Performance of jet reconstruction and calibration in first ATLAS data

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on behalf of the ATLAS Collaboration

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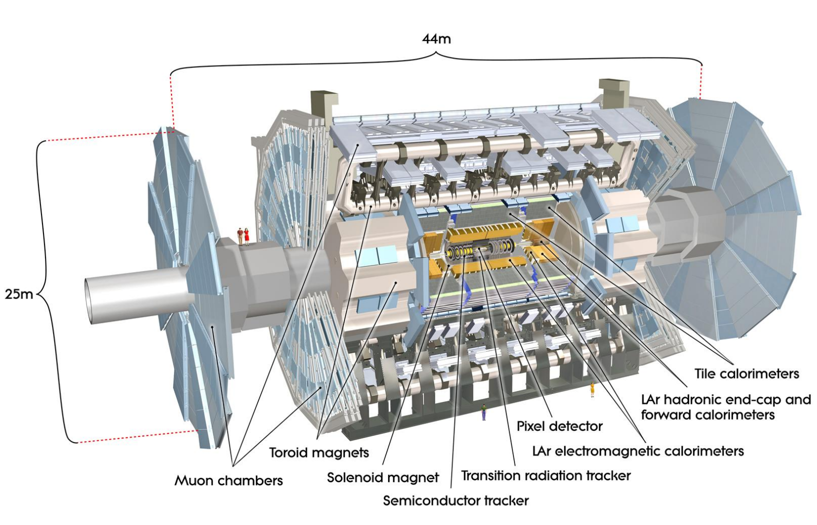
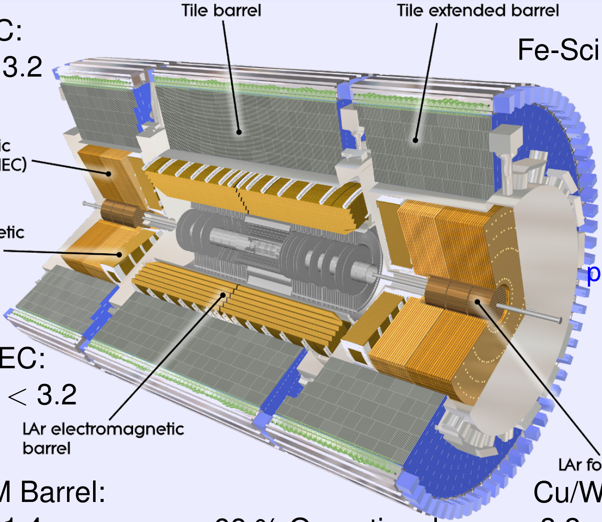
The ATLAS Detector



