Interaction of Charged Particles with Different Materials

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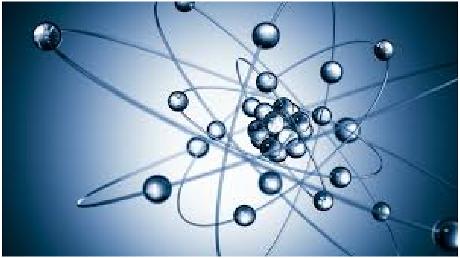
What is a Particle?

- small collection of matter
- described by mass, charge, and type


[1]

[1] [https://www.innovationnewsnetwork.com/wp-content/uploads/2021/02/Success-in-particle-physics-1536x864.jpg]

Project Description

- How do particles interact with different materials?
- Parameters of Experiment:
  - Particles: p, e-, mu+, mu-
  - Materials: Aluminum (Al), Gold (Au), Iron (Fe), Plastic, Uranium (U)
  - Energy Levels: 1,000 MeV, 10,000 MeV, 100,000 MeV

Geant4 Software

- Stands for GEometry ANd Tracking
- Uses Monte Carlo methods
- Simulation of the passage of particles through matter
- Written in C++

Figure: LHC Tunnel

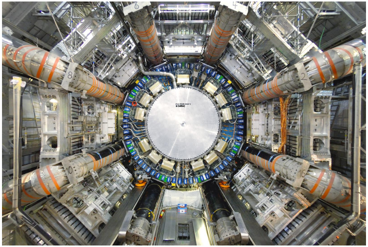
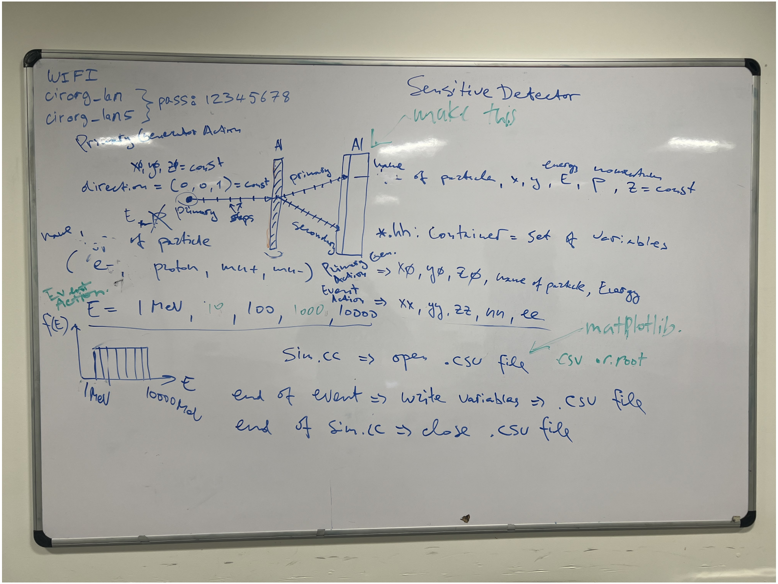


