Machine learning for noise removal in NEWS-G

CAP 2022

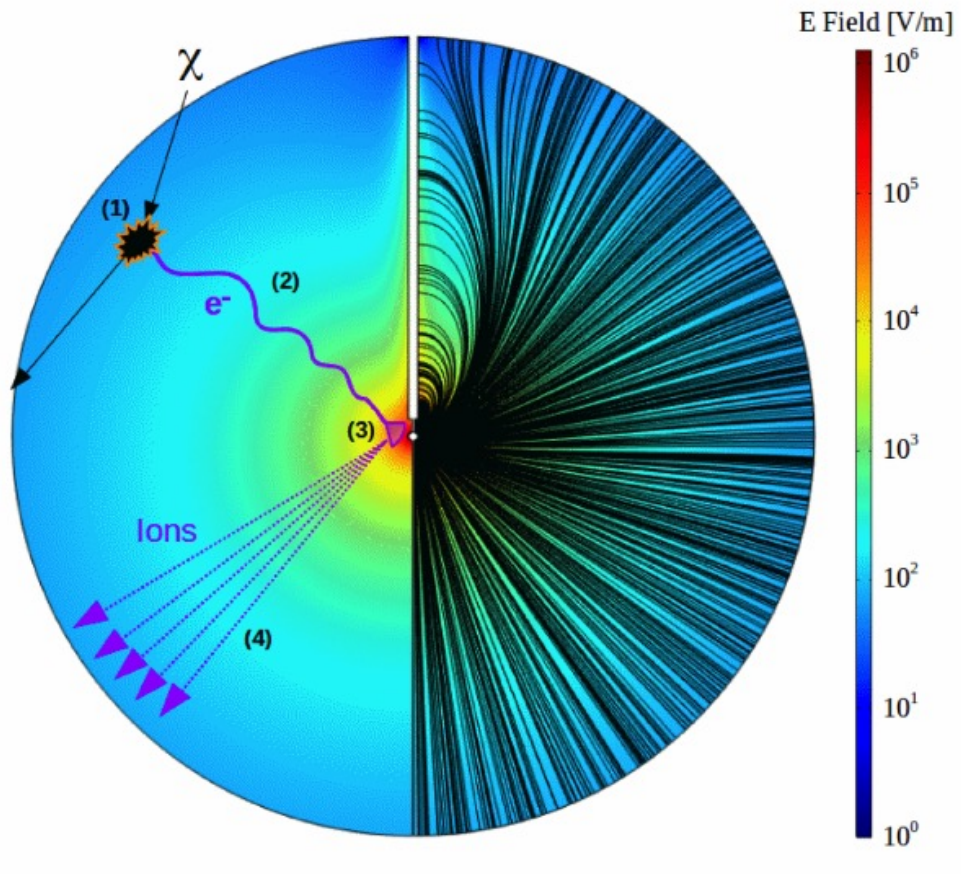
Noah Rowe

June 8th 2022

Presentation Outline

1. NEWS-G Background
2. Problem Definition
3. Signal Denoising Model
4. Single Output Model

NEWS-G – Spherical Proportional Counter



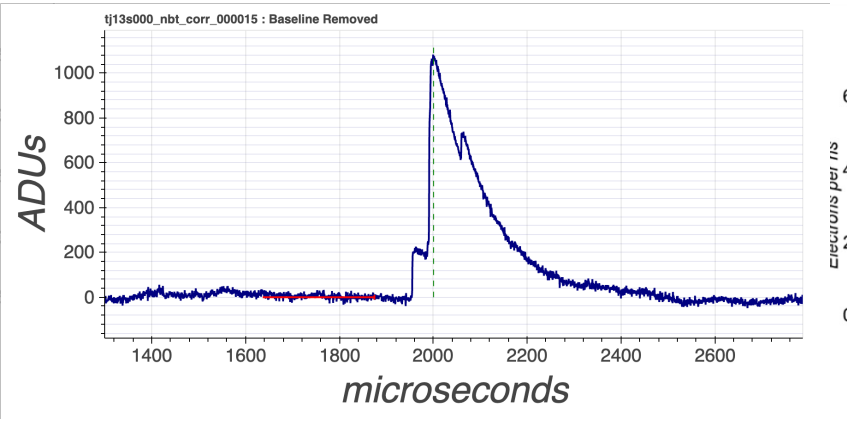
Signal Generation:

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

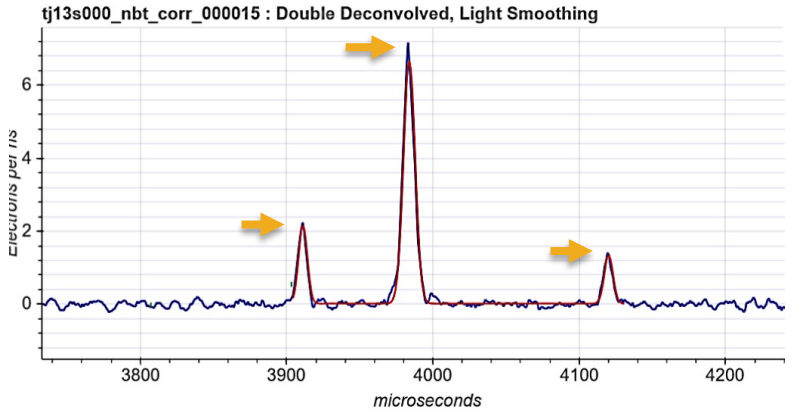
Analysis data taken from SEDINE at LSM in France

