Particle Flow Validation for CLICdet

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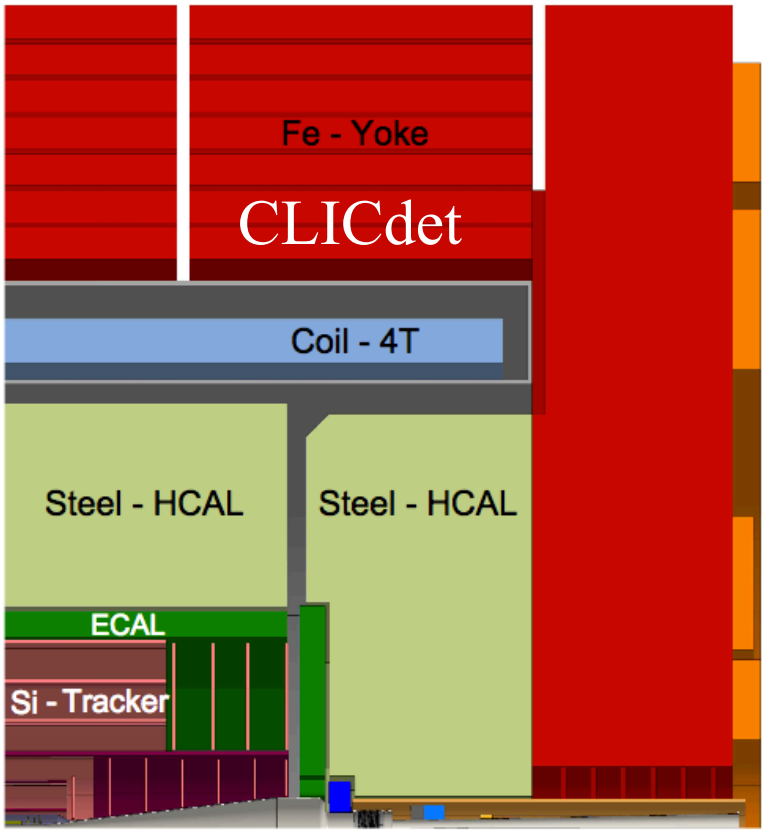
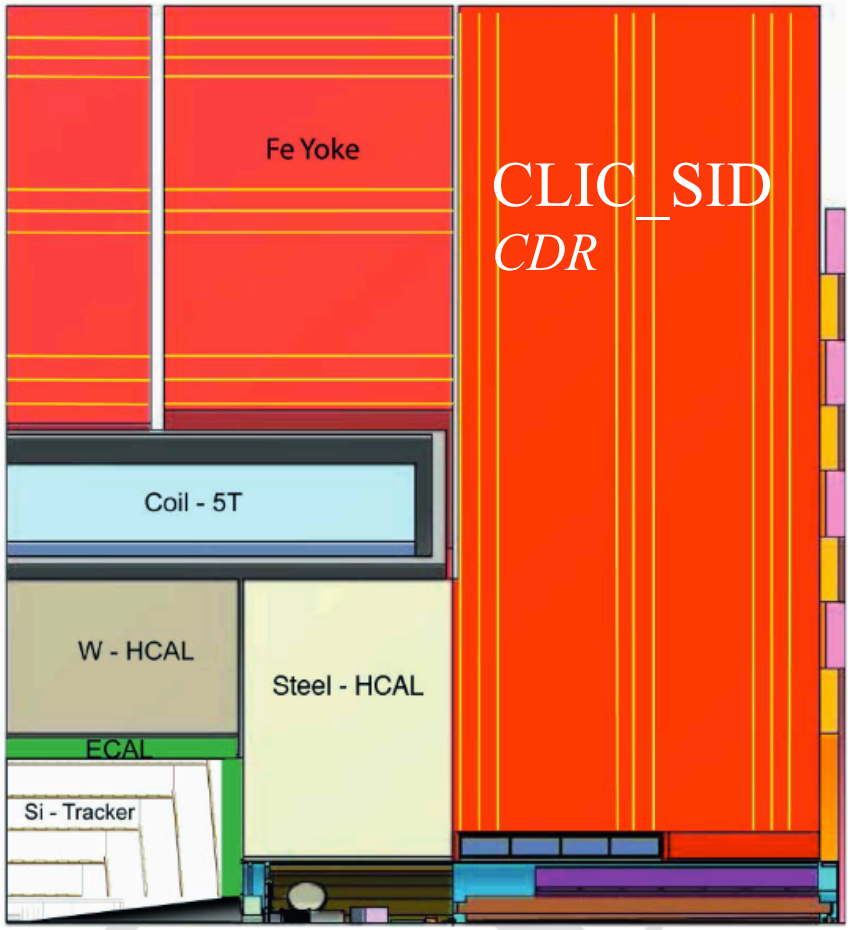
New CLIC detector model CLICdet





New optimised model **CLICdet** for new benchmark studies:
Single detector, 4 Tesla solenoid field, all steel HCAL, smaller return Yoke,
quadrupole magnet outside of detector allowing better forward HCAL coverage

CLICdet: model CLIC_o3_v08

- Studies performed using DD4hep, model CLIC_o3_v08 from ILCSoft CERN release from 2017-02-17
- Calorimeters calibrated using 10 GeV photon, 10 GeV muon and 50 GeV K^0_L single particle gun samples, new tuning of photon identification
- In general use default values of Pandora identification algorithms
- Software release: HEAD release, available under /cvmfs/clicdp.cern.ch from 2017-02-02
- Study performance of conformalTracking for the Vertex hits with an extrapolator for Inner and Outer Tracker Hits, compared to TruthTracking

Particle Flow validation of CLICdet

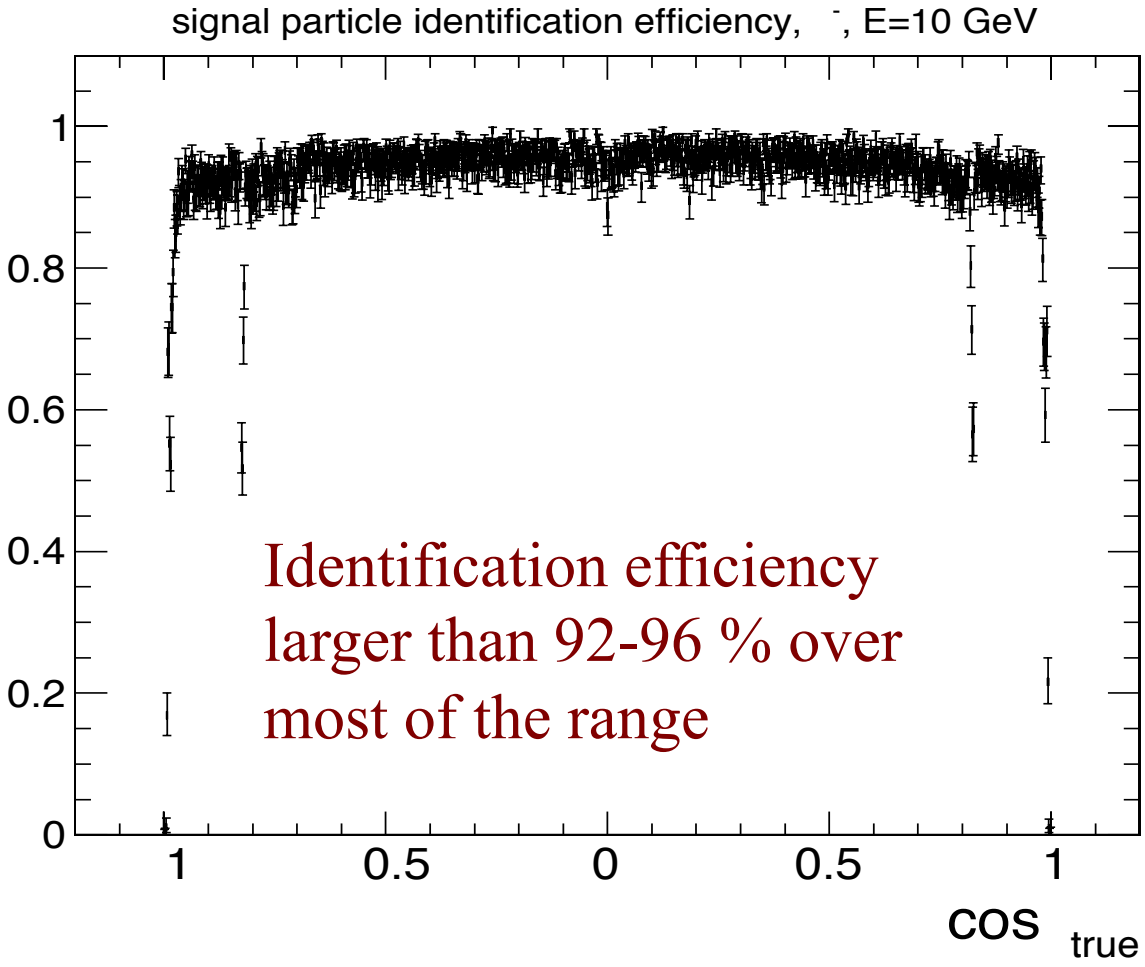
- Study performance of PandoraPFA with simulated and reconstructed particle gun events of isolated **electrons**, **pions, photons**, neutrons and muons for a few energy points
- Study details in the identification algorithms to check if selections could be optimized to adapt to the new detector model

- Study the performance of PandoraPFA for the new detector model in hadronically decaying Z events (decays into u,d,s)
  - generated with Pythia6
  - Simulated and reconstructed using DDsim and DDMarlinPandora interfaced with PandoraPFA

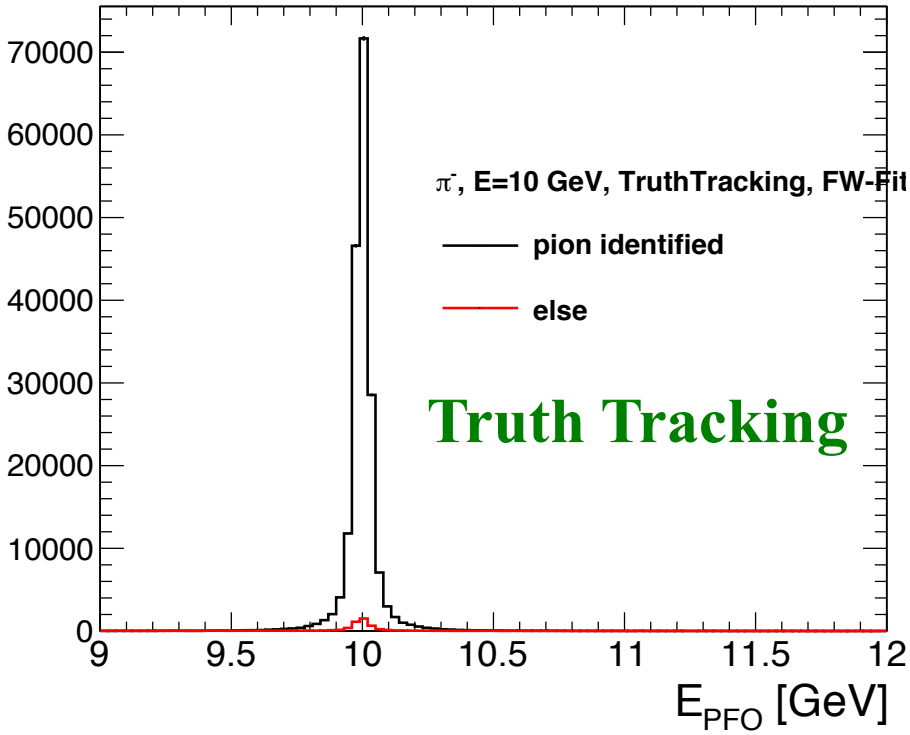
⟹ Performance of pandora identification algorithms in a dense environment, check energy resolution and reconstruction in jet events

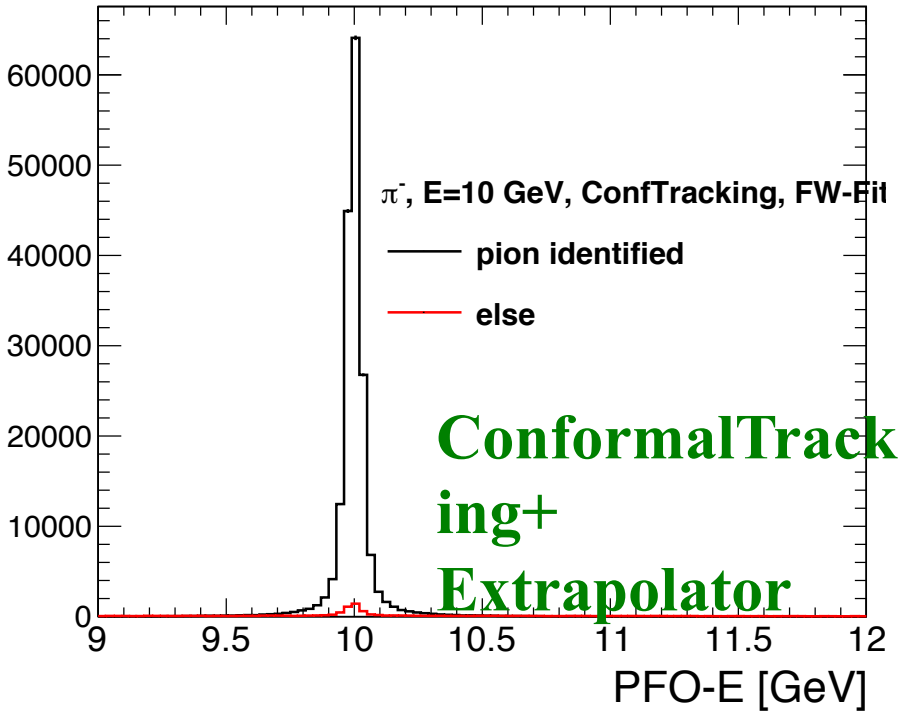
Pions at 10 GeV: Truth Tracking, FitForward

Pions: charged tracks matched to clusters, cluster not compatible with MIP (muons) and electromagnetic cluster (electrons)



