NEWBY SHIFTS IN ODD-ODD TRANSITIONAL NUCLEI AT A~190

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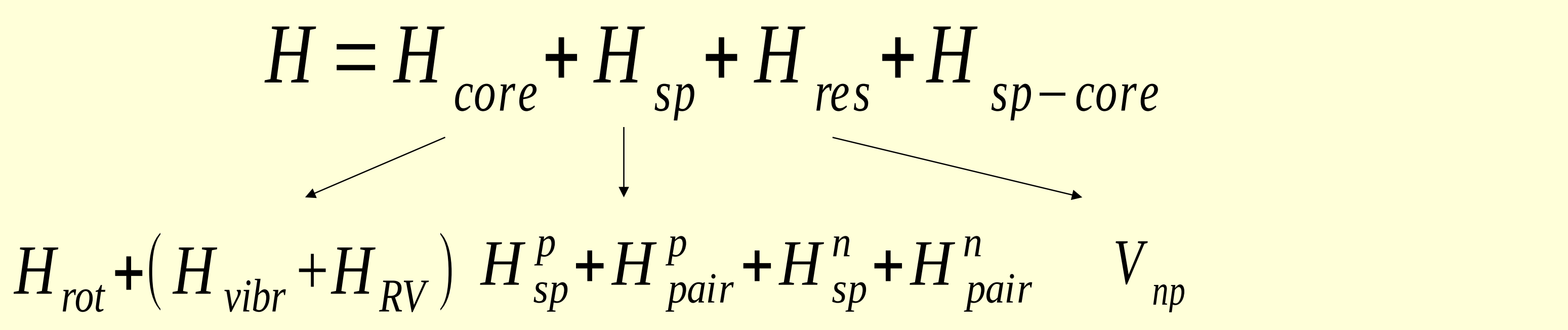
Introduction

Correct accounting for residual NN-interaction between valence particles is of utmost importance for structure interpretation of deformed odd-odd nuclei. This interaction manifests itself in such effects as the Gallagher-Moszkowski (GM) energy splitting of two-quasiparticle doublets, the Newby shift of odd-even spin value levels in K=0 rotational bands, as well as the ΔK=0 mixing of rotational bands due to non-diagonal matrix elements when wave function components of both valence particles exchange.

In two-particle plus rotor model calculations, one usually uses the residual NN-interaction potential parameter values obtained via a fit to empirical matrix element values derived from a wide range of well-deformed odd-odd nuclei (see, e.g., [1-3]). However, it is hard to perform similar studies for transitional nuclei due to a lack of confident experimental data about complete doublets.

Detailed experimental nuclear structure studies performed recently for ^{186,188}Re and ^{192}Ir [4-6] allowed to obtain empirical values for a number of residual NN-interaction matrix elements responsible for Newby shifts in transitional deformation region at A~190. These empirical values have been used to fit the parameters of the finite-range residual proton-neutron interaction potential including both the short, and the long range central forces with spin polarization, as well as the tensor interaction terms.

Unified model of deformed odd-odd nuclei



$$H = H_{core} + H_{sp} + H_{res} + H_{sp-core}$$

$$H_{rot} + \left(H_{vibr} + H_{RV}\right) \quad H^{p}_{sp} + H^{p}_{pair} + H^{n}_{sp} + H^{n}_{pair} \quad V_{np}$$

Model basis functions

$$\Psi_0\left(I,M,K,\Omega_p,\Omega_n\right)_i = \sqrt{\frac{2I+1}{16\pi^2}}\left(\chi_{\Omega_{pi}}\chi_{\Omega_{ni}}D^{I}_{MK_i} + (-1)^{I+K_i+\delta_{K_i,0}}\chi_{-\Omega_{pi}}\chi_{-\Omega_{ni}}D^{I}_{M-K_i}\right)$$

Single particle Hamiltonian – modified h.o. potential [1]

