Hadronic Calibration of the ATLAS Calorimeter

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for the ATLAS Hadronic Calorimeter Calibration Group

Introduction
Jet Energy Scale / Local Hadronic Calibration
Dead Material Correction
Conclusion

Introduction

- Jets important ingredient for many physics analysis: QCD, top, searches, Higgs, ...
- jets made out of hadrons – in ATLAS response different than for electrons !
- non-compensating calorimeters in ATLAS require software calibration of calorimeter

Introduction, cont'd

- precision physics at LHC : PDG(2005)
  top mass to 1 GeV (~0.5%) 178 ± 4.3 GeV
  W mass to 20 MeV (~0.025%) 80.425 ± 0.038 GeV

- precise knowledge of response of calorimeters necessary $Z_0 \to e^+e^-$ @~1Hz

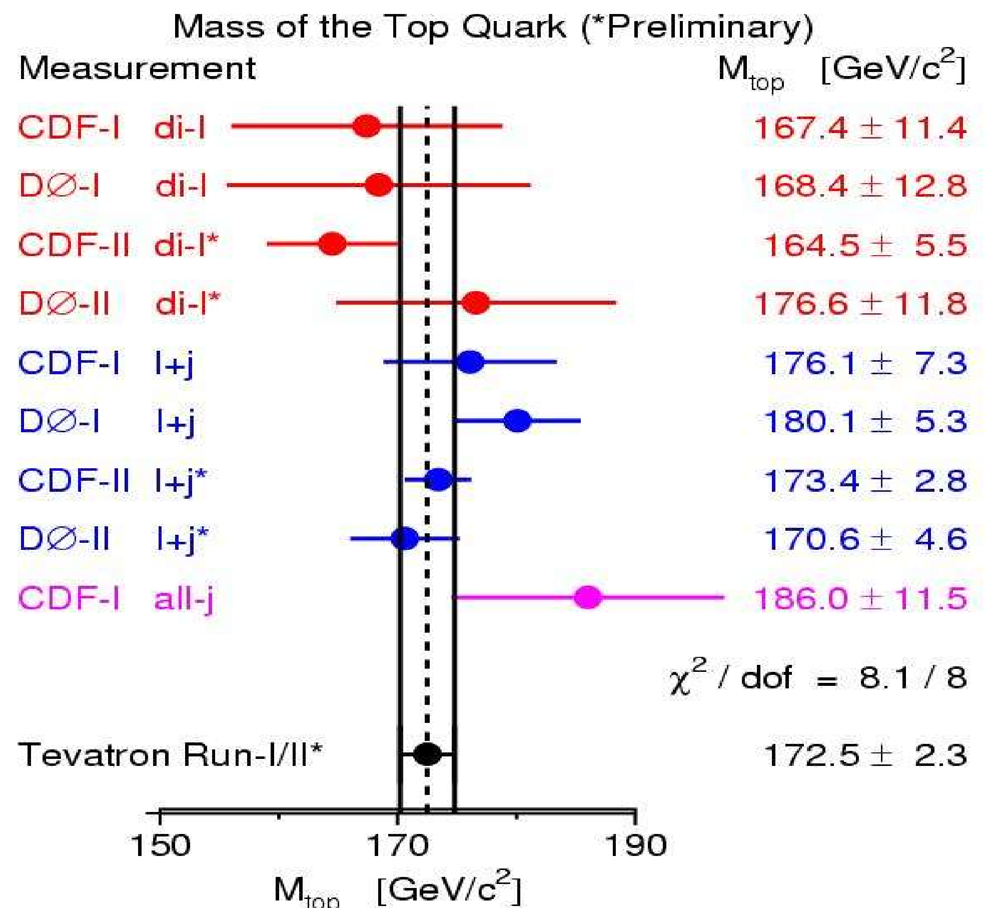
- precise knowledge of response of calorimeters to hadrons necessary

