Track reconstruction for LoI

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Introduction - *reminder*

- relatively simple topology of $\mu e \rightarrow \mu e$ scattering

  $\rightarrow$ 3 tracks to be reconstructed:

  - incoming muon before target

  - outgoing electron and muon after target

- detector setup assumes rather clean physics environment

  $\rightarrow$ low detector occupancy

  $\rightarrow$ no hardware-based trigger

- boosted kinematics of the collision $\rightarrow$ *cover large part of acceptance*

- time structure of the beam $\rightarrow$ *keep the background at low level*

- in practice no CPU time limit

  $\rightarrow$ track reconstruction can be treated as offline-like

  $\rightarrow$ quality of the track reconstruction can be maximized

  $\rightarrow$ it can boost much the reconstruction efficiency and precision

Pattern recognition - *reminder*

GOAL → maximum possible track reconstruction efficiency!

- first stage - performed in the *x-z* and *y-z* projections

  → *constructing pairs from all the combinations of hits in x, y and stereo layers separately*

- two-dimensional lines in *x-z* or *y-z* projections for each pair of hits
- for each 2D line collect all the hits within a certain window
- at least 3 hits to accept 2D track candidate
- no unique combinations of hits forming two-dimensional lines imposed
- use robust fit to the selected 2D lines in *x-z* or *y-z* projections

  → *reconstruct 2D tracks*

- fast fitting procedure with removal of outlier hits

  → *assumed uncertainties of the x and y hit positions as in detector layout*

- all fitted *x-z* and *y-z* lines will be paired to create 3D lines
- all 3D lines will be fitted using least square method

  → *using all hits collected within a certain window wrt initial 3D line*

Track reconstruction in 3D - *reminder*

- all combinations of 2D line segments will be combined into 3D track candidates

  $\rightarrow$ no prior requirements on quality of such combinations
  (to maximize reconstruction efficiency)

- for each 3D track candidate initial parameters of 3D line determined from corresponding 2D lines

  $\rightarrow$ seed for track fitting

- iterative fitting procedure using a least square method

  $\rightarrow$ all hits along initial trajectory collected within a certain window

  $\rightarrow$ after each iteration outlier hits will be removed and the fit will be repeated until no outlier is found

  $\rightarrow$ at least 3 hits in x-z and 3 hits in y-z projections to accept the track

- clone removal procedure

  $\rightarrow$ tracks with largest number of hits accepted first

  $\rightarrow$ *(if same nr of hits)* minimum χ^2/ndf

- after accepting a track hits used by this track will be marked as used

MC samples used

Purely LO elastic events with monochromatic incoming muon energy = 150 GeV

- samples with 2 and 5 modules tested *(provided by Umberto)*
- 1 module = 1 Be target of 1 or 2 cm thickness + 3 tracking stations
- 1 tracking station = 4 Si sensors (2x + 2y) of 330 μm thickness

Module = 1 target + 6 detectors

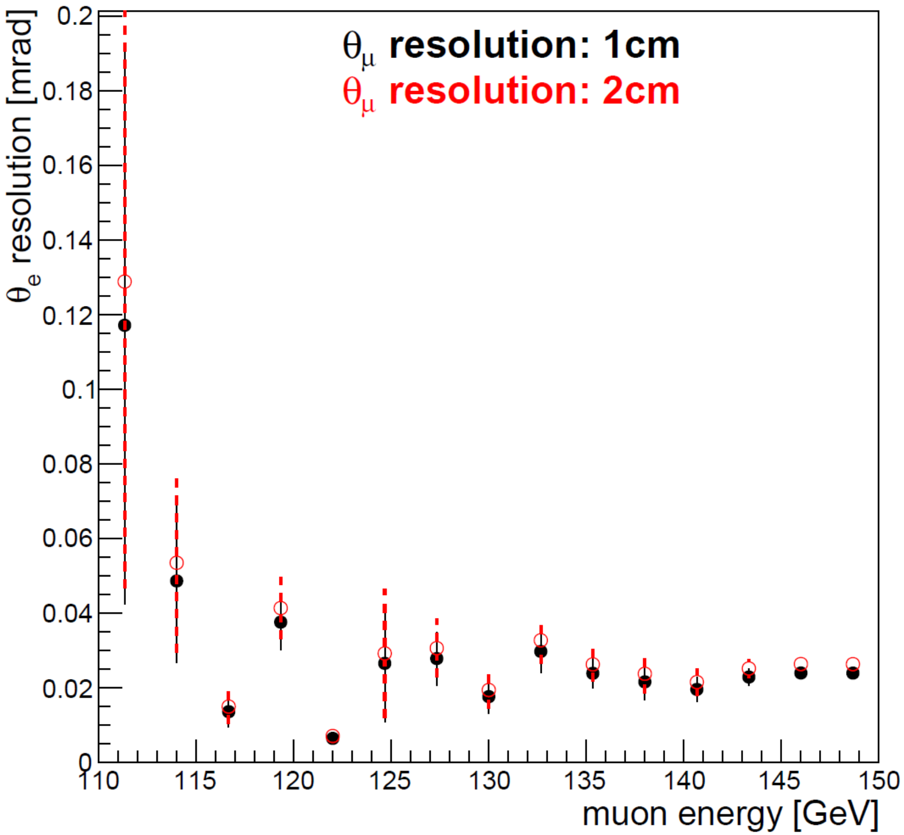
- level arm is L=1m between first and last tracker station

