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Imaging with, spatial resolution of, and plans for upgrading a minimal prototype muon tomography station

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Outline

- **Motivation**
- **Background**
  - Concept
  - Origin
  - Reconstruction algorithm
  - Voxelization
- **Prototype**
  - Design
  - Imaging real targets
  - Spatial resolution of detectors
- **Upgrade**
  - Design
  - Monte Carlo simulation

Motivation

Nuclear contraband is smuggled across borders.

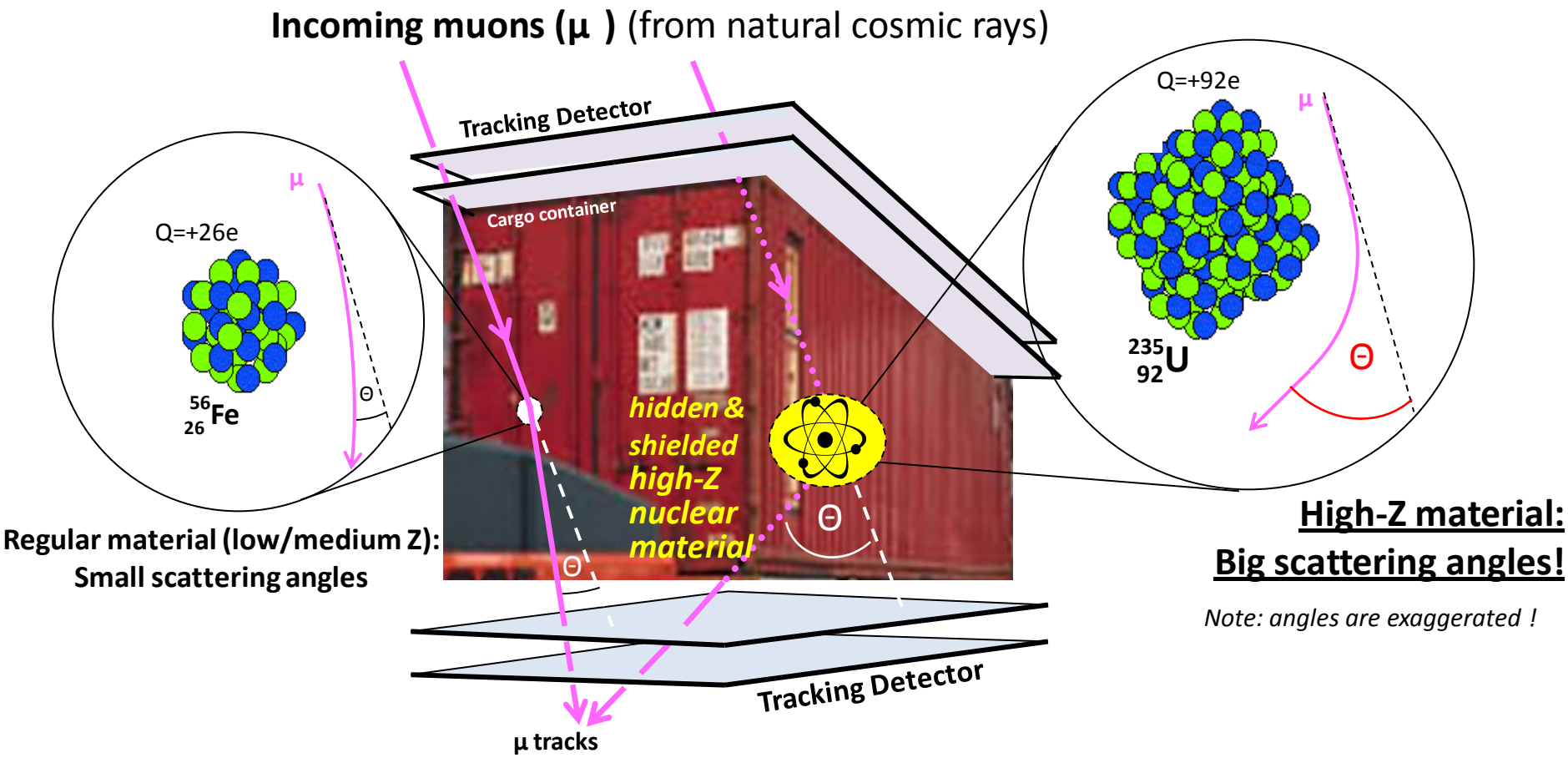
Current radiation scanners use gamma and neutron emissions to detect nuclear contraband.

About 800 radiation portal monitors in the U.S.

Only ***3.25 mm thick lead shielding*** needed to absorb 99% of gammas emitted by ^{235}U.

How can we detect shielded nuclear contraband?

Muon Tomography Concept

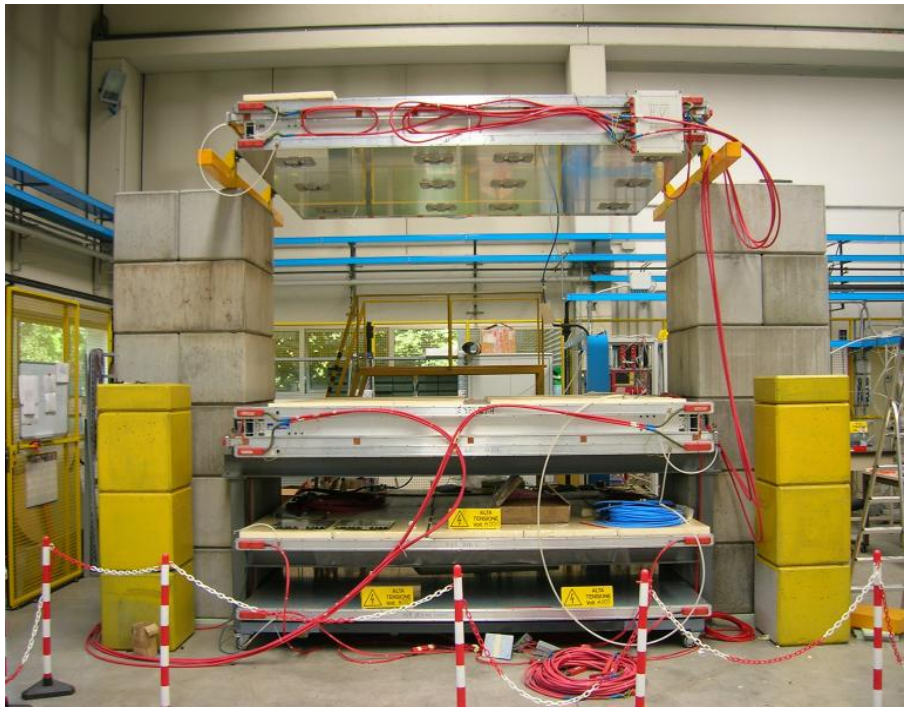


Idea: Use <u>multiple scattering of charged particles in matter</u> to detect high-Z material

