Web Based Monitoring for the CMS experiment

J. Lopez-Perez, K. Maeshima, S. Maruyama, J. Patrick, V. Rapsevicius, (Fermilab, USA)
M. Stankevicius, B. Sulmanas (Vilnius University, Lithuania)
S. Toda (Kansas State University, USA)
U. Behrens (DESY, Germany)
(on behalf of the CMS Collaboration)
Web Based Monitoring (WBM)

Outline:
- Need of WBM
- WBM services
- WBM infrastructure
- WBM past and future
Need of WBM

- WBM services
- WBM infrastructure
- WBM past and future
CMS experiment at CERN

- CMS is a complex system which needs fast and reliable monitoring
- Quick feedback is needed for efficient data taking

**CMS DETECTOR**
- Total weight: 14,000 tonnes
- Overall diameter: 15.0 m
- Overall length: 28.7 m
- Magnetic field: 3.8 T

**STEEL RETURN YOKE**
- 12,500 tonnes

**SILICON TRACKERS**
- Pixel (100x100 μm) ~16m² ~66M channels
- Microstrips (80x180 μm) ~200m² ~9.6M channels

**SUPERCONDUCTING SOLENOID**
- Niobium titanium coil carrying ~18,000 A

**MUON CHAMBERS**
- Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
- Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

**PRESHOWER**
- Silicon strips ~16m² ~137,000 channels

**FORWARD CALORIMETER**
- Steel + Quartz fibres ~2,000 Channels

**CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)**
- ~76,000 scintillating PbWO₄ crystals

**HADRON CALORIMETER (HCAL)**
- Brass + Plastic scintillator ~7,000 channels
Thousands of collaborators all over the world.

- Currently >3500 scientists from 194 institutes in 43 countries
Example

- Tools needed for remote status display
- Must be easy to use, flexible, drillable
- Cooperative with firewall, security
- Must survive trans-Atlantic crossing
WBM overview

Global Trigger – Trigger Rates

Luminosity – Collision Rates

LHC – Beam currents, losses, status

LHC – Real time clock and event signal

Sub-system specific information stored in relational databases

WBM:
Web with user-friendly information + provide monitoring and reporting web services
Information we need to monitor

- DAQ
- Triggers
- Luminosity
- DQM
- Up/down time
- Experimental running conditions in database

- LHC
  - Beam loss monitors, collimators, position
- Magnet
- Sub-system specific
- Hardware (DCS)
- Any other non-event data
WBM motivation

- That information must be monitored **efficiently**
  - Or data taken might not be useful for physics
- Problems found -> need to be solved quickly
  - Otherwise we lose important luminosity
  - Experts can be outside experiment area
- Experts from different systems need to **correlate** information to identify the cause of problems
- Managers, sub-detectors and data certification groups have **specific needs**
WBM as a solution

- **WBM** gives a **global picture**
  - **Centralized** place of lots of systems
    - CMS operation, sub-detectors, magnet, LHC...
  - **Real time** information about data being taken
  - **Historical** information about past runs
  - Operation and efficiency **reports**
  - Available for experts outside CMS detector area
  - Different from Data Quality Monitoring services, which look at event data
WBM services

- Need of WBM
- WBM services
- WBM infrastructure
- WBM past and future
Homepage and Examples…

Worldwide: http://cmswbm.cern.ch

P5 (CMS network): http://cmswbm.cms

CMS Web Based Monitoring

Subdetectors WBM
- ECALSummary
- DTSummary
- RPCSummary
- HCALHome
- CSCSummary
- BCM1F Bunch Info
- TriggerModes
- TrackerTools
- PixelHome
- S3 ScreenSnapShots

Core Services
- RunSummary [24h] [24h&1+trig]
- RunTimeSummary [LHC Fills] Deadtime
- FillReport [Latest Stable Fill] DataSummary
- LumiScalars | Automatic Fill eMails
- DQM Run Registry | DQL [Online] [Offline, ?]
- TriggerHistory | TriggerRunListing
- TriggerRates [Pre-DT L1] [Post-DT L1] [HLT]
- LastValue | ConditionBrowser [iPlot]
- MagnetHistory | CurrentBunches | BunchFill
- LhcMonitor | LHCStatusDisplay | BLM | BPM | DIP
- LhcCollimators | AbortGaps
- ShiftAccountingTool
- wbm4lh
- PageZero | CMS Page 1

Links
- Online DQM GUI
- FNAL ROC
- Commissioning & Run Coordination
- CMS Twiki: OnlineWB TriDAS
- CMS Online
- Shift eLog
- Snappy eLogViewer
- LHC Page 1

Simple and direct starting points
Real time information (CMS Page 1)

LHC / CMS status. Useful quantities, coming from both database and real-time sources.

Worldwide visible

Last 24h status of delivered and recorded data taking

Physics with 518 bunches, 100/150 ns
# Fill Report

**Fill 6274 Report**

- **Specific Fill:** 6274
- **Begin:** 6274
- **End:** 6274
- **Stable:** Go
- **Last n Fills:** 20
- **Stable:** Go

## CMS Fill 6274 Report

- **BunchFill:** LhcEvents | RuntimeLogger | ConditionBrowser | Magnet
- **CreateTime (declared):** 2016.09.02 07:55:53
- **BeginTime (stable):** 2016.09.02 11:36:35
- **toReady (to HV on):** 0.791 minutes
- **toDumpReady:** n/a minutes
- **DumpReadyToDump:** n/a minutes
- **EndTime (dumped):** 2016.09.03 06:39:49

- **Type:** Proton – Proton vs Proton
- **BField:** 3.800 T
- **Energy:** 8499 GeV
- **InitialLumi:** $11553.845 \times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
- **PeakLumi:** $11581.473 \times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
- **PeakPileup:** (interactions/BX) $\langle n \rangle = 37.266$
- **PeakSpecificLumi:** $4.627 \times 10^{27} \text{ cm}^{-2} \text{ sec}^{-1} (10^{16} \text{ p})^2$
- **DeliveredLumi:** 486.428 pb$^{-1}$
- **RecordedLumi:** 471.246 pb$^{-1}$
- **Efficiency by lumi:** 96.879%
- **Efficiency by time:** 99.921%

## Runtime chart for fill LHCfill05274

- **Date:** 2016.09.02 11:00:00 - 2016.09.03 06:00:00
- **Begin:** 279931
- **End:** 279931
- **Time:** 15:53:58 - 15:54:52

## CMS and LHC performance for any given fill at a glance
Direct links to other important WBM services which provide CMS and LHC information

Example: clicking in Run Number brings us to WBM Run Summary
Run Summary

<table>
<thead>
<tr>
<th>RUN</th>
<th>LUMI_NB_LIVE_DELIV</th>
<th>SEQUENCE</th>
<th>TRIGGER_MODE</th>
<th>L1_KEY</th>
<th>HLT_KEY</th>
<th>STARTTIME</th>
<th>STOPTIME</th>
<th>TRIGGERS</th>
<th>BFIELD</th>
<th>TIER0</th>
<th>COMPONENTS</th>
</tr>
</thead>
</table>

Sub-system specific WBM services:

- CSC
- DT
- ECAL
- HCAL
- PIXEL
- RPC
- TRACKER

Other services:
- Clock
- DBS
- DCS
- DQM GUI Online
- DQM GUI Offline
- eLog
- FMM DeadTime
- Lhc Events
- Lumi Sections
- Prescale Changes
- Prescale Sets
- Prescale Change Paths
- Run Info
- Storage Manager Files
- Dataset Summary

WBM Run Summary. Displays aggregated information for that specific CMS run. Also includes links to many other WBM services.
L1 Trigger Rates

Pre deadtime L1 Trigger Rates for Run Number 280383

<table>
<thead>
<tr>
<th>RunNumber</th>
<th>280383</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSCKey</td>
<td>collisions2016_TSC/v134</td>
</tr>
<tr>
<td>GTKey</td>
<td>UGT_BASE_KEY/v55</td>
</tr>
<tr>
<td>GTRunSettingsKey</td>
<td>collisions2016_RS/v167</td>
</tr>
<tr>
<td>L1Menu</td>
<td>n/a</td>
</tr>
<tr>
<td>GTSource</td>
<td>Not yet available for uGT</td>
</tr>
<tr>
<td>HLTConfiguration</td>
<td>/cdaq/physics/Run2016/25ns15e33/v3.1.8</td>
</tr>
<tr>
<td>Database Updates</td>
<td>Active</td>
</tr>
<tr>
<td>Last Sampled</td>
<td>2016-09-09 08:11:44</td>
</tr>
<tr>
<td>Last LS Start Time</td>
<td>2016-09-09 08:11:44</td>
</tr>
</tbody>
</table>

Instant Lumi: 5,186.45

<table>
<thead>
<tr>
<th>Counts</th>
<th>Inst Rate</th>
<th>Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>TotalTriggers</td>
<td>43922910</td>
<td>26,538.90</td>
</tr>
<tr>
<td>LumiSegmentNr</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Orbits</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>L1AsPhysics</td>
<td>42896508</td>
<td>25,918.73</td>
</tr>
<tr>
<td>L1AsRandom</td>
<td>877655</td>
<td>530.29</td>
</tr>
<tr>
<td>L1AsCalibration</td>
<td>148757</td>
<td>89.88</td>
</tr>
<tr>
<td>TriggersPhysicsLost</td>
<td>12487731</td>
<td>7,645.28</td>
</tr>
<tr>
<td>TriggersPhysicsLostBeamActive</td>
<td>11459845</td>
<td>6,920.59</td>
</tr>
<tr>
<td>TriggersPhysicsLostBeamInactive</td>
<td>1033886</td>
<td>624.69</td>
</tr>
<tr>
<td>Deadtime</td>
<td>16990142040</td>
<td>28.63</td>
</tr>
<tr>
<td>DeadtimeBeamActive</td>
<td>18541759276</td>
<td>27.95</td>
</tr>
<tr>
<td>DeadtimeBeamActiveTriggerRules</td>
<td>168019494</td>
<td>0.25</td>
</tr>
<tr>
<td>DeadtimeBeamActiveCalibration</td>
<td>34305742</td>
<td>0.05</td>
</tr>
<tr>
<td>DeadtimeBeamActiveFWPause</td>
<td>165570650</td>
<td>0.25</td>
</tr>
<tr>
<td>DeadtimeBeamActivePartitionController</td>
<td>1601903814</td>
<td>24</td>
</tr>
<tr>
<td>DeadtimeBeamActiveSWPause</td>
<td>12744780705</td>
<td>19</td>
</tr>
<tr>
<td>DeadtimeBeamActiveDACBackpressure</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

L1 trigger counters, rates, and configurations with real-time plotting. Important to achieve good quality analysis data.
Detector Displays across CMS

Alarms and limits.
Drill-down details.
Plotting: current and historical
Operation tools (Runtime Logger)

- Tracks reasons for losing data during data taking periods to improve efficiency.

- It involves several services:
  - **Runtime Summary**: information for a single fill or runtime period.
  - **Runtime Analyss**: produces custom reports (any time range and downtime type).
  - **RTL GUI**: allows the shift leader and sub-detector experts to assign downtime and specify comments about downtime causes.
And many more...

- Check backup slides for more examples.
WBM infrastructure

- Need of WBM
- WBM services
- **WBM infrastructure**
- WBM past and future
Allowing External access

System of Reverse Proxies

CMS WBM server

Protected experimental network

.CMS
users

CMS Online Gateway

CERN network

.CERN
users

CERN IT

cmswbm.cern.ch

Outside world

.Offsite
users

Authentication required.
CMS membership required.
Exceptions for LHC coordinators.
Diagram of WBM infrastructure

2 machines collect, aggregate, store and propagate information from both LHC accelerator and CMS experiment.

WBM servers in CMS and CERN networks make the information available to shifters and experts.
WBM past and future

- Need of WBM
- WBM services
- WBM infrastructure

WBM past and future
WBM history

- **Present!** 10 years have passed.
- **LHC Run 2** starts. Many things have changed and WBM has adapted. New requests keep coming.
- Long shutdown 1 starts.
- WBM keeps evolving. New services appear. New technologies are evaluated and integrated into the growing framework.
- **LHC Run 1** starts. WBM proves itself useful when CMS records the first collisions data.
- WBM is already being used for **commissioning** the CMS experiment.
- WBM **gets proposed** and development starts.

- 2016
- 2015
- 2013
- 2010
- 2008
- 2006
WBM future

- LHC Run 3 will start. WBM must be ready for new challenges!
- Long Shutdown 2 will start. Many CMS sub-systems will drastically change. Monitoring needs to adapt.
- Present! Continues to be heavily used in Run 2.

