Data Quality Monitoring for the CMS Silicon Tracker

S. Dutta[*], SNS and INFN Pisa, Italy
V. Chiochia, University of Zurich, Switzerland, *M. S. Mennea, G. Zito*, INFN Bari, Italy

Abstract

The CMS silicon tracker, consisting of about 17,000 detector modules and divided into micro-strip and pixel sensors, will be the largest silicon tracker ever realized for high energy physics experiments. The detector performance will be monitored using applications based on the CMS Data Quality Monitoring (DQM) framework and running on the High-Level Trigger Farm as well as local DAQ systems. The monitorable quantities of this large number of modules are divided into hierarchical structures reflecting the detector sections. In addition, they are organized into structures corresponding to the levels of data processing. The information produced are delivered to client applications according to their subscription requests. The client applications summarize and visualize the quantities received. We describe here the functionalities of the CMS tracker DQM applications and report preliminary performance tests.

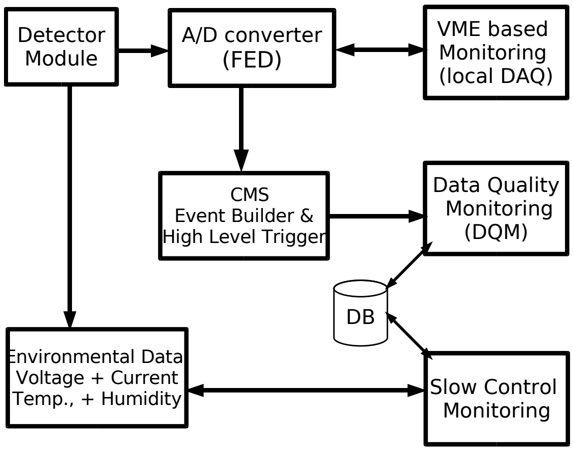

Figure 1: Monitoring Systems for the CMS Silicon tracking detectors

INTRODUCTION

The tracking system of the CMS experiment at the Large Hadron Collider (LHC) at CERN will be made of silicon detectors [1]. The innermost part will have pixel sensors and the rest of the system will be equipped with microstrip sensors. They are arranged in cylinders and discs in the barrel and forward-backward regions, respectively. There are about 1750 pixel and 15140 strip sensors which all together correspond to $\sim$ 75 million readout channels. Such a huge silicon tracking system has never been envisaged in any high energy physics experiment. The challenge for the monitoring system of the CMS tracker is to ensure that the system runs smoothly and good quality data are recorded. It should also ensure that any possible problem is identified efficiently at a very early stage of the data acquisition chain so that actions can be taken promptly.

Monitoring of the tracker is performed at various stages using different sources of information. In figure 1 the different parts of the detector monitoring are represented in a block diagram.

- At the VME level in the local Data Acquisition (DAQ) system the detector performance is monitored following synchronisation errors, buffer occupancy, digital levels etc.
- The environmental information of the tracker consisting of the bias voltage, leakage current, temperature and humidity of the detector modules together with the general state of the power supplies and the cooling system will constitute a large volume of data not correlated with event data. Part of this information will be utilized in the Detector Control System (DCS)[3] logic and will be monitored to ensure reliable running of the tracker. This is referred to as the Slow Control Monitoring.
- Monitoring based on event data accessed from the Filter Farms of the CMS Trigger and Data Acquisition System (TriDAS)[2] is known as Data Quality Monitoring (DQM).

We are going to describe the DQM system of the tracker in the following sections.

THE DATA QUALITY MONITORING

The DQM system of tracker is based on the "Physics and Data Quality Monitoring" framework [4] of CMS. The task is fulfilled in three steps: (a) The Monitoring Elements (ME) are defined, filled with relevant event information by the "Producer" application; (b) A "Consumer" application accesses the MEs, performs further analysis and generates alarms; (c) The "User Interface" provides tools for visualisation of the monitoring elements.

Depending on the type of data accessible by the producer, the monitoring application can be classified in several categories.

- Online : the producer applications can directly run on the Filter Unit (FU) nodes of the Filter Sub Farm of

[*] Corresponding Author, email: suchandra.dutta@cern.ch

the CMS Trigger & Data Acquisition system [2]. The monitoring elements are created and filled there and sent to the consumers. This has the shortest delay. However, it introduces some overhead on FU.

- Event Consumer : selected events can be shipped from the Storage Manager to the processors dedicated to monitoring application.
- Quasi Online : events can be accessed from the Hot Buffers of the disk server by the monitoring application.
- Offline : the monitoring application reads events from the stored files.

Tracker Monitoring Elements

The Monitoring Elements containing event information can be histograms, integers, floats or strings. These elements can be classified into different classes corresponding to the levels of data processing and reconstruction of the tracker sub detectors.

- Commissioning : before data taking the detectors need to be synchronized and the channel gain, amplitude etc must be adjusted [5]. All these variables will be monitored accordingly.
- Digitized or Raw Hits : the raw charge collected in the detectors, its position and distribution will be monitored at this level. The frequency as well as the average charge per detector will give an indication of dead or noisy channels.
- Reconstructed Hits : charge collected in neighboring pixels or strips above threshold are merged into clusters by the reconstruction software and the hit position is calculated. The distributions of the cluster position, cluster size and cluster charge will be monitored for individual detectors. Since the charge released in silicon varies with the track length, i.e. the incident angle of the particle, the charge collected for single strip clusters, where almost normal incidence is ensured, will be considered. However, this quantity, as well as the cluster size, is best studied by considering only the clusters attached to tracks, where the track inclination is precisely known.
- Reconstructed Tracks : a number of quantities will be monitored once tracks are reconstructed. The number of hits per reconstructed track, χ^2 of the fit, impact parameter etc. are the ones which will ensure the overall quality of tracks. Events with high momentum isolated tracks are preferable here to ensure reconstruction quality. The cluster width as a function of track incidence angle, and the mean and r.m.s of hit residuals will be used to monitor individual detector performance.

  A few specific items, namely the pixel track seeds (pairs or triplets), pixel tracks, primary vertices from pixel tracks and impact parameter of the pixel tracks with respect to the primary vertex will be monitored exclusively in the pixel system.
- Radiation Damage Parameters : the silicon sensor response is expected to change during the detector operation due to irradiation. A number of quantities – like Lorentz deflection, signal trapping, and inter-channel couplings – will be monitored to guarantee a precise determination of the hit positions.

Tracker DQM Producer

The MEs, corresponding to the tasks described above, are defined and filled by independent producers. A producer for a given task can be initialized independently and can be plugged in or out at run-time using configuration files.

Due to the large number of detector modules in the tracker, the monitoring elements need to be arranged in hierarchical folders for easy navigation. The structure may reflect different views depending on the task. For MEs related to reconstruction tasks a geometrical view is more relevant where folders for individual detectors are arranged according to the mechanical structure of the tracker. On the other hand, for the commissioning task it is better to have the readout or control view where folders are arranged according to the connections to Front End Drivers (FED) or Front End Controllers (FEC) respectively.

Tracker DQM Consumer

Given the large number of MEs in the tracker it is not possible to scan each of them individually to check the detector performance. The consumer must perform further analysis on them once the MEs are subscribed and accessed from the producer. A few representative tasks are described below.

A given producer application might run on a number of FU nodes creating the same MEs filled with information from different events. In such a case the consumer collates them to produce the complete information from a set of events.

Monitoring elements are compared with the reference ones in the consumer where the later accesses them from the Database (DB). The comparison tool is provided by the CMS DQM framework and a number of different tests are possible : purely statistical in nature, identical content, contents within a given range etc. The statistical test includes χ^2 and Kolmogorov tests and is applicable to 1-D histograms. After comparison a set of alarms (Ok, Warning, Failed etc.) is generated. In cases of warnings the consumer application needs to access the Environmental Data, stored in the DB by the slow control monitoring application, to look for possible correlations.

The Consumer is supposed to create summary information scanning MEs from a number of detector modules, grouped according to mechanical structure or electrical connection. In Figure 2 the average hit multiplicity from all the detector modules of the inner barrel forward disc #1 is shown as a function of the detector number in the disc.

