Insight into the reaction dynamics of proton drip-line nuclear system ^{17}F + ^{58}Ni at near-barrier energies†

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In recent times, the availability of high-quality radioactive beams has greatly increased our ability to study the reactions induced by exotic nuclei.[1)] In contrast to neutron-halo projectiles, reactions induced by weakly bound proton-rich nuclei, especially those with proton-halo or valence-proton structures, present distinctive properties. Both the core and valence proton have long-range Coulomb interaction with the target; thus, the dynamic Coulomb polarization effect is of particular importance.[2)] So far, research on reactions with proton drip-line nuclei is still in its infancy, and the reaction mechanism is not yet clear.

^{17}F can be treated properly with a two-body model as an inert ^{16}O core and a loosely bound proton.[3)] In this report, we present the results of complete kinematics measurements to investigate the reaction mechanisms of ^{17}F interacting with ^{58}Ni at energies around the Coulomb barrier. The experiment was performed at the Center for Nuclear Study Radioactive Ion Beam separator (CRIB).[4)] The Multi-layer Ionization-chamber Telescope Array (MITA)[5)] was used to detect the reaction products over a large range of Z. Angular distributions of elastic scattering, exclusive and inclusive breakup, as well as the total fusion (TF) cross sections were derived simultaneously for the first time.

The excitation functions of the total reaction (σ_{R}), inclusive ($\sigma_{\mathrm{Inc.}^{16}\mathrm{O}}$) and exclusive ($\sigma_{\mathrm{Exc.}^{16}\mathrm{O}}$) ^{16}O, as well as the TF from evaporation protons are shown in Fig. 1. Fusion is dominant in the above-barrier region, and it reduces exponentially as the energy decreases. The $\sigma_{\mathrm{Inc.}^{16}\mathrm{O}}$ and $\sigma_{\mathrm{Exc.}^{16}\mathrm{O}}$, however, vary smoothly with the energy, and $\sigma_{\mathrm{Inc.}^{16}\mathrm{O}}$ becomes the major component in the sub-barrier region. The behavior of the TF cross section can only be reproduced by the continuum-discretized coupled-channels (CDCC) calculation considering the couplings from the continuum states, indicating that the enhancement of TF at the sub-barrier energy is mainly due to the breakup coupling.

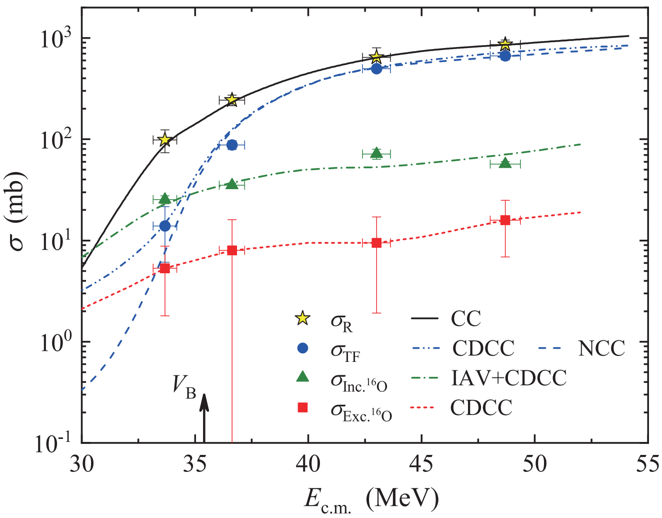

Fig. 1. Excitation functions of the total reaction (stars), exclusive (squares) and inclusive (triangles) breakups, and the TF (circles). The curves denote the corresponding theoretical results: the solid line denotes the coupled channel (CC) result; the dot-dot-dashed and dotted curves are the CDCC results for TF and elastic breakup, respectively; the dashed line shows the CDCC calculations performed by switching off the couplings from the continuum states (NCC); and the dot-dashed line is the result of the three-body model proposed by Ichimura, Austern, and Vincent[6)] plus CDCC. The arrow indicates the nominal position of the Coulomb barrier.

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