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Silicon Detectors for the LHC Phase-II Upgrade and Beyond –RD50 Status Report

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It is foreseen to significantly increase the luminosity of the LHC by upgrading towards the HL-LHC (High Luminosity LHC). Especially the Phase-II-Upgrade foreseen for installation in 2023 will mean unprecedented radiation levels, significantly beyond the limits of the silicon trackers currently employed at the LHC experiments. As a consequence, all-silicon central trackers are being studied in ATLAS, CMS and LHCb, with extremely radiation hard silicon sensors required especially in the innermost layers. Within the RD50 Collaboration, a large R&D program is underway across experimental boundaries to develop silicon sensors with sufficient radiation tolerance. Key areas of recent RD50 research include new sensor fabrication technologies such as High-Voltage (HV) CMOS, exploiting the wide availability of the CMOS process in the semiconductor industry. We also seek for a deeper understanding of the connection between the macroscopic sensor properties such as radiation-induced increase of leakage current, doping concentration and trapping, and the microscopic properties at the defect level. Another strong activity is the development of advanced sensor types like 3D silicon detectors, designed for the extreme radiation levels expected for the vertexing layers at the HL-LHC.
A separate line of RD50 activities is the development of dedicated methods for sensor characterization, such as the laser-based Two-Photon-Absorption (TPA) technique for highly localized measurements of the signal and gain in a sensor as a function of depth, or the system for edge-Transient-Current-Technique (TCT) to study the field profile inside the sensors.
One particular focus area with increasing importance in both ATLAS and CMS is the field of Low Gain Avalanche Detectors (LGADs). In these sensors, a very thin dedicated multiplication layer, designed to create a high field region is built into the sensor. As a result of this thin gain layer, LGADs are characterized by a very high signal compared to traditional Silicon detectors, and in addition a very fast signal with rise times in the order of 50ps. This fast timing makes them ideal candidates for ATLAS and CMS timing layers in the HL-LHC, with the ability to differentiate between multiple vertices in the same event using timing information in addition to space coordinates.

Author: PARZEFALL, Ulrich (Albert Ludwigs Universitaet Freiburg (DE))

Presenter: PARZEFALL, Ulrich (Albert Ludwigs Universitaet Freiburg (DE))

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