Performance of the Tile Calorimeter Demonstrator system for the ATLAS Phase-II Upgrade

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The High Luminosity Large Hadron Collider (HL-LHC) will deliver five times the LHC nominal instantaneous luminosity, after a series of upgrades that will take place during the shutdown of 2024 -2026. The ATLAS Hadronic Calorimeter (TileCal) (Figure 1) will require the complete replacement of the readout electronics in order to accommodate its acquisition system to the increased radiation levels, trigger rates, and high pile-up conditions during the HL-LHC era. The upgraded readout electronics will digitize the PMT signals from every. TileCal cell for every bunch crossing and will transmit them directly to the off-detector electronics. In the counting rooms, the off-detector electronics will store the calorimeter signals in pipelined buffers while transmitting reconstructed trigger objects to the first level of trigger at 40 MHz. The Demonstrator module has been assembled and is being operated and read out using a prototype of Tile PreProcessor (TilePPr) which also permits integrating the Demonstrator module into the present ATLAS TDAQ system. This contribution presents the status and performance of the Demonstrator module in the ATLAS experiment.

ATLAS Tile Calorimeter

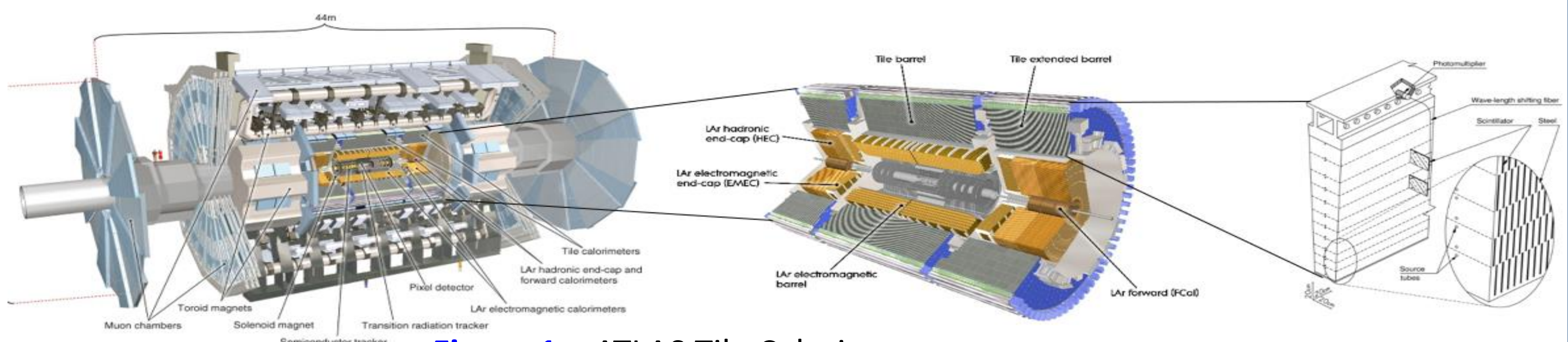

Figure 1 – ATLAS Tile Calorimeter structure

- Two barrel and two extended barrel modules, each consists of 64 detector wedges.
- Sampling hadronic calorimeter, iron as absorber and plastic scintillator as active material.
- Scintillation light is collected to photomultiplier tubes (PMTs) through wavelength shifting fibers and a total of ~10,000 PMTs are used.

Phase-II Upgrade Demonstrator and readout chain

- Demonstrator module used to evaluate the new readout electronics while preserving compatibility with the current system.
- The **Demonstrator system** [1] will continuously sample data of **two digitized gains** of up to 48 TileCal PMTs at **40 MHz** (Figure 2)