Pions at 10 GeV: Energy Resolution

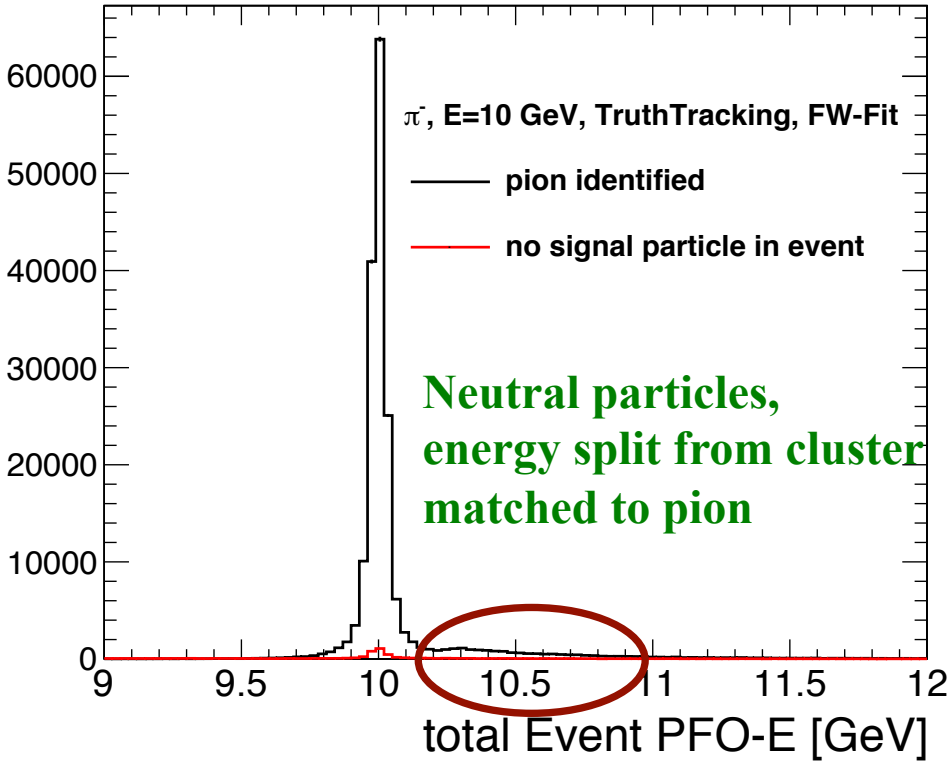


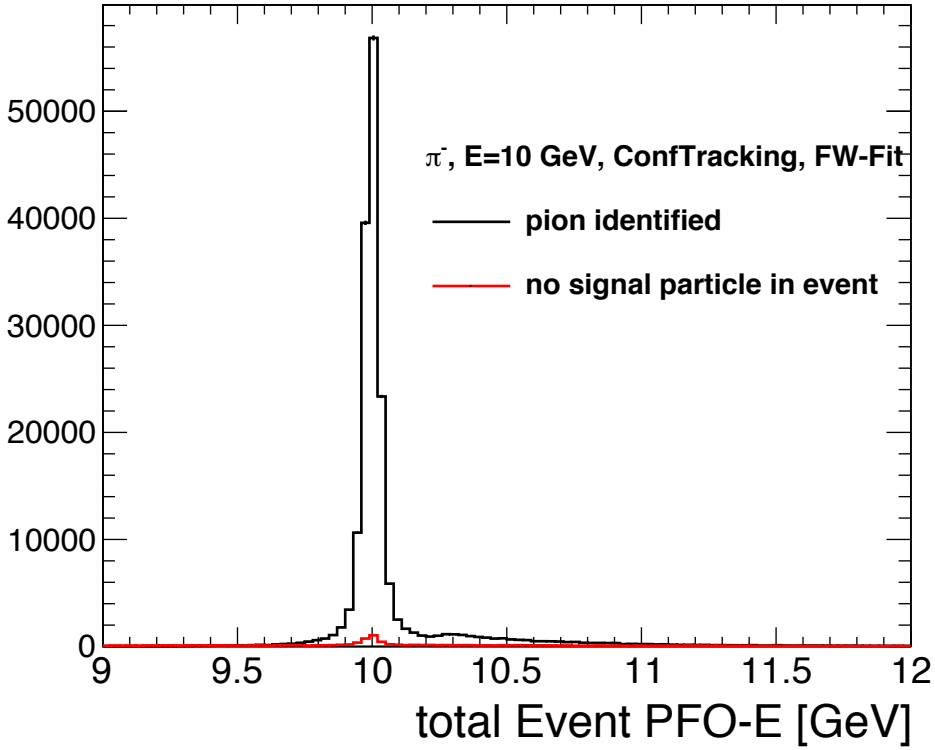


Correctly identified pion:
Energy scale (mean): 1.000±2.9e-05
Relative RMS: 0.872±0.002 %

Energy scale (mean): 1.000±3.5e-05
Relative RMS: 1.12±0.002 %

Pions at 10 GeV: total energy resolution



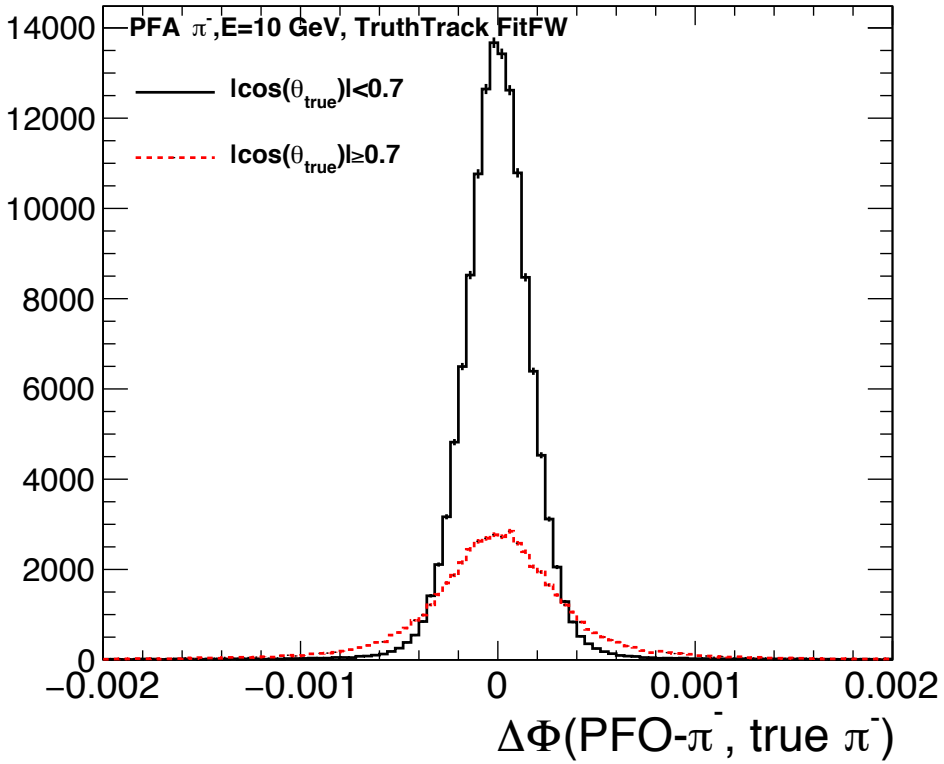


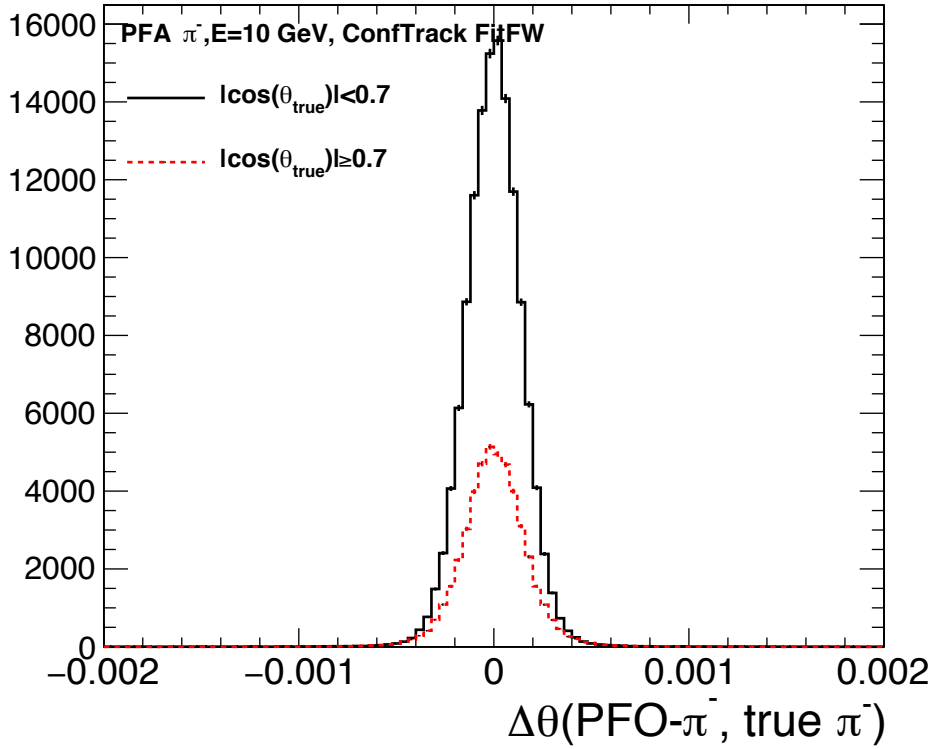
Correctly identified pion events:
Energy scale (mean): 1.000±2.9e-05
Relative RMS: 2.53±0.0042 %

Energy scale (mean): 1.007±6.4e-05
Relative RMS: 2.67±0.0045 %

Pions at 10 GeV: position resolution

Pions: charged tracks matched to clusters, cluster not compatible with MIP (muons) and electromagnetic cluster (electrons)





Symmetric distributions with TruthTracking (Conformal Tracking) values

RMS phi barrel:0.000247 (0.000321)

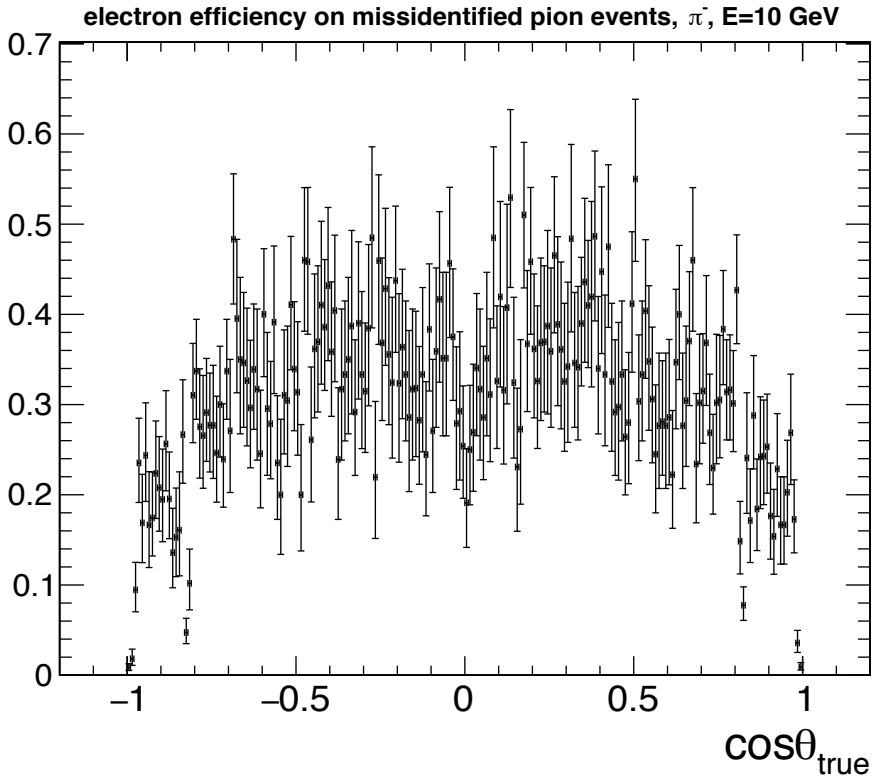
RMS phi endcap: 0.000497 (0.000598)

RMS theta barrel: 0.000221 (0.000160)

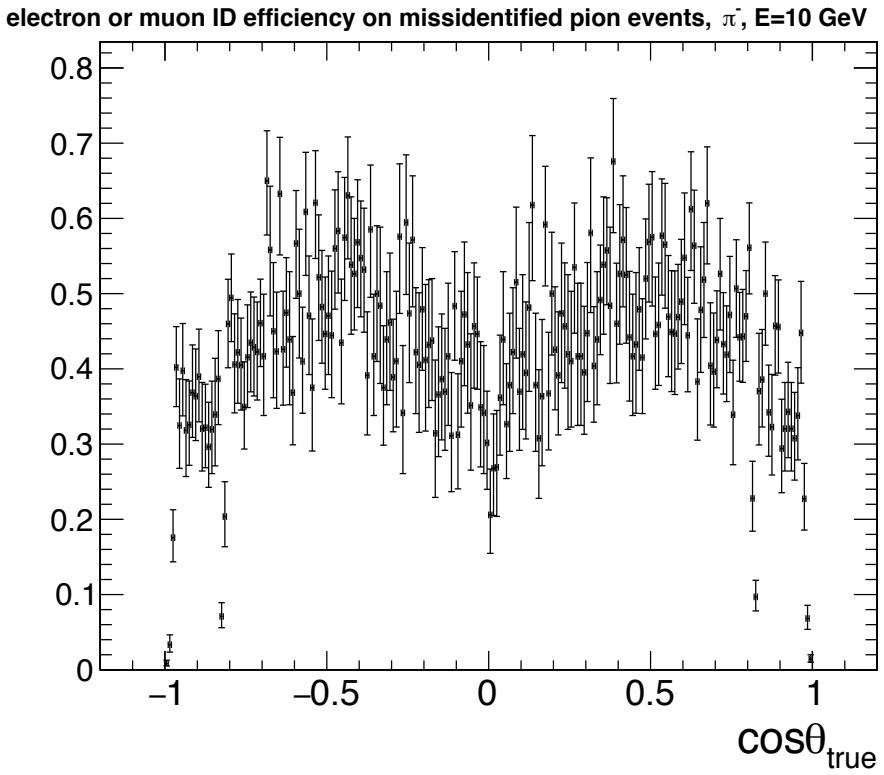
RMS theta endcap: 0.000189 (0.000194)

Pion Identification losses (I): as fraction of misidentified events

Pions misidentified as other charged particle (electrons and muons)

