Beam induced backgrounds at the HL-LHC : CMS perspective

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ON BEHALF OF THE CMS AND ATLAS COLLABORATION

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Beam Induced backgrounds (BIB)

- BIB can arise from
  - Interactions of the beam with either the residual gas in the beam pipe
  - Or the collimators that define the beam aperture

- Different types of BIB based on the source
  - Inelastic beam-gas interactions are the dominant source near interaction region
  - Beam-halo particles are produced when off-orbit components of the beam scrape one of the collimators in the cleaning sections of the LHC
    - Resulting collision products are absorbed downstream by the tertiary collimators (TCT)
    - Products of the nuclear-electromagnetic showers started in the TCT can reach the CMS cavern

BIB in HL-LHC

- Divide them into different types based on the source
  - Elastic beam gas interactions that occur anywhere around the ring can make several turns before they hit a collimator.
  - When they interact with the TCT, they can produce particle showers that are similar to produce by beam halo

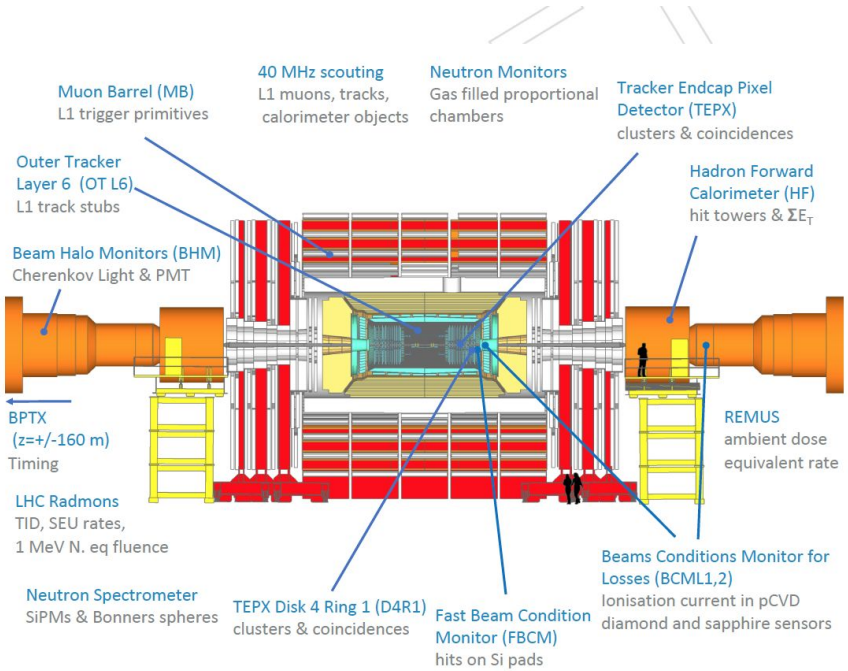
- Beam Halo is two or three orders of magnitude less than beam gas (for LHC)
  - Depends on the machine performance and collimator settings
  - Higher when beta* small because of tighter relative TCT collimator settings to protect losses in the triplets
  - **Expected to be higher for HL-LHC**

BIB measurement plans

- CMS has published the "*The Phase2 upgrade of the CMS Beam Radiation, Instrumentation and Luminosity Detectors: Conceptual Design*" https://cds.cern.ch/record/2706512?ln=en
- Now working on the Technical Design Report
- Techniques for measurement and locations

