Study on Time-of-Flight Compton Imaging System for Environmental Monitoring

* Agus Nurrachman[1], Zhong Zhihong[1], Donghwan Kim[1] , Kenji Shimazoe[1], Hiroyuki Takahashi[1], Takuya Kishimoto[1], Hiroki Kogami[1], Atsushi Mukai[2], Shintaro Hara[2], Keita Yamagishi[2], Hideki Tomita[2], Hidetake Ebi[2], Yusuke Tamura[3], Hanwool Woo[3], Kei Kamada[3], Fumihiko Ishida[4], Eiji Takada[4], Hajime Asama[4], Jun Kawarabayashi[5], Kosuke Tanabe[6], Kenichi Tsuchiya[6], Mizuki Uenomachi[7]

[1]The University of Tokyo., [2]Nagoya University., [3]Tohoku University., [4]National Institute of Technology, Toyama College., [5]Tokyo City University., [6] National Research Institute of Police Science, [7]RIKEN

Abstract

A Compton camera with high time resolution (GRASP Gamma-RAy SPhere) is under construction for the 4-pi gamma-ray imaging. We have adapted GFAG crystal readout by MPPC for detectors. The purpose of this work is to demonstrate the time of flight (TOF) method for image reconstruction created by the Compton camera. TOF in Compton camera is used for getting information of the event order in the detectors. By knowing the first interaction event in the detector, we can identify the correct position of the incoming radiation source.

Keywords: Gamma-ray imaging, Compton Imaging, GFAG Crystal, TOF

Introduction and Method

The time of flight (TOF) method has received attention in radiation measurement, especially for 3D imaging. TOF mostly used in positron emission tomography (PET) to improve the image quality[1]. From the study TOF on PET system can improve the time coincident resolution, lower noise and higher contras recovery (high signal to noise ratio). Currently, we are developing a sphere Compton imaging system for 4pi field of view gamma camera. The system will apply TOF to improve the image reconstruction process. By knowing the order of interaction in the sphere shape detector, we can localize the direction of the source with lower background.

In this paper, we develop a Compton detector and did an examination of the time resolution and feasibility of time of flight (TOF) measurement for improving the image reconstruction. We have adapted gadolinium fine aluminum gallate (Ce:GFAG) crystal readout by multi-pixel photon counter (MPPC) from Hamamatsu Photonic. We used 8×8 Ce:GFAG crystal arrays and the individual crystal elements were $2.5 \times 2.5 \times 5$ mm^3. This scintillator coupled with 8×8 MPPC arrays. The MPPC has an effective photosensitive area of 3×3 mm^2. To read the signal from the detector, we have developed an application-specific integrated circuit (ASIC) for reading 64 channels. Each channel in the ASIC has an amplifier, slew-rate limited shaper, comparator, and time over threshold (TOT). The high time resolution data acquisition circuit (PETnet) based on FPGA is used to acquire energy and time data from ASIC.

Conclusion

We have measured the time resolution on our system. The measurement results show that our system has a 1.8 ns (FWHM) time resolution. After calibration channel to channel, the time resolution improves to 345ps (FWHM). The time resolution measurement is important to determine the ability of our system to differentiate interaction in the Compton detector. By the information of time resolution, we can apply the time of flight (TOF) for our detector. Simulation on time of flight using Geant4 has been done.

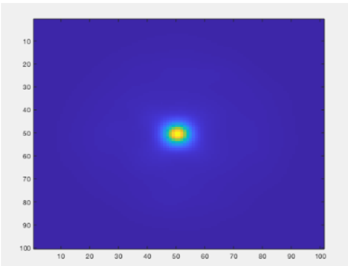

Figure. 1. Iteration 5, energy selection in scatter 10 keV-100 keV

In the simulation we set two 64-pixel GFAG with size of $30 \times 30 \times 5$ mm^3 . Distance between scatterer and absorber is 8 cm distance between scatterer and absorber. It is fired with 50×10^6 beam of 662 keV energy. Fig. 1 shown the image reconstruction from Geant4 simulation. The energy selected in scatterer are 10 keV to 100 keV. The image reconstruction method is Maximum-Likelihood Expectation-Maximization (MLEM). After 5 iteration, The spatial resolution we can get is 7,4 mm FWHM.

Reference

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