Run II Performance of Luminosity and Beam Condition Monitors at CMS

Jessica Leonard

On behalf of

CMS BRIL

DPG 2016, Hamburg, T 33.1

February 29, 2016

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

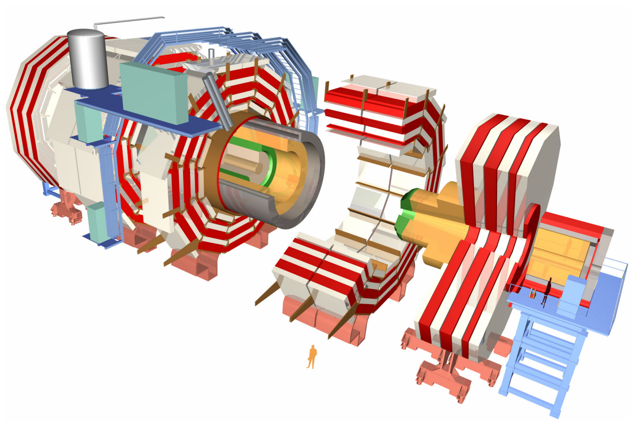
University of Tennessee

Vanderbilt University

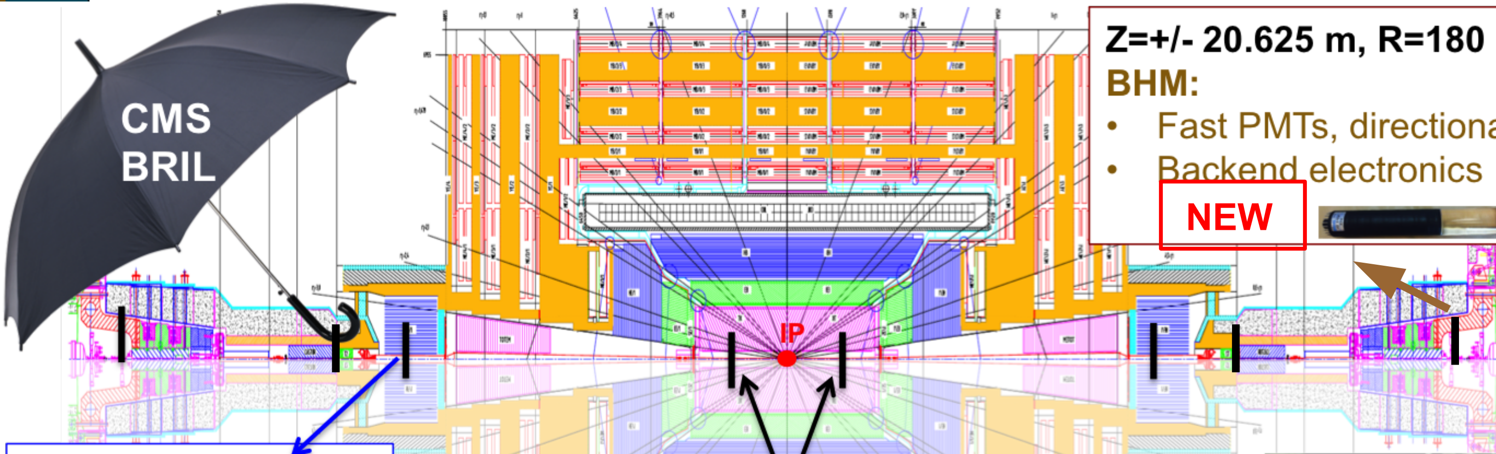
University of Wisconsin

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



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

BHM:

- Fast PMTs, directionality
- Backend electronics

NEW

HF Luminosity:

- Photo-detectors
- backend electronics & BRIL DAQ

Upgraded

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

PLT:

- 48 si-pixel sensors
- Special 40 MHz readout

NEW

BCM1F:

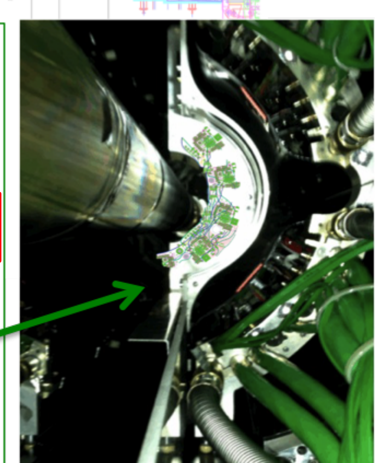
- 24 sCVD diamond sensors, 48 channels
- Fast MIP counter, triggerless readout

Upgraded

BCM1L:

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

Upgraded



Z = +/-14.4m

BCM2L

Upgraded

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

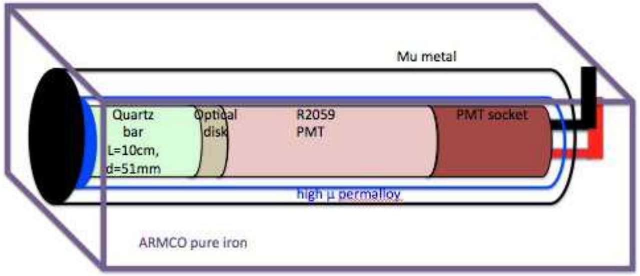
"Golden" locations for maximum incoming-outgoing separation

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

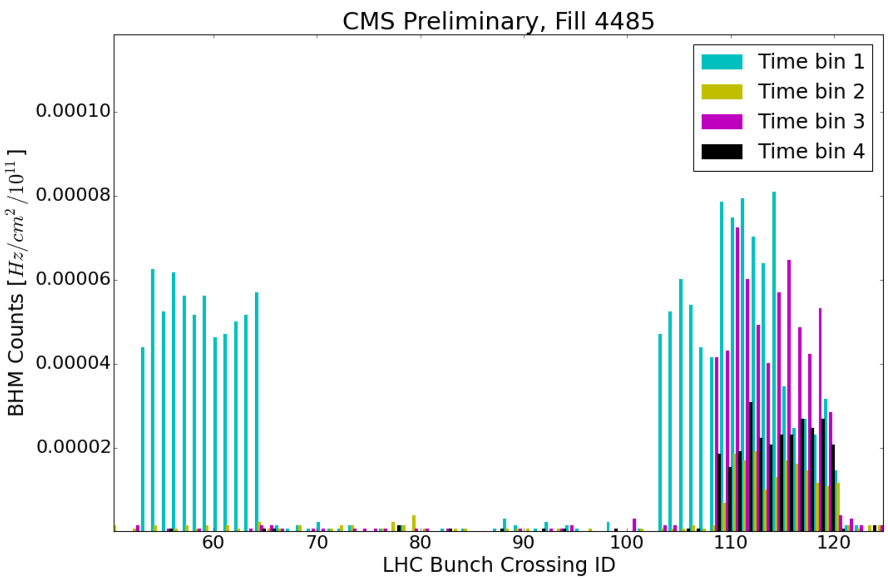
Beam Halo Monitor (II)

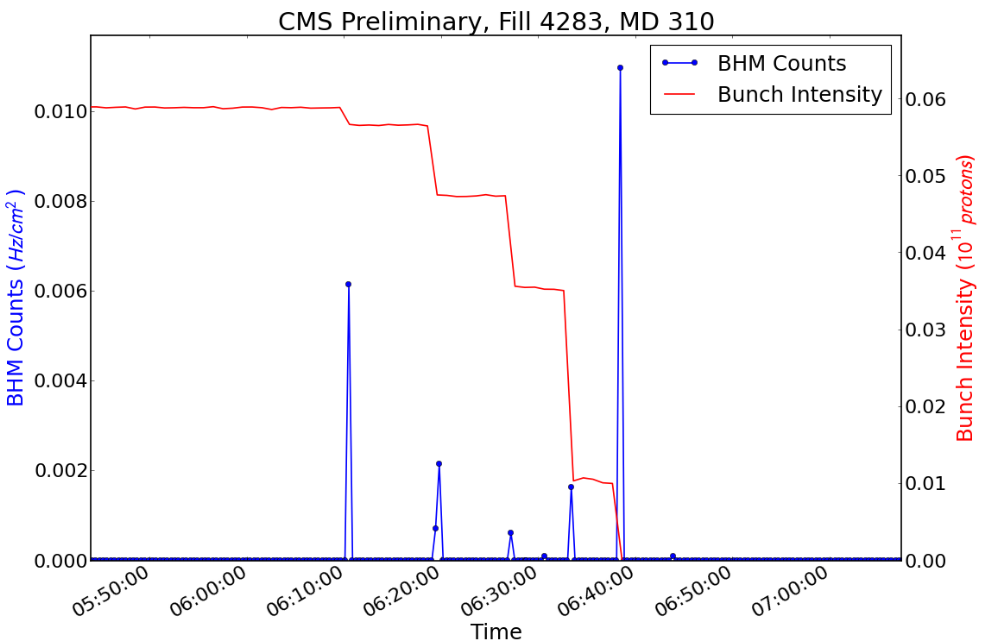
Binning allows for separation between beams

