Measuring the jet reconstruction performance in the ATLAS experiment

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Abstract

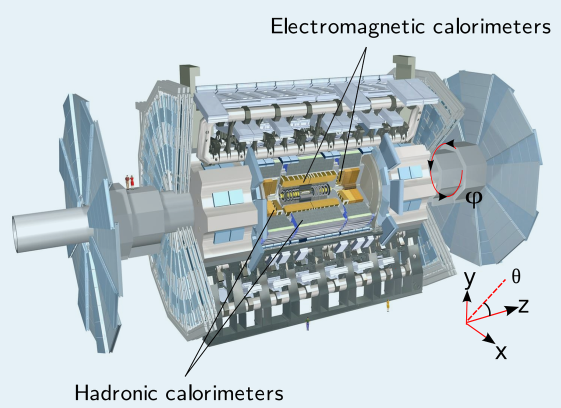
Jets will be among the key physics objects in measurements at the LHC: understanding and measuring the performance of jet reconstruction is crucial for many physics analyses. The JetPerformance software package has been developed and deployed in the software framework of the ATLAS experiment for this purpose.

Jets in the ATLAS detector

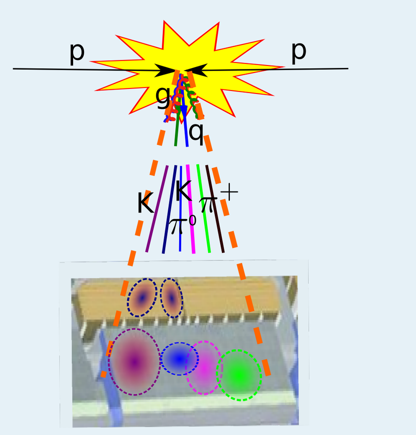
ATLAS calorimeters

The ATLAS (**A** **T**oroidal **L**HC **A**pparatu**S**) experiment is a general purpose detector located at the Interaction Point 1 of the LHC [2].

The ATLAS calorimeters are the key subsystem for the reconstruction of jets. The **electromagnetic calorimeter** employs liquid argon as the active material and lead as absorber. The **hadronic calorimeter** barrels make use of plastic scintillator and iron; copper and liquid argon are used for the endcaps and forward component.



Jet reconstruction and calibration



ATLAS Calorimeters

The aim of **jet reconstruction** is to reconnect the energy measured in the detector to the kinematics of the partons generating the jets. The energy deposits in the calorimeters need to be associated to a jet: the *AntiK$_t$* [3] algorithm will be one of the methods employed for **jet finding** in ATLAS. A **calibration** procedure is also needed to translate the calorimeter readout signal into a measurement of the energy of the particles.

The ATLAS calorimeters are **non-compensating**: the response to hadrons is lower than the response to particles interacting electromagnetically.

The first step for the calibration of the calorimeter signal is a measurement of the deposited energy at the ***electromagnetic scale***. The calibration constants used for this process are derived from a comparison of test-beam data with simulations of electrons. Therefore in a non-compensating calorimeter system the energy of hadronic deposits measured at the electromagnetic scale is underestimated, and the hadronic calibration is needed to rescale their energy to the correct scale (***jet energy scale***).

Jet performance

Figures of merit

One needs to **compare** **reconstructed jets** to matched **reference objects** for different jet finding algorithms, calibration sequences and samples, in bins of kinematic and spatial variables. The main performance quantities for evaluating the jet performance are quoted below.

- linearity (response) $L = \frac{K_{Reco}}{K_{Reference}}$
- resolution $R = \frac{\sigma(K_{Reco})}{K_{Reco}}$
- purity $P = \frac{N_{Reco,Matched}}{N_{Reco}}$
- efficiency $E = \frac{N_{True,Matched}}{N_{True}}$

(where K is the chosen kinematic quantity)

The assumption of a gaussian response in order to derive the performance quantities above could introduce biases that lead to serious consequences for many physics processes; an extensive statistical analysis is therefore needed.

The JetPerformance software package

Scope and structure

The comparison and cross checking of jet reconstruction procedures is more effective if a uniform approach through the ATLAS software framework is adopted. The goal of the JetPerformance package [3] is to provide a common set of definitions and algorithms to measure quantities relevant to the performance of jet reconstruction through a series of **standardised validation plots**.

The jet reconstruction performance can be evaluated using ***in-situ*** **techniques** with references balancing the jet kinematics, as well as comparison to **truth jets** built from Monte-Carlo particles. Every method of comparison is implemented in the code through a JetPerformance *Tool*.

