3NID – An Advancement in Nuclide Identification

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Context

Gamma spectroscopy is a key technology for the detection and identification of radioactive materials in homeland security and field operations. In real use, operators must distinguish genuine threats from benign, medical, or industrial sources under challenging conditions such as low statistics, shielding, background variability, and mixed-isotope spectra. 3NID was developed to address these operational challenges and improve identification support in demanding scenarios. It is therefore mainly intended for use in Homeland Security (HLS) scenarios by intervention forces or customs for border control. Mirion Technologies Security and Search (SnS) line offers a range of products responding to these use cases.

Figure 1 - A few products from the Security & Search line.

What Is 3NID?

3NID (Neural Network for Nuclide Identification) is Mirion's AI-based radionuclide identification technology for gamma spectroscopy. It combines convolutional neural network models with a broad training strategy designed to capture realistic detector behavior and measurement variability. The current approach has evolved from a detector-specific concept into a **multi-detector solution**, and the technology has now reached **TRL 6**.

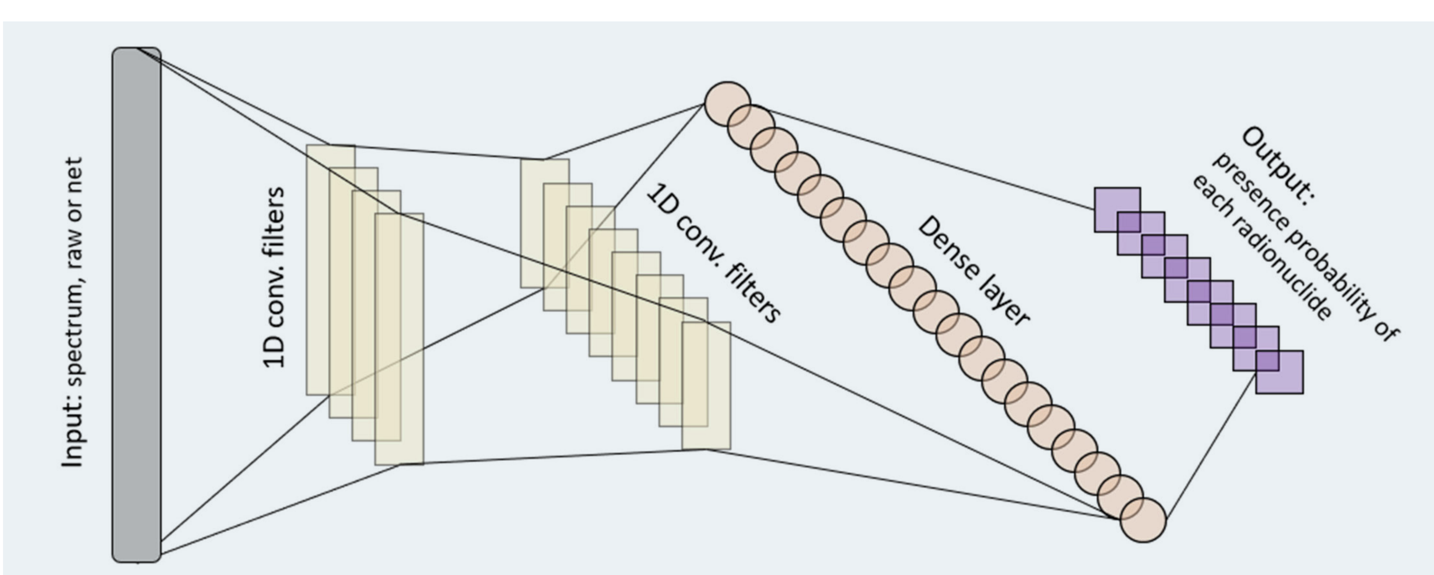

Figure 2 - General scheme of the 3NID convolutional neural network.

What It Brings To The User

For the operator, the value of 3NID is practical and immediate:

- **More reliable identification support** in difficult spectra, including low-statistics or partially masked cases.
- **Better discrimination between threat and non-threat radionuclides**, including complex combinations of SNM, industrial, and medical sources.
- **Much lower false positive rates in many challenging scenarios**, helping reduce ambiguity, unnecessary escalation, and operator workload.

