ATLAS Tile Calorimeter Performance

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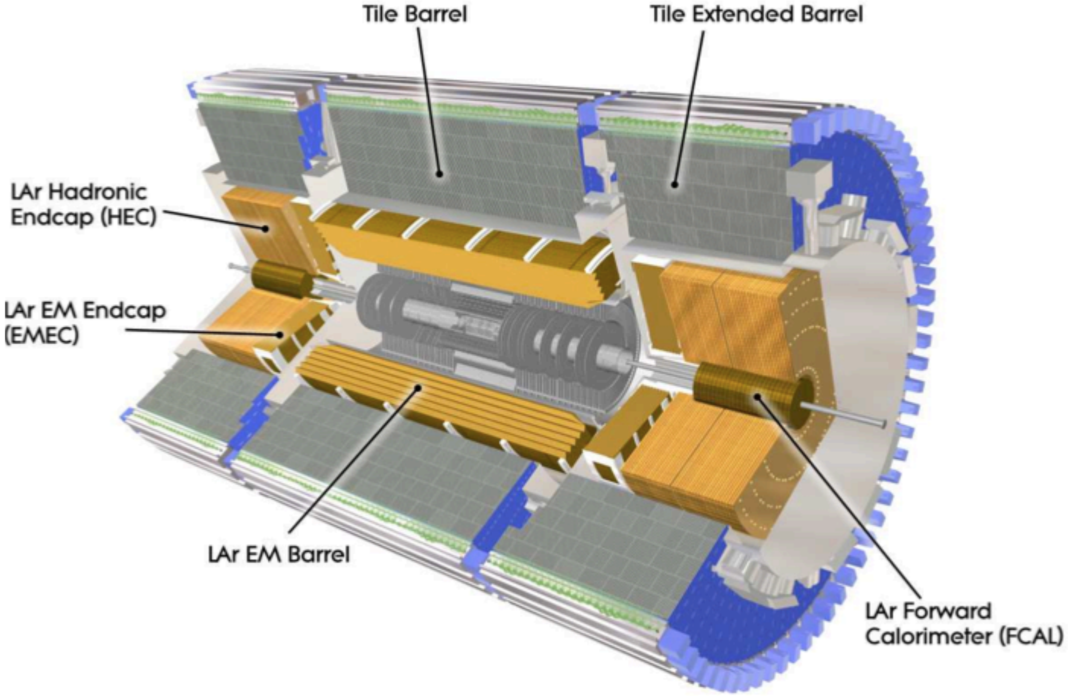
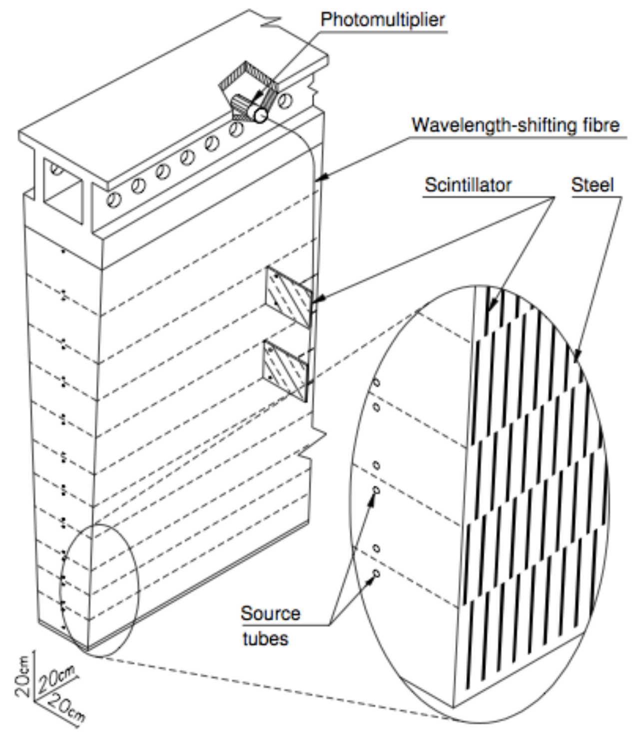
on behalf of the ATLAS collaboration.

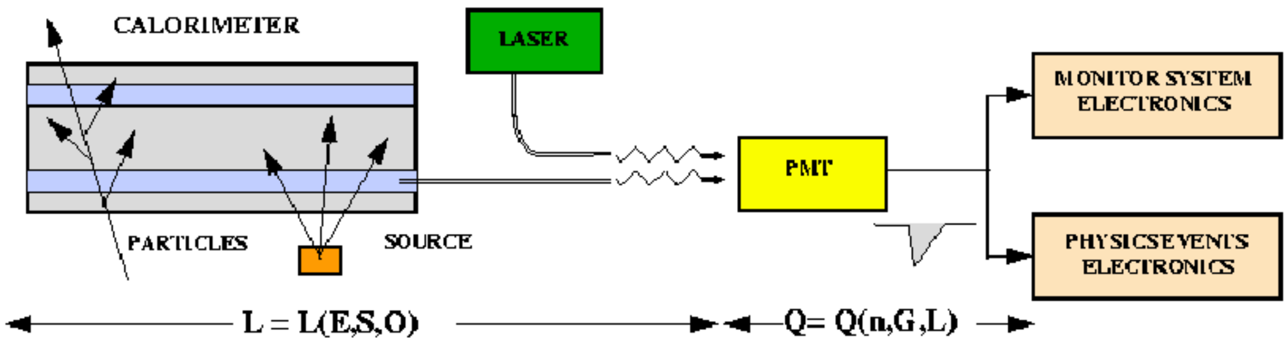
The Tile Calorimeter





- Steel absorber plates and plastic scintillator tiles
- Coverage: Long Barrel $|\eta| < 1.0$, Extended Barrel $0.8 < |\eta| < 1.7$
- Four partitions, over 4,900 cells, two PMTs per cell, two gains per PMT
- Three longitudinal layers: A, BC, & D total thickness of about 7λ
- Design resolution for jets(LAr + Tile): $\frac{\sigma}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$

