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Upgrade of the Belle II Vertex Detector with depleted monolithic active pixel sensors

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The Belle II experiment currently records data at the SuperKEKB e+e- collider, which holds the world luminosity record of 4.7x10^34 cm-2.s-1 and plans to push up to 6x10^35 cm-2 s-1. In such luminosity range for e+e- collisions, the inner detection layers should both cope with a hit rate dominated by beam-induced parasitic particles and provide minute tracking precision. A R&D program has been established to develop a new pixelated vertex detector (VTX), based on the most recent pixel detection technologies. The VTX strategy entails higher space-time granularity, lighter overall structure and services compared to the current operating VXD based on two different technologies.
The expected gains include more robustness against the machine background as well as higher vertexing and tracking performance.

The VTX design matches the current vertex detector radial acceptance, from 14 mm up to 140 mm. It includes 5 to 6 layers for an overall material budget lower than 3 % of X0. All layers are equipped with the same depleted monolithic active pixel sensors, OBELIX This contribution focuses mainly on the latest expected performances after the sensor design finalisation.

The first OBELIX sensor version is designed in the Tower 180 nm technology, which pixel matrix is derived from the TJ-Monopix2 sensor originally developed for the ATLAS experiment. Featuring a 33 µm pitch and a time over threshold digitisation over 7 bits, OBELIX time-stamps hits with a 50 ns binning. The digital trigger logic matches the required 30 kHz average Belle II trigger rate with 10 µs trigger delay and a maximum hit rate of 120 MHz/cm2.
Two switchable additional features are intended for the outer layers coping with hit rates below 10 MHz/cm2. One corresponds to time stamping hits outside the matrix with 3 ns precision. The other provides continuous hit-information with 30 ns binning but with degraded position-precision for track-triggering. Recent simulations showing that the degraded spatial granularity can still lead to excellent track reconstruction efficiency will be discussed.

The radiation environment requires a tolerance to 5x10^14 1 MeV n_eq/cm2 and 1 MGy. In addition, the minimal material budget limits the cooling power and hence necessarily mean warm operation of the sensor, considering that its power dissipation is estimated to 200 mW/cm2 at the average hit rate of the inner layer.
We will review the latest characterisation of the TJ-Monopix2 forerunner sensor in beam after irradiation to assess the expected performance of the pixels and decide the tuning range of the OBELIX matrix.

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