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Simulation of gold-ions hitting beam elements in the ATR

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I. Introduction

In the 2010 RHIC run, gold beams of low energies have been collided at RHIC. The beam emittances and sizes at these low energies caused considerable beam losses and this has raised some concerns about issues such as soil activation. Simulations with MCNPX[i] with the gold ions of total energy of 3.85×197 GeV (ie. total kinetic energy of 2.9188664×197 or 575.0166808 GeV)[ii] have been used to find the fluxes so that one may estimate the soil activation. In addition, doses were also obtained from the simulations so that one may compare the relative doses in different locations of the modeled objects (such as magnets) with the real dose readings obtained from the chipmunks in the ATR (AGS-to-RHIC) line. Both beampipe and magnet are treated as stainless steel in all the simulations described in this note.

II. Results

Simulation results are shown below for different configurations. The nominal beampipe in the simulations always has a radius of 5 cm with a thickness is always 1/16 of an inch (0.15875 cm) of stainless steel. Objects in this simulation are all in cylindrical shapes (cylindrical symmetry). *In all figures, the initial gold-ion beams move towards the right-handed side along the (positive) z-axis.*

In each case, doses (in rad) and fluxes of hadrons (protons and neutrons) (in cm^{-2}) per gold-ion calculated within a cell of soil 5 feet from the center of the beampipe with a 10 cm thickness and a length of 1 m are shown in all configurations. The doses are obtained from the simulations in energy per unit mass deposited in the soil and converted to "rad" with the conversion factor of 1 MeV/g = $1.602176487 \times 10^{-8}$ rad. The hadronic fluxes of 3 categories have been shown, namely, of hadrons with kinetic energies above 20 MeV, above 15 MeV and above 10 MeV.

A. Gold ions hitting the "restricted" beampipe

Gold-ion beams are parallel to the beampipe and are made to hit the restricted beampipe at z=0 (the beginning of the restricted beampipe labeled as cell 6 in Figure 1), head-on and distributed uniformly around the circumference of the beampipe. The front face of magnet (emulating Q11) is 1 m from z=0. The restricted beampipe has a radius of 4 cm (instead of the nominal 5 cm). The simulated doses and hadron fluxes are shown in Figure 2 and Figure 3 respectively.

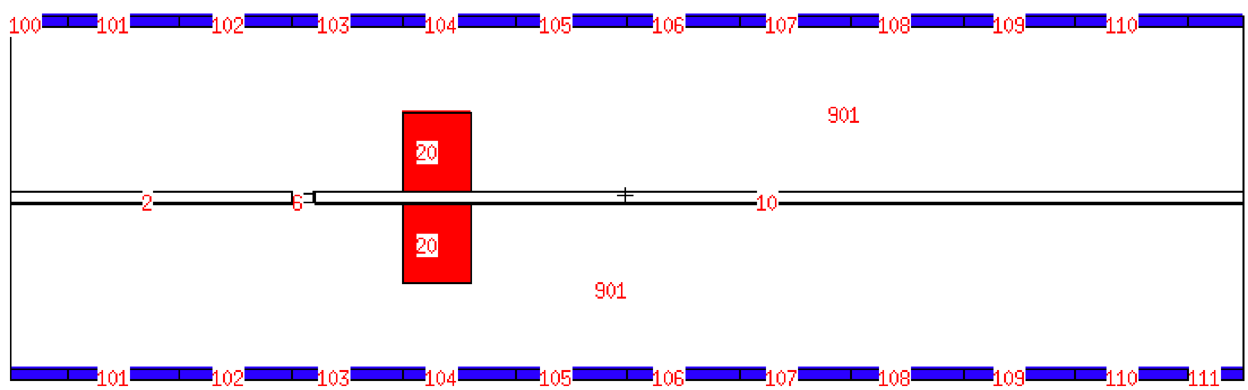

Figure 1: shows the model in the MCNPX simulation. The numbers above indicate the cell numbers in the simulation. Cell 20 is the (Q11) magnet with radii ranging from 5.65875 cm to 76.2 cm. The cells of soils numbered 101-110 are all used as "detectors" of 1 m long and 10 cm in thickness.

