Beam Tests on the ATLAS Tile Calorimeter Demonstrator Module

(1) Introduction

The High-Luminosity LHC (HL-LHC) will have an instantaneous luminosity of five times the nominal design value. The Phase-II upgrade program of ATLAS (figure 1c) Hadronic Tile Calorimeter (TileCal) [1] will compensate for the higher rates of pileup, higher radiation levels and the aging of the current electronics, by replacing the readout electronics to adopt a fully-digital trigger system that will provide full-granularity digital data to the off-detector systems. The new design will provide better timing and energy resolution, and less sensitivity to out-of-time pileup. The Demonstrator Project consists in prototype upgrade electronics that has been tested by exposing them in a calorimeter module to muons, electrons and hadrons at the CERN's Super Proton Synchrotron (SPS). In order to check the calibration and to determine the performance of the detector, data were collected with beams of various incident energies and impact angles. The measurements exploit the features of the interactions of the muons, electrons and hadrons with matter.

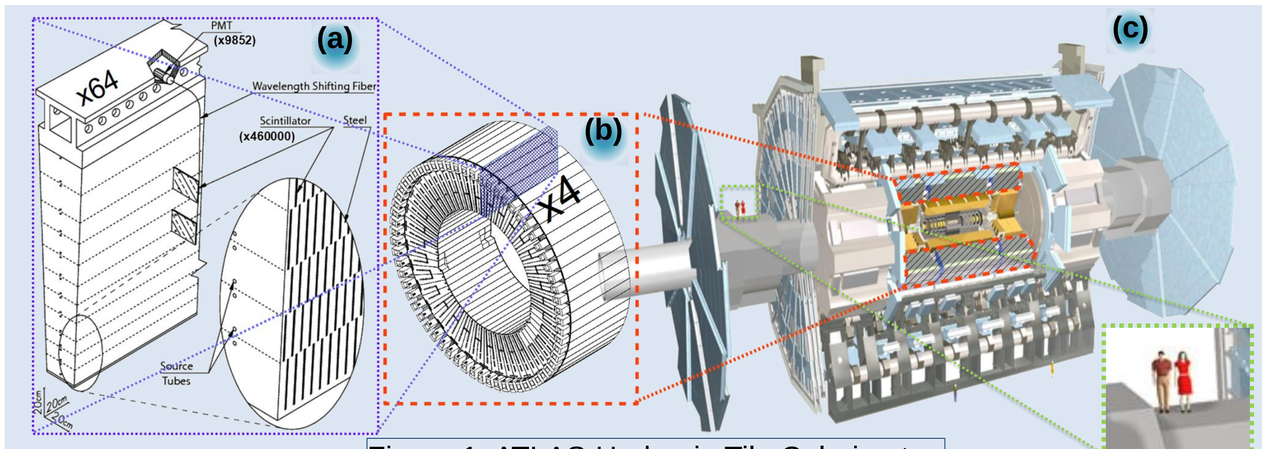

Figure 1: ATLAS Hadronic Tile Calorimeter

(2) ATLAS Hadronic Tile Calorimeter (Figure 1).

- ATLAS TileCal[2] is a sampling calorimeter composed of steel plates and approximately 460000 plastic scintillator tiles.
- TileCal is divided in four cylindrical barrels: the two central "long barrel" segments (LBA, LBC) and shorter "extended barrel" segments (EBA, EBC) at each end (figure 1b).
- Each cylindrical section is composed of 64 wedge-shaped modules
- The scintillators in each module are grouped in pseudo-projective cells module (figure 1a).
- Light from two sides of a cell is collected by wavelength shifting fibers and read out by two photomultiplier tubes (PMTs) (figure 1a).

