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Notes on CBETA dump shield

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CBETA Tech Note 41
March 5, 2019

NOTES ON CBETA DUMP SHIELD

V.O. KOSTROUN

1. Introduction

Tho location of the CBETA electron dump is shown in figure 1. The dump is in a location that is inaccessible to the overhead crane so that it cannot be shielded by large shielding blocks. In this note, the radiation field produced by a 1 mA, 6 MeV electron beam collected by the dump is investigated and a possible shielding arrangement proposed. The radiation field was calculated using the code MCNP6 [1].

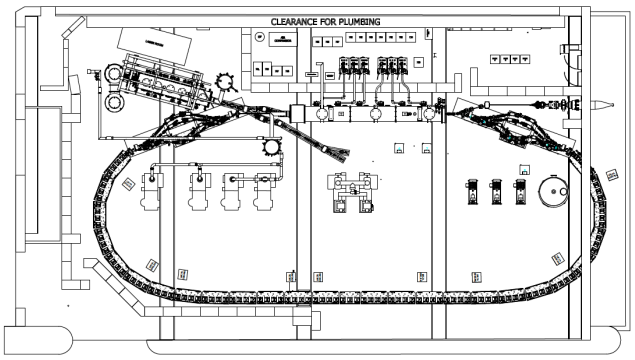

Figure 1. CBETA Layout (File 7200-000, dated 8/20/2018). The position of the CBETA electron dump is as indicated.

2. Overall geometry

On 11/5/2018 Adam Bartnik pointed out the need for redoing some of the original ERL beam dump radiation simulations, since the design of the dump shielding is going to have to be different for the present location of the CBETA dump. As mentioned in the Introduction, it is not possible to get the standard

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[1] C.J. Werner(editor), "MCNP Users Manual - Code Version 6.2", Los Alamos National Laboratory, report LA-UR-17-29981 (2017).

heavy cement blocks around the back of the dump since there is no crane access there.
A detailed measurement of the new location was undertaken, and the results are show in figure 2.

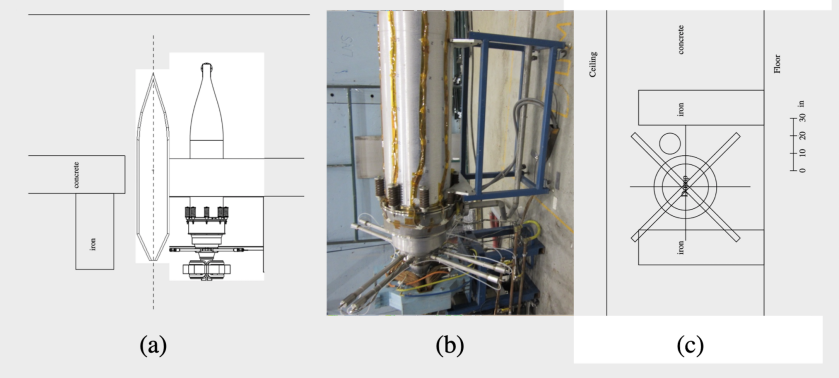

FIGURE 2. (a) Shows the dump arrangement in the horizontal plane, along with a scaled drawing of the dump taken from figure 1. (b) Shows a photograph of the dump and (c) Shows the dump arrangement in the vertical plane.

3. UNSHIELDED DUMP

The MCNP6 input geometry for the unshielded dump is shown in figure 3.

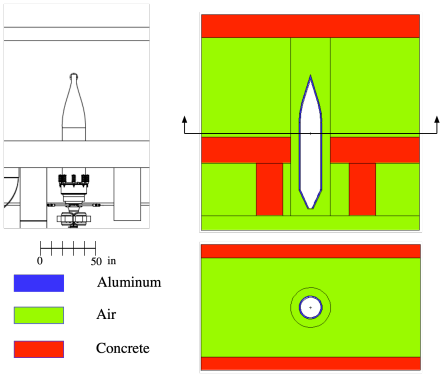

FIGURE 3. MCNP6 input geometry for the unshielded dump. The overall dimensions in the horizontal plane are 500 x 500 cm, and 500 x 290 cm in the vertical plane.

While the geometry is straightforward, the modeling of the electron source needs some mention. To prevent damage to the electron collector, the electron beam is spread out and rotated at 60 Hz. This is simulated as shown in figure 4. The

electron beam is broken up into 11 different beams as shown in figure 4 (a), each of which is rotated about the collector central axis and strikes the collector in 14 different places as shown in figure 4 (b). Each of the "beams" is chosen with equal probability.

