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Memo

date: *March 21, 2012*

to: *RSC*

from: *D. Beavis* *& S. Nemesure*

subject: *Distribution and Size of BLM Initiated Beam Aborts at RHIC*

Motivation

The RHIC Project assumed that Maximum Credible Incidents[1] (MCI) for beam faults could occur anywhere in the ring. The Project assumed that the entire beam in a ring could be lost on a high beta quad or other limiting aperture and half the beam in a ring could be lost at any other location[2]. These large losses were anticipated to occur several times a decade but for planning purposes the RHIC Project assumed once a year[3]. These assumptions coupled with an exposure criteria established the radiation protection scheme for RHIC. Now with more than ten years of operating experience we can determine if these assumptions were reasonable or conservative. The locations and size of beam loss locations around the RHIC ring when Beam Loss Monitors (BLM) initiated a beam abort will be examined.

Upgrades in beam intensity are being performed to increase the beam intensity of both the ion and proton beams. The information in this report may help assess the risk of exposures due to large beam loss events and the planning for improvements to prevent exposures.

The analysis showed that no losses above 6% of the maximum beam allowed per ring occurred from events when the beam permit was pulled by the BLM system between run05 and run10 inclusive.

There are only a few losses where the beam exceeded 1% of the maximum allowed beam per ring.

Data Selection

The archived data from RHIC runs were filtered for fills in which the stored beam was aborted due to the loss of the beam permit by a BLM. The runs selected for this study were run05 to run10 inclusive. Aborts for beam at energies lower than 100 GeV were not considered. Lower energy operations typically produce fault dose for an MCI at least a factor of three below full energy operations. The selected runs include Au+Au, P+P , d+Au , and Cu+Cu. The data selected does not include beam that was lost on the ramp. The P+P operations is tabulated

separately from the ion fills. Simple factors are used to account the mass difference of Au, Cu, and deuterons.

The data files may include several BLMs that exceeded their beam permit threshold. We only use the location of the loss monitor that was registered as the one that initiated the abort. This may not be the location of the largest beam loss. The current transformers are used to determine the maximum amount of beam that could have been lost at the BLM location. This may be spread among several beam loss locations and is thus expected to be conservative on estimating the size of local beam losses.

It should be noted that the loss monitors are installed to protect the machine from large beam losses. Some machine components are more sensitive to beam losses then others and may have their abort threshold set at a lower value to provide sufficient protection. The BLMs are not under the same configuration control system that the access controls and radiation monitor system utilizes.

Results

The aborts initiated by BLMs are displayed in Figure 1 for all the ion beams excluding protons. The distribution is seen to be very structured. Most large losses are expected to occur near the IRs where the beam optics can be dynamic and clearance to apertures is a minimum. A simple listing of Intersection Region (IR) locations is given in Table I.

