PROCEEDINGS OF SCIENCE

ATLAS Tile Calorimeter Time Calibration, Monitoring and Performance

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The Tile Calorimeter (TileCal) is the hadronic calorimeter covering the central region of the ATLAS experiment at the LHC. This sampling device is made of plastic scintillating tiles alternated with iron plates and its response is calibrated to electromagnetic scale by means of several dedicated systems. The accurate time calibration is important for the energy reconstruction, non-collision background removal as well as for specific physics analyses. Every year, the time calibration is performed with first physics collisions and fine-tuned with subsequent data. The stability of the time calibration is monitored with laser system and physics collision data. Recent developments in the monitoring tools are shown and the corrections for various observed problems are discussed. Finally, the time resolution as measured with jets are presented separately in individual radial layers of the calorimeter.

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1. Introduction

The Tile Calorimeter (TileCal) is the central hadronic calorimeter of the ATLAS experiment [1] located at LHC, CERN. TileCal is responsible for measuring the energy of incoming particle jets and single hadrons. The calorimeter consists of two alternating types of layers: passive (steel absorber, where incident particles interact and develop into a particle shower) and active (plastic scintillator tiles, where incident particles create a measurable signal proportional to the particle's energy). The signal made of scintillated photons is collected via optic fibers connected to opposite sides of each tile and directed into photomultiplier tubes (PMTs) corresponding to appropriate signal channels[1]. At the level of front-end electronics, the electric signal pulse from the PMT is shaped, split into two branches (gains), digitized, and finally sent to back-end electronics for signal reconstruction. The key parameters reconstructed are the amplitude of the shaped signal and its phase, which is the offset in channel timing w.r.t. a known reference pulse synchronized with the LHC clock [2].

2. Time Calibration and Monitoring

To reconstruct the incident particle energy with the necessary precision, TileCal must be routinely calibrated w.r.t. its energy response, but also time. Due to the design of the signal propagation and readout, a particle travelling from the ATLAS interaction point at light speed must generate a signal with phase equal to zero. A set of channel-specific time constants is introduced to account for channel-to-channel differences in signal propagation time. These constants enter the Optimal Filtering (OF) algorithm responsible for signal reconstruction. They are evaluated via timing in jets and monitored using the laser calibration system, which injects a controlled light pulse into TileCal PMTs during the empty gap between bunch-crossings. The laser timing data is then analysed via a software tool, which allows for precise detection of timing issues in each channel. In 2022, the software tool had undergone an overhaul, significantly improving its ability to detect several known recurring problems in front-end hardware.

3. Performance

The time resolution of TileCal (understood as the width of the cell time[2] gaussian fit) is an important measure of the detector performance and is routinely investigated as a function of cell energy [3], [4]. The time resolution is derived using jet event data and fitted in both gains separately using a formula based on the OF algorithm. The time resolution of the whole detector in year 2022 has recently been updated to reflect an improved calibration technique applied during the reprocessing (see Fig. 1). A first-look qualitative analysis of time resolution in the individual radial layers of the detector was also performed (see Fig. 2). The most notable results include the visible offset in the time resolution of the outermost D-cells at high cell energies, and the comparatively worse time resolution in the extended barrel for each layer, as well as the sudden growth of the A-cell time resolution at low cell energies. The first two of these effects can be attributed to detector geometry and the size of the D-cells, while the A-cell behaviour is attributed to pile-up.

[1] Typically, a cell is read out by two PMTs connected to the opposite sides of the cell.

[2] The cell time is the average of the two times reconstructed by each channel connected to the cell.

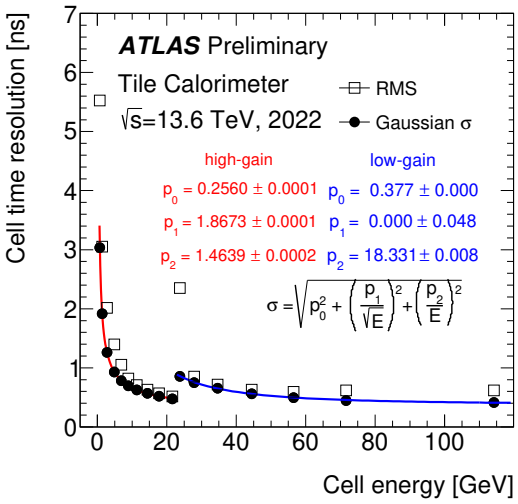

Figure 1: A plot of cell time resolution (closed circles) and the cell time std. deviation (open squares) vs cell energy for all four partitions of the detector combined [5].

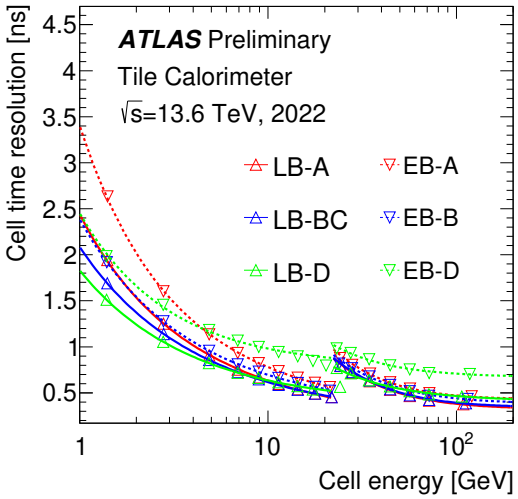

Figure 2: A plot of cell time resolution vs cell energy for each radial layer of the detector. Solid (dashed) lines are used for long (extended) barrel data [5].

Conclusions

A basic description of the ATLAS Tile Calorimeter is shown, including a summary overview of the signal propagation and readout. The importance of time calibration is highlighted and the associated systems of laser calibration and improvements thereof are explained in brief. The time resolution of TileCal is presented, with additional attention placed on the improvements made to the combined time resolution for 2022, as well as the first look at the time resolution in individual radial layers.

References

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[3] ATLAS collaboration, *Operation and performance of the ATLAS Tile Calorimeter in Run 1*, *Eur. Phys. J. C* **78** (2018) 987 [1806.02129].

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[5] ATLAS Collaboration, "Tile Calorimeter Public Plots." https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TileCaloPublicResults.