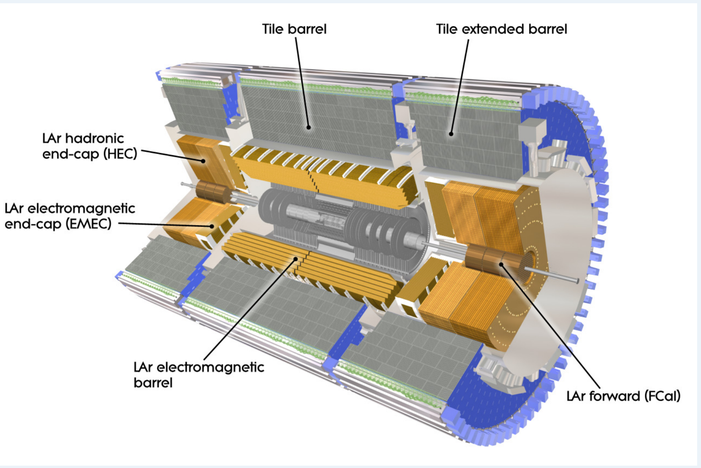
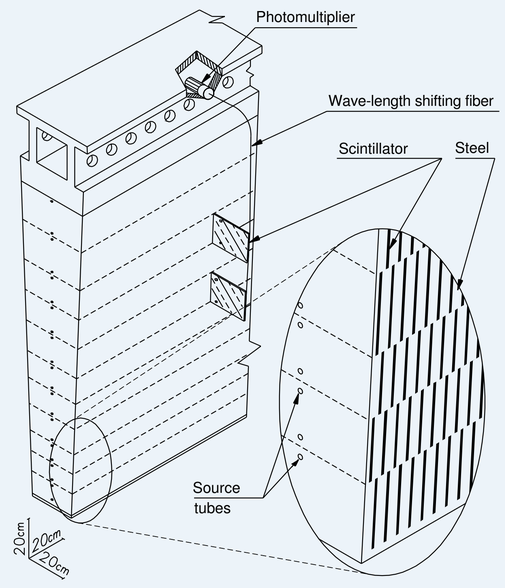
Time calibration, monitoring and performance of the ATLAS Tile Calorimeter in Run 2

Kristina Mihule, on behalf of the ATLAS collaboration

Charles University, Prague

The Tile calorimeter

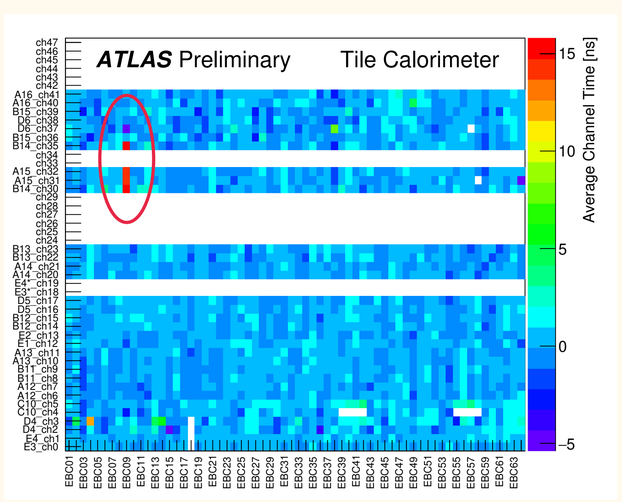




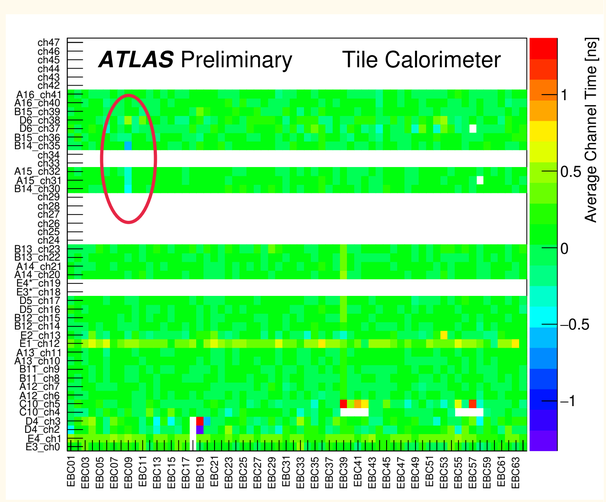
- The TileCal is the central hardonic calorimeter at the ATLAS experiment (LHC), covering $|\eta| < 1.7$.
  - Provides data for reconstruction of jets, τ_h, hadrons, and missing transverse energy.
  - Assists in muon identification.
  - A sampling detector: steel and plastic tiles.
- Charged particles passing through the tiles produce the light transmitted by wavelength shifting fibers to photomultiplier tubes (PMTs).
- Comprises 5182 cells, a cell is typically read out by two PMTs (channels).
- The signal is passed to front-end electronics for shaping, amplification (2 gains, 1:64 ratio), and digitization (10-bit ADC).
- The Optimal Filtering algorithm reconstructs the signal amplitude and phase based on 7 digitized samples.
- The deposited energy is evaluated based on the reconstructed amplitude.