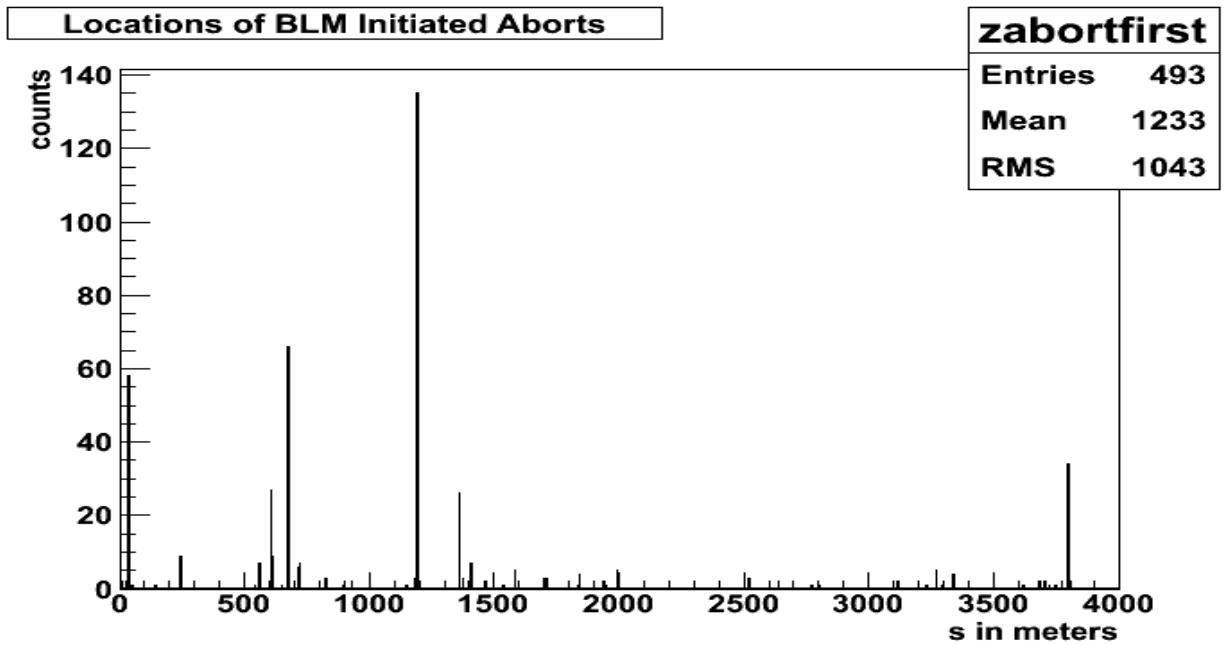

Figure 1: Locations of loss monitors that pulled the beam permit. The fills were required to be at store and include Au, Cu and deuteron ions. The low energy fills are excluded as well as the protons.

Table I. IR locations in meters

Item	Z coordinate (m)	Comment
IR6	0.	Small beta* for STAR
IR8	639	Small beta* for PHENIX
IR10	1278	No experiment
IR12	1917	No experiment
IR2	2556	Run05 was last exp.
IR4	3195	No experiment
IR6	3834	Provides end-same as 0.

Most of the aborts are initiated at discrete locations. The triplets that focus the beam for the IRs are located at +- 30 meters from the Intersection Point (IP). For most of these runs only IR6 and IR8 had small betastar. Losses in the triplets near IRs with small betastar account for nearly 50% of the aborts. The berm areas above all triplets are inside locked fences that encloses the area above the IR roof and triplets. The Q4 magnets are approximately +- 80 meters from each IP. The section of the ring between the triplets and Q4 can have equipment that is protected by BLMs. The components in these Q3-Q4 sections include the Siberian snakes, spin rotators, spin flippers, abort kickers, beam dumps, collimators, and more recently stochastic cooling components. A partial list of special component locations is presented in Table II.

Table II: Special Machine Components

Item	Location (m)	Comment
Snake-9 O'clock	1160.	In both rings
Snake-3 O'clock	3068	In both rings
Spin rotator-6 O'clock	3770	In both rings
Spin rotator-6 O'clock	49	In both rings
Spin rotator-8 O'clock	567	In both rings
Spin rotator-8 O'clock	710	In both rings

The maximum amount of Au-yellow beam lost is displayed in Figure 2. The largest single loss is about 6% of the total beam allowed in the yellow ring. The average Au-yellow loss in a BLM abort event is about 0.4%. These events include aborts initiated by the blue beam and therefore the average is impacted[4]. The beam losses in the blue ring are about a factor of two smaller and no blue loss exceeded 5% for the data sample. The Cu and d losses were examined and found to be smaller than the example shown for the Au-yellow beam. For run05 through run10 there were no ion losses that approached the MCI in the RHIC SAD in the sample selected.

