PROCEEDINGS OF SCIENCE

Time calibration and monitoring in the ATLAS Tile Calorimeter

Stanislav Poláček[*], **on behalf of the ATLAS Collaboration**

Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University , Prague, Czech Republic

E-mail: stanislav.polacek@cern.ch

The Tile Calorimeter (TileCal) is the hadronic calorimeter covering the central region of the ATLAS experiment at the LHC. This sampling device uses steel plates as an absorber and scintillating tiles as the active medium. Its response is calibrated to the electromagnetic scale by means of several dedicated calibration systems. The accurate time calibration is important for the energy reconstruction, non-collision background removal as well as for specific physics analyses. The time calibration as performed with collision data is presented. Its monitoring with laser system and collision data is discussed as well and the corrections for various identified problems. Finally, the time resolution as measured with jets in Run 2 is presented.

**** Particles and Nuclei International Conference - PANIC2021 ****
**** 5 - 10 September, 2021 ****
**** Online ****

[*]Speaker

PoS(PANIC2021)106

1. Introduction

TileCal is the central hadronic calorimeter of the ATLAS experiment [1] at LHC at CERN. It measures the energy and the direction of travel of jets and single hadrons. In addition, TileCal assists in muon measurements and together with remaining calorimeters contributes to the missing transverse energy measurement. TileCal is a sampling calorimeter built from alternating layers of plastic scintillator and steel absorber [2]. Calorimeter cells are defined by groups of scintillators.

Light from the scintillators is transmitted to the photomultiplier tubes (PMTs) by wavelength-shifting fibers. Calorimeter cells are usually read out by two PMTs (channels). Signal from PMT is split into two branches—high-gain and low-gain (with a gain ratio of 64:1). This allows precise energy measurement over a wide range. Signal amplitude and phase (with respect to the expected signal time synchronized with the LHC clock which defines the bunch-crossing period of 25 ns [1]) of physics events are reconstructed using so-called Optimal Filtering (OF) algorithm [2].

2. Time calibration

The purpose of the time calibration is to adjust the time settings of each TileCal channel in such a way that the particle traveling at the speed of light that originated from the ATLAS interaction point generates a signal pulse with the time phase equal to zero. Precise time calibration is necessary for correct energy reconstruction (OF depends on time constants), non-collision background removal, and also time-of-flight measurements.

One method of time calibration uses so-called splash events where a single bunch of protons collides with a closed collimator in front of the detector. High-energy particles produced in the collision are used to derive the time constants in the calorimeter.

The final method of the time calibration uses *pp* collision data. Only channels belonging to reconstructed jets are used. Because of slight dependence of the average channel time on the energy, specific energy range 2 GeV $< E_{\text{chan}} <$ 4 GeV is used [2]. The average channel time is then used to adjust the corresponding time constant.

3. Time monitoring

The first method of time monitoring uses laser data. Laser events are shot during empty bunch-crossings of physics runs (so-called laser-in-gap events) [3]. A software monitoring tool fills a 2D histogram for each channel with the reconstructed time and luminosity block[1] for each event. These histograms are then checked for anomalies.

A complementary time monitoring method uses collision data. Similar conditions as for the time calibration using collision data are used (Section 2). For each run, the average reconstructed time for each channel is calculated.

3.1 Time problems

Examples of timing problems encountered during the Run-2 data-taking are timing jumps and bunch-crossing offsets.

[1]Luminosity block is a basic time unit for storing ATLAS luminosity information [4]. It is approx. one minute long.

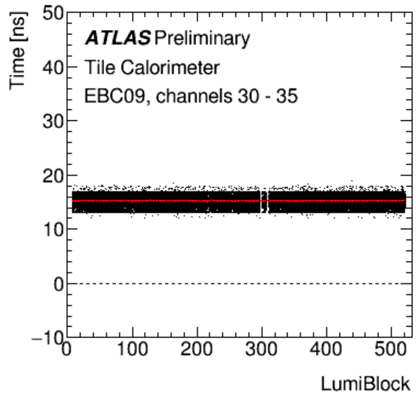

Figure 1: Timing jump observed in the laser-in-gap data [5]. All events are shifted by approximately +15 ns (jump occurred at the beginning of the run).

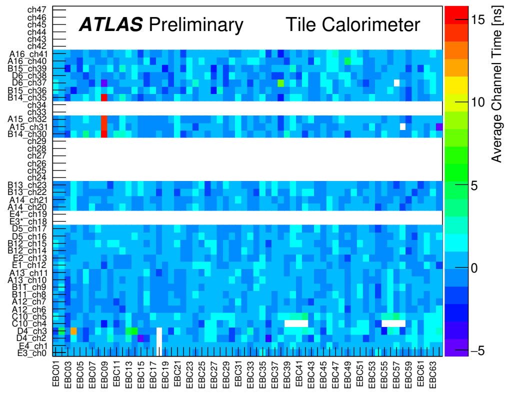

Figure 2: Timing jump observed in the physics data (module EBC09, channels 30–35) [5]. The x-axis shows the detector modules. The y-axis shows the module channels.

