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

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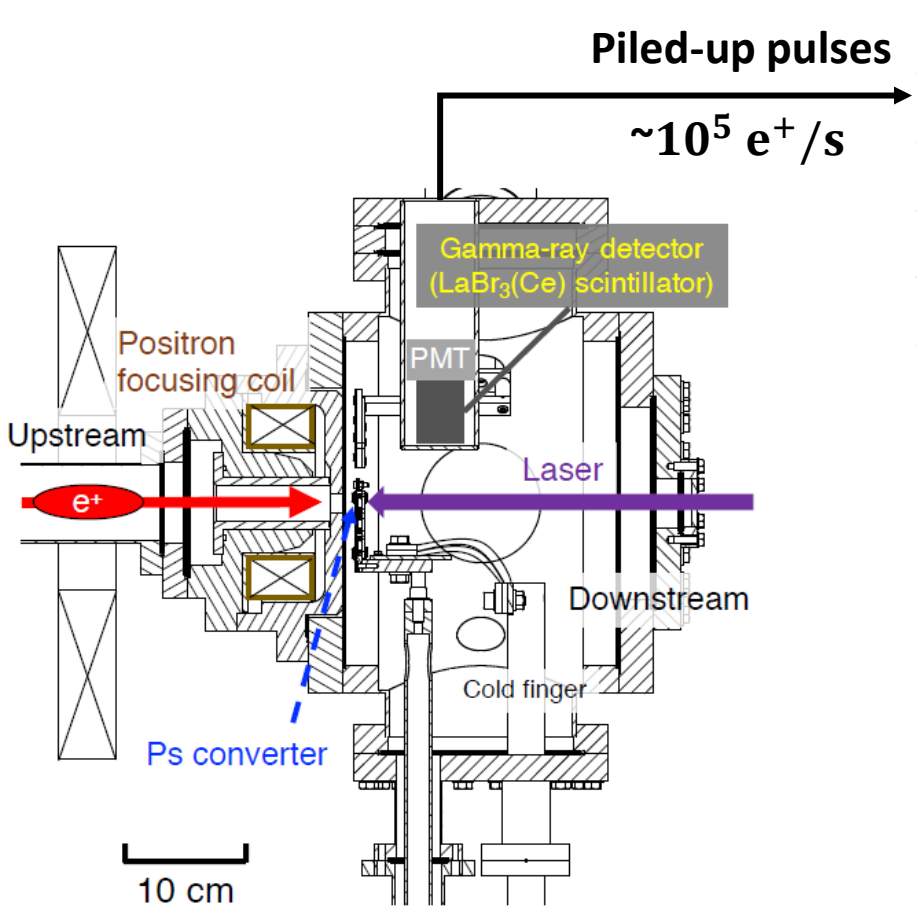
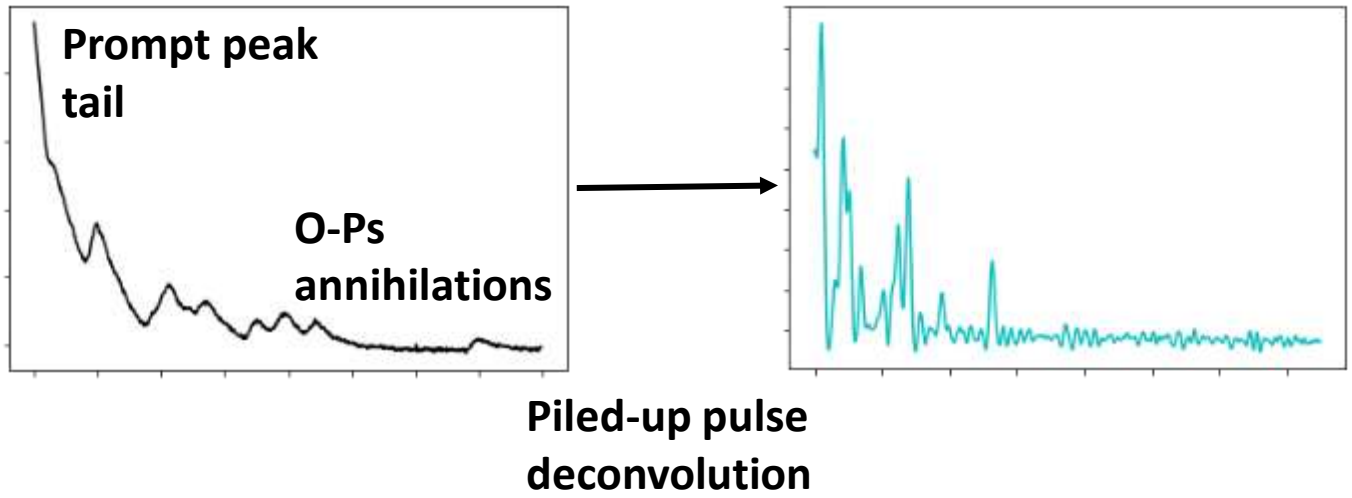
Experiment and Motivation





