Performance of the Fast Beam Conditions Monitor BCM1F in the CMS experiment at LHC

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on behalf of the CMS-BRM group

The Fast Beam Conditions Monitor, BCM1F, is one of the beam conditions and radiation monitors installed in and around the CMS detector. It is installed near the beam pipe, inside the central tracker and monitors the flux of particles with nanosecond time resolution. It was designed to give a fast response of the beam halo and collision product intensities. Since November 2009, when the LHC restarted running with beams and providing proton-proton collisions, BCM1F has been recording data from beam-halo and collision particles.

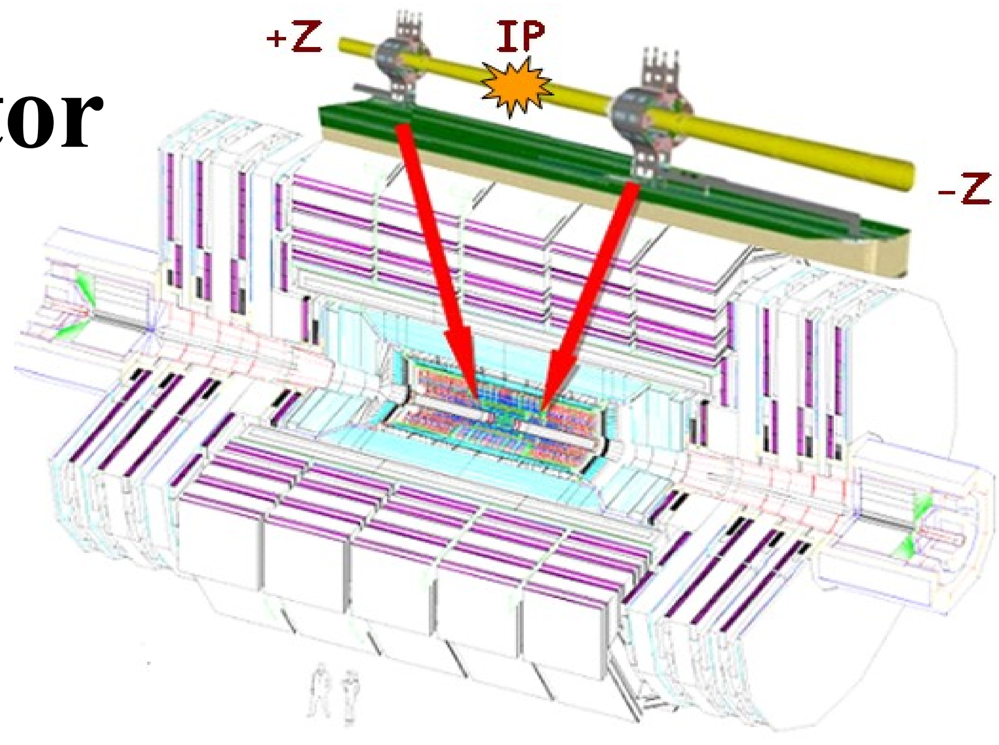
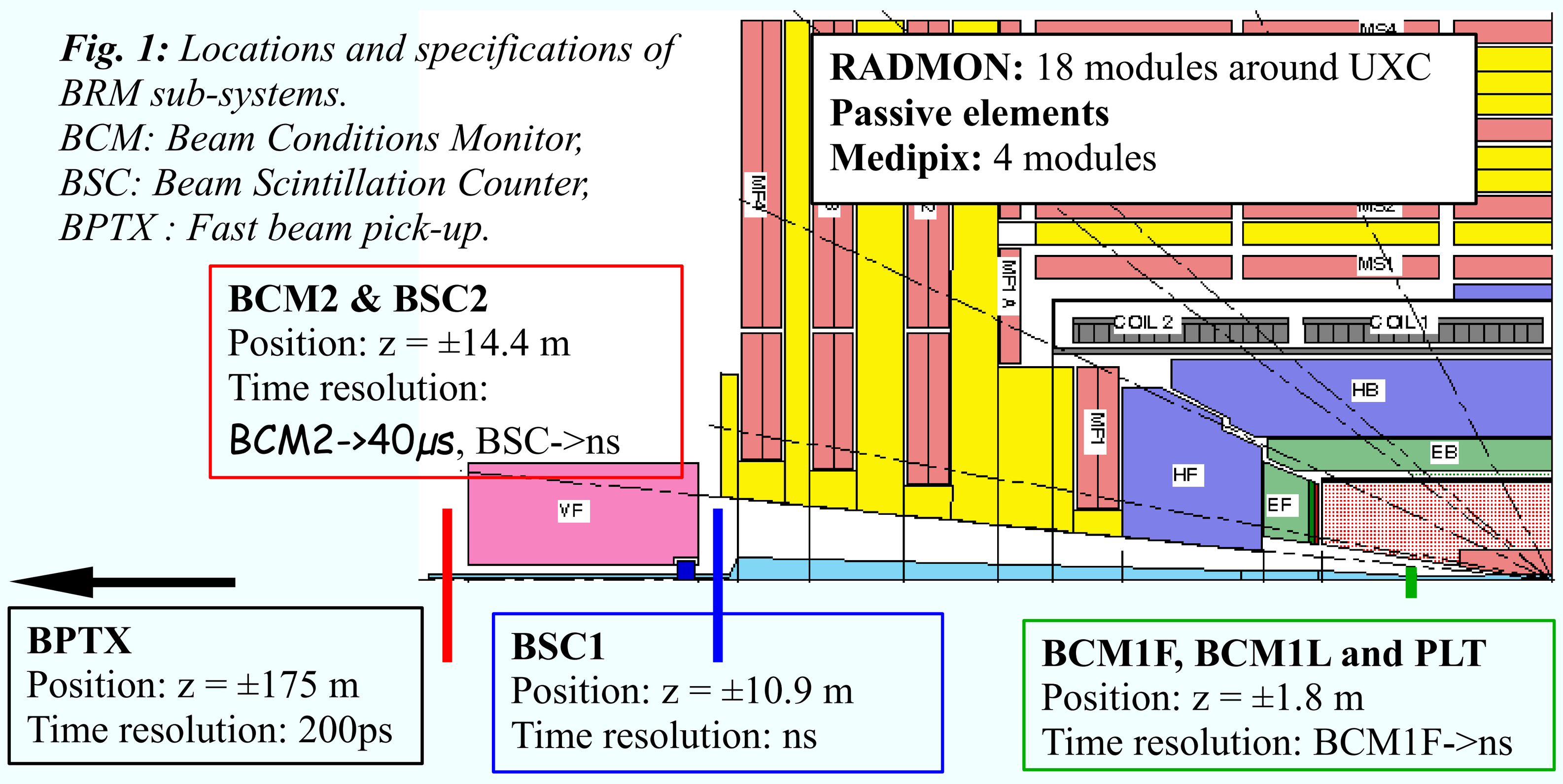


