Structure of Cd isotopes within the beyond-mean-field IBM

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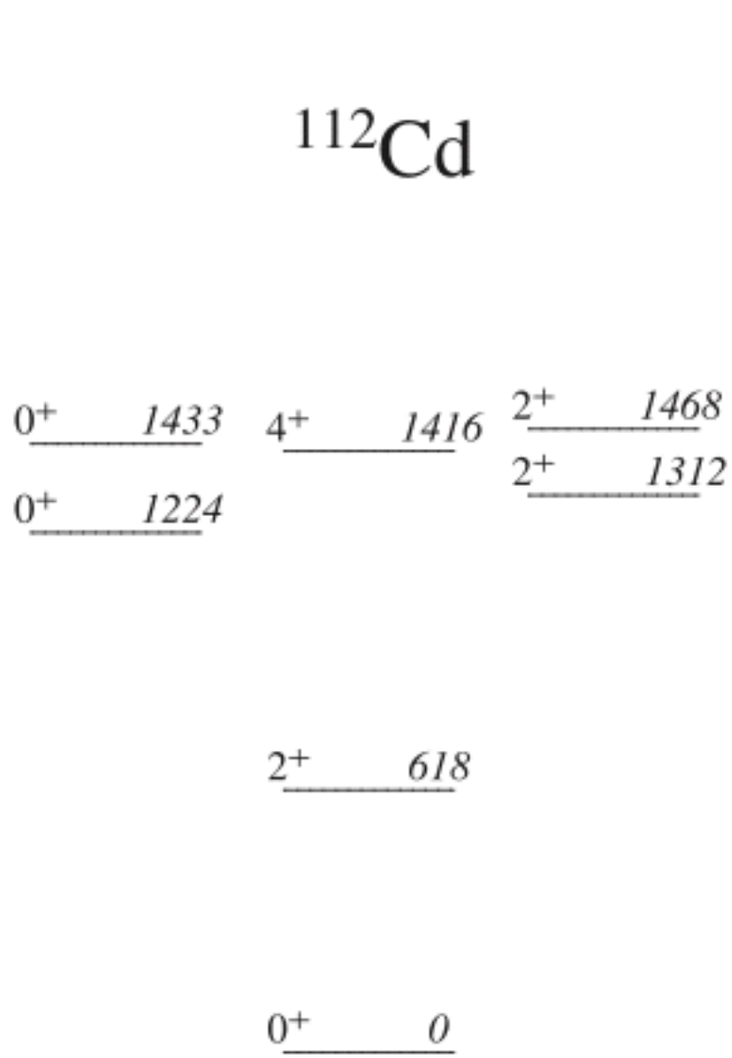
Even-even $^{106-116}$Cd

- Deviation from vibrational picture, due to additional 0+ and 2+ states —> intruder?
- Experimental evidence:

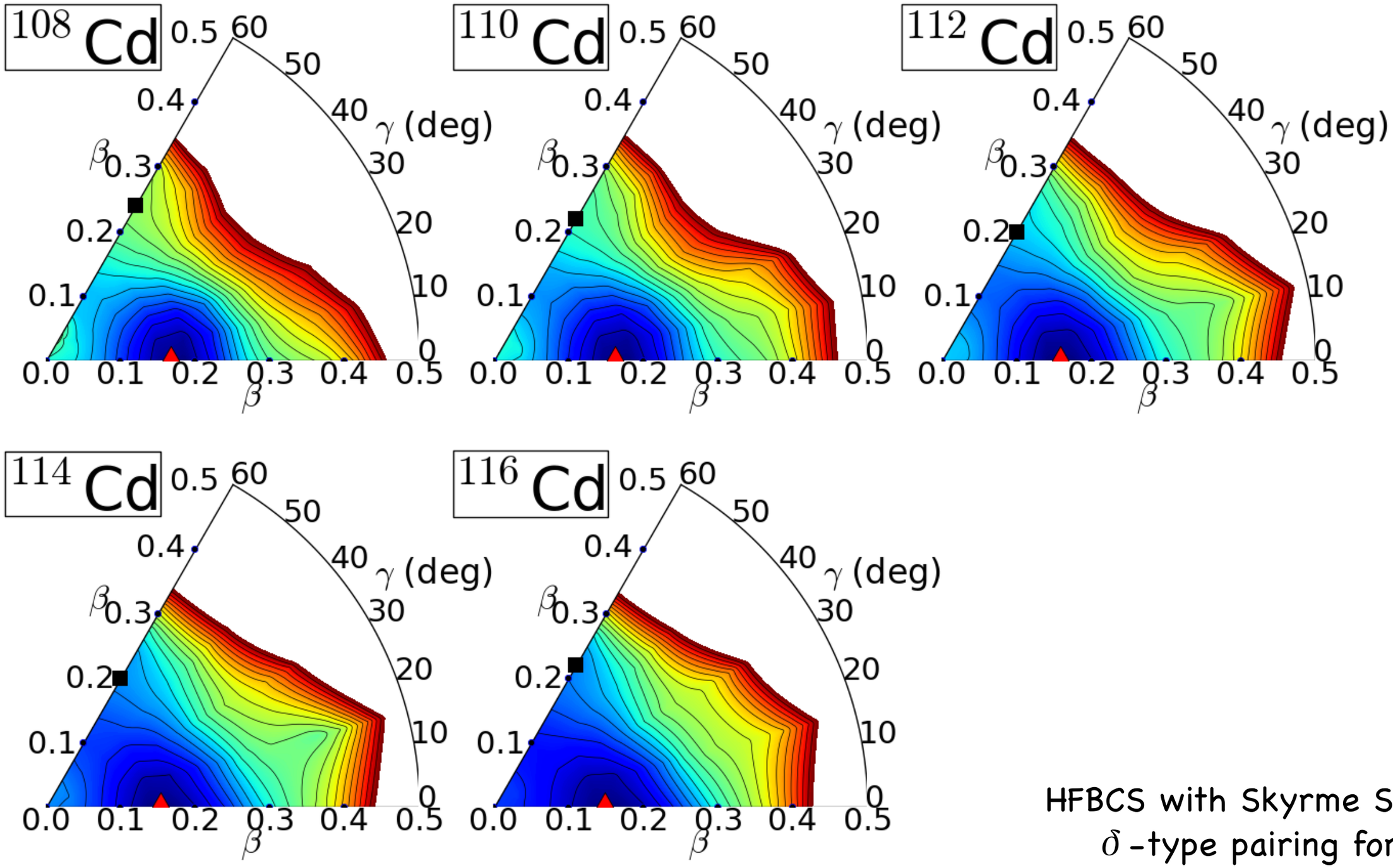
  P. E. Garrett (2016), etc. and refs therein



