Event Reconstruction in SiD02 with a Dual Readout Calorimeter

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- Detector Geometry
- EM Calibration
- Cerenkov/Scintillator Correction
- Jet Reconstruction Performance

Dual Readout Detector Geometry

Dual Readout Calorimeter *in SiD02 Shell (Barrel and EC)*

DR ECAL

3 cm x 3 cm x 3 cm BGO

8 layers – 21.4 X_0 (1.1 λ_I)

127 cm IR – 151 cm OR

Scin/Ceren analog hits

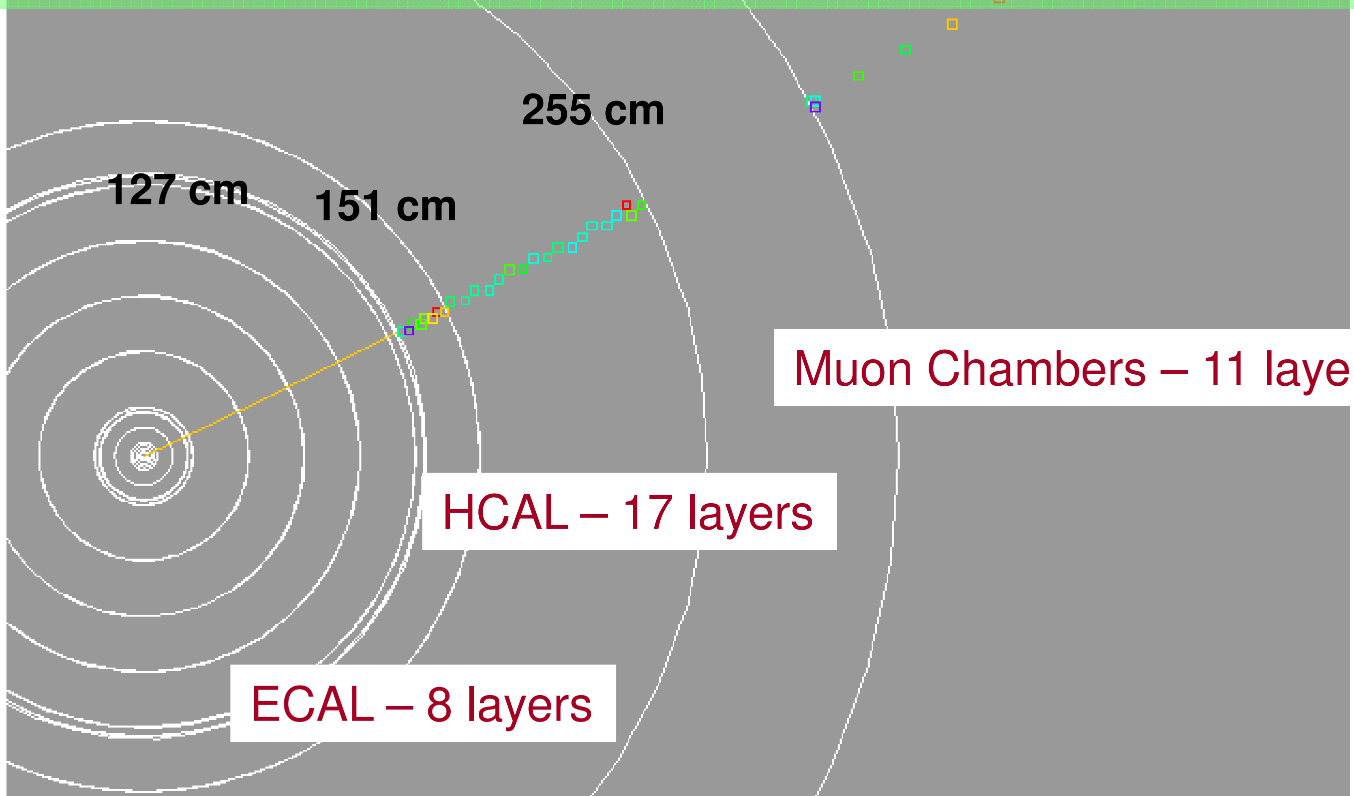
DR HCAL

6 cm x 6 cm x 6 cm BGO

17 layers – 4.6 λI

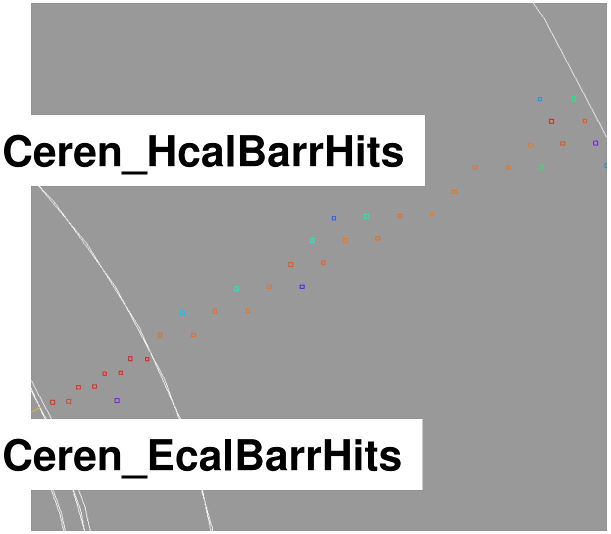
151 cm IR – 253 cm OR

Scin/Ceren analog hits

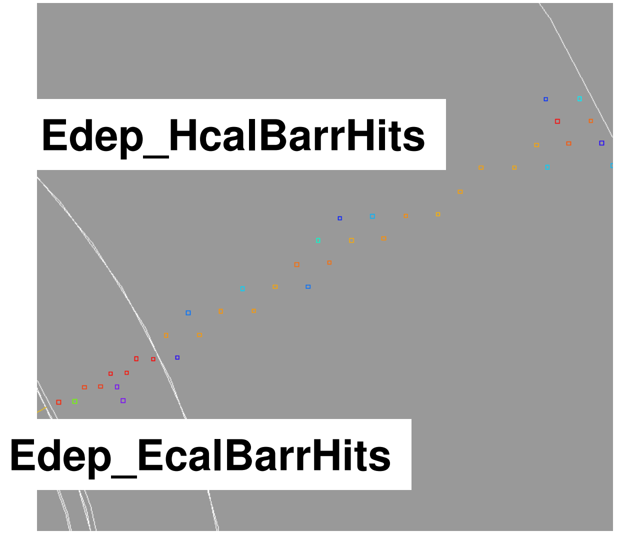


Muons

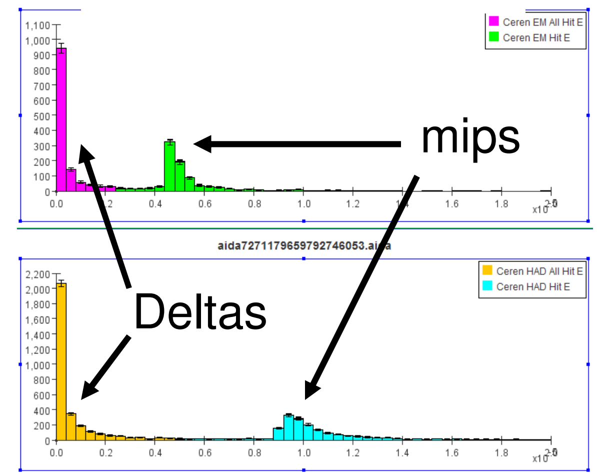
Cerenkov Collections



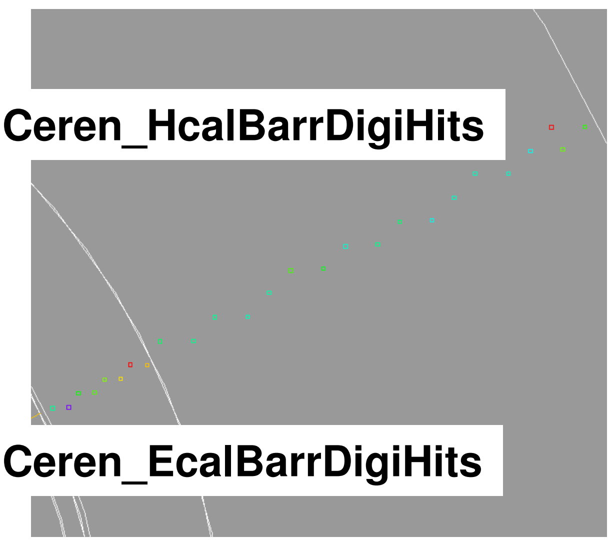
Scintillator Collections

