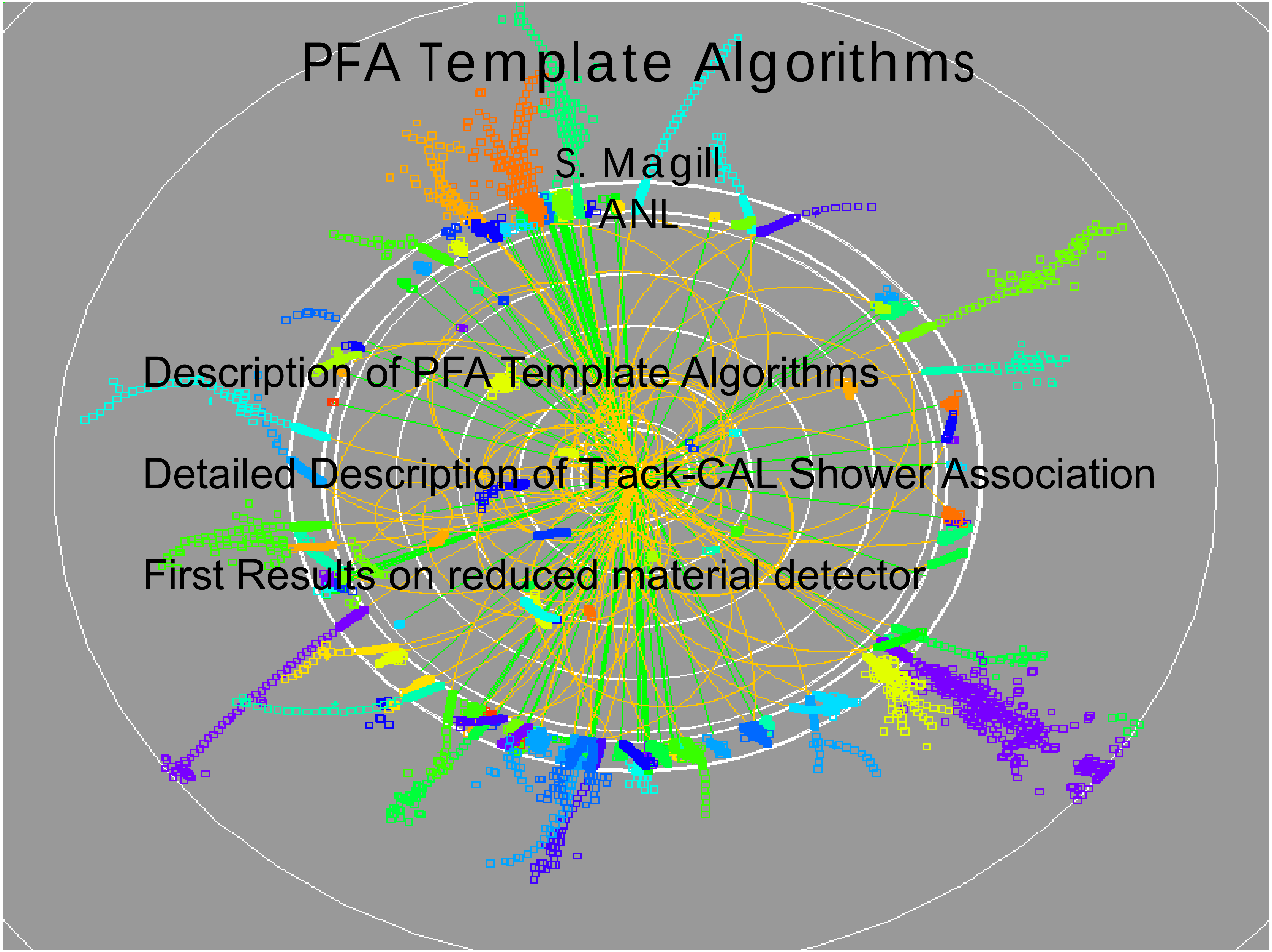
PFA Template Algorithms

S. Magill
ANL



Description of PFA Template Algorithms

Detailed Description of Track-CAL Shower Association

First Results on reduced material detector

PFA Template Concept

Modular PFA composed of multiple individual particle ID algorithms

Common IO throughout PFA for cluster, ID algorithms
- allows interchangeability of algorithm order, cluster algorithms
- ease of adding, swapping algorithms

Relies as much as possible on single particle tuning of individual algorithms (as opposed to process tuning)
- can test/tune individual algorithms in test beam(s)

Common Starting Algorithms for Templates

DigiSim
- hit digitization, timing, threshold cuts

Perfect PFA
- standard Perfect RPs, cheated tracks

PFA Template 1

Cheated Tracks
Track Extrapolation Maps
Track-Mip Association
Track-Cal Cluster Matching
Photon Finder I (R. Cassell)
Photon Finder II (Low E photon clusters)
Track Proximity Cleaner for photon candidates
Neutral Hadron Finder (includes Track Proximity Cleaner)
Reconstructed Particles
    -> Jet Finding

rms90 = 4.00 GeV
α = 40% (qqbar100 ESum)

PFA Template 2

Cheated Tracks
Track Extrapolation Maps
Track-Mip Association
Photon Finder I (R. Cassell)
Track-Cal Cluster Matching
Photon Finder II (Low E photon clusters)
Track Proximity Cleaner for photon candidates
Neutral Hadron Finder (includes Track Proximity Cleaner)
Reconstructed Particles
    -> Jet Finding

rms90 = 3.71 GeV
α = 37% (qqbar100 ESum)

Associating Cal Showers with Tracks
Track/Mip and Track/Shower Algorithms for PFA Template

Tracks

- cheated, from Perfect PFA (ReconFSTracks)
- extrapolated using helical swimmer with MC p, MC origin, charge, Bz
- ready for real track extrapolation with measured p, origin, charge, Bz

Track Extrapolation Map Utility

-maps spacepoint to track extrapolated to E0, EM Shower Max, H0

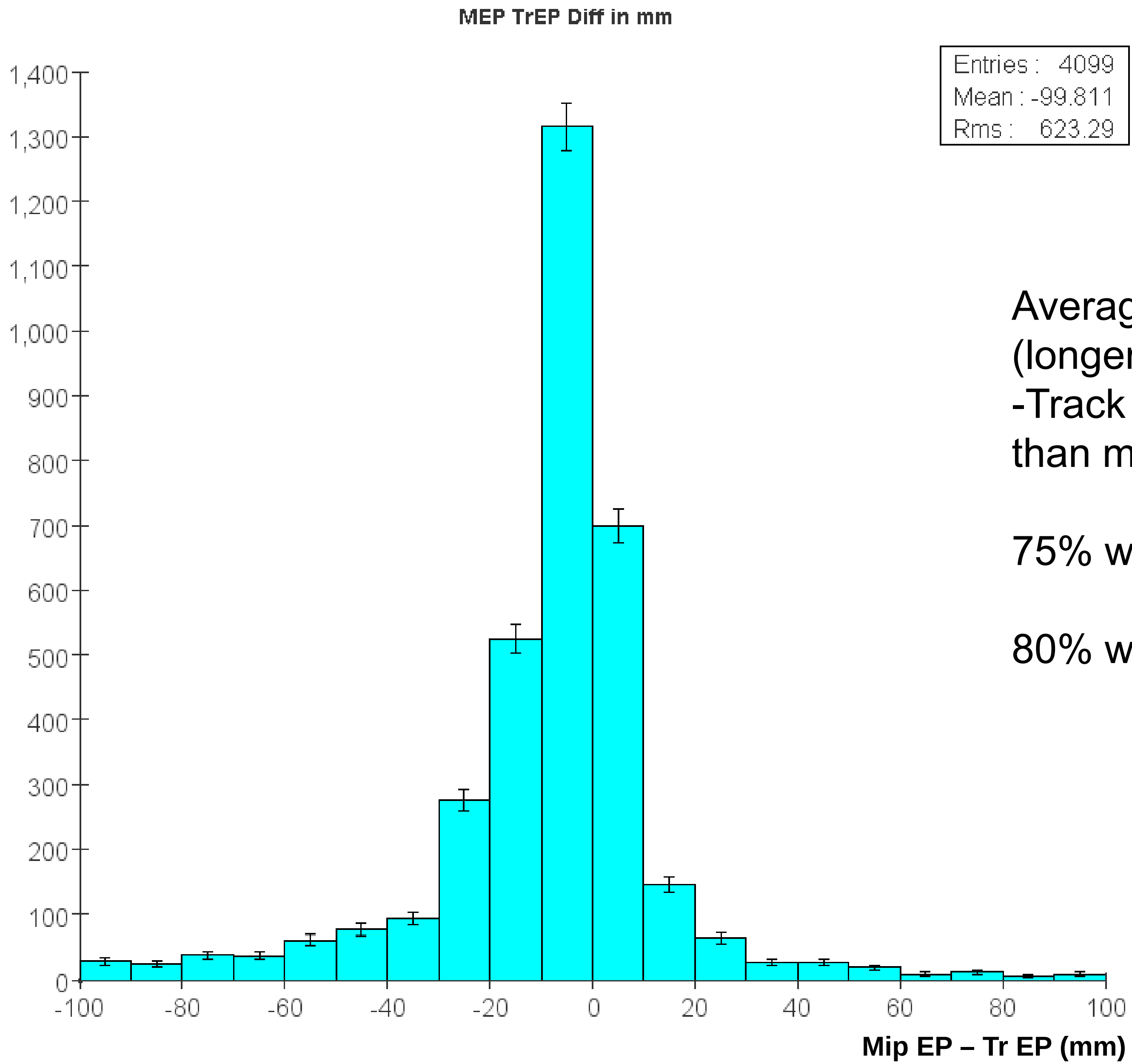
Track Mip Cluster and Interaction Layer Finder

- uses CAL hits layer-by-layer to build mip cluster on extrapolated track
- based on hit densities, independent of hit energies
- outputs are mip cluster, interaction layer of track (IL), extrapolated track spacepoint at IL

Track Shower Cluster Finder

- currently uses DT cluster algorithm with 3 hit minimum
- associates clusters to tracks starting from IL
- first, finds core clusters by searching in same region as mip finder
- uses cluster proximity ($\Delta\theta$,$\Delta\phi$) and E/p measure based on CAL resolution for p
- iterates expanding cone until E/p window is met or max cone size is reached
- outputs are track shower clusters (includes mips, core, and shower)

