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Shielding & background studies around the 6 oclock area at RHIC (STAR)

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ES&F Division Technical Note # 161

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1. *Introduction and basic assumptions*

The STAR experiment has experienced considerable background problems during the FY2005 RHIC run. A lot of simulation work (using MARS15) has been done by the author to understand and find the best way to shielding the background at 6 o'clock.

The End-cap Electromagnetic Calorimeter (EEMC) at STAR is used as the "detector" or gauge to judge the effectiveness of various shielding configurations. EEMC is mainly made up of lead and there is more than 1 foot of pole-tip (iron) in front of it. We simulate the side of the RHIC tunnel (west of the STAR interaction point, 6 o'clock) which has the EEMC (and EEMC only exists on one side of the STAR detector). This simulation covers the area from the EEMC at one end and the end of the Q3 (3^{rd} quadruple magnet from the interaction point) at the other end.

Since this is an electromagnetic calorimeter with high energy thresholds, a 1 GeV energy cut on the individual particles (ie., particles with energy less than 1 GeV are not tracked and the energy is deposited locally) has been applied to all simulations leading to the plots shown below.

The source of the background in this simulation has been assumed to be a proton beam hitting at the inner (ie., closer to the center of curvature of the RHIC ring) rim of the end of the Q3 (ie., the side closer to the Q4) in essentially the same orientation as a nominal beam would.

2. *Closer is better*

Figure 1 shows the distribution of the original X-Y coordinates of the particles which eventually hit the EEMC. These particles may suffer scattering or lose energy in the middle of their journey until they hit the EEMC but they have not decayed. (If a particle decays to another particle and if that particle eventually hits the EEMC, the X-Y coordinates of the new particle would be entered as an entry in this histogram.) The center of X-Y plane (0,0) is the center of the beam line.

As one can see from Figure 1, most particles are concentrated in the middle of the X-Y plane. Therefore, the closer to the beam line the shielding can be, the more effective it would be, though there is always some materials which may prevent one from doing so. This principle has been readily used by the engineer in charge of the shielding construction, Al Pendzick.

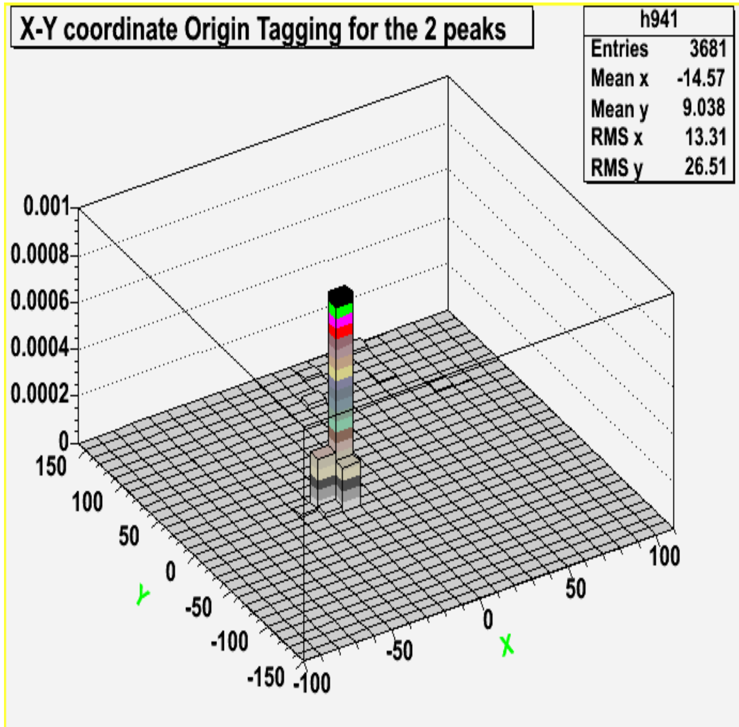

Figure 1: Distribution of the originated particles in the plane of X-Y coordinates.

3. Reduction factor of 3

With the shielding shown in (which is close to what was put in the summer of 2005), the simulation has showed that there is roughly a factor of 3 in the reduction of the energy deposited on the EEMC after the shielding is put in.

