Shape Coexistence in Odd Au Isotopes. Description within the Interacting Boson-Fermion Model framework.

Pablo Martín-Higueras

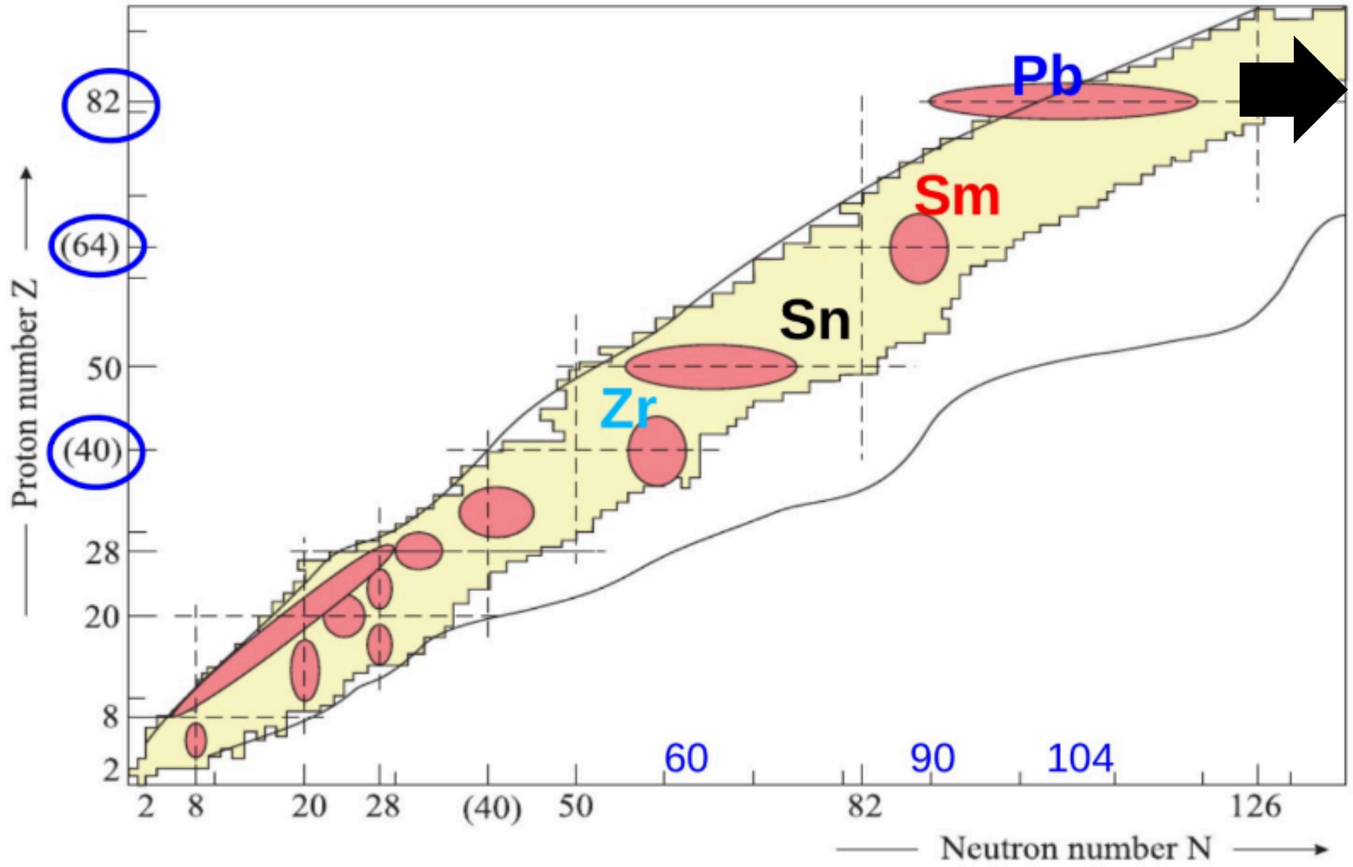
José Enrique García-Ramos

CPAN 2025

Departamento de Ciencias Integradas y Centro de Estudios Avanzados en Física, Matemáticas y Computación, Universidad de Huelva