NEWS-G Signal Generation

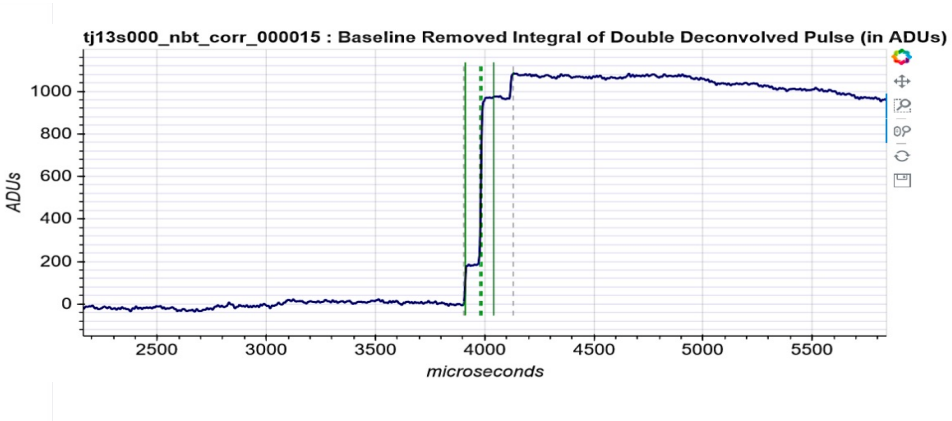
Raw Pulse



Double Deconvolved Pulse



Integrated Double Deconvolved Pulse



Double Deconvolution Algorithm →

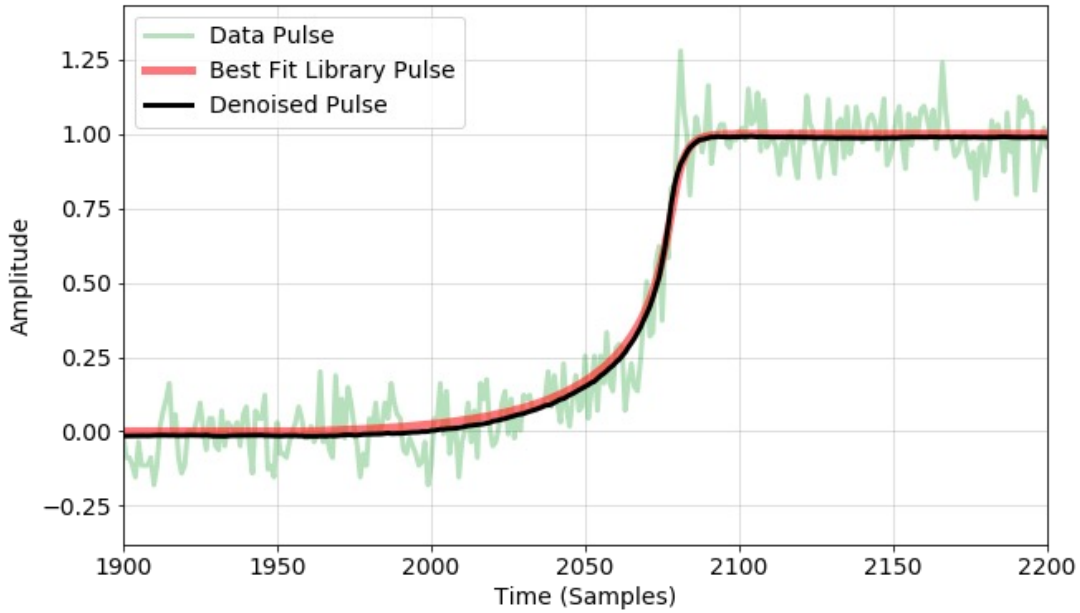
← Detector Response

Integration →

Problem Definition

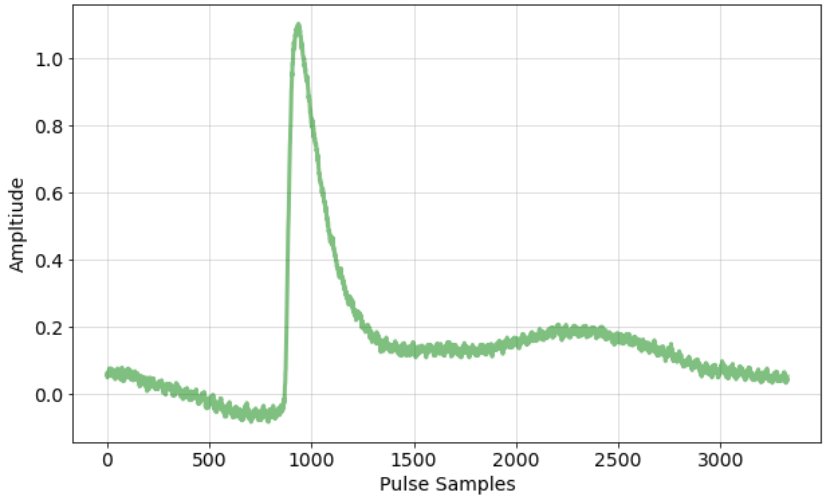
Goals:

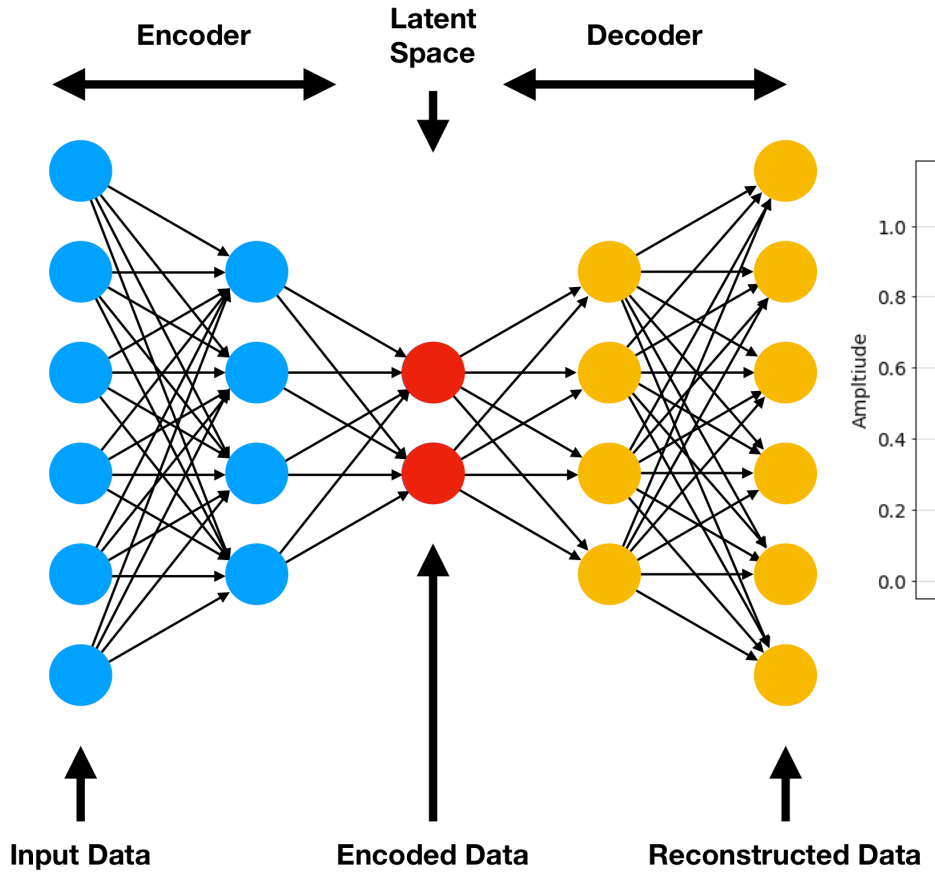
- Utilize machine learning methods to remove noise from recorded detector signals
- Model implementation should aid in measuring important signal characteristics, such as amplitude and rise-features
- Extend existing work on Germanium detector signals to NEWS-G

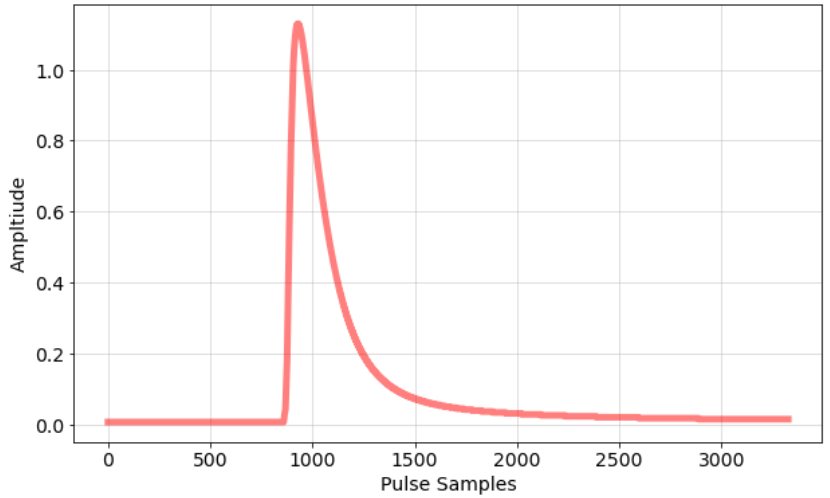


Our group has designed and trained such a model for a Germanium P-Type Point Contact Detector (arXiv:2204.06655)

