Upgrade of the ATLAS Tile Calorimeter for the High Luminosity LHC

Agostinho Gomes (LIP and FCUL, Lisbon)

on behalf of the ATLAS Tile Calorimeter

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Acknowledgements:

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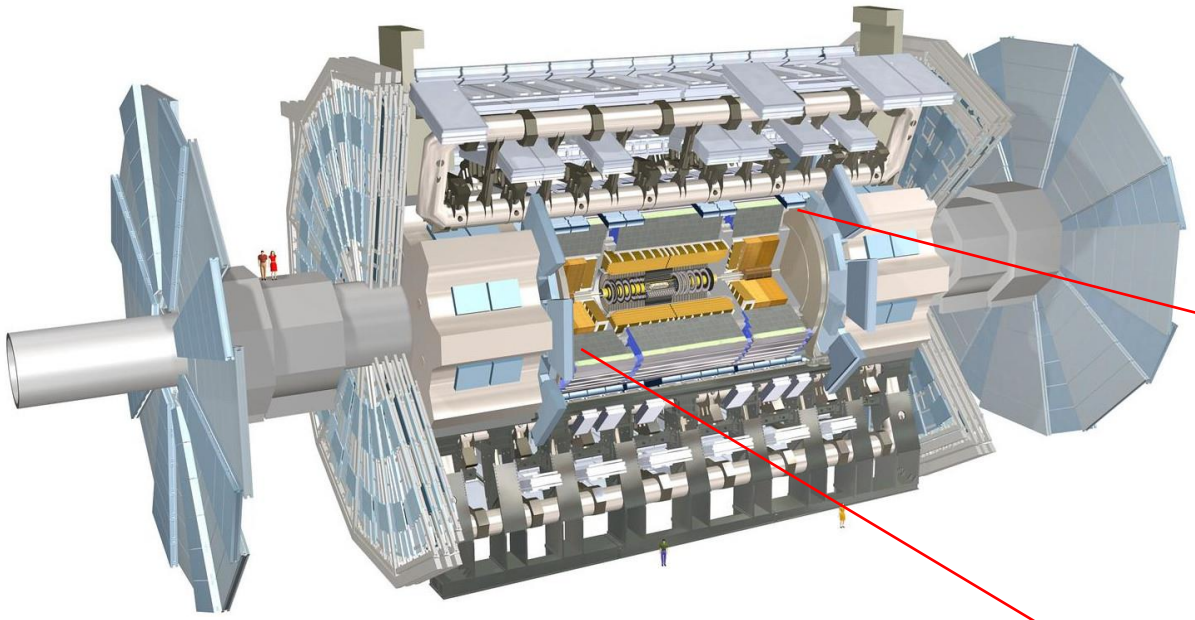
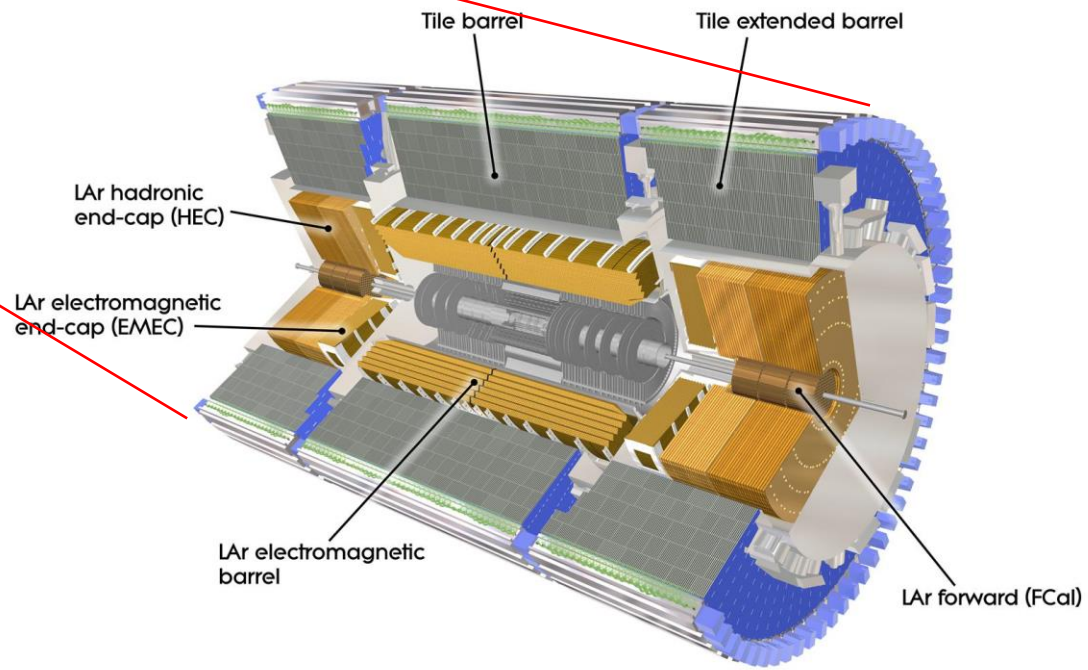
GOVERNO DE PORTUGAL

