A new electronic board to drive the Laser Calibration system of the Atlas Hadronic Calorimeter

Ph. Gris, on behalf of the ATLAS Tile Calorimeter System

***Abstract*– The new laser calibration scheme of the ATLAS Tile calorimeter is presented with a focus on a major improvement: a new electronic board used to control the system.**

I. Introduction

THE Tile Calorimeter (TileCal) is the barrel and endcap hadronic sampling calorimeter of the ATLAS [1] experiment at the CERN LHC. It uses plastic scintillator as active material and low-carbon steel (iron) as absorber. Wavelength shifting fibres connected to the tiles collect the produced light and are readout by photomultiplier tubes (PMTs). PMT response drift is one of the main sources of systematic uncertainty in estimating the calorimeter energy scale: a continuous, percent-level calibration of each cell is then required to maintain the overall performance within 4%.

To achieve this goal, a redundant calibration scheme is operated (Fig. 1). A survey of the entire acquisition chain (from the plastic scintillator to the digital signal) is performed thanks to a moving radioactive Cesium source inside the detector, and a charge injection system which is used to follow the stability of the front-end electronics. The laser system monitors both the PMTs and the front-end electronics. Light pulses similar to those produced by ionizing particles are transmitted simultaneously to all TileCal PMTs through a bunch of ~100 meter long clear fibres. The light injected is measured by a set of photodiodes.

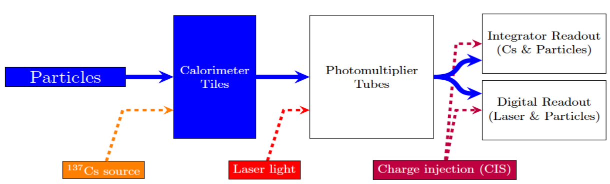

Fig. 1: Scheme of the TileCal calibration system.

The laser system has been upgraded for 2015 LHC run with the goal to monitor signal stability at the sub-percent level. Its main components include (Fig. 2) :

1. The optics box : houses the main optical elements of the system (laser head, filter wheel, beam expanders, optics fibres). The light issued by the beam expanders is transmitted to a set of ten photodiodes measuring the light intensity at three points of the laser light path (ouput of the laser head, after the filter wheel, after the beam expander).
2. The photodiode box : composed of ten modules (referred to as "K7") containing each a photodiode and its preamplifier.
3. The PMT box : contains two PMTs that are used to trigger the acquisition when the laser is flashing.
4. The PHOtodiode CALibration (PHOCAL) system : it is composed of a reference photodiode monitored by a radioactive source. It also contains a Light Emitting Diode (LED) to follow the response of the photodiodes.
5. The VME crate : houses two cards : a VME processor (to communicate with ATLAS) and a special (6U VME32) board designed to drive the laser system, perform signal digitization, and communicate with LHC: the LASer Calibration Rod (LASCAR) card is a major component of the new Laser electronics.

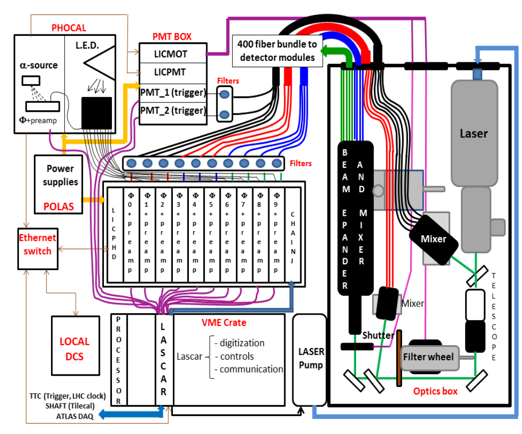

Fig. 2: Scheme of the new laser calibration system.