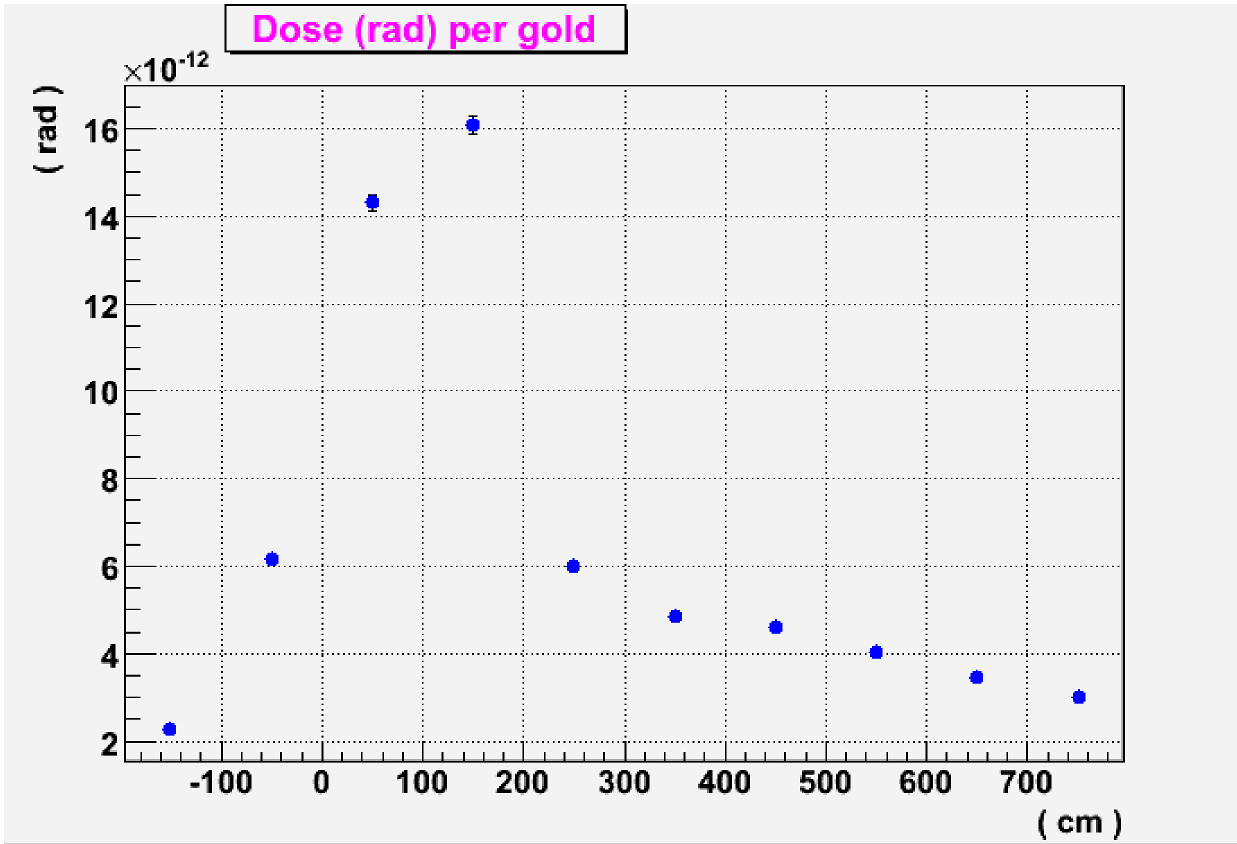

Figure 2: The doses (rad) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning of the restricted beampipe where the gold-ions hit.