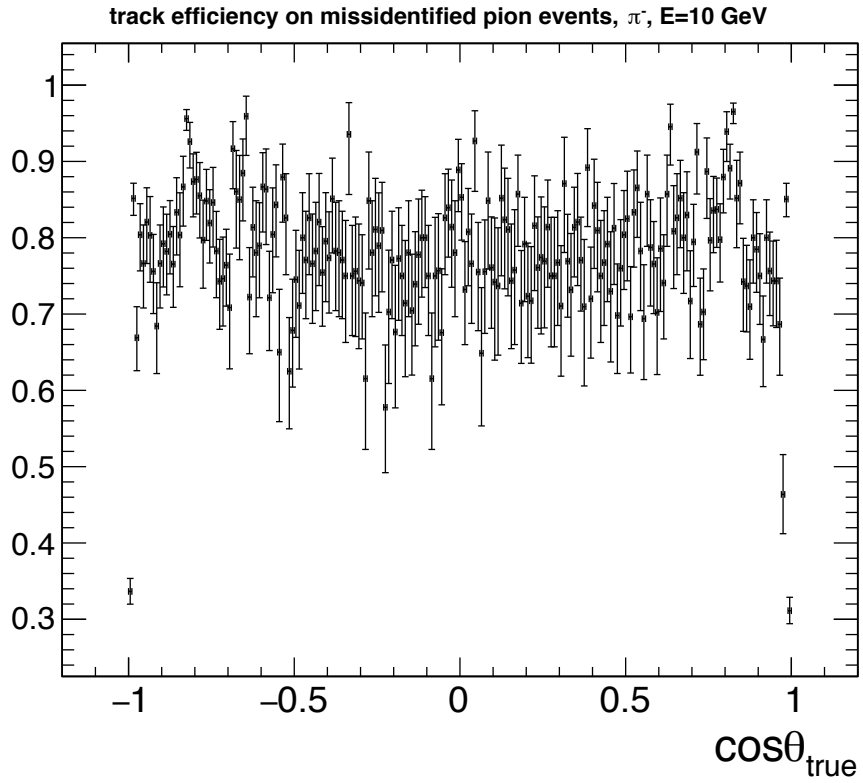


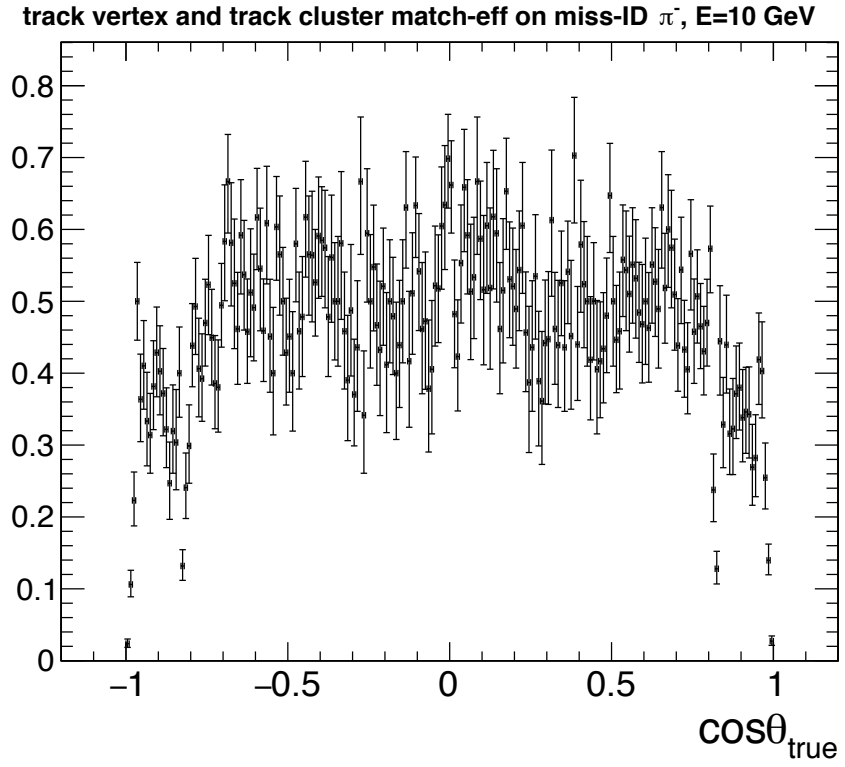
20-30 % misidentified as electrons



Additional 10-20 % misidentified as muons

Pion Identification losses (II): as fraction of misidentified events (4-8 %)

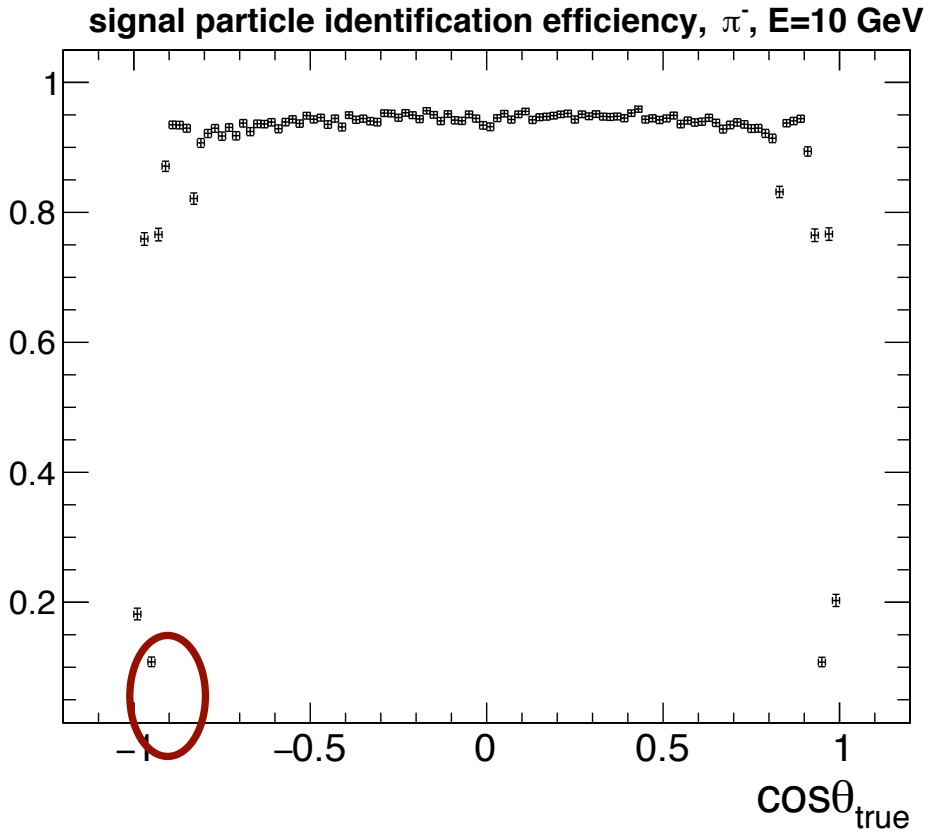


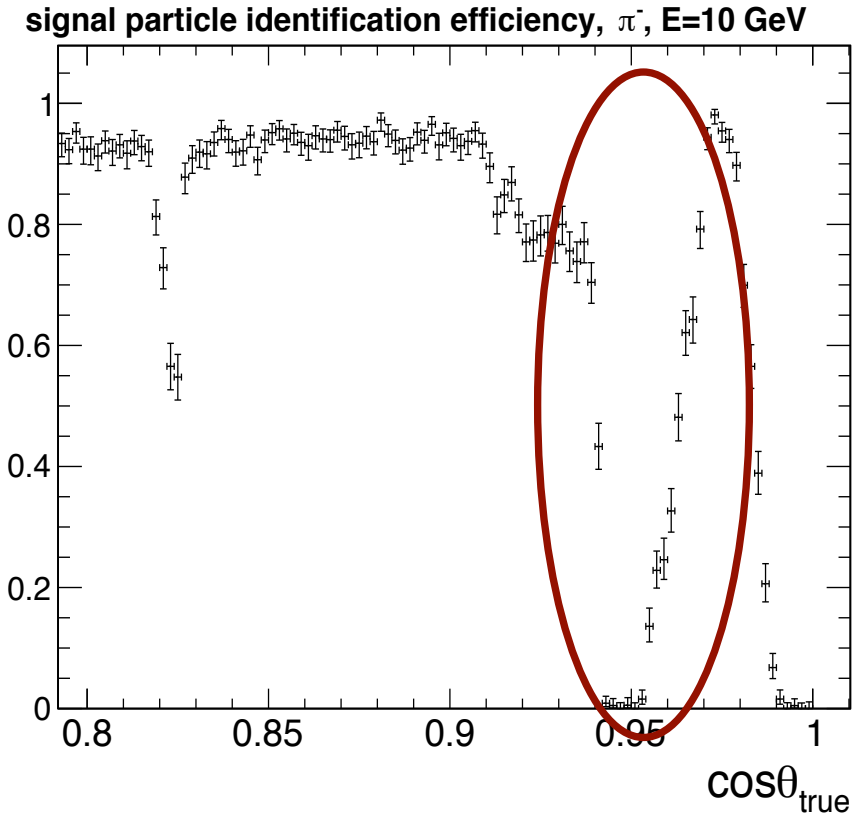


15-20 % of misidentified events without any reconstructed track

Additional 30-40% lost due to failing track-cluster matching →increased inefficiency in transition region

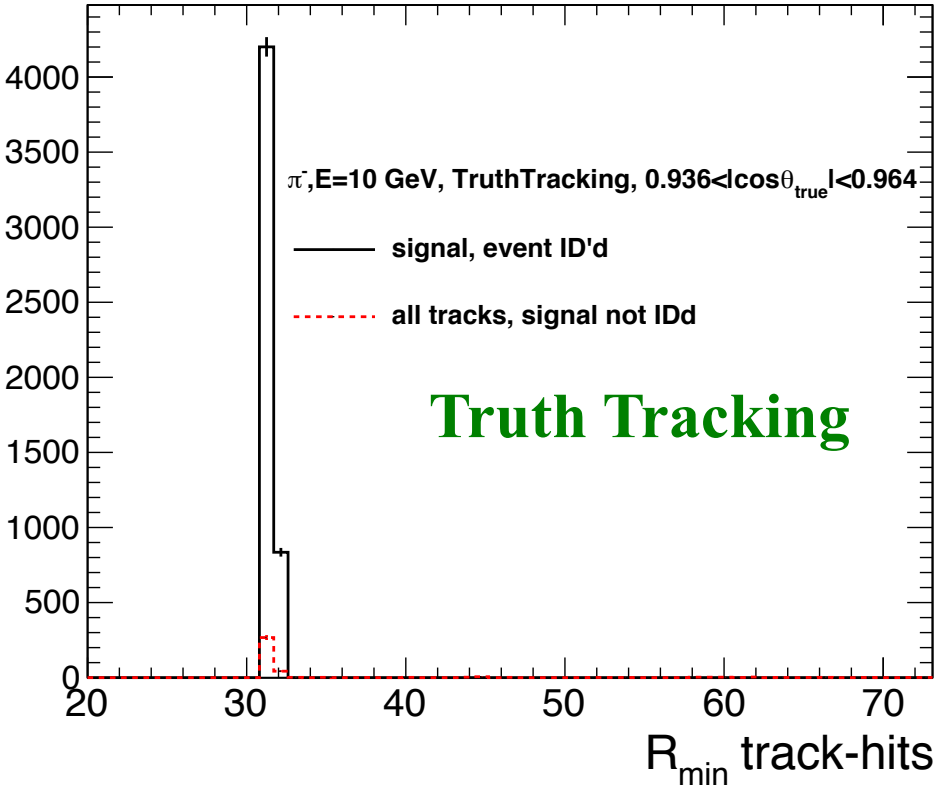
Pions at 10 GeV: conformal tracking identification efficiency

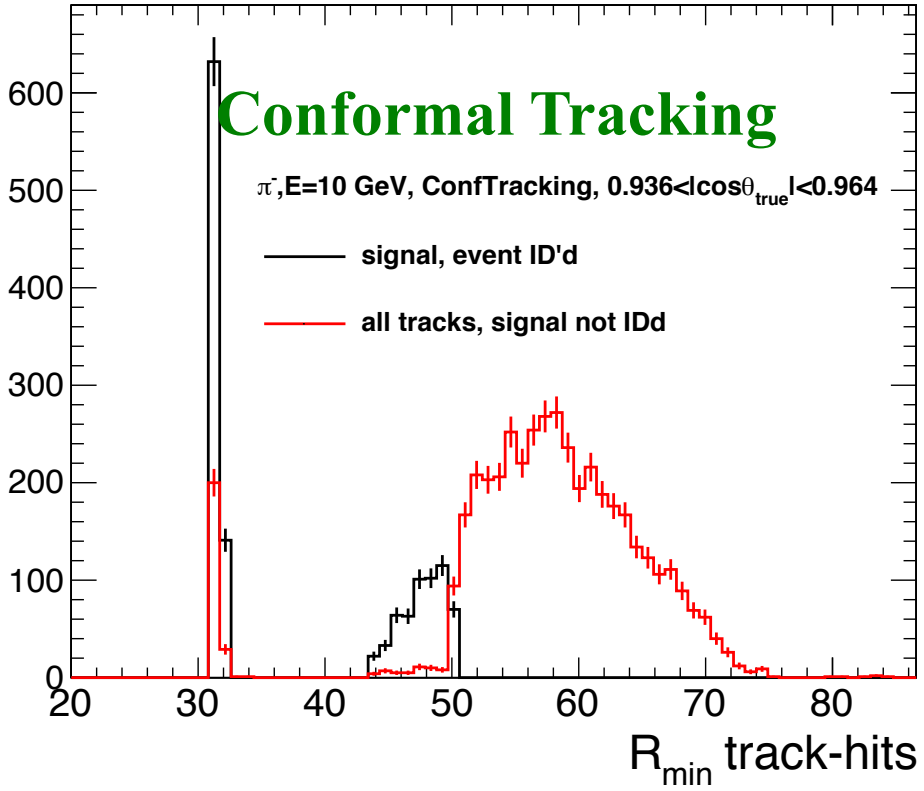




New identication inefficiency (besides transition region), originating from switch to conformal tracking from truth tracking

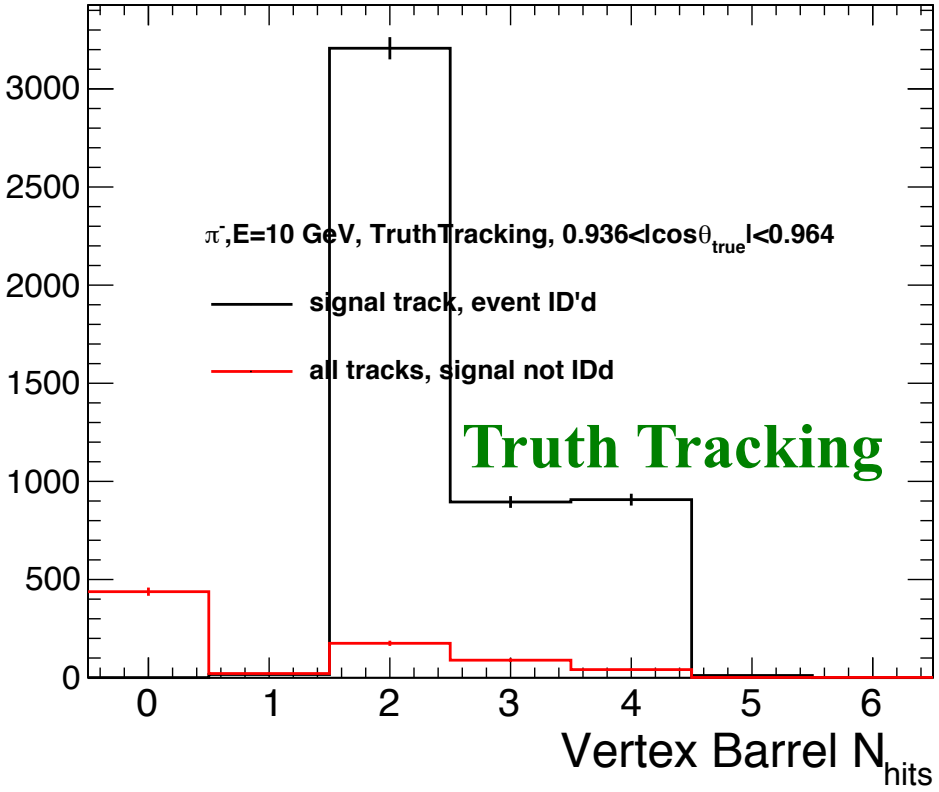
Pions at 10 GeV: conformal tracking identification efficiency (I)

