Study of quasielastic barrier distributions as a step towards the synthesis of superheavy elements with hot fusion reactions[†]

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The excitation functions of quasielastic scattering cross sections for reactions relevant to the syntheses of superheavy nuclei, that is, the ^{22}Ne+^{248}Cm, ^{26}Mg+^{248}Cm, and ^{48}Ca+^{238}U systems, were measured using the gas-filled recoil ion separator GARIS to understand systematically the reaction dynamics of the hot fusion reactions. From the measured cross sections, the barrier distribution was extracted, which shows a distribution of the barrier height in the entrance channel. The experimental data were well reproduced by the coupled-cannels calculations.[1)] The calculated results indicate that the shape of barrier distribution is affected dominantly by deformation of the actinide target nuclei, but also by vibrational/rotational excitations of the projectile nuclei as well as neutron transfer processes before capture. Contribution from each colliding angles to the barrier distribution is systematically shown in Fig. 1 (black thin solid curves) by showing the barrier distribution from each colliding-angle range with 10° interval. Here, the distribution for the side collision 80–90° is highlighted by the red dashed curve. The total barrier distributions, which are the sum of the black thin solid curves and the red dashed curves, are also shown by the blue solid curves. The peak of the sum of the evaporation residue cross sections for Sg ($Z = 106$),[2–6)] Hs (108),[7)] Cn (112)[8,9)] and Lv (116)[8,10)a)] coincide not only with the barrier distribution for 80–90°, but also with that for 70–80° etc. However, the overlap with the barrier distribution for the tip collision, such as 0°–20°, is negligibly small, indicating that these hot fusion reactions take advantage of the compact collision, where the projectile approaches along the short axis of a prolately deformed nucleus, as was discussed in Refs. 11–13).

For hot fusion reactions, the optimum incident energy, at which the evaporation residue cross section is maximized, can be estimated by an experimentally determined barrier distribution, if the trend of compact collision is not changed. Importantly, it would take only about one day to measure a barrier distribution for one reaction, which is much shorter than a typical experiment to synthesize new superheavy element, *e.g.*, more than one hundred days using one pμA beam. This new method will significantly contribute to future experiments to synthesize both new superheavy elements and superheavy nuclei in the island of stability.

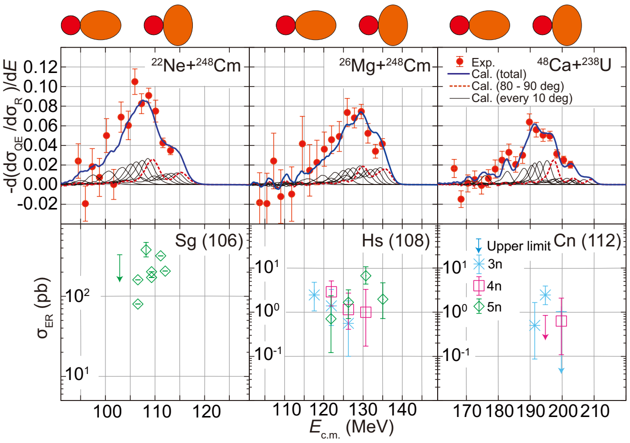

Fig. 1. A comparison between the measured quasielastic barrier distributions (the upper panels) and the evaporation residue cross sections reported at different center-of-mass energies for the syntheses of Sg, Hs, and Cn[2–9)] (the lower panels). The red symbols indicate the experimental data from this work. The detailed explanations of the calculated results are described in main text.

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[a)] The result of ^{48}Ca+^{248}Cm$\rightarrow$^{296}Lv* is omitted from the Fig. 1 due to the space limit. See the original article.