Nuclear chart region

Shape coexistence in nuclei

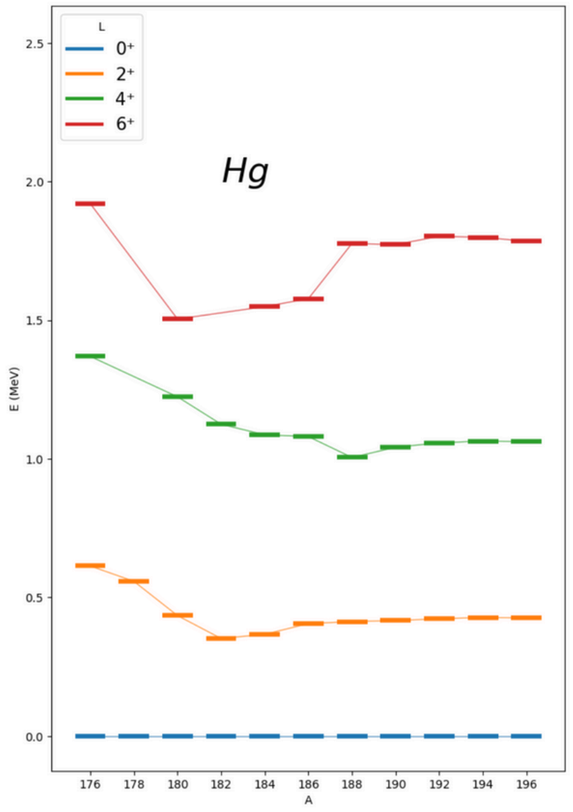


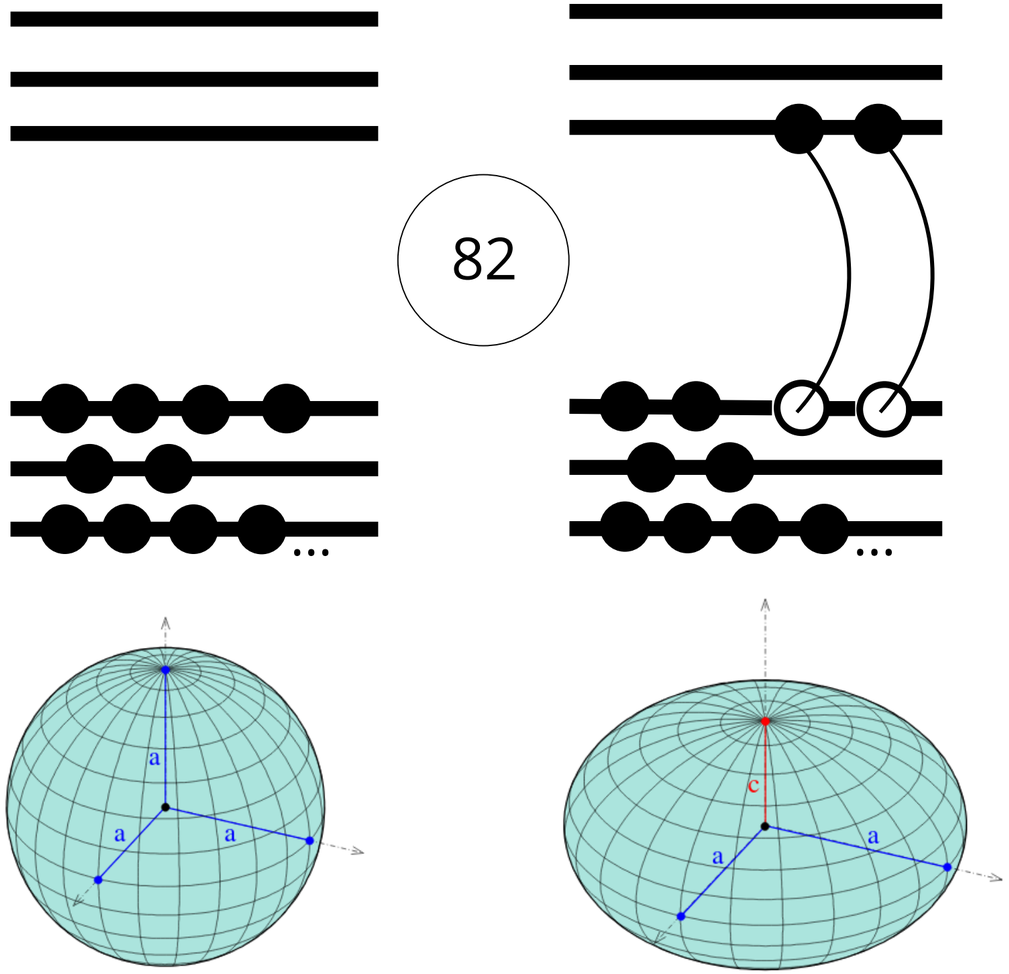
Z =	***78***	***79***	***80***	***81***	***82***
	Pt	**Au**	**Hg**	**Tl**	**Pb**

- *Z* = *82* proton closure shell
- *N* near *104* neutron midshell
- Near *Bound-nuclei limit*

