Test of the ATLAS Pion Calibration scheme in the ATLAS Combined Test Beam

CALOR08

Pavia, 14th-16th May 2008

The 2004 ATLAS Combined test beam

Pion calibration techniques

Performance on simulation and data

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IN THE CITY OF NEW YORK

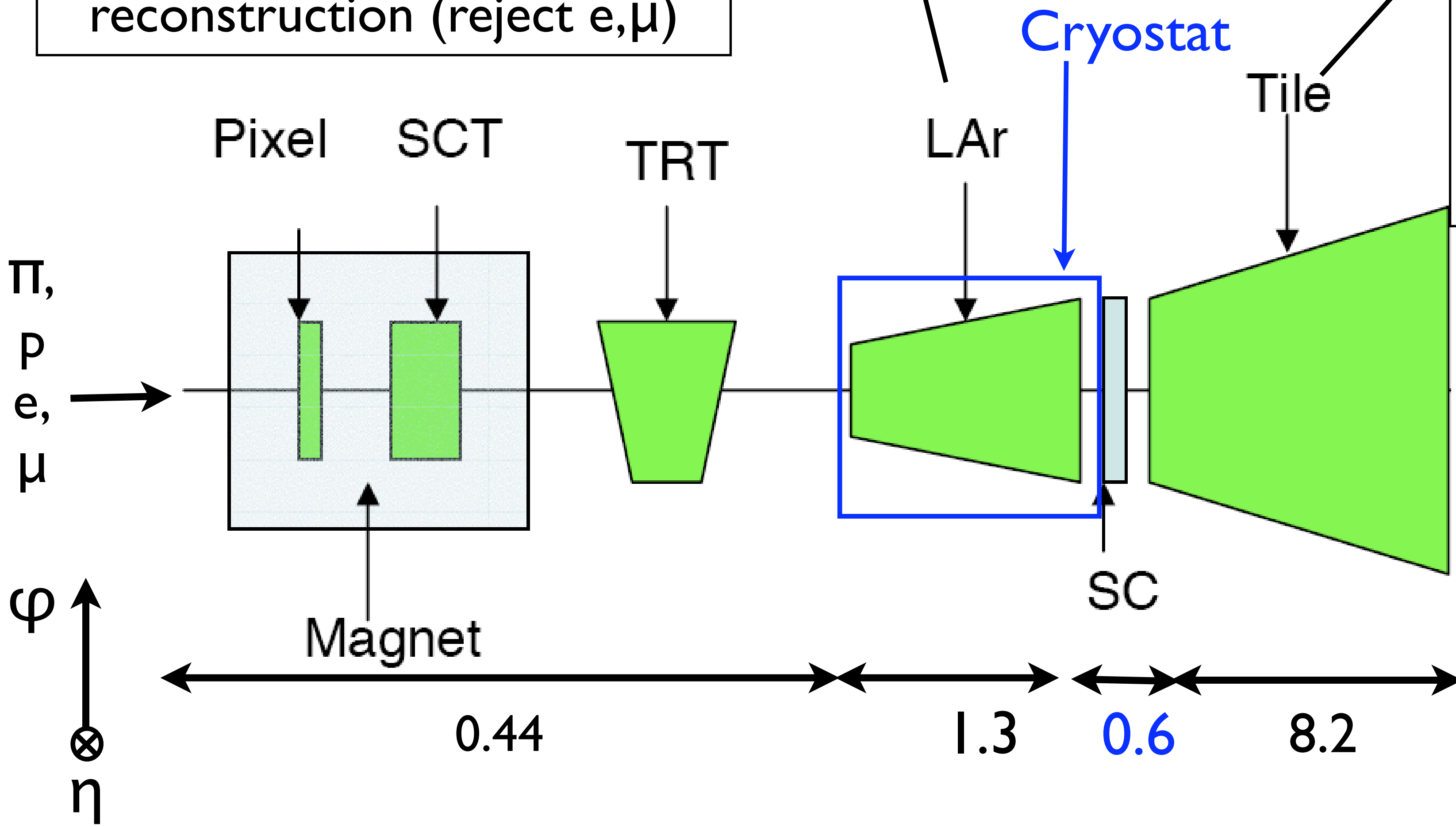
on behalf of the Combined Test Beam and Hadron Calibration ATLAS groups

2004 ATLAS Combined Test Beam

1 LAr/Pb EM barrel module with accordion shape

3 iron/ scintillator modules stacked vertically (along φ)

particle ID (select π) by track reconstruction (reject e,μ)



Calo coverage
η:(-1.6,1.6)
φ:(-0.15,0.15)

λ_{int} @ η=0.45

Data and Monte Carlo Samples

pions shot “centrally” at (φ=0, η=0.45)

Data

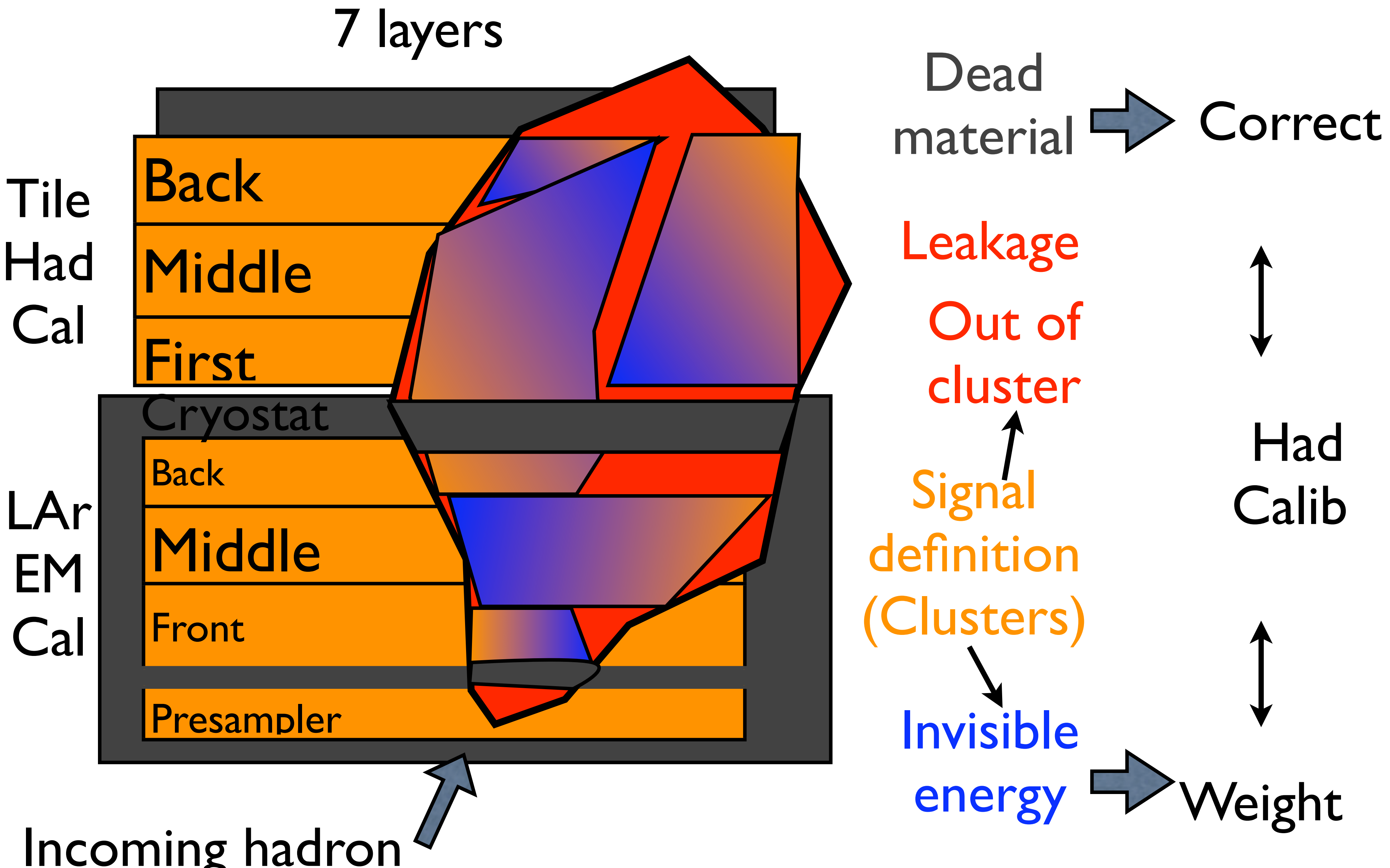
#ev after sel	Energy (GeV)	Particle	Proton fraction
~8000	20	π^+	0 %
~15000	50	π^+	41 %
~7000	100	π^+	59 %
~5000	180	Select π^+ from e^+ run	75 %

proton fraction measured by TRT

Monte Carlo Simulation

- Simulate pions and protons in energy range (15, 230) GeV
- Geant 4.7 QGSP_BERT with consistent description of fully combined test beam set-up
- Divided into two statistically independent samples for calculating corrections and applying them
- $\sim 4 \cdot 10^6$ events in total

Pion in ATLAS Calo



Calibration techniques

Local Hadron Calib. (LH)

(See G Pospelov's talk)

Classified Cluster

Cell en. density, η, E_{clus} ←

Cluster position ←

Parametrization ←

Calibrated clusters used to form calibrated jets

Signal definition

Corrections

Invisible energy

Out of cluster

Leakage

Dead material

All values from 2 sigma Gaussian fit to energy

Layer Correlation Calib. (LC)

