Particle Flow Validation for CLICdet

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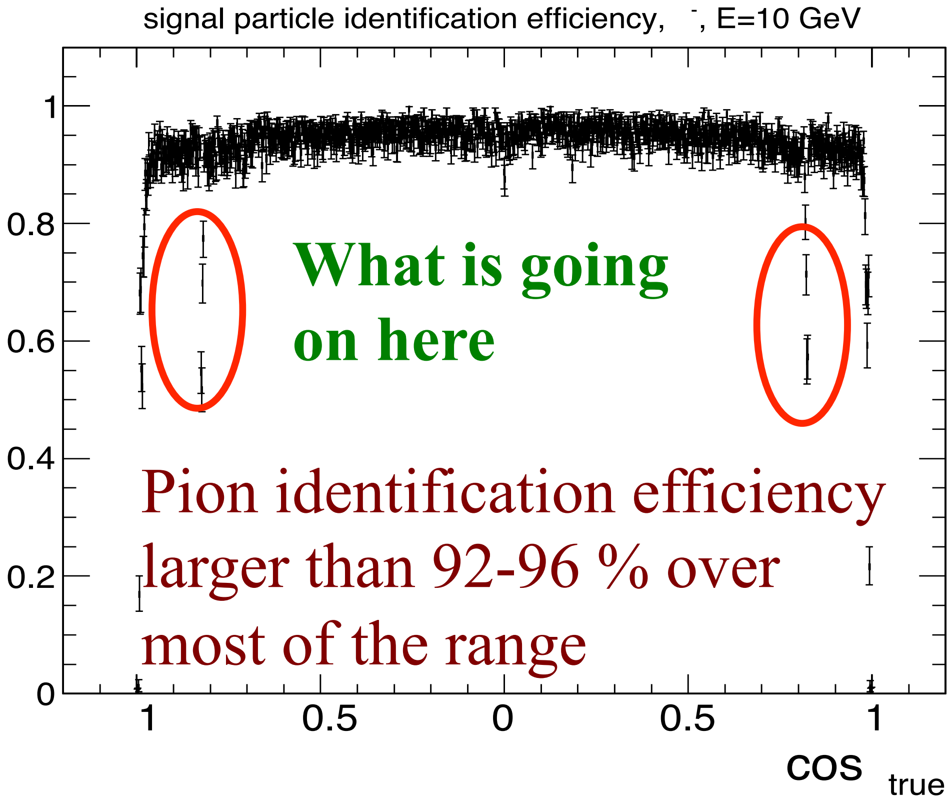
Reminder: Particle Flow validation of CLICdet

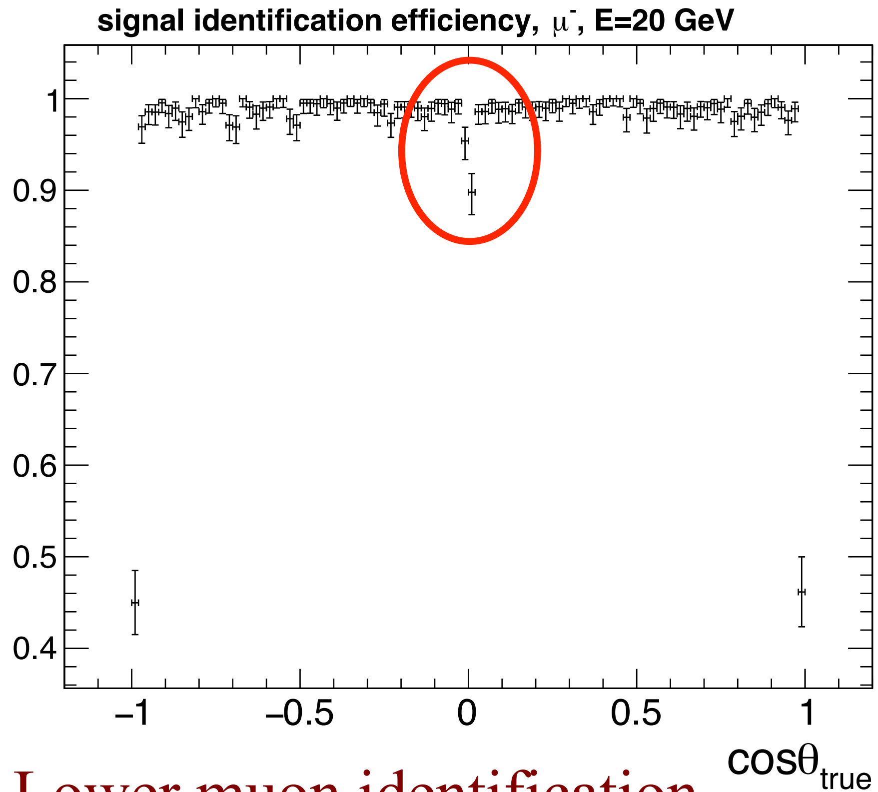
Study performance of PandoraPFA with simulated and reconstructed particle gun events of isolated **electrons**, **pions, photons**, neutrons and muons for a few energy points →presentation at CLIC workshop



What is going on here

Pion identification efficiency larger than 92-96 % over most of the range

How can we tackle this issue?

