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#6-251 Neutron/gamma discrimination with proportional counter using artificial intelligence

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The Micro-irradiation, Neutron Metrology and Dosimetry Laboratory (i.e. the LMDN) from IRSN Cadarache in France, is responsible for the national references in the field of neutron dosimetry. For this purpose, the LMDN produces reference neutron fields and has spectrometers to characterize them. Among these instruments is ROSPEC (ROtating SPECtrometer), a multidetector system comprising six spherical proportional counters designed for neutron detection and spectrometry across a wide energy range. Four of the counters, called SP2-1, SP2-4, SP2-10 and SP6, are designed to cover neutron energy ranges between 50 keV and 5 MeV. The fifth counter is a 3He-filled detector designed to detect thermal neutrons (E < 25 meV), while the final counter, 3He+10B, has a boron-coated inner surface for detecting neutrons between 1 eV and 10 keV. The proportional counters are sensitive to both neutrons and gamma rays. Neutrons are detected through elastic scattering with hydrogen atoms, which produces recoiling protons that ionize the gas and generating a signal. Gamma rays interact with the cathode of the detectors, producing electrons that also ionize the gas.
The main objective of this work is to improve the ROSPEC working by extending the energy range below 50 keV. To achieve this, it is necessary to discriminate between neutrons and gamma rays. This study concerns the SP2-1 counter which covers the energy range from 50 to 250 keV. A numerical acquisition is used by coupling the preamplifier of the SP2-1 counter with a digitizer. The digitizer records the set of detected signals. To detect low-energy signals (< 50 keV), we need to lower the detection threshold, which will consequently increase background signals.
Therefore, the first step is to eliminate noise from the data. One solution is to use an AI-based method called Convolutional Neural Network (CNN). To be efficient, the algorithm must be trained with simulated signals (sigmoïde functions for neutrons and photons, and mixture of different operations on normal distribution for background signals). The CNN method applied to the measured data has proven to be effective, as it provides reliable probability estimates. These estimates are essential for setting a discrimination threshold (X) to classify gamma and neutron signals separately from noise. Specifically, a signal classified as a neutron or gamma with a probability ≥ X% is accepted as such, while signals below this threshold are considered noise. The disadvantage of this method is the high demand for computing resources for neural network training. As well as the risk of overfitting should be considered.
After noise reduction, the second step is to determine the amplitudes and rise times of the remaining signals. The rise time gives an information about the particle type and the amplitude an information about the particle energy. A smoothing method based on the algorithm of SavitzkyGolay was used. Once this analysis has been carried out for all the pulses, a plot of rise time versus amplitude can be obtained. Two distinct groups theoretically appear: neutrons, which exhibit high amplitudes and short rise times (τ), and gamma rays, with low amplitudes and long rise time τ.
The final stage involves neutron/gamma discrimination. One way is to use a machine learning method called clustering. Several algorithms exist as DBSCAN, OPTICS or KMEANS. The challenge is to apply the right algorithm by choosing the right input parameters.
The first two steps in signal processing, noise reduction and determining amplitude and rise time, produce consistent results. The final step which is neutron/gamma discrimination using clustering method is in progress. If successful noise filtering and clustering are achieved, only neutron pulses should remain, enabling the creation of a 1D histogram that represents the neutron distribution by channel, which can then be compared to MCNP (Monte-Carlo N-Particles) simulation results for validation.

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