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To: RSC, J. Hock, A. Fedotov, J. Tuozzolo, D. Phillips, W. Fischer, and A. Drees

From: D. Beavis

Subject: LEReC Diagnostic Beam Dump in RHIC Tunnel

A small water cooled beam dump will be located in the RHIC tunnel for diagnostics of the LEReC beam. The beam dump is expected to have a maximum average power of 50 Watts and is located just past the triplet cryostat\(^1\),\(^2\). The beam dump is shown in Figure 1. The dump is constructed with titanium (Ti) and has a water channel for cooling. The Ti endplate has a twenty degree slope relative to the electron beam. The electron beam size on the endplate is approximately 0.8 mm high by 30 mm wide\(^3\). The dump has been designed assuming the entire thermal load is deposited in the thin Ti window. This note will address the radiation dose, ozone production, and possible hydrogen generation in the cooling water.

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\(^1\) D. Beavis, Oct. 19, 2016; [http://www.c-ad.bnl.gov/esfd/RSC/Memos/5_23_16_LEReC.pdf](http://www.c-ad.bnl.gov/esfd/RSC/Memos/5_23_16_LEReC.pdf)


A simple model of the dump geometry was created in MCNPX to evaluate the radiation issues. The beam pipe is assumed to have azimuthal symmetry as compared to the actual design which has a rectangular structure. The dimensions for the water, Ti window, Ti backplate, and side walls are representative of the actual design\textsuperscript{4}. An artificial Ti window is placed in the backward direction to terminate backscattered electrons. These electrons would need to transverse the beam pipe to get into the air, which surrounds the beam dump. A side view of the MCNPX model is shown in Figure 2. A pencil beam of 2.5 MeV electrons strike the window in the middle.

\textsuperscript{4} The dimensions used are: 0.203 cm for Ti window, 0.330 cm for water, 2.01 cm of Ti for end of plate, 0.6 cm for wall thickness of pipe, and 4.4 cm for interior radius of beam pipe.
Figure 2: MCNPX model of the beam dump. The red, blue, and yellow areas are air, Ti, and water respectively.

The energy loss of the electrons is dominated by ionization. 68% of the electron energy is deposited in the Ti window. A few percent of the energy goes into photon production and about 29% is deposited into the beam pipe with a large fraction of the energy deposited in the beam pipe being below the tilted window. The end-plate and the beam pipe near it have 97.6% of the beam energy. The remainder of the energy is deposited in the air and the upstream beam pipe. The energy deposition projected onto the x-y plane is shown in Figure 3. The width of the central peak is distorted by the 0.5 cm bin size. Some features in the contour plot are artifacts of the spline processing of the data. The increased energy deposition opposite the tilted Ti window is clearly evident in the contour plot.
The dose rate was tallied in the forward direction at z=30cm is displayed in Figure 4. The dose rate peaks at negative y, which is caused by the reflected electrons off the tilted window face. These electrons stop in the beam pipe wall and generate photons. The peak at negative y values is 3000 rads/hr and the peak at the mid-plane is 500 rads/hr. 2000 hours of operations per year at 50 Watts would produce 1-6 Mega-rads/yr at 30 cm in the forward direction. The dose rate averaged on a cylinder around the beam dump at a distance of 60 cm has a dose rate of 140 rads/hr. The dose rate at large angles is relatively constant in the backward direction. The dose rates can be scaled with solid angle to estimate the dose at locations where there is equipment that may have a low radiation tolerance. The dose rates are sufficiently low that little are no shielding is expected to be needed to protect equipment from the dump radiation.

The production of ozone can be estimated by calculating the ionization in the air surrounding the beam dump. 7.4 ozone molecules are produced per 100 eV of ionization. 50 W of 2.5 MeV electrons into the beam dump the deposit $2.2 \times 10^{15}$ MeV per hour in a column of air 6 meters in diameter 6 meters long, centered around the beam dump. The ozone concentration will be the hourly production rate ($2.2 \times 10^{15} \times 7.4 \times 10^4$) times the decay rate (0.833 hours) divided by the air atoms in the volume $(6.023 \times 10^{23} \times 1.7 \times 10^9 \text{cm}^3 / 22400 \text{ cm}^3)$. The ozone concentration will be $3.0 \times 10^{-9}$. The Threshold Level Value (TLV) for ozone is $10^{-7}$, which is 30-40 times higher than the estimate calculated in this note. The air volume used is for 6 meters of tunnel, which is a small portion of the tunnel length and should be conservative.

The ionization in water was tallied and is $7.64 \times 10^{-4}$ of the beam energy. The ionization of 0.038 Watts in the water will result in $4 \times 10^{-5}$ liters of hydrogen per hour. This is a negligible quantity of hydrogen.

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Figure 4: Photon dose rate 30 cm downstream of the endplate center for 50 Watts of 2.5 MeV electrons.

The electron energy is below the activation threshold for producing radionuclides in the materials used. The low average power on the beam dump will not create radiation external to the shielding or shielding penetrations. It is concluded that the diagnostic beam dump design has no radiation issues to mitigate.