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Charge Collection Efficiency Simulations of Irradiated Silicon Strip Detectors

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Position sensitive silicon detectors are largely employed in the tracking systems of High Energy Physics (HEP) experiments due to their outstanding performance. They are currently installed in the vertex and tracking part of the CMS experiment at LHC the world's largest particle physics accelerator at Centre for European Nuclear Research (CERN), Geneva.

An upgrade of LHC accelerator is already planned, namely the high luminosity phase of the LHC (HL-LHC foresee for 2023). The tracking system of CMS at HL-LHC will face more intense radiation environment than the present system was designed for. This requires the upgrade of the full tracker that will be equipped with higher granularity as well as radiation hard sensors, which can withstand higher radiation levels and higher occupancies. In order to address the problems caused by intense radiation environment extensive measurements and simulations studies requirements have been initiated for investigating different designs and materials options for Si micro-strip sensors.

The simulation studies of silicon detectors, based on commercial packages (Silvaco and Synopsys TCAD), are performed in order to investigate sensor characteristics before and after irradiation for fluences up to 1.5×10ˆ15 neq cm−2.

Essential information of the performance of an irradiated silicon detector is obtained by monitoring its Charge collection efficiency (CCE). From the evolution of the CCE as a function of fluence it is possible to directly observe the effect of the radiation induced defects to the ability of the detector to collect charge carriers generated by traversing minimum ionizing particles (mip).

The talk covers the numerically simulated CCE and CCE loss between the strips of irradiated silicon strip detectors using Synopsys Sentaurus package. A two level and non-uniform three level defect models were applied for the proton irradiation simulations and two level model for neutrons. The results are presented together with measured CCE of Hamamatsu Photonics K. K. produced strip detectors irradiated by different particles and fluences. Simulated CCE is simply defined as the ratio of the charge collected by an irradiated detector to the collected charge of a non-irradiated detector. CCE simulations included both n-in-p and p-in-n silicon strip detectors. Simulations were done in 2D and the third dimension was taken into account by an area factor. As for the measurement of real detectors, the simulation temperatures were RT for non irradiated and -20C for irradiated devices. Irradiation was simulated by 1 MeV neutron equivalent fluences, ranging from 10^{14} to 1.5×10^{15} cm−2. Also the significant increase of surface damage with fluence was considered in proton irradiated detectors. This required the application of the non-uniform 3-level defect model to maintain the experimentally observed strip isolation in n-on-p detectors. Simulated charge was injected either by a mip or IR laser. The experimentally observed CCE loss between the strips was simulated by first varying the position of charge injection from the middle of the pitch to the center of the strip. Then the CCE loss was determined as the ratio of the difference in the collected charge at the center of the strip and in the middle of the pitch to the charge collected at the strip. Simulations were then compared with the CCE measurements done with Silicon Beam Telescope (SiBT) and ALiBaVa setup.

Results show considerable agreement with measurements in both CCE and its position dependency. By being able to verify experimental results, the numerical CCE simulations are proven

to have also predictive power. This can lead to reduced time and cost budget in the R&D of the novel silicon radiation detector designs with upgraded radiation hardness.

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