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Proposed 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 reach 6x10^35 cm-2 s-1 at the end of the decade. 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 proposed VTX will be more robust against the expected higher level of machine background and more performant in terms of standalone track finding efficiency.

The VTX design matches the current vertex detector radial acceptance, from 14 mm up to 140 mm, and can be composed of 5 to 6 layers.

All layers are equipped with the same depleted monolithic active pixel sensors, OBELIX. The first 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, OBELIX integrates hits over 100 ns while dissipating less than 200 mW/cm2 at an average hit rate of 60 MHz/cm2. 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. Additional features are intended for the outer layers coping hit rates below 10 MHz/cm2. They correspond to time stamping hits with 3 ns precision and providing fast but degraded position-precision hit inforrmation for track-triggering.

The two innermost layers (iVTX) have a sensitive length of about 12 cm and aim for a material budget below 0.2 % X0/layer, benefitting from air cooling. One ladder is made of a 4-sensor wide module cut out from processed wafers and submitted to post-processing operations in order to connect them at one end.

The three to four outer layers (oVTX) target material budget ranging from 0.3 % X0 for the shortest length up to 0.8 % X0 for the 70 cm-long and outermost layer. The ladder concept uses a light mechanical structure supporting a liquid-cooled plate in contact with the sensors connected to a flex printed cable.

This contribution will review the recent project progresses: tests of the TJ-Monopix2 sensor at the required irradition level, OBELIX-1 simulated performance, improved geometry optilisation, prototype fabrication and tests for the iVTX and oVTX concepts, including their cooling.

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