We consider the problem within the DFT framework

K.N., J. Jolie, arXiv:1802.02348

Self-consistent mean-field potential energy surface



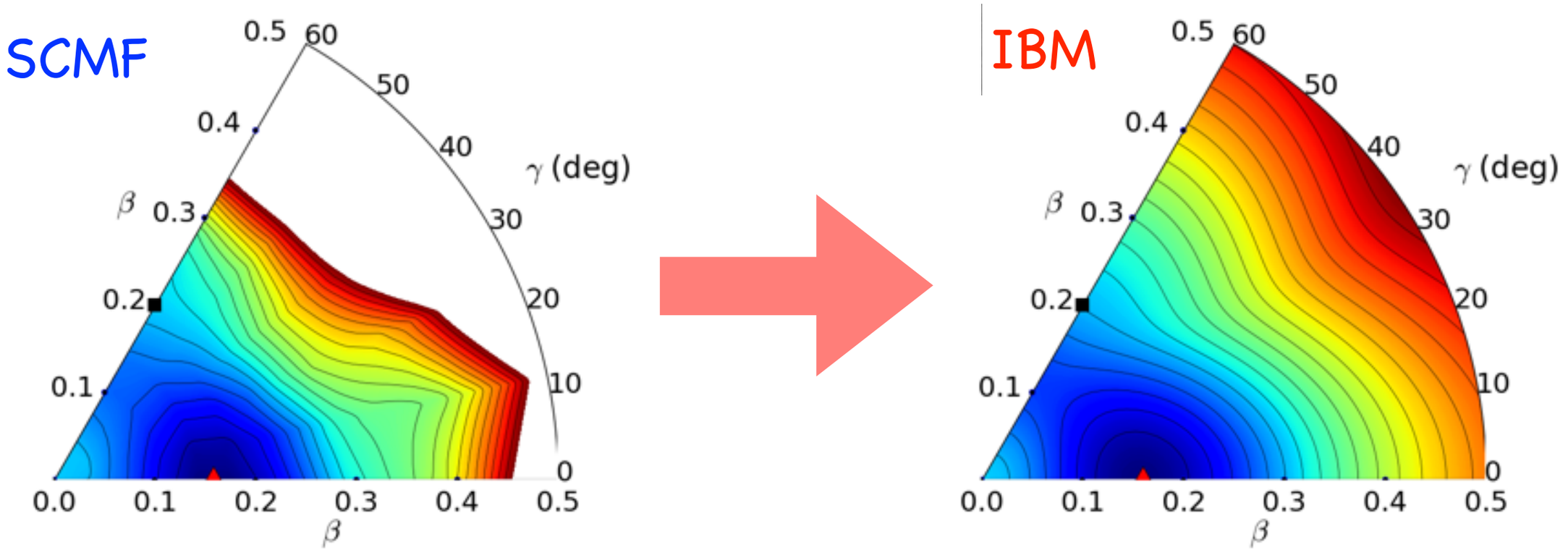
HFBCS with Skyrme SLy6 +
δ -type pairing force

spectroscopic properties → calculated by the IBM Hamiltonian

SCMF-to-IBM mapping

1. SCMF calculation of energy surface

2. ... mapped to config. mix IBM surface —> strength parameters of the IBM Hamiltonian



3. energies and electromagnetic transition rates —> diagonalization in lab frame

K.N., N. Shimizu, T. Otsuka, Phys. Rev. Lett. 101, 142501 (2008)

IBM with configuration mixing

Normal (π(0p-0h)) config: prolate global minimum

Intruder (π(2p-2h)) config: oblate local "minimum"