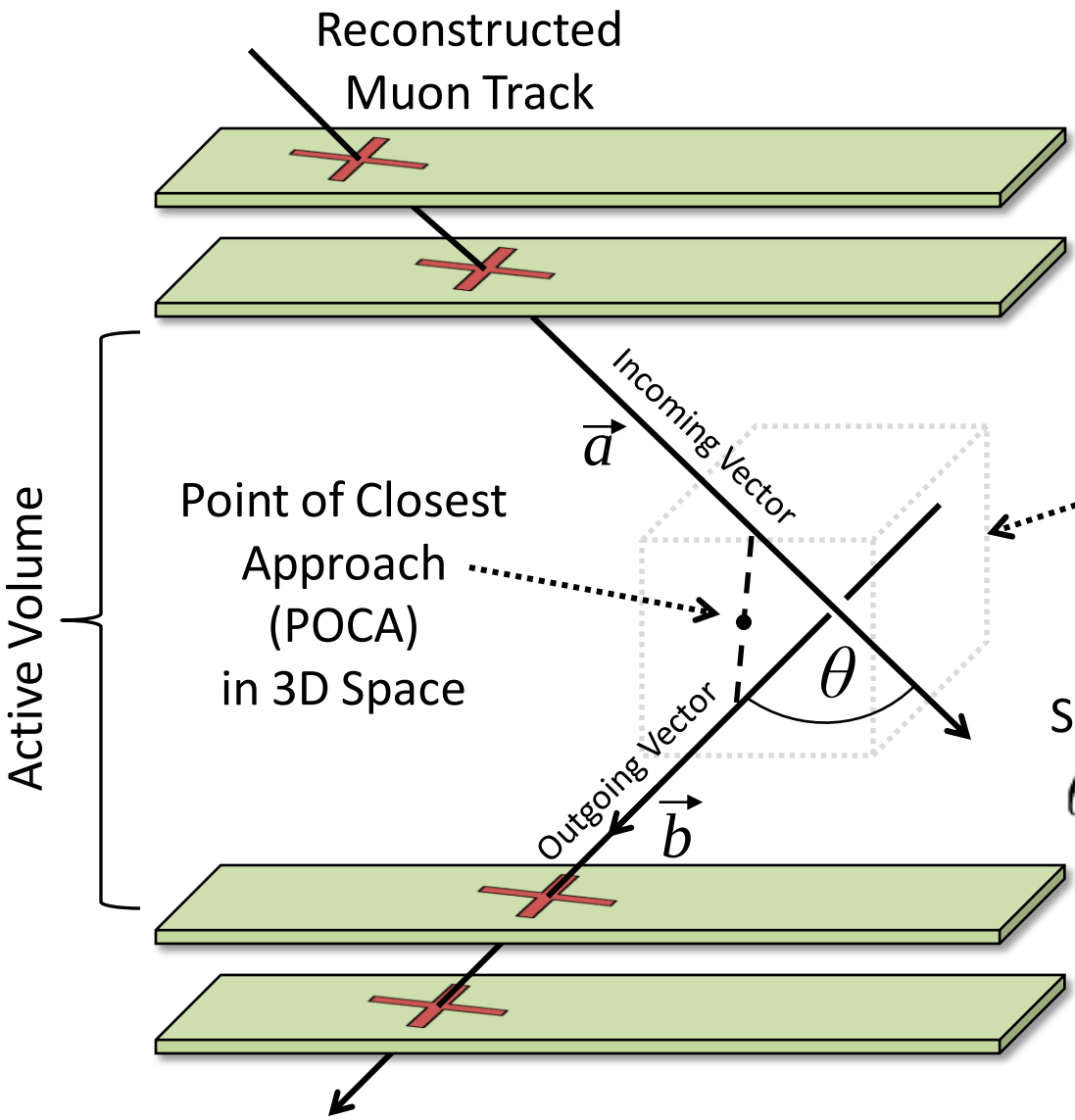
Origin of Muon Tomography

Original idea from Los Alamos (2003): Muon Tomography with Drift Tubes

INFN Padova, Pavia & Genova: Muon Tomography with spare CMS Muon Barrel Chambers (Drift Tubes)



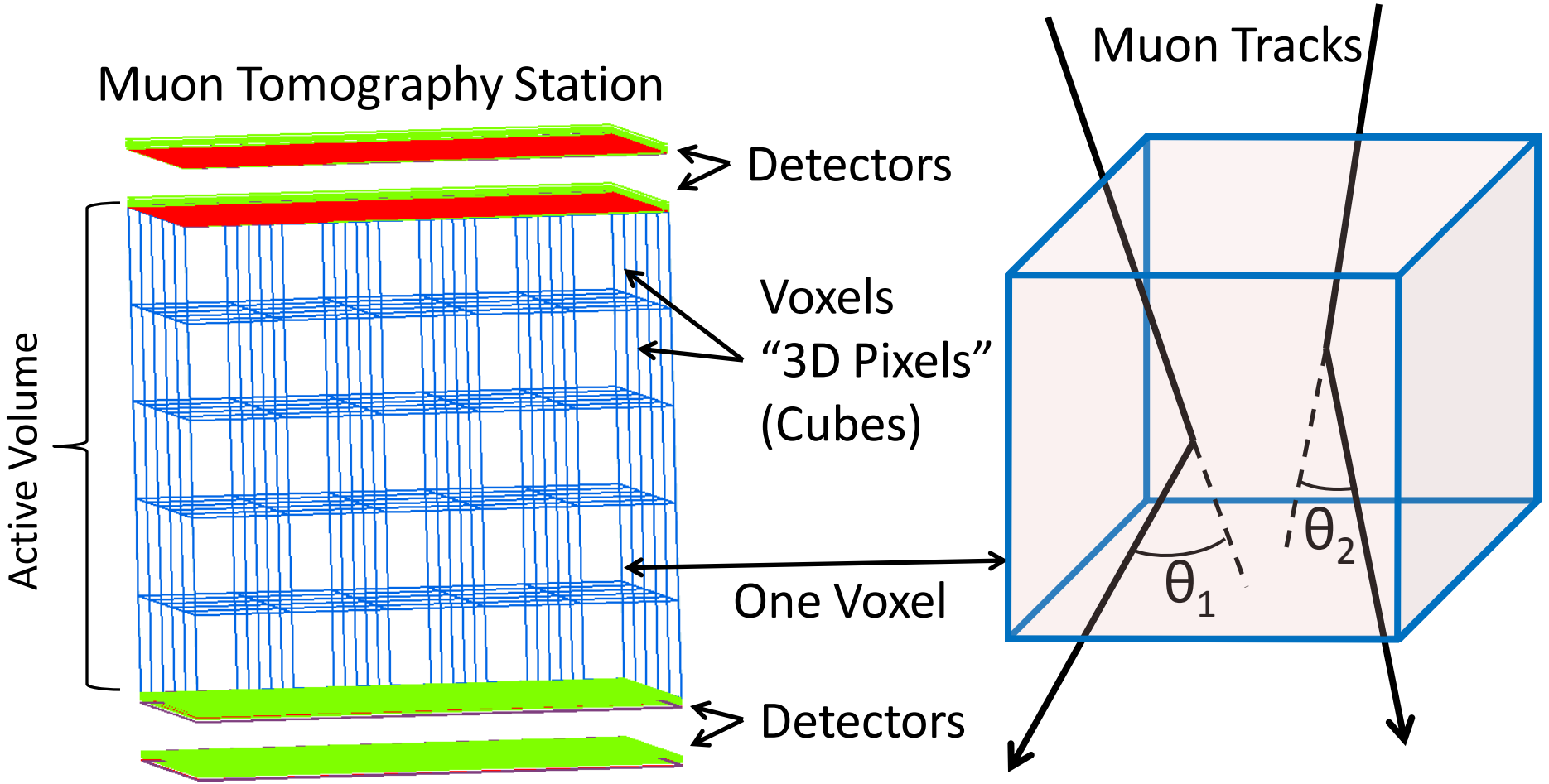
Reconstruction Algorithm (POCA)



Scattering Angle

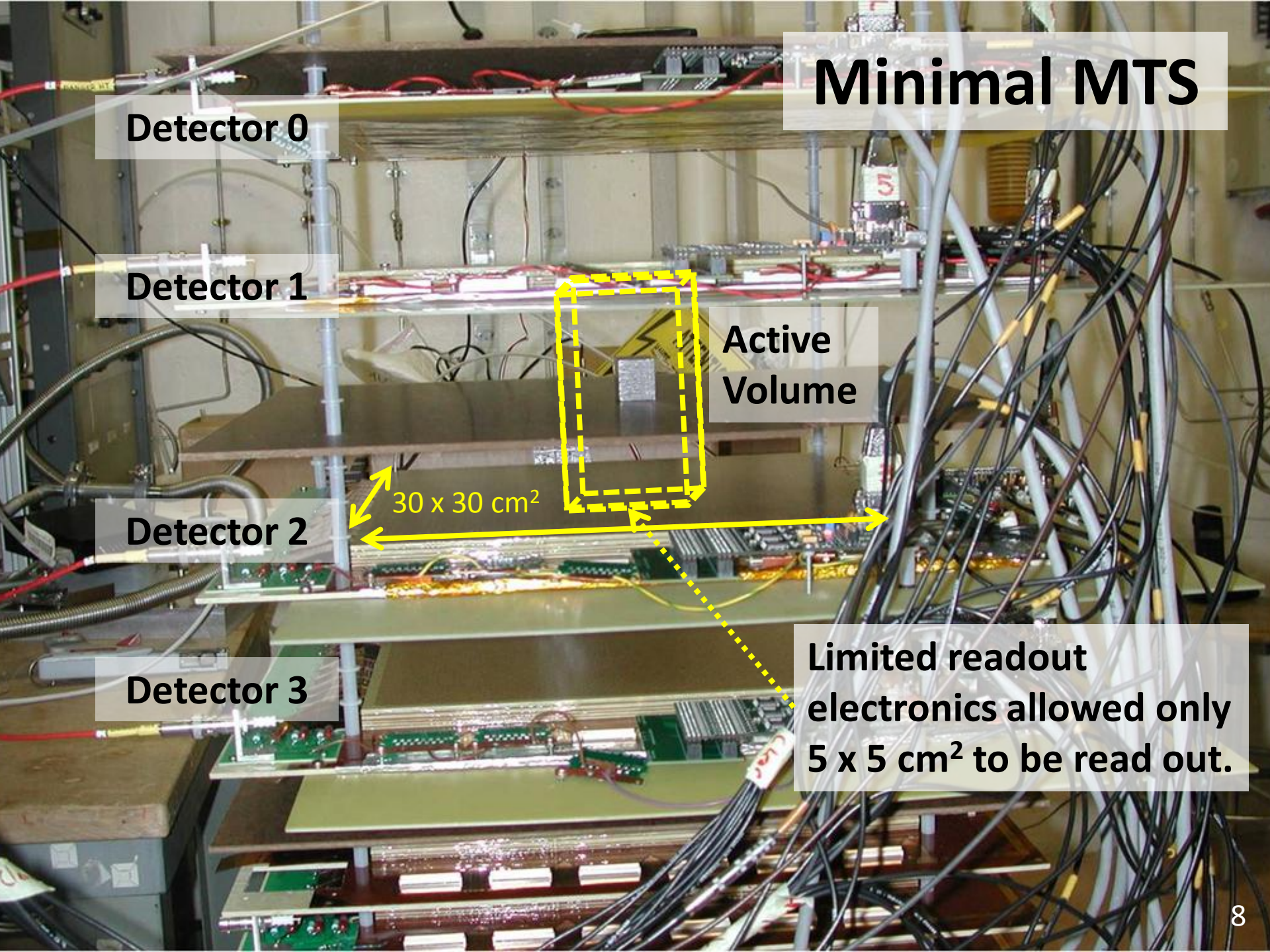
$$\theta = \cos^{-1}\left(\frac{\vec{a}\cdot\vec{b}}{|a||b|}\right)$$

