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Picosecond timing resolution with 3D trench silicon sensors

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Future vertex detectors operating in colliders at very high instantaneous luminosity will face great challenges in the event reconstruction due to the increase in track density. In particular the high luminosity LHC phase, with the collider operating at 1.5x10^{34}/cm/s, will pose strict requirements on subdetectors capabilities. Concerning the LHCb Upgrade2, 2000 tracks from 40 pp interactions will cross the vertex detector (VELO) at each bunch crossing. To guarantee good detector performance the additional information of the hit time stamping with an accuracy of at least 50ps is needed. There are several studies looking for the best technology to achieve this level of timing precision, but a very promising option today is the 3D trench silicon pixel, developed by the INFN TimeSPOT collaboration. This kind of sensor would allow to build a 4D tracker, capable of excellent resolution in both space and time measurements. Two sensors batches were produced by Fondazione Bruno Kessler (FBK) in 2019 and 2021. The 3D trench silicon pixels have dimensions 55μmx55μm and are built on a 150μm-thick silicon: a 40μm planar junction is delimited by two continuous bias junctions, with the readout electrode in between. This configuration allows shorter charge carriers drift paths if compared to planar sensors, hence inducing fast signals.
The latest beam test with the 3D trench sensors has been performed at SPS/H8 in 2021. By means of low-noise custom electronics boards featuring a two-stage transimpedance amplifier it was possible to test silicon pixels and strips made with the 3D trench technology. To extrapolate the sensor time resolution, the crossing time of a particle was estimated using two 5.5mm-thick quartz window MCP-PMTs as time tag, with an accuracy of approximately 7ps. The device under test, an additional 3D trench sensor and the two MCP-PMTs were aligned with respect to the expected beam trajectory. In this way it was possible to acquire coincidences between the MCP-PMTs and one of the silicon sensors, allowing to study the second sensor properties in a trigger-less condition. The output waveforms were recorded and analyzed offline by means of dedicated software algorithms: amplitude, time of arrival and efficiency of the signals were estimated and the sensors response makes them a suitable candidate to build a full tracking detector. Preliminary results show that the standard deviation of the core of the pixels time distribution is about 10ps and the tilted sensor have shown an efficiency close to 100%.
In the search for excellent time resolution technologies, the 3D trench silicon pixels have proved to be a promising option for future vertex detectors operating at very high instantaneous luminosity.

In-person participation

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