Calibration and performance of the ATLAS Tile Calorimeter in Run 2

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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, $\tau_{\text{had}}$ and hadrons, MET.

Composed of alternating 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:

$$E[\text{GeV}] = A[\text{ADC}] \cdot C_{\text{ADC}}^{\text{CIS}} \cdot C_{\text{Cs}} \cdot C_{\text{laser}} \cdot C_{\text{EM scale}}^{\text{pC \rightarrow GeV}}$$

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 Charge Injection System (CIS) calibrates FEE response to known charge $C_{ADC\rightarrow pC}$.
- 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].
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 impact point [4].

**Figure:** Pile-up noise as a function of $<\mu>\ [5]$. **Figure:** TileCal time resolution vs. $E_{cell\ [6]}$. 

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\sigma = \sqrt{p_0^2 + \left( \frac{p_1}{E} \right)^2 + \left( \frac{p_2}{E^2} \right)^2}
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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 $\frac{\sigma}{E} = \frac{50\%}{\sqrt{E}} \pm 3\%$ (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

2. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileElectronics/
5. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileNoise/
8. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileDetectorStatus
10. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileTestBeamResults