

ATLAS Hadronic Tile Calorimeter Demonstrator system

For the High-Luminosity LHC era.

22nd IEEE Real Time Conference

Introduction (Abstract)

The High Luminosity **Large Hadron Collider (HL-LHC)** will have a peak luminosity of $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, five times higher than the design luminosity of the LHC. The hadronic **ATLAS Tile Calorimeter (TileCal)** (Figure 1) [1] is a sampling calorimeter with steel as absorber and plastic scintillators as active medium. The light produced in the scintillating tiles is guided to photomultiplier tubes (PMTs), where analog signals are produced to be shaped and conditioned before being digitized every 25 ns. **TileCal Phase-II Upgrade for the HL-LHC** will allow the system can cope with the **increased radiation levels** and **out of time pileup**. The upgraded system will **digitize and send all the calorimeter sampled signals to the off-detector systems**, where the **events will be reconstructed and shipped to the first level of trigger**, all at **40 MHz rate**. Consequently, development of more complex trigger algorithms will be possible with the more precise calorimeter signals provided to the trigger system. The new hardware comprises **state of the art electronics** with a **redundant design** and **radiation hard electronics** to avoid single points of failure, in addition to **multi-Gbps optical links** for the high volume of data transmission and Field Programmable Gate Arrays (FPGAs) to drive the logic functions of the off- and on-detector electronics. A **hybrid demonstrator prototype** module containing the new calorimeter module electronics, but still compatible with the present system was assembled and **inserted in ATLAS** during June 2019, so that the **Phase-II system can be tested in real ATLAS conditions**.

