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Strategies for using GAPDs as tracker detectors in future linear colliders

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After the recent discovery of the Higgs boson, refined measurements need to be done to unravel the properties of the new particle with high precision. These measurements will be performed in great part at future linear colliders, namely the International Linear Collider (ILC) and the Compact LInear Collider (CLIC). Nevertheless, the physics goals at the mentioned facilities impose such extreme requirements on detector systems that exceed those met by any previous technology. Amongst others, Geiger-mode Avalanche PhotoDiode (GAPD) detectors are being developed to track high energy particles at the next generation of particle colliders.

GAPDs offer outstanding qualities to meet the severe specifications of ILC and CLIC, such as an extraordinary high sensitivity, virtually infinite gain and ultra-fast response time, apart from compatibility with standard CMOS processes. In particular, GAPD detectors enable the direct conversion of a single particle event onto a CMOS digital pulse within the sub-nanosecond time scale. As a result, GAPDs can be read out after each single bunch crossing, a unique feature that none of its competitors can offer at the moment. In spite of all these advantages, GAPD detectors suffer from two main problems, specifically the inherently generated noise pulses and the low fill-factor. The noise pulses worsen the detector occupancy, while the low fill-factor reduces the detection efficiency.

In this work, solutions to the two problems commented that are compliant with the severe specifications of the future linear colliders have been thoroughly investigated. In particular, we will present the design and characterization, including the results of a beam-test campaign, of a prototype GAPD pixel detector in a standard CMOS process. The prototype is operated in the time-gated mode to fit the occupancy requirement. In addition, the design of a GAPD pixel detector in a 3D process to overcome the fill-factor limitation will also be discussed in detail. The 3D GAPD detector shows the maximum fill-factor ever reported with this sensor technology.

Summary

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