Laser Calibration of the ATLAS Tile Calorimeter

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Introduction

The Tile Calorimeter (TileCal) is the central sampling hadronic calorimeter of the ATLAS experiment. Its purpose is to reconstruct and measure hadrons, jets, tau-particles and missing transverse energy.
It is built with plastic scintillator tiles (active material) and steel plates (absorber material), with the scintillating light being guided by wavelength-shifting fibers to reach the photomultiplier tubes (**PMTs**).

The TileCal **calibration and monitoring systems** measure fluctuations of different detector components and are used to keep the detector energy response constant:

$$E[GeV] = \frac{A[ADC]}{f_{pC\to GeV} \cdot f_{Cs} \cdot \boldsymbol{f_{Las}} \cdot f_{ADC\to pC}}$$

One example is the **Laser system,** which is responsible for monitoring the **PMTs** and readout electronics.

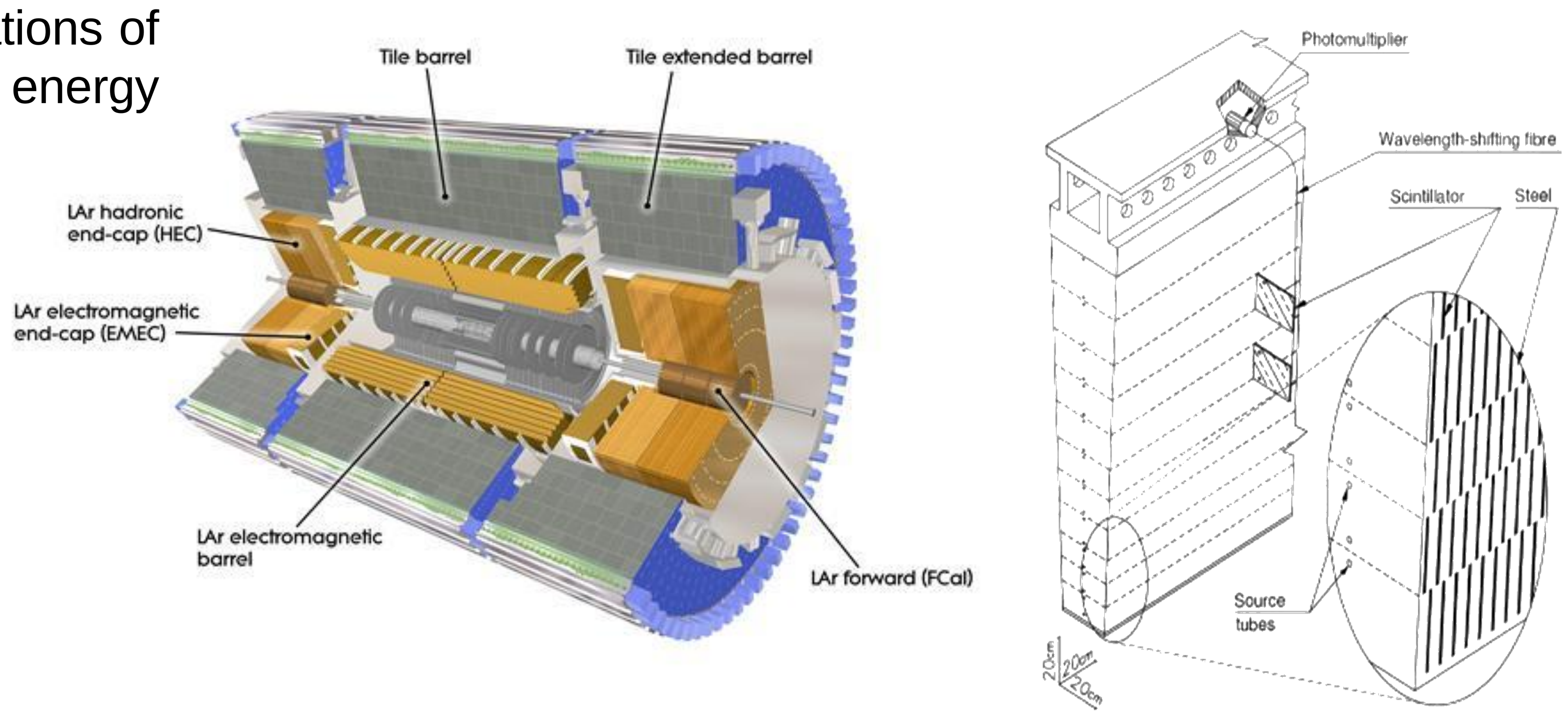

Fig. 1 – ATLAS detectors - Tile Calorimeter wedge module. [1]

