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CMS Remote Monitoring at Fermilab

Alan L. Stone on behalf of the CMS FNAL ROC Group

***Abstract*—The recent activities for remote monitoring operations at Fermilab are described. The Compact Muon Solenoid (CMS) experiment is in the commissioning stages of the data acquisition, trigger, sub-detector and data transfer systems, and it is vital that a coherent and effective monitoring system be developed for the experts as well as local and remote shift crews. The experiences and contributions of the Fermilab participation in the first CMS global data taking with vertical slices of several sub-detectors using cosmic rays during the Magnet Test and Cosmic Challenge are presented. The involvement from Fermilab in the Hadronic Calorimeter Test Beam and the Tracker Slice Test operations and monitoring are detailed. Also discussed are some general monitoring tools being developed at Fermilab such as Web-Based Monitoring and the Screen Snapshot Service.**

***Index Terms*—CMS, Remote Operations, Web-Based Monitoring, Tracker, Trigger, Event Display.**

I. Introduction

The Remote Operations Center (ROC) [1] at the Fermi National Accelerator Laboratory (FNAL), aka Fermilab, was built on the 11th floor of Wilson Hall during 2005. The FNAL ROC room is equipped with a dozen Linux PCs with multiple LCD displays, a gigabit network connection, a 3 TB file server, a web server, high quality videoconferencing capability and a web camera. The main focus of the FNAL ROC group is independent of location; the development and commissioning of remote monitoring tools is portable and has practical uses at both Fermilab and CERN [2] CMS [3] sites. The CMS colleagues based at both Fermilab and CERN have been working closely in the areas of data acquisition, triggers, data monitoring, data transfer, software analysis and database access, in order to commission the sub-detectors with the common goal of efficient and high-quality data taking for physics.

II. Web-Based Monitoring

The online Web-Based Monitoring (WBM) system [4] of the CMS experiment consists of a web services framework based on Jakarta/Tomcat [5] [6] and the ROOT [7] data display package. Due to security concerns, many monitoring applications of the CMS experiment cannot be run outside of the experimental site. As such, in order to allow remote users access to CMS experimental status information, a set of Tomcat/Java [8] servlets running in conjunction with ROOT applications have been implemented to present current and historical status information to the remote user on their web browser. The WBM services act as a portal to activity at the experimental site. In addition to HTML, Javascripts are used to mark up the results in a convenient folder schema. No special browser options are necessary on the client side. The primary source of data used by WBM is the online Oracle [9] database; the WBM tools provide browsing and transformation functions to convert database entries into HTML tables, graphical plot representations, XML, text and ROOT-based object output. The ROOT-object output includes histogram objects and n-tuple data containers suitable for download and further analysis by the user. A system of meta-data entries describing the heterogeneous database which allows the user to plot arbitrary database quantities has been devised, including multiple value versus time plots and time correlation plots. The server consists of two dual CPUs and a 5 TB RAID configuration on which to store up to a year of monitoring output.

Fig. 1. The RunSummaryTIF query page, the multiple run results for a date query, and the run-file and logbook entry associated to the Tracker Slice Test Run 7647.

One of the more established WBM tools is the RunSummary servlet. Fig. 1 shows an example of the the web browser form with a date-query result and further links to

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Dr. Alan L. Stone is with the Fermi National Accelerator Laboratory, Batavia, IL 60510 USA (phone: 630-840-2174; e-mail: alstone@fnal.gov).

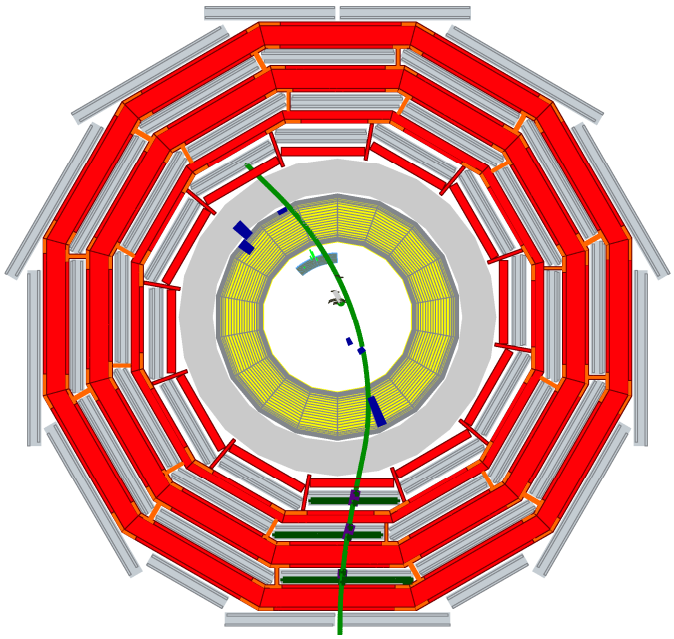

Fig. 2. A cosmic ray muon transversing the CMS detector in a 4.1 T magnetic field [12]. The path of the muon was reconstructed from information recorded by several sub-detectors.

detailed information. From the query page, users can search for runs and various optional criteria such as date and time, run range, run mode (physics, pedestal, timing, and calibration), trigger configuration, and more. From the single run results, links are provided to the online data quality monitoring histograms, the online logbook, magnet history, and high voltage status. Development continues to provide more functionality and access to additional monitoring information.

III. Magnet Test and Cosmic Challenge

The Magnet Test and Cosmic Challenge (MTCC) took place at CERN during two phases in August and October of 2006. MTCC was the first time CMS included more than one sub-detector in the global readout and in the presence of a magnetic field up to 4.1 Tesla. In MTCC-I, some fraction of several sub-detectors were available: Tracker, Electromagnetic (ECAL) and Hadronic (HCAL) Calorimeters, Muon Cathode Strip Chamber (CSC) and Muon Drift Tubes (DT).Only muon triggers were used in MTCC-I; calorimeter triggers were added in MTCC-II. The Tracker participated only in MTCC-I. Reprocessing of the MTCC-I data was crucial to clustering, algorithm and alignment studies since no additional magnetic tracking data would be available for over a year. The FNAL ROC provided a common sample of ROOT files for the tracker data analysis.

In Fig. 2, the event display using the Interactive Graphics for User Analysis (IGUANA) visualization toolkit [10] [11] illustrates a cosmic muon that was detected by all four sub-

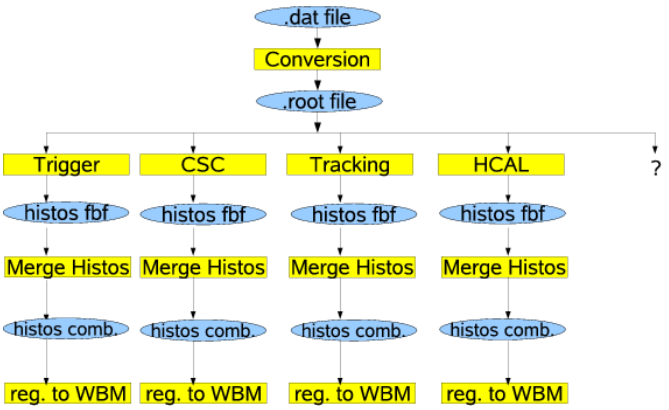

Fig. 3. FNAL ROC data processing flow chart.

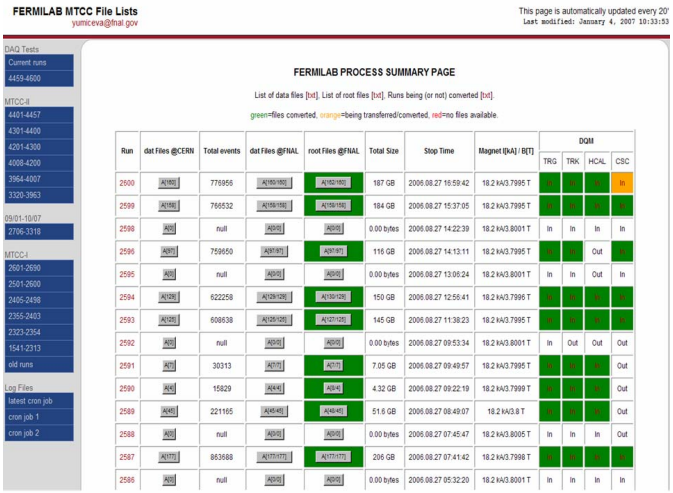

Fig. 4. FNAL ROC MTCC process summary web page.

detectors which participated in MTCC-I. The event display shows how the particle transversed the CMS detector with the reconstructed 4D segments in the Muon DT (magenta), the reconstructed hits in the HCAL (blue), the uncalibrated reconstructed hits in the ECAL (light green), and the locally reconstructed track in the Tracker (green). A muon track was reconstructed in the DT and extrapolated back into the detector taking into account the 3.8 T magnetic field.

The computing facility teams at CERN and Fermilab, Tier-0 and Tier-1 respectively, handled all of the MTCC data transfer and mass storage. However, the files wre not in the user-friendly ROOT format, nor was a database in place which allowed users to track file movement. The FNAL ROC group devised a solution for MTCC data bookkeeping and created an automation scheme for job submissions, file conversions and file processing. Python [13] scripts were run in cronjobs. If new files arrived at Fermilab, jobs were submitted to the Condor-based [14] work cluster batch system. The Condor DAGman facility synchronized processes file by file and then created a single merged ROOT file. An automated logbook entry was made after all of the files for a run were transferred

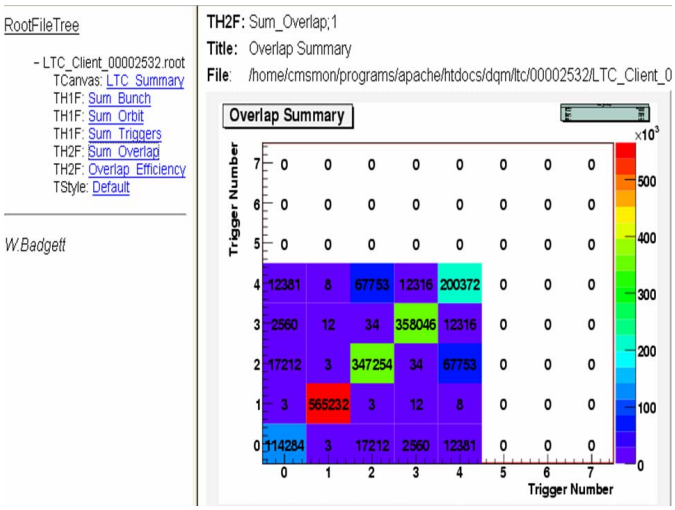

Fig. 5. DQM output for Run 2532 of the online high level trigger made available through the WBM tools.

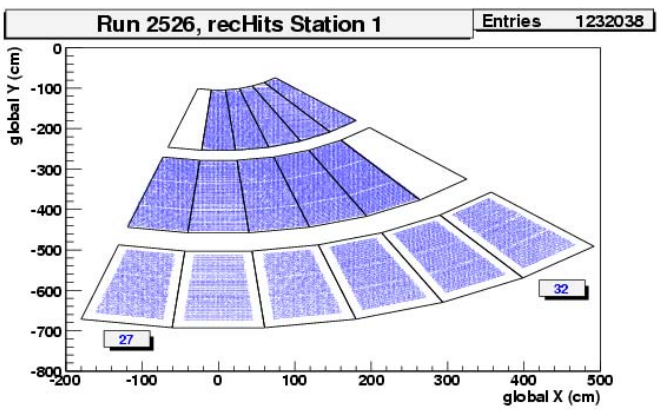

Fig. 6. r-φ distribution of the reconstructed hits of the CSC Muon chambers in Station 1 for Run 2526 from MTCC-I.

to Fermilab and then converted, processed and merged into a single ROOT file. Fig. 3 illustrates the different processes used to analyze the data files and to make the histogram results available with the WBM tools.

The FNAL ROC MTCC process summary page, shown in Fig. 4, contains information on the status of the MTCC data, ordered by the most recent run number, which is also linked to the WBM RunSummary page. The process summary color coding guides shifters about the state of data transfer (CERN to Fermilab), file conversion (to ROOT) and file processing (Trigger, Tracker, HCAL or CSC, with links to WBM). For reference, the number of events, the total number of files per run, the stop time and the magnet current is also included. Remote data quality monitoring (DQM) shifts were taken from the FNAL ROC, and shifters were tasked with running as many DQM modules as possible as well as the IGUANA event display. Shifters communicated through video and telephone conferencing, logbook entries and frequent emails. Web cameras were in the FNAL ROC and CERN remote operation centers.

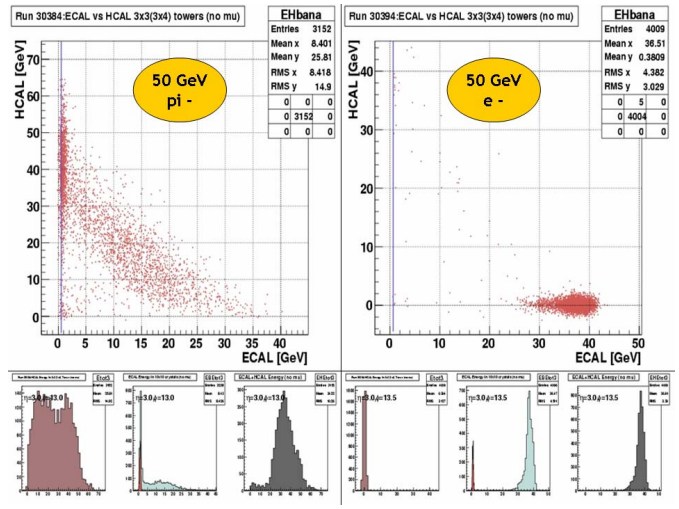

Fig. 7. ECAL vs HCAL energy scatterplots and the total energy distributions for a run with 50 GeV pions (left) and for a run with electrons (right) taken at the H2 facility in 2006.

Fig. 5 shows the DQM overlap summary histogram for the online high level trigger from Run 2532. This and other histograms were made available through the WBM tools to the CERN and FNAL shifters in live-time for prompt monitoring and feedback to the trigger experts.

The CSC Muon chambers provide signals from anode wires (cathode strips) along a constant η (φ). Each chamber has six layers of wires and strips, and are arranged in rings around the beam pipe. There are four separate layers of rings referred to as *Stations*, with Station 1 (closest to the interaction point) through Station 3 (furthest from the interaction point) included in MTCC. Fig. 6 shows the r-φ distribution of the reconstructed hits of the chambers in Station 1 for Run 2526. Similar distributions for Stations 1 through 3 were automatically produced for all MTCC runs in which CSC was included, and the distributions were published as image files to a public web page as another remote monitoring tool.

IV. HCAL Test Beam

From the H2 facility at the CERN Prevessin facility in France, the HCAL test beam data taking ran from June through September 2006. The slice test of the calorimeter included two wedges of the HCAL barrel, four segments of the HCAL endcap, three HCAL outer rings, one ECAL tile and the production electronics. Data was transferred to Fermilab typically within five minutes of the end of a run, and then reconstructed. An example of the summary results is shown in Fig. 7. The HCAL results were made available for online monitoring by anyone with a web browser.

V. Tracker Slice Test

About 20% of the CMS Tracker was assembled and instrumented for readout from January 2007 in warm (20 C) and then cold (-10 C) stages. A cosmic muon trigger with an

adjustable geometry provides a rate of about 1 Hz. The CMS FNAL ROC group supports the Tracker activities with data transfer (Tier-1), bookkeeping (process summary web page), logbook (ELog [15] installation and account administration), IGUANA event display, RunSummaryTIF, slow controls monitoring, and web-based documentation (Plone) [16] [17].

The shifters of the CMS Tracker Slice Test were the first users of the LHC@FNAL Remote Operations Center which is described in detail in [18]. In addition to commissioning the brand new infrastructure, the Tracker shifters participated in live-time DQM monitoring. Fig. 8 shows a collection of plots which characterize the tracking and cluster performance and the strip noise for six layers of the Tracker Outer Barrel. Similar summary plots are filled for each tracker subsystem.

An IGUANA event display is shown in Fig. 9 from Run 7636 of the Tracker Slice Test. A cosmic muon was detected in the Tracker Inner Barrel (TIB), Outer Barrel (TOB) and End Cap (TEC). The TIB (black) is in the center, followed by the TOB (lighter gray) and then the TEC (darker gray). The track is drawn by a red line, the hits are represented by green dots, and the clusters of hits are shown as blue dots. IGUANA can also run remotely on a live stream of data (about one event per minute) through a WBM tool called the Event Proxy.

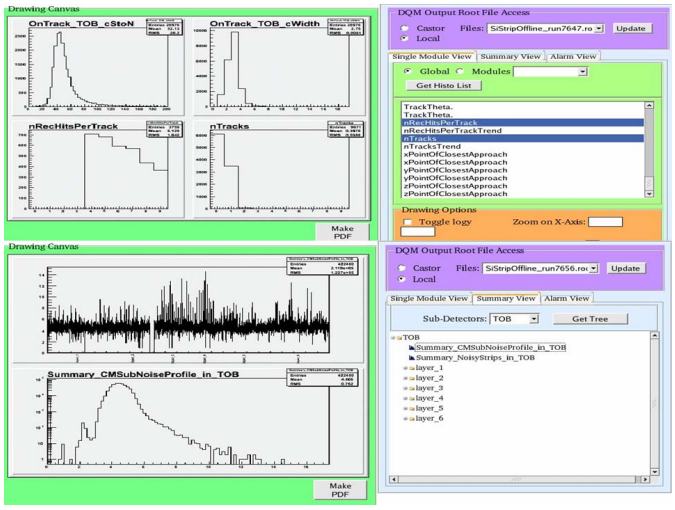

Fig. 8. Signal-to-noise ratio and width of clusters associated with tracks (top), number of reconstructed hits per track and number of tracks per event (top-middle), summary of the strip noise for six layers of the Tracker Outer Barrel (bottom-middle), and strip noise in the form of a distribution (bottom). The panels to the right show a list of all available histograms or allows a selection of a specific layer.

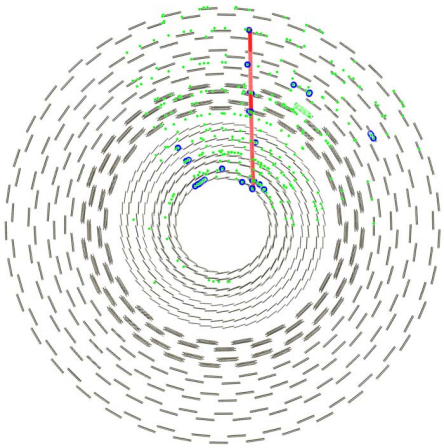

Fig. 9. Event display showing a cosmic muon from Run 7636 detected in the TIB, TOB and TEC.

Another WBM tool developed at the FNAL ROC is the DCSLastValue servlet which allows slow controls remote monitoring from a web browser. Detector Controls System (DCS) data is imported from the Oracle database. Comfort displays visualize the DCS status of high and low voltage, current and temperature with geometrical detector cartoons within a web browser. By pointing a mouse cursor over a single channel, a pop-up window will appear and display channel information and values in live-time. Clicking on a single channel device gives the user access to more details and a histogram plot for the last hour. Histograms can be rescaled by value or time. Fig. 10 shows an example of the DCSLastValue display; this particular snapshot was generated from a link in the RunSummaryTIF for Run 7647 (see Fig. 1).

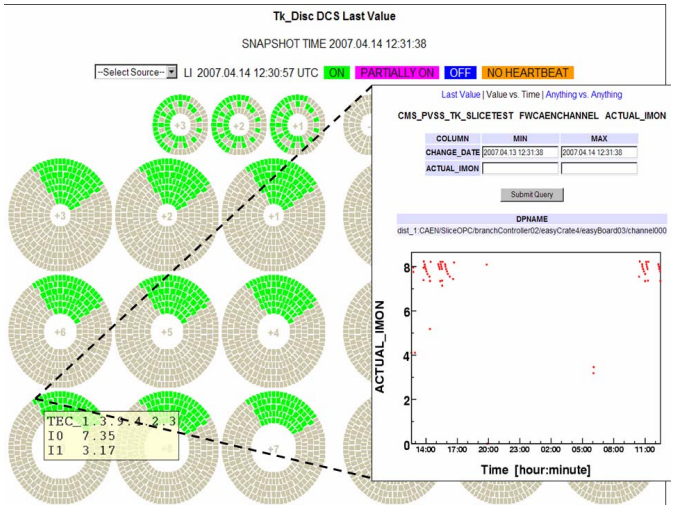

Fig. 10. DCS last value display for the Tracker disks. The current status is selected for all disks, and the value for a single channel device is plotted over a twenty-four hour period.

VI. Screen Snapshot Service

The Screen Snapshot Service (SSS) is comprised of three components: producer, server and consumer. The producer, implemented as a Java application, periodically captures screen images of a specified computer desktop and sends the snapshots to a server. After receiving the images from the producer, the server converts images to PNG format, and serves them to consumers. The server runs under Tomcat. The consumer periodically fetches snapshots from the server and displays snapshots in a web browser. The SSS can be used by CMS to share desktop content, e.g. Run Control, from within the CERN private network in a secure, read-only manner to the FNAL ROC. The SSS was tested successfully during the Tracker Slice Test and installed on several desktops to monitor remotely the slow control information, e.g. high voltage, current and temperature.

VII. Conclusion

Although Fermilab and the CMS detector are separated by a distance of 7,000 km, the CMS FNAL ROC group is involved in a wide variety of CMS activities. The WBM tools, e.g. RunSummary and DCSLastValue, are now used at both Fermilab and CERN. The successful experiences from MTCC Phases I and II, HCAL Test Beam and Tracker Slice Test have made Fermilab a primary location outside CERN to perform remote monitoring. With the newly established LHC@FNAL Remote Operations Center, the CMS FNAL ROC group is looking forward to collider beam and physics in early 2008.

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