THE CMS BEAM HALO MONITOR AT LHC

IMPLEMENTATION AND FIRST MEASUREMENTS

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Introduction The increase in beam energy and luminosity in the LHC Run II also meant an increase in ***Machine Induced Background*** (MIB) for the experiments. The Beam Radiation Instrumentation and Luminosity (BRIL) project designed, built and currently operates detectors that measure Luminosity and MIB in several regions of the CMS experiment [1]. Among the MIB detectors are instruments designed for protection of the sensitive inner silicon detectors of CMS from severe beam loss events and others that detect when the MIB reaches levels that would interfere with data taking efficiency. The Beam Halo Monitor (BHM) [2], shown here in the background, is the outermost such detector, and it is sensitive to beam gas interactions happening upstream of CMS as well as beam halo interactions with the upstream collimators.

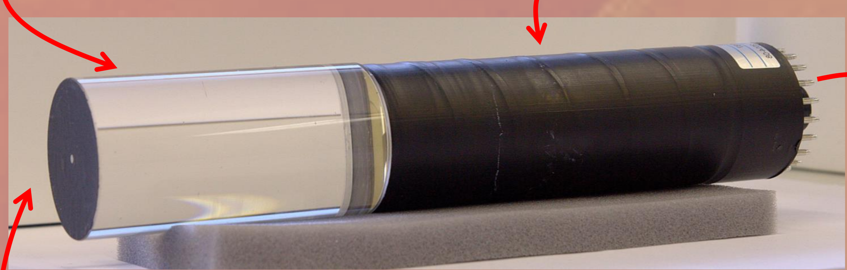
Take a step back!

The Detector The BHM has to identify MIB particles among a large flux of particles coming from *pp*-collisions. A few key differences allow their discrimination:

- The MIB flux is dominated by muons, while a significant fraction of the pp-collision products is neutral.
- The MIB originated from the incoming beam and the *pp*-collision products travel in opposite direction. MIB comes from the left in this poster...
- The MIB and the majority of *pp*-collision products are out of time in specific locations.

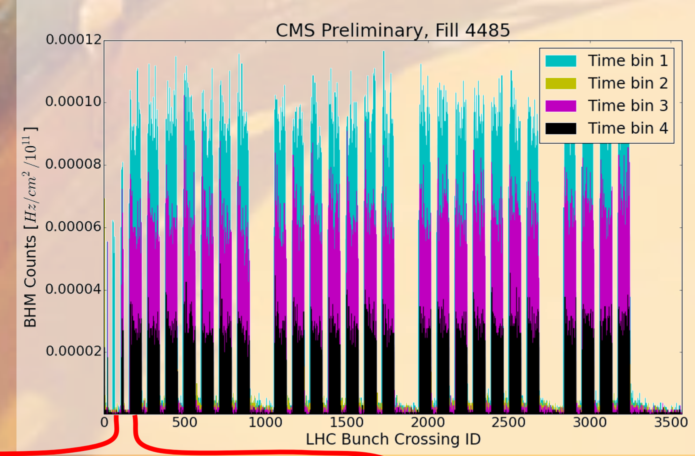
A ***Cherenkov detector*** can use all these characteristics, since Cherenkov radiation is emitted promptly and in a specific direction with respect to the particle trajectory.

The BHM is composed of forty detector units placed around the CMS rotating shielding, at a radius of 1.8m and a distance of 20.6m from the Interaction Point. A BHM detector unit is composed of a synthetic quartz cylinder, 100mm long and 52mm in diameter, acting as Cherenkov radiator, directly coupled to a fast, UV-sensitive photomultiplier tube.