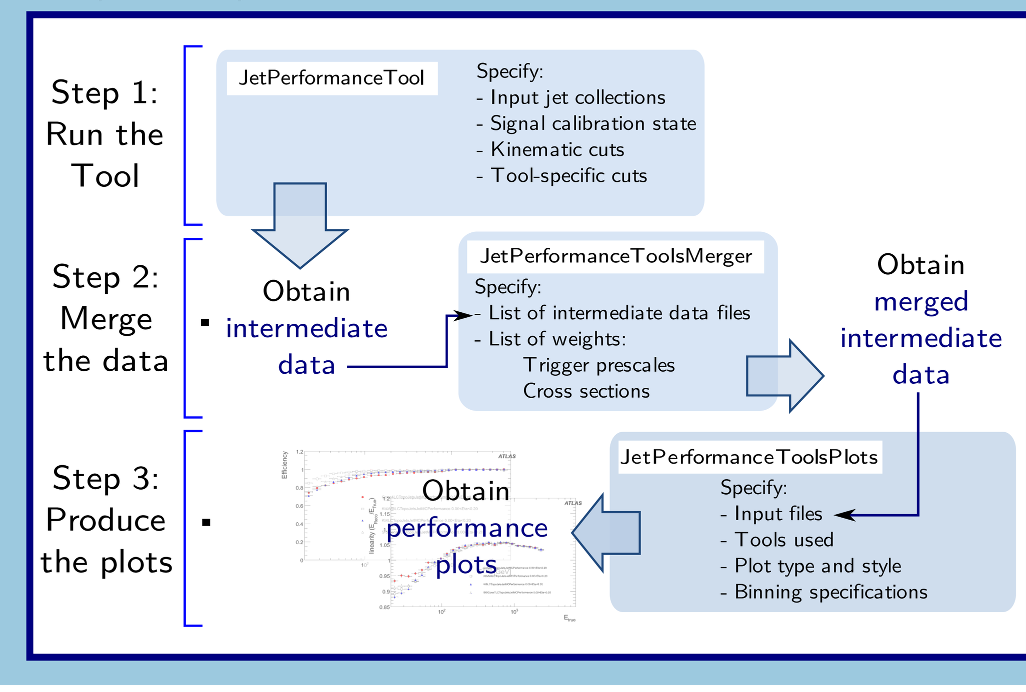
While providing standardised methods for measuring the jet performance, this package is still readily extensible via the addition of user-defined *Tools* and plots.

The package is currently undergoing a **structural rewrite** in order to increase the plotting flexibility, streamline the signal selection and add statistical tools for the response function evaluation.

Workflow

The JetPerformance workflow is composed of three steps:

1. The *Tools* extract basic quantities (e.g. reconstructed energy for each jet) and make them available for further analysis;
2. the output of the *Tools* can be reweighted and merged;
3. the desired plots are obtained by running standardised algorithms that calculate the performance quantities based on the (merged) output of the *Tools*.