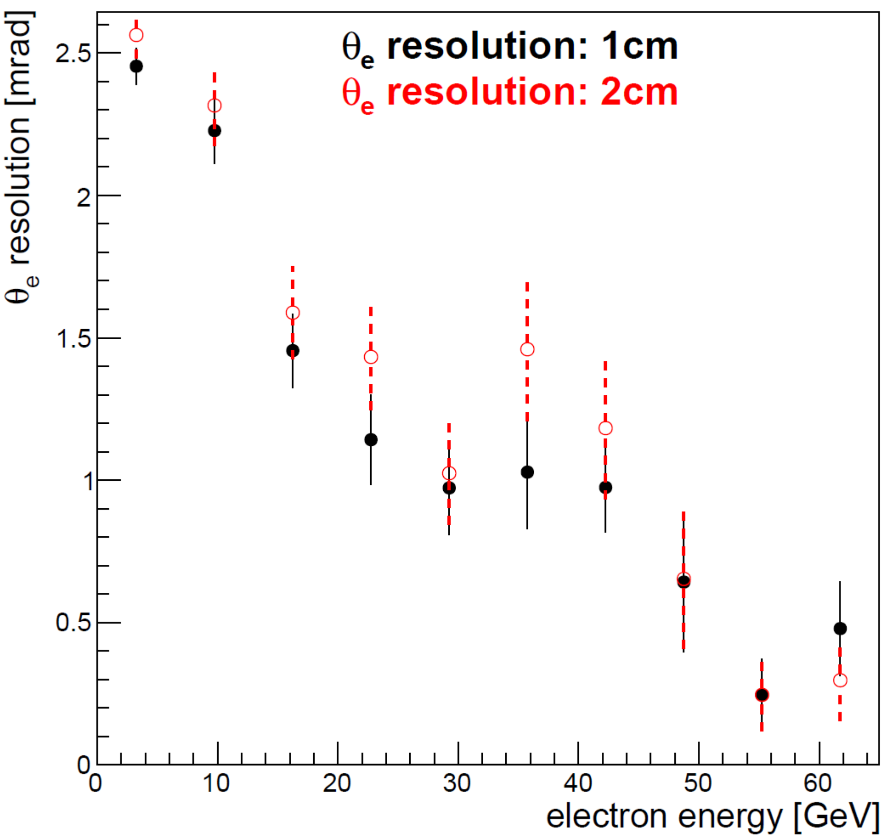
Reconstruction

- *μ-e* scattering only in the first target
- hits smeared by 18 μm
- electron reconstructed only from the hits in 1st module
- muon reconstructed from all the hits in all modules
  (most of the plots done for 2 modules)

