Date: March 29, 2006
To: RSC, A. Pendzick, J. Alessi
From: D. Beavis
Subject: EBIS Penetration into the Booster

The EBIS facility will require a penetration into Booster for the beam transport. It is proposed that:

1) The penetration will be a 10-inch pipe 8.0 meters long.
2) The beam pipe will be 6-inch diameter.
3) There will be packing between the beam pipe and the penetration pipe at both ends.
4) Space will be allocated in the linac building for shielding on the right hand side of the EBIS beam and across.
5) A chipmunk will be placed in the linac building near the EBIS penetration.
6) A fault study will be conducted with Booster beam and linac beam to see if shielding is necessary and if potentially an offset in the beam line (a dogleg) is required to provide better shielding from neutrons from the Booster enclosure. The B6 dump will be checked as a source.
7) The area near the penetration will be posted and have a barrier pending the results of the fault studies.
8) The linac loss monitors with the fast beam interrupt will be used to limit linac beam faults in duration.

The penetration will be constructed during the summer FY06 shutdown. The fault studies will be conducted as early as possible during FY07 Booster operations.

Numerous discussions have occurred between J. Alessi, A. Pendzick and myself regarding the design of the Booster penetration. The proposed penetration (see Figure 1 and Figure 2) looks directly at the linac beam. There is a beam-pipe tee in the linac beam transport to allow the EBIS beam to enter the Booster. There is a desire to keep the beam optics as simple as possible. After discussions of the potential fault levels it has been decided to propose the direct penetration anticipating that the predicted fault levels are too conservative. However, the options for shielding and horizontal bends in the linac building will be kept in the design plans pending the results of the fault studies.