Fig. 2: BCM1F planes in CMS at ±1.8m away from IP.

The CMS Beam Conditions and Radiation Monitoring System (BRM)[1]

The CMS detector [2] is equipped with a safety system, BRM, that monitors the beam conditions and radiation level to prevent damages in case of adverse beam conditions by initiating beam aborts or shutting down vulnerable sub-detectors. BRM is composed of seven sub-systems working on different time scales.

Fig. 1: Locations and specifications of BRM sub-systems.
BCM: Beam Conditions Monitor,
BSC: Beam Scintillation Counter,
BPTX : Fast beam pick-up.

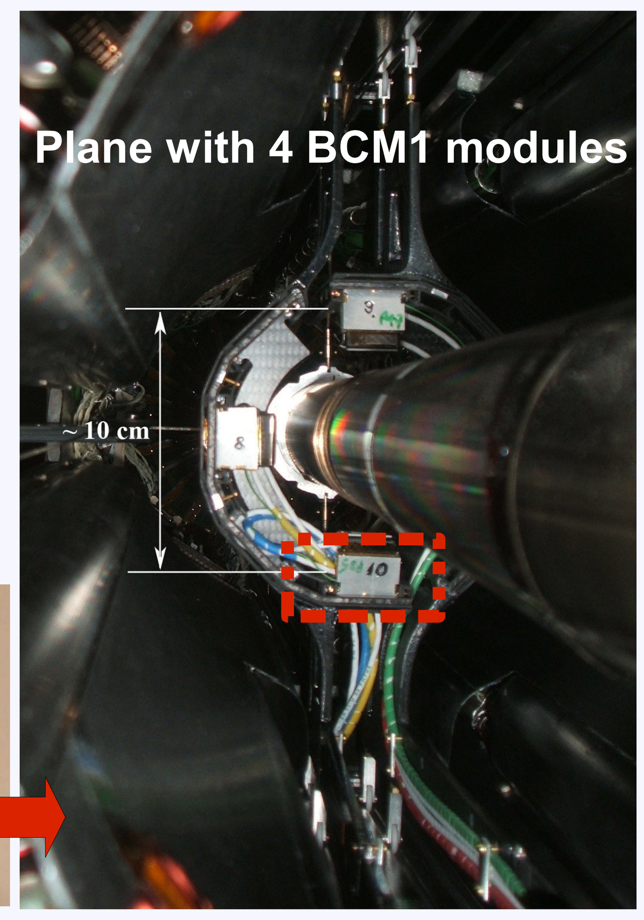


The Fast Beam Conditions Monitor (BCM1F) [3][4]

Four modules, consisting of: sensor, pre-amplifier and optical driver, sit around the beam pipe at 4.5cm from nominal beam axis and on both sides of the IP at a distance of ±1.8m.

They measure flux of beam halo and collision products and deliver CMS BCKD1 to LHC.

Requirements: radiation hard components, low power dissipation, detection of single relativistic particles bunch by bunch.



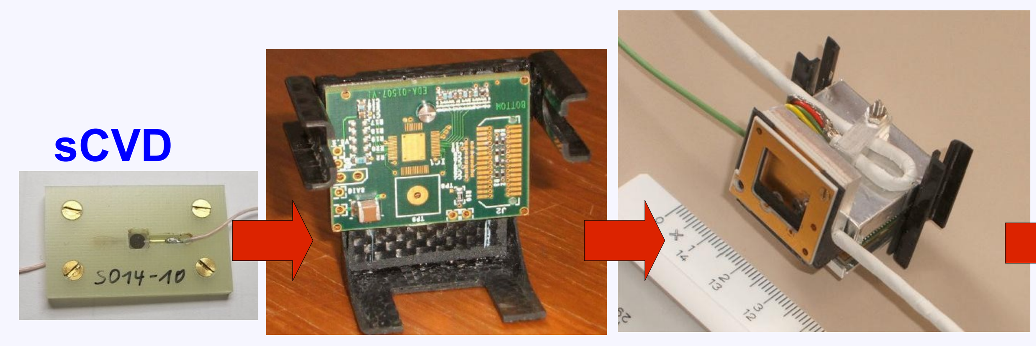


Fig. 3: Sensor and front-end electronics are assembled to a module and mounted in CMS.

Components of BCM1F

Front-end: The sensors are single-crystal chemical vapor deposition diamonds (scCVD) of the size 5 mm x 5 mm x500 μm. They are metalized on both sides and operated as solid state ionization chambers. A charge sensitive pre-amplifier collects the induced charges and shapes a proportional signal that is transmitted to the counting room as analog optical signal.

Back-end: the optical signal is converted into electrical signal and is processed and stored independently of the CMS framework. The main data-acquisition devices are: scalers, ADCs and TDCs.

