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

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Abstract

TileCal, the hadron calorimeter of the ATLAS experiment at LHC, is a 10000 channel detector readout by photomultipliers (PMTs). A challenging goal is to understand whether the full sample of PMTs installed at the beginning of the ATLAS detector operation can be used until completion of the High-Luminosity Large Hadron Collider (HL-LHC) program or not. For this reason, a reliable study of the PMT robustness against ageing is required. Detailed studies modelling the PMT response variation as a function of the integrated anode charge were done.

Keywords: ATLAS, Tile Calorimeter, Laser system, photomultiplier, PMT response, PMT robustness

1. Introduction

The Tile Calorimeter (TileCal) [1] is the central section ($|\eta| < 1.7$) of the hadronic calorimeter of the ATLAS detector [2]. It provides important information for reconstruction of hadrons, jets, hadronic decay of τ leptons and missing transverse energy. It is a sampling calorimeter made up of steel and scintillating tiles. Two sides of scintillating tiles are readout by wavelength shifting fibers by two photomultipliers (PMTs). Fibers are grouped in bundles to define the unit cell (Fig 1). TileCal is readout by approximately 10000 8-stage fine-mesh PMTs, a special version of the Hamamatsu model R5900. TileCal PMT version is R7877.

To maintain the calorimeter high performance, a continuous percent-level calibration of each cell is required. TileCal response is calibrated via three main systems: a Cesium system, a Laser system and a Charge Injection System [3]. Each calibration system tests specific elements of the readout chain. The Laser system monitors both the PMTs and the front-end electronics used for data acquisition. It measures the stability of the PMTs response between two subsequent Cesium calibrations and the time stability of the readout electronics. Laser

Figure 1: TileCal readout map with individual cell identifier.

light pulses, similar to those produced by ionizing particles, are transmitted simultaneously to all the TileCal PMTs through an optical system and a bundle of 100 meter long clear fibers as shown in Fig. 2.

2. TileCal PMT response

The average TileCal PMT response variation is studied with the Laser system. Figure 3 shows the average PMT response for some TileCal cells (A10, A12, A13, A14, E1, E2, E3, E4). The average PMT response evolution is characterized by down-drifts and up-drifts. The observed down-drift mostly affects PMTs reading out the most exposed and irradiated cells. The down-drift of the PMT response coincides with the p - p collision periods, while a response recovery occurs during heavy ion collisions and technical stops of the LHC.

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Figure 2: TileCal Laser system [4].

Figure 3: Average TileCal PMT response variation during LHC Run 2 [6].

It is also possible to study the average TileCal PMT relative response as a function of the integrated anode charge (Fig. 4). A double exponential function $R(Q) = p_0 \cdot \exp(p_1 \cdot Q) + p_2 \cdot \exp(p_3 \cdot Q)$, where Q is the integrated anode charge, has been used to fit the points corresponding to data taken during LHC Run 2. The double exponential function $R(Q)$ describes fairly well both the initial part of the response evolution and the high value region of the integrated charge. The fit function is used to drive a prediction on the expected PMT response loss in HL-LHC era. The expected integrated luminosity at the end of HL-LHC is 4000 fb^{-1} , corresponding to 600 C of integrated anode charge for PMTs reading out the most exposed cells. These PMTs are expected to loose $> 25\%$ of their response. For this reason, 8% of the total TileCal PMTs (Hamamatsu model R7877) will be replaced with a newer version (Hamamatsu model R11178) having the same geometry but improved performance.

3. PMT response - measurements in lab

In order to make specific studies of the long term PMT robustness, a dedicated test-bench is operating in Pisa [5]. The optical system used in the lab to excite the tested PMTs is similar to the one used in TileCal for laser calibration. The current and the new PMT model are tested in the lab (Fig 5). A sample is formed by 7 R7877 PMTs dismantled from TileCal detector in February 2017, which integrated 1 to 5 C since beginning of LHC operation. The other sample is formed

Figure 4: Average TileCal PMT relative response as a function of the integrated anode charge during LHC Run 2 [6].

by 4 R11178 PMTs. The average PMT relative responses for the two groups are fitted with the double exponential function. The new model PMTs show a smaller down-drift as a function of the integrated anode charge.

Figure 5: Average PMT relative response for two different PMT models. Test bench results [6].

4. Conclusion

The double exponential decay of the PMT response loss allows to estimate the expected response loss of ATLAS PMTs during the HL-LHC period. To preserve safe detector operation, TileCal collaboration decided to replace PMTs whose response loss is expected to exceed 25%. Only 8% of the total number of PMTs will be substituted. The replacement PMTs will have the same geometry and improved performance in terms of response loss versus the integrated anode charge, as it was verified in test-bench measurements.

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