Hadronic shower energy reconstruction

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ProtoDUNEs Sim&Reco Meeting, 03 May 2017

Plan

Aim: reconstruct kinetic energy of a hadronic shower,
- corrections needed: electron lifetime, recombination and missing energy

1. Focus on pion samples in the range of energy expected in the test beam (1 - 7) GeV/c (no cosmics).
2. Baseline: energy estimated from all hits in the event:
   a. Average calibration factor.
   b. Estimate the energy resolution.
3. Identification of electromagnetic and hadronic parts of events:
   a. EM/hadronic part corrected by dedicated avarage factors.
   b. Estimate the energy resolution (compare to 2b).
   c. Hadron-like 3D tracks energy estimated with hit-by-hit recombination correction (Birks/Box model).

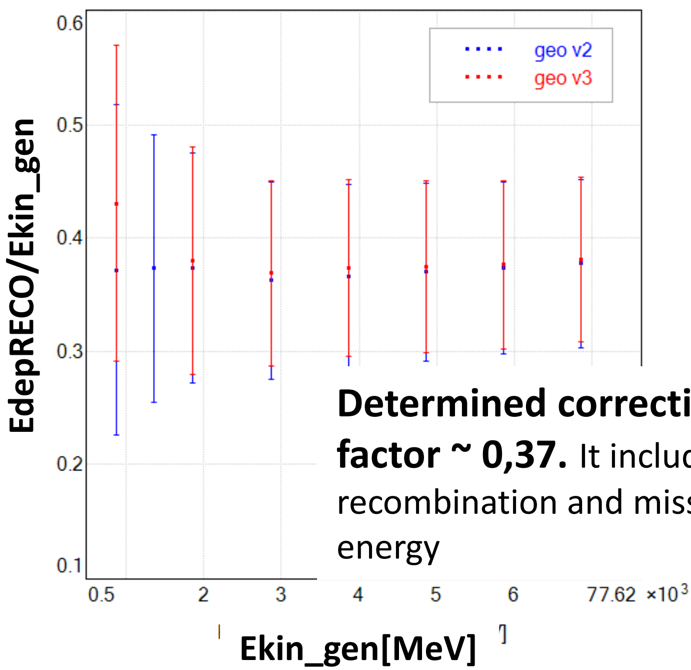
today

4. Beam particle with cosmic muon: clean events selection, cosmic muon subtraction,.
5. Improve hadronic part: identify different interaction topologies.
6. In parallel, I will start working on e/γ separation using hadronic interactions and π^0 produced there.

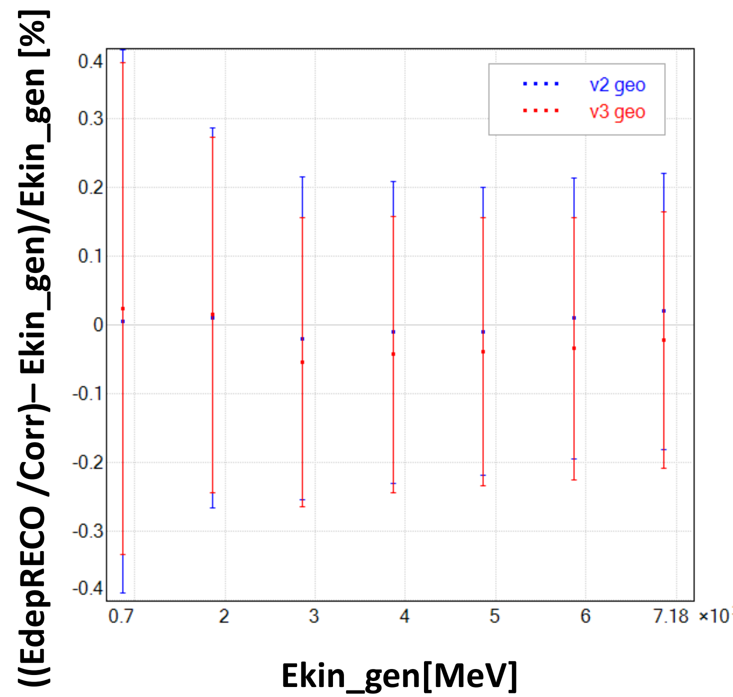
next

Pion shower reconstruction: hit energy deposition

Energy estimated from all hits, geometry v2 & v3



Determined correction factor ~ 0,37. It includes recombination and missing energy

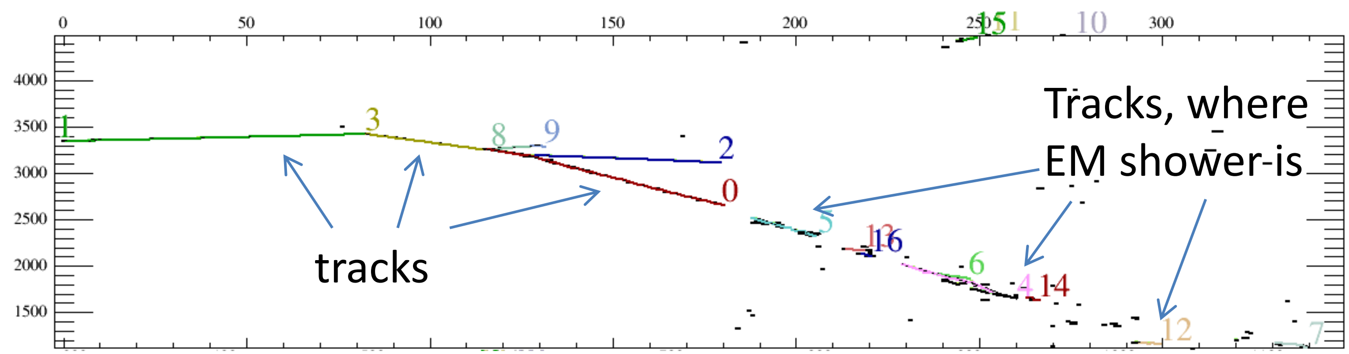


EdepRECO:
Energy deposition corr. for electron lifetime only
Ekin_gen:
Kinetic energy of particle generated

Energy resolution for hadronic showers in LArTPC, **as usually stated**: **ΔE/E = ~30% / sqrt(E[GeV])**

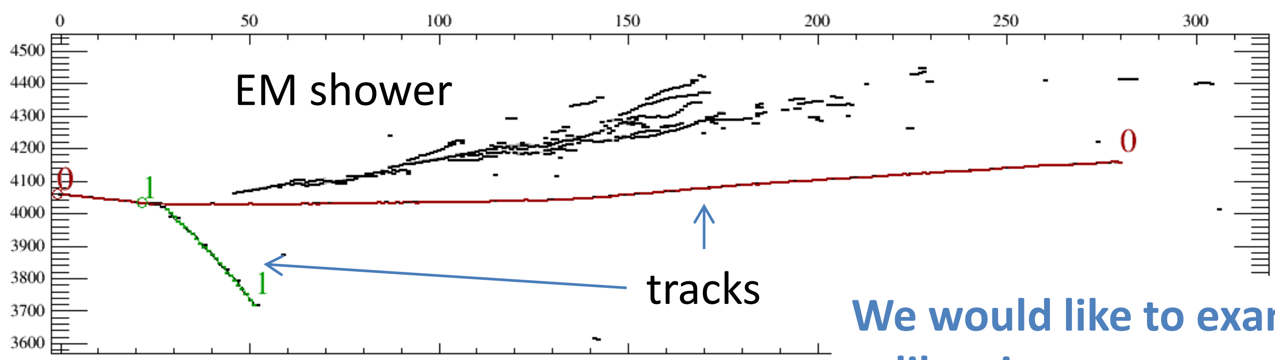
Seperation of electromagnetic from track-like component

Illustration of the reconstructed ProtoDUNE event without electromagnetic shower separation.



PMA

Illustration of the reconstructed ProtoDUNE event using CNN based EM/track separation.

