Spatial correlation of a particle-hole pair with a repulsive isovector interaction†

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It has been well recognized that the pairing correlation among valence neutrons plays a decisive role in the structure of weakly bound nuclei. In particular, there have been several theoretical studies of a strong dineutron correlation, in which two neutrons attract each other and show a large probability of a two-body wave function with a small correlation angle in the coordinate space. A strong signature of the dineutron correlation has also been experimentally observed in several weakly bound nuclei such as ^{11}Li, ^{6}He, and ^{19}B.

It would be an interesting question to ask what happens to the spatial correlation when the interaction is repulsive rather than attractive. Besides the trivial Coulomb repulsion between protons, a well-known repulsive interaction in nuclear physics is the isovector particle-hole (p-h) interaction, which plays an important role in generating collective giant dipole resonances (GDRs). In this paper, we pursue the correlation induced by the repulsive interaction, studying nuclei with one neutron particle and one proton hole on top of a doubly magic nucleus, such as ^{56}Co ($=$ ^{56}Ni$+n-p$) and ^{40}K ($=$ ^{40}Ca$+n-p$). To construct the density distribution for the p-h state, we perform the Hartree-Fock (HF) plus Tamm-Dancoff approximation (TDA) with Skyrme-type interactions.

The spatial distribution for the proton hole in the two-dimensional (z, x) plane is shown in Fig. 1(a) for the 4^+ state in ^{56}Co with the azimuthal angular momentum component $M = 0$. The reference neutron ($2p_{3/2}$ particle state) is placed at $(z, x) = (3.7, 0.0)$ fm. The upper panel shows the unperturbed case with the $(1f_{7/2})_p^{-1}$ wave function. As expected, the hole wave function $(1f_{7/2})_p^{-1}$ has two symmetric peaks at the positions opposite to the center of the core nucleus. The correlated hole density, in which the p-h repulsive interaction is active, is shown in Fig. 1(b). One can see a strong repulsive correlation, where the component close to the reference neutron-particle state is largely hindered. This is analogous to the Coulomb hole observed in many-electron systems and is completely opposite to the dineutron configuration, in which the two valence neutrons mainly remain on the same side of the two-dimensional plane with a small relative distance, that is, a small correlation angle.

In Ref. 1), as an outcome of the repulsive correlation of an isovector p-h pair, a suppression of a ground-state-to-ground-state deuteron transfer reaction, *e.g.*, ^{54}Fe(^{3}He$, p)^{56}$Co, was pointed out. Note that the two proton holes in ^{54}Fe prefer the spatial configuration in which the two holes are close to each other. If one of those proton holes is filled in via deuteron transfer, the neutron in the deuteron and the other proton hole would be located close to each other. This would correspond to an excited state of ^{56}Co; thus, the transfer to the ground state of ^{56}Co would be largely suppressed. It would be interesting future work to estimate the transfer cross sections with the coupled-reaction-channel method or second-order distorted wave Born approximation.

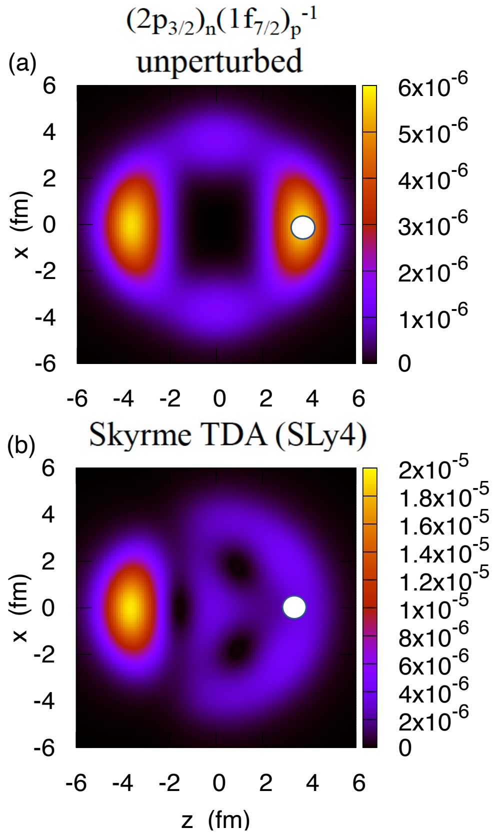

Fig. 1. Uncorrelated (upper panel) and correlated (lower panel) proton-hole distributions in the two-dimensional (z, x) plane for the 4^+ state in ^{56}Co when the neutron-particle is located at $(z, x) = (3.7, 0.0)$ fm indicated by a white circle. The azimuthal angular momentum component is set to be $M = 0$.

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Reference

1) G. F. Bertsch, Phys. Lett. B **25**, 62 (1967).