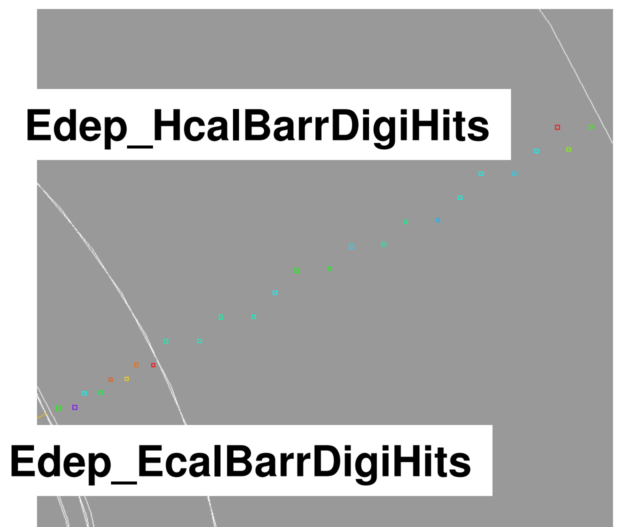


Cerenkov EM,HAD

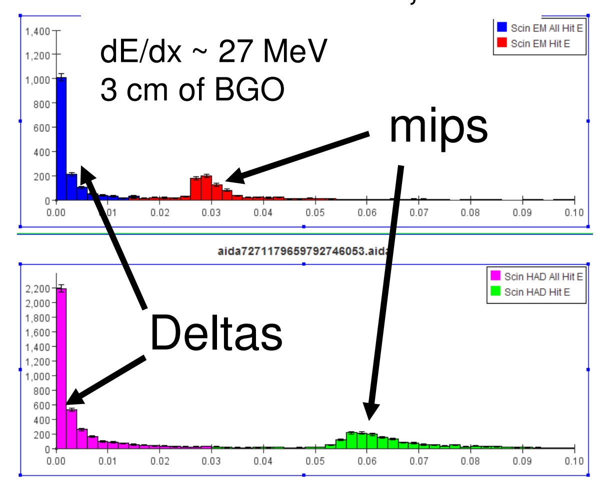


DigiSim - ½ MeV threshold (scin, *ceren*), 100 ns timing cut

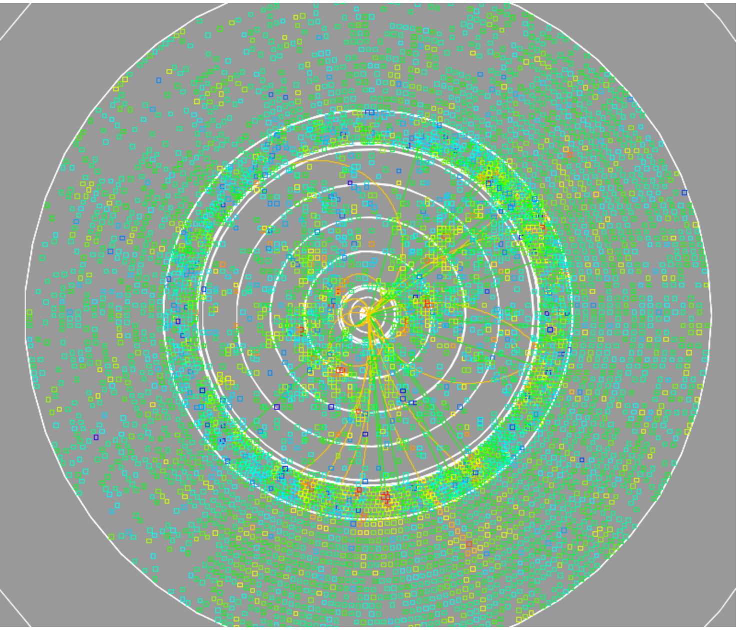


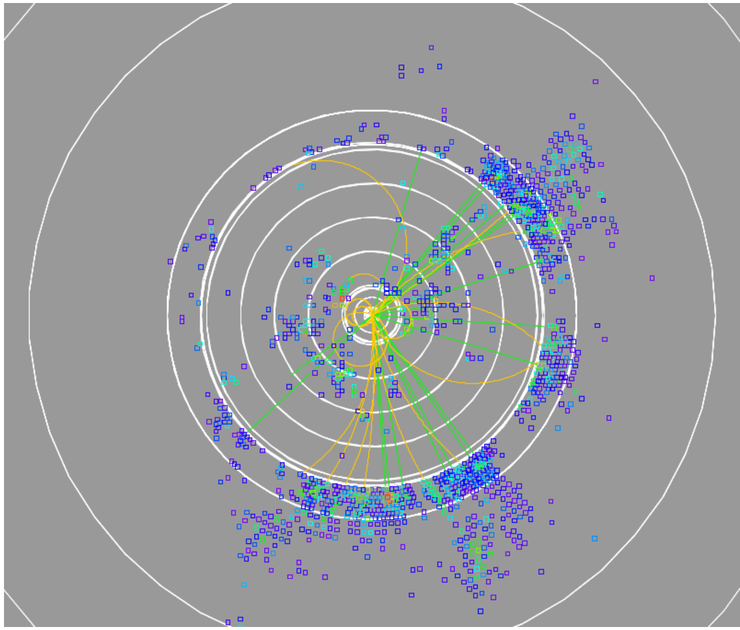


Scintillator EM,HAD

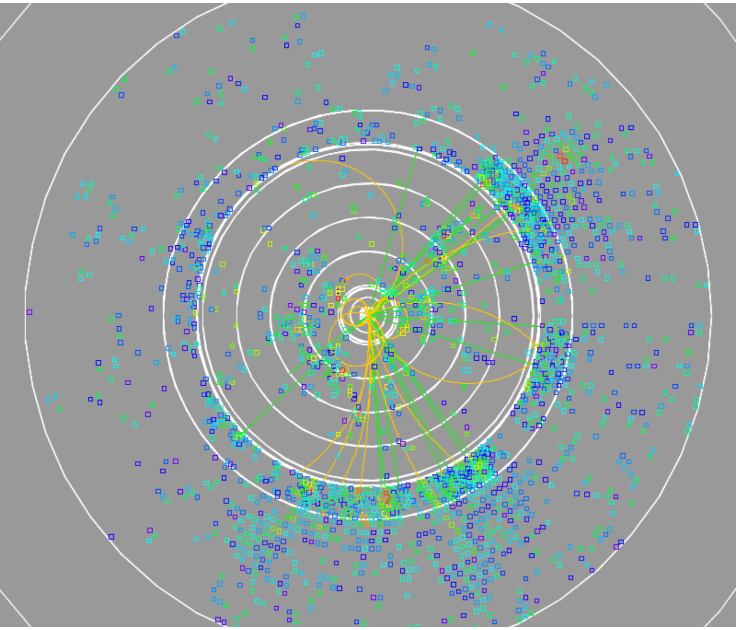


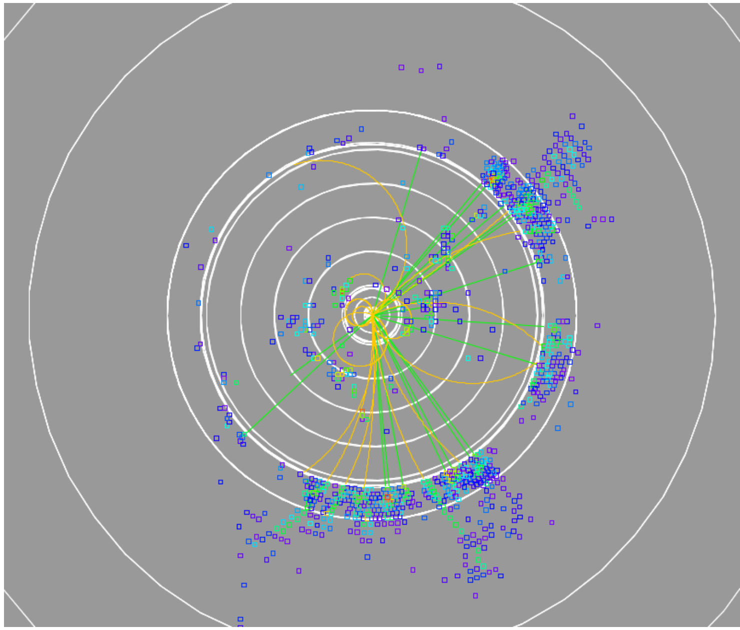
e+e- -> ZZ -> ννqq @ 500 GeV





Scintillator Hits





Cerenkov Hits

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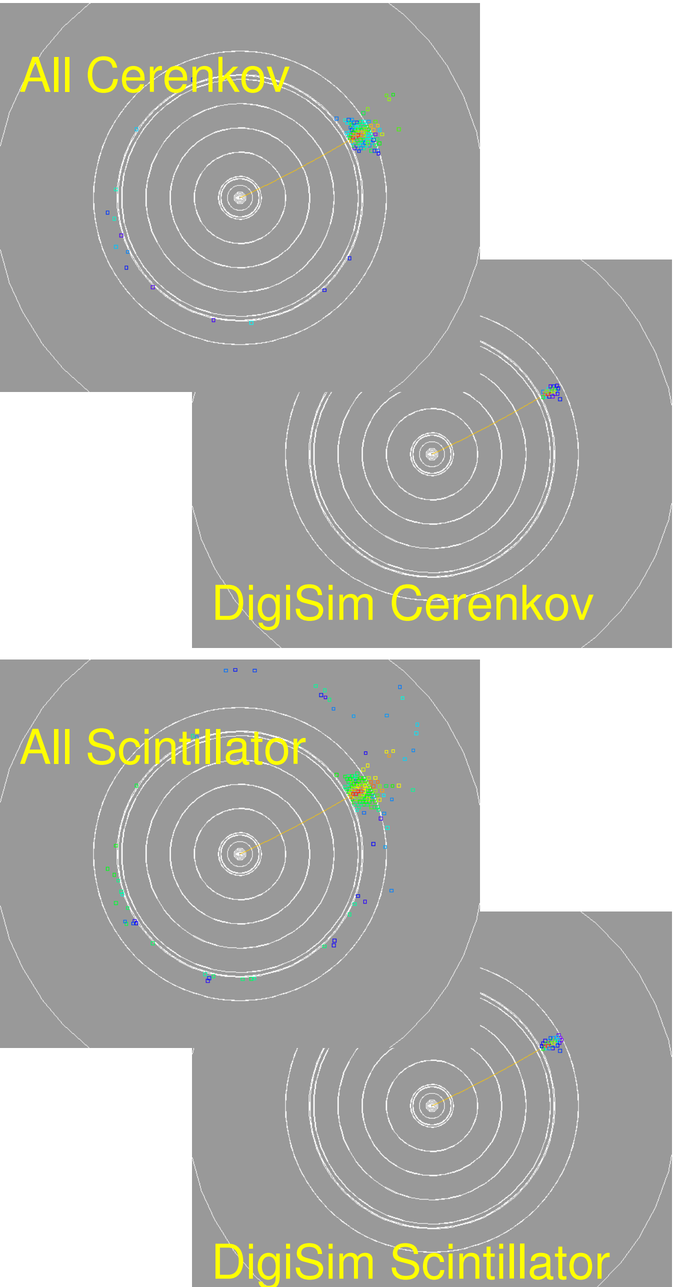
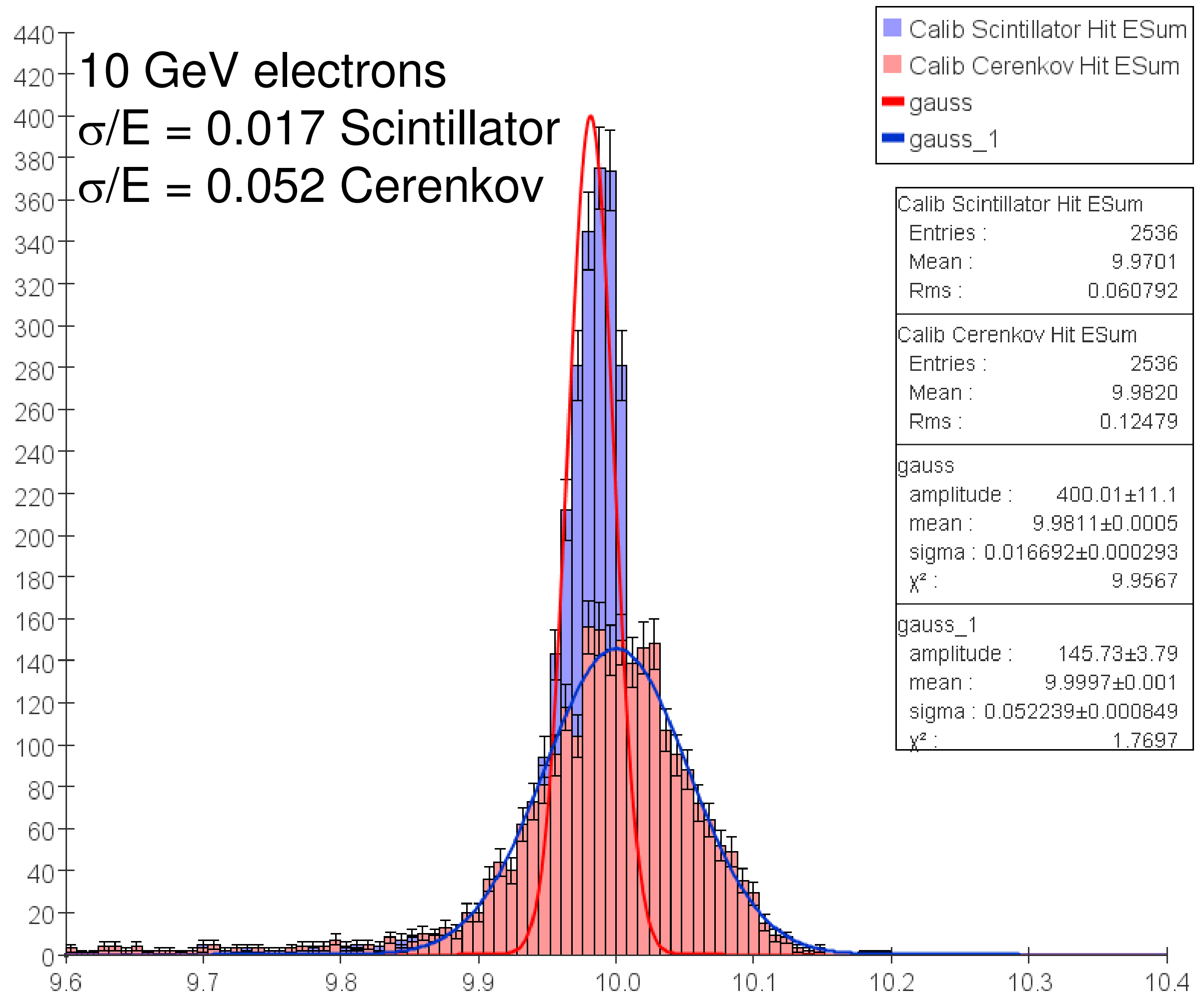
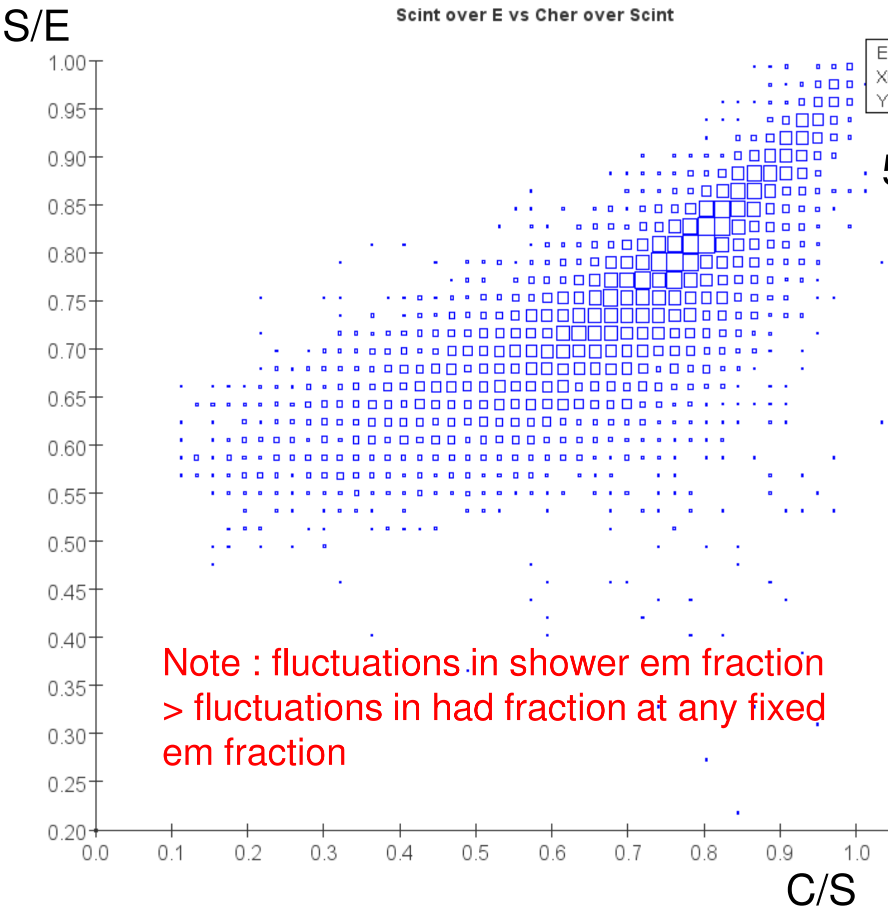
Electron Calibration for Scintillator, Cerenkov





$S = 1.004 \times s_{raw}$ $C = 7692 \times c_{raw}$

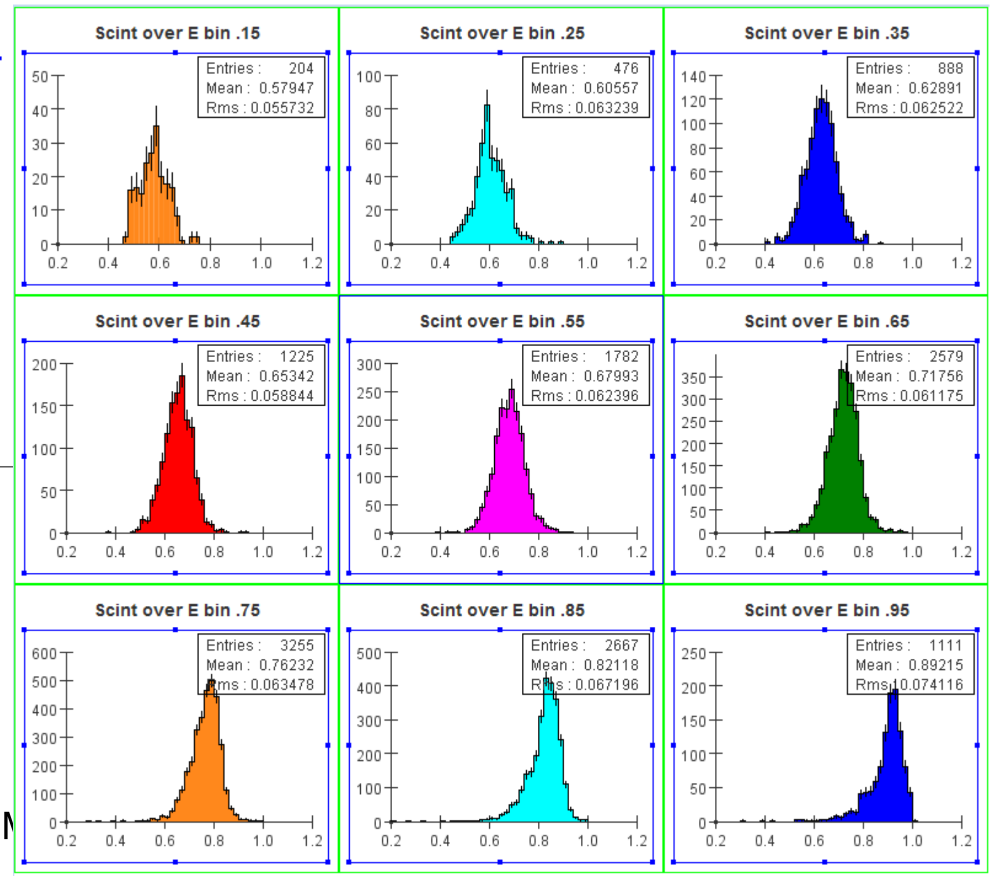
Cerenkov/Scintillator Correction for Hadrons