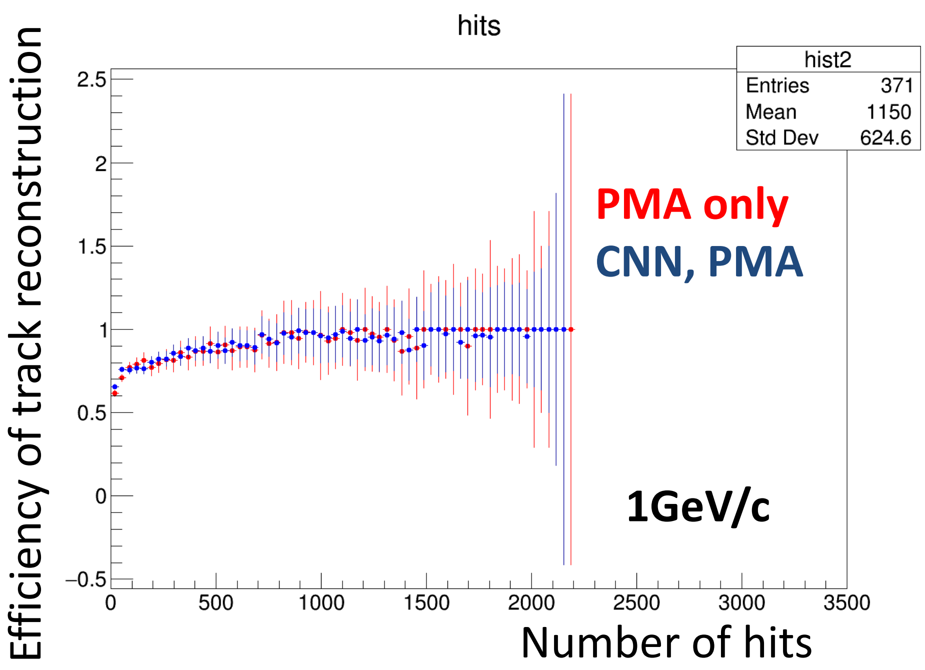


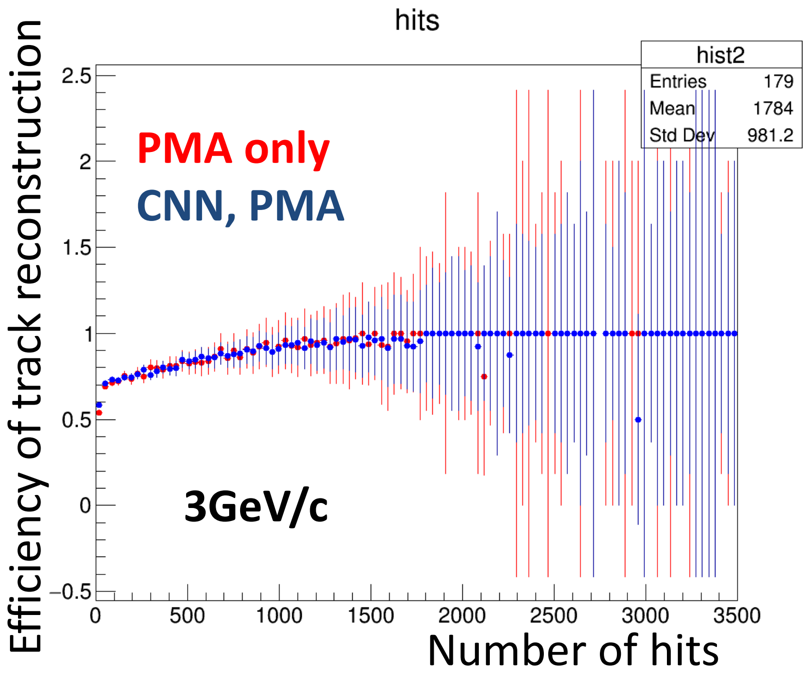
Tracking only on clusters tagged as track-like.

We would like to examine energy calibration constants individually for EM showers and tracks.

CNN, PMA

Inefficiency due to EM/track seperation: not significant

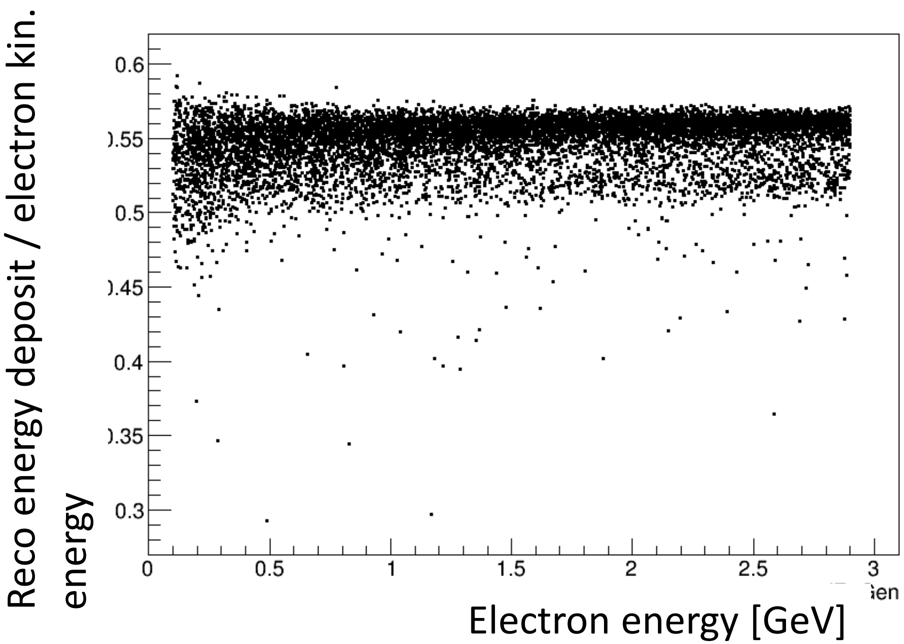


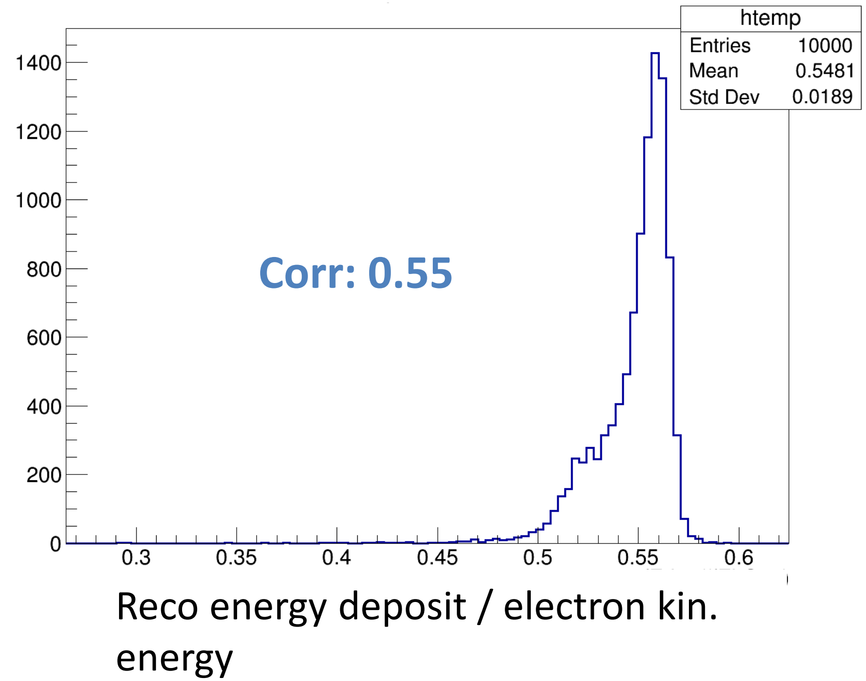


Definition of reco efficiency:
Numerator – number of reconstructed tracks that matched MC truth (reconstructed track must have more than half of MC truth energy of particle, which contributed max energy to this reco track).
Denominator – number of visible MC tracks (more than 5 hits in collection and induction view).

The efficiency curves are similar for both samples: CNN correctly tagged clusters, we can use it safely in chain with PMA to estimate energy of both event components.

