

Electronics of LHCb calorimeter monitoring system

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Abstract

All calorimeter sub-detectors in LHCb, the Scintillator Pad Detector (SPD), the Preshower detector (PS), the Electromagnetic Calorimeter (ECAL) and the Hadron Calorimeter (HCAL) are equipped with the Hamamatsu photomultiplier tubes (PMT) as devices for light to electrical signal conversion [1]. The PMT gain behaviour is not stable in a time, due to changes in the load current and due to ageing.

The calorimeter light emitting diode (LED) monitoring system has been developed to monitor the PMT gain over time during data taking. Furthermore the system will play an important role during the detector commissioning and during LHC machine stops, in order to perform tests of the PMTs, cables and FE boards and measurements of relative time alignment.

The aim of the paper is to describe the LED monitoring system architecture, some technical details of the electronics implementation based on radiation tolerant components and to summarize the system performance.

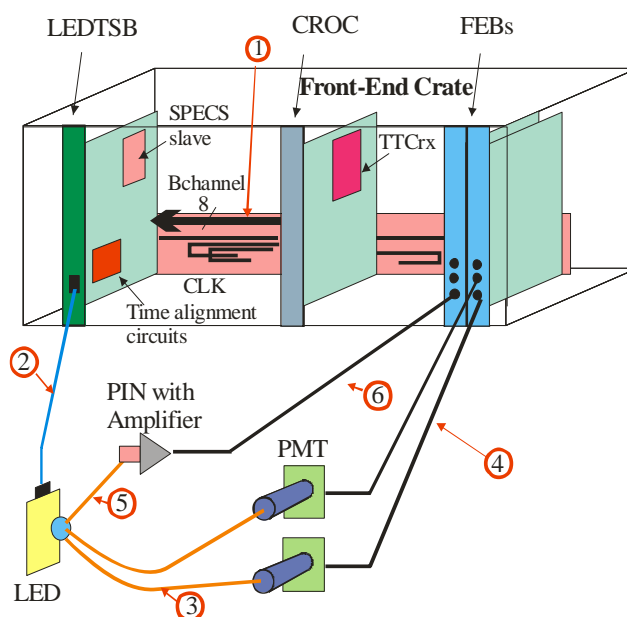


Figure 1: Sketch of the ECAL and HCAL LED monitoring signal chain

I. INTRODUCTION

The main aim of the calorimeter light emitting diode (LED) monitoring system is to monitor the PMT gain in time of data taking. The other important role of the system will be during the detector commissioning and testing in the LHC machine stops for PMT, cables and FE board tests and relative time alignment.

Each LED of the system illuminates up to 40 tubes and total amount of the monitoring channels is about 700.

The LED monitoring system consists of three functional parts:

- Subsystem for a LED intensity control for variation of the LED intensity across a wide range includes 40 boards.
- 12 9U –VME bards for a LED triggering pulse control and distribution placed into the front-end crates.
- 700 of the LED drivers with LV power distribution.

Sketch of the ECAL and HCAL LED monitoring signal chain is shown on the Figure 1.

II. CALORIMETERS PHOTO-DETECTORS AND LED MONITORING OPTICS

All calorimeters are equipped with Hamamatsu photo tubes as devices for light to signal conversion. Eight thousand R7899-20 tubes [2] are used for the electromagnetic and hadronic calorimeters and two hundred 64 channels multi-anode R7600 -00-M64 for Scintillator-Pad/Preshower detectors.

R7899-20 tube has the following characteristics:

- Dimension: 25 mm Diameter, 81 mm Length
- Spectral Response: 185 to 650 nm
- Photocathode: Bialkali, effective area 20 mm dia.
- Window material: UV glass
- Number of dynodes: 10
- Supply voltage: 1800 V max
- Average Anode Current: 0.1 mA max
- Quantum Efficiency: 15 % at 520 nm
- Current Amplification: 106
- Dark Current: 2.5 nA
- Time Response: 2.4 ns
- Pulse Linearity: + - 2 %

Figure 2: An HCAL light distribution schema

The PIN diode signal after amplification is sent to the FE electronics board.

III. ELECTRONICS OF LED MONITORING SYSTEM

A. LED driver and intensity control board

Designed LED driver produce the LED signals in a wide intensity range with pulse shape similar the particle response.

Design peculiarities:

- 1) Edge triggering circuit with fast pulse shaper on the board;
- 2) Decoupling by air transformer.

