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Improving Two-Neutron Detection Efficiency on the NEBULA Detector using XGBoost Algorithm

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In the field of nuclear physics, multi-neutron detection plays a critical role in revealing specific nuclear properties(e.g. the structure of light exotic nuclei or four-neutron resonance states). However, one neutron can interact several times in different bars of neutron detector array, since it will likely pass through the detectors without losing all its energy. The phenomenon commonly called CrossTalk. Effectively distinguishing CrossTalk from real two-neutron events poses an important challenge becomes an essential problem to address. The conventional approach for eliminating CrossTalk events has been well established in previous work[1, 2], which relies on the physical relations between signal pairs in detectors, such as distance of time and space, causality condition and light output. However, many real two-neutron events will be eliminated at the same time, which results in a significant decrease in neutron detection efficiency, particularly in smaller relative energy range.
In this study, we will illustrate the application of the XGBoost algorithm based on ensemble learning and tree models to remove the CrossTalk events, using the experimental and simulation data on ^{11}Li (p,pn)^{8}Li+2n of the SAMURAI18 experiment at the RIKEN. XGBoost method not only enhances the efficiency of two-neutron detection but also exhibits superior interpretability compared to deep learning. Furthermore, it is well-suited for handling structured data without necessary normalization for feature inputs. The potential application of this method in the future extends to increasing the detection efficiency of multiple neutrons (triple neutrons, quadruple neutrons, etc.) or to address diverse particle identification tasks.

[1]T. Nakamura, Y. Kondo., Nucl. Instrum. Methods Phys. Res., Sect. B 376, 156 (2016) https://doi.org/10.1016/j.nimb.2016.01.003
[2] Y. Kondo, T. Tomai, and T. Nakamura, Nucl. Instrum. Methods Phys.Res., Sect. B 376, 156 (2016) https://doi.org/10.1016/j.nimb.2019.05.068

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