Analysis of nuclear structure of doubly-odd ^{92,94}Rb isotopes

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Introduction

Study of doubly-odd nuclei is of particular interest from both the nuclear structure as well as astrophysics points of view. In the recent years, the newly developed experimental facilities have allowed to produce and study the doubly-odd neutron excess nuclei. With these experimental techniques, the effect of addition of excess of neutrons to the nuclear structure properties of the doubly odd nuclei has also been investigated. Besides, a variety of theoretical approaches have also been developed to analyse the nuclear structure of these nuclei. Further, the neutron rich nuclei lying in the mass region A ~100 are observed to be unique owing to sudden change in their ground state properties [1]. Again, several fascinating nuclear structure phenomena have also been observed for the nuclei near the spherical sub-shell gap of N = 56, such as isotopes of Se, Kr, Sr, and Zr near A = 100 [2]. The experimental as well as theoretical investigations on the Rb nuclei lying in the mass region A ~ 100 are quite attention-grabbing as the valence neutron lies in the neighbourhood of N ~ 56 spherical sub-shell gap, thereby, offering a wide view-point to study the role of proton-neutron correlations. For Z < 38 nuclei, ^{78}Ni, which is doubly magic nucleus, can be considered as best core for describing the nuclear structure of these set of nuclei within the context of single particle deformed Nilsson potential. Such deformed Nilsson basis can then be used to predict various unexplored nuclear structure properties of nuclei lying in the vicinity of ^{78}Ni core and this can lead an opportunity for the experimentalists to look for these properties in future. Thus, the present study is devoted to investigate the yrast structures of the doubly-odd ^{92,94}Rb nuclei by employing a quantum mechanical phenomenological framework- Projected Shell Model (PSM). The quasi-particle structure of the yrast bands has also been described.

The Theory

The detailed description of applied framework Projected Shell Model (PSM) can be found in review article [3]. Projected shell model is the natural extension of the shell model which basically begins with the deformed Nilsson single-particle states at a deformation ε_2. It makes use of angular-momentum projection technique in order to project out energies from the deformed Nilsson basis and hence makes shell model type of calculations possible for deformed nuclei. Pairing correlations are incorporated into the Nilsson states by BCS calculations. Finally, a two-body shell model Hamiltonian is diagonalized in the projected basis thereby obtaining the energy levels for a given spin. A brief account on the Hamiltonian along with the important input parameters used in the present calculations is given hereunder. The Hamiltonian used for the present PSM calculations is

$$\hat{H}_{QP} = \mathrm{H_o} - \frac{1}{2}\chi\sum_{\mu} \hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_M\hat{P}^{\dagger}\hat{P} - G_Q\sum_{\mu}\hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}$$

where H_o represents the spherical single particle shell model Hamiltonian, involving spin-orbit interactions while the second, third and fourth terms represent the quadrupole-quadrupole, monopole and quadrupole pairing interactions respectively. χ denotes the strength of quadrupole-quadrupole two body interaction and is adjusted with the quadrupole deformation parameter, ε_2,. For the present set of PSM calculations, three major shells (N = 2, 3, 4) for both protons and neutrons have been used. The shell model space is truncated at a quadrupole deformation parameter, ε_2 ~ -0.128 and -0.098, for ^{92,94}Rb nuclei respectively.

Results and Discussions

In the present study, the yrast levels and their composition i.e., band structures from multi-quasi-particle configurations for doubly-odd ^{92,94}Rb nuclei have been investigated. The calculated yrast levels for ^{92,94}Rb have also been compared with their experimental counterparts (experimental data is taken from Ref. [4]). The comparison is shown in the Figs. 1(a)-(b). From the comparison, it has been found that an overall good agreement has been obtained.

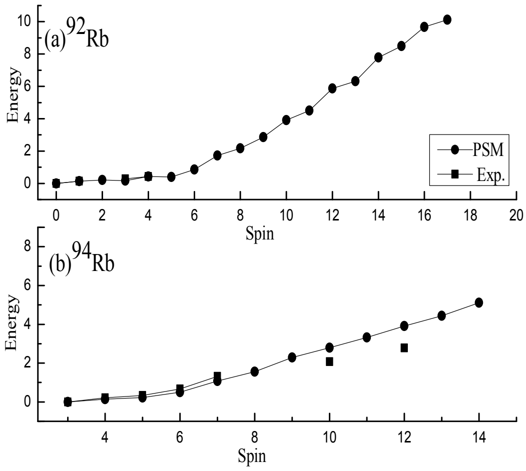

Fig. 1 Yrast energy states of the ^{92,94}Rb nuclei.

Furthermore, the quasi-particle structure of the yrast levels for ^{92,94}Rb nuclei has been presented in the Figs. 2(a)-(b). From Fig. 2(a), it has been found that yrast levels of ^{92}Rb are comprised of two 2-quasi-particle (qp) bands K = -1[ν-7/2, π5/2] and K =1[ν 5/2, π-3/2] upto the spin of 2$^-$. Beyond this spin, two more 2-quasi-particle bands having configuration: K = 3[ν5/2, π1/2] along with the previously mentioned 2-qp bands form the yrast band up to the spin value of 5$^-$. Afterwards, one more 2-qp band identified as K = 5[ν5/2,π5/2] along with the above said mixture of bands, thereby, giving its contribution for the formation of yrast band upto the last calculated spin value. Similarly, Fig. 2(b) presents the band diagram of ^{94}Rb. From the figure, it has been found that yrast levels are composed of K = -3[ν-3/2,π-3/2] band upto spin 5$^-$. At this spin value, another low lying 2-qp band with configuration, K = -5[ν-7/2,π-3/2] contributes to the formation of yrast levels along with K = -3[ν-3/2,π-3/2] band which contributes only to the odd yrast levels (5$^-$, 7$^-$, 9$^-$). At spin of 9$^-$, K = -3[ν-7/2, π1/2] band crosses K = -3[ν-3/2,π-3/2] band and thus construct the yrast spectra with K = -5[ν-7/2,π-3/2] band up to the last spin value.

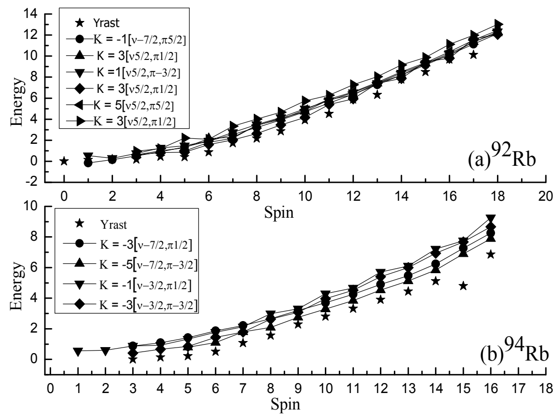

Fig. 2 Band diagrams of ^{92,94}Rb nuclei.

Summary

The neutron rich doubly-odd ^{92,94}Rb isotopes have been studied within a theoretical microscopic technique - Projected Shell Model. The composition of the yrast levels from various multi-quasi-particle configurations for doubly-odd ^{92,94}Rb isotopes has been well described. Further, the comparison of the yrast levels with the available experimental data has also been made. An overall good agreement has been obtained from the comparison.

References

[1] W. Urban et al., Nuclear Phys. A **689**, 605 (2001).
[2] J. H. Hamilton *et al.*, Prog. Part. Nucl. Phys. **35**, 635 (1995).
[3] K. Hara and Y. Sun, Int. J. Mod. Phys. E **4,** 637 (1995).
[4] W. Urban *et al.,* Phys. Rev. C **85**, 014329 (2012)