In short, 3NID is designed to help users make faster and more confident field decisions.

Broad Applicability Across Detector Platforms

3NID is designed for a broad range of mid-resolution detectors relevant to Mirion's spectroscopy portfolio. It can process spectra from detectors with a resolution at 662 keV ranging from **2.5% to 9%** and volumes from **10 cm³ to several liters**, covering all SPIR detector configurations, and beyond. Its development has specifically focused on devices such as **SPIR-Pack, SPIR-Ace NaI, SPIR-Ace LaBr3,** and **SPIR-Ident**. This makes 3NID more than a single-product demonstrator: it is a scalable identification technology with relevance across multiple Mirion platforms.

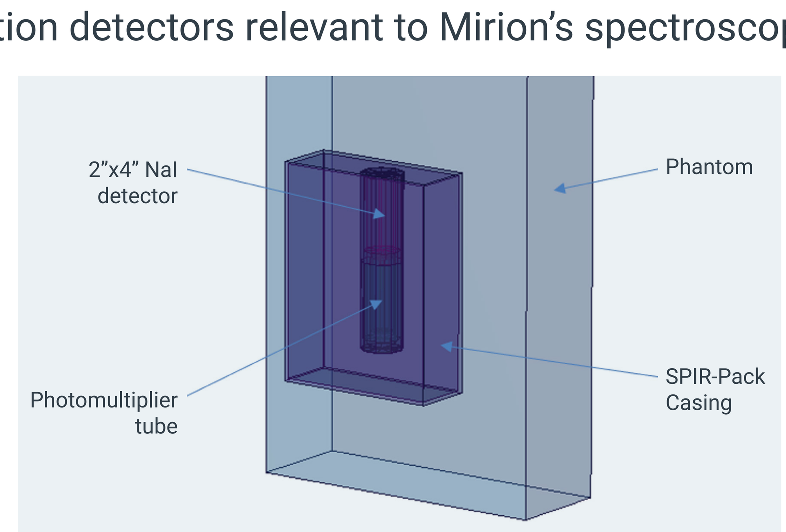

Figure 3 - MCNP model of SPIR-Pack.

Scientific Foundation

3NID is trained entirely on synthetic gamma spectra generated from **Monte Carlo simulations**, then enriched with realistic sources of variability such as gain shifts, energy broadening, counting noise, background variability, raw/net modes, and isotope mixtures. The full training effort includes nearly **20,000 Monte Carlo simulations** and produces datasets totaling close to **5 million spectra**. This simulation-driven strategy is essential because it allows the algorithm to generalize across detector types, source configurations, shielding conditions, and spectral statistics while maintaining a rigorous physical basis.

