Study of three-body repulsive force via ^{12}C + ^{12}C scattering at 100A MeV

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The role of three-body force in complex nuclear systems is one of the key issues not only in nuclear physics but also in nuclear astrophysics relevant to high-density nuclear matter in neutron stars and supernova explosions [1]. Elastic scattering is one of the general nuclear reactions induced by nucleons and the composite-nucleus projectiles on the different target nuclei. It has been provided the valuable information about nuclear many-body dynamics. Present study aims to confirm the effect of three-body force and the channel coupling (CC) in heavy-ion collisions at high energies to continue to higher energies. We have measured the elastic and inelastic scatterings of ^{12}C + ^{12}C at 100A MeV at the first stage. The obtained angular distributions were compared with the theoretical models. It thus provides the first discussion of the three-body force with the CC effect.

The experiment was performed using the high-resolution "Grand Raiden" spectrometer at the Research Center for Nuclear Physics (RCNP) cyclotron facility in Osaka University. A beam of ^{12}C was delivered from the RCNP ring cyclotron and transported to a carbon target placed in a scattering chamber under achromatic focusing. The measured angular range in laboratory frame was 1.0°-7.5°. The excitation energy above 6 MeV includes the contributions from the 7.65, 9.64, and 10.30 MeV states in addition to the simultaneous excitation of both target and projectile nuclei. Therefore, it is difficult to obtain the angular distributions of the inelastic scattering of those states separately. As a result, we calculated the angular distribution of the inelastic scattering including all those states.

The experimental angular distributions were analyzed by the microscopic coupled channel (MCC) calculation [2]. The complex potential in the MCC calculation for many composite projectiles was constructed by the double-folding-model procedure based on the complex G-matrix nucleon-nucleon interactions CEG07b [3], M-Pa [4], and ESC [5, 6] models. Here, ESC model was derived from the ESC08c model without three-body force. The detailed theoretical frame of the MCC calculation with the complex G-matrix interaction was described in Ref. [2]. For the MCC calculation, we have used the diagonal and transition densities in Ref. [7]. The present MCC calculation includes the G.S. (0_1^+), 7.65 MeV (0_2^+), 14.04 MeV (0_3^+), 14.88 MeV (0_4^+), 4.44 MeV (2_1^+), 10.3 MeV (2_2^+), 13.25 MeV (2_3^+), 16.54 MeV (2_4^+), and 9.64 MeV (3_1^-) states of the ^{12}C nucleus.

The CC calculations were performed with the three interaction models. It was found that the CC significantly changes the cross section and better reproduces of the experimental data. Based on this finding, the ESC model without three-body force failed to reproduce the measured cross sections in both the elastic and inelastic scattering channels. The calculations including three-body force better reproduced the experimental cross section, though they were imperfect in both the elastic and inelastic scatterings. Among two models that include three-body force, the MPa model reproduced the data more accurately than CGE07b model. The MPa model exactly indicates the importance of the measurement of the excited states in addition to the elastic scattering. Therefore, the present data makes clearly the important role of the repulsive three-body force and the CC effect in high-energy heavy-ion collisions.

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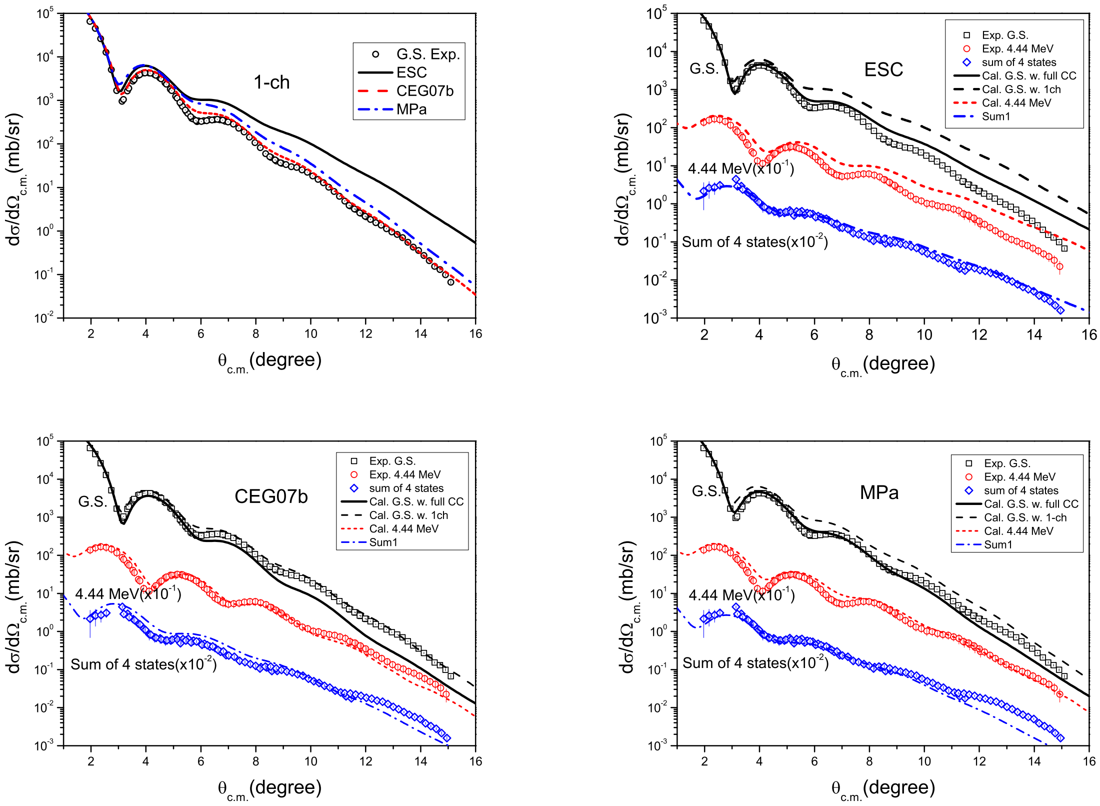

Figure 1: (color online) The experimental and calculated angular distributions for ^{12}C + ^{12}C scattering at 100A MeV with $N_w = 0.6$ by using ESC, CEG07b, and MPa models with 1ch and full-CC. The experimental angular distributions of ground state (G.S.) and 4.44 MeV (2_1^+) state, as well as the sum of 7.65 (0_2^+) state, 9.64 (3_1^-) state and simultaneous excitation both the projectile and target nuclei are shown in these figures. Sum1 represents the sum of 7.65 (0_2^+) state, 9.64 (3_1^-) state and the simultaneous excitation when total angular momentum J=0.