

# Radiation doses at PHENIX due to various faults

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## I. Introduction

This note is report on the simulation done to estimate the radiation doses at the 8 o'clock (PHENIX) outside the movable and its South side. The z-coordinate is along the beam direction (with  $z=0$  at the junction where the Experimental Hall meets the tunnel and the +ve z direction is the direction pointing from the Interaction Point to DX), y-coordinate points vertically towards the sky and the remaining x-coordinate is fixed by the right-hand-rule.

The author has adapted an earlier geometry of PHENIX and used substantial time to add a lot more details (probably the most realistic ever) in the PHENIX Experimental Hall and the South side for the following simulations. The geometry is probably the closest to being realistic (though it may be a mirror image of the real geography).

From [1], the full and maximum beam after the upgrades will be  $5 \times 10^{13}$  protons per ring. The (kinetic) energy of proton beam used in all simulation described is 250 GeV.

When protons hit DX, Q2 or the beampipe, they are at an angle about 3.67 mrad which has been an angle recommended (by the machine physicists) and used in background simulation several years ago.

The author has tried to use MARS to do simulation first but it seems always to give results with about 100% error and therefore the following results are all due to MCNPX v2.7.0 which is the newest available official version (and the last one from the beta-testing versions ever from LANL as they have stopped the beta-testing program).

All the dose results shown below are due to neutrons (eg. photons typically contribute around 1 to 2% of the neutron doses in the simulation and are ignored).

## II. Outside the 8 o'clock (PHENIX) movable shield wall

From [2] and [3], the largest threat of radiation comes from a fault at DX (a proton beam) and scraping along a 3 m length of beampipe in the nose cone-piston region --- the range of z coordinates in this simulation is [-729.6 cm to -429.6 cm]. The source of the largest fault of these kinds has been deemed to be half of the total proton beam. Figure 1 shows a part of the details of the geometry of the simulation at  $y=0$  (beam height) and structures not crossing  $y=0$  are not shown. The proton beam is moving towards the IP when it hits DX (such that the movable shield wall is in the forward direction of the radiation). The locations (z-coordinates) where the protons (running from right towards the left) hit the DX inner aperture are uniformly distributed along the DX length (on a side nearer to movable shield wall) and is at  $y=0$  (the nominal beam height). In reality, the two “cones” of the PHENIX detectors are different and the author has chosen the smaller “cone” as it should give less shielding.

Figure 2 shows the structures  $y \cong 6$  feet above the floor and the numbers starting with 8 indicate where the doses are measured. In Figure 2, in reality somewhere in the labyrinth, there is a door of polyethylene which is ignored in this calculation.

Figure 3 shows the doses outside the movable shield wall when the beam hit the DX and the highest dose is less than  $1 \times 10^{-16}$  rem per incident proton. Since only half-beam is possible for a DX fault, the highest dose per fault is  $0.5 \times 5 \times 10^{13} \times 10^{-16}$  rem or **2.5 mrem**.

Figure 4 shows the doses outside the movable shield wall when the beam scrapes a 3 m beampipe in the cone-piston region. The highest dose is about  $4.3 \times 10^{-16}$  rem per incident proton. Since only half-beam is deemed possible for scraping at this location of the beampipe, the highest dose per fault is  $0.5 \times 5 \times 10^{13} \times 4.3 \times 10^{-16}$  rem or **10.75 mrem**.

