Simulations of radiation-induced charge loss in ALICE ITS3 MAPS prototypes

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The ITS3 upgrade of the ALICE experiment at CERN will introduce ultra-light, bent monolithic pixel sensors using the TPSCo 65 nm CMOS process. This design reduces the material budget to 0.09% X_0 per layer and the innermost layer radius to 19 mm, improving the impact parameter resolution by a factor of 2 for momenta < 1 GeV/c.

As part of the ITS3 R&D effort, multiple prototype sensors were developed and characterized, with extensive testing conducted using radioactive sources, particularly ^{55}Fe. Unlike charge deposition from minimum-ionizing particles, ^{55}Fe X-ray spectra offer a more stringent probe of charge collection dynamics and subtle detector effects, but are correspondingly harder to model precisely. Accurately reproducing these spectra indicates a deep understanding of the sensor's internal processes.

Although the sensors have met the radiation hardness requirements of 4 x 10^{12} 1 MeV n_{eq} cm^{-2}, higher irradiation levels (up to 10^{16} 1 MeV n_{eq} cm^{-2}) lead to notable degradation in the ^{55}Fe spectral response, due to radiation-induced effects in silicon. To investigate this, simulations were carried out using TCAD for electric field modeling and Garfield++ for charge transport. This presentation will highlight the simulation approach, its role in understanding sensor performance post-irradiation, and will showcase the excellent compatibility with experimental data.

These results not only support the ongoing optimization of sensor performance for ITS3, but also lay the groundwork for developing next-generation monolithic sensors capable of operating reliably in even harsher radiation environments.