II. LASCAR Card

The LASCAR board (Fig. 3) controls the laser system and provides an interface with ATLAS Data AcQuisition (DAQ). Digitization of the photodiode signals is performed with a charge analog-to-digital converter (QDC). A monitoring of electronic stability response is done with a charge injection system dubbed LILAS. The time response of the laser as a function of its intensity is estimated with a Time-to-Digital converter (TDC). An interface is used to drive the laser

Manuscript received May 30, 2016. This work was supported in part by by the CERN, European Organization for Nuclear Research, Switzerland, by the Centre National de la Recherche Scientifique (CNRS), France, by the Instituto Nazioanle di Fisica Nucleare (INFN), Italy, and by the Laboratorio de Instrumentacao e fisica experimental de Particulas (LIP) , Portugal.

Ph. Gris is with the Laboratoire de Physique Corpusculaire (IN2P3/CNRS) of Clermont-Ferrand, Campus des Cézeaux, 24 avenue des Landais, BP 80026, 63171 Aubière Cedex (gris@clermont.in2p3.fr).

(power, trigger). Two parts handle an interface with the ATLAS DAQ : the TTCrx chip retrieves LHC signals, and the HOLA card sends data fragments to the ATLAS DAQ.

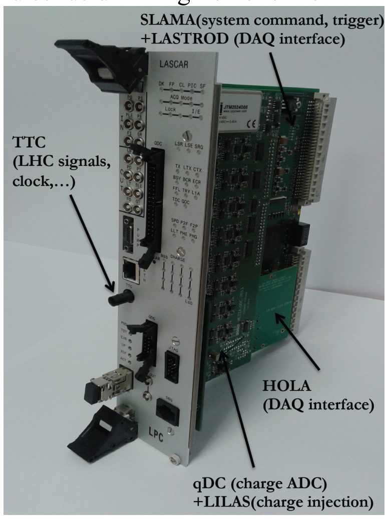

Fig. 3: Picture of the LASer Calibration (LASCAR) card.

The heart of the LASCAR card is composed of a Field Programmable Gate Array (FPGA) Cyclone V manufactured by ALTERA [2]. The following inputs-outputs (Fig. 4) are available: 16 analog channels (differential mode) for the QDC, four digital entries (NIM format), two analog entries for the photomultipliers, eight digital outputs (NIM format), one analog/digital interface with the laser, one fibre (entry) to get information from the Timing Trigger and Control (TTC) LHC system, two fibres (input-output) for data acquisition, one ethernet link for the Detector Control System (DCS), one interface with the VME bus, one JTAG interface to configure the FPGA.

The QDC has 32 channels, each with a 14-bit, high speed, low power, successive approximation ADC that operates from a single 2.5 V power supply and features throughput rates of up to 4.2 MSPS. Each channel contains two ADCs, each preceded by a low noise, wide bandwidth track-and-hold circuit that can handle input frequencies in excess of 110 MHz. This part receives inputs from two charge amplifiers with different slopes. The analog signal at the entrance of the QDC is integrated during 500 ns (value adjustable through a VME register) and the maximum charge that may be integrated is approximately of 2000 pC. Analog signals coming from the eleven photodiodes, the two PMTs, and from the charge injection system (three channels, one internal to the QDC, and two from the photodiode box) are converted into digital signals by the QDC.

The LILAS part aims at injecting a known charge in each photodiode preamplifier in order to monitor the linearity and the stability of the electronics with time. The charge is injected in the system through three ways: a direct link to one of the QDC channels (since the QDC and LILAS are located on the same printed board), and via two Lemo connectors plugged in the photodiode box and in the LED box.

The TDC is an integrated device manufactured by ACAM (TDC-GP1) [3]. It contains two channels with a typical resolution of 280 ps. This TDC aims at measuring the laser time response as a function of its intensity. The LASCAR card is equipped with a delay system to provide a constant offset from laser request from the SHAre Few Triggers (SHAFT) [4] electronic module and the laser pulse irrespective of the laser pulse amplitude. A delay system is activated to send the laser light in an "empty" bunch-crossing in a coherent way during the physics runs of the LHC.

