The ATLAS Tile Calorimeter performance and its upgrade towards the High-Luminosity LHC

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The ATLAS Tile Calorimeter

- **The Tile-Calorimeter (TileCal)** is a sampling calorimeter which forms the central region of the Hadronic calorimeter of ATLAS;
- **Tilecal** is responsible for the measurement of jet- and missing-energy, jet substructure, and triggering (including muon information);
- **Modular** 256 wedge shaped modules arranged azimuthally around the beam axis make up TileCal. An individual module consists of alternating steel (absorber) tiles and plastic scintillating (Active media) tiles with a Super Drawer (SD) housing the Front-End (FE) electronics inside the Tile Module.
- **Particles produce light** when passing through the tiles.This light is then transmitted to Photo-Multiplier Tubes (PMTs) located in SDs via wavelength shifting fibres.

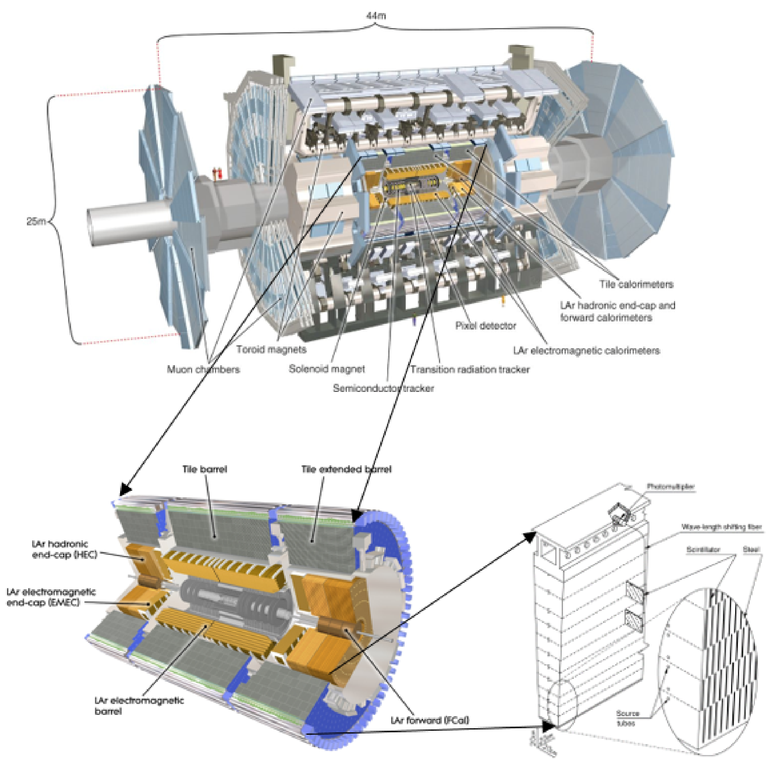

Fig. 1 Top - The ATLAS detector, Bottom left - The inner Barrel, Bottom right - A TileCal module.

Legacy Low-Voltage System

- **A 2-stage system;** in which Bulk 200VDC power is converted to the voltages required by the FE electronics by different types of Brick(Transformer coupled buck converter);
- **Provides ON/OFF control (Via Aux-boards)** of the bricks in two groups which start successively.

LV System Upgrade

- **Conversion to a 3-stage system** which makes use of Point-of-load regulators (POLs). POLs function to step-down the 10VDC received from an LVPS Brick to the voltage required by local circuits. This allows for the use of a single type of brick with a standardized 10V output;
- **Tri-state functionality** is being introduced which allows for individual Bricks startup/shutdown. This functionality is so named due to the Aux boards ability to send 3 different state signals to an LV Brick;
- **An extensive radiation** campaign is underway in order to validate LV system components operation within HL-LHC environment.

