Calibration and Performance of the ATLAS Tile Calorimeter

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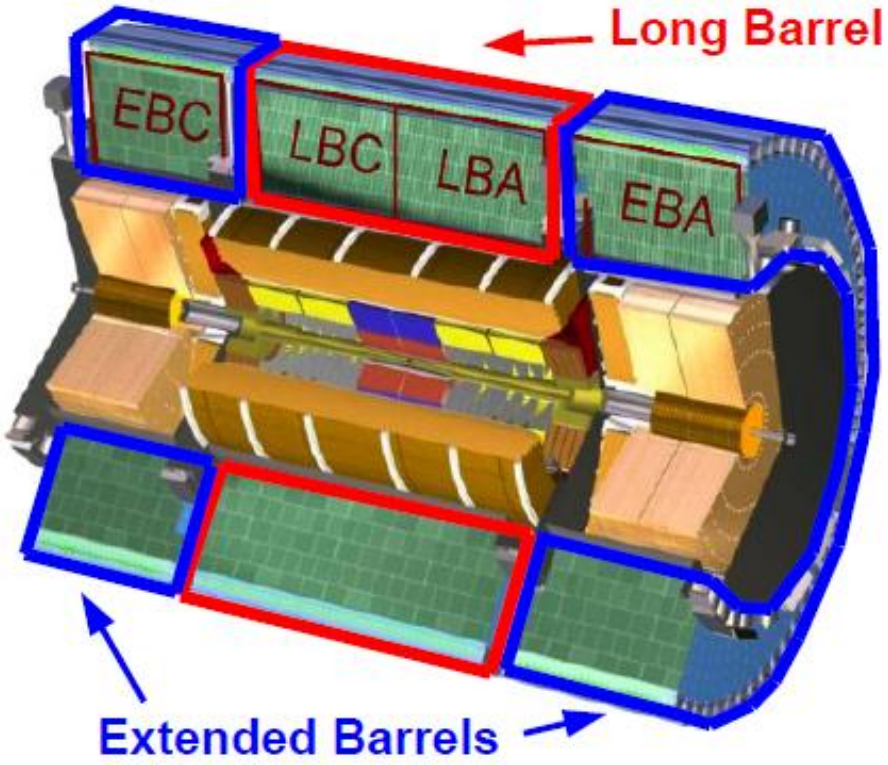
Outline

- The ATLAS Tile Calorimeter
- Signal Processing Chain
- Electronic noise
- Calibration Systems
- Performance
- Conclusions

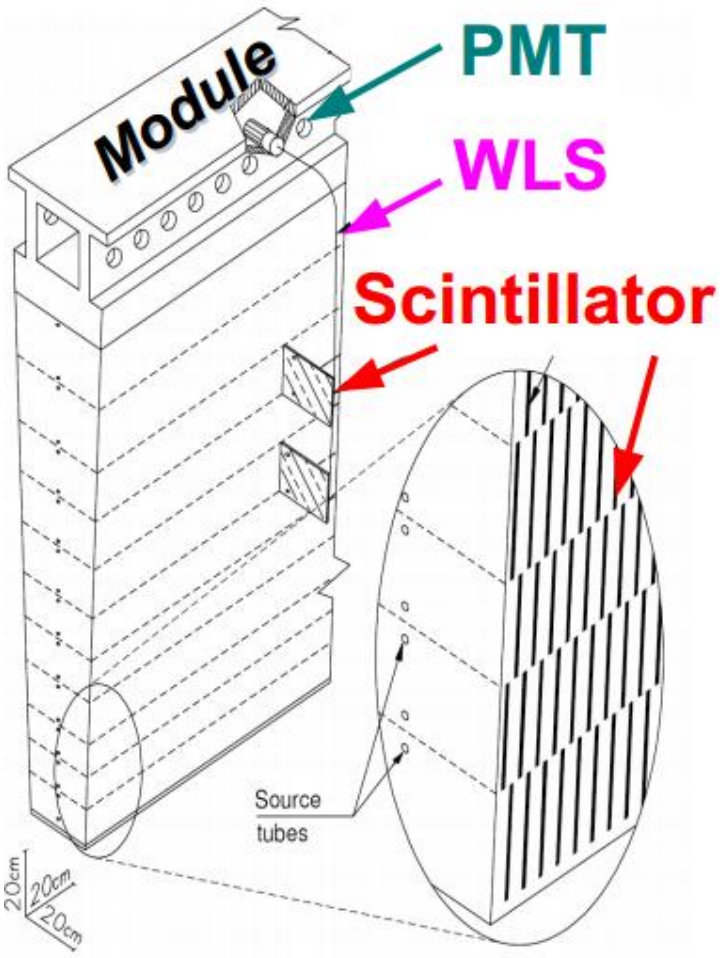
Tile Calorimeter

- ATLAS central hadronic calorimeter
- Sampling calorimeter
  - Steel as absorbing material
  - Plastic scintillating tile as active material
- Three Cylinders
  - Long barrel (covering $|\eta|<1.0$)
  - Extended barrels (covering $0.85<|\eta|<1.7$)
- Total length 12 m, diameter 8.8 m, weight 2900 tons
- Jet linearity (design)
  - ~1-2% in the range 25 GeV to fewTeV
- Jet energy resolution (design)
  - $\sigma(E[GeV])/E[GeV] \sim 50\%/\sqrt{E/GeV}+3\%$