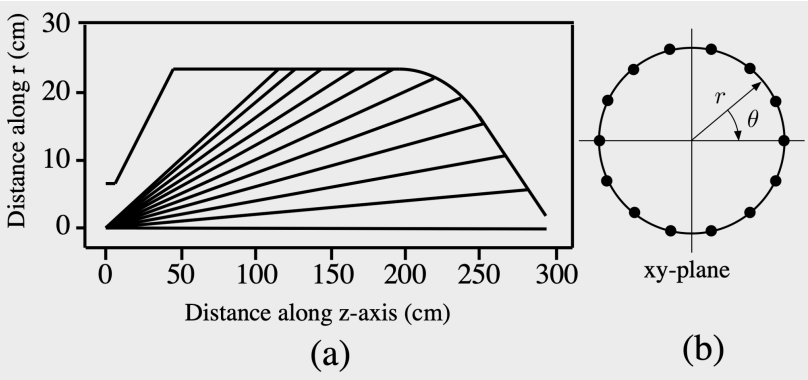

FIGURE 4. (a) Shows 11 different positions where the electron beam strikes the collector and (b) shows 14 different angular positions for each position shown in (a).

The resulting gamma dose rate contours in the horizontal plane passing through the center of the beam dump are shown in figure 5.

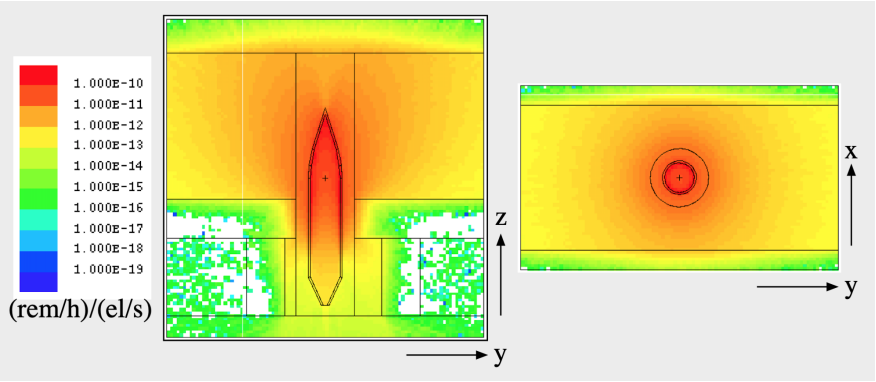

FIGURE 5. Gamma dose rate contours in (rem/h)/(el/s).

However, these are somewhat hard to read. Figure 6 shows the gamma dose rates along the y-axis at different distances from the 2' thick wall. The colors in the right part of the figure, (b), correspond to distances shown in the left part (a). From the figure, the average dose rate at 250 cm from the center of the dump is 3.0×10^{-13} (rem/h)/(el/s). For a 1 mA electron beam, or 6.24×10^{15} (el/s), this corresponds to a dose rate of 1872 rad/h.

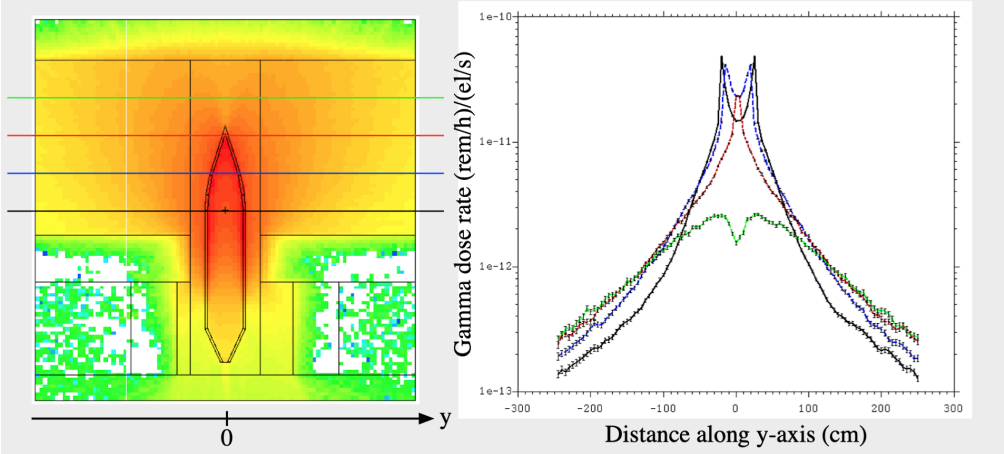

FIGURE 6. Left figure: Gamma dose rate contours in the horizontal plane passing through the center of the beam dump. Right figure: Gamma dose rates along the y-axis at different distances from the 2' thick wall. Colors correspond to distances shown in the left figure.

4. SHIELDED DUMP

The MCNP6 input geometry for the shielded dump is shown in figure 7. The shielding consists of a labyrinth with a 32" wide entrance and exit made from 1 ft. thick high density concrete (244 lbs/ft^3 or 3.91 gm/cm^3) as shown.

