Positronium Laser Cooling: Improving detector pulse analysis efficiency via machine learning

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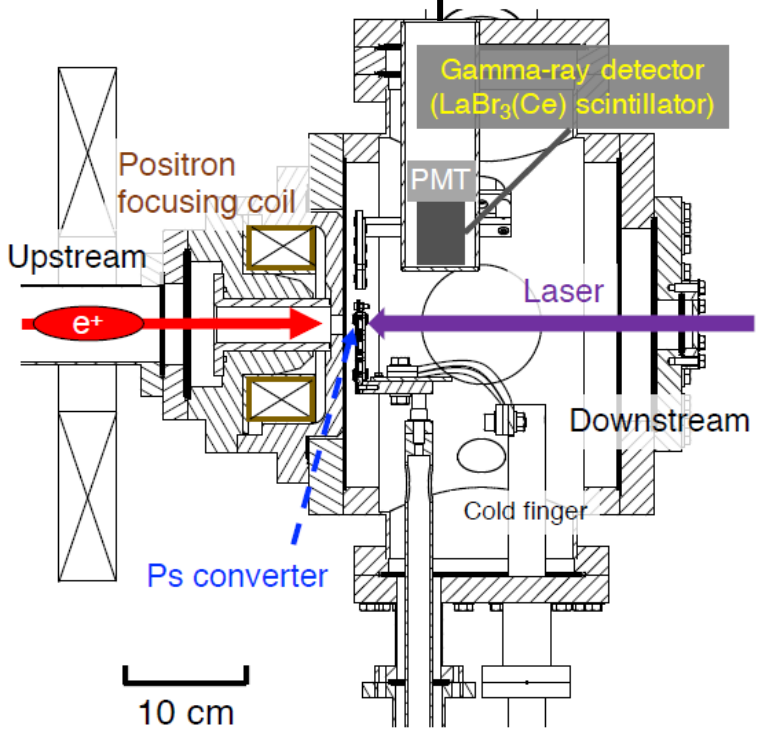
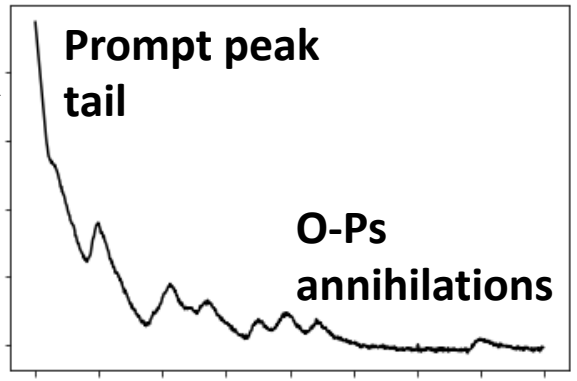
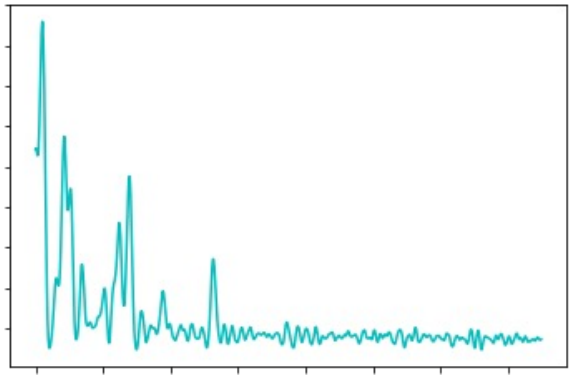
Experiment and Motivation



