Improving Particle Classification in WIMP Dark Matter Detection Experiments Using Neural Networks

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Weakly Interacting Massive Particles (WIMPs) are a hypothesized model of dark matter. Many experiments intended to directly observe WIMPs are being developed; if successful, they would contribute greatly to our understanding of the universe. In all such experiments, it is essential to develop a classifier that can distinguish potential WIMP events from background radiation. Most often, classifiers are developed manually, via physical modeling and empirical optimization; however, these approaches take extensive time and effort, and the resulting classifiers often perform suboptimally. Machine learning (ML) is a promising but non-trivial solution. In this research, two major challenges for ML and conventional classifiers have been identified and successfully addressed: impure calibration data, and chaotic physical dynamics within the detector. Approaching the former challenge, I used semi-supervised learning, which is used primarily for incompletely labeled data; I hypothesized it would apply to complete but impure data, and developed two novel algorithms for this purpose. Data from the PICO-60 bubble chamber was used for training and evaluation. I observed 98.3% classification accuracy, while the previous best ML method reached 80.2%. To solve the latter challenge using simulated data from the DEAP-3600 scintillation detector, perceptrons were unsuccessfully tested; I thus hypothesized spatial data in spherical images must be taken advantage of. I developed two 3D adaptations of convolutional neural networks. Compared to the best conventional classifier, the rate of successful identification of WIMP events was increased by 170%; real-world data was used for verification. Both of these results have the potential to enable considerably more efficient collection of conclusive observations.

Awards Won:

Second Award of $1,500

National Security Agency Research Directorate : Honorable Mention Mathematics

China Association for Science and Technology (CAST): Award of $1,200