Simulation of an MPGD application for Homeland Security

Muon Tomography for detection of Nuclear contraband

Kondo Gnanvo,
M. Hohlmann, P. Ford, J. Helsby, R. Hoch, D. Mitra

Florida Institute of Technology

Outline

- MPGD for Muon Tomography
  - Muon Tomography to prevent Nuclear material smuggling
  - GEM detectors for Muon Tomography
- Simulation of Muon Tomography Station performaces
  - 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 understudy to prevent smuggling and contraband of such dangerous materials across borders
- Muon Tomography based on cosmic ray muons is one promising detection technique

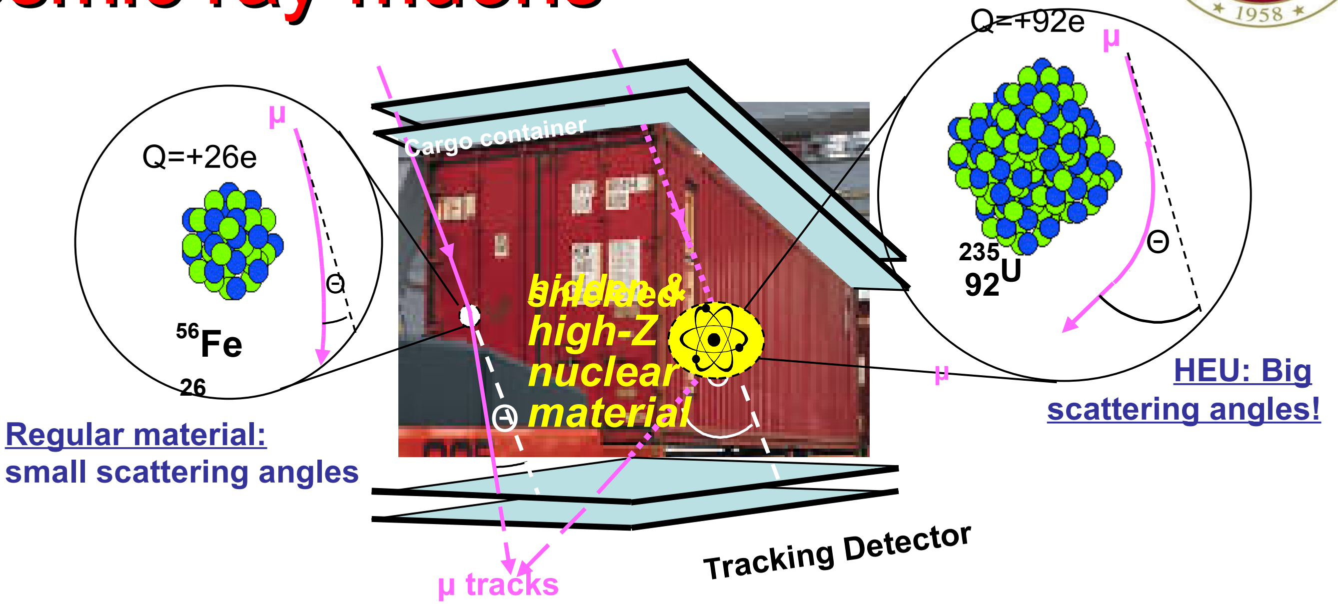
Muon Tomography Station (MTS) based on cosmic ray muons

