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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) in order to harvest the maximum physics potential. Especially the Phase-II-Upgrade foreseen for 2023 will mean unprecedented radiation levels, significantly beyond the limits of the silicon trackers currently employed. All-silicon central trackers are being studied in ATLAS, CMS and LHCb, with extremely radiation hard silicon sensors to be employed on the innermost layers. Within the RD50 Collaboration, a large R&D program has been underway for more than a decade across experimental boundaries to develop silicon sensors with sufficient radiation tolerance for HL-LHC trackers.
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 at very competitive prices compared to the highly specialised foundries that normally produce particle detectors on small wafers. 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 further focus area is the field of Low Gain Avalanche Detectors (LGADs), where a dedicated multiplication layer to create a high field region is built into the sensor. LGADs are characterised by a high signal also after irradiation and a very fast signal compared to traditional silicon detectors with make them ideal candidates for ATLAS and CMS timing layers in the HL-LHC.
We will present the state of the art in several silicon detector technologies as outlined above and at radiation levels corresponding to HL-LHC fluences and partially beyond. As an example, Figure 1 shows a summary of signal measurement results for irradiated LGAD silicon detectors (left), indicating a good radiation tolerance at high bias voltages, and efficiency measurements for 3D detectors (right) irradiated to 1015neq/cm2, demonstrating a high efficiency even at moderate bias voltages.
Fig. 1: Signal measurements on LGAD detectors irradiated to a range of fluences (left) and efficiency measurements for irradiated 3D detectors (right)

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