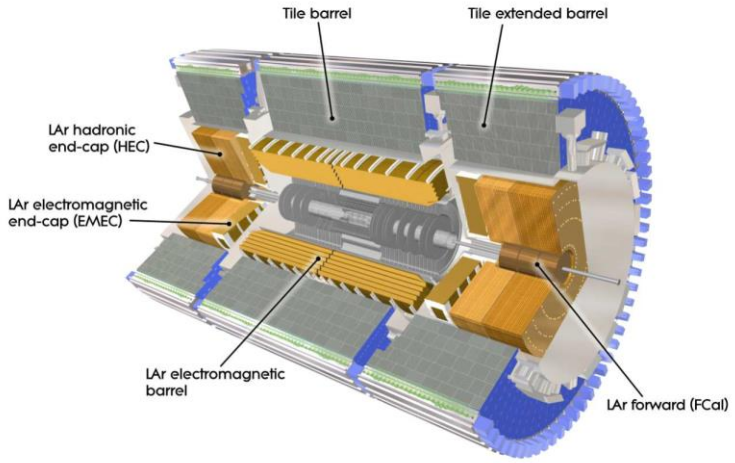
The Demonstrator of the HL-LHC ATLAS Tile Calorimeter

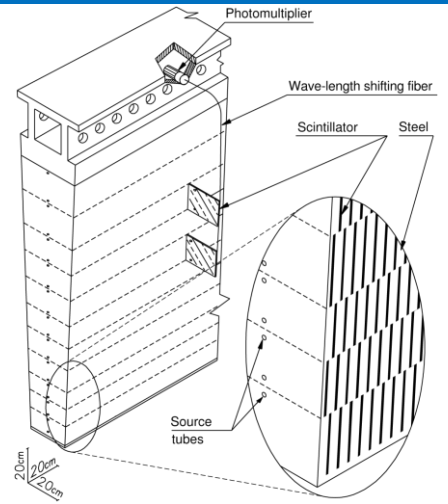
Pavle Tsotskolauri on behalf of the ATLAS Tile Calorimeter system
Tbilisi State University, Tbilisi, Georgia

The ATLAS Tile Calorimeter



ATLAS Tile Calorimeter Barrel

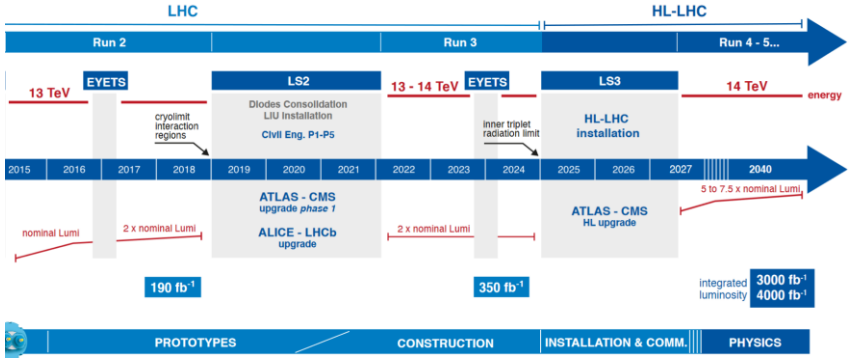
- Tile Calorimeter is a sampling calorimeter constructed of steel and plastic scintillator plates and is located at the central section of the hadronic calorimeter of ATLAS.
- 460 000 scintillators are read out by two PMTs (Photomultiplier Tube)
- Divided into four barrels: two long barrels and two extended barrels.
- 256 Super-drawers constitute the full detector in four barrels, each having 64 wedges.
- Measurement of jets, missing energy, jet structure, electron isolation, triggering (including muon information)



Tile Calorimeter Wedge Module

High Luminosity LHC (HL-LHC)

- Major upgrade to its on- and off detector electronics
- HL-LHC will deliver ten-time integrated luminosity (3000-4000 fb^{-1})
- 200 simultaneous proton-proton interactions per bunch crossing.
- Fully digital calorimeter trigger with higher granularity and precision.
- Radiation tolerant electronics
- Improved reliability and redundancy.

