

The ATLAS Tile Calorimeter

- The **Tile-Calorimeter (TileCal)** is a sampling calorimeter which forms the central region of the Hadronic calorimeter of the ATLAS experiment.
- **Tilecal** performs several critical functions within ATLAS such as the measurement and reconstruction of hadrons, jets, hadronic decays of τ - leptons, and missing transverse energy. It also participates in muon identification and provides inputs to the Level 1 calorimeter trigger system.
- **TileCal is composed of 256 wedge-shaped modules** which are arranged azimuthally around the beam axis. An individual module consists of alternating steel (absorber) tiles and plastic scintillating (active medium) tiles with a Super Drawer (SD) housing the Front-End (FE) electronics located inside the widest section of a Tile Module.

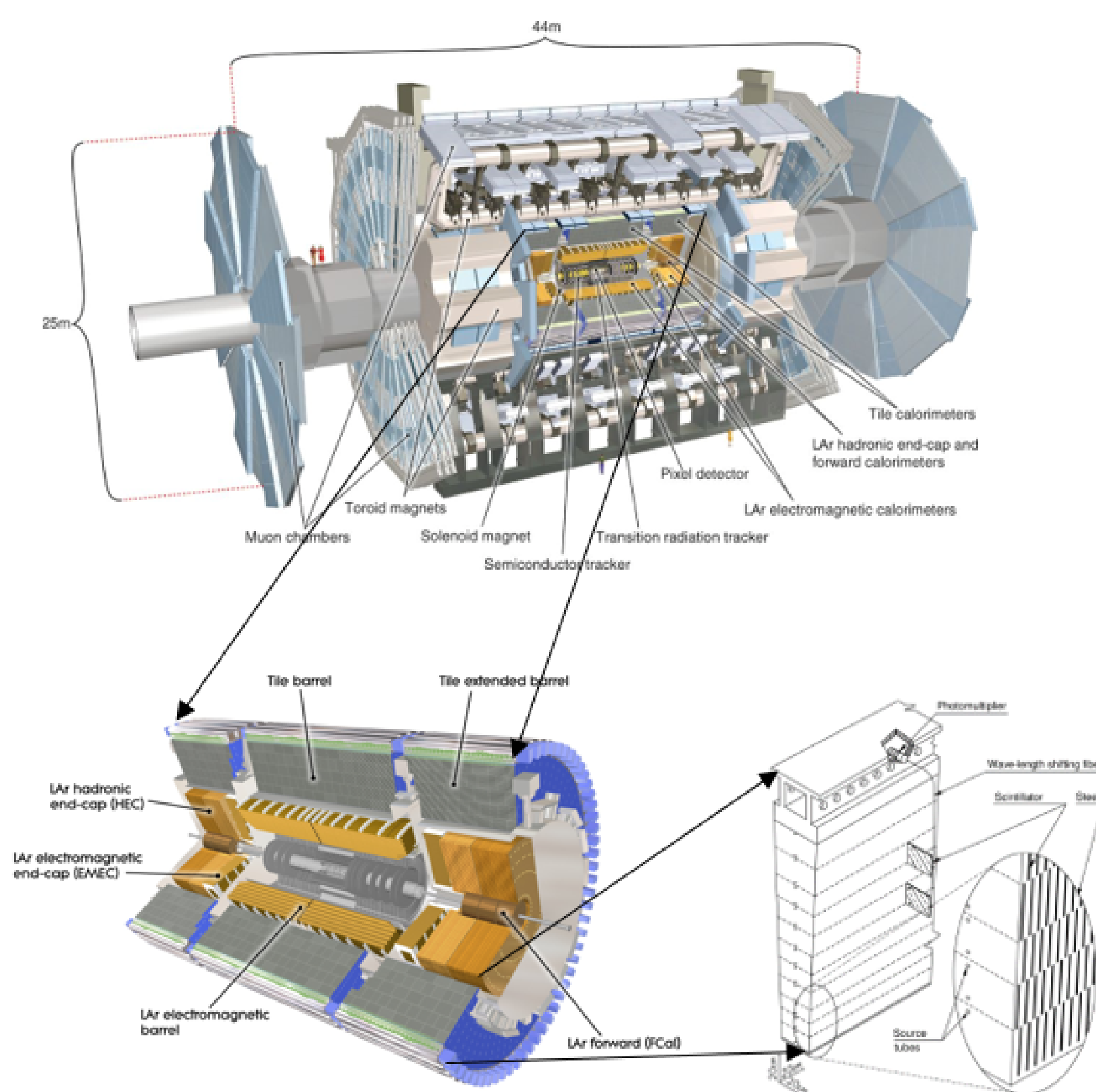


Fig. 1 Top - The ATLAS detector, Bottom left - The inner Barrel, Bottom right - A TileCal module. J. Pequeno, Computer Generated image of the ATLAS calorimeter, (2008), <https://cds.cern.ch/record/1095927>

Upgrade Power Distribution

High Voltage (HV) Distribution System

- The HV distribution system provides regulated high voltage to individual HVADs. It consists of HVremote boards that provide primary HV which is distributed to the HVADs via passive HVbus boards located within the Minidrawers.
- The upgrade removes the radiation hardness requirements of the HV regulators as regulation is now implemented off-detector.