Residual NN-interaction between valence particles

$$V_{np} = (u_W + u_B\vec{\sigma}_p\vec{\sigma}_n + u_M P_M + u_H P_H\vec{\sigma}_p\vec{\sigma}_n)\cdot V_c(r) +$$
$$+ (V_T + V_{TM}P_M)\cdot V_T(r)\cdot\left((\vec{\sigma}_p r)(\vec{\sigma}_n r)/r^2 - \frac{1}{3}(\vec{\sigma}_p\vec{\sigma}_n)\right)$$

a) Gallagher-Moszkowsky (GM) spliitting of the two-quasiparticle doublet);

$$E_{GM} = A^{even}_{res} - A^{odd}_{res} + (-1)^{(I_{even}+1)} B_{res}\,\delta_{K,0}$$

$$A_{res} = \left\langle \chi_{\Omega'_p N'_p l'_p \Lambda'_p \Sigma'_p}\chi_{\Omega'_n N'_n l'_n \Lambda'_n \Sigma'_n} \middle| V_{np} \middle| \chi_{\Omega_p N_p l_p \Lambda_p \Sigma_p}\chi_{\Omega_n N_n l_n \Lambda_n \Sigma_n} \right\rangle$$

b) Newby shift of odd-even spin value levels in K=0 bands);

$$B_{res} = \left\langle \chi_{\Omega'_p N'_p l'_p \Lambda'_p \Sigma'_p}\chi_{-\Omega'_n N'_n l'_n -\Lambda'_n -\Sigma'_n} \middle| V_{np} \middle| \chi_{-\Omega_p N_p l_p -\Lambda_p -\Sigma_p}\chi_{\Omega_n N_n l_n \Lambda_n \Sigma_n} \right\rangle \cdot \pi_p \pi_n$$

Table 1. Empirical Newby energy values E_N of K=0 bands in odd-odd ^{186,188}Re and ^{190,192,194}Ir derived from energies of lowest spin value (I=0,1,2) levels using formula $E=E_0+A_0I(I+1)+(-1)^IE_N$ Experimental data from: ^{186}Re [5]; ^{188}Re [4], ^{190}Ir [8]; ^{192}Ir [6], ^{194}Ir [9]

Nuclide	Configuration	$E_{K=0}$ (keV)	Number of levels	A_0 (keV)	E_N (keV)
^{186}Re	(p:9/2[514]↑-n:9/2[505]↓)	821.4	3 (0+; 1+; 2+)	14.85	-57.18
^{188}Re	(p:9/2[514]↑-n:9/2[505]↓)	207.9	5 (0+; 1+; 2+; 3+; 4+)	15.48	-57.47
	(p:7/2[404]↓-n:7/2[503]↑)*	611.6	3 (0-; 1-; 2-)	20.55	3.85
	(p:1/2[411]↓-n:1/2[510]↑)*	701.4	1 (0-)		
^{192}Ir	(p:3/2[402]↓-n:3/2[512]↓)	128.7	5 (0-; 1-; 2-; 3-; 4-; 5-)	14.60	6.60
	(p:1/2[400]↑-n:1/2[510]↑)	226.3	4 (0-; 1-; 2-; 3-)	14.12	7.37
	(p:11/2[505]↑-n:11/2[615]↑)	265.1	4 (0-; 1-; 2-; 3-)	10.99	-0.55
^{190}Ir	(p:3/2[402]↓-n:3/2[512]↓)*	183.4	3 (0-; 1-; 2-)	21.67	26.47
^{194}Ir	(p:3/2[402]↓-n:3/2[512]↓)*	43.1	4 (0-; 1-; 2-; 3-)	11.52	-8.08
	(p:1/2[400]↑-n:1/2[510]↑)*	143.6	3 (0-; 1-; 2-)	8.65	-74.05
	(p:11/2[505]↑-n:11/2[615]↑)*	245.5	3 (0-; 1-; 2-)	15.37	-30.68

* Tentative configuration assignment. In ^{192,194}Ir all three K=0 bands are strongly mixed by ΔK=0 interaction, hence, structure assignment of (p:11/2[505]-n:11/2[615]) and (p:3/2[402]-n:3/2[512]) configurations is ambivalent

Table 2. Calculated Newby energy values (in [keV]). Expressions and parameter definitions of Ref. [1] have been used. Nilsson single-particle wave function amplitudes have been calculated with ε_2=0.15; γ=0; ε_4=0.02, and κ,μ parameter values as suggested in [7]. Parameter values used for calculations are listed in Table 3.

