Robustness studies of the photomultipliers reading out TileCal, the central hadron calorimeter of the ATLAS experiment

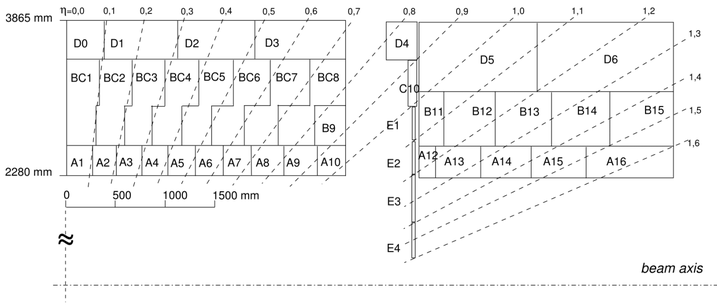
Giulia Di Gregorio(*)

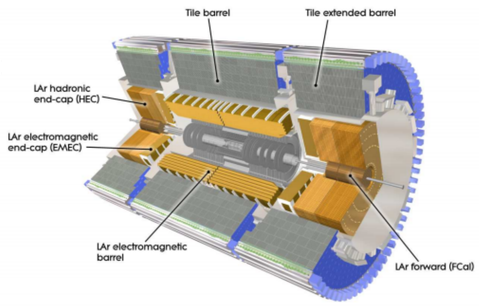
On behalf of the ATLAS Tile Calorimeter System

(*) University & INFN of Pisa

ATLAS Tile Calorimeter and its calibration systems

- The Tile Calorimeter (TileCal) is the central section (|η| < 1.7) of the hadronic calorimeter in the ATLAS detector.
- It is a sampling calorimeter made up of steel and scintillating tiles. Tiles are coupled to WLS fibers and readout by two photomultipliers (PMTs). Fibres are grouped in bundles to define the unit cell.

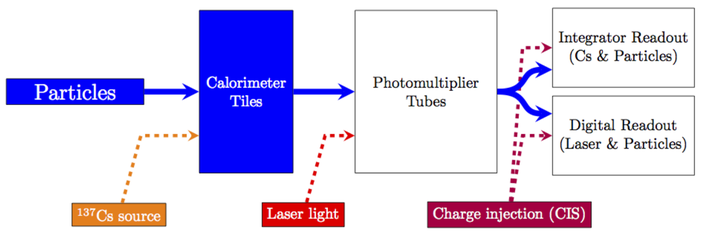




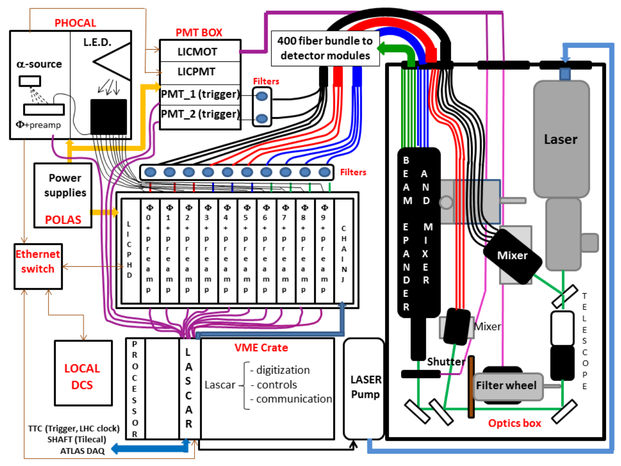
TileCal is divided into:
- 4 partitions
- 64 modules per partition
- up to 48 PMTs per module

→ TileCal is readout by ~10k PMTs

TileCal response is calibrated with 3 systems:
- Cesium sources (full chain calibration);
- Laser light (readout calibration);
- Charge injection (electronics calibration).