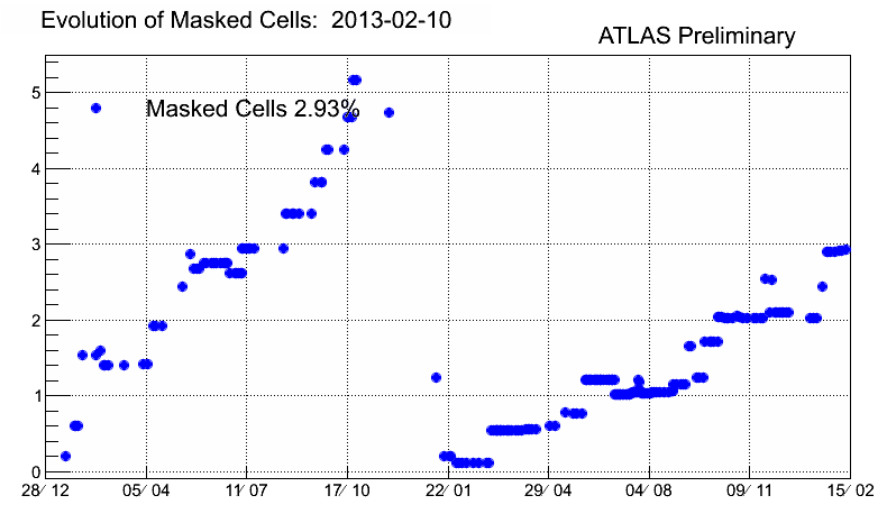
Tile Calorimeter

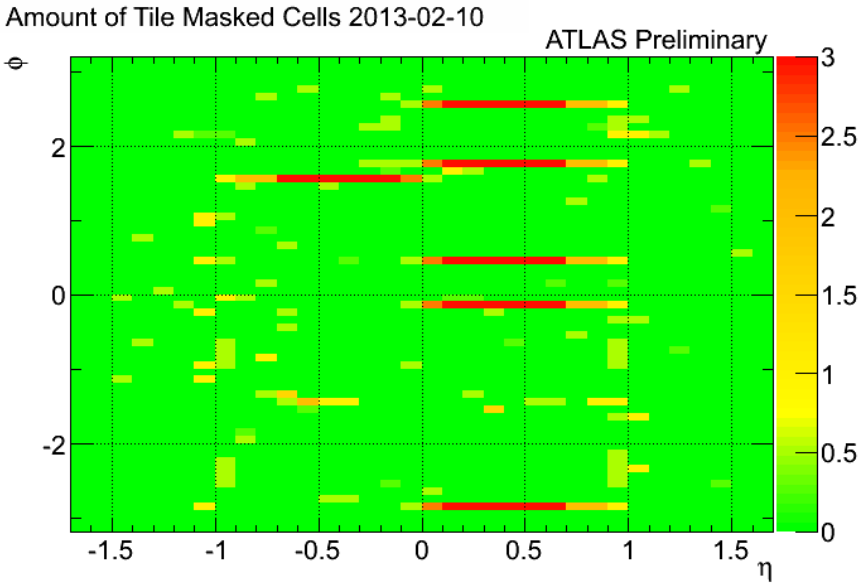
- 64 independent modules in each Tile cylinder
- Scintillator tiles inserted in the iron structure
- Light produced in scintillators collected by wavelength shifting fibres (**WLS**) and delivered to photomultipliers (**PMT**s - Hamamatsu R7877)
- Readout granularity
  - Three radial layers (λ_{int} =1.5, 4.1 & 1.8)
  - $\Delta\eta \times \Delta\varphi$=0.1 x 0.1 (0.2 x 0.1 in outermost layer). Each cell readout by 2 different PMTs except for the special cells



Tile Calorimeter

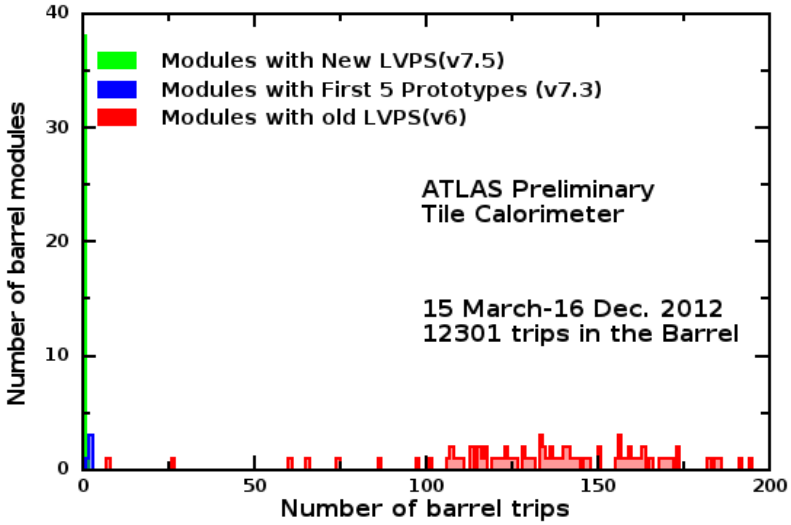
- 2011 status:
  - 99.2% of good data for physics
  - 5% of TileCal cells were masked (most of them from modules that were off due to LVPS problems)
- Masked cells recovered during 2011/12 winter shutdown
- 2012 status:
  - ~3% of Tile cells masked (mostly LVPS)

