CREAM TEA Update

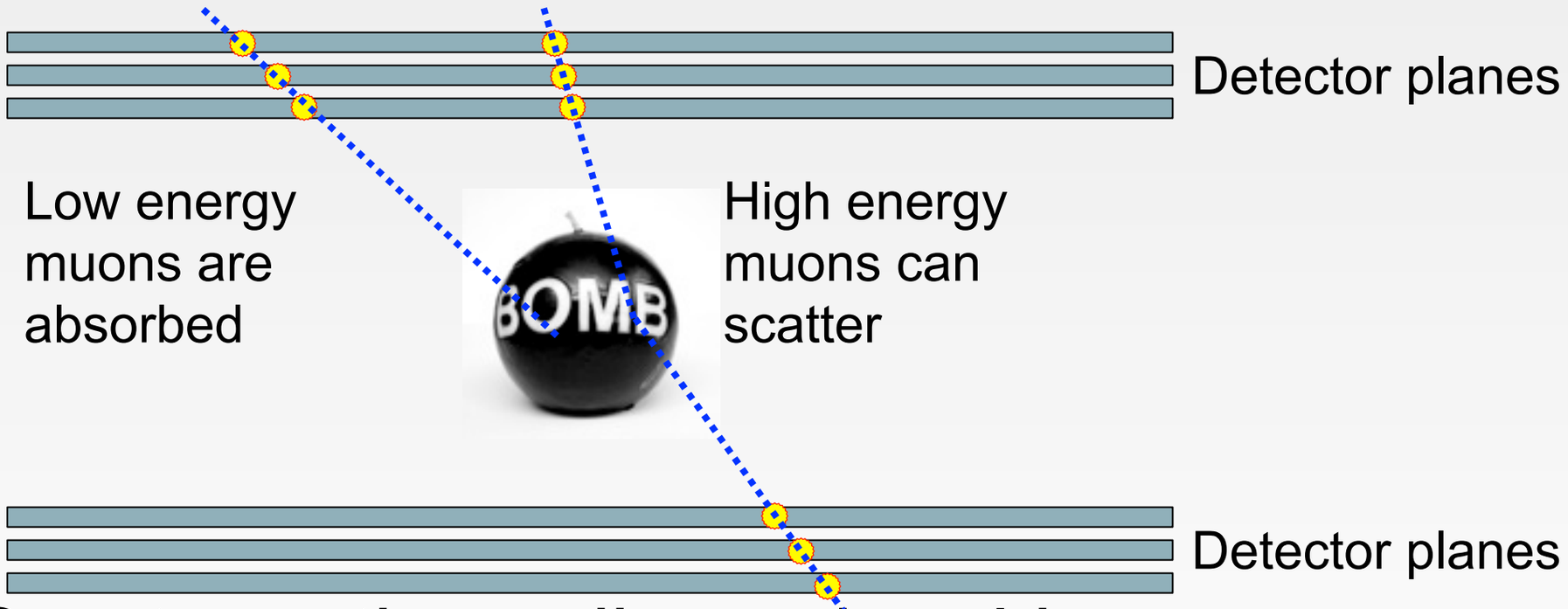
10th June 2010

Outline

- Introduction
- GEANT Simulation
  - Reconstruction
- Detector Optimisation Studies
  - Comparison with ideal detectors
- Detector Test Stand Progress

The Idea - Cosmic Ray Muon Tomography

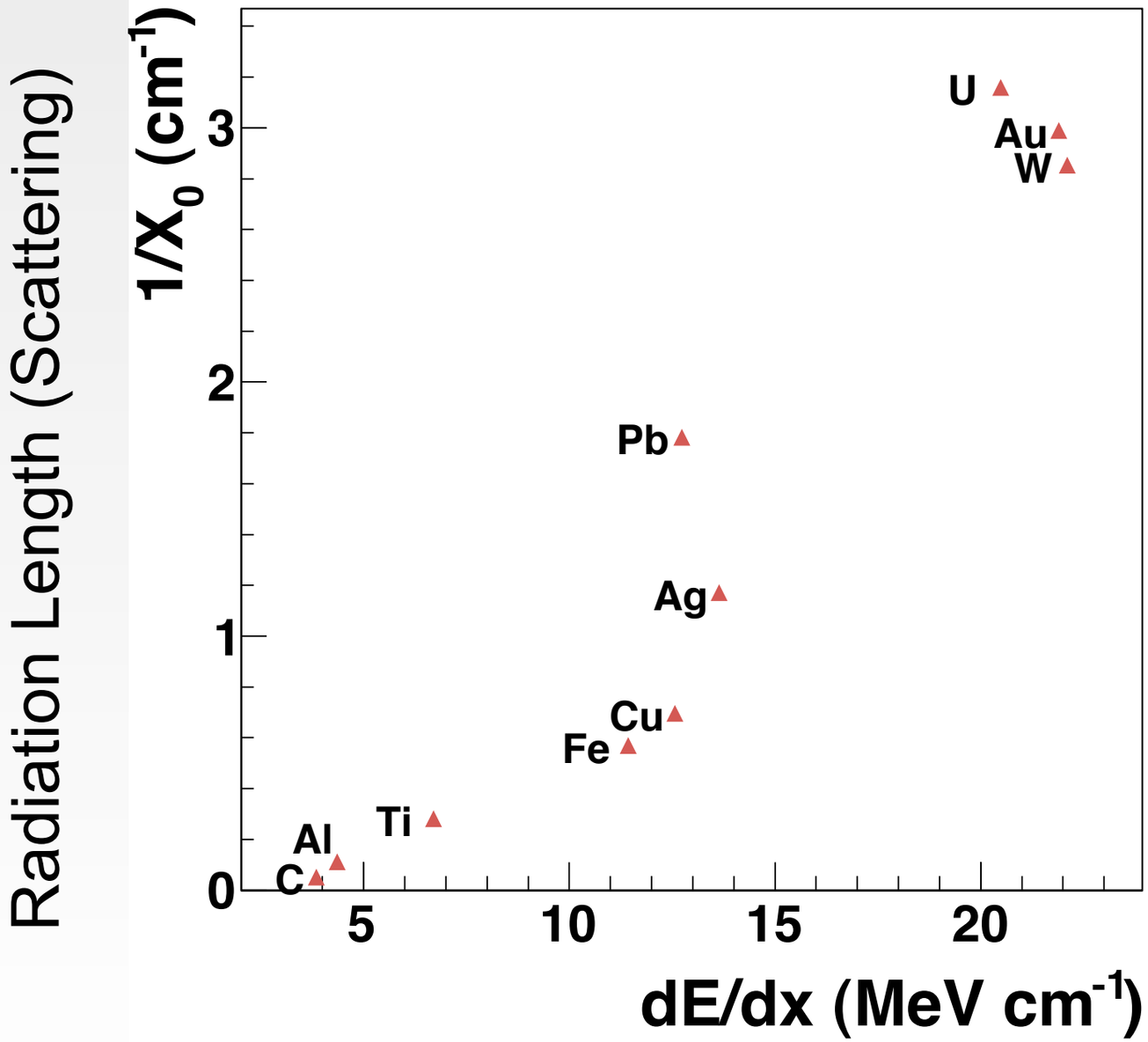
- Over 10,000 cosmic ray muons a minute stream through each square metre of the Earth's surface.
- These particles either scatter (high energy) or are absorbed (low energy) as they pass through matter.



- Creates a three dimensional image.
  - Cosmic ray imaging is an old idea (1950's) and has been used to image: pyramids, volcanoes, mines, ...

