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: *Dec. 18, 2014*

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

From: *D. Beavis*

Subject: *Comparison of MCNPX with ERL Fault Study 232*

The electron beam at ERL was transported to a stainless steel flange at the end of the straight beam line in Fault Study 232. During Fault Study 233 the beam was transported onto the copper slits and into the first bend. The beam was measured to have a current of 0.7 micro-Amperes during the beginning of FS 232 and decrease with time. The energy was measured to be between 1.2-1.3 MeV. During the two fault studies there was no radiation detected outside the shielding above the minimum detectable level. It is of interest to determine if the detected radiation levels inside the shielding enclosure agree with expectations.

There will be many factors which will make a careful comparison difficult including, the dark current, the x-rays from the gun, low pulsed beam current, and the scattering from numerous surfaces. Therefore the intent should be to determine if the radiation detected is reasonable to an order of magnitude. It will be concluded that radiation levels are consistent to an order of magnitude but to draw any real conclusions the signal to noise in the measurements in the future will need to be improved.

There are a total of six chipmunks inside the ERL enclosure. The results from a simple MCNPX model will be compared to three of the chipmunks. Several of the chipmunks were not able to detect the radiation since they were setup with the intention to allow the ERL to operate with a beam loss of at least 10W at an energy of 3 MeV. Chipmunk NM177 was on the enclosure floor at a distance of 4 meters from the flange. The polar angle was approximately 155 degrees. Chipmunk NM181 was on the west wall surrounded with approximately 1 foot of light concrete (patio blocks). Chipmunk 181 location is two feet downstream of the flange and 5.8 meters away. The intent of this chipmunk was to monitor the beam on the flange and prevent high current. Chipmunk NM176 sits behind a heavy-concrete wall that is 81cm thick. The heavy concrete wall forms a portion of the south labyrinth. The location of NM176 was chosen to allow it be sensitive to x-rays reflecting off the back-wall. The flange to the heavy concrete wall is 7.1 meters. The gun structure obstructs some of the x-rays directed towards the back wall. NM176 is 2.8 meters off axis from the beam and the wall starts at 1.8 meters.

The beam current decreased with time during the studies. The relative current for the three loss points are:

Loss point	Current (micro-A)	Relative to beginning FS 232
Faraday Cup	0.7	1
Copper slits	0.26	0.37
After first bend	0.12	0.17

The chipmunk NM177 detects radiation from the gun and the beam losses. The radiation level in mr/hr by NM177 is given in Figure I. There are three distinct periods of time with elevated radiation. From 12:00 to 14:00 the beam is on the flange. At 18:04 the beam is on the copper slits before the first dipole. Finally, at about 20:04 the beam is bent down in the first leg of the vertical chicane by the dipole. Examining the data for when the laser is off suggests that 22 mrads/hr come from the gun. Therefore at the beginning of FS232 only 6 mrem/hr is from the flange.

The ERL enclosure was approximated light concrete 3 meters from the beam axis with rotational symmetry about the beam axis. 1.25 MeV electrons struck a copper target 4 cm in radius and 1 cm thick to approximate the stainless steel flange. The photons were tallied along the inside surface of the wall and then at increments of 15 cm into the light concrete to a thickness of 60cm. The dose was tallied in 1 meter segments. The segment from z=0 to z=100cm was examined at a depth of 60 cm (1 foot). The dose per electron[1] was $1.1*10^{-20}$ rads/e. The dose rate at NM181 is expected[2] to be 0.05 mrad/hr. Based on the chipmunk readout the dose rate during the fault study was 0.03 mrad/hr (see Figure III). The time period near 18:00 has about half the radiation detected while the beam is on the copper slits. There is no line of sight between the slits and the chipmunk. The radiation scattered from the walls and floor.

The MCNPX dose per electron in the backward direction was $2.7*10^{-18}$ rads/hr at a distance of 5.4 meters. The estimated[3] dose rate at the chipmunk is 78 mrads/hr compared to the measured 6 mrads/hr. The calculation only includes the direct radiation and not the components scattered from the surfaces. The agreement is poor but reasonable. It would be hoped that with high beam current a closer agreement can be obtained. For the copper slits the difference in distance and beam current nearly compensate, although NM177 measures nearly twice the dose rate than the flange. Material upstream of the flange may shield some of the x-rays from reaching NM177.