Configuration	E_N (exp)	E_N (calc)					
		I (CPL)	II	III	IV	V	VI (fit)
(p:1/2[411]↓-n:1/2[510]↑)		-82	-11	55.9	47.7	63	23.2
(p:3/2[402]↓-n:3/2[512]↓)	6.60	-162.6	-114.1	21.2	-33.1	17.3	9.5
(p:1/2[400]↑-n:1/2[510]↑)	6.48*	-232	-195.1	-18.3	-42.5	13.8	16.8
(p:9/2[514]↑-n:9/2[505]↓)	-57.47	-0.9	-75.1	-65.7	-57.8	-69.6	-24.2
(p:9/2[514]↑-n:9/2[624]↑)		-173.5	-142.8	1.4	-74.3	-12.1	-1.5
(p:11/2[505]↑-n:11/2[615]↑)	-0.55	-331.8	-302.8	-36.7	-92.6	-19.1	-1.6

* experimental value have been corrected for theoretical H_{RPC} energy when Ω_p=1/2 and Ω_n=1/2

Table 3. V_{np} parameter values (parameter set Roman numbers correspond to the calculated Newby energy values im Table 2)

Parameter set	r_0 [fm]	V_W [MeV]	V_B [MeV]	V_M [MeV]	V_H [MeV]	V_T [MeV]	V_{TM} [MeV]	λ	r_{0L} [fm]	α_L
I (CPL of [1])	1.4	0	1.43	-12.41	-51.80	0	0	0.55	4.5	-0.0875
II	1.4	0	1.43	-12.41	-51.80	-42.5	10.3	0.55	4.5	-0.0875
III	1.4	0	1.43	-12.41	-10.80	-42.5	10.3	0.55	4.5	-0.0875
IV	1.4	0	1.43	-12.41	-10.80	-42.5	10.3	0.55	4.5	0
V	1.4	0	1.43	-12.41	-4.5	-42.5	10.3	0.55	4.5	0
VI (fit)	1.4	0	1.43	-12.41	-1.3	-12.5	5.3	0.55	4.5	0
E_N dependence	strong	zero	Min.	Min.	Max.	strong	strong	Min.	Min.	Min.

Conclusions

1. Empirical values of Newby shift energies E_N have been obtained for 10 K=0 bands in ^{186,188}Re and ^{190,192,194}Ir.
2. Analysis of the theoretical E_N value dependence on V_{np} parameters has shown that only three of them (V_H,V_T,V_{TM}), as well as the Gauss radial interaction range r_0 have essential impact. The central long-range interaction effect on Newby shifts can be compensated by the change of Heizenberg interaction strength V_H; the impact of the core polarization contribution λ is small.
3. The values of parameters V_H, V_T and V_{TM} were fitted to obtain best possible agreement between empirical and calculated Newby shift energies of three K=0 bands in ^{192}Ir and one K=0 band in ^{188}Re (see the last column in Table 2). Calculated Newby shift energies of the two-quasiparticle configuration (p:11/2[505]↑-n:11/2[615]↑) are most sensitive to the change of V_{np} parameters.
4. In future, we plan to perform analogous study also for GM-splitting energies, as well as the off-diagonal residual NN-interaction matrix elements (both direct, and exchange ones). Preliminary results of our studies show that in order to describe the empirical values of direct and exchange matrix elements of residual NN-interaction one must use different central interaction range r_0 values, as it was already noted in [10].

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Institute of Solid State Physics, University of Latvia as the Center of Excellence has received funding from the European Union's Horizon 2020 Framework Programme H2020-WIDESPREAD-01-2016-2017-TeamingPhase2 under grant agreement No. 739508, project CAMART²

LXX International conference "Nucleus-2020. Nuclear physics and elementary particle physics. Nuclear physics technologies"
St.Petersburg, 11-17 October, 2020