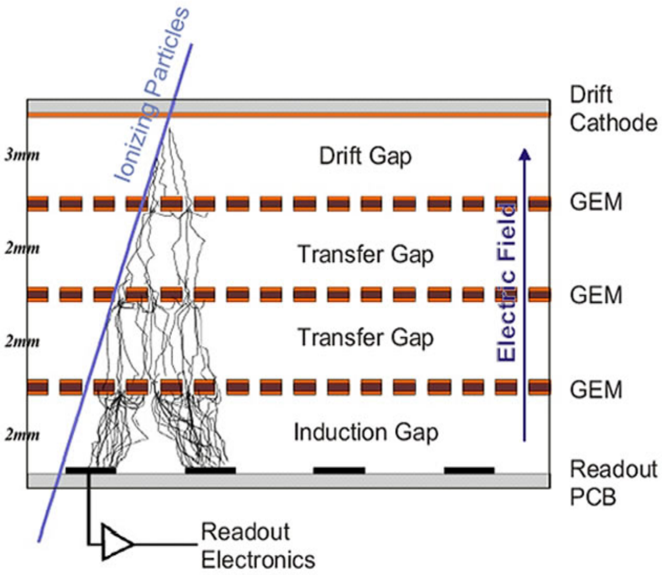
- Multiple Coulomb scattering is ~ prop. to Z and could discriminate materials by Z

$$\theta_0 = \frac{13.6\,\text{MeV}}{\beta cp}\sqrt{\frac{x}{X_0}}[1+0.038\ln(x/X_0)] \text{ with } \frac{1}{X_0} \propto Z(Z+1)$$

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

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





F. Sauli

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

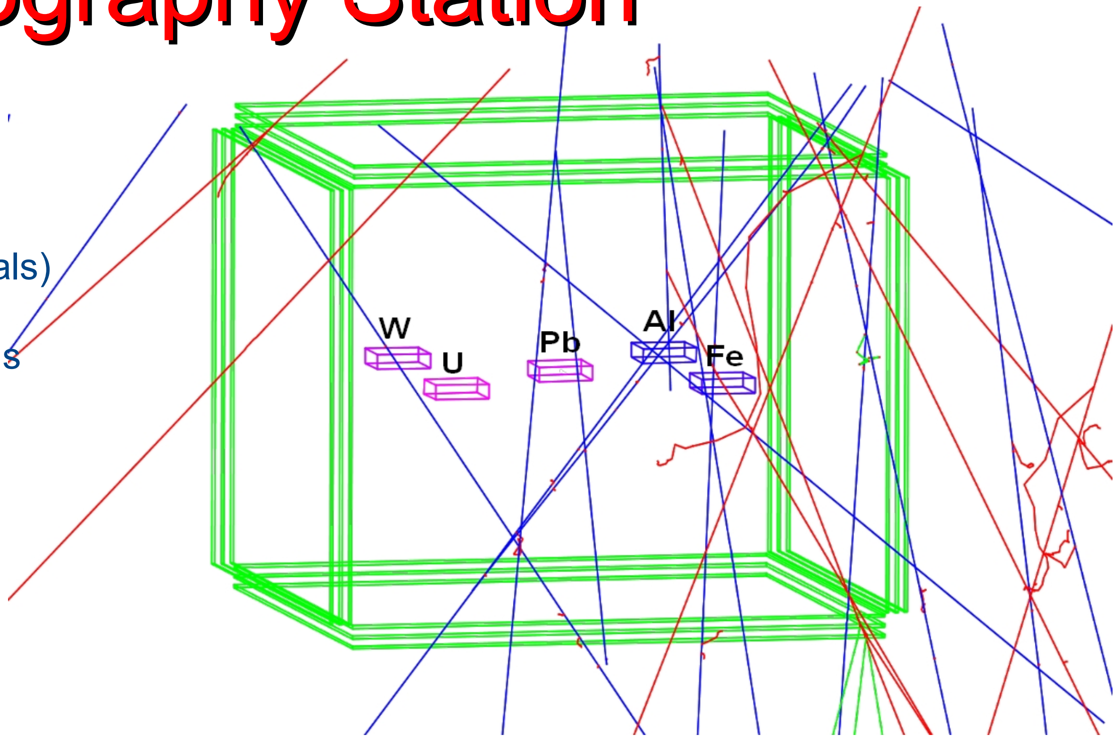
- Advantages:
  - Excellent 2D spatial resolution =>precise scattering angle measurement
  - Thin detectors layer => low material => low scattering with the detectors
  - Compact
- Challenges:
  - Building large size detectors
  - Maintaining the excellent resolution for large size detectors
  - Cost of the readout and electronics

