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to: RSC

from: D. Beavis

subject: Upgrades of the STAR Shield Wall

A sub-committee established design criteria for RHIC shielding for proposed machine upgrades. Specifically, the committee proposed that shield walls near experiments be designed to limit the dose in a Maximum Credible Incidence (MCI) to 100 mrem in areas near experimental IRs. This would prevent the need for users to wear TLDs. This note provides a first estimate of the amount of shielding that is required to meet the design goals for the STAR removable shield wall. The present shield walls designed under the RHIC Project typically do not satisfy the design criteria presently established by the committee.

The proposed upgrades have the potential to increase the beam intensity by a factor of 2 and the energy by 30%. A factor of 2.5 will be used to consider the increased radiation from a MCI. Several detector upgrades are planned at STAR. A portal is proposed for the shield wall to enable large items into the IR during maintenance days, which may add in repairs and installations.

STAR Shield Wall

The STAR shield wall consists of 5.5 feet thick light concrete blocks stacked in a single layer. The estimated dose through the shield wall for a MCI of $1.14 \times 10^{13}$ 250 GeV protons hitting the DX magnet was 267 mrem. It was assumed that the DX magnets could be hit with only half of the beam. The STAR detector systems, as designed at the time of the note, were approximated in the analysis. An additional factor of 1.3 was used to account for increased dose on the machine bend plane. For this note the factor of 1.3 for the bend plane will be removed and an MCI would give 205 mrem. The beam upgrades could produce a dose from an MCI of 513 mrem outside the STAR shield wall.

Simple empirical formulas can be used for estimated the dose from an MCI. An MCI with $2.28 \times 10^{13}$ protons at 250 GeV would produce dose outside the shield given by:

$$\text{Dose (in rem)} = 38,800 \times e^{-d \times \text{att}} / (r_t \times r_t),$$

Where $d$ is the thickness of the shield, $\text{att}$ is the effective attenuation in ft$^{-1}$, and $r_t$ is the transverse distance in feet. Light concrete has $\text{att}$ equal 0.62 ft$^{-1}$. The STAR shield wall is 5.5 feet thick and the outside surface is 46 feet from the beam line. The estimated dose outside
would be 605 mrem. Note that the analysis in reference 2 assumes that half the beam interacts on DX in an MCI. Thus the numbers for 100% beam loss are in agreement. If the formula from Sullivan\(^4\) is used to estimate the dose from a full beam fault then the formula would be the same except the coefficient is 34,700. The agreement is reasonable. For the conceptual discussion in this note the RHIC Project value of 205 mrem will be used. It is expected that a more thorough analysis will be conducted for a final design.

There are several sections of the STAR shield wall that are thinner than 5.5 feet of light concrete. There are vertical sections of poured concrete walls on each side of the area where the labyrinths are. These sections of wall are only 3 feet thick and have a distance to the outside of 55 feet. If a source was able to illuminate these sections of wall with the same intensity of radiation as the main shield wall then the dose in an MCI would be 3.15 times higher or 650 mrem. For the upgrades this would escalate to 1625 mrem. The lower sections of these weak locations have additional shielding as part of the labyrinth construction. The area outside the shielding is presently posted for work restrictions ground level. In addition, these areas are shadowed either by the tunnel wall or the main shielding wall so that the shielding is not as challenged as the central wall.

Above the central wall there is a section of the poured concrete wall that is three feet thick. This section of wall is not shadowed by the tunnel shielding or the main central wall. It would be expected to have 650 mrem in a present MCI. This area is very high and posted.

**Proposed Upgrade for the STAR Shield Wall**

It is obvious that the present design of the shield wall does not meet the committee’s recommendation for future designs. The present design did meet the RHIC Project criteria for MCIs. To design the wall to satisfy the committee recommendations and the future upgrades would require about four feet of light concrete which provides a reduction of a factor of 0.08 in the external radiation.

It is proposed that the 4 feet of light concrete be added to the exterior of the removable wall to a height of 16 feet. This shielding would shadow the assembly building since the beam height is 14 feet. The assembly area outside the experimental hall should be posted as no allowed working above 10 feet. This would present exposure above 100 mrem in an MCI. The labyrinth shielding should also provide shielding to 16 feet although credit could be given to the shadowing of these thin sections if they are modeled or estimated.

The area outside the central shield wall is not within the assembly building crane reach. It is suggested that the shielding be made so that a forklift can install and remove it. The block sizes should be chosen so that there are appropriate forklifts available to install and remove the blocks. The forklift slots could have small concrete plugs which could be removed by hand prior to lifting with the forklift.

The present section of removable wall is picked by the experimental crane and moved to the back wall behind the STAR experiment. If desired, a portion of this wall could also be made to
be removed and installed by forklift. There are advantages and disadvantage that would need to be weighed by the experiment and engineers.

In addition to increasing the wall thickness it is recommended for the experiment to have a portal placed in the shield wall enabling large equipment to be installed and removed on long maintenance days. The size of the portal should be large enough to accommodate the largest equipment that STAR envisions they might need for installations or repairs. It is suggested the portal accommodate the Genie Boom which would require a portal about 7 feet wide by 8 feet high. The shielding inside the portal should again be made to be installed with a forklift and have small inserts for the forklift slots. The shield wall is scheduled to be removed in the summer of FY11 to allow for the installation of the Forward Gem Tracker (FGT). This would be an excellent time to modify the shield wall for the portal. The future Heavy Flavor Tracker (HFT) will have a pixel detector that can be removed during maintenance days. The frame that holds the pixel detector will not fit through the labyrinths and will require a means such as the portal for it to be installed and removed. The pixel detector is not planned till FY13 but the experiment may benefit by having the portal for other work.

The labyrinths will also need to be modified for the beam upgrades, but that is a minor detail that can be examined when the final design is generated.

4ftx4 ftx4 ft light concrete blocks are expected to cost $3,000 each. The shield wall is 36 feet wide and would require about 36 blocks with an estimated cost of $110,000. This does not include rigging time. The portal would require a steel plate to form the lintel and eight blocks depending on the size of the portal. If the portal is constructed when the wall is removed then the cost of the rigging for the portal construction will be small.

**Options**

The present design of the shield wall does not meet the present criteria that the committee has established for MCIs. The analysis presently assumes that only half the beam can strike a thick object. The RHIC Project found that the worst case was the DX magnet. With a smaller beam pipe planned for installation in the summer of FY11 this assumption should be reexamined. STAR is not planning to place large masses near the small diameter beam pipe. There will be several flanges that the beam can strike. The magnets and detector systems will most likely provide adequate shielding to reduce potential dose outside the shield wall.

If adding an additional layer of shielding is not considered desirable then the other options that may help meet the design criteria are:

1. Add apertures to the beam in the warm sections either before the triplets or between D0 and DX. An MCI at the triplets are expected to involve the entire beam. However since the STAR shield wall is shadowed by the tunnel the triplets do not challenge the shielding as much as faults on DX.
2. Add shielding between the tunnel wall and the STAR magnet thus shadowing the main shield wall from DX. This would probably produce interference for the experiment but layouts could be examined.
3. Justify that the present MCI criteria on the amount of beam that can be lost near the experimental area is too conservative.

Conclusion

Two conceptual upgrades have been proposed for the STAR shield wall. The first is to increase the thickness of the wall to meet the criteria established by the RSC and planned future upgrades. The second upgrade is to establish a portal in the present and future shield wall that will enable large equipment into the experimental area during maintenance days.

References

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CC:
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