ATLAS Tile calorimeter calibration and monitoring systems

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On behalf of the ATLAS Collaboration

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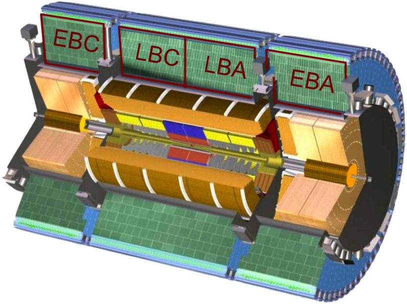
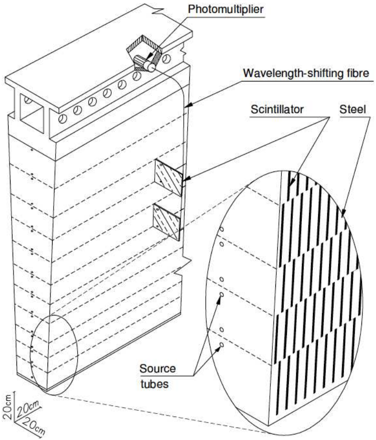
Clermont-Ferrand

The Tile Calorimeter in the ATLAS experiment



- Hadronic calorimeter of the ATLAS experiment
  - Contribute to measurement of jets and missing transverse energy
- Sampling calorimeter
  - Steel plates used as absorber
  - 460,000 scintillating tiles configured as 5182 cells as active medium
- Divided into one Long Barrel (LB) and two Extended Barrels (EB)

The Tile Calorimeter



- Passage of charged particle producing light
  - Transmitted to photomultiplier by wavelength shifting fibres
  - Normal cell seen by two PMTs (total of 9852 PMTs)
  - Three longitudinal layers defined into the modules (A, BC and D)
  - Cells in special layer E, in EB modules in gap/crack region, read out by a single PMT each

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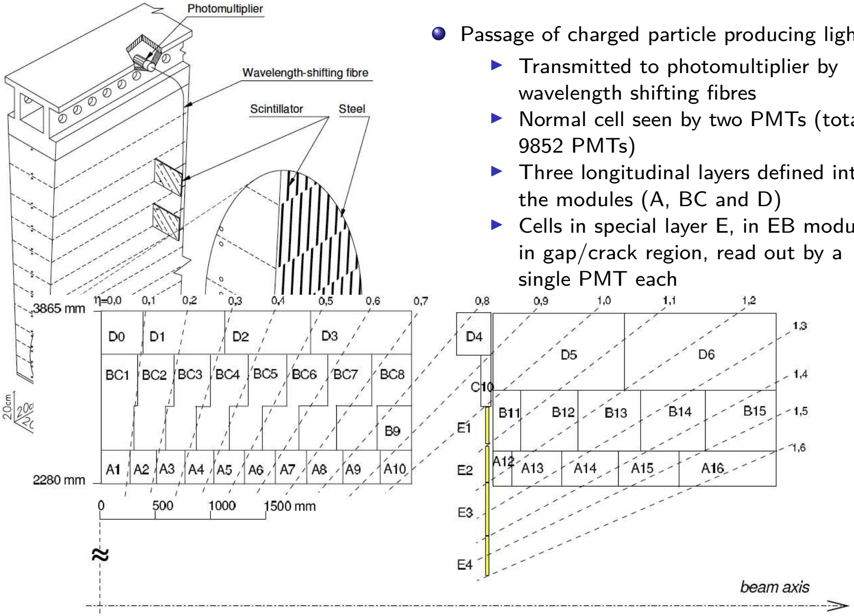
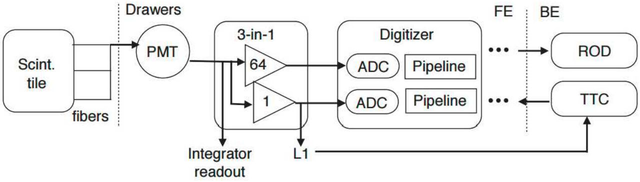
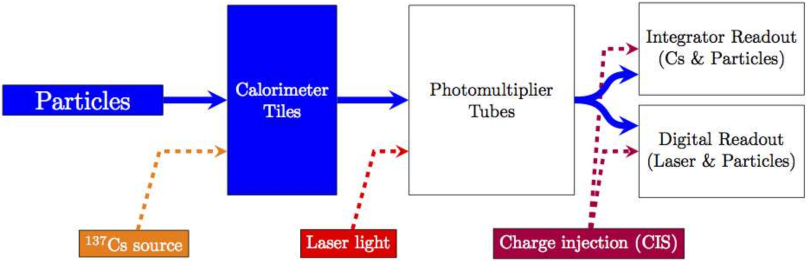