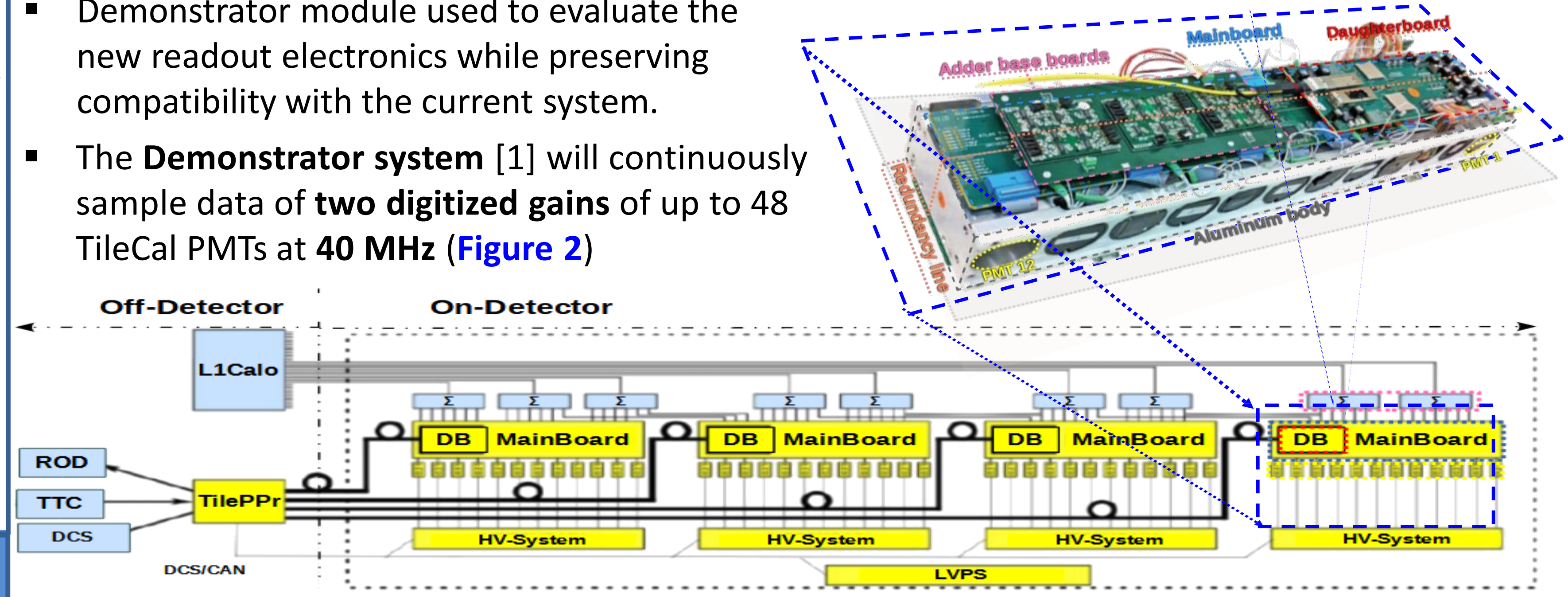

Figure 2 – Demonstrator module readout chain

- The Demonstrator modularizes a legacy TileCal Drawer in four **Mini-drawers (MDs)**, each **MD** (Figure 2) serves up to **12 channels** by means of:
  - **12 Photomultiplier (PMTs)** to turn light pulses to electric signals.
  - **12 Front-End Boards (FEBs)** to shape and condition the PMT signals.
  - An **Adder based board** to group the PMTs in cell pseudo-projective towers and send analogue sums to the legacy **L1 Calo** trigger system.
  - **Mainboard (MB)** to continuously sample and digitize **two gains** of PMT signals.
  - **a Daughterboard (DB)** to distribute **LHC synchronized timing**, configuration and control to the front-end, and **continuously read-out** of the digital data from all the MB channels to the off-detector systems via multi-Gbps optical links.
  - The data is sent off-detector to be stored in pipelines, reconstructed and triggered-out by **Tile Preprocessors (TilePPr)** that receives previous **legacy TTC (Timing Trigger and Control)** commands and triggers, **DCS (Detector Control Systems)** commands, and sends the triggered data to the legacy **ROD (Read Out Driver).**

Demonstrator status and test results

- For accurate cell energy reconstruction, the Demonstrator was used together with the entire TileCal for taking calibration and data quality runs. The main objectives for Demonstrator data analysis are: (i) pedestal stability over long periods (Figure 3), (ii) stability of the noise, (iii) stability of the timing in Laser runs and (iv) PMT Response variation.

