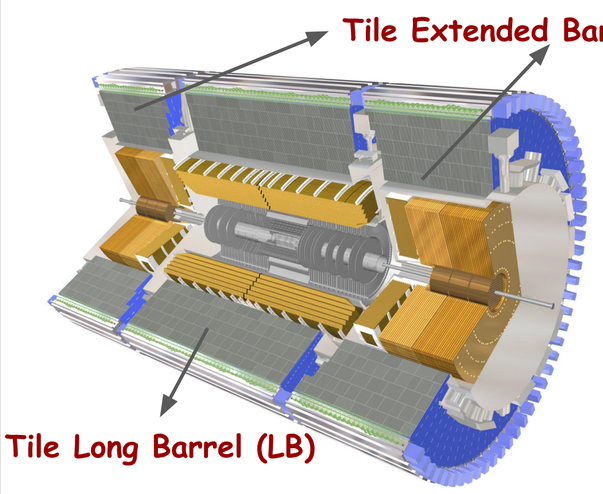
EuNPC 2025 September 22-26,2025

Performance and upgrade of the ATLAS Hadronic Tile Calorimeter

Marina Kholodenko (LIP, Portugal) on behalf of ATLAS collaboration

Hadronic Sampling calorimeter

- Scintillation tiles and steel absorber
- Hadrons, missing transverse energy measurements
- Analog input to the Level 1 hardware calorimeter trigger
- Covering $|\eta|<1.7$

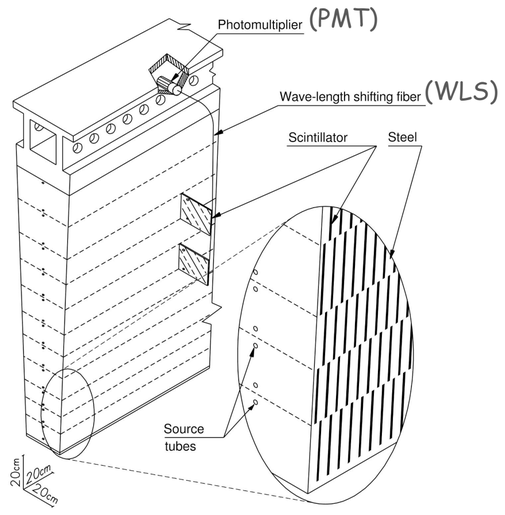


- Double PMT cell readout through **WLS optical fibers**
- Single **hadron energy resolution** goal: $\frac{\Delta E}{E} \sim \frac{50\%}{\sqrt{E}} \oplus 3\%$

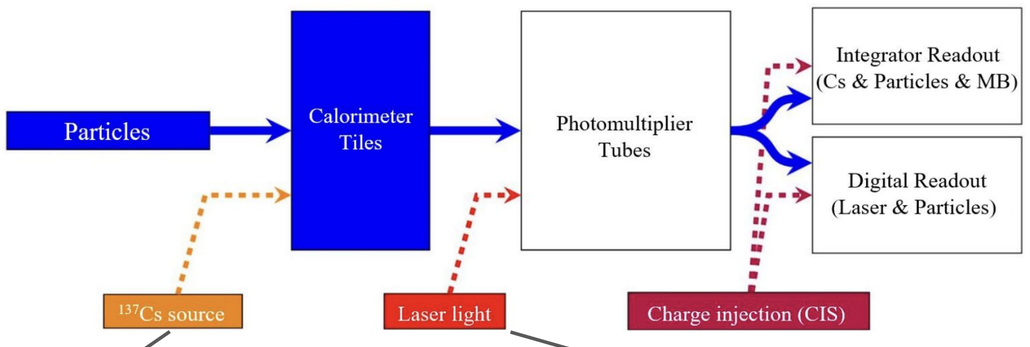
ATLAS Tile Calorimeter

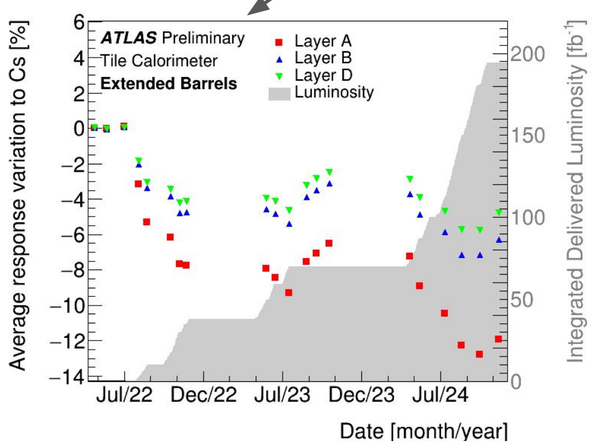
- **256 modules, 3 radial layers**
- **9852 readout channels**
- **cell granularity in (η,φ):** 0.1 (0.2) x 0.1