Signal processing in TileCal



- Light produced in scintillating tiles converted to electric currents by PMTs
- Signal from PMTs shaped, amplified using two gains (ratio of 1:64) with the total dynamic range going from ∼10MeV to ∼800GeV
  - High Gain up to ∼12 GeV and then Low Gain above this value
- Signal then digitized by 10-bits ADCs at 40 MHz and stored into local memory (Pipeline)
- Events passing level 1 trigger → digitized signals collected and processed by Read-Out Drivers (RODs)
- Integrator measures integrated currents from PMTs (10ms of integration time) and used for detector calibration and luminosity estimation

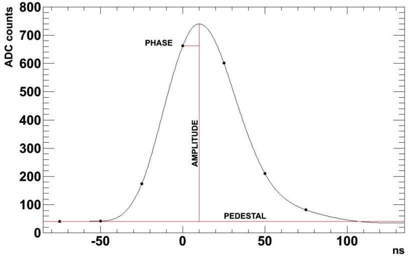
Calibration and Read-out systems



- Three systems are used for calibration of the TileCal
  - Cesium System → to monitor optical components and PMTs
  - Laser System → to monitor variation due to electronics and PMTs
  - Charge Injection System → measurement of conversion factor pC↔ ADC counts
- Minimum Bias system (same monitoring as Cesium system), using integrated currents linked to minimum bias events, used with Laser and cesium system to understand variation of a channel

Energy reconstruction

- Digitized signals reconstructed with the Optimal Filtering algorithm, computing for each channel the signal amplitude, time and quality factor

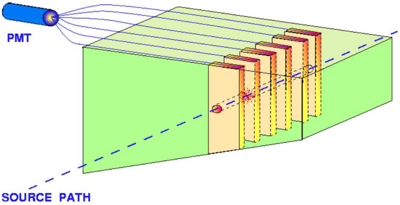


- Energy obtained from reconstructed amplitude in ADC counts (A) by using a serie of calibration constants (Ci)

$$E = A \; . \; C_{ADC \to pC, CIS} \; . \; C_{pC \to GeV, TB} \; . \; C_{Cs} \; . \; C_{Laser}$$

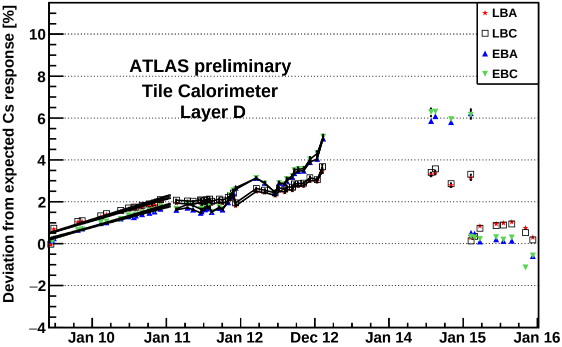
- $C_{pC \to GeV, TB} = 1.05 \; pC/GeV$ obtained during test beam on 1/8 of the modules

Cesium system



- Movable Cs-137 γ-source
  - 0.662 MeV photons to illuminate all scintillators
  - Hydraulically driven through a system of steel tubes
- Test response of scintillating tiles, fibres and PMTs
  - Analog integrator used so no monitoring of electronic readout used for physics
- Calibration taken about once a month in Run 1 and about every two months in Run 2
- Improved stability and safety of the operation due to new water storage system, lower pressure and more precise water level metering during the scans

