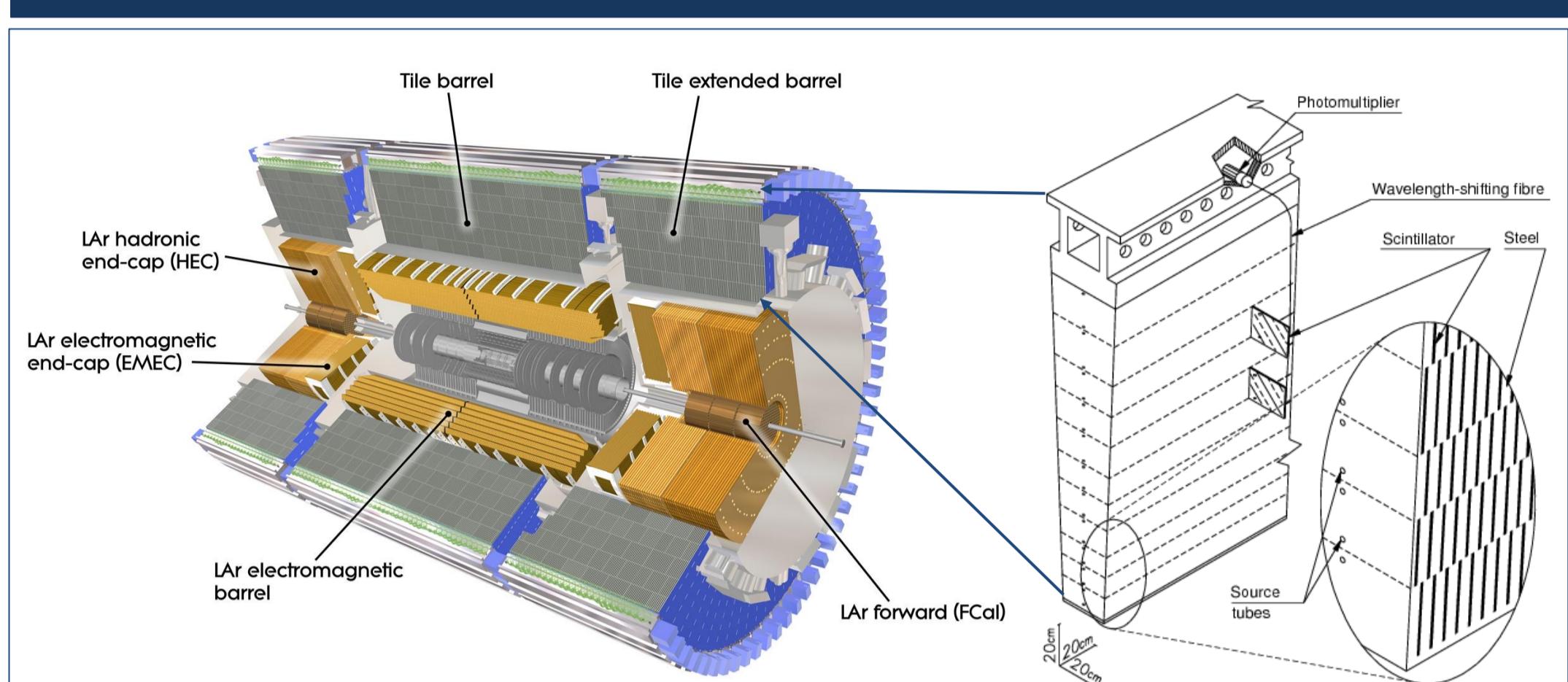


Integration and Commissioning of the ATLAS Tile Demonstrator Module for Run 3

Introduction

The ATLAS Tile Calorimeter electronics will be replaced for the High Luminosity LHC (HL-LHC). The HL-LHC is expected to deliver an instantaneous peak luminosity of up to $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ in 2029. Upgrades will improve data transfer rates, redundancy and reliability of the electronics, and component radiation hardness [1]. A Demonstrator module with upgraded on-detector readout electronics built in 2014, was evaluated during seven test beam campaigns, and inserted into the ATLAS experiment in 2019. The module provides backward compatibility with the present ATLAS systems.