[1] This is for photons with energy greater than 100 keV. The ion chamber has a rapidly decreasing response to photons below 100 keV. The dose per electron is 1.210^{-20} rads per electron if the response is ignored. See Figure II for the chipmunk ion chamber response.

[2] The distance of 5.8 meters to 3.3 meter is used to adjust for the scale difference in the model and the actual geometry.

[3] The distance has been scaled and the dose corrected to include only photons above 100 keV. It has been assumed that the angular distribution is isotropic in the backwards direction at this energy.

NM176 measured 0.06 mrads/hr with the beam on the flange. Using the wall area on the unblocked side of the gun structure an estimated 0.24 mrads/hr would be detected at the chipmunk. The calculation again overestimates the dose registered by the chipmunk. A substantial portion of the detected radiation may come from the gun as in the case for NM177

The next beam tests are expected to occur on Dec. 3. To increase the sensitivity of NM181 9.5 cm of concrete was removed from around the detector. NM182 had 9.5 cm removed[4] from the side and 20 cm from the front. NM 178 has been place downstream of the flange elevated to avoid shielding by ring components. These changes should help to provided better measures of the radiation source. To increase the beam radiation to gun x-rays the wavetrain will be made longer to get more beam intensity. Some points of FS 232 and 233 will be repeated along with FS 234. The results will be examined to see if the measurements provide additional information.