The ATLAS Tile Calorimeter



The Tile Calorimeter is the central barrel hadronic calorimeter of the ATLAS detector

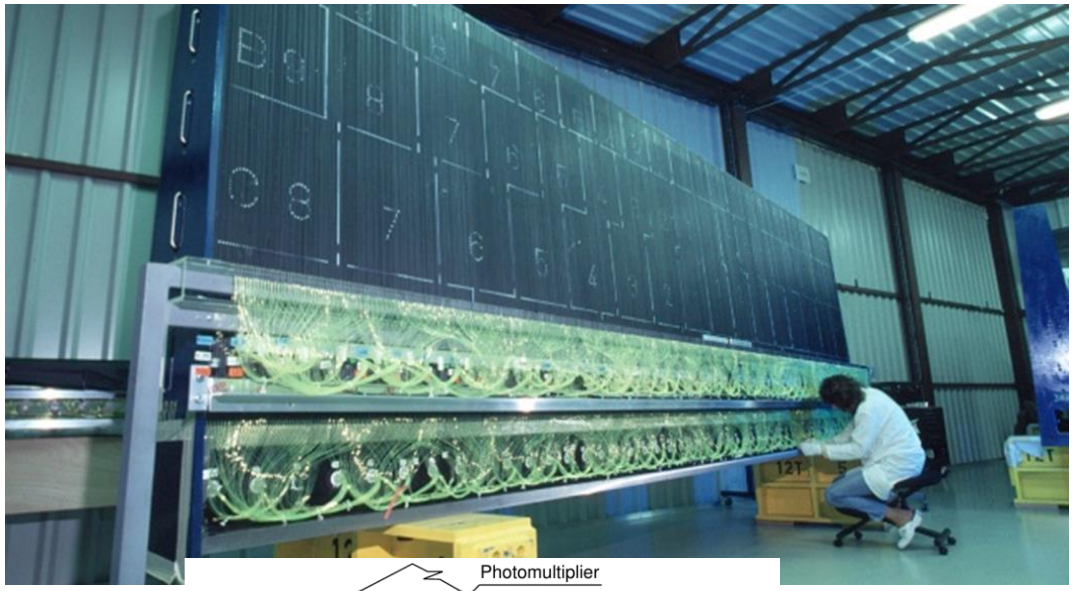


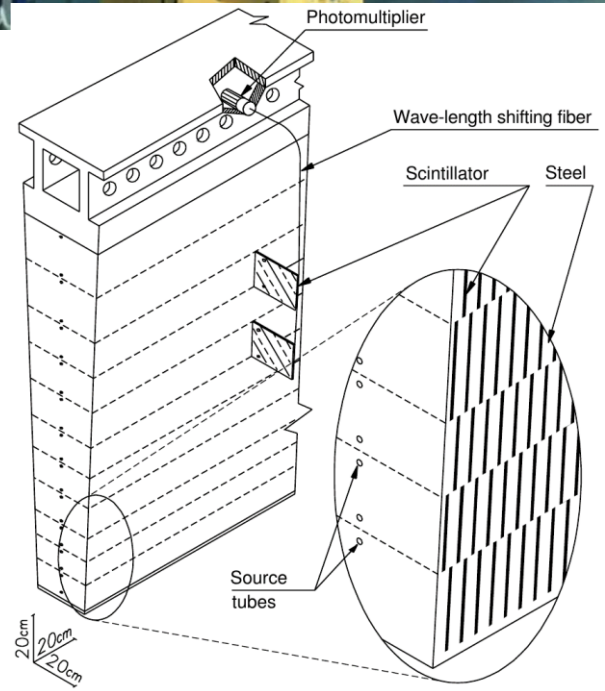
- Provides inputs to L1 trigger and muon identification
- Participates in the reconstruction of hadrons, jets, tau leptons, etc
- Key for missing transverse energy
- Contributes for luminosity measurements

Tile calorimeter

Hadron sampling calorimeter

- Design resolution for jets: $\Delta E/E = 50\%/\sqrt{E} \oplus 3\%$
- Coverage: $|\eta|<1.7$
- Three longitudinal layers
- Cell granularity $\Delta\eta \times \Delta\phi$: 0.1x0.1 (0.2x0.1 in outer layer)
- Absorber: steel
- Active medium: plastic scintillators
- Scintillators: 3 mm thick, made of polystyrene + PTP + POPOP, oriented perpendicular to beam axis, wrapped in Tyvek
- Light collection and transport: via green WLS fibres (Kuraray Y11) connected to both short edges
- Photosensors: Hamamatsu R7877 PMTs, located in module's girder, collect light from fibre bundles

