Investigation of deformation in the lowest $11/2^-$ band of odd-mass $^{99-129}$Cd isotopes

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Motivation

PHYSICAL REVIEW C **98**, 011303(R) (2018)

Rapid Communications

Spins and electromagnetic moments of $^{101-109}$Cd

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PRL **110**, 192501 (2013) — Selected for a Viewpoint in *Physics* — PHYSICAL REVIEW LETTERS — week ending 10 MAY 2013

Spins, Electromagnetic Moments, and Isomers of $^{107-129}$Cd

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- Electromagnetic moments in the odd-A Cd isotopes measured in between both neutron shell closures $N = 50$ and $N = 82$.

- The observed linear increase in the quadrupole moments of $11/2_1^-$ states in Cd isotopes with neutron number suggests the systematic investigation of shape changes in the $11/2_1^-$ band throughout the chain with novel theoretical approaches.

Effective interaction for shell-model calculations

Model space: $^{88}_{38}\mathrm{Sr}_{50}$ is considered as a inert core

Protons $\rightarrow 1p_{1/2}$ and $0g_{9/2}$ $(Z = 38 - 50)$
Neutrons $\rightarrow 1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$, $0g_{7/2}$, and $0h_{11/2}$ $(N = 50 - 82)$

➢ Proton-proton and proton-neutron part of the TBMEs is taken from

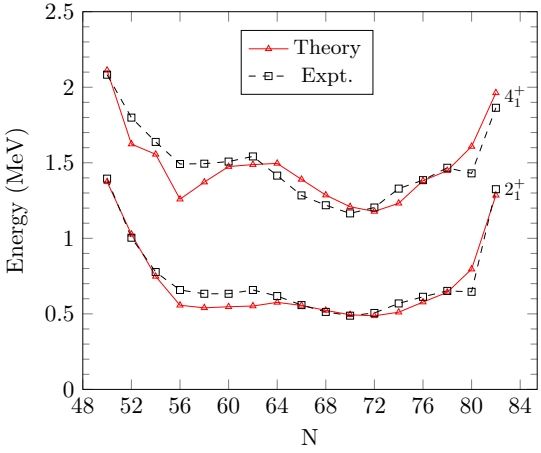
N. Boelaert *et al.*, Phys. Rev. C **75**, 014316 (2007)

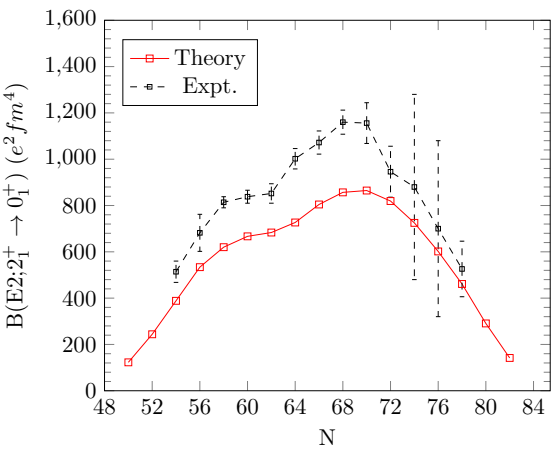
Some issues in neutron-neutron TBMEs hinder the reproduction of spectroscopic properties in mid-shell and neutron-rich regions

➢ Neutron-neutron part is taken from SNBG1 interaction

M. Honma *et al.*, RIKEN Accel. Prog. Rep. **47**, 64 (2014)

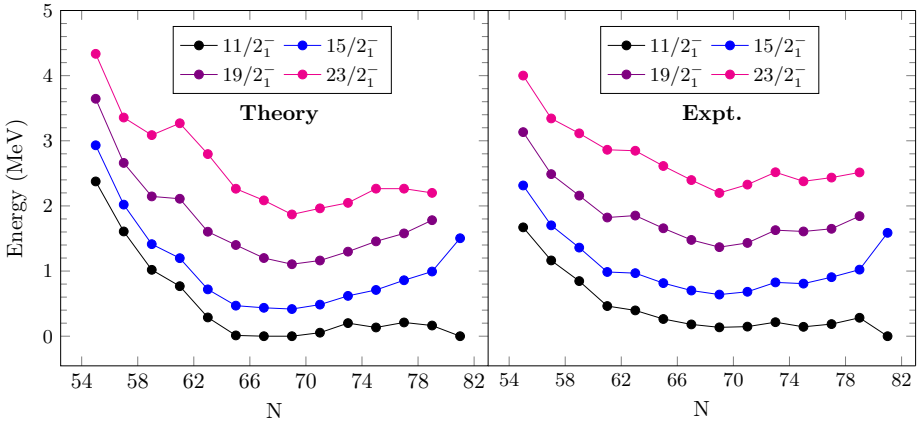
Test for even-A Cd isotopes





- The modified effective interaction accurately describes the spectroscopic properties of low-lying states in even-A Cd isotopes.

