Three-body model for IS spin-triplet neutron-proton pair in ^{102}Sb†

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As the progress of radio-isotope beam facilities allows to access nuclei near the $N = Z$ line, the neutron-proton pairing has been attracting more interest than before. In general, a condition expected to maximize the chance for valence nucleons to form $T = 0$ pairs is that they lie in the orbitals on top of a $N = Z$ closed-shell core, and that both $j_>$ and $j_<$ orbitals with low l are vacant in the valence space. In addition, a large nuclear mass is favorable because the effect of the spin-orbit field at the surface becomes relatively weak. In the present study, we focus on the $^{102}\mathrm{Sb} = {}^{100}\mathrm{Sn}+p+n$ system, the core of which, ^{100}Sn, is the largest $N = Z$ doubly-magic nucleus located immediately below the proton drip line. In this system, the valence nucleons can occupy d-wave states as in the ^{18}F nucleus, in which the strong effect of the $(S, T) = (1, 0)$ coupling channel is observed as an implementation of the good SU(4) symmetry.[1)]

In the present study where we have ^{100}Sn as the core, we take a self-consistent mean-field Hamiltonian for the single-particle part, $H = h_{\mathrm{HF}}(p) + h_{\mathrm{HF}}(n) + V_{\mathrm{res}}(p, n)$, where h_{HF} is the single-particle Hartree-Fock Hamiltonian. For the residual interaction V_{res}, we take density-dependent zero-range pairing interactions which have both spin-singlet and spin-triplet channels.

We calculate the neutron single-particle energies in the ^{100}Sn nucleus with three non-relativistic (SLy4, SkM*, and SIII) and three relativistic point-coupling (PC-F1, PC-PK1, and PC-LA) EDFs. In particular, we found that, with the relativistic interactions, the $1g_{7/2}$ level is nearly degenerate with the $2d_{5/2}$ level. In contrast, with the Skyrme functionals except for SIII, the $1g_{7/2}$ level is located well above the $2d_{5/2}$ state and close to the $2d_{3/2}$ level. This difference may induce a substantial effect on the structure of the system as well as the $(T = 0, S = 1)$ pair coupling because it prevents the valence nucleons from efficiently gaining the pairing energy in $(d)^2$ configurations. This near degeneracy with the relativistic EDFs is due to the pseudo-spin symmetry which originates from the cancellation of large scalar and vector fields. Note that a γ ray of 172 keV between the first-excited and the ground states of ^{101}Sn has been measured in Refs.[2,3)] and interpreted as a single-neutron transition between the $d_{5/2}$ and $g_{7/2}$ levels.

We have applied a new three-body model based on self-consistent HF fields to the $^{102}\mathrm{Sb} = {}^{100}\mathrm{Sn} + p + n$ nucleus. The low-lying 0^+ and 1^+ states are discussed in terms of the relation between their excitation energies and the coupling between the two valence nucleons in the $T = 0$ channel. The $T = 1$ interaction strength is fixed by the empirical neutron pairing gap, and the $T = 0$ strength is estimated from the 1^+_1 and 0^+_1 energy differences in known $N = Z$ odd-odd nuclei.

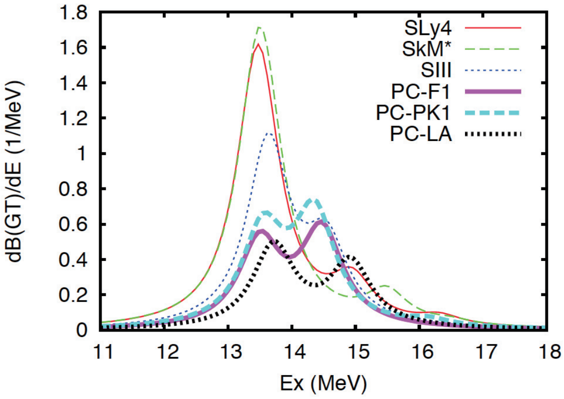

Fig. 1. (Color online) Gamow-Teller strength distributions as a function of the excitation energy from the ground state of ^{102}Sn. The ratio between IS and IV pairing strength is taken as $f = 1.5$.

We show in Fig. 1 the B(GT) distribution as a function of the excitation energy with respect to the 0^+_1 state of ^{102}Sn. A clear difference between non-relativistic and relativistic cases is observed while the low-lying 0^+ and 1^+ energy spectra are similar to each other, i.e., the strength distribution is concentrated at the first peak for SLy4 and SkM*, whereas it is fragmented into the first and second peaks for PC-F1, PC-PK1, and PC-LA. SIII shows a characteristic in between those of the two types of EDFs. By analyzing the compositions of wave functions, we observe that the enhanced occupation of the $g_{7/2}$ orbital in the relativistic model breaks the $(L, S, T) = (0, 1, 0)$ coupling scheme of the two valence nucleons, and it results in the substantial difference in the low-lying Gamow-Teller strength distributions.

In conclusion, it is expect that the coupling in the $(L, S, T) = (0, 1, 0)$ channel is strongly suppressed in the $^{100}\mathrm{Sn} + p + n$ nucleus owing to the $g_{7/2}$ orbital, which is nearly degenerate with the $d_{5/2}$ orbital. The effect appears clearly in the low-lying B(GT$_-$) distribution rather than in the energy difference between 1^+_1 and 0^+_1 states.

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