Dineutron correlation and rotational excitations in neutron-rich Mg isotopes

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The spatial two-neutron correlation between two weakly-bound neutrons, called dineutron correlation, is one of the unique features of nuclei around the neutron drip line. It is considered to be a universal phenomenon that appears over all mass-number regions. However, experimental probes for this phenomenon are still under intense debate, except for light-mass nuclei such as ^{11}Li. In this study, the influences of the novel pairing effect on rotational excitations in neutron-rich Mg isotopes are clarified.

The experimental moment of inertia (MOI), which can be extracted from the excitation energy $E(2_1^+)$, is smaller than the rigid-body values by a factor of 2 to 3. The most important influences in this respect are pairing correlations. I calculate the Thouless-Valatin (TV) MOI, which includes the pairing correlations and residual interactions within the framework of the quasiparticle random phase approximation (QRPA).

The Hartree-Fock-Bogoliubov (HFB) equation with the Skyrme energy density functional (EDF) is solved in the three-dimensional wave-number mesh space.[1)] On top of the HFB states, the QRPA equation in the A-B matrix form[1)] is solved for the TV MOI:

$$\mathfrak{I}_{\mathrm{TV}} = 2 \sum_{kk',ll'} (J_x)^*_{kk'} (A+B)^{-1}_{kk',ll'} (J_x)_{ll'}. \quad (1)$$

The Skyrme SkM* EDF predicts the neutron drip line at ^{44}Mg. The quadrupole deformations of ^{34,36,38,40,42,44}Mg are β = 0.35, 0.30, 0.28, 0.28, 0.21, and 0.15 respectively. Figure 1 shows the neutron pairing gaps Δ_n in neutron-rich Mg isotopes. The pairing gaps Δ_n are almost constant in calculation using the surface-type pairing force. This pairing force has a strong continuum-coupling effect and creates dineutron correlation around ^{40}Mg.[1,2)] The continuum-coupling effect is weak in the volume-type pairing force, and the neutron pairing gaps Δ_n decrease as a function of mass number A.

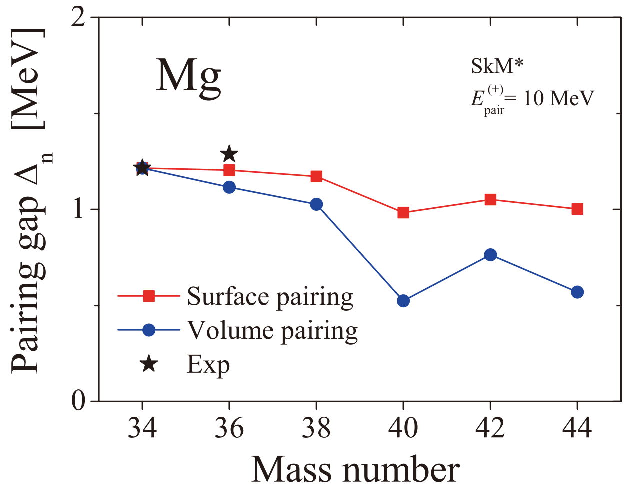

Fig. 1. Neutron pairing gaps Δ_n in neutron-rich Mg isotopes. The results obtained using the surface-type and volume-type pairing forces are compared with the experimental data.

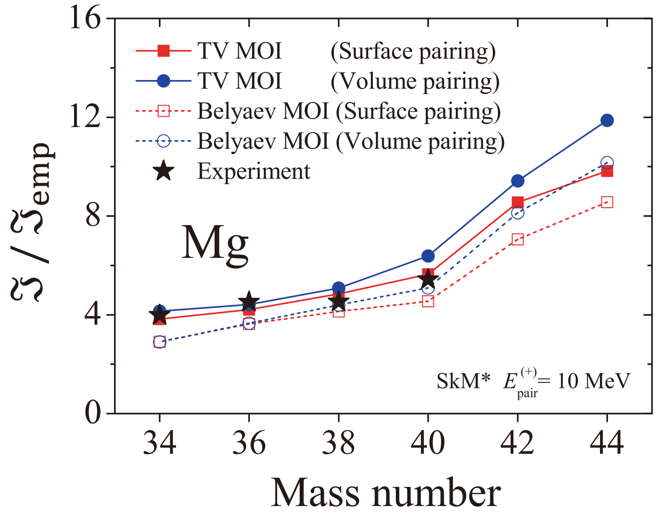

Fig. 2. Same as Fig. 1 but for the Thouless-Valatin (TV), Belyaev, and experimental MOIs. They are divided by the empirical value.

Figure 2 shows the TV MOIs in neutron-rich Mg isotopes. The Belyaev MOIs, in which the residual interactions in QRPA are neglected, are also shown. They are divided by the empirical value $\mathfrak{I}_{\mathrm{emp}} = \beta^2 A^{7/3}/400$ [MeV^{-1}]. The TV MOIs using the surface-type pairing force agree well with the experimental values, whereas the Belyaev MOIs underestimate the experimental values by about 20%.

The ratios of TV MOIs $\mathfrak{I}_{\mathrm{TV}}/\mathfrak{I}_{\mathrm{emp}}$ are almost constant in Mg isotopes with $A \leq 40$, but they are substantially enhanced in ^{42,44}Mg owing to the weak-binding effect.

In conclusion, it is emphasized that the experimental MOIs in neutron-rich Mg isotopes are well reproduced by the TV MOIs using the surface-type pairing force, which creates dineutron correlations. The difference between the TV MOIs using the surface-type and volume-type pairing forces increases on approaching the neutron drip line, and the difference is 20.7% in ^{44}Mg.

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References
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