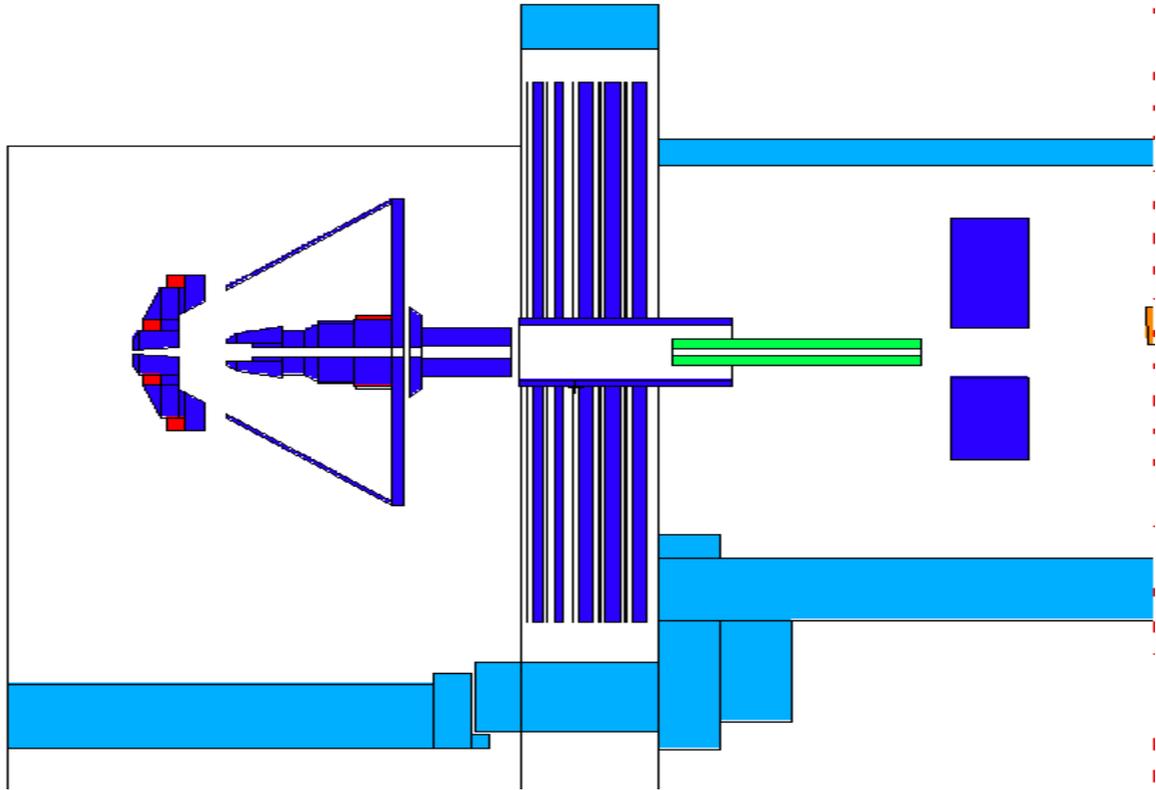


Figure 1: The above diagram shows a plan/top view of a part of the geometry seen at vertical coordinate  $y=0$  used in simulation (and structures not touching the plane  $y=0$  are not visible in this diagram). The  $z$ -coordinates run from the left to the right whereas the  $x$ -coordinates run from the bottom to the top. The material in green is where DX is and Q2 is further down (to the right of the picture) about 14 m away from DX.

