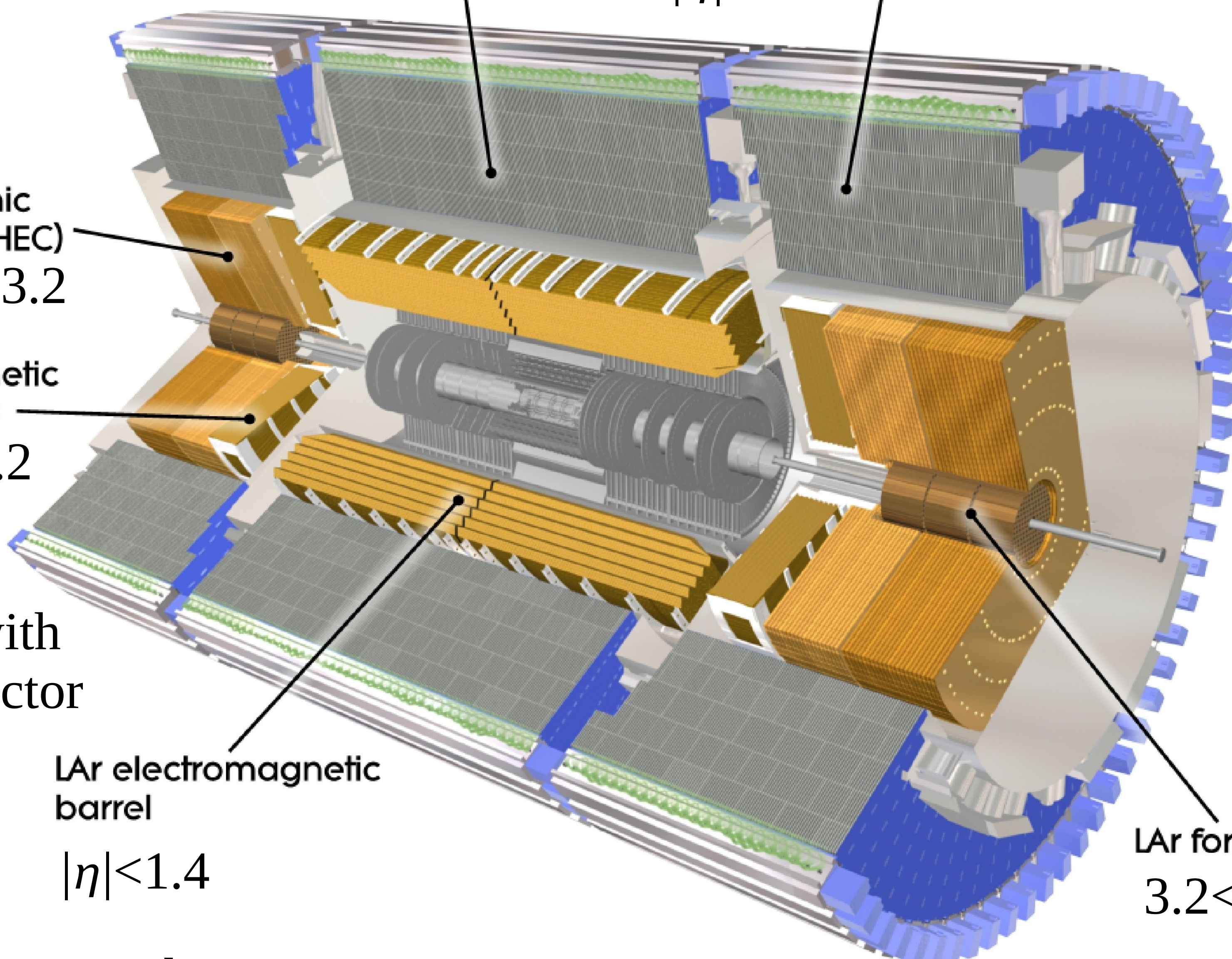
Performance of jet reconstruction and calibration in first ATLAS data at centre-of-mass energies of 7 TeV and 900 GeV

Rolf Seuster (MPP Muenchen)
on behalf of the ATLAS Collaboration
Physics at the LHC, DESY, June 2010

- Introduction
- Jet Reconstruction
- Jet Calibration
- Conclusion

Atlas Calorimeter systems



two regions with changing detector technology:
$|\eta|\sim1.5$
$|\eta|\sim3.2$

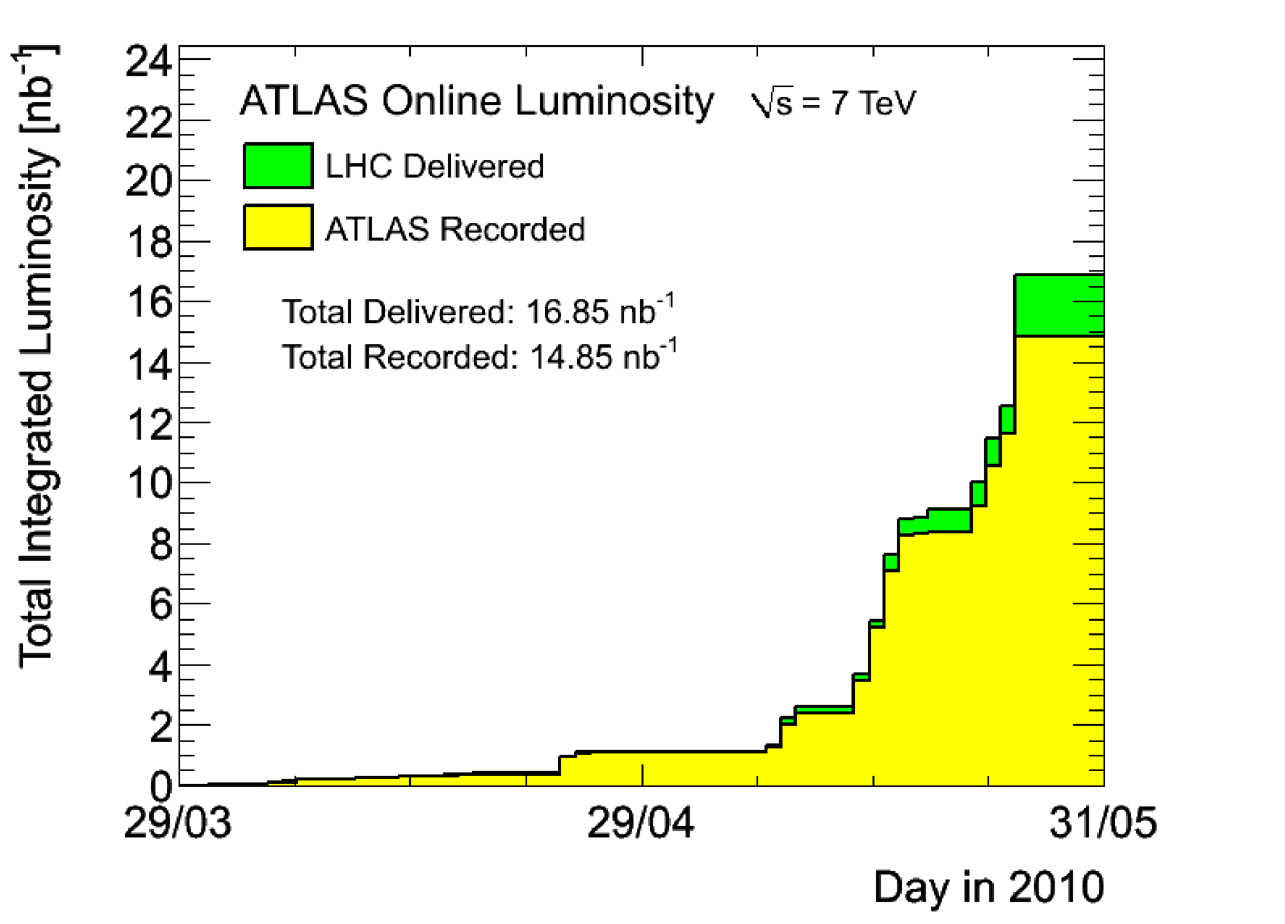
non-compensating calorimeter !

