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Memo

Date: *June 19, 2014*

To: *RSC, D. Phillips, and D. Kayran*

Cc: *I. Ben-Zvi, G. McIntrye, and W. Xu.*

From: *D. Beavis*

Subject: *ERL Roof Shims*

This memorandum reports on calculations of the potential radiation external to the ERL shield adjacent to the location of the roof shims. The committee is asked to decide if the present wood shims are acceptable or at least acceptable until the ERL gun is removed at the end of the year.

Roof Shims

Roof beams are typically placed on spacers (shims) so that they sit well on the wall and no edges are stressed. The shims used for ERL are wood and are the width of the roof beam (2 feet in this case), one foot (30 cm) along the direction of the roof beam, and up to 0.5 inches thick. This space can act as a seam allowing elevated levels of radiation exterior to the shielding. The end sections of the ERL roof have had the wood replaced with steel shims that are as thin as possible. The center section of the roof still has wood shims. It is possible to replace the shims and an opportune time would be when the ERL gun is removed for rework which is scheduled for the end of the year. This would mean that initial beam operations with beam to the beam dump would start with the wood shims in place.

Method of Calculation

The calculations are conducted in analogous[1] fashion to those conducted for the laser port and cryo ports in the ERL shielding. MCNPX 2.7.C was used to calculate the photon and electron distribution at two meters from a 10 cm long copper target with a radius of 0.1 cm or 0.75 cm. There was no shielding in the model so that the distributions represent radiation from the target. The electron and photon distributions were then used as sources directed at the area of the roof shims. The dose distribution for 3.5 MeV and 25 MeV electrons is shown in Figure I and II. For a thin rod the electrons can escape the target and contribute to the dose. For 3.5 MeV electrons

[1] D. Beavis, " ERL Shielding Holes, Seams, and Penetrations for 3.5 MeV beam", May 27, 2014; http://www.c-ad.bnl.gov/esfd/RSC/Memos/ERL_Holes_5_27_14.pdf

striking the target the electron dose quickly decreases in the forward direction. The dose inside the shielding can be dominated by the electrons from the target. The roof shims are sufficiently thick[2] to remove all the electrons scattered from the target. The electrons from the target will be ignored when considering the wood shims. The wood shims do not have sufficient mass density to effectively remove the photons. The wood will be ignored[3] in examining the photon dose. The wood shims may be replaced in the future with steel shims. Steel shims would be nearly as effective[4] as the 4 feet of light concrete which comprise the side walls.

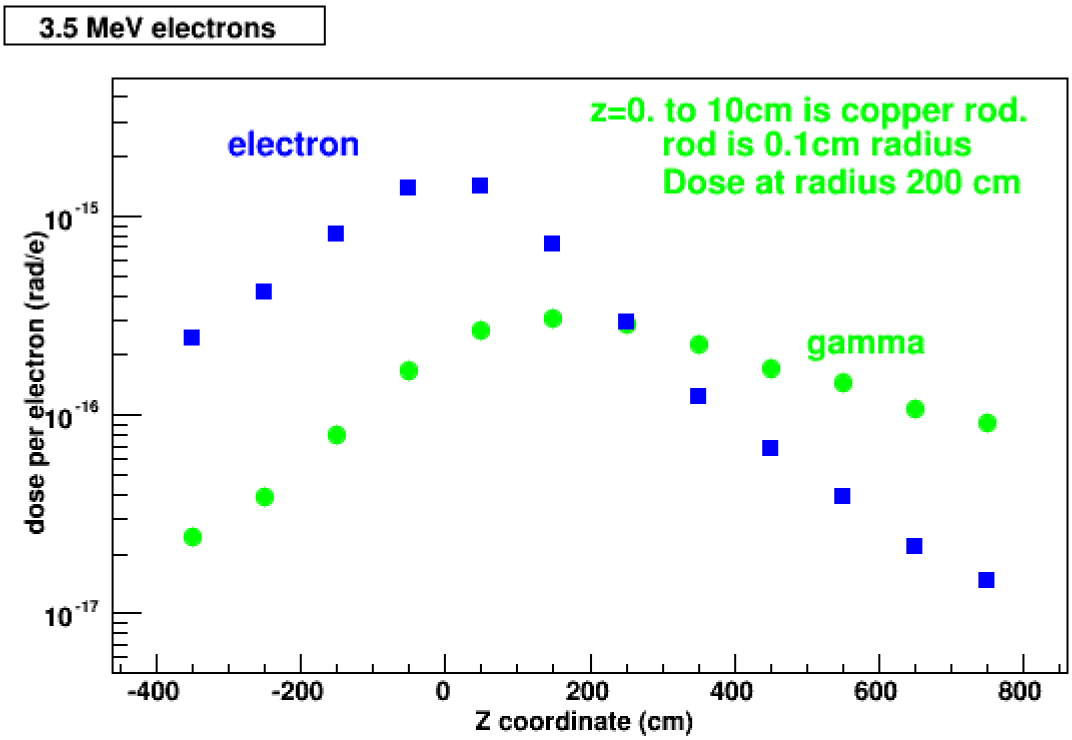

Figure I: The photon and electron dose per 3.5 MeV electron striking a copper target tallied on a two meter cylindrical surface. The doses are averaged over 100 cm sections of the surface.