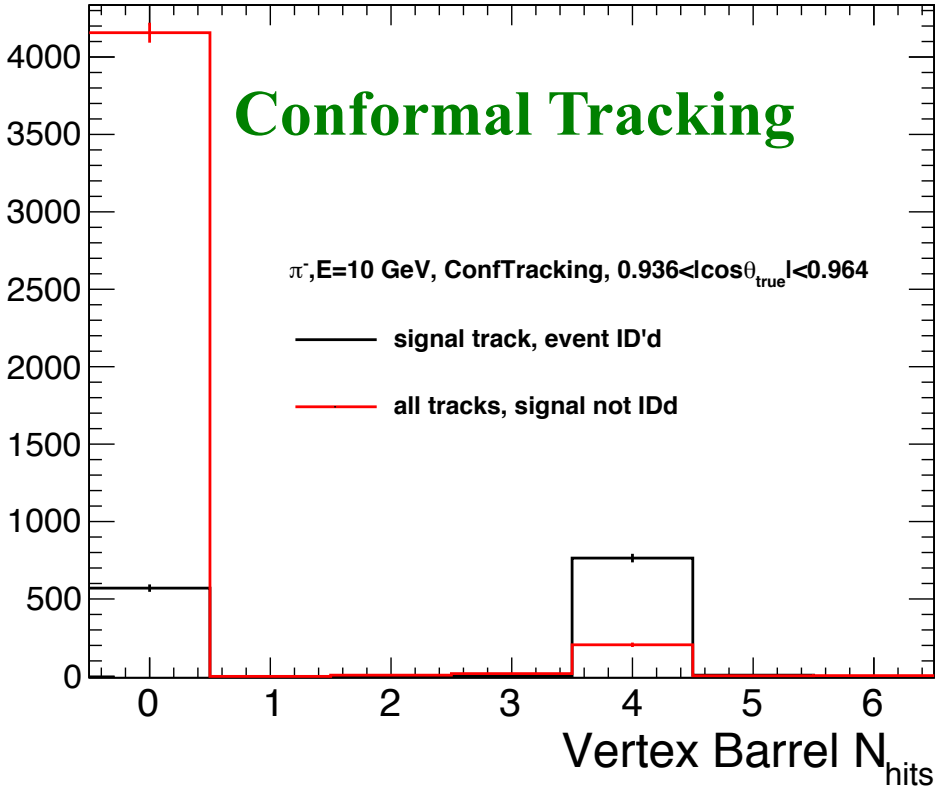




Conformal tracking does not pick up hits in inner two barrel layer in this region, fails cut in pandora PFA on R_{min} of track-hits

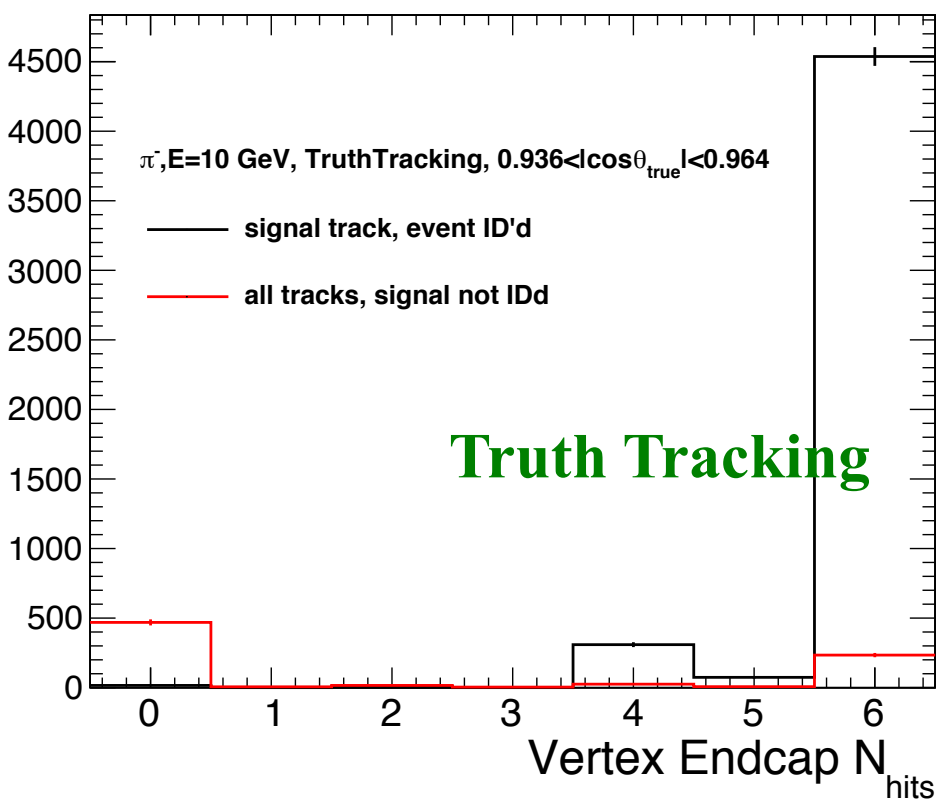
Pions at 10 GeV: conformal tracking identification efficiency (II)

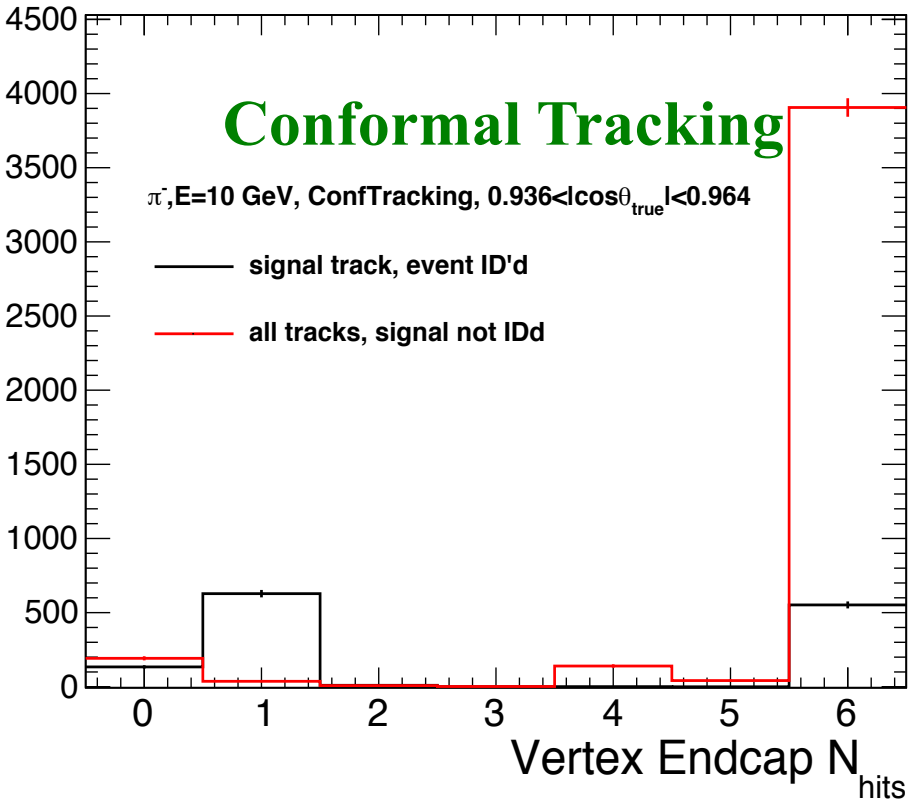




Conformal tracking does not pick up hits in inner two barrel layer in this region, fails cut in pandora PFA on R_{min} of track-hits → tracks have typically 6 hits in vertex endcap for both tracking processors

Pions at 10 GeV: conformal tracking identification efficiency (II)





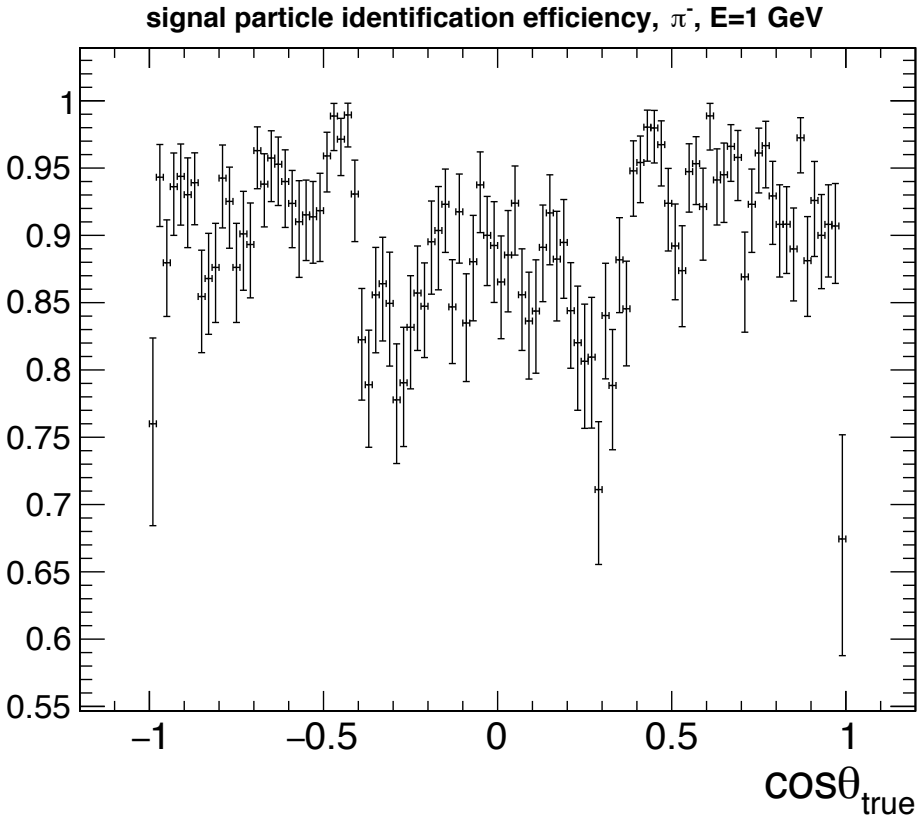
Conformal tracking run in a mode optimized for speed as well. In case 6 hits are found in the endcap, the algorithm stops.

→PandoraPFA track quality parameters not adopted to this behavior yet

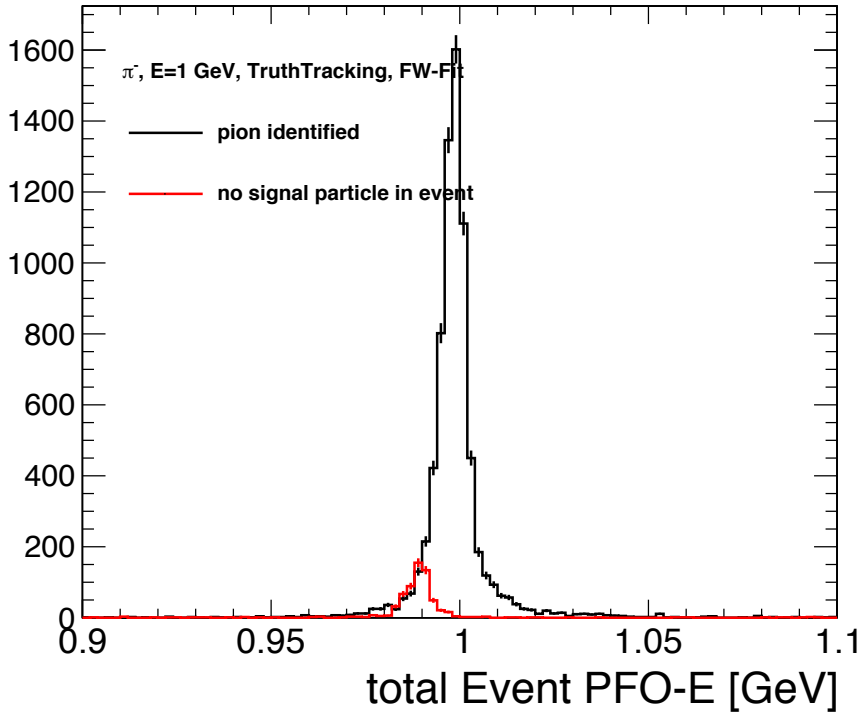
Pions at 1 GeV: efficiency

Pions: track with p < 5 GeV not required to be matched to a calorimeter cluster

→ Not allowed to electron identification, so many very low energetic electrons misidentified as pions



