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Optimizing Charge Sharing Simulation for Deep Learning Enhanced Spatial Resolution of the MÖNCH Detector

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Deep learning can significantly enhance spatial resolution beyond the pixel pitch of hybrid detectors. We have successfully demonstrated it for electron microscopy with 200 keV electrons using the MÖNCH 25 um pitch charge integration pixel detector. The deep learning models have been trained using simulation data, which are easier to produce with varied parameters, and measurement data, which are more cumbersome to acquire since they need a special setup of the electron microscope.

However, challenges arise when comparing simulation-based deep learning models to measurement-based models for electrons, as the spatial resolution achieved through simulations is notably worse than that of measurements. When directly comparing X-ray simulations with measurements, discrepancies are also observed, particularly in the spatial resolution and the spectral output of single pixels. These observations collectively indicate that further optimization of the current simulation is necessary.

In this study, a Monte-Carlo simulation is conducted to model the dynamics of charge carriers within the silicon sensor. It aims to better model the charge sharing effect and generate simulation samples of higher quality for deep learning applications. The simulation encompasses various factors, including the initial charge cloud generated by X-rays or electrons, charge drift and diffusion, charge repulsion, and electronic noise. The incorporation of charge repulsion into the simulation proves crucial for better reproducing measurements. Detailed information regarding the simulation setup will be provided, along with a comparative analysis between simulation outcomes and empirical measurements. Additionally, the simulation-based deep learning results achieved through the improved simulation model will be presented and discussed.

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