Collider-Accelerator Department

BROOKHAVEN NATIONAL LABORATORY

Building 911B – P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344 7124
Fax 631 344 5568
beavis@bnl.gov
www.bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

Date: *Oct. 24, 2014*

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

From: *D. Beavis*

Subject: *ERL Shielding Changes*

Changes have been made to the ERL shielding to reduce the potential dose outside weak locations. Shielding was added to reduce the chronic dose near the roof transition that is downstream from the beam dump.

The following improvements were installed and discussed below:

- 15 cm thick steel bars placed over roof seams on top of the concrete shielding.
- Roof beams were shifted two feet to the west so that two feet of concrete could cover roof seams on the east side.
- 15 cm thick steel bars hang over seams on west side
- 10 cm of Pb was placed over vertical seams that can have x-rays shine directly through the seam.
- The south end was has concrete blocks extend above end wall roof seam to prevent shine through roof joint.
- Two roof beams were added to reduce routine leakage out roof from beam dump.
- Some steel blocks were added around the structure for the ventilation fan to reduce cracks. (not discussed below)

The radiation that can leak through roof seams at ERL was discussed in a previous note[1]. Dose rates created by a 1MW beam loss can be as high as 110,000 rads/hr one foot above the shielding roof seam and 30,000 rads/hr on the building roof if the loss point is well aligned with the seam. Several options were considered for covering the roof seams to reduce the potential dose from a beam fault.

The corrective action selected and installed was to cover the seams with steel billets (bars) that are 15 cm thick and typically 15 cm wide. The input file used to calculate the dose through the seams using MCNPX was modified to place the steel shielding over a 1 cm wide seam. The dose was tallied at several locations above the seam for a strip 1 cm wide. The results are given in Table I.

[1] D. Beavis, "ERL Shielding Holes, Seams, and Penetrations for 3.5 MeV beam", July 28, 2014 ; http://www.c-ad.bnl.gov/esfd/RSC/Memos/ERL_Holes_5_27_14.pdf

Distance above seam (cm)	Dose rate (mrads/hr)	Dose in 0.2 seconds (mrads)	Dose in 3 sec. (mrads)	Dose in 9 sec. (mrads)
15	160,000	9	133	450
75	100,000	5.6	83	250
285	52,000	3	43	130
585	24,700	1.4	21	60

The dose rates are still large with 15 cm of steel covering the seams. The building roof would have a dose rate of 25,000 mrads/hr directly over the seam. If should be kept in mind that these dose rates are for the width of the seam and drop quickly with distance to each side of the seam. The credited control that reduces the potential dose in an accident is the array of radiation detectors (chipmunks) that are distributed around the facility and interfaces with the access control system. For a 1 MW beam loss two chipmunks or more would be expected[2] to interlock the beam off. The duration before a chipmunk can terminate the beam has often been taken as 9 seconds. However, for large faults the interlock will occur in a shorter time and is expected to be less than 3 seconds. Thus we would expect to see a total dose on the building roof of 20 mrads. The building roof is posted as no access when ERL is operating. Access to the EEBA and NEBA building roofs and crane cabs are covered by OPM 4.99 and 4.99.a.

The maximum dose rate on the shielding top is large. At a distance of 75 cm above the steel the dose in a three second fault could be 83 mrads. The shield roof is swept and posted as no access. The access ladder is locked. Some of the steel blocks have been placed on top of others to avoid seams in the steel. The gammas rays can reflection off the steel which may be up to 15 cm above the seam. This results in a dose of 200 mrads to the feet of a person standing 30 cm to the side of the steel for a three second beam fault. The nearest steel bar is approximately 20 feet from the north or south sides of the shielding. The dose due to scattering off an elevated steel bar would be 1.5 mrads for a 3 second fault. See photo I below for examples of the steel bars.