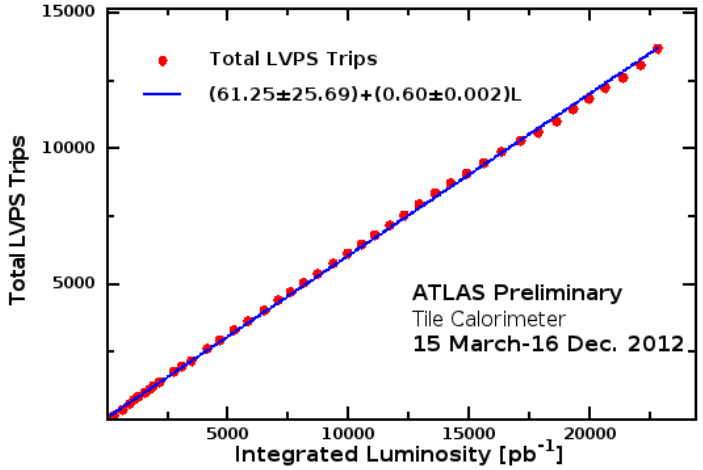




Tile Calorimeter

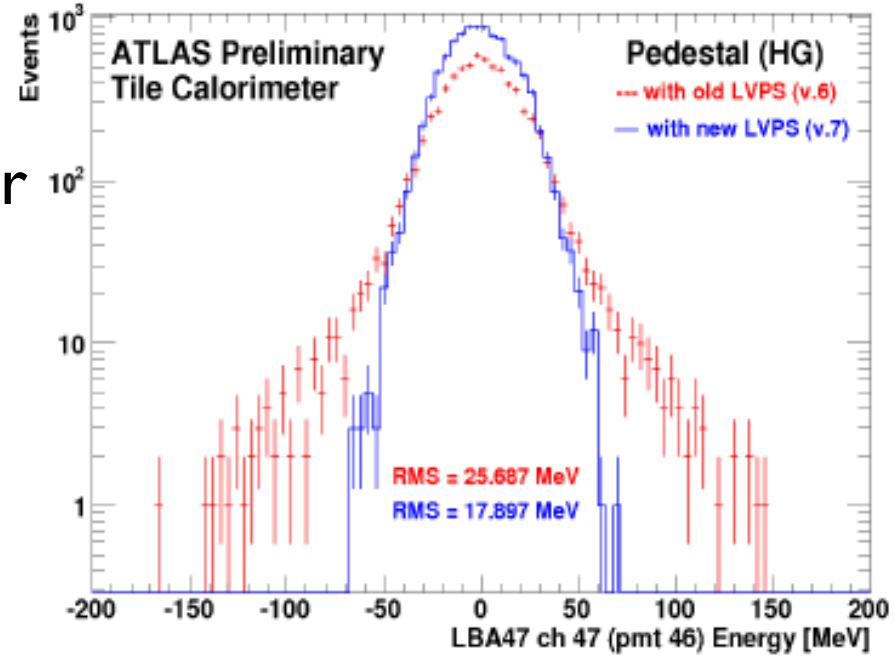
- Low voltage (LVPS) power supply used for front end electronics
- One LVPS per module
- Located on the detector (high radiation environment)
- In 2011, ~5000 LVPS trips (~80% in long barrel)
- In 2012, 14714 trips in total
- New production of LVPS (more robust with better knowledge from experience)
  - 5 units installed in 2011
  - 40 units in 2012
  - 2013 – Full production under way





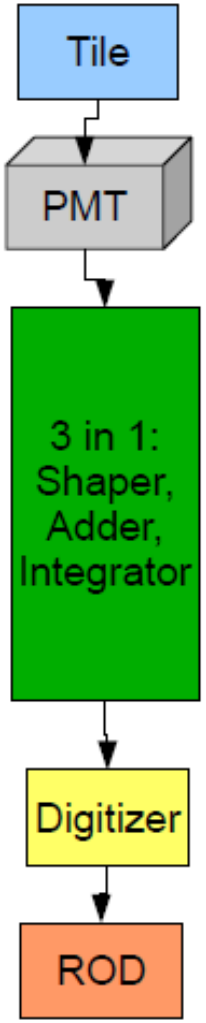
Electronic noise

- Noise parameters taken periodically from pedestal runs
- Deviation from single Gaussian mostly due to the instability of the LVPS
- Double gaussian model used for signal/noise discrimination
- With new LVPS, noise significantly reduced
  - Reduction of noise tails
  - Gaussian behaviour
- Log-Normal model for pile-up noise (under evaluation)



Signal Processing Chain

- Light produced from scintillating tiles is transmitted to PMTs allocated inside the modules and converted into electric signals
- PMT output signal is shaped and amplified with two different gains (1:64)
- Signals are sampled at 40 MHz and digitized samples are sent to ROD
- Digital signal processing is carried out at ROD level
- Energy, time and quality are computed
- Raw data from all signals above 70 MeV are recorded for offline analysis

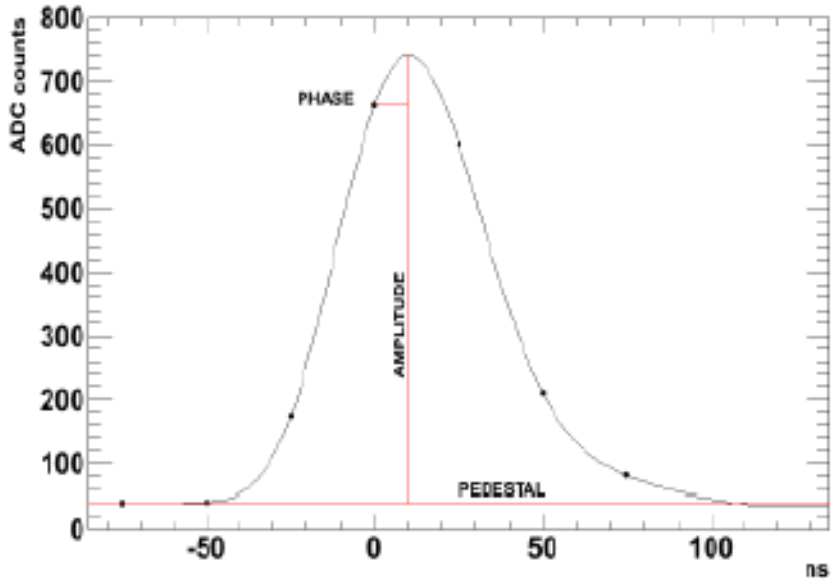


Signal reconstruction

- Performed online and offline by optimal filtering algorithm
- Goal is to estimate the peak