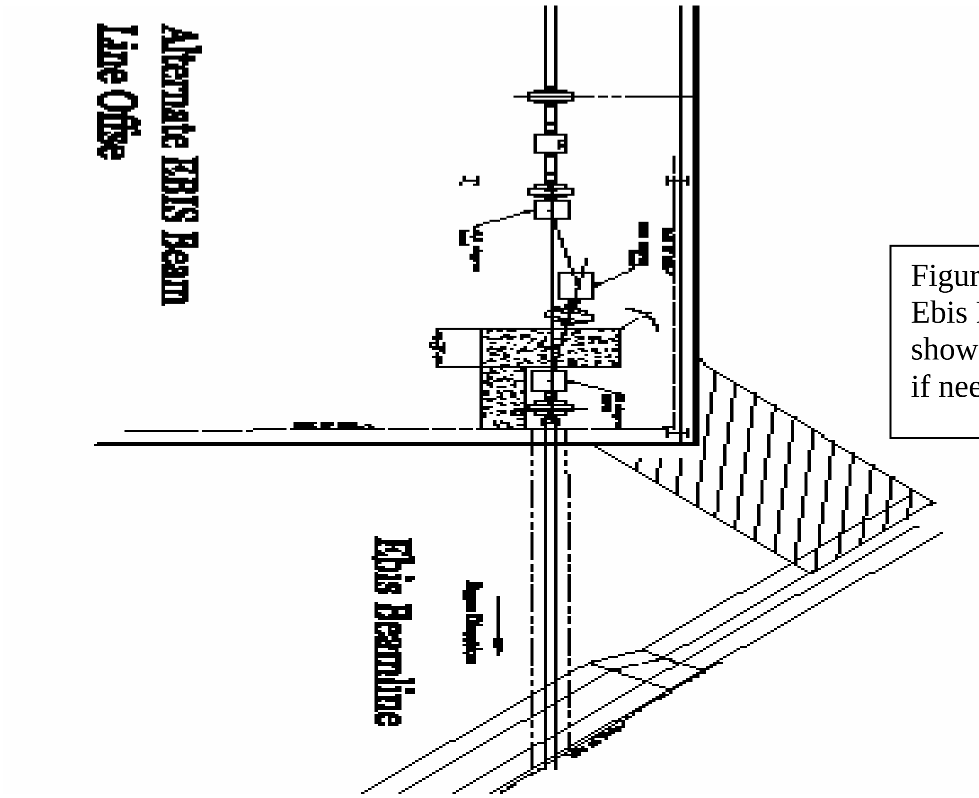

Figure 1.
Ebis Penetration
showing alternate plan
if needed

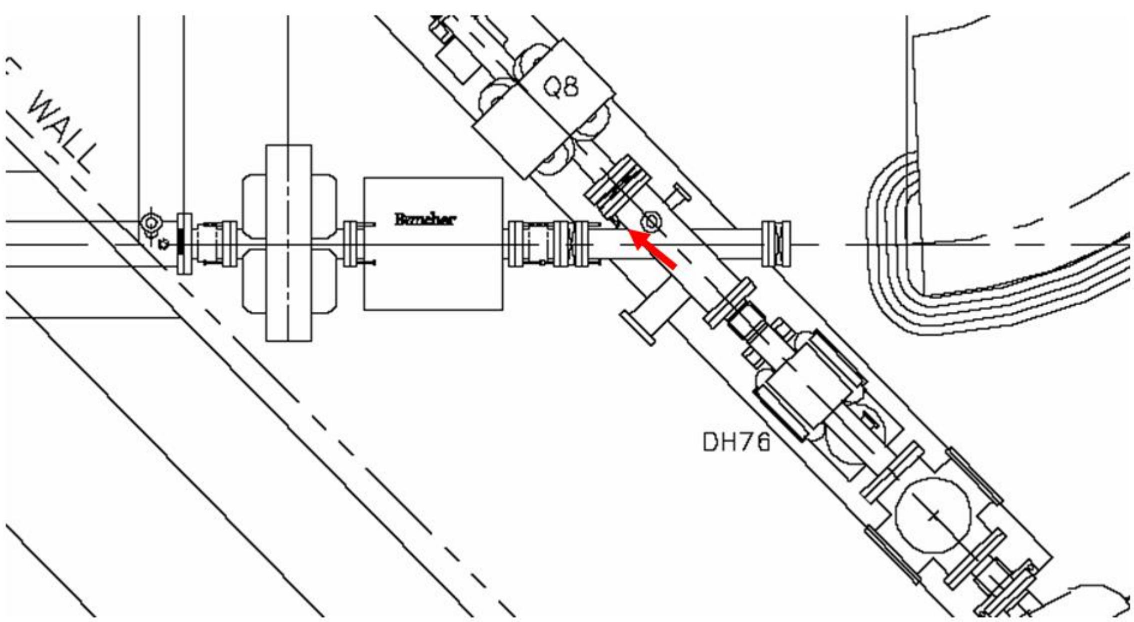

Figure 2. Booster side of EBIS Penetration

The Booster or the linac beam can create faults, which will cause neutrons to propagate through the penetration. Booster faults occurring before C1 have sidewall shielding between the fault location and the penetration. The Booster magnets C1 and C2 will eventually have the large bending magnets for the EBIS beam as shielding. In the final configuration faults downstream of C2 can have direct line of sight to the penetration opening at an angle of 45 degrees or more. A conservative estimate would be to use a thick target formula for the booster fault and the labyrinth formula of Goebel for the attenuation in the pipe. The numbers used are:

1) Protons faulting = 3 GeV and 1.8*10**17 p/hr (this is the ASE)
2) 5.5 meters from the Booster beam to the penetration
3) Penetration is 10 inch diameter (no credit for packing at either end)
4) Penetration is 8.0 meters long.
5) Dose at penetration is from thick target formula = 3*10**7 mrem/hr
6) Goebel attenuation for 10 inch pipe = 2.6*10**-5
7) Estimated max. fault dose at the linac building = 750 mrem/hr
8) Without the EBIS bending magnets the faults between C1 and C2 should be a factor of 4-10 times higher (3-10 rem/hr).
9) Experience has shown that typically faults are 5-10 times lower than predicted by the thick target formula.