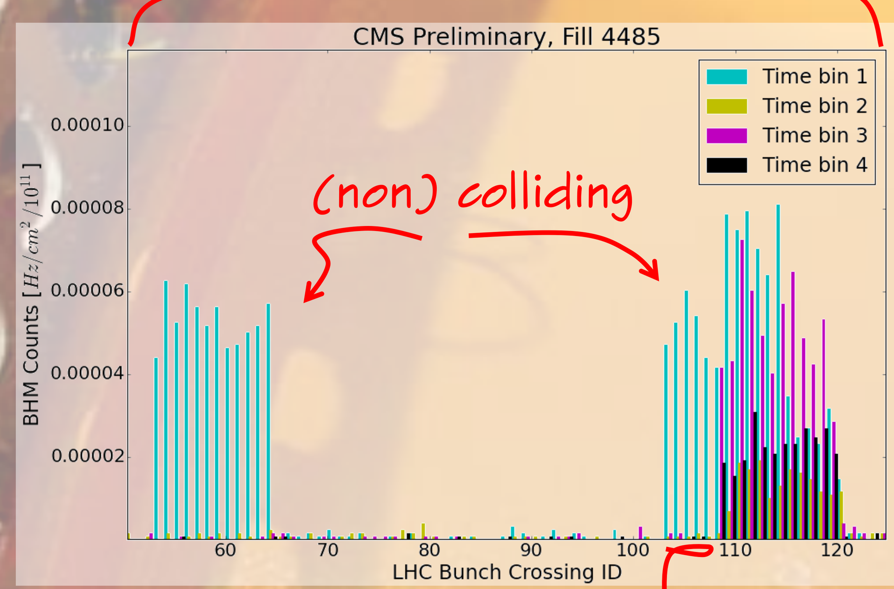


This goes inside the blue tube

Particles travelling from the quartz towards the PMT emit Cherenkov light that reaches the photocathode. Particles travelling in the opposite direction also emit light, but this is instead absorbed by a layer of black paint applied to the free face of the quartz. These elements are enclosed in a three layer shielding to protect the PMT from the residual field of the CMS solenoid and to absorb the large flux of low energy particles present in the experimental cavern. The ***μTCA***-based readout electronics [3] is located in the service cavern.

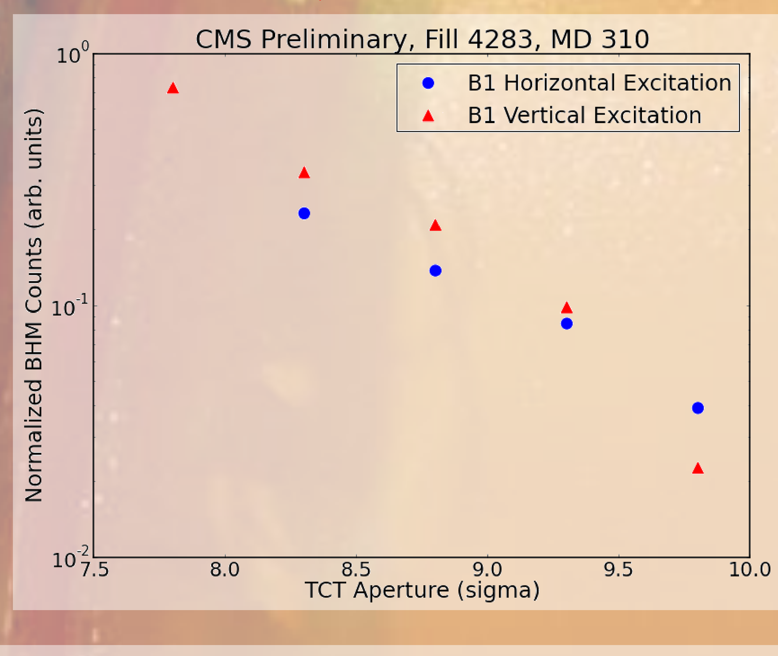


Rate calculation Both timing and amplitude are used for the discrimination of MIB. One BX is subdivided into four time slices; the MIB is contained within one such slice (shown in cyan), while collision products are distributed over all slices, due to variations in their time of flight.

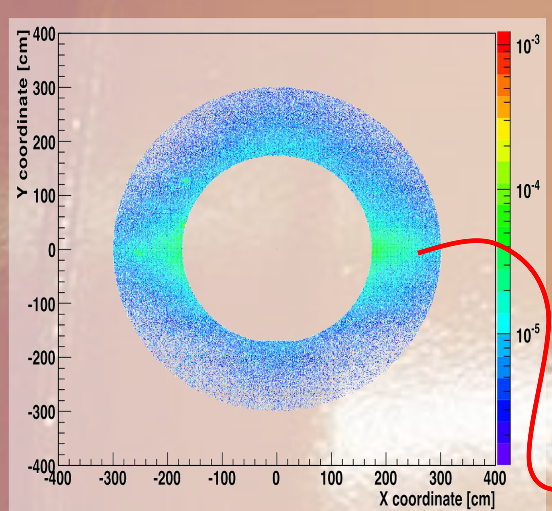


There is a large difference in the proportion of collision products to MIB within a bunch train. For N consecutive colliding bunches, the BHM will measure 6 which contain only MIB hits, N – 6 which contain hits from both MIB and *pp*-collisions and a further 6 with only collision hits. Software corrections, calculated using these last 6 bunches in each train, are then applied to the MIB time slice counts in the middle of the train to subtract the contamination from collision products.