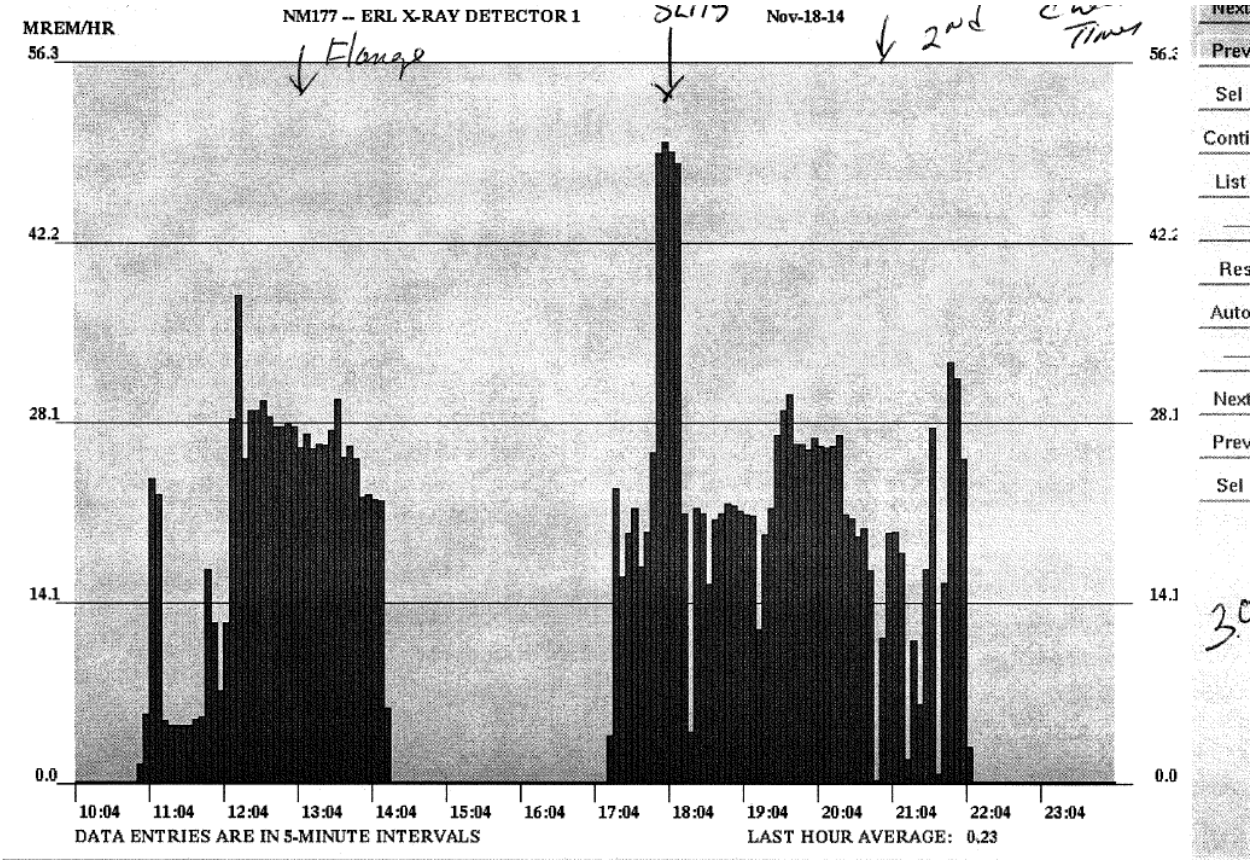

Figure I: NM177 readings during the Fault Study 232 and 233. The beam on flange produces a dose rate of 28 mrads/hr. The beam on the slits produces a dose rate of 50 mrads/hr. The beam in the first bend has a dose rate of 25 mrads/hr.

[4] 15cm of light concrete provides a factor of 10 in radiation production.

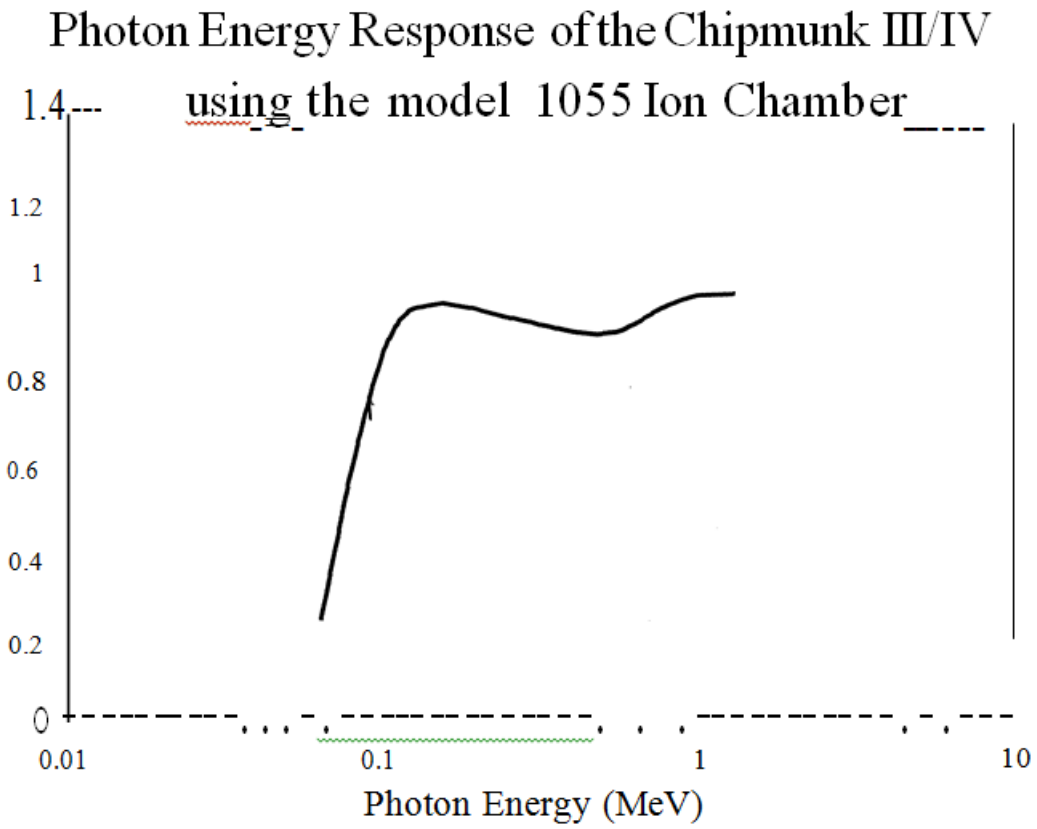

Figure II: Ion chamber response for the chambers used in chipmunks. From F. Krueger and J. Larson, FERMILAB_Pub-01/337 Nov. 2001 by.