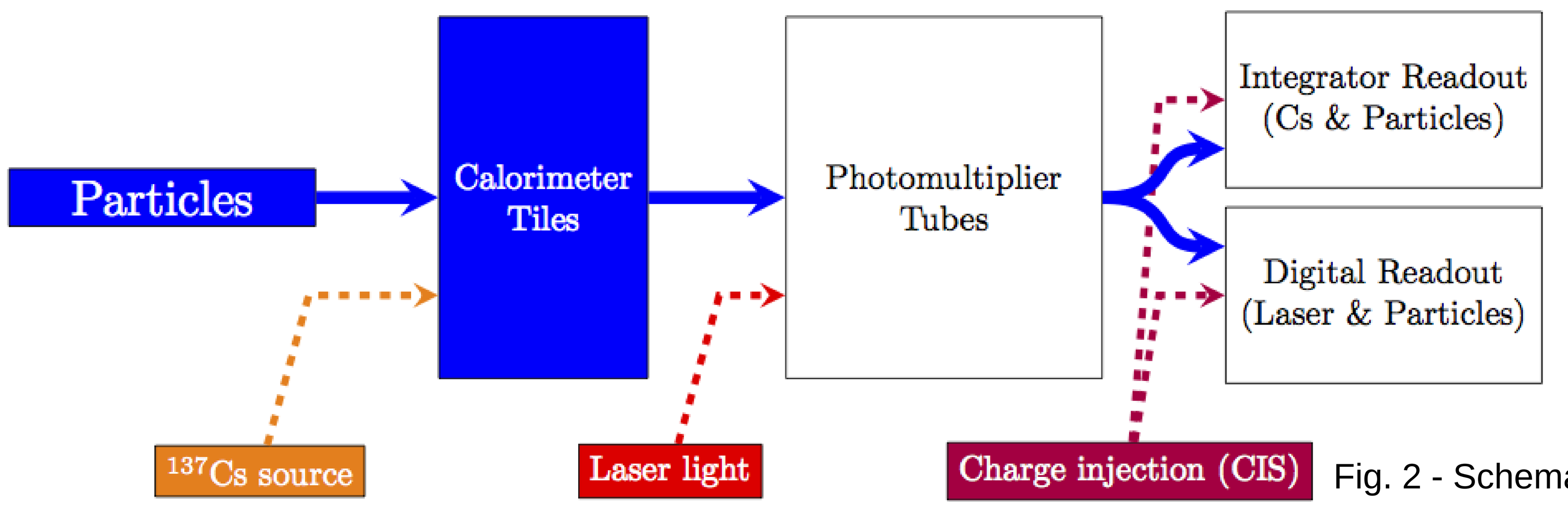

Fig. 2 - Schematic of the TileCal Calibration Systems. [2]

Laser System

A **laser system** was assembled to **monitor** the TileCal **PMTs**.
A set of laser pulses are sent via long clear fibers and read by the PMTs.
Reference diodes are used to monitor the stability of the light source.
The **PMT response** is the amplitude ratio between the PMT signal (A_i) and the reference diode signal (A_D):

$$R_i = \frac{A_i}{A_D}$$

The laser constant ($\boldsymbol{f_{Las}}$) is calculated w.r.t a reference response (near the Cs scan):

$$\boldsymbol{f^i_{Las}} = \frac{R_i}{R_i^{ref}}$$

The $\boldsymbol{f^i_{Las}}$ must be corrected for instabilities due to:

- Fluctuations in the Laser system coherence.
- Time variation in the light transmission between clear fibers.