Note : fluctuations in shower em fraction
> fluctuations in had fraction at any fixed
em fraction

5, 10, 20, 50, 100 GeV pions

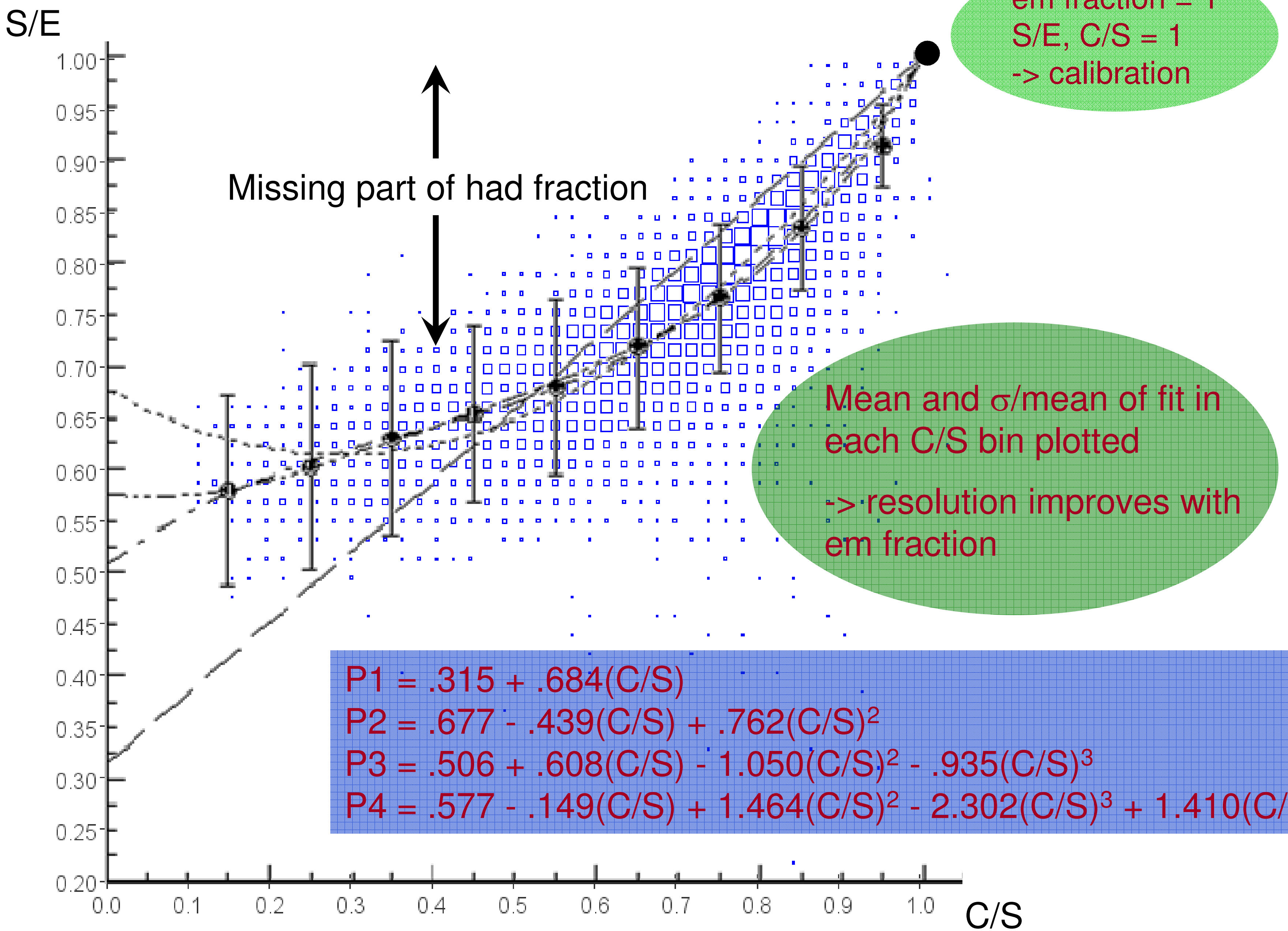
S/E slices in em fraction (C/S) bins



S (e calibrated scintillator response)
-> em and had visible energy
C (e calibrated cerenkov response)
-> em part of shower
C/S = em fraction of visible energy
S/E = total fraction of energy seen

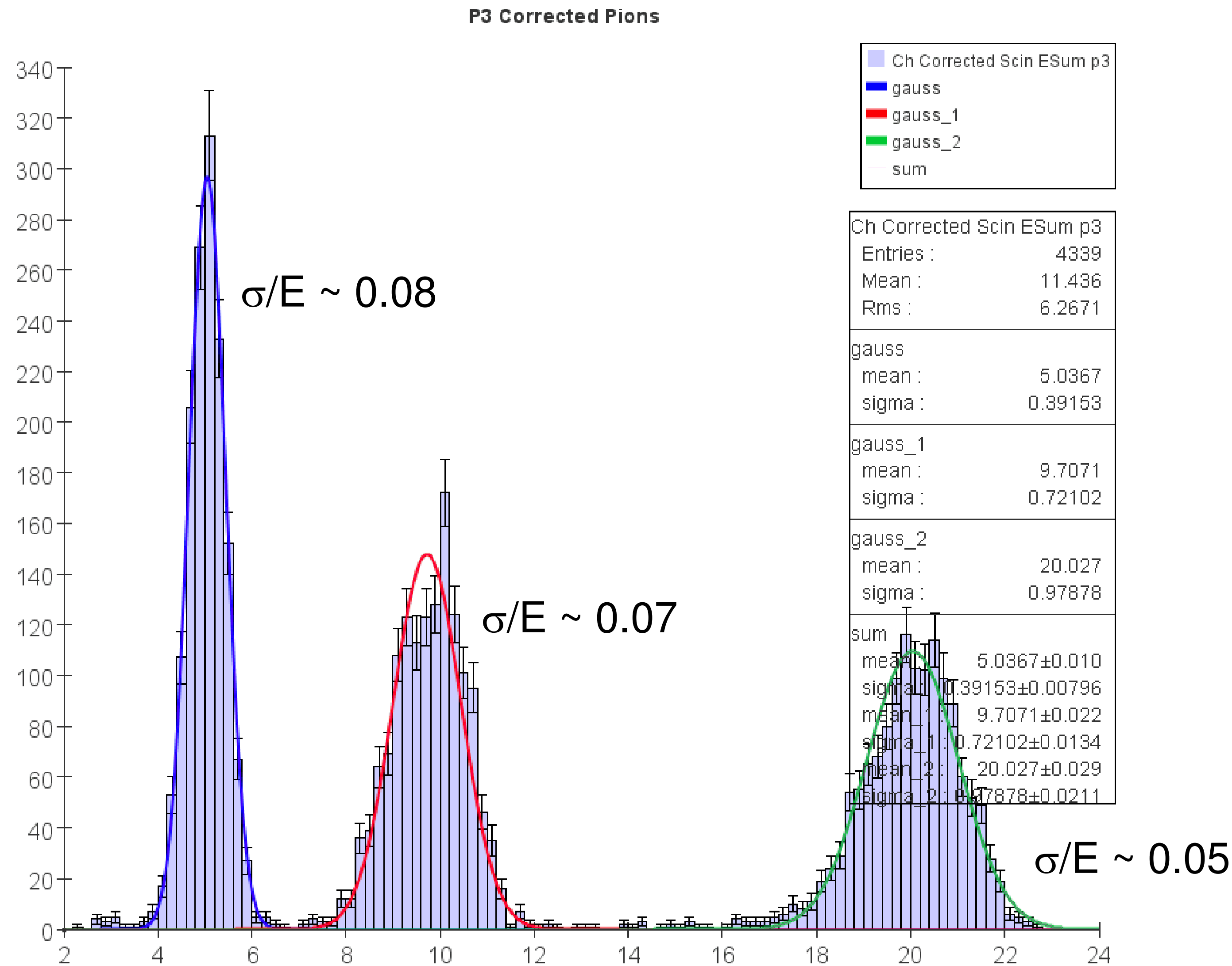
S.R. M

Polynomial Correction Functions : E = S/Pn



$$P1 = .315 + .684(C/S)$$
$$P2 = .677 - .439(C/S) + .762(C/S)^2$$
$$P3 = .506 + .608(C/S) - 1.050(C/S)^2 - .935(C/S)^3$$
$$P4 = .577 - .149(C/S) + 1.464(C/S)^2 - 2.302(C/S)^3 + 1.410(C/S)^4$$

Corrected Scintillator signal for pions using P3 Polynomial



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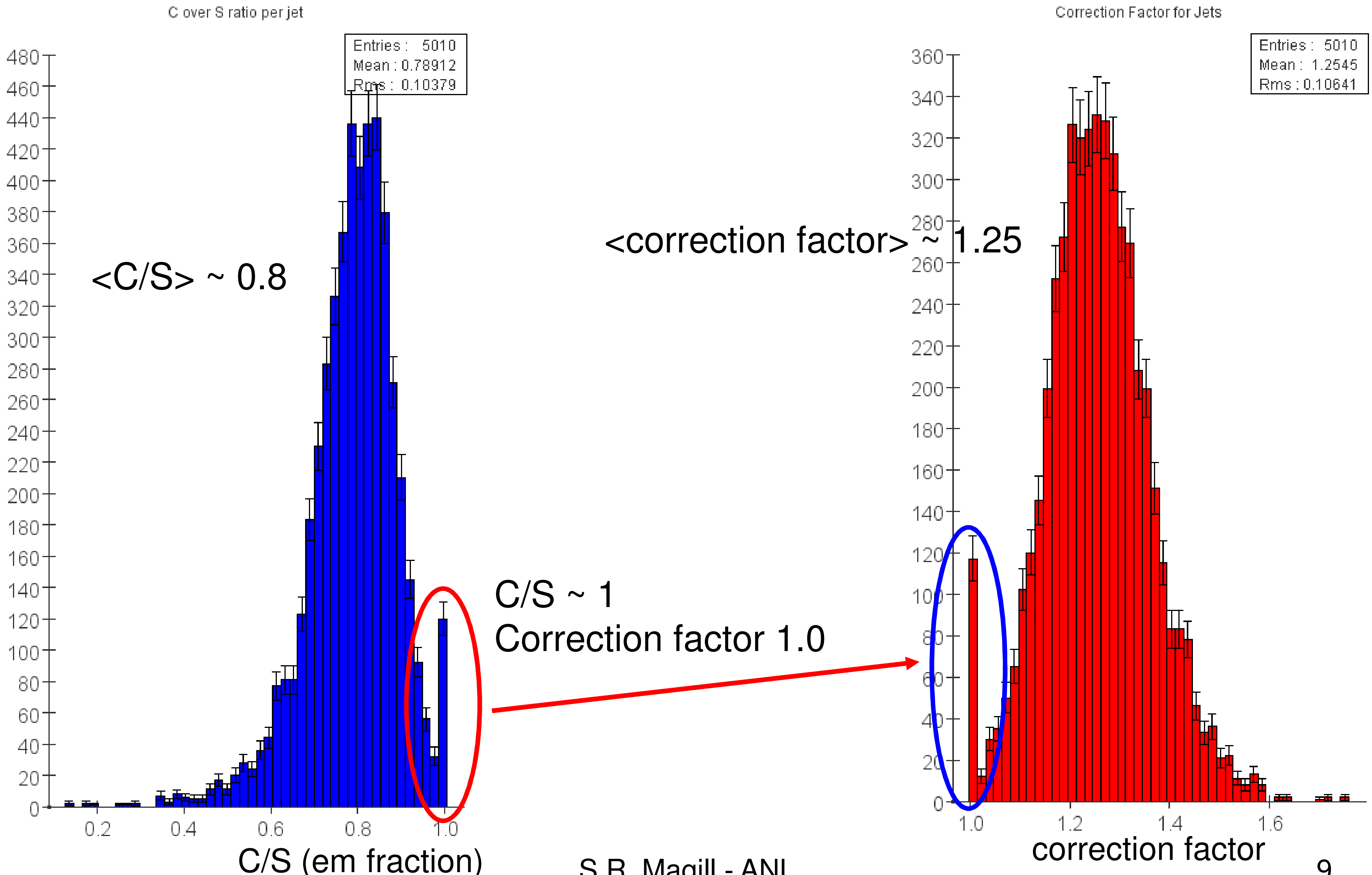
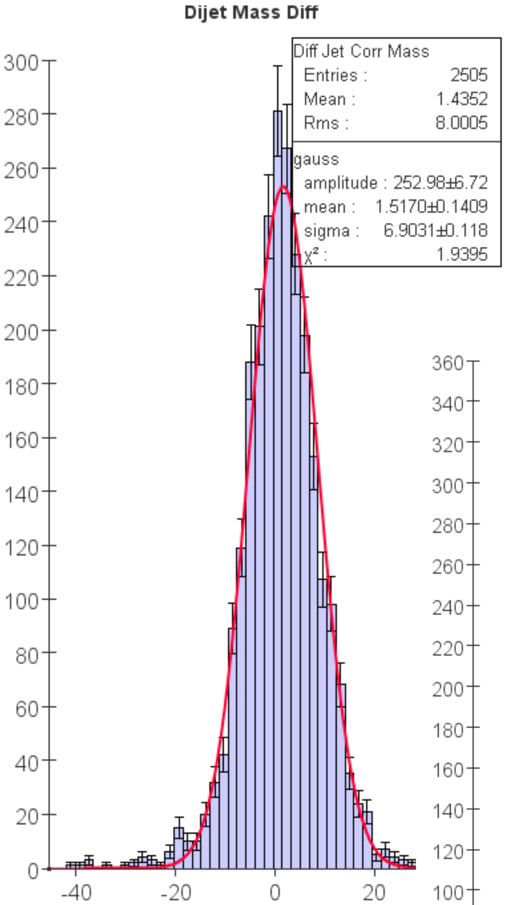
Jet Corrections in Dual Readout Detector