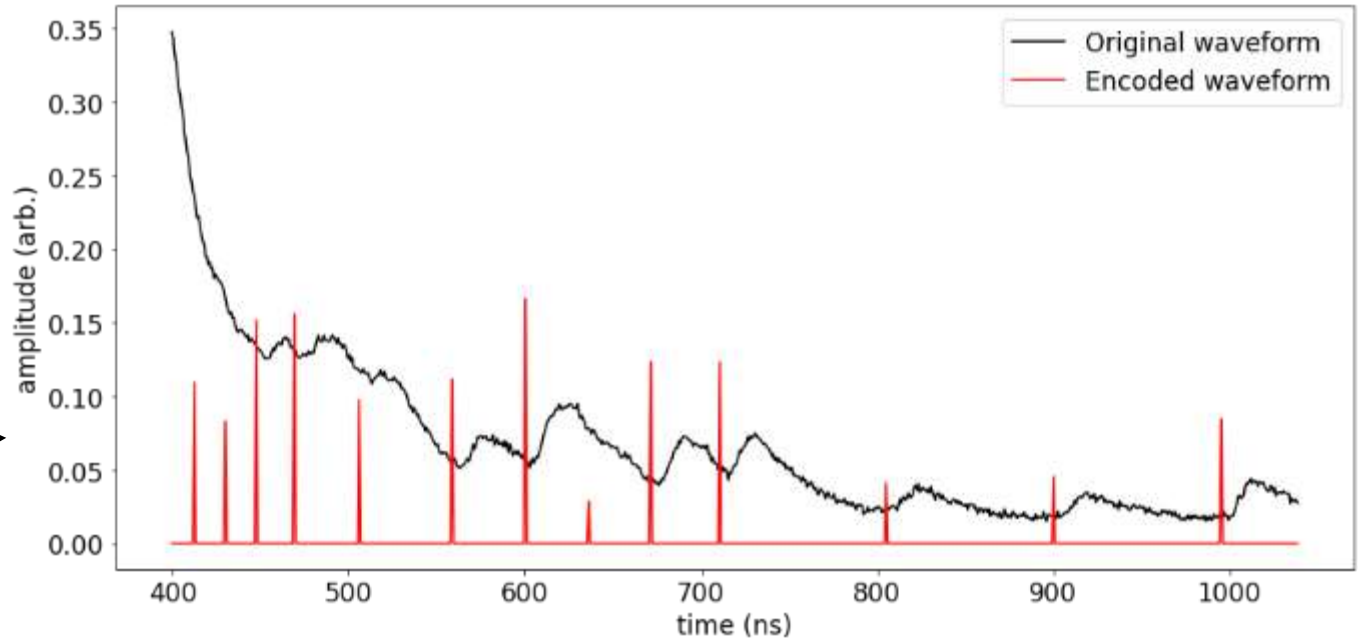
Piled-up pulse deconvolution

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

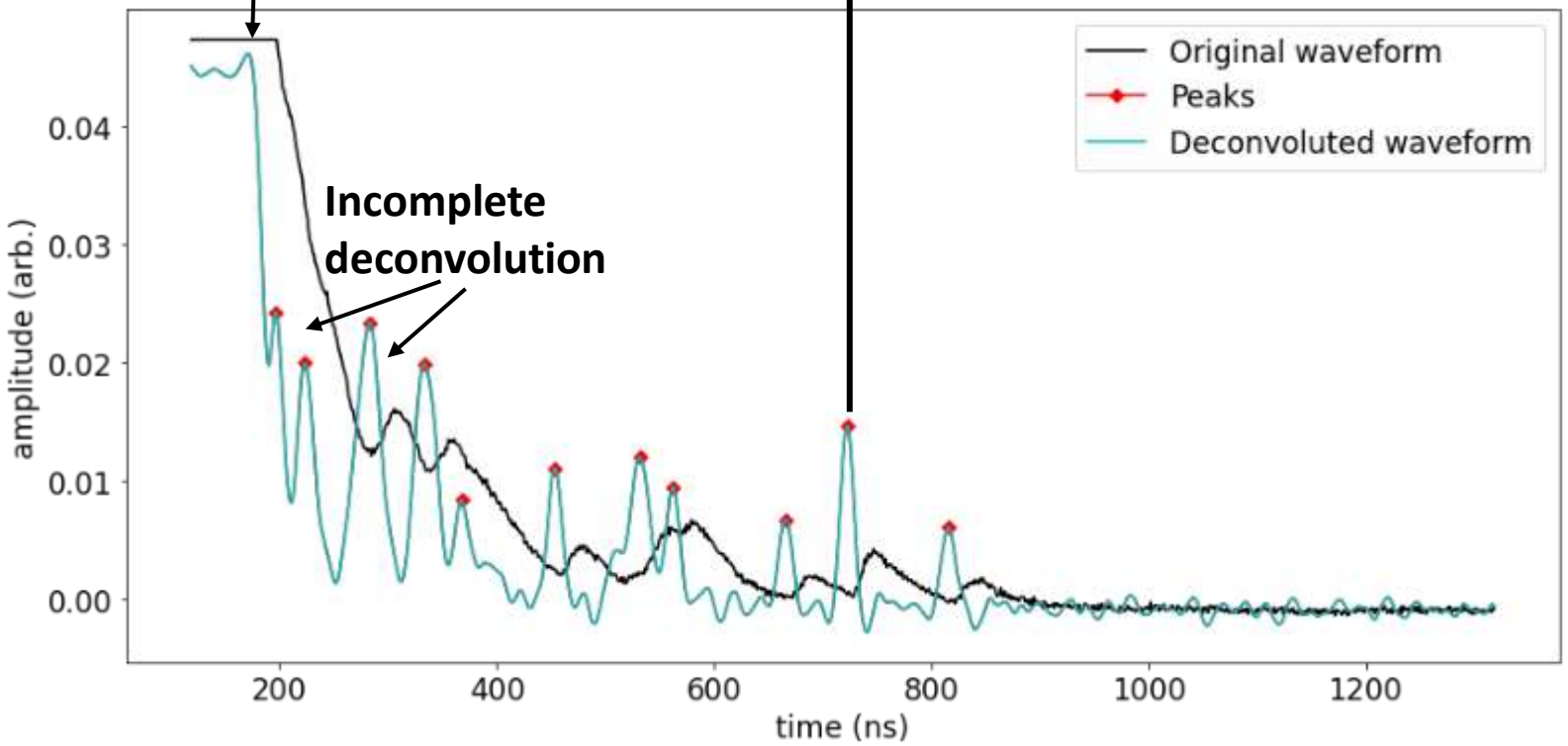
Data Transformation



Extract peak indices and amplitudes

Digitizer saturation