Low Voltage Distribution, Control and Monitoring System (LVDCMS)

- This system provides low voltage power to the front-end electronics of the Superdrawers. The off detector Auxiliary boards (AUXboards) operate as 200 VDC power supplies as well as perform control and monitoring functions via the Embedded Local Monitoring Board (ELMB) of the Low Voltage Power Supplies (LVPS), of which there is one per TileCal module. The new on detector LVPS is radiation hard and is comprised of eight Bricks which function to step-down the 200 VDC received from the AUX boards to the 10 VDC required by the Point-of-load regulators located on the MBs as well as an ELMB.

Upgrade TileCal Mechanics

- The On detector electronics are housed in a new modular configuration in which one drawer (Superdrawer) is composed of 4 functionally independent Minidrawers.
- The new configuration simplifies installation and manipulation creating better conditions for servicing within the high radiation environment.

Upgrade FrontEnd Electronics

PMTs and High Voltage Active Dividers (HVADs)

- PMTs receive scintillation light via wavelength-shifting fibres. This light is then converted into electrical signals. A total of 768 PMTs located in the most exposed regions will be replaced due to aging.
- The HVADs make use of transistors and diodes in addition to passive components. They are responsible for dividing the received high voltage power between the individual dynodes of a PMT.
- The Upgrade ensures that the calorimeter performance, in terms of linearity and energy resolution for the measurement of highly energetic jets is maintained.

Front End board for the New Infrastructure with Calibration and signal Shaping (FENICS)

- A readout board responsible for the amplification and shaping of current received from a single PMT that is also involved in calibration as it contains the Charge injection system.
- FENICS reads the fast signals (full width at half maximum 25 ns) using two gains ($\times 32$, $\times 1$) and reads the averaged current (integration time 10 ms) using six gains (0.3, 25, 25.3, 50.3, 125.3, 150.3 $V/\mu A$).

Mainboard (MB)

- There is an MB located in each Mini-drawer of TileCal. A single MB interfaces with twelve FENICS and one DB. A MB digitizes the low and high gain signals received from the FENICS which are then sent to its associated DB.
- An Upgraded MB is functionally divided into two halves for redundancy, provides digital control of the front end boards using Field-Programmable Gate Arrays (FPGAs), and features voltage and current monitoring.

Daughterboard (DB)

- The DB is the primary interface between the on and off detector electronics of TileCal and is mounted on an MB. A DB sends detector data to the off detector electronics, receives and distributes LHC clocks, configurations and slow-control commands.
- Major changes to the DB include using FPGAs with improved power sequencing as well as improved routing from the MB Analogue to Digital Converters (ADCs) to achieve better readout timing performance.