Methods – Model Architecture



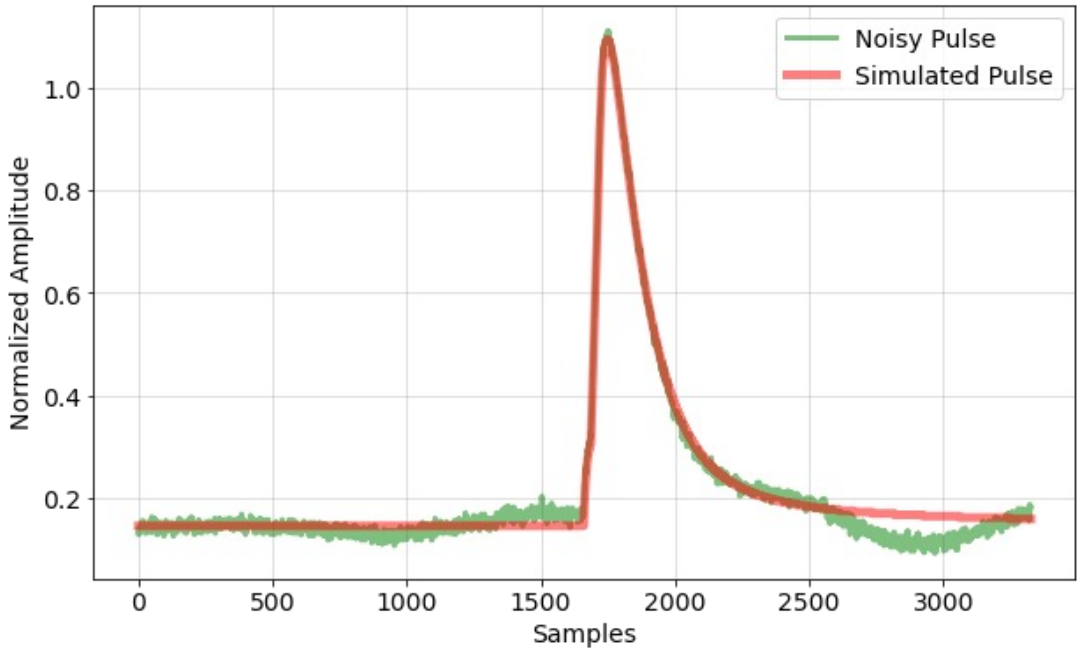




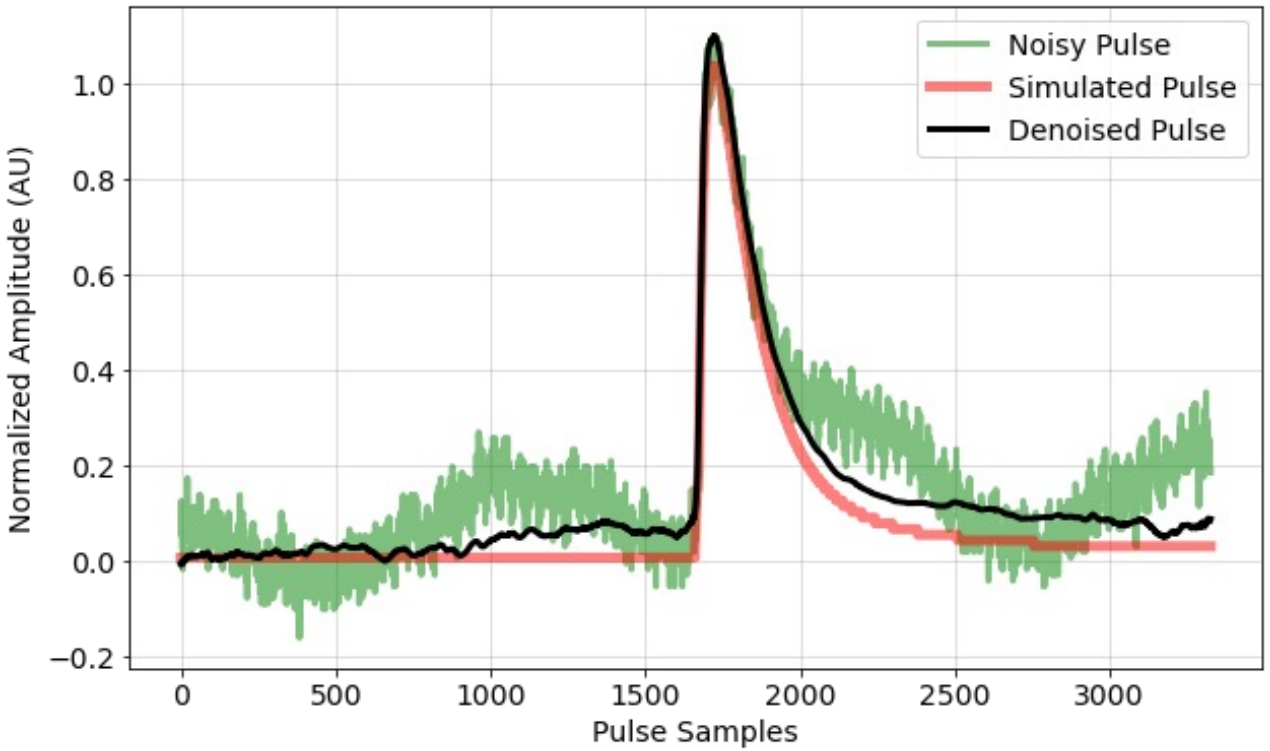
Methods – Model Training

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

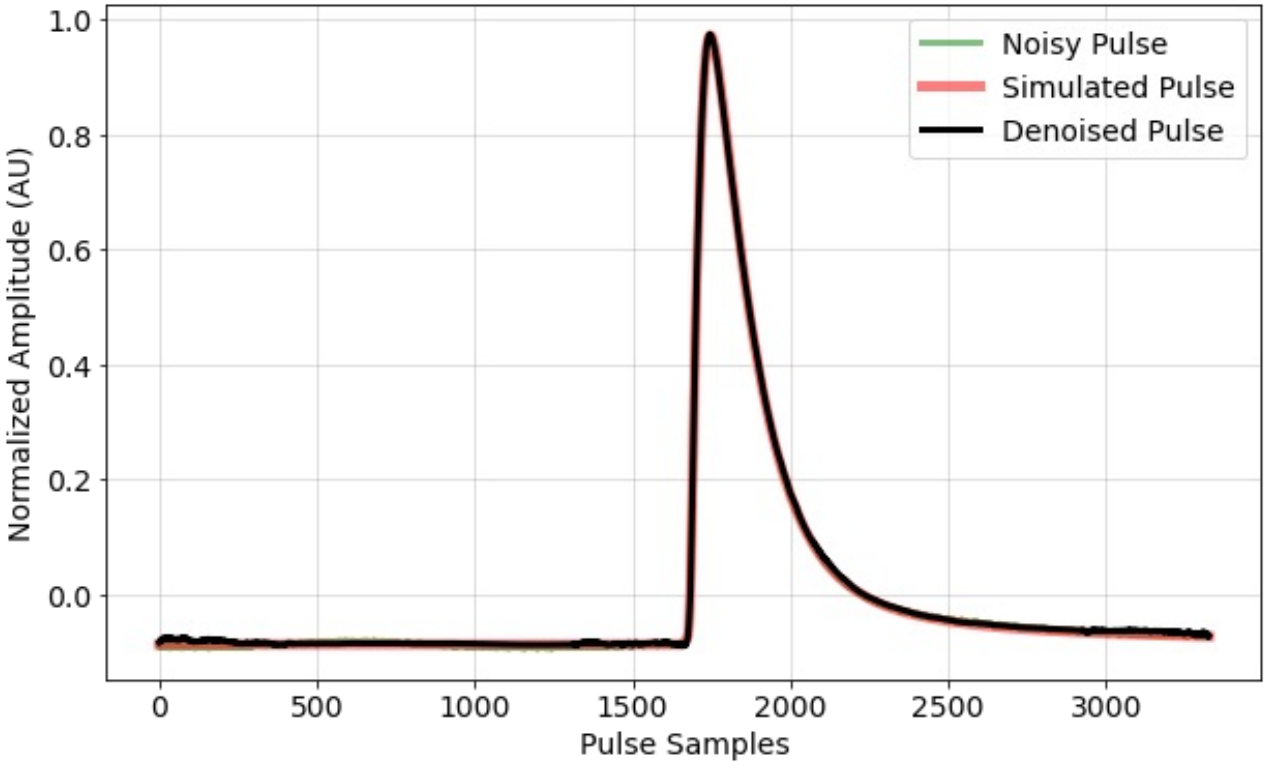
X	Simulated pulses + real noise
Y	Simulated pulses



