Relativistic mean field treatment for the fusion cross-section of Ni-based reaction systems

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The traditional goal of nuclear physics is to understand the properties of atomic nuclei in terms of the bare interaction between a pair of nucleons. Though substantial progress has taken place to understand the nucleon-nucleon interaction within several theoretical and experimental attempts, remains an open problem at present. A large number of interactions have been constructed via studying nucleon-nucleon (*NN)* scattering, but there exist extensive modifications in the scattering behavior due to the presence of surrounding nucleons in a nucleus [1]. Further, the reconstruction of *NN*-potential through particle exchanges is made possible by the development of quantum field theory [2].

At low energy, the system can fuse either by penetrating the interaction barrier or have sufficient energy to overcome Coulomb barrier to getting absorbed. In the present study, we have considered the Ni-based reactions as their fusion excitation functions are available experimentally and also known for fusion hindrance [3]. Hence, it is one of the great interests at present to see the performance of recently developed relativistic nucleon-nucleon interaction entitled 'R3Y' potential along with the microscopic relativistic mean field density to estimating the nuclear interaction potential for the study of fusion reaction at low energies. The present calculations are limited to the spherical coordinate system to generate the nucleus-nucleus interaction potential. More detail studies of the fusion barrier and their effect on the fusion dynamics can find from the Refs. [4].

A microscopic approach based on an axial deformed relativistic mean field with recently developed NL3* force parameter has been used along with the Wong formula to provide a transparent and analytic way to calculate the fusion cross-section using a convenient approach to nucleus-nucleus optical potential. We have considered the well-known M3Y and the recently derived relativistic R3Y *NN*-interaction to obtaining the nuclear interaction potential.

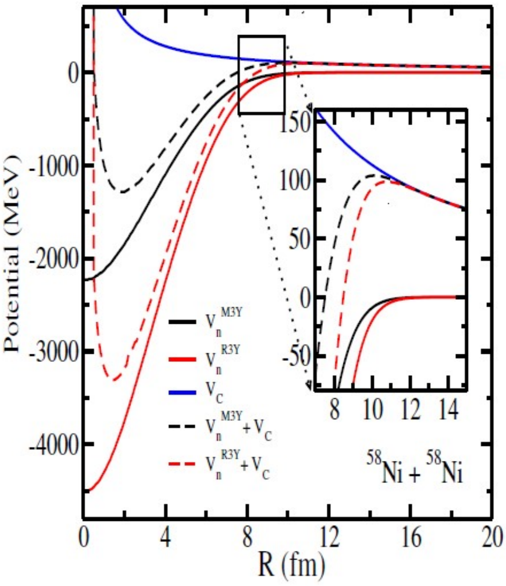

Fig.1 The total nucleus-nucleus optical potential V (R) and the individual contributions [the nuclear potential V_n for M3Y and R3Y, and the Coulomb V_C (R) potential] as a function of R.

In the first step, we calculate the nuclear structure properties such as the binding energy, quadrupole moment Q_{20}, the total density distribution (i.e., the sum of the proton and neutron densities), the root-mean-square nuclear (neutron, proton, and charge) radii and the single particle energy level for nucleons. Instead of concentrating on nuclear structure output profile for the NL3* force parameter, we use the monopole component of the densities for the target (t) and projectile (p) as the input for estimation of the optical nucleus-nucleus interaction potential within double folding procedure [4]. In the second step, adding Coulomb potential, V_C (R) results in nucleus-nucleus interaction potential V_T (R), used for calculating the fusion properties.

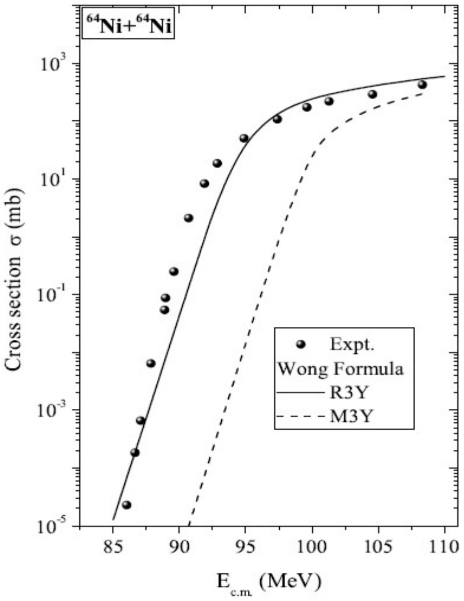

Fig. 2 Fusion-evaporation cross-section as a function of center-of-mass $E_{c.m.}$, calculated by using the Wong formula for R3Y and M3Y NN-interactions, and compared with experimental data for ^{64}Ni + ^{64}Ni [3]. See the text for details.

As a representative case, the obtained results for total interaction potentials along with the Coulomb potential and the nuclear interaction potential V_n (R) without Coulomb for M3Y and R3Y interactions for ^{58}Ni + ^{58}Ni system is displayed in Fig. 1. From the figure, we note that the nature of the total [V_T (R)] and the nuclear [V_n (R)] potentials have similar trends for both the R3Y and M3Y *NN*-interactions (see Fig. 1). Quantitatively, both the nuclear potentials obtained from M3Y and R3Y differ significantly particularly in the central region, and this difference reduced simultaneously with respect to the radial distance, which play an important role in the cross-sections. Fig. 2 shows the comparison of fusion cross-section obtained for ^{64}Ni + ^{64}Ni around the Coulomb barrier with the experimental data [3] at below barrier energies. The solid line shows the fusion cross-section using R3Y interaction and dashed line using M3Y potential within the Wong formula for NL3* densities. It is observed that R3Y performs relatively superior than M3Y interaction in comparison with the experimental data [3] below barrier.

In summary, we have investigated possible relationships between the nucleon-nucleon interaction potential and the fusion reaction cross-section for a few Ni-based systems, known for fusion hindrance phenomena. We found that the R3Y interaction is proven to be a better choice than M3Y for considered fusion reactions below the barrier energies in the prediction of cross-section. More details of the present analysis can be found in the Ref. [4]. It is worth mentioning that the quadrupole, odd multipole (octupole, etc.) shape degrees of freedom and the corresponding space reaction symmetry may provide some of these interesting issues and will throw more light on the fusion properties.

References

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