A Geant4 simulation tool for a muon tracker prototype

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Outline

- Geometry of the muon tracker using plastic scintillators
- Physics lists and readout in simulation
- Track reconstruction algorithm
- Preliminary results and prospects

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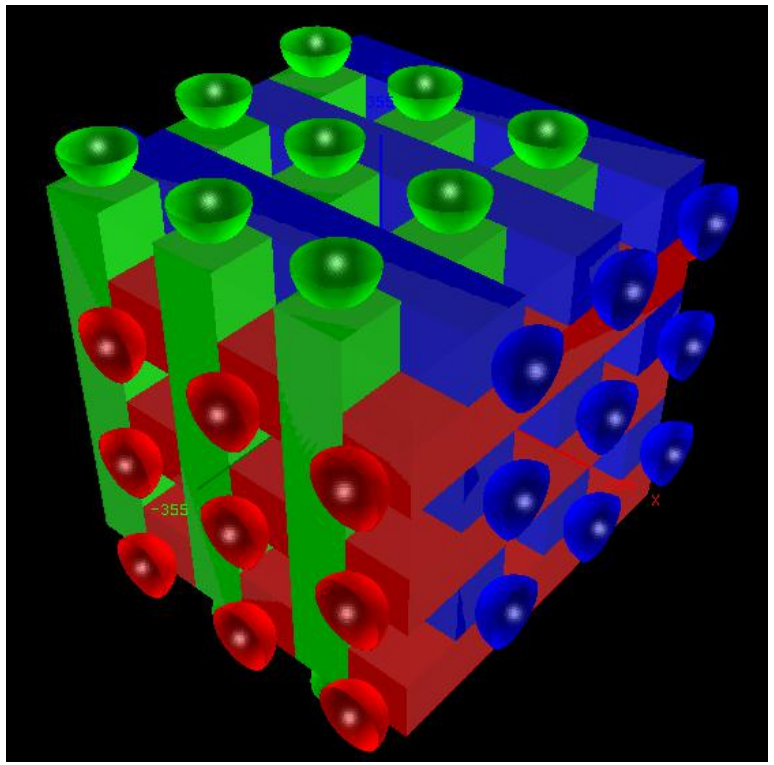
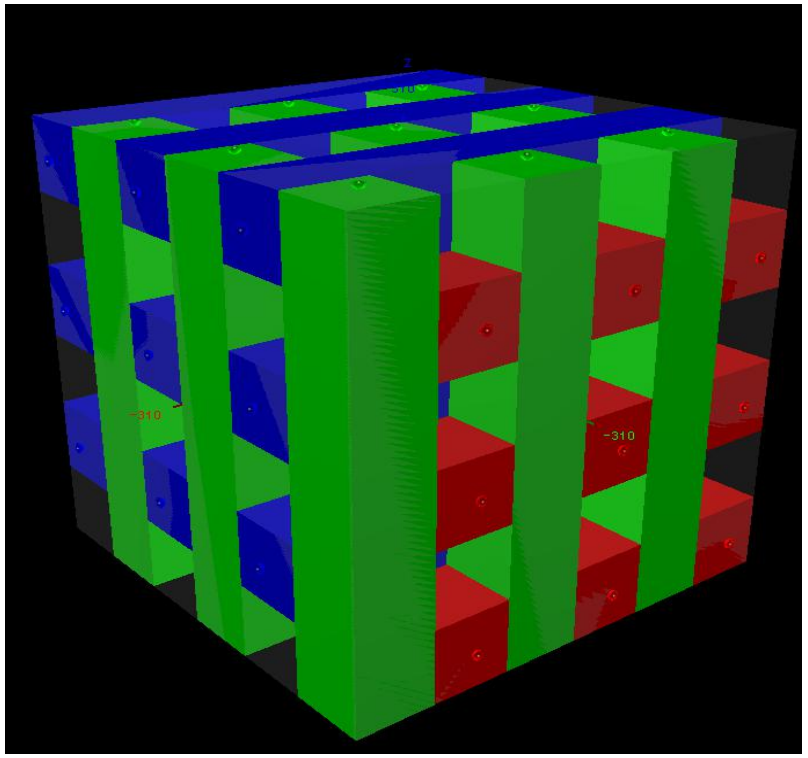
Geometry of the muon tracker using plastic scintillators





Cuboid plastical scintillator with height of 600 mm and length and width of 100 mm is the target material.orthogonal arrangement plastical scintillator(total 27), each of which is wrapped in a reflective film.At each end of the plastical scintillator, a PMT(left) or SiPM(right) is used as a light readout sensors. SiPM receives photons generated in each scintillator independently.

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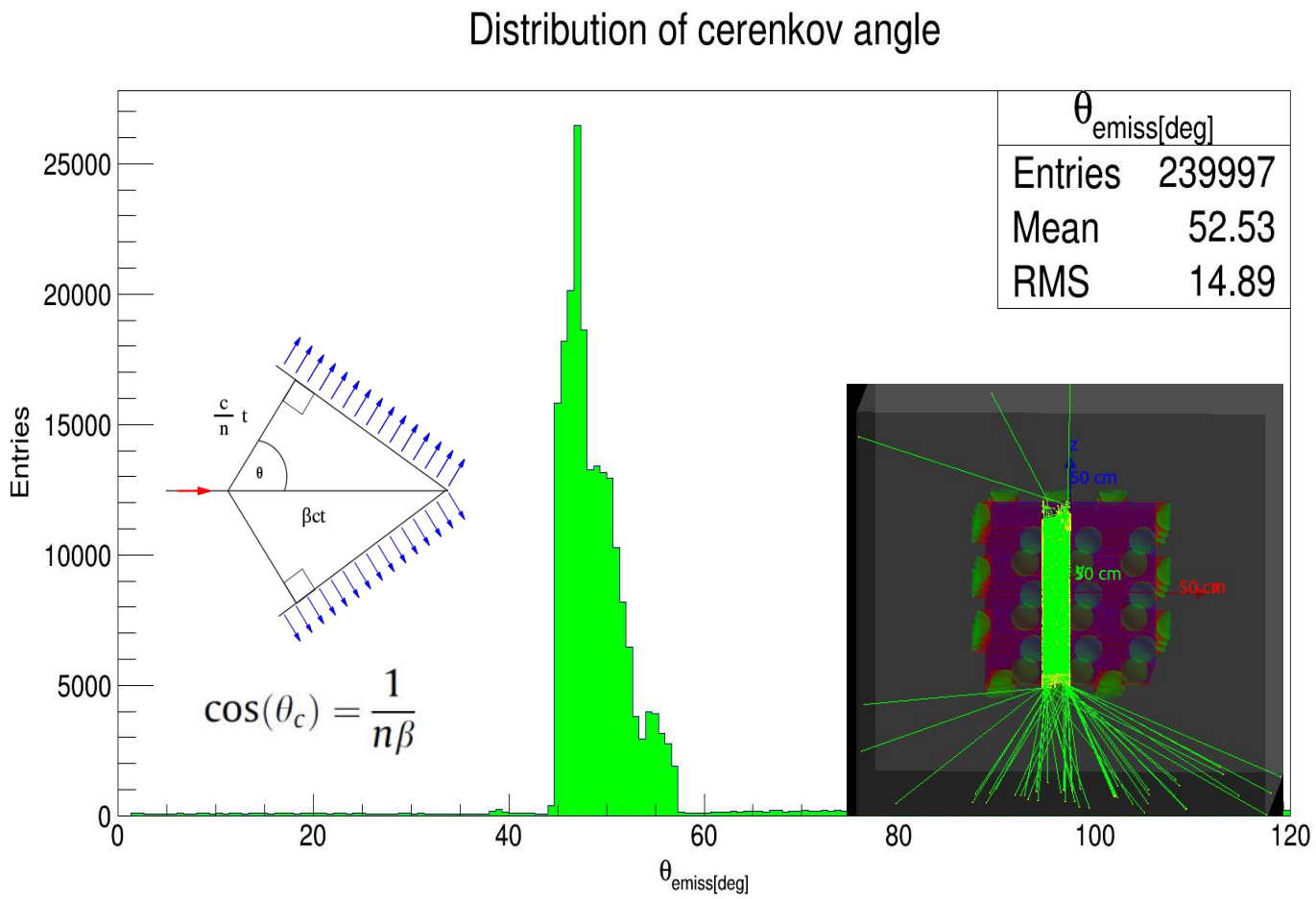
Physics lists in simulation

- Physical process of multiple scattering of Mu with matter, photonuclear process, ionization interaction, bremsstrahlung process.