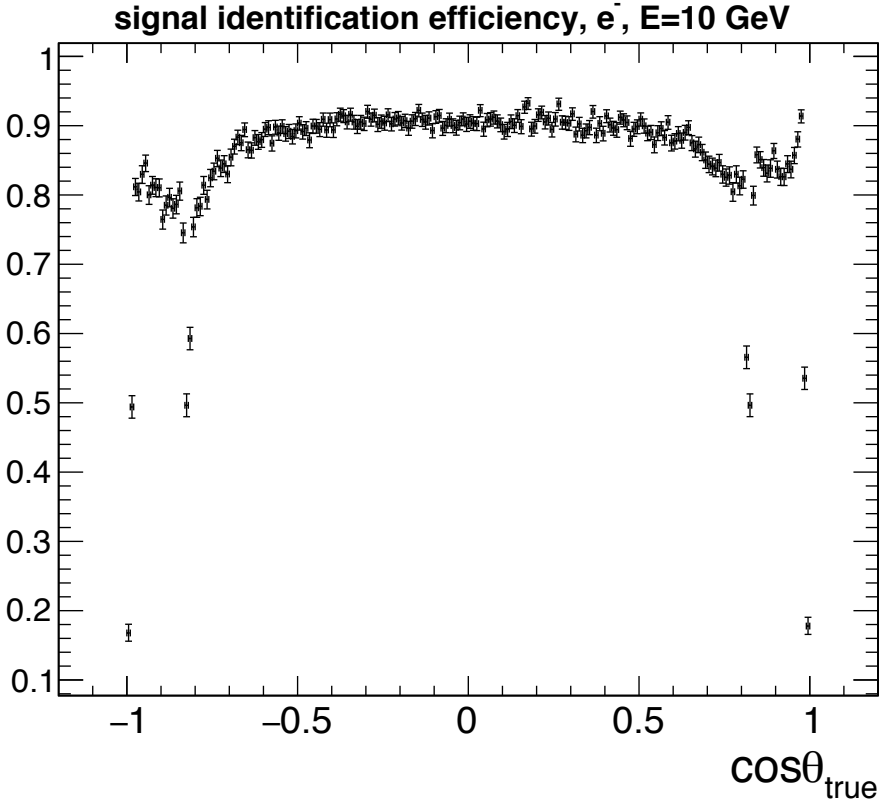
Identification efficiency above 80 %

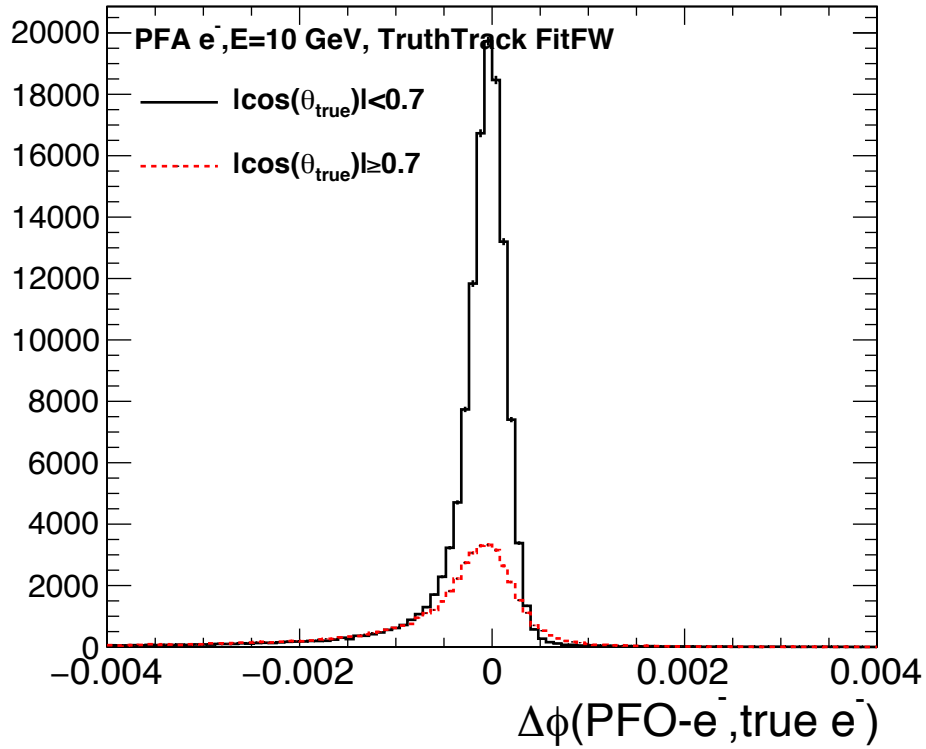


relative energy scale: 0.985
relative energy resolution: 1.69 %

Electrons at 10 GeV

charged tracks matched to electromagnetic clusters with compatible E/p

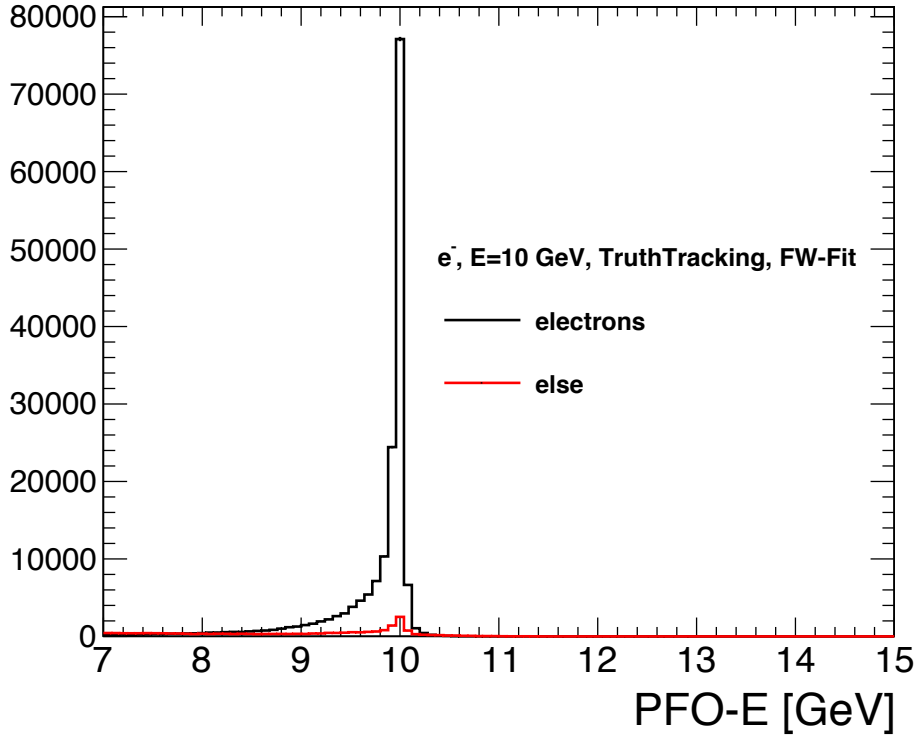


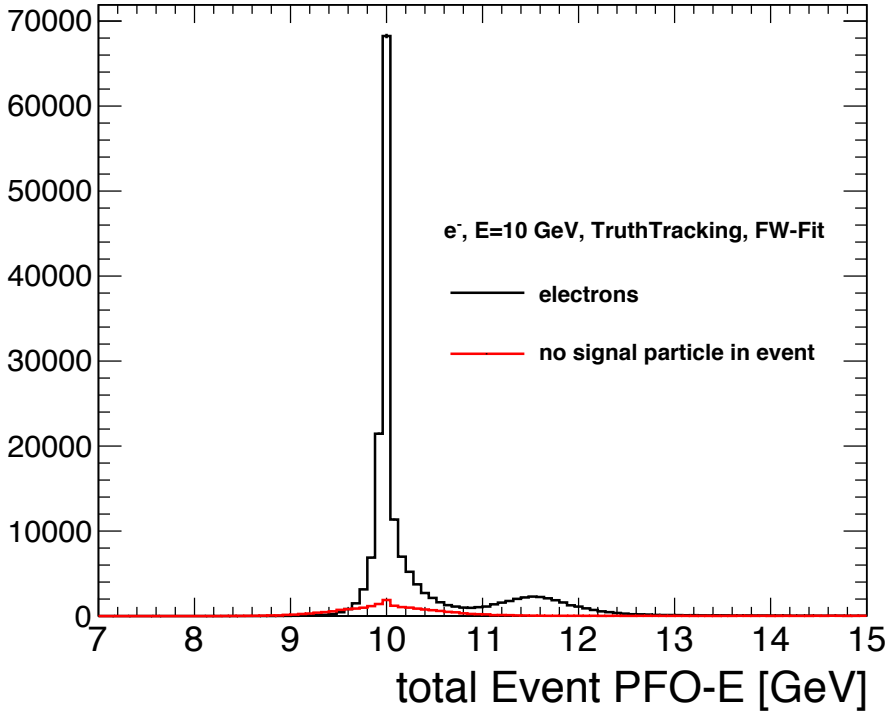


Identification efficiency around 90 % in barrel, decreased to 80 % in endcap

bremstrahlung photons bias directions and energy of reconstructed electron, give also rise to additional “excess” neutral clusters

Electrons at 10 GeV: energy reconstruction



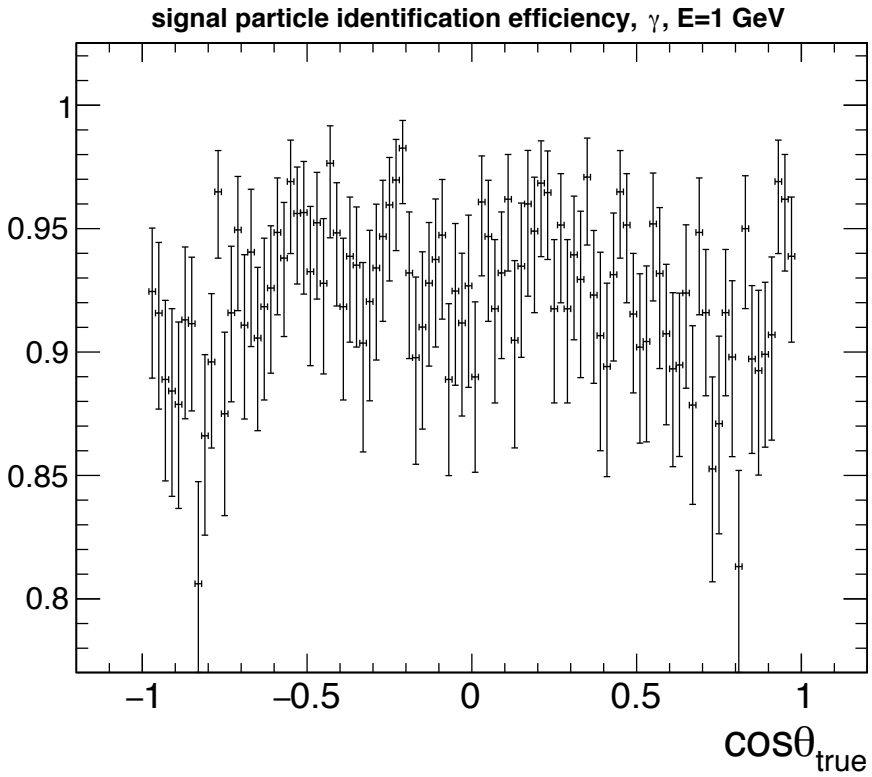


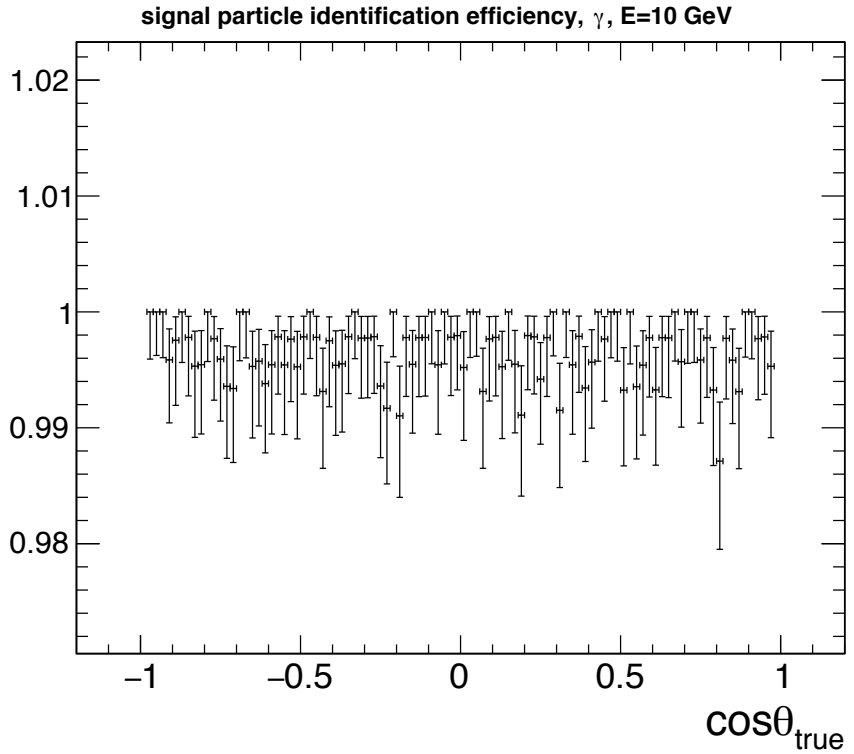
loss of energy to brem photons when considering the electron alone

In total energy sum of reconstructed PFO's brem photon contribution overcorrected/ double counted

Photons: efficiencies at 1 and 10 GeV

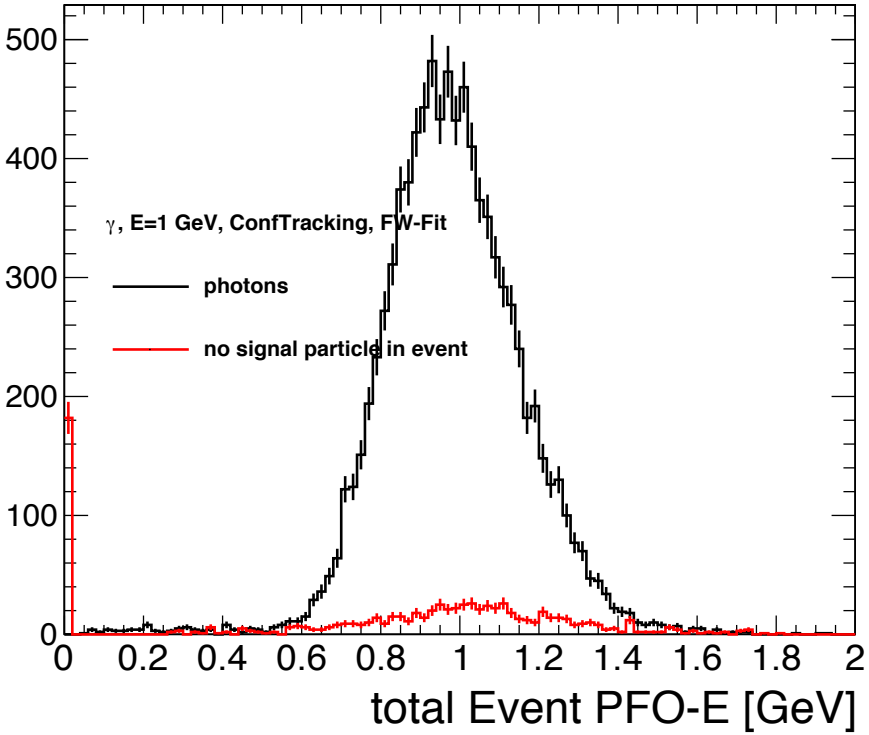
Electromagnetic clusters without a matched track

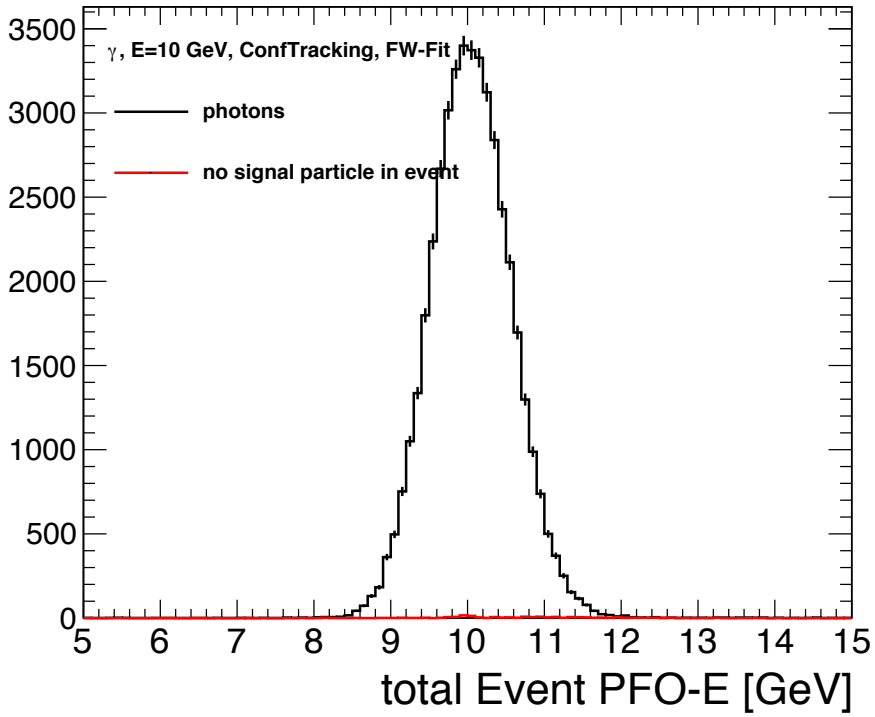




At 1 GeV identification efficiency already over 90 %, for 10 GeV beyond 99 %

Photons: Energy resolution at 1 and 10 GeV





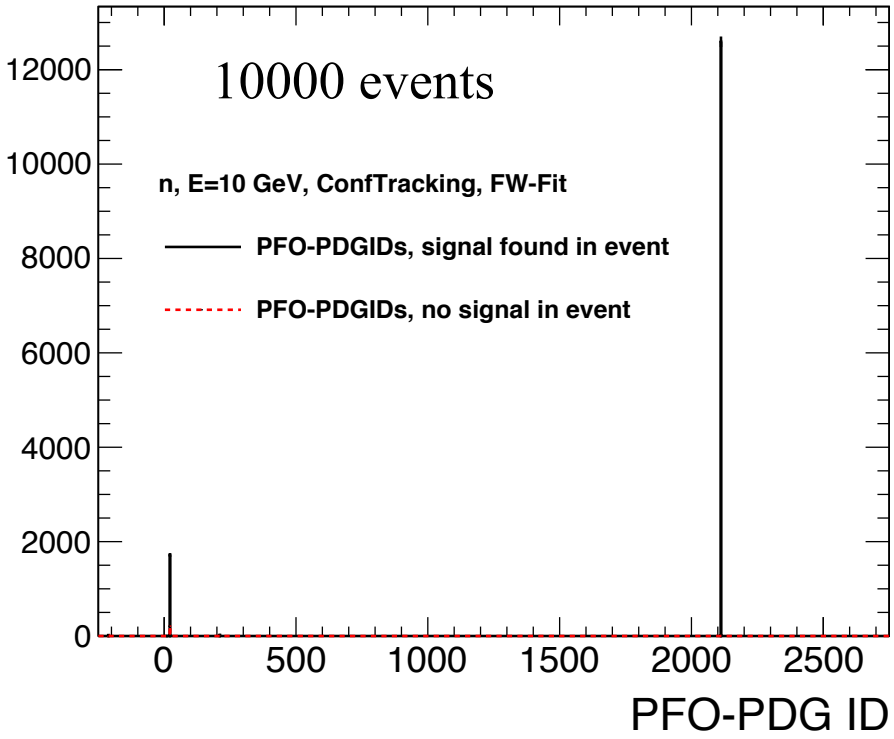
Total event energy in single photon events:

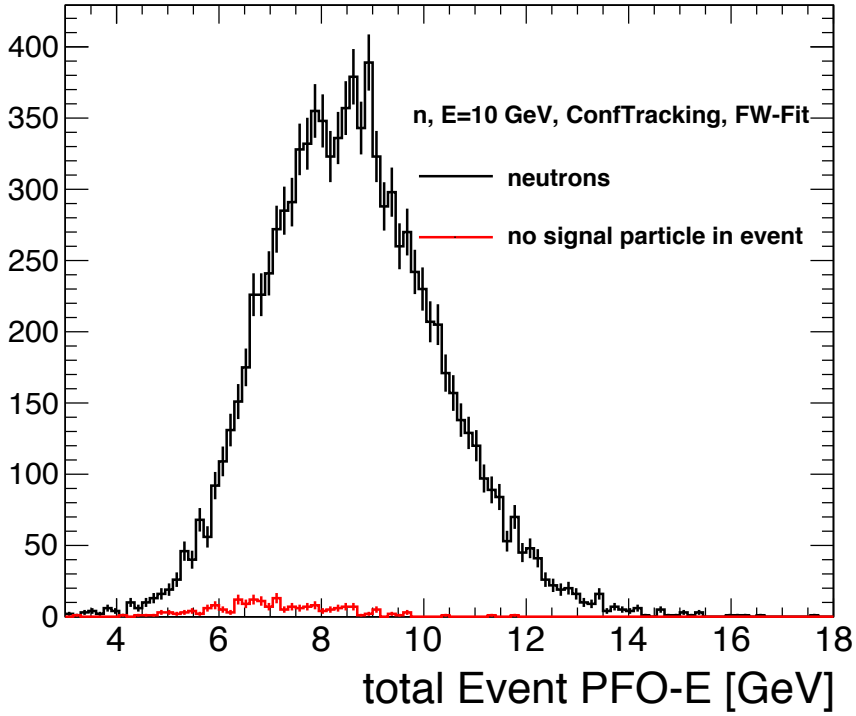
Scale: 0.985
RMS: 16.9 %

Scale: 1.000
RMS: 5.41%

Neutrons: at 10 GeV

Non electromagnetic calorimeter clusters, not matched to any track



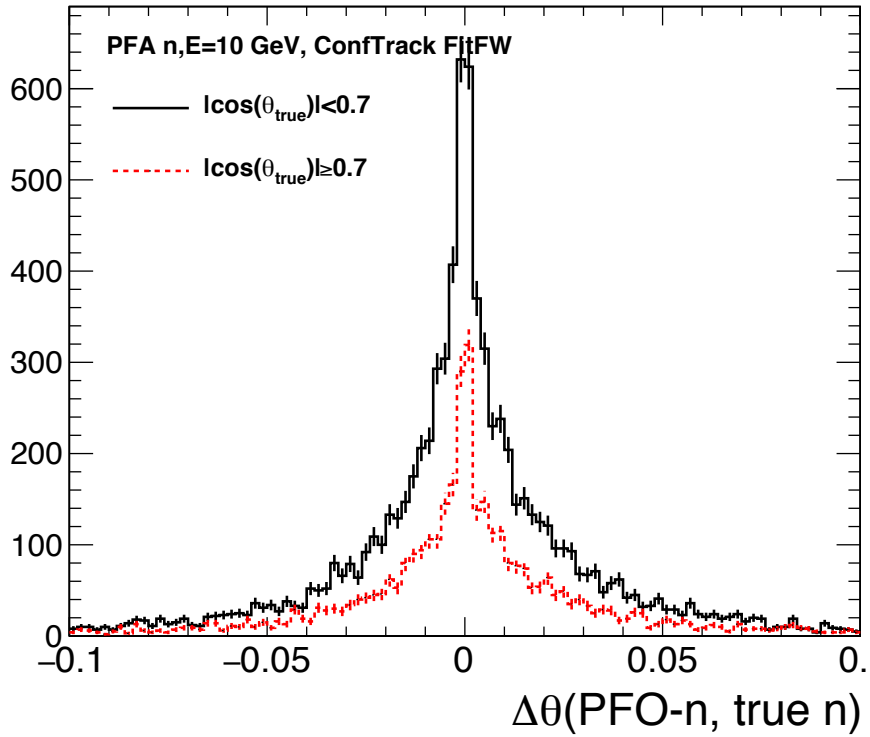


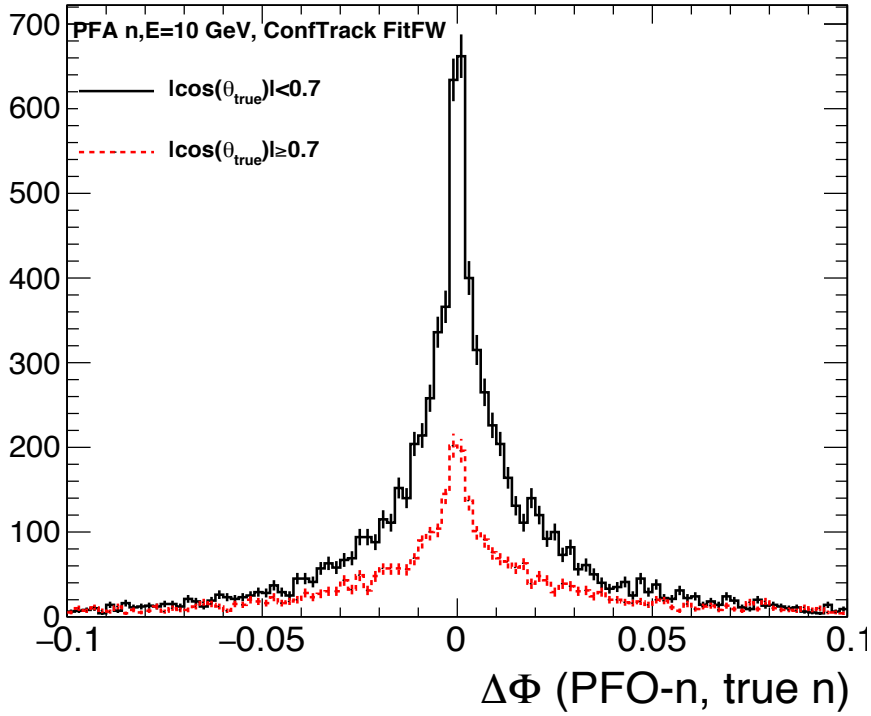
in almost all neutron event a neutron is identified, event often contains an additional neutral particles

Clearly worst resolution and scale of all particle types:
Relative energy scale 0.860
Relative resolution: 16.1 %

Neutrons: at 10 GeV: position resolution

Non electromagnetic calorimeter clusters, not matched to any track





As expected worse position resolution than for other particle types

Hadronically decaying Z events

Z->uds decays: Truth Tracking

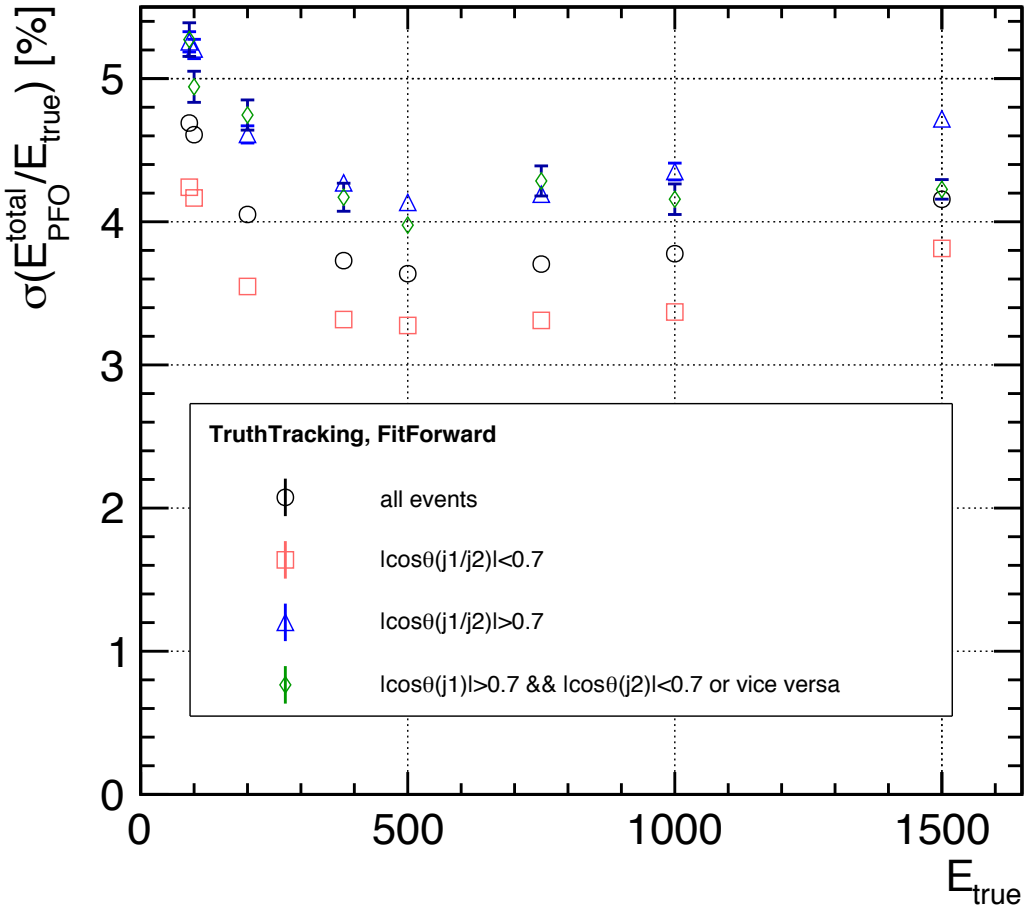
Generated using pythia6, simulate stdhep files with ddsim, reconstructed using PandoraPFA interface of DDMarlinPandora

Energy [GeV]	Relative energy scale Mean [GeV]	Relative energy resolution [%]	Energy [GeV]	Relative energy scale Mean [GeV]	Relative energy resolution [%]
91	0.991	4.69	750	0.999	3.70
100	0.991	4.61	1000	0.995	3.78
200	1.000	4.05	1500	0.986	4.16
380	1.001	3.73	2000	0.984	5.40
500	1.001	3.64	3000	0.954	5.60

Z->uds decays: Truth Tracking

Study different event configuration, determined by orientation of reconstructed k_T jets, R = 0.7, exclusive mode of 2 jets

Resolution of sum of all reconstructed PFOs to true total event Energy

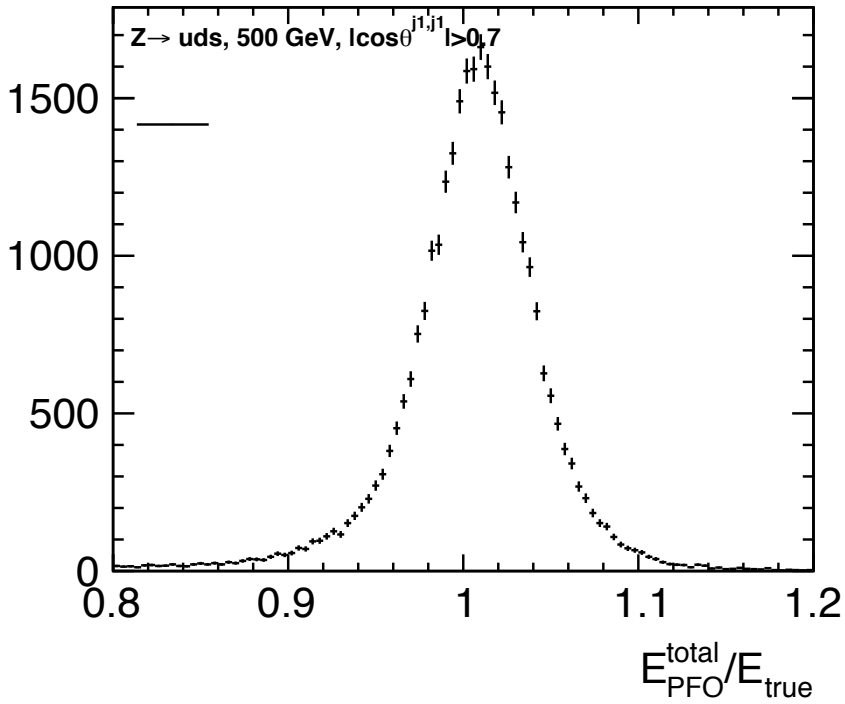


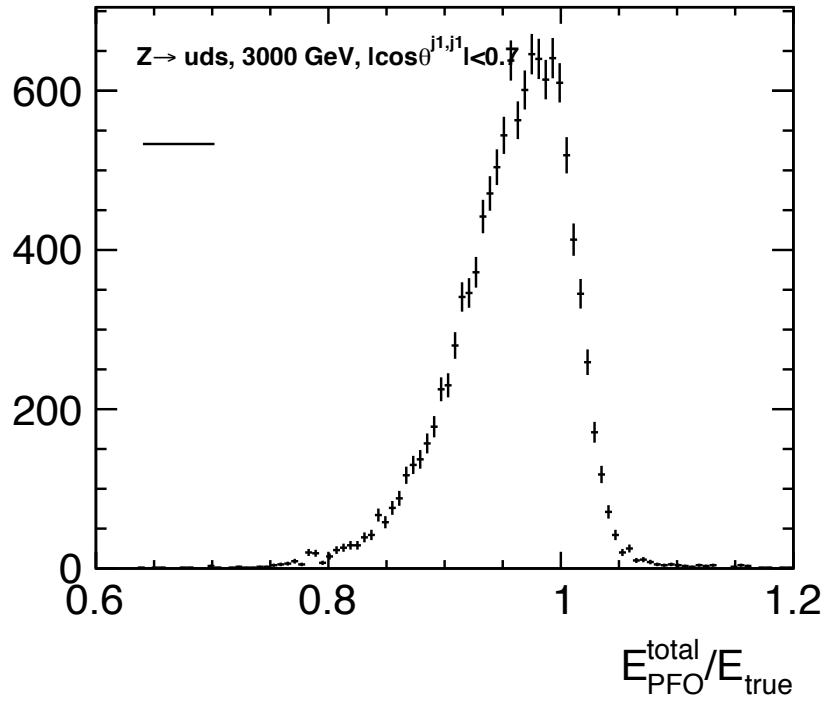
Lowest event resolution values, if both jets central (3.2-4.2 %)

