Energy scale validation and inter calibration of the ATLAS TileCal using Run-2 cosmic rays data -LHCC 2019-

The ATLAS experiment records data from the proton-proton collisions produced by the Large Hadron Collider (LHC). The Tile Calorimeter is the hadronic sampling calorimeter of ATLAS in the region |η| < 1.7. It uses steel absorbers and scintillators as the active material. Cosmic ray data are used to validate the energy reconstruction and calibration in different layers and regions of the Tile calorimeter cells, complementing the collision data. The cosmic muon data collected in 2015 is used in this study.

ATLAS detector

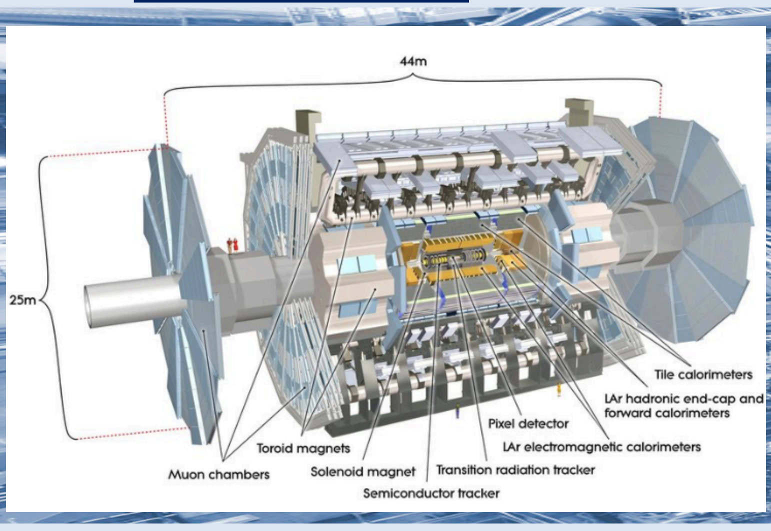


Fig. 1: ATLAS detector (Ref1)

- The ATLAS detector is a multipurpose detector in the Large Hadron collider,
- It has three main sub-systems: the Inner Detector, the calorimeters and the Muon Spectrometer.

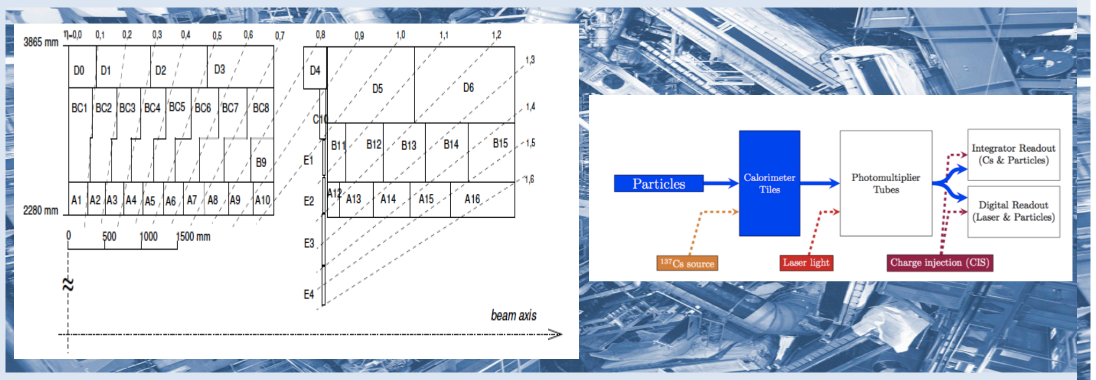


Fig. 2: TileCal cell map (Long Barrel and Extended Barrel) and TileCal calibration chain (Ref1)

- The TileCal contains several calibration systems, namely: Cesium system, Laser system and Charge Injection System.
- The Cesium system is used to calibrate the entire signal chain and it checks the quality of optical component.
- The Laser system carries out the calibration of PMTs gains and the readout electronics.
- The Charge Injection System is used to calibrate the readout electronics.

Data acquisition method and events selection

Cuts
All Events
μ ==1
nPSHits
$\|d_0\| \leq 380$
$\|z_0\| \leq 800$
$10<P_\mu<30$
Loop over Cells
dE > 60
$\Delta\phi(\mu, cell) < 0.05$
$dx_\mu > 200$

- The ATLAS detector consists of a hardware-based Level 1 (L1) and a software-based high-level trigger (HLT).
- Muon selection used in this studies relies on L1 trigger.
- Exactly one combined reconstructed muon is required (Inner Detector + Muon Spectrometer).
- At least 8 hits in Pixel and SCT to enhance the quality of extrapolation (from SCT and Pixel Detector) used in constructing Muon trajectories.

- $|d_o| \leq 380$ mm and $|z_0| \leq 800$ mm: To ensure the reconstructed tracks follow the projective geometry of the calorimeter.
- $10 < P_\mu < 30$ GeV: To reduce the effect of muon radiative energy losses in the detector and error from multiple scattering.
- $\Delta\phi(\mu, cell) < 0.05$: This region ensures each cell and the muon track are fully contained.
- Muon Path $(dx) > 200$ mm: To reduce noise contribution to the signal.

