

# SDHCAL PFA Study: Single Particle Event Analysis

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# Outline



- Introduction
  - SDHCAL reco soft status
  - Observation: UDS jet reconstruction with SDHCAL
- Single pion event:
  - Performance at SDHCAL barrel
  - Comparison to Endcap and corner region
  - Comparison to AHCAL
- Single Klong event
  - AHCAL/SDHCAL Comparison
- Summary and Plan

# Introduction

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- Finer granularity...  
SDHCAL: 1 by 1 cm  
AHCAL: 3 by 3 cm

- SDHCAL reconstruction software status

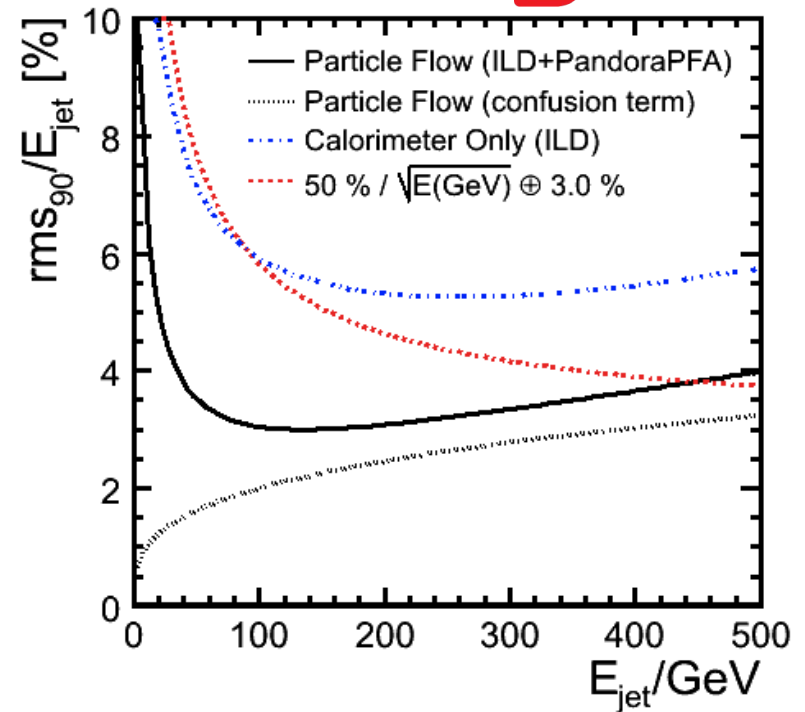
- PandoraPFA based reconstruction chain:

- Preliminary RPC digitization ( *with 3 thresholds: 0.5, 2, 10 mips* ): *to be upgraded with multiplicity effects*: R.Han et.al: <http://ilcagenda.linearcollider.org/getFile.py/access?contribId=19&sessionId=8&resId=1&materialId=slides&confId=4776>
    - PandoraPFA: learning phase -> *optimize the parameters & orders of different modules*

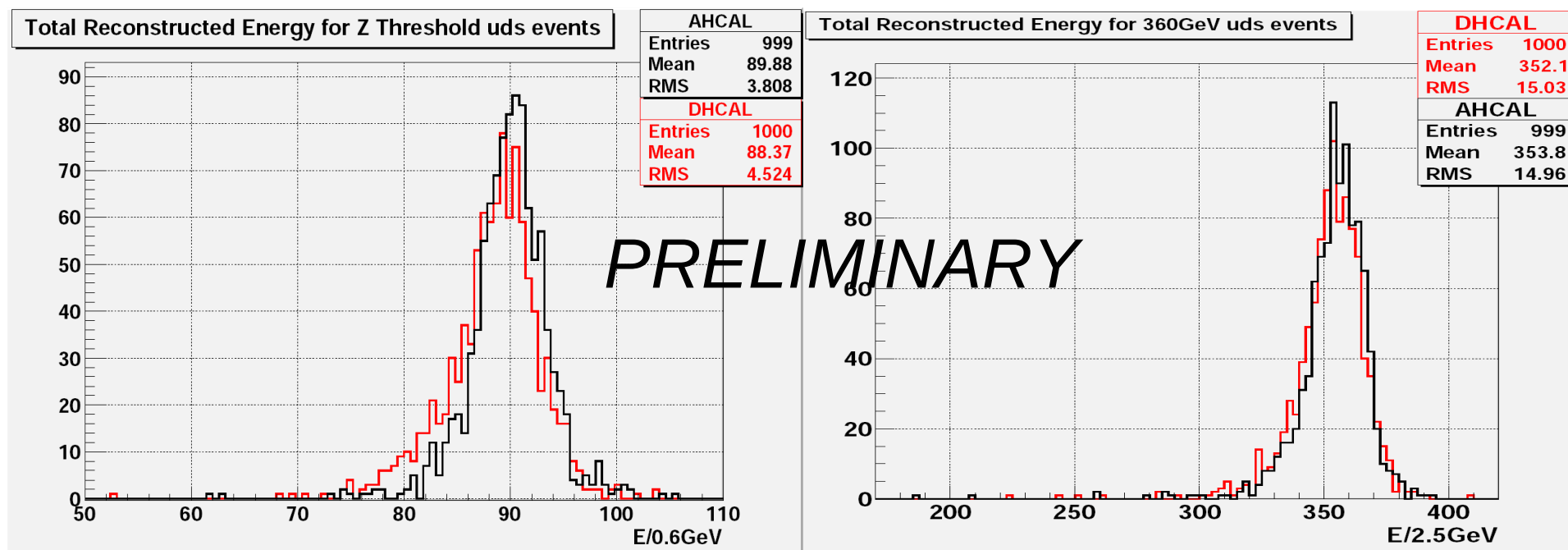
- SDHCAL based algorithms: under development

- Density & NN analysis, Kalman filter, Hough transform...
    - Dedicated clustering + shower energy estimator: to be developed and integrated*

- Event Display: heavily employed to understand the performance

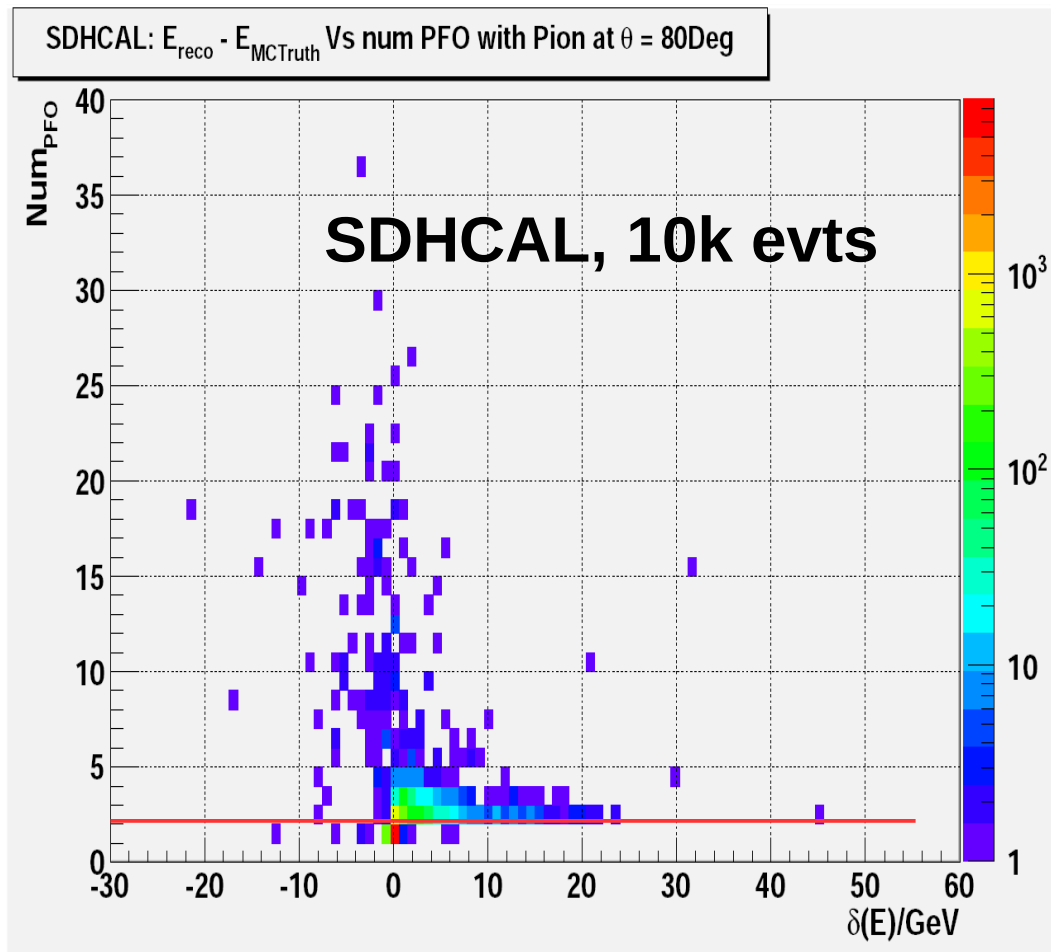


# Pandora: learning phase

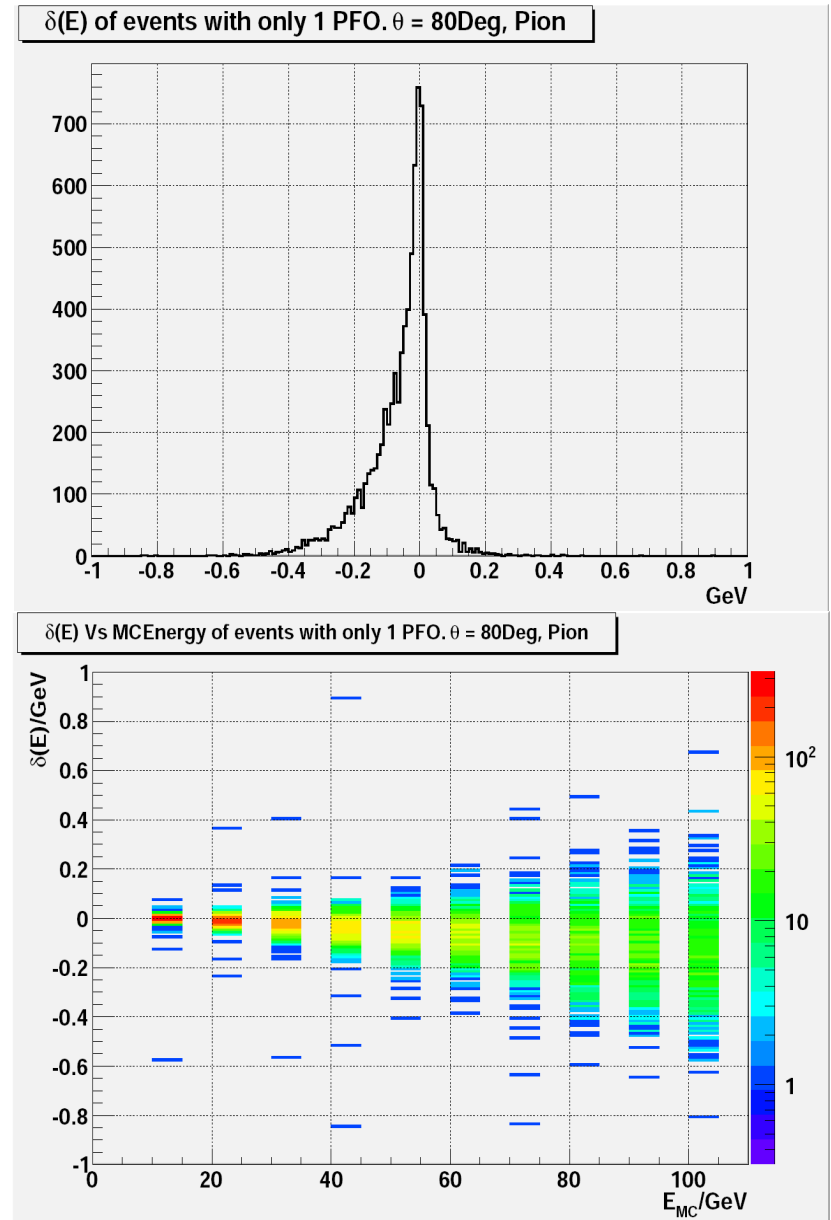


- For SDHCAL: treated Pandora as black box
  - Pandora + Preliminary Digitization + Calibration constant tuning
  - Performance with uds evts: slightly worse @ Zthreshold, much closed @ 360GeV
- To achieve better understanding: Single Particle events
  - Single Pion, Klong and Tau
  - Statistic: ~300k each. 1 ~ 2k \* 10 energies (10 ~ 100GeV) \* 9 polar angles (10° ~ 90°) \* 2 concepts
  - Simulation ( with grid & mokka 06-07 ) almost finished. Analysis on going.

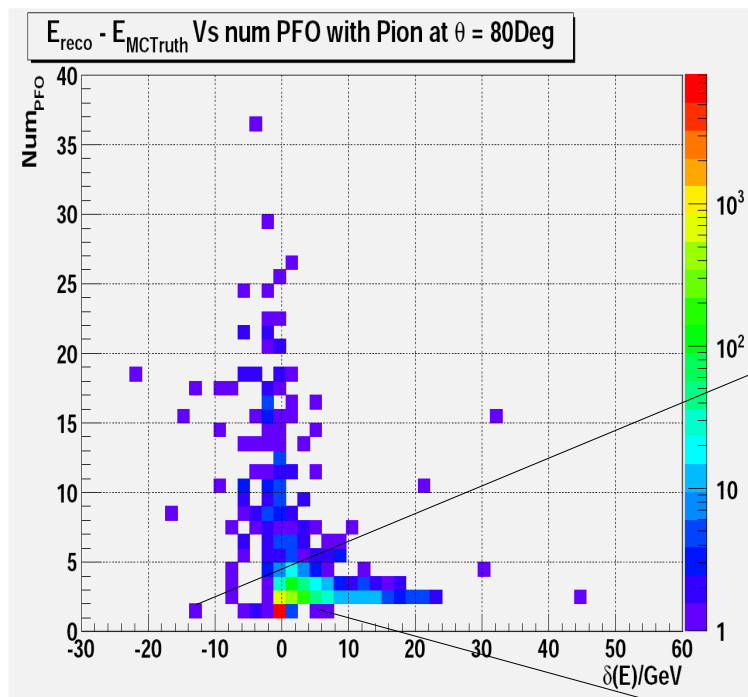
# SDHCAL, Pion at $\theta = 80^\circ$



81% evts (8097) has single PFO  
Low energy tail in  $\delta(E)$  spectrum, correlated with MCEnergy: energy loss



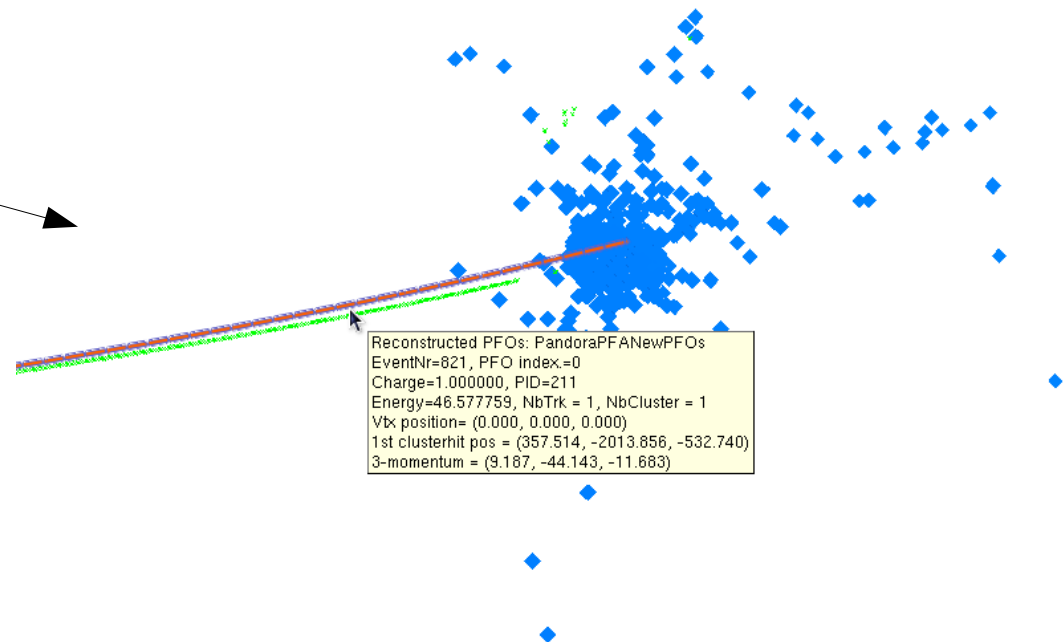
# Single PFO evts in the tail, $\theta = 80^\circ$



