ATLAS Tile Calorimeter Upgrades for HL-LHC

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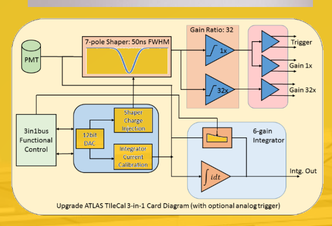
on behalf of the ATLAS TileCal collaboration

The Large Hadron Collider (LHC) at CERN is scheduled to undergo a decisive upgrade (2024-2026) which will boost its physics capabilities well beyond the initial design goals. The High-Luminosity (HL) LHC will be delivering a luminosity of ~5x10^{34} cm^{-2}s^{-1}, with up to 200 interactions per 25 ns bunch crossing. In order to cope with the expected high trigger rates and intense radiation environment, the ATLAS Tile Calorimeter (TileCal) will be upgraded with re-designed electronic systems to maintain its optimal performance in its future operation.

3-in-1 Front–End cards

1. ***Amplification*** of the PMT pulse (dual gain: x1, x32).
2. ***Shaping*** of the PMT pulse to a low bandwidth waveform, for sampling at 40 MHz, by 7-pole passive LC shapers.
3. ***Slow integration*** of the PMT signal for the measurement of the low amplitude current produced by a ^{137}Cs source (calibration runs) as well as the monitoring of the luminosity.

\+ **Charge Injection System** upgraded to cover the entire input dynamic range.

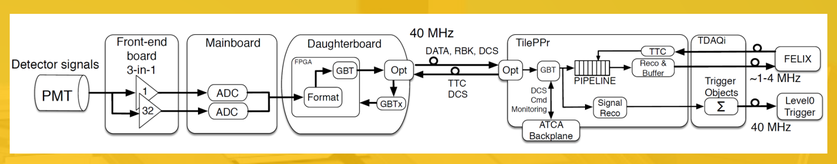


Mainboard

- Signal digitization with 12-bit, 40 Msps ADCs, establishing a **17-bit output dynamic range,**
- Data serialization and transmission to the Daughterboard.

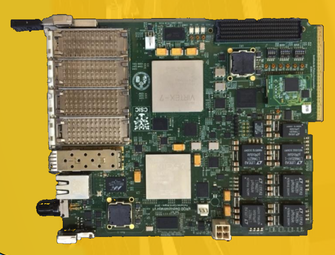
Daughterboard

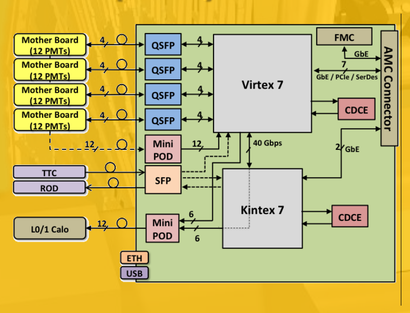
- Control of 12 3-in-1 boards (1 mini-drawer).
- Deserialization of the data and transmission to the PPr, through high speed optical links.
- LHC clock recovery using GBTx chips.



Pre-Processor (PPr)

- Back- to front-end interface.
- Pipeline buffering of digitized samples.
- Feeding of reconstructed data to the trigger system (40 MHz).
- Data transmission to the ATLAS central DAQ upon trigger reception.



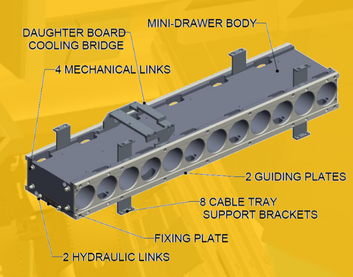


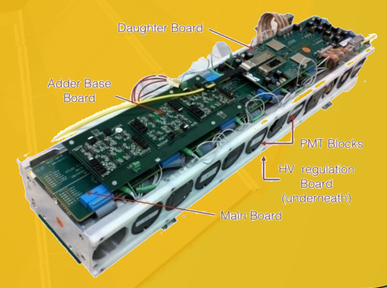
PPr modules will be upgraded into full-size ***ATCA blades***, to comply with the new ATLAS TDAQ.