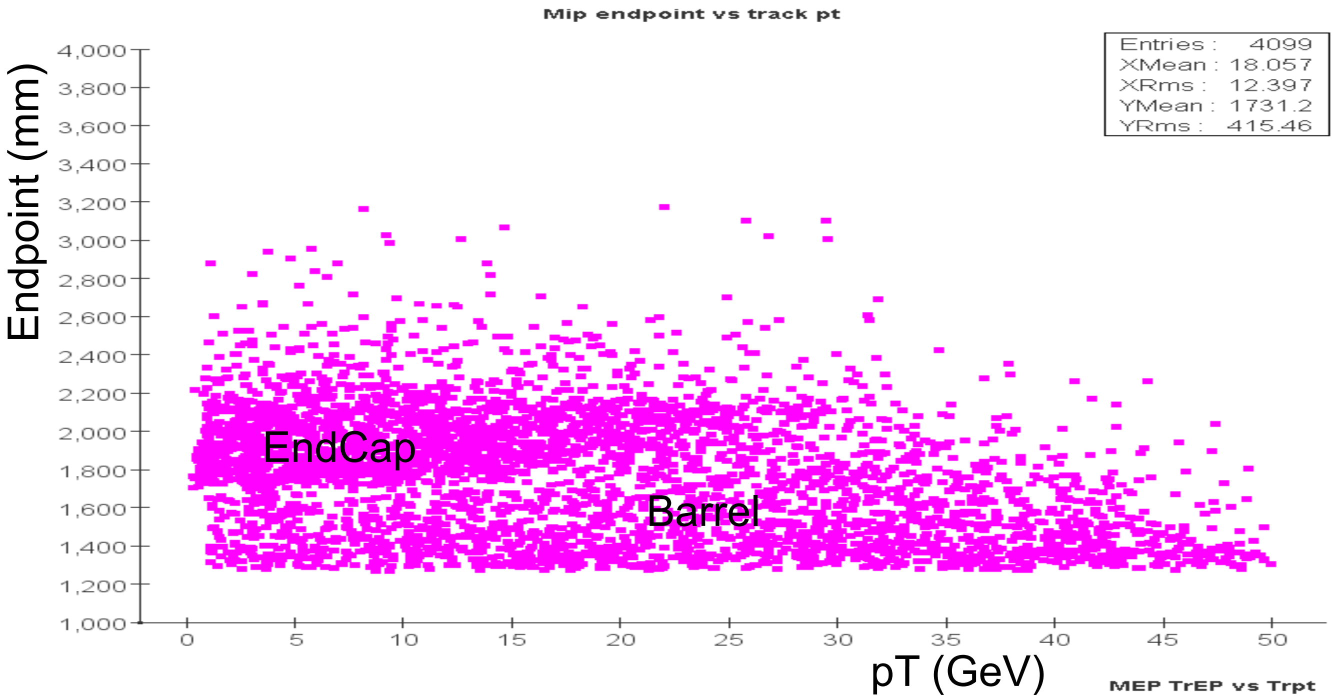
Comparison of Mip Cluster endpoint and Track (MC Truth) endpoint



Average is -10 cm
(longer negative tail
-Track endpoint deeper
than mip endpoint)

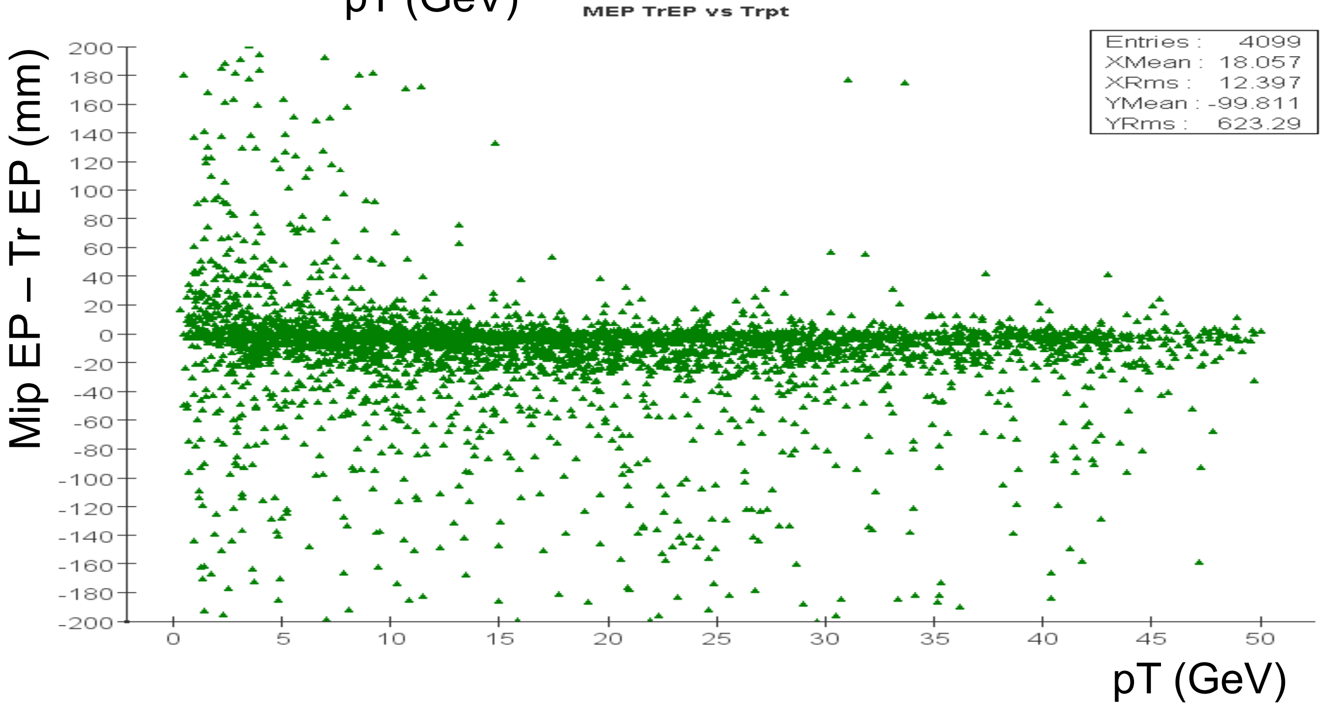
75% within 3 cm

80% within 5 cm

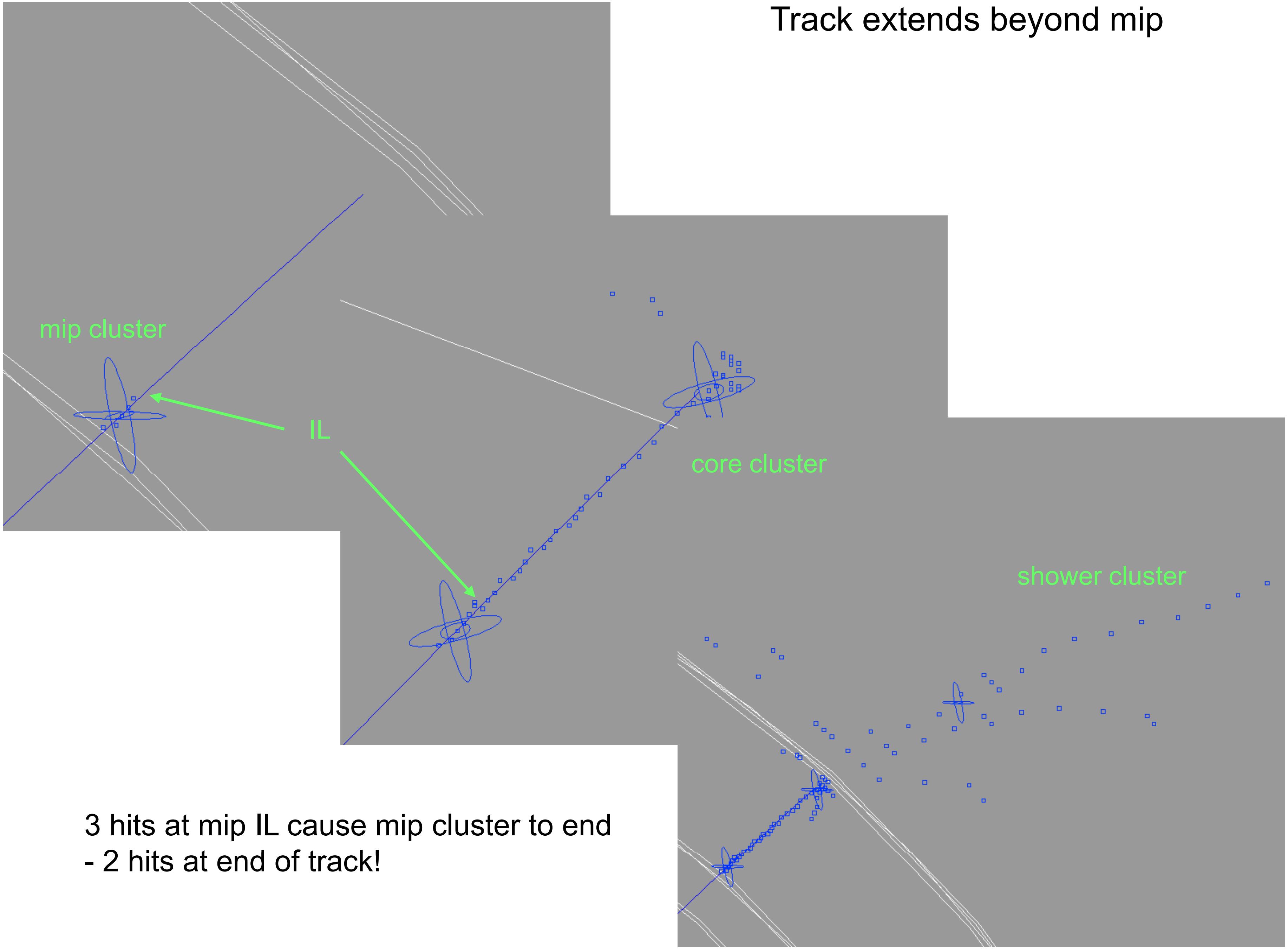


Track shorter than mip occurs at lower pT (density parameter)

Track longer than mip - no pT dependence (mostly no mip IL=0)

