Single hadron response measurements in ATLAS

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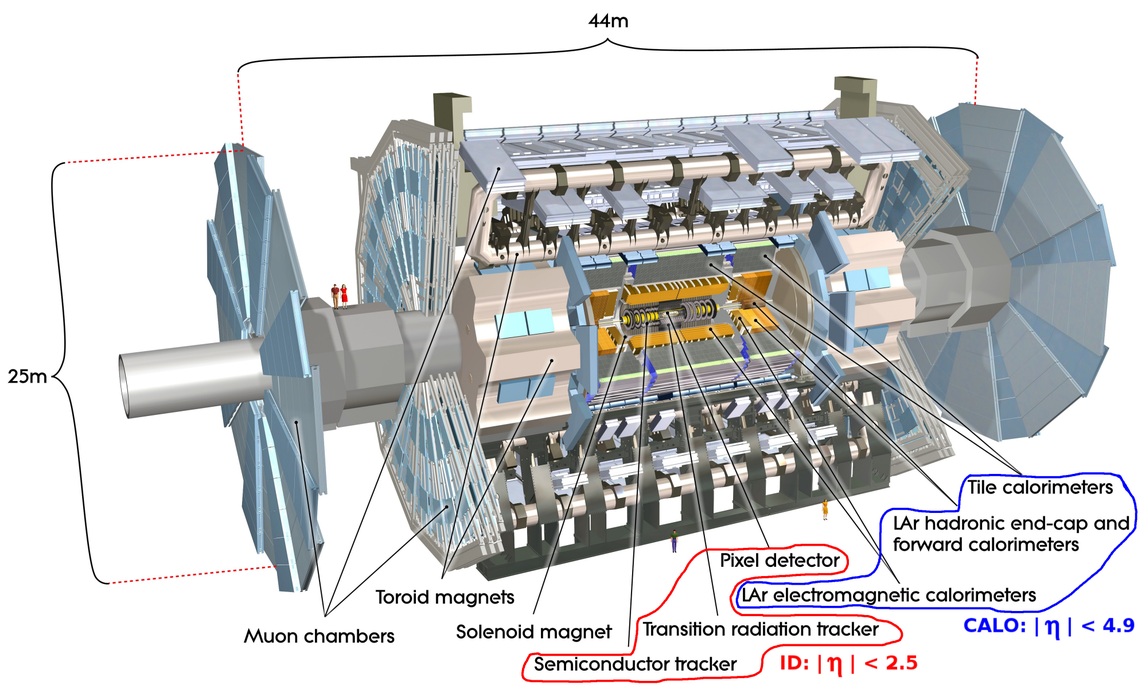
1. The ATLAS detector at the LHC

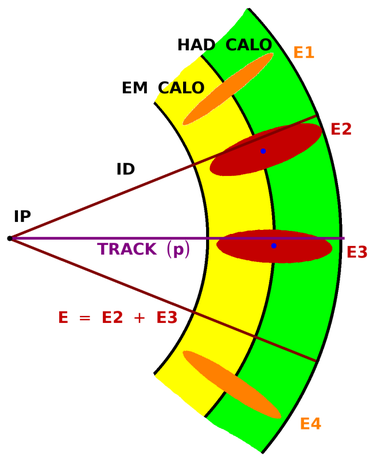


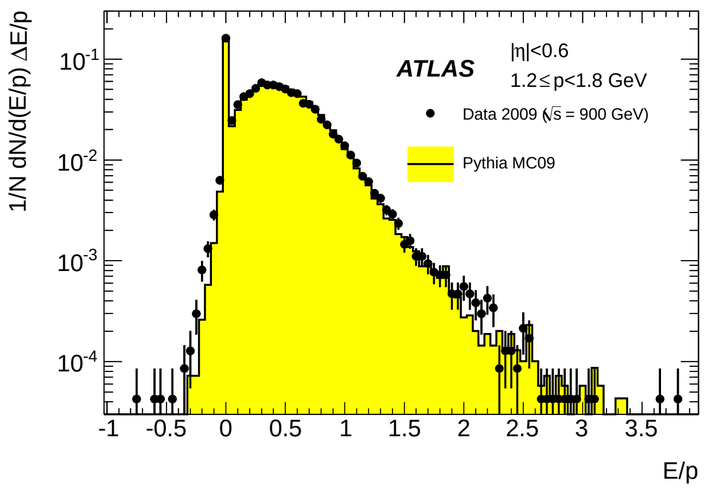
2. Introduction

- Compare the calorimeter energy (E) from single isolated hadrons to the precise measurement of the track momentum (p).
- The modeling of the calorimeter response to single isolated hadrons in the Monte Carlo simulation is assessed.
- This response is the largest contribution to the Jet Energy Scale uncertainty, which is one of the main systematic uncertainty in many physics analysis.