from the 7 digitized samples

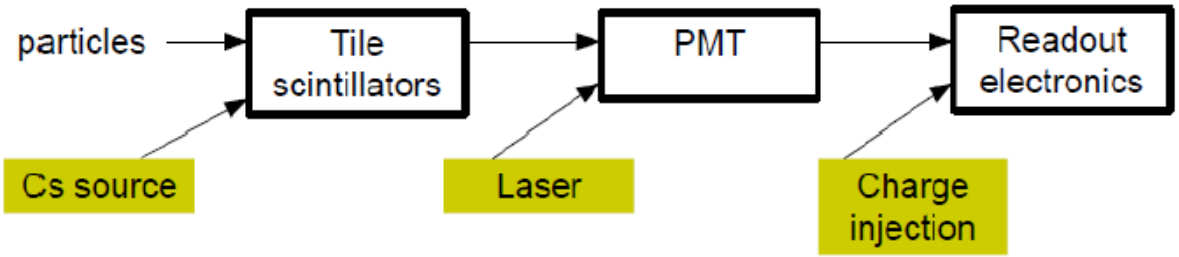
- OF weights are defined by:
  - Channel pulse shape
  - Noise autocorrelation matrix (currently the diagonal approximation is implemented)
  - Expected signal phase
- New methods to deal with pile-up are currently under evaluation
  - Matched filter and deconvolution



Calibration systems

- Three systems:
  - Charge injection: it injects well defined charge into readout circuits
  - Laser: it sends light pulses to monitor PMT gain and timing of individual channels
  - Cesium: it equalizes cell response
- Use to mask problematic channels (noise, digital problems)
- $C_{ADC->pC}$ was measured in the testbeam calibration period

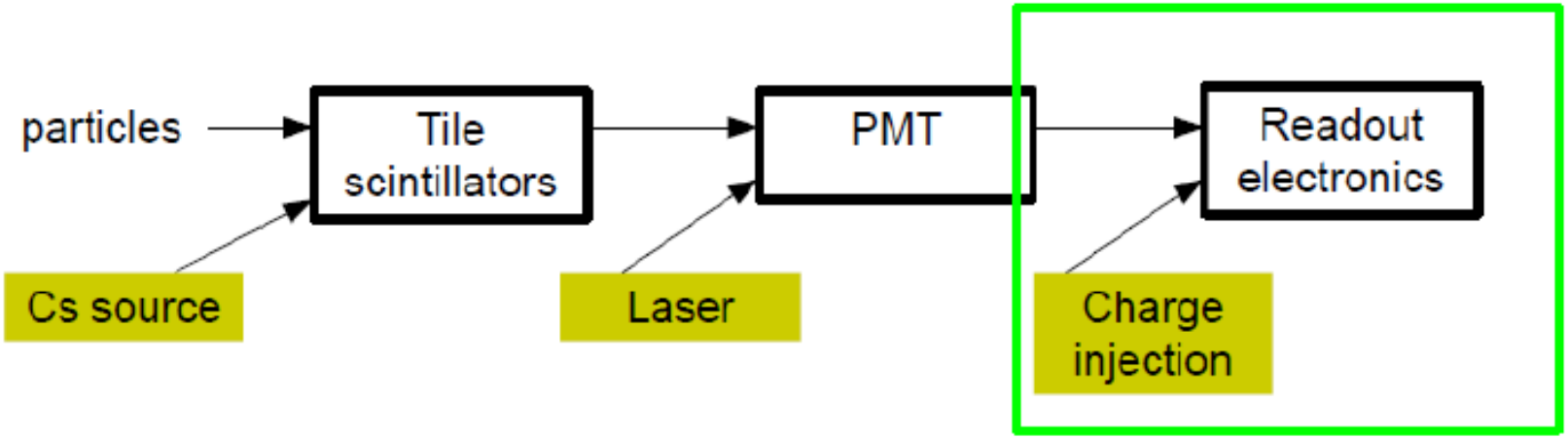
$$\text{Energy [GeV]} = \text{Amplitude [ADC]} \times C_{ADC \rightarrow pC} \times C_{laser} \times C_{Cs} \times C_{pC \rightarrow GeV}$$



- MinBias monitoring (integrator): it integrates the PMT anode current to monitor the cell response evolution