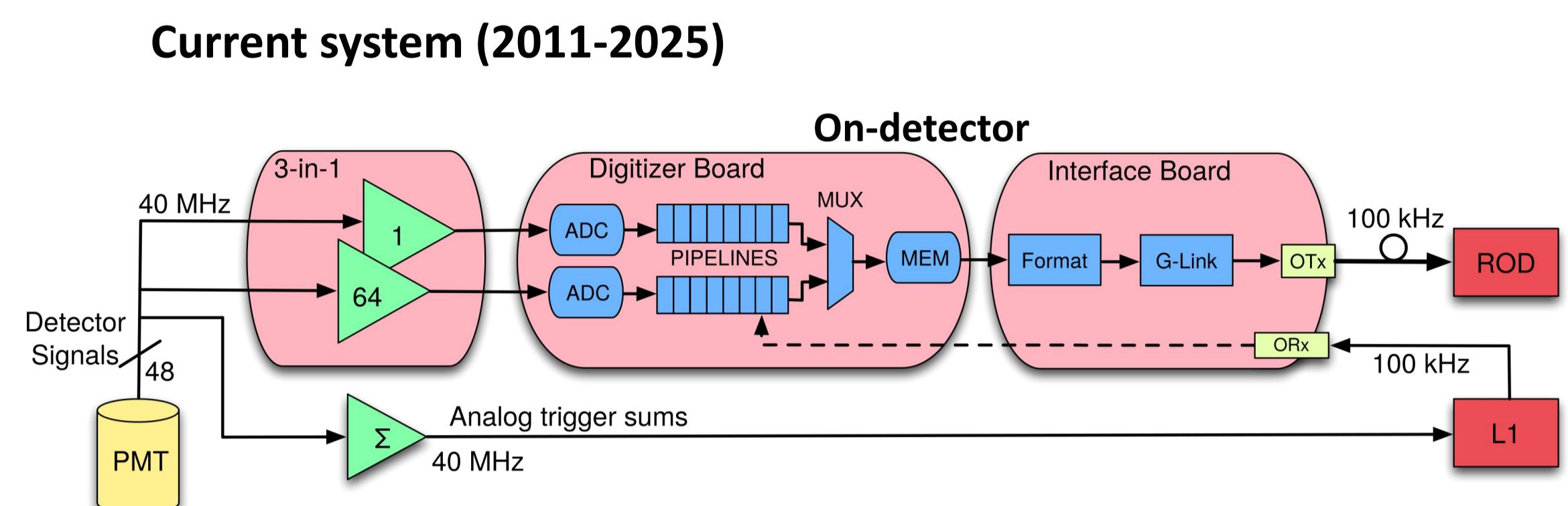
The ATLAS Tile Calorimeter



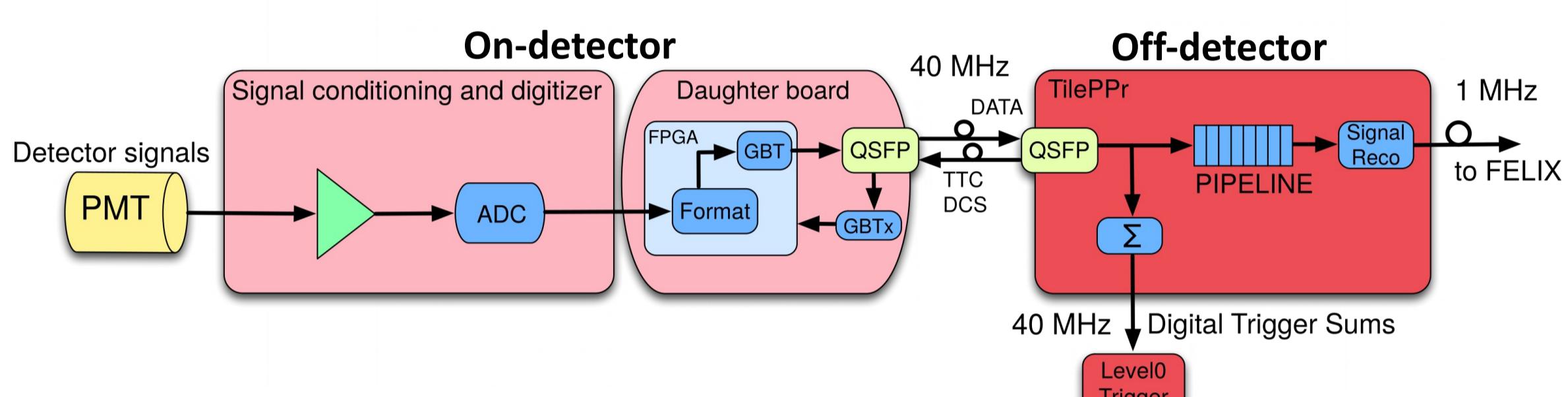
The Tile Calorimeter (TileCal) is the central hadronic calorimeter of the ATLAS experiment, it contributes to the measurement of hadrons, jets, taus, and the missing transverse energy [2].