Piled-up pulses

$\sim 10^5\ e^+/s$





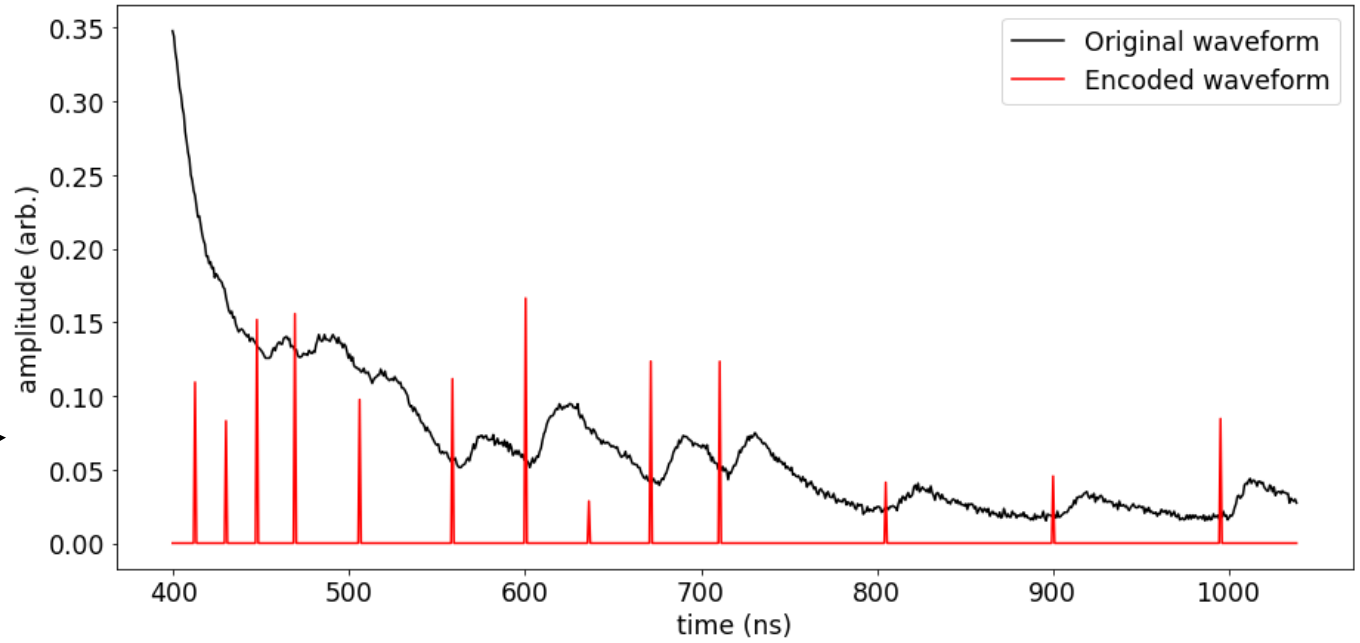
Piled-up pulse deconvolution

Deconvolution tends to be computationally intensive; can we make it faster?

