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

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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)

Karlsruher Institut für Technologie (KIT)

University of Minnesota

University of Canterbury

Northwestern University

Princeton University

Rutgers, State University of New Jersey

University of Tennessee

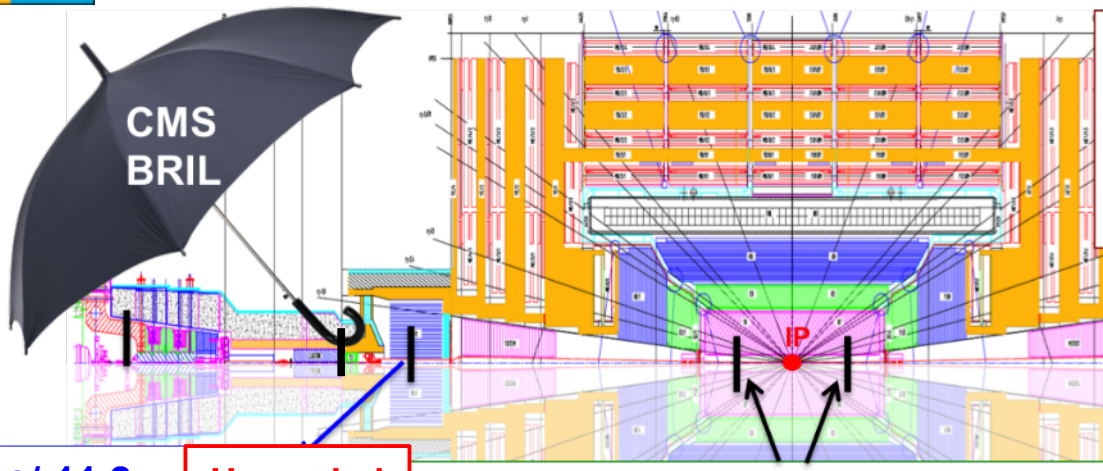
Vanderbilt University

University of Wisconsin

Deliverables include

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

BRIL Systems Overview



Z=+/- 20.625 m, R=180 cm

BHM:

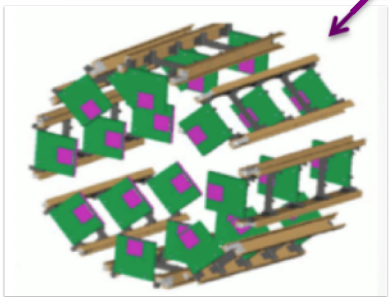
- Fast PMTs, directionality
- Backend electronics

NEW

Z = +/-11.2 m **Upgraded**

HF Luminosity:

- Quartz fiber calorimeter
- Photodetectors
- uTCA backend



Z=+/- 1.8 m, R=5 cm

PLT: **NEW**

- 48 si-pixel sensors
- Special 40 MHz readout

BCM1F: **Upgraded**

- 24 sCVD diamond sensors, 48 channels
- Fast MIP counter, triggerless readout

BCM1L: **Upgraded**

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

Z = +/-14.4 m **Upgraded**

BCM2L:

- Inner ring: 4 sensors, R = 5 cm
- Outer ring: 8 sensors, R = 28 cm

"Golden" locations for maximum incoming-outgoing separation

Systems complementary

Beam Abort System: BCML

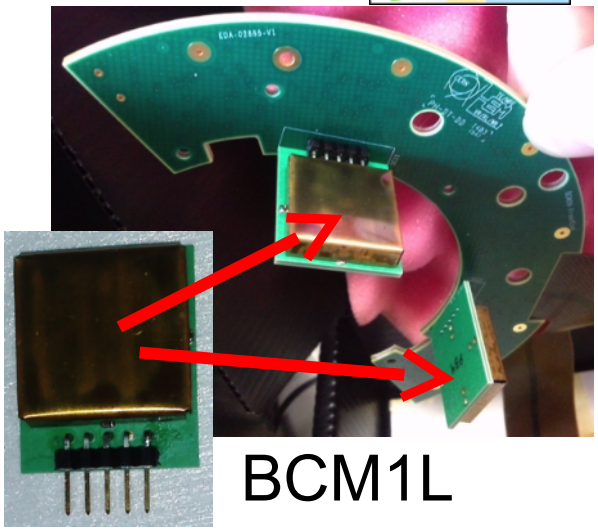
Purpose: Protect silicon tracking detectors from catastrophic beam loss events

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

Upgrade

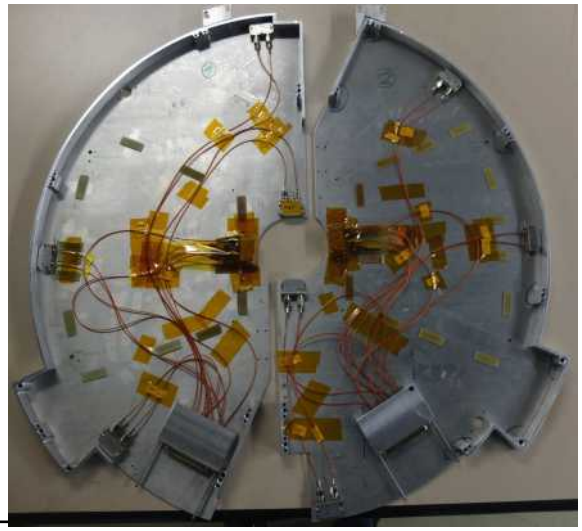
- BCM1L: Replacement of all sensors, integration into BCM1F module
- BCM2L: Replacement of highly-damaged sensors

Beam loss events detected already in 2015



BCM1L

BCM2L



Beam Halo Monitor (I)

New system: measure machine-induced background (MIB) at high radius (180 cm)

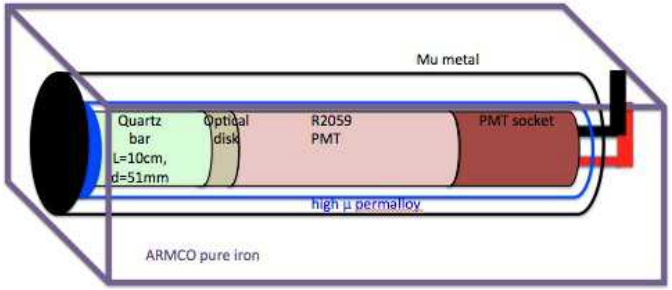
- Charged MIB particles (muons) from incoming beam
- Directional Cherenkov light produced in quartz bar
- Light detected by photomultiplier

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



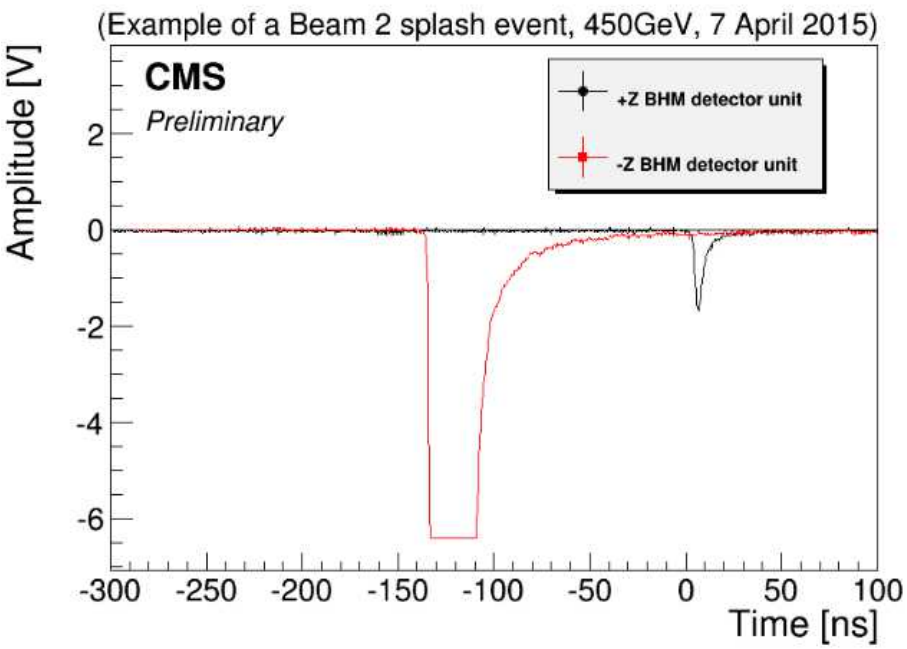
Beam Halo Monitor (II)

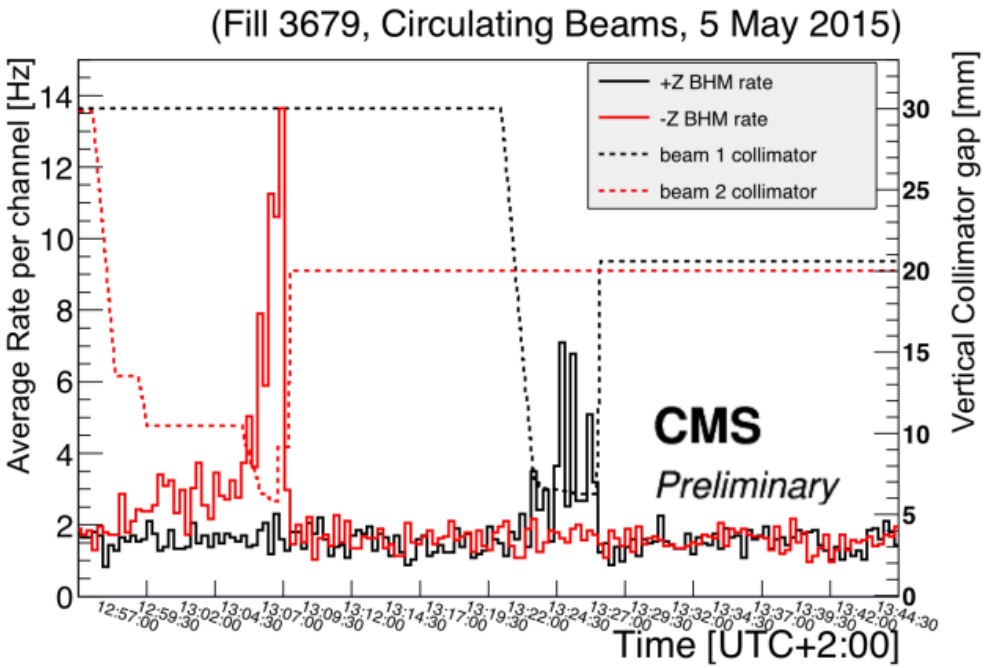
Directionality of signal response demonstrated during “splash” events

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

Beam background events observed during collimator scans

- Hit rate correlates with collimator position





Forward Hadronic Calorimeter: HF

Online luminosity measurement (Run I standard): 3.7% precision

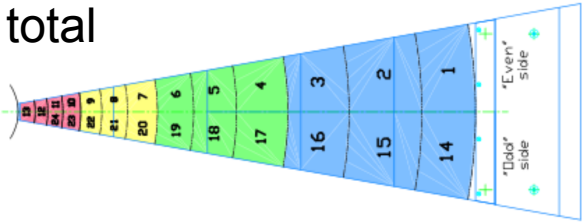
- 864 towers, zero-counting algorithm

Upgrades for Run II:

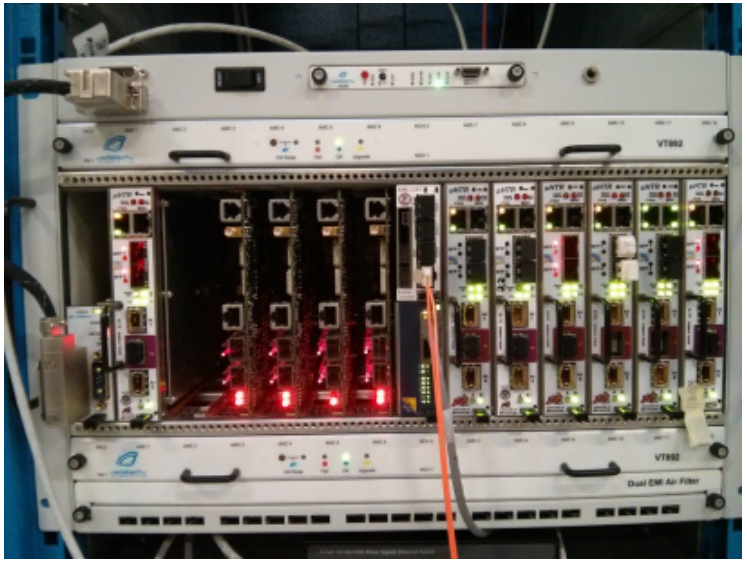
- New photomultipliers
  - Address anomalous signals seen during Run I
  - Multiple channels per PMT
- Move to uTCA backend electronics
  - Readout boards provide bunch-by-bunch occupancy and transverse energy sums
  - Lumi readout independent of CMS DAQ and decoupled from trigger stream

HF wedge

36 wedges in total



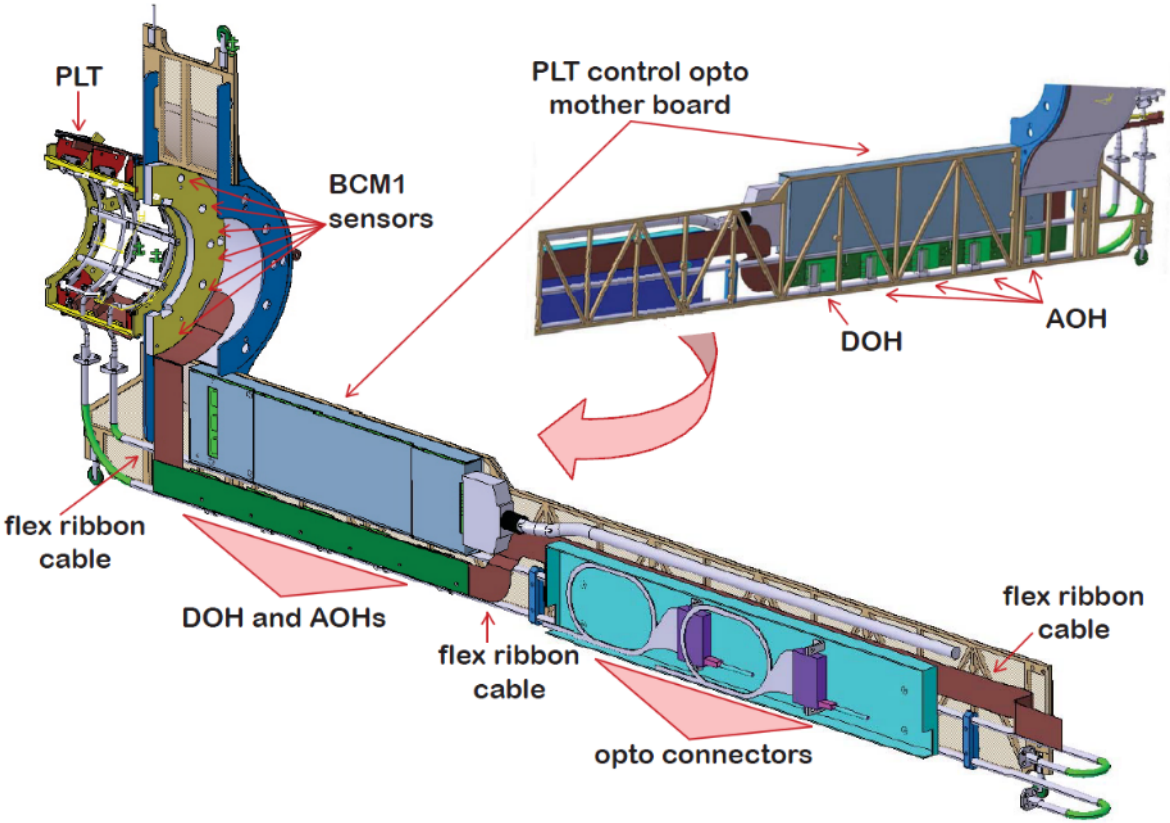
µTCA backend crate

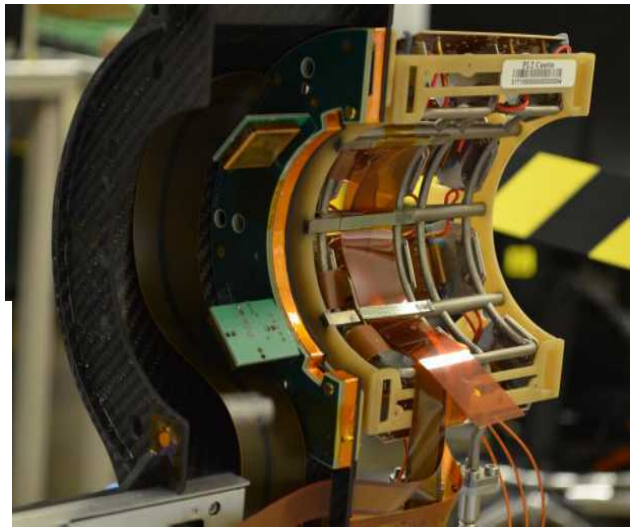


BCM1/PLT carriage

BCM1L, BCM1F, PLT integrated into single structure, 2 per end

- Large, connector-free semi-rigid PCB hosts BCM wiring





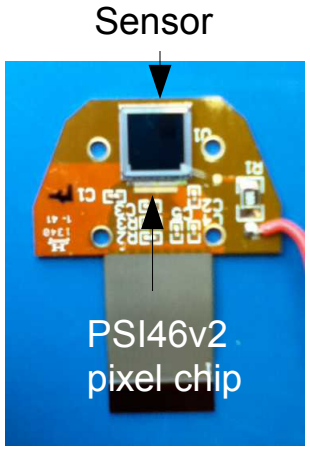
Pixel Luminosity Telescope (I)

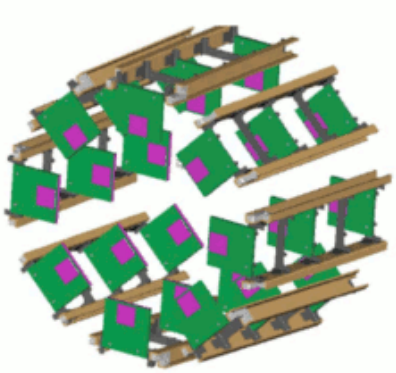
New dedicated standalone luminosity monitor

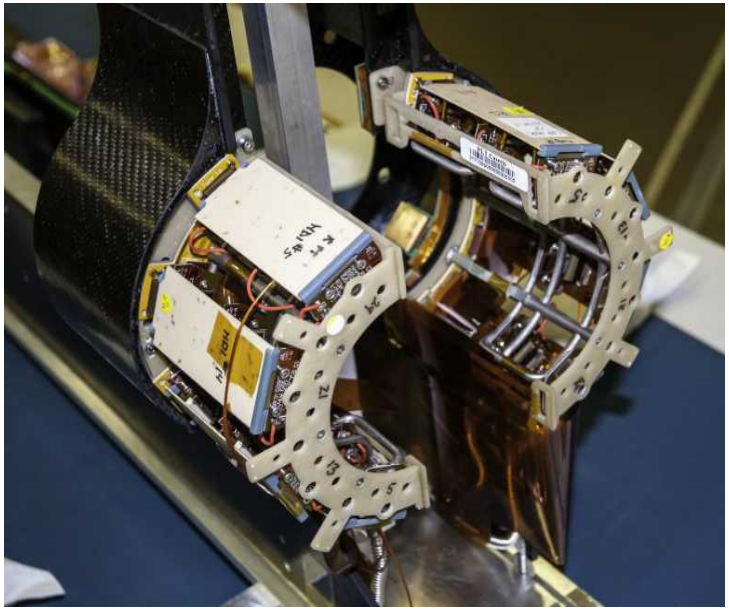
- 8 3-plane silicon-pixel telescopes per end

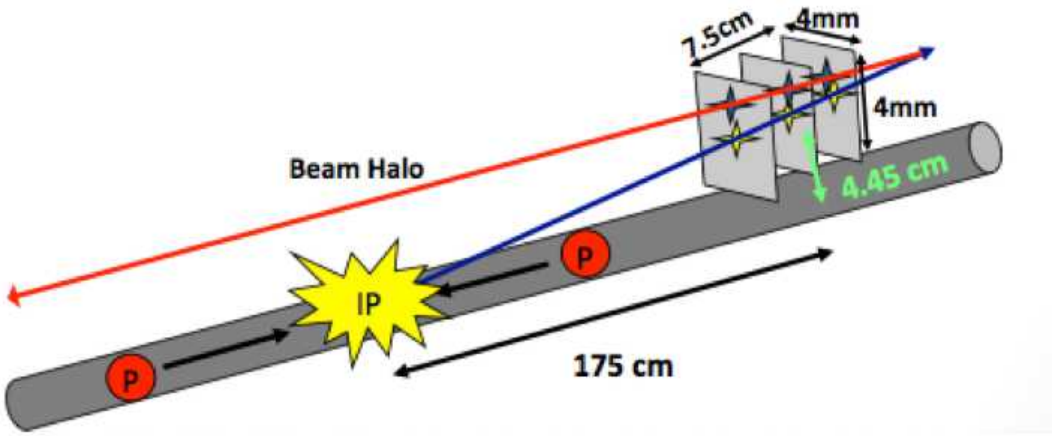
Bunch-by-bunch luminosity: 1% statistical precision at 1 Hz

- Deadtime-free 3-fold coincidences using standard CMS pixel chip
- Full pixel readout: systematics, alignment, background studies, etc.





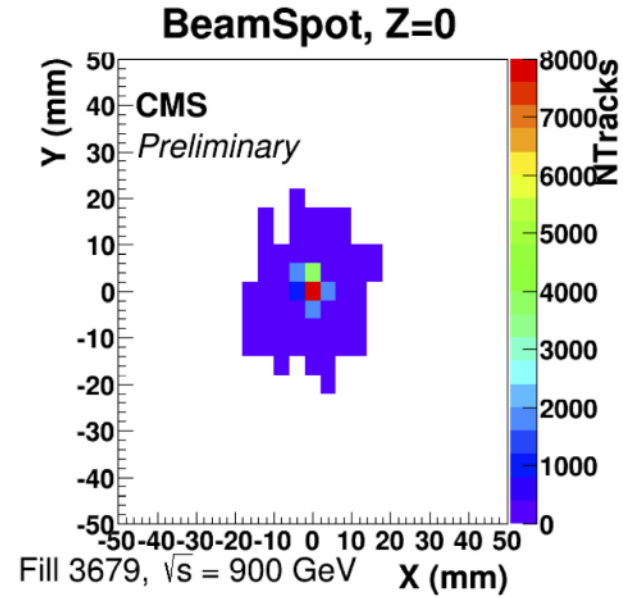




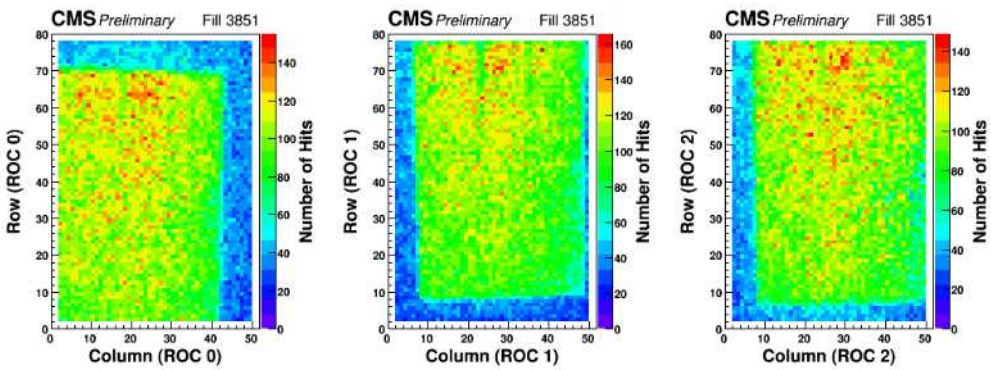
Pixel Luminosity Telescope (II)

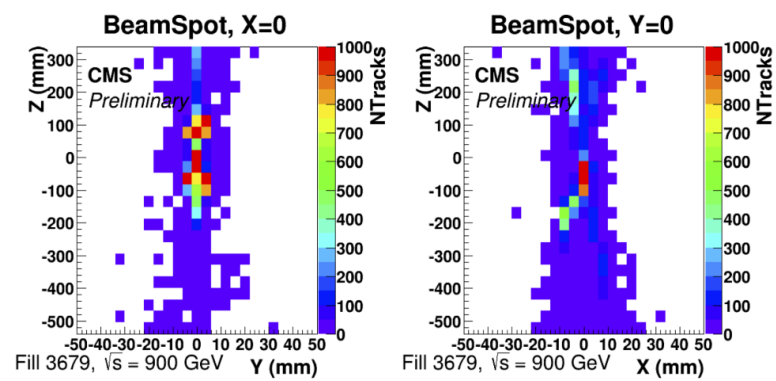
Successfully installed and commissioned earlier this year

- 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





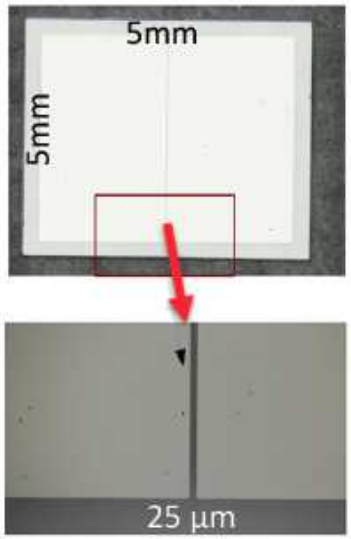
Fast Beam Condition Monitor BCM1F (I)

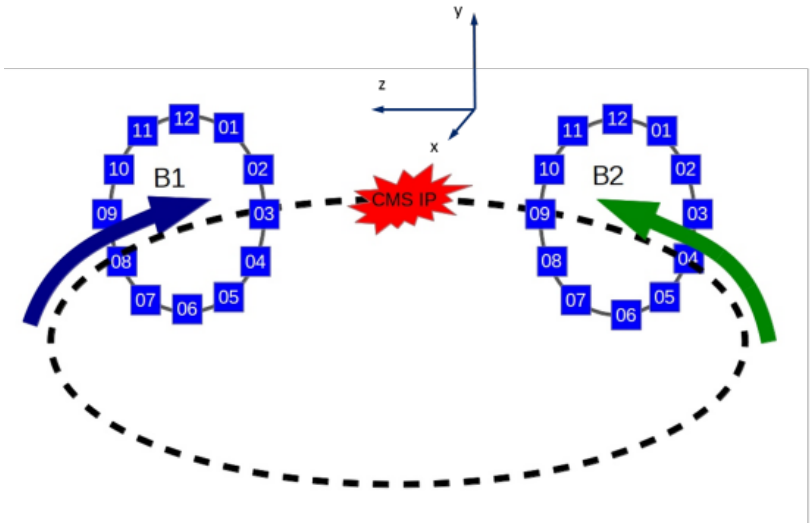
Upgraded system for bunch-by-bunch measurement of beam background flux and collision products

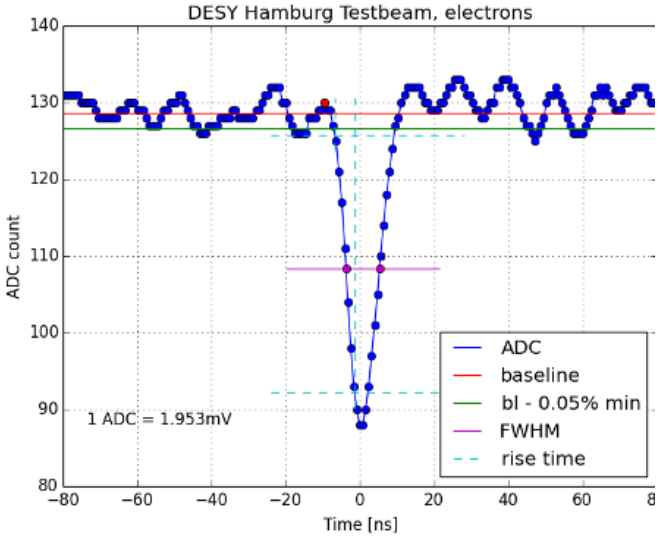
- 24 5mm x 5mm single-crystal CVD diamond sensors (Run I: 8 sensors)

New fast frontend ASIC

- 130 nm technology, fast rise time and recovery







Fast Beam Condition Monitor BCM1F (II)

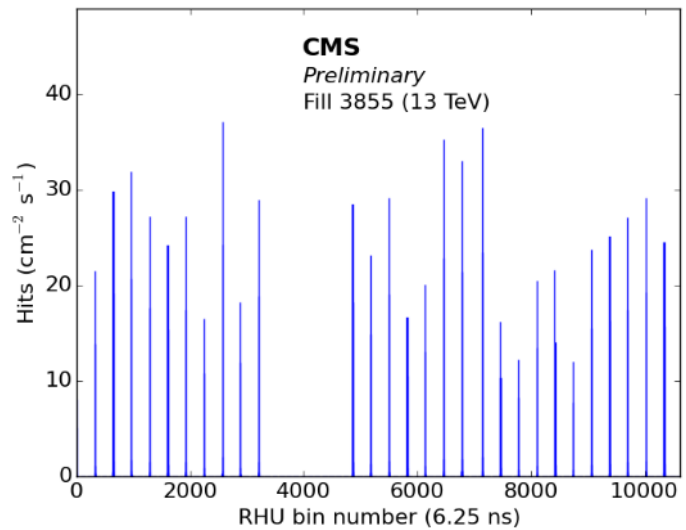
New DAQ system: Realtime Histogramming Unit (RHU)

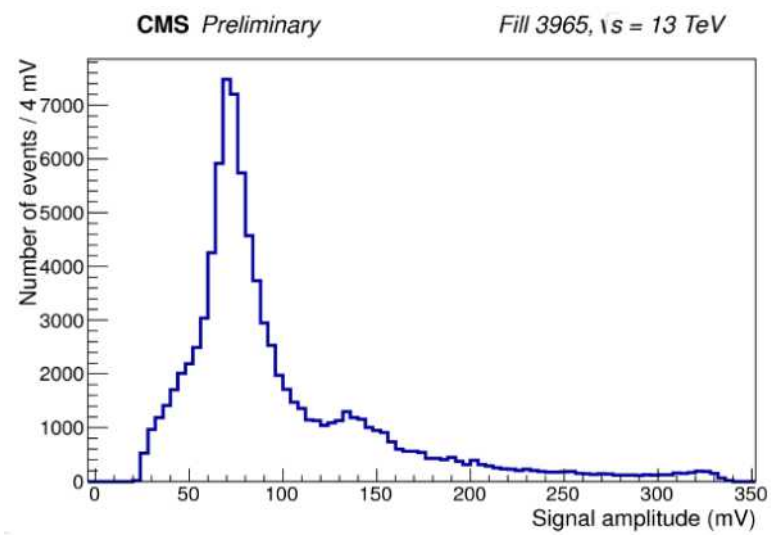
- Deadtimeless full-orbit histograms
- 6.25-ns binning = 4 bins per bunch crossing