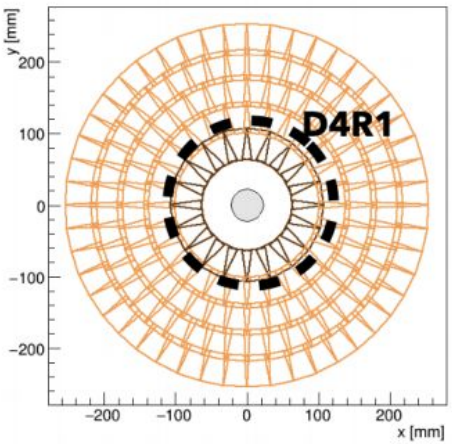
BIB measurement plans for HL-LHC

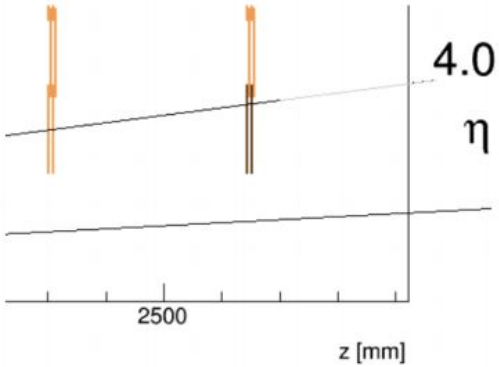
- To perform BIB measurements
  - Continue to use the Beam Hal Monitor (BHM) from Phase1
  - In addition:
    - use CMS Inner tracker Endcap Pixel Detector (TEPX) disk 4 ring 1 (TEPX D4R1)
    - FBCM (Fast Beam Condition Monitor)

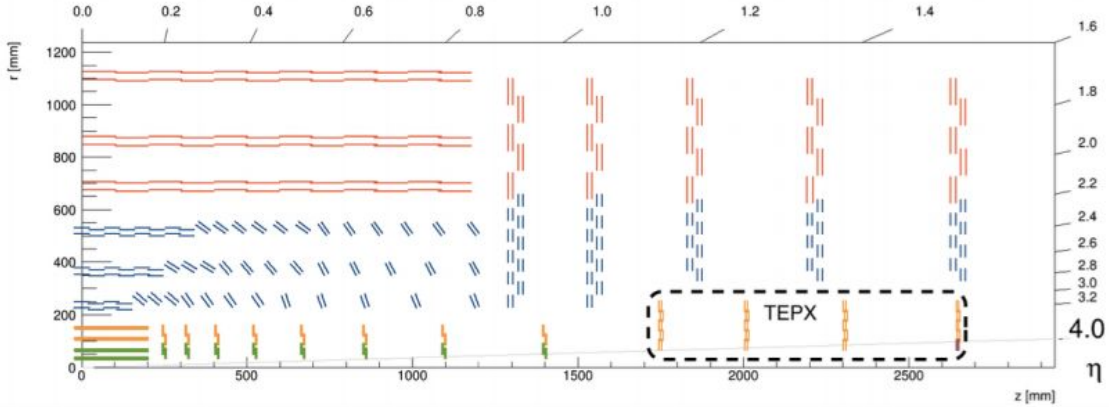


D4R1 FOR LUMINOSITY & BIB

- Disk 4 Ring 1 is beyond eta=4 and thus not particularly useful for tracking
  - dedicate this part of the detector entirely to luminosity (&BIB) with full read-out BW (750 + 75 ++ kHz)
  - 290 cm² per side (of which 100 cm² are module overlaps)
- make D4R1 look like a streaming detector to the outside world
  - allows to measure lumi & BIB during the whole LHC machine cycle
  - several major implications on trigger & clocking scheme
    - a second set of independent local lumi (&L1) triggers
    - dedicated back-end with control stream based on LHC clock
    - see next slides
  - requires completely independent services