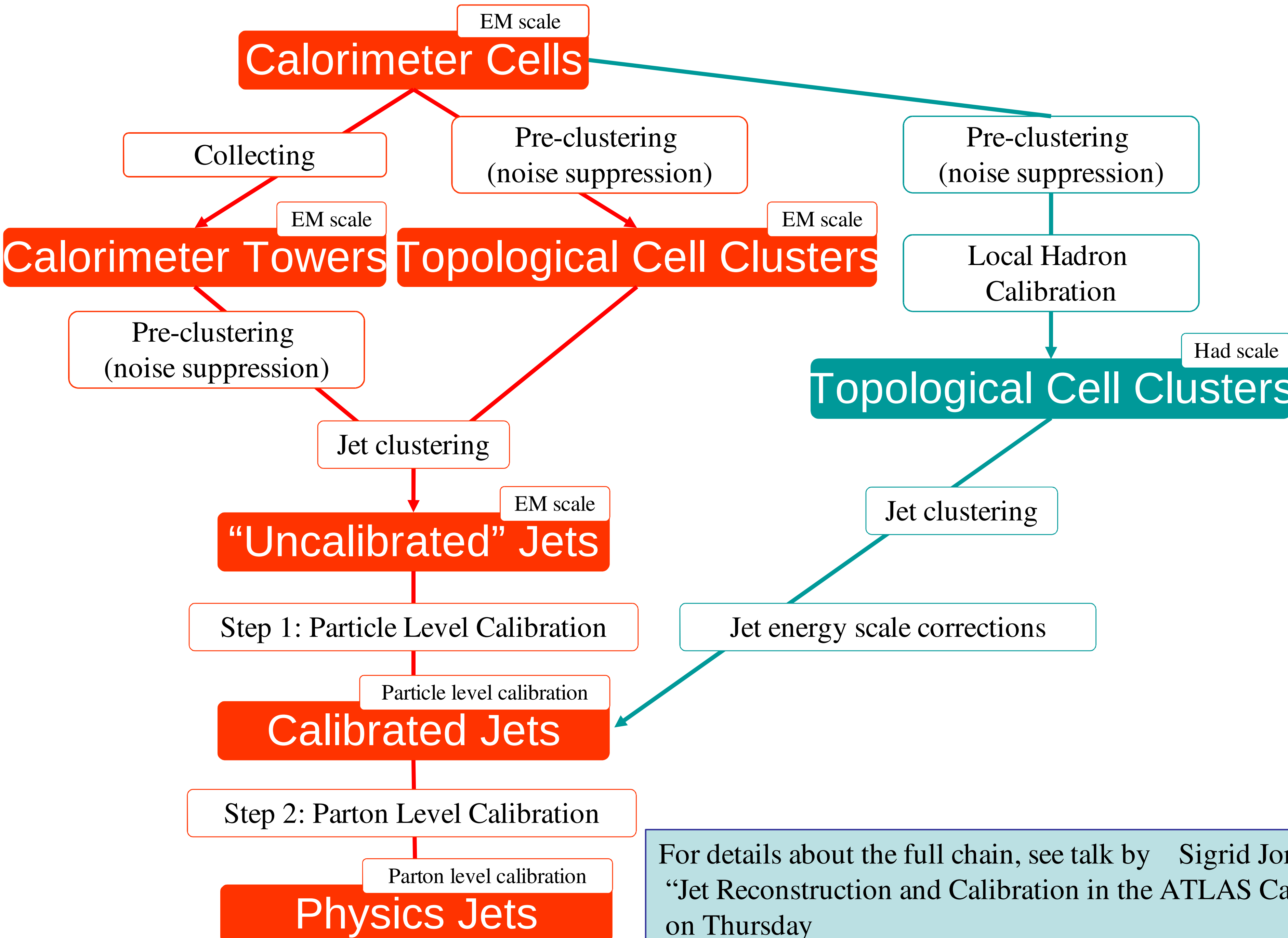
  no obvious process for calibration,

  top, dijets for cross checking the calibration

Mass of the Top Quark

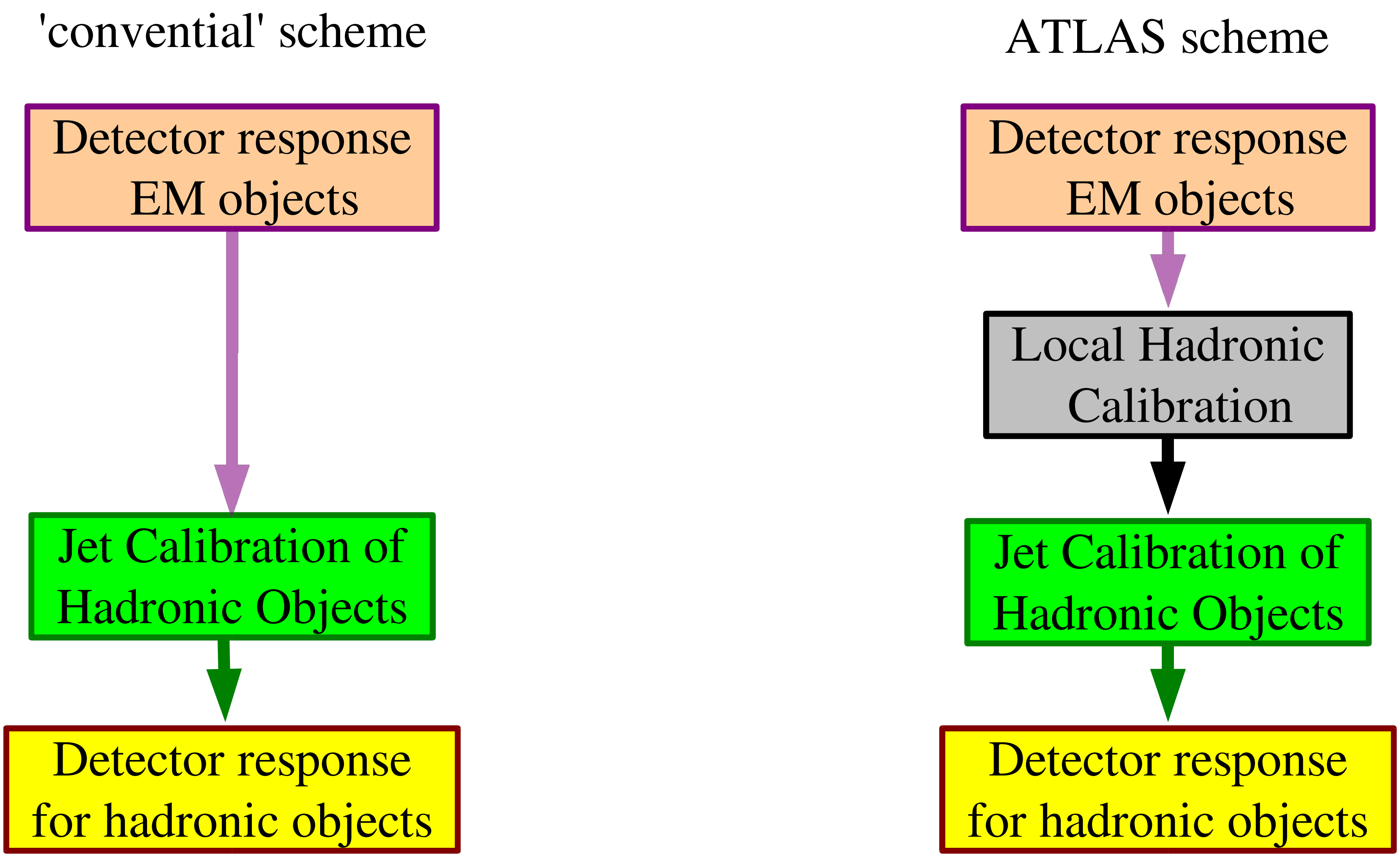
- best current value (preliminary) :
  $172.5 \pm 1.3(\text{stat}) \pm 1.9(\text{syst})\ \text{GeV/c}^2$
- 1.3% precision !!
- Tevatron average (see hep-ex/0603039)
- already now, systematics dominated!
- dominant error:
  Jet Energy Scale