Cesium results

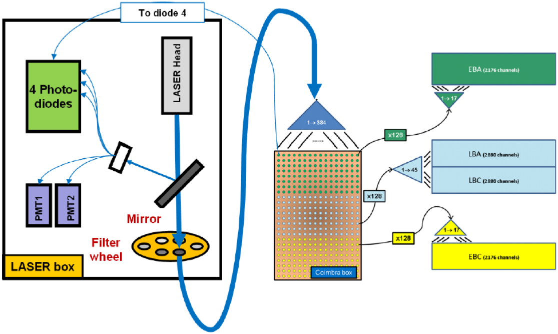


- Variation of TileCal response over 6 years (Run 1 and Run 2) averaged over all D-cells (cells with smallest variation)
- Cesium scan used to follow evolution of the detector
- In first scan of each Run (June 2009 and Feb. 2015) TileCal equalized
  - Following C_{Cs} calculated as ratio of measured to expected signals
- Precision of the measurement at the order of 0.5%
- First four measurements from 2014 without magnetic field

Laser calibration procedure

- Performed about twice a week
- For monitoring of PMTs gain between two Cs scans
  - Illuminating PMTs with Laser pulse of known intensity and a wavelength close to the one of physical signals
  - Readout electronics used for physics monitored
- Calibration consists in two type of runs testing low and high gain ADC for all channels:
  - a Low Gain run (LG) with 10^4 pulses
  - a High Gain run (HG) with 10^5 pulses
- Laser pulses also interleaved with collision during physics runs (1Hz frequency) $\rightarrow$ in particular used to control calorimeter timing (see talk by Tomas Davidek)

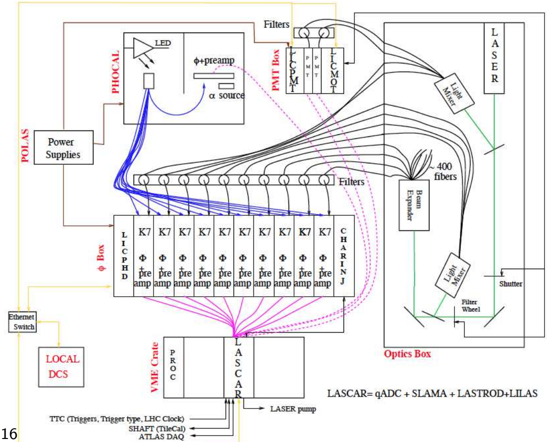
Run 1 system and its shortcomings



- Stability at the order of 0.6% observed over a few months period
- Resolution at the order of 0.5%
- Limitations identified during Run 1
  - Optical cross-talk in the calibration system of the photodiodes
  - Instability over time of light sent to each module
  - Non-uniformity of the filters
  - Electronics: desynchronisation with LHC clock

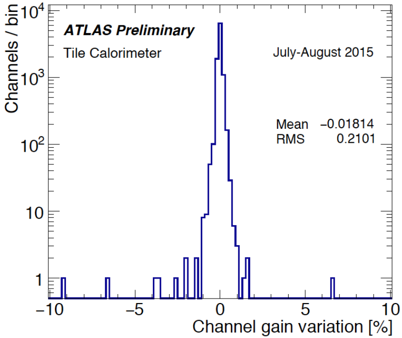
Change from Run 1 to Run 2

- New Laser system (Laser 2 system) used
  - Better estimation of Laser light injected (from 4 to 10 photodiodes)
  - Redundant calibration scheme (LED) to correct problems in Photodiode system
  - New design for electronics
  - Optic box from vertical to horizontal position (reduce dust and ease maintenance)