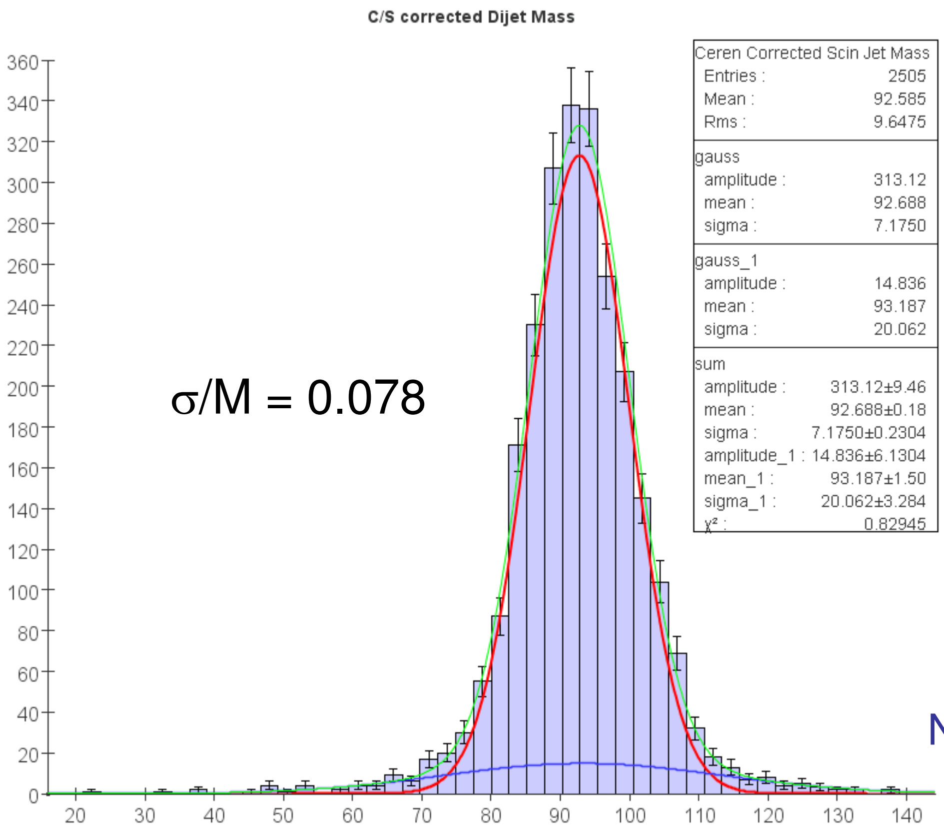
DiJet Mass : e^+e^- -> ZZ -> $qq\nu\nu$ @ 500 GeV



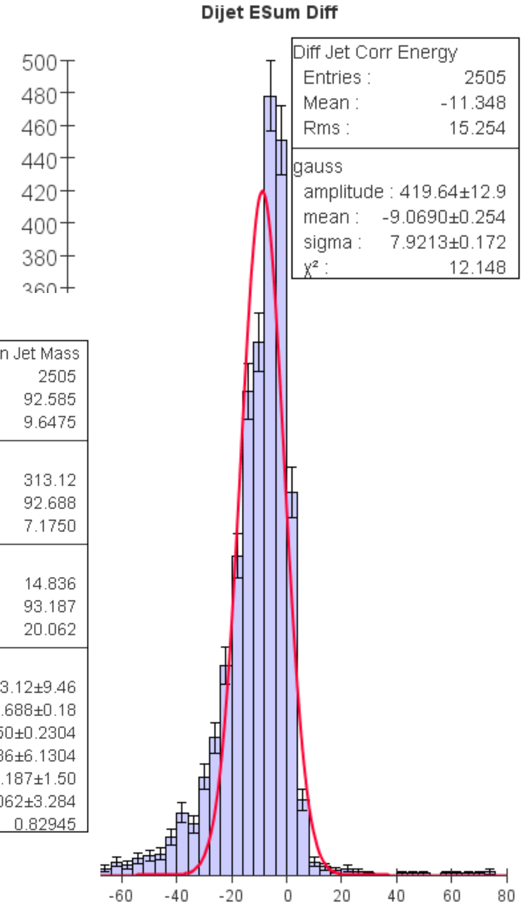
$\Delta M/M = 0.076$

C/S correction per jet
No PFA

$\sigma/M = 0.078$



M (GeV)

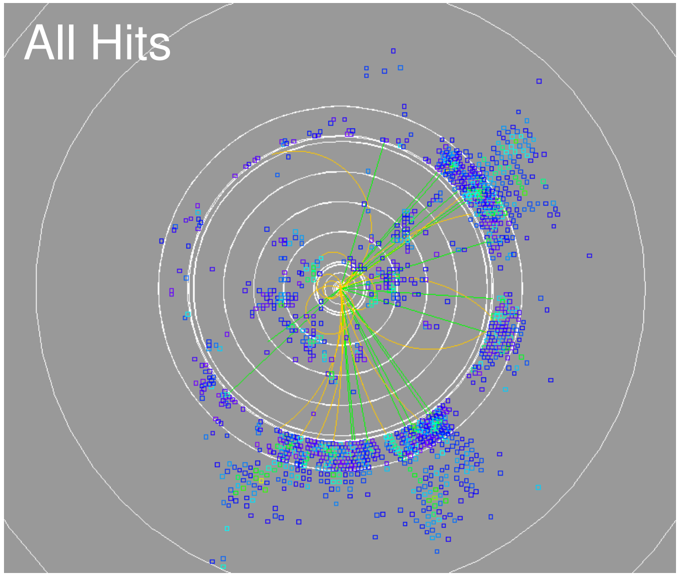


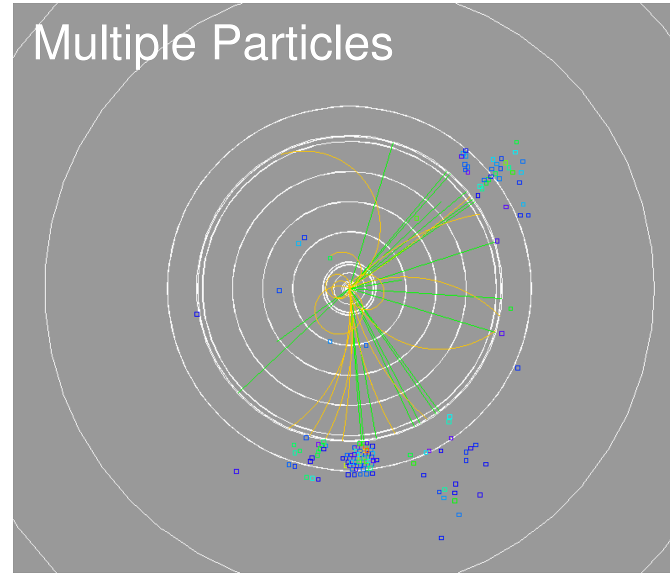
$\Delta E/E = 0.036$

No leakage correction yet

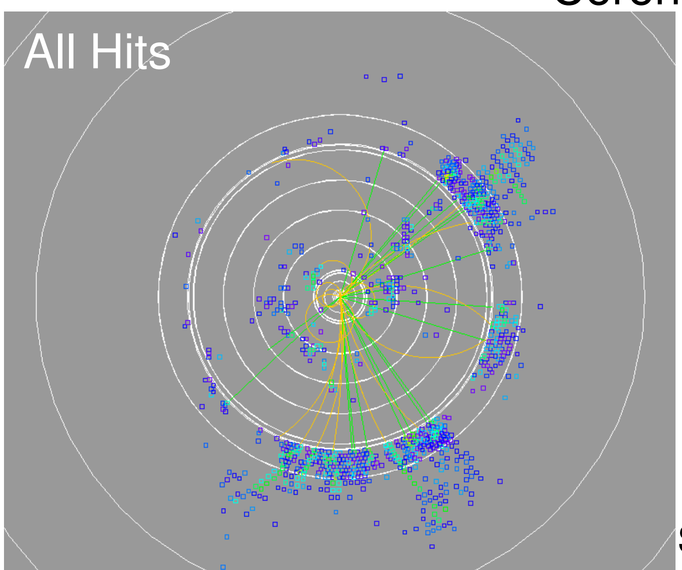
PFA Possibility? - MC Particle Contribution to DR Cal Cells

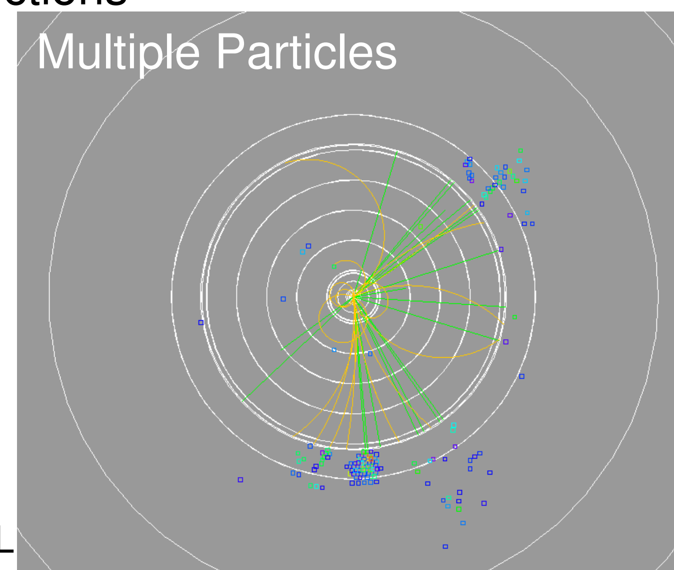
Scintillator Hit Collections





Cerenkov Hit Collections





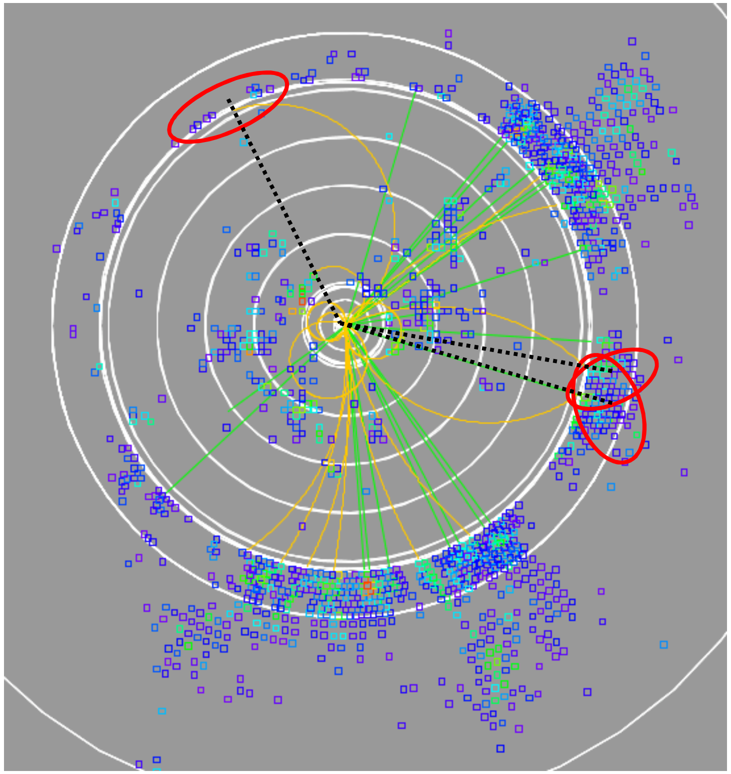
PFA in Dual Readout Calorimeter

PFA Template developed for SiD and variants :

