Cesium and Laser Calibration of ATLAS Tile Calorimeter

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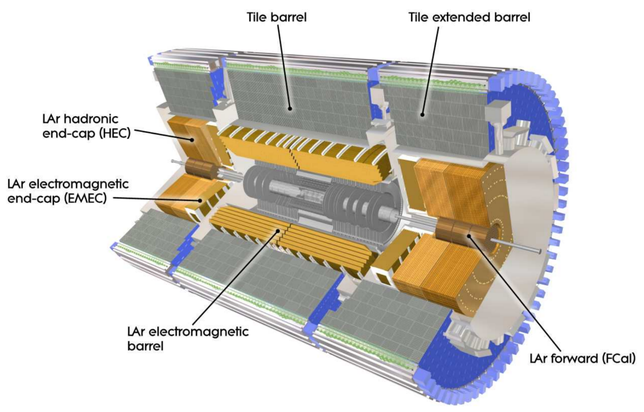
Motivation

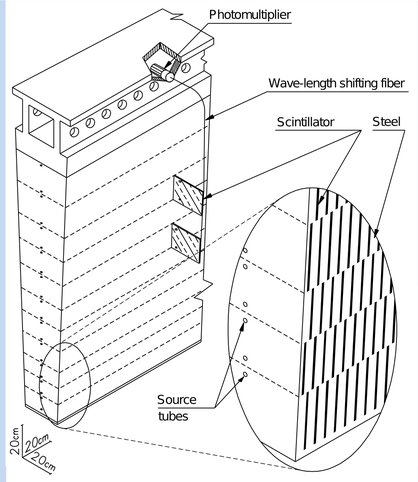
The response measurements by the laser and cesium calibration systems of the ATLAS Tile Calorimeter in 2015 are studied. The goals are:

- Measure the response drift and its RMS (root mean square) variation over time.
- Study the difference (ΔPMT) between measurements of two PMTs connected to a cell, and its variation over time.
- Compare the laser and cesium measurements to evaluate a systematic uncertainty for the laser system.