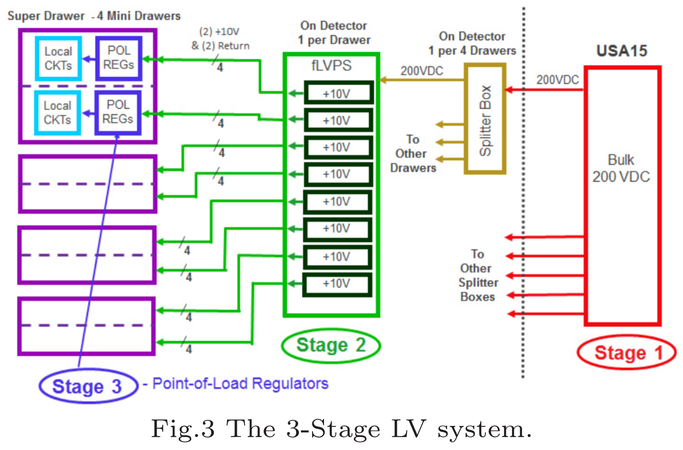

Fig.3 The 3-Stage LV system.

HL-LHC Tilecal Front-End

- **PMTs** convert light to electric signals.
- **Front-End electroNICS** (FENICS) boards perform signal shaping and amplification;
- **Mainboard** receives analogue data and converts it to digital data which is then sent to the Daughterboard;
- **Daughterboard** responsible for Data collection, formatting transmission to the Back-End and clock and command distribution to the Front-End.
- **Low-Voltage Power Supply (LVPS)** provides power to the FE electronics while also monitoring critical values such as its operating temperature and output voltages;
- **High-Voltage (HV) Power Supply** The Tile high voltage power control system supplies HV to the 10,000 PMTs in the system, control the voltage for each tube and monitor the applied voltage.

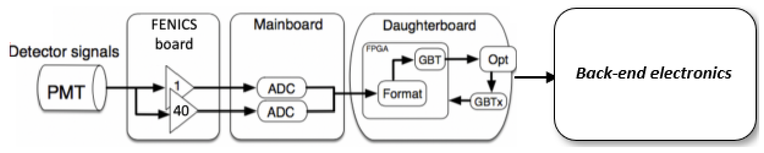

Fig. 2 HL-LHC Tilecal Front-end electronics.

Performance during Run-II

- The ratio of the calorimeter energy at EM scale to the track momentum ⟨E/p⟩ of single hadrons is used to evaluate both uniformity and linearity during data taking;
- Good agreement between Data and MC sim.

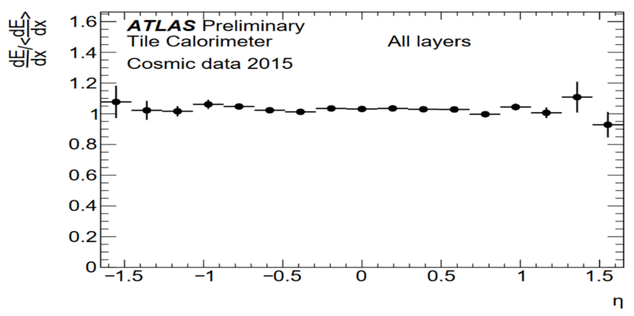

Fig. 4 Ratios of the truncated means of the distributions of the energy deposited in the layer cells by cosmic-ray muons per unit of path length dE/dx.

- Isolated muons from cosmic rays are used to study the EM scale in-situ EM as well as the cells inter-calibration;
- Cell response is evaluated as the energy deposited by the muon path length dE/dx;
- Non-uniformity in eta (η) below 5%;

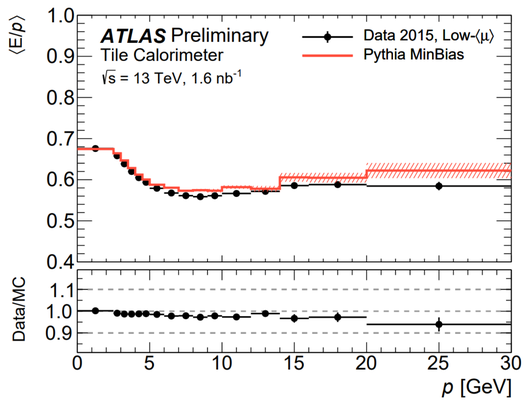

Fig. 5 Calorimeter response to single isolated charged hadrons.

