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Development of ultrafast silicon sensors for precision timing and 4D tracking

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Low Gain Avalanche Detectors (LGADs) are thin silicon detectors with moderate internal signal amplification, providing time resolution of <20 ps for minimum ionizing particles. LGADs are the key silicon sensor technology for the timing detectors of the CMS and ATLAS experiments in the HL-LHC. In addition, their fast rise time and short full charge collection time (as low as 1 ns) is suitable for high repetition rate measurements in photon science and other fields. However, while radiation hardness and fabrication of such sensors on a larger scale are maturing, electric field termination structures remain a major restricting factor for spatial resolution as they currently limit the granularity of LGAD sensors to the mm scale.

New ultrafast silicon sensors, produced by HPK, FBK, BNL and other vendors, are studied with C-V/I-V measurements, red and IR laser scans, radioactive sources and charged particle test beams. The results are used to recommend base-line sensors for near-future large-scale detector applications like the Electron-Ion Collider, where simultaneous precision timing and position resolution is required. The studies also serve research and development of silicon sensors for other future colliders.

AC-LGADs, also referred to as resistive silicon detectors, are a more recent variety of LGADs based on a sensor design where the multiplication and n+ layers are continuous, and only the metal layer is patterned. This simplifies sensor fabrication and reduces the dead area on the detector, improving the hit efficiency while retaining the excellent fast timing capabilities of LGAD technology. In AC-LGADs, the signal is capacitively coupled from the continuous, resistive n+ layer over a dielectric to the metal electrodes. A high spatial precision on the few 10‘s of micrometer scale is achieved by using the information from multiple pads, exploiting the intrinsic charge sharing capabilities provided by the common n+ layer. A balance between all tunable parameters (comprehending location, the pitch and size of the pads, as well as the doping concentrations) has to be identified for future uses of AC-LGADs: the sensor design can be optimized for each specific application to achieve the desired position and time resolution compromised with the readout channel density. Their precise temporal and spatial make AC-LGADs primary candidates for future 4-D tracking detectors, and they are currently the chosen technology for near-future large-scale application like the Electron-Ion Collider detector at BNL, or the PIONEER experiment at the Paul Scherrer Institute in Switzerland.

Another type of sensor design aimed at reducing the inactive area is the trench-insulated (TI-)LGAD, in which the gain regions are isolated from each other by etching narrow trenches into the silicon substrate between segments. Furthermore, prototypes of LGADs with a continuous, but buried gain layer (deep-junction, DJ-LGADs) are being investigated.

In all aforementioned varieties of LGADs, the contribution of Landau energy transfer fluctuations on the timing resolution are sought to be reduced by decreasing the substrate thickness, from a typical 50 µm to 25-35 µm and less, to approach a timing resolution of ultimately around 10 ps.

In-person or Virtual?

In-person

Primary authors: MOLNAR, Adam (SCIPP (Santa Cruz Institute for Particle Physics)); OTT, Jennifer (University of California, Santa Cruz (US)); MAZZA, Simone (UC Santa Cruz)

Presenter: MOLNAR, Adam (SCIPP (Santa Cruz Institute for Particle Physics))

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