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The CMS-ECAL laser monitoring system: data generation, acquisition and processing at LHC

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Abstract

This note is an update of CMS-IN/2002-012, taking into account changes occurred in the electronic architecture and better understanding of the Upper-level Readout System. We hope that this note can be used as a reference document to define the communication protocol between the components implied in the monitoring system : TTC, CCS, DCC, SRP, Laser.

In this report, we describe also our present understanding of the monitoring system of the CMS-ECAL. We explain what we consider are the roles of the monitoring system (hereafter called "laser-monitoring tasks") and how these "laser-monitoring tasks" should be fulfilled. Some technical details are given on how the laser-monitoring tasks should be performed during the LHC running period, which we consider essential to the final ECAL calibration.

1 Introduction

Based on the test beam experience acquired from 1997 to 2006 in H4, we present here what we feel should be the laser monitoring data processing procedure starting from VFE electronics and going to the short term calibration correction coefficients. As **short term calibration correction coefficients**, we mean those correction factors which permit to correct the calorimeter response in such a way that its stability is ensured during the time necessary to perform a global ECAL calibration with physics events. We include under the heading ”laser-monitoring tasks” all those activities concerning the CMS-ECAL surveillance which are not directly concerned with the readout and processing of physics events. In this view, the laser-monitoring system is concerned with 3 main tasks:

- computation of short term calibration correction coefficients to follow damage/recovery of the calorimeter with irradiation
- part of VFE and monitoring electronics calibration
- off-line analysis of previous tasks for detector supervision.

All these tasks will be detailed in section 6. The slow control measurements are devoted to the DCS system and are no more a task of the monitoring system since the redesign of the ECAL electronics architecture in 2002.

Four types of events are needed to implement these tasks:

- laser events,
- pedestal events,
- PN diodes test pulse events,
- APD test pulse events.

2 Description of the monitoring system

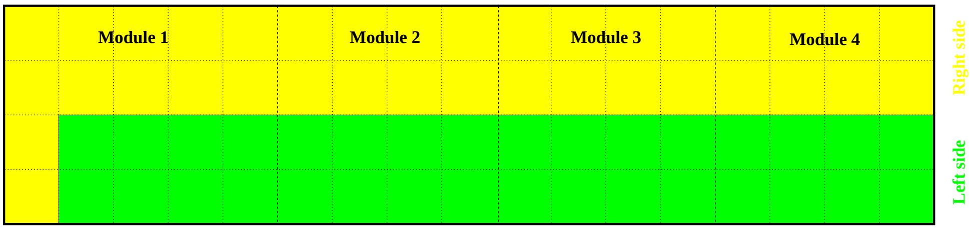

Figure 1: Barrel laser monitoring regions. The two regions are separated by a black lines. The right side consists of 900 crystals and the left one consists of 800 crystals. Both sides are read out by the same DCC (number 1..36). The dotted lines represent the module separations and the dashed lined the trigger towers/readout units.

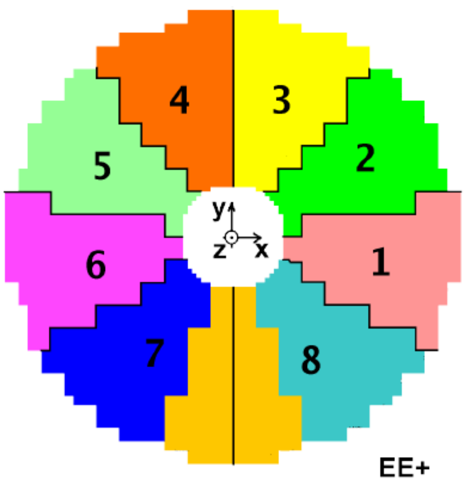

Figure 2: Endcap laser monitoring regions. The regions are separated by black lines and numbered here from 1 to 8. The colours represent the DCC regions. There are 2 monitoring regions (7 and 8) which are read out by two DCCs. There are 9 DCCs for each End-Cap (number 37..54). Region 7+ is read-out by DCCs 43 and 44, 8+ by DCCs 44 and 45, 7- by DCCs 52 and 53, and 8- by DCCs 53 and 54.

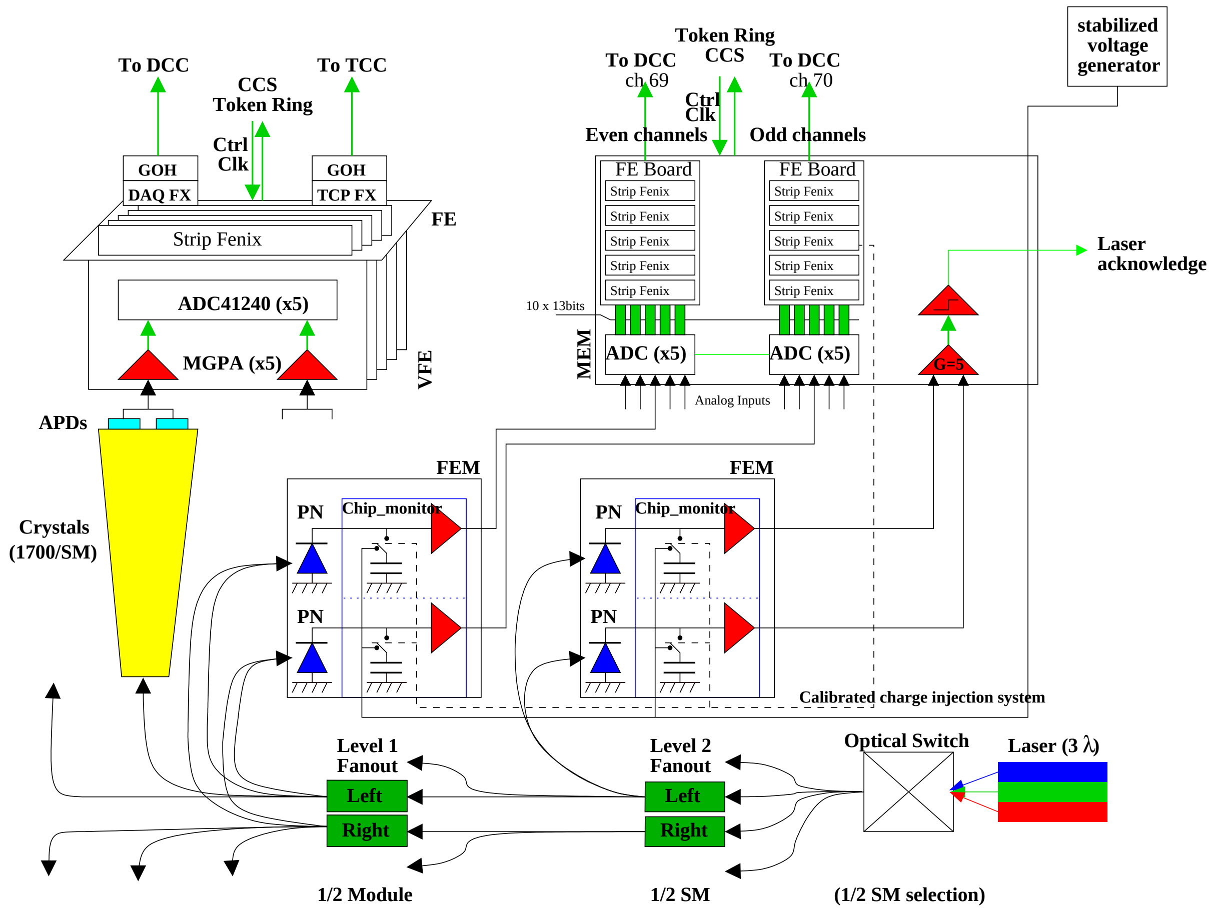

Figure 3: Schematic view of the monitoring system in CMS-ECAL

The light injection system provides 4 different wavelengths: 440 nm (blue) to follow the crystal's radiation damages, 500 nm (green) which is needed for redundancy and $\approx$ 680 nm (red) and 796 nm (far red) which are much less sensitive to radiation damages than the blue and which should enable us to disentangle the electronics unstability from the radiation induced fluctuations. In normal running conditions, only 2 are used: blue one at 440 nm and red one at 796 nm. There are 2 monitoring units per Super-Module (Fig.1) in the barrel and 4 per End-Cap Dee (Fig.2). In total, there are 88 monitring units in CMS-ECAL (72 in the barrel part and 16 in the end-cap one). These unit modularity will also be kept for the other measurements (pedestals and test-pulses).

In figure 3, one can see a schematic view of the monitoring system as it is installed on super–modules and Dee's. The light produced by a laser system is sent to the front face (for barrel) or to the rear face (for end–caps) of each crystal via a 3–level distribution system: The first level (level 1) distributes light to crystals of a given half module (groups of 200 crystals). The second level (level 2) distributes light inside a super–module to the first level half–in–phi modules and finally the third level (optical switch 3x88) switches the light coming from the lasers (choice between 3 colors) to the relevant half super–module. The amount of light sent to the crystals is monitored at the level 1 and the level 2 by PN diodes and is read out by the MEM modules. The level 1 PN response is the reference enabling the monitoring system to follow the variation of the crystals response. A charge injection system is also available on the FE-ASIC chips to allow an absolute calibration of the monitoring electronic chain.

To follow the ECAL behavior in real-time, we need to perform the laser-monitoring tasks during normal data taking (physics run, beam on), without disturbing it. For this purpose we will use the LHC abort gaps which last 3 μs every 90 μs. For this reason, all events taken in these gaps and devoted to hardware calibration will be called **gap-events**.

3 Sequence of operations

3.1 Sequence description

A laser-monitoring sequence consists of a complete scan of the ECAL with 2 wavelengths (blue and red), pedestals measurement of the MGPAs and electronics stability check with Test-Pulse. The laser-monitoring sequence will not include a scan of the End-Caps with the red laser since the VPT used in the End-Caps are not sensitive to the red wavelength.

In order to be able to measure and correct the changes in the crystal transmission in an efficient way, even at the beginning of beam periods, we need to perform a laser-monitoring sequence every 30 minutes. The laser-monitoring procedure should run such that one gets a full reference point for CMS-ECAL every 1/2 hour.

Other complementary measurements will be performed during beam-off periods, as summarized in the next table:

Event type	LHC gap	beam off
laser	2 wavelengths G12	3 wavelengths free gain G12-G6-G1
pedestals	G12, G6$^{(*)}$	G12-G6-G1
PN test pulse	G16	G16-G1
APD test pulse	G12$^{(*)}$	G12-G6-G1

(*) During collision periods, we can choose between measuring the MGPA test-pulse and measuring the pedestal in gain G6 or G1 without reconfiguration of the electronics setting. All other combinations needs reonfiguration of the FE cards through the CCS links.

Obviously, the pedestal measurements have to be done without zero suppression.

3.2 Example of a calibration run sequence

A possible scenario fulfilling the requirements on laser run given in previous Section, assuming that the barrel is covered by the monitoring regions 1 to 72 and the two endcaps by the regions 73 to 88:

1 take 200 pedestal events at rate f_{pulse} on monitoring region 1 while the optical switch is operated to position laser on region 1,

2 take 200 test-pulse events at rate f_{pulse} on monitoring region 1 while the optical switch is operated to position laser on region 1,

3 take 600 events of blue laser on monitoring region 1 at rate f_{pulse},

4 take 200 pedestal events at rate f_{pulse} on monitoring region 2 while the optical switch is operated to position laser on region 2,

5 take 200 test-pulse events at rate f_{pulse} on monitoring region 2 while the optical switch is operated to position laser on region 2,

6 take 600 events of blue laser on monitoring region 2 at rate f_{pulse},

...

262 take 200 pedestal events at rate f_{pulse} on monitoring region 88 while the optical switch is operated to position laser on region 88,

263 take 200 test-pulse events at rate f_{pulse} on monitoring region 88 while the optical switch is operated to position laser on region 88,

264 take 600 events of blue laser on monitoring region 88 at rate f_{pulse}

265 make a pause of duration t_p, while the laser selection switch and the laser attenuator is set for the red laser.

266 take 400 empty events at rate f_{pulse} while the optical switch is operated to position laser on region 1,

267 take 600 events of red laser on monitoring region 1 at rate f_{pulse}

268 take 400 empty events at rate f_{pulse} while the optical switch is operated to position laser on region 2,

269 take 600 events of red laser on monitoring region 2 at rate f_{pulse}

...

408 take 400 empty events at rate f_{pulse} while the optical switch is operated to position laser on region 72,

409 take 600 events of red laser on monitoring region 72 at rate f_{pulse}

410 make a pause of duration t_p, while the laser selection switch and the laser attenuator is set for the blue laser.

411 restart at 1.

Such a sequence cycle time is given by:

$$t_{seq} = (88 + 72) \times (600 + 200 + 200)/f_{pulse} + 2\ t_p$$

We propose to take 200 pedestal and 200 test-pulse events (or 400 empty events) before taking laser data on a monitoring region to let time to the optical switch to set in the correct position. The time for changing optical switch channel has been measured to be 2s (with laser monitoring on). We take a safety factor of 2 and thus acquire 400 extra events in between 2 laser runs on 2 consecutive monitoring regions. We assume $t_p = 28\ s$, is enough to set the optical switch and the optical attenuator in position when we switch from one laser to another. The minimum time required for a laser-only calibration sequence with f_{pulse}=100 Hz is:

$$t_{seq} \approx 28\ \mathrm{mn}$$

The trigger sequence required for the described monitoring sequence can be summarized by the formula:

$$(200.Ped + 200.TP + 600.L^{blue}) \times 88 + 2800.e + (400.e + 600.L^{red}) \times 72 + 2800.e$$

where 'L^{red}' (resp. 'L^{blue}') represents a calibration trigger used to acquire a red laser (resp. blue laser) event, Ped is a pedestal trigger, TP is a test-pulse trigger and e represents an "empty event" trigger. The number of pedestal, test-pulse and empty events can be tuned to accomodate to the actual behaviour of the optical switches and attenuators. For instance, if the time to switch from one monitoring unit to another one can be reliably set at 2 seconds, the total time needed to performed a laser monitoring sequence can be reduced to 22 minutes.

4 Hardware setting and trigger generation

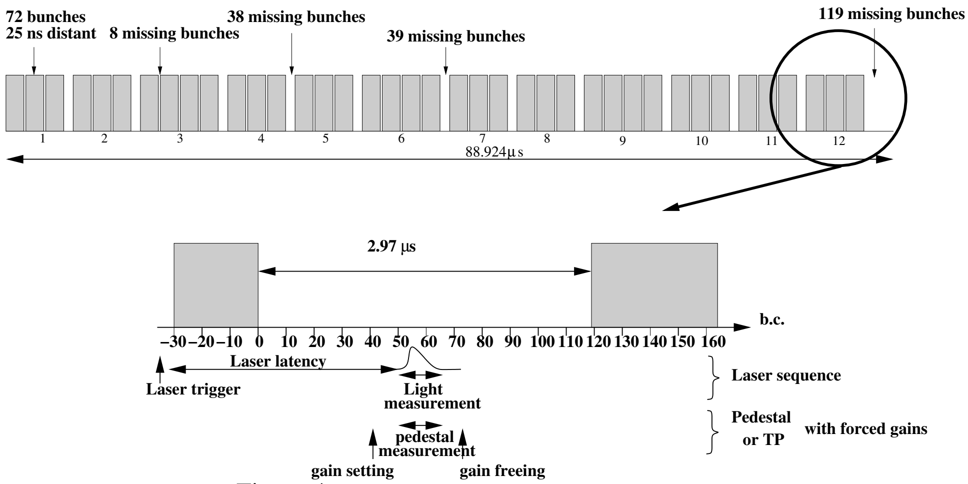

Figure 4: Example of monitoring cycle within LHC cycle

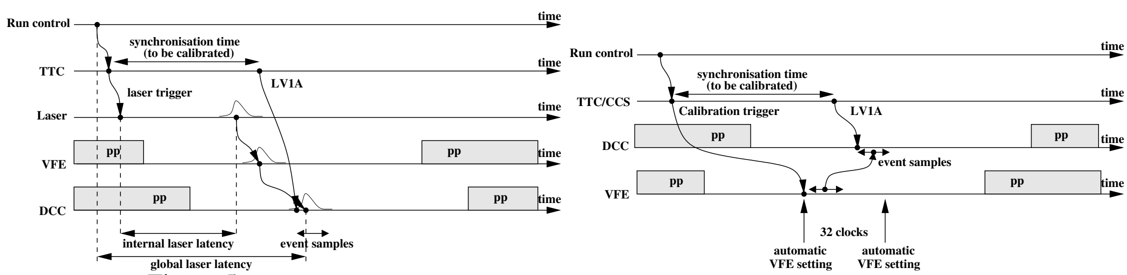

Figure 5: Typical time sequences for monitoring laser events (left) and for pedestal events (right)

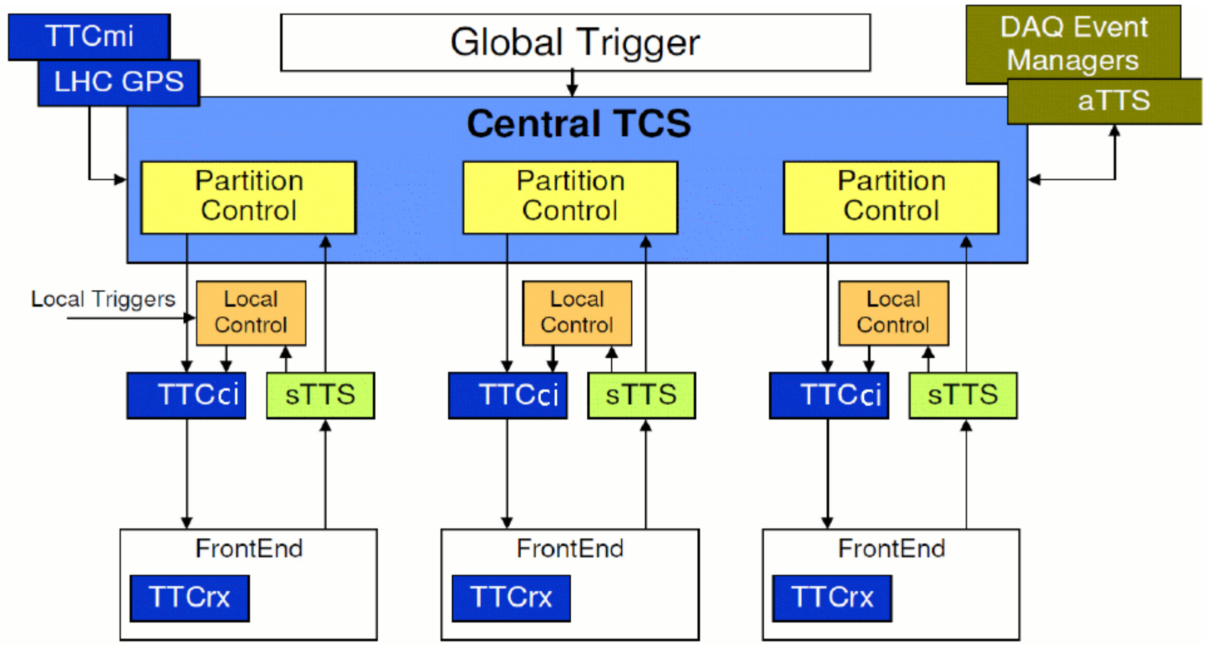

Figure 6: CMS TTC architecture. The TTC is divided in 32 partitions (only 3 represented in the figure), including4 partitions for the ECAL.

4.1 Sequence driving

The **TCS** (trigger control system) will be responsible during normal LHC running conditions for driving the monitoring sequence. It decides which gap will be allocated to the gap-events in CMS. On reception of a calibration trigger (Test Enable, TE), a predefined sequence loaded in the TTC system will send to the ECAL all the information necessary to set the laser system (monitoring unit, wave length, actual power) and the Read-Out electronics. To handle with the delay needed by the laser to pump before sending a light pulse, a signal ("Warning Test-Enable, WTE) is send by the TCS before each TE. The WTE will be received 400 clocks before the TE signal.

The trigger is distributed in the LHC experiments through the Trigger, Time and Command (TTC) system[2]. The TTC is a communication system based on a 80MHz synchronous link composed of two time division multiplexed channels; one channel, channel A, is used to sends the commands requiring the minimum latency, in principle the level one trigger accept (L1A); the second channel, channel B, is used to send different fast commands. The TTC is designed to minimize the communication latency. The TTC is used at the same time for distributing the LHC clock. The TTC is divided in partitions, including four for the ECAL: one for each endcap and one for each half-barrel. The partitions can run in parallel and receive different triggers but in a normal physics run all the partitions receive the same triggers. The TCS sends the trigger (and other TTC commands) to the input cards of each partitions, called TTC-ci (TTC CMS input)[6]. The TTC-ci's are then responsible to distribute the trigger and TTC commands inside the trigger partition, in particular to the Front-End readout. The trigger distribution is made through 1310nm multimode optical links, a dedicated chip, the TTC-Rx[7], is used to decode the TTC signal. In order to receive the trigger of the 4 ECAL partitions, 4 optical receivers and 4 TTC-rx chips are required. The TCS will send regularly, at a frequency of about 100Hz, calibration trigger which can be used by the subdetectors to acquire calibration data during LHC main gaps. A B-channel command, "Test Enabled" (TE) is sent in advance to the TTC-ci's indicating that the next L1A is for calibration. The TTC-ci's translates received TEs into the TE commands distributed to the connected TTC-Rx. The sent commands are specific to the calibration task of each sub-detector. For ignoring a TE, a "send an empty event at next L1A" command is sent. On reception of a TE a TTC-ci can send one or two consecutive commands. These commands can be short (8 bit of payload) or long (16 bit of payload). In the configuration where a short command followed by a long one are sent, the minimal latency between the time the TTC-ci has received and deserialized the TE from the TCS and the time the short command is received and decoded in the TTC-Rx connected to the TTC-ci is 1.6μs.

The corresponding TE command to be sent by a TTC-ci at each calibration trigger is stored in a FIFO. Each FIFO can contain 16,384 single-command triggers or 8192 double-command triggers. The TTC-ci has two additional parameters, called prescale and postscale. If the prescale is greater than 1 then only 1-every-prescale calibration trigger received from the TCS (or LTC) is used for calibration. If the postscale is greater than one then each FIFO trigger entry will be sent 'postcale' times before going to the next FIFO entry. The TTC-ci can run in two modes: single mode and repetitive mode. In repetitive mode, the TTC-ci cycles on the FIFO content while in single mode it makes only one cycle. It is not yet clear if it is possible to run during a physics run by feeding continuously the FIFO through VME. Therefore we will envisage here only the repetitive mode where the FIFO is filled before starting the CMS run.

The monitoring laser will be triggered by a ”laser trigger” send by the TTC-ci upon reception of a WTE signal. A programmable delay is available in the EMTC (see next section) to tune the actual delivery time of the light pulse to be in the LHC abort gap. With this system, the LV1 timing remain the same whatever the event type (laser, test-pulse, pedestal).

To summurize, 2 FIFOs will be filled in the TTC-ci's to handle the TE and the WTE signals. These FIFOs will be synchronized in order to send only ”laser trigger” signals (from WTE) only for ”laser events” (from TE).

The system should be able to handle *special requests* from ECAL experts to perform off-sequence measurements if necessary for debugging purposes. In this case, the sequence loaded in the TTC system should be replaced with a new one.

4.2 Proposed laser trigger system

The interface between the laser and the TTC will be done with a dedicated card, the ECAL Monitoring Trigger Card (EMTC). The EMTC will receive the signals genrated by the ECAL TTC-ci's upon reception of the WTE, the TE and the L1A through 4 TTC optical inputs, one for each ECAL partition. This card will provide two NIM triggering signals, one to trig the monitoring laser, one to trig the MATACQ acquisition stop. This is a 6U-VME board which will be located in the same crate as the MATACQ near the laser diagnostic system. The following information is sent together with the TE signal:

- The calibration trigger type : pedestal, test-pulse, laser, empty gap-event.
- The laser wavelength : Blue, green, red, far red, led1, led2.
- The identification of the ECAL monitoring region which is under study.

The identification of the ECAL region is used by the DCCs to limit the readout to the monitored region; the laser wavelength information is sent with the TE in order to be inserted into the laser event headers. The EMTC will decode the ECAL region information and inform the laser supervisor to switch to another position whenever it is required. This will be done during test-pulse and pedestal measurements inserted between 2 consecutive laser sequences of 600 events. The EMTC will wait for a ”ready” signal, until which it will inhibit the laser trigger. With this setting, the laser system will run in a complete slave mode. The online monitoring will check the consistency of the data and warn ECAL shift crew in case of desynchronisation of the sequence.

The laser-monitoring sequence can be achieved by setting the TTC-ci B-Go(2) postscale parameter to 200 and filling the TTC-ci B-Go(2) FIFO (see section IV) with

$$(Ped + TP + 3L^{blue}) \times 88 + 14.e + (2.e + 3L^{red}) \times 72 + 14.e$$

This pattern is actually:

$$(Ped_1 + TP_1 + 3.L_1^b) + ... + (Ped_{88} + TP_{88} + 3.L_{88}^b) + 14.e + (2.e_1 + 3.L_1^r) + ... + (2.e_{72} + 3.L_{72}^r) + 14.e \quad (1)$$

where L_i^{blue}, L_i^{red}, Ped_i, TP_i and e_i represent the triggers sent to the monitoring region i. The trigger sequence (Eq.1) is 828 long. The FIFO is large enough to contain the whole sequence at once so the repetitive mode can be used. The FIFOs of the 4 TTC-ci's must be filled with this sequence. In the FIFO of a TTC-ci the L_i trigger commands for the monitoring region covered by the three other TTC-ci's may be replaced by ”empty event” commands.

The synchronized TTC-ci B-GO(13) FIFO to handle the WTE will be :

$$(2.NoOp + 3.trigger) \times 88 + 14.NoOp + (2.NoOp + 3.trigger) \times 72 + 14.NoOp$$

where $NoOp$ means that the TTC-ci does nothing for this WTE and $trigger$ means that the TTC-ci encodes the ”laser trigger” signal.

Ideally, the information to propagate on reception on a TE by the TTC-ci is the folowing :

- Monitoring region to consider: 6+1 bits (DCC number/side).

- Event type: 3 bits (pedestal/TP/Blue/Green/Red/IR/LED1/LED2/empty)
- Laser power: 7 bits (0-99 %)
- Laser attenuator: 2 bits (0-10-20-30 dB)

In normal monitoring sequences, the laser power and the laser attenuator have not to be changed and the information has not to be propagate through the TTC system. We end up with 10 bits. These can be propagated by sending two broadcast commands in a raw on TE reception. In fact, since the 2 lsb of a broadcast command are used internally by the TTC-Rx (BC reset and EC reset), they cannot be used to propagate information to the end user and we end up with 6 usefull bits.

Taking into account the other ECAL broadcast messages, we obtain, for the first broadcast, the codes described in Table 1. The bit 7 of these codes is used to select the side of the SM which has to be fired. The TTC-Rx in the ECAL partitions (TCC, DCC, CCS, SRP, EMTC) should be able to handle these codes and in particular detect the bit 6 of the message: If this bit is set to 1, they have to wait for a second broadcast message. This second broadcast contain the information of the selected DCC for read-out. (DCC number from 1 to 54 in bit 7-2). This is used by the EMTC to set the laser optical switch, by the DCCs to select only relevant readout units and potentially by the CCS to send only TP triggers to the according token-rings (Table 2):

- The calibration trigger type : pedestal, test-pulse, laser types, empty gap-event. This is encoded in bit 5..2 of the first broadcast (Table 1).
- The identification of the ECAL monitoring region which is under study: This is computed with bits 7..2 of the second broadcast (Table 2) which gives the DCC number of the selected region and the bit 7 of the first braodcast which gives which side is considered. For the barrel, we can then select which side of the Super-Module has to be fired by the laser (monitoring region 1..72 = 2xDCC-side). For the End-Cap, we use only the ”side bit” to determine which region is read by DCCs 44 and 53 (Fig. 2):
DCC 43 and 44-side 0 = EE monitoring region 7+, DCC 45 and 44-side 1 = EE monitoring region 8+,
DCC 52 and 53-side 0 = EE monitoring region 7- , DCC 54 and 53-side 1 = EE monitoring region 8-.

TCS Signal	TTC-ci input channel	ECAL Signal	TTC broadcast bus [7..0]	TTC Decoder Reg [5..0] (= bits [7..2] of TTC bus)
BC0	1	BC0	H30=00110000	H0C
Private gap	3	Private gap	H20=00100000	H08
Private orbit	4	Private orbit	H24=00100100	H09
ReSync	5	ReSync	H38=00111000	H0E
Hard Reset	6	Hard Reset	H3C=00111100	H0F
Evt Counter reset	7	Evt counter reset	H04=00000100	H01
Orbit Counter reset	8	Orbit counter reset	H08=00001000	H02
Start	9	Start	H2C=00101100	H0B
Stop	10	Stop	H28=00101000	H0A
Tx empty event	11	Tx Empty event	H10=00010000	H04
End of Burst	12	End of Burst	H0C=00001100	H03
Warning Test Enable	13	laser warning	H0D=00010100	H05
Test Enable	2	Laser Blue	Hx0=s1000000	H10-H30
Test Enable	2	Laser Red	Hx4=s1000100	H11-H31
Test Enable	2	Laser IR	Hx8=s1001000	H12-H32
Test Enable	2	Laser Green	HxC=s1001100	H13-H33
Test Enable	2	LED λ_1	Hx0=s1100000	H18-H38
Test Enable	2	LED λ_2	Hx4=s1100100	H19-H39
Test Enable	2	Test Pulse	Hx0=s1010000	H14-H34
Test Enable	2	Pedestal	Hx4=s1010100	H15-H35
Test Enable	2	Empty gap-event	Hx4=01011000	H16

Table 1: Broadcast codes sent by ECAL TTC-ci and corresponding TCS B-Go commands. The bit 7 (s) of the Test Enable codes is used to select the side selected SM (see Table 2)

ECAL Signal	TTC broadcast bus	TTC Decoder Reg [5..0]
DCC number	Hxx=nnnnnn00	Hxx

Table 2: 2nd broadcast codes sent by ECAL TTC-ci when first broadcast has bit 6 set to 1 : The 6 usefull bits are used to encode the DCC number (1..54)

4.3 Laser control PC - run control communication

[I put some ideas in this section, but in principle this communication should be defined by Caltech people and DAQ people].

The EMTC control software and the laser control software will run in different processes. The communication between the processes will be done through a TCP/IP connection (XDAQ can be used as communication framework but it is not a requirement). In this way, the two softwares can either run on the same PC or on two different PCs. In the one-PC configuration the communication being done through the loopback interface the average communication latency should be less than 100μs (measurement on a laptop cadenced at 600MHz gave 565μs) but the time is not guaranteed and the latency distribution has a long tail.

Command/data name	Communication way	minimum data size	comment
monitoring region	Laser controller - EMTC	7 bits	
wavelength	Laser controller - EMTC	2 bits (10 bits if given in nm)	
laser trigger inhibit/resume	Laser controller - EMTC	1 bit	required only if trigger inhibition is done in the EMTC
EMTC configuration	Laser controller - EMTC	?	depending if EMTC has its own RC supervisor or if it's controlled by the laser system RC supervisor.
number of missed triggers	EMTC - Laser controller	16 bits	1. required only if trigger inhibition is done in the EMTC 2. could be sent only if it is not null (error case).
level-1 event number	EMTC - Laser controller	24 bits	Can be used by the Laser controller in conjunction with the PC clock (and/or orbit number?) to precisely assign data (e.g. pulse information) to a laser event.
orbit number	EMTC - Laser controller	32 bits	Can be used by the Laser controller to precisely assign data (e.g. pulse information) to a laser event.

Table 3: Data and command exchanged between the laser controller and the EMTC.

As noted before, the laser monitoring sequence is operated during a physics run without requiring any transmission of command from the run control. In an ideal run, the command for the laser control are sent by the run control only outside physics run, in particular before a run start for configuration. Nevertheless the system should also have the possibility to receive configuration commands during an LHC run. The laser run sequence should allow to change laser configuration keeping laser run consistent: in principle it should be possible to send a configuration command to be executed at the next monitoring region change during the trigger pause.

FIXME : TTC-ci reconfiguration - warm restart.

5 Data flows

In the laser-monitoring tasks one defines three types of entities: event, run and sequence.

- Event: set of 10 time samples coming from the VFE electronics for a given set of channels (i.e. 1/2 Super–Module).
- Run: set of events (600 for laser, 200 for pedestal and test-pulse) coming from a given monitoring region.
- Sequence: set of runs necessary to perform a monitoring measurement on the whole calorimeter (**reference point**). The laser energy will be choosen to optimized the calorimeter stability at the Z energy (about 50 GeV energy equivalent in the crystal). To get this reference point one has to measure the MGPA pedestal in G12, check the electronics stability with Test-Pulse and measure the laser response of each crystal for two wavelengths.

In this section, the ECAL size of each entity going through the DAQ bus is given. We assume 10 samples per event both for the crystal data and PN diode data (samples around the maximum). The values are calculated for a monitoring region. According to the FENIX documentation, the number of 16-bit words to read is equal to: $n_{W16} = n_{tower} * [5_{strip} * (5_{crystal} * (n_{samples} + 1_{crystalheader}) + 1_{strtipheader}) + 4_{towerheader}]$.

Event type	event size [kbytes]	run size [Mbytes]	Sequence size [Gbytes]
pedestal	18.9/21.2	9.2/10.4	3.37
laser	18.9/21.2	27.6/31.1	4.59
Test pulse	0.29	0.28	negligible

The data flux generated by this sequence is less than 10 Mbytes/s. It is important to note that for each event, one has to read 1/2 DCC. With the present design of the DCC, this is not a constraint. The data can be accessed in two ways:

Local DAQ A 2-buffer system is present in the DCC which makes possible to read the monitoring data from a buffer in parallel to the normal data taking mode. This second buffer is read-out trough the VME bus.

Global DAQ The monitoring data in send to the main CMS DAQ stream. After the event builder the calibration events are collected by a "Gap-Event Collector" and each CMS calibration task can retreive the events from this server. This system is described more in details in the next section.

In case of Local DAQ acquisition, the monitoring sequence has to be optimized to smooth the VME bus loading. In the present architecture, we have 3 Super-Modules per crate for the Barrel part and 3 Dee sectors per crate for End-Caps part. One can look at Fig.7 for the organization of Off-Detector electronics in the ULR crates. It is also interesting to factorize the monitoring sequence accordingly to the ECAL partition to simplify the TTC-ci programming, and also to to set a sequence which minimize the time for switching the laser from one sector to another (use of adjacent optical outputs).

EE+ 9	**EE+ 1**	**EE+ 2**	**EE– 9**	**EE– 1**	**EE– 2**	**EE– 6**	**EE– 7**	**EE– 8**	**SRP**	**EE+ 6**	**EE+ 7**	**EE+ 8**	**EE+ 3**	**EE+ 4**	**EE+ 5**	**EE– 3**	**EE– 4**	**EE– 5**
EB+ 4	**EB+ 5**	**EB+ 6**	**EB+ 7**	**EB+ 8**	**EB+ 9**	**EB+ 1**	**EB+ 2**	**EB+ 3**	**TST**	**EB+ 16**	**EB+ 17**	**EB+ 18**	**EB+ 10**	**EB+ 11**	**EB+ 12**	**EB+ 13**	**EB+ 14**	**EB+ 15**
EB– 4	**EB– 5**	**EB– 6**	**EB– 7**	**EB– 8**	**EB– 9**	**EB– 1**	**EB– 2**	**EB– 3**		**EB– 16**	**EB– 17**	**EB– 18**	**EB– 10**	**EB– 11**	**EB– 12**	**EB– 13**	**EB– 14**	**EB– 15**

Figure 7: Physical implementation of ULR crates

EB+ Super–Modules correspond to SM01 to SM18, EB- Super–Modules correspond to SM19 to SM36. End–Caps sectors are more complicated since Trigger-Sector 5 is located on two Dees. This sector is thus fired with 2 different optical fibers, one for each Dee.

6 Data processing

In normal LHC running conditions, the gap-events data will follow the main DAQ stream. These gap-events will have the normal CMS data structure. At the HLT level, these events will be flagged and transmitted to a special "Event data node" which will transmit them to the requestting processes for the different sub-detectors.

One requesting process will run for ECAL on a dedicated PC which will be the master PC of the monitoring farm.

Once the monitoring events are read-out, they will be processed in real time in the different laser-monitoring tasks. Here are the different step of processing of the data :

Raw data: For each event one has a fix number of time samples. Each sample is a 4-byte word and is read-out from DCC cards. The number of samples is set at the beginning of the run by the Run-Control. In the following, events are supposed to have 10 samples. The laser-monitoting analysis is a statistical analysis on so-called monitoring regions. It is therefore important that the data are derandomized before arriving in the laser-monitoring farm to maintain the order of the events and not mix laser, pedestal and TP events or mix different monitoring regions.

Converted data: The **pulse analysis process** extracts the pulse characteristics from the 10 time samples. Each pulse is characterized by its height, pedestal (gain 12), time position of maximum and quality factor (χ^2). This information is called **converted data** ([1]). This process can be parallelized for each 1/2 Super-Module since a sample of 600 laser events for instance, is independent of another sample coming from another 1/2 Super-Module. These process is done within the CMSSW framework.

Reduced data: The first step is to apply APD and PN data corrections (non linearities corrections, etc.). Next, compute quantities which will enter the final analysis. These **reduced data** consist of the average values, the standard deviations and other quality factors (non exhaustive) computed for each channel over a **run** for some physical quantities (e.g. APD, PN, APD/PN, PED, TP(PN)). This is done for each wavelength of the laser and each gain of the FPPA depending on the monitoring sequence definition (Table 3.1). This process is also part of the CMSSW framework. At this stage, all the computed quantities are written to the Condition-DB.

Correction coefficients: The most important step in the monitoring sequence is the so-called **monitoring analysis process**. At this level one has to handle all the reduced data coming from the present measurement but also all the history of these quantities for a **time window** which is of the size of the time needed to perform a physics calibration of the ECAL. These quantities are retreived from the Condition-DB. In this process, one looks for bad points, steps and kinks in the response of the calorimeter for all the reduced quantities. One classifies these problems and interprets them. Looking at the modularity of the incidents, one can conjecture the origin of the problem (LV, HV, PNs, Temp, Laser, ...). The hypotheses are confirm or denied by searching for relevant quantities measured by DCS and the Matacq board (Condition DB). Once these incidents are localised, confirmed and corrected for, remaining drifts in the ratios APD/PN are supposed to come from radiation damages and the transparency correction coefficients are computed. The resulting corrections are written to the Condition DB. In some special cases, like for instance if a big drift in the laser characteristics is found, it could be necessary to reprocess the raw data with some updated quantities. It is necessary to keep the raw data easily accessible for such a case for at least one week.

6.1 Parameters, links and constants

In order to performe all the previously defined tasks in the monitoring farm, some external information is necessary. This information is composed of **parameters**, **links** and **constants** which are outlined here. **Constants** are numbers or tables which never change (C_inj, $d(L.Y.)/dT$, etc.); **links** are mandatory to link for instance a given channel number in the DCC to the corresponding VFE channel number (construction DB) and **parameters** are calibrating factors, functions or tables used by the monitoring system to perform the tasks. These parameters can evolve with time (e.g. pedestals, gains, ...).

6.1.1 Description

A list of the required parameters for the laser-monitoring tasks is given here:

Xtal	PN	APD/VPT	
	pedestal x2 gain x1 non linearities noise x2 error matrix	pedestal x3 gain x2 non linearities noise x3 error matrix pulse shape	pulse analysis
$\Lambda(\lambda)$ $S/R(\lambda)$ $d(L.Y.)/dT$ T Xtals parameters	$\epsilon_Q(\lambda)$ C_{inj} V_{inj}	$\epsilon_Q(\lambda)$ $V_{nominal}$ $1/M(dM/dV)_{V_{nominal}}$ $1/M(dM/dV)_{V_{nominal}}$ T, V	corrections & consistencies
Size of the time window to look for in the history file ($\approx$ month) including pre–calibration coefficients at LHC start			analysis
decision criteria to validate data quality and monitoring results (to be defined)			decision

This is a part of CMSSW to retreive all these informations from the condition DB.

6.2 Electronics calibration

The monitoring system allows direct electronics calibration of the PN electronics chain and relative measurements of the APD chain. Excluding physics events, the only reference system for the ECAL calibration response is the PN diode monitoring system. The electronics calibration is foreseen in the following way:

- Scan over the whole dynamical range of the PN electronics with the reference voltage injection system. We then get the absolute relation between the output of the PN electronics and the charge at the entrance of the PN pre–amplifier: $s_{PN} = f_{PN}(Q)$ for the two ASIC gains.
- Scan over the whole dynamical range of the APD electronics with the light injection system. For each crystal, we get a signal s_{APD} and the corresponding signal on the PN diodes s_{PN}. The relation between the signal on the APD and the equivalent charge seen by the PN electronics can then be computed: $s_{APD} = g(Q) = g(f_{PN}^{-1}(s_{PN}))$. This charge measures the amount of light sent to the crystal.

With these measurements, we can obtain the absolute gains of the PN electronics and the non-linearity curves. We can measure the relative gains of the APD electronics and their non-linearity curves. The absolute gains of the APD electronics chain are unmeasurable because there is no physical access to the amount of charge at the input of the APD pre–amplifier since the VFE Test-Pulse is not absolutely calibrated.

This process is foreseen to work off-line, analysing the converted data written in the Condition-DataBase by the Online process.

6.3 Detector check

In the monitoring system, we have enough information to perform a complete cross-check of the CMS-ECAL apparatus. This process will be able to identify problems with crystals, APDs or VFE electronics.

It will provide warning and alarm messages as well as graphical information to the shift crew if anomalous behavior of the calorimeter is detected. The experience acquired during the pre–calibration of the CMS-ECAL will be fully exploited to get a powerful and efficient surveillance system.

6.4 Supervision of the monitoring system

A particular task in the laser-monitoring system is devoted to the supervision of the laser-monitoring system itself. It could be done in two ways:

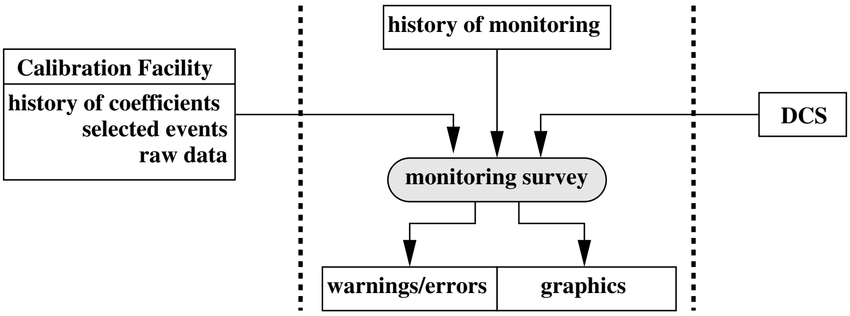

Figure 8: Supervision of monitoring tasks

- **Over the short term**, a comparison of the measured variation of the short term calibration correction coefficients with respect to the expected values computed knowing the received dose and the crystals characteristics. This specific task for instance needs access to DCS in order to obtain the local dose history.
- **Over the long term**, a comparison between the evolution of the short term calibration correction coefficients and the calorimeter response for Z^0 and $W^{\pm}$ can be done. That means that access to physics calibration data and calibration coefficients computed by the calibration task in the ECAL-calibration facility (partition in the general computing services) should be available (Fig.8). The aim is to be able to detect and understand, for example, long term differential drift between monitoring response and physics event response: although short term calibration coefficients involve only corrections over time periods of the order of 1 month, long term drifts due to radiation or possible aging of PN/APD/electronics must be understood. This is important for full understanding of the calorimeter and to deal with long shutdowns for instance. The requirements at this level, for the *gold-plated* calibration events as selected and reconstructed by the calibration task, is to obtain the contents of the raw data in order to compare the relative light collection evolution for physics events versus laser events.

This survey process will provide some graphical information allowing the ECAL experts or shift crew to understand the measurements and decisions made by the laser-monitoring system. It will eventually send warning and alarm messages if something goes wrong. This task is made by analyzing the content of the Condition DataBase in which all monitoring processes write their intermediate and final results and makes some book-keeping on the way the process is done (e.g. warning and error messages sent by each individual process).

7 System architecture

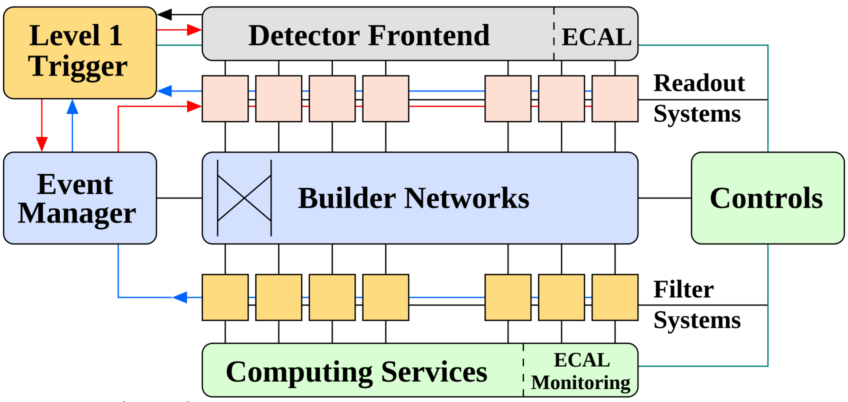

Figure 9: Localization of the monitoring farm in the general DAQ system

According to the present scheme of the general DAQ system, the monitoring data will go through the Event-Builder switch and the laser-monitoring farm will be a partition in the online computing services (Fig.9).

The gap-events will propagate through the CMS-DAQ as normal CMS-events. After the event building, these events will be recognized as gap-events and routed to a dedicated server.

All users of gap-events will pick-up the events from this server as the laser-monitoring farm will do.
FIXME : The communication protocol with the gap-event server has to be defined. To avoid overhead in the processing time, the data has to be handled in binary format. There is no need at this stage to transform into pool format to redecode the event.

7.1 Management of the monitoring data

In order to performe a reprocess of the data if an obvious problem occurs, the raw data has to be stored locally for a approximatly 10 days. (Time needed to get enough history to validate the laser-monioring results.) If reprocessing of the laser-monitoring data is required on a longer term, data has to be retreived from Castor.

The reduced data are stored in the Condition DataBase for ever as well as the transparency correction coefficients. A versionning system is foreseen in the DB management to handle multiple processing and/or analysis programs.

8 Conclusions

The main points to keep in mind concerning the generation and processing of laser-monitoring data at LHC are the following:

- The TCS is responsible for driving of the monitoring sequences in order to ensure that the system will not interfere with the normal running of the CMS experiment.
- Gap-events are handle as normal CMS events up to the event builder.
- The computation of transparency correction coefficients is splitted in two parts : Laser-monitoring task 1 is done online in real time in a partition of the online filter farm. Its results are written in teh Condition data-Base. Laser-monitoring task 2 is done by analysing the content of the Condition DataBase Its results (transparency correction coefficients) are written also in the Condition DB.
- The monitoring process is a continuous and non-stop process. It has to run during the beam periods and during the shut–downs. It has to be operational and running as soon as the super–modules are installed in the CMS experiment.
- In order to perform all the monitoring tasks, the **laser-monitoring system** must have access to additional information from the CMS experiment: DCS, Construction DB, Calibration DB and ECAL-calibration facility.

References

[1] The ECAL pre–calibration in H4, sequences of operations
CMS Internal Note IN2001-005 (2001)

[2] The TTC web site : http://www.cern.ch/TTC