- made of alternating layers of steel plates and plastic scintillator tiles
 - wavelength shifting fibres and 2 Photo-Multiplier Tubes (PMTs) per cell
- divided into four cylindrical readout partitions along the beam axis
 - one central long barrel (LBA, LBC) and two extended barrels (EBA, EBC)
 - each barrel is segmented azimuthally into 64 wedge-shaped TileCal modules, staggered in the ϕ direction
- on-detector electronics are located in extractable "drawers" at the outermost part of the module and each drawer houses up to 45 PMTs

Phase-II Tile Calorimeter upgrade design



Upgrade system (2029-2040)



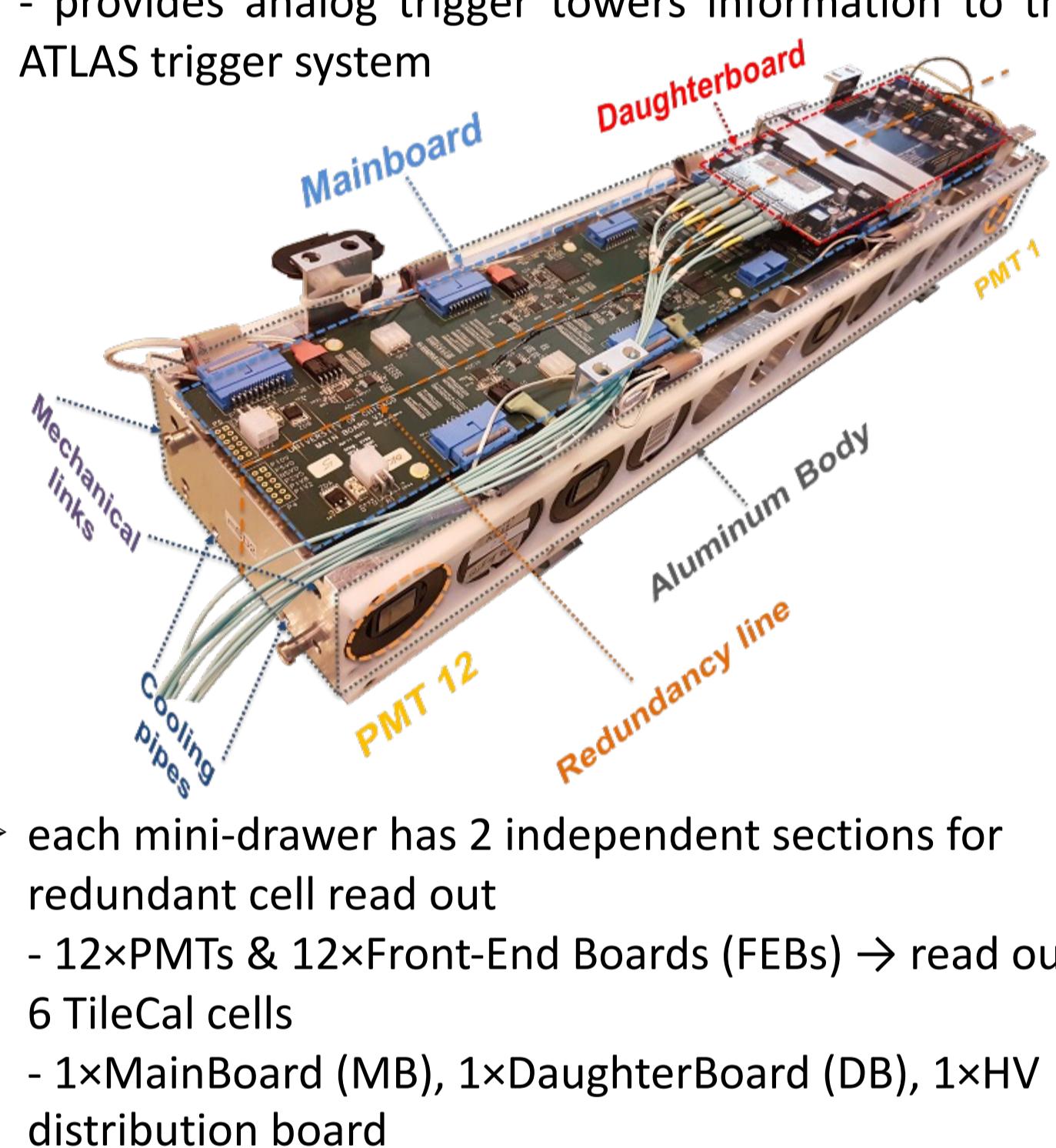
- upgraded super-drawer consists four independent readout elements, *mini-drawers* - **reliability**
- each *mini-drawer* is split into two independent sides with independent power, data and monitoring links - **redundancy**
- new trigger system will have access to the digital information with a low level of electronic noise and accurate energy calibration
- trigger objects computed with the information from TileCal cells will be transmitted at 40 MHz with a maximum latency of about $1.7\mu\text{s}$