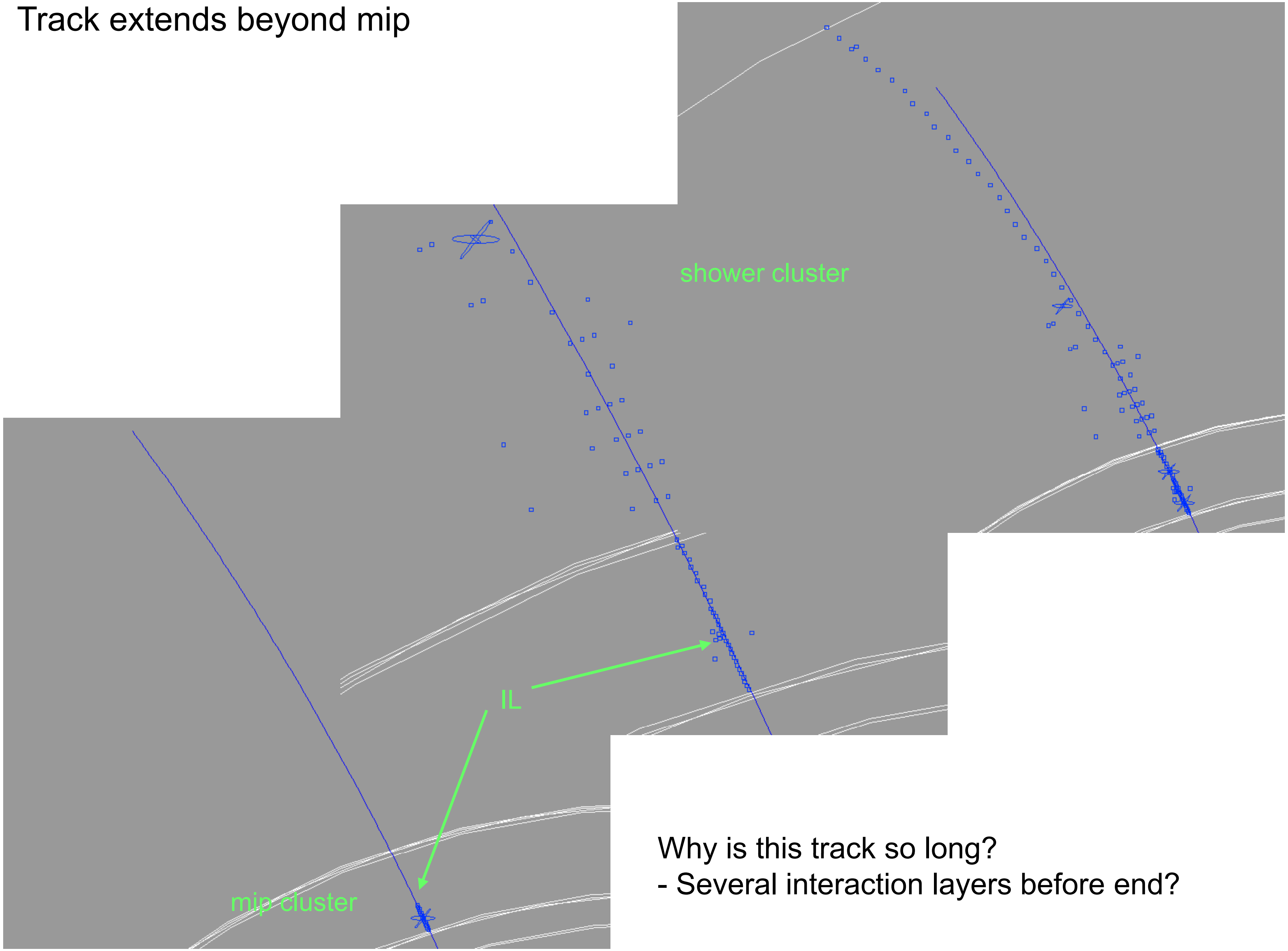


Track extends beyond mip



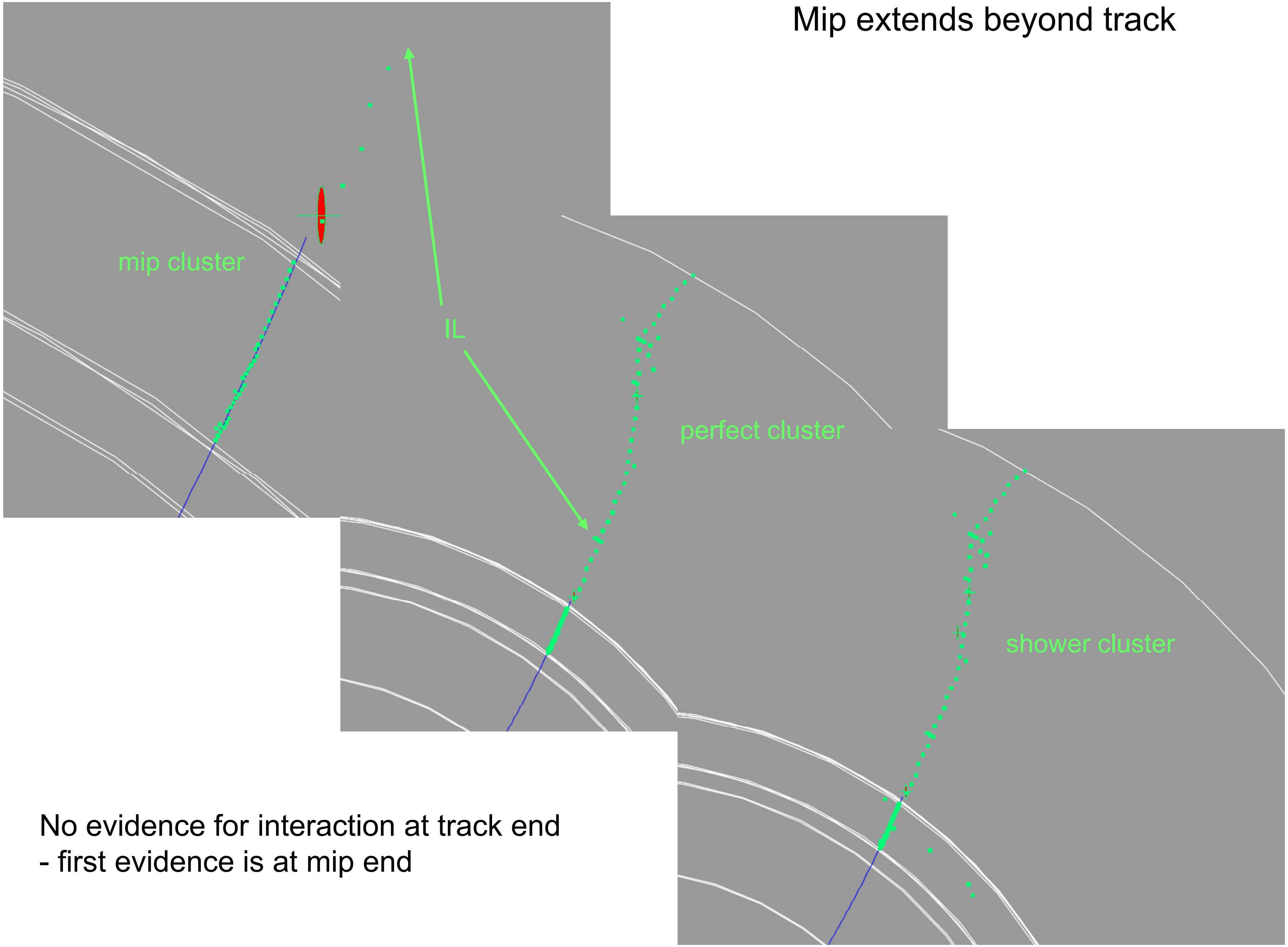
3 hits at mip IL cause mip cluster to end
- 2 hits at end of track!

Track extends beyond mip



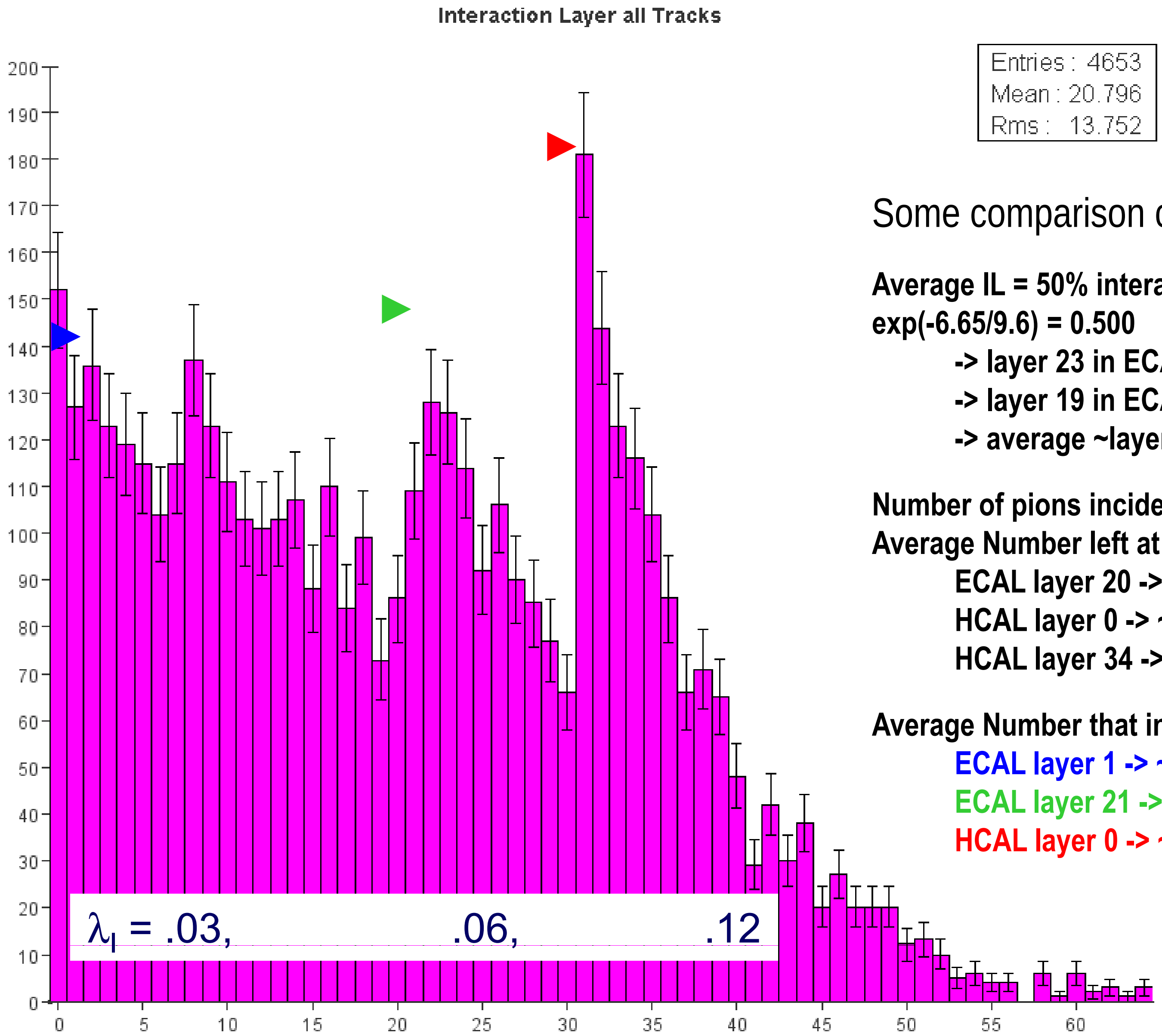
Why is this track so long?
- Several interaction layers before end?