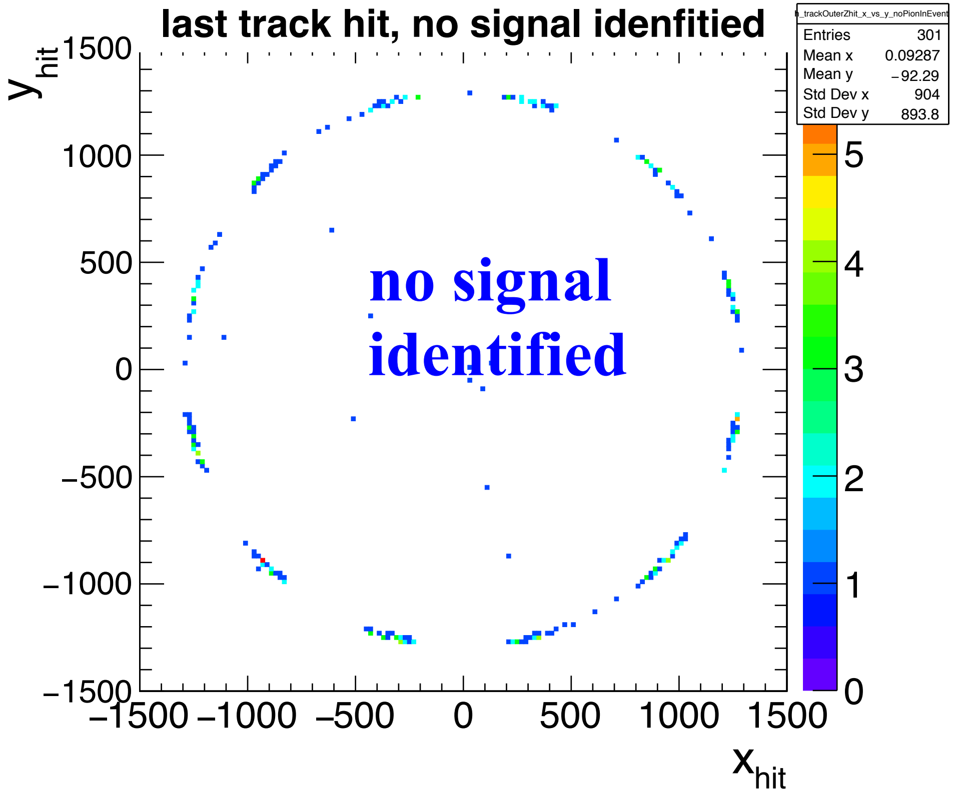


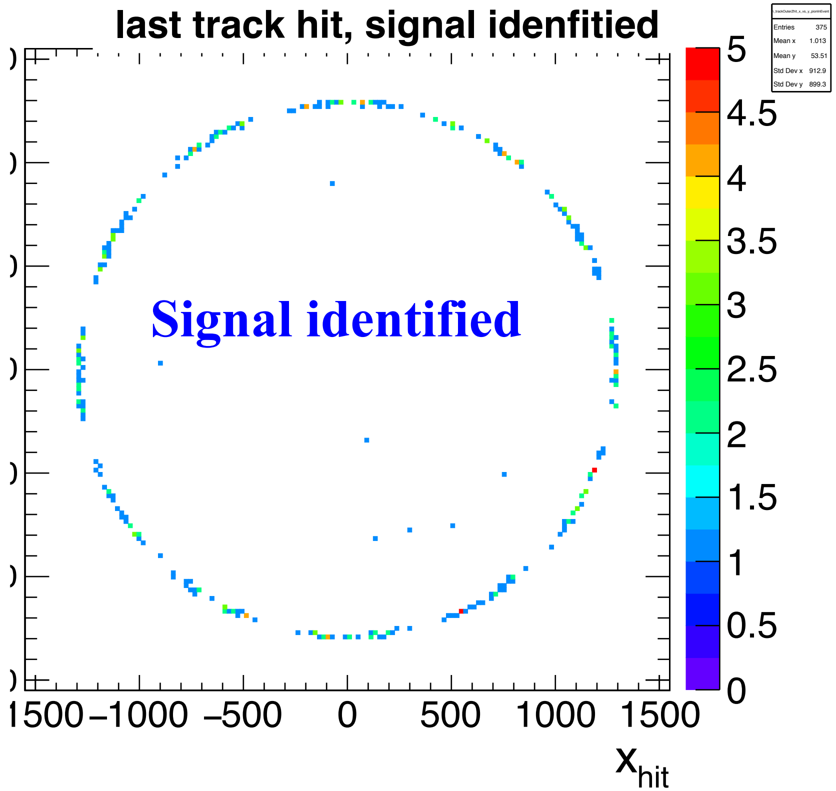
Lower muon identification around 90°

Pions: Barrel-Endcap transition

Pion inefficiency in barrel/endcap transition

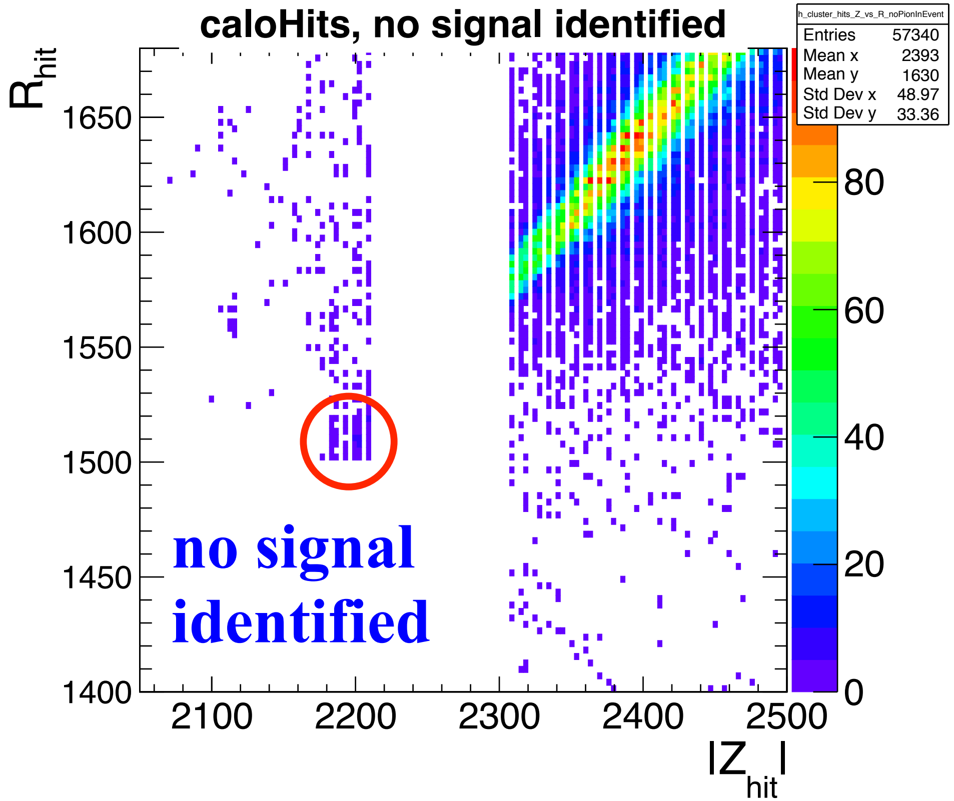
Position of last track hit before calorimeter surface

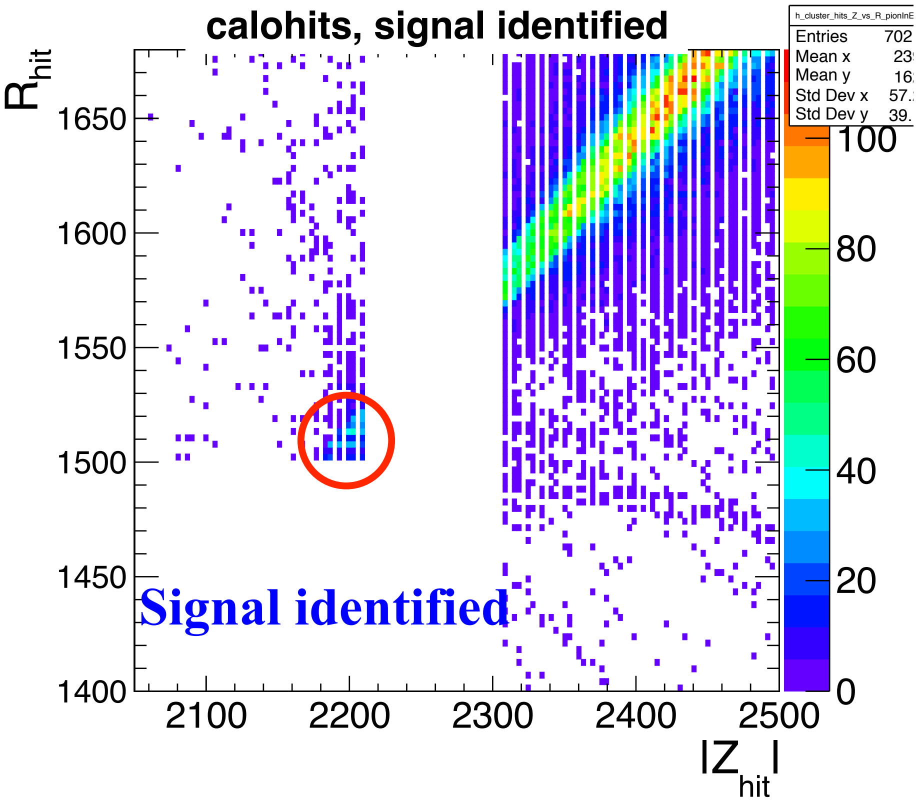




Identification largely dependent on geometry.
Signal not identified in edges of barrel geometry →last hit typically in last tracker layer (tracker endcap)

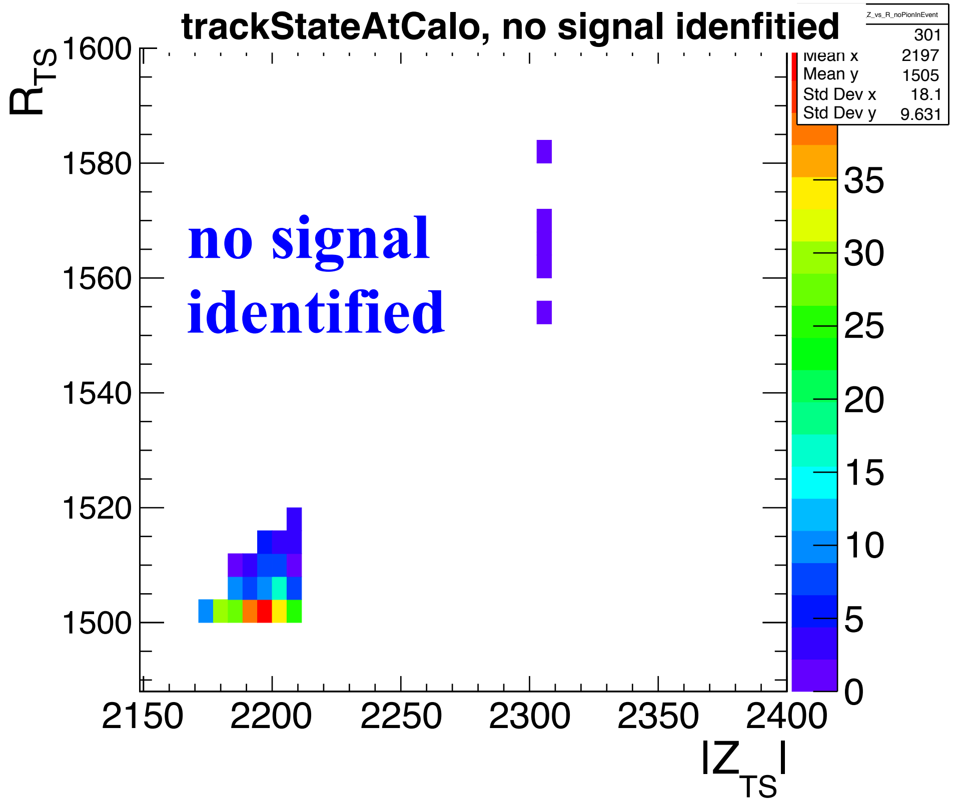
Pion inefficiency in barrel/endcap transition

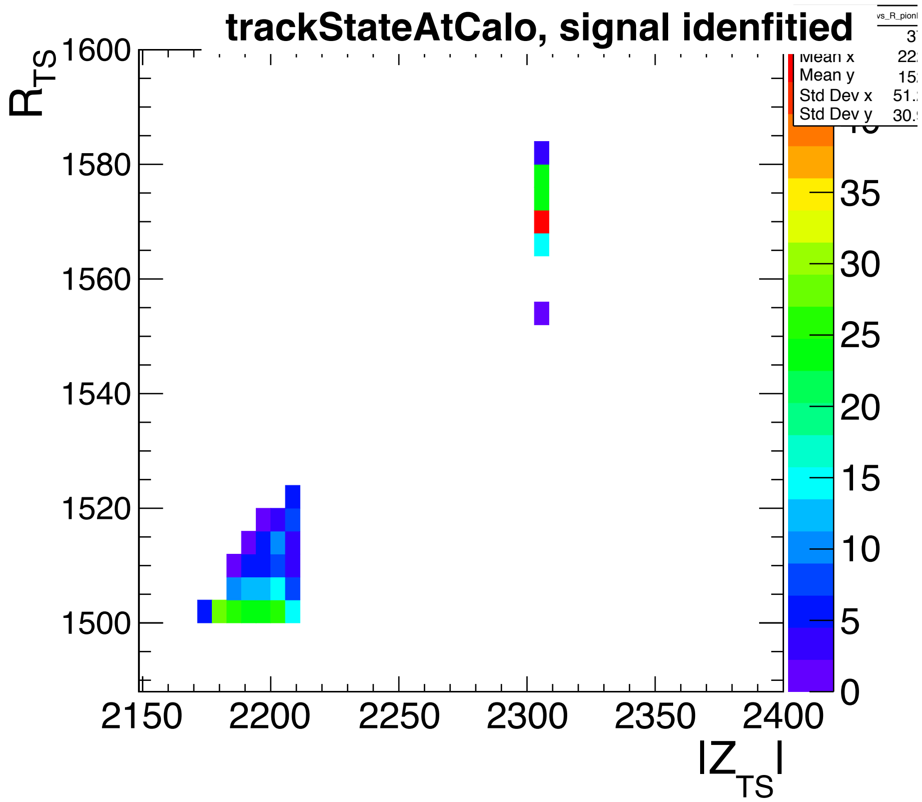




In the ECAL Endcap the are showers very similar; for non identified events almost no hits recorded in first layers of the barrel

