Investigation of blue diode and new protection bump location

1. BO10-D19 Diode Shorted

During Run 16, on March 17 in store 19702, the diode of blue dipole BO10-D19 started to be shorted after an acute beam loss there, although it could run for another store after that acute beam loss. After chronic beam loss on the dipole from store 19705, it couldn't run as nominal anymore. The shorted diode is most likely caused by the beam loss radiation at the protection bump area.

2. Introduction to protection bump and compensation bump

To prevent the STAR and PHINEX detector damage from abort kicker pre-fire, a protection bump and a compensation bump were installed in both blue and yellow ring in Run14 for Au-Au operation. Their locations are shown in figure 1.

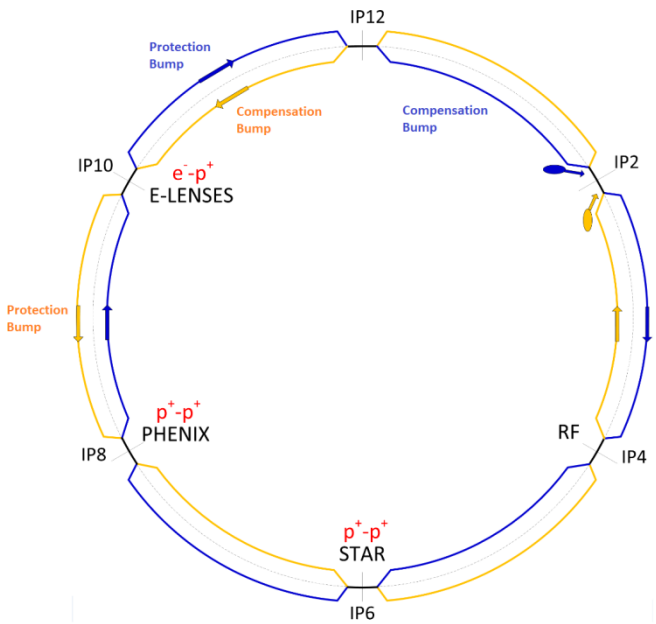

Figure 1: the location of protection bump and compensation bump for blue and yellow

These bumps are also shown in Figure 2 with measured beam orbits. The protection bump maximum amplitude is 20 mm, while compensation bump maximum amplitude is 15 mm, for both blue and yellow ring.

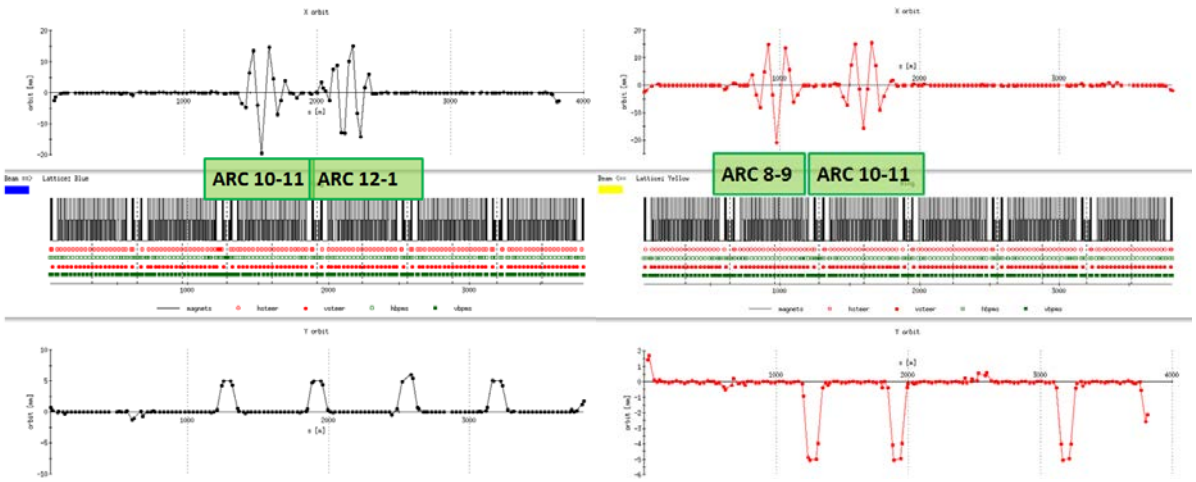

Figure 2: blue (left) and yellow (right) orbit display with protecion and compensation bumps

3. Beam loss round bump locations

The purpose of these bumps is to absorb pre-fire in the bump area, instead of lossing beam too close to the detectors. One acute beam loss is presented in Figure 3.

