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Timing performance of the Timepix3 and Timepix4 pixel ASICs

Precise timing will be an important part of future detector upgrades in order to prepare particle physics experiments for the High-Luminosity LHC. The higher luminosity, which is essential to observe rare phenomena, is obtained through higher pile-up rates making it more difficult to distinguish between collisions. Precise time measurements will help tracking algorithms separate spatially overlapping tracks. In this presentation we will show detailed studies of the temporal performance of the Timepix3 ASIC, and the first detailed timing measurements with Timepix4, which is the latest generation fine-pitch pixel ASIC that is used for the characterisation of sensors that will be used in future upgrades.

The Timepix3 ASIC has 256×256 pixels with a pitch of 55×55 μm², and uses 640 MHz oscillators (one per group of 2×4 pixels) to timestamp hits with a granularity of 1.56 ns. Recently, an elaborate time calibration of the LHCb VELO Timepix3 telescope has been performed in order to assess the feasibility of future large scale 4D trackers consisting of many readout channels. In this study, a detailed understanding of the timing systematics of the Timepix3 ASIC was obtained, and the track-time resolution was improved from 438(16) ps to 236(4) ps by applying per-pixel corrections to the time measurement. The knowledge obtained in this study has been used to carefully characterise the timing performance of both a 3D sensor and a thin planar sensor, which were bonded to Timepix3 ASICs. Using test-beam measurements, the timing performance was determined as a function of both the deposited charge and the track intercept location within a pixel (˜2 μm resolution). For a perpendicularly incident beam, the 3D detector reaches an overall resolution of 567(6) ps compared to an overall resolution of 683(8) ps for the thin-planar detector. The results were compared to lab measurements of their respective analog- and digital front-ends using externally timed test pulses. For a perpendicularly incident beam, the resolution of the 3D detector is dominated by the digitisation whereas the resolution of the thin-planar detector also has an important contribution from jitter in the analog front-end due to its smaller typical signal size.

Timepix4 will be used to further study fast sensor technologies for future 4D trackers. It has, among other improvements, a bigger matrix consisting of 448×512 pixels with a pitch of 55×55 μm², a higher maximum hit rate of 358 Mhits/s/cm², and an improved timestamp granularity of 195 ps. Detailed timing measurements of the analog and digital front-ends have been performed, and will be presented.

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