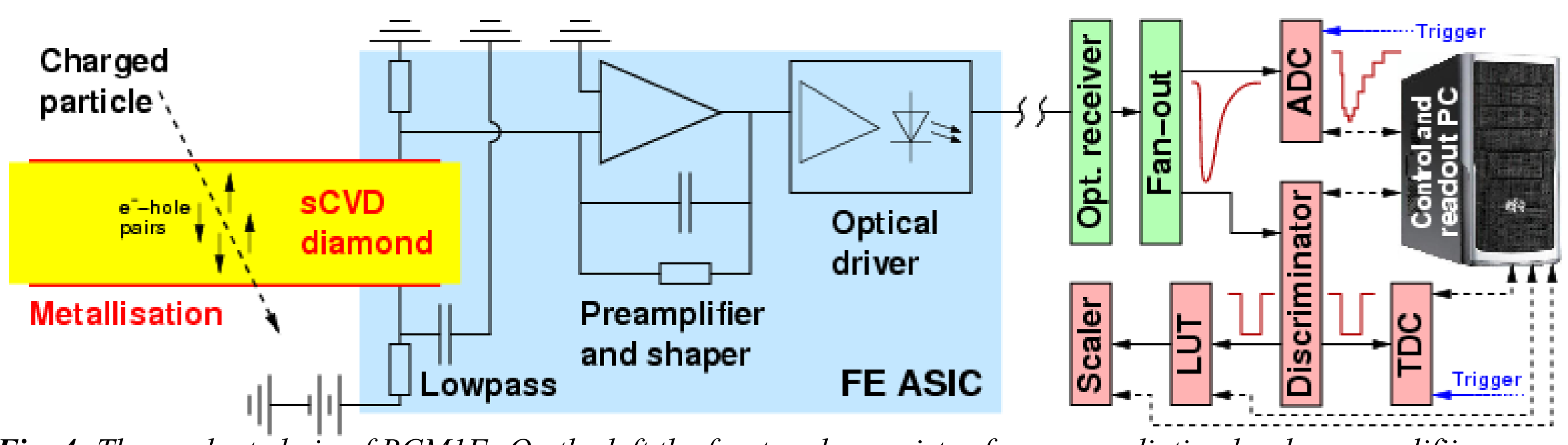


Fig. 4: The readout chain of BCM1F. On the left the front-end , consists of sensor, radiation hard pre-amplifier and optical driver. On the right, the back-end composed of the data readout devices: scaler, LUT, ADC and TDC.

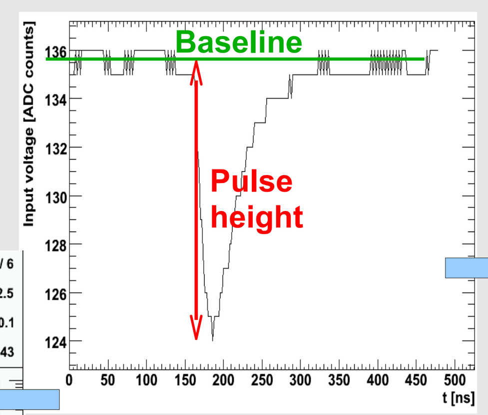
BCM1F performance

Signal sampling and amplitude spectra

The sensor signals are digitized in a CAEN v1721 flash ADC.

The amplitude spectra with colliding bunches show a pedestal peak around zero for the baseline and a signal region with the maximum at the position of a MIP.

Fig. 5:Hit signal digitized by ADC



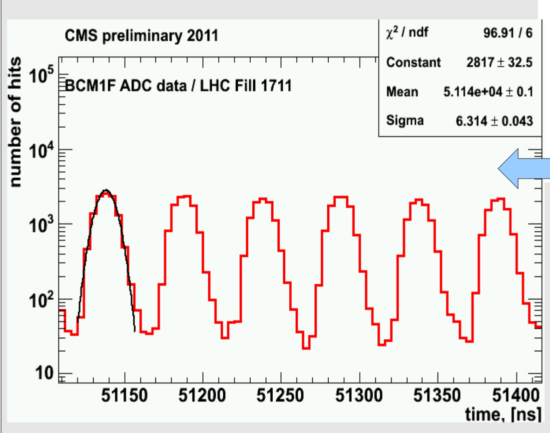


Fig. With of arrival time distribution (6ns) obtained from 50ns colliding bunches