Data sample, luminosity

- data set recorded by ATLAS as of May 31st
  - 14.85 nb^{-1} at 7 TeV
    865 $\times$ 10^6 events
  - peak luminosity
    21 $\times$ 10^{28} cm^{-2} s^{-1}

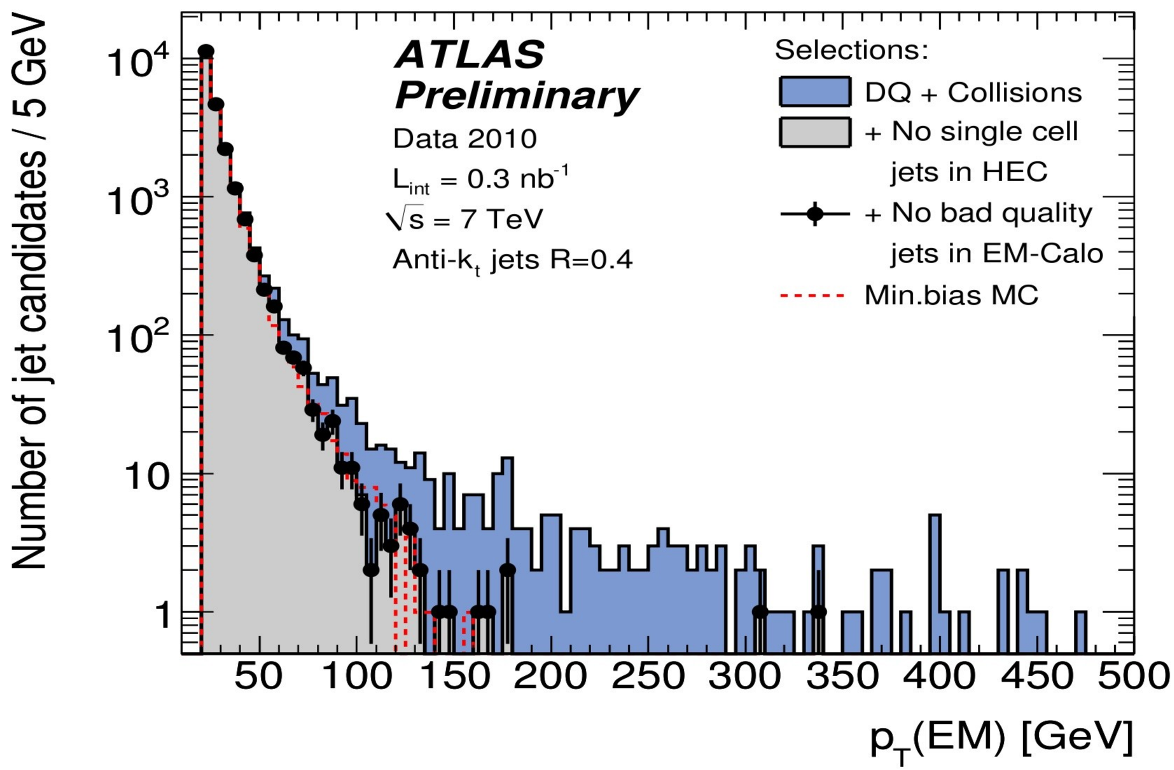
  - presented data set:
    taken in April 2010
    after preselection
    0.3 nb^{-1} at 7 TeV
    14.4 $\times$ 10^6 events

  - for Jet Calibration:
    0.3 $\times$ 10^6 events
    at 900 GeV taken
    in 2009:
    ATLAS-CONF-2010-016



Event Preselection and Jet Selection

- run and event selection:
  - stable beam flag from accelerator
  - calorimeter fully operational with nominal performance
  - primary vertex from center of ATLAS detector
  - event timing consistent with collisions
  - effectively no bkg due to cosmic ray shower and beam related bkg left
- veto jets with:
  - noisy cells in endcap region (largest effect)
  - out of time deposits
  - jets with large energy fractions from cells with bad signal quality
  - see talk by A.Yurkewicz, ATL-COM-PHYS-2010-247



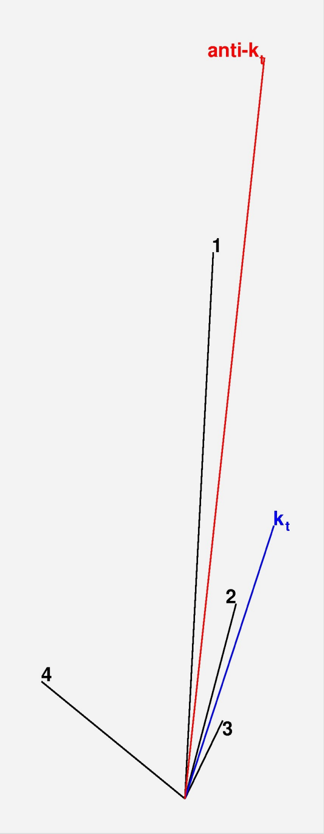
Jet Algorithms in ATLAS

- FastJet k_T(p=+1), Cambridge/Aachen(p=0) and anti-k_T(p=-1)
  - fast jet finder, theoretically clean (IRC safe)
  - iterative procedure to combine proto-jets
  - search for min(d_{ij},d_{ii}). if d_{ij} recombine (i,j) or if d_{ii}: jet i is final

$$d_{ij} = min(p_{T,i}^{2p}, p_{T,j}^{2p}) \cdot \Delta_{ij}^2 / R^2 \qquad d_{ii} = p_{T,i}^{2p}$$

$$\Delta_{ij} = (\phi_i - \phi_j)^2 + (y_i - y_j)^2$$

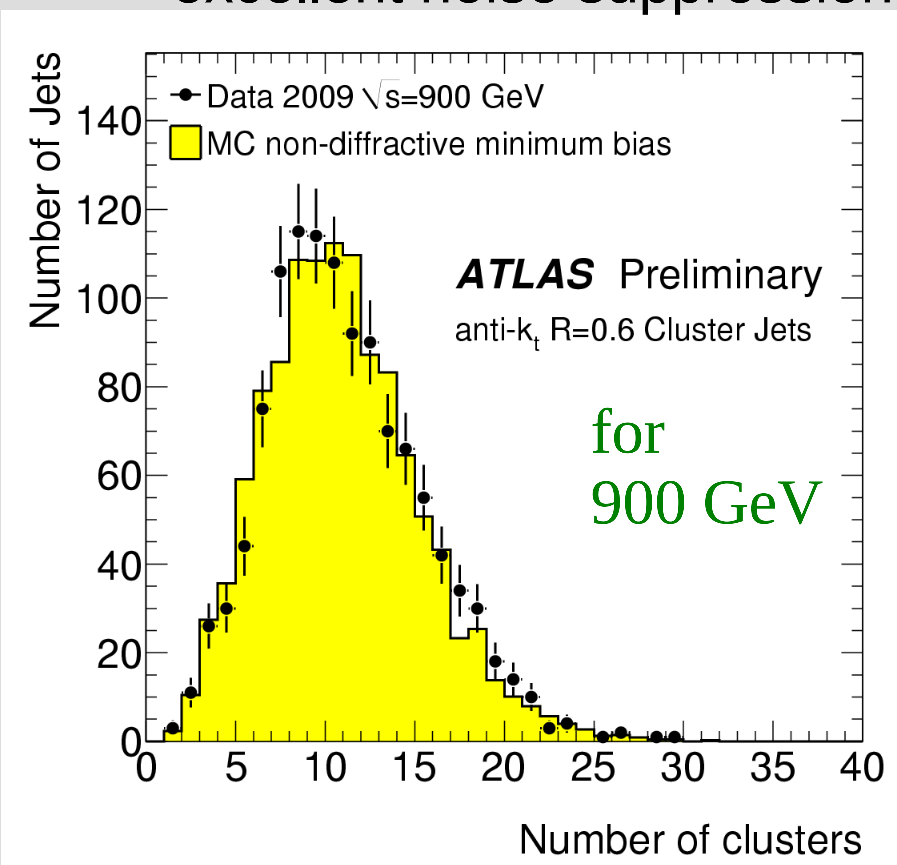
$p_{T,i}, \phi_i, y_i$ transverse momentum, azimuth and rapidity

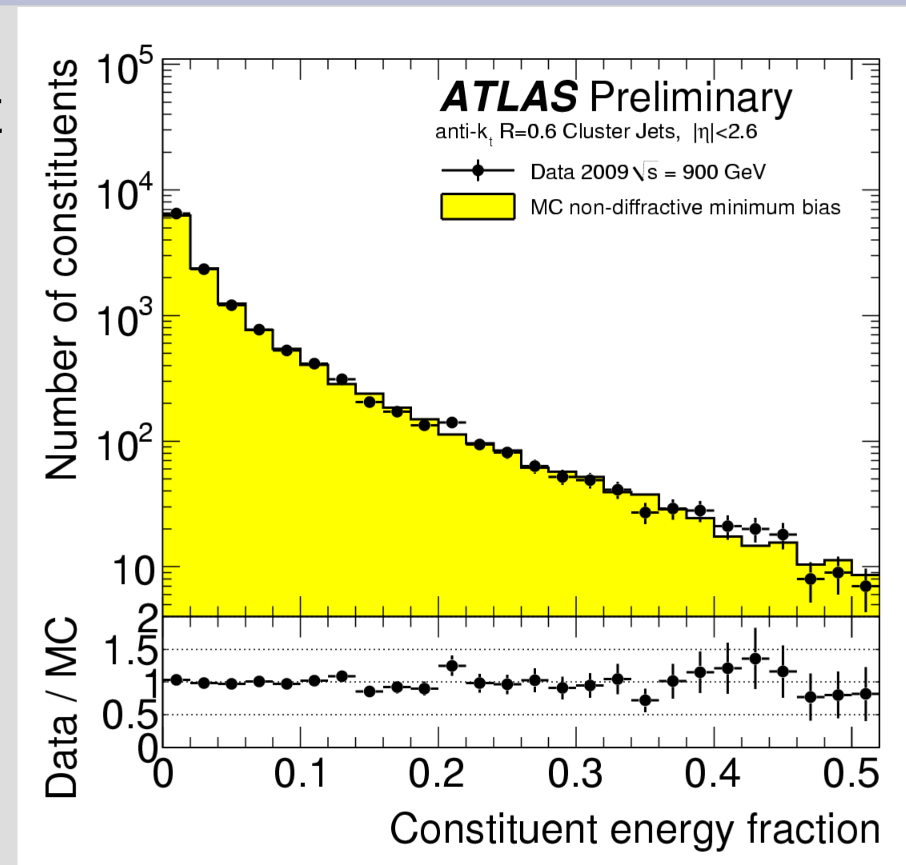


  - in Atlas anti-k_T with radii of R=0.6, 0.4 commonly used
- AtlasCone
  - iterative cone finder w/o ratcheting, split/merge, not IR safe
  - used during commissioning, slowly being retired
- SISCone
  - Seedless IR Safe Cone, split/merge
- other, less common algorithms, some historic

