Spin-singlet and spin-triplet pairing correlations on shape evolution in sd-shell $N = Z$ Nuclei†

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Pairing correlations play an important role in nuclear structure, and have an important effect on nuclear electro-magnetic (EM) and weak transitions. The pairing correlations are classified into like-pairing (neutron-neutron (nn) and proton-proton (pp)) and unlike-pairing (neutron-proton (np)) correlations. In particular, for $N = Z$ nuclei, the np pairing may become significant because protons and neutrons occupy the same orbital and have the maximum configuration overlap, which is important especially for the $T = 0$ pairing. The nn and pp pairings have isovector (IV) spin-singlet ($T = 1$, $J = 0$) mode, while the np pairing correlations have peculiar isoscalar (IS) spin-triplet ($T = 0$, $J = 1$) as well as IV spin-singlet mode. Over the last few decades, there have been many discussions regarding the np pairing correlations, in particular, the coexistence of IS and IV correlations and their competitions in some specific nuclear observables.

Recently, interesting experimental data have been reported, which show more quenching in the IV M1 spin transition data for the $N = Z$ sd-shell nuclei[1)] than the IS data. These features are not expected according to former theoretical discussions.[2,3)] It was pointed out in Ref. 4) that the $T = 0$ pairing plays a significant role to cause these features in the spin dependent observables.

We studied the shape evolution of $N = Z$ nuclei, ^{24}Mg, ^{28}Si, and ^{32}S in the deformed Woods-Saxon (DWS) and deformed BCS (DBCS) approximations taking into account both $T = 0$ and $T = 1$ pairing correlations. In the filling approximation for the DWS potential, it is shown that the shape evolution strongly correlates with the shell structure of s.p. energies near the last occupied orbit (Fermi energy). The effect of two types of pairing correlations with isospin $T = 0$ and $T = 1$ are studied by the DBCS model with G-matrix-based pairing interactions. We adopted an enhanced $T = 0$ pairing interaction to clarity the effect of $T = 0$ pairing on the ground state energy. In Fig. 1, we used a stronger $T = 0$ interaction (50% stronger than the G-matrix results[4)]), which makes the pairing correlations more transparent, especially at the large prolate deformation and leads to the deep prolate deformation minimum in ^{24}Mg. A drastic change in the pairing correlation energy is induced by the active $T = 0$ pairing channel on top of the usual $T = 1$ channel, implying that the two paring channels co-exist in the large deformation region.

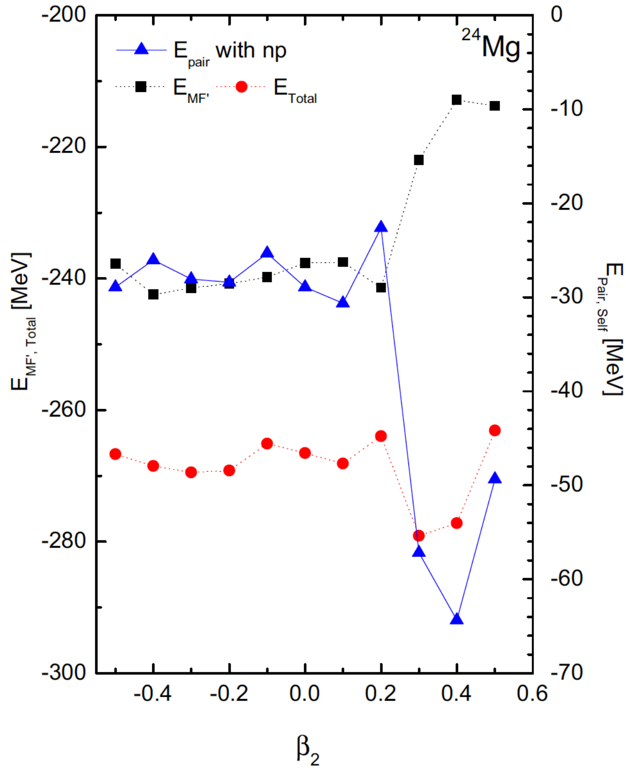

Fig. 1. The ground state energy ($E_{\rm total} = E_{\rm MF'} + E_{\rm pair}$) for ^{24}Mg by the DBCS model with Woods-Saxon potential. Mean field energy by the DBCS is denoted as $E_{\rm MF'}$. $E_{\rm pair}$ is the pairing energy in the right y-axis. The pairing energies are estimated with enhanced T = 0 pairing in np channel.

In summary, we found a coexistent phase of two types of superconductors in the large deformation region $|\beta_2| > 0.3$ in ^{24}Mg, ^{28}Si and ^{32}S with the enhanced $T = 0$ pairing. The competition between $T = 0$ and $T = 1$ pairing channels substantially affect the energy minima of ^{24}Mg, ^{28}Si and ^{32}S. Our model gives a reasonable deformation minima for these nuclei, *i.e.*, prolate for ^{24}Mg and ^{32}S and oblate for ^{28}Si.

References

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