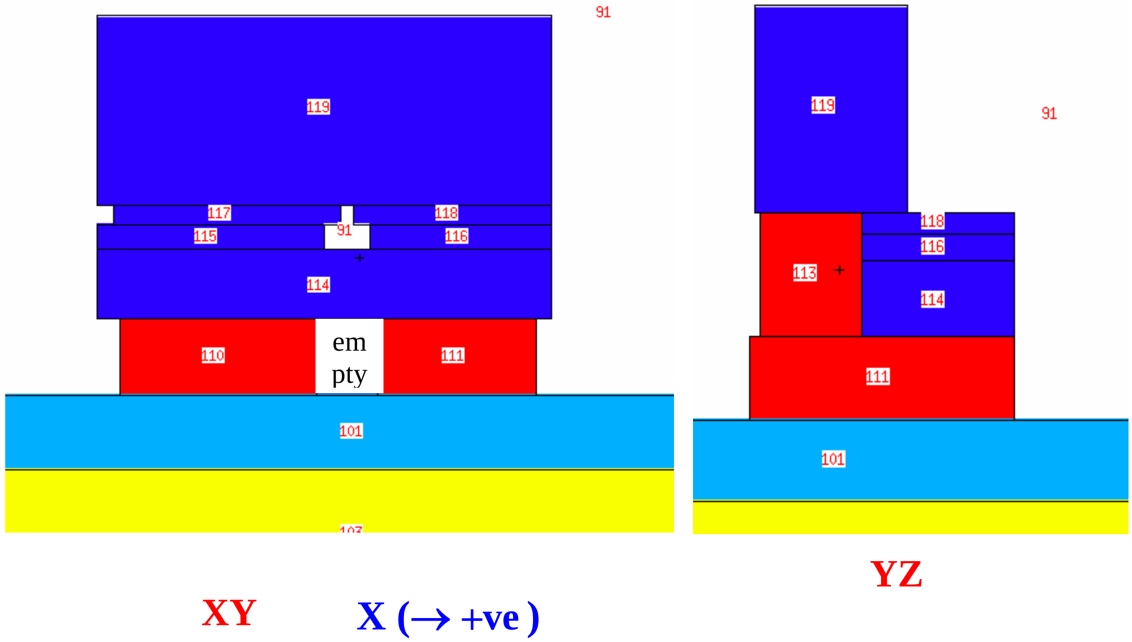

Figure 2: The X-Y and Y-Z cross-sectional views of the planned shielding.

4. The platform floor in the tunnel results in an asymmetry

Figure 3 shows the distribution of energy deposition without the above shielding. One can see in general the upper (near the ceiling with larger Y-coordinate) energy deposition is more than the lower (near the floor with smaller Y-coordinate). This pattern of energy deposition on EEMC is generally observed in the data from the STAR experiment, though the data have even more specific pattern than what the simulation can produce.

People have been puzzled why there is such an asymmetry for some time. The simulation work resulting in the plots shown in Figure 4 explains such an asymmetry. It is due to the asymmetry of the concrete floor over the entire tunnel compared to the ceiling. Over the entire RHIC tunnel, the floor is much closer to the beam line than the ceiling. In this simulation work, most of the floor is taken away such that the beam line is approximately equidistant from both the floor and ceiling. This way, from Figure 4, one can see the upper and lower sides have much more similar energy distribution. This is an accumulative effect of particles bouncing back and forth over the entire tunnel.

muon-subtracted

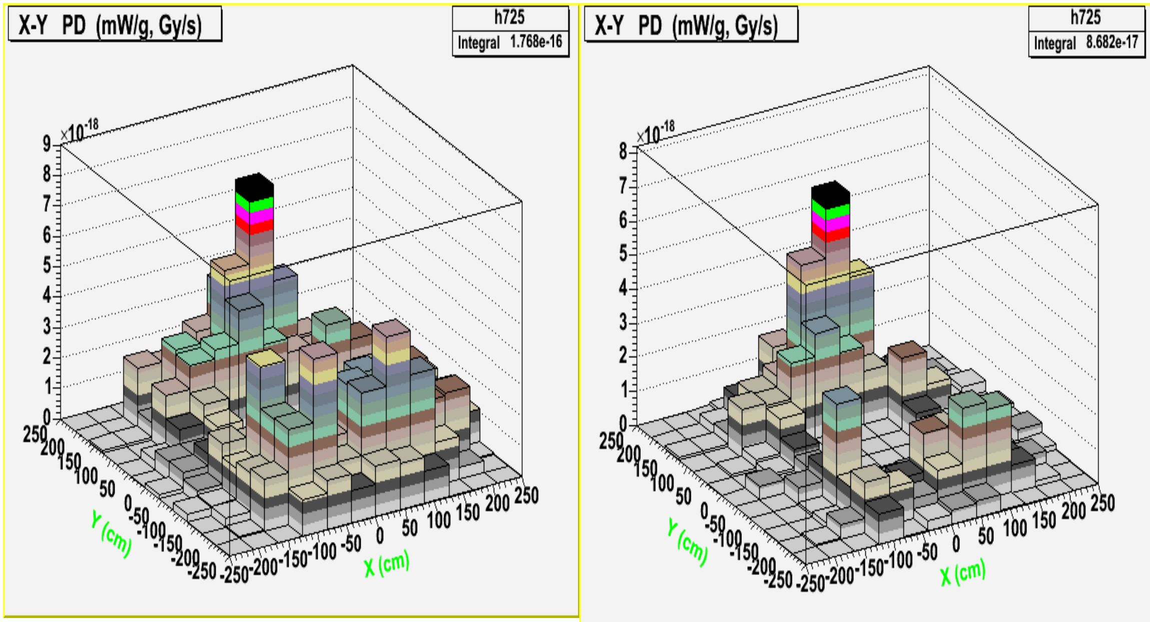

Figure 3: The profile of energy deposition in the EEMC on the X-Y plane. The plot on the left includes the contribution from all particles whereas the one on the right has subtracted the energy deposition due to muons.