Input to Jet Algorithms: topological Clusters

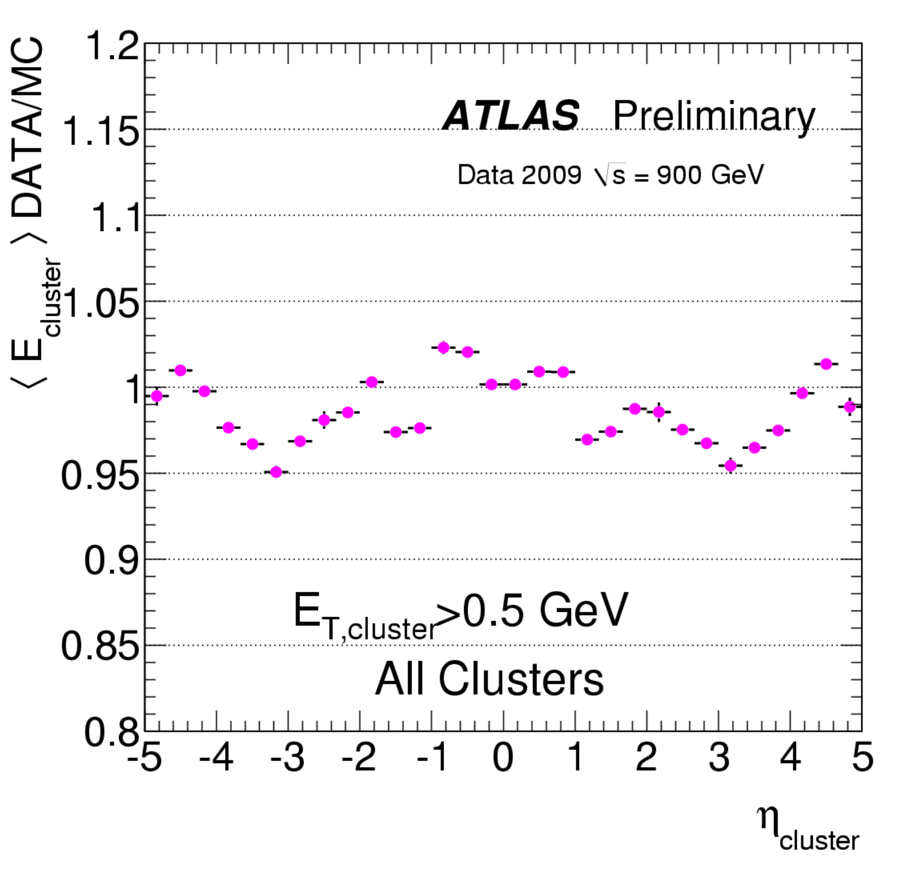
- topological clusters seeded from cells w. $|E/\sigma|>4$, then grow, can split
  - evolution in all 3 dimensions
  - excellent noise suppression





- good agreement btw. data and MC

Inputs to Jet Algorithms: topological Clusters, cont'd



- Transition regions between different calorimeter systems clearly visible
 |n|~ 1.5 and |n| ~ 3.2

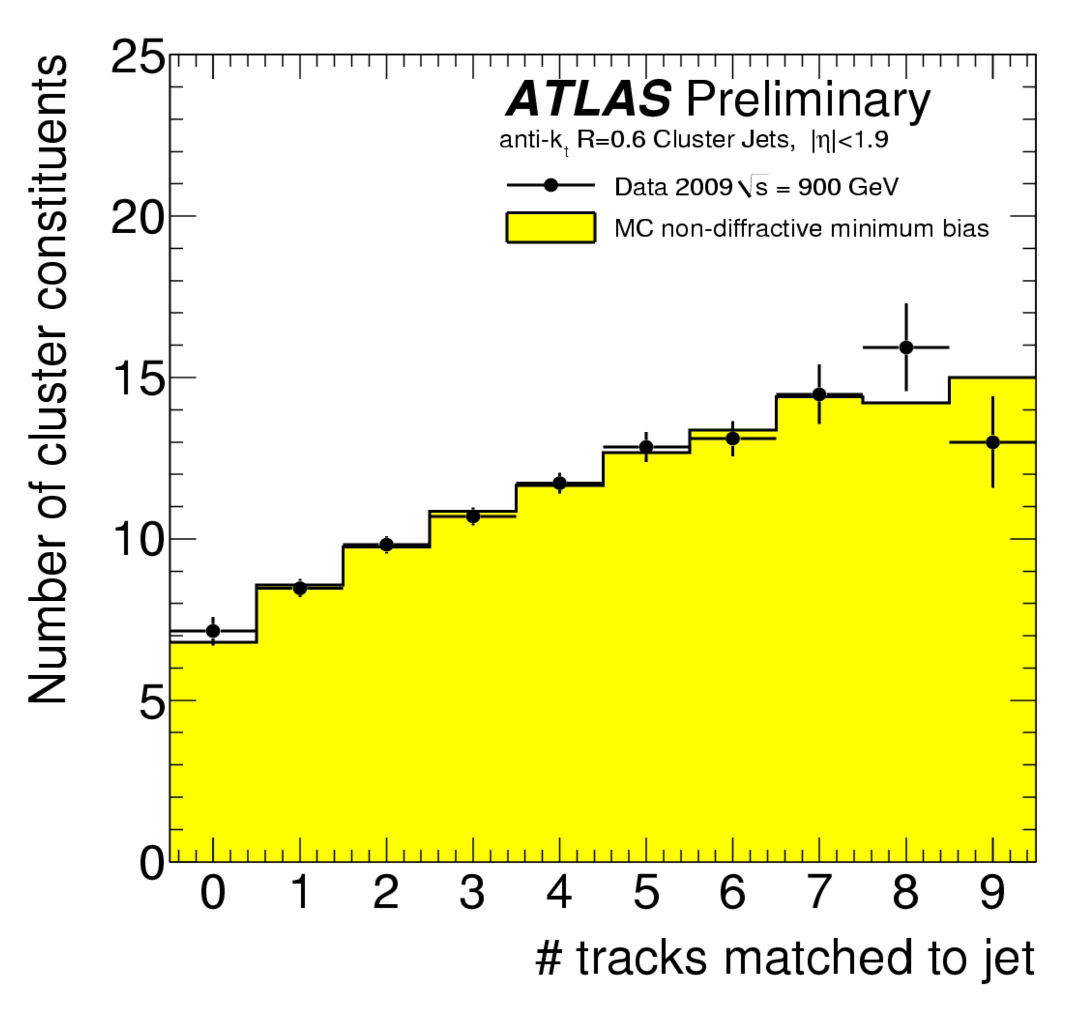
- also available as input (not shown): Towers, fixed grid in eta/phi in 2d
- Noise suppressed Towers:
  - only cells used in topological clusters put onto fixed η-ϕ grid
  - further noise suppression
  - possible advantage for pileup

- However
agreement data/MC slightly worse

- good agreement overall:
 ~ 2%(5%) in barrel (endcap)

Matching Tracks to Jets

- as cross check:
  - match tracks to jets with
    $\Delta R<0.6$ (=jet radius)
    $p_{Track}>500$ MeV
    track consistent with IP
  - restrict jet to $|\eta|<1.9$
    due to tracking acceptance
- nice correspondence of tracks to constituents (topoclusters) !
  - diluted due to neutrals, more than one particle per cluster, ...