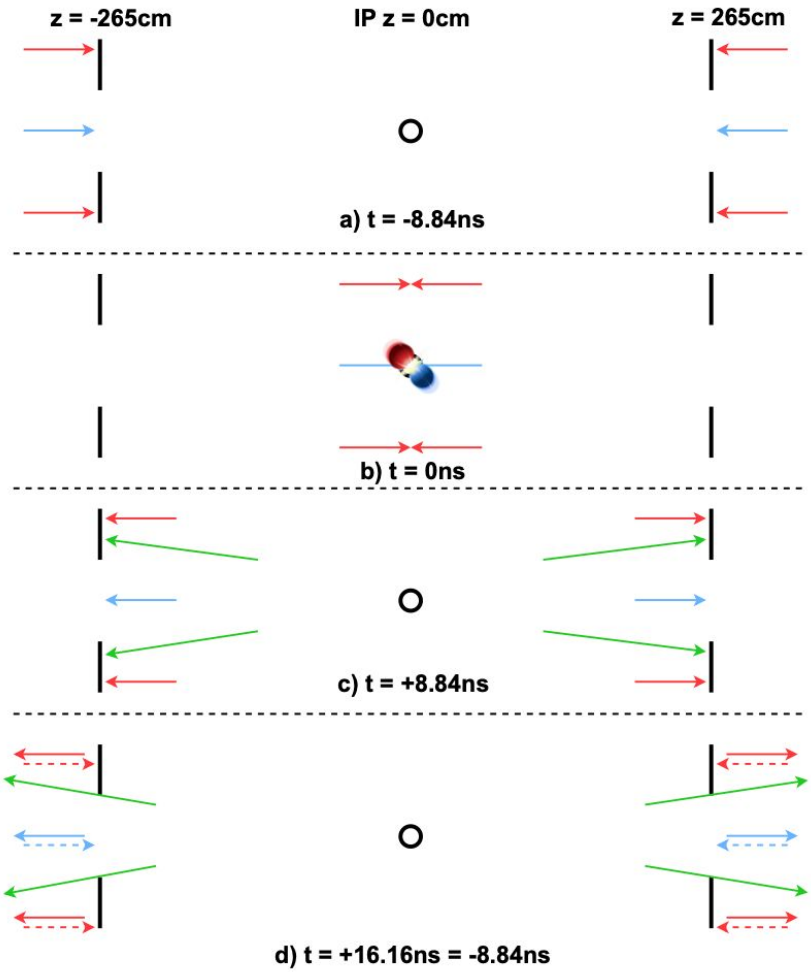




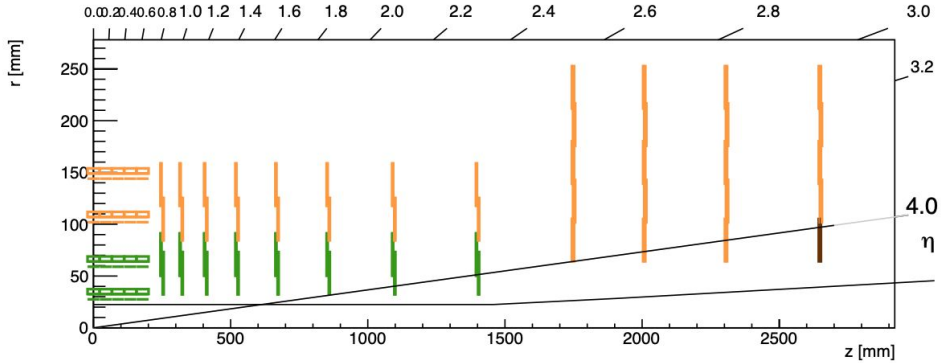
TEPX D4R1

Beam-induced background perspective

- Measure before the first colliding bunch in a train (to exclude collision products and albedo)
- Appropriate time tuning to measure both luminosity and BiB



Tracker endcap pixel detector (TEPX)

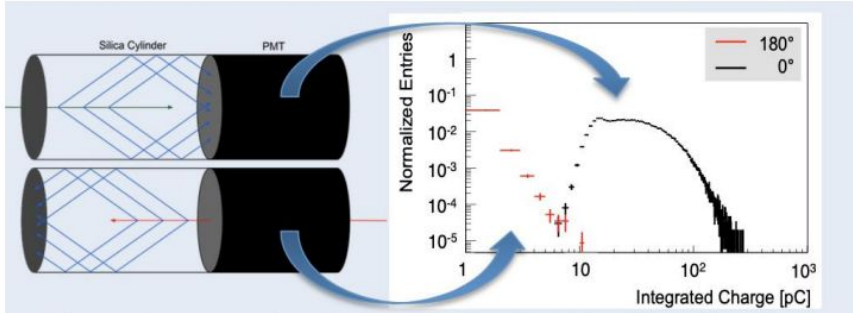


Hit counting with directional information at high radius

- Exploit direction or topology of BIB event
- See fronted design “An innovative Beam Halo Monitor system for the CMS experiment at the LHC : Design Commisioning and First Beam results thesis http://cds.cern.ch/record/2231966?ln=en
- See backend electronics focus “The new Beam Halo monitor for the CMS experiment at the LHC” http://cds.cern.ch/record/2124191

BHM Hit counting with directional information

The BHM detectors, placed around the forward shielding



Forward events give high readout values, backwards event are suppressed.