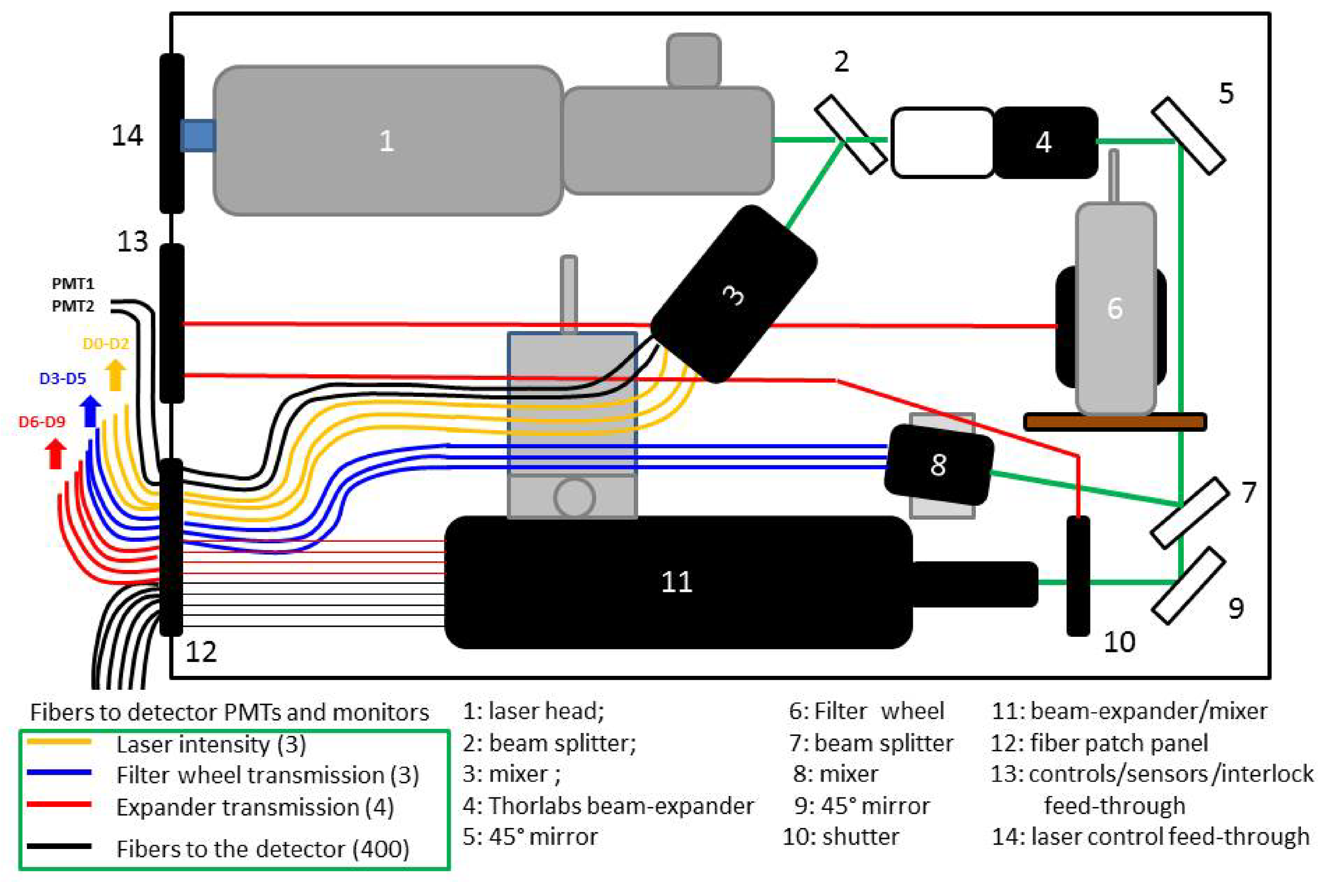

Fig. 3 – Scheme of the Laser II optics box, depicting the internal elements and optical paths. [2]

PMT Response Monitoring and Calibration

In **Run 2** and **3**, the PMT responses decreased during $\boldsymbol{pp}$ **collisions** and increased for **heavy ions** and **non-collision** scenarios.
The **negative variations** are related to the amount of **charge integrated** by the PMTs.
PMTs connected to scintillators closer to the beam pipe exhibit **more degradation**, specifically E and A cells, due to **higher light exposure**.
At the end of **Run 2**, the response variation for the most affected cell of the extended barrel, A13, was **-4.4**%.
During Run 3 and after pp collisions, the **A13** cell shows a response of **-8.4**%.