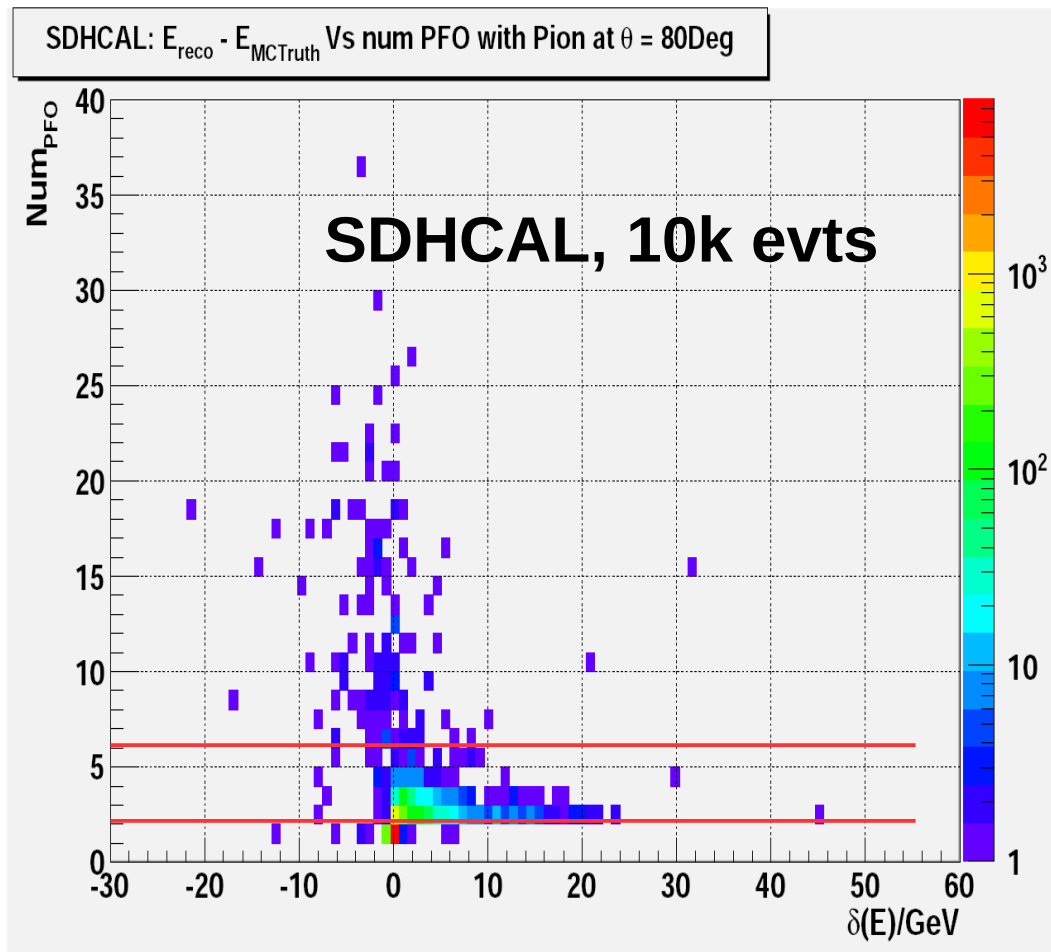
Evt 821,  
40GeV Pion at MCTruth  
Identify as 46.6GeV PFO  
with 38GeV cluster

Failure of track energy  
Reconstruction?  
Rare... but happens

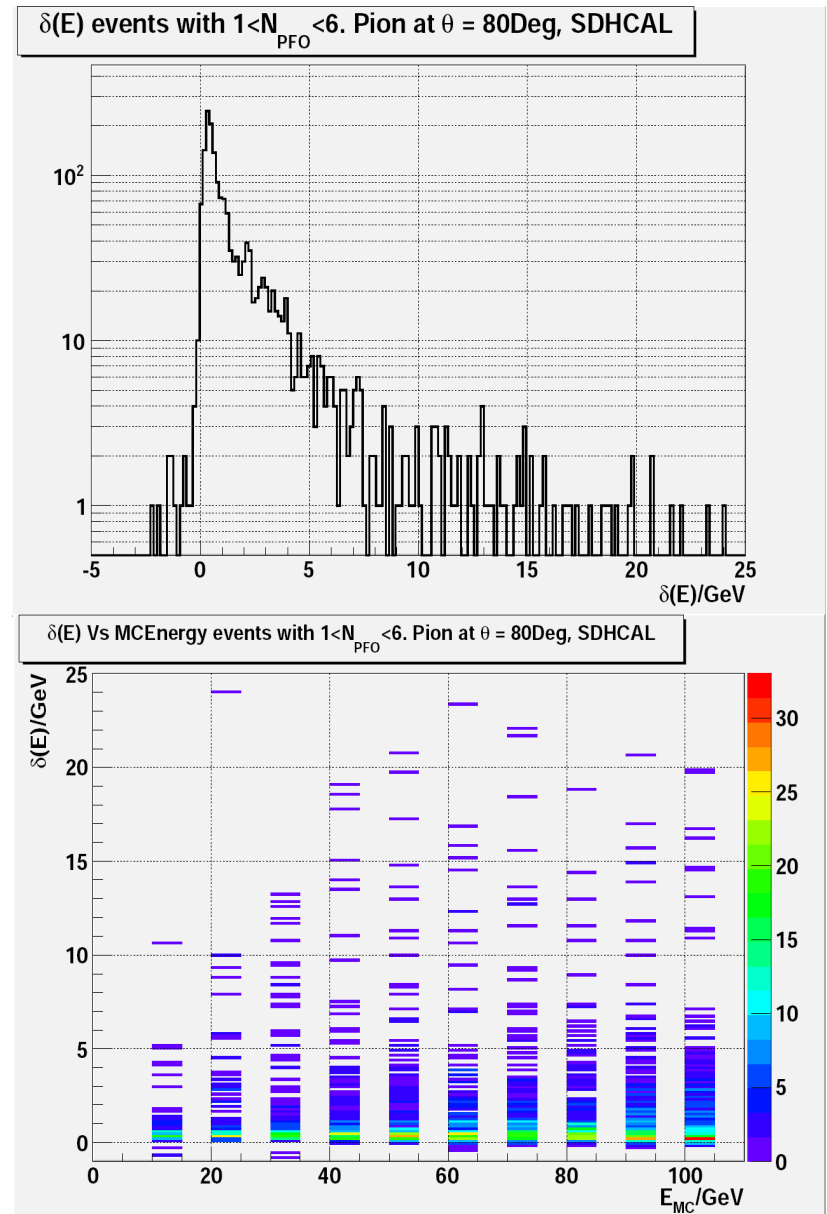
Pion decay:  
40GeV Pion  $\sim$  12GeV neutrino + 28GeV muon...



# Events with 2 - 5 PFOs



~ 18% (1766) events has 2 - 5 PFOs  
Higher estimated energy



# Events with 2 - 5 PFOs



(Evt 286) 2 PFOs, Identify as  
100GeV Pion (80.7GeV cluster) +  
45GeV Neutron (45.4GeV)  
Total PFO energy = 145GeV  
Seed at deep ECAL Layer...

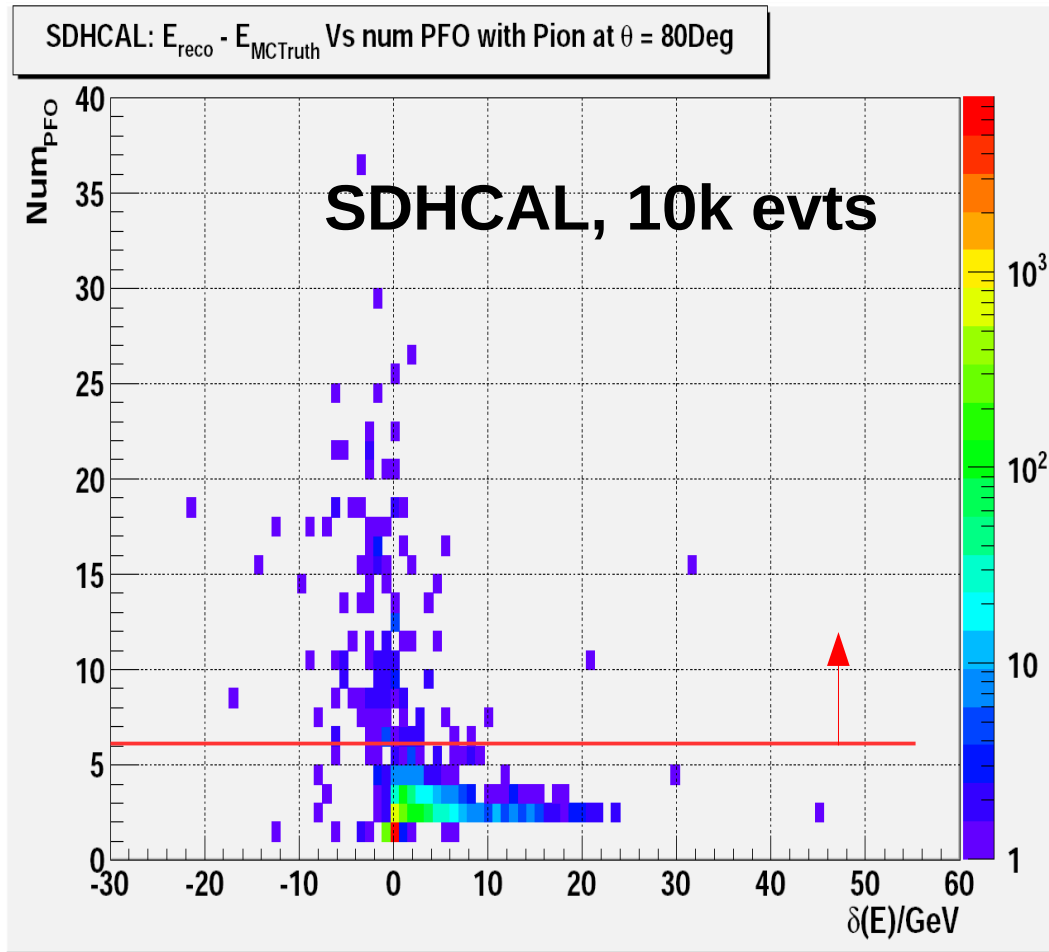
Evt 216  
Simulation level

Reconstruction: 4 PFOs:  
100GeV Pion (86.3GeV) +  
28GeV Neutron (24.4GeV) + ...  
Total PFO energy = 130GeV

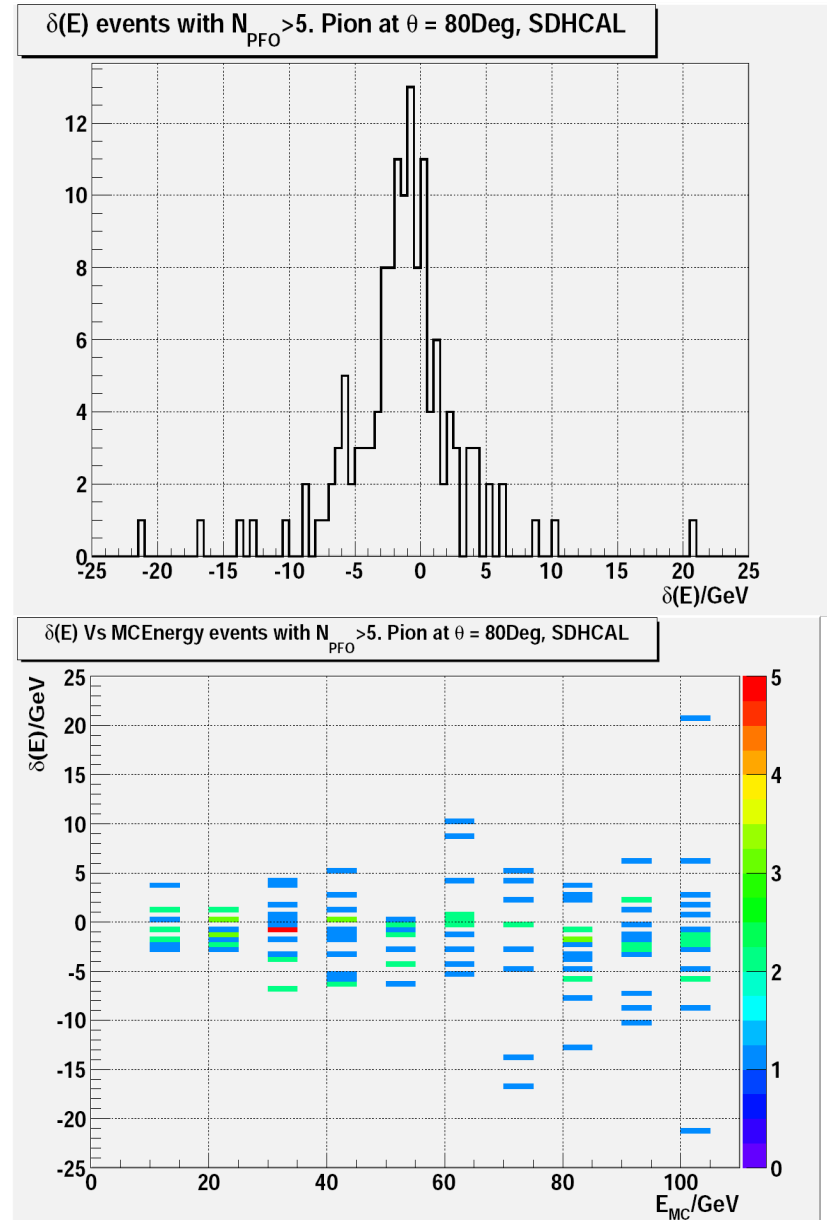
**Double counting! To be improved...**



# Events: more than 5 PFOs



~ 1.4% (137) events have more than 5 PFOs  
Large smearing in measured energy  
( Smearing amplitude increase with MC energy )