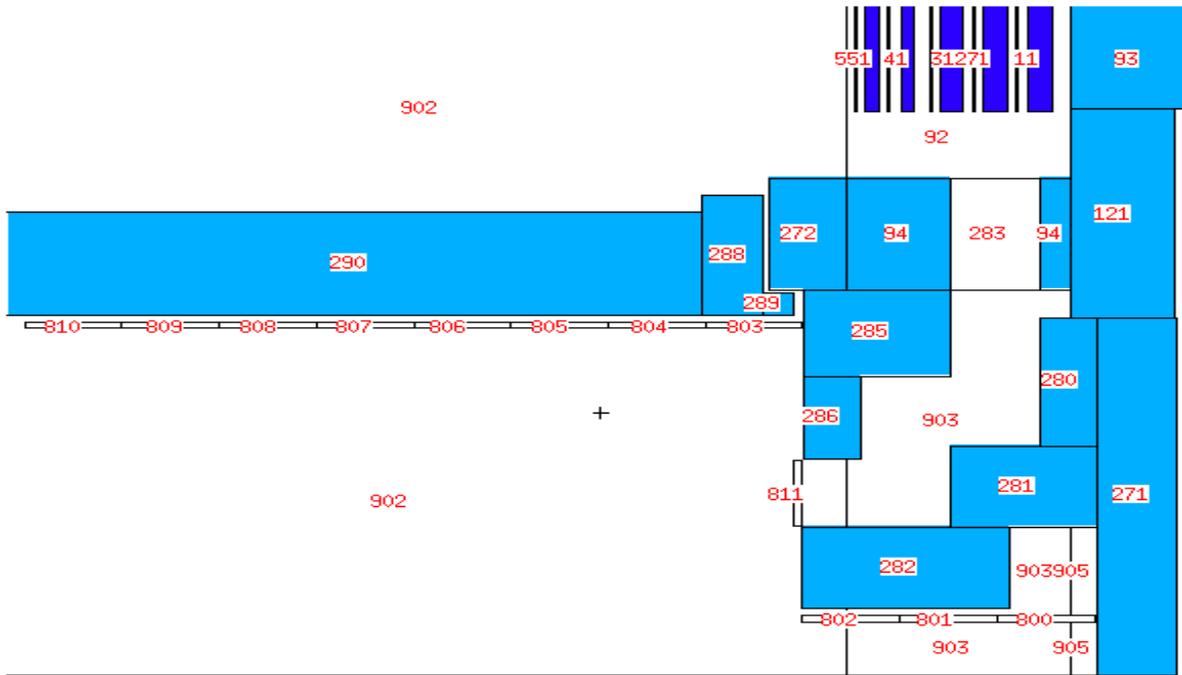


Figure 2: In this diagram, the red numbers (and the black boxes around them), 800, 801, ..., 811, indicate where doses are measured, which are 6 feet above the floor in the Experimental Hall. The z-coordinate runs from the left to the right whereas the x-coordinate runs from the bottom to the top.

