Radiation hardness of the ATLAS Tile Calorimeter optical components

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1-Introduction

The **TileCal** is an hadronic calorimeter, an essential part of the ATLAS experiment at LHC. This sampling detector is made of plastic scintillator tiles (active medium), interleaved with steel plates (absorber) [1]. The scintillation light is produced through the passage of particles, reaching the photomultiplier tubes (PMTs) through two wavelength-shifting optical fibres connected to each edge of the tile.

TileCal is segmented into three radial layers and the cells granularity, in η and ϕ, is $0.1(0.2) \times 0.1$ for the A and BC (D) layers.

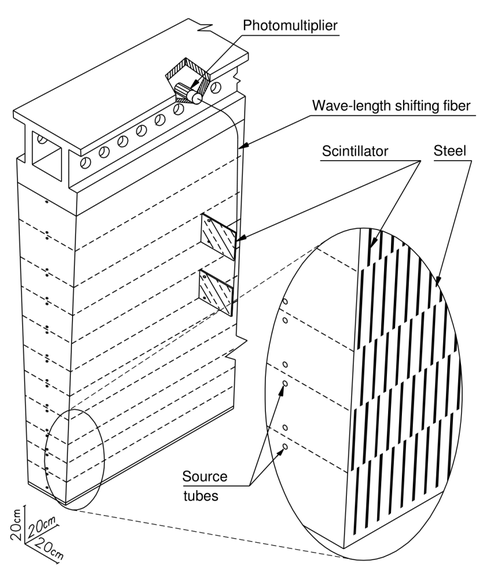


Fig. 1- Tile Calorimeter wedge module [1].

2-TileCal Calibration Systems

The TileCal employs three dedicated systems to calibrate the energy measurement concerning fluctuations of the response of each readout element. The **Cesium source** system (**Cs**) calibrates the response of the optics including the PMTs. The **Laser** system (**Las**) only calibrates the PMTs and the electronics. The **Charge injection** system calibrates the electronic readout.

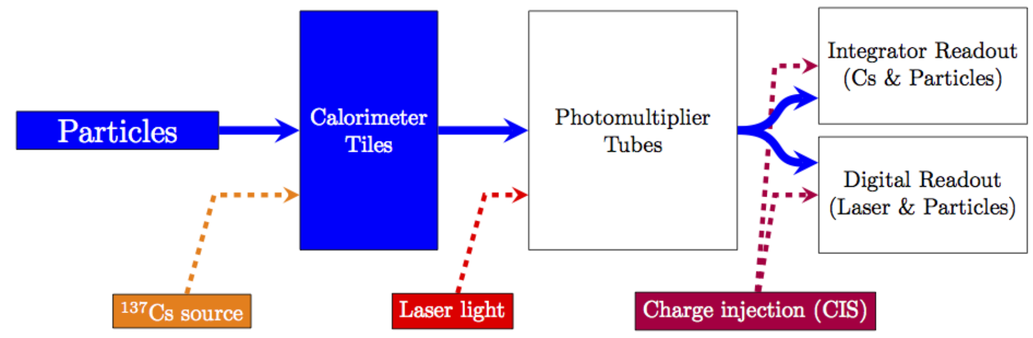


Fig. 2- Schematic of the TileCal Calibration Systems [2].

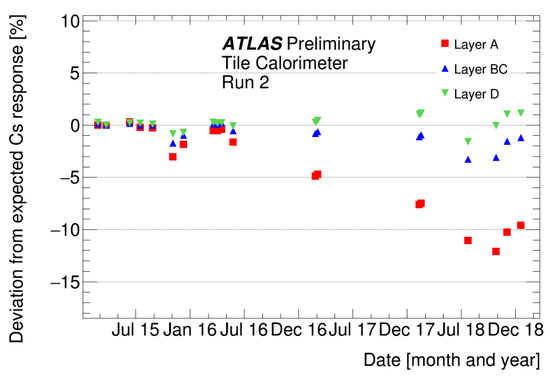
3-Radiation hardness of scintillators and fibres

The current LHC plans foresee a Run 3 and a higher luminosity LHC phase and will extend the TileCal lifetime further from the design goals. Since the optical components **can not be replaced,** the radiation damage must be evaluated.