Machine learning inference time is generally fast compared to other methods

K. Shu, *Laser Excitation of Confined Positronium in Porous Materials for Rapid Cooling*, 2019

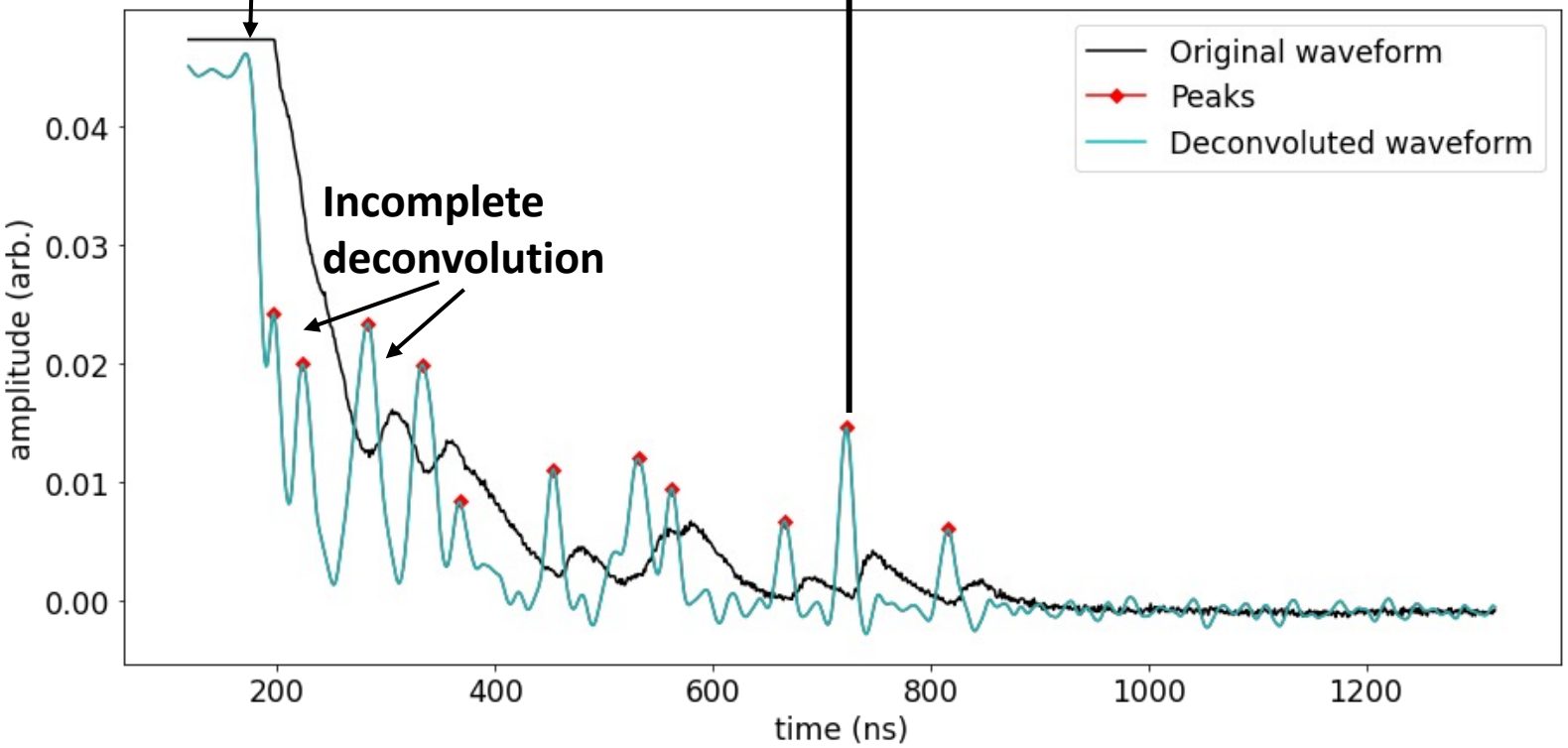
Data Transformation



Extract peak indices and amplitudes

Digitizer saturation

Incomplete deconvolution

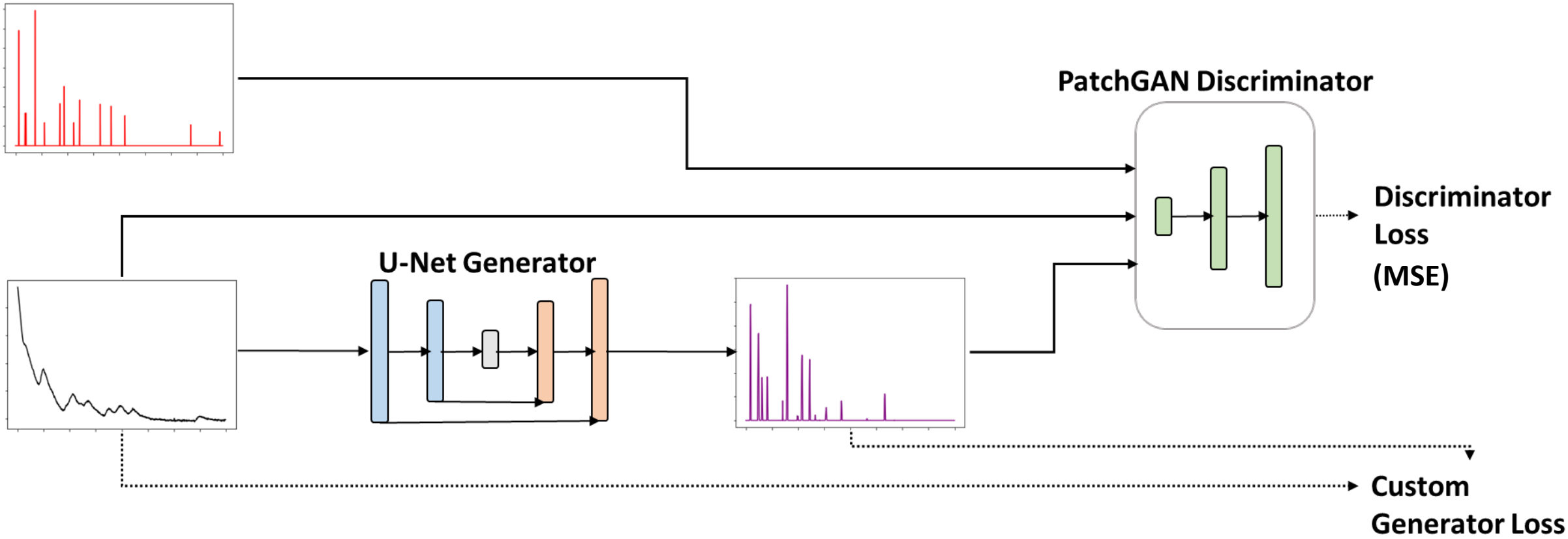


Wiener Deconvolution

(K. Shu, *Laser Excitation of Confined Positronium in Porous Materials for Rapid Cooling*, 2019)

Architecture and Training

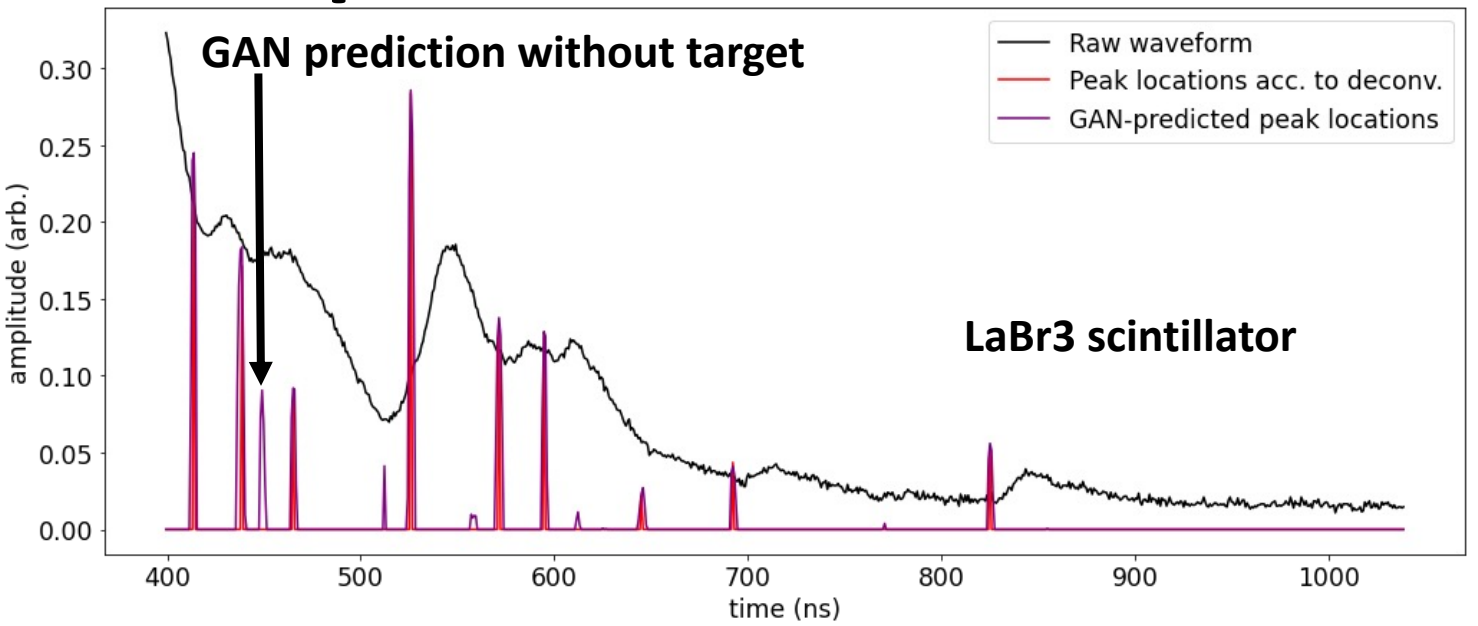
Generator loss using only the difference (residuals or MSE) between waveforms is difficult to train when using delta-like peaks. Current loss: $\sum|x-y| + c * \sum|x_{peaks} - y_{peaks}|$. The loss function is almost (or just) as important as the architecture.