For details about the full chain, see talk by Sigrid Jorgensen "Jet Reconstruction and Calibration in the ATLAS Calorimeter" on Thursday

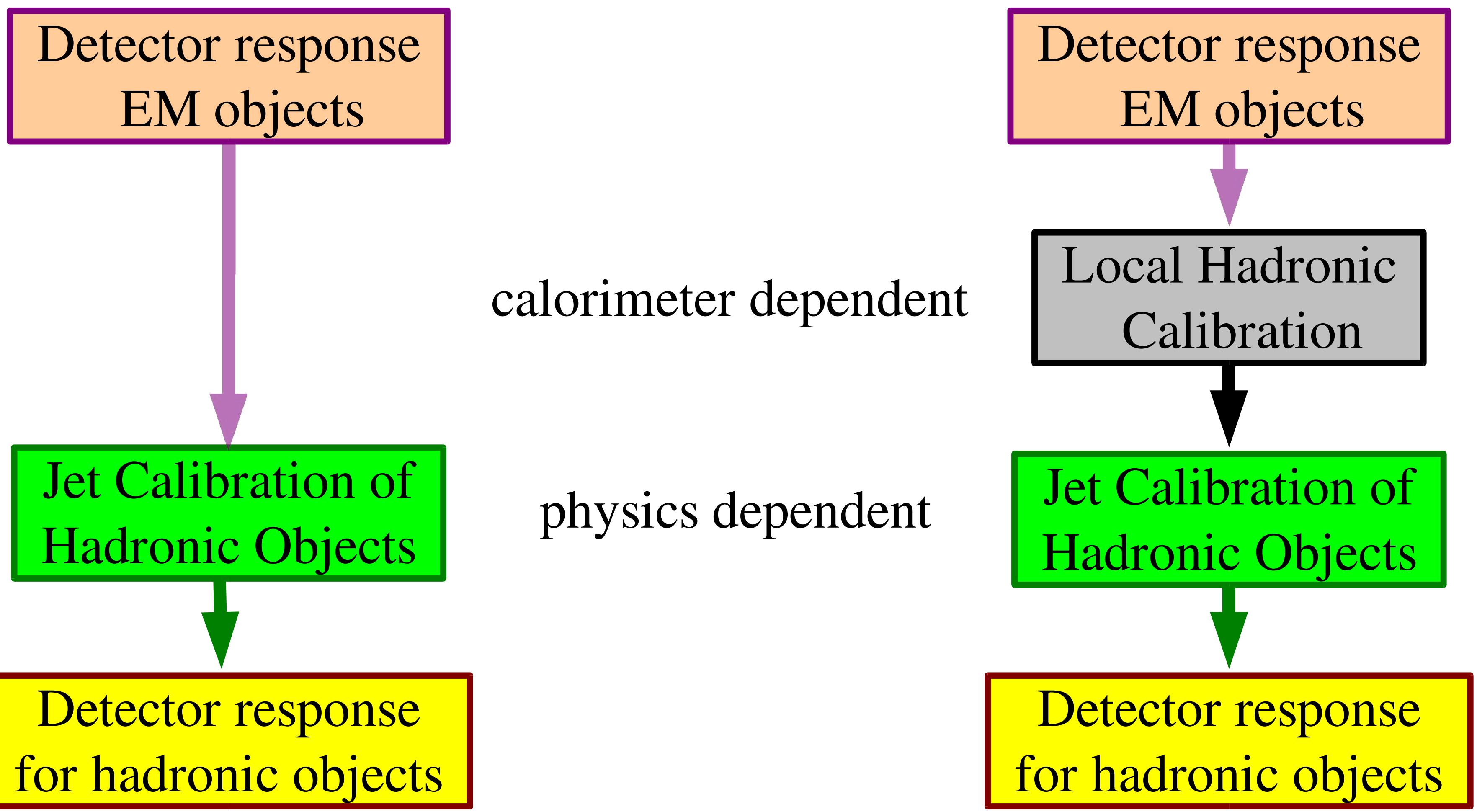
Jet Energy Scale



Jet Energy Scale

'convential' scheme

ATLAS scheme



Local Hadronic Calibration

Classify Energy deposits as EM/had. → Which cluster need correction for hadronic activity ?

apply weights to had. clusters → determine correct energy response for hadrons relative to electrons

apply correction for energy loss between subdetectors (dead material corr.) → correct for leakage and energy loss inside and between subdetectors

Jet Energy Scale in ATLAS

- ingredients to calibrate the jet energy scale:
- build clusters of neighbouring calorimeter cells
- “cluster classification”
  and apply correction accordingly
- calibrate energy in these clusters ('energy blobs')
  as good as possible
  “w eights”
- then, go to physics objects : 'jets'
  possibly apply second correction

Building Cluster

- several different clusters in ATLAS:
  Region-of-Interest (trigger),
  Sliding Window (e/γ), ...

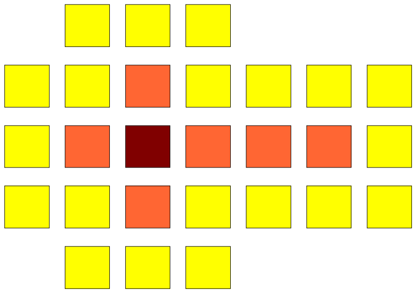
- mostly used : "CaloTopoCluster"
  topological clustering
  several options:
  -seeds, which neighbours to include (2d,3d)
  -cluster also over subdetector boundaries, ...