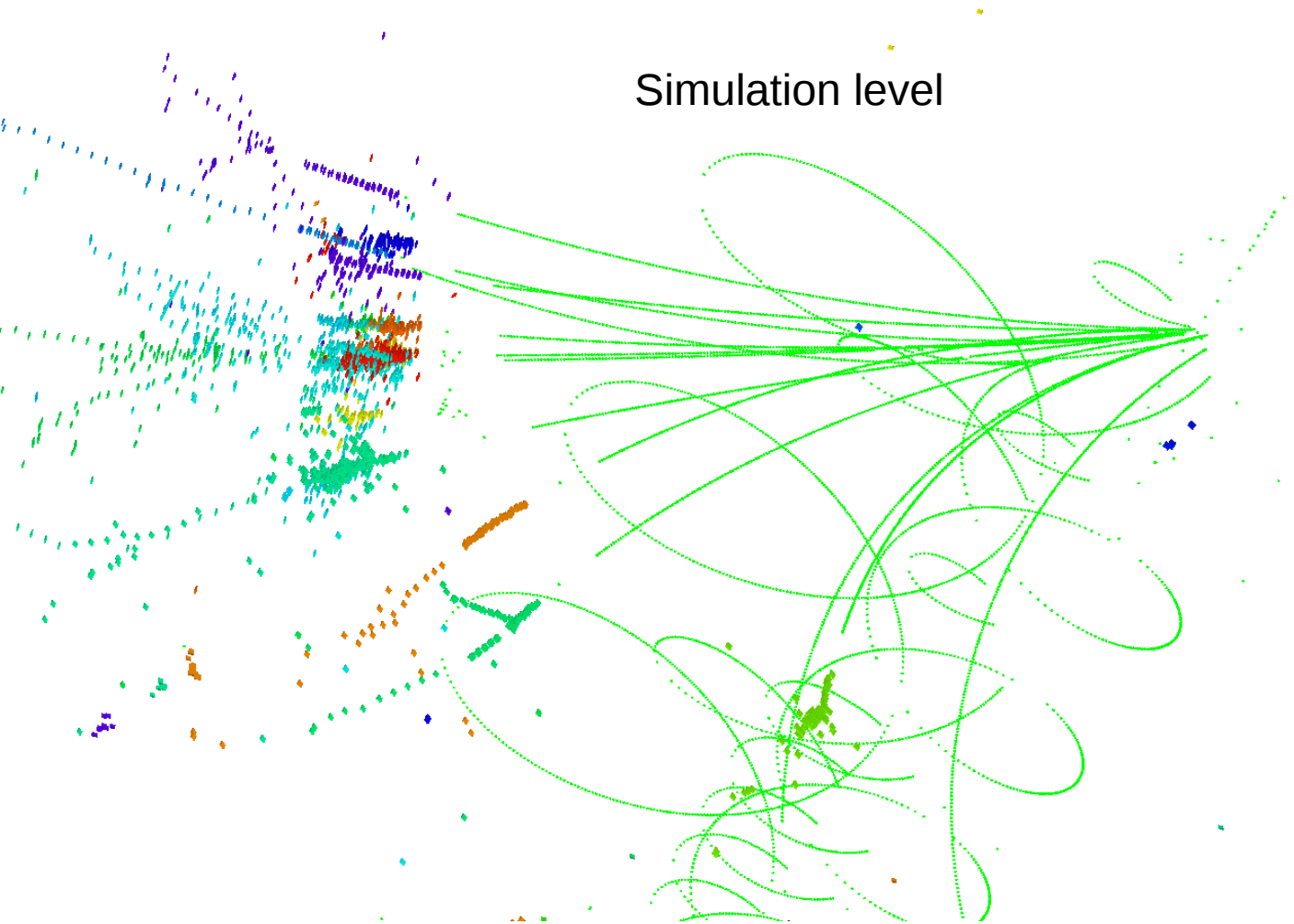
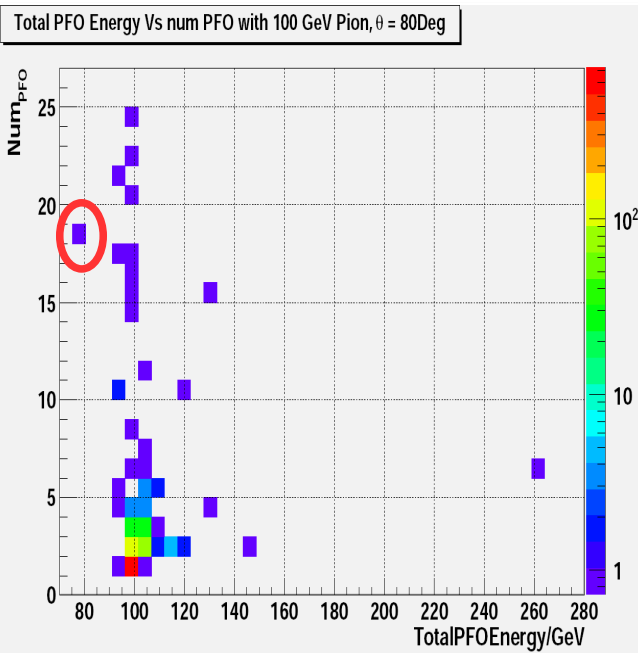
# “Lower” estimated energy for NPFO > 5 events



Evt 346,  
Interaction at TPC  
entrance

18 PFOs,  
Total Energy 79GeV

Simulation level



*dude... you are a pion?*

# Higher estimated energy for NPFO > 5 events



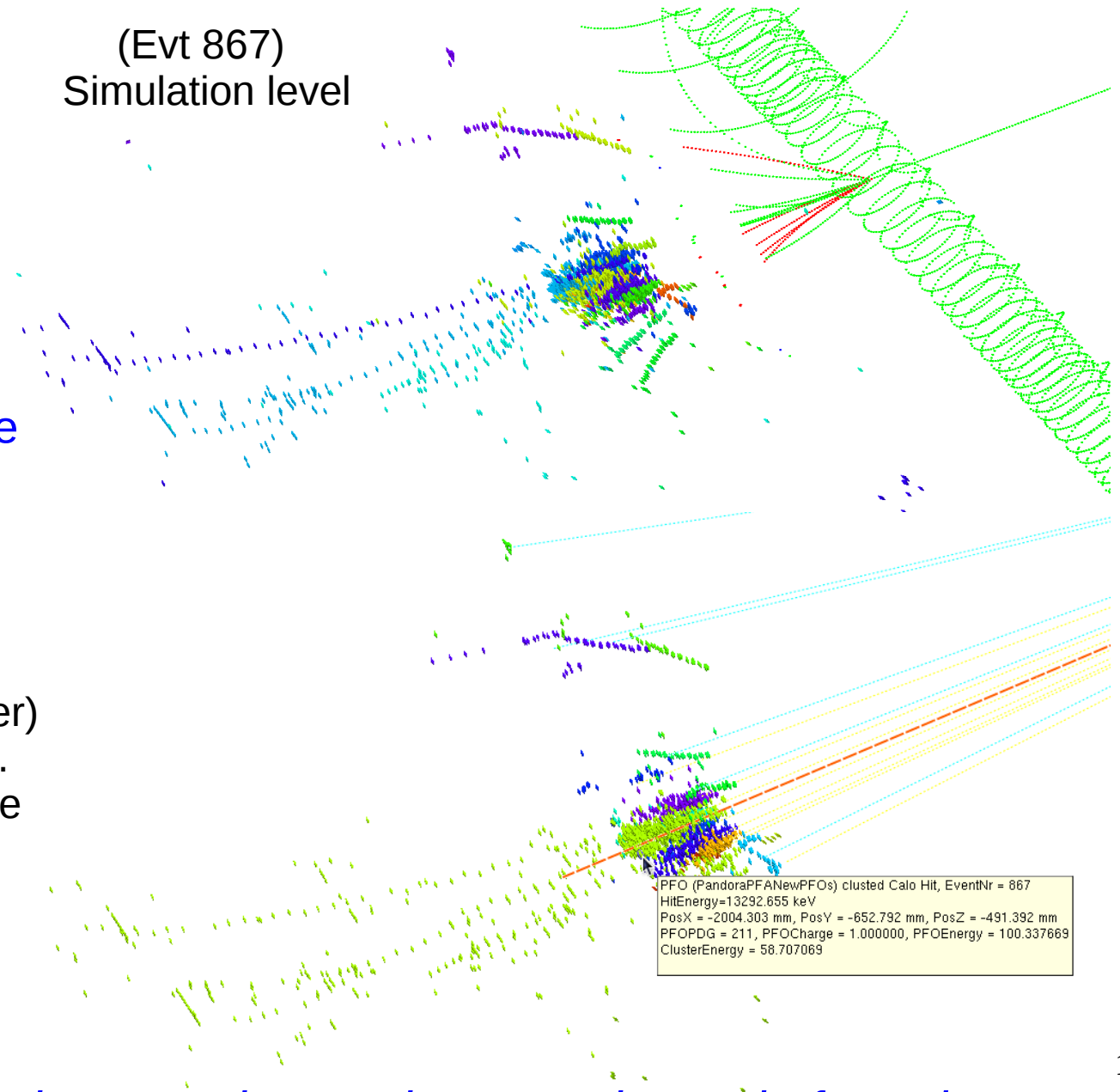
(Evt 867)  
Simulation level

Interaction based double  
counting

Reconstruction level:

15PFOs

Leading PFO (54GeV cluster)  
identified as 100GeV pion.  
Others contribute to double  
counted 32GeV...



PFO (PandoraPFANewPFOs) clustered Calo Hit, EventNr = 867  
HitEnergy=13292.655 keV  
PosX = -2004.303 mm, PosY = -652.792 mm, PosZ = -491.392 mm  
PFOPDG = 211, PFOCharge = 1.000000, PFOEnergy = 100.337669  
ClusterEnergy = 58.707069

# Even more crazy...

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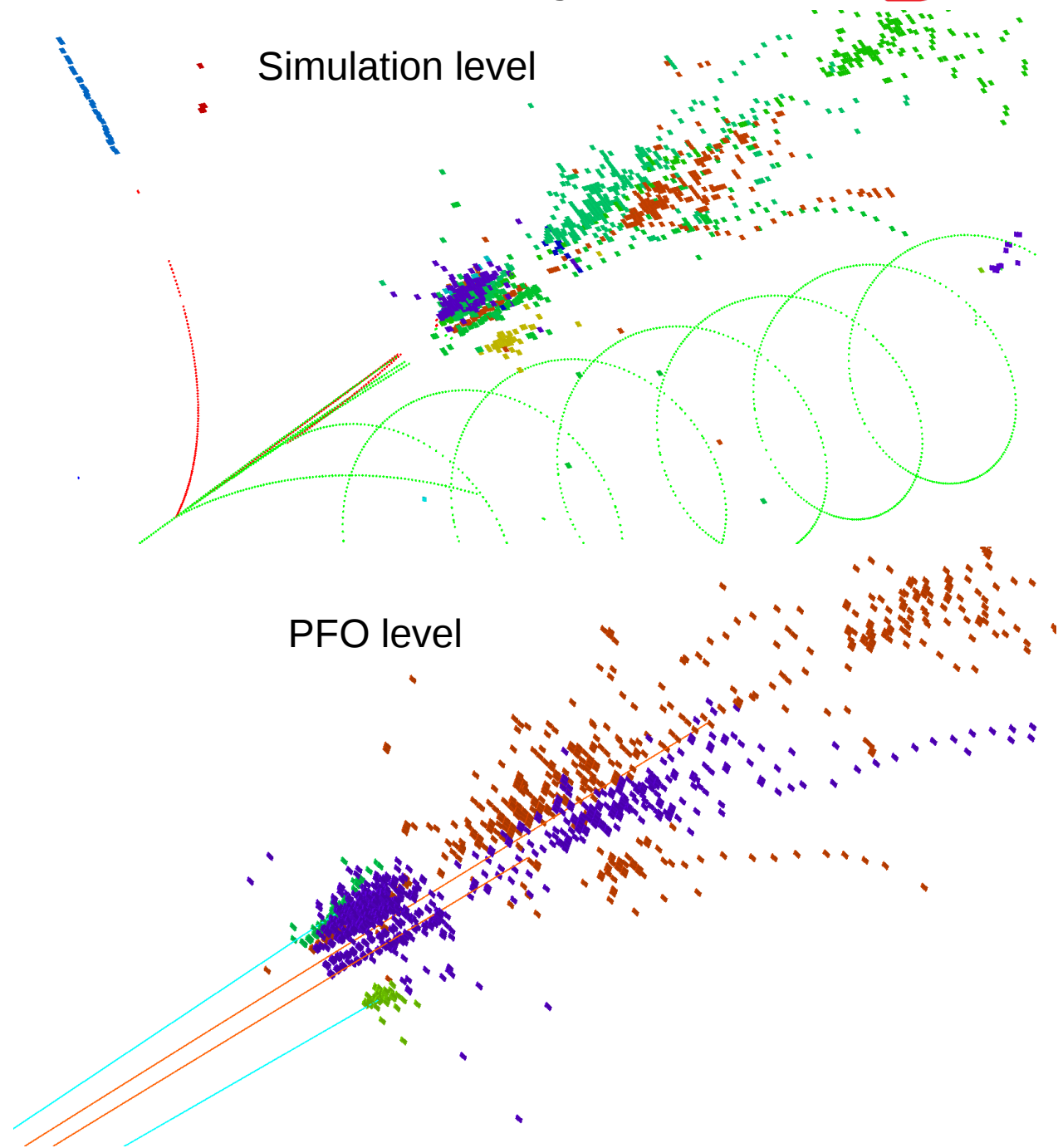
Evt 646: Interaction  
Inside TPC (1/3 of the  
radius)

Confused tracker: 3  
LDCTrack found

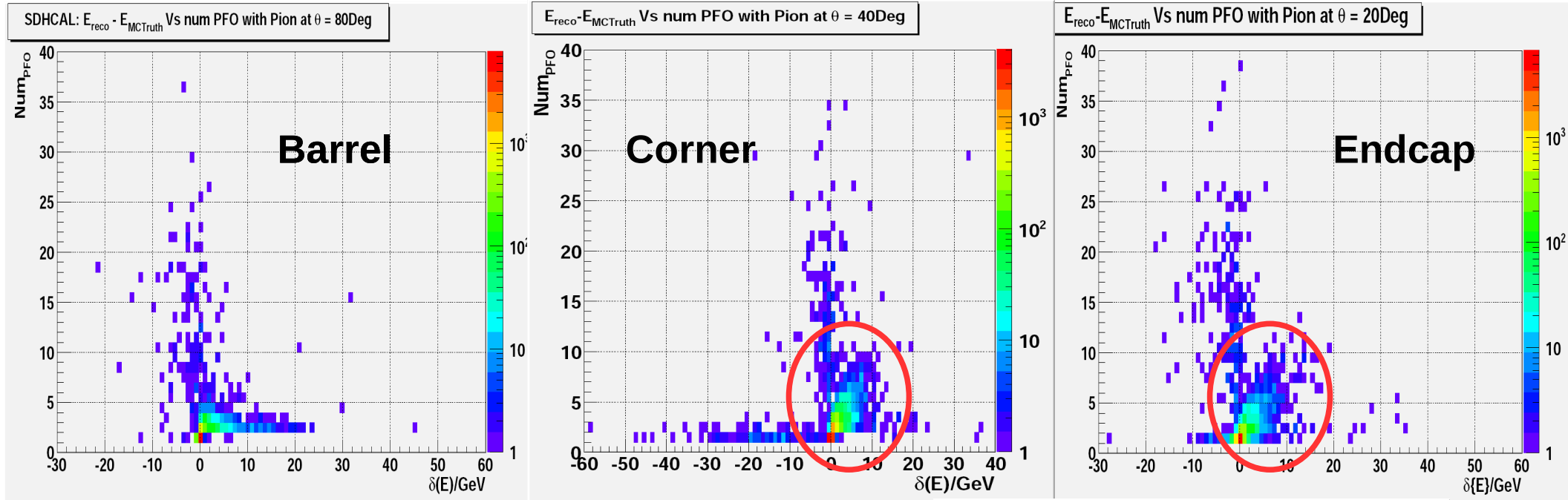
6PFOs:  
2 leading PFO  
assigned with tracks +  
cluster, with energy  
110GeV (40GeV  
cluster) and 148GeV  
(55GeV cluster)

Totally reconstructed  
energy: 264GeV

*Judgement on trk quality?  
Flag on those kind of evts  
Rely more on cluster info?*



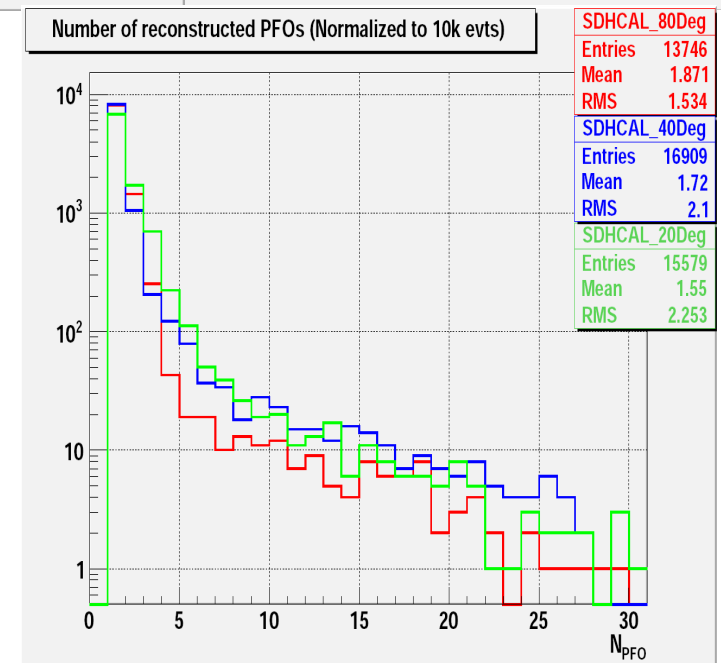
# Compare to corner & endcap



- For single PFO events:
  - Large low energy tail in Corner (also for 2-PFO events)
  - Large energy smearing in Endcap region (track smearing)
- Corner & Endcap: More material near the end of tracker
  - More Interactions
  - Linear dependency of  $\delta(E)$  and NPFO ~ [interaction based double counting?](#)