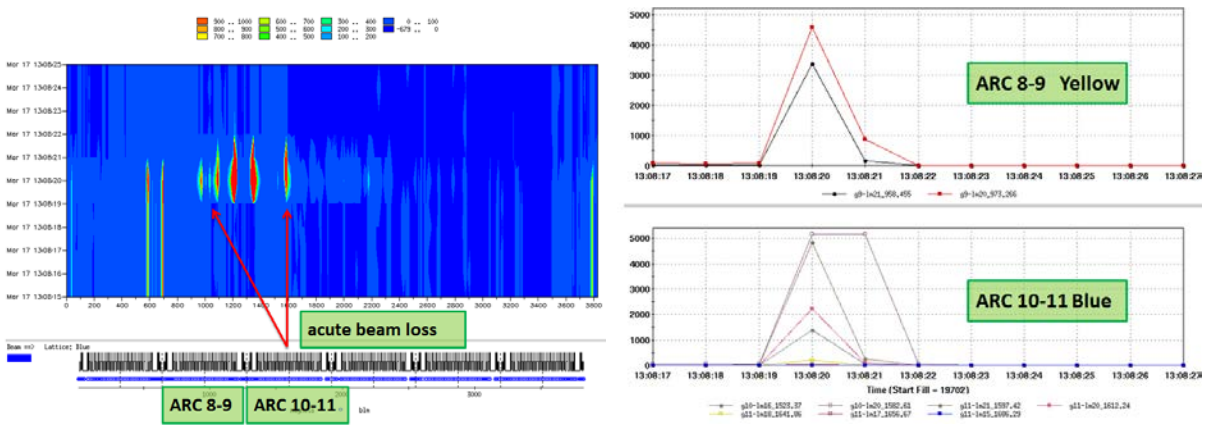

Figure 3: acute beam loss pattern (left) and several individual beam loss monitors (right)

Figure 4 shows the acute beam loss during run 16 as measured by loss monitors in the bump peak areas. Each spike in the plot represents an acute loss events.

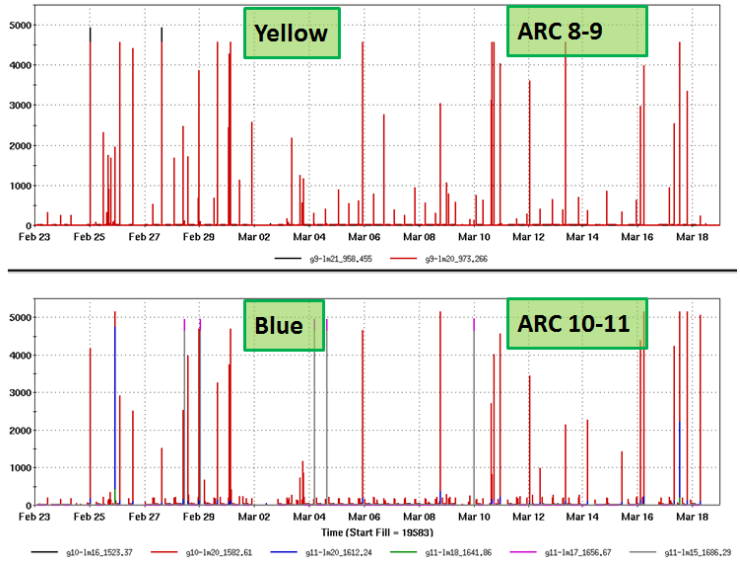

Figure 4: acute beam loss peaks from beam loss monitors

Besides acute beam loss, there is also chronic beam loss at the protection bump locations, which is shown in Figure 5. The chronic beam loss could be caused by off-momentum Au79 or Au78. Although one can't distinguish the cause for the shorted BO10-D19 diode between chronic beam losses and acute beam losses (single event), or a combination of both, **moving the blue protection bump to another ARC is necessary as a precaution, to avoid similar issues for other dipoles nearby**.