Pion inefficiency in barrel/endcap transition

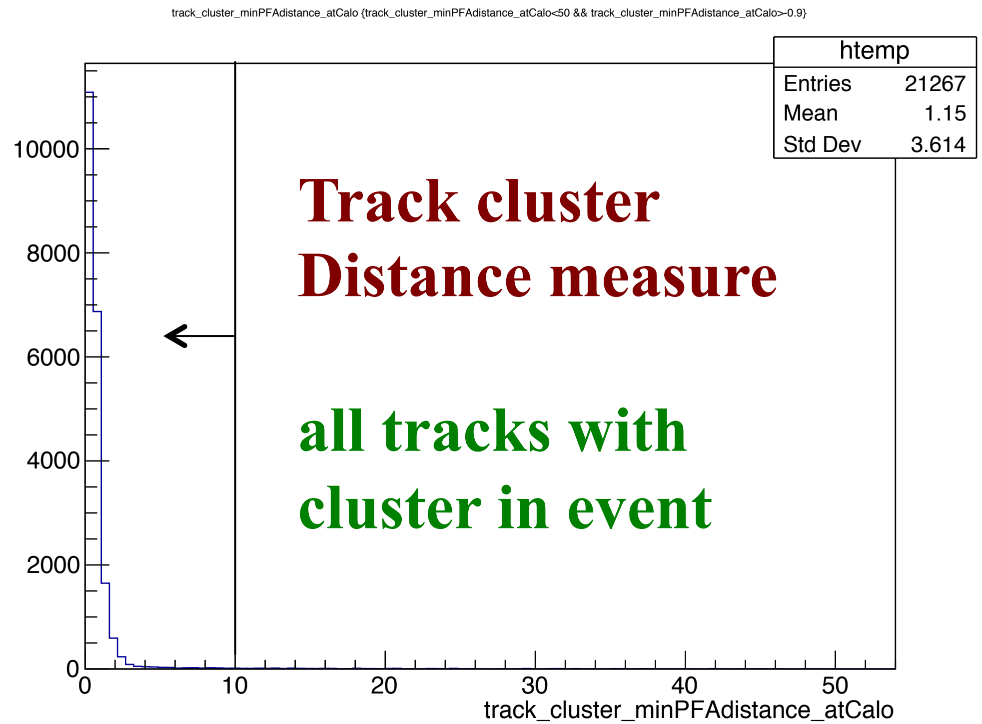


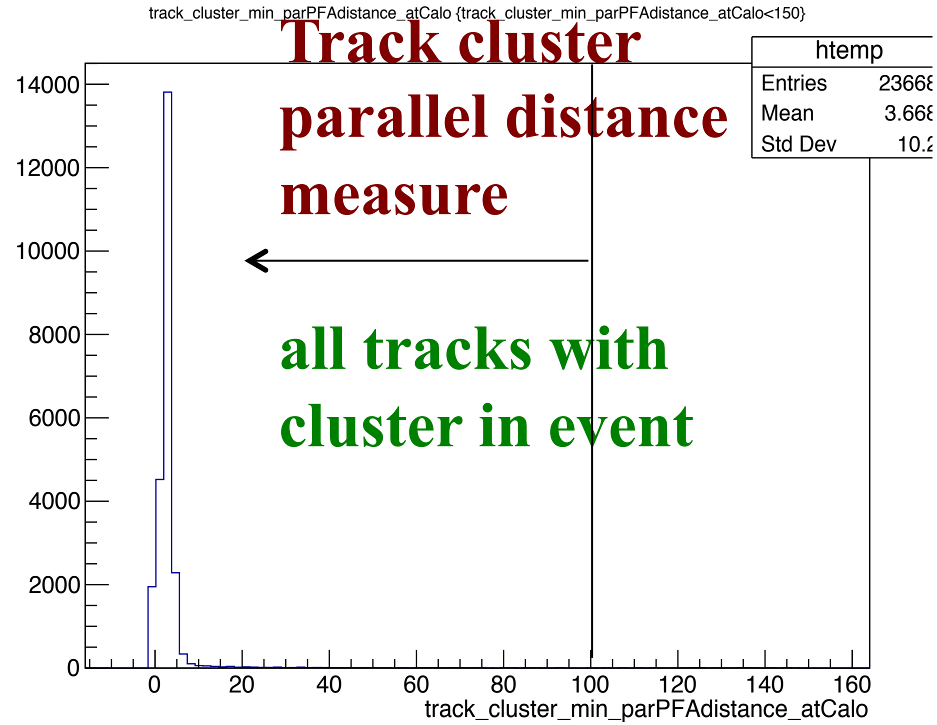


For non identified events trackstate placed almost exclusively at ECAL barrel, for identified events more before endcap

Model CLIC_o3_v10
distance measures

PandoraPFA assigns tracks to calorimeter clusters by checking the distance of the first hits in ECAL with respect to the TrackStateAtCalo position → 2 distance measures in depth and in parrallel distance, cluster with smallest distance measure is associated to the track

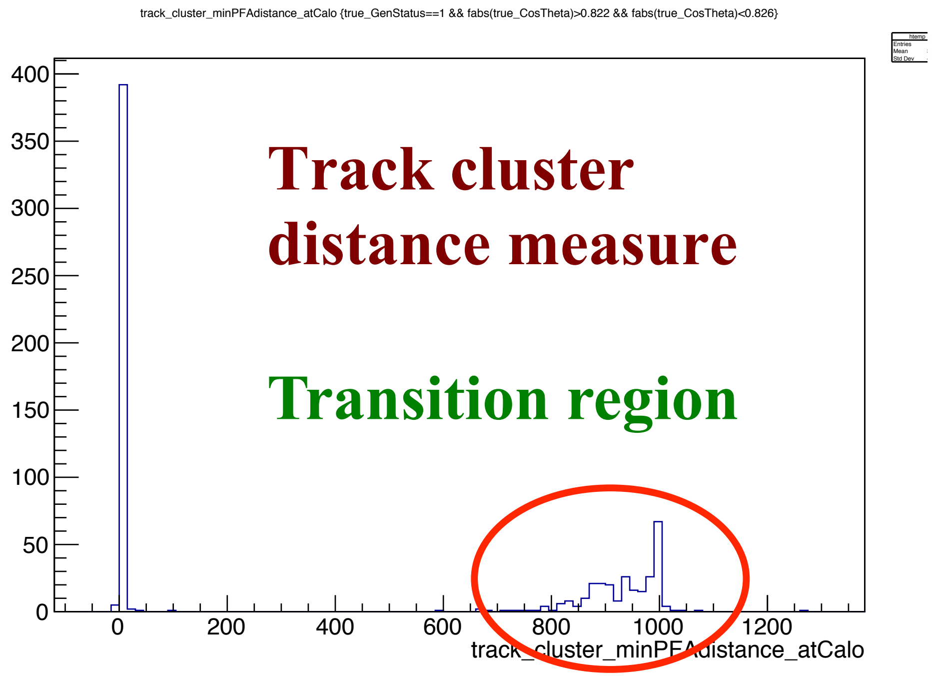


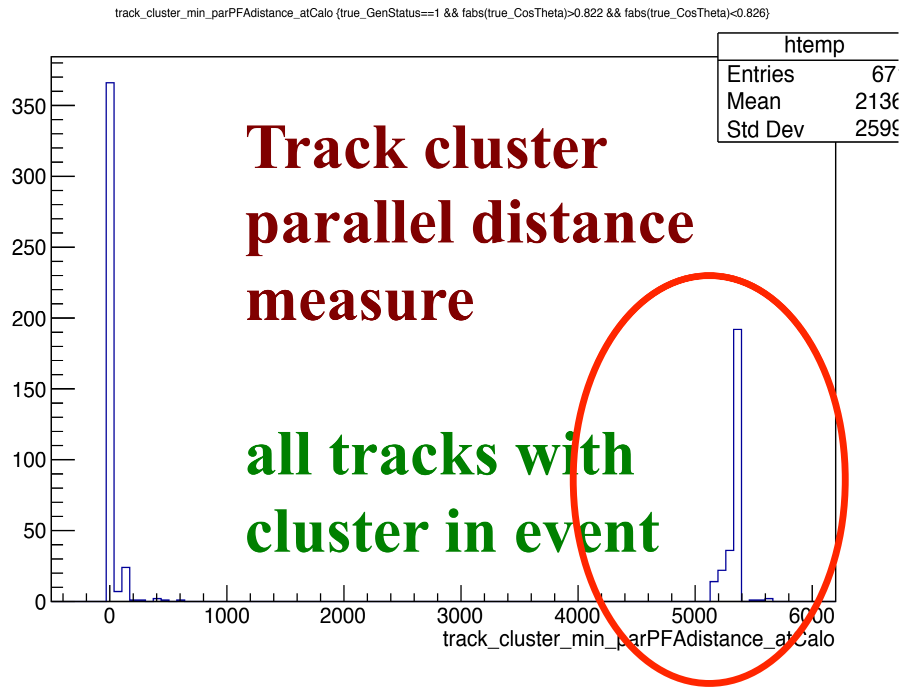


Model CLIC_o3_v10
distance measures in transition region

TrackStateAtCalo not optimally set in transition region → distance measure cut values too tough for gap clusters →relax cuts and see if signal is recovered

