ATLAS NOTE

GROUP-2014-XX

21st July 2015

Draft version 0.1

Upgrade of the LASER calibration system of the ATLAS Tile Calorimeter

The ATLAS Collaboration

Abstract

This is a bare bones ATLAS document. Put the abstract for the document here.

Contents

1 Introduction

The Atlas Tilecal hadronic calorimeter is equipped with a 3-level calibration system to monitor and calibrate the response of the active devices (plastic scintillating tiles), the response of the PMTs receiving the light from clusters of tiles (cells), and the response of the Front End and digitization electronics of the individual readout channels.

The global detector calibration is performed monthly by measuring the individual cell response to a reference excitation produced by calibrated Cesium sources which float inside the detector through a suitable pipe network. Calibration of the PMTs and of the readout chain are performed between two sucessive Cesium scans; laser pulses are distributed to each individual PMT cathode (approximatively 10,000 channels) by a suitable optical distribution line having a power laser (several μJ per pulse) as a source. Laser calibrations can be performed every two-three days during pauses of LHC collisions and during collision runs by pulsing the laser in the empty bunch intervals.

During the Long Shutdown I of LHC operations, the Tilecal laser calibration system has been re-designed, tested, and installed for the Run II operations. The shortcomings of the optical part have been studied, understood and solved. The LASER light injected in the PMTs is measured by sets of photodiodes at several stages of the optical path. The monitoring of the photodiodes is performed by a redundant internal calibration scheme using an LED, a radioactive source, and a charge injection system.

A challenge of the new LASER project lied in the design of electronics boards that would overcome the shortcomings of the previous LASER system (interface with the LHC clock and saturation of the electronics for higher LASER intensities) and that would be compatible with the new requirements (increase of the number of photodiodes, new internal calibration scheme). A new electronics has been designed to achieve these goals.

2 The LASERI system during P1: performance and shortcomings

2.1 Overview of the LASER I system

The LASER I system is composed of three main parts: optical, calibration and electronics.

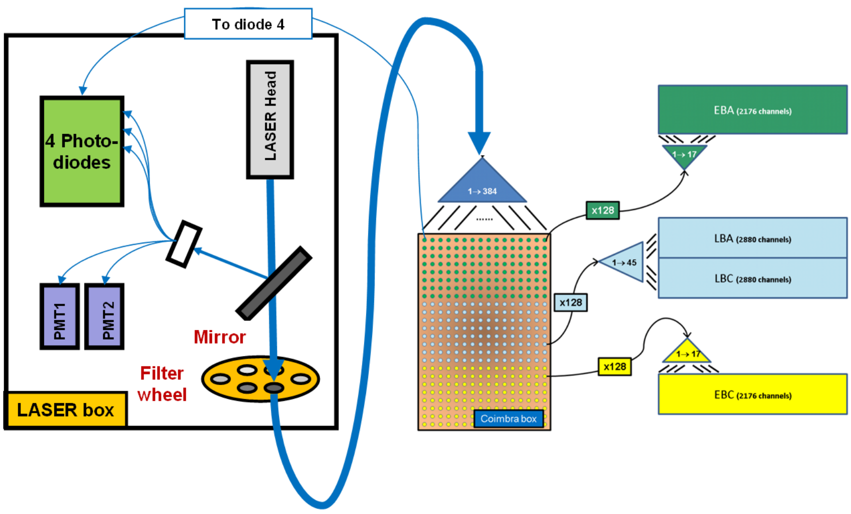

Figure 1: Sketch of the optical part of the LASER I system. At first 3 photodiodes were measuring the light before the filter wheel and one photodiode was plugged after the Coïmbra box. The configuration is now different: one photodiode before the filter wheel and three after the Coïmbra system.

- optical part
  The optical part of the LASER I system is sketched on Figure 1. It is composed of three parts:
  - the LASER box (Fig. 2): the light emitted by the diode pumped solid state LASER from SpectraPhysics (green beam with $\lambda = 532$ nm) is splitted by a semi-reflecting mirror. A small amount of the light (about 9%) is sent to a light-mixing block, composed of

reflective filters, light diffusers and a light mixer, and transmitted to a bundle of 9 fibers.