Mip extends beyond track



No evidence for interaction at track end
- first evidence is at mip end

Performance of Track Mip Finder – Determination of IL



Layer 20.8

Some comparison calculations :

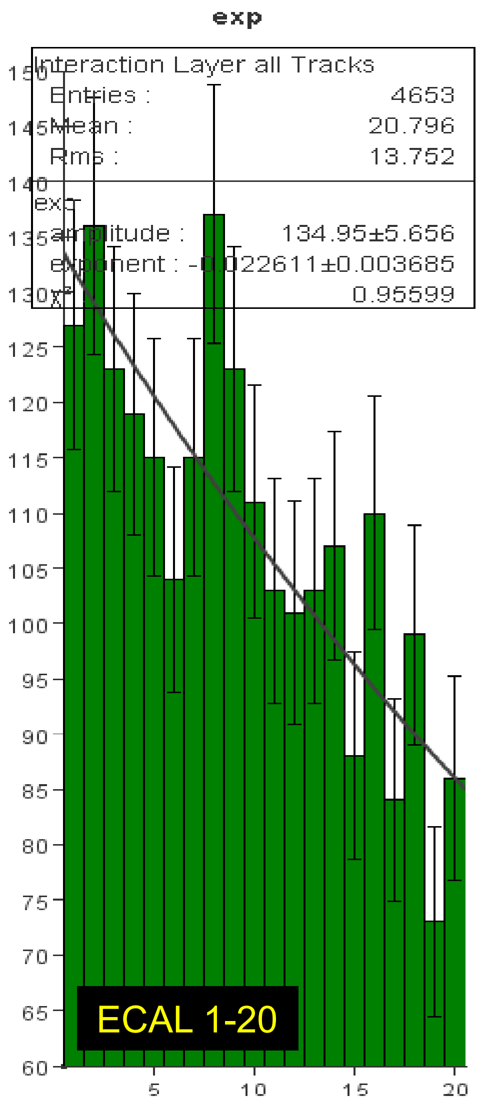
Average IL = 50% interact/pass = ~6.65 cm W ->
exp(-6.65/9.6) = 0.500
- **-> layer 23 in ECAL (incident at 90 degrees)**
- **-> layer 19 in ECAL (incident at 45 degrees)**
- **-> average ~layer 21 == plot (20.8)**

Number of pions incident at layer 1 = 4500
Average Number left at :
- **ECAL layer 20 -> ~2422**
- **HCAL layer 0 -> ~1312**
- **HCAL layer 34 -> ~3**

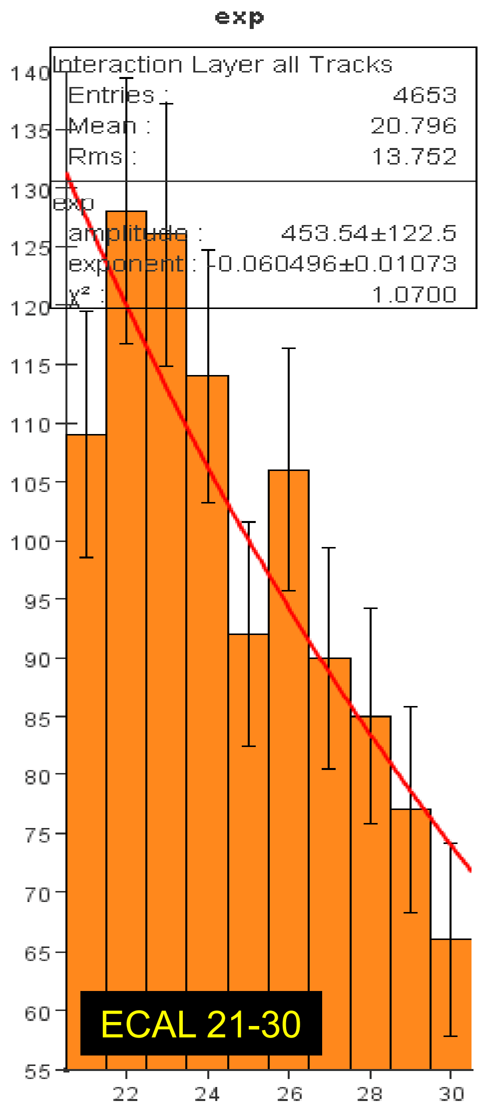
Average Number that interact :
- **ECAL layer 1 -> ~141** ▶
- **ECAL layer 21 -> ~150** ▶
- **HCAL layer 0 -> ~182** ▶

1-50 GeV pions, 4-176 degrees in SiD01

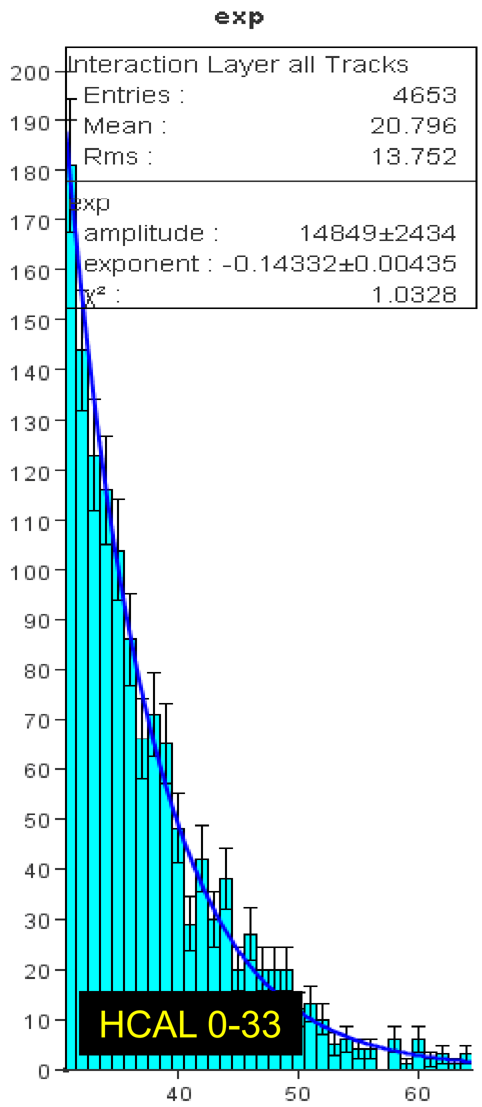
Performance of Track Mip Finder – Fits of exponential to shape



