

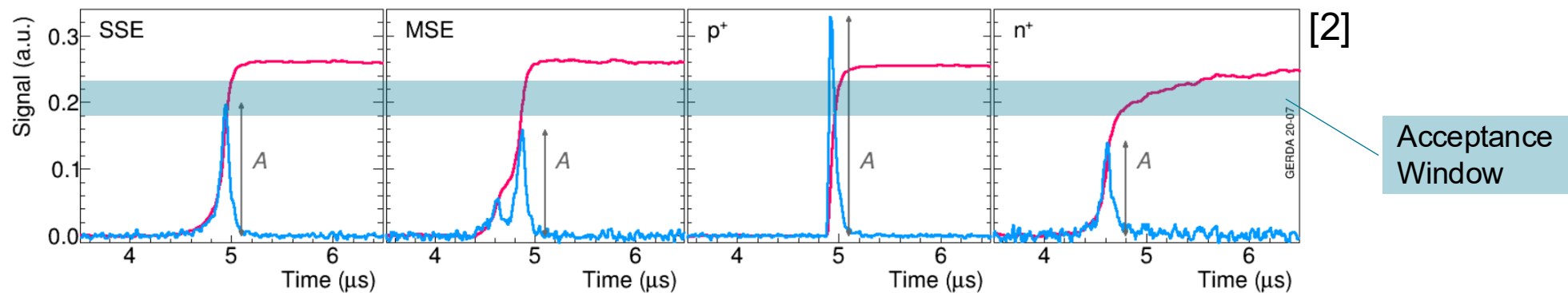
Enhancing Pulse Shape Discrimination with Gradient Boosted Decision Trees and Twin Neural Networks

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Motivation

- High-purity germanium (HPGe) detectors play critical role in nuclear physics experiments
 - Neutrinoless double beta decay (LEGEND, Majorana Demonstrator, GERDA)
- Higher-than-expected background acceptance rates in LEGEND-200 [1]
 - Mitigation: Low-background materials + enhanced pulse shape discrimination (PSD)
- Traditional PSD relies on thresholded scalar shape parameters of the signal pulses



[1] L. Varriano, Low Radioactivity Techniques Conference, Oct. 2024.
[2] M. Agostini et al., Eur. Phys. J. C , 82, Feb. 2022.

Architecture

1400×2

699×32

348×64

173×128

85×256

41×512

19×1024

8×2048

3×2048

Multilayer Perceptron

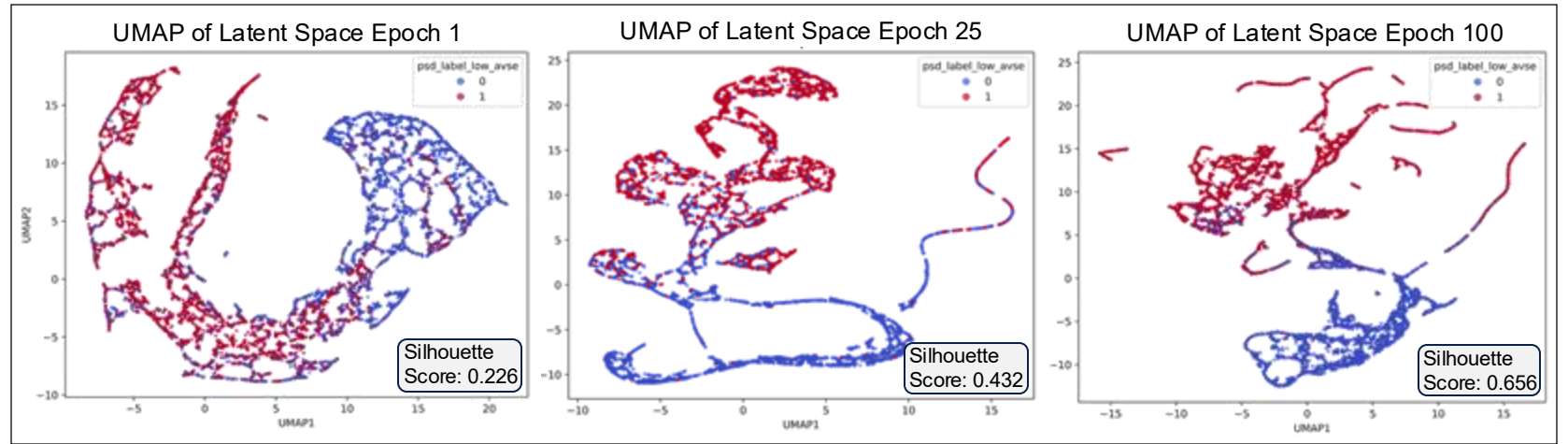
6144 → 6144 → 4096 → 2048 → 1024 → 512 → 256 → 128 → 64