Largest resolution of both jets are forward (4.1- 5.2 %)

Lowest event energy resoltution around 500 GeV

Z->uds decays:



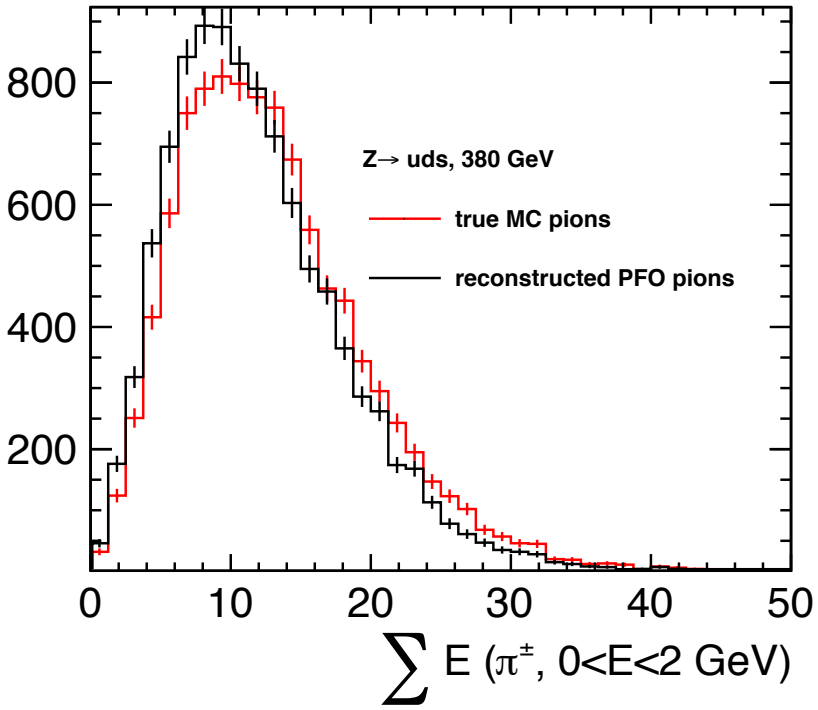


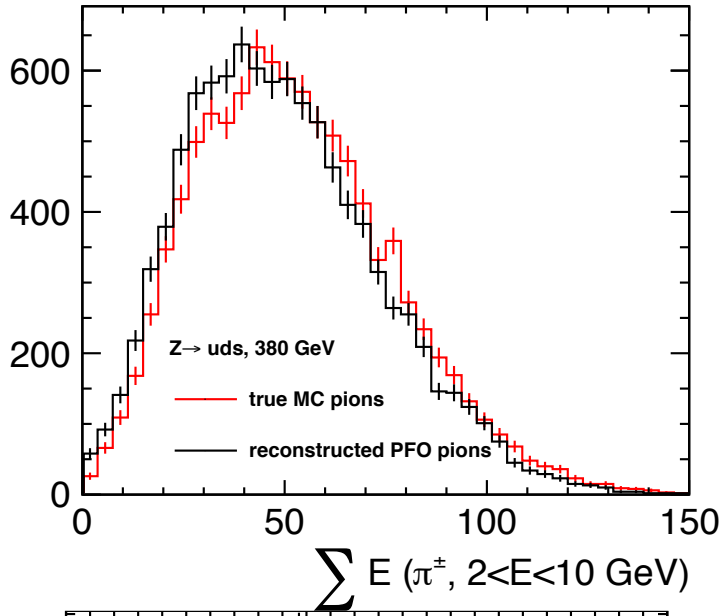
Energy resolution fairly symmetric up to 1500 GeV, with non negligible non gaussian tails

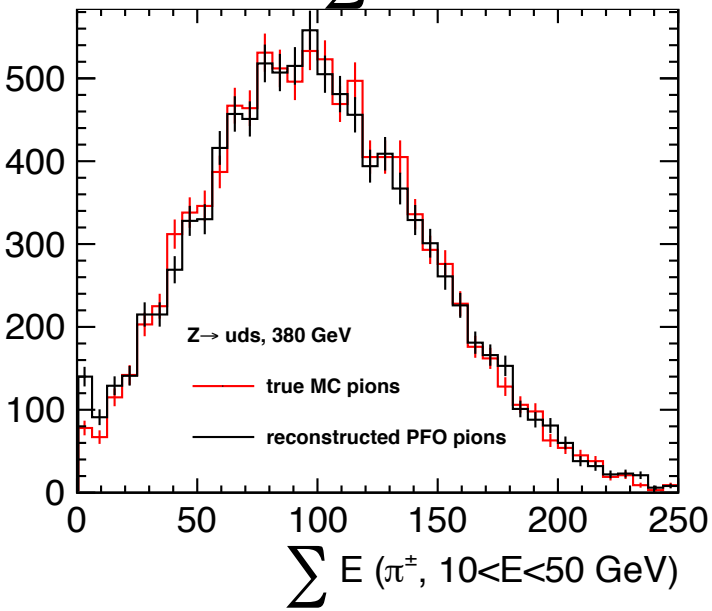
For high energy samples tail to lower energy values

→ Software compensation not tuned for this model and not applied yet, could lead to improvement of the high energy behavior

Z→uds, pion energy components

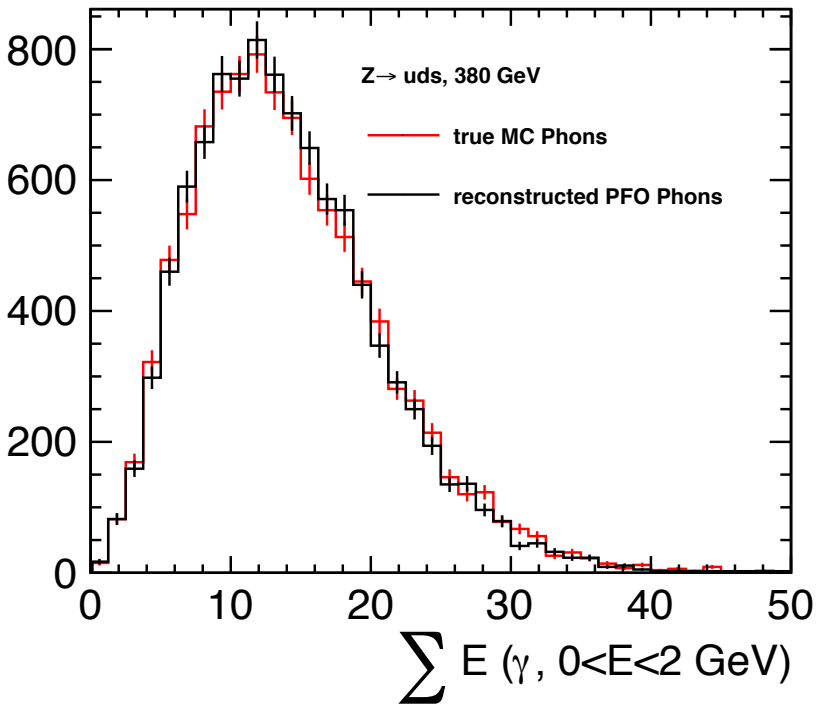


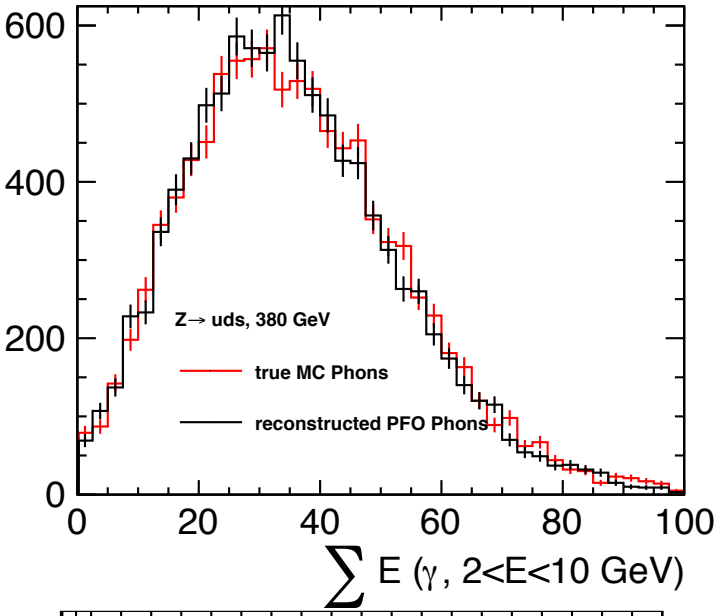


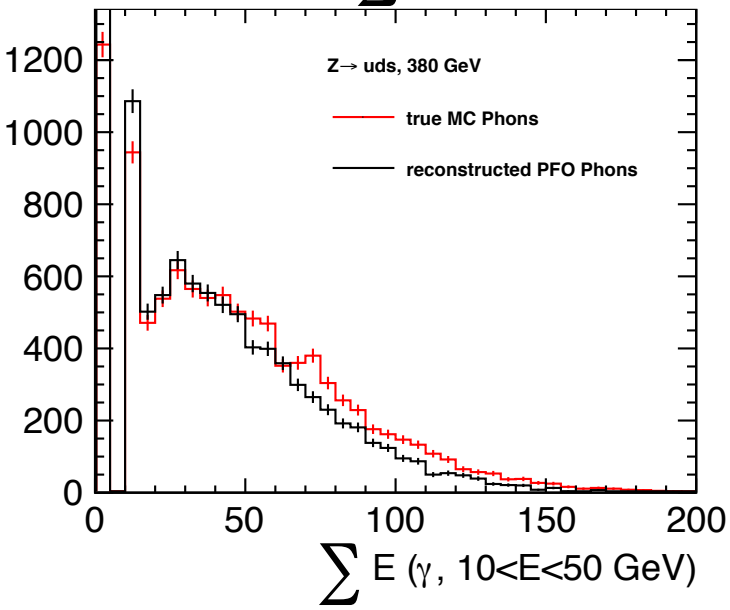


Sum of pions in different energy intervalls, compare reconstructed energy sums with energy sums of true pions
→works for all intervalls

Z→uds, photon energy components



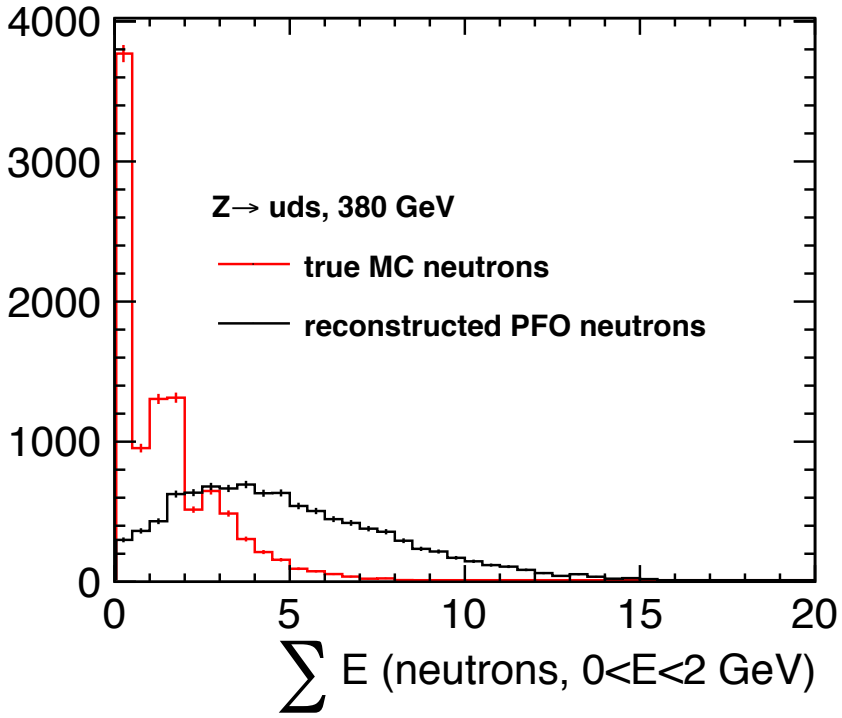


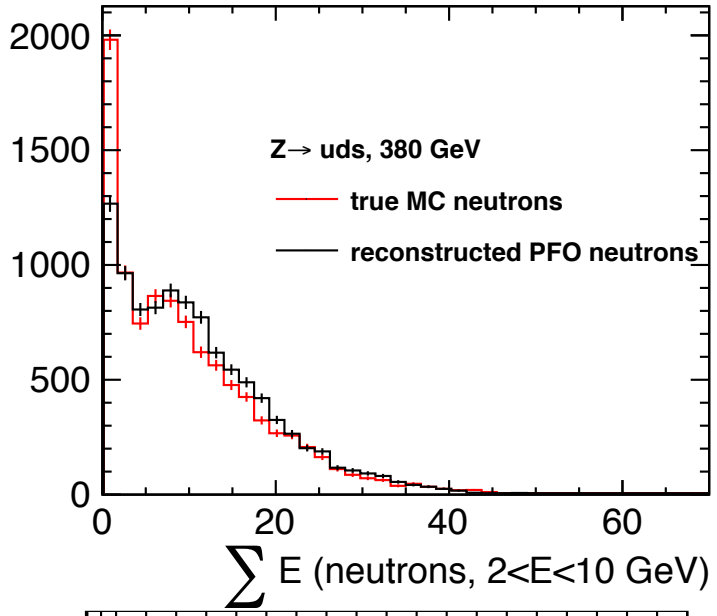


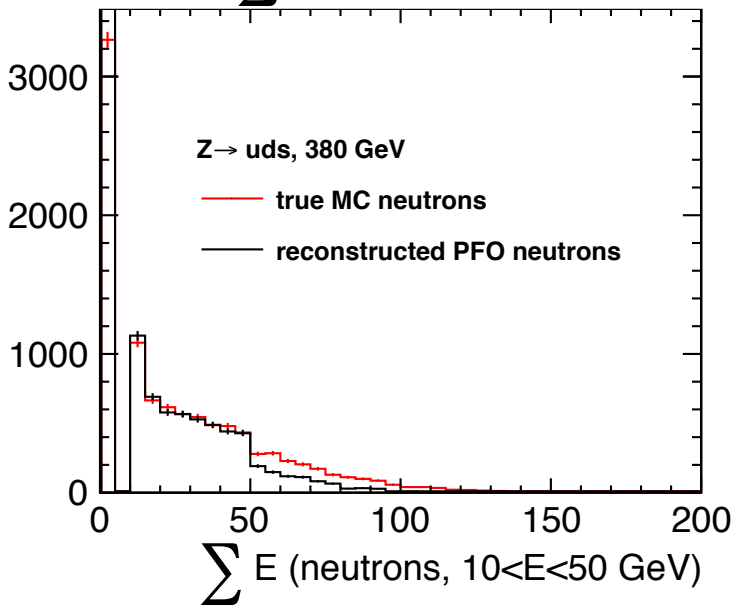
Sum of photons in different energy intervalls, compare reconstructed energy sums with energy sums of true photons