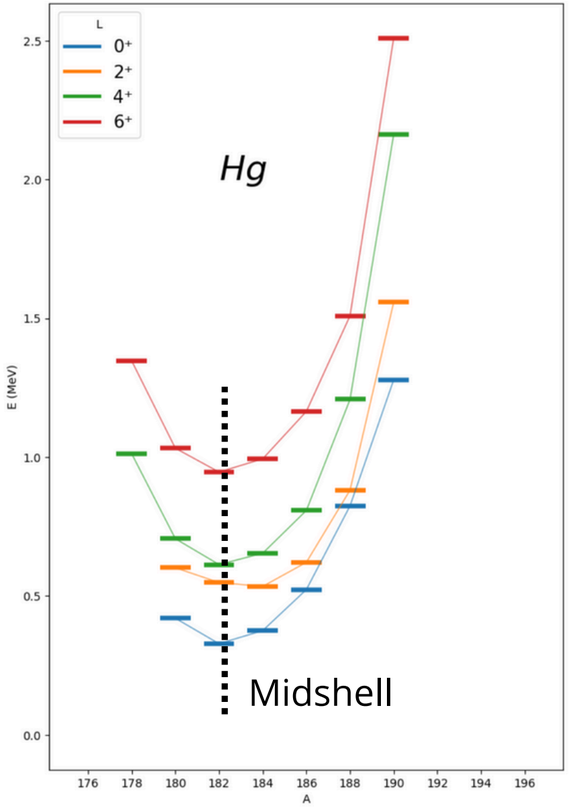
Shape coexistence: Hg case

$[N_b]$



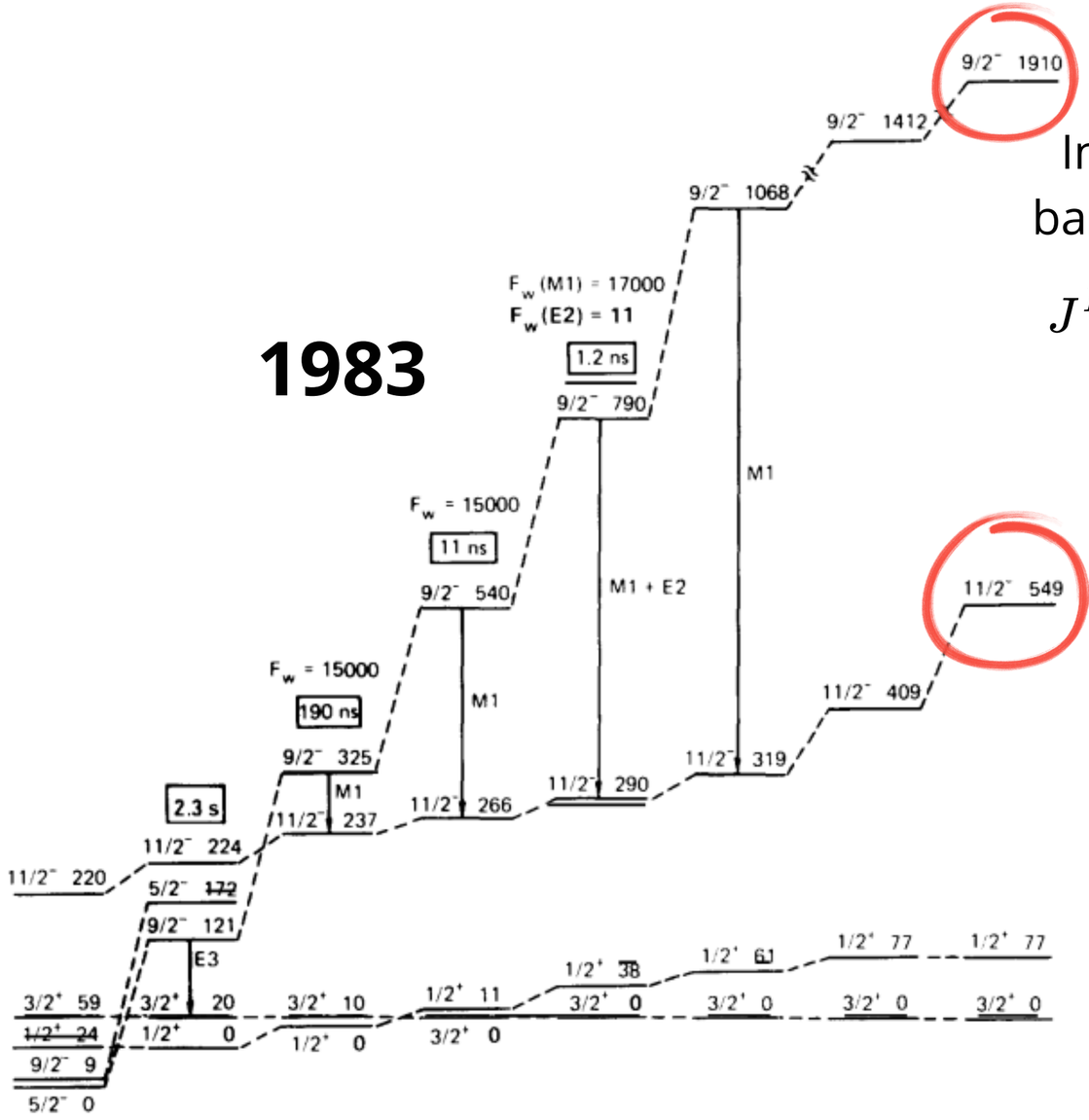


$[N_b + 2]$



[1] J.E. García-Ramos, K. Heyde *"Nuclear shape coexistence: A study of the even-even Hg isotopes using the interacting boson model with configuration mixing*". In: Physics Review C (2014)

