Entrance-channel effect on fusion suppression in the framework of improved fusion function (IFF)

Nancy Garg[1],* Rupinderjeet Kaur[1], Priyanka[1], Soni Devi[1], Katyayni Tiwari[1], V. A. B. Zagatto[2], J. Lubian[2], L. F. Canto[3], and Pushpendra P. Singh[1]
[1] *Department of Physics, Indian Institute of Technology, Rupnagar - 140001, Punjab, India*
[2] *Instituto de Fsica, Universidade Federal Fluminense, Av.Litoranea s/n, Gragoat, Niteri, R.J., 24210-340, Brazil and*
[3] *Instituto de Fsica, Universidade Federal do Rio de Janeiro, CP 68528, 21941-972, Rio de Janeiro, RJ, Brazil*

Introduction

In the last few decades, extensive investigations have been carried out on nuclear reactions involving radioactive ion beams. The effect of break-up and neutron-halo structure of nuclei is fascinating; however, experimental studies become difficult due to the low intensities of radioactive ion beams. In that case, stable weakly bound projectiles (WBP), e.g., ^{6,7}Li and ^{9}Be, have been used, considering the reaction mechanism involved would be the same for both stable and unstable WBPs. The nuclear reaction studies with such projectiles serve as seeds for producing heavier elements via fusion reactions in stars, supernovas, and other astrophysical environments, influencing their energy production, structure, and evolution. Understanding their properties is essential for advancing the knowledge of stellar astrophysics and the origin of elements in the universe.

It has been experimentally established that complete fusion (CF) cross-sections are found to be enhanced at sub-barrier energies while getting suppressed at above-barrier energies. Recently, Canto et al. [1] introduced an improved version of the fusion function (IFF) and also a new method, the classical fusion function (CFF), based on an improved classical approximation for fusion cross-sections. This method has the nice feature of leading to a straightforward universal function - a straight line with an angular coefficient equal to one, which is termed a classical fusion line [G_0(y)]. On the other hand, since the classical approximations break down below the Coulomb barrier, they can only be applicable to the above-barrier energies. Using the proposed reduction method, a comparative study of CF data in collisions of ^{6,7}Li,^{9}Be, and ^{6}He with different targets, covering a broader mass range, has been presented. However, unlike ^{6,7}Li, no systematic or reliable conclusion could be drawn for the ^{9} Be-induced reactions. CF excitation functions of reactions involving ^{9}Be have been previously studied by applying the universal fusion function, but for the first time, we have attempted to understand the systematic suppression effect for reactions induced by the same projectile, i.e., ^{9}Be using improved fusion function (IFF). Additionally, CF data (on a reduced scale) involving different projectiles with different break-up thresholds have been compared to understand the entrance-channel dependence of fusion suppression in the framework of IFF.

Results and Discussion

Fig.1 presents the comparative study of experimental IFFs. In this figure, an improved reduction method is applied to the CF data involving ^{9}Be projectile with ^{89}Y, ^{93}Nb, ^{124}Sn, ^{144}Sm, ^{169}Tm, ^{181}Ta, ^{186}W, ^{187}Re, ^{197}Au, ^{208}Pb, and ^{209}Bi as targets [2–8]. In this analysis, light mass targets have not been included in the discussion. Fig.1 shows the re-normalized experimental IFFs ($\tilde{G}_{exp}$(y)) of several systems, considering targets over a significant mass range. The potential parame-

*Electronic address: nancy.22phz0004@iitrpr.ac.in

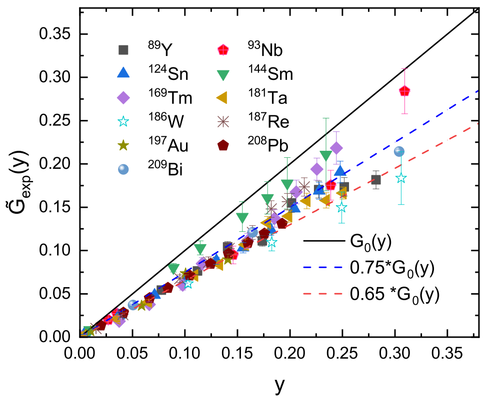

FIG. 1: The Re-normalized IFF against y for ^{9}Be + x systems, where x stands for the different targets ranging from low-medium to heavy-mass region.

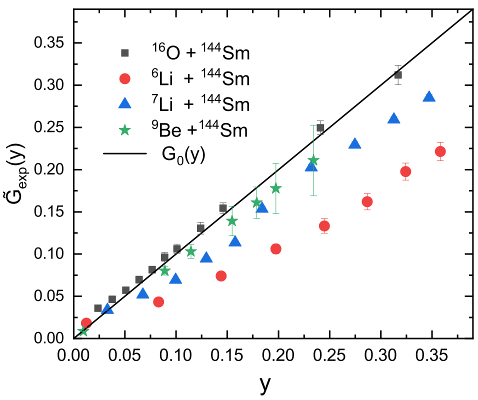

FIG. 2: Experimental IFF plotted against y for different projectiles with ^{144}Sm. The solid line represents the CFL. Symbols are self-explanatory.

ters were derived using the Woods-Saxon parameterization of the Akyuz-Winther potential. Since, in the sub-barrier region, couplings to the inelastic channels are very crucial, the re-normalization of CFF has been done by multiplying it by the $\frac{\sigma_{exp}^{CF}}{\sigma_{cc}^{CF}}$ ratio. This re-normalization would eliminate the influence of couplings with bound channels.

The experimental IFFs for all 11 systems are similar except for ^{144}Sm and ^{186}W. The reduced data can be fitted by a linear function through $\tilde{G}_{exp}$(y) in the range of (0.75-0.65)*G$_0$(y), indicating the fusion suppression in a range of $\sim$ 25-35% for ^{9}Be projectile. Further, to investigate the disparity observed in ^{144}Sm, we have plotted the CF data for different projectiles involving ^{144}Sm in Fig.2. The experimental IFF for a tightly bound projectile, e.g., ^{16}O, lies very close to the CFL, where nuclear structure does not influence the cross-sections at above-barrier energies. Substantial suppression has been observed for ^{6,7}Li projectiles. However, barely any suppression could be seen in the case of ^{9}Be projectile. This observation diverts attention from the suppression factor being sensitive to the projectile break-up threshold energy. The observed behavior of ^{9}Be + ^{144}Sm system in the framework of IFF is quite strange. Further, some data points do not follow the trend at the highest energies and grow much faster with energy. This behavior needs to be further investigated for suitable projectile-target combinations. Detailed analysis will be presented during the symposium.

Acknowledgments

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