

Scientific Reporting for the project: Lumi-FCC-hh

During the first year activities were mainly focused on understanding the beam-beam (BB) effects related to the luminosity measurement in low pile-up VdM conditions. Extensive studies were carried out to understand the common luminometry systematics arising from accelerator physics as well as beam dynamics, and their influence on current and future precision luminometry (i.e. FCC and HL-LHC). Cross-checks with the available Run 2 data were performed (2018 VdM).

Cross-talk between experiments was explored, providing insight into the impact on the precision of the luminosity calibration. Coherent effects were considered showing relevant differences dependent on the number of witness collisions and collision partners. Multi-collision tune shift was investigated, with dedicated COMBI simulations and resulted in the recipe for the parametrization of the beam-beam correction to the luminosity measurements, thus reducing the BB related systematic uncertainty of the absolute calibration taken during the VdM scans. COMBI development was necessary to extend the studies for VdM configurations with the crossing angle. The obtained results were already useful for the recently updated calibration of the 2015-2016 Run 2 CMS data, improving the beam-beam systematic uncertainty.

In parallel, the new Fast Beams Conditions Monitor (BCM1F) C-shape PCBs were produced and had to undergo thorough qualification. The printed circuit boards mounted with ASIC chips were tested with internal electric pulses and the sensors with a radiation source. The activities intensified in the beginning of 2021, as all the final BCM1F pieces had to be assembled and carefully integrated with another luminometer – the PLT, onto a common structure. The installation inside the CMS volume was performed in the beginning of July 2021. In October 2021, first pilot test beams arrived to the LHC and its experiments after almost 3 years of Long Shutdown 2 (LS2). This period was used for commissioning of the BCM1F detector.

During the October 2021 LHC Beam Test with pilot bunches at injection energy 450 GeV, prior to the start of Run 3, BCM1F was commissioned. The first circulating beams were used for the frontend and backend validation, and detector timing. "Splashes" were provided by the LHC. One of the closest collimators to the CMS Interaction Point was closed, creating the target for the beam, thus generating a shower of secondary particles. In the Fig. 1 this first signal is shown as detected by two example BCM1F channels. BCM1F used Beam Position for Timing at the Experiments (BPTX) as the splash trigger by taking the logic OR of the signals coming from the two beams.

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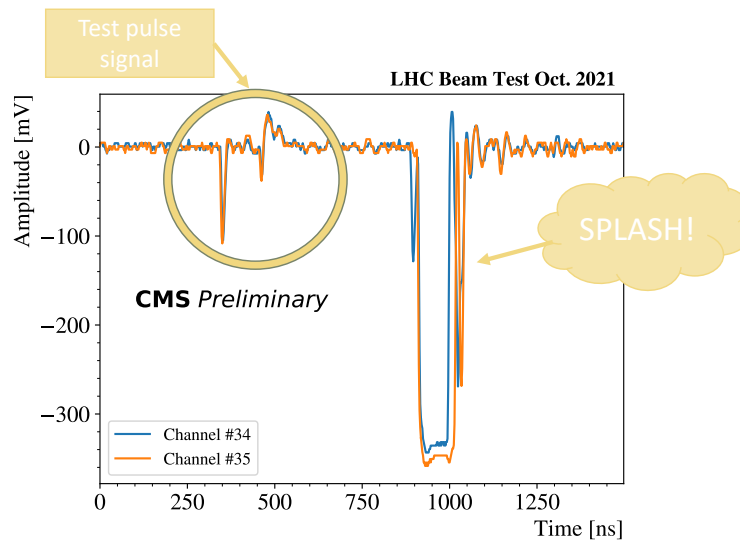


Figure 1 Splash event during LHC Beam Test Oct. 21

First collisions during the beam test were used for BCM1F per channel timing adjustments. BCM1F Realtime Histogramming Unit (RHU) has 6.25 ns granularity - 4 bins per bunch-crossing. The main contribution is adjusted in the 2nd luminosity bin (out of 4). The beam induced background is estimated from counts in the bin prior to the bunch crossing and unpaired BCIDs (non-colliding). BCM1F was already publishing per beam background to the LHC and other CMS subsystem, giving the green light for safe operation.