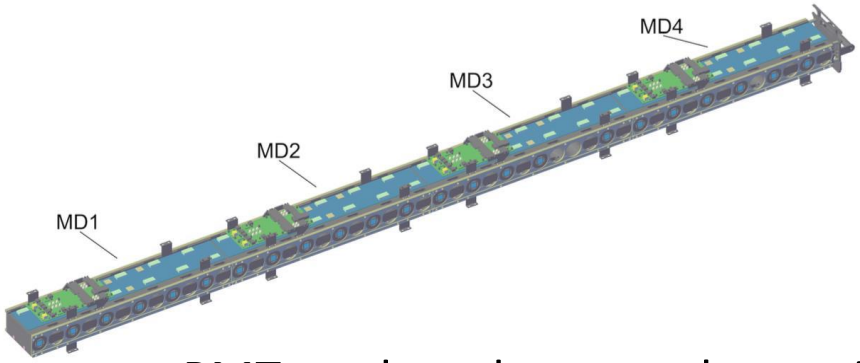


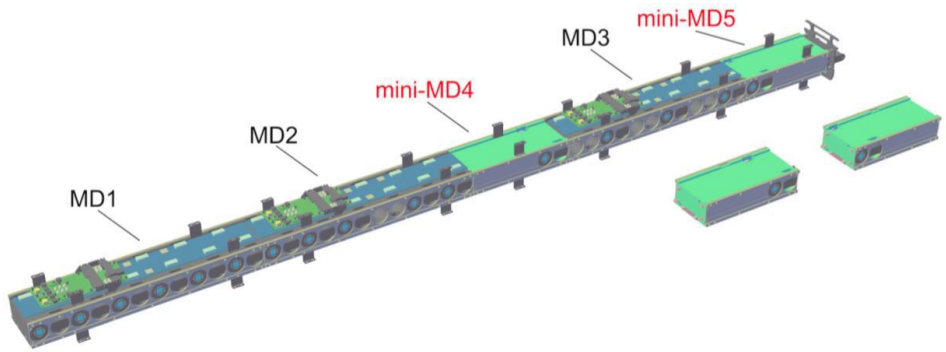


Tile Calorimeter Upgrade

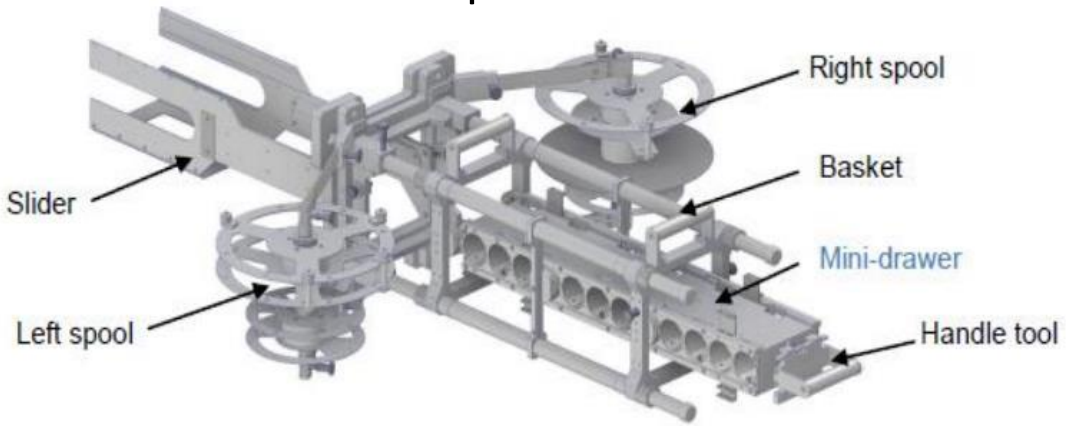
- Replacement of on detector and off detector readout electronics
  - Make readout architecture compatible with new fully digital Trigger and DAQ architecture
  - Improve redundancy in data links and power distribution
  - Replace most exposed and degraded PMTs
- Replacement of LV and HV systems
  - New design to cope with new electronics and higher radiation
  - Improved redundancy and reliability
- Upgrade of calibration systems
  - New design to cope with new electronics and higher radiation
  - Improved redundancy and reliability
- New super-drawer mechanics
  - Smaller micro-drawers, with more robust mechanical/cooling supports
  - Better handling and access capabilities