1 cm vs 2 cm *(1 module)*

Be target of 1 or 2 cm thickness

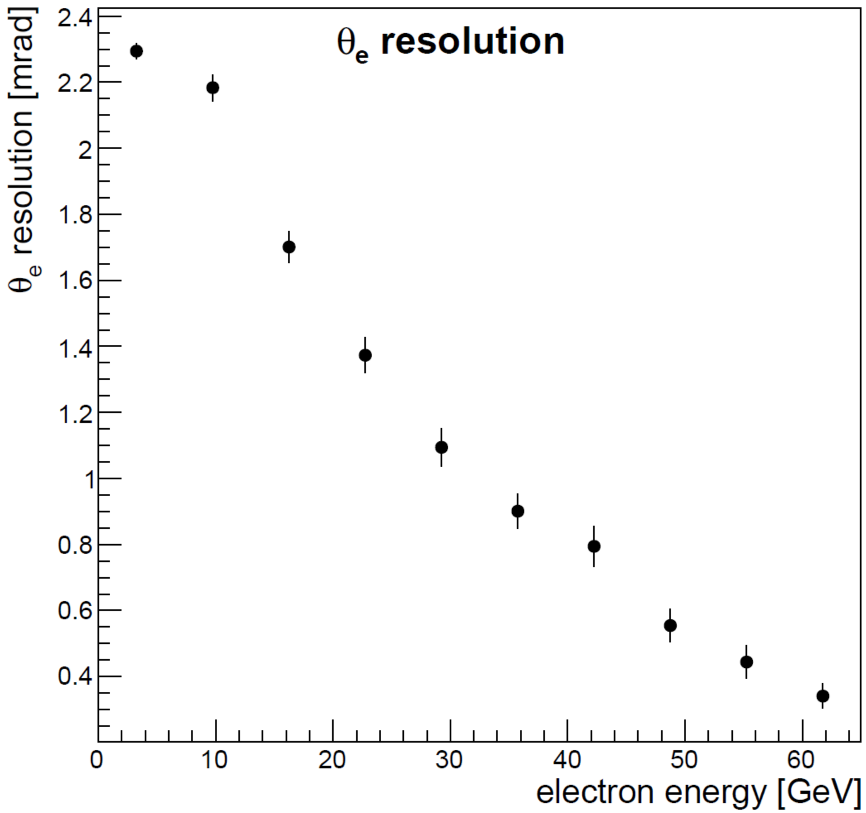




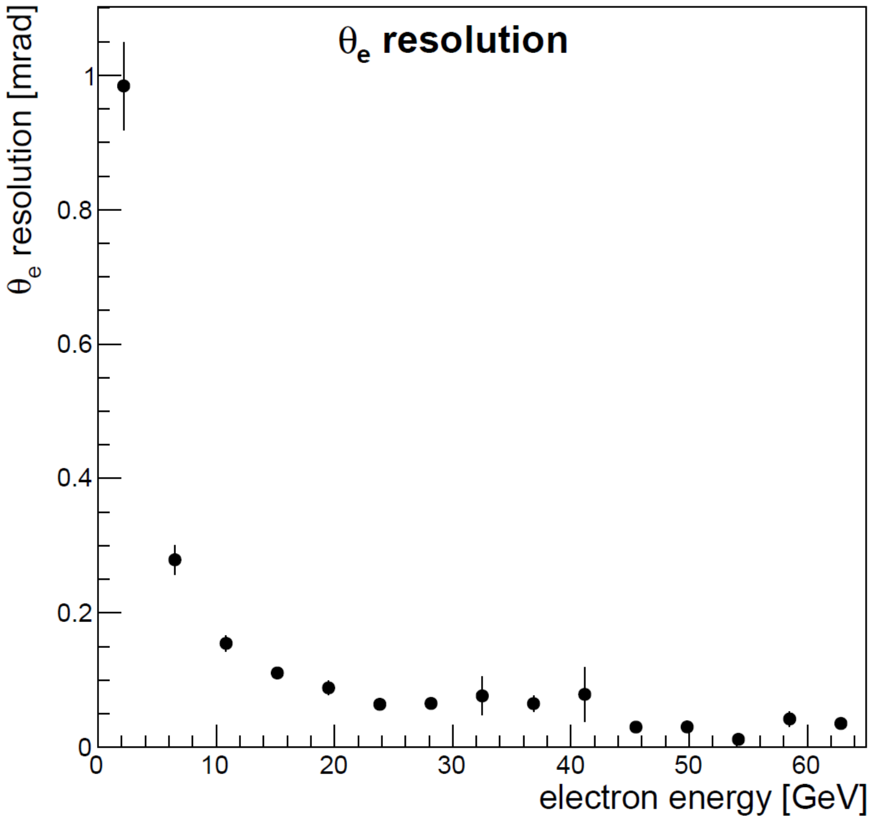
Loose and strong cuts *(2 modules)*

- loose cuts on track χ^2 and MC matching
  $\rightarrow$ *to gain efficiency*
- strong cuts
  $\rightarrow$ *to achieve assumed precision*