Incomplete deconvolution

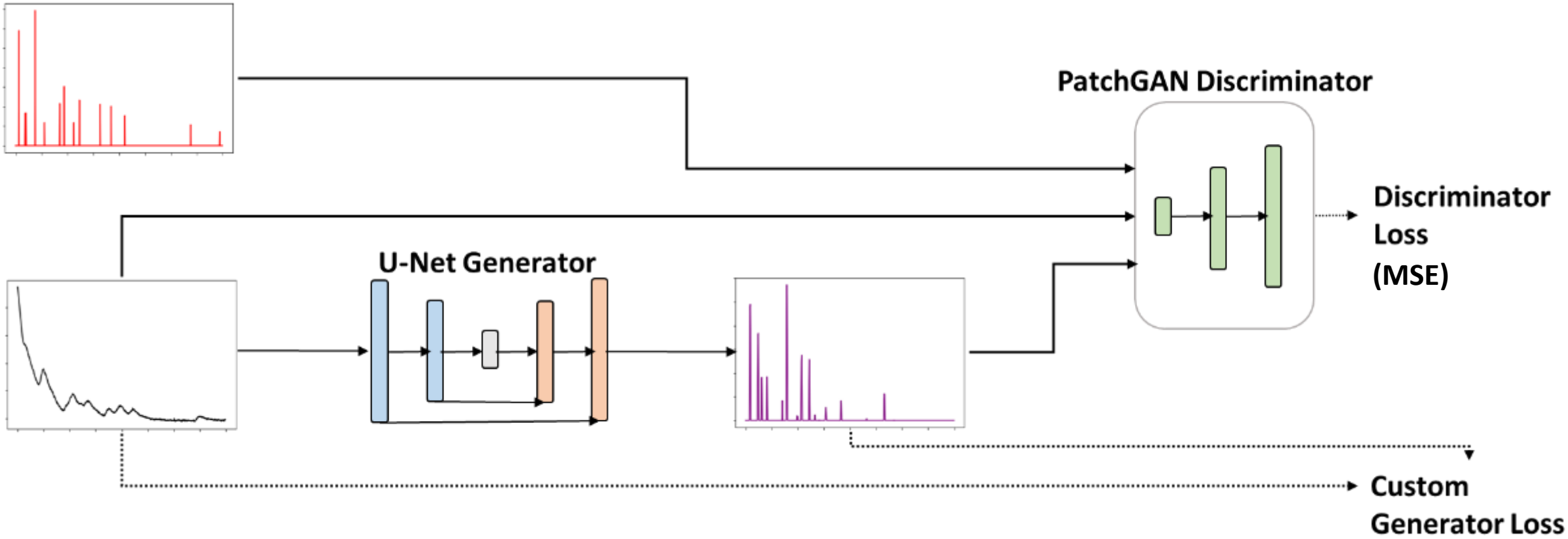


Wiener Deconvolution

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

Architecture and Training

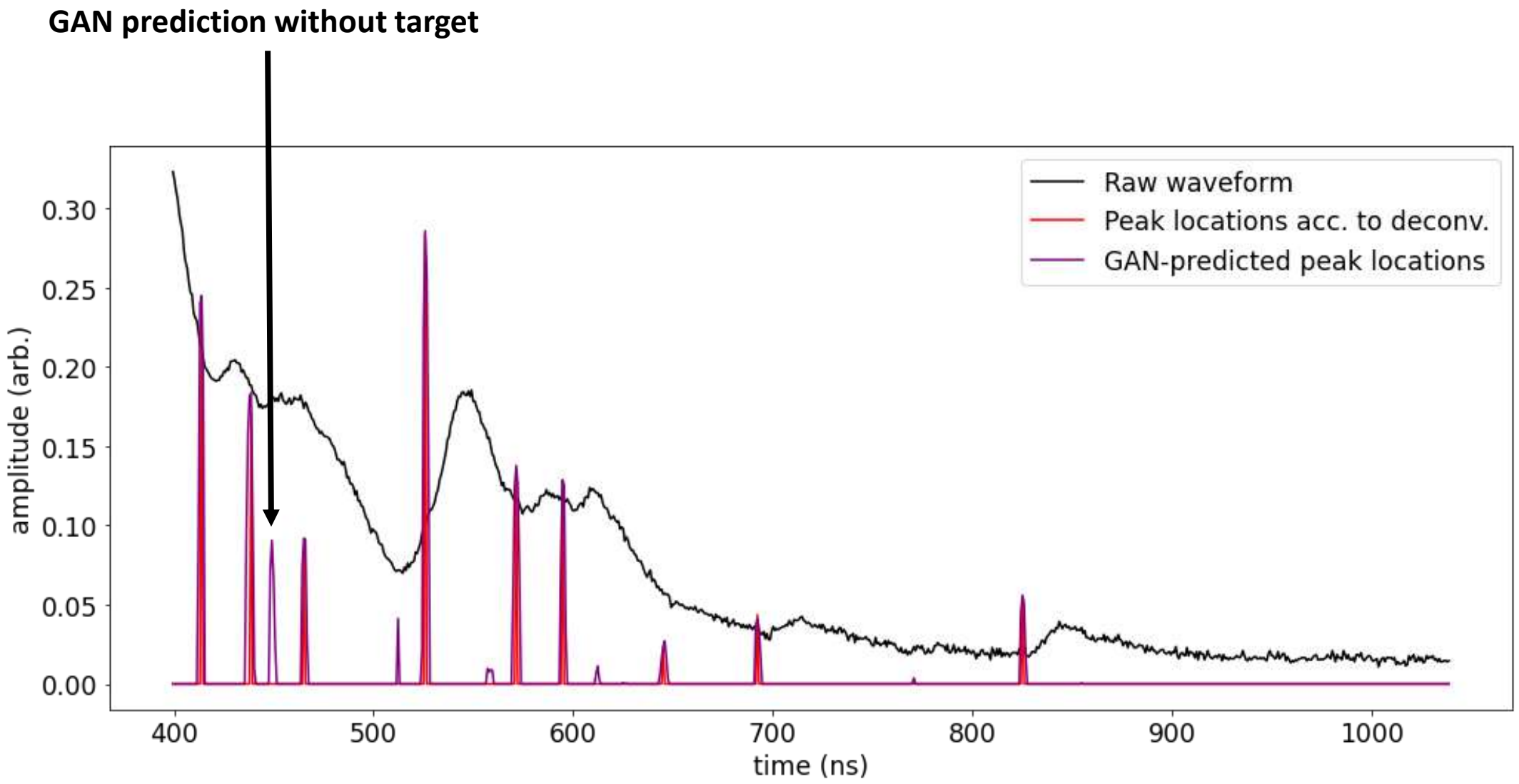
Generator loss using only the difference (residuals or MSE) between waveforms is difficult to train when using delta-like peaks. Current loss: $\sum|x-y| + c * \sum|x_{peaks} - y_{peaks}|$. The constant, c, should vary throughout training (start large).