→decent agreement for low energy intervalls, more deviations for high energies, even more for high Z energies

Z→uds, neutron energy components







Sum of pions in different energy intervalls, compare reconstructed energy sums with energy sums of true neutral hadrons
→larger disagreement than for other contributions, already for low energy neutrons

Z->uds decays: ConformalTracking

Energy [GeV]	Relative energy scale Mean [GeV]	Relative energy resolution [%]	Energy [GeV]	Relative energy scale Mean [GeV]	Relative energy resolution [%]
91	0.998	5.02	750	1.013	5.43
100	0.999	4.91	1000	1.01	5.80
200	1.006	4.55	1500	1.007	11.9
380	1.010	4.85	2000	0.999	13.16
500	1.012	5.43	3000	0.977	14.67

Higher Resolution than for truth tracking, especially for high energy samples

Summary

PandoraPFA targets to correctly identity particles by type to achieve the best jet resolution

- correct identification of charged hadrons (pions), photons and neutral hadrons (assigned as neutrons) achieved beyond 95 % for most of the detector range (checked using single particle gun events)

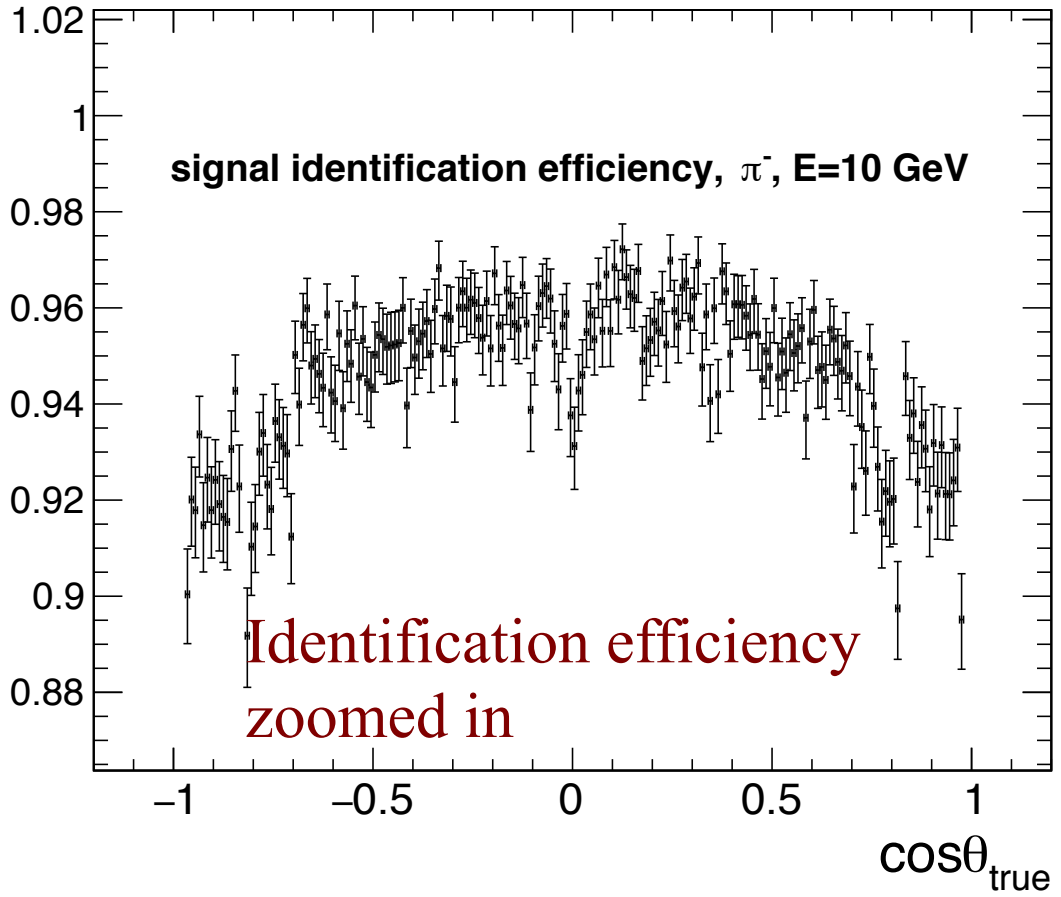
- In a dense environment in hadronically decaying Z's energy contribution from different particle species correctly reproduced

- PandoraPFA parameters not adapted yet to achieve same performance for ConformalTracking →investigation to modify parameters has been started

BACKUP

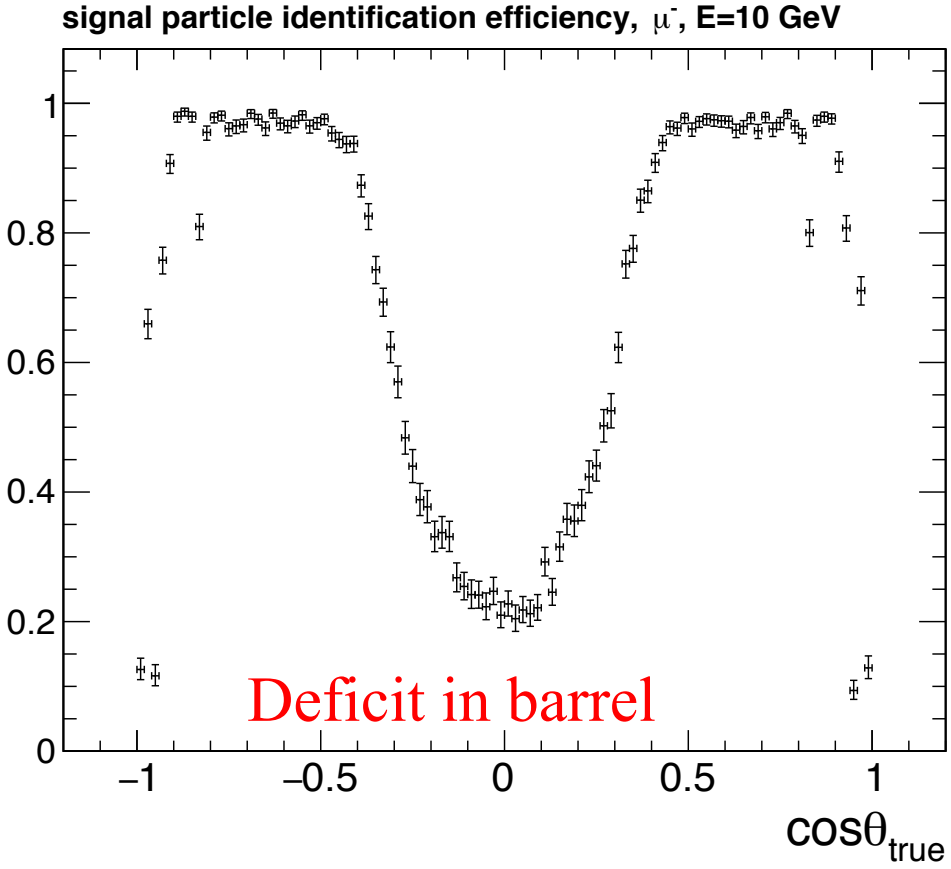
Pions at 10 GeV: Truth Tracking, FitForward efficiency: zoomed plateau

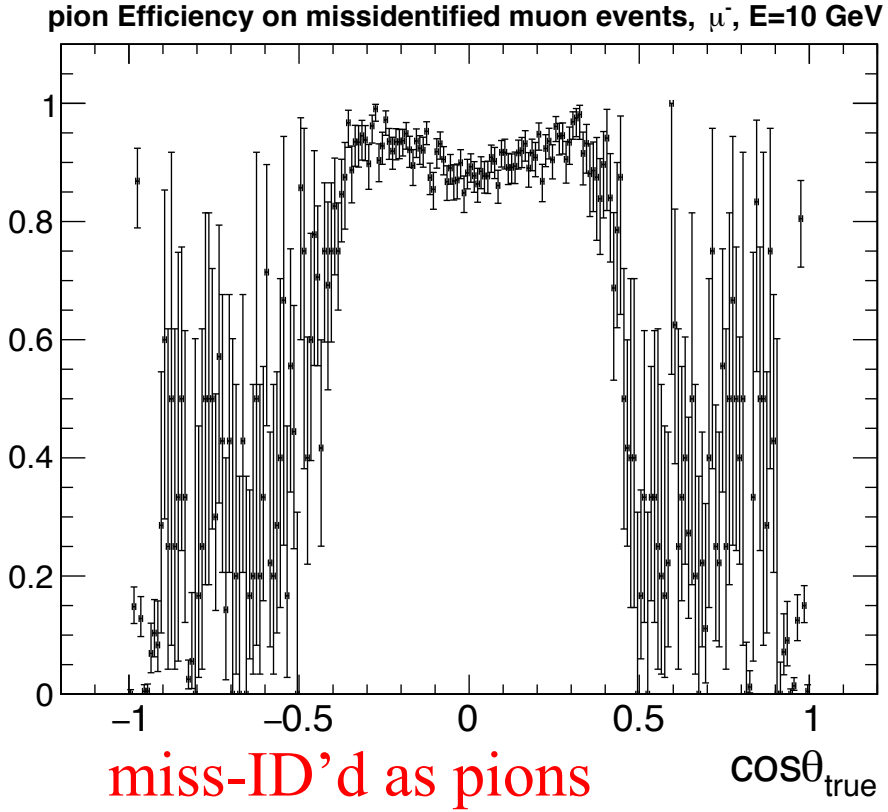
Pions: charged tracks matched to clusters, cluster not compatible with MIP (muons) and electromagnetic cluster (electrons)



Muons at 10 GeV: Truth Tracking, FitForward Identification efficiency

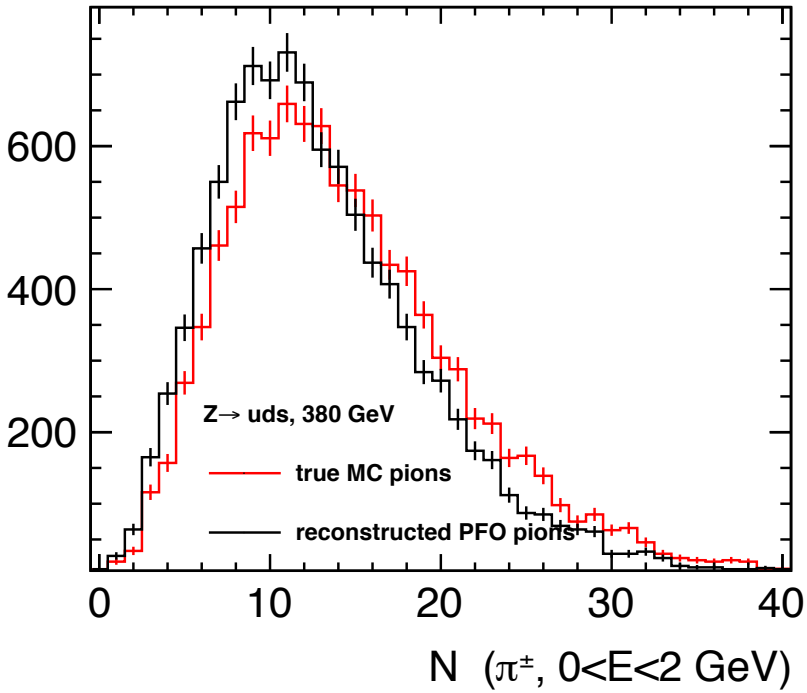
Muons: charged tracks with clusters identified as consisting of isolated MIP

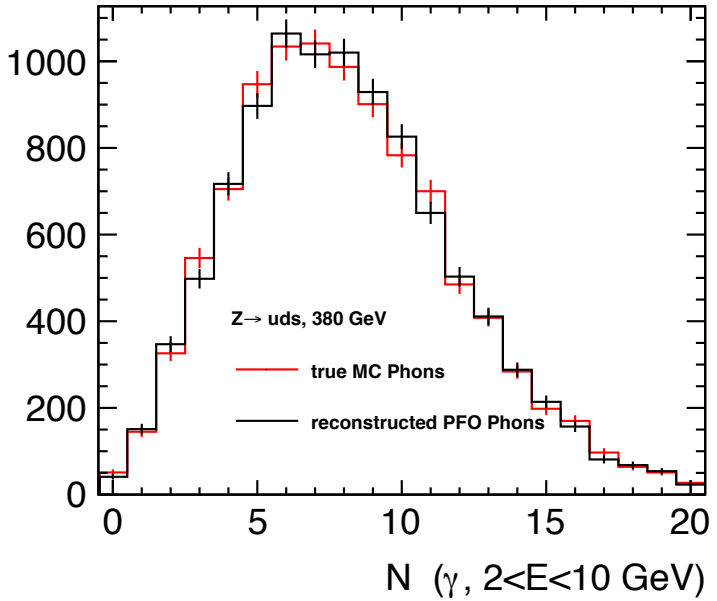


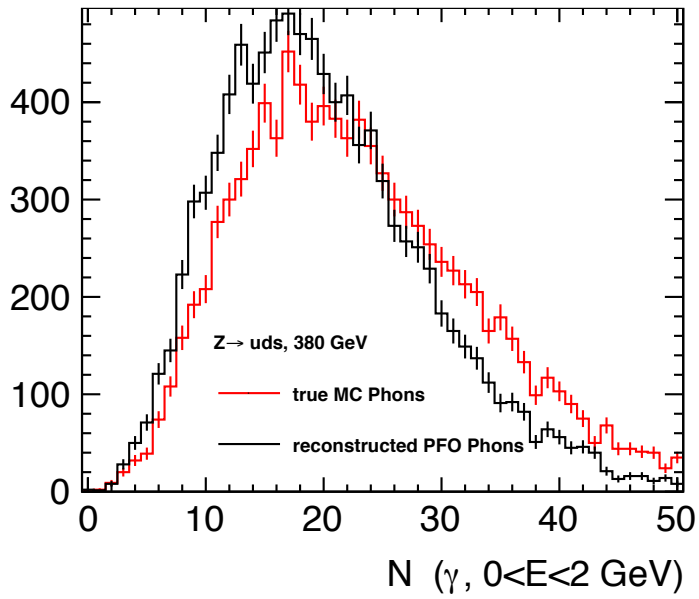


In past for studies involving isolated muons, PandoraPFA has been run in a special muon targeted configuration →default settings works in outer barrel and endcap, deficit in barrel

Z→uds, particle multiplicities







Multiplicities show similar shape for reconstructed particles and true MC Particle multiplicities