Voxelization

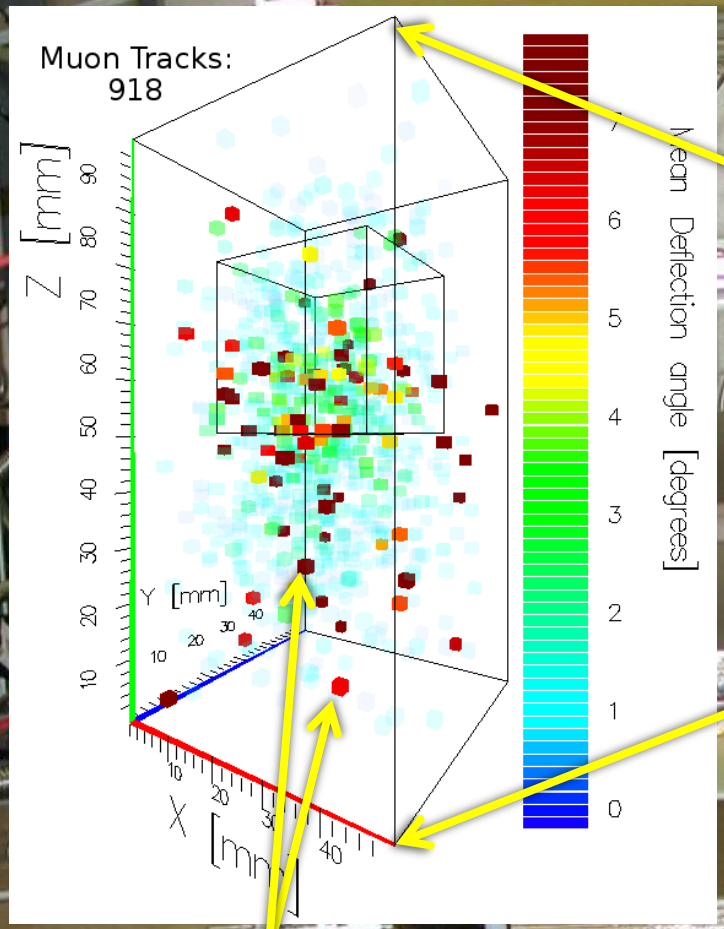


Voxel color indicates mean scattering angle in voxel $< \theta >$

Minimal Prototype
Muon Tomography Station (MTS)
with
Gas Electron Multiplier (GEM) Detectors


Minimal MTS
Detector 0
Detector 1
Active Volume
30 x 30 cm²
Detector 2
Detector 3
Limited readout electronics allowed only 5 x 5 cm² to be read out.

