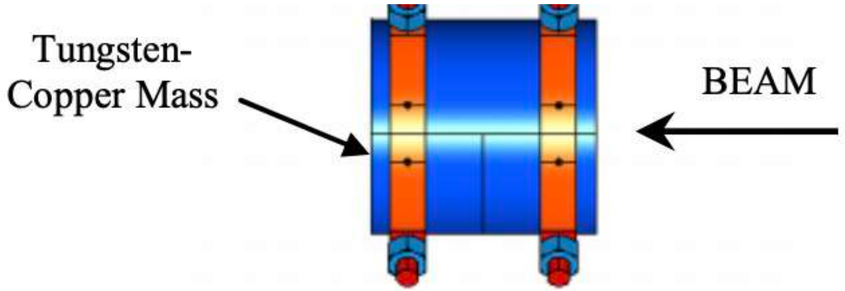
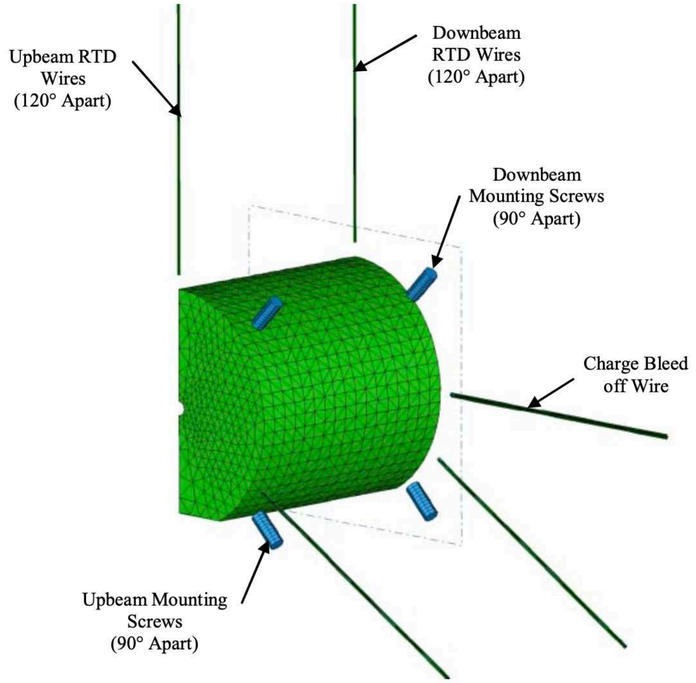
Tungsten-Copper Calorimeter simulation with Geant4

Hector Chinchay

MECHANICAL AND THERMAL DESIGN OF THE CEBAF HALL A BEAM CALORIMETER

Tungsten- copper (95:5) Calorimeter

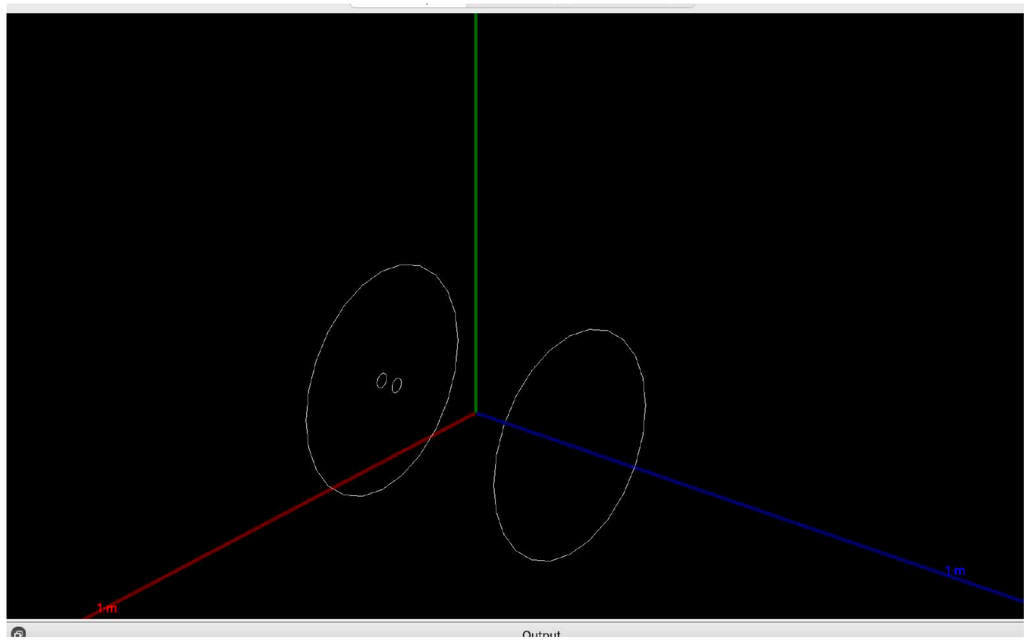


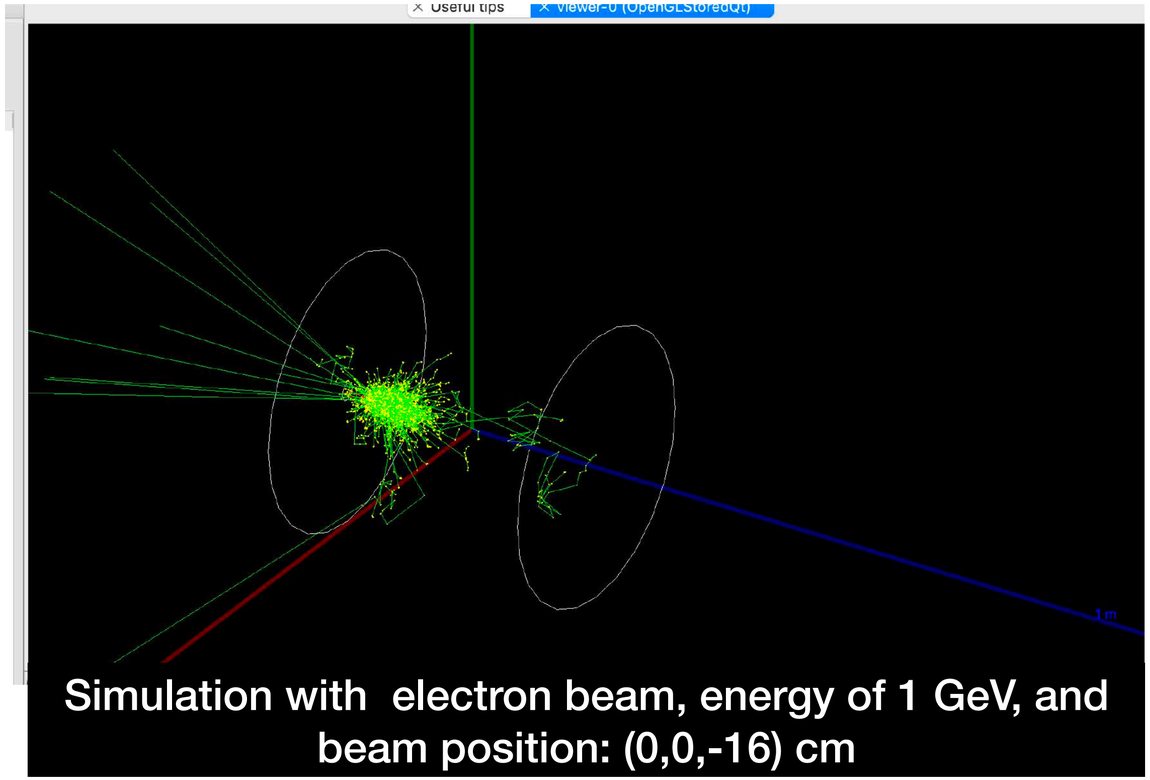


16cm diameter by 16cm long tungsten mass with a 1cm diameter by 2.5cm long entrance hole

(Bevins et al., 2006)

