The ATLAS Tile Calorimeter performance at LHC

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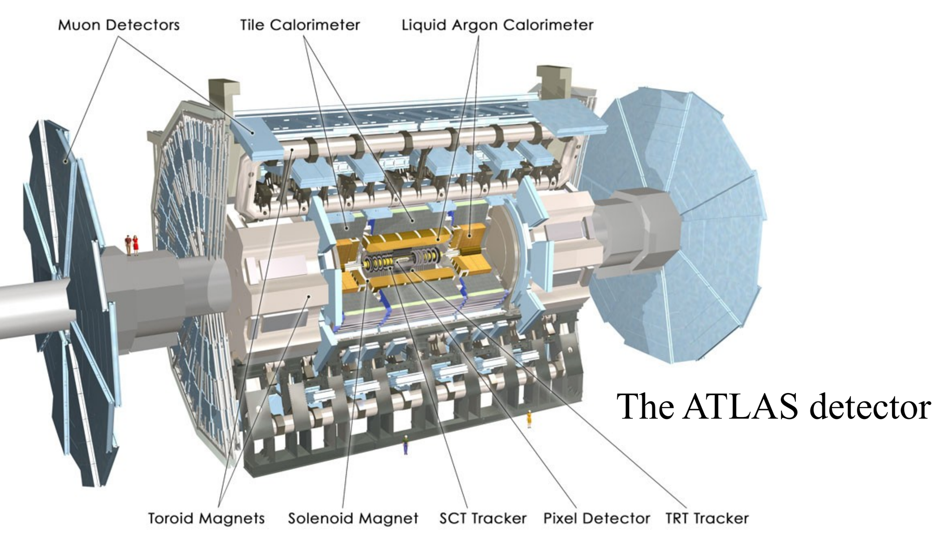
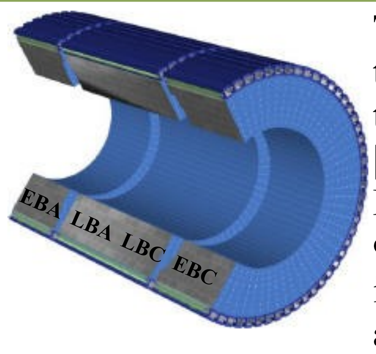
On behalf of the ATLAS Collaboration

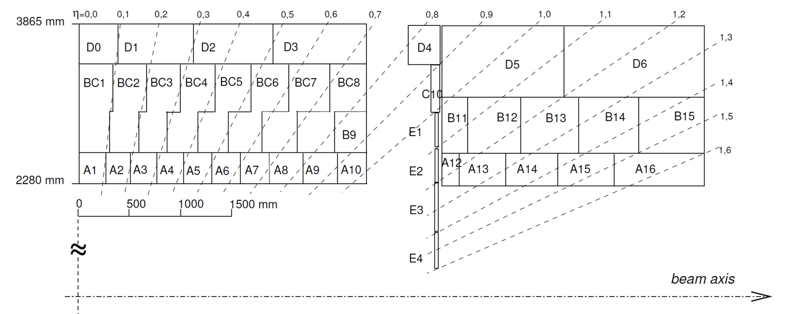
The ATLAS Tile Calorimeter



ATLAS is a general purpose experiment installed at the Large Hadron Collider (LHC) at CERN. LHC is delivering stable proton beams since 2009 and currently provides collisions at a center of mass energy of 8 TeV.
The Tile Calorimeter (TileCal) is the central section of the ATLAS hadronic calorimeter. It detects hadrons, jets and taus, while also contributing to the jet energy and Missing E_T reconstruction, as well as assisting the spectrometer in the identification and reconstruction of muons.