Reconstructing the Active Volume

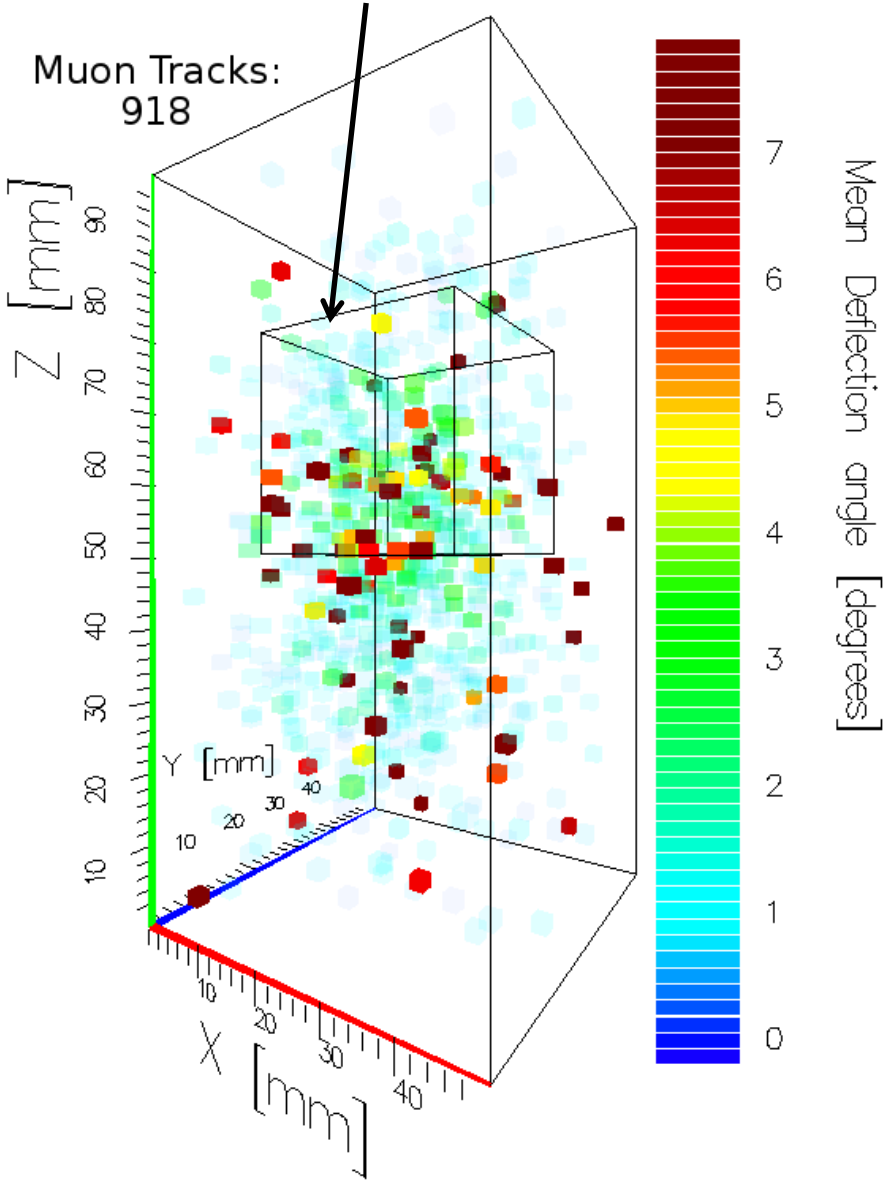


Active Volume

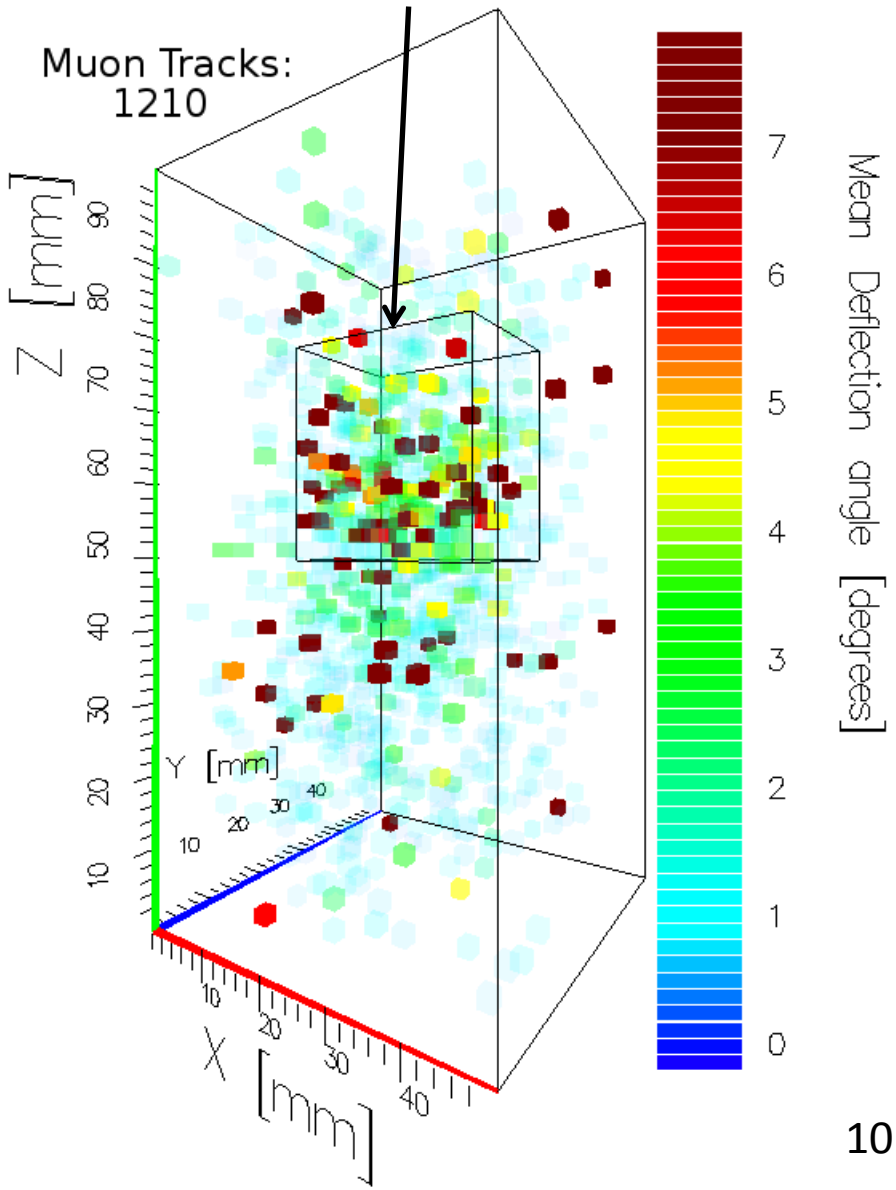
Voxels

Min. MTS Reconstruction with Real Data

3 x 3 x 3 cm^3 Iron Cube



3 x 2.8 x 3 cm^3 Lead Block

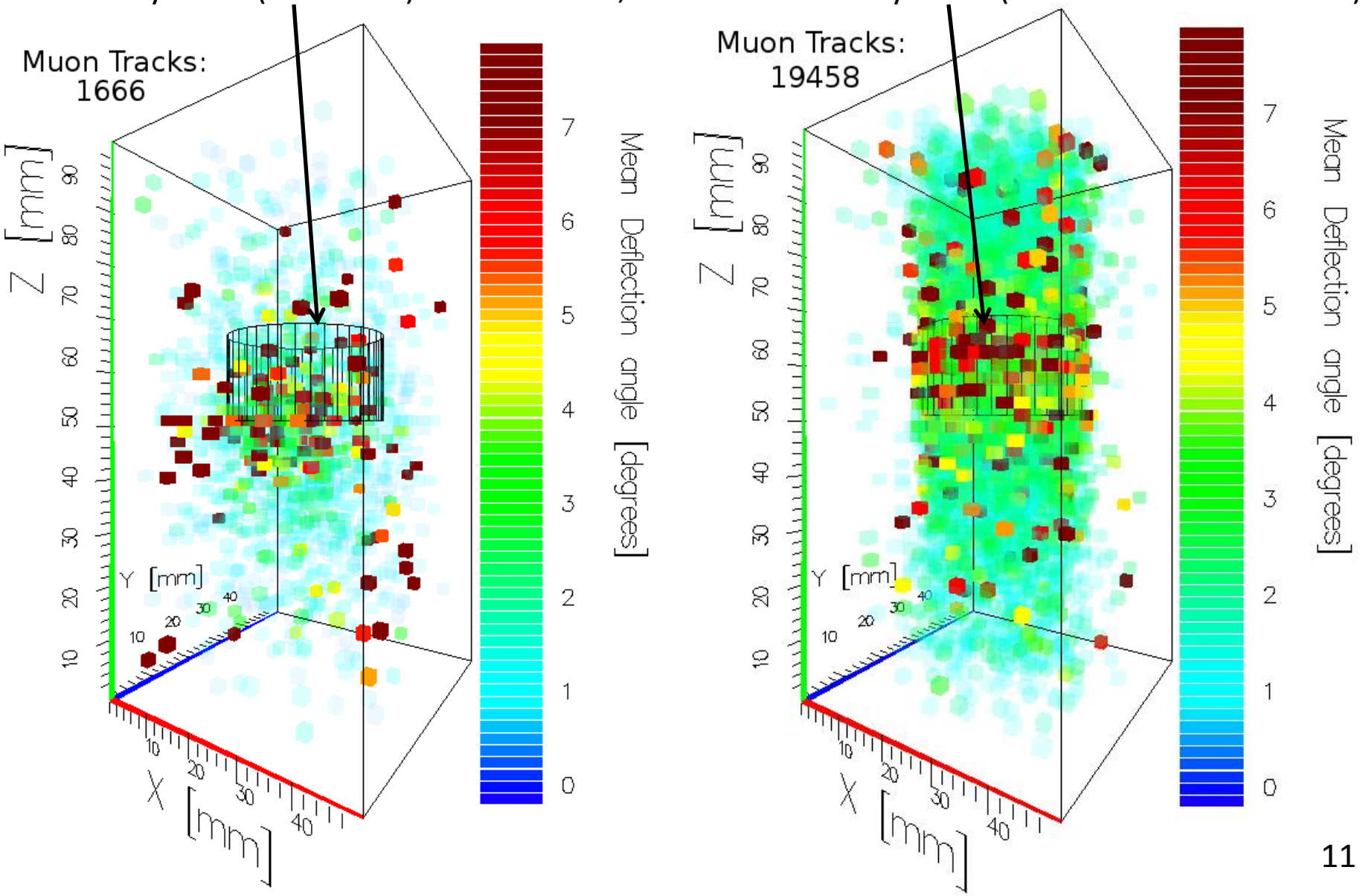


Comparing Real Data to Monte Carlo Simulation

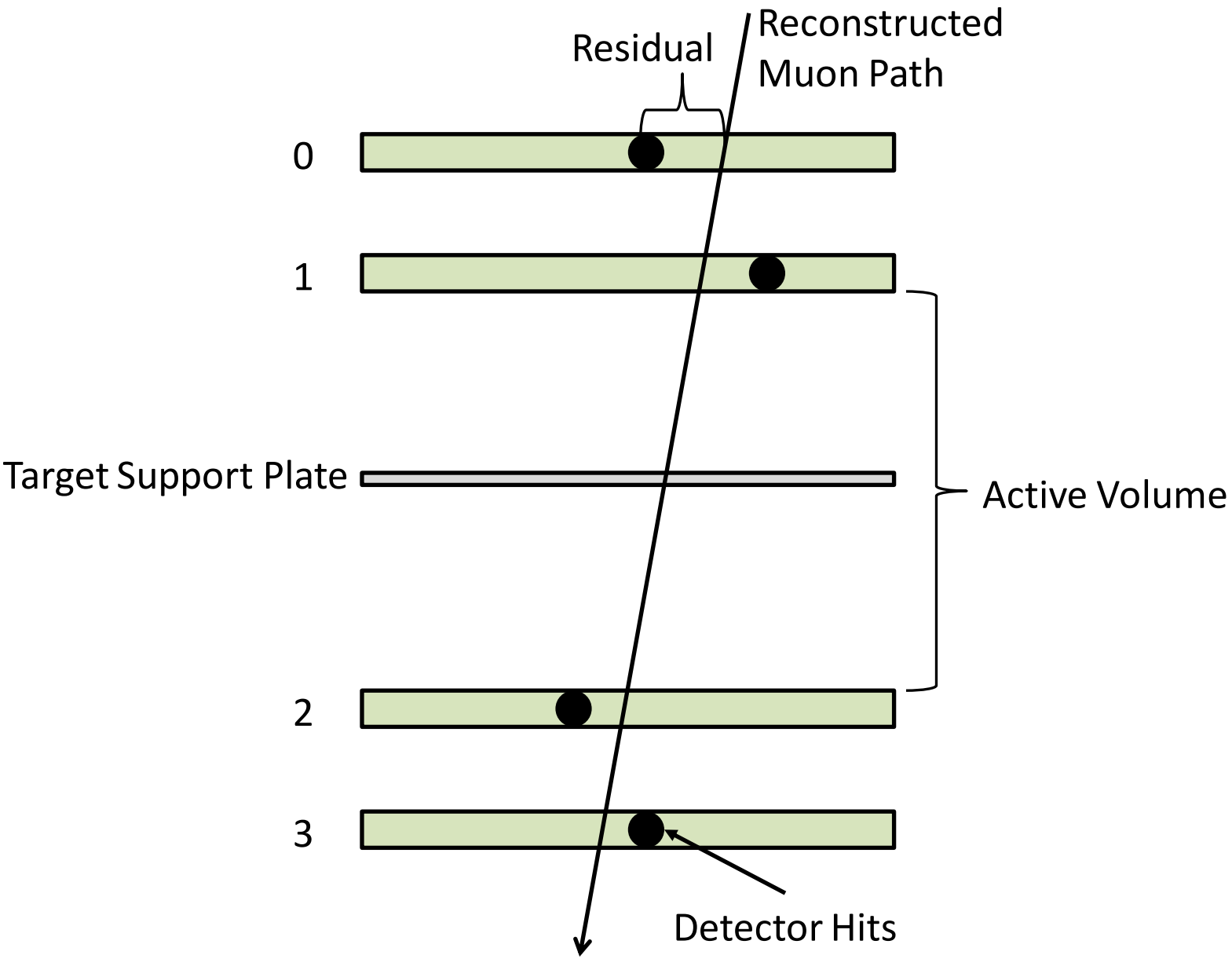
Tantalum Cylinder (Real Data)