The ATLAS Calorimeters

Cu-LAr HEC:
$1.5 < |\eta| < 3.2$

Fe-Scintillating Tile:
$|\eta| < 1.7$



Segmented in pseudo-rapidity (η) and ϕ

Non-compensating

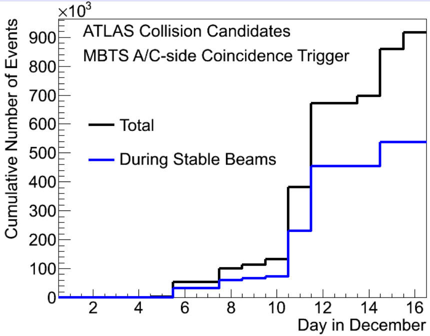
Pb-LAr EMEC:
$1.375 < |\eta| < 3.2$

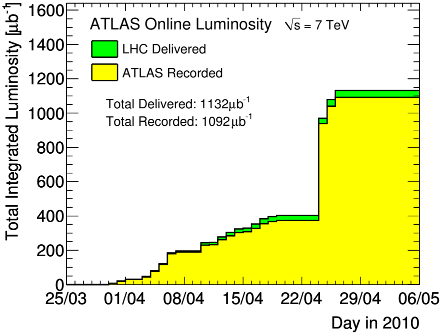
Pb-LAr EM Barrel:
$|\eta| < 1.4$

$>$ 98 % Operational

Cu/W-LAr FCal:
$3.2 < |\eta| < 4.9$

The 2009 and 2010 Data Samples





900 GeV (2009)

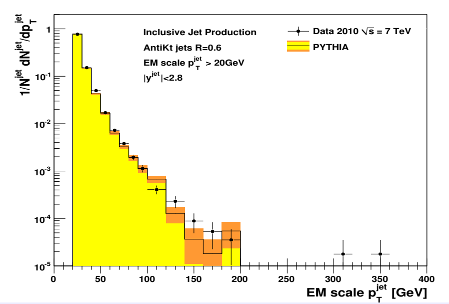
- Peak Luminosity $\approx 7 \times 10^{26}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Integrated Luminosity: $12\ \mu\mathrm{b}^{-1}$

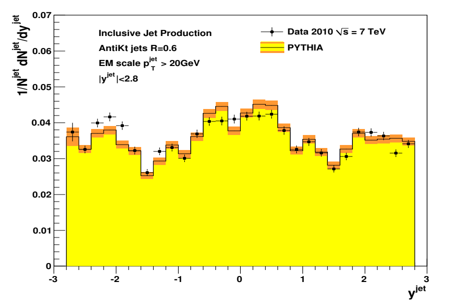
7 TeV

- Peak Luminosity $\approx 2 \times 10^{28}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Integrated Luminosity: $\approx 1.1\ \mathrm{nb}^{-1}$

Observation Jets at $\sqrt{s} = 7$ TeV

- Using **AntiKt** [1] jets with $R = 0.6$
- Infrared and collinear safe
- First analysis use uncalibrated ("EM-scale") jets with $p_T > 7$ GeV





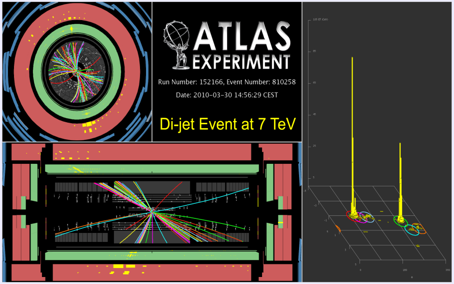
- Jets must be contained in the barrel and endcap calorimeter:

$$|\eta| < 2.8$$

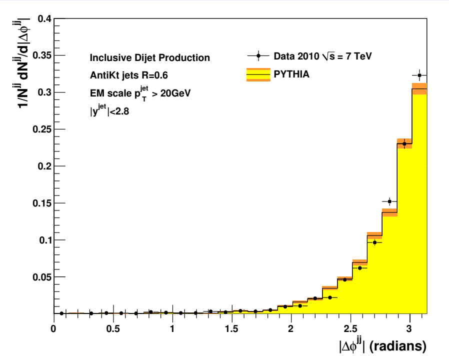
- Kinematic distributions well reproduced by MC

Di-Jet Events at $\sqrt{s} = 7$ TeV

EM-scale $p_T^{\mathrm{jet}} \approx 300$ GeV



- Di-jet events observed in early data
- MC reproduces kinematic balance (back-to-back)

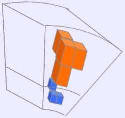


- Minimum bias data and MC agree well for EM scale jets without hadronic calibration
- MC normalized to 350 μb^{-1} of data

Jet Algorithm Inputs

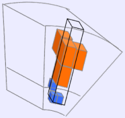
Clusters

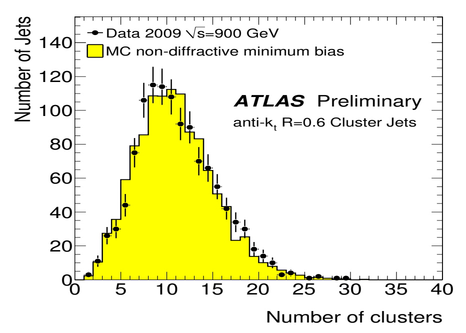
Nearest neighbor cells selected by energy significance

