Performance of the special C10 cells of the Tile Calorimeter of the ATLAS detector during Run 2 data taking period

Test

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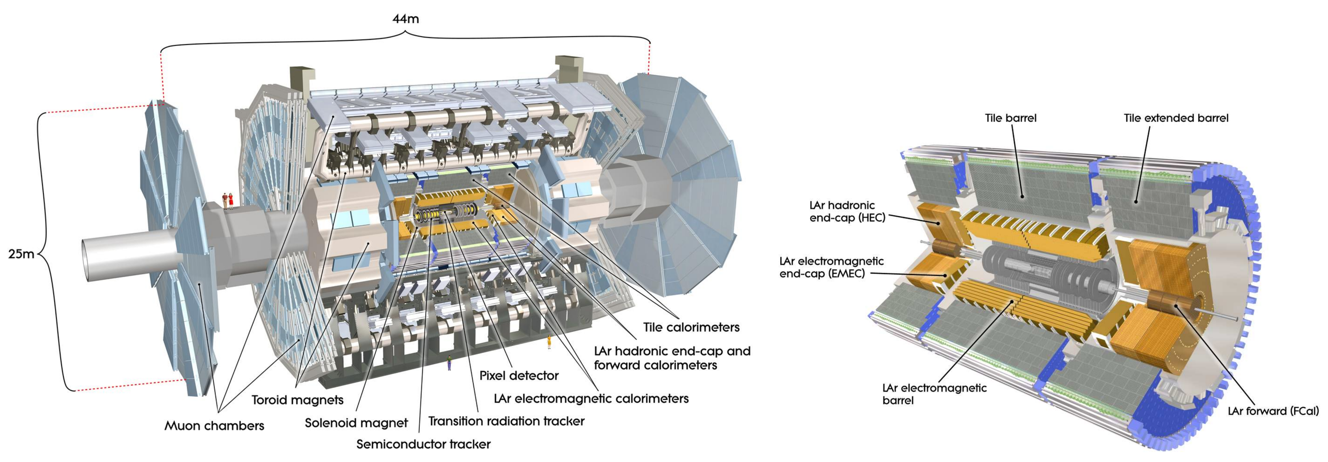
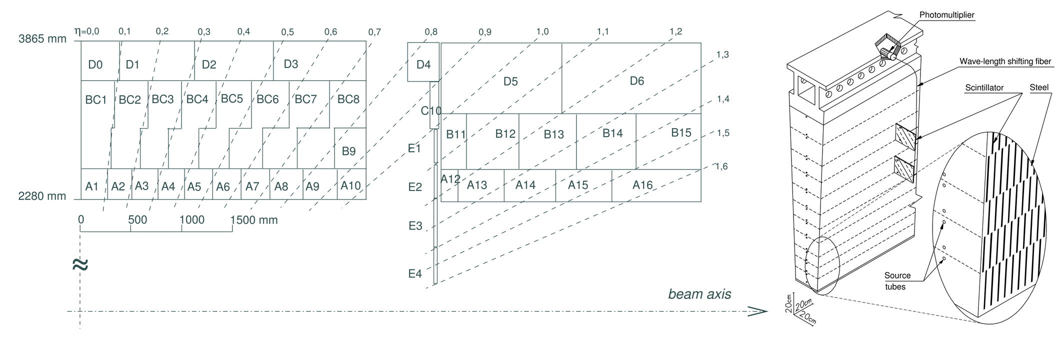
The ATLAS detector

- The detector layout is typical for a collider detector
- Tracking detectors measure the position of crossing charged particles
- Calorimeters measure the energy carried by particles



Tile Calorimeter

- Plays an important role in the reconstruction of hadrons, jets, τ-lepton hadronic decays and missing transverse energy
- Sampling calorimeter made of tiles of plastic scintillators sandwiched between steel plates
- Divided into three segments along the beam axis. One central barrel and two extended barrels on either side of the central barrel
- The barrels are segmented into 64 wedge shaped modules in ϕ corresponding to $\Delta\phi = 0.1$ granularity