Energy Calibration



$$E_{pmt} = \text{Amplitude} \times C_{ADC\rightarrow pC} \times \xi_{laser} \times \xi_{Cs} \times C_{pC\rightarrow MeV}$$

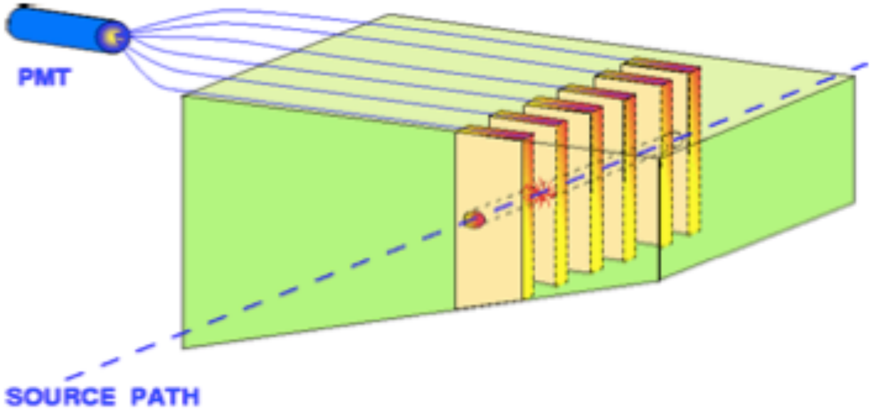
Factors in the calibration:

- $C_{ADC\rightarrow pC}$: The Charge Injection System monitors electronics stability. *Calibrated 3 times/week*.
- ξ_{laser}: A laser system monitors PMT gain and timing of individual channels. *Calibrated 3 times/week + Empty bunch crossings (1Hz)*
- ξ_{Cs}: Maintain same cell response to known source. *Calibrated monthly.*
- $C_{pC\rightarrow MeV}$: 11 % of the Tilecal modules where calibrated at the SPS with e^{+-}, μ^{+-}, hadrons, to determine the Electromagnetic Scale.

Calibration strategy: Use the laser to tune channels that drift more than a few % in between monthly Cs runs to maintain the determined E-scale

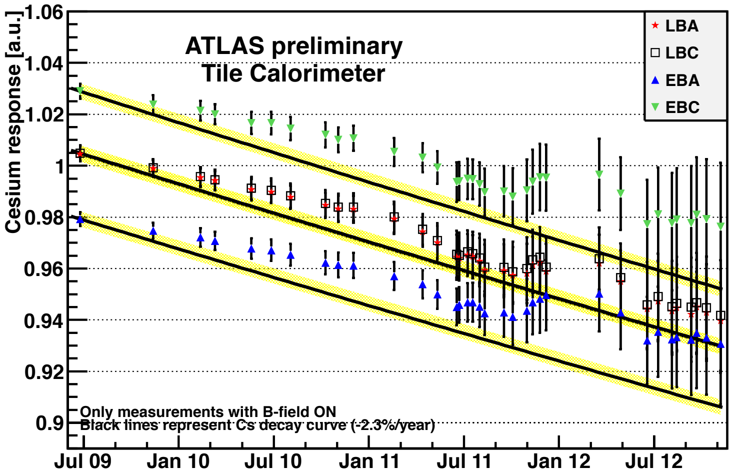
Cesium calibration

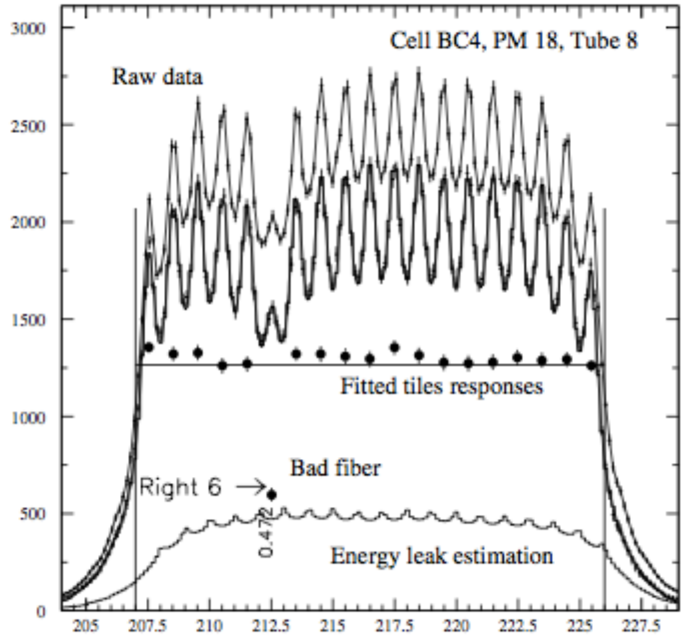
Each Tilecal cylinder is equipped with a system of pipes, transporting a Cs^{137} source through each of the tiles. (~17km of pipes in total).