Shape-Coexistence in Odd-Even Au



Intruder band-head

$$J^P = \frac{9}{2}^-$$

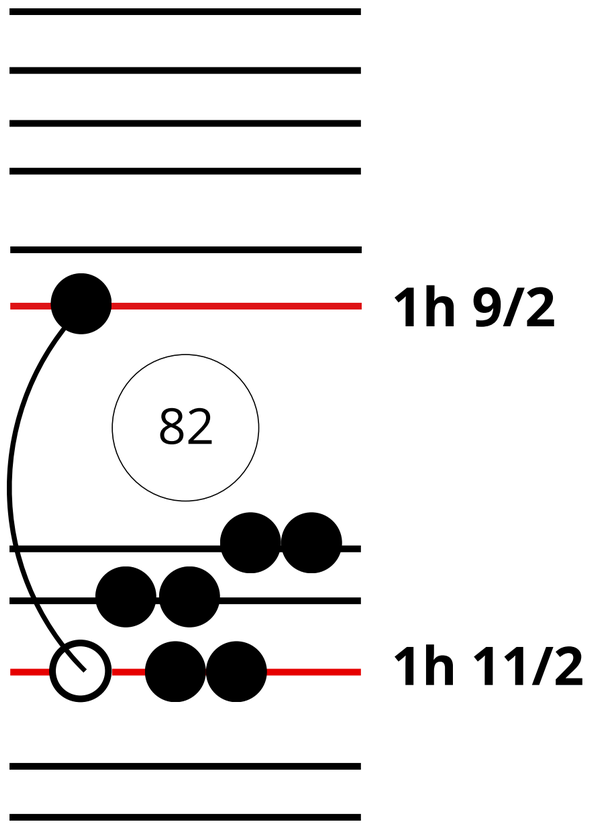
Regular band-head

$$J^P = \frac{11}{2}^-$$

G.S

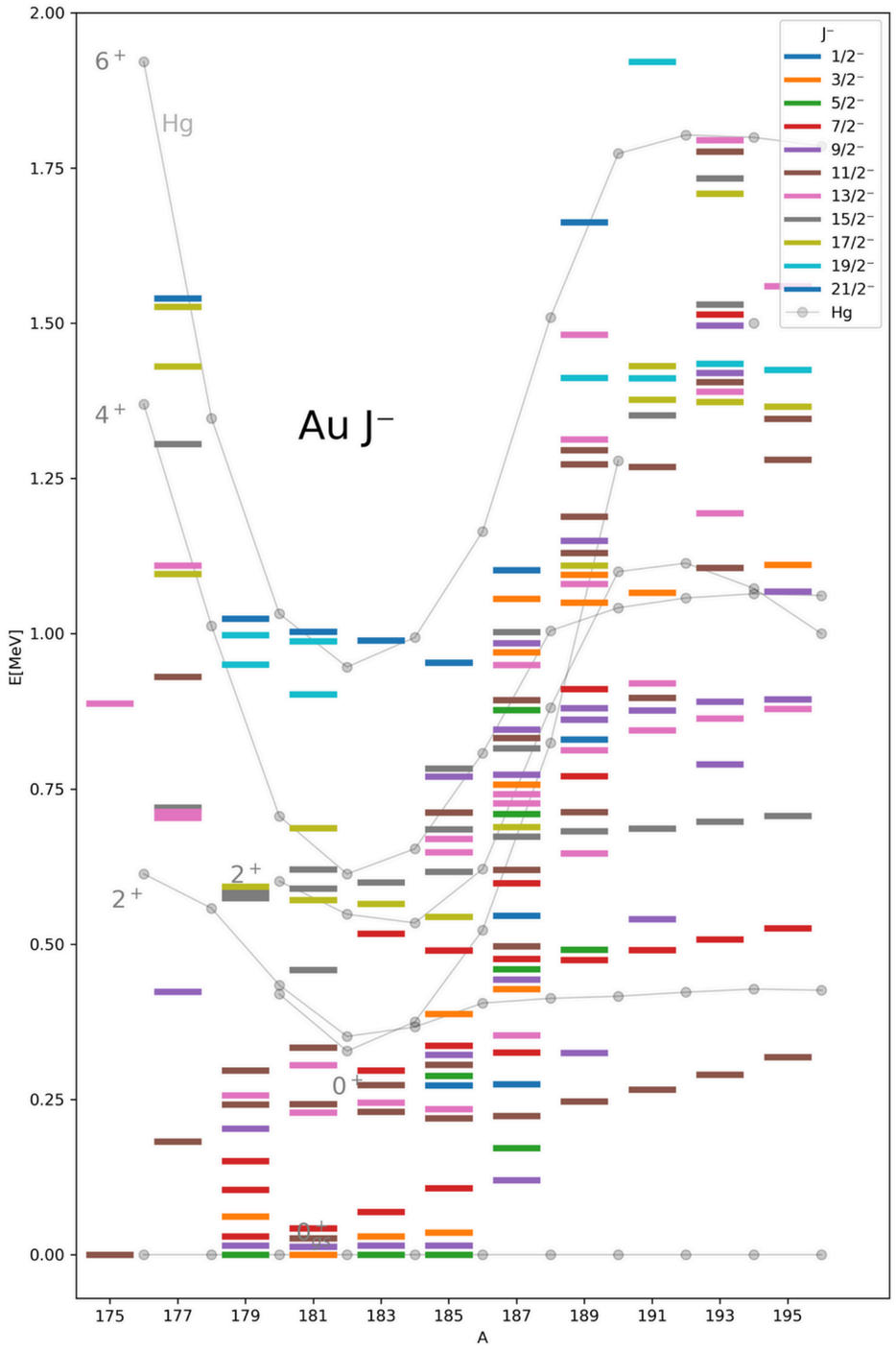
$$J^P = \frac{3}{2}^+, \frac{1}{2}^+$$

- Pure-particle state
- 1p-1h excitation

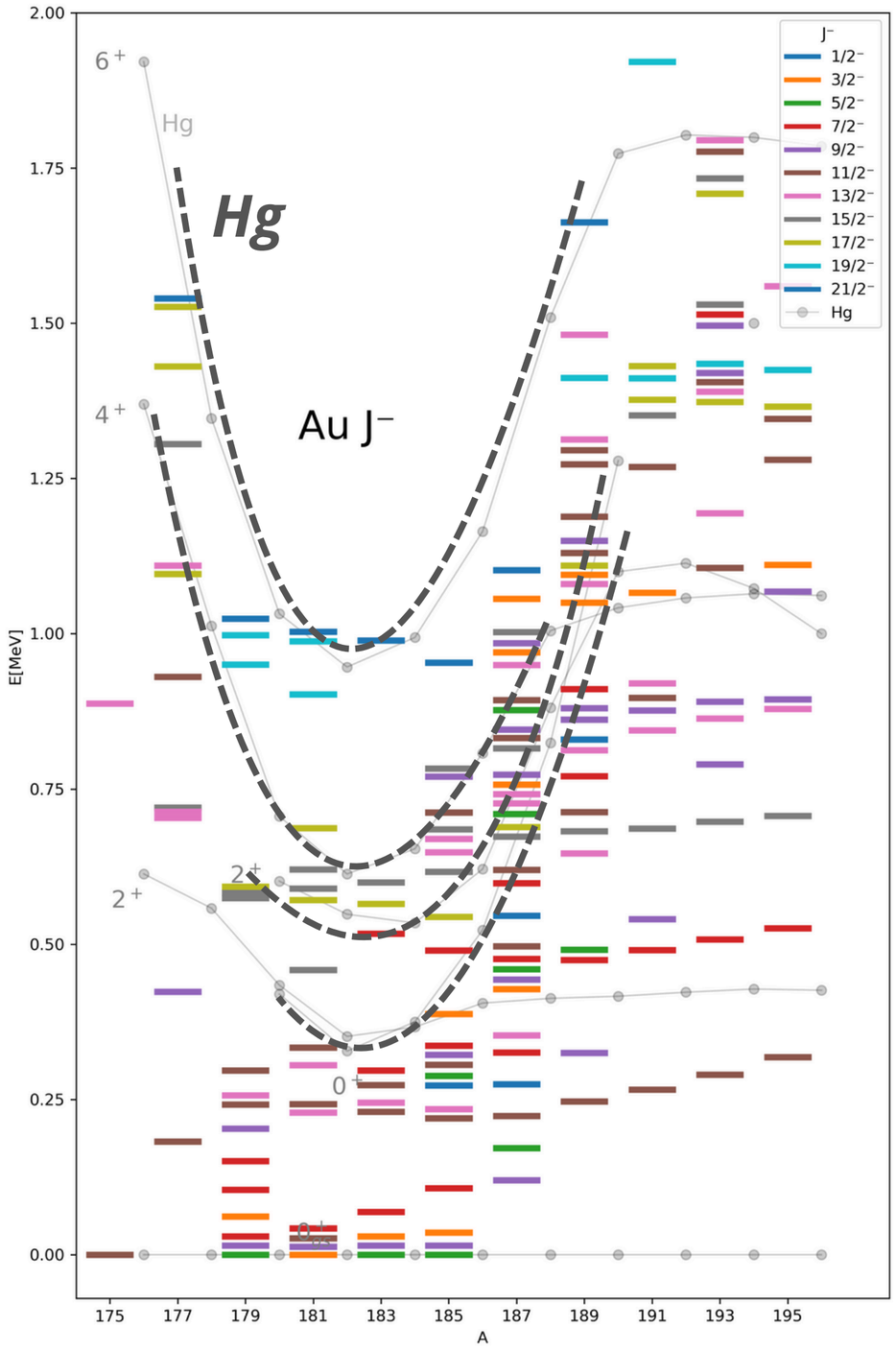


[2] K. Heyde, P. Van Isacker et al. "*Coexistence in Odd-Mass Nuclei*". In: Physics Reports (1983)