r = 1.5 cm, *h* = 1.6 cm

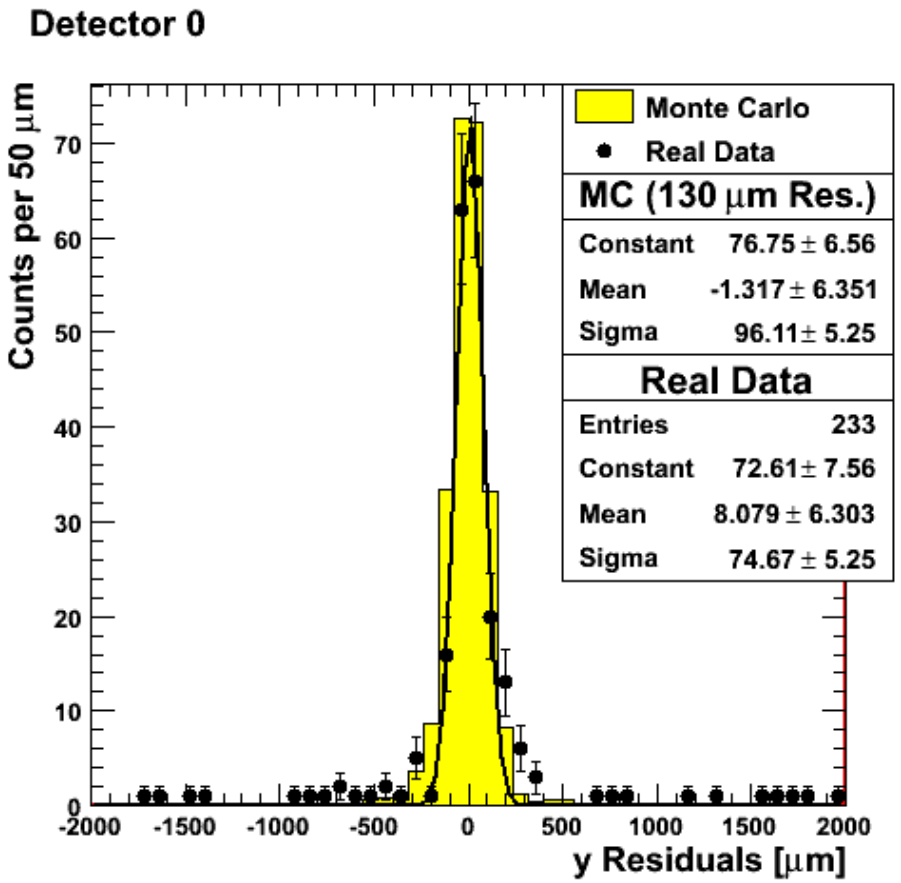
Ta Cylinder (Monte Carlo Simulation)