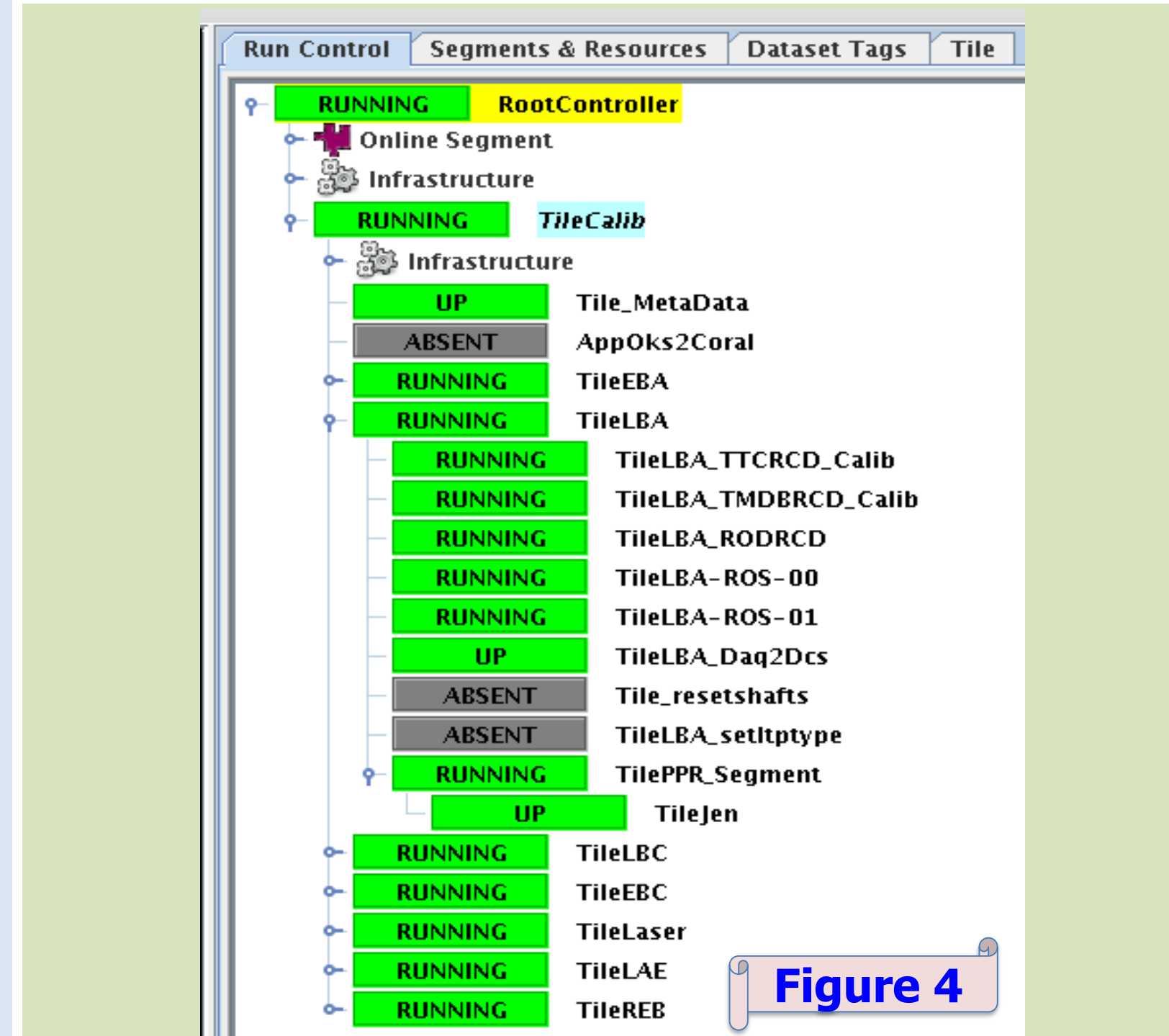
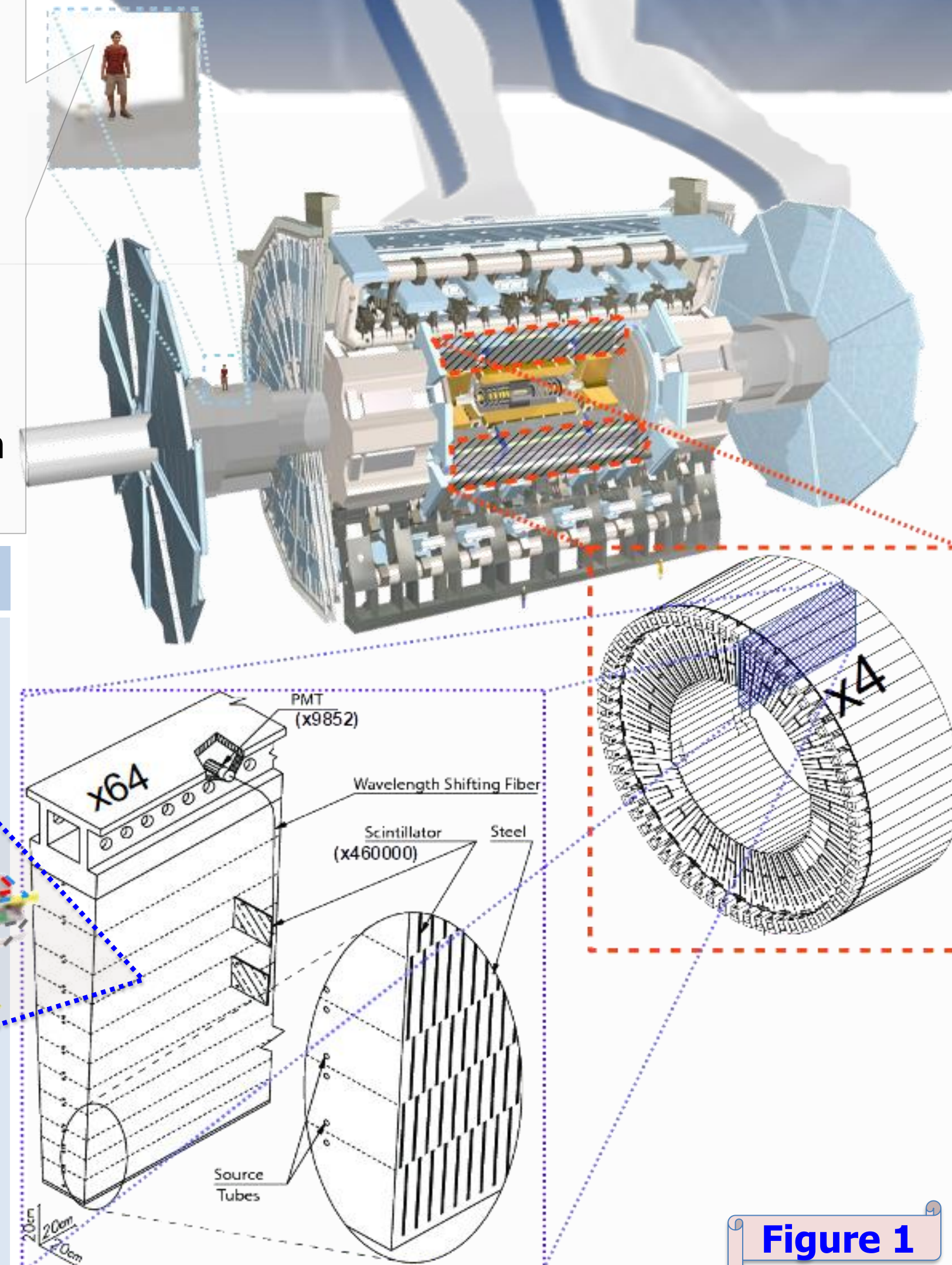