LED driver simplified circuit diagram is shown on Figure 3 and the signal shapes oscillogram for PMT response on 50 Gev particle and LED signal are shown on Figure 4 and 5.

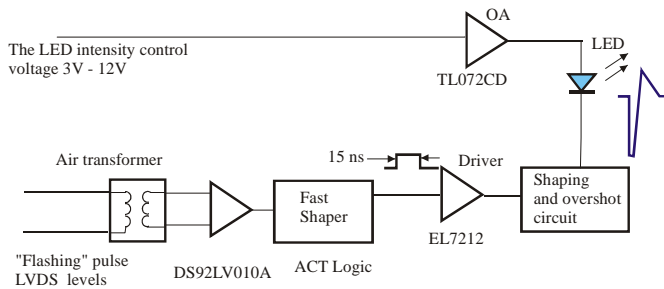


Figure 3: LED driver simplified circuit diagram

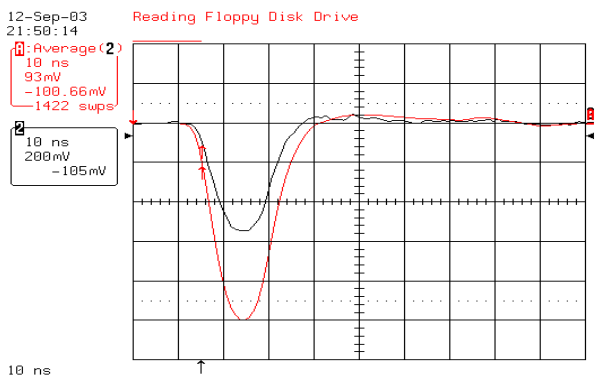


Figure 4: Oscillograms of PMT response on a particle

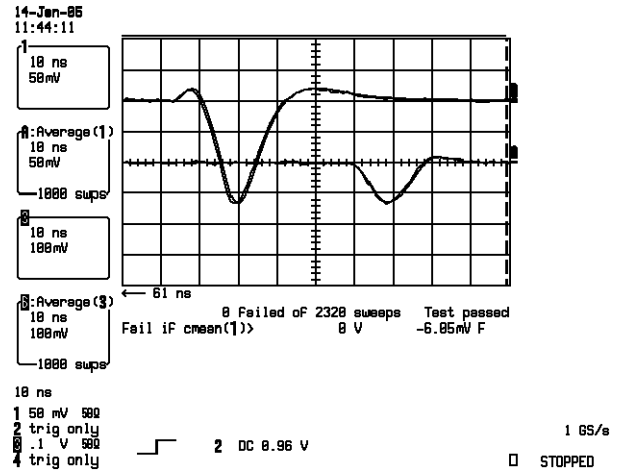


Figure 5: Oscillograms of PMT (right shape) and PIN amplifier responses on a LED

LED intensity signals are produced by the electronics board common with HV system. The LED intensity signal distribution board consists of the mother card and four types of the mezzanine board:

- SPECS slave for interconnection with the LHCb ECS system.
- Control Logic board for interface between the SPECS slave and others functional parts of Distribution board.
- HV control signal generation mezzanine.
- LED control signal generation mezzanine with 12 bits DACs.



Figure 6: Photo of the LED intensity signals distribution board

B. LEDTSB – 64 channels LED triggering board

The source of the calibration signal is the TTCrx broadcast command, generated by Read Out Supervisor. Then this command is distributed by LHCb TTC system to each detector and propagated throughout the detector specific chains. In the calorimeter electronics this command is distributed by a CROC card to each slot of FE crate. There is no any delay time compensation of the bus length difference for different slots of the FE crate. The time spread of the broadcast command on the FE backplane could be up to 3 ns. Due to the reason mentioned above, an additional time-alignment with 40 MHz clock is needed and implemented in LED Trigger Signal Board (LEDTSB).

LEDTSB distributes the LED trigger pulses to LED drivers by a twisted pair cable (RJ-45) with a different for each sub-detector length. Then a light pulse from LED comes to PMT through the optic fiber and from PMT the signal comes to FEB.