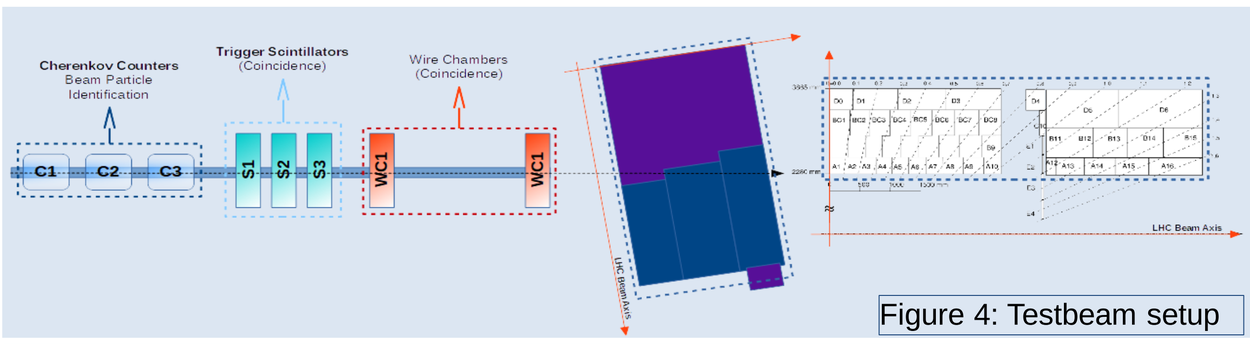

Figure 4: Testbeam setup

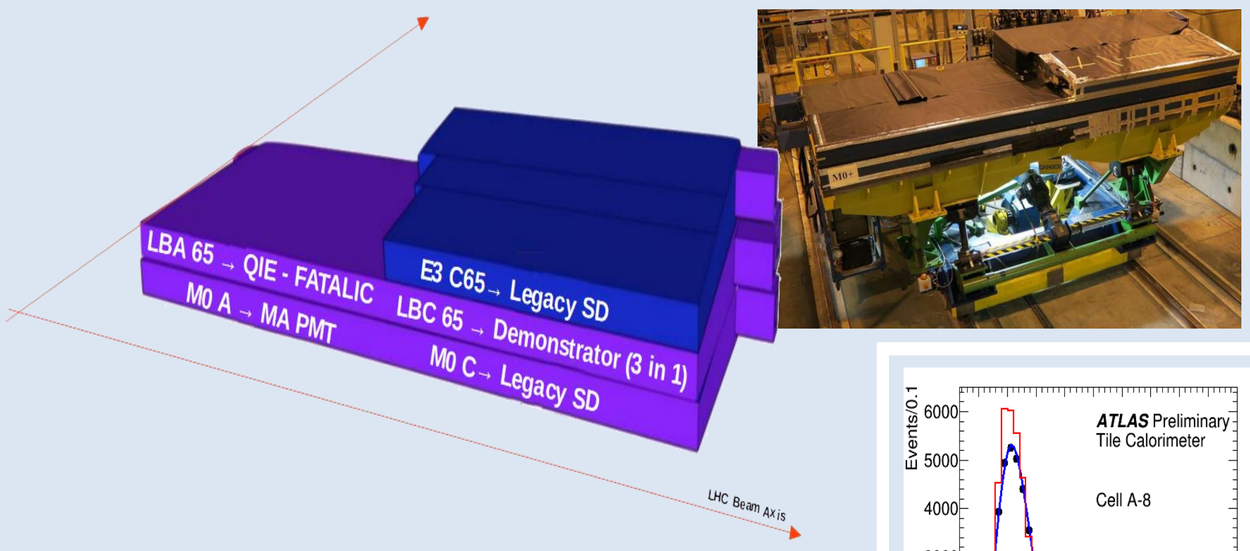

Figure 5: Module layout on the scanning table.

