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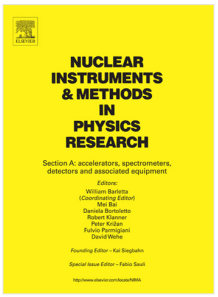

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PII: S0168-9002(17)31178-6
DOI: https://doi.org/10.1016/j.nima.2017.10.089
Reference: NIMA 60235

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date : 22 June 2017
Revised date : 27 September 2017
Accepted date : 27 October 2017

Please cite this article as: M.M. Vignetti, F. Calmon, P. Pittet, G. Pares, R. Cellier, L. Quiquerez, T. Chaves de Albuquerque, E. Bechetoille, E. Testa, J.-. Lopez, D. Dauvergne, A. Savoy-Navarro, 3D Silicon Coincidence Avalanche Detector (3D-SiCAD) for charged particle detection, *Nuclear Inst. and Methods in Physics Research, A* (2017), https://doi.org/10.1016/j.nima.2017.10.089

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ACCEPTED MANUSCRIPT

3D Silicon Coincidence Avalanche Detector (3D-SiCAD) for charged particle detection

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Abstract

Single-Photon Avalanche Diodes (SPADs) are p-n junctions operated in Geiger Mode by applying a reverse bias above the breakdown voltage. SPADs have the advantage of featuring single photon sensitivity with timing resolution in the picoseconds range. Nevertheless, their relatively high Dark Count Rate (DCR) is a major issue for charged particle detection, especially when it is much higher than the incoming particle rate. To tackle this issue, we have developed a 3D Silicon Coincidence Avalanche Detector (3D-SiCAD). This novel device implements two vertically aligned SPADs featuring on-chip electronics for the detection of coincident avalanche events occurring on both SPADs. Such a coincidence detection mode allows an efficient discrimination of events related to an incoming charged particle (producing a quasi-simultaneous activation of both SPADs) from dark counts occurring independently on each SPAD. A 3D-SiCAD detector prototype has been fabricated in CMOS technology adopting a 3D flip-chip integration technique, and the main results of its characterization are reported in this work. The particle detection efficiency and noise rejection capability for this novel device have been evaluated by means of a β^- strontium-90 radioactive source. Moreover the impact of the main operating parameters (i.e. the hold-off time, the coincidence window duration, the SPAD excess bias voltage) over the particle detection efficiency has been studied. Measurements have been performed with different β^- particles rates and show that a 3D-SiCAD device outperforms single SPAD detectors: the former is indeed capable to detect particle rates much lower than the individual DCR observed in a single SPAD-based detectors (i.e. 2 to 3 orders of magnitudes lower).

Keywords

Avalanche pixel; coincidence; SPAD; charged particle detection; 3D integration

1. Introduction

The development and optimization of position sensitive charged particle detectors in vertex tracking applications is becoming today increasingly important, in the fields of High Energy Physics experiments as well as in emerging Medical Physics applications such as hadron therapy and Proton

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