Illuminates tiles with 662 keV photons (source ~10MBq), readout through the integrator system.

Runs last long, not compatible with collisions, ie are taken during MD/TS (~1month).



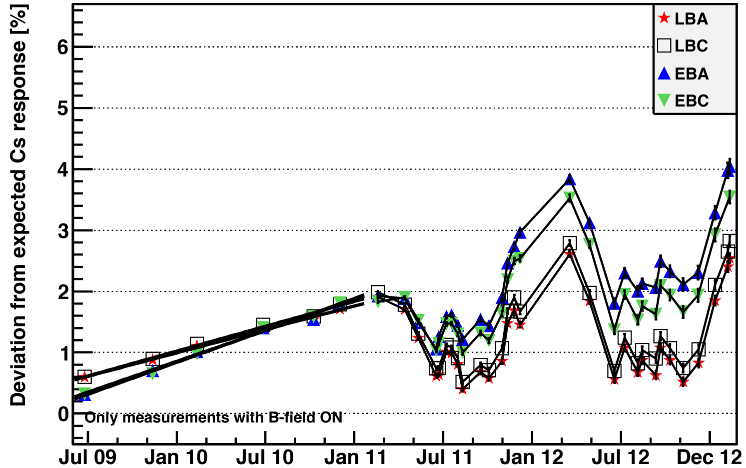


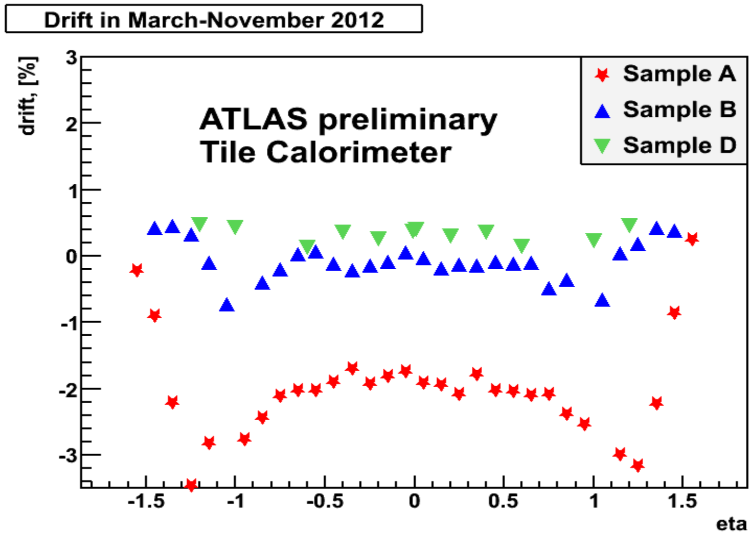
Stability of the Cesium Response

Cs calibration has a precision of 0.3%.

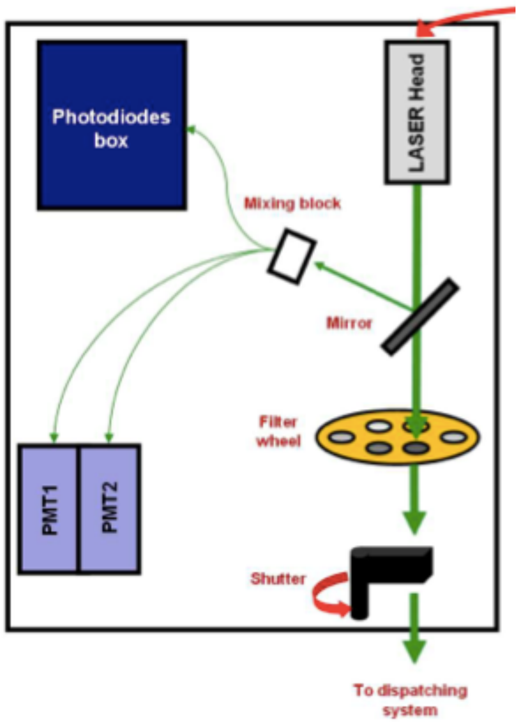
Corrects for deviations from the expected Cs decay response:

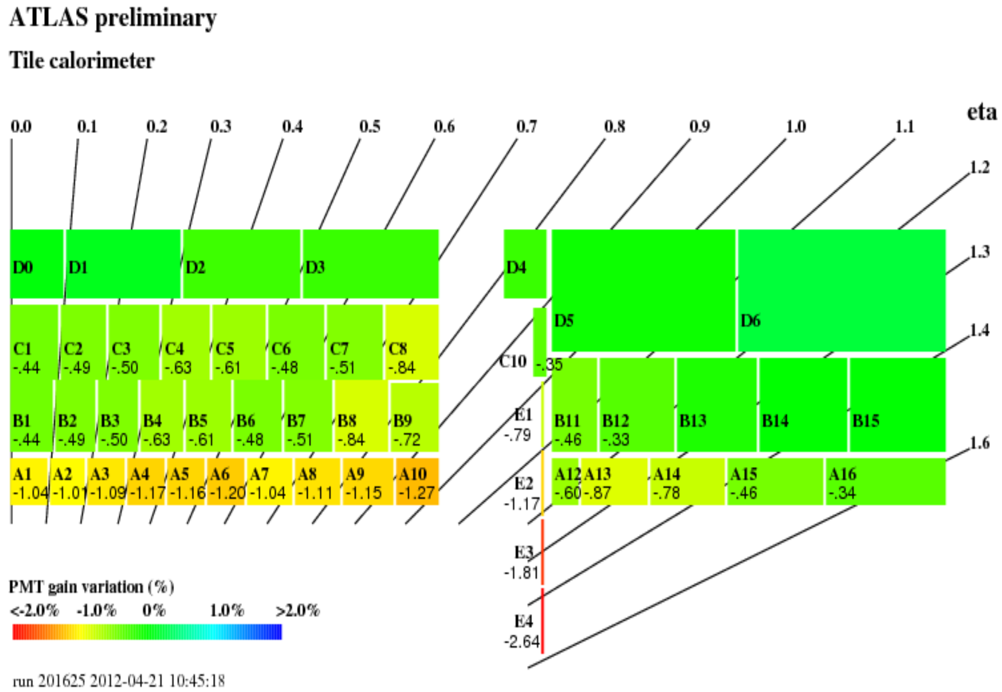
- 2009-2010: up-drift of about 0.8% per year.
- since 2011: down-drift when beam is on, up-drift when beam is off & during low luminosity heavy ion run.
- largest down-drift in innermost part of the tile calorimeter (sample A), is < –3.5%.