The TTCrx [5] is an integrated circuit developped at CERN that retrieves LHC signals: Bunch Crossing (BC), Bunch Counting Reset (BCR), Event Counter Reset (ECR), Level one Accept (L1A), Level one Identity (L1id), Trigger Type (TT). The FPGA will process these data prior to a transmission to the DAQ.

The HOLA card [6] has been developed at CERN and is mounted on LASCAR. It is used to send data fragments to the Read Out System (ROS) via an optical fibre for each L1A at a maximum frequency of 100 kHz. LASCAR has the ability to stop a L1A signal generation by issuing a busy signal to the ATLAS Central Trigger Processor (CTP) when the HOLA card has received some busy signal from the ROS.

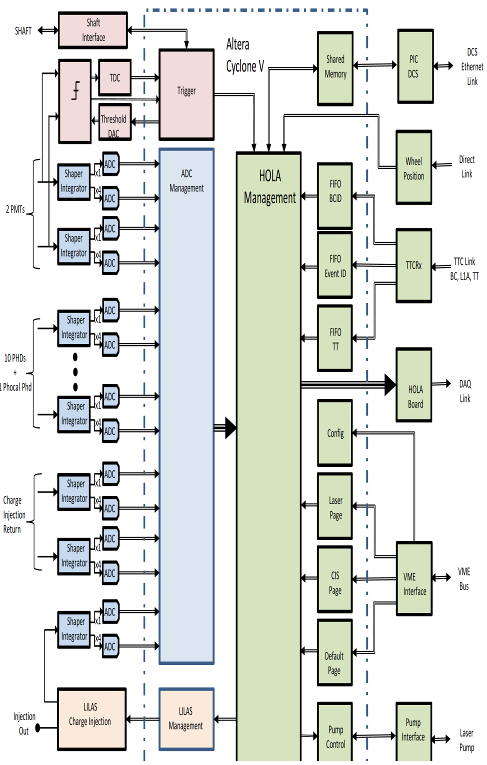

Fig. 4: Scheme of the LASCAR card.

There are two independent ways of running the laser system: the stand-alone mode and the "ATLAS DAQ" mode.

The stand-alone mode can be used to check that the Laser system is responding as expected. Reference runs can be performed so as to monitor the stability of the system. The control interface of the QDC and of the TDC is done with the VME bus and the running frequency reaches about 100 Hz. The following possible modes are:

- Pedestal: to measure of the QDC output distributions when no input signal is injected,
- Alpha: to estimate the response of the reference (PHOCAL) photodiode to alpha particles emitted by the Americium source,
- LED: the LED signal is transmitted to all the photodiodes via optical fibres. In this mode the stability of the ten photodiodes used to monitor the laser light can be controlled,
- Linearity: a known charge is injected in the preamplifiers of the photodiodes in order to estimate the linearity and the stability of the electronics,
- Laser: laser signals with varying intensities are sent in the system. The light can be transmitted to the TileCal PMTs, depending on the status of the shutter located inside the optics box.

Raw data are stored using the ROOT [7] framework. For each event (i.e. each time a gate is open), the date, the number of QDC counts for each photodiode and each gain (32 words), the TDC values, the order (filled in case of a laser run or for the linearity mode) are information that may be used for analysis.

The "ATLAS-DAQ " mode is used in two ways. Twice a week when calibration runs are performed and during physics runs, when laser pulses are emitted in empty bunch-crossings. The control interface is provided by the SHAFT electronic module which sends requests to LASCAR. Output data fragments are transmitted via the HOLA card for each L1A and laser Trigger Type.

The modes available are the same as in stand-alone: Pedestal, Alpha, LED, Linearity, Laser. One possibility has been added. The "combined" mode consists in running Pedestal, LED and Alpha modes in a row. For each mode, the sum of the output values and of their squares are calculated and stored in a RAM. These values are then transmitted in a data fragment (through the HOLA card for each L1A and laser Trigger Type) when the laser mode is activated.