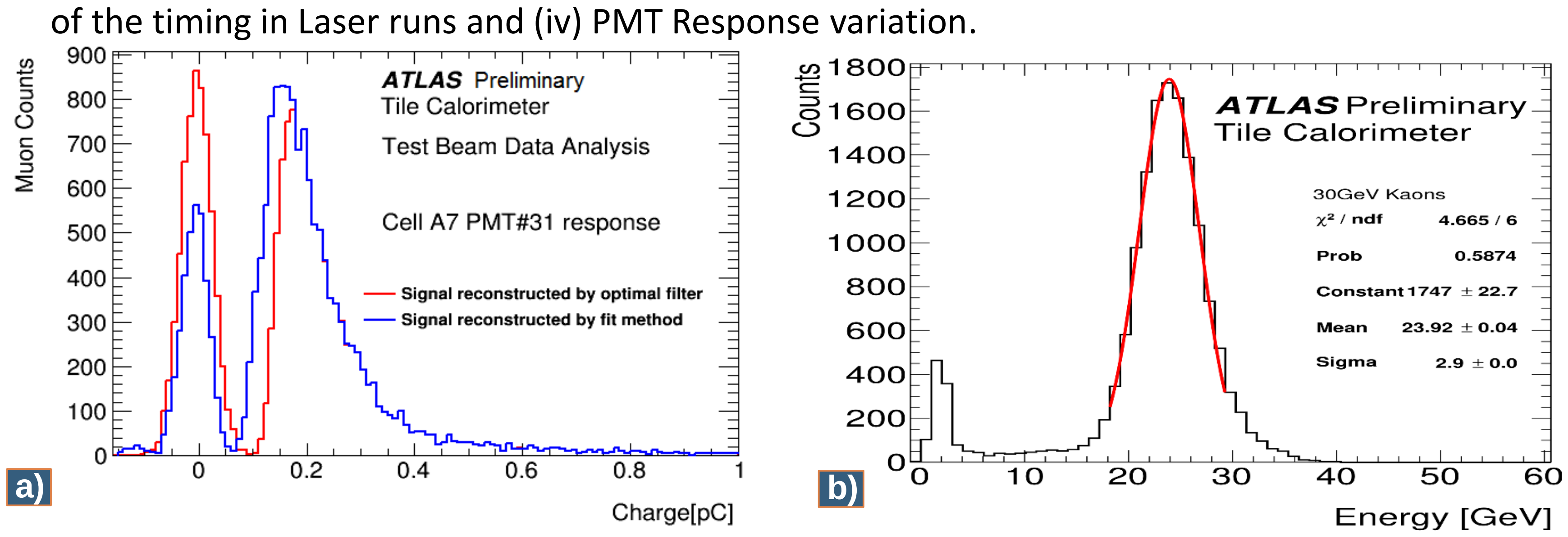

Figure 3 – Demonstrator performance exemplification during test-beam campaigns; a) reconstructed muon signals and b) measured energy for 30 GeV Kaons

- **Pedestal tests** showed slightly **lower noise in the demonstrator for April run 2021** (Figure 4).
- The **Demonstrator readout** was **fully integrated in the TDAQ software** with **very stable links.** (Figure 5)

