Design and Experiences with the Beam Condition Monitor as protection system in the CMS Experiment of the LHC.

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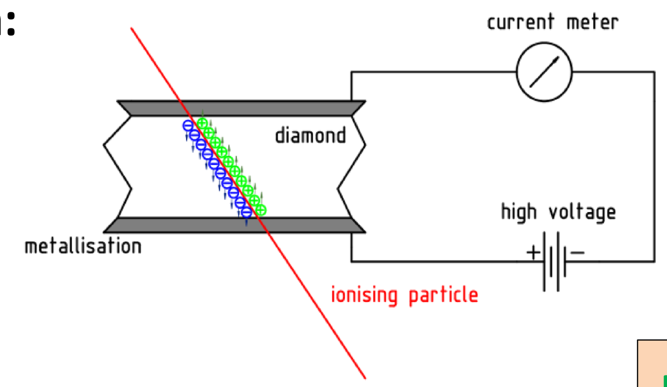
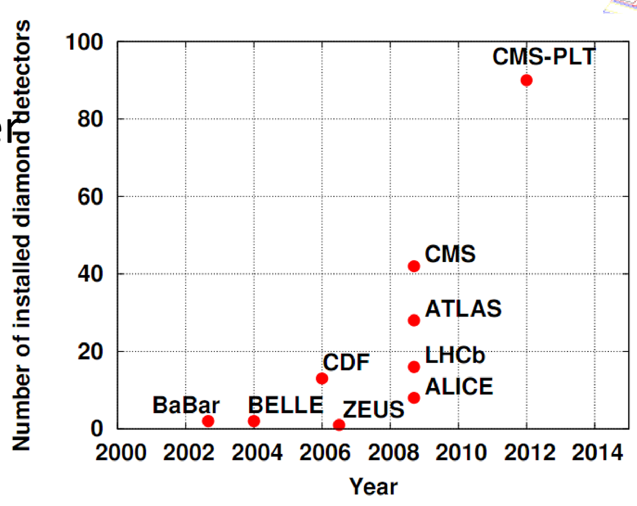
System overview

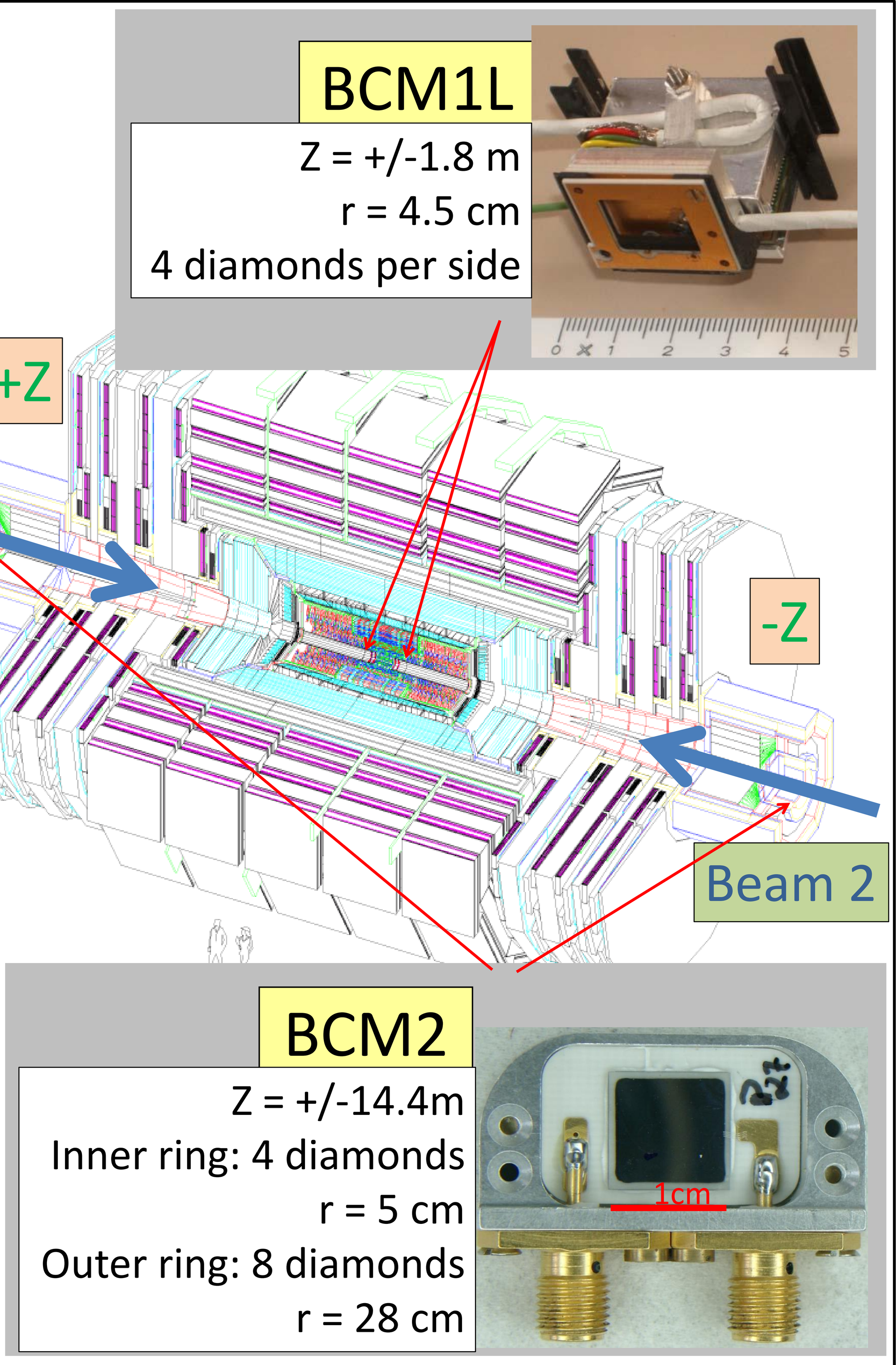
CMS Beam Condition Monitor (BCM) system:
- Transparent extension of LHC Beam Loss BLM. (See box on the right.)
- Measures leakage current in diamonds.
- Two subsystems: BCM2 and BCM1L.
- Utilizes the LHC-BLM readout electronics.
- Diamond detectors are cross calibrated to give a directly comparable signal to the BLM.