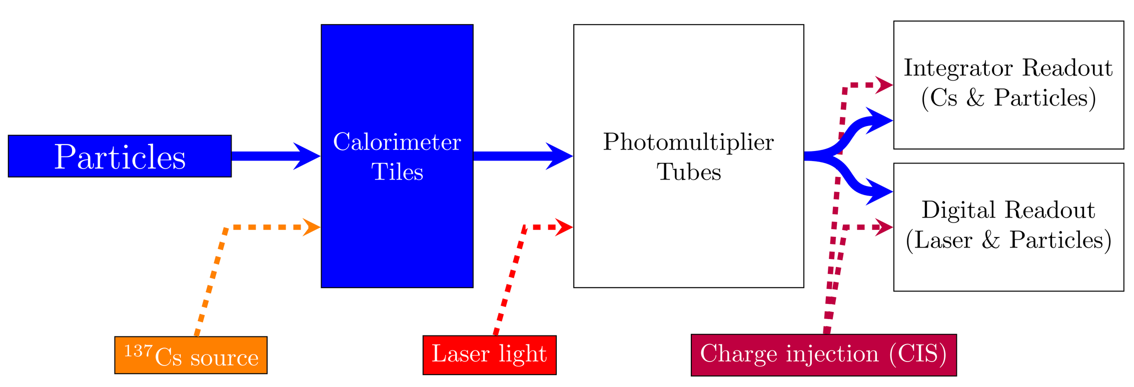
- The ϕ and η segmentation define the cell structure of the Tile Calorimeter (TileCal)
- Light produced when a charged particle traverses through a cell is collected by wavelength-shifting fibres and then transported to photomultiplier tubes (PMTs)

Calibration chain

- The conversion of analogue PMT signal to units of energy in GeV is determined using the following formula:

$$E[\text{GeV}] = \frac{A[\text{ADC}]}{f_{\text{pC}\rightarrow\text{GeV}} \cdot f_{\text{Cs}} \cdot f_{\text{Las}} \cdot f_{\text{ADC}\rightarrow\text{GeV}}}, \quad (1)$$

where f is a set of calibration constants. $f_{\text{pC}\rightarrow\text{GeV}}$ is determined in dedicated electron and muon test beam analyses



Three calibration systems are used to monitor the signal reconstruction

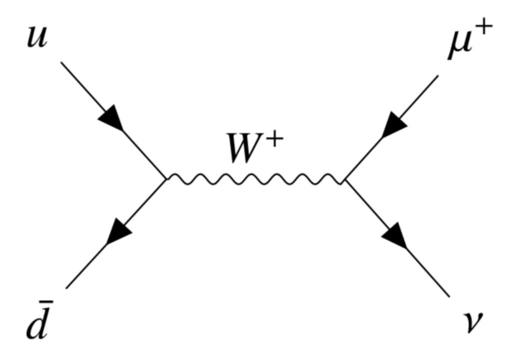
- The Caesium (Cs) calibration uses ^{137}Cs source to monitor the response to the optical and electrical response of each PMT
- Laser calibration system is used to monitor and correct for PMT response variations in between Cs scans and to monitor timing during data taking periods.
- The charge injection system is responsible for calibrating the frontend electronics

How do we check our calibrations?

- Interactions of muons with matter are a well understood process.
- Ionization is the primary energy loss mechanism for muons with energies below 100 GeV
- The cell's response to passing muons can be characterized by dE/dx, where dE and dx are the deposited energy and the path length, respectively
- By studying the response of the cells, we can identify and quantify any residual systematics

Event Selection and Data Sets

- Muons originating from the decay of a W boson to a muon and muon neutrino are used to study the response



	Variable	Run 2 Requirement
1	Number of Muons	$N_{\text{muons}} = 1$
2	Transverse invariant mass	$40 < M_T < 140$ GeV
3	Missing transverse energy	$30 < E_T^{\text{miss}} < 120$ GeV
4	Track isolation	$\sum p_T\|_{\Delta R=0.4} < 1$ GeV
5	Calorimeter isolation	$E_{\text{LAr}}\|_{\Delta R=0.4} < 1.5$ GeV
6	Momentum of the muon	$20 < p^\mu <= 80$ GeV
7	Transverse momentum of the muon	$p_T^\mu > 28$ GeV

- Data from proton-proton collisions collected during the LHC Run 2 data taking at $\sqrt{s} = 13$ TeV is used
- SHERPA was used to simulate W boson production and then interfaced with PYTHIA8 for parton showering

What makes c10 special?

