Calibration and performance of the ATLAS Tile Calorimeter in Run 2

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on behalf of the ATLAS collaboration and the Tile Calorimeter system

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The Tile Calorimeter at the ATLAS experiment

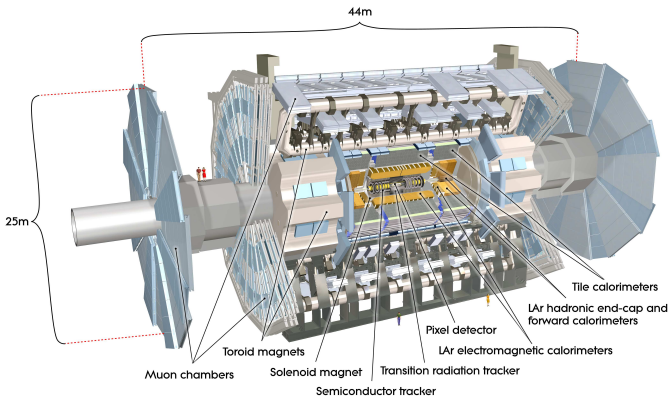


Figure: Cut-away view of the ATLAS experiment [1].

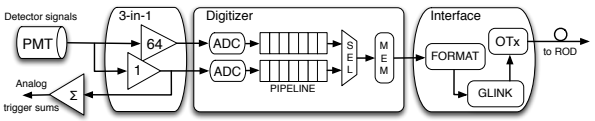


Figure: The TileCal FEE layout [2].

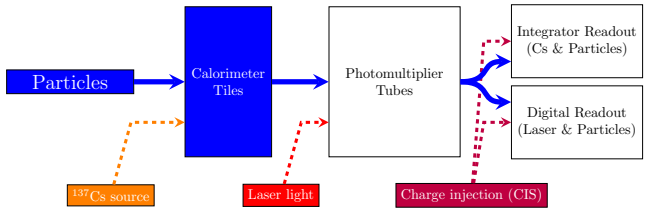


Figure: The TileCal calibration flow diagram [3].

- Provides information for reconstruction of jets, τ_{had} and hadrons, MET.
- Composed of altering layers of plastic scintillator and steel absorber.
- The charged particles passing through the tiles produce the light transmitted by wavelength shifting fibers to photomultiplier tubes (PMTs).
- FEE shapes, amplifies (2 gains), digitizes the signal (10-bit ADC).
- The deposited energy is estimated from the raw response as follows:
  $E[\mathrm{GeV}] = A[\mathrm{ADC}] \cdot C^{\mathrm{CIS}}_{\mathrm{ADC}\rightarrow\mathrm{pC}} \cdot C_{\mathrm{Cs}} \cdot C_{\mathrm{laser}} \cdot C^{\mathrm{EM\ scale}}_{pC\rightarrow GeV}$
- The TileCal calibration systems monitor the detector status and provide a means for equalizing the calorimeter response at each stage of the signal propagation.

TileCal. Calibration results

- Cesium calibration determines the response of the scintillating tiles, PMTs, and slow FEE readout with a Cesium (Cs) radioactive source C_{Cs}.
- Laser calibration measures the response of PMTs, optic and fast FEE path C_{laser}.
  - Provides additional checks of high voltage and time stability.
- The **C**harge **I**njection **S**ystem (CIS) calibrates FEE response to known charge $C^{\mathrm{CIS}}_{\mathrm{ADC}\to\mathrm{pC}}$.
- The Integrator (Minimum Bias) system monitors optical path and PMT gain.
  - Provides measurement of instantaneous luminosity measuring signal.
- Calibration systems partially overlap: cross-check and reliable data-taking.

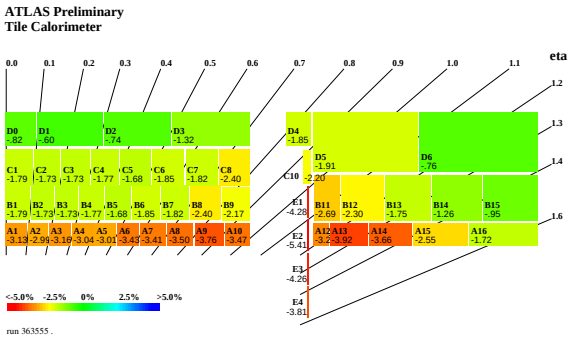


Figure: The mean gain variation between the end and start of 2018 *pp* collisions [3].