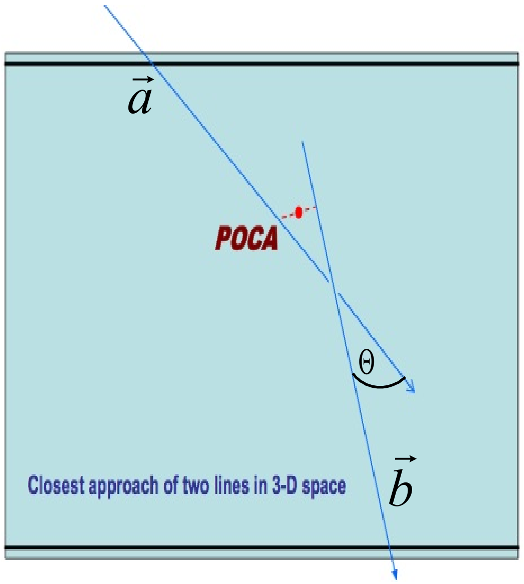
Simulation of the performances of Muon Tomography Station

- We use CRY to generate the cosmic ray muons
  - cosmic ray package developped 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





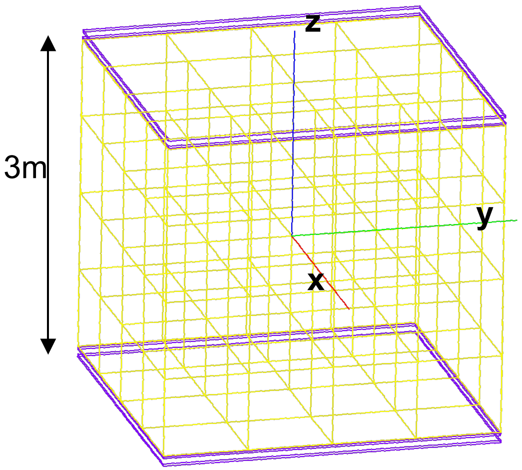
$$\theta = \cos^{-1}\left(\frac{\vec{a}\cdot\vec{b}}{|a||b|}\right)$$

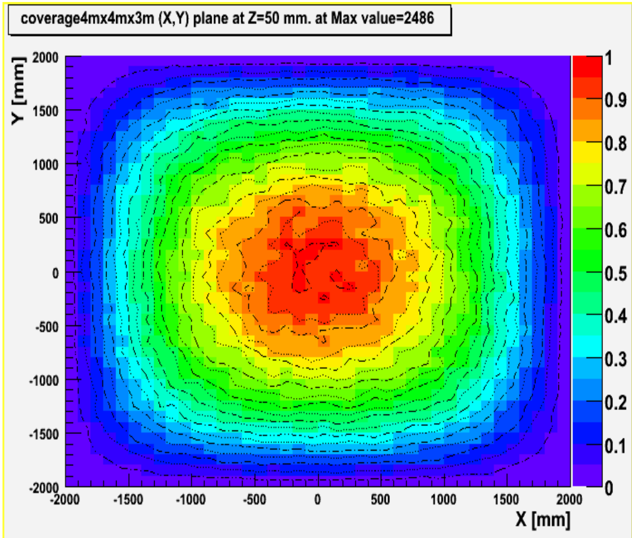
- Reconstruction of the muon's track
  - Point Of Closest Approach (POCA) algorithm is used to get the interaction point of each muon
  - The scattering angle of the muon calculated
  - The MTS volume is divided in voxels (10 cm); each voxel displays the mean scattering angle of all the POCA points it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