Time calibration monitoring

- Time calibration monitored with two independent methods:
  – with reconstructed jets in physics data
  – in response to laser pulses emitted during empty bunch-crossings.
- Time offsets above 3 ns were identified and promptly addressed before full ATLAS data processing.
  - The readout gains with time instabilities → recalibrated or vetoed for usage in timing-sensitive studies.
  - Monitoring with laser per Luminosity Block (LB) → biases are corrected in affected LBs.

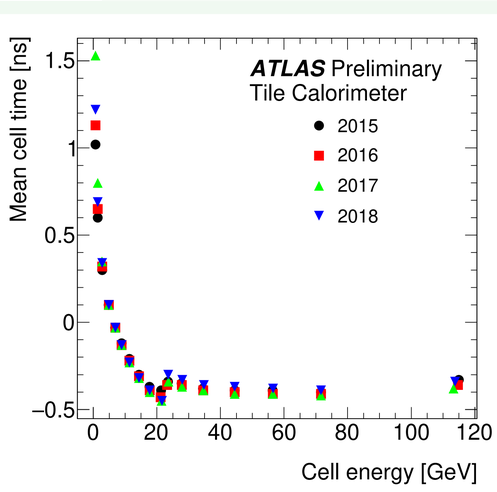


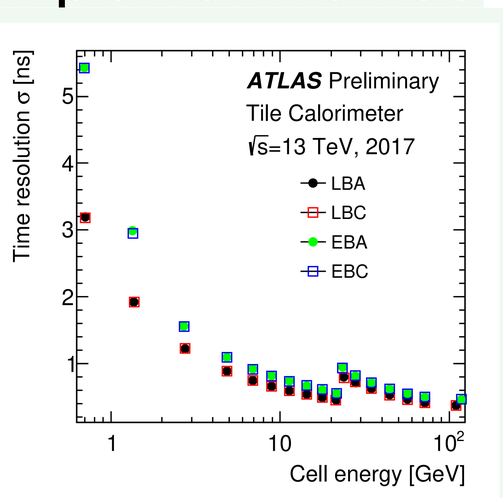
The mean time before time correction

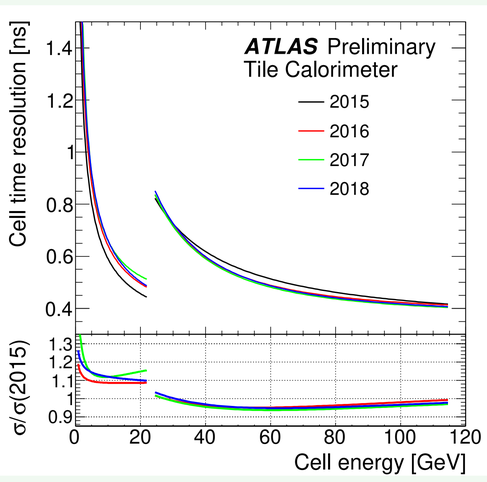


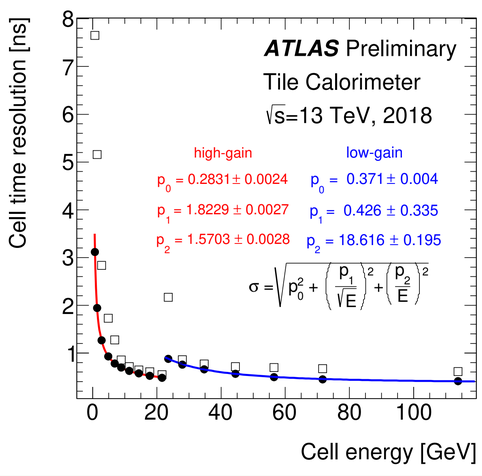
The mean time after time correction

Time calibration performance



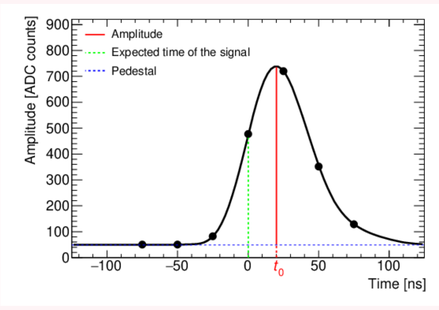


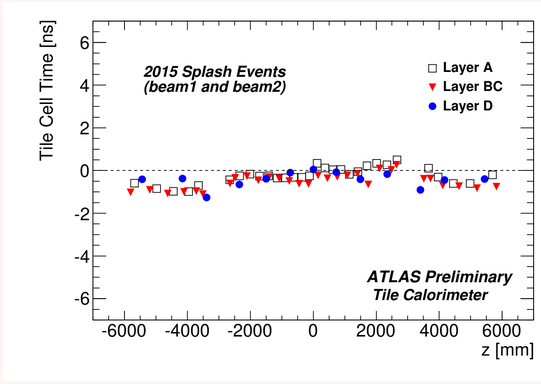




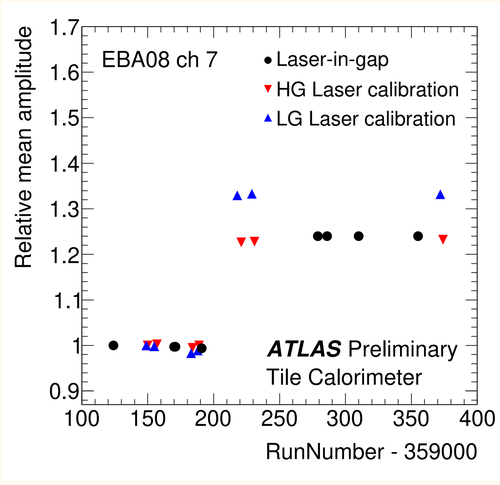
Time calibration

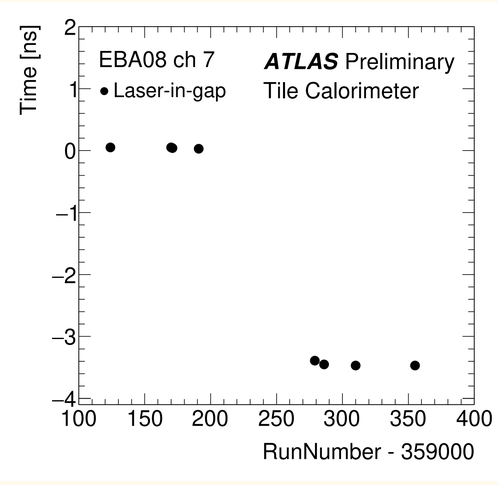
- Time calibration adjusts the phase of the sampling clock to the peak of the signal produced by the traversing particle.
  - The signal phase $t_0 \sim 0 \rightarrow$ the amplitude is properly reconstructed.
  - Time measurement is used for time-of-flight studies, non-collision background removal.



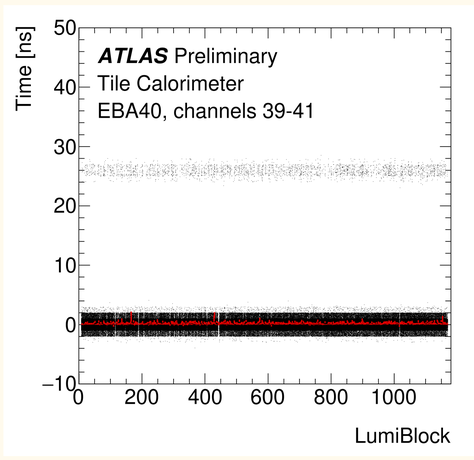


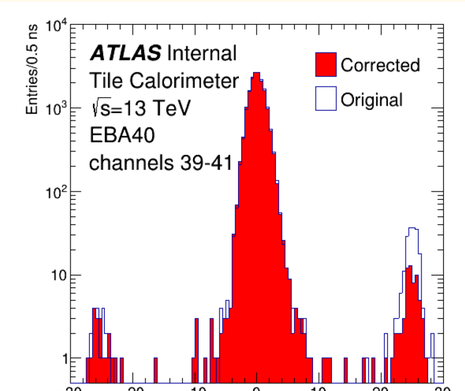
- Before Run 2 physics collisions, time calibration was performed with high-energy muons in splash events.
  - Time calibration constants = the average reconstructed time + corrections for time-of-flight.
- The final calibration was derived with first proton-proton collision data.
  - The time distribution in jet-associated cells → Gaussian mean = a calibration constant.
  - Channels with $2 < E_{ch} < 4$ GeV are exploited for high gain (HG) calibration.
