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

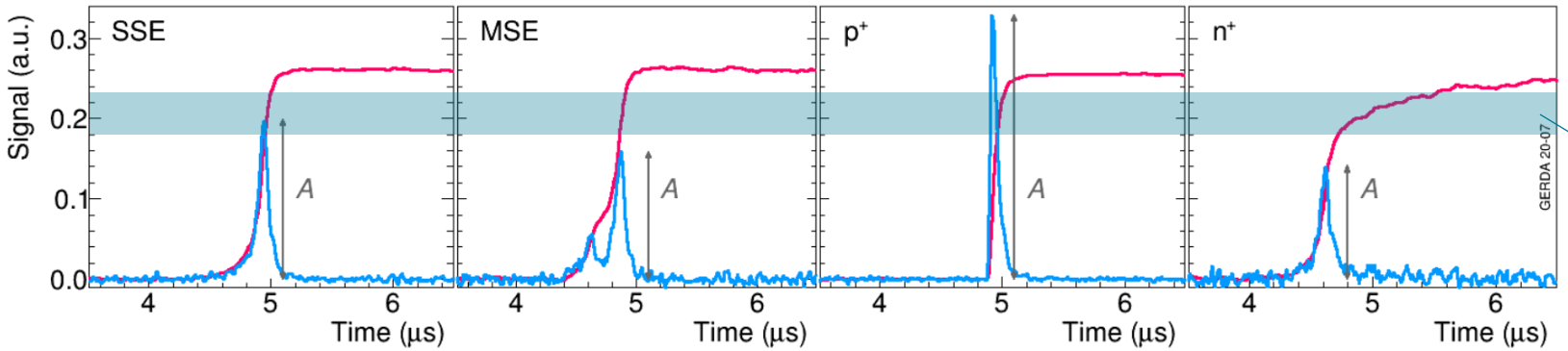
Alain Fauquex[1,2], Marta Babicz[2], Laura Baudis[2]
[1]Department of Physics, ETH Zürich; [2]Physics-Institute, University of Zurich

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 threshholded scalar shape parameters of the signal pulses

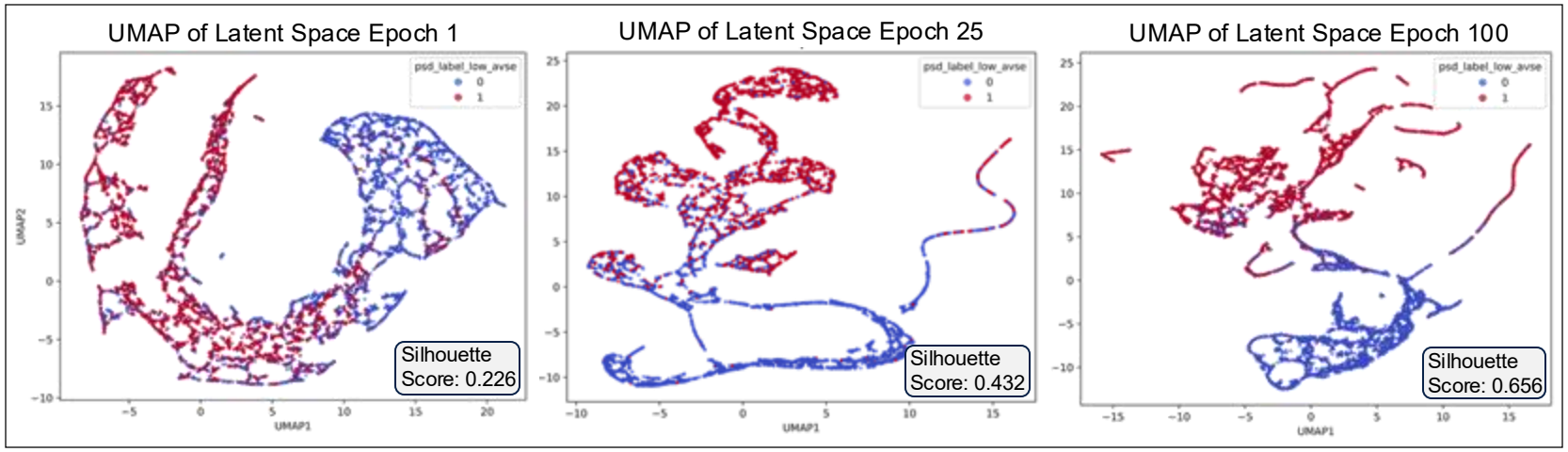


[2]