Transition region defined by $0.822 < |\cos\theta_{true}| < 0.826$

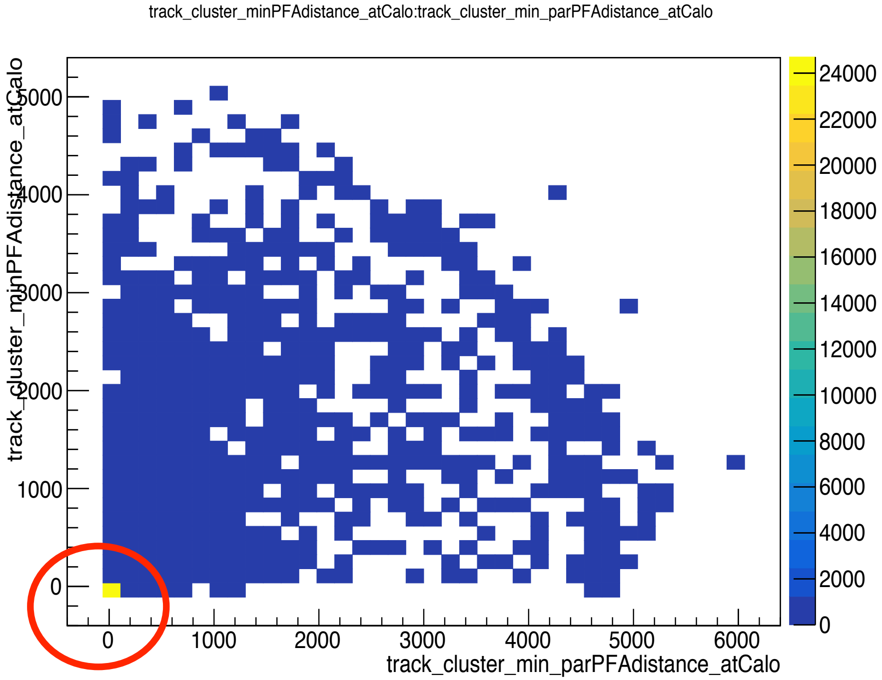


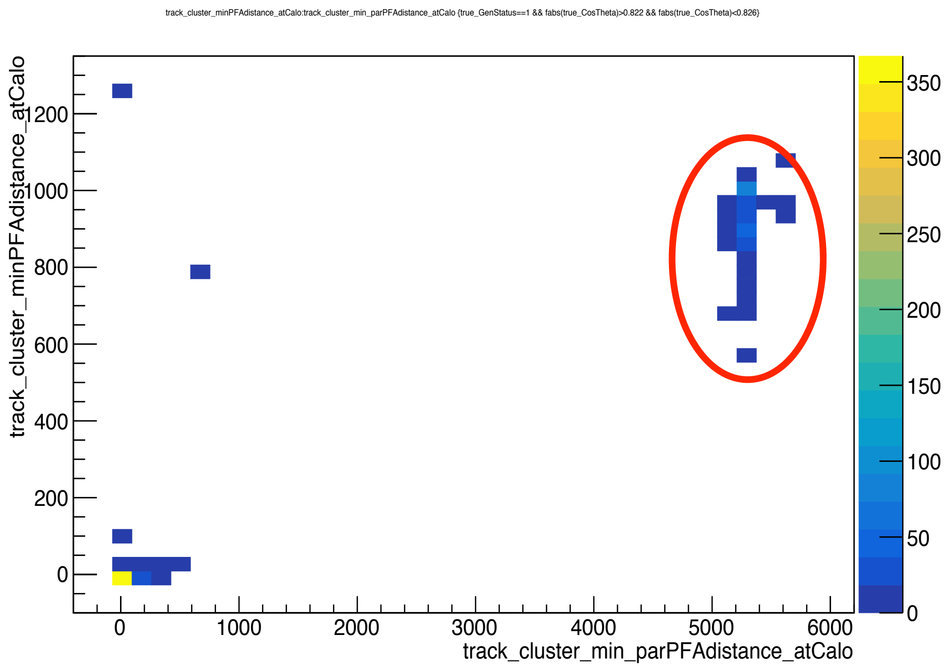


Events of second peak fail → increase cut for parallel distance from 100 to 5500 and for distance measure from 10 to 1100 A.U.

Model CLIC_o3_v10
distance measures in transition region

Parallel distance cut and PFA distance cut correlated

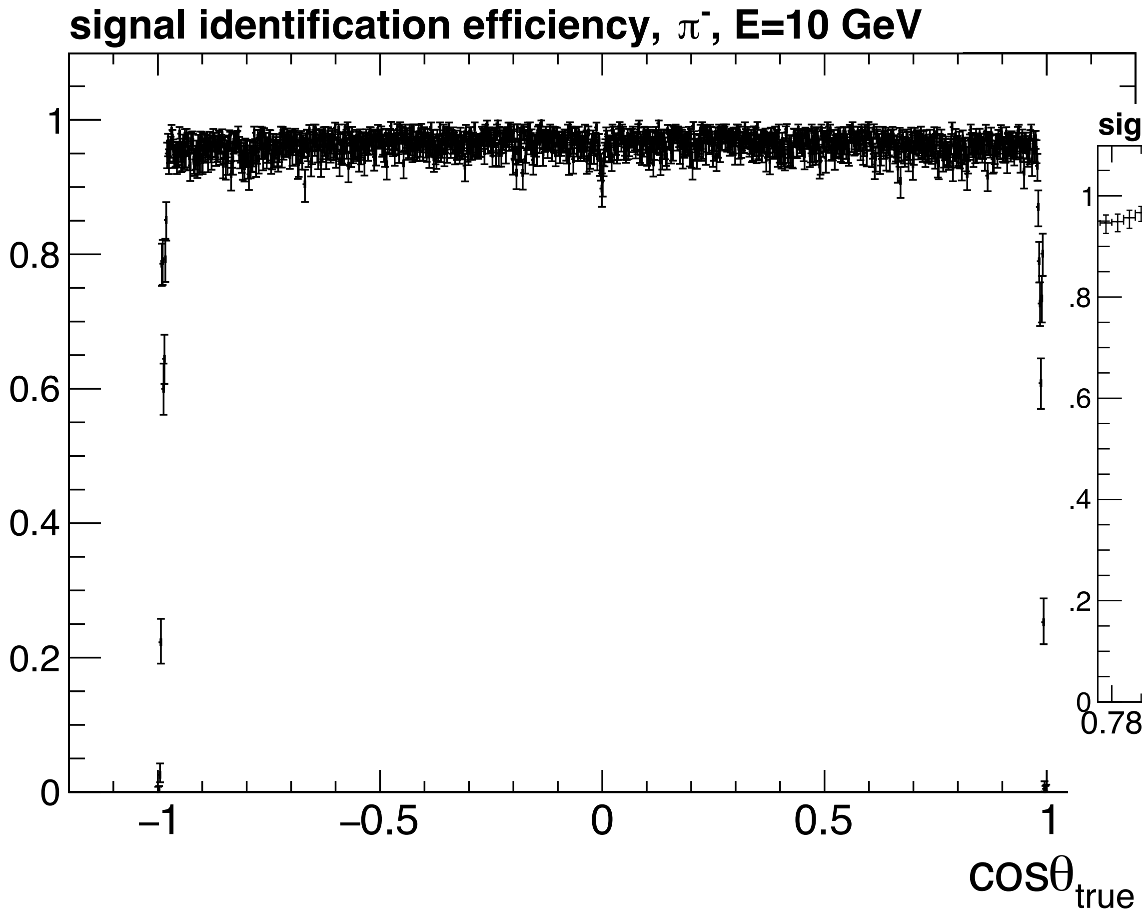


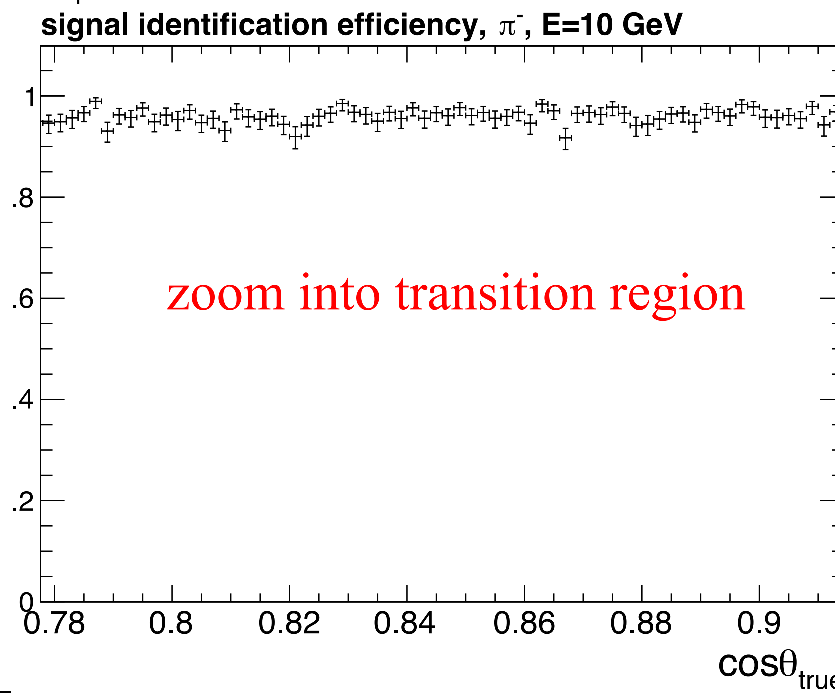


In overall event numbers correlation for high second peak events of transition region absolutely negligible

Pion 10 GeV sample

Pion particle gun with increased track-cluster distance cuts →dip in identification efficiency **GONE**





Efficiency drop at barrel-endcap transition region

Pion (and electron) identification inefficiency at endcap-barrel transition not an issue related to calorimeter clustering →calorimeter clustering is fine, but issue related rather to cluster-track matching, two possible solutions

- **Clean solution (suggested to be used by PandoraPFA experts)**: Introduce two track states at calorimeter, separately for barrel and endcap→check distance against both of calorimeter trackstates, use same track cluster matching cuts as everywhere else in detector

  → functionality exists to add additional trackstate for tracks in Barrel-Endcap calorimeter transition region, which can be used then in DDMarlinPandora