E^{LAYER} = clustered energy in LAYERs

Hadronic and Em energy deposits have different fluctuation properties

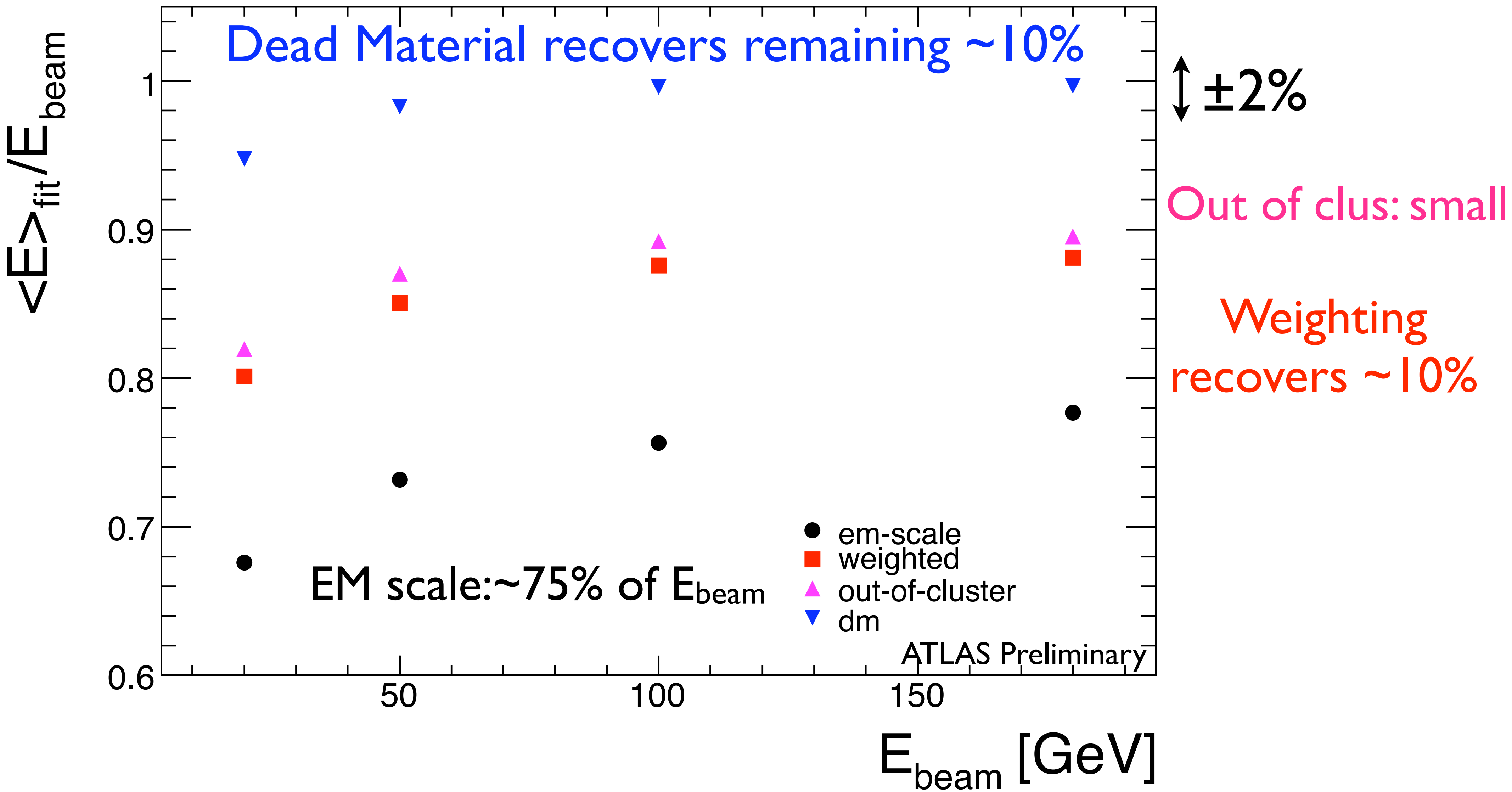
→ Variables sensitive to fluct. to compensate and improve resolution

Calibrated layer energies

technically extendable to jets, need to calibrate jet itself

Local Had Calib Linearity - Simulation

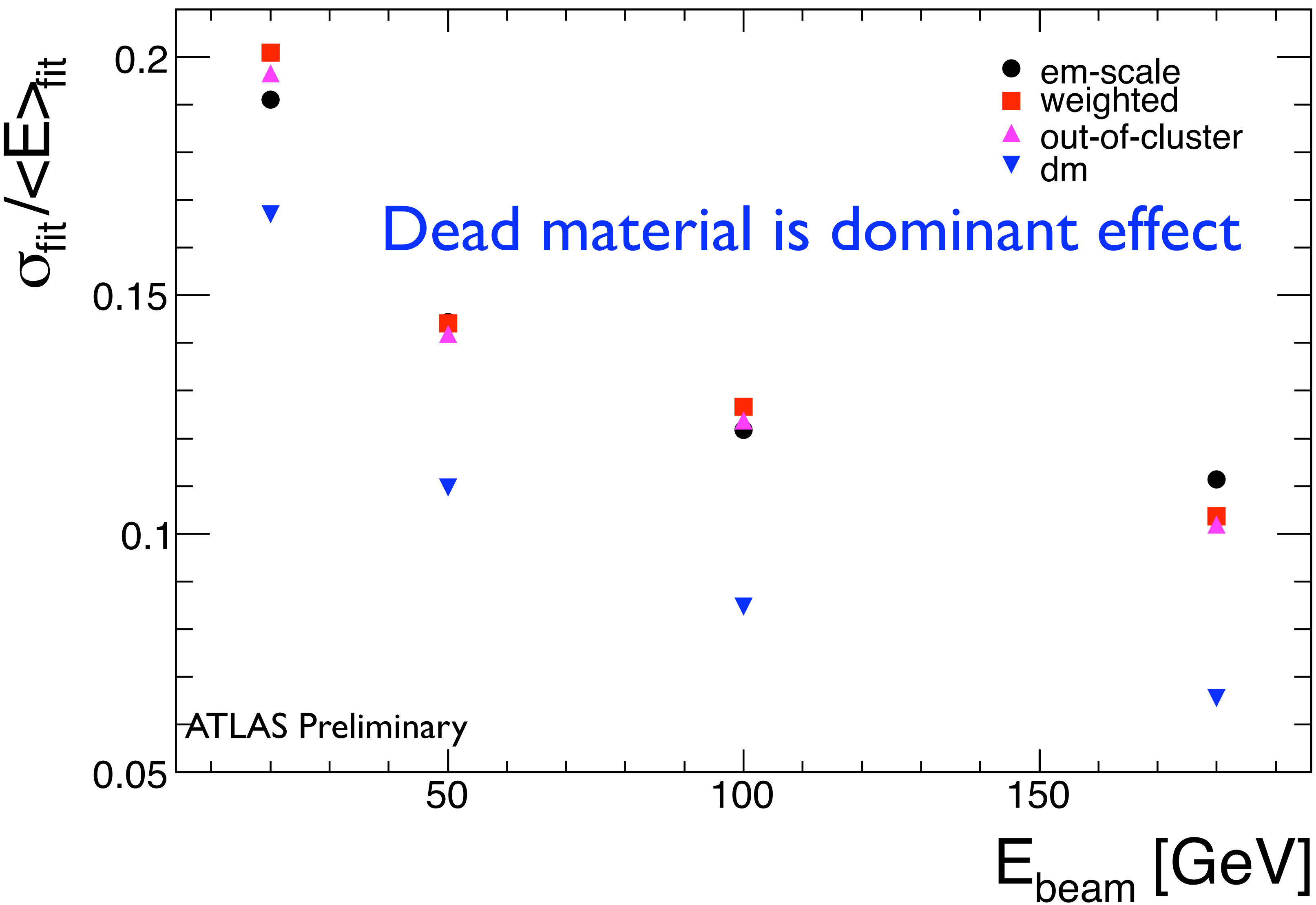
pure π^+ beam



Expect linearity recovered within 2% for E_{beam} > 20 GeV

Local Had Calib Resolution - Simulation

pure π^+ beam

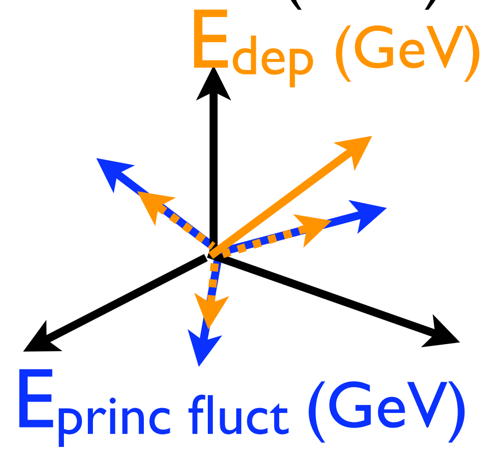


Expect improvement by 11% to 40% in relative resolution

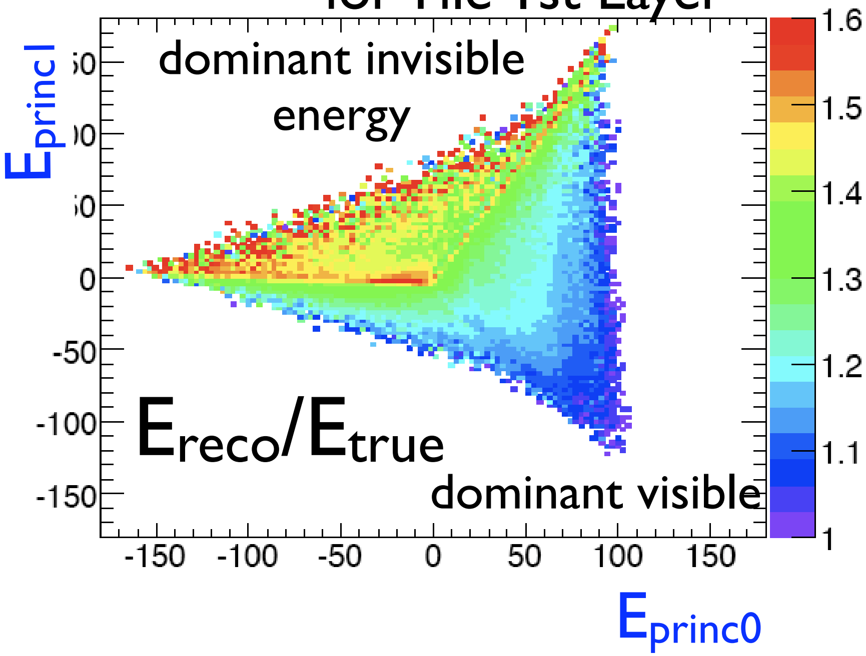
Layer Correlation Calibration (LC)