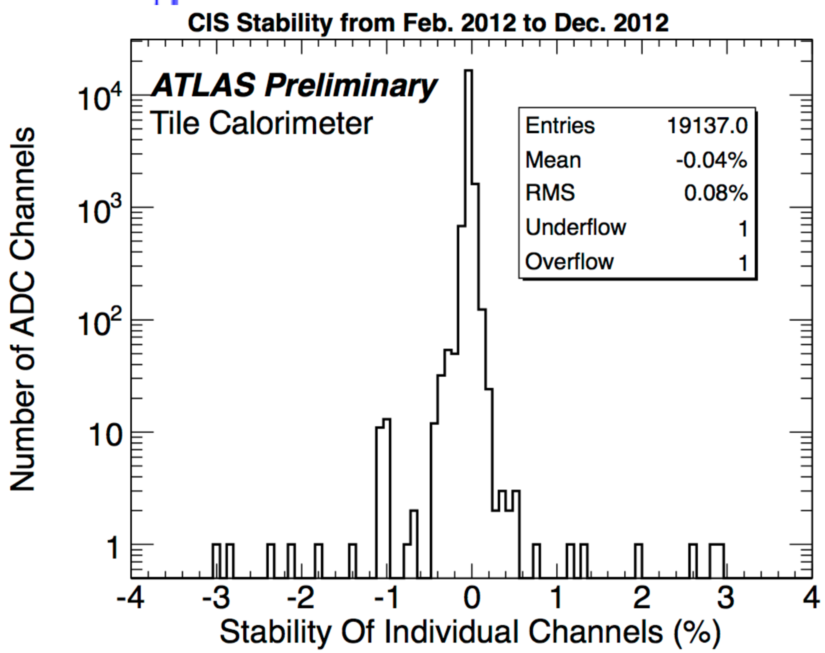
Laser system

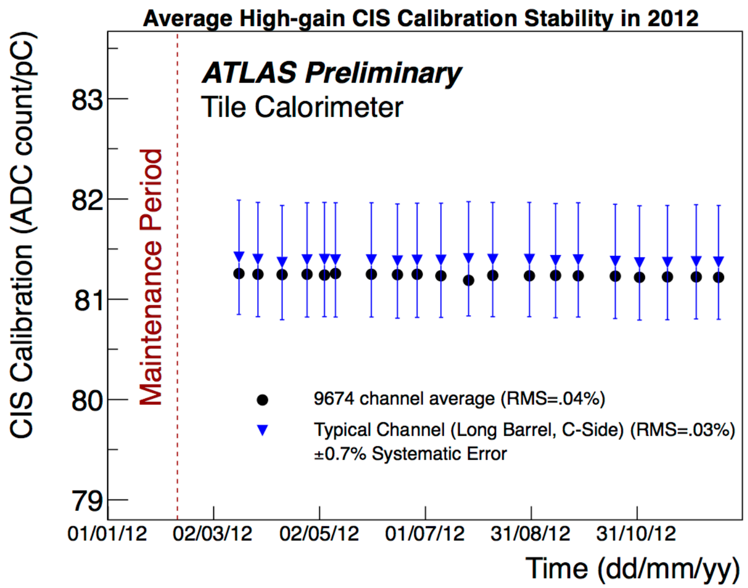




- Laser system has a precision of < 1%.
- Gain variation observed by the laser system is compatible with the variation seen by the Cs system.
- Excellent agreement between laser and Cs calibrations

