Performance of New and Upgraded Detectors for Luminosity and Beam Condition Measurement at CMS

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CMS BRIL: Beam Radiation Instrumentation and Luminosity

Deliverables include

- Real-time integrated and per-bunch luminosity
- Machine-induced background measurements
- Tracker safe-operation condition
- Beam abort functionality

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Deutsches Elektronen-Synchrotron (DESY)
Karlsruher Institut für Technologie (KIT)
University of Minnesota
University of Canterbury
Northwestern University
Princeton University
Rutgers, State University of New Jersey
University of Tennessee
Vanderbilt University
University of Wisconsin
BRIL Systems Overview

“Golden” locations for maximum incoming-outgoing separation
Systems complementary

Z = +/-11.2 m
HF Luminosity:
- Quartz fiber calorimeter
- Photodetectors
- uTCA backend

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

Z = +/-14.4 m
Upgraded
BCM1F:
- 24 sCVD diamond sensors, 48 channels
- Fast MIP counter, triggerless readout

Upgraded
BCM1L:
- 8 pCVD diamond sensors
- Beam background monitoring
- Protection of CMS pixel detector

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

NEW

Upgraded

Upgraded
Beam Abort System: BCML

Purpose: Protect silicon tracking detectors from catastrophic beam loss events

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

Upgrade

- BCM1L: Replacement of all sensors, integration into BCM1F module
- BCM2L: Replacement of highly-damaged sensors

Beam loss events detected already in 2015
Beam Halo Monitor (I)

New system: 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)

Multiple readout systems currently

- VME scalers provide hit rates integrated over orbit
- uTCA ADC system (in development) produces full-orbit histograms
Beam Halo Monitor (II)

Directionality of signal response demonstrated during “splash” events

- Beam hits collimator upstream from CMS, producing large particle shower

Beam background events observed during collimator scans

- Hit rate correlates with collimator position

(Example of a Beam 2 splash event, 450GeV, 7 April 2015)

(Fill 3679, Circulating Beams, 5 May 2015)
Forward Hadronic Calorimeter: HF

Online luminosity measurement (Run I standard): 3.7% precision
- 864 towers, zero-counting algorithm

Upgrades for Run II:
- New photomultipliers
  - Address anomalous signals seen during Run I
  - Multiple channels per PMT
- Move to uTCA backend electronics
  - Readout boards provide bunch-by-bunch occupancy and transverse energy sums
  - Lumi readout independent of CMS DAQ and decoupled from trigger stream

HF wedge
36 wedges in total

μTCA backend crate
BCM1L, BCM1F, PLT integrated into single structure, 2 per end

- Large, connector-free semi-rigid PCB hosts BCM wiring
Pixel Luminosity Telescope (I)

New 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)

Successfully installed and commissioned earlier this year

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

Tracking information allows initial reconstruction of beam spot
Fast Beam Condition Monitor
BCM1F (I)

Upgraded system for 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
New DAQ system: Realtime Histogramming Unit (RHU)
- Deadtimeless full-orbit histograms
- 6.25-ns binning = 4 bins per bunch crossing

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

Current efficiency/signal characteristics monitoring: VME ADC system
Luminosity Measurement

All luminometers (HF, PLT, BCM1F) have provided luminosity since beginning of collisions

- All track each other well
- Per-bunch measurement

One luminometer “official” lumi provider at a time

- Others used as cross-check/backup

LHC beam optimization scans

- Allow testing of van der Meer scan analysis workflow
- Provide preliminary absolute calibration factor
Conclusion

BRIL subsystems installed, commissioned, performing well

- BCML: new diamonds for beam abort system
- BHM: Cherenkov detector for high-radius background monitoring
- HF: new readout electronics for proven online luminometer
- PLT: new silicon telescopes for online luminosity
- BCM1F: scaled-up diamond system for online background and luminosity measurements

Luminosity measurements from three luminometers being published, initial data-driven absolute calibrations done

BRIL is looking forward to a successful Run II of luminosity and background monitoring