Signal: clustered energy in LAYERs

Space of E^{LAYER} (GeV)

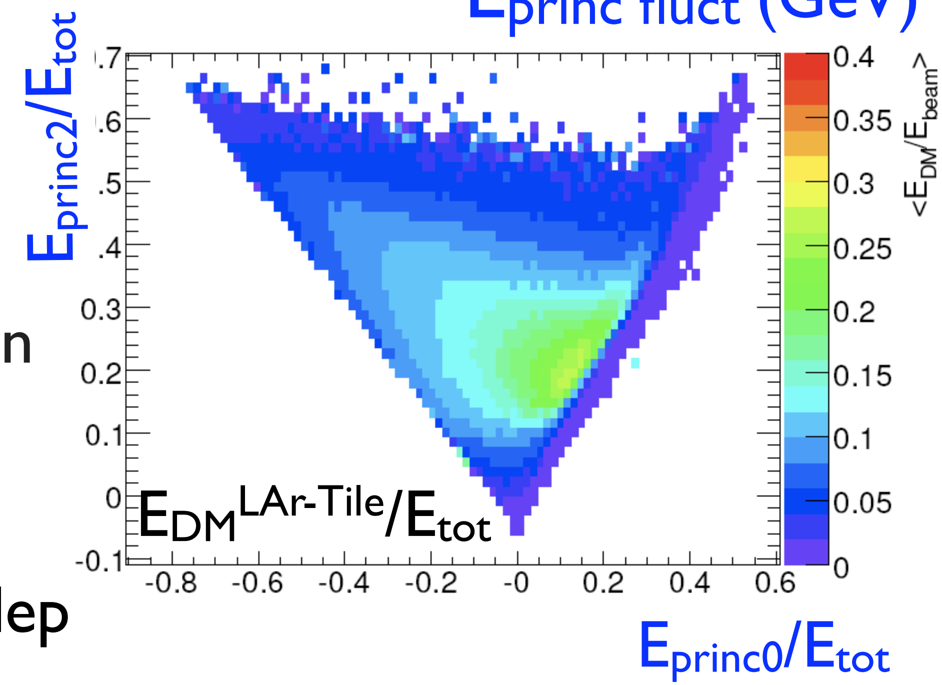


Corrections: function of
linear comb of LAYER energies
with largest expected fluctuations



