Influence of pairing interaction on pairing enhancement in a two-neutron transfer

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Advancements in experimental techniques and facilities all over the world, like the large gamma ray arrays combined with charged particle detectors and the advent of radioactive ion beam (RIB) facilities has now made it possible to analyse fascinating phenomenon like enhancement in a pair transfer between specific selected states of weakly bound nuclei. This has rendered neutron transfer reactions, especially two-neutron transfers, to be elegant spectroscopic tools to study the structure of even the exotic nuclei, inlcuding nuclear halos.

As these exotic nuclei are extremely weakly bound with just one or two bound states and usually a broad featureless continuum, the inclusion of the continuum in calculations of the transfer matrix elements is inevitable. One of the reasons for this is because the Cooper pair in a two-neutron transfer will scatter into the low lying continuum. The couplings amongst these continuous positive energy states and pairing correlations then strongly enhance two particle or cluster transfer reactions, giving rise to larger transfer cross-sections than otherwise. These correlations arise from the coherent interferences of the many transfer paths available to the neutrons when traversing to through the intermediate A+1 nucleus (going from a nucleus A to A+2). Information about these correlations can be directly obtained from single particle transfer form factors, whose knowledge can in turn be derived from initial and final state wave functions. The correlated neutrons, thus, play a crucial role in pairing enhancement in two-neutron transfers [1].

The inclusion of this continuum, however, is tricky because of the highly oscillatory and non-square integrable nature of the continuum wave functions. Moreover, the quantification of the contribution of the continuum towards pairing enhancement is a vital problem that needs to be solved. Recently, attempts have been made to quantify this contribution towards pairing enhancement by proper inclusion of the continuum states [2, 3] using the transformed harmonic oscillator (THO) approach for discretisation [4] via a modified version of the Transfer Form Factors (TFF) code [5]. The process, through the ^{18}O(^{4}He,^{6}He)^{16}O reaction, involved sequential addition of two neutrons to form ^{6}He, which was described as housing two neutrons in the orbitals of the intermediate ^{5}He nucleus. Pairing enhancement comparisons were made by considering bound and unbound ^{5}He systems and it was found that pairing enhancement was, indeed, more prevelant through the continuum. When passing through the unbound continuum of ^{5}He, the existence of a resonance proved crucial. Further, the final bound state of ^{6}He was fixed while the pairing interaction between the two neutrons, described by contact delta interaction, was kept constant.

This contribution tries to deal with the situations when the pairing interaction is not fixed, such that final state in ^{6}He could be different. This variation is crucial to put the fundamental understanding of the role of the continuum on a firmer footing, as then it can be coupled with future studies of transfers from higher lying resonances. The reaction studied was again ^{18}O(^{4}He,^{6}He)^{16}O, but unlike in Ref. [2], only the high beam energy case, with a total lab beam energy of 100 MeV is considered. This enabes to negate any effects that the Q-value might have during the transfer, besides facilitating the occupation of higher energy spectrum. The calculations, not unlike the ones in Refs. [2, 3], followed the sequential two-neutron transfer formalism by Broglia and Winther [6] under the *prior* form. However, unlike Ref. [2], only the bound case of ^{5}He is discussed here, which has a hypothetical bound state at 1 MeV. This is done with

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a view to enable an understanding of transfer reactions with all weakly bound intermediate systems. In all, eight states were used for the descretisation of the ^{5}He spectrum.

The results for the calculation of occupation probabilities for each of the resultant basis state configurations generated via the THO basis are dislayed in Fig. 1. Two extreme values of the pairing interaction, Δ are chosen: (i) $\Delta = 1\,\text{MeV}$ to be comparable to the bound state energy of the intermediate nucleus ^{5}He, and (ii) An absurdly large $\Delta = 17\,\text{MeV}$ (generated from the same coupling strength as in Ref. [2]) to explore the other end of the rope. It must be acknowledged here that though the possibility of a simultaneous transfer increases tremendousy at this value of Δ, however, the correlation length of the Cooper pair would still be large enough such that there is a significant contribution of the sequential transfer. Further, as the projectile and target are spin zero entities, the simultaneous contribution gets cancelled exactly by the non-orthogonal terms [1, 6].

It is found that when the pairing interaction, induced by contact pairing interaction, changes significantly for the bound ^{5}He, the probability of occupation also changes. However, noteworthy is that even with a Δ as large as 17 MeV for a bound system with $S_n = 1\,\text{MeV}$, the rise in the probability of occupation of higher lying states is too small and almost negligible. The total contribution of the bound state, denoted as $|1, p\rangle$ with at least one particle in the ground state and the other in any of the p states ($1 \leq p \leq 8$) decreases marginally from 99.9% to 97%. The contribution of the ground state alone ($|1, 1\rangle$), on the other hand, reduces from 98% to 79%, but still has the overall majority.

This points to the affinity of the transfer to populate strongly through the bound state, even though the bondage in the Cooper pair is much stronger and the higher lying spectrum is available for occupation. Of course, for a complete understanding, similar analysis much be done for the naturally unbound ^{5}He, where results manifest an even more interesting feature (and which will be presented at the meeting; they are not shown here for brevity) where the higher lying states start to contribute significantly more. It is essential, therefore, to quantify the role of the intermediate nucleus during a two-neutron transfer, as then mechanisms for formation of Boromean halos and weakly bound exotic nuclei lying near the drip lines becomes clearer. The absence of a resonance in such an intermediate state and the quantification of its contribution is an open problem that can then be tackled in a better manner, as can the studies of multi-nucleon transfer be better comprehended and understood.

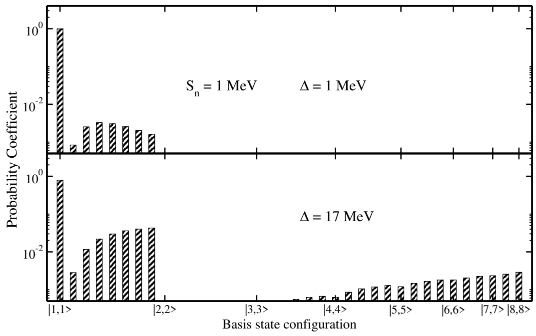

FIG. 1: Probaility of occupation for different basis states used to generate the spectrum of a hypothetically bound ^{5}He in the sequential two-neutron transfer reaction ^{18}O(^{4}He,^{6}He)^{16}O for two comparative cases of pairing interaction. The rising occupation for higher lying states is observed, but is not significant enough when seen in light of the strength of the pairing.

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