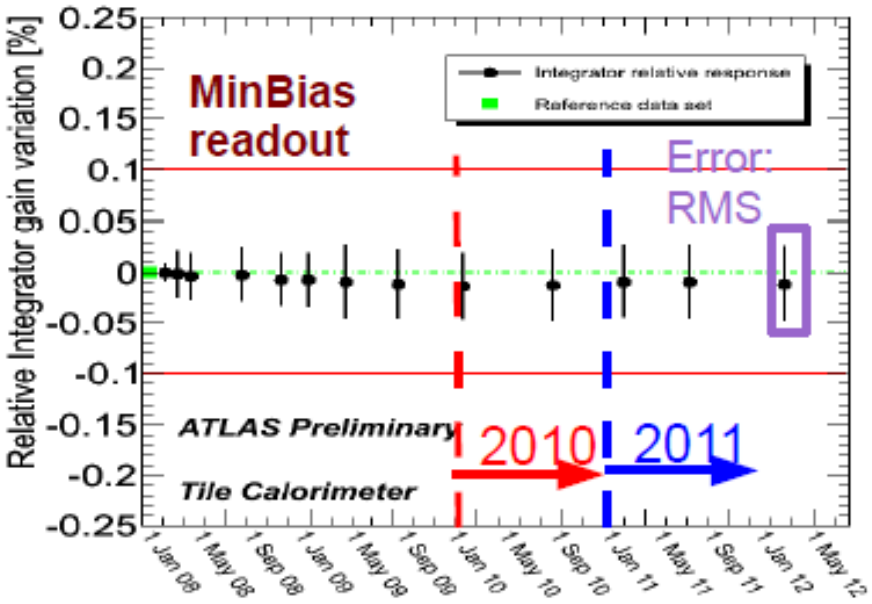
Calibration systems

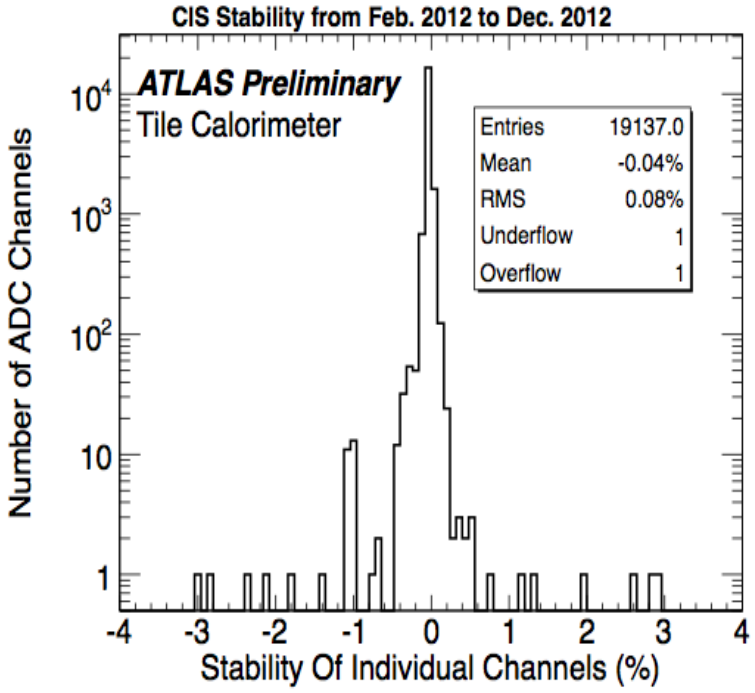
- Charge injection system
  - It determines the pC / ADC factor
  - Pulses are generated from discharge capacitors in the readout circuit
  - Pulse amplitude is controlled by 10 bit DAC
  - 2 capacitors 5.2 pF and 100 pF
  - Calibration taken about 3 times a week



Calibration systems

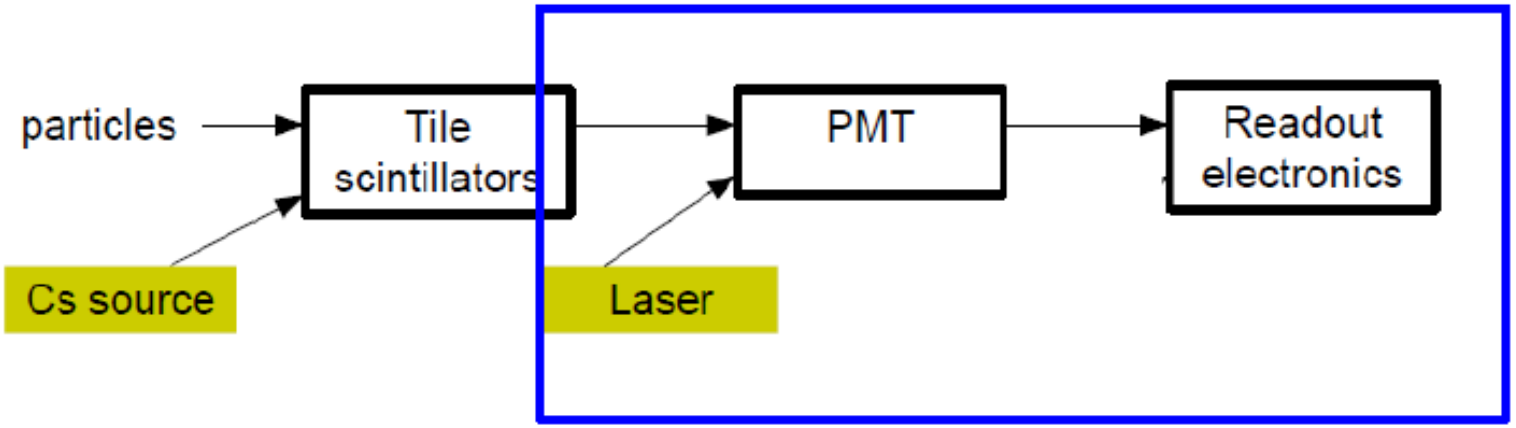
- Performance of the charge injection system
  - Variation in electronic gain: ~0.1% or less
  - Very stable in time
  - Calibration data is averaged over a month and only channels drifting more than 1% are updated





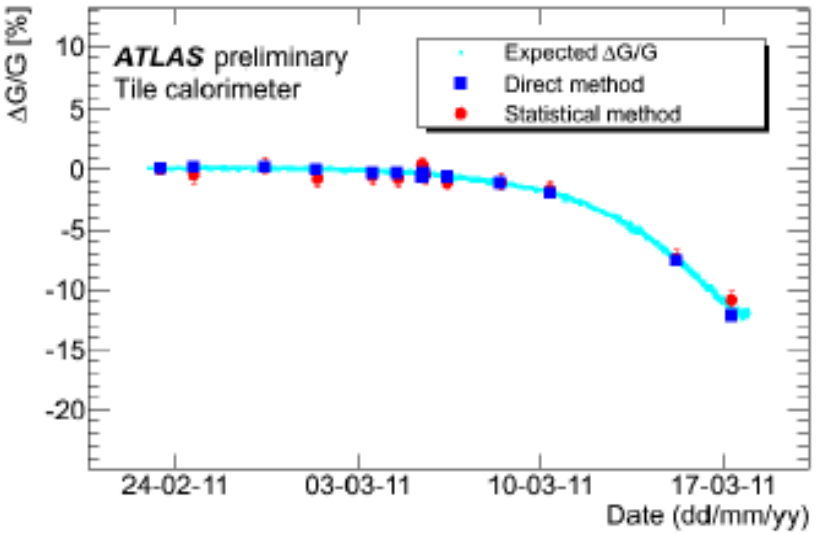
Calibration systems

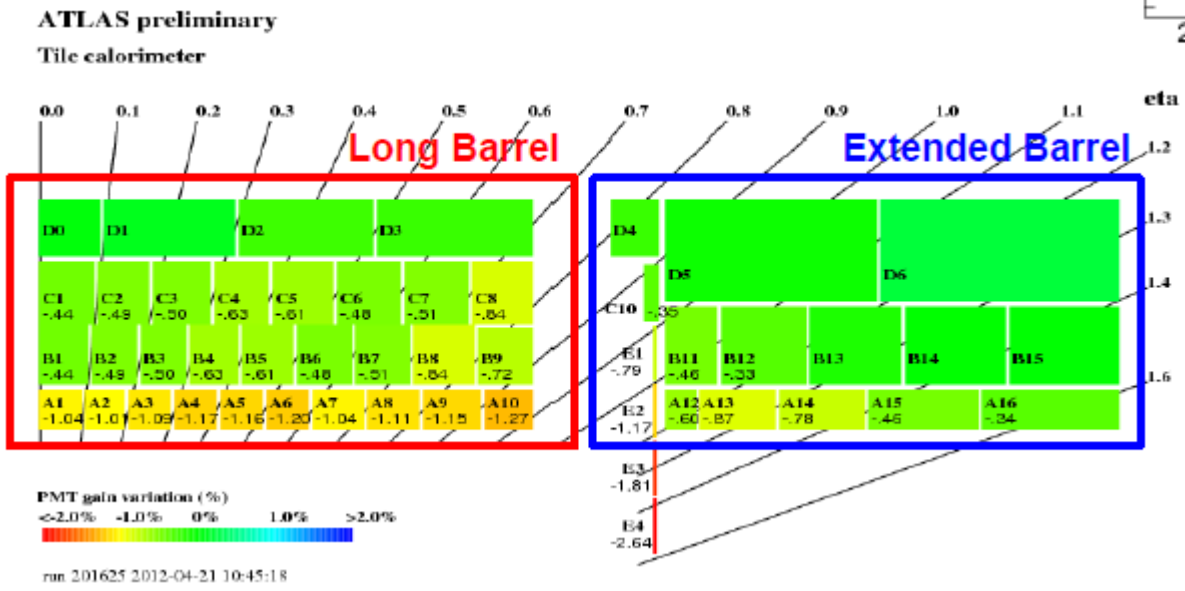
- Laser system
  - Used to correct channel variations responses happening between two Cs runs
  - Light from a laser (532 nm, 10 ps pulse) is sent to normalization photodiodes and the TileCal PMT (~10k)
  - Stability of the diodes is monitored and a set of filters allows to adapt the light intensity
  - Still have to apply several corrections to get reasonable precision
  - Recently used for calibration purposes, before only for monitoring



Calibration systems

- Performance of the laser system
  - The laser is used to correct the PMT response variations between two Cs scans
  - Precision about 1%
  - Two independent methods

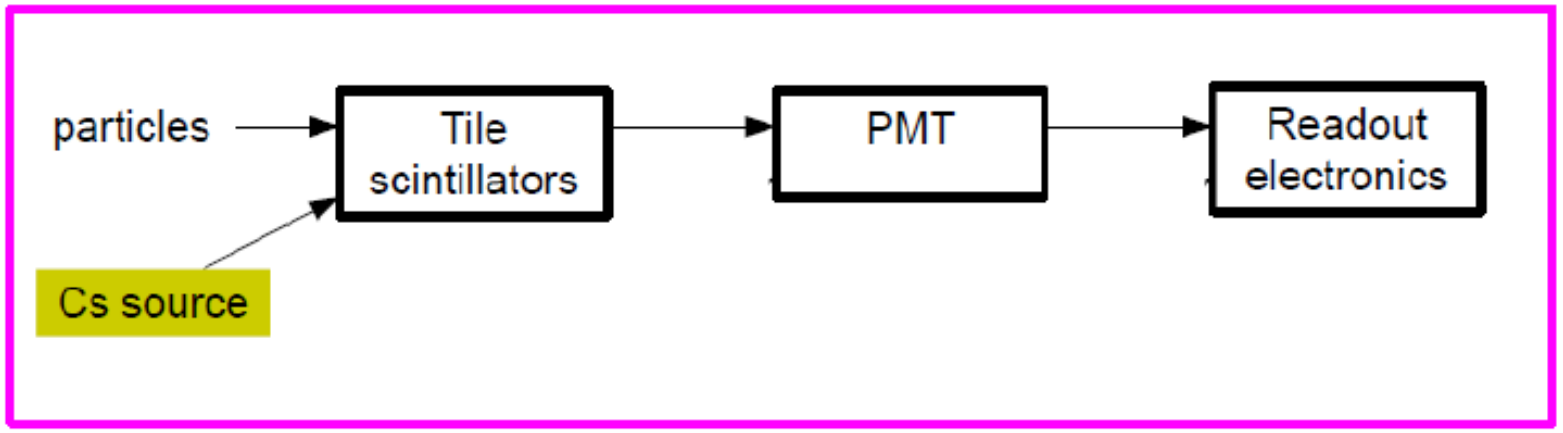


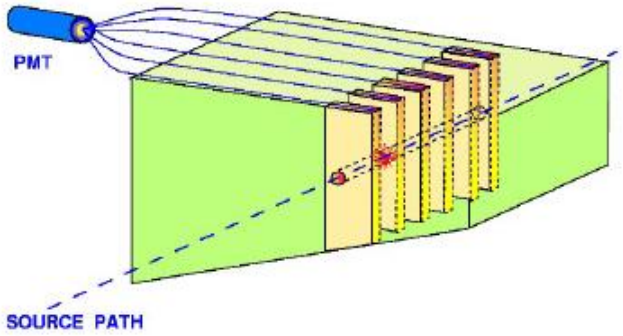


- Laser used to monitor global PMT gain variation (collisions 2012)

