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Conference Report

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The Data Quality Monitoring for the CMS Silicon Strip Tracker

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Abstract

The CMS Silicon Strip Tracker (SST), consisting of more than 10 million channels, is organized in about 15,000 detector modules and it is the largest silicon strip tracker ever built for high energy physics experiments. The Data Quality Monitoring system for the Tracker has been developed within the CMS Software framework. More than 100,000 monitorable quantities need to be managed by the DQM system that organizes them in a hierarchical structure reflecting the detector arrangement in subcomponents and the various levels of data processing. Monitorable quantities computed at the level of individual detectors are processed to extract automatic quality checks and summary results that can be visualized with specialized graphical user interfaces. In view of the great complexity of the CMS Tracker detector the standard visualization tools based on histograms have been complemented with 2 and 3 dimensional graphical images of the subdetector that can show the whole detector down to single channel resolution. The functionalities of the CMS Silicon Strip Tracker DQM system and the experience acquired during the SST commissioning will be described.

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1 Introduction

The Compact Muon Solenoid (CMS) is one of the general purpose detectors which will be operated at the Large Hadron Collider at CERN, Geneva. It is composed of different sub-detector components, with a tracking system in its internal part consisting of a Silicon Pixel detector, surrounded by a Silicon Strip Tracker (SST). The SST is close to the interaction point, so it will be irradiated with a high density of particles. For this reason it is highly granular and it has a large number of readout channels ($\sim$10 million). It is the largest silicon detector ever used in particle physics, consisting of an area of almost 200 m^2 of Silicon sensors, organized in more than 15,000 modules grouped in 4 subsystems [1] (Tracker Inner Barrel - TIB, Tracker Outer Barrel - TOB, Tracker Inner Disk - TID and Tracker End Caps - TEC), as shown in Fig.1.

The SST is a very complex object and needs to be constantly monitored during the data taking. The SST Data Quality Monitoring (DQM) system has been developed to fulfill this requirement. It has to ensure that all the sub-detector components and the data acquisition work properly during the data taking, so that the recorded data are optimally useful for later physics analysis.

The main requirement for a data monitoring tool is to be very effective in spotting problems at the earliest possible stage of data acquisition in order to allow the relevant expert to take immediate action.

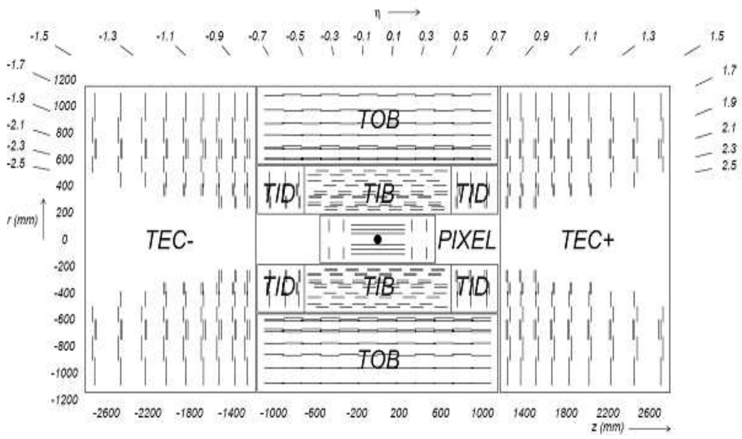

Figure 1: The CMS Silicon Strip Tracker Layout.

2 The Data Quality Monitoring deployment

The Tracker DQM is a versatile tool that can run in different environments. It runs during on line data taking as well as off line, together with the prompt reconstruction of the collected events. In on line environment the DQM system receives samples of events from the Data Acquisition system [2] [3] and runs on real time. Its main task is to detect severe detector problems which need a prompt action. After few hours of data taking, during off line reconstruction at the Tier0, the DQM application runs on the whole statistics of data. Despite of the slight time delay, the advantage here is that the best calibration parameters are available and the events are fully reconstructed. In this phase, the DQM is more focused on spotting problems in the reconstruction algorithms.

The output from both online and offline DQM applications are archived for future reference.