Cell Response vs Track phi

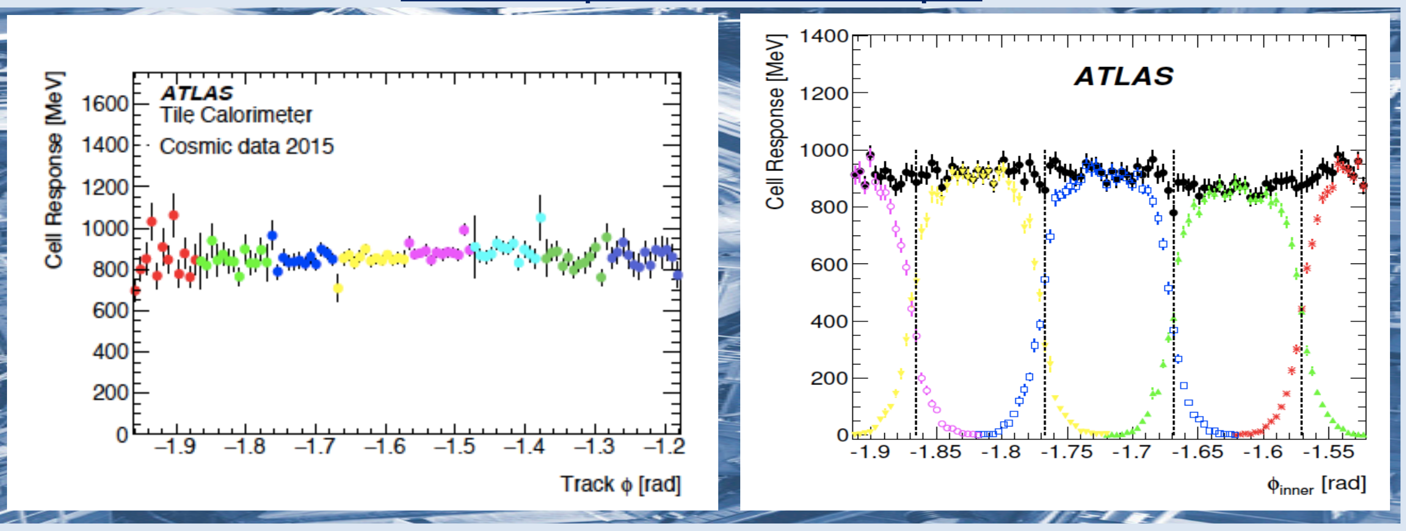
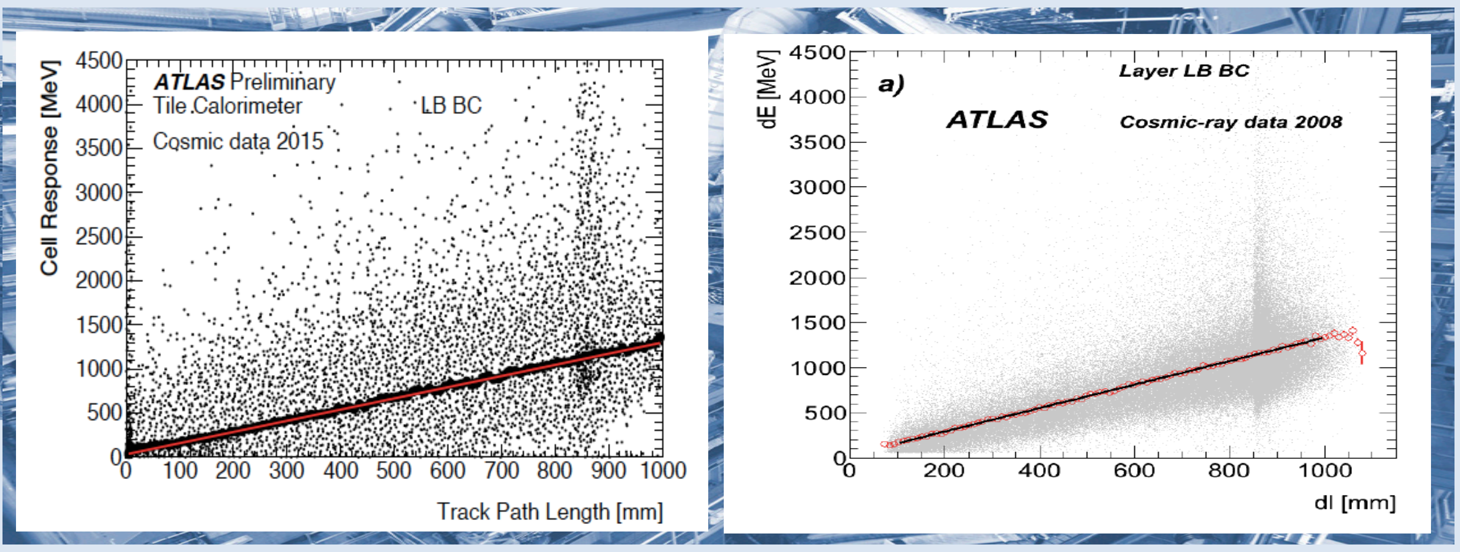