Build geometry of calorimeter





Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-16) cm

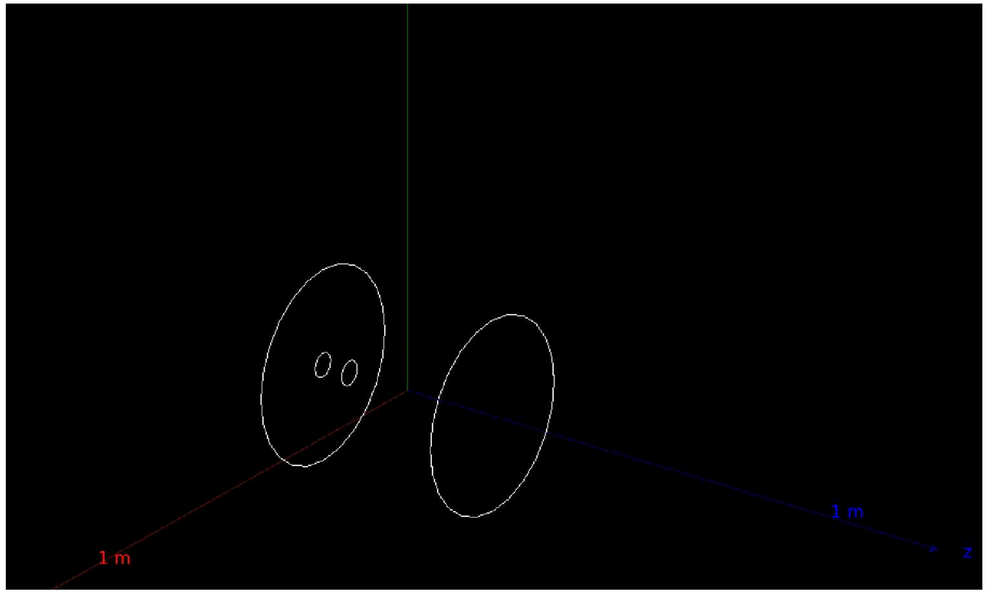
Hole: diameter 1cm, long entrance 2.5cm

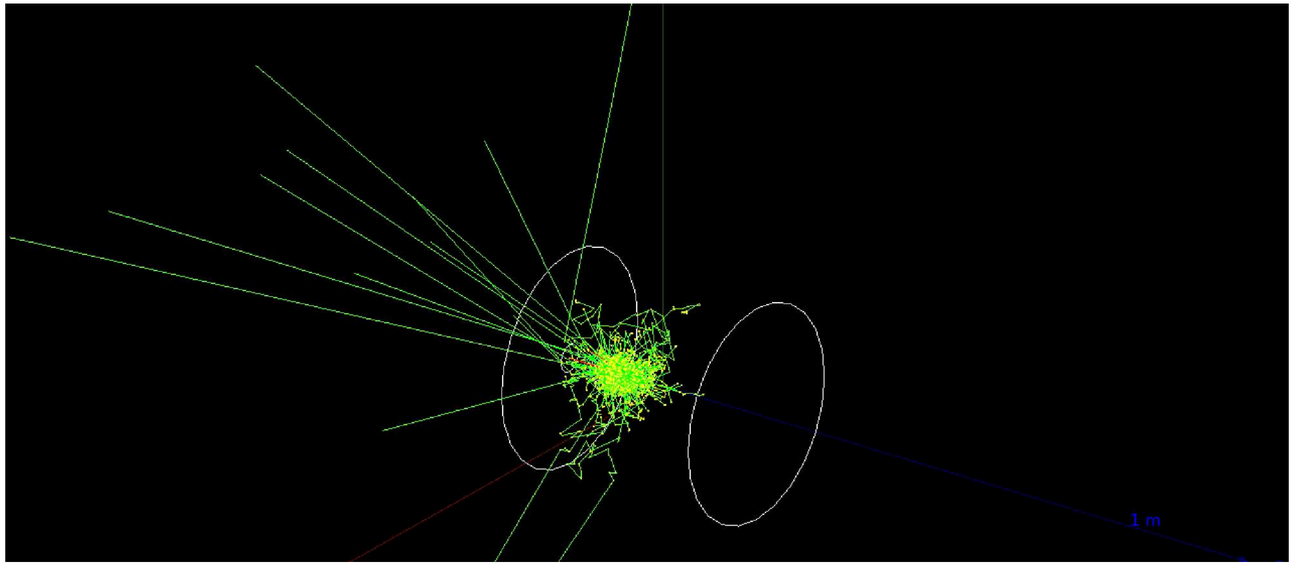
```
# User defined icon :
/gui/addIcon "Run beam on" user_icon "/run/beamOn 1" run.png
 Changing export format to "jpg"
/gun/particle e-
/gun/energy 1 GeV
Matching commands :
/gun/position
/gun/polarization
/gun/position 0 0 -16 cm
```

Session : /run/beamOn 10

```
G4Material* material = G4Material::GetMaterial("CuW");
  G4Material* material = G4Material::GetMaterial("CsI");
G4VSolid* Cylinder1
= new G4Tubs("Cylinder1",0.,16.*cm,16.*cm,0.,2*M_PI*rad);
G4VSolid* Cylinder2
= new G4Tubs("Cylinder2",0.,1.*cm,2.5*cm,0.,2*M_PI*rad);
G4VSolid* hadCalorimeterSolid
= new G4SubtractionSolid("HadCalorimeterTubs", Cylinder1, Cylinder2, 0, G4ThreeVector(0., 0., -16.*cm));
```

Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-16) cm
Hole: diameter 2cm, long entrance 5cm

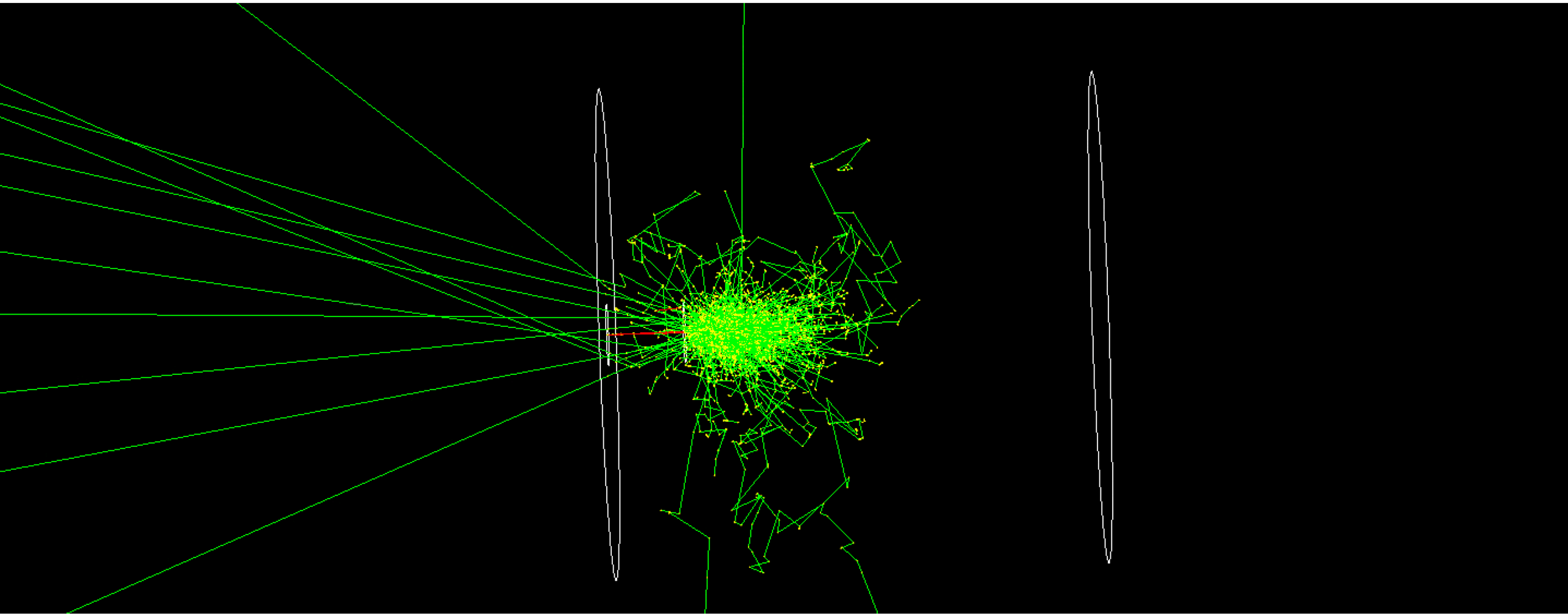




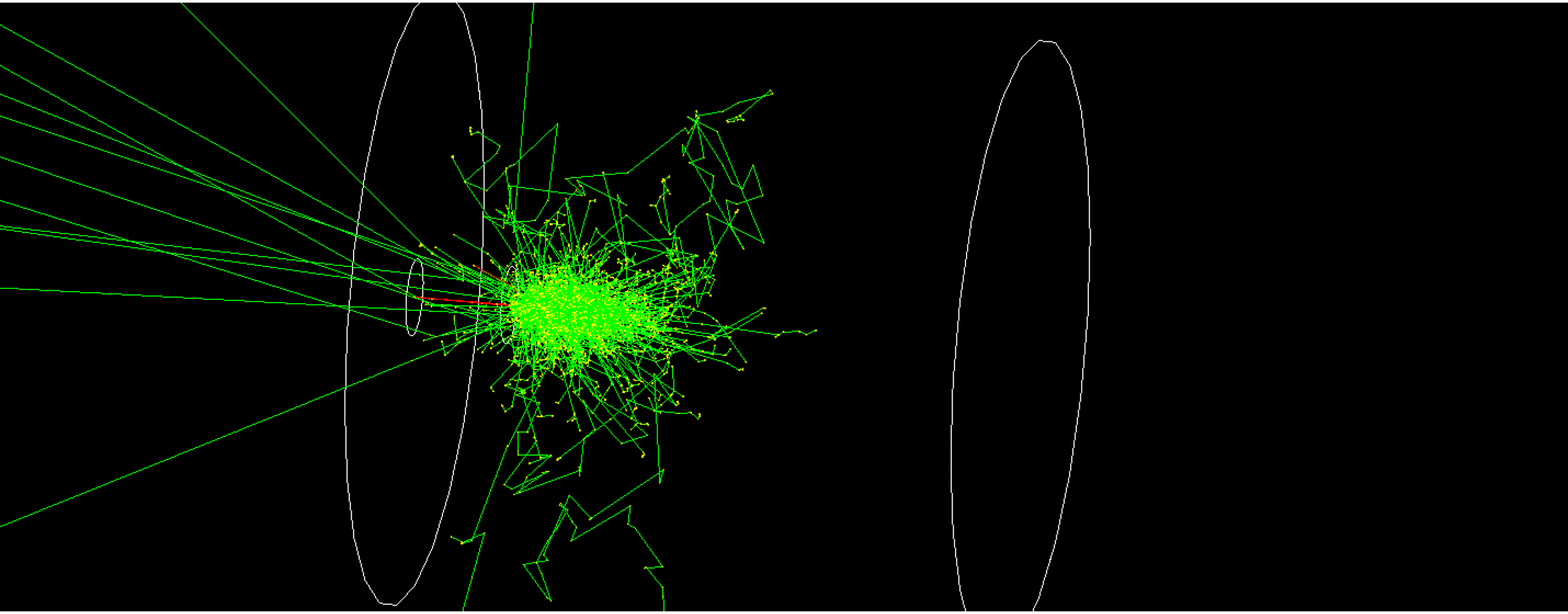

```
/gui/addButton viewer "Set style wireframe" "/vis/viewer/set/style wireframe"
/gui/addButton viewer "Refresh viewer" "/vis/viewer/refresh"
/gui/addButton viewer "Update viewer (interaction or end-of-file)" "/vis/viewer/update"
/gui/addButton viewer "Flush viewer (= refresh + update)" "/vis/viewer/flush"
/gui/addButton viewer "Update scene" "/vis/scene/notifyHandlers"
#
# User defined icon :
/gui/addIcon "Run beam on" user_icon "/run/beamOn 1" run.png
 Changing export format to "jpg"
/gui/particle e-
/gui/position 0 0 -16 cm
/gui/energy 1 GeV

Session : /run/beamOn 10
```

```
    // ========================================================
    G4Material* material = G4Material::GetMaterial("CuW");
//    G4Material* material = G4Material::GetMaterial("CsI");
    G4VSolid* Cylinder1
    = new G4Tubs("Cylinder1",0.,16.*cm,16.*cm,0.,2*M_PI*rad);
    G4VSolid* Cylinder2
      = new G4Tubs("Cylinder2",0.,2.*cm,5.*cm,0.,2*M_PI*rad);
    G4VSolid* hadCalorimeterSolid
    = new G4SubtractionSolid("HadCalorimeterTubs", Cylinder1, Cylinder2, 0, G4ThreeVector(0., 0., -16.*cm
));
```