- Optical physical processes: scintillation process, Cherenkov process, Rayleigh scattering and so on.

- Photon transport process. Boundary process: including refraction, reflection and absorption.

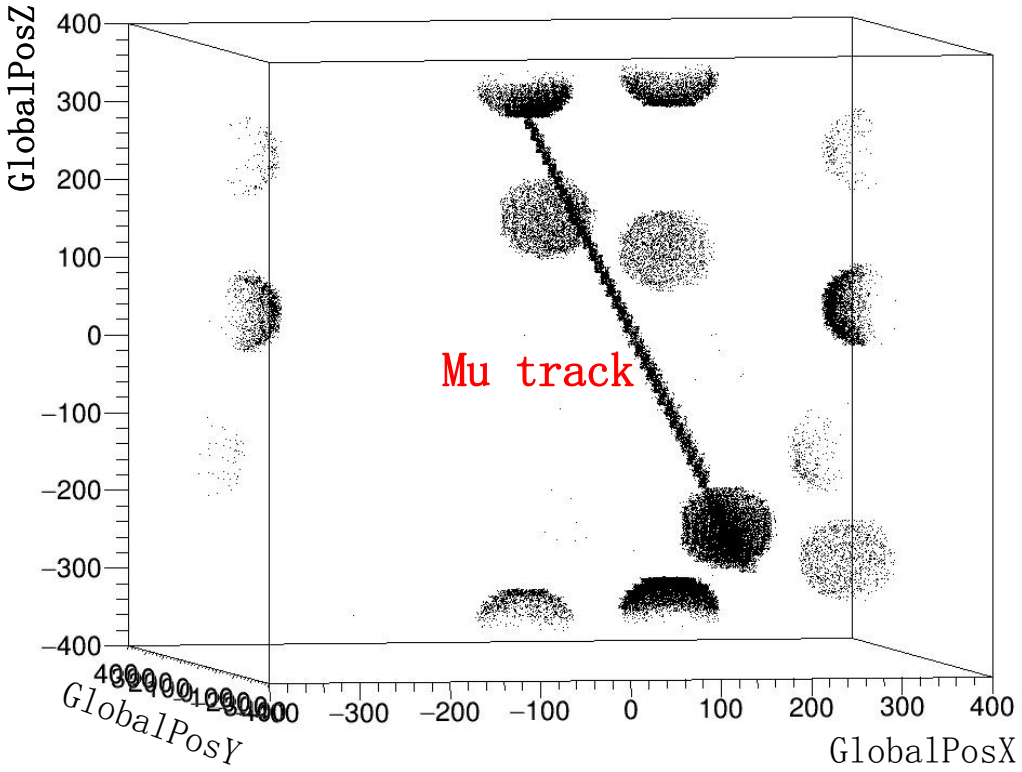
Physics lists in simulation



The angular distribution of cerenkov photons generated by muons of energy 1 GeV crossing scintillator.
This is in agreement with the theoretical calculation of the Cherenkov angle

Readout in simulation

Muon with kinetic energy of 1 GeV, initial position (-50mm, -50mm, 310mm), direction vector (0.5, 0.5, -1)



The simulation of Mu passing through the scintillator will produce many photons. The left figure is a three-dimensional picture of the hit PMT. It contains the information of the PMT hits (including the number of photons and the time of the photon hit) that are to be used in the reconstruction.

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Method of Reconstructing Position Point

- Reconstruction of the location of the Scintillator hit by muon.By fitting these points, we can get a straight line in space, that is, muon's track.
- Reconstruction method: barycenter

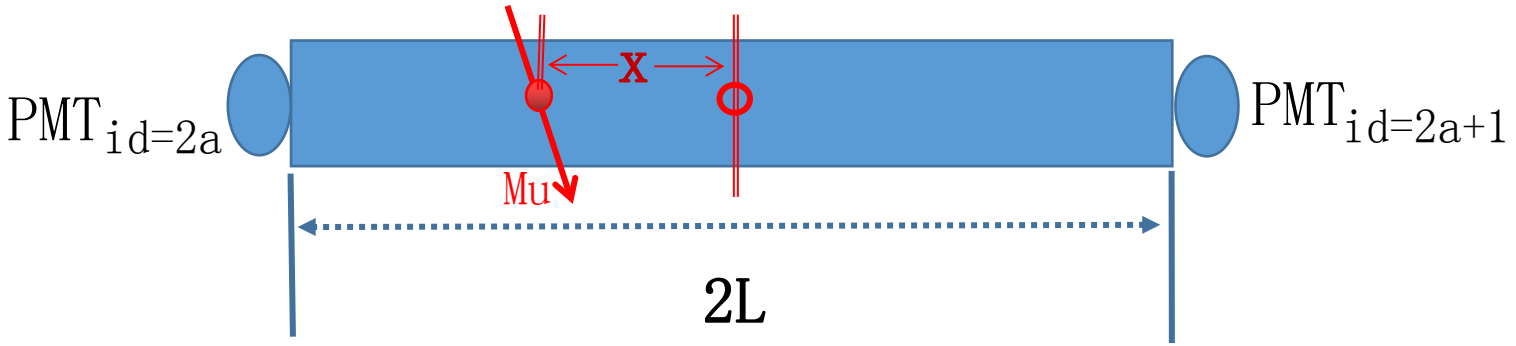
$$Pos_{x,y,z} = \frac{nPhotons[PMT_{id=2*a}] * Pos[PMT_{id=2*a}] + nPhotons[PMT_{id=2*a+1}] * Pos[PMT_{id=2*a+1}]}{nPhotons[PMT_{id=2*a}] + nPhotons[PMT_{id=2*a+1}]}$$

$$nPhotons[PMT_{id=2*a}] : Numbers\ of\ photons\ in\ PMT\ which\ it's\ id\ is\ 2*a.$$
$$Pos[PMT_{id=2*a}] : Position\ of\ the\ PMT\ which\ it's\ id\ is\ 2*a.\ a \in [0, 26]$$

This method is simple, but the quality of reconstruction depends on the reflectivity of film, the light yield and the attenuation length of plastic flash.

Method of Reconstructing Position Point

- Reconstruction of the location of the Scintillator hit by muon. By fitting these points, we can get a straight line in space, that is, muon's track.
- Reconstruction method: using the first hit time



$$L + x - (L - x) = 2x = \frac{(t1 - t2) * c}{n}$$

c : *Speed of photons in vacuum*

n : *Refractive index of plastic scintillator*

This method has nothing to do with the properties of the reflective film and the light yield of the scintillator. But it needs PMT or SiPM with high time resolution, which can not be achieved in reality. So all of our subsequent reconstruction methods are barycenter.

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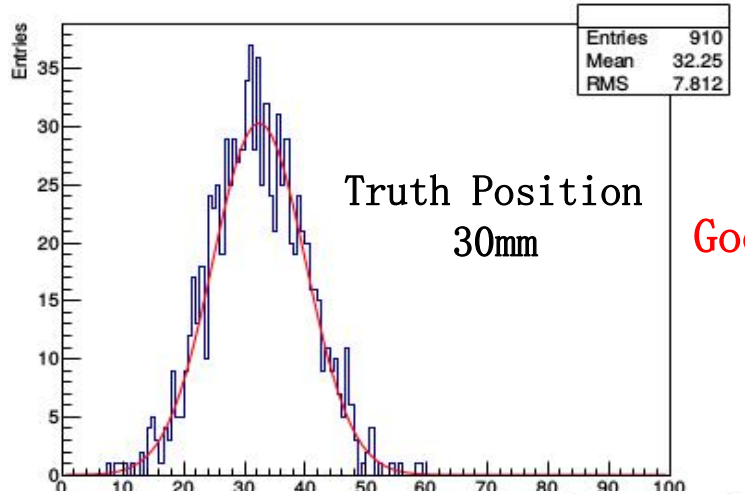
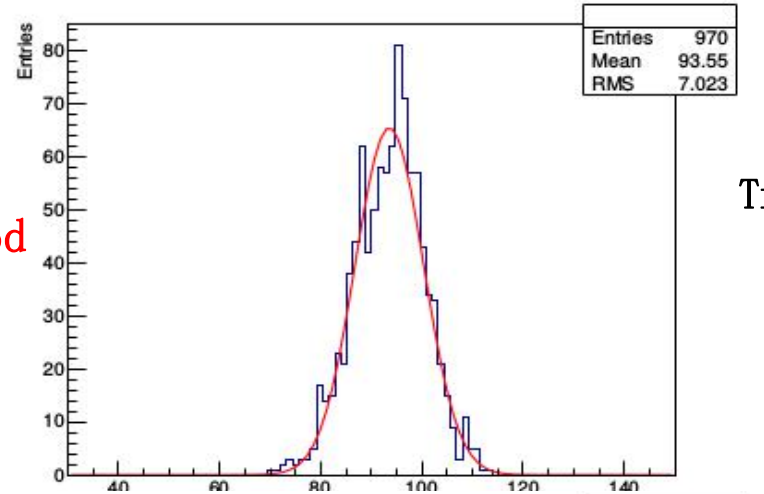
The effects of reflectivity of film on Reconstruction of the position

