Particle Flow Validation for CLICdet

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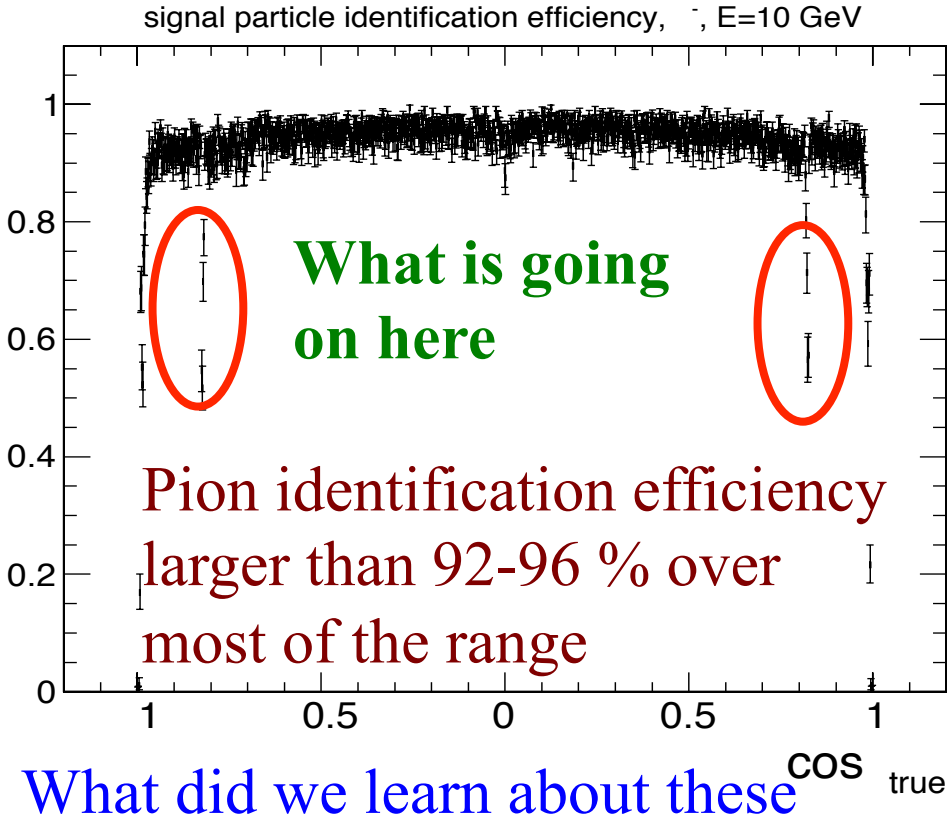
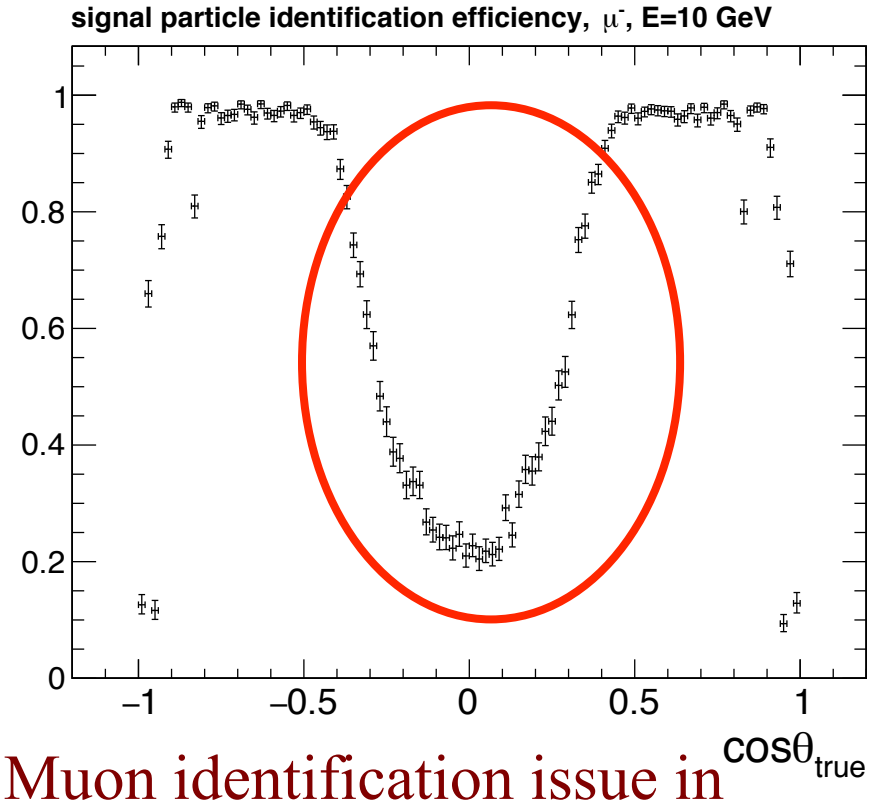
Reminder: Particle Flow validation of CLICdet

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 did we learn about these issues in the last 5 weeks

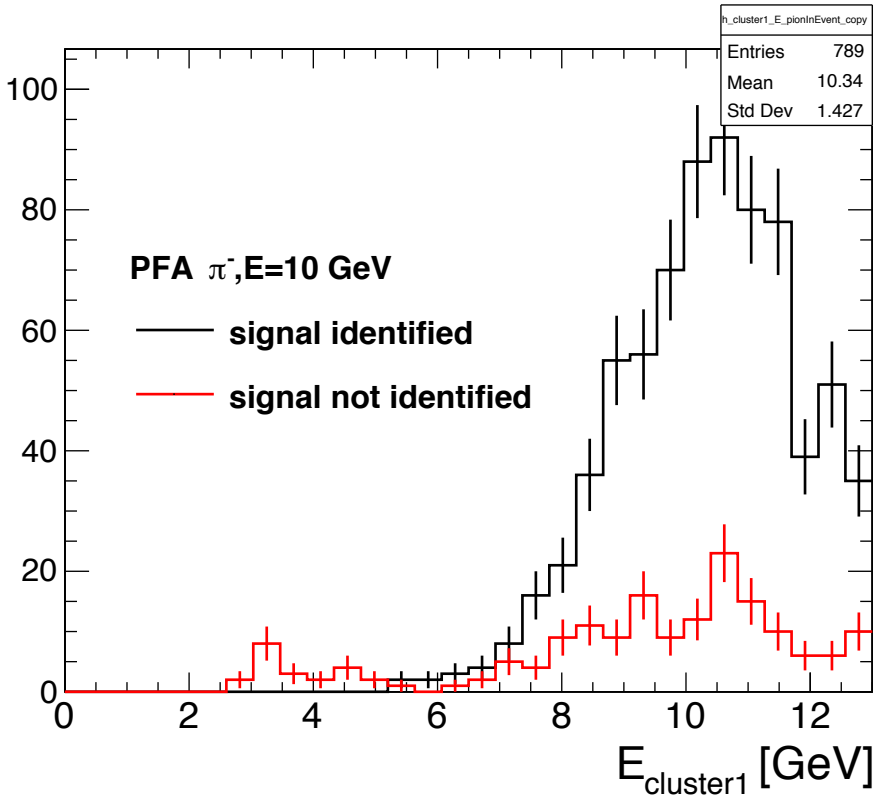


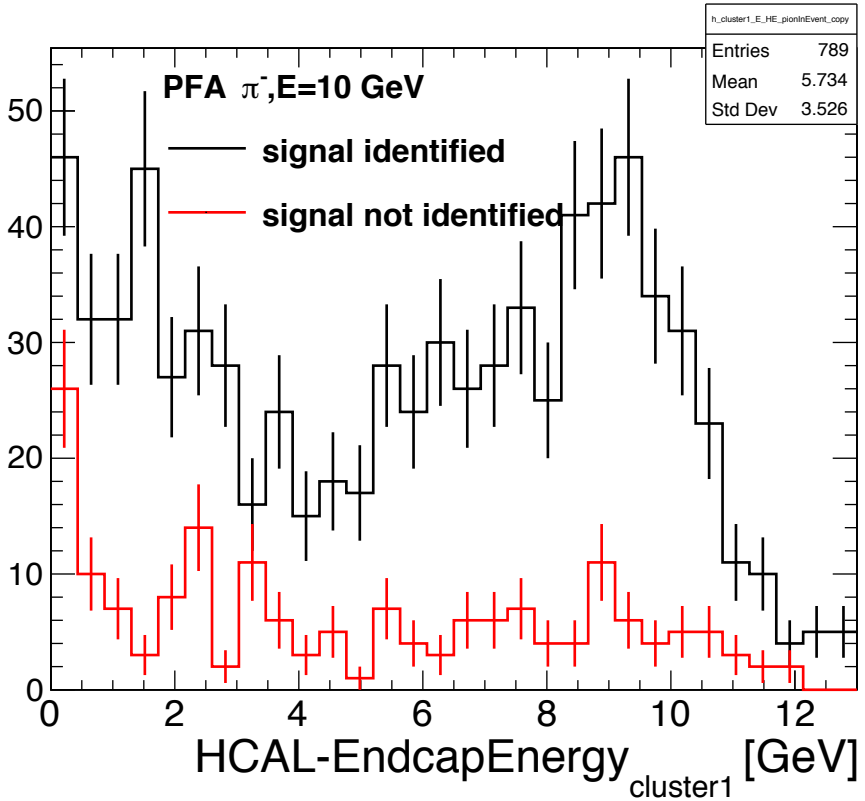
Muon identification issue in central part of detector

Pions: Barrel-Endcap transition

Pion identification efficiency drop in barrel-endcap transition region

Pions efficiency drop around $|\cos\theta| \approx 0.8$ → transition region between barrel and endcap, hypothesis: maybe not perfect handling of split clusters in Pandora