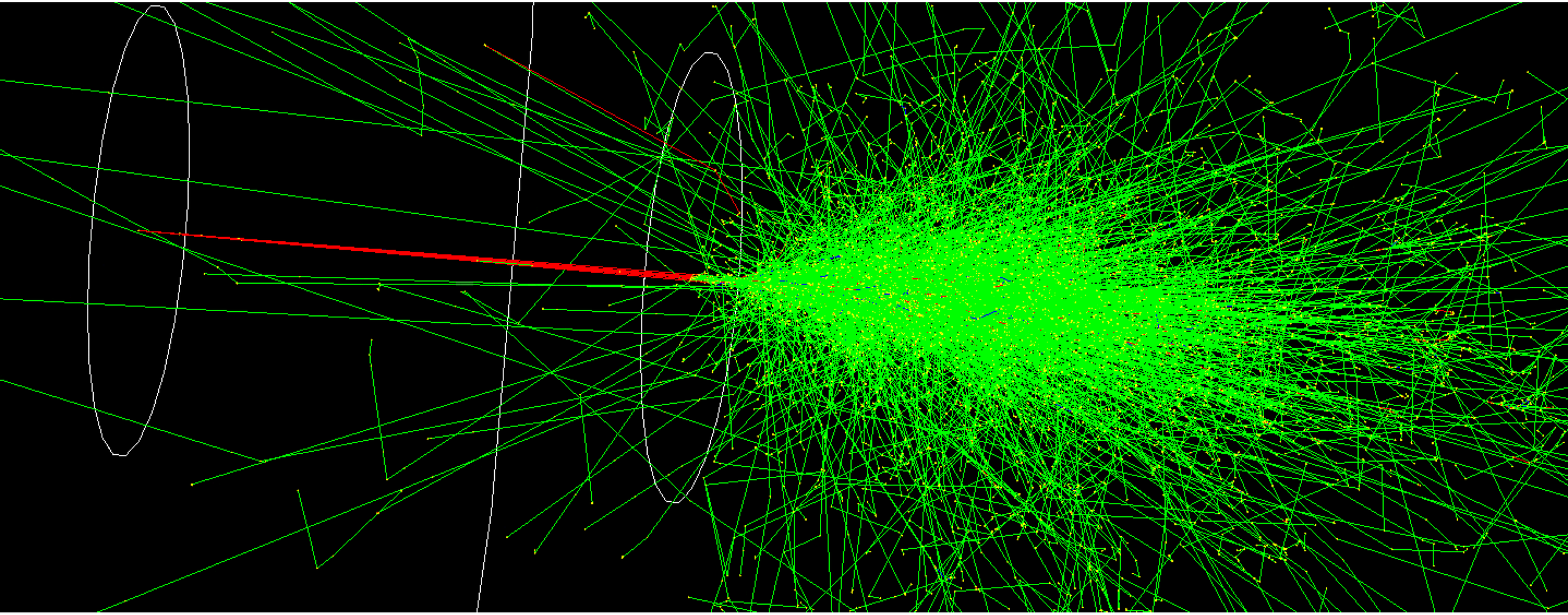
Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-16) cm
Hole: diameter 2cm, long entrance 5cm



Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-16) cm
Hole: diameter 2cm, long entrance 5cm



Zoom in the hole



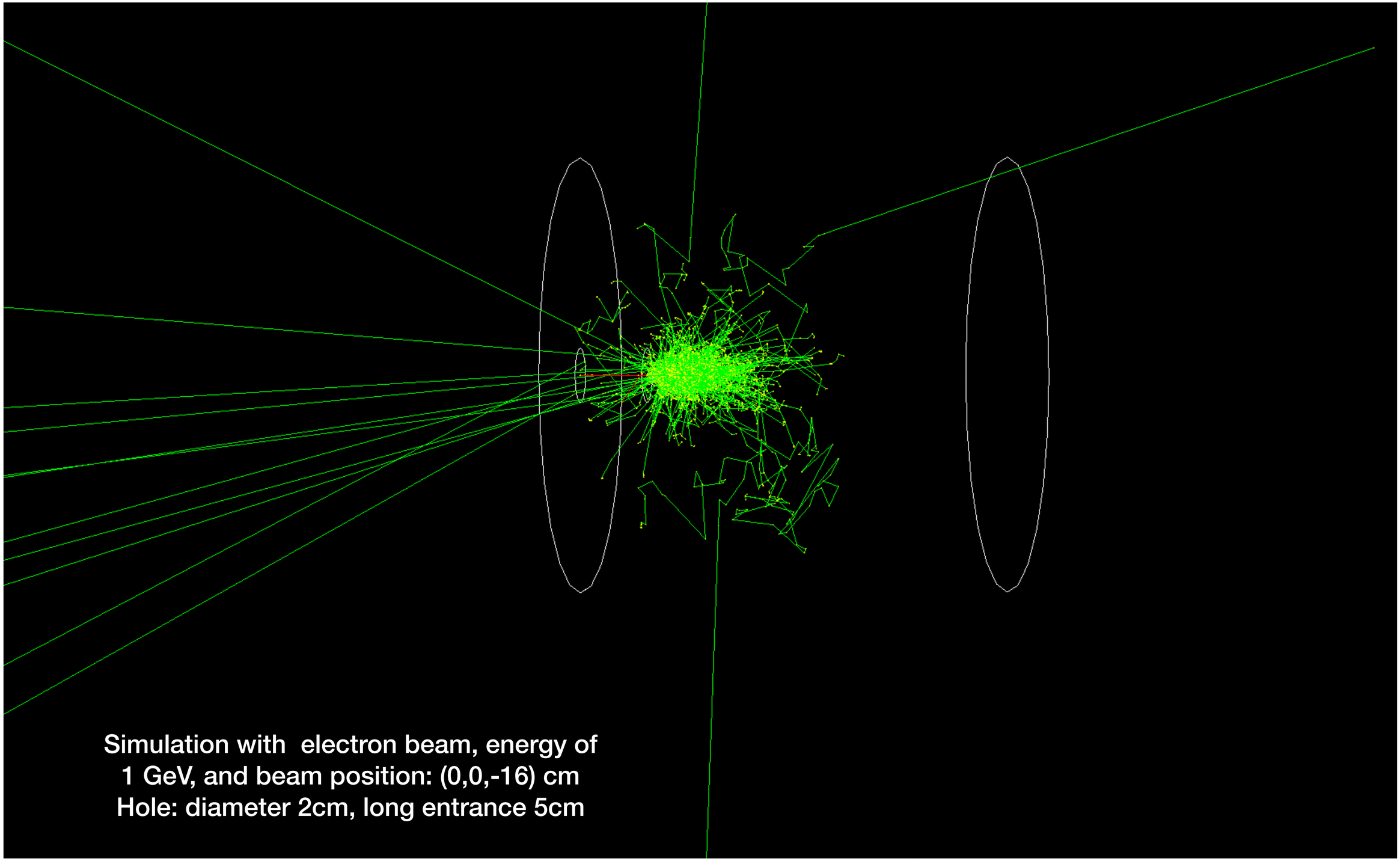
Define material of calorimeter

Materials:
CuW
Air
Air_lowDensity

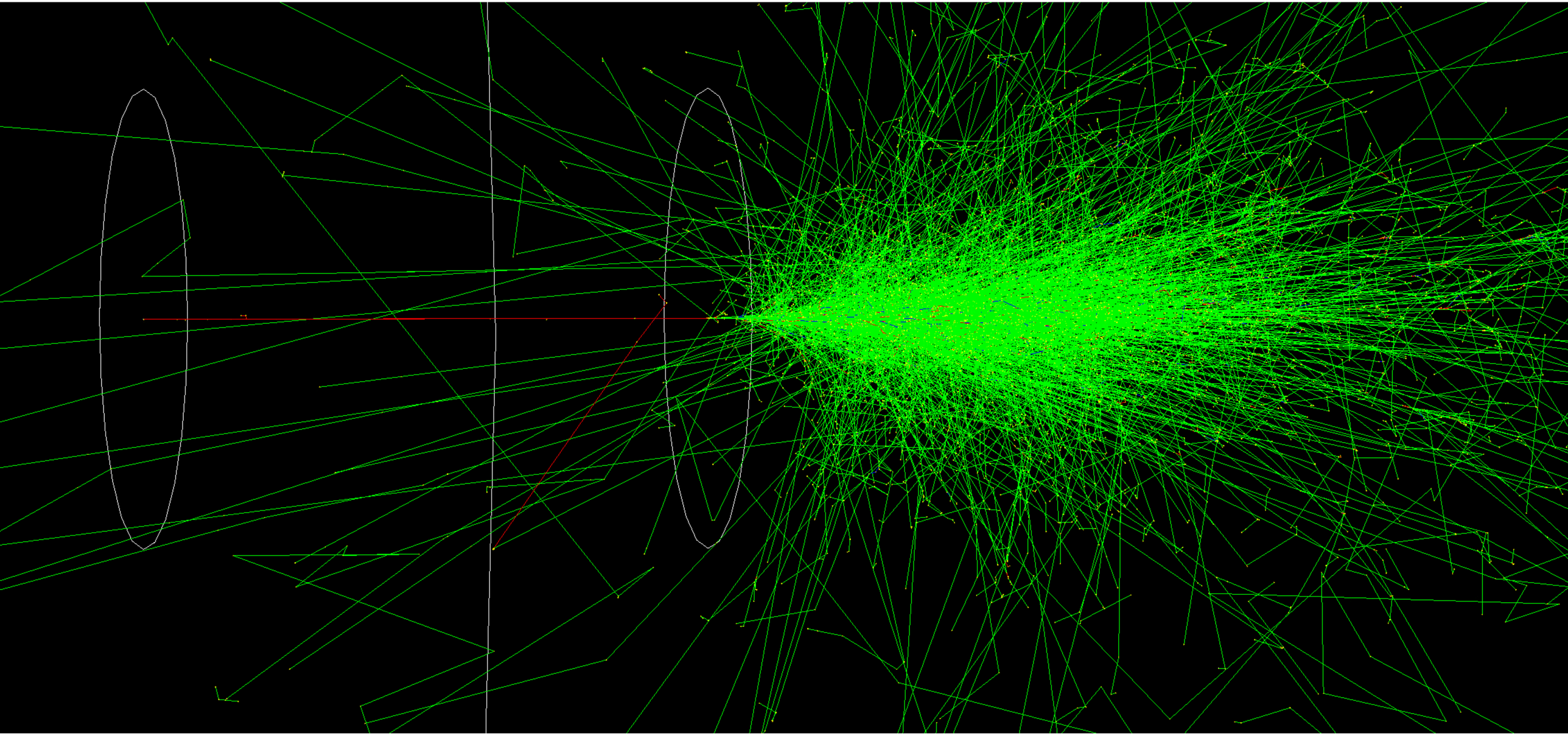
```
Material:      CuW    density: 16.750 g/cm3   RadL:   4.238 mm   Nucl.Int.Length:  11.396 cm
                      Imean: 663.705 eV   temperature: 293.15 K  pressure:   1.00 atm

 --->  Element: Copper (Cu)    Z = 29.0    N =    64    A = 63.550 g/mole
       --->  Isotope:  Cu63    Z = 29    N =  63    A =  62.93 g/mole    abundance: 69.170 %
       --->  Isotope:  Cu65    Z = 29    N =  65    A =  64.93 g/mole    abundance: 30.830 %
        ElmMassFraction:  10.00 %  ElmAbundance  24.32 %

 --->  Element: Tungsten (W)    Z = 74.0    N =   184    A = 183.800 g/mole
       --->  Isotope:  W180    Z = 74    N = 180    A = 179.95 g/mole    abundance:  0.120 %
       --->  Isotope:  W182    Z = 74    N = 182    A = 181.95 g/mole    abundance: 26.500 %
       --->  Isotope:  W183    Z = 74    N = 183    A = 182.95 g/mole    abundance: 14.310 %
       --->  Isotope:  W184    Z = 74    N = 184    A = 183.95 g/mole    abundance: 30.640 %
       --->  Isotope:  W186    Z = 74    N = 186    A = 185.95 g/mole    abundance: 28.430 %
        ElmMassFraction:  90.00 %  ElmAbundance  75.68 %
```

```
/material/g4/printMaterial
Material:   G4_AIR    density:  1.205 mg/cm3  RadL: 303.921 m    Nucl.Int.Length: 710.095 m
                      Imean:  85.700 eV   temperature: 293.15 K  pressure:   1.00 atm

 --->  Element: C (C)    Z =  6.0    N =    12    A = 12.011 g/mole
       --->  Isotope:   C12    Z =  6    N =  12    A =  12.00 g/mole    abundance: 98.930 %
       --->  Isotope:   C13    Z =  6    N =  13    A =  13.00 g/mole    abundance:  1.070 %
        ElmMassFraction:   0.01 %  ElmAbundance   0.02 %

 --->  Element: N (N)    Z =  7.0    N =    14    A = 14.007 g/mole
       --->  Isotope:   N14    Z =  7    N =  14    A =  14.00 g/mole    abundance: 99.632 %
       --->  Isotope:   N15    Z =  7    N =  15    A =  15.00 g/mole    abundance:  0.368 %
        ElmMassFraction:  75.53 %  ElmAbundance  78.44 %

 --->  Element: O (O)    Z =  8.0    N =    16    A = 15.999 g/mole
       --->  Isotope:   O16    Z =  8    N =  16    A =  15.99 g/mole    abundance: 99.757 %
       --->  Isotope:   O17    Z =  8    N =  17    A =  17.00 g/mole    abundance:  0.038 %
       --->  Isotope:   O18    Z =  8    N =  18    A =  18.00 g/mole    abundance:  0.205 %
        ElmMassFraction:  23.18 %  ElmAbundance  21.07 %

 --->  Element: Ar (Ar)    Z = 18.0    N =    40    A = 39.948 g/mole
       --->  Isotope:  Ar36    Z = 18    N =  36    A =  35.97 g/mole    abundance:  0.337 %
       --->  Isotope:  Ar38    Z = 18    N =  38    A =  37.96 g/mole    abundance:  0.063 %
       --->  Isotope:  Ar40    Z = 18    N =  40    A =  39.96 g/mole    abundance: 99.600 %
        ElmMassFraction:   1.28 %  ElmAbundance   0.47 %
```