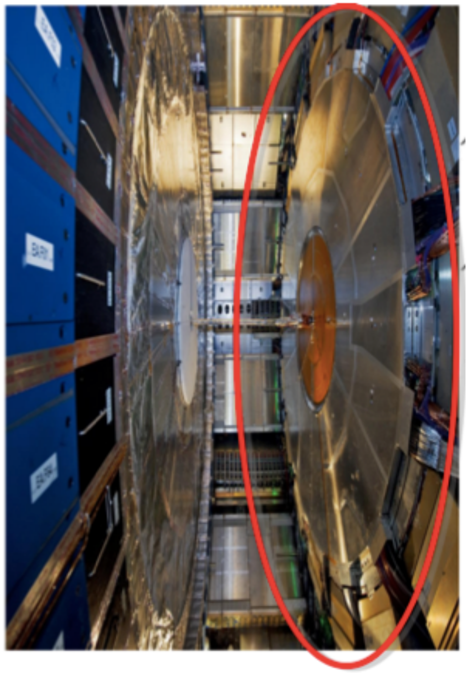
Charge Injection System

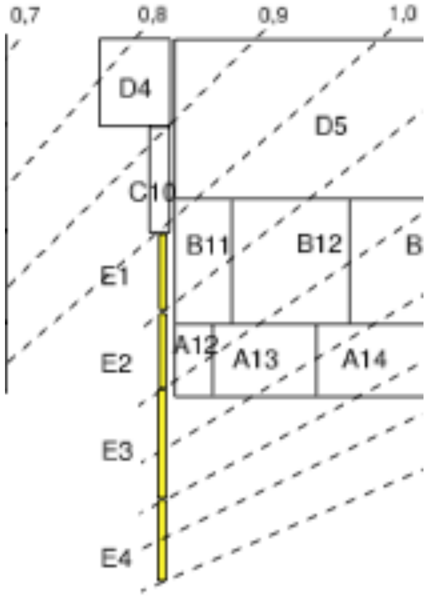


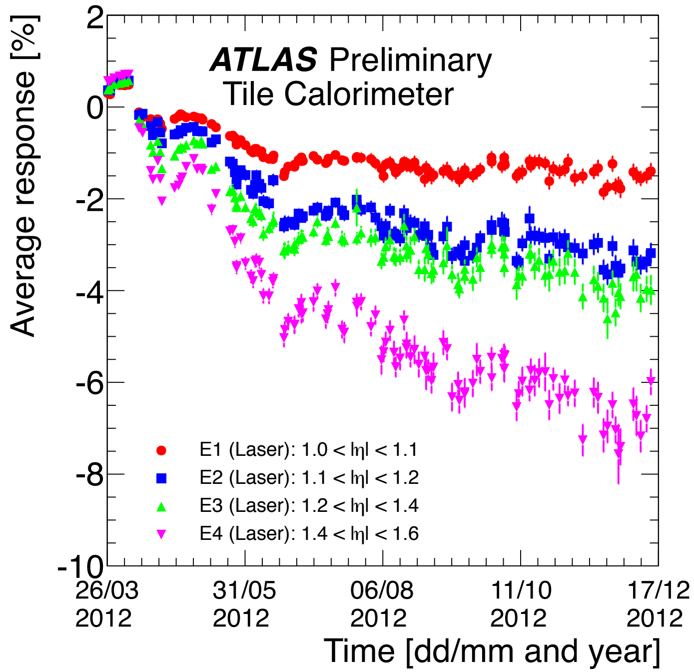


- Only ~ 0.04% shift in calibration constants of fully functional channels (~ 99%) over the entirety of 2012
- Tile-wide calibration constants for all channels in both gains are very stable
- Typical channel calibrations deviated little from the average

