

G4 hand-in exercise

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1 Introduction

The following simulation covers the study of three different particles, gammas (γ), neutron (n), and muons (μ), and their transmission through a truck sized object. Inside several objects, including a human analog, was placed. Figure 1, 2 shows an overview of the first setup, including rows of barrels (stacked two high), a human analog made from G4_A-150_TISSUE and a box of uranium. A CsI detector was placed on the other side of the truck opposite the incoming radiation (γ/n). Figure 3 shows an overview of the second setup (μ irradiation from above). Here the detectors (CsI) were placed one above and one below.

Energies used were: γ (15 MeV), n (5 MeV) and μ (4 GeV). Scoring was done by looking at the deposited energy in the detector plane (with a $1 \times 1 \text{cm}^2$ cell size).

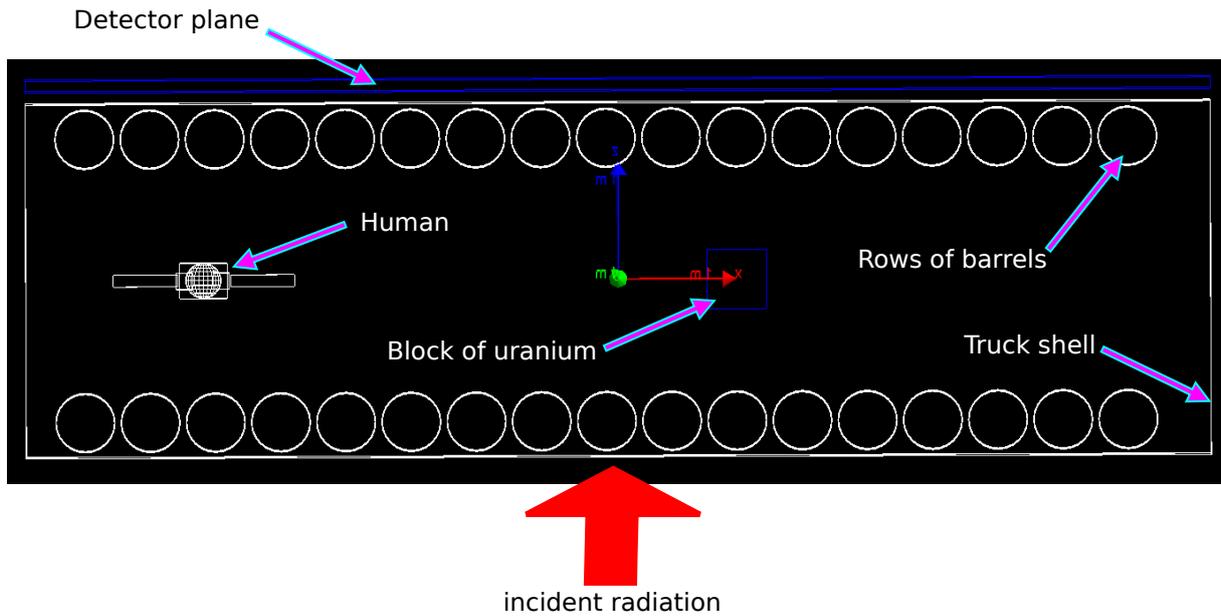


Figure 1: Top view: an overview of γ/n irradiation geometry.