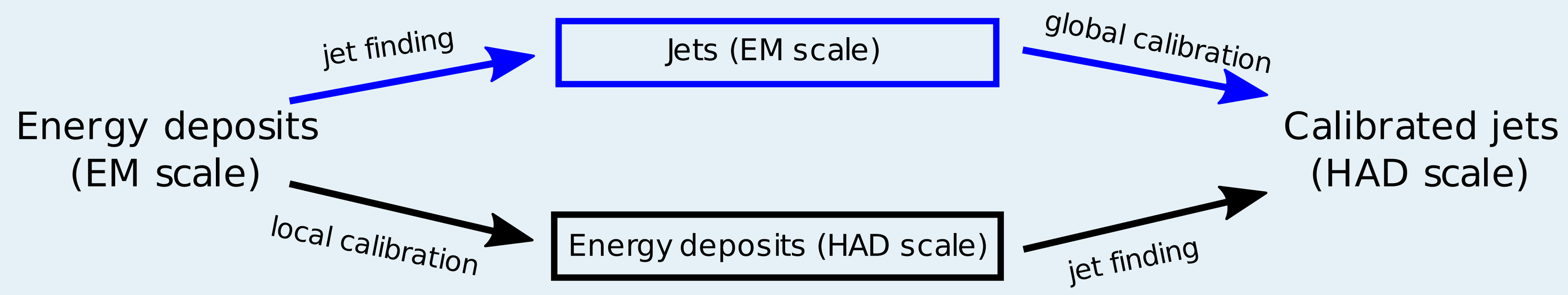


Example plots: comparing calibration methods

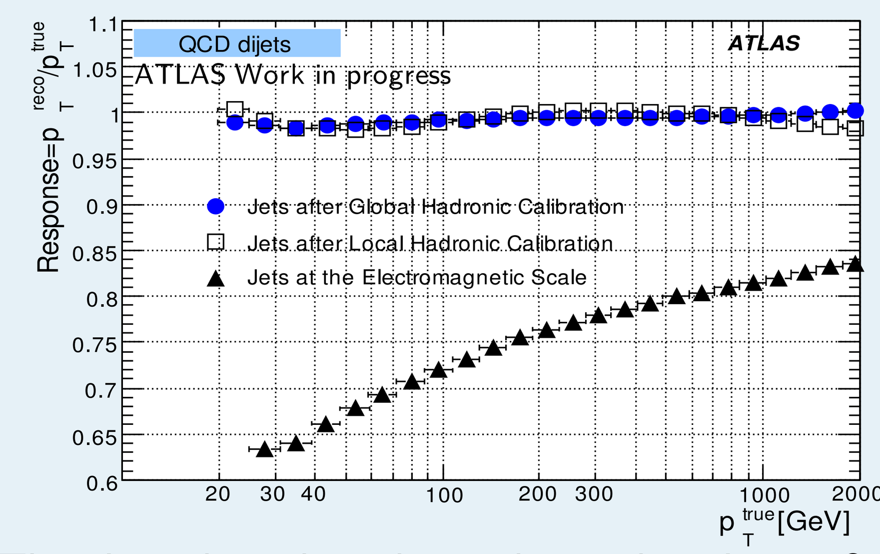
Hadronic calibration in ATLAS

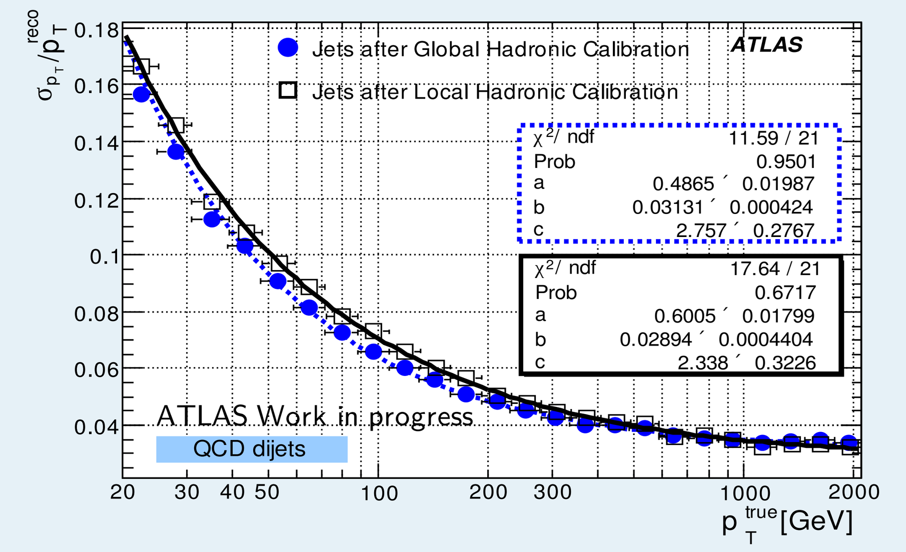
Two hadronic calibration strategies are employed in ATLAS. In the ***global calibration*** [4] the jet finding is performed on the calorimeter energy deposits at the electromagnetic scale. Then the energy of the deposits belonging to a jet is reweighted to the jet energy scale. In the ***local calibration*** [5] the jet finding is performed on energy deposits which have already undergone a reweighting. Both methods use further Monte-Carlo based corrections (*Numerical Inversion*, [6]) in order to restore the jet energy scale.

The global calibration method is physics dependent, since the cell weights have been obtained by comparing the reconstructed jet energy to the energy of Monte-Carlo particle jets for a specific sample (dijet) and a specific jet finding procedure. The advantage of the local calibration is that the corrections applied to the calorimeter objects are modular and do not depend on the physics sample or on the jet finding, but this method does not yet perform as well as the global calibration, and will be employed at a later stage.



Linearity and resolution for hadronic calibration





The plots above have been obtained analysing QCD dijet data from proton-proton collisions at 10 TeV generated by Pythia with the JetPerformance package.

The **linearity** plot (above, on the left) shows how the local and global calibration methods restore the true jet energy scale **within 2%**. The calorimeter response to hadronic jets on the electromagnetic scale improves with energy: this is due to the enhancement of the electromagnetic content of hadronic showers from neutral pions decaying into photons and producing secondary electromagnetic showers.

A fit to the **resolution** data points in the plot (above, on the right) with the function $\frac{\sigma}{R} = \frac{a}{\sqrt{R}} \oplus b \oplus \frac{c}{R}$, where $R = p_T$ shows that both the stochastic (a) and constant (b) terms for the global calibration are **within the ATLAS design specifications** for energy resolution: a=0.5, b=0.03 (from [4]).

References:

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[4] The ATLAS Collaboration. Expected Performance of the ATLAS Experiment: Detector, Trigger and Physics, 2008
[5] The ATLAS Collaboration, Local Hadron Calibration, ATLAS-LARG-PUB-2009-001,
[6] D. Lopez Mateos et al. A simple pT and eta dependent Monte Carlo Based jet calibration. ATL-COM-PHYS-2009-076, 2009

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