PROCEEDINGS OF SCIENCE

Jet calibration in the ATLAS experiment at LHC

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Jets produced in the hadronisation of quarks and gluons play a central role in the rich physics program that will be covered by the ATLAS experiment at the LHC, and are central elements of the signature for many physics channels. A well understood energy scale, which for some processes demands an uncertainty in the energy scale of order 1%, is a prerequisite. Moreover, in early data we will face the challenge of dealing with the unexpected issues of a brand new detector in an unexplored energy domain. The ATLAS collaboration is carrying out a program to revisit the jet calibration strategies used in earlier hadron-collider experiments and develop a strategy which takes into account the new experimental problems introduced from higher precision measurement and from the LHC environment. The ATLAS calorimeter is intrinsically non-compensating and we will discuss the use of different offline approaches based on cell energy density and jet topology to correct the linearity response while improving the resolution. In addition, we will present the steps in jet calibration which account for detector and experimental conditions such as noise and energy depositions from overlapping events. We will also discuss the validation analysis done both with data from test-beam and from benchmark physical channels.

The 2009 Europhysics Conference on High Energy Physics,
July 16 - 22 2009
Krakow, Poland

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[†]on behalf of the ATLAS Collaboration, thanks to T. Carli, P. Loch, J. Proudfoot, C. Roda, A. Schwartzman

PoS(EPS-HEP 2009)471

1. Introduction

ATLAS is a general purpose detector for the new proton-proton collider LHC (CERN). It was designed to cover the rich physics program, exploring the TeV mass scale where groundbreaking discoveries are expected. Most of the physics channels in the physics program of the experiment (such as the search of Higgs boson(s), supersymmetry, exotic physics...) will contain jets in their final state. The jets produced by quantum chromo-dynamics (QCD) interactions constitute also a background for almost all the physics channels of interest. The jet kinematics is linked to the one of the parton from which they emerge. For this reason, a good jet energy measurement is fundamental for the study of the interaction between elementary particles. To reach the requested discovery potential of the experiment, the goal is 1% precision on the jet energy scale.

2. The jet energy scale in ATLAS

The goal of the calibration of the jet energy scale is to correct the energy of the jets measured trough the calorimetric signals ($E_{Calorimetric\ Jet}$) in order to obtain an estimate of the energy of the jet at the hadronic level ($E_{Reference\ Jet}$). Several effects degrade the measurement of the jet energy and have to be taken into account to assess the hadron jet energy scale.

The calorimeter response at the non-calibrated scale depends on the type of the particles. This effect is named non-compensation (higher response for γ and e than for π) . A second effect is due to the energy deposited in the dead material before reaching the calorimeters, or to the particles ended up in non instrumented regions. Another important effect is the bending of the magnetic field: some particles are bent out of the reconstructed jet by the tracker magnetic field. As a result, $E_{Calorimetric\ jet} < E_{Reference\ jet}$ with large non-linearity and non-uniformity. On average we expect $E_{Calorimetric\ Jet}/E_{Reference\ Jet}$ =70% for energy of 100 GeV.

The procedures to calibrate the jets consist of several subsequent corrections. The common starting point is to assess the calorimetric calibration for the energy deposited by electrons and photons ("electromagnetic, EM, scale"). Corrections based on Monte Carlo simulation or on in-situ measurements will be used on top of the EM scale to calibrate the jets and to check the correctness of the jet energy scale. The understanding and the cross-check of every step in the calibration are fundamental to have an estimate of the systematics after the calibration procedure. To obtain the final goal, the deployment of the calibration procedure will change with the understanding of data and with the possibility to use more data samples to estimate the energy scale systematics. In the following section we show a description of these strategies and an example of the study on the systematics and cross-checks done for one of the methods.

3. Jet calibration in ATLAS

3.1 Signal definition

A first selection of the calorimetric cells is done to reduce the effect of the noise. These cells, grouped together in calorimetric objects, according to topological criteria ("topocluster") or in radial slices of the detector, are used to reconstruct the jets. Different jet algorithms which group these objects together were studied in ATLAS. The main calibration effort will be based on the

