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Development of AC-LGADs for high-rate Particle Detection

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Low-Gain Avalanche Detectors (LGADs) are thin silicon detectors with moderate internal signal amplification yielding excellent time resolution of close to 10's ps. AC-LGADs (aka Resistive Silicon Detectors RSD) have un-segmented gain layer and N-layer, and a di-electric layer separating the metal readout pads, guaranteeing a 100% fill-factor. The high spatial precision of few 10's μm is achieved by using the pulse height information from multiple pads.

We present an evaluation of the high-rate suitability of AC-LGADs based on focused IR-Laser scans wrt the limitations that high-speed readout ASICs can expect from high-flux charged particles and X-rays.

Summary (500 words)

Development of AC-LGADs for high-rate Particle Detection

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Low Gain Avalanche Detectors (LGADs) are thin silicon detectors with moderate internal signal amplification (up to a gain of ˜50) [1]. LGADs with 50 ⊠m thickness have been shown to be capable of providing timing measurements for minimum-ionizing particles with resolution of about 30 picoseconds [2], [3]. In addition, the fast rise time (as low as 150 ps for 20 ⊠m thickness) and short full charge collection time (around 1 ns) of LGADs are suitable for high repetition rate measurements in photon science and other fields [4].

The first implementation of this technology will be with the High-Granularity Timing Detector (HGTD) in ATLAS and the Endcap Timing Layer (ETL) in CMS. The addition of precise timing information from LGADs will help mitigate the increase of pile-up and improve the detector performance and physics sensitivity. The LGAD pads planned are 1.3mmx1.3mm. The current major limiting factor in granularity is due to structures preventing breakdown caused by high electric fields in near-by segmented implants.

We present here an evaluation of the high-rate suitability of AC-LGADs (also named Resistive Silicon Detectors RSD) that can be made with much greater segmentation for the charge collection while maintaining a 100% fill factor. This is achieved by employing un-segmented (p-type) gain layer and (n-type) N-layer, and a di-electric layer separating the metal readout pads. The design allows great flexibility in the choice of the geometry of the metal readout pads, both in terms of pitch and size. The high spatial precision is achieved by using the information from multiple pads, exploiting the intrinsic charge sharing capabilities of the AC-LGAD provided by the common N-layer. It depends on the location, and the pitch and size of the pads. A version of these LGADs has been shown to provide spatial resolution on the few 10's of micrometer scale [4].

We tested the performance of AC-LGAD with focused IR-Laser scans directed alternatively at the read-out side on the front and the bias side on the back of the AC-LGAD, which allows to investigate the following detector parameters: sheet resistance and termination resistance of the n-layer, thickness of the isolation di-electric, doping profile of the gain layer, pitch and size of the readout pads and the bulk thickness.

We use the data to evaluate the limitations high-speed readout ASICs can expect from high-flux charged particles and X-rays and from constraints of power consumption in the readout chain.

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