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

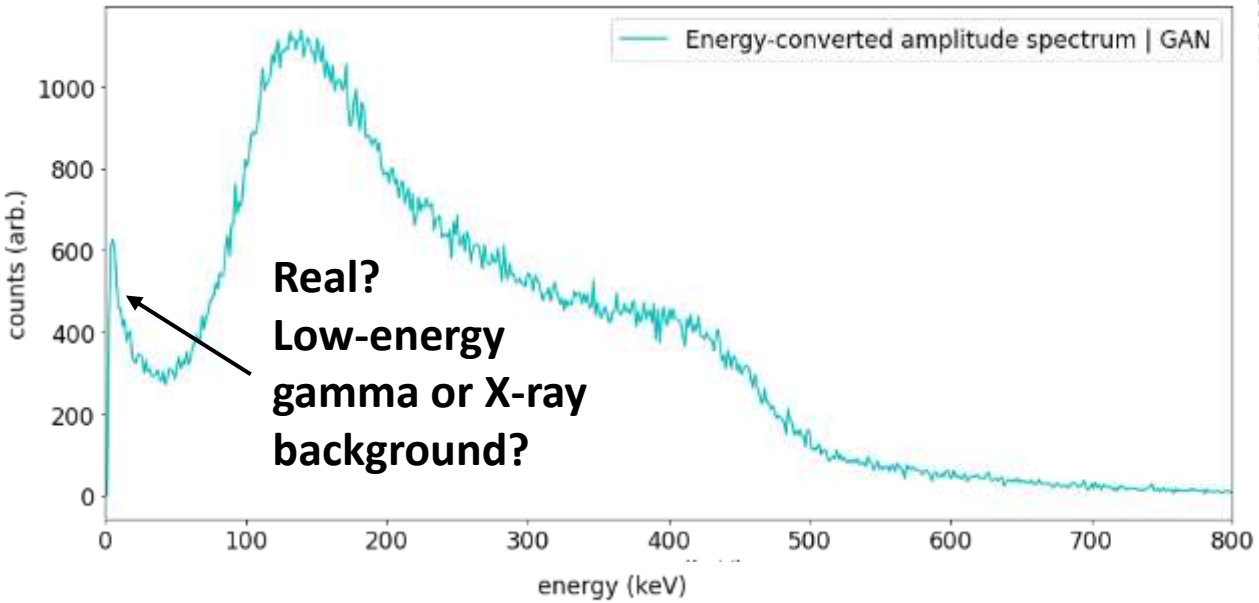
GAN Predictions | LaBr3 Scintillator

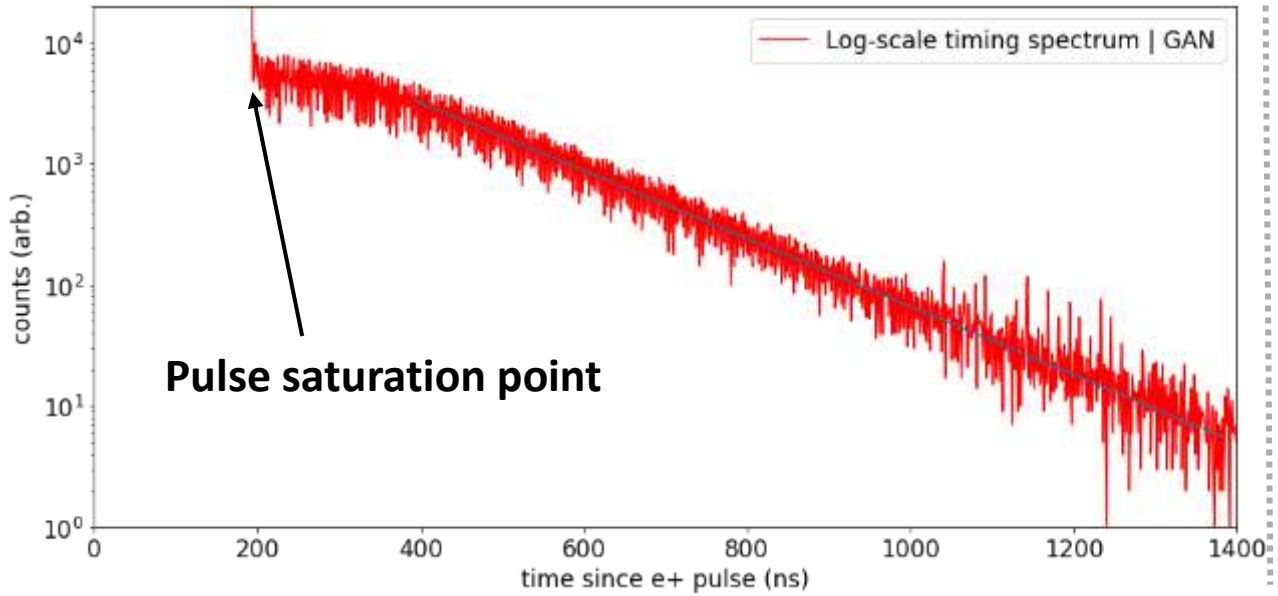


Preliminary Results

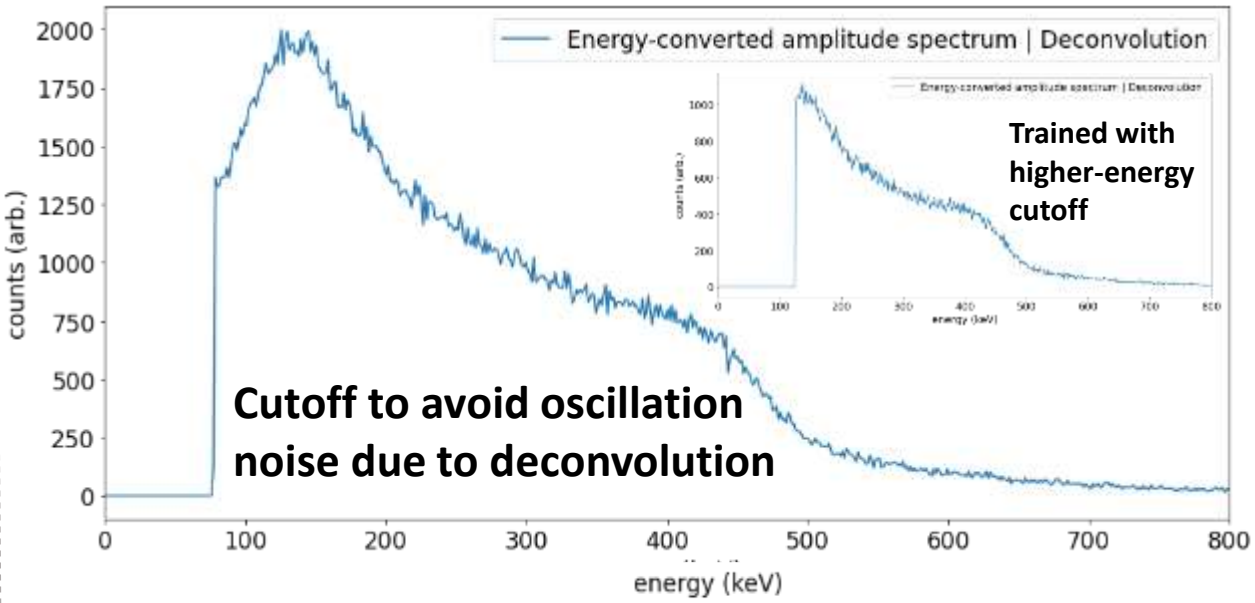
Amplitudes are taken from 420 ns after e+ pulse due to incomplete deconvolution along tail (~190 ns for timing spectra)

