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Operational voltage of silicon heavily irradiated strip detectors utilizing avalanche multiplication effect

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Recent results on the collected charge Qc in heavily irradiated Si detectors developed by RD50 collaboration for SuperLHC showed a significant Qc enhancement if detectors were operated at the bias voltage beyond 1000 V. Our investigations showed that this enhancement arises from a fundamental effect of carrier avalanche multiplication in high electric field of n+-p junction. The goal of the study is estimation of the minimal bias which initiates the avalanche process and is important for maintaining an appropriate power dissipation. Simulations of the collected charge vs. bias voltage and fluence demonstrated that:
• double peak electric field distribution is still the main feature for heavily irradiated detectors operated in the avalanche multiplication mode;
• the electric field near the n+ strips is stabilized via voltage drop redistribution and electric field extension towards the p+ contact;
• this redistribution depends on the concentration ratio of radiation defects with deep levels, Ndd/Nda (Ndd and Nda are deep donors and deep acceptors concentrations, respectively).

The other factors which are sensitive for enhancement of avalanche multiplication at lower bias voltage are strip detector geometry which affects the electric field focusing near the strips, and the temperature of detector operation. The concentration ratio is the impact parameter for the E(x) distribution and bias voltage minimal for charge enhancement. The ratio depends on the radiation type and affects E(x) asymmetry due to potential redistribution over the detector caused by carrier trapping. Predictions on the position sensitivity and detector behavior under mixed irradiation of the real experimental environment are made. In the case of neutron radiation prevailing introduction of deep acceptors leads to a severely asymmetric profile which may reduce the bias specific for avalanche multiplication in strip detectors. This effect is translated on the detector performance at different temperature and radiation environment.

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