Machine learning applications in NEWS-G

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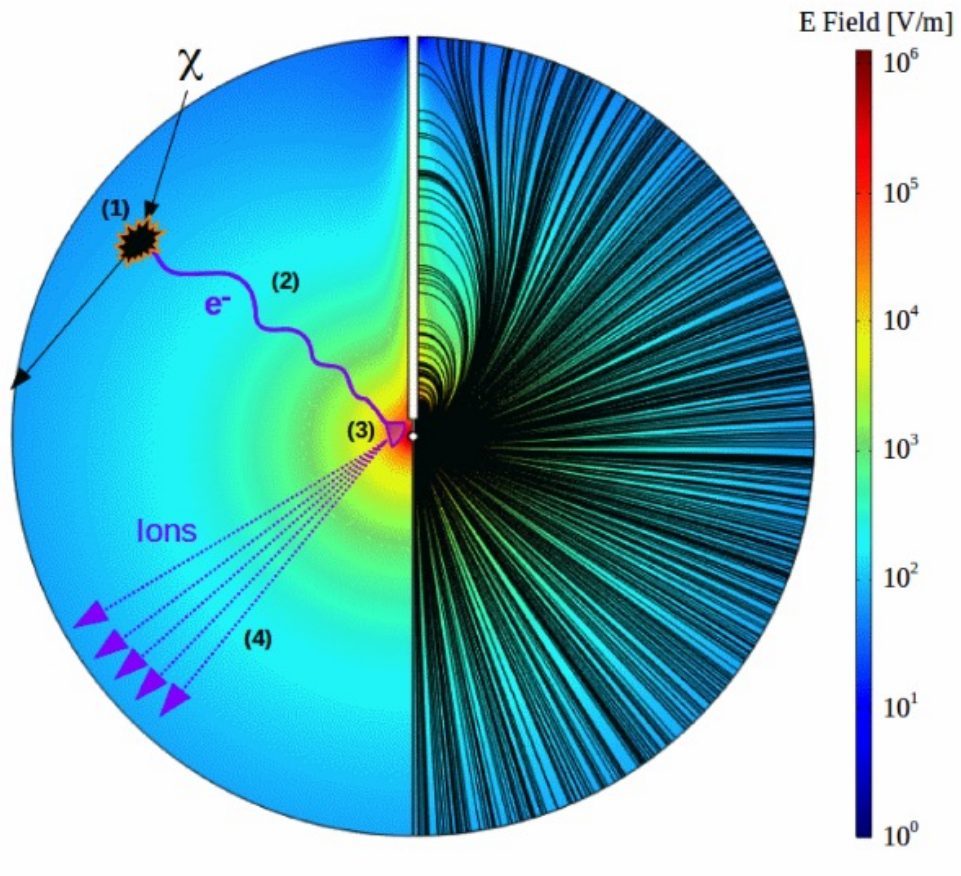
NEWS-G – Spherical Proportional Counter



Signal Generation:

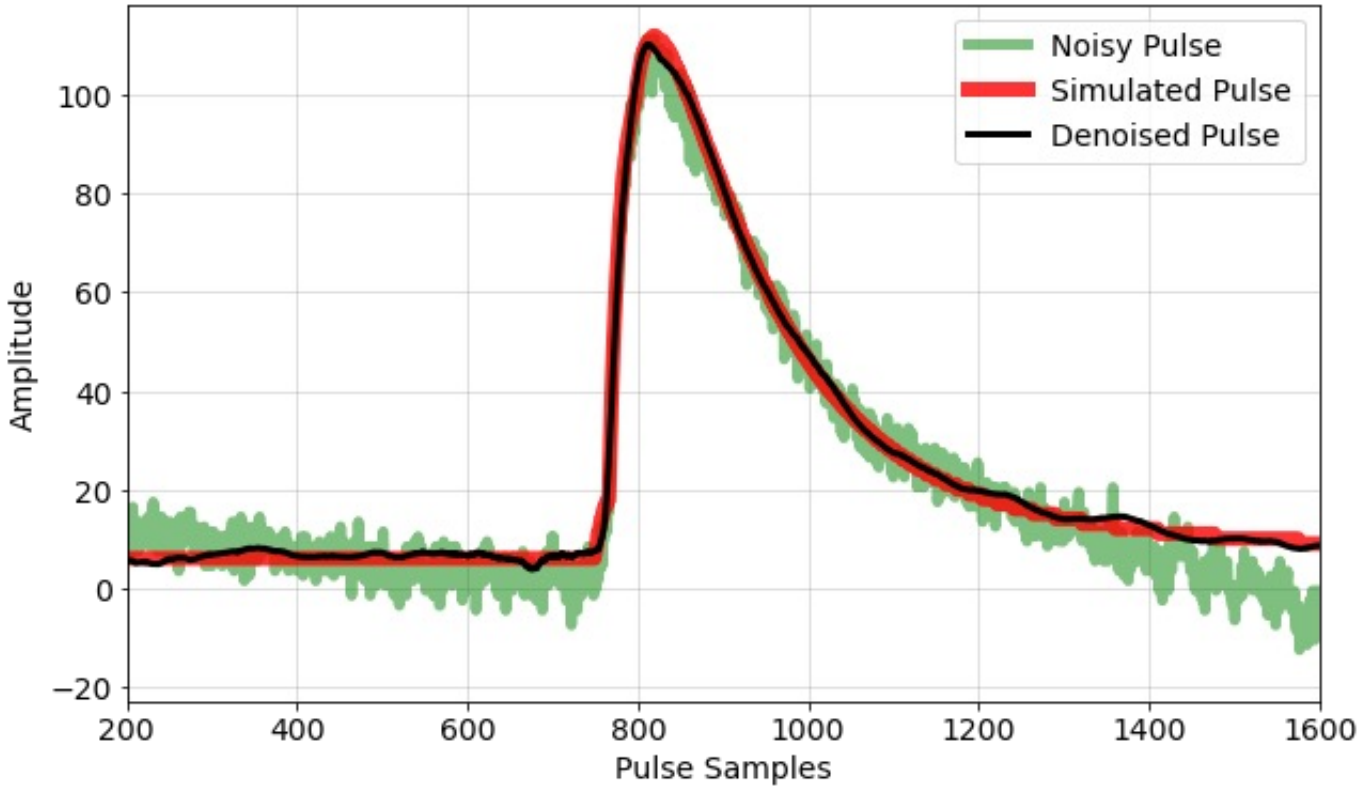
1. Primary ionization
2. Electron drift
3. Townsend avalanche
4. Positive ion drift

Analysis data taken from SEDINE at LSM in France

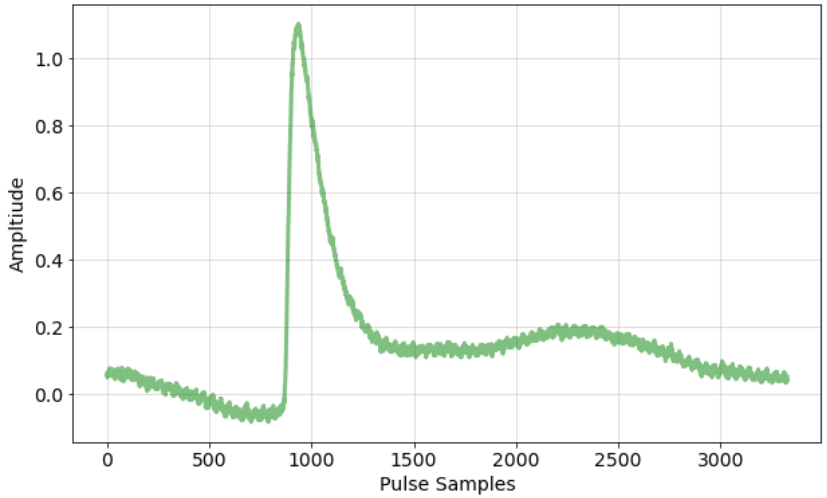
Problem Definition

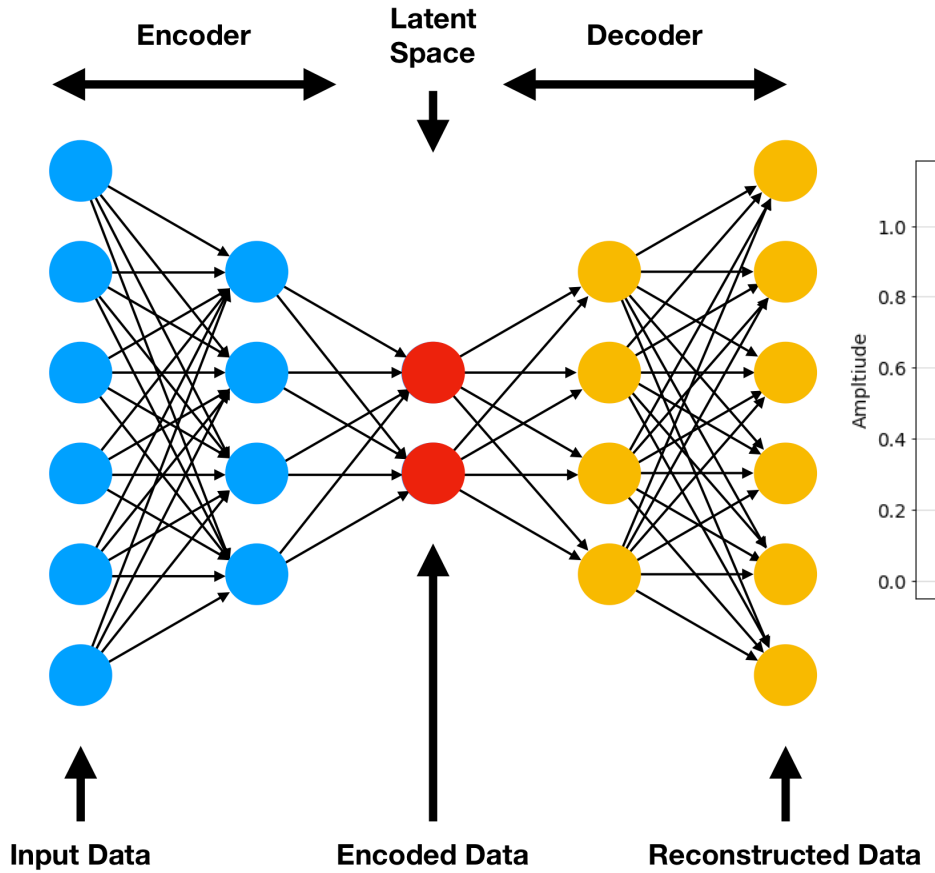
Goals:

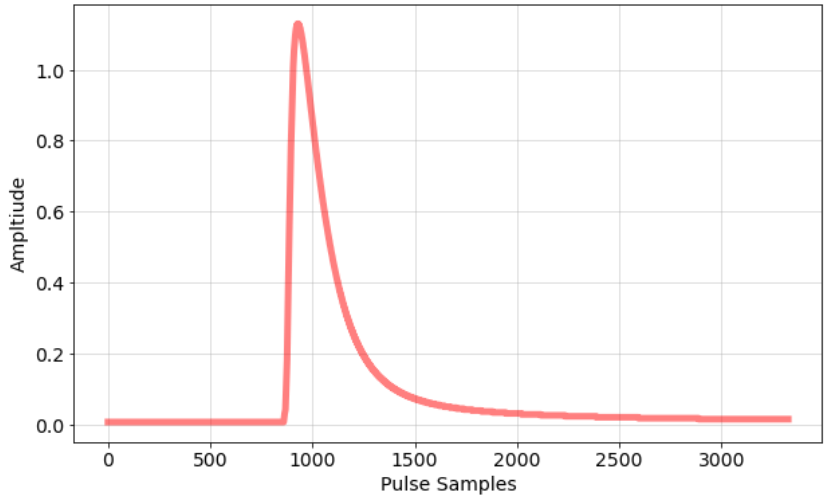
- Utilize machine learning methods to remove noise from recorded detector signals
- Model implementation should aid in measuring important signal characteristics, such as amplitude and rise-features



Methods – Model Architecture



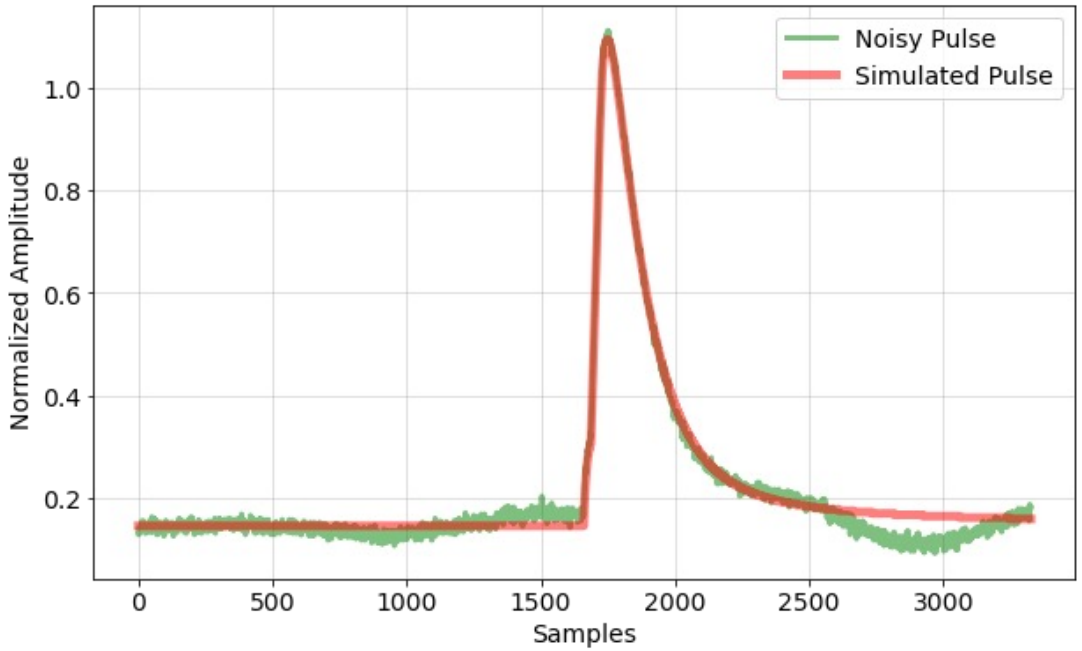




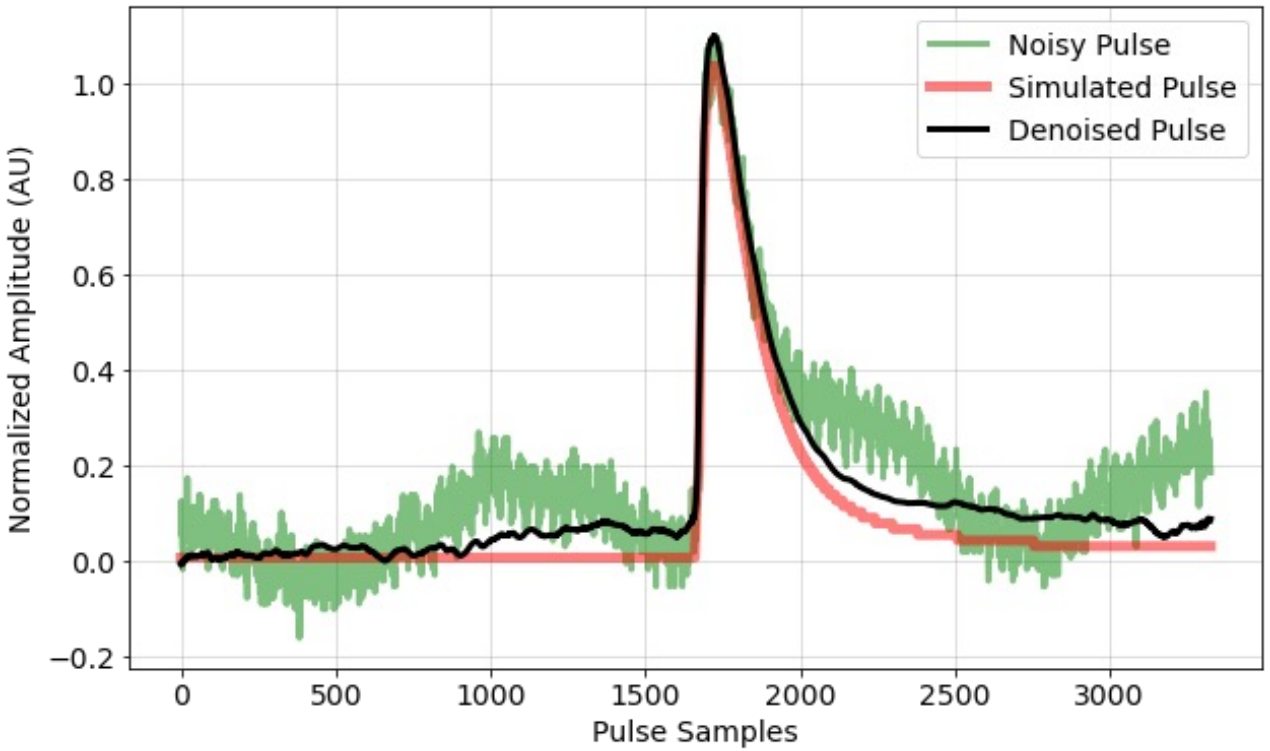
Methods – Model Training

Trained on a simulation-based dataset modeled after our real detector

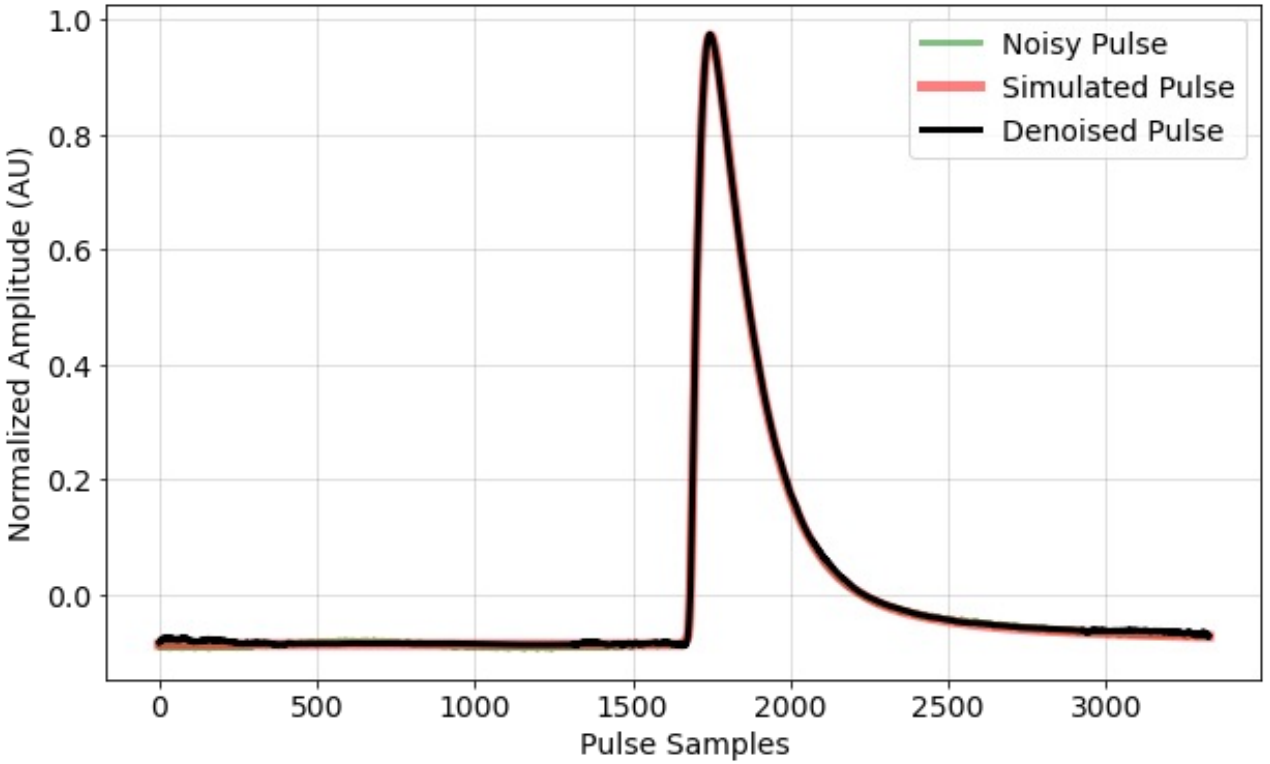
X	Simulated pulses + real noise
Y	Simulated pulses