Diamond as detector:
- Standard material for beam monitors in HEP detectors.
- Works like a solid state ionisation chamber
- BCM uses polycrystalline CVD diamonds
- Size: 1x1cm^2 500µm thick, gives a signal comparable to a 1m ionisation tube.
- Bias voltage of 200V, Charge collection distance ~210µm (at used bias voltage).



Radiation hardness:
- BCM2 is exposed to high level of radiation.
- Diamonds are very radiation hard due to a high displacement energy .
- High beam losses will not destroy the diamonds.
- Monte Carlo simulations of CMS predict a halflife of ~6 years at 14TeV and design luminosity (10^{34} cm^{-2}s^{-1}).
- No replacement of diamonds necessary in the next 10-15 years.



Damage potetial of the beam:
- Beam energy 350MJ,
- 3x10^{34} protons, 7TeV
- Melts 500kg copper

Test: 10cm copper, 6x10^{12} and 8x10^{12} protons, 450GeV

LHC Beam Loss Monitor system:
- 3700 Ionization chambers
- Main purpose: Preventing quenches of the superconducting magnets induced by high beam losses.
- If the beam loss is too high the beam is duped automatically.
- 43m gap in CMS area

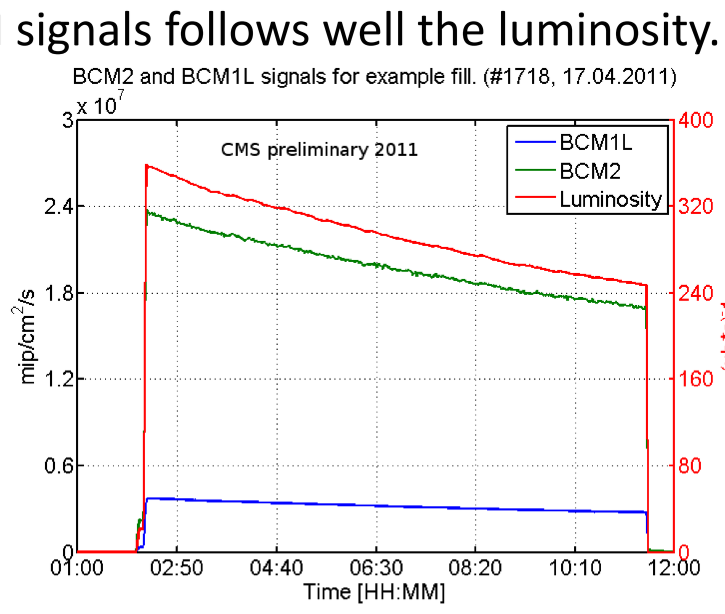
References:

- E.Effinger, et al.: The LHC beam loss monitoring system's data acquisition card. 12th Workshop on Electronics For LHC and Future Experiments 2006, pp.108-112
- B.Dehning et al., LHC Beam Loss Monitor System Design, BEAM INSTRUMENTATION WORKSHOP 2002: Tenth Workshop, Vol.648/1p.229-236

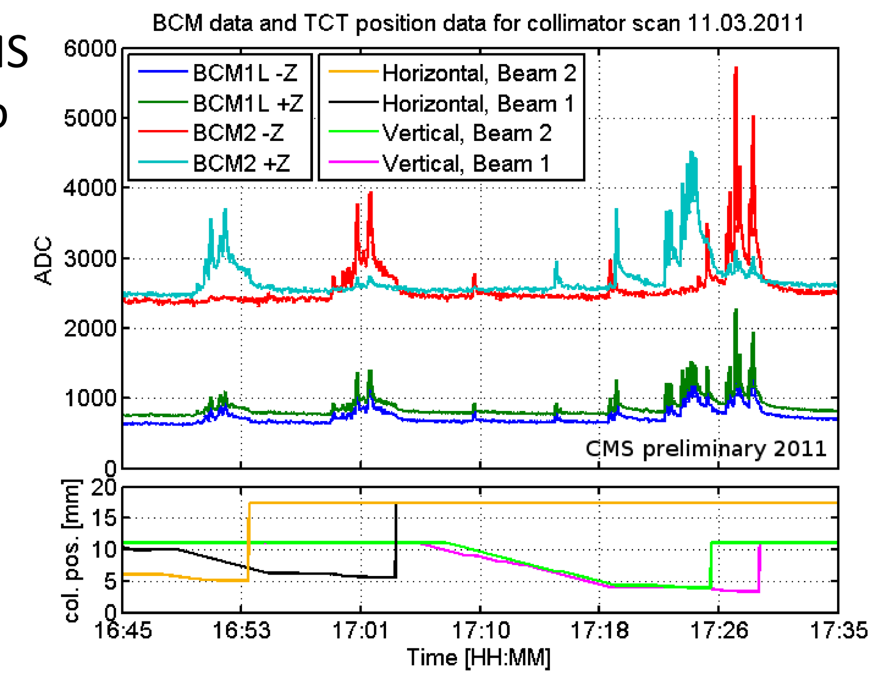
Abort system:
- BCM2 active in CMS beam abort.
- Abort thresholds are set to protect Pixel and Tracker from too high particle fluxes.
- No situation occurred so far that would have been bad enough to trigger a beam dump.

Measurements with beam

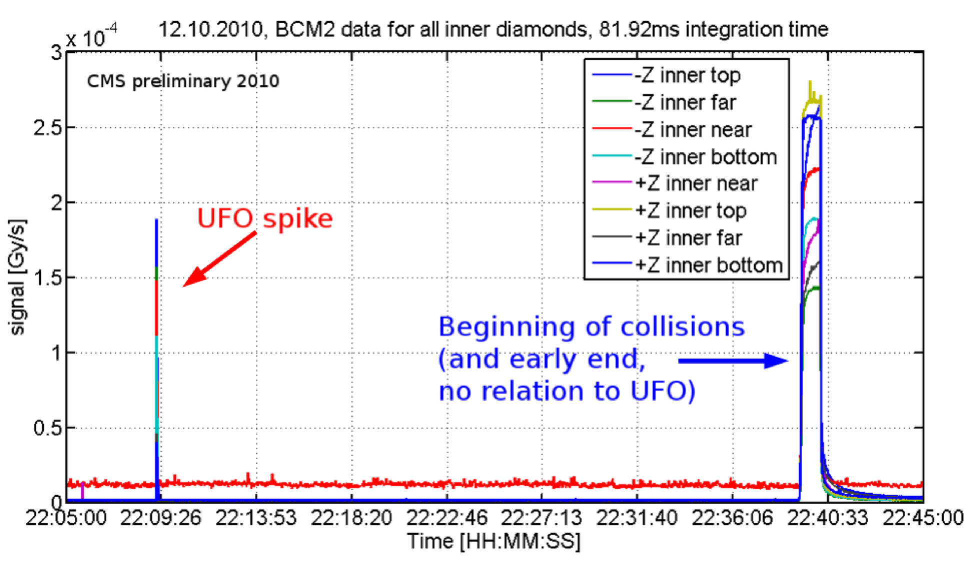
Typical signals during one fill:
- BCM2 signal is about 6 times higher than BCM1L.
- BCM signals follows well the luminosity.