Calibration of the Gap & Crack Scintillators



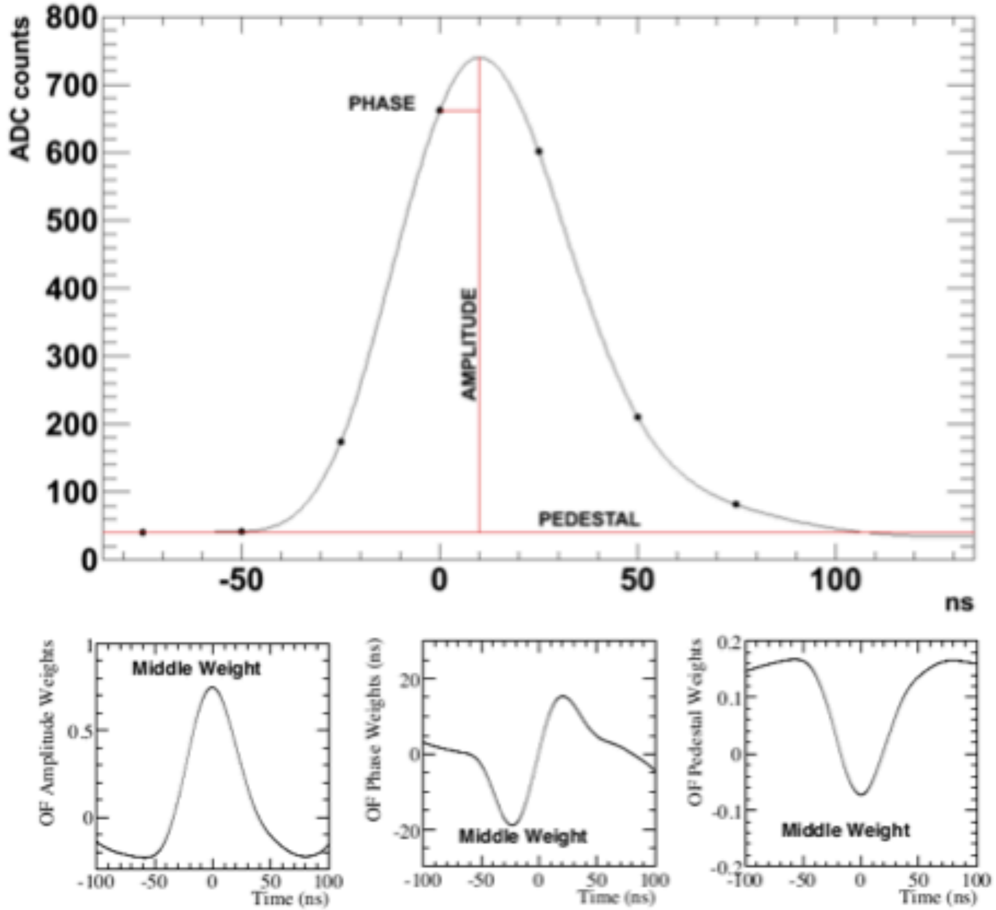




- Gap scintillators (E1, E2): –3%, mostly PMT gain variation (laser ~ Cs response)
- Crack scintillators (E3, E4): ~ –15% 1/3 scintillator irradiation, 2/3 PMT gain drift.
- Re-calibrate with laser/Cs info (no Cs in E3/E4), checked with muons
- *Z* → *ee* analysis (by *e*/γ group) showed a stable response.
- Partial recovery seen when beam is off, f.i during machine developments and technical stops.

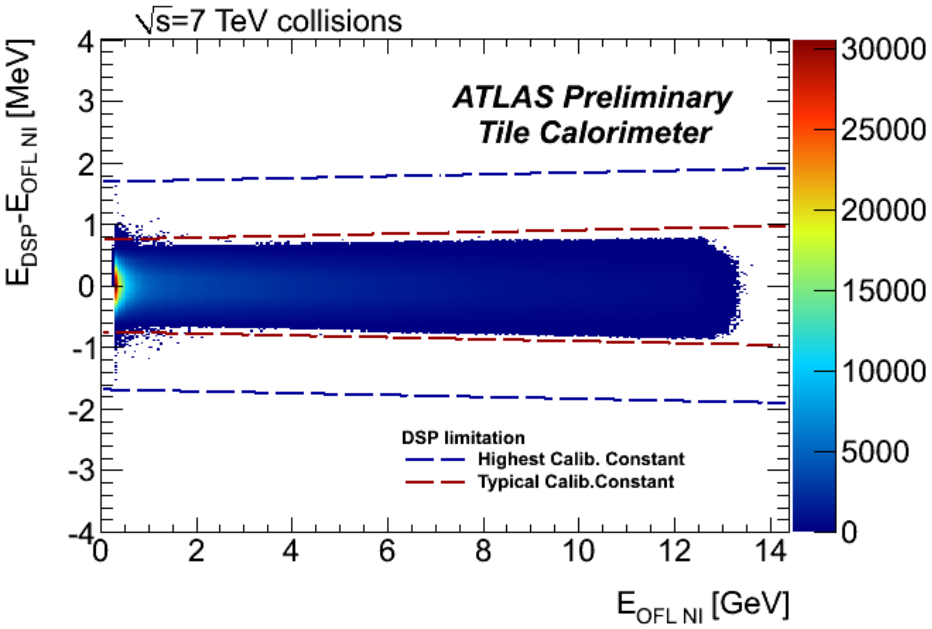
Signal reconstruction

- The signal from a PMT is made up of seven ADC samples spaced 25 ns apart.
- An optimal filtering algorithm is used to determine the amplitude, timing, and pedestal of the signal



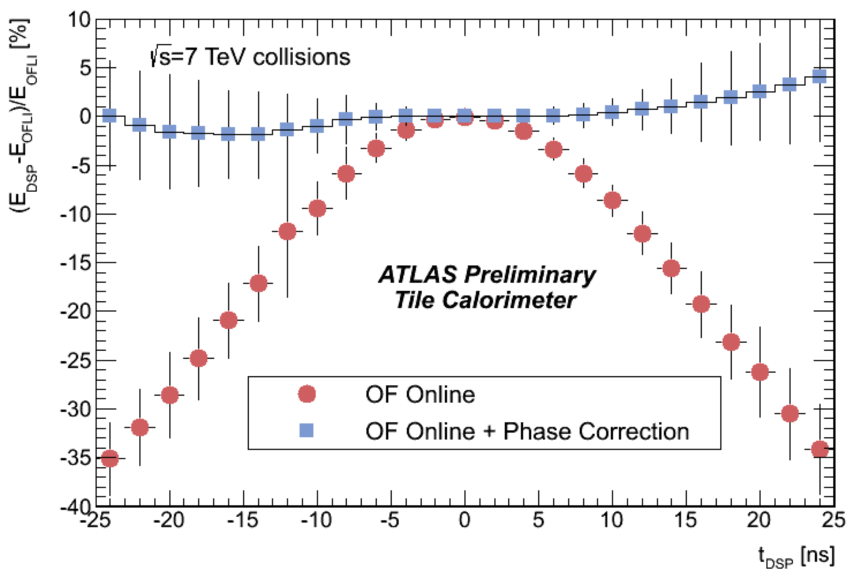
$$Amp = \sum_{i=1}^{7} a_i s_i, \quad \tau = \frac{1}{Amp} \sum_{i=1}^{7} b_i s_i, \quad Ped = \sum_{i=1}^{7} c_i s_i \qquad (1)$$

