Microscopic study of the deformed neutron halo of ^{31}Ne†

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^{31}Ne is a deformed halo nuclei. Its deformed core (^{30}Ne) mixes the f- and p-waves of the valence neutron, and couples them to the rotational excitation of the core.[1,2] These feature have been investigated by semi-phenomenological models,[3–5] but have not been verified by microscopic models. Here, we have studied these aspects by combining microscopic models of antisymmetrized molecular dynamics (AMD) and resonating group method (AMD + RGM).[6] We also employed analytical continuation of the coupling constant (ACCC) to investigate the resonances.

Figure 1 shows the calculated spectra of ^{30}Ne and ^{31}Ne obtained by using Gogny D1S density functional. The normal AMD reasonably describes the deformed rotational ground band of ^{30}Ne, but fails to explain the binding of ^{31}Ne.

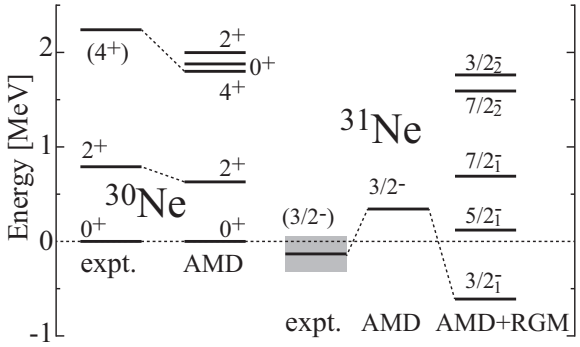

Fig. 1. Energy spectrum of ^{30}Ne and ^{31}Ne.

By contrast, the AMD + RGM reproduces the binding of ^{31}Ne, although the calculated one-neutron separation energy, $S_n = 610$ keV, slightly overestimates the observed value $S_n = 150 \pm 160$ keV.[2] In addition, AMD + RGM yields an increased r.m.s. radius of 3.69 fm compared to that with AMD (3.45 fm). Improvement in the description of the halo is obvious in the valence neutron wave functions shown in Fig. 2.

Table 1 lists the S-factor of the ground state, which reasonably reproduces the observed value of 0.32 ± 0.21 in the $0^+_1 \otimes p_{3/2}$ channel.[2] It is remarkable that AMD + RGM yields larger S-factors for core-excited channels (2^+_1 and 4^+_1 states of ^{30}Ne) than those for the $0^+_1 \otimes p_{3/2}$ channel, due to the strong coupling of the neutron halo and rotational core excitation.

Finally, using ACCC, we also calculated the resonances as presented in Fig. 1 and Table. 2. The first excited state is the $5/2^-_1$, in which the core-excited $2^+_1 \otimes p_{3/2}$ and $2^+_1 \otimes f_{7/2}$ channels dominate. Hence, it is regarded as the rotational excitation of the ^{30}Ne core coupled to the neutron halo. The $3/2^-_2$ and $7/2^-_2$ states are significantly different from the other states. They are decoupled to the deformed ground and 2^+_1 states of ^{30}Ne, but strongly coupled to the spherical 0^+_2 state. This indicates the coexistence of the deformed halo and spherical non-halo states in the bound and continuum states of ^{31}Ne.

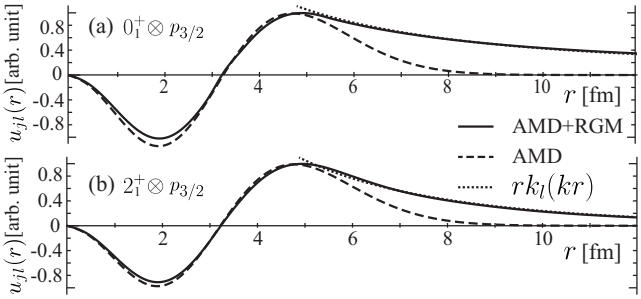

Fig. 2. Overlap functions of the ^{31}Ne in the (a) $0^+_1 \otimes p_{3/2}$ and (b) $2^+_1 \otimes p_{3/2}(2^+_1)$ channels.

Table 1. The S-factors of the ground state of ^{31}Ne in the dominant channels (the 0^+, 2^+, and 4^+ states of ^{30}Ne are coupled to the valence neutron in $p_{3/2}$ and $f_{7/2}$).

	$0^+_1 \otimes p$	$2^+_1 \otimes p$	$2^+_1 \otimes f$	$4^+_1 \otimes f$
AMD	0.13	0.32	0.78	0.66
AMD + RGM	0.30	0.43	0.57	0.47

Table 2. Resonance parameters in MeV.

J^π	S_n	Γ	J^π	S_n	Γ
$5/2^-_1$	−0.12	0.07	$7/2^-_1$	−0.69	0.18
$3/2^-_2$	−1.76	0.29	$7/2^-_2$	−1.60	0.21

In summary, we have investigated the ground and excited resonances of ^{31}Ne by AMD + RGM combined with ACCC. This study not only revealed the deformed halo structure of ^{31}Ne, but also opened a path to investigate other deformed halo nuclei.

References
1) T. Nakamura *et al.*, Phys. Rev. Lett. **103**, 262501 (2009).
2) T. Nakamura *et al.*, Phys. Rev. Lett. **112**, 142501 (2014).
3) I. Hamamoto, Phys. Rev. C **81**, 021304 (2010).
4) Y. Urata *et al.*, Phys. Rev. C **83**, 041303 (2011).
5) Y. Urata *et al.*, Phys. Rev. C **86**, 044613 (2012).
6) R. Takatsu *et al.*, Phys. Rev. C **107**, 024314 (2023).

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