muon-subtracted

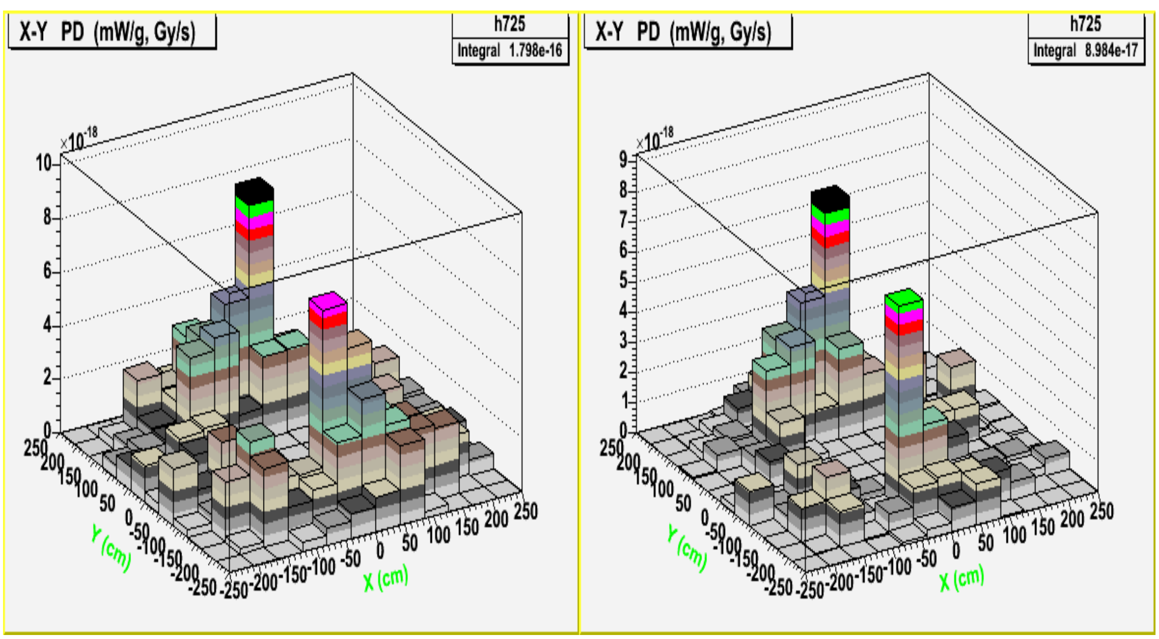

Figure 4: Same as in Figure 3 but the floor is taken out away from the geometry in the simulation.

5. *The Best shielding configuration*

The best shielding configuration found in all the simulation attempts is as shown in Figure 5 (the 112.5 cm cylinder pointed to by the words “My imaginary shielding”). The important feature is that it is the closest to the EEMC and in front of all the magnets including DX. This has greater chance of obstructing any particles from hitting the EEMC.