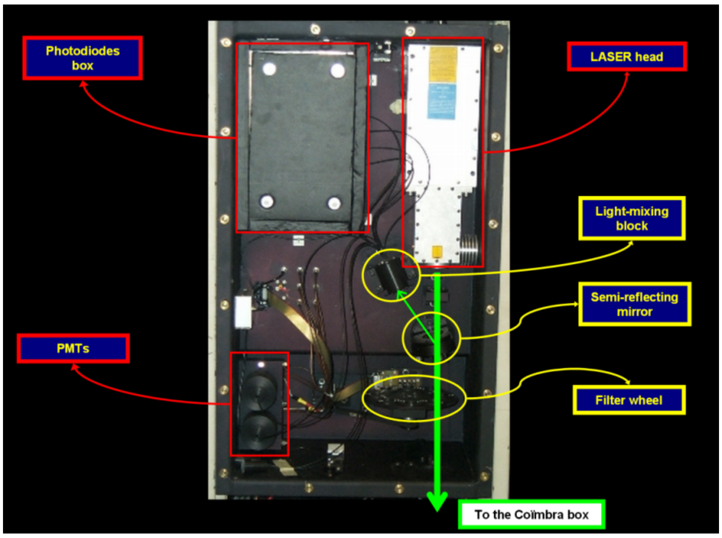

Figure 2: Picture of the LASER box of the LASER I system

Two of these fibers are connected to two PMTs, used for timing purposes (trigger), and one is linked to a photodiode to ensure an absolute measurement of the light. The other part of the LASER light is sent to one of the attenuating filter located on a wheel and then to a liquid fiber that transmits the output light to the Coïmbra system.

The LASER box is equipped with a custom-built electromechanical shutter for safety purpose. This semi-passive component aims at isolating the LASER box from the TILECAL: the LASER light is transmitted only to the optical components of the box and not to the PMT of the TILECAL.

- the Coïmbra box : this system transmits the light coming from a liquid fiber to a bundle of long clear fibers that are connected to the PMTs of the TILECAL. It is composed of a divergent lens, an unpolished acrylic disk (used as a diffuser), and a convergent lens.
- clear fibers of about 100 to 120 m long transfer the light coming out of the Coïmbra box to the 9852 PMTs of the TILECAL. There are 400 fibers (1 fiber for two half-modules for the central calorimeter, 1 fiber for each half-module of the extended barrels, and 16 spare fibers).

- calibration part

The photodiodes box, located inside the LASER box, houses four photodiodes and their electronics calibrated thanks to an Americium α-source (3.7 kBq). The box temperature is regulated with Peltier modules and the humidity is controlled via an air dry flow. The inter-calibration of the photodiodes is performed regularly via specific runs when the embedded source is moved along the photodiodes.

- electronics part

The set of electronics modules used to control and command the LASER I system is shown on figure 3. It is housed inside a VME crate and is composed of the following modules:

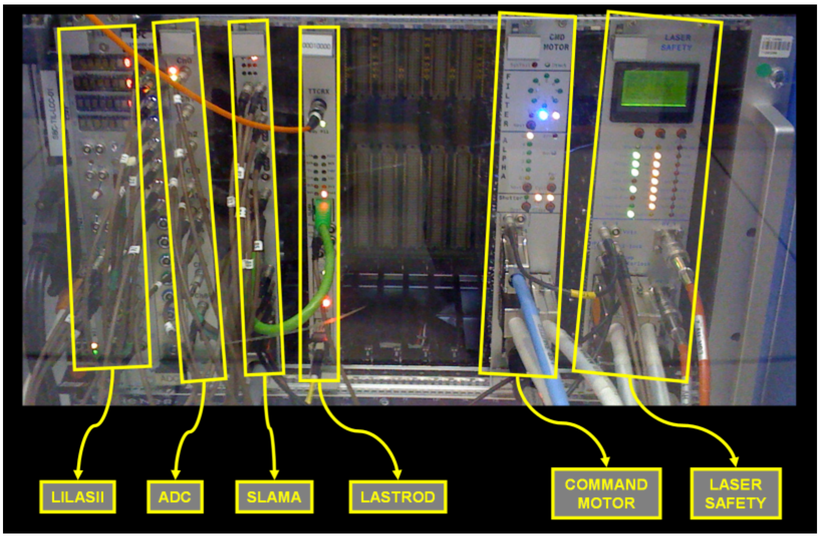

Figure 3: Picture of the electronics part of the LASER I system

- LILASII: dedicated to the measurement of the linearity of the electronics of the photodiodes
- ADC: converts the LASER box analog signals (from the two PMTs and the four photodiodes) into digital ones.
- SLAMA: system command (trigger) and communication with ATLAS.
- LASTROD: LASER TILECAL ReadOut driven: sends the LASER data to ATLASDAQ.
- MOTOR COMMAND: used for mechanical commands (wheel of filters, shutter, radioactive α-source)
- LASER safety: system monitoring and control (DCS, interlocks)

2.2 Performance

A monitoring of the various components of the LASER system is performed regularly and its performance evaluated. The measurements considered are:

- pedestal runs

Pedestal may be estimated with dedicated runs or during the calibration runs (with the α-source). Significant variations may show potential electronics problems. A stability better than 0.5% has been observed on the mean pedestal values [**laserb**].

- photodiode stability monitoring

  The monitoring is performed during the calibration runs thanks to the α source. The mean of the photodiodes signal is chosen to monitor the stability, which is about 0.15% over few months.

- linearity of the electronics of the photodiodes

  The linearity of the electronics of the photodiodes is performed through LILASII. A known charge is injected to the electronics (preamplifiers, ADC and the related electronics chain) that digitize the photodiode signals. An additional ADC is used to digitize the charge injected.

- PMT/Diode ratio in the LASER box

  The two PMTs of the LASER box are primarily used for triggering purpose. But they may also be part of the stability surveys of the LASER system through the study of the ratio of the PMTs signal to the Diode1 one. Over a few months period, a stability at the level of 0.6% has been observed [**laserb**].

- TILECAL channels stability monitoring

  This is the main purpose of the LASER system: monitoring the behavior of the 9852 PMTs of the TILECAL and pointing at possible drifts. Signals from the PMTs may be normalized to diode measurements so as to minimize the instabilities of the intensity of the light emitted by the LASER.

  For each PMT the ratio $f_{las} = \frac{PMT\ signal}{Diode1\ signal}$ is estimated for a LASER reference run, defined as the first LASER run performed after a Cesium scan, and for a given run. A fiber-to-fiber correction is applied to compensate for light instabilities and inhomogeneities, which account for the main source of systematic uncertainties. The channel variation may be estimated from $\frac{f_{las}^{run}}{f_{las}^{ref}} - 1$ and a stability at the level of 0.6% has been observed over a few month period.

2.3 Shortcomings

The LASER system installed in USA15 is performing extremely well. Nonetheless few shortcomings have been observed and may be solved to get an even better system:

- Coïmbra box instabilities

  The amount of light sent to each of the 400 fibers coming out of the Coïmbra system must be very stable in time, since it is this signal that is used to estimate the stability of the PMTs of the TILECAL. But a decrease of the light in the fibers of about 4% over a period of 1.5 month has been observed. This effect is at the moment handled via software corrections but understanding and solving this problem would allow a gain of sensitivity of the system.

- Photodiode box grounding problem

  During an α-source run, it has been shown that, when the source is in front of a given photodiode, the pedestals measured by the other photodiodes are not the same as the ones measured during a pedestal run, when the source is located in its garage position. This problem is related to cross-talk of the ground. It has been solved by re-designing the bus card along which transit the low voltages for the electronics of the photodiodes and the signals coming from the preamplifiers. This new card has been installed in USA15 in 2011.