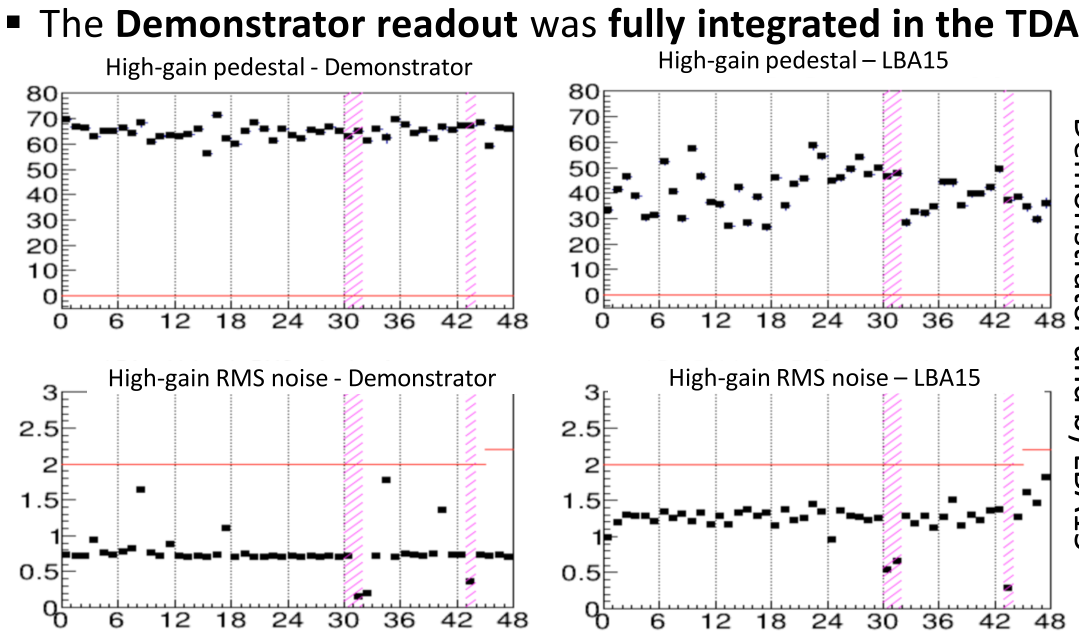

Figure 4 – Average pedestal and pedestal noise for the a) Demonstrator and b) LBA15