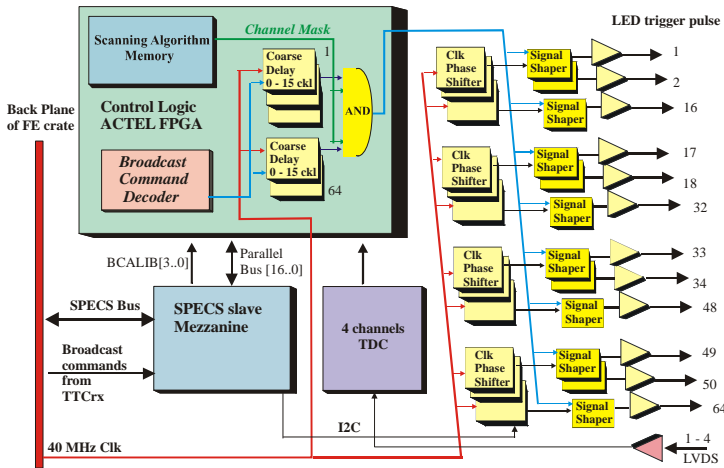


Figure 7: Block diagram of the LED triggering signals distribution board

The LEDTSB board consists of the mother board and two types of the mezzanine cards: SPECS slave mezzanine for interconnection with the LHCb ECS system and Control Logic mezzanine based on radiation tolerant ACTEL FPGA. Block diagram and photo of the LEDTSB board are shown on Figure 7 and 8.

LEDTSB specification

- Number of channels – 64.
- 16 output connectors RJ45 type on a front panel,
- A level of the output signals is LVDS,
- Each channel equipped with individual delay line that varies from 0 to 300 ns with 1 ns step,
- A LED trigger signal width is 50 ns,
- LEDTSB boards, the same size as LFB board, will be placed in the FE crate,
- Control Logic FPGA is placed on a mezzanine card for simplifying the chip exchange from non radhard to radiation hard ACTEL proASIC chip,
- Memory of the scanning algorithm FPGA with 64 patterns of the output trigger signals allows perform all needed sequences for LED flashing,

- SPECS slave mezzanine card (developed in LAL) is used for connection with ECS and TTCrx decoding,
- There are two operational mode:
 - A. The main mode, when the LED trigger signals are generated from TTCrx command,
 - B. The trigger signals are generated from a build in internal generator (Freq. ~ 1 kHz).

Power consumption: +3.3 V \rightarrow 0.6 A; +5 V \rightarrow 0.1 A; -5 V \rightarrow 0.16 A.

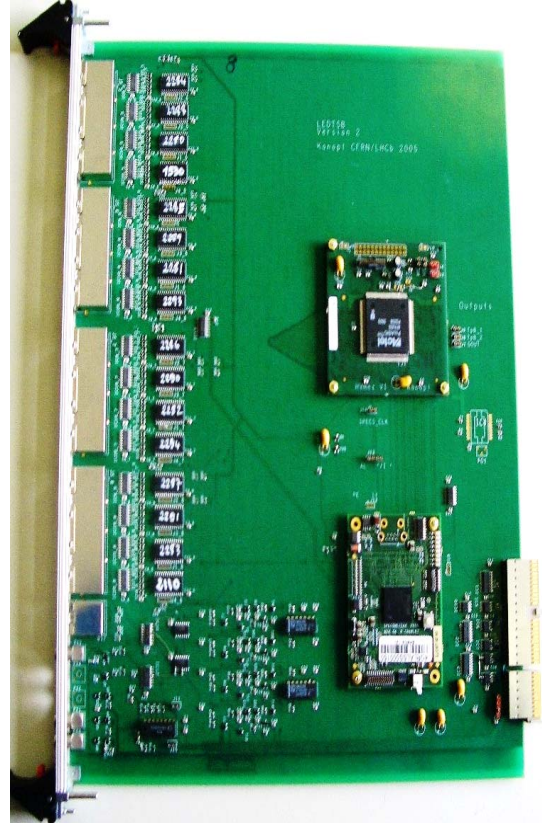


Figure 8: Photo of the LED triggering signals distribution board

IV. PERFORMANCE OF THE LED MONITORING SYSTEM

The calorimeter monitoring system is placed on the detector in a radiation hard environment. The electronics has been designed taken into account this factor. Main characteristics of the monitoring system are mentioned below:

- Precision of the PMT gain monitoring is about 0.3 %.
- LED stability monitoring by a PIN diode with precision of 0.1 %.
- Individual time setting for each LED in range of 400 ns with 1 ns step.
- PIN diode with amplifier is used for monitoring the LED stability itself.
- Control Logic FPGA is placed on a mezzanine card and equipped with radiation hard ACTEL pro-ASIC chip APA300.

- Memory of the scanning algorithm FPGA with 64 patterns of the output trigger signals allows perform all needed sequences for LED flashing.
- The calorimeter monitoring system is linked to the LHCb ECS system by the SPECS serial bus (developed in LAL).

