Analysis of the measurement of ^{48}Ca(^{12}C, ^{12}Be(0_2^+)) aiming at the observation of double Gamow-Teller giant resonance

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The double Gamow-Teller (DGT) transition is the nuclear process in which both of the spin and isospin are flipped twice without a change in the orbital angular momentum. The existence of the giant resonance in double Gamow-Teller transition (DGTGR) was predicted in 1989,[1)] but it still remains unobserved experimentally. The experimental information of the DGTGR will provide new insight into the two phonon excitation, as well as the nuclear matrix element of neutrino-less double β decay.[2)]

We are aiming at observing the DGTGR using the double charge exchange (DCX) reaction of (^{12}C, ^{12}Be(0_2^+)). The first measurement using this reaction at RIBF was performed in 2021.[3)] The DCX reaction was induced by bombarding a 10.3 mg/cm^2-thick ^{48}Ca target at F0 with the primary beam with the energy of 250 MeV/nucleon. The ^{12}Be was momentum analyzed using a BigRIPS spectrometer, and the track at F5 plane was measured using multi-wire drift chambers. We measured the excitation energy of the residual nucleus with a sufficient resolution of 1.6 MeV (FWHM). The isomeric state of ^{12}Be(0_2^+) was identified by measuring the de-excitation γ ray via DALI2 at F8.

For the present status of the analysis, we have obtained the preliminary result of the excitation energy distribution of the double differential cross section for the ^{48}Ca(^{12}C, ^{12}Be(0_2^+)) reaction, as shown in Fig. 1. Here, we focus on the excitation energy region of $E_{\rm ex} < 32$ MeV thus far. This is because the ^{12}C(^{12}C, ^{12}Be(0_2^+))^{12}O reaction resulting from the graphene sheet attached to the ^{48}Ca target for the region of $E_{\rm ex} > 32$ MeV appears to be contaminated, and most of the predicted DGT strength lie below 35 MeV.[2)] In the preliminary spectrum, an enhancement of approximately 20 MeV occurs, particularly at the forward angles. The integrated cross section for $0 < E_{\rm ex} < 32$ MeV for the most forward angular region of $0° < \theta_{\rm CM} < 0.4°$ is 1.18 ± 0.09 μb/sr (stat. only).

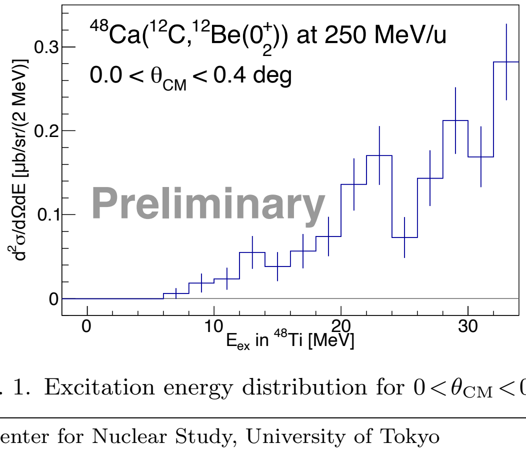

Fig. 1. Excitation energy distribution for $0 < \theta_{\rm CM} < 0.4°$.

To evaluate the DGT component contained in the observed structure, the angular distributions were compared with the calculated ones. The angular distribution of DCX reaction was estimated by performing the coupled channel calculation using ECIS97.[4)] For the transfer of the orbital angular momentum ΔL, the following two types are assumed. The first type is such that in both of the transition from the initial state to the intermediate state and from the intermediate state to the final state, $\Delta L = 0$ ($[\Delta L = 0] \times 2$), which corresponds to the DGT transition. The other type is $\Delta L = 2$ for the transition from the initial state to the intermediate state, and $\Delta L = 0$ for from the intermediate state to the final state ($[\Delta L = 2] + [\Delta L = 0]$).

The experimental angular distribution was decomposed by the combination of $[\Delta L = 0] \times 2$ and $[\Delta L = 2] + [\Delta L = 0]$ for each energy bin, as shown in Fig. 2 for $E_{\rm ex}$ = 22–24 MeV for example. The proportion for each ΔL was determined using the maximum likelihood method. The decomposed result suggests that the $[\Delta L = 0] \times 2$ component occupies a certain amount of the cross section in the forward-peaking structure at approximately 20 MeV.

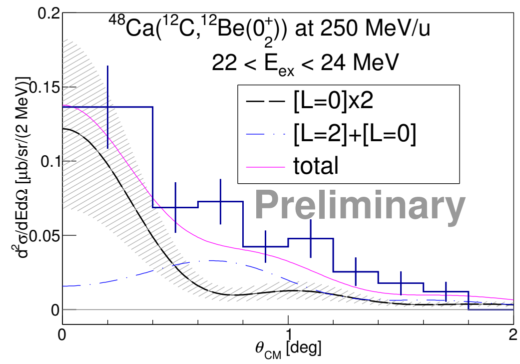

Fig. 2. Angular distribution of the cross section for $22 < E_{\rm ex} < 24$ MeV. The decomposed results (black line: $[\Delta L = 0] \times 2$, blue line: $[\Delta L = 2] + [\Delta L = 0]$) are also shown. The shaded area corresponds to 1σ statistical uncertainty for $[\Delta L = 0] \times 2$.

We are attempting to extract the DGT transition strength from the extracted $[\Delta L = 0] \times 2$ cross sections to discuss the averaged excitation energy and the sum rule value of DGTGR.

References
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