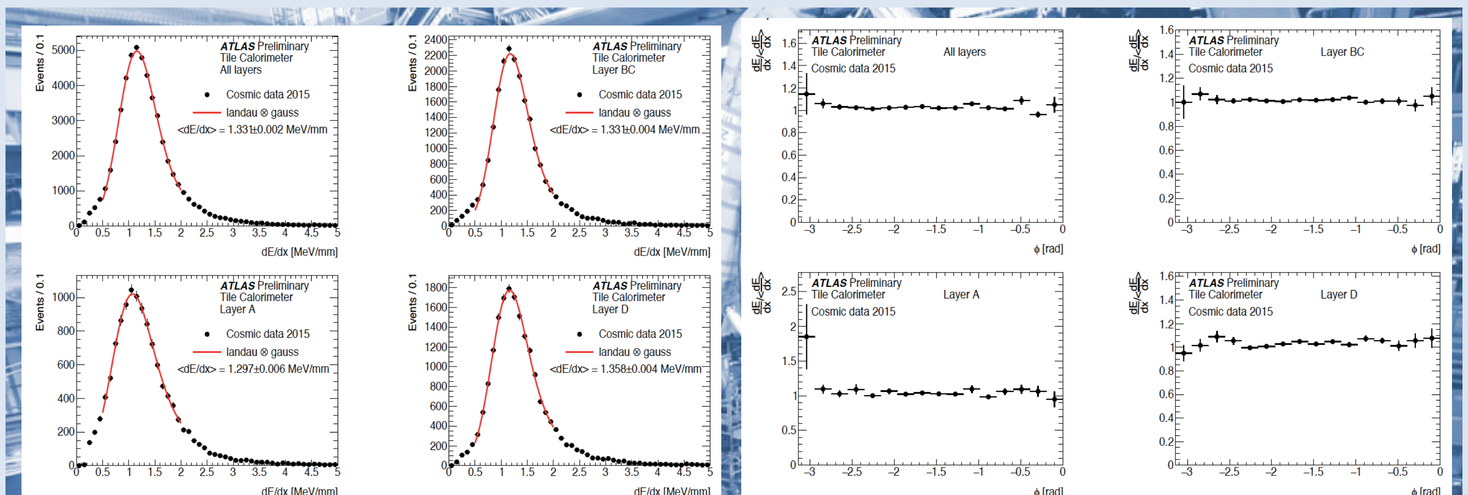
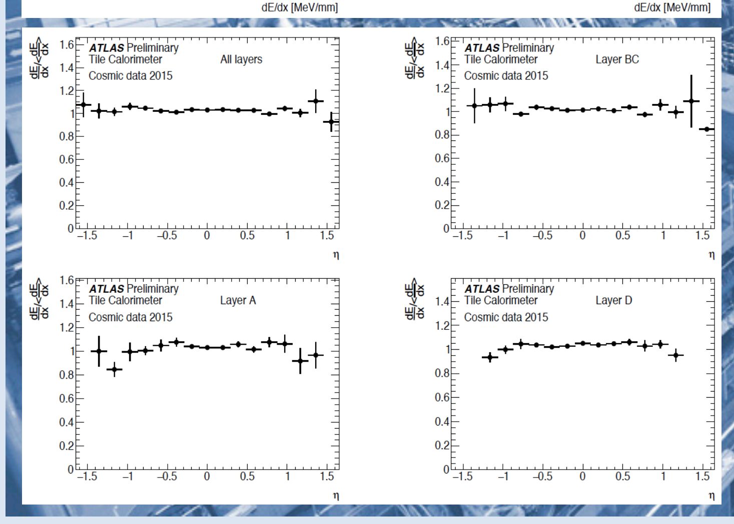
Fig. 4: Cell response vs muon track phi 2015 (Left) 2008 (right, Ref2)

- dx > 200 mm and dE > 60 MeV
- Individual module shown in different colors (see Fig. 4)
- A comparable result is obtained in 2015 and linearity is observed in the cell response



- Muon response scales linearly with path length.
- This shows dE/dx is a good quantity to be used to study the calorimeter inter-calibration.

dE vs dx and uniformity in different region of TileCal

Layer	$\langle dE/dx \rangle$ 2015
LB-A	1.297±0.006
LB-BC	1.331±0.004
LB-D	1.359±0.004
EB-A	1.291±0.071
EB-B	1.275±0.038
EB-D	1.350±0.051

Fig. 6: dE/dx in different TileCal region. Tab1: Mean of dE/dX for 2015

References

1. ATLAS Collaboration, Readiness of the ATLAS Tile Calorimeter for the LHC Collision, CERN-PH-EP-2010-024.
2. ATLAS Collaboration, Calibration of the ATLAS hadronic barrel calorimeter TileCal using 2008, 2009 and 2010 cosmic-ray muon data, ATL-TILECAL-PUB-2011-001.

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