TileCal Laser Calibration System



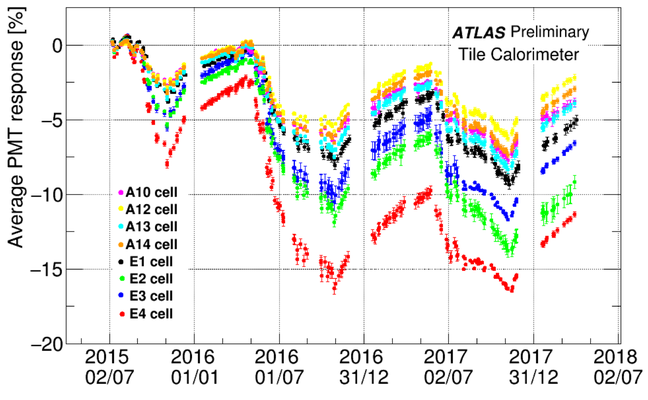
- The laser system monitors the PMTs and the front-end electronics.
- Laser light pulses are transmitted simultaneously to all TileCal PMTs through a bundle of about 100 m long clear fibers.
- The laser calibration constants are updated between two subsequent calibrations made with the Cesium system.
- The laser is also used to cross-check the stability of timing settings during data taking sending laser pulses in empty bunch crossings.

TileCal PMT

- TileCal PMT is a special costumized version of the Hamamatsu model R5900. TileCal PMT version is Hamamatsu R7877.
- It is a 8-stage fine-mesh PMT with dimension 20x20mm².
- It is characterized by response linearity in a huge interval of incident light intensity and fast rise time (<2.5 ns).

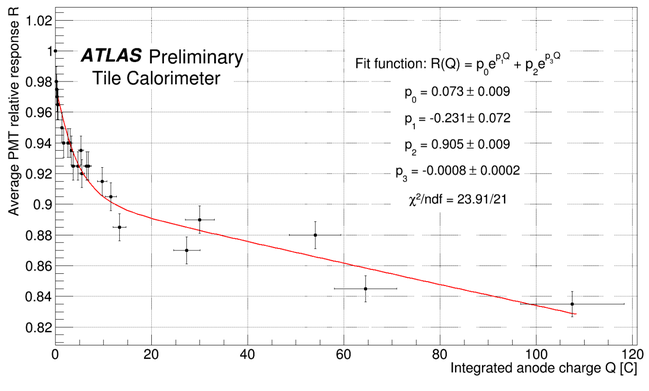
TileCal PMT response

- The average response variation with time for different cell types is studied using the laser system.



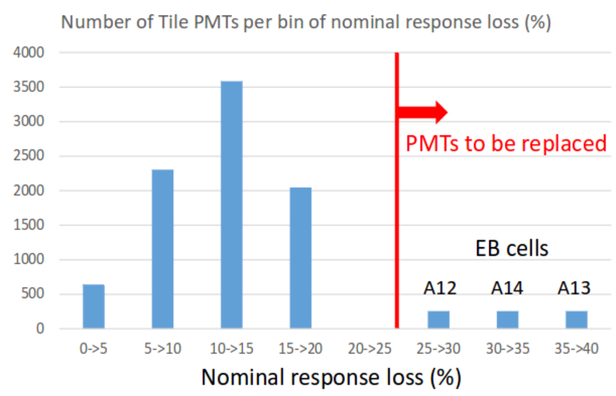
- The response variation is normalised to the first day of observation (17/07/2015).
- Observed down-drifts mostly affect PMTs reading out the most exposed cells.
- The down-drift of the PMT response coincides with the p-p collision periods, while the response recovery occurs during heavy ion collisions and technical stops.

- Average TileCal PMT relative response as a function of the integrated anode charge.

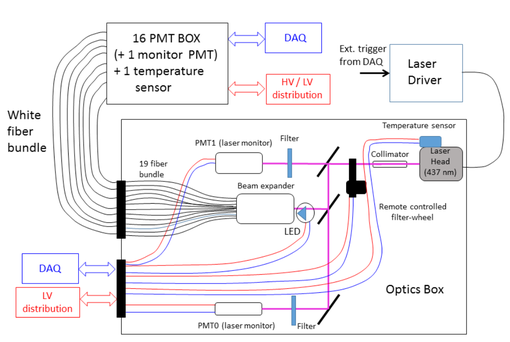


- Points correspond to the average relative response loss of different cell types (A10, A12, A13, A14, E1, E2, E3, E4) measured at the end of each year of p-p collisions during LHC Run 2. Each cell enters three times into the plot.
- The points are fitted with a double exponential function: $R(Q)=p_0\exp(p_1Q)+p_2\exp(p_3Q)$
- Points at high anode integrated charge values (>20 C) correspond to E2, E3 and E4 cell response.