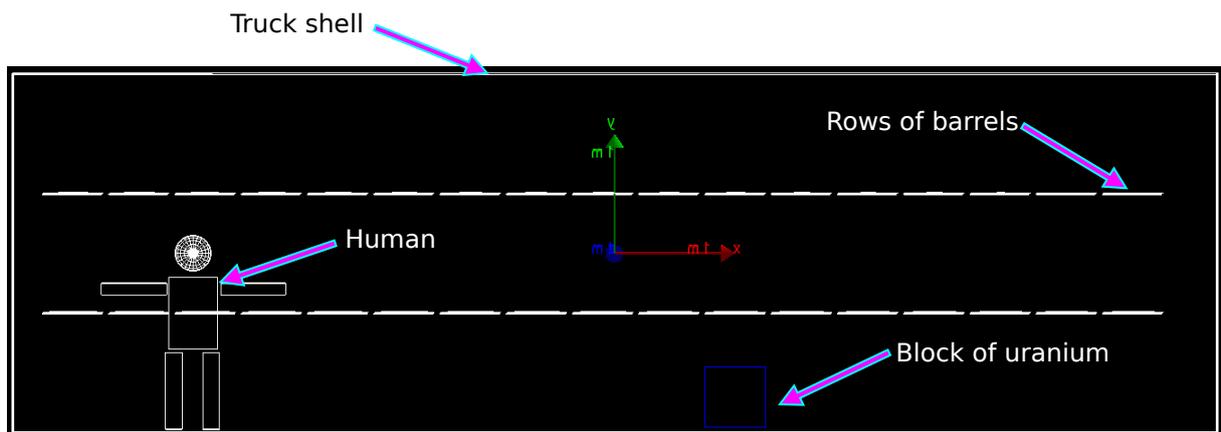


Figure 2: Side view: an overview of γ/n irradiation geometry.

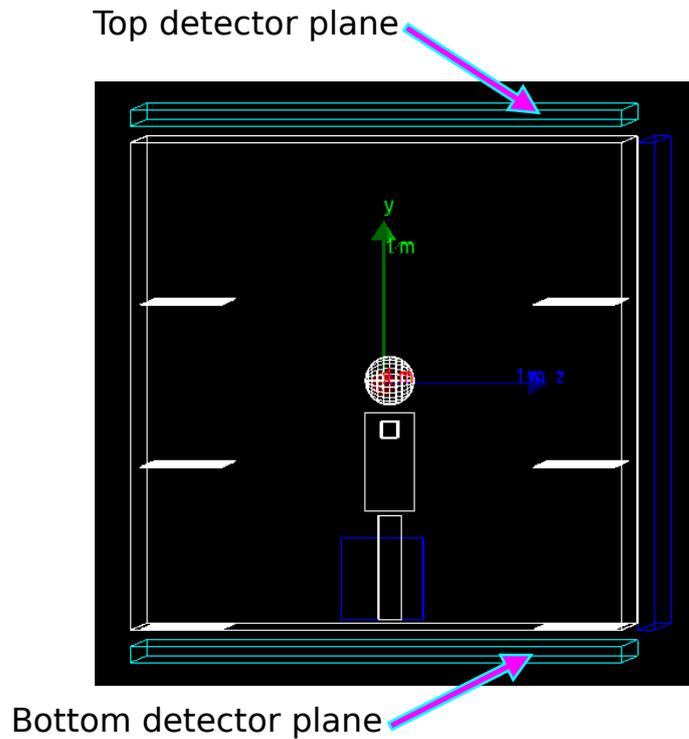


Figure 3: End view: an overview of μ irradiation geometry.

2 γ /neutron transmission

For this setup several 68 cylinders (referred to as barrels) of aluminium was arranged in two rows on either side of the human analog and an uranium block. These barrels contains wither water or concrete. Below, the resulting transmission is presented for both neutron and γ -ray irradiation.

For the neutron study (Figure 4, 5) it was clear that, given the 5 MeV neutron energies, these barrels (radius=.5 m) were enough to essentially completely block the neutrons from exiting the truck. Both the water and concrete. However, it is interesting to note the shape of the human analog between the gap of the 2nd and 3rd barrel. It obvious that the there is some less regular shape in this area. Arguable there are more neutron making it through the concrete barrels than the water barrels but is very hard to say. It would however correlate well with the higher cross section between neutrons and more hydrogen rich materials, like water. The uranium block, directly behind one of the barrels, was not visible.

