Radiation damage of the optical components of the ATLAS TileCal calorimeter at the High-Luminosity LHC

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1-Introduction

The **TileCal** is an hadronic calorimeter and an essential part of the ATLAS experiment at LHC. The tiles of this detector are made of plastic scintillator material, where light is produced. Then it reaches the photomultiplier tubes (PMTs) through two optical fibres connected to each edge of the tile.

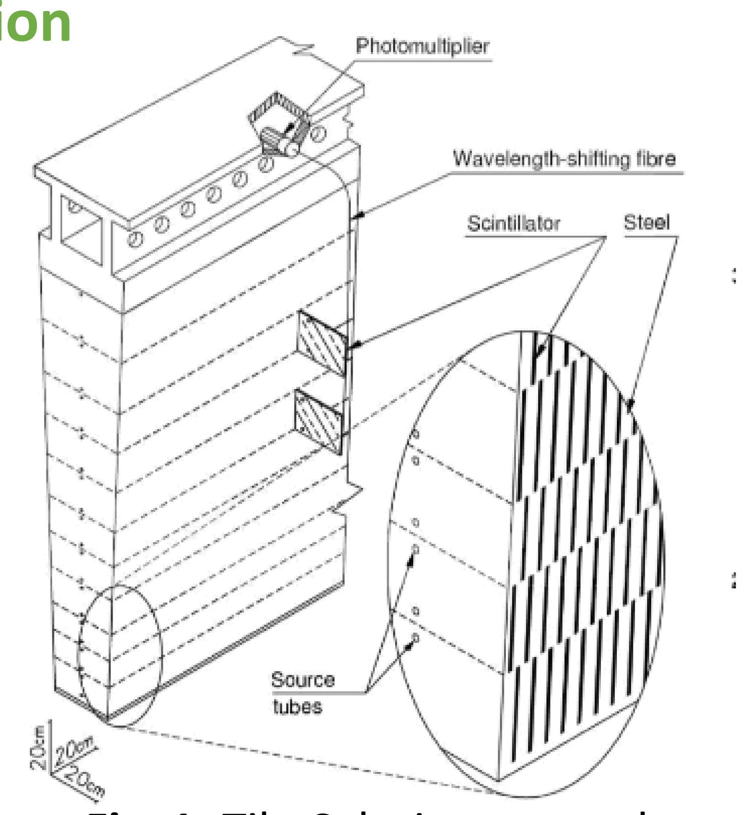

Fig. 1- Tile Calorimeter wedge module [1].

2-TileCal Calibration System

The TileCal calibration employs three dedicated systems to calibrate the energy measurement concerning fluctuations of the response of each readout element. The **Caesium source** calibration system is responsible for calibrating the response of the fibre and tiles, of the PMTs and the readout components. The **Laser** calibration system only calibrates the PMTs and the readout components. Charge injection system is used to calibrate the readout.

