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A new model for the TCAD simulation of the silicon damage by high fluence proton irradiation

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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 experiments, 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 12 MGy. The optimisation 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 bulk-damage 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 $\geq 1 \cdot 10^{15}$ $\text{n}_{eq}/\text{cm}^2$.
Therefore, for the development and validation of a new accurate bulk damage model 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. For the determination of the radiation-induced damage parameters we utilise the “optimiser” of Synopsys TCAD, which allows the minimisation of the difference between the measured and simulated I-V, C-V and CCE. The outcome of this optimisation, the Hamburg Penta Trap Model (HPTM), provides a consistent and accurate description of the measurements of diodes irradiated with protons in the fluence range from $3{\cdot}10^{14}$ $\text{n}_{eq}/\text{cm}^2$ to $1.3{\cdot}10^{16}$ $\text{n}_{eq}/\text{cm}^2$.

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