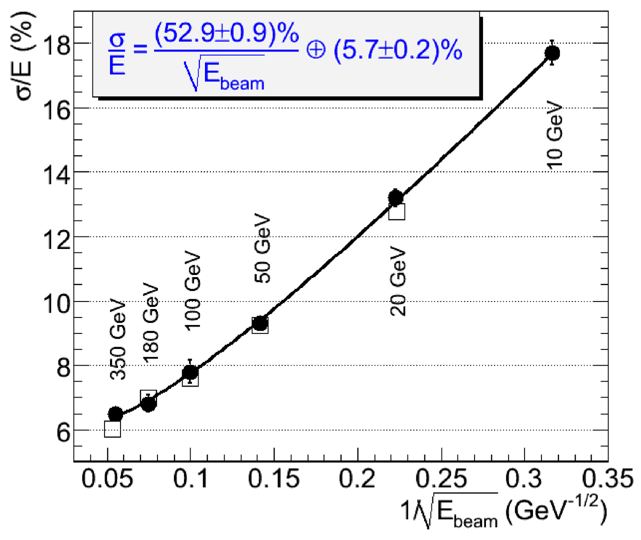
TileCal is a sampling calorimeter using plastic scintillating tiles as the active medium and steel plates as the absorber. It covers the pseudorapidity range up to $|\eta| < 1.7$ with one central Long Barrel (LB) and two Extended Barrels (EB). Each barrel is segmented in Φ in 64 modules. Radially each module is divided into three layers which are approximately 1.5, 4.1 and 1.8 λ (nuclear interaction length for protons) thick for the LB and 1.5, 2.6 and 3.3 λ for the EB. The total number of cells is 5182, while the number of channels is ~10000, as most cells are read by two PMTs.

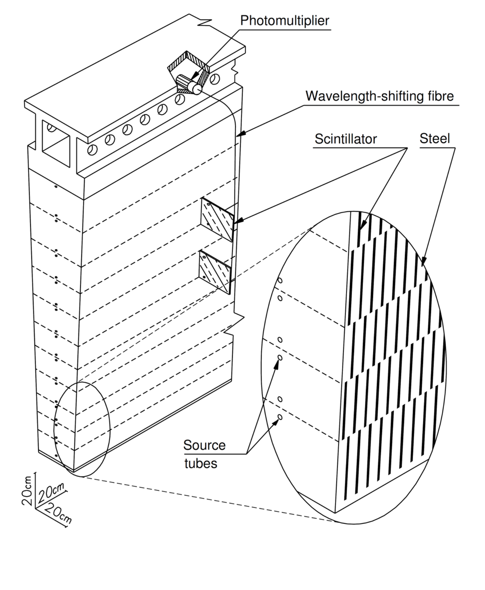


Distribution of cells in pseudorapidity and distance from the beam axis in a module.

Cell granularity
First two layers:
$\Delta\eta \times \Delta\Phi = 0.1 \times 0.1$
Outermost layer:
$\Delta\eta \times \Delta\Phi = 0.2 \times 0.1$

Each cell is composed of several steel and scintillating plates, the latter being read out on each side by wavelength shifting fibers. Each side of a cell is being read by a different PMT. This improves the response uniformity and provides readout redundancy.





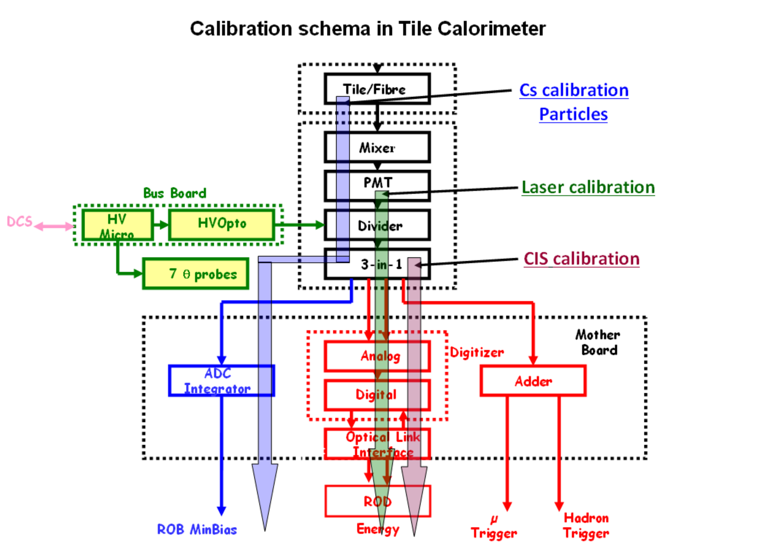
The TileCal standalone energy resolution for pions from beam tests is presented in the left plot. The data (full circles) are in good agreement with MC simulations (open squares).