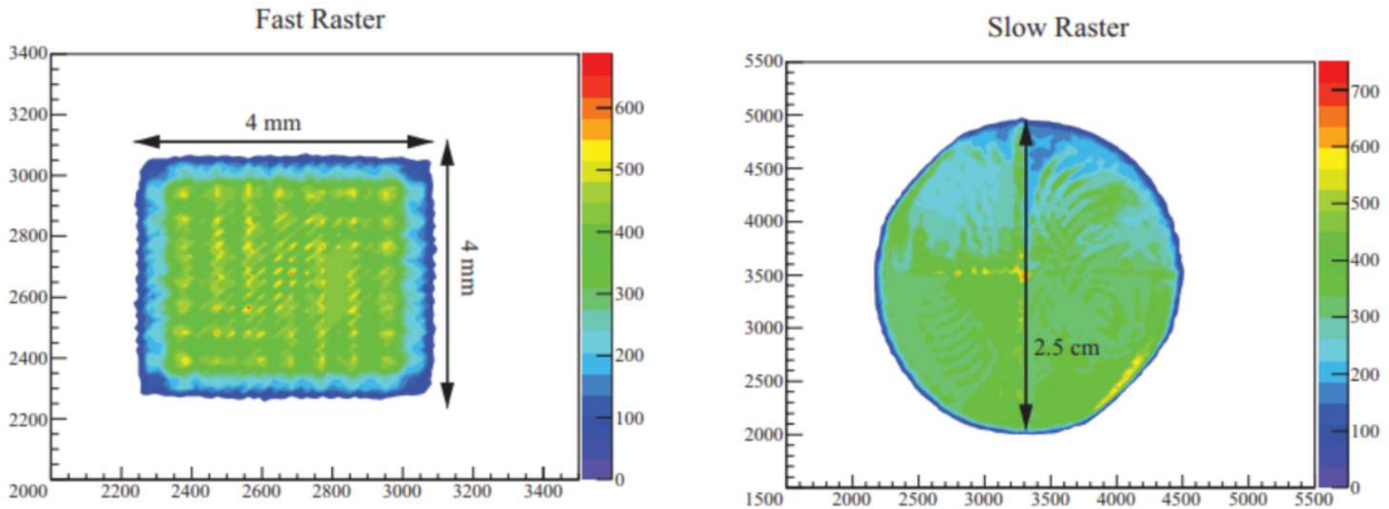
```
Material: Air_lowDensity    density:  0.000 mg/cm3  RadL: 30392.070 km   Nucl.Int.Length: 71009.501
                      Imean:  85.700 eV   temperature: 293.15 K  pressure:   1.00 atm

 --->  Element: C (C)    Z =  6.0    N =    12    A = 12.011 g/mole
       --->  Isotope:   C12    Z =  6    N =  12    A =  12.00 g/mole    abundance: 98.930 %
       --->  Isotope:   C13    Z =  6    N =  13    A =  13.00 g/mole    abundance:  1.070 %
        ElmMassFraction:   0.01 %  ElmAbundance   0.02 %

 --->  Element: N (N)    Z =  7.0    N =    14    A = 14.007 g/mole
       --->  Isotope:   N14    Z =  7    N =  14    A =  14.00 g/mole    abundance: 99.632 %
       --->  Isotope:   N15    Z =  7    N =  15    A =  15.00 g/mole    abundance:  0.368 %
        ElmMassFraction:  75.53 %  ElmAbundance  78.44 %

 --->  Element: O (O)    Z =  8.0    N =    16    A = 15.999 g/mole
       --->  Isotope:   O16    Z =  8    N =  16    A =  15.99 g/mole    abundance: 99.757 %
       --->  Isotope:   O17    Z =  8    N =  17    A =  17.00 g/mole    abundance:  0.038 %
       --->  Isotope:   O18    Z =  8    N =  18    A =  18.00 g/mole    abundance:  0.205 %
        ElmMassFraction:  23.18 %  ElmAbundance  21.07 %

 --->  Element: Ar (Ar)    Z = 18.0    N =    40    A = 39.948 g/mole
       --->  Isotope:  Ar36    Z = 18    N =  36    A =  35.97 g/mole    abundance:  0.337 %
       --->  Isotope:  Ar38    Z = 18    N =  38    A =  37.96 g/mole    abundance:  0.063 %
       --->  Isotope:  Ar40    Z = 18    N =  40    A =  39.96 g/mole    abundance: 99.600 %
        ElmMassFraction:   1.28 %  ElmAbundance   0.47 %
```


Simulation with electron beam, energy of
1 GeV, and beam position: (0,0,-16) cm
Hole: diameter 2cm, long entrance 5cm