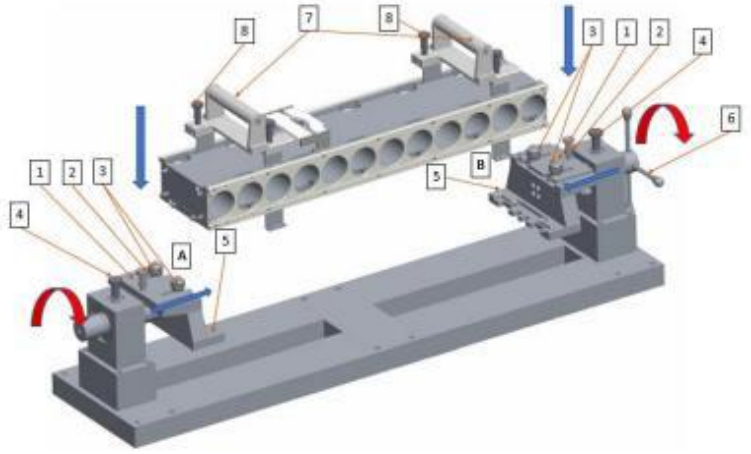
Mechanics





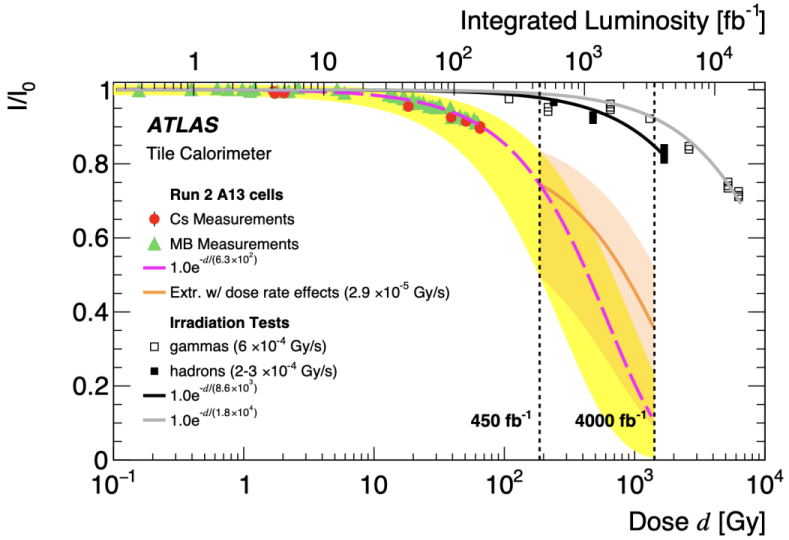
- PMTs and on-detector electronics are housed in “drawers”
- New design have 4 mini-drawers (MD) in central barrel, 3 MDs in extended barrel (plus 2 smaller micro-drawers to save on electronics)
- Robust mechanical links
- New cooling system
- Special installation tooling
- Services and new tooling
- Production is complete