A 1 MW beam loss is not expected to be a realistic sustainable loss for the 3.5 MeV beam. A simple simulation was conducted to examine how long a stainless steel beam pipe could sustain a 1 MW beam loss. The 3.5 MeV beam was uniformly painted on a 10cm section of stainless steel tubing with an angle of incidence of 1 milli-radian. The pipe had a internal radius of 23.9 mm and a wall thickness of 1.5 mm. The pipe was extended beyond the scraping area by several meters in both directions. The stainless steel beam tube reached its melting point in 0.2 seconds and most likely would fail after 0.1 second of beam irradiation[3]. The uniform scrapping used in this analysis is not expected to be a very likely scenario. More likely modes of beam scrapping would be expected to cause the beam pipe to fail in a shorter time. There are portions of the beam pipe where thick flanges may enable the pipe to withstand longer durations of full beam exposure. This calculation is presented to provide evidence that 1 MW losses are unlikely to occur for any potion of a minute or even a second.

The roof seams have the potential to leak out the sides either to the second floor of the utility building or into the adjacent building near the SVTF or VTF, but high above the floor. The roof

[2] The beam fault studies will verify that large beam faults are detected by multiple chipmunks.
[3] ANSYS thermal calculations were conducted by C. Cullen and the results communicated by e-mail.

beams were shifted to the west to allow the installation of two feet of light concrete. The light concrete covers any shim seam as well as the vertical seam between roof beams. Simple scaling provides an estimate of 1 mrad/(3 sec.) for scraping in the low energy beam line. The arrangement can be seen in Photo II.

Steel is placed over the west seams until there is sufficient coverage by the side wall concrete. In some locations the steel bars on the roof extend over the side wall to shadow the rays that exit the seam. Photo III shows some the the steel bars on the west side. The closest that a person can get to the seam is six feet away[4]. In addition, the radiation travels through the seam and the steel at an angle of 26 degrees for the low energy beam line. With the increased distances and 11% thicker steel the **dose for a 3 second fault is estimated to be 10 mrads.** This would occur at an height of 14 feet or more above the concrete floor. The dose from photons scattered off the bottom surface of the overhanging steel bars would produce a similar dose. The SVTF and the VTF have roof areas that are at least this high. The increased distance would cause additional reduction in the potential dose in a beam scrapping event. These areas have been posted as no access with ERL operating with beam.

The vertical wall seams have the same behavior as the roof seams except the gap is much smaller than 1 cm. The seams that can have direct shine are covered on the inside or outside with a layer of Pb 10cm thick. The input file for MCNPX for the steel on the roof was used to estimate the dose through a side wall vertical seam with a gap of 1 cm. The dose out the seam was one half that through the 15 cm thick steel used on the roof. This would result in 10 mrads for a 3 second beam fault. The seams on the west side are farther away and the dose would be 2 mrads for a 3 second beam fault. A vertical seam covered with Pb is shown in Photo IV.

The south end wall does not have a roof seam over the labyrinth walls with the same issues as the north end wall. The lack of a direct seam is caused by roof beams over the labyrinth that are lower than the adjacent shielding walls of the labyrinth. The lifting fixtures can also shine out in this direction. Two roof beams over the south end wall were removed and replaced with 4.5 foot high shield blocks[5]. The extra height provides shadowing for the potential weaknesses in this area.

The four foot vertical transition on the north end of the shielding roof had two roof beams added. The additional roof beams reduce[6] the chronic dose from the beam dump to less than 10 micro-rads/hr. The additional shielding would also reduce the potential dose due to scrapping in the transport for both the low energy and 25 MeV transports.

---

[4] The west isle way is swept and locked if ERL is operating.

[5] The top of these blocks are 13.5 feet above the experimental floor, which is posted that no elevated work can be conducted while ERL is operating.

[6] This estimate was conducted by scaling the results for 2 MeV electrons on the beam dump.

PHOTOS

A few selected photographs to assist in understanding the description in the text.

Photo I: Photon of steel billets covering the roof seams. To avoid seams between ends of billets some billets are tilted or placed on top of the adjacent steel bar.

Photo II: The roof beams have been moved to the west so that two feet od concrete can cover the seams between blocks to the side. The roof of the utility building is seen at the right hand side. The steel bars block rays that penetrate partially through the roof seam.