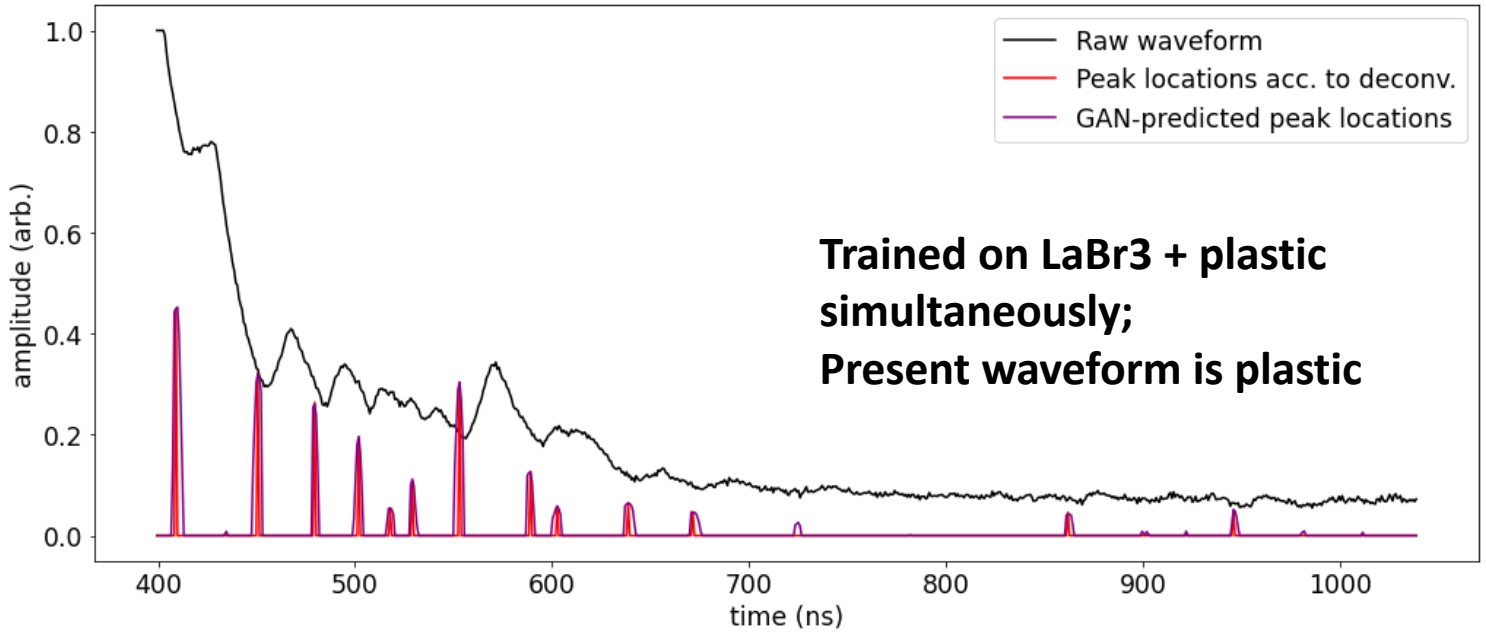


K. Schawinksi, et al., *Generative adversarial networks recover features in astrophysical images of galaxies beyond the deconvolution limit*, 2017
https://doi.org/10.1093/mnrasl/slx008

P. Isola, et al., *Image-to-Image Translation with Conditional Adversarial Networks*, 2016 (Pix2Pix GAN)
arXiv:1611.07004