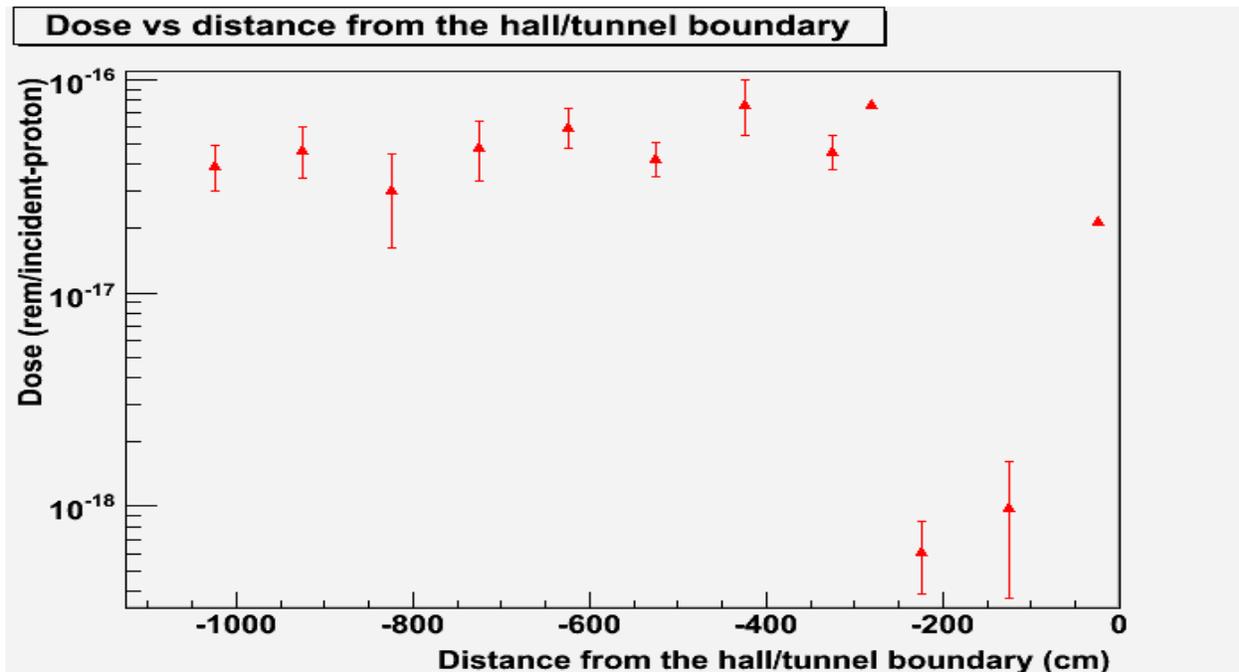


Figure 3: The doses in the PHENIX Experimental Hall as a function of distance from the boundary where the Experimental Hall meets the tunnel, when there is a fault at DX. The dose at about -280 cm is one outside the labyrinth gate.

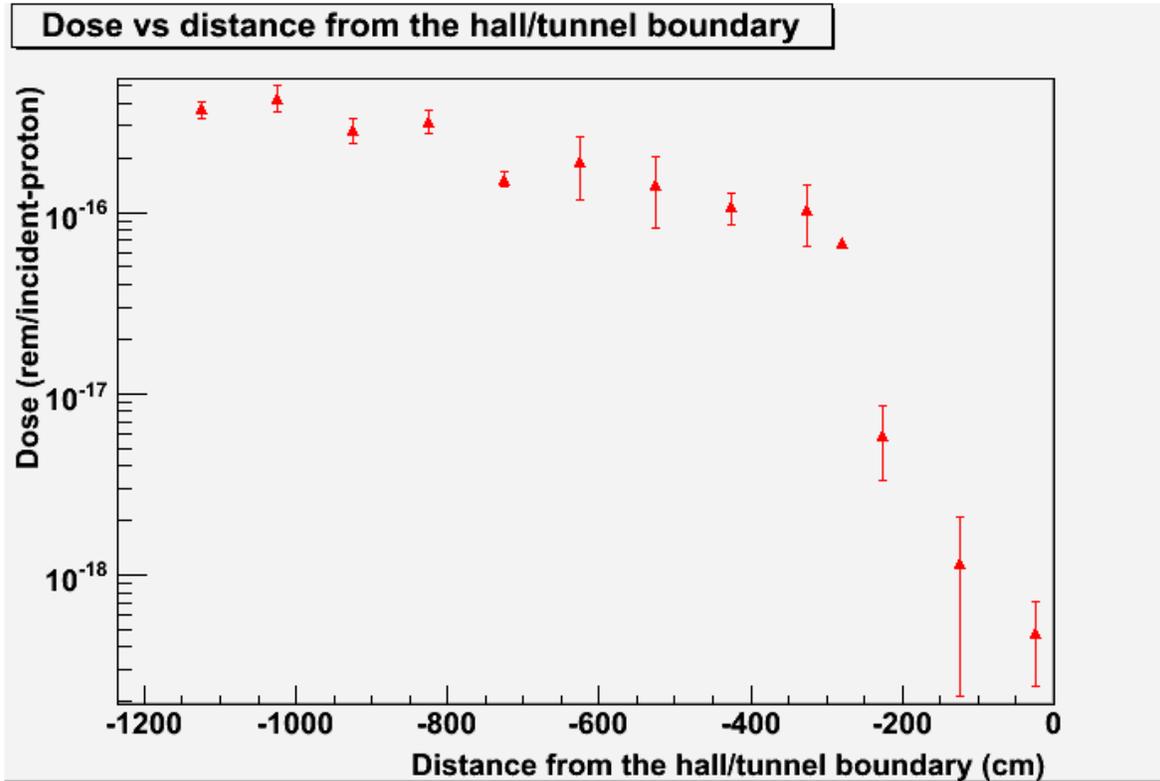


Figure 4: The doses in the PHENIX Experimental Hall as a function of distance from the boundary where the Experimental Hall meets the tunnel, when the beam scrapes the beampipe in the nose cone-piston region. The dose at about -280 cm is one outside the labyrinth gate.