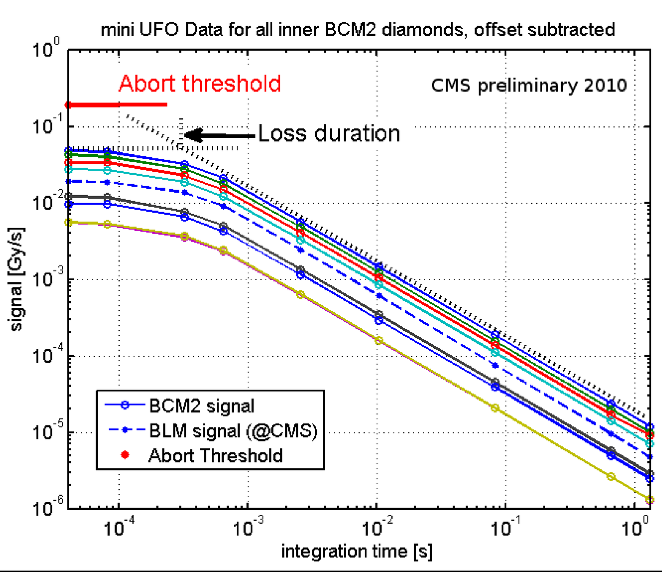


Losses during collimator scan:
- During machine commissioning 2011 the last collimator in front of CMS (TCT) was moved in to measure the collimator position with respect to orbit.
- Losses seen in BCM1L and BCM2
- BCM1L measures the same for +/-Z movements. As expected because they are close together with no material in between.
- BCM2 sees the signal almost only downstream. This is expected from simulations because the particle shower is generated in the massive parts of CMS.
- No Hor./Vert. correlation of signal with respect to collimator movements. -> secondary particle shower go in all directions.

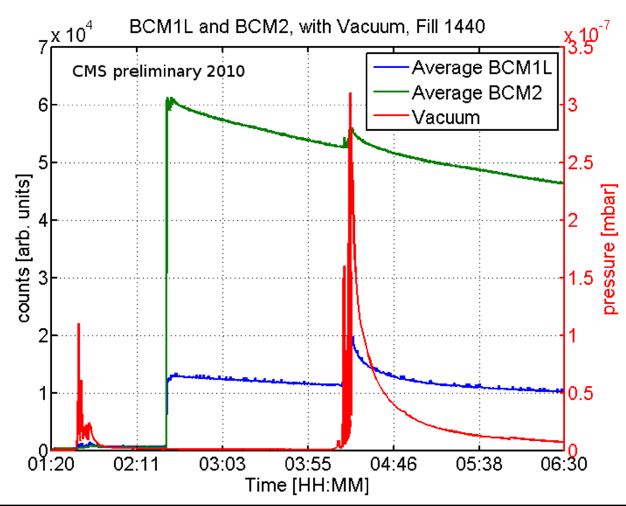


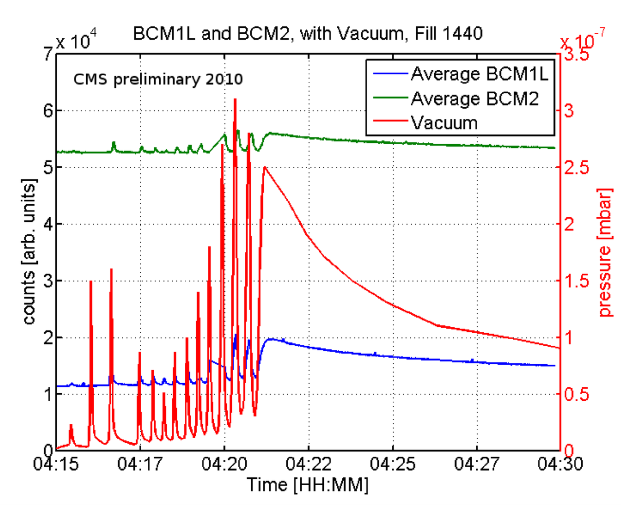
Short time scale beam loss event:
- So called UFO (unidentified falling object) events are believed to be dust particles falling into the beam.
- They produce beam losses with ~1ms duration.
- Only one occurred close enough to CMS to give a clear signal in CMS BCM detectors.
- A time scale of ~0.3ms can be found by analysing different integration times.



