  and taking the air density as  $1.205 \times 10^{-3} \text{ g/cm}^3$  and the attenuation coefficient as  $9.562 \times 10^{-2} \text{ cm}^2/\text{g}$ , the thickness of air is  $3.67 \text{ g/cm}^2$  and the radiation reaching the detector is reduced by a factor of  $e^{-0.09562 \times 3.37}$  or 0.70. The higher energy gammas are reduced by less.

An MCNP6 calculation with no shielding in front of the dump, i.e. the present configuration, shows that the dose rate is around 117 mrem/h at  $10 \mu\text{A}$ . See figure 7, thus 82 mrem/h would easily set the detector off if set to 2.5 mrem/h.