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4D tracking and vertexing for LHCb Upgrade II

LHCb has recently submitted a physics case for a an Upgrade II detector to begin operation in 2031. The upcoming upgrade stage is designed to run at instantaneous luminosities of $2\times10^{34}cm^{-2}s^{-1}$, an order of magnitude above Upgrade I, and accumulate a sample of more than 300 fb^{-1}. At this intensity, the mean number of interactions per crossing would be 56, producing around 2500 charged particles within the LHCb acceptance. To meet this challenge it is foreseen to modify the existing spectrometer to exploit the use of precision timing.

In particular, the LHCb upgrade physics programme is reliant on an efficient and precise vertex detector (VELO). The higher luminosity poses significant challenges which need the construction of a new VELO with enhanced capabilities. Compared to Upgrade I there will be a further order of magnitude increase in data output rates accompanied by corresponding increases in radiation levels and occupancies. To cope with the large increase in pile-up, new techniques to assign correctly each b hadron to the primary vertex from which it originates, and to perform the real time pattern recognition, are needed. To solve these problems a new 4D hybrid pixel detector with enhanced rate and timing capabilities in the ASIC and sensor will be developed. Improvements in the mechanical design of the Upgrade II VELO will also be needed to allow for periodic module replacement. The design will be further optimised to minimise the material before the first measured point on a track (which is dominated by the RF foil) and to achieve a more fully integrated module design with thinned sensors and ASICs combined with a lightweight cooling solution. As well as improving the VELO performance, quantified by the impact parameter resolution and vertex reconstruction efficiencies, these changes will also be beneficial both in improving the momentum resolution of the spectrometer and reducing the impact of secondary interactions on the downstream detectors.

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