loose cuts

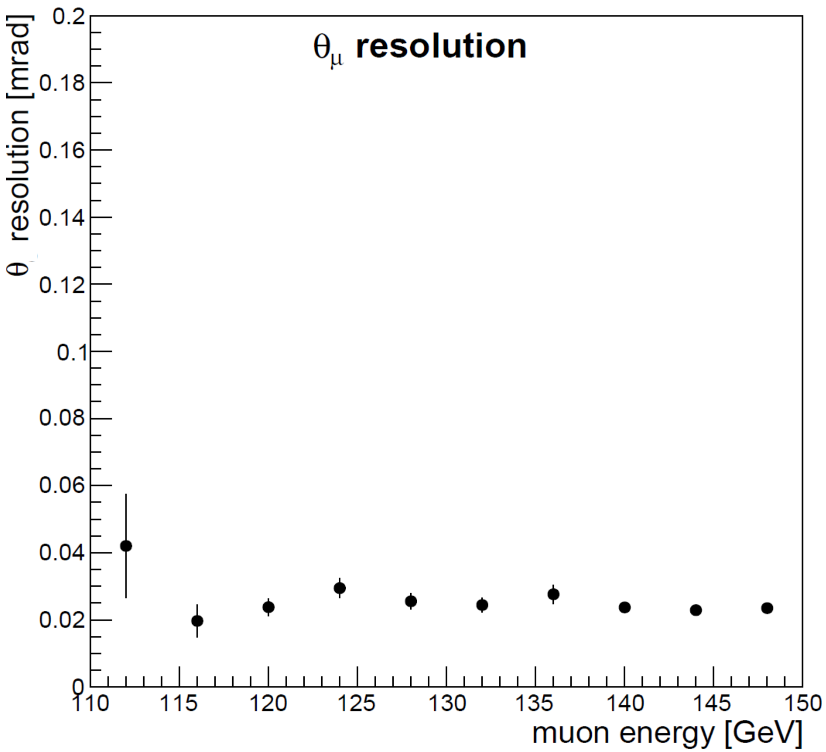


strong cuts

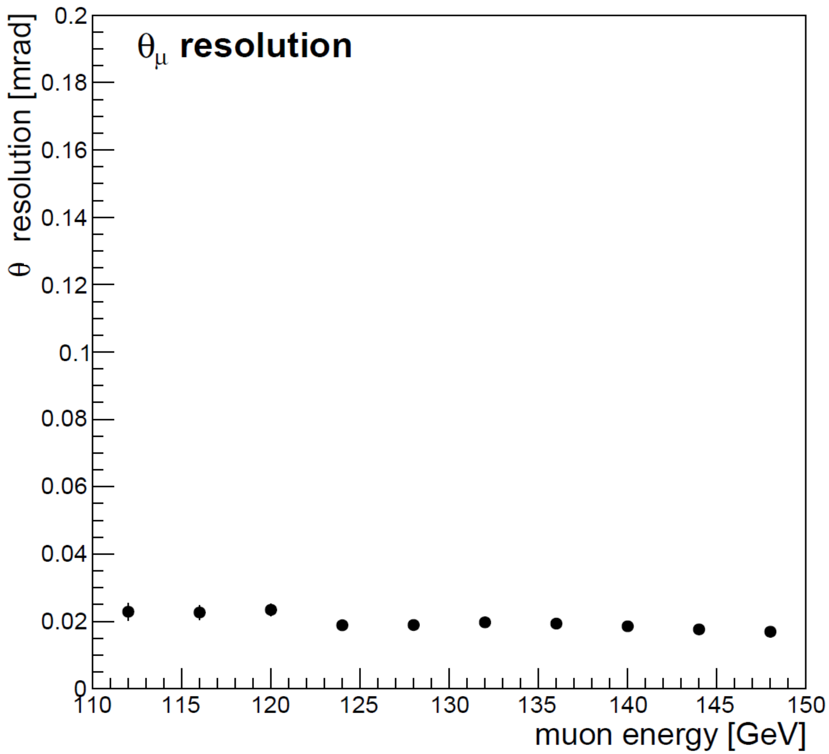


Muon resolution *(2 modules)*

loose cuts



strong cuts



Question about optimal working point

Optimal working point should be chosen to get the best final physics results

- working point for tracking can be chosen as a compromise between efficiency and the background reduction

- slope resolution should be minimized for the signal

No full simulation with inelastic processes

- cannot properly estimate the backgrounds

- efficiency studies must be done wrt final expected result

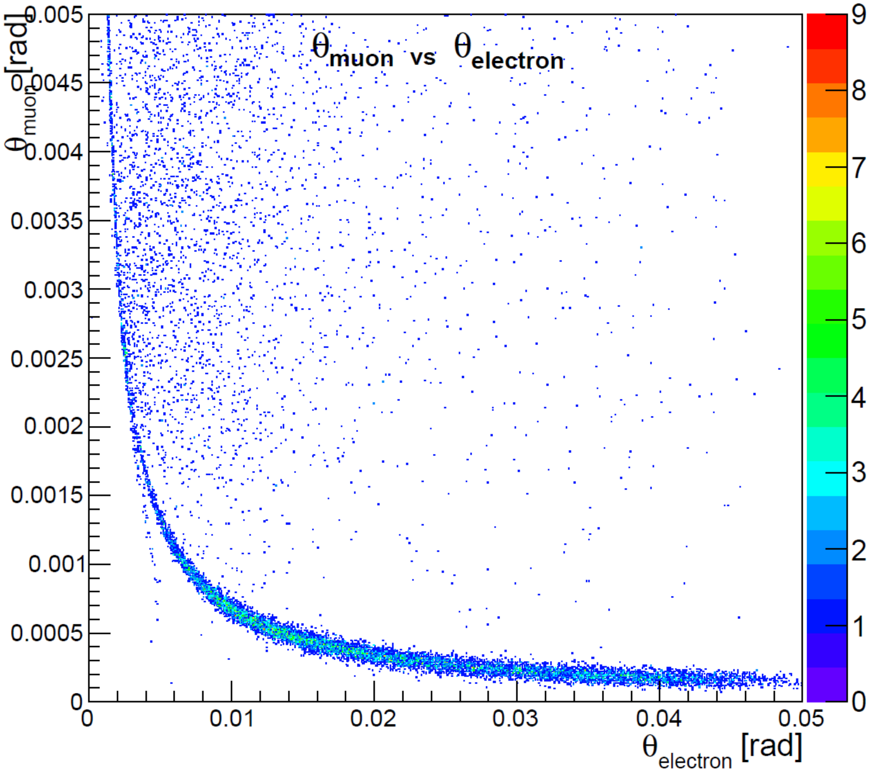
For the LoI current tracking algorithms are not final

- need to define properly the reconstructible track to properly measure the efficiency
  $\rightarrow$ *not dependent on geometrical acceptance or other inefficiencies*

