Performance of the ATLAS Hadronic Tile Calorimeter

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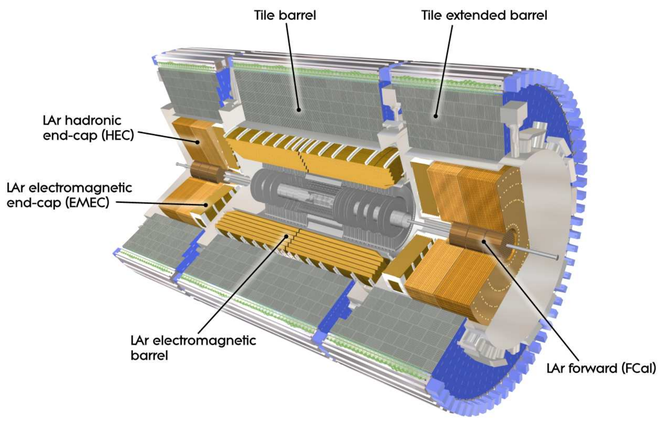
No. 165

The ATLAS Tile calorimeter

- The hadronic sampling calorimeter which uses steel as absorber and scintillating tiles as an active medium which are read out by wavelength shifting fibers

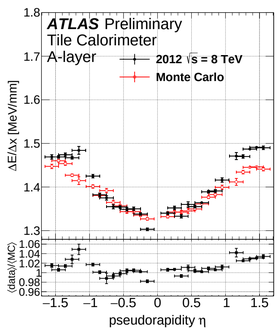


- Divided into long barrel (LB) and two extended barrels (EB) with overall dimensions of $\sim$ 12 m length and 4.25 m (2.28 m) outer (inner) radius
- Granularity:
  - 64 wedge-shaped modules $\Delta\phi = 0.1$
  - 3 radial layers: A ($\Delta\eta = 0.1$), BC ($\Delta\eta = 0.1$), D ($\Delta\eta = 0.2$)
- Each normal cell is read out by two photomultiplier tubes (PMT) to achieve uniform response; 5k cells, 10k PMTs
- Performance goals:
  - Energy resolution for jets $\frac{\sigma}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$
  - Linear within 2% (4 TeV jets)
  - Hermetic coverage for E_T^{miss} reconstruction

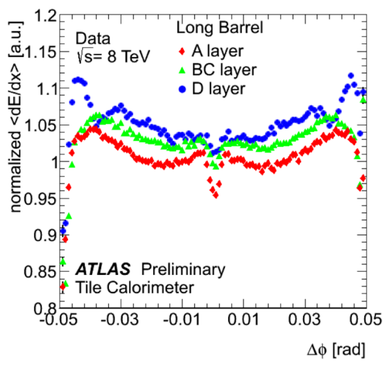
Performance

Collision muons

- Collision events with muons produced in $W \to \mu\nu$ decays
- 2012 experimental data and Monte Carlo simulations (MC)

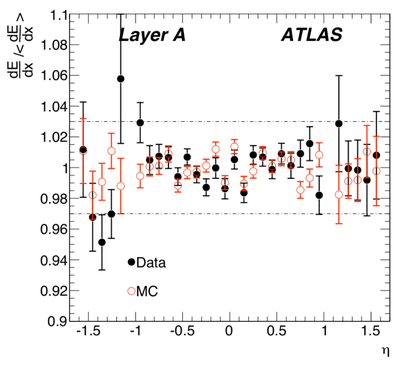


- Truncated mean of cell response $\Delta E/\Delta x$ versus pseudorapidity η for layer A, obtained from the average in ϕ
- Data and MC agreement is worse in the cells close to the gap between LB and EB due to higher noise contribution from pileup



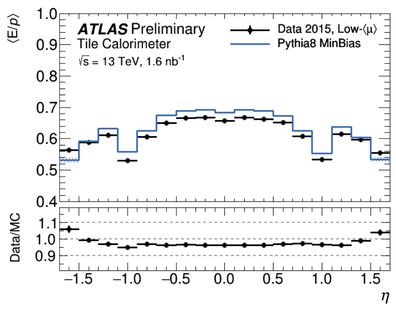
- Normalised truncated mean of cell response $\langle dE/dx \rangle$ as a function of $\Delta\phi$ ("U-shape")
- $\Delta\phi$ – azimuthal angle difference between muon impact point and cell center
- The observed asymmetry in the response in the two extremities of the cells is attributed to a mis-alignment between the Tile hadronic calorimeter and the Inner tracker
- U-shape obtained with Run-1 data was used to improve the MC simulation for Run-2