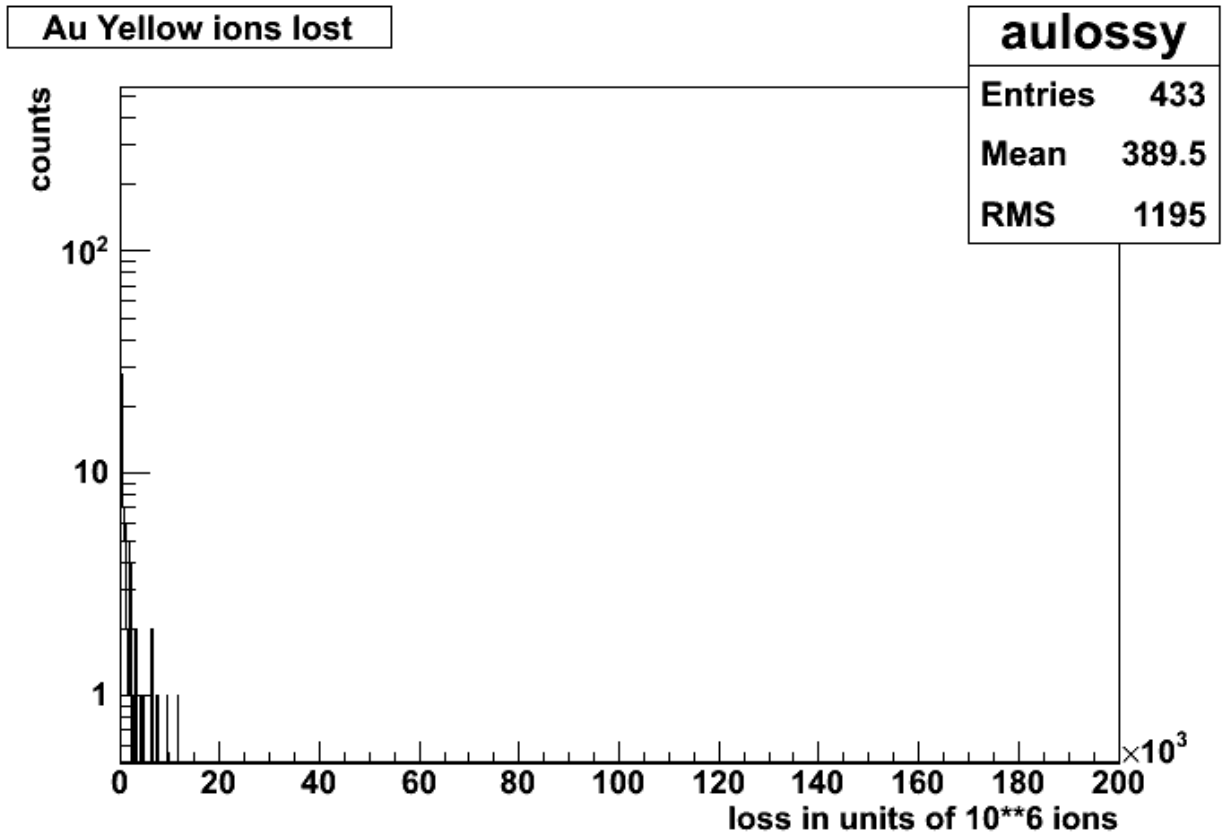

Figure 2: The maximum local beam loss for the yellow beam.

The proton data was also examined during the sample period. Figure 3 shows the locations where the beam permit was pulled by a loss monitor. The pattern is similar but one difference from Au beam losses is the number of aborts that are pulled to protect the Siberian snakes. The peak at 1165 in Figure 3 is from the snake. There are also contributions from the spin rotators. We can make a cut on the beam losses by requiring at least 10% of the stored beam was lost in the event and that there was a minimum of 5% of the maximum allowed beam in the ring. These events are shown in Figure 4. There are a total of 17 events that passed the selection criteria. None of these events exceed 6% of the maximum allowed beam in a ring. The locations are the triplets at STAR, the triplets at PHENIX, the spin rotators, near Q4 at 10 O'clock, and the snakes. All are presently under fenced[5] areas of the RHIC berm, except the snake at 3 O'clock (s=3070).

Figure 5 displays the yellow proton losses including the events when a blue loss monitor pulled the beam permit. The beam losses for protons are similar to the losses for ions and the average loss is small typically less the 1%. The loss monitor thresholds are established to protect the superconducting magnets from loss induced quenches and most likely make these distributions similar.

