Performance of the ATLAS Hadronic Tile Calorimeter at the LHC Startup

C. Solans on behalf of the ATLAS Tile Calorimeter Group

Abstract—The Tile hadronic calorimeter is the central hadronic barrel calorimeter of the ATLAS experiment at CERN. Its performance has a direct impact on physics signatures involving hadrons, jets and missing E_T. Good signal timing is required for good off-detector energy reconstruction, where the digital samples are calibrated to the electromagnetic scale. We present the current status on detector timing with latest results from beam data, initial electronic noise characterization with cosmic data and the status of the energy intercalibration to the electromagnetic scale for the LHC startup.

I. THE ATLAS TILE CALORIMETER

The ATLAS Tile Calorimeter [1] is based on a sampling technique where plastic scintillating plates (tiles) are embedded in iron absorber plates and read-out by wavelength shifting fibers. Groups of tiles are bundled together into cells, each of them is read-out by two photo-multiplier tubes (PMTs).

The Tile Calorimeter is a hollow cylinder with inner radius of 2.28 m and outer radius of 4.23 m. The length of the central Long Barrel (LB) is 5.56 m and the length of the Extended Barrels (EB) is 2.91 m each. The Long Barrel is divided into two partitions LBA and LBC. The two extended barrels are labeled as EBA and EBC. Figure 1 shows the layout of the Tile Calorimeter within the ATLAS experiment [2].

Each partition is assembled out of 64 wedge-shaped modules, staggered in ϕ. Radially it is divided into three layers (A,BC and D going outwards). The cell segmentation in $\Delta\eta$ x $\Delta\phi$ is 0.1 x 0.1 for A and BC type cells and 0.2 x 0.1 for D type cells. It contains approximately 10000 read-out channels and it weighs around 2300 tons.

II. CALIBRATION SYSTEMS

The calibration of the energy of the cell to the electromagnetic scale is the main purpose of the calibration systems. Each calibration system acts on a specific element inside the read-out chain as shown in Figure 2. The derived calibration factors are combined together to obtain the ulterior calibration for each read-out channel.

The Charge Injection System (CIS) [3], injects a known charge in the 3-in-1 cards prior to the signal digization. This allows the calibration of the signal from ADC counts to pC in two gains that cover the full expected dynamic range. In situ high and low gain calibration yield a typical channel-to-channel variation of 1.5% as shown on Figure 3.

C. Solans is with the Instituto de Fisica Corpuscular, Universitat de Valencia and CSIC, Spain. E-mail: carlos.solans@cern.ch
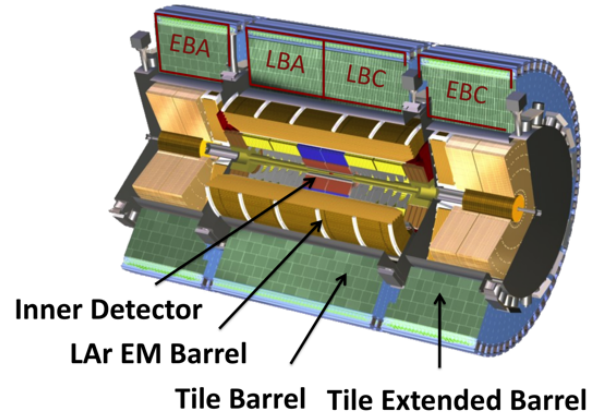

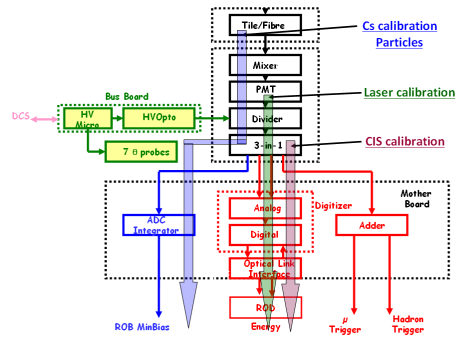Fig. 1: Layout of the Tile Calorimeter within the ATLAS experiment.

