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Isolated Charged Hadron Response and Determination of the Jet Energy Scale Uncertainty with the ATLAS Detector

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The ATLAS calorimeter response to single charged hadron has been measured for particles with momenta up to $\sim$ 20 GeV and $|\eta| < 2.3$ using about 300 μb^{-1} of proton proton collisions at a center of mass energy $\sqrt{s}$=7 TeV. The uncertainty on the calorimeter response to single particles has been used to evaluate the calorimeter jet energy scale uncertainty.

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1. Introduction

In a typical jet produced in proton-proton collisions, about 60% of the jet energy is carried by charged hadrons (mostly $\pi^{\pm}$). Photons produced in the $\pi^0 \rightarrow \gamma\gamma$ decay carry another 25%, while the remaining 15% is carried by neutral hadrons (mostly neutrons and K_L^0). The response of the ATLAS calorimeter to charged hadrons has been measured using isolated tracks produced in $\sqrt{s} = 7$ TeV proton proton collisions. The resulting uncertainty, together with that estimated for photon and neutral hadrons response, has been propagated to obtain the estimated uncertainty on the calorimeter jet energy scale.

2. Measurement of the Calorimeter Response to Charged Hadrons

High quality tracks have been selected using the ATLAS SCT and Pixel detector [1]. The track selection is based mainly on the number of hits in the silicon layers and on the estimated transverse and longitudinal impact parameter with respect to the identified primary vertex of the interaction [2]. The selected track impact point at the calorimeter surface P is determined taking into account the 2 T solenoidal magnetic field present in the ATLAS inner detector. An isolation criteria based on the angular distance with respect to the estimated impact points of any other track in the event is applied ($\Delta R_{iso}^{min} = \sqrt{\Delta\eta^2 + \Delta\phi^2} > 0.4$)[1].

A cone with radius angle $\Delta R = 0.2$ is opened around the track impact point P. The energy associated to the track E is measured, and its ratio E/p with the track momentum p (measured by the inner detector) is computed.

The mean response $\langle E/p \rangle$ is compared with the Monte Carlo predictions in Figure 1. The prediction agrees well with the data. Deviations at a level of 5% are observed for the largest momentum bin investigated. Similar results have been obtained also in other detector regions.

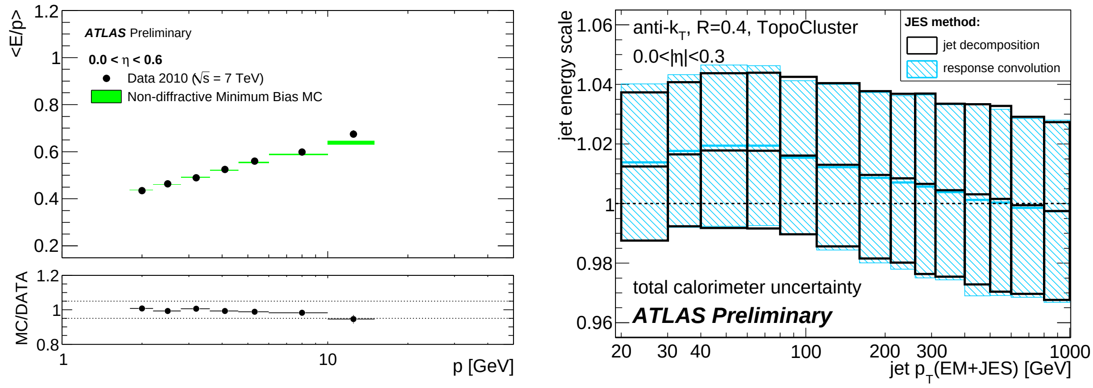

Figure 1: Left: the mean response $\langle E/p \rangle$ as a function of the track momentum p in the central region of the detector. Right: total calorimeter uncertainty on the jet energy scale for jets reconstructed with the anti-k_t algorithm ($R = 0.4$) in the range $0.0 < |\eta| < 0.3$ as function of the transverse jet momentum.

[1]The ATLAS reference system is a cartesian right-handed coordinate system, with the nominal collision point at the origin. The azimuthal angle (ϕ) is measured around the beam axis, and the polar angle θ is measured with respect to the z-axis. The pseudorapidity is defined as $|\eta| = -\ln(\tan\theta/2)$ and p_T is the track momentum transverse to the beam direction.

3. Calorimeter Jet Energy Scale Uncertainty Estimation

The analysis is performed with inclusive di-jet Monte Carlo events simulated with Pythia. The jet energy is first decomposed into the energy of the constituent particles of the jet. The uncertainty on the jet energy scale is then determined by convolving the uncertainty on the single particle response with the jet particle composition. Two methods have been implemented to define the particles that are used as input for the calculation of the uncertainty of the jet energy scale. The first method, called "jet decomposition" starts from reconstructed Monte Carlo simulated jets and identifies, using Geant4 truth information, all the particles produced by the event generator that deposit energy in calorimeter cells belonging to the jet. The second method, called "response convolution" uses directly the particles produced by the event generator. Particles belonging to the particle jets are convolved with the single particle response and the associated uncertainties.
The uncertainty is evaluated for jets with 20 GeV$< p_T <$1 TeV and $|\eta| < 0.8$. The response uncertainties used for the different particles are:

- Charged hadrons: the MC/DATA ratio of the $\langle E/p \rangle$ measurement shown in Figure 1 (left) is used for particle momenta below $15-20$ GeV. Test beam results have been used for higher momenta. The response uncertainty is about 1%.

- Photons from $\pi^0 \rightarrow \gamma\gamma$: the uncertainty is set by knowledge of the absolute calorimeter energy scale (known at about 3% level [3]).

- Neutral hadrons: due to the lack of experimental constraints for momenta below 10 GeV, a conservative uncertainty of 20% is assumed.

The results are shown in Figure 1 (right) for both the jet decomposition and the response convolution method. The total jet calorimeter uncertainty is estimated to be about $3-4$%, and it is dominated by the assumed uncertainty on neutral hadrons.

4. Conclusions

The ATLAS calorimeter response to single hadrons has been measured using proton proton collisions at $\sqrt{s} = 7$ TeV. It is reproduced by the simulation within 5%. The uncertainties on the single particle response have been propagated to jets using the Monte Carlo information. The global calorimeter jet energy scale uncertainty is estimated to be 3-4%.

References

[1] ATLAS Collaboration, *Expected Performance of the ATLAS Experiment*, CERN-OPEN-2008-020 (2008).

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[3] ATLAS Electromagnetic Barrel Calorimeter Collaboration, M.Aharrouche et al., *Energy linearity and resolution of the ATLAS electromagnetic barrel calorimeter in an electron test- beam*, Nucl. Instrum. Meth. A568 (2006) arXiv:physics/0608012.