Contribution ID: **71** Type: **poster**

Modelling of Silicon Drift Detectors using a full-stack Energy Dispersive X-Ray Spectroscopy Simulation

Energy Dispersive X-Ray Spectroscopy (EDS) is a well-established chemical element analysis method with applications in material characterization, device testing, biosciences, forensics, food science and many more. In EDS, characteristic X-rays are generated by hitting a sample with an electron beam. These X-rays are then captured by a Silicon Drift Detector (SDD), where the photon energy is converted to a signal by creating and transporting electron-hole pairs.

In these SDDs, various parasitic effects, such as recombination and electrons captured in the front layer of the detector, cause Incomplete Charge Collection (ICC). Other effects, such as electron repulsion in the created electron clouds, cause signal rise-times, a key quantity in signal processing. To correct for incorrect signal measurements caused by these effects, a full understanding of the physical processes inside the SDD is required.

We have developed a full EDS simulation pipeline, from electron beam to signal creation, to allow accurate modelling of these physical processes. Monte Carlo simulations are performed using CERN's software package Allpix Squared [1] to simulate the electron-hole transport inside the SDD. To model the physical processes causing the ICC, we perform Scikit-FEM simulations to calculate the electric field, with an extra focus on the first micron of the front contact of the SDD: the P+ layer. Using these methods, we achieved results that show the ICC and rise-time effects. These results were validated by comparing them to analytical expressions [2] and experimental results [3] found in literature.

This validation of our EDS simulation pipeline opens the possibility to answer complex design questions and gain system understanding by running simulations, where this would normally require expensive experiments.

References

[1] Spannagel et al., Allpix2: A modular simulation framework for Silicon Detectors 2018, https://doi.org/10.1016/j.nima.2018.06.020

[2] Scholze & Procop, Modelling the response function of energy dispersive x-ray spectrometers with Silicon Detectors 2009, https://doi.org/10.1002/xrs.1165

[3] Prigozhin et al., Characterization of the silicon drift detector for NICER instrument 2012, https://doi.org/10.1117/12.926667

Workshop topics

Detector systems

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