EXPLORING CONTINUUM STRUCTURES WITH A PSEUDO-STATE BASIS

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Nuclear Reactions

During the last few years, reactions involving loosely bound exotic nuclei have been one of the most active fields in Nuclear Physics. This kind of reactions is known to be strongly influenced by the coupling to the unbound states. Therefore, there has been a great interest in finding a realistic description of the continuum of these nuclei.

In this respect, the development of the Continuum-Discretized Coupled-Channels (CDCC) method [1] has allowed the inclusion of the coupling to the break-up channels by means of a representation of the continuum of the weakly bound nucleus. Since the continuum consists of an infinite number of states, a correct discretization into a finite number of representative states is critically important to reproduce the possible excitations and de-excitations. The standard method of continuum discretization consists on dividing the continuum into a set of energy or momentum intervals. For each interval, or bin, a representative wave function is constructed by means of a weighted average of scattering states within the interval (the average method). Alternatively, one can use a pseudo-state (PS) method, in which the wave functions describing the internal motion of the projectile are obtained as the eigenstates of the projectile Hamiltonian in a truncated basis of square-integrable functions. In practice this Hamiltonian will be a two-body decomposition of the projectile, not excluding future applications to more complicate Hamiltonians.

In this work we investigate a PS method based on the application of a Local Scale Transformation (LST) to the Harmonic Oscillator (HO) basis, giving rise to the so called Transformed Harmonic Oscillator (THO) basis. Specifically, for the LST we adopted the parametric form of Ref. [2]:

$$s(r) = \frac{1}{\sqrt{2}b}\left[\frac{1}{\left(\frac{1}{r}\right)^m + \left(\frac{1}{\gamma\sqrt{r}}\right)^m}\right]^{\frac{1}{m}} .$$

Asymptotically, the functions obtained by applying this LST to the HO basis behave at large distances as $exp(-\gamma^2 r/2b^2)$. Therefore, the ratio γ/b can be related to an effective linear momentum, $k_{eff}=\gamma^2/2b^2$, which governs the asymptotic behaviour of the THO functions; as the ratio γ/b increases, the radial extension of the basis decreases and, consequently, the eigenvalues obtained upon diagonalization of the Hamiltonian in the THO basis tend to explore higher energies. Therefore, γ/b determines the density of PS as a function of the excitation energy as we have found in previous studies [3]. That allows us to concentrate the eigenstates in the region of interest for each case, drastically reducing the minimum number of THO functions, N, needed to obtain

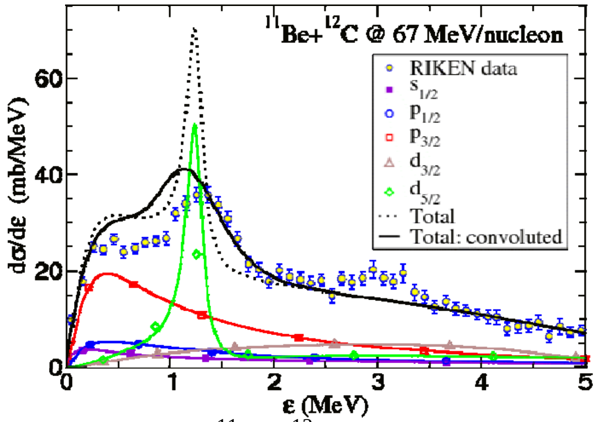

Fig. 1. Break-up cross section for ^{11}Be+^{12}C reaction including the contribution of the different waves, the total sum, the total convoluted with the experimental resolution and the experimental data from [5].

convergence of the scattering observables. Even more interesting is the fact that, if the potential supports a resonance, for low values of *N*, one or two eigenstates tend to concentrate in the neighbourhood of the resonance. As a consequence, these eigenstates reproduce the main contribution of the resonance whereas in the binning method we would need a large number of bins to describe it accurately.

In order to show this, we have studied three different nuclei using in all cases a two body model. In the well-known deuteron case, we have found that the THO method obtains accurate values of important magnitudes such as the energy of the ground state, the E1 and E2 electromagnetic transition probabilities, and the polarizability with a considerably small basis. To illustrate the use of the THO basis to nuclear collisions, we have considered the reactions ^{6}He+^{208}Pb, ^{6}He+^{12}C and ^{11}Be+^{12}C. Both ^{6}He and ^{11}Be are weakly bound exotic nuclei with well-known low-lying resonances. For ^{6}He we find that a simple di-neutron model (^{6}He=^{4}He+2n) is able to reproduce the break-up cross sections of ^{6}He+^{208}Pb and ^{6}He+^{12}C [4]. In the latter case, we find that only one eigenstate perfectly describes the amount of break-up produced by the resonance. In the ^{11}Be+^{12}C reaction we use a two-body description of the projectile where only the ground state of ^{10}Be is considered explicitly. In Fig. 1 we compare the calculated energy differential break-up cross section with the data from Ref. [5]. We find that about 11 eigenstates are enough to reproduce the whole $d_{5/2}$ contribution while in the average method a recent study [6] needs 15 bins just to reproduce the $d_{5/2}$ resonance.

In conclusion, the PS method using a THO basis is able to accurately reproduce break-up observables related with the structure of the continuum of the projectile. Moreover, compared with other methods and bases, the THO method allows us to reduce the number of functions needed to describe reactions with loosely bound nuclei. This is particularly suitable in situations where narrow resonances are involved.

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