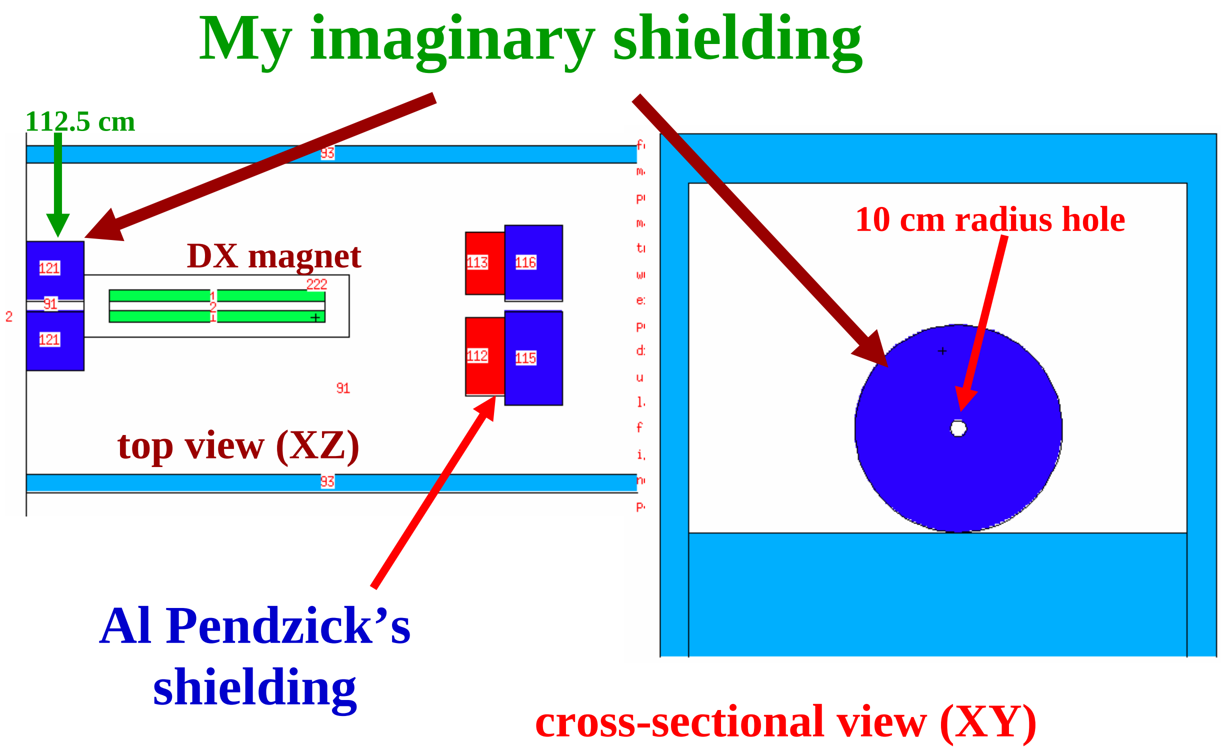

Figure 5: The extra shielding dubbed as “My imaginary shielding” which seems to provide the best shielding configuration for the background coming from beams hitting Q3.

From Figure 6, you can see the effectiveness of this extra shielding in front of the DX magnet. Looking at the muon-subtracted plots, there is a reduction factor about 100, when comparing Figure 3 and Figure 6, ie., before and after the shielding in Figure 5 is added.

Unfortunately, the space before DX has had some other usage and at least it could not be used at the time of writing this note.

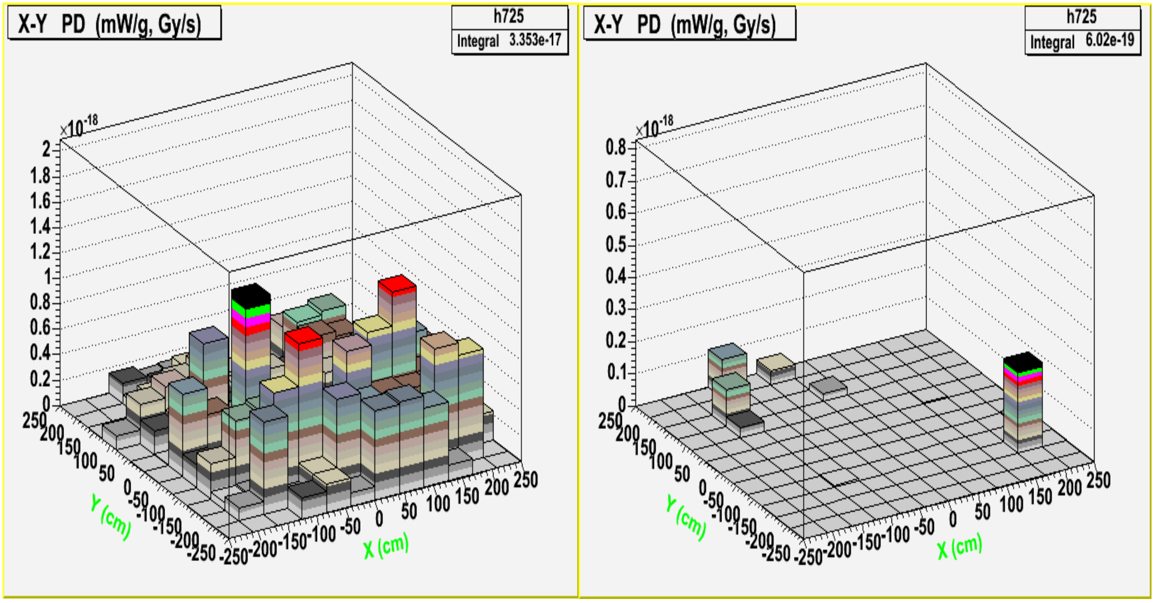

Figure 6: The energy deposition distribution on the EEMC after the shielding in Figure 5 is implemented in the simulation.

6. Other configurations have been tried but found

Many other configurations have been tried but none has proved to be really useful to beat down the energy deposition on the EEMC. Among other attempts, we have tried to put thick shieldings above the DX magnets and also between the DX and D0 magnets. But all these have not resulted in significant reduction as compared to the above.