Example Pulses

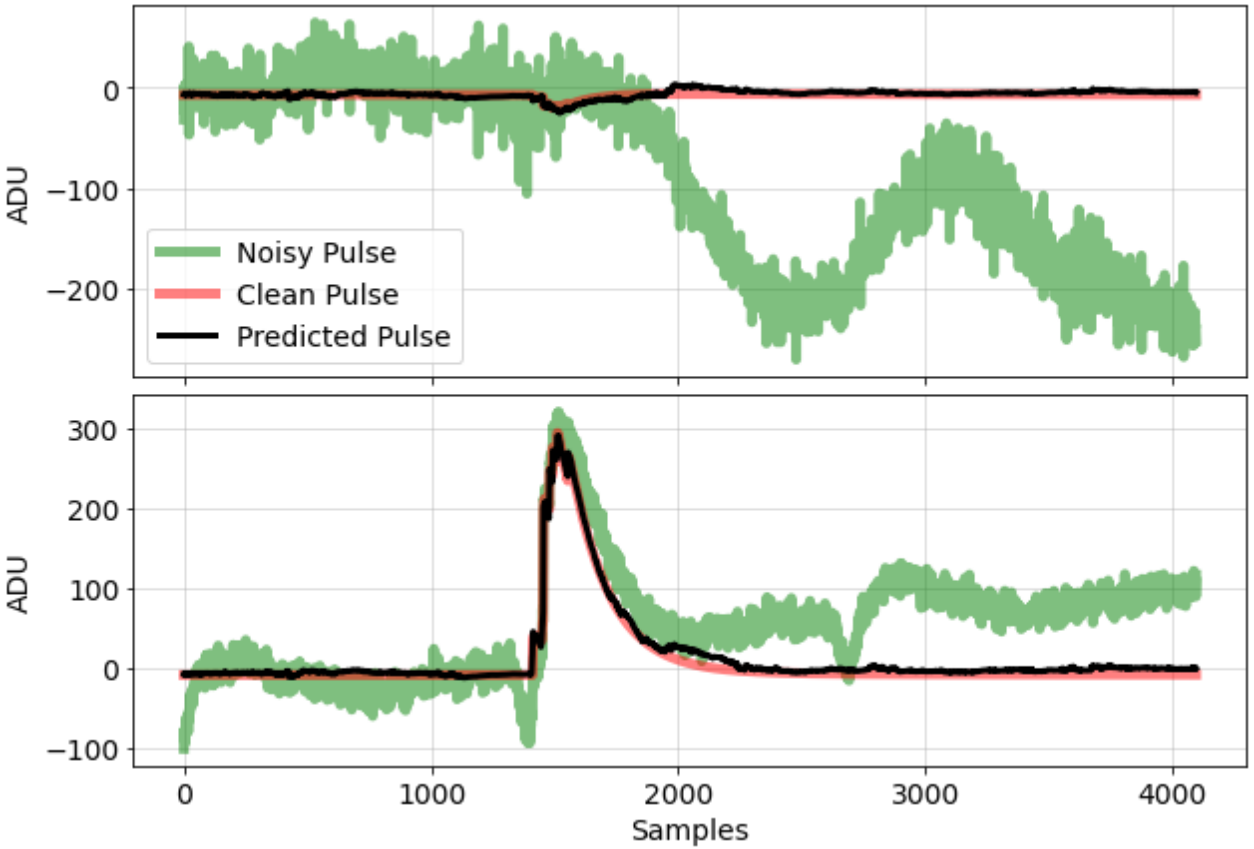


Energy: ~170eV

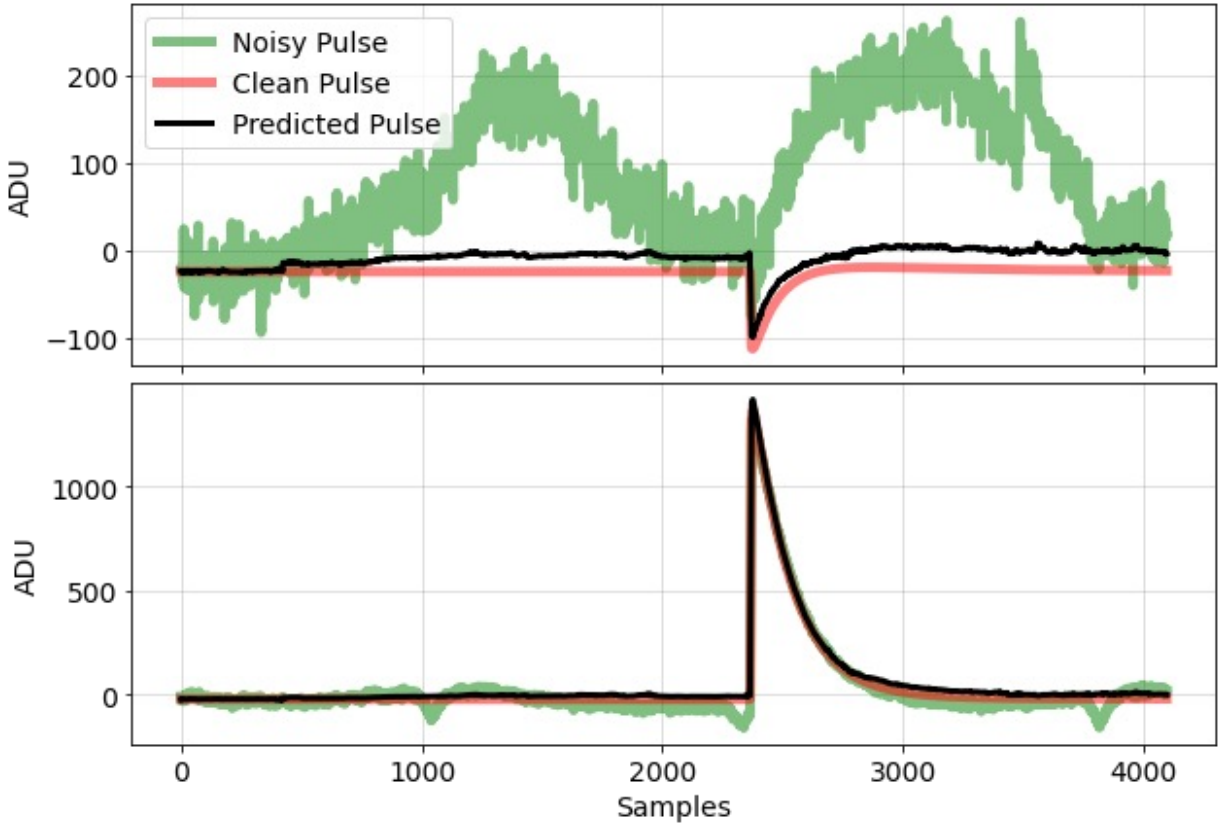


Energy: ~1370eV

Example Pulses

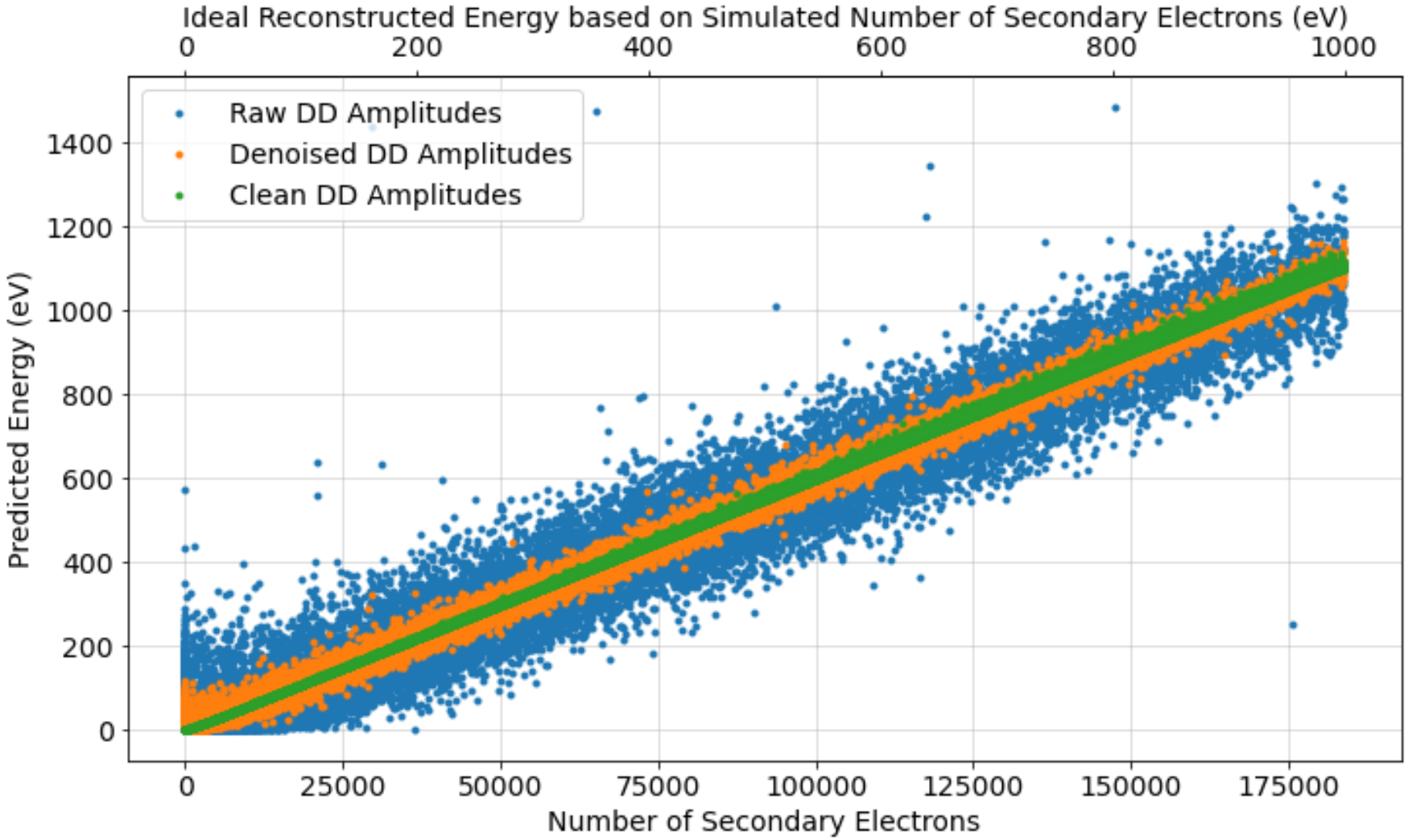


Energy: ~250eV

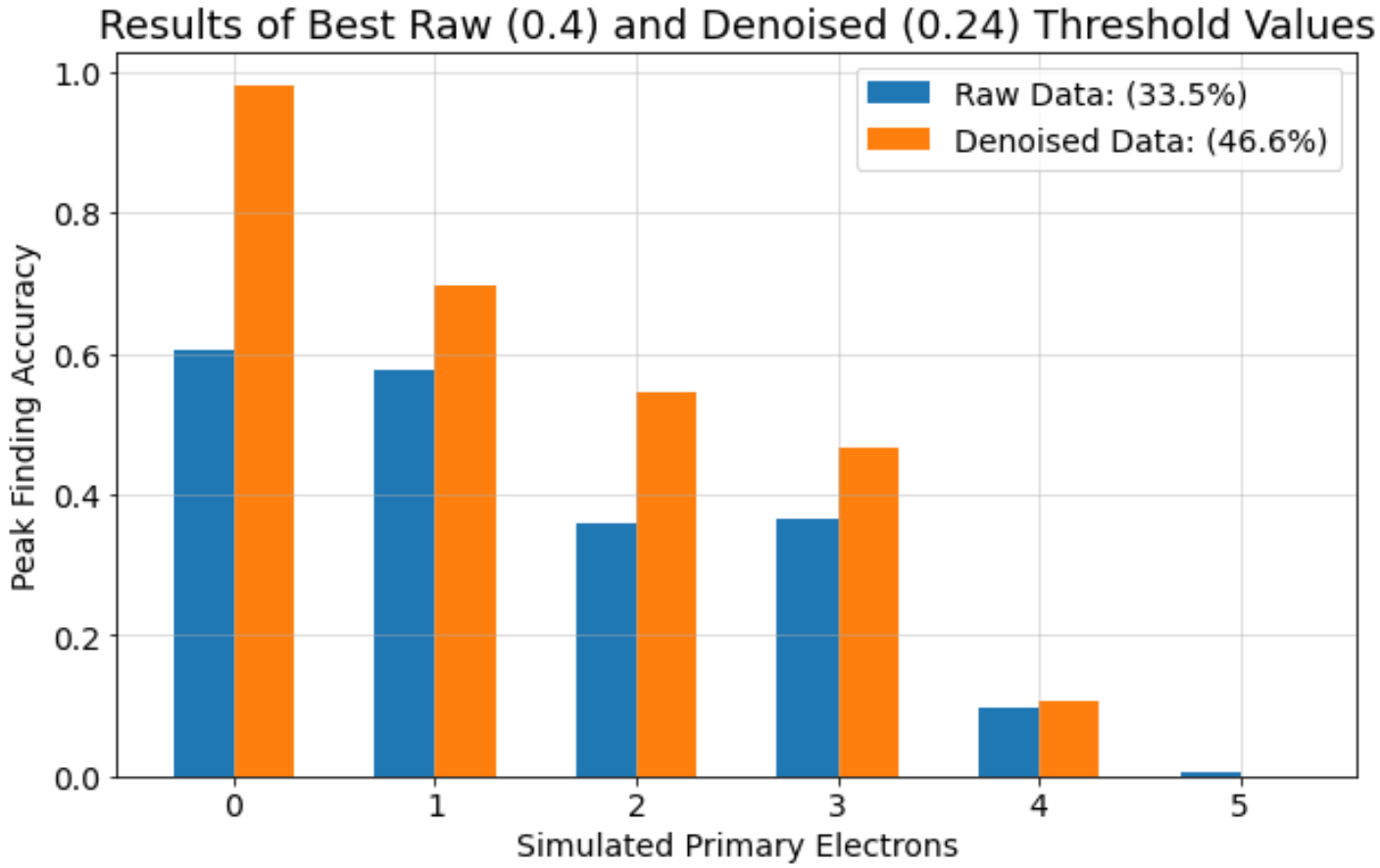


Energy: ~330eV