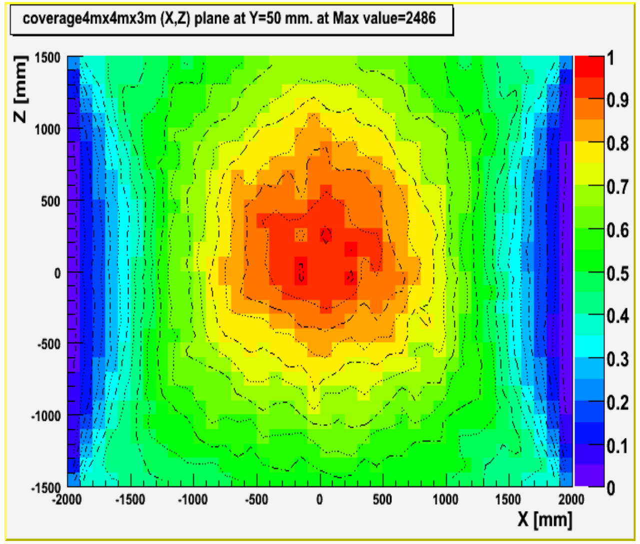
Acceptance and coverage of the MTS

MT station type | **Top View (x-y plane)** | **Side View (x-z plane)**

Top & bottom detectors only

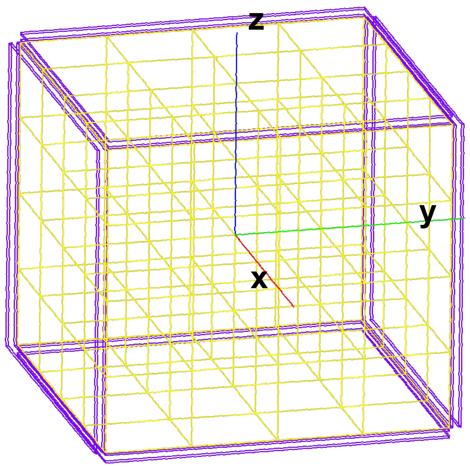


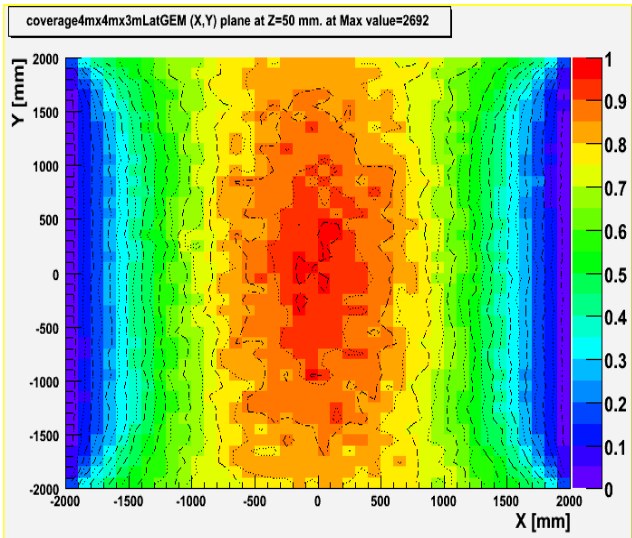


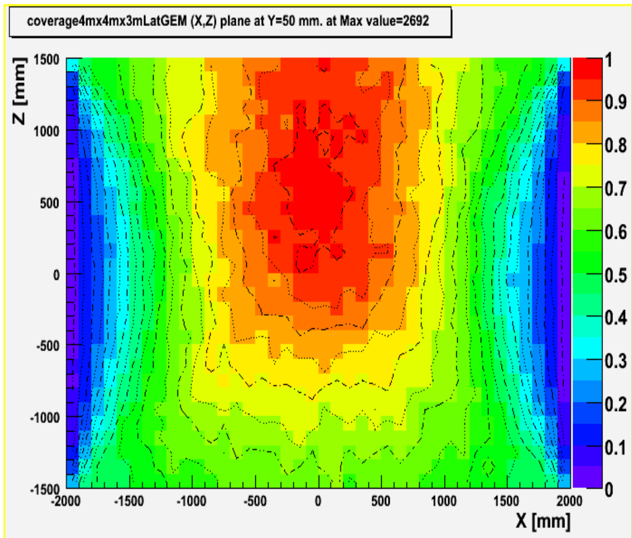


3% of the volume around the center with 80% of voxel with max muons

Top, bottom & side detectors







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