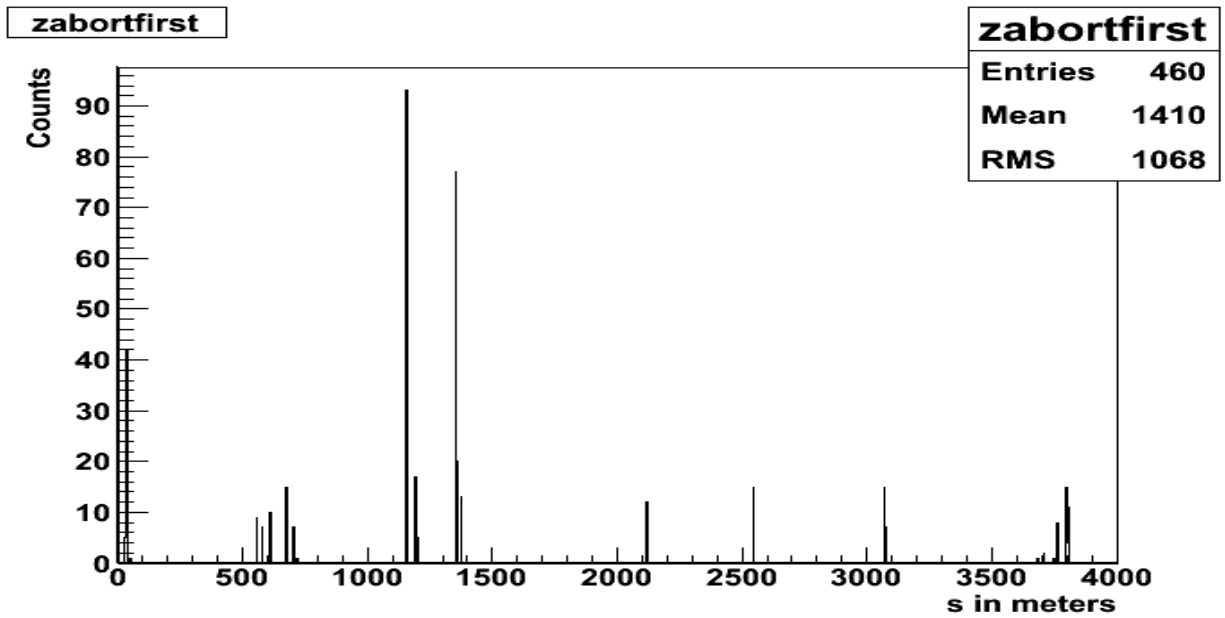

Figure 3: Locations were the loss monitors pulled the beam permit for proton stores at 100 GeV and higher energy.

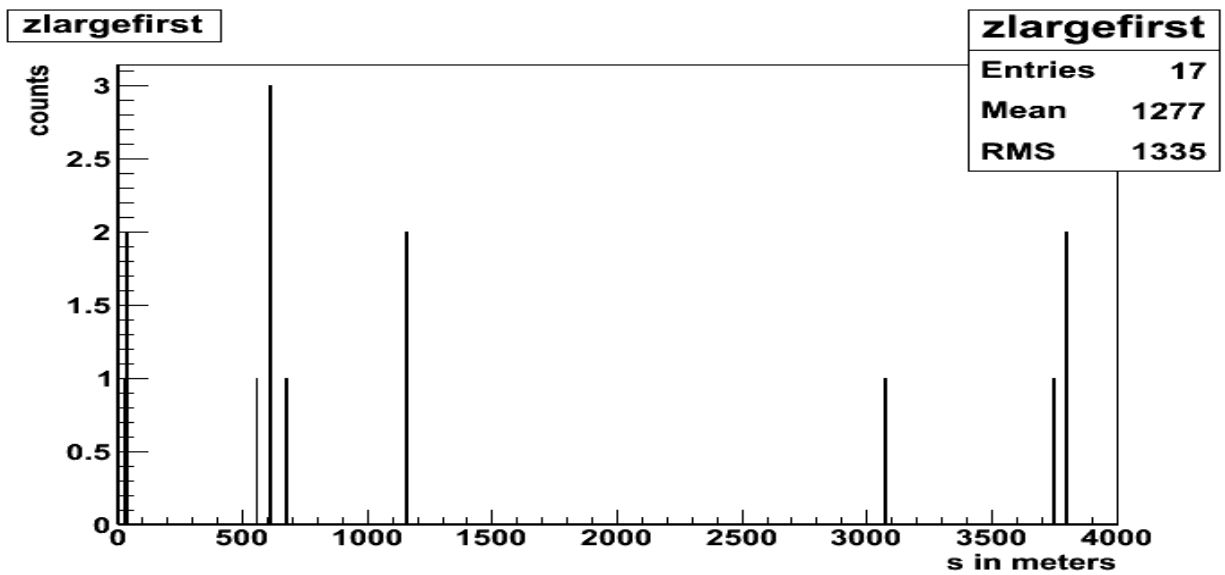

Figure 4: Locations of BLM initiated beam permit pulls when at least 10% of the beam stored in a ring was lost and the machine had at least 5% of the allowed maximum in the ring.

