Di-neutron correlation in pair-addition vibrational mode of the neutron-rich Sn isotopes†

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Recently, two-neutron transfer in unstable nuclei has attracted attention since the experiments using radioactive ion beams became possible[1,2]. Anticipating future experiments, we have been theortically investigating two-neutron transfer modes in heavy-mass neutron-rich nuclei. A good example is of neutron-rich Sn isotopes with $A \geq 132$, for which we predict enhanced pair-addition transfer populating the ground states (pair rotation) or the low-lying 0^+ states (pair vibration) in the neighboring $\Delta N = 2$ isotopes[3]. In this works we analyze in detail the microscopic structure of the two-neutron transfer modes, and we show that di-neutron correlation appears in the pair vibrational mode of the neutron-rich Sn.

We describe the two-neutron transfer using the Hartree−Fock−Bogoliubov (HFB) mean-field theory and the continuum quasiparticle random phase approximation (QRPA)[3,4]. The Skyrme functional with the parameter SLy4 is adopted. For pairing interaction, we choose the density-dependent delta interaction.

We analyze the microscopic structure of the two-neutron transfer modes in the Sn isotopic chain, especially the pair-addition vibrational mode in $^{132-140}$Sn. Within the QRPA theory, one can characterize an excitation mode in terms of forward- and backward-propagating amplitudes $X^{\nu}_{ii'}$ and $Y^{\nu}_{ii'}$ for the two-quasiparticle configuration $ii' = (nlj)\,(n'l'j')$. The index ν is a label for QRPA normal modes, and excitation energy is denoted as $\hbar\omega_\nu$. Concerning the low-lying pair vibration state predicated to appear at $\hbar\omega_\nu = 3.81$ MeV in ^{134}Sn, for example, the main two-quasiparticle configurations ($|X^{\nu}_{ii'}| > 0.1$) are $[3p_{3/2}]^2$, $[1h_{9/2}]^2$, $[2f_{7/2}]^2$, $[2f_{5/2}]^2$, $[1i_{13/2}]^2$, $[3p_{1/2}]^2$, and $[3p_{3/2}][4p_{3/2}]$. These quasiparticle orbits are weakly bound or unbound resonant quasiparticle states. Similarly, the transition density $P^{(\mathrm{ad})}_{\nu L=0}(r)$ for the monopole ($L = 0$) pair-transfer operator can be decomposed as $P^{(\mathrm{ad})}_{\nu 0}(r) = \sum_{ii'} P^{(\mathrm{ad})}_{\nu 0,ii'}(r)$ in terms of the two-quasiparticle configurations. For the main components, the amplitude of these decomposed transition densities are significantly smaller than that of the total transition density. Even if we sum the main decomposed transition densities, it reproduces approximately half of the total transition density. This suggests that the low-lying pair vibration in ^{134}Sn has a some degree of collectivity.

Figure 1 shows the transition density $P^{(\mathrm{ad})}_{\nu 0}(r)$ and the partial sums of the decomposed transition densities, $P^{(\mathrm{ad})}_{\nu 0,l_{cut}}(r) = \sum_{ii',l\leq l_{cut}} P^{(\mathrm{ad})}_{\nu 0,ii'}(r)$, for various values of the angular momentum cut-off l_{cut}. Although the partial sums ($P^{(\mathrm{ad})}_{\nu 0,l_{cut}}(r)$) of each high-l component are very small, the inclusion of these small transition densities is necessary to reproduce the total transition density. The highest orbital angular momentum of the occupied Hartree−Fock single particle orbit in ^{134}Sn is $l_{occ} = 5(1h_{11/2})$. However it is clear that the large value of the orbital angular momentum contributes to the total transition density. The coherent accumulation up to high-l contributions in the pair-addition vibrational mode suggests the di-neutron[5] correlation discussed in the same manner in Ref.[4, 6].

We find that the di-neutron correlation in the low-lying pair vibration of $^{132-140}$Sn is formed by large numbers of weakly bound and unbound continuum quasiparticle states. Therefore, even if the positions of the quasiparticle states are varied for other Skyrme parameter sets, this di-neutron character may be observed in the low-lying pair vibration or pair rotation of the neutron-rich Sn isotopes with $N \geq 82$.

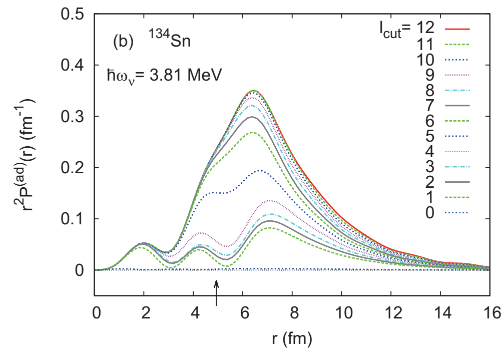

Fig. 1. Decomposition of the pair-addition transition density $P^{(\mathrm{ad})}_{\nu 0,l_{cut}}(r)$ of the pair-addition vibrational mode in ^{134}Sn with respect to the orbital angular momentum cutoff $l_{cut} = 0, 1, 2, \cdots, 12$. The arrow indicates the neutron rms radius $R_{N,rms} (= \sqrt{\langle r_n^2 \rangle}) = 4.93$ fm.

References

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