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: *May 16, 2011*

to: *RSC*

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

subject: *Store Losses at the RHIC Primary Collimators*

The RHIC Project assumed very conservative estimates for the beam losses on the RHIC primary collimators. The archived files for the last five RHIC runs have been examined to compare actual operation losses on the collimators to the initial RHIC Project estimates. It is found that the amount of beam scrapped on the collimators is substantially lower than the design assumptions. This provides confidence that the beam intensity and energy can be increased without exceeding the analysis of the original RHIC SAD or the requirements for compliance with regulations, BNL guidelines, and ALARA principles.

Radiation Issues and the RHIC estimates

The calculations for the primary RHIC collimators[1] addressed two external radiation issues. The first is the dose on the berm directly above the collimators. The maximum dose rate in an hour was estimated to be 11 mrem. This area is fenced and access strictly controlled. The second external issue was the skyshine dose to other site facilities and offsite. The offsite dose is important to consider for any potential upgrades. The closest offsite point is William Floyd Parkway where the maximum annual dose was estimated to be 0.9 mrem per year from the primary RHIC collimators.

The estimation of the offsite dose is dominated by the amount of beam and beam energy onto the beam collimators. In this note we will compare the amount of beam scrapped by the collimators compared to the assumptions used by the RHIC project.

Method of Comparison

The archived files of past RHIC operations were scanned to provide lists of fill numbers, peak beam at store and the amount of beam lost before the store end. The amount of beam energy on the primary collimators is dominated by stored beam. The analysis does not take into account beam that was injected but lost before store energy. Since the external radiation scales[2] as $E^{0.8}$ in the transverse direction it is important to know the energy of the beam, where E is the beam energy. Minor tests and short special runs where ignored in the analysis. A ring was assumed to be at store if there was a decreased beam current before the beam was aborted. This method provides an upper limit estimate on the beam scrapped on the collimator since it assumes all lost beam current occurred on the primary collimator.

The RHIC Project assumed that the maximum beam lost on the primary collimators each year would be less than the equivalent of $1.1*10^{14}$ Au ions at 100 GeV per year. This is the number that was used to determine a skyshine dose of 0.9 mrem on William Floyd Parkway. The totals extracted for the years of operations will be expressed in terms of the percentage of the RHIC SAD value. The Table I displays the runs and fill number ranges used in the analysis. Table II has the ratio of the ions lost in a run relative to the RHIC Project assumptions expressed as a percentage. The overall trend is that the ratio has been increasing but even for run 10 is well below the conservative estimates used in the RHIC Project analysis.

Table I: Runs and fill ranges used in analysis

Year	**Energy (GeV) and Beam**	**Range of Fill No.**
Run 10	100 GeV AuAu	11107-12178
	3.85 GeV AuAu	12222-14260
Run 09	250 GeV PP	10017-10555
	100 GeV PP	10556-10888
Run 08	100 GeV dAu	9400-9660
	100 GeV PP	9661-9999
Run 07	100 GeV AuAu	8176-9054
Run 06	100 GeV PP	7411-7957
	31 GeV PP	8063-8115

Table II: Estimated maximum percentage of beam on collimator of RHIC SAD assumption.

Year	**Blue %**	**Yellow %**
Run 10	21	22
Run 09	10.3	11.6
Run 08	5.1	4.6
Run 07	10.5	8.9
Run 06	3.2	2.4

There are some inaccuracies in this analysis. A small number of special fills have been ignored. Fills with beam in either ring not making it to store are ignored. The high energy portions of runs 10 and 09 were examined to consider runs in which either beam was ramped to store energy. The Blue beam numbers in Table II were nearly unchanged. The accuracy of the analysis is considered sufficient to conclude that past operations of RHIC have been well below the operations scenario for beam lost on the collimators.