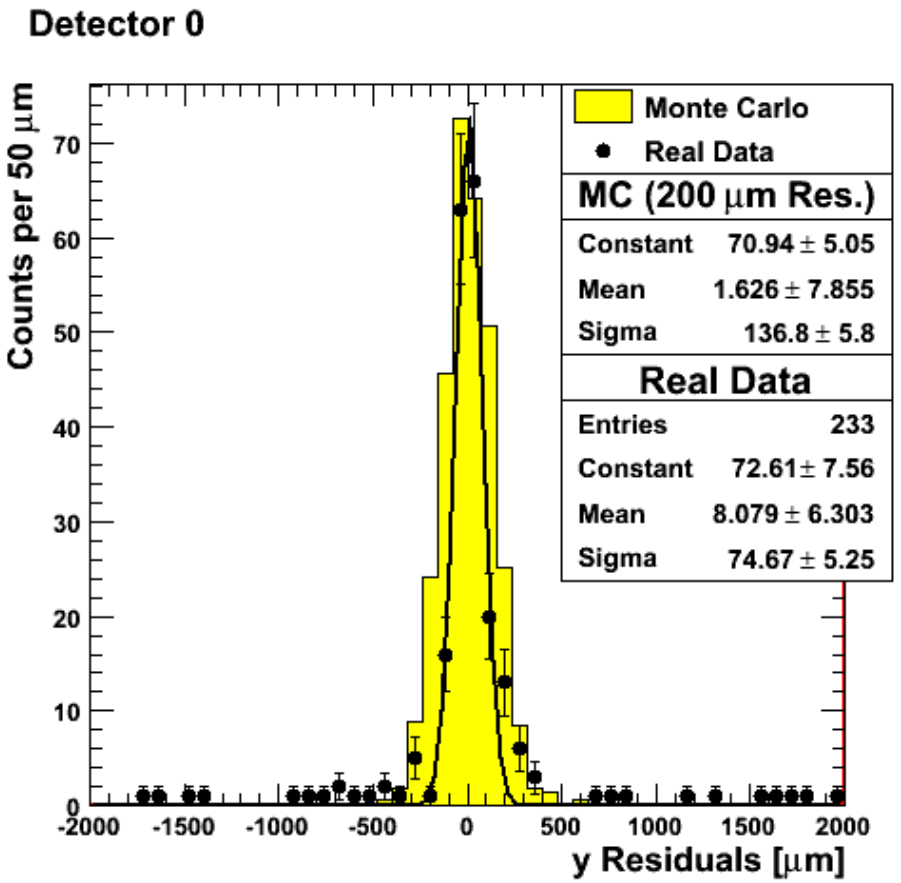


Fit Residuals

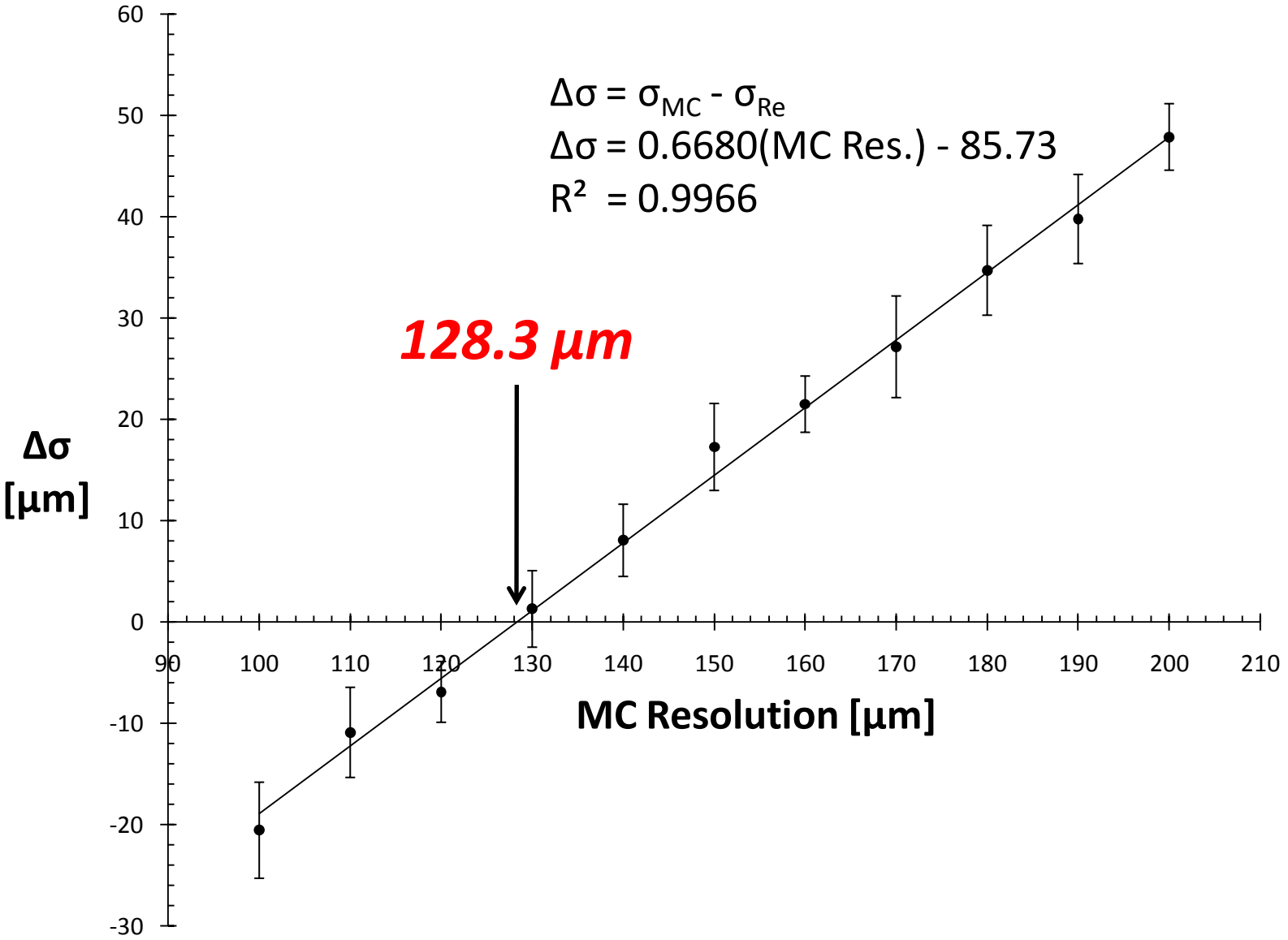


Determining Spatial Resolution





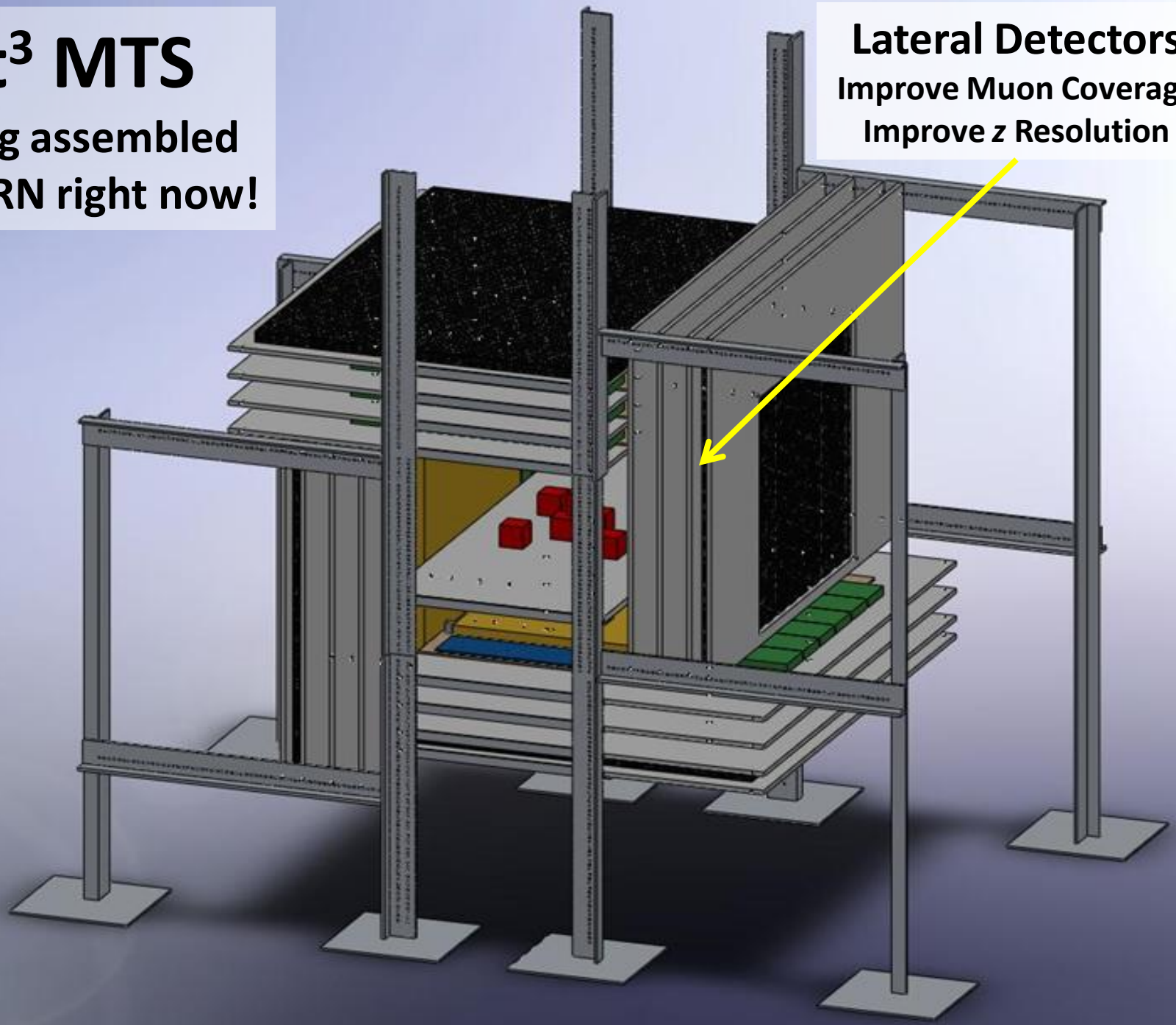
Determining Spatial Resolution



ft^3 MTS

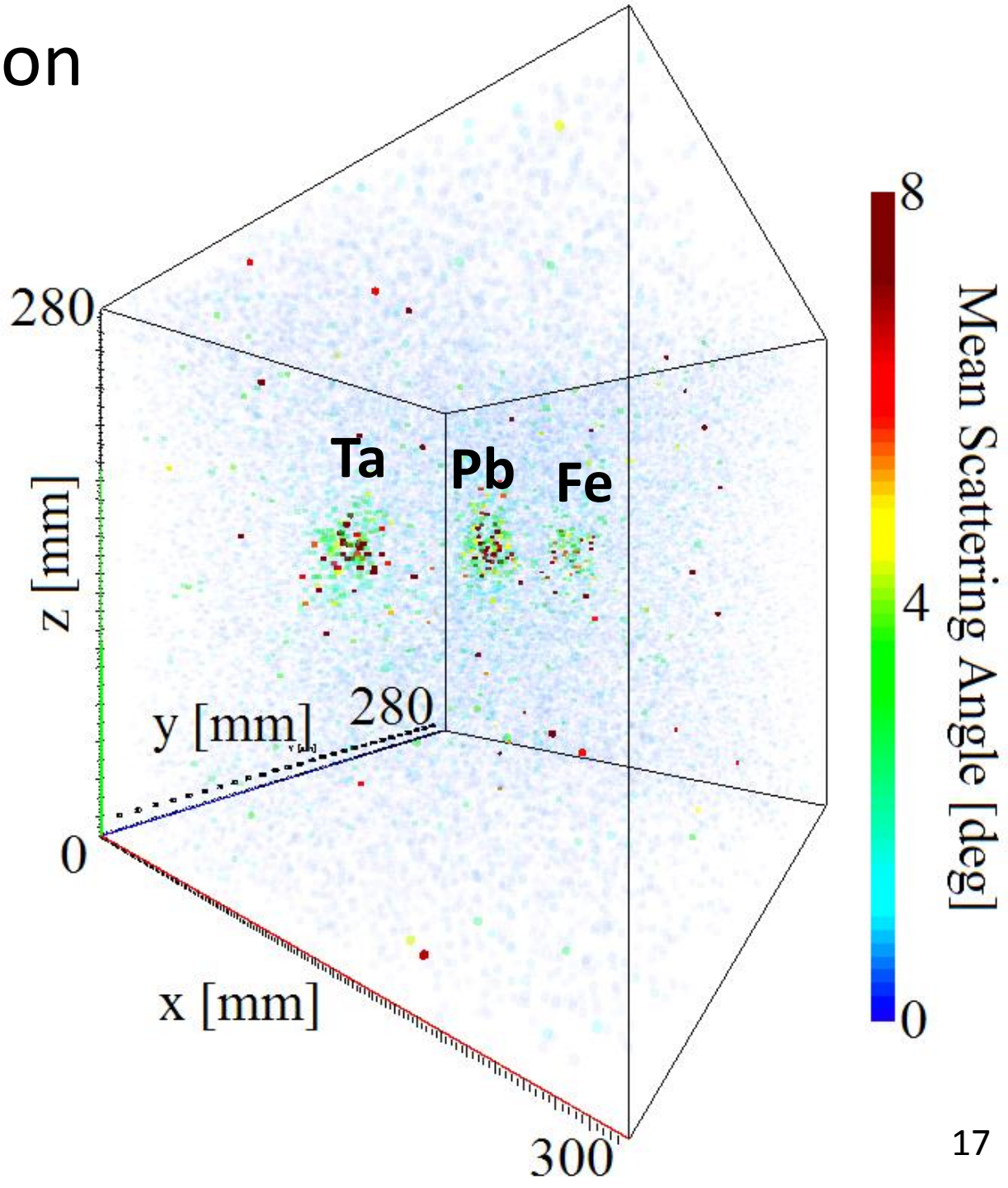
ft^3 MTS

Being assembled at CERN right now!