Muon Tomography Capabilities

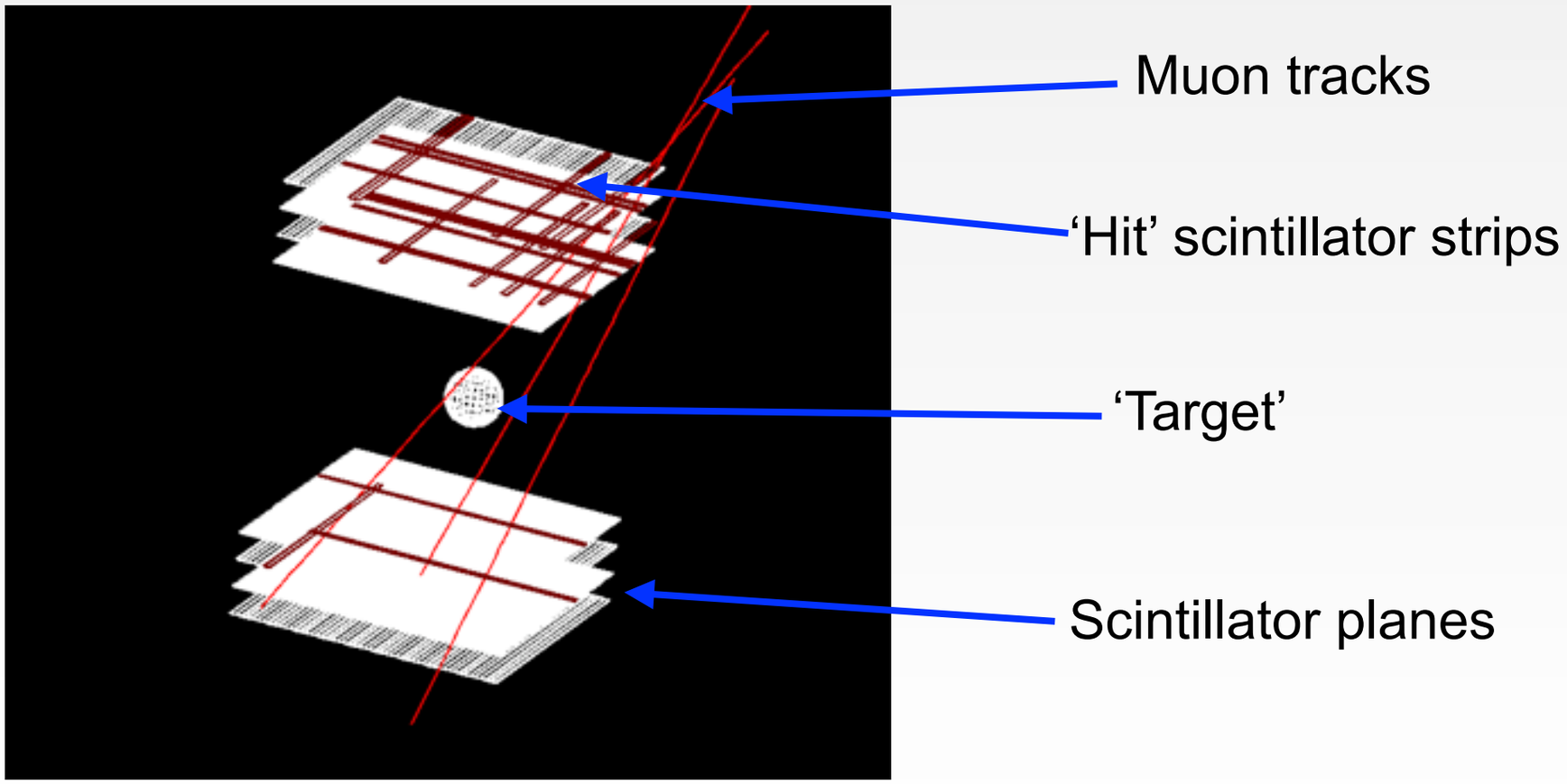
- The scattered and absorbed muons can be used to make two independent measures of the target material



The Simulation - Current Status

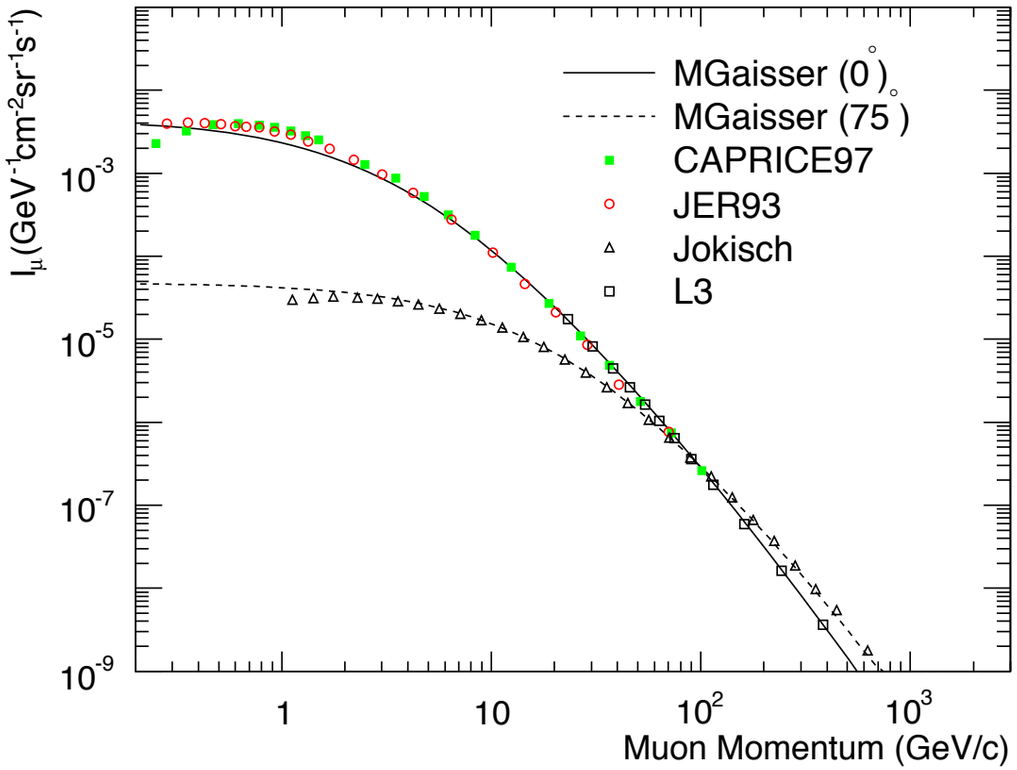
- GEANT4 is the particle physics tool of choice for simulation.
  - Contains all known particle interactions with matter.
- We have a simulation that we can use to test a variety of target geometries

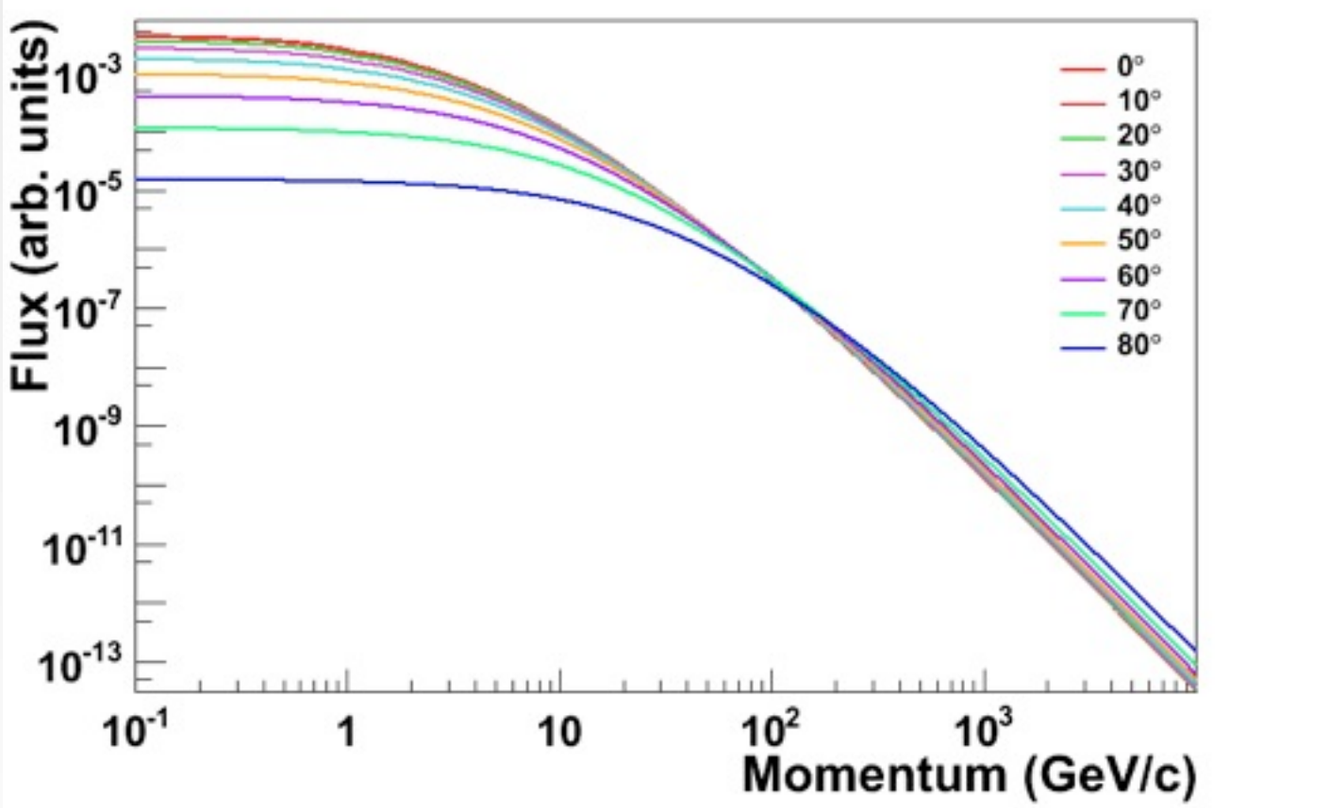
GEANT4 visualisation of CREAM TEA test-stand



