CMS Conference Report

The Data Quality Monitoring for the CMS Electromagnetic Calorimeter

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Abstract

The detector performance of the CMS electromagnetic calorimeter is monitored using applications based on the CMS Data Quality Monitoring (DQM) framework and running on the High-Level Trigger Farm as well as on local DAQ systems. The monitorable quantities are organized into hierarchical structures based on the physics content. The information produced is accessible by client applications according to their subscription requests. The client applications process the received quantities, according to pre-defined analyses, making the results immediately available, while also storing the results in a database, and in the form of static web pages, for subsequent studies. We describe here the functionalities of the CMS ECAL DQM applications and report about their use in real environments.

1 Introduction

The Compact Muon Solenoid (CMS) [1] electromagnetic calorimeter (ECAL) [2] is a hermetic, homogeneous calorimeter comprising 61200 lead tungstate ($PbWO_4$) crystals mounted in the central barrel part, closed by 7324 crystals in each of the two endcaps (see figure 1).
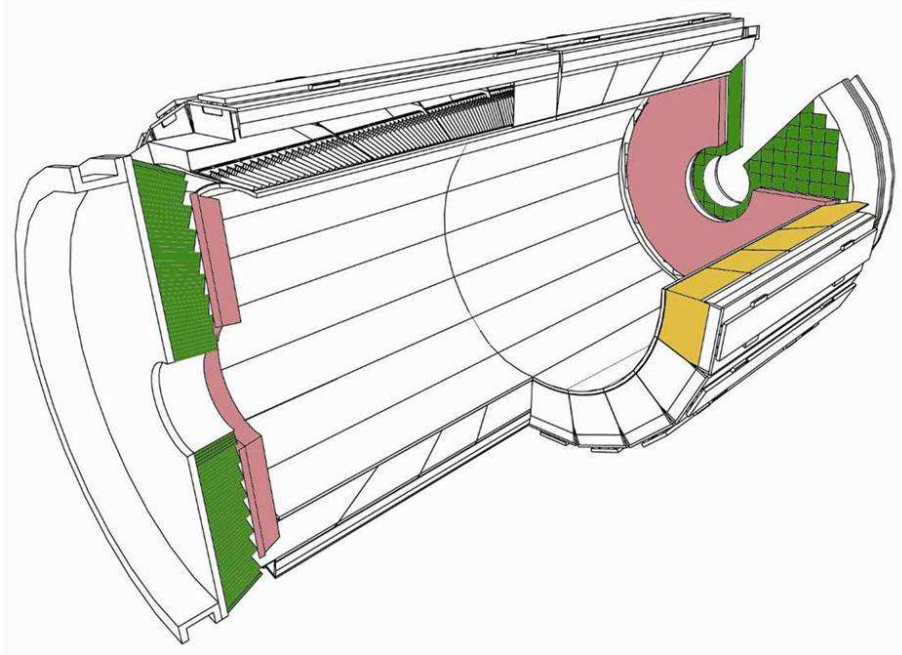

Figure 1: View of the CMS ECAL structure.

The use of $PbWO_4$ crystals has allowed the design of a compact calorimeter inside the solenoid that is fast, has fine granularity, and is radiation resistant. The barrel section (EB) has an inner radius of 129 cm, and is structured as 36 identical "supermodules", each covering half the barrel length and corresponding to a pseudorapidity interval of $0 < |\eta| < 1.479$. The crystals have a front face cross-section of $\approx 22 \times 22$ mm^2 and a length of 230 mm, corresponding to 25.8 X_0. The endcaps (EE) are located at a distance of 314 cm from the vertex and cover a pseudorapidity range of $1.479 < |\eta| < 3.0$. The endcap crystals have a front face cross section of 28.6×28.6 mm^2 and a length of 220 mm, corresponding to 24.7 X_0. A preshower detector is placed in front of the crystal calorimeter over much of the endcap pseudorapidity range. Its active elements are two planes of silicon strip detectors, with a pitch of 1.9 mm, which lie behind disks of lead absorber at depths of 2 X_0 and 3 X_0.

2 The Data Quality Monitoring

The purpose of the ECAL Data Quality Monitor (DQM) is to follow the time evolution of relevant quantities describing the running conditions of the detector and its performance. The aim is to spot possible problems or system instabilities, and promptly correct for them during the data-taking, and to monitor all the high-level quantities that are needed by the offline reconstruction. The data to be monitored consist not only of standard proton-proton collision events, but also of special ECAL-only triggers acquired during the normal physics data-taking by triggering either within the LHC machine orbit gap, or outside of normal physics data-taking periods. These special ECAL-only triggers can provide: laser events (a laser light pulse is shone into a group of ECAL channels), test pulse events (a known amount of charge is injected in the three amplifiers of each channel), and empty events (pedestal). The "monitorable quantities" can be classified and organized in different categories:

2.1 Raw data quantities

They show problems in the decoding of the raw data, data integrity, correct read-out order of towers and active channels, reasonable read-out values.