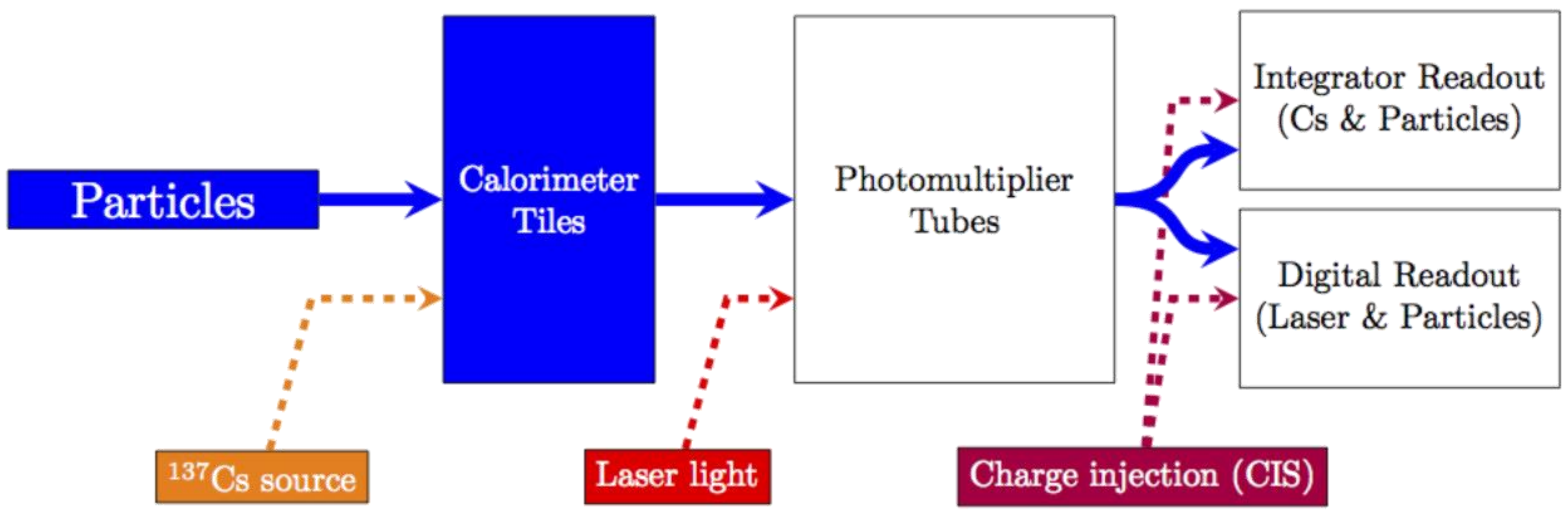

Fig. 2- Schematic of the TileCal Calibration System [2].

3-Radiation hardness of scintillators and fibres

The current plans foresee a higher luminosity LHC phase. This luminosity can reach **seven times higher** than the one that TileCal was designed for.

The scintillators and WLS fibres light yield are affected by the radiation exposure [2]. In **Fig. 4** it is possible to see that there are scintillators and fibres more exposed to radiation, for ex. at red (A layer, E layer, etc). Since they **can not be replaced** the radiation damage (**ageing**) must be evaluated with best precision.

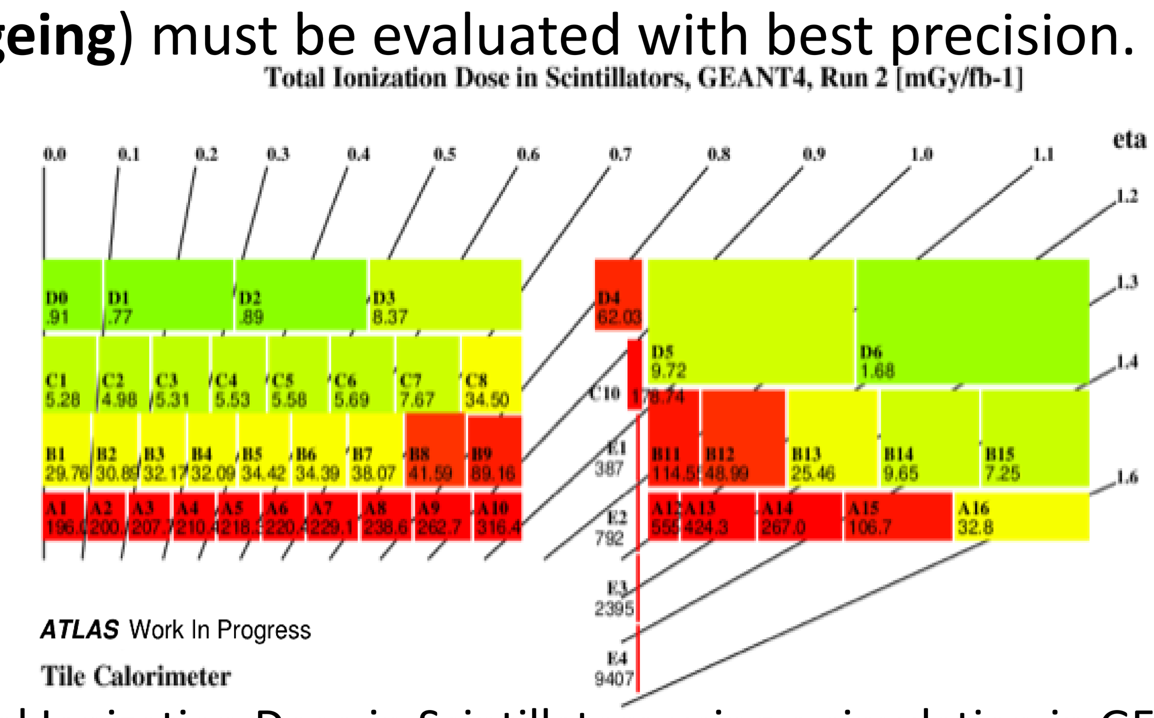

Fig. 4- Total Ionization Dose in Scintillators using a simulation in GEANT4.