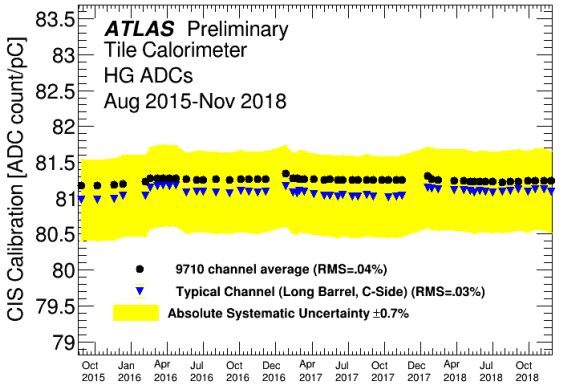


Figure: Evolution of CIS calibration constants in the entire Run 2 [3].

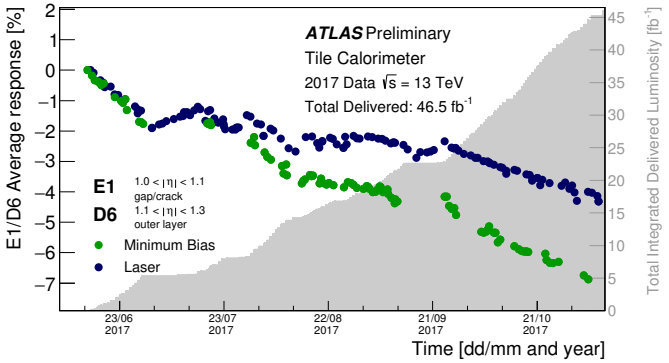


Figure: Evolution of response in Minimum Bias and Laser calibration [3].

TileCal. Performance in Run 2

- The response of isolated cosmic muons verifies the measured energy at the EM scale, isolated hadrons are used as a probe of the hadronic response.
- The electronic noise is measured to be at the level of 20-40 MeV, in dedicated pedestal runs without signal exposure.
- The pile-up noise is measured with zero-bias triggered events and compared to minimum bias Monte Carlo (MC) simulations.
- The time resolution studied with multijet events is within 1 ns for the cell with energy input above 30 GeV.

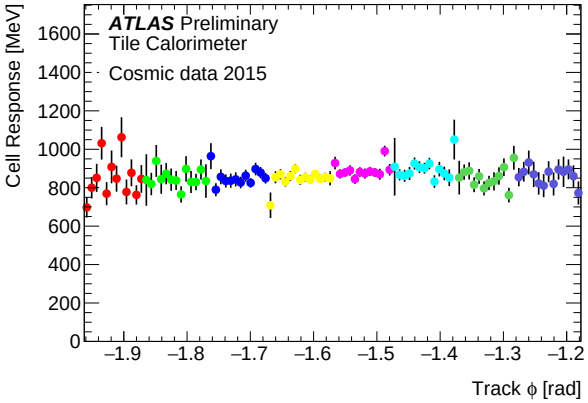


Figure: Cosmic muon energy deposition profile as a function of track ϕ impact point [4].

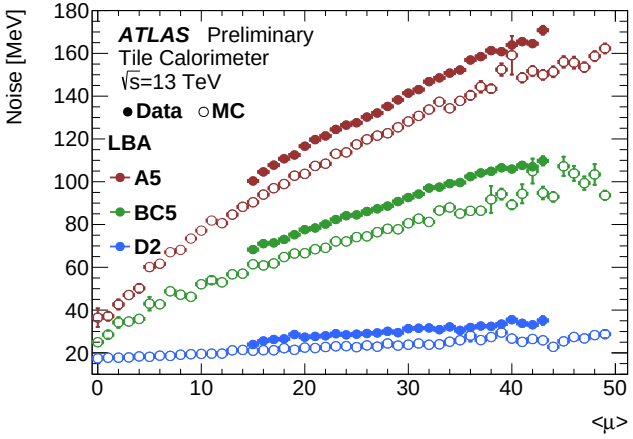


Figure: Pile-up noise as a function of $< \mu >$ [5].