GAN Predictions | LaBr3 Scintillator

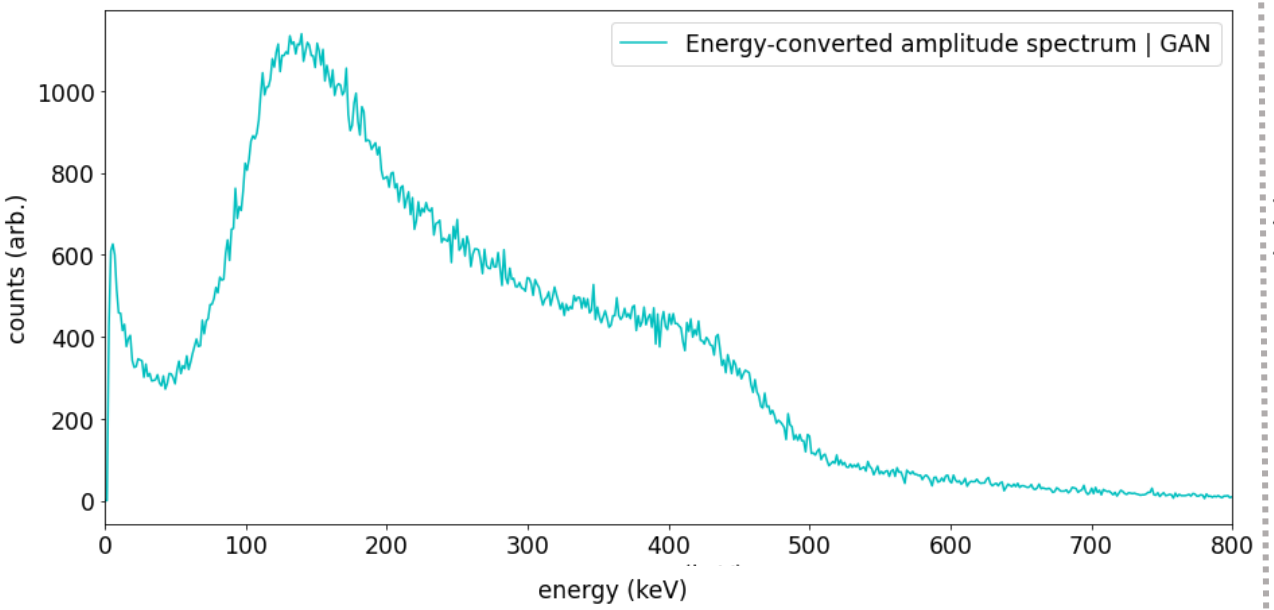


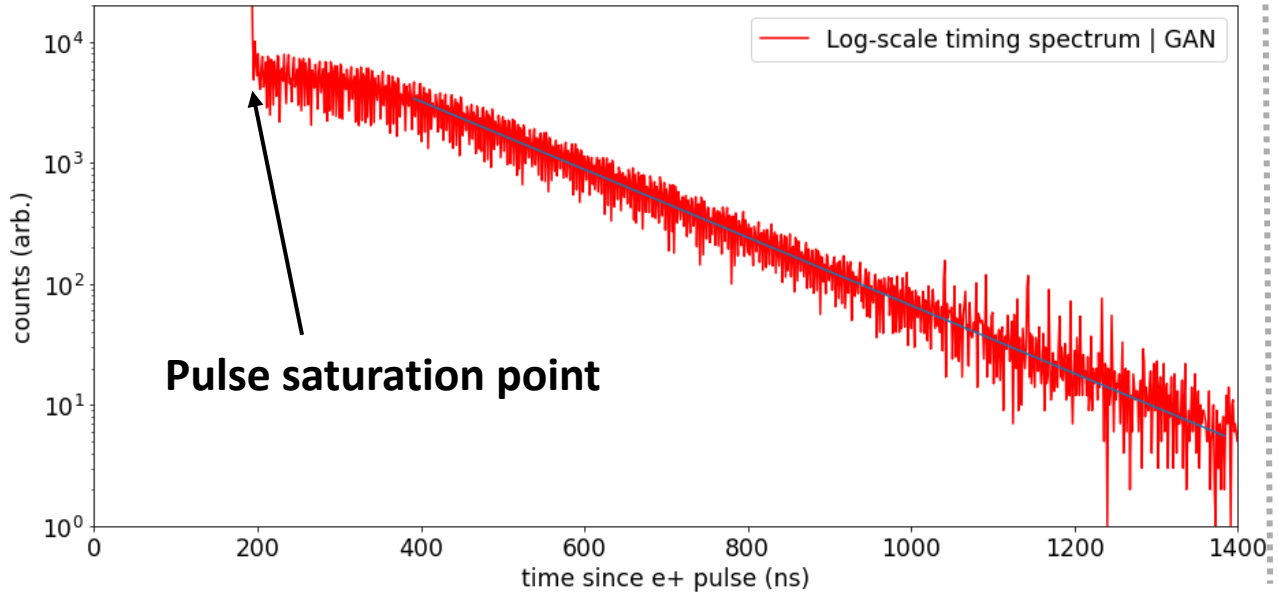


Preliminary Results

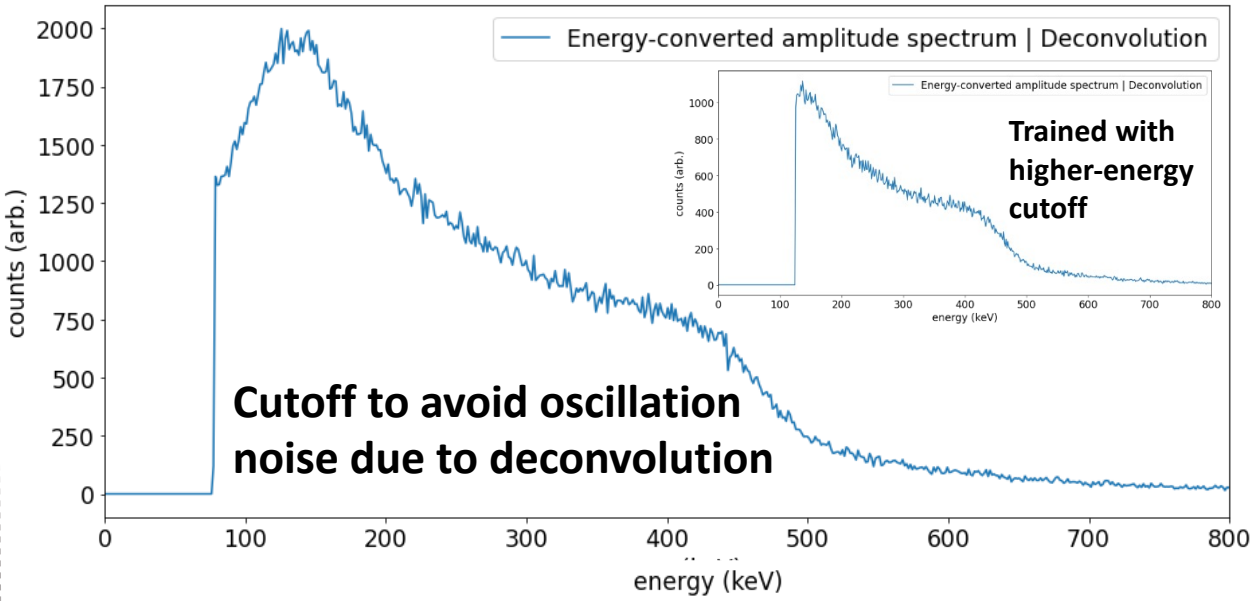
Amplitudes are taken from 420 ns after e+ pulse due to incomplete deconvolution along tail (~190 ns for timing spectra)