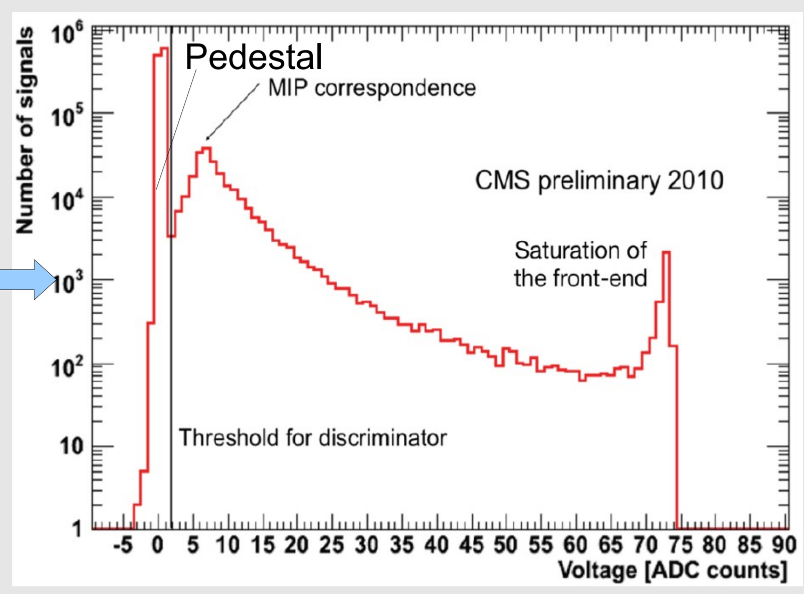


Fig. 7:Pulse height spectrum with 3 peaks: pedestal on the left, signal in the middle and front-end saturation peak on the right.

ADC data are used for characterization and maintenance: baseline monitoring, test pulse readout, signal spectra (for SNR estimation or signal-noise separation), performance studies.

Timing information

Discriminated sensor signals are time digitized by a multi-hit TDC CAEN v767 board with 0.8ns resolution using the LHC orbit as trigger. Using the arrival time distribution of he hits mapped to an orbit, the bunch number identification is done and published to the CMS control room.