Figure III displays the energy distribution for 3.5 and 25 MeV electrons striking a 10 cm long copper target. The fluence was tallied at 300 cm on a surface forward of 90 degrees. The target for 25 MeV has a radius of 0.75 cm and the 3.5 cm Target has a radius of 0.1 MeV. The thicker target causes a substantial reduction in the photon fluence in the low energy region.

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[2] The density of plywood is approximately 0.55 gm/cc. The 12 inches provides approximately 16 grams of material to range out electrons scattered from the target.

[3] One calculation was conducted with 30 cm of carbon with density of 0.55 gm/cc. The exiting gamma dose was reduced by 15%.

[4] Using TVLs for 10 MeV the 12 inches of steel is equivalent to 3.7 feet of light concrete.

The photon distributions shown in Figure III were used as the source distributions in MCNPX. The photon fluence was directed at the roof to wall interface with a uniform angular distribution confined around a vector directed at the interface. The size of the angular distribution was changed to determine the impact of scattering off the roof. The attenuation of the roof to wall seam from inside to outside the shielding was determined by tallying the dose with point detectors. The dose at the inside of the wall was then multiplied by the attenuation to obtain the dose per electron external to the shielding. Typically the dose per electron was tallied at the outside wall rather than 30 cm from the wall.

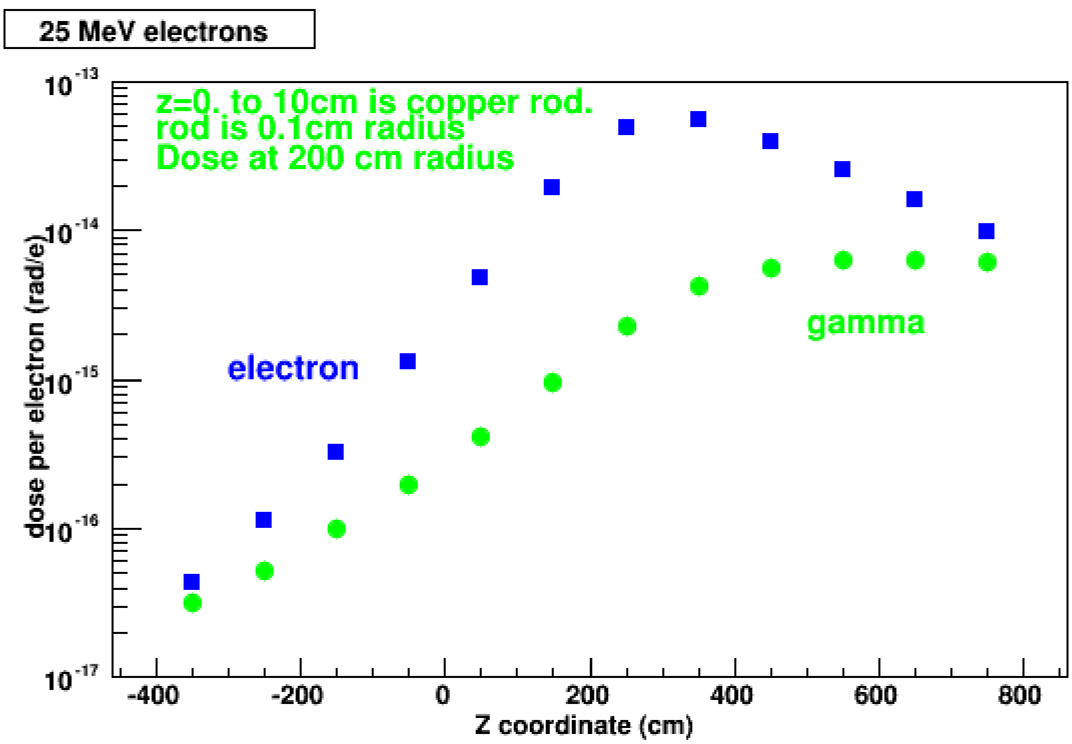

Figure II: Same as figure I except to 25 MeV electrons striking a copper target.

