First measurement of double Gamow-Teller giant resonance at RIBF

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The double Gamow-Teller (DGT) transition is a nuclear process characterized by a $(\sigma\tau)^2$ operator in which both the spin and isospin change twice. Experimental information about the DGT transition is currently limited to data of double β decays, whose transition strength accounts for only a small proportion of the entire transition strength of the DGT transition. The remainder of the strength is expected to form a giant resonance in a high-excitation energy region. This resonance, called the DGT giant resonance (DGTGR), was proposed in 1989[1] and is still undiscovered experimentally. The aim of this research was to observe the evidence of the DGTGR for the first time, thereby extending the study on two-phonon excitations to a regime in which the spin-degrees of freedom contribute. Although knowledge of the anharmonicity of the nuclear response in such a domain is scarce, observables of the DGTGR, such as the centroid energy or the width, might provide its information.

Experimental information of the DGTGR is also potentially important for determining the nature of neutrinos. The transition strength and centroid energy of the DGTGR are suggested to be strongly correlated with the nuclear matrix element of a neutrinoless double β decay.[2] Theoretically predicted values of the nuclear matrix element have a large uncertainty depending on the chosen model.[3] Experimental information of the DGTGR will provide reference for the calculation of the nuclear matrix element.

In this study, the DGTGR was observed by missing mass spectroscopy using a double-charge exchange reaction (^{12}C, ^{12}Be(0_2^+)). We utilized an isomeric decay of ^{12}Be(0_2^+), for event selection. ^{12}Be(0_2^+) has a lifetime of 331 $\pm$ 12 ns and decays into the ground state by emitting an electron-positron pair.[4] Detecting back-to-back photons with an individual energy of 511 keV from the positron served to tag the events of the double spin-flip mode.

In May 2021, we performed the first measurement of the (^{12}C, ^{12}Be(0_2^+)) reaction at the RI Beam Factory (RIBF). A ^{12}C primary beam with an intensity of 500 particle nA was accelerated to 250 MeV/nucleon and impinged on a target at F0 focal plane of the BigRIPS separator. We used ^{48}Ca or ^{116}Cd as the target, which are important double β decaying nuclei. The thickness of the target was 10 mg/cm^2 for ^{48}Ca and 50 mg/cm^2 for ^{116}Cd. The ^{48}Ca target was sandwiched between 4-micrometer-thick graphene sheets for preventing oxidation and nitridization when installing in the F0 vacuum chamber. Momentum spread of the primary beam was suppressed by dispersion-matching optics. The momentum of the ejected particle was measured by using F0-F5 as a spectrometer, as established in pionic atoms experiments.[5] After passing through the tracking detectors of low-pressure multiwire drift chambers (MWDCs) at F5 focal plane, a particle was transferred to F8 focal plane and stopped in a ^{9}Be stopper with a thickness of 18.8 mm.

Delayed γ rays were detected by a DALI2 array at F8. During the beam time, we measured the double-charge exchange reaction for 40 hours for ^{48}Ca and 20 hours for ^{116}Cd, respectively. The left panel of Fig. 1 shows the energy spectrum of the photons measured by DALI2 for the ^{48}Ca target. A peak at the energy of 511 keV is noticeable in the spectrum. The right panel of Fig. 1 shows the timing of the photon detection relative to the signal from a plastic scintillator at F7. Here, the timing distribution of the events in the energy region of 500 $\pm$ 100 keV is also shown. The decay histogram is fitted by an exponential curve and a constant background. The decay constant is 302.3 $\pm$ 8.2 ns, which is close to the known value of the lifetime of ^{12}Be(0_2^+). This suggests that ^{12}Be(0_2^+) is successfully detected.

The analysis is ongoing. The excitation energy spectrum of ^{48}Ti will be obtained from the position measured by the MWDCs at F5. Currently, we are analyzing the MWDCs at F5.

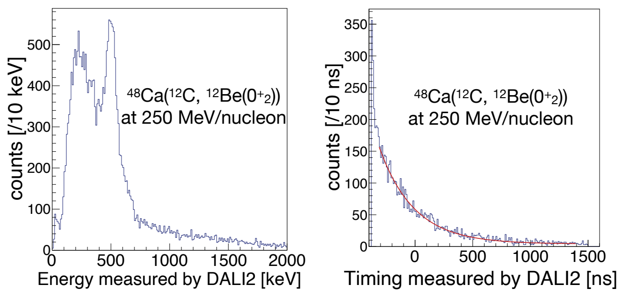

Fig. 1. (Left) Energy distribution of delayed γ rays measured by DALI2. (Right) Timing distribution of delayed γ rays for events in energy region of 500 $\pm$ 100 keV. Red curve is fitting result.

References

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