The Atlas Tile Calorimeter performance at LHC

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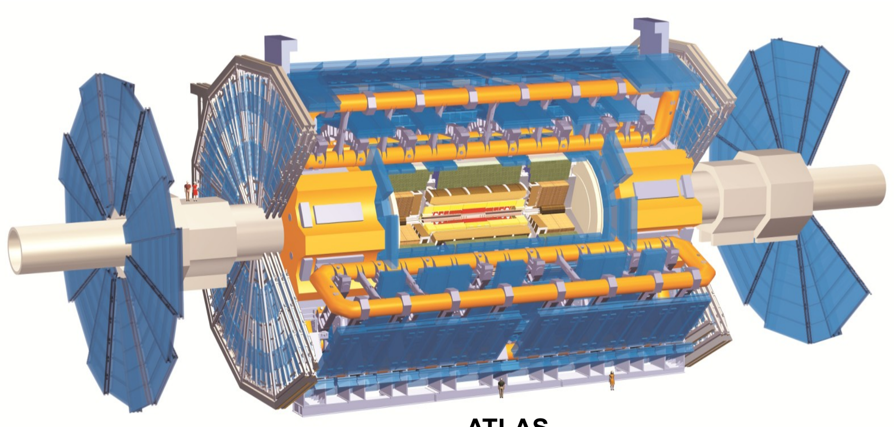
The ATLAS Tile Calorimeter



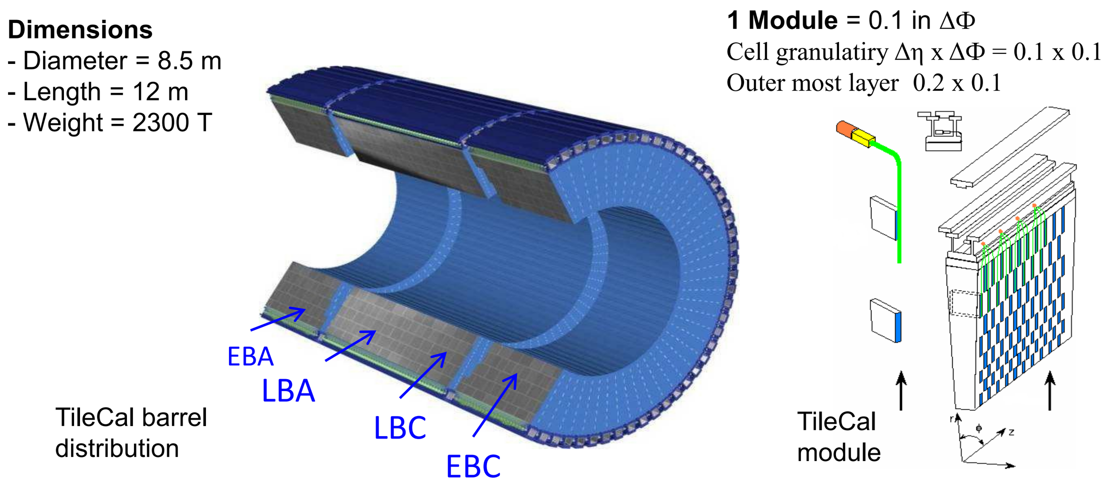
ATLAS

ATLAS is one of two large general purpose experiments installed at Large Hadron Collider (LHC) at CERN. LHC is delivering stable proton beams since 2009 and now operates at a centre-of-mass energy of 8 TeV.
The Tile Calorimeter (TileCal) is the hadronic calorimeter of ATLAS and its main purposes are detect hadrons, jets and taus; contribute to the jet energy and Missing E_T reconstruction and assist the spectrometer in the identification of muons.

TileCal is a sampling calorimeter employing scintillating tiles as active material and iron as absorber medium. It is divided into three cylindrical sections along the beam axis, one central Long Barrel (LB) and two Extended Barrels (EB), globally covering the region up to |η| < 1.7. Each cylinder is composed of 64 equal modules staggered in Φ. The total number of cells is 5182 and there are ~10000 channels, because the majority of cells are read by two PMTs. **The double read-out system improves the response uniformity** and provides redundancy.