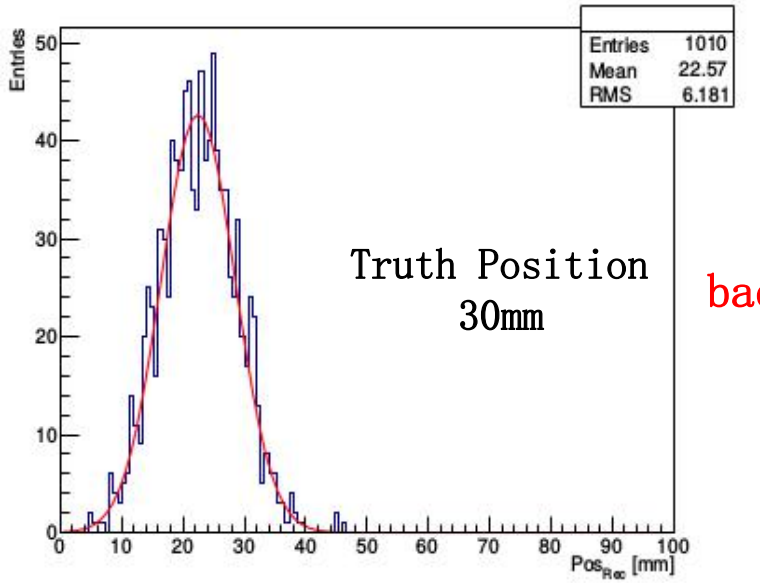
Reflectivity:0.3



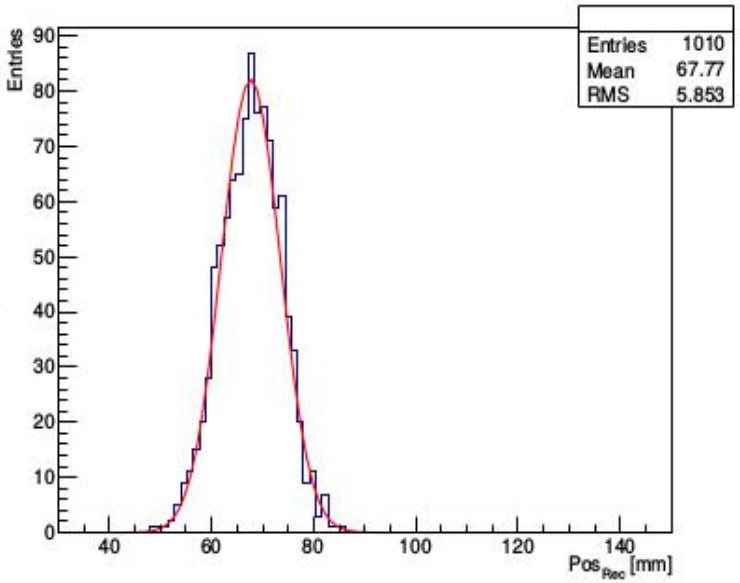
Good



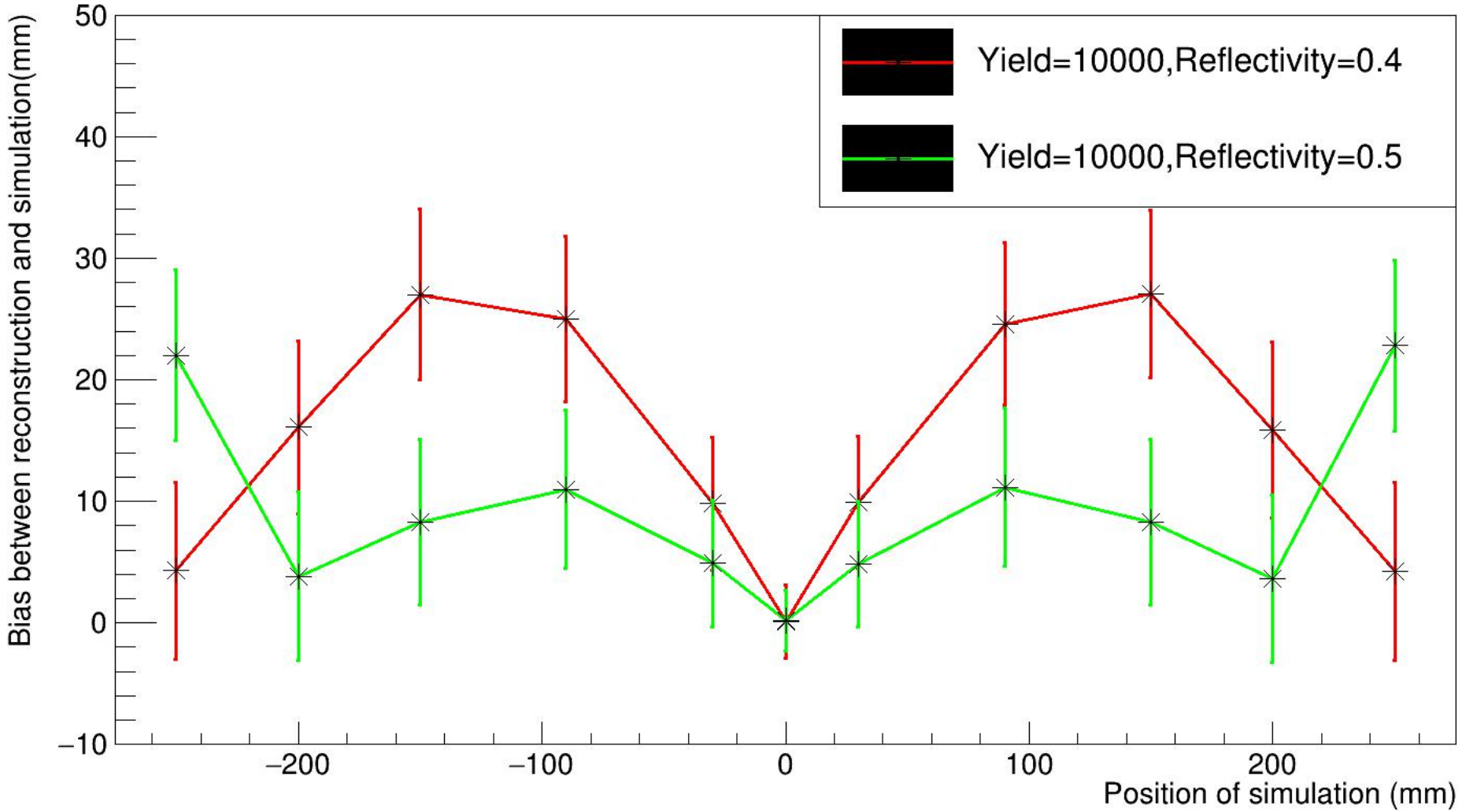
Reflectivity:0.7



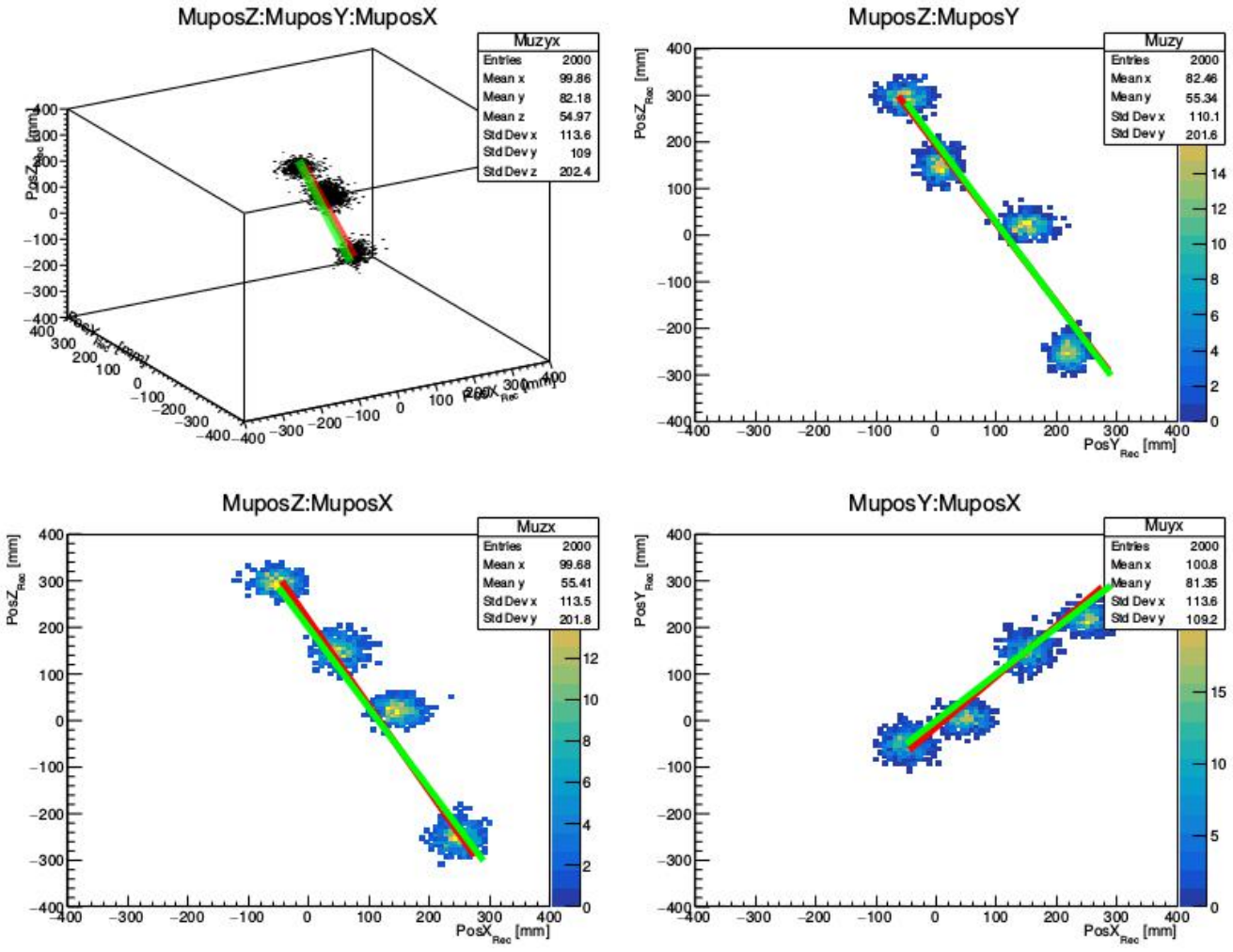
bad



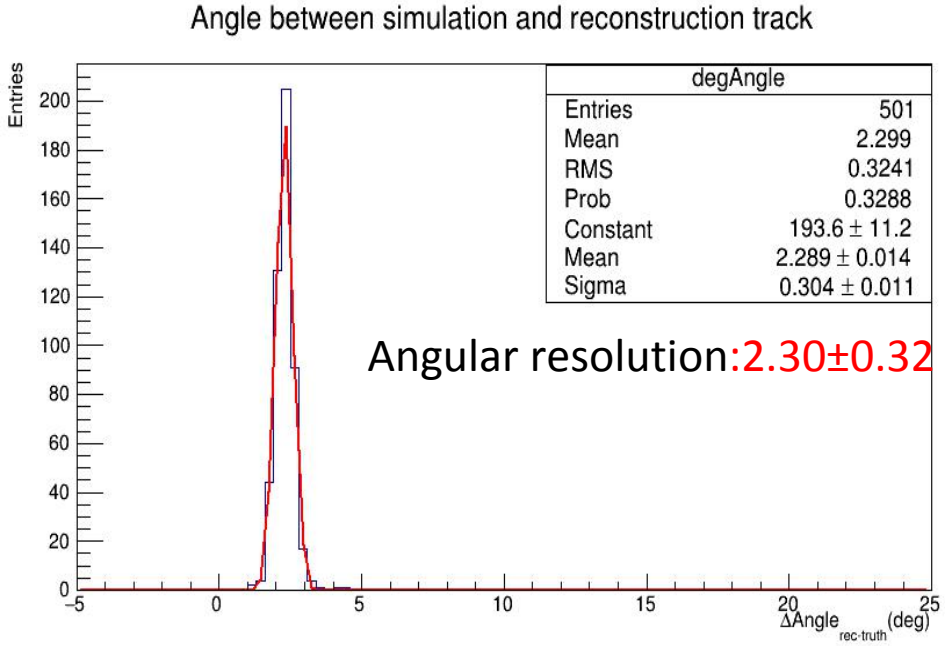