"CaloTopoCluster"

- 3 main variables determine the algorithm

- seed : default 4 σ of total noise (elec.$\oplus$pileup)

- neighbour : default 2 σ



- cell : default 0 σ

- can span over subdetectors

Splitting the Clusters

- objects closeby can have overlaping clusters
  → need to split clusters

- splitter looks for local maxima inside a cluster
  one cell can share energy between two clusters

- objective:
  - electrons contained in one cluster
  - pions can deposit energy in several clusters

Energy Scale: EM

- EM scale is basic scale to start from, possibly corrected for well known HV problems
- Liquid Argon Calorimeters – day 0: comparison test beam - MC
- Tile Calorimeter – day 0: ^{137}Cs intercalibration and test beam
- after few days of running, $Z \rightarrow e^+e^-$ allows cross check of calibration, refinement possible goal permille level

Cluster Classification

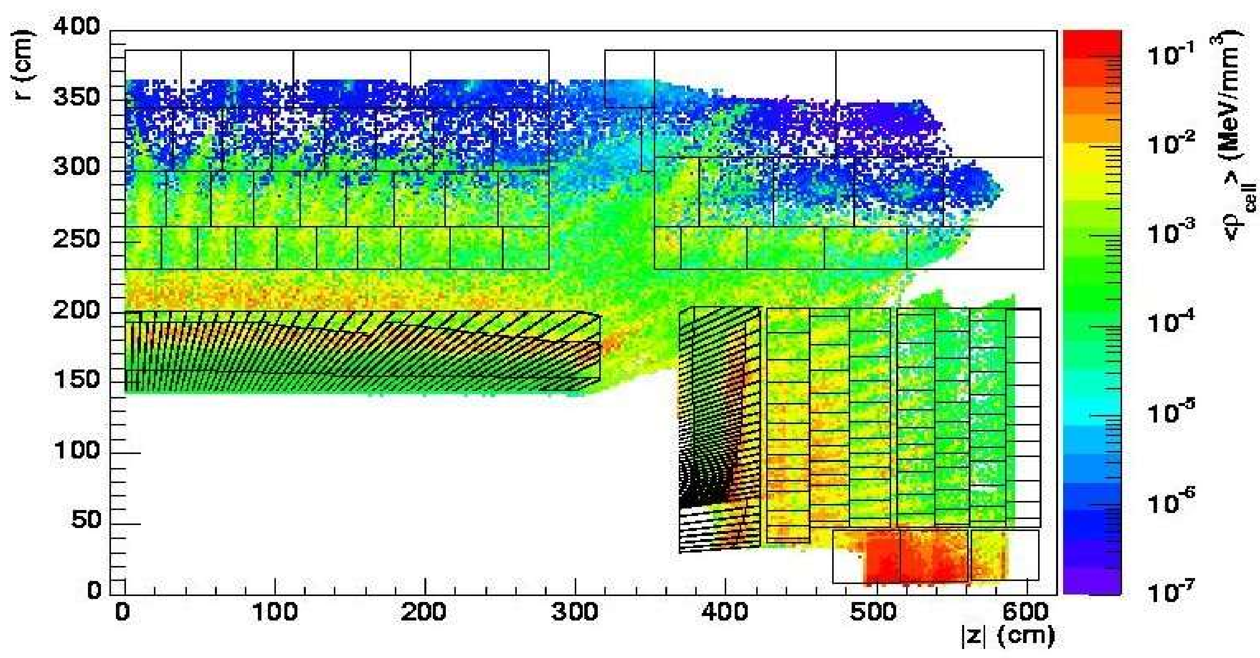
- determine correct weights for different types of clusters : electromagnetic, hadronic, muonic, ...

- currently based on two observables:
  -longitudinal maximum of energy deposit: λ
  -average energy density: ρ
- cut on e.m. fraction of a cluster, determined from single pion MC : f_{em}

Hadronic Energy Scale: Classification of EM Clusters

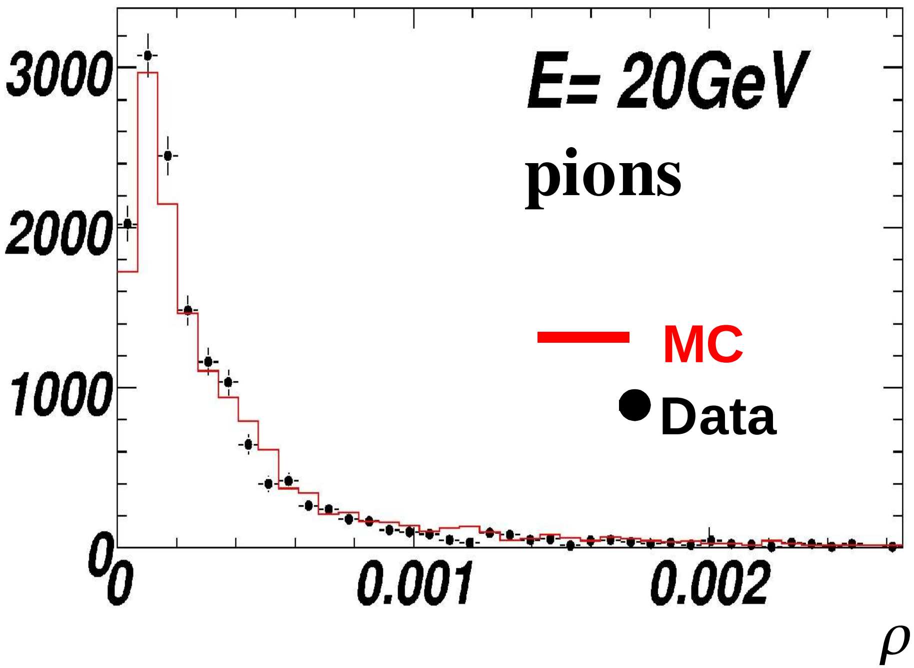
. . . ▶ Cluster Moments ▶ $\langle \rho_{\text{cell}} \rangle$