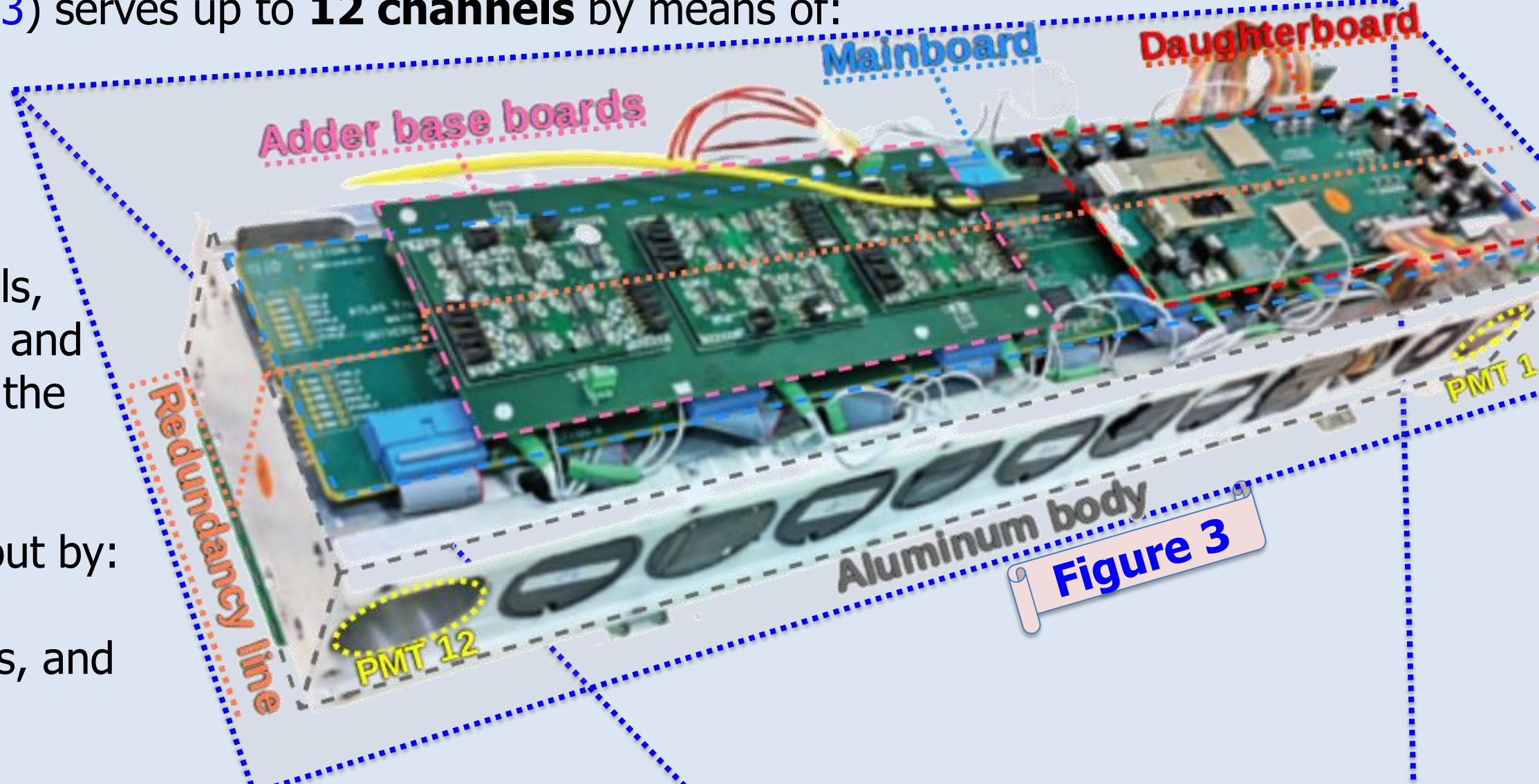