Calibration

Description

TileCal uses a complex calibration scheme which allows for individual components to be tested and calibrated. Different types of calibration allow the following:

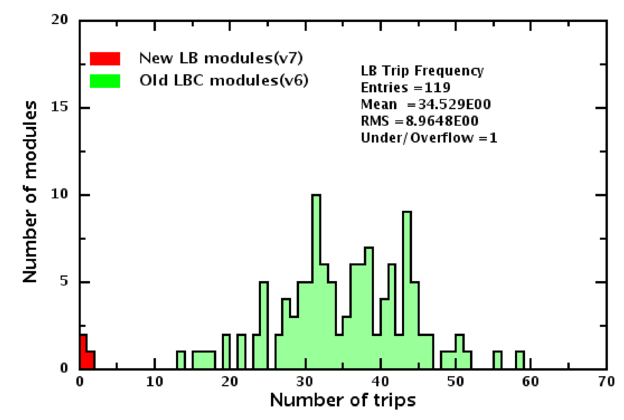
- Calibration of the initial part of the signal readout path (including the optics elements and the PMTs) with movable radioactive ^{137}Cs γ-sources
- Monitoring of the gains of the photomultipliers by illuminating all of them with a laser system
- Calibration of the front-end electronic gains with a charge injection system
- Current integration over several thousand bunch crossings during collision data-taking to monitor luminosity and to assist response uniformity studies



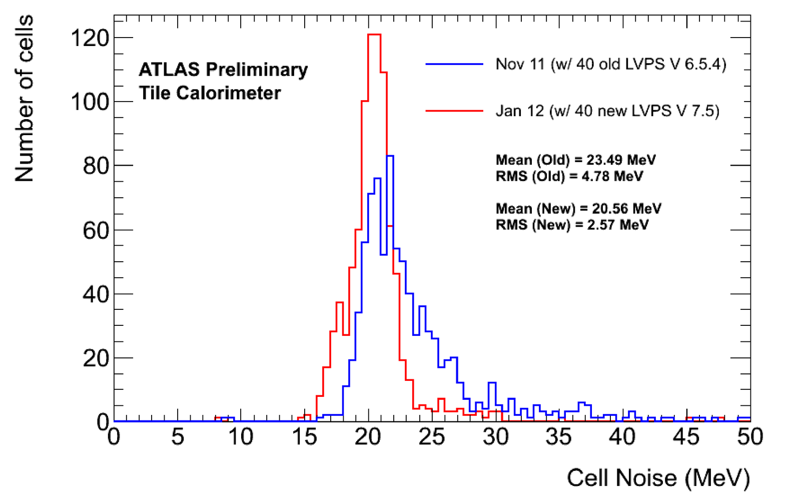
Flow diagram of the readout signal paths of the different TileCal calibration types. The paths are partially overlapping, allowing for cross-checks and easier identification of component failures.

Trip rate and noise improvement

A major issue during the 2011 data taking were the frequent low voltage power supplies (LVPS) trips. A solution at the hardware level was found and new LVPS will replace the current ones, with 40 being installed now and the full production scheduled for 2013. These LVPS are more reliable and robust under the high luminosity conditions that are expected. The new version also benefits from a better noise performance.