	Current System	Upgrade system
Level 1 Trigger Signals	Analog Sum	Fully Digital
Pipeline Memory	On-Detector	Off-Detector
Up-links		
Number of fibres	256	2048
Link bandwidth	800 Mbps	9.6 Gbps
Back-end Input bandwidth	6.4 Gbps	625 Gbps
Back-end output bandwidth to DAQ	3.2 Gbps	40 Gbps

Phase-II Tile Calorimeter upgrade electronics

The Demonstrator Module

- hybrid module composed of four mini-drawers
 - uses the clock and readout strategy for the HL-LHC
 - provides analog trigger towers information to the ATLAS trigger system



Off-detector electronics

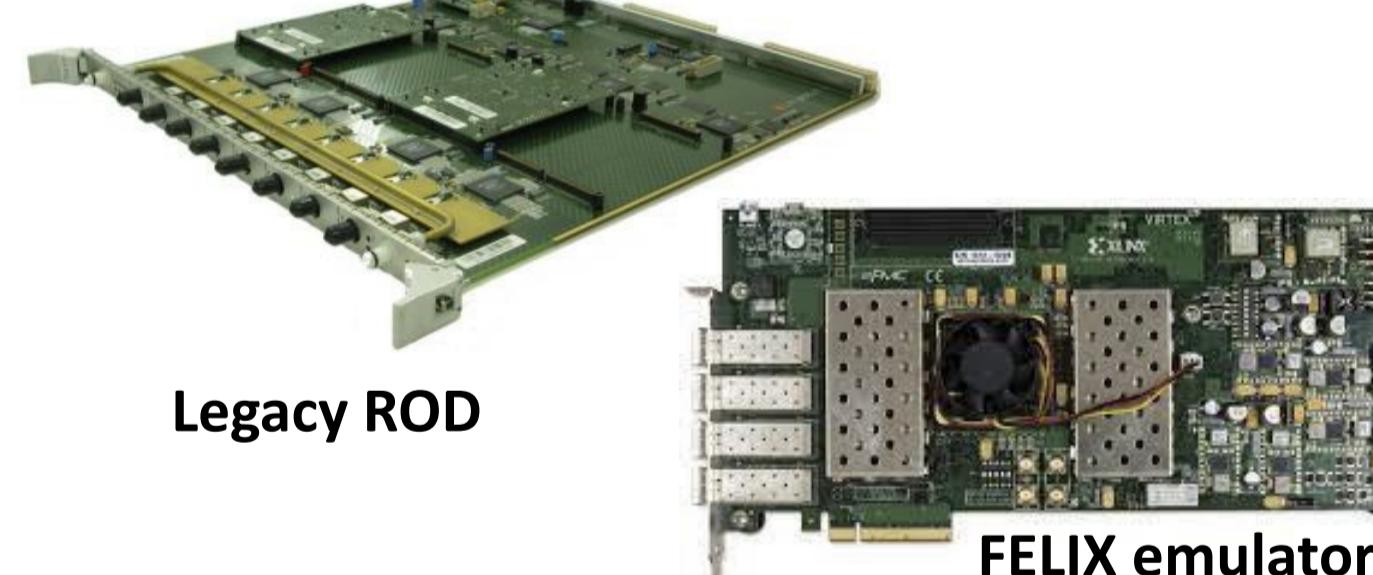
Tile PreProcessor Demonstrator (TilePP)