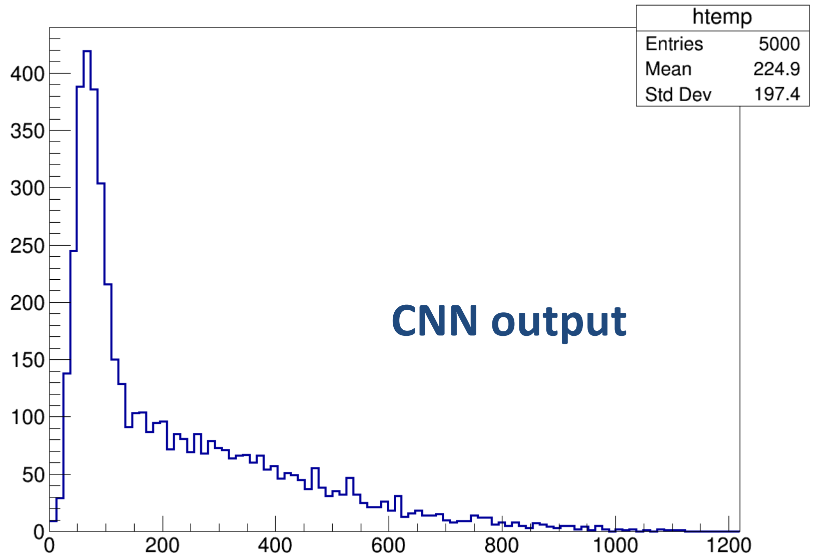
Electromagnetic showers: average factor



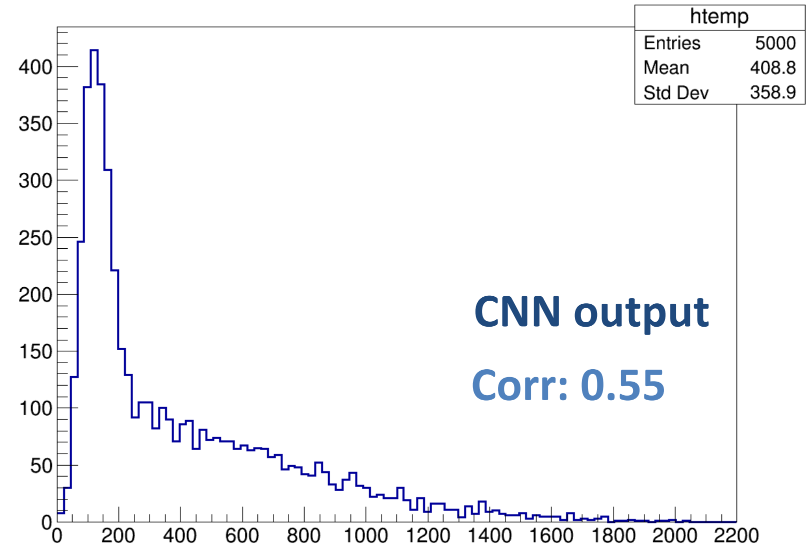


- Electrons simulated at the center of the detector to ensure full containment of electromagnetic showers. Electron energy: 0.1 – 3.0 GeV.
- Hit energy, corrected for electron lifetime.
- Observed dependance of correction factor on the shower orientation.
- For now, constant correction factor (hit reco inefficiency + recombination correction) used: 0.55.

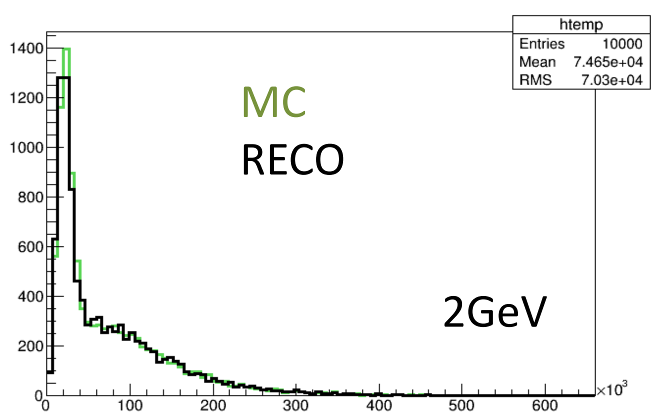
Electromagnetic part of 2GeV/c pion event



Energy deposit in hits (corrected for electron lifetime) [MeV]



Kinetic energy in hits [MeV]

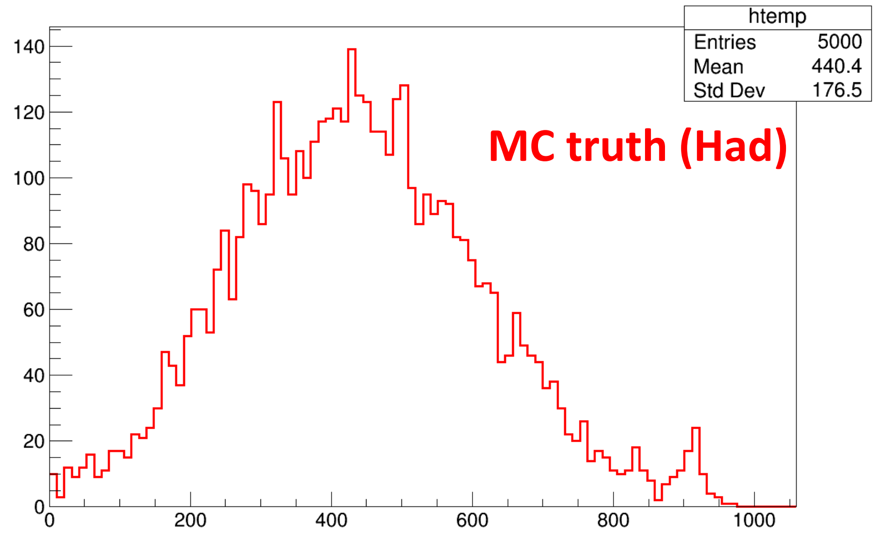


ADC_sum of EM hits

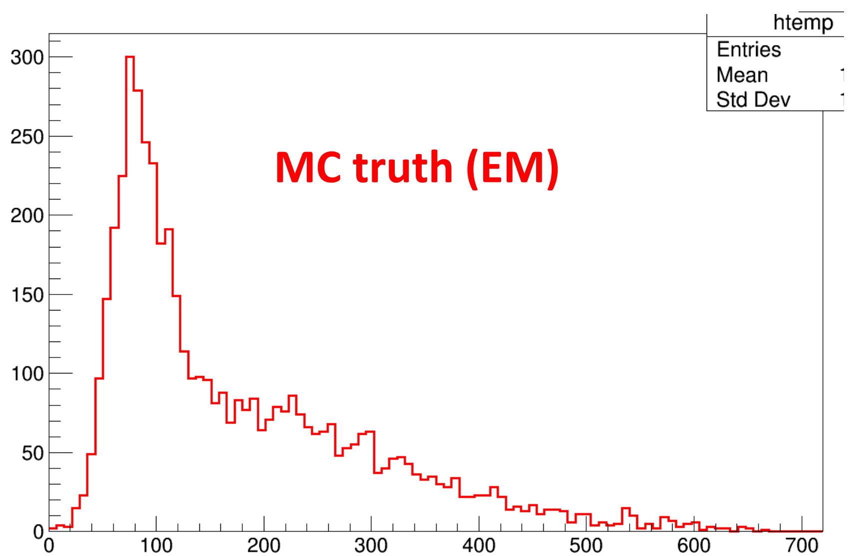
Loop over reconstructed hits:

- Green: deposition in hits selected as EM by MC truth, per event.
- Black: deposition in hits tagged as EM by CNN, per event.