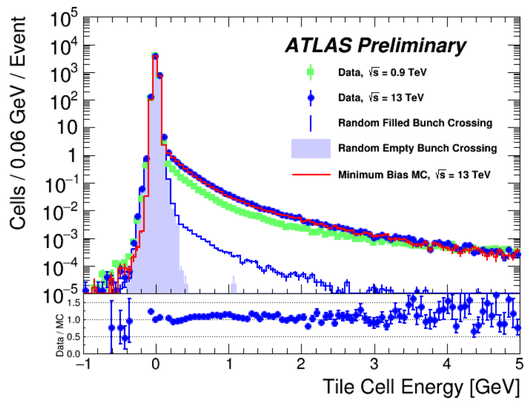

Fig. 6 Deposition of energy in TileCal cells for 0.9 and 13 TeV 2015 collision data, Minimum Bias MC, and randomly triggered events.

TileCal and the HL-LHC

- **The start of the operation of HL-LHC** is planned for 2027 with foreseen integrated luminosity of 4000 fb^{-1};
- **TileCal must be upgraded** to allow for continued high performance in the new HL-LHC environment.

A summary of the TileCal HL-LHC upgrade:

- **Readout, Front and Back end electronics are to be upgraded**;
- **Active dividers** are replacing passive dividers to provide better linearity for the HL-LHC;
- **10% of PMTs** to be Replaced in the most exposed regions;
- **Mechanical alterations** to the Super-Drawers structure;
- **The High Voltage system** is being upgraded to provide HV to PMTs with greater temperature and voltage stability, as well as remote/internal control;
- **The Low-Voltage system** is undergoing extensive upgrades;
- **The Calibration systems** are being upgraded with improvements to the stability and safety of the Cesium system as well as the Laser system receiving upgraded electronics and optical components;

Test-Beam Performance

- **Seven test beam campaigns** were carried out 2016 – 2018 with prototype FE electronics as well as prototype elements of the low/high voltage systems.
- **The test beams** show good performance of the new Front-End electronics;

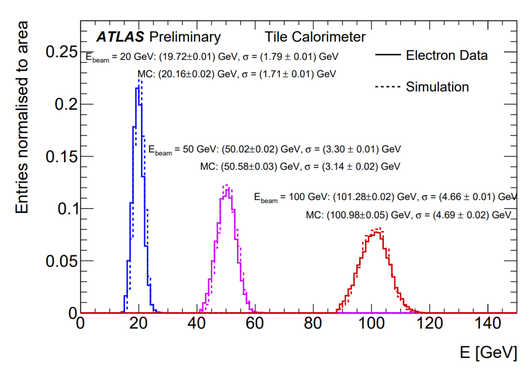

Fig.6 Distributions of the total energy deposited in the calorimeter obtained using electrons beams.

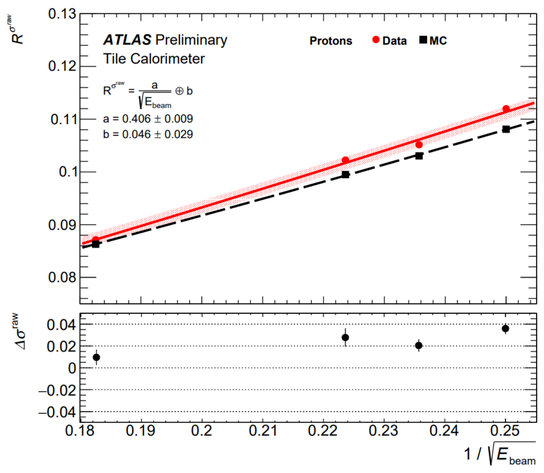

Fig. 7 Fractional resolution and predicted by Monte Carlo simulation obtained in the case of protons.

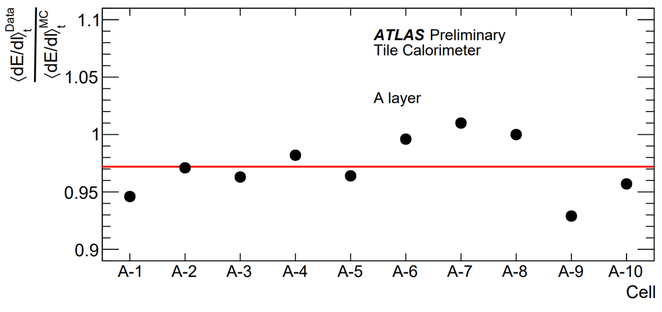

Fig. 8 Experimental and simulated muon data as a function of the cell number.

References:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

- /ApprovedPlotsTileTestBeamResults
- /ApprovedPlotsTile
- /ApprovedPlotsTileElectronics