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P1.5: The LHCb VELO Upgrade II: design and development of the readout electronics

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The LHCb Upgrade-I detector is currently operating at the Large Hadron Collider at CERN and it isexpected to collect about 50 fb^{-1} by the end of Run 4 (2032), when many sub-systems of the detector will reach their end of lifetime. In order to fully exploit the High-Luminosity LHC potential in flavour physics, the LHCb collaboration proposes a Phase-II Upgrade of the detector, to be installed during the LHC Long Shutdown 4 (2032-2034). This Upgrade will consist of a re-designed system with the capability of operating at an instantaneous luminosity of 2×10^{34} $cm^{-2}s^{-1}$, i.e. a factor 10 larger than that of the Phase-I Upgrade detector andwill allow the experiment to accumulate an integrated luminosity of about 300 fb^{-1}.

Operatingin the HL-LHC environment poses significant challenges to the design of the upgraded detector, and especially to its tracking system. In particular, the performance of the VErtex LOcator (VELO), which is the tracking detector surrounding the interaction region, is essential to the success of this Phase-II Upgrade. Data rates are especially critical for the LHCb full software trigger, and with the expected higher particle flux, the VELO Upgrade-II detector will have to tolerate a dramatically increased data rate: assuming the same hybrid pixel design and detector geometry, the front-end electronics (ASICs) of the VELO Upgrade-II will have to cope with rates as high as 8 Ghits/s, with the hottest pixels reaching up to 500 khits/s. With this input rate, the data output from the VELO will exceed 30 Tbit/s, with potentially a further increase if more information is added to the read-out.

The VELO collaboration is currently exploring new sensor technologies, and the benefits that would derive from adding a time stamp to the track reconstruction, such that interactions in the same bunch crossing can be more effectively disentangled. Achieving a hit resolution of 50 ps per pixel is considered possible within the timescale of the Phase-II Upgrade. With such resolution, each VELO track would have multiple time measurements from the traversed pixels, which will lead to a precise estimation of the production time of charged particles. Moreover, at the hit level, a precise timing information will also help reducing the number of possible combinations to be considered for the track reconstruction, thus improving its quality. The most recent advances in this field, and the potential candidates that can meet the VELO Upgrade II requirements, will be presented, with special focus on the PicoPix ASIC (an evolution of the Timepix4 design) and the TIMESPOT ASIC prototypes.

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