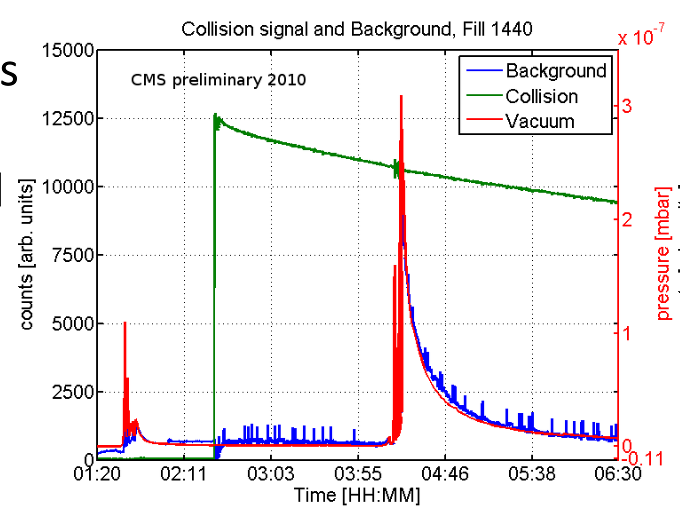


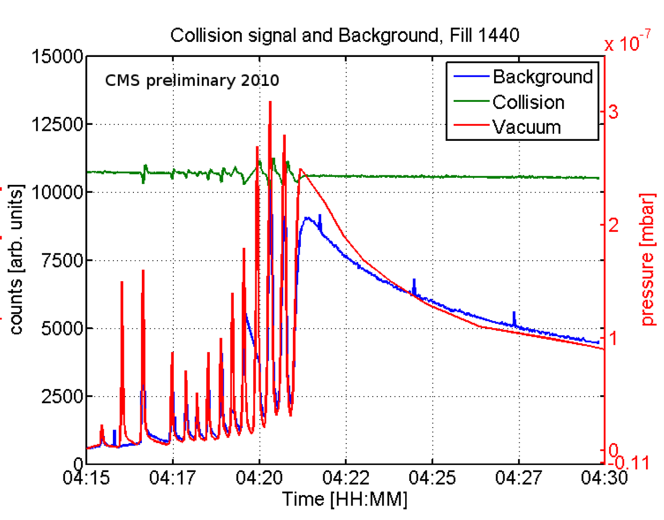
Long time scale beam loss event:
- Bad vacuum conditions increase the beam gas interactions and produce beam losses. Oscillating electron cloud can produce spikes in the vacuum pressure.
- Duration of several minutes.
- In this event high losses seen in BCM detectors due to interaction with the gas. (25.10.2010)
- Beam gas event can be clearly distinguished from constant signal from collisions.





Background discrimination:
- The different sensitivities of BCM1L and BCM2 with respect towards collision signals and machine induced background allow to extract luminosity and background signal.
- Inclusion: measurement$_{BCM1L}$ = background + collision
  measurement$_{BCM2}$ = background * c_b + collision * c_p
- Relative sensitivities c_p, c_b found by analysing beam loss events.
- Shown here is the calculated background and collision signal for the vacuum event. The background measurement follows the vacuum pressure.





Conclusions:
- BCM system works fine, no major problems, no LHC downtime due to system failure.
- No beam aborts so far, the closest was the UFO event with a signal of ~25% of the abort threshold. -> LHC delivers a very good beam quality.

References:

- Steffen Müller, PhD thesis: The Beam Condition Monitor 2 and the Radiation Environment of the CMS Detector at the LHC.
- A.Bell, Beam & Radiation Monitoring for CMS, IEEE Nucl. Sci. Symp .Conf. Rec. (2008) 2322.
- LHC Design Report , CERN-004-003

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