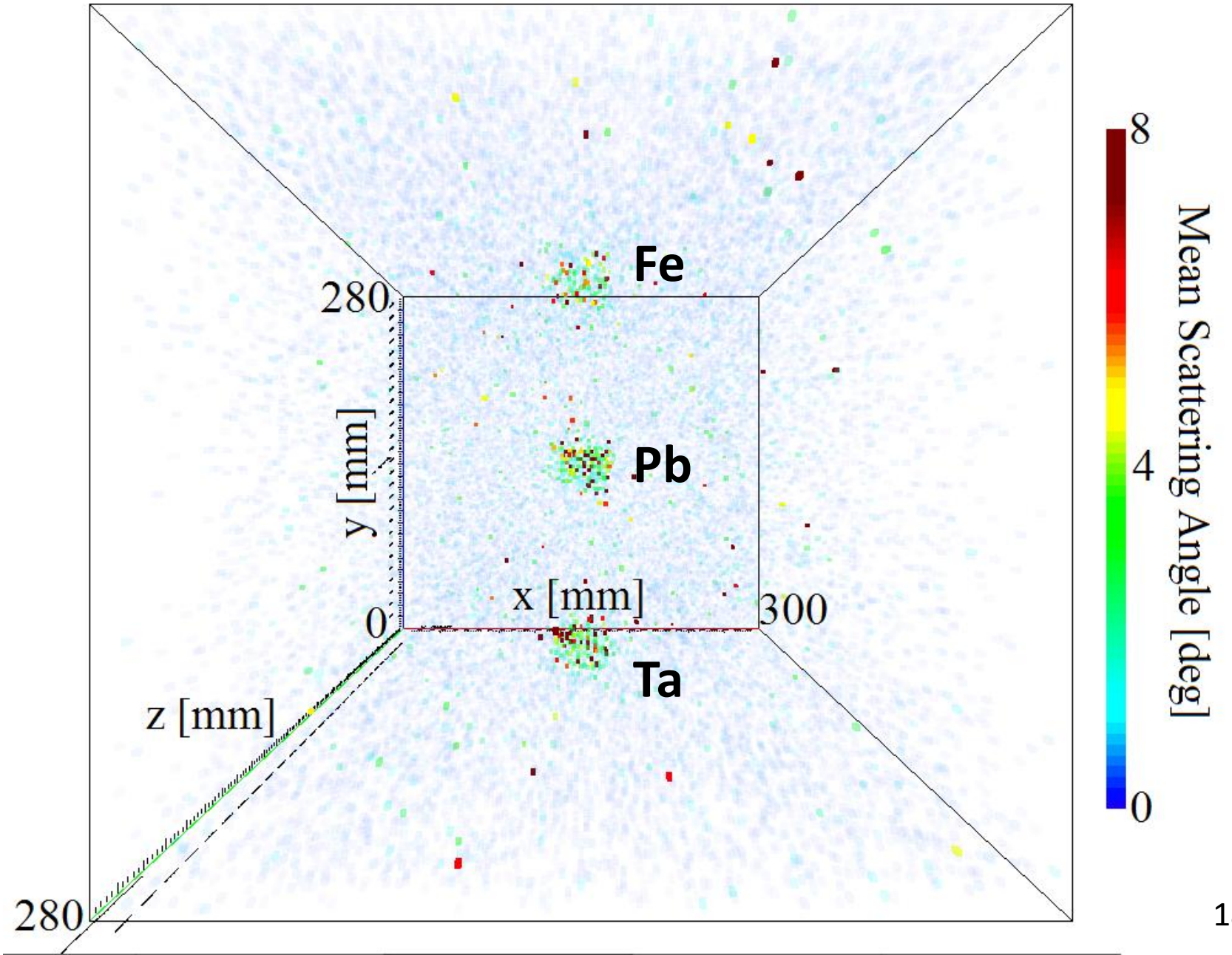


ft^3 MTS Simulation Reconstruction

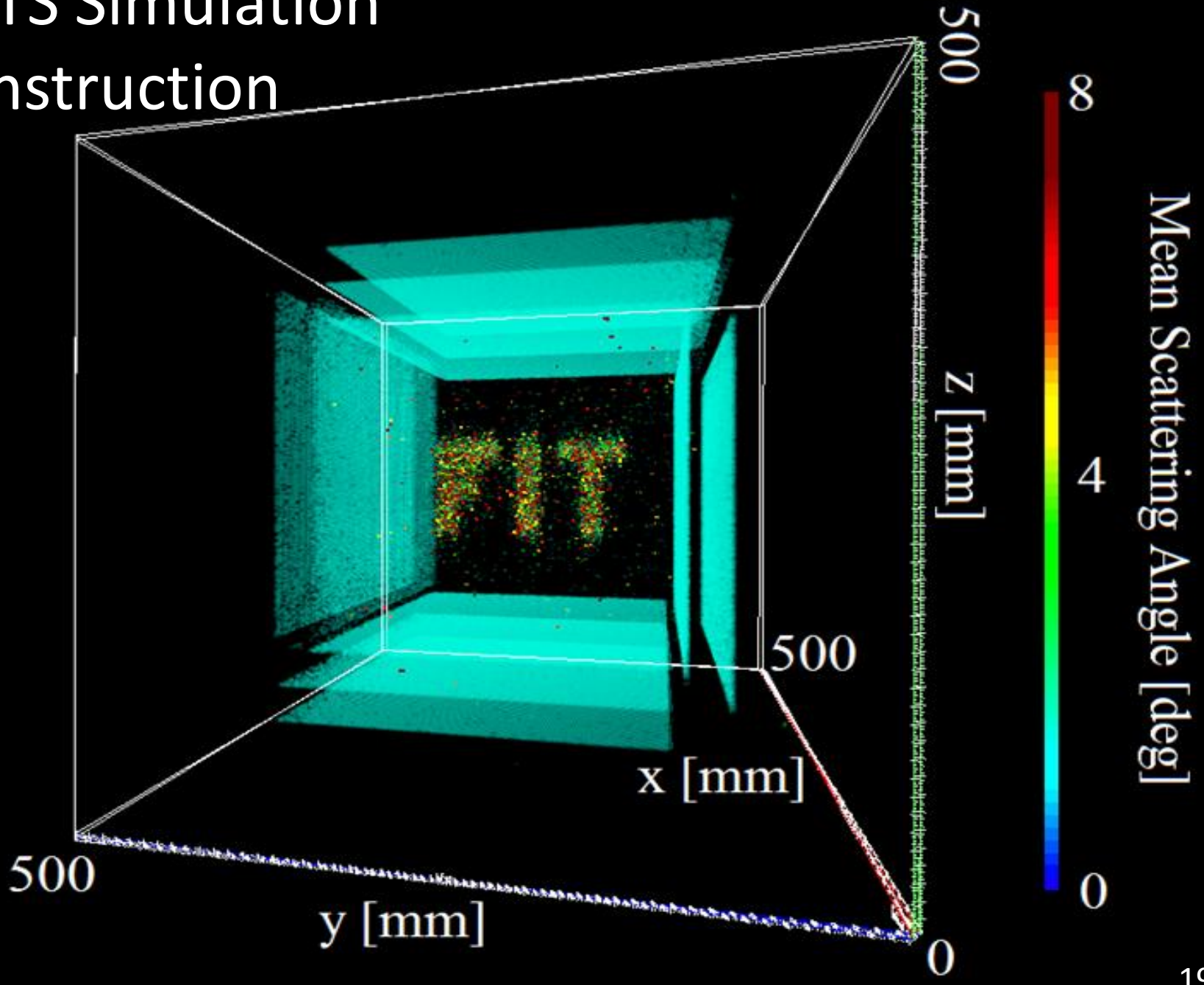
Same targets imaged with minimal prototype MTS.



ft^3 MTS Simulation Reconstruction (Top view)



