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Adaptive Intra-Block Time Alignment Firmware for a Time-Of-Flight Positron Emission Tomography Camera

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SUMMARY

Individual sensor channels within a single detection block of a TOF PET camera are successfully aligned in time to within 60ps by use of predominant scatter and absorption type events. The calibration method is local to each detection block and needs no coincidence events in the full-ring sense. The fully systolic approach is well suited for gate array implementation.

Each read-out block of a present-day design high-resolution Positron Emission Tomography medical diagnostic camera consists of a bundle of LYSO rods, optically coupled to individual solid-state photomultipliers, read-out by highly integrated high-bandwidth transimpedance preamplifiers.

Due to the complexity of this read-out chain, individual detection channels come misaligned in time by up to several hundred nanoseconds. Furthermore, these differences in time calibration tend to drift on the characteristic scale of several minutes of operation.

The physical nature of gamma-ray detection favors in small detection blocks an event geometry where a single Compton scattering in a given scintillation rod is followed by a photoelectric absorption in another rod of the same block, typically up to 150ps later (See Fig. 1). This makes for a convenient block-relative time reference that remains available at all times throughout the normal operation of a camera.

An array of 64 time-adjust registers is prepared and zeroed. Of all detected event clusters in a detection block (clustering any group of detection hits that occurred within 2ns), all double hit clusters are considered for time calibration. Hits of each cluster are assumed to be precisely simultaneous in time and the corresponding two registers are always modified according to weighted measured time difference between the two hits, while maintaining zero mean over all 64 registers.

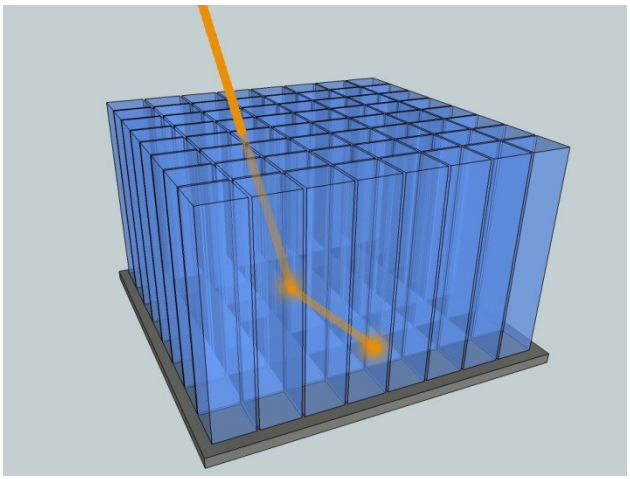

Fig. 1: Inelastic scattering of a gamma photon, followed by photoelectric absorption, serves as a precise relative temporal marker for any pair of 64 readout channels in a TOF PET detection block.

Geometrically decreasing update weights guarantee fast convergence upon power-up, while a small but finite system dynamics noise constant keeps the system slightly adaptive in order to keep following long-scale systemic drifts. Bias due to the ignored time difference between detection hits averages out to less than 25ps of systematic error.

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