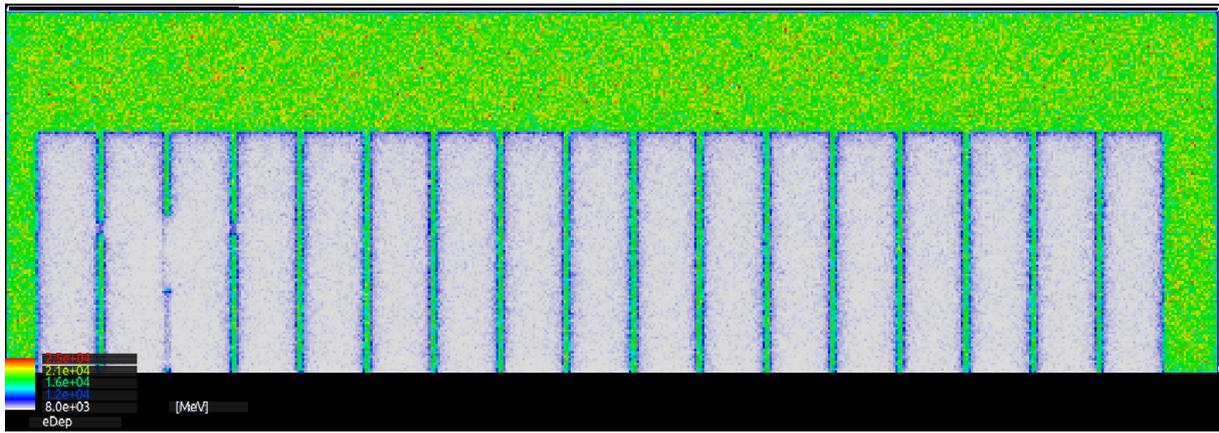


Figure 4: Energy deposition of barrel test (water) using 5 MeV n -rays. [5 million particles shot]

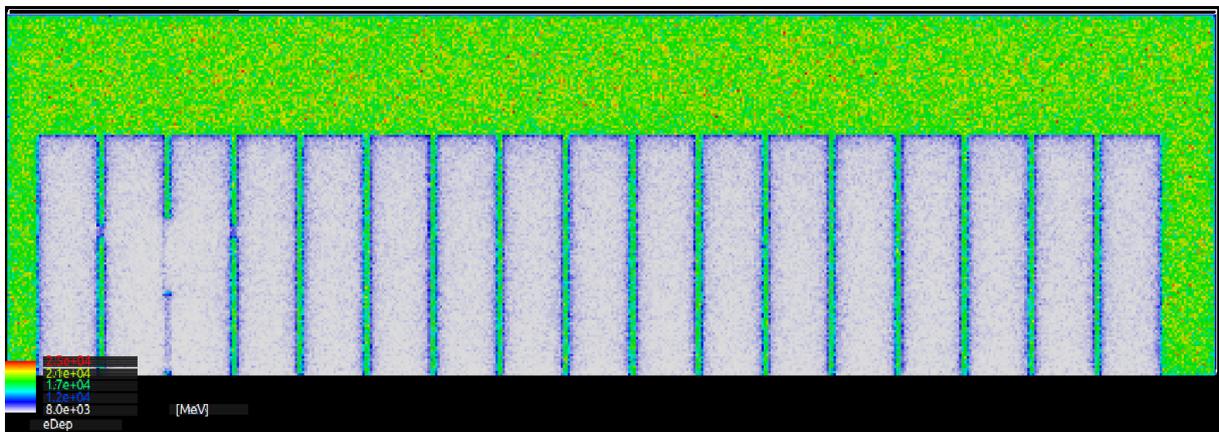


Figure 5: Energy deposition of barrel test (concrete) using 5 MeV n . [5 million particles shot]

In the case of the γ -rays, the difference is much more different. Photon interaction with matter has a strong correlation with the density or atomic number of the material, so the fact that concrete had the lowest transmission yield was not unexpected. It is interesting to note that the uranium block is clearly visible through the water barrels and only slightly for the water transmission tests. Arguable, for the water barrels, one can make out a slightly lower γ transmission through the third barrel that also corresponds well with the position of the human analog torso. Similarly, for the concrete barrels, a slight dip in intensity can be observed between barrel 2 and 3 where the human analog is located.

