ATLAS Local Hadron Calibration

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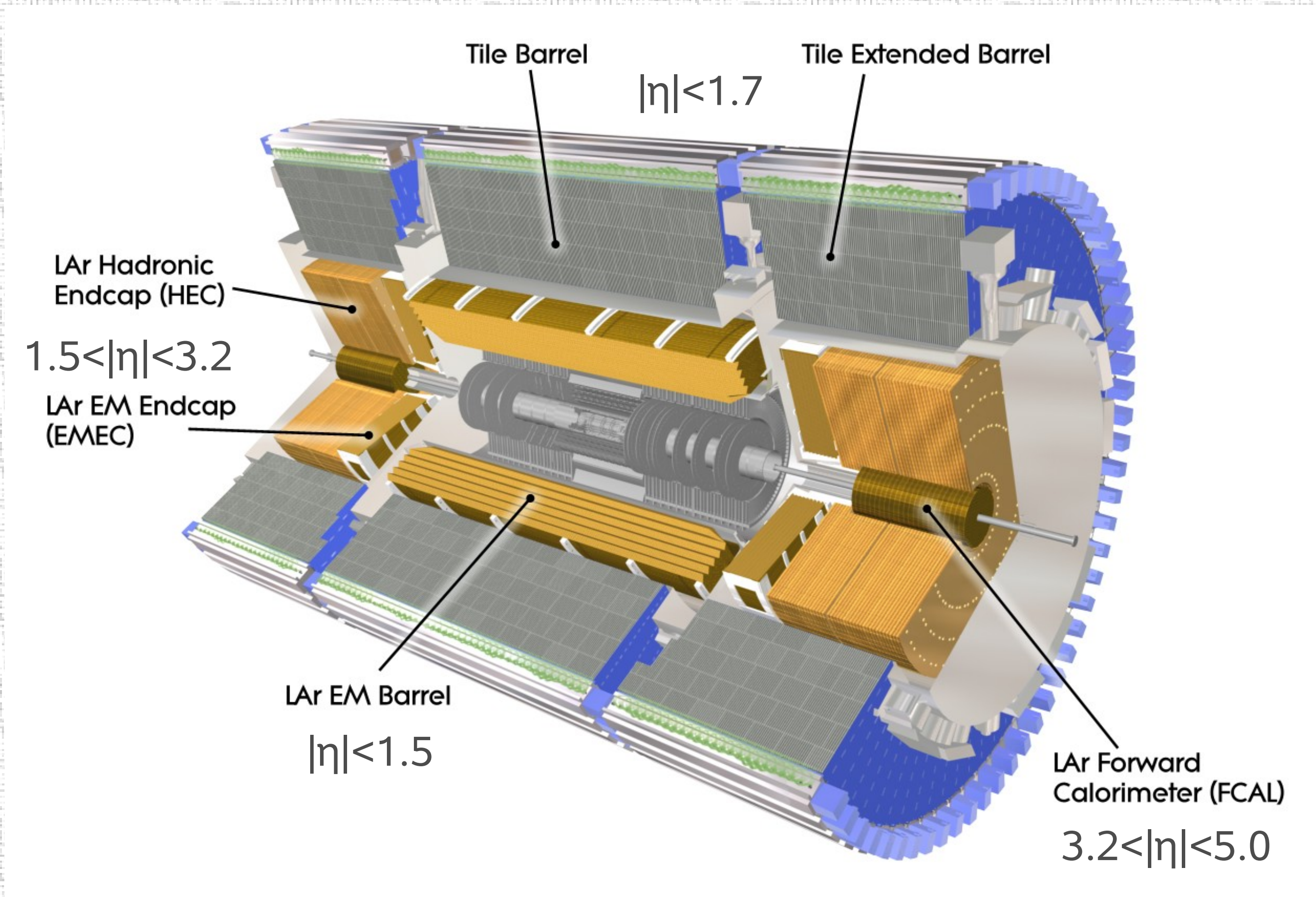
ATLAS calorimeters



EM calorimeters:
coverage up to |η|<5.0

Top mass

Calibration of Jets: from parton to calorimeter signals

Global and local calibration approaches

Calorimeter cells
(em scale)

- 0.1x0.1 fixed size tower building
- tower noise suppression

Calorimeter towers
(em scale)

- Jet finding algorithms
- K_T, Cone, ...

Uncalibrated Jets
(em scale)

- matching a truth particle jet with reco jet
- apply calibration function to all matched jet pairs.

$w_{cell}=f(E_{cell}/V_{cell})$, $w_{jet}=f(E_{jet},\eta)$, ...

- H1-style, Pisa calibration, Pseudo H1

Calibrated Jets
(particle level)

- 3D topological cell clustering
(noise suppression included)

Topo clusters
(em scale)

Local Hadron Calibration

Topo clusters
(HAD scale)

- Jet finding algorithms
- K_T, Cone, ...

Calibrated Jets
(particle level)

Final in-situ calibration

- $tt \rightarrow WbWb \rightarrow l\nu j_b jjj_b$, ...