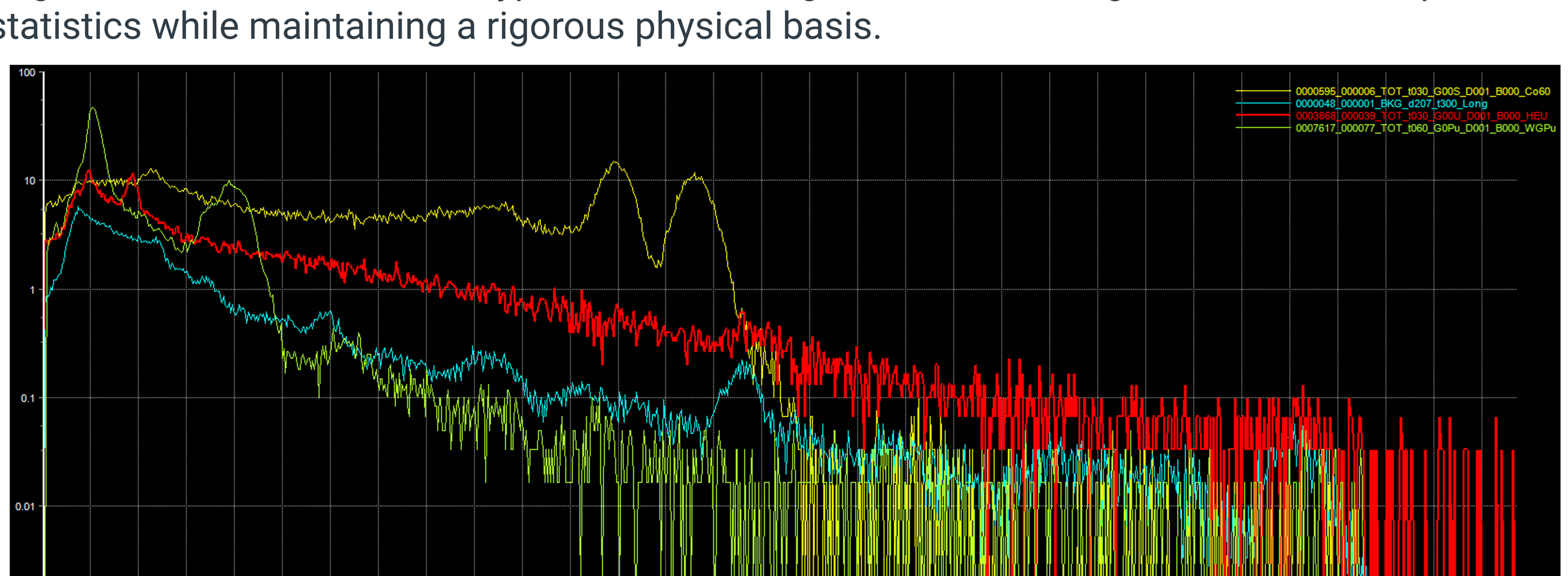

Figure 4 - A few spectra from the 3NID training dataset.

Performance That Matters

3NID demonstrates strong identification performance on both synthetic and measured-data-based benchmarks. For all detector families, reported synthetic-data F-scores are very high, and the embedded implementation remains closely aligned with the base model. Compared with the conventional identification algorithm used as benchmark, 3NID generally shows **better limits of identification** (lowest signal-to-noise ratio for which a radionuclide is consistently identified) and a **marked reduction in false positives**, especially in masking scenarios where several radionuclides are present simultaneously. This false-positive control is one of the most important practical benefits for field use.