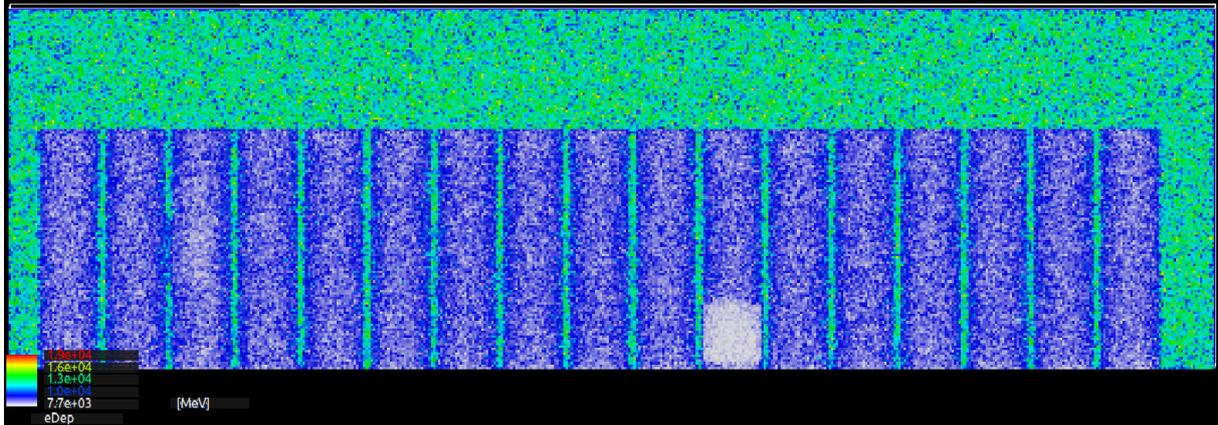


Figure 6: Energy deposition of barrel test (water) using 15 MeV γ -rays. [5 million particles shot]

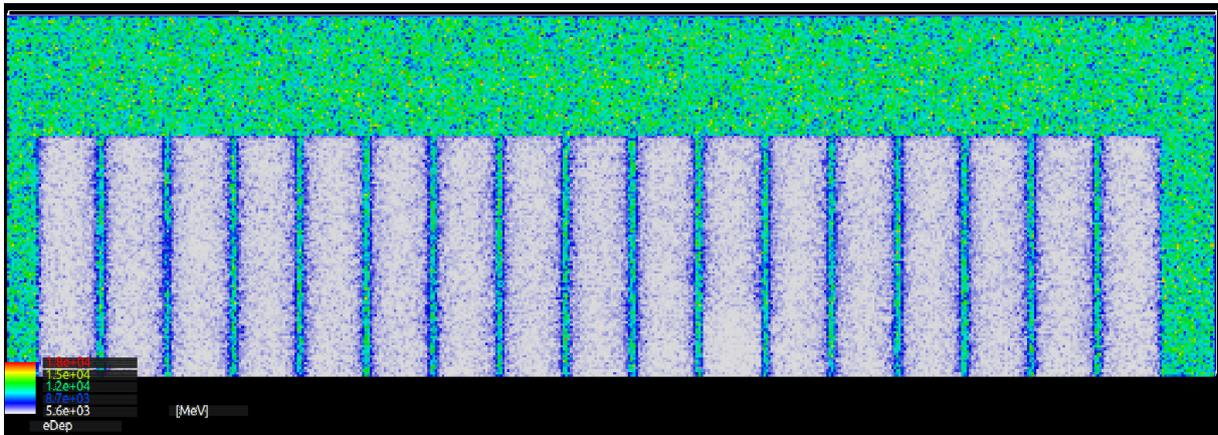


Figure 7: Energy deposition of barrel test (concrete) using 15 MeV γ -rays. [5 million particles shot]

3 μ transmission

Create a myDetector.cc file where each interaction can be handled. This can then be called via a sensitiveDetector method in detectorConstruction.cc file for both the top and bottom muon detector. After, in myDetector.cc, it should be possible to get the world position of the particle interaction in both the top and bottom sensitiveDetector and save it to file. A python script then should be able to analyze and plot the particle interaction on the top detector weighted with the muons scattering angle relative the bottom sensitiveDetector.