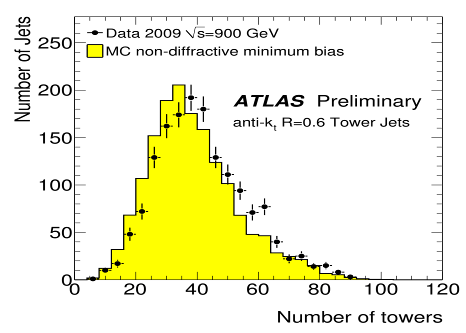


Topological Towers

Noise suppressed towers from cells in clusters



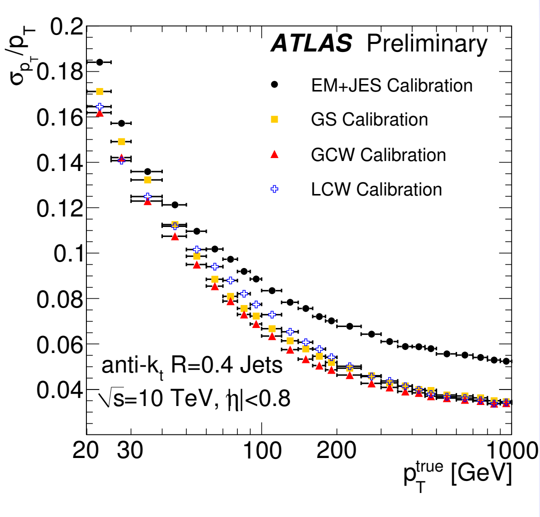




Cluster distribution in good agreement

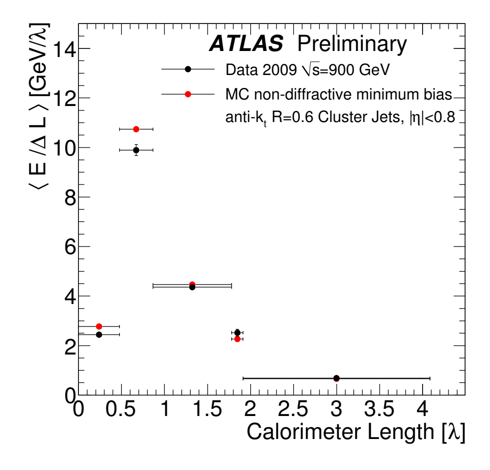
Jets wider and clusters bigger in data

Jet Calibration Schemes



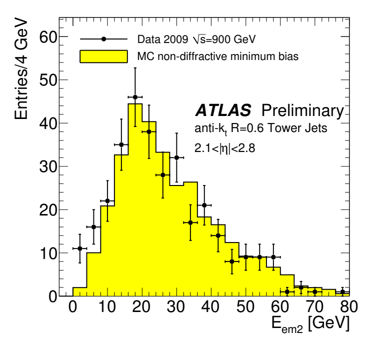
- **EM+JES (Early Data)**
  p_T and η dependent scale correction factor (MC or data based)
- **GS**
  Global sequential calibration using jet properties (MC or data based)
- **GCW**
  Cell energy-density weighting in jet context (MC based)
- **LCW**
  Cell energy-density weighting in cluster context (MC based)

Global Sequential (GS) Calibration



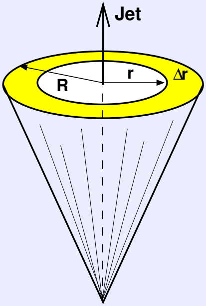
Energy deposited in calorimeter depth for data (black) and MC (red)

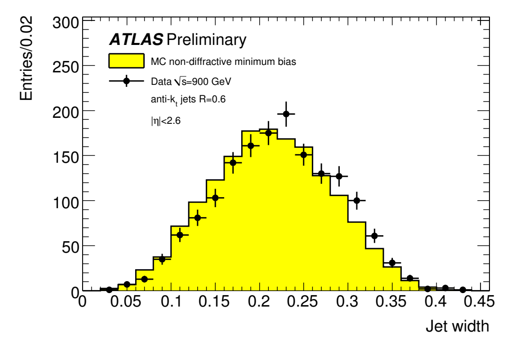
- Weighting by longitudinal shower development and jet area
- Jet shape well modeled by MC for early calibration