Typical LED and PMT stability plots are shown on Figure 9 and 10. Each point corresponds of the mean value of PM amplitude for 200 events

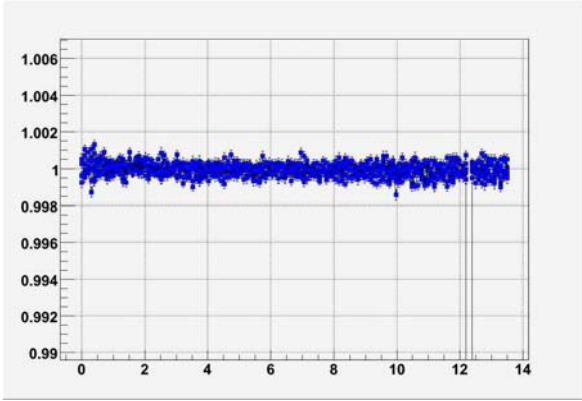


Figure 9: Typical LED stability plot (time in hour)

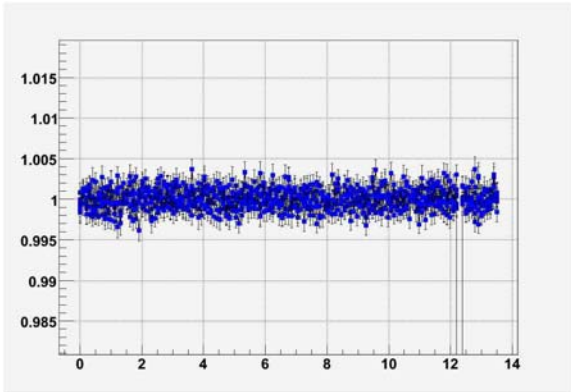


Figure 10: Typical LED stability plot (time in hour)

Time scan technique is used for a correct time adjustment of the LED monitoring system and checking an inter-crate synchronization. For doing the detector time alignment the automated process has been implemented to scan the LED delay from PVSS project and collect data by DAQ (increment step by step the 1 ns delay of the LEDTSB). Precision and stability of the signal arriving time measurement [3] is about of 0.3 ns. Figure 11 illustrates the LED signal scanned shapes of the HCAL module [4] and Figure 12 shows the time and amplitude distributions of the PMT response on LED flash.

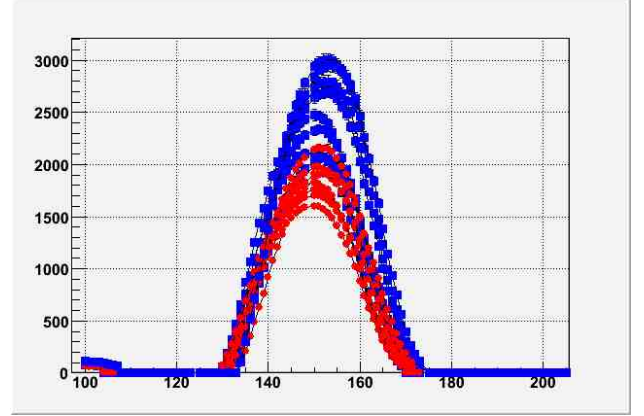


Figure 11: Typical LED integrated signal scanned shapes of the HCAL module (time in ns)

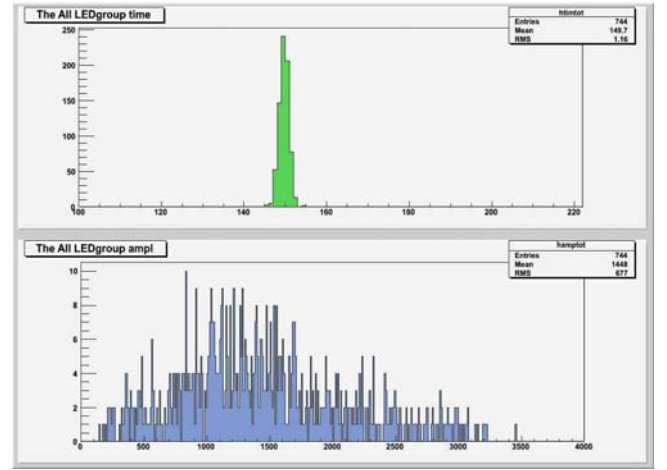


Figure 12: Time and amplitude distributions of the PMT response on LED for HCAL

V. ECS SOFTWARE FOR CONTROL OF THE LED MONITORING SYSTEM

LHCb's Experiment Control System is in charge of the configuration, control and monitoring of all the components of the online system. This includes all devices in the areas of: data acquisition, detector control (ex slow controls), trigger, timing and the interaction with the outside world.

The control framework of the LHCb is based on a SCADA (Supervisory Control and Data Acquisition) system called PVSSII. Which provides the following main components and tools:

- A run time database
- Archiving
- Alarm Generation & Handling
- A Graphical Editor
- A Scripting Language
- A Graphical Parameterization tool

The LEDTSB and LED intensity boards configuring is performed by standard FSM way. In the same time to prepare or modify a recipe one needs a mechanism to update recipe content. The *LEDTSB half Configuration* panel allows loading new values from the configuration files or from the dedicated CALO Data Base. The LEDTSB parameters could be modified and with using the expert LEDTSB panels too. After updating the recipe content one can save the recipe with specified name. Examples of the LED monitoring panels are shown on Figure 13 and 14.

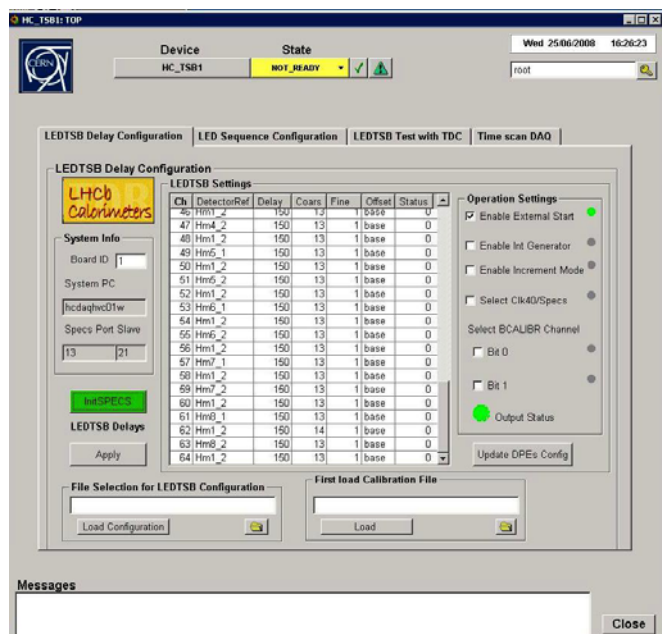


Figure 13: Device Unit panel of the LEDTSB delay triggering pulse configuration

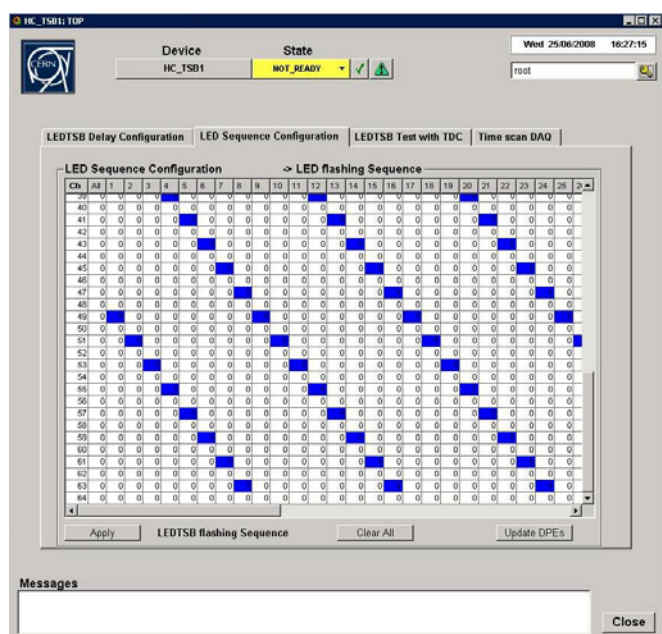


Figure 14: Device Unit panel of the LEDTSB triggering pulse sequence configuration

The designed LED monitoring electronics have been successfully commissioned and using now for preparing the calorimeter detectors for first beam.

VI. REFERENCES

[1] LHCb Calorimeters, Technical Design Report, CERN/LHCC/2000-0036, 6 Sept. 2000.

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[3] “Zero dead-time charge sensitive shaper for calorimeter signal processing”, A.Konopliannikov, LHCb 2000-041.

[4] “The LHCb Hadron Calorimeter”, R.Djeliadine, NIM A494/1-3, p332, 2002.