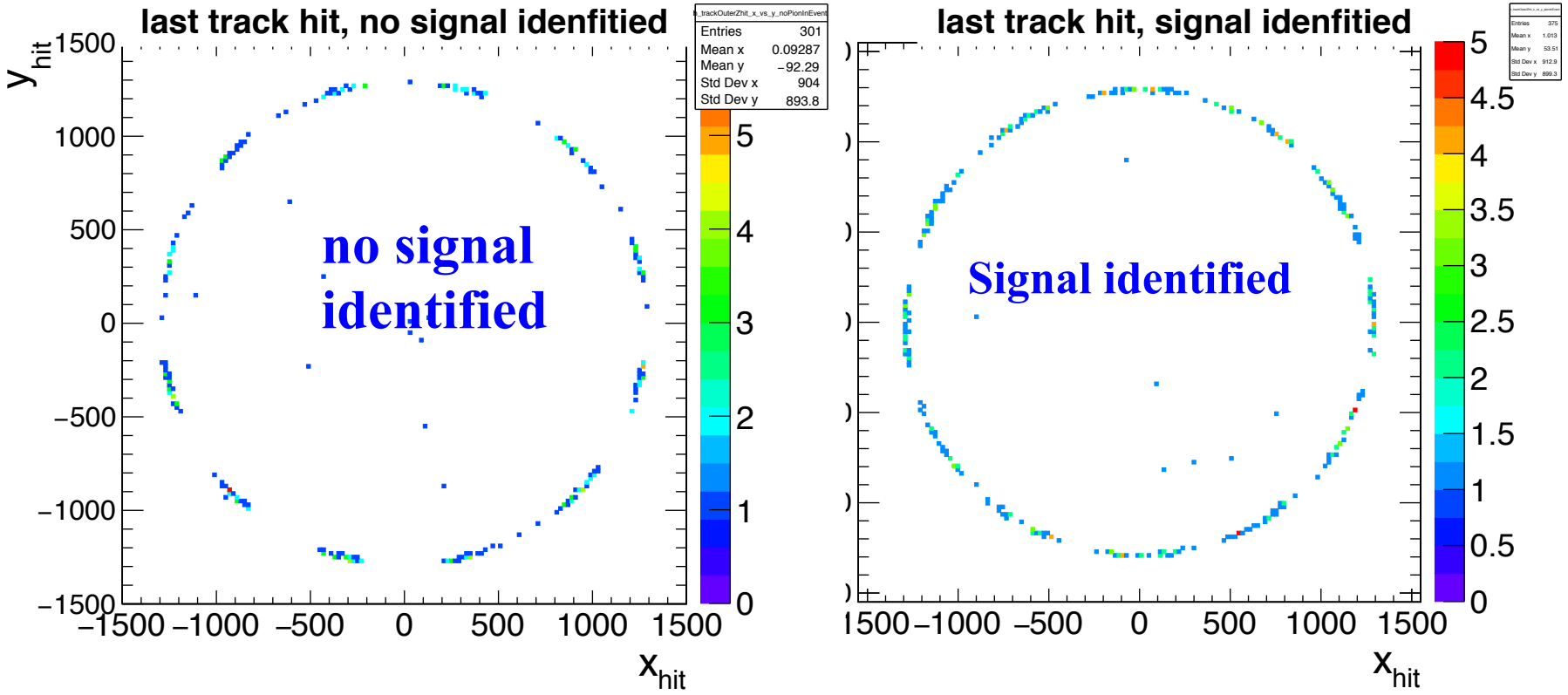




Energy almost exclusively recorded in endcap (predominately HCAL), energy coming from barrel region negligible, leading cluster dominates by far, less than 20 % of events have two clusters

Pion inefficiency in barrel/endcap transition

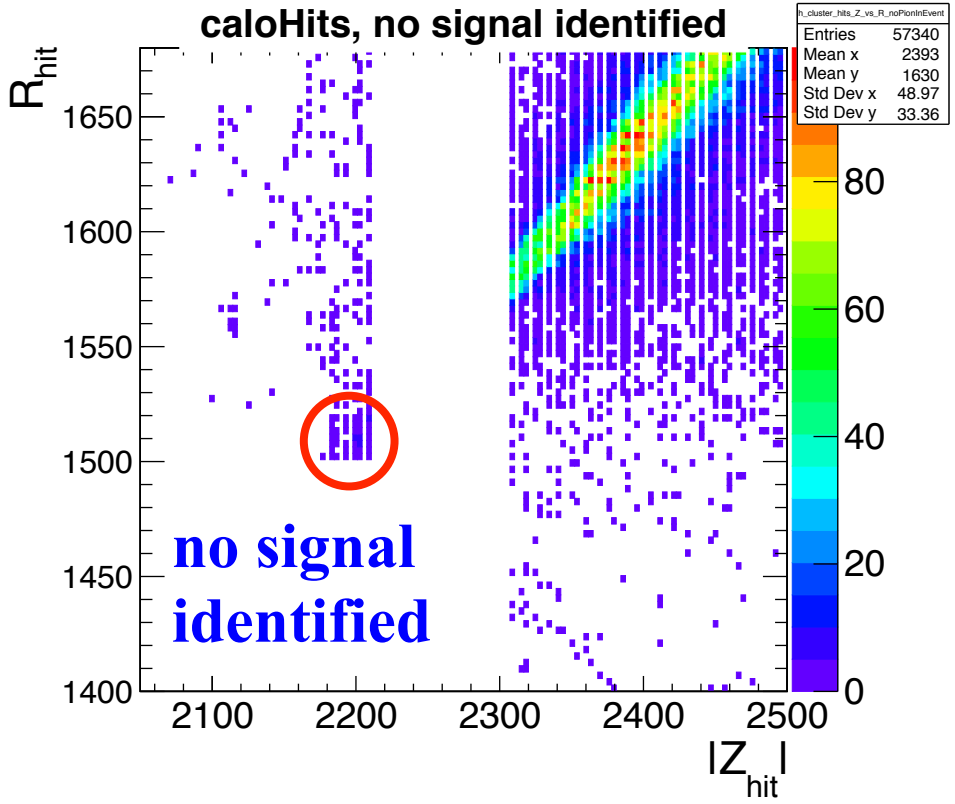
Position of last track hit before calorimeter surface

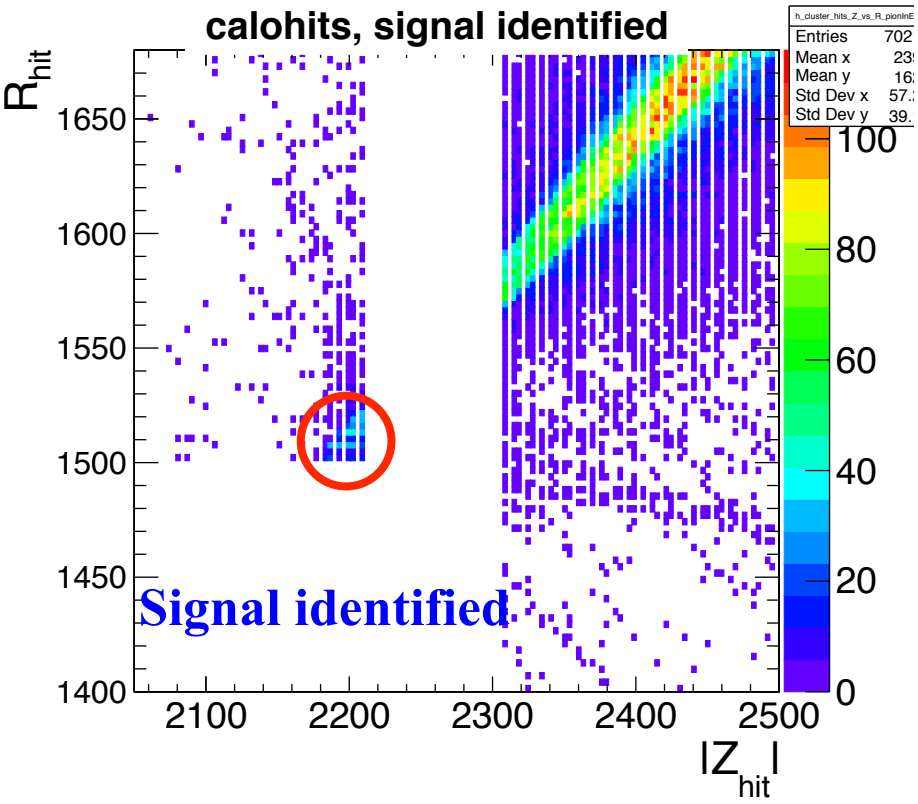


Identification largely dependent on geometry
signal not identified in edges of barrel geometry
→last hit typically in last tracker layer (tracker endcap)

Pion inefficiency in barrel/endcap transition

For non identified even almost no hits recorded in first barrel layers close to gap