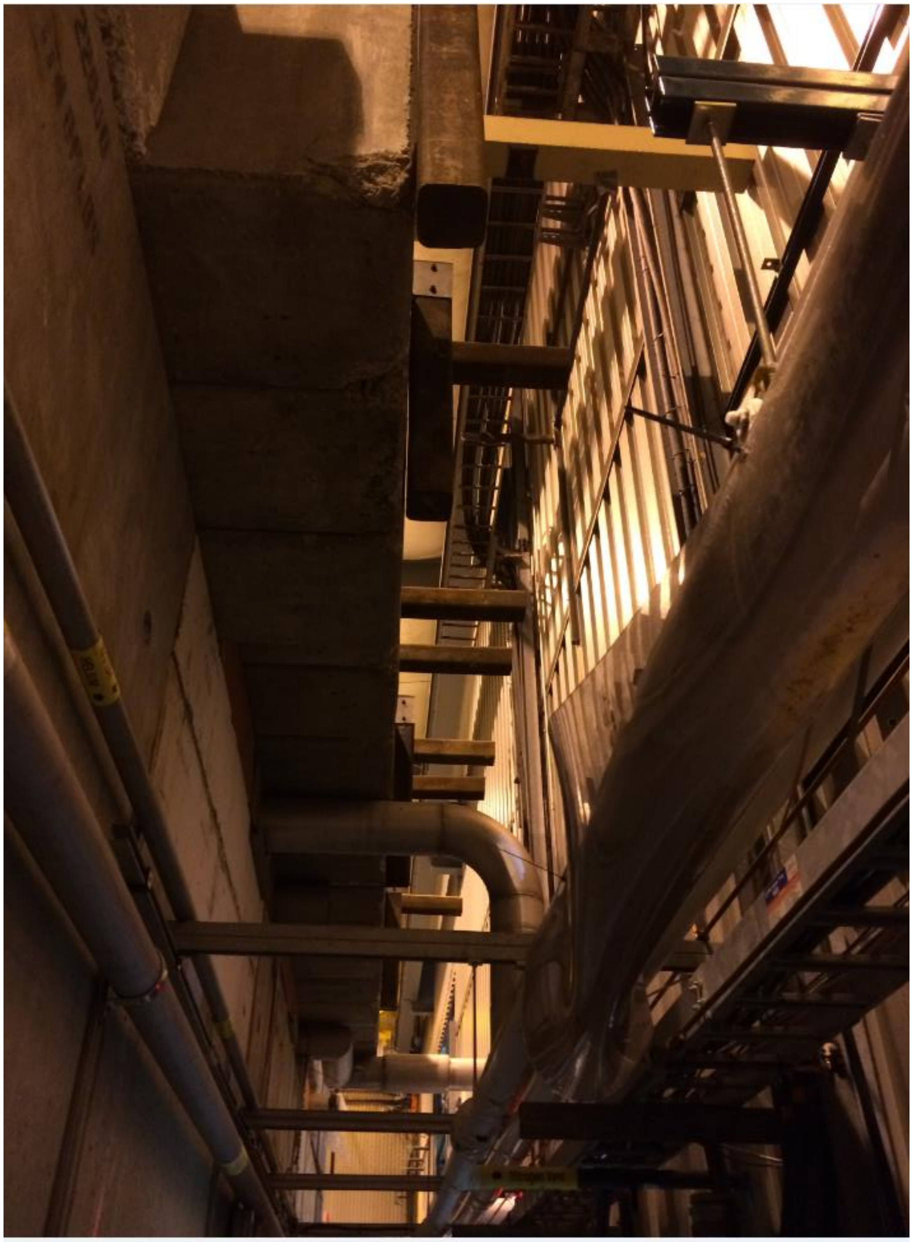

Photo III: The semas between roof beams on the east side were covered by steel hanging vertically down or by extending the steel bars over the sides to shadow the seams between roof beams. The extended steel bars can range for 30 to 46 inches long.