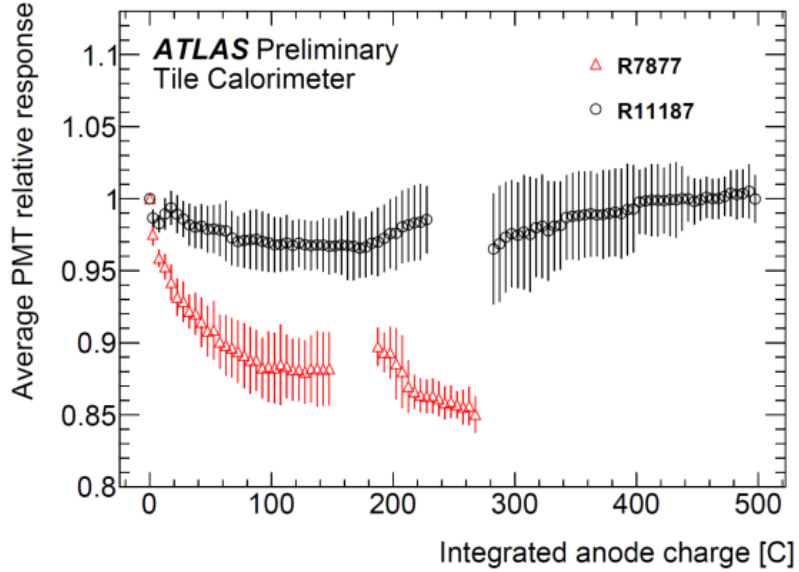


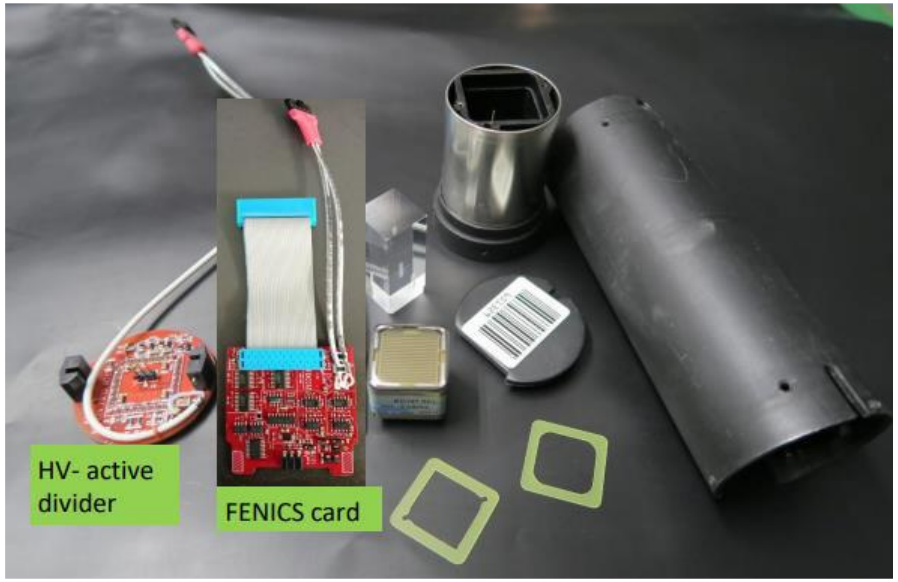


PMT and active dividers

Most degraded PMTs (~10%) will be replaced
(example of relative light loss for cell A13 below)
PMTs improved version: Hamamatsu R11187
Production and certification are ongoing





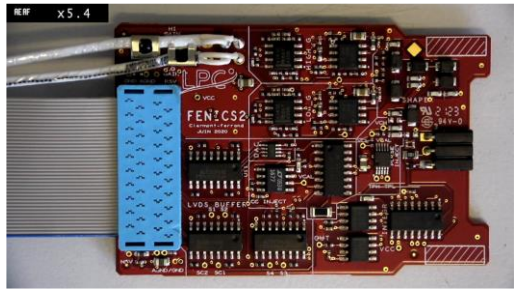


New high voltage active dividers, more stable at high currents
Production is complete

On detector electronics

FENICS:
- PMT pulse shaping
- bi-gain amplification with 1:40 ratio, 0.2->1000pC
- current integration
- charge injection calibration

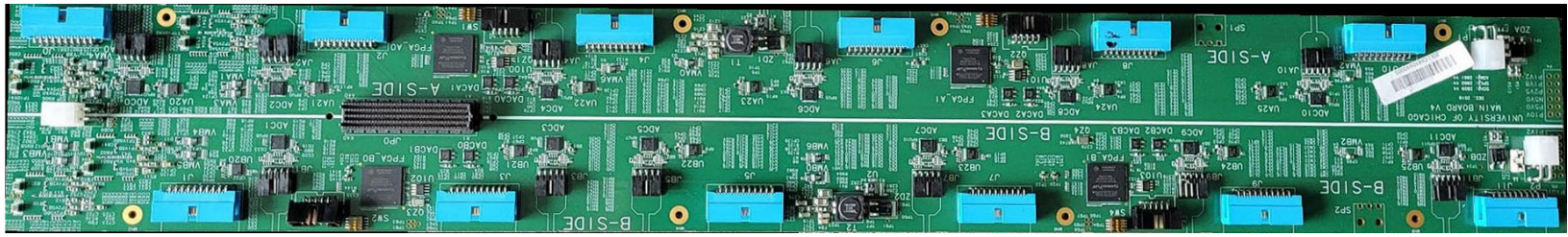
production and certification are ongoing



MainBoard:
- power conversion (from input 10V)
- digitization of FENICS outputs

2x12-bit/40MHz +16-bit (integrator)
- configuration control for FENICS
- Connects to DaughterBoard

production is complete



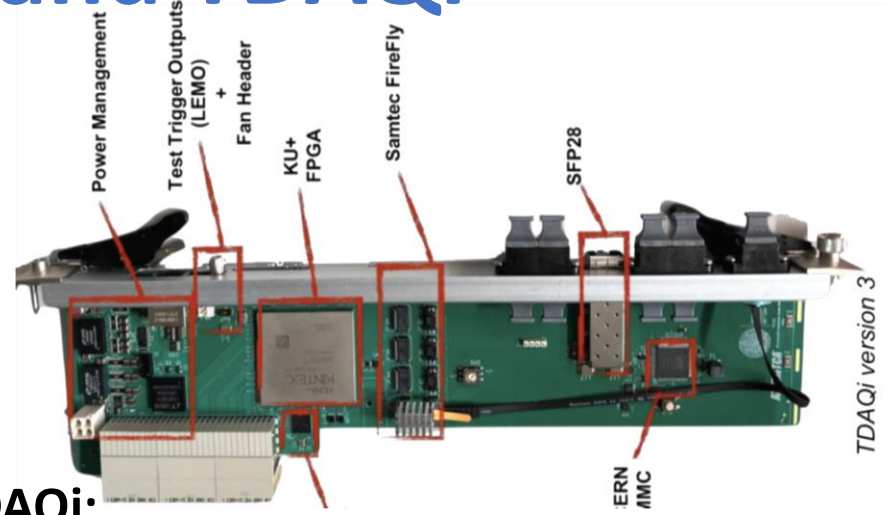
DaughterBoard:
- collects and sends digitised data to the off-detector electronics via optical links
- GBT protocol at 9.6 Gb/s, using SFP+
- Kintex Ultrascale FPGA