Hadronic part of 2GeV/c (Ek ~1865 MeV) pions

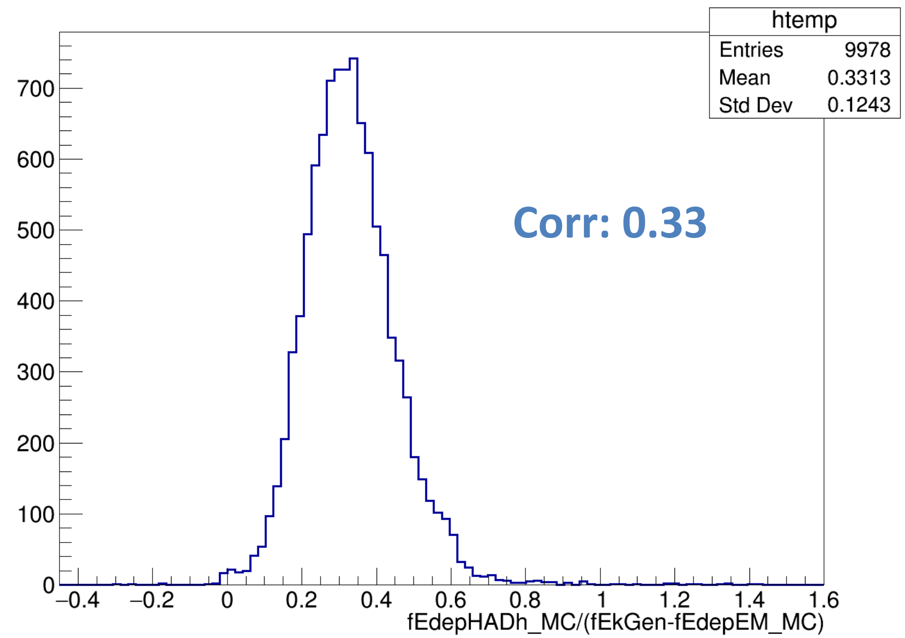


Energy deposit (corrected for electron lifetime) [MeV]



Energy deposit (corrected for electron lifetime) [MeV]

Correction factor

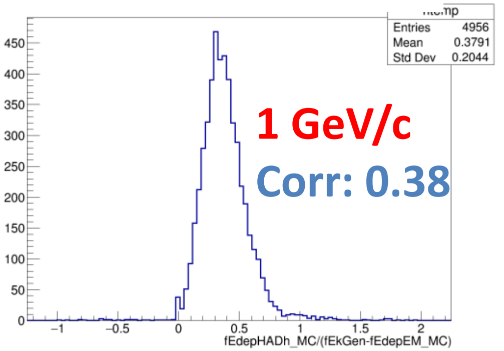


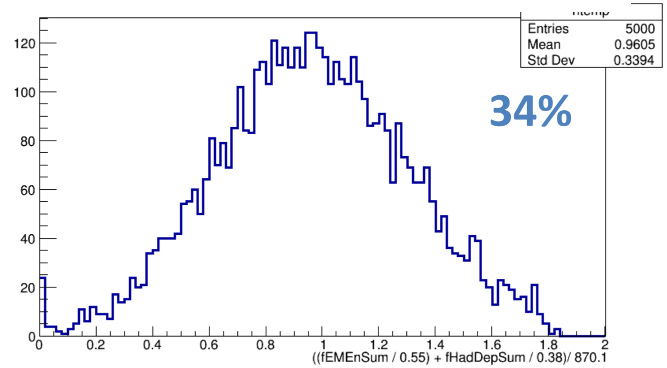
Ratio: (MC energy deposit)/(Truth kinetic energy of hadronic part)