2.2 Single channel raw quantities

The number and location of dead, noisy and in general malfunctioning channels need to be monitored. This category includes checks on

- signal pulse phase: the time of signal pulse maximum ($t_{\max}$) needs to be monitored for both physics and laser events.

- pedestal events: the mean values and widths of the pedestals are monitored, to make sure that they fall within the expected ranges. Correlations between channels are computed and monitored.

- test pulse events: the amplitude of the response to a test pulse are verified to be within an expected range.

- laser events: the response of each channel to the injection of a laser light (normalized to the laser light detected by reference PN diodes) are monitored as a function of time.

2.3 Global raw quantities

The operation of selective readout needs to be monitored and validated. The monitoring of the zero suppression algorithms is possible using a map of active channels, averaged over several events.

2.4 Trigger related quantities

The quantities used for the trigger decisions (trigger primitives) are read out from the detector together with the actual data. A comparison needs be made between the primitive as produced during the trigger decision and the primitive as emulated from the raw data to spot and notify possible inconsistencies.

2.5 Reconstructed quantities

After reconstruction of the electromagnetic shower energy from the crystal with maximum energy deposit and the neighboring crystals (cluster), it is possible to identify problematic channels using maps of the average energy deposition. Several other useful higher level quantities need to be monitored in standard physics triggers:

- number of crystals above a given threshold per event

- number of clusters per supermodule

- number of crystals per energy cluster

- number of clusters per event

- raw/calibrated energy per trigger tower

- energy per event in (phi, eta) bins

- energy per event

- pedestal values (only pedestals in the lowest gain range are available in normal running conditions).

The histograms of the "monitorable quantities" are made available *online* through a common DQM histogram framework using the CMS Physics and Data Quality Monitoring package [3]. The histograms and the monitoring results are available also *offline* in the form of Web pages, and from the ECAL Conditions Database, where the monitoring results are saved at the end of each run. A prototype system has been commissioned and tested during the ECAL precalibration with cosmic muons (started in 2005), the test of two supermodules in the CMS magnet during August 2006, and the test beam data taking in 2006. It included a *producer* and a *consumer* application, allowing to visualize the histograms, to save them to ordinary ROOT files, and to store the relevant information to the conditions database. The monitoring was performed following two different and complementary approaches. In the so-called *on-line mode*, the ECAL Cross-Platform Data Acquisition Framework (XDAQ) [4] provided the data stream to be analyzed by the DQM, while in the *off-line mode* the data were read-out from files stored on disk. The former allowed for prompt expert actions in case of problems, while the latter permitted more time-consuming operations, like Web pages preparation and database access, and allowed for later consultation.

2.6 The ECAL DQM Producer

The DQM *producer* application has been realized as a collection of independent plug-in modules belonging to the CMS software framework CMSSW [3], each module implementing a specific algorithm or analysis task. The CMSSW executable is configured at run-time by the user's job-specific configuration file. This file contains which data to use, which modules to run, which parameter settings to use for each module, and in what order to run the modules. Required modules are dynamically loaded at the beginning of the job. This approach allowed use of the same data unpacking and reconstruction modules used offline for the physics analysis. The ECAL DQM specific modules are responsible for defining the histograms of the "monitorable quantities", and for filling them using the information extracted from the event data flow. The histograms are organized in folders, corresponding to the analysis/parent module for easy navigation.

Figure 2: The CMS ECAL Conditions Database Web interface, showing a list of "test beam" runs.

2.7 The ECAL DQM Consumer

The DQM *consumer* application has been implemented as a CMSSW module, using a set of *sub-consumers* closely matching the structure of the *producers* modules. This application is responsible for analyzing the histograms, spotting possible problems, and record the results of the analysis in the ECAL Conditions Database, storing them also as Web pages for future reference.

3 The ECAL DQM Web Pages

The DQM Web servers allow to access the DQM information for all the runs taken with the ECAL detector through a single interface, connected with the ECAL Conditions Database (see figure 2). The ECAL DQM "pedestals" (figure 3), "test pulse" (figure 4), and "test beam" (figure 5) Web pages are shown, as real-life examples. Monte Carlo samples were used to develop the ECAL DQM "cluster" (figure 6, 7) and "summary" (figure 8, 9), for the ECAL barrel and the endcaps, respectively.