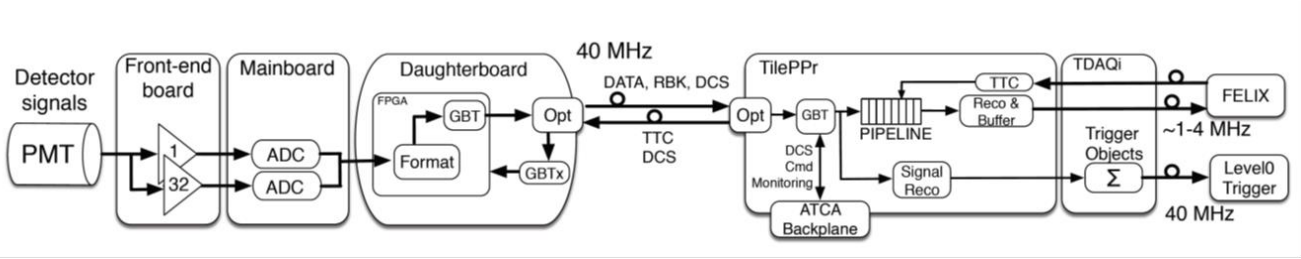


The HL-LHC schedule

Phase-II Upgrade of Tile Calorimeter

Upgraded Design

- Upgraded **super-drawer** consists four independent read out elements, **mini-drawers** – Reliability
- Each **mini-drawer** is split into two independent sides with independent power, data and monitoring links – Redundancy

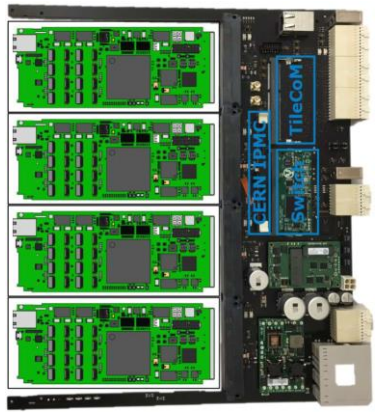


	Current System	Upgraded System
Level 1 Trigger	Analog Sum	Fully Digital
Pipeline memory	On-Detector	Off-Detector
Number of fibres	256	2048
Link bandwidth	800 Mbps	9.6 Gbps
Back-end Input bandwidth	6.4 Gbps	1 Tbps
Back-end output bandwidth to DAQ	3.2 Gbps	40 Gbps

- In Phase-II design analog trigger will be replaced with fully digital trigger.
- New trigger system will have access to the digital information with a low level of electronic noise and accurate energy calibration.
- Data will be sent from the Tile cells to the trigger system at 40MHz with maximum latency of about 1.7μS.

The Tile PreProcessor

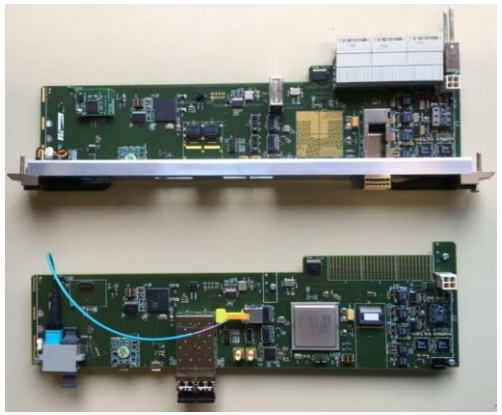
- Core element of the off-detector system
- Phase-II PreProcessor is implemented In full size ATCA format
- 32 PPr ATCA-compliant modules: composed of 4 Compact Processing Modules (CPM) in 1 Carrier Base Board (ACBB) and TDAQi
- Main power distribution
- LHC clock distribution, control and configuration
- IPBus Communication



ATCA Carrier

Trigger and DAQ interface

- Receives cell energy data from PPr
- ATCA standard RTM Module
- Interface with Trigger Processors and the Front-End Link eXchange (FELIX)
- Fixed-latency.
- Trigger formation, cell selection and sorting.