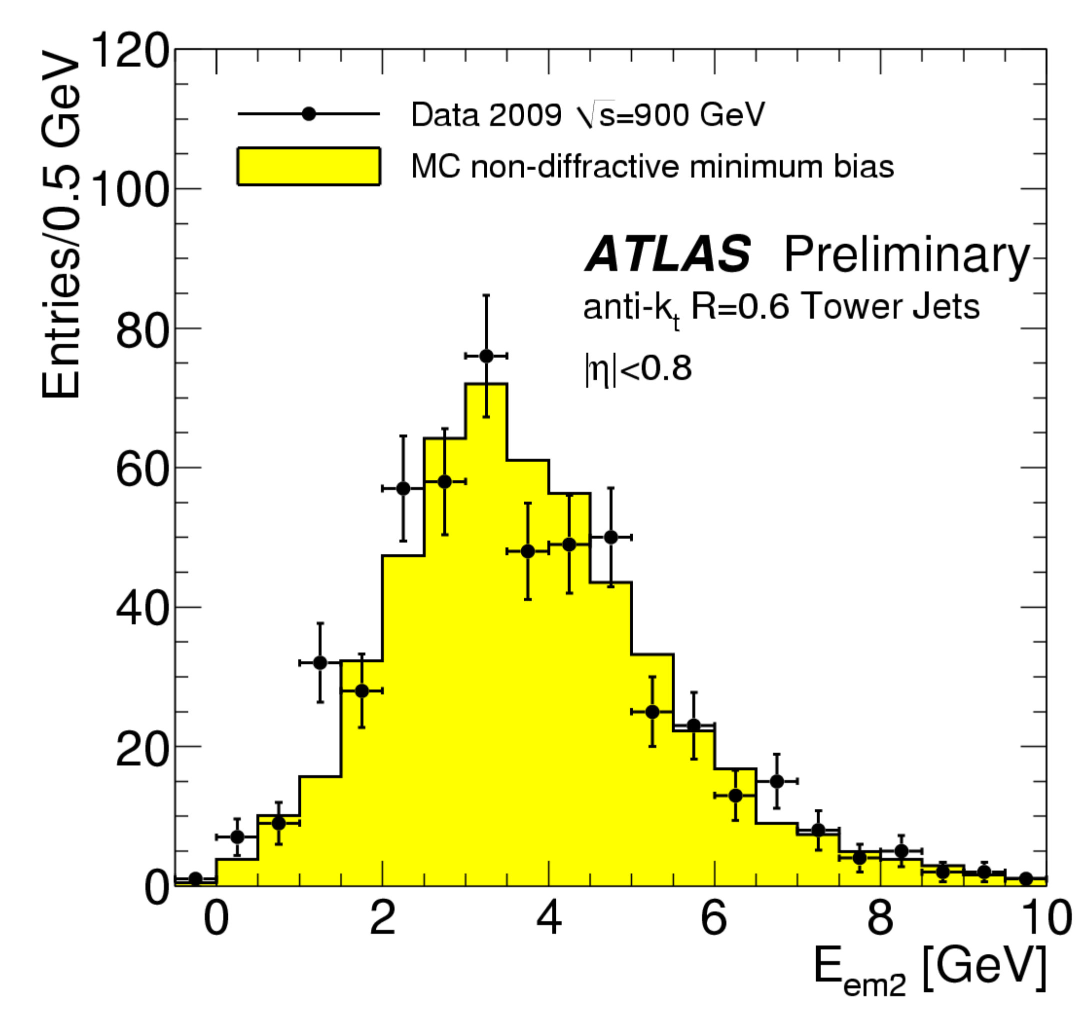
- slightly worse agreement for jets made from towers (not shown)

Jet Calibration

- non-compensating calorimeters in ATLAS require software calibration of energy deposits of pions to equalize response to electrons and pions, referred to as Jet Calibration
- currently 4 different calibration schemes available:
  - EM+JES, jet on electromagnetic scale plus simple correction factor for jet energy scale
    - currently simple correction factor in eta/pt derived from MC, could be derived in-situ from gamma-jet/di-jet balance
  - Global Sequential
  - Global Cell Weighting
  - Local Cluster Weighting
- GCW and LCW rely on good Geant 4 detector description !
  GS in parts, too
- In the following slides, last 3 methods are introduced, and data / MC comparisons of observables on which the calibration schemes depend are shown

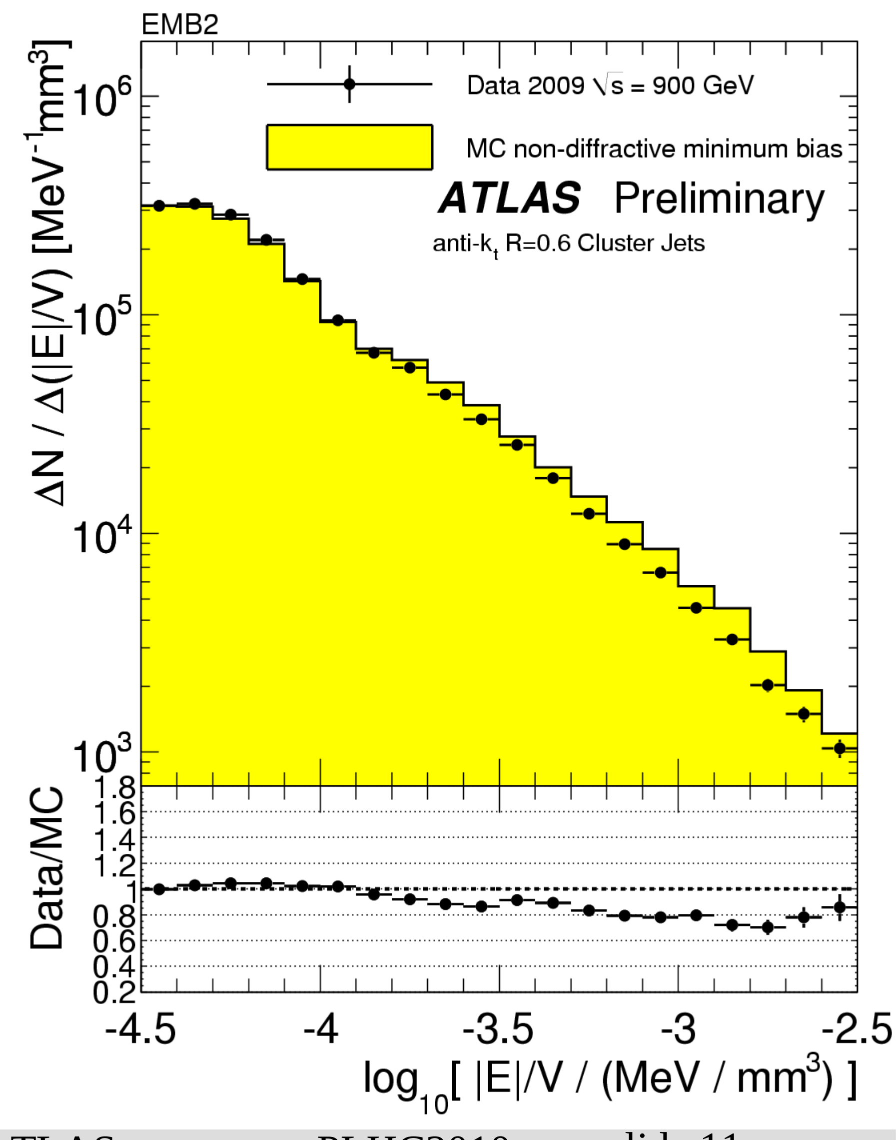
Global Sequential Jet Calibration

- applied after EM+JES, attempt to improve resolution based on jet properties:
  - energy per layer
  - jet width (not shown here)
- 900 GeV: mostly low p_T jets: typically most energy deposited in second layer of EM calorimeter in barrel and in endcap regions
- good agreement at 900GeV also for other layers in calorimeter



Global Cell Weight Jet Calibration

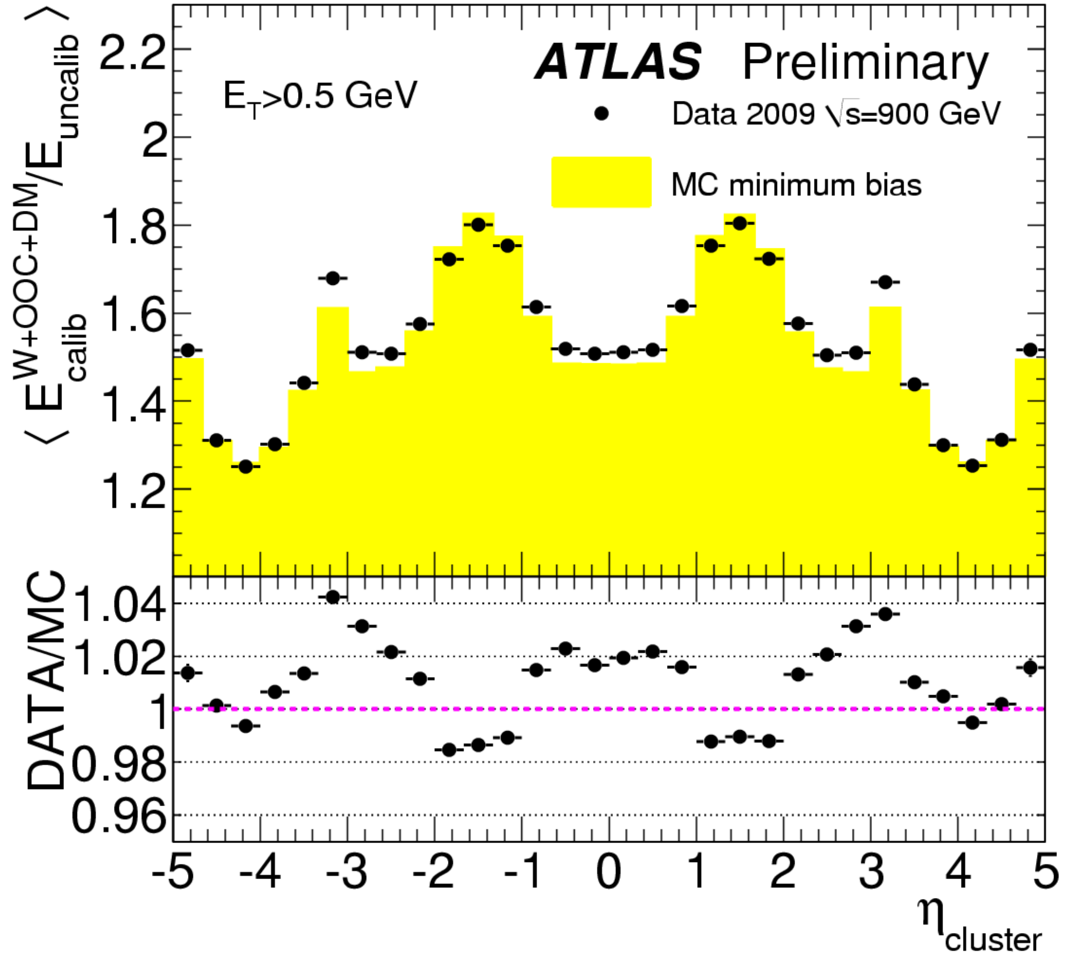
- Global fit to minimize jet energy fluctuations
- cell weights depend on cell densities bins in eta
- good agreement between MC and data for cell energy density distrib. However, MC predicts more events with higher energy density
- more studies needed to understand this effect
- difference could be from
  - MC particle spectra
  - hadronic shower modelling, etc.
  - e.g. compare jets from tracks