Global Sequential (GS) Calibration - Jet Area

- Wider jets usually need higher calibration coefficient
- Discriminates quark from gluon jets
- Jets are wider in data

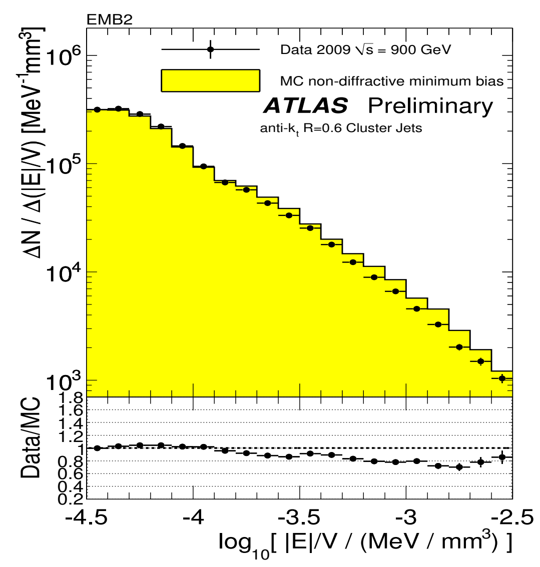




- First moment of radial energy distribution:

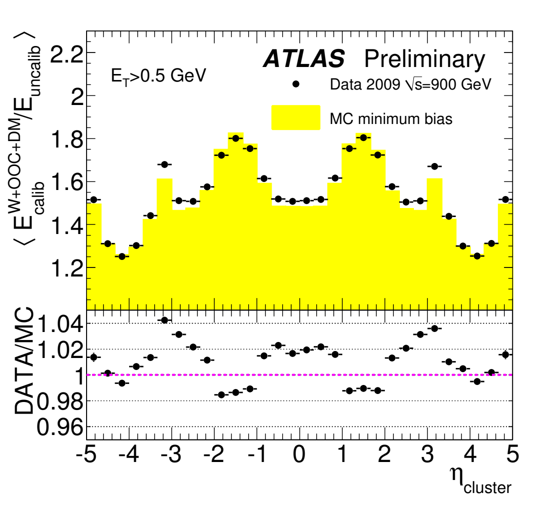
$$\text{width} = \frac{\sum_i^{Constituents} \Delta R^i \cdot E_{\mathrm{T}}^i}{\sum_i^{Constituents} E_{\mathrm{T}}^i}$$

Global Cell Weights (GCW)



- Obtained by matching jets to truth jets in MC and fitting cell weights as a function of cell energy density
- Small excess of high energy density cells in MC
- Overestimate of global correction weights for data

Local Cell Weights (LCW)



- **W:** Energy density based correction weights for cells in a cluster
- **DM:** Cluster corrections for dead material
- **OOC:** correction for cells not picked up by clustering algorithm
- Cluster corrections are larger in data, but agree within 4 %

Summary and Outlook

- ATLAS recently recorded data at $\sqrt{s} = 900$ GeV, and is currently recording data at $\sqrt{s} = 7$ TeV
- Jet properties are well-reproduced by Monte Carlo simulation
- Various calibration schemes are under study and show excellent agreement between MC and data
- Jet properties suggest important differences which are likely a combination of detector and physics effects
- Jets are expected in the final state of most physics channels such as:
  - Early QCD (di-jet cross-section), early SM (W/Z+jet(s)) and top analysis
  - Eventually in and searches for the higgs and new physics!

The AntiKt Jet Algorithm

- Using AntiKt algorithm of the fastjet [1] library
- Use clusters or towers as proto-jets and define a distance measure:

$$d_{ij} = min\left(\frac{1}{{p_T}_i^2}, \frac{1}{{p_T}_j^2}\right)\frac{\Delta_{ij}^2}{R^2} \quad (1)$$

$$d_{ii} = \frac{1}{{p_T}_i^2} \quad (2)$$

where:

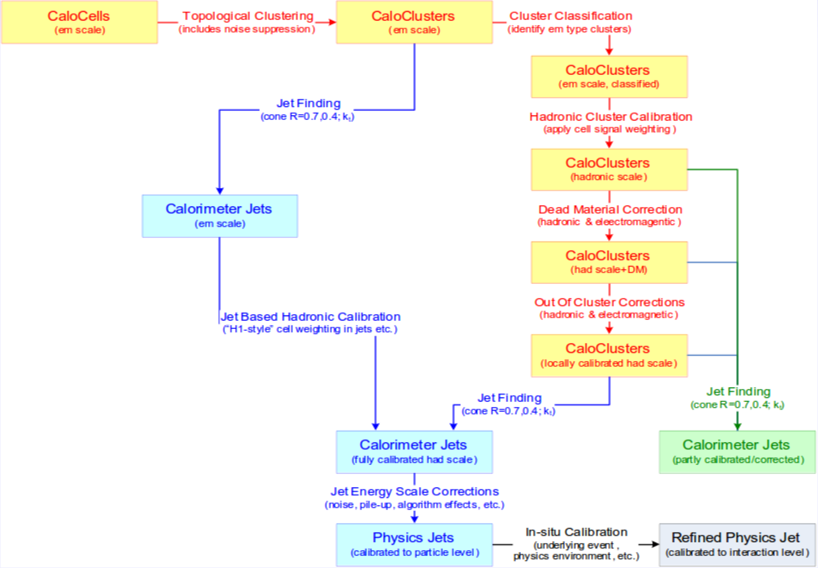
  - $\Delta_{ij} = (\phi_i - \phi_j)^2 + (y_i - y_j)^2$
  - ${p_T}_i$, y_i, and ϕ_i are the transverse momentum, rapidity and azimuth of proto-jet i
  - $R = 0.6$ (0.4) in ATLAS reconstruction

- Until no proto-jet are left compute all d_{ij} and take smallest d_{ij}:

$i \neq j$ Remove proto-jet i and j and add 4-vector sum as new proto-jet

$i = j$ Remove proto-jet i and call it a final jet

Local and Global Calibration Flow

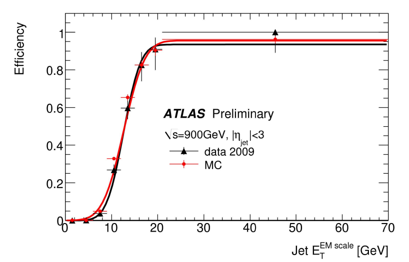


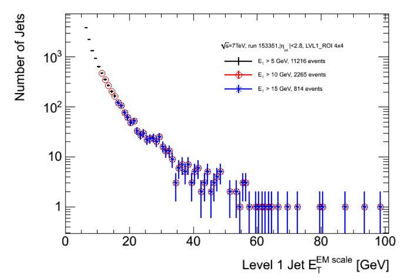
Clustering Algorithm

- Topological clustering
  - Identifies energy deposits in topologically connected cells
    - Cell significance criteria based on $\sigma_{\text{noise}} = \sigma_{\text{electronic}} \oplus \sigma_{\text{pileup}}$
    - Over entire calorimeter
  - Offers noise suppression
- Seed, Neighbor, and Perimeter cells (S, N, P)
  - Seed cells with $|E_{\text{cell}}| > S \cdot \sigma_{\text{noise}}$ ($S = 4$)
  - Expand in 3D adding neighbors with $|E_{\text{cell}}| > N \cdot \sigma_{\text{noise}}$ ($N = 2$)
  - Add perimeter cells with $|E_{\text{cell}}| > P \cdot \sigma_{\text{noise}}$ ($P = 0$)
  - (S, N, P) = (4, 2, 0) for good results in beam tests

Trigger Bootstrapping

- Identify number of events in minimum bias data containing jets also triggered the jet trigger
- Plot efficiency of jet trigger to identify jet events as function of jet energy ("EM-scale")





- Fit efficiency turn on with:

$$eff(E_{\mathrm{T}}) = \frac{\epsilon}{2}\left(1 + Erf\left(\frac{E_{\mathrm{T}} - \mu}{\sqrt{2}\sigma}\right)\right)$$

- "Bootstrap" to high threshold trigger by using triggers with known turn on curves

Bibliography I

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CALOR2010

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