- 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

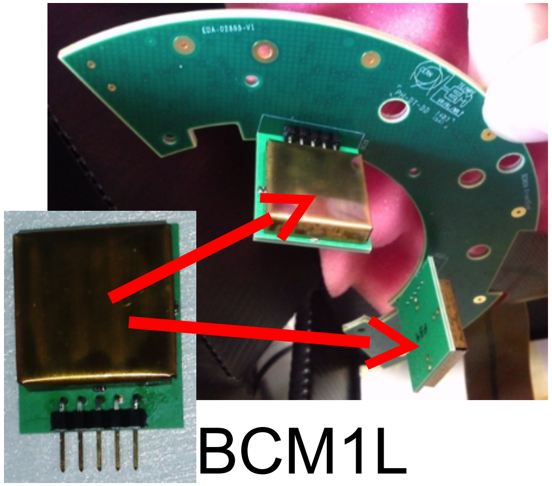
Protect silicon tracking detectors from catastrophic beam loss events

- 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

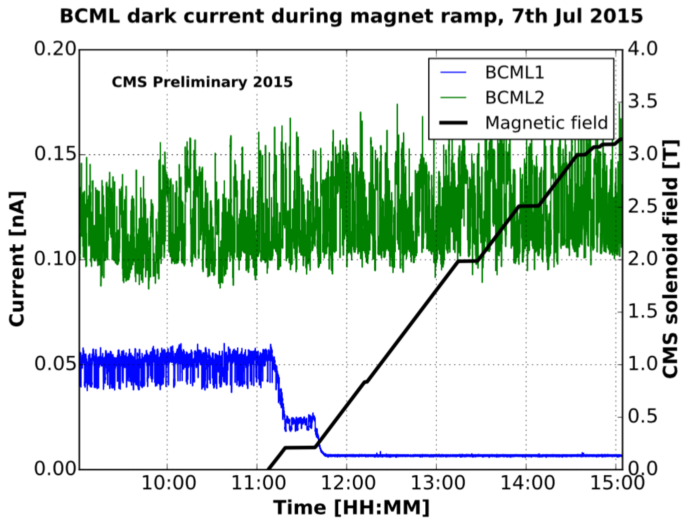
- BCML2 outside magnetic field range



BCM1L

BCM2L

BCML talk later in this session: Radiation damage in BCML diamonds, F. Kassel



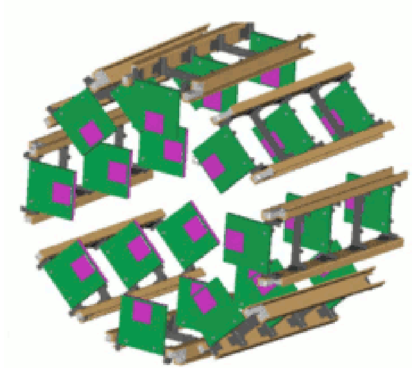
Pixel Luminosity Telescope (I)