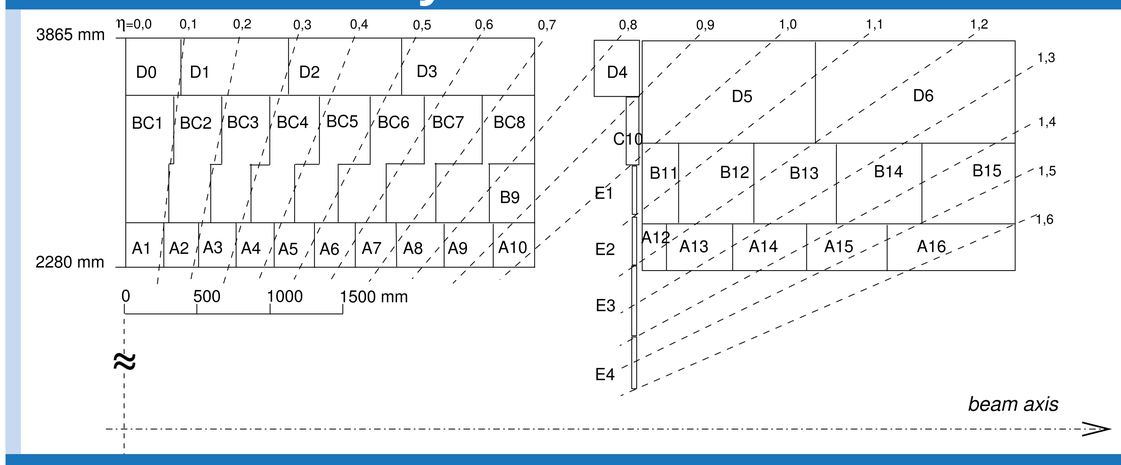
The ATLAS Tile Calorimeter



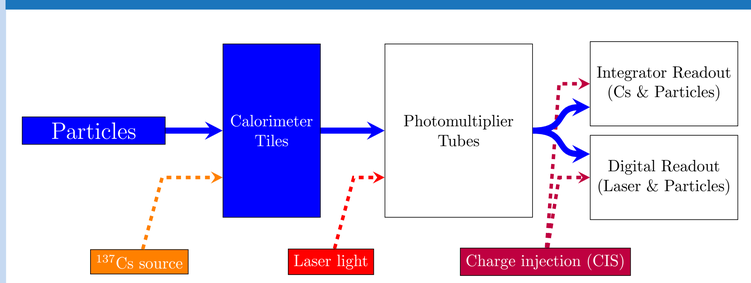
- The ATLAS Tile Calorimeter (TileCal) is the central (|η| < 1.7) hadronic scintillator–steel sampling calorimeter.
- Divided into three sections: Long Barrel (LBA, LBC; 0 < |η| < 1.0) and two extended barrels (EBA, EBC; 0.8 < |η| < 1.7).
- TileCal provides information for energy reconstruction of hadrons, jets, tau-leptons and missing transverse energy.
- Around 10000 channels (mostly two per cell) measuring energies ranging from ~30 MeV to ~2 TeV.
- Longitudinal segmentation – 3 radial layers (7.4 λ in total).
- Transverse granularity (Δη × ΔΦ) = (0.1 × 0.1); in the last layer (0.2 × 0.1).
- Light signal is amplified by the photomultiplier tubes (PMTs), and is shaped and digitised by the electronics.



Layers in TileCal



Calibration Chain



CESIUM SOURCE

Circulates a radioactive gamma source through all cells to equalize their response, monitors scintillators and PMTs.

LASER SYSTEM

Monitors the PMTs and downstream electronics by sending well calibrated light pulses into PMTs.

CHARGE INJECTION (CIS)

Determines conversion factor from ADC counts to pC by injecting known charge (ADC range: *0-800 pC; 1 pC ~ 1 GeV*).

$$E[GeV] = A[ADC] \cdot C_{ADC->pC} \cdot C_{pC->GeV} \cdot C_{Cs} \cdot C_{Las}$$

Laser Study

A single laser source is used to monitor ~10000 PMTs. Laser light replicates the optical signal that PMTs originally receive via scintillation of the active material stacked in the calorimeter.One third of the laser calibration data taken during 2015 is used for these studies. The Laser combined method is used to calculate the corrections.

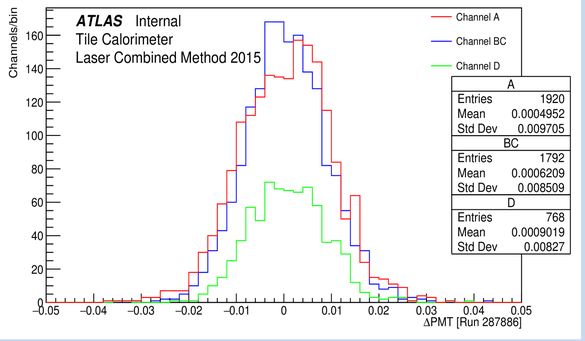


Fig.: Distribution of ΔPMT (Dec 12, 2015)

