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: *April 19, 2013*

to: *RSC*

from: *D. Beavis*

subject: *Increasing RHIC Proton Intensity per ring to $3.0*10^{13}$ protons per ring*

Introduction

The RHIC program has requested a recommendation to operate up to $3.0*10^{13}$ protons per ring for the rest of the FY13 run. Work is nearly completed to support a recommendation for operations to $5.0*10^{13}$ protons per ring at 300 GeV. The documentation is nearing completion for the IRs and the rest of the facility has complete documentation. The program would benefit from a partial increase immediately. The material below supports a recommendation to $3.0*10^{13}$ protons per ring. The upgrade to $5*10^{13}$ is expected to be needed at the end of this run or for next year and the expectation is that the documentation will be completed soon for the full intensity increase.

There are three simple points that should make the decision to recommend increasing the intensity to $3*10^{13}$ protons per ring trivial and actually the same holds for $5*10^{13}$ protons per ring. However, for the larger increase it is prudent to ensure that all the documentation is complete. The completed and reviewed analysis of the STAR shield wall identifies the conservative components of the RHIC Project analysis that make the decision to recommend the partial increase trivial. These points are:

1. The Project increased the duty factor for neutrons by a factor of two as recommended by DOE to anticipate the expected changes in 10CFR835. The new weighting factors are now known and based on an analysis by FNAL the average effective change in the neutron dose iasabout 1.4. This would provide a reduction in RHIC Project dose estimates of 0.7. There is nothing in hadronic cascades that would suggest using the FNAL numbers would be inappropriate at RHIC within very minor factors. This reduction factor is appropriate for thick shields or penetrations.
2. The RHIC Project used a star density to dose conversion factor that was 1.84 times higher than recommended by G.R. Stevenson. The reviewed analysis of the STAR shield wall and berm show that the dose is much lower than estimated by the RHIC project. This introduces a factor of 0.54. This factor is appropriate only for thick shield calculations and not penetrations.
3. Since the initial analysis of the RHIC ring the entire berm and interior of the ring has been upgraded to a Controlled Area. Most penetration exit the ring on the berm and were

evaluated for being in an uncontrolled area. This implies using the RHIC project criteria that most penetrations would be allowed in low occupancy area to have a beam increase of 1000mrem/160mrem, which is a factor of 6.25. This would result in allowing $14*10^{13}$ protons per ring for some locations where the posting was changed.

4. The combined items of 1 and 2 above provide a combined identified reduction of 0.38 for thick shields and 0.7 for penetrations. For thick shields this implies the limit on protons per ring could be raised a factor of 2.62 or to to $5.9*10^{13}$ protons per ring at 250 GeV. It also implies that any penetrations should meet the RHIC Project criteria to $3.2*10^{13}$ protons per ring.
5. For shield walls in the forward direction it was known and demonstrated in the reports that CASIM overestimated the radiation in the forward direction. Examples for STAR and 4 O'clock are in the Draft report.

It should be noted that on all the issues the RHIC project was aware that the factors they were using were conservative. The Project took the approach that if there was some uncertainty to take the most conservative approach. Therefore, the items above should not be considered as errors of judgment but rather a systematic approach to ensure they would overestimate the potential dose. Now with newer and better simulation tools it is possible to reevaluate some of the issues and remove some of the conservatism.

Misc. Penetrations

Miscellaneous penetrations on the RHIC berm were discussed in a memo of Feb. 11, 2010. These estimates were scaled from the RHIC Project numbers. The MCI dose results range from small doses up to 100 mrem, excluding the survey shafts. All these penetrations open on the berm which is a Controlled Area. The doses are expected to be decreased when the correct neutron weighting factor is applied and if MCNPX is used to provide the entrance dose rather than CASIM.

For details see: http://www.c-ad.bnl.gov/esfd/RSC/Memos/RHIC_misc_pene.pdf

Conclude these penetrations are acceptable for full be upgrade.

Survey and Ventilation Shafts

The survey shafts and vents have been evaluated with MCNPX and the new neutron weighting factor. They are within the 1000 mrem allowed in Controlled Areas. Work planning has been implemented for areas near locations were high doses could result in an MCI, such as the B1 ventilation shafts.

For Details see: http://www.c-ad.bnl.gov/esfd/RSC/Memos/Survey_Shift_07132012.pdf
http://www.c-ad.bnl.gov/esfd/RSC/Memos/RHIC_vent_B2_061412.pdf

Conclude these Shafts are acceptable for the full upgrade.

Labyrinths

The labyrinths for RHIC were estimated using the same techniques and source term as the RHIC Project. Some minor differences were noted. The highest dose when scaled by 2.5 for the full upgrade is 125 mrem. Most are well below 100 mrem. All exit into Controlled Areas.

For details see : http://www.c-ad.bnl.gov/esfd/RSC/Memos/RHIC_labys.pdf

Conclude these Labyrinths are acceptable for full beam upgrade to $5*10^{13}$ protons at 300 GeV.