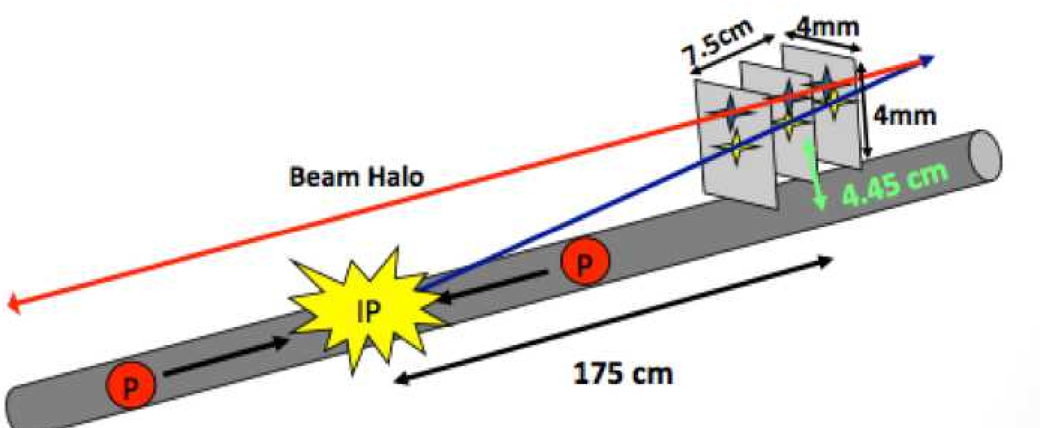
Dedicated standalone luminosity monitor

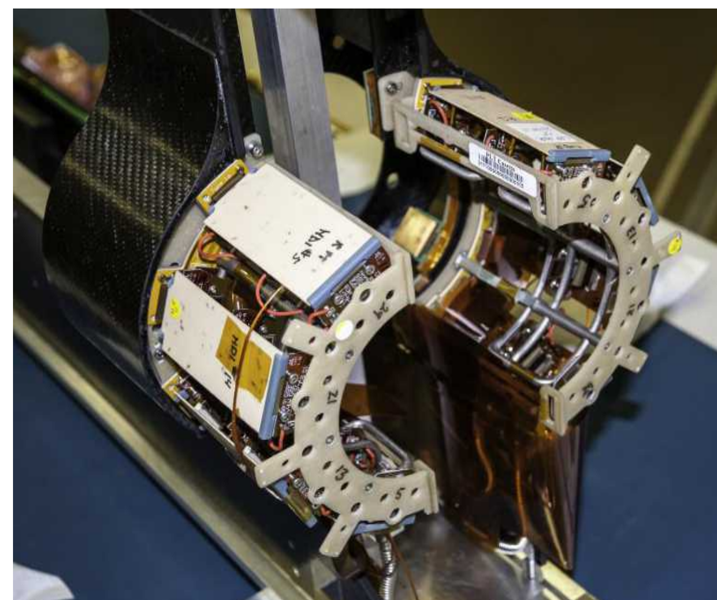
- 8 3-plane silicon-pixel telescopes per end

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.