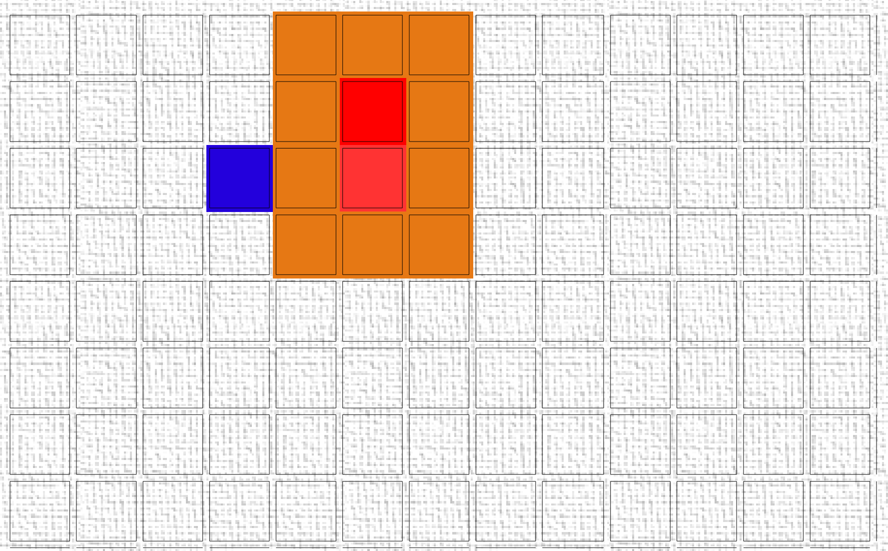
Calibrated jets
(parton level)

Local Hadron Calibration Schema

3-d topological clusters with cells at em scale.	• topo clusters is efficient tool to supress electronic and pile up noise • $N_{particle}/N_{clusters}=1.6$ in jet context
Classify clusters as EM, HAD or Unknown	• classification to identify em/non-em part of the shower • relay on cluster calorimeter depth and cluster energy density
cluster calibration	• H1-style hadronic weighting of clusters classified as HAD
out-of-cluster correction	• correction for energy deposited in calorimeter cells outside of any cluster
dead material correction	• correction for dead material deposits in front and between calorimeter modules
calibrated clusters	

- Calibration is independent of any jet algorithm; defines the same hadronic scale for all signals (missing E_T, jets, τ's).
- Factorization of different effects (e/h, out-of-cluster, dead material...).
- Based on single pions simulation.

Topological cell clusters



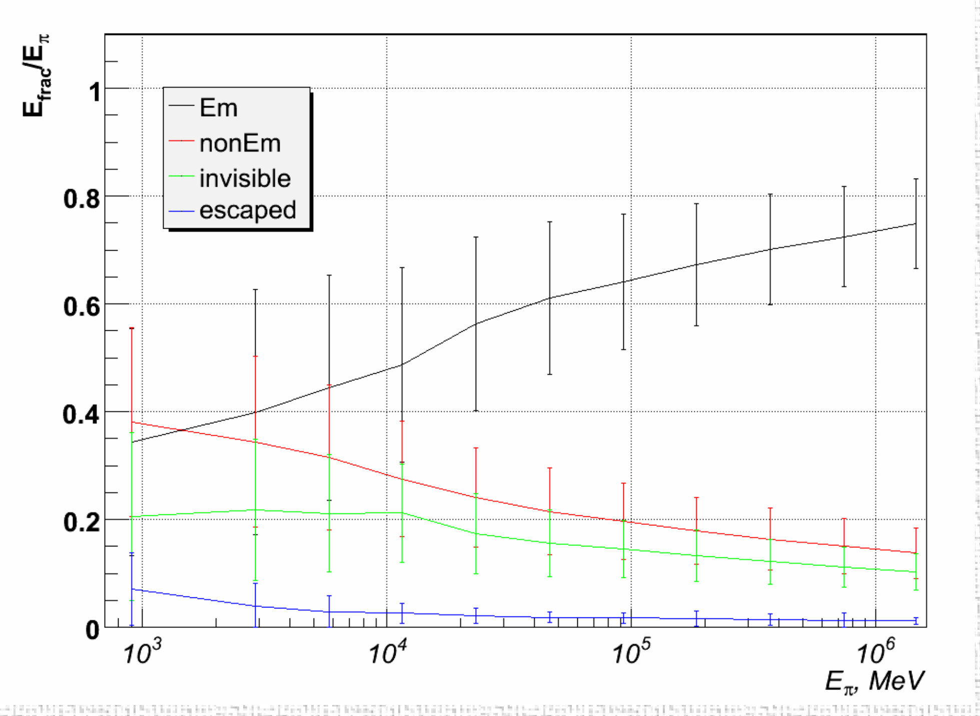
Calibration hits

Calibration hits are implemented into ATLAS Geant4 simulation to save 4 energy categories:

EM ($e^{\pm}$, γ)	O(50%)
nonEM (dE/dX from $\pi^{\pm}$, $\mu^{\pm}$)	O(25%)
Invisible (nuclei excitation)	O(25%)
Escaped (ν)	O(2%)

for each calorimeter cell:

active cells (LAr)
inactive cells (Absorber)
dead material cells
(i.e. virtual cells containing inactive material outside calorimeter cell volumes, with 0.1x0.1 typical granularity)



Calibration energies depends on pion energy and are the subject of big fluctuation.

