Memo

**date:** May 21, 2009

**to:** RSC

**from:** D. Beavis

**subject:** Estimate for the Second Beam Scrubbing of RHIC

The proposed beam scrubbing will be conducted with beam in both rings at injection energy. The usual bunch intensity will be increased to $4 \times 10^{11}$ protons per bunch with 109 bunches in each ring. The concentration of Na$^{22}$ determines the limit to the number of protons that are allowed to be lost in a specific location based on a model in the SBMS. BNL limit would require we produce less that $1.05 \times 10^6$ Na$^{22}$ atoms per cc of soil outside of the tunnel wall where it can be leached into the water table below. This limit is 5% of the EPA drinking water standard.

The number of protons that are allowed to be lost at a single point is

$$N_p = \frac{IL \times (1.05 \times 10^6)}{(NI \times flux)}$$

Where

- $N_p$ is the number of protons lost at a single point,
- $IL$ is the interaction length ($IL=40$ cm)
- Flux is hadrons flux in the soil with energy greater than 20 MeV per lost proton
- $NI$ is the number of Na$^{22}$ ions, which is 0.02

A conservative estimate of the maximum flux can be scaled from a calculation by A. Stevens at 25 GeV which is slightly higher than injection energy. The calculation was done assuming the tunnel wall is five feet from the source. At RHIC the typical distance is ten feet, which provides a factor of 4 reduction. The maximum flux at RHIC is $2 \times 10^{-5}$ hadrons(e>20 MeV)/cm$^2$ per lost proton.

For a loss at a single point we should keep the losses below $1.05 \times 10^{14}$ protons lost at a single location that is not under a soil cap to insure that the concentrations are below the BNL limits.

The scrubbing will use 109 bunches in both ring with $4 \times 10^{11}$ protons/bunch. The scrubbing will be terminated when approximately 20% of the beam is lost or a total of $8.7 \times 10^{12}$ protons per ring. The loss pattern from the last scrubbing was examined and it was determined that 90% of the losses occurred near the beam dumps under soil caps. The injection septum is the next highest local loss point. The floor under the magnet is capped by the concrete structure but there
is no cap over the side shielding. 1.7*10^{11} protons are lost at a particular injection magnet per fill (10% of 20%).

The concrete side walls allow for a factor of two reduction in the potential concentrations in the soil.

We need a safety margin to account for other potential losses for operations and limit ourselves to 50% of the BNL limit for this test. 600 fills can be used for this scrubbing operation. This is substantially more than required for the operation.

There are removable soil sample located near at least one injection magnet to monitor the potential for soil activation. If the data is reviewed from the previous runs we may be able to increase the limit on the number of scrubbing fill.

Based on this analysis it is recommend that 8 fills be allowed for the scrubbing operation with the intensity and bunch parameters given above. Further analysis or consideration may allow this limit to be increased.

Cc: A. Drees
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