4 The ECAL DQM Graphical User Interface

The ECAL DQM has been used together with the CMS visualization package (IGUANA-CMS) [5], to access the histograms in *online mode*, while they were being filled by the DQM *producer* and analyzed by the DQM
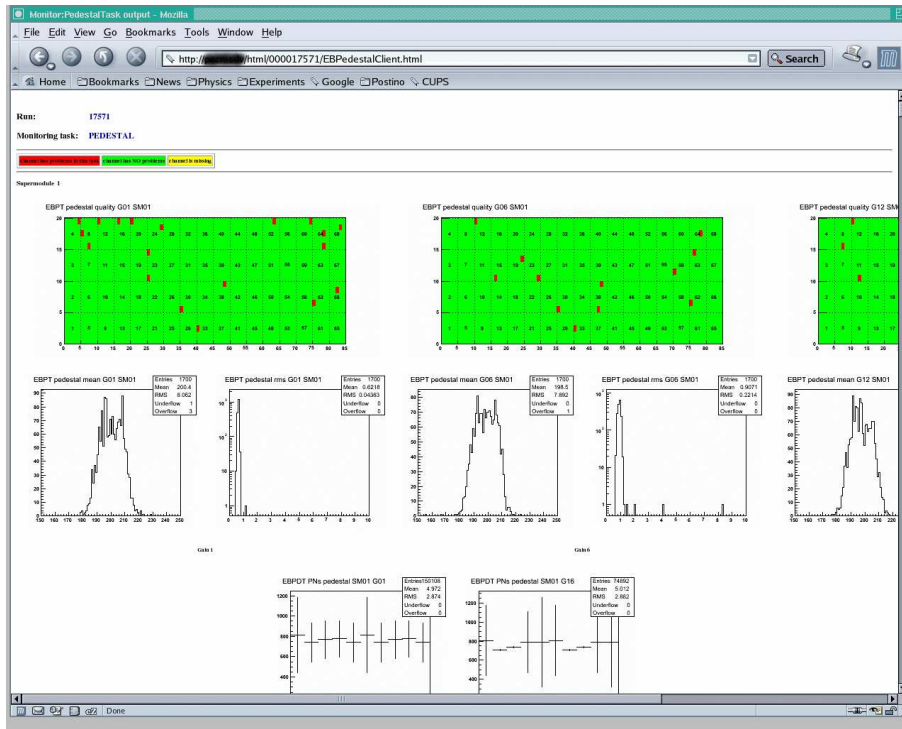
Figure 3: The ECAL DQM "pedestals" Web page, showing in the first row the results of the *consumer* analysis in the form of good and problematic channels, and in the second row the pedestals' mean and RMS distributions, for different amplifier gains.
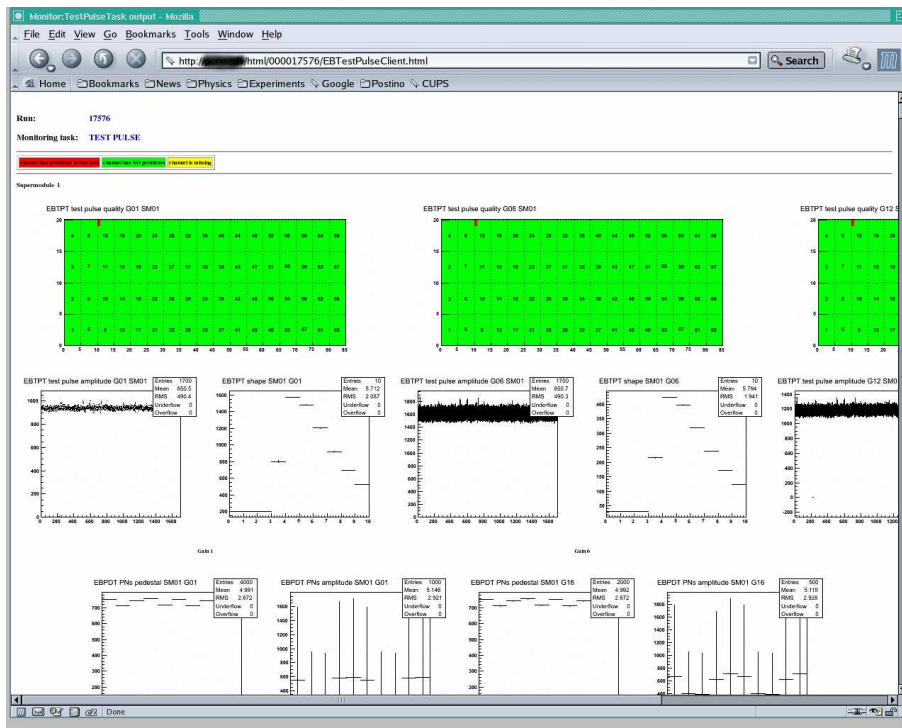