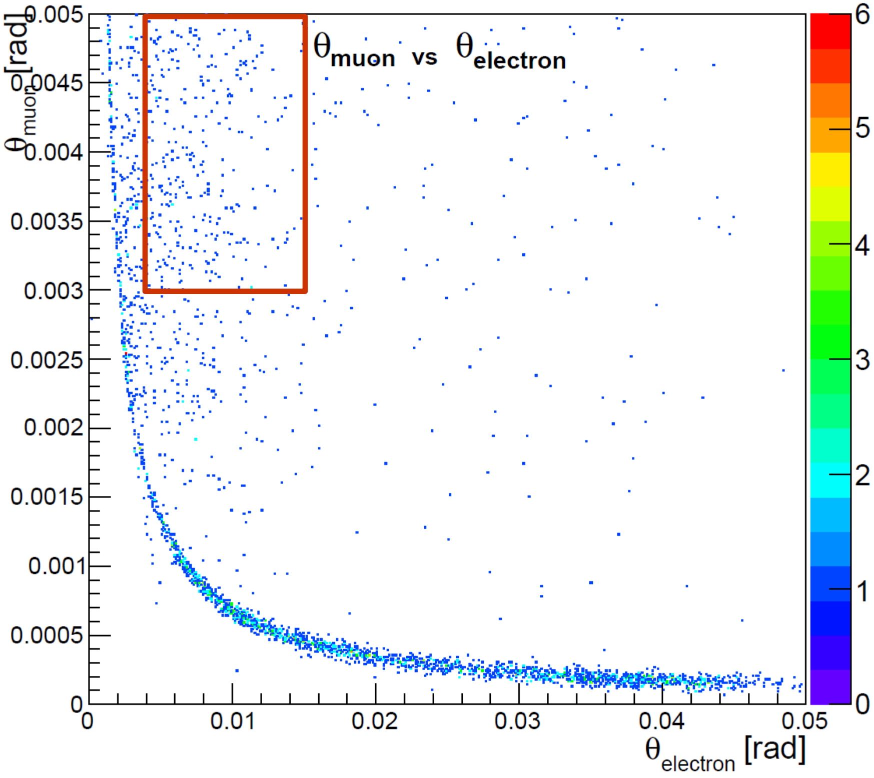
- issue of momentum estimation was not clear *(cannot use Kalman without momentum)*

θ_μ vs θ_e (2 modules)