Run 10 is used to demonstrate the fill characteristics for an operating year. Figure 1 has the number of fills as a function of initial beam intensity for the 100 GeV portion of the Au run. There is a clustering of fills with an initial intensity of $1.2\text{-}1.5*10^{11}$ Au ions in the blue ring. There is another clustering of stores with Blue ring intensities below $2*10^{10}$ Au ions, which are typically test stores and studies. The average of the stores used in the analysis is $6.3*10^{11}$ Au ions in the blue ring at the beginning of a store. The average intensity is well below the $2*10^{11}$ Au ions assumed by the RHIC Project.

Figure II shows the fills as function of blue ring intensity for the 3.85 GeV beam stores. The reproducibility of the low energy stores is evident from the plot. Although there are many more stores during the 3.85 GeV beam operations the expected skyshine dose from these stores only contributed about 25% of the total expected skyshine dose due to the lower energy and lower intensity.

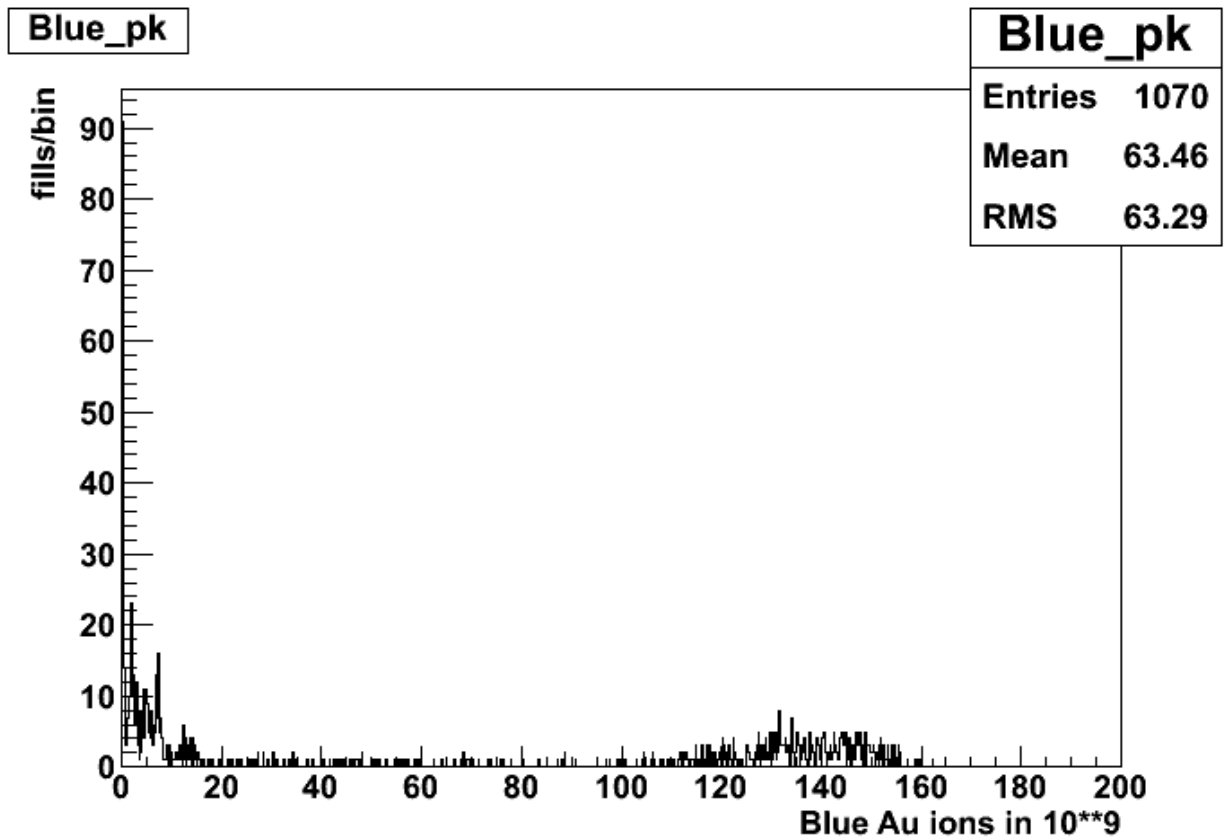


Figure I: Blue ions at the initial start of a 100 GeV store.