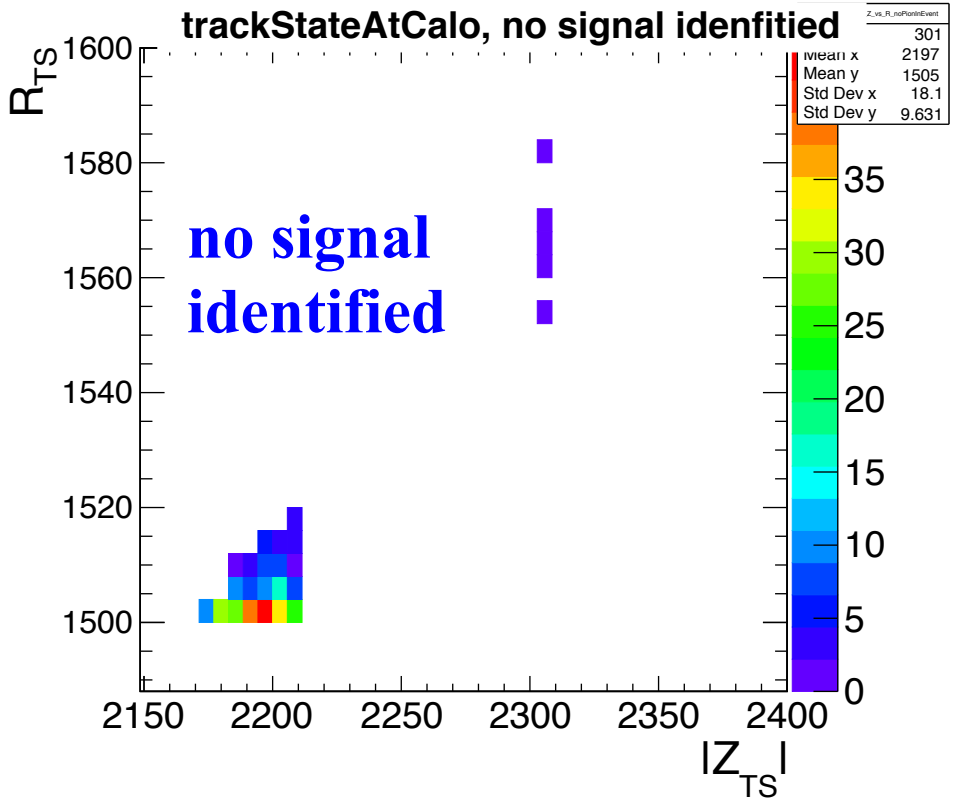


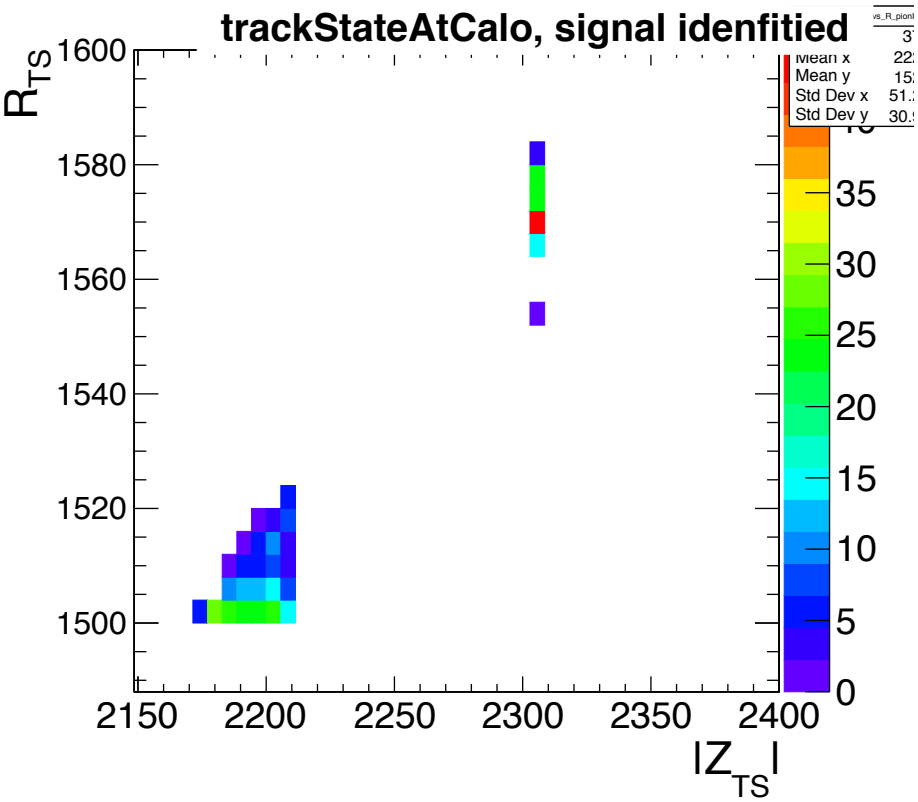


In ECAL Endcap the shower very similar, for non identified events almost no hits recorded in first layers of ECAL barrel

Pion inefficiency in barrel/endcap transition

For non identified even almost no hits recorded in first barrel layers close to gap

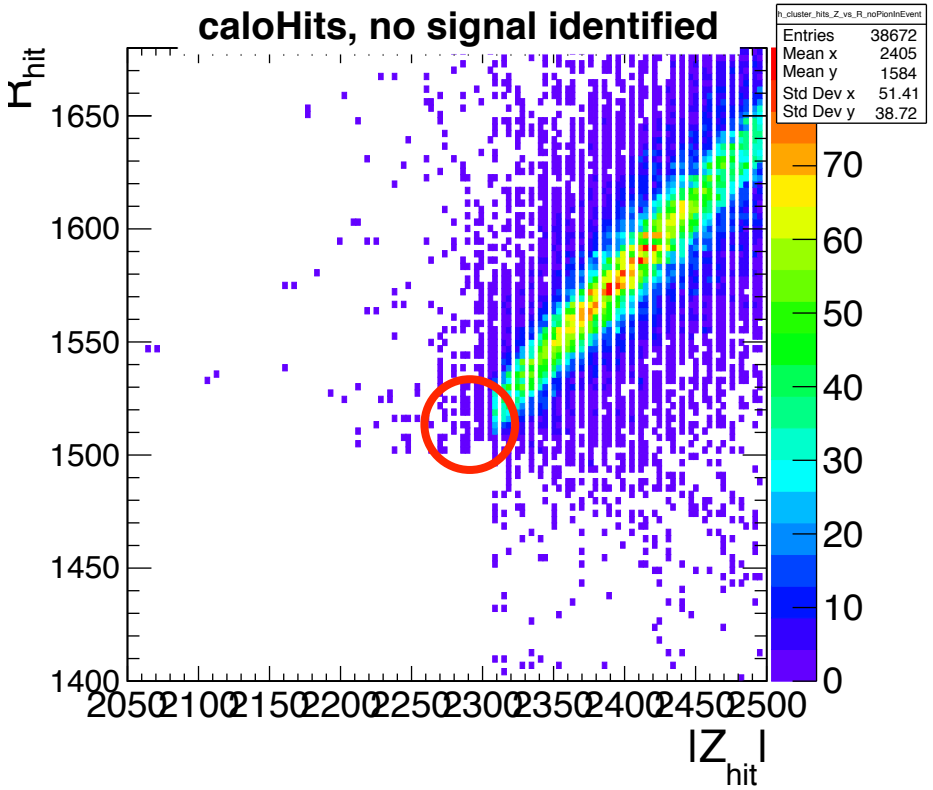


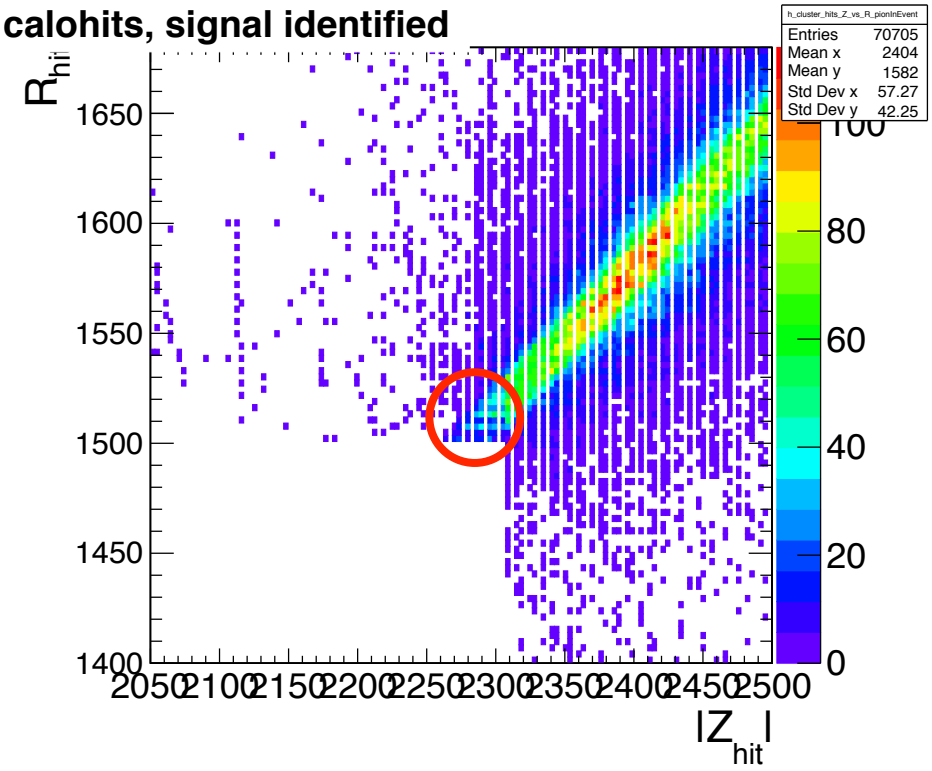


For non identified events trackstate set almost exclusively at ECAL barrel, for identified events more before endcap

Pion inefficiency region: check model without gaps

Pions misidentified as other charged particle (electrons and muons)

