Fusion suppression in the ^{9}Be + ^{110}Pd system

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Introduction

Fusion processes are sensitive to the effects of coupling of internal degrees of freedom to the relative motion of the two colliding nuclei, particularly in the vicinity of the potential barrier between them. Of late, there have been developments in the theoretical modeling of reaction systems which offer a more realistic picture. Complete fusion (CF) suppression in reactions induced by weakly bound projectiles at above barrier energies, w.r.t theoretical predictions, has been a topic under investigation since several decades. These nuclei have low binding energy and the breakup feeds states in the continuum, leading to loss of flux from the CF channel. In the case of fusion reactions induced by ^{9}Be projectile, CF suppression by $\sim$ 20% with ^{89}Y [1], $\sim$ 28% with ^{124}Sn [2], $\sim$ 10% with ^{144}Sm [3], $\sim$ 40% with ^{197}Au [4] and $\sim$ 32% with ^{208}Pb [5] have been reported. For fusion studies with light mass targets with $A < 65$, CF cross sections could not be isolated from total fusion. To add to the existing pool of information on CF suppression, and also explore the effects of reaction dynamics on the fusion channel, new measurements have been performed using a target in the medium-mass region: ^{110}Pd. Fusion of ^{110}Pd with ^{9}Be forms the compound nucleus ^{119}Sn, where the residues formed due to neutron emission channels ($3n$-$5n$) are stable ^{115,116,117}Sn isotopes (no β-activity present), making the online γ counting measurement possible. The preliminary results obtained at above-barrier energies are presented in this contribution.

Measurement

The experiment was performed using ^{9}Be beam at lab energies 25-37 MeV at the TIFR-BARC Pelletron Facility, Mumbai. The target comprised of an enriched and self-supporting ^{110}Pd foil of thickness $\approx$ 2.1 mg/cm^2. Emitted γ-rays from the recoiling $^{115-117}$Sn nuclei were detected using the Indian National Gamma Array (INGA), then consisting of fourteen Compton-suppressed HPGe clover detectors, each mounted at a distance of 25 cm from the target center. The clovers were distributed at different angles with respect to the beam direction, namely, two at 40°, four at 90°, two at 115°, three at 140°, and three at 157°. Two Si detectors were placed at $\pm$35° for flux normalization. Time-stamped data were acquired using digital data acquisition system.

Results & Calculations

Emission cross sections for γ-transitions of interest have been extracted using the relation:

$$\sigma(J) = \frac{Y_\gamma(J)}{Y_M}\frac{\mathrm{d}\Omega_M}{\varepsilon_\gamma}\sigma_{\mathrm{Ruth}} \qquad (1)$$

where $Y_\gamma(J)$ is the yield of a γ line after correcting for internal conversion, Y_M and $\mathrm{d}\Omega_M$ are the monitor yield and solid angle, respectively, and ε_γ is the absolute efficiency for that particular γ line. The emission cross sections of the well-studied γ-transitions obtained from the measured inclusive γ-ray spectra are summed to arrive at the CF cross section at each collision energy. Measured excitation function of CF cross section is presented as filled symbols in Fig.1. The lines show the calculations with different models, namely FRESCO and CCFULL. Within the CDCC formalism employed using FRESCO, the ^{9}Be nucleus was considered as a two-body structure composed of i) α + ^{5}He and ii) n + ^{8}Be clusters. The continuum of ^{9}Be $\rightarrow$ α + ^{5}He (2.46 MeV) and ^{9}Be $\rightarrow$ n + ^{8}Be (1.66 MeV) was discretized into momentum bins of width 0.25 fm^{-1} and 0.1 fm^{-1}, respectively, up to a maximum excitation of 6.5 MeV above the breakup threshold. The cluster-folded bare potential in each case has been computed from the individual fragment-target interaction potentials. For the ^{5}He + α structure, relative angular momenta $L = 0, 2$ were chosen to

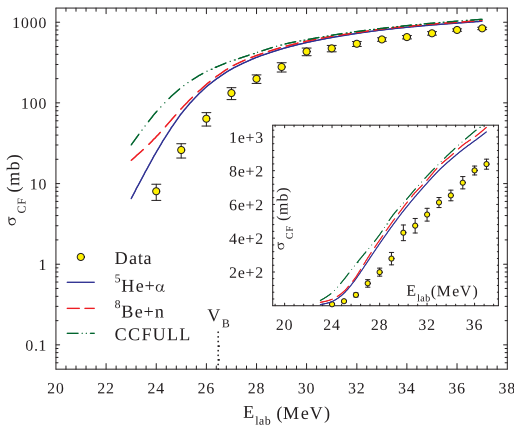

FIG. 1: Measured and calculated excitation function of complete fusion cross section for ^{9}Be+^{110}Pd system.

account for the highly-deformed ground state of ^{9}Be, while the same ground state was constructed with $L = 1$ for the ^{8}Be + n structure. Specific resonant states were defined in accordance with Ref.[6]. The CDCC calculations are seen to overpredict the data throughout the measured energy range. Larger difference between the α + ^{5}He and n + ^{8}Be structures is seen at lower energies. In addition, the data are also compared with CCFULL calculations which exclude any breakup couplings, and are seen to be enhanced over the data as well as FRESCO results.

For comparison among the different models, a reduction method is employed, introduced in Ref.[7], which expresses the differences only in terms of dynamic effects of channel couplings around the barrier energy. In this prescription, the cross sections and collision energies are reduced to dimensionless forms, by defining the Fusion Function, $F(x)$, that effectively points out model-dependent differences in fusion. When no couplings are involved, the Universal Fusion Function (UFF) describes the fusion process in accordance with the Wong fusion model. Fig. 2 lays emphasis on the deviations of $F(x)$ calculated using the results of FRESCO and CCFULL from UFF. A suppression of ∼21% is obtained w.r.t the CDCC framework with α + ^{5}He and n + ^{8}Be clusters, which increases to ∼26% with the CCFULL model, thereby highlighting the inadequacies in each framework.

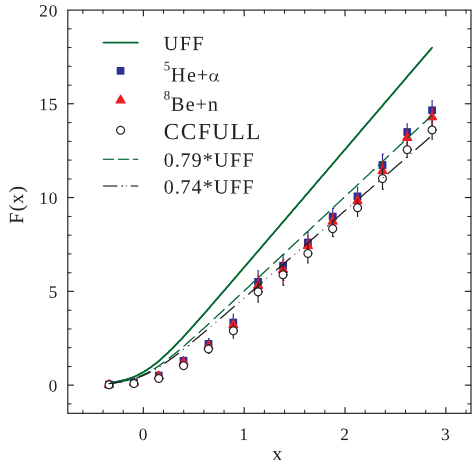

FIG. 2: Experimental fusion functions for the ^{9}Be+^{110}Pd system with the results of the ^{5}He+α, ^{8}Be+n and CCFULL models, compared with the UFF.

Acknowledgments

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