Routine losses in the Booster are expected to be substantially lower then these fault levels. Injection losses from heavy ions are at much lower energies and intensities. The B6 beam dump may provide a diffuse cloud of neutrons striking the wall near the penetration and should be checked as a chronic routine source. The area near the penetration should be a radiation area and have an interlocking chipmunk to protect against faults. This should be sufficient for Booster operations and HtB injection losses.

Linac beam faults have the potential to create the largest neutron dose rates through the penetration. A couple of simple estimates have been made. The linac beam will be assumed to be 200 MeV protons with a maximum of 10**15 p/sec (slightly above the Booster ASE). A thick target formula can be used assuming the target is directly in front of the opening. The dose at the penetration opening in Booster is 1.5*10**-13 rem/proton giving 150 rem/sec or 540,000 rem/hr. Assuming the source is directly in front of the opening implies the attenuation is only 1/(r**2) or 0.03 (giving 4.5*10**-15 rem/p in the linac building). A very conservative dose rate of 4.5 rem/s or 16,200 rem/hr is obtained. It is not expected that such a situation can be created. Therefore a more realistic but still conservative example was run.

Kin Y. performed a MCNPX calculation for the 10-inch penetration. He assumed that the entire beam strikes the beam pipe at the downstream end of the vacuum tee with a 1-degree angle (see Figure 2) . He obtains 4.4*10**-16 rem/p at the exit of the penetration in the linac building which gives 0.44 rem/sec or 1584 rem/hr. A substantial difference between the MCNPX calculation and the simple formula above is that the beam pipe is not a thick target. In addition the source is offset in the MCNPX calculation by 3 inches in the 5-inch radius.

It is expected that these numbers are still very conservative relative to a fault that can actually be achieved. The MCNPX calculation does not account for the packing that will be placed between the beam pipe and the 10-inch penetration pipe. It also does not account for the partial shielding provided by the quadrupole, which is between the penetration and the linac beam pipe tee. The packing could easily account for a factor of 4 or more in dose reduction. In addition it is expected that only a fraction of the linac beam can be scrapped near the penetration. The last LtB dipole has a gap of 2.5 inches and the closest quadrupole is in the linac side of LtB. Vertical scrapping is almost impossible near the penetration opening. The four LtB dipoles are powered in series, which makes it difficult to bend the beam into a localized location near the penetration. Once losses have a substantial angle relative to the opening of the penetration, the 1/(r**2) attenuation of 0.03 can be converted to using the Goebel attenuation of 3*10**-5 giving a factor of one thousand reduction. It is reasonable to expect that with the pipe packing at both ends coupled with the actual physically fault conditions that the dose rates are expected to be substantially lower than the MCNPX calculation (10 to 100 times lower). This would put the fault dose rate at 15-150 rem/hr or 4-40 mrem/sec.

An interlocking chipmunk is expected to limit the duration of a large fault to 1-2 seconds. The loss monitors in the fast beam interrupt (FBI) system will limit the duration to less that one linac pulse. For the present conservative MCNPX calculations the chipmunk would limit the dose to a worker in a radiation area to less than 1 rem under a maximum fault. The loss monitors with the FBI system would limit the dose to less than 100 mrem to a worker. It is noted that this level of potential exposure to non-badged workers in allowed for a design base accident at RHIC. We expect that the actual potential exposure will be substantially lower and will be reviewed after the fault studies are conducted.

Figure 1 displays the option of adding shielding and if necessary a dogleg to the EBIS beam in the linac building. The EBIS project will reserve the space for the shielding and a horizontal shift to the beam line pending the fault study results. With the shielding in place, the area near the penetration would within a locked or interlocked area. Other options that can be considered to limit the potential fault dose are:

1) Placing critical LtB optics elements into the interlock system to prevent faults.
2) Placing a horizontal aperture near the exit of the last LtB dipole to prevent horizontal scrapping of the linac beam near the EBIS penetration.
3) A second chipmunk could be added for redundancy.

CC: RSC Booster file
RSC EBIS file