exponent = -0.023 ± 0.004
(-0.031 expected)
-> 2σ too flat

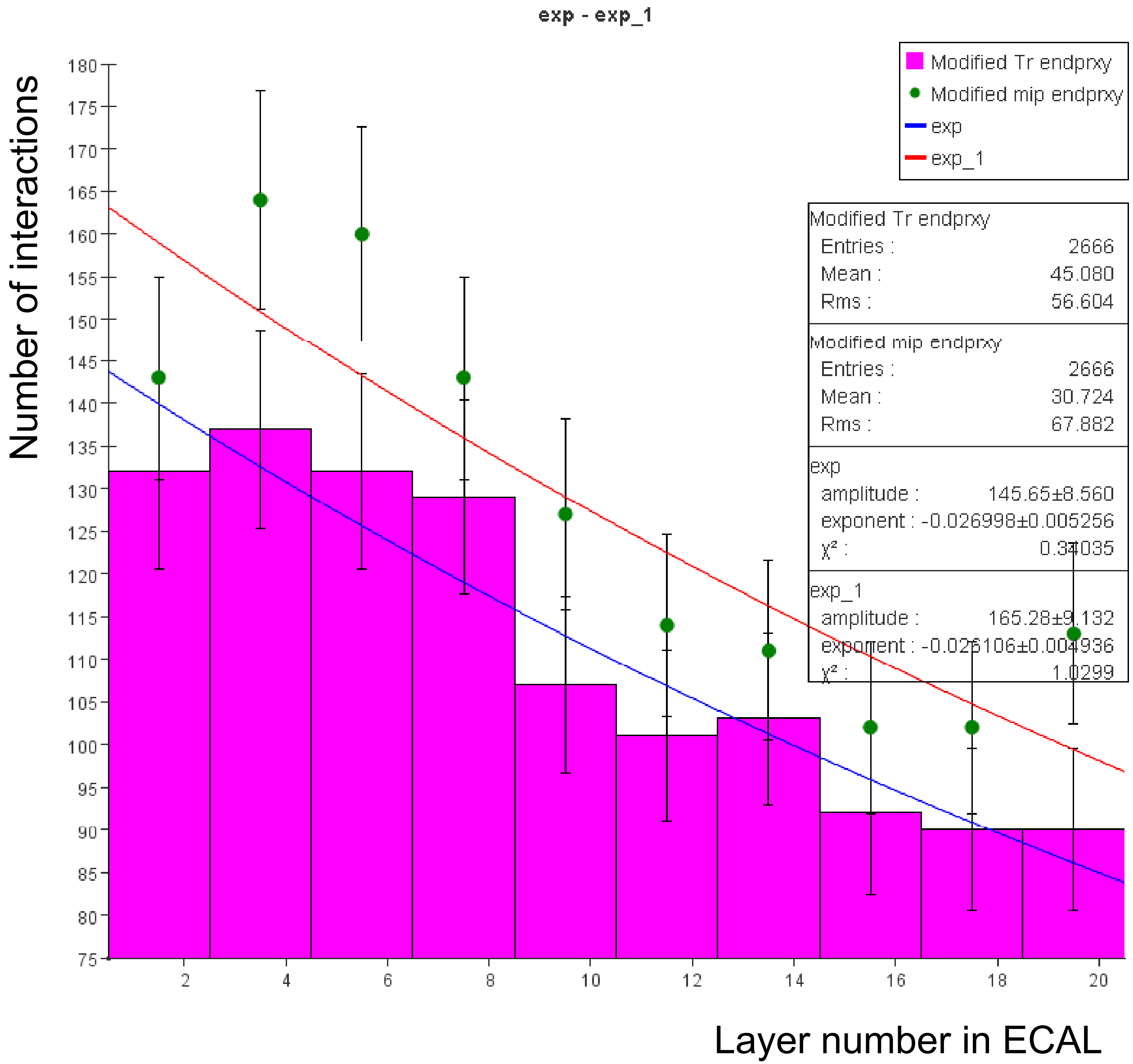


exponent = -0.060 ± 0.011
(-0.063 expected)
-> perfect



exponent = -0.143 ± 0.004
(-0.143 expected)
-> perfect

Comparison of Track and Mip Endpoints – exponential fit to ECAL 1-20

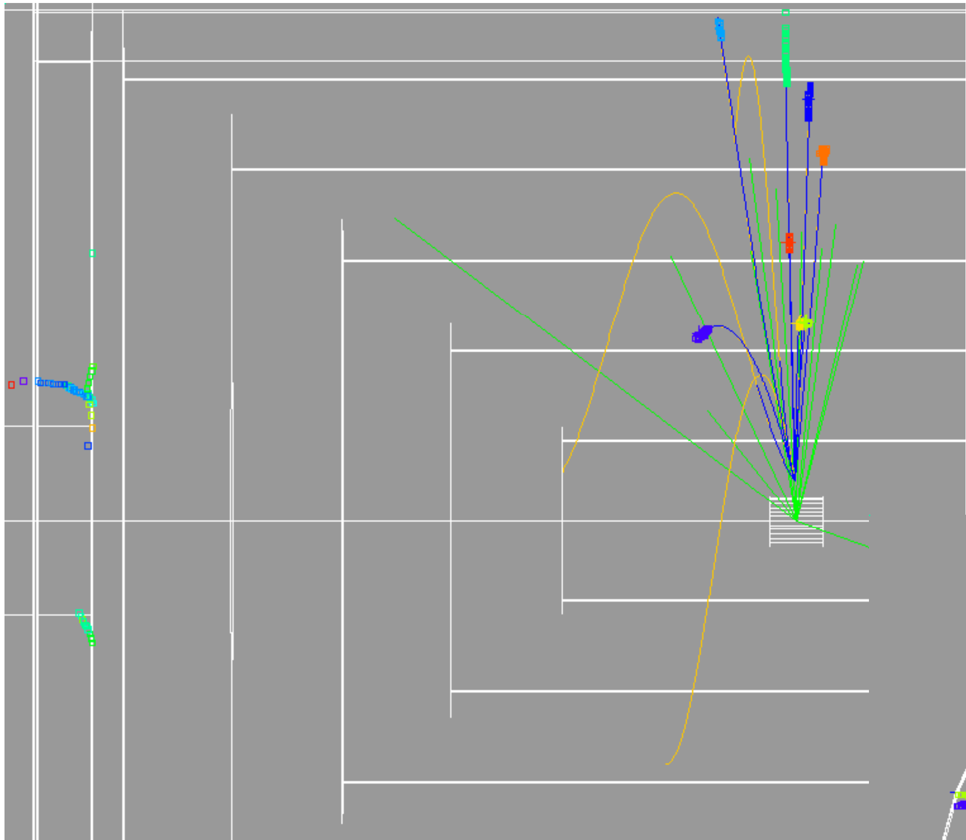


exp = -0.027 ± 0.005

exp = -0.026 ± 0.005

Mip and MC Track EPs display the same shape close to expected value (within 1σ)

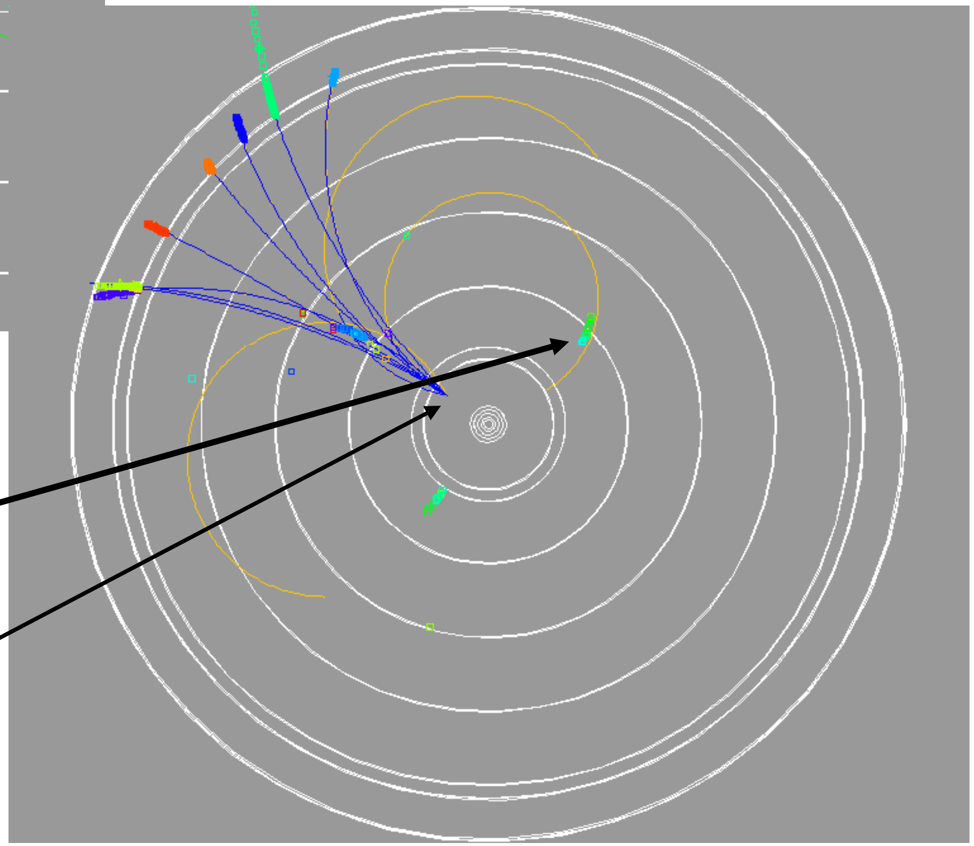
Normalization – different # of interactions in first layer



Why are there no mip clusters – IL=0?

(this started as a single pion!
-ended as 11 perfect PFA tracks!)

Effects PFA performance!!!



Fix with helix accounting for Eloss along trajectory?

Mip finder adjusts for non-IP tracks

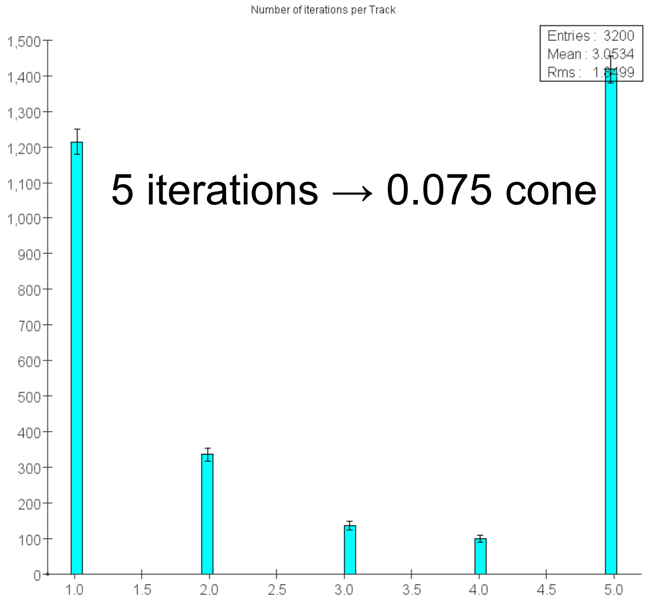
Summary of Track Mip Finder Performance

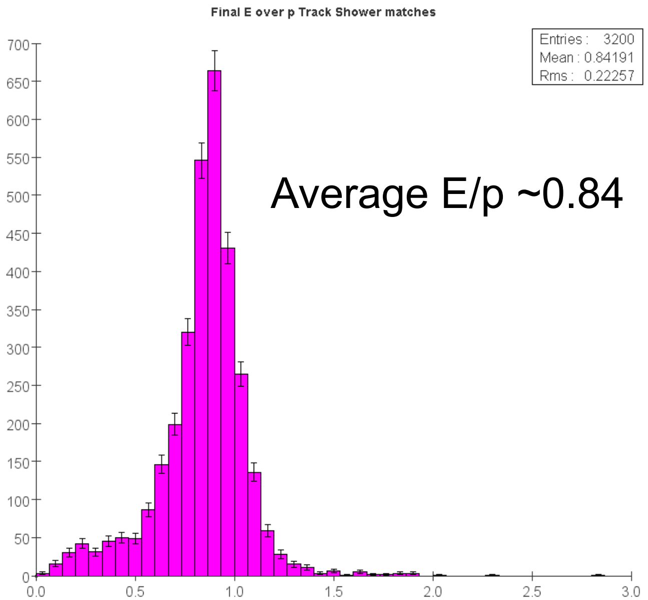
Mip finder associates CAL hits to extrapolated tracks
- uses cal hit density defined in code – no energy needed
- no calibration for mip cluster energy – dE/dx used (required)*

