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Improving Timing Resolution of BGO with and without Deep Learning

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The renewed interest on BGO scintillators for TOF-PET is driven by the improved Cherenkov photon detection with new blue-sensitive SiPMs. However, its slower scintillation light causes time walk, degrading coincidence time resolution (CTR) measured with leading edge discrimination (LED). To address this, a time walk correction (TWC) can be done by using the rise time measured with a second threshold. Deep learning, particularly convolutional neural networks (CNNs), can also enhance CTR by training with digitized waveforms. It remains to be explored how timing estimation methods, utilizing one, two, or multiple waveform data points, compare in the quest for superior CTR. In this work, we compare classical timing estimation methods (LED, TWC) with a CNN-based method using BGO crystals read out by NUV-HD-MT SiPMs and high-frequency electronics. For 2x2x3 mm^3 crystals, employing TWC results in a CTR FWHM of 129 ± 2 ps, while the CNN yields 115 ± 2 ps, marking an improvement of 18% and 26% compared to LED, respectively. For 2x2x20 mm^3 crystals, both methods yield similar CTR (around 240 ps FWHM), offering a ~15% gain over LED. The CNN, however, exhibits better tail suppression in the coincidence time distribution. The higher complexity of waveform digitization needed for CNNs could potentially be mitigated by adopting a simpler two-threshold approach, which appears to capture most of the essential information for improving CTR in longer BGO crystals.

Field

Detectors and electronics

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