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Precision luminosity measurement at CMS with the Pixel Luminosity Telescope

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The Pixel Luminosity Telescope (PLT) is a silicon pixel detector dedicated to luminosity measurement at the CMS experiment. It is arranged into 16 "telescopes" of three planes each, with eight telescopes arranged around the beam pipe at either end of the CMS detector, outside the pixel endcap. In the talk, the commissioning, calibration, operational history, and performance of the detector during Run 2 (2015-2018) of the LHC is presented. Studies of detector performance and the monitoring and mitigation of radiation damage effects will be highlighted.

Summary (500 words)

The PLT was installed during the LHC's Long Shutdown 1 as part of the CMS Phase 1 upgrade and consists of silicon sensors arranged into 16 "telescopes" such that particles originating from the CMS interaction point will pass through all three planes in the telescope. It takes advantage of the "fast-or" readout mode built into the CMS phase-0 PSI46v2 pixel readout chip (ROC) which can be processed at the full LHC bunch-crossing frequency of 40 MHz to determine the instantaneous luminosity from the rate of triple coincidences. The readout electronics for this signal path require custom FPGA firmware developed for the PLT to histogram the number of triple coincidences in each telescope. The full pixel information, including hit position and charge, is read out at a lower rate of ˜3.3 kHz and organized by a Token Bit Manager chip which distributes clock and trigger signals, coordinates the readout of the three individual ROCs, and produces a single readout for each telescope. The analog signals corresponding to a fourth of the detector reach the opto-motherboard (OMB) where they are converted into optical signals using analog optohybrids. The OMB also contains a digital optohybrid that receives and distributes optical clock, trigger, and control signals from the back-end hardware. The silicon sensors are actively cooled using C6F14 at a temperature of -15 ºC and provided by a cooling structure fabricated from titanium powder using a selective laser melting process, resulting in cooling tubes of 2.8 mm in diameter with several small-radius bends. A full rebuild of the PLT is scheduled to be installed for Run 3 of the LHC, which incorporates a new OMB slow hub chip design to coordinate I2C control signals and includes an extensive burn-in period under thermal cycles for the assembled components. Several detailed studies were carried out to determine the impact of radiation damage on the performance of the detector. In particular, the depletion voltage can be determined for each telescope by processing data from configurable and automated bias scans in order to anticipate the need for changes in the operational high voltage. Furthermore, pulse heights and sensor efficiencies, which rely on the full pixel readout, were examined and shown to be complementary measurements of the detector performance. Careful consideration of the quality of gain calibrations and effects such as time-walk and noise was required in order to get conclusive results from the analysis of pulse heights. The measurement of sensor efficiency relies on track reconstruction to determine the fraction of events where a hit is expected in all three sensors but is not reported by one of them and includes the optimization of track selection designed to reduce contributions from background tracks. The lessons learned from Run 2 and outlook for Run 3 will be highlighted, with emphasis on the monitoring of detector performance and mitigation of the effects of radiation damage.

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