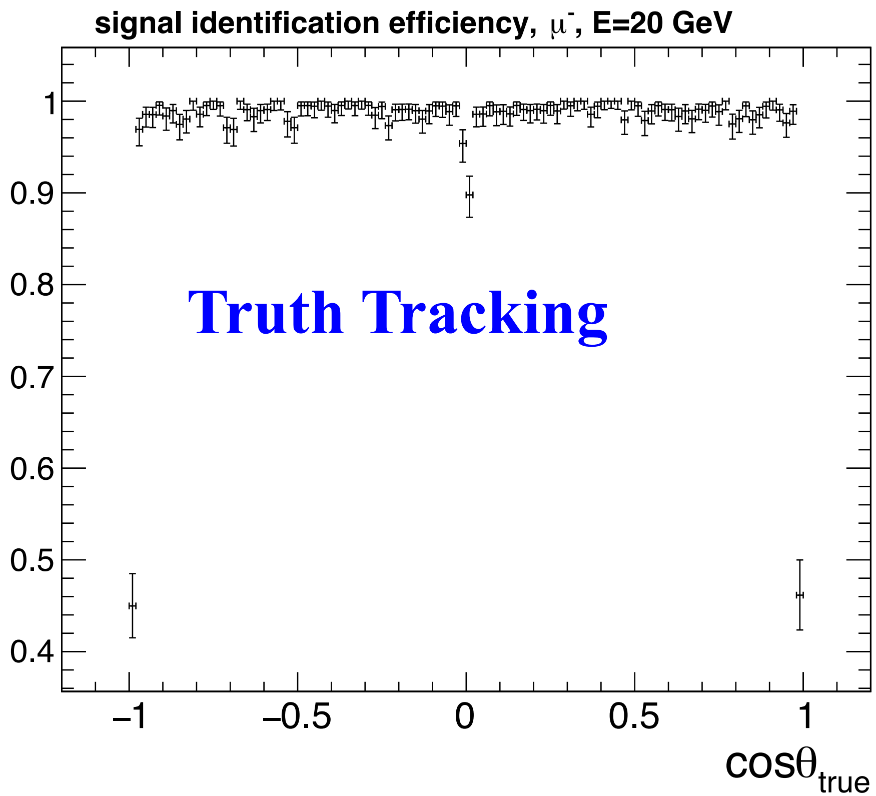
- **Second (less clean) option**: change cuts for cluster-track distance calculation for transition regions, use original cuts or cuts in window of second peak of higher values → relaxed values recover inefficiency

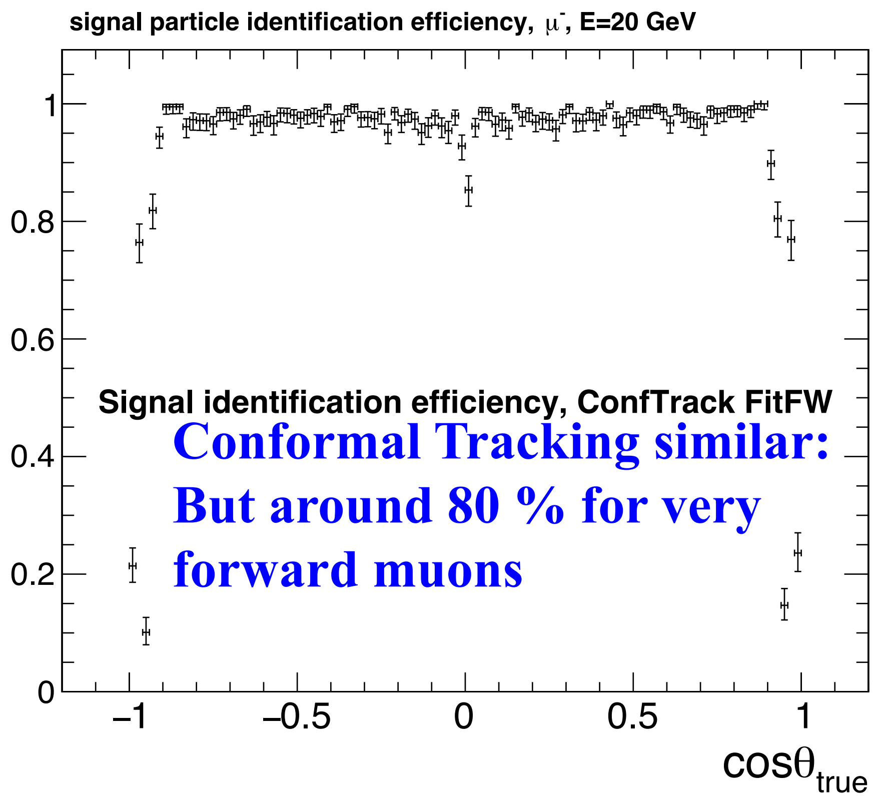
Muons

CLIC specific PandoraPFA parameter set
Muon identification

Muon identification (20 GeV) now constant vs. theta beyond 96 %

→same behavior at 10 and 50 GeV, now inefficiency in barrel/endcap transition





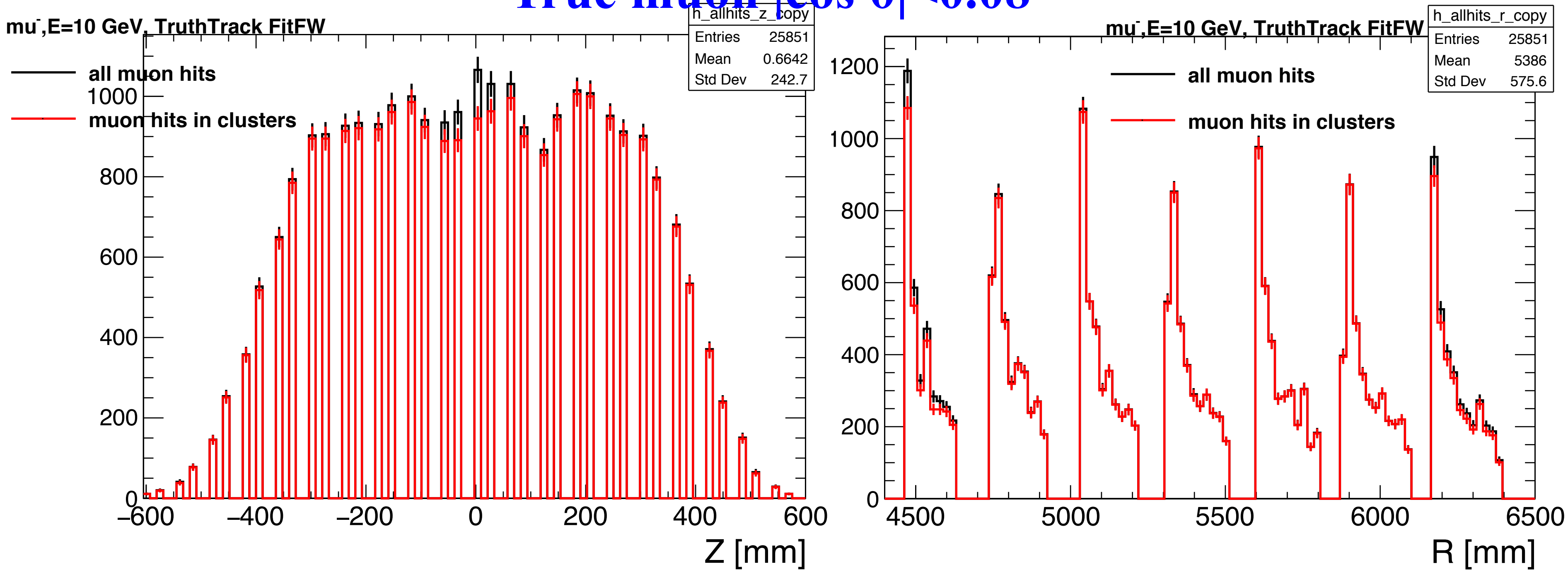
Identification efficiency larger than 96 % over most of the range

→ Dip around 90 degrees, work ongoing for very forward tracking for conformal tracking

Efficiency dip at 90 degrees

All muon simhits are reconstructed, correct position of reconstructed muon hits →check cluster of muon hits and calorimeter hits