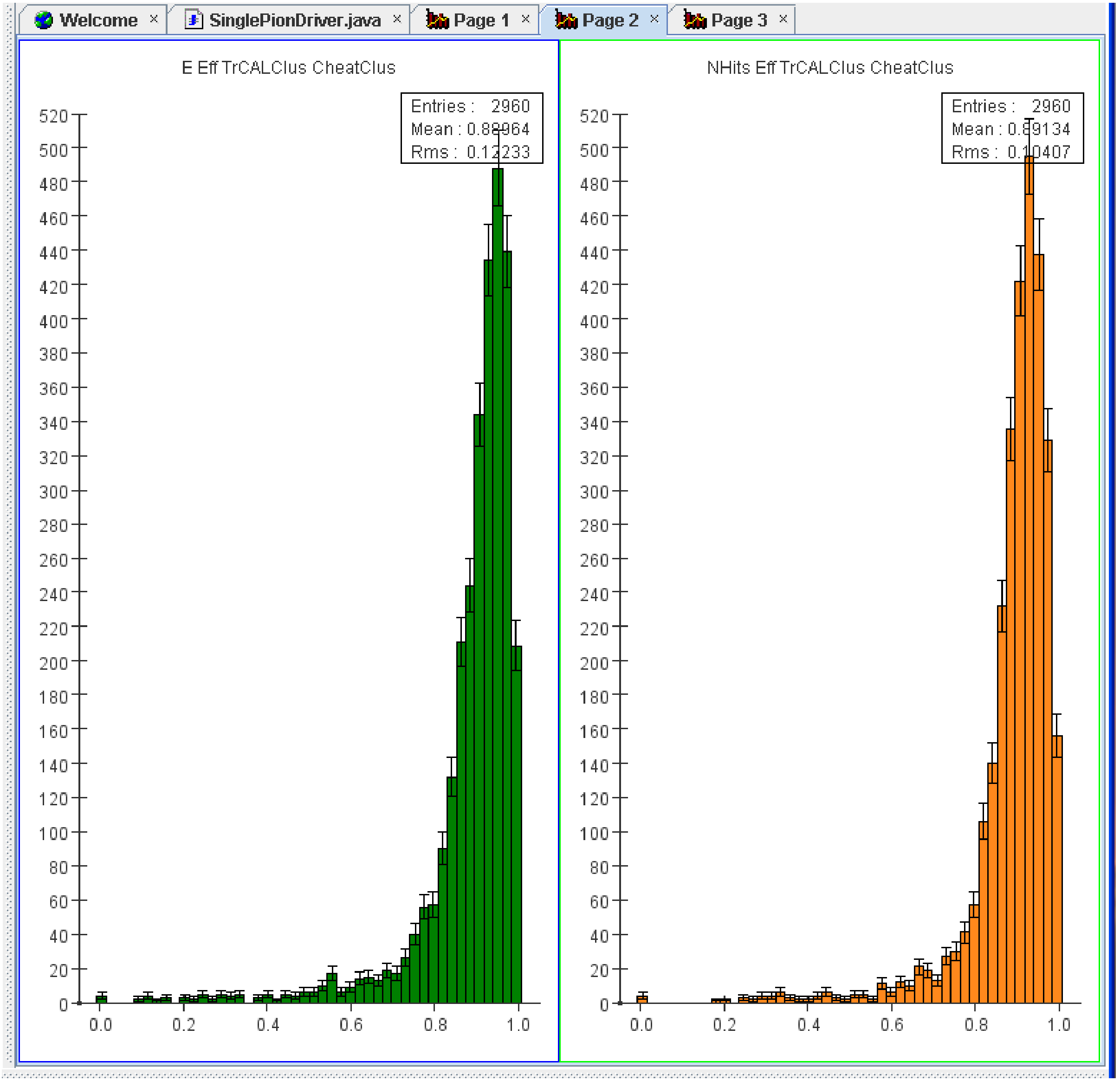
Also determines layer of first particle shower interaction
- good agreement with expected IL distribution from material
- good agreement with MC Track endpoint (understood differences)
- useful as starting point for Track/Shower association

Left to do :
- optimize density cut (done?) tune to muons?
- use Eloss-dependent helix to improve endcaps
- allow for tracks that enter ECAL from beampipe after layer 0

Track/Shower Association on single pions

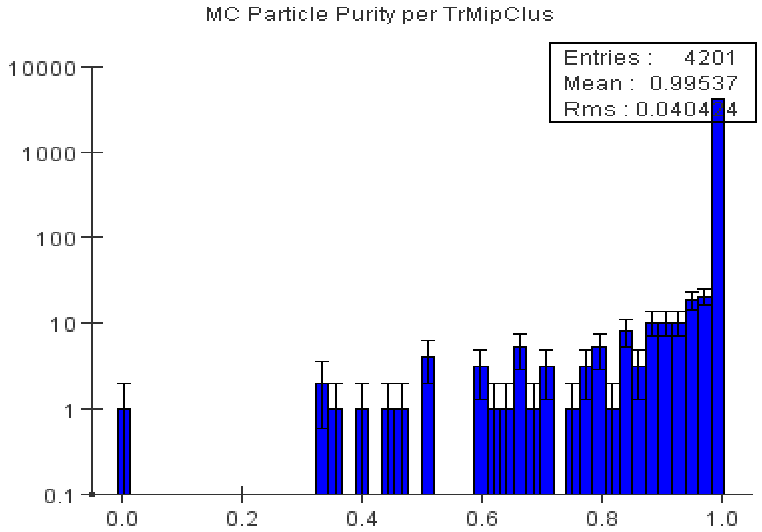


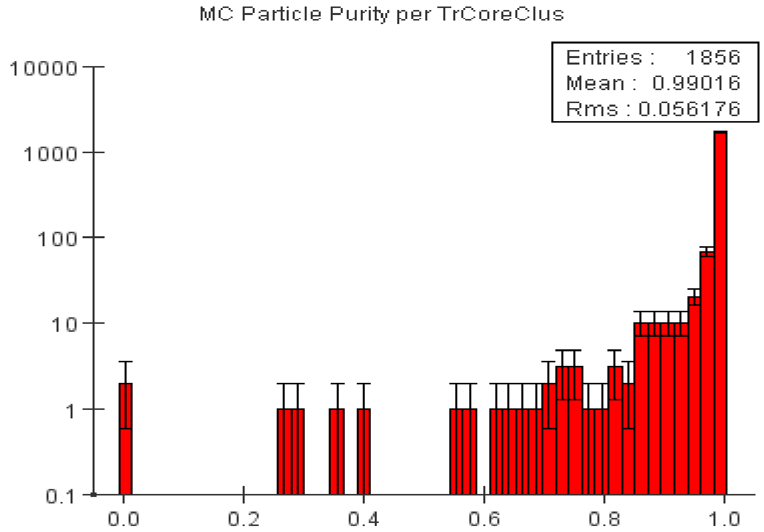


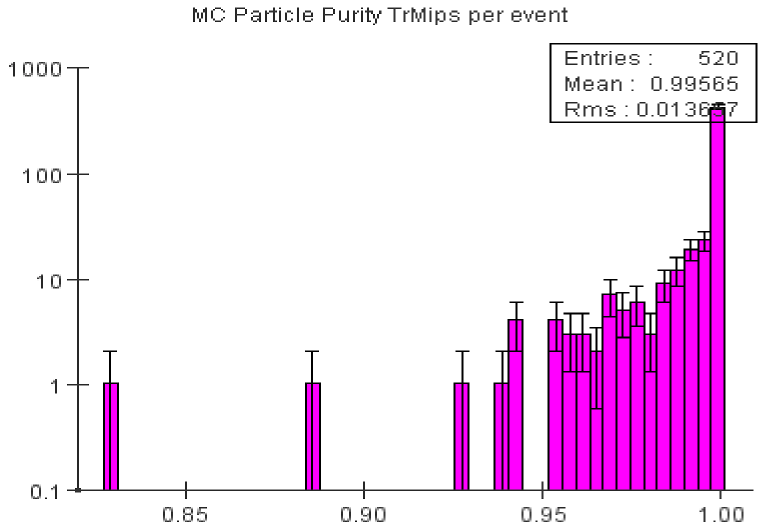


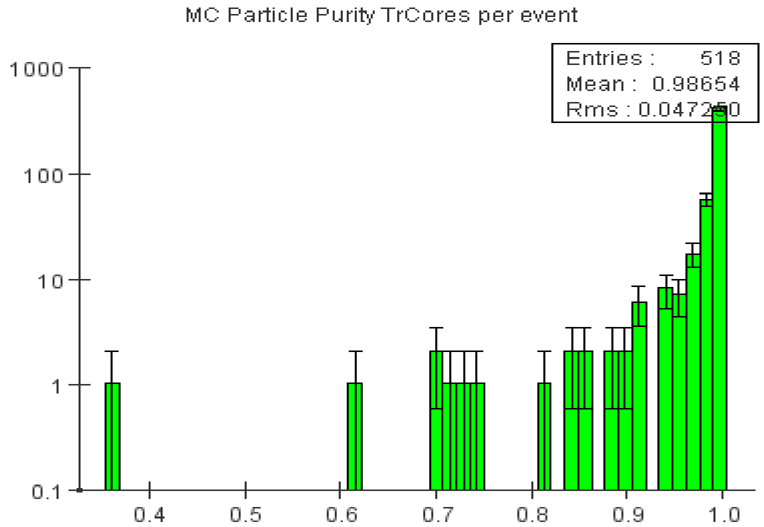
Efficiency ~ 89% E or hit

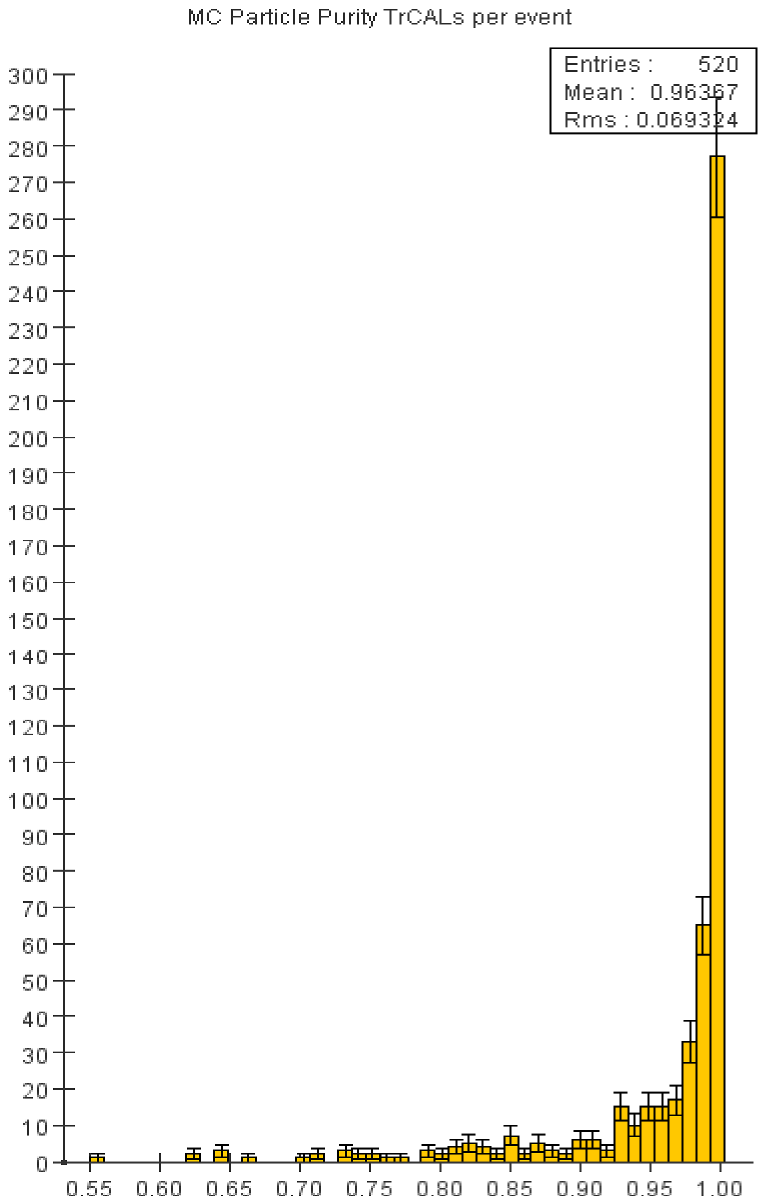
Track-Mip, Track-Shower Association Performance – qqbar100 SiD01