Zoom in the hole



Size of electron beam on target



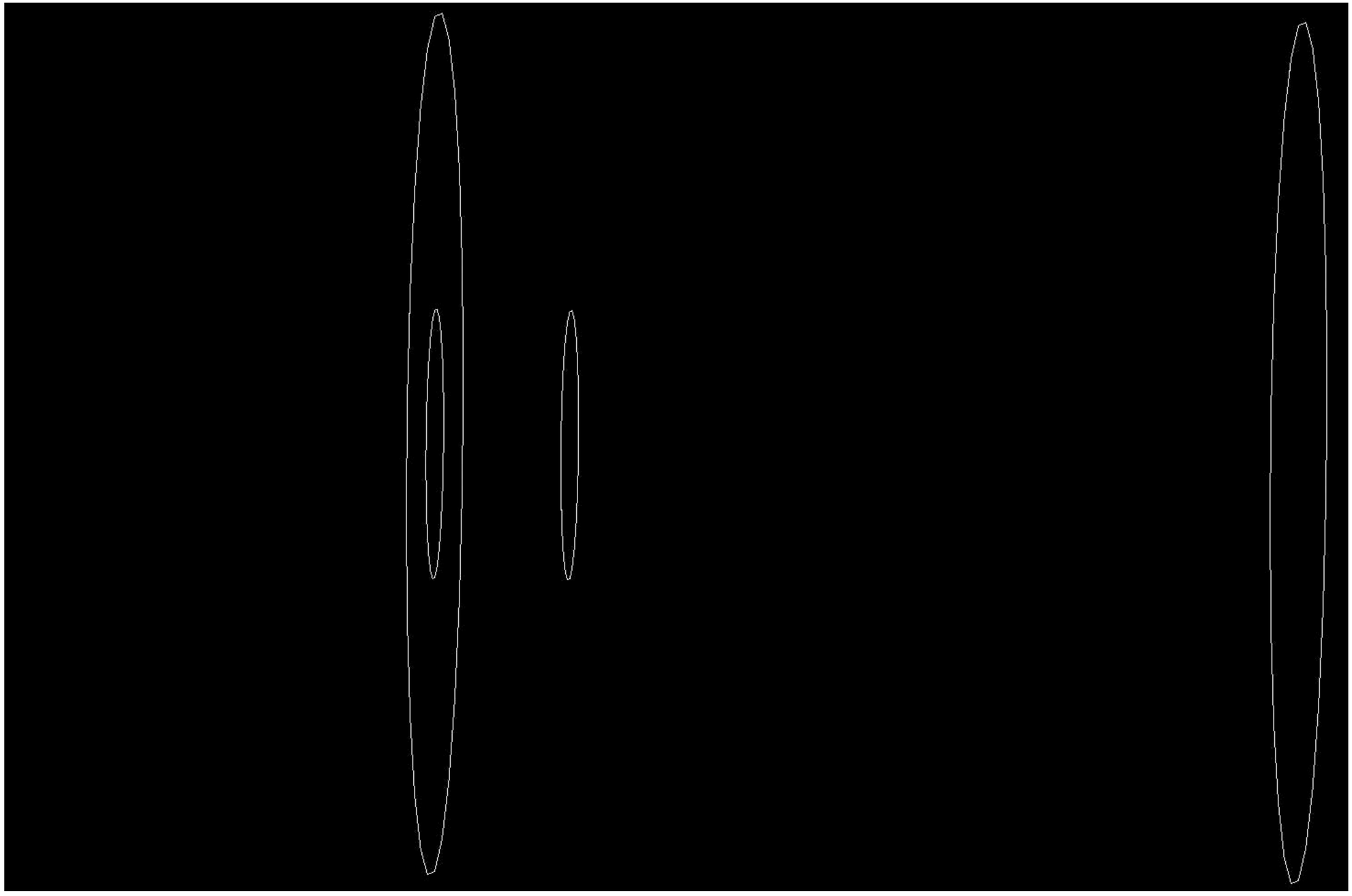
(a) Fast Raster

(b) Slow Raster

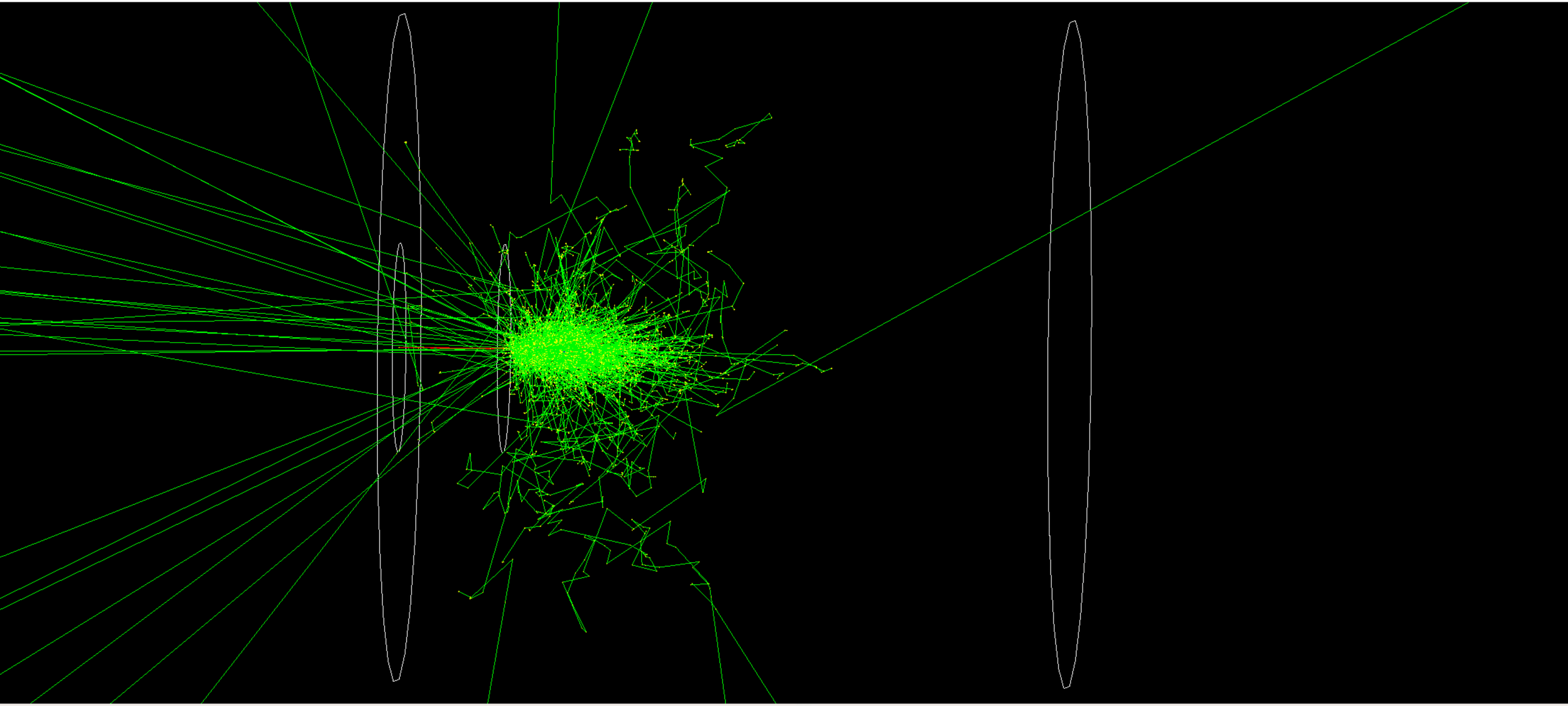
Figure 4.4: Raster swept beam profiles. Plots are a function of current in arbitrary units. Reproduced from Zielinski [2017]

Figure courtesy of D. Ruth dissertation.

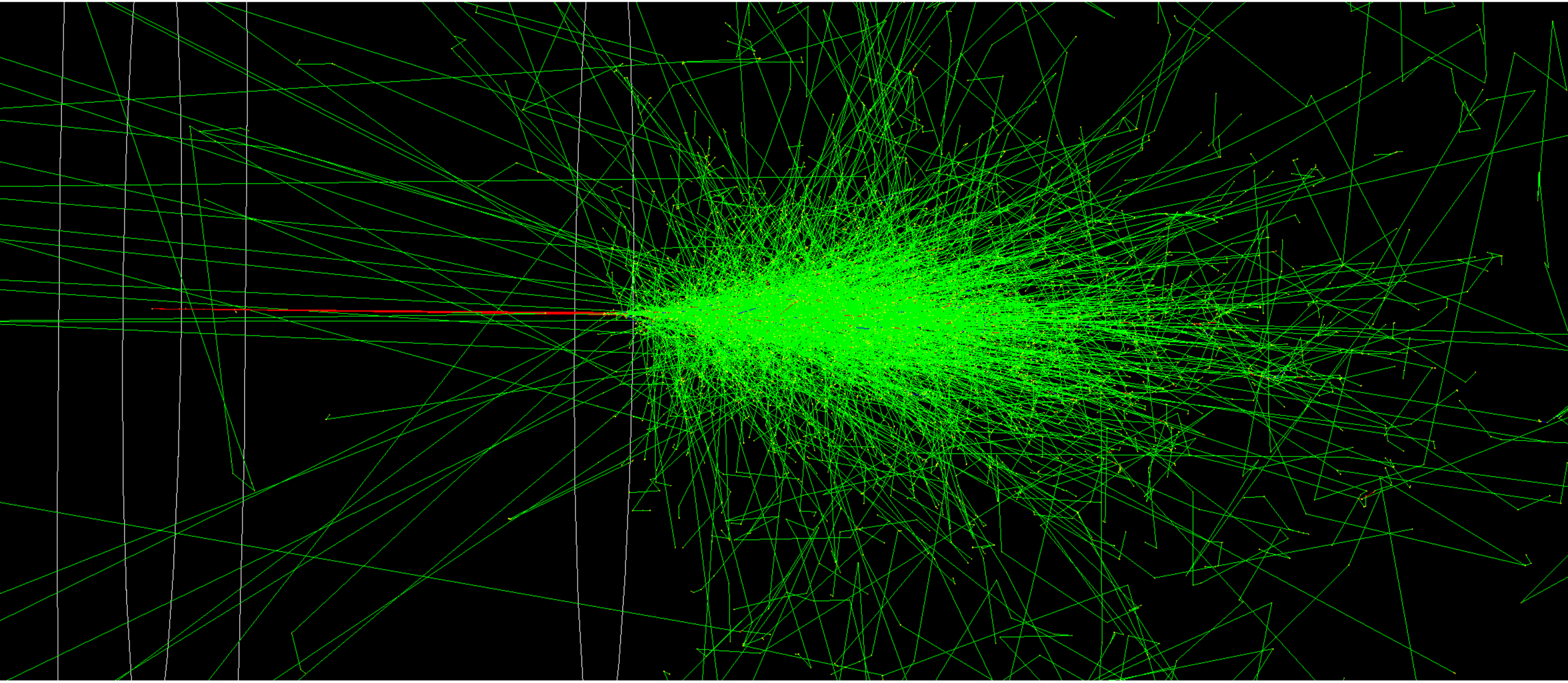
Hole: diameter 5cm, long entrance 5cm



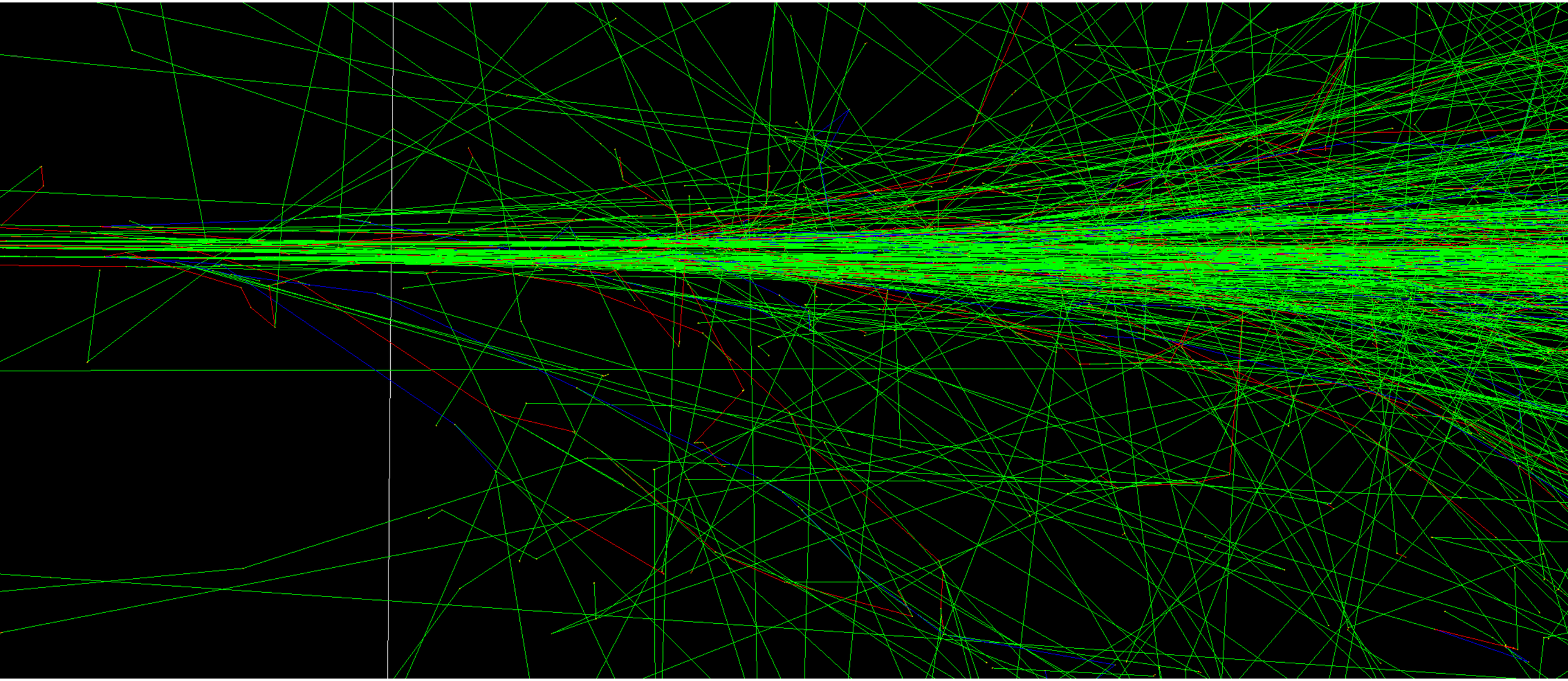
Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-16) cm
Hole: diameter 5cm, long entrance 5cm