True muon |cos θ|<0.08

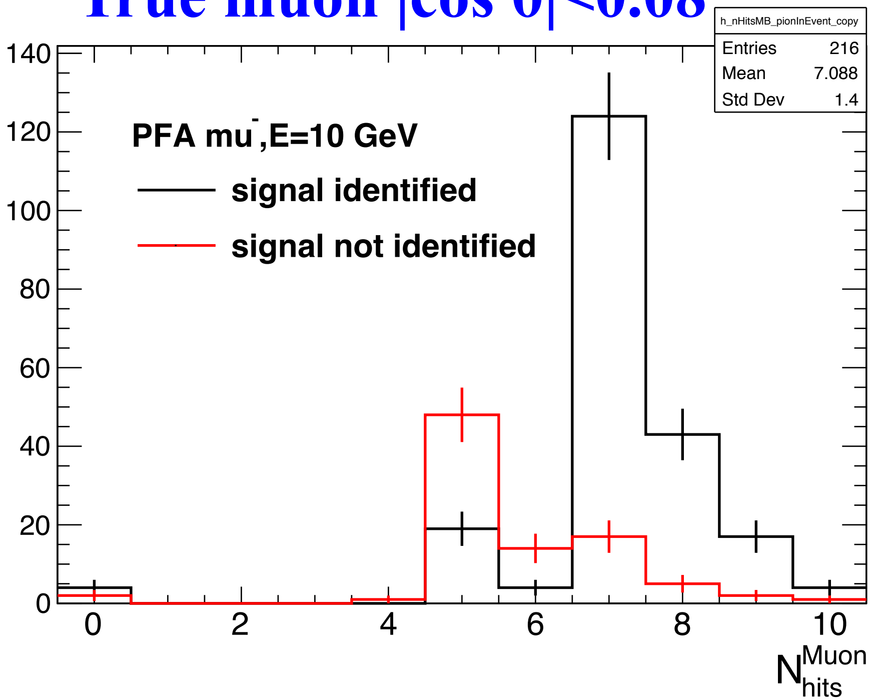


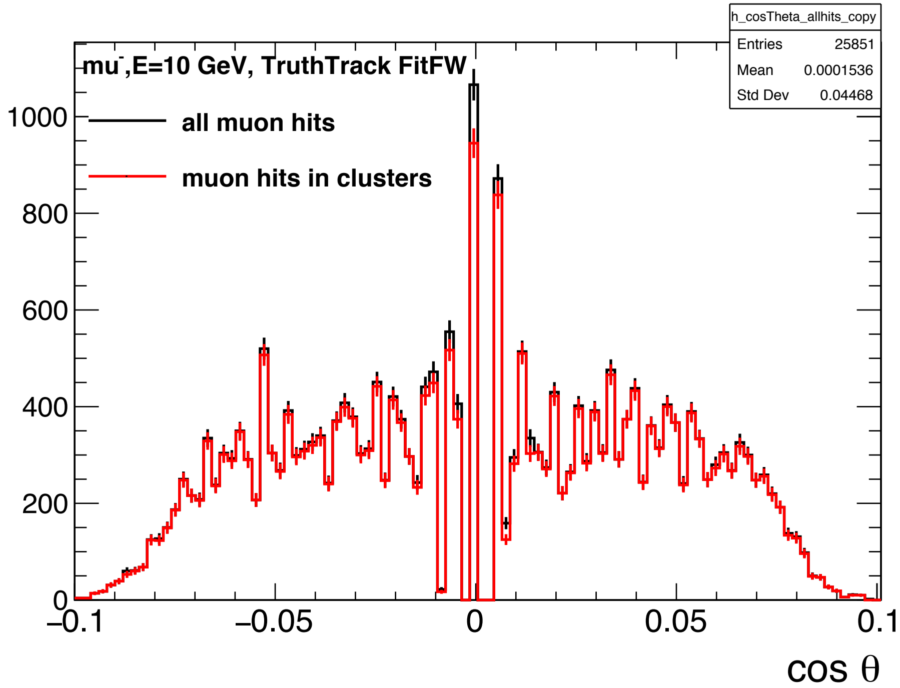
Muon hits around Z=0 missed, end up unclustered, typically hits in first and last muon chamber (see distribution of hit radii)

Efficiency dip at 90 degrees

Number of muon hits in reconstructed particles (misidentified muons reconstructed as pions)

True muon |cos θ|<0.08





Check cos θ of hit position vector → hits at 0 found most of the time (observe rather segmentation in Z of hits)

Muon identification efficiency dip at 90 degrees

- All muon simhits are reconstructed, correct position of reconstructed muon hits
- At exactly 90 degrees some muon hits are not assigned to calorimeter cluster →typically first hit, or last hit
- Muon ID inefficiency might be solved if we can recover those two hits

→ Suggestions by PandoraPFA experts: check if something goes wrong in the calculation of pseudo-layers, which might lead to hits being ignored

Energy Resolution in hadronic Z events

Jet Energy Resolution

Determined using RMS_{90} of the total relative energy resolution

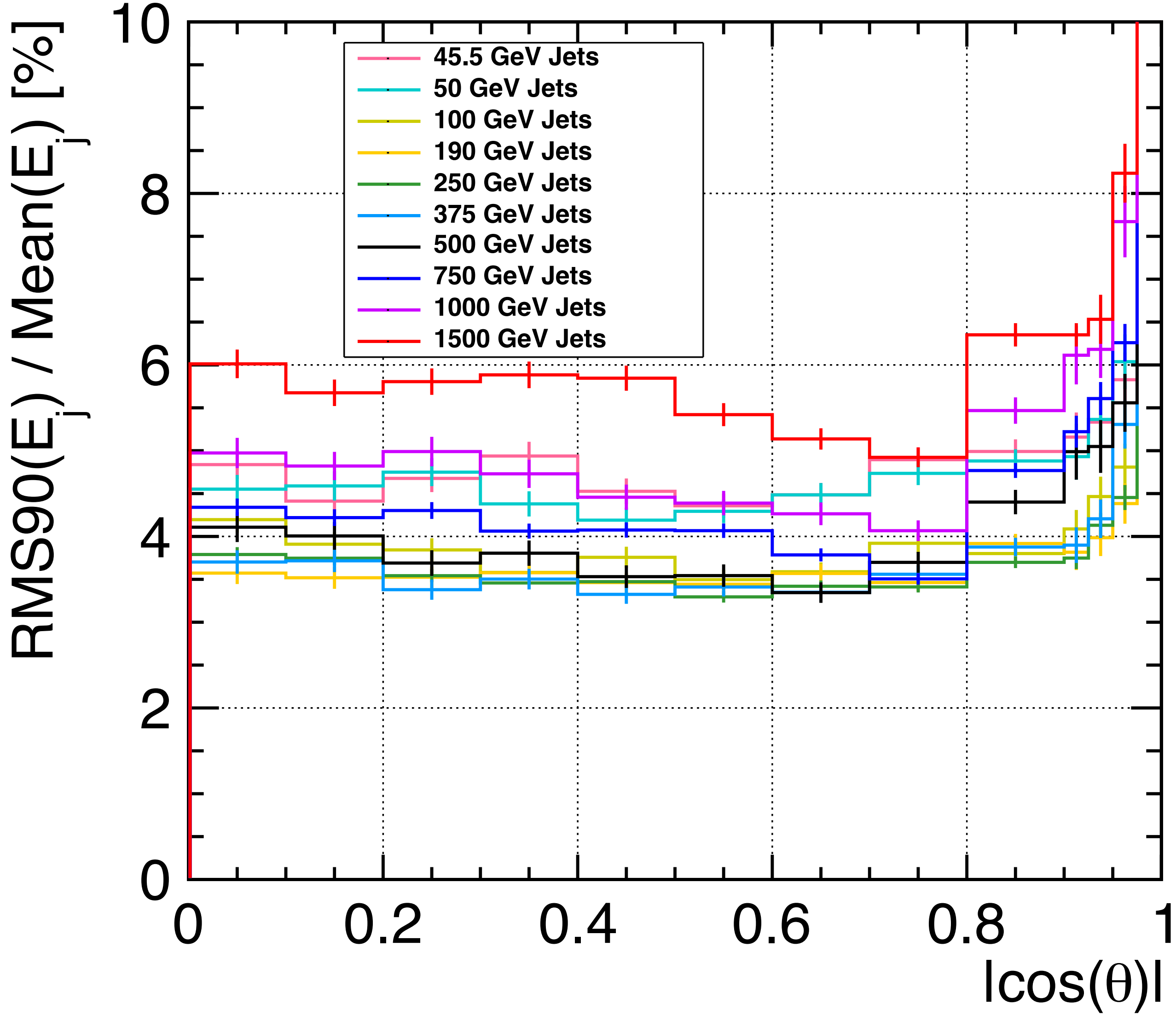
$\Sigma E_{PFO} / \Sigma E_{MC}$, where all stable visible MC particles are used in the denominator, ignoring the energies of neutrinos

→ Multiply by a factor of $\sqrt{2}$ to get the jet energy resolution values

→compare results of RMS_{90} with total RMS (large non gaussian tails for 1500 and 3000 GeV datasets)

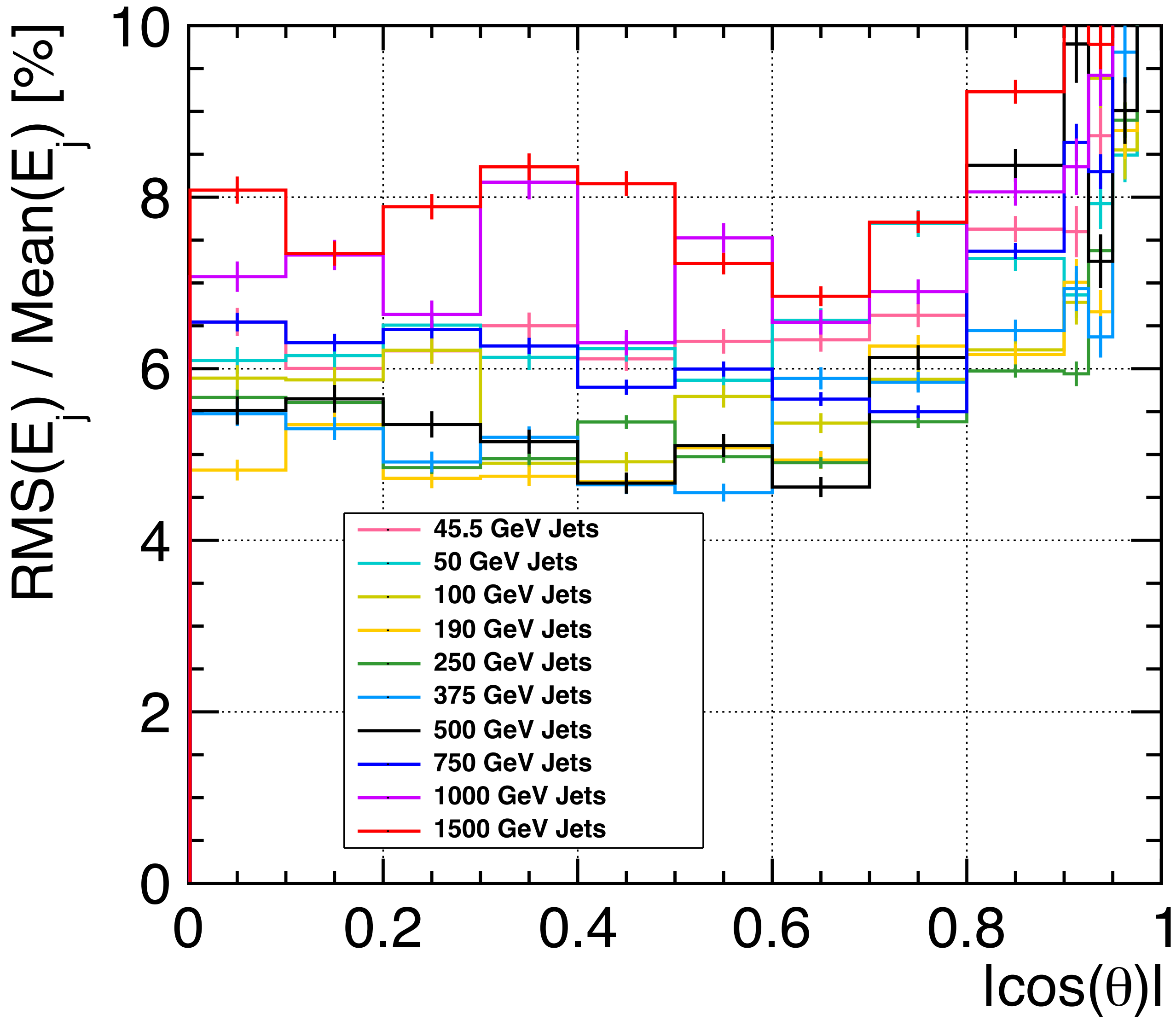
N.B.: Results with MHHHE=1 (MaxHCalHitHadronicEnergy), which was shown to result in worse resolution by Nikiforos