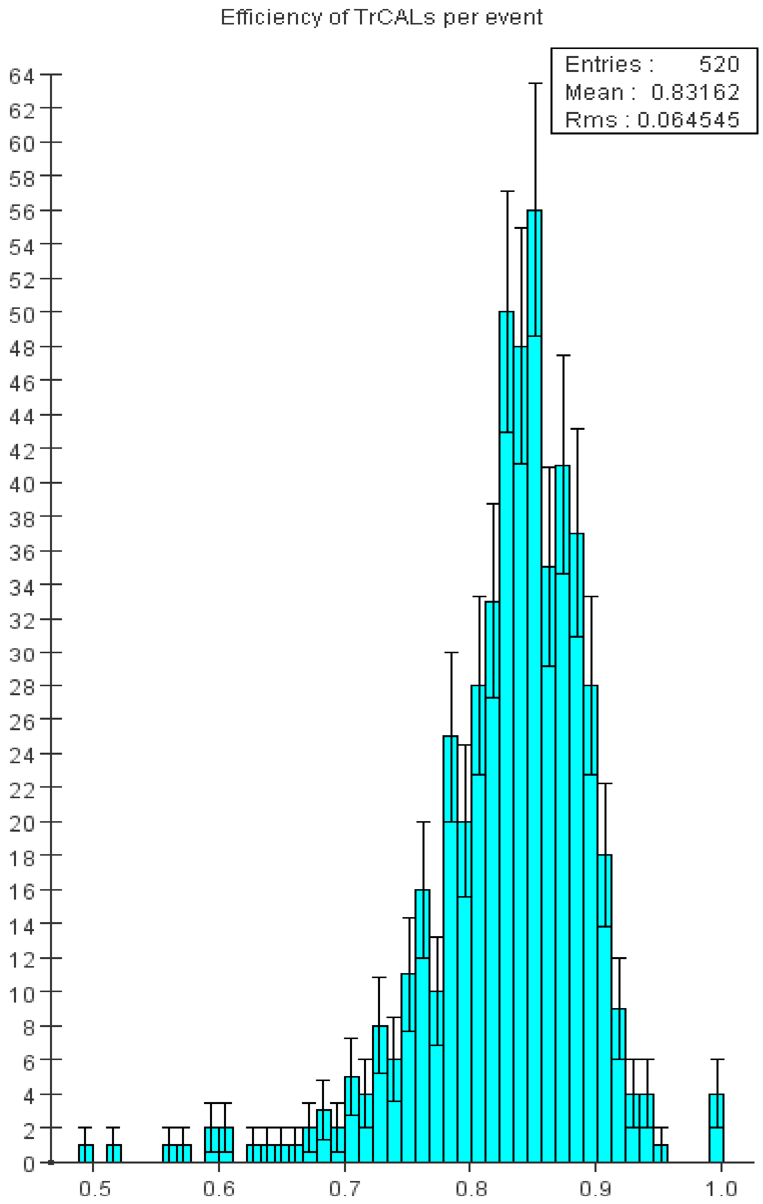




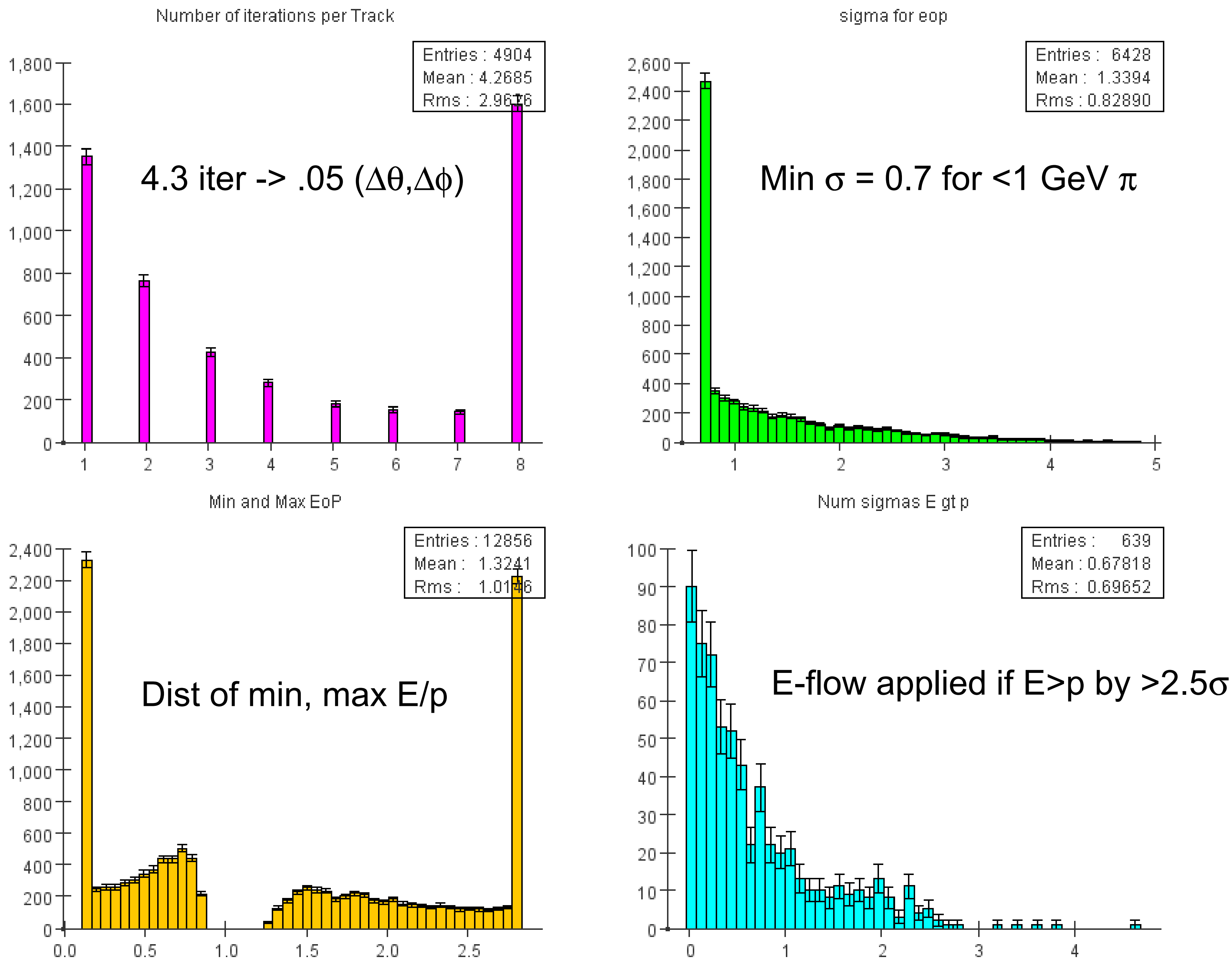




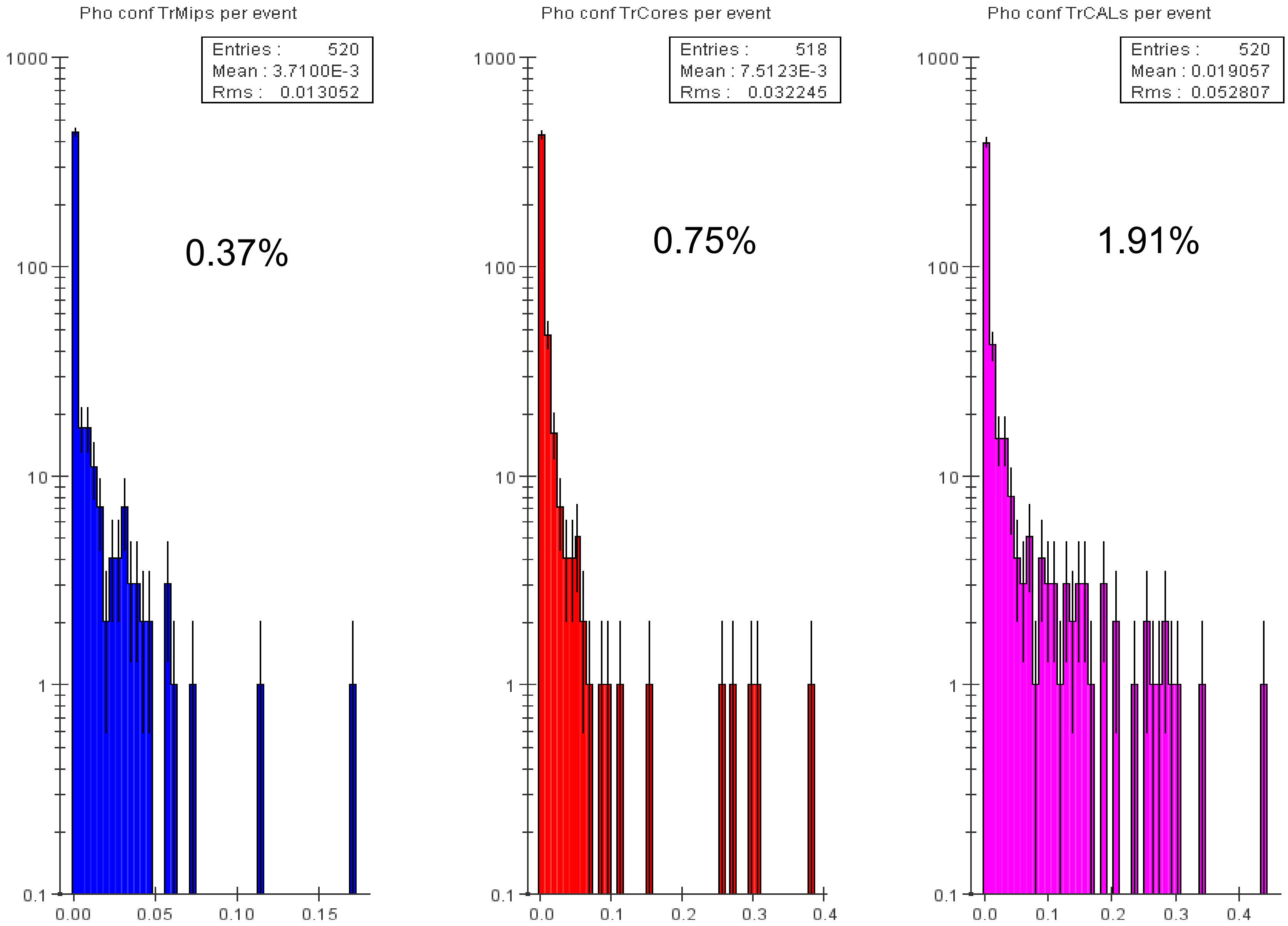
96% purity per event



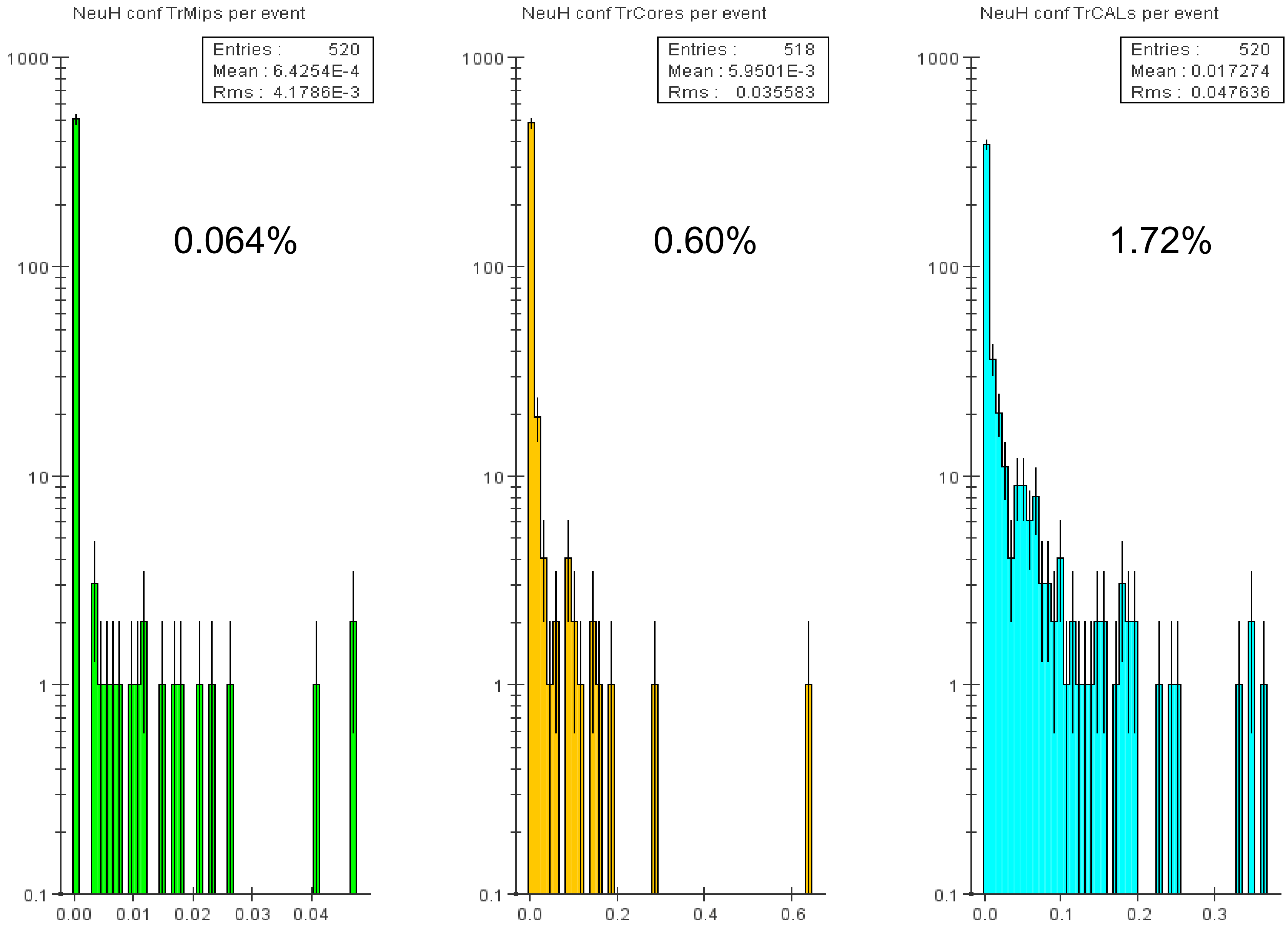
.83/.89 = 93% efficiency (normalized to single pion result)



Number of iterations per Track
Entries : 4904
Mean : 4.2685
Rms : 2.9676
4.3 iter -> .05 (Δθ,Δϕ)
sigma for eop
Entries : 6428
Mean : 1.3394
Rms : 0.82890
Min σ = 0.7 for <1 GeV π
Min and Max EoP
Entries : 12856
Mean : 1.3241
Rms : 1.0146
Dist of min, max E/p
Num sigmas E gt p
Entries : 639
Mean : 0.67818
Rms : 0.69652
E-flow applied if E>p by >2.5σ



Photon hits in mips . . . cores . . . tracks



Neutral Had hits in mips . . . cores . . . tracks

Summary of Track Shower Matching Performance

+90% purity and efficiency for matching showers to tracks in these qqbar100 events

Worse for higher E events and for these events, 4% contamination could mean as much as 5 GeV of misidentified energy

Also, the ~10% missing hits from pions could combine with other particles in the event to make clusters -> extra counting of energy/particles

Improvements coming :

-> re-clustering scheme for large clusters (E>>p matches) becomes more important at higher energies