Derive from simulated samples with E_{beam} in (15,230) GeV

No E_{beam} dep



Weight E^{LAYER} to recover E_{inv} + Dead material estimate

include out of clus. corr

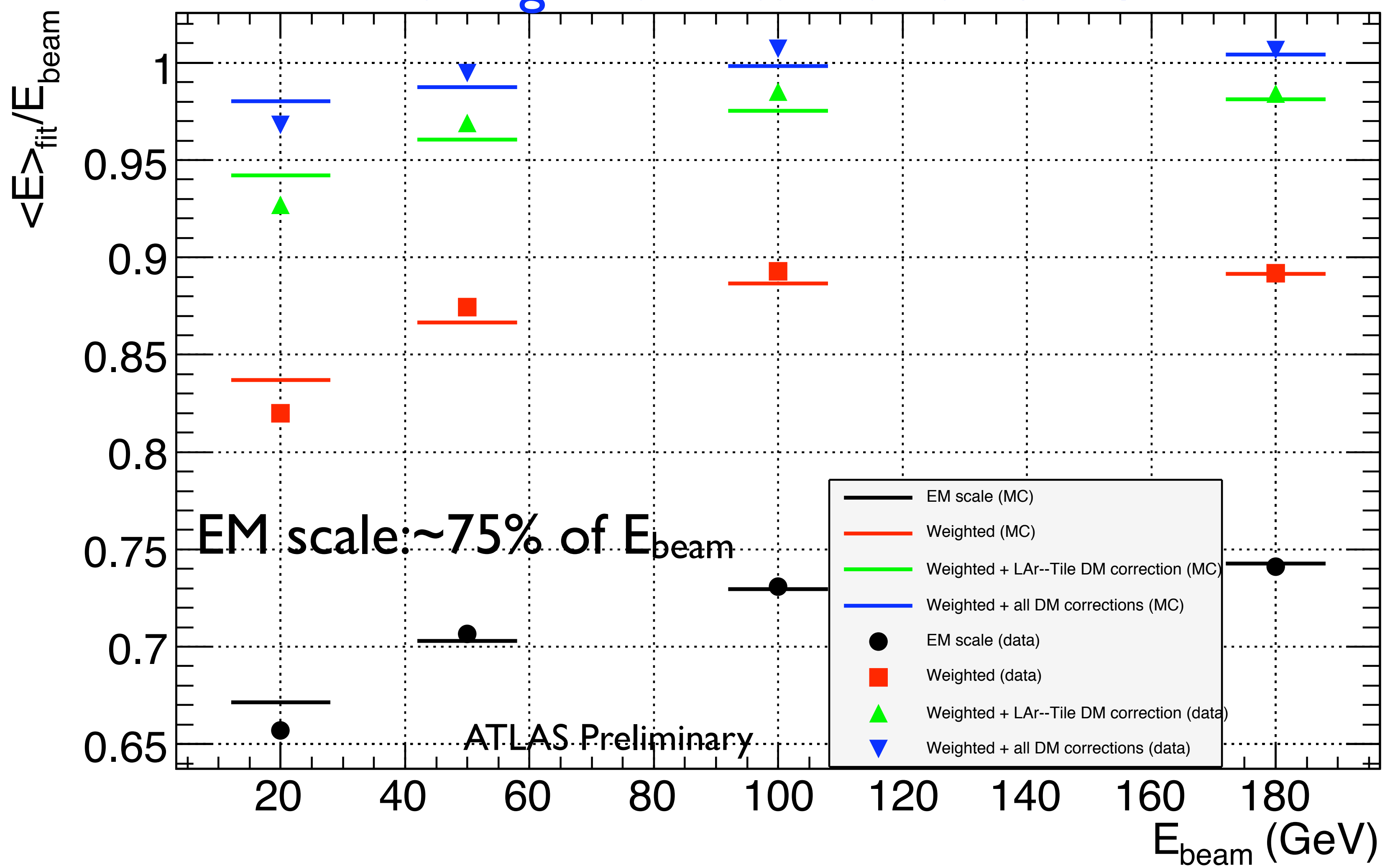
Iterate

param for upstream loss+ leakage

LC Linearity - Data and Simulation

consistent π^+-p mix in data and simulation

Remaining dead material adds ~2%



LAr-Tile Dead material accounts for ~8%

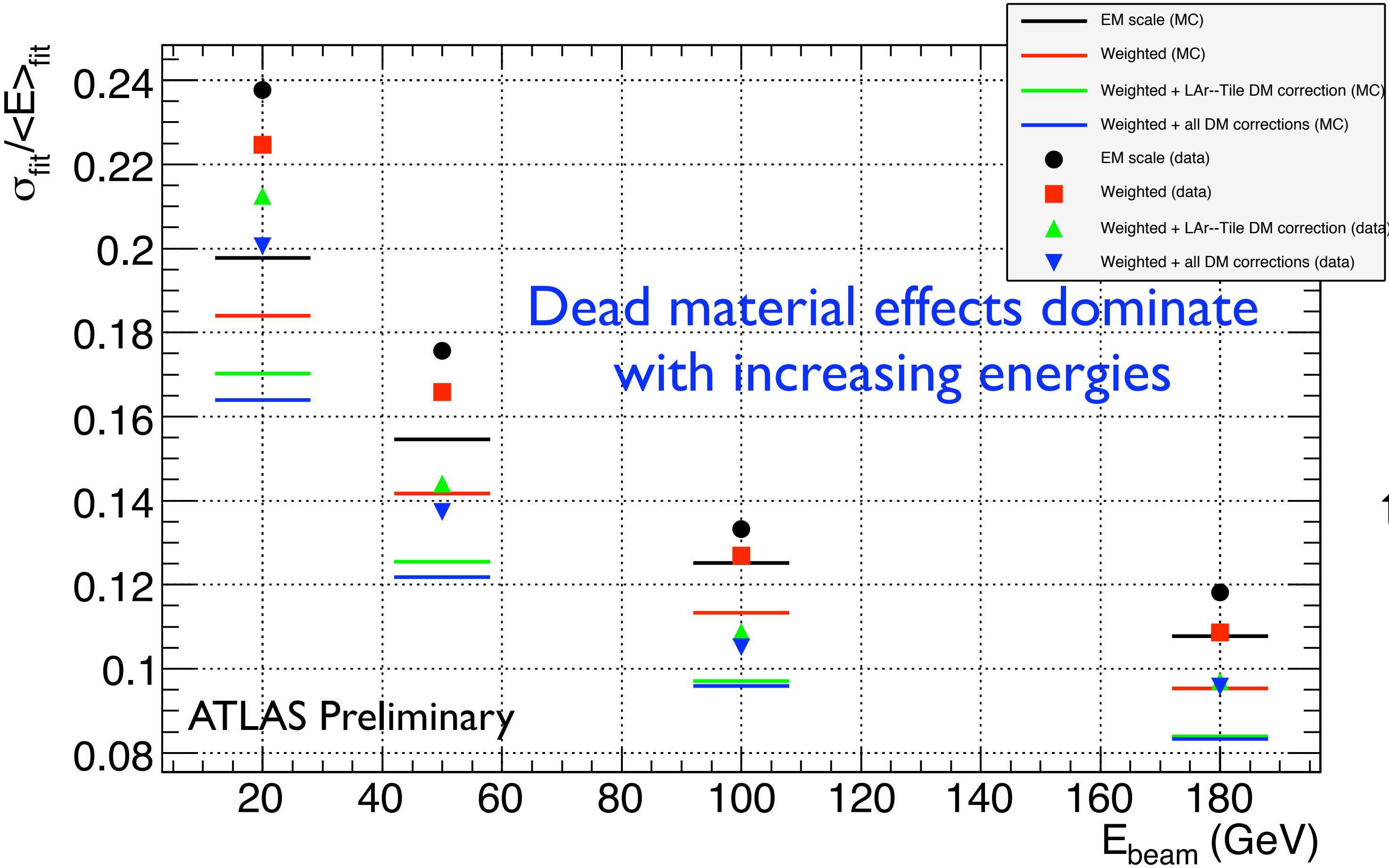
Weighting recovers ~12%

Data - sim. agreement is within 2% at all stages

Linearity is recovered within 3%

LC Resolution - Data and Simulation

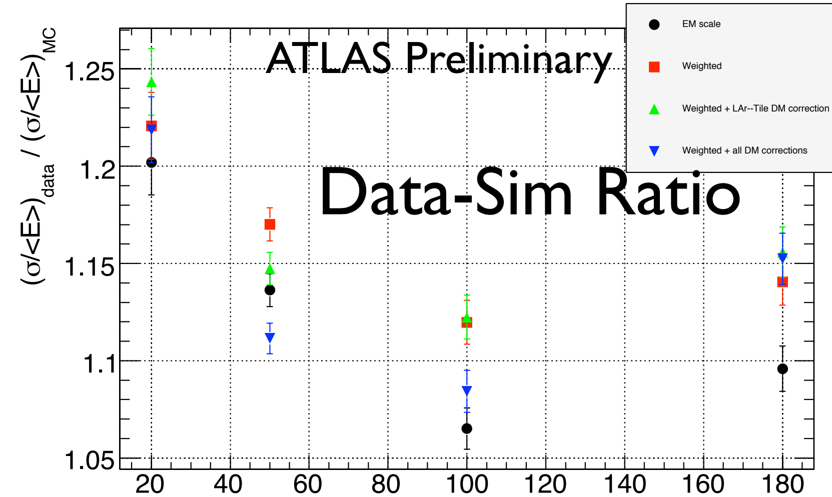
Consistent π^+-p mix in data and simulation



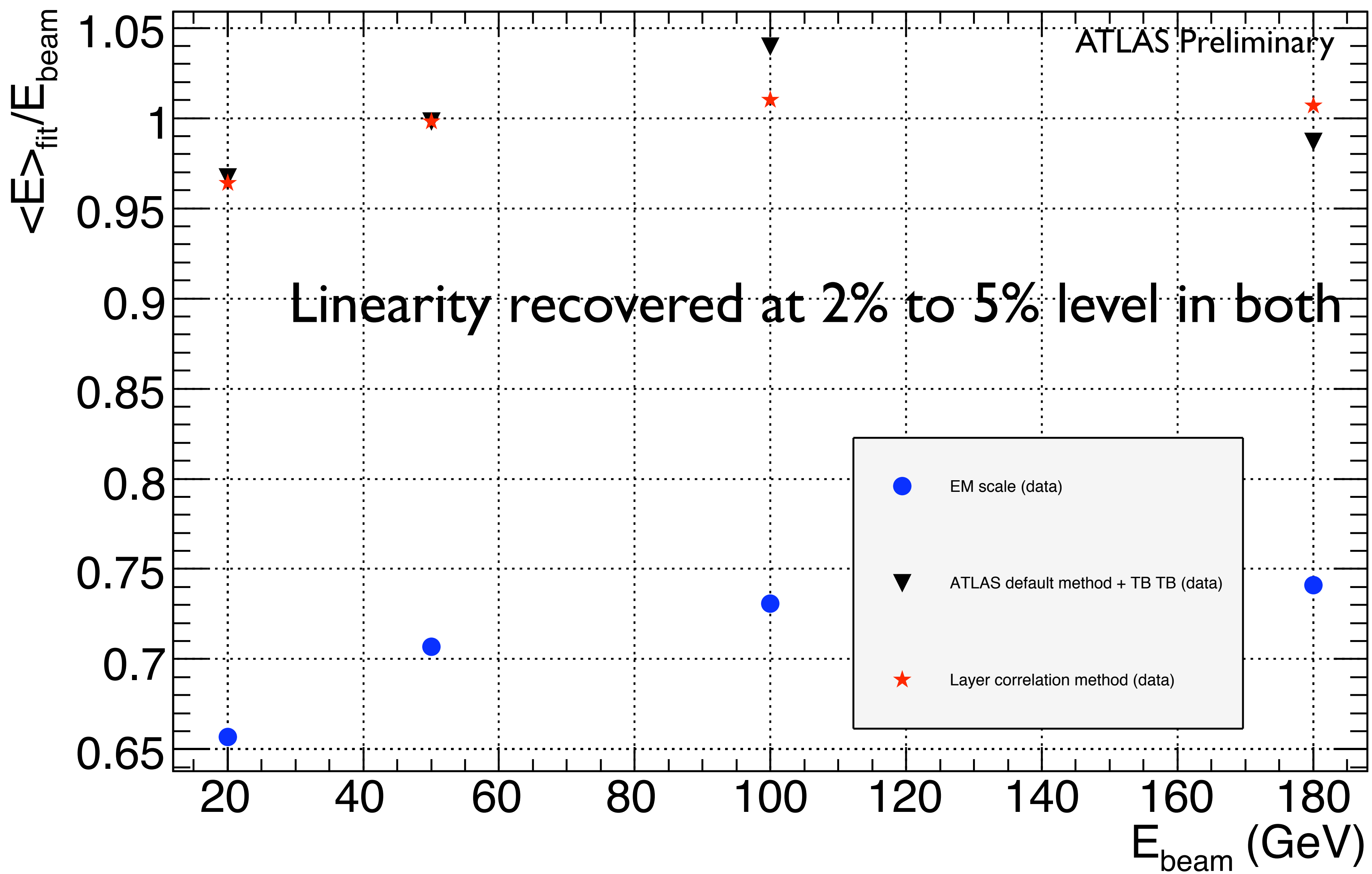
Calibration improves relative resolution by 17% to 21% (expect 17 to 24%)

Simulation underestimates data relative resolution by 10% to 25%

G4.9 improves resolution description (see P. Speckmayer's talk)



Local vs Layer: Linearity (Data)



EM scale taken from LC method: slight difference with LH due to different reco version

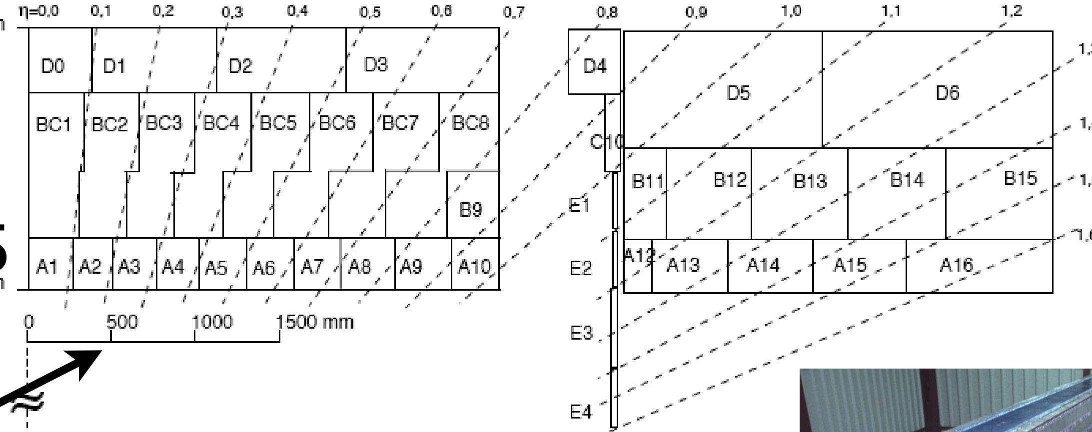
Conclusions

- A simulation-based technique for hadronic signal calibration (LH) was applied to pion energy reconstruction in 2004 ATLAS combined test beam for E_{beam} in (20 GeV, 180 GeV). A novel technique based on layer correlation (LC) was also used.
- Pion linearity is recovered within 2 to 5% by both approaches in good agreement between data and simulation. Weighting and dead material effect have similar impact.
- Relative energy resolution is expected to improve (by 20-30% to 40% in LH/LC). LC actually achieves 17 to 21% improvement. Simulation underestimates data resolution by 10 to 25%. Dead material effects are dominant.
- Data-sim. discrepancies at EM scale kept at all stages: simulation performance is limiting factor.