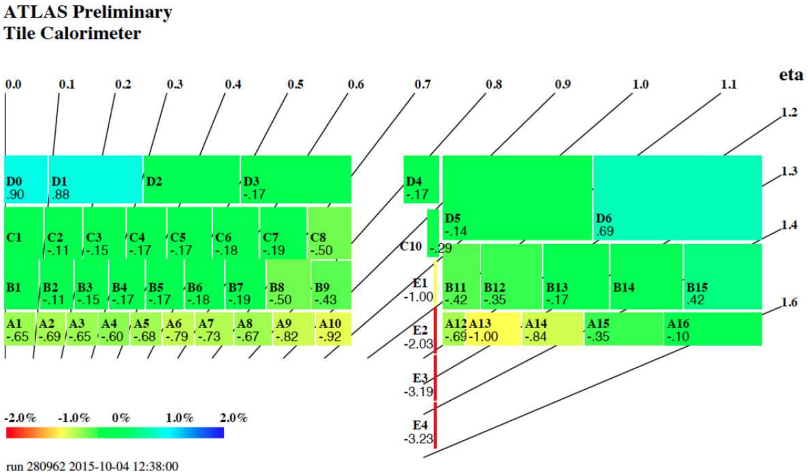


Laser results obtained at beginning of Run2

- Laser calibration constants applied to drifting channels
- Results obtained using Laser II system with an improved resolution w.r.t Run 1



Observed drift using Laser calibration

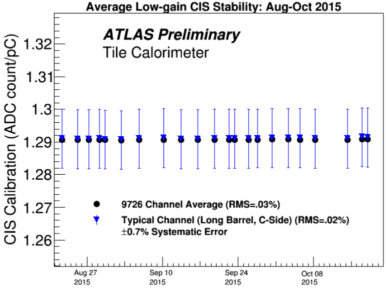


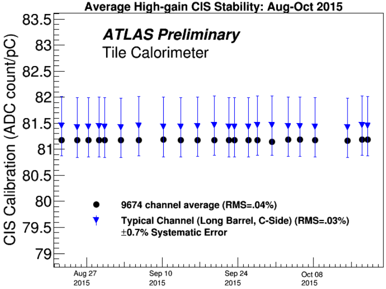
- Maximal drift observed in E and A cells (cells with higher energy deposits)

Charge Injection System (CIS)

- Injection of a known charge to the readout electronics to measure the electronic response
- Test low and high gain ADC for all channels
- Determination of conversion factor from injected charge to ADC counts
  - Calibration constants updated for a channel if its deviation is above the CIS systematic error (around 0.7%)
  - Around 1% of the channels corrected at each update (around once a month)
    - Calibration taken around twice a week
- Used to monitor front-end electronics and correct for non-linearity

Results from CIS

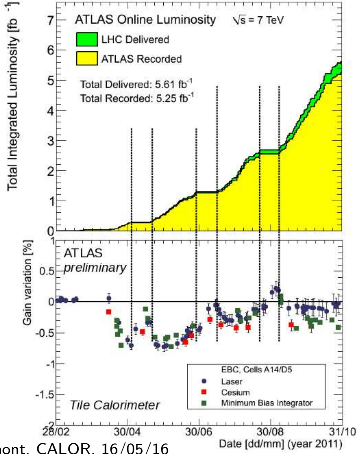




- Typical systematic uncertainty is at 0.7%
- Stability of conversion factor over time is below 0.05%

Minimum Bias system

- Use the integrator readout
- Measure detector response to minimum-bias events
- Used for monitoring of instantaneous luminosity
- Same monitoring as Cesium (from scintillating tiles to PMTs)
  - Same variation in PMT response over time expected



- Can be used in combination with Laser and Cesium system to understand gain variation
- Same variation → PMT deviation
- Different behaviour → could be interpreted as effect of scintillators irradiation (see talk by Cora Fischer)

Summary and conclusion

- Necessary to control the energy scale of the Tile Calorimeter of ATLAS to measure energy of the jets and missing energy
- Several systems used to calibrate and to monitor during the Run 1 and at the beginning of the Run 2: Cesium, Laser, Charge Injection and Minimum Bias systems
- Stability of absolute energy scale better than 1% attained through the Run 1 data taking
- Some shortcomings observed in Cesium and Laser systems during the Run 1 have been corrected for Run 2
  - New Laser system developed
  - Improvements to the Cesium system's hydraulics
- Set of calibration systems used since the beginning of the Run 2 in high luminosity and energy environment and with fewer Cs scans than in Run 1
  - Improved precision w.r.t what obtained at Run 1