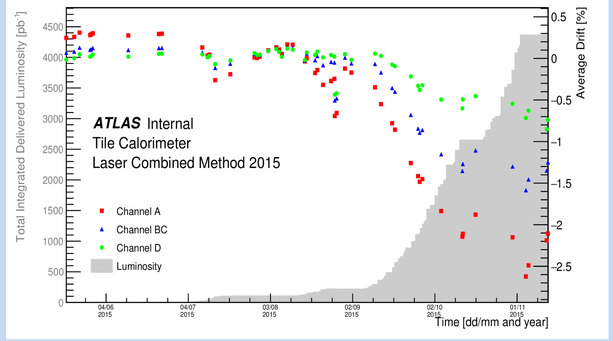


Fig.: Average PMT gain drift vs time

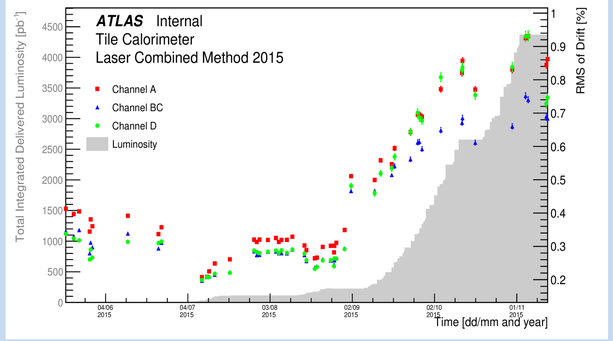


Fig.: RMS of PMT gain drift vs time

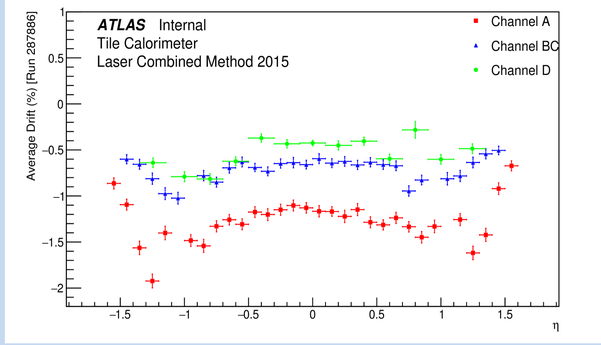


Fig.: Average PMT gain drift vs η (Dec 12, 2015)

- During period of data taking, the PMT gain reduces because of the reduction of secondary emissions from the PMT dynode. When there is no data taking, the PMT starts recovering.
- Due to distribution of the upstream material and distance of cells from the interaction point, the PMT gain drift seen in TileCal is not expected to be uniform. Since Layer A is closer to the beamline than Layers BC and D, it is more irradiated resulting in larger gain drift.

The largest drift is seen for layer A cells which are closest to the interaction point, A13 located in the EB (with minimum upstream material) exhibits the maximum drift. Layer BC and D show smaller gain drift.

Comparison with Cesium

A radioactive Cesium–137 source is moved by a hydraulic system through steel tubes into small holes in each tile scintillator. The beta decay of Cs–137 source produces 0.665 MeV photons at a rate of 1 MHz, generating scintillation light in each tile. Cesium measurements taken in the year 2015 are used for the analysis.

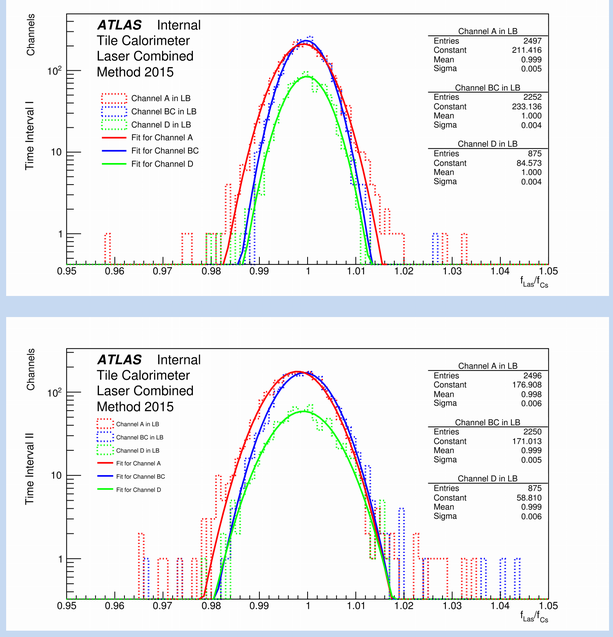
Two time periods taken for comparing drift are:

Time Interval I: 11/June/2015 – 17/July/2015
Time Interval II: 17/July/2015 – 3/Nov/2015

Definition of the correction factor:

$$f = \frac{1}{1+\Delta drift}$$

The gaussian fitted distributions are centered at one. From the sigma of the distribution we can estimate the systematic uncertainty of the laser measurement assuming negligible uncertainty from the cesium measurement.