Results

The calculations were conducted for 3.5 MeV and 25 MeV electrons. The distances to the wall and the vertical heights approximated the geometry from either beam line to the near wall and the far wall. These geometries cover the conditions for beam in the low energy transport and for the 25 MeV beam in the ring. The results are shown in Table I. Sources at beam height that are farther from the wall have smaller angles relative to the seam resulting in less attenuation but the increased distance reduces the dose at the wall interface causing a nearly dose outside the shield.

The cone of photons challenging the roof to wall transition was limited in size to reduce computing time. Albedo from the concrete roof was examined by increasing the angular cone of photons and the calculation repeated for the 3.5 MeV case for 610 cm. The attenuation increased by approximately a factor of two. The last column in table I has this factor of two included as an estimate to account for the additional dose. The calculation for the top row was repeated with a 0.6 cm gap rather than 1.2 cm. The attenuation was a factor of two smaller. In addition the dose was tallied 1 foot from the wall was a factor or two smaller than at the wall.

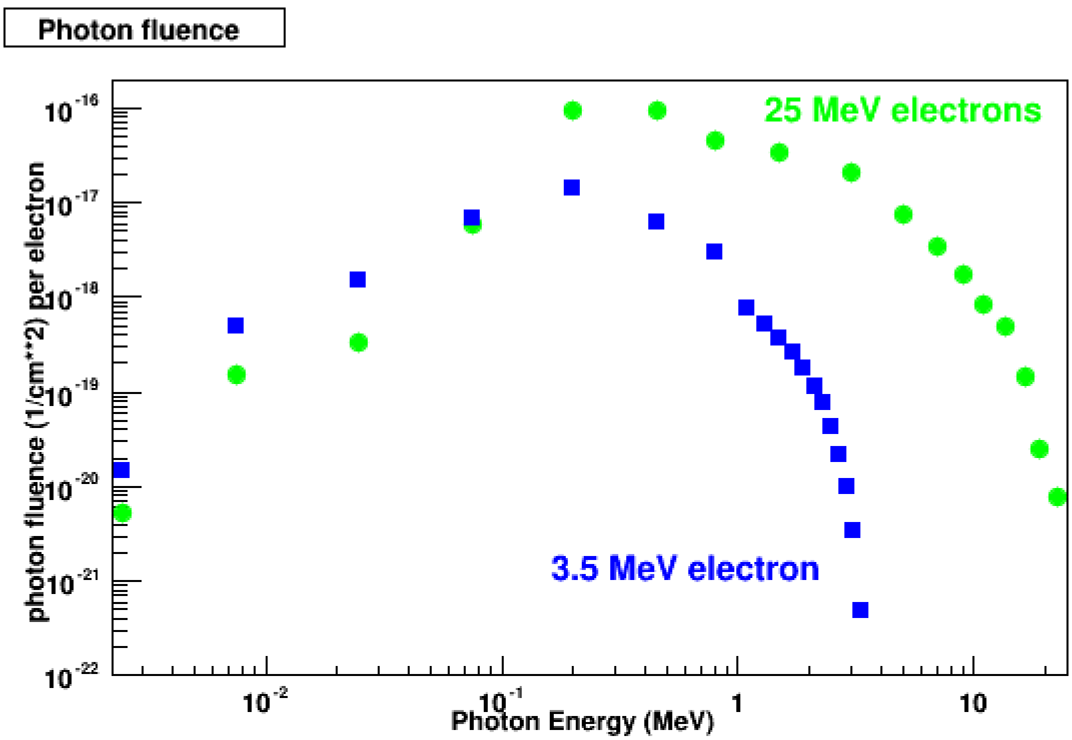

Figure III: Energy distribution for 3.5 MeV electrons striking a 0.1cm radius copper target 10 cm long at a distance of 300cm (blue squares). The green circles are for 25 MeV electrons striking a 0.75cm radius copper 10 cm long.