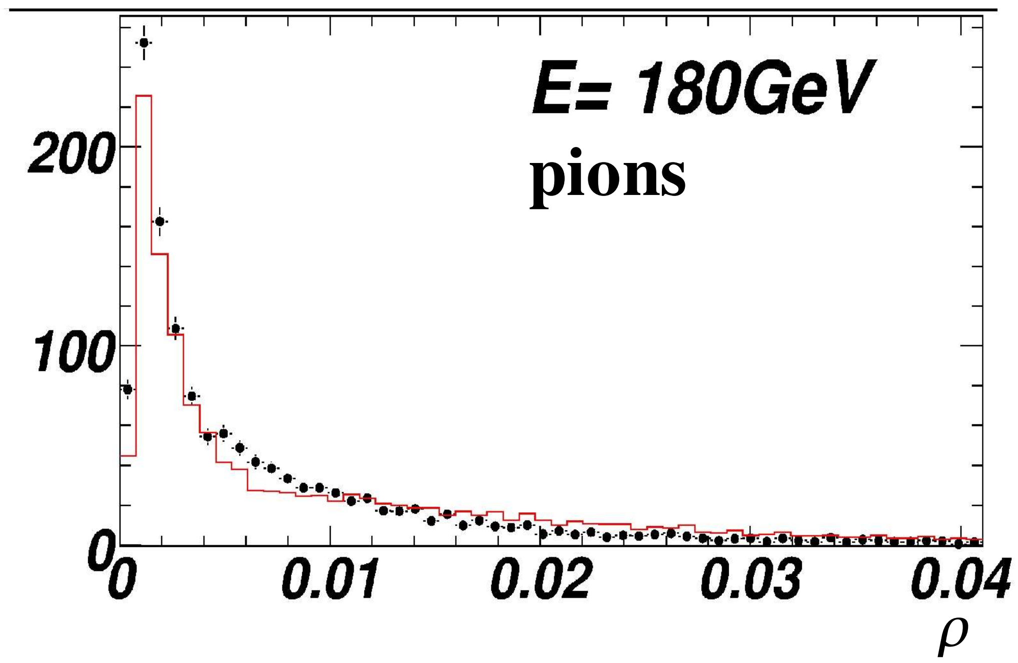
- $\langle \rho_{\text{cell}} \rangle$: energy weighted average (first moment) of cell energy densities inside the cluster for 200 k single pions from 3 GeV to 1 TeV



Hadronic Energy Scale: Classification of Clusters

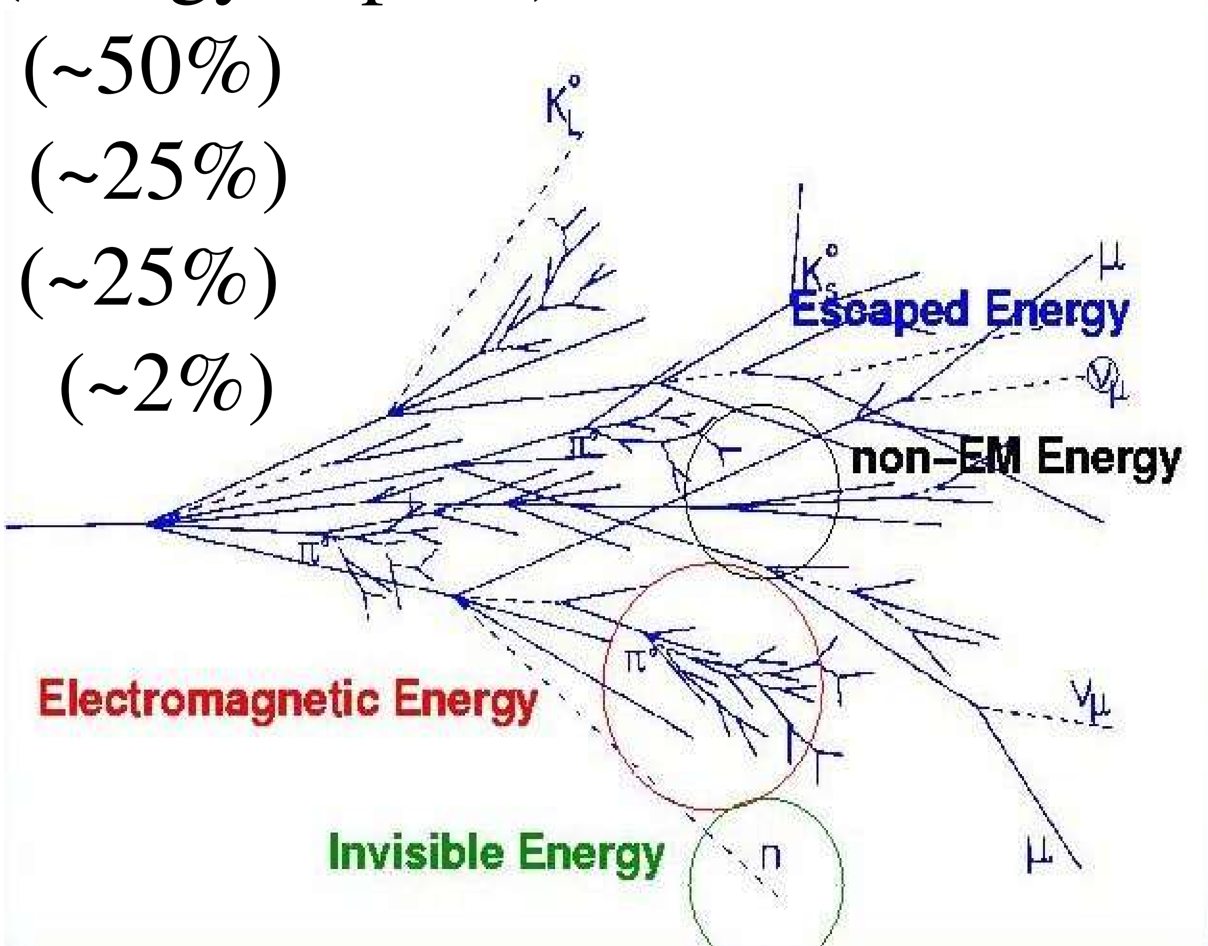
- classify as em, hadron or muon based on cluster shapes (e.g. average density, shower max., etc.)
- compare test beam data and MC:





Hadronic Energy Scale: Weights

- weights based on MC :so called 'Calibration hits' each GEANT4 hit (energy deposit) classified as:
  - -EM energy (~50%)
  - -non-EM energy (~25%)
  - -invisible energy (~25%)
  - -escaped energy (~2%)
- fractions vary with particle's energy
- large fluctuations



Hadronic Energy Scale: Weights cont'd

- weights:

$$E_{CELL}^{reco} = w(\vec{x})\, E_{CELL}^{raw}$$

$$w(\vec{x}) = \frac{\langle E_{EM} + E_{non-EM} + E_{invisible} + E_{escaped} \rangle}{\langle E_{EM} + E_{non-EM} \rangle}$$

- depending on several parameters $\vec{x}$ →next slide
- can include dead material inside cluster
- introduces MC dependence into calibration
  some sensitivity on modelling hadronic showers

Hadronic Energy Scale: Weighting Schemes

- different weighting schemes under investigation:

- current standard (by S. Menke):

$$w(\vec{x}) \equiv w(E_{Cluster}, \rho_{Cell})$$

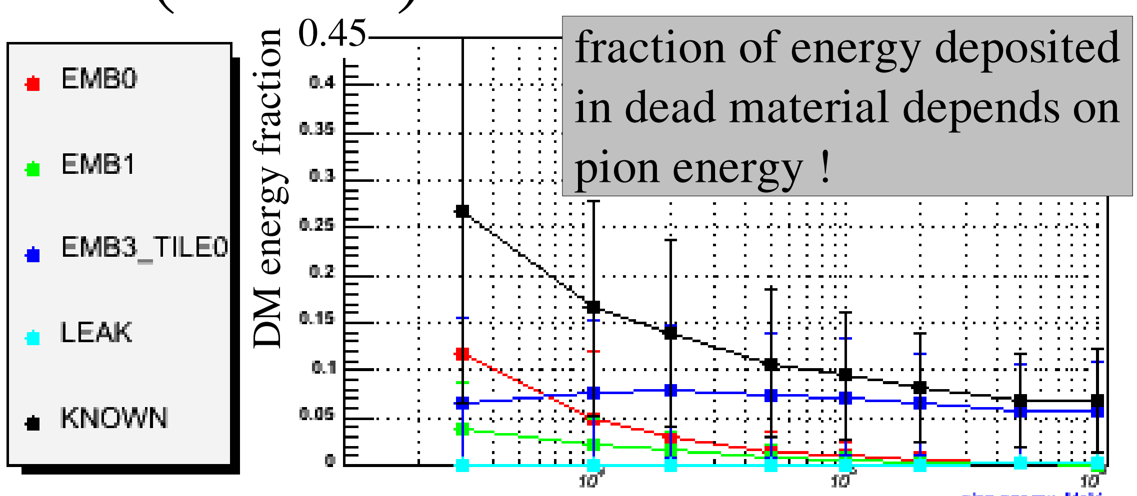
- alternative approach (C. Issever & Stockholm group):

$$w(\vec{x}) \equiv w(E_{global}, \rho_{Cell})$$

E_{global}: energy in cone (11 degrees) around cluster

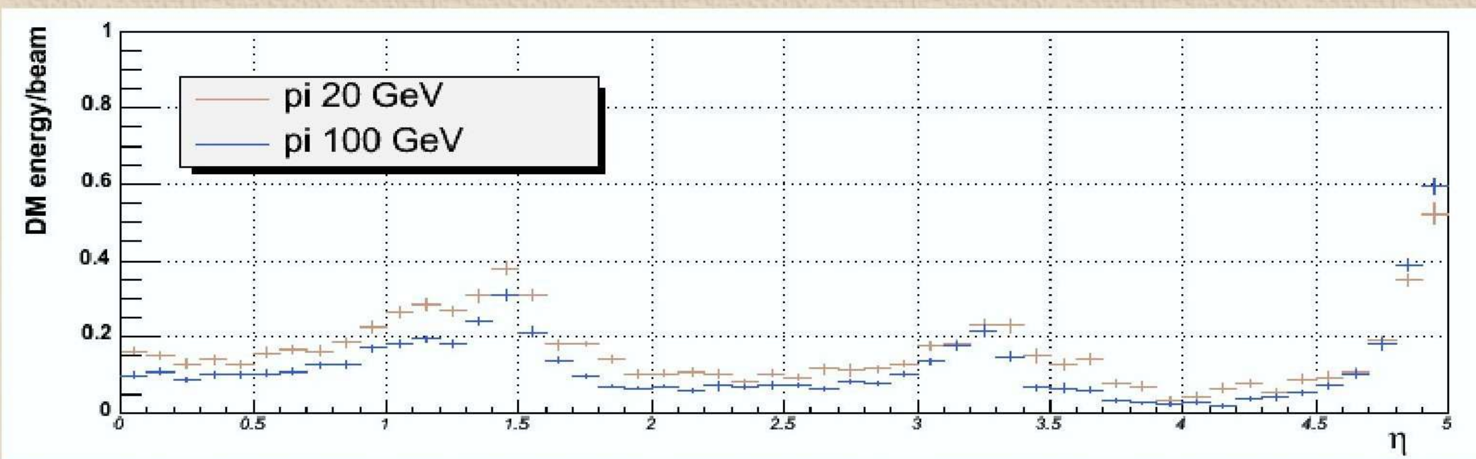
Dead Material Correction

- last important ingredient:
  energy deposits in dead material
  need MC with calibration hits for correcting this
- super-3D Topocluster span over different calorimeters:
  energy deposits between (before) subdetectors
- correction relies on good description of detector