Muon Flux

- A realistic muon flux that depends on energy and angle is used



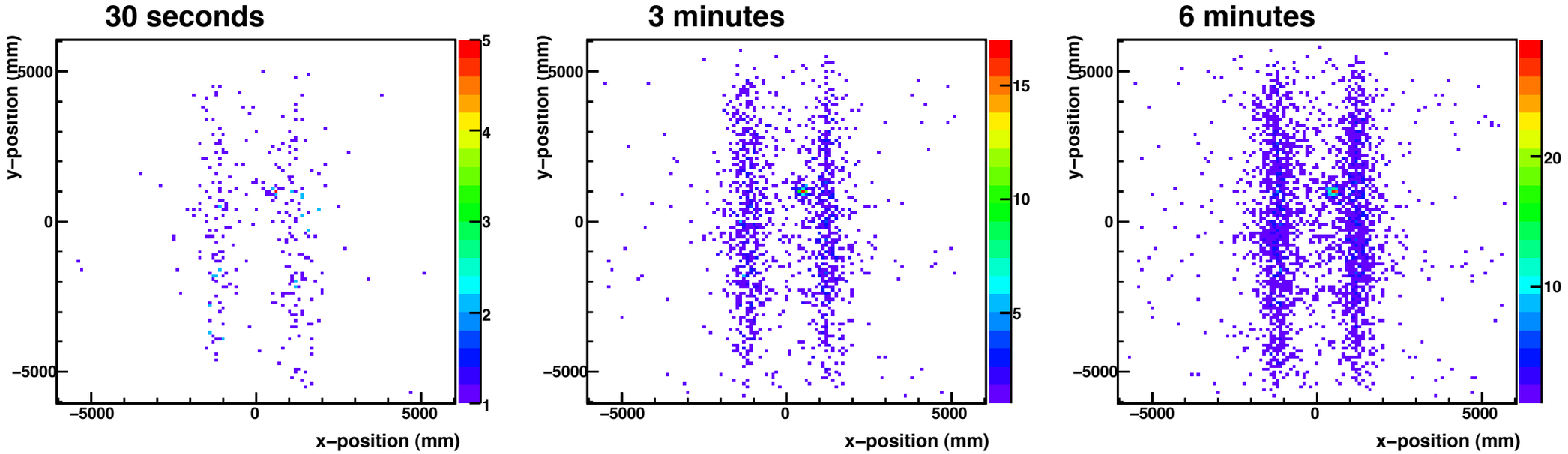


Qing He, Kirk McDonald, Princeton University, May 14 2009, Muon Rate in the μ-BooNE TPC