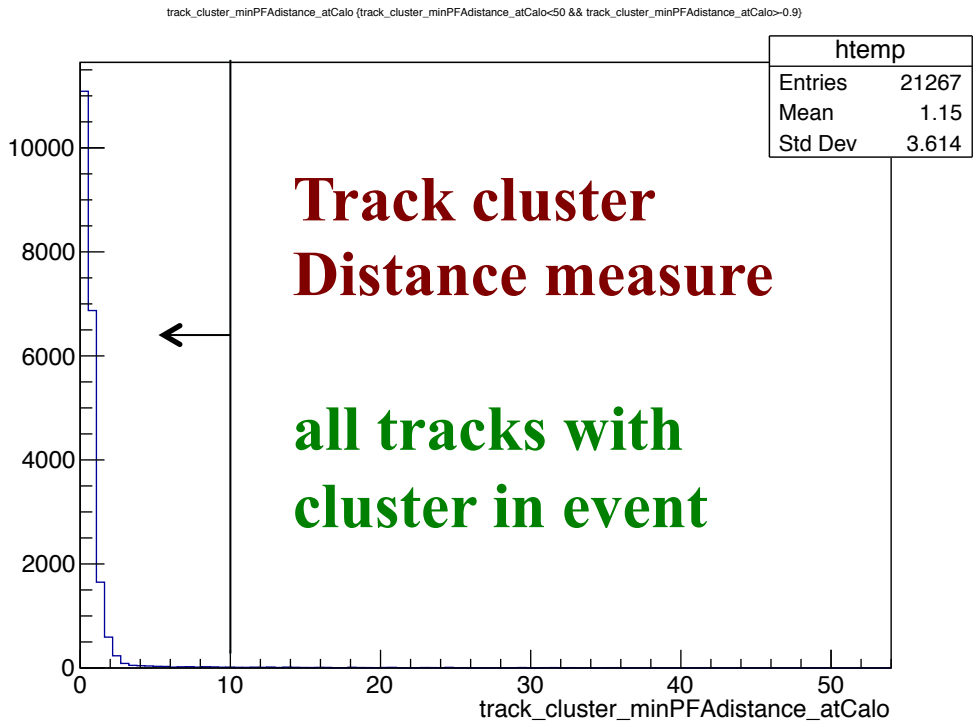


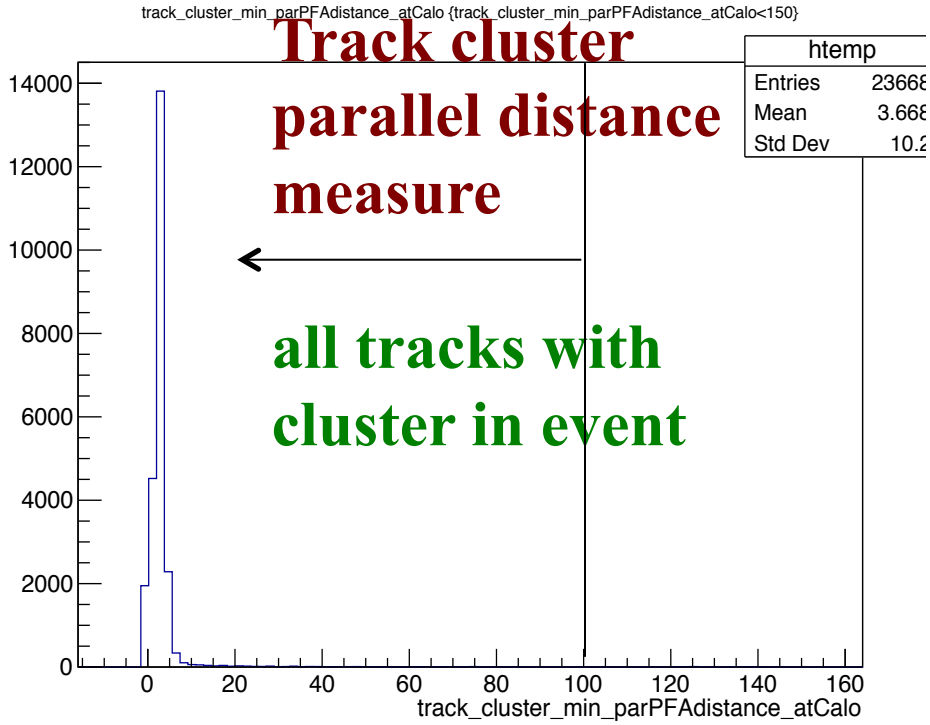


In this model trackstateAtCalorimeter always at barrel phase, same issue as previously, for non identified events track pointed to corners of ECAL barrel, not many hits in first layers of ECAL barrel →gap itself is not the issue, but track-cluster matching

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

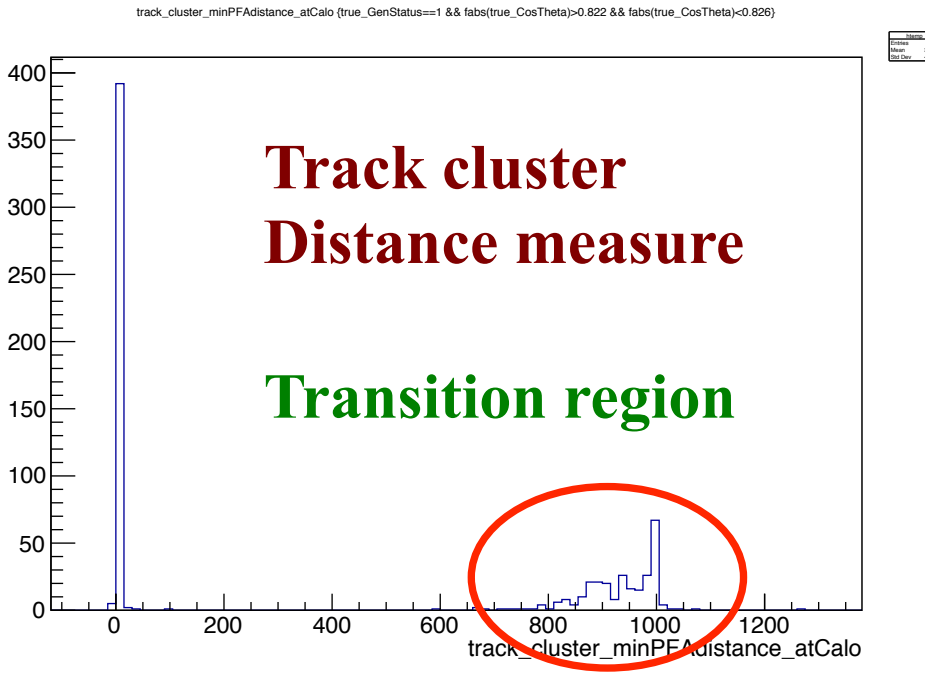


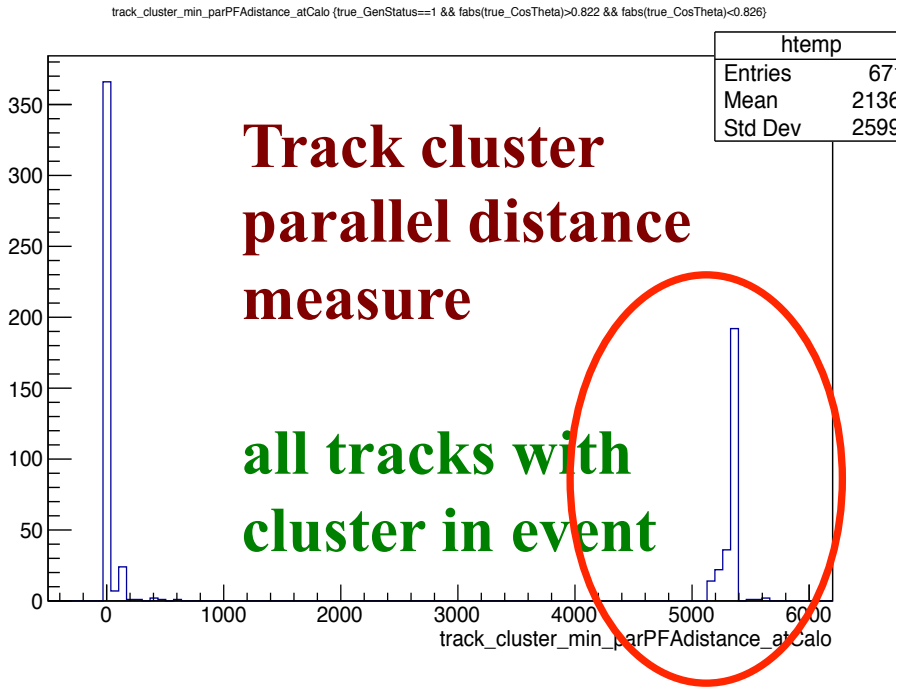


Model CLIC_o3_v10
distance measures in transition region

TrackStateAtCalo not optimally set in transition region → distance measure cut values too tough gap clusters →relax cuts