Mechanics

The front-end electronics are installed on a mechanical structure, called super-drawer, inserted in each module. In the new design, each super-drawer is comprised of 4 individual "***mini-drawers***", allowing:

- fast access to the front-end electronics,
- easy replacement of malfunctioning components in a limited space,
- and therefore less exposure of the personnel to radiation.

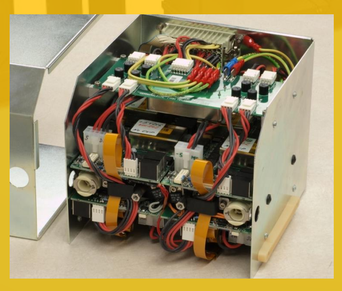




Low Voltage Power Supply (LVPS)

Optimization of the current reliable architecture:

- 1 LVPS box per super-drawer. Installation at the "finger" of each TileCal module, right outside of the super-drawer,
- 8 identical LVPS boards (bricks) per module, converting a 200V input voltage to 10V (supplied to the Mainboards),
- voltages for individual loads are generated with point-of-load regulators, located at the loads,
- redundancy: 8 bricks grouped into four sets of two (2 redundant bricks per mini-drawer).



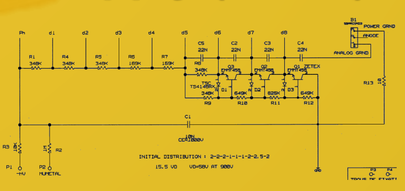
High Voltage Power Supply (HVPS)

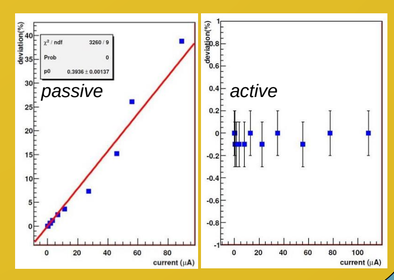
Active PMT voltage dividers to account for the large currents expected at the HL-LHC:

- improved linearity for a large range of DC currents,
- PMT pulse shape stability with large injected charges,
- radiation hardness.

Remote HV regulation for individual channels:

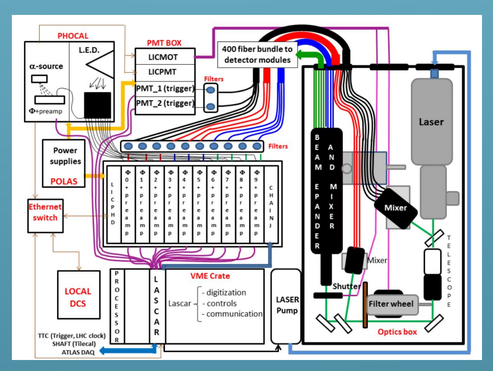
- radiation immunity,
- permanent access to the electronics.





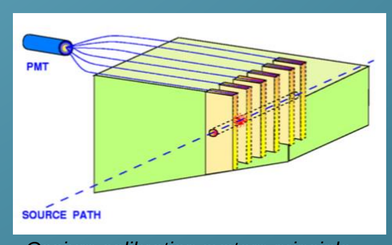
TileCal Calibration Systems

1. The on-board **Charge Injection System**, has been redesigned for the new 3-in-1 cards, allowing:
   - Injection of known charge in the entire input dynamic range,
   - constant monitoring of the operation of the front-end electronics,
   - determination of [ADC count → pC] conversion factors.
2. The current architecture of **the laser calibration system** (monitoring of the PMT gains) will be kept, with:
   - substitution of aged components,
   - upgrade of the current interface to the TDAQ, called LASCAR, to be compliant with the TDAQ planned for the HL-LHC.



Architecture of the Laser calibration system.

3. The **Cesium system** allows calibration of the entire optical path by means of a ^{137}Cs gamma source. The upgrade plan includes:
   - integration of the control data flow into the standard data read-out electronics (GBT slow control stream),
   - possible change of the working media, optimization of the operation mode and revision of the principle of the source movement.



Cesium calibration system principle.