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

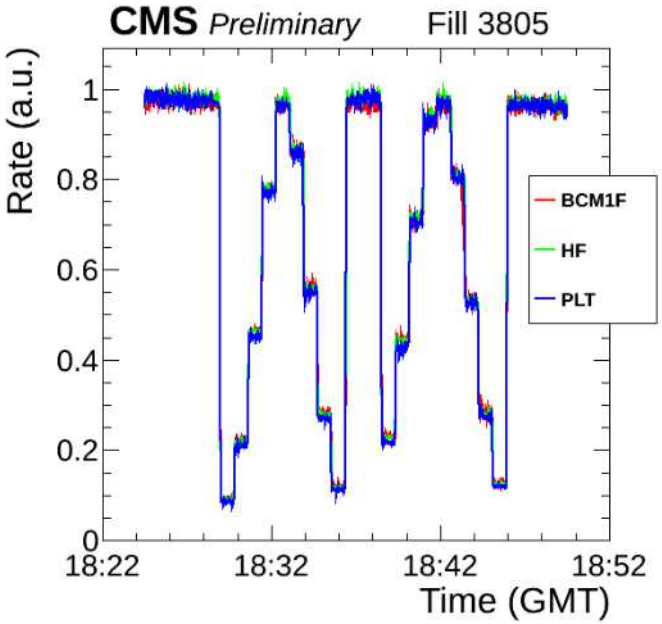
- All track each other well
- Per-bunch measurement

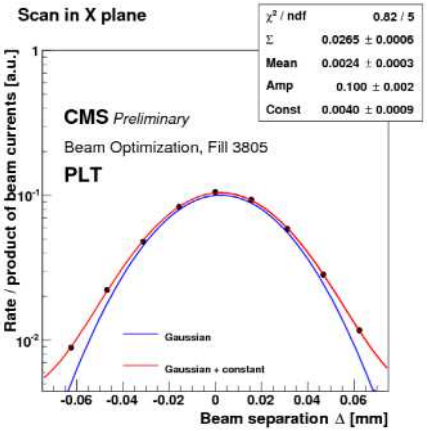
One luminometer "official" lumi provider at a time

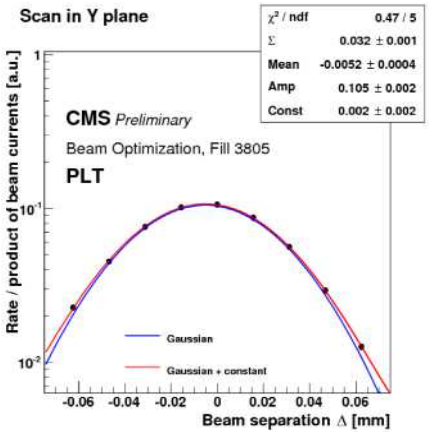
- Others used as cross-check/backup

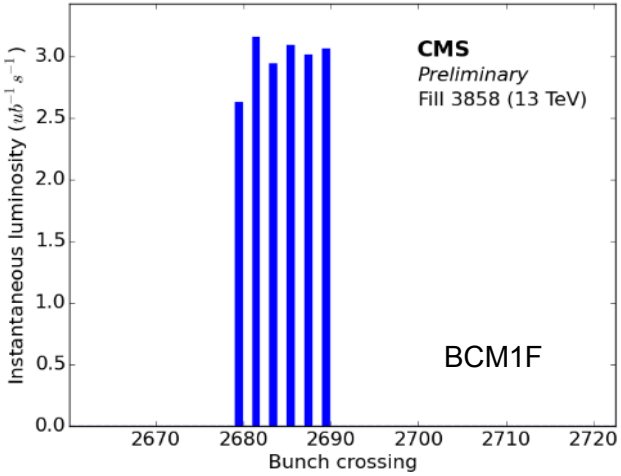
LHC beam optimization scans

- 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