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Validation strategy for the simulation of highly irradiated silicon pixel sensors

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For the high-luminosity phase of the Large Hadron Collider (HL-LHC), at the expected position of the innermost pixel detector layer of the CMS and ATLAS experiment, the estimated equivalent neutron fluence after 3000 fb^{-1} is $2{\cdot}10^{16}$ $\text{n}_{eq}/\text{cm}^{-2}$, and the IEL (Ionizing Energy Loss) dose
in the SiO_2 is 5 MGy. The optimization of the pixel sensors and the understanding of their performance as a function of fluence and dose makes a radiation damage model for TCAD simulations, which describes the available experimental data, highly desirable. The currently available models are not able to describe simultaneously the measurements of dark current (I-V), capacitance-voltage (C-V) and charge collection efficiency (CCE) of pad diodes for fluences > $1{\cdot}10^{15}$ $\text{n}_{eq}/\text{cm}^{-2}$. For the development and validation of an accurate radiation damage model of the silicon bulk we use I-V, C-V and CCE measurements on pad diodes available within the CMS-HPK campaign and data from samples irradiated recently with 24 GeV/c protons. To determine the parameter of a radiation damage model (energy levels, concentrations and cross sections) we use the "optimizer" of Synopsys TCAD to minimize the difference between the measured and simulated I-V, C-V and CCE. By this method we study in a systematic way the number and type of the defects, which are required for a consistent description of the bulk damage.

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