Example Pulses

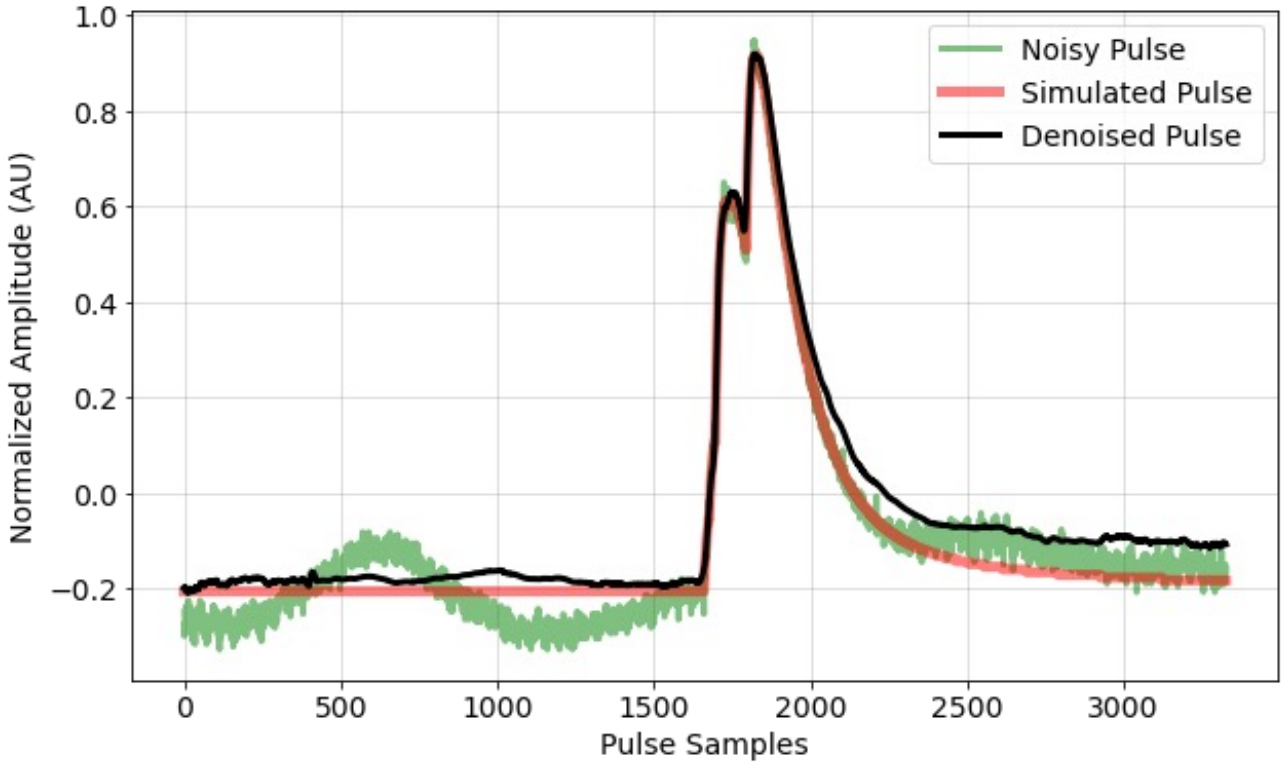


Energy: ~170eV

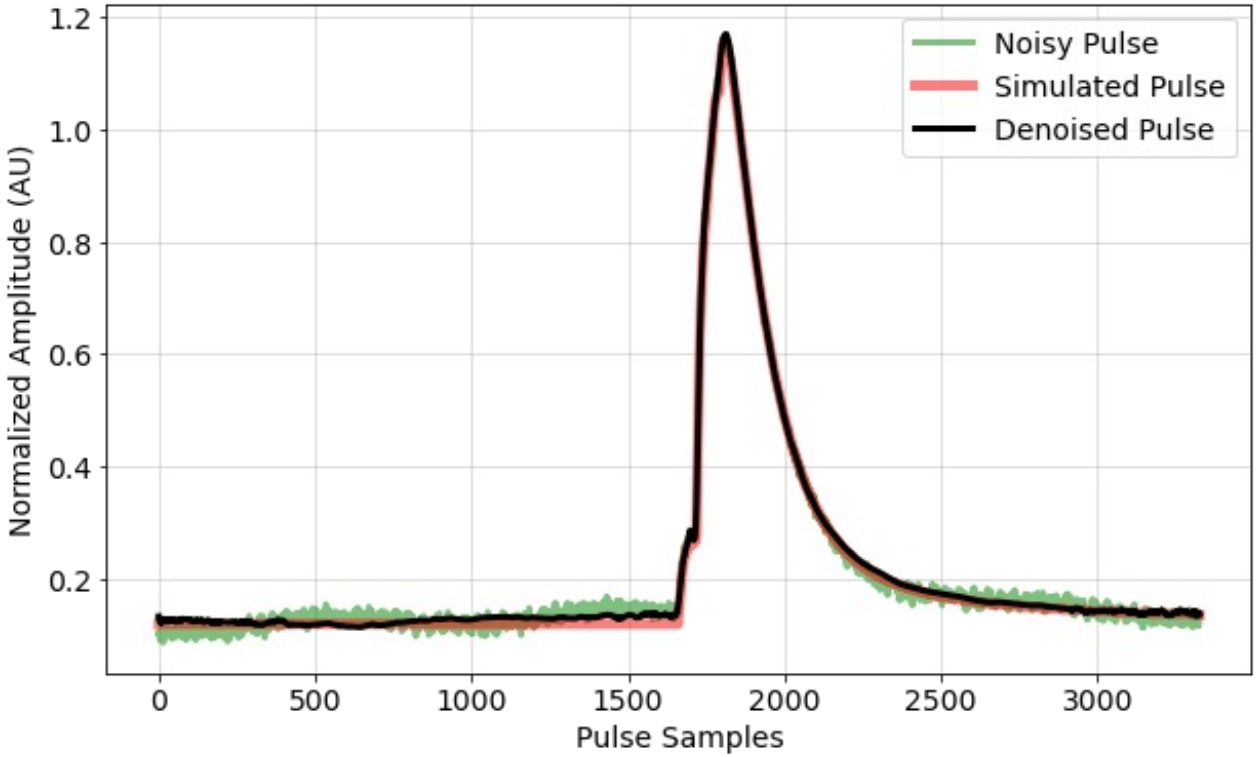


Energy: ~1370eV

Example Pulses

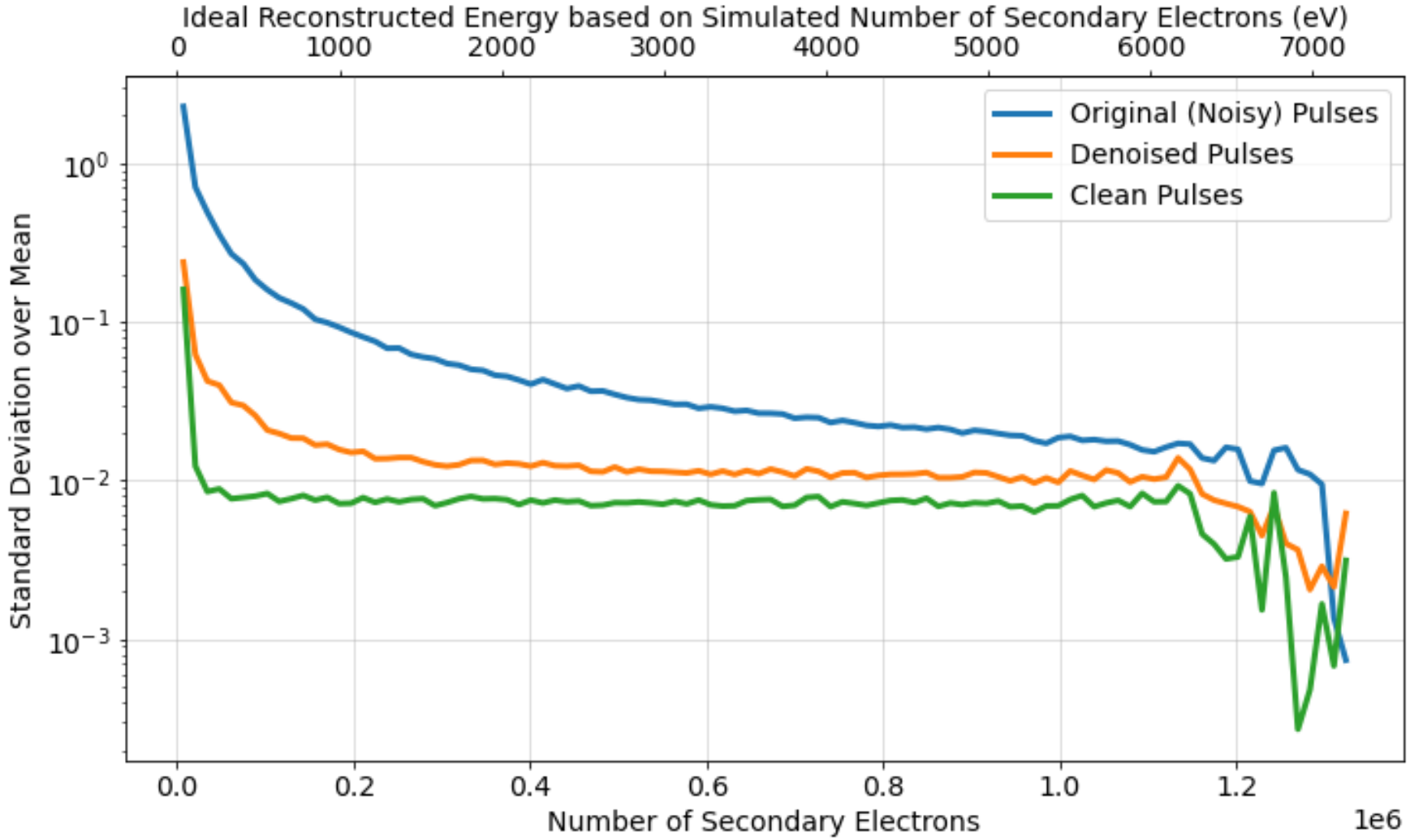


Energy: ~380eV

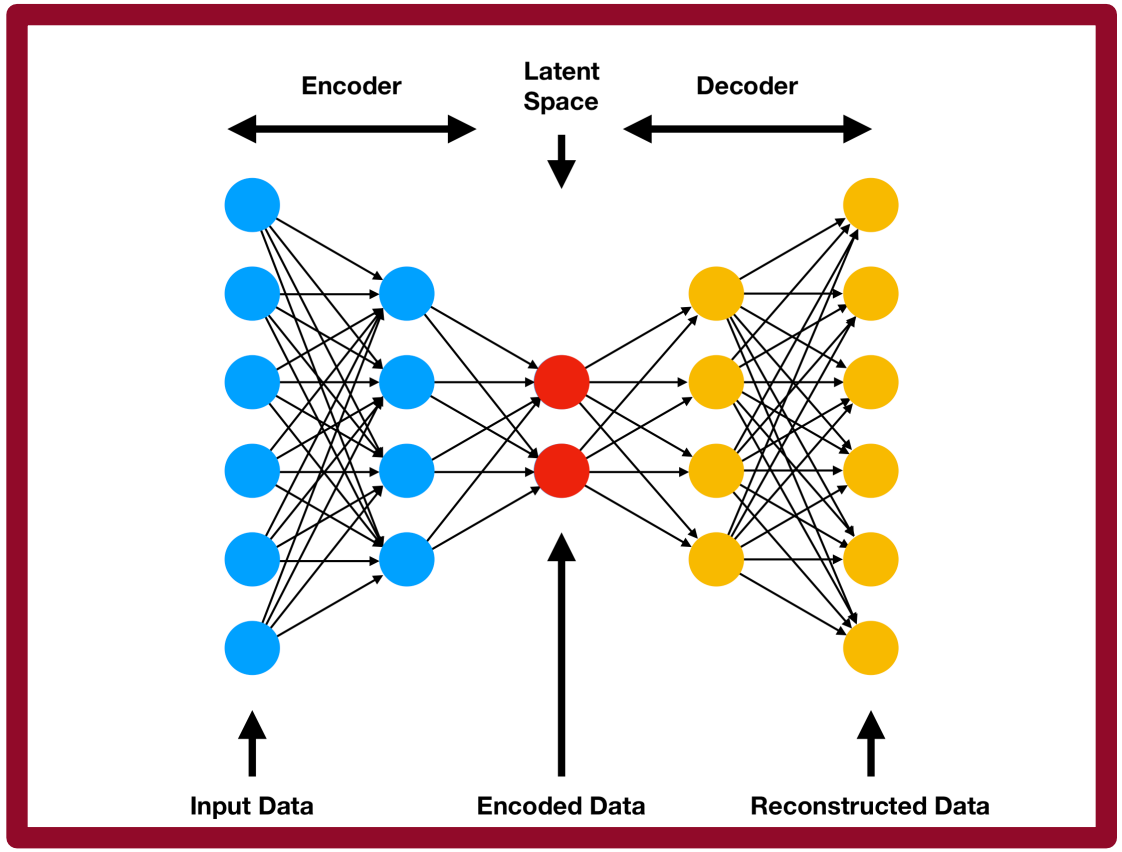


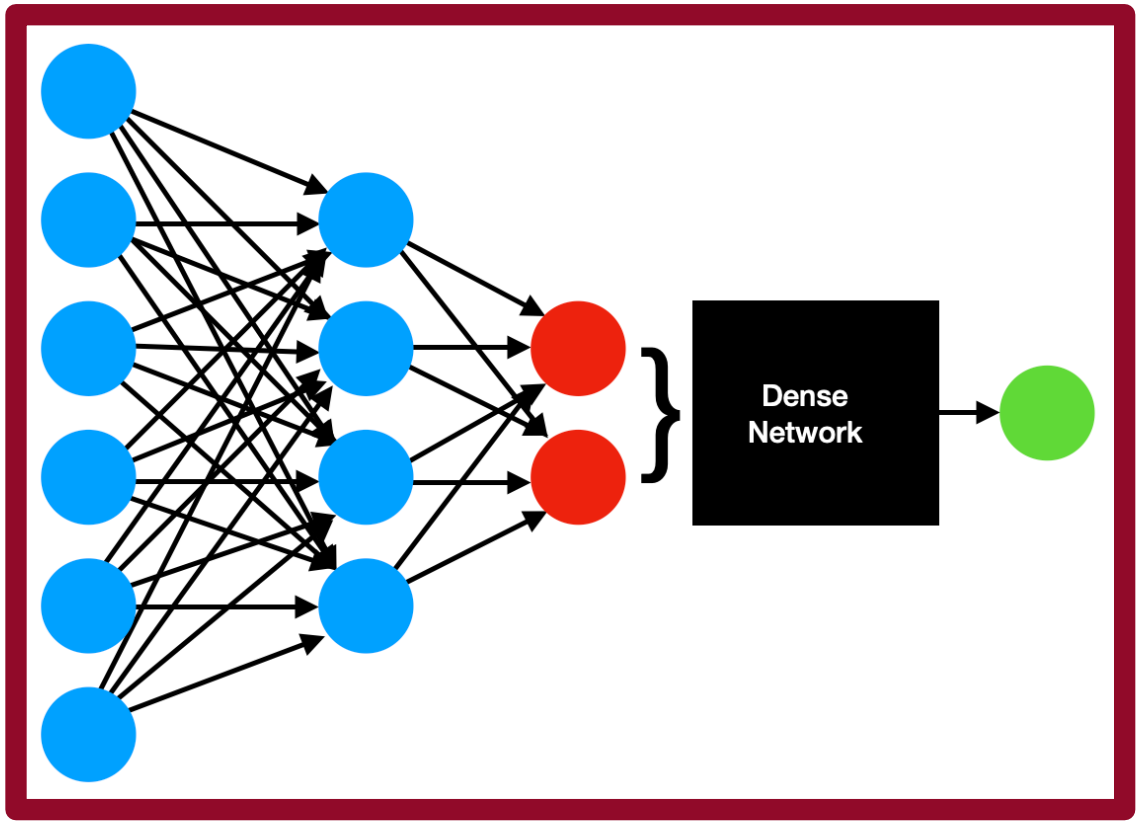