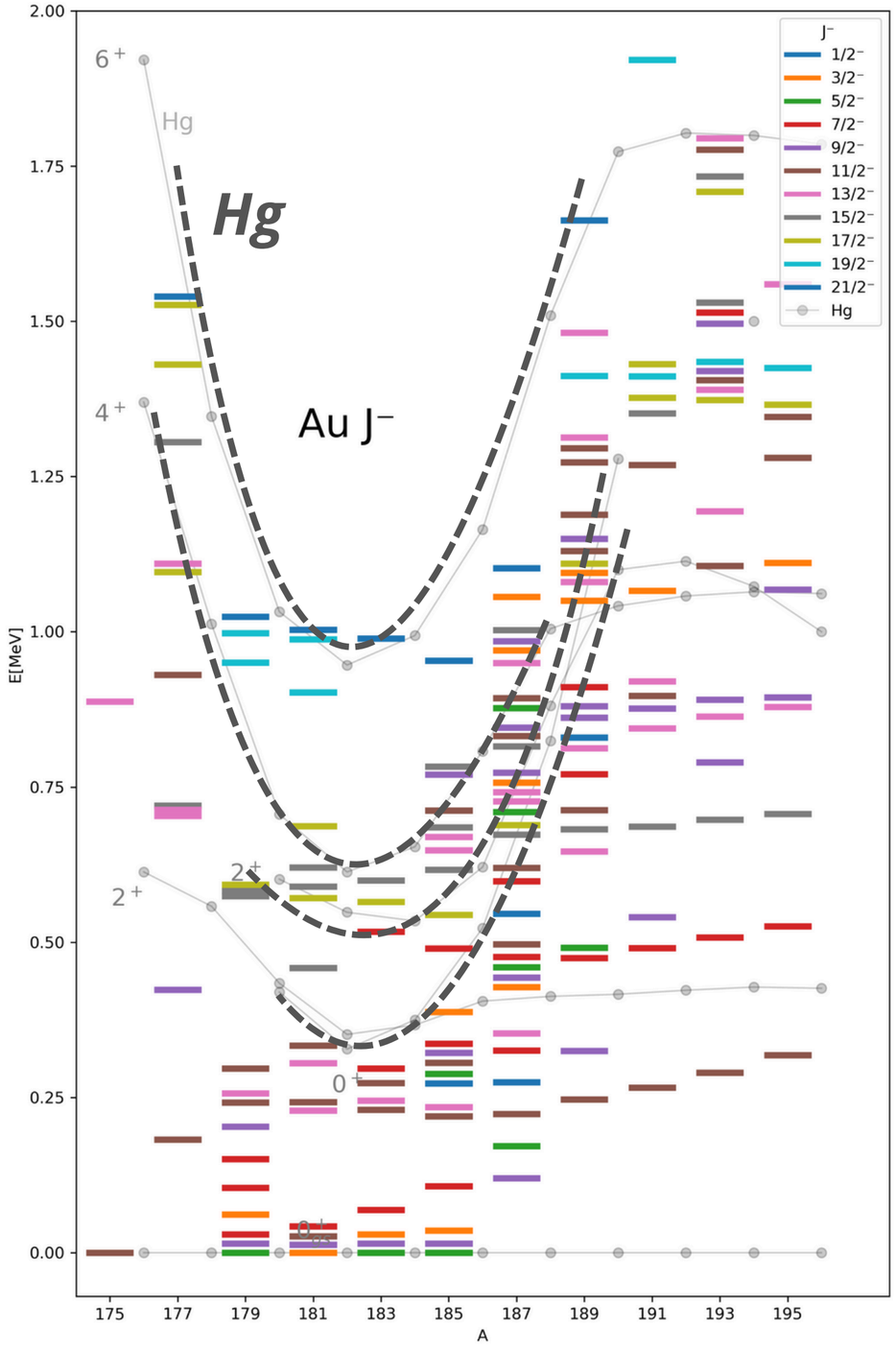
Experimental situation nowadays: Negative Parity

