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Radiation hardness and timing performance in MALTA monolithic Pixel sensors in Tower 180 nm

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The MALTA family of DMAPS produced in Tower 180 nm CMOS technology target radiation hard applications for the HL-LHC and beyond. Several process modifications and front-end improvements have resulted in radiation hardness up to 2×10^{15} n/cm² and time resolution below 2 ns, with uniform charge collection efficiency across the Pixel of size 36.4×36.4 μm^2 with a $3 \mu\text{m}^2$ electrode size. The MALTA2 demonstrator produced in 2021 on high-resistivity epitaxial silicon and on Czochralski substrates implements a new cascoded front-end that reduces the RTS noise and has a higher gain. This contribution will show results from MALTA2.

Summary (500 words)

The MALTA family of depleted monolithic Pixel sensors have been produced in TowerJazz 180 nm CMOS technology with small collection electrode and a novel asynchronous read-out that reduces the front-end power needs that allows to capture 100 MHit/s [1-3]. The challenge is to make this designs radiation hard to the levels of the inner trackers of the experiments at HL-LHC and beyond [4]. Prototypes have been produced with several process modifications to improve the charge collection. Starting from an n- blanket extends the junction to the full pixel size (standard), another one with a gap in the n- blanket (NGAP), and a third one with an extra deep p-well structure at the pixel edges (EDPW) [5].

The latest front-end modification flavour introduces a new transistor in series, so called cascoded, along with an increase size for selected transistors, that address the RTS noise and improves the threshold reach. This is important for the uniformity of the matrix because it doesn't have in-pixel tuning of the threshold [6]. Samples have been produced on high-resistivity epitaxial silicon, and on Czochralski substrates exhibit larger cluster sizes to those produced on epitaxial silicon before irradiation with an average 1.8 pixels for Cz standard, 1.4 pixels for Cz NGAP, and 1.2 pixels for epitaxial silicon. After irradiation the standard process suffers more from radiation damage, resulting in the NGAP having larger cluster size (1.4 vs 1.2 pixels) than standard modified process. Time resolution evaluated through means of the Pico-TDC ASIC as the time difference of the leading edge of the signal from one of the planes used as a reference and the other planes in a beam telescope setup, yields 2.60 ± 0.05 ns at 6 V for epitaxial high-resistivity, and 1.7 ± 0.1 ns between 10 V and 30 V for the Czochralski samples. This is compatible with the assumption of a larger electrical field in the Czochralski samples.

The work being presented here is of interest for the HEP community and in special for that working on applications for the HL-LHC and beyond. Technical details on the integration with of ASICs like the Pico-TDC might be of interest for the community. This technology is being developed at CERN in the context of the EP R&D and the AIDA innova programmes.

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