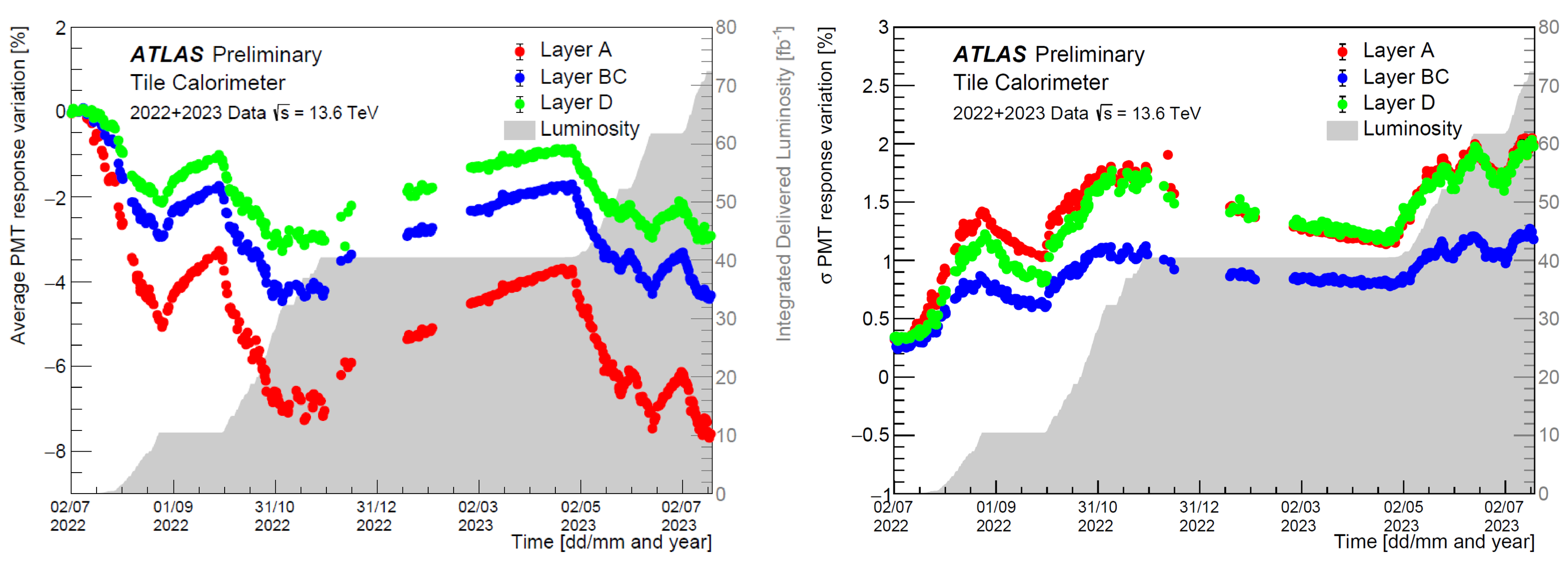

Fig. 4 – Average/Standard deviation PMT response variation during Run 3. [3]