Fig. 2: Calibration schema in the Tile Calorimeter.
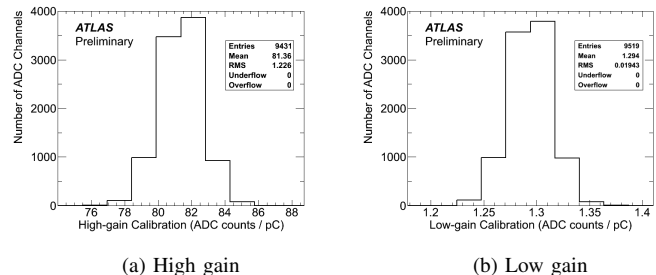

(a) High gain

(b) Low gain

Fig. 3: ADC to pC calibration distribution for TileCal channels for high and low gain using the Charge Injection System.

The Laser System [4] sends a LASER pulse with known intensity to the PMTs. It provides a correction for the gain linearity and stability over time. Average gain variation is shown in Figure 4(a) as a function of time from the reference

run taken on 25th July 2008 to the beginning of December 2008. This variation of the gain of the PMTs is found to be within 0.5% over the considered period.
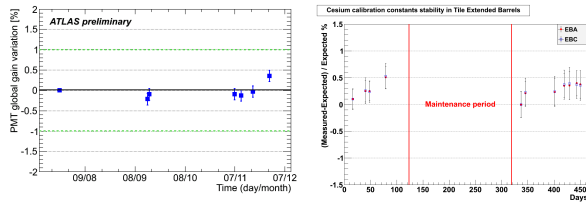
(a) PMT global gain variation over time

(b) Cesium calibration constants over time

Fig. 4: Laser and Cesium stability.

The Cesium System [5] acts on the optics elements by means of a ^{137}Cs radioactive source which is circulated through the calorimeter. It is used to correct for non-uniformity of the optics response. These corrections are computed from the response of the PMTs to the source photons after the equalization via the HV settings from their nominal value. Figure 5 shows the Cesium corrections immediately after equalization in June 2009. Figure 4(b) shows the timeline of the deviation of the mean response of EBA and EBC cells from the expected Cs decay curve. Days 0 (15th July 2008) and 330 (17th June 2009) mark the equalization via the HV settings.
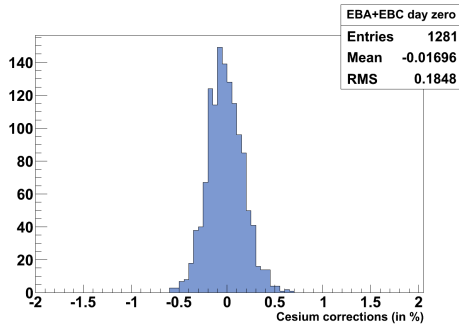

Fig. 5: Cesium corrections distribution.

The last step in the calibration of the cell energy is to convert the pC into GeV. Results from Testbeam data analysis provide an electromagnetic scale constant of 1.05 pC/GeV with an RMS of 2.4% (Figure 6).
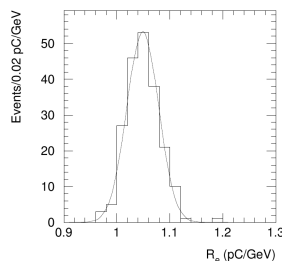

Fig. 6: Response to electrons (R_e) entering the calorimeter modules exposed to the beam at incidence angle of 20 degrees normalized to beam energy. The plot contains energies from 20 to 180 GeVs.

III. PERFORMANCE

A. Timing

The Optimal Filtering algorithm used online [6] to reconstruct the energy and the time is very sensitive to time variations. During LHC operation, the timing will be fixed with small deviations. The computation of the time corrections has been possible using cosmic and first beam data as shown in Figure 7. Time offsets are computed using time of flight information and agree within 2 ns at cell level.
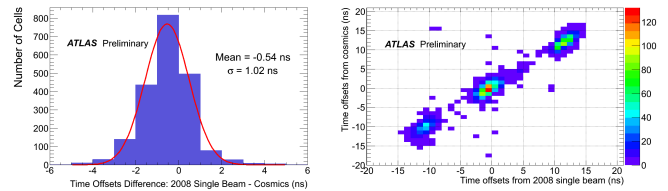
(a) Distribution of the difference between time offsets from cosmics and offsets from single beam

(b) Time offsets from cosmics vs time single beam

Fig. 7: Distributions of time calibration offsets per cell as seen in the single beam and cosmic data.