Local Cluster Weighting for Jet Calibration

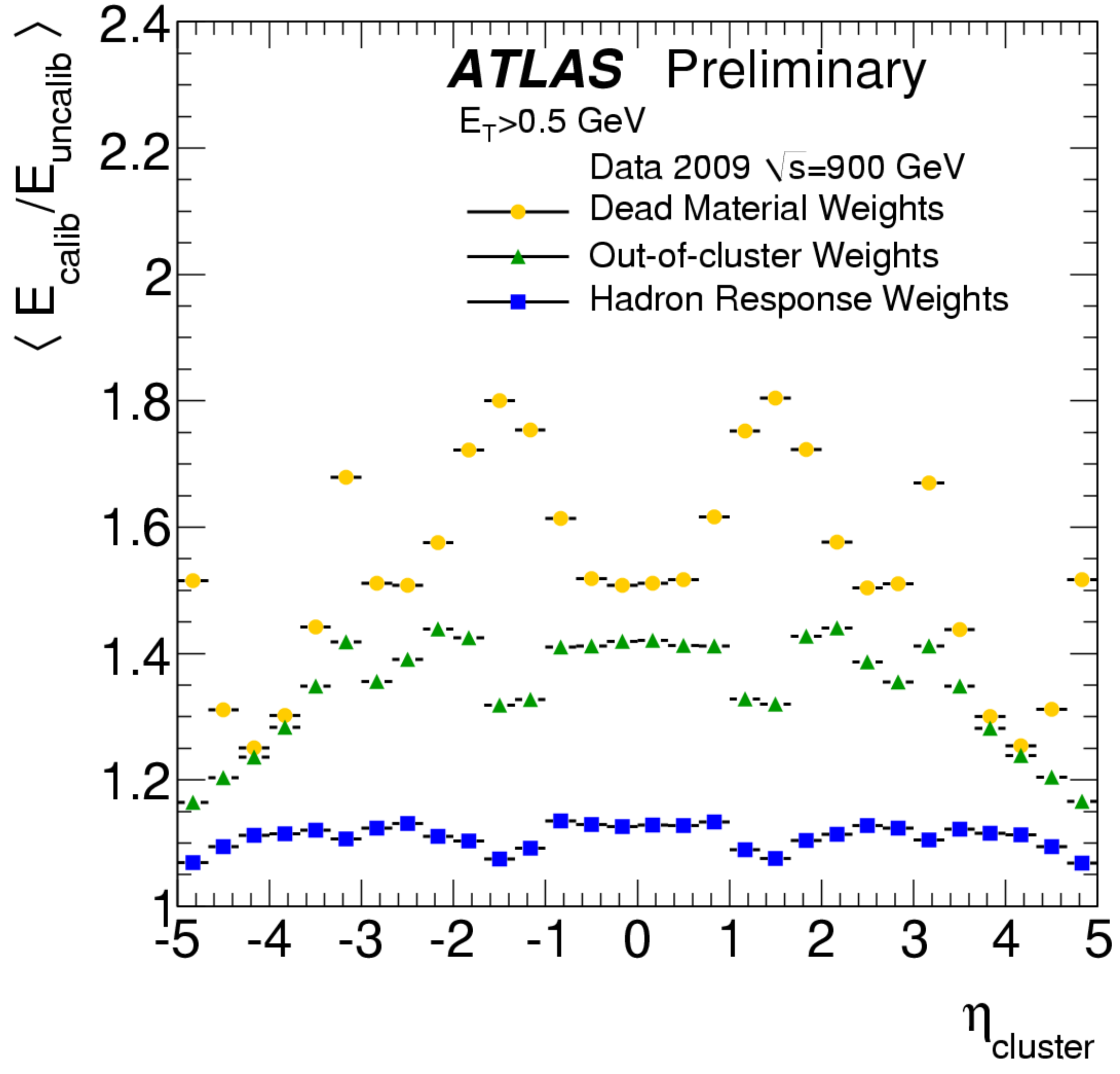
- inputs to jet algorithm calibrated first, then simple jet calibration
- most elaborate, calibrate local energy deposits in calorimeter based on simulation of charged, neutral pions
- attempt to separate detector effects (non-compensating calorimeter, dead material, ...) and physics effects

- calibrated clusters vs eta
- detector structure visible e.g. |η|~3 transition region endcap and forward detectors



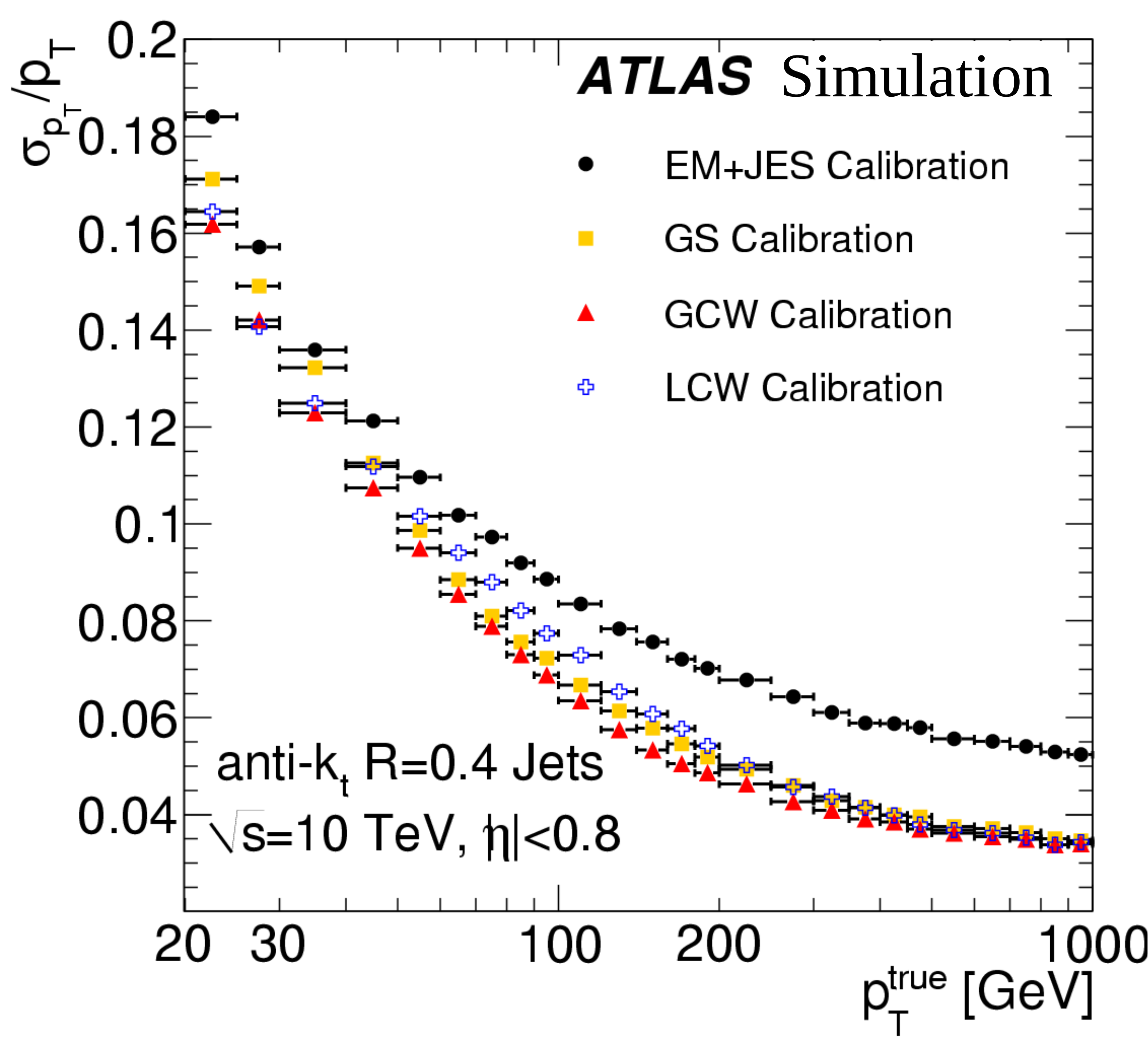
Details about Local Cluster Weighting

- Topological clusters:
  3 steps during weighting:
- classify energy deposits as electromagnetic or hadronic and weight them (W, blue)
- correct for energy deposits in calorimeter, but not collected in this or other clusters (OOC, green triangles)
- correct for energy deposits outside of active calo (DM, yellow points)
- all weights derived from detector simulation
- largest effect from DM in transition regions $|\eta|$~1.5 and $|\eta|$~3.2



