Simulation of an MPGD application for Homeland Security

Muon Tomography for detection of Nuclear contraband

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Outline

• MPGD for Muon Tomography
  • Muon Tomography to prevent Nuclear material smuggling
  • GEM detectors for Muon Tomography

• Simulation of Muon Tomography Station performances
  • GEANT4 and CRY for MC simulation
  • ROOT and AIDA/JAS for Analysis

• Results and limitations

• Plans for GEMs performances simulation
  • Garfield & Maxwell with G4
Muon tomography to prevent nuclear material contraband

• Highly Enriched Uranium (HEU) or highly radioactive material could be smuggled across border for terrorist attack

• Various detection techniques in place or under study to prevent smuggling and contraband of such dangerous materials across borders

• Muon Tomography based on cosmic ray muons is one promising detection technique
Muon Tomography Station (MTS) based on cosmic ray muons

- Multiple Coulomb scattering is $\sim$ prop. to $Z$ and could discriminate materials by $Z$

$$\theta = \frac{13.6 \text{MeV}}{\beta cp} \sqrt{x/X_0} [1 + 0.038 \ln(x/X_0)] \frac{1}{X_0} \times \frac{1}{Z} (Z + 1)$$

- Cosmic ray muons: natural radiation source or no beam needed

- Muons highly penetrating; potential for sensing high-Z material shielded by Fe or Pb

Gas Electron Multipliers (GEMs) as tracking detectors for the MTS

- Advantages:
  - Excellent 2D spatial resolution $\Rightarrow$ precise scattering angle measurement
  - Thin detectors layer $\Rightarrow$ low material $\Rightarrow$ low scattering with the detectors
  - Compact

- Challenges:
  - Building large size detectors
  - Maintaining the excellent resolution for large size detectors
  - Cost of the readout and electronics
Simulation of the performances of Muon Tomography Station

- We use CRY to generate the cosmic ray muons
  - cosmic ray package developed at Laurence Livermore NL
  - Package interfaced with GEANT4
- We GEANT4 to simulate the interaction with matter
  - Physics of muons interaction with matter
  - Tracking of the muons with their recorded position measurement by the GEM detectors
- ROOT and AIDA/JAS for analysis and plotting of the results
Simulation of the performances of Muon Tomography Station

- **G4 simulation Geometry for the MTS:**
  - 4 set of 3 Detectors planes (top, bottom laterals)
  - From 1 to up to 10 targets of different materials from low Z Al to high Z U
  - CRY for cosmic muons as primary particles
  - We collect the incoming and outgoing muon position recorded at the detectors level

- **Reconstruction of the muon's track**
  - Point Of Closest Approach (POCA) algorithm is used to get the interaction point of each muon
  - The scattering angle of the muon calculated
  - The MTS volume is divided in voxels (10 cm); each voxel displays the mean scattering angle of all the POCA points it contains. The value of the angle is then a good approximation of the z value of the material

\[
\theta = \cos^{-1} \left( \frac{\vec{a} \cdot \vec{b}}{|a| |b|} \right)
\]
Acceptance and coverage of the MTS

MT station type

Top & bottom detectors only

Top, bottom & side detectors

3% of the volume around the center with 80% of voxel with max muons

18% of the volume around the center with 80% of voxel with max muons