Imaging with 1 ft^3 Muon Tomography Station and Analysis of Future Station Geometries

Nathan Mertins, Michael Staib, William Bittner

Faculty Advisor: Dr. Marcus Hohlmann, Dept of Physics & Space Sciences, Florida Institute of Technology

Introduction

Muon tomography uses multiple Coulomb scattering of cosmic-ray muons in high-Z (atomic number) materials to image them. Scattering angle increases with a material's Z-content, allowing us to distinguish between two materials such as iron and uranium. In this regard, muon tomography naturally lends itself to the detection of nuclear contraband, even in the case where radiation shielding is present [1].

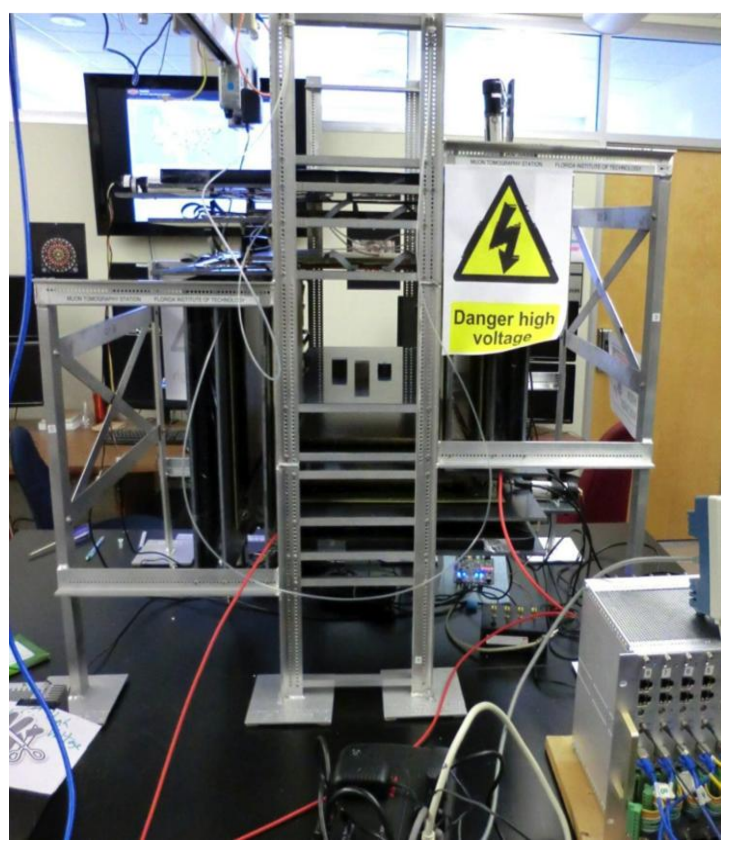

Figure 1: FIT's muon tomography station.

Methodology

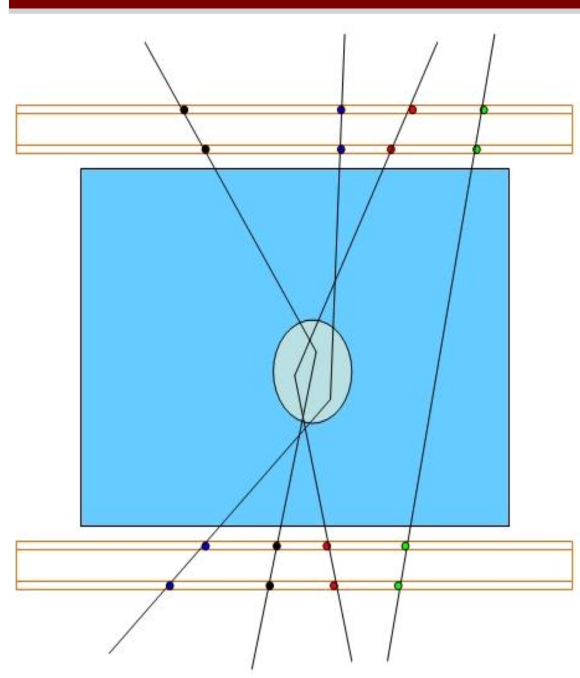

Figure 2: The muon's coordinates in the detector planes are recorded and incoming and outgoing tracks are fitted to the points. From these tracks we can calculate the amount by which the muon was scattered as well as the point where scattering occurred [2].