Total sum of EM+*nonEM+invisible+escaped* energies in all active/inactive/dead material calibration hits == total energy of generated primary particles.

Classification

The goal of classification is identify EM and non-EM parts of the shower for later applying of correction (weighting) to non-EM part.

High average cell energy density $\langle\rho_{cell}\rangle$ in cluster and small calorimeter cluster depth λ denotes EM nature of the cluster.

$\langle\rho_{cell}\rangle$ and λ cluster moments are used to populate appropriate 2D phase spaces; data from single π^+, π^- and π^0 simulation are used to calculate probabilities.

$$w = \left(\frac{N^i_{\pi^0}}{\sum N_{\pi^0}}\right) / \left(\frac{N^i_{\pi^0}}{\sum N_{\pi^0}} + 2\,\frac{N^i_{\pi^-}}{\sum N_{\pi^-}}\right)$$

, where $N^i_{\pi^{\pm 0}}$ is number of events in given phase-space point.

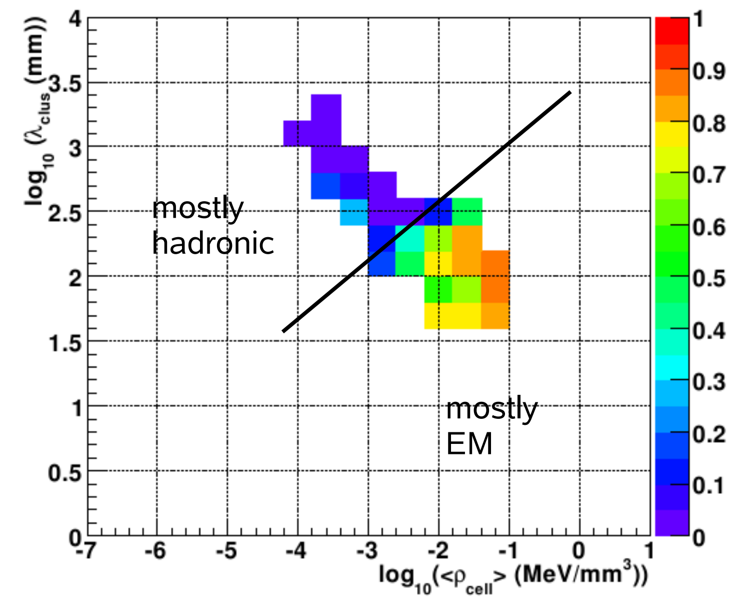
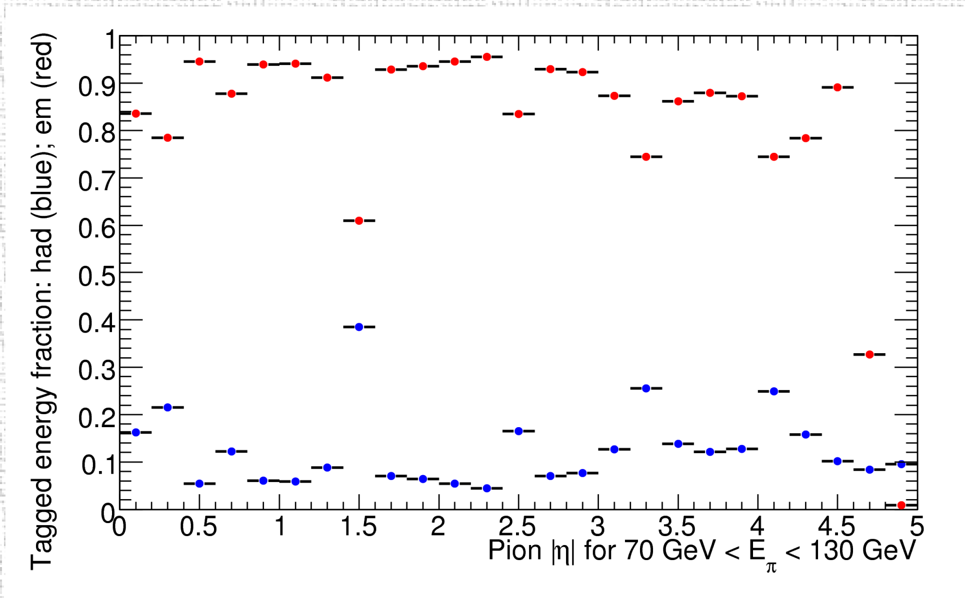
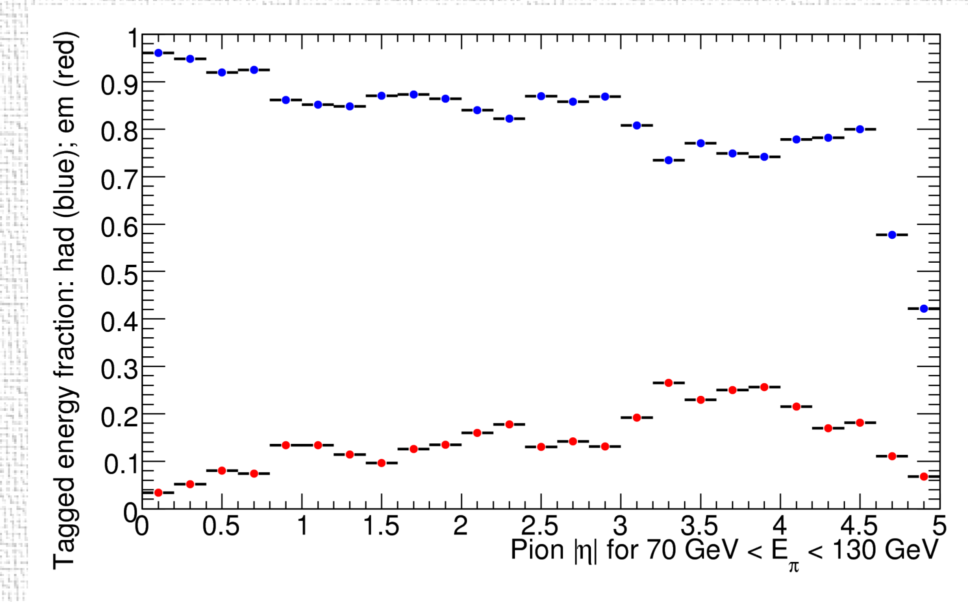


