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Web Based Monitoring in the CMS Experiment at CERN

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Abstract

With the growth in size and complexity of High Energy Physics experiments, and the accompanying increase in the number of collaborators spread across the globe, the importance of widely relaying timely monitoring and status information has grown. To this end, we present online Web Based Monitoring solutions from the CMS experiment at CERN. The web tools developed present data to the user from many underlying heterogeneous sources, from real time messaging systems to relational databases. We provide the power to combine and correlate data in both graphical and tabular formats of interest to the experimentalist, with data such as beam conditions, luminosity, trigger rates, detector conditions and many others, allowing for flexibility on the user side. We also present some examples of how this system has been used during CMS commissioning and early beam collision running at the Large Hadron Collider.

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Web based monitoring in the CMS experiment at CERN

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Abstract. With the growth in size and complexity of High Energy Physics experiments, and the accompanying increase in the number of collaborators spread across the globe, the importance of widely relaying timely monitoring and status information has grown. To this end, we present online Web Based Monitoring solutions from the CMS experiment at CERN. The web tools developed present data to the user from many underlying heterogeneous sources, from real time messaging systems to relational databases. We provide the power to combine and correlate data in both graphical and tabular formats of interest to the experimentalist, with data such as beam conditions, luminosity, trigger rates, detector conditions and many others, allowing for flexibility on the user side. We also present some examples of how this system has been used during CMS commissioning and early beam collision running at the Large Hadron Collider.

1. Introduction

The Compact Muon Solenoid (CMS) [1] experiment at the Large Hadron Collider (LHC) [2] at CERN [3] started recording proton collisions with a center of mass energy of 3.5 TeV on March 30, 2010. With tens of millions of sensor channels, substantial supporting infrastructure, and complex trigger and data acquisition (DAQ) systems, monitoring CMS is a formidable challenge. However, it is a key component in the effort to achieve efficient and high quality data taking. Monitoring tools, which are most useful if they function equally well regardless of where they are used, are employed by shift crew members, detector subsystem experts, operations coordinators, and those performing physics analyses. The vast and diverse information to monitor includes detector and environmental conditions, DAQ status, run configuration, trigger rates, luminosity, and accelerator parameters. The type of monitoring described in this paper is complementary to additional data quality monitoring tools that are based on event data. The goal of CMS Web Based Monitoring (WBM) is to provide a suite of tools that is easy to use, accessible through firewalls, secure, flexible, and maintainable.

The CMS collaboration is truly global, with approximately 3380 collaborators, from 176 institutions, spread over 39 countries. With such distributed expertise, there is a need for remote monitoring. Not everybody can be in the control room, and shift takers and experts often need to contribute to detecting, diagnosing, and fixing problems from remote locations.

The World Wide Web was established at CERN and continues to be a favorite collaborative tool in high energy physics. It is the main portal for accessing the WBM services.

2. System infrastructure

A simplified view of the WBM system architecture is displayed in Figure 1. The following sections provide details of the system components.

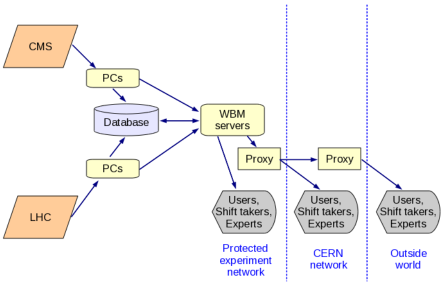

Figure 1. Overview of the systems used to provide the WBM services. The suite of tools is available directly within the private network or, via one or two proxies, to the CERN network or world wide, respectively.

2.1. Sources of information

Information is obtained via specialized hardware from both the CMS experiment and the LHC accelerator. WBM provides monitoring of both real-time and archival data.

The LHC General Machine Timing (GMT) system provides synchronous event timing and status information over dedicated serial lines throughout the accelerator complex. The GMT signal from the LHC is available to CMS through a PC that the WBM team has installed at the CMS experiment site. That PC has a hardware interface card that receives the incoming GMT events and several fields indicating the current status of the LHC, including beam intensities, beam energy, safety and permit flags, and other information. The PC runs software supplied by the CERN beams department and a CMS specific interface to the hardware card. The WBM software receives this information and converts it into other formats, including Extensible Markup Language (XML), Oracle database entries, and other formats to provide monitoring inside and outside the CMS experiment private network

Data is also exchanged between the LHC equipment and the experiments using the Data Interchange Protocol (DIP). This system allows relatively small amounts of real-time data to be exchanged between very loosely coupled heterogeneous systems. It is intended for systems that do not require very low latency. The data is assumed to be mostly summary data rather than low-level parameters from the individual systems. Information is published over DIP by CMS, as well as by the LHC. The data can be accessed via software by *subscribing* to the published trees of information. The servers publishing the information are located in different private networks, such as the LHC technical network and the CMS experiment private network, and are not trivially accessible across networks, especially from outside CERN. Different parts of the WBM software subscribe to LHC and CMS DIP information branches, to monitor and display the data. The WBM code also stores some of this information in a database for later retrieval.

Important real-time meta data, such as the status of the trigger and DAQ systems, are provided using the so-called XDAQ flashlists [4]. XDAQ is a software platform designed at CMS specifically for the development of distributed data acquisition systems. A flashlist is an object that represents variables of the XDAQ environment that are to be monitored. Flashlists have attributes that are values, status flags, or text. They refer to a set of data variables that belong to one or more qualified info-spaces. The WBM infrastructure looks at, for example, flashlists from the trigger system to monitor and display real-time trigger information for shift takers and experts. Such information is also stored by the WBM code in the database for later debugging and validation of the data.

2.2. Database

The CMS online database contains a wealth of information regarding the current and past states of the CMS detector. It is an Oracle database, with several servers working within the private CMS experiment network. These data were not originally readily searchable and viewable from outside the CMS site due to security restrictions. A natural method to convey and display that information is a web server, and the WBM server was proposed and implemented to allow globally useful, but carefully controlled, access to the data for people at the CMS site, as well as for people at remote locations. WBM code writes to the online database, as well as reading from it.

2.3. Core WBM hardware

The WBM infrastructure includes the following 64-bit SLC5 linux [5] machines. The main use for each machine is also listed.

- lhcgmt: continuously receives LHC GMT and DIP information, as well as other useful information, including the current luminosity;
- scalers machine: receives real-time scaler quantities, such as trigger rates. It also uses changes in the DAQ and beam status to automatically log information about periods of down time (see Section 4);
- SCAL Function Manager: managed by the central DAQ run control software and controls the functioning of the lhcgmt and scalers machines;
- WBM web servers: currently two production WBM servers are available for CMS users;
- WBM development and spare machines: several machines are used to develop and test new services and new releases before deployment to production. These machines also function as working spares.

2.4. Software implementations

On the server side, the WBM server runs an Apache daemon [6] to respond to HTTP requests. Most of the user interactive work is handled through Apache Tomcat [7], using a java servlet architecture. The ROOT [8] package is used for some historical plotting and data manipulation. Many of the pages use SQL to communicate with the underlying database.

On the Client side, the bulk of the data is displayed using simple HTML. Some of the services employ Java Applets, JFreeChart [9], or HTML5 canvas [10] for real-time plotting. JavaScript is used to perform real-time updating of page data. The JavaScript periodically polls data updates, matching incoming XML data with corresponding HTML Document Object Model elements.

2.5. Security and proxies

All of the computers that are part of the core WBM infrastructure are located within the CMS private network at the experiment site. For security reasons they are not directly accessible from outside the private network, with the exception of the two production servers, which are visible from the CERN network through a proxy. These servers are then made visible from outside CERN using a second proxy.

Access is providing using standard CERN authentication, the so called CERN Single Sign On (SSO) mechanism [11]. The WBM use-case requires, with few exceptions, that the user has CMS experiment collaboration membership. When CMS collaborators located outside CERN need to access the WBM web server, they are asked to enter their CERN credentials just as they would with many other restricted CERN web-based services. This system is integrated across many CERN services so that the authentication only needs to be carried out once per active session.

2.6. Documentation, code repository, and support

The WBM project is documented primarily using Twiki [12] pages, but also in some of the shift taker instructions and internal collaboration notes. As an additional project, the WBM team has developed a mechanism for creating daily Twiki replicas. A subset of the pages that are hosted outside the experiment private network are copied into the private network. This is done so that people are able to access key documentation and continue running the experiment even in rare instances when the network connection is interrupted.

Two Sub-version (SVN) [13] repositories are used for WBM software, as well as for the Twiki replica tool mentioned above and other web page content related to CMS operations. For the main WBM services, development code is kept in the *trunk* of the repository and *tags* are created for each new release.

Issue tracking and problem reporting are carried out using a Savannah [14] system. Developers use this to keep track of current tasks, while WBM users use it to provide feedback, report possible problems, and request new features. User support and internal communications are also performed through CERN mailing lists.

3. WBM services

The WBM services are accessible through a simple web page, shown in Figure 2, that provides a single point of entry. The following sections give examples of the services.

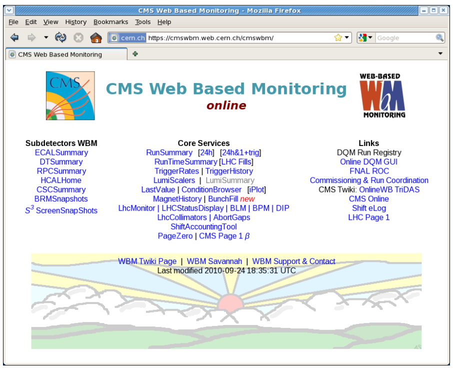

Figure 2. WBM main page.

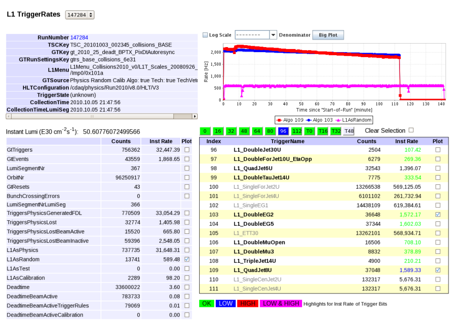

Figure 3. TriggerRates service.

The middle column of the main page contains links to the WBM core services. The RunSummary service displays meta information about the CMS data taking runs. It is searchable and provides links to another WBM servlet called L1Summary that contains summary tables of the Level 1 trigger performance. There, the user can view and download plots and numerical data showing the trigger rates as a function of time. The TriggerRates service (see Figure 3) displays trigger counts, rates, and configurations, either in real time, for the current run, or historically, from the database. It includes color-coded alarms for triggers that operate outside of their preset ranges, and includes check boxes to select which trigger rates are plotted.

The LastValue service consists of interactive displays for sub-detectors. It includes schematic representations of the detector geometries and a browsable tree, either of which can be clicked to drill down into details of the detector operating parameters (voltages, currents, etc.) and environmental conditions (temperatures, humidity levels, etc.). Quantities can be plotted as a function of time, and plots and raw data are downloadable. The entrance page for LastValue is shown in Figure 4.

ConditionsBrowser is a service that allows for the plotting of a vast selection of monitoring quantities, either as a function of time, or one quantity versus another.

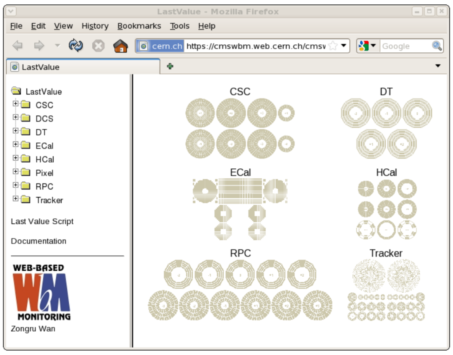

Figure 4. Front page of LastValue.

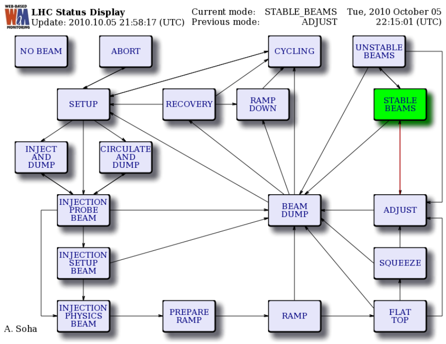

Figure 5. LhcStatus displays the current LHC mode.

The LhcStatus display (see Figure 5) indicates the current mode of the LHC, in the context of the possible states. The page utilized Scalable Vector Graphics to update the display on the client without refreshing the entire image. The LhcMonitor service presents more detailed information about the LHC parameters in tabular form.

The BunchFill service (see Figure 6) provides a visualization of the complex bunch patterns that populate the LHC accelerator rings. The chart and tables are available for the current collision period, or for previous periods.

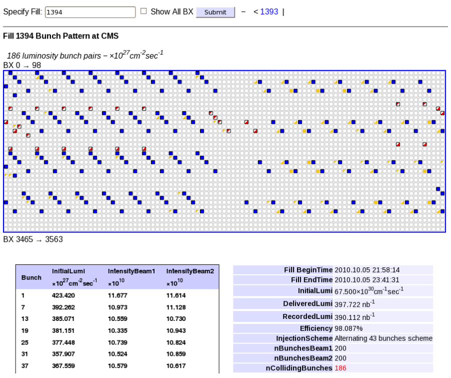

Figure 6. BunchFill shows the LHC bunch pattern.

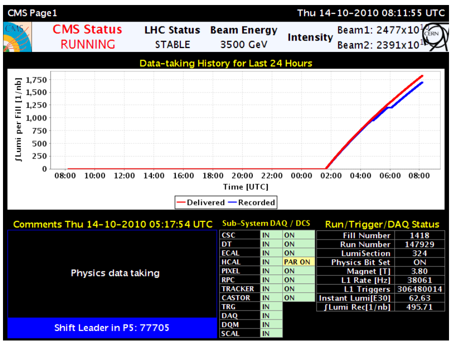

Figure 7. CMS Page 1 provides a summary of LHC and CMS status.

PageZero summarizes the status of CMS and the LHC in various tables, while CMS Page 1 (see Figure 7) gives a high level summary which includes beam conditions, delivered and recorded luminosity, detector high voltage and readout status, trigger rate, and a comment from the shift leader.

In addition to the core services discussed above, the WBM infrastructure has enabled subsystem experts to implement specialized monitoring pages for their specific subdetectors. Finally, the WBM main page also provides links to other frequently accessed pages related to monitoring and operations.

4. CMS Run Time Logger

The primary goal of the CMS Run Time Logger is to improve CMS data taking efficiency by reporting real time and historical operational efficiency details, for use by the shift crew, operations group, detector experts, and management. In addition to keeping track of down time, live time, and luminosity, it also logs the reasons for down times, allowing users to identify the sources of down time that have the largest impact on data taking. There are four main components to this tool: (1) The underlying Oracle database stores details of the downtime events, categories, run periods, detector state, and luminosity. (2) Gaps in data taking, as evidenced by the absence of triggers, are automatically detected and logged by dedicated hardware, firmware, and software, including a custom linux device driver. (3) A Graphical User Interface (GUI) (see Figure 8), implemented in Java, is used by the shift crew to enter causes and details of down times. (4) A Web-based reporting tool provides summary plots, pie charts, and sortable tables of down times and efficiencies. An example showing the reasons for down times for the data taking periods between March 30 and October 5, 2010 is shown in Figure 9.

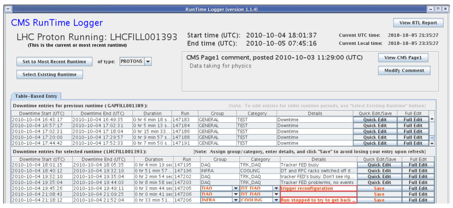

Figure 8. Run Time Logger GUI.

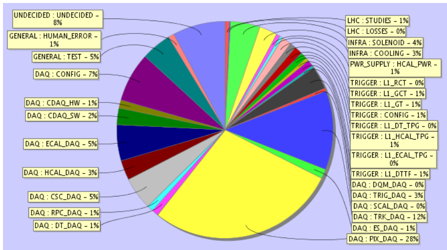

Figure 9. Run Time Logger reported down times.

5. Conclusions

To meet the critical need for monitoring, the WBM project provides a broad suite of tools to convey diverse information from various sources. The services are made accessible both locally and remotely, to address the challenges of a global collaboration. The first months of collision data taking have shown that Web Based Monitoring is a key element in successfully operating CMS.

6. Acknowledgments

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[9] http://www.jfree.org/jfreechart
[10] http://www.whatwg.org/specs/web-apps/current-work/multipage/the-canvas-element.html
[11] CERN Single Sign On: https://cern.ch/authentication
[12] Twiki documentation tool: http://www.twiki.org/
[13] Sub-version revision control system: http://subversion.apache.org/
[14] Savannah at CERN: https://savannah.cern.ch/ , based on Savane: http://gna.org/projects/savane