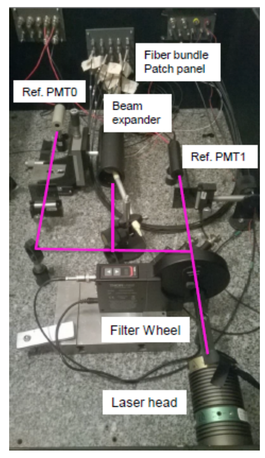
- Using the two exponential model it is possible to make projections about the expected PMT response loss in HL-LHC era.
- At the end of HL-LHC period (4 ab^{-1}) only PMTs reading out the inner cells (A cells) are expected to loose >25% of their response.
- PMTs whose response loss is expected to be >25% (8% of the total) will be replaced with a newer version with same geometry but improved performance.



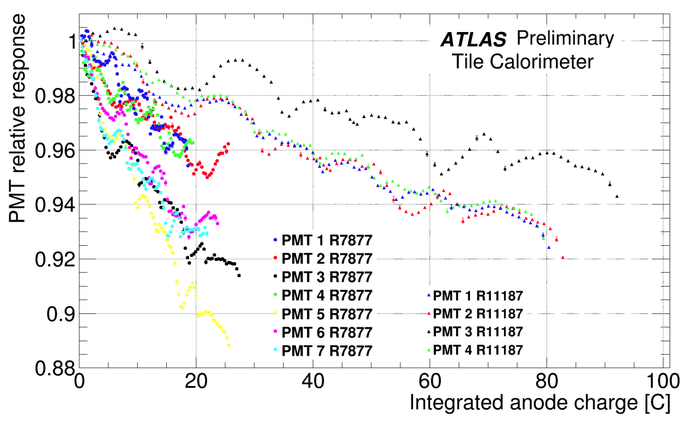
Pisa experimental setup



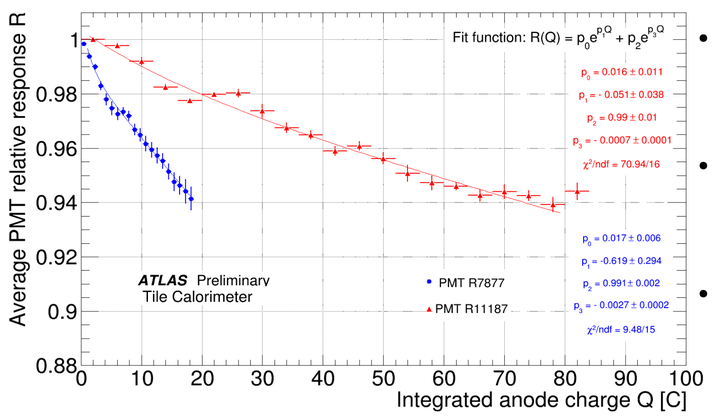
- A local test bench to study PMT robustness is operating in the Pisa-INFN labs.
- The optical system to excite the tested PMTs is similar to the one used in TileCal for laser calibration.



PMT response – measurements in lab



- In Pisa lab two different types of PMTs are tested:
  - 7 PMTs (circles) dismounted from TileCal detector in February 2017 (model Hamamatsu R7877). They integrated 1 to 5 C since beginning of LHC operation.
  - 4 new PMTs (triangles) model Hamamatsu R11178, an evolution of R7877). This model is proposed for the PMT replacement for HL-LHC.
- New model PMTs show a smaller down-drift as a function of the integrated anode charge.



- Blue circles represent the average response of the 7 PMTs model Hamamatsu R7877.
- Red triangles represent the average response of the 4 PMTs model Hamamatsu R11187.
- The average PMT relative responses are fitted with a double exponential function: $R(Q)=p_0\exp(p_1Q)+p_2\exp(p_3Q)$

Conclusion:

- To preserve safe detector operation, TileCal collaboration decided to replace PMTs whose response loss is expected to exceed 25% (8% of the total).
- Replacement PMTs will have same geometry and better performance.
- Test bench results comparing old and latest version PMTs show the latter to have improved performance in terms of response loss versus the integrated anode charge.