loose cuts

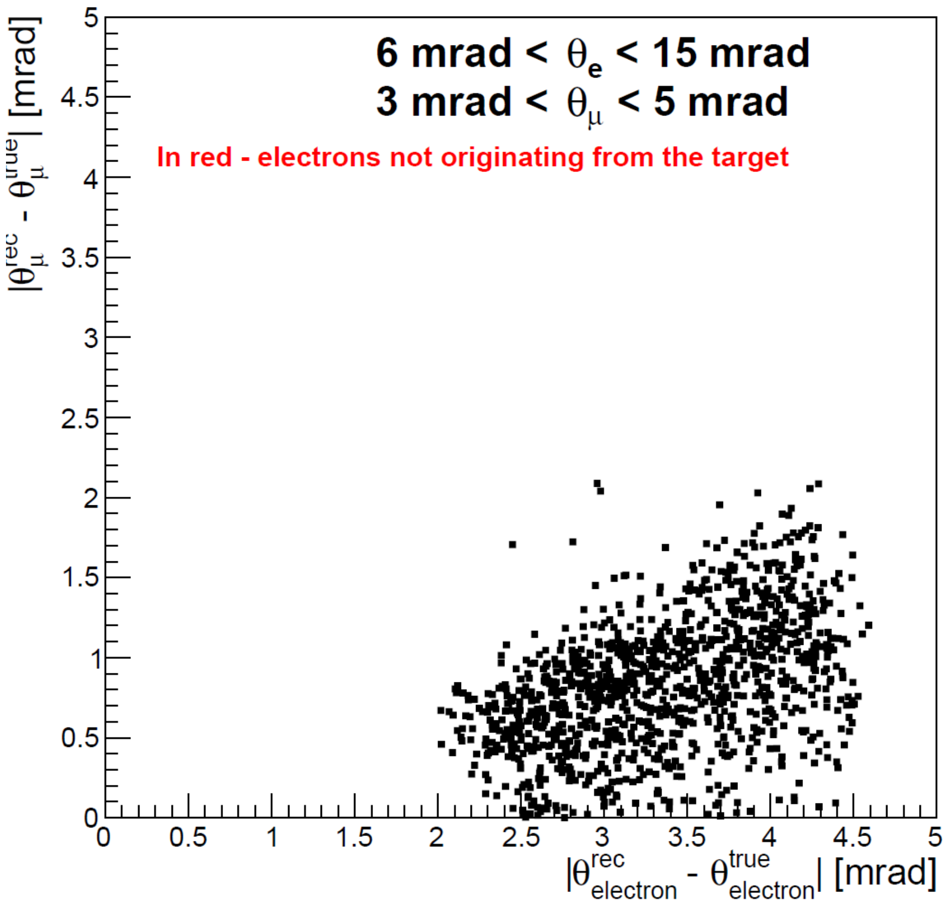


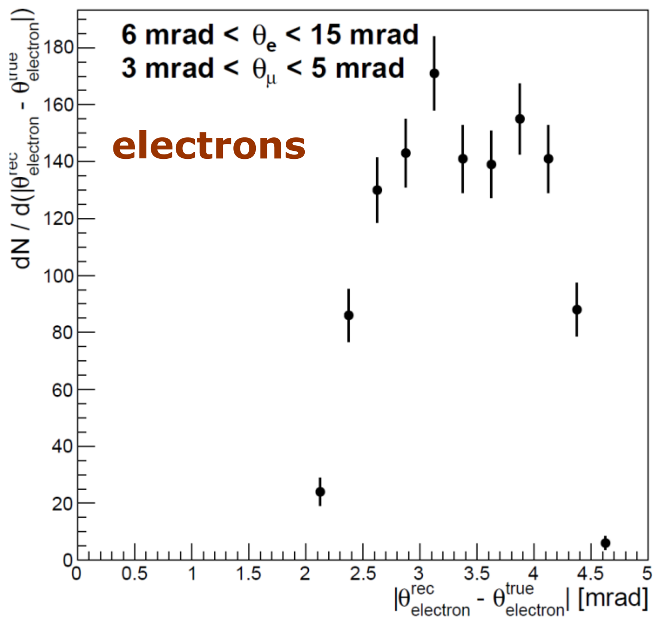
strong cuts

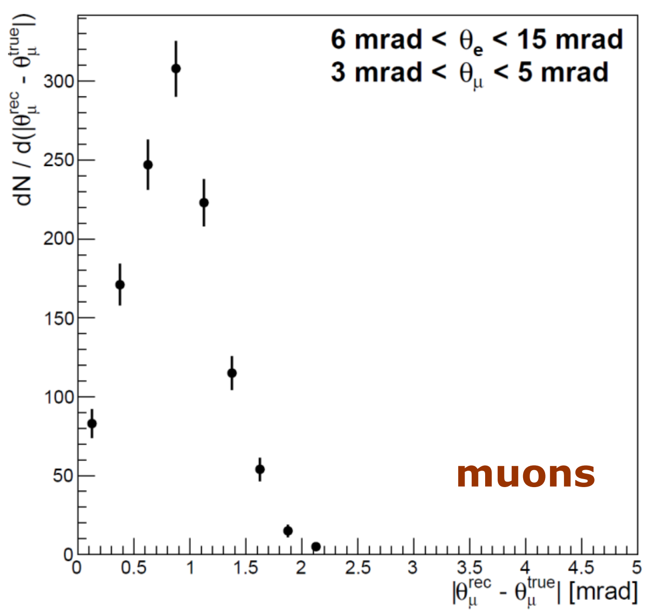


First look at background

seems more related to electrons
→ *rather Bremsstrahlung etc.*

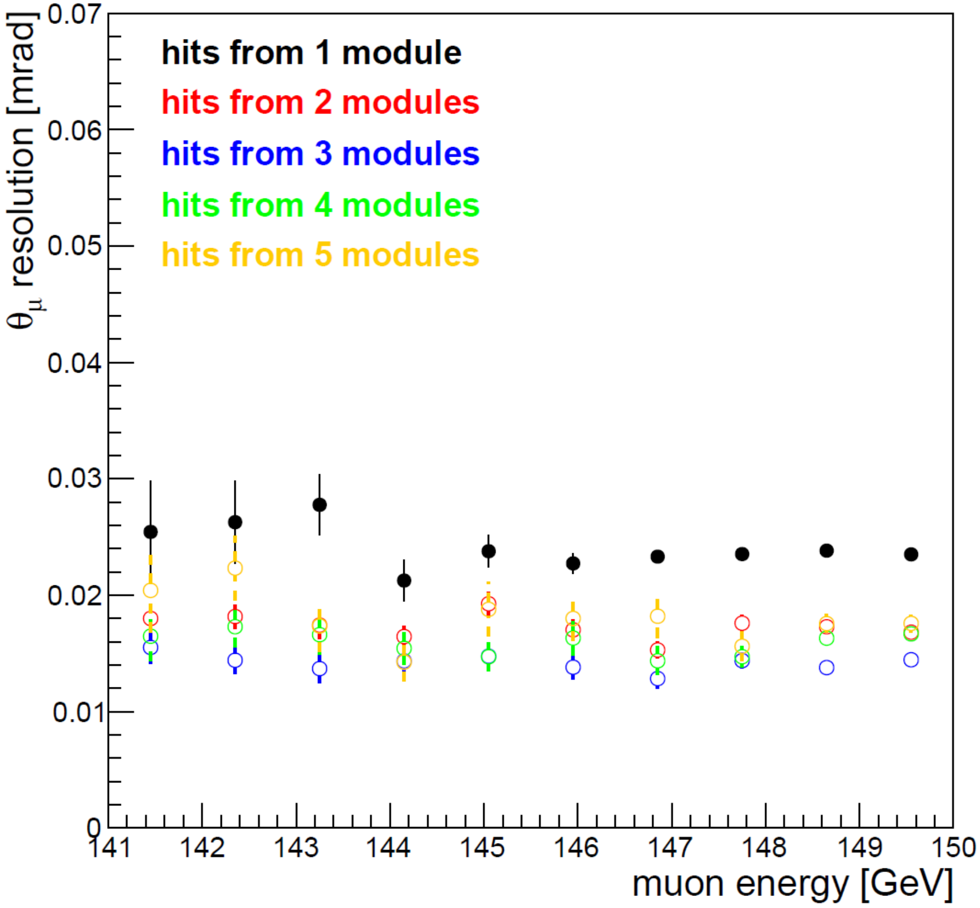


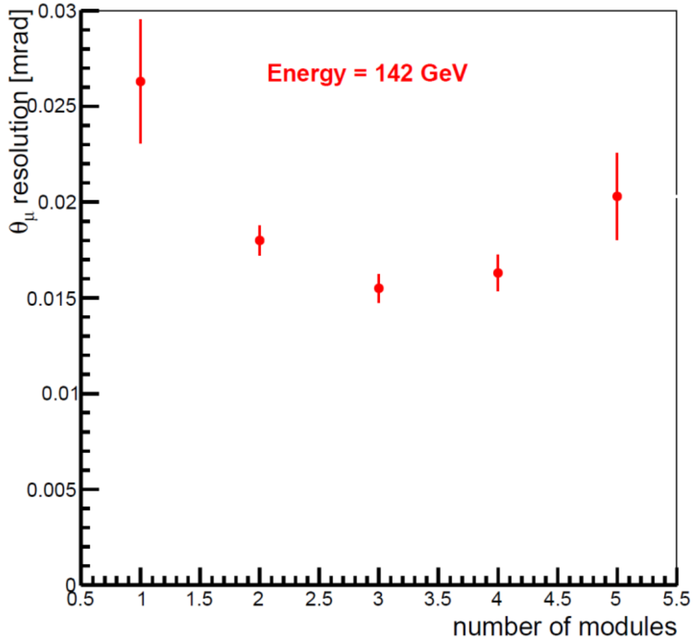


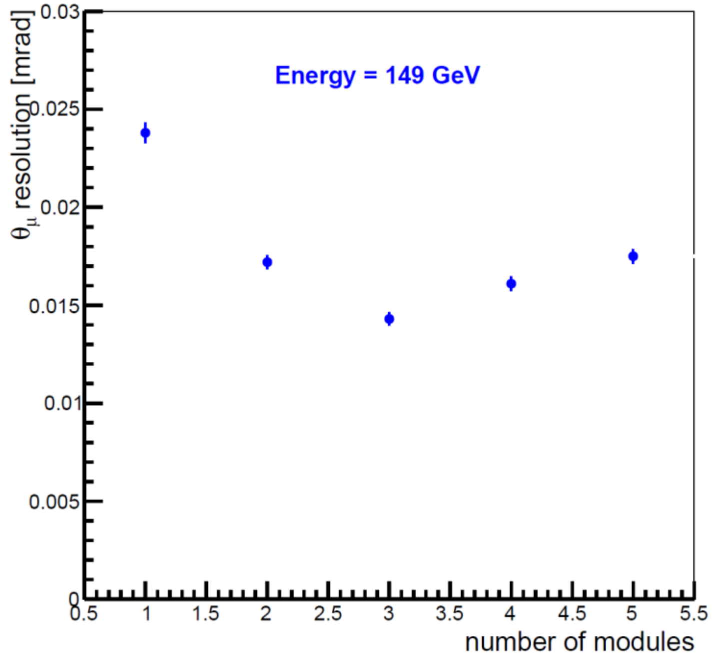


Nr of modules

one only module disfavoured!







Summary on MC

Plots to be included in LoI

- precision for θ_μ and θ_e
  (stronger cuts)
- scatter plots θ_μ vs θ_e
  (stronger cuts)
- muon precision wrt nr of module
- muon precision wrt nr of module for given energies

Fast simulation

- Basic information
  - Main purpose – study track slope resolution
  - Particle gun e or μ
  - z start coordinate of particle uniform in the target
  - Same sensor geometry as in full simulation (20 cm, 70 cm and 120 cm after the target)
  - Target thickness: 1 cm and 2 cm
  - Momenta 1, 2, 5, 10, 20, 30, 50, 70, 90, 120, 150 GeV
  - Angle in xz and yz uniformly distributed (0-5) mrad
  - Propagation of particle trough part of the target and silicon sensors. Collect hits with 100% efficiency.
  - Perform Kalman fit using generated momentum to determine multiple scattering contribution (idealization).

