Enhancement of pairing fluctuation in neutron-rich Mg isotopes studied by Skyrme QRPA calculation

M. Yamagami *1

Nuclei close to the drip line often exhibit novel features that do not appear in stable nuclei. An example is dineutron correlation, which is the strong spatial correlation between two neutrons of a Cooper pair. The pair excitation into continuum states (continuum effect) plays a key role to create the strong correlation. Dineutron correlation has been extensively investigated both experimentally and theoretically in light-mass nuclei such as ^{11}Li. We also expect dineutron correlation in medium-heavy neutron-rich nuclei, for example, around ^{40}Mg,[1] which are accessible in RIKEN RIBF. However, no evidence has been obtained thus far. In this study, we discuss $K^\pi = 0^+$ isoscalar quadrupole excitations in neutron-rich Mg isotopes as a probe of dineutron correlation. We emphasize the continuum effect for the collectivity of excitations.

At first, we solve the Hartree-Fock-Bogoliubov (HFB) equation by using the Fourier-series expansion method. The Skyrme SkM* parametrization and the mixed-type density-dependent zero-range pairing force are employed. The pairing correlation is active among single-particle states with the energies ε_k satisfying $|\varepsilon_k - \lambda| < E_{cut}$. Here, λ is the chemical potential and E_{cut} is the cut-off energy. On top of the HFB states, we solve the quasiparticle random phase approximation (QRPA) equation in the matrix form.[2]

The ground states of ^{34,36,38,40}Mg have quadrupole deformations β_2 = 0.243, 0.262, 0.265, and 0.259, and neutron pairing gaps Δ_n = 2.13, 2.05, 2.02, and 2.04 MeV in our calculation. Figure 1 (upper) shows the excitation energies E of the $K^\pi = 0^+$ isoscalar quadrupole excited states $|\nu\rangle$. Figure 2 shows the transition strength of quadruple-pair excitations $B(P_{20}^{(ad)}) = |\langle\nu| P_{20}^\dagger |0\rangle|^2$ with the quadrupole-pair additional operator $P_{20}^\dagger$. The results with E_{cut} = 6, 8, 10, and 12 MeV are compared. Here, $E_{cut} = 6$ is a typical value in stable nuclei. A larger E_{cut} increases the coupling to continuum states. We found the large enhancement of $B(P_{20}^{(ad)})$ as a function of E_{cut} in ^{38,40}Mg, the neutron chemical potentials of which $\lambda_n = -1.57$ and -0.77 MeV satisfy $|\lambda_n| < \Delta_n$. Here, the $B(P_{20}^{(ad)})$ with E_{cut} = 12 MeV is small at approximately 10% in ^{40}Mg from the converged value of 215 fm^4 from extrapolation with the exponential-type function of E_{cut}.

Figure 1 (lower) shows the isoscalar transition strength $B(IS2) = |\langle\nu| r^2 Y_{20} |0\rangle|^2$. This vibration of matter density is induced by the fluctuation of neutron-pair occupation among Nilsson orbits with different spatial shapes. In ^{34}Mg, the prolate-type orbits [330]1/2 and [321]3/2 and the oblate-type orbit [202]3/2 are involved. In ^{38,40}Mg, the prolate-type orbits [310]1/2 and [301]1/2 and the oblate-type orbit [303]7/2 are the main contributors. The large pairing fluctuation enhances the $B(IS2)$ around ^{40}Mg. Actually, the ratio of $B(IS2)$ in ^{40}Mg and ^{34}Mg is 1.32 with E_{cut} = 12 MeV, while 1.01 with E_{cut} = 6 MeV.

In conclusion, we discussed the pairing fluctuation and the induced $B(IS2)$ values of $K^\pi = 0^+$ isoscalar quadruple excitations in neutron-rich Mg isotopes. We predicted the enhancement of $B(P_{20}^{(ad)})$ by the continuum effect in ^{38,40}Mg. This phenomenon suggests the presence of dineutron correlation and can be observed by a two-neutron transfer experiment. The $B(IS2)$ values also contain indispensable information about the shell structure and pairing properties.

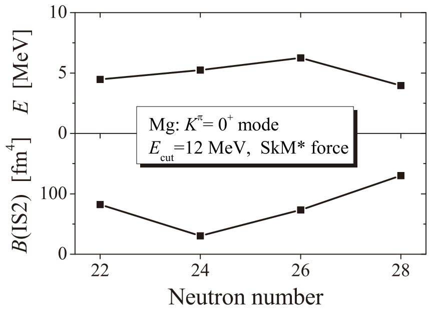

Fig. 1. Excitation energies E and $B(IS2)$ values of the $K^\pi = 0^+$ excitations in neutron-rich Mg isotopes.

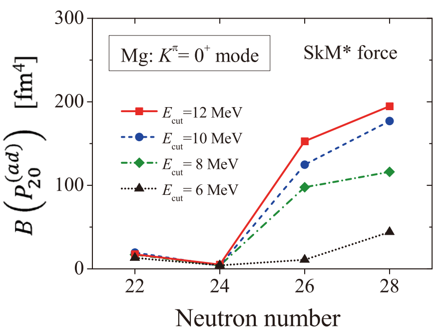

Fig. 2. Transition strength of quadruple-pair excitations $B(P_{20}^{(ad)})$ of the $K^\pi = 0^+$ excitations. The results with E_{cut} = 6, 8, 10, and 12 MeV are compared.

References
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2) M. Yamagami *et al.*, RIKEN Accel. Prog. Rep. **50**, 92 (2017).

*1 Department of Computer Science and Engineering, University of Aizu