- responsible for operating and handling the data from the Demonstrator module
- enables backward compatibility between the upgraded on-detector electronics and the current ATLAS TDAQ and Trigger, Timing, and Control (TTC) systems

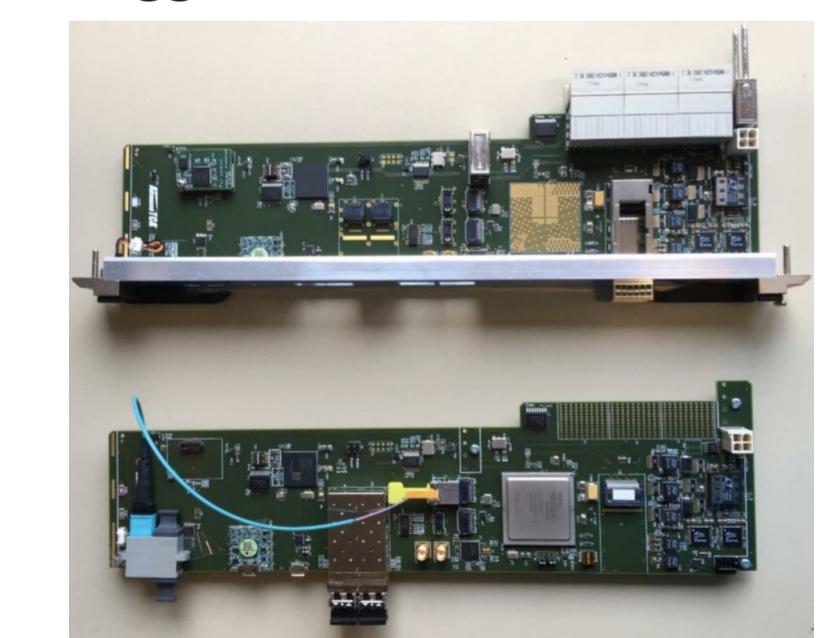


- based on FPGAs and high-speed modules
 - data acquisition and processing @ 40 MHz
 - distribution of LHC clock towards the on-detector electronics
 - interface with the ATLAS readout system via the Trigger and DAQ interface module
 - double AMC board equipped with 4 QSFPs, Virtex 7, Kintex 7 and Spartan 6
 - capable of operating 1 upgraded TileCal module
 - up to 4 Mini-drawers
 - operated in an ATCA shelf in the counting room

- triggered events are transferred to the Read-Out Drivers (ROD) and the FELIX system