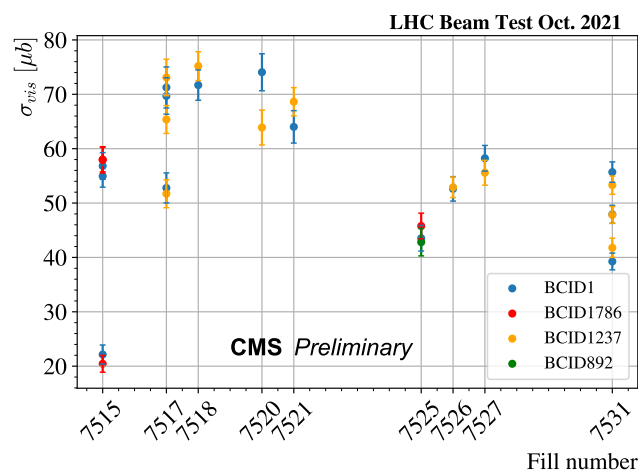


Figure 2 CM1F visible cross section per bunch over the Test Beam collision periods

BCM1F measured instantaneous luminosity throughout the October 2021 LHC Beam Test collision periods. In most of the Stable Beams fills Emittance scans were performed - short scans passing the beams through each other in the horizontal and vertical plane to measure the beam-overlap shapes. Short integration steps (sim 30,s) at each

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separation were used. Preliminary visible cross section σ_{vis} was extracted from each scan pair in all Test Beam fills two bunches were colliding at CMS. The average per BCID values are very close to the estimated 59.8 μb , based on Run 2 BCM1F visible cross section (scaled for injection energy and new sensor size). Results are visible in Figure 2.

Publications and Presentations:

- The CMS Collaboration, “CMS luminosity measurement for the 2018 data-taking period at $\sqrt{s} = 13$ TeV”, May 2019, LUM-18-002, CMS AN-2018/228
- Aaij et al., “Upgrade trigger: Biannual performance update”, February 2017, LHCb-PUB-2017-005
- The CMS Collaboration, “Precision luminosity measurement in proton-proton collisions at $\sqrt{s} = 13$ TeV in 2015 and 2016 at CMS”, CMS-LUM-17-003;
- The CMS Collaboration, “Luminosity measurement in proton-proton collisions at 5.02 TeV in 2017 at CMS”, CMS-PAS-LUM-19-001;
- I.L. Azhgirey and others, “Benchmarking of the Radiation Environment Simulations for CMS Experiment at LHC”, Proc. IPAC’21.
- “Impact of Beam-Beam Effects on Absolute Luminosity Calibrations at the CERN Large Hadron Collider”, in preparation.

Meetings Reporting:

- Possible bunch-family-dependence of beam-beam effects at the CMS IP, <https://indico.cern.ch/event/915337/#2-possible-bunch-family-depend>
- Multi-IP studies using COMBI, <https://indico.cern.ch/event/933647/#2-multi-ip-studies-using-combi>
- Multi-IP simulations and collision-pattern dependence of beam-beam corrections, <https://indico.cern.ch/event/948569/#1-multi-ip-simulations-and-col>
- Impact of a non-zero crossing angle on beam-beam corrections to vdM calibrations, <https://indico.cern.ch/event/1017978/#1-impact-of-a-non-zero-crossin>
- Impact of crossing angle on beam-beam corrections: COMBI vs. B*B, 26.04.2021; <https://indico.cern.ch/event/1026675/#1-impact-of-crossing-angle-on>
- CMS week – Technical Coordination Plenary Session – BRIL in Run 3, 21.04.2021; <https://indico.cern.ch/event/1029141/#5-bril-in-run-3>
- BRIL week, November 2021
- CMS LUM POG Meetings
- BCM1F working group meetings
- EPFL activity meetings Joanna Wańczyk