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Application of the RNN in the fundamental physics with KamLAND experiment

Shingo Hayashida
Tohoku University, Japan

The development of the machine learning in recent years has begun to profit the elemental physics research. In the neutrino detector KamLAND getting to unravel the mysteries of the universe, discriminating gamma-ray that inhibits the signal has been ultimate task. This research made it possible by using recurrent neural networks (RNN).

Neutrinos are a kind of elementary particles, and their masses are hardly understood except that they are extremely light. As one of the mysteries of neutrinos, there is the possibility that the particle and anti-particle are the same property (Majorana). It is possible for only neutrinos to have this property, which is a clue to unravel the mass of neutrinos and mystery of matter dominant universe. Majorana property is verified by detecting characteristic energy peak of the neutrinoless double beta decay (0νββ) of nuclei. A experiment to realize this is KamLAND-Zen in Japan. KamLAND-Zen measures radiation energy by detecting liquid scintillation light with optical sensors.

Although 0νββ decay has not been found yet in KamLAND-Zen, it has the lower limit of 0νββ half-life (1.07×1026 yr, 90% C.L.), which represents the difficulty of 0νββ decay. In the measurement, the 10C decay background event has the same energy as 0νββ, which hinders the observation. The identification of 10C decay is important to discovery 0νββ signal.

Methods and Materials : For 0νββ decay, 10C decay includes γ-rays which has a spread in time, and it is reflected in the scintillation waveform In addition to this, ~50% of 10C decay have ortho-positronium (oPs) which half-life is ~2.9 ns in LS .In this research, 10C decay is identified by discriminating the scintillation waveform difference using "Recurrent Neural Networks (RNN)". * ~50% of 10C decay have para-positronium (pPs) which half-life is short.

Results: The conditions of 10C identification is decided from classifier output distributions. It shows that each event type has a different distribution. If ββ inefficiency ~20% is allowed, 10C decay events are able to be rejected with ~55% efficiency. In this evaluation, MC samples are used. Since Efficiency/Inefficiency are evaluated by MC, support by Data is necessary. 60Co source calibration Data (γ-ray) is useful for evaluation. In comparison of MC and Data, distribution of classifier output and rejection efficiency are in good consistency. Efficiency/Inefficiency calculated by MC have enough confidence.

The neutrino detector "KamLAND" aims to unravel the mysteries of the universe. Reduction of 10C decay background is indispensable for verifying the Majorana property of neutrinos. To identify 10C decay events, discriminating the scintillation waveform difference by using RNN. In this research, 2-layers stacked LSTM was developed. And then it is able to reject ~55% of 10C decay events with ββ inefficiency ~20% is allowed. From the evaluation by using 60Co source calibration data, this efficiency/inefficiency have enough confidence. This research realizes the improvement of the sensitivity to discover 0νββ signals.

RNN processes the time valuation of data. It is thought that RNN which developed in this research classified the event type based on the spread of scintillation waveform. As its basis, 10C-oPs with larger scintillation spread are lower in ββ classification output than 10C-pPs in.