4 Source Code: (DetectorConstruction.cc)

I based my code on tutorial 2. For these tasks new materials and volumes were created by modifying the DetectorConstruction.cc file. Some examples follow below:

```
G4VPhysicalVolume* DetectorConstruction::Construct()
{
    G4bool checkOverlaps = true;
    ConstructMaterials();
    //Concrete
    G4Material *concrete = G4Material::GetMaterial("G4_CONCRETE");
    //Polyethylene
    G4Material *polyethylene = G4Material::GetMaterial("G4_POLYETHYLENE");
    //Water
    G4Material *water = G4Material::GetMaterial("G4_WATER");
    //Uranium
    G4Material *uranium = G4Material::GetMaterial("G4_U");
    ... etc...

    // DEFINING GEOMETRIES -----
    //Make world volume
    //Define solid using G4Box for "worldSolid".
    G4VSolid* worldSolid = new G4Box("worldBox",12.*m,6.*m,6.*m);
    //Make logical volume, define material composition.
    G4LogicalVolume* worldLogical = new G4LogicalVolume(worldSolid ,air , "worldLogical");
    G4VPhysicalVolume* worldPhysical = new G4PVPlacement(0 , G4ThreeVector(), worldLogical, "
        worldPhysical" ,0 , false, 0, CheckOverlaps);

    // Truck shell (Al)
    G4VSolid* truckSolid
        = new G4Box("truckBox",5*m,1.5*m,1.5*m);
    G4LogicalVolume* truckLogical
        = new G4LogicalVolume(truckSolid,aluminium,"truckLogical");
    new G4PVPlacement(0,G4ThreeVector(0.*m,0.*m,0.*m),truckLogical,
        "truckPhysical",worldLogical,
        false,0,checkOverlaps);

    // Defining inside of truck volume as air.
    G4VSolid* truckInsideSolid
        = new G4Box("truckInsideBox",4.9975*m,1.4975*m,1.4975*m);
    G4LogicalVolume* truckInsideLogical
        = new G4LogicalVolume(truckInsideSolid,air,"truckInsideLogical");
    new G4PVPlacement(0,G4ThreeVector(0.*m,0.*m,0.*m),truckInsideLogical,
        "truckInsidePhysical",truckLogical, false,0,checkOverlaps);

    //Defining gamma/neutron detector
    G4VSolid *detGammaSolid = new G4Box("detGammaBox", 5. * m, 1.5 * m, 0.05 * m);
    G4LogicalVolume *detGammaLogical = new G4LogicalVolume(detGammaSolid, scintillator, "
        detGammaLogical");
    new G4PVPlacement(0, G4ThreeVector(0. * m, 0. * m, 1.65 * m), detGammaLogical,
        "detGammaPhysical", worldLogical,
        false, 0, checkOverlaps);
}
```

```

// HUMAN ANALOG
-----
//Torso
G4VSolid *torsoSolid = new G4Box("torsoBox", .2 * m, 0.3 * m, .15 * m);

G4LogicalVolume *torsoLogical = new G4LogicalVolume(torsoSolid, tissue, "torsoLogical");
//Place torso volume and make daughter to truck volume.
new G4PVPlacement(0, G4ThreeVector(-3.5 * m, -.5 * m, 0. * m), torsoLogical,
    "torsoPhysical", truckInsideLogical,
    false, 0, checkOverlaps);

//Head
G4VSolid *headSolid = new G4Orb("headOrb", .15 * m);
G4LogicalVolume *headLogical = new G4LogicalVolume(headSolid, tissue, "headLogical");
new G4PVPlacement(0, G4ThreeVector(-3.5 * m, .0 * m, 0. * m), headLogical,
    "torsoPhysical", truckInsideLogical,
    false, 0, checkOverlaps);

... etc...

//Making rows of aluminium barrels with water inside.
//First, using a rotational matrix to "stand up" the barrels.
G4RotationMatrix* tilt_barrel=new G4RotationMatrix();
    tilt_barrel->rotateX(90*deg);
//Defining barrels shell
G4VSolid *barrelSolid = new G4Tubs("barrelTubs", 0, .25 * m, .5 * m, 0, 360*deg);
G4LogicalVolume *barrelLogical = new G4LogicalVolume(barrelSolid, aluminium, "barrelLogical");
//Defining barrels inside
G4VSolid *barrelInsideSolid = new G4Tubs("barrelInsideTubs", 0, .245 * m, .495 * m, 0, 360*deg);
    G4LogicalVolume *barrelInsideLogical = new G4LogicalVolume(barrelInsideSolid, water, "
        barrelInsideLogical");
new G4PVPlacement(0, G4ThreeVector(0. * m, 0 * m, 0 * m), barrelInsideLogical,
    "barrelInsidePhysical", barrelLogical,
    false, 0, checkOverlaps);

//Several barrels are placed along the length of the truck in two layers (68 total)
new G4PVPlacement(tilt_barrel, G4ThreeVector(-4.5 * m, -1.0 * m, -1.20 * m), barrelLogical,
    "barrelPhysical", truckInsideLogical,
    false, 0, checkOverlaps);
new G4PVPlacement(tilt_barrel, G4ThreeVector(-3.95 * m, -1.0 * m, -1.20 * m), barrelLogical,
    "barrelPhysical", truckInsideLogical,
    false, 1, checkOverlaps);
new G4PVPlacement(tilt_barrel, G4ThreeVector(-3.40 * m, -1.0 * m, -1.20 * m), barrelLogical,
    "barrelPhysical", truckInsideLogical,
    false, 2, checkOverlaps);

... etc...

//Visual attribute are set to relevant logical volumes.
G4VisAttributes* visAttributes = new G4VisAttributes(G4Colour(1.0,1.0,1.0));
visAttributes->SetVisibility(false);
worldLogical->SetVisAttributes(visAttributes);
fVisAttributes.push_back(visAttributes);

... etc ...

return worldPhysical;
}

