Run II Performance of Luminosity and Beam Condition Monitors at CMS

Jessica Leonard
On behalf of
CMS BRIL
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CMS BRIL: Beam Radiation Instrumentation and Luminosity

Università & INFN, Bologna
Conseil Européen pour la Recherche Nucléaire (CERN)
Deutsches Elektronen-Synchrotron (DESY)
IHEP Protvino
Karlsruher Institut für Technologie (KIT)
University of Minnesota
University of Canterbury
University of Kansas
Moscow State University
Northwestern University
Princeton University
Rutgers, State University of New Jersey
University of Tennessee
Vanderbilt University
University of Wisconsin

Highlighted BRIL deliverables include

- Real-time integrated and per-bunch luminosity
  - Luminosity essential for physics analysis
- Machine-induced background measurements
  - Vital monitoring of LHC beams
- Tracker safe-operation condition
  - Necessary for CMS data-taking
- Beam abort functionality
  - Protects CMS detector
BRIL Systems Overview

HF Luminosity:
- Photo-detectors
- Backend electronics & BRIL DAQ

Z = +/- 14.4 m
- BCM2L: Upgraded
  - Inner ring: 4 sensors, R = 5 cm
  - Outer ring: 8 sensors, R = 28 cm

Z = +/- 1.8 m, R = 5 cm
- PLT: Upgraded
  - 48 si-pixel sensors
  - Special 40 MHz readout

Z = +/- 20.625 m, R = 180 cm
- BHM: NEW
  - Fast PMTs, directionality
  - Backend electronics

“Golden” locations for maximum incoming-outgoing separation
Systems complementary
Beam Halo Monitor (I)

Measure machine-induced background (MIB) at high radius (180 cm)

- Charged MIB particles (muons) from incoming beam
- Directional Cherenkov light produced in quartz bar
- Light detected by photomultiplier

40 modules: 20 modules per incoming beam

Distance from IP: 20.6 m (rotating shielding)

uTCA ADC system produces full-orbit histograms
Beam Halo Monitor (II)

Binning allows for separation between beams

- Collision products can be subtracted out from machine-induced background hits

Beam loss events observed during bunch excitation

- Hit rate correlates with beam losses
Beam Abort System: BCML

Protect silicon tracking detectors from catastrophic beam loss events

- Polycrystalline CVD diamond sensors
- Initiates beam abort if current in one channel above predefined threshold

Upgrade: sensor replacements

BCML1 location inside tracker volume: magnetic field suppresses erratic currents

- BCML2 outside magnetic field range

BCML talk later in this session:
Radiation damage in BCML diamonds, F. Kassel
Pixel Luminosity Telescope (I)

Dedicated standalone luminosity monitor

- 8 3-plane silicon-pixel telescopes per end

Bunch-by-bunch luminosity: 1% statistical precision at 1 Hz

- Deadtime-free 3-fold coincidences using standard CMS pixel chip
- Full pixel readout: systematics, alignment, background studies, etc.
Pixel Luminosity Telescope (II)

Pixel information verifies performance of triple coincidences

- Triple-coincidence tracks seen during collisions
- No tracks seen without collisions – zero noise
- Uniform track occupancies across active area of pixel sensors

Tracking information also allows reconstruction of beam spot

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CMS Preliminary Fill 4449, $\sqrt{s} = 13$ TeV

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Fast Beam Condition Monitor
BCM1F (I)

Bunch-by-bunch measurement of beam background flux and collision products
- 24 5mm x 5mm single-crystal CVD diamond sensors (Run I: 8 sensors)

New fast frontend ASIC
- 130 nm technology, fast rise time and recovery

Realtime Histogramming Unit (RHU)
- Deadtimeless full-orbit histograms
- 6.25-ns binning = 4 bins per bunch crossing

uTCA fast ADC system
- In development: Peak-finding/deconvolution algorithms

BCM1F talks later in this session:
- Test beam results, M. Hempel
- Luminosity measurement, O. Karacheban
Fast Beam Condition Monitor BCM1F (II)

Golden location, histogram binning: separation between beams
- Incoming beam background
- Outgoing beam background + collision products

Machine-induced background measurement
- Detector hit rate corresponds to beam loss

![Graph showing hits vs RHU bin number and time vs counts](image)
Luminometer Performance

All online luminometers (HF, PLT, BCM1F) have provided luminosity for full 2015 running period

- All track each other well
- Per-bunch measurement

One luminometer “official” lumi provider at a time

- Others used as cross-check/backup

Other detectors provide additional offline luminosity numbers

- Pixel cluster counting, drift tubes
Luminosity Calibration and Uncertainties

Van der Meer scan provides absolute calibration factor: visible cross section

- Beams scanned across each other in x,y; hit rate measured

BCM1F chosen as “official” primary luminometer for 50-ns data-taking

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-ns running</td>
<td></td>
</tr>
<tr>
<td>Calibration uncertainty</td>
<td>2.6%</td>
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<tr>
<td>Stability</td>
<td>4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.8%</strong></td>
</tr>
<tr>
<td>25-ns running</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.6%</strong></td>
</tr>
</tbody>
</table>

Uncertainties for 50- and 25-ns running will be updated for Moriond, stay tuned...

Public analysis summary will follow
Conclusion

New BRIL subsystems performed well during 2015:

- Background monitors: machine-induced background, protection of CMS
- Luminometers: consistent, well-calibrated luminosity measurement

Luminosity analysis for 2015 ongoing, refined version to be presented soon

BRIL is looking forward to more successful luminosity and background monitoring in 2016