Figure: ATLAS Detector

Visualization of Build

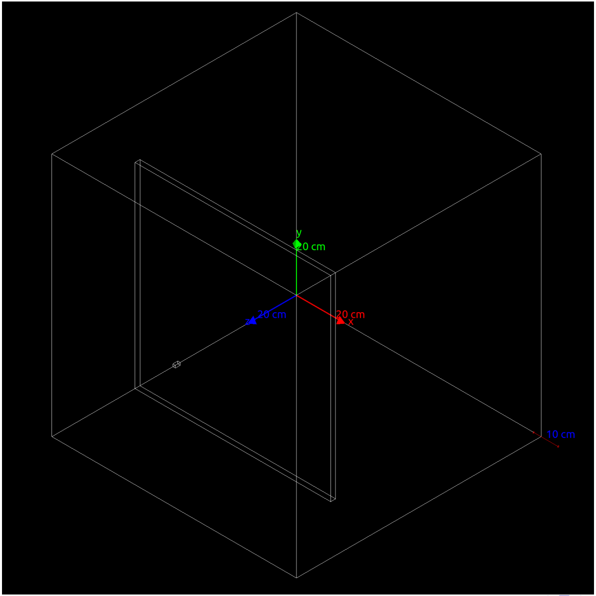


Code for Build

```
// Define World volume
G4Box* solidWorld = new G4Box("World", 0.5*m, 0.5*m, 0.5*m);
G4LogicalVolume* logicWorld = new G4LogicalVolume(solidWorld, world_mat, "World");
G4VPhysicalVolume* physWorld = new G4PVPlacement(0, G4ThreeVector(0., 0., 0.), logicWorld, "World", 0, false, 0, true);

// Define Slab volume
G4Box* solidSlab = new G4Box("Slab", 0.4*m, 0.4*m, 0.01*m);
G4LogicalVolume* logicSlab = new G4LogicalVolume(solidSlab, Gold, /*This is where you define what material you want to use
new G4PVPlacement(0, G4ThreeVector(0., 0., 0.25*m), logicSlab, "Slab", logicWorld, false, 0, true);

// Define Detector volume
G4Box* solidDet = new G4Box("Detector", 0.005*m, 0.005*m, 0.01*m);
G4LogicalVolume* logicDet = new G4LogicalVolume(solidDet, world_mat, "Detector");
new G4PVPlacement(0, G4ThreeVector(0., 0., 0.49*m), logicDet, "Detector", logicWorld, false, 0, true);
```

```
G4ParticleDefinition* particle = particleTable->FindParticle(particleName="e-");
// In the line above where it asks for particleName, define the particle you want to define.
// The ones I used are protons, electrons, and positively and negatively charged muons.
// Electron Input: e-
// Positively Charged Muons: mu+
// Negatively Charged Muons: mu-
// Proton Input: proton

fParticleGun->SetParticleDefinition(particle);
fParticleGun->SetParticleEnergy(100000.0*MeV);
// Define amount of Energy you want to shoot your particle at.
// I used 1000, 10000, and 100000 MeV for my data visualizations.
```

Sketch

- 

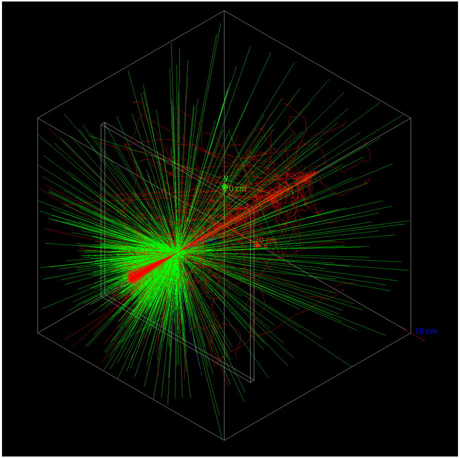
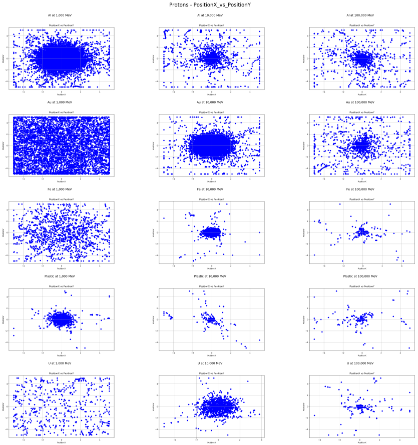
- 

Figure: This is an example visualization of 100,000 negatively charged muons being shot at 1,000 MeV at a Gold Slab.

Data Visualization

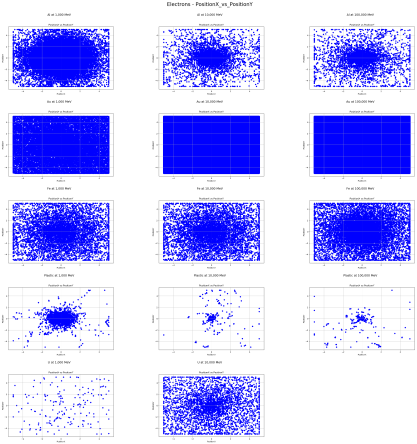
- Data was given in .csv file
- Three Types of Graphs:
  - Position X vs. Position Y
  - # of Particles vs. Radius of Detector Plane
  - Momentum vs. f(Momentum)