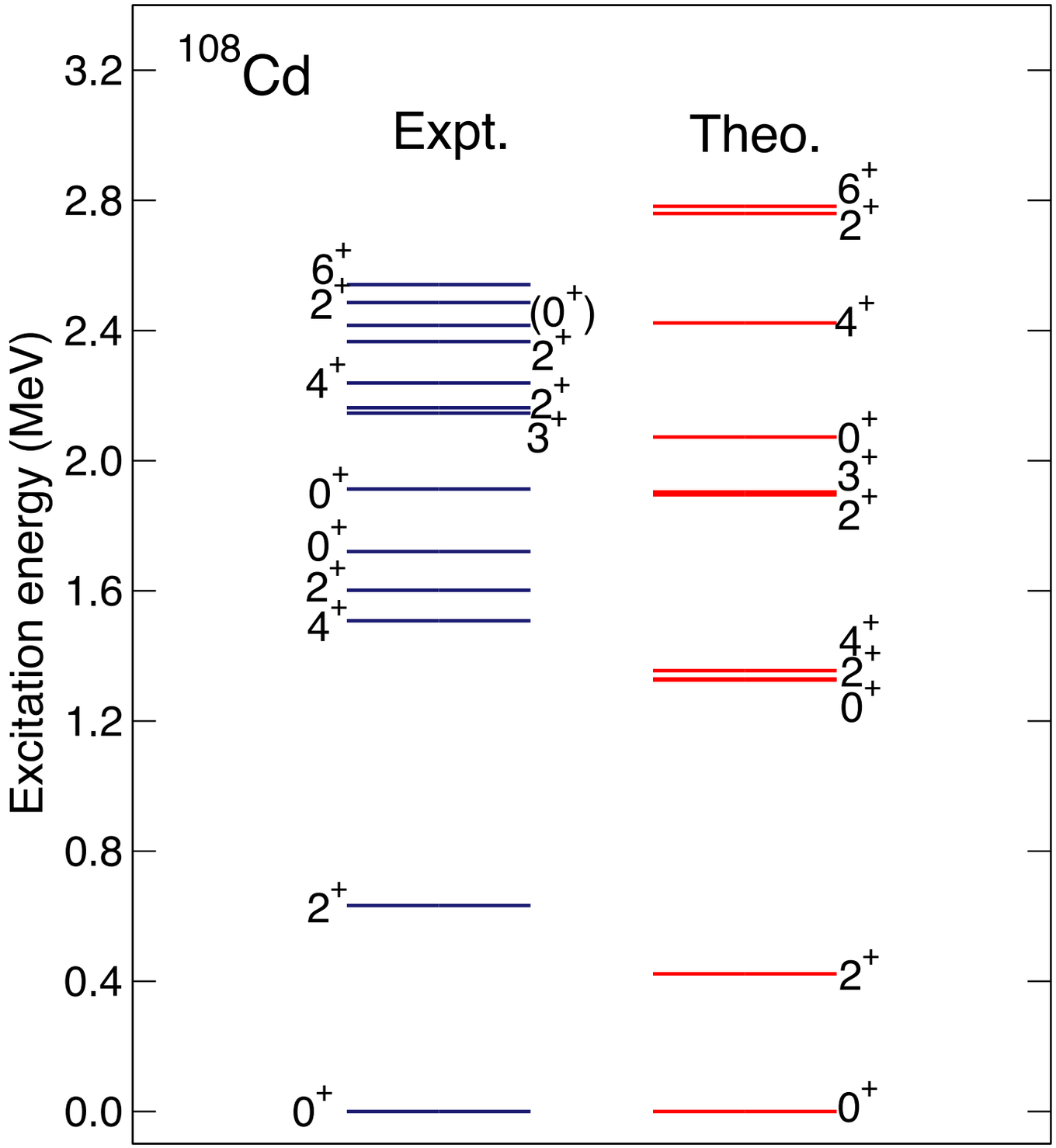
$$\hat{H} = \hat{\mathcal{P}}_1 \hat{H}_1 \hat{\mathcal{P}}_1 + \hat{\mathcal{P}}_3 (\hat{H}_3 + \Delta) \hat{\mathcal{P}}_3 + \hat{H}_{\rm mix},$$