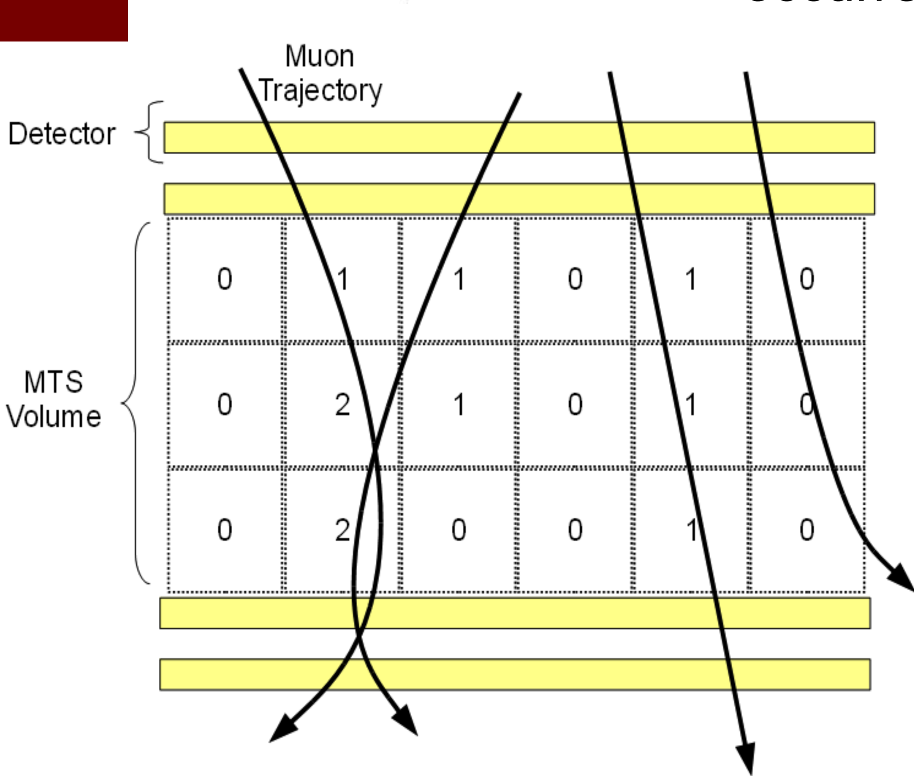

Figure 3: Coverage is a map of muon acceptance for a given detector geometry and is used to compare different station geometries. Higher coverage means faster imaging and better resolution.

Results

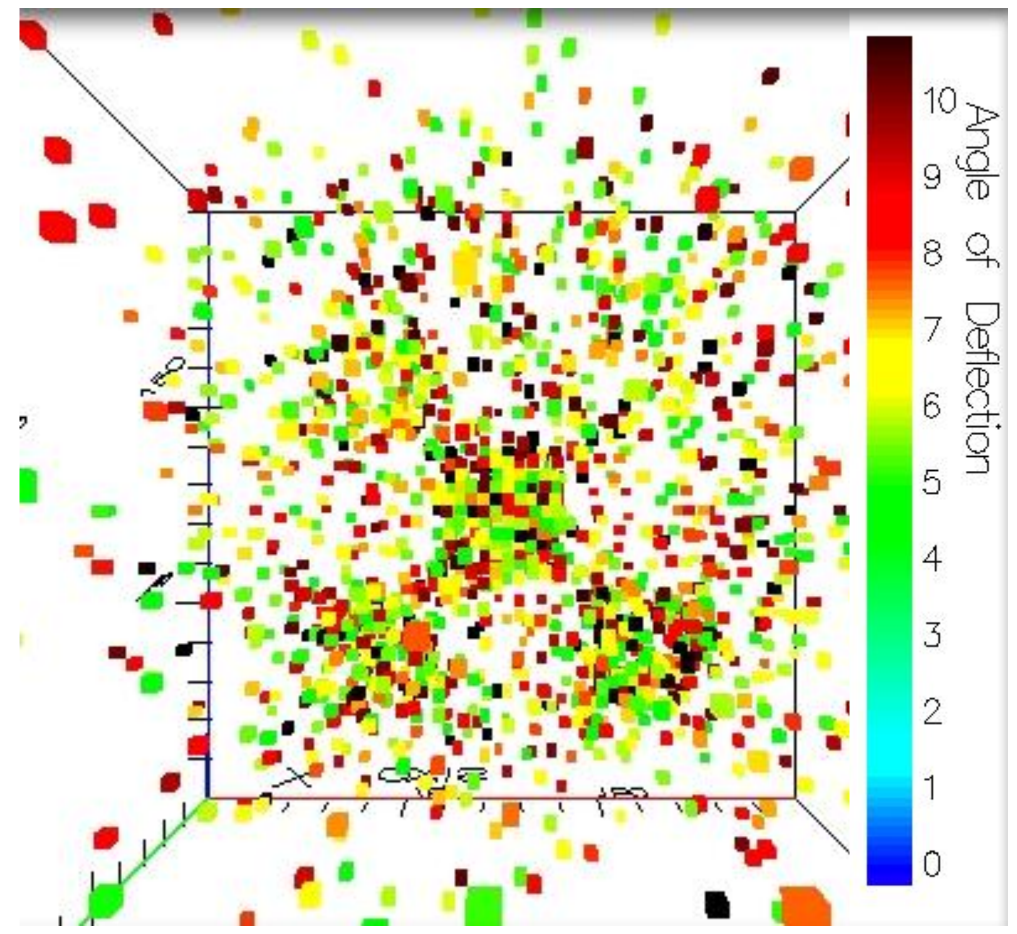

Figure 4: Reconstructed image of 5 targets from data taken with current station. Counter-clockwise the top-right: iron, tin, lead, tungsten, and depleted uranium in the center.

