Time calibration and monitoring in the ATLAS Tile Calorimeter

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Tile Calorimeter

- Central hadronic calorimeter of the ATLAS experiment at LHC at CERN — measurement of the energy and direction of particles and jets
- Sampling calorimeter — steel absorber, plastic scintillators
- Scintillator signal → wavelength-shifting fibers → photomultiplier tubes (PMT)
- PMT signal → two-gain electronics — high-gain & low-gain (precise energy measurement over a wide range)
- Signal amplitude and phase of physics events reconstructed using so-called Optimal Filtering algorithm (OF)
- Calorimeter cell — usually 2 PMTs (channels) on both sides of the module, ∼5000 cells in total

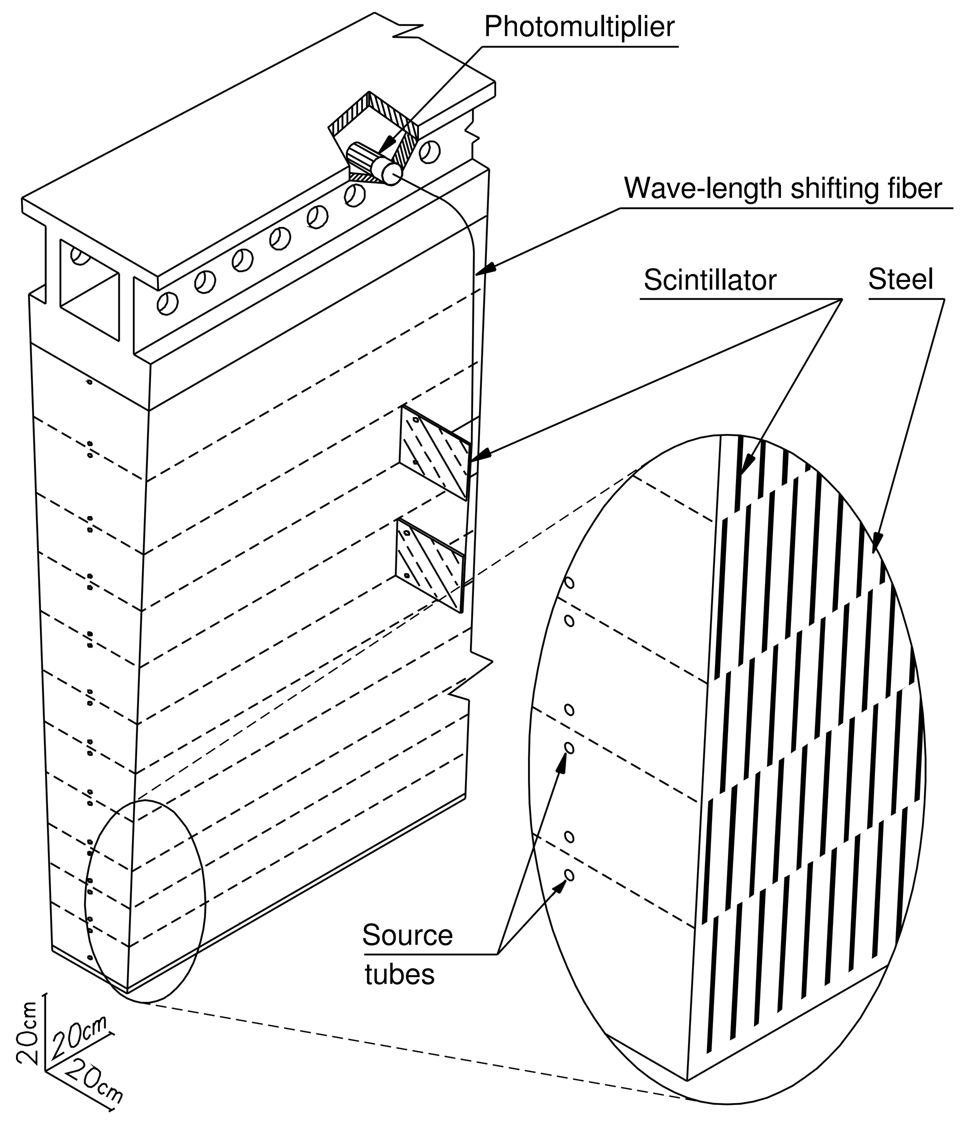


Fig. 1: TileCal module

Timing jumps

- Timing jump = sudden change in the time settings in a group of usually six channels caused by faulty electronics
- Problem primarily monitored using the laser-in-gap events (Fig. 3), later confirmed in the physics events (Fig. 4)
- Correction of corresponding time constants → jump disappears in both laser and physics plots