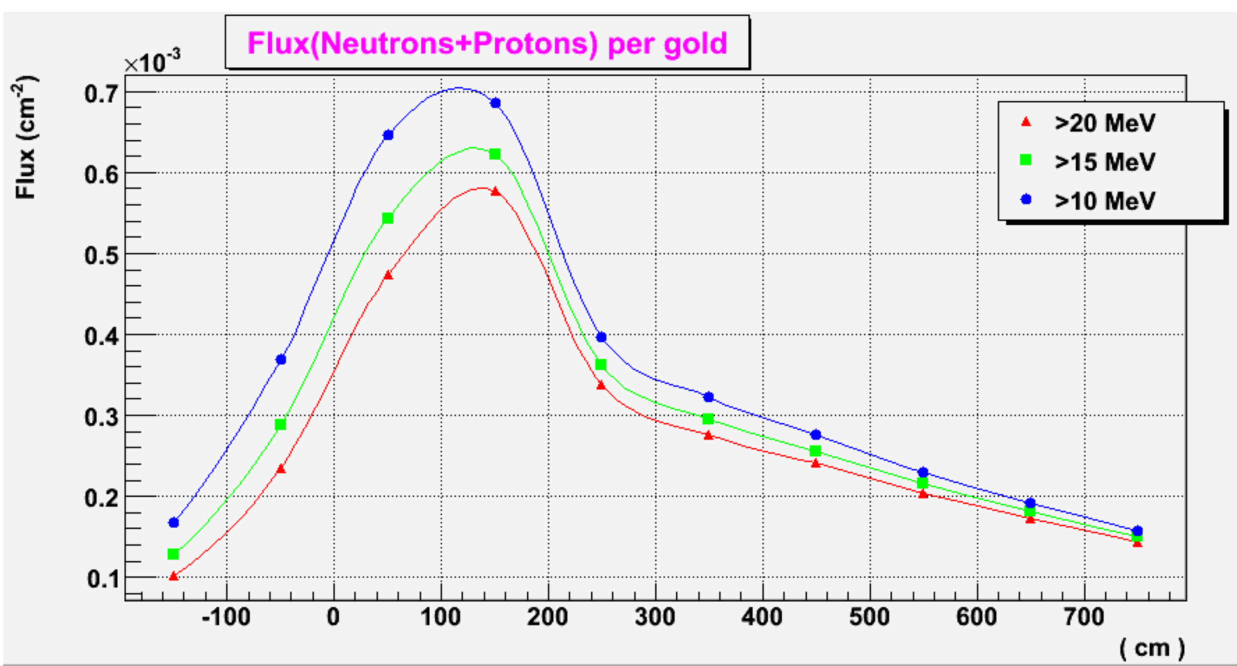

Figure 3: The fluxes of protons and neutrons (cm^{-2}) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning of the restricted beampipe where the gold-ions hit.

B. Gold ions hitting the beampipe just inside the magnet

The geometrical setup is the same as in Figure 1. The only difference is that, this time the gold-ion beams hit the beampipe just inside and at the beginning of the magnet (at z=100 cm) and the points of hitting are also uniformly distributed around the circumference of the beampipe at the inner radius of the beampipe (ie. ~5 cm). The simulated doses and hadron fluxes are shown in Figure 4 and Figure 5 respectively.