Results for odd-A Cd isotopes



- The states in $11/2^-$ band are connected with strong B(E2) transitions from the shell-model and shows similar trends with the experiment.
- The decrement in the energy of $11/2^-$ state in increase of neutron number is due to the fact that neutron Fermi-surface approaches the $h_{11/2}$ orbital.

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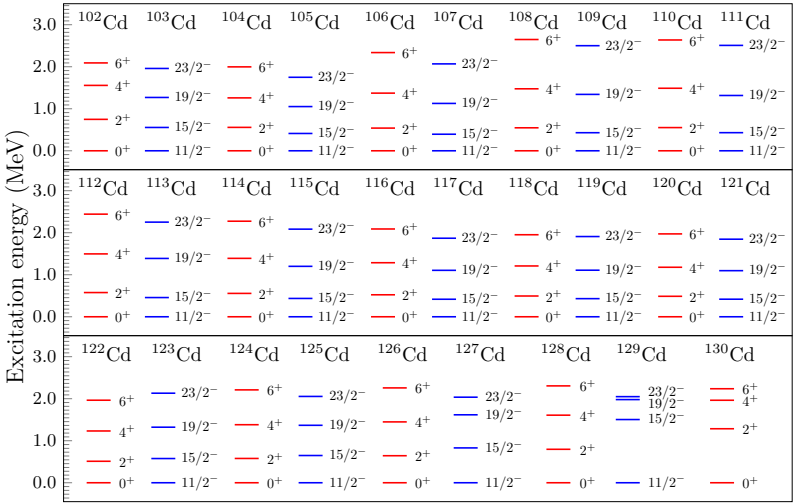
➢ The $11/2^-$ band is dominated by the state that an unpaired neutron in $h_{11/2}$ is coupled to the ground state band of even-A Cd isotopes.



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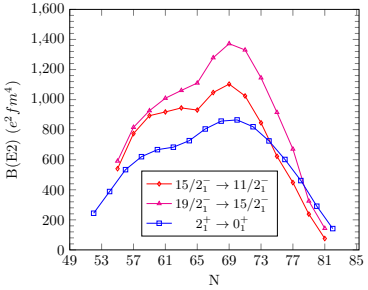
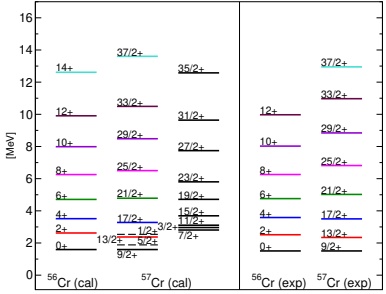
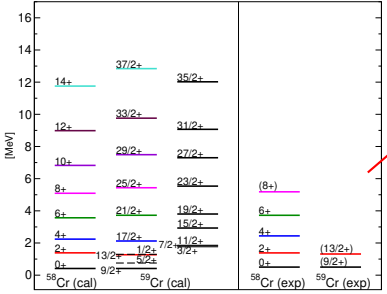
- The similarity in the $B(E2)$ values for the $2_1^+ \rightarrow 0_1^+$, $15/2_1^- \rightarrow 11/2_1^-$, and $19/2_1^- \rightarrow 15/2_1^-$ transitions in odd-A Cd isotopes supports this behavior.

- This situation is also similar to the $9/2_1^+$ bands in neutron-rich Cr and Fe isotopes.







T. Togashi *et al.*, Phys. Rev. C **91**, 024320 (2015)

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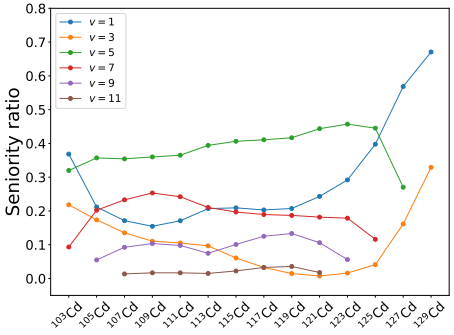
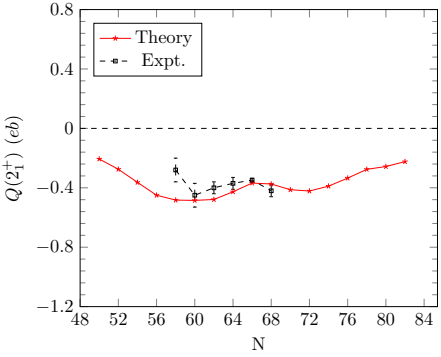


➢ A negative Q-moment in the 2_1^+ state points to a prolate shape, as the ground band is $K = 0$ dominated. Thus, adding a neutron likely preserves this shape, making it reasonable to claim the dominance of prolate shapes in the $11/2_1^-$ states.

