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The ECAL online software in the commissioning of the CMS detector

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Abstract

The Electromagnetic Calorimeter (ECAL) of the Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is a crystal homogeneous calorimeter made of about 76000 Lead Tungstate crystals.

The detector was installed in the CMS experimental cavern in 2007 and 2008 and was commissioned with cosmic rays and with LHC beams in 2008.

The trigger and data acquisition system of the CMS ECAL comprises 35000 Front End ASICs and 170 Off Detector VME Boards. The operation of the system, performed by the ECAL online software, requires the configuration of $\mathrm{O}(10^7)$ parameters and the realtime monitoring of $\mathrm{O}(10^5)$ registers.

In this paper we discuss the design and architecture of the ECAL online software and its performances in cosmic ray runs and with the first LHC beams.

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1 Introduction

The Electromagnetic Calorimeter (ECAL) of the Compact Muon Solenoid (CMS)[1] detector at the CERN Large Hadron Collider (LHC) is a homogeneous crystal calorimeter made of about 76000 Lead Tungstate crystals. The detector is designed to provide excellent energy and position resolution for electrons and photons in the 1GeV-1TeV energy range. A diagram showing the calorimeter layout is shown in figure 1. ECAL is organised in an Barrel and and Endcap part and its mechanical design is modular. The Barrel detector is divided in 36 Supermodules, while each of the Endcaps comprises two Dees. The scintillation light produced by the electromagnetic showers inside the detector is read through two different kind of photo detectors: Avalanche Photo Diodes in the Barrel and Vacuum Photo Triodes in the Endcaps.

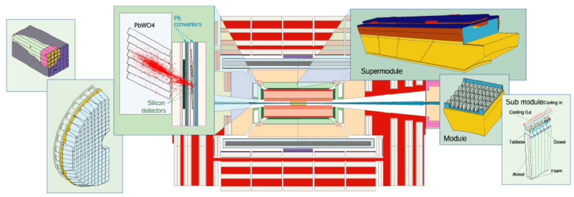

Figure 1: Overview of the CMS ECAL detector, showing the mechanical organisation of the system and its geometrical disposition.

2 Architecture of the system

The high granularity of the ECAL design implies an equally high number of readout channels. ECAL information is used both in the CMS Level 1 Trigger, which receives coarse informations on energy deposit (trigger primitives), and the High Level Trigger systems, which uses full granularity data. The readout system[2] is physically divided in two sections: the on-detector and the off-detector electronics. The first is responsible for the signal digitisation and the trigger primitives production. The second is responsible for the finalisation of the trigger primitive calculation and for the readout and reduction of the full granularity data. The off-detector electronics are organised in 54 Readout Units each comprising three type of VME boards: the Clock and Control System (CCS), the Trigger Concentrator Card (TCC) and the Data Concentrator Card (DCC). Data reduction is achieved using Selective Readout algorithm based on the classification of the detector in high and low interest regions performed by the Selective Readout Processor (SRP)[3].

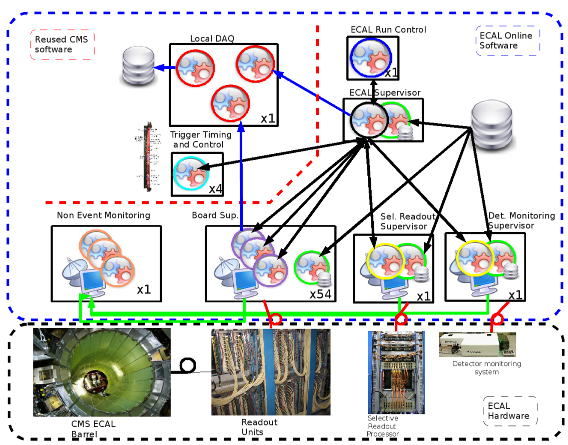

Figure 2: Overview of the CMS ECAL online software.

The The operation of the ECAL Trigger and Data Acquisition system requires the configuration of 10^7 registers and the monitoring of 10^5 registers and memories. The ECAL Online Software is the system responsible for the operation of the ECAL detector during data taking. The system, sketched in figure 2, is a web-based distributed one developed in the C++ and Java languages and built on top of the CMS data acquisition and run control frameworks, XDAQ[4] and RCMS[5]. The architecture of the system is modular in order to allow good scalability. The XDAQ framework is the layer upon which the implementation is based. It provides the basic services needed by the ECAL online software, such as inter-process communication, by means of SOAP-based communication channels[6], data transport, using the I2O [7] binary protocol, an hardware access library, a vendor-independent database access service and a distributed logging, monitoring and error-reporting infrastructure.

On top of this framework, a number of applications have been developed:

ECAL Run Control. This part of the system is implemented using the CMS run control framework, (RCMS). It is responsible for the lifetime management of all the other applications in the system and to receive commands from the shifters and from the CMS Run Control.

ECAL Supervisor. This application is responsible for the configuration of the Electromagnetic calorimeter. It receives commands from the ECAL run control and dispatches them to the applications responsible for the configuration of the different parts of the system.