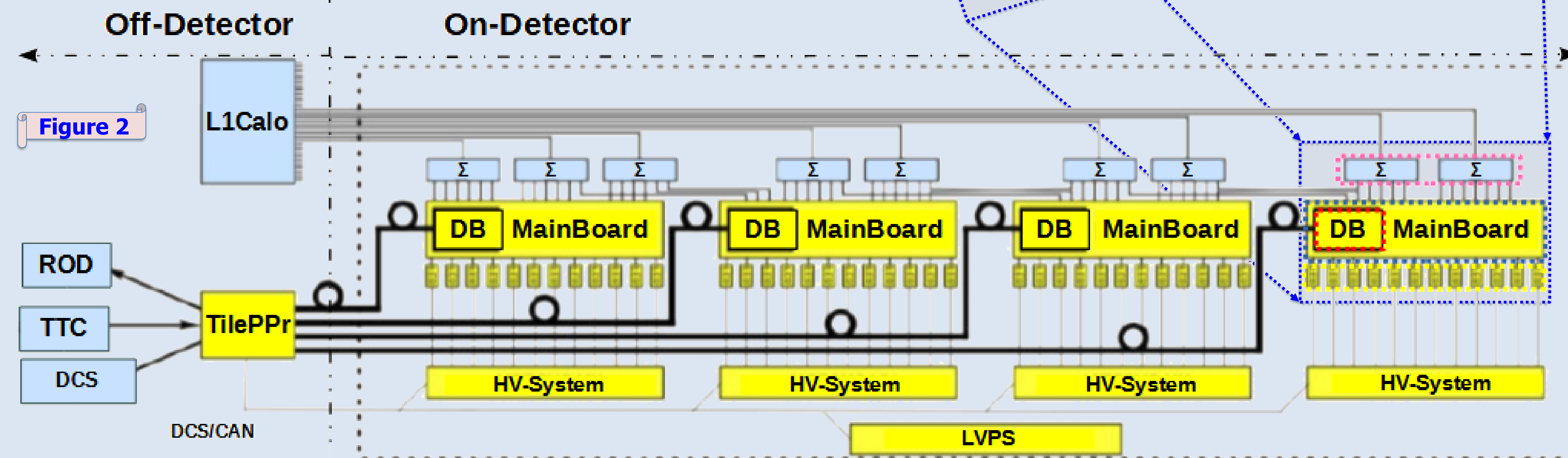
The Demonstrator read-out system.