(5) Results [4] [5]

- Deposited muon energy follows a Landau distribution (figure 6a).
- Different reconstruction methods and different noise thresholds were implemented (figure 6b).
- For muons, the truncated mean of the distribution of 97.5% was used for the analysis, resulting in a ratio of data over simulation within 4% and layer uniformity of 1% (figures 6c, 6d, 6e).
- Demonstrator and Legacy system electron energy distributions agree (figure 7a).
- Electrons data and simulation agree nicely for all energies (figures 7b, 7c).
- Hadron response was estimated using Gaussian fit in the range ±2σ around peak value (figure 8a - for 30 GeV kaons)(figures 8b, 8c).
- Analysis of the calorimeter response as a function of the beam energy for hadrons resulted in higher response for pions and kaons than to protons (figures 8b, 8c).
- It was observed good agreement with Geant4 FTFP_BERT_ATLMC[4], which improves with increasing beam energy (figures 8b, 8c).

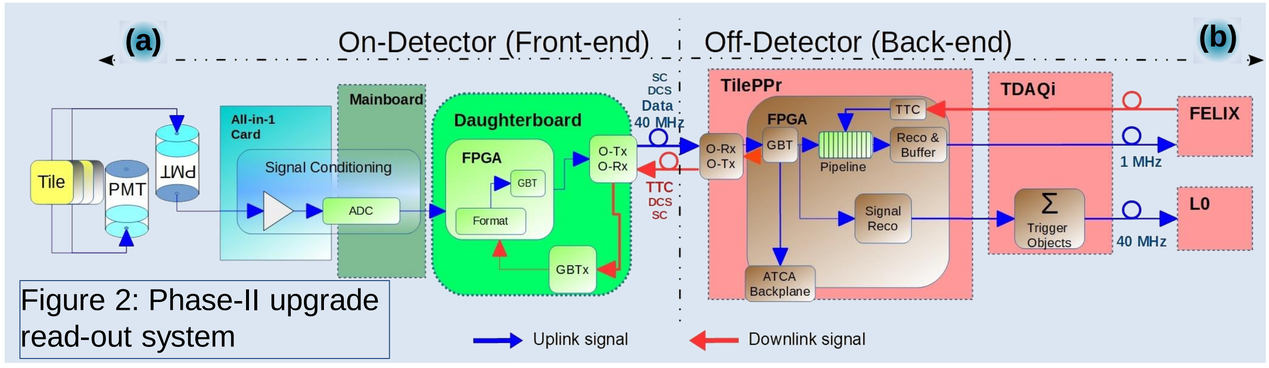

Figure 2: Phase-II upgrade read-out system

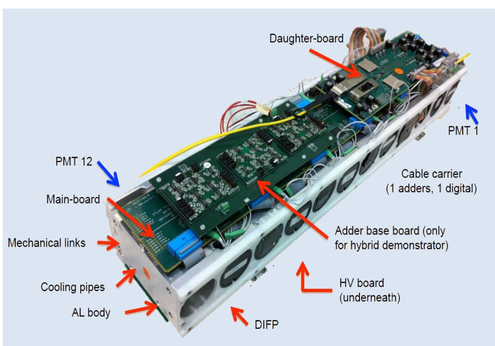

Figure 3: Demonstrator Minidrawer

(3) Demonstrator and read-out system [1].

- Phase II read-out system (figure 2) samples TileCal at 40 MHz.
- A Superdrawer (SD) is composed by 4 Minidrawers (MDs) (figure 3)
- Each MD serves up to 12 PMTs.
- Front-end boards (FEB) shape and condition the PMT signals (3 alternatives were under test).
- A Mainboard (MB) digitizes 2 gains of FEB signals at 40 Mhz (figure 2a).
- A Daughterboard (DB) provides the interface between the MB and the off-detector systems by receiving timing and slow control commands and transmitting data over redundant fiber-optic links (figure 2a).
- A Tile Preprocessor receives and stores in pipelines two gains of PMT data from the DB until a trigger decision event while providing reconstructed data to the trigger, all at 40 MHz (figure 2b).
- Given a trigger event, the data is read out by the FELIX system (figure 2b).

(4) Testbeam setup and module layout on the scanning table [3].