Figure 4: The ECAL DQM "test pulse" Web page, showing in the first row the results of the *consumer* analysis in the form of good and problematic channels, and in the second row the testpulse mean amplitude vs. channel number and mean shape, for different amplifier gains.
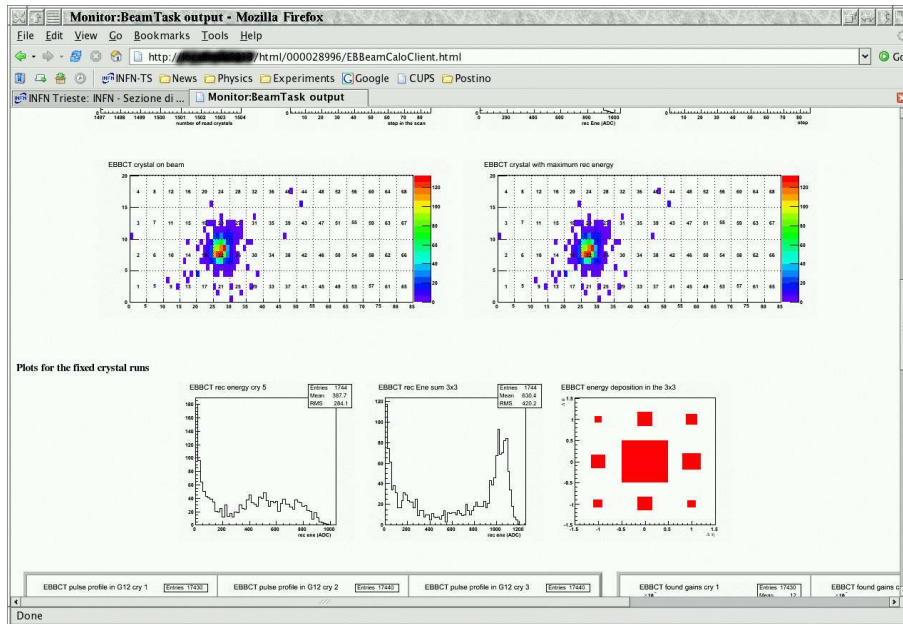
Figure 5: The ECAL DQM "test beam" Web page, showing in the first row the mean energy deposited in the different channels, and in the second row the maximum energy deposit distribution, and the distribution of the sum of the energy deposits in a 3 by 3 crystal matrix.

consumer, together with the results of the analysis performed by the latter. An example of this interface is shown in figure 10. The information available *online* is similar to the one saved in the Web pages.

5 Summary

The ECAL Data Quality Monitor, developed within the CMS DQM framework, proved to be well suited to cope with the requirements of the detector, under real-life stress-test conditions, during several test-beam periods and pre-calibration activities. Its development will continue with the implementation of the higher level, more detailed detector studies.

References

[1] The CMS Collaboration, The Compact Muon Solenoid Technical Proposal, *CERN/LHCC* 1994/38

[2] The CMS Collaboration, The Electromagnetic Calorimeter Technical Design Report, *CERN/LHCC* 1997-33

[3] The CMS Collaboration, CMS Physics Technical Design Report, Volume 1: Detector Performance and Software, *CERN-LHCC* 2006-001

[4] The CMS Collaboration, Trigger and Data Acquisition Project, Volume 1 & 2, *CERN-LHCC* 2000-38 and *CERN-LHCC* 2002-26.