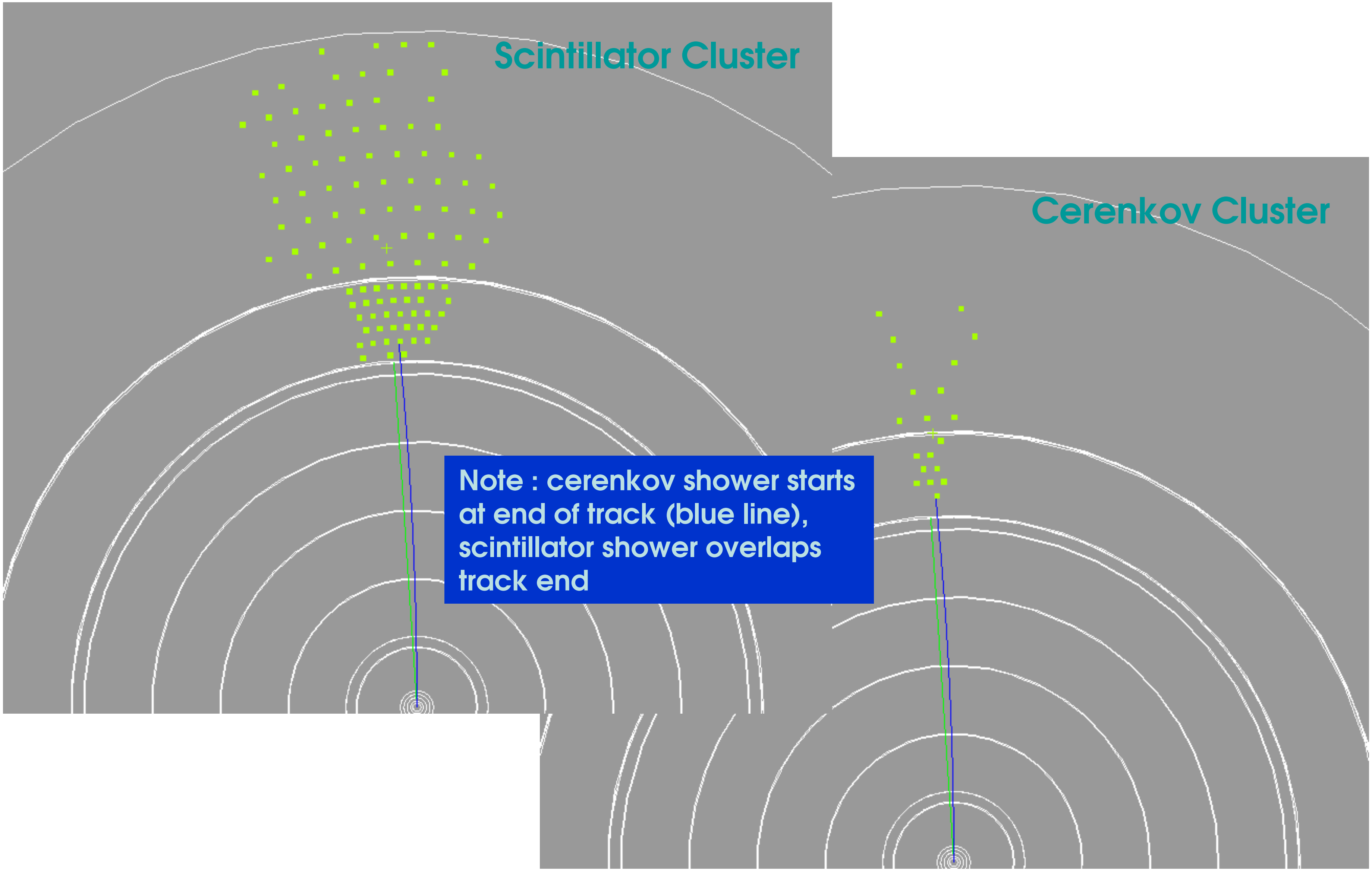
- Fully modular construction
- Common IO for all modules :
  - Mip-finding/Track Endpoint, Cluster Algorithms, Cluster pointing, Core cluster matching, Track-Shower association, Cut-based photon ID, H-Matrix photon ID, Neutral hadron finding
- All modules run on both Dual Readout collections with zero -> minimal modifications

First use of PFA : Mip-finder Track endpoint determination -> ΔM correction from charged particles in event (see Adam Para's talk later) or per jet

Same parameters as for SiD, only modification was to change collection names

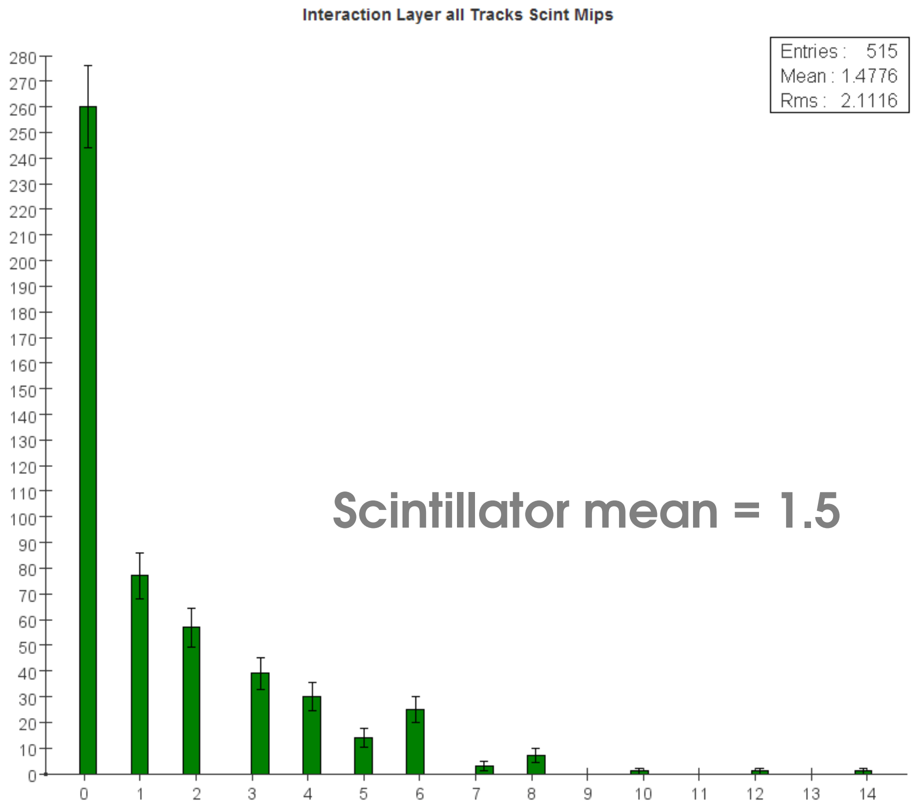


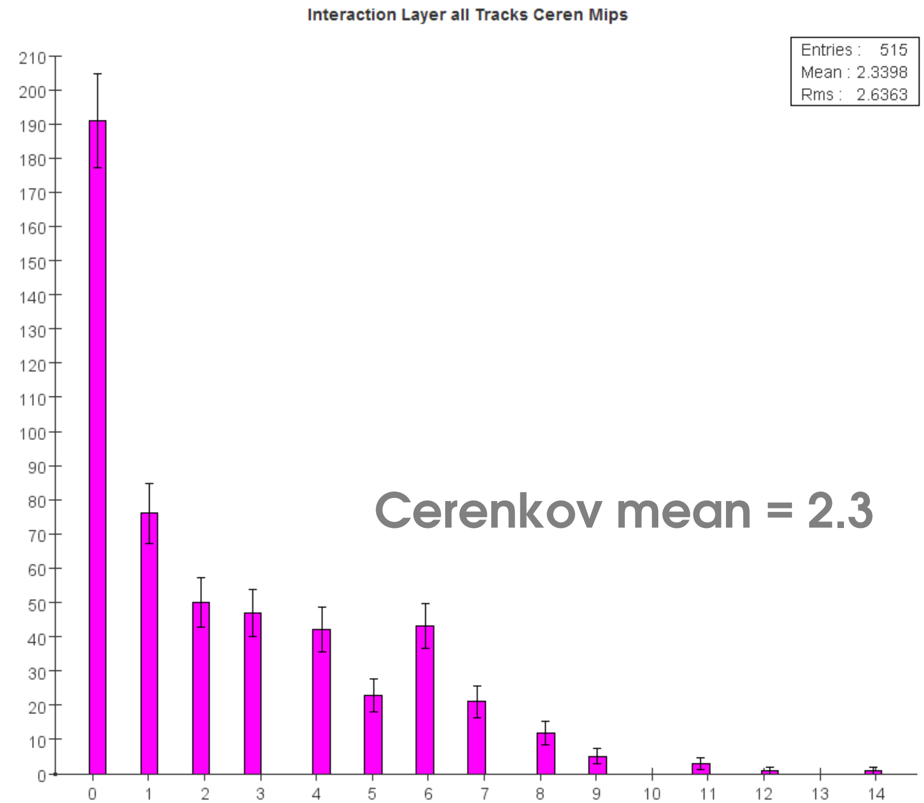
20 GeV pion shower in Dual Readout Calorimeter



Note : cerenkov shower starts at end of track (blue line), scintillator shower overlaps track end

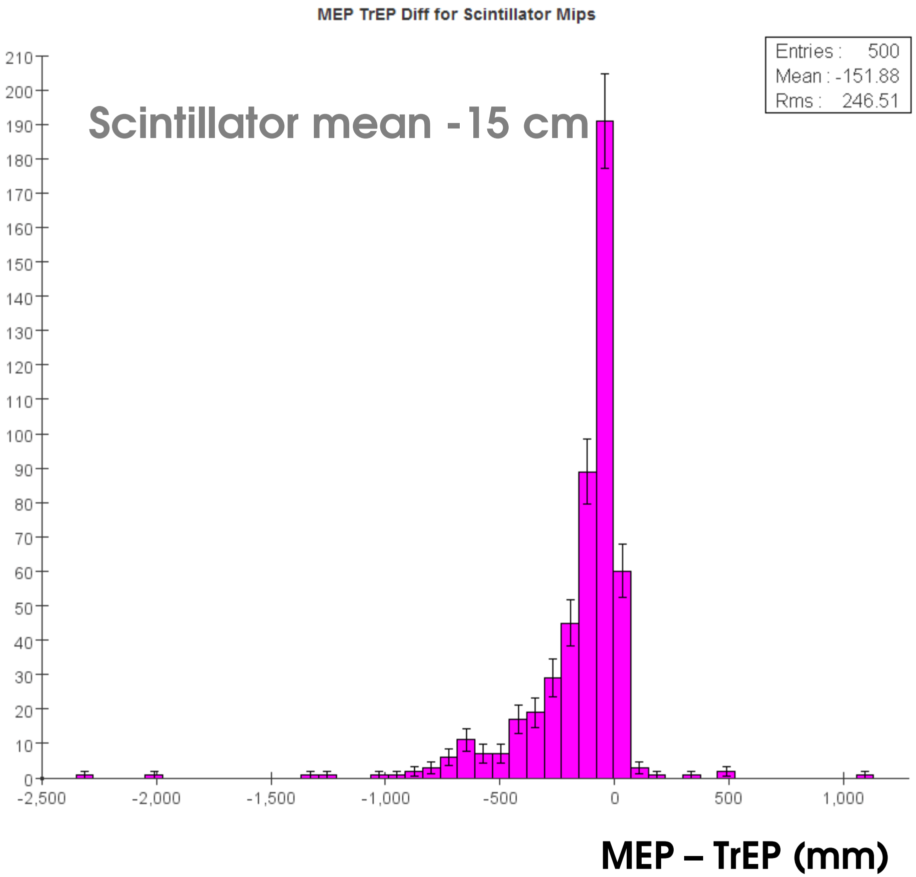
Interaction Layer Comparison

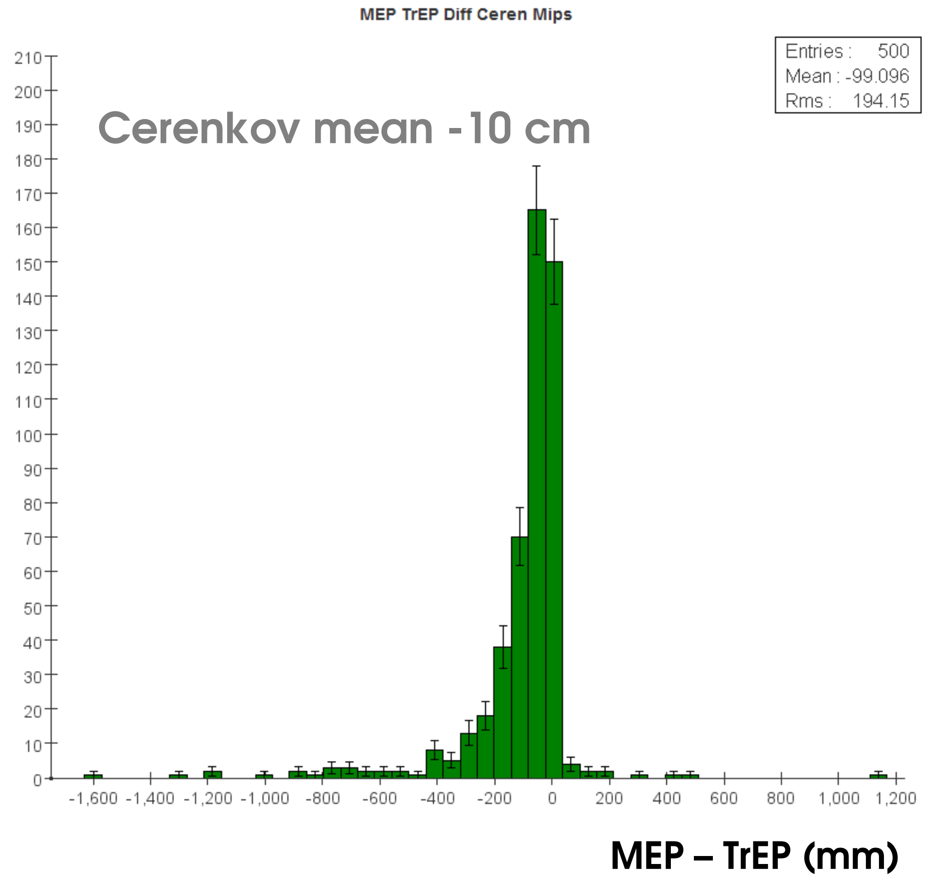




Interaction layer determined by either 0 or multiple hits in layer in a window defined by the position of extrapolated track
~ 1 layer deeper using Cerenkov hits