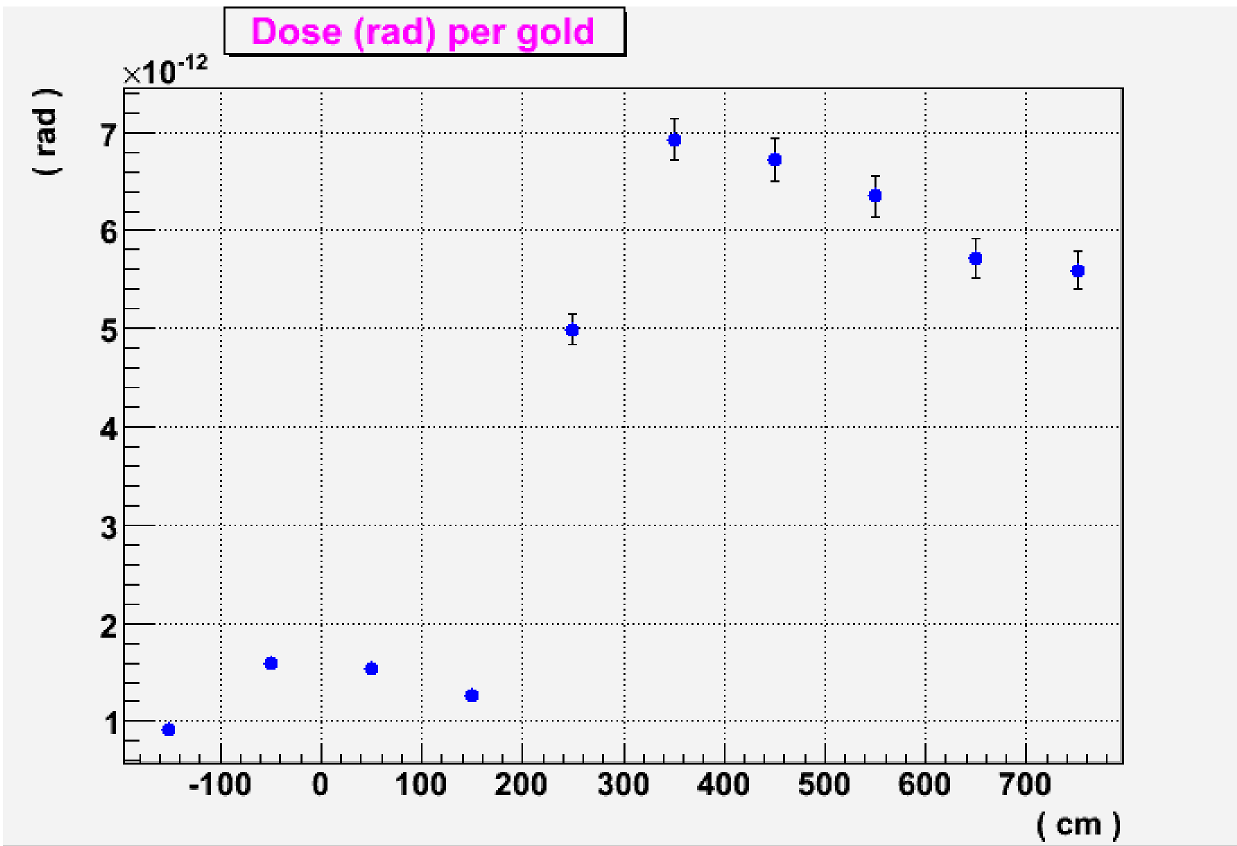

Figure 4 : The doses (rad) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning of the restricted beampipe and z=100 cm is the beginning of the magnet where the gold-ions hit.

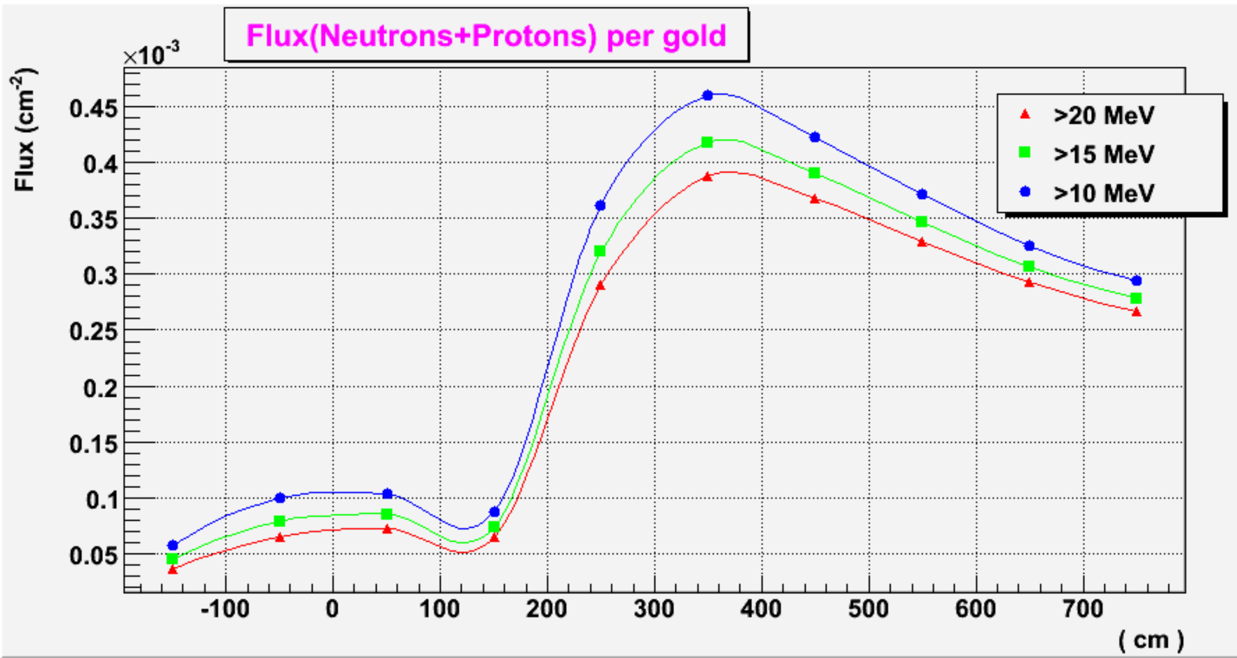

Figure 5: The fluxes of protons and neutrons (cm^{-2}) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning of the restricted beampipe and z=100 cm is the beginning of the magnet where the gold-ions hit.