### III. PHENIX South side

Figure 5 shows the structures  $y \cong 6$  feet above the floor and the numbers starting with 8 indicate where the doses are measured. ( Structures not crossing  $\cong 6$  feet above the floor are not shown. ) The floor of the South side is about 6.5 feet above the Experimental Hall.

In the simulations for the South side, we have hit both DX and Q2 (which further down the beamline, to the right of DX in Figure 2) to examine the dose at the South side. When the fault is at DX, the proton beam is almost along the +z (except the above-mentioned small angle); whereas the proton beam is almost along the -z direction when the fault occurs at Q2.

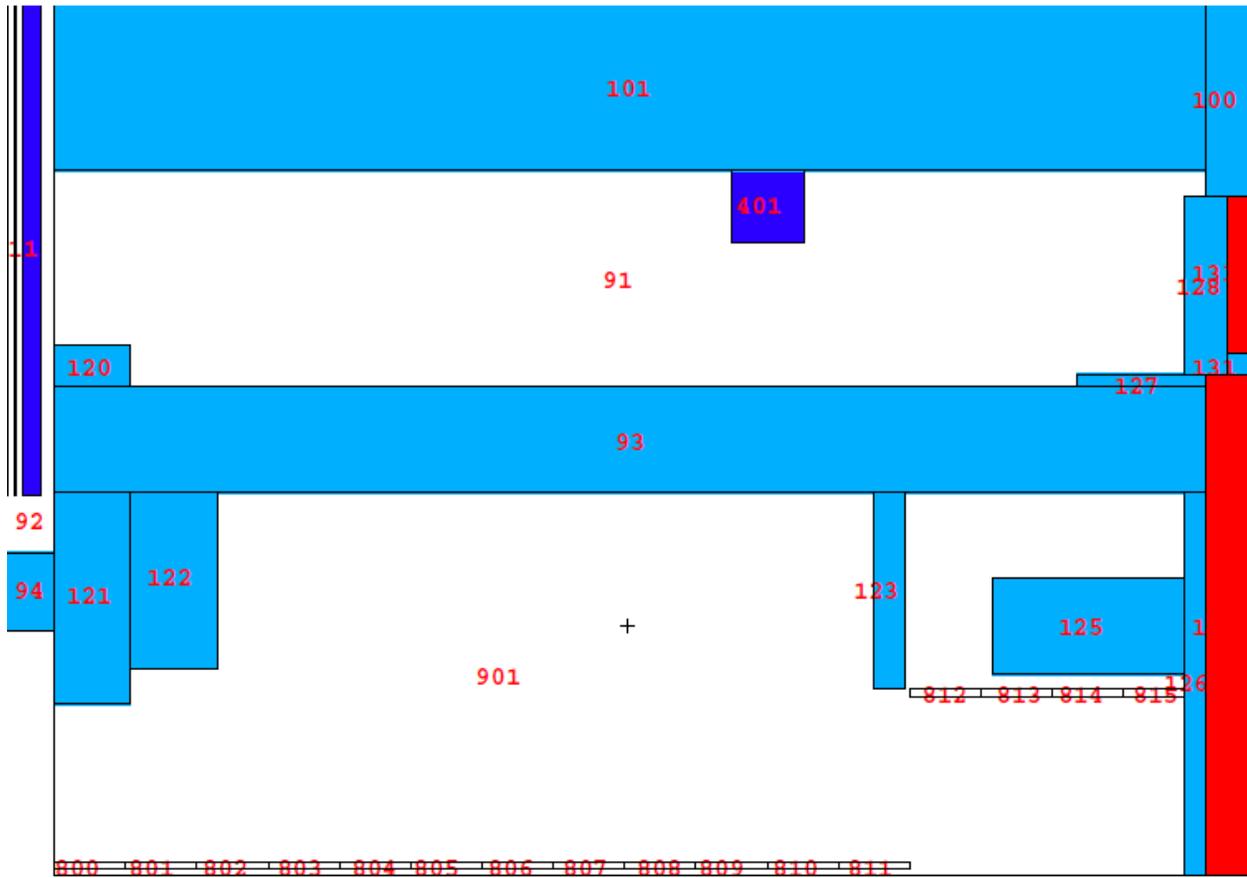


