Exploring quasifission characteristics for $^{34}S + {}^{232}Th$ forming ^{266}Sg

E. Prasad,* A. Wakhle,† D. J. Hinde, E. Williams, M. Dasgupta, M. Evers,‡ D. H. Luong, G. Mohanto,§ C. Simenel, and K. Vo-Phuoc

Department of Nuclear Physics, Research School of Physics and Engineering, Australian National University, Canberra, ACT 2601, Australia

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Background: Fission fragments from heavy ion collisions with actinide nuclei show mass-asymmetric and mass-symmetric components. The relative probabilities of these two components vary rapidly with beam energy with respect to the capture barrier, indicating a strong dependence on the alignment of the deformed nucleus with the partner in the collisions.

Purpose: To study the characteristics of the mass-asymmetric quasifission component by reproducing the experimental mass-angle distributions to investigate mass evolution and sticking times.

Methods: Fission fragment mass-angle distributions were measured for the $^{34}S + {}^{232}Th$ reaction. Simulations to match the measurements were made by using a classical phenomenological approach. Mass ratio distributions and angular distributions of the mass-asymmetric quasifission component were simultaneously fit to constrain the free parameters used in the simulation.

Results: The mass-asymmetric quasifission component—predominantly originating from tip (axial) collisions with the prolate deformed ^{232}Th—is found to be peaked near $A = 200$ at all energies and center-of-mass angles. A Monte Carlo model using the standard mass equilibration time constant of 5.2×10^{-21} s predicts more symmetric mass splits. Three different hypotheses assuming (i) a mass halt at $A = 200$, (ii) a slower mass equilibration time, or (iii) a Fermi-type mass drift function reproduced the main experimental features.

Conclusions: In tip collisions for the $^{34}S + {}^{232}Th$ reaction, mass-asymmetric fission with $A \sim 200$ is the dominant outcome. The average sticking time is found to be $\sim 7 \times 10^{-21}$ s, independent of the scenario used for mass evolution.

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I. INTRODUCTION

Although the last stable element to be discovered was added to the periodic table nearly 100 years ago, the synthesis of new heavy elements and isotopes [1,2], and the study of their properties, continues to be a very important subject in nuclear physics. Impressive progress has been achieved, with superheavy elements ($Z \geqslant 104$) up to $Z = 118$ [1,2] having been created by using heavy ion fusion reactions.

Superheavy element (SHE) synthesis is very difficult due to very low production cross sections, often on the order of picobarns or less [1,2]. These low cross sections can partly be attributed to the presence of a nonequilibrium process called quasifission [3–5]. Quasifission is a fission-like process, where the intermediate system formed after capture reseparates before forming a compact, completely equilibrated compound nucleus (CN) [6]. Because reseparation occurs before CN formation, evaporation residue (ER) cross sections are reduced [7,8]. The selection of the optimum reaction for SHE synthesis would be helped by a detailed understanding of the quasifission process. However, though considerable progress has been made, a quantitative model does not exist at the moment.

In 1981, Świątecki predicted that quasifission should occur in nuclear collisions with $Z_P Z_T \geqslant 1600$ [4], where Z_P and Z_T are the atomic numbers of the projectile and target nuclei, respectively. However, subsequent measurements using a variety of projectile-target combinations have reported the onset of quasifission in mass-asymmetric collisions with much lower $Z_P Z_T$ values [8]. Beyond the suppression of ER cross sections, quasifission signatures can also be observed in many other experimental fission observables, such as large fission-fragment mass widths [9–13], correlations between fission masses and observation angles [9,13–15], and large fission-fragment angular anisotropies incompatible with CN formation [13,16–18].

Quasifission is now understood to have a strong dependence on gross entrance channel properties such as mass asymmetry [8,19,20] and beam energy [21–24]. It has also been shown to be sensitive to nuclear structure effects—namely, static deformation [17,25–27], closed shells [28,29], and the N/Z matching of the projectile and target nuclei [28]. In addition, the fissility of the compound nucleus being formed has been found to play a role in quasifission outcomes [12,14]. However, the complex dependence of quasifission on these variables makes it difficult to understand this process completely. Despite its conceptual simplicity as a process intermediate between a deep-inelastic process and the formation of an equilibrated CN through true fusion, the measurement of quasifission is complicated by the fact that experimental quasifission observables overlap with those of fusion-fission.

*Permanent address: Department of Physics, School of Mathematical and Physical Sciences, Central University of Kerala, Kasaragod 671314, India; prasad.edayillam@anu.edu.au

†Present Address: National Superconducting Cyclotron Laboratory, Michigan State University, Michigan 48824, USA.

‡Present Address: ANU College of Medicine, Biology and Environment, The John Curtin School of Medical Research, Canberra, ACT 2601, Australia.

§Present Address: Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India.