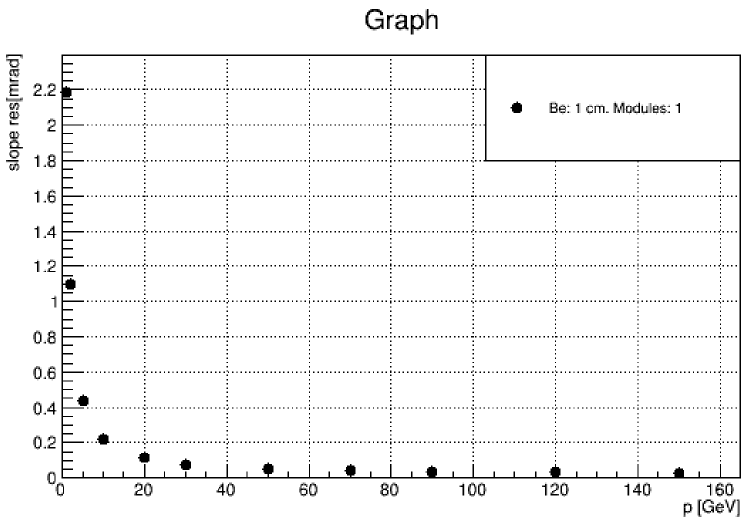
Fast simulation

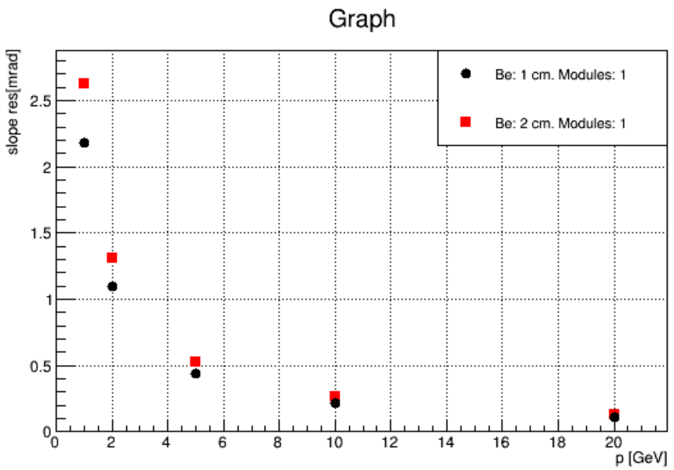
- What we expect
  - For muons with momenta ~100 GeV multiple scattering negligible, track slope resolution dominated by spatial resolution of silicon sensors.
  - For electrons with momenta ~ few GeV the resolution determined by two contributions
    - Scattering in target (independent of silicon sensors resolution)
    - Precision of track state at first measured point

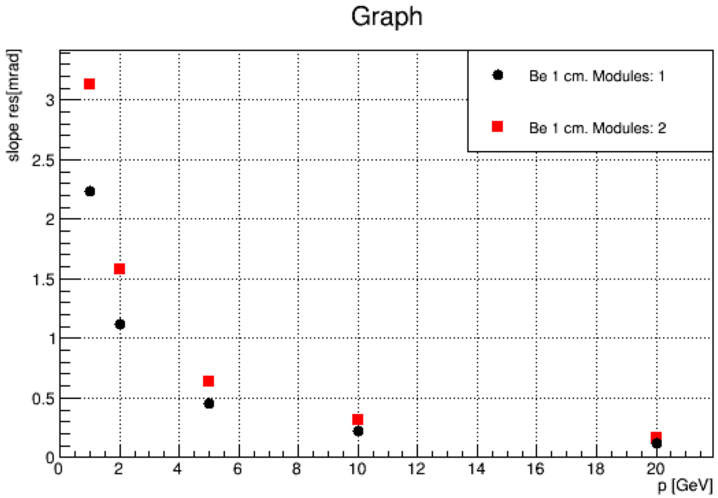
- Numbers we expect:
  - Slope uncertainty of 1 GeV electron in 2 cm (1cm) target traverse in average 1 cm (0.5 cm) of Beryllium giving angular spread of 2 mrad (1.4 mrad).
  - Slope uncertainty due to spatial resolution of silicon sensors (25 μm per sensor of 0.33 mm thickness (18 μm per pair of two close sensors) is ~0.025 mrad.

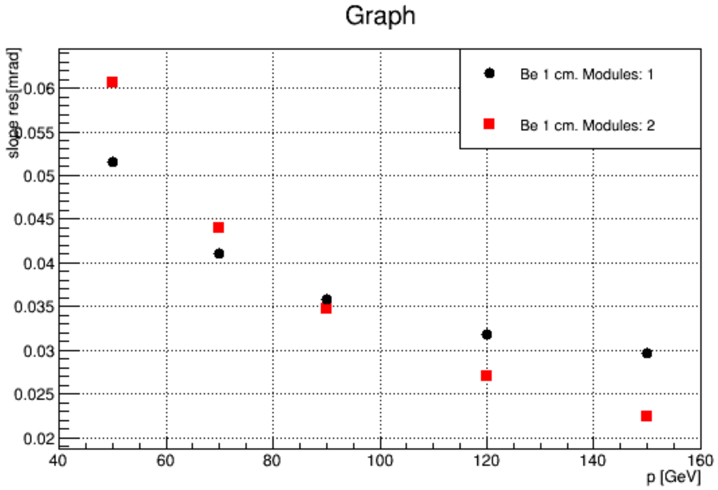
- Alignment considerations
  - One can assume that alignment in x and y is perfect (infinite number of straight tracks of high momentum).
  - Assuming misalignment in z position of sensors of 0.5 mm. Systematic shift we expect for track with slope 0.01 is below 0.02 mrad (kind of pessimistic maximum).

Fast simulation - results









Results are reasonable but still preliminary.

Resolutions for 2 modules should not be worse than for one modul in the case of Kalman filter.

Backup