Table I: The Photon Dose for 100 Watts of Beam Loss (1.2 cm gap)

Electron Energy (MeV)	Distance to wall (cm)	Dose (mrads/hr)	Attenuation	Dose (mrads/hr) With roof reflection
3.5	260	4	$1.4*10^{-4}$	8
3.5	610	4	$3.9*10^{-4}$	8
25	260	10	$1.4*10^{-4}$	20
25	610	17	$8*10^{-4}$	34

Most locations of the roof to wall transition are adjacent to areas that are not typically occupied by personnel. The roof to wall transition is at an elevation of 13 to 14 feet above the floor where the wood shims exist for the east and west walls. Figure IV displays the ERL facility. The shielding wall at the top of Figure IV is the west wall. The area outside the west wall has an exclusion area for about six feet. The Klystron power supply house is excluded of personnel for beam operations. Eight foot thick walls exist south of the power supply house and the seams are effectively shielded. Further along the east wall the second floor of the utility building can have personnel present. The heavy concrete interior wall will reduce the dose challenging the shim seam substantially for the portions of the transport that are close to the wall. Losses in the ERL ring far for that wall will not be shadowed. A portion of the low energy transport just after the gun can also illuminate the seam before the interior wall starts. Increasing the height of the wall may be appropriate if the chipmunks[5] are not sensitive to the faults that can direct radiation past the interior shield wall.

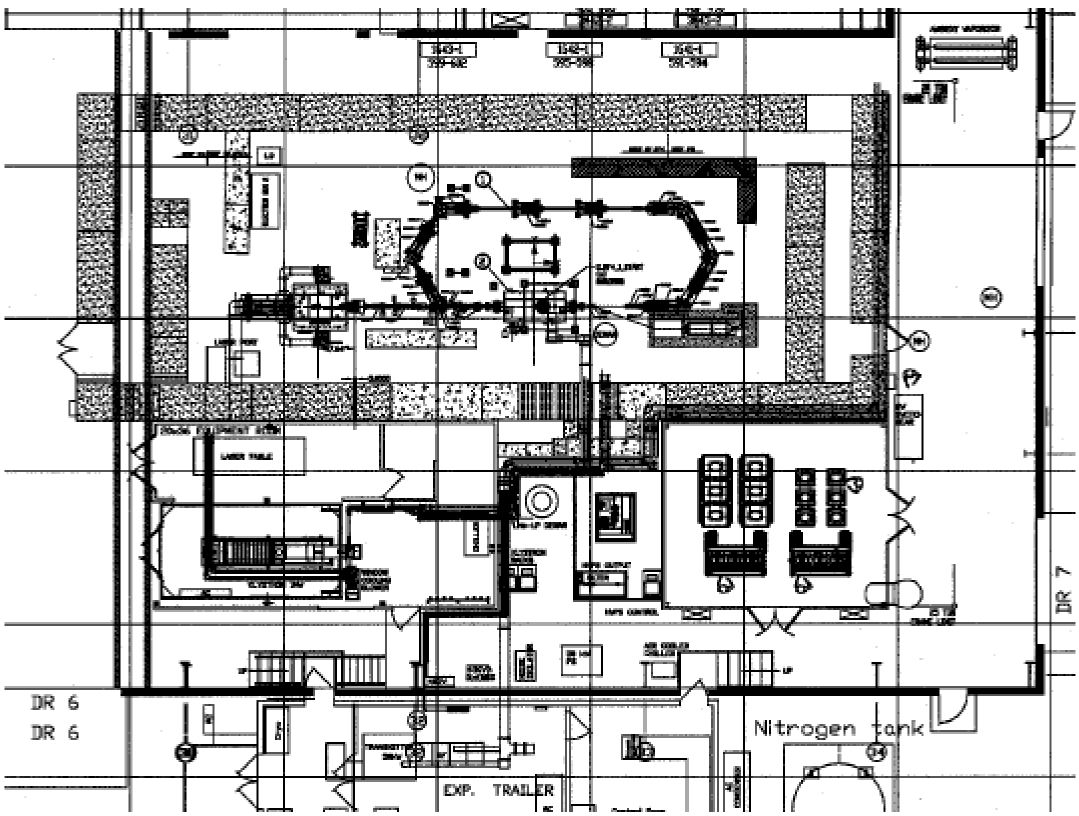

Figure IV: Plan view of the ERL block house and adjacent areas.

Localized 3.5 MeV electron beam losses of 1000 Watts will have potentials dose rates[6] less than 100 mrads/hr. For 25 MeV beam the dose rates for 1000 Watts will be less than 350 mrads/hr. For areas posted and controlled for no elevated work these potential dose rates are probably acceptable for the short term. The second floor of the utility building could have occupany with these potential dose rates. Beam fault studies should help determine an appropriate beam power limit with the wood shims in place. Once the steel shims are in place the roof to wall transition is expected to have dose rates similar to the side wall shielding.

[5] The west cryo port exit chipmunk (NMO174) and 50 kW waveguide chipmunk (NMO173) are expected to be sensitive to most of the ring loss locations that could challenge the roof to wall shim area adjacent to the electrons building. However, a small portion of the south ring may illuminate a potion of the seam and be chipmunks either shadowed or in the backward direction.

[6] The exposure area would have a vertical height of less than 2 cm.