Online Luminosity Measurement at CMS for Energy Frontier Physics after LS1

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Scientific Report Subsequent to completion of the project:

Abstract

This proposal was directed towards the measurement of Bunch-by-Bunch and Total Luminosity in the CMS experiment using Single-Crystal Diamond (sCVD) installed close to the Interaction Point - known as the Fast Beam Conditions Monitor, or BCM1F detector. The proposal was successfully carried out and in February 2015 CMS installed its upgraded BCM1F detector. At first collisions in June 2015 the BCM1F was used as the primary luminometer, then in August 2015 a Van De Meer scan has been carried out and the detailed luminometer calibration is under study. In all aspects of performance measurement the upgraded detector has satisfied its design parameters and as an overview of its performance in this report will show, we have high expectations that the detector will be a powerful addition to the luminosity measurement at CMS and LHC.

The proposed upgrade of BCM1F was a collaboration of CMS Institutes in Germany (DESY-Zeuthen) and the USA (Princeton) and of CERN itself.

Summary of the Submitted Proposal

The sCVD diamond BCM1F detector has been demonstrated to be well matched to the task of making a ~1% measurement of Online Luminosity in the CMS environment. In order to turn this into an internally self-sufficient system for post 2014 LHC operation an upgrade project has been laid out and work is underway to implement this project. All of the issues identified in the 2011-2012 operation of BCM1F have been addressed in this upgrade project

As Coordinator of the CMS BRM group Stickland has responsibility for the execution of this project. As with all upgrade projects, the construction and installation of the hardware is in reality only one step in the process of turning a detector concept into Physics results. Stickland's experience is particularly well suited to the task of both carrying through the hardware project and in turning that rapidly and effectively into the Physics measurement that is required for the next long run of the LHC starting in 2015. This proposal therefore addresses the funding of Stickland's participation and leadership to this work. This proposal does not request Hardware or Operations funding for this upgrade or for the CMS BRM activity.

Activities completed under this grant

As the CMS Project Manage for Background and Luminosity systems, Stickland oversaw the testing, fabrication, installation and commissioning of the BCM1F detector system. Due to external factors the installation at CMS actually took place in February 2015 rather than summer 2014. Since the startup of LHC in the Spring the BCM1F has been in operation continuously for background and luminosity measurement.

Below we list the principle stages of this work:

- The installed system consists of 24 sCVD diamonds. The diamond metallization was performed at Princeton and uses a novel twin-pad approach. This split-pad design was adopted after Monte-Carlo analysis indicated it would give better linearity in zero counting response up to the highest luminosities foreseen in LHC-Run 2. The selection f 24 diamonds was made form a production sample of 68, these were optically and electrically classified and measurements of the Charge Collection Efficiency and log leakage current as a function of bias voltage were used to select the final installed diamonds.
- Due to the very limited space at the installation position and the need to minimize the radiation length of materials to limit introduction of extra backgrounds to the CMS Tracker system a single carbon fibre

structure was designed and fabricated to mount the BCM1F diamonds and front-end electronics; the BCM1L abort-system diamonds and the PLT Silicon Pixel Luminosity Telescope.

- The PCB for the BCM1F was a hybrid construction with three rigid and 3 flexible parts. It was made in the way to avoid the requirement for heavy and space consuming connectors in this high radiation environment and to remove concerns of broken contacts intros inaccessible region.
- A backend readout system based on discriminators followed by a DESY-Zeuthen developed “Real-time Histogramming Unit” has been commissioned. This allows dead timeless accumulation of channel by channel hit rates with a 6.25ns time-bin granularity (4 bins per LHC bunch crossing). This timing resolution is used to separate incoming background signals from outgoing luminosity related signals.
- A more sophisticated backend readout system making use of an FPGA to perform real-time digitization and pulse-shape analysis is currently being commissioned, this will be important going beyond Run2 to even higher luminosities at LHC.
- The BCM1F data processing is integrated in a BRILDAQ data acquisition system that makes use of the standard CMS tools for DAQ but for this subset of systems that do not feed data into the standard CMS event stream (Luminosity and background measurements are needed whether or not CMS is in Datataking operation)
- The BCM1F system has been demonstrated to have the timing resolution allowing it to identify and measure incoming background rates - its primary function.
- The BCM1F system has been used in the running this year as one of the three online luminometers. It has almost perfect (~1%) correlation with the measurements made in the Pixel Luminosity Telescope yet because the measurement techniques are very different it allows us to gain extra insight into sources of eventual systematic error in the luminosity measurement. CMS is targeting a final luminosity systematic uncertainty in the 1-2% range, these detector systems will be vital to achieve this.