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

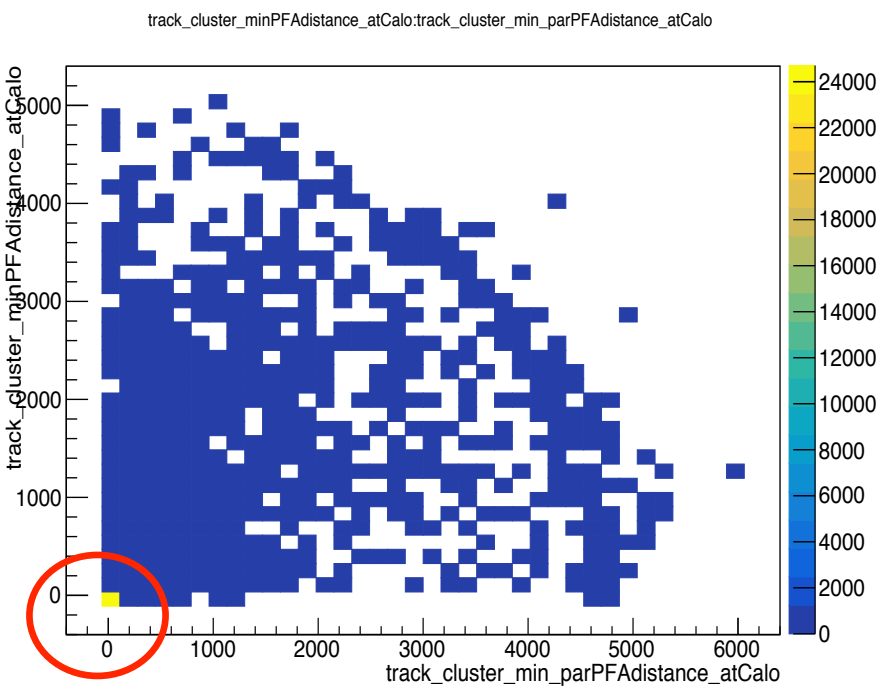


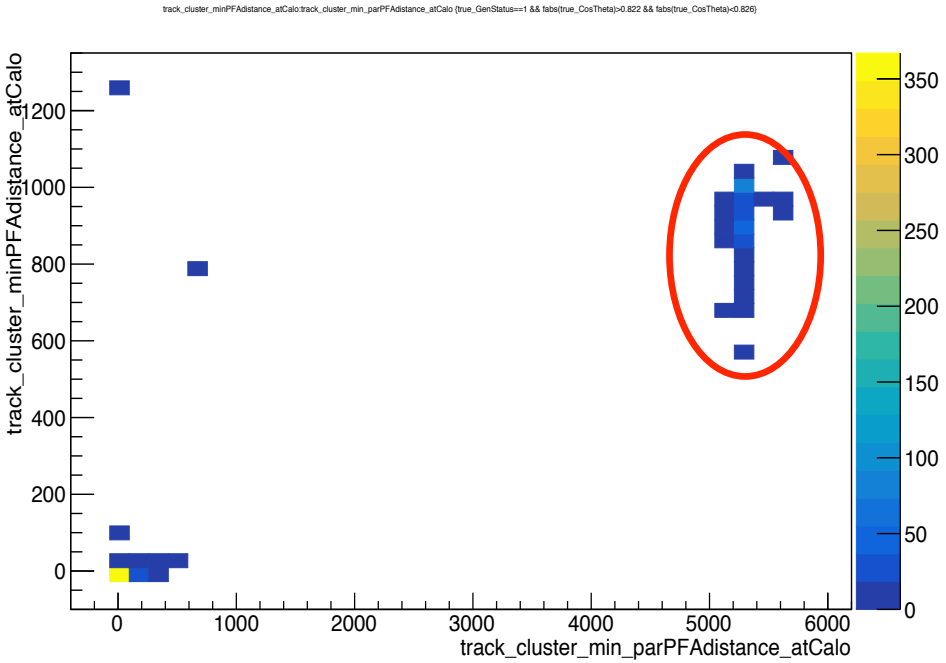


Events of second peak fail → increase cut for parallel distance from 100 to 5500 and for distance measure from 10 to 1100

Model CLIC_o3_v10
distance measures in transition region

Parallel distance cut and PFA distance cut correlated

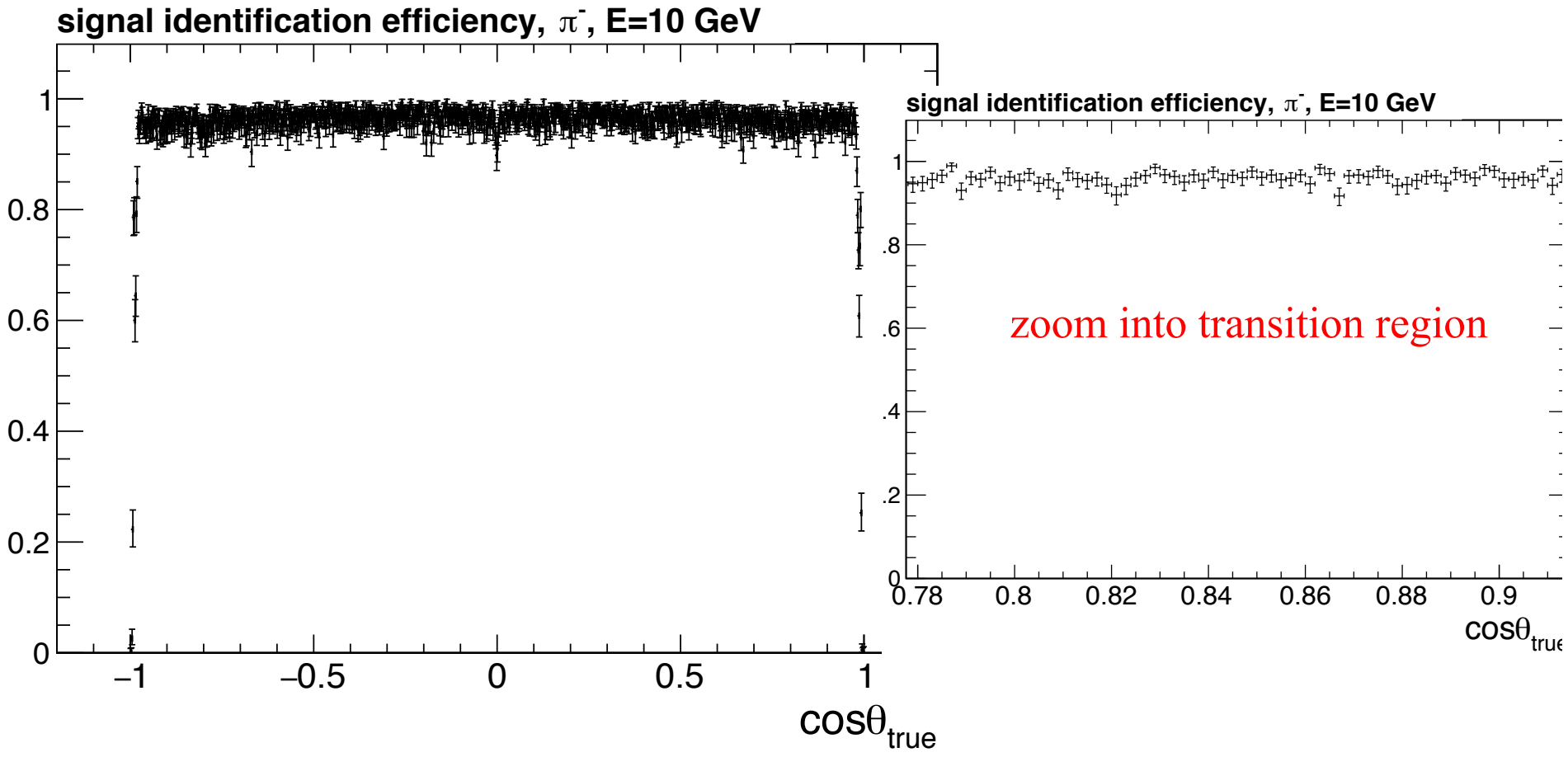




In overall event numbers correlation for high second peak events of transition region absolutely negligible

Pion 10 GeV sample

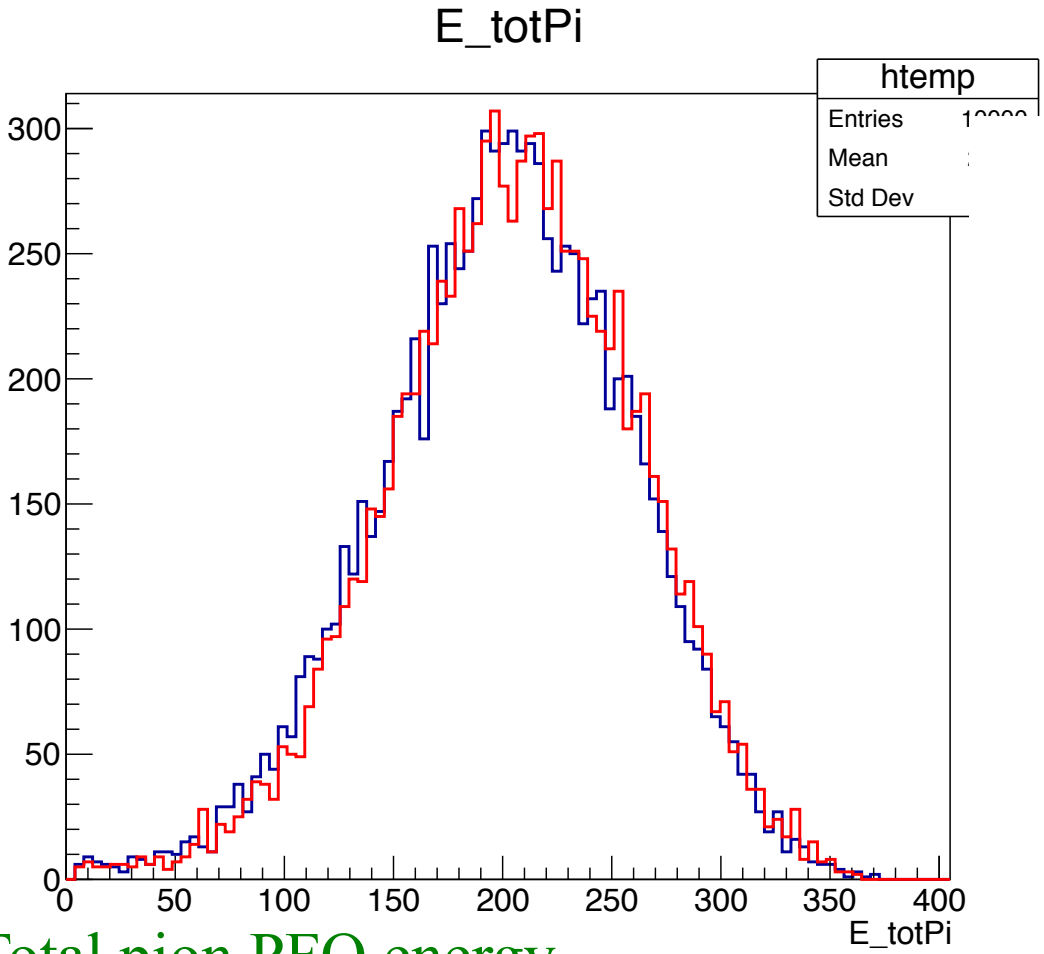
Pion particle gun with increased track-cluster distance cuts →dip in identification efficiency **GONE**