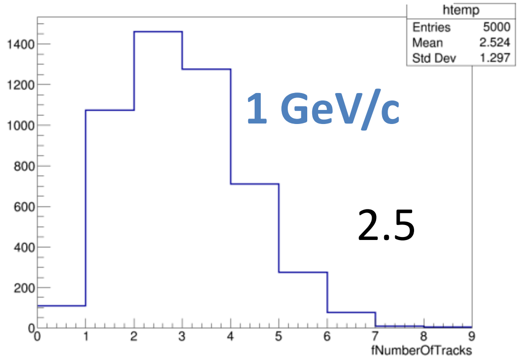
Correction factor

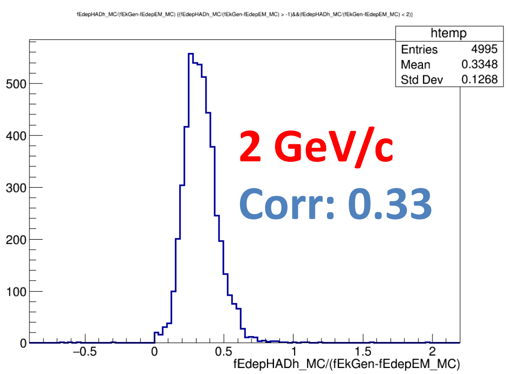
E reco resolution: EM + had

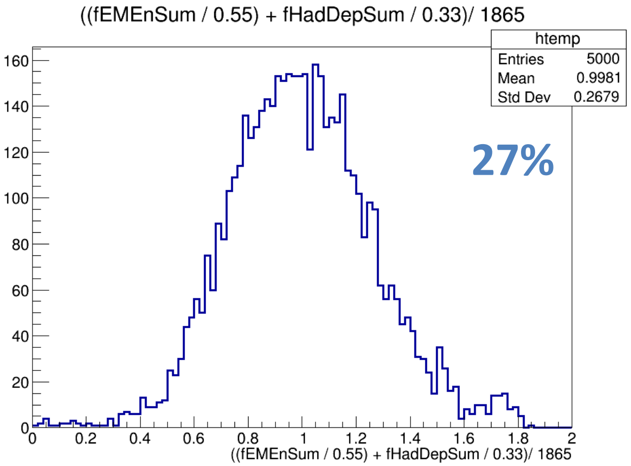
number of tracks

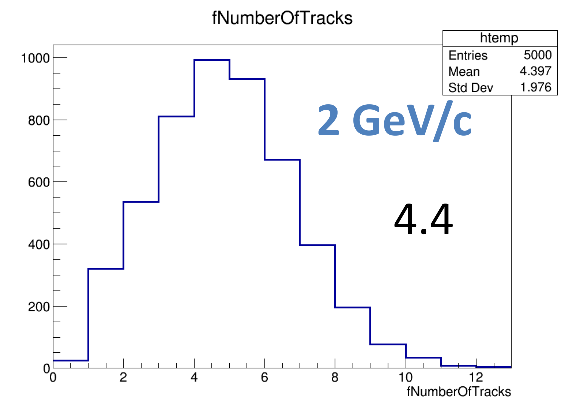


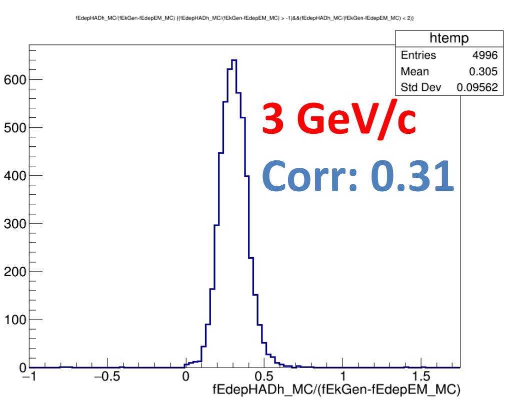


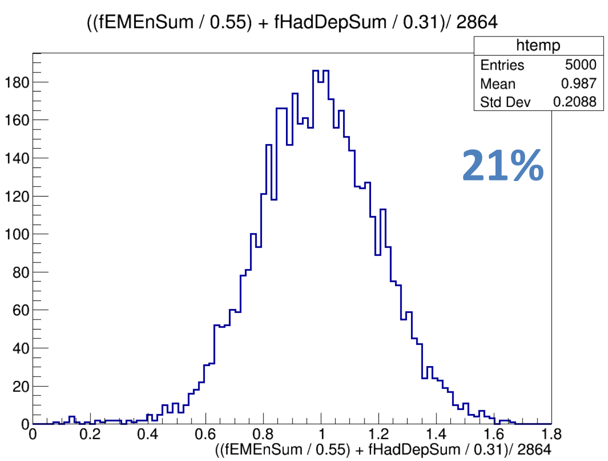


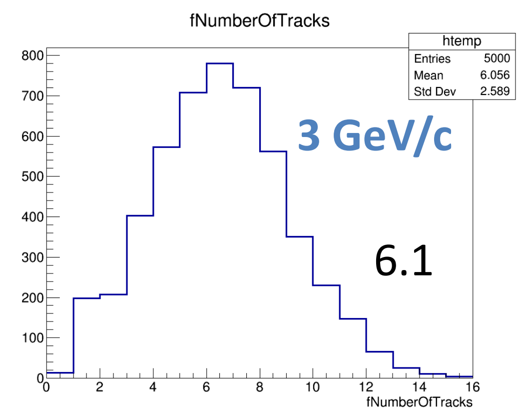


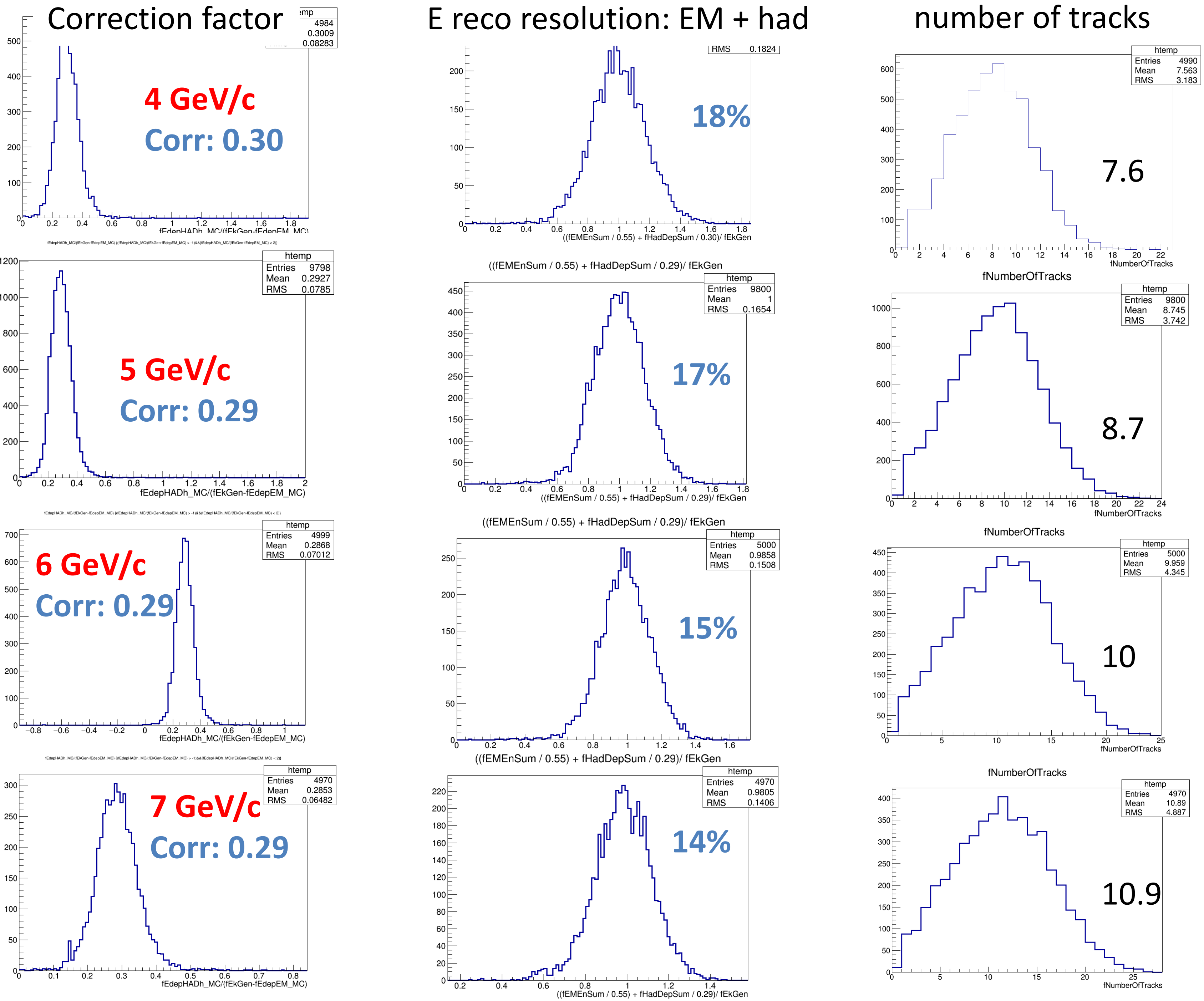










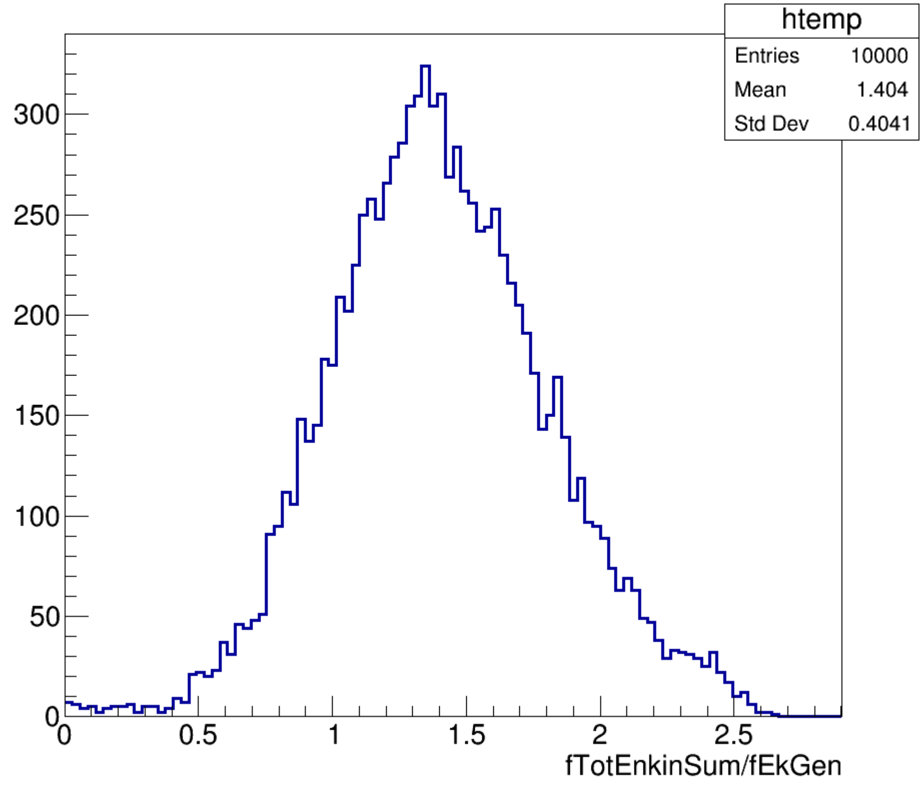

Correction factor
E reco resolution: EM + had
number of tracks
4 GeV/c
Corr: 0.30
18%
7.6
5 GeV/c
Corr: 0.29
17%
8.7
6 GeV/c
Corr: 0.29
15%
10
7 GeV/c
Corr: 0.29
14%
10.9
htemp
Entries 9798
Mean 0.2927
RMS 0.0785
Entries 4999
Mean 0.2868
RMS 0.07012
Entries 4970
Mean 0.2853
RMS 0.06482
Entries 9800
Mean 1
RMS 0.1654
Entries 5000
Mean 0.9858
RMS 0.1508
Entries 4970
Mean 0.9805
RMS 0.1406
Entries 4990
Mean 7.563
RMS 3.183
Entries 9800
Mean 8.745
RMS 3.742
Entries 5000
Mean 9.959
RMS 4.345
Entries 4970
Mean 10.89
RMS 4.887
fEdepHADh_MC/(fEkGen-fEdepEM_MC)
((fEMEnSum / 0.55) + fHadDepSum / 0.30)/ fEkGen
((fEMEnSum / 0.55) + fHadDepSum / 0.29)/ fEkGen
fNumberOfTracks

Energy resolution obtained by using two methods

	1	2	3	4	5	6	7 GeV/c
ΔE/E (all hits):	36%	26%	21%	20%	19%	19%	19%
ΔE/E (EM/track division):	34%	27%	21%	18%	17%	15%	14%

- Use full energy deposition in all hits – easy to do, we have just one correction factor.
- Separation of EM/Track is more accurate method and opens possibility of exploring hadronic showers in more details.

