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Radiation Hard Pixel Sensors for the Phase 2 Upgrade of the CMS Inner Tracker

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The Inner Tracker (IT) of the Compact Muon Solenoid (CMS) experiment of the Large Hadron Collider at CERN will be upgraded for the High-Luminosity LHC (HL-LHC). In the ultimate running scenario, the expected integrated luminosity at the end of the HL-LHC running phase is 4000 fb^{-1}, corresponding to a 1 MeV neutron equivalent fluence of 3.5×10^{16} cm^{-2} and a total ionizing dose (TID) of 19 MGy at the innermost layer of the IT. All the layers of the IT (except for the innermost barrel layer) will be equipped with planar n^{+}-p pixel sensors with an active thickness of 150 µm and pixel sizes of 25 µm x 100 µm. The innermost barrel layer will feature 3D silicon sensors owing to their excellent radiation hardness and lower power consumption; and it is foreseen to be exchanged at least once during HL-LHC operation. Planar and 3D prototype sensors from different producers and with a variety of pixel cell designs were bump bonded to the demonstrator readout chip (RD53A) and to the CMS prototype chip (CROC), both implemented in 65 nm CMOS technology. In this presentation, we report on an extensive qualification campaign performed over the last four years in the laboratory and at the CERN and DESY test beam facilities. The sensor-chip assemblies were tested before and after proton irradiation up to end-of-lifetime fluences of 2×10^{16}. Measurements of the hit efficiency, spatial resolution, crosstalk, and noise studies are presented. For all parameters investigated, the results meet or exceed the specifications by CMS. Based on the results of these measurements and on tracking and thermal simulations, sensor designs were chosen for the IT Upgrade and CMS has started to prepare for the production phase of pixel sensors and modules. The main lessons learned on the path to the choice of a radiation hard sensor will be summarized.

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