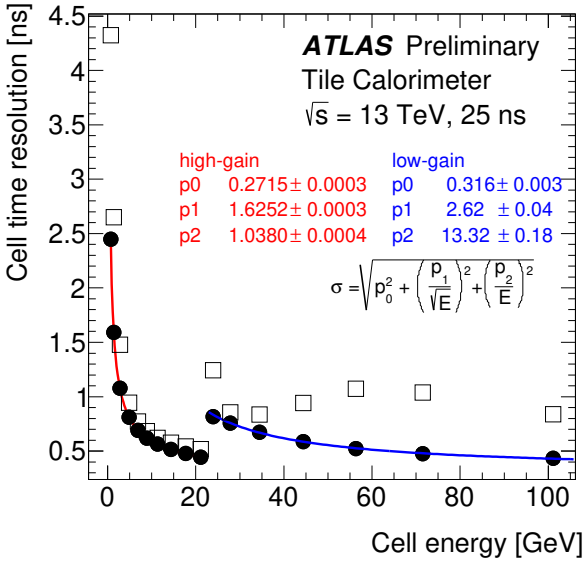


Figure: TileCal time resolution vs. E_{cell} [6].

TileCal. Run 2 results and Outlook

- With continuous calibration monitoring, cell response is stable within 1%.
- Data Quality efficiency: 100% (2015), 98.8% (2016), 99.4% (2017), 100% (2018).
- Jet energy resolution is within designed $\frac{\sigma}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$ (Figure 11).
- The TileCal HL-LHC upgrade is designed to withstand higher ambient radiation dose & pile-up level, to provide fully digital input for L0 trigger at the LHC rate.
- Large-width links, detached readout, component modularity, off-detector memory buffer, redundant power supplies, improved control and calibration systems.
- A HL-LHC prototype module underwent beam (SPS, 2015-18) and radiation tests.
- The module with the new electronics set was inserted in the ATLAS detector in July 2019 for the project validation and evaluation for Run 3.

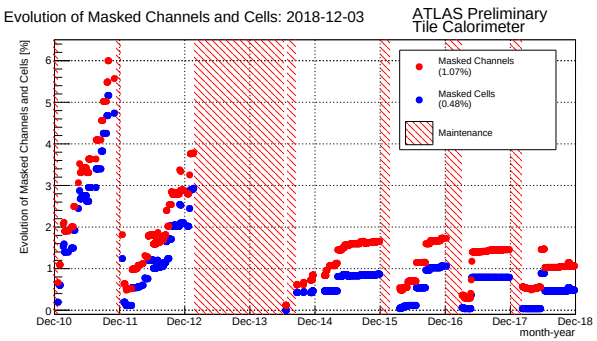


Figure: Evolution of cell masking [8].

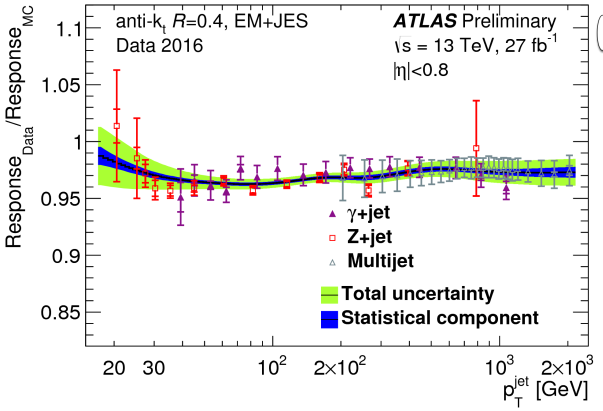
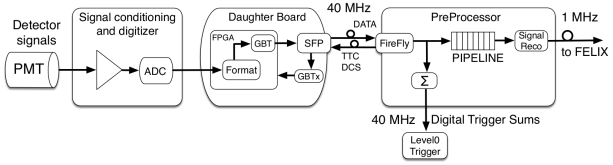


Figure: Ratio of jet response in data & MC [7].



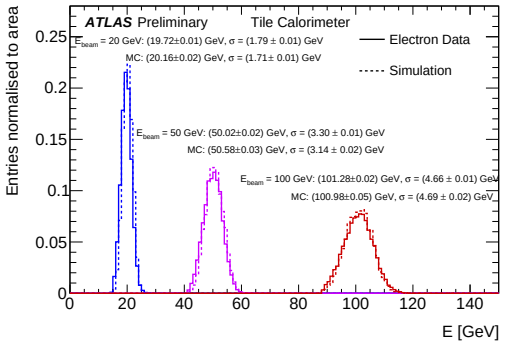


Figure: HL-LHC readout [9].
Distributions of the electron energy [10].

References

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