Energy Performance

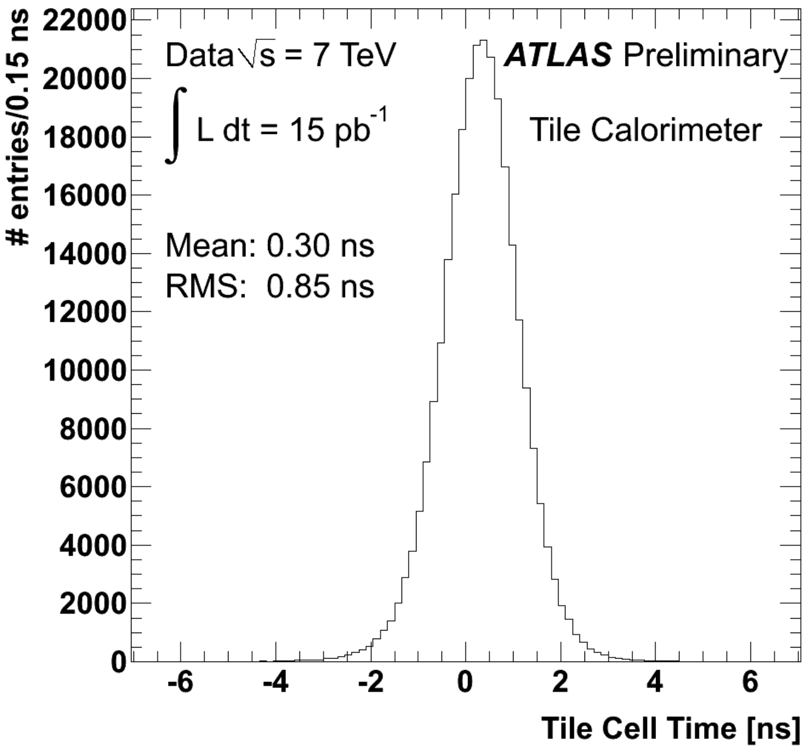


- Large phases bias the reconstructed energy
- Apply phase corrections on pulses with $E > 160$ MeV
- Energy difference vs online time before (red points) and after phase correction (blue points)

- Difference between energy calculated online with the Digital Signal Processor (DSP) and offline
- Max expected difference scales with the overall calibration of each channel

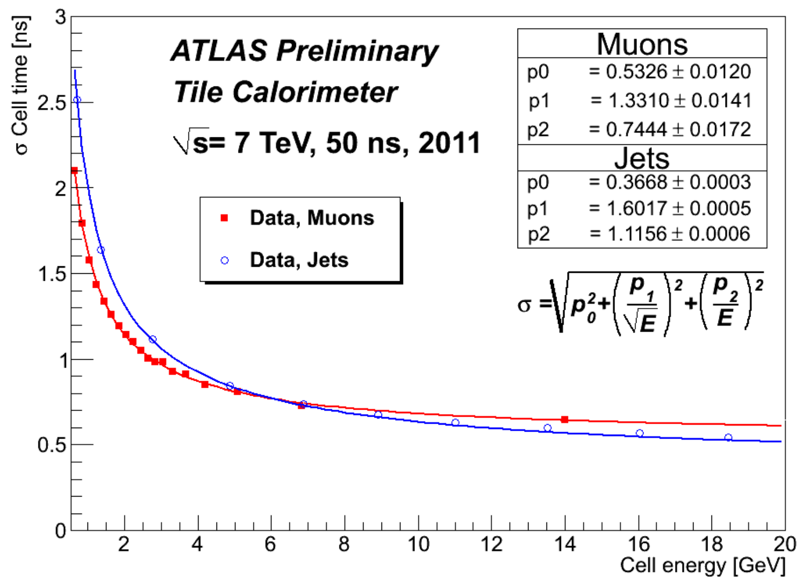


Timing performance

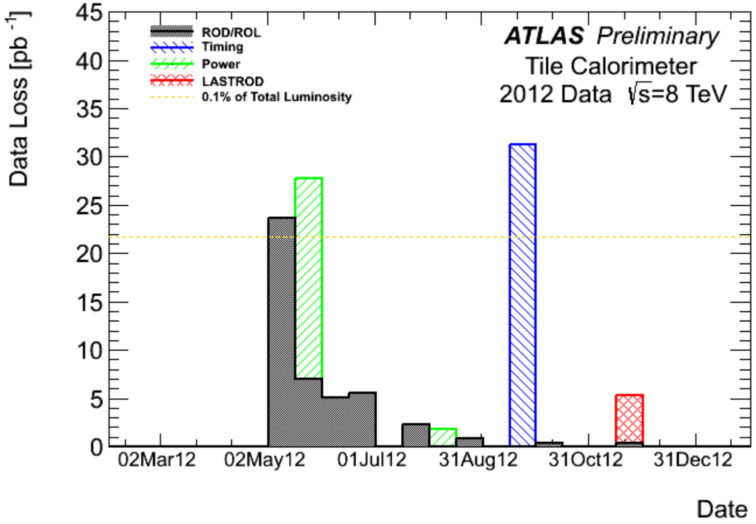


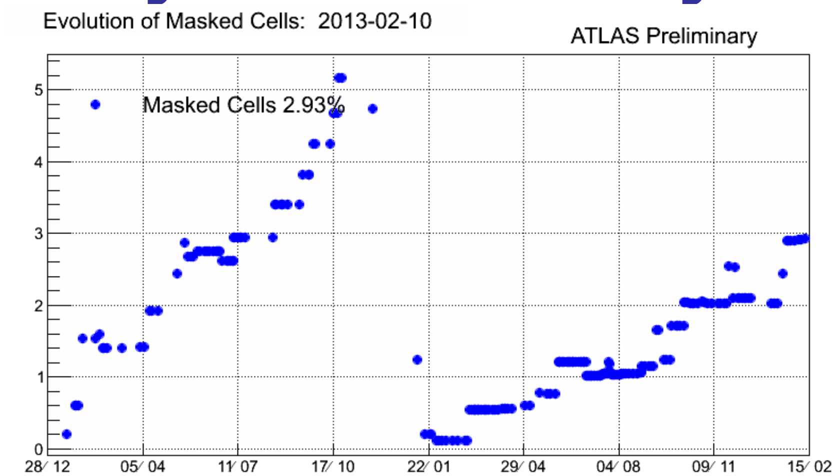
- Selected cells E_{cell} > 20 GeV belonging to reconstructed jets.
- Excluded tile cells with unstable timing (1% of cells)