Kinetic energy: average factor for EM part, Birks formula for hadronic part.



Total kinetic energy / Truth initial kinetic energy

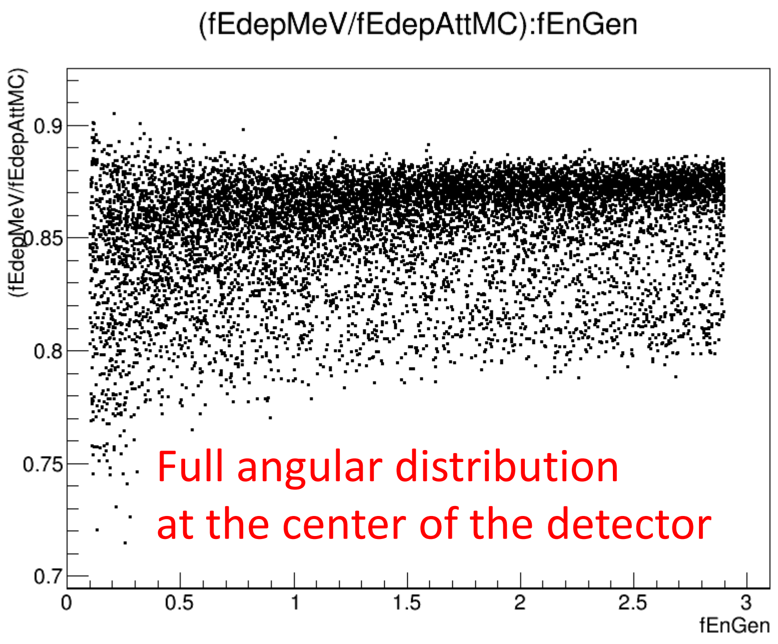
Kinetic energy of hadronic part gets overestimated: fluctuation in energy loss can easily overestimate energy (correction is non-linear).

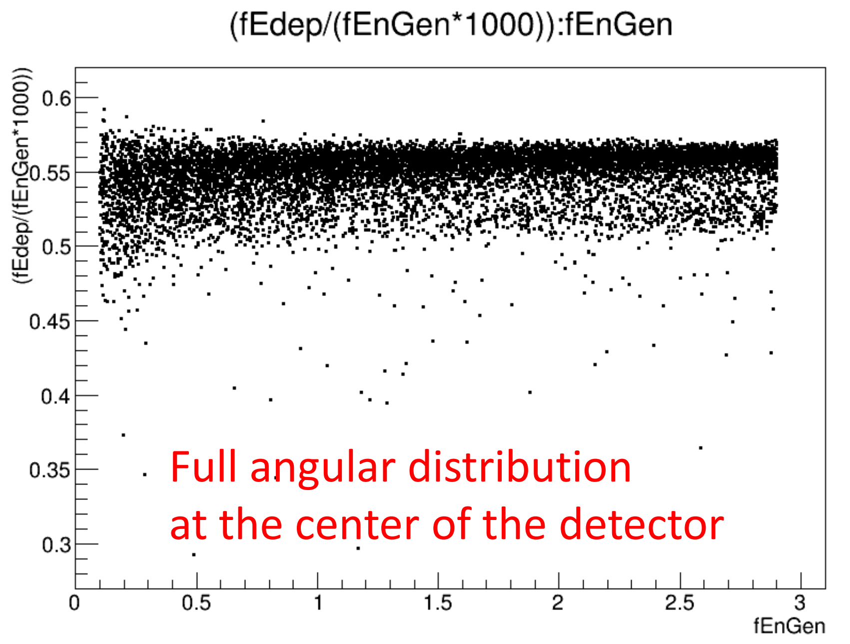
Summary

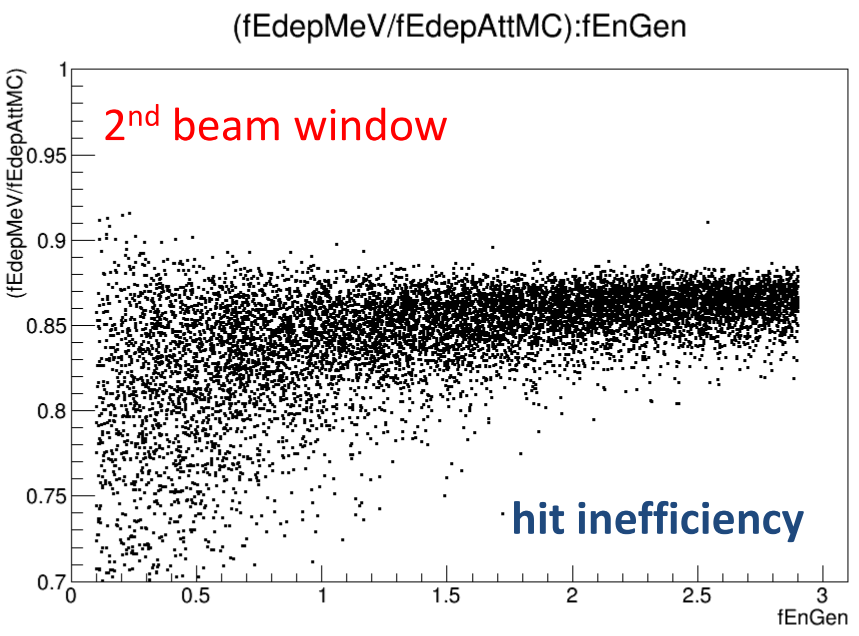
- Two average calibration factors have been estimated:
  - For EM part: using simulation of single EM showers.
  - For hadronic part: using simulation of pion events in the momenta range from 1 to 7 GeV/c.

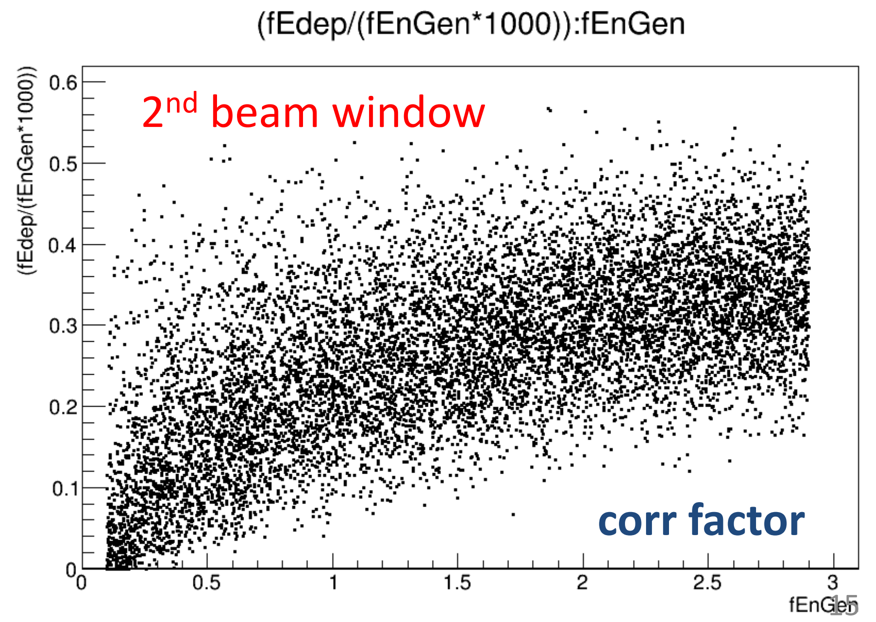
  → obtained resolution, $\Delta E/E$, is better for higher energies of incoming particle, as expected.
- The energy resolution is better when we apply separate calibration factors for electromagnetic and hadronic parts.
- Applying Birks/Box model to each 3D track overestimates the energy: fluctuations in hit energy or dx reconstruction accumulate.
- Having identified hadronic part of events allows us to study different interactions topologies (separation of stopping particles, possible different missing energy contrbutions).