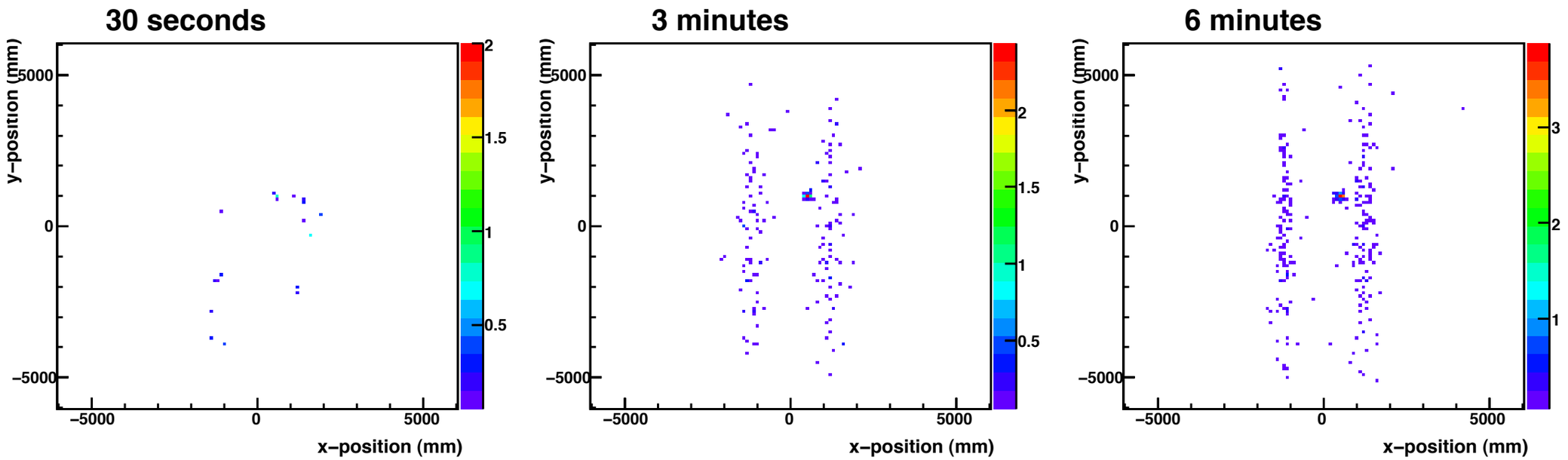
Initial Results -- Absorbed Tracks

- 10cm ‘tungsten’ target in a shipping container

Raw Absorption Slices

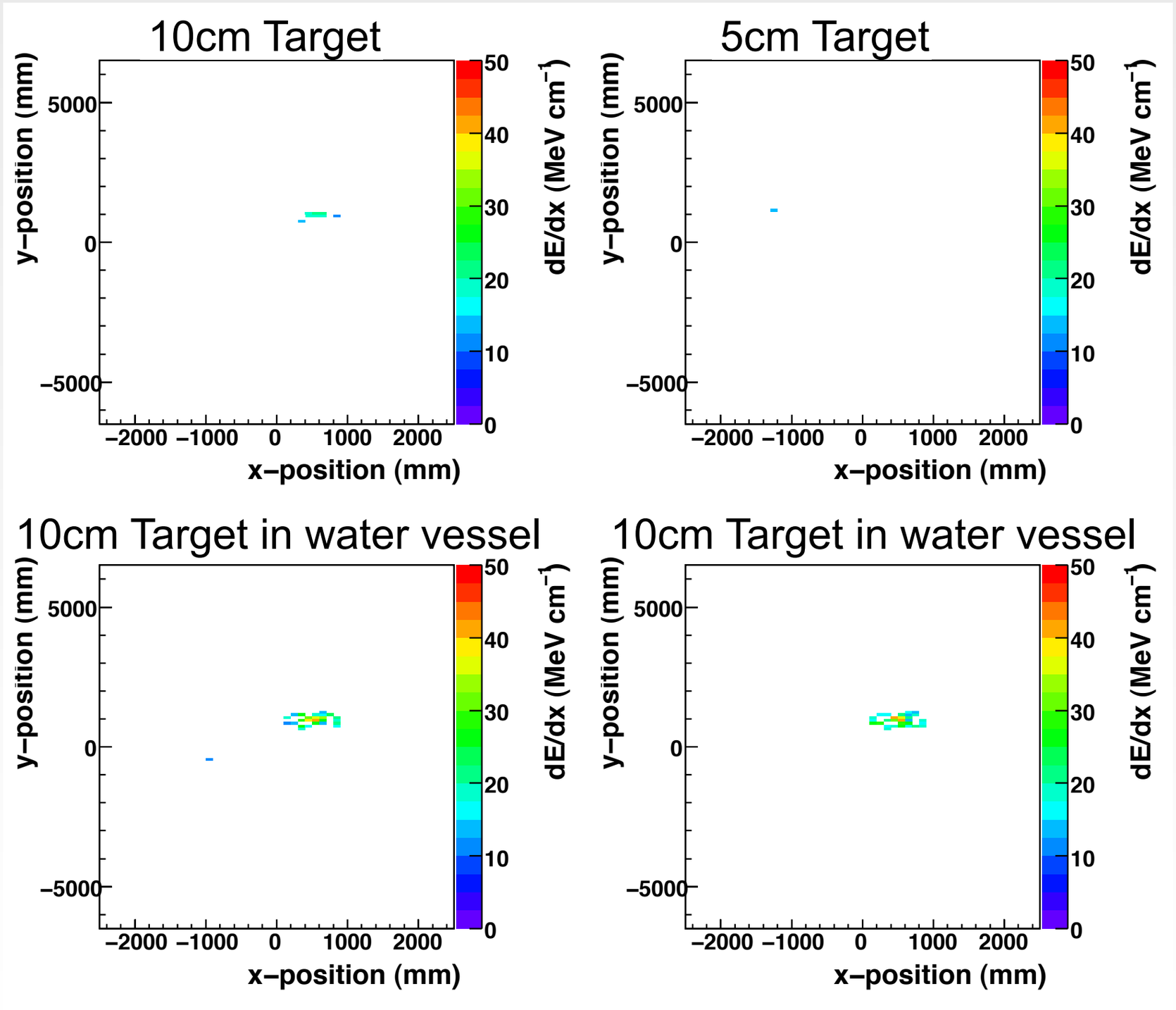


Weighted Absorption Slices



Initial Results -- dE/dx measurement

- Six minute exposures



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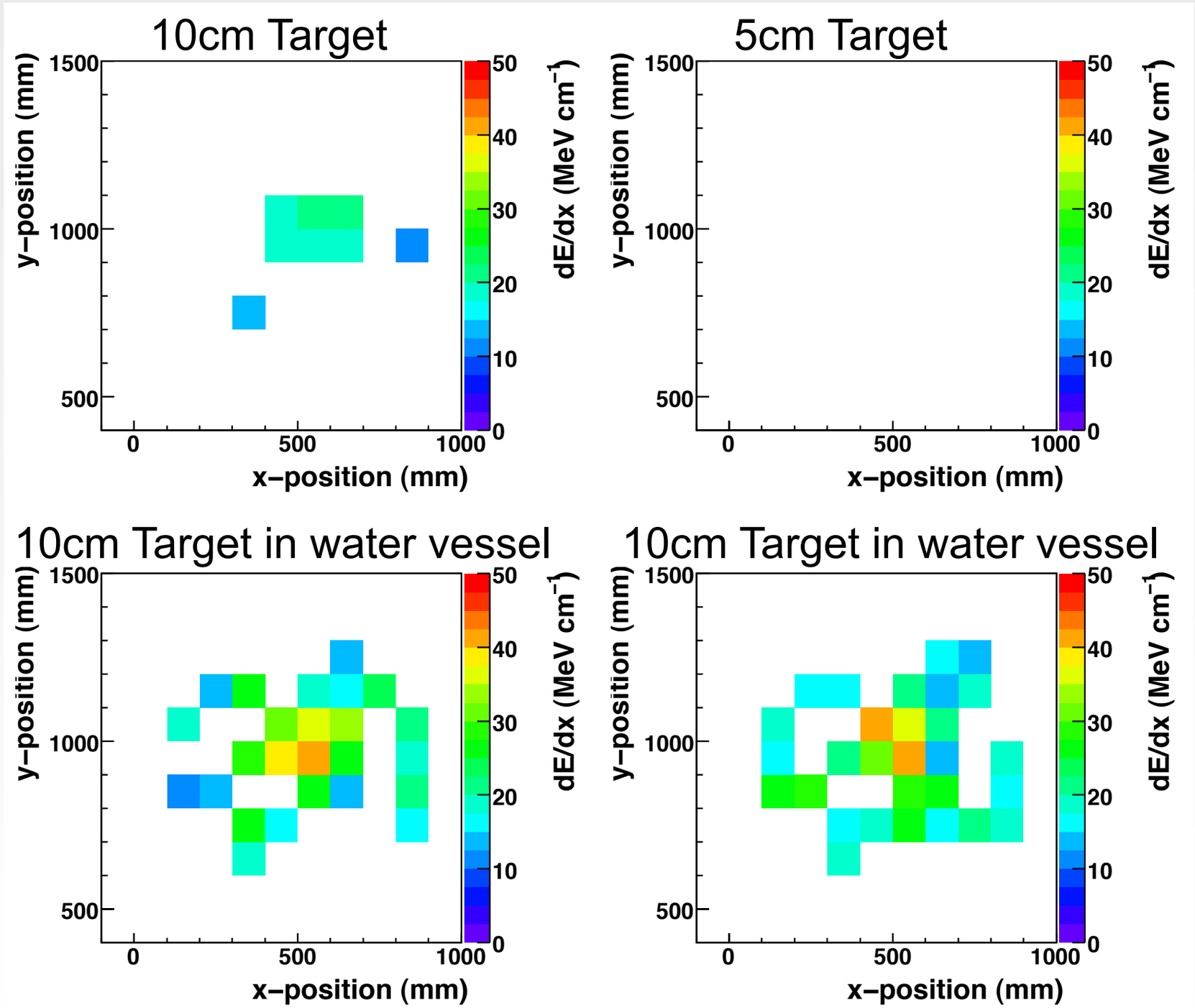
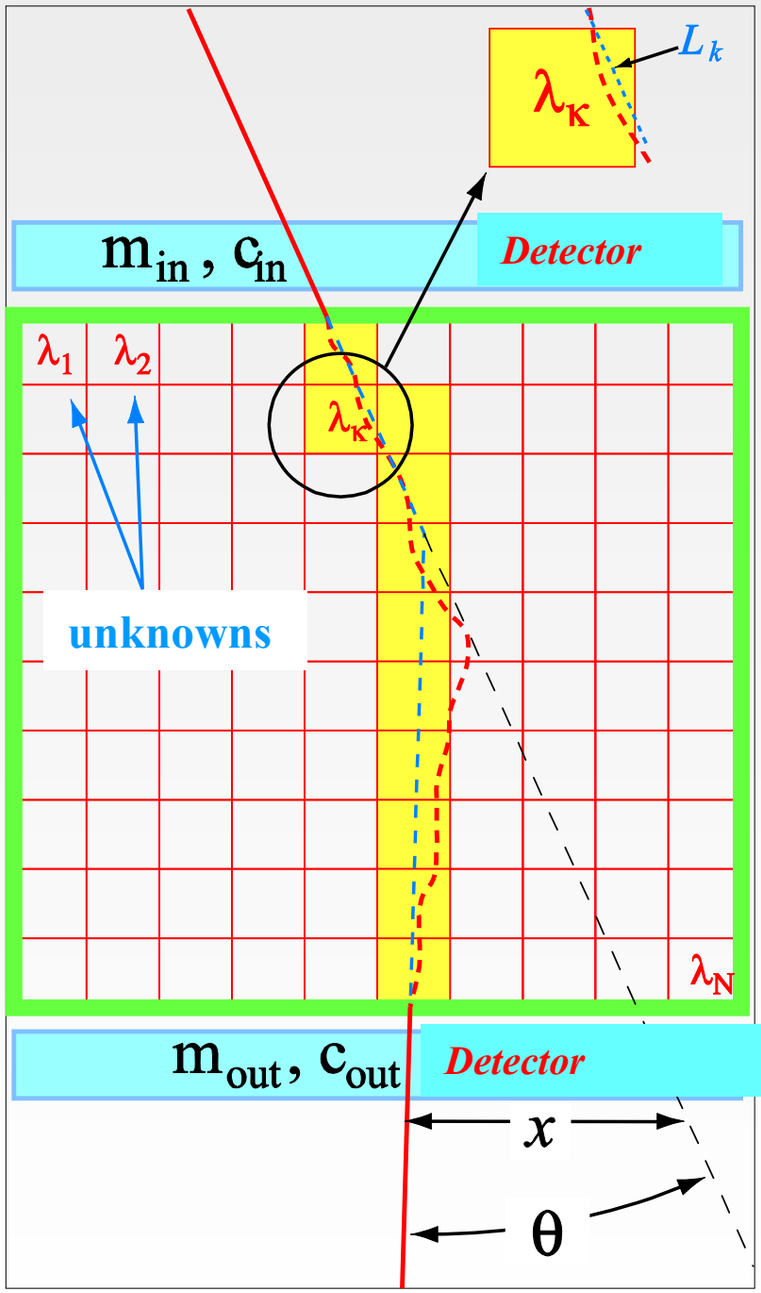


Reconstruction Techniques

Tomographic (List Mode Iterative Algorithm)