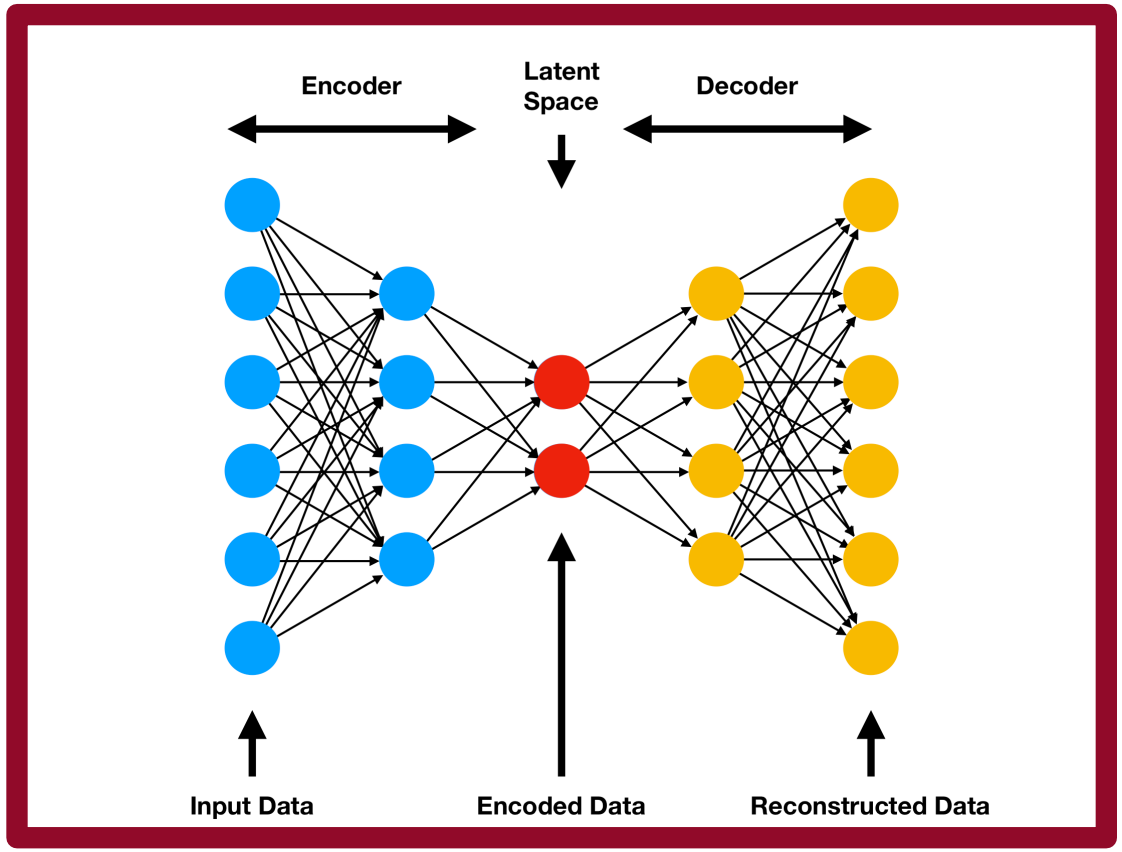
Simulated Energy Resolution

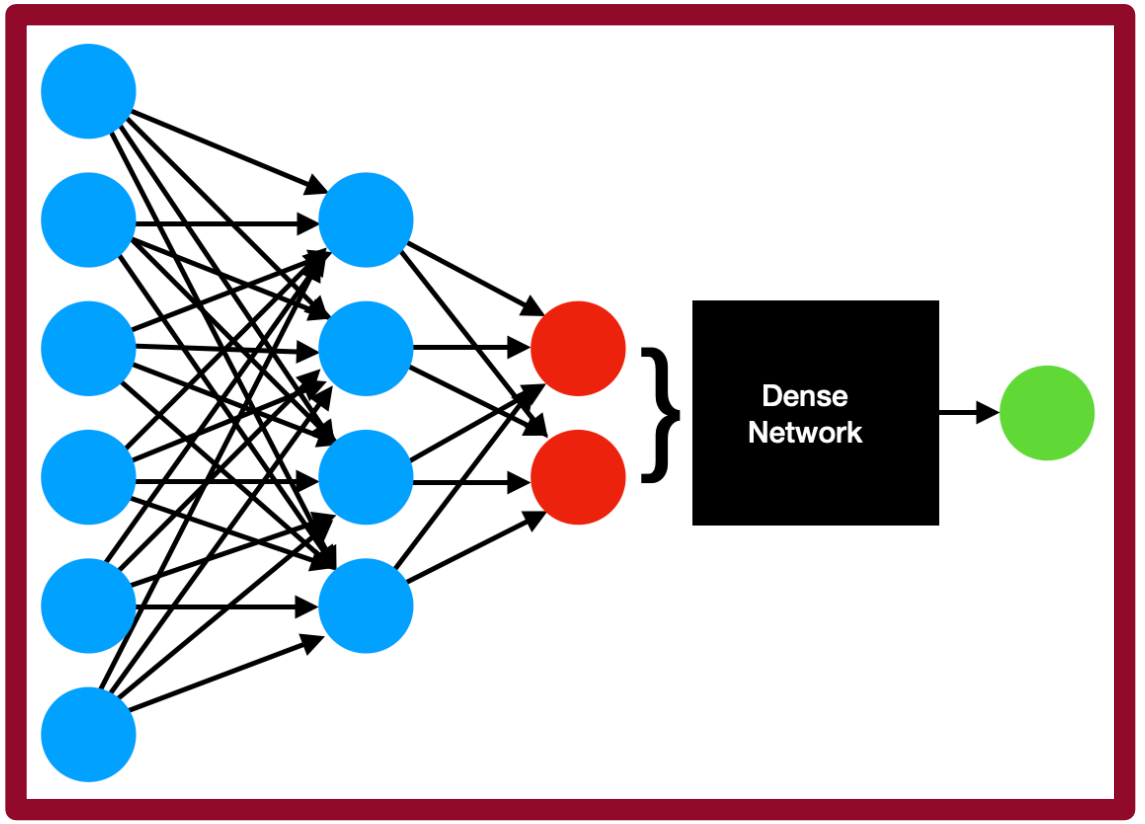


Primary Electron Counting

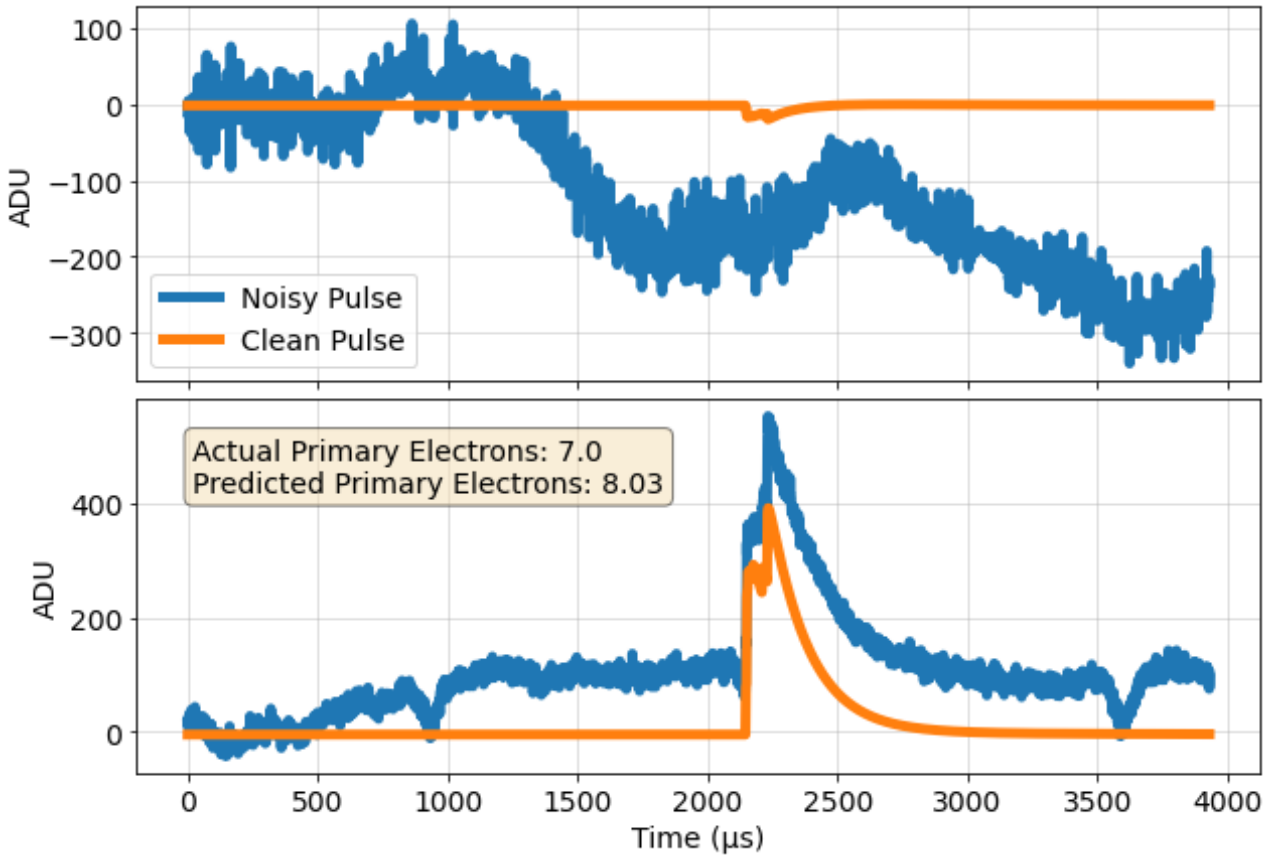


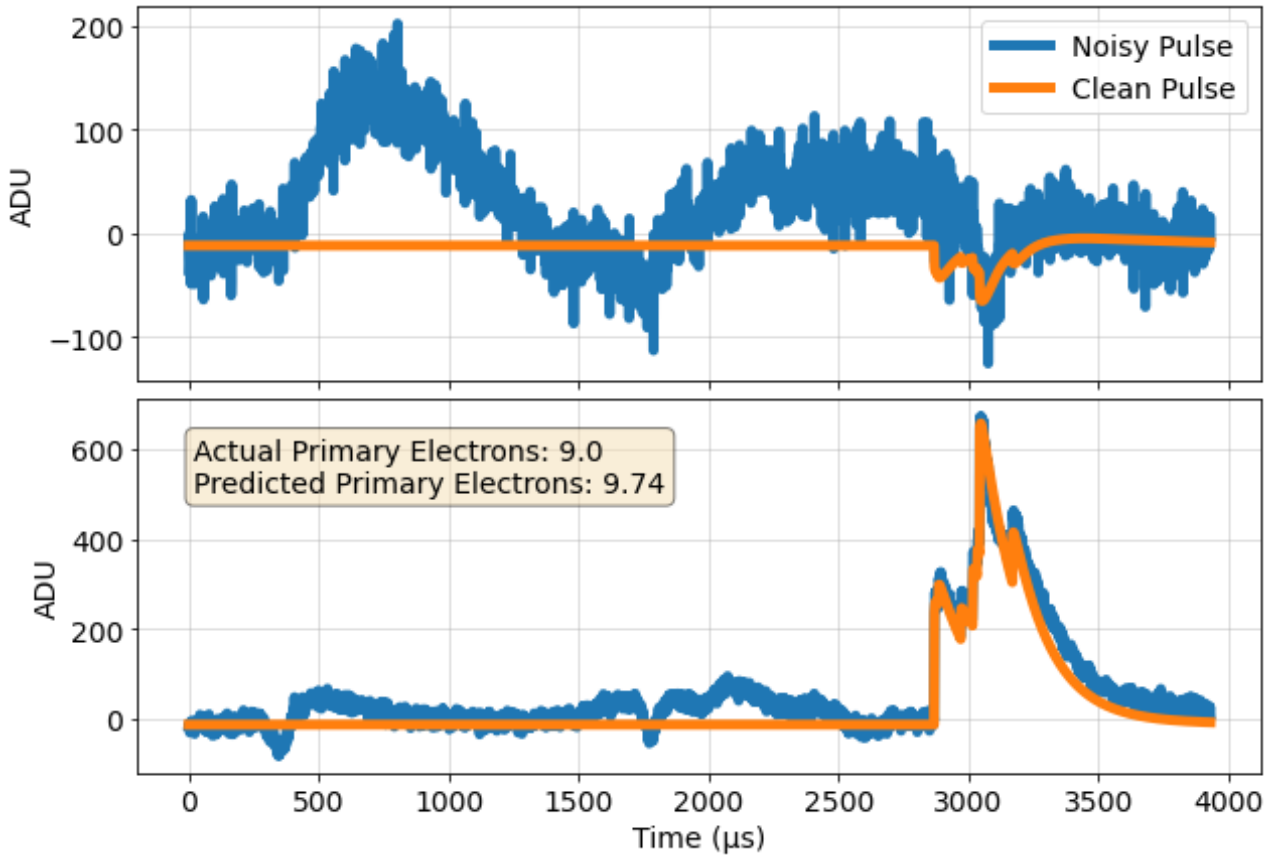
Single Output Model



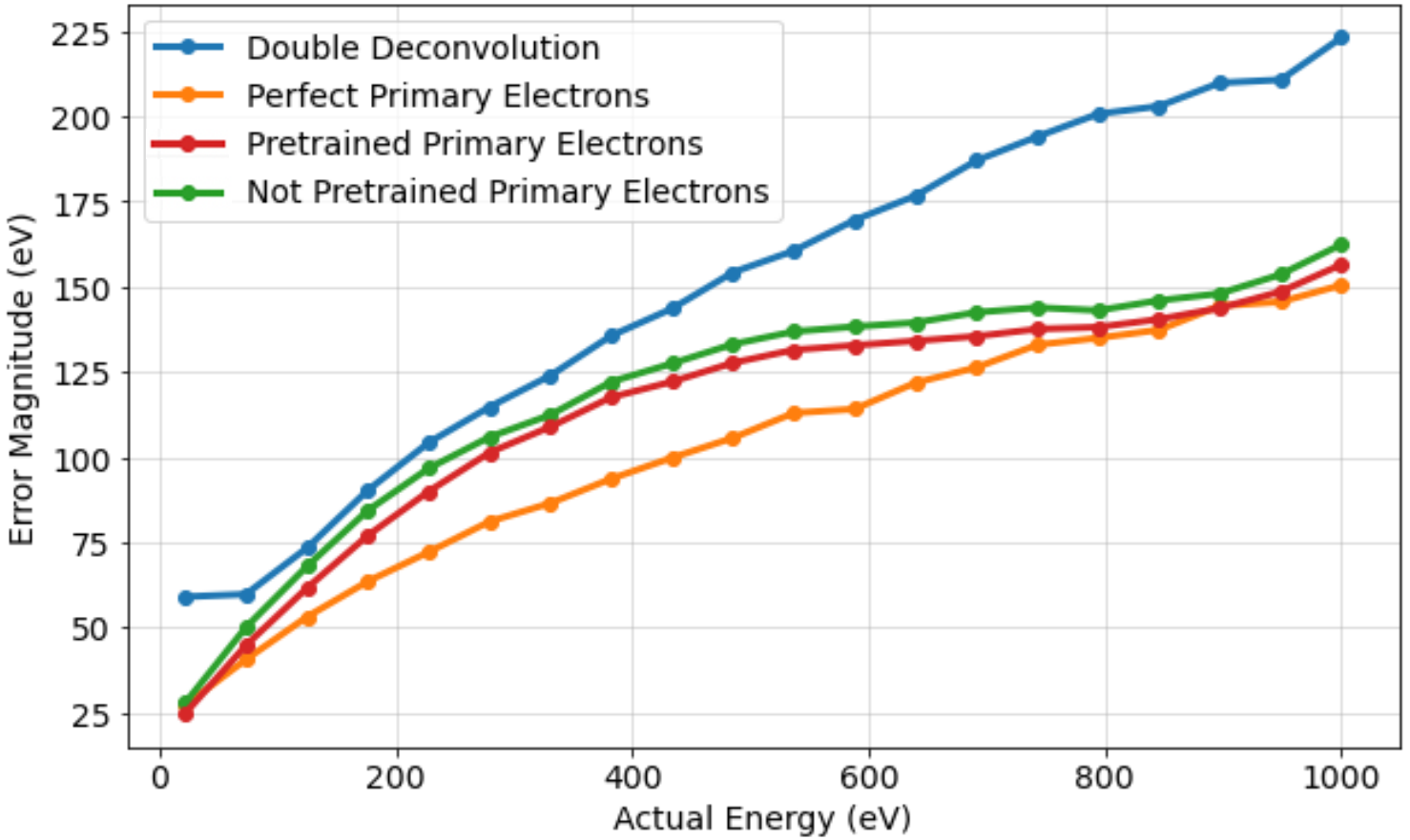