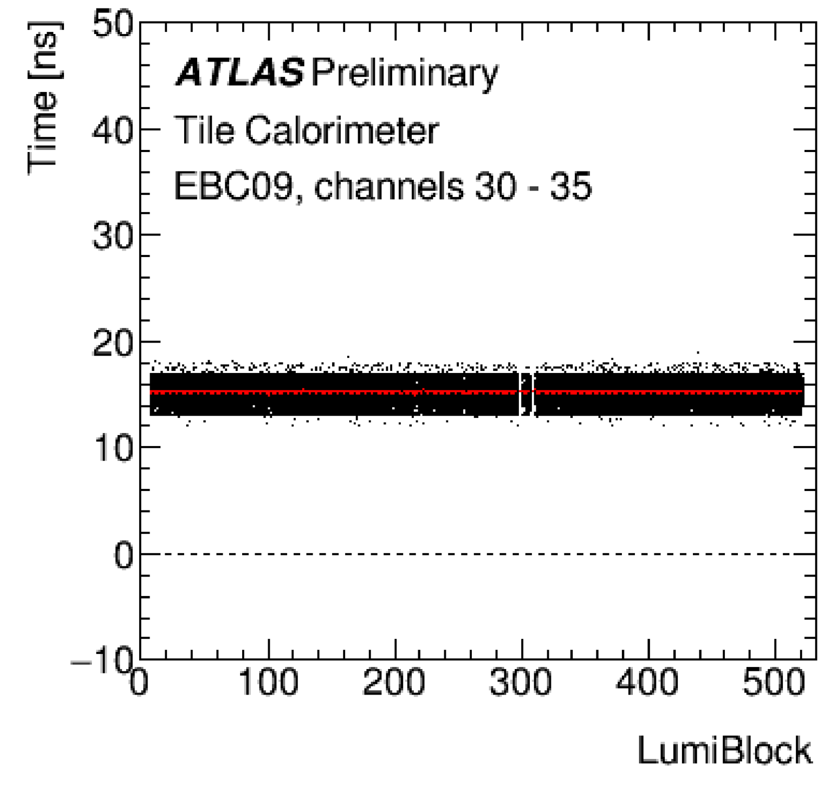


Fig. 3: Jump observed in laser-in-gap

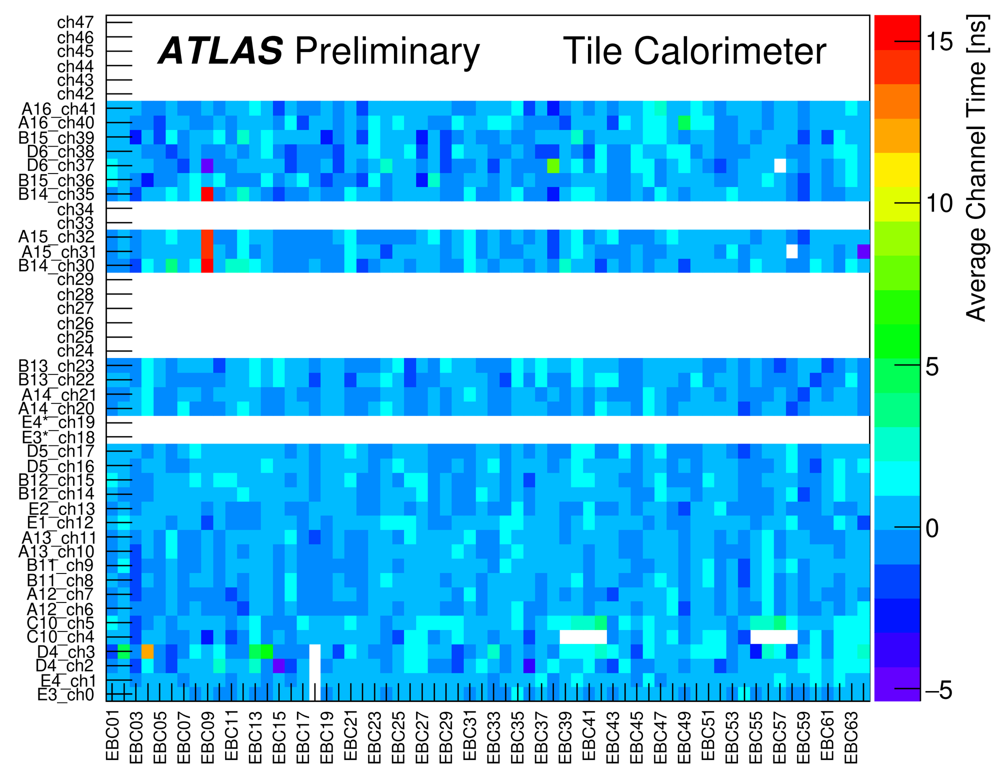


Fig. 4: Jump observed in physics

Calibration & Monitoring

- Time calibration necessary for energy reconstruction (OF depends on time constants), background removal, ToF measurement
- Goal: particle traveling at the speed of light from the ATLAS interaction point generates a signal with the time phase equal to zero
- Final time calibration using *pp* collision data
- Time monitoring using laser calibration events
  - Laser events during empty bunch crossings = laser-in-gap
  - Reconstructed time and luminosity block of each laser event (Fig. 3, 5)
  - Automatic software tool checks for anomalies
- Time monitoring using *pp* collision data — average time for each channel (Fig. 4)

Bunch-crossing offset

- Bunch-crossing offset (BCO) = simultaneous shift of timing in a group of 3 channels by 1 or 2 bunch-crossings caused by faulty electronics
- Intermittent problem — usually about 1 % of events
- First observed in laser-in-gap events (Fig. 5), also seen in physics events (Fig. 6)
- Affected channels identified using laser-in-gap
- Software tool (based on physics data) for identification of events with BCO → masking corresponding channels in affected events
- Physics plot — comparison of data processed with (Corrected) and without (Original) the software tool
- Tool significantly reduces events close to +25 ns
- Tool used for the Run-2 data reprocessing