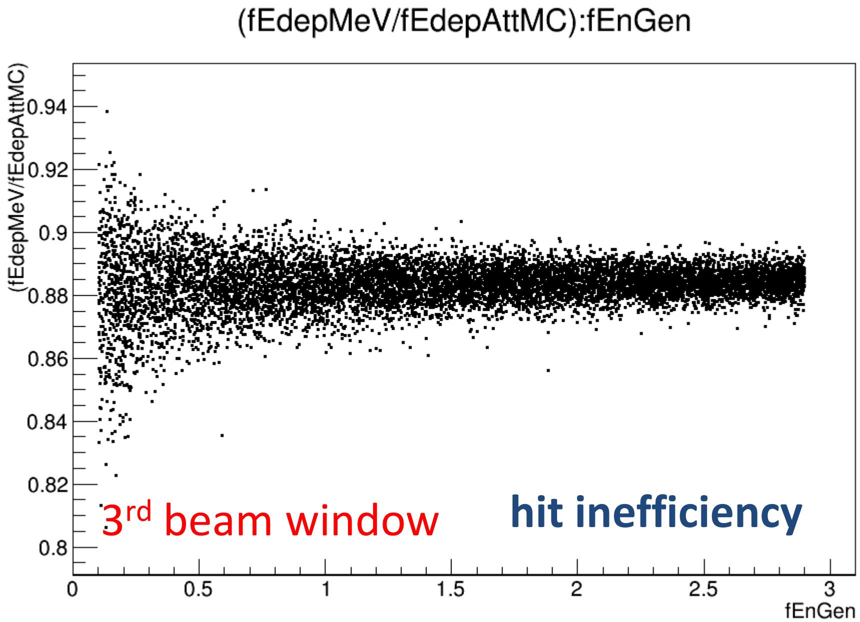
backup

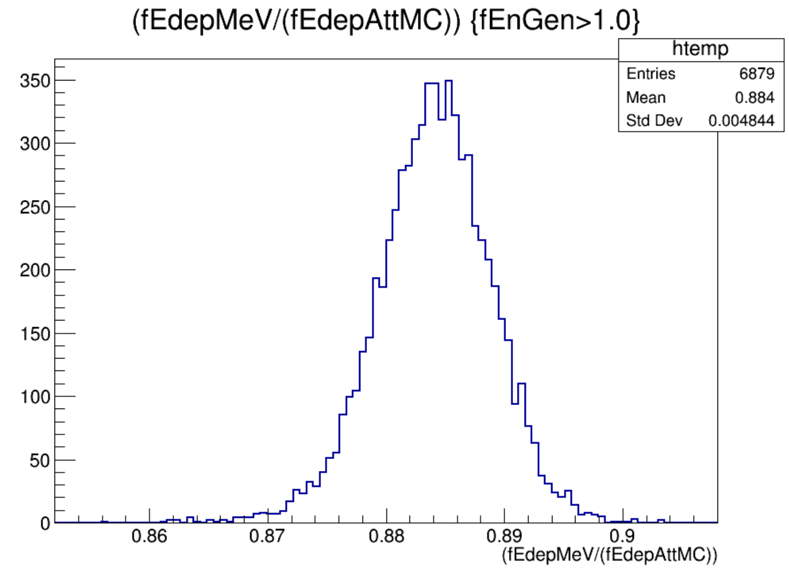

(fEdepMeV/fEdepAttMC):fEnGen
(fEdepMeV/fEdepAttMC)
fEnGen
Full angular distribution
at the center of the detector

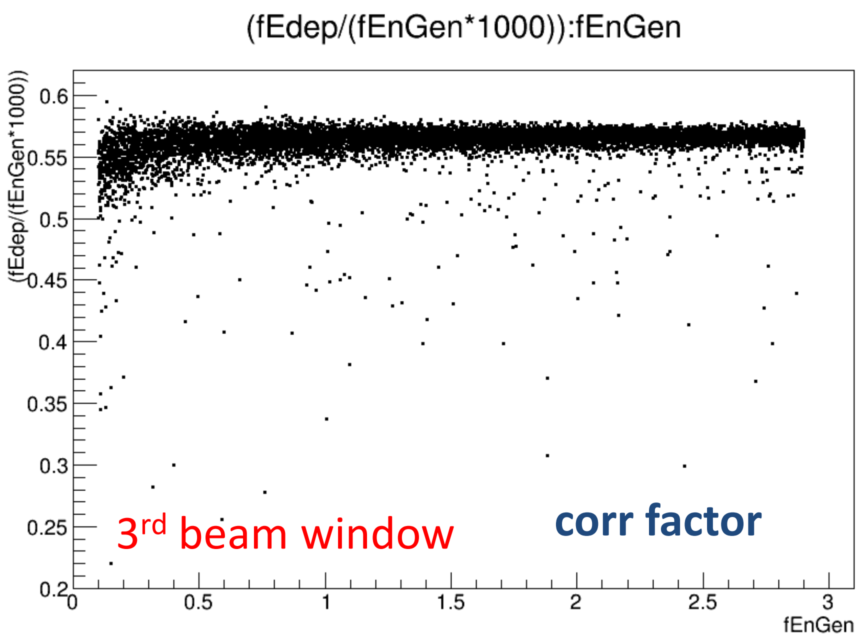

(fEdep/(fEnGen*1000)):fEnGen
(fEdep/(fEnGen*1000))
fEnGen
Full angular distribution
at the center of the detector

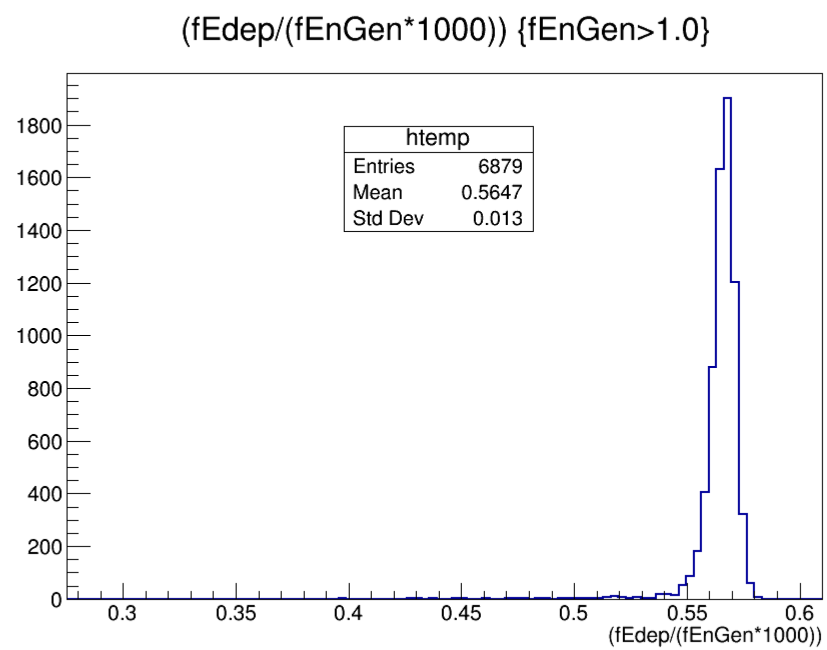

(fEdepMeV/fEdepAttMC):fEnGen
(fEdepMeV/fEdepAttMC)
fEnGen
2nd beam window
hit inefficiency


(fEdep/(fEnGen*1000)):fEnGen
(fEdep/(fEnGen*1000))
fEnGen
2nd beam window
corr factor