[5] Alverson G, et al., IGUANA: a high-performance 2D and 3D visualisation system, *Nucl. Instrum. Meth. A* **534** 143 (2004).
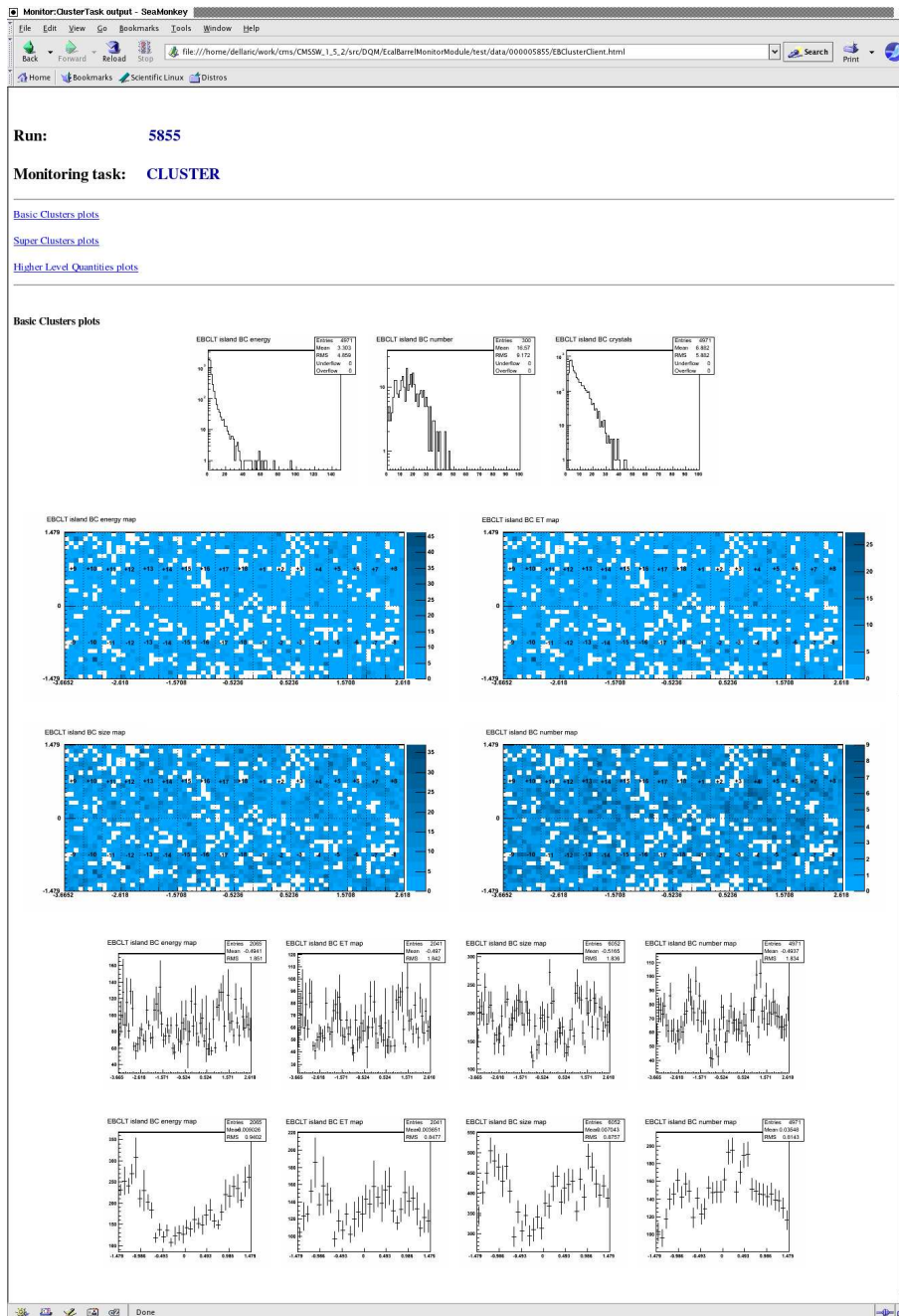