final prototype DB6v4 produced and is being tested

Off detector electronics – PPr and TDAQi

PreProcessor (PPr):
- comm. with front-end
- comm. with ATLAS DAQ
- signal reconstruction
- **ATCA Carrier Board:**
- power distribution
- comm. between CPM and TDAQi
- hosts TileCoM and GbE switch
- **CPM (4/PPr):**

(compact processing module)
- Kintex UltraScale 115
- Samtec FireFly
- GBT 16 Tx@4.8Gb/s+32 Rx@9.6Gb/s
- +8 Tx@9.6 Gb/s+1 Rx@9.6 Gb/s
- **TileCoM:**
- interface with ATLAS DCS
- Zynq UltraScale+ SoC



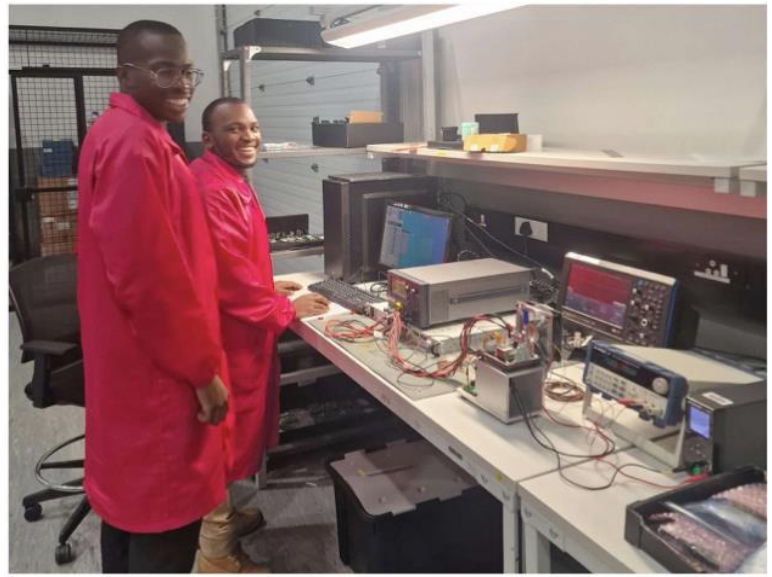
TDAQi:
- produces primitives for ATLAS L0 triggers:
  - L0Muon: 6x9.6 Gb/s
  - L0Calo: 26x11.2 Gb/s
  - L0Global: 8x11.2 Gb/s
- ATCA Rear Transition Module
- Kintex UltraScale+
- Samtec FireFly

several prototypes are made
final design is being prepared

Power supplies – LV and HV

- Three-stage **low-voltage (LV) system**
  - Bulk 200V AC-DC (off detector)
    - 10V DC-DC converters
      - Point-of-load regulators

LV bricks with 200V->10V converters are the components most exposed to radiation

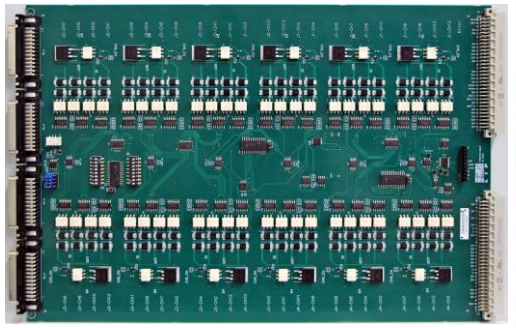


pre-production ongoing

- Remotely regulated **High Voltage (HV)**
  <1kV over 100m cable for 10k channels