-> directed core finding after mips for non-spherical clusters using hit association by layer (helps in RPC detector)

-> (unrelated) cluster merge algorithm for neutral hadron finding

Tests of SiD01 with reduced material

Detector model – SiD01 with tracking supports removed, silicon minimized

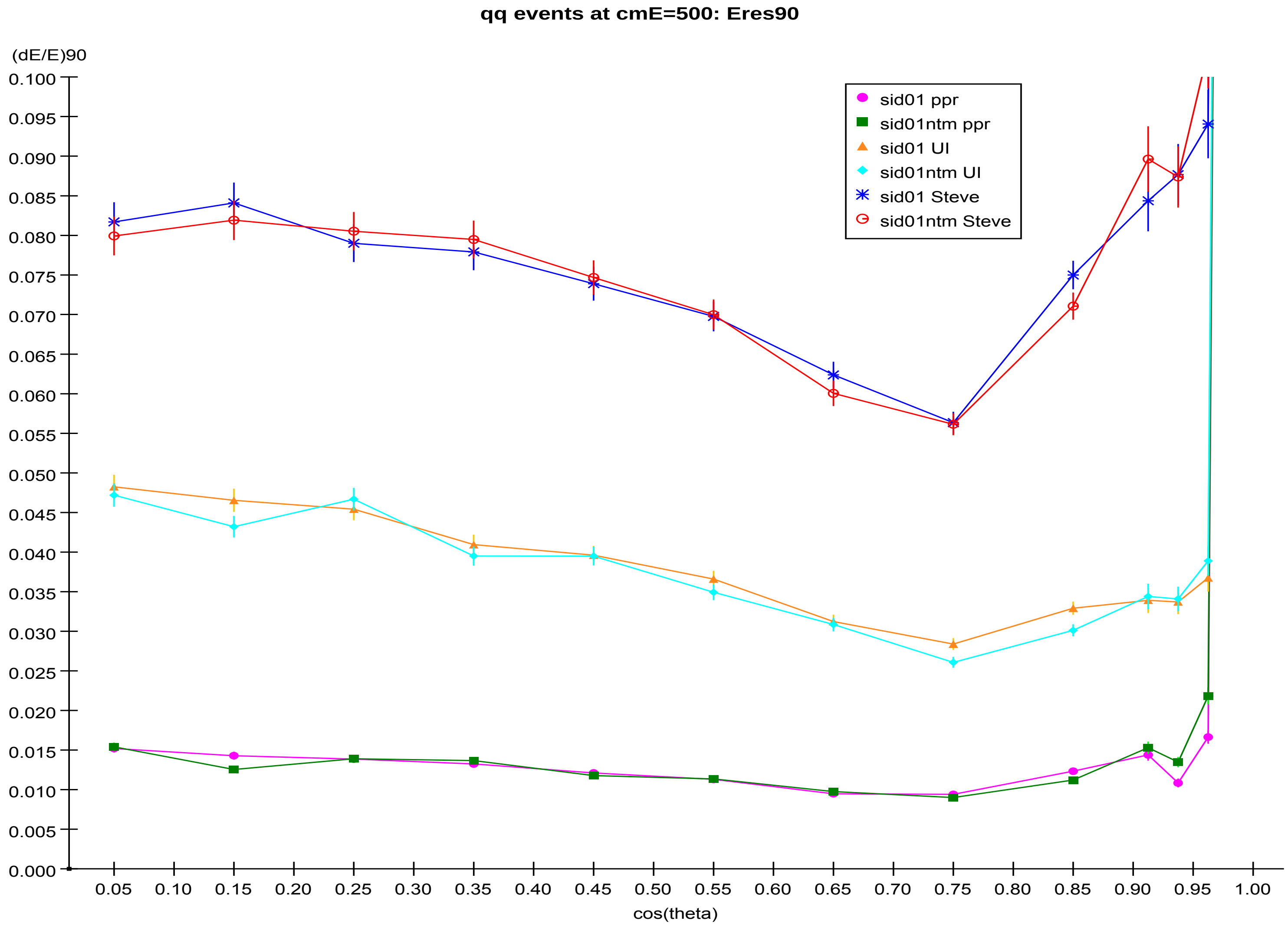
Why?

MC Generator final state particles ≠ Perfect PFA particles

Perfect PFA ESum is NOT just the sum of gaussian distributions as determined by the calorimeter performance of photons and neutral hadrons (early “back-of-the-envelope” calculations of PFA performance)

Perfect PFA depends on the detector design and material – non-gaussian contributions to the total ESum rms for the Perfect PFA could be large and could also affect even more the real PFA performance

- -> ILD (gaseous tracker) performance better than SiD due in part to this effect?
- -> is the size of the contribution from the effects of decays and interactions large compared to the figures of merit to be optimized in SiD (ECAL and HCAL resolutions)?
- -> is this contribution smaller than our real PFA confusion?



Looks like effect is small – no effect on perfect or real PFA for qqbar500 events -> will check more thoroughly and with other processes to get estimates of the size of contribution to the ESum