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Shell-model description of low-lying states in Rn isotopes

N. Yoshinaga*[1] and K. Higashiyama*[2]

Polonium and radon isotopes below the neutron closed shell at $N = 126$ provide an important region for testing shell-model structure. The isomeric 8_1^+ states in $^{206-214}$Rn were experimentally confirmed to be based on a proton $(0h_{9/2})^4$ configuration[1)]. The low-lying near-yrast states were analyzed in terms of the interacting boson model plus two quasiparticles model[2)], where one of the bosons is replaced by a pair of nucleons at high spin. A good agreement with experiment was achieved for both the energy spectra and electromagnetic transitions.

In this work, the band structure of the Rn isotopes is studied in terms of the full-fledged shell model. As for single-particle levels, all the six orbitals, $0h_{9/2}$, $1f_{1/2}$, $0i_{13/2}$, $1f_{5/2}$, $2p_{3/2}$, and $2p_{1/2}$, in the major shell between the magic numbers 82 and 126 are considered for both neutrons and protons. The effective interactions comprise single-particle energies and monopole and quadrupole pairing plus quadrupole-quadrupole interactions, whose strengths are adjusted to fit experimental data. The interaction strengths adopted in the present calculations are assumed to be the same for all the nuclei.

In Fig. 1, the measured spectra for even-even Rn isotopes are compared with the shell model results. The even-spin yrast sequences are well reproduced except for the 8_1^+ states, which are lower in energy than the experimental data. For better reproduction of the 8_1^+ states, multipole pairing interactions more than quadrupole might be necessary. Concerning other states, good agreements between theory and experiment are achieved.

In order to investigate the collective behavior at low energies and the effect of the single particle excitations at high spins, the energy spectra in the shell model are compared with those in a pair-truncated shell model (PTSM)[3,4)]. The building blocks of this model are angular momenta zero (S) and two (D) collective pairs together with non-collective pairs. The Hamiltonian in this truncated space (PTSM space) is set identical to that used in the shell model. In Fig. 2, the energy levels obtained by the PTSM for ^{208}Rn are compared with those of the shell model. There is a good correspondence between the energy levels of the shell model and those in the PTSM. This means that the model space spanned by the PTSM is sufficient for describing the shell model results.

In search for the microscopic structure of the yrast band, we analyze the expectation values of the numbers of pairs (not shown). It is found that the valence neutron excitation plays an essential role in describing the low-lying states, and the pair of $0h_{9/2}$ protons is indispensable for the states above spin 8.

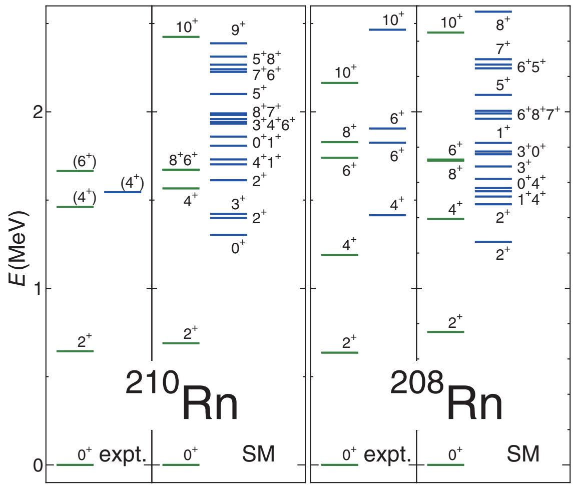

Fig. 1. Comparison of the experimental energy levels (expt.) with those of the shell model (SM) for ^{208}Rn and ^{210}Rn.

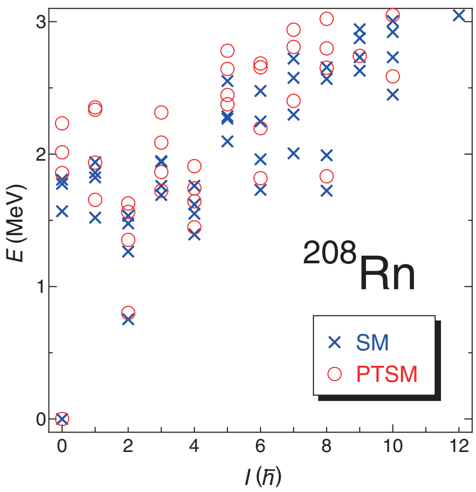

Fig. 2. Comparison of the calculated energy levels in the PTSM (PTSM) and the shell model results (SM) for ^{208}Rn.

References
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*1 Department of Physics, Saitama University
*2 Department of Physics, Chiba Institute of Technology