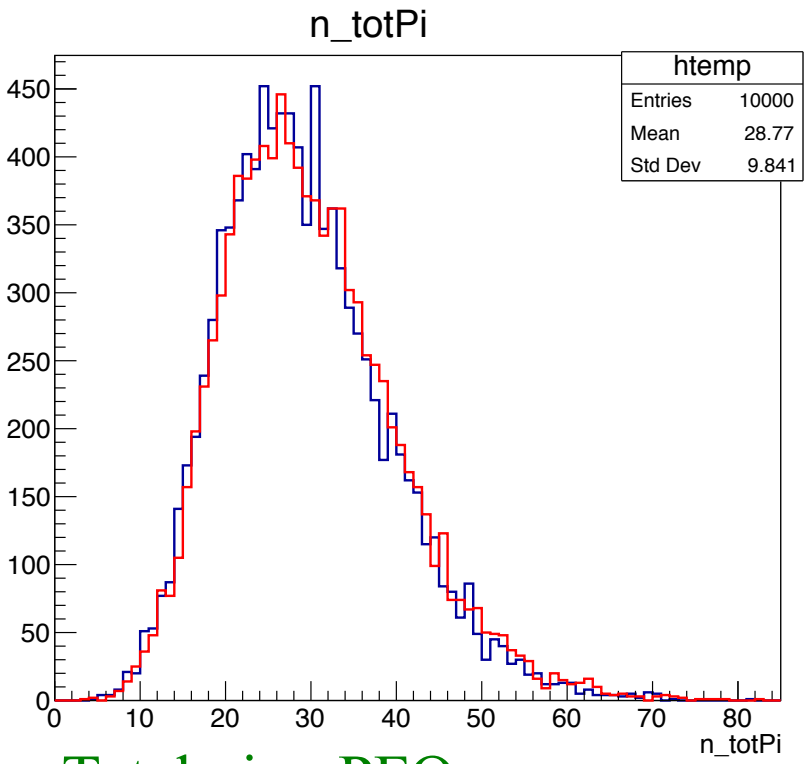
Z→uds, default relaxed trackCluster cuts 380 GeV sample

Pion energy and charged multiplicity pretty similar

Default track cluster distance values vs Relaxed track cluster distance values



Total pion PFO energy

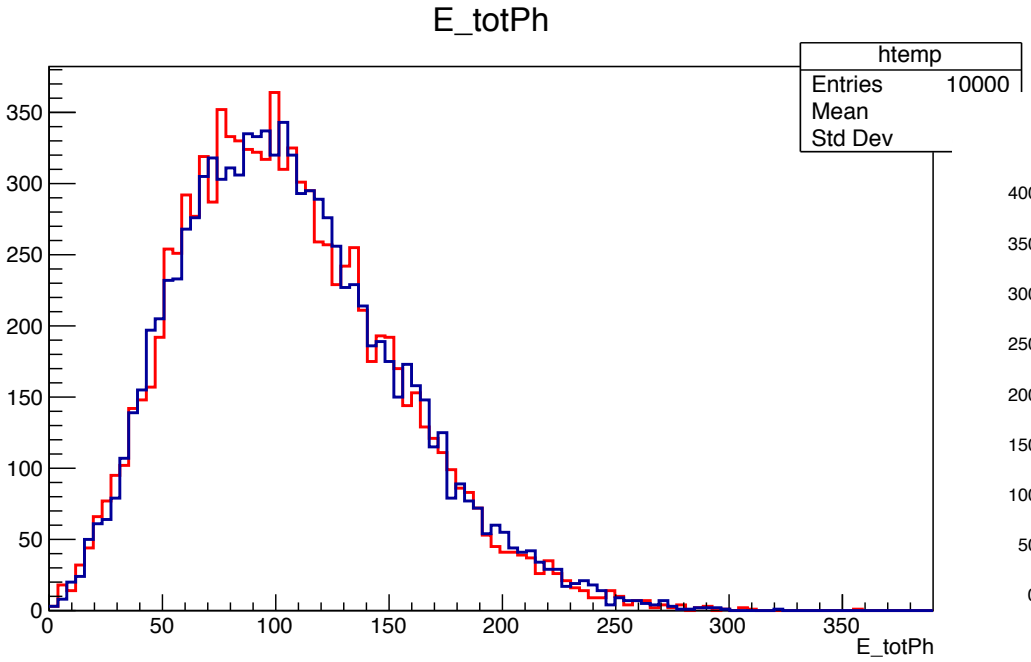


Total pion PFO multiplicity

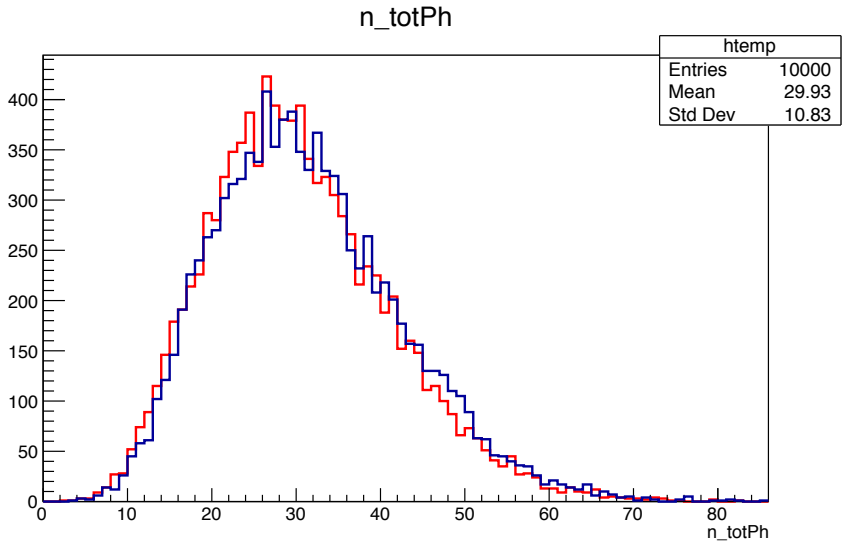
Z→uds, default relaxed trackCluster cuts 380 GeV sample

Photon energy and photon multiplicity pretty similar

Default track cluster distance values vs Relaxed track cluster distance values



Total photon PFO energy

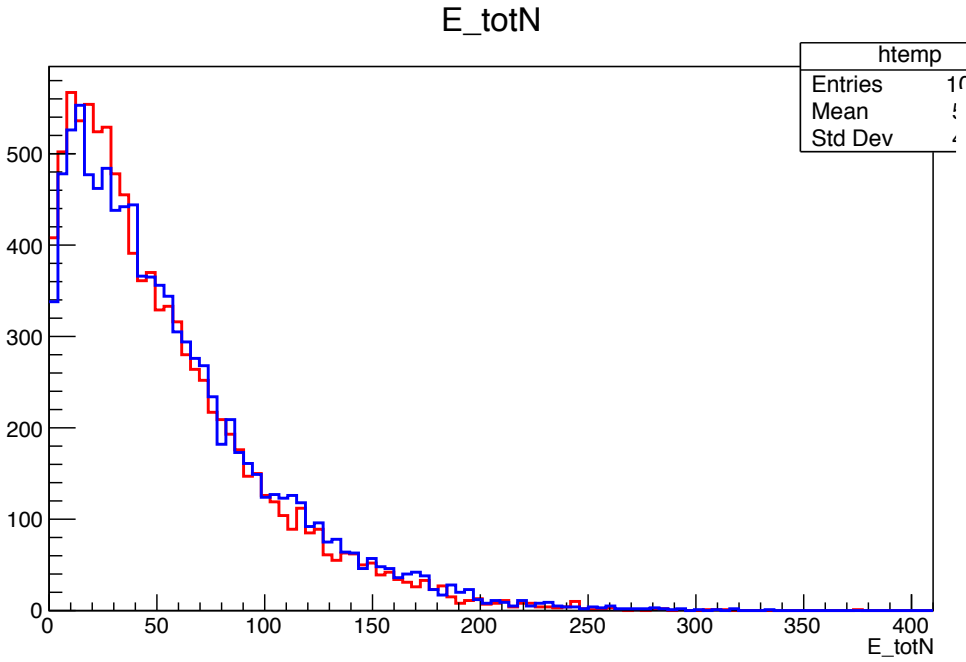


Total photon PFO multiplicity

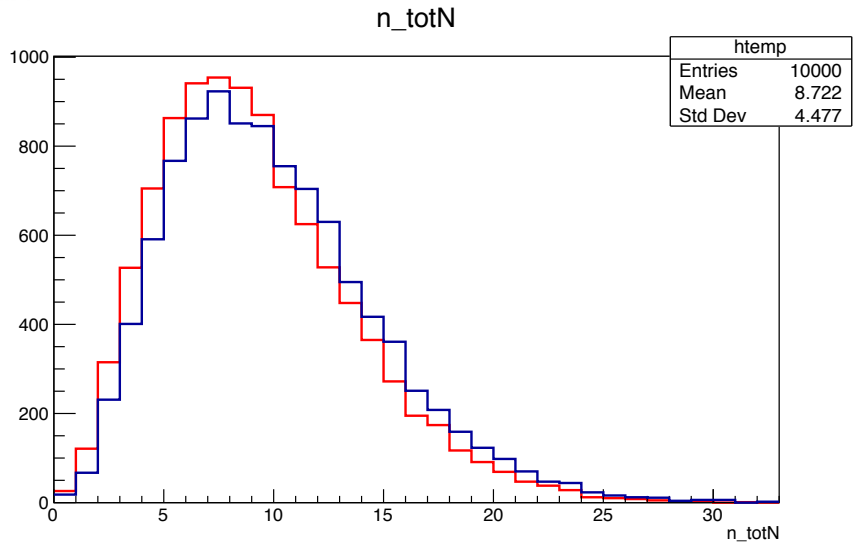
Z→uds, default relaxed trackCluster cuts 380 GeV sample