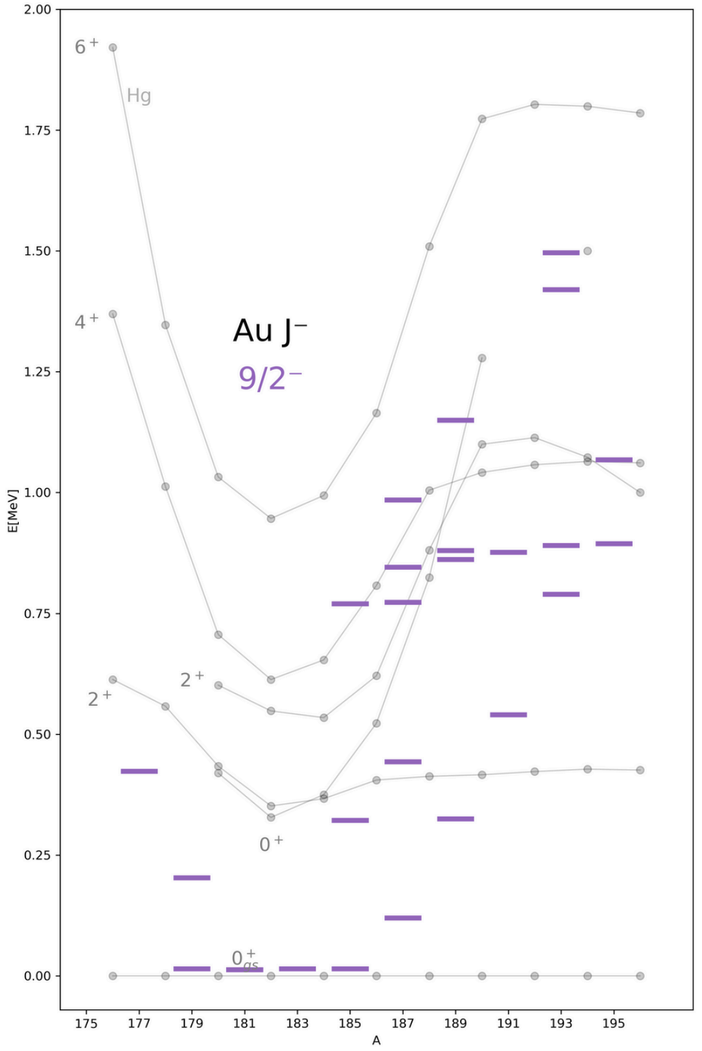


Experimental situation nowadays: Negative Parity

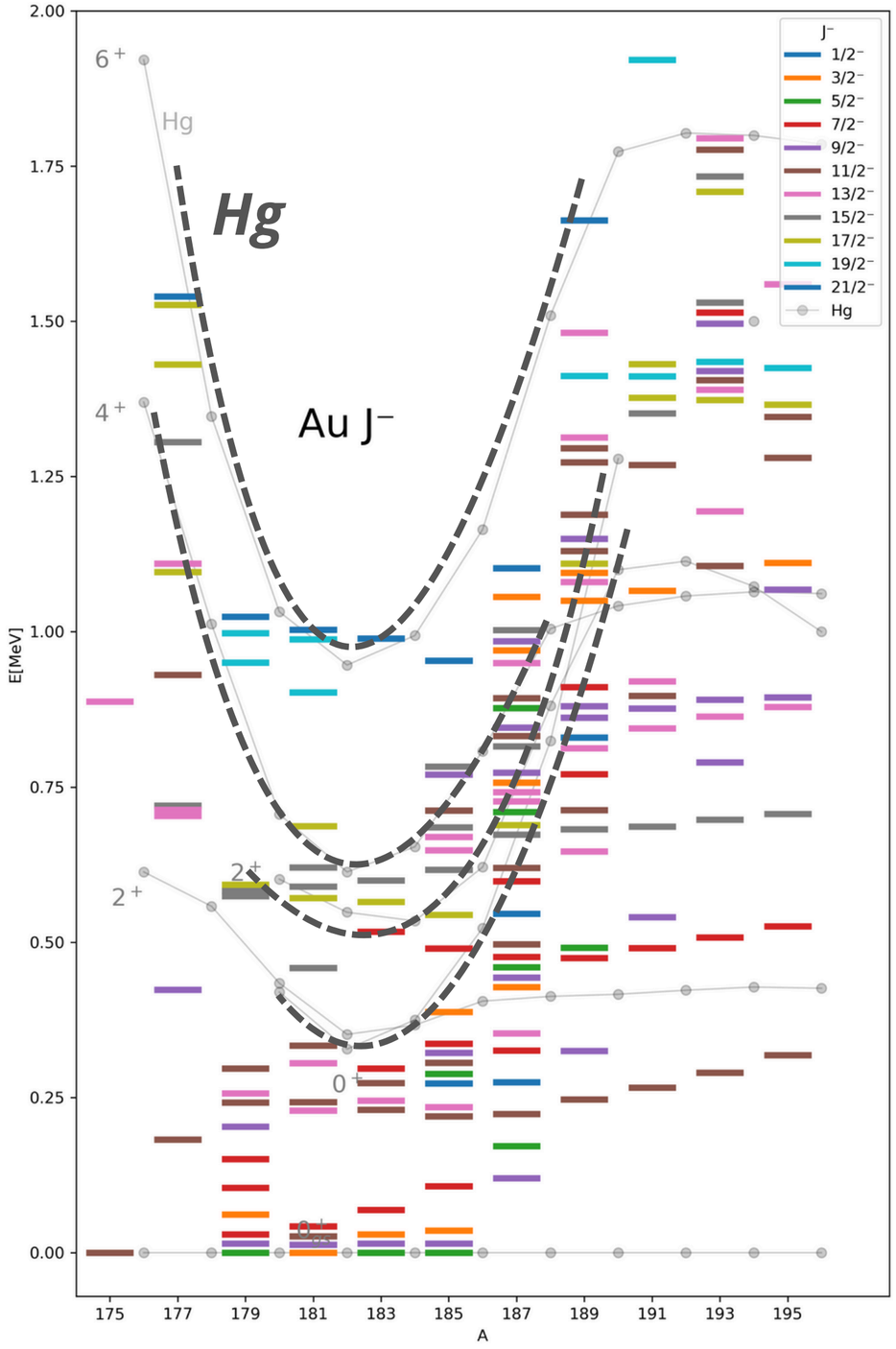


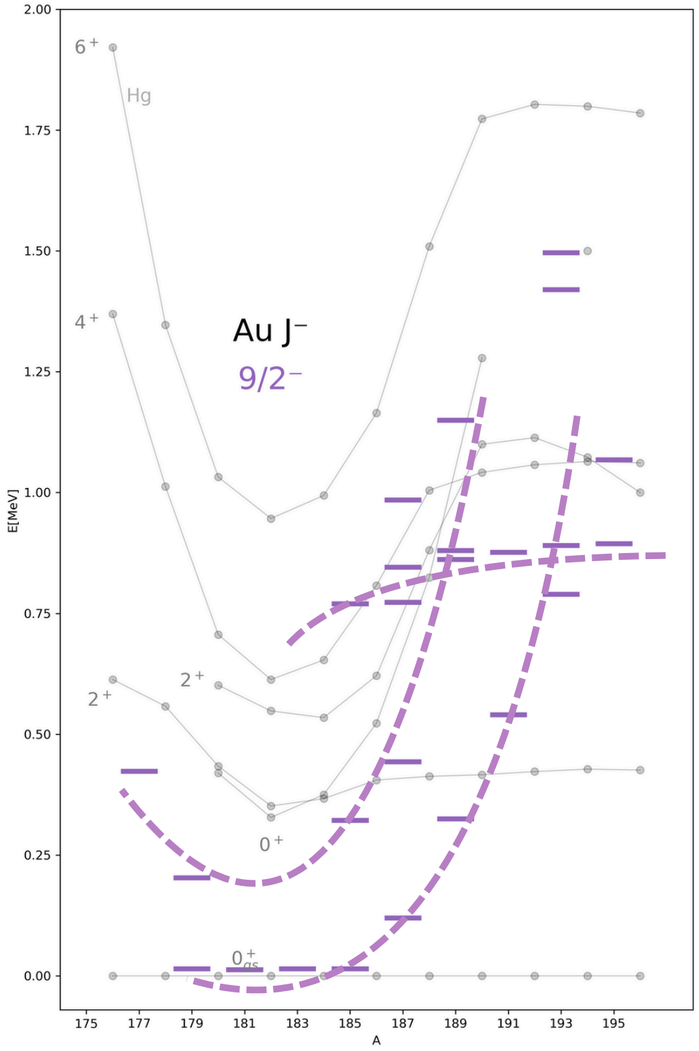
Experimental situation nowadays: Negative Parity





