Search for the double Gamow-Teller giant resonance using double charge exchange reaction

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The double Gamow-Teller (DGT) transition is the nuclear process where the spin and isospin are changed twice by a $(\sigma\tau)^2$ operator, where σ and τ are the spin and isospin operators, respectively. It is theoretically predicted that there is a giant resonance which occupies most of the whole DGT transition strength in a high-excitation energy region.[1)] This resonance, called the DGT giant resonance (DGTGR), remains undiscovered experimentally. The observable of the DGTGR such as the strength or the width will provide information about the two-phonon excitations with spin-dependent correlations. In addition, it is suggested that such observables will give a constraint to the nuclear matrix element of neutrinoless double β decay, which has a large ambiguity in the current theoretical calculation.[2)]

We observe DGTGR using the double charge exchange reaction (^{12}C, ^{12}Be(0_2^+)) at RIBF. We employ an experimental method developed in the pionic atoms spectroscopy[3)] using a part of BigRIPS, from the F0 focal plane to the F5 focal plane, as a spectrometer. A reaction target at F0 is bombarded with the primary beam of ^{12}C and the (^{12}C, ^{12}Be(0_2^+)) reaction is induced. The momentum of the ejected particle is obtained by measuring the position at F5 and thus the excitation energy of the residual nucleus of F0 is deduced. To select events with spin-flip mode, ^{12}Be is transported to the stopper of ^{9}Be at F8 and delayed γ rays deriving from ^{12}Be(0_2^+) are detected by DALI2; ^{12}Be(0_2^+) decays into the ground state by emitting an electron-positron pair with the lifetime of 331 ± 12 ns.[4)]

We successfully detected the delayed-γ rays from ^{12}Be(0_2^+) for the ^{48}Ca target at F0 in the experiment conducted at RIBF in May 2021 using this method for the first time.[5)] The signal-to-background ratio is estimated to approximately $5:1$ for the events with photons of 500 ± 100 keV detected in DALI2. It is improved from the one of the pilot experiment performed at RCNP, approximately $1:1$.[6)]

The preliminary spectrum of the position at F5 for the measurement of the ^{48}Ca target is shown in Fig. 1. Here the event selection is such that the timing of the photon is between 20 ns and 700 ns after from the timing of prompt γ-rays, and the energy is in the region of 510 ± 100 keV. Each color corresponds to the scattering angle of ^{12}Be at F0 target in the laboratory system, which is reconstructed from the position and the angle measured at F5, within 0.0–0.3° (blue line, blue hatched), 0.3–0.6° (red line, green hatched), and 0.6–0.9° (black line, black hatched). In this spectrum, the kinematical position aberration with the scattering angle is corrected for. The preliminarily calibrated energy of ^{48}Ti is shown below the figure. The energy resolution and the angular resolution was evaluated as 1.6 MeV and 0.17°, respectively. The main background is an accidental coincidence of ^{12}Be and γ rays from room backgrounds. The amount of the background is estimated to about 5% with the event selection by the gate of DALI2 described above. This background is subtracted by assuming that its energy spectrum is same as events that are not gated by DALI2. In the region of the position from -10 mm to 0 mm, which corresponds to about from 23 to 30 MeV in the excitation energy where the DGTGR is expected to be observed[2)], there seem to be enhancements at -2 mm and -8 mm especially in the forward angle, though statistics are limited. The structure around -20 mm, on the other hand, is likely due to the events of the ^{12}C(^{12}C, ^{12}Be)^{12}O$_{\rm g.s.}$ reaction from the graphene sheet attached to the ^{48}Ca target.

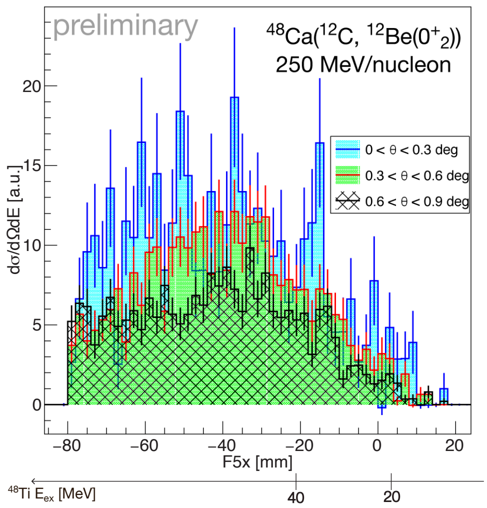

Fig. 1. Preliminary result of position measured at F5. Line and hatching colors correspond to selected regions of scattering angles: 0–0.3° (blue line, blue hatched), 0.3–0.6° (red line, green hatched), and 0.6–0.9° (black line, blacked hatched).

In order to interpret the structure, we are now working on the comparison of the angular distribution with the calculated ones.

References
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