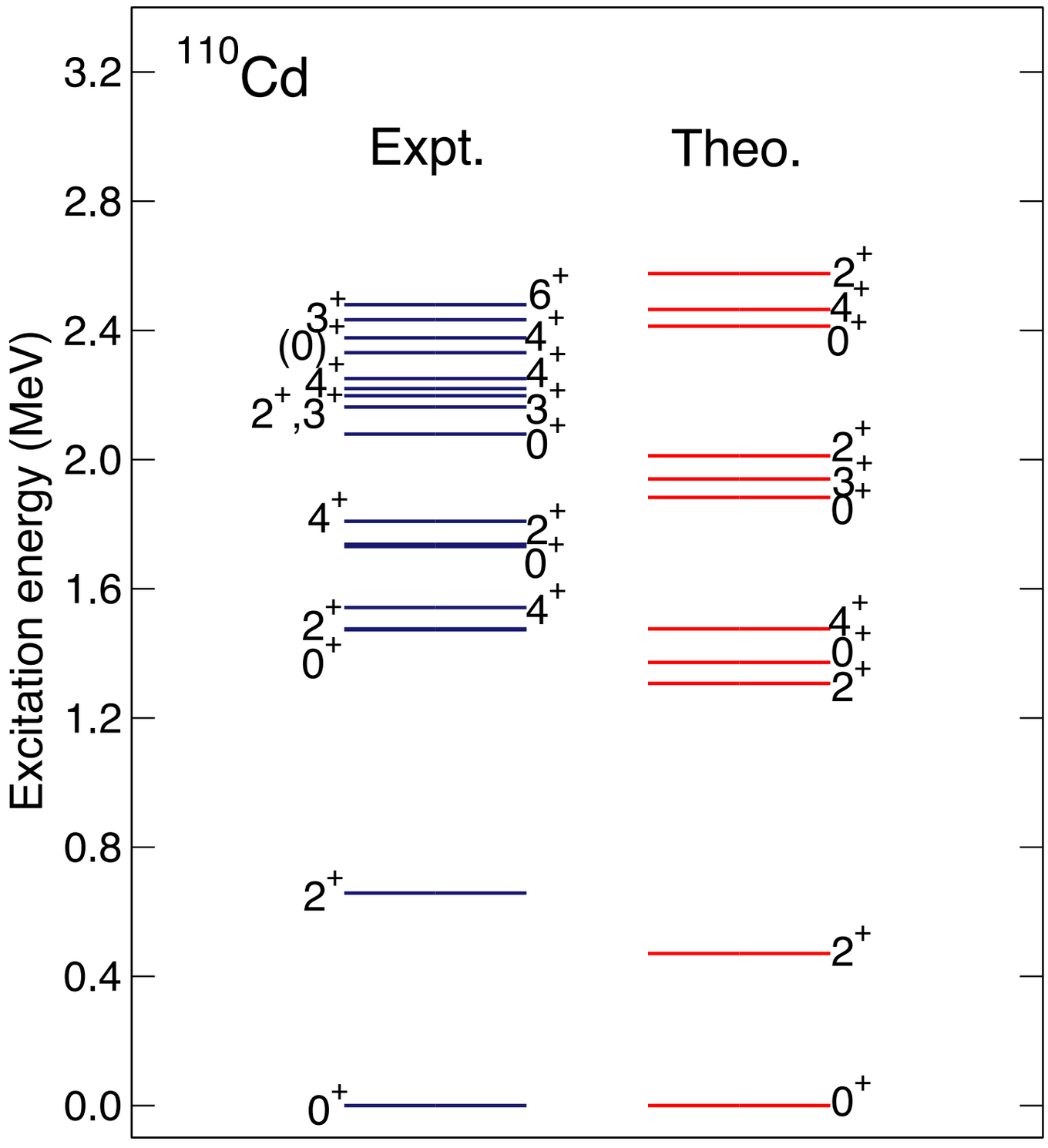
energy needed to promote protons across Z=50

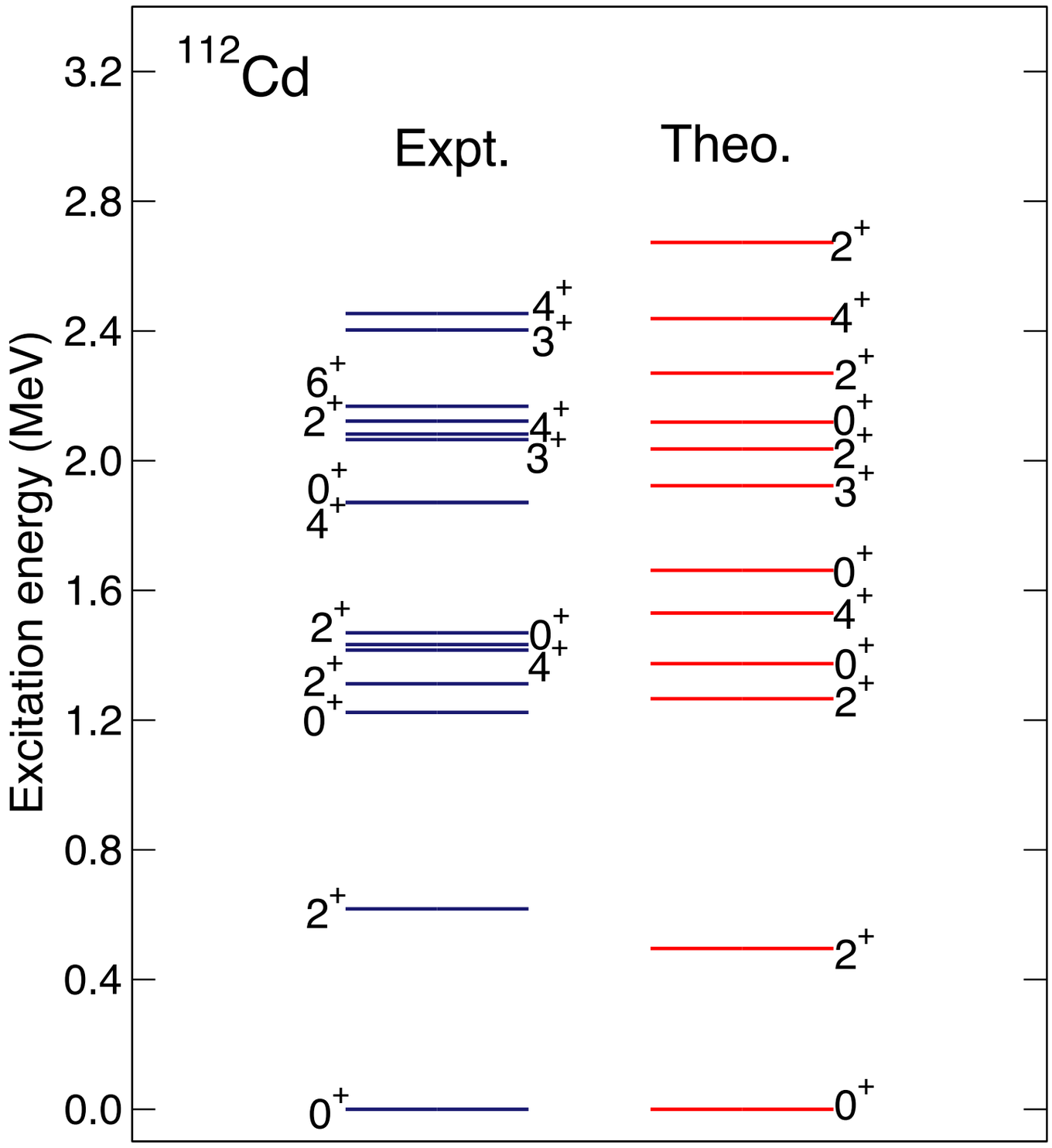
$$\hat{H}_i = \epsilon_d (\hat{n}_{d\nu} + \hat{n}_{d\pi}) + \kappa \hat{Q}_\nu \cdot \hat{Q}_\pi + \kappa' \hat{L} \cdot \hat{L},$$