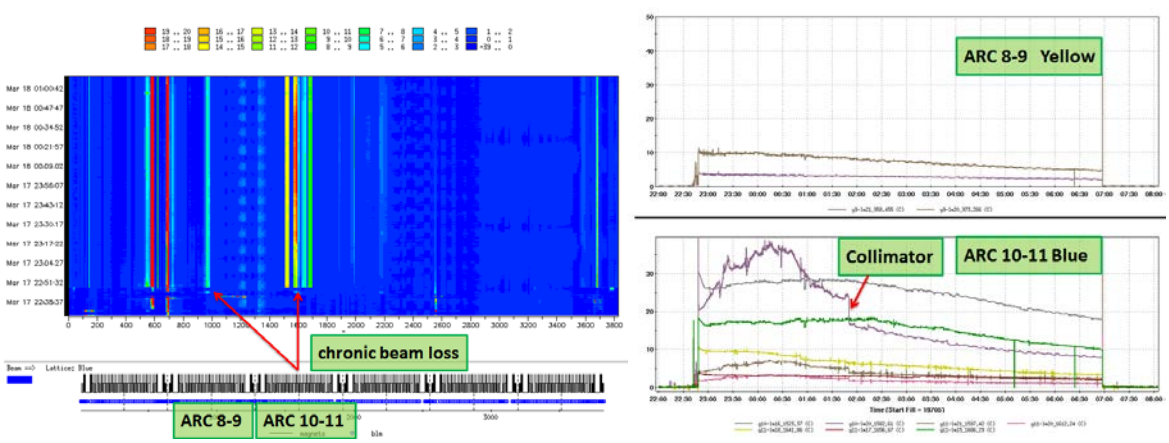

Figure 5: chronic beam loss pattern (left) and several individual beam loss monitors (right)

Furthermore, from the right plot of Figure 5, one can see that the chronic beam loss in ARC8-9 (which is the yellow protection bump location) is much less than the beam losses in ARC10-11(blue protection bump location and yellow compensation bump location). And from Figure 6, it seems it is blue beam decay that dominates the beam loss at g10-blm20. This excludes the yellow compensation bump as a potential culprit.

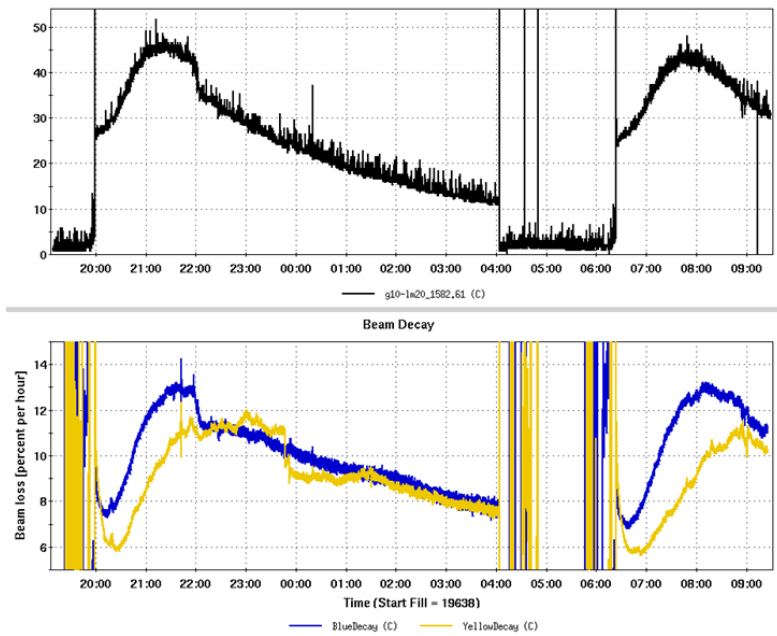

Figure 6: Blue beam decay and beam loss at g10-lm20.

As an explanation for the difference in the amount of chronic losses (of about a factor 3) between the blue and yellow bump in Figure 5, it is suspected that the **longer traveling length from the interaction region to protection bump**, which yellow beam has (anti-clockwise from IP8 and IP6) is the reason. **Longer traveling length is NOT anticipated to reduce acute beam loss**.