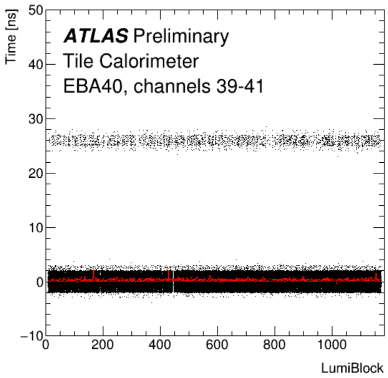

Figure 3: Bunch-crossing offset problem observed in the laser-in-gap data [5]. Fraction of the events is shifted by +25 ns throughout the whole run.

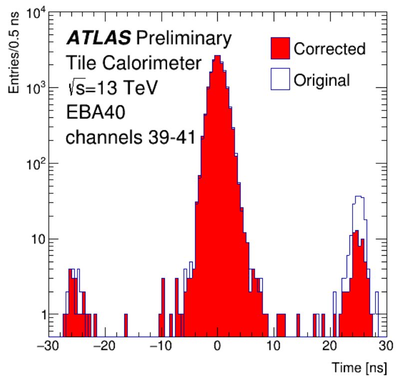

Figure 4: Bunch-crossing offset problem observed in the physics data [5]. Data processed with (Corrected) and without (Original) the TileTimeBCOffsetFilter tool are compared.

Timing jump is a sudden change in the time settings in a group of usually six channels caused by faulty electronics [2]. This problem is primarily monitored using the laser-in-gap events (Figure 1) and it is usually confirmed in the physics events (Figure 2). After the corresponding time constants are corrected the jump disappears in both laser and physics plots.

Few groups of three channels in the Tile Calorimeter suffer from the so-called bunch-crossing offset, where a fraction of events (usually about 1%) is simultaneously shifted by 1 or 2 bunch-crossings (i.e. 25 or 50 ns) in all three channels. This problem was first seen in the laser-in-gap events (Figure 3) and is also visible in physics events (Figure 4). A dedicated software tool (TileTimeBCOffsetFilter) was developed to identify events with the bunch-crossing offset problem in order to mask the corresponding channels in the affected events on the fly. This tool is used for the Run-2 data reprocessing.

4. Time resolution

The cell time resolution (cell time is the average time of the two associated channels) in collision data depends on the measured energy. For high cell energies, the resolution approaches 0.4 ns (Figure 5).

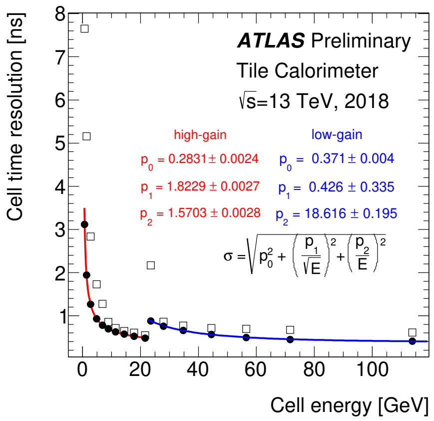

Figure 5: The cell time resolution in jet events from 2018 as a function of the cell energy [5]. The closed circles indicate the Gaussian σ and the open squares indicate the RMS of the underlying time distributions. The RMS values are higher than the Gaussian σ due to non-Gaussian tails of the time distributions caused by out-of-time pileup. The resolution is fitted with the displayed formula for high-gain and low-gain separately.

5. Conclusions

Methods of the time calibration and monitoring of the ATLAS Tile Calorimeter using laser and collision data are summarized.

Timing problems encountered during the LHC Run-2 data-taking, such as timing jumps and bunch-crossing offset problems, are presented. Methods for correcting these problems are mentioned.

References

[1] ATLAS Collaboration. The ATLAS Experiment at the CERN Large Hadron Collider. *JINST*, 3:S08003, 2008.

[2] ATLAS Collaboration. Operation and performance of the ATLAS Tile Calorimeter in Run 1. *Eur. Phys. J. C*, 78:987, 2018.

[3] ATLAS Collaboration. The Laser calibration of the Atlas Tile Calorimeter during the LHC run 1. *JINST*, 11(10):T10005, 2016.

[4] ATLAS Collaboration. Luminosity determination in pp collisions at $\sqrt{s}$ = 8 TeV using the ATLAS detector at the LHC. *Eur. Phys. J. C*, 76:653, 2016.

[5] ATLAS Collaboration. Tile Calorimeter public plots. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TileCaloPublicResults.