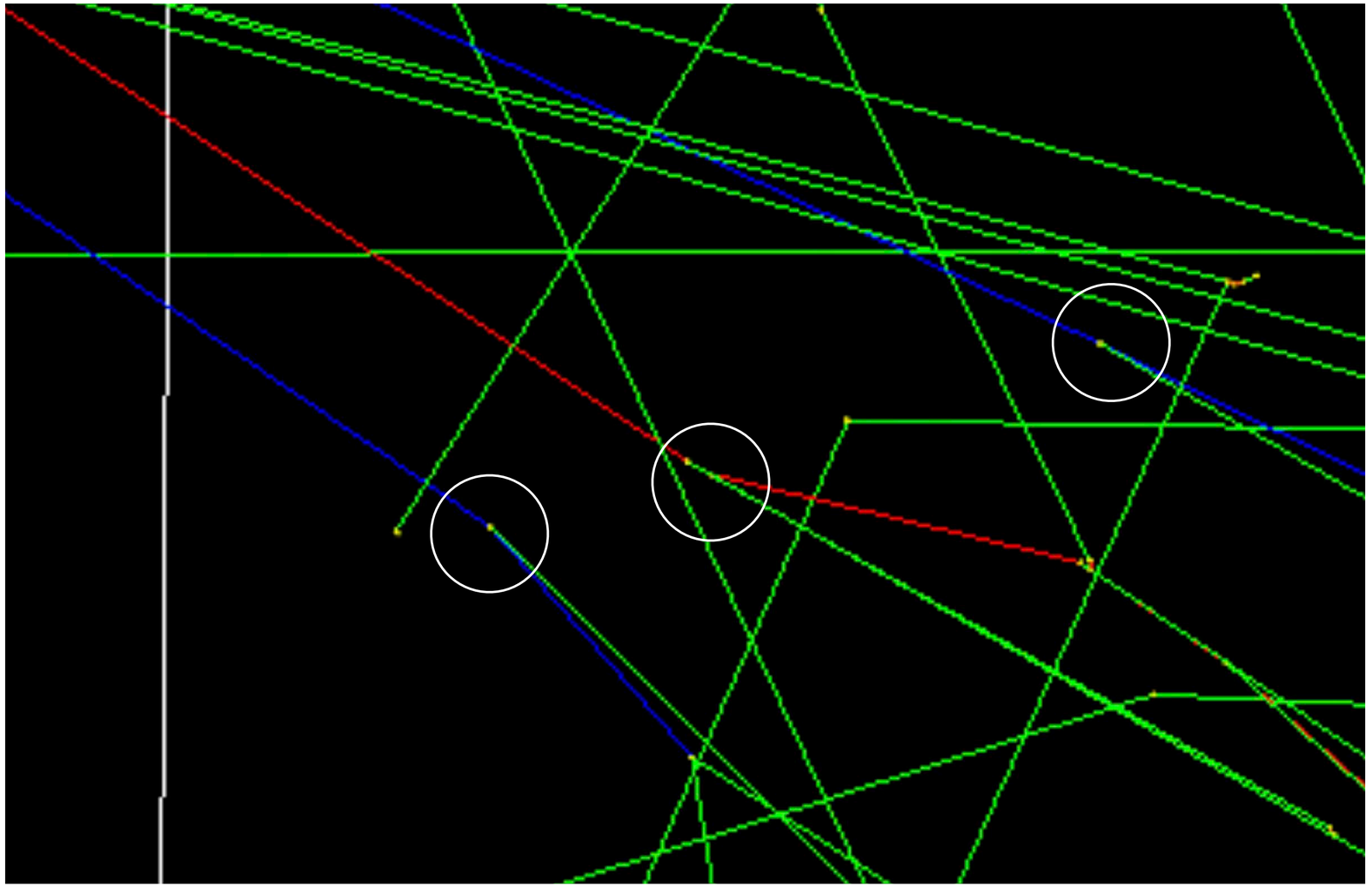
Zoom in the hole



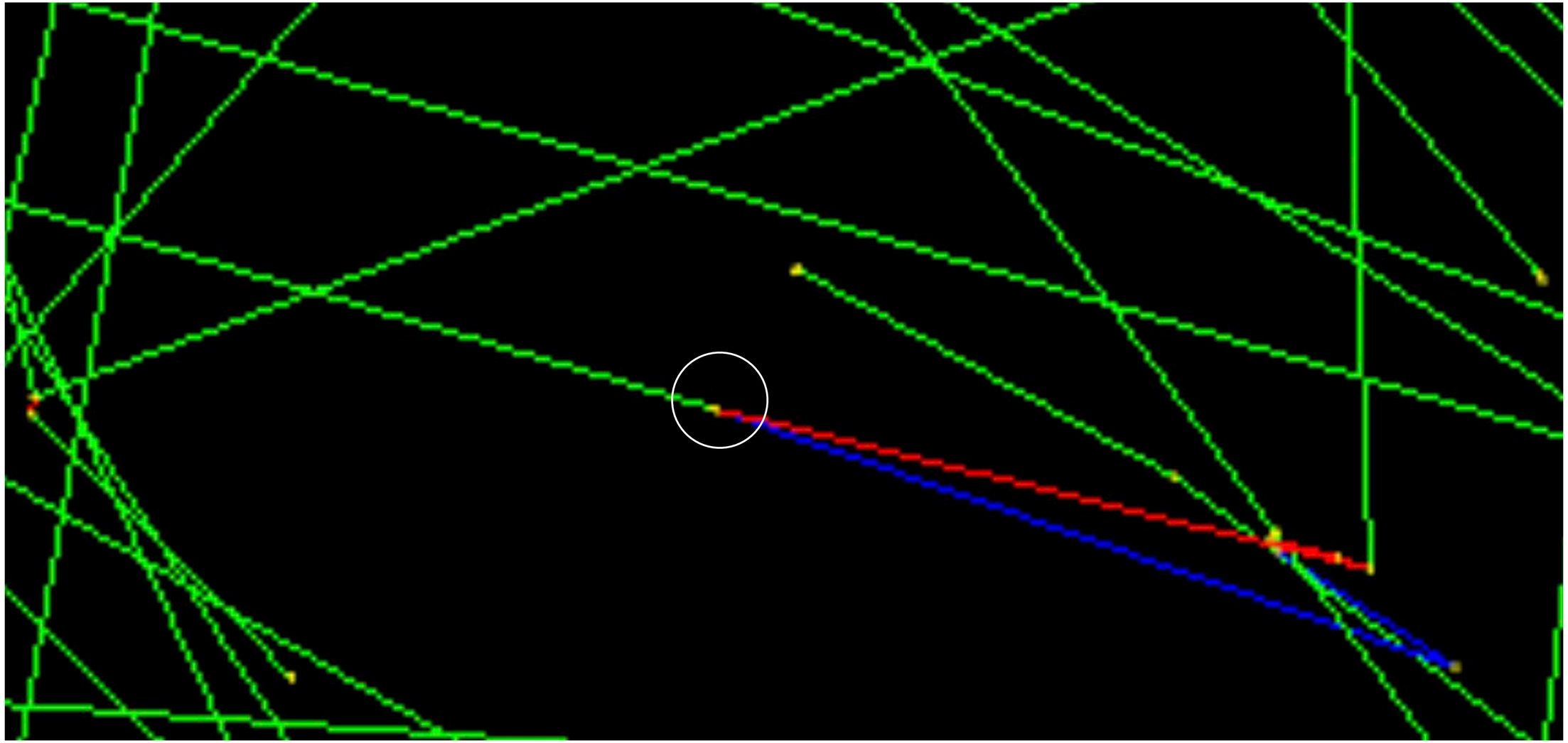
Zoom in the hole



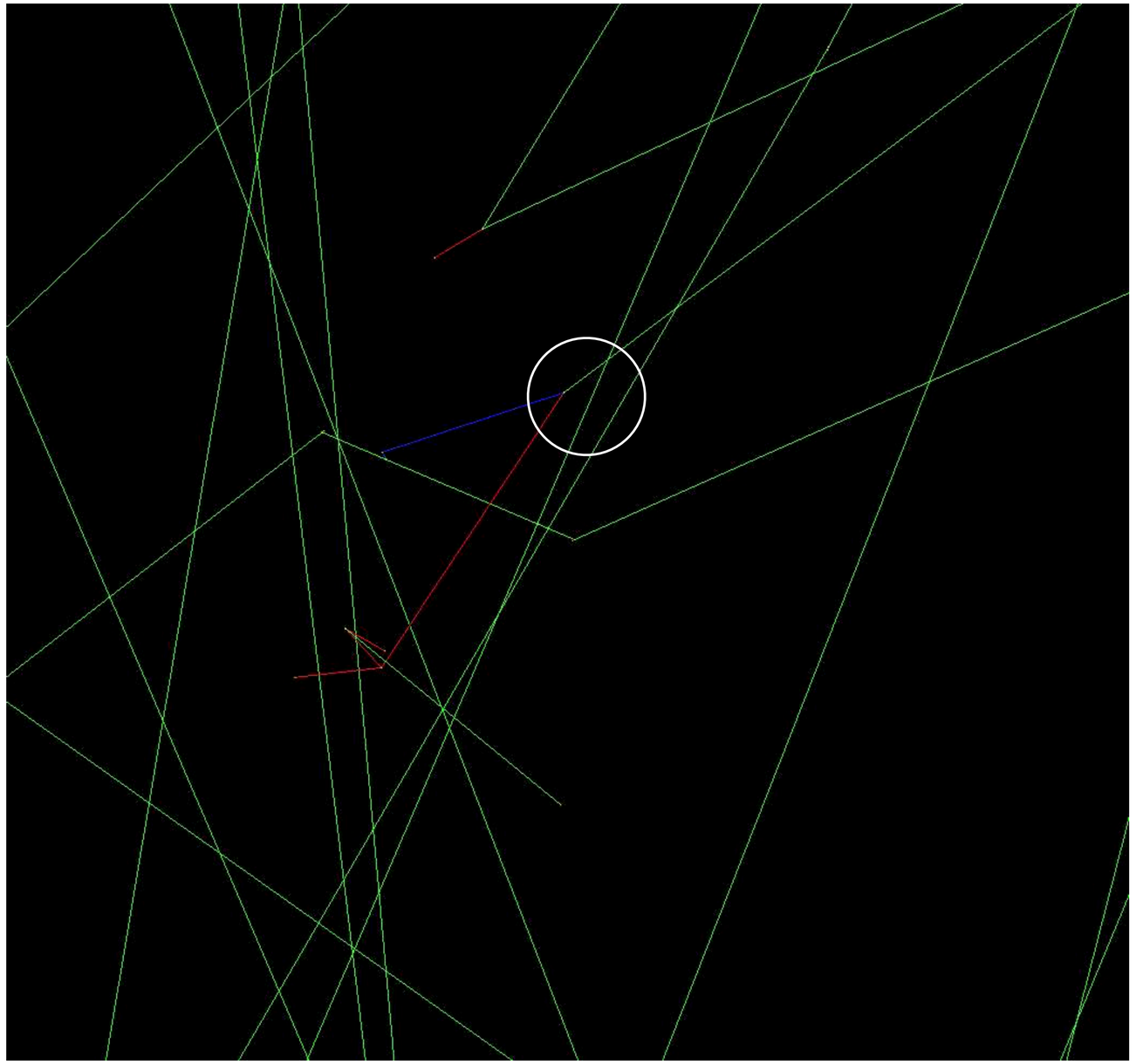
Electrons (Positrons) can accelerate (change direction of motion) by absorbing or emitting a photon.