➢ The strong mixing in seniority is a natural consequence of the development of deformation in the $11/2_1^-$ states.

$$Q(2^+) = -\frac{2}{7}Q_0 \text{, } Q_0 \rightarrow \text{positive}$$



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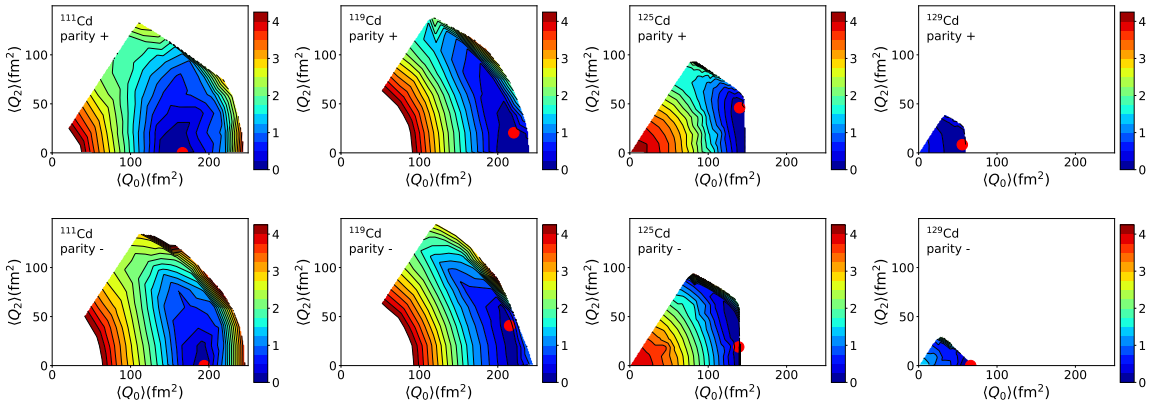
- Energy-surface plots are analyzed for ^{111,119,125,129}Cd isotopes via Q-constrained Hartree-Fock calculation with variation after parity projection.



- Prolate shapes are favored both for the positive- and negative- parity states throughout the Cd chain.
- Deformation peaks at around $N = 70$, which is consistent with the $B(E2)$ values.

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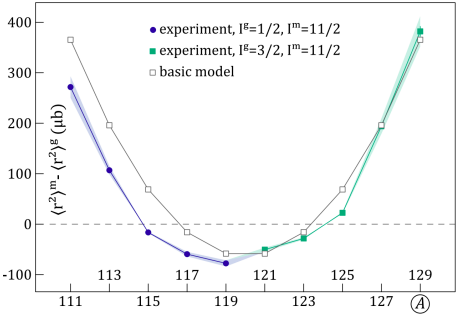
➢ For ^{111}Cd, the optimum $\langle Q_0 \rangle$ value for the negative-parity state is clearly larger than that for the positive-parity state. This result is consistent with the isomer shift observed in

Phys. Rev. Lett. **116**, 032501 (2016)



Mean square charge-radii difference

$$\delta\langle r^2\rangle^{\mathrm{g,m}} = \frac{5}{4\pi}\langle r_0^2\rangle\langle\beta_m^2 - \beta_g^2\rangle$$

$$Q_0 \propto \beta$$

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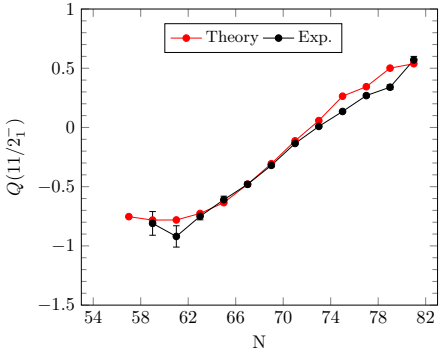
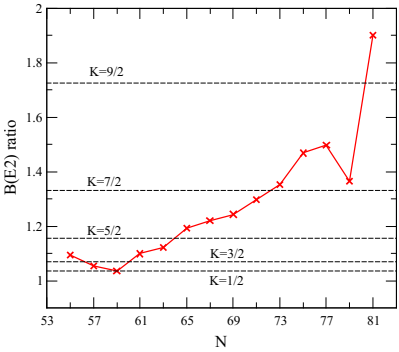