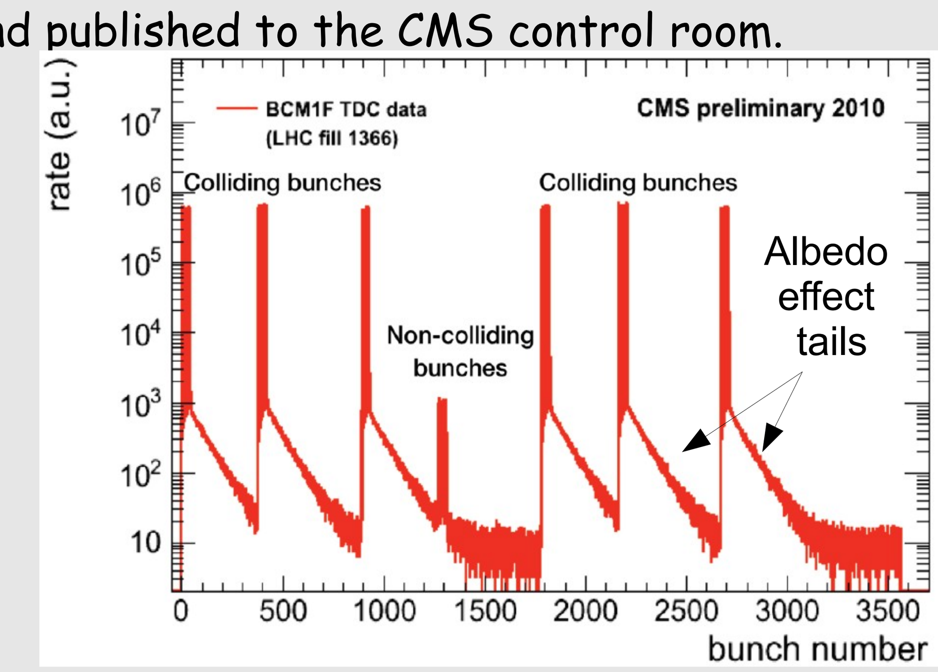


Fig.10:Hit rate as a function of bunch number

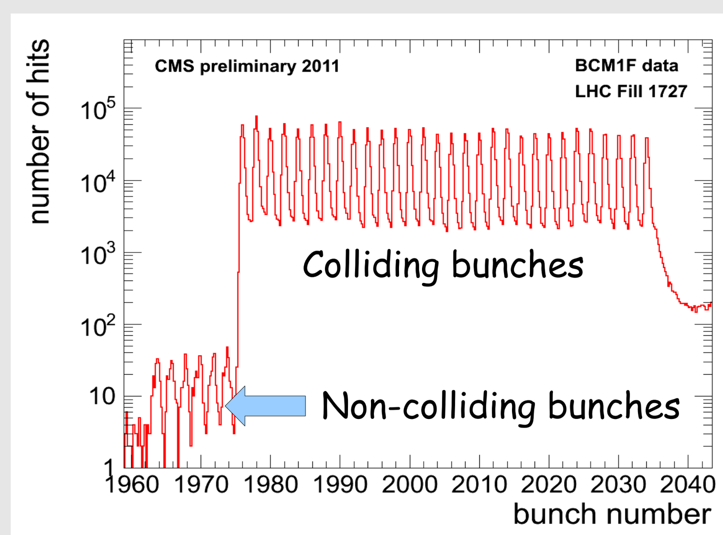


Fig. 11:Zoomed train of 50ns spaced bunches

The Albedo effect

After collisions, long tails of 2.12 μs decay are observed. Simulations using the FLUKA Monte Carlo [5] describe the tails as being produced by neutrons, photons, electrons and positrons

Particle rates

Discriminated sensor signals are counted in a CAEN v560B scaler and the hit rate is provided to the CMS control room and to LHC as BCKD1.

The rates reflect the different stages of a beam fill. For high intensity beam and after dump, the rates drop exponentially for ~34 min due to de-activation of material around BCM1F. A longer deactivation tail of ~40 h is also present.

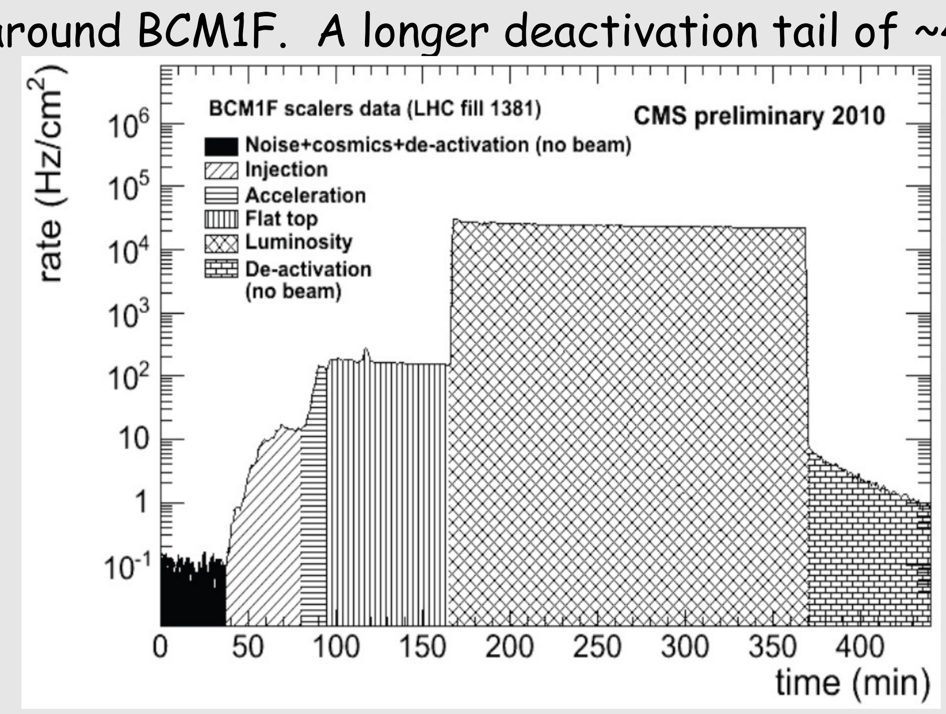


Fig. 8:. Hit rate with the scalers during an LHC fill. Different steps of fill are reflected by BCM1F.