```

5 Source Code: (scoring.mac)

Following macro was made to get display the energy deposition in the detector for the scoring mesh.

```
/run/initialize
/score/create/boxMesh boxMesh_1
#Create a mesh for the gamma/n detector
/score/mesh/boxSize 5. 1.5 0.05 m
#Position it over the detector
/score/mesh/translate/xyz 0 0 1.65 m
#Determine the detector cell size (1x1cm2 was used)
/score/mesh/nBin 500 150 1
/score/quantity/energyDeposit eDep
/score/close
/score/list
#Do not show particle tracks.
/vis/disable
/run/verbose 1
#Start simulation with number of particles
/run/beamOn 10000000
#Show deposited energy (eDep) on scoring mesh.
/score/drawProjection boxMesh_1 eDep
```

6 Just for fun...

Figure 8, 9 shows a neutron transmission test using 20 cm of shielding between source and detector consisting of either concrete or polyethylene. As expected, the polyethylene stops more of the neutrons due to the higher cross section of neutrons on more hydrogen rich materials. Both the human analog and uranium block are clearly visible for both materials.

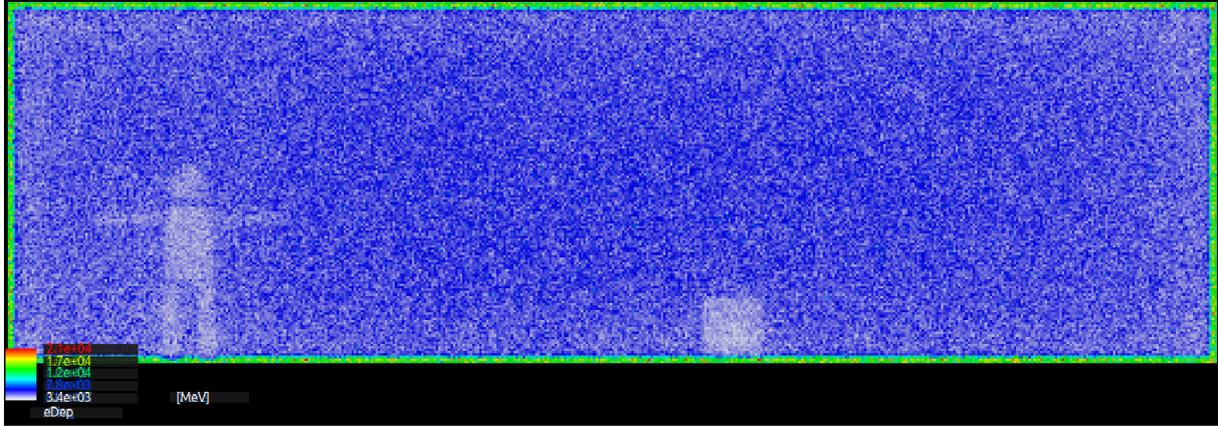


Figure 8: Energy deposition with 20 cm concrete shield using 5 MeV n . [1 million particles shot]