Define scattering density for a material: $\lambda_0 = 1/X_0$

the average square deviation expected for a particle i crossing *L*

$$\sigma_i^{\,2} \approx \left(\frac{13.6\,MeV}{p_i c} \right)^2 L\lambda_0$$

If the material is not homogeneous the volume can be divided into N cubic voxels and $L\lambda_0 \rightarrow \sum_k L_{ik}\lambda_k$

where $\{\lambda_k ; k=1,\ldots N\}$ **are N unknowns**

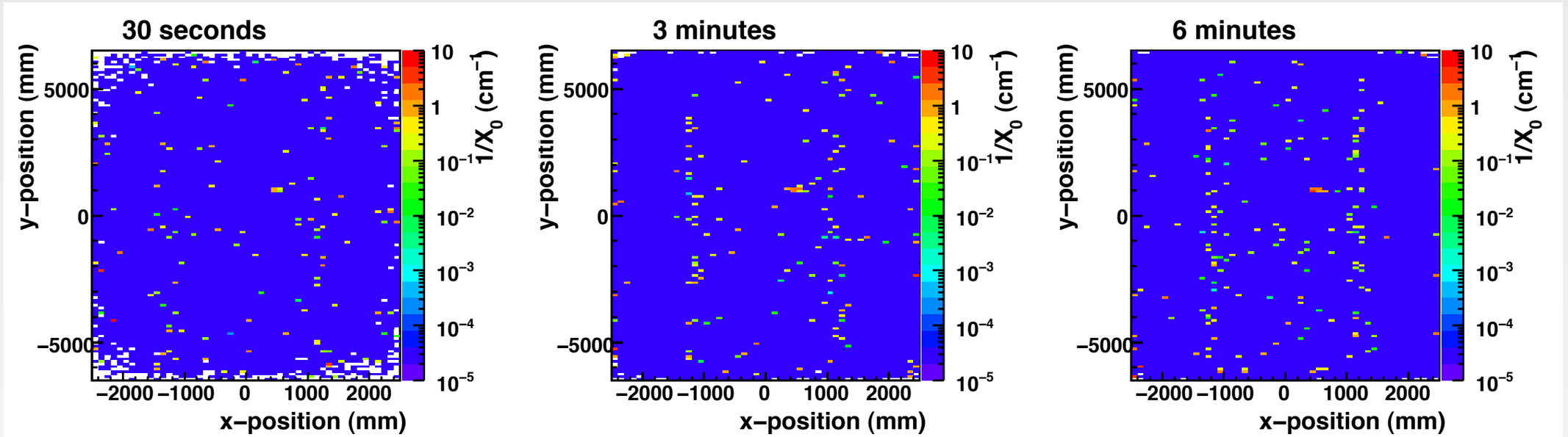
with $\{s_i^2=\Delta\theta_i^2 ; i=1,\ldots M\}$ **M measurements.**

given the Gaussian p.d.f. $P_i = P(s_i \mid \sigma_i) = \frac{1}{\sigma_i\sqrt{2\pi}} e^{-\frac{s_i^2}{2\sigma_i^2}}$

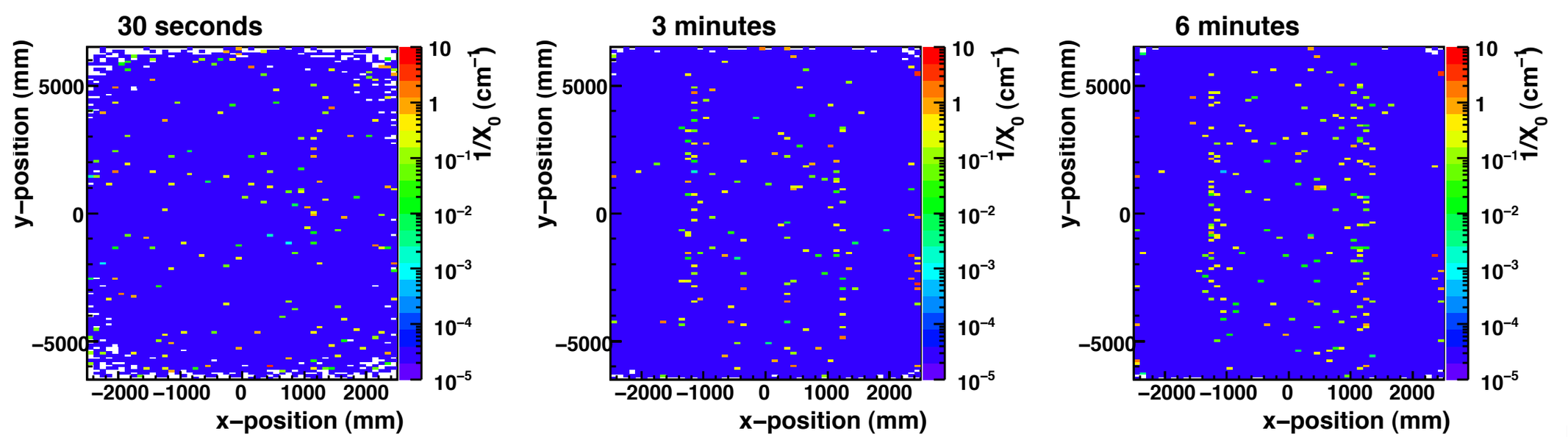
with an iterative optimization algorithm (LMIA) applied to a Maximum Log-likelihood functional the system can be solved

