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Study of fusion dynamics for ^{64}Ni+^{124,132}Sn and ^{64}Ni+^{208}Pb reactions within the relativistic mean-field formalism

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Introduction

The study of nuclear matter incompressibility plays a significant role in the nuclear physics as well as in astro-nuclear physics [1, 2]. The value of incompressibility for the nuclear matter is constrained through experimental measurements of the isoscalar giant monopole resonance (ISGMR) strengths for the finite nuclei. The experimental ISGMR data of doubly magic ^{208}Pb nucleus has been used as the optimal route to investigate the nuclear matter incompressibility by various relativistic and non-relativistic models [1, 2]. Although this approach of obtaining the incompressibility of infinite nuclear matter is assumed to be independent of the choice of finite nuclei, still the experimental ISGMR data for even-even Sn-isotopes is found to be inconsistent with the nuclear incompressibility value (K) obtained using ^{208}Pb. The even-even Sn-isotopes appear to be “soft” or “compressible” as both relativistic and non-relativistic models overestimate their ISGMR energies. Despite several theoretical and experimental investigations, the so called “softness of Sn-isotopes” remains an open problem in nuclear structure physics [1].

The low-energy heavy-ion induced reactions serve as an useful tool to interpret the correlation between the nuclear structure and reaction dynamics. The objective of present analysis is to study the influence of above discussed softness of Sn-isotopes on the nuclear fusion dynamics within the relativistic mean-field (RMF) formalism [2, 3, 4]. For this we have considered ^{64}Ni+^{124,132}Sn reactions involving Sn-isotopes and ^{64}Ni+^{208}Pb involving the heaviest doubly magic ^{208}Pb nucleus. The nuclear density distributions of the interacting nuclei and the R3Y effective nucleon-nucleon (NN) potential are obtained for the the NL3* (K=258.25 MeV) [4] and Hybrid (K=230.01 MeV) [2] RMF parameter sets which yield different values of nuclear matter incompressibility. These densities and R3Y NN potentials are further used to obtain the nuclear potential within the double folding approach and the fusion and/or capture cross-section within the well-known $\ell-$summed Wong model [3]. The theoretical cross-section is also compared with the available experimental data [5, 6, 7].

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Theoretical Formalism

The short-range attractive nuclear interaction potential provides the foundation to study the fusion mechanism of two interacting heavy-ions at low energies. Here, the nuclear potential is estimated within the well-adopted double folding approach [3] as,

$$V_n(\vec{R}) = \int \rho_p(\vec{r}_p)\rho_t(\vec{r}_t)V_{eff}(|\vec{r}_p - \vec{r}_t + \vec{R}|\equiv r) d^3r_p d^3r_t. \quad (1)$$

The main ingredients of the double folding approach are the nuclear density distributions (ρ_p and ρ_t) of the interacting nuclei and an effective NN potential (V_{eff}). These inputs of the double folding approach are obtained from the well-known RMF formalism [2, 3, 4]. The repulsive Coulomb and centrifugal potentials are then added to the attractive nuclear potential to obtain the total interaction potential. The characteristics of the fusion barrier formed due to this interaction potential are further used to determine the transmission coefficient under Hill-Wheeler approach and cross-section using the $\ell-$summed Wong model[3].

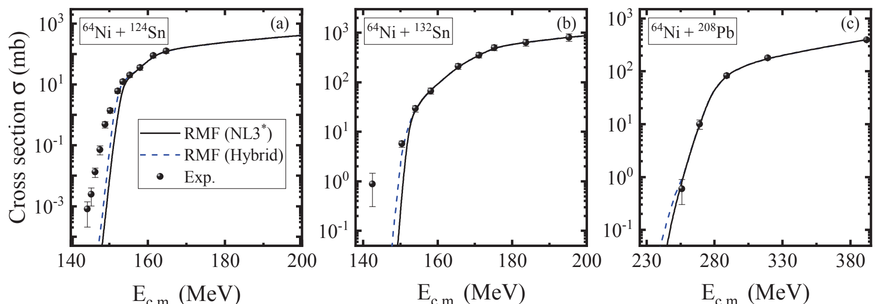

FIG. 1: The cross section σ (mb) calculated using NL3* (solid black) and Hybrid (dashed blue) parameter sets using the $\ell-$summed Wong model as a function of center of mass energy $E_{c.m.}$ (MeV) for (a) ^{64}Ni+^{124}Sn, (b) ^{64}Ni+^{132}Sn and (c) ^{64}Ni+^{208}Pb systems. The experimental data [5, 6, 7] is also plotted for comparison.

Results and Discussion

The fusion barrier characteristics for the three reactions under study i.e., ^{64}Ni+^{124,132}Sn and ^{64}Ni+^{208}Pb are obtained by folding the RMF densities and R3Y NN potential obtained for NL3* [4] and Hybrid [2] parameter sets. The NL3* parameter set with K=258.25 MeV provides a reasonable match to the ISGMR data of ^{208}Pb [4] whereas the Hybrid parameter set with K=230.01 MeV was constructed to describe the ISGMR data of Sn-isotopes. The present study aims to analyze the impact of fusion barrier characteristics obtained for RMF parameter sets with different values of nuclear matter incompressibility on the fusion dynamics of the reactions involving Sn-isotopes and ^{208}Pb nucleus.

The fusion and/or capture cross-section σ (mb) obtained using the NL3* (solid black) and hybrid (dashed blue) parameter sets for (a) ^{64}Ni+^{124}Sn, (b) ^{64}Ni+^{132}Sn and (c) ^{64}Ni+^{208}Pb reactions is shown in Fig. 1 as a function of center of mass energy $E_{c.m.}$ (MeV). It can be observed from Fig. 1 that the NL3* parameter with higher value of K gives lower cross-section than the Hybrid parameter set having comparatively lower value of K. The comparison of the theoretical results with the experimental data [5, 6, 7] shows that for ^{64}Ni+^{208}Pb reaction, the NL3* parameter gives a nice match with the experimental data. However, for reactions involving Sn-isotopes the NL3* parameter set underestimates the experimental cross-section at below barrier energies. The Hybrid parameter set with softer value of K gives slightly better match than the NL3*, but the results are still away from the experimental data. The reason for this discrepancy for reactions involving Sn-isotopes can be connected with the above discussed "softness" of the Sn-isotopes. These are the preliminary results and a more comprehensive study involving more reactions systems with other Sn-isotopes and RMF parameter sets with wider range of nuclear incompressibility values will be carried out shortly.

Acknowledgments

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