3 The DQM Framework

The DQM framework is designed to provide all necessary tools for the creation, filling, transport and visualization of the data quality information in the form of histograms. To fulfill this requirement, a “Producer/Consumer“ architecture has been chosen. The “Producer“ modules access the information from the events, book and fill the histograms, organizing them in a tree structure. They define the quantities to be monitored. The histograms are then accessed periodically by the “Consumer“ modules which performs some further analysis.

A custom web-based Graphical User Interface (GUI) is used for visualization.

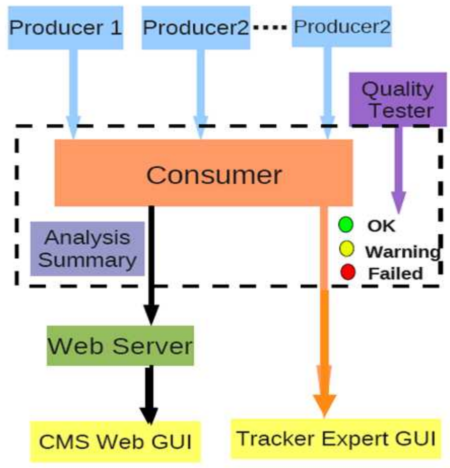

Figure 2: Tracker DQM framework: producer/consumer architecture.

3.1 DQM Producer

The Producers are responsible for defining and filling the monitoring elements of the DQM system, which are the histograms. They are pluggable modules into the CMS Software (CMSSW). The modules are classified depending on the type of the event information to deal with at various levels of reconstruction.

In the Silicon Strip Tracker the monitoring is done at the following levels:

- Raw Data: the basic event information with different error codes
- Digitization: charge amplitude and number of digis monitoring, hottest and coolest strips identification
- Clusters: cluster properties (i.e. charge, position, width, noise, etc.) monitoring
- Tracks: reconstructed track parameters (i.e. momentum, angles, χ^2, number of hits, etc.)
- Clusters to track association: properties of the clusters associated to reconstructed tracks ("on-track" clusters) and those not associated to any track ("off-track" clusters)

Histograms can be defined for the whole tracker structure or for individual sub-detectors depending on the quantity to monitor. Due to the very large number of silicon strip modules in the tracker, it is necessary to arrange the histograms in such a way that allows easy access. For this purpose, the geometrical structure of the SST is followed to create a tree like folder structure, as shown in Figure 3. The histograms are then placed accordingly into the tree. For example, the histograms related to the reconstructed track properties are placed in the top level of the structure, whereas the ones for the cluster properties will be placed accordingly to the individual detector folders.

3.2 DQM Consumer

The DQM Consumer accesses the histograms already created and filled by the Producers and performs further analysis on them:

- creation of summary histograms
- performing Quality Tests, producing alarms and spotting problems
- saving all histograms in the output root files
- data certification