- Cell time corrected for its mean time.
- Muons deposit only a small fraction of their energy:
  - ~2GeV: 1.15 ns < σ_{Time} <1.3 ns.
  - ~20GeV: σ_{Time} ~0.6ns



2012 Tile Efficiency Summary

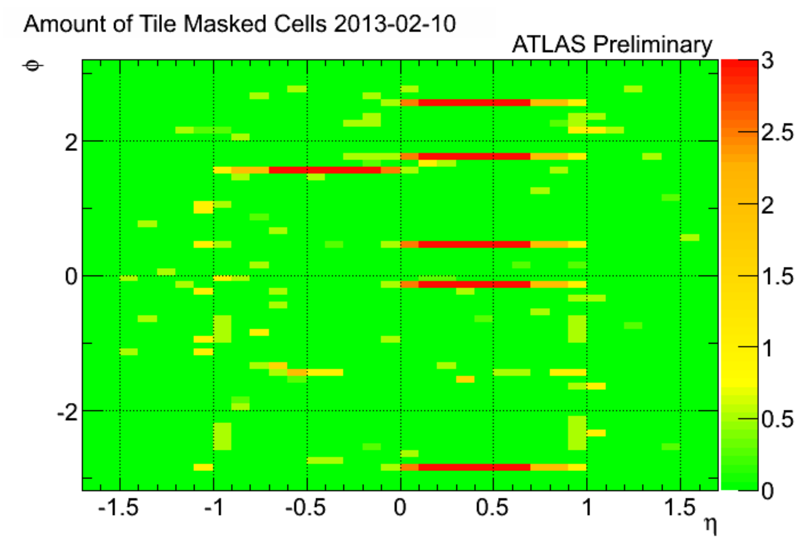




Tile Data Quality efficiency for 2012 was 99.6%.

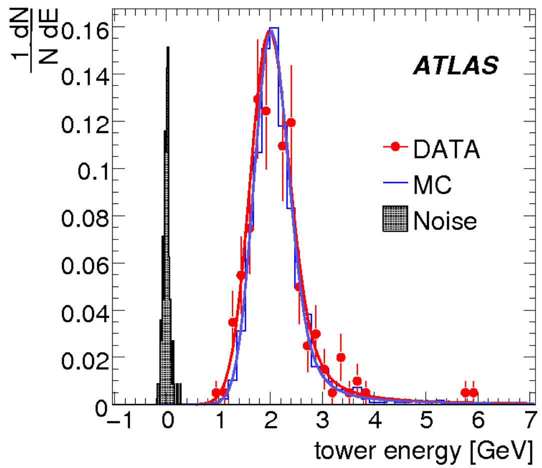
Data is rejected when ≥ 4 consecutive modules are not recording.

Better stability of the electronics in 2012.



Energy scale validation

The electromagnetic energy scale is studied with muons: cosmics, scraping beams, and collisions.



Shown in the table is dE/dx [MeV/mm] for data and monte carlo for the cosmic muon analysis.

Radial layer		A	BC	D
Cosmic muons, LB	Data	$1.28^{+0.03}_{-0.04}$	1.32 ± 0.05	1.35 ± 0.04
	MC	1.32 ± 0.04	1.35 ± 0.05	1.34 ± 0.04
	Data/MC	$0.97^{+0.01}_{-0.02}$	0.98 ± 0.02	1.01 ± 0.01
Cosmic muons, EB	Data	1.27 ± 0.06	1.29 ± 0.06	1.32 ± 0.05
	MC	1.31 ± 0.03	1.32 ± 0.06	1.34 ± 0.05
	Data/MC	0.97 ± 0.04	0.98 ± 0.03	0.99 ± 0.02
Testbeam, LB	Data	1.25 ± 0.03	1.39 ± 0.04	1.39 ± 0.03
	MC	1.30 ± 0.02	1.37 ± 0.03	1.36 ± 0.02
	Data/MC	0.96 ± 0.02	1.02 ± 0.04	1.02 ± 0.02
Double ratio $\frac{(\mathrm{Data/MC})_{\mathrm{Cosmic\ muons,\ LB}}}{(\mathrm{Data/MC})_{\mathrm{TB,\ LB}}}$		1.01 ± 0.03	0.96 ± 0.04	0.98 ± 0.03

Study with muons from W decays in pp collisions is ongoing.

The current uncertainty on the energy scale is 3%.

Conclusions

- The calibration systems were improved and continued to perform well:
  - Cs and laser calibrations have excellent agreement allowing inter-CS calibrations with laser.
  - CIS calibration saw only ~ 0.04% shift over 2012.
- Time in each cell is reconstructed with an average time of 0.30 ns with a RMS of 0.85 ns.
- The Tile Calorimeter performed very well over the last three years:
  - 99.6% data quality efficiency in 2012.
  - DAQ/DQ inefficiency considerably reduced in the second half of 2012.
- The performance of Tilecal is studied with muons, allowing us to quote a 3% uncertainty. We work on improving this number.