Quadrupole collectivity in island-of-inversion nuclei ^{28,30}Ne and ^{34,36}Mg†

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We report here on the in-beam γ-ray spectroscopy in very neutron-rich even-even nuclei of ^{28,30}Ne and ^{34,36}Mg by proton inelastic scattering using a liquid hydrogen target in inverse kinematics. The ^{30}Ne nucleus has a conventional magic number of 20, and ^{36}Mg is located in the middle of the shell closures of $N = 20$ and 28. The ^{30}Ne and ^{36}Mg are closer to the neutron drip line than the nuclei belonging to the so-called "island of inversion (IOI)". We have studied the evolution of quadrupole deformation on the side with more neutrons and less protons than IOI. The report is a condensed version of our published paper[1)].

The experiment was performed using the RIPS beamline at the RI Beam Factory. A radioactive secondary beam, containing neutron-rich nuclei ^{32,34,36}Mg and ^{28,30}Ne, was produced by fragmentation reactions from 63-MeV/nucleon ^{48}Ca. Details of the experimental setup around the secondary target and beam conditions are provided in Ref.[1)].

The angle-integrated cross sections for population of the 2_1^+ states were obtained from the yields of the $2_1^+ \rightarrow 0_1^+$ transitions with γ-detection multiplicity equal to one. The spectra are shown in Figs. 3–6, 8 in Ref.[1)]. The deduced cross sections and deformation lengths are summarized in Table 1.

The present results extended the measurements of quadrupole collectivity along Ne and Mg isotopic chains by providing deformation lengths with improved accuracies for ^{28,30}Ne, ^{34}Mg and a new measurement for ^{36}Mg. The systematic trends of the deformation lengths are displayed in Fig. 1(a) and (b). The filled and open circles indicate the deformation lengths deduced in the present work and those that have been estimated from the previous results using the WP09 potential[2)], respectively. The thin black and thick orange error bars represent statistical and systematic errors, respectively. The squares indicate previous results of Coulomb excitation experiments.

Figures 1(a) and (b) also display several theoretical results that can be compared to the experimental results. The solid-blue and dashed-red lines are predictions by AMPGCM[3)] and the shell model with the SDPF-M effective interaction[4)], respectively. The shell model calculations in a $0\hbar\omega$ model space are shown by the green dotted[5)] and orange dotted[6)] lines. For Mg isotopes, the AMPGCM and SDPF-M calculations, which implement configuration mixing around $N = 20$, reproduce the systematic trend of experimental deformation lengths in a satisfactory manner. In addition, they agree with the trend for the Ne isotopic chain, although they both systematically overestimate the experimental values.

Table 1. Angle-integrated cross sections for the 2_1^+ states and deduced deformation lengths in ^{28,30}Ne and ^{32,34,36}Mg.

Nucleus	$\sigma(2_1^+)$ (mb)	$\delta_{(p,p')}$ (fm)
^{28}Ne	23(2)	1.33 ± 0.06 (stat) ± 0.05 (syst)
^{30}Ne	37(4)	$1.59^{+0.08}_{-0.09}$ (stat) ± 0.07 (syst)
^{32}Mg	40^{+9}_{-8}	1.85 ± 0.20 (stat) ± 0.08 (syst)
^{34}Mg	63(5)	$2.30^{+0.09}_{-0.10}$ (stat) ± 0.16 (syst)
^{36}Mg	47(8)	$1.90^{+0.16}_{-0.17}$ (stat) ± 0.16 (syst)

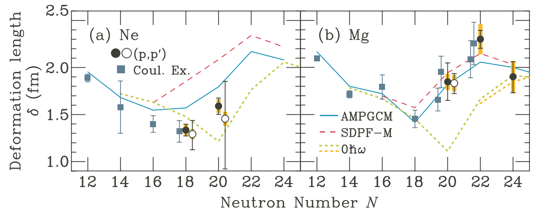

Fig. 1. Systematics of deformation lengths around the IOI region. Panels (a) and (b) show deformation lengths of Ne and Mg isotopes, respectively. Details are described in the text.

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References
1) S. Michimasa *et al.*, Phys. Rev. C **89** (2014) 054307.
2) S.P. Weppner *et al.*, Phys. Rev. C **80** (2009) 034608.
3) R.R. Rodríguez-Guzmán *et al.*, Eur. Phys. J. A **17** (2003) 37; Nucl. Phys. A **709** (2002) 201; Phys. Lett. B **474** (2000) 15.
4) Y. Utsuno *et al.*, Rhys. Rev. C **60** (1999) 054315.
5) E. Caurier *et al.*, Rhys. Rev. C **58** (1998) 2033.
6) F. Nowacki and A. Poves, Phys. Rev. C **79** (2009) 014310.