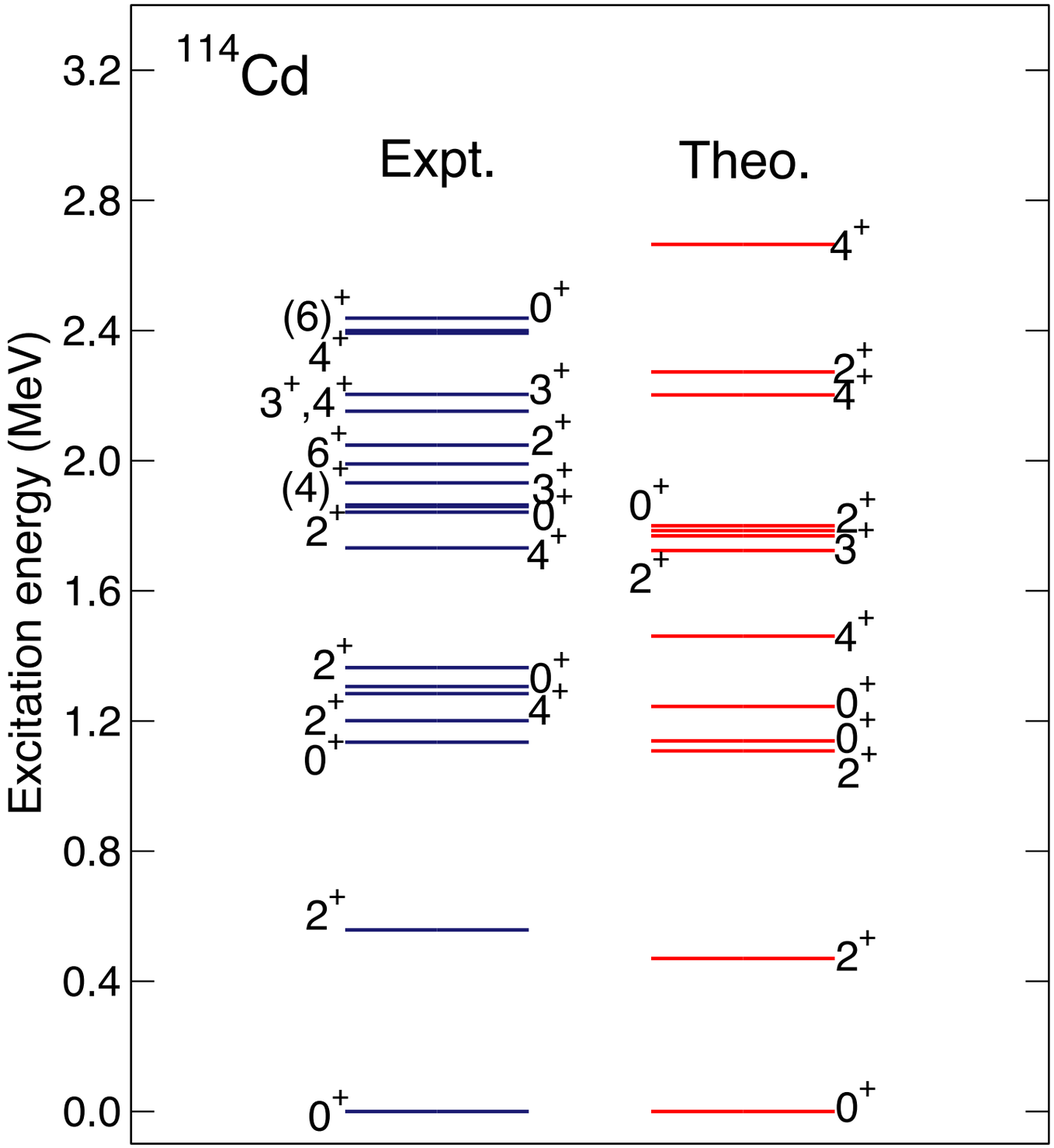
$$\hat{H}_{\rm mix} = \omega (s^\dagger_\pi s^\dagger_\pi + d^\dagger_\pi d^\dagger_\pi)^{(0)} + H.c.$$

Duval-Barrett (1981)