Dimensions
- Diameter = 8.5 m
- Length = 12 m
- Weight = 2300 T

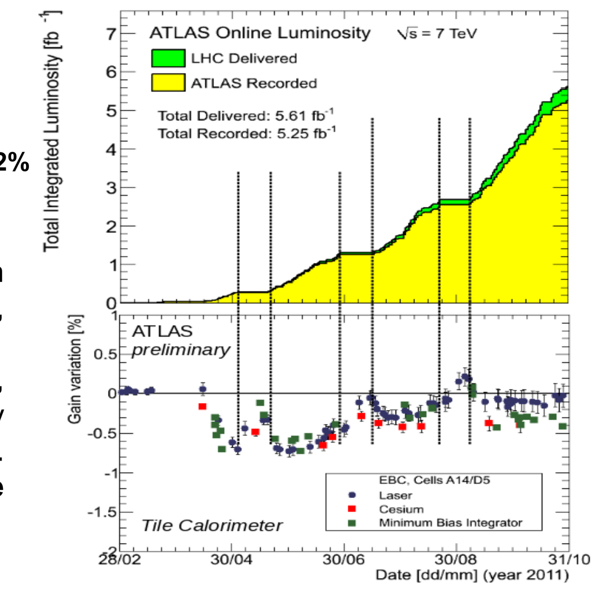
1 Module = 0.1 in ΔΦ
Cell granularity Δη x ΔΦ = 0.1 x 0.1
Outer most layer 0.2 x 0.1



The assessment of the detector performance is done through the acquisition, monitoring, reconstruction and validation of calibration signals as well as by careful analysis of the data obtained with the detector. The TileCal detector has taken data successfully and according to expected performance:

- **Energy resolution for hadrons** $\frac{\sigma}{E} = \frac{50\%}{\sqrt{E}} \oplus 5\%$
- **Jet scale uncertainty < 3 % limit**
- **Response linearity is required to be within 2%**

The TileCal design includes four calibration and monitoring systems: minimum bias, charge injection, laser and Cesium. Since all systems show a similar behavior, the observed drifts can be attributed mostly to a variation of photomultiplier response. **The cell energy scale is preserved at the level of 0.5%.**



Vertical lines mark periods without beam

Splash events and cosmic muon data

TileCal cell timing

During special single-beam runs in 2011, the beam was made to hit a closed collimator resulting in the so-called **splash event**.

It is characterised by millions of particles arriving almost simultaneously and parallel to the beam axis, depositing large amounts of energy in the Tile Cal. The signals coming from a splash event are correlated in time and can be used to evaluate the TileCal cells synchronization. The results for the three different layers integrated over cells in the Φ coordinate show that

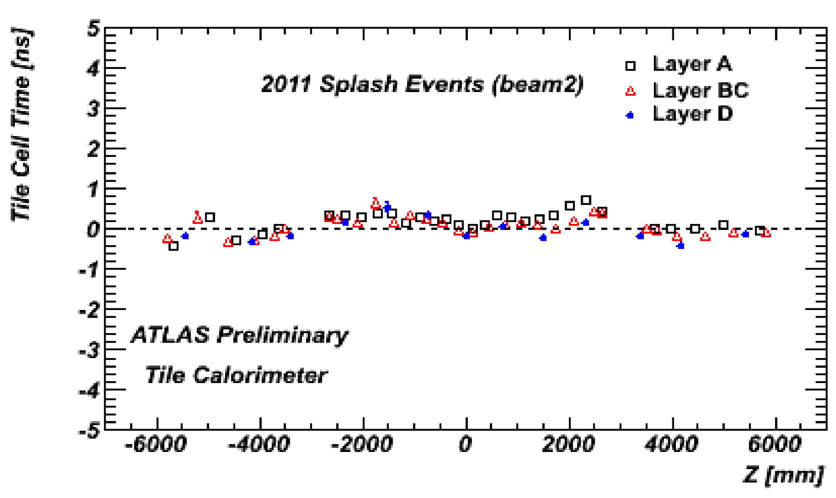


Figure 1. TileCal cell synchronization as a function of the cell z coordinate along the beam axis. The plot shows the results for the three radial layers after corrections for particle time-of-flight and fiber-length have been applied.

all cells are synchronized within 1 ns

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 production benefits also from a better noise performance, reducing it about 15%, less correlation among pairs of channels and non-Gaussian tails are strongly reduced.

