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Calibration and performance of the ATLAS Tile Calorimeter during the LHC Run 2

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Summary. — The central hadronic calorimeter of the ATLAS experiment at the Large Hadron Collider (LHC) is a sampling calorimeter made up of steel and scintillating tiles. TileCal is regularly monitored and calibrated by different calibration systems. A description of the different sources and of the results on the calorimeter performance during the LHC Run 2 is presented.

1. – Introduction

The Tile Calorimeter (TileCal) [1] is the central section ($|\eta| < 1.7$) of the hadronic calorimeter of the ATLAS detector [2]. It is a sampling calorimeter made up by steel plates as absorber, and scintillating tiles as active material. The calorimeter is divided into a long barrel (LB) and two extended barrels (EB). The LB (EB) is composed of 64 azimuthal modules each occupying $\Delta\eta \times \Delta\phi \sim 0.1$ (0.2) $\times$ 0.1.

The light produced by the passage of particles is transmitted to readout PMTs by wavelength shifting fibers. The signal from the PMTs is then sent to the readout electronics and converted by ADCs.

2. – Energy reconstruction and calibration

The reconstructed energy (E) of each channel is

$$E[\text{GeV}] = A[\text{ADC}] \times C_{ADC\to pC} \times C_{laser} \times C_{Cs} \times C_{pC\to GeV},$$

where A[ADC] is the measured amplitude in ADC units, $C_{ADC\to pC}$, C_{Cs}, C_{laser} are the factors derived by the dedicated calibration systems. The last factor $C_{pC\to GeV}$ sets the global electromagnetic scale (derived during test beams using electrons).

The TileCal response is calibrated via three systems (cesium source, laser light, charge injection) in order to monitor independently different parts of the readout chain.

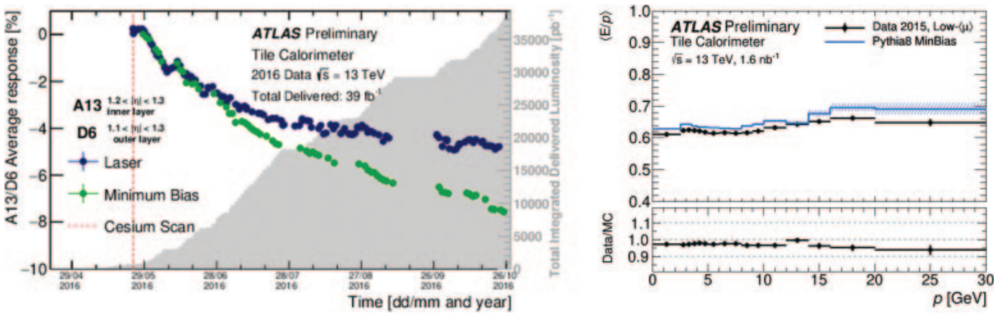

Fig. 1. – Left: evolution of the A13/D6 cell response to laser pulses (blue) and MB events (green). Right: E/p as a function of the momentum of the track [3].

The cesium system consists of a radioactive source which passes through the calorimeter. The system is used for the calibration of the entire signal chain and it monitors scintillators and PMTs. The calorimeter response is equalized at the beginning of each year of p-p collisions. Each month the constant C_{Cs} is evaluated as the ratio between the measured signal and the expected value. The precision of the measurement is better than 0.3% for each channel. The laser system is used for the calibration of the PMT response and the readout electronics. Laser light pulses, similar to those produced by ionizing particles, are transmitted simultaneously to all the TileCal PMTs to measure the PMT response variation (C_{laser}) between two cesium scans. The precision of the measurement is better than 0.5% for each channel. The charge injection system (CIS) determines a conversion from ADC counts to pC by comparing a known injected charge with the response of the readout electronics. The typical uncertainty of this calibration system is 0.7% per channel. The conversion factor is stable in time at the level of 0.02%. Additionally the detector response to soft parton interactions, the so-called minimum bias (MB) events, is measured by the slow integrator readout. This method is used to provide an independent cross-check of Cs calibration. The response to MB events together with results from the laser system are shown in fig. 1 (left). The difference between the MB and the laser is interpreted as an effect of scintillators ageing due to irradiation.

3. – Status and performance of TileCal

A good description of the cell energy distribution and of the noise in the calorimeter is important for the construction of topoclusters which are used, *e.g.*, for jet and missing transverse momentum reconstruction. The two main contributions to the noise in a cell are the electronic noise and the pile-up. The first one is measured in dedicated runs with no signal in the detector. The second is originated by multiple interactions occurring at the same bunch crossing or from the minimum bias events and it is the dominant effect under the LHC Run 2 conditions. The largest noise values are found in the regions with the highest exposure to radiation.

The validation of the energy reconstruction and calibration methods of the TileCal has been done using isolated charged hadrons during LHC Run 2. The energy to the momentum ratio E/p, where E is the cluster energy measured in TileCal and p is the momentum of the associated track measured in the Inner Detector, is used to evaluate the uniformity and the linearity of the calorimeter response. The agreement between data and Monte Carlo simulations is within 5% (fig. 1, right), which is the expected systematic error for the electromagnetic scale uncertainty of TileCal.

A precision time calibration is important for the cell energy reconstruction. The reconstructed time in all the channels is done monitoring the channel response to laser pulses sent in empty bunch crossings. The TileCal time resolution is better than 1 ns for energy deposits in a cell larger than few GeV.

4. – Conclusions

TileCal provides important information for reconstruction of hadrons, jets, hadronic decay of τ leptons and missing transverse energy in the ATLAS experiment at the LHC. A set of calibration systems is used to monitor and calibrate the calorimeter response with precision better than 1%.

REFERENCES

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