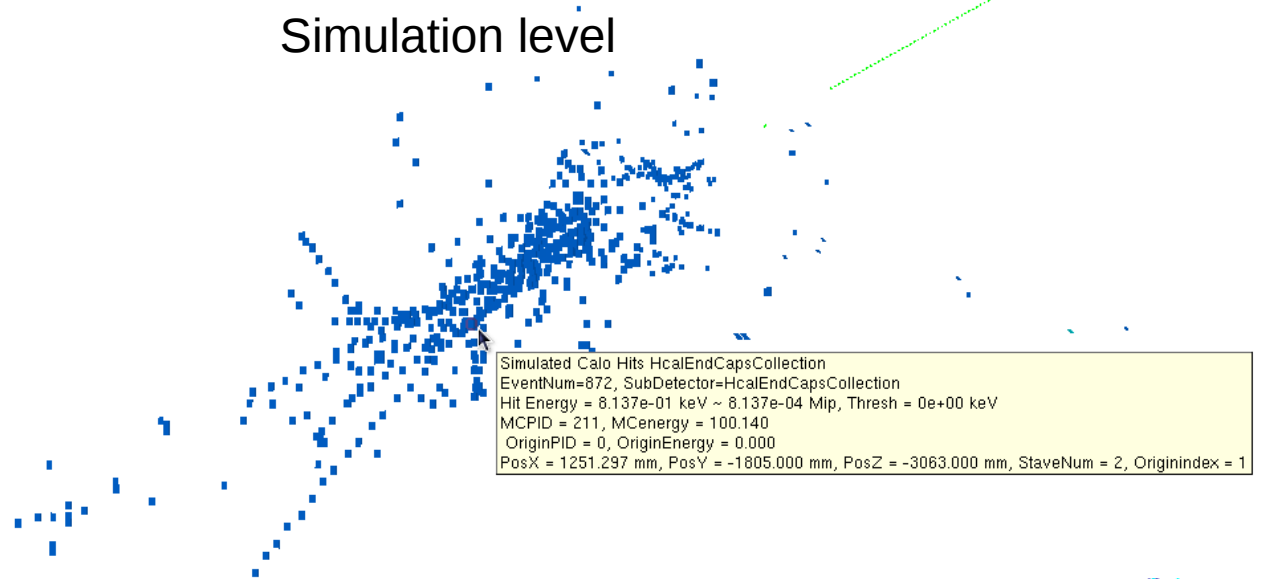
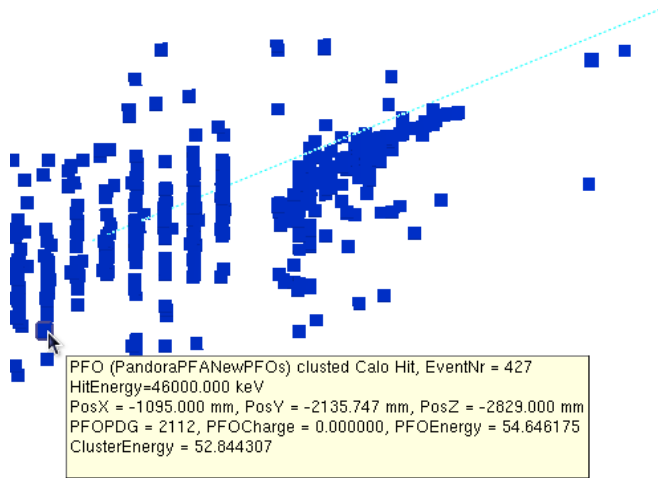
21/10/2010

ECFA 2010 @ CERN



# Low energy tail at $\theta = 40^\circ$

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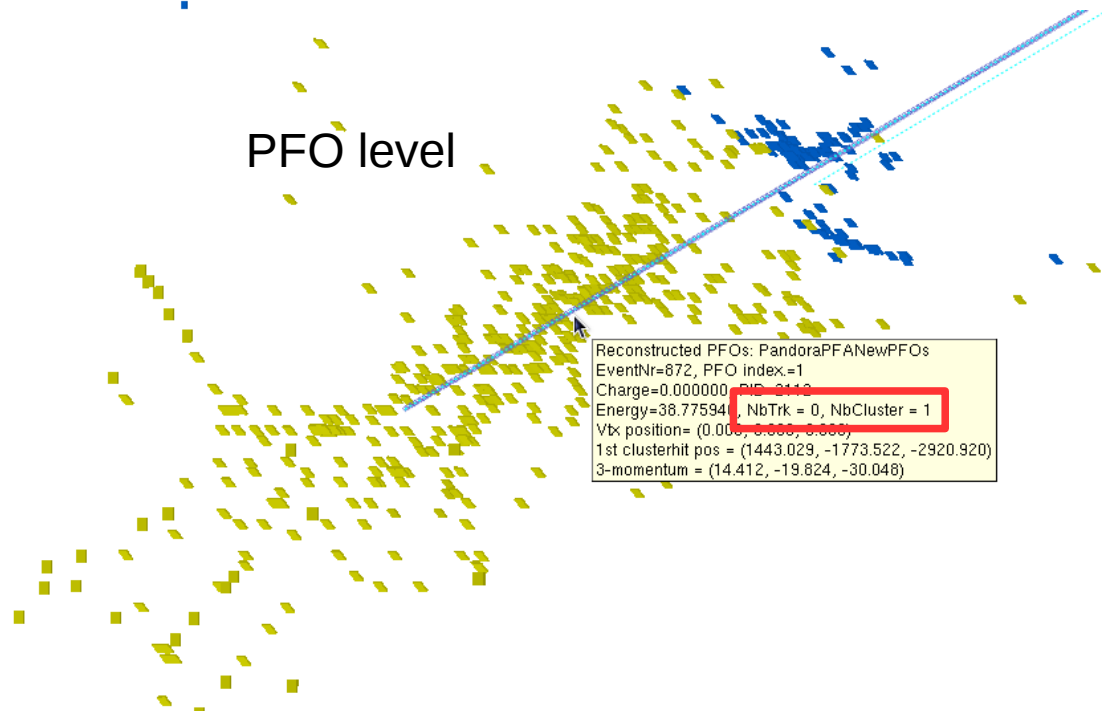
## Failed to link the track

(Track reconstructed: LDCTrack  
Number = 1):

100GeV Pion at 40Deg:

Above: Evt 427, Single PFO

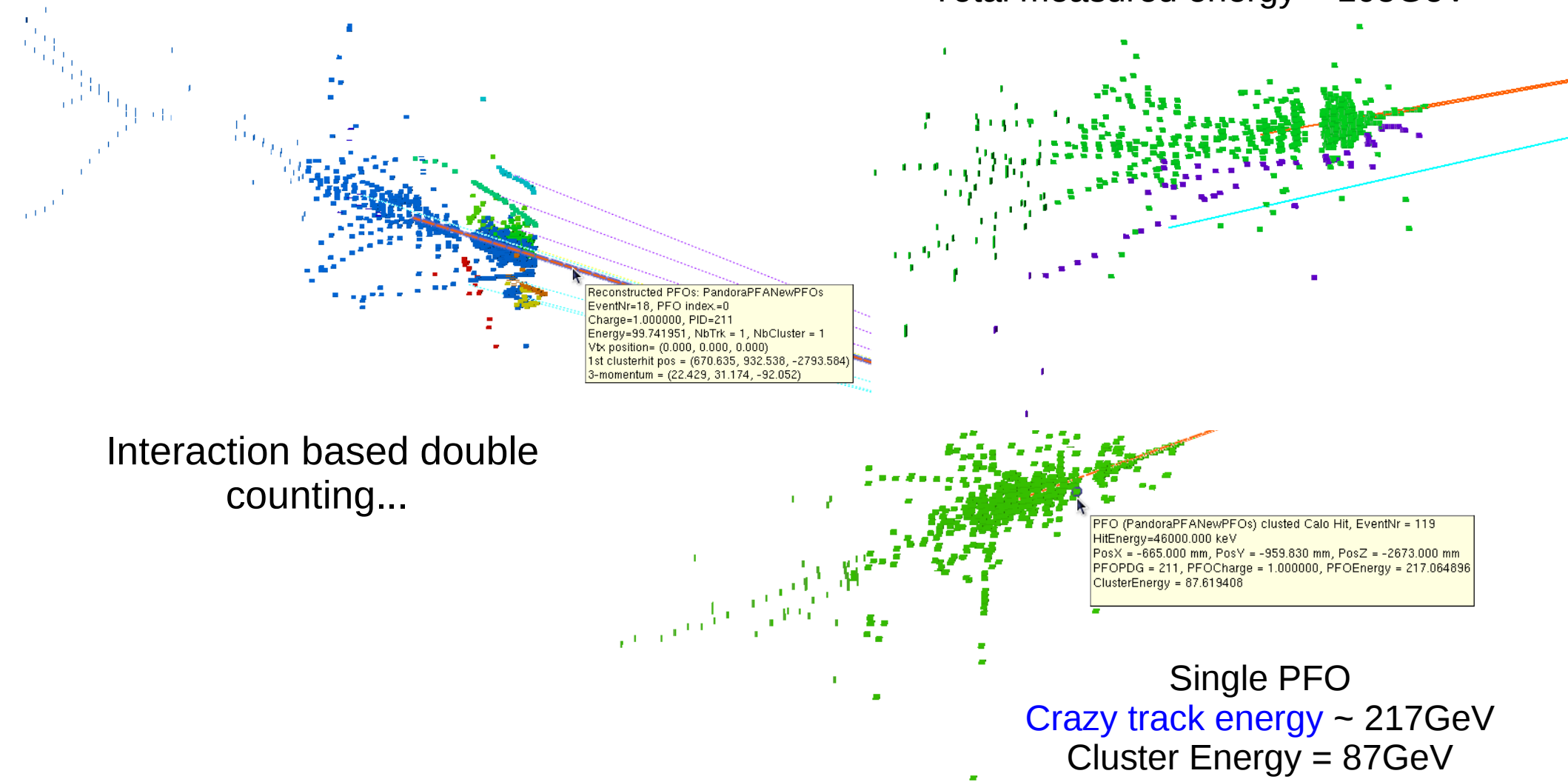
Left: Evt 872, Double PFOs  
Neither linked to track...



# Higher estimated energy at $\theta = 20^\circ$



Double counting: 2 PFOs,  
Total measured energy = 105GeV

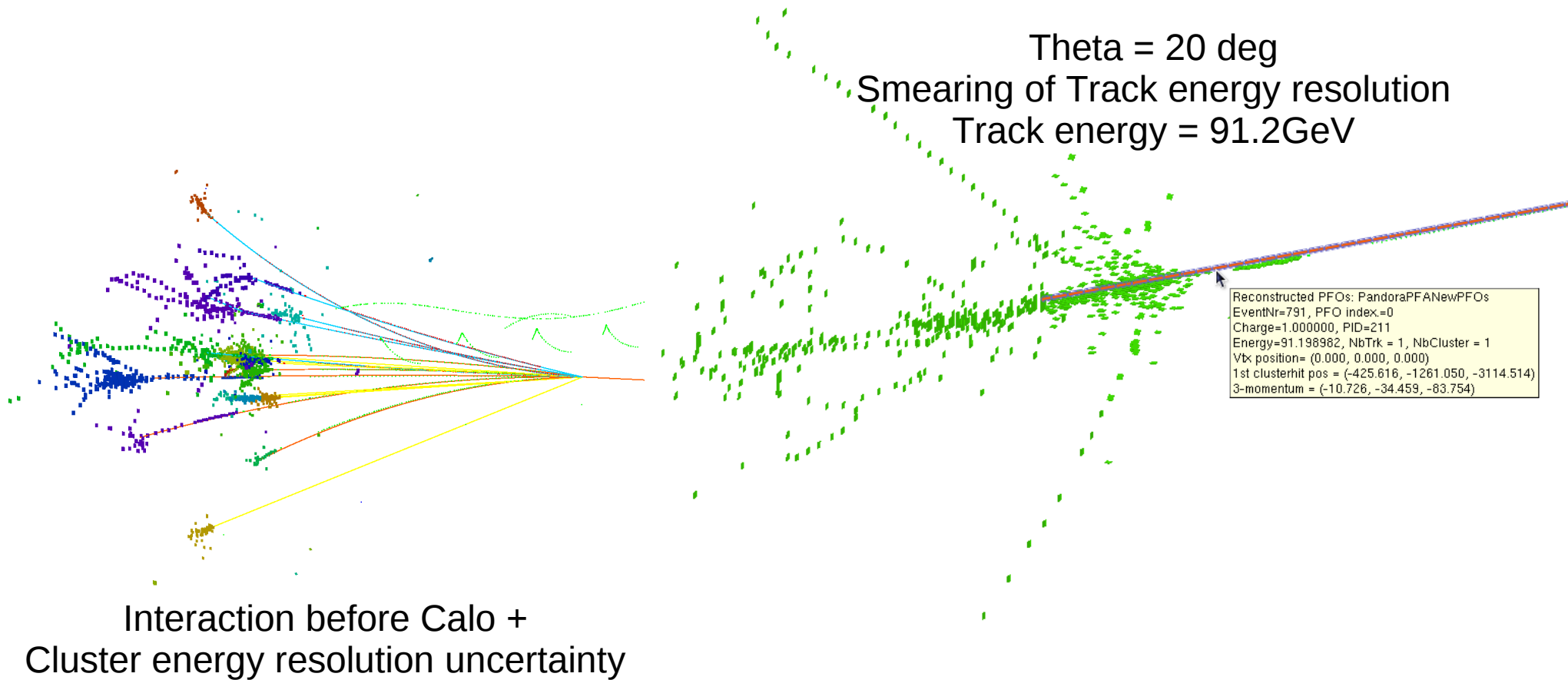


Interaction based double  
counting...

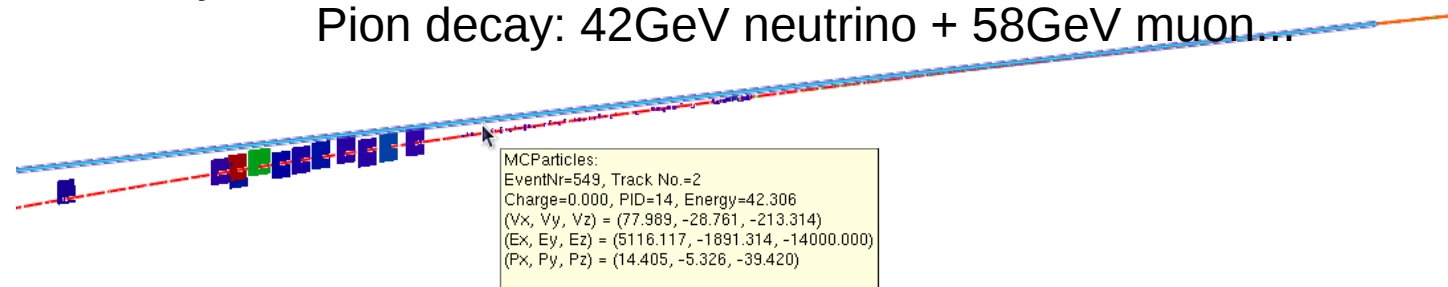
Single PFO  
Crazy track energy ~ 217GeV  
Cluster Energy = 87GeV



# “Lower” energy at $\theta = 20^\circ$

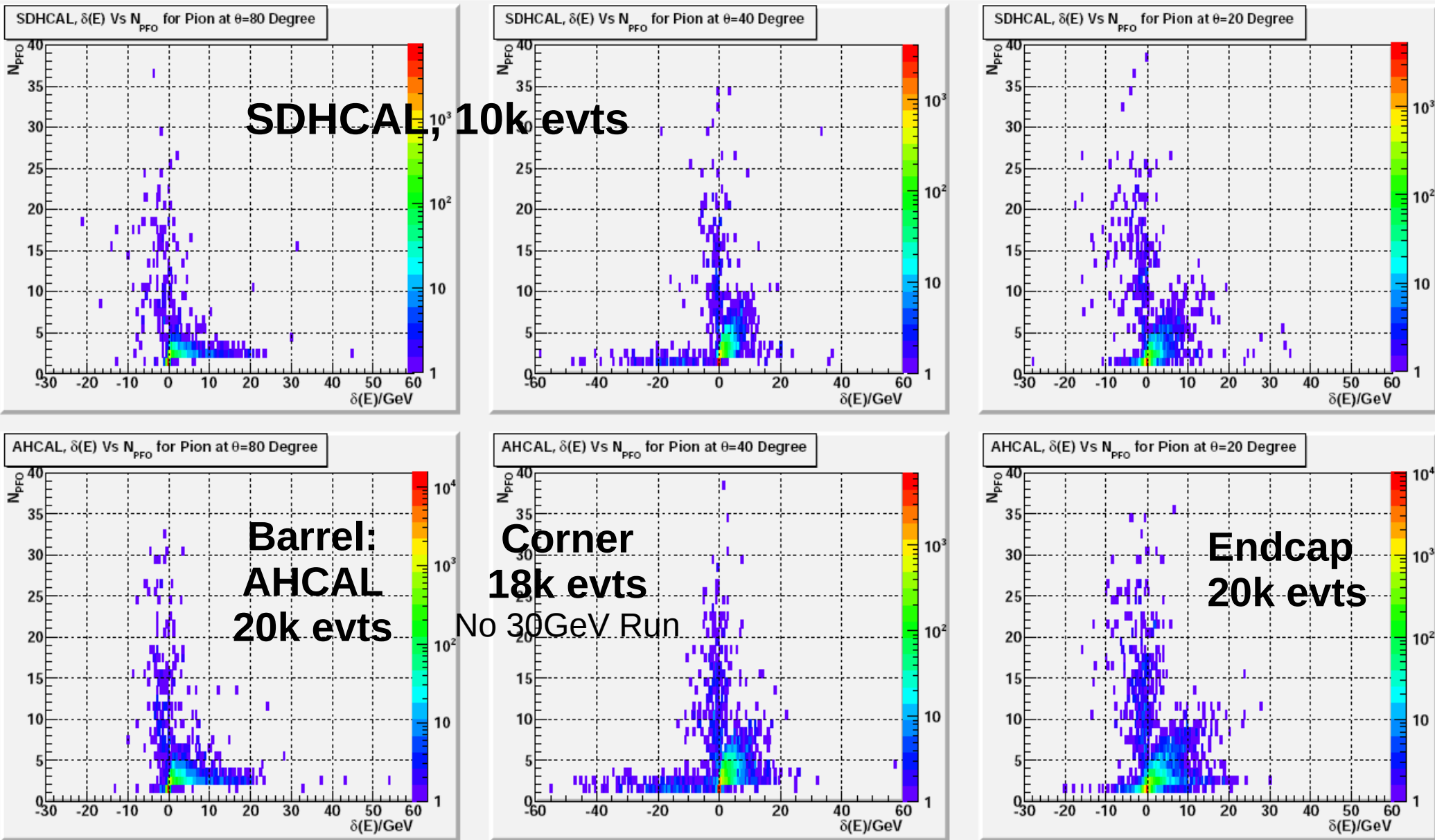


Pion decay: 42 GeV neutrino + 58 GeV muon...