Bias between point of reconstruction and simulation will affect fitting of track



Preliminary results and prospects

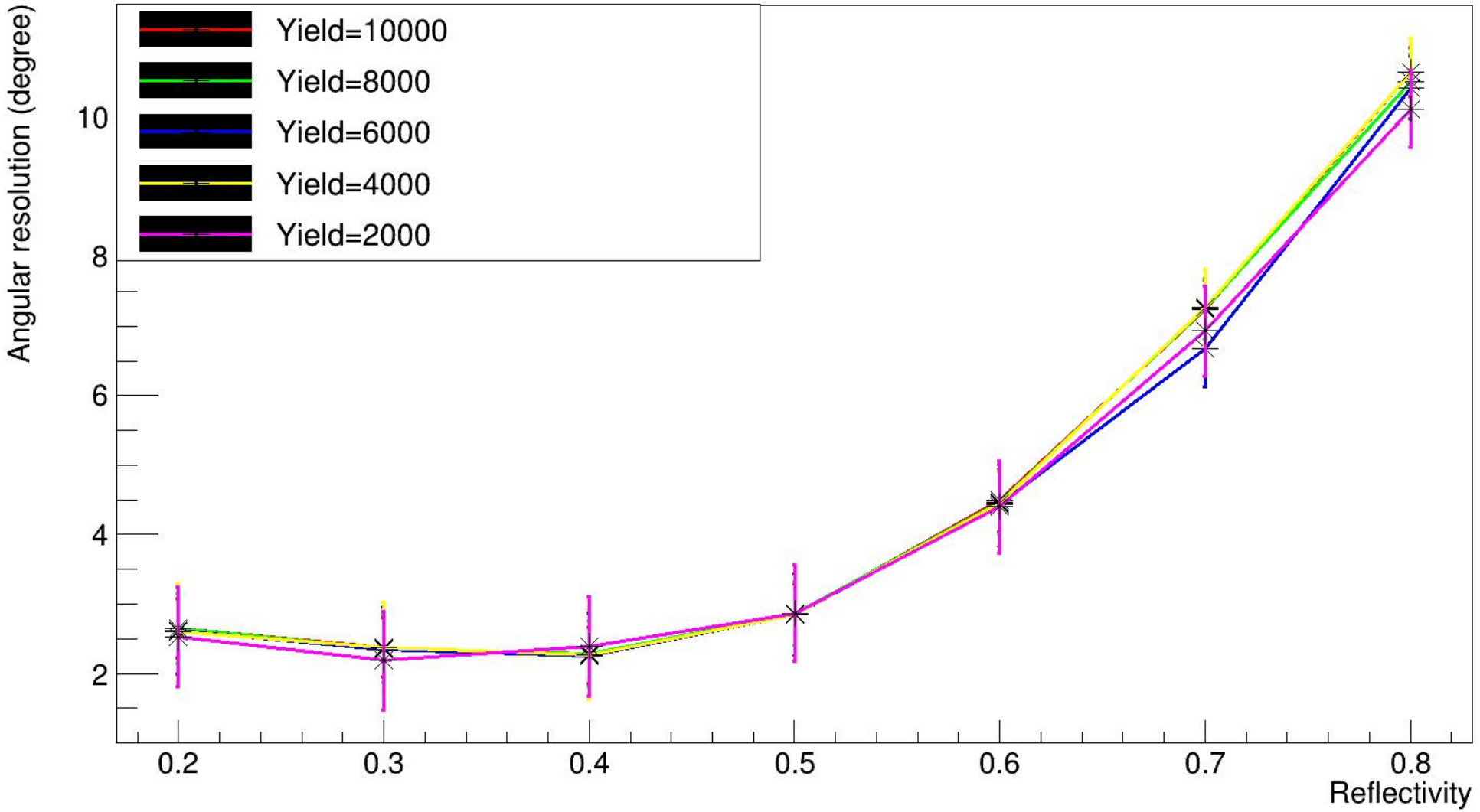


Clusters(reconstruction point) are reconstructed by barycenter method. Red lines are simulated Mu tracks and green lines are reconstructed mu tracks.