Cosmic muons



- Uniformity of the cell response to cosmic muons as a function of η for layer A, expressed in terms of normalised truncated mean $\langle dE/dx \rangle$
- The response is integrated over all cells in each η bin

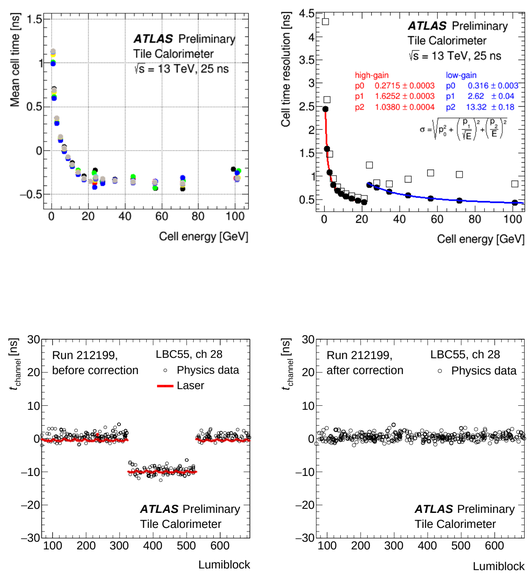
Single hadrons



- Calorimeter response to single isolated charged hadrons, characterised by the mean of the energy-momentum-ratio $\langle E/p \rangle$ as a function of pseudo-rapidity integrated over the ϕ coverage of the calorimeter
- E is measured by the Tile Calorimeter and p by the Inner Detector
- 2015 data and MC agree within 5%

Time calibration

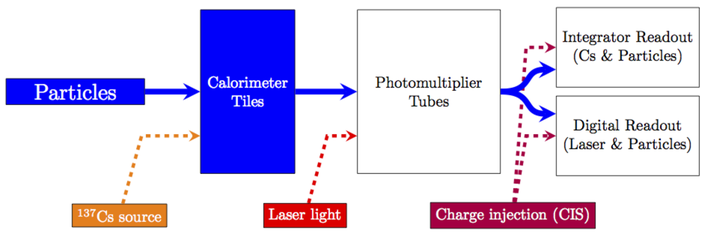
- The time calibration is important for the energy reconstruction; aims to set the phase in each channel so that a particle from the interaction point gives signal with measured time equal to zero
- The reconstructed time in all Tile calorimeter cells/channels is monitored in physics runs with laser calibration events during empty bunch crossings



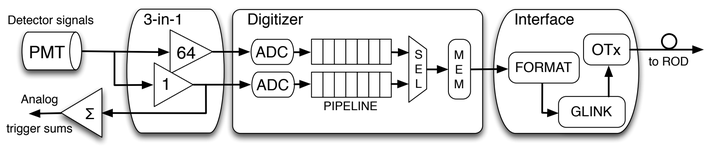
- The plot on the left shows mean cell time in jet events as a function of the energy deposited in cells, each color corresponds to a different run
- The mean cell time decreases with deposited energy due to neutrons/slow hadronic components of the hadronic shower
- The plot on the right shows cell time resolution in jet events as a function of the energy deposited in cells, the closed circles correspond to Gaussian σ, the open squares indicate the RMS of the underlying time distributions
- Some channels suffer from sudden time changes due to configuration issues, which are seen in both physics and laser events
- Laser events are used to correct reconstructed time before processing of physics data
- The plots show reconstructed time in laser events in one channel (LBC55 ch 28) before and after timing correction

Energy reconstruction and calibration procedure

- Each of the Tile calibration systems tests a different part of the signal path $\to$ identification of the source of deviation



- The signal from the PMTs is shaped and amplified using two gains (1:64) and read out by 10-bits ADCs each 25 ns



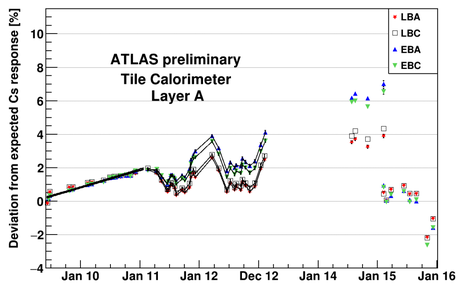
- Amplitude and time are reconstructed using Optimal filtering algorithm

$$A = \sum_{i=1}^{7} a_i S_i \qquad A\tau = \sum_{i=1}^{7} b_i S_i$$

$$E[\text{GeV}] = A[\text{ADC}] \times C_{\text{ADC}\to\text{pC}} \times C_{\text{laser}} \times C_{\text{Cs}} \times C_{\text{pC}\to\text{GeV}}$$