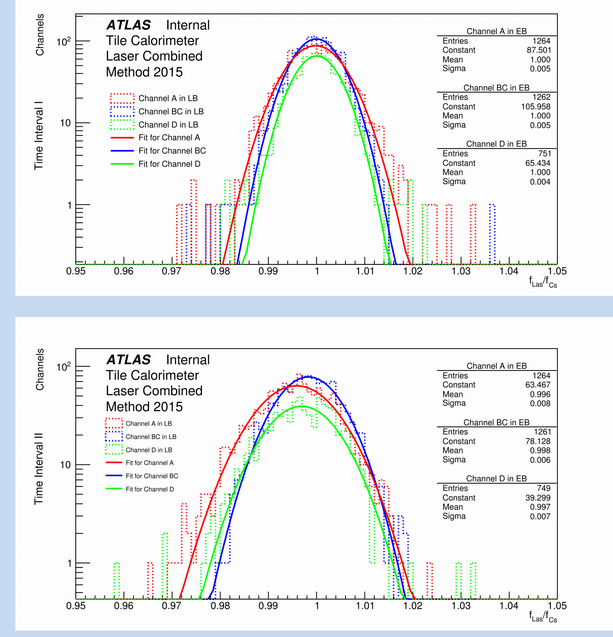


Fig.: Ratio plots between the Laser and Cesium gain for Time Interval I (top) and Time Interval II (bottom)

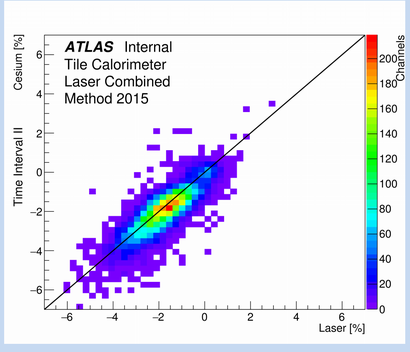


Fig.: The distribution of Cesium vs Laser response drift for Time Interval II is spread around the y = x line

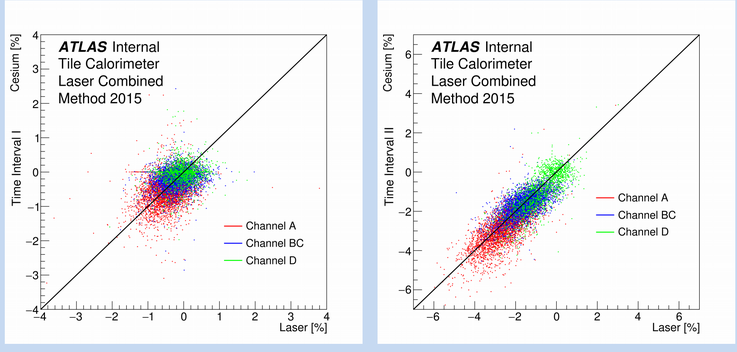
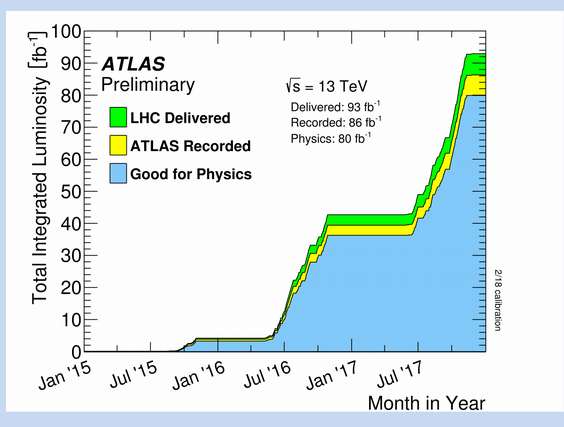


Fig.: Cesium vs Laser response drift for Time Interval I (left) and Time Interval II (right)

As expected, for both periods, the distribution is spread around the (*y* = *x*) black line. As the data taking period started during the second time interval, downdrift can be observed. The different cell types are well separated due to the varying irradiation levels.

Outlook

- This study will continue to include a comparison of Cesium – Laser for 2016 and 2017 (covering the full year).
- Due to the larger amount of delivered luminosities in these years, larger drifts in the response are expected.
- For the last years, we expect a deviation between the laser and cesium response drift measurements for some of the more irradiated cells. This can be attributed to scintillator ageing.



References

- ATLAS Collaboration, Tile Calorimeter Technical Design Report (1996), CERN/LHCC 96-42
- ATLAS Collaboration, Operation and performance of the ATLAS Tile Calorimeter in Run 1 (2018), arXiv:1806.02129

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