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10ps timing with 3D trench silicon pixel sensors

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Future collider experiments operating at very high instantaneous luminosity will greatly benefit in using detectors with excellent time resolution to facilitate event reconstruction. In the case of the LHCb Upgrade2 at CERN, when the experiment will operate at 1.5x10ˆ34/cm/s, 2000 tracks from 40 proton-proton interactions will cross the vertex detector at each bunch crossing. To properly reconstruct primary vertices and b-hadron decay vertices, it is required to develop sensors and electronics capable of a hit time stamping with 50ps accuracy. Within such developments, several technologies are under study and one of the most promising today is the 3D trench silicon pixel, developed by the INFN TimeSPOT collaboration. These 55µmx55µm pixels are built on a 150µm-thick silicon and consist of a 40µm-long planar junction located between two continuous bias junctions, providing charge-carriers drift paths of about 20µm and total charge collection time close to 300ps. Two batches of sensors were produced by FBK in 2019 and 2021. The most recent beam test was performed at SPS/H8 in November 2021. Various test structures were readout by means of low-noise custom electronics boards featuring a two-stage transimpedance amplifier, and the output signals were acquired with an 8GHz 20GS/s oscilloscope. The arrival time of each particle was measured with an accuracy of about 7ps using two 5.5mm-thick quartz window MCP-PMTs. Two 3D trench silicon pixel test structures and the two MCP-PMTs were aligned on the beam line and acquired in coincidence. Signal waveforms were analyzed offline with software algorithms and pixel signal amplitudes, particle time of arrival and efficiencies were measured. Data analysis indicates efficiencies close to 100% for particles impinging at more than 10 degrees with respect to normal incidence, and time resolutions close to 10ps. 3D trench-type silicon pixels appear to be a promising technology for future vertex detectors operating at very high instantaneous luminosity

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