Primary Electron Prediction Examples





Primary Electron Prediction



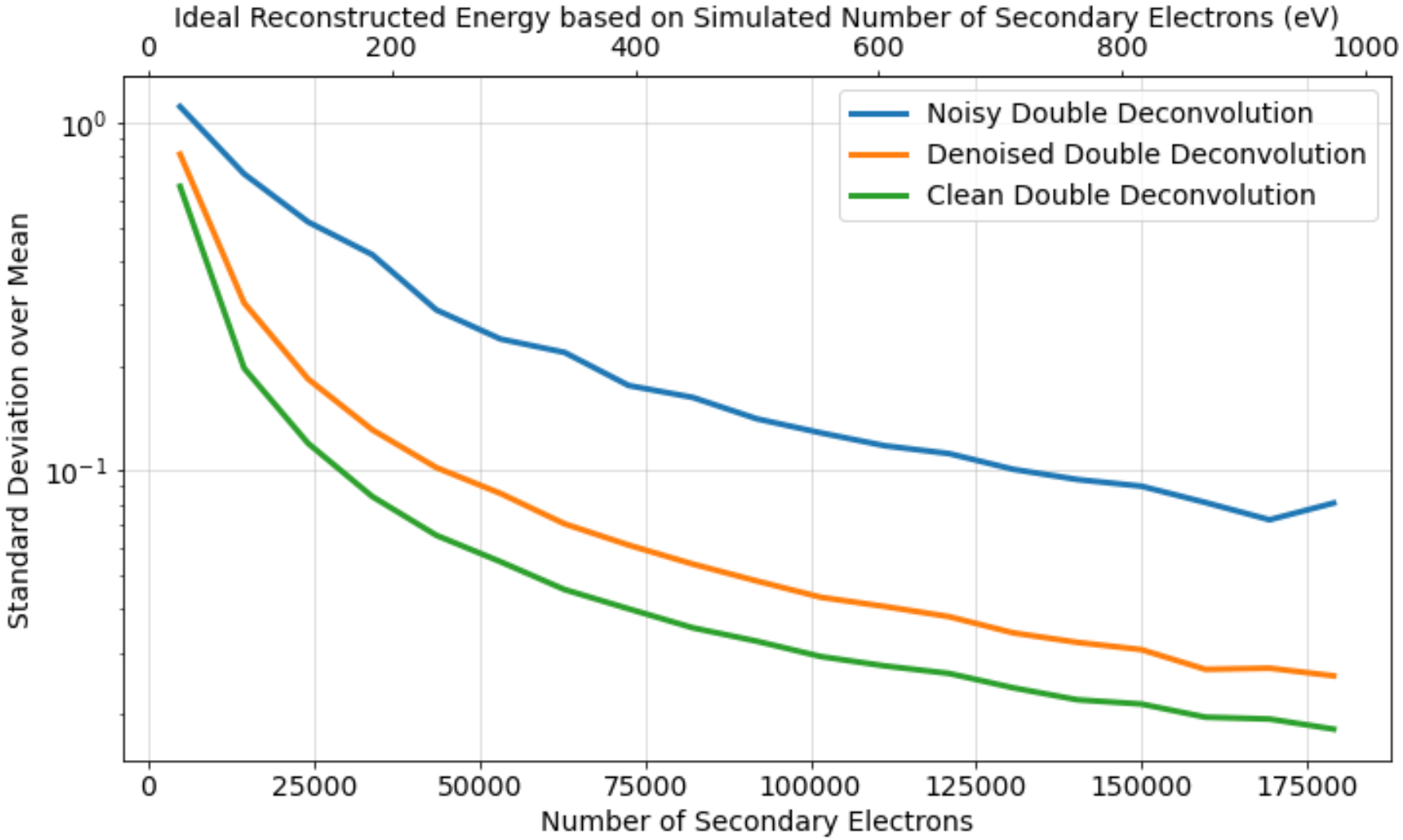
Machine Learning Extensions

- Other single-output predictions
  - Direct energy prediction, pulse shape classification
- Double-deconvolution layer implementation