^{108}Cd
Expt.
Theo.
Excitation energy (MeV)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
6^+
2^+
(0^+)
2^+
4^+
2^+
3^+
0^+
0^+
2^+
4^+
2^+
0^+
6^+
2^+
4^+
0^+
3^+
2^+
4^+
2^+
0^+
2^+
0^+
0^+


^{110}Cd
Expt.
Theo.
Excitation energy (MeV)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
6+
3+
4+
(0)+
4+
4+
2+,3+
3+
0+
4+
2+
0+
4+
2+
0+
2+
0+
2+
4+
0+
2+
2+
3+
0+
4+
0+
2+
2+
0+


^{112}Cd
Expt.
Theo.
Excitation energy (MeV)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
4^+
3^+
6^+
2^+
4^+
3^+
0^+
4^+
2^+
0^+
4^+
2^+
0^+
2^+
0^+
2^+
4^+
0^+
2^+
2^+
0^+


^{114}Cd
Expt.
Theo.
Excitation energy (MeV)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
(6)$^+$
4$^+$
3$^+$,4$^+$
6$^+$
(4)$^+$
2$^+$
0$^+$
2$^+$
3$^+$
2$^+$
0$^+$
4$^+$
2$^+$
0$^+$
4$^+$
2$^+$
0$^+$
2$^+$
4$^+$
0$^+$
2$^+$
3$^+$
2$^+$
4$^+$
0$^+$
0$^+$
2$^+$
2$^+$
0$^+$

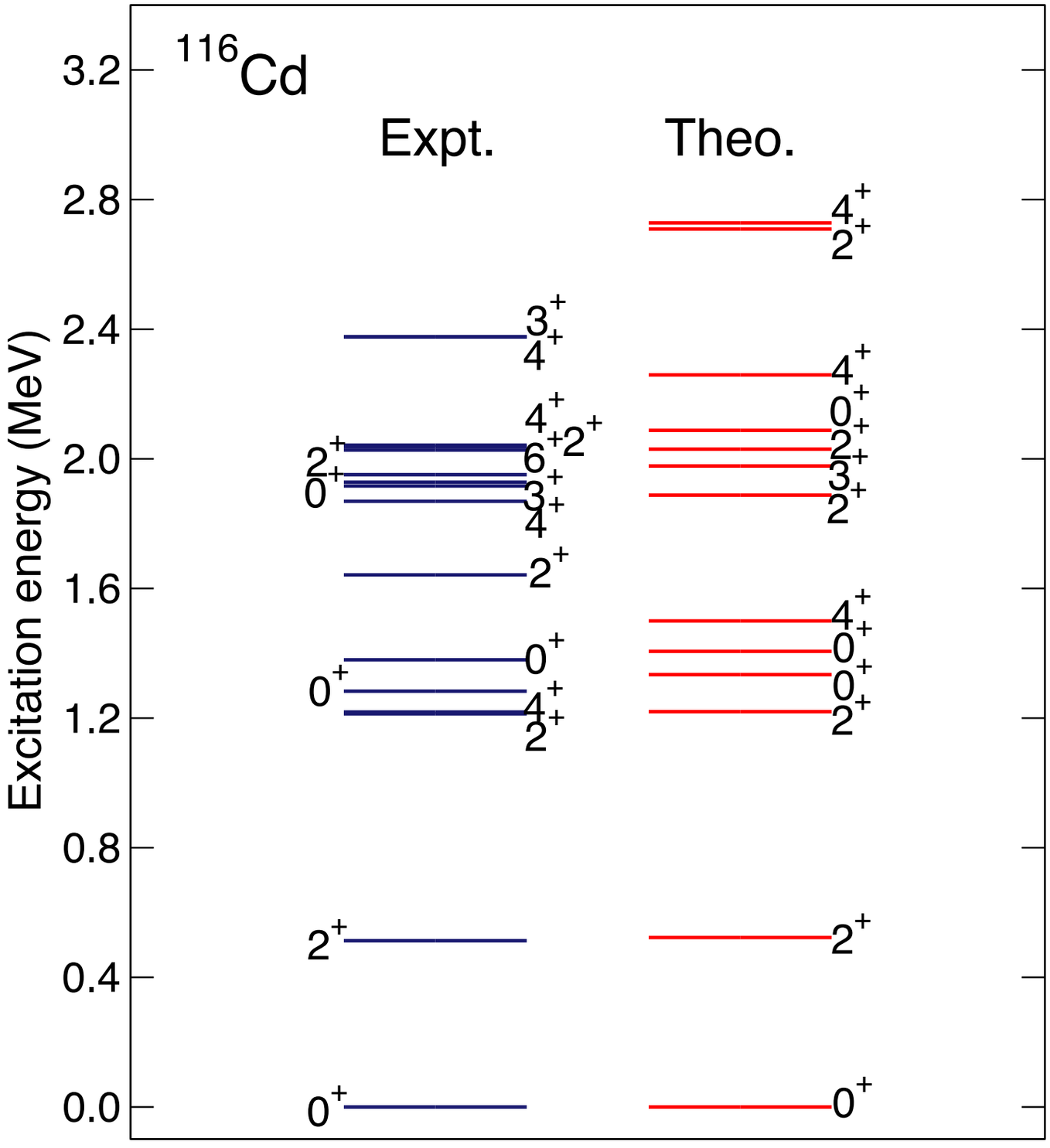

^{116}Cd
Expt.
Theo.
Excitation energy (MeV)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
3^+
4^+
4^+
2^+
2^+
6^+
0^+
3^+
4^+
2^+
0^+
0^+
4^+
2^+
2^+
0^+
4^+
2^+
4^+
0^+
2^+
0^+
0^+
2^+
2^+
0^+

TABLE II: Comparison between experimental and theoretical $B(E2; J_i^+ \rightarrow J_f^+)$ values in Weisskopf units.