3. E/p measurement

- Select isolated hadrons:
  - ★ $\mathbf{p_T > 500\ MeV}$.
  - ★ No other track in isolation cone around the track.
- Measure **p** in the inner detector.
- Measure **E** in the calorimeter.
- Remove background from neutral particles.



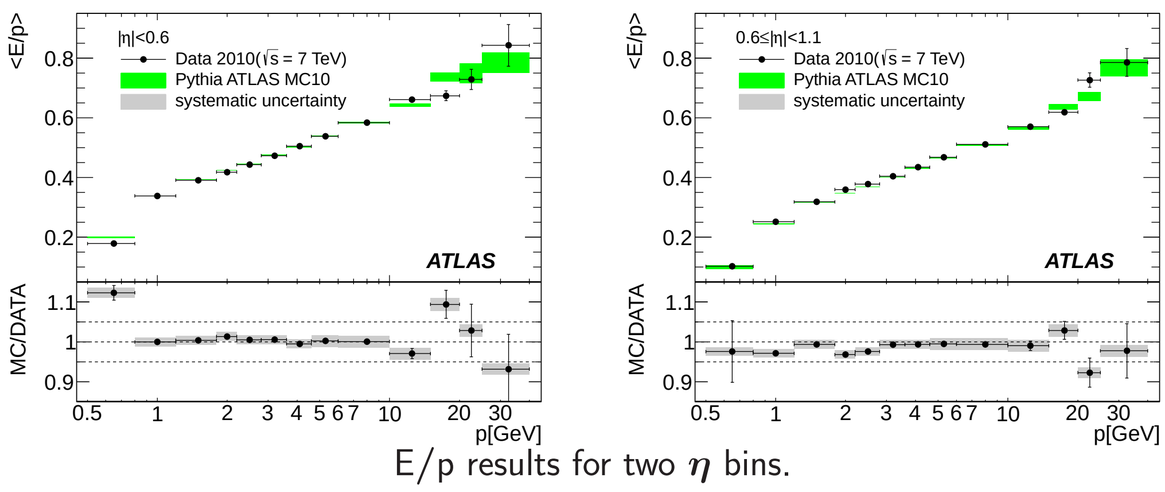


$E/p_{\ RAW}$ distribution for one $\eta, \mathbf{p}$ bin. Geant4 physics model: QGPS_BERT

$\langle \mathbf{E/p} \rangle_{\mathbf{corr}} = \langle \mathbf{E/p} \rangle_{\mathbf{RAW}} - \langle \mathbf{E/p} \rangle_{\mathbf{BG}}$, where $\langle \mathbf{E/p} \rangle_{\mathbf{BG}}$ is estimated using late-showering hadrons that leave low energy in the EM calorimeter.

4. E/p results for 2010

- Sample: 24 million of minimum bias events from 2010 at $\sqrt{\mathbf{s}} = \mathbf{7\ TeV}$.
- All tracks used pass the good quality criteria.



E/p results for two η bins.

Data and MC agreement:
within **2%** for $\mathbf{1 < p < 10\ GeV}$ and **5%** for $\mathbf{10 < p < 30\ GeV}$.

Acknowledgments:
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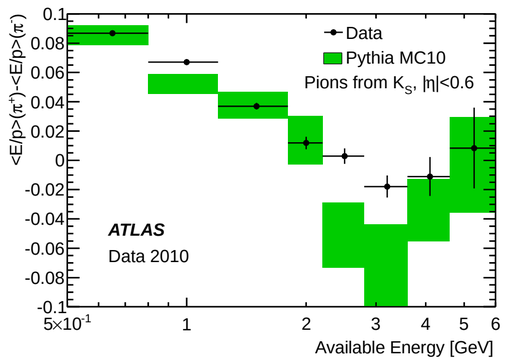
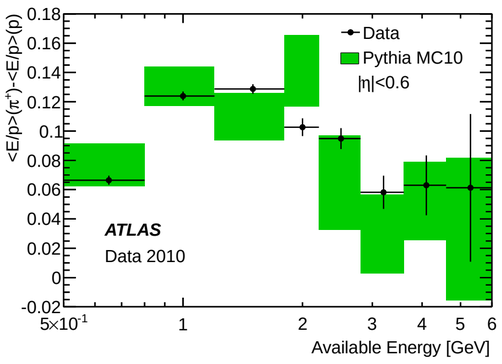
5. Calorimeter response to identified hadrons

Extrapolation from single hadron response to jet environment requires the understanding of the response to:

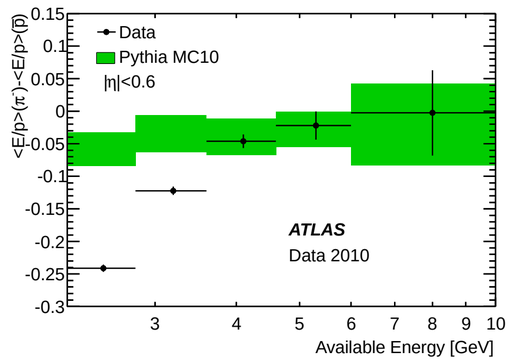
- Different hadrons:
  - ★ Identify π's from $\mathbf{K_S}$ and $\mathbf{\Lambda}$ decays: $\mathbf{K_s} \longrightarrow \pi^+\pi^-$, $\mathbf{\Lambda} \longrightarrow \pi^-\mathbf{p}$ and $\bar{\mathbf{\Lambda}} \longrightarrow \pi^+\bar{\mathbf{p}}$.
- Non-isolated hadrons:
  - ★ Requiring isolation on $\mathbf{K_S}$ and $\mathbf{\Lambda}$ but not on their decay products.



