Development of Time-over-Threshold readout system used in 1.36mm PET detector

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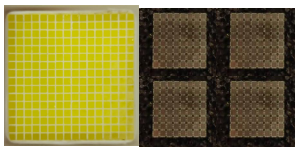
It is commonly recognized that Positron Emission Tomography (PET) has been developed and commercially used for a long time. To achieve a high spatial resolution and sensitivity, researchers many efforts has been made. In this study,to make a higher spatial resolution, we made the effort with small size of GAGG crystal and SiPM (Fig.1(a)). For higher sensitivity, we developed a (Time-over-Threshold) ToT individual readout system. And the signal and control flow in the experiment set up are shown in Fig.1(b). We have developed and used 64 channel ASIC to deal with the pulse signal from the detector. The ASIC circuit including the buffer, signal devider, the pre-amplifier and slew-rate shaping amplifier and discriminators to covert signals to ToTs with fast timing and good energy resolution. In ASIC control, adjusting of 7 IBais makes make the ASIC work in stable status because different position of GAGG crystal and different SiPM would influence the working voltage. Then the threshold and baseline of ToT signal are optimized. (To change the current pulse signal generated by detector to time width, which could simplified spatial resolution calculation through TOF and system complexity, meaning we could get high quality imaging in a relative short time.) The typical ToT principle is shown in Fig.2. With same Vth, the longer the time width, the higher the pulse height. With this principle, we could distinguish different energy. In addition to the simplicity, we developed slew rate limited ASIC to make the response approximately linear. Therefore, the ToT signal has different resolution with different energy. In data acquisition FPGA based timing measurement device PETnet[1] (resolution up to 62.5ps) have developed, which is used to attach the time stamp for every single counting. It counts T_width and TOF, then send the information to PC as Fig.3 shows, which could be used for locating the source. T0 is used to synchronize multiple modules and correct the timestamp.



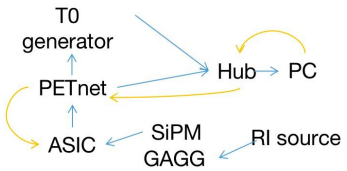


Fig.1. (a) GAGG with 4 SiPM array **(b)** Experimental Setup (Blue: detection signal; Yellow: control signal)

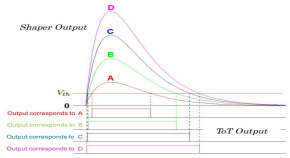


Fig.2 ToT signal principle

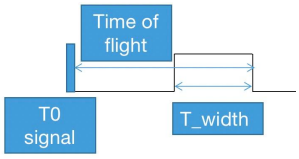


Fig. 3 Relationship of TOF & ToT data

Keyword: PET imaging, GAGG SiPM Array, ToT Readout, Spatial Resolution, Energy Resolution.

[1] Sato, Setsuo, Mizuki Uenomachi, and Kenji Shimazoe. "Development of multichannel high time resolution data acquisition system for TOT-ASIC." IEEE Transactions on Nuclear Science 68.8 (2021): 1801-1806.