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Fastissimo-Plus: ..or the ultimate design for ultra-high speed radiation sensors.

We propose to develop silicon sensors with superior time (~ 10 ps) and position (~ 10 μm) resolutions with the required robustness to be used in very harsh radiation environments. This can be achieved by taking advantage of the fast response properties of MEMS based 3-Dimensional (3D) sensors with trench-electrodes processed throughout the silicon bulk rather than on the wafer's surface and a modified read-out electronics based on fast current amplifiers.

3D sensors are particularly favoured for timing applications due to their electrodes configuration, which allows strong and homogeneous electric fields, inter distance as close as 50 microns and large signals. The particle arrival time can be measured by using the rise time of the induced current signal with reduced fluctuations due to the fact that in 3D sensors all charges along the ionization track, including those from delta rays, are generated within similar, and at the same time shorter, distance from the collecting electrode. This is to be compared with planar sensors where each charge carrier from an impinging minimum ionising particle is generated at a different distance from the collecting electrode, inducing peak signals at different times.

So far the fast response characteristics of 3D sensors have not been fully exploited, because of both non-optimized sensor design and technology, and limits coming from the read-out electronics. However, a time resolution ranging from ~ 30 ps to ~ 180 ps, depending on the signal amplitude, was already obtained [1] giving hope to further improvements with a dedicated design of both sensor and electronics.

Preliminary TCAD simulations have shown that electric field values high enough for carrier velocity saturation can be obtained in most of the sensitive volume by adopting an hexagonal 3D cell, with current signal rise times of ~ 10 ps, regardless of the particle impact position.

Proposed Workflow:

For the feasibility study phase (12 months) we plan to process Trench-Electrodes devices and to test their time response with fast commercial single channel readout electronic chips and multi channel front-ends designed for the CERN-NA62 Giga Tracker experiment. For the following phase we plan to research and develop the entire fast-system chain including exploring state of the art fast data transmission lines, and explore the use of GPUs and parallel algorithms for ultra fast processing of big data and finally explore the best optimization of data storage.

It should also be stressed that the proposed sensors maintain all earlier features of 3D sensors such as extreme radiation hardness and sensitivity to the last few microns of the sensors's volume by the use of active edges. These are essential requirements in high multiplicity collider experiments and make this approach unique with respect of alternative proposals using charge multiplication techniques.

[1] S. Parker et al., "Increased speed: 3D silicon sensors; fast current amplifiers", IEEE Trans. Nucl. Sci. NS-58, 2, 404-417 (2011)

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