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The LHCb VELO detector: design, operation and first results

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LHCb is a high precision experiment, operating at the LHC accelerator at CERN. The experiment is primarily devoted to the search for new physics beyond the Standard Model by studying CP violation and rare decays in the b and c-quark sectors. During the second long shutdown of the Large Hadron Collider at CERN, the LHCb experiment has been upgraded and the new detector is currently operating at the LHC. The Vertex Locator (VELO) is the detector surrounding the interaction region of the LHCb experiment, responsible of reconstructing the proton-proton collision (primary vertices) as well as the decay vertices of long-lived particles (secondary vertices).

The VELO consists of 52 modules with hybrid pixel detector technology. Compared to the previous VELO detector, the upgrade VELO encompass an enhanced track reconstruction speed and precision, even at the expected higher occupancy conditions of the upgrade, due to its pixel geometry as well as a closest distance of approach to the LHC beams, with the first sensitive pixel being at just 5.1 mm from the beam line. Cooling is provided by evaporative CO2 circulating in 500 µm thick silicon microchannel substrates. The sensors consist of 200 µm thick n-on-p planar silicon sensors, read out via 3 front-end ASICs. The detector contains 41 million 55 µm x 55µm pixels, read out by a custom developed front-end ASIC (VeloPix). The VELO operates in an extreme environment, which poses significant challenges to its operation. During the lifetime of the detector, the sensors are foreseen to accumulate an integrated fluence of up to $8x10^{15}$ 1MeV neq cm^{-2}, roughly equivalent to a dose of 400 MRad. Moreover, due to the geometry of the detector, the sensors will face a highly non-uniform irradiation, with fluences in the hottest regions expected to vary by a factor 400 within the same sensor. The highest occupancy ASICs foresee a maximum pixel hit rate of 900 Mhit/s and an output data rate exceeding 15 Gbit/s. The detector has started operation together with the rest of the upgraded LHCb experiment after the LHC LS2 shutdown, in 2022. The new detectors have performed very well throughout the first two years of Run 3 of the LHC, but face new operational challenges with increased radiation damage foreseen till the end of this run. The cumulative radiation damage poses challenges in reaching full depletion in the most irradiated zones of the detectors, which have highly non-uniform exposure. The overall damage is monitored through regular measurements of the leakage current and charge collection efficiency (CCE) as function of the bias voltage.

The design, operation and early results evaluating the radiation damage and detector performance throughout the first years of operation in LHC run 3 will be presented.

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