Two kinds of data fragments may be transmitted, depending on the DAQ mode selected : a short one, used in the LaserCalib (Pedestal+Alpha+LED+Linearity) or LaserAlpha modes , and a long one, used in the Laser mode (laser light injected in the PMTs of the TileCal). Each fragment is composed of a header and of a data fragment. Information such as the DAQ type (Pedestal, LED, Alpha, Linearity, Laser), number of events, laser or charge intensity, raw QDC values of the photodiodes, TDC values, are stored in the short data fragment. The long data fragment contains the same information (but for the laser only) and is completed by the sum of the output values of the photodiodes (and of their squares) (for each QDC channel) of the most recent pedestal, alpha and LED runs. These data are transmitted in a sequential way.

III. Performance

The laser upgraded system was installed in October 2014 and has been used on a regular basis since then (Fig. 5 illustrates typical results obtained). During collision runs, laser pulses are emitted every second (in empty bunch-crossings). Internal calibration runs are performed twice a week. Performance of the new laser system may be expressed in terms of stability both for the internal calibration system and for the PMTs of the TileCal.

Three aspects of the internal calibration system may be monitored: the electronics, by studying the pedestal stability and the response to the charge injection; the ten photodiodes, by analyzing the LED signal normalized to the reference photodiode one; the reference photodiode, by quantifying how its response is stable with respect to the radioactive source emission. A RMS-variation response at the sub-percent level is observed for electronics and photodiodes over a three-month period. These results make us confident about the possibility for using the photodiodes as reliable monitors.

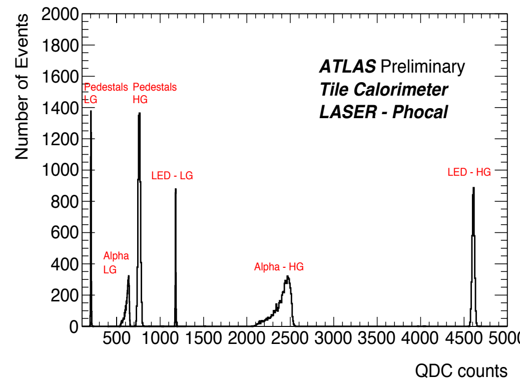

Fig. 5: Illstration of the Laser system output.

IV. Conclusion

The laser system is a centerpiece of the calibration scheme of the ATLAS Tile calorimeter. A new setup has been designed, built and installed to monitor the response of the TileCal PMTs. Improvements to critical parts of the system (light distribution, internal calibration, electronics) have led to stability results at the sub-percent level [8], a performance compatible with expectation.

References

[1] The ATLAS Experiment at the CERN Large Hadron Collider, 733 JINST 3 (2008) S08003.

[2] ALTERA - Cyclone V FPGAs $&SoCs, https://www.altera.com/products/fpga/cyclone-series/cyclone-v/overview.html

[3] ACAM – TDC-GP1, http://www.acam.de/fileadmin/Download/pdf/English/DB_GP1_e.pdf

[4] The SHAFT is a 6U, 1 slot VME board that accepts the LHC TTC and CTP signals, such as TURN, ORBIT, BC, and BUSY and, based on the logic implemented in FPGA, and generates calibration triggers for three calibration systems of Tile detector.

[5] TTCrx:Timing, Trigger and Control Receiver ASIC, J. Christiansen *et al*, http://cmstrackercontrol.web.cern.ch/cmstrackercontrol/documents/PauloMoreira/TTCrx.pdf

[6] High-speed Optical Link for Atlas, CERN, http://hsi.web.cern.ch/HSI/s-link/devices/hola

[7] Rene Brun and Fons Rademakers,, *ROOT - An Object Oriented Data Analysis Framework*, Proceedings AIHENP'96 Workshop, Lausanne, Sep. 1996, Nucl. Inst. & Meth. in Phys. Res. A 389 (1997) 81-86. See also http://root.cern.ch/

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