- WBM team is currently evaluating new technologies for upgrading the current framework for Run 3.
- Data aggregation part will be separated from data visualization part.
Thanks!

Backup slides follow
RunSummary Example

RunSummary selection form yields list of runs matching criteria

Run listing links to details about specific run
L1Summary TriggerRates

Drill-down from rates to plot vs. time and lumisection. Allows to apply cuts on time and rates. Pre- and post-downtime rates. Displays from different information sources (production and development L1 systems) in parallel for debugging.
Data Summary

Yearly online lumi. & eff.
Computed LHC & CMS records
(luminosity, pileup, bunches, time in Stable Beams, efficiency...)

Daily, weekly and yearly accumulated luminosity and efficiency information
Problems can be investigated with drill-down details and time plotting.
Correlation plots

Example: magnet current vs. temperature

- Browse hundreds of environmental and experimental data samples
- Dynamically produce plots
- Download Root, XML, text, HTML
- OR construct your own URL for in-line linking or non-interactive access

Plot any database quantity vs time or vs any other database quantity
Subdetector Contributions
ECAL (EM Calorimeter)

CMS subdetectors are unique
CMS WBM provides a platform and infrastructure in which they can develop specific tools and displays

ECal Calibration RunSummary with data quality monitoring results and plots

Giovanni Organtini
Run Time Logger Reports

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Begin time</th>
<th>End time</th>
<th>Run time</th>
<th>Live time</th>
<th>Eff. (Lumi)</th>
<th>Eff. (Time)</th>
<th>Downtime ev. count</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHCFILL005274</td>
<td>PROTONS</td>
<td>2016.09.02 11:36:35</td>
<td>2016.09.03 06:39:49</td>
<td>19:00:13</td>
<td>19:02:15</td>
<td>96.88%</td>
<td>99.92%</td>
<td>1</td>
</tr>
</tbody>
</table>

Delivered Luminosity, pb⁻¹ | Recorded Luminosity, pb⁻¹ | Luminosity Lost, pb⁻¹ | Lumi lost at Downtime Events, pb⁻¹ | Lumi lost while taking data, pb⁻¹
486.42834375 | 471.24581250 | 15.18253125 | 0.81925000 | 14.36328125

Delivered and Recorded luminosity vs. time, including downtime reasons details provided by CMS shift leader
Example of Live Plotting (DIP)

Simulated (x,y,z) Beam Spot at CMS

Both CMS and LHC real-time information
Real-time LHC Monitor at CMS

LhcMonitor: From synchronous clock and event hardware signal sent to CMS

Audible alarms on critical events like “inject beams” “dump beams”

Like TevMon at Tevatron
SAT (Shift Accounting Tool) provides reports about shifts done per institution and person

DQL (Data Quality Logger) provides data quality reports for Data Certification

Different specific LHC, DCS and Magnet related monitoring services also exist

- Some monitor real-time quantities while others provide historical reports
WBM infrastructure and support

- 2 WBM production servers in experiment network and 2 more in CERN network
  - Regular security code reviews and restricted access

- WBM data aggregation machines
  - Collect, organize, store and propagate information from both LHC accelerator and CMS experiment
  - Both have a “hot spare” so they can be quickly replaced

- Several restricted development servers are available for WBM core developers and sub-detector contributors
WBM SW deployment & development

- Several WBM development servers in experiment network and 1 more in CERN network
  - Available for WBM core developers and sub-detector contributors for developing and testing
  - Restricted access, not accessible from outside
- Code in SVN (revision control system)
- In RPM packages & managed by Puppet
- Documentation, both public-wide for users and private one only for developers
- Weekly group coordination meetings
WBM support

- WBM JIRA project
  - Support, bugs, tasks, feature requests...
- Support and announcements mailing lists
- Weekly WBM meetings with sub-system experts and vidyo connection
- Daily and weekly reports and feedback from Run Coordination meetings
- 24-7 expert on-call
For all external access, we use the CERN Single Sign On mechanism (SSO)

Uses the Shibboleth organizational site authentication

Allows users to log in once per session, and access all CERN sites supporting Shibboleth, using personal certificate or kerberos user/passwd