Energy: ~540eV

Energy Resolution Results

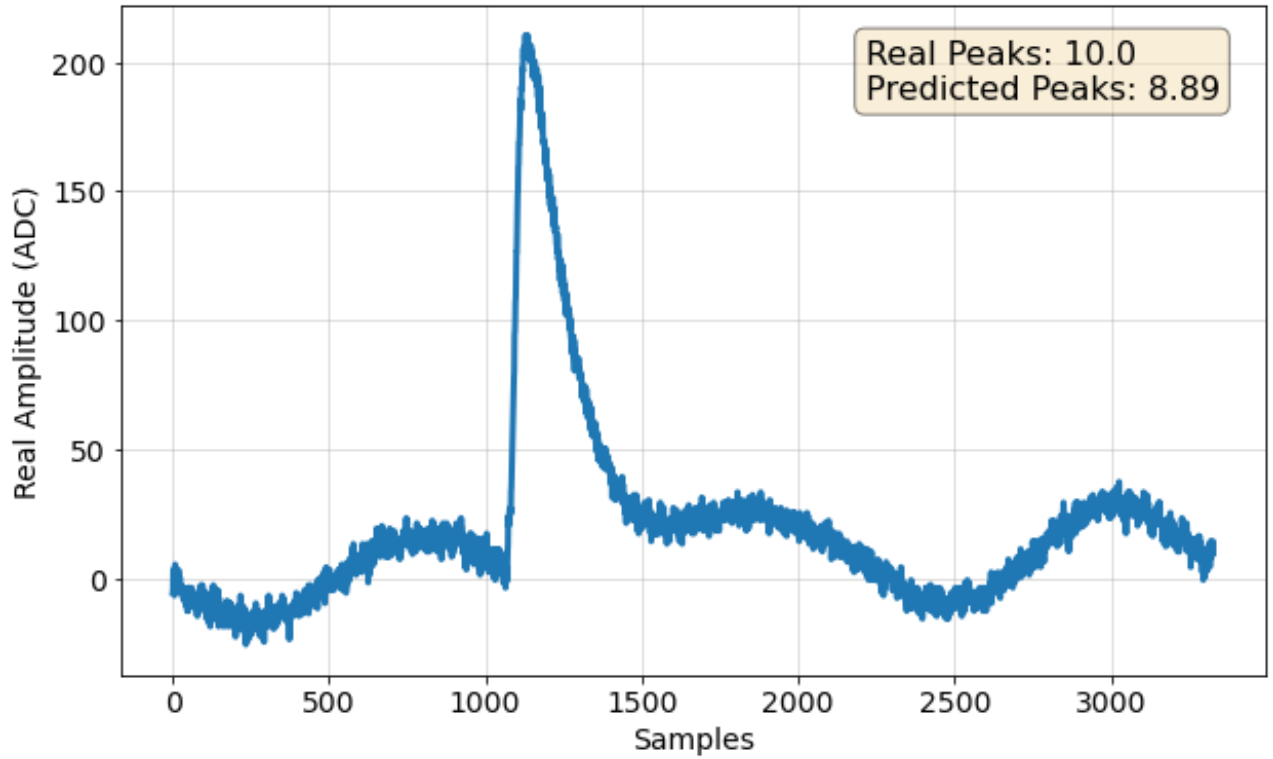


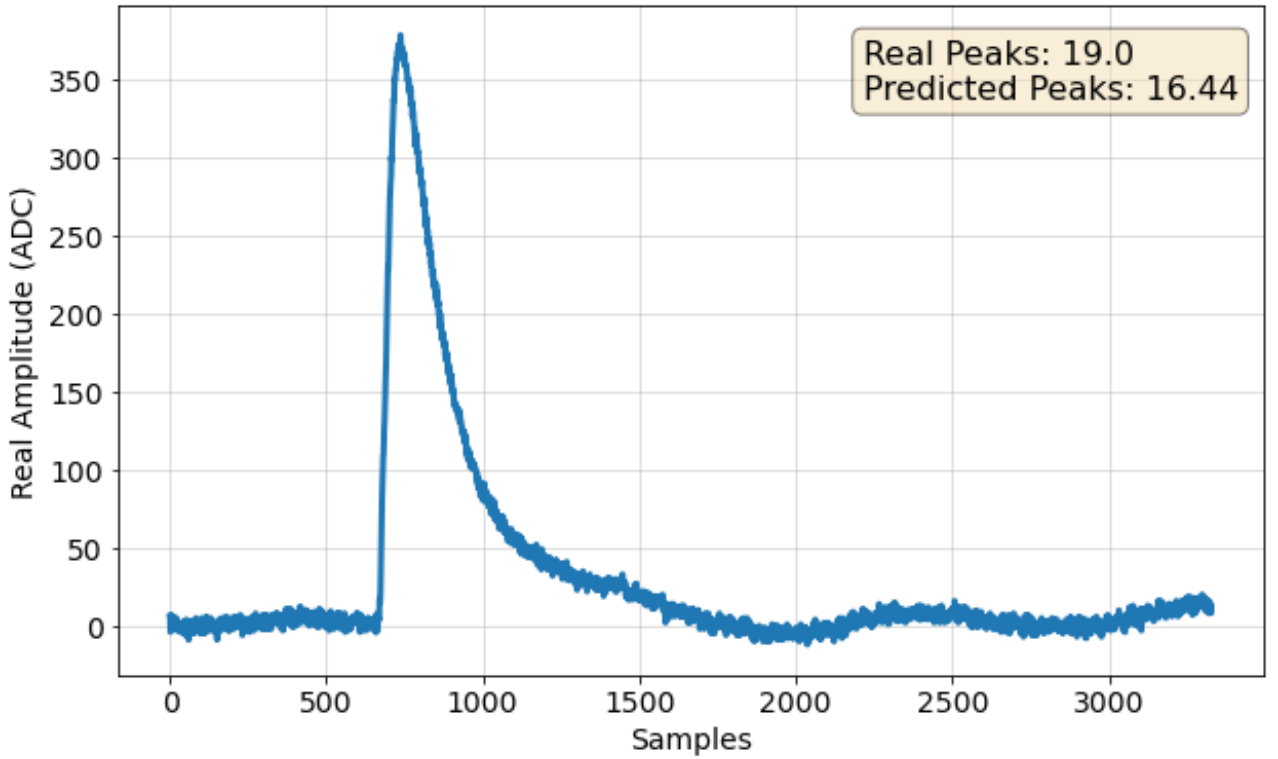
Single Output Model



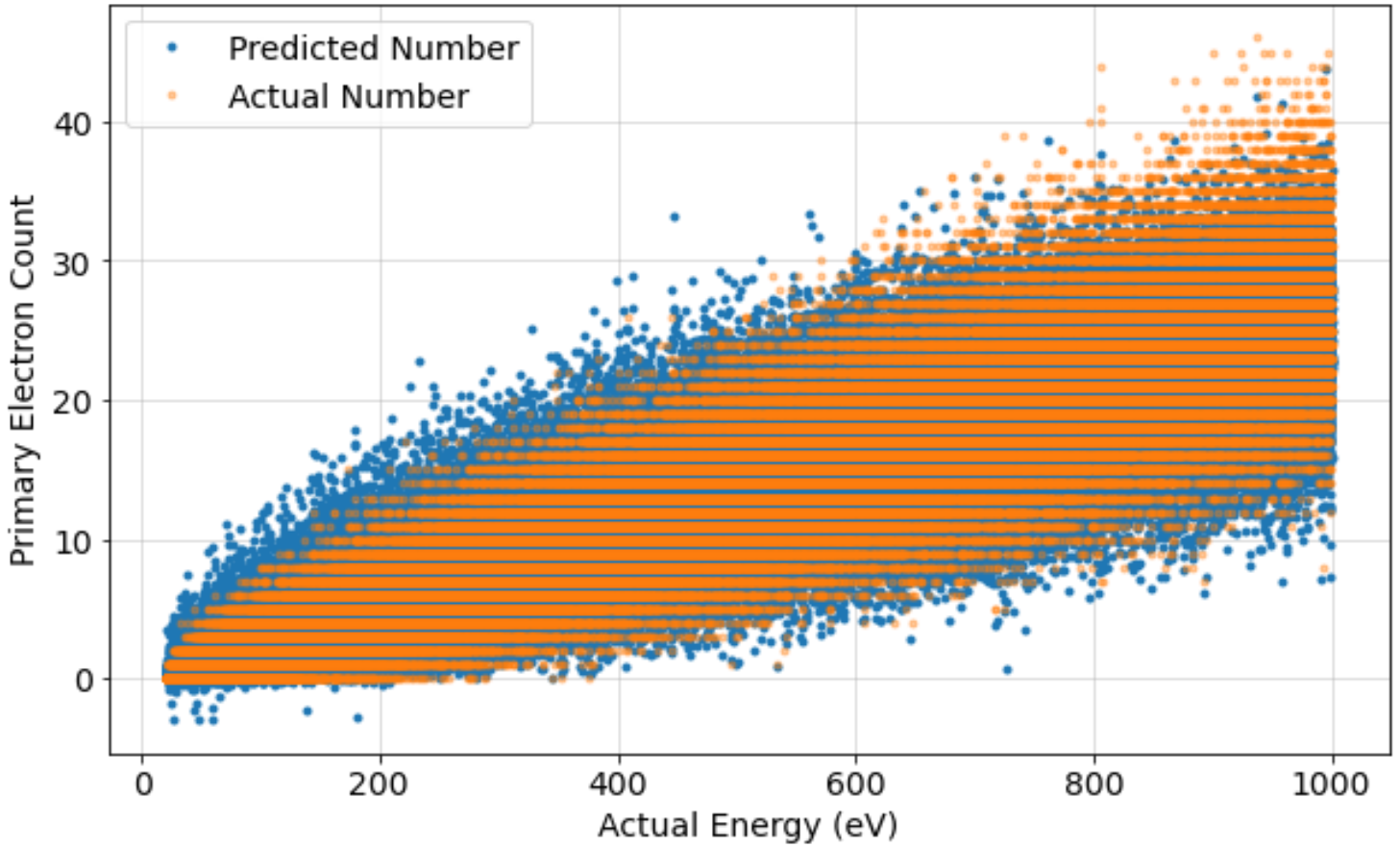


Primary Electron Prediction Examples

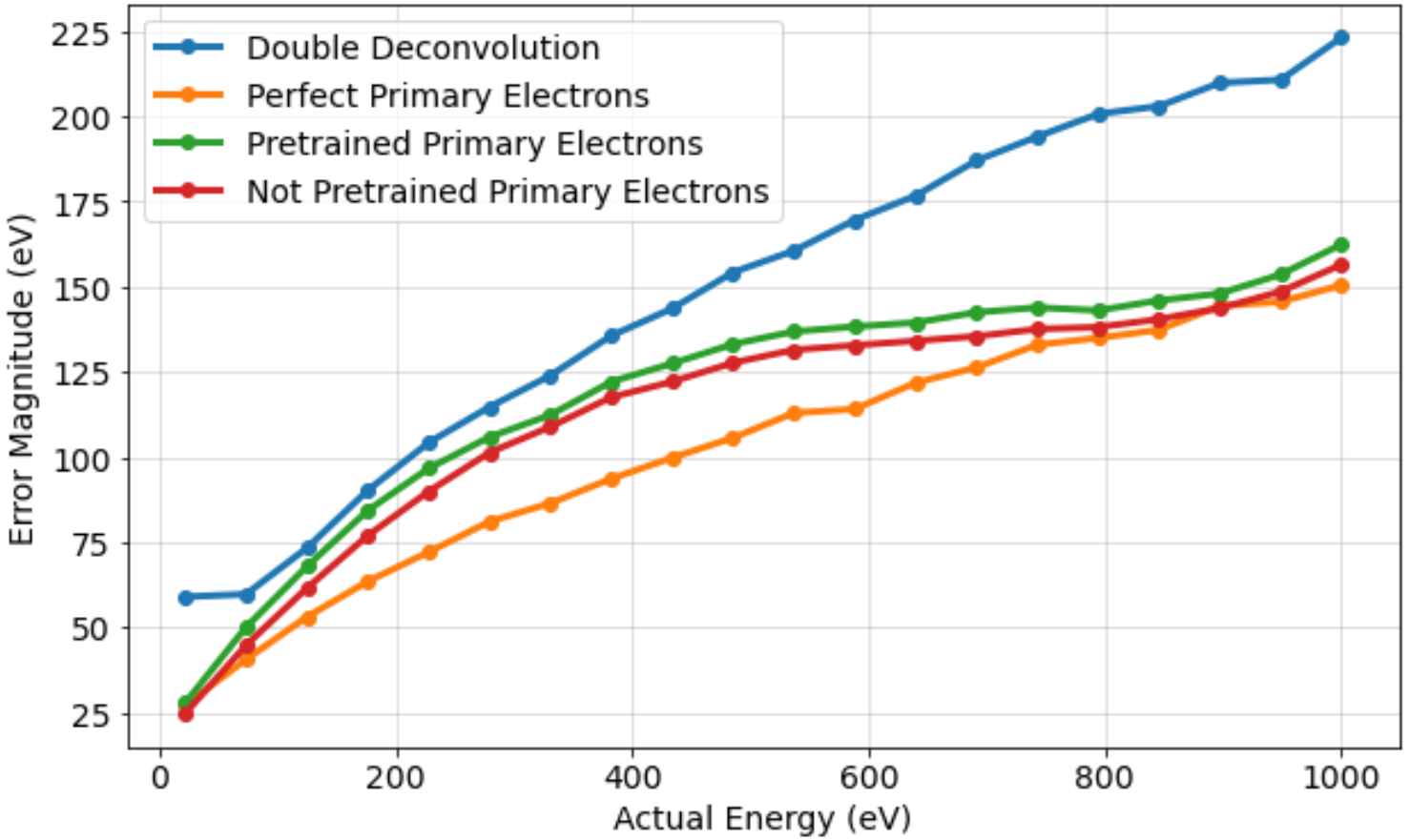




Primary Electron Prediction