The RHIC Project assumed[4] about 60% of the ion losses in a store would occur at the primary collimators. If we use this percentage in the comparison then the run 10 result in Table II of 21% would become 12% on the average. This is deceiving since it includes two different operations scenarios and not the percentage of beam taken to store. Using the same data[5] we can plot the percentage of beam scrapped by the collimators. Using the average given by the distribution we get that 35% of the stored beam is lost for the blue gold ions in run 10. The analysis assumes that all losses are on the collimator. We note that the yearly total lost beam on the collimators is small compared to the assumption in RHIC SAD mainly due to the large average intensity used by the RHIC Project and the large number of stores at full energy. The actual percentage of stored Au beam scrapped on the collimators may be higher than assumed in the RHIC SAD (14%) but the absolute amount is the important parameter for potential off-site dose.

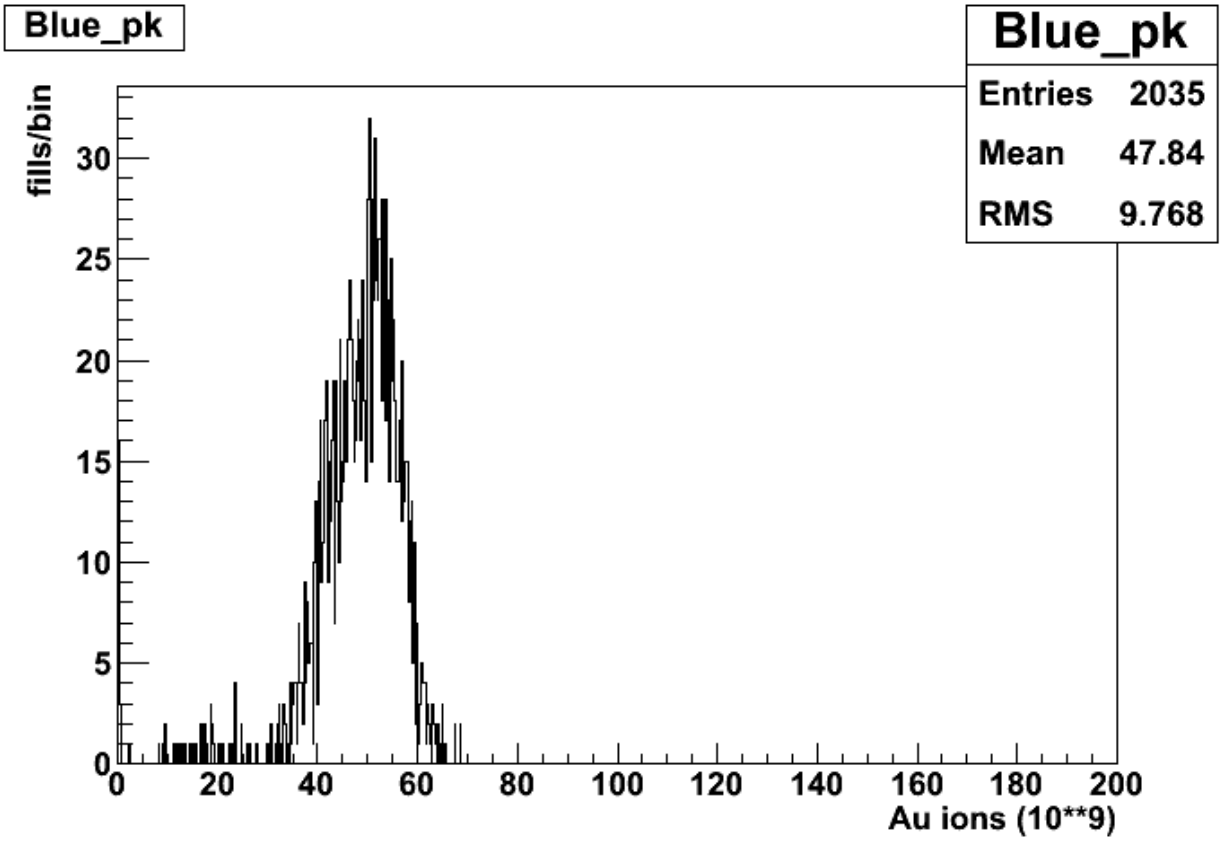


Figure II: Initial blue ring store intensity for 3.85 GeV operations.