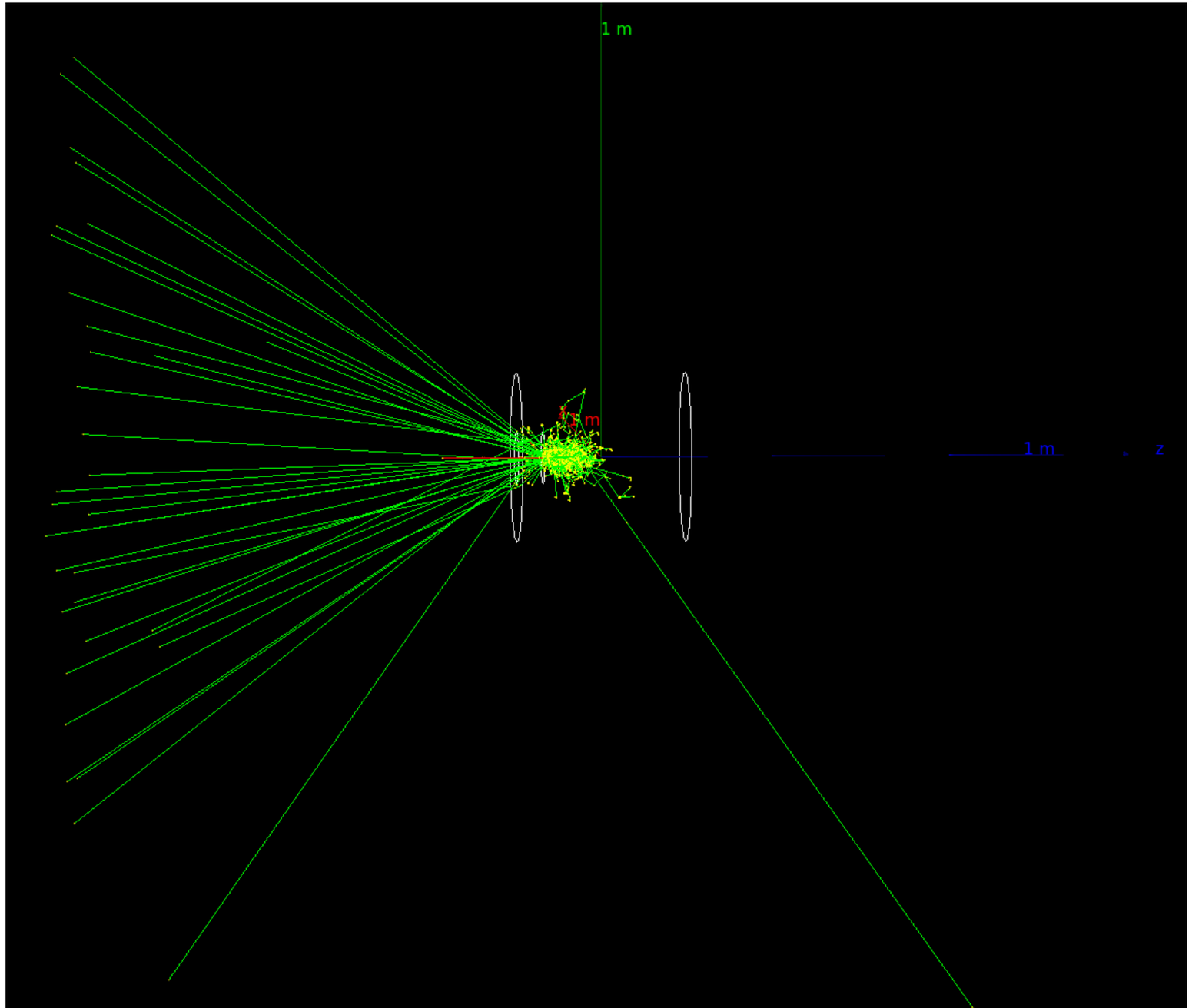
Electron-Positron Pair production from a photon (γ)



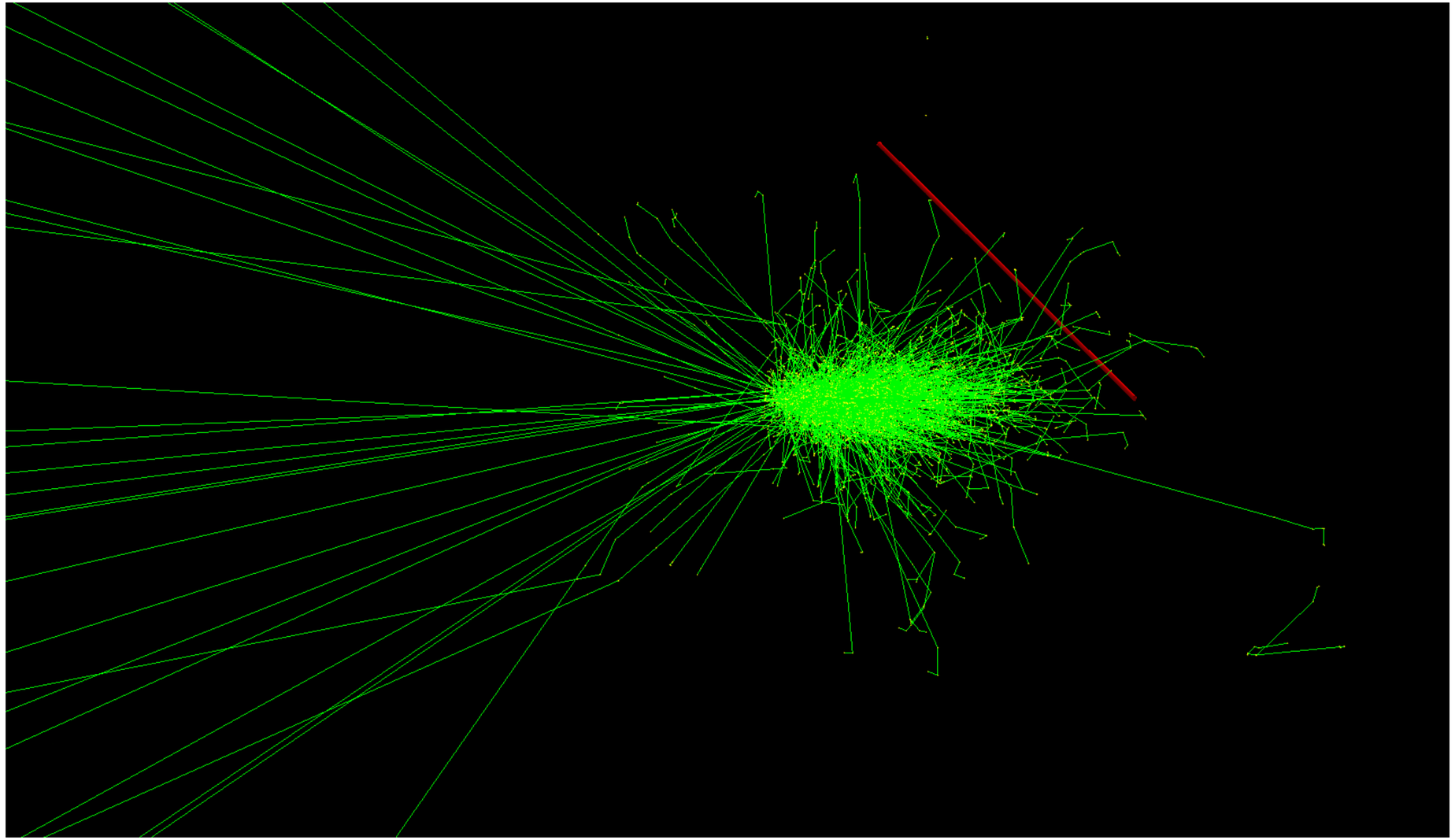
Annihilation of an electron and positron into a photon (γ)



