Practical method for decomposing discretized breakup cross sections into components of each channel†

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The continuum-discretized coupled-channel method (CDCC)[1)] is one of the most powerful tools for describing breakup reactions. In the 1980s, three-body CDCC was first applied to d scattering by assuming the $n+p+T$ three-body model, where T denotes a target. Three-body CDCC has been successful in describing many kinds of three-body reactions. Nowadays, three-body CDCC has been developed mainly in two directions. One is four-body CDCC[2)] and the other is three-body CDCC with core excitation.[3)] These methods address breakup reactions including multi-breakup channels. For example, for ^{6}Li scattering in the four-body model ($n+p+\alpha+T$), the four-body channel ($^{6}\mathrm{Li}+T \to n+p+\alpha+T$) and the three-body channel ($^{6}\mathrm{Li}+T \to d+\alpha+T$) coexist and couple each other during scattering. In CDCC, these breakup channels are precisely considered on an equal footing. However, the corresponding breakup cross sections (BUXs) are obtained as an admixture of these channels owing to the discretization in the calculations. In this work, we propose a practical method for decomposing discretized BUXs into components of each channel. This method is referred to as the "probability separation (P separation)."

Before going to four-body scattering, we first consider $^{11}\mathrm{Be}+T$ scattering in the three-body model with core excitation ($^{10}\mathrm{Be}+n+T$) because this scattering provides an analogy regarding the mixture of different channels as

$$^{11}\mathrm{Be}+T \to {}^{10}\mathrm{Be(g.s.)}+n+T \quad \text{(core-ground channel)},$$
$$^{11}\mathrm{Be}+T \to {}^{10}\mathrm{Be}^{*}+n+T \quad \text{(core-excited channel)},$$

where g.s. represents the ground state. This scattering has an advantage in that it allows us to easily obtain each channel's exact breakup wave functions for the ^{11}Be two-body projectile, unlike the ^{6}Li three-body projectile. In the actual analysis,the BUXs are calculated using extended distorted-wave Born approximation (xDWBA)[4)] with the particle-rotor model. The xDWBA enables us to calculate both the *exact* (continuous) and the *approximate* (discretized) T-matrix elements. Then, we can compare the approximate BUXs with the exact ones quantitatively. In this report, we show only the validity of the P separation.

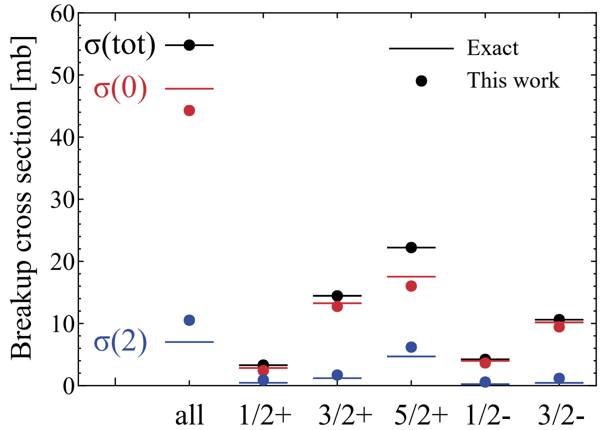

Fig. 1. Decomposition of the breakup cross sections for the scattering of $^{11}\mathrm{Be}+p$ at 63.7 MeV/nucleon. The solid lines represent the exact BUXs (σ), whereas the solid circles correspond to the approximate BUXs ($\hat{\sigma}$).

Figure 1 shows the decomposition of the breakup cross sections. The spin-parities $J^{\pi} = 1/2^{+}$, $3/2^{+}$, $5/2^{+}$, $1/2^{-}$, and $3/2^{-}$ are considered for ^{11}Be. First, the discretized total BUX $\hat{\sigma}(\mathrm{tot})$ is compared with the exact BUX $\sigma(\mathrm{tot})$. For the total breakup cross sections), $\hat{\sigma}(\mathrm{tot}) = \sigma(\mathrm{tot})$ is satisfied, which suggests that the model space is sufficiently large for calculating the BUX. Next, the discretized BUX is decomposed into the core-ground and the core-excited BUXs with the P separation. The total [$\sigma(\mathrm{tot})$], core-ground [$\sigma(0)$], and core-excited [$\sigma(2)$] BUXs are shown from top to bottom. The approximate BUXs are in good agreement with the corresponding exact ones for each spin parity. Thus, the P separation is found to work for the discretized BUX.

The P separation has an advantage that it is easily applied to four-body scattering for which the exact breakup wave functions for the three-body projectile are difficult to obtain. The systematic analysis for the validation and the application to four-body CDCC are presented in the original paper.†

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