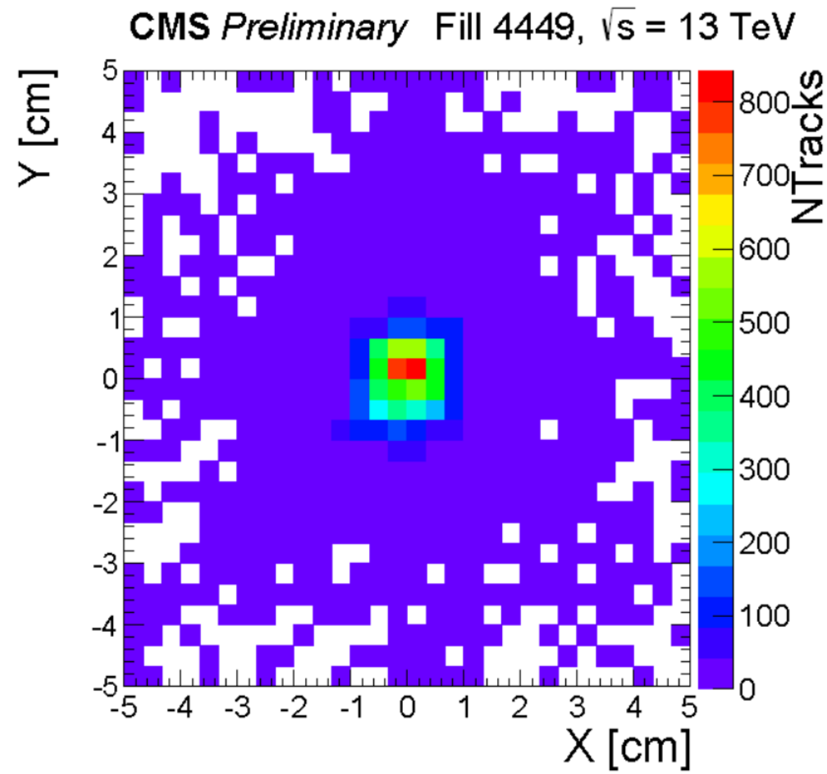




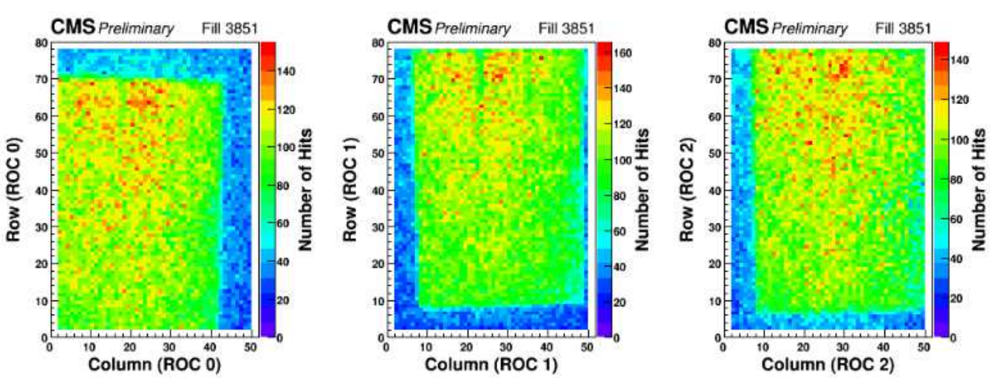
Pixel Luminosity Telescope (II)

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



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

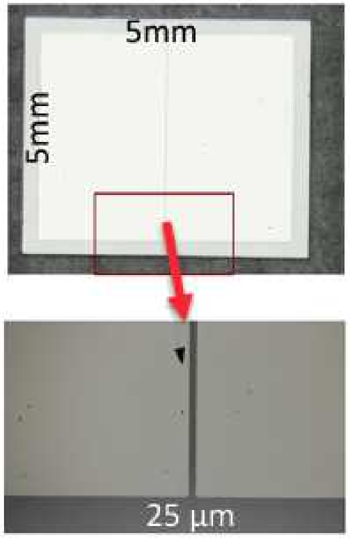
- 130 nm technology, fast rise time and recovery

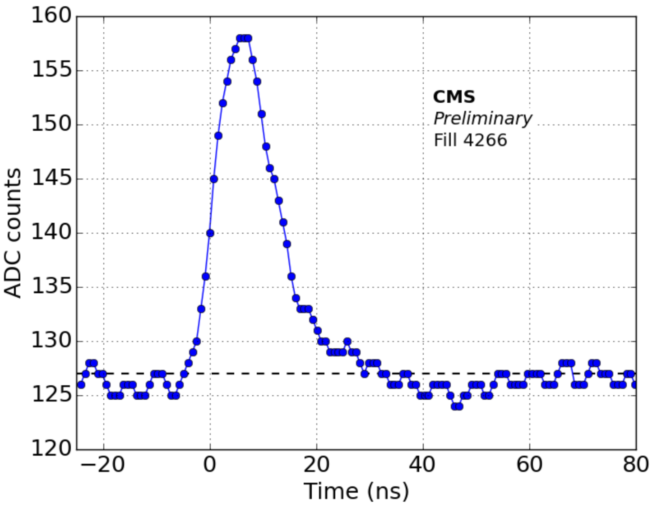
Realtime Histogramming Unit (RHU)