RHIC Berm

The RHIC berm was evaluated using MCNPX for the beam upgrades. The maximum dose was 130 mrem in an MCI. The berm is a Controlled AREA and has work controls mainly to prevent personnel from working at weak locations such as ventilation shafts.

For details see: http://www.c-ad.bnl.gov/esfd/RSC/Memos/RHIC_berm_052312.pdf

Conclude the typical berm is acceptable for the full upgrade.

Site Boundary

The potential for exposure at the site boundary was examined for both neutrons and muons. The ring intensity does not directly impact an MCI dose at the boundary, which would be very small. The increase in intensity does increase the site boundary dose for a fixed number of fills. The maximum estimated proton fills of 570 250 GeV protons with the upgraded intensity of $5*10^{13}$ protons per ring is 0.3-1.5 mrad. One of the notes below mistakenly quotes 2345 fills per year for protons, which is the estimate for 100 GeV gold. The request is for 500 fills per year. Monitor programs have been established for the collimator and beam dumps.

For details see: http://www.c-ad.bnl.gov/esfd/RSC/Memos/RHIC_dump_082310.pdf
http://www.c-ad.bnl.gov/esfd/RSC/Memos/coll_history_final.pdf
http://www.c-ad.bnl.gov/esfd/RSC/Memos/Muons_300.pdf

Conclude there are no MCI issues for the site boundary.

Shielding At IRs

The revaluation of the shielding at the IR is nearly complete. With the understanding of the causes for lower doses per proton it is actually not necessary to complete detailed examinations of each IR. The original analysis was used as part of the effort to design the shields and it is not necessary to redesign them. However, evaluations of some shields will be useful to potentially allow access to areas such as the 1002A and 1004A roofs.

The Incomplete draft analysis can be found at (and archived) the RSC memo section of the WEB.

The STAR IR has had substantial re-analysis conducted. The only items to be documented are the evaluations of the conversion factors from high energy neutron fluence to dose. The calculations are already complete.

The 4 O'clock analysis is essentially complete. One shield wall is being changed to better reflect the actual configuration. However, the actual configuration has been tested and does not change the conclusions.

The 2 O'clock IR has had several analysis runs but a few more are desired to justify the operation to full intensity.

Analysis has also been conducted at the PHENIX IR and the 12 O'clock IR by Kin Y. It demonstrates that the shielding is acceptable for the full upgrade.
See for 12 O'clock: http://www.c-ad.bnl.gov/esfd/RSC/Memos/12%20o'clock%20dose.pdf
See for PHENIX: http://www.c-ad.bnl.gov/esfd/RSC/Memos/Kin_Phenix_9_8_12.pdf

Results from the various completed reports and the draft report for the IRs are Tabulated below.

Location	**RHIC Project (mrem)**	**RHIC Upgrade (mrem)**	**Comment**
Berm	114	87	1
STAR Shield Wall	267	130	2
PHENIX Shield Wall	340	11	3
4 O'clock fence (1004B)	85	85	4
4 O' Clock fence at (1004A)	223	10	5
2 O'clock-CeCpop	320	25	6
10 O'clock-berm		130	7
12 O'clock fence	174	7	8

1. Evaluated at 250 GeV and 3 feet above berm.
2. Adjusted the 5 foot number to 5.5 feet of concrete for the RHIC Project estimate. The upgrade has an extra factor of 1.5 to account for difference seen between MARS and MCNPX. A factor of 1.3 is also applied for mid-plane asymmetry as was for the RHIC number.
3. The difference is partially due to the fact that at the time the shield wall was designed there was only a north muon range stack. A south one was added and reduces the dose substantially.

4. The present upgrade calculation has some concrete missing. The number should decrease about a factor of 2. There is 6 feet of concrete near the retaining wall not 5 feet. This is from a fault for full beam on Q2.
5. The RHIC Project dose is from Q2. Q2 was checked but does not dominate this location. This is the result of the overestimate via CASIM. The dose is from DX. In the new calculation. The wall is actually 11 feet of light concrete and has been checked in a rerun of MCNPX. The dose is changed only a small amount. The 1.3 and 1.5 factors were not used in the new calculation as discussed in comment 2.
6. Both results are from DX on the 1 O'clock side with the CASIM result from the upstream end but the MCNPX result from the downstream end. The MCNPX result from the upstream end is 9 mrem. Thus a large fraction of the difference is attributed to the forward overestimate in CASIM similar to the 1004A result.
7. The typical berm value is used. A more explicit number will be calculated.
8. Calculation by K. Yip. The 174 from the RHIC Project may be at a different location.

Conclusion

It is concluded that the intensity upgrade to $5*10^{13}$ protons per fill meets the requirements used for the RHIC Project. In most cases the results meet the C-AD RSC requirements, which are typically more restrictive and were not used by the RHIC Project. The conclusions as to why the RHIC estimates are very conservative add substantial weight to justifying either a full increase or a partial increase to $3*10^{13}$ protons per ring.
It is recommended that the RSC or a subcommittee recommend the partial increase to $3*10^{13}$ protons per ring pending the final documentation on the IRs.