Neutron energy and neutron multiplicity pretty similar (due to low neutron multiplicity the neutron multiplicity distribution seems to be larger affected although we observe rather a negative shift by 1 neutron per event)

Default track cluster distance values vs Relaxed track cluster distance values



Total neutron PFO energy



Total neutron PFO multiplicity

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 (issue not present for muons, check next slides)s

- Introduce two track states at calorimeter, separately for barrel and endcap→check distance against both of calorimeter trackstates, would solve the issue, but large overhead
- Second option: change cuts for cluster-track distance calculation for transition regions → relaxed values recover inefficiency

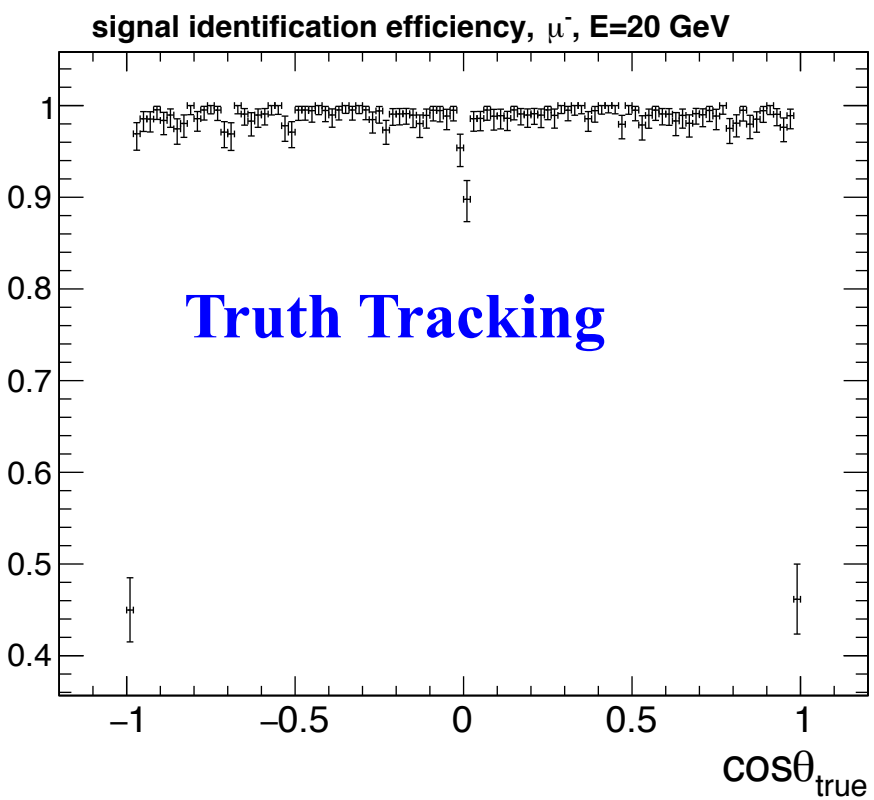
- Check behavior of relaxed track-cluster matching cuts on first CLIC stage energies of 380 GeV →no significant changes observed, using relaxed cuts in whole detector → propose relaxed cuts in transition region while keeping the current default everywhere else

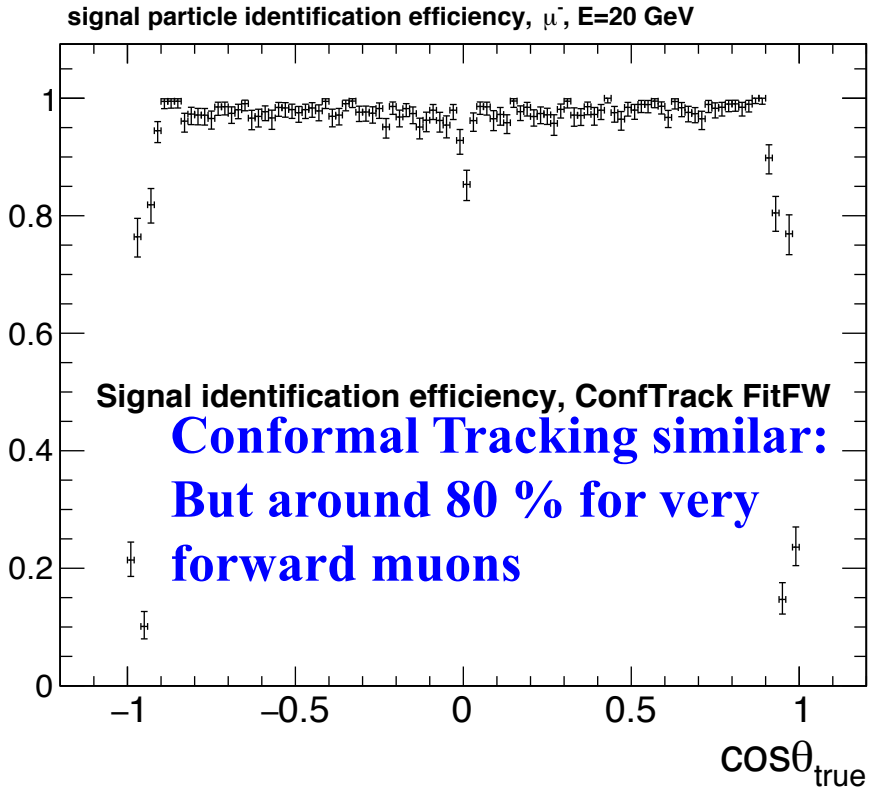
Muons

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





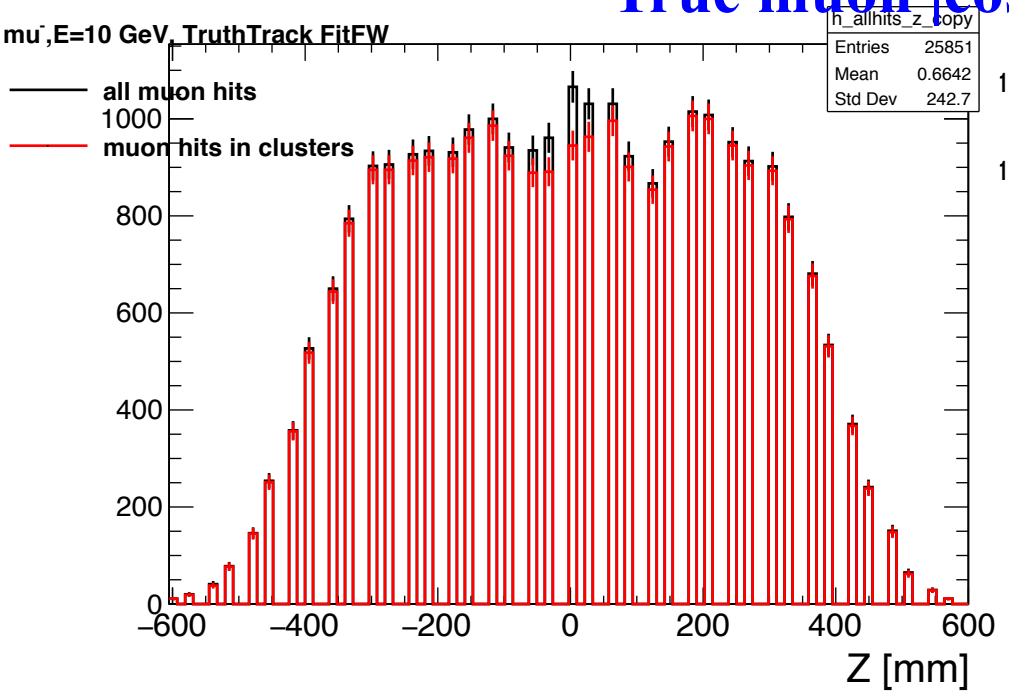
Identification efficiency larger than 96 % over most of the range

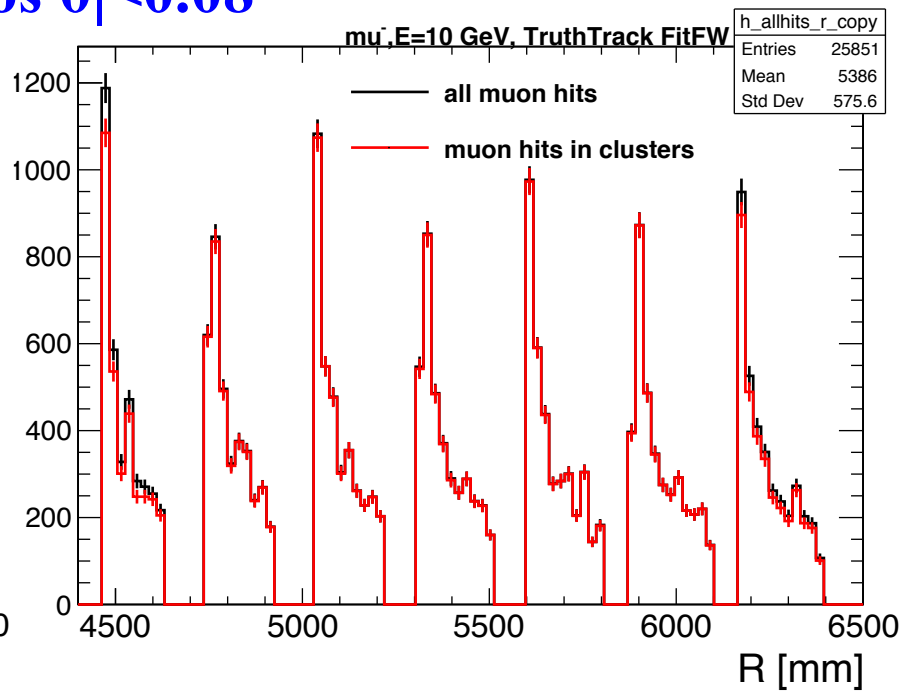
→ Dip around 90 degrees, work ongoing for very forward tracking for conformal tracking