Particles from collisions arrive later: 2 d(BHM, IP5) / c / 25 ns ~ 6 BXs

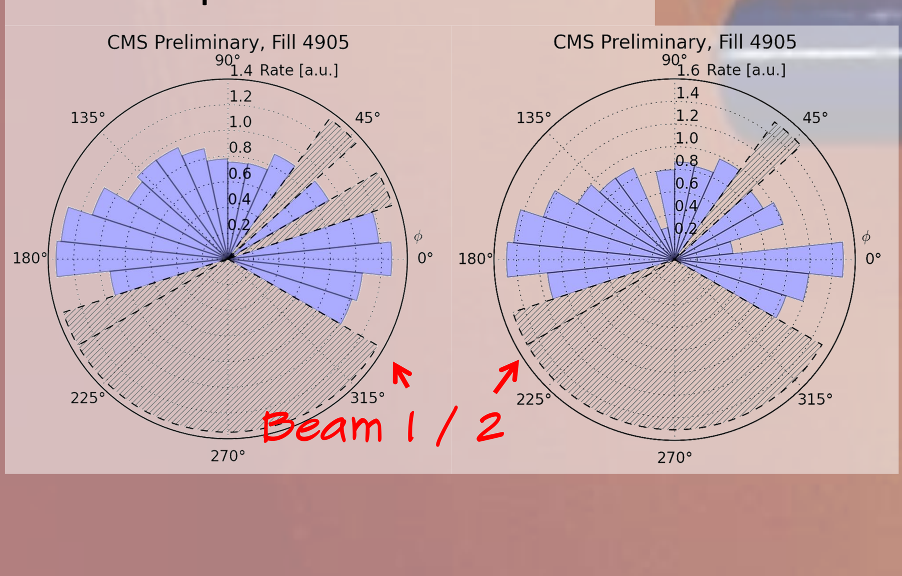


Collimator scans As part of the LHC Machine Development 310, pilot bunches were excited provoking beam losses, while LHC collimators, including the Tertiary Collimators (TCT) adjacent to CMS, were adjusted across a wide range of apertures. An approximate exponential dependence of the BHM rates with collimator aperture is observed, consistent with expectations. One data point corresponds to one beam loss event, and is normalized with the total loss upstream of the TCTs.