B. Noise

Runs of randomly triggered events collected in 2008 were used to evaluate the stability of the electronic noise. The average value has been set to 1.44 ADC counts, or equivalent energy of 50 MeV per cell as shown in Figure 8. Green lines represent the plus minus 1% variation limits around the average value of 1.44 ADC counts. Blue dots represent the average over the Tile Calorimeter and the red dots represent a typical channel
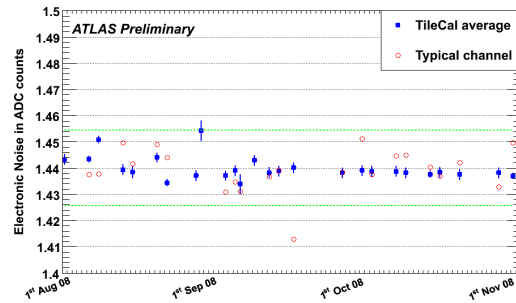

Fig. 8: Stability of the electronic noise.

C. Energy

Although the Tile Calorimeter is a hadronic detector, it is also efficient in detecting cosmic muons. The energy distribution of muons in the Tile Calorimeter triggered by RPCs and reconstructed by the *Tile Muon Fitter*[1] [7] (blue) compared to the noise from the same cells (red) measured from random trigger stream show a good signal and noise separation as shown in Figure 9. Muons crossing both top and bottom modules are considered.

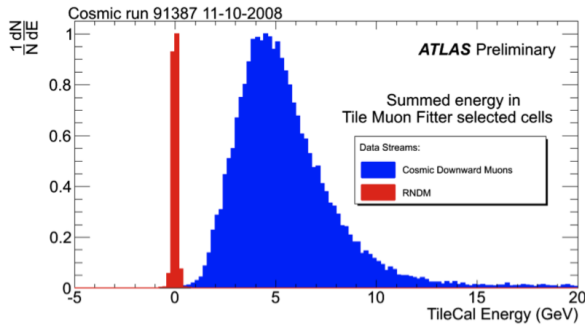[1]A tool that identifies muons in the calorimeters alone.

Fig. 9: Summed energy in Tile Muon Fitter selected cells.

Response of BC type (middle layer) cells as a function of reconstructed track ϕ is shown in Figure 10. The response for the individual cells is shown by the different colored points whereas the total response summed over all cells is shown by the black points. The results shows that the response of the calorimeter is independent of the ϕ coordinate using cosmic data.
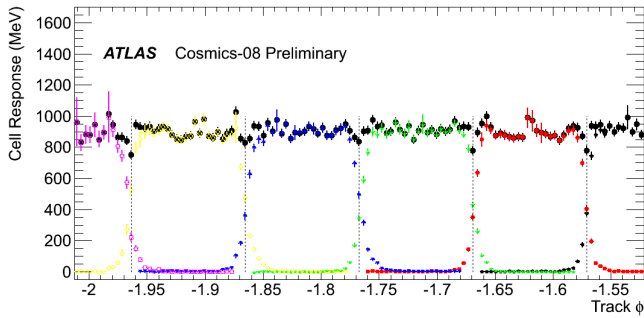

Fig. 10: Energy response vs ϕ.

Prior to the LHC beams, dedicated test beam measurements and ^{90}Sr radioactive source tile scans, indicated the need for radial sampling corrections to the electromagnetic scale constant from the test beam. These corrections are due to the fact that each of the three radial samplings has a different Cs to particles response ratio. Figure 11 shows the Most Probable (MP) value of the dE/dx distribution for muons crossing the TileCal horizontally (parallel to the particle beam) as a function of the radial sampling. Colors represent calorimeter response before (blue) and after (red) the corrections.
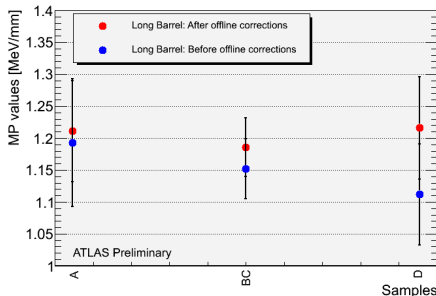

Fig. 11: Energy scale corrections per radial sampling.

IV. CONCLUSIONS

The calibration systems of the Tile Calorimeter are in advanced state. Timing of the detector has been possible with single beam and cosmics. Characterization of the electronic noise has gone through a full campaign. The intercalibration to the electromagnetic scale with single beam data and cosmics is ongoing.

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