Table of probability for cluster to be hadronic
$2.0<|\eta|<2.2$, $4\text{GeV} \leq E_{clus} < 16$ GeV

On reconstruction stage cluster will be treated as hadronic if lookup value for w *at a* given cluster phase-space point < 0.5.

Classification





Energy fractions of single pions with 70 GeV <E < 130 GeV classified as electromagnetic (red) or hadronic (blue) as a function of the pion |η| averaged over all Φ.

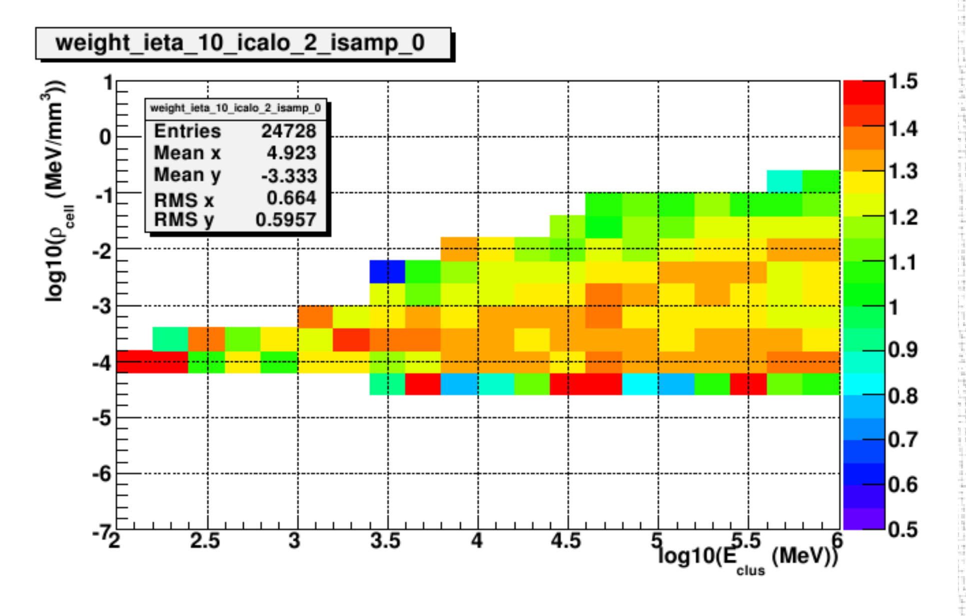
Weighting

$$E'_{cell} = w \cdot E_{cell},$$
$$w = \left\langle \left(E^{Em}_{cell} + E^{nonEm_{vis}}_{cell} + E^{nonEm_{invis}}_{cell} + E^{escaped}_{cell} \right) / \left(E^{Em}_{cell} + E^{nonEm_{vis}}_{cell} \right) \right\rangle$$

Readout cell weights to account for invisible energy are derived from Geant4 simulation true energy deposits in LAr+Absorber (calibration hits).

Weights are done as a function of cluster energy E_{cls} and average cell energy density $\langle\rho_{cell}\rangle$, for set of η regions and each longitudinal sampling.

Weights are applied only to the clusters classified as hadronic.