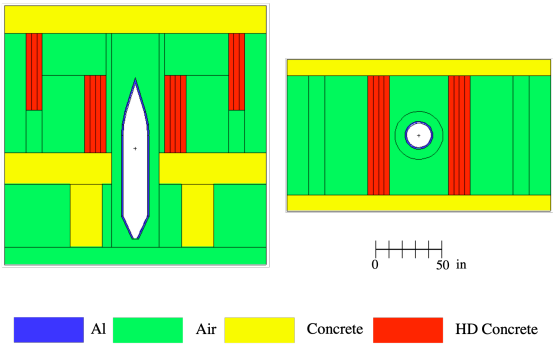

FIGURE 7. MCNP6 input geometry for the shielded dump. The overall dimensions are the same as those in figure 3.

The resulting gamma dose rate contours in the horizontal plane passing through the center of the beam dump are shown in figure 8. Figure 9 shows the gamma dose rates along the y-axis at different distances from the 2' thick wall. The

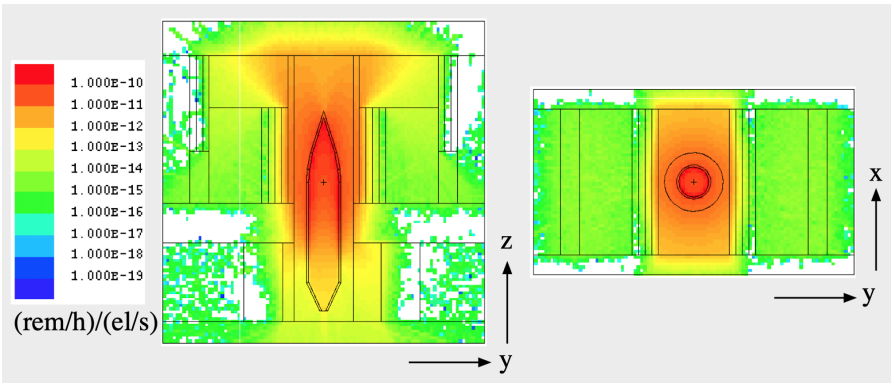

FIGURE 8. Gamma dose rate contours in (rem/h)/(el/s).

colors in the right part of the figure, (b), correspond to distances shown in the left part (a). From the figure, the average dose rate at 250 cm from the center of the dump is $\sim 5.0 \times 10^{-15}$ (rem/h)/(el/s). For a 1 mA electron beam, or 6.24×10^{15} (el/s), this corresponds to a dose rate of 31.2 rad/h.

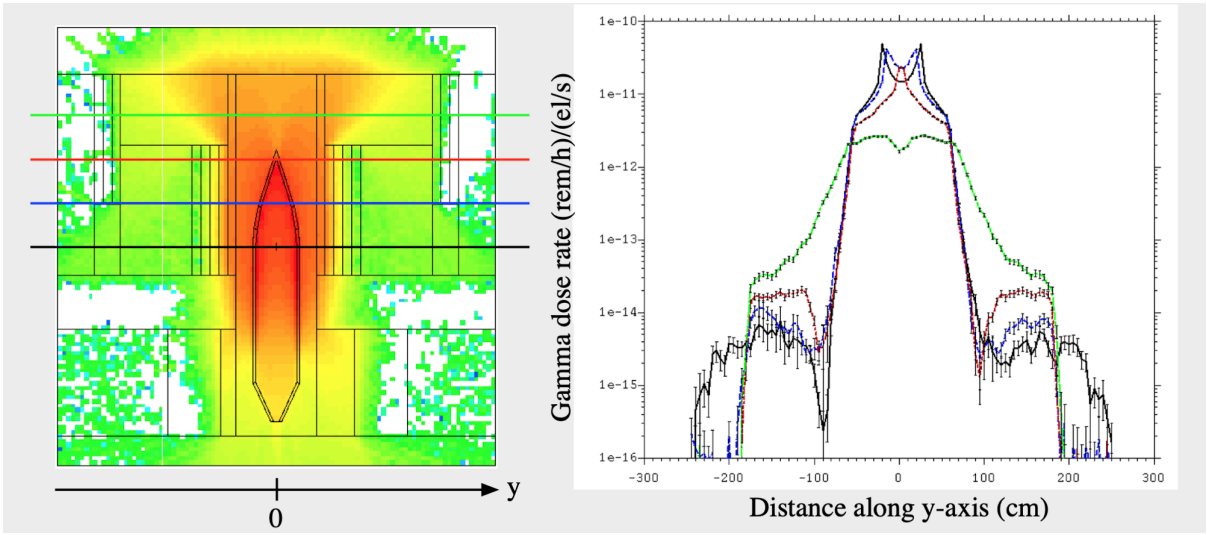

FIGURE 9. Left figure: Gamma dose rate contours in the horizontal plane passing through the center of the beam dump. Right figure: Gamma dose rates along the y-axis at different distances from the 2' thick wall. Colors correspond to distances shown in the left figure.