  - Explicitly add preprocessing steps to network layers
  - Learn to return primary electron arrival times
- Different model architectures for improved performance
  - Adversarial networks (see Tianai's poster)

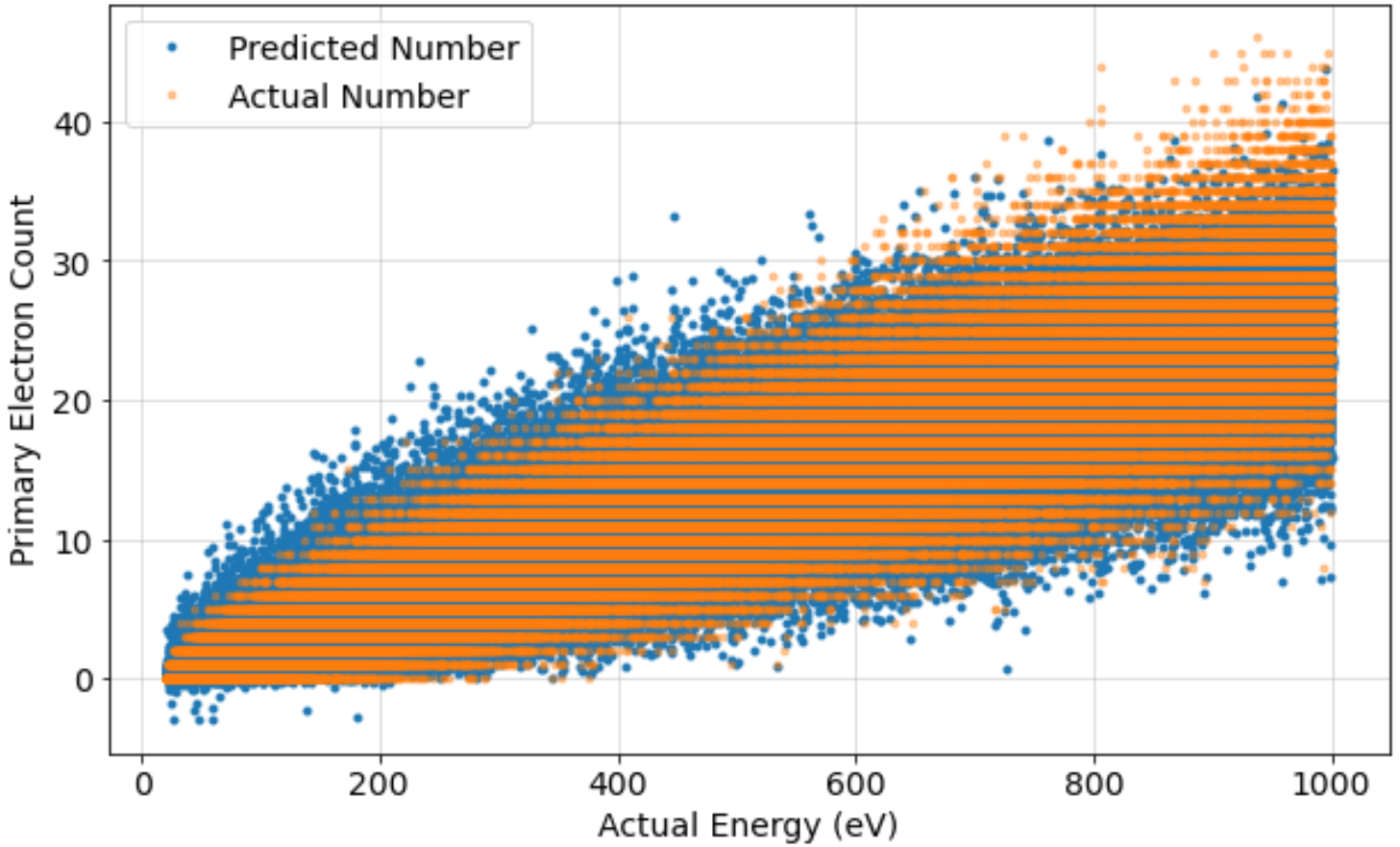
Thank you!

