Eleventh International Workshop on Semiconductor Pixel Detectors for Particles and Imaging

ID de Contribution: **90** Type: **Poster**

# Design and production of timing optimised 3D silicon sensors for future LHC experiments and beyond

*jeudi 21 novembre 2024 14:45 (3 minutes)*

During the last years, the need for innovative technologies that allows to enhance performance of particle tracking detectors has become a very important point. New sensor technologies play a key role in detector R&D, focusing the development on increased radiation hardness, improved timing and space resolution.
Among the currently developed sensor technologies, the 3D silicon sensor has already demonstrated its validity in terms of optimum space resolution and large field coverage within large scale LHC experiments, such as the ATLAS experiment within the IBL and current ITK tracking detector. Using the 3D silicon technology also for 4D tracking with intrinsic time resolution below 20 ps has been already investigated within different research groups, especially related to the LHCb collaboration. The R&D achieved over the last 8 years has brought to the development of a timing optimised sensor based on a trenched-shaped electrode instead on the more classical columnar shape pixel like the ones used within the IBL and ITK. R&D projects such as TimeSPOT and, successive, AIDAinnova developed and produced already 3 prototype production batches at FBK, two of them already demonstrating intrinsic time resolution of less than 20 ps and the possibility to operate after an integrated damage of $1*10^{17}$ 1 MeV n_eq /$cm^2$.
This study aims to present a current design and evaluation process for a new, 3D silicon sensor batch that aims to achieve timing close to the TimeSPOT/AIDAinnova 3D trench geometry by using a simplified geometry using columnar electrodes in specific organised setting and with a reduced pixel size.
The design approach is based on Synopsys TCAD with the support of the TCoDe GPU-Multy Thread transient simulator that allows to simulate very large statistic of events over a very short simulation time compared to similar tools available in HEP. Different sensor geometries with different pixel sizes have been designed and analysed, in terms of intrinsic charge collection time and intrinsic capacitance. Among the simulated geometries, 3 have been chosen to be explored more deeply by simulating the behaviour of the single pixel within a 3x3 pixel matrix. From the collected data, a trend is evident that also columnar electrode-based 3D pixel geometries are suitable for being implemented within 4D tracking detectors with ps time resolution.
This design study is also propaedeutic towards future beam test campaigns that will include timing optimised 3D silicon sensor based on trench electrodes from the AIDAinnova project, as well as a newer sensor batch, with production beginning scheduled for the third quarter of 2024, based on columnar electrodes with smaller pitch and pixel matrices, with a more refined production process for easier and higher yield hybridisation that will be compatible with future INFN IGNITE-1 and INFN-IGNITE-X readout chips respectively.

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**Classification de Session:** Posters

**Classification de thématique:** Timing with pixels