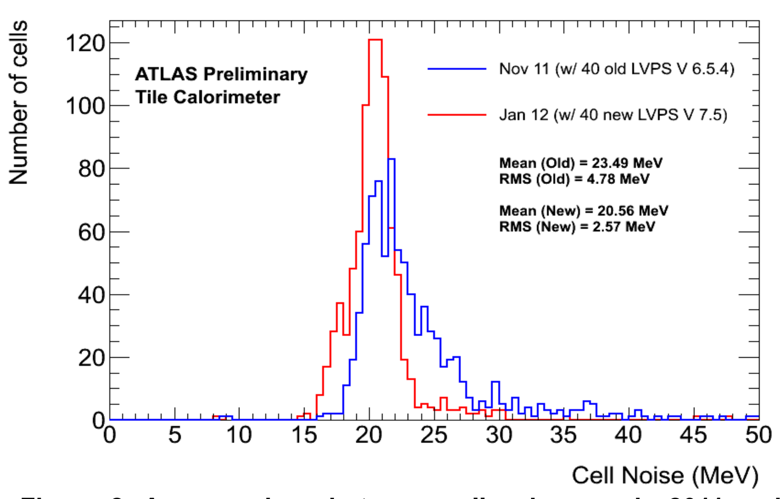


Figure 2. A comparison between cell noise rms in 2011 and 2012 in all cells in the 40 modules that had their LVPS changed. Values taken from ped run 192130 (2011) and run 195843 (2012).

Cell energy uniformity

Cosmic muons depositing energy in the TileCal are used to provide information on the EM scale calibration and uniformity across cells. 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 (less sensitive to the muon's radiative losses in the cells).

Signal is flat and uniform within 3%

Larger stadistical uncertainties are due to reduced coverage at higher pseudorapidity than in the central region.

The gap in the region around Φ = 0 corresponds to horizontal modules poorly populated by muons.

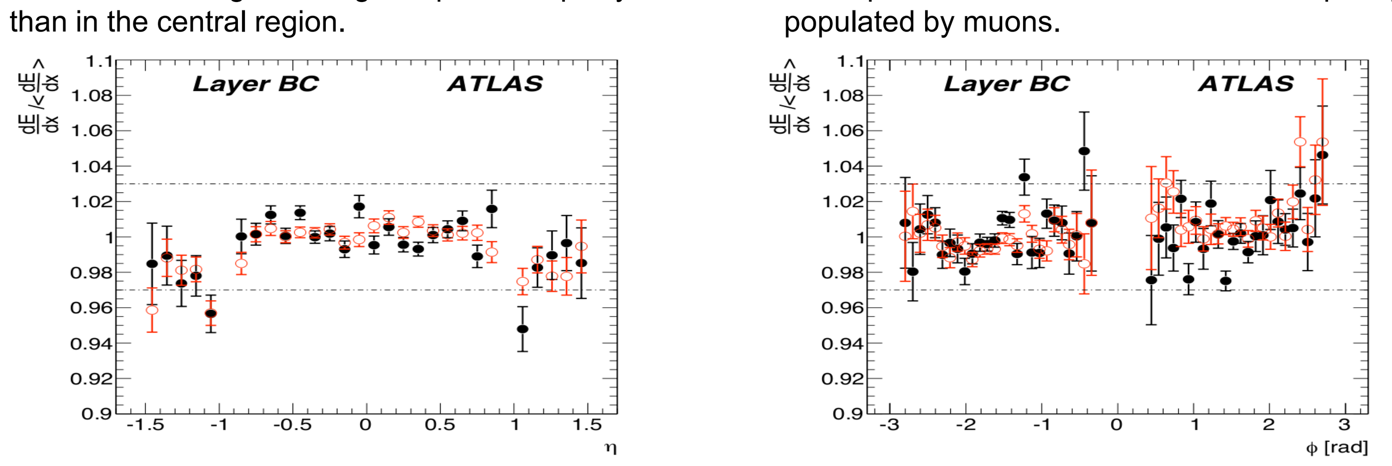


Figure 3. Cell energy uniformity using cosmic muon rays. The TileCal cell energy is uniform within 3% (horizontal lines) both in η and Φ coordinates inside each radial layer. Data (closed circles) are well reproduced by Monte Carlo predictions (open circles).