  Another effect has been observed: when photodiodes are illuminated all at a time by a LASER signal with a given intensity, the signal seen by the electronics for a given photodiode differs significantly from the one measured when only this photodiode receives a LASER light of the same intensity. This optical cross-talk had already been observed in 2009, and was attenuated in the following way: when a given photodiode is illuminated with a LASER light corresponding to a given intensity, all other photodiodes are operated in reverse.

- Filters non-uniformity

  The filters that are used to increase the LASER dynamic range are inserted into a moving wheel. The reproducibility of the position of the wheel has been estimated by performing consecutive LASER runs at a given intensity after a rotation of the wheel. An effect at the level of few % has been observed. This could be measured and corrected with photodiodes inserted between the rotating wheel and the Coïmbra box.

3 The LASERII system

3.1 Overview

The main concern of the LASERII project was to design a calibration system without LASERI shortcomings while maintaining a high performance level in terms of precision and stability. The major improvements are summarized in table 1.

A better estimation of the LASER light injected in the system is possible thanks to an increase of the number of photodiodes. In that case, the calibration scheme of the photodiodes used for the LASERI (a moving radioactive source) is difficult to use. We thus moved to a system comprised of a Light Emitting Diode (LED) and of a static radioactive source. The LED signal

Critical Point	LASERII
Measurement of the LASER light at each point of the optical path	Number of photodiodes increased to 10+1
Adapt the calibration system of the photodiodes	Redundant calibration scheme: (Light Emitting diode (LED) and a static radioactive source
Insufficient light mixing of each optical set	New design of the beam expander (light to the 400 fibers of the TileCal) and of other mixers (LASER head and filter wheel outputs)
Optics box in a vertical position	Optics box in an horizontal position
Saturation of the photodiode electronics	Dynamic range increased (13 bits-ADC)
Electronics shortcomings (LASTROD memory, LHC clock)	new card including all functionnalities

Table 1: Critical points of the LASERI system and improvements in the LASERII

is injected in the ten photodiodes dedicated to the measurement of the LASER light and in a reference photodiode monitored through the static radioactive source.

The optical path is a critical point of the LASERII system. A lot of efforts has been devoted to ensure good stability and uniformity of the light transmitted to the PMTs of the TileCal. Two aspects have been worked on, the layout of optical elements and the light mixers. The optics box is set in an horizontal position to minimize the dust accretion on optical parts and to ease interventions and maintenance. The goal of light mixers is to expand the LASER beam diameter from about 700 μm(original size) up to few centimeters (size of the bundle of 400 fibers). As described below, they have been redesigned to optimize homogeneity of the light distribution, minimize beam pointing effects and guarantee the stability of the light transmitted.

Electronics has been redesigned to correct for shortcomings seen with the LASERI system. The dynamic range of the photodiode preamplifiers has been extended to avoid saturation effects for higher LASER intensities. The boards used to drive the LASERI system (LASROD, LILAS, SLAMA,...) are now gathered on a single card, LASCAR, to improve the communication between the boards.

A scheme of the LASERII system is given on figure 4 and is comprised of the following parts:

- Optics box: at the output of the LASER head, the beam is transmitted through a beam expander (x2.5) and divided in two parts: one is sent to a light mixer that dispatches the light to seven optics fibers (3 are connected to photodiodes) while the other is reflected by a miror and trasmitted to a filter wheel. At the output of the filter wheel, the beam is splitted with one part sent to a light mixer (of the same kind as the first one, connected to three photodiodes) and the other part is sent to a beam expander which magnifies and dispatches the input light to a bundle of about 400 fibers. 4 fibers are connected to photodiodes while all others transmit the light to the modules of the TileCal.