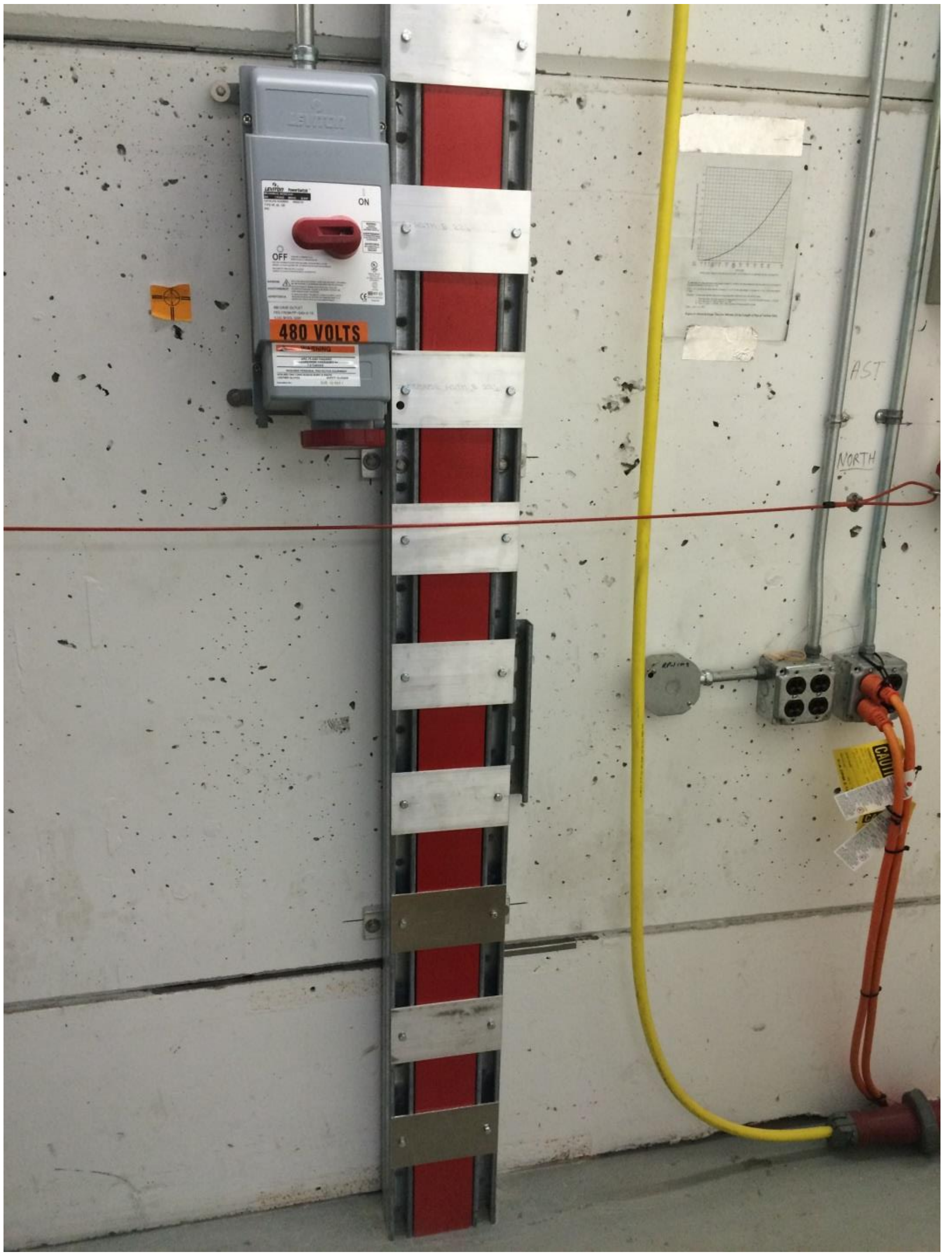

Photo IV: Vertical seam covered with 10 cm of Pb. Two layers of Pb bricks are used and the seams in the Pb are staggered.