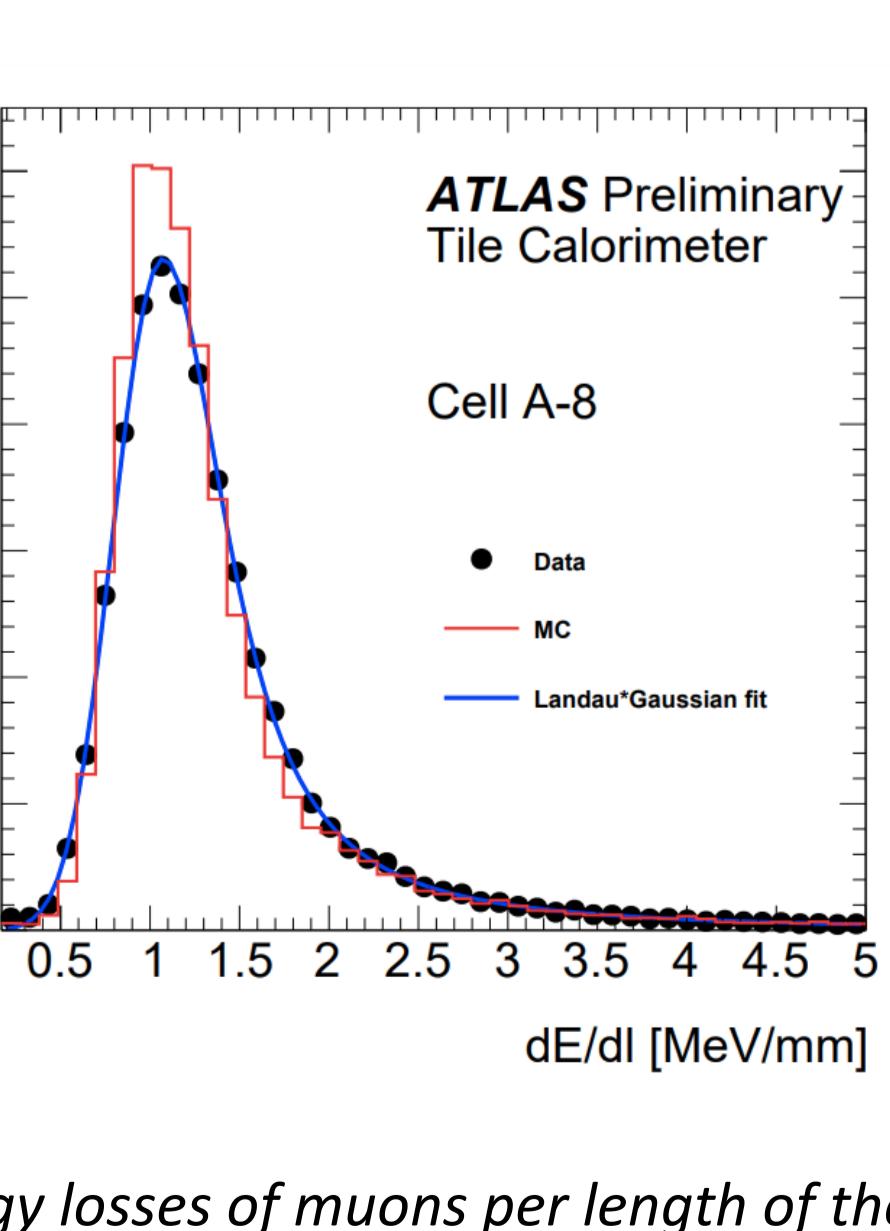