Angular resolution:2.30±0.32

The effects of reflectivity of film on angular resolution

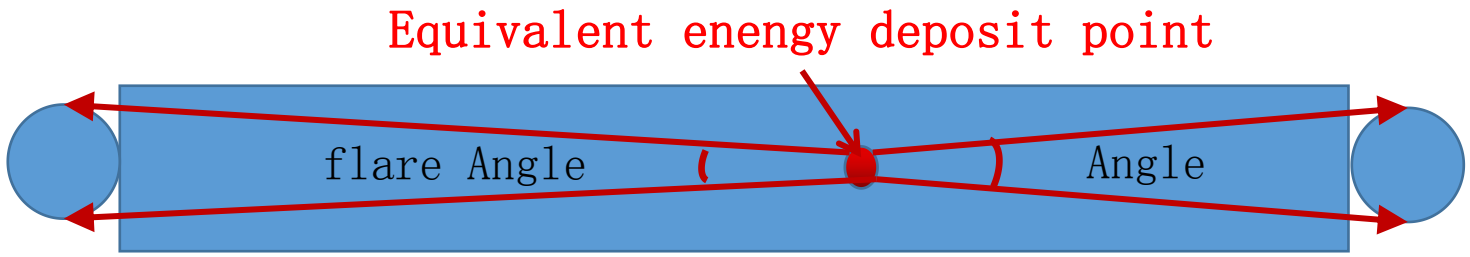


Prospects

- Improve reconstruciton methed to achieve better angular resolution.
- Angular resolution distribution spectrum：
  - with attenuation length of plastical sintillator
  - with Size of sintillator and SiPM(PMT)
  - with muon different incident angles

Thank you very much

Backup



Reasons:

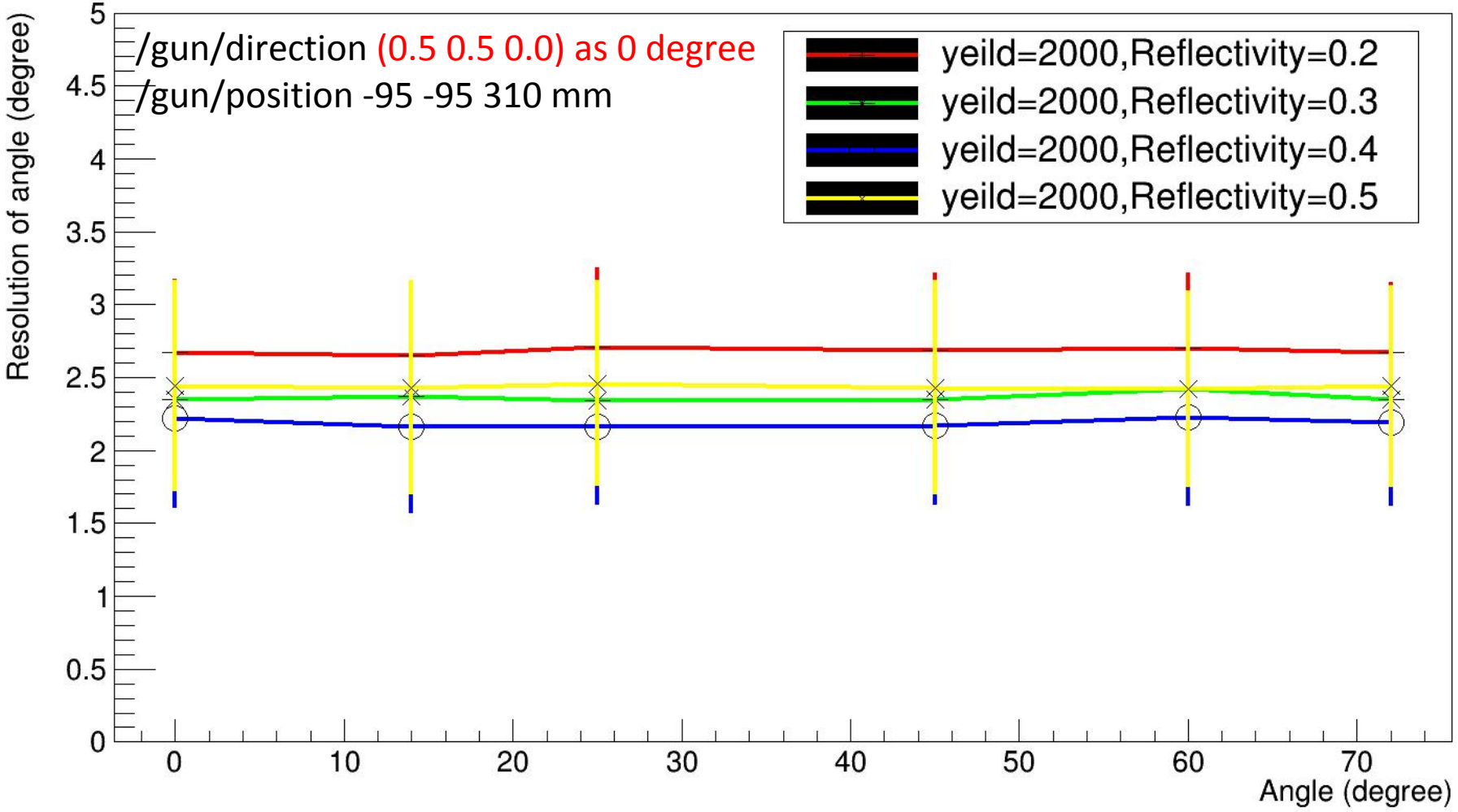
Attenuation length(scintillator)

Yield(scintillator)

Reflectivity(film)

