Renormalized self consistent continuum random phase approximation

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The random-phase approximation (RPA) has been widely used in the theoretical study of nuclei within the valley of β-stability. The success of the RPA is mainly based on the use of the quasiboson approximation (QBA), which considers fermion pairs as boson operators, just neglecting the Pauli principle between them. As a result, a set of linear equations, called the RPA equations, was derived, which reveals the physics of collective excitations generated by the RPA boson like modes. The simplicity of the RPA equations allows a feasible treatment of a number of many-body problems, which would be computationally intractable otherwise. However, this approach suffers a drawback: It breaks down at a certain critical value of the interaction's parameter, where the RPA yields imaginary solutions. The reason of this well-known RPA instability is the violation of Pauli principle within the QBA.

In β-stable medium and heavy nuclei, the QBA is a good approximation, and the RPA is a very powerful tool for the description of several important quantities such as the ground state and excited-state energies, electro-magnetic transition probabilities and their distribution, transition densities, etc. However, with the decrease of particle number, the concept of collective excitations, which are described by the RPA modes, becomes less and less firm. The ground-state correlations (GSC) that are beyond the RPA become stronger in light systems. This feature makes the validity of the QBA, and therefore of the RPA itself, questionable in systems with small particle numbers. Several approaches were developed to take into account the GSC beyond RPA in a simple way in order to restore the Pauli principle among the fermion pairs, from which the RPA operators are constructed. The popular one, known as the renormalized RPA (RRPA) [1,2], includes the expectation values over the ground state of the diagonal elements of the commutator between two fermion-pair operators, which are neglected in the QBA. In this way the Pauli principle is approximately taken care of. The inclusion of GSC beyond RPA within the RRPA eventually renormalizes the interaction in such a way that the collapse of RPA is avoided, and the RRPA has solutions at any values of the interaction's parameter.

By approaching the drip line the Fermi level is getting closer to zero. The continuum starts to be involved into the phase space around the Fermi surface, where the particle correlations are strongest. This means that the coupling between bound states and the continuum becomes more and more important. The discretized RPA approaches, which are constructed using discrete single-particle states, should be replaced with the continuum RPA (CRPA), where the effect of coupling to continuum is properly taken into account.

Therefore, for a proper study of unstable light nuclei one should take into account simultaneously both effects of the GSC beyond RPA and the coupling to the continuum. This is the aim of the our research work. We will apply the method of renormalizing RPA proposed by Catara, Dang, and Sambatarto [2] to renormalize the selfconsistent CRPA (SCRPA) developed by Shlomo and Bertsch [3]. As a result of such renormalized SCRPA (RSCRPA), we obtain a set of equations for the single-particle transition densities, which should be solved self-consistently with the equations for the Green functions within the RSCRPA. The developed approach will be applied to calculate the properties of electromagnetic excitations such as pygmy and giant resonances in stable and unstable nuclei.

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