Hadronic cell weight table for 2.0<|η|<2.2, HEC layer 1

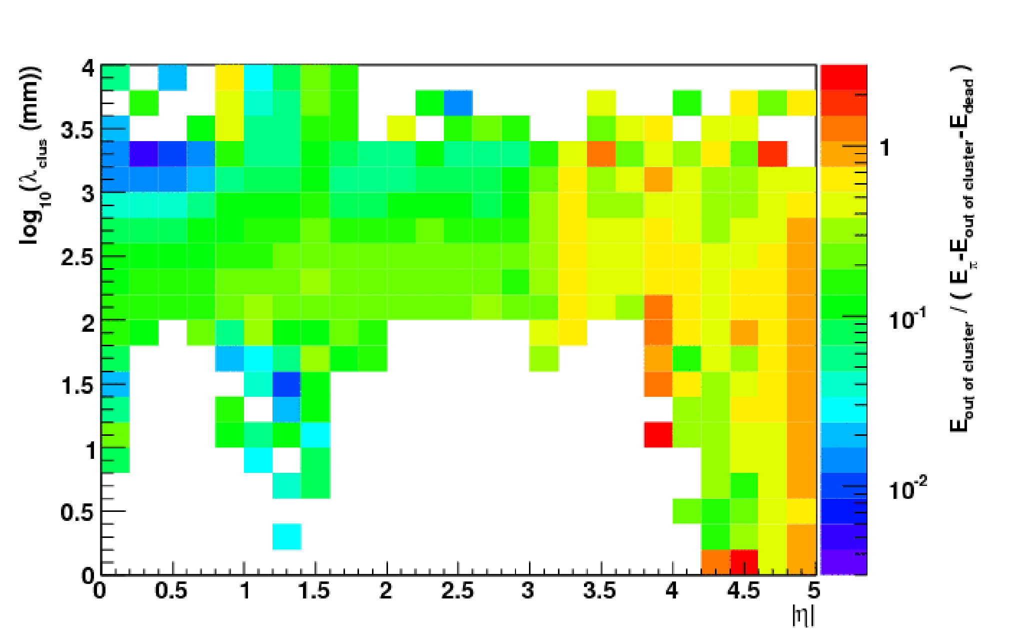
Out-Of-Cluster correction (OOCC)

Accounts for energy deposited in cells which are not part of any cluster.

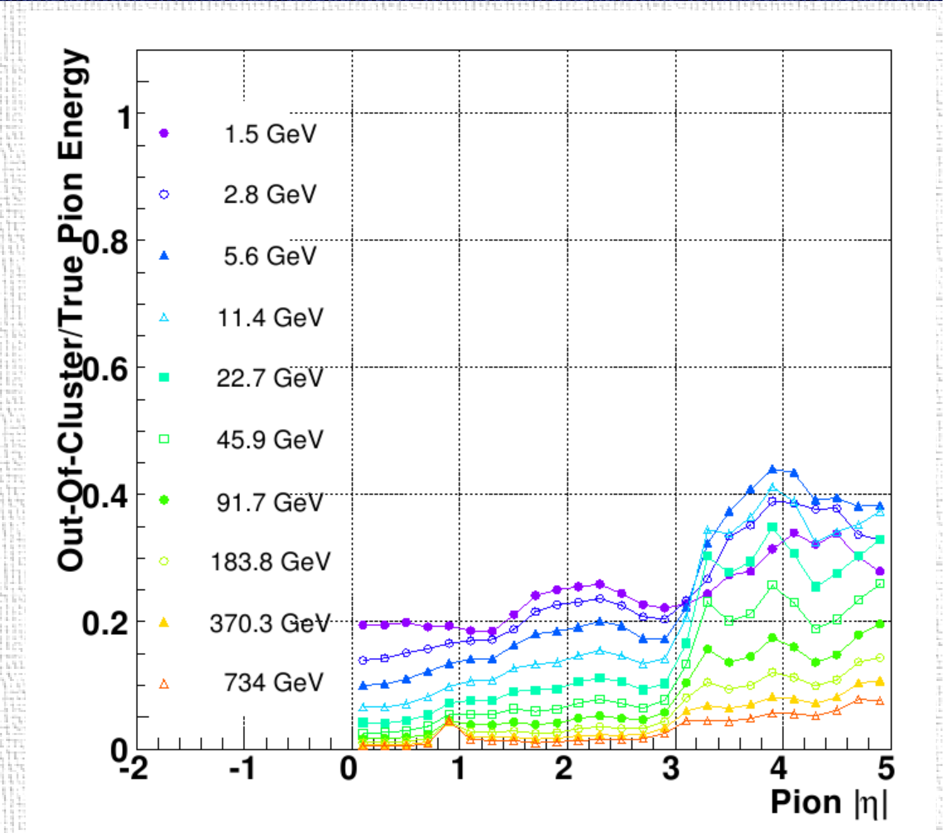
- derived from single pion simulation
- use calibration hits info
- correction factor is $$\left(1+\frac{E_{ooc}}{E_{cluster}}\right)$$

OOC energy stored in look-up tables

- E, |η|, λ bins



GeV E< 16GeV



OOC energy ratio for single π^- at different energies.vs. |η|

Out-Of-Cluster correction (OOCC)