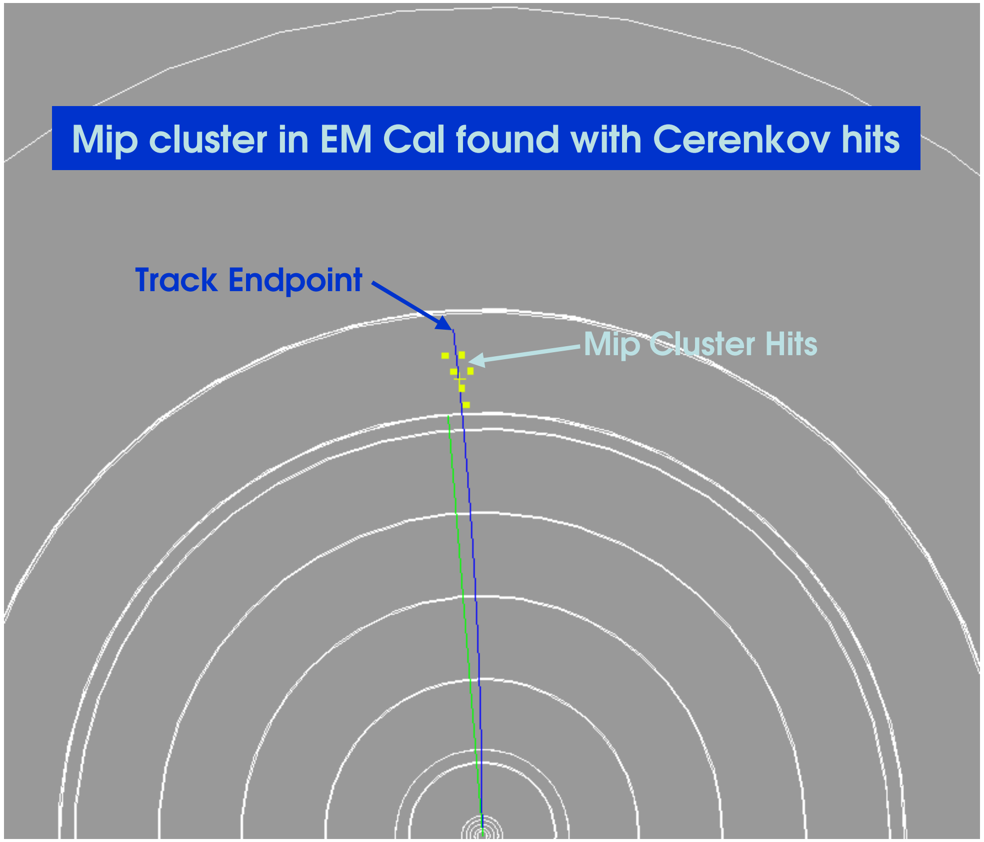
Difference between Mip and Track Endpoints

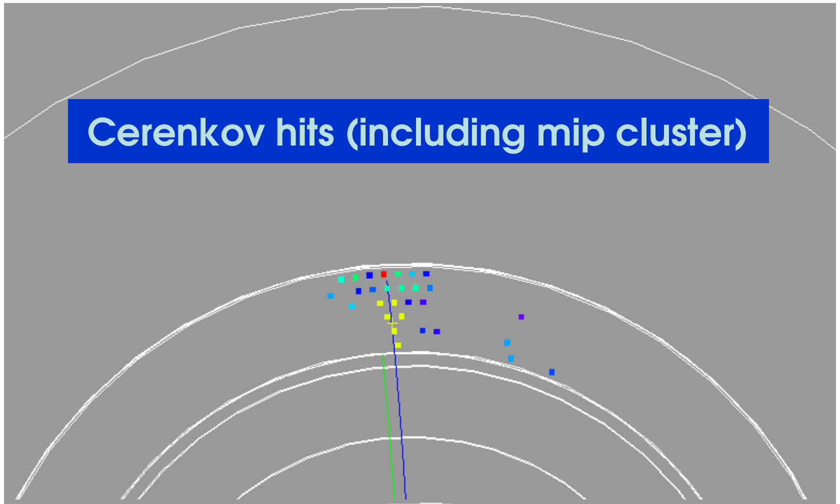


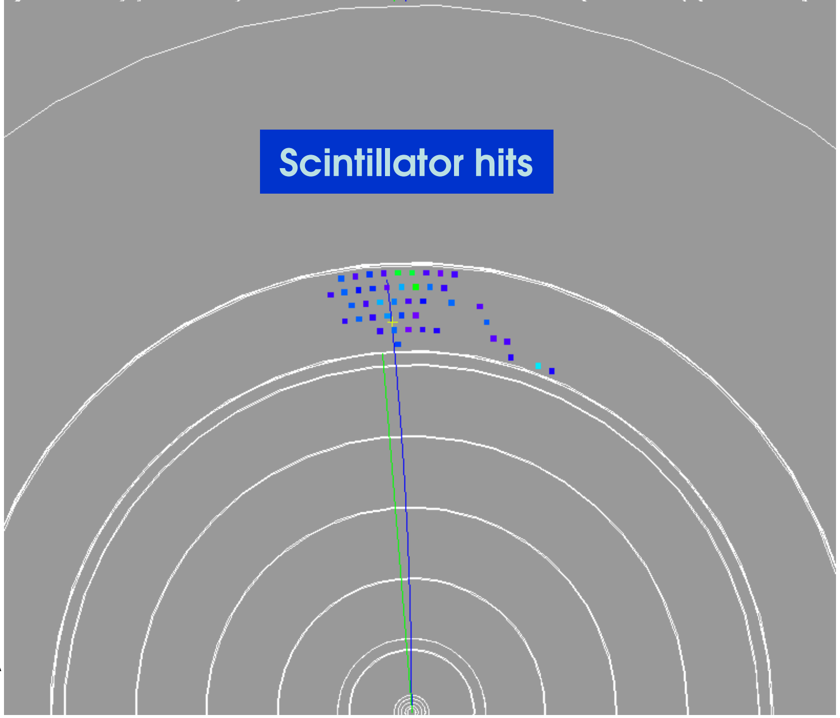


Both Mip EPs shallower than track EP, but average Cerenkov Mip EP closer to track endpoint, again by 5 cm which is 1 layer in the ECAL

Mip Cluster compared to Hit Collections



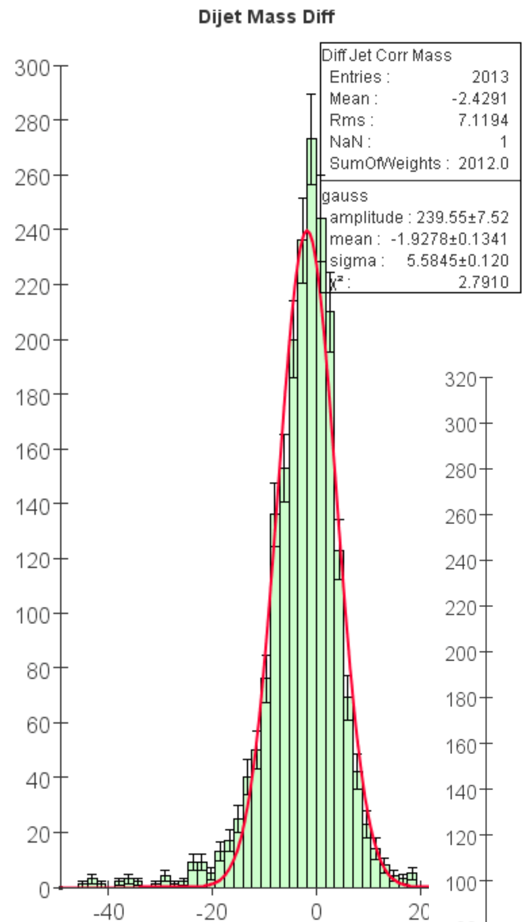




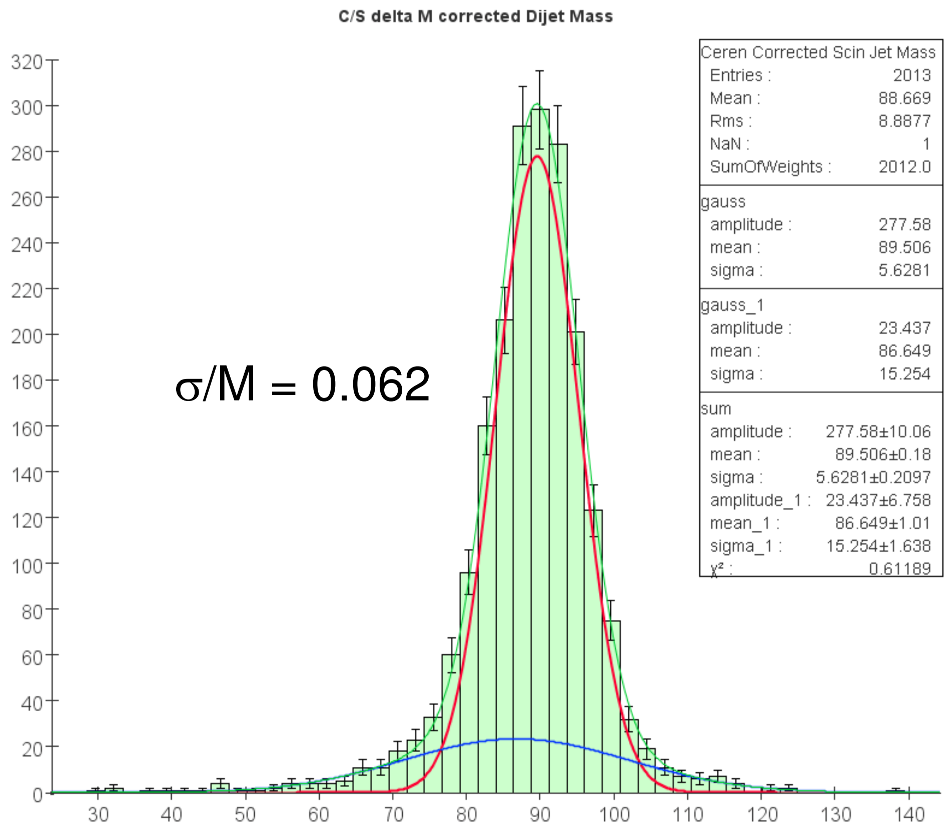
DiJet Mass : e^+e^- -> ZZ -> $q q \nu \nu$ @ 500 GeV

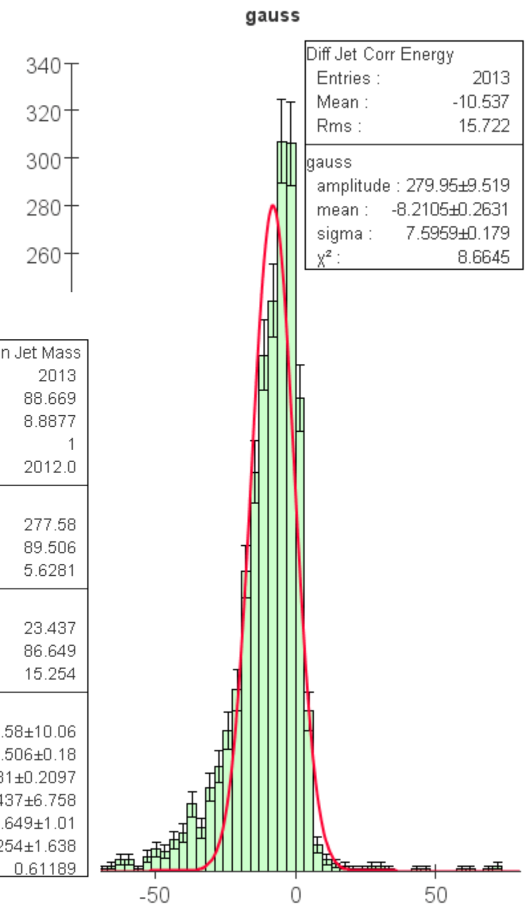
C/S correction per jet

PFA Mip finder -> ΔM per jet



$\Delta M/M = 0.062$





$\Delta E/E = 0.035$

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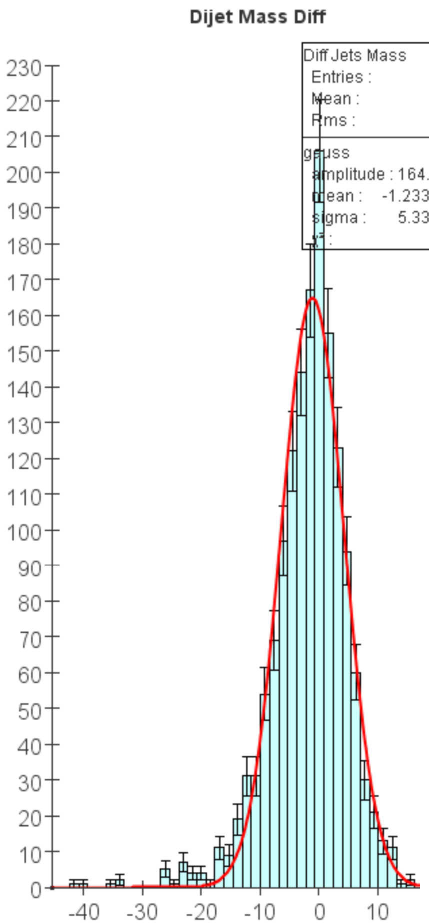
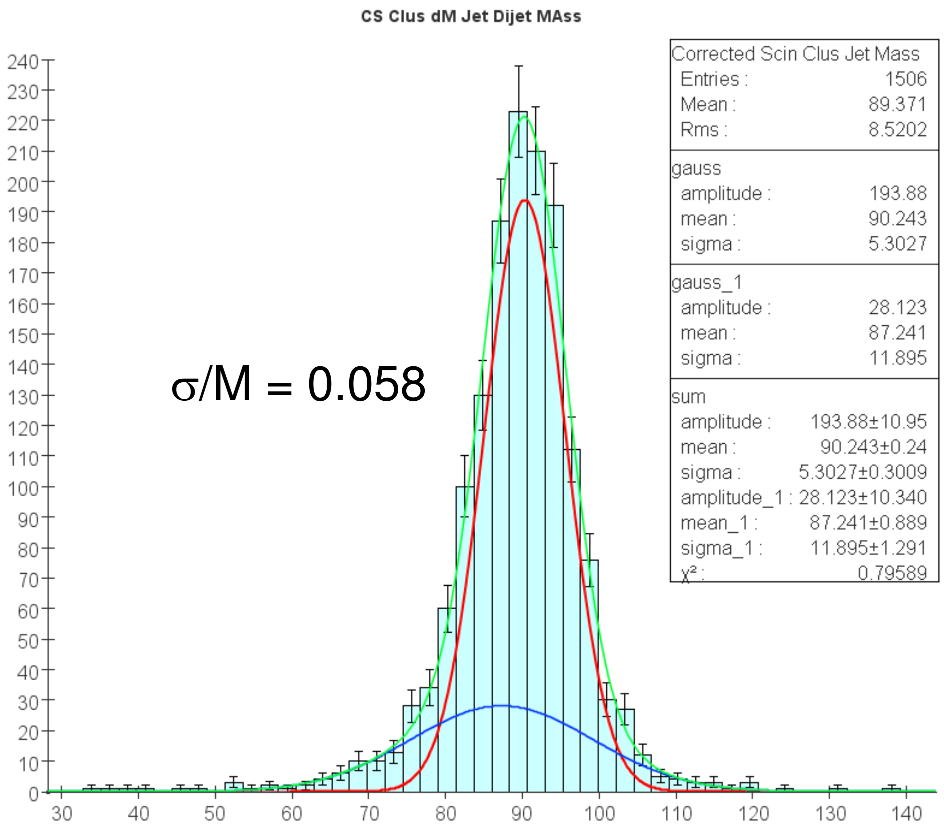
DiJet Mass : e^+e^- -> ZZ -> $qq\nu\nu$ @ 500 GeV

