Assembly and Commissioning of the CMS Fast Beam Condition Monitor for Run 3
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BCM1F - Introduction
• The Fast Beam Condition Monitor (BCM1F) is a dedicated, standalone luminometer.
• Full detector consists of four C-shapes, with a total of 48 channels.
• To achieve the required high luminosity precision during the Run 3 LHC operations, it was upgraded.
• It was rebuilt with new sensors, produced as part of the CMS Phase 2 Outer Tracker sensor production.
• It was installed inside the Compact Muon Solenoid (CMS) behind the CMS Pixel detector, at a distance of 1.8 m from the Interaction Point (IP).
• Timing information with a sub-bunch crossing precision, enabling the measurement of beam-induced background.
• Two BCM1F C-shapes forming a ring around the beam pipe.

Full LHC orbit signal
BCM1F Realtime Histogramming Unit (RHU) has 6.25 ns granularity - 4 bins per bunch-crossing. Full LHC orbit has 3564 bunch crossings (BCIDs) - which gives 14256 RHU bins. During the beam test data taking in fill 7516, there were two colliding bunches (BCID2 and BCID3127) - corresponding two high peaks in the beginning of the orbit and 2 unpaired bunches (BCID1786 and BCID3022) - two lower peaks correspond to the beam induced background. The highest peak located at the end of the orbit (in the abort gap) is generated by the external test pulse. Plot consist of 30 lumi-sections (~690 s).

Timing adjustment
BCM1F needs per channel timing adjustments due to the differences in signal transfer line lengths. 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 publishes per beam background to the LHC and other CMS subsystem, giving the green light for safe operation.

Luminosity measurement overview
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 (~30 s) at each separation were used.

Results of the emittance scans calibration
Luminometer visible cross-section $\sigma_{L}$ 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 $\mu$b, based on Run 2 BCM1F visible cross-section (scaled for 450 GeV per beam and new sensor size).