Time of Flight in PET Using Fast Timing and Leading Edge Fit Optimization

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Abstract

In a traditional PET detector, the back-to-back photons produced by a positron annihilation are detected at two locations on the detector ring. The annihilation event can only be localized to the line connecting the two hit locations. With high resolution time-of-flight detectors, however, the annihilation can be further localized to a small segment on that line, improving the image resolution.

We have developed methods for extracting time-of-flight information from data acquired from a test setup comprised of two PET detectors and a ^{22}Na source placed at the center. Each detector consists of a $6.25\times6.25\times25\ mm^3$ LSO crystal wrapped in Teflon, positioned with one of the $6.25\times25\ mm^2$ rectangular faces lying flat against an R-9800 Hamamatsu photomultiplier, and the photons entering through the square face[1]. Libraries of pulse pairs were acquired using a 40 GS/sec Tektronix oscilloscope and also using a two-channel BLAB1, a fast-sampling analog chip which samples at up to 6 GS/sec[2]. Our time extraction methods involve fitting the leading edge of the pulse to a template function under the transformations of a time shift, a time scale (about a point defined in the template), and a voltage scale. We calculate the r.m.s. deviation in the time difference between the two input channels over a large library of representative pulse pairs. Then, we use an optimization algorithm to generate a near-optimal template shape. We have found the optimization process to be successful: it significantly improves the timing resolution of the template fit. The resulting template-fit method performs better than other common methods such as linear fitting, and the result is repeatable on pulse pairs not contained in the original library. We have attained time resolutions better than 290 p.s. FWHM on the two-channel difference, or approximately 87 p.s. sigma per channel.

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2. Developed at the University of Hawaii Instrument Development Laboratory. We thank Gary Varner and his group for providing these boards and help.