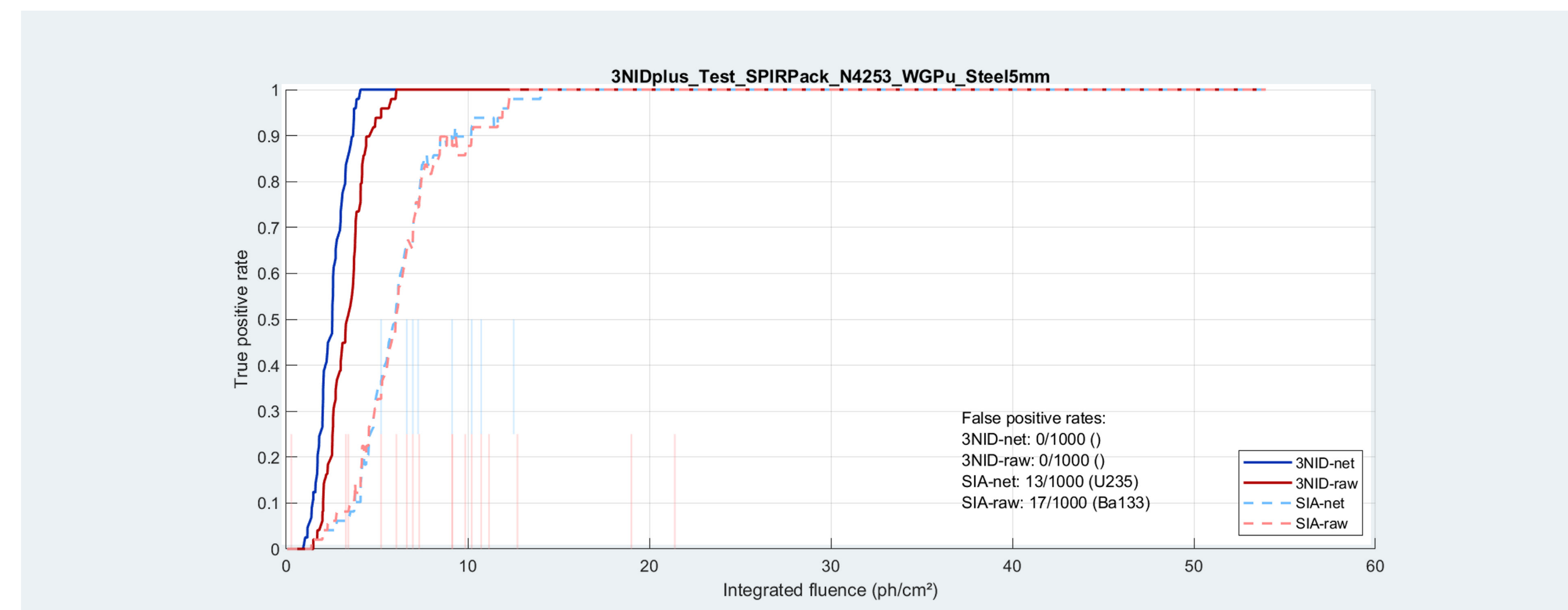

Figure 5 - True positive rate vs integrated fluence for WGPu with 5 mm steel shielding, SPIR-Pack (example graph).

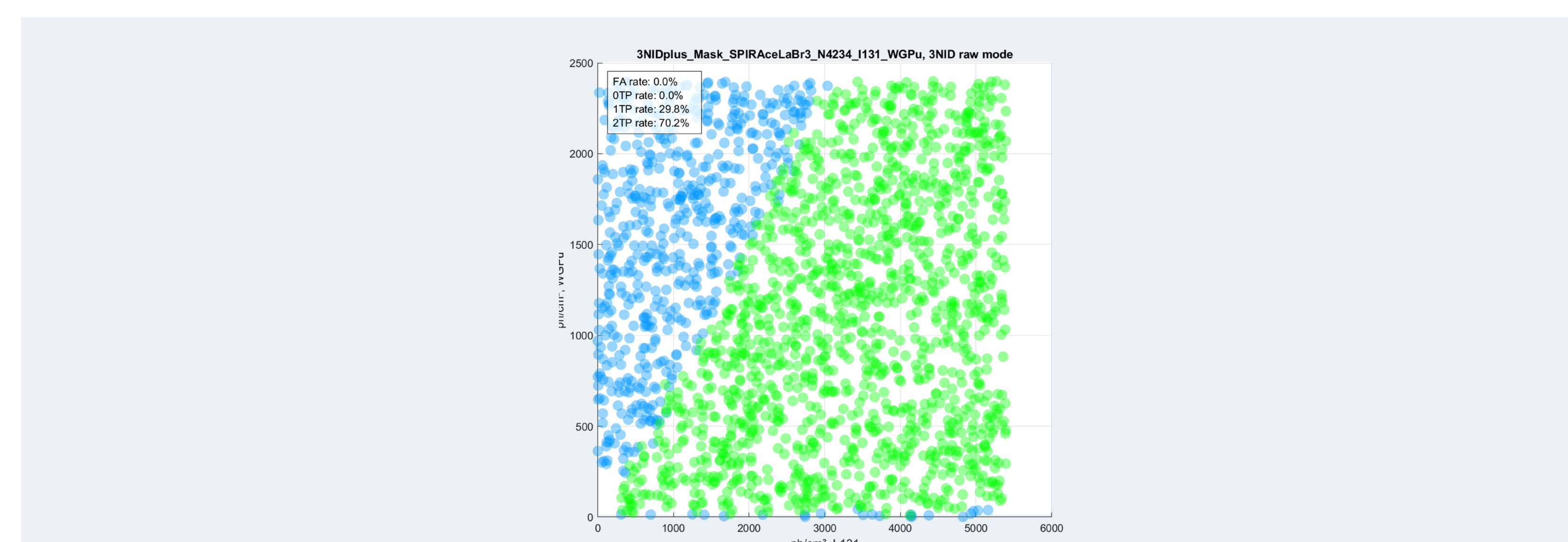

Figure 6 - WGPu + I-131 masking scenario results, SPIR-Ace LaBr3 (example graph).