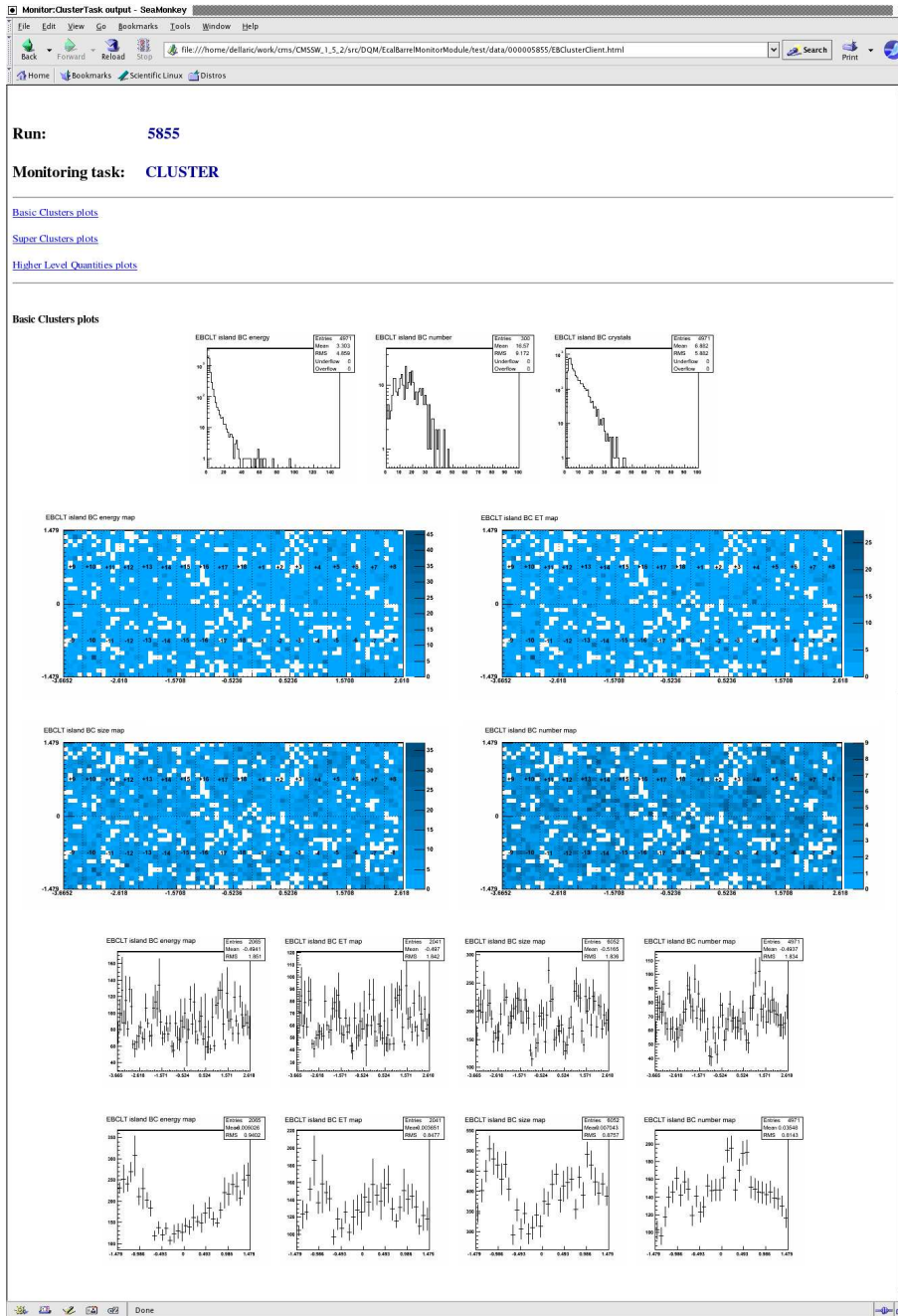Figure 6: The ECAL DQM "barrel cluster" Web page, showing the results of the clusters analysis.

