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Machine learning applications in PMT waveform analysis

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In high energy physics experiments, the scintillating materials or the Cherenkov radiators are widely used which emit light pulses at certain wavelength when interacting with the incident particle. The information carried by the light pulse reflects the characteristics of the incident particle. Since the light directly emitted is always weak (restricted by the light yield of the medium), the photomultiplier tube (PMT) is used to realize the photoelectric conversion and the electron multiplication so that the signal output by the PMT can be discriminated by the back-end data acquisition system. The time to digital convertor (TDC) and charge to digital convertor (QDC) are two kinds of waveform analysis plug-in which can record the time and charge information of the input waveform. In recent years, the development of the fast analog-to-digital converters (FADC) which can record the whole waveform makes it possible to offline analyze the information carried by the waveform with different methods and obtain more information.

Pulse shape discrimination is a waveform-based method to discriminate between different kinds radiations. For the potassium cryolite crystals, the main difference between the gamma and neutron pulses is the presence of fast components on the falling edge with different time constants, which leads to the difference of the shape of gamma and neutron pulses. The traditional used PSD method here is the charge comparison method whose performance strongly depends on the energy range of the incident particle. Inspired from literatures, a model based on convolutional neural network (CNN) was developed and the accuracy of the n/γ discrimination for single-particle waveform for both CLYC crystal and CLLB crystal can reach 99%.

Besides the energy information carried by the pulse, the time information is also important when reconstructing the particle trajectory especially in the application of time-of-flight detectors. The traditionally used timing methods, including the leading edge discrimination (LED) and the constant fraction discrimination (CFD), are easily realized in the circuit but obviously the time information of the pulse has not been precisely obtained since only a part of the points are used in the waveform. Former studies have shown that the CNN-based model can improve the timing performance of the paired PMTs by nearly 20%. But the methods show a bios of regression since the number of labels are limited. Therefore, we developed a new method to train a CNN model for the timing of the paired PMTs. Instead of using real waveforms with different distances to the radiative source, only a group of waveforms are obtained with fixed distance to the radiative source. The paired waveforms input with different labels are produced by delaying or advancing the time of one waveform. The results show a 50% improvement with the CFD method at 50% threshold. The validations process is still going on to prove the model is well-trained for the real paired waveforms with different distances to the radiative source.

In-person participation

No

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