Figure 5: It's a top/plan view on the south side but it shows structures only if they exist at vertical coordinate (y) equal to about 6 ft from the floor. Some structures are not shown if they do not reach that particular vertical coordinate. The PHENIX interaction point is to the left of this diagram. The red numbers (and the black boxes around them), 800, 801, ..., 815, indicate where doses are measured. DX is close to the left end of the diagram and the Q2 is closer to the right end of the diagram.

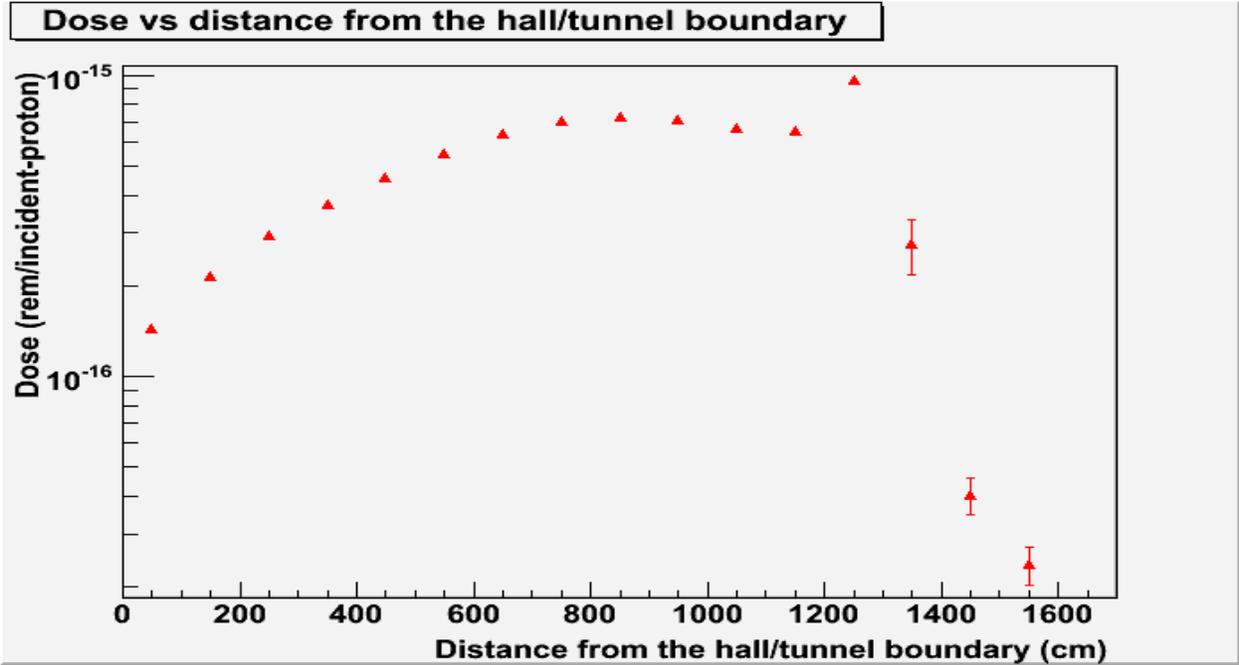


Figure 6: The doses in the South side of PHENIX as a function of distance from the boundary where the Experimental Hall meets the tunnel when there is a fault at Q2. The proton beams hit towards the -z direction.

