PET image background reduction of prompt γ emitting ^{86}Y through quantum entanglement property of annihilation γ rays

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PET data correction for random and prompt gamma events has been based on estimation from acquired data. A previous study showed a different approach to PET data correction utilized the quantum entanglement of annihilation γ ray.[1] The two γ ray state is represented in orthogonal polarization as

$$|\psi\rangle = |x\rangle_1|y\rangle_2 + |y\rangle_1|x\rangle_2$$

where subscripts 1 and 2 indicate two different γ rays traveling in approximately opposite directions. Owing to the entangled state expressed by the above equation, the double Compton scattering (DCS) cross-section represents the probability that both γ rays are Compton scattered and its preferred azimuthal scattering angle difference, $\Delta\phi = \phi_1 - \phi_2$. The magnitude of modulation becomes maximum when the polar scattering angle of both γ rays is $\theta_1 = \theta_2 = 81.7°$. Figure 1 shows the dependence on $\Delta\phi$ on the magnitude of DCS.

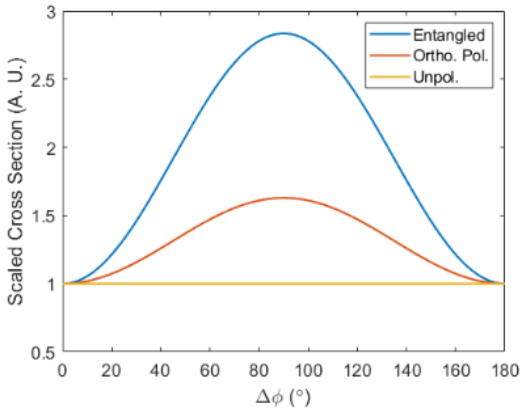

Fig. 1. $\Delta\phi$ dependence on DCS compared with orthogonal polarization and unpolarized cases.

Extracting data at approximately $\Delta\phi = 90°$ will increase the true fraction in the acquired data. If the γ rays are from different annihilation events, the two γ rays have no correlations; therefore, the resulting $\Delta\phi$ distribution will be similar to the unpolarized case.

In addition to random events, prompt γ rays can be reduced. If two γ rays leave traces of Compton scattering and absorption in each block of detectors and one or both of them are prompt γ rays, we also expect that no $\Delta\phi$ dependency and the distribution would be flat.

Expecting that this method can reduce background caused by prompt γ rays similar to the high random rate case, an experiment with ^{86}Y, which emits many prompt γ rays with the energy of 628, 443 keV, *etc.*

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The activity of ^{86}Y was 10 MBq. HR:GAGG was used as a scintillation detector. The pulse height information was processed through the dynamic time over threshold (dTOT) method.[2]

Figure 2 shows the energy spectrum obtained from the experiment.

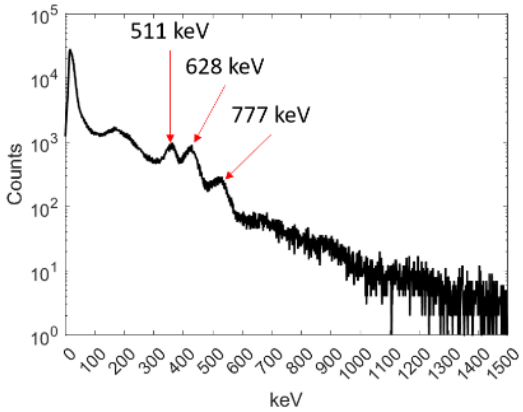

Fig. 2. Energy spectrum and observed peak positions.

The energy spectrum shows that the peak was shifted toward the lower energy. This indicates that the activity was excessively high for the system to measure energy correctly. This phenomenon is expected to occur if two consecutive events occur before the threshold returns to the baseline, requiring approximately 10 μs.

For PET image reconstruction, the data was obtained with the energy window 300 keV $< E$. Figure 3 shows the reconstructed image.

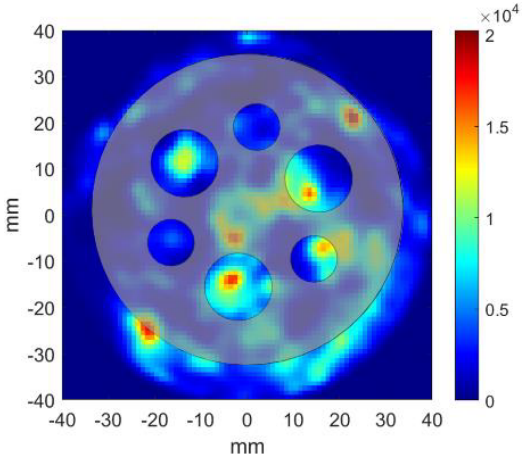

Fig. 3. Reconstructed PET image with phantom structure overlayed. The holes in the phantom structure are hot areas and others are cold areas.

The image shows an extensive background; therefore, the original structure was not reconstructed well.

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After this interim report, the energy spectrum will be corrected, or an additional experiment with low activity will be conducted to observe the effect of QEPET on background reduction.

References
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2) K. Shimazoe *et al.*, IEEE Trans. Nucl. Sci. **59**, 3213 (2012).