The **Demonstrator system** [1] will continuously sample data of **two digitized gains** of up to 48 TileCal PMTs at **40 MHz** (Figure 2). The Demonstrator modularizes a legacy TileCal Drawer in four **Minidrawers (MDs)**, each MD (Figure 3) 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 **L1Calo** trigger system.
- a **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:

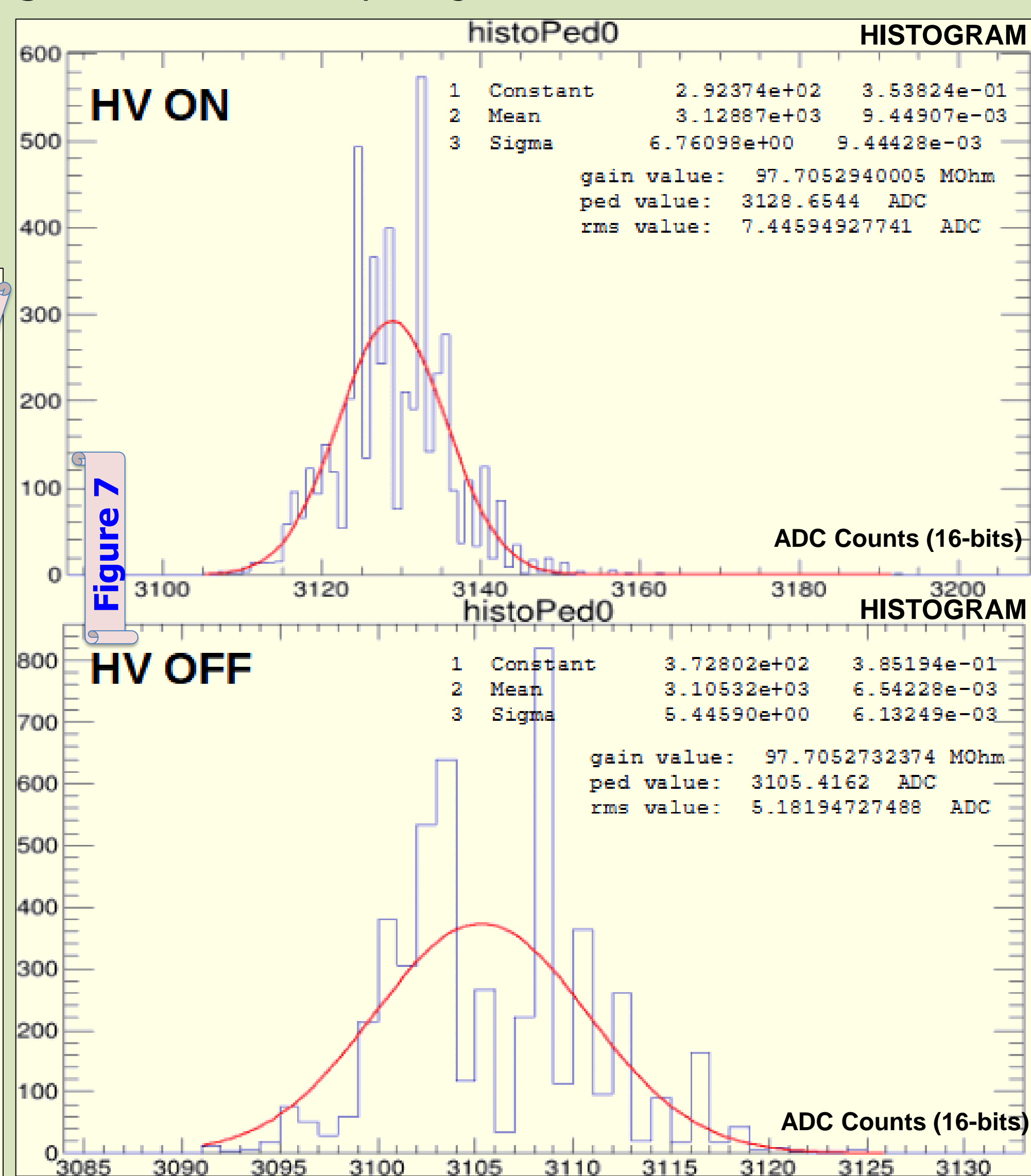
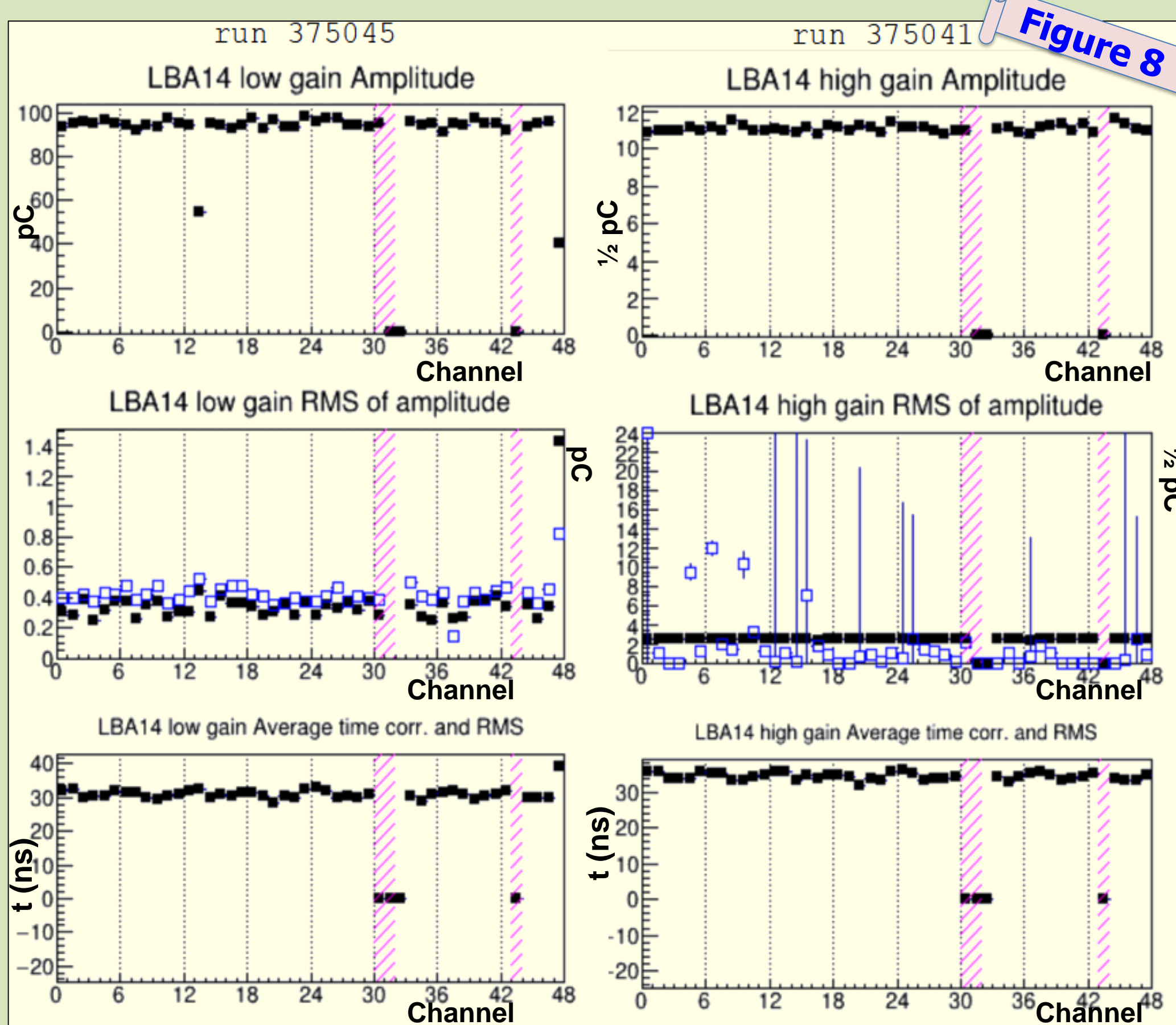
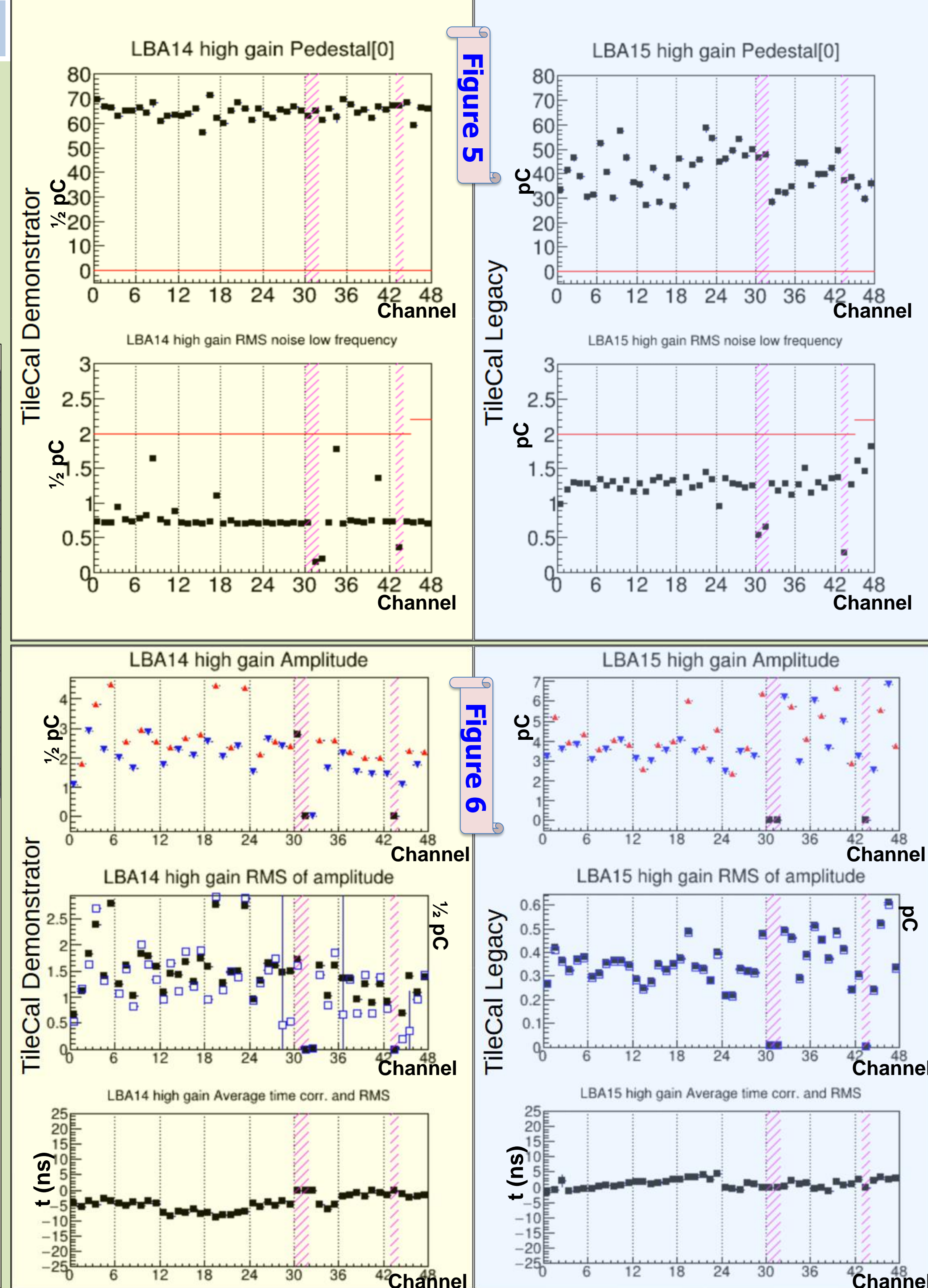
- **Tile Preprocessors (TilePPr)** that receives **legacy TTC (Timing Trigger and Control)** commands and triggers, **DCS (Detector Control Systems)** commands, and sends the triggered data to the legacy **ROD (Read Out Driver)**