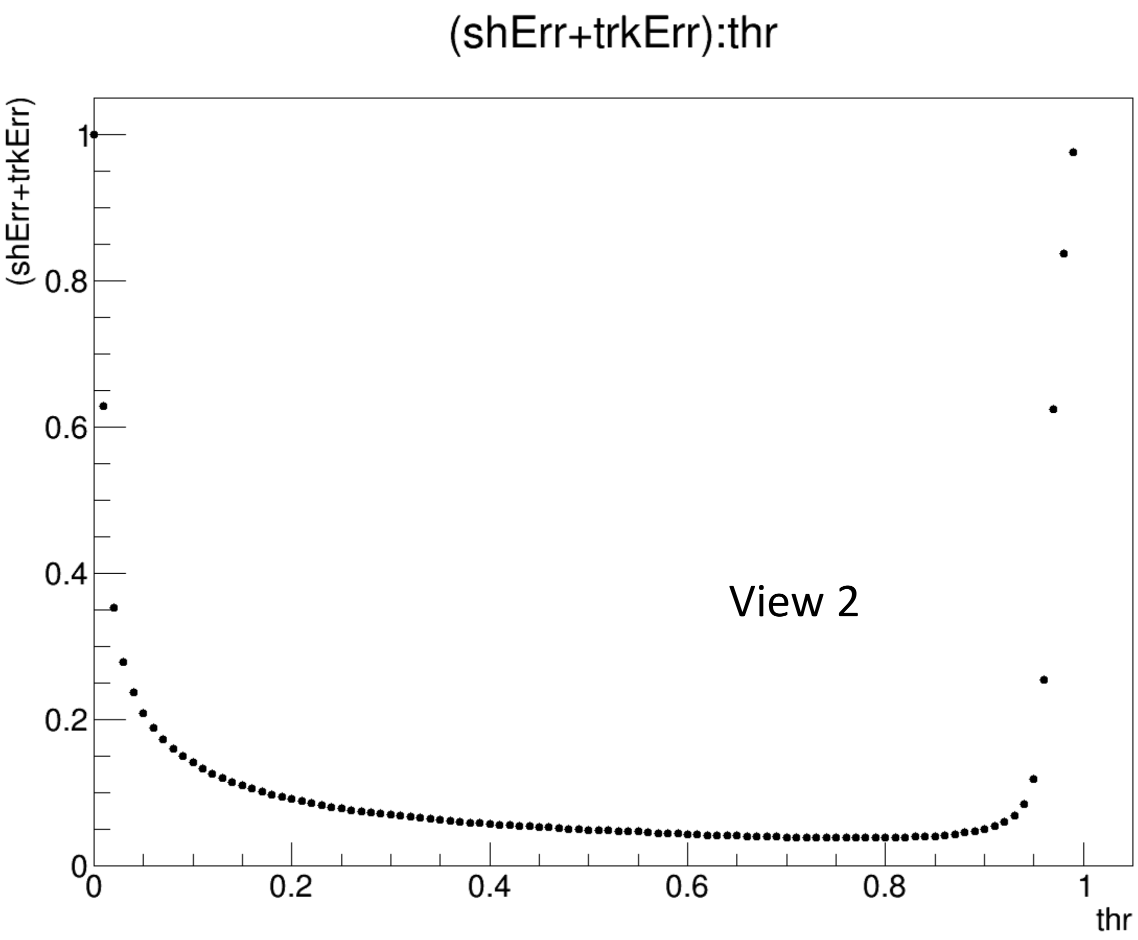

(fEdepMeV/fEdepAttMC):fEnGen
(fEdepMeV/fEdepAttMC)
fEnGen
3rd beam window
hit inefficiency

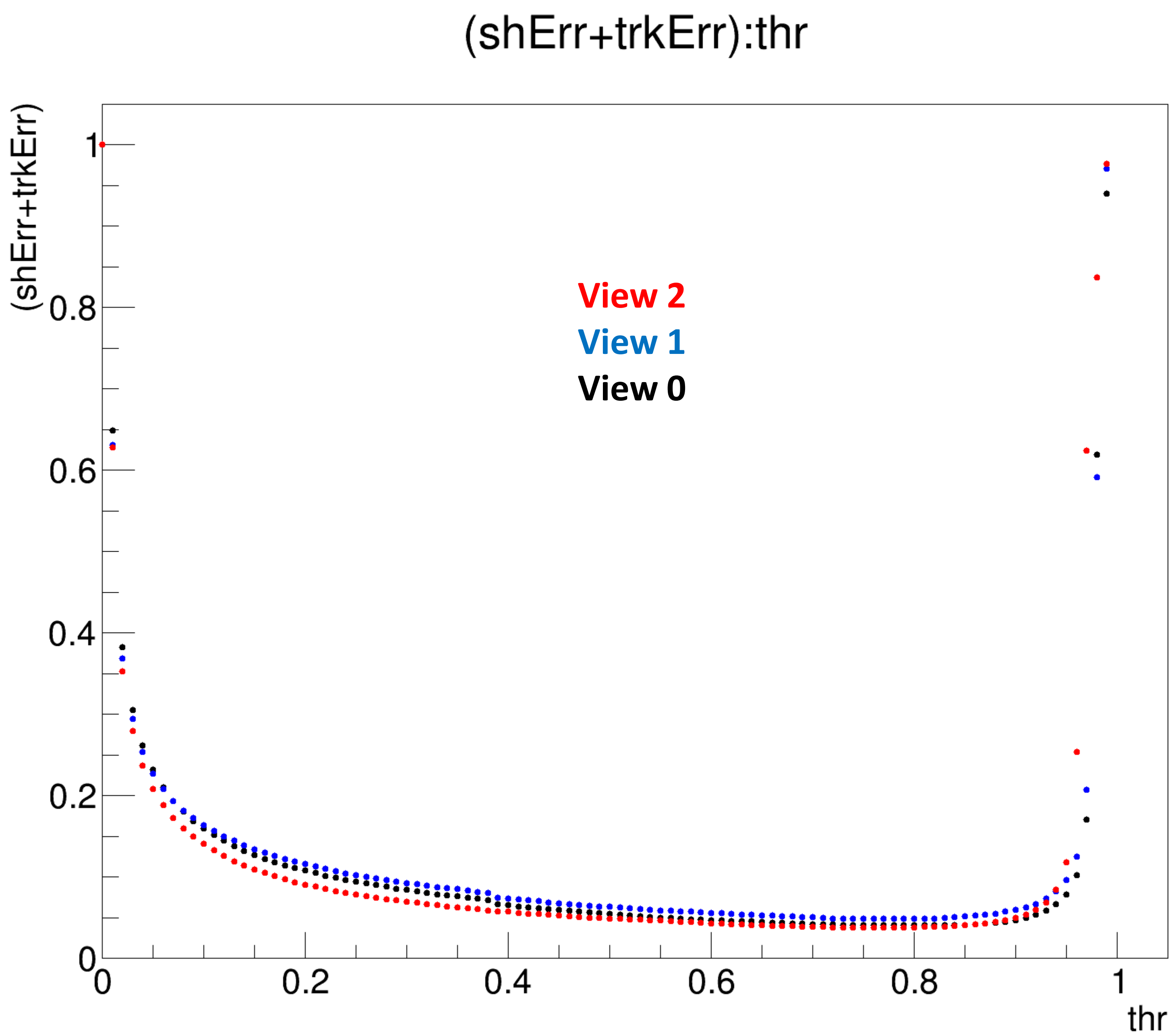

(fEdepMeV/(fEdepAttMC)) {fEnGen>1.0}
htemp
Entries 6879
Mean 0.884
Std Dev 0.004844
(fEdepMeV/(fEdepAttMC))


(fEdep/(fEnGen*1000)):fEnGen
(fEdep/(fEnGen*1000))
fEnGen
3rd beam window
corr factor


(fEdep/(fEnGen*1000)) {fEnGen>1.0}
htemp
Entries 6879
Mean 0.5647
Std Dev 0.013
(fEdep/(fEnGen*1000))

New model for Michel electrons/EM showers




(shErr+trkErr):thr
(shErr+trkErr)
thr
View 2
View 1
View 0
0
0.2
0.4
0.6
0.8
1