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ML-processed Silicon Device signal-sharing with BNL AC-LGAD sensors

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Resistive Silicon Devices (RSDs), such as AC-coupled Low Gain Avalanche Diodes, achieve a fine spatial resolution while maintaining the LGAD's timing resolution with near to 100% fill factor, achieving time and space (4D) tracking measurements for collider experiments in High Energy Physics (HEP) at the Large Hadron Collider (LHC), Electron-Ion Collider (EIC), and Lepton Collider experiments. Technological limitations in segmented detection technologies impose a geometrical disposition as an array of linear strips with 1D spatial resolution or a matrix of pixels with 2D spatial resolution. In contrast, for RSDs, the shape and disposition of the readout pads along the detector surface can be easily tuned and modified. When ionizing radiation hits these devices, the collected charge spreads well beyond the two adjacent pixels. The limitations due to the lower amplitudes and Landau fluctuations on the pixels further apart from the true particle's hit limit the full potential of the readout. Using pixelated AC-LGADs fabricated at Brookhaven National Laboratory, with different geometric pad arrangements, we study and characterize the possible improvements on the position resolution through multi-channel collection complex machine learning-based algorithms, such as Recurrent Neural Networks. The sensors are built with a pixel density of 500 micrometers x 500 micrometers in a square and triangular arrangement.. In contrast to traditional methods, we use full wave-form information to infer the particle's hit position, improving the resolution capabilities of these sensors and opening the path to arbitrary geometrical pixel arrangements. We compare their performance to that of traditional charge-imbalance algorithms as well as geometry-based matrix inversion methods. We perform these studies with infrared lasers using the TCT technique and at test beams. Further, we study how to compress the resulting information through wave-form rasterization techniques while maintaining the improved spatial resolution, opening the path to implementing such algorithms on Field Programmable Gate Arrays for fast signal processing.

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