Determination of fusion barrier distributions from quasielastic scattering cross sections towards superheavy nuclei synthesis†

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The excitation functions for quasielastic (QE) cross sections were measured for the reactions relevant to the synthesis of superheavy nuclei, the ^{48}Ca+^{208}Pb, ^{50}Ti+^{208}Pb, and ^{48}Ca+^{248}Cm systems. Owing to the excellent performance of the gas-filled-type recoil ion separator GARIS and the focal plane detector system, the QE scattering events were effectively separated from deep-inelastic (DI) events and precise barrier distributions were deduced for all of these systems.

Coupled-channels calculations[1)] were performed by taking into account the couplings to the vibrational and rotational excitations in the colliding nuclei, as well as the neutron transfer processes before contact. The experimental data are well reproduced by the calculations, which demonstrates the importance of including channel couplings in all of the systems. The maxima of the barrier distribution were shown to coincide in energy with the peak of the 2n evaporation residue cross sections[2–5)] in the reactions of ^{48}Ca and ^{50}Ti on ^{208}Pb target. For the hot fusion reaction, the evaporation residue cross sections[6,7)] peak at an energy well above the barrier region. This clearly suggests that the evaporation residue cross sections are enhanced at energies that correspond to a compact collision geometry with the projectile impacting the side of the deformed target nucleus.

From the results presented in this paper, we conclude that a measurement of the barrier distribution provides a powerful tool for understanding the underlying reaction dynamics for an unknown very heavy nuclei. In particular, it provides an effective way to determine the optimal bombarding energy. Importantly, this determination is independent of theoretical predictions that may include a large model dependence.

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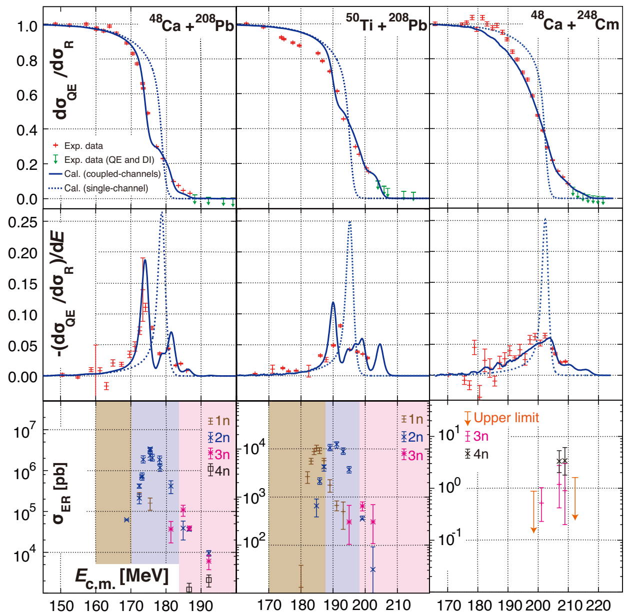

Fig. 1. Measured excitation function for the QE scattering cross section relative to the Rutherford cross section $d\sigma_{QE}/d\sigma_R$ (top panels). Left, middle, and right panels are for the ^{48}Ca+^{208}Pb, ^{50}Ti+^{208}Pb, and ^{48}Ca+^{248}Cm systems, respectively. The corresponding QE barrier distribution (middle panels) and the evaporation residue cross sections reported at different center-of-mass energies from the syntheses of No, Rf, and Lv evaporation residues[2–7)] (lower panels) are also shown. Red symbols indicate the experimental data from this work, for which the error bars include only the statistical uncertainty. Green symbols indicate the experimental data for mixed QE and DI events. These data points provide an upper limit for $d\sigma_{QE}/d\sigma_R$. Blue solid curves indicate the best fit of the coupled-channels calculation. Blue dashed curves show the results of the single-channel calculations with the same internuclear potential as that used for the blue solid lines.

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