Additional Slides

Simulated Energy Resolution Results

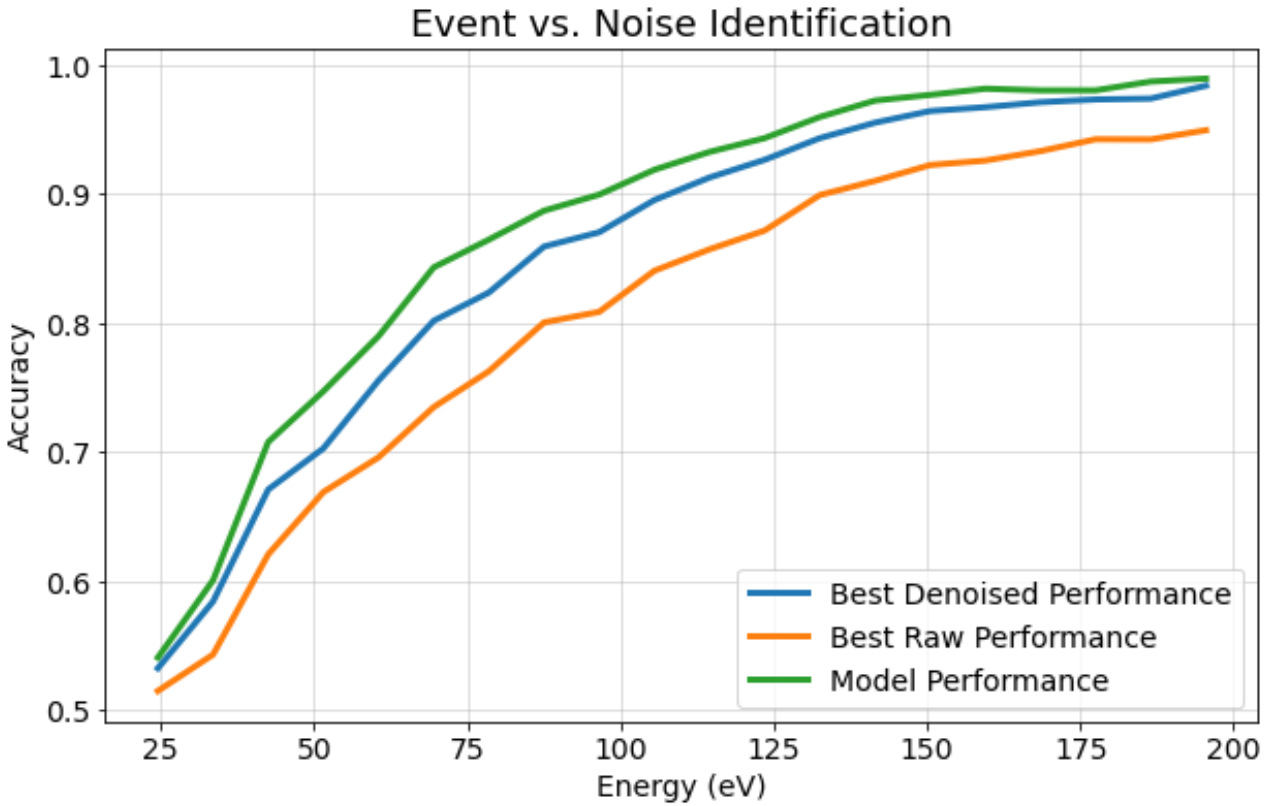


Primary Electron Prediction

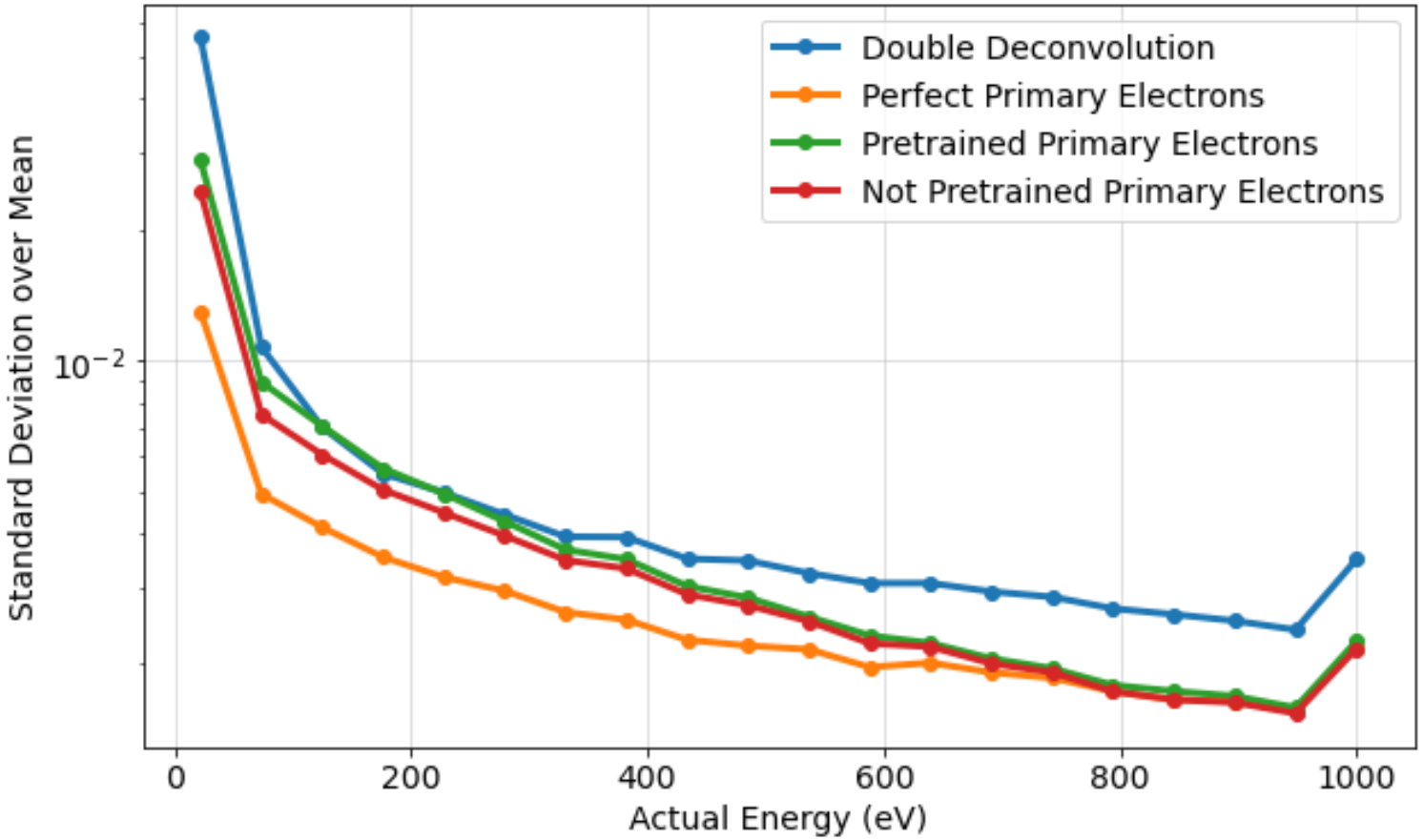


Event Triggering Results

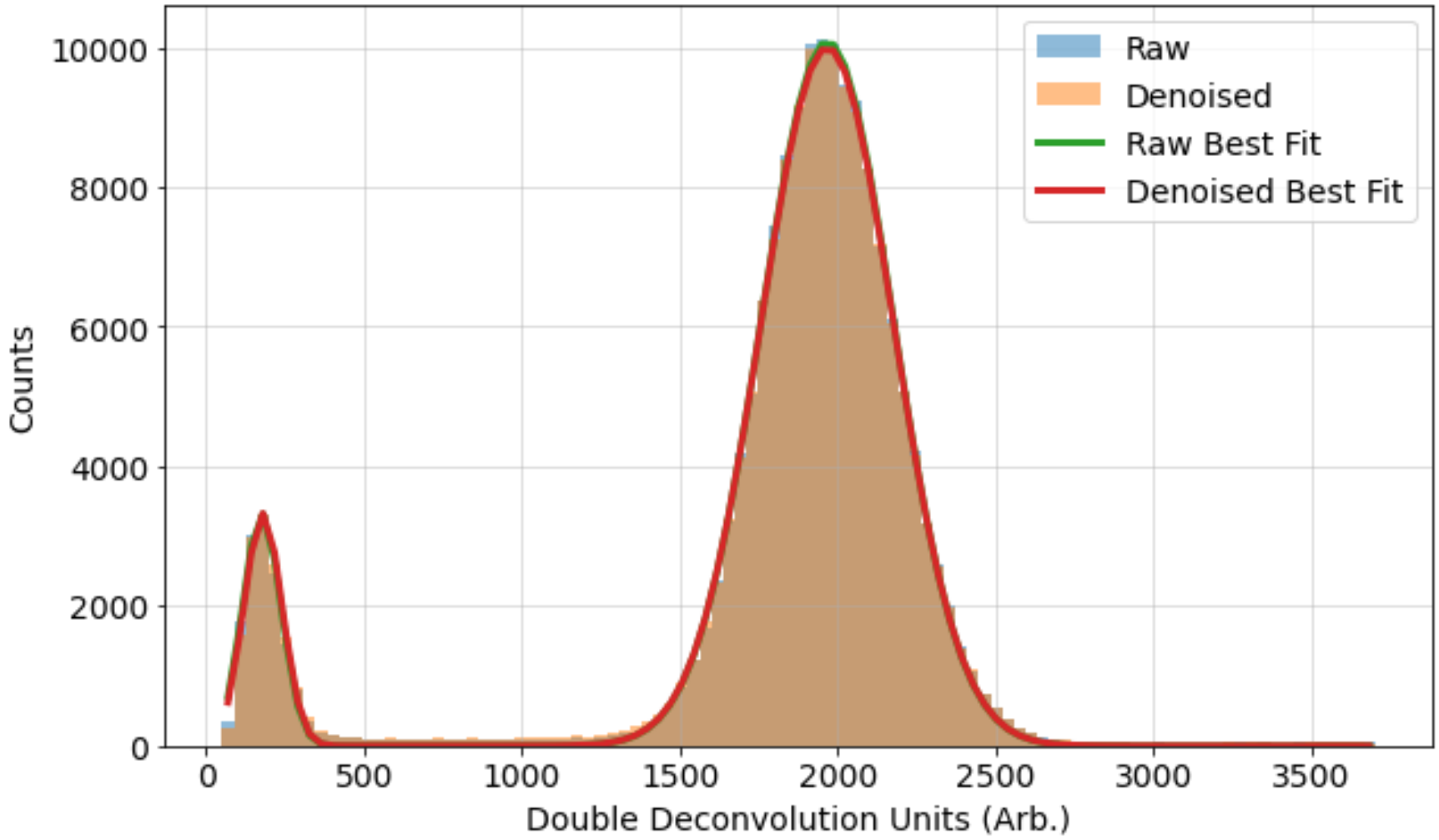
- Triggering efficiency test on simulated data
- 10000 events with a simulated pulse, 10000 noise traces
- Modelled electronic triggering
- Preliminary results