- Beam elements (figure 4):
  - Cherenkov counters for beam particle identification.
  - Scintillators in coincidence.
  - Wire chambers.
- The testbeam setup accommodates up to 5 SDs (figure 5):
  - The Demonstrator super-drawer was equipped with the 3-in-1 FE upgrade option and mounted in LBC 65.
  - LBA 65 was populated with the ASIC alternatives (FATALIC/QIE).
  - M0 C and EBC 65 were equipped with the Legacy SD system.
  - M0 A was equipped with Multi-Anode (MA) PMTs for special tests.

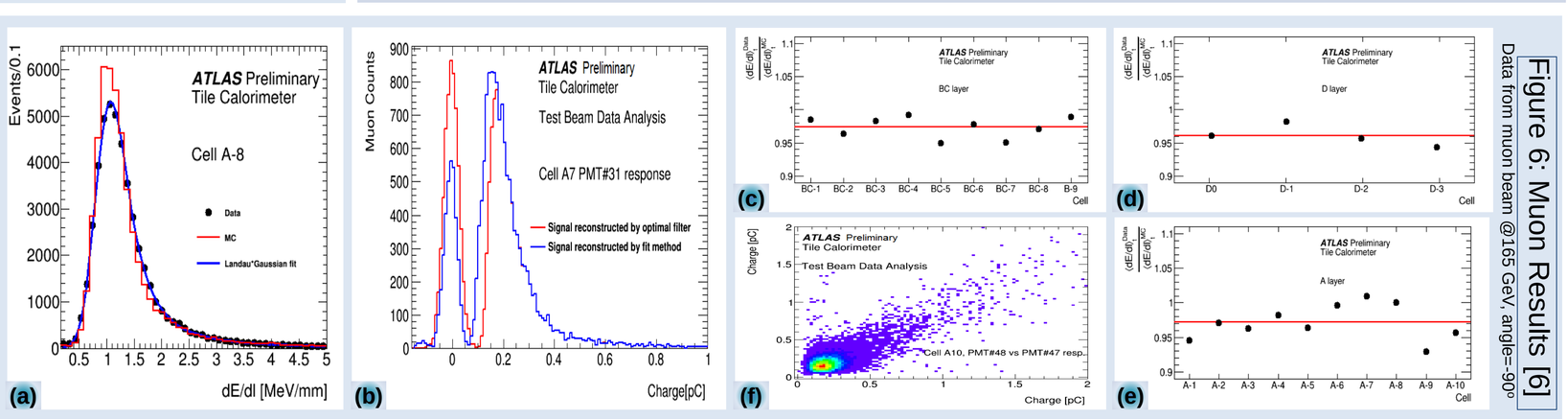

Figure 6: Muon Results [6]
Data from muon beam @165 GeV, angle=-90°

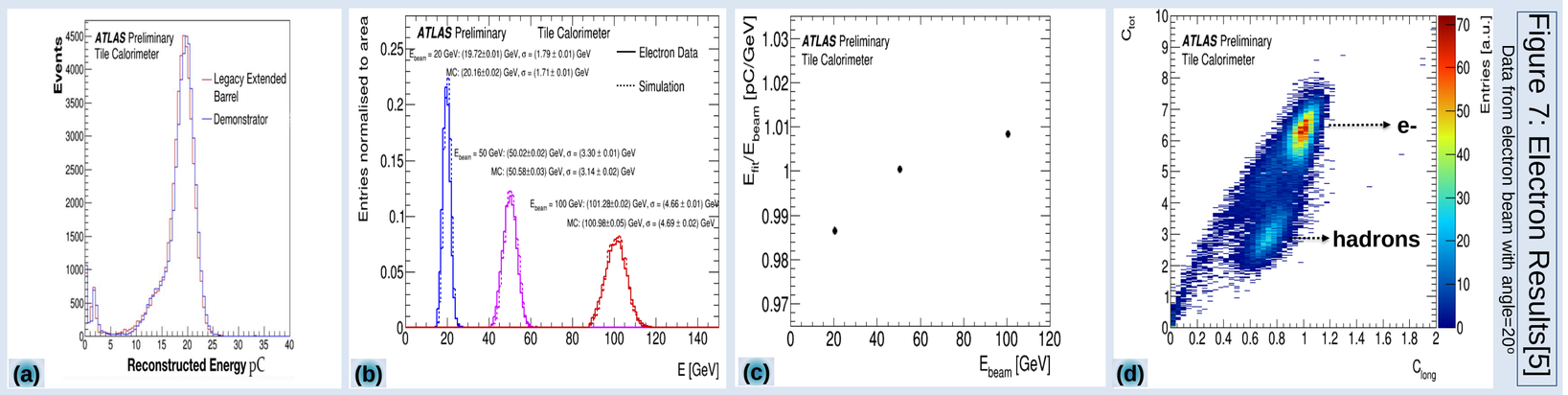

Figure 7: Electron Results[5]
Data from electron beam with angle=20°

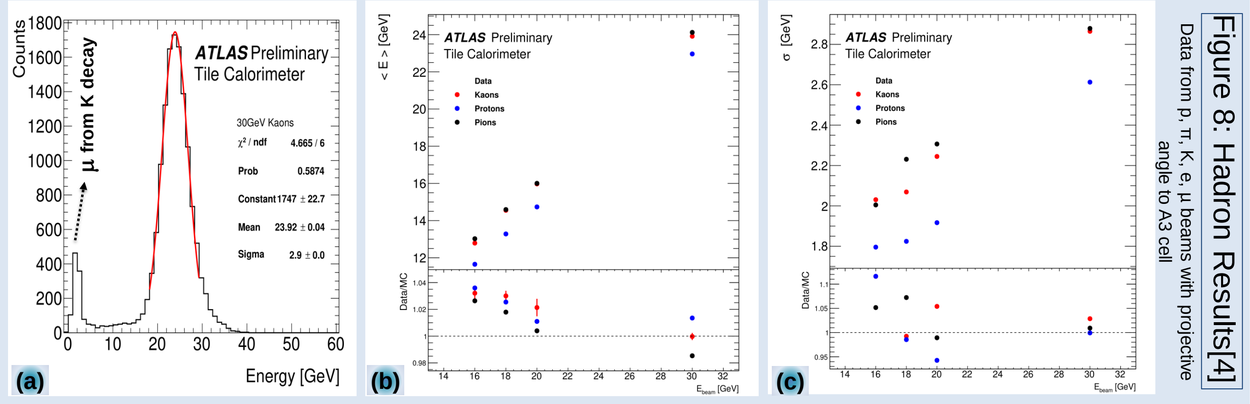

Figure 8: Hadron Results[4]
Data from p, π, K, e, μ beams with projective angle to A3 cell

(6) Outlook.

- Five testbeam campaigns of 2 weeks between 2015 and 2017 with three detector modules equipped with different readout systems resulting in a good performance of new electronics, and agreement with calibration and simulated data. Two more testbeams are scheduled during May and November 2018 following more integration with old and new revisions of the Phase-II upgrade hardware, mechanics and electronics.

(7) References.

[1] E. Valdes, ATLAS Collaboration, **Upgrade of Tile Calorimeter of the ATLAS Detector for the High Luminosity LHC,** in Journal of Physics: Conference Series, Volume 928, 2017.

[2] ATLAS collaboration. **ATLAS tile calorimeter: Technical design report.** *CERN-LHCC-96-42*, 1996.

[3] A. Valero, ATLAS Collaboration **Data acquisition and processing in the ATLAS tile calorimeter phase-II upgrade demonstrator,** Journal of Physics Conference Series, Volume 898, 2017.

[4] Cecella, ATLAS Collaboration, **ATLAS TileCal Performance Meeting**, **ATL-COM-TILECAL-2009-001,** 2009.

[5] T. Mkrtchyan, P. Pani, ATLAS Collaboration, **ATLAS TileCal Performance Meeting**, **ATL-COM-TILECAL-2018-002,** 2018.

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