The response to Cs (ΔR_{Cs}) and Laser (ΔR_{Las}) (**Fig. 3**) is used to **isolate the optical response** and derive the **relative light yield**:

$$I/I_0 = 1 + \frac{(\Delta R_{Cs} - \Delta R_{Las})}{100\%}$$

I/I_0 is presented as a function of the Geant4 simulated dose (TID) (**Fig. 4**). The cell light output degrades with radiation exposure. Measured I/I_0, at the end of Run 2, are presented for all cells (**Fig. 5**). Cells in the A layer, and B11 and C10 are the most affected for being more exposed to radiation.



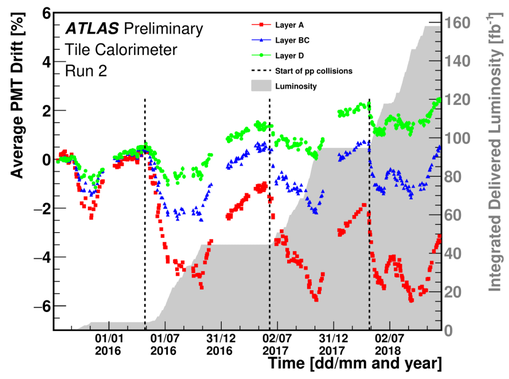


Fig. 3- Deviation of the average cell response to the Cs, ΔR_{Cs}, *(left)* and to the Laser, ΔR_{Las}, (*right*) during the Run 2 [2].

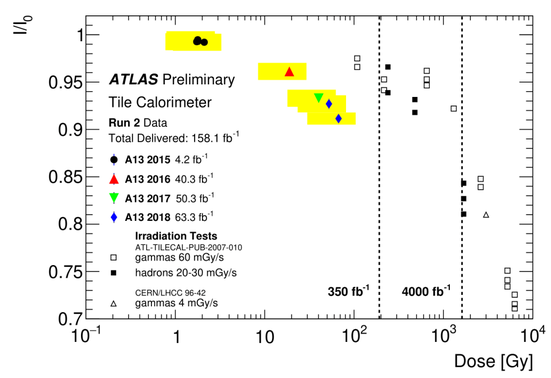


Fig. 4- Measured I/I_0 for the A13 cell as a function of the simulated dose. The vertical errors are associated to the precision of the Cs (~0.3%) and the Laser (~0.5%) systems, and the horizontal error correspond to the dose spread within the large cell volume. The points with no error bars illustrate the laboratory measurements done on bare optical components (tiles or fibers) prior to the calorimeter construction [2].