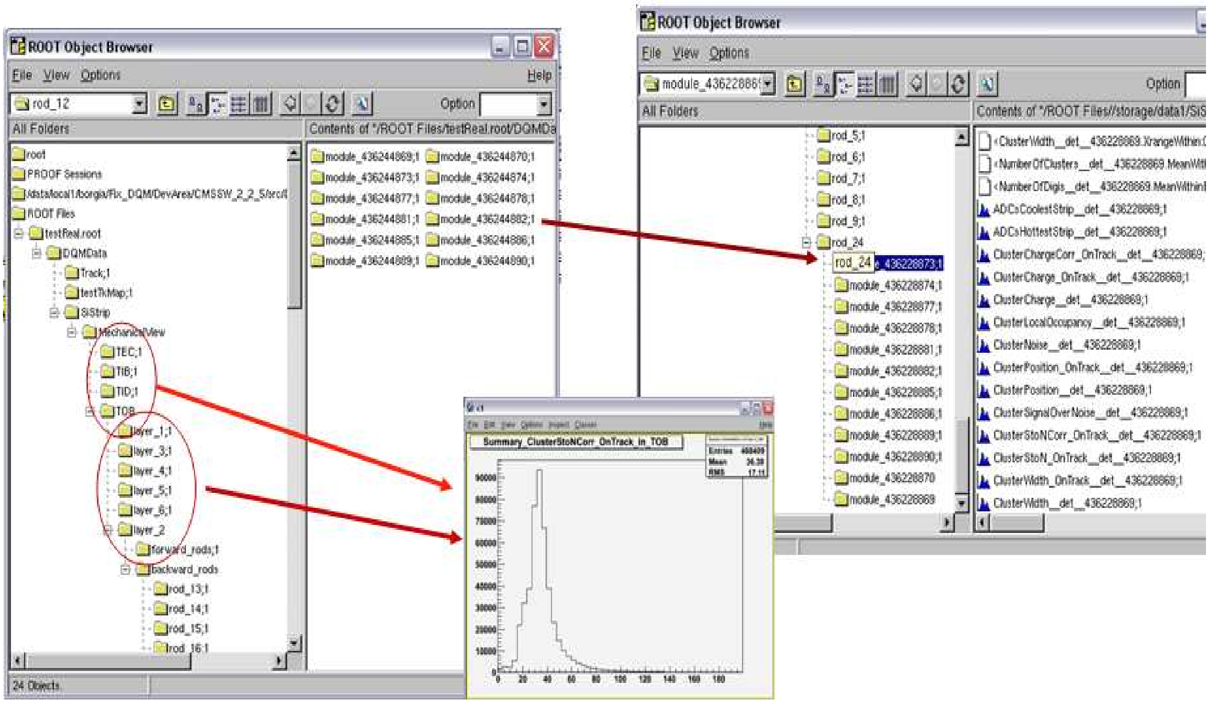

Figure 3: An example of the structure of a DQM output file.

Creation of summary information is particularly important in a complex system like the SST DQM, which comprises almost 300 K histograms which are impossible to inspect individually.

Summaries are created by the Consumer combining information from individual detector level histograms. For example, the mean values of a given histogram type in the lowest level of the tree structure are accessed to fill new histograms at the geometrically higher levels. The user can check the histograms at the top level of the tree structure, and then if there are anomalies navigate down the tree structure to locate individual modules responsible for the deviation from the ideal behavior.

Automatic statistical tests are performed to check the quality of histograms. These automatic tests (named Quality Tests - QT) are essential to check this large amount of histograms quickly, and they are widely used in all DQM systems in CMS. Different kind of tests can be applied, from the very simple statistical ones (i.e. check if the mean or the r.m.s. of a certain quantity is in the expected range), to sophisticated ones (i.e. the comparison with a reference histogram). A label with the result of the test (“OK“, “Warning“ or “Error“) is generated at the end of the check and is attached to the histogram and also reported in the visualization tool described below. The alarm level can be adjusted depending on the need. This can be done via an xml file, which makes the configuration procedure very user friendly.

3.3 The Graphical User Interface

The Graphical User Interface is a visualization tool used to rapidly navigate and check the histograms defined by the Producers and the Consumer. It is web-based, which permits users all over the world to access the data and to check the results. Thanks to the web technology, users don’t need to install experiment specific software. Moreover, shifters can check the histograms quickly because they are grouped consistently by the experts in a specific layout. This avoids the navigation through folders to check the histograms, because they are already arranged in a coherent way.

A snapshot of the first page of the CMS Tracker Web GUI is shown in Figure 4. The top level page contains a simple 2D histogram which represents the overall status of the detector modules from the Quality Test results and they are plotted all together to give a global overview. The X axis represents the SST sub-detectors and the Y axis contains the layers/discs in which the sub-detectors are organized. The color code used represents the fraction of sub-detectors with a positive QT result.