Jet Energy Resolution: RMS_{90}



Plotted vs. cos θ of leading quark
→ Fairly flat up to outer endcap, values around 4 % up 500 GeV, 5 % up to 1000 GeV jets, considerably worse at very high jet energies of 1500 GeV (around 6 %)

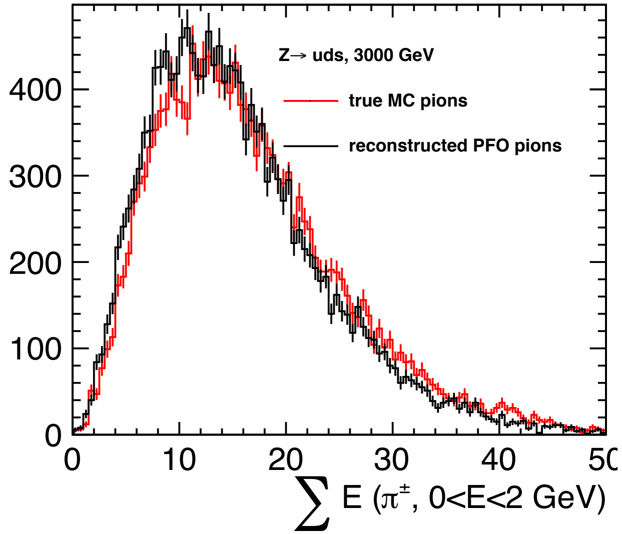
Jet Energy Resolution: RMS

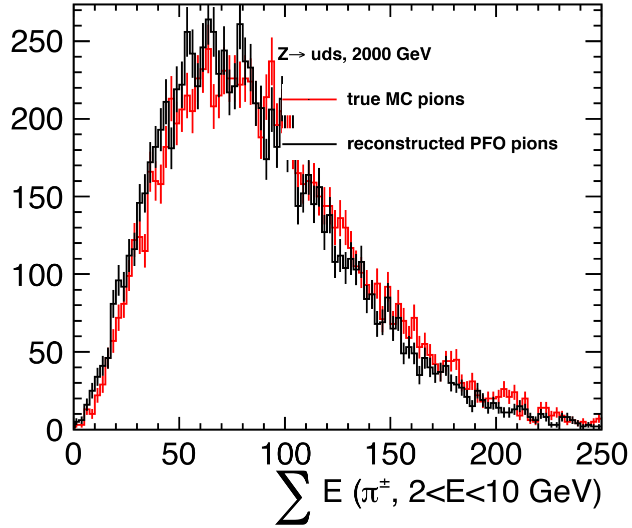


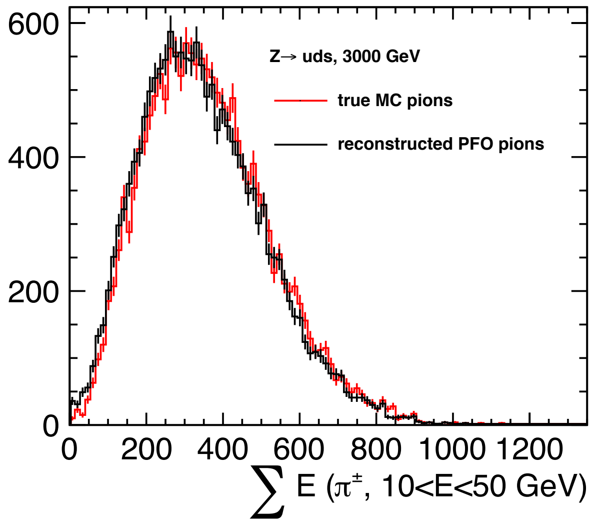
Plotted vs. cos θ of leading quark
→ Full RMS values around 5-6 % for almost all samples, around 8 % for 3 TeV dataset (1500 GeV jets)

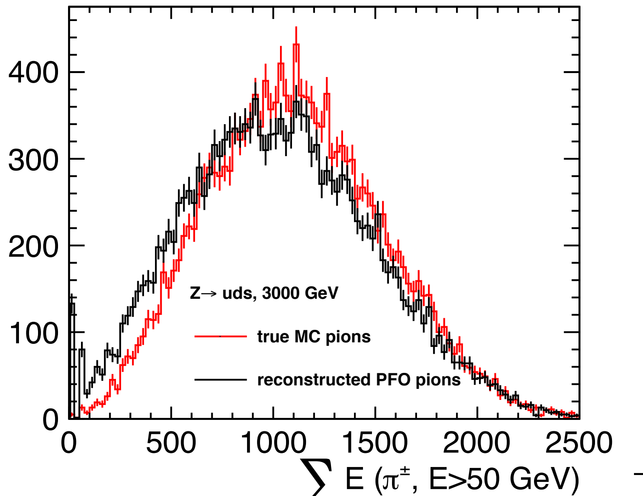
Jet Energy Resolution: contribution from charged pions

Check what might cause the higher jet energy resolution values for high energetic jets: pion energy distributions → sum of energies of pions from different energy bins







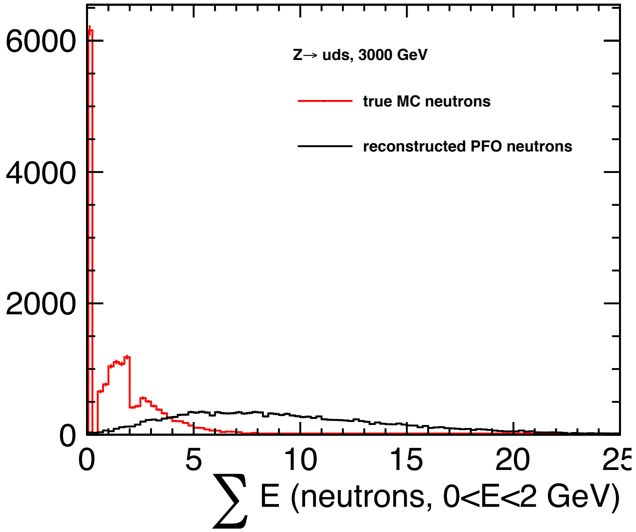


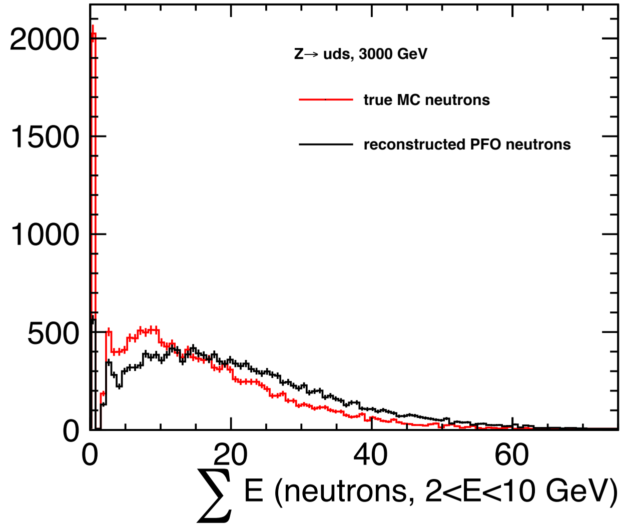
Pion energy contributions reconstructed well →for very high energetic pions a little bit underestimated

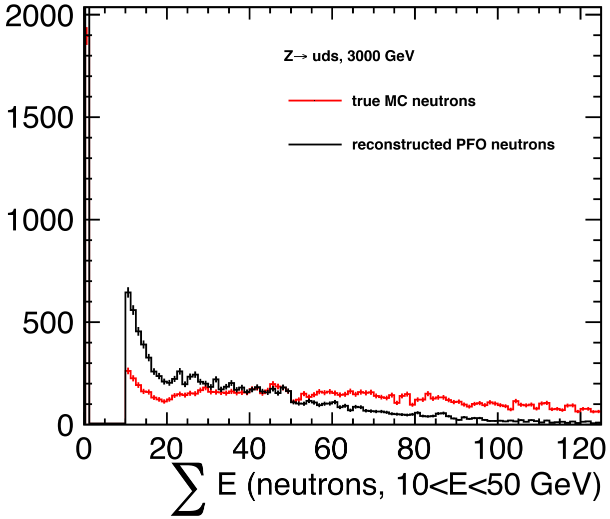
MC pion energies sum of MC pions and MC protons (charged particles reconstructed as pions per default)

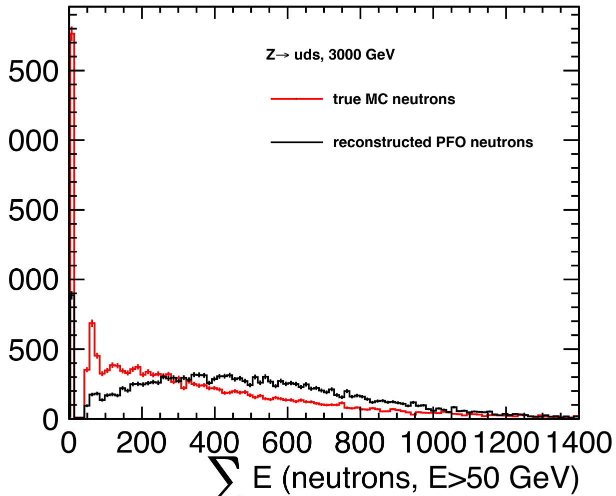
Jet Energy Resolution: contribution from neutrons