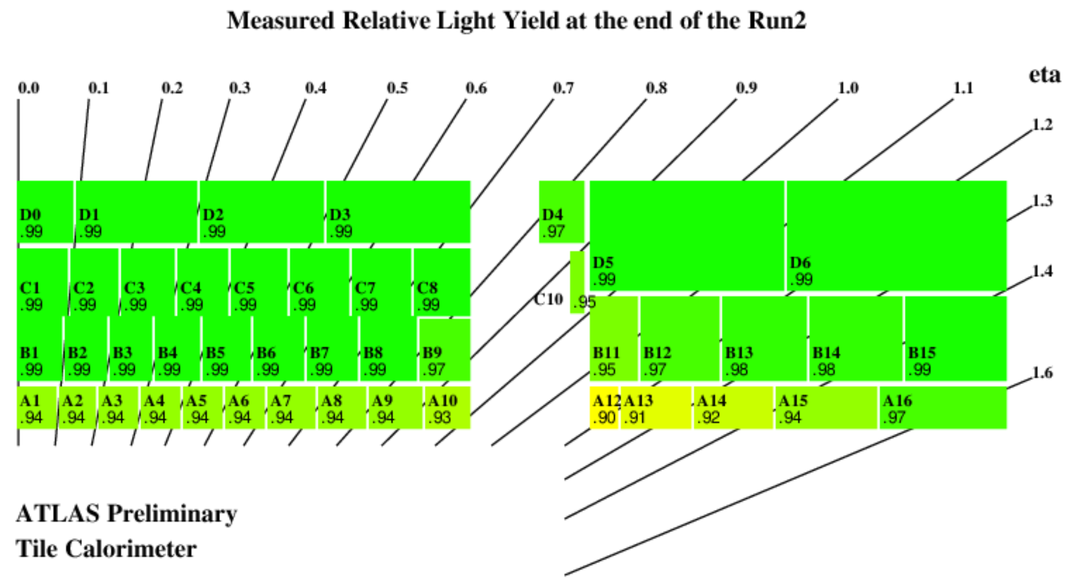


Fig. 5-Measured I/I_0 of the TileCal cells in the end of Run 2. The relative uncertainty is of the order of 1%. Measurement in the D layer are not yet sensitive to a light yield degradation [2].

4-Expected light yield at the end of Run 3

The I/I_0 measurement was extrapolated to the end of Run 3, by fitting the Run 2 data with a simple exponential function (**Fig. 6**).

$$I/I_0 = e^{(p_0 + p_1 \times dose)}$$

Again, results show that the more affected cells are in layer A, the B11 and C10 (**Fig. 7**).

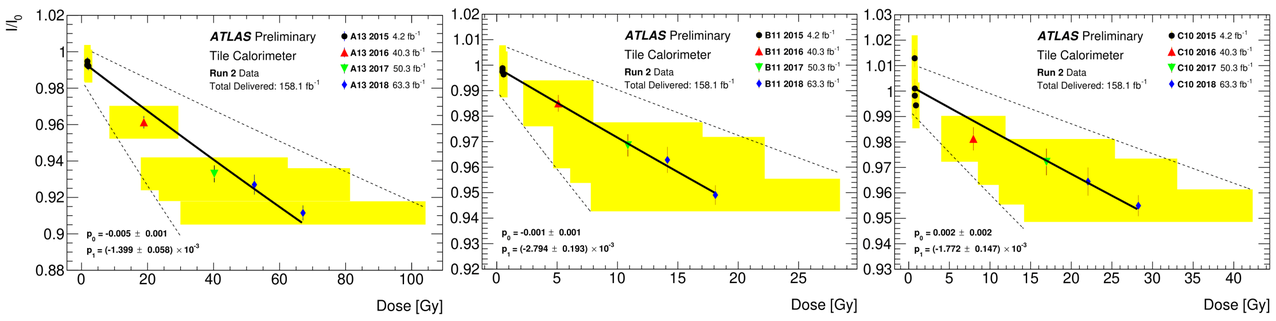


Fig. 6- I/I_0 for the A13 (left), B11 (center) and C10 (right) cell as a function of the simulated dose during the LHC Run 2. The black solid line is the exponential fit, with the dashed black line corresponding to the exponential fit to the up and down uncertainty variations [2].

Fig. 7- Expected I/I_0 of the TileCal cells in the end of Run 3. The relative uncertainty on the extrapolation ranges from 8 to 16% for cells in the A layer, in the Extended Barrel B layer, and the C10 cell, and is around 5% for the remaining cells [2].

5-Summary and Conclusions

The radiation hardness of the TileCal optics was studied in Run 2 using data from the calibration systems. One of the goals of this analysis is to predict well in advance the expected light yield degradation at the HL-LHC phase. Currently, the extrapolation uncertainty is large, and more data needs to be explored (from Run 3) to reach better precision and validate the fit model.

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6-References

[1] ATLAS Collaboration 1996 ATLAS Tile Calorimeter: TDR CERN-LHCC-96-042

[2] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileCalibration

[3] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/RadiationSimulationPublicResults