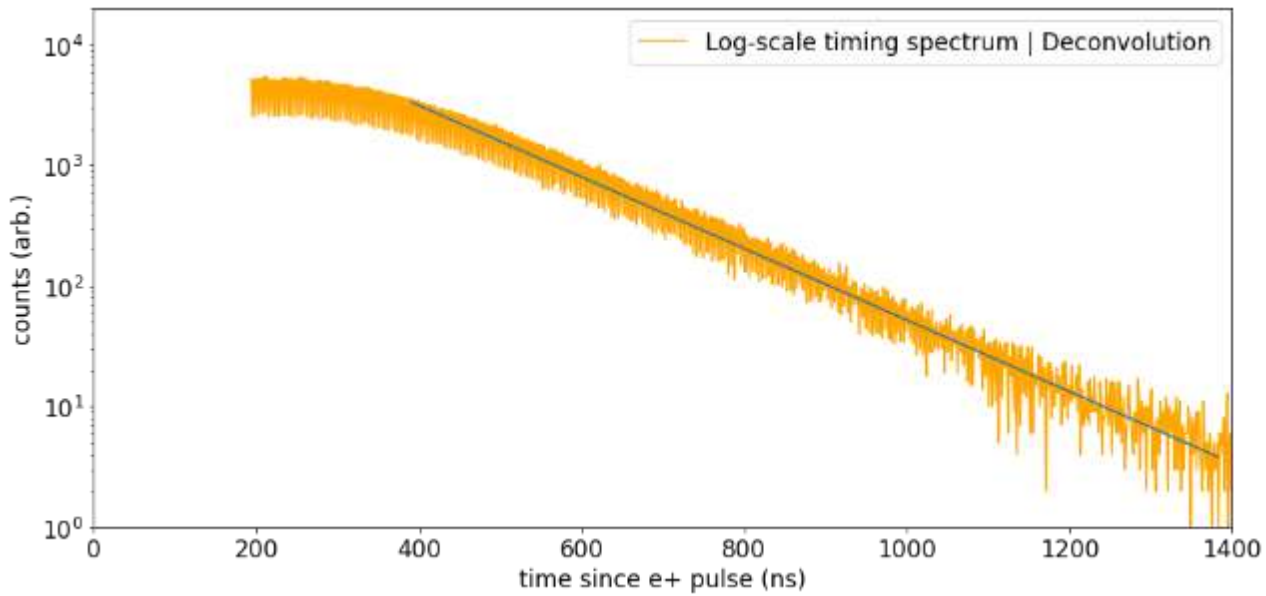
GAN



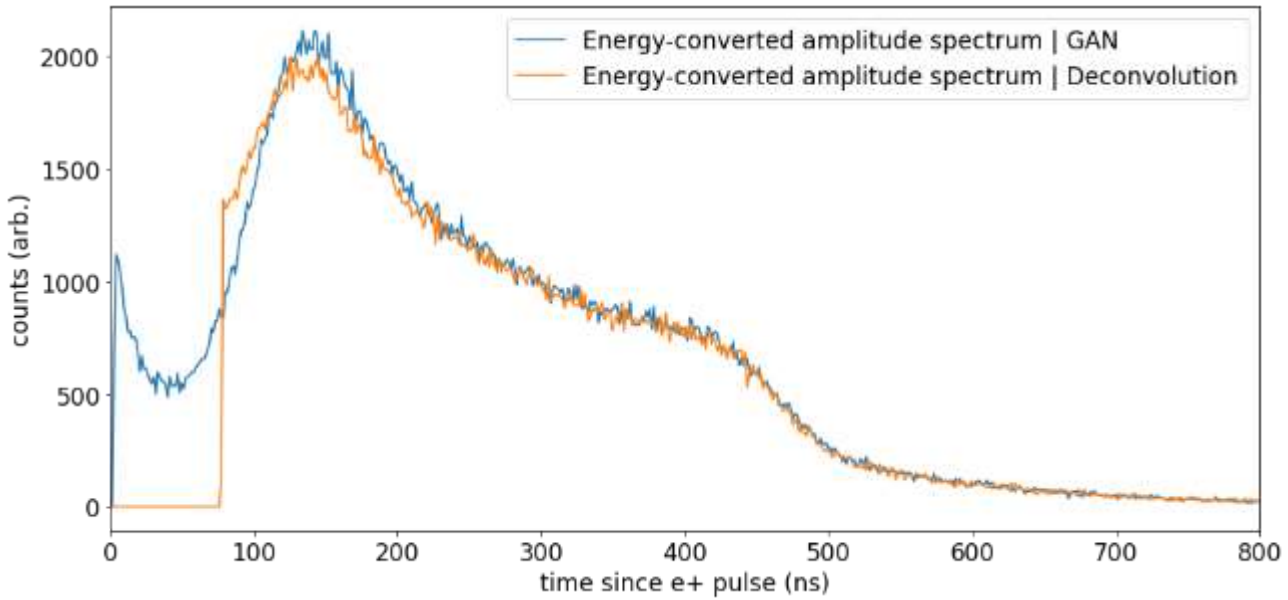


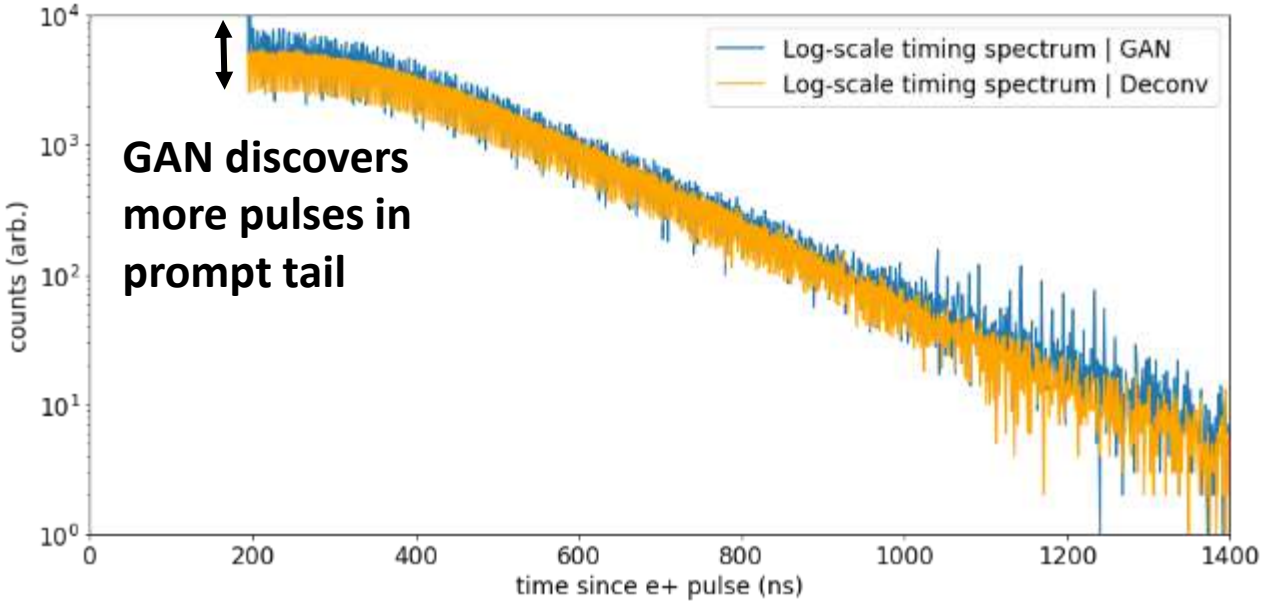
Deconvolution

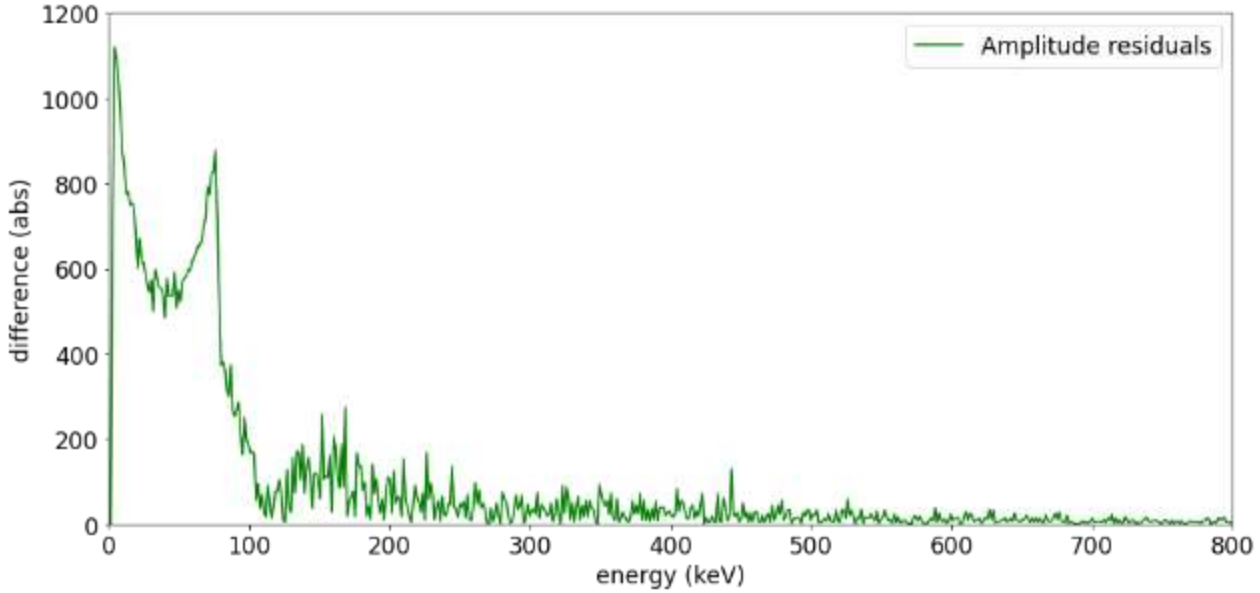


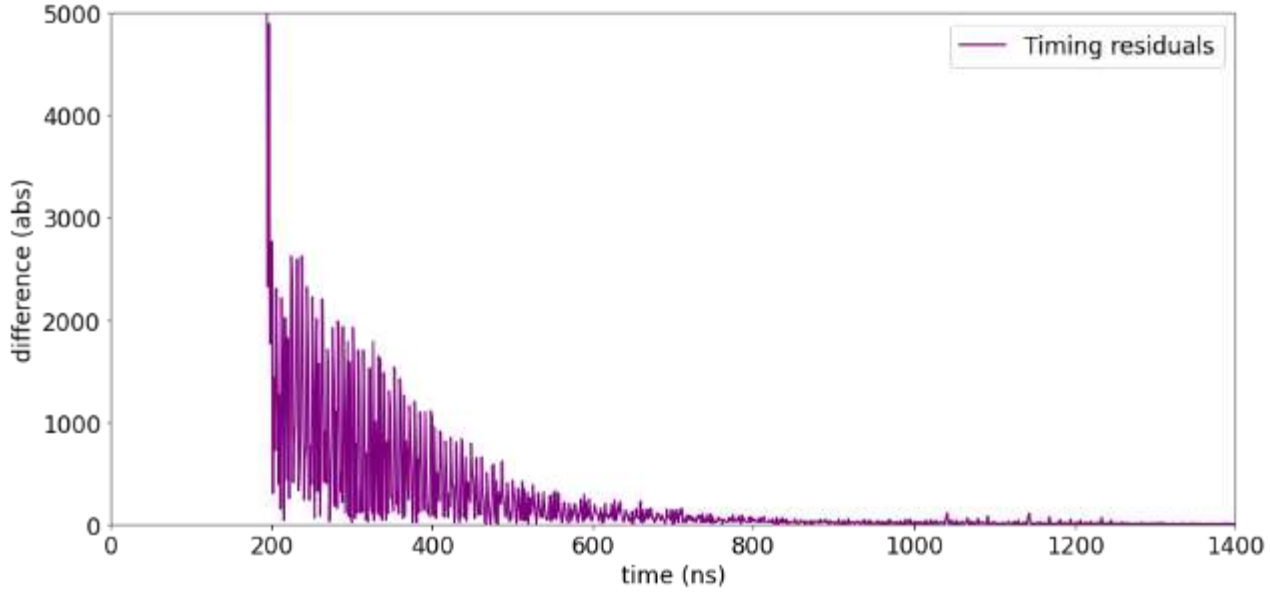


Preliminary Results