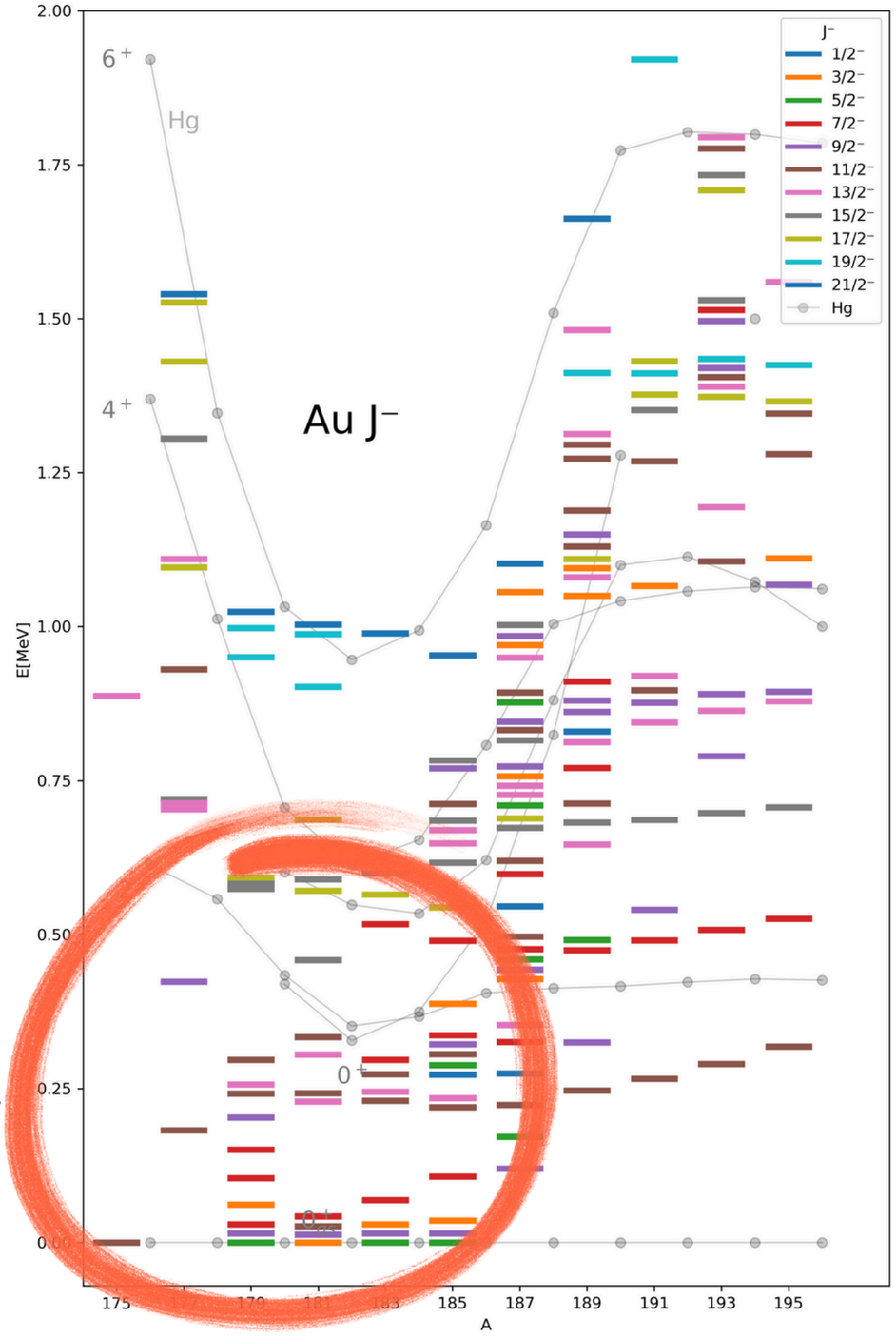
Experimental situation nowadays: Negative Parity

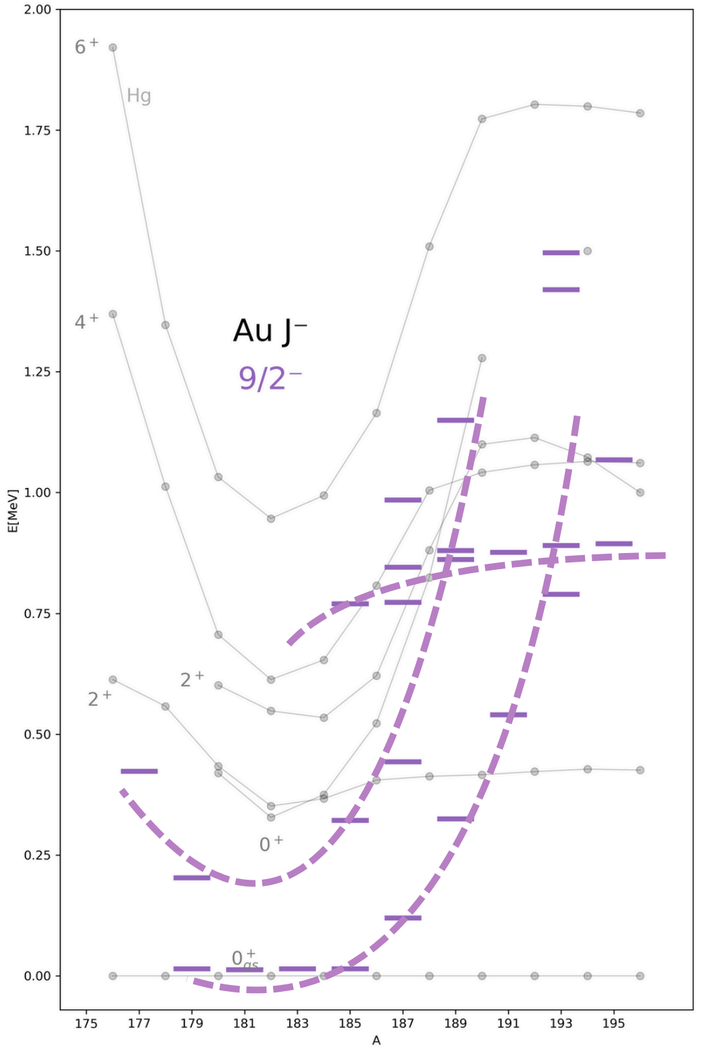




Experimental situation nowadays: Negative Parity

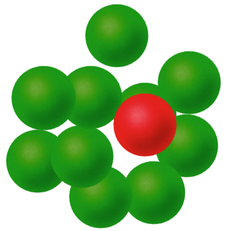
A	year
175	2004
179	2009
181	2006
185	2006