Performance of different Jet Calibration schemes

- as expected 'simple' EM+JES performs worst at high pT
- GS, GCW, LCW show very similar performance over almost all p_T although corrections depend on different input



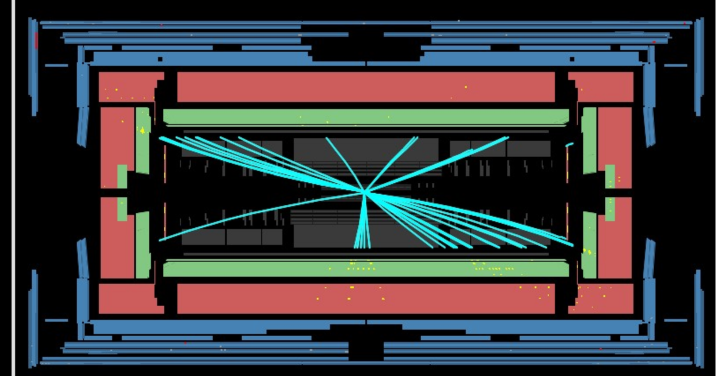
Summary and Conclusion

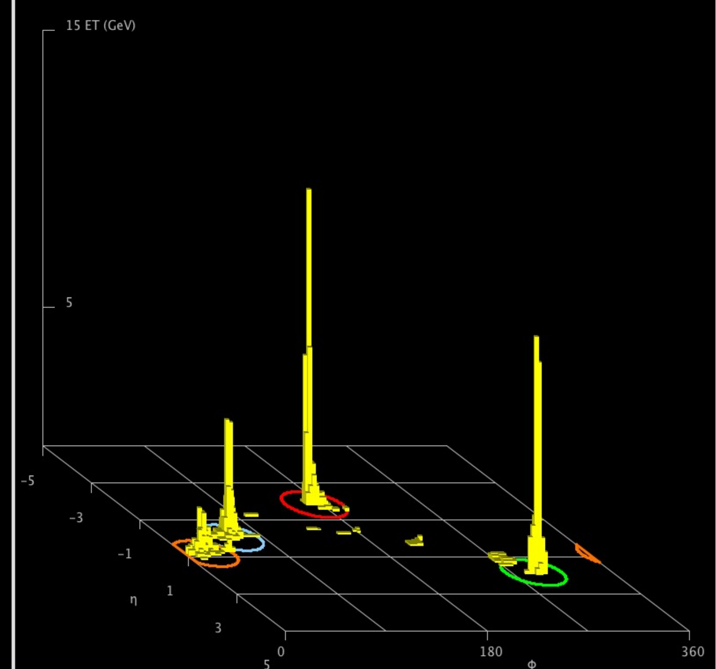
ATLAS EXPERIMENT

Run Number: 152441, Event Number: 4918171

Date: 2010-04-06 10:26:47 CEST

- Jet Reconstruction in ATLAS in good shape:
  - impressive agreement between data / MC
  - few discrepancies need further studies, not surprising after just few weeks of data taking !
- Jet Calibration in ATLAS also in good shape
  - extensive test beam analyses and continous improvement of Geant4 simulation pay off !
  - 4 different jet calibrations available despite different input, 3 of which with comparable, very good performance !
  - updated results with 7 TeV for ICHEP