When analysing **Fig. 5**, the uncertainties in the light yield are very big. The **Laser calibration** systematics are contributing to **limiting** the precision of the evaluation of the optics radiation damage and need careful understanding.

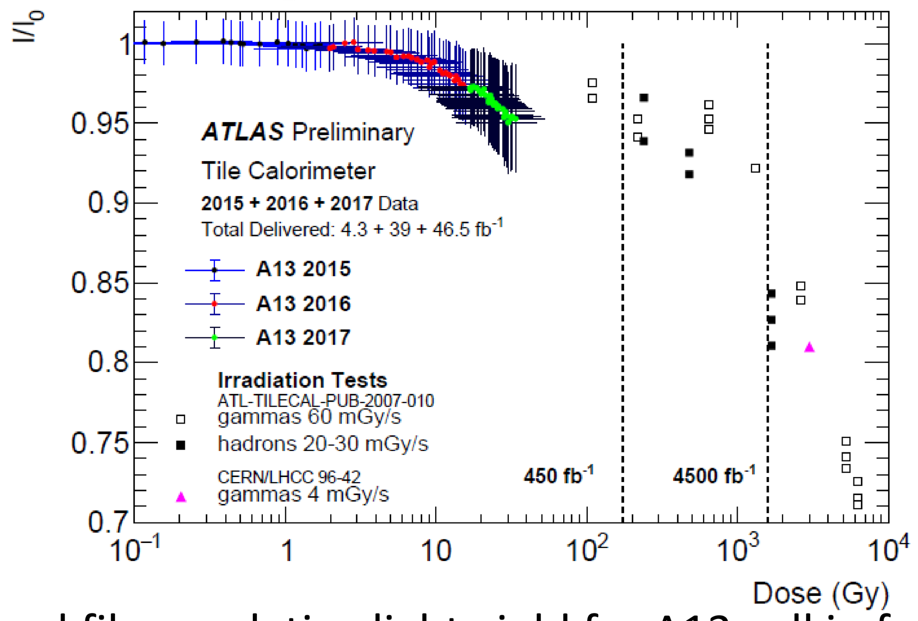

Fig. 5- Scintillators and fibres relative light yield for A13 cell in function of dose [3].

4-Systematics Uncertainties of the Laser Calibration system

Using the Cs and Laser calibration system it is possible to **isolate the optical response** ($R(tile + fibre)$) and derive the **systematic errors of the PMT relative response** measurement:

- The response to the Cs system is given by:
  $$R(Cs) = R(tile + fibre) \times R(PMT)$$
- Each tile is read by two PMTs (Left and Right);
- Assume the same relative response from left and right fibers;
- PMT relative response ($R(PMT)$) is determined analysing Laser data from the calibration system ($R(Las)$).

To derive the uncertainties of the $R(PMT)$ measurement with laser we use:

$$\frac{1}{\sqrt{2}}\left(\frac{R_L(Cs)}{R_L(Las)} - \frac{R_R(Cs)}{R_R(Las)}\right) \times 100 = \Delta[\%]$$

The values of the standard deviation (SD) of the gaussian fit were used to parametrized the uncertainties in function of the integrated luminosity (L) as shown in **Fig. 7**.

A global scale systematic on the PMT calibration would not be captured by this method.

