K-isomeric Bands of highly deformed neutron-rich Neodymium Nuclei in PHF Model

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Introduction

The study of rotational structures of neutron-rich nuclei is one of the main topics of nuclear physics. For rotational nuclei the coupling of single-particle and collective rotational degrees of freedom leads to a variety of phenomena. The current experimental facilities using spontaneous fission of ^{252}Cf, make it possible to study band structures of heavier deformed rare-earth nuclei. Moreover, the information about the nuclear isomers can be extracted from fission fragments. Motivated by the recent experimental observations and as there are very few systematic theoretical descriptions so far of these nuclei, we have studied the K-isomeric band structures for neutron-rich even-even Nd nuclei with mass numbers $A = 152$ to $A = 160$ in a self-consistent microscopic model.

Projected Hartree-Fock Method

We have used the deformed Hartree-Fock and Angular momentum Projection technique [1–3] for the present study.

The Hartree-Fock (HF) equation is derived from the nuclear Hamiltonian which consists of single-particle and residual two body interactions terms. The residual interaction causes mixing of single-particle orbits of nucleons, leading to an average deformed field. Here we use an axially symmetric basis. This is actually not a limitation of our model, because we can diagonalise among various K configurations after projection.

Results and Discussion

The deformed HF orbits are calculated with a spherical core of ^{132}Sn, the model space spans the proton orbits $2s_{1/2}$, $1d_{3/2}$, $1d_{5/2}$, $0g_{7/2}$, $0h_{9/2}$, $0h_{11/2}$ having energies 3.654, 3.288, 0.731, 0.0, 7.1, 2.305 MeV and the neutron orbits $2p_{1/2}$, $2p_{3/2}$, $1f_{5/2}$, $1f_{7/2}$, $0h_{9/2}$, $0i_{13/2}$ having energies 4.462, 2.974, 3.432, 0.0, 1.667, 2.963 MeV respectively. We use surface delta interaction as the residual interaction among the active nucleons in these orbits with the interaction strength and is taken to be 0.3 MeV for p-p, n-n and p-n interactions in the present calculation. We have used prolate deformed HF solutions for $^{152-160}$Nd as these are energetically lower than the oblate.

Experimentally a low lying $K = 5^-$ isomeric-band (with a few states built on the bandhead) is known in ^{156}Nd [5], while for ^{154}Nd only a single $K = 5^-$ isomeric state in known [4]. Recently, $K = 4^-$ isomer band is observed experimentally for ^{154}Nd [5] There is no experimental evidence for the K-isomer band in ^{152,158,160}Nd. Our calculations describe the experimental results quite well. We further predict some low-lying 2-qp and 4-qp isomeric bands for these nuclei. As an example, in Fig. 1 we have shown the calculated energy spectra in comparison with available experimental data for ^{156}Nd. For Nd isotopes with $N > 98$ the $\mathrm{i}_{\frac{13}{2}}(7/2)$ state is very close to the neutron Fermi surface so we

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obtained a low-lying neutron 2-qp $K = 4^-$ band with bandhead energy about 0.5 MeV for ^{160}Nd.

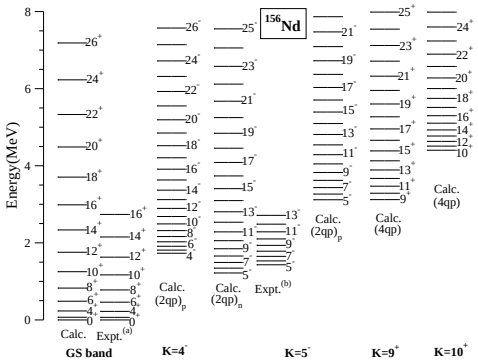

FIG. 1: Energy spectra for ^{156}Nd. (a) Ref. [5].

we have also calculated the reduced transition matrix elements e.g. B(E2), B(M1) as well as spectroscopic quadrupole moments (Q_S) and magnetic dipole moment (μ) for the K-isomeric bands. A few results are shown in Tab. I. The details of these will be discussed at the time of presentation.

Conclusion

Using our PHF model with band mixing we predict K-isomeric bands upto high spin values. The spectra for both two-quasiparticle and four-quasiparticle bands as well as electromagnetic properties like B(E2), B(M1) of these bands are obtained. These results can be useful in future experimental studies of these nuclei.

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TABLE I: Comparison of calculated and experimentally observed band head energy (BHE), Q_S and μ of Nd nuclei. Here Q_S are calculated with effective charges $e_p = 1.7$ and $e_n = 0.7$. The g-factors of $g_l^\pi = 1.0$, $g_l^\nu = 0.0$, $g_s^\pi = 5.586 \times 0.5$ and $g_s^\nu = -3.826 \times 0.5$ are used to calculate μ. '(a)' denotes proton excitation and '(b)' denotes neutron excitation

K^π	BHE (MeV)		Q_S (eb)	μ (nm)
	Theory	Expt. [Ref.]		
^{152}Nd				
4^-(a)	2.0516	–	2.7567	3.4989
4^-(b)	1.1094	–	2.6080	0.1386
5^-(b)	2.3347	–	2.2677	0.1347
5^-(a)	3.7741	–	3.0344	4.5384
9^+	3.9071	–	3.8367	3.7329
10^+	5.0516	–	3.8698	4.7339
^{154}Nd				
4^-(a)	2.8622	–	2.8575	3.5161
4^-(b)	1.0357	1.2980 [5]	3.0174	0.2687
5^-(b)	1.6644	1.348 [4]	3.3648	0.1306
5^-(a)	3.1832	–	3.1466	4.5386
9^+	3.0651	–	4.0577	3.7488
10^+	4.0333	–	4.0969	4.7390
^{156}Nd				
4^-(a)	1.7308	–	3.0021	3.5005
5^-(b)	1.2186	1.4312 [5]	3.5664	0.2694
5^-(a)	3.1181	–	3.3117	4.5353
9^+	3.1211	–	4.3061	3.8841
10^+	4.4025	–	4.3220	4.8955
^{158}Nd				
4^-(a)	1.9652	–	3.1179	3.5127
5^-(b)	2.8203	–	3.6161	0.2186
5^-(a)	3.3823	–	3.4399	4.5418
9^+	5.5992	–	4.4629	3.8729
10^+	6.0933	–	4.4437	4.8306
^{160}Nd				
4^-(b)	0.5272	–	3.3536	0.2544
4^-(a)	1.6855	–	3.2417	3.5023
5^-(a)	2.9253	–	3.5807	4.5335
8^+	2.2104	–	4.4304	3.8387
9^+	3.2361	–	4.4830	4.8425

References

[1] G.Ripka, Advances in Nuclear Physics, **Vol. 1** (1966) Ed. M.Baranger and E.Vogt (Plenum).

[2] C.R. Praharaj, Phy. Lett. B119 17(1982).

[3] S. K. Ghorui *et al.*, arXiv:nucl-th/1106.3152v1.

[4] C. Gautherin *et al.*, Eur. Phys. J. **A 1**, 391 (1998).

[5] G. S. Simpson *et al.*, Phys. Rev. **C 80**, 024304 (2009).