Initial Results -- Scattering

- 10cm Target



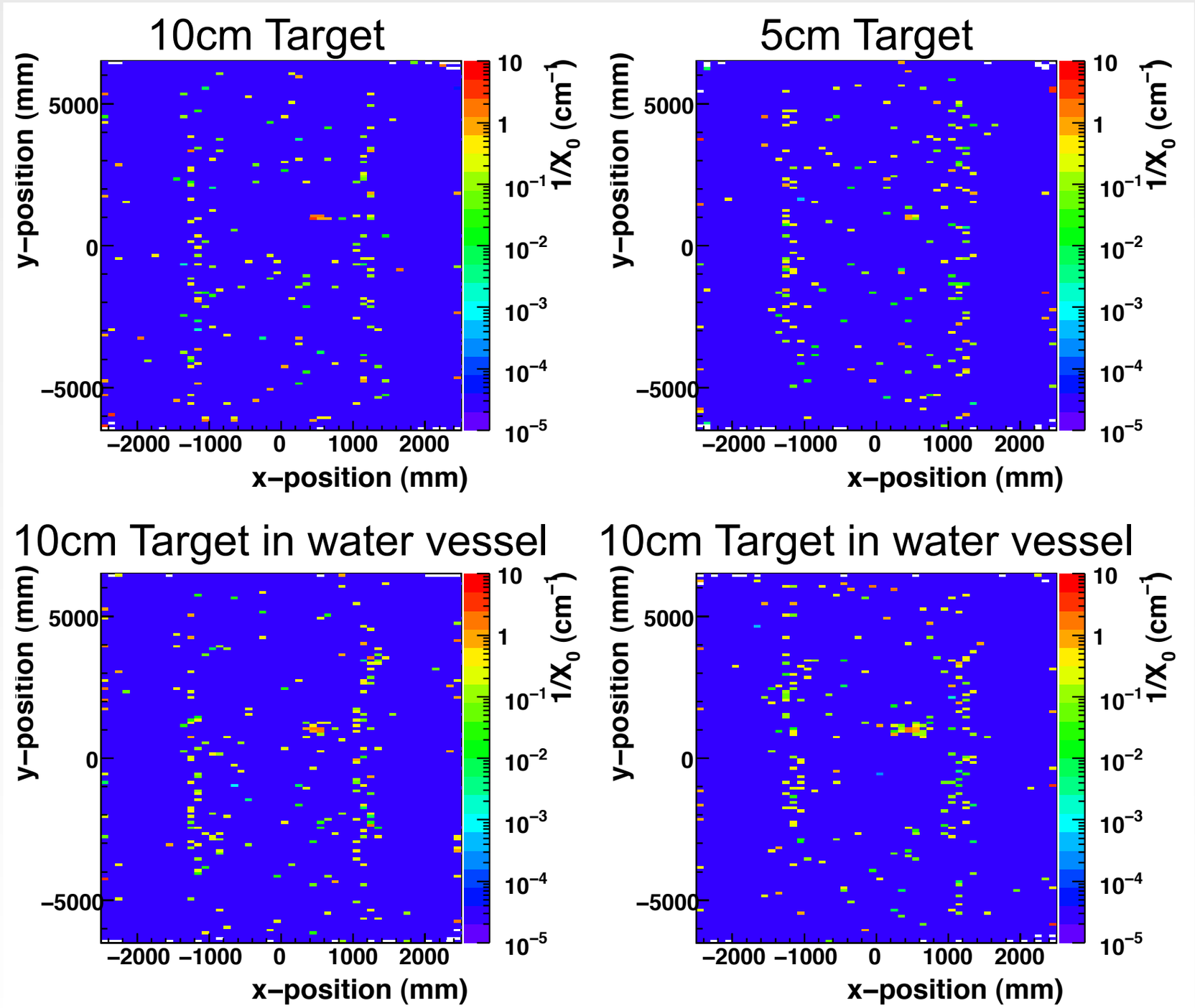
- 5cm Target



Nuclear Instruments and Methods in Physics Research A 604 (2009) 738–746

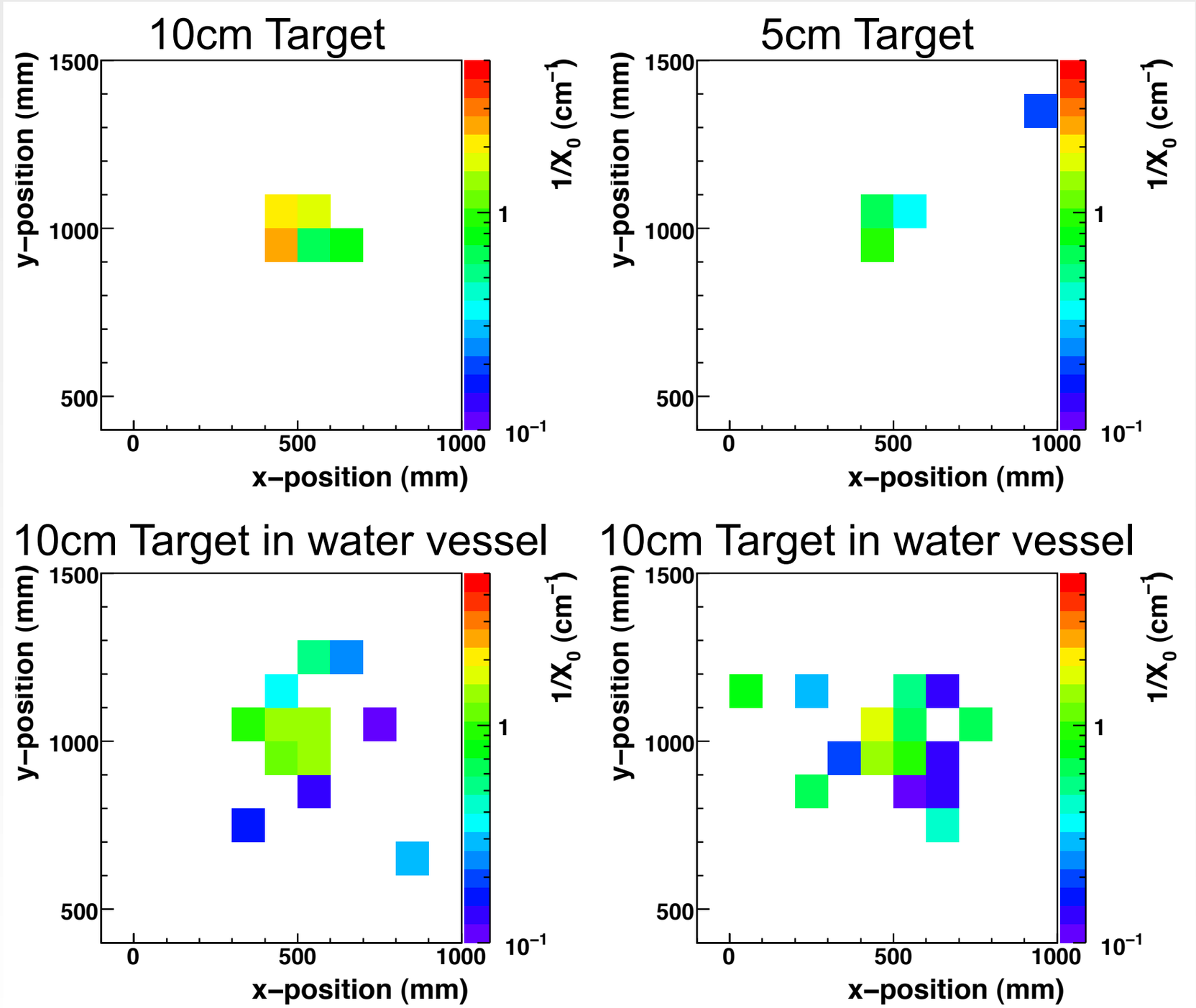
Initial Results -- Scattering

- Six Minute Exposure



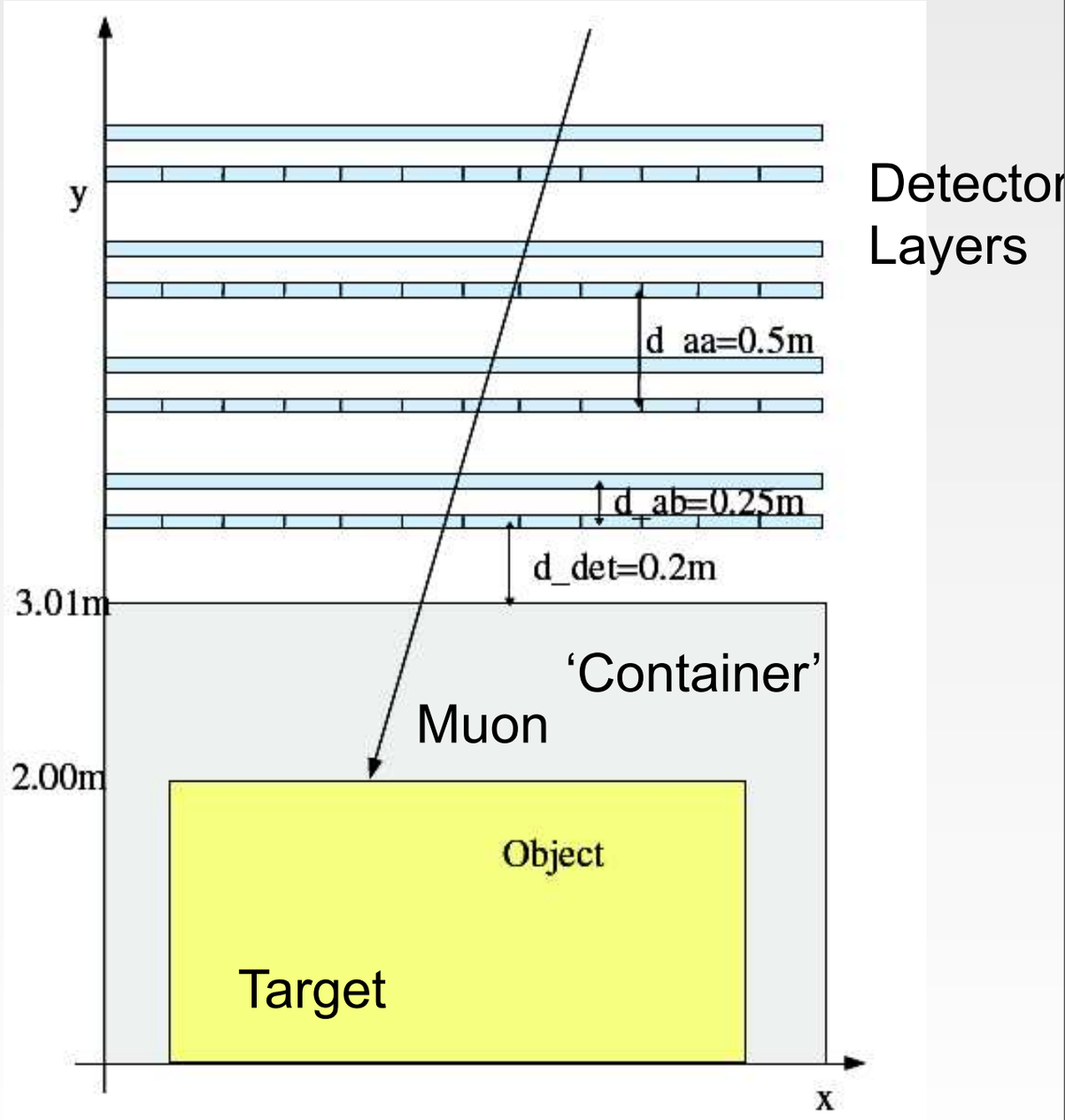
Initial Results -- Scattering

- Six Minute Exposure



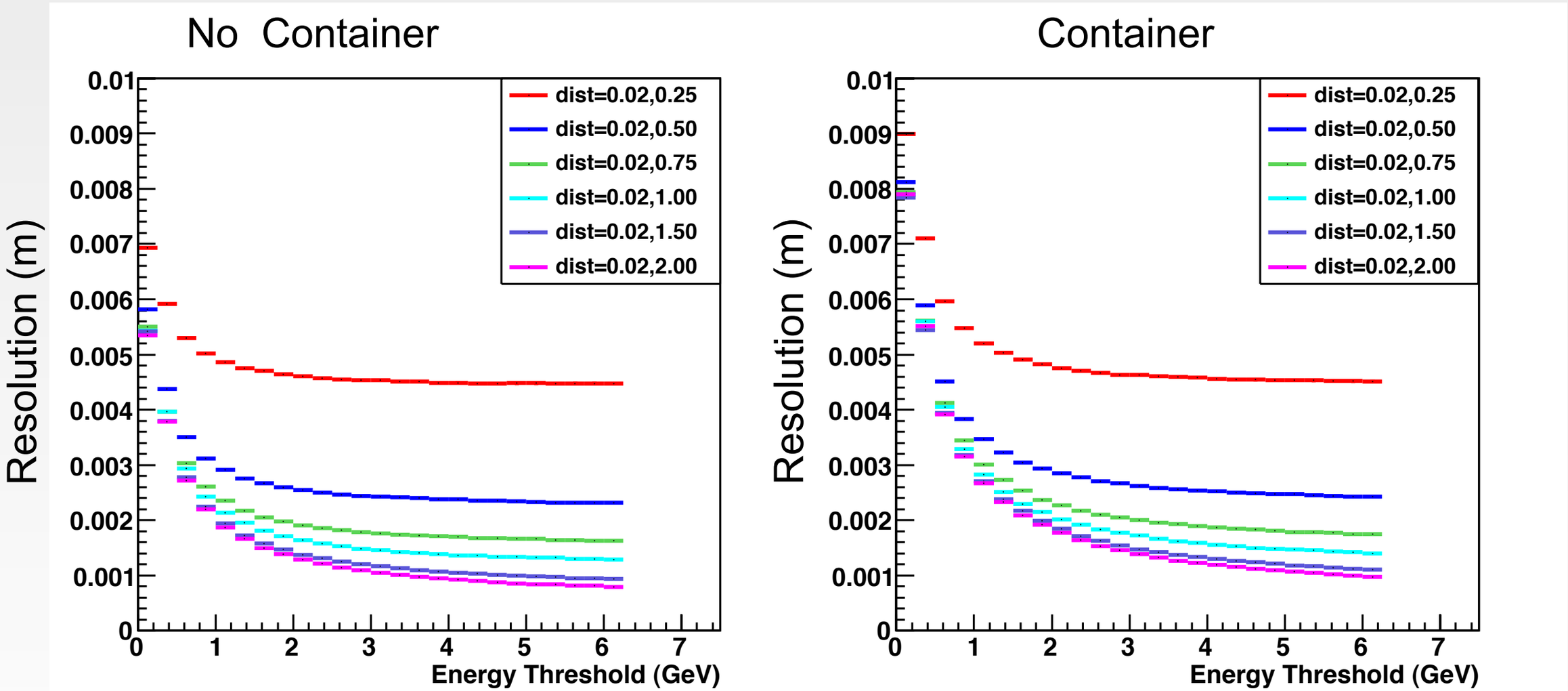
Detector Optimisation Studies

- A number of detector parameters have been investigated
  - Number of detector layers
  - Separation of layers
  - Detector resolution
  - Detector material
- Using
  - Realistic energy and angular spectra
  - Multiple scattering in detector and target (i.e shipping container walls)



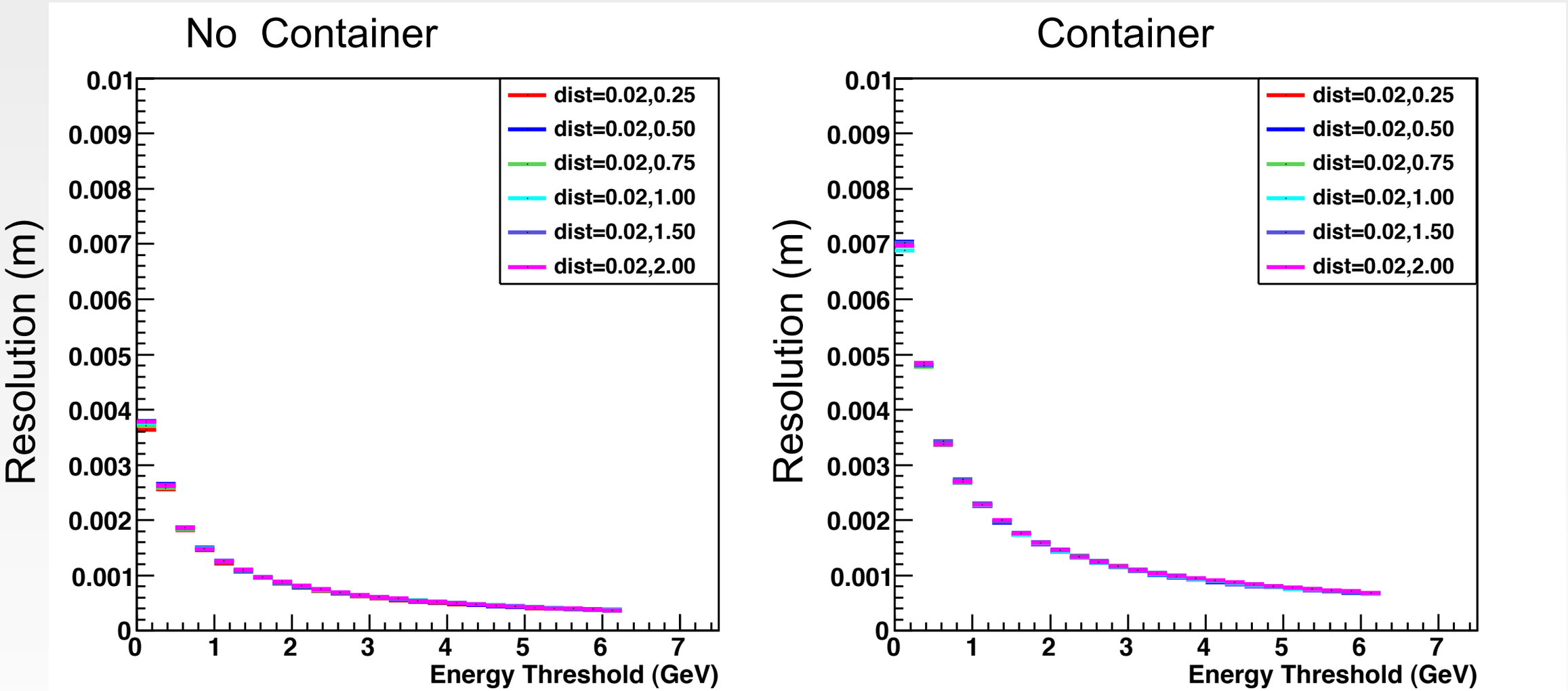
Two Layer Scintillator Resolution

- The resolution at the target for two layers of scintillator detector



Two Layer Drift Chamber Resolution

- The resolution at the target for two layers of drift chamber detector



- Drift chamber modelled as 2mm of scattering material with 1 micron resolution

Detector Optimisation

- The optimal detector consists of
  - two layers of detectors
  - separated by as large a distance as possible
  - increasing detector position resolution allows one to reduce the separation between detector layers
- Multiple scattering in the detectors limits resolution
  - Particularly below 1-2 GeV
- The walls of the container (2mm steel) provide an additional limit to the optimal sensitivity
- The GEANT4 simulation studies will be updated using an optimised detector geometry