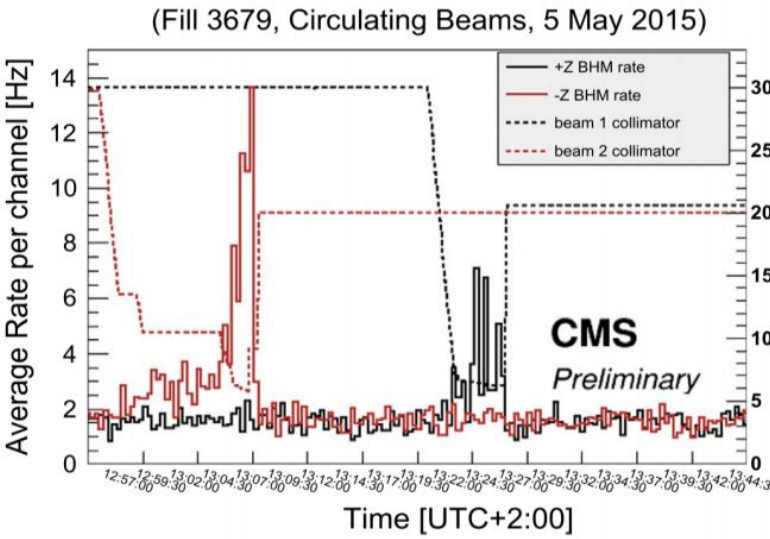


Fig. 9. Signals measured in BHM due to beam loss created in collimator scans tog with respective collimator positions.

BHM Hit counting with directional information

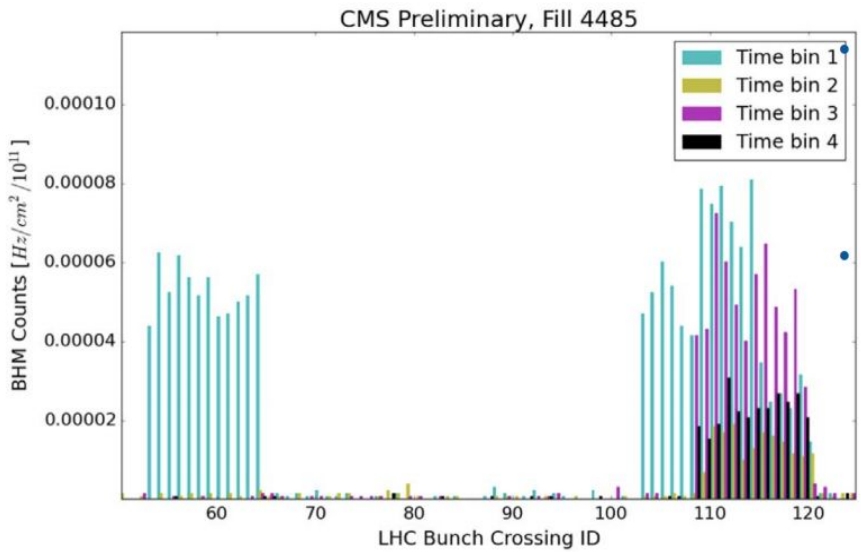


Fig. 6. Timing histogram obtained with BHM showing a non-colliding and a colliding bunch train.