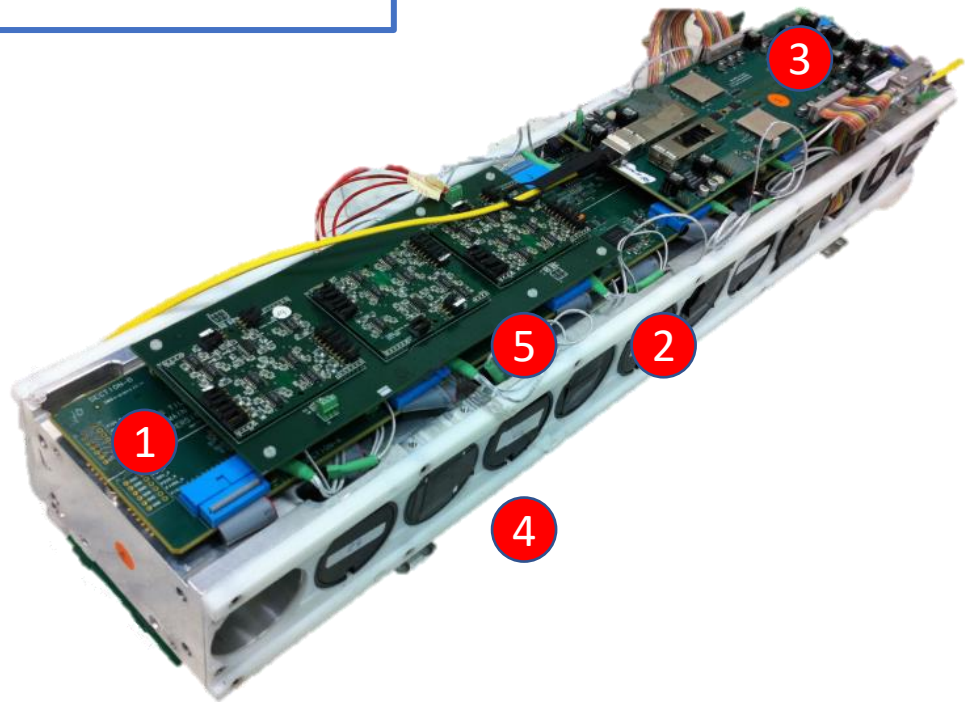
TDAQi

The Tile Demonstrator

- The Demonstrator is a hybrid prototype, basically combining a fully functional Phase-II read-out system with the analog trigger signals of the present system and other legacy interfaces with the current ATLAS systems.
- The module was intensively tested at test beam before its insertion into ATLAS during LS2 where it will stay for Run 3.

PreProcessor

- Interface between Front-end electronics and ATLAS data acquisition system.
- Storing data in pipelines until trigger decision.
- Energy reconstruction.
- 40MHz Data input



MainBoard Final Version (V4) 1

- Communication between FENICS and Daughterboard
- Timing, Charge Injection
- Data digitization
- Low voltage control

PMT Blocks 2

- Amplification of scintillating light signal received via the wavelength shifting fibers

DaughterBoard V4 3

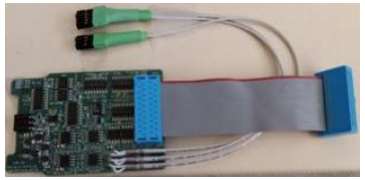
- Control and Data Collection
- Multi-gigabit Redundant communication
- Front-end electronics configuration
- Update with latest version (V6) is considered

HV bus (underneath) 4

- Delivers high voltage to ≈10 000 PMTs
- Individual control over individual PMT blocks
- Voltage monitoring and data reporting.

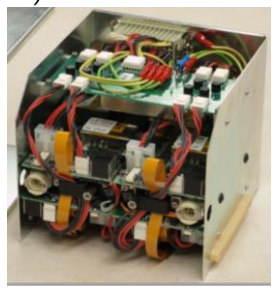
3-in-1 Card 5

- Fast readout with two gains
- Integrated slow readout
- Analog trigger (for backward compatibility)