Performance in pp collisions

Time resolution

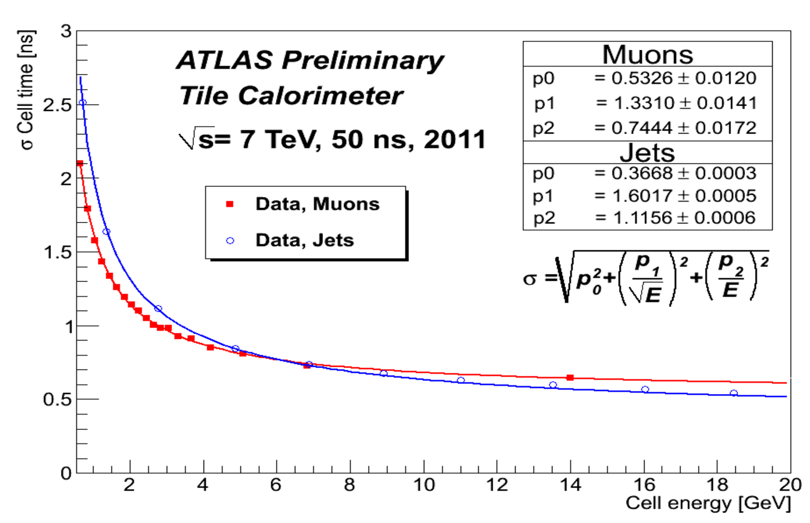


Figure 4. TileCal cell timing resolution with collision data with high luminosity environment at 7 TeV.

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

A cell time resolution of the order of a few ns is required in order to distinguish signals in the calorimeter coming from different events close in time or coming from non-collision backgrounds.
The cell time resolution has been studied as a function of the cell energy using 2011 collision data at center-of-mass energy of 7TeV and high luminosity (50 ns of bunch spacing).

The measured resolution dependence with cell energy is qualitatively similar for jets and muons, with an expected resolution of 0.5 ns for high energy depositions.

Resolution improves at higher energies as expected and it is below 1 ns above 3 GeV for both muons and jets.

The different nature of the energy deposition results in a difference in the measured mean time.

The contribution of slow hadrons in the jet becomes relevant at low energies, shifting the mean time to higher values.

This effect is not present in muon events, translating into a flat response of the measured mean time with energy.

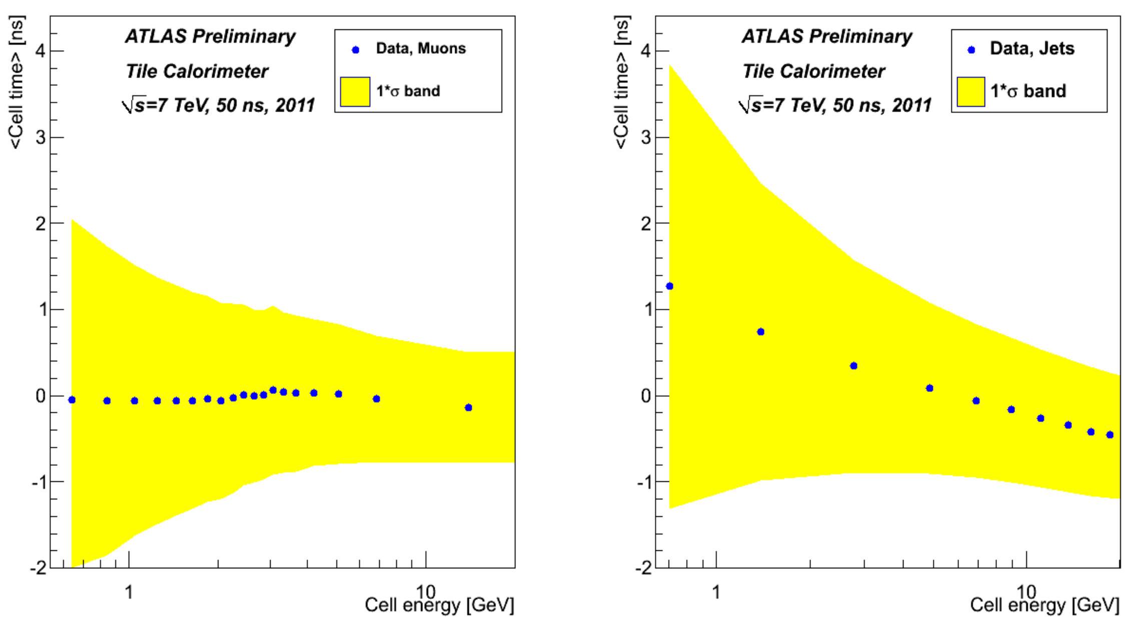
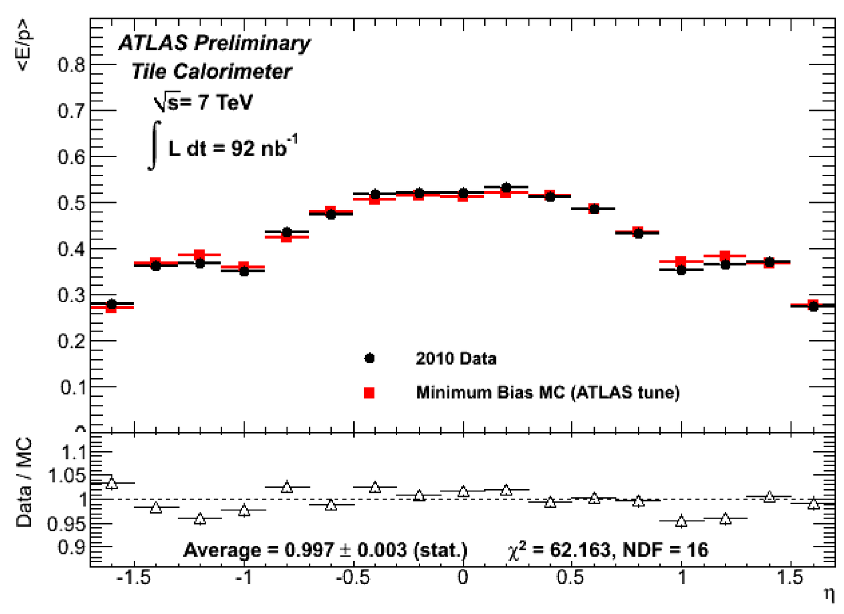