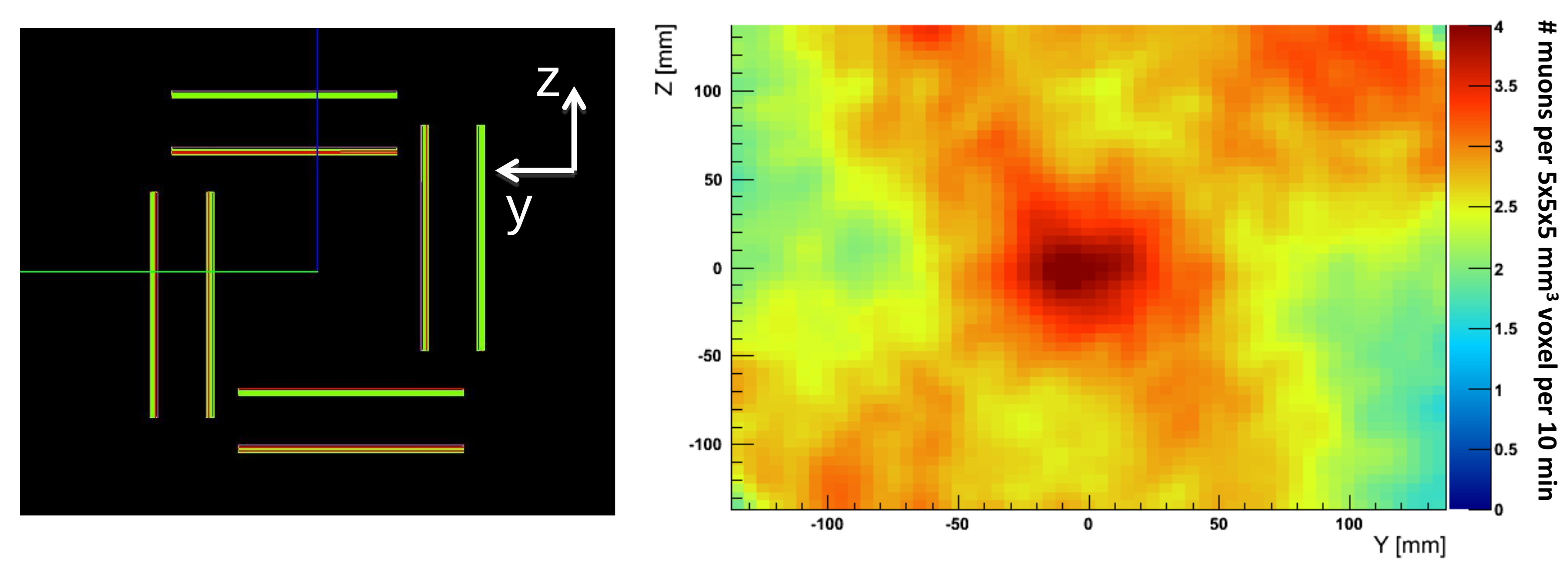

Figure 5: Simulation of the current station (left) and its characteristic coverage map (right). Highest coverage is focused in the center of the volume and along the top and bottom detectors.

