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Radiation hard monolithic CMOS sensors with small electrodes for HL-LHC

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The upgrade of the tracking detectors for the HL-LHC requires the development of novel radiation hard silicon sensors. The development of Depleted Monolithic Active Pixel Sensors (DMAPS) target the replacement of hybrid pixel detectors with radiation hard monolithic CMOS sensors. We designed, manufactured and tested DMAPS in the TJ180nm CMOS imaging technology with small electrodes pixel designs. These designs can achieve pixel pitches well below current hybrid pixel sensors (typically 50x50µm) for improved spatial resolution. Monolithic sensors in our design allow to reduce multiple scattering by thinning to a total silicon thickness of only 50µm. Furthermore monolithic CMOS sensors can substantially reduce detector costs. These well-known advantages of CMOS sensor for performance and costs can only be exploited in pp-collisions at HL-LHC if the DMAPS sensors are designed to be radiation hard, capable of high hit rates and have a fast signal response to satisfy the 25ns bunch crossing structure of LHC.

Through the development of the MALTA and MiniMALTA sensors we will show the necessary steps to achieve radiation hardness at 1E15 1MeV-neq/cm2 for DMAPS with small electrode designs. The sensors combine high granularity (pitch 36.4x36.4µm2), low detector capacitance (<5fF/pixel) of the charge collection electrode (3µm), low noise (ENC<20e-) and low power operation (1µW/pixel) with a fast signal response (25ns bunch crossing). The sensors feature arrays of 512x512 (MALTA) and 16x64 (MiniMALTA) pixels. To cope with high hit rates expected at HL-LHC (>200MHz/cm2) we have implemented a novel high-speed asynchronous readout architecture.

The presentation will show the optimization of the pixel implant structures and front-end to achieve radiation hard pixel designs with full efficiency after irradiation. Beam tests results will be presented to show the overall efficiency (>98% after 1E15 1 MeV neq/cm2) and timing properties of the sensors in recent measurements before and after irradiation.

Submission declaration

Original and unpublished

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