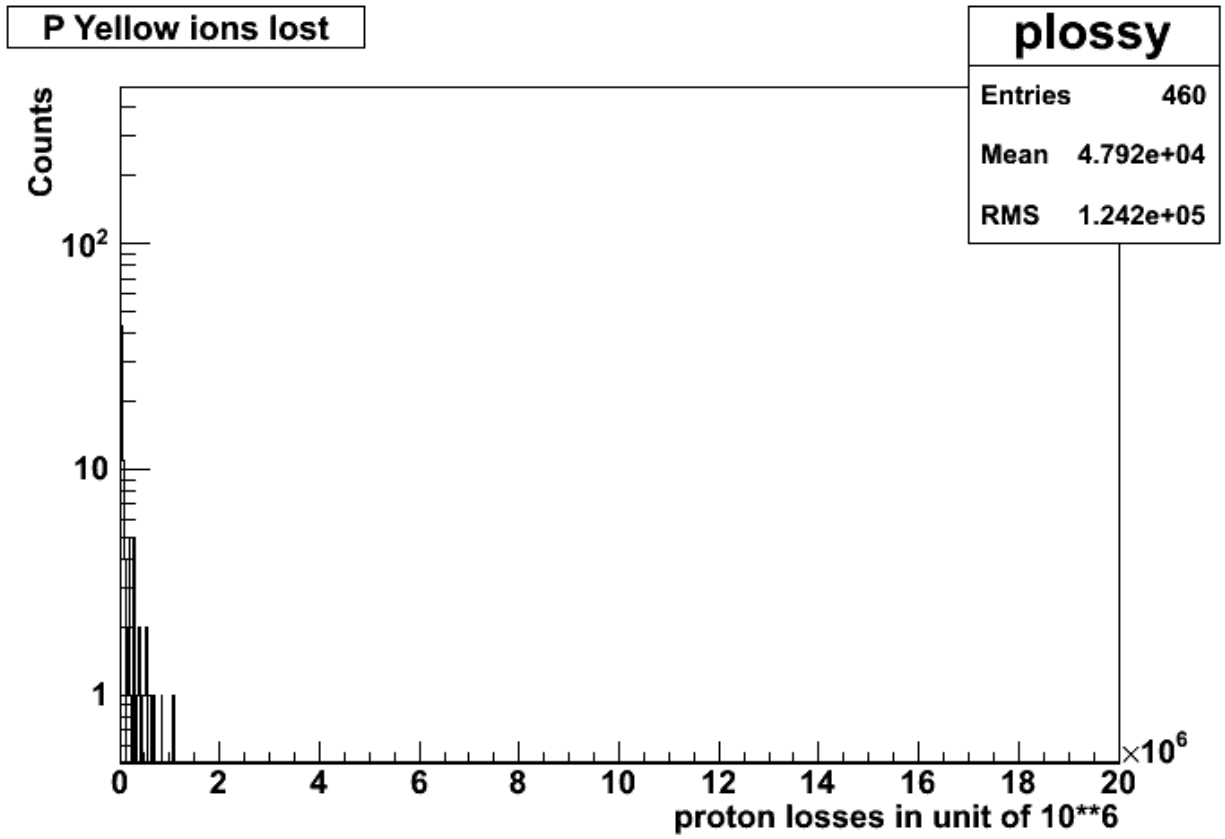

Figure 5: Yellow proton losses related to beam aborts.

Conclusions

The loss monitors are effective in preventing large beam losses during ion and proton operations. Most losses are associated with aperture restrictions and the insertion regions of the IRs where special devices are located. There may be losses that the data sample did not find either due to a loss monitor being masked (not in the permit) or the fill not meeting the criteria that a loss monitor pulled the permit[6]. Based on this analysis it is unlikely that a large loss would occur at an arbitrary location around the RHIC ring. The most likely loss locations are discrete and well identified locations.

References

1. The RHIC Project referred to these events as Design Basis Accidents (DBA) in the reports.
2. RSC minutes of Nov. 2, 1992, http://www.c-ad.bnl.gov/esfd/RSC/Minutes/11_02_92Minutes.pdf
3. See Appendix 1 of the RHIC SAD, http://www.c-ad.bnl.gov/ESSHQ/SND/RHICSAD/appendices/app01.pdf
4. More careful analysis of the events could be conducted to remove this bias. The beam losses in the events are small and it was decided not to pursue additional analysis.

5. The loss on q4 has not been analyzed to determine how much of radiation pattern would be under the fence that encloses the berm over the beam dump.
6. One loss of substantial beam was not in this data sample. During run06 the beam was being prepared to be aborted and a vertical separation was being placed between the beams. A power supply on one side of 6 O'clock did not track there associated power supply on the other side causing a large beam crash. Apparently, the beam permit was not pulled by a loss monitor.

CC:

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