Check what might cause the higher jet energy resolution values for high energetic jets: neutron energy distributions







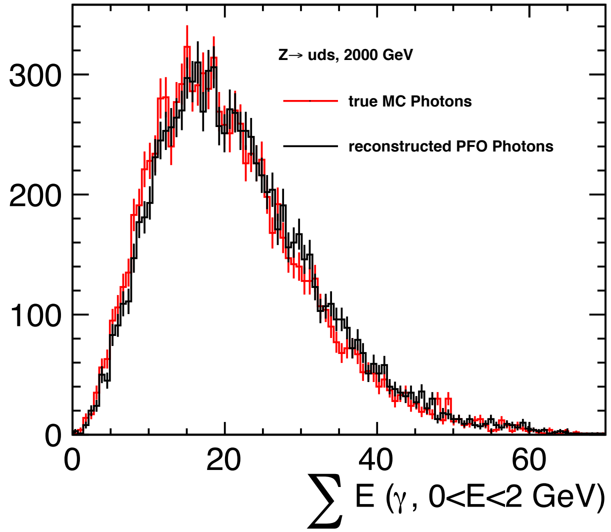


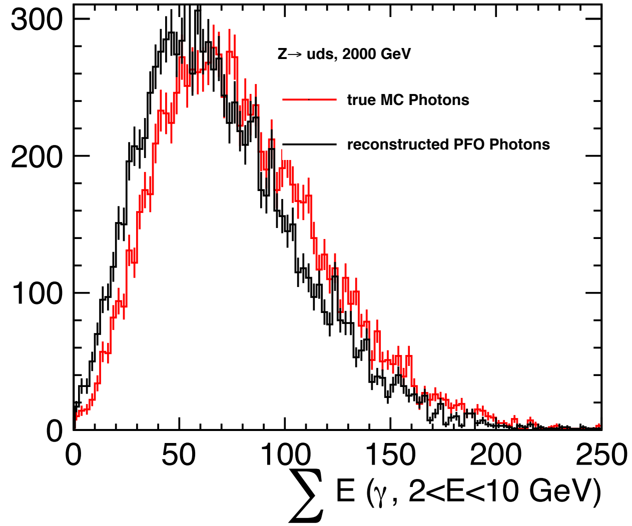
Contributions reproduced less well (as expected), everywhere overestimated

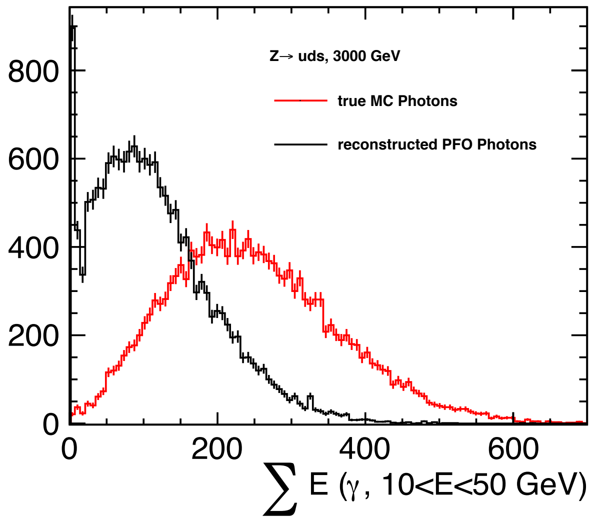
MC neutron energies sum of MC neutrons and MC K^0_L

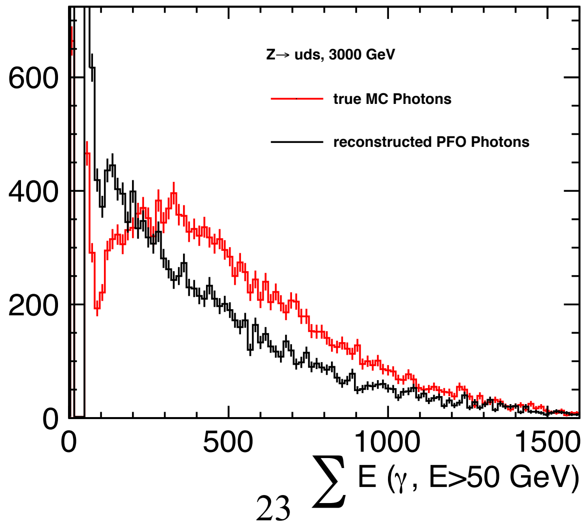
Jet Energy Resolution: contribution from photons

Check what might cause the higher jet energy resolution values for high energetic jets: photon energy distributions









For low energetic photons contribution well reconstructed, contribution from photons between 10 and 50 GeV vastly underestimated

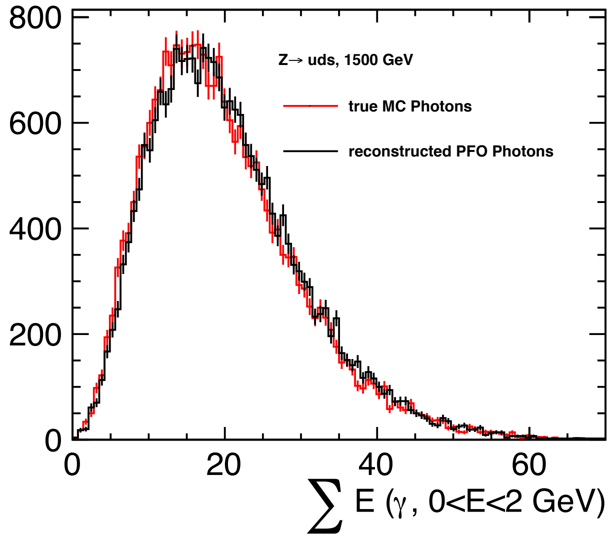
Jet Energy Resolution

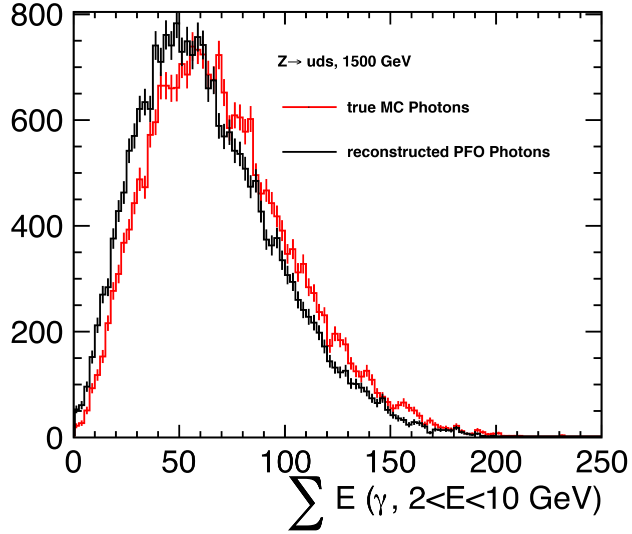
- Jet Energy resolution (using RMS_{90}) in Z→uds dijet events are for datasets of sqrt(s)<1500 GeV around 4 %, distributions are fairly symmetric
- For datasets at higher energies resolution unsymmetric with tail to lower values → charged component reproduced fairly well, largely a result of underestimated photon contribution, particularly of photons between 10 and 50 GeV

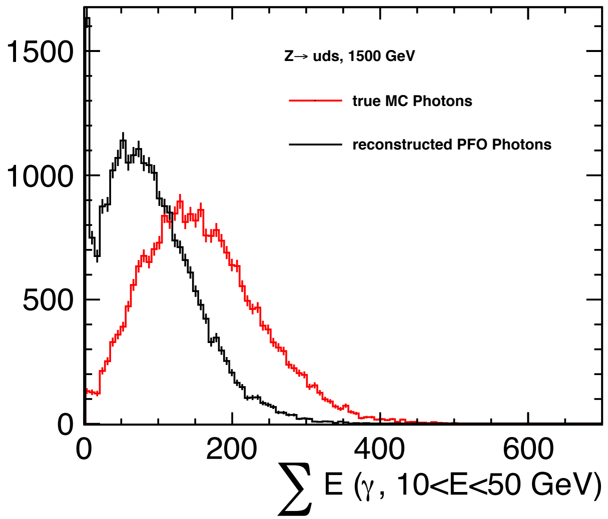
Backup Slide

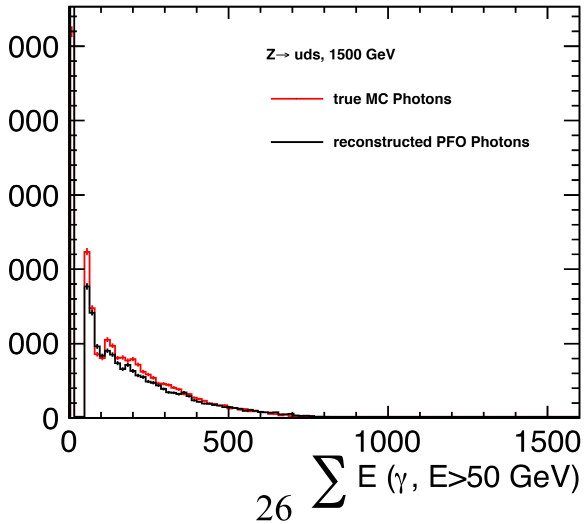
Jet Energy Resolution:: 1500 GeV contribution from photons

Check what might cause the higher jet energy resolution values for high energetic jets: photon energy distributions









For low energetic photons contribution well reconstructed, contribution from photons between 10 and 50 GeV vastly underestimated