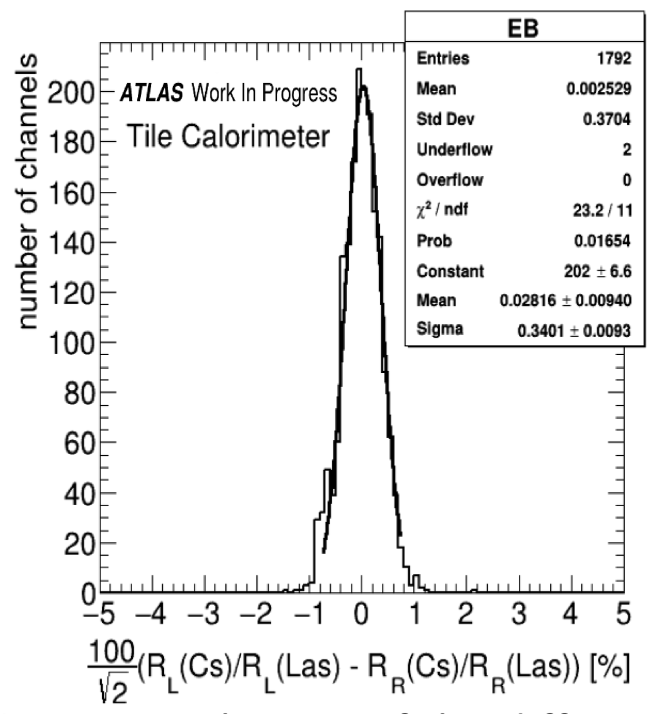

Fig. 6- Distribution of the difference between $R(tile + fibre)$ measured by the left and right side PMTs for EB cells

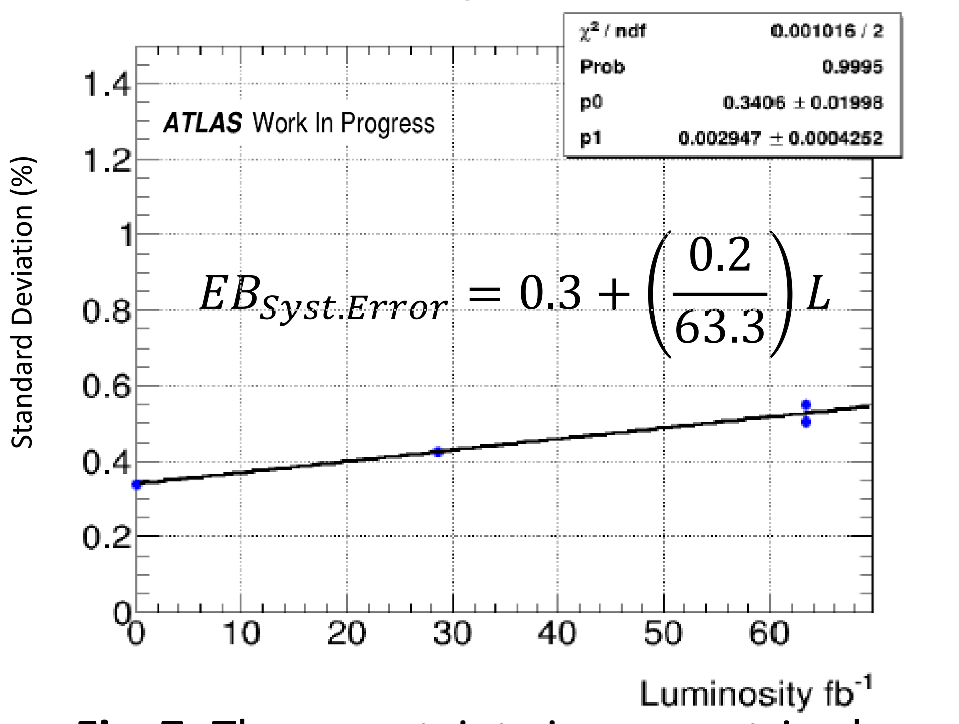

Fig. 7- The uncertainty is parametrized as a function of L fitting the SD points of the EB with a linear function.

A study showed that the global scale is no more than 0.4% [2]. So this value was sum in quadrature to the values.

When this method was applied the results obtained for the Extended Barrel (EB) and Long Barrel (LB) were:

$$EB_{Syst.Error} = 0.5 + \frac{0.2}{63.3}L; \quad LB_{Syst.Error} = 0.5 + \frac{0.1}{63.3}L$$

5-On going work

The evaluation Laser systematics led to an improvement in the precision of the ageing study, about 20% for Long Barrel and 50% for Extended Barrel.

6-Rerefencies

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

[2] "ATLAS Tile Calorimeter calibration with Laser 2 system during LHC Run 2"–Internal note, A. Ahmad, D. Boumediene, A. Gonzalez, G. Gregorio, P. Klimek, R. Pedro, B. Pereira, H. Wilkens.

[3] Pedro, R. "Optics robustness of the ATLAS Tile Calorimeter." *Journal of Physics: Conference Series*. Vol. 1162. No. 1. IOP Publishing, 2019.

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