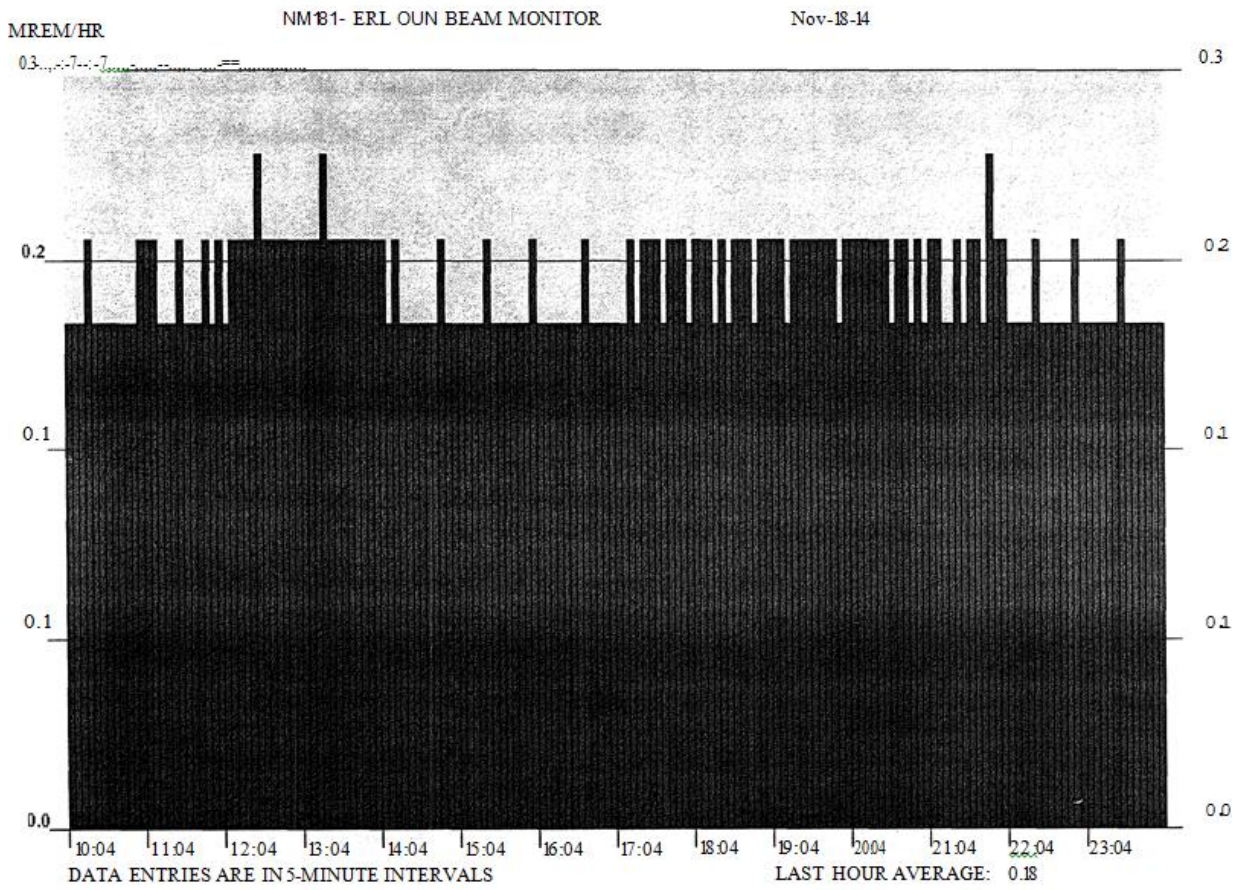

Figure III: Chipmunk 181 data during the fault studies 232 and 233. The data from 12:00 to 13:00 is for beam on the flange. The time window near 18:00 is for beam on the slits and for 20:00 for beam bent by the first dipole.