ft³ MTS Simulation Reconstruction

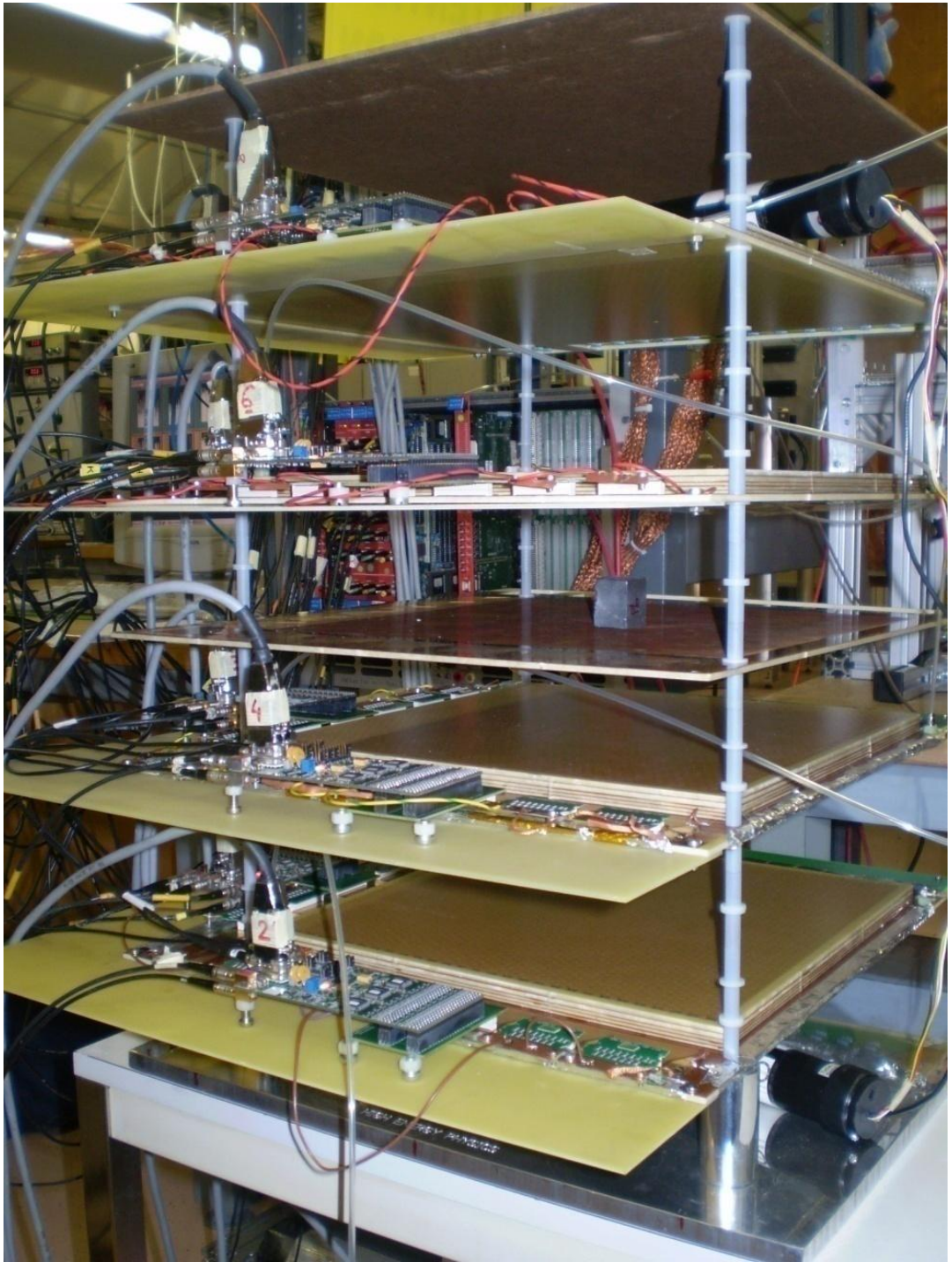


Summary

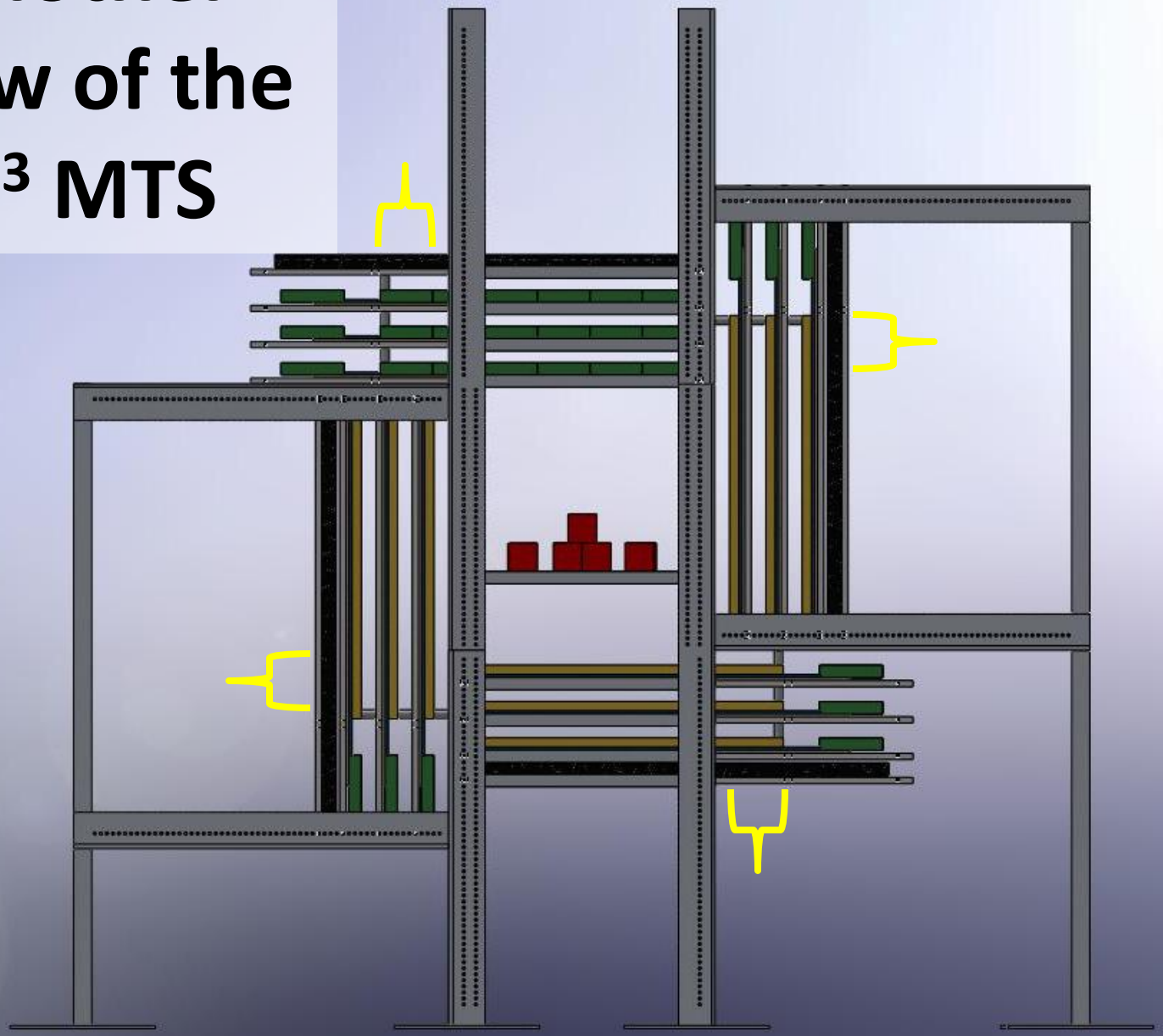
- Muon tomography can be used to **detect shielded nuclear contraband**.
- **Iron, lead, and tantalum blocks were successfully imaged with a** minimal **prototype** muon tomography station.
- We estimate our **GEM detectors to have 130 µm spatial resolution** with *preliminary electronics*.
- The next generation muon tomography station will have **improved reconstruction abilities**.

Backup Slides

Another View of the Minimal MTS

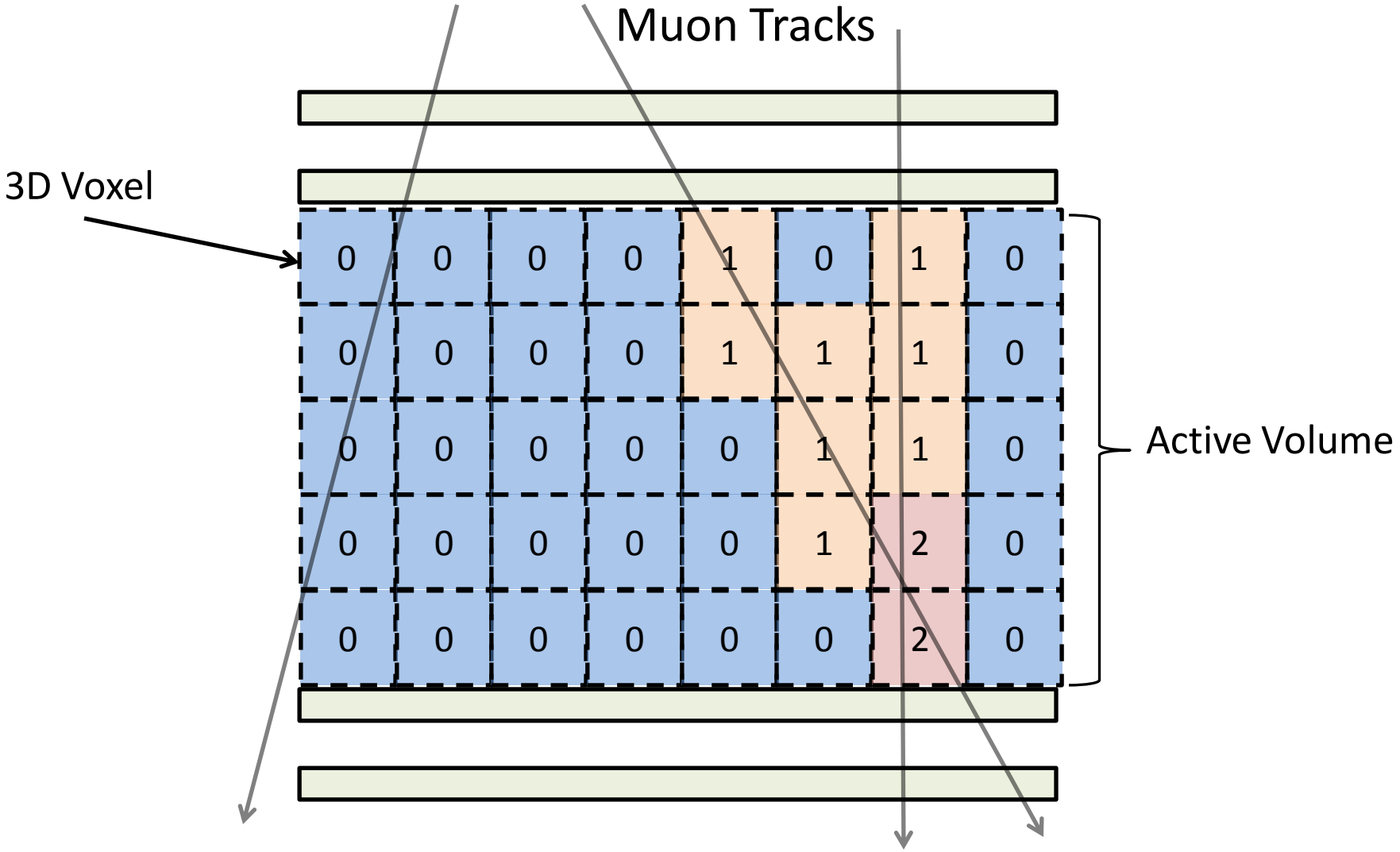


Another View of the ft^3 MTS




ft³ MTS in the Lab

Coverage Concept



Higher coverage → Higher statistics for reconstruction