Primary Electron Prediction



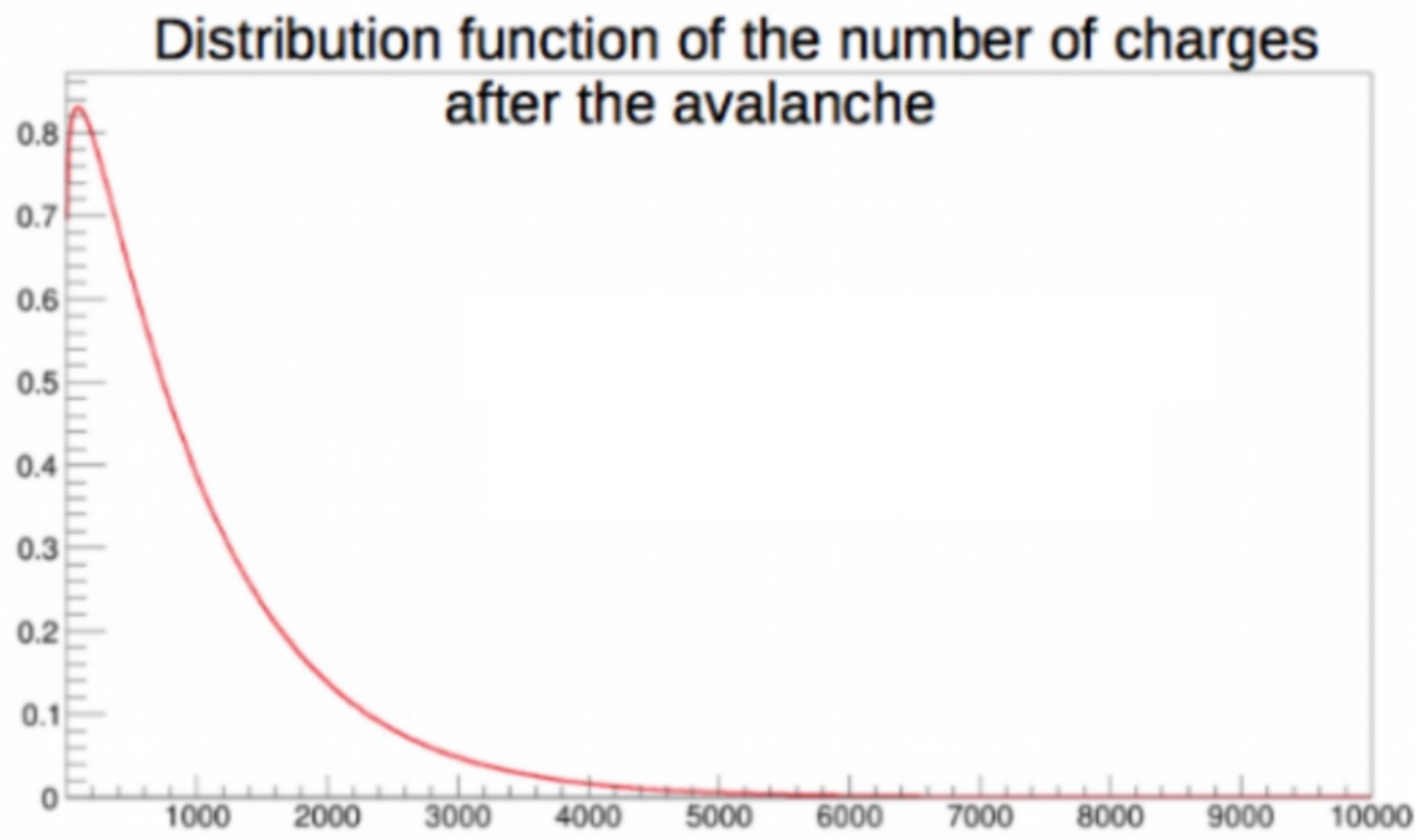
Conclusion

- Developed an effective machine learning noise removal model resulting in more accurate energy measurements
- Developed a single output model to predict the number of primary electrons for a given event
  - Offers improvements in energy measurements
- Single output model can be extended to different targets
  - Direct energy prediction
  - Event drift time

Thank you!

Additional Slides

POLYA Distribution



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

Dark Matter Search from Electron Counting

- NEWS-G searches for dark matter terms of 2, 3, and 4 peak event dispersion times
  - Highlighting the need for accurate primary electron counting techniques
- Dan Durnford presented on this: *"The NEWS-G light Dark Matter search experiment: Current status and preparation for experiment at SNOLAB"*