- 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

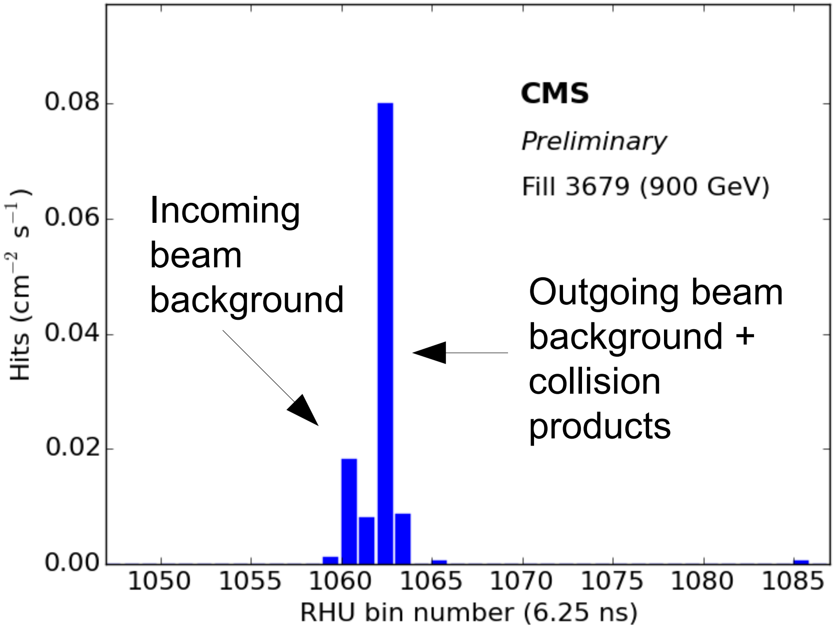
Fast Beam Condition Monitor BCM1F (II)

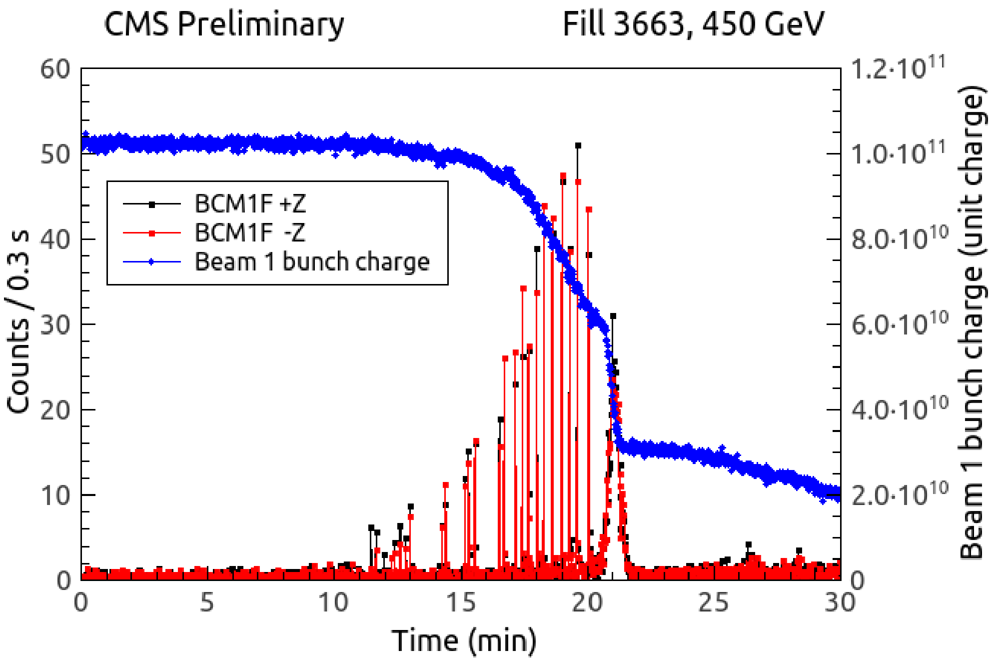
Golden location, histogram binning: separation between beams