Acceptance Window

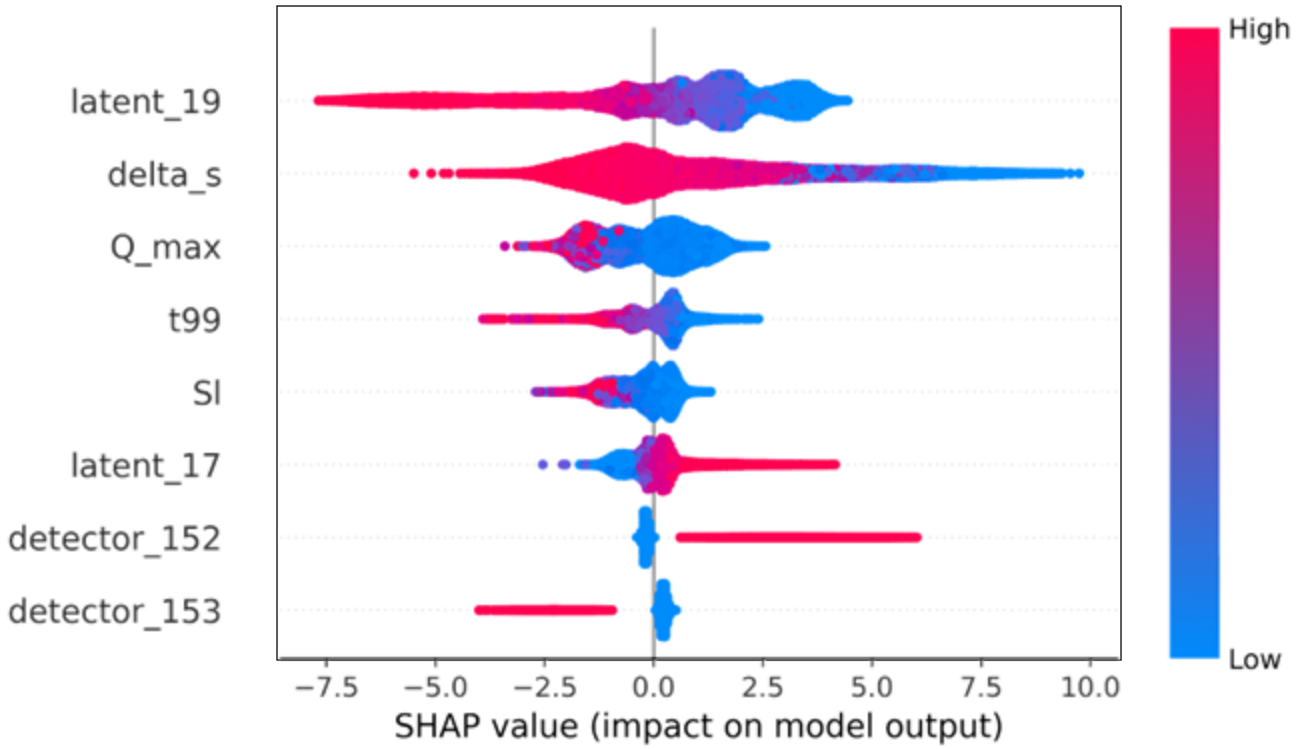
[1] L. Varriano, Low Radioactivity Techniques Conference, Oct. 2024.
[2] M. Agostini et al., Eur. Phys. J. C , 82, Feb. 2022.

Architecture

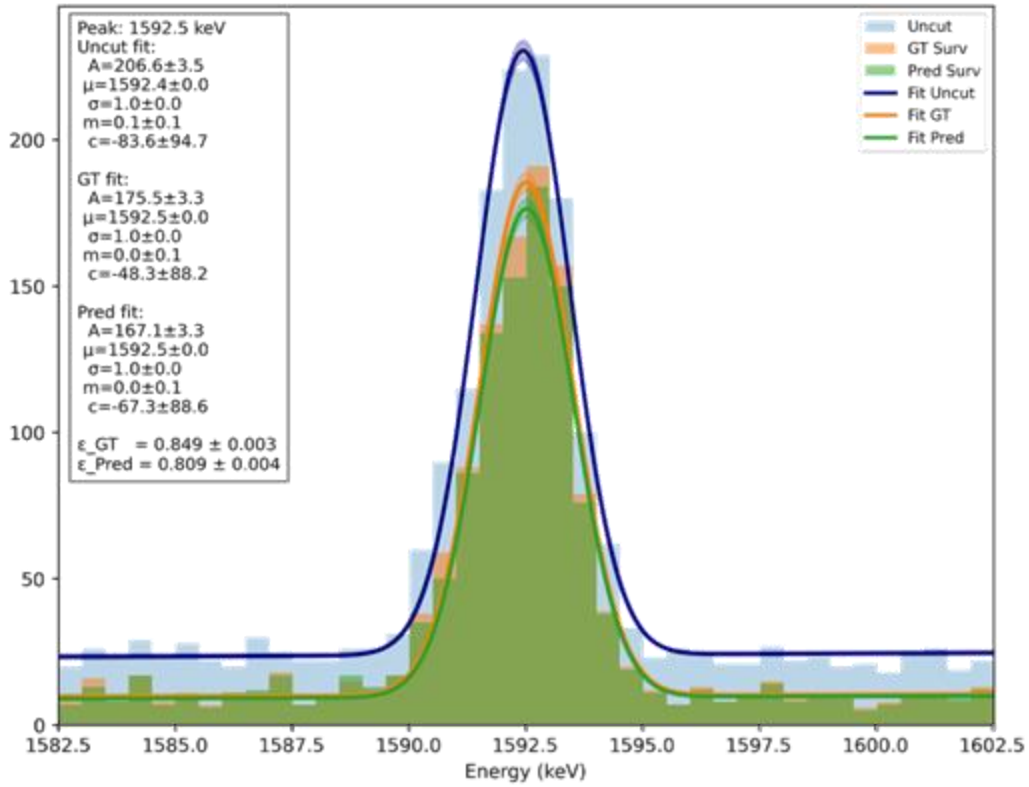


Results

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
TWINNN+GBDT	80.9±0.4%	10.5%±0.4%	89.2%
GBDT	75.2±0.5%	11.2%±0.4%	87.7%
Traditional PSD	84.9±0.3%	11.8%±0.5%	100%