Time-of-Flight Compton Imaging System

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Abstract:

We propose the use of coincidence events resulting from cascade decay of certain radioactive nuclides to increase the spatial resolution of a 3-D Compton imaging system. The Time-of-flight (TOF) technique is applied to ensure a good image quality on the third direction. Geant4 simulation is performed to evaluate the design. The result shows that the TOF technique can greatly improve the image quality. Experiments have shown a coincidence resolving time (CRT) of 300~400 ps in FWHM, which proves the feasibility of the system in practice.

Keywords: Compton Imaging, Time-of-Flight, Simulation, Coincidence Resolving Time

1. Introduction

Compton imaging has been widely used in many areas in which locating source of photons is needed. The angular resolution of Compton imaging system has become a major drawback. We propose the use of coincidence events, which comes from cascade decay of certain radioactive nuclide, to increase the spatial resolution. These nuclides have a meta-stable state with short half-life after the first decay. One candidate nuclide is K-43. It would consecutively emit a 617-keV photon and a 372-keV, with a half-life of the meta-stable state of 49 ps. The use of coincidence events would greatly increase image quality.

The coincidence method would have a degradation when used in 3-D image reconstruction, due to the additional dimension. We propose to apply the time-of-flight (TOF) technique to solve this problem. In commercial TOF-PET systems, the timing resolution of TOF measurement could be as good as 300 ps using fast scintillators with SiPM readout. To verify the capability of TOF-based 3-D Compton imaging, we build a system using Geant4 toolkit.

2. Simulation Setup and result

A system consisting of two opposite Compton cameras is built. The timing resolution is set to be 400 ps. Considering the speed of light, the distance between the two cameras is 30 cm. As shown in figure 1, after applying the TOF technique, the distribution of probable source location (in the reconstructed image) is better constrained, in the depth dimension.

Fig 1. Reconstructed image without (left) and with (right) the TOF technique

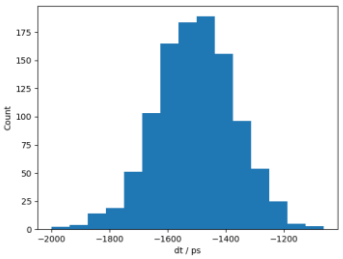

Fig. 2 CRT histogram

3. CRT measurement

Experiments have been done on the data acquisition system to test the timing capability. The time spectrum shows a coincidence resolving time (CRT) of 300~400 FWHM, as in Figure 2. This shows that the practical system has the potential to be used in a TOF system.

References

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