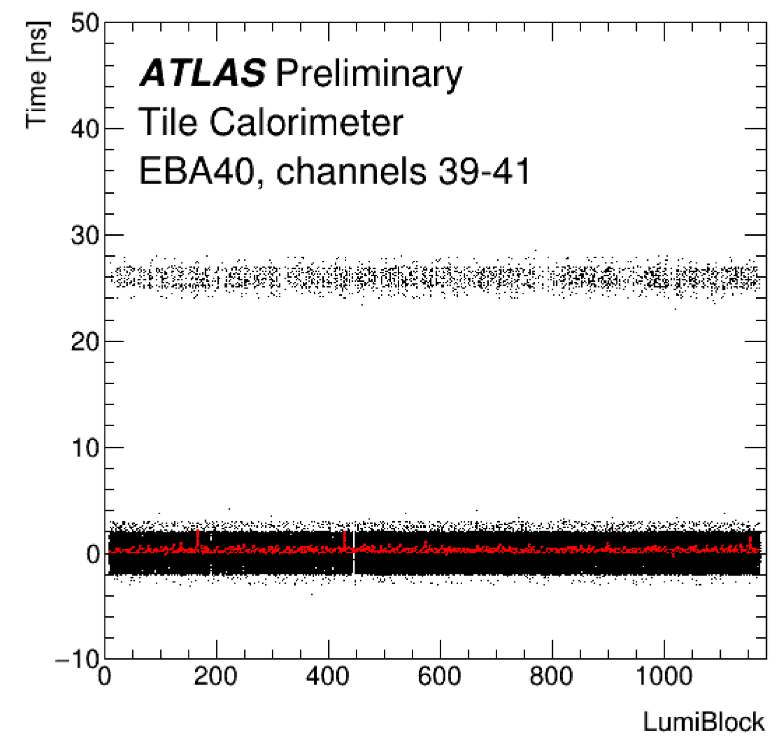


Fig. 5: BCO observed in laser-in-gap

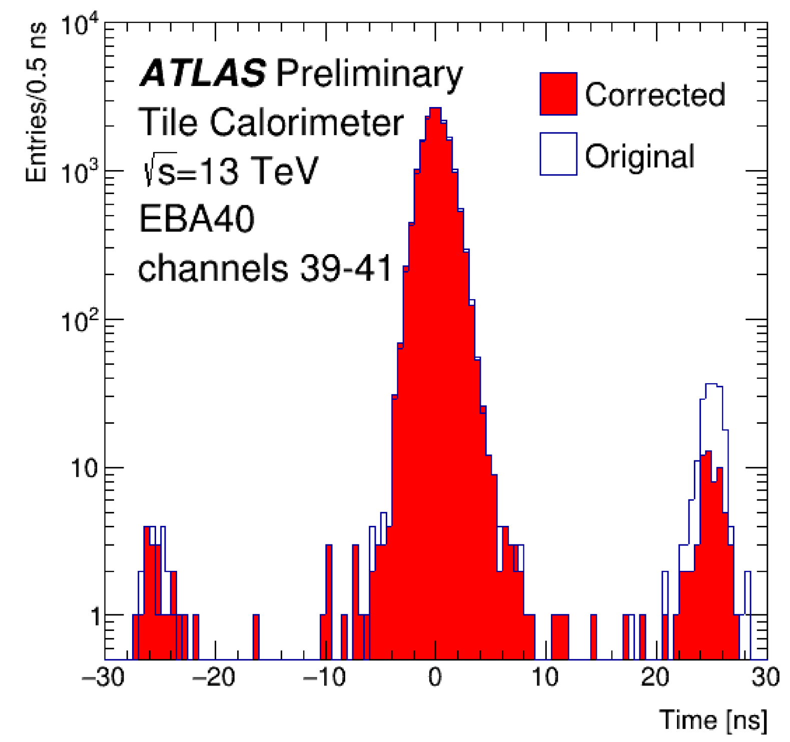
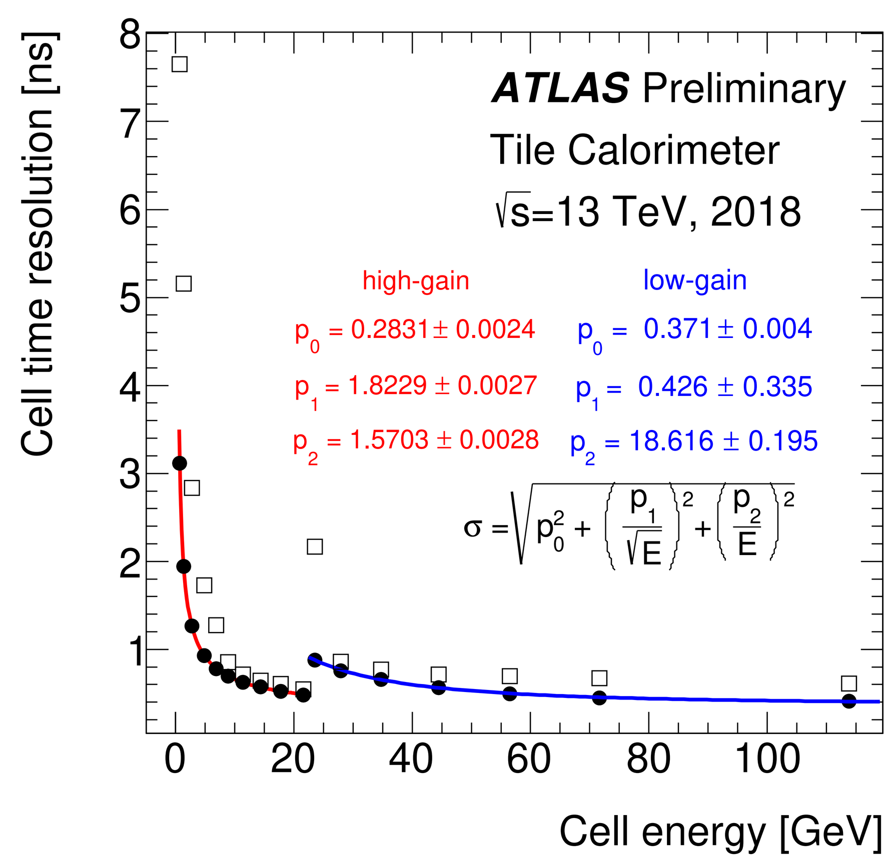


Fig. 6: BCO observed in physics

Time resolution

- Only cells belonging to reconstructed jets are considered
- Gaussian fit of the reconstructed cell time for each energy bin — time resolution = σ (closed circles)
- Open squares = underlying time distributions RMS
- RMS > σ because of out-of-time pileup (LHC proton bunch-crossings every 25 ns)
- Resolution gets better with increasing cell energy (approaches 0.4 ns for high cell energies)



$$\sigma = \sqrt{p_0^2 + \left(\frac{p_1}{\sqrt{E}}\right)^2 + \left(\frac{p_2}{E}\right)^2}$$

Fig. 2: TileCal time resolution

References

[1] ATLAS Collaboration. Operation and performance of the ATLAS Tile Calorimeter in Run 1. *The European Physical Journal C*, 78(12), Nov 2018.

[2] T. Davídek. ATLAS Tile Calorimeter time calibration, monitoring and performance. *Journal of Physics: Conference Series*, 928:012003, Nov 2017.

[3] Tile Calorimeter public plots. *https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TileCaloPublicResults*.