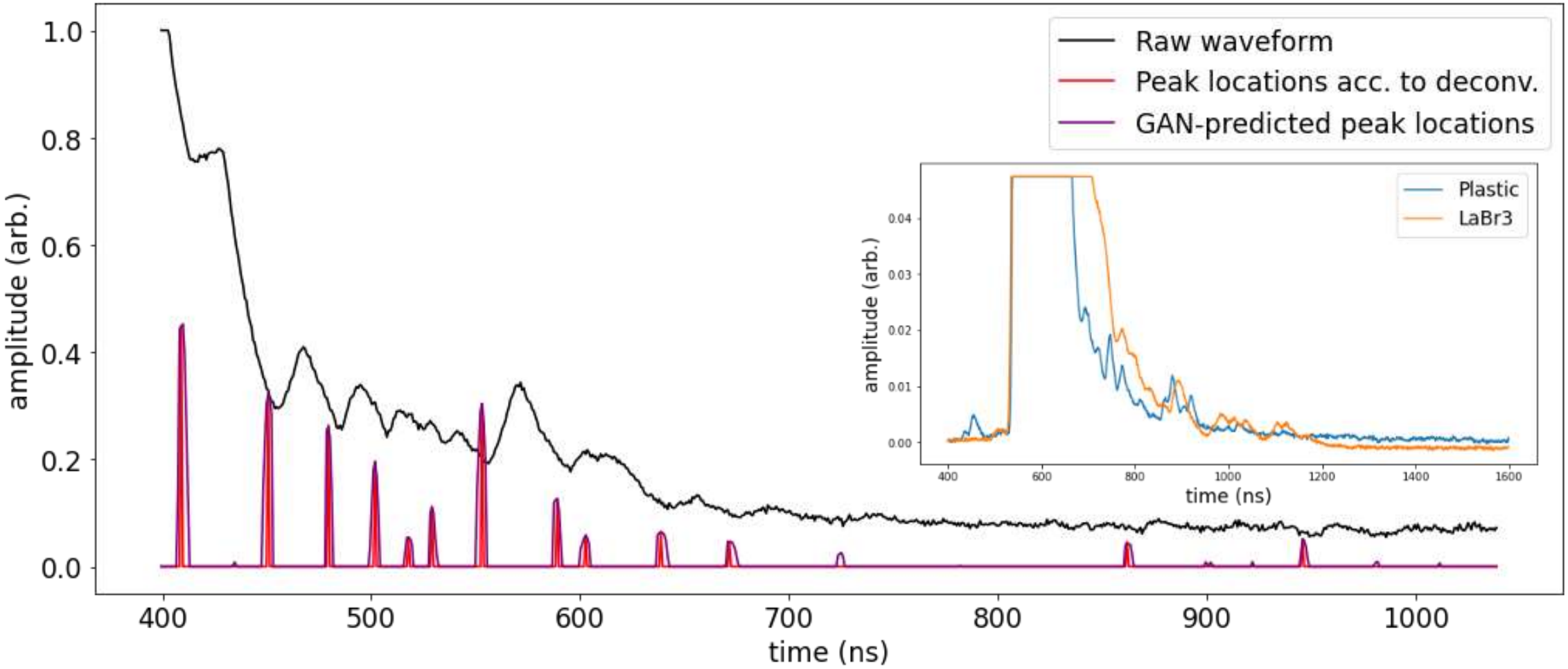






Further Results | Plastic Scintillator

Data produced by a plastic scintillator can be deconvoluted by the GAN by training on both the LaBr3 and plastic scintillator data simultaneously