C. Gold hitting the beampipe 15 feet from the magnet

The configuration is similar as in Figure 1 but two flanges (of stainless steel) 5 feet (starting from z=-152.4 cm) and 9 feet (starting from z=-274.32 cm) from the beginning of the restricted beampipe are added. Both flanges are 1 cm long and 1 cm thick in radial direction immediately. This time, the way that the gold-ions hit the beampipe is the same but only that the beampipe is 15 feet from the face of the (Q11) magnet (ie. z=-357.2 cm). The detector volumes have been extended to cover the interesting regions. The simulated doses and hadron fluxes are shown in Figure 7 and Figure 8 respectively.

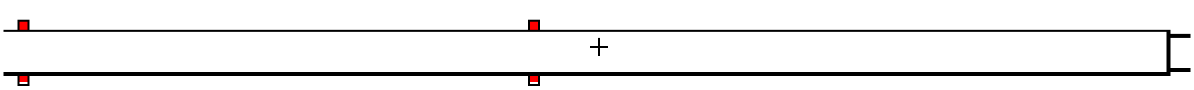

Figure 6: In this configuration, In addition to Figure 1, we add two flanges (colored in red) 5 feet (starting from z=-152.4 cm) and 9 feet (starting from z=-274.32 cm) from the beginning of the restricted beampipe. Both flanges are 1 cm long and 1 cm in radial direction immediately outside the beampipe.

