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Measurements and 3D simulation of novel ATLAS planar pixel detector structures including edgeless and alternative bias grid geometries for the HL-LHC upgrade

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In 2022, the LHC accelerator complex will be upgraded to the High-Luminosity-LHC to substantially increase statistics for the various physics analyses. These modifications will result in an increase in occupancy and of radiation damage to the ATLAS Inner Detector (ID). In order to operate under these challenging new conditions, and maintain excellent performance in track reconstruction and vertex location, the ATLAS pixel detector must be substantially upgraded and a full replacement is expected.

A vital selection parameter for the innermost layers of the ATLAS pixel detector will be radiation hardness, which can be achieved through the thinning of sensors. Through new pixel designs, such as active edges and alternative bias rail geometries, minimisation of inactive regions and reductions in efficiency loss can be obtained, allowing sensors to be placed adjacent to each other. This layout is preferable to shingling as it reduces the material budget of the ID as well as cooling requirements and power consumption.

Characterisation of novel pixel designs in a laboratory environment will be presented, including IV and CV measurements, and charge collection measurements with a laser, radioactive sources and cosmic muons. Non-perpendicular particle tracks, forming clusters of charge within the pixel devices, have been analysed. Pixel designs studied include novel layouts for coupling to the ATLAS FE-I4 readout chip and also reduced pixel pitch designs (50 x 50 μm) for the new 3D OmegaPIX front-end chip.

Processing techniques for novel pixel designs are optimised through 3D simulations with Technology Computer Aided Design (TCAD). Comparison of simulation with Secondary Ion Mass Spectrometry (SIMS) measurements to study the doping profile of structures will also be included.

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