Demonstrator integration, status and test results

A Demonstrator with Phase-II electronics tested during 5 testbeam campaigns [3] was successfully installed in ATLAS and interfaced with the TileCal legacy system.

- The **LVPS and HV system** were **powered and monitored from DCS**.
- The **Demonstrator readout** was **fully integrated in the TDAQ software** (Figure 4) with **very stable links**.
- **Temperature and humidity** sensors showed operation **within the specification ranges**.
- **Pedestal tests** showed **slightly lower noise in the demonstrator** (Figure 5 - pedestals from Optimal Filter).
- **Laser tests** showed **comparable performance between the Demonstrator** (Figure 6 - Laser - High Gain (HG)).
- **Dark current measurements** showed **no significant difference in gain measurements** (Average for all channels: $\Delta(\text{Ped}) = 47 \text{ ADC counts} = 29 \text{ pA}$) (Figure 7 - measurement for channel 0).
- **Timing calibration with Charge Injection System (CIS)** tests were **successfully performed** (Figure 8).



Conclusions

The demonstrator is fully integrated with the TileCal Legacy TDAQ, and DQ plots are available for it each time a calibration is taken. However, more tests and tuning (e.g. position of PMT holes) in DQ need to take place. The Demonstrator timing was adjusted by CIS and laser, and the integrator pedestals are in general lower when the DAC is disconnected compared to when it is connected and set to zero. No significant difference could be seen when the HV is ON vs OFF. The Demonstrator data acquisition runs have taken place without data losses. Future plans include more integration and further studies with new optimized a new TilePPr firmware. The Demonstrator activities will proof reliability and provide valuable experience for the future installation of the HL-LHC upgraded electronics.

Relevant 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, urn:nbn:se:su:diva-175281, 10.1016/j.nima.2018.10.066

Eduardo Valdes Santurio, on behalf of the Tile Calorimeter System.

Post Doctoral Researcher at Fysikum, Stockholm University. Email: eduardo.valdes@fysik.su.se, eduardo.valdes@cern.ch

