Intermediate continuum pairings enhancing two-neutron transfer cross-sections

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Introduction

Transfer reactions have played an instrumental role in building our pyramid of knowledge about light exotic nuclei, mainly because the reaction processes are simple enough to analyse the structure and properties of the nuclei involved. Specifically speaking, two-neutron transfer reactions have enabled an enhanced understanding of the halo nature for two-neutron halo nuclei as they can manifest vital details about valence neutron correlations [1, 2].

These short range correlations can get modified in case of diffused halos as then the so formed Cooper pairs can scatter into the continuum. This would render the consideration of the continuum states into any theoretical study a non-negligible factor. In fact, the couplings among such continuous positive energy states resulting in pairing correlations are thought to strongly enhance two-particle transfer [2, 3]. The enhancement is a result of the coherent interferences of the initial and final wave functions representing the different states that are available in the intermediate $(A+1)$ nucleus. Since Borromean systems are weakly bound, this means the enhancement due to the wave function correlations must involve the transfer to the ground state of the final product nucleus, but through the continuum of the intermediate $(A+1)$ system.

Our aim is to quantify this enhancement due to the pairing correlations via the continuum of the intermediate nucleus. For this purpose, we consider the two-neutron transfer reaction ^{18}O(^{4}He,^{6}He)^{16}O under two different circumstances. In one of the cases, we assume that the neutron transfer takes place from ^{4}He to ^{5}He via the continuum of the latter. Then another neutron is sequentially added to this unbound ^{5}He and ^{6}He is formed. In the second case, we consider the intermediate ^{5}He to have a hypothetical bound state with a one-neutron separation energy $S_n =$ 0.1 MeV, through which the sequential two-neutron transfer occurs.

Formalism

It is known that inclusion of the continuum in reaction studies is a non-trivial task. We discretise the continuum of ^{5}He, both for the unbound and the hypothetically bound case using the pseudostate method. We describe the continuum using the transformed harmonic oscillator (THO) basis [4, 5] and employ the so generated THO wave functions for the bound as well as continuum states. THO allowed us to easily control the density of pseudostates for each of the two cases by varying the γ/b ratio. A smaller ratio usually provides a larger density of states near the threshold. We fixed the values of γ(a factor related to the transition radius) and b (oscillator strength) for the bound and unbound cases at 2.0, 2.0 and 1.0, 1.2 fm, respectively.

Using the THO wave functions, we computed the form factors [6] for the one-neutron transfer process in the *prior* form using the Transfer Form Factors (TFF) code [7]. This was crucial because a wrong choice of the potential can give enormous amounts of transfer. The one-neutron transfer cross-section was then evaluated for the ^{18}O(^{4}He,^{6}He)^{16}O reaction with a lab beam energy of the ^{18}O projectile taken at 100 MeV. This higher beam

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energy enabled us to populate the higher lying states in the ^{5}He continuum while also negating any Q-value effects that might affect the transfer.

The two-neutron transfer cross-sections were calculated in the *prior-prior* form using the modified version of the TFF code. However, we did not consider any excitations or de-excitations in any of the Oxygen or Helium isotopes and also neglected the contribution of $s_{1/2}$ state to the ground state of ^{5}He. Further, the simultaneous transfer terms were assumed to be cancelled by the non-orthogonality transfer terms [6].

Results and Discussion

Fixing the resonant state at $\sim 0.7\,\text{MeV}$ in our discretized continuum basis (which was the third out of a total of 9 basis states considered to represent the ^{5}He continuum), we show in Fig. 1 the results for the probability contribution of each of the basis state configurations.

As can be seen, the major contribution to the transfer should come from the resonant state. However, the correlations between the continuum states and the subsequent pairings result in vital contributions from the non-resonant states as well [3]. The total contribution of the resonant state, using 9 states for discretization, was $\sim$55%, meaning that about 45% of the transfer should be carried out via the non-resonant continuum. The contribution of the continuum state decreases as expected while increasing the number of states for discretization [3] as more channels are available for transfer to occur. On the other hand, one would expect that with a given bound state, most of the contribution should be through the bound ^{5}He. This continuum contribution should provide a way for Borromean ($A + 2$) systems to form in stellar plasma despite the ($A + 1$) system being unbound.

We will also present the results in comparison with the hypothetically bound ^{5}He case and discuss the role of the continuum enhancing the two-neutron transfer cross-section due to pairing correlations.

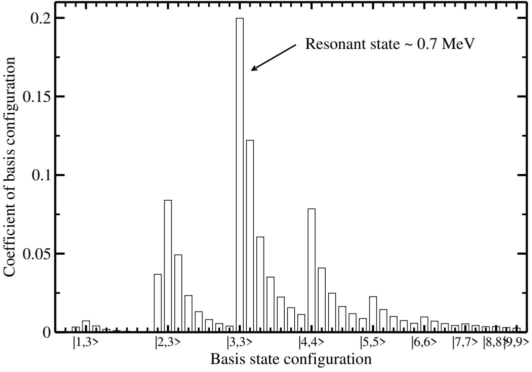

FIG. 1: Probability contribution of each of the basis state configurations discretizing the continuum of ^{5}He for a two-neutron transfer reaction ^{18}O(^{4}He,^{6}He)^{16}O.

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