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Database usage for the CMS ECAL Laser Monitoring System.

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Abstract

The CMS detector at LHC is equipped with a high precision electromagnetic crystal calorimeter (ECAL). The crystals experience a transparency change when exposed to radiation during LHC operation, which recovers in absents of irradiation on the time scale of hours. This change of the crystal response is monitored with a laser system which performs a transparency measurement of each crystal of the ECAL within twenty minutes. The monitoring data is analyzed on a PC farm attached to the central data acquisition system of CMS. After analyzing the raw data, a reduced data set is stored in the Online Master Data Base (OMDS) which is connected to the online computing infrastructure of CMS. The data stored in OMDS, representing the largest data set stored in OMDS for ECAL, contains all necessary information to perform a detailed crystal response monitoring as well as an analysis of the dynamics of the transparency change. For the CMS physics event data reconstruction, only a reduced set of information from the transparency measurement is required. This data is stored in the offline Reconstruction Conditions data base (ORCOF). To transfer the data from the OMDS to ORCOF, the reduced data is transferred to Off-line Reconstruction Conditions DB On-line subset (ORCON) in a procedure known as Online to Offline transfer, which includes various checks for data consistency. In this talk we describe the laser monitoring work flow and the specifics of the data bases usage for the ECAL laser monitoring system. The strategies implemented to optimize the data transfer and to perform quality checks are being presented.

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Database usage in the CMS ECAL Laser Monitoring System

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Abstract. The CMS detector at the LHC is equipped with a high precision electromagnetic crystal calorimeter (ECAL). The crystals undergo a transparency change when exposed to radiation during LHC operation, which recovers in absence of irradiation on the time scale of hours. This change of the crystal response is monitored with a laser system which performs a transparency measurement of each crystal every twenty minutes. The monitoring data is analyzed on a PC farm attached to the central data acquisition system of CMS. After analyzing the raw data, a reduced data set is stored in the Online Master Data Base (OMDS) which is connected to the online computing infrastructure of CMS. The data stored in OMDS, representing the largest data set stored in OMDS for ECAL, contains all the necessary information to perform detailed crystal response monitoring, as well as an analysis of the dynamics of the transparency change. For the CMS physics event data reconstruction, only a reduced set of information from the transparency measurement is required. This data is stored in the Off-line Reconstruction Conditions Database Off-line subset (ORCOFF). To transfer the data from the OMDS to ORCOFF, the reduced data is transferred to Off-line Reconstruction Conditions DB On-line subset (ORCON) in a procedure known as Online to Offline transfer, which includes various checks for data consistency. In this talk we describe the laser monitoring work flow and the specifics of the database usage for the ECAL laser monitoring system. The strategy implemented to optimize the data transfer and to perform quality checks is being presented.

1. Introduction

One of the main physics motivations for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Colider (LHC) is to elucidate the nature of electroweak symmetry breaking for which the Higgs mechanism is presumed to be responsible. In the low mass range between 115 and 150 GeV the Higgs discovery potential in the $\gamma\gamma$ decay channel is directly related to the reconstructed mass width, or the energy resolution of the electromagnetic calorimeter (ECAL).

The CMS ECAL is a hermetic, high-resolution, high-granularity scintillating crystal calorimeter comprising 61200 lead tungstate ($PbWO_4$) crystals mounted in the central barrel part, and 7324 crystals in each of the 2 endcaps. $PbWO_4$ crystals were chosen because they have short radiation length($X_0 = 0.89$ cm) and Moliere radius (2.2 cm), are fast (80% of the light is emitted within 25 ns) and radiation hard (up to 10 Mrad).

The ECAL designed energy resolution is

$$\sigma E/E = 2.7\%/\sqrt{E} \oplus 0.55\% \oplus 0.16/E$$

for the barrel and

$$\sigma E/E = 5.7\%/\sqrt{E} \oplus 0.55\% \oplus 0.77/E$$

for the endcaps, where $\oplus$ stands for addition in quadrature and E is in GeV [1]. A crucial issue, however, is to maintain this energy resolution, especially the 0.55% constant term, in situ at the LHC.

