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Enhancing spatial resolution in MÖNCH detectors for electron microscopy via deep learning

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Hybrid Pixel Detectors (HPDs) have been widely adopted for diffraction-based modalities in electron microscopy thanks to their high frame rates (> 1 kHz) and large dynamic range. However, they are less suitable for imaging applications because of their poor spatial resolution due to relatively large pixels (≥ 25 µm) and to the multiple scattering of high-energy electrons (> 100 keV) in the thick sensor layer. For cryogenic electron microscopy (cryo-EM) the state-of-the-art are thin monolithic CMOS devices with small pixels (≤ 15 µm pitch). To fully realize the potential benefits of fast, radiation hard HPDs for all modalities of electron microscopy, we are developing deep learning methods to reconstruct the impact points of incident electrons for the 25 µm MÖNCH pixel detector [1]. Exploiting the small pixels to track the electrons and using deep learning to obtain subpixel resolution, we aim to extend the use of HPDs to cryo-EM imaging and develop a detector for both diffraction and imaging applications.

We have developed several deep learning models to localize the electron impact point based on both simulations and measured data, extending the work presented in [2, 3], which was based on only synthetic data. Simulation samples are obtained using Geant4-Medpix [4]. For the measurement-based training, we have focused the electron beam to a sub-pixel region to label tracks with ground truth impact points. A sub-pixel spatial resolution has been achieved for 200 keV electrons. We will show details of the deep learning model design, training scheme, and evaluation results. Example images of some standard samples will also be presented, in addition to the detective quantum efficiency measurements, to act as a benchmark of the system's abilities. Lastly, the data processing pipeline for the MÖNCH detector for its use in electron microscopy will be discussed.

[1] M. Ramilli et al., JINST 12 (2017) C01071
[2] J. Paul van Schayck et al., Ultramicroscopy, 218 (2020), 113091
[3] B. Eckert et al., IEEE Transactions on Nuclear Science, 69 (2022), 1014-1021
[4] A. Schübel et al., JINST 9 (2014) C12018

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