C/S correction per cluster
Jet finding with corr. clusters
PFA Mip finder -> ΔM per jet

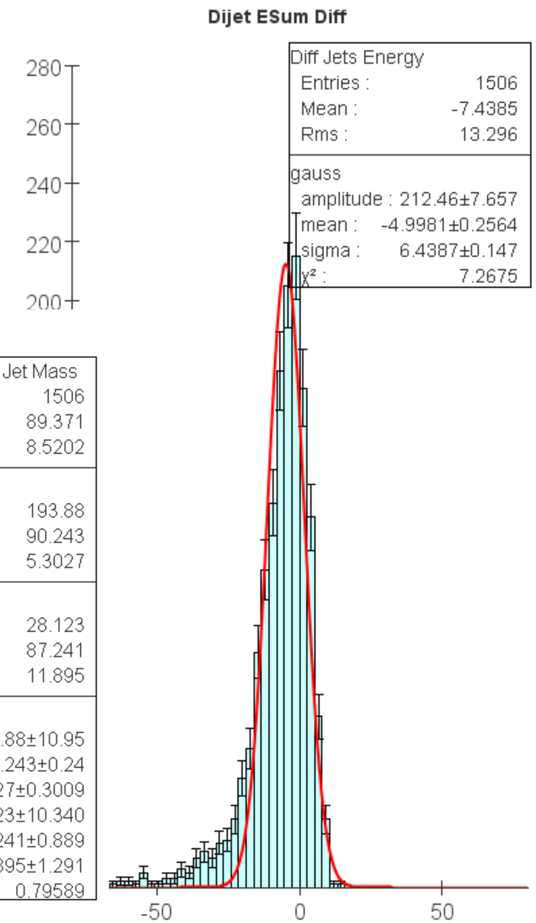


$\Delta M/M = 0.059$



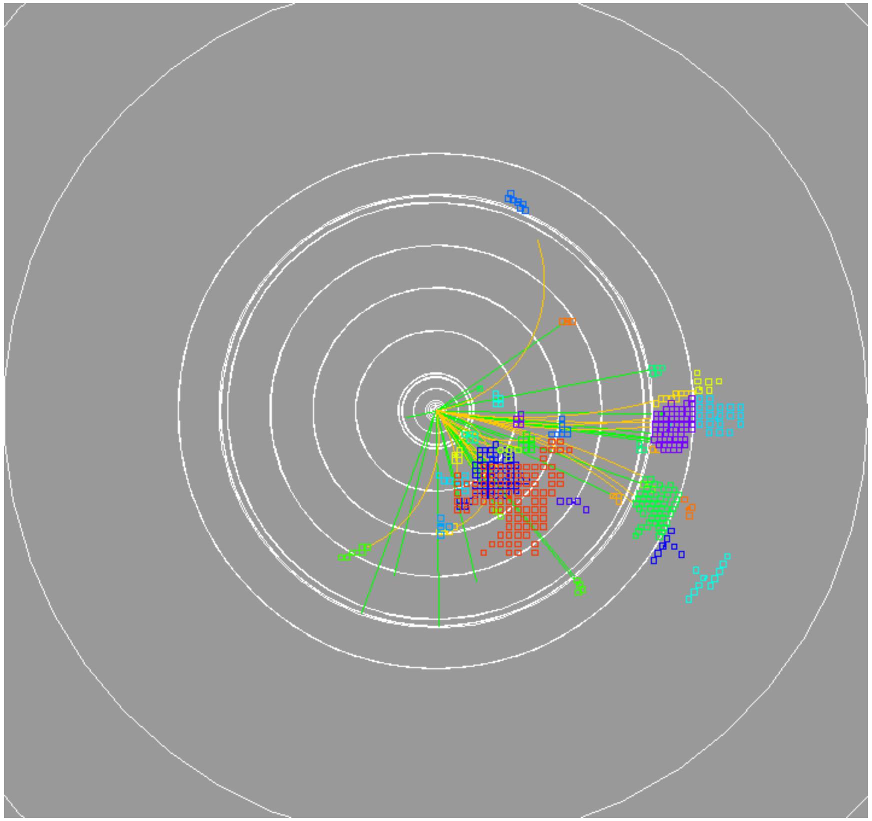
$\sigma/M = 0.058$

M (GeV)

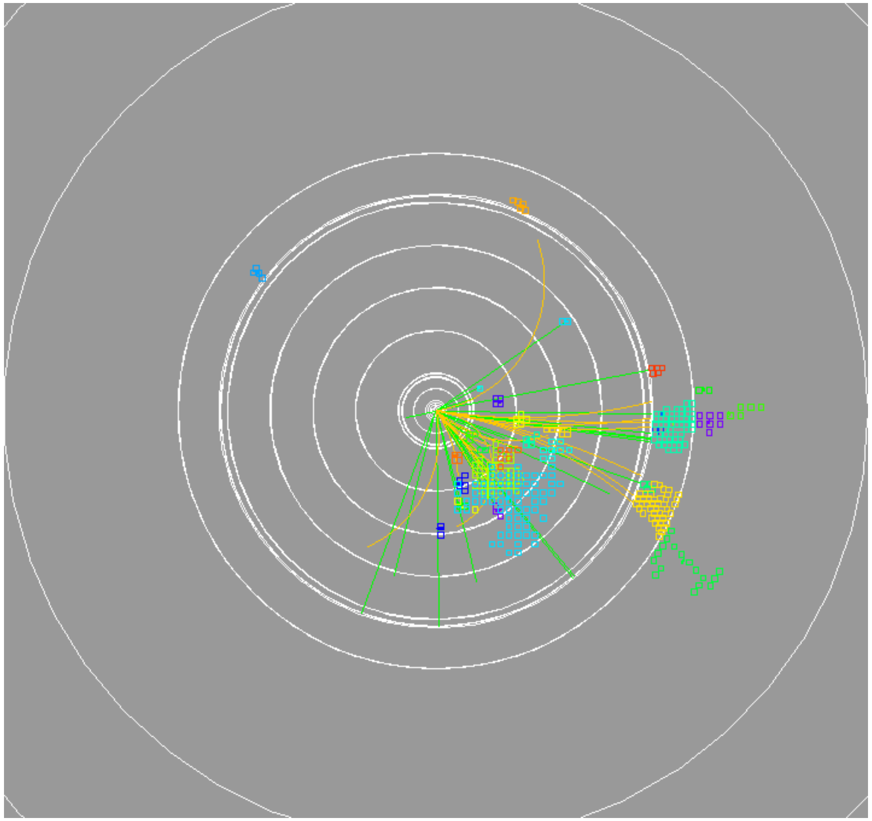


$\Delta E/E = 0.029$

Nearest Neighbor Clustering

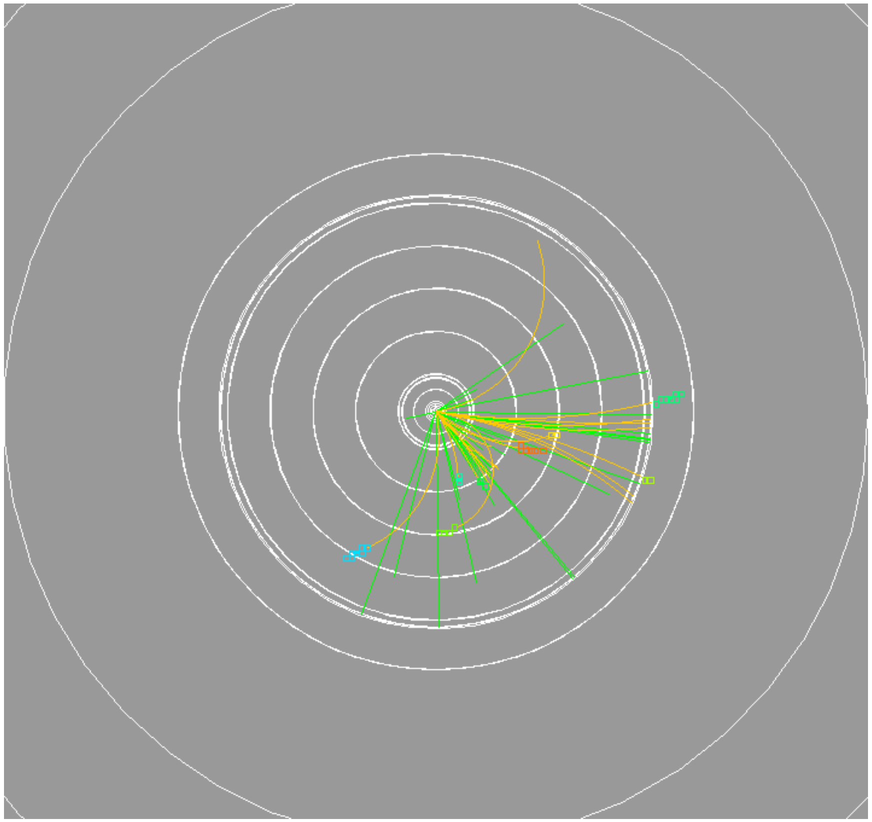


Scintillator Clusters

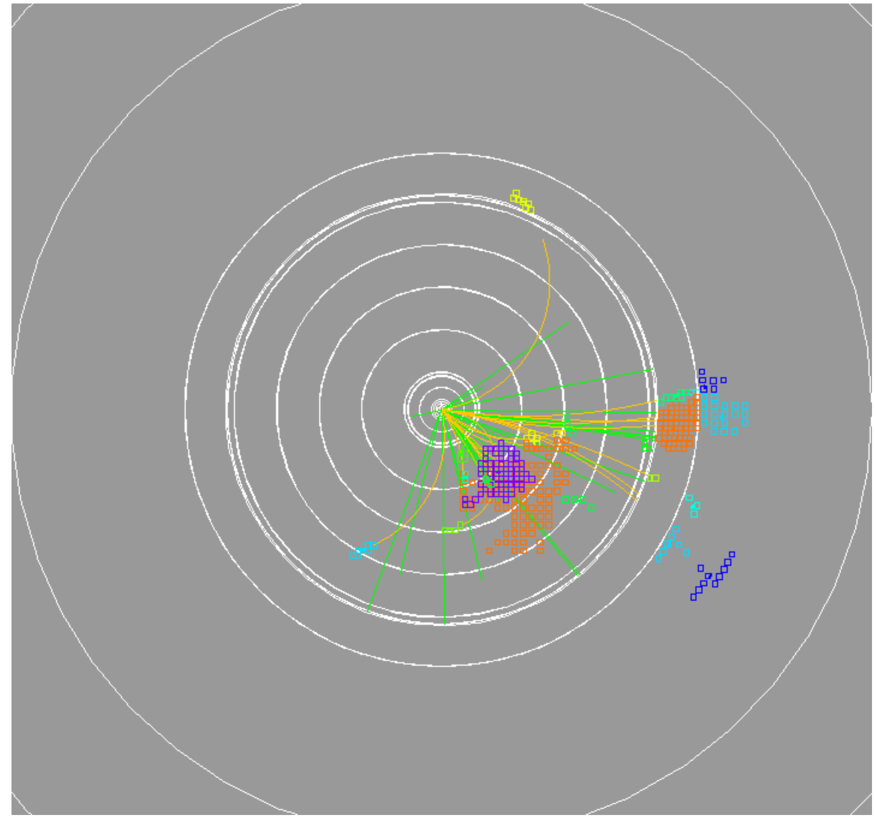


Cerenkov Clusters

Clusters Associated with Charged Particles (Tracks)