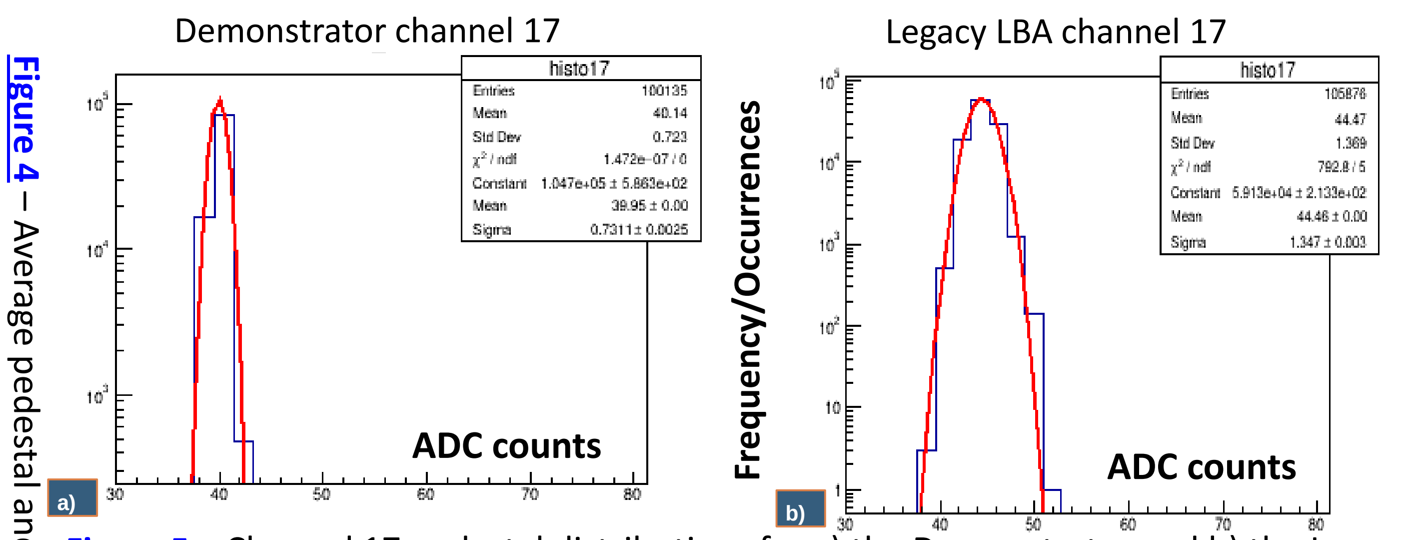

Figure 5 – Channel 17 pedestal distributions for a) the Demonstrator and b) the Legacy

- Correlations for pedestal measurements in-between all 12 channels within mini-drawers MD1, MD2, MD3 a Reduced correlation coefficients show that no linear association exists between pedestal measurements and MD4 were performed (Figure 6) for mini-drawer channels sharing the same electronics.

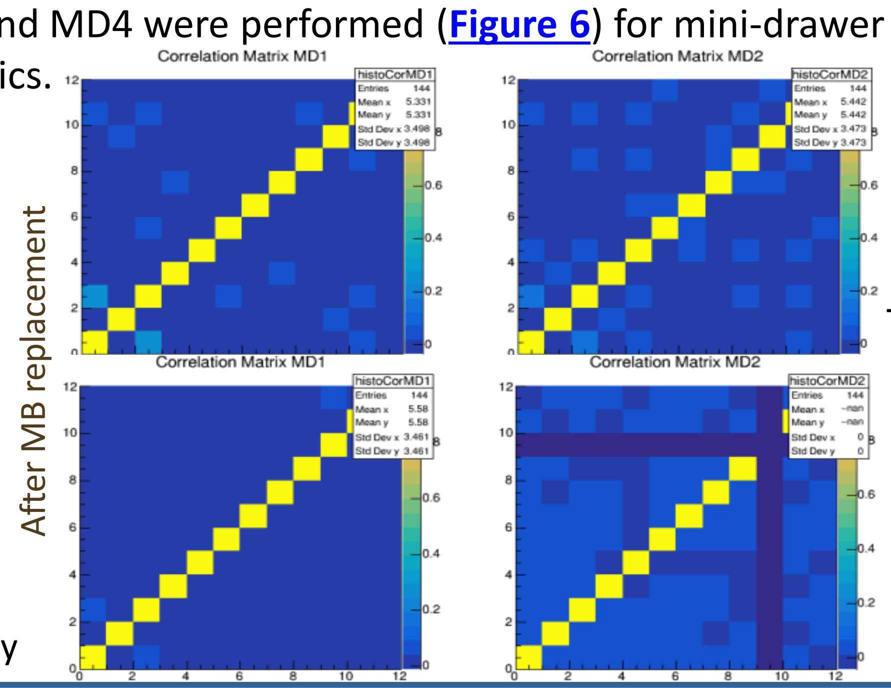

Figure 6 – Correlation analysis for the Demonstrator pedestal distributions

Conclusion

Replacement of MBs and fixing noisy channels was completed for the Tile demonstrator module and is now fully integrated with the TileCal TDAQ system. The Demonstrator timing was adjusted by CIS and laser, and the integrator pedestals tests with L1Calo showed no noisy towers. The Demonstrator data acquisition runs which included a new optimized TilePPr firmware have taken place without data losses. The pedestal analysis showed better performances compared with the legacy system.

References

1. ATLAS collaboration. Technical Design Report for the Phase-II Upgrade of the ATLAS Tile Calorimeter. CERN-LHCC- 234 2017-019, ATLAS-TDR- 028, 2018.
2. Upgrade of Tile Calorimeter of the ATLAS Detector for the High Luminosity LHC. Journal of Physics, DOI:10.1088/1742- 6596/928/1/012024, 2017.
3. Beam tests on the ATLAS Tile Calorimeter Demonstrator Module,-175281,10.1016/j.nima.2018.10.066

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