Proton (p) - PositionX vs PositionY



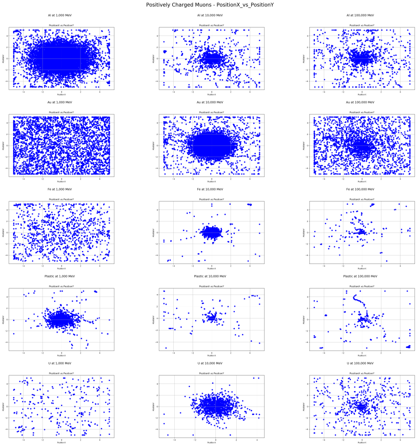
- Starts off as scattered everywhere and then concentrates into one point.

Electron (e-) - PositionX vs PositionY

- 

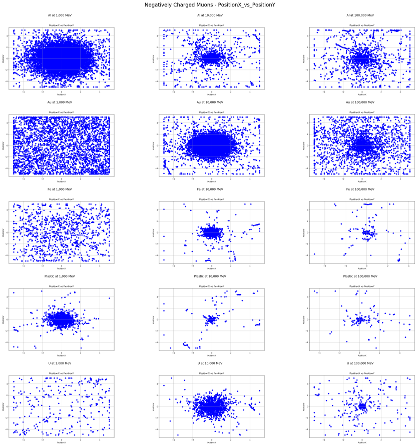
  Electrons just scatter everywhere.

Positively Charged Muons (mu+) - PositionX vs PositionY



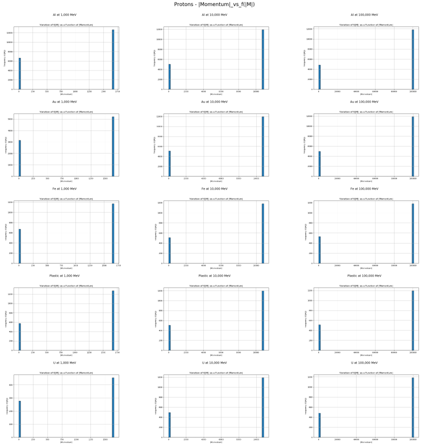
- Starts off as scattered everywhere and then concentrates into one point.

Negatively Charged Muons (mu-) - PositionX vs PositionY



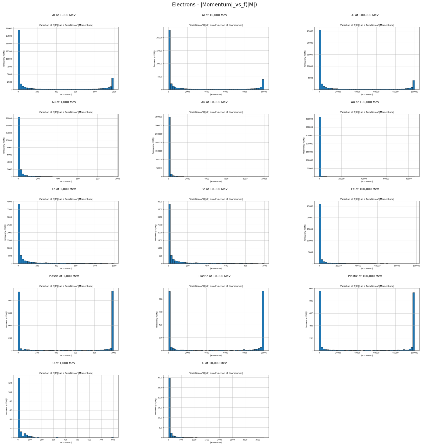
Starts off as scattered everywhere and then concentrates into one point.

Proton (p) - Momentum vs f(Momentum)

- 

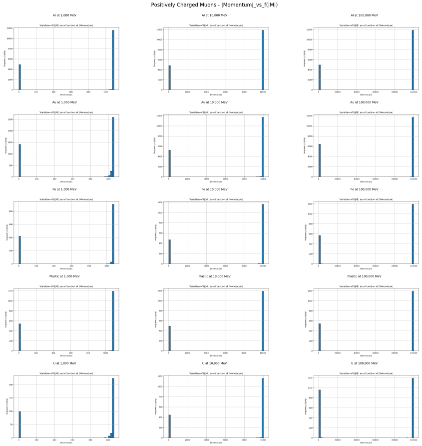
  Momentum is usually very frequent between 1500-1750 MeV/c.