Over correcting problem

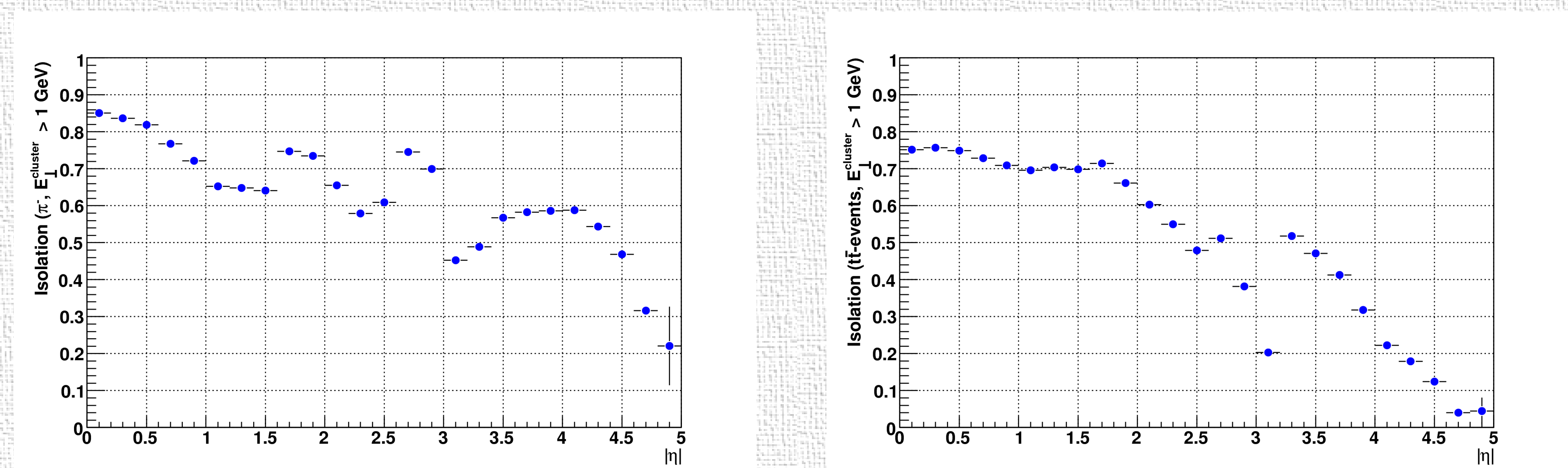
- OOC energy for one cluster could actually be deposited in another cluster.
- especially important for jets

Cluster isolation moment

- fraction of cells on the outer cluster perimeter that are not included in other cluster

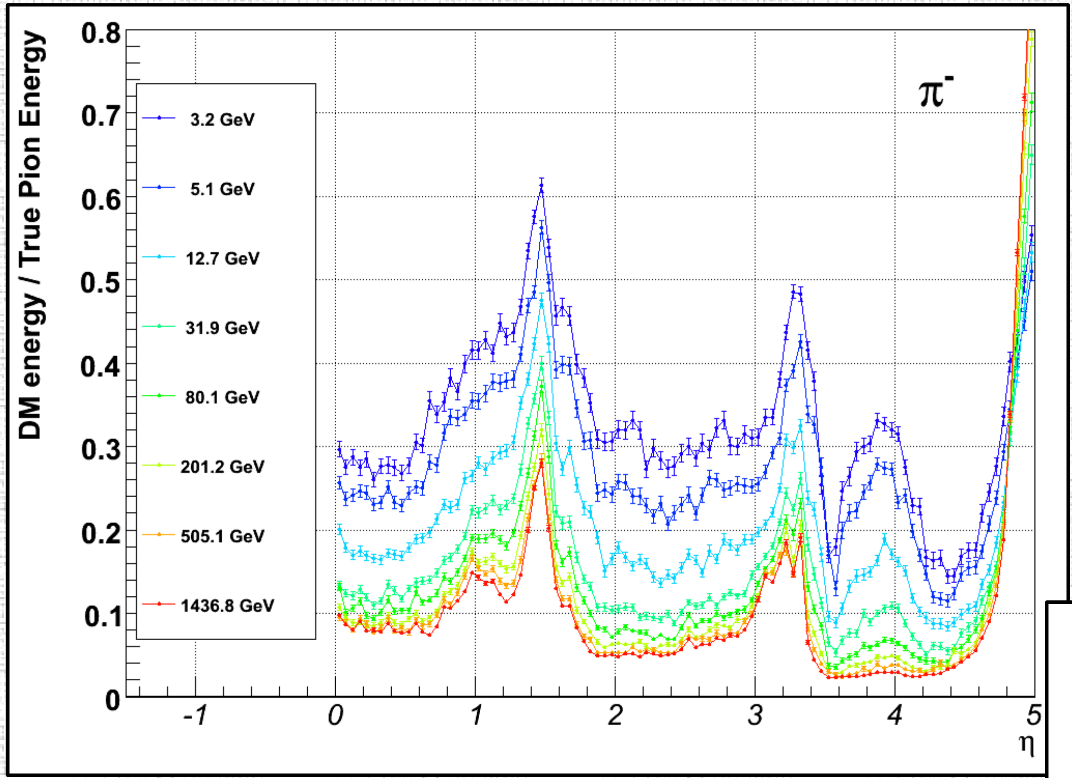
Out-of-cluster correction final estimate

- it's a product of OOC correction from look-up table and cluster isolation moment
- Correction is applied as a multiplicative factor to all cells in the cluster



Level of isolation for clusters above 1GeV versus |η| for single charged pion (left) and tt sample