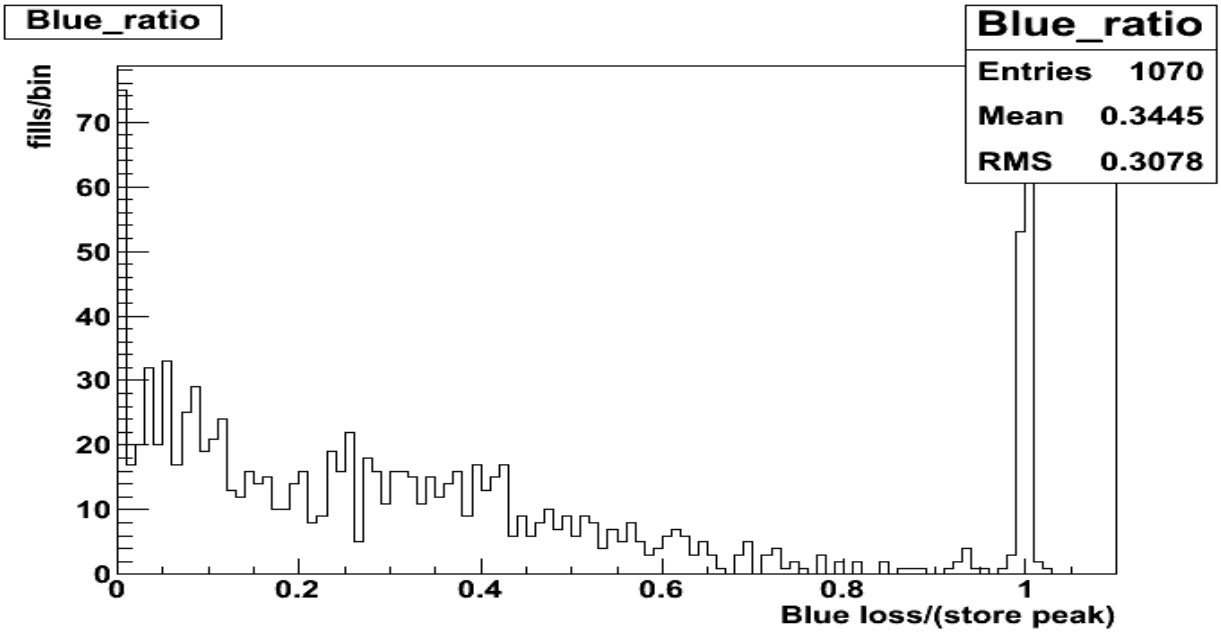
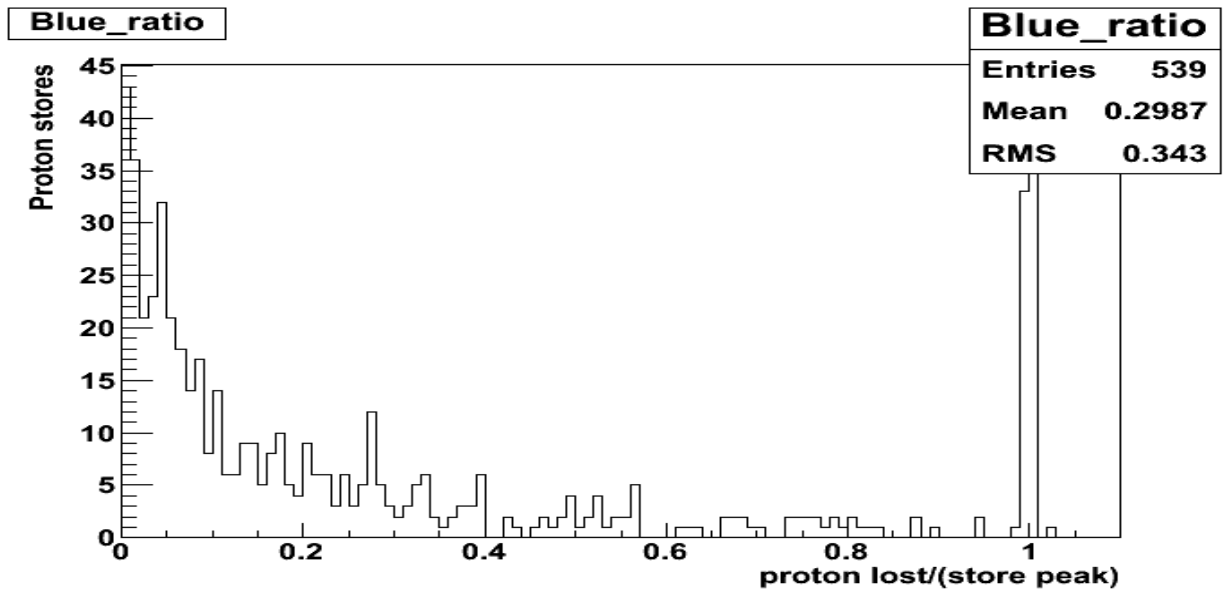