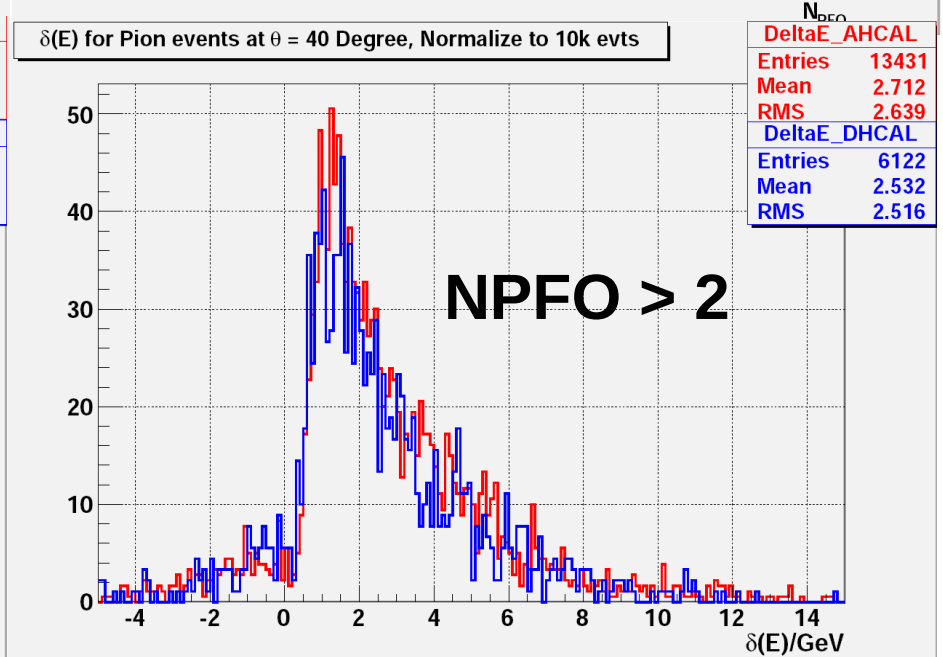
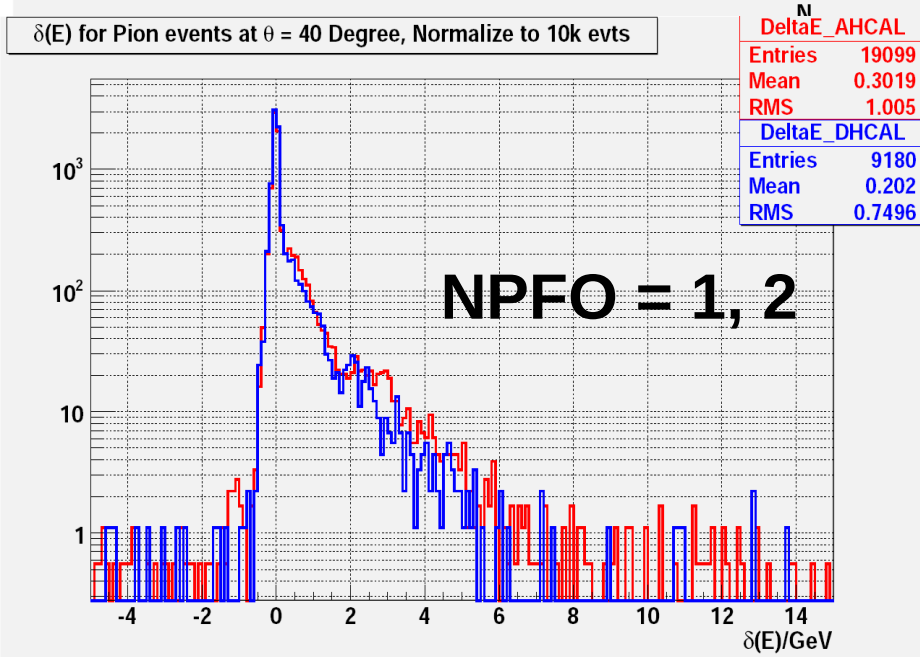
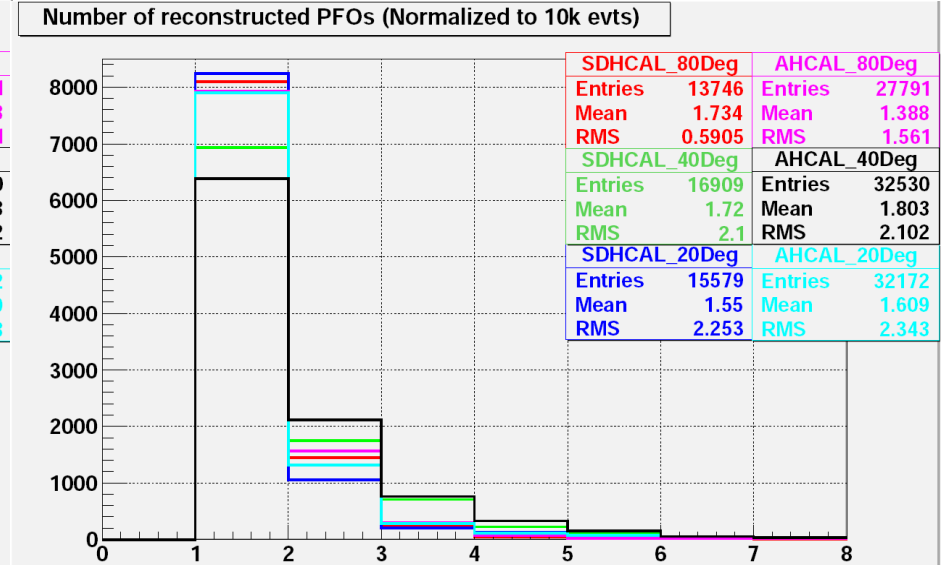
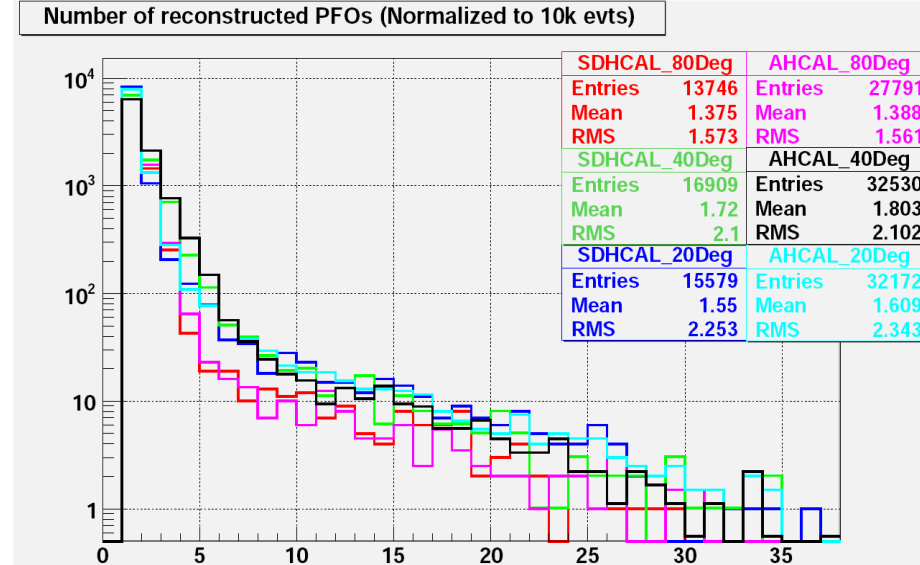




# Comparing with AHCAL



# Compare to AHCAL: NPFO



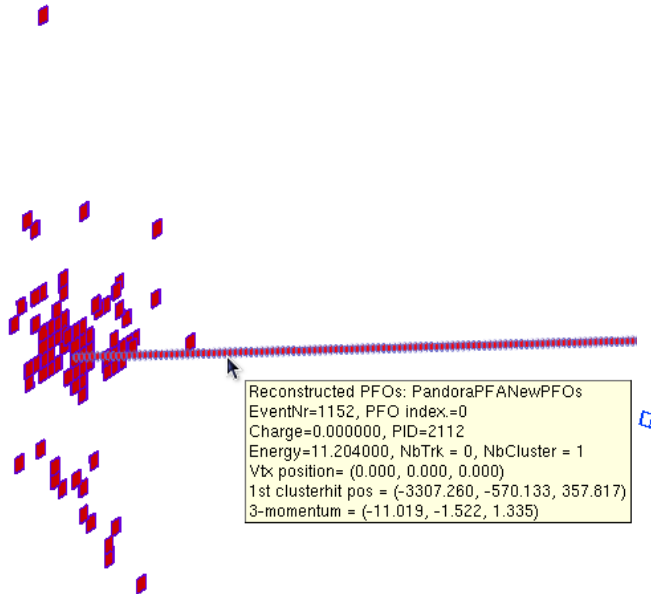
A little surprising: AHCAL has more double PFO events, especially in corner region: Geometrical effects? Neutron effect?

- SDHCAL Barrel Region
  - More than 80% events has only one PFO:
    - Lower estimated energy: energy loss, pion decay and track energy resolution smearing
    - Higher estimated case. Very rare. Due to Failed track energy resolution?
  - ~18% events with 2-5 PFOs, most of which coming from wrong cluster splitting, and result in double counted energy. [Where we might improve.](#)
  - ~1.4% events has heavy interaction inside the tracker (could happen even at the entrance of TPC), caused lots of uncertainty. [Some more dedicated treatment?](#)
- (SDHCAL) Endcap and corner:
  - More interactions, more double counting observed
  - Corner: [linking of track – cluster need to be improved](#) ( 1% ~ 2% events fails,  $\theta = 35^\circ - 45^\circ$  )
  - Endcap: Larger track energy resolution smearing. Rely more on cluster info?
- Comparing to AHCAL:
  - Similar behaviour
  - More single PFO event in SDHCAL: [Geometrical/Neutron effects?](#)

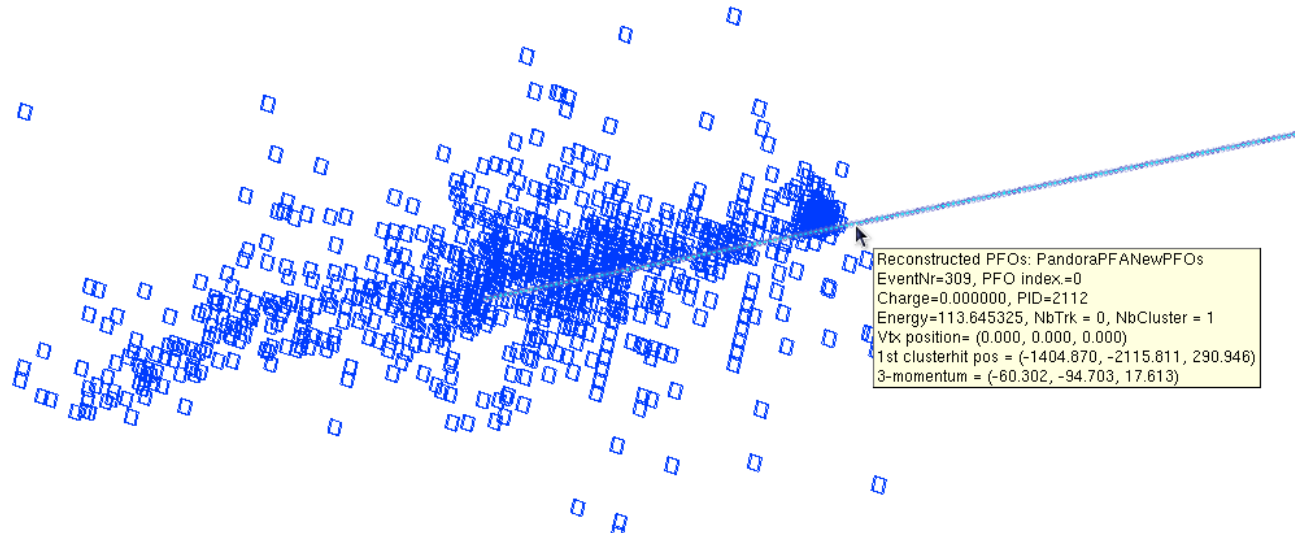
# Klong events (SDHCAL)



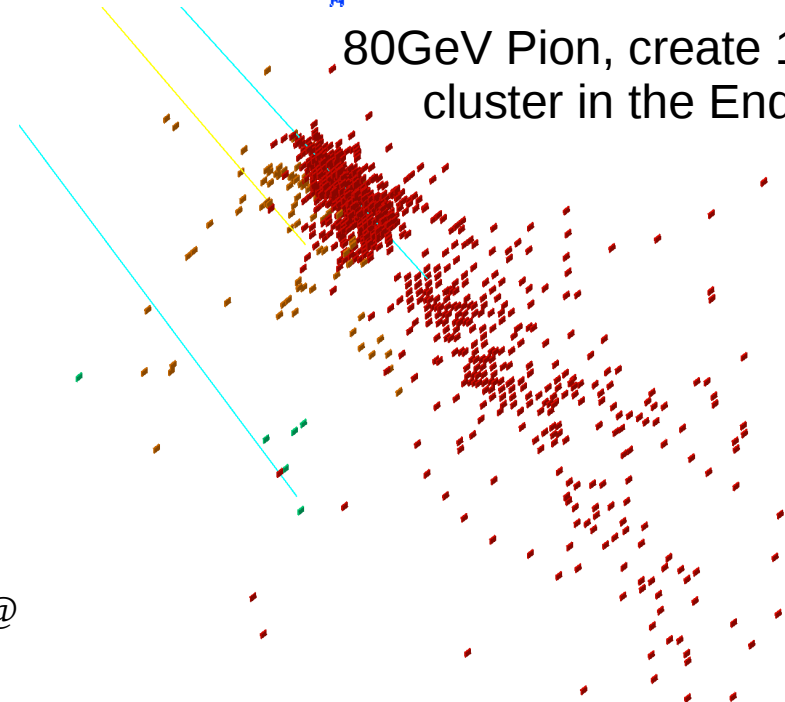
Klong (90GeV)  
can be really penetrate  
deposit only 11GeV energy  
in the end of Calo



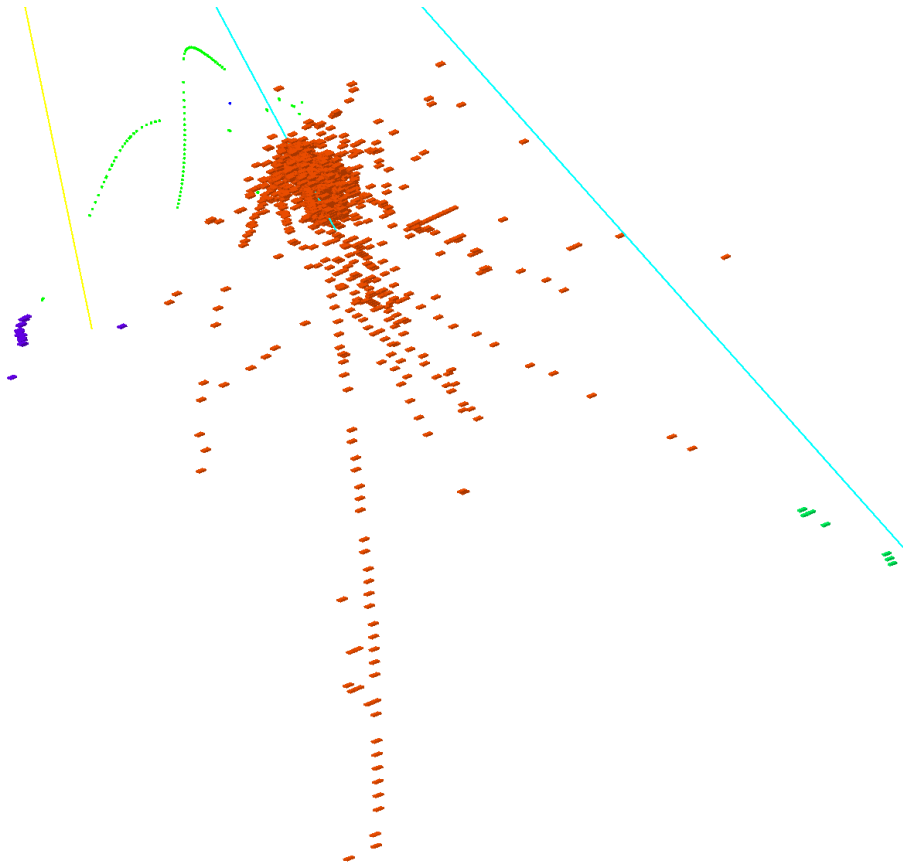
Or create a huge cluster...