Calibration systems

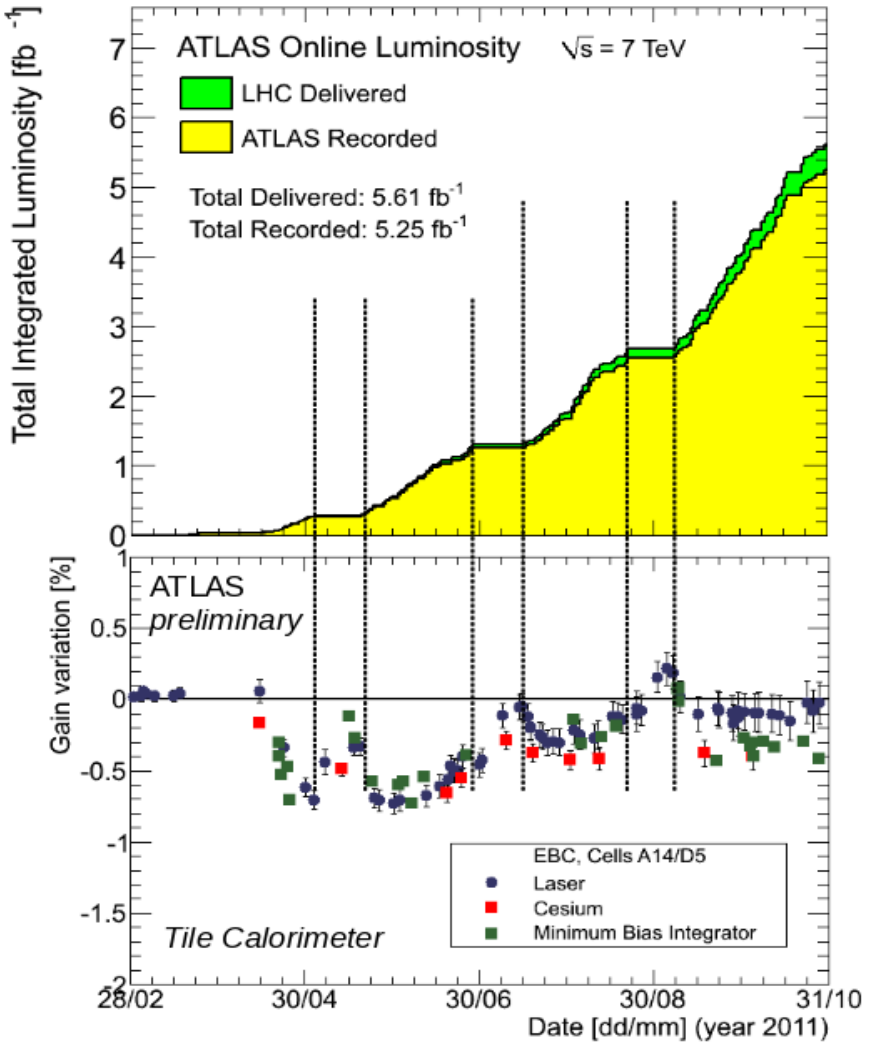
- Cesium system
  - Radioative sources (Cs^{137}) are transported by hydralic system through every scintillator tile