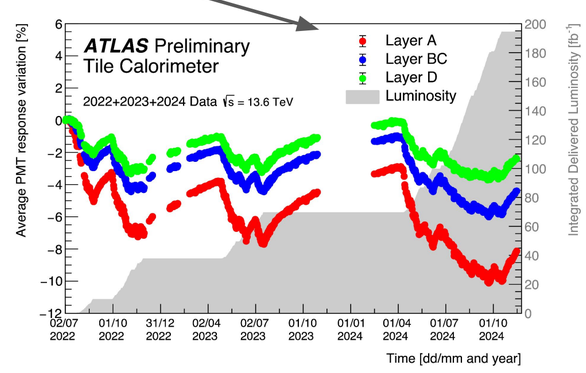
TileCal module



Calibration systems







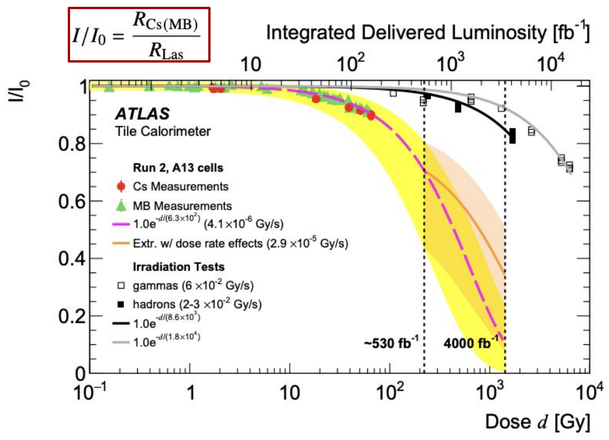
$$E\ [\mathrm{GeV}] = \frac{A\ [\mathrm{ADC}]}{C_{\mathrm{ADC\to pC}} \times C_{\mathrm{pC\to GeV}} \times C_{\mathrm{Cs}} \times C_{\mathrm{MB}} \times C_{\mathrm{Las}}}$$

- Shaped (50ns) PMT signal
- Two 10-bit ADCs
- 7 signal samples to reconstruct signal amplitude *A*

TileCal Performance Studies

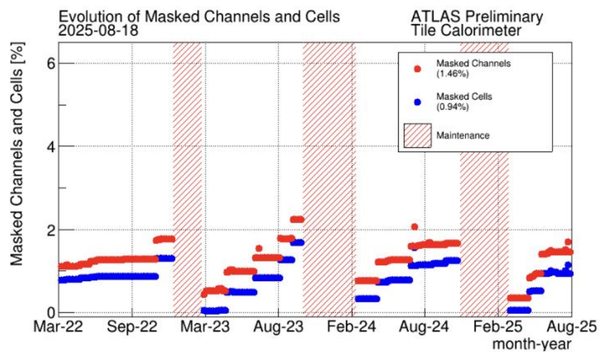
Radiation hardness studies

$$I/I_0 = \frac{R_{\mathrm{Cs(MB)}}}{R_{\mathrm{Las}}}$$



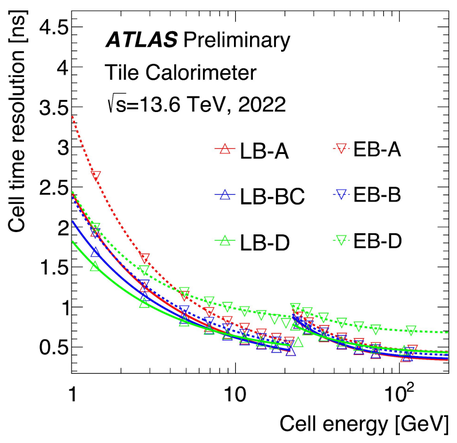
- Scintillator and WLS fibers response degradation studies
  - By factoring out PMT response contribution
- Extrapolation to the end of Run 3 and HL-LHC

Evolution of masked channels and cells



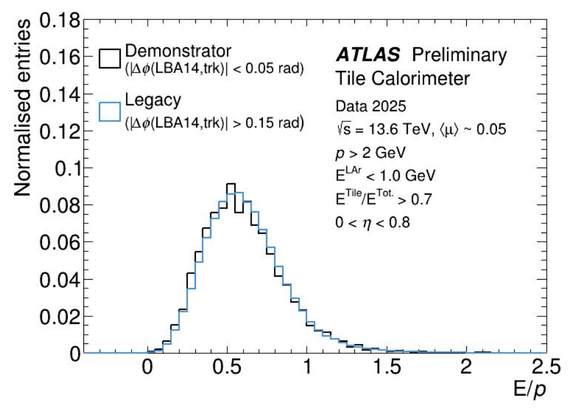
- **Fraction of data suitable for physics analysis:**
  - ~99.7% in 2022, ~99.6% in 2023
  - ~99.3% in 2024