1×64
(Latent Space Vector)

Physically Informed
Signal Shape Parameters

GBDT

Cut Prediction



- Batch Normalization
- 1D-Convolution; Size=4, Stride=2
- Leaky ReLU (0.01)

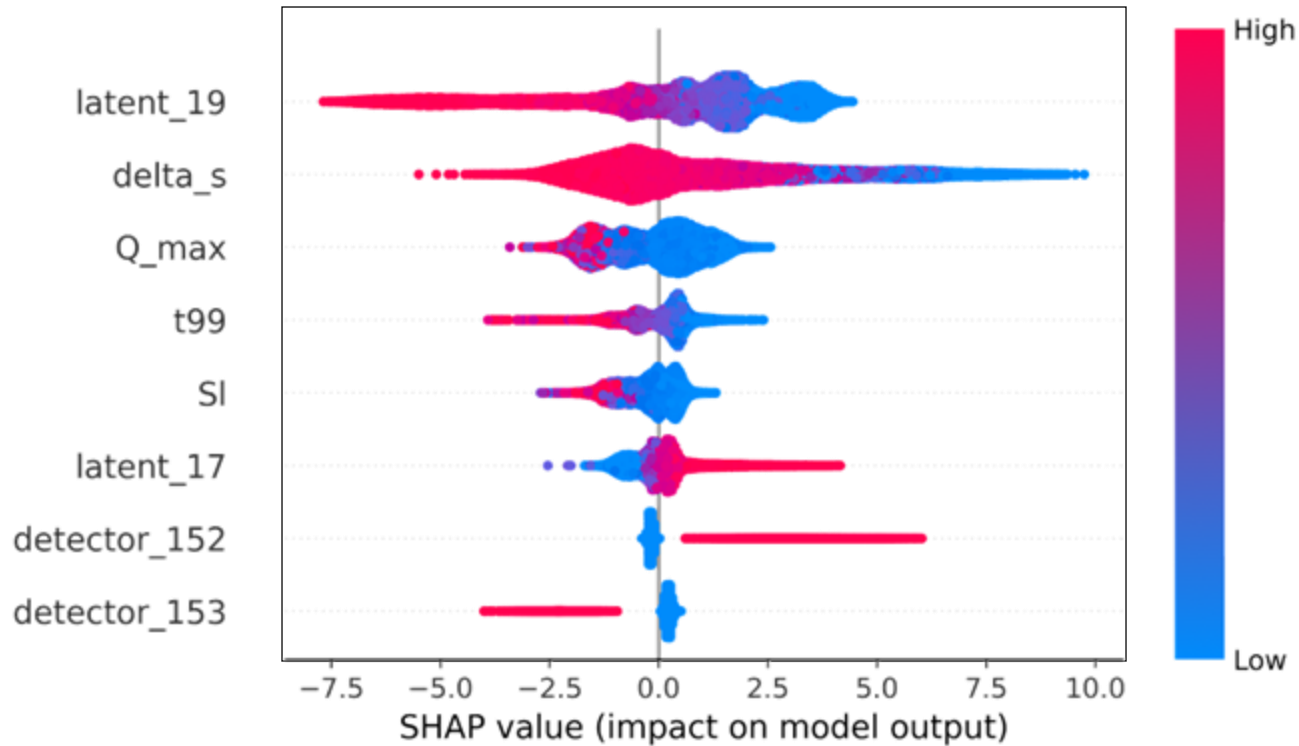
- Fully Connected Layer
- ReLU

→ Flatten

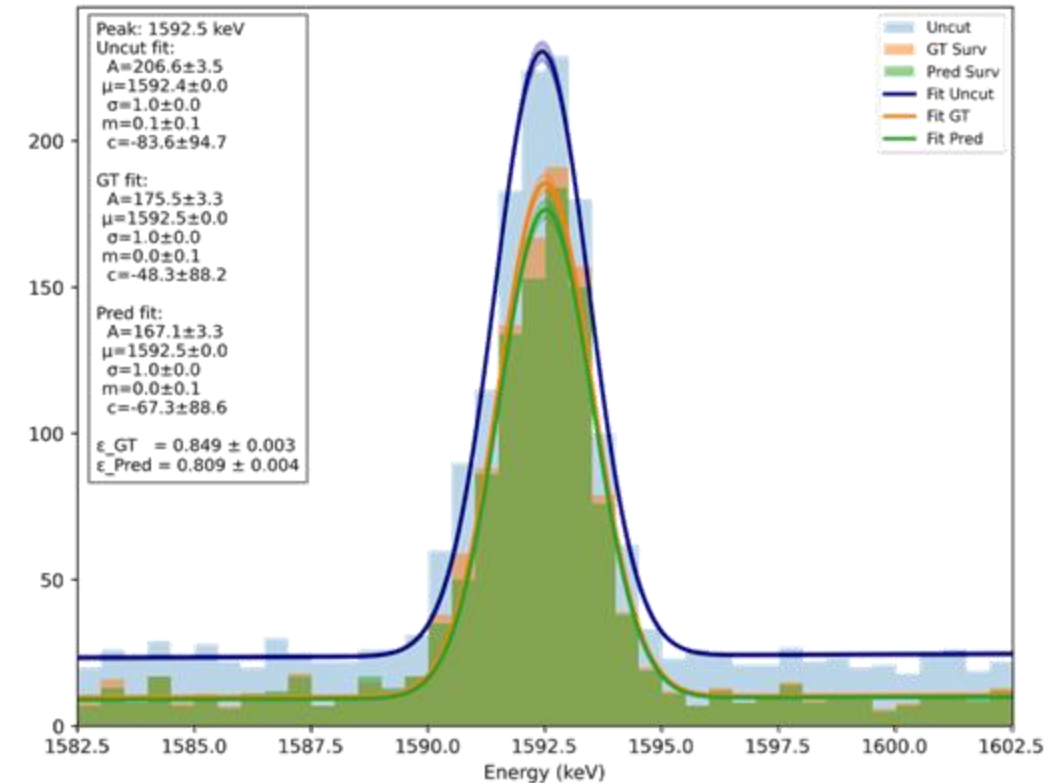
→ GBDT Input

Results

SHAP analysis of „Low AvsE“ predictor



^{208}Tl double escape peak of the ^{228}Th spectrum



Survival fractions and intersection over union (IoU) between traditionally derived and ML-based ^{228}Th spectrum

Cut Type	Survival Fraction DEP	Survival Fraction SEP/FEP	IoU
TWINN+GBDT	80.9 $\pm$ 0.4%	10.5 $\pm$ 0.4%	89.2%
GBDT	75.2 $\pm$ 0.5%	11.2 $\pm$ 0.4%	87.7%
Traditional PSD	84.9 $\pm$ 0.3%	11.8 $\pm$ 0.5%	100%