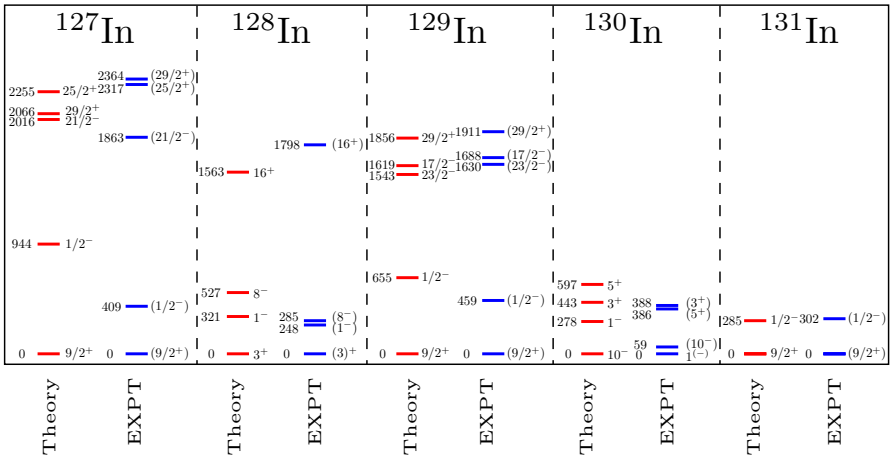
$$Q(J) = \frac{3K^2 - J(J+1)}{(J+1)(2J+3)} Q_0$$

Intrinsic quadrupole moment

$$R \equiv \frac{B(E2; 19/2^- \rightarrow 15/2^-)}{B(E2; 15/2^- \rightarrow 11/2^-)} = \frac{(19/2\, K\, 2\, 0 | 15/2\, K)^2}{(15/2\, K\, 2\, 0 | 11/2\, K)^2}$$

➢ The analysis of linear change in the $Q(11/2^-)$ values with increasing neutrons based on K numbers validates our argument of the dominance of prolate shapes in the $11/2_1^-$ states.

Isomers in $^{127-131}$In isotopes



Experimental data are taken from ⟶ **Phys. Lett. B 808, 135642 (2020)**

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Table. Electromagnetic moments of ground and isomeric states in neutron-rich In isotopes. The effective charges are taken as $(e_p, e_n) = (1.6, 0.8)e$ for the quadrupole moments, and the spin g factor is quenched by a factor of 0.7 for the magnetic moments.

		Q (eb)		μ (μ_N)	
Isotope	J^π	Theory	Exp.	Theory	Exp.
^{127}In	$9/2^+_1$	0.602	0.588(29)	5.399	5.5321(14)
	$1/2^-_1$	–	–	-0.323	-0.4355(24)
	$21/2^-_1$	0.778	0.806(22)	5.303	5.3398(38)
	$29/2^+_1$	0.751	–	3.432	–
^{128}In	3^+_1	0.431	0.416(22)	3.916	4.0883(19)
	1^-_1	-0.019	–	-2.710	–
	8^-_1	0.431	0.462(21)	3.658	4.6549(33)
	16^+_1	0.764	–	4.607	–
^{129}In	$9/2^+_1$	0.487	0.487(13)	5.517	5.5961(23)
	$1/2^-_1$	–	–	-0.200	-0.38709(58)
	$23/2^-_1$	0.672	0.598(32)	5.666	5.9349(39)
	$17/2^-_1$	0.606	–	3.463	–
	$29/2^+_1$	0.639	–	3.521	–
^{130}In	1^-_1	0.069	0.0599(96)	-3.568	-3.4542(34)
	10^-_1	0.545	0.578(26)	4.616	5.0138(44)
	5^+_1	0.309	0.372(15)	2.224	2.8686(18)
	3^+_1	0.316	–	4.441	–
^{131}In	$9/2^+_1$	0.336	0.31(1)	5.955	6.312(14)
	$1/2^-_1$	–	–	0.015	-0.051(3)

Summary and Conclusions

- Large-scale shell-model calculations are performed for investigating the nuclear structure in odd-A Cd isotopes between $N = 50 - 82$.
- The SNBG1 interaction as the neutron-neutron TBME reproduces the spectroscopic properties of the entire Cd isotopic chain well.
- The $11/2^-$ band is dominated by the state that an unpaired neutron in $h_{11/2}$ is coupled to the ground state band of even-A Cd isotopes.
- We further propose that the $11/2^-_1$ state have prolate deformation throughout the odd-A Cd chain.
- Different isomeric states in $^{127-131}$In isotopes have been analyzed in terms of shell-model configurations and seniority quantum number (v).

D. Patel, P. C. Srivastava, N. Shimizu and Y. Utsuno, Phys. Rev. C **109**, 014310 (2024)

Thank you for your kind attention !