Figure III: The ratio of lost blue beam to peak blue beam for 100 GeV run 10.

The RHIC Project assumed that the proton losses on the collimators would be less than 2%. Figure IV shows the ratio of lost protons to peak stored protons for the run 250 GeV operations of run 09. Based on this distribution the average proton to peak store beam is 30%. If one divides the total 250 GeV protons lost during store to the in the peak beam in the blue ring a value of 15% is obtained. Although this is an upper limit, it is substantially higher than the values assumed in the RHIC SAD. This increased value does not impact issues related to transverse radiation such as skyshine, but could have an impact on the muon dose calculated[6] to the site boundary from the Limiting Aperture Collimators (LAC).



Discussion

The most immediate conclusion is that present operations are well below the equivalent of $1.1*10^{14}$ Au ion equivalents per year on the RHIC primary collimators. There is substantial allowance for increasing the amount of beam on the collimators, increasing the beam in each ring per fill, and increasing the energy 10-20%. The preliminary RHIC ASEs have the beam per ring increased by a factor of 2.5 and the maximum energy increased by 20%. For transverse radiation and specifically the skyshine the change in energy[7] will have no substantial impact. The potential off-site dose from skyshine for the primary collimators is not expected to be an issue.

It is recommended that a few monitor TLDs be placed near the ring road, which would be able to detect any potential dose from skyshine before it would be detectable at the site boundary. **(CK-RHIC-FY2012-776)**

It is recommended that either a more careful analysis of the protons lost on the the Blue primary collimator be conducted or that the muon calculation be redone for the 300 GeV protons.
(CK-RHIC-FY2012-777)

It is recommended that instrumentation to provide the amount of beam scrapped by the collimators be considered to allow for more accurate analysis in the future. **(CK-RHIC-FY2012-778)**

References

1. A.J. Stevens, "Radiation Safety Considerations near Collimators", AD/RHIC/RD-113, April 1997 (RHIC SAD Appendix 25).
2. A.H. Sullivan, A Guide to radiation and radioactivity Levels Near High Energy Particles Accelerators, Nuclear Technology Publishing, 1992
3. D. Beavis, "Extending Routine Operations of RHIC and AtR to Low Energies", August 28, 2009.
4. M. Harrison and A.J. Stevens, "Beam Loss Scenario in RHIC", AD/RHIC/RD-52, January 1993 (also Appendix 8 of the RHIC SAD).
5. This uses the same selection criteria as previously discussed.
6. A. Stevens, "Radiation from Muons at RHIC", AD/RHIC-46, Feb. 1, 1989; Memorandum A.J. Stevens to S. Musolino, "Muon Dose at the Site Boundary", Jan. 06, 1993 (see RHIC SAD Appendix 18).
7. The energy is proposed to go to a maximum of 120 GeV per nucleon for ions and 300 GeV for protons.

CC: W. Fischer
A. Drees
K. Brown
RSC RHIC File