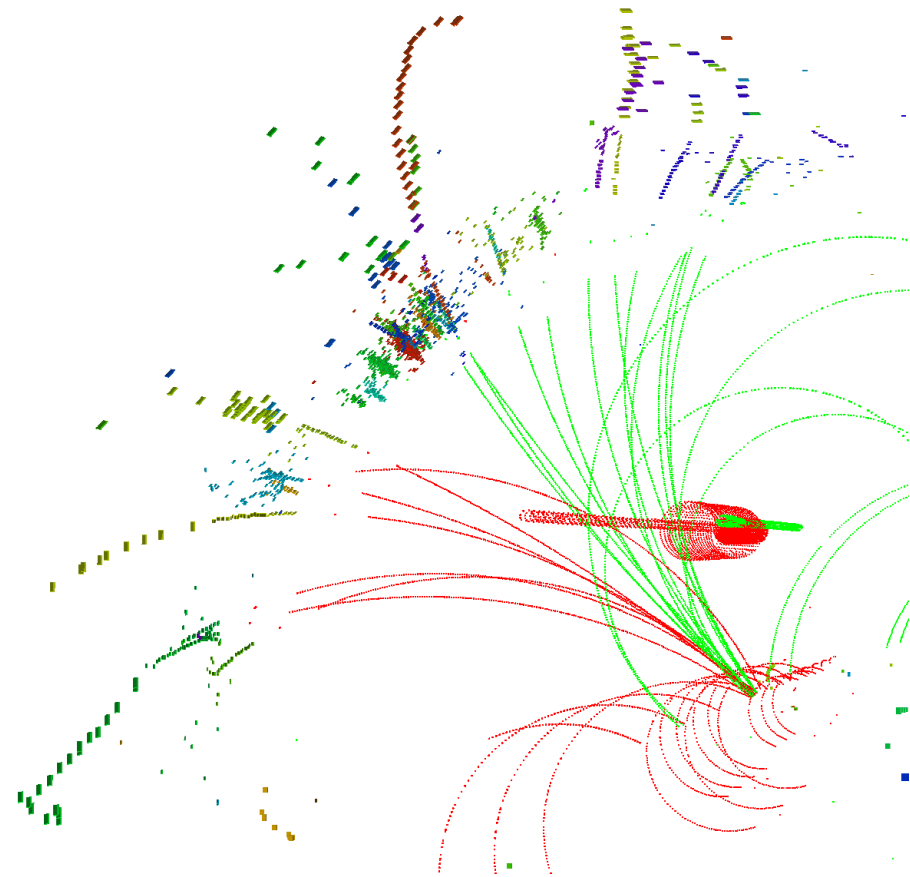
80GeV Pion, create 127GeV  
cluster in the Endcap



# Multiply PFO Klong events

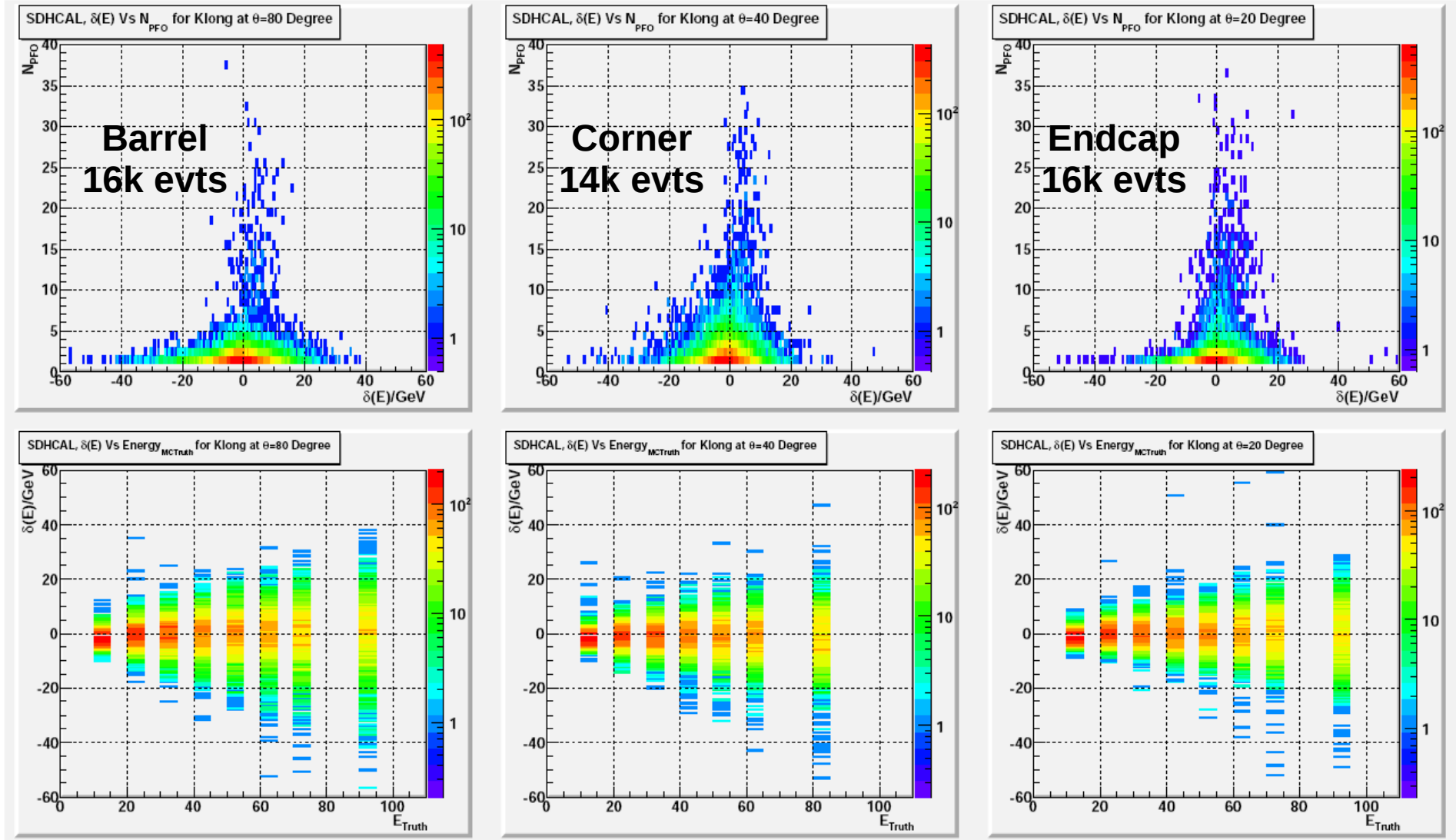


3PFOs: Back scattering +  
wide HCAL Shower



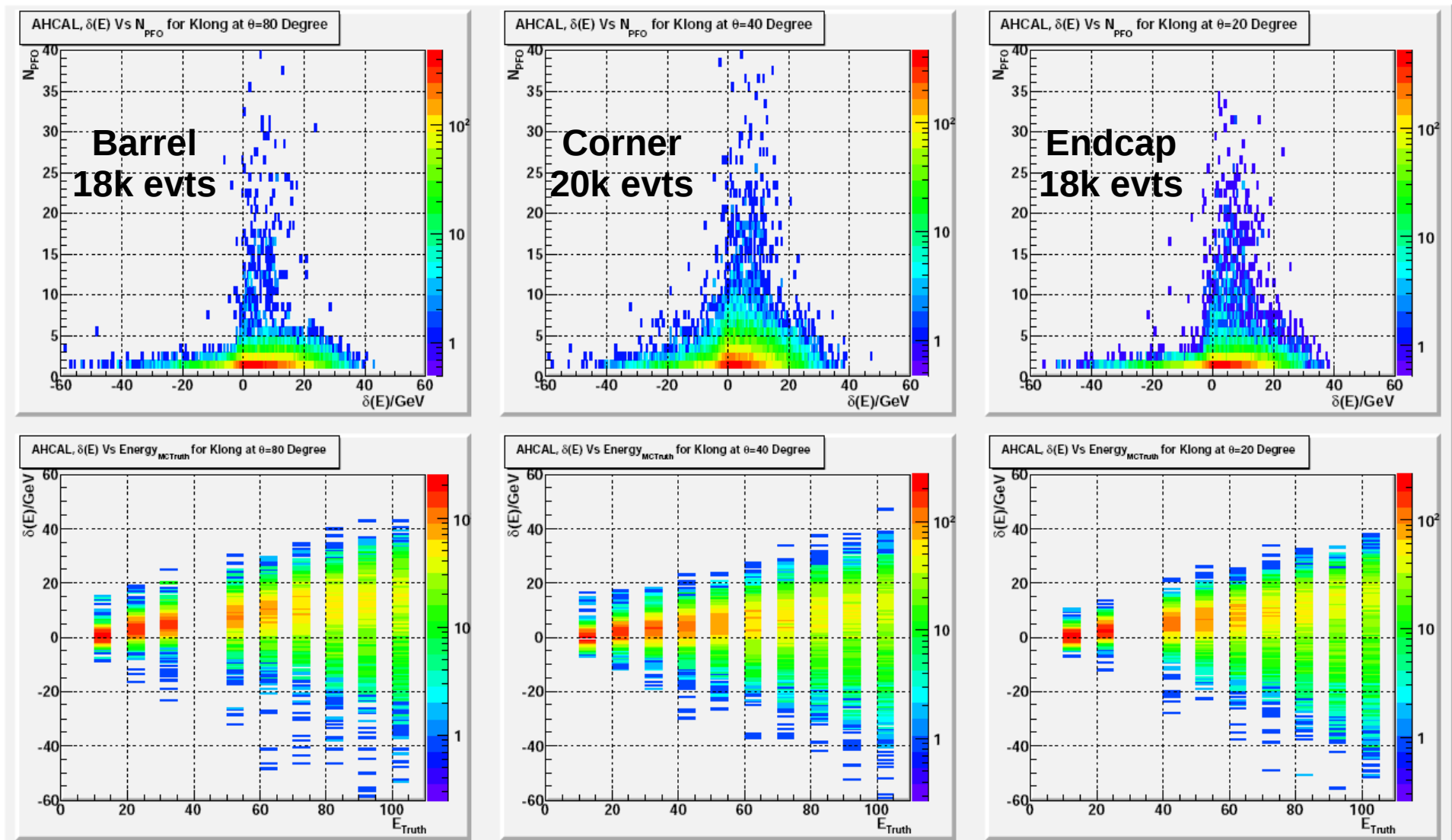
Interaction inside tracker

# SDHCAL, Klong



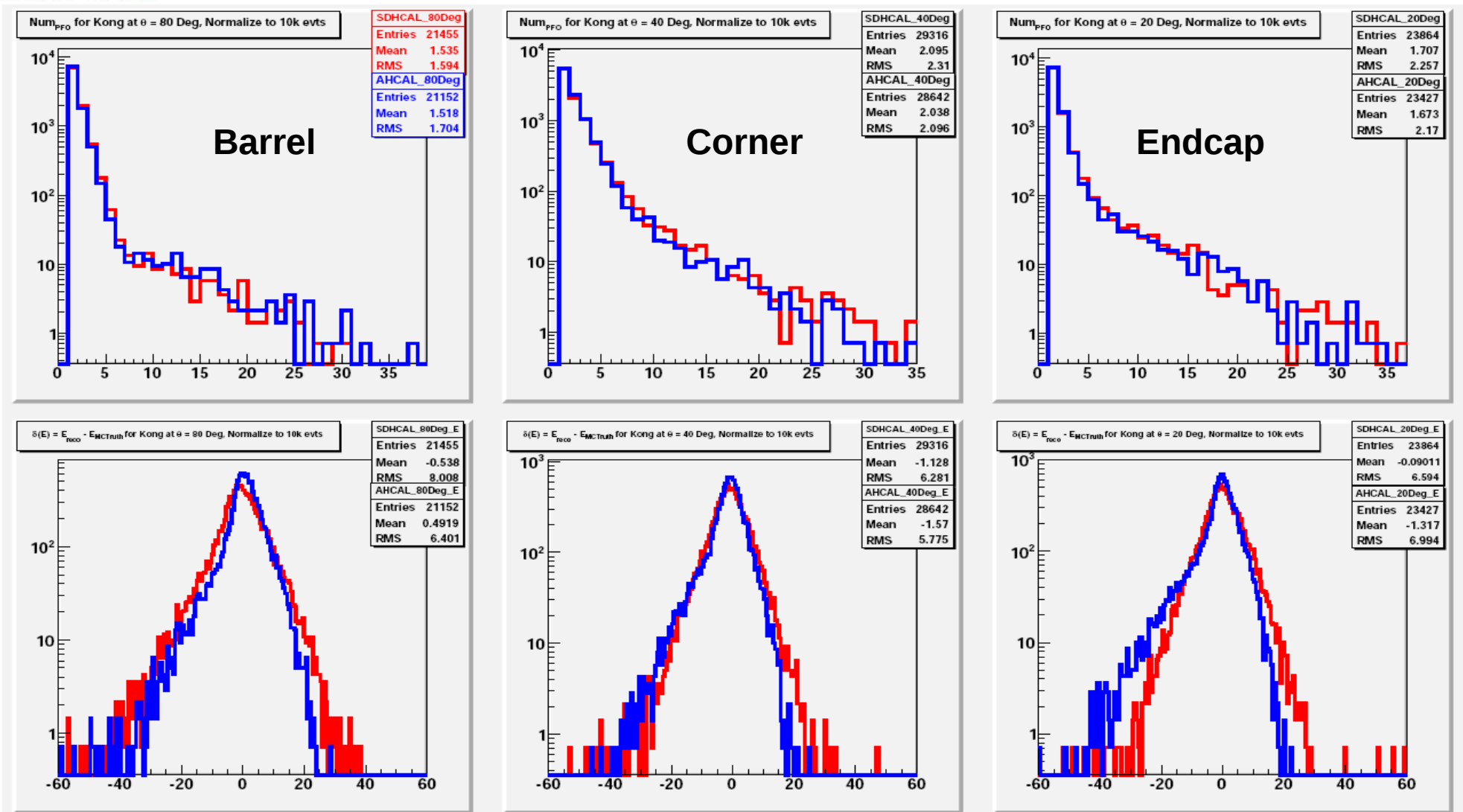
- $NPFO(\text{Barrel}) < NPFO(\text{EndCap}) < NPFO(\text{Corner})$
- Large smearing in energy resolution: better energy estimator and correction needed...