Details are under investigations

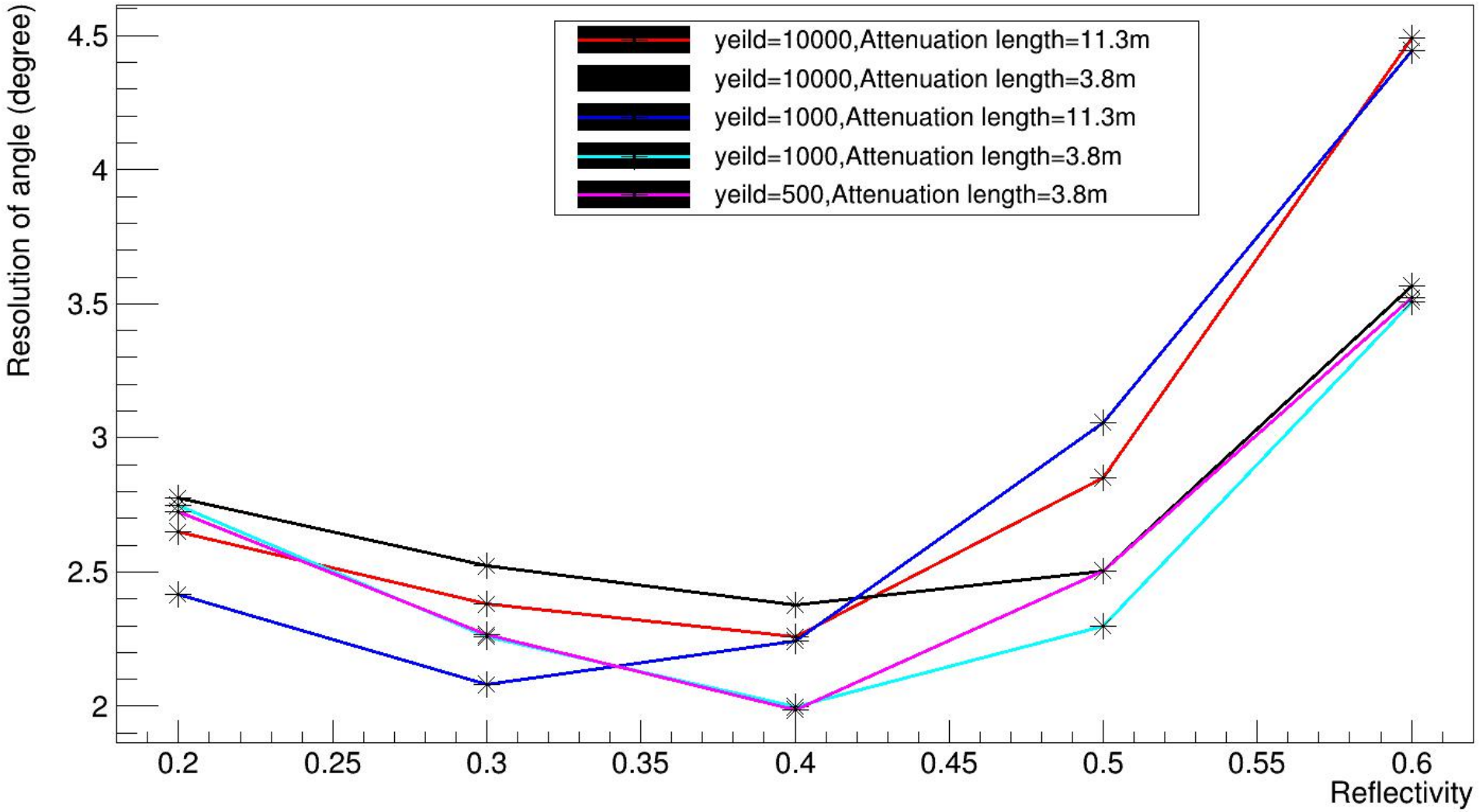
Angular resolution distribution spectrum with muon different incident angles



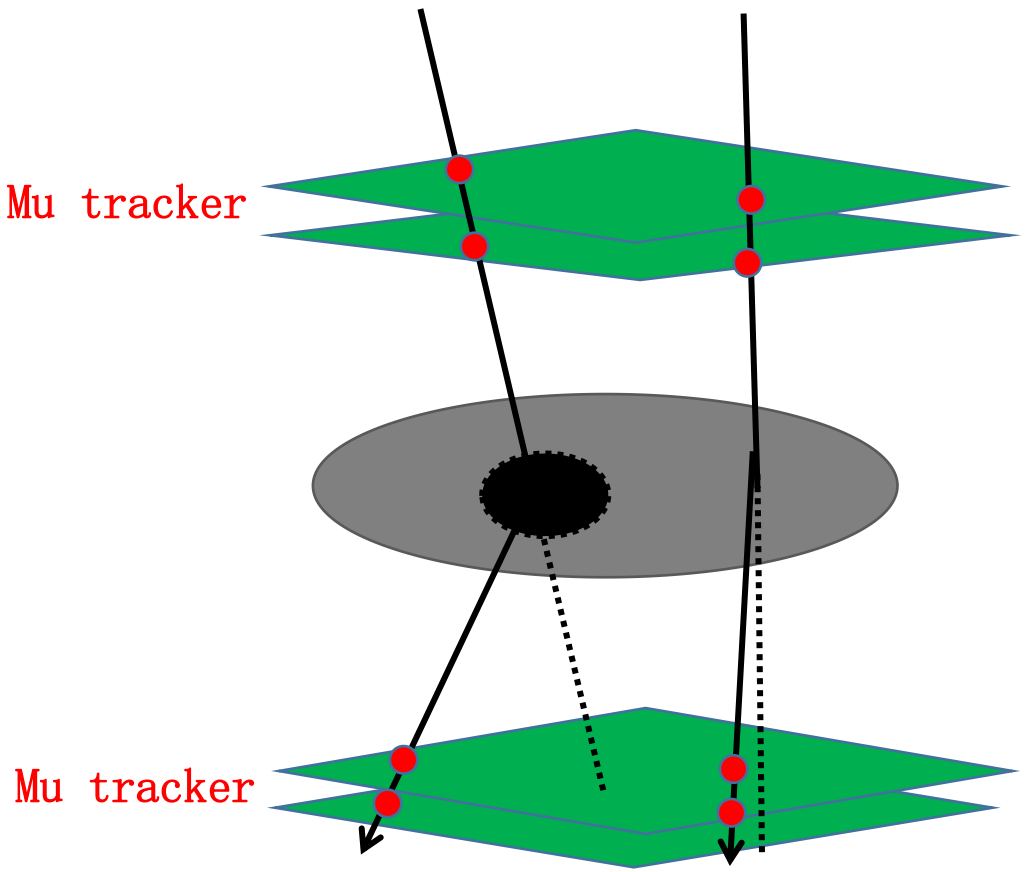
Keep the X and Y directions unchanged and change the Z direction.

for example: (0.5,0.5,1) as 90 degree

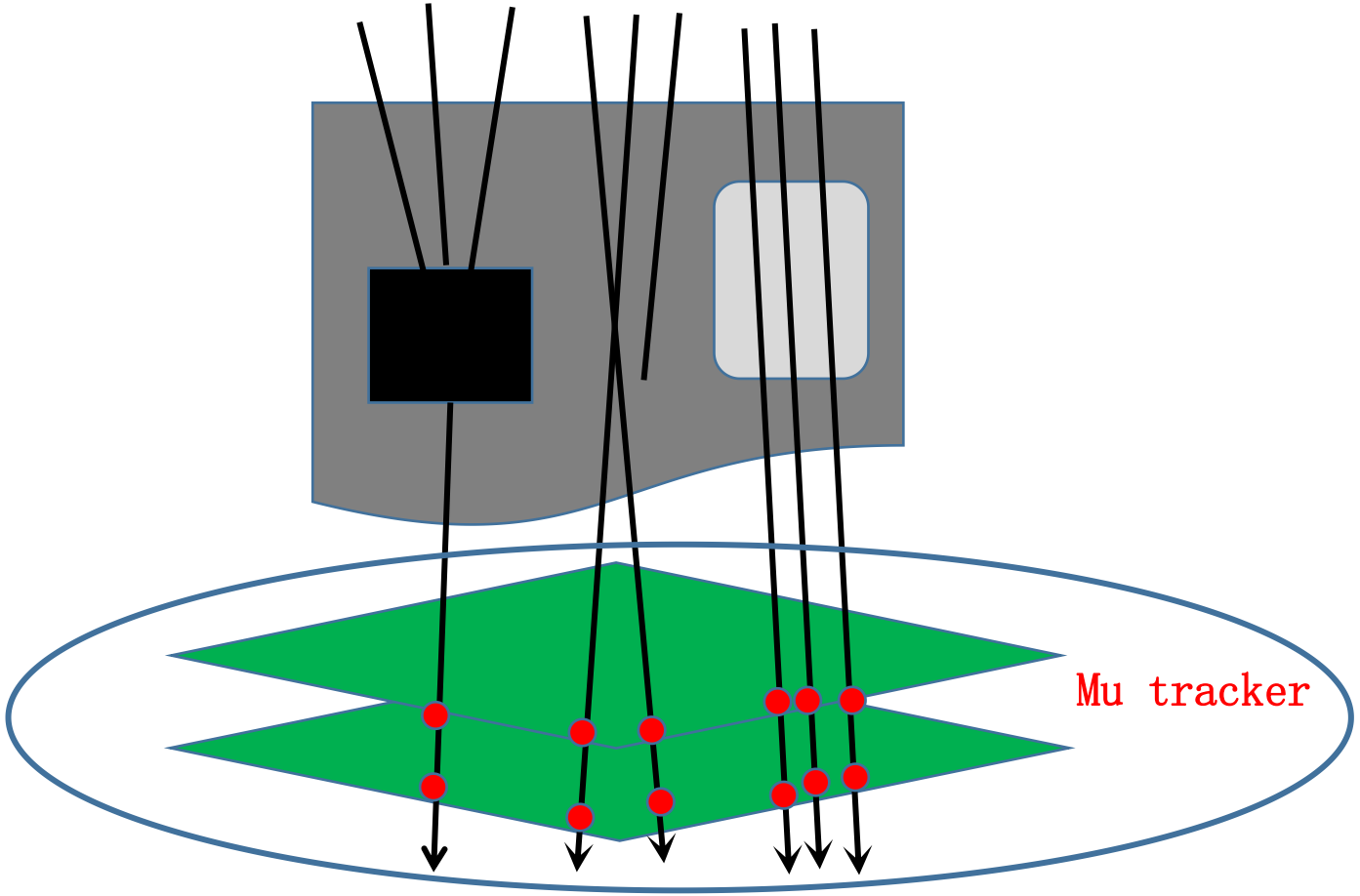
The effects of Attenuation length of scintillator on angular resolution