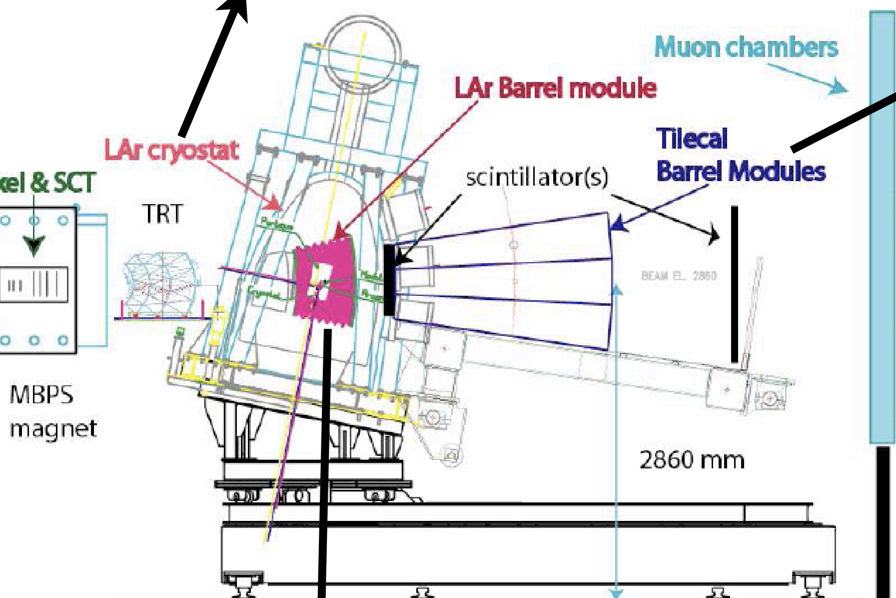
Back-up

ATLAS Calorimeters @Test beam 04

3 Tilecal iron scintillator stacked modules

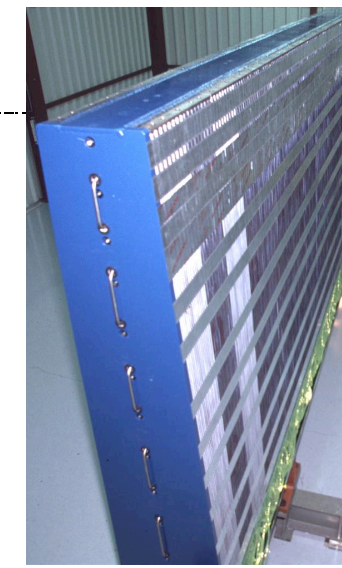


Dead mat: 0.6 λ_{int} @ eta=0.45



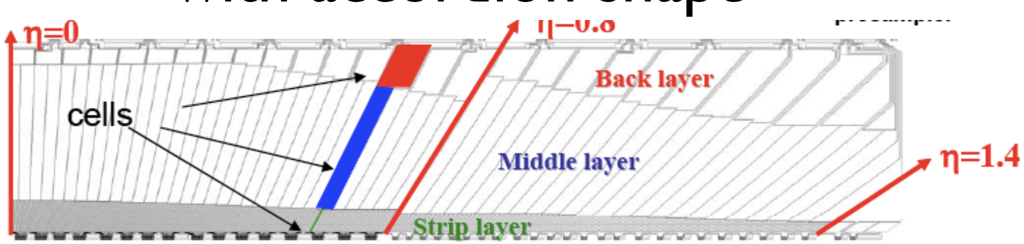
8.2 λ_{int}@ η=0.45

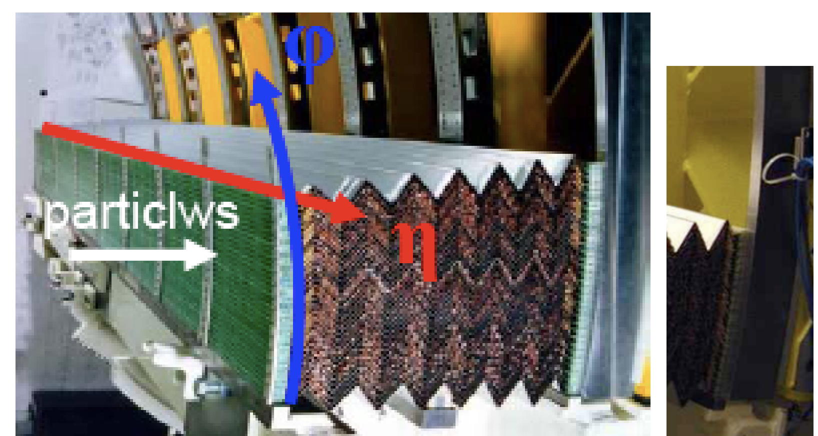
Coverage:
Phi (-0.15,0.15),Eta(-1.6,1.6)



1.3 λ_{int}@ η=0.45

1 LAr/Lead EM barrel module with accordion shape

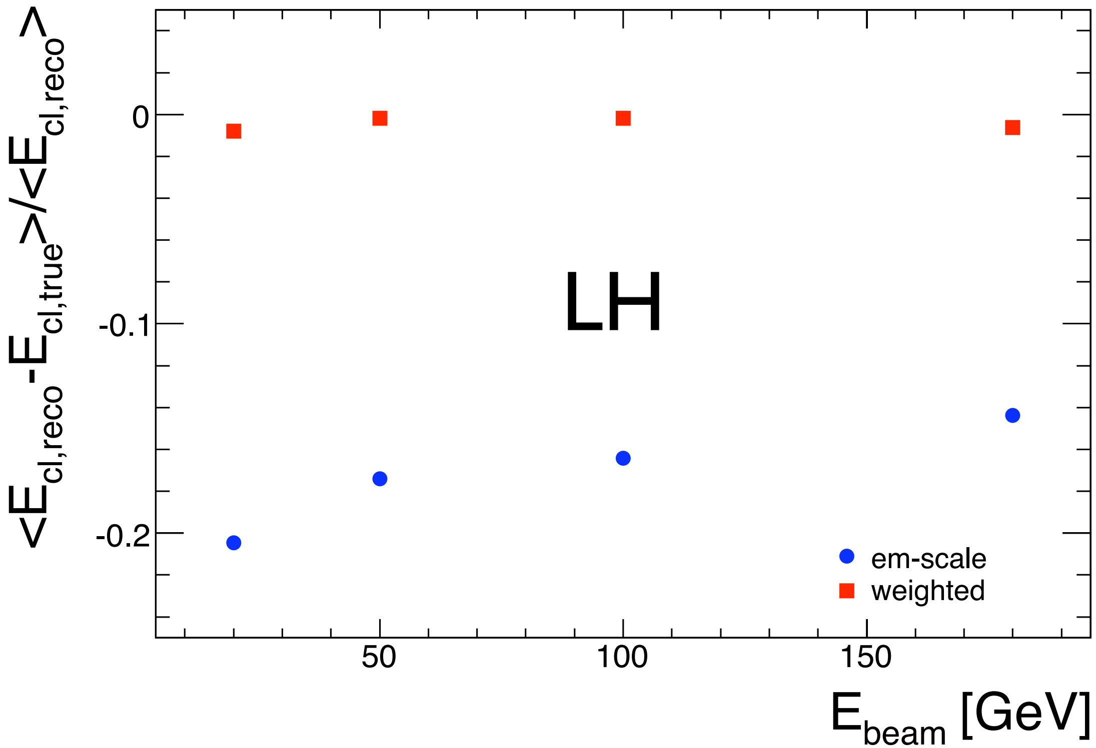


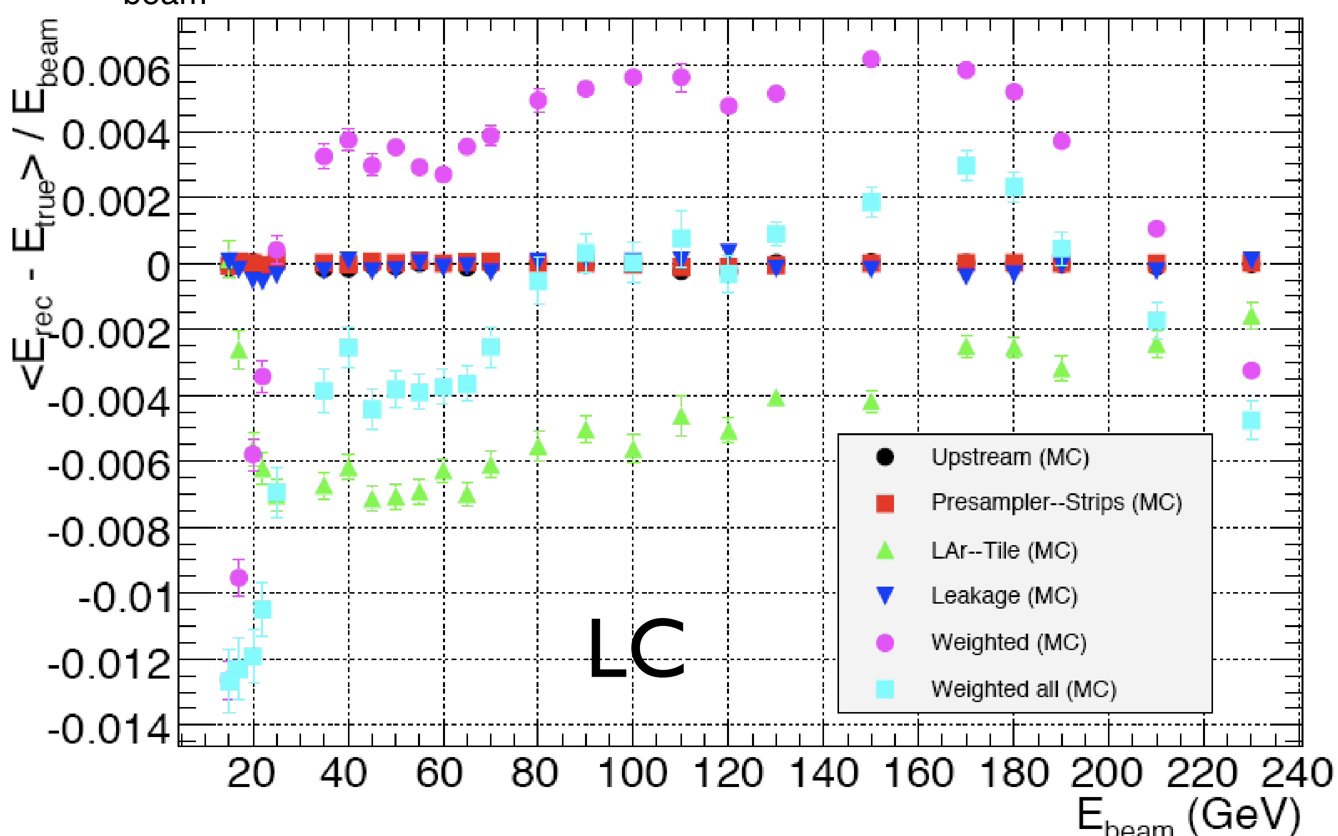


Weighting performance: Average

(Simulation)