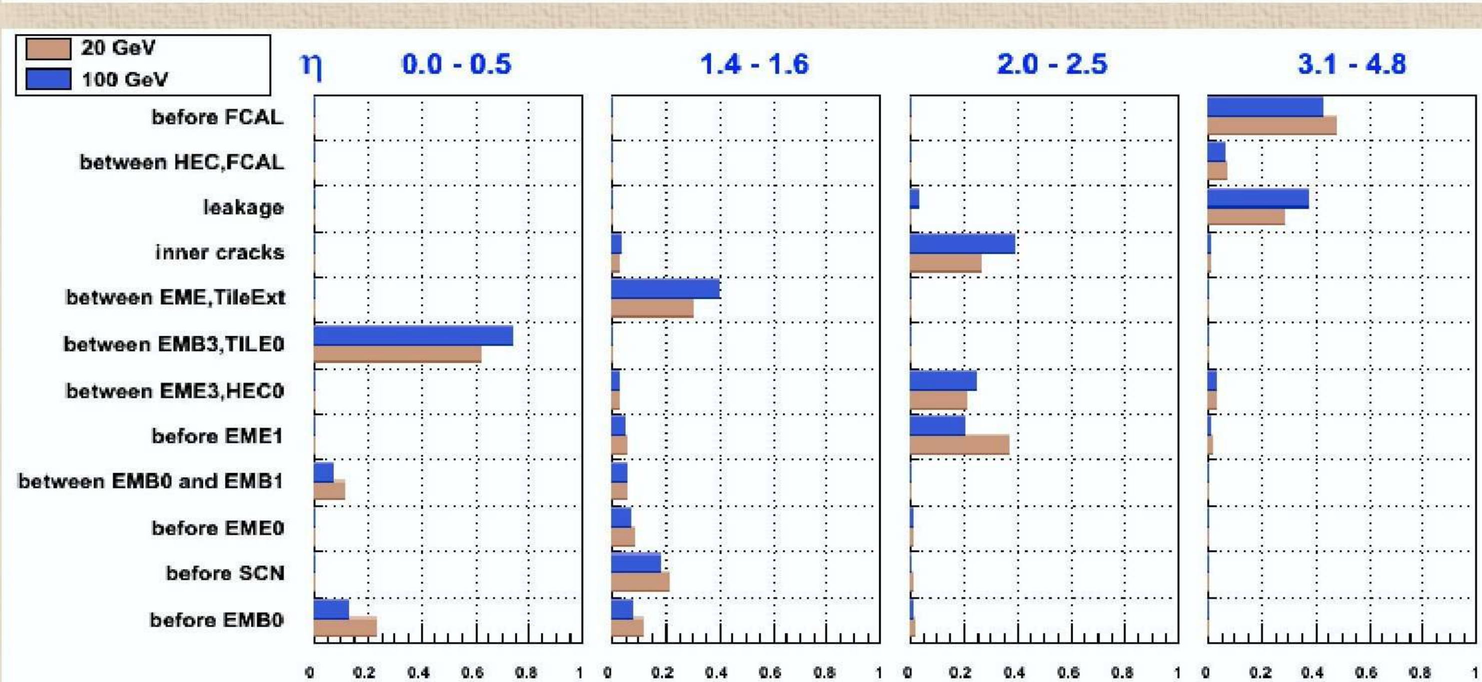


Dead Material Corrections

DM energy in different zones for 20 and 100 GeV pi-.