4. New bump configuration (same risk for physics as before)

Figure 7 shows the proposed new blue protection and compensation bump location. The protection bump is placed outside of the blue ring, to reduce the radiation upsets in the alcove, which is located on the inside of the ring. The maximum of the bump will be positive and beam loss will point to the outside of the ring. With the old design (Figure 2, left), the BPM at the maximum has a negative reading and beam loss points to the inside of the ring. The dipole diode and the alcove are both located on the inside of the ring.

In yellow there is a potential for off-momentum beam to get lost before it reaches the protection bump while this chance is much smaller in the blur due to the shorter travel length between point of origin (IPs) and loss location.

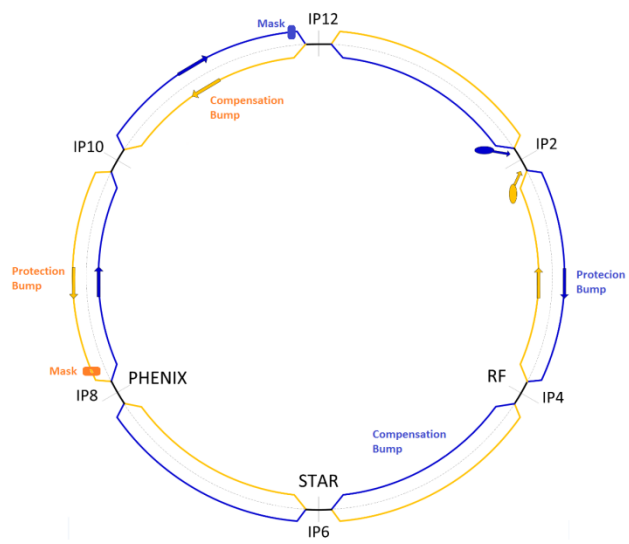

Figure 7: new bump configuration

5. Protection bump and CeC wiggler (NO more/additional risks were found compared with before)

Compensation bump and protection bump around IP2 (Figure 8) were also considered, to protect the CeC wiggler from potential beam loss in a pre-fire event.

- It turned out that it may make potential beam losses worse at IR2 if we put the protection bump between IP12 and IP2, and the compensation bump between IP2 and IP4, because the dispersion function would be distorted between two bumps. With distorted dispersion, when a pre-fire event happens, all bunches which were not intercepted in the protection bump could be lost at IR2. This scenario is less desirable because of this. But more simulation is needed **if that were required**, to further demonstrate this configuration is same/better, at least not worse than others.

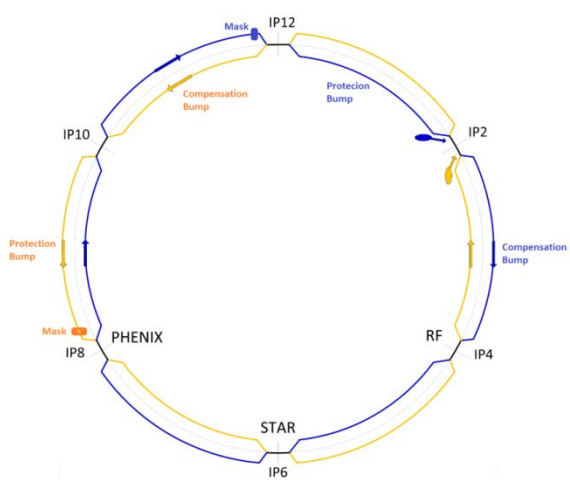

Figure 8: compensation bump between IP12 and IP2

- Additionally, there was a pre-fire test (store 19557) and there is no significant beam loss at IR2 with halved blue protection and compensation bump at that moment. Please see Figure 9.

