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Hexagonal vs. Quadratic 3D Pixel Architectures: Optimizing Silicon Sensors for Future Colliders by utilizing the Three-Dimensional Mapping of Timing Resolution

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The High Luminosity LHC (HL-LHC) requires a resolution of around 30 ps, and future colliders like the FCC-hh will demand below 10 ps. To meet these requirements, Low Gain Avalanche Diodes (LGADs) were developed, utilizing charge multiplication for fast signals. However, at high luminosities, LGADs lose gain due to acceptor removal. To improve radiation hardness,3D detectors (without a gain layer) were designed, with n+ and p+ columns etched through the bulk, minimizing charge drift distance and improving timing. In this study, two types of 3D pixel sensors from the Centre Nacional de Microelectrónica (CNM) were investigated. In the "double-sided"3D architecture, n+ columns are etched from the front and p+ from the back, leaving a gap between columns on opposite sides, creating a dead electric field region. A key improvement in the RD50 3D project, with prototypes delivered in 2023, was changing from a quadratic to a hexagonal unit cell layout, avoiding zero-field spots. The studied hexagonal layout with 25 pixels (5x5), and the quadratic one with 100 pixels (10x10) were studied utilizing the fs-laser-based TCT-SPA (with sub-micron resolution) and 3D TPA. The X-Y and X-Z laser scans over 3D device were performed in steps of one micron. This allows us to construct the 3D information on timing resolution. The results will be for the first time presented in this contribution.

Primary experiment

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