PROCEEDINGS OF SCIENCE

Performance and calibration of the ATLAS Tile Calorimeter

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The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The scintillators are read-out by the wavelength shifting fibres coupled to the photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped, digitized by sampling the signal every 25 ns and stored on detector until a trigger decision is received. The TileCal frontend electronics reads out the signals produced by about 10,000 channels measuring energies ranging from about 30 MeV to about 2 TeV. Each stage of the signal production from scintillation light to the signal reconstruction is monitored and calibrated. Results using LHC Run-2 and Run-3 data will be shown. A summary of the performance results, including the calibration, stability, absolute energy scale, uniformity and time resolution, will be presented.

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1. The ATLAS Tile Calorimeter

High-energy experiments aim at probing the most fundamental aspect of the particles and how they interact. The Large Hadron Collider (LHC), built at CERN, is the largest operational particle collider. It comprises a ring of 27 kilometers at approximately 100 meters underneath the ground. In order to increase its discovery capability, the LHC has been gradually increasing its luminosity, reaching unprecedented conditions and exploring an ambitious physics program. Among the largest experiments at the LHC, ATLAS [1] plays a fundamental role in particle discovery research, covering a large physics program, including the Higgs boson discovery and characterization and possible beyond Standard Model physics. Several systems comprise the ATLAS experiment such as a particle tracking system, which measures the momentum of charged particles, the calorimeter (highly-segmented energy measurement system) and a muon chamber, which detects and measures the muon momentum [1].

Regarding the ATLAS calorimetry system, it consists of two main sections: the electromagnetic section, which measures the energy of electromagnetic particles like electrons and photons, and the hadronic section, which accurately measures the energy of hadronic particles such as protons and neutrons. The Tile Calorimeter (TileCal) is the main ATLAS hadronic calorimeter and provides precise measurements of hadrons, jets, taus and contributes to the reconstruction of the missing transverse energy as well as to provide input signals to ATLAS online particle selection system (trigger). It consists of three cylinders, one long barrel (LB) split into two readout partitions, LBA and LBC (LBs), and two extended barrels (EBs), EBA and EBC, covering the most central region $|\eta| < 1.7$ of ATLAS, as shown in Figure 1.

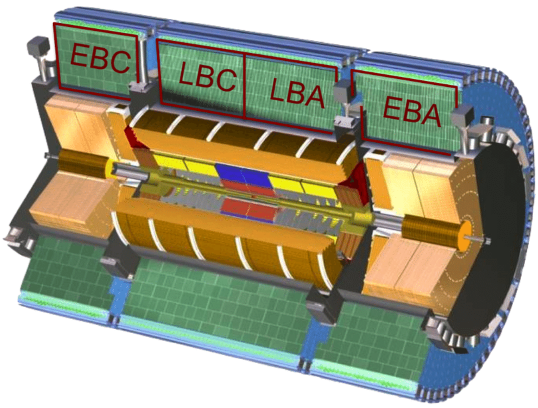

Figure 1: Computer-generated image of the ATLAS Calorimeter System and its partitions.

In order to sample the particle energies, TileCal uses iron plates as the absorber material and plastic scintillating tiles as the active material. Therefore, the particles produced in the collisions that travel through the calorimeter produce light in the scintillating tiles that is proportional to the energy deposited by the particles in the absorber material. Then, the light is transmitted by wavelength shifting fibers and feed photomultiplier tubes (PMTs), which finally generate analog pulses. Each of TileCal central and extended barrel modules are divided, respectively, into 46 and 32 readout channels, resulting in almost 10,000 signals to be processed.

The analog fast electronic pulse produced by each readout channel has a width of approximately 150 ns and is conditioned by a sharper circuit in such a way that the processed pulse amplitude is proportional to the deposited energy. Analog to digital conversion (ADC) is performed at the particle collision rate (40 MHz), and the time samples are used for estimating the pulse parameters, such as amplitude, phase and pedestal (signal offset).