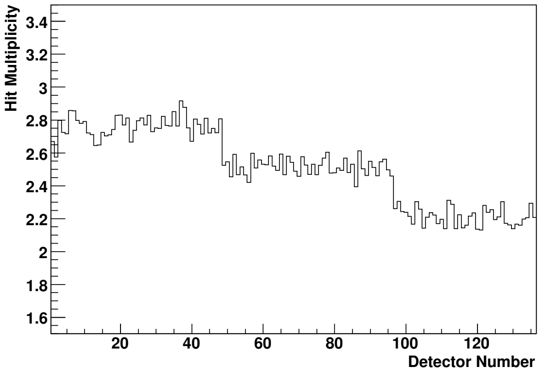

Figure 2: Average hit multiplicity as a function of the detector number in the first disc of the inner strip tracker

USER INTERFACE

The MEs, summary information, generated alarms are accessed from the consumer application and visualised by the Graphical User Interface (GUI). Two general purpose GUIs are available in the CMS DQM package. One of them is based on the Cross-Platform DAQ Framework (XDAQ) [3] and visualises MEs through web browsers. The customization of the web interface for a specific application can be achieved using the set of widgets provided by the framework. The other GUI is based on the CMS visualisation package, IGUANA-CMS and uses Qt-Root for the graphics. It is possible to perform a number of interactive plotting actions on the MEs.

A simple and very useful tracker specific GUI, called the "Tracker Map" has been developed [7]. The tool allows to visualize the whole tracker in a single two-dimensional image. In figure 3 such an image is presented showing all modules arranged in their mechanical structures, flattened layers for the barrel layers and disks for the end-caps. Monitoring information of each detector module can be attached to the image. The Tracker Map can be used interactively with zooming functionality and the MEs corresponding to the selected module can be visualised. The alarm generated or the average value of a given ME can be color coded in the image allowing the users to have an overall view of all the detectors at once. The hot spots or dead zones can easily be located and the corresponding detector can be identified.

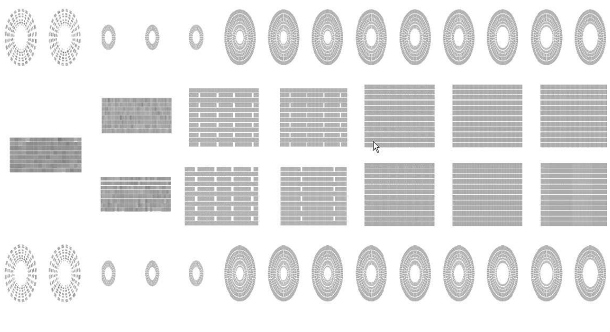

Figure 3: Example of the Tracker Map image representing the barrel layers and the endcap discs in a 2-D view

SUMMARY

The size and complexity of the CMS tracker makes the Data Quality Monitoring system very challenging. The system that will fulfill the task is being developed within the CMS-DQM framework. The basic functionalities of the producer and consumer applications have been implemented. The producer applications corresponding to different monitoring tasks are currently under development. More sophisticated analysis will be included in the consumer applications to ease navigation of MEs, find detector problems etc.

In 2006, two important milestones are foreseen for the CMS Tracker project. The first is the Magnet Test and Cosmic Challenge (MTCC) where CMS has planned a slice test using Cosmic Rays [6] where about 1 % of the strip tracker is expected to be operational in the 4 T magnetic field. The second milestone is a 25% read-out test of the tracker. The above two milestones will provide the opportunity to evaluate and eventually improve the DQM performance.

REFERENCES

[1] The Tracker Project Technical Design Report
CERN/LHCC 1998-6, CMS TDR 5, Addendum CERN/LHCC 2000-016

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

[3] The Trigger and Data Acquisition Project, Volume II
Data Acquisition and High Level Trigger
Technical Design Report
CERN/LHCC/2002-26, CMS TDR 6.2, 15 December 2002

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

[5] Commissioning Procedures and Software for the CMS Silicon Strip Tracker
R. Bainbridge
Proceeding of CHEP06, 2006

[6] Software for the CMS Cosmic Challenge
G. Bruno
Proceeding of CHEP06, 2006

[7] Use of Interactive SVG Maps and Web Services to Monitor CMS Tracker
M. S. Mennea, G. Zito
Proceedings of IEEE-NPSS Real Time Conference, 2005 June 4-10, Stockholm