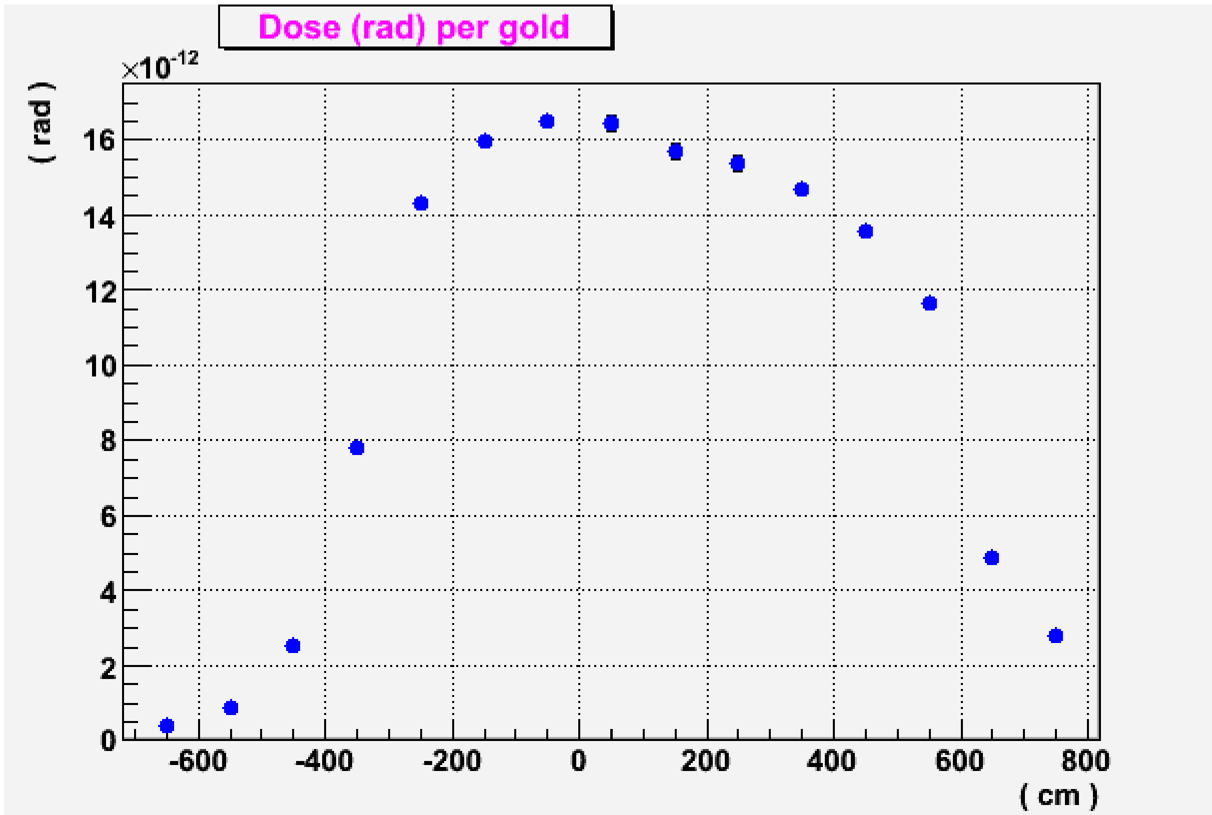

Figure 7: The doses (rad) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning of the restricted beampipe. The gold-ions hit the beampipe 15 feet from the magnet (z=-357.2 cm).

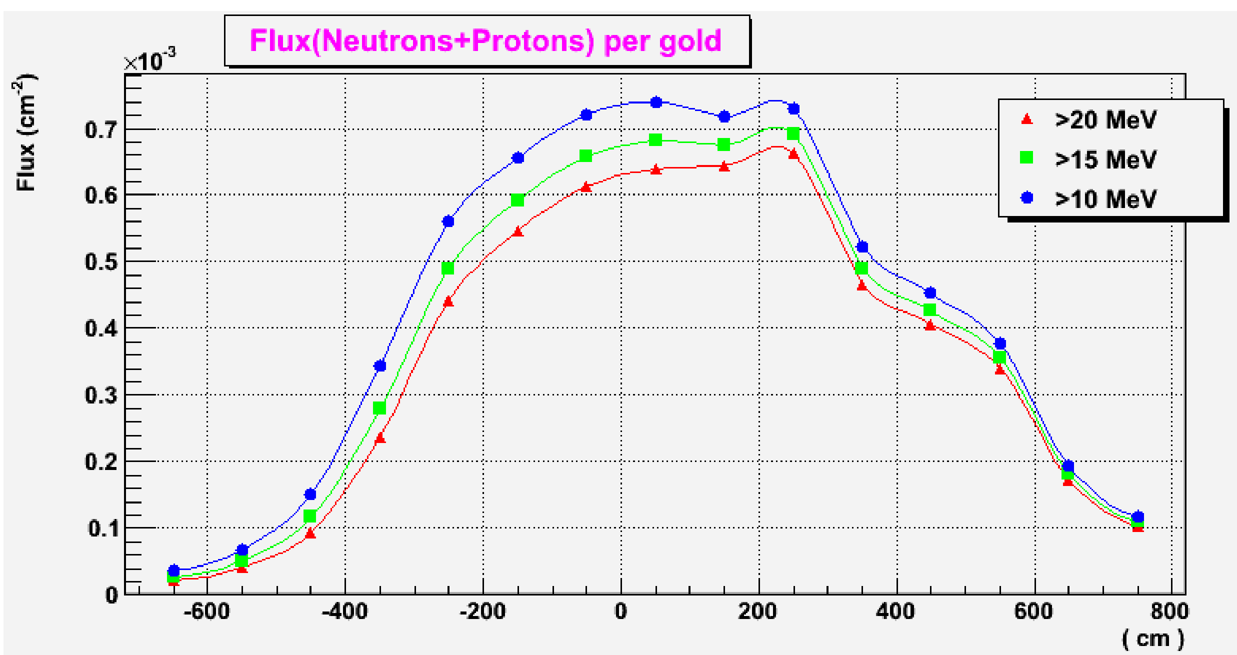

Figure 8: The fluxes of protons and neutrons (cm^{-2}) per gold 5 ft from the center of the beampipe. z=0 is the beginning of the restricted beampipe. Golds hit the beampipe 15 feet from the magnet (z=-357.2 cm).

D. Gold-ions hitting the WD3 magnet

This time, we simulate the situation when the gold-ion beams hit the WD3 magnet as shown in Figure 9. The radii of the cylindrical magnet range from 2.5 cm to 22.5 cm and the magnet is 3 m long. z=0 is at the left-end of the magnet. The gold-ions hit head-on at the magnet at the inner radius with a uniform distribution around the circumference at that inner radius. The simulated doses and hadron fluxes are shown in Figure 10 and Figure 11 respectively.