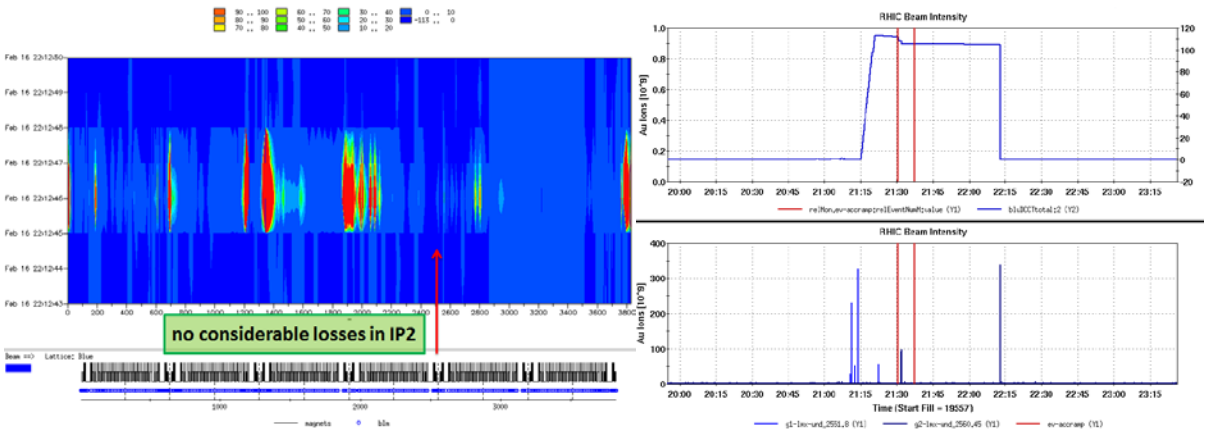

Figure 9: Beam loss at IR2 during pre-fire test

- Further checking of the difference between no bump at all between blue kicker and IR2, and halved protection/compensation bump, is done by comparing the different phase advances between full bump and no bump between kicker and IR2. The difference in phase advance is less than 2 degree. That means it **is not expected a significant difference** between the pre-fire test and a real blue pre-fire without any bump before IR2 (Figure 7).
- The beam trajectory **without any bump before IR2** is shown in Figure 10, which is the case in the Figure 7 configuration. The red line beam envelope is 6 sigma of beam size with one abort kicker module at 100% strength. The bottom left shows the beam trajectory around IP2, where the beam pipe is still clear with nominal aperture. The bottom right plot depicts the case for IP6.
- Other slow beam loss scenarios at IP2 are not considered.

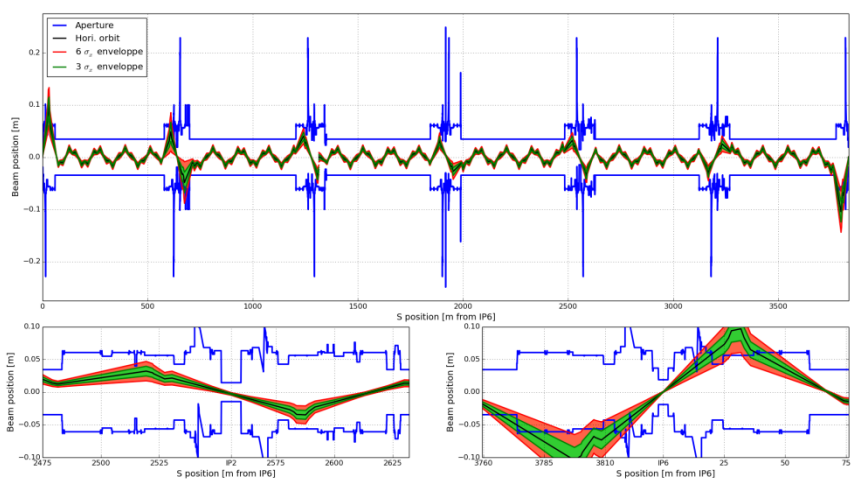

Figure 10: 6 sigma beam envelope at IR2 (bottom left) and IR6 (bottom right)

6. Mask and orbit bump (reducing risk of machine)

With the new protection bump configuration, one can see that the blue mask is on the upstream of the protection bump as well as IR2. That mask can intercept some bunches from a pre-fire first before these bunches travel through IR2 and the protection bump. This should result in less acute beam loss for protection bump compared to before with the same pre-fire.

Furthermore, it is planned to increase the local orbit bump to get beam closer to the blue mask, even if suffering a little bit more chronic beam loss. This could provide additional protection for both IR2 and the protection bump.

7. Summary

In this report the new blue bump configuration is proposed. It consists of the protection bump located between IR2 and IP4, and the compensation bump located between IR4 and IR6. This configuration provides same protection as before for STAR. With this configuration, no more/additional risk for CeC wiggler is found, based on the pre-fire test with halved bumps before IR2, as well as the 6 sigma beam size beam envelope at IR2 with one abort kicker module at 100% strength. The planned push of the beam orbit closer to the blue mask could further reduce the risk of both CeC wiggler, as well as protection bump area.