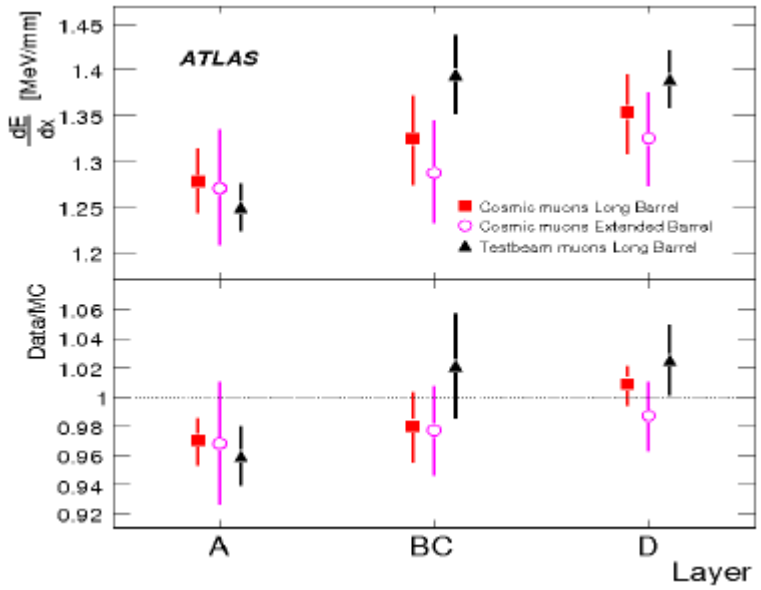
Calibration systems

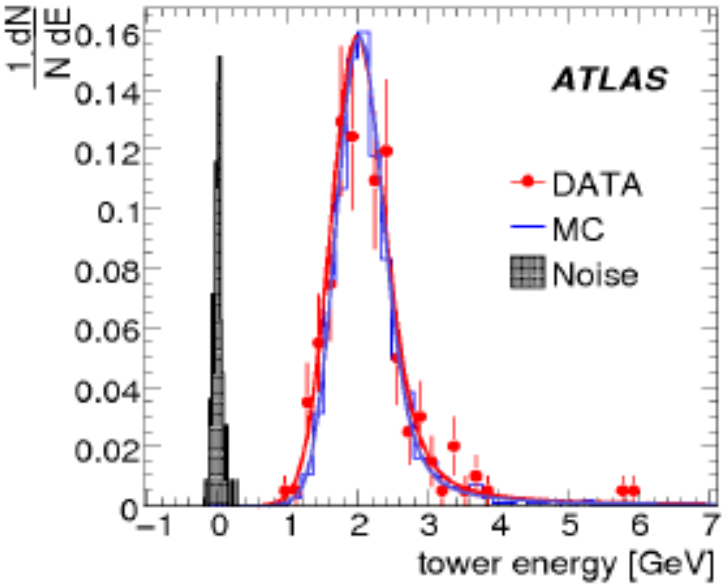
- Stability of the calibration
  - Each point corresponds to an average over 64 modules in φ
  - Ration between EBC cells A14 (η=1.35) and D5 (η=1.0)
  - Laser, Cesium and Minimum Bias integrator show a similar behavior
  - Drifts observed can be attributed mostly to a variation of the A14 photomultiplier response (see slide 15) and not to the scintillator irradiation
  - PMT is "downdrifting" during data taking and recovering during the beam-off periods



Response to muons

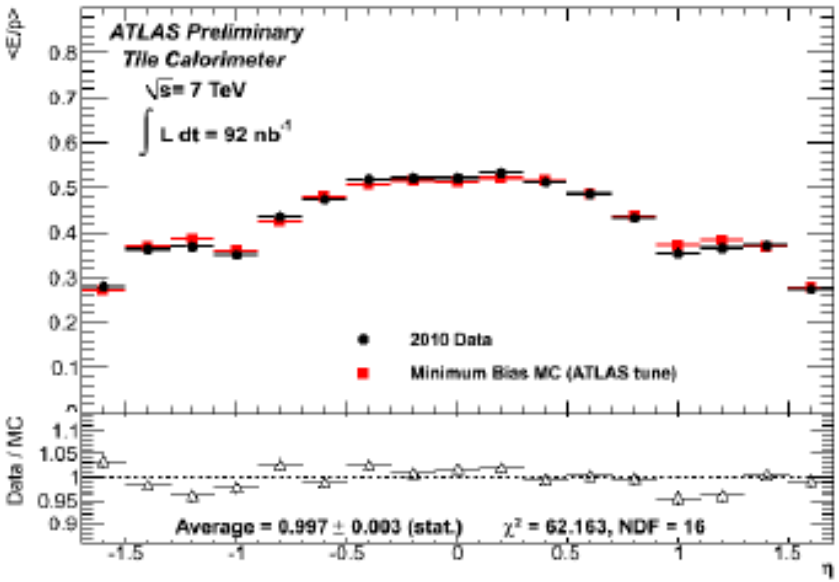
- TileCal response to muons is well separated from background noise
- Results show good uniformity in η and φ
- Overal cell uniformity within a radial detector layer is ~2-4%

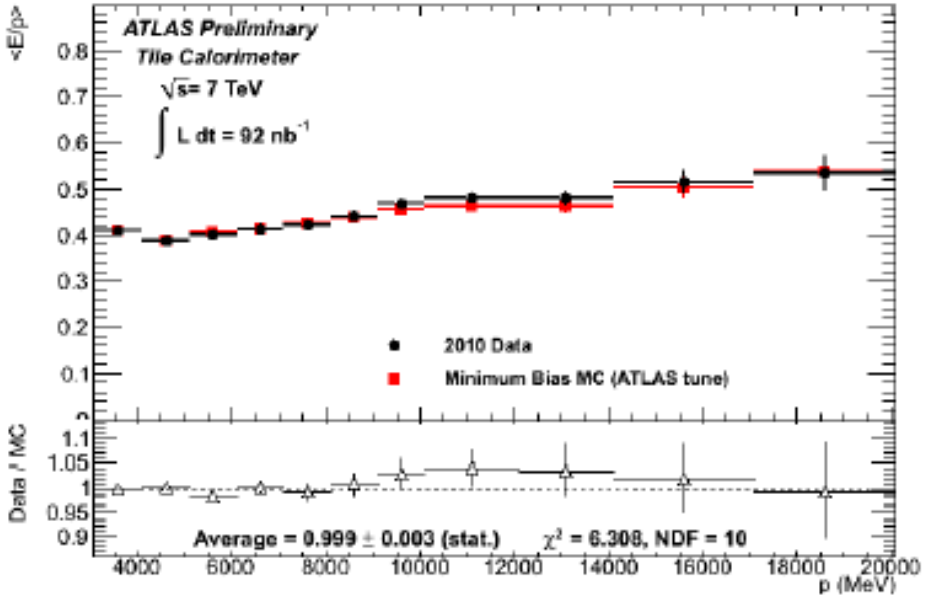




E/p from isolated hadrons

- Isolated charged particles showering in TileCal
- The momentum is measured by tracking inner detector
- Agreement with MC is observed





Conclusions

- TileCal is performing very well during the first years of LHC data taking
- TileCal has provided good data despite 5.1% of its channel masked in 2011 (mainly due to LVPS related problems)
- With new LVPS, masked channels reduced to about 3% in 2012
- Calibration systems are commissioned and working well. They allow to monitor the evolution of the response of the different components of TileCal
- Precision of individual calibration system is about 1%
- MC simulation agrees with data (noise description, response to muons, single hadrons)
- During phase 1 (2013-2015) shutdown, systems and drawers will be repaired and improved