J_i^+	J_f^+	^{108}Cd		^{110}Cd		^{112}Cd		^{114}Cd		^{116}Cd	
		Expt	Theo	Expt	Theo	Expt	Theo	Expt	Theo	Expt	Theo
2_1	0_1	26.6(3)	29	27.0(8)	33	30.3(2)	39	31.1(19)	46	33.5(12)	36
0_2	2_1	-	1.4	<40	2.8	51(14)	4.5	27.4(17)	2.9	0.79(22)	9.5
2_2	0_1	1.8(3)	1.1	0.68(14)	1.7	0.65(11)	2.4	0.48(6)	3.2	1.11(18)	1.9
2_2	2_1	17(5)	6	19(4) or 30(5)	11	39(7)	18	22(6)	21	25(10)	27
2_2	0_2	-	1.7	1.35(20)	1.2	-	2.6	3.4(7)	11	-	1.7
4_1	2_1	41(6)	39	42(9)	47	63(8)	55	62(4)	65	56(14)	51
0_3	2_1	-	0.003	<7.9	0.10	0.0121(17)	0.82	0.0026(4)	4.4	30(6)	1.6
0_3	2_2	-	13	<1680	29	99(16)	42	127(16)	39	-	96
2_3	0_1	-	0.02	0.28(4)	0.051	0.88(17)	0.085	0.33(4)	0.072	1.11(18)	0.25
2_3	2_1	-	0.02	0.7^{+3}_{-4}	0.068	0.12(7)	0.14	<0.045	0.17	6.2^{+22}_{-26}	0.0083
2_3	0_2	-	16	29(5)	20	120(50)	25	65(9)	32	-	2.8
2_3	2_2	-	0.17	<8	0.46	-	0.79	-	0.22	-	7.8
2_3	0_3	-	0.56	-	0.43	-	0.98	-	1.9	86^{+24}_{-30}	76
3_1	2_1	-	1.5	0.85(25)	2.5	1.8(5)	3.3	-	4.2	2.6(7)	2.0
3_1	2_2	-	30	22.7(69)	38	64(18)	47	-	55	61(17)	39
3_1	4_1	-	3.9	2.4^{+9}_{-8}	6.8	25(8)	10	-	12	18(10)	11
3_1	2_3	-	2.3	<5	1.9	-	1.6	-	1.9	-	3.6
4_2	2_1	-	0.035	0.14(6)	0.083	0.9(3)	0.14	0.50(5)	0.32	3.0(7)	0.22
4_2	2_2	-	15	22(10)	23	58(17)	31	32(4)	45	230(130)	44
4_2	4_1	-	4.8	10.7^{+49}_{-48}	8.6	24(8)	13	17(6)	16	150(90)	18
4_2	2_3	-	1.4	<0.5	0.98	59(20)	0.79	119(12)	5.9	-	31
6_1	4_1	-	39	62(18)	49	-	59	119(15)	72	110(46)	58
8_1	6_1	-	34	80(22)	45	-	58	86(28)	73	-	61