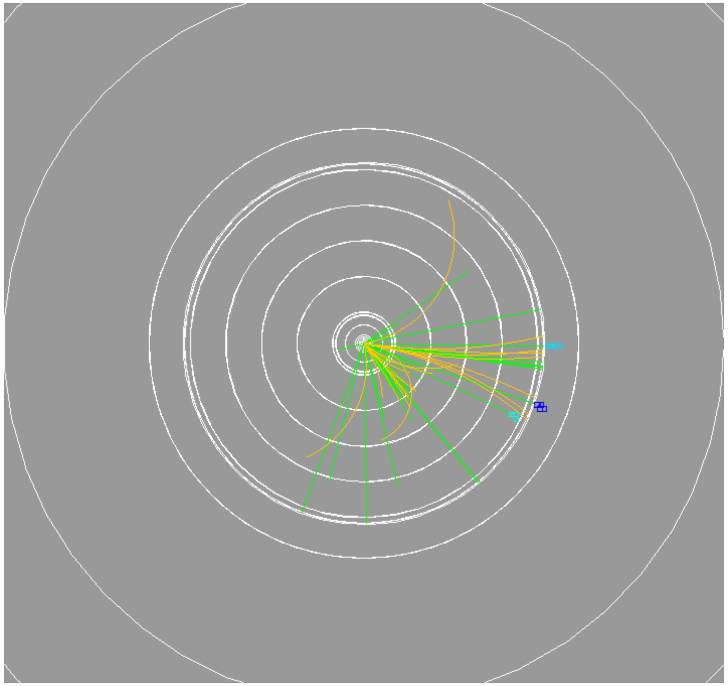
Mip clusters



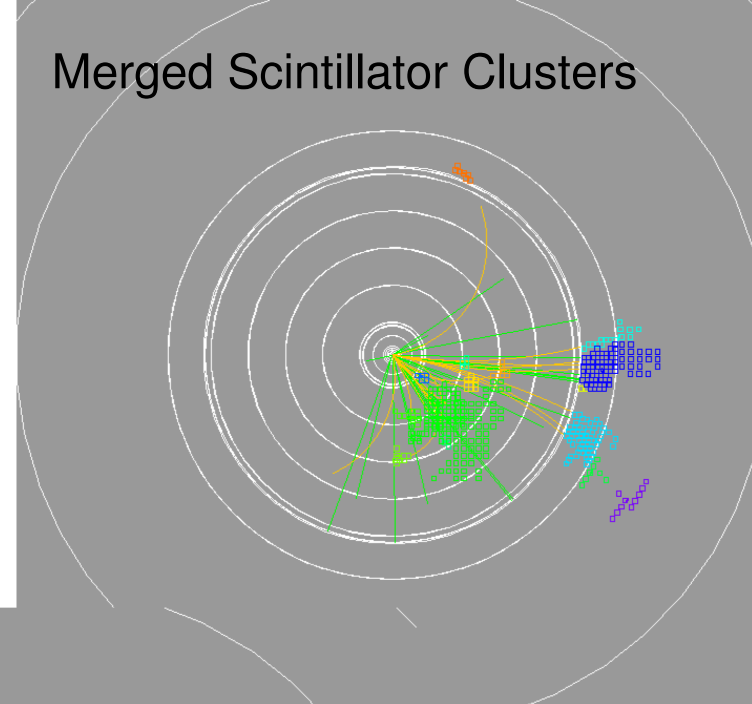
Track-associated clusters

Uses : Core Cluster Algorithm, Cluster-Pointing Algorithm, E/P, etc.

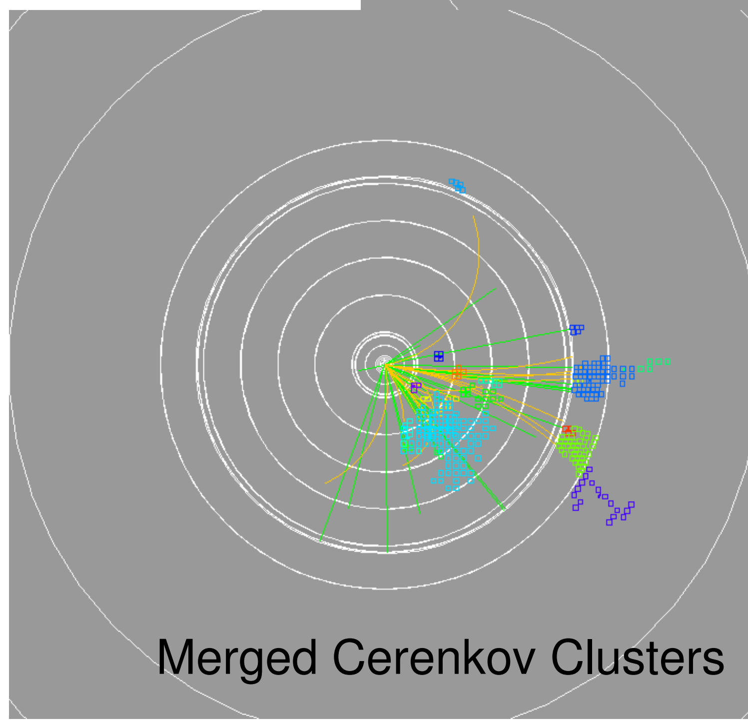
Photon Clusters and Merged Clusters



Photon Clusters



Merged Scintillator Clusters

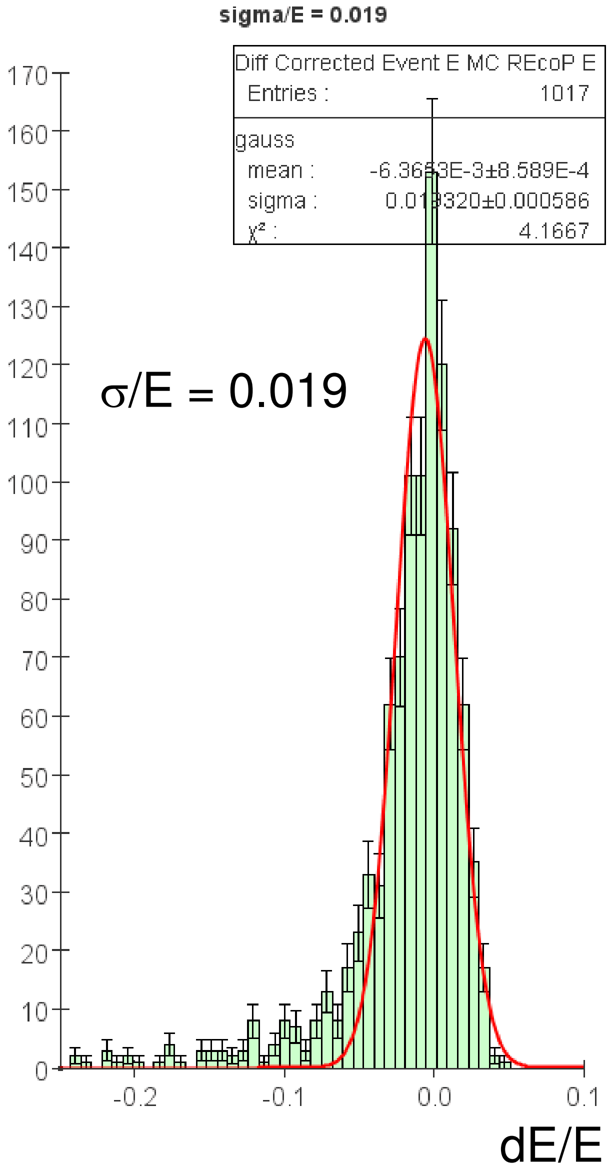


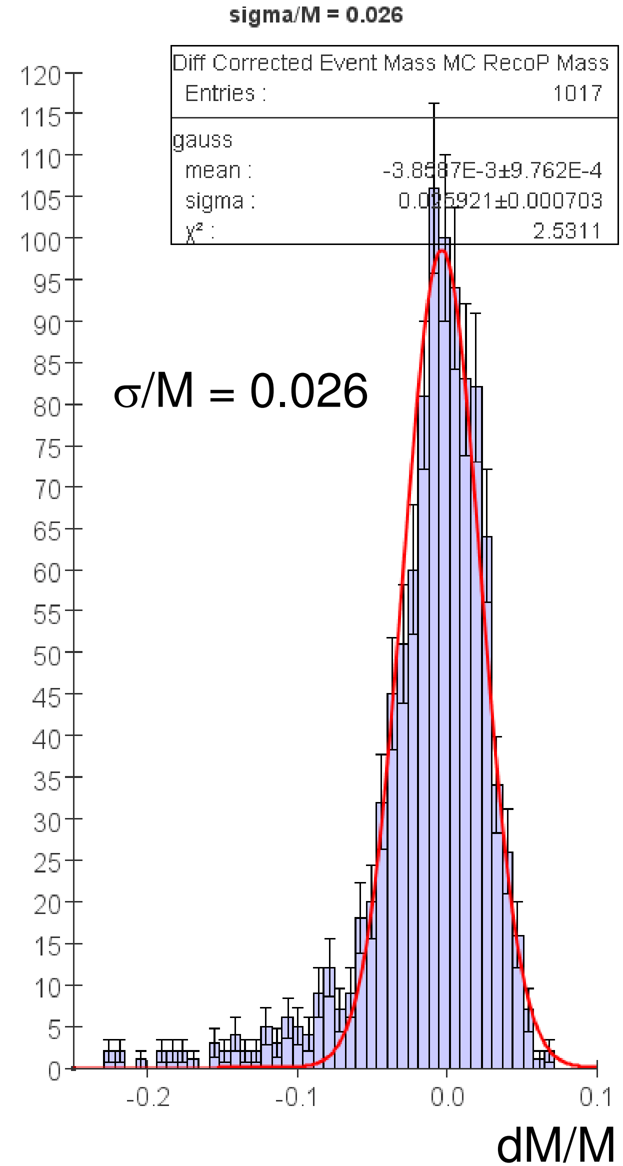
Merged Cerenkov Clusters

Cluster correction – can use merged cerenkov clusters linked with merged scintillator clusters to apply polynomial correction

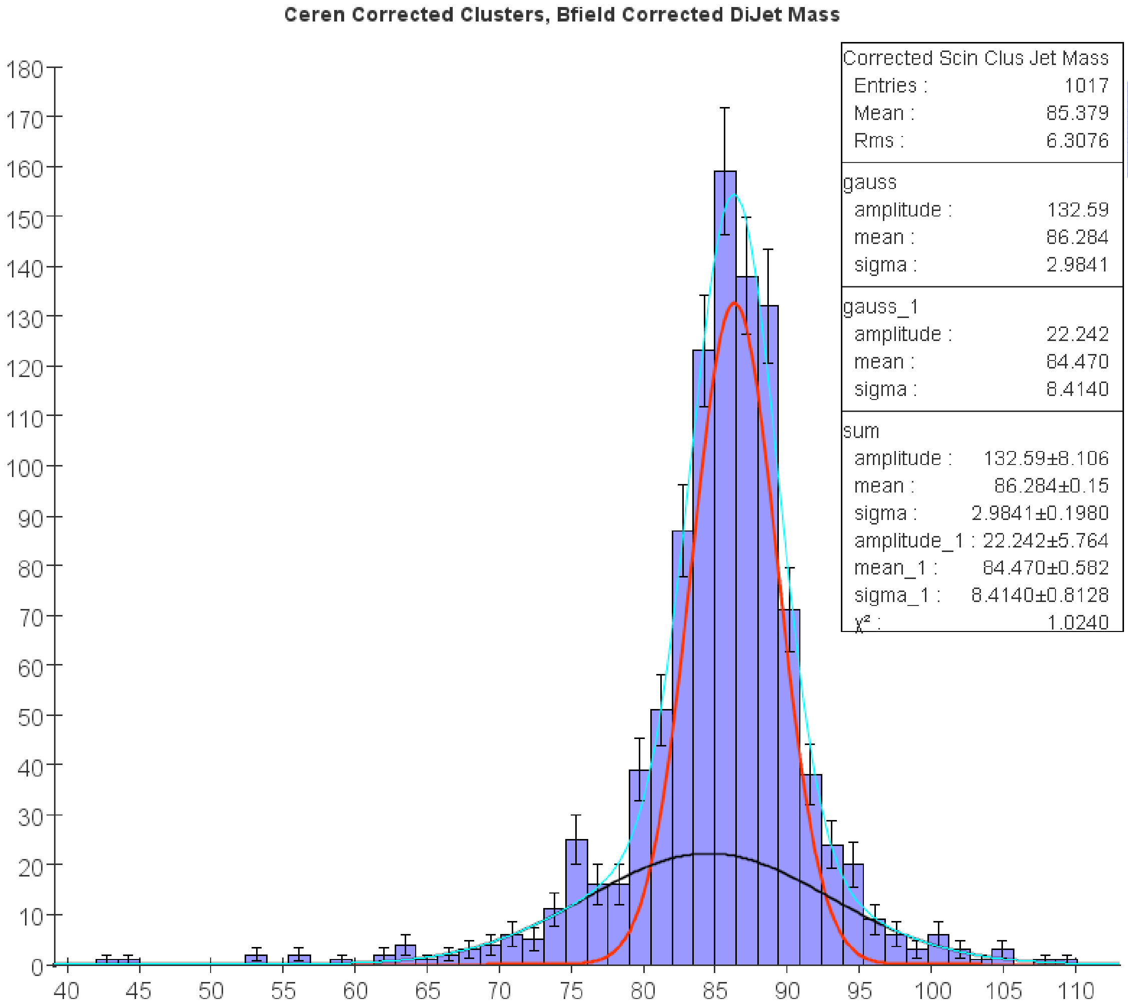
~ Z-Pole performance – C/S + PFA Mip-finder
104 GeV (Total E) Zs @ 90 degrees, Z -> qq

Detector – CCAL002
CAL Threshold – 1/50 mip
CAL Timing cut – 100 ns





Reconstructed Z mass from dijets (fixed 2-jet mode)



σ = 2.98 GeV for Z

$\sigma/M = 0.035$
$\rightarrow 33\%/\sqrt{M}$

Individual cluster (nearest-neighbor) C/S corrections
Jet ΔM correction from PFA Track endpoints

Summary

- ➢ Revised compact.xml and DigiSim to accommodate dual readout calorimeter -> 2 hit collections per readout volume
- ➢ Applied independent thresholds and timing cuts to both collections
- ➢ Calibrated Scintillator and Cerenkov hit colllections with electrons
- ➢ Determined C/S correction polynomial for hadrons by plotting S/E vs C/S for pions
- ➢ Applied polynomial corrections to jets and clusters to obtain dijet mass
- ➢ Used PFA Mip-finder to determine track endpoint and calculate ΔM correction per jet

Plans

Will continue use of PFA modules to associate tracks with calorimeter clusters, replacing the cal clusters with the track 4-vector in jet finder -> reduced ΔM correction per jet

Continue to improve performance and extend to higher e^+e^- CM and higher jet energies

Ultimately determine optimal mix of C/S corrections and PFA applications

PFA Template

Same algorithm (code) used on DR and SiD detectors -> can directly compare PFA performance using same code in different detectors