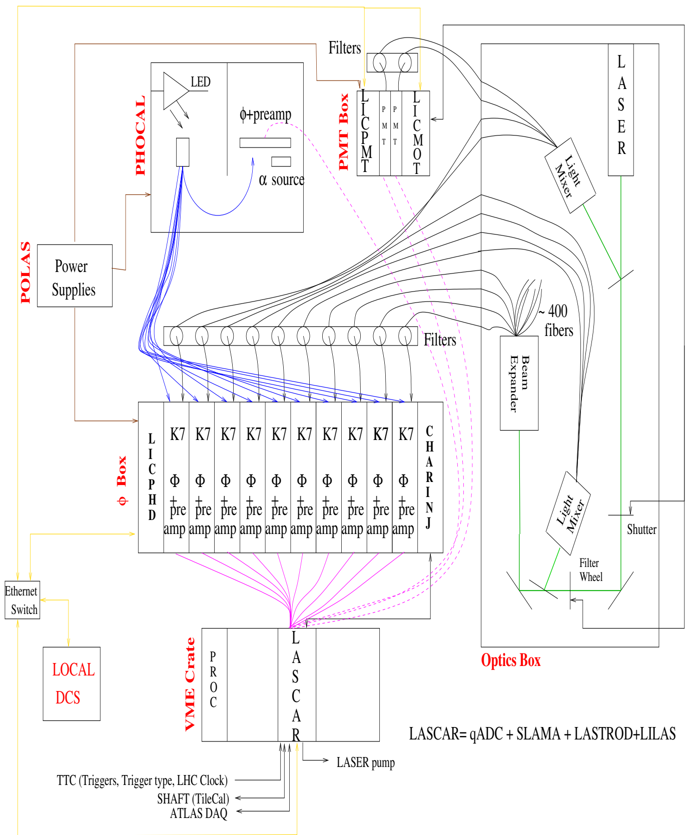

Figure 4: Scheme of the LASERII system

- Photodiode box: this box houses ten photodiodes (and their amplifier) receiving light from the optics box (LASER beam) or from PHOCAL (LED signal). This box also contains two electronic boards, LICPHD and CHAR_INJ_SPLIT.
- PHOCAL: an internal calibration system named PHOCAL (Photodiode Calibration) has been setup to monitor the stability of the ten photodiodes located in the photodiode box. It is composed of a LED emitting a signal in a light mixer that transmit the light to a set of 11 optics fibers, with 10 connected to the photodiode box, and one coupled to a reference photodiode. The stability of the ten photodiodes is performed through the monitoring of the LED signal received normalized to the magnitude measured by the reference photodiode. The stability of the reference photodiode is estimated thanks to a static radioactive source.
- PMT box: two PhotoMultiplier Tubes (PMTs) are used to trigger the acquisition when the LASER is flashing. The PMT box also contains two electronic cards, LICPMT and LICMOT.
- Optical filters are used to attenuate the LASER signal transmitted to the photodiodes and the PMTs.
- VME crate: two boards located in the VME crate are used to drive the LASERII system: a VME processor, and LASCAR, that incorporates a charge analog-to-digital converter (qADC), and SLAMA, LASTROD and LILAS cards.

- POwer LASer (POLAS): power supplies of the LASERII system. POLAS provides low voltages (+5V, -5V, ±15V,+12 V, +24 V) to electronic boards.
- Local DCS: a PC is used to collect slow-control information (such as temperatures, position of the filter wheel,...) from LICMOT,LICPMT,LICPHD and LASCAR through ethernet connections.

3.2 Internal calibration part

3.2.1 PHOCAL

3.2.2 Charge injection

3.3 Optics box

3.3.1 Optical path

3.3.2 Light mixers and filter wheel

3.3.3 Beam expander

3.4 Electronics

3.4.1 LASCAR

3.4.2 VME

3.4.3 Processor

3.5 DAQ

- description of the LASERII DAQ; interface with ATLAS; type of runs, data sent (fragments structure) ; Decoder(tuples structure)

3.6 DCS

- description of the DCS: structure+data available+database access

4 Conclusion

Place your conclusion here.

Appendix

List of contributions