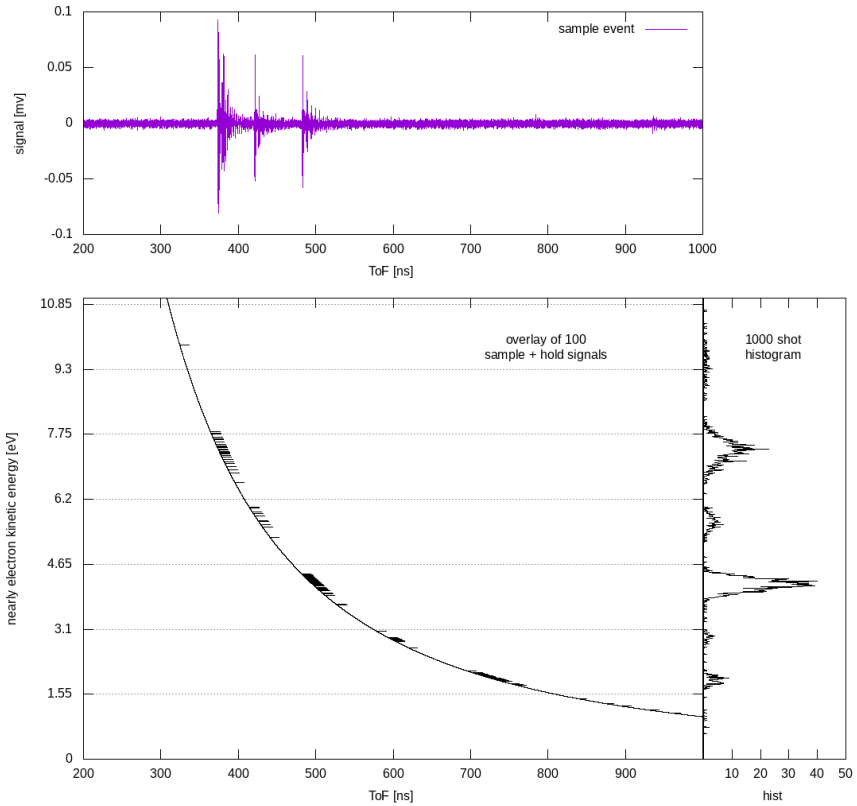
Analog pre-processing for down-stream ML models



HHG based electron spectra transformed from Time-of-Flight to nearly energy domain using derivative amplifier and software non-linear TAC logic. The top panel shows a few-hit single shot, central demonstrates the non-linear voltage ramp used for the "sample and hold", and the right panel the resulting histogram.

Work was performed at PULSE HHG laser lab by a combination of PULSE and LCLS scientists supporting the CookieBox project.

Scientific Achievement

Non-linear time-to-analog conversion for direct production of "featurized" wave forms for EdgeML based electron spectroscopy

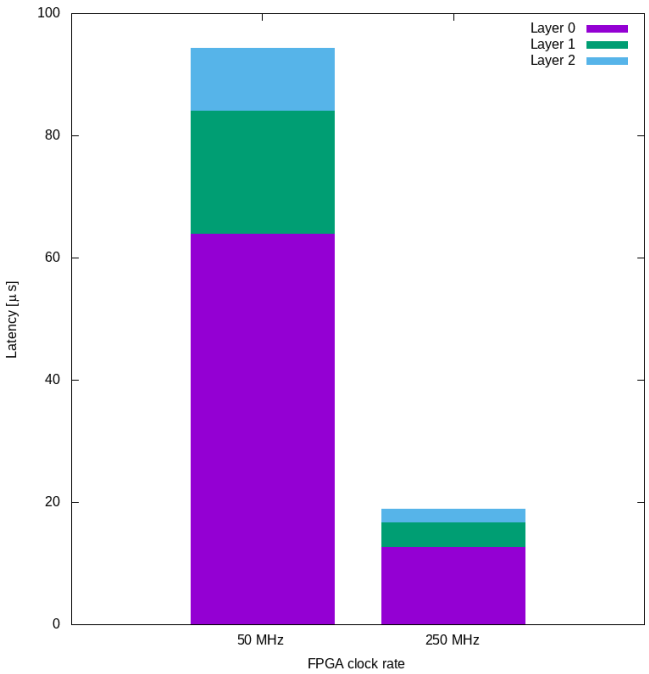
Significance and Impact

Identified analog electronics logic for pre-processing of electron Time-of-Flight wave forms that alleviates need for high digitizer bandwidth and sampling.

Research Details

- Initial test, using surrogate HHG laser source with prototype electron spectrometer (CookieBox)
- Developed analysis chain using analog pre-processing that feeds a non-linear Time-to-Analog converter for transforming raw wave forms directly into the representation needed by the down-stream FPGA-based inference engine.
- Next steps: Use known HHG spectra with 8-fold differential retardation to simulate angular streaking results. Install prototype detectors into dual sided streaking geometry in PULSE lab and measure linear streaking with analog pre-processing circuit and on-digitizer logic.

Autonomous data routing and veto decisions at rate



SASE sub-structure inference neural network for to infer the fate of streaming data, on the fly, using the CookieBox detector. Neural Network layers by color, 3 layer fully connected neural network, for two representative FPGA clock frequencies.

Work was performed at the LCLS with the help of TID with close integration into L2SI data systems efforts.

Scientific Achievement

Ultra-low latency inference engine for identifying desirable x-ray shots based on SASE sub-structure

Significance and Impact

Initial demonstration of ultra-low latency FPGA-based inference for autonomous decisions in data routing and veto; compatible with as few as 20 event buffer depth.

Research Details

- Shallow Neural Network model for Level-0 on-the-fly decision making based on the 16-fold angular array of electron spectrometers (CookieBox)
- Correctly identifies single spike versus two spike versus 3 or 4 spike SASE shots with inference latency in the 10 microsecond range for 250MHz clock FPGA.

- Next steps: Incorporate recently measured wave forms in both over- and under-sampling regimes. Improve the “purity” of the output confusion matrix for higher number of sub-spikes