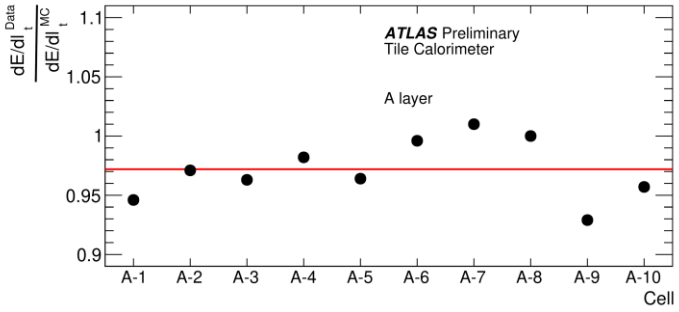


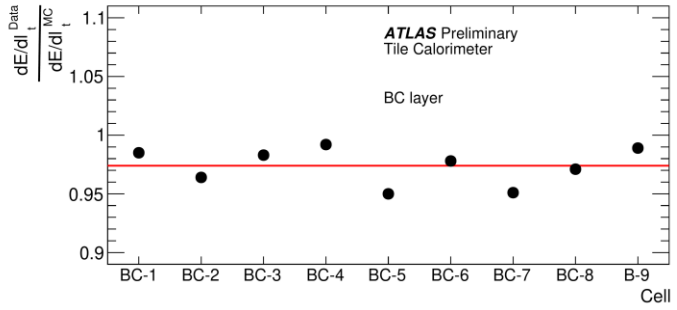
Low Voltage Power Supply

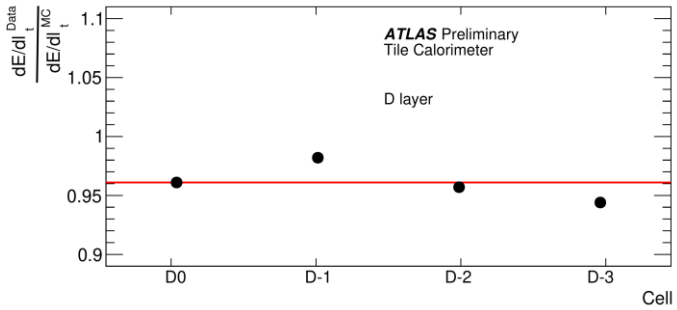
- Power supply for Front-End Electronics
- Power monitoring
- Eight individual bricks with +10V supply (Four is redundant).



Results from Test Beam and ATLAS Operation







Ratios of the energy deposited in the A, BC and D layers' cells per unit of path length using experimental and simulated muon data as a function of the cell number

- The Goal of the test beam is to study the performance of the upgrade electronics and to compare it with the legacy system.
- Test beam results indicates that The Demonstrator module performs at least as good as Legacy Module.

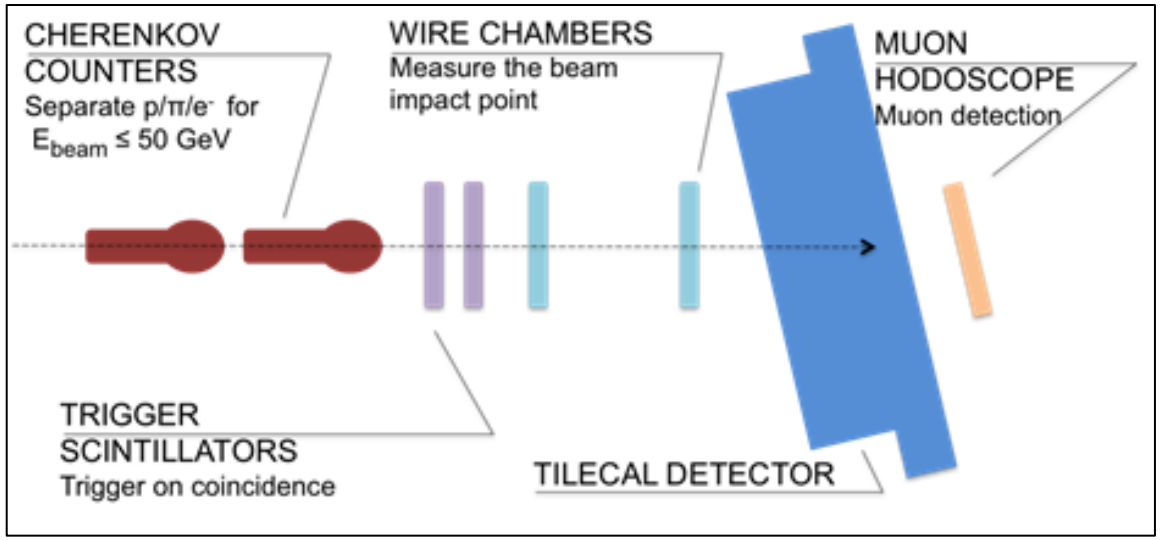
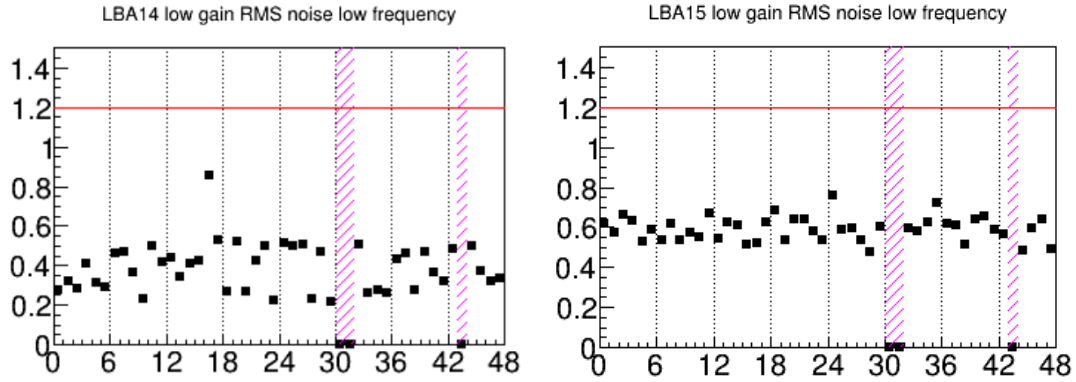
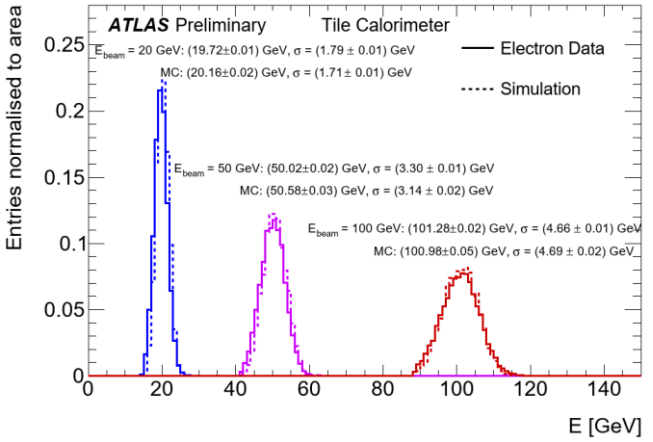