# AHCAL, Klong



- Energy measurement: biased (Correction included?)
- Asymmetry low energy tail – Leakage

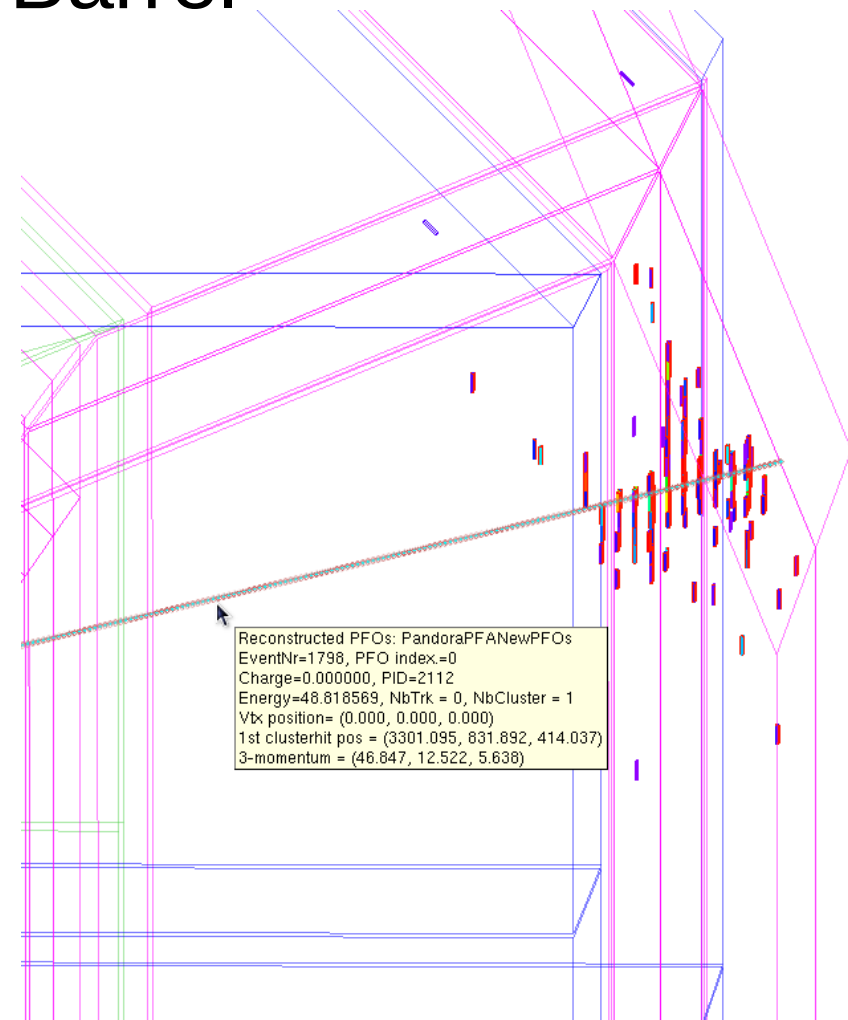
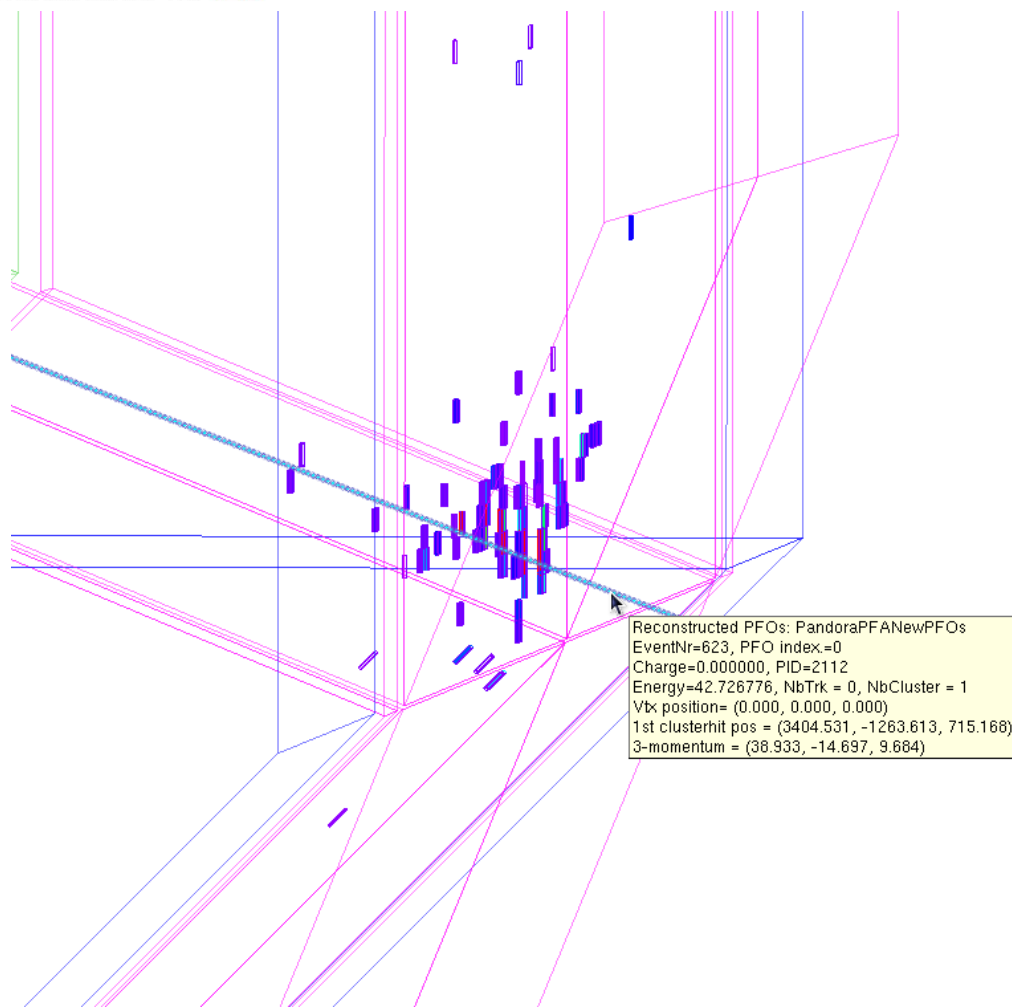




- Similar NPFO distribution (with data files with same set of energies)
- AHCAL has better energy resolution – but larger lower energy tail in Endcap



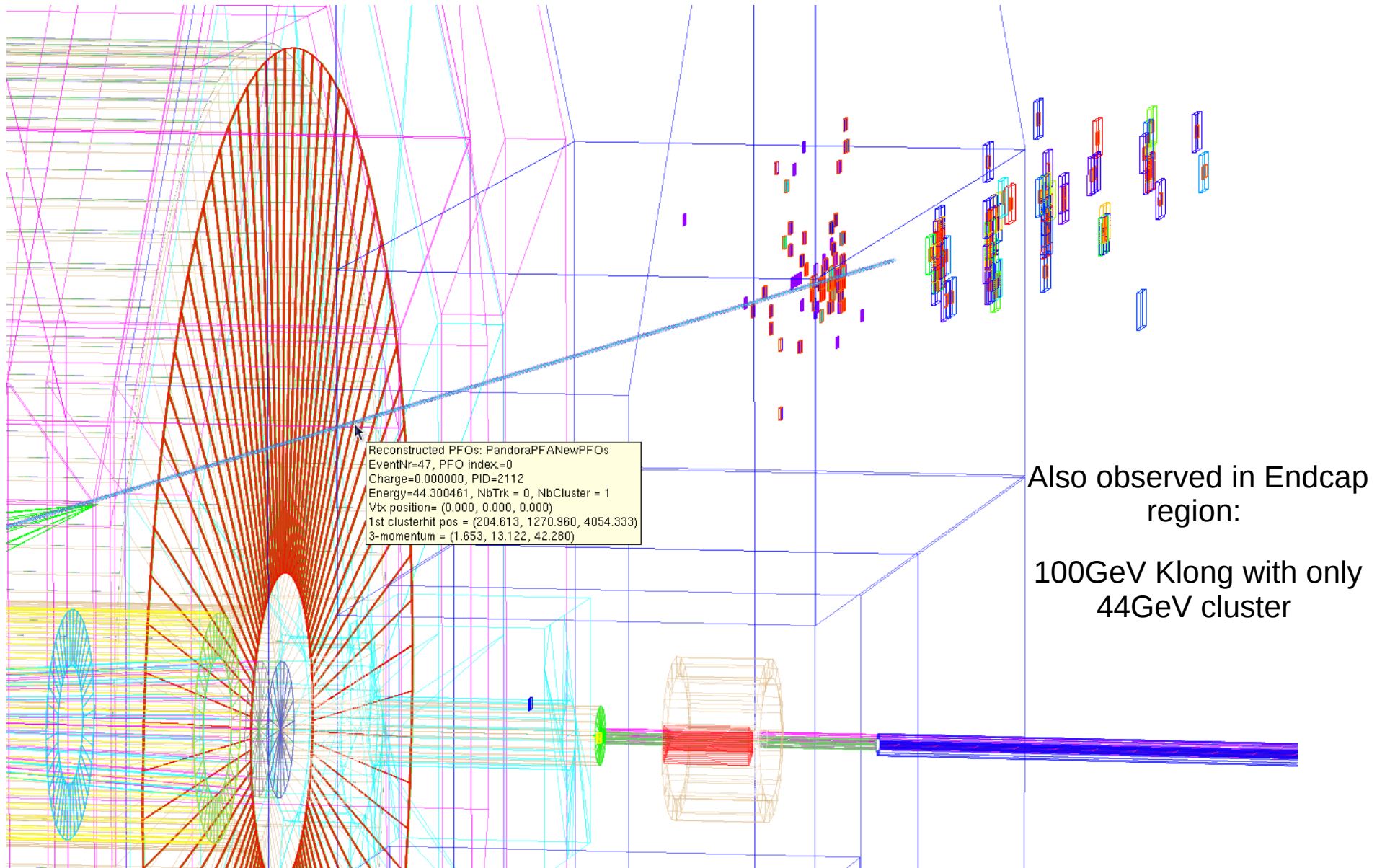
# Lower estimated energy in AHCAL Barrel



100GeV Klong at  $\theta = 80^\circ$ . High penetrating events, interact deep inside HCAL.

Left (evt 623), Reconstructed Energy 42.7GeV.

Right (evt 1798), Reconstructed Energy 48.8GeV



# Checking geometry

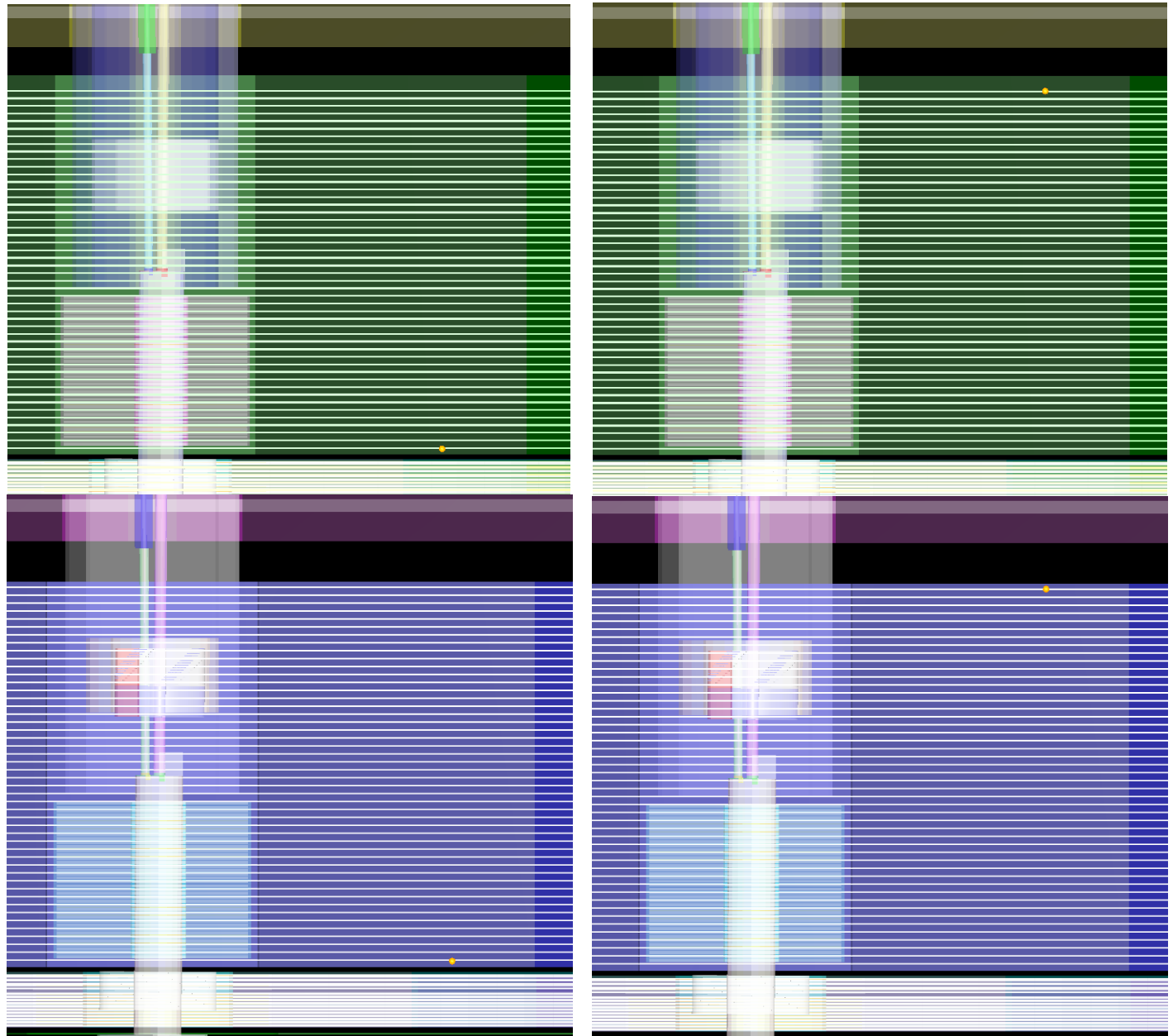


## Checking from gdm1

Above: SDHCAL  
below: AHCAL

Reference points (cm):  
(100, 0, 267), (100, 0, 392)