- Incoming beam background
- Outgoing beam background + collision products

Machine-induced background measurement

- Detector hit rate corresponds to beam loss





Luminometer Performance

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

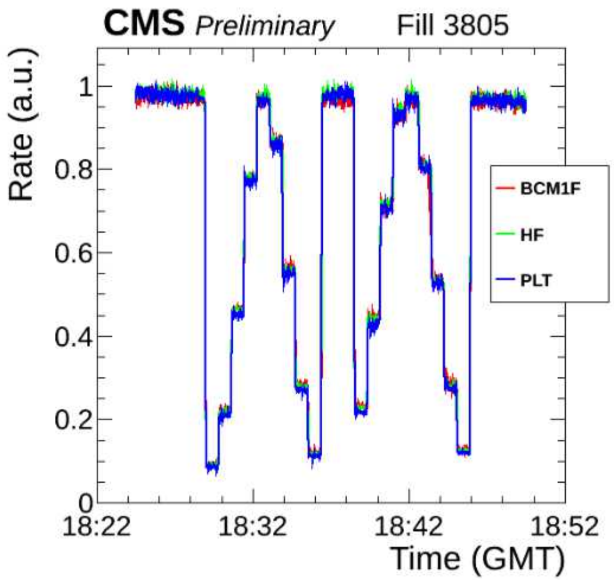
- All track each other well
- Per-bunch measurement

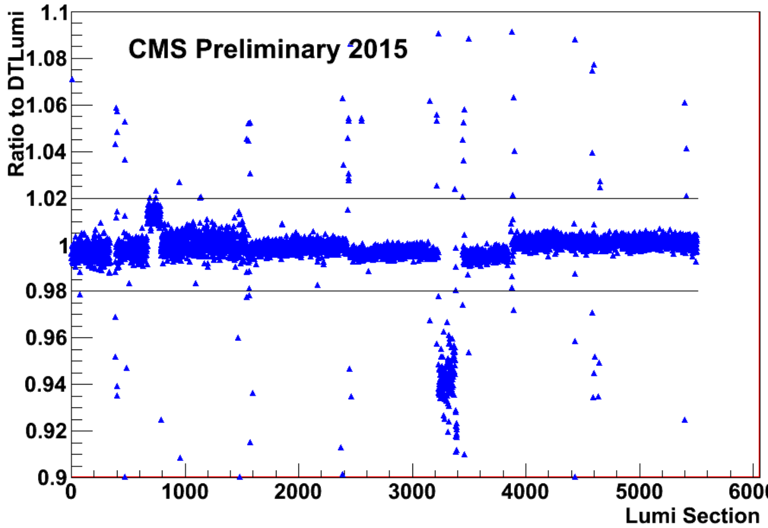
One luminometer "official" lumi provider at a time