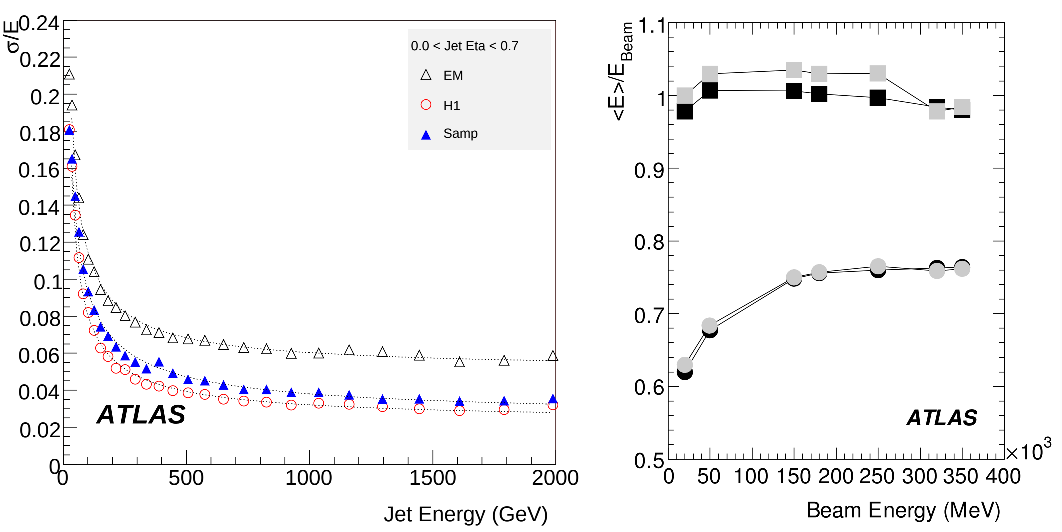
Anti-Kt jet algorithm [1] as working default. The first effect to be corrected is due to the presence of energy depositions due to multiple proton proton interaction per bunch crossing (pile-up).

Once this correction is applied, several possibilities are studied to restore the jet scale, shown in the next subsections.

3.2 Correction based on Monte Carlo simulations

The simulation of the fundamental processes producing jets or hadrons, and the simulation of the detector response to the particles in the jets (interaction particle/matter) are used to develop the corrections to be applied in order to recover the reference jet energy.

Weight factors are used to correct for the non-compensation and the energy losses in the dead material of the calorimeter. These weights depend on the energy densities of the calorimetric cells in a jet (H1 Calibration), on the energy in the longitudinal layers of the calorimeter (Sampling Calibration) or on the characteristics of the topoclusters (Local Hadron Calibration). Three calibration procedures are being followed: in the first two cases (H1 and Sampling [2]), since the corrections are derived to calibrate a jet as a single global object, the strategies are called global calibrations. On the contrary, in the third case (Local Hadron Calibration [2, 3]), since the calibration procedure is derived to correct the local calorimetric signals (topoclusters) before the jet reconstruction, the strategy is called local calibration. As an example, the comparison between the jet energy resolution obtained at the EM scale and the jet energy resolution obtained using two different global calibration is shown in figure 1(a). These methods improve the resolution (similar results are obtained for the local calibration).



(a) (b)

Figure 1: a) Example of energy resolution improvement using two different simulation driven corrections (H1 and Sampling) compared with the resolution of the non calibrated jets, in the central region of the detector [2]. b) Example of calibration using simulation driven corrections on single pions data taken in the test-beam. The uncalibrated (dots) and calibrated (squares) data is reported gray, and are compared with the simulations (in black) [2].

Several cross-checks were done to asses the performance of these strategies. A first closure test was done deriving the correction in a di-jet sample which simulates events of quantum chromo-dynamics interactions (QCD di-jet events) and applying them on a sample of supersymmetry events. The highest discrepancy in the jet energy scale is of the order of 4% . The effect of a non perfect geometry description in the simulation was investigated, with a similar result.

By using real data collected in a test-beam where a slice of the ATLAS calorimeter was exposed to single pions, the ability of the hadronic shower models to extract the energy corrections has been tested. The calibration factors were obtained from the simulation of single pions and applied both to data and simulation. The result for single pions is shown in the figure 1(b) and the agreement is of the order of 4%. Further improvement in the test-beam data analysis are expected.

3.3 Performance measurements with data-samples

Once the detector will be operating, we will acquire many data samples that can be used to assess the quality of the calibrations based on the Monte Carlo simulation and, if needed, to obtain correction factors in in-situ measurements to be used in the calibration deployment. The first samples that can be used to assess the performances (with a consistent statistics at an early data-taking stage) are di-jet events and direct photon (with jet(s)) production. Different samples allow us to study different jet properties in various kinematic and geometrical regions.

In events with γ and a recoiling jet, the balance in P_T is used to check/calibrate the energy of the jet. With an integrated luminosity equal to 10 pb^{-1}, and an energy per proton beam of 5 TeV, $P_T \sim 250$ GeV/c can be reached with statistic uncertainty of 2%. Events with jets maybe used with different aims depending on the topology and jet multiplicity.

Di-jet balance: This strategy is used to set a uniform response for the jets across different regions in pseudo-rapidity, correcting for the non-uniformity in the detector geometry and technology.

Multi-jet balance: In events with more than 3 jets, the P_T of the leading jet can be estimated by the vector sum of all the other jets. In this way corrections/checks for high P_T jets can be derived. The jet energy scale can be studied up to 1 TeV with the first fb^{-1}.

4. Conclusions

The procedures to calibrate the jets consist of several subsequent corrections. Several strategies of calibration are developed and the validation of the corrections will heavily rely on measurements that will be performed as soon as the first data will be available. Corrections based on Monte Carlo simulations or on in-situ measurements will be used to calibrate the jets and to check the correctness of the jet energy scale. To obtain the final goal of the calibration, the deployment of the calibration procedure will change with the understanding of data and with the possibility to use more data samples to estimate the energy scale systematics.

References

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