Figure 5. Mean cell reconstructed time as a function of cell energy in the 2011 collision data for muons on the left and jets on the right.

Response from single hadrons



Calorimeter response to single pions has been also investigated. Isolated tracks in the Inner Detector with momentum p > 3 GeV were required to deposit small energy in the electromagnetic calorimeter in front of TileCal, it is largest fraction of their energy E is deposited via showers in the hadronic section.

Mean **value of the ratio E/p as a function of pseudorapidity** for 2010 data show a **data / Monte Carlo agreement at the level of few percent**.

Figure 6. E/p ratio as a function of η for 2010 collision data (black circles) compared to Monte Carlo (red circles).

Luminosity monitoring measurement

The current measured from the integrator can be used as a measurement of the luminosity. Dedicated studies show a linear dependence between the integrator signal and the instantaneous luminosity measured by the forward LUCID detector. A special configuration of the integrator allows the measurement of the luminosity during van der Meer scans, providing an absolute calibration at very low luminosity

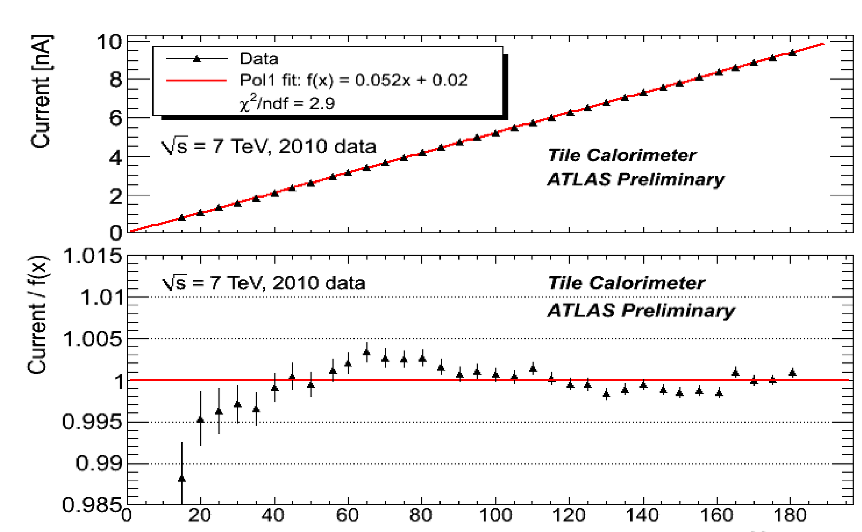


Figure 7. An average anode current for A13 cell of the TileCal is shown as a functon of the instant luminosity on full data sample taken in 2010

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