Device Supervisors. For each of the components of the system, a dedicated application, called Device Supervisor has been implemented has been implemented. This applications receive the configuration parameters from the database, according to the directives coming through the ECAL supervisor, and are responsible for the configuration of the particular resource they are assigned to.

Middleware applications. In order to exploit the services provided by the XDAQ framework, dedicated modules, used by all the applications in the system have been realised. These modules are responsible for the hardware discovery (Crate Scanner), resource locking (Resource Locker) and to retrieve the parameters from the database (DB Manager).

Monitoring system. During data taking, all system components are constantly monitored in order to detect and diagnose possible problems arising during data taking. The monitoring system has been built using the monitoring capabilities of the XDAQ framework and is integrated with the rest of the system.

3 Role and performances in the commissioning of the CMS Electromagnetic Calorimeter

The data acquisition system of the Compact Muon Solenoid (CMS) Electromagnetic Calorimeter (ECAL) has been an essential tool for detector commissioning.

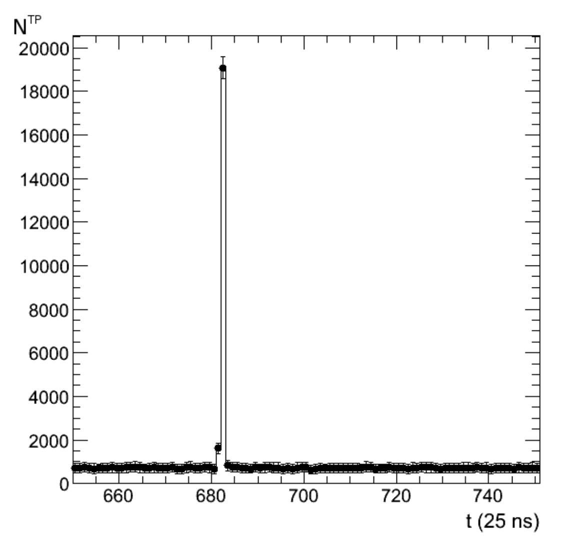

Figure 3: Timing of one the LHC beam splash event, as recorded by the monitoring system. The plot shows the number of trigger primitives with $\mathrm{E_t} > 2.25\mathrm{GeV}$, integrated over the full Barrel and a time window of several minutes, as a function of the LHC bunch crossing. The peak corresponding to the beam splash event can be clearly seen over a flat baseline due to cosmic ray events.

Since September 2008, the CMS detector has been closed and has been operated with the first LHC beams as well as with cosmic rays and a 3.8 T magnetic field. Very valuable data for detector commissioning have been acquired. Overall, more than $350\mathrm{M}$ cosmic ray events have been accumulated during 2008.

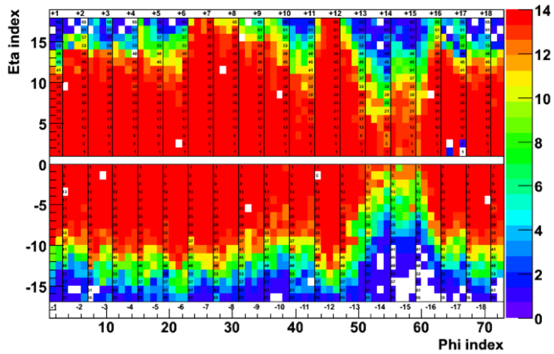

Figure 4: Energy deposit in the ECAL during on the LHC beam splash event, as recorded by the monitoring system. The plot shows the value of the trigger primitive, proportional to the deposited transverse energy, as a function of η and ϕ. In the Least Significative Bit is 750 MeV. Channel-to-channel intercalibration is not applied.

The development of the ECAL online software started with the Barrel electronics integration. The system constantly evolved to follow the detector construction and commissioning. All the on detector and off detector electronics have been tested and validated during the integration campaigns. After construction, a large fraction of the detector has been pre-calibrated with electron beams and all the Barrel using cosmic rays and. During the in-situ installation, detector functionalities have been carefully verified employing the DAQ system. Over time, the system has been optimised, made more robust and has always been operated with very good efficiency.

The configuration of the different system components proceeds as much as possible in parallel, allowing to configure the full calorimeters in a time of roughly $1\ \mathrm{min}$. This includes both the time needed to retrieve all parameters from the database and the one used to download them in the electronics. In stable data taking conditions, such operation is performed once per $8 - 12\ \mathrm{hours}$. The monitoring system has proven to be able to acquire and process the required information with a rate of the order of a few Hz and became in time an essential tool for commissioning, data taking and system debugging. During the first LHC run, the online monitoring was the first system detecting the signal of the energy deposition in the ECAL (see figures 3 and 4).

So far, the system has accumulated more than 1600 hours of operation in test-beams and more than 3000 in situ, proving to be stable and reliable.

4 Conclusions

We presented the design and architecture of the CMS ECAL online software and we discussed the role of the software in the commissioning of the detector. The system played an important role during the construction installation of the detector, allowing to test and verify all the system components in all phases. During CMS runs with cosmic rays and with first LHC beam the software proved to be very reliable and robust.

References

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