pions only



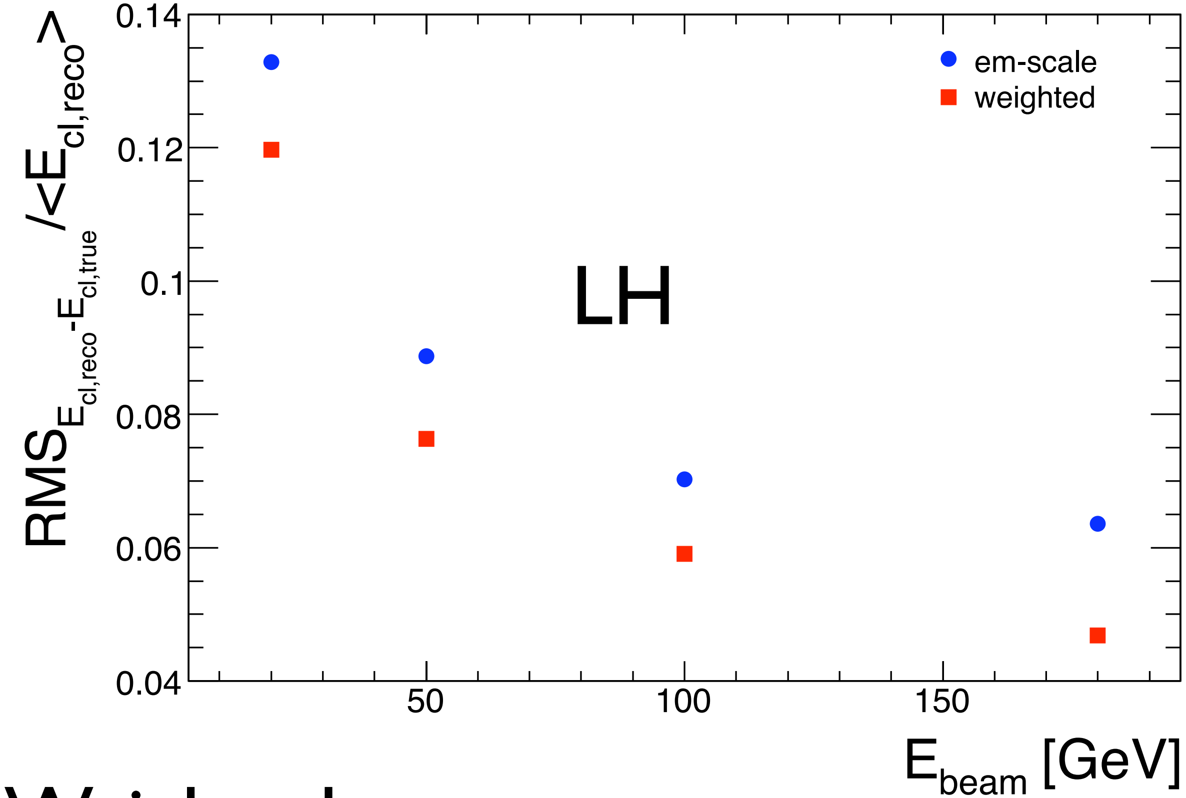


On average weighted energy reproduces energy deposited in calorimeter within 1 to 2%

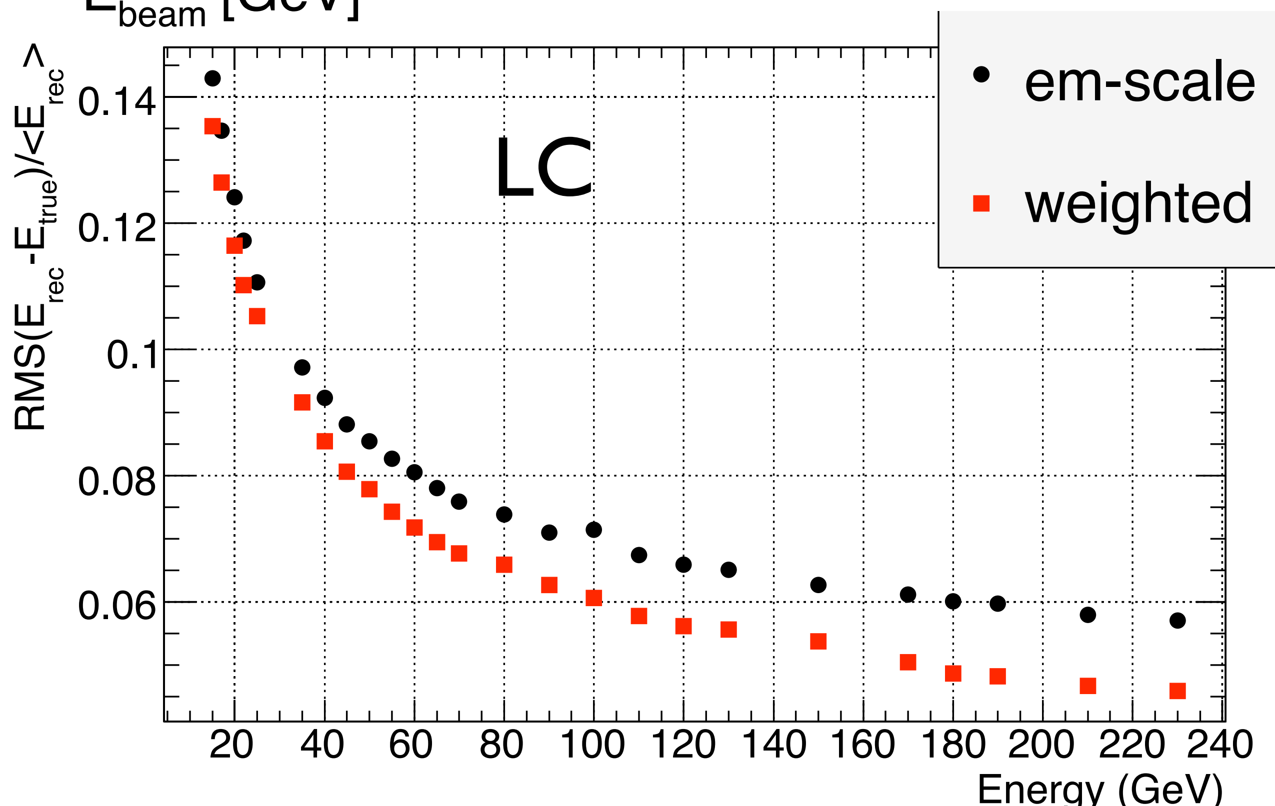
Weighting Performance: Spread

(Simulation)

pions only

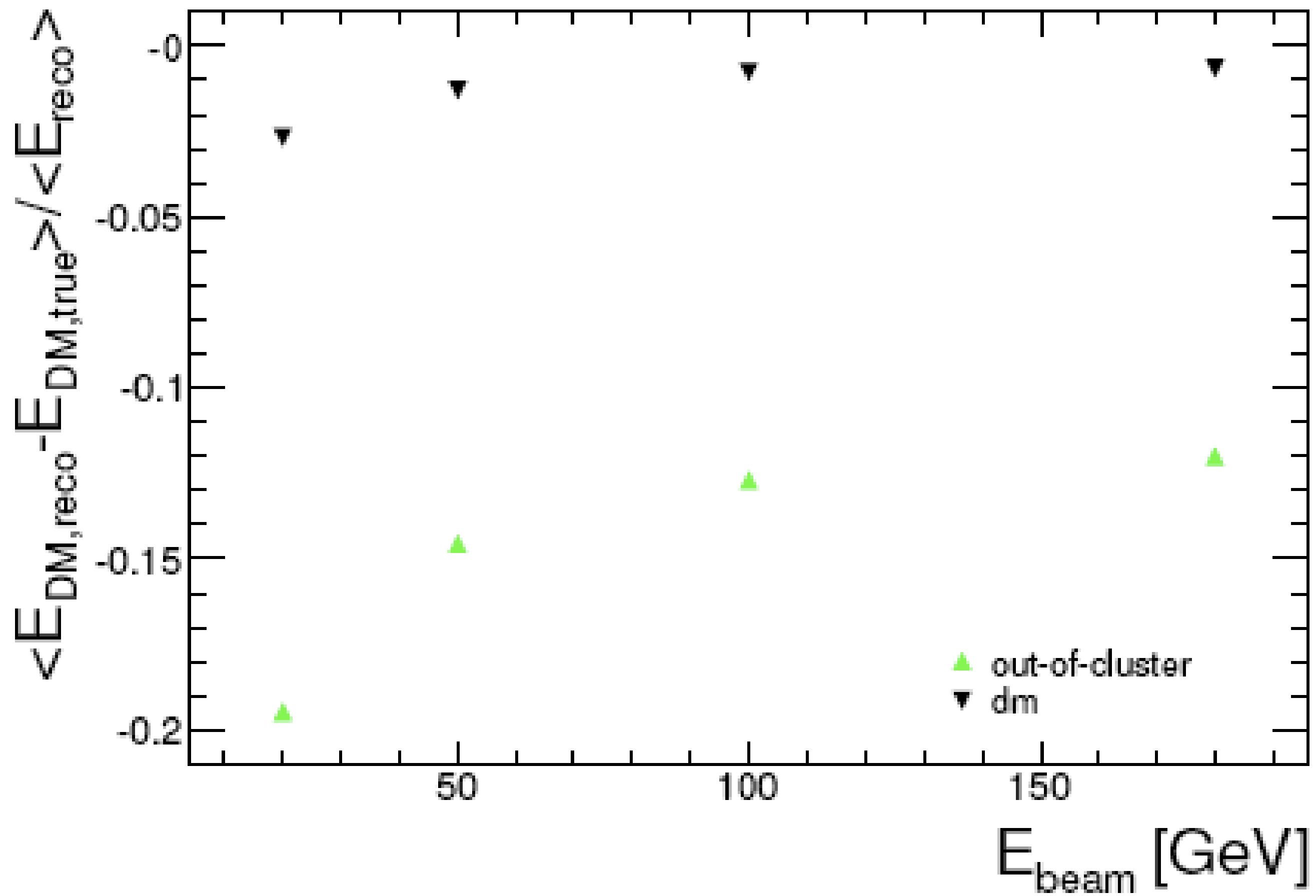


Weighted energy follows deposited energy more closely than em scale: smaller spread → better agreement on event-by-event basis



Dead Material effects in LH

(simulation - pion only)