Introduction of Muon Imaging Methods



Deviation (Muon Tomography)
Multiple Coulomb Scattering



Transmission and Absorption
Radiography

Application of muon imaging

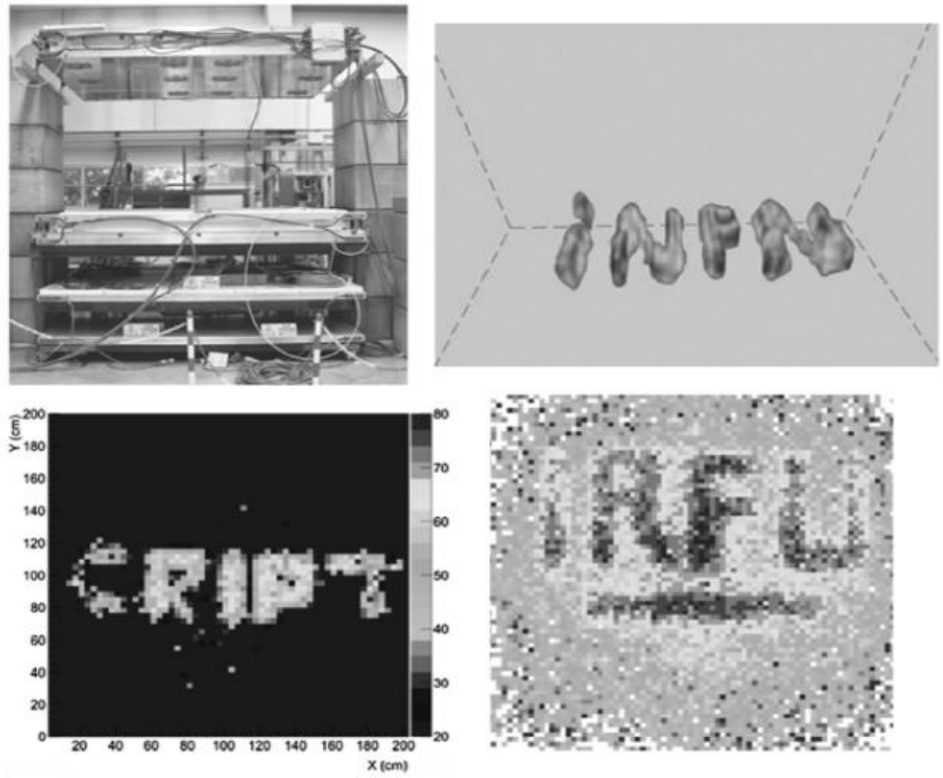


Fig. 13. (Top left): one of the largest muon scanners in the world, at INFN Legnaro, and images obtained with Lead bricks using the Legnaro (top right), CRIPT (bottom left) and Irfu (bottom right) scanners.

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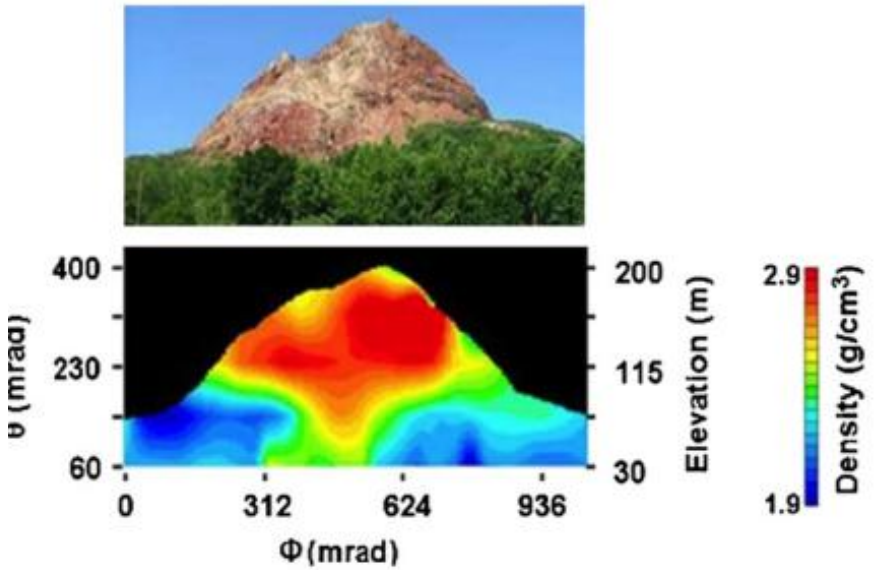
http://dx.doi.org/10.1016/j.nima.2017.08.004



ig. 7. Top: view of the Showa-Shinzan lava dome. Bottom: average density istribution projected onto the detector's plane.