Figure 7: The ECAL DQM "endcap cluster" Web page, showing the results of the clusters analysis.
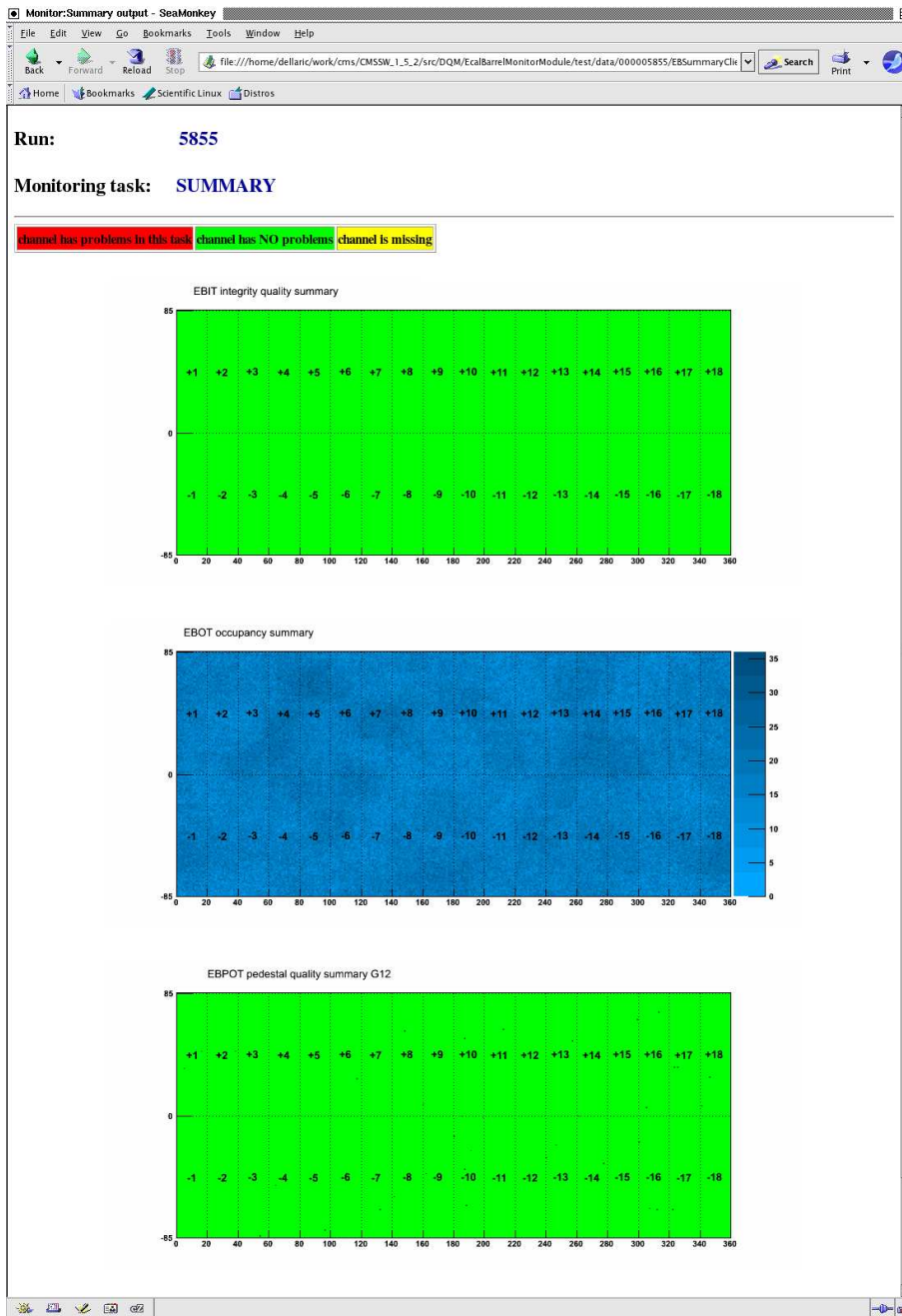
Figure 8: The ECAL DQM "barrel summary" Web page, showing in the first row the results of the data-integrity analysis in the form of good and problematic channels, in the second row the number of hits per channel, and in the third row the results of the pedestals analysis.
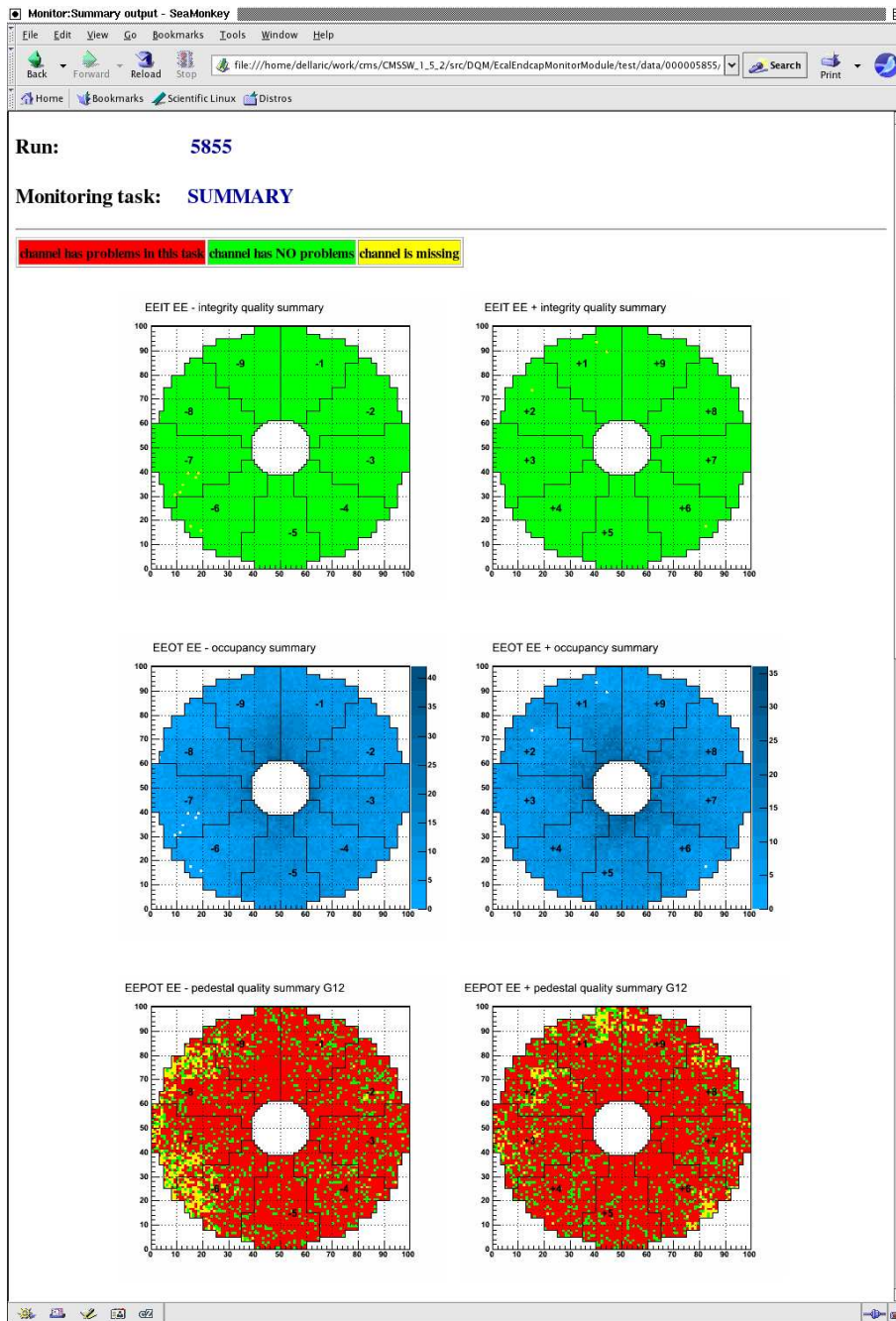
