Average angular momentum for fusion of halo and weakly bound nuclei

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Fusion involving weakly bound stable and radioactive nuclei is a topic of current interest [1] and is not well understood. While systems involving stable projectiles show below barrier fusion enhancement as compared to one dimensional barrier penetration model prediction due to coupling to their internal degrees of freedoms, systems involving weakly bound stable nuclei show overall fusion suppression in addition to the below barrier enhancement. Recently measured fusion cross sections for weakly bound radioactive ^{8}B ion on a ^{58}Ni target shows enhancement at all energies rather than showing enhancement at bellow barrier energies only [1]. This has been attributed to proton halo nature of ^{8}B.

Recently, an analytical model for fusion of halo and weakly bound systems has been proposed by Aguilera *et al.* [2]. This model is an extension of the Wong model [3], which is very successful in explaining fusion of tightly bound stable nuclei, for weakly bound stable and radioactive nuclei. The Wong model was actually proposed for reaction cross-section. Since fusion is the most dominant part of the reaction cross section for system involving tightly bound nuclei, Wong model has been extensively used to analyze fusion data and extract fusion barrier parameters for those systems. However, in case of systems involving weakly bound nuclei, contribution of direct reaction channels to the reaction cross section are significant and application of Wong model to fit fusion excitation functions to extract barrier parameters may lead to ambiguous results.

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In the new analytical model [2], the fusion cross section is expressed as

$$\sigma_{fus} = \frac{\pi}{k^2}\sum_{l=0}^{\infty}(2l+1)T_l P_l. \quad (1)$$

The above expression is same as the Wong model expression with $P_l = 1$ for all l values. In the present analytical model it is assumed that $P_l = 1$ for $l \leq L_f$ and $P_l = 0$ for $l > L_f$. This means only partial waves with l less than or equal to L_f (angular momentum limit to fusion) will contribute to fusion cross section.

Fusion data for several systems have been analyzed using the above model and the values of L_f have been extracted [2]. The data for the proton halo system ^{8}B+^{58}Ni, loosely bound system ^{7}Li+^{59}Co, and neutron rich system, ^{6}He+^{209}Bi indicates a linear energy dependence for L_f:

$$L_f = A + B \times E_{c.m.} \quad (2)$$

where A and B are constant.

Balantekin and Reimer has given a prescription to calculate average angular momentum from the fit to fusion excitation [4]. This prescription has been used to calculate average angular momentum and they are found to be in good agreement with the average angular momentum obtained from multiplicity data for systems involving tightly bound nuclei [5]. Good agreement has been also found between the average angular momentum extracted from the fit to the fusion excitation function and the multiplicity data for weakly bound projectile ^{7}Li on ^{165}Ho target [6].

In the present work, we have obtained average angular momentum from the fit to the fusion excitation function as a function of $E_{c.m.}$

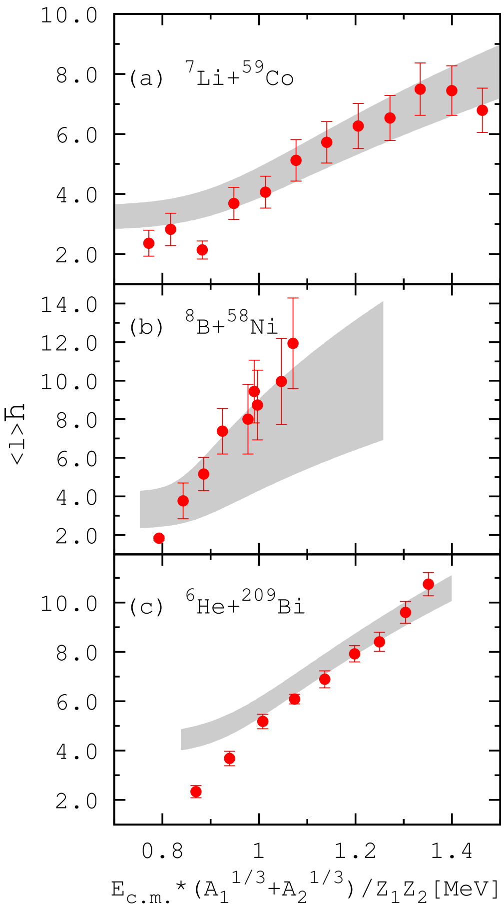

FIG. 1: Results of average angular momentum calculations from the fits to fusion excitation functions and from angular momentum limit (L_f) (see text) are compared for different systems (a) loosely bound system, ^{7}Li+^{59}Co (b) proton rich system,^{8}B+^{58}Ni and (c) neutron rich system, ^{6}He+^{209}Bi.

for three different systems, viz., loosely bound nuclei, ^{7}Li+^{59}Co, proton rich nuclei, ^{8}B+^{58}Ni and neutron rich nuclei,^{6}He+^{209}Bi systems.

Average angular momentum extracted from the fit to the fusion excitation functions according to Balantekin et al. [4] (gray shaded region) are compared with those calculated using the extracted values of L_f from Ref. [2] (filled circles) in Fig. 1. In case of ^{7}Li+^{59}Co, good agreement has been found at above barrier energies. There are agreements within the uncertainties between average angular momentum estimated from these two methods for ^{8}B+^{58}Ni and ^{6}He+^{209}Bi systems at above barrier energies. The average angular momentum values calculated from L_f at above barrier energies are found to be higher for ^{8}B+^{58}Ni, but lower for ^{6}He+^{209}Bi, as compared to those from fit to fusion excitation functions. At below barrier energies, the average angular momentum values extracted from fit to fusion excitation function start to deviate from linear behavior and those calculated from the extracted values of L_f from Ref. [2].

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