2. TileCal Calibration Systems

The TileCal response is calibrated and continuously monitored at each stage of the signal path (see Figure 2) using dedicated systems that overlaps to detect any potential component failures [2], as follows:

- The Cesium system uses ^{137}Cs gamma-ray sources moved through all tiles using hydraulic system aiming at calibrating optical components: scintillators, fibers and PMTs, detecting possible degradation of tiles and fibers.
- The Laser system uses light pulses distributed by fibers to all PMTs, monitoring the gain stability and timing in all readout channels with a precision of about 5%.
- Charge Injection system (CIS) monitors the stability of the electronics and response of ADCs by injecting a signal with a well-defined charge, with various magnitude values, to the electronics of all readout channels with a precision of 0.7%.
- Integrator (Minimum Bias) system monitors luminosity and the detector optical path performance by integrating the signal from Minimum Bias (MB) inelastic pp interactions using the integrator readout shared with the Cesium system.

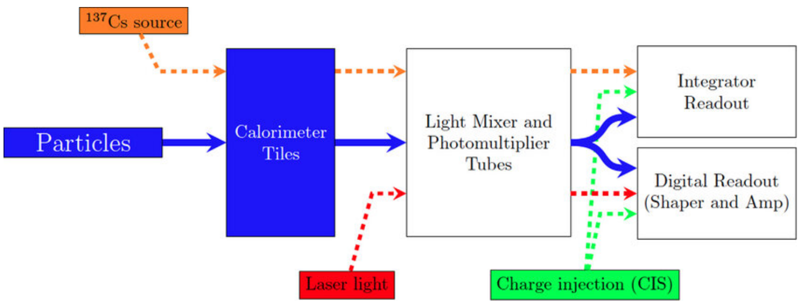

Figure 2: Flow diagram of the readout signal path of different TileCal calibration systems.

3. Performance Results

The calorimeter response can be assessed using single hadrons from pp collisions, measured by the ATLAS Tile Calorimeter, utilizing 144.9 pb^{-1} of pp collision data at 13 TeV collected in 2017. The ratio E/p energy to momentum can be used as a function of the corresponding momentum p and pseudorapidity eta, as shown in Figure 3a and Figure 3b, respectively. Due to the non-compensating nature of the calorimeter, the ratio E/p is approximately 60% and shows dependence on the jet momentum and pseudorapidity.

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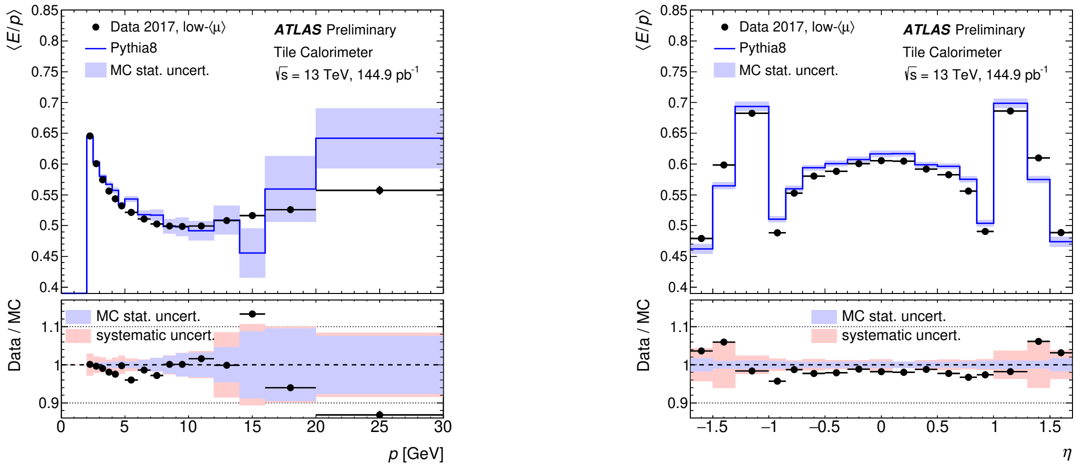

(a) (b)

Figure 3: Calorimeter response to single isolated charged hadrons using collision data as a function of (a) the momentum p and (b) the pseudorapidity η [4].

4. Conclusions

The ATLAS Tile Calorimeter employs dedicated, high-precision calibration systems to ensure component efficiency and monitor the entire signal production and processing chain. Isolated hadrons from LHC pp collisions were used to evaluate detector performance and stability, demonstrating the system's expected high efficiency.

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