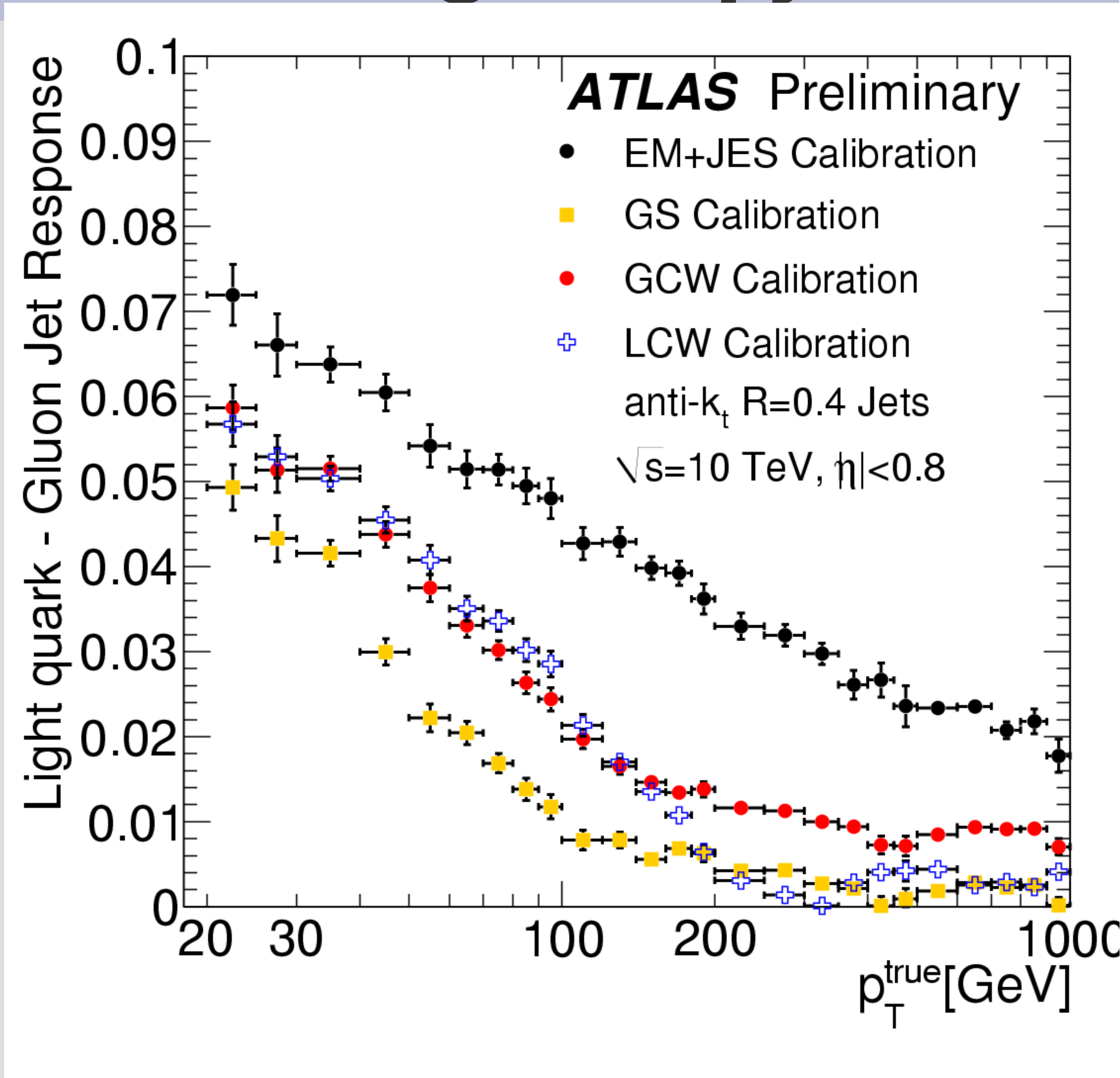




BACKUP

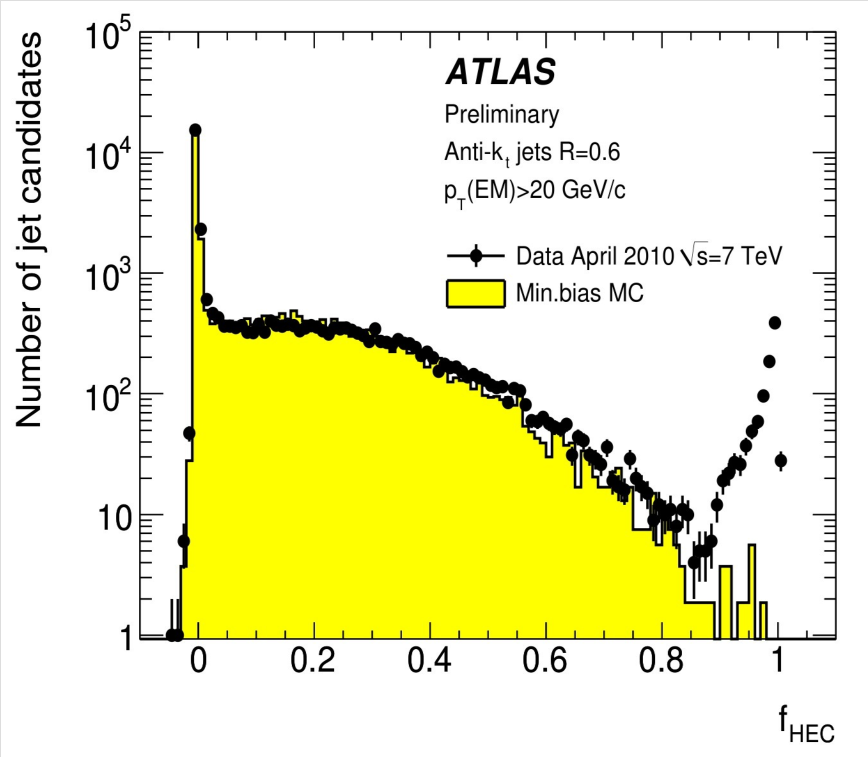
Performance of different calibration schemes: g vs q jets

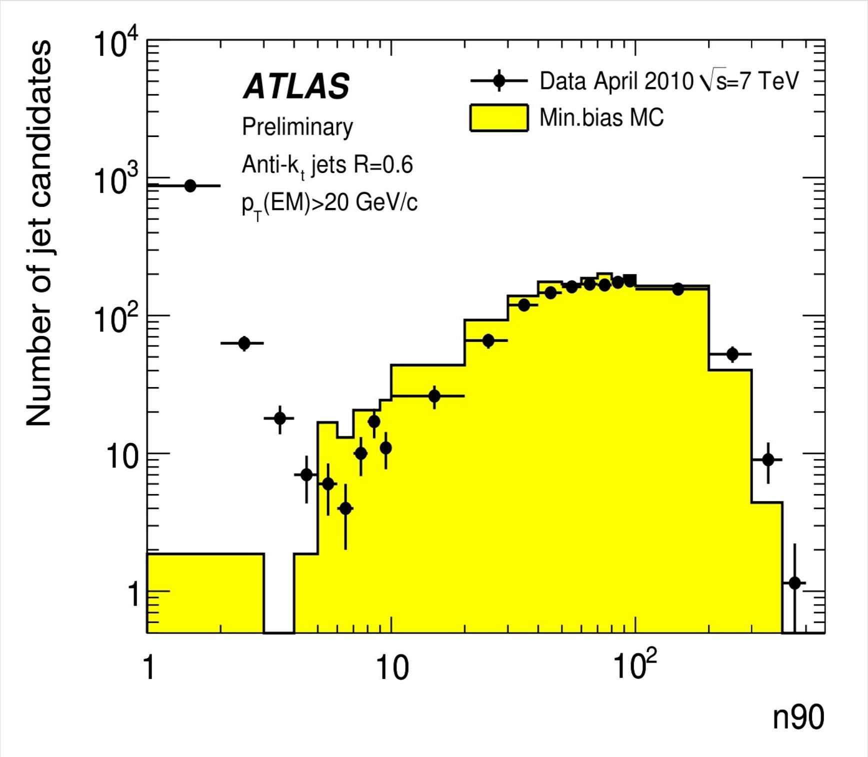
- GS calibration only calibration taking
  jet properties (jet width) into account, helps in separating gluon from quark jets



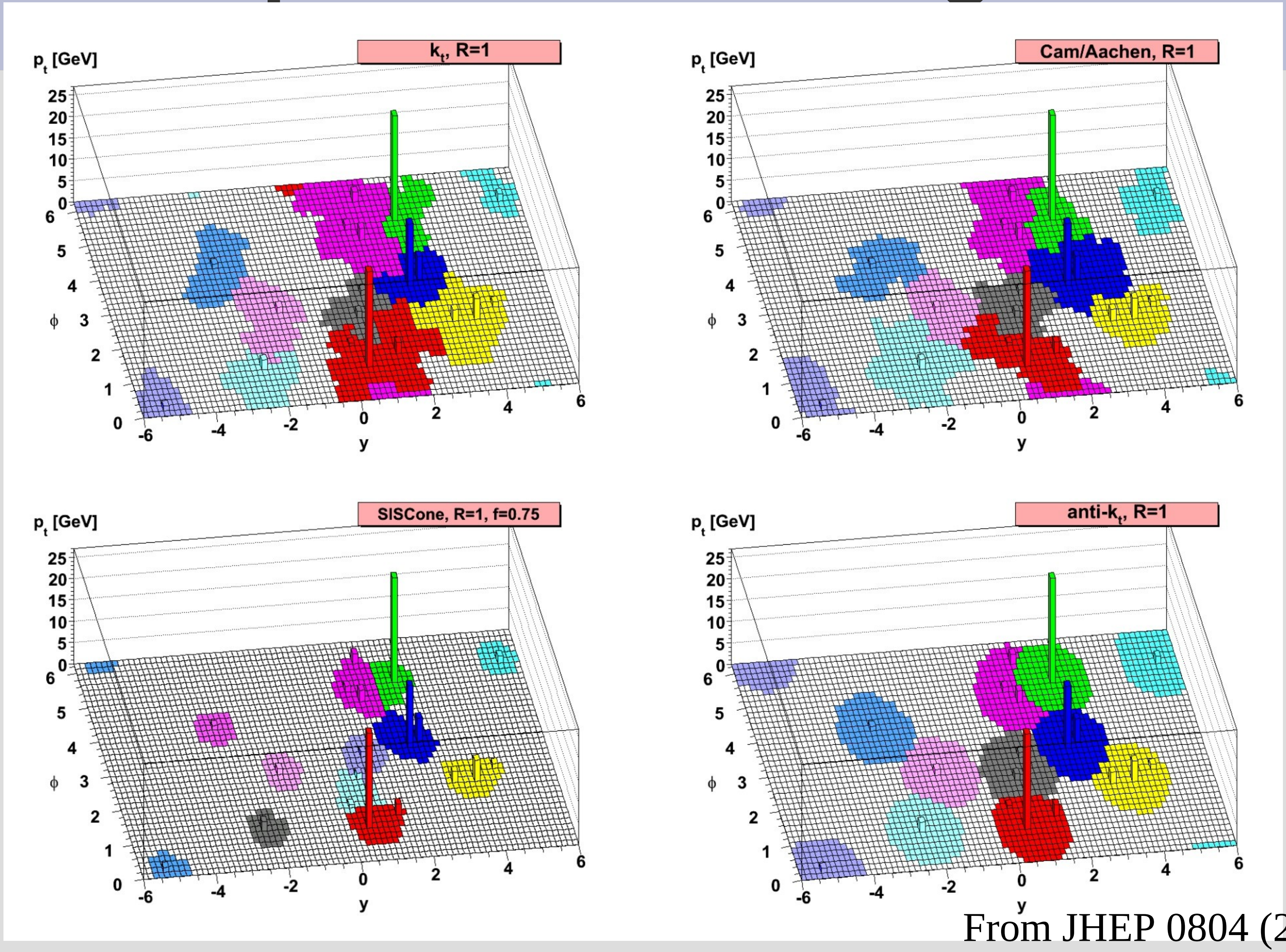
Jet Quality cuts: f_{HEC} and n90

- f_{HEC}: fraction of energy of jet from HEC
- n90: minimum number of cells which have more than 90% of E_jet