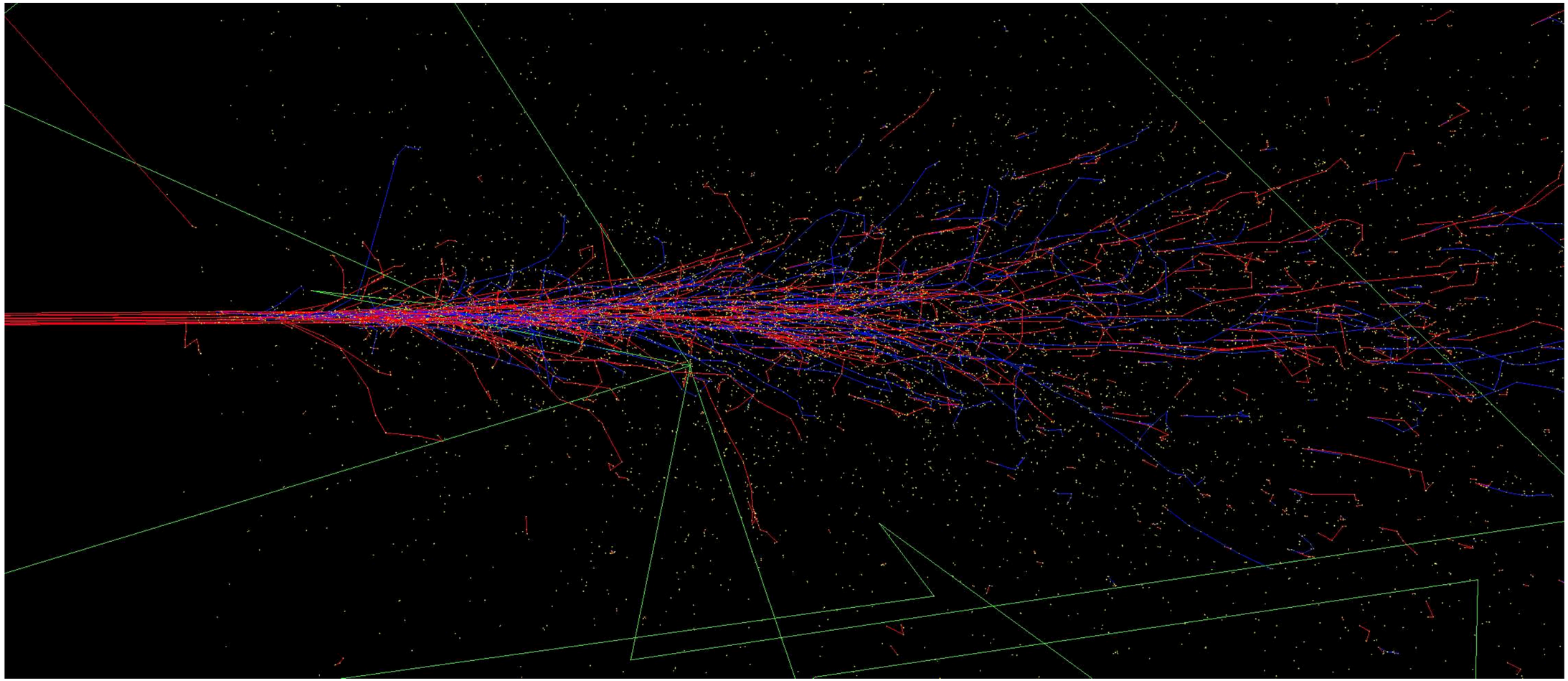
Simulation with electron beam, energy of 1 GeV, and beam position: (0,0,-30) cm
Hole: diameter 2cm, long entrance 5cm



Filtering trajectories: Only allows gammas

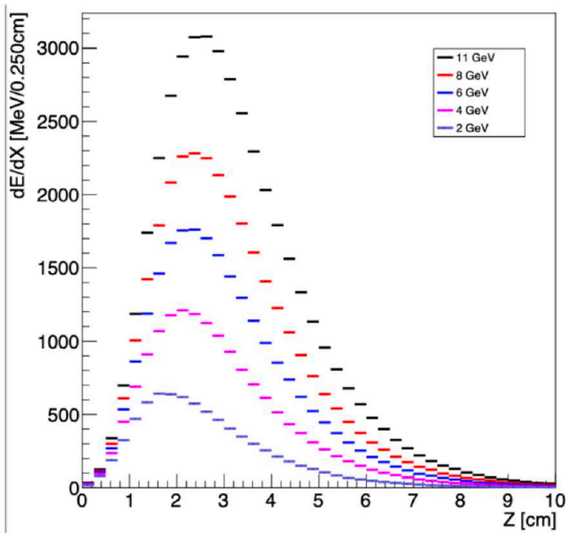


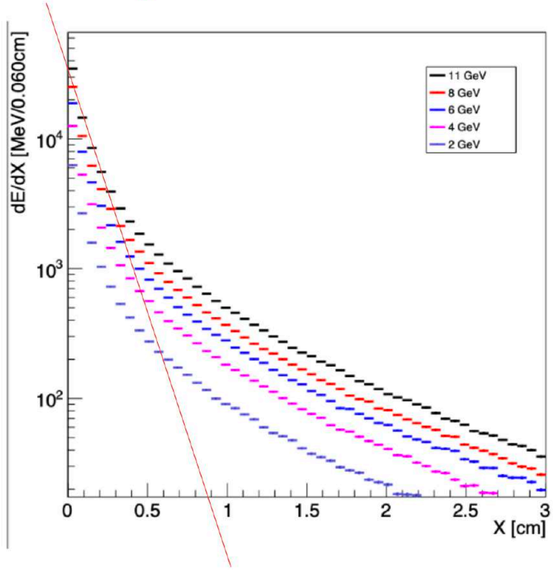
Filtering trajectories: Only allows electrons/positrons

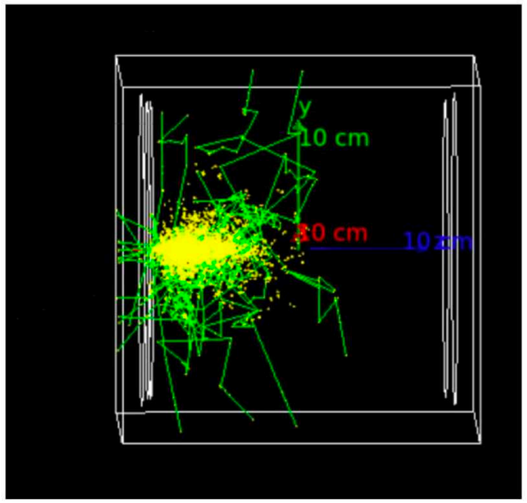


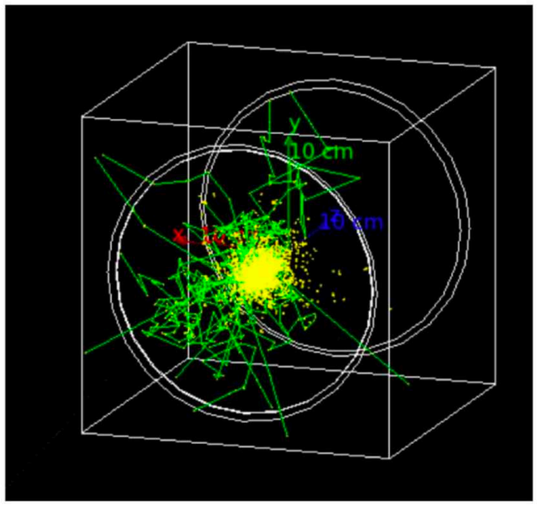
Next step: Reproduction of dE/dx vs Z (cm) and dE/dx vs X(cm) and plots

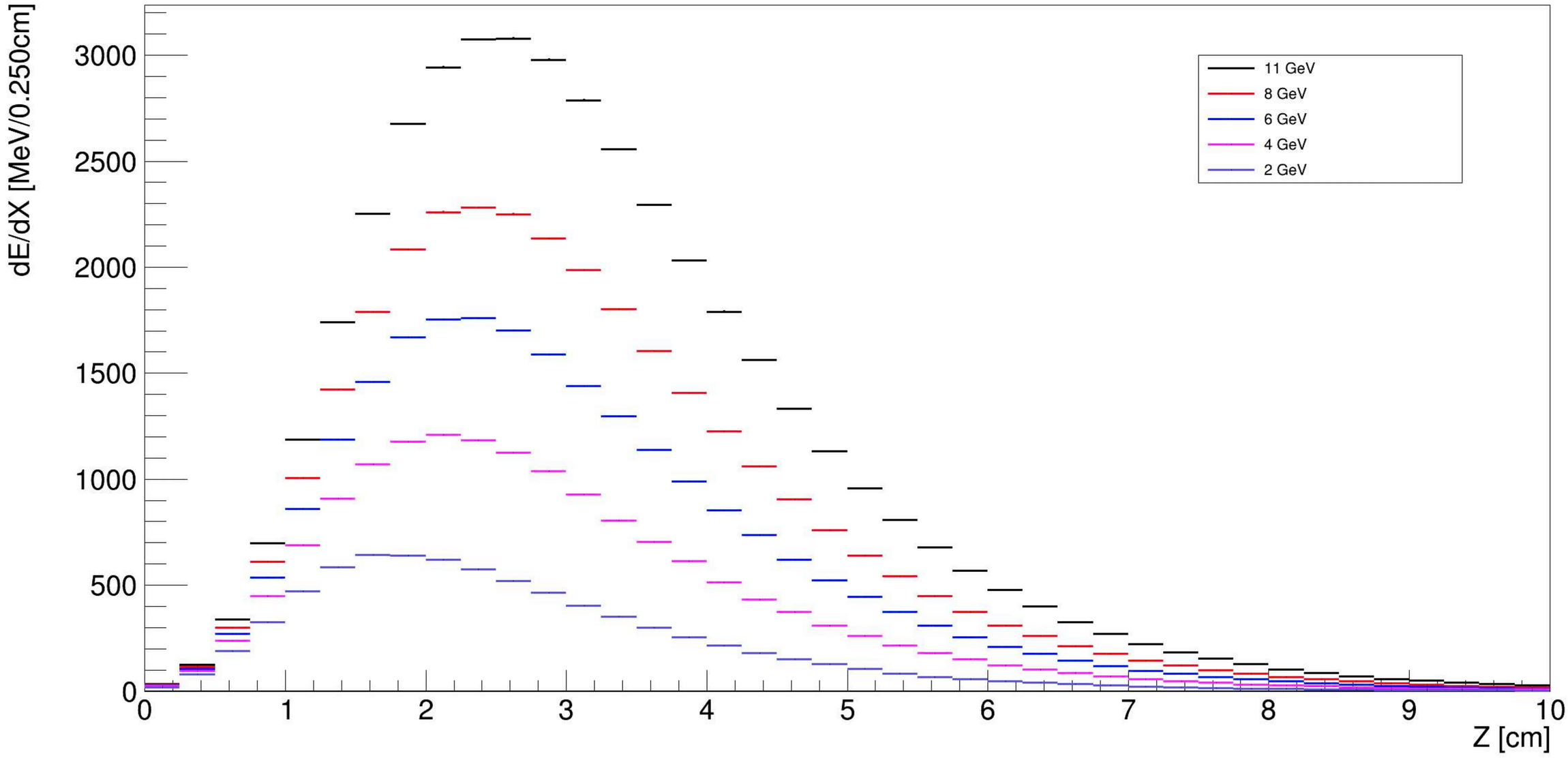
Related G4 Simulations by Nathaly Santiesteban










dE/dX [MeV/0.250cm]
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
10
Z [cm]
11 GeV
8 GeV
6 GeV
4 GeV
2 GeV