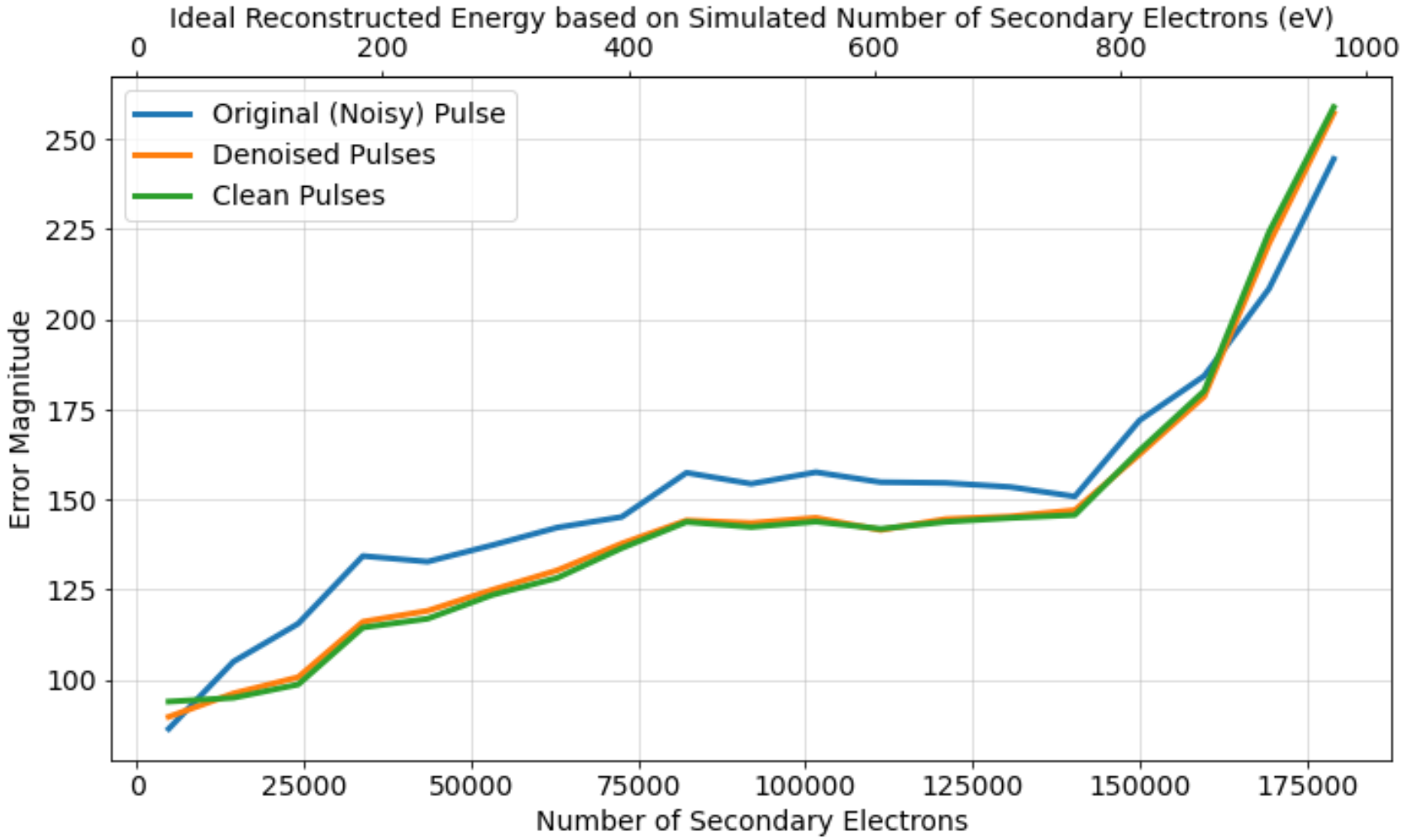
Primary Electron Prediction



Real Data Energy Spectrum Analysis



Energy Prediction Error Magnitude

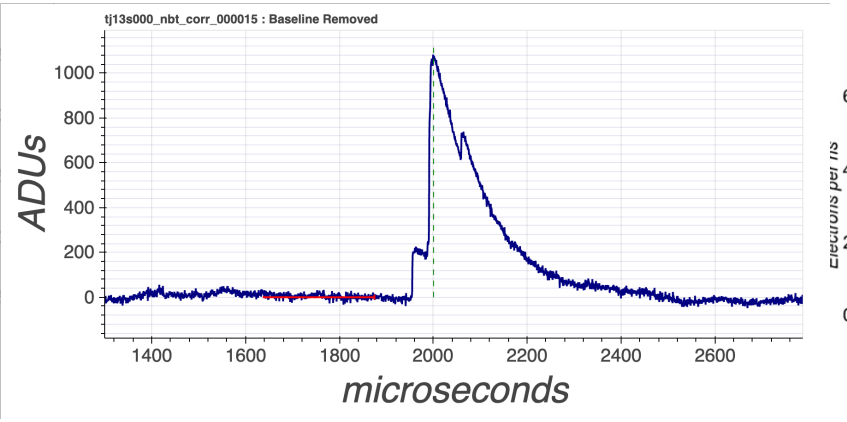


Model Architecture

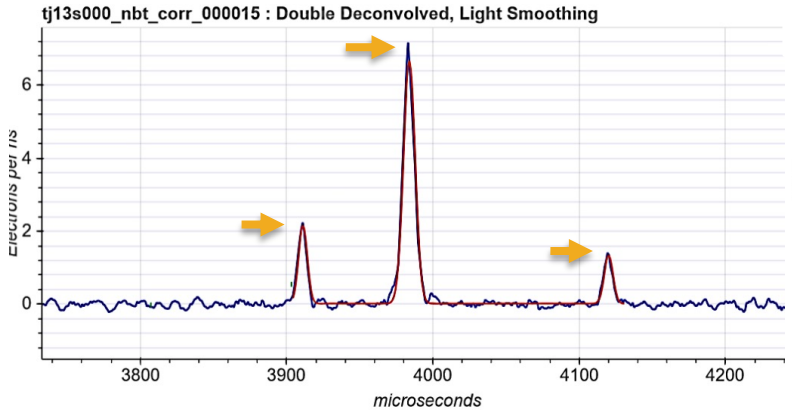
Layer	Stride	Window	Output
Input			4096, 1
Convolution	1	1	4096, 8
Convolution	1	9	4088, 16
Average Pooling	2	2	2044, 16
Convolution	1	17	2028, 32
Average Pooling	2	2	1014, 32
Convolution	1	33	982, 64
Average Pooling	2	2	491, 64
Convolution	1	33	459, 32
Transpose Convolution	1	33	491, 32
Upsampling	2	2	982, 64
Transpose Convolution	1	33	1014, 64
Upsampling	2	2	2028, 64
Transpose Convolution	1	17	2044, 32
Upsampling	2	2	4088, 32
Transpose Convolution	1	9	4096, 16
Convolution (output)	1	1	4096, 1

NEWS-G Signal Generation

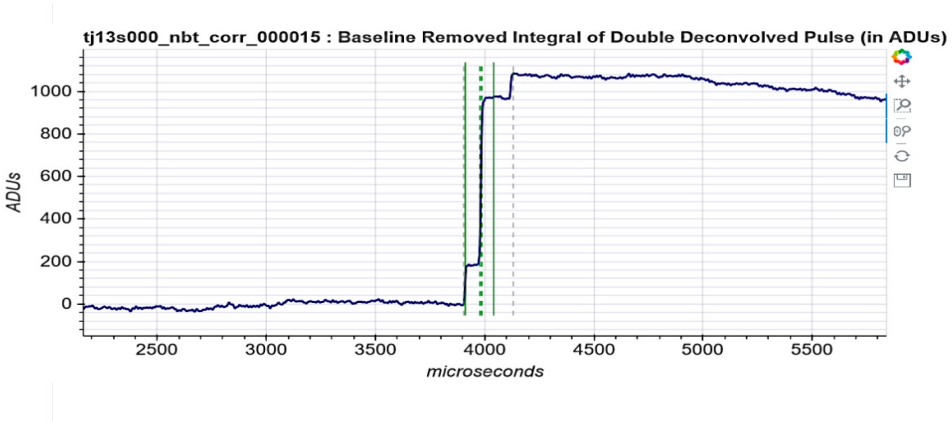
Raw Pulse



Double Deconvolved Pulse



Integrated Double Deconvolved Pulse



Double Deconvolution Algorithm

Detector Response

Integration

Conclusion

- Developed an effective deep learning noise removal model
  - Resulting in more accurate energy measurements, primary electron counting
- Developed a single output model based on denoising architecture
  - Offers improvements in energy measurements
- Outlined further avenues for machine learning applications in NEWS-G