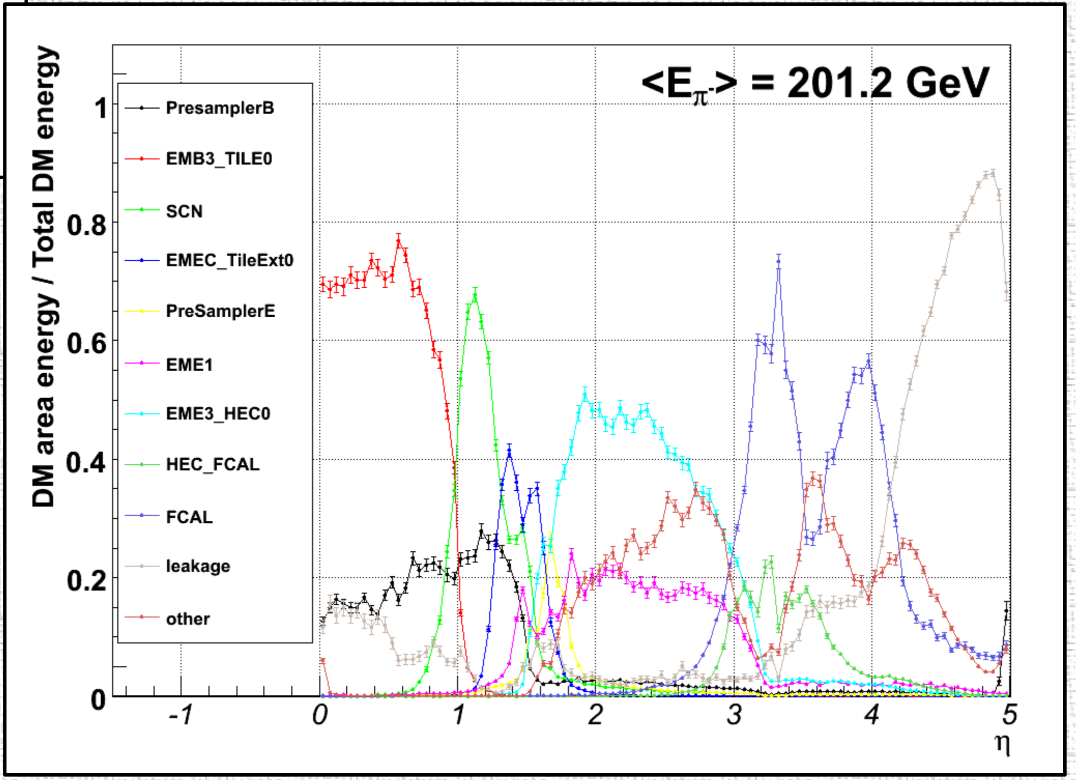
Dead material correction



Dead material (DM) correction accounts for energy deposited outside of active calorimeter volumes.

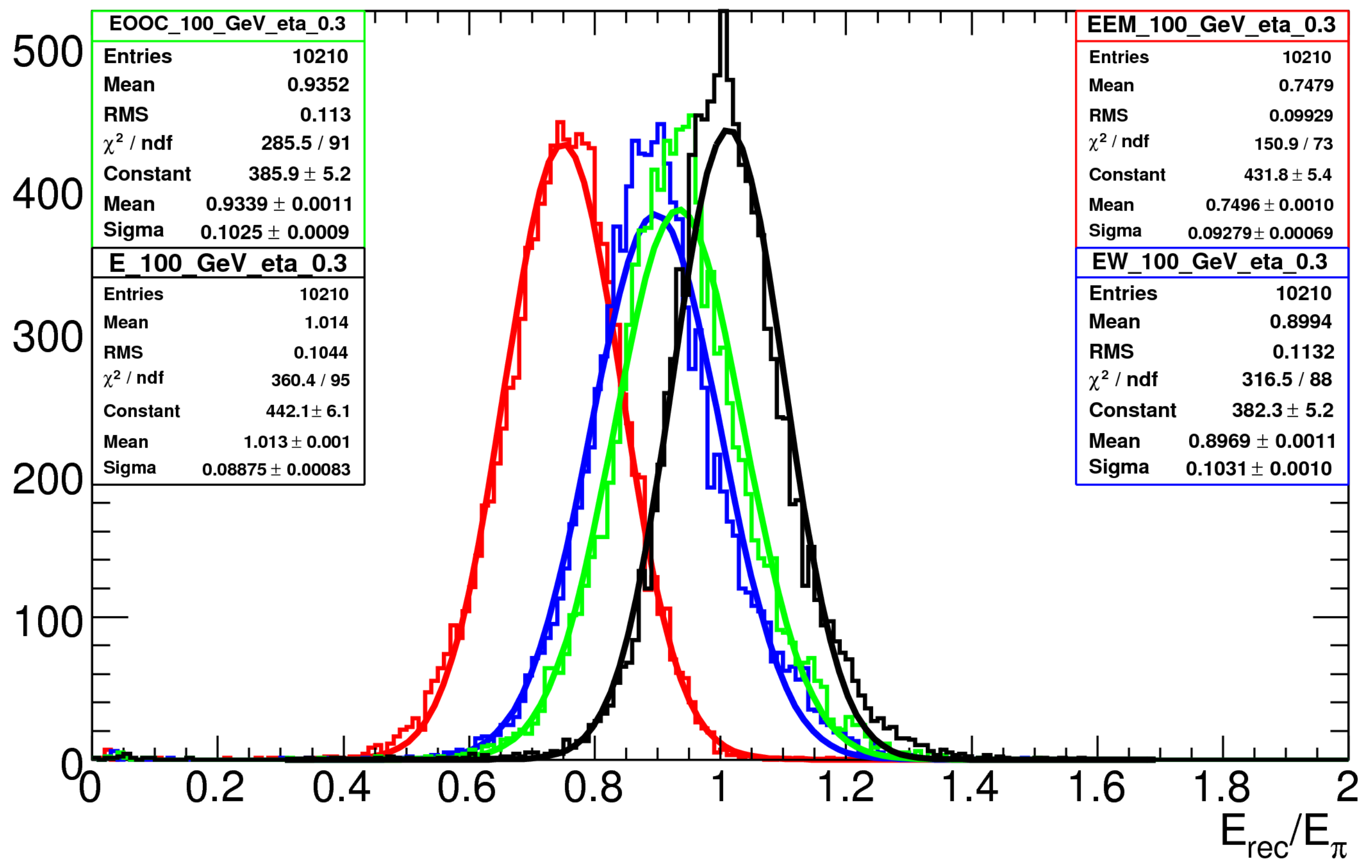
< Average ratio of DM energy to the beam energy versus |η| for charged single pions at different energies (calibration hits).

