Research on imaging based on cascade gamma-ray photons and magnetic fields

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Abstract:

The Perturbation Angular Correlation of radioactive nuclides with cascade gamma decay in magnetic field is studied. For instance, In-111 would undergo a cascade decay before turning to the stable Cd-109, emitting two gamma photons consecutively. The angle between these two correlated photons is affected by the electro-magnetic field of the nucleus. In our experiment, the In-111 sample is placed inside the magnetic field with maximum strength of 2.5 T. By measuring the angle distribution and compute its time dependency, we clearly observe its relationship with respect to magnetic field, which results from the nucleus's perturbation in the field. With this being determined, we can use this principle for nuclear imaging in a magnetic field.

Keywords: cascade decay, perturbed angular correlation, magnetic field

1. Introduction

The perturbed angular correlation (PAC) of cascade gamma ray has long been used in areas such as investigation of crystal structure, since it could be used to reveal the local electro-magnetic environment of the probe radioactive nucleus. In the cascade decay of nuclides such as In-111, the two gamma photons are correlated and the angle between them has a distribution that also changes over time. This is time-differential PAC (TDPAC)

We propose the use of PAC of such nuclides in magnetic field as a way of imaging. For TDPAC, in practice we measure the angular distribution at 90 degrees and 180 degrees. By changing the strength of magnetic field, we can measure the frequency of change in TDPAC, which in return could be used as an indicator of magnetic field.

2. Experiment and result

We use arrays of pixelized GAGG detector and MPPC for gamma ray detection. The signal from MPPC is process by dynamic time-over-threshold (dToT) circuit and collected by DAQ system. We used 8 arrays to form a ring around the magnet pole, each with 8×8 pixel, which is $3.2 \times 3.2 \times mm^3$ in size. The layout is shown in figure 1.

The results are shown in figure 2 and figure 3. In this measurement, we calculate the value $R(t)$, as defined in equation 1, and observe its change over time. Figure 2 shows the R(t) at 1T and figure 3 at 2T. The frequency of oscillation at the first 400 ns (that is, 5 times of In-111's half-life of the meta-stable state) also shows a ratio of two at these two magnetic field strengths.

$$R(t) = 2\frac{N(180°,t) - N(90°,t)}{N(180°,t) + 2N(90°,t)} \qquad \text{Eq.(1)}$$

Fig. 1 Layout of arrays

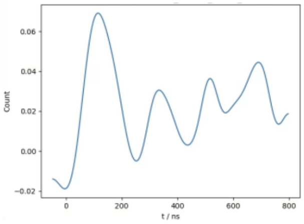

Fig. 2 R(t) at 1T

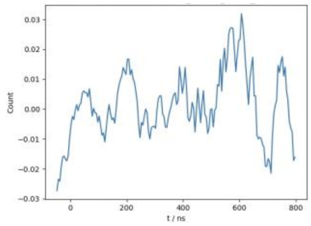

Fig. 3 R(t) at 2T

References

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