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# Radiation hardness and slim edge studies of planar n-in-n ATLAS pixel sensors for HL-LHC upgrades

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ATLAS plans two major upgrades of its pixel detector on the path to HL-LHC: First, the insertion of a 4th pixel layer (Insertable B-Layer, IBL) is currently being prepared for 2013. This will enable the ATLAS tracker to cope with an increase of LHC's peak luminosity to about 3E34 cmˆ-2 sˆ-1 which requires a radiation hardness of the sensors of up to 5E15 n_eq cmˆ-2. Towards the end of this decade, a full replacement of the inner tracker is foreseen to cope with luminosities of up to 1E35 cmˆ-2 sˆ-1 at HL-LHC. Here, the innermost pixel layer will have to withstand a radiation damage of 2E16 n_eq cmˆ-2.

Because of an inactive safety margin around the active area, the sensor modules of the present ATLAS pixel detector have been shingled on top of each other's edge which limits the thermal performance and adds complexity. For the IBL and the HL-LHC upgrade of ATLAS, a flat arrangement of the sensors is foreseen. Therefore, it is essential to reduce the inactive edge to a minimum so the required level of detector hermeticity can be achieved.

N-in-n sensor assemblies based on the current ATLAS pixel read-out chip FE-I3 as well as on the new FE-I4 chip have been irradiated to IBL and HL-LHC fluences using thermal neutrons in Ljubljana as well as protons in Karlsruhe and at CERN PS. Magnetic-Czochralski bulk sensors were irradiated with neutrons and protons which models the expected scenario for the medium layers. Space resolved analysis results such as hit efficiencies from data taken in CERN SPS and DESY test beams are going to be shown. Further unirradiated and irradiated pixel sensors with a dedicated design were studied in test beams to investigate the efficiency performance in their edge region.

A promising method to reduce the inactive peripheral sensor region to a minimum is the scribe, cleave and passivate (SCP) technique. First results of such post processed planar n-in-n pixel sensors will be shown.

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