SnT 2025
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Computer Analyst: AI/ML assisted analyses of radionuclides from high resolution gamma-ray spectra

B. Archambault, K. Truax, S. Emmons, M. Lonsway, B. Pierson, L. Metz, J. Friese, and M. Douglas

Pacific Northwest National Laboratories, Richland, WA, USA

Pacific Northwest NATIONAL LABORATORY

NUCLEAR FORENSICS Transformational Innovation Initiative @PNNL

INTRODUCTION AND MAIN RESULTS

We are developing a comprehensive database of over 100,000 analyzed gamma-ray spectra from an archive containing decades of radiometric analyses of a diverse range of radionuclide samples by trained gamma spectroscopists.

This dataset was curated and leveraged to embed domain expert interpretation and analysis of gamma-ray spectra to train semi-supervised AI/ML models and algorithms as powerful tools for enhancing the speed, precision and robustness of gamma spectroscopic analysis.

SnT 2025 CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE

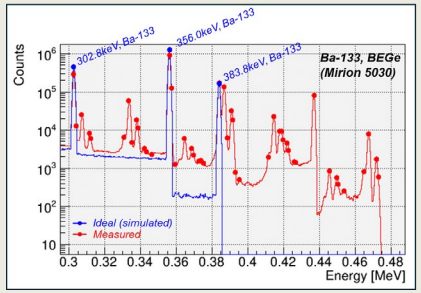
Computer Analyst: AI/ML assisted analyses of radionuclides from high resolution gamma-ray spectra

B. Archambault, K. Truax, S. Emmons, M. Lonsway, B. Pierson, L. Metz, J. Friese, and M. Douglas

P3.6-220

The Challenge

High resolution gamma spectroscopy remains a powerful and essential tool for characterization of nuclear materials in support of treaty verification regimes. However, accurate characterization remains challenging due to a variety of phenomena, including interfering and overlapping peaks, escape peaks, and coincidence sum peaks. These phenomena often drive a requirement for tedious and manual analysis by trained spectroscopists to accurately interpret the results. We aim to leverage decades of embedded domain expert interpretation and analysis of gamma-ray spectra into semi-supervised AI/ML tools and algorithms generating powerful tools for enhancing the precision and robustness of gamma spectroscopic analysis.

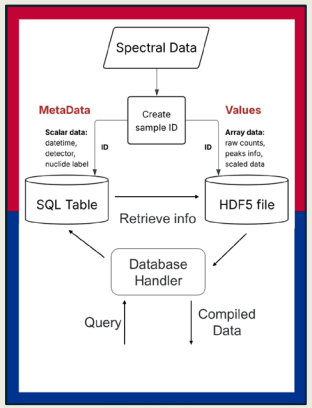


The Database

A comprehensive archive of over 100,000 analyzed gamma-ray spectra from decades of radiometric analyses performed at the Radiological Processing Laboratory at PNNL were made available, spanning the environmental monitoring, medical isotopes, nuclear power, and nuclear safeguards and security domains.

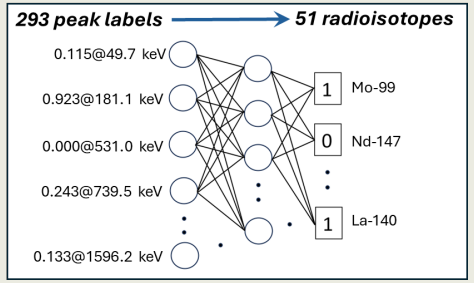
Archived data cleaning, labeling, pruning, balancing, and preprocessing were performed to ensure model generalizability and reliability, resulting in a subset of 1120 analyzed HPGe spectra hand curated by trained gamma spectroscopists at PNNL. The curated data was organized into a searchable SQL database containing:

- *Raw HPGe gamma spectra*
- *Key detector metadata*
- *Efficiency, energy and resolution calibration data*
- *Full energy peak detection efficiency normalized spectra*
- *Detailed peak info (energy, isotope, area) reviewed and vetted by SMEs for accuracy*



Automated Interpretation & Reporting

This database was leveraged to train a fully-connected dense neural network to aid the interpretation and reporting of automated radionuclide identification and characterization of the gamma spectra by Mirion's Genie 2000 gamma spectroscopy software. Hyper parameter optimization of the FC-DNN was accomplished by leveraging Bayesian probabilistic regression using Gaussian processes.



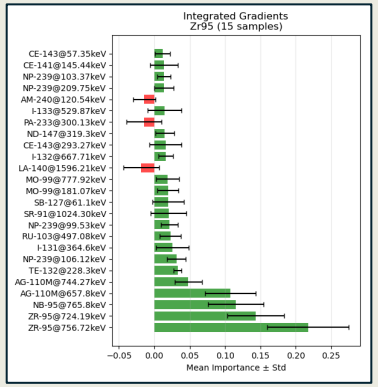
Average Accuracy for Radionuclide ID

# of Isotopes	25	34	51
Bayes Tuned	97.96%	98.18%	98.25%
50 searches	0.92	0.91	1.01
15 iterations			

The trained automated computer analyst achieved a ***98.25% accuracy for nuclide identification*** for a list of 51 radioisotopes (results detailed above.)

Towards Trustworthy AI

It is critical for international treaty verification regimes to ensure accuracy, transparency, and accountability in the data analysis and decision-making process. Automated interpretation and reporting of radionuclides from gamma spectra may provide opportunities to reduce biases imparted unknowingly by the human analyst therefore improving accuracy and confidence in results. A user with understanding of which features contributes the most to a prediction verifies the decision-making process is transparent and trustworthy. One example (right) demonstrates the use of one such tool: LIME (Local Interpretable Model-Agnostic Explanations).



Pacific Northwest NATIONAL LABORATORY

NUCLEAR FORENSICS Transformational Innovation Initiative @PNNL