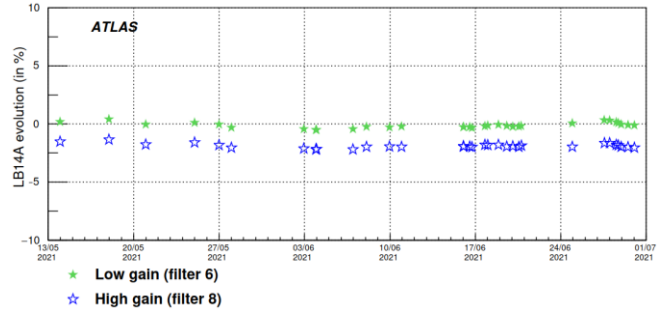
Diagram of the beam detectors in the test beam setup



Comparison of noise between Demonstrator and legacy module



Distributions of the total energy deposited in the calorimeter obtained using experimental and simulated electron data



Stability of Laser over time

Summary

- HL-LHC upgrade for Tile Calorimeter will feature completely modernized electronic modules, redundant and reliable design, fault tolerance, improved radiation tolerance.
- The Tile Demonstrator module is prototype for upgraded readout system and is compatible with current and legacy systems.
- Tile Demonstrator is fully integrated in upgraded in the ATLAS Trigger and Data Acquisition and Detector Control systems.
- It was extensively tested during 2015, 2016 and 2017 test beams and demonstrated good performance.
- New test will take place in November 2021 in order to validate new on-detector electronics in radiation environment and associated off-detector electronics.
- Tile Demonstrator module will also be present in Tile Calorimeter during Run-3 period.

Acknowledgments

- The author was supported by Shota Rustaveli National Science Foundation of Georgia through the grant project No DI-18-293

Reference

- High-Luminosity Large Hadron Collider (HL-LHC): Technical design report, CERN-2020-010, https://cds.cern.ch/record/2749422
- The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003, https://cds.cern.ch/record/1129811
- Technical Design Report for the Phase-II Upgrade of the ATLAS Tile Calorimeter, ATLAS-TDR-028, https://cds.cern.ch/record/2285583
- Upgrade of the ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC, ATL-TILECAL-PROC-2020-009, https://cds.cern.ch/record/2716325