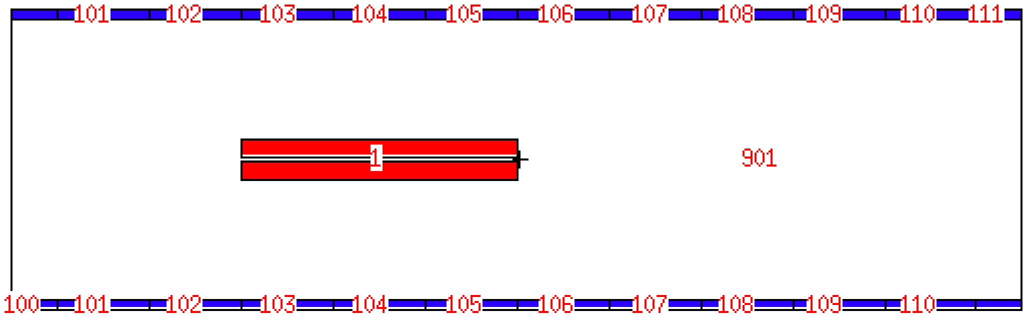

Figure 9: shows the model in the MCNPX simulation. Cell 1 is the simplified WD3 magnet with radii ranging from 2.5 cm to 22.5 cm and is 3 m long. The cells of soils numbered 101-110 are all used as “detectors” of 1 m long and 10 cm in thickness. z=0 is at the left-end of the magnet.