Figure 9: The ECAL DQM "endcap summary" Web page, showing in the first row the results of the data-integrity analysis in the form of good and problematic channels, in the second row the number of hits per channel, and in the third row the results of the pedestals analysis.
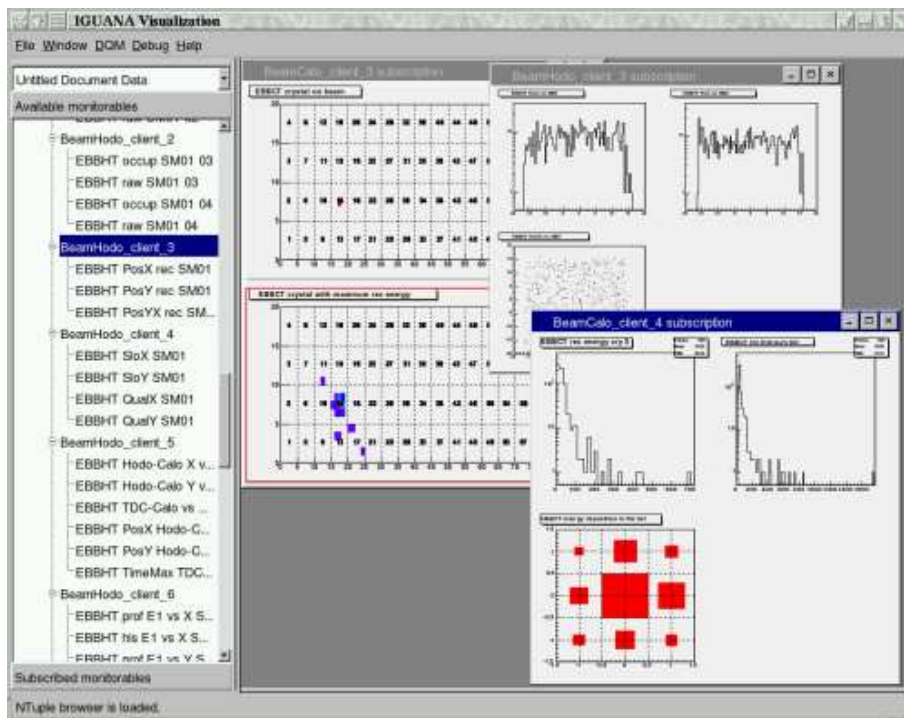
Figure 10: The ECAL DQM IGUANA "test beam" Graphical User Interface, showing a set of typical histograms.