Location of Z ~ 20 m and excellent timing (Cherenkov + 4 samples per BX in backend electronics)

Allows for excellent sensitivity to incoming BIB with very little background to collision products and albedo

- Comparable rates

- Baseline, BX/BX measurement of the Halo averaged over many LHC turns, e.g. per LS
- Compared to hit measurements, directional measurements allow for increased BIB relative sensitivity
  - Can study mechanism where BX/BX loss patterns are expected, like electron cloud
- Trigger not in the baseline, would require effort in the backend electronics

Conclusions

- Presented the Beam induced background sources at the HL-LHC from the CMS perspective
- Discussed measurement plans of the CMS using the proposed detectors at the low and high radius
- Low radius BIB measurement
  - TEPX D4R1 (triggered) + FBCM (triggerless) (Discussed)
  - First BX of incoming bunch
  - Coincidence counting
- High radius BIB measurement
  - BHM exploiting directional response of detector and fast timing
- Exploring:
  - parallel muon stubs from Endcap Muon Trigger Finder for both BIB monitoring and trigger high purity BIB events

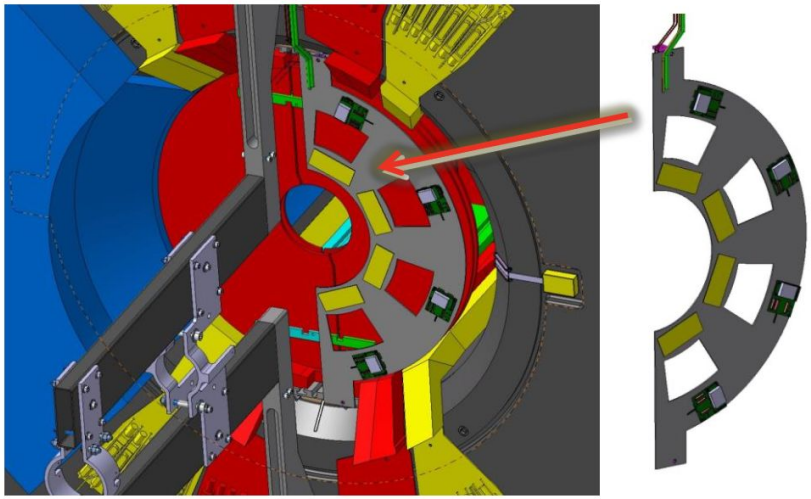
Thank You

FBCM - Fast Beams Conditions Monitor

Location and environment

- At z= ± 283.5 cm
  there is a 14-cm space
- 8.5 cm < R < 21 cm, $|\eta| \sim 3.5$
- 84 sensors per quarter

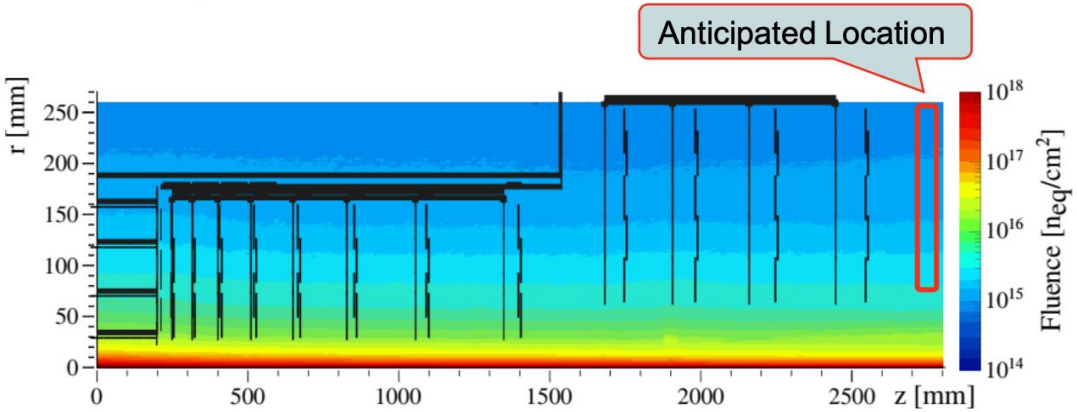
A quarter of FBCM as an illustration



- Radiation environment:
  - For R > 12 cm
    - ~3.5 hits/cm^2 per bunch-crossing

@ 3000 fb^{-1}

- TID < 200 Mrad
- 1MeV neq fluence < 3.4x10^{15}



Integrated particle fluence in 1 MeV neutron equivalent in silicon per cm^2, with total integrated luminosity of 3000 fb^{-1} of pp collisions at $\sqrt{s}$ = 14 TeV, using CMS FLUKA v3.7.2.0.
Ref: https://cds.cern.ch/record/2272264