Beam induced backgrounds at the HL-LHC: CMS perspective

BHAWNA GOMBER
UNIVERSITY OF HYDERABAD, INDIA
ON BEHALF OF THE CMS AND ATLAS COLLABORATION

CMS Compact Muon Solenoid

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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

- 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 Halo 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)

- $z = -265\text{cm}$
- $IP\ z = 0\text{cm}$
- $z = 265\text{cm}$

- $a) t = -8.84\text{ns}$
- $b) t = 0\text{ns}$
- $c) t = +8.84\text{ns}$
- $d) t = +16.16\text{ns} = -8.84\text{ns}$
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 Commissioning 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.

(Fill 3679, Circulating Beams, 5 May 2015)

Average Rate per channel [Hz]

Time [UTC+2:00]

Fig. 9. Signals measured in BHM due to beam loss created in collimator scans top with respective collimator positions.
BHM Hit counting with directional information

Location of $Z \sim 20$ 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 $z = \pm 283.5$ cm, there is a 14-cm space
- $8.5 \text{ cm} < R < 21 \text{ cm}$, $|\eta| \sim 3.5$
- 84 sensors per quarter

**Radiation environment:**
- For $R > 12$ cm
  - $\sim 3.5 \text{ hits/cm}^2$ per bunch-crossing

@ 3000 fb$^{-1}$
- TID $< 200$ Mrad
- 1MeV neq fluence $< 3.4 \times 10^{15}$

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](https://cds.cern.ch/record/2272264)