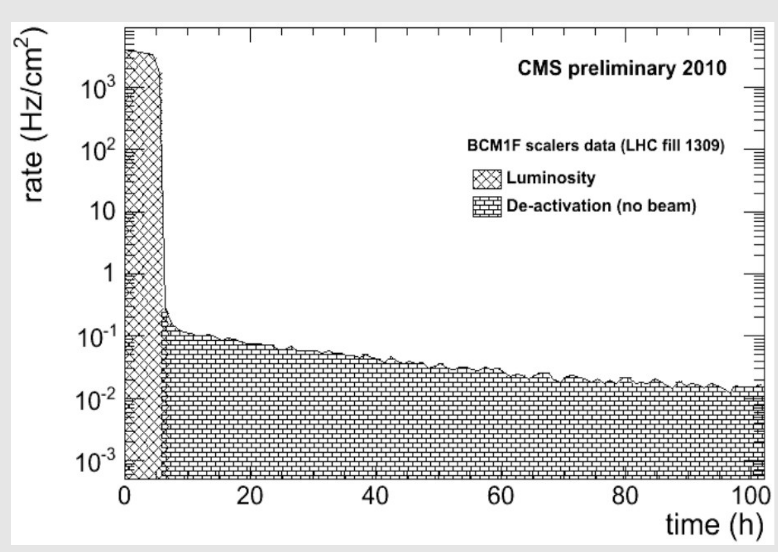


Fig. 9:.Rates after beam dump: de-activation of material around BCM1F occurs for ~40hours

Sensitivity of the system to beam conditions

BCM1F showed to be very sensitive to beam conditions inside CMS such as vacuum quality, collimator and van der Meer scans. Also, BCM1F delivers a fast luminosity estimate.

BCM1F reflects vacuum degradation

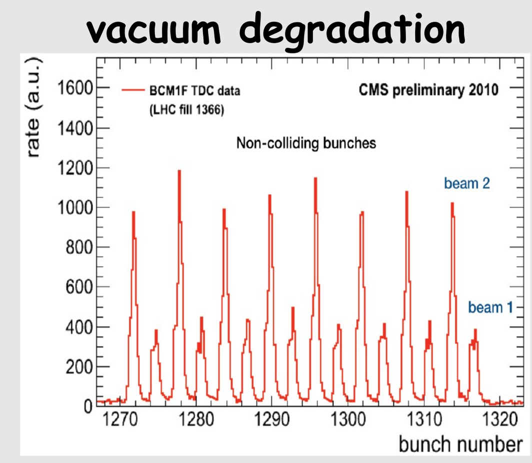


Fig. 13: Hit rate in a bunch train of non-colliding bunches reflecting degradation in vacuum conditions by increasing rates of Beam 2.

BCM1F delivers a fast Luminosity estimate

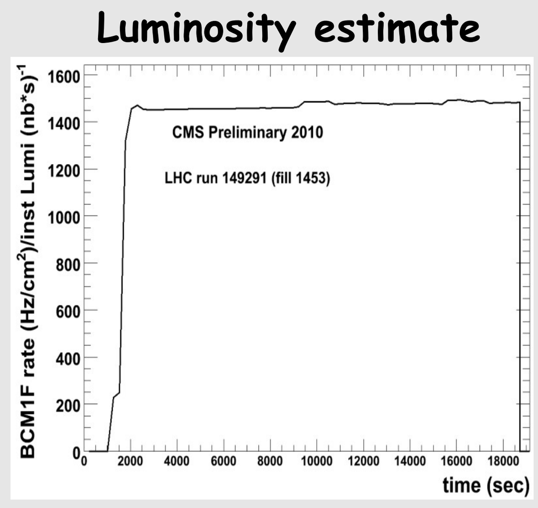


Fig. 14:. Hit rates normalized to HF instant luminosity

[1]L. Fernandez-Hernando et al., Nucl. Instr. And Meth. A614, 433 (2010)
[2]S. Chartchyan et al. JINST, 3S08004 (2008)
[4] W. Lohmann et al., Nucl. Instr. And Meth.A 614 (2010) 433-438
[5]S. Mueller, PhD Thesis (2010)

Conclusions

The BCM1F, has been used as a beam conditions monitoring tool since the LHC restart in autumn 2009. Thanks to the data acquisition architecture, it provides: rates, bunch identification and luminosity estimation to the CMS operators and background rates to LHC. BCM1F became a key tool in the BRM system by giving valuable beam information and it shows, in the day-by-day operation, that new monitoring capabilities are still to be exploited.