- HV supply boards using Hamamatsu DC-DC converters
- Remote regulation for individual channels in boards outside of high radiation area
- Boards housed in custom crates
- One passive distribution board on detector

moving towards pre-production



Calibration systems

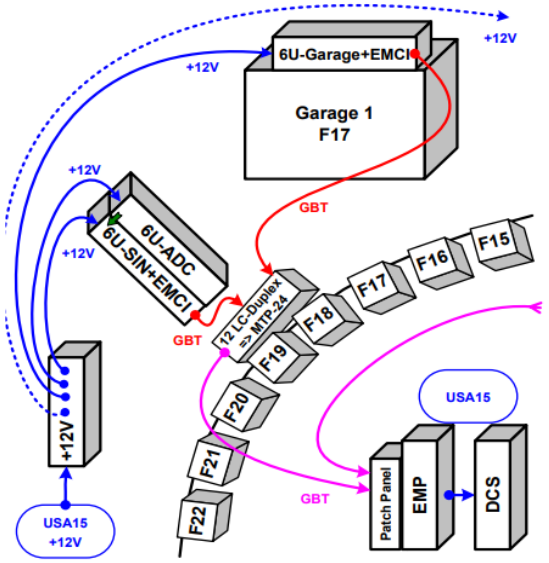
Calibration systems follow DAQ upgrade

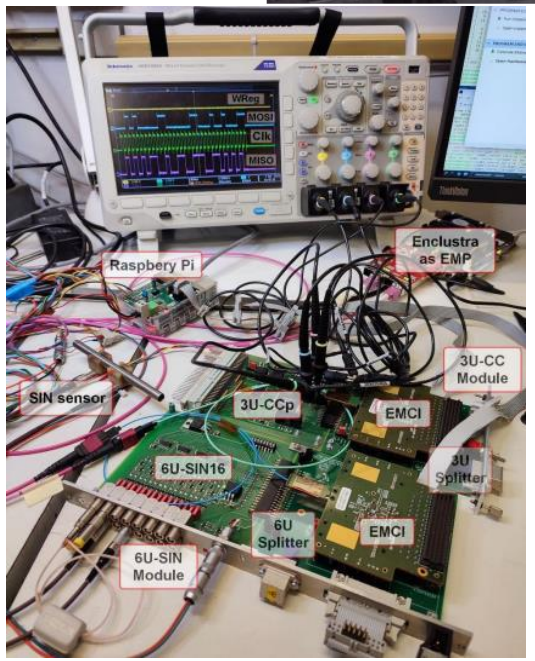
Laser calibration system for PMTs
- New DAQ and control interface (ILANA)
- New optical line with new integrating sphere for mixing LASER light and light from new LED matrix to simulate pile-up

prototype tests ok

Cs137 movable source
- New on and off detector electronics using optical links
- Updated hydraulics is under study, with increased segmentation and reduced pressure to reduce risk of leaks

part of the boards are in production

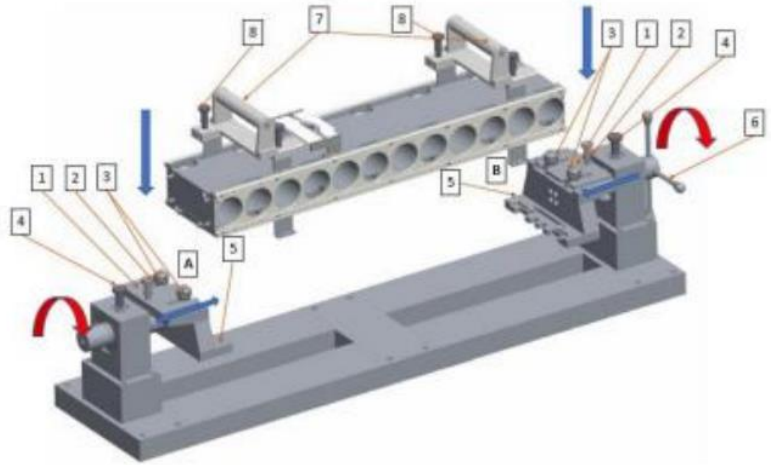




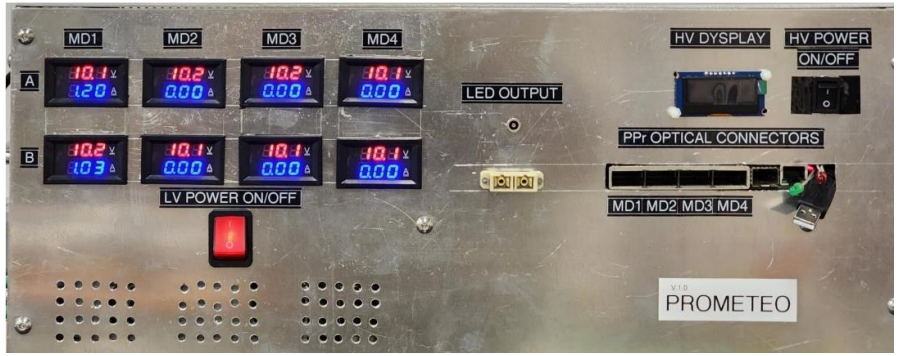
Assembly, tests and installation

- Front-end electronics to be assembled from multiple components into super-drawers before installation
- PROMETEO portable standalone test bench for up to four mini-drawers, used to certify the functionality and performance
- Test results and boards IDs saved in the installation database
- Assembly and installation plans have been prepared