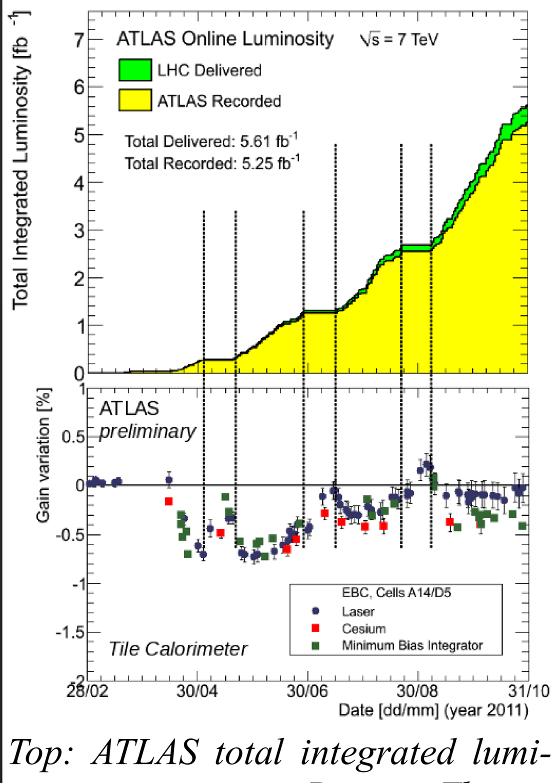


The number of LB modules that have tripped a specific number of times. This is for the period between March 13th 2011 and October 30th 2011. Red shows the new type of power supplies which, at the time, were installed in four modules.



A comparison between cell noise RMS in in 2011 and 2012 in all cells in the 40 modules that had their LVPS changed. Values taken from pedestal run 192130 (2011) and run 195843 (2012).

Combined calibration



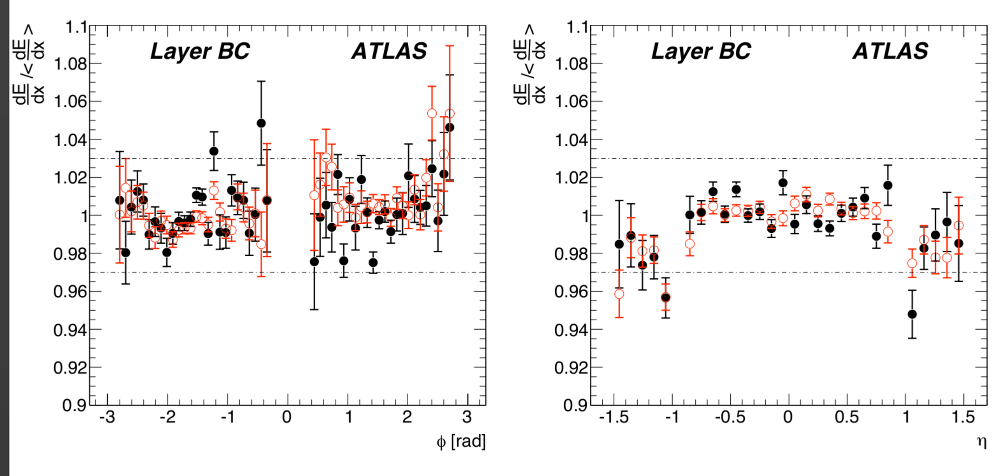
Top: ATLAS total integrated luminosity versus time; Bottom: The ratio between the response of cells A14 and the cell D5 as a function of time in EBC

The plot on the left shows on the top the evolution of ATLAS total integrated luminosity and on the bottom the evolution of the ratio between the response of cells A14 and the cell D5 as a function of time in EBC. Data are collected during standalone TileCal calibration runs. Each point on this plot corresponds to an average over 64 modules in phi. The measurements are normalized to the first run taken as a reference (taken on 18 February 2011).
The response is measured by the Cesium, the Laser and the Minimum Bias calibration systems. Since all three systems show a similar behavior, the drifts that are observed can be attributed mostly to a variation of A14 photomultiplier response and not to the scintillator irradiation.
The downdrift periods coincide with the periods of data taking with high instantaneous luminosity, while the updrifts coincide with the technical stops (no collisions). The maximum variations are below 1% over all 2011 data taking period with an integrated luminosity of ~5.6fb^{-1}. The cesium calibration system is used every 2 weeks to recalibrate all the cells and restore the electromagnetic scale.