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





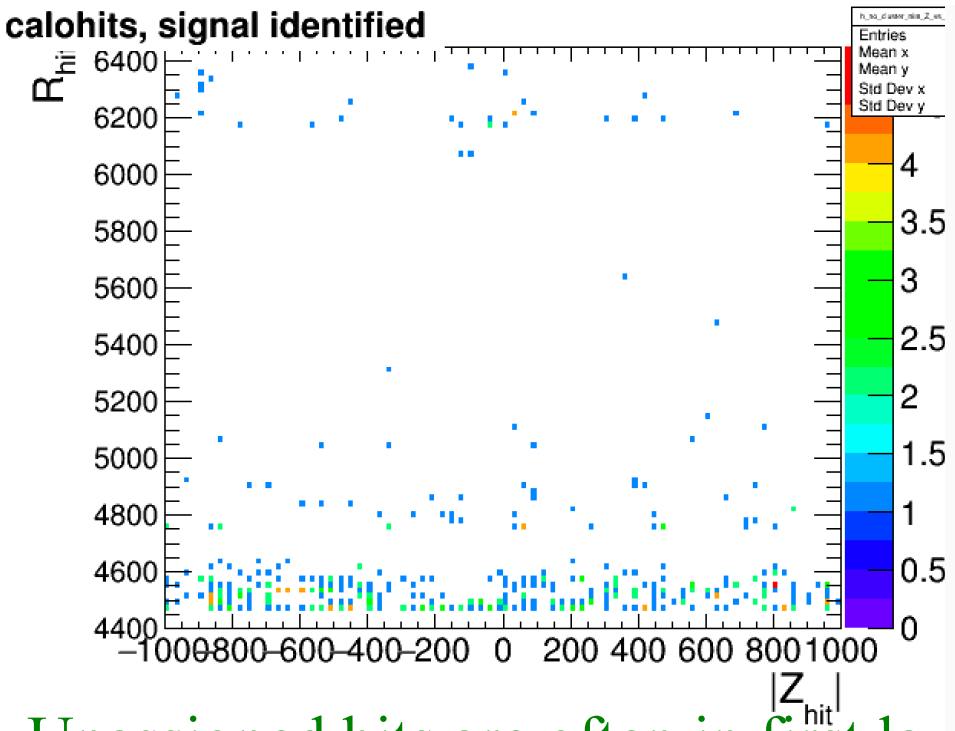
Muon hits around Z=0 missed end up unclustered, typically hits in first end last muon chamber (see distribution of hit radii)

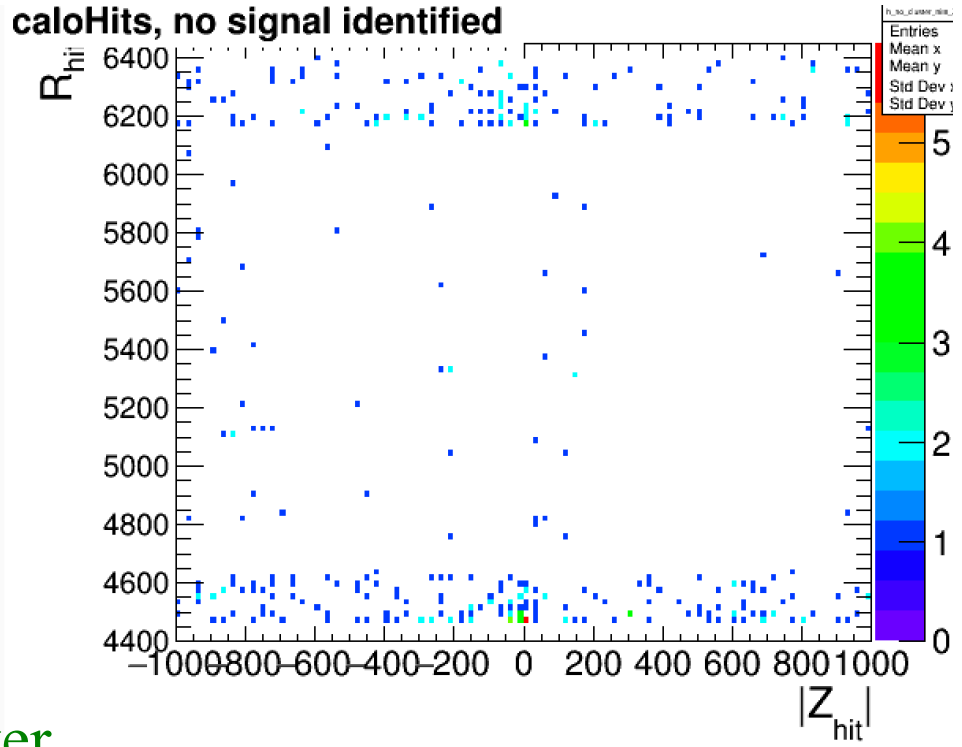
MuonHits positions unassigned to clusters 2D plot

Muon hits inside cluster for identified and missed muon events

→ Most of unassigned hits in first layer, or last layer

→ For 90 degrees it can happen that all muon hits in are not assigned to clusters, so MuonHit to CalorimeterCluster association misses those completely





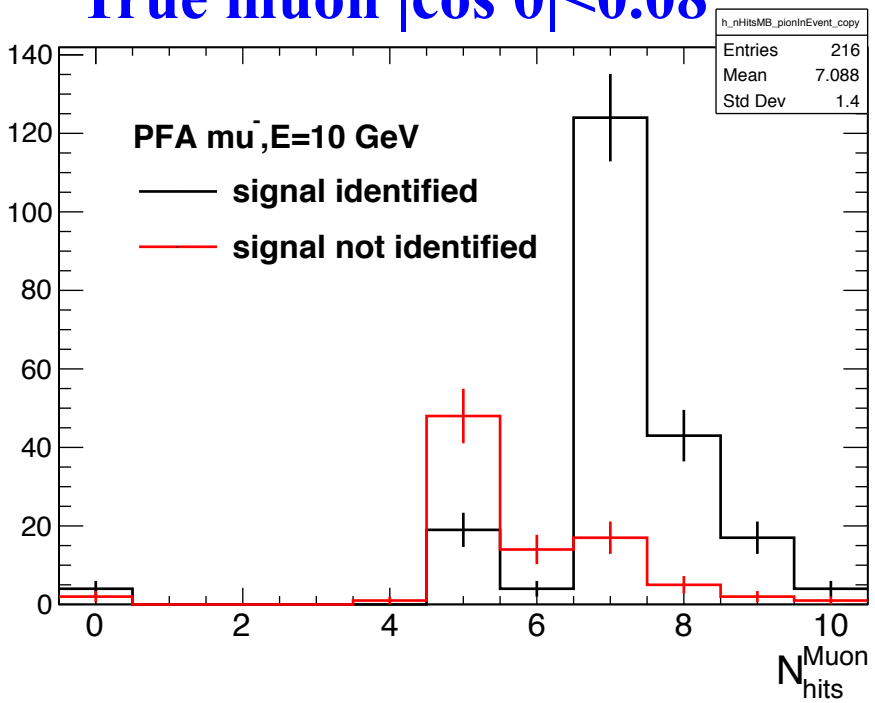
Unassigned hits are often in first layer

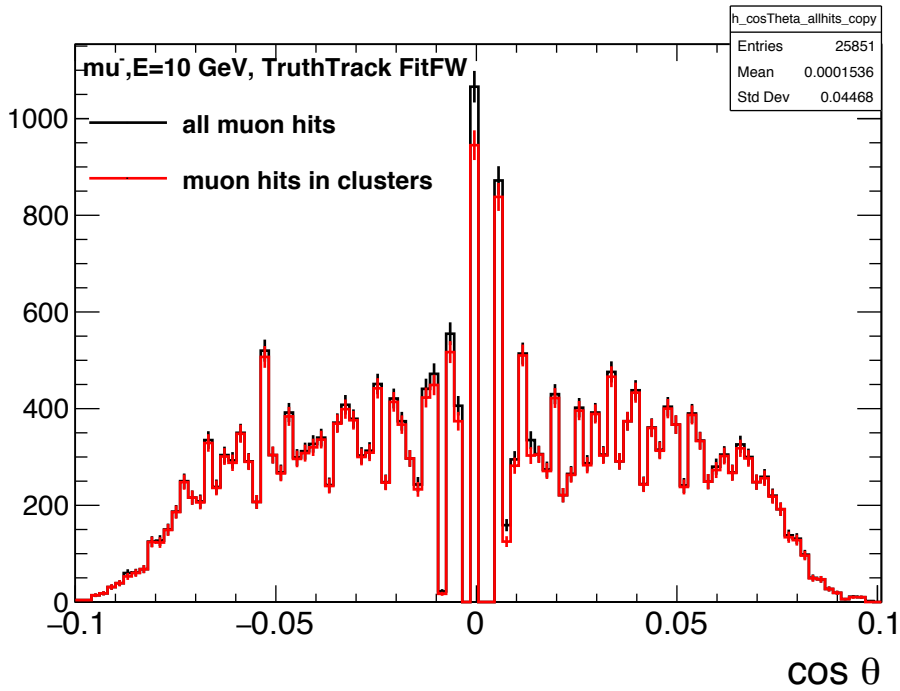
→should still pass requirement of 5 hits in muon reconstruction

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

- Issue might be solved if we can recover those two hits