Test Stand Construction Progress

‘Test Stand’ Stand

Scintillator Modules

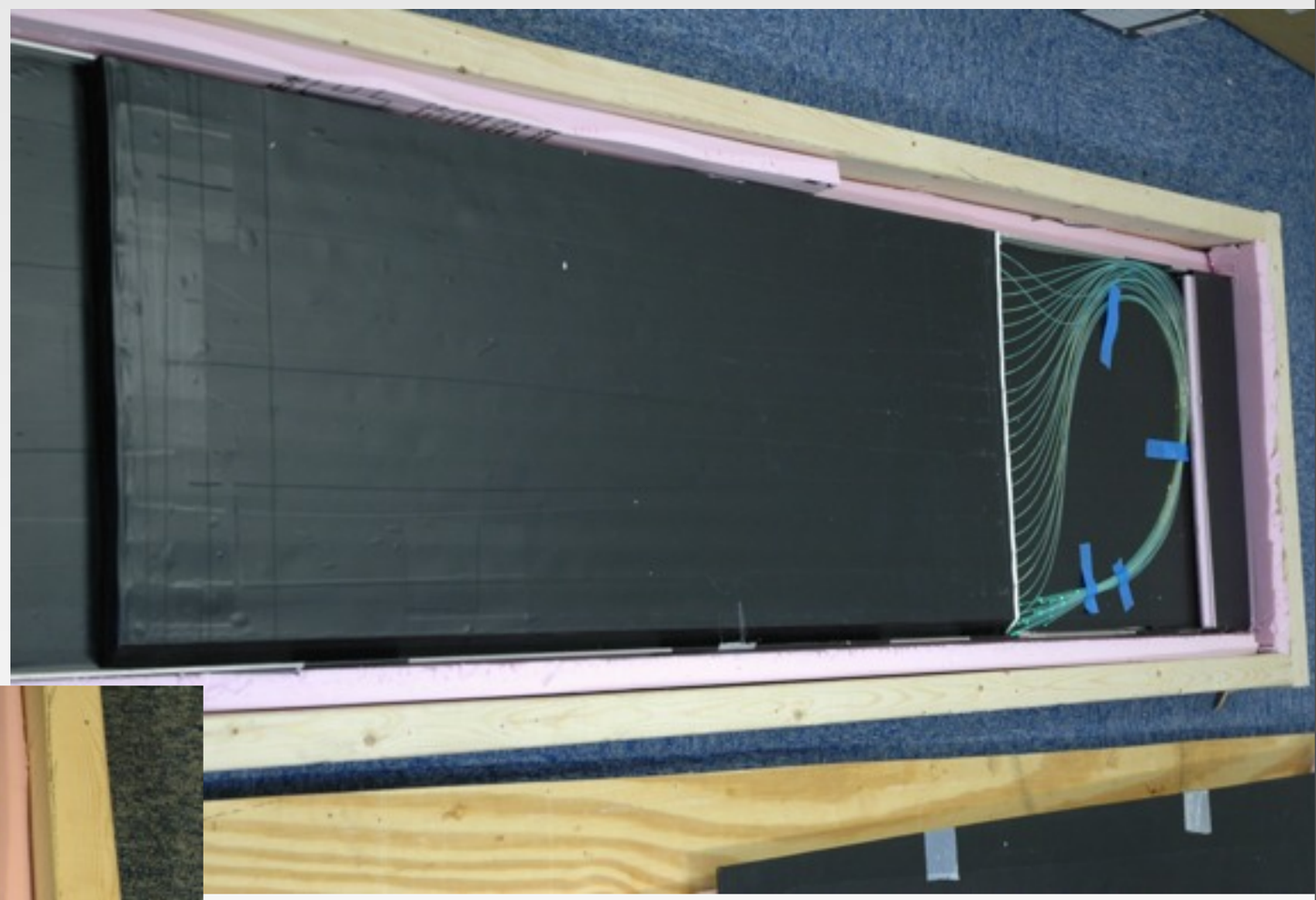
4xTARGET Digitiser

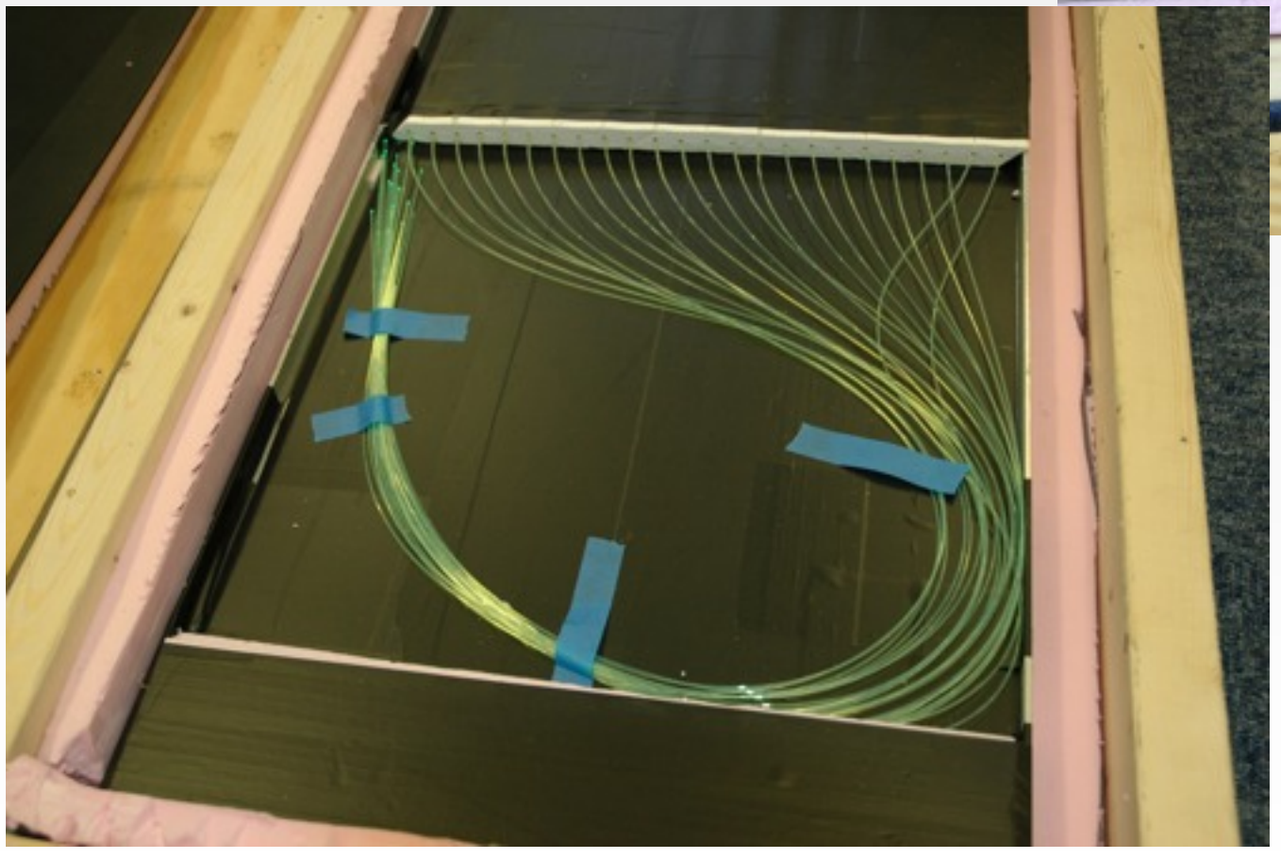
64 Channel PMT

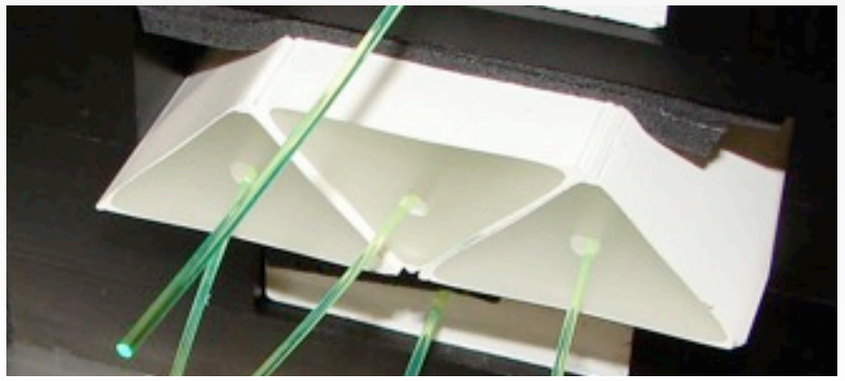
Readout Cables

New Scintillator Planes

- First evaluation models are in the laboratory in MSSL







UCL Muon Tomography Summary

- Preliminary studies have shown that muon tomography techniques can be applied to security areas
- We have moved from a feasibility stage to a detector optimisation stage
- The test stand construction at the ν-lab at MSSL is proceeding well
- Extra funds would enable
  - construction and testing of higher resolution scintillator planes
  - the addition of a muon spectrometer below the test stand
  - an increase on the 256 PMT/electronics channels currently in testing