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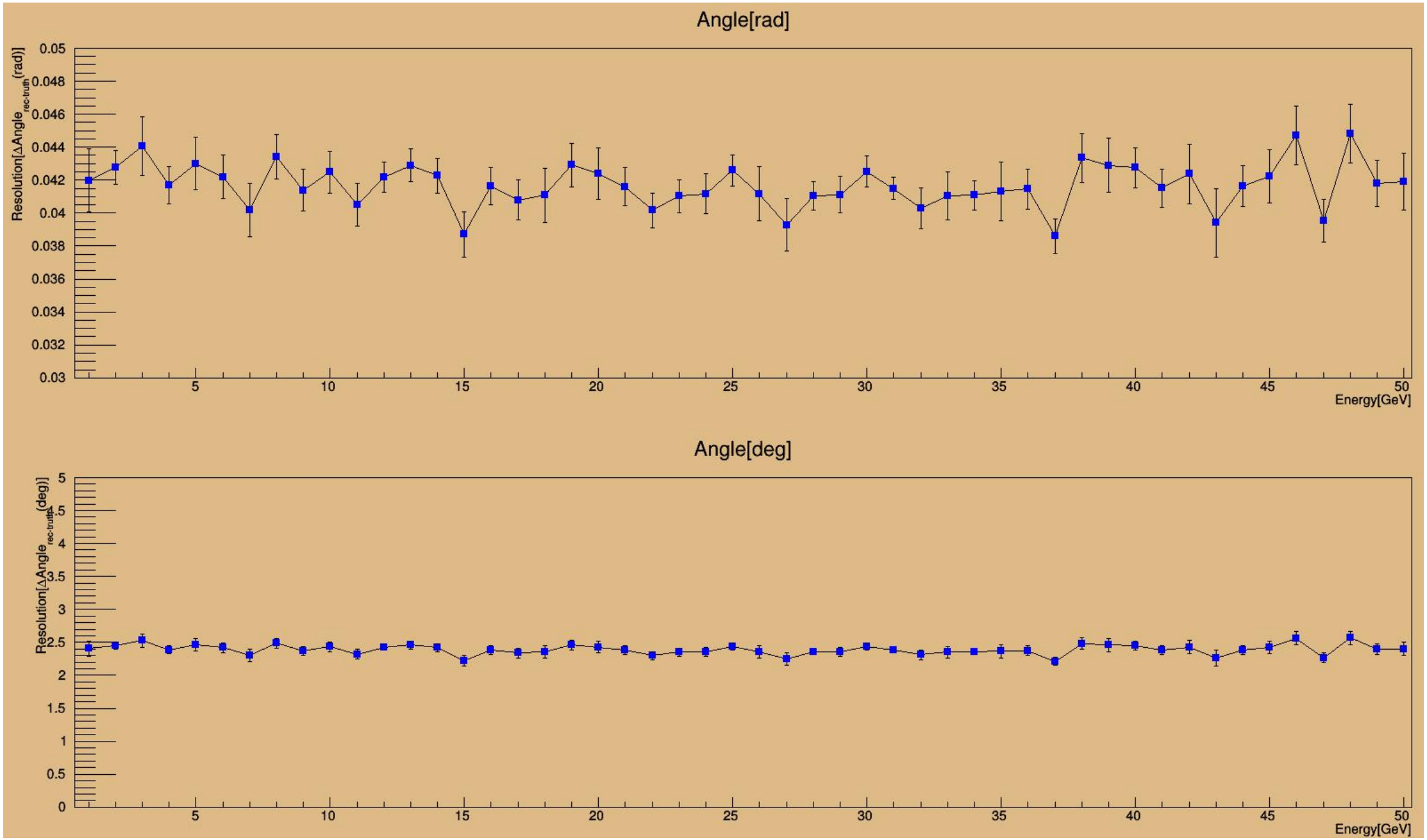
doi:10.1016/j.nima.2011.11.061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0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
5
10
15
20
25
30
35
40
45
50
Energy[GeV]
Angle[deg]
Resolution[ΔAngle rec-truth (deg)]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
5
10
15
20
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30
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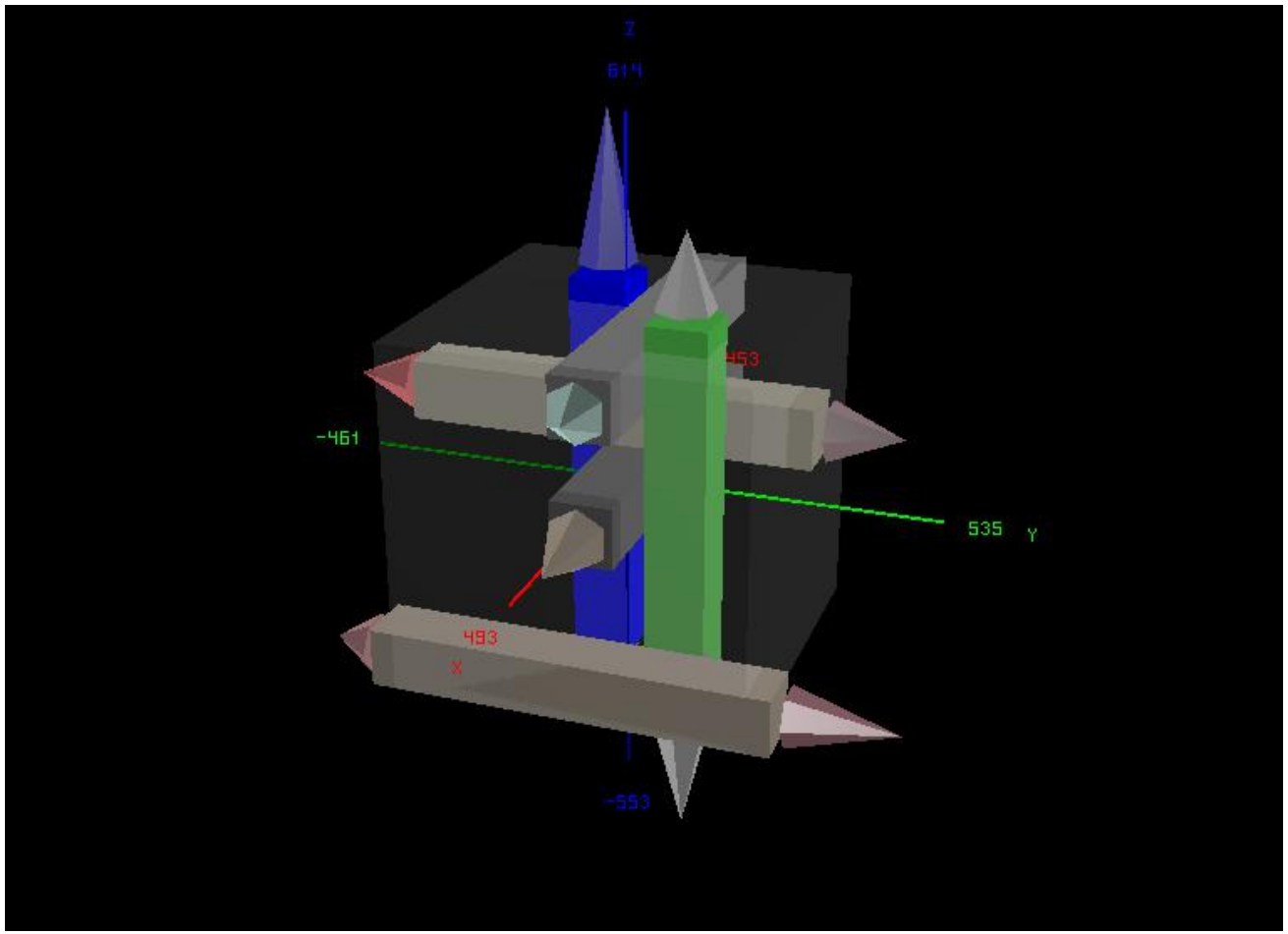
40
45
50
Energy[GeV]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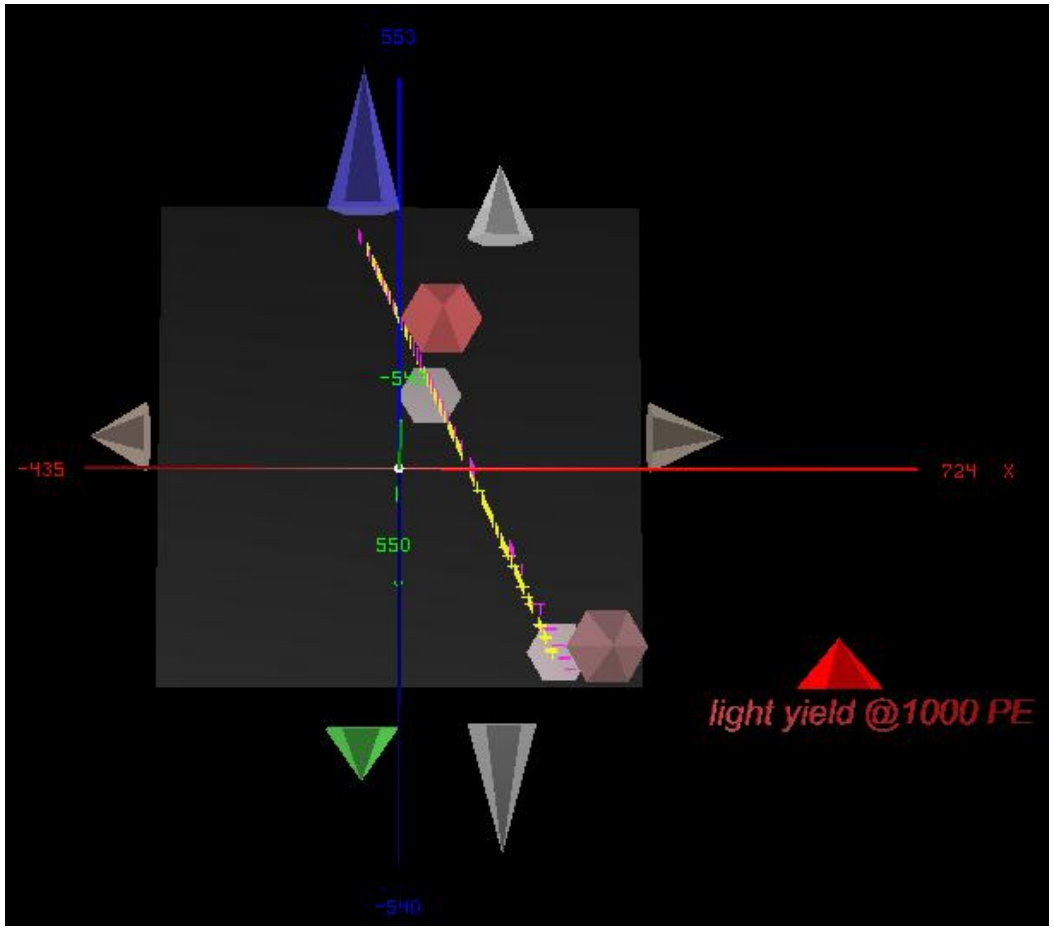
-461
535
Y
483
X
-553


553
-435
724
X
550
-540
light yield @1000 PE