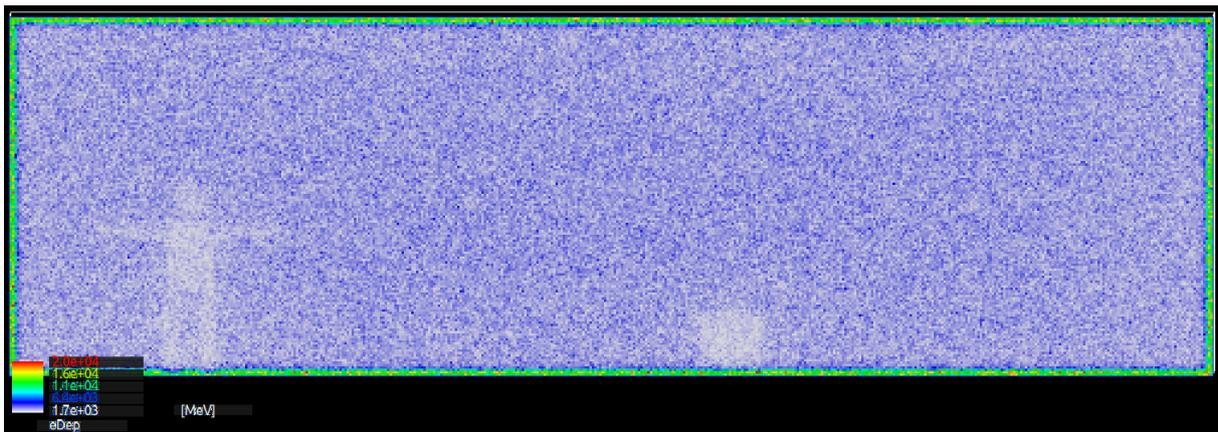


Figure 9: Energy deposition with 20 cm polyethylene shield using 5 MeV n . [1 million particles shot]

Figure 10, 11 shows a γ -ray transmission test using 20 cm of shielding between source and detector consisting of either concrete or polyethylene. Here, the concrete shields more of the photons compared to the polyethylene. Through the polyethylene the uranium block can easily be discerned is less defined through the polyethylene.

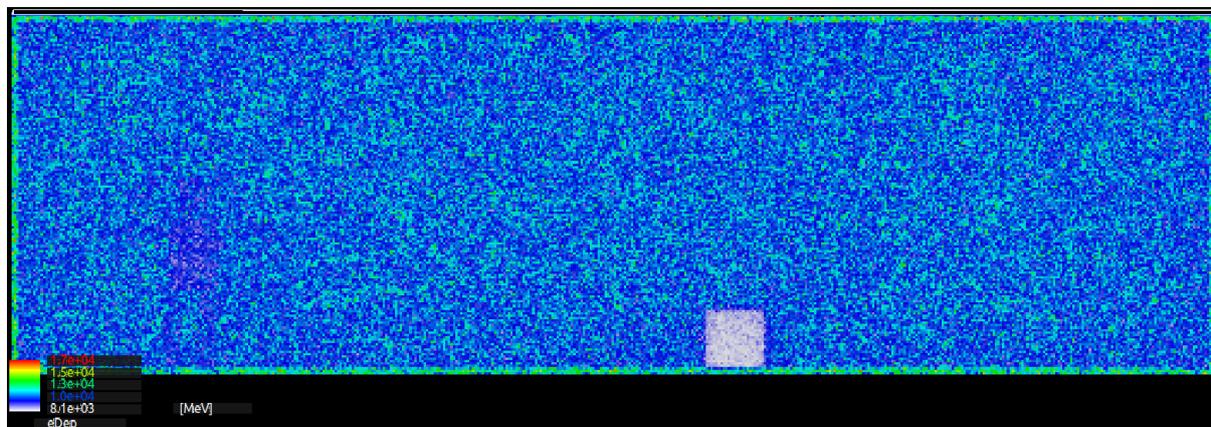


Figure 10: Energy deposition with 20 cm concrete shield using 15 MeV γ -rays. [1 million particles shot]