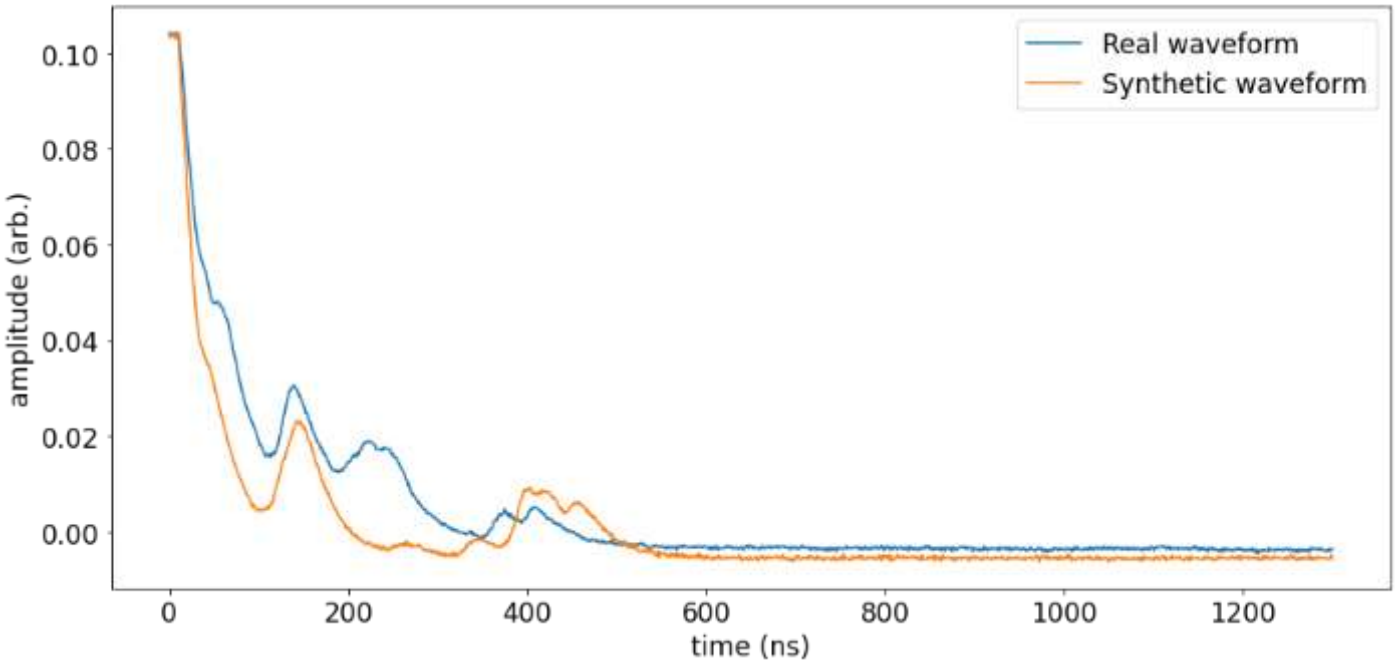


Future

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 allow the full tail up to the pulse saturation point to be deconvoluted.



Mixture of Experts

Benefit:

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