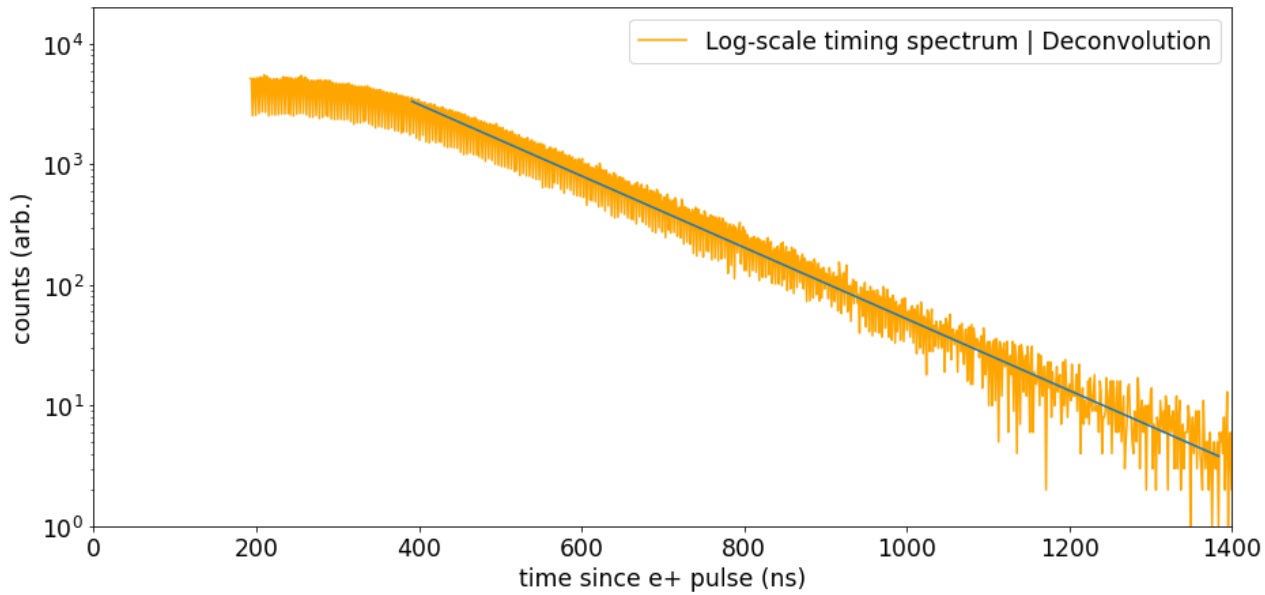
GAN



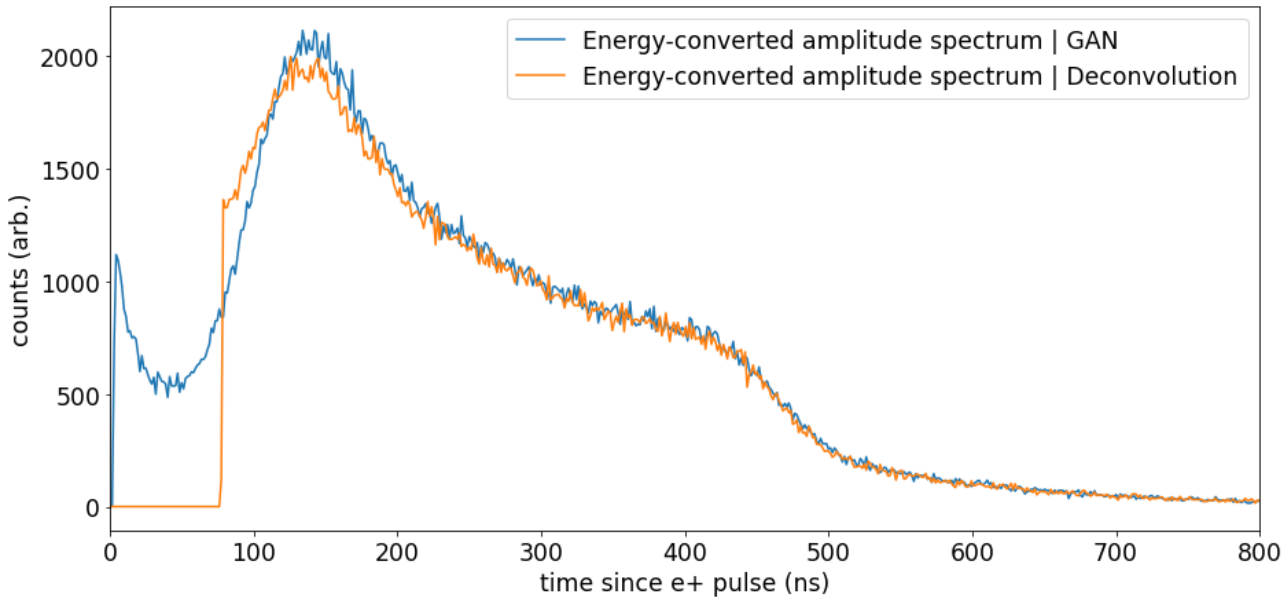


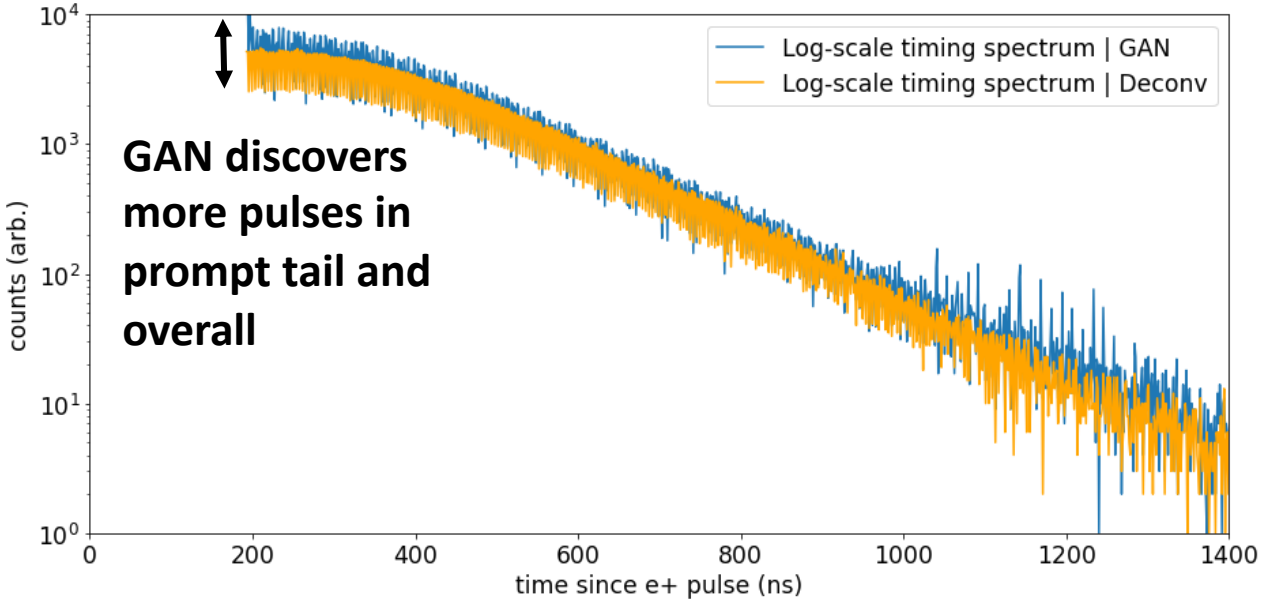
Deconvolution

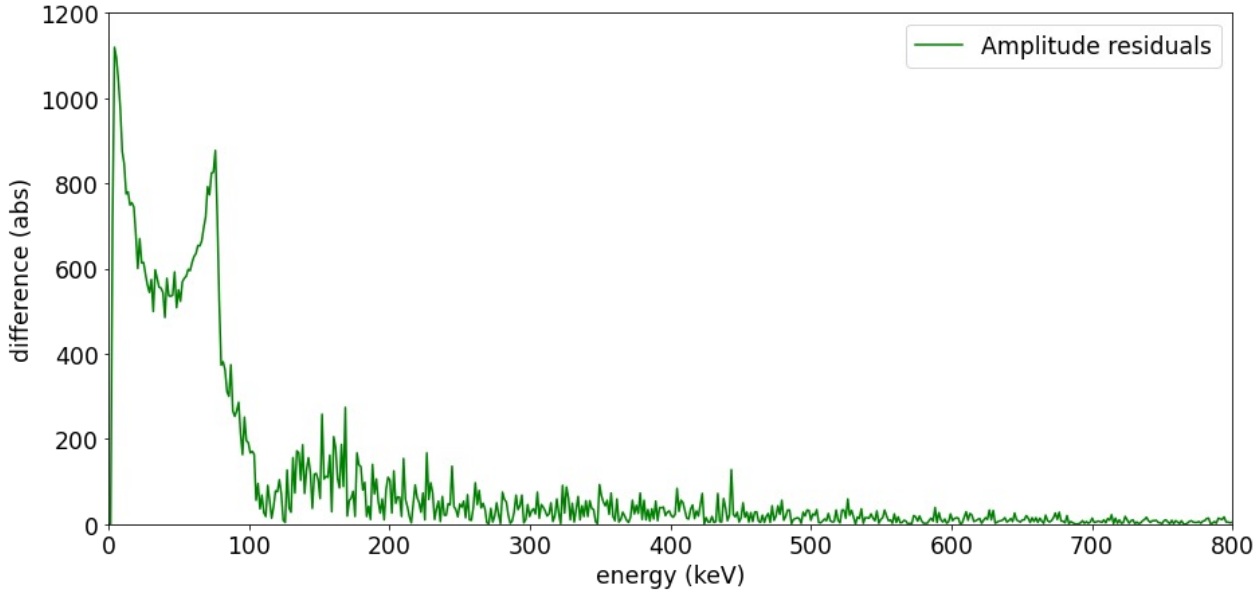


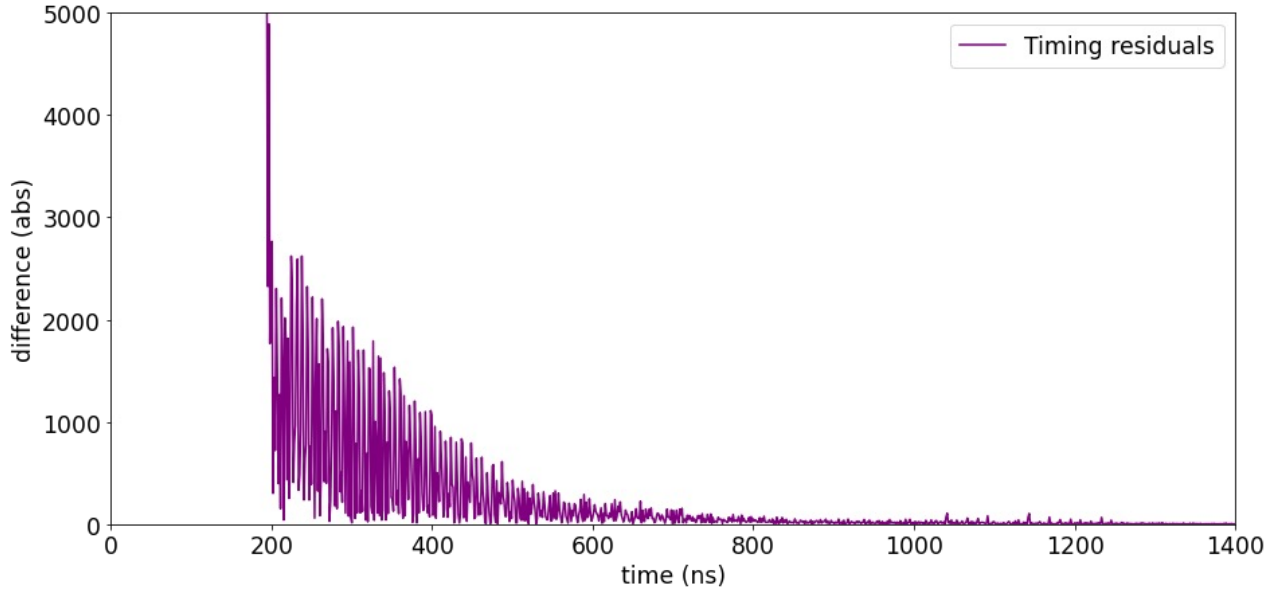


Preliminary Results