Ratio of DM energy deposited in different detector parts ("DM areas") >

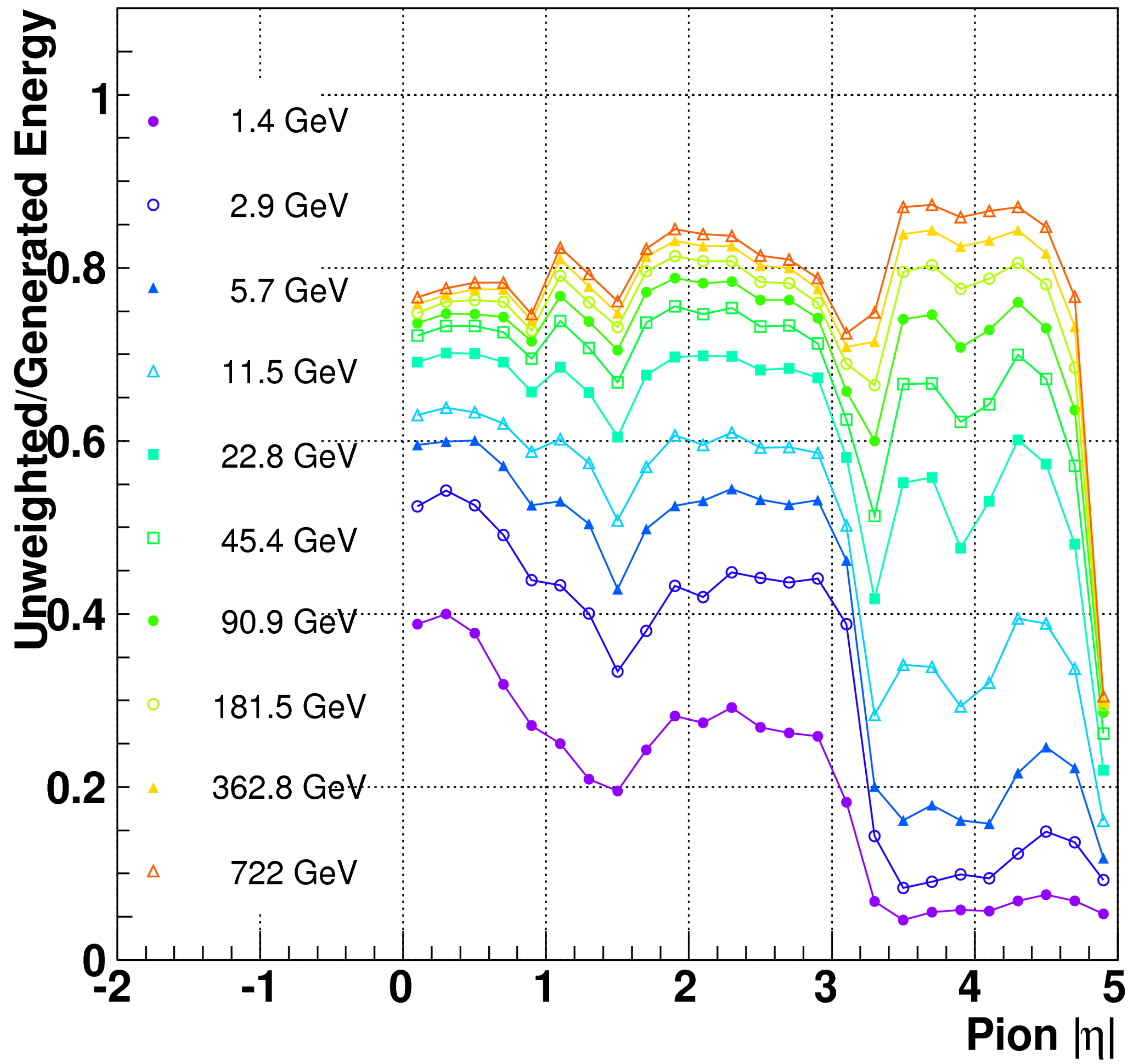


Dead material correction

Performance 1



Performance 2



Conclusion

Local Hadron Calibration is called to deal with non-compensating nature of hadron calorimeter.

It consists of 4 steps:
- Classification, weighting, out-of-cluster correction, dead material correction.

Factorization of these effects simplifies the future validation.

Calibration provides jet algorithms with calibrated constituents and defines the same hadronic scale for all signals.

Current jet scale provided by local hadron calibration is 8% off which is explained by misclassification (3%), calorimeter inefficiency for low energetic pions (3%) and out-of-jet effects (2%).