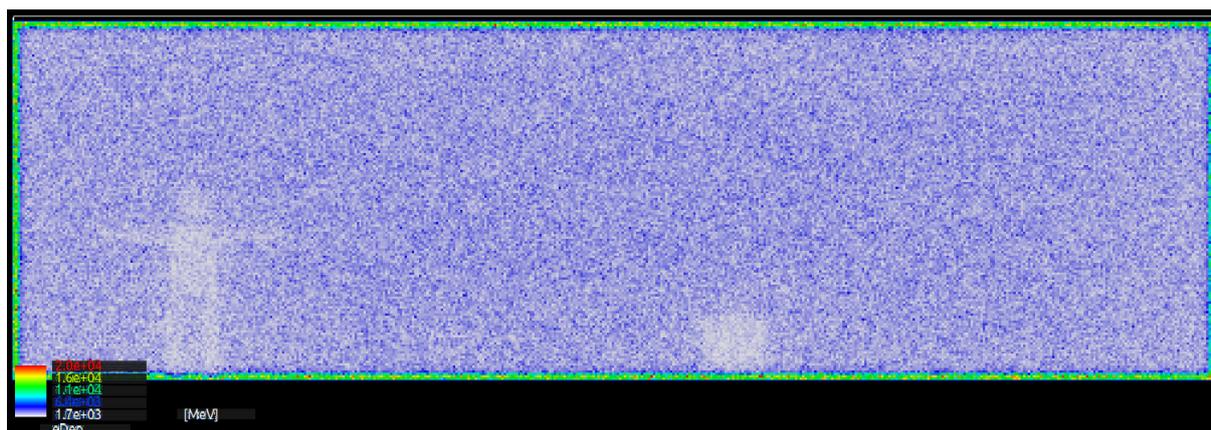


Figure 11: Energy deposition with 20 cm polyethylene shield using 15 MeV γ -rays. [1 million particles shot]

7 Particle tracks

Figure 12 shows a sample of some particle tracks (γ -rays) incident on the experimental setup.

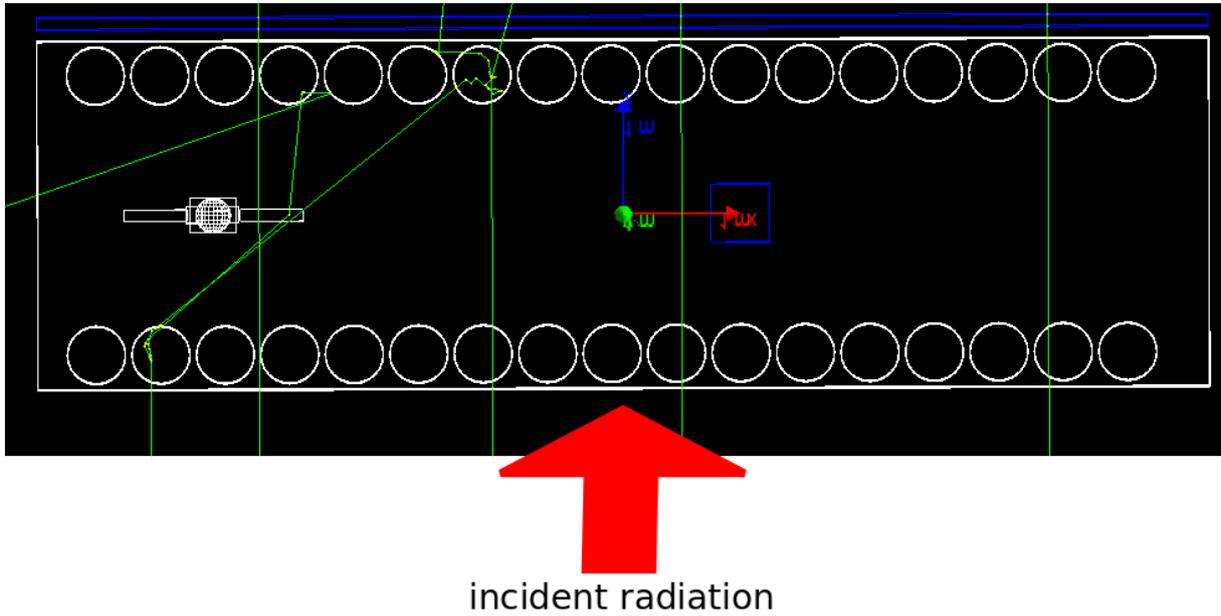


Figure 12: Sample of particle tracks from 15 MeV γ -rays.