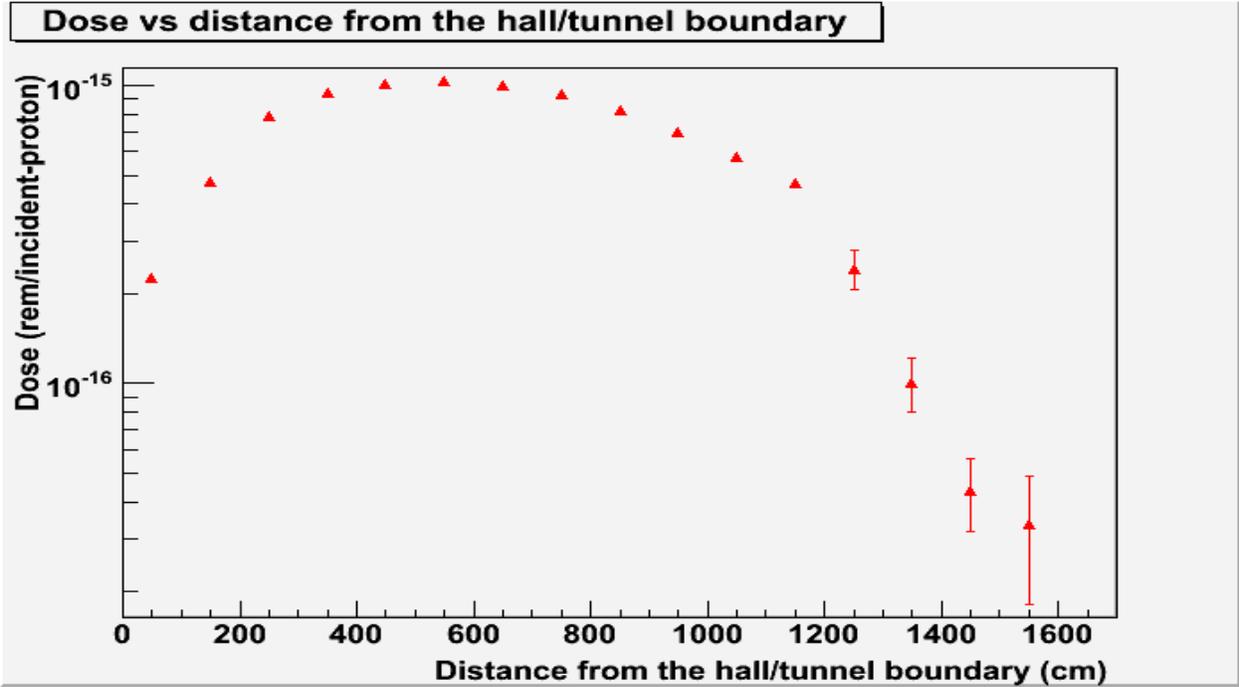


Figure 7: The doses in the South side of PHENIX as a function of distance from the boundary where the Experimental Hall meets the tunnel when there is a fault at DX. The proton beams hit towards the +z direction.

Figure 6 and Figure 7 show the doses 6 feet above the floor in the South side of PHENIX (when the proton beams hit in the direction such that the South side is in the forward direction of the beams) and the highest doses are  $9.6 \times 10^{-16}$  rem per incident proton and  $1.0 \times 10^{-15}$  rem per incident proton. The statistical errors for these two highest doses are smaller than 2% according to MCNPX in both cases.

Since a full-beam fault is deemed possible at Q2 but only half-beam at DX, the highest dose per fault is  $9.6 \times 10^{-16} \times 5 \times 10^{13}$  rem or **48 mrem**.

## IV. References

- [1] Dana Beavis's Radiation Safety Committee memo on [Apr. 20, 2012](#).
- [2] RSC Minutes of Meetings held on [Sept. 10, 1996](#) and [Oct. 20, 1997](#) as indicated from D. Beavis memo on [Feb. 5, 2010](#).
- [3] RHIC/DET Note 13 (Rhic Detector Note), "Estimated Shielding Requirements for the PHENIX Detector", Dec. 1994.