  - HG calibration + correction for faster signal propagation in low gain (LG) and the time on dependency on measured energy → low gain (LG) calibration.
  - The LG calibration was fine-tuned in high-energy channels $15 < E_{ch} < 50$ [GeV] in 2016-18.
- Maintenance campaigns during technical stops → components replacement → time constants in affected channels were adjusted w.r.t. the time offsets seen in laser events.
- Majority of time calibration fluctuations were traced to electronic components problems.
  - Damage of a 3-in-1 card due to overcurrent → reconstructed phase and amplitude change in the related channels.





- Bunch-crossing time offsets in a group of three channels (coupled to the same Data Management Unit).





- Improved stability of electronics in Run 2 → lower in Run 1 rate (∼ a dozen per year) of “time jumps” (changes of time settings for 6 channels related to the same digitizer).
- Each year, time calibration was revised at the end of data-taking year → precise conditions for data reprocessing.

- The TileCal time performance was stable throughout Run 2.
- The mean cell time depends on the deposited energy due to different dynamics for fast and slow components of hadronic showers.
- Fluctuations of the mean time during Run 2 is within 0.05 ns.
- The time resolution raised by ∼10% in cells $E_{cell} < 20$ GeV due to higher pile-up since 2016.
- In cells with $E_{cell} > 4$ GeV, the time resolution is below 1 ns.
- An improved procedure for low-gain calibration resulted in 5% better resolution in 2016-18.
- The low-gain resolution constant term approaches ~ 0.4 ns.

References:
[1] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TileCaloPublicResultsTiming
[2] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTile
[3] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/PublishedTilecalFigures