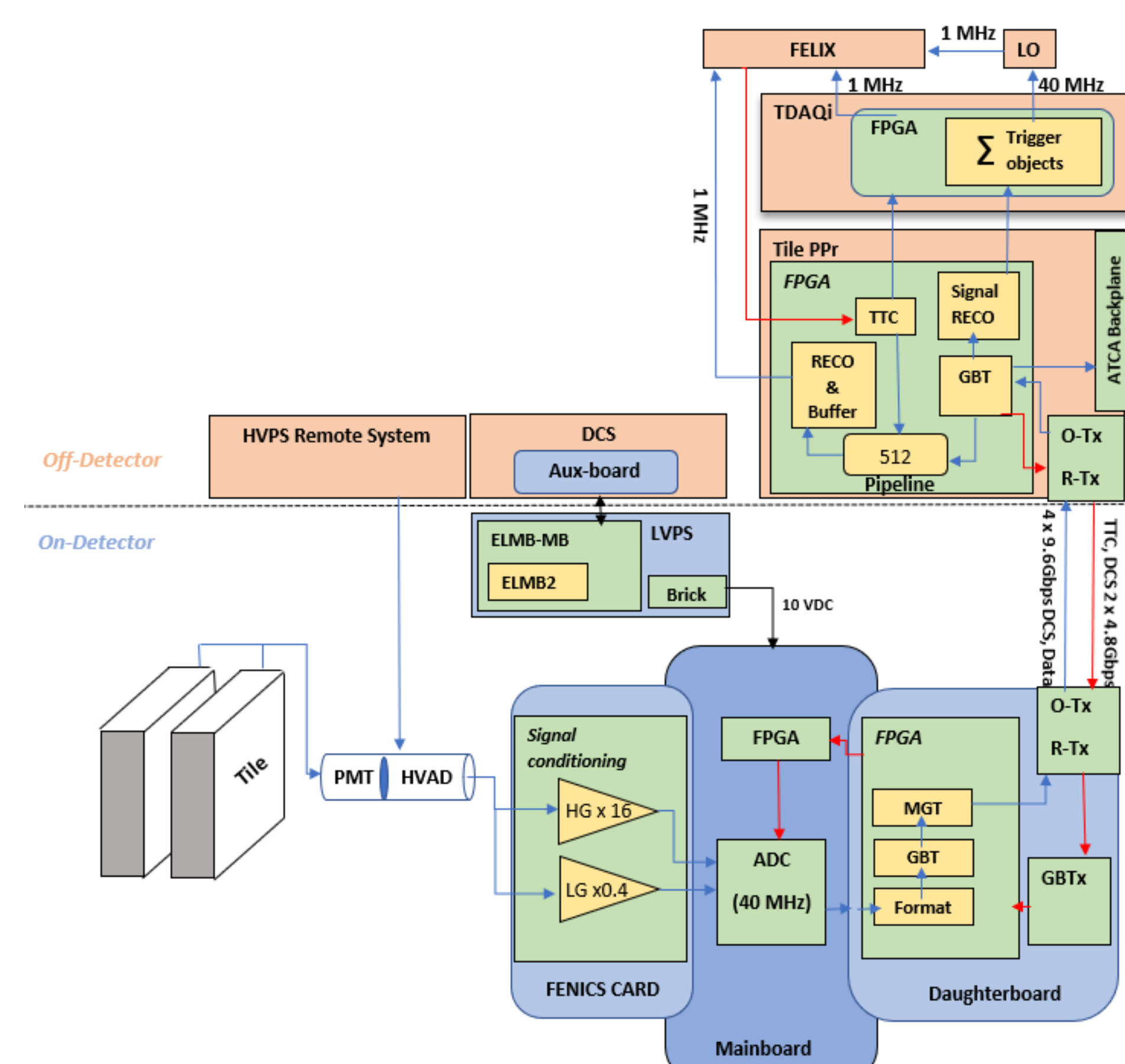


Fig. 2 The upgraded readout chain and power distribution of TileCal.

Upgrade BackEnd Electronics

PreProcessor (PPr)

A PPr is composed of four Compact Processing Modules (CPMs) and an Advanced Telecommunications Computing Architecture (ATCA) carrier board. Each CPM will read out and operate up to two TileCal SDs via high-speed optical links.

- A CPM implements a bi-directional GigaBit Transceiver communication with four 9.6 Gbps uplinks and two 4.8 Gbps downlinks per mini-drawer. The uplinks transmit detector and monitoring data to the CPMs. The downlinks provide Detector Control System (DCS) commands and Timing, Trigger, and Control information to the on-detector electronics, as well as the LHC clock for the sampling of the PMT signals.
- Deposited energy is reconstructed and calibrated in real-time using the received digitized samples. The CPM transmits this data to the TDAQi via the ATCA carrier board at the LHC frequency via four 9.6 Gbps optical links.

Trigger and Data Acquisition Interface (TDAQi)

All interfaces between the TileCal and TDAQ are implemented in the TDAQi module. The TDAQi constructs the trigger primitives and interfaces with the trigger and FELIX systems. The Trigger FPGAs compute trigger objects for electrons, jet, global, and muon triggers and the results are transmitted through low latency high-speed optical links to the L0 trigger.

- Trigger sums changing from analog to digital.

Upgrade Calibration Systems

TileCal is equipped with calibration systems that allow for monitoring and calibration of the responses of the different components of the detector.

Cesium System

To calibrate and monitor the full optical path of TileCal a system of Cs^{137} gamma sources, driven by a liquid flow through all the scintillating tiles, is used.

- New highly radiation-tolerant control boards of the Cs^{137} system to be implemented as well as a new optical link interface with the DCS.

Laser System

A laser source is installed off-detector which provides light to the PMTs through 400 optical fibres.

- A new control and interface board with TDAQ and DCS is being introduced. The light mixer will also be replaced by an integrating sphere to add a controlled source of DC light to simulate underlying minimum bias events during calibration.

2021 Test Beam Campaigns

The calorimeter setup in the H8 beam of the CERN SPS consists of two fully functional long-barrels and one extended-barrel module allowing for the testing of any upgrade electronics without the need to install them within TileCal.

- Building upon past successful test beams, two new test beams will be undertaken in September and November of 2021.
- The primary goal is to test the response of the HL-LHC module readout.
- The following electronics will be installed: Upgrade HV Distribution System, Upgrade LVPS-DCS, Upgrade V4 MBs, Upgrade V6 DBs, Upgrade FENICS2, Upgrade PPr and CPM.

References

- The ATLAS Collaboration, ATLAS-TDR-028 (2017), <https://cds.cern.ch/record/2285583>