Multipole decomposition analysis for the derivation of Gamow-Teller strength from the ^{64}Zn(^{3}He,t)^{64}Ga spectra at $\theta_{\mathbf{GR}} = 0°$

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From the ^{64}Zn(^{3}He,t)^{64}Ga data measured at the Grand Raiden spectrometer-angle $\theta_{\rm GR} = 0°$ and at 140 MeV/nucleon taken in the E378 beam time, total value of reduced Gamow-Teller strengths, B(GT), was evaluated by a multipole decomposition analysis (MDA).

The RCNP high resolution facility, which consists of Grand Raiden spectrometer and the WS beam line [1] together with the dispersion matching techniques [2], is a powerful tool to study nuclear structure by hadron reaction, e.g., Gamow-Teller (GT) transitions by (^{3}He,t) charge-exchange reaction at 0° [3]. However, heavier mass nuclei can show higher level density, which can not be resolved even by high resolution measurements. In such case, MDA would be another option to deduce GT transitions, which have $\Delta L = 0$ nature. For this purpose, MDA was performed for the ^{64}Zn(^{3}He,t)^{64}Ga data (E378) taken at 0° and 140 MeV/nucleon. Details of the measurements and data analysis to create the energy spectra are given in Ref. [4].

As the components for the analysis, transitions with $\Delta L = 0 - 3$ and quasi-free scattering (QFS) were included. In $\Delta L = 1$ transition, for example, $\Delta J^{\pi} = 0^{-}$, 1^{-}, and 2^{-} are allowed. Since these transitions show similar angular distributions, that of $\Delta J^{\pi} = 2^{-}$ was chosen as the representative one in the MDA. In addition, those of $\Delta J^{\pi} = 1^{+}$, 3^{+}, and 4^{-} were assumed for the $\Delta L = 0$, 2, and 3 components, respectively. The obtained angular distributions for $\Delta L = 0 - 3$ for the reaction Q-values of 0, -10, -20, and -30 MeV are shown in Fig. 1, which were calculated with the series of computer code for distorted wave Born approximation (DWBA) calculation, WSAW, FOLD, and DWHI [5]. Transition densities obtained with the computer code NORMOD [6] were used. The optical potential parameter set given in Ref. [4] was applied.

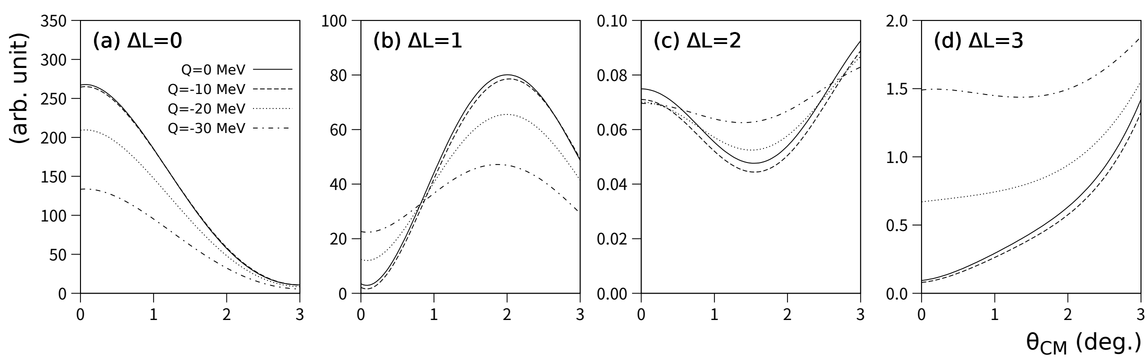

Figure 1: Results of the DWBA calculations for the reaction Q-values of $Q = 0$, -10, -20, and -30 MeV. For the calculations of the $\Delta L = 0$, 1, 2, and 3 components, $\Delta J^{\pi} = 1^{+}$, 2^{-}, 3^{+}, and 4^{-} were assumed, respectively. Note that the Q-value for the ground state transition is -7.190 MeV.

Above the proton separation energy of $S_p = 3.91$ MeV, the so-called quasi-free scattering (QFS) process becomes possible. In the present analysis, the energy distribution of the QF-scattered tritons in the spectra estimated in Ref. [4] was applied. Since various processes can contribute in the QFS, it is known that the angular distribution of QFS tritons show rather moderate shape [7]. Therefore, within the spectrometer acceptance at $\theta_{\rm GR} = 0°$, which corresponds to $0.0° \leq \theta_{LAB} \leq 2.0°$, we assume that the reaction cross sections of the QFS do not change as a function of scattering angle.

In the present MDA, the amount of the QFS component was further normalized by two different ways. In the first method, we assume that the spectra at 17 MeV, where the center of the $\Delta L = 1$ spin-dipole resonance (SDR) locates, consist of only the $\Delta L = 1$ and QFS components. Under this assumption, the normalization factor was estimated to realize the best fit at this energy. As the second method, we determined the normalization factor simply by the least-square method for the whole spectra. As results of these methods, the factors of 0.89 and 0.0 (no QFS) were obtained, respectively.