At the LHC design luminosity, the CMS detector will be operated in a severe radiation environment (dose-rates of 15 $rad/hour$ for the barrel and 500 $rad/hour$ for the endcaps at $10^{34}\ cm^{-2}s^{-1}$). The $PbWO_4$ crystals are radiation hard to high integrated dose, but suffer from dose-rate dependent radiation damage. Radiation causes a degradation in crystal transparency due to radiation induced absorption [2]. The change in scintillation signal response due to a particle traveling a crystal is directly proportional to the change in response to the directly injected laser light for $PbWO_4$ crystals. This dependence can be described by the following equation

$$E(t)/E(t_0) = [L(t)/L(t_0)]^{\alpha}$$

where $E(t)/E(t_0)$ is the normalized electron response and $[L(t)/L(t_0)]^{\alpha}$ normalized response to the laser light, and α is the correlation constant. Therefore, changes in crystal transparency to laser light can be used to correct for changes in response to incident particles. To maintain the energy resolution of the detector these corrections must be performed. Figure 1 shows the results from testbeam irradiation studies.

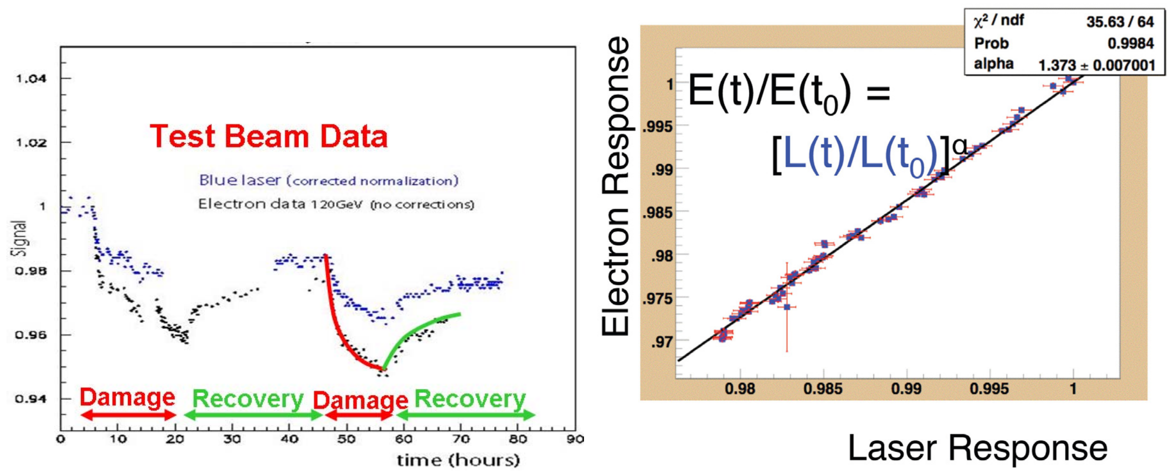

Figure 1. Results from the testbeam irradiation studies. On the left plot one can see a degradation in response to electrons on the order of 4% with transparency to the laser light following the same functional dependence. On the right plot the correlation between crystal response to laser light and to incident electrons is shown.

The CMS ECAL utilizes a laser monitoring system to monitor the light output of the crystals. With this system, we can measure the change in transparency of each crystal continuously during LHC running, with very high precision. In this paper we present the overview of the ECAL Laser Monitoring Dataflow strategy designed for LHC operation. Special attention is paid to the use of databases in this context. The performance optimization for the data transfer is also presented.

2. The ECAL Laser Monitoring System

The CMS ECAL Laser Monitoring System represents a system which utilizes a powerful laser source to monitor the transparency of each of the ECAL $PbWO_4$ crystals. Transparency changes recorded by the Laser Monitoring System are translated into the equivalent change in ECAL response to electrons. This information collected for each crystal is used to correct the reconstructed data for the effect of crystal radiation damage.

