RSC MEMO

Subject: LEReC 2 MeV Pulsed beam and CW beam between 1 and 18 mA loss and fault studies

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On Saturday, June 29th 2019, LEReC delivered about 1.2 mA of CW beam at 2 MeV to the HP dump. Fig. 1 shows the beam current as measured by the DCCT (bottom graph) and the readings from the chipmunk NM326 and the local RHIC BLM at the Blue Q3 magnet (b1-lm3) in the top graph as a function of time.

Fig. 1: e-beam current, NM326 and b1-lm3 readings during the HP survey
The survey was performed between 17:35 and 18:00. The results are shown in Fig.2 and demonstrate no radiation of concern outside the shielding. According to the Fault Study Plan for LEReC, 1mA at 2 MeV was not one of the mandatory hold points. Of the mandatory hold points, two were reached (with...
0.1 mA being so low that no losses or radiation could be measured even on the inside):
- 1 mA at 1.6 MeV and 10 mA at 1.6 MeV (email sent Thursday, September 6, 2018 5:31 PM, copy in CA Fault Study Logbook 2)

Both showed no radiation outside the shielding and were reported earlier. On Wednesday July 3rd 2019, LEReC delivered about 16-18 mA CW beam at 2 MeV (i.e. about 34-36 kW) to the HP dump.

Fig. 3: CW current to HP dump (bottom) and RHIC b1-lm3 loss signal (top, Y1) and NM326 chipmunk (top, Y2).

The CW beam was maintained for over one hour during which an HP survey was performed. There were 111 ion bunches at 4.59 GeV circulating in RHIC during most of the time covered in Fig. 3. However, the ions typically do not induce losses in this area and it can be assumed that all losses shown here and in the following figures are caused by the electrons, not the ions.

The results of the survey are reported in Fig. 8, attachment to this memo. No radiation above background could be detected on the outside of the shielding. In fact, the outside measurement showed an even smaller dose than during the previous measurement on 06/29. This variation can be attributed to increased background radiation due to other facilities on site.
Inside the shielding, at approximately 1 ft from the HP dump about 100 rad/h were measured and about 3 rad/h up on the wall at the HP dump, about 5-6 ft away from the HP dump. The ratio of the two calibrated loss monitors corresponds fairly well to the $1/r^2$ law. The radiation measured on the tunnel wall by the NM327 chipmunk at the next penetration did not exceed 0.2 rad/h. Readings from other (not calibrated) loss monitors from the area close to the HP dump are shown in Fig. 4 together with b1-lm3 at the bottom. bi1-cool.pmt4 and dmp.pmt1 are fibers strung along the beam pipe at the end of the blue cooling section and the extraction line to the HP dump respectively. dmp.lm1 and dmp.lm2 are ion chamber style loss monitors (similar to b1-lm3), both are attached to the extraction line, lm1 is at the start of the extraction line, lm2 closer to the dump. Readings that are higher on lm1 than lm2 indicate the ongoing tuning process while LEReC is prepared for CW beam operation.

Fig. 4: Area loss monitor during delivery of 36 kW of CW beam to the HP dump.

The tuning efforts are also visible in the changed correlation of radiation apparent at chipmunk NM326 as a function of CW current delivered to the HP dump. During the first attempt of CW beam delivered to the HP dump on June 29th, about 400 mrad/h appeared at the location of NM326 per delivered mA (Fig. 5). This could be reduced to about 150 mrad/h per 1mA during the 2\textsuperscript{nd} attempt on July 3\textsuperscript{rd} (Fig. 6).
Fig. 5 Radiation at NM326 as a function of CW beam delivered to the HP dump on 06/29.

Fig. 6: Radiation at NM326 as a function of CW beam delivered to the HP dump on 07/03.

It can be assumed that with more experience, time and tuning, the correlation improves some more. Delivering 18 mA CW beam to the HP dump was an attempt to get close to the hold point of 1.6 MeV and 30 mA, i.e. 48 kW. In this measurement we reached 75% of it with no detectable radiation on the outside of the enclosure.

In addition to the hold-point we attempted one fault study with pulsed beam at 40% Laser Intensity (LI) delivering single bunches with 54 pC each. The study was done with 3 Macro Bunches (each containing 30 single bunches) and thus a total beam current of 4.8 nC. One of the dipole magnets steering the e-beam into the extraction line, dmp.d1, was powered with half the nominal current for about 45 minutes on July 2nd from 10:00 to 10:45 (Fig. 7, bottom).
Fig. 7: Dipole current (bottom), local loss fiber style loss monitors (center) and other selected area loss monitors in the extraction line area (top) on 07/02/19 during the pulsed beam fault study.

The scintillating fiber style loss monitor signal locally jumps up to about 5000 a.u. (arbitrary units, Fig. 7, center). However, none of the area radiation monitors detects any losses or radiation during this time (Fig. 7, top). Beam losses that are below trip level of the machine protection system are of no concern for the RSC.

**Conclusion**

Given that there is not even a small detectable increase of radiation levels outside the enclosure when LEReC was operated at 75% of the 48 kW hold point with CW beam and fault studies with pulsed beam showed no detectable radiation even on the tunnel wall on the inside of the enclosure, I recommend
to hold operation at a much higher hold point corresponding to 75 mA at 1.6 MeV or 60 mA at 2 MeV. Scaling the measured outside dose of approximately 10 μRem/h with a factor of 3.33 (i.e. 120 kW/36 kW), the result is still expected to be below the lower boundary for controlled areas of 50 μrem/h (see OPM 9.1.11.a). Additionally, the area outside of IP2 is controlled (upper limit of 5 mRem/h). Consequently, the 1 mA and 10 mA holdpoints at 2.6 MeV when 2.6 MeV operation is attempted should be waived and resumed when we reach a power level above what was already reached and surveyed at lower energies. If we do not exceed 36 kW in FY19, we should adhere to the 30 mA at 2.6 MeV hold point. Operation at 2.6 MeV is not planned for FY19.

This Survey was taken at 1002. Survey locations include seams in the shielding, two cable ports, laser beam penetration and berm penetrations. Survey began at 1515 and finished at 1525. Beam power during survey: 34Kw
survey during the 07/03/19 CW operation with 34 kW CW beam in the HP dump.