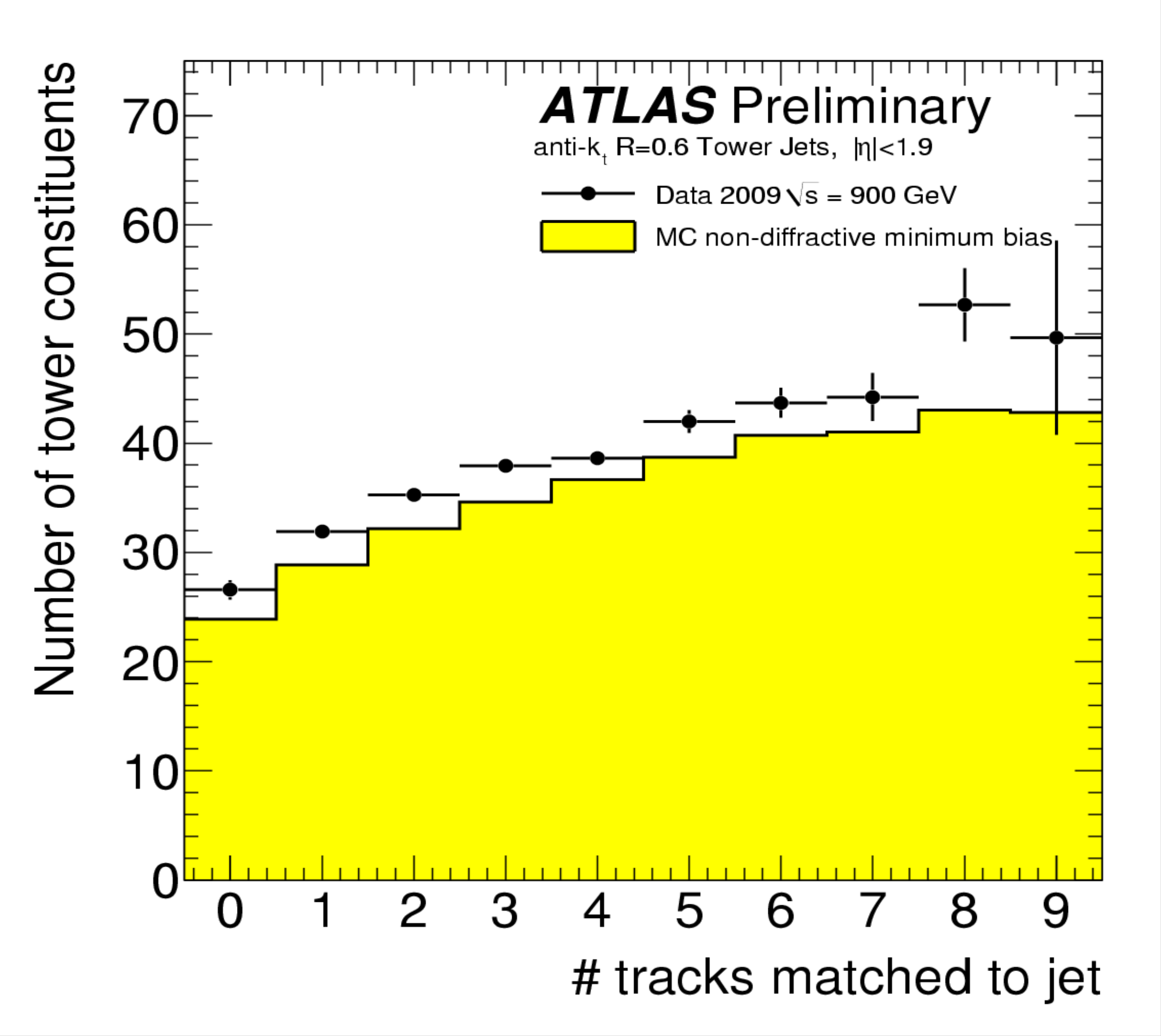
Jet Shapes for some Algorithms



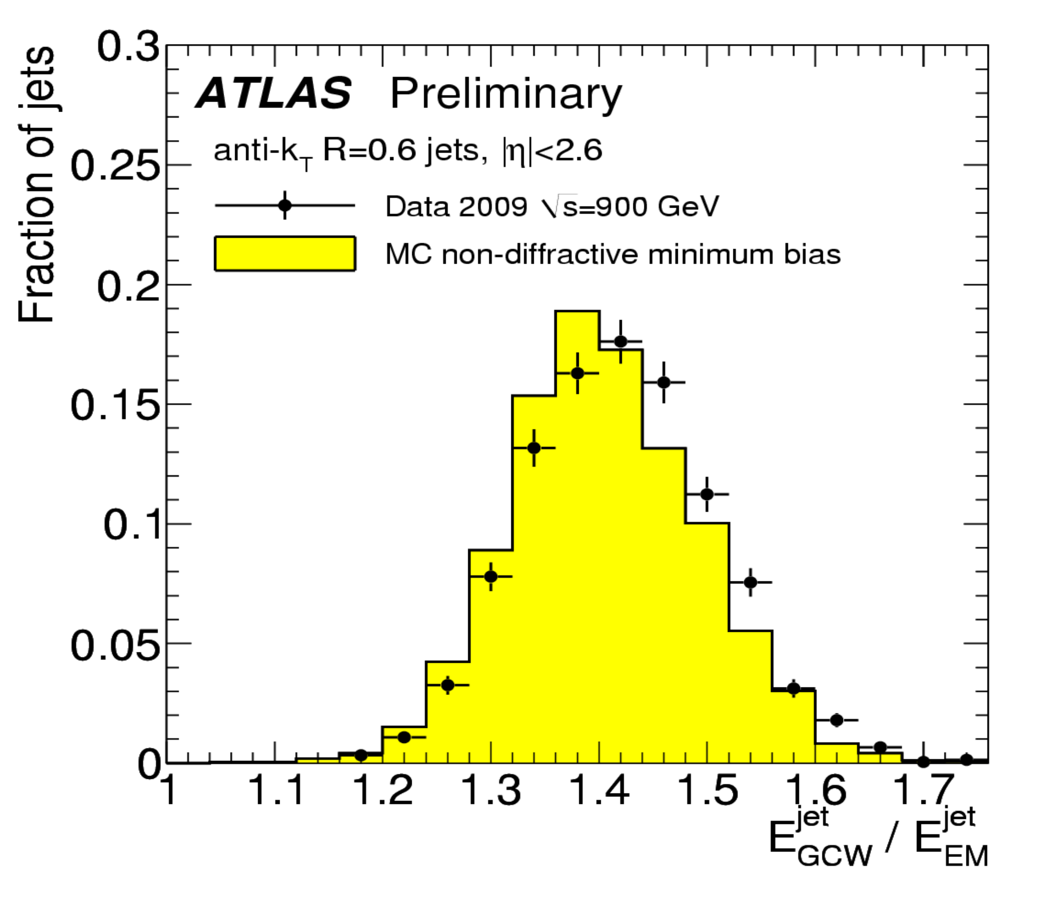
From JHEP 0804 (2008) 063

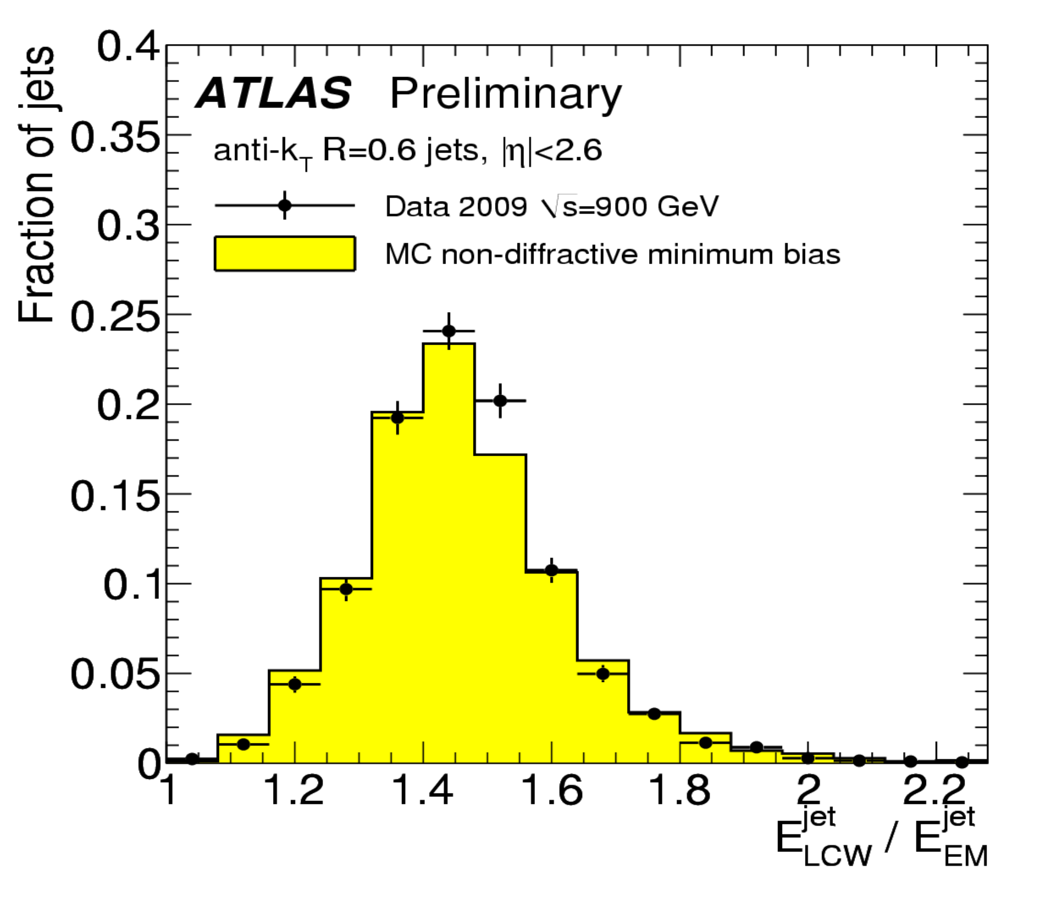
Matching Tracks to Jets

- noise suppressed towers



Jet Energies after weighting





- Correction factor in agreeement with expectation from e/π, from non-compensating calorimeter