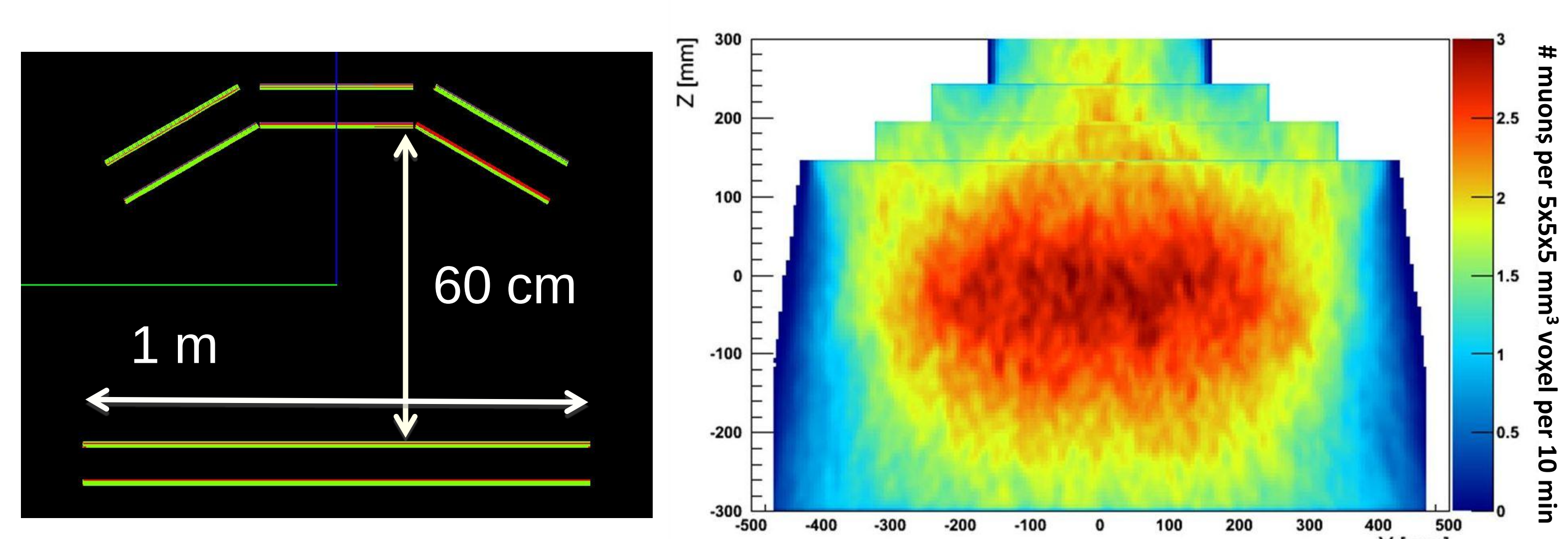

Figure 6: Simulation of a new geometry proposed for the next station (left) and its characteristic coverage map (right). The geometry expands the imaging volume using largely the same detectors used in the current station.

Conclusions

Our station can successfully image targets of different materials. It is also possible to differentiate between high-Z and low-Z objects. These results demonstrate muon tomography's promise in the detection of nuclear contraband from being smuggled into the country. My investigation of possible geometries for future stations has shown that we should be able to significantly increase our imaging volume using mainly our current detectors.

Future Work

- Improve reconstruction algorithm to get clearer images
- Expand analysis code to allow for more novel station geometries
- Establish limit of current station's imaging capabilities for shielded-target scenarios
- Continue to fine-tune large station geometries to improve coverage

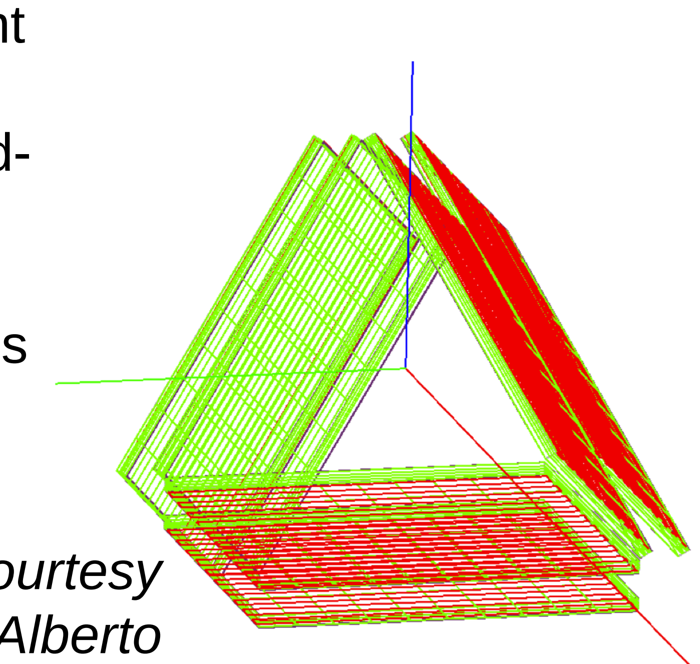

Figure 7: Image courtesy of Joao Alberto

Acknowledgements

I'd like to thank Ben Locke who wrote much of the simulation and analysis code used here.

References

[1] L.J. Schultz, "Cosmic ray muon radiography," Ph.D. thesis, Dept. Elect. Comput. Eng., Portland State Univ., Portland, OR, 2003

[2] K. Gnanvo, et al., "Detection and Imaging of High-Z Materials with a Muon Tomography Station Using GEM Detectors," Proc. of IEEE Nucl. Sci. Symp. 2010, Knoxville, Tennessee

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