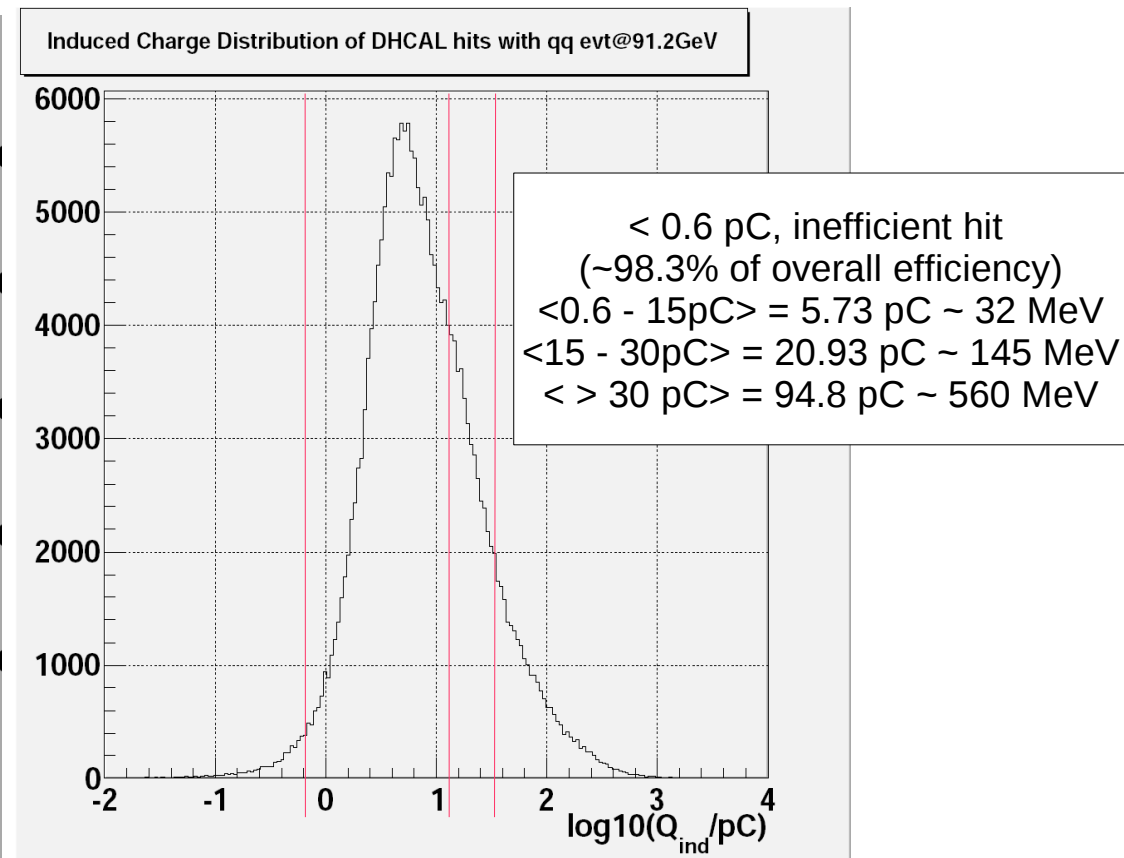
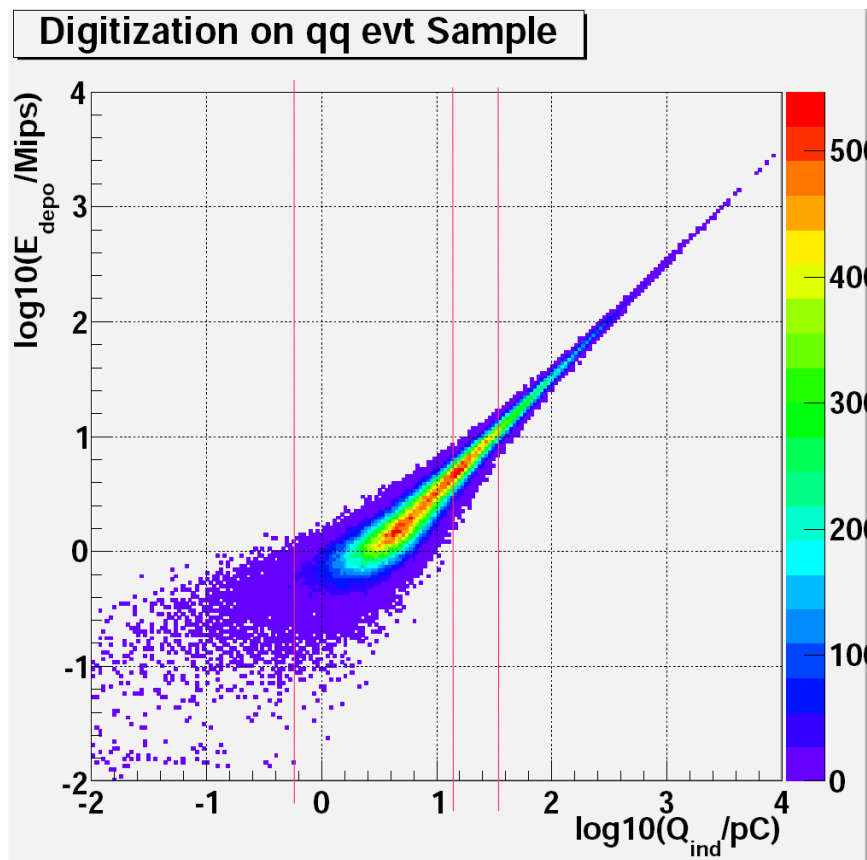
Sensor layer location is the  
same, but has more iron  
(~3cm) in the SDHCAL  
Endcap back...



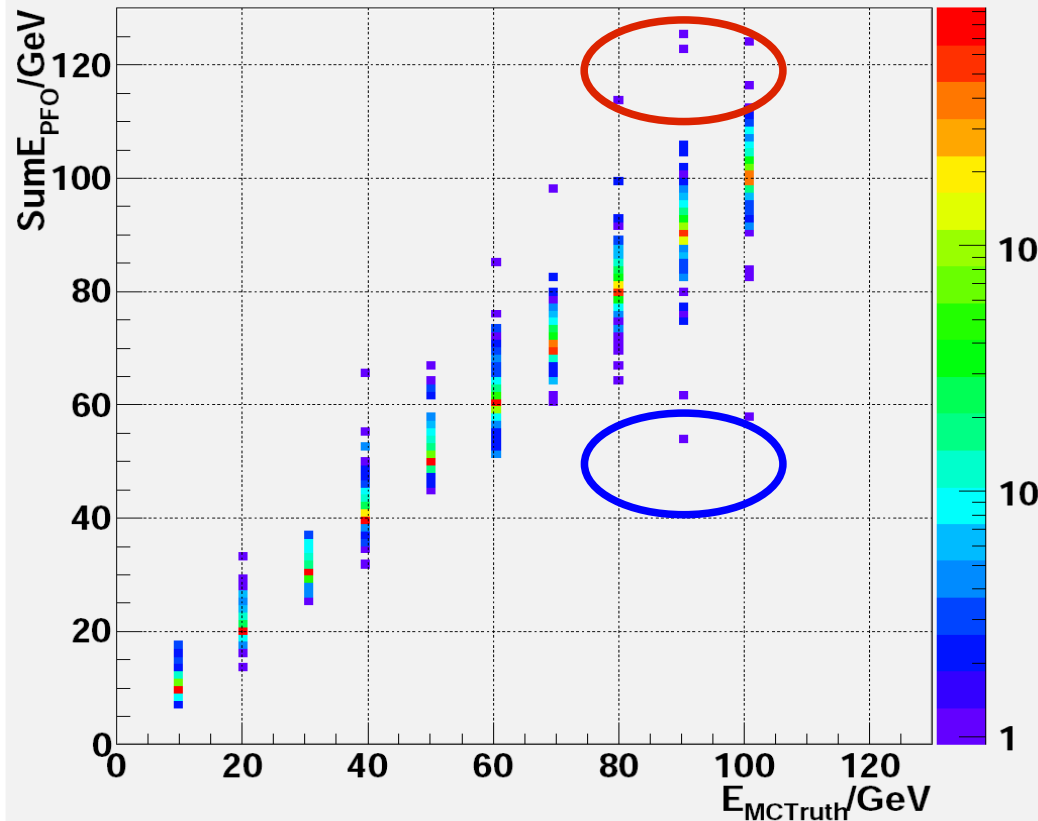
- Study of single particle reconstruction with Pandora:
  - Pion:
    - AHCAL & SDHCAL has similar behaviour. SDHCAL has slightly more Single PFO event, might be **geometrical effect**
    - Possible to improve on **double counting** ( ~ 10% - 20% of events), **track cluster linking** in corner, identification and specialized treatment on **pre-interaction pion**
  - Klong:
    - Similar NPFO for AHCAL & SDHCAL
    - Need **leakage correction and better energy estimator for SDHCAL**
    - More leakage in AHCAL: More material in SDHCAL?
- To do: analysis with tau (neutron, electron), disentangle the geometrical/sensor effects
- SDHCAL Reco software is progressing in various directions with Looooooooong to do list
  - **Identify man power**
  - Parameters & order optimization of PandoraPFA
  - SDHCAL energy estimator & clustering development and integration
  - Testing on benchmark processes at different energy (*qq, ZZ, ZH, ttbar, multiple jet SUSY events...*)

# BK Slides

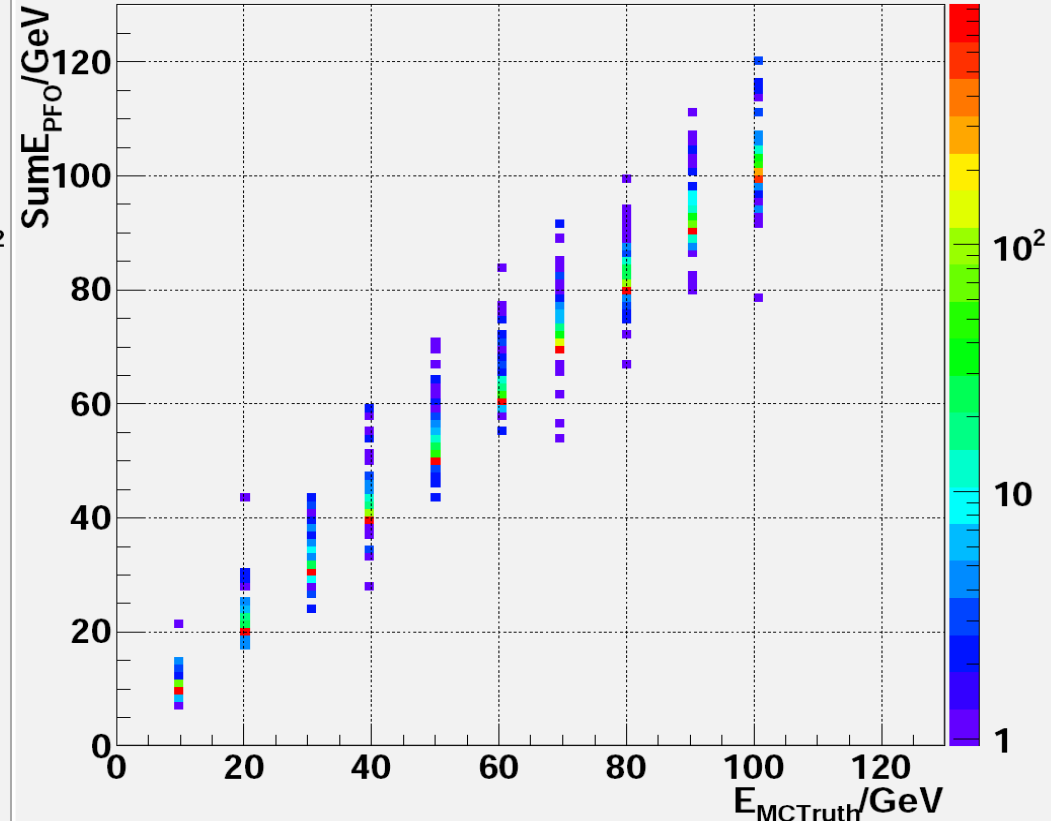
- Preliminary DHCAL Digitization module based on latest cosmic ray experiment: convert the energy deposition information into the induced charge
- Specify thresholds (0.6pC, 15pC and 30pC, corresponding to 0.2, 5 and 10 mips) on induced charge. Calibration constant fixed by Klong samples.



Total Reconstructed PFO Energy Vs MCTruth Energy,  $\theta = 20(^{+5}_{-5})$  Degree Pion



Total Reconstructed PFO Energy Vs MCTruth Energy,  $\theta = 80(^{+5}_{-5})$  Degree Pion



Most of the Event has nice energy resolution (from tracker)

Higher estimated total PFO energy ~ **Track energy resolution smearing (forward region) + double counting + interaction before calo**

Lower estimated total PFO energy: **Pion decay, interaction before calo, track energy smearing (forward), cluster energy smearing...**

# Checking geometry (DD = 1)



## Checking from gdml + Druid

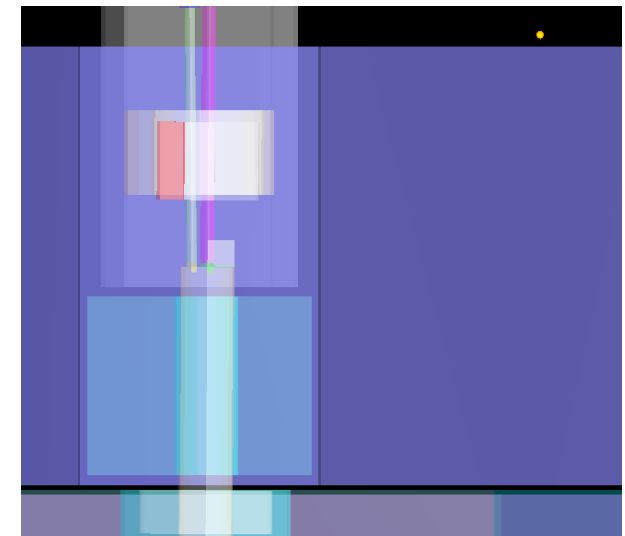
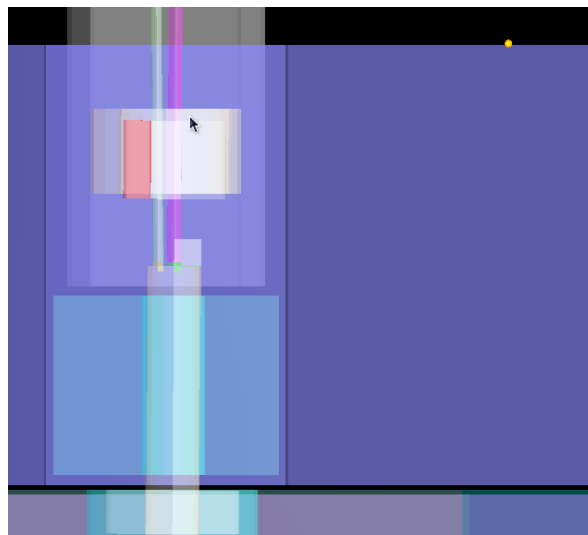
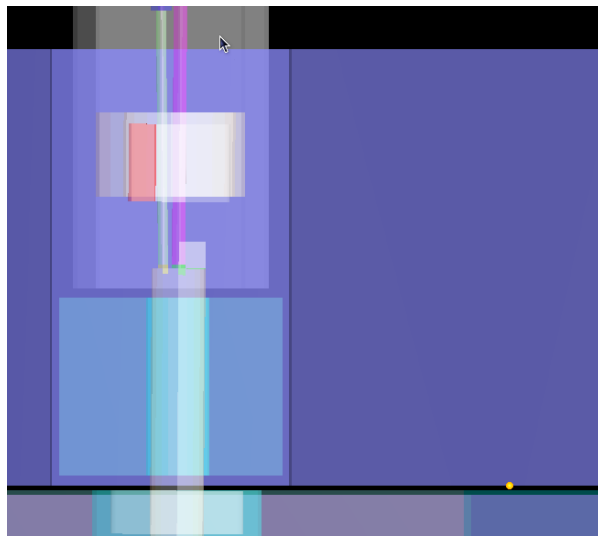
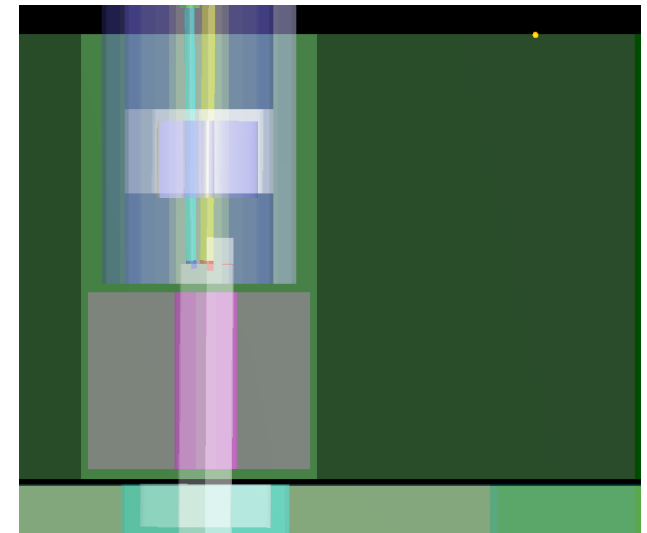
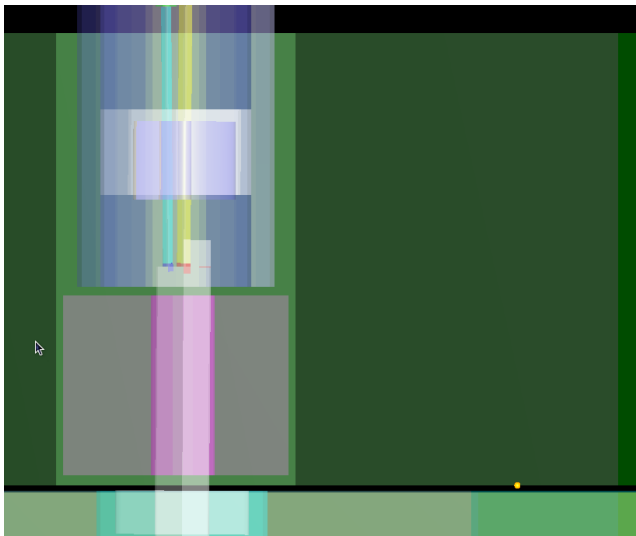
Reference points (cm):

SDHCAL: (100, 0, 265), (100, 0, 397)

AHCAL: (100, 0, 265), (100, 0, 394),  
(100, 0, 397)

One more layer in SDHCAL?

Sufficient to explain the difference??



**From gearfile:** same in both...  $(2.0/2.65 \text{ cm}) * 48 \text{ layer} = 96\text{cm iron}/127.2\text{cm thickness}...$