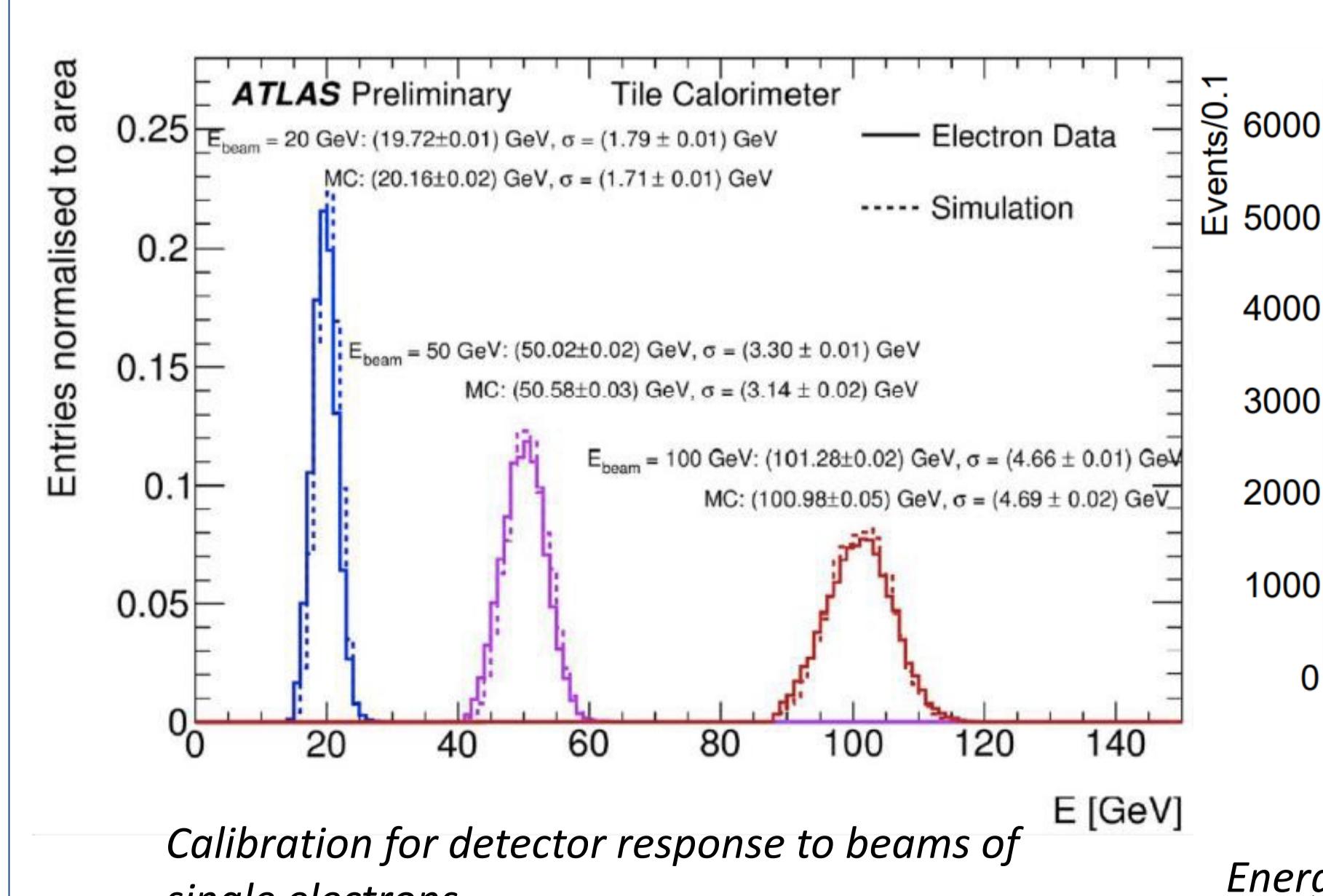
Trigger and DAQ interface