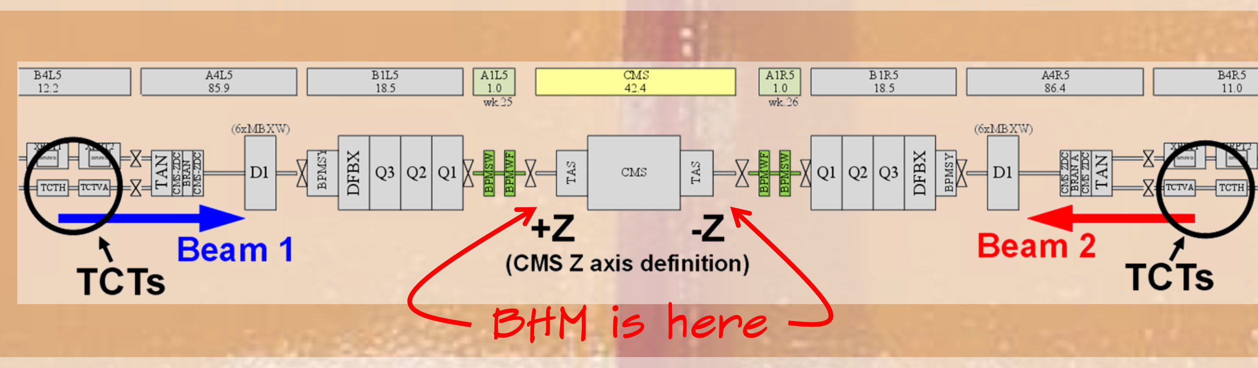


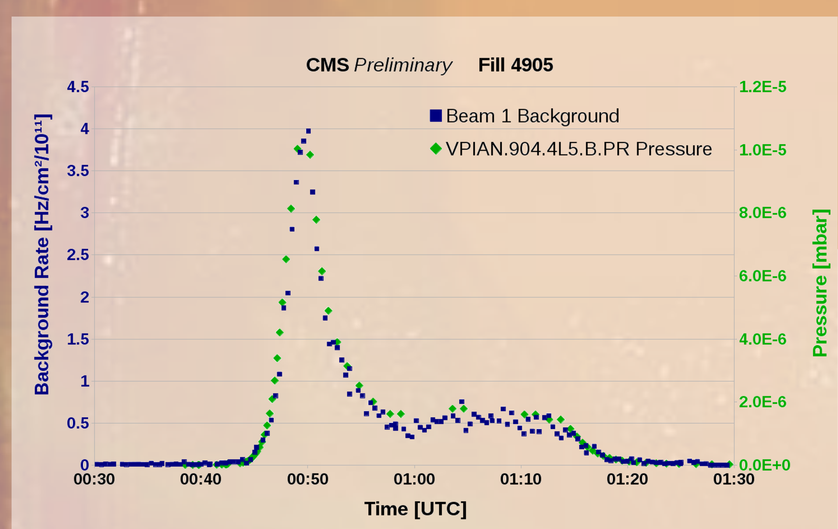
This one sees the highest flux

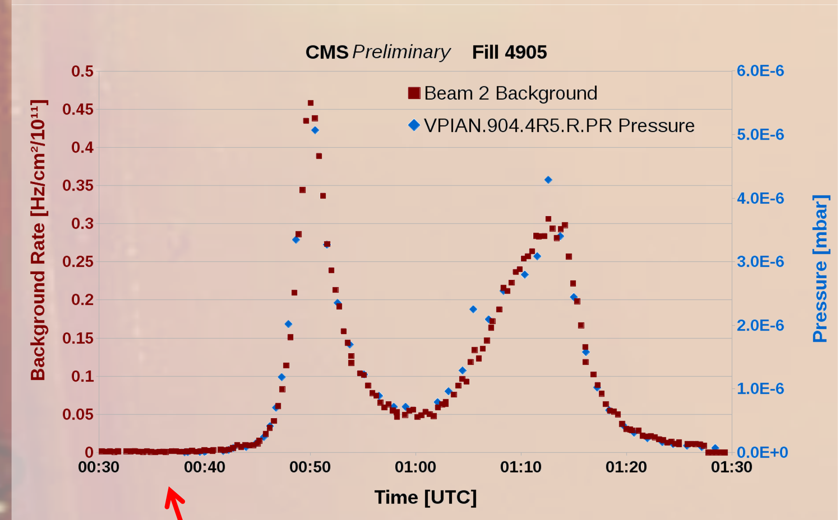
Angular Distribution The shape of the LHC tunnel and beamline elements dictates the angular distribution of MIB around the beamline. A simulation (above, from [2]) of the MIB predicted a low flux of particles below the beamline, due to absorption by the tunnel floor, as well as an increased flux on the horizontal plane, in correspondence of the collimator jaws. Measurements (below, normalized with average rate) show a general agreement with the prediction.

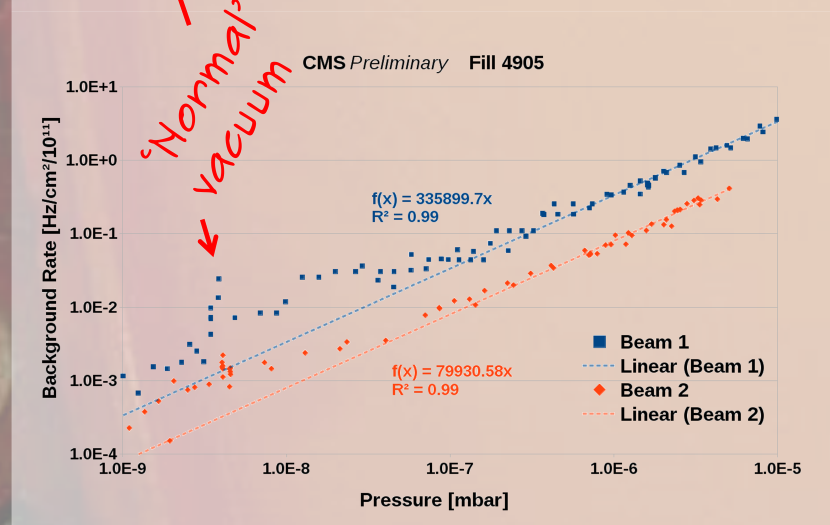


Which is why the BHM ends here









Beam Gas Test A series of tests was conducted between May and June 2016 to determine the effect of beam gas interaction in the LHC experiments. In the first such test, during LHC fill 4905, a vacuum getter cartridge was heated, releasing trapped atoms into the beam, in the vicinity of the TCTs, at about 150 m from the CMS interaction point.

Vacuum pressure, measured by several gauges, increased by five orders of magnitude with respect to normal operating conditions, and the MIB rate measured by BHM followed closely the evolution of the pressure over time.

A linear correlation exists between measured pressure and MIB rate above a certain pressure. Below about 10^{-7} mbar, additional contributions to MIB, such as the baseline halo background and occasional noise hits, spoil the linear dependence.

Conclusions The Beam Halo Monitor was installed in CMS to measure Machine Induced Background. It has met all its design requirements, and it is sensitive to increase of MIB beyond the normal operating conditions. Analyses are in progress to quantify the effect of the increasing MIB rate on the CMS data taking efficiency. The detector is expected to remain operational and sensitive to beam background even with the upgrade to High Luminosity LHC.

References

[1] A. Dabrowski *et al.*, "Upgrade of the CMS Instrumentation for luminosity and machine induced background measurements", *Nucl.Part.Phys.Proc.*, vol. 273-275, p. 1147, 2016.
[2] S. Orfanelli *et al.*, "A novel Beam Halo Monitor for the CMS experiment at the LHC" *J.Inst.* 10 no.11, P11011, 2015.
[3] N. Tosi *et al.*, "The CMS Beam Halo Monitor electronics" *J.Inst.* 11 no.02, C02039, 2016.