Structures of 0+ and 2+ states

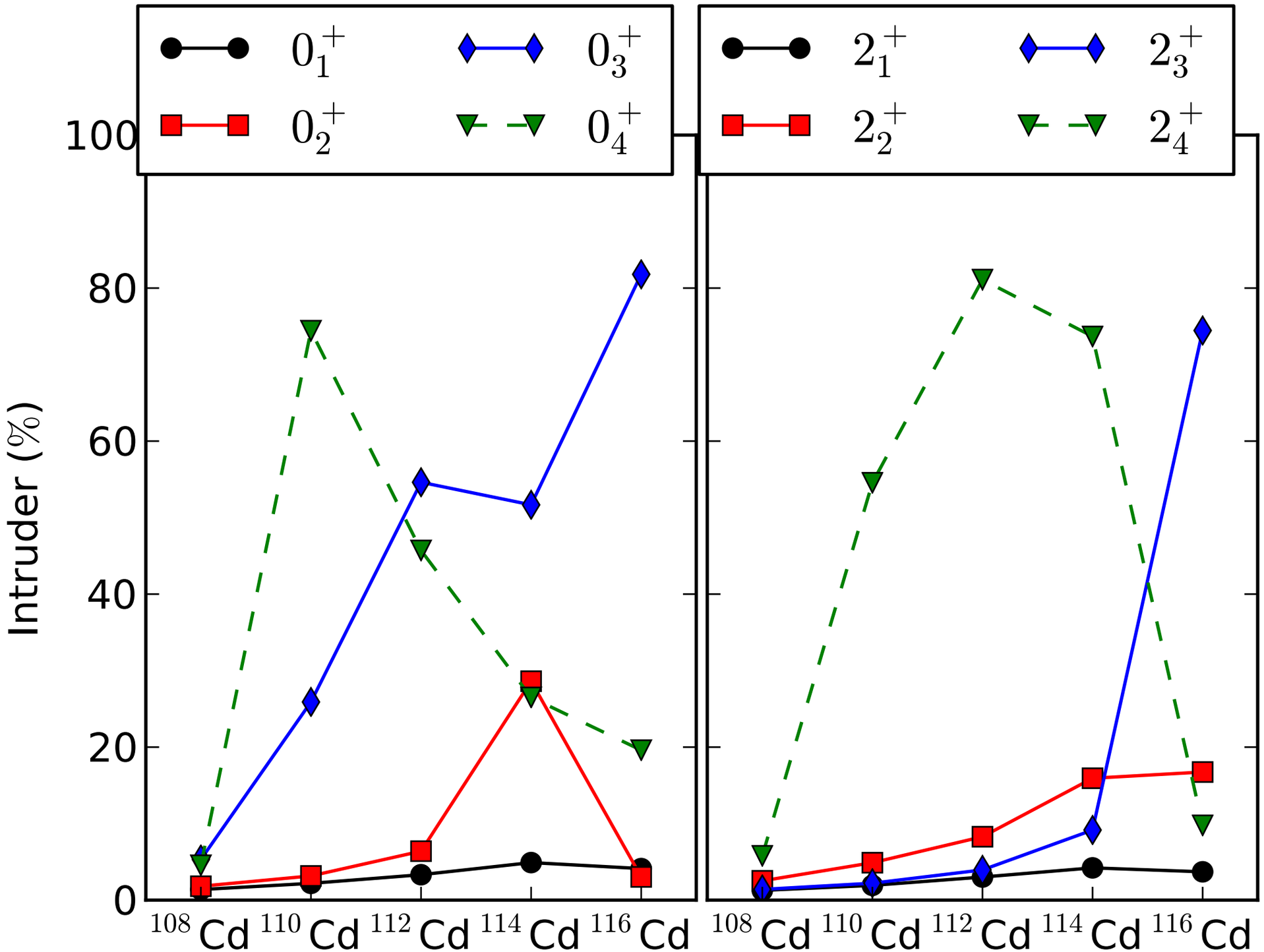


Table IV. Comparison between experimental and theoretical $\rho^2(\mathrm{E0}; J_i^+ \to J_f^+)$ values. The experimental $\rho^2(\mathrm{E0})$ values are not known for ^{108}Cd and ^{116}Cd.

	J_i^+	J_f^+	$\rho^2(\mathrm{E0})\times10^3$ Exp	$\rho^2(\mathrm{E0})\times10^3$ Theory
^{110}Cd	0_2	0_1	$<31(5)^{a}$	37
	0_3	0_1	$<11^{b}$	1.1
	2_2	2_1	$20(15)^{c}$	1.1
	2_3	2_1	$9(8)^{a}$	26
	4_3	4_1	$106^{+98\,a}_{-91}$	0.44
^{112}Cd	0_2	0_1	$34(9)^{d}$	36
	0_3	0_1	$0.87(5)^{d}$	8.6
	0_3	0_2	$10.7(6)^{d}$	12
	2_3	2_1	$31(20)^{c}$	27
^{114}Cd	0_2	0_1	$19(2)^{d}$	12
	0_3	0_1	$1.83(13)^{d}$	44
	0_3	0_2	$0.65(5)^{d}$	100
	0_4	0_1	$0.9(4)^{d}$	8.8
	2_2	2_1	$<28^{c}$	0.25
	2_3	2_1	$38(5)^{e}$	22
	2_3	2_2	$22(6)^{e}$	1.1
	2_4	2_2	$<20^{e}$	57
	3_2	3_1	$<130^{e}$	35
	4_2	4_1	$67(10)^{e}$	0.38

Summary

Configuration-mixing IBM based on SCMF

- overall good description of energies and transition rates without empirical fit

- predicts intruder states

- mixing between normal and intruder configs not correctly reproduced

- normal states predicted to be rotational like —> too deformed prolate minimum

Thank you

Geometrical Structure

Coherent-state matrix

$$\mathcal{E} = \begin{pmatrix} E_{11}(\beta,\gamma) & E_{13}(\beta,\gamma) \\ E_{31}(\beta,\gamma) & E_{33}(\beta,\gamma) + \Delta \end{pmatrix}$$

$$E_{ii}(\beta,\gamma) = \langle \phi_i | \hat{H}_i | \phi_i \rangle$$

$$E_{ij}(\beta,\gamma) = E_{ji}(\beta,\gamma) = \langle \phi_j | \hat{H}_{\rm mix} | \phi_i \rangle$$

Boson coherent state

$$|\phi_i\rangle = \Pi_{\rho=\nu,\pi}(s^\dagger_\rho + \beta_\rho \cos\gamma d^\dagger_{\rho 0} + \frac{1}{\sqrt{2}} \sin\gamma (d^\dagger_{\rho 2} + d^\dagger_{\rho -2})^{N_\rho} |{\rm o}\rangle$$

IBM energy surface —> lower eigenvalue of the matrix

Frank, Van Isacker, Vargas (2004)

Construct config-mix IBM Hamiltonian

1. associate unperturbed 0p-0h config (E_{11}) to prolate global minimum and 2p-2h config (E_{33}) to oblate local "minimum"
   —> parameters for unperturbed IBM Hamiltonians

2. reproduce energy difference between the minima
   —> Δ

3. mixing term introduced perturbatively to reproduce "barrier"
   —> ω

KN, R. Rodriguez-Guzman, L. M. Robledo, N. Shimizu, Phys. Rev. C 86, 034322 (2012)