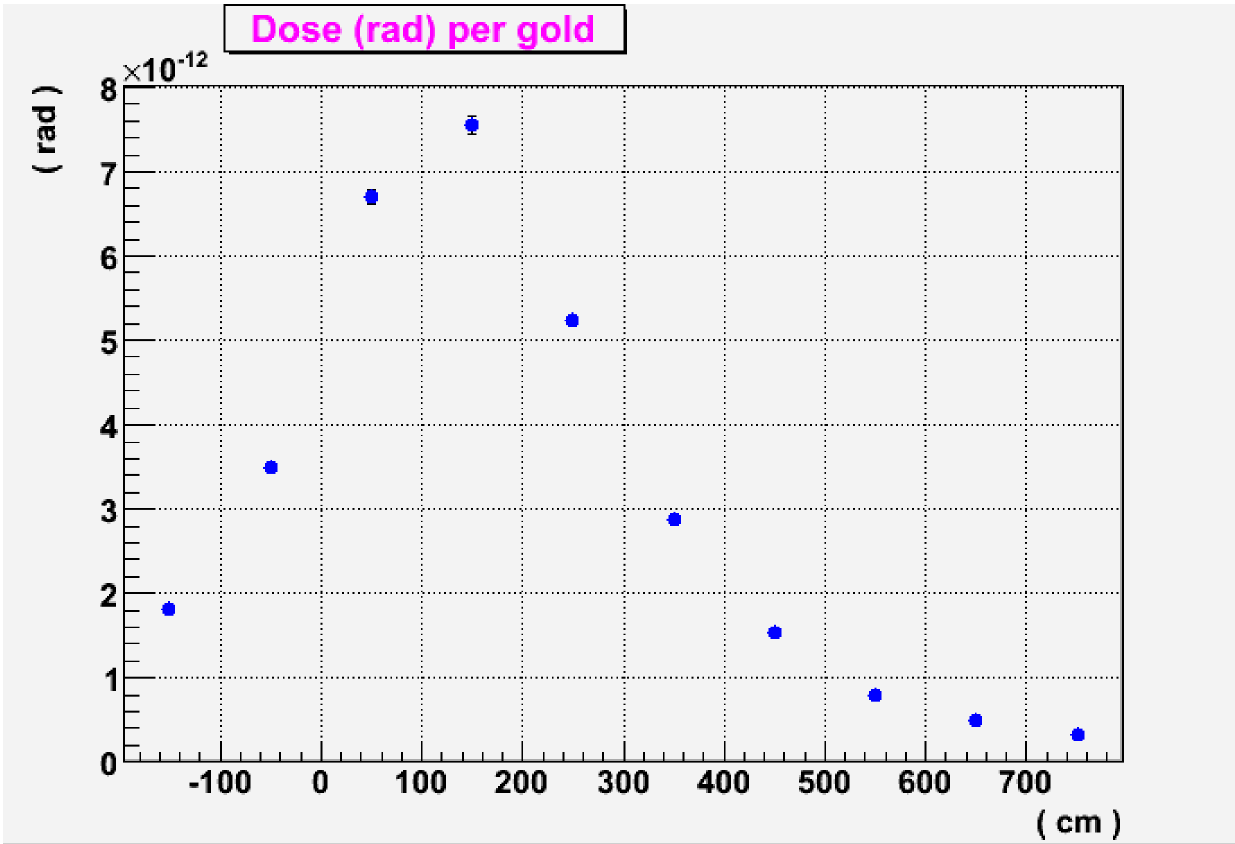

Figure 10: The doses (rad) per gold 5 feet from the center of the beampipe. z=0 cm here is the beginning (ie. left-end) of the magnet where the gold-ions hit the magnet.

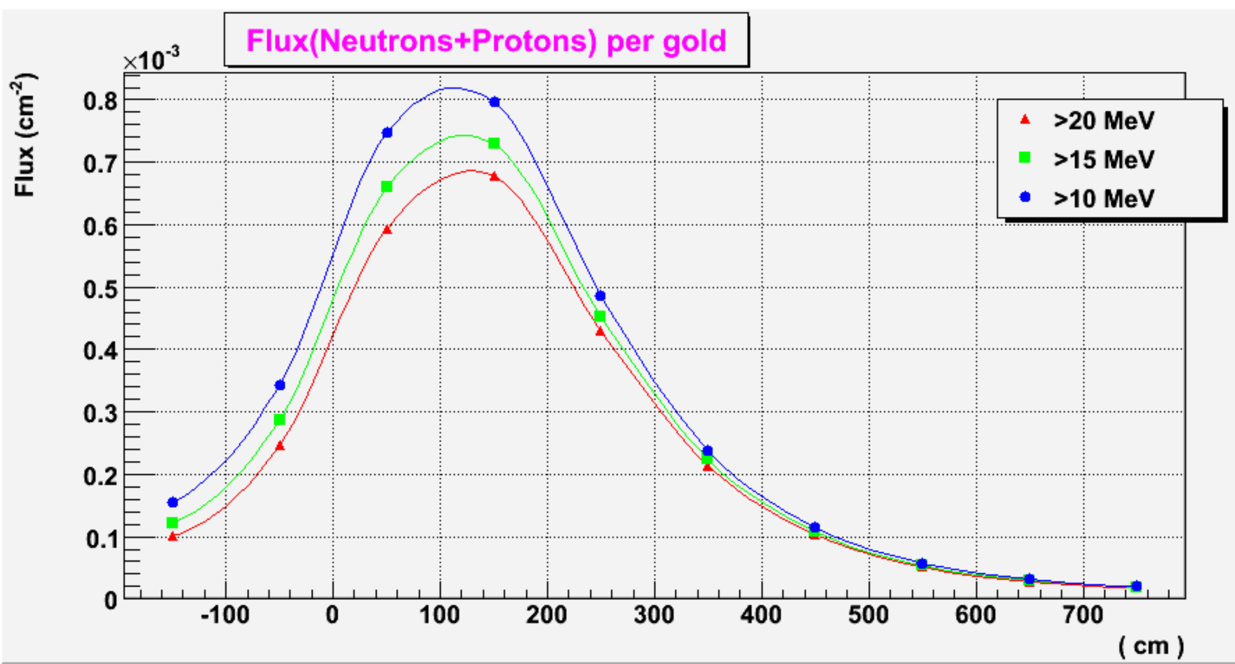

Figure 11: The fluxes of protons and neutrons (cm^{-2}) per gold 5 ft from the center of the beampipe. z=0 is the beginning (ie. left-end) of the magnet where the gold-ions hit the magnet.

The MCNPX input files and the plots in gif may be found in the AFS system : /afs/rhic.bnl.gov/rcfstaff/kinyip/public/radiation/rhic/ atr_dose_flux.tar.bz2.

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[i] MCNPX, version 2.7.c, http://mcnpx.lanl.gov .

[ii] The total and kinetic energies can be found in Section 12 on page 13 of the document written by Kip Gardner: http://www.cadops.bnl.gov/AGS/Operations/GardnerNotes/RhicRunParameters/barp10.pdf