Cosmic Muons & Splash Events

TileCal cell energy uniformity

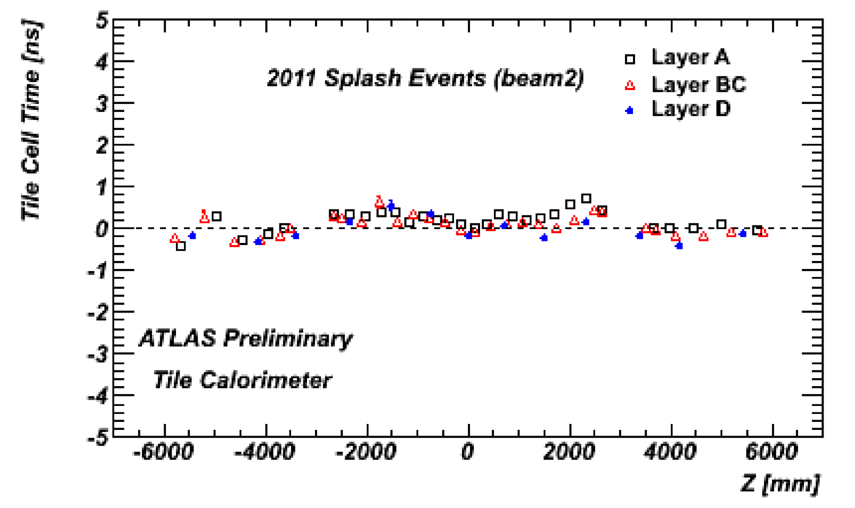
Cosmic muons pass through the detector leaving some of their energy in the calorimeter. The estimator for the muon response is the truncated mean of dE/dx, defined as the mean after 1% of the events in the high-energy tail of the distribution were removed. The truncated mean is less sensitive to the muon's radiative losses in the cells.



Uniformity of the cell response to cosmic muons, as a function of Φ (left) and η (right) for layer BC. Data are shown with closed circles and is well predicted by MC, shown with open circles. Horizontal lines limit a ±3% band.
The gap in the region around Φ = 0 corresponds to horizontal modules poorly populated by muons passing through the Inner Detector.
The larger statistical uncertainties at higher η in the Extended Barrels are due to reduced coverage than in the central region.

TileCal cell timing

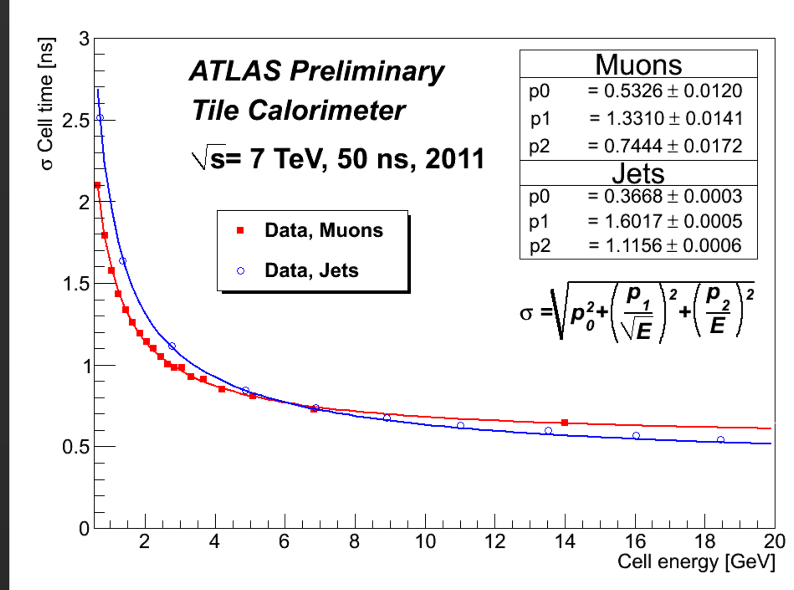
Splash events are produced when a single beam is run into a collimator approximately 150m upstream of the detector. This produces a splash of particles that hit the detector at very low angles with respect to the beam axis, allowing for checking the synchronization of the TileCal cells. The obtained distribution shows that the cells are synchronized within 1ns.