For the shielded dump, two other measurements are of interest. Near the Eastern wall, there are some pipes attached to the ceiling that drop down one foot. Figure 10 shows a plot along the z-axis, one third of the way in the 32" labyrinth passage way and 13.5" below the ceiling. This is of interest if the South section of the labyrinth wall has to be extended all the way to the ceiling. If it is built

one foot short short of the ceiling, the dose rate below the ceiling is $\sim 2.0 \times 10^{-15}$ (rem/h)/(el/s) though it can reach 10^{-13} (rem/h)/(el/s) near the East wall. For 1 mA the dose ranges from 12.5 rem/h to 624 rem/h.

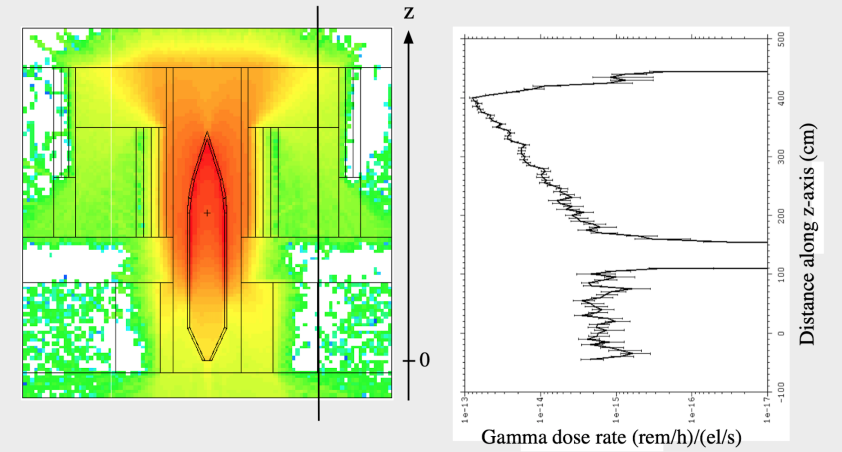

FIGURE 10. Dose rate along the black line in the left figure and 13.5" below the ceiling.

5. Shielding of the dump entrance

Thus far, no mention has been made of shielding the entrance to the dump. This was partly due to the fact that in figure 2 (c) the scaling of the long arms in (b) shows that these do not fit within the existing shielding block in LOE. However, since the dimensions are not known exactly, and scaling from the photograph cannot be relied upon, shielding of this part of the collector was not done. Figure 11 shows the gamma dose rate along different lines in the horizontal plane passing through the beam dump center line. Of particular interest is the black line passing along the dump center line. Near the entrance to the dump, the dose rate is $\sim 2 \times 10^{-14}$ (rem/h)/(el/s), so that at 1 mA, the dose rate is 125 rem/h, and could be reduced significantly with 8" of lead. At 40 ma, the dose rate would be 5000 rem/h, and this would require additional shielding using heavy concrete. In any case, once the final position of the dump is settled, on the shielding calculations can be re-done and additional shielding added.

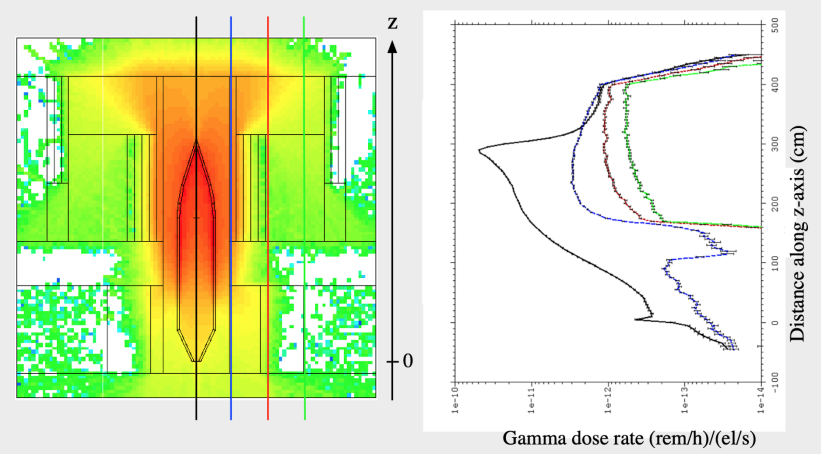

FIGURE 11. Dose rate along the z-direction in the plane through the collector central axis and at different distances from the axis.