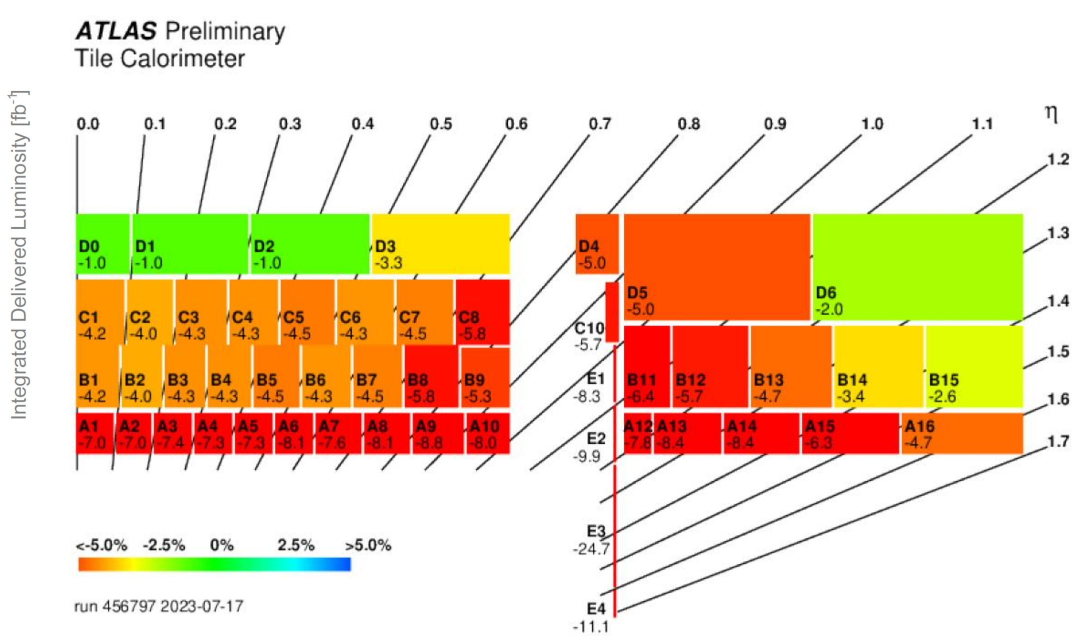

Fig. 5 – PMT response variation at the end of Run 3 pp collisions . [3]

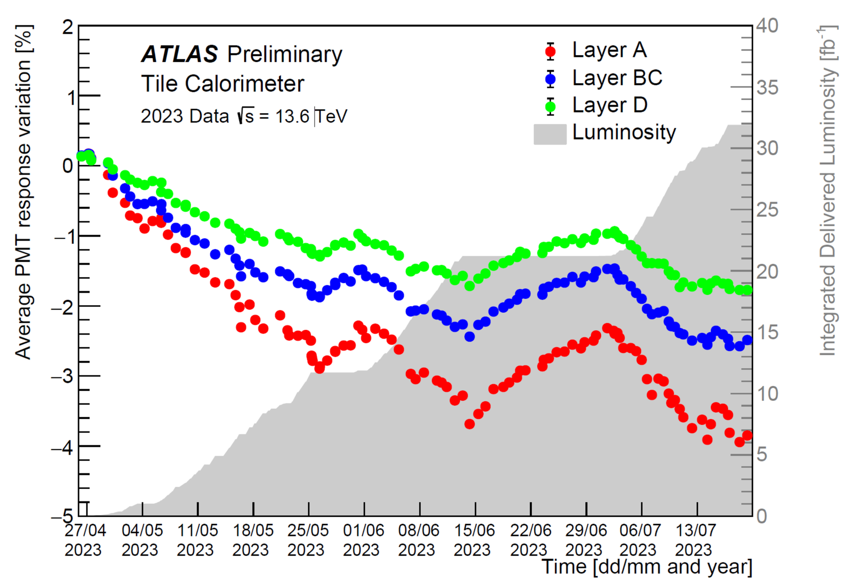

Fig. 6 – Average PMT response variation during 2023. [3]

Dedicated runs for monitoring are taken ~daily and **calibrations** are done ~weekly to **compensate** for the response variations on the **PMTs**.
This system also serves for **time calibration stability monitoring,** that is essential to **discard** signals which do not originate from collisions.

Conclusions

The Laser system contributes to good and precise detector performance with an **uncertainty** of ~**0.5%**.
The **PMTs** that are **more exposed** to scintillating light have a **lower response** to the **Laser** system, suggesting **more PMT degradation**.
During the periods with **no collisions**, most PMTs show **partial recovery** from the damage.

References

1. ATLAS Collaboration 1996 ATLAS Tile Calorimeter: TDR CERN-LHCC-96-042
2. Agaras, M. N., et al. "Laser calibration of the ATLAS Tile Calorimeter during LHC Run 2." Journal of Instrumentation 18.06 (2023): P06023.
3. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileCalibration

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