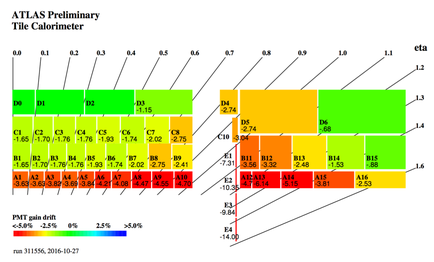
A[ADC]	Measured signal amplitude in a given channel in ADC counts
$C_{\text{pC}\to\text{GeV}}$	Electromagnetic scale measured during the test beam

The cesium system



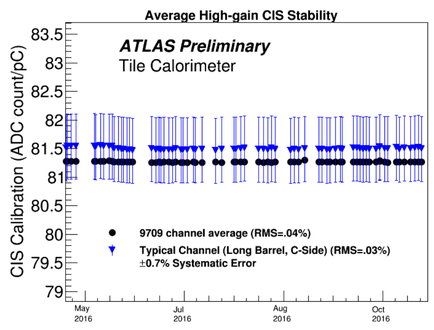
- ^{137}Cs γ-source is circulated through all the detector cells to equalize their readout response
- In first scan calorimeter is equalized and in subsequent scans C_{Cs} is calculated as a ratio of measured to expected signals
- Cesium system and associated constants are used to calibrate the scintillators, PMTs and to correct residual cell differences
- Precision of the measurement is better than 0.3% for each channel

Laser calibration



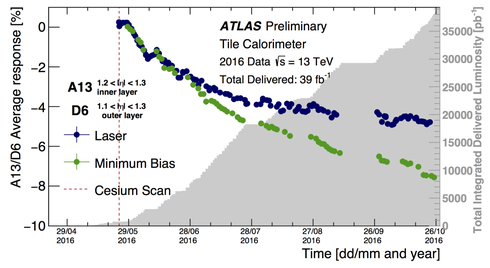
- Calibration of the PMTs gain and readout output
- Light pulses of adjustable intensity are sent to the PMTs to measure PMT gain variation C_{laser} between two Cesium scans
- Precision of the measurement is better than 0.5% for each channel
- The maximum drift is observed in E and A cells which are the cells with the highest energy deposit

The charge injection system (CIS)



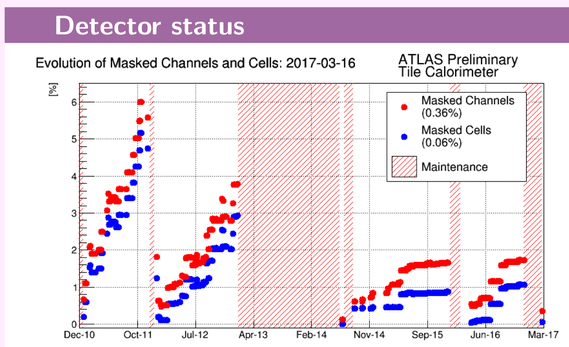
- Calibration of the readout electronics
- A known charge is injected in readout chain and measured to determine $C_{\text{ADC}\to\text{pC}}$ factor for low and high gain ADCs connected to PMT
- Typical uncertainty is 0.7%
- The conversion factor is stable in time at the level of 0.02%

Combination of calibration systems



- Minimum Bias system
  - The system uses the integrator readout and measures the detector response to the minimum-bias events
  - It is used for monitoring of the instantaneous luminosity in ATLAS
- The difference between Laser and Minimum Bias (or Cesium) response gives the effect of the scintillators irradiation

Detector status



- Faulty channels are masked and not used for reconstruction
- The current number of masked channels is 0.36% and masked cells (both channels masked) is 0.06%
- Repairs performed during the maintenance period decreased the fraction of masked channels/cells
- The large maintenannce period corresponds to the LHC long shutdown in 2013-2014

References

- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/...
  ...PublishedTilecalFigures ...ApprovedPlotsTileSingleParticleResponse
  ...TileCaloPublicResultsTiming ...ApprovedPlotsTileEnergyCalibration
  ...ApprovedPlotsTileUShape ...ApprovedPlotsTileDetectorStatus
  ...ApprovedPlotsTileElectronics ...ApprovedPlotsTileCalibration

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