Timing of TileCal signals recorded with single beam data on February 2011. The average time over all cells with the same Φ coordinate is shown as a function of the cell Z coordinate, for all three radial samplings. Timing corrections based on laser data had been applied.

Collision Performance

Cell time resolution

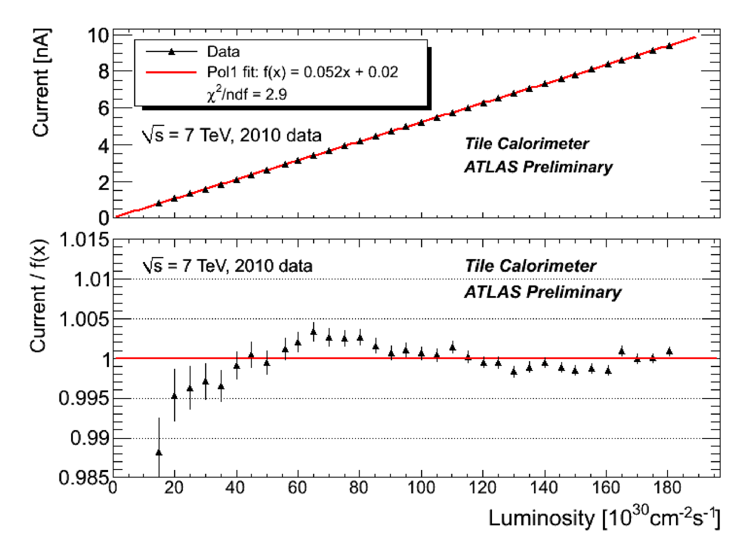


Cell time resolution as a function of cell energy in the 2011 high luminosity 7 TeV collision data.

The time resolution is 0.5-0.6ns for E~20GeV and 1.3-1.15ns at ~2GeV for cells in jets and muons respectively. This high level of precision is required in order to distinguish signals in the calorimeter coming from different events close in time or to tag out-of-time energy deposits coming from non-collision backgrounds.
The resolution improves at higher energies as expected and it is below 1ns above 3GeV for both muons and jets. Since muons deposit a small fraction of energy in the calorimeter, the corresponding data mainly cover the low energy range.

Monitoring of the instantaneous luminosity

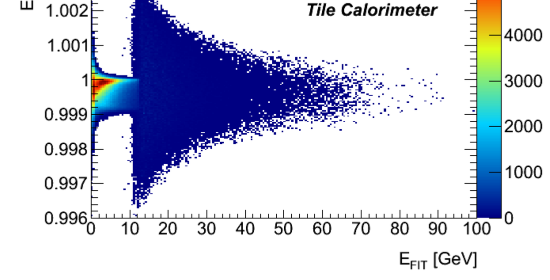
A dedicated TileCal read-out providing the anode currents for each photomultiplier is used to measure the Minimum Bias current, which is proportional to the interaction rate. The 2010 data have been used to prove they follow the luminosity evolution within 0.5%.



Average anode current for A13 cell of the TileCal as a functon of the instantaneous luminosity.

Online energy reconstruction performance

Due to the limited bandwidth of the TileCal readout, during high luminosity runs the digitized samples from the ADCs cannot be transferred. Instead, just the energy and timing information obtained from the Digital Signal Processor (DSP) are available. However, during lower luminosity runs, when both of these can be obtained, the ratio of the two provides valuable insight to the quality of the reconstruction performed by the DSP. It is shown here for well synchronized pulses to be less than 0.4%.



Ratio between the signal amplitude calculated on Collision data (run number 156682) with the Non Iterative Optimal Filtering Algorithm online and a simple pulse fit algorithm offline .