The IBFM-CM Hamiltonian

$$\hat{H}_{IBFM-CM} = \hat{H}_{IBM-CM} + \hat{H}_F + \hat{V}_{BF}$$



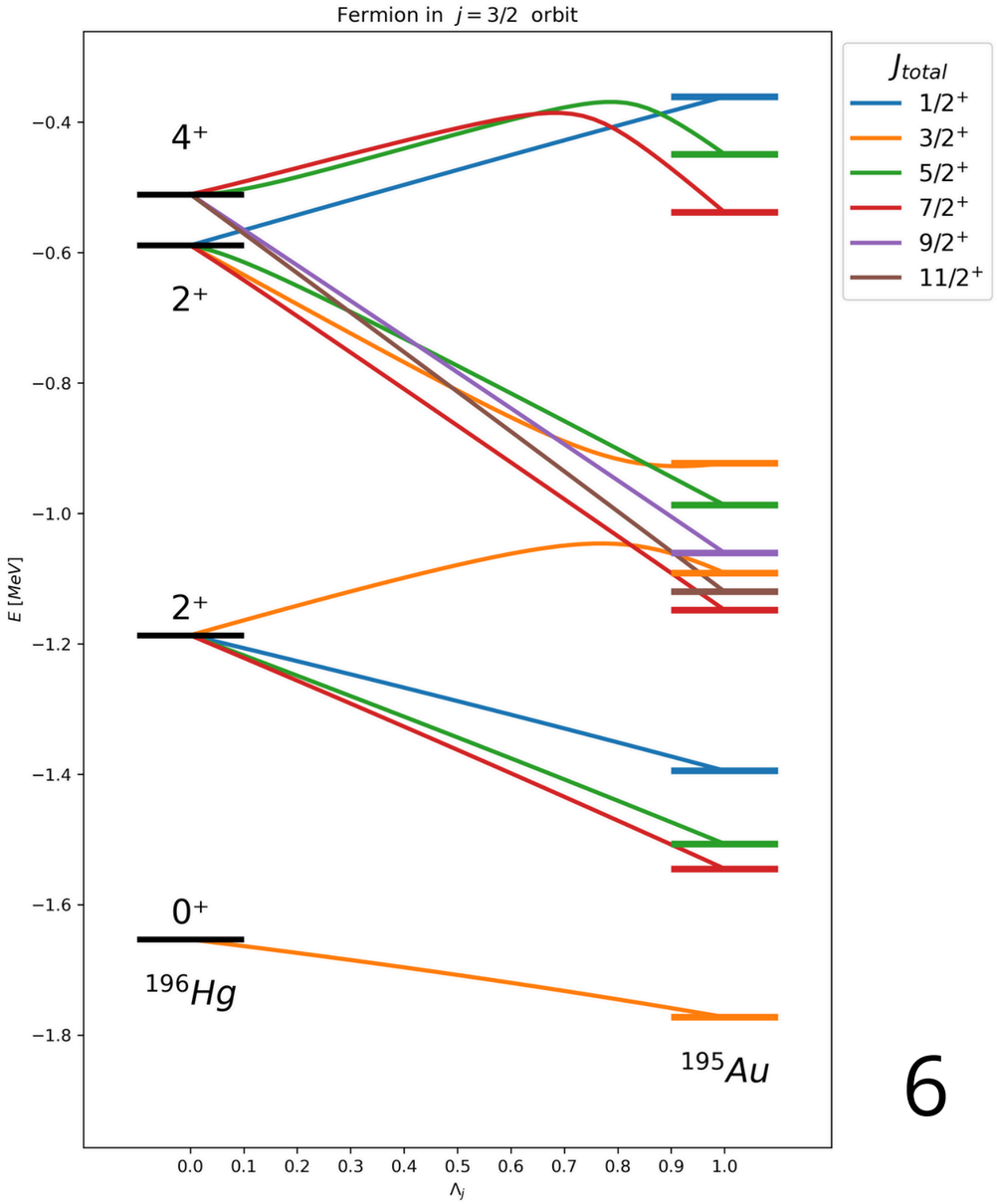
Boson-Fermion Interaction

$$\hat{V}_{MON} = A_j \left[[d^\dagger \times \tilde{d}]^{(0)} \times [a_j^\dagger \times \tilde{a}_j]^{(0)} \right]^{(0)}$$

$$\hat{V}_{QUAD} = \Gamma_j \left[\hat{Q}_B^\chi \times [a_j^\dagger \times \tilde{a}_j]^{(2)} \right]^{(0)}$$

$$\hat{V}_{EX} = \Lambda_j : \left[[d^\dagger \times \tilde{a}_j]^{(0)} \times [a_j^\dagger \times \tilde{d}]^{(0)} \right]^{(0)} :$$

(Single-orbit squematic calculation)

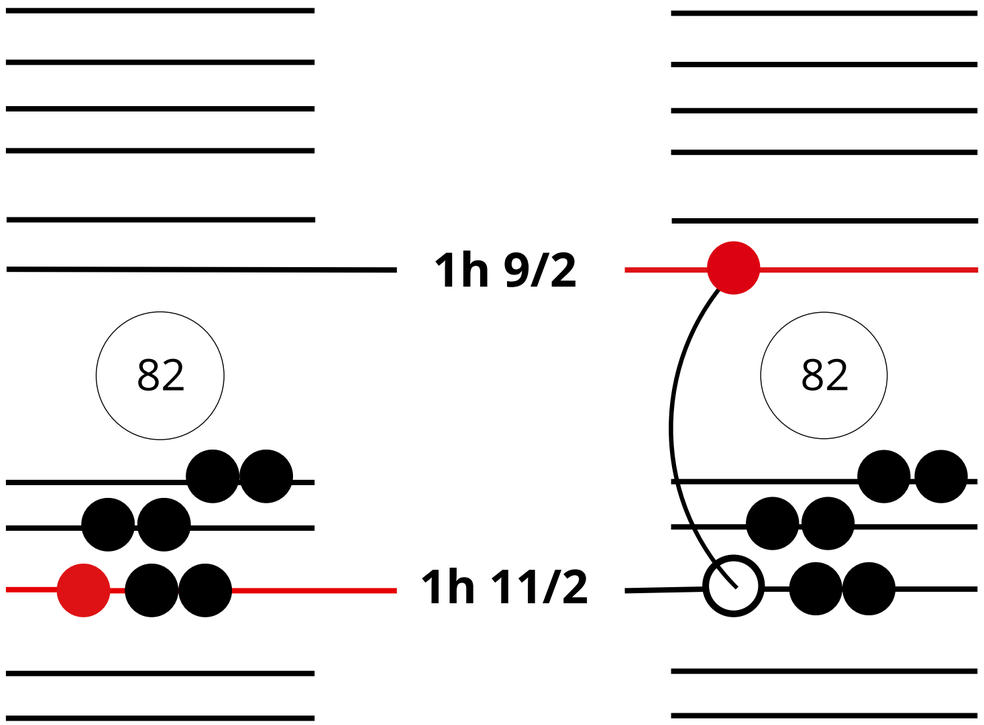


Au

1p - 1h

Regular

Intruder