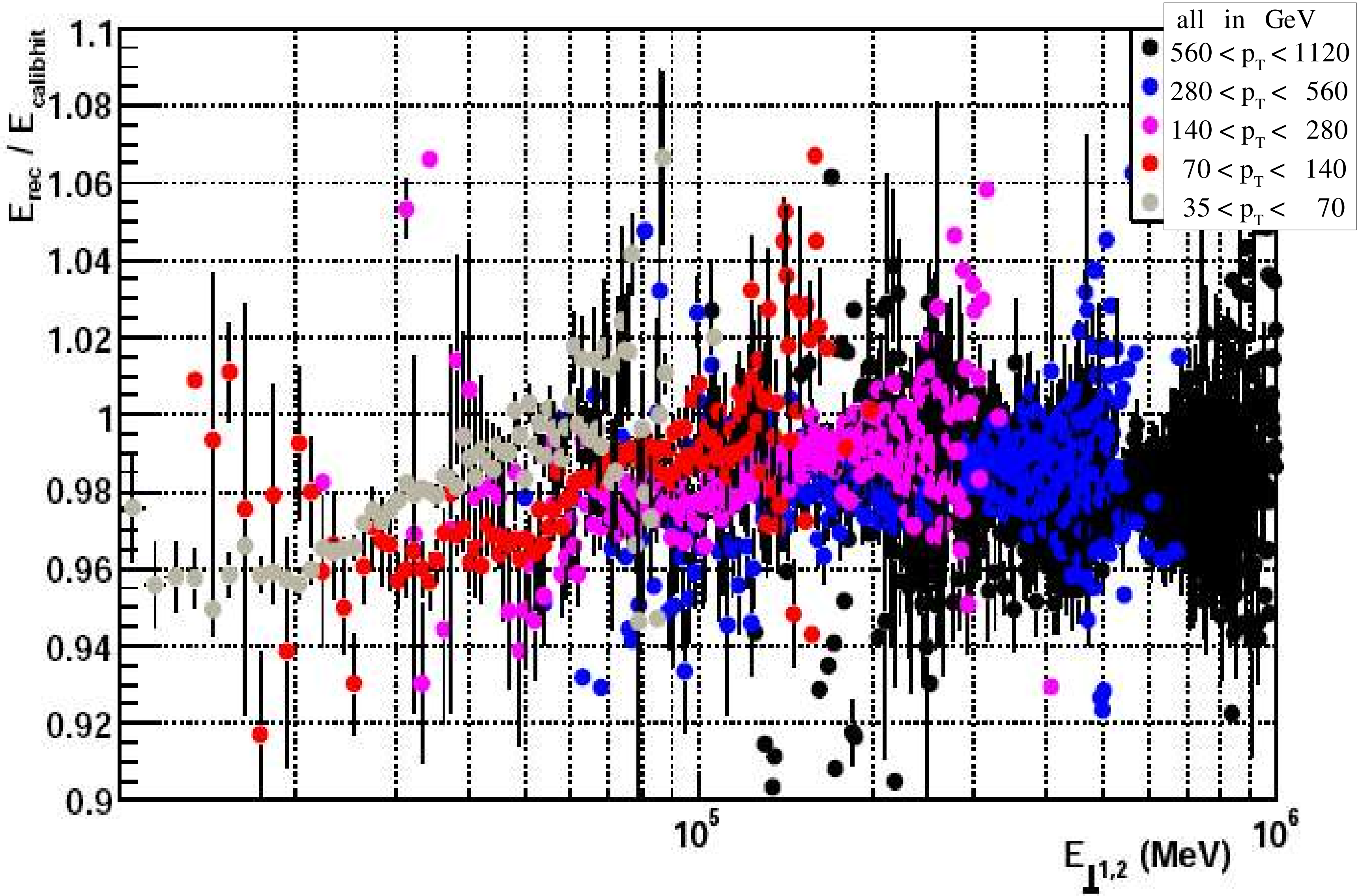
Ratio of total DM energy to the beam energy as a function of particle eta.



Ratio of DM energy released in particular zone to full DM energy accumulated in container. Four different eta areas are shown.

Adding all together ...

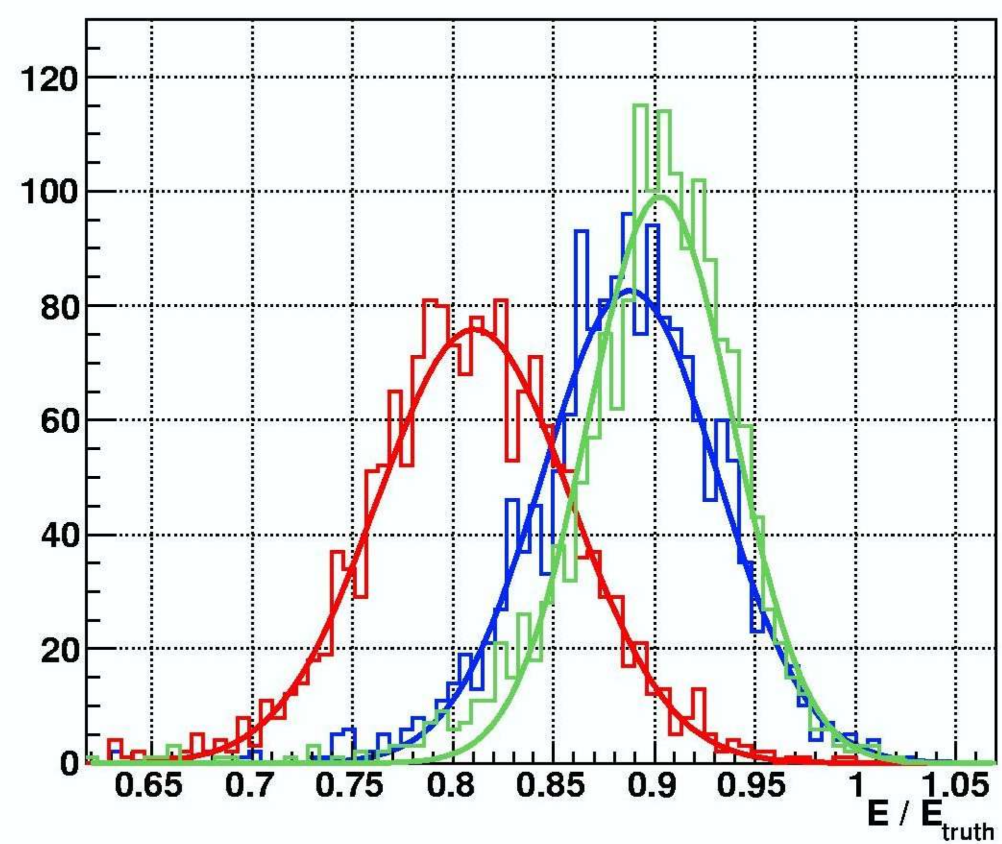
applying to QCD di-jets, only 2 highest jets shown here



Improvement in Resolution

Performance on Dijets ► Resolution

- leading 2 jets in J4 sample with truth matching
- select $1.9 < |\eta| < 2.3$
- plot E/E_{truth} for raw (red), weighted (blue) and true calibration hits (green)
- scale is correct to 98 % after weighting
- resolution improves from 5.9 % to 4.9 % (theoretically achievable is 4.0 %)



Conclusions

- idea and current status of local hadronic calibration of ATLAS Calorimeter presented

- first very preliminary results show good behaviour :

  improvement in resolution