The monitoring light source consists of three pairs of lasers. Each pair consists of a Nd:YLF pump laser and a tunable Ti:Sapphire laser. All three Ti:Sapphire lasers provide a laser pulse intensity up to 1 mJ, corresponding to about 1.3 TeV energy deposition in $PbWO_4$ crystals, at a repetition rate up to 100Hz. Two wavelengths are available from each pair of lasers. Two pairs provide 440 nm (blue) and 495 nm (green) and the third provides 709 nm (red) and 796 nm (IR). 440 nm was chosen as the monitoring wavelength as it provides the best linearity between the variations of crystal light output and transmittance [3]. 796 nm wavelength is used to monitor the gain variations of the readout electronics chain. The laser light, through a system of optical switches and optical fibers, is delivered from the light source to the surface of each individual crystal in the ECAL and to the PN diodes for reference. The schematic light distribution system is shown in the Figure 2.

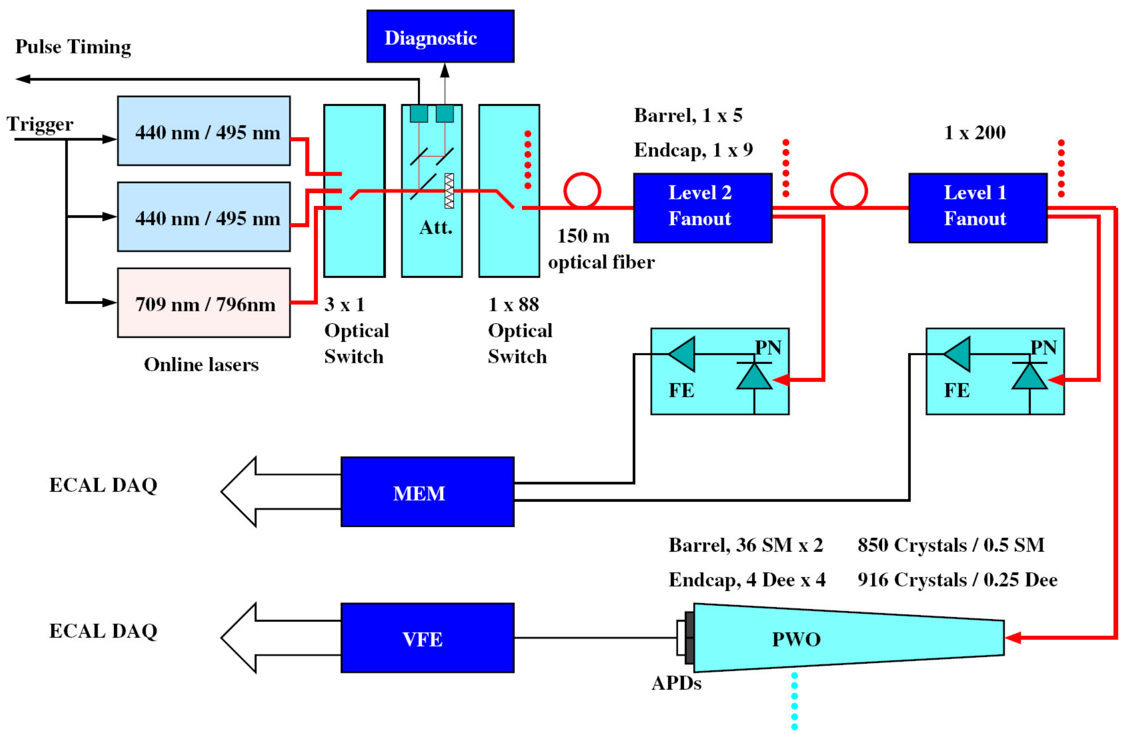

Figure 2. Laser Monitoring system is equipped with three pairs of lasers capable of providing the laser light at the frequencies of 440, 495, 709 and 796 nm. Through a system of optical switches and optical cables the light is delivered to the surface of each of the ECAL crystal and to the reference PN diodes.

By means of a 1x88 optical switch, the monitoring laser pulse is sent to one of the 88 light monitoring modules of the ECAL. Each light module consists of a group of crystals: 900 and 800 in the barrel region and around 900 in endcap region. At the same time, the light is sent to reference PN diodes located within the light monitoring modules.