- The region occupied by the C10 cells is between $0.9 < |\eta| < 1.0$ of the TileCal
- The special geometry accommodates services and read-out electronics for other ATLAS detector systems

Analysis procedure

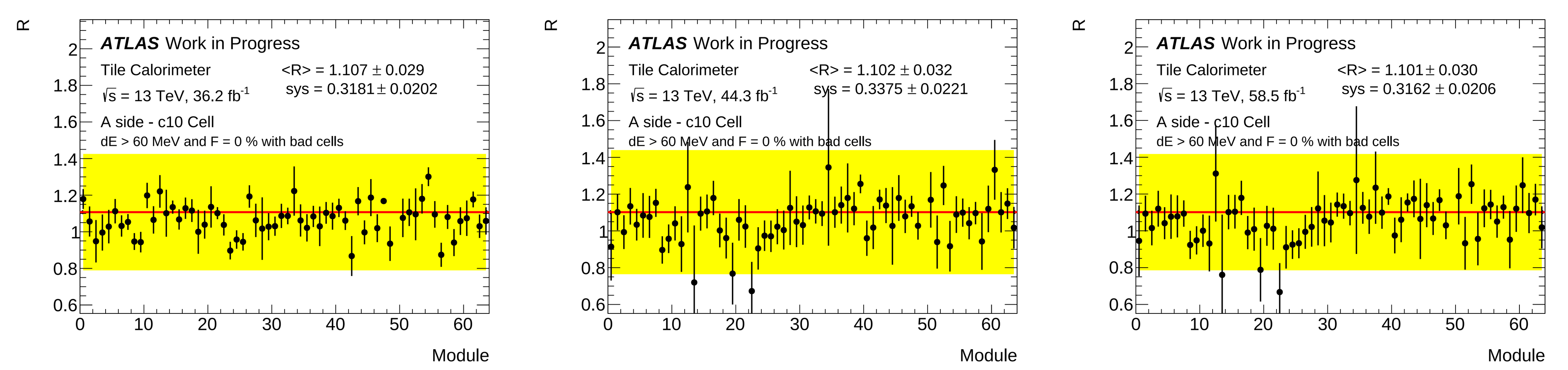
- The response of the cells given by the double ratio $R \equiv \frac{<dE/dx>^{\text{Data}}_{F=1\%}}{<dE/dx>^{\text{MC}}_{F=1\%}}$
- The events are truncated to minimise the effect of rare energy loss processes, such as bremsstrahlung or energetic δ rays.
- A Gaussian likelihood function is defined for a cell c in a module m:

$$\mathcal{L}_c = \prod_{m=1}^{64} \frac{1}{\sqrt{2\pi}\sqrt{\sigma_{c,m}^2 + s_c^2}} \exp\left[-\frac{1}{2}\frac{(R_{c,m} - \mu_c)^2}{\sigma_{c,m}^2 + s_c^2}\right], \quad (2)$$

where $R_{c,m}$ and $\sigma_{c,m}$ are the observed R and its statistical uncertainty for a given cell in module m.

- The $-\log\mathcal{L}$ is minimised find $R_{c,m}$ and σ_c which are the $< R >$ and the systematic uncertainty attributed to the non-uniformity across the modules.

Results



- The red lines represents the fitted average response and the yellow band is the systematic uncertainty
- $\int\mathcal{L} = 36.2$ fb-1, $\int\mathcal{L} = 44.3$ fb-1 and $\int\mathcal{L} = 58.5$ fb-1 correspond to the 2015+2016, 2017 and 2018 data taking periods, respectively.
- The possible cause of the drift in response might be due to factors like PMT drift response and ageing effects of the scintillators and wavelength shifting fibres
- The results are similar for the C - side of the detector.

Conclusions and Future Work

- The average response of the c10 cell response over time across all modules has be constant, showing only small deviations.
- The source of the large systematics band is an ongoing study