From Desktop Software To Embedded Deployment

3NID is available in both desktop-compatible and embedded formats. The embedded implementation is optimized for low power microcontrollers with a model size of **304 kB** and an average execution time of **65 ms**, enabling real-time deployment on portable systems. This supports integration not only into desktop software environments, but also directly into low-power instruments where fast, onboard identification is required.

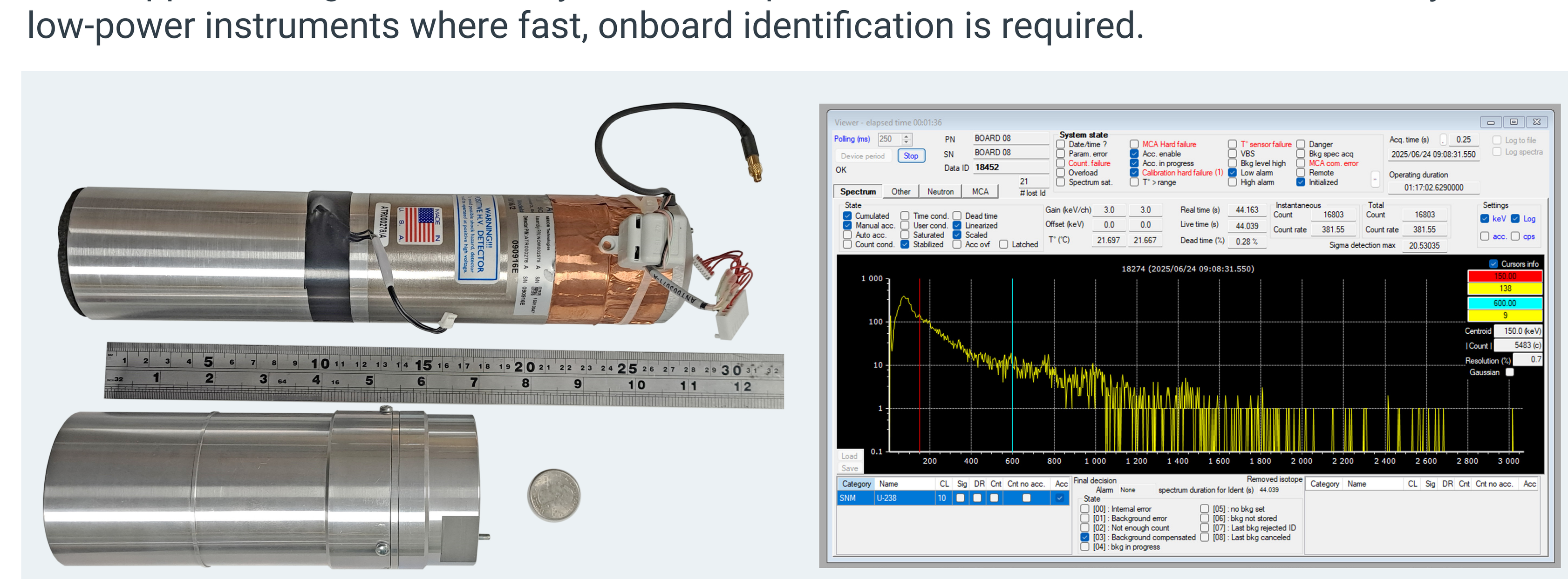

Figure 8 - Prototype and spectroscopy tool.

Extensive Laboratory Validation In Progress

3NID is currently under **extensive laboratory testing** in a dedicated campaign focused on identification performance. The test program includes both **static and dynamic measurements** with a broad range of **industrial sources, medical isotopes, and depleted uranium**, with a specific focus on realistic field identification conditions. This ongoing validation phase is a key step in consolidating the transition from simulation-driven development to robust laboratory confirmation under controlled test conditions.

Figure 7 - Lab testing.

Conclusions

3NID represents a major step toward the next generation of nuclide identification at Mirion. It combines a strong scientific foundation, broad detector applicability, high identification performance, and ongoing large-scale laboratory validation. Most importantly, it is designed to deliver direct operational value: **better identification confidence, better handling of complex spectra, and fewer false positives in real field conditions.**

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