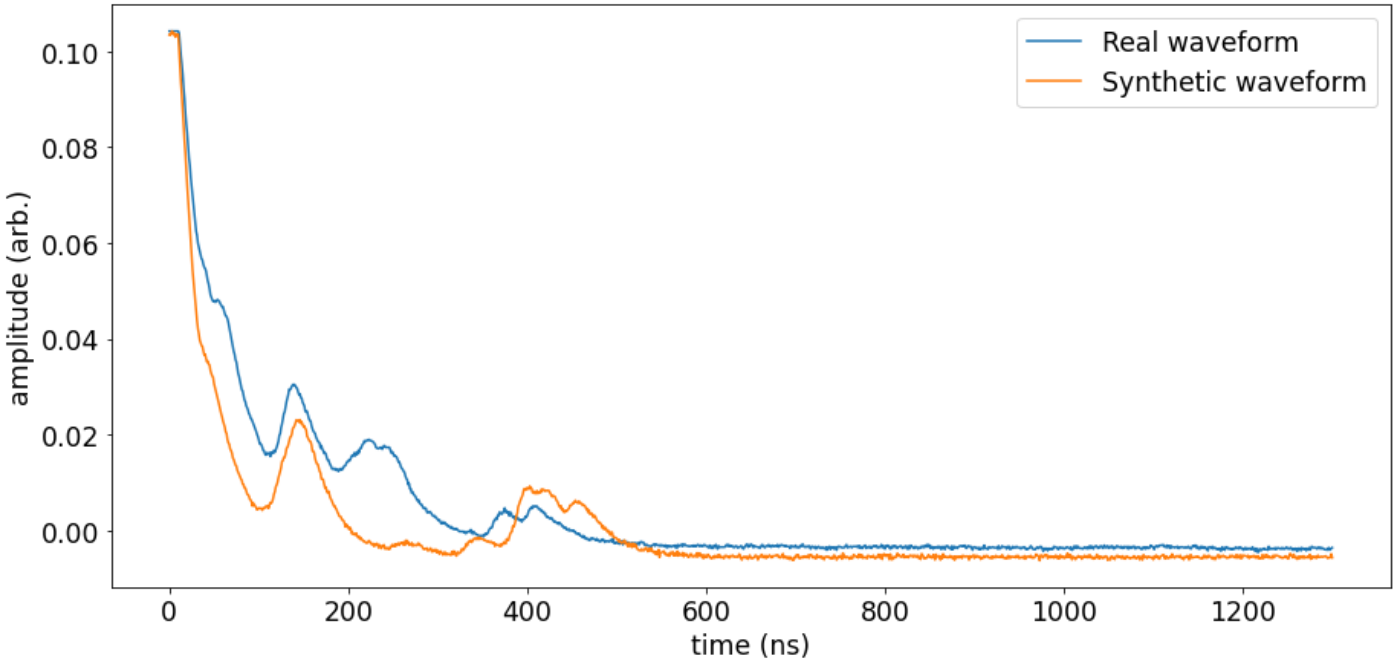


Future

Training on synthetic data

Benefit:

- **Know exact location and amplitude of peaks—i.e., not dependent on incomplete deconvolution of the prompt peak's exponential tail. This will potentially allow the full tail up to the pulse saturation level to be deconvoluted. The difficulty lies in make realistic synthetic data.**



Mixture of Experts

Benefit:

--One model can deconvolute waveforms from a variety of detectors (LaBr3, NaI, plastic, HPGe, etc.)