Test beam results

- seven test beam campaigns between 2015 and 2018 at the North Area of the SPS accelerator (CERN)
 - detector modules equipped with upgraded and legacy electronics for performance comparison
- beams of hadrons, electrons and muons at different energy ranges and projective angles
 - study the calorimeter response and S/N performance of the new electronics

Data to Monte Carlo response with hadrons, electrons and muons

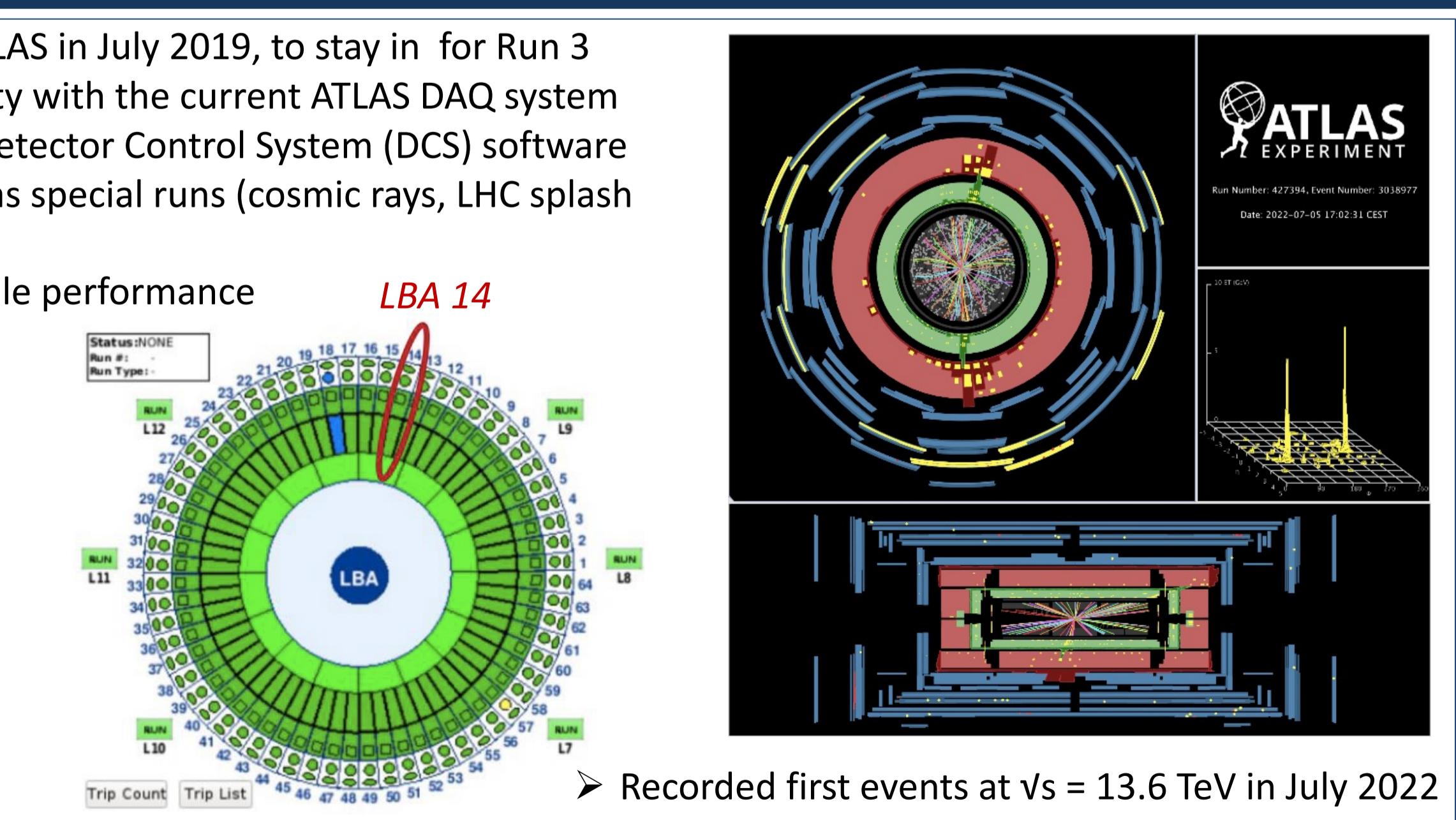


Commissioning and operation in ATLAS

- Demonstrator module inserted in ATLAS in July 2019, to stay in for Run 3
- operating with backward compatibility with the current ATLAS DAQ system
- fully integrated with the TDAQ and Detector Control System (DCS) software
- tested in Run 2 physics data, as well as special runs (cosmic rays, LHC splash events, calibration)
- Demonstrator shows a good and stable performance



Insertion of the Demonstrator in LBA



Summary

- HL-LHC conditions require a complete redesign of the readout electronics of the Tile Calorimeter
- Demonstrator module was constructed in 2014 and tested in several test campaigns with particle beams between 2015 and 2018 to study the performance of the new readout electronics
- Demonstrator module inserted and commissioned in ATLAS in Run 2 and participating in Run 3 data-taking
- Demonstrator module performs well, and the new electronics fulfill its requirements as observed in Demonstrator