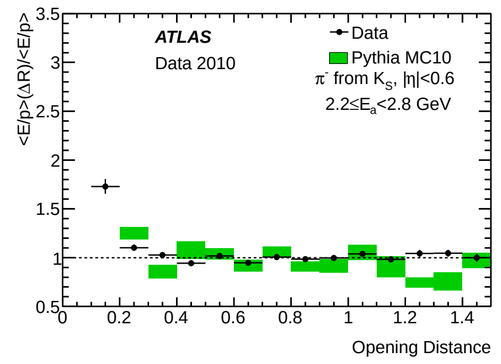
E/p diff in $\mathbf{K_s}$: $\pi^+ - \pi^-$



E/p diff: $\pi^+(\mathbf{K_s}) - \mathbf{p}(\mathbf{\Lambda})$

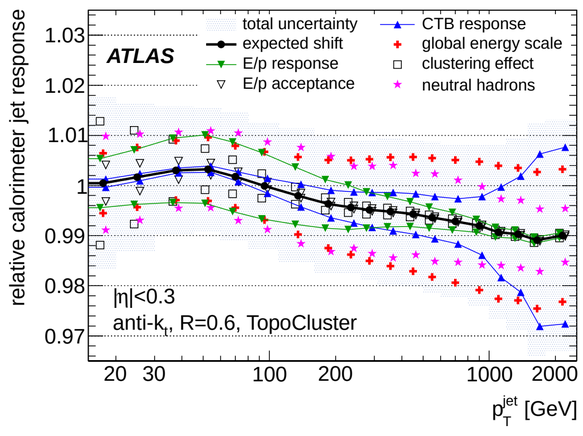


E/p diff: $\pi^-(\mathbf{K_s}) - \bar{\mathbf{p}}(\bar{\mathbf{\Lambda}})$



E/p vs $\mathbf{\Delta R}(\pi^+ \leftrightarrow \pi^-)$

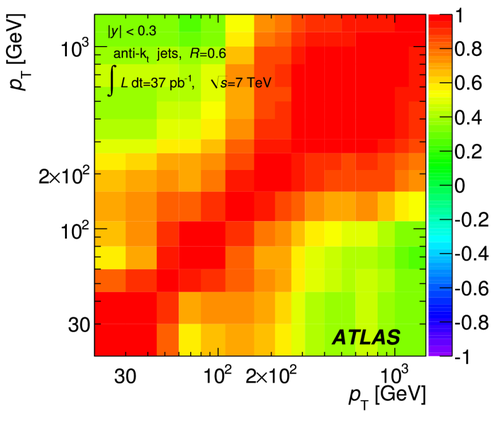
6. Calorimeter jet energy scale uncertainty



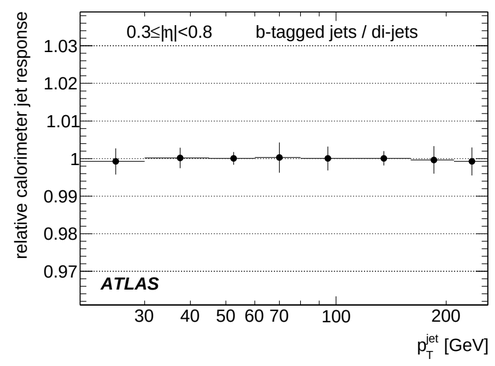
Using single hadron response measurement from in situ measurements and in test-beam.

- Calorimeter response uncertainty smaller than 2%.
- Expected shift of JES smaller than 0.5%.

7. Jet energy scale correlations



- Detailed break down in individual sources used to evaluate jet energy correlation between p_T bins.
- Relative calorimeter response cancel out all common shifts and uncertainties.
  - ★ Negligible for high-p_T for b-tagged jets.
  - ★ $\sim$ 0.5% for low-p_T jets and negligible for high-p_T for quark enhanced jets.



Conclusions

- Data/MC agreement in E/p better than 2% (5%) for particles with p $\in$ [1,10] GeV ([10,30] GeV).
- Data and MC agrees for charged pions and protons within the uncertainties.
- For anti-protons, the data/MC disagreement is up to 10%.
- The calorimeter response uncertainty to jets is 1-3% in $|\eta| < \mathbf{0.8}$ for $\mathbf{p \in [0.15, 2.5]\ TeV}$.