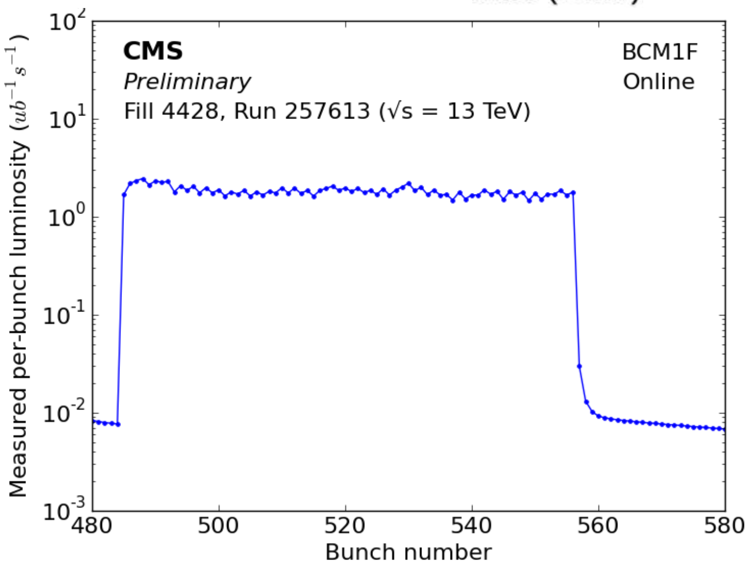
- Others used as cross-check/backup

Other detectors provide additional offline luminosity numbers

- Pixel cluster counting, drift tubes



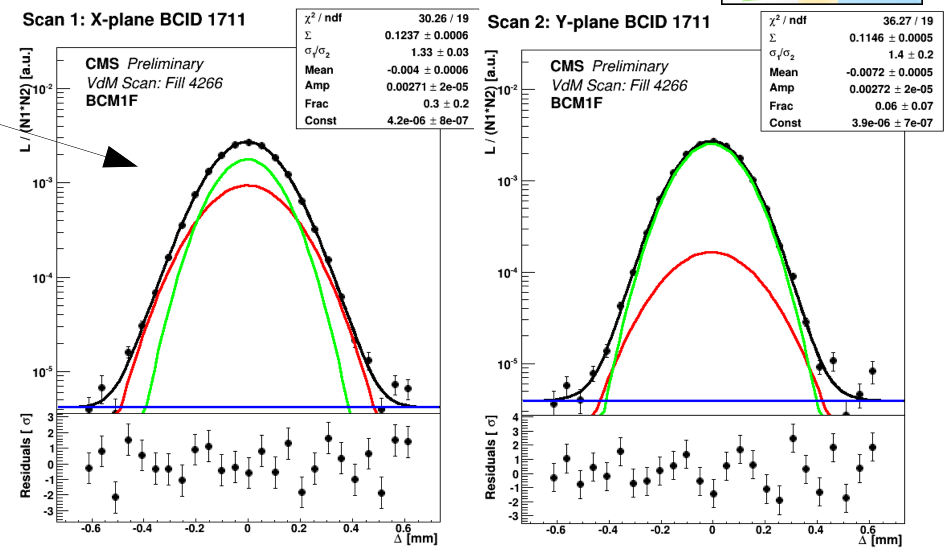




Luminosity Calibration and Uncertainties

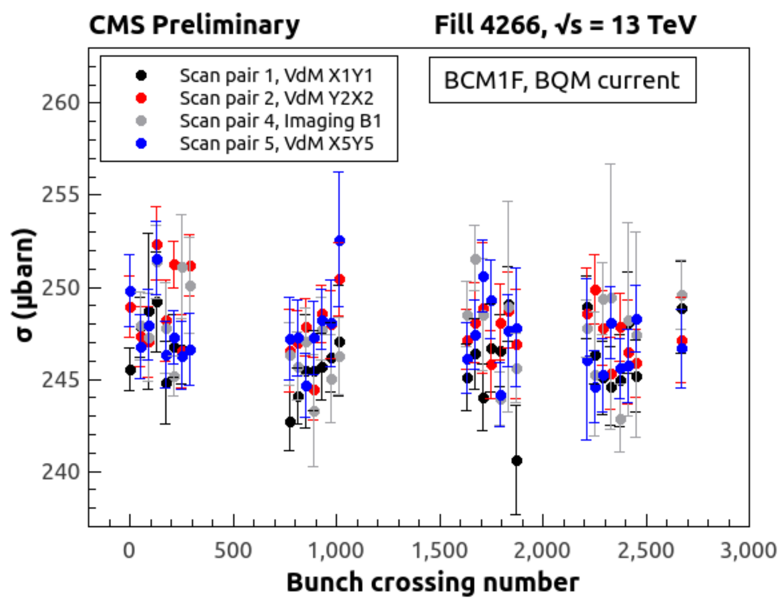
Van der Meer scan provides absolute calibration factor: visible cross section

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



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

Source	Value
50-ns running	
Calibration uncertainty	2.6%
Stability	4%
Total	**4.8%**
25-ns running	
Total	**4.6%**



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