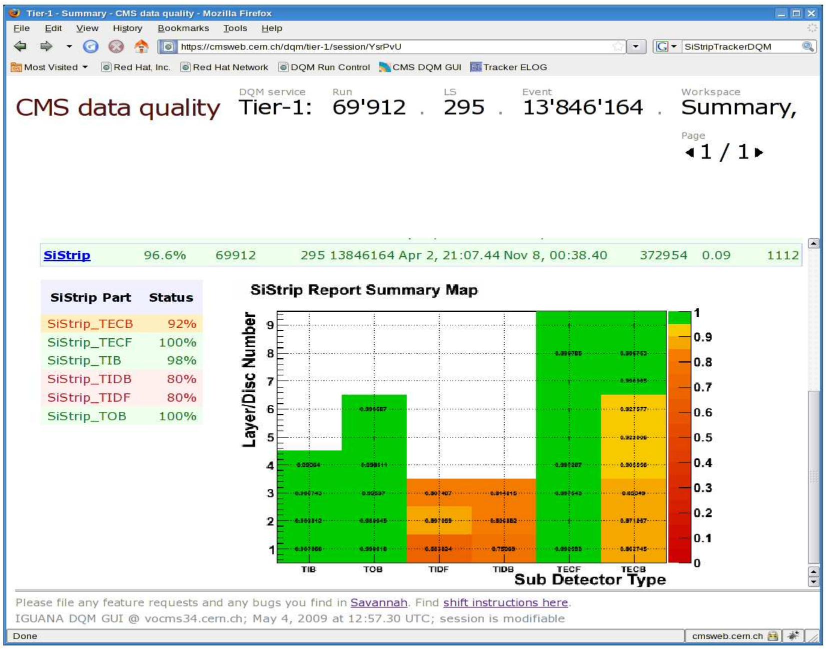

Figure 4: The Graphical User Interface web page, representing the summary of the SST status.

In detail, the color is:

- green for a fraction between 95% and 100%
- yellow for a fraction between 85% and 95%
- red for a fraction minor than 85%

In addition to the CMS general GUI, the Strip Tracker DQM has implemented a specific expert Web GUI, which can be looked at by the tracker experts in case of particular problems.

4 Data Certification

The final aim of the data quality monitoring is to provide a set of certification flags to define the quality of the data. This is done via the Data Certification procedure, which starts on line and continues off line, and is composed of two steps: an automatic procedure and a manual one. The automatic one is based on the Quality Test results, already introduced. The manual one consists in the work done by the shifters: the histograms are checked manually. The combination of the two steps gives the final certification flags and it is also cross checked by the tracker experts.

At the end of the procedure, the results are stored in a database and the run is declared good or bad for further physical analysis.

5 Long term monitoring

This tool is intended to study the stability of the detector in medium/long period, on a run by run basis. A few important histograms are selected for the long term monitoring, for which the main statistical quantities are stored in a database run by run. Then these values can be easily and flexibly plotted later, and one can easily trace back what happened in a certain period. For example in Figure 5 it is possible to see how stable was, on a month-scale period (the data taking last autumn) the number of clusters associated to a track. Different colors correspond to different CMS tracker subsystems.

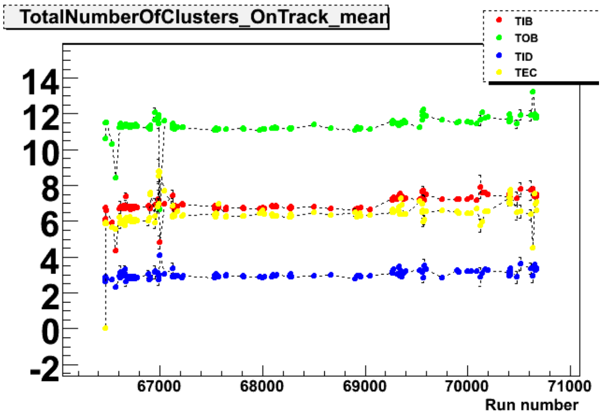

Figure 5: An example of long term monitoring: a trend plot of the total number of clusters associated to a track, during a period of three months.

6 Conclusions

The SST DQM tool has been extensively used during CMS cosmic data taking in 2008. It has been able to run stably throughout the entire data taking period, even for very long runs that lasted more than 12 hours.

A total amount of 350 million events have been processed and used both for monitoring performance and for data certification.

During this long data taking the DQM has shown its "userfriendness", even for non expert people, and its efficiency in summarizing information from such a large amount of detectors (~15,000).

It has also shown to be fast to spot problems, and it has proved to be a fundamental tool to monitor the detector and the reconstruction quality both in the on line and off line operation, proving its functionality and reliability in the data taking.

References

[1] **JINST 0803:S08004,2008, The CMS Collaboration (R. Adolphi et al.).** ***"The CMS experiment at the CERN LHC"***

[2] **CERN/LHCC 2000-38, CMS TDR 6.1, 15 December 2000, CMS Collaboration,** ***"The Trigger and Data Acquisition Project, Volume I The Trigger System Technical Design Report"***

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[4] Physics and Data Quality Monitoring at CMS C. Lionidopulus Proceeding of CHEP06, 2006