# Machine Learning Assisted Pulse Shape Analysis for Detector Inference

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In the Advanced Gamma Tracking Array (AGATA), the technique of Pulse Shape Analysis (PSA) is used to provide insight into a variety of detector properties and is a critical step in gamma-ray tracking. Optimization-based (kNN) PSA used in AGATA offers significant improvement to localization accuracy over parametric methods but requires significant effort in simulation and substantial computational overheads. In this work we propose an intermediate method that utilizes Machine Learning to form bespoke learned approximations of detector responses using experimental data. Self-Organising Maps (SOMs) are used to form approximations of detector responses, these maps are used by subsequent algorithms to analytically infer the number of interactions in experimental signals and their underlying properties.

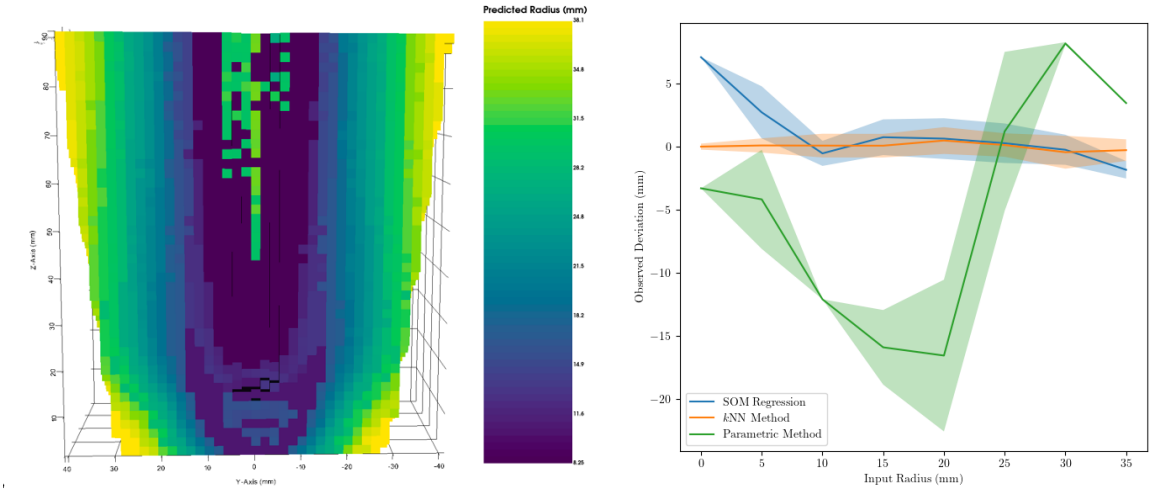


*Figure 1- Predicted distance from the core for an AGATA coaxial HPGe detector (left) and observed deviations (right) compared against exhaustive kNN and parametric methods.*

Our approach is seen to produce comparable results to exhaustive kNN methods whilst operating at MHz rates. By using our method, we can intelligently quantify the probability of individual signals being single-site or multi-interaction events. This allows for bespoke vetoes and processing, providing an efficient preprocessing method before more demanding PSA. Multi-interaction inference is made possible with simplex de-mixing, providing an avenue for real-time inference in large-volume and monolithic HPGe crystals. Deviations from expected signal responses can also be easily quantified. We believe this work has great applicability in applied physics, with applications from Compton imaging to real-time detector monitoring.

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# Nondestructive Testing at ELI-NP for Security Applications: Advanced Machine Learning Algorithms and Enhanced Position Sensitive Scintillators*

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A broad applied research program anchored in the unique characteristics of laser and gamma beams is developing at Extreme Light Infrastructure - Nuclear Physics. The facility is gradually shifting from implementation to user operation [1]. The two-arm hybrid high-power laser system (HPLS) is able to deliver 2 × 10 PW femtosecond pulses with four additional outputs, two at 1 PW and two at 100 TW. The main features of the gamma beams to be available at ELI–NP are: high-intensity, highly monochromatic (bandwidth of less than 0.5%), high degree of linear polarization (> 95%) and continuously tunable in the 1- 19.5 MeV energy range. The unique characteristics of these beams offer significant potential for various applications but also impose additional requirements on the available detection and characterization techniques.

Highly penetrating gamma beams with very small energy dispersion coupled with an advanced gamma-ray detection system are the perfect solution for active interrogation of special nuclear materials, industrial tomography, and cultural heritage studies. The nondestructive and noninvasive inspections planned at ELI-NP use nuclear resonance fluorescence and computed tomography to perform quantitative assays of objects of various nature and composition.

In this work we introduce the applications that are being developed at ELI-NP [2-4], the challenges they entail and opportunities for collaborations. In addition, we discuss our results aimed at refining the detection techniques by enhancing the position sensitivity of scintillators for high-energy gamma photons. Silicon photomultipliers are utilized to transform scintillators into viable alternatives, overcoming the limitations of conventional detectors. In addition, Monte Carlo simulations were employed to optimize the internal structure of the pixelated scintillators for high-energy gamma-ray detection.

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# Development of HPGe Detectors for Ultra High Rate Spectroscopy and Imaging

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While High Purity Germanium (HPGe) detectors are the gold standard for high-resolution gamma-ray spectroscopy, conventional, coaxial HPGe detectors show significant performance degradation at high rates (tens of thousands of counts per second (cps)). A new HPGe detector prototype has been designed at Lawrence Berkeley National Laboratory (LBNL). It is intended to maintain resolution and throughput performance at ultra-high rates (5 Mcps) and feature 3D position sensitivity.

The detector geometry, a double-sided strip detector with fine strip pitch, was selected by performing analytic and numerical calculations to evaluate the expected efficiency, throughput, timing, energy, and position resolution for various geometries and electrode configurations. The design of this prototype and characterization of an initial device will be presented.

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# ARIES: A High-Efficiency, High-Granularity Beta-Tagging Scintillator Array with Ultra-Fast Timing for Decay Spectroscopy Studies

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The combination of large arrays of high-purity germanium (HPGe) detectors with auxiliary particle detection systems is among the most powerful methods for studying atomic nuclei. It is done through nuclear spectroscopy at radioactive ion beam facilities such as TRIUMF-ISAC [1] together with the use of high-efficiency gamma-ray spectrometers like GRIFFIN (The Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei) [2].

The use of ancillary detectors is key for disentangling complex level schemes, providing high isotopic selectivity and giving access to physics observables which give direct insight to the nuclear structure.

The ARIES detector (Ancillary Detector for Rare-Isotope Event Selection) is a high-efficiency ultra-fast β-particles detector designed to operate as the main ancillary detector at the GRIFFIN spectrometer. Its design matches 1:1 the GRIFFIN geometry, allowing β-γ angular correlations with more than 114 unique angles. ARIES entails low g-ray attenuation, superior counting rate greater than 20MBq and Fast Timing capabilities allowing lifetime measurement down to the few ps range.

In addition to it novel design it also includes leverage technologies such flex-circuit electronics, magnetron sputtering for coating the plastic scintillators and many more. The design, performance and status of ARIES along with an overview of the scientific opportunities will be presented.

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