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Development of n-in-p pixel modules for the ATLAS upgrade at HL-LHC

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Thin planar pixel modules are promising candidates to instrument the inner layers of the new ATLAS pixel detector for HL-LHC, thanks to the reduced contribution to the material budget and their high charge collection efficiency after irradiation. 100-200 um thick sensors, interconnected to FE-I4 read-out chips, have been characterized with radioactive source scans and beam tests at the CERN-SPS and DESY. The results of these measurements will be discussed for devices before and after irradiation up to a fluence of $1.5x10^{16}$ n_{eq} cm^{-2}. The charge collection and tracking efficiency will be compared for the different sensor thicknesses.
The outlook for future planar pixel sensor productions will be discussed, with a focus on sensor design at the pixel pitches (50x50 and 25x100 μm²) foreseen for the RD53 Collaboration read-out chip in 65 nm CMOS technology. An optimization of the biasing structures in the pixel cells is required to avoid the hit efficiency loss presently observed in the punch-through region after irradiation. For this purpose the performance of different layouts have been compared in FE-I4 compatible sensors at various fluence levels by using beam test data at DESY and CERN-SPS.
Highly segmented sensors will represent a challenge for the tracking in the forward region of the pixel system at HL-LHC. In order to reproduce the performance of 50x50 μm² pixels at high eta, FE-I4 compatible planar pixel sensors have been studied before and after irradiation in beam tests at high incidence angle (80°) with respect to the short pixel direction. Results on cluster shapes, charge collection and hit efficiency will be shown.

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