Requested Change in Deuteron Parameters for the TtB line

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It has been requested to change two conditions on the deuteron beam for the upcoming RHIC run. The first parameter is to use one rather than two harp planes to monitor the beam intensity. The second is to increase the deuteron energy to about 18.5 MeV so that a different charge state of the Au beam can be used with the deuterons and gold ions at the same rigidity in the TtB.

The removal of one plane from the beam should reduce the beam losses on the harp from 15% to 7.5%. The desire is to increase the beam intensity by removing part of loss on the harp. This issue is more of a judgment call by the committee and I will leave it for the committee to consider.

The change in energy from approximately 17.5 MeV to 18.5 MeV will cause increases in the potential dose to personnel near the transport line in the event of beam scrapping. The integrated beam is an important input to this issue. Originally, A. Stevens[1] used a **conservative estimate of 6.96*10**17** deuterons transported into the TtB tunnel for the 2002 run. Loss scenarios were considered and an estimated **2*10**16 deuterons per year were expected to be lost at a single point and 4.5*10**13 deuterons in an hour at a single point.** Recently, C.J. Gardner estimated[2] the amount of integrated deuterons required for the upcoming RHIC run. This estimated was based on experience from the previous run and changes in operations. He estimated that a **total of 8.3*10**17 deuterons** are required for this year's RHIC program at the end of the TtB. Accounting for beam losses the RHIC program will require 1*10**18 deuterons. Light ions, usually protons, are used occasionally by NSRL and a 20% factor will be added to account for this use bring the total to **1.2*10**18 deuterons or equivalent delivered into the TtB.**

The loss numbers at a single point provided by A. Stevens will be scaled for considering the potential dose on the berm for chronic losses during the program. The maximum dose in an hous is obtained by using the maximum expected beam in an hour given by C. Cardner[2] and the 2% clocal chronic loss aummed by A. Stevens[1]. The loss numbers are (were):

3.5*1016 d per year (2.*10**16) and**
2.8*1013 d in an hour (4.5*10**13).**

K. Yip has done an MCNPX calculation[3] for a 20 MeV deuteron beam striking an iron valve. The dose rate after 3 feet of soil is 10**-17 rem/d. A hypothetical loss point with the minimum overburden (no actual high loss point has been identified in past operations) is assumed. The following doses for the hypothetical loss point with a hypothetical thin berm located over it is:

350 mrem per year - ground contact
0.28 mrem in an hour - ground contact.

The numbers above do not have several factors incorporated, which may be relevant to estimate a more accurate dose. I will briefly mention these factors and which I will incorporate into the expected dose.

For chronic exposure a facility is allowed to fold in an occupancy factor. This factor is the longest expected time an individual is expected to spend in the dose area divided by the operating time[4]. I will assume that light ion beam will be transferred for 18.5 weeks, seven days a week, and 24 hours a day. The total time period over which light ions are transferred is 3108 hours. Occupancy on the berm is very low. If we assume that a person spends 0.5 hours a day on the berm, 5 days a week, and for the entire 18.5 weeks we arrive at a total of 46 hours. Thus the occupancy factor is 0.015. I will apply this number to the yearly chronic exposure.

Past measurements on the berm have shown that the dose rate at waist height is a factor of 2-3 lower than the value measured in contact with the ground[5]. I will assume that the dose at waist height is a factor of two lower than that at ground contact. This factor will be applied to both the yearly and hourly numbers.

There is the expectation that the quality factor for neutrons may be increased in the future[6]. The calculation used the standard dose factor for neutrons.

Past comparisons between the MCNPX calculations and dose measurements have shown demonstrated that the dose is lower than the calculation. A reduction in the calculation of 1.9 was applied previously[7] for the 12 MeV deuteron operations. I will not incorporate this factor into the present numbers.

With the above factors incorporated into the dose estimate I get the expected dose for routine operations to be:

2.6 mrem per year and
0.14 mrem in an hour-maximum

The large decrease in the yearly exposure is the result of the 0.015 occupancy factor that was applied along with the 0.5 factor to extrapolate to waist height. The 0.14 mrem in an hour is a maximum expected for routine operating while tuning the Booster and AGS and are not expected during the entire running period.

We can estimate the **maximum fault for 200 nano-Amps of 20 MeV** deuterons striking an iron target. Based on the 10**-17 rem/d for 3 feet of soil, 4.5*10**15d in an hour, and a factor of 0.5 for waist height we get 22.5 mrem in an hour. This would require that the operators ignore the chipmunk alarm for an hour. In addition most of the berm exceeds 3 feet in thickness. More realistic is to consider a shorter time such as 15 minutes, which would give 5.5 mrem.

A more credible loss would be operating at the present alarm limit of 120 nano-Amps and the beam faulting under a thin spot with 3 feet of soil. This would create 13.5 mrem in an hour.

The most likely location for the berm to be occupied is for pedestrians crossing over the tunnel along Rutherford Dr. Measurements with 17.5 MeV deuterons were conducted at this location. The dose at waist height for 200 nano-amps fault would be 6.7 mrem in an hour for a full beam fault for an hour. There is only a small increase in dose from 17.5 MeV to 20 MeV.

Measurements were also taken[8] for 17.5 MeV deuterons striking iron near the new HEBT gate (N137). Scaled to 200 nano-Amps the dose would be between 100-200 mrem/hr. The area outside the gate is a high radiation area and should not be compliance issue.

The dose rates in the tunnel for the forward direction with deuterons striking Fe and W targets have been calculated for several energies and are shown in Table I. The tuning of TtB with light ions has been restricted to 25 nano-amps DC equivalent deuterium beam. The dose rates in Table I are for 25 nano-amps.

Table I. Dose Rates at a foot for 25 Nano-amps

Deuteron Energy in MeV	Steel Target (rem/hr)	Tungsten Target (rem/hr)
20	35.6	16.7
18.5	25.6	11.9
12.	8.1	0.9

The initial tuning of TtB is the only process where the light ion beam is expected to strike a target for an hour or more. With the restriction of current on the beam for tuning, the levels in the tunnel at a foot are lower than 50 rem in an hour. Tungsten was used to simulate the dose from hitting the Tantalum Faraday cups. The low energy numbers have a large error.

References

1) A. J. Stevens, "TTB Operating scenario for Deuterons Delivered to RHIC", Sept. 14, 2001.
2) C.J. Gardner, "Estimate of Number of Deuterons Delivered and Lost in the TtB Line", Sept. 30, 2007.
3) K. Yip, e-mail to D. Beavis, August 31, 2007.
4) NCRP Report no. 151, Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-ray Radiotherapy Facilities, Dec. 31, 2005.
5) F. Zafonte, radiation survey, Nov. 25, 2002.
6) E.T. Lessard. E-mail to R. Karol and CCed to D. Beavis, August 2, 2007
7) Radiation Hazards from Low Mass Ions in the Tandem to Booster (TtB) Line, Unreviewed Safety Issue, Nov. 15, 2001.
8) F. Zafonte, Radiation Survey, Nov. 25, 2002.