Electron (e-) - Momentum vs f(Momentum)



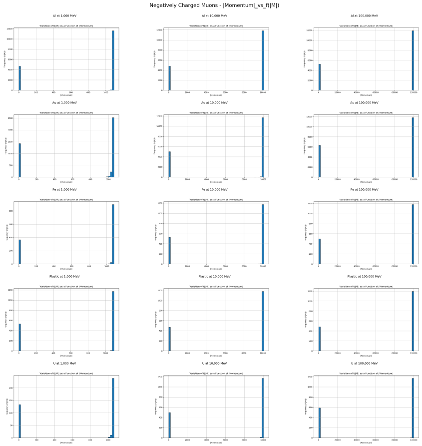
- Momentum depends on which material you are looking at.

Positively Charged Muons (mu+) - Momentum vs f(Momentum)

- 

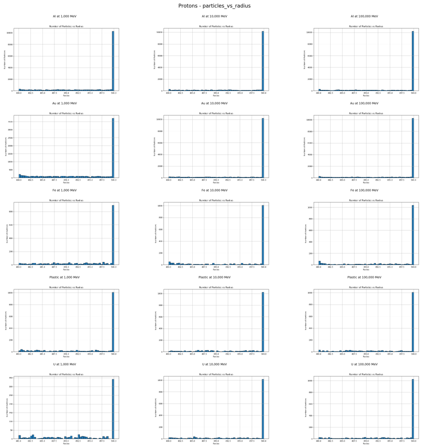
  Momentum is usually very frequent between 1500-1750 MeV/c for 10,000 MeV and 100,000 MeV. It depends what material it is for 1,000 MeV.

Negatively Charged Electrons (mu-) - Momentum vs f(Momentum)

- 

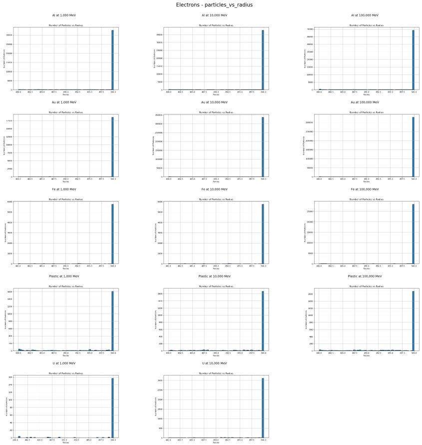
  Same as positively charged muons.

Proton (p) - # of Particles vs Radius of Detector Plane

- 

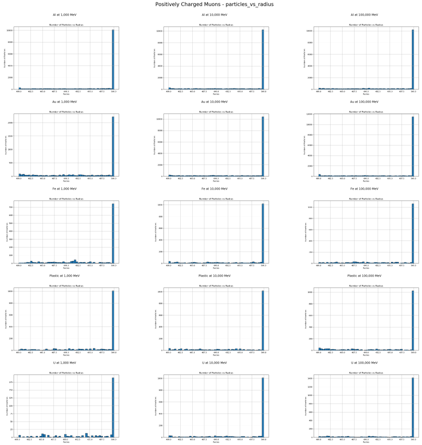
  Constant for 10,000 and 100,000 MeV, but really depends on what material you are using for 1,000 MeV.

Electron (e-) - # of Particles vs Radius of Detector Plane



Very much depends on what material you are using.

Positively Charged Muons (mu+) - # of Particles vs Radius of Detector Plane



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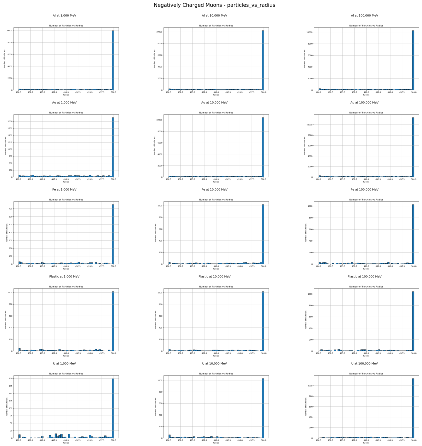
Negatively Charged Electrons (mu-) - # of Particles vs Radius of Detector Plane

- 

  Same idea as previous one.

Challenges

- Not much documentation
- Didn't enable Multi-thread Mode
- Extracting data from simulation

Future Work

- Run it on Multi-threading mode
- More quantitative data analysis
- More volumes
- Try more materials, particles, and energy levels