Cell time resolution



- **Cell time resolution** ~1 ns for cell energy > 4 GeV

Response to charged hadrons



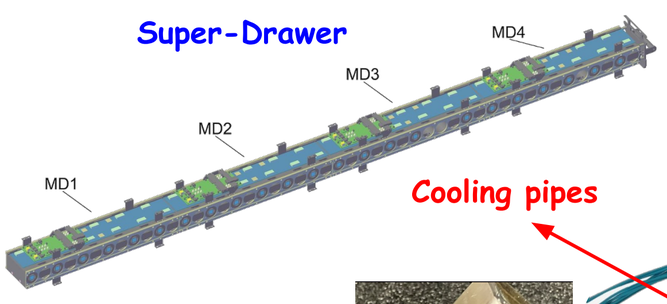
Demonstrator: Installed in ATLAS in 2019 and operates in Run 3

- Equipped with upgraded electronics
- Response to isolated hadrons is comparable to legacy modules

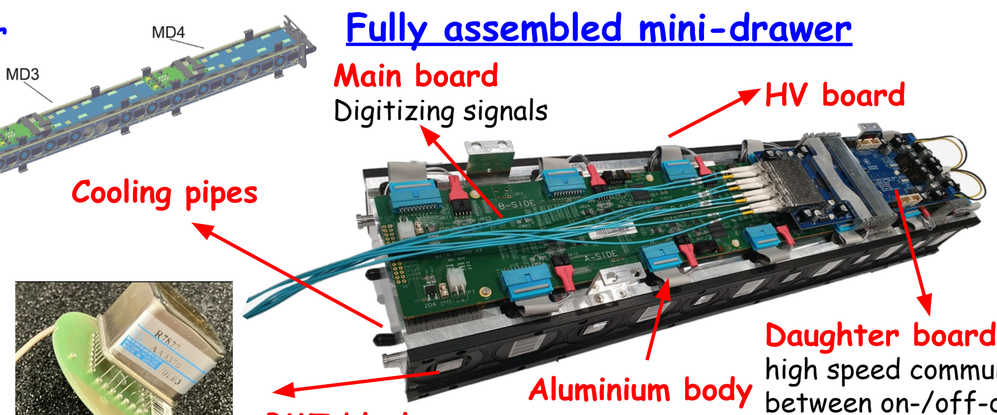
HL-LHC Tile Calorimeter Upgrade

- **HL-LHC:** 2030 - 2041
- Luminosity↑5-7.5x
  - **up to 200 proton-proton collisions per bunch**
- **Challenges for detector:**
  - Higher radiation doses
  - Higher data rates

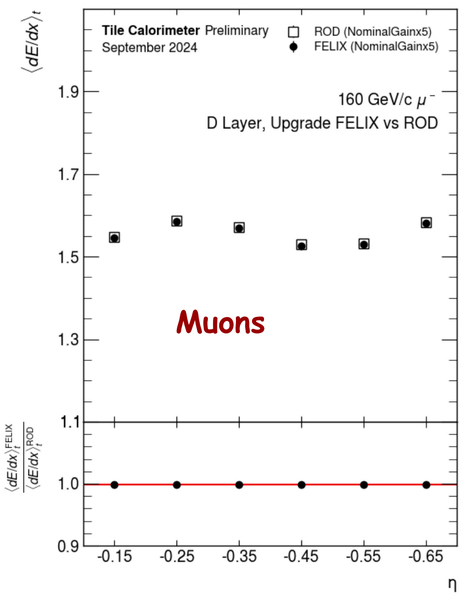
Super-Drawer



Fully assembled mini-drawer

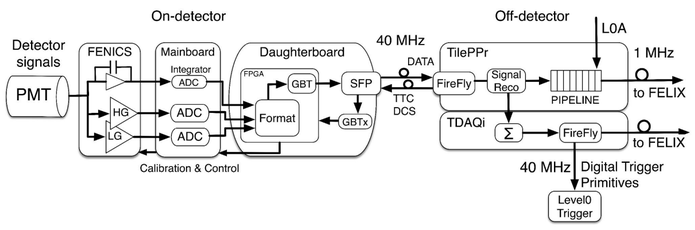


Test beam campaign (10 years)



Upgrade overview:

- On- and off-detector electronic replacement
- Replacement of ~10% PMTs (Hamamatsu R11187)
- New mechanical frames for easier access
- New high and low voltage power supplies
- Calibration system upgrade
- New fully digital 40 MHz readout architecture



CPM

Off-detector electronics: Energy and time reconstruction, trigger primitives

Tile PreProcessor:

- **ATCA Carrier BaseBoard:** power distribution, communication infrastructure
- **Compact Processing Modules (CPM):** main processing, handle full calorimeter readout
- **TDAQ interface:** TileCal to ATLAS TDAQ interface

- To validate the performance of upgraded modules
- The setup fully integrated with ATLAS Trigger and Data Acquisition (TDAQ) system
- Electron, muon, hadron beams of wide energy range

Acknowledgments:

fct Fundação para a Ciência e a Tecnologia 2024.00227.CERN

REPÚBLICA PORTUGUESA Co-funded by the European Union

References:

1. Operation and performance of the ATLAS Tile Calorimeter in LHC Run 2
2. Study of the Radiation Hardness of the ATLAS Tile Calorimeter Optical instrumentation with Run 2 data
3. Technical Design Report for the Phase-II Upgrade of the ATLAS Tile Calorimeter
4. TileCal Public plots