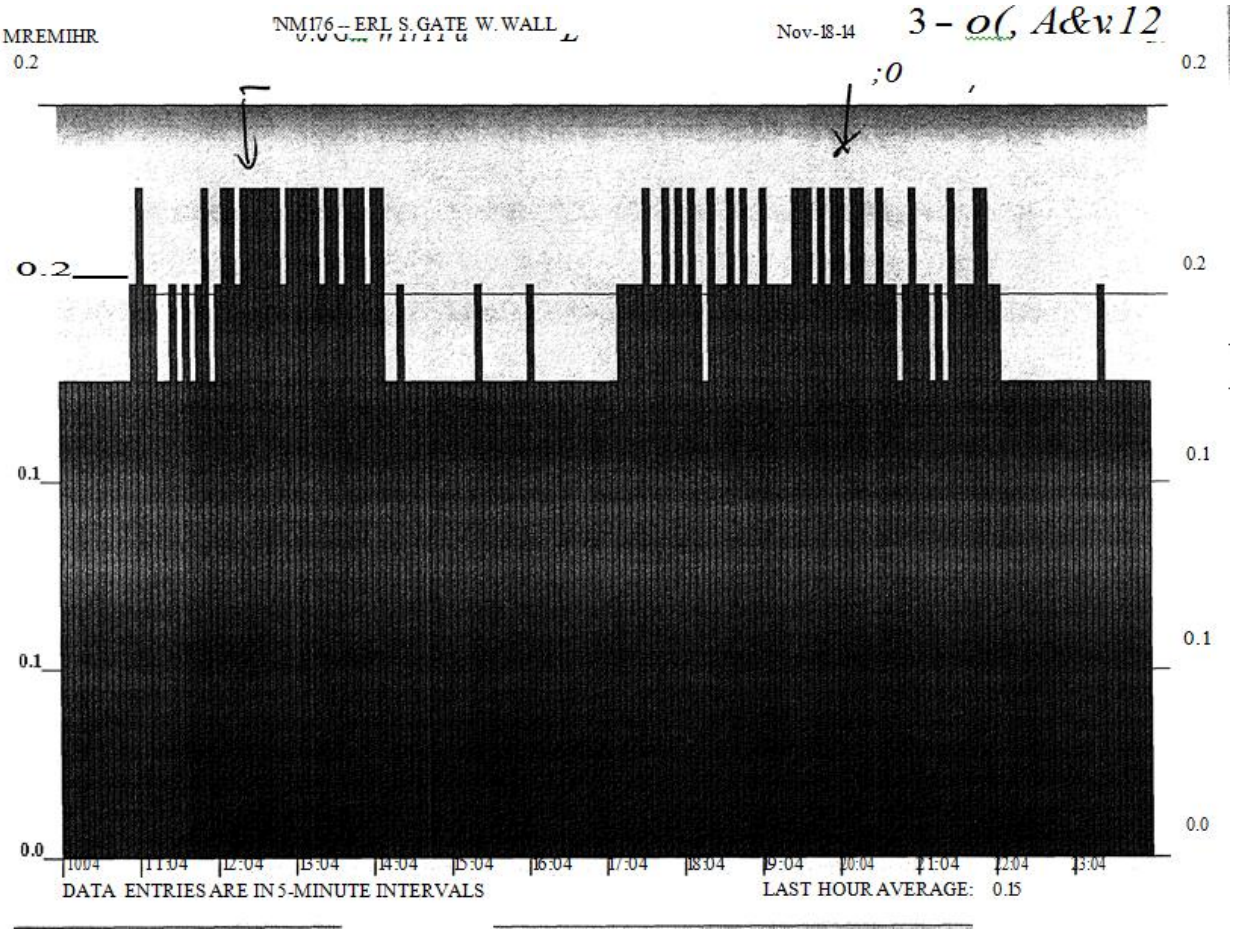

Figure IV: NM176 response during the Fault Studies 232 and 233.