production ongoing



Sketch for assembly of a mini-drawer



PROMETEO test bench

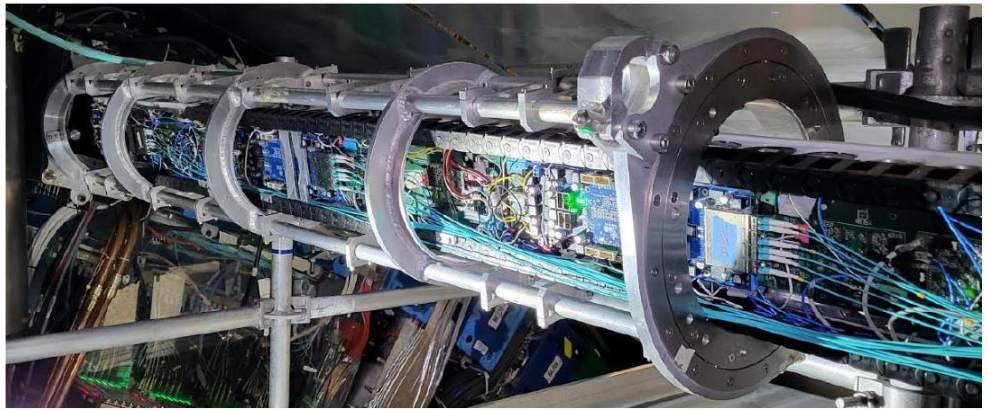
Extraction/insertion of a super-drawer

Test of a full super-drawer

Hybrid Demonstrator module and test beam

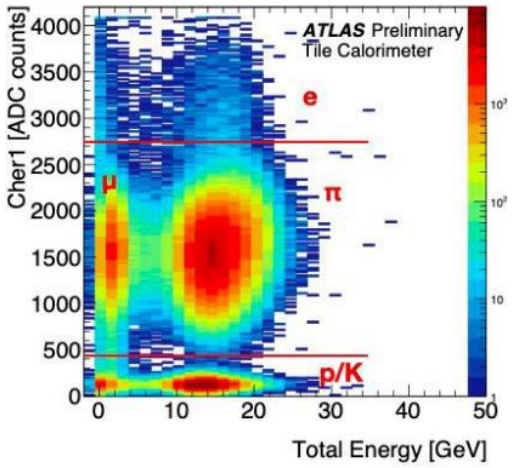
Demonstrator

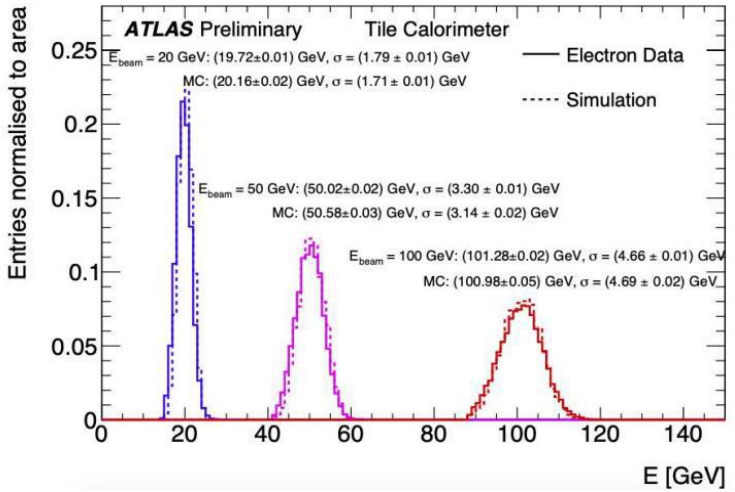
- full Long Barrel super-drawer with new electronics and analog trigger (backward compatible)
- new back-end electronics interfaced to legacy
- takes data in ATLAS since 2020
- useful experience with real operation
- good stability and in-situ performance



Test beams

- fixed target test beams of various particles and energies at SPS at CERN
- validate new electronics in more realistic conditions
- full slice tests
- performance measurements
- encouraging results





Summary

- The high radiation doses and high pile-up foreseen for HL-LHC are huge challenges for the ATLAS detector and its electronics
- ATLAS Tile Calorimeter needs a major upgrade to operate at HL-LHC
- The major upgrade of the Tile Calorimeter on and off detector electronics to cope with the new challenges is underway
- Part of the mechanics and calibration systems are also being upgraded
- Many upgrade deliverables have been already produced
- Test beam campaigns help to validate new designs and involve new people
- Upgrade demonstrator module is successfully taking pp collisions data in ATLAS