The results of MDA up to $E_x = 30$ MeV with the QFS normalization factor of 0.89 and without the QFS are shown in Fig. 2 and 3, respectively. In Fig. 2, main part of the $\Delta L = 0$ component, which corresponds to the GT transitions except for the IAS at 1.91 MeV, is found at $E_x \leq 15$ MeV. Another $\Delta L = 0$ component was found above 25 MeV, however, this can be due to the ambiguity in the reconstruction of scattering angles. The $\Delta L = 1$ component distributes above 10 MeV as a broad bump. The bump becomes prominent in the

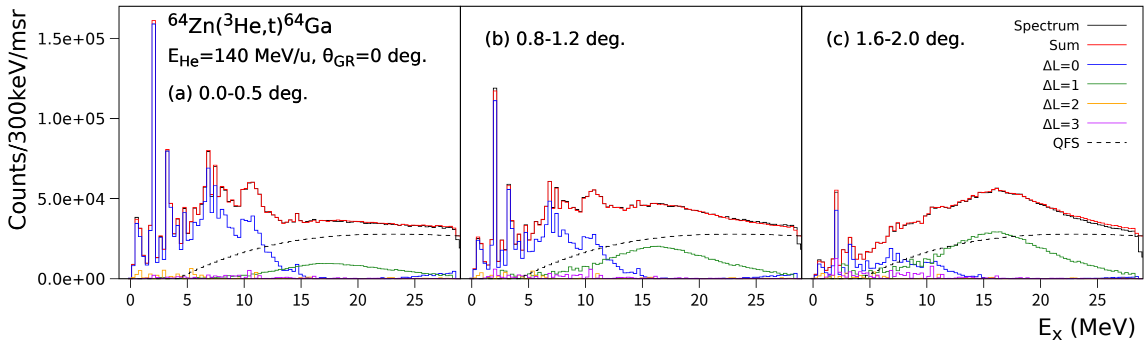

Figure 2: Results of the MDA for the ^{64}Zn(^{3}He,t)^{64}Ga data taken at $\theta_{\rm GR} = 0^\circ$ with the QFS normalization factor of 0.89. Note that yields of the spectra are normalized by the solid angles.

$1.6^\circ - 2.0^\circ$ spectrum (Fig. 2 (c)), and thus it should be the SDR. The $\Delta L = 2$ and 3 components are very small, suggesting that the ΔL up to 3 is enough in the present MDA.

On the other hand, in Fig. 3, in which no QFS is assumed, large amount of highly excited continuum was exhausted by the $\Delta L = 2$ component. Above 20 MeV, the $\Delta L = 0$ component becomes large again and shares strength with the $\Delta L = 1$. This would be because the $\Delta L = 2$ component with relatively flat angular distribution and sum of the $\Delta L = 0$ and $\Delta L = 1$ components, which decreases and increases at larger scattering angles (see Fig. 1), respectively, act like the QFS in Fig. 2, which has flat angular distribution.

Although these are preliminary values, sum of the B(GT) values, S(GT), were deduced by using the $R^2 = \hat{\sigma}_{\rm GT}/\hat{\sigma}_{\rm F} = 9.1(4)$ [4]. From the first method, S(GT) of 6.1(6) was obtained up to 15 MeV, which agrees reasonably with 50% of the GT sum rule value, i.e., $3(N-Z) = 12$. From the second method, $S({\rm GT}) = 10.4(10)$ was obtained up to 30 MeV. Detailed comparison with the B(GT) distribution shown in Ref. [4] is in progress.

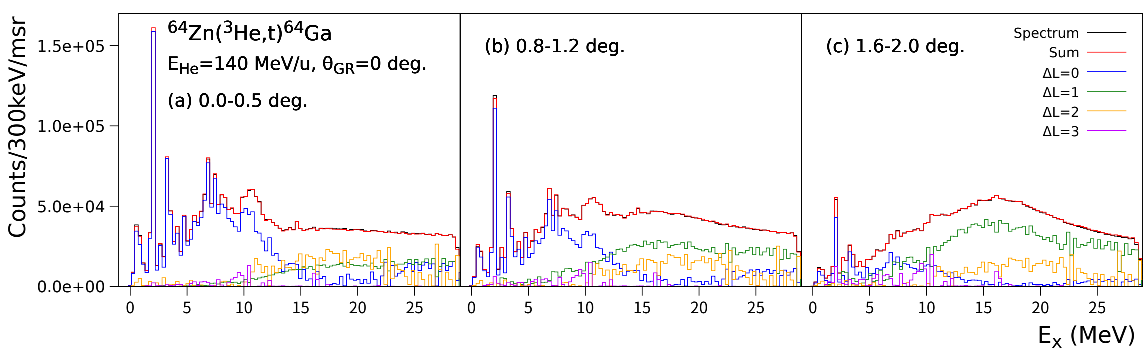

Figure 3: Results of the MDA for the ^{64}Zn(^{3}He,t)^{64}Ga data taken at $\theta_{\rm GR} = 0^\circ$ without the QFS component.

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