Laser pulses are injected in the ECAL at a rate of 100 Hz, taking advantage of the gaps in LHC cycle used for kicker magnet operation. These LHC beam gaps occur every 89.924 μs and last 3.17 μs. Only about 1% of the beam gaps are used for ECAL monitoring data taking.

During LHC running this sequence will be performed continuosly, providing monitoring data for each individual crystal every 20 min.

The Laser Monitoring data is read out from the detector electronics, reconstructed, analyzed and then compressed to the appropriate format convenient for offline event reconstruction. This data is used to correct the physics data for the effect of radiation induced crystal transparency change.

The Laser Monitoring System was tested in various test beam exercises as well as in the full global run environment of CMS. The System performs according to design specifications and has exhibited the required stability for maintaining the ECAL energy resolution.

3. Laser Monitoring System dataflow

To apply laser corrections to the physics event data only a very reduced subset of the laser data is required. However to ensure that the corrections are right and to correct for various systematic effects the amount of data handled at various steps is significant. To ensure coherent availability of robust data, a specialized data flow was designed and implemented for the Laser Monitoring System operation.

3.1. General dataflow strategy

Laser monitoring data will be taken during the LHC running every 90s. Event data will arrive at the Filter Farm, containing, among other data, the ECAL laser event data, which will be sorted and then analyzed in a PC farm to extract transparency values. Transparency values represent the ratio of the response to the laser light of the crystal readout electronics and the reference PN diodes. In the barrel Avalanche Photo Diodes (APD) are used for the crystal readout and Vacuum Photo Triodes (VPT) are used in the Endcaps. The main monitoring quantity is APD/PN (VPT/PN) ratio. The schematic representation of the CMS ECAL Laser Monitoring System dataflow is presented in Figure 3.

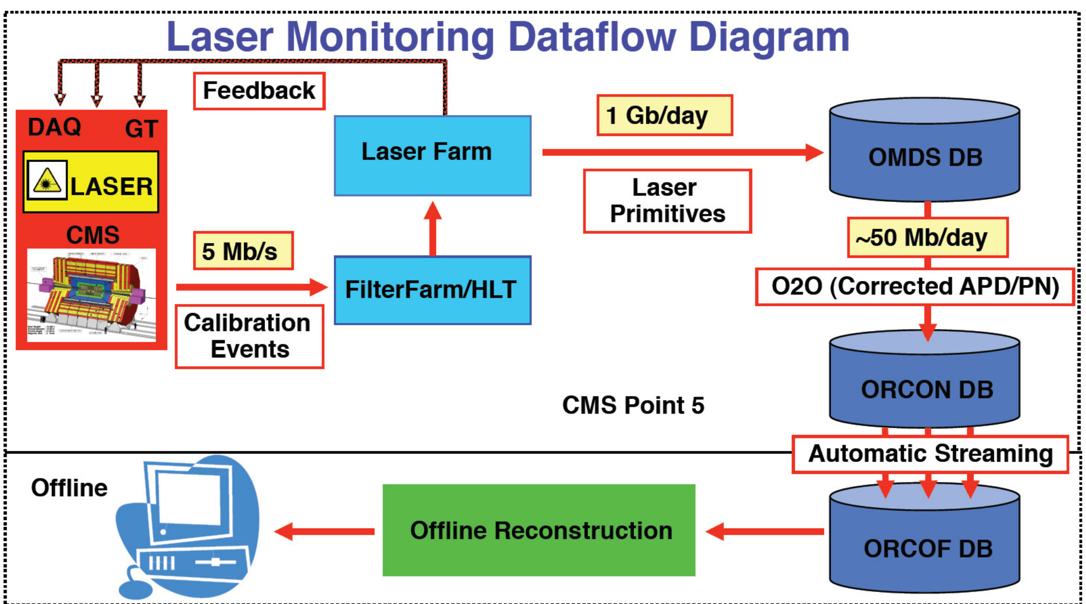

Figure 3. Laser Monitoring System dataflow. It schematically shows steps and procedures involved in production and transfer of the laser corrections from the CMS detector to the offline reconstruction step.