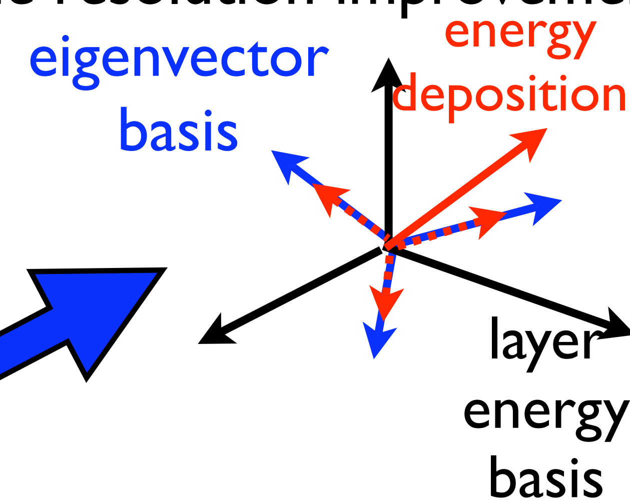


(e) dead material: relative difference

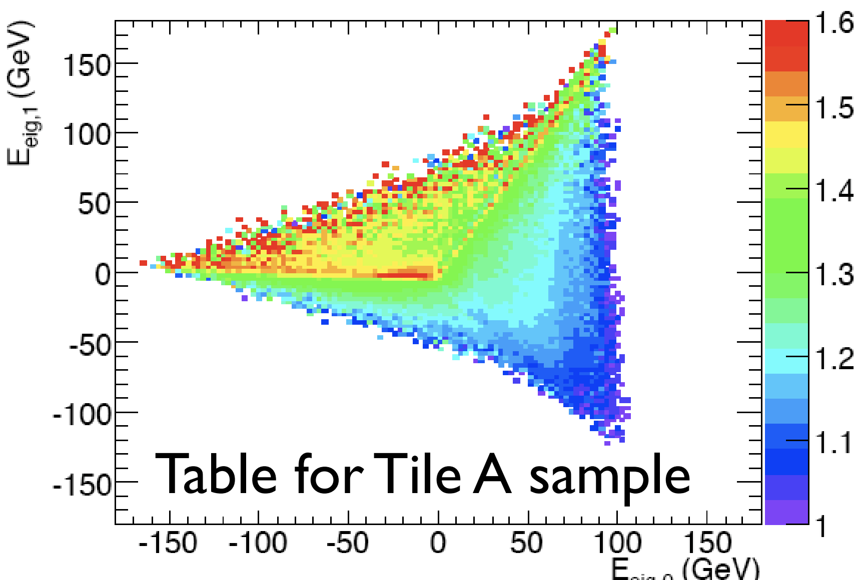
Layer correlation Calibration: more details

Basic idea: hadronic and em energy deposits. have different fluctuation properties
Variables sensitive to fluct. can compensate and provide resolution improvement

- Derive weight by principal analysis technique
  - Calorimeter energy layers (sum of topo-clusters) make an N dimensional vector (E_1, ...E_N)
  - Calculate covariance matrix between layer energies and diagonalize it
  - Derive Layer Energies Components (LEC) (E_{Eig0},..,E_{EigN}) along new basis of covariance matrix eigenvectors

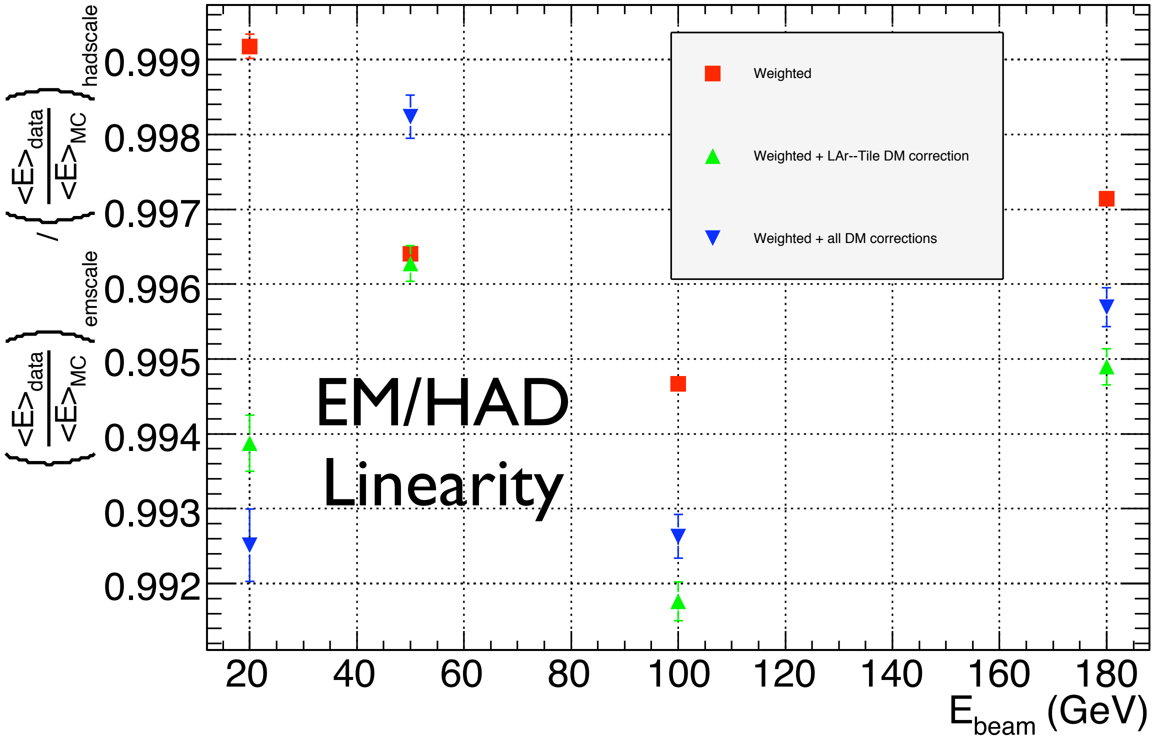


Eigenvalue ordered eigenvec: first few sensitive to most of shower fluctuations



- Build weights
  - One weight table per layer obtained as function of first 2 LECs $w(E_{Eig0},E_{Eig1}) = \langle E_{tot,k}/E_{rec,k} \rangle$ for all events in given bin
  - Superpose various fixed energy samples to avoid beam energy dependence

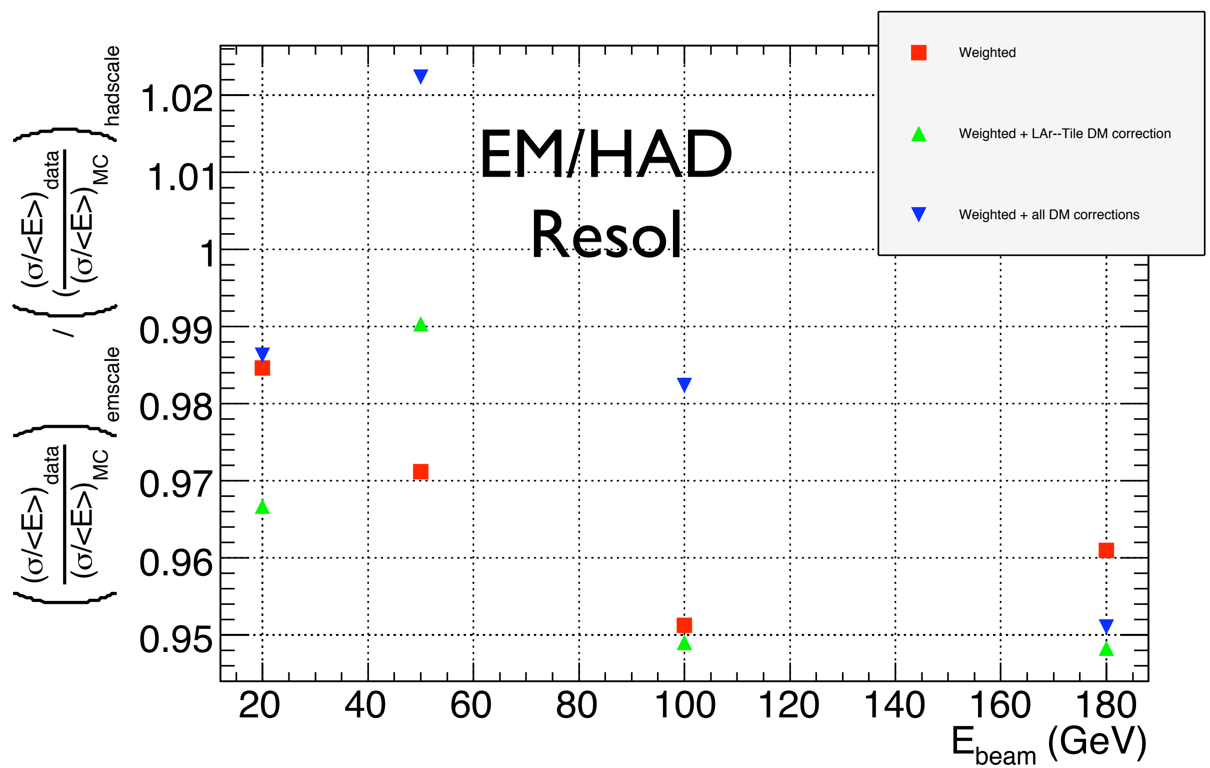
Effect of LC Calibration



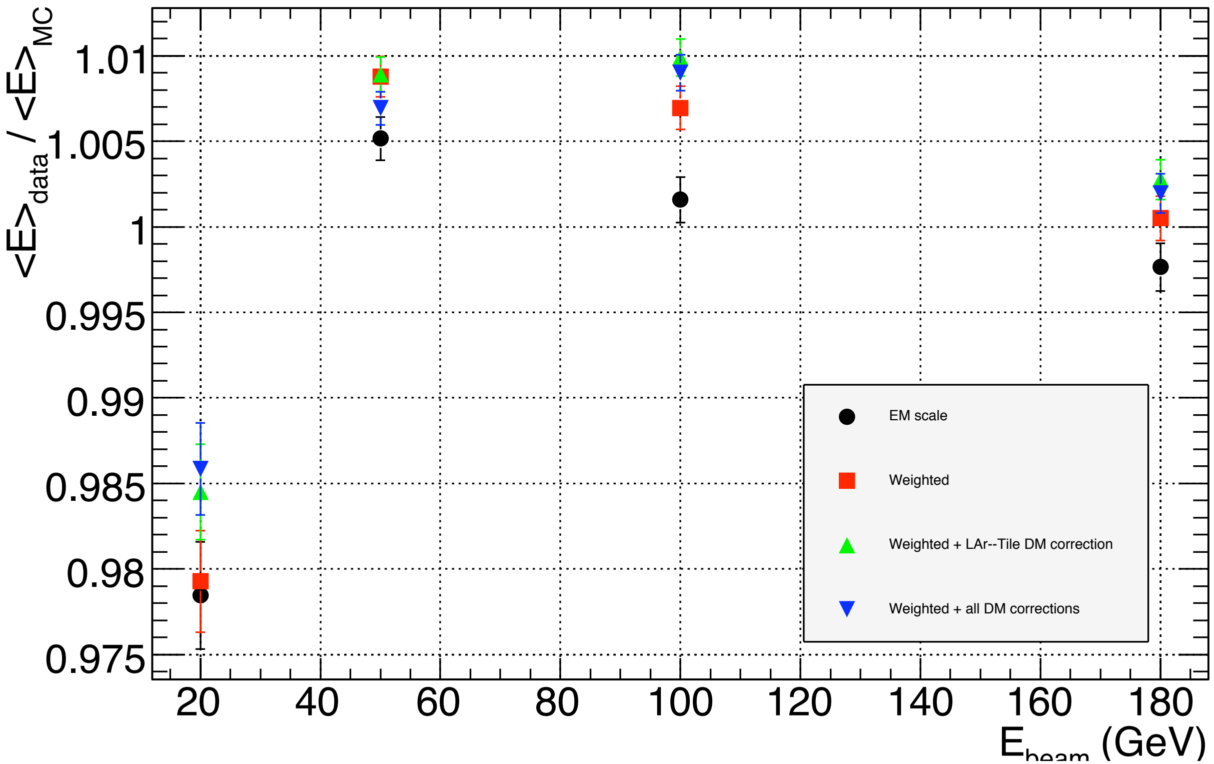
Data/simulation ratios are not varying significantly from em to had scale

LC Calibration does not introduce distortions sizeable in the initial EM description.

uncertainties on em and had ratios are assumed to be fully correlated

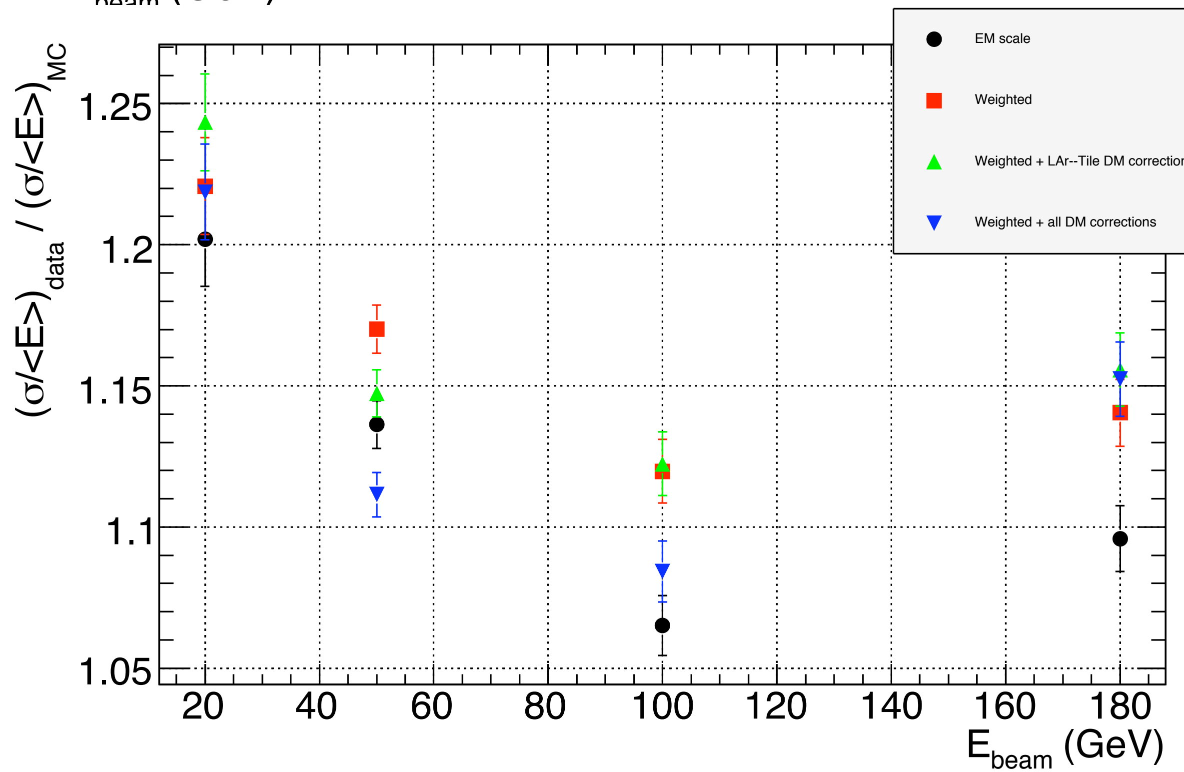


Data-Simulation Ratios in LC

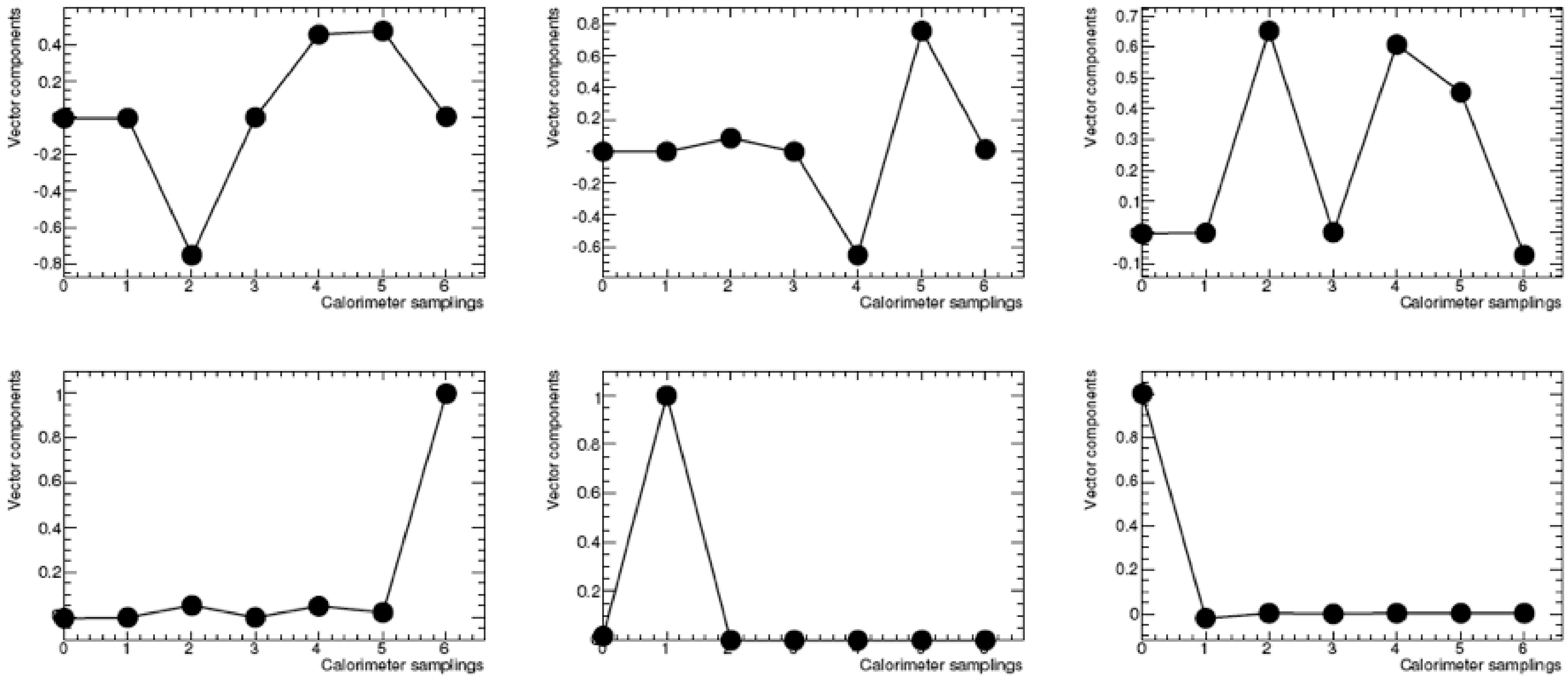


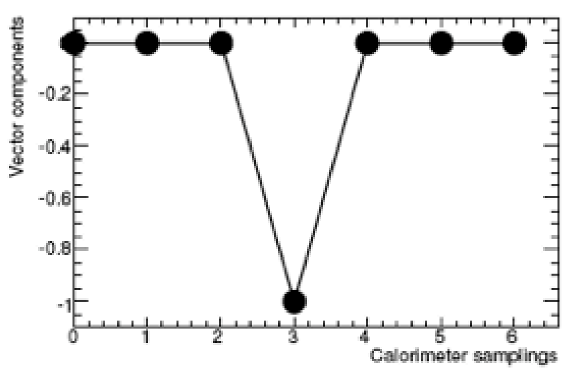
Linearity described at 2% level

Simulation underestimates data relative resolution by 10% to 25%



LC Eigenvectors





- $\vec{E}^{rec}_{eig0} \approx$ “Difference between Tile and LAr”
- $\vec{E}^{rec}_{eig1} \approx$ “Difference between Tile second (middle) layer and Tile first layer”
- $\vec{E}^{rec}_{eig2} \approx$ “Total Energy”
- $\vec{E}^{rec}_{eig3}$ to $\vec{E}^{rec}_{eig6} \approx$ “Individual layers”