Contribution ID: **250** Type: **Invited speaker**

INVITED: Monolith - picosecond time stamping capabilities in fully monolithic highly granular silicon pixel detectors

Wednesday, 28 June 2023 10:50 (30 minutes)

The Horizon 2020 MONOLITH ERC Advanced project aims at producing a monolithic silicon pixel ASIC with 50μm pixel pitch and picosecond-level time stamping. The two main ingredients of the project are fast and low-noise SiGe BiCMOS electronics and a novel sensor concept, the Picosecond Avalanche Detector (PicoAD). The PicoAD uses a patented [1] multi-PN junction to engineer the electric field and produce a continuous gain layer deep in the sensor depleted volume. The result is an ultra-fast current signal with low intrinsic jitter in a full fill factor and highly granular monolithic detector.

A proof-of-concept PicoAD monolithic prototype was produced in the SG13G2 130nm process of IHP. It contains a matrix of hexagonal pixels with 100 μm pitch. Laboratory measurements with a 55Fe X-ray source showed that the sensor displays avalanche gain up to a maximum electron gain of 23, although a study of the avalanche characteristics, corroborated by TCAD simulations, indicates that space-charge effects due to the large primary charge produced by the conversion of X-rays from the 55Fe source limits the effective gain [2].

The proof-of-concept ASIC was tested [3] with a beam of 180 GeV pions at the CERN SPS. At a sensor bias voltage of 125 V, the detector provides full efficiency and average time resolution of 30, 25 and 17 ps in the overall pixel area for a power consumption of 0.4, 0.9 and 2.7 W/cm2, respectively. In this first prototype the time resolution depends significantly on the distance from the center of the pixel, varying at the highest power consumption measured between 13 ps at the center of the pixel and 25 ps in the inter-pixel region.

A second monolithic prototype with improved electronics, for the moment produced on a 350Ωcm substrate without internal gain layer, provides full efficiency and 20 ps time resolution. As shown in Figure 1, this second prototype shows less dependency of the time resolution on the position within the pixel [4]. Special PicoAD wafers, including different junction depths and several gain-layer implants, have been produced. Monolithic matrices containing the new and improved electronics using these wafers are in production.

[1] G. Iacobucci, L. Paolozzi and P. Valerio, Multi-junction pico-avalanche detector, 19/11/2018, EU patent EP3654376A1 and US patent US2021280734A1.
[2] L. Paolozzi et al., Journal of Instrumentation 17 (2022) P10032.
[3] G. Iacobucci et al., Journal of Instrumentation 17 (2022) P10040.
[4] S. Zambito et al., Journal of Instrumentation 18 (2023) P103047.

This research is supported by the H2020 MONOLITH project, ERC Advanced Grant ID: 884447. The authors acknowledge the support of EUROPRACTICE in providing design tools and MPW fabrication services.

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Session Classification: Sensors

Track Classification: Invited Speaker