After reconstruction and analysis, the laser data is stored in the On-line Master Data Storage (OMDS) database located in the underground cavern, which is the main Laser Data storage for service, commissioning and monitoring needs. This database, together with APD/PN (VPT/PN) ratios, will be storing various service parameters connected with the Laser Monitoring System operation, referred to as Laser Primitives. Access to the rest of conditions data for the general CMS operation will also be available.

Then a reduced subset of Laser Data, namely the APD/PN or APD/PN values for each crystal, which will only be required for the offline reconstruction, is transferred to the Off-line Reconstruction Conditions DB On-line subset (ORCON) database in a procedure known as Online to Offline (O2O) transfer. Namely APD/PN (VPT/PN) for each crystal. During this (O2O) procedure, corrections and consistency checks are applied.

The data stored in ORCON, located in underground cavern, will be automatically transferred to the Off-line Reconstruction Conditions DB Off-line subset (ORCOFF) with the rest of the CMS Conditions Data.

The laser APD/PN ratios, reference values, and scale factors necessary to implement the transparency correction will be kept in ORCOFF, and the radiation induced transparency correction will be applied in the offline reconstruction step.

3.2. Online Database

The On-line Master Data Storage (OMDS) database represents a standard relational database. It is used to store all conditions necessary for online detector operations and for the bookkeeping of the status of the detector. The data stored in OMDS may also be required for data reprocessing if needed.

All subsystems of CMS share the same database infrastructure Laser Monitoring System being one of them. The Laser Monitoring part of the DB schema is presented in Figure 4. The logic of the OMDS Schema is centered on the CMS Run (RUN_IOV), which uniquely defines a physical CMS run and connects the information from all the subsystems valid for a specific CMS run.

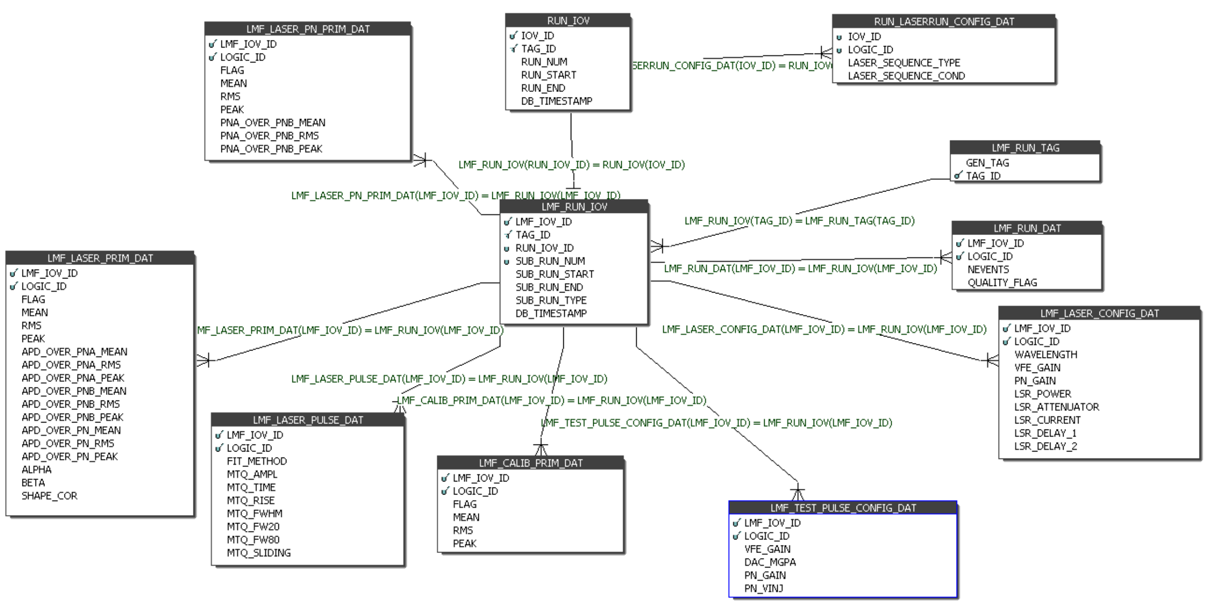

Figure 4. OMDS Laser Monitoring System Schema.

The center of the Laser Monitoring part of the OMDS Schema is LMF_RUN_IOV, where LMF stands for Laser Monitoring Farm. It allows the unique definition of runs within the Laser Monitoring Sequence and the connection of all the conditions data corresponding to those runs.

Information about LMF runs is stored in multiple databese tables. The table RUN_LASERRUN_CONFIG_DAT represents the global information about the current Laser run. LMF_RUN_TAG allows us to make internal LMF run tags. LMF_RUN_DAT provides general information about the LMF Run. LMF_LASER_CONFIG_DAT provides specifics about the configuration used for a specific Laser Run. LMF_TEST_PULSE_CONFIG_DAT gives specifics of test pulse Laser Runs. LMF_LASER_PULSE_DAT contains details about the Laser Pulse itself. LMF_CALIB_PRIM_DAT contains reduced calibration data. LMF_LASER_PRIM_DAT, containing APD/PN (VPT/PN) values required for the online reconstruction. LMF_LASER_PN_PRIM_DAT provides detailed PN diode readout information.

3.3. Offline Database

The Offline Database is represented by the Off-line Reconstruction Conditions DB. It consists of two subsets On-line (ORCON) and off-line (ORCOFF). The Off-line subset is located in the IT department facilities building in direct proximity to the CMS Analysis Facilities and Tier 0; this allows prompt access to conditions data at the reconstruction step for data arriving from CMS. The on-line subset is physically located in the CMS underground cavern allowing a fast link to the OMDS. It has exactly the same internal structure as ORCOFF; thus from the software point of view, writing to ORCON is equivalent to wring directly to ORCOFF. ORCON and ORCOFF are centrally synchronized, thus preventing each separate subsystem from writing straight to ORCOFF, and providing consistent data for off-line reconstruction.

To fill ORCON/ORCOFF we use the Pool/ORA software which fills the database directly from the c++ objects. Each entity of the object has an Interval Of Validity (IOV) assigned to it. Access to the data is organized so that only the objects whose IOV contains the current time can be retrieved, thus providing conditions which were valid for that specific moment in detector history.

Each crystal of ECAL detector will be flashed with laser light on average every 20-30 min. At this timescale, the transparency change can be approximated with a linear hypothesis. If the event being reconstructed took place in between laser measurements for a specific crystal, the value of the transparency will be approximated from the last two transparency values. This requires that we store for each crystal both the current transparency value and the previous one, as well as the time when both values were measured. As crystals belonging to the same light monitoring region are flashed with laser pulses at the same time, it is enough to keep only the time for the measurement of each monitoring region and not for each crystal individually. For the offline reconstruction, reference values of the crystal transparencies are required together with the coefficient of α values for each crystal. Figure 5 shows three objects which represent Laser Monitoring part of ORCON/ORCOFF. One can easily see the level of reduction from OMDS schema to ORCON/ORCOFF objects.

EcalLaserAPDPNRatiosRef
Channel ID
APD/PN

EcalLaserAlphas
Channel ID
Alpha

EcalLaserAPDPNRatios	
Channel ID	Group ID
APD/PN pair	Time pair

Figure 5. ORCON/ORCOFF Laser Monitoring System Objects.

4. Database performance optimization

Laser Primitive data represent a large amount of data stored for each individual ECAL crystal, leading to a considerable time consumption for data transfer. Access tests showed that using the standard upload procedure is not satisfactory for the required working conditions and a DB Access Optimization should be performed.

To improve performance, standard OCCI optimization techniques for bulk writing setDataBuffer, executeArrayUpdate and bulk reading setPrefetchRowCount methods were used:

```
writestmt=conn->createStatement();
writestmt->setSQL(insert.values (:1, :2, ))
writestmt->setDataBuffer(1,(dvoid*)values_array, OCCITYPE, sizeof(value[0]), val_len);
writestmt->executeArrayUpdate(nrows);

readstmt=conn->createStatement();
readstmt->setSQL(select. );
readstmt->setPrefetchRowCount(1000);
ResultSet* rset=readstmt->executeQuery();
While(rset->next(){
rset->get }
```

In one update, all 61200 values contained in an array are written to the database, and in one transaction 1000 lines are retrieved; this allows significant reduction of multiple network round trips to the server.

For testing purposes, we retrieved from and filled into the Online DB, data of a full transparency measurement cycle of the ECAL Barrel, i.e. 1700×36 (61200) channels. For each channel we read/write APD, PN, APD/PN from/in appropriate tables. The results before and after optimization are summarized in Table 1.

Table 1. Online DB access optimization results.

	Before optimization	After optimization
Writing	75 sec	2 sec
Reading	22 sec	3 sec

5. Visualization

Information stored in OMDS DB can be conveniently browsed through and visualized using Web Based Monitoring (WBM) System [4]. An example of typical Monitoring plot for the CMS ECAL Laser Monitoring Run is shown in Figure 6.

6. Conclusions

The CMS ECAL Laser Monitoring System is designed to monitor the changes in the crystal response due to radiation induced damage. The precision of the crystal transparency measurement is below 0.2%, which is requred to keep the resolution of the ECAL at the 0.5% level. We heve shown how the Laser Monitoring System is organized and what is the dataflow structure required for the optimal system operation. Performance optimization for the bulk amounts of data handling brings the dataflow well within the design requirements.

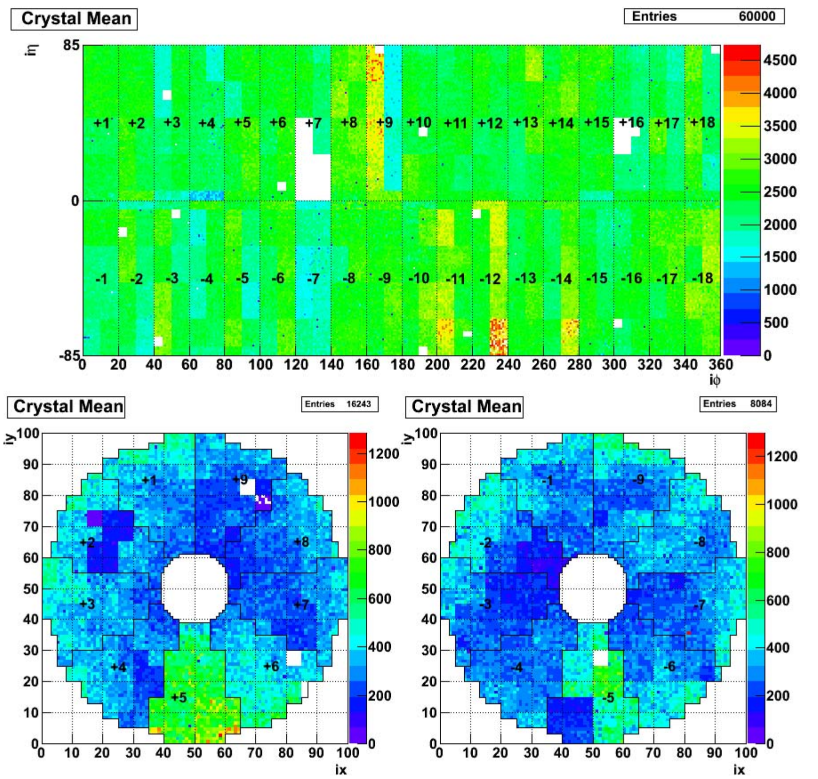

Figure 6. A typical Web-based monitoring system output. One can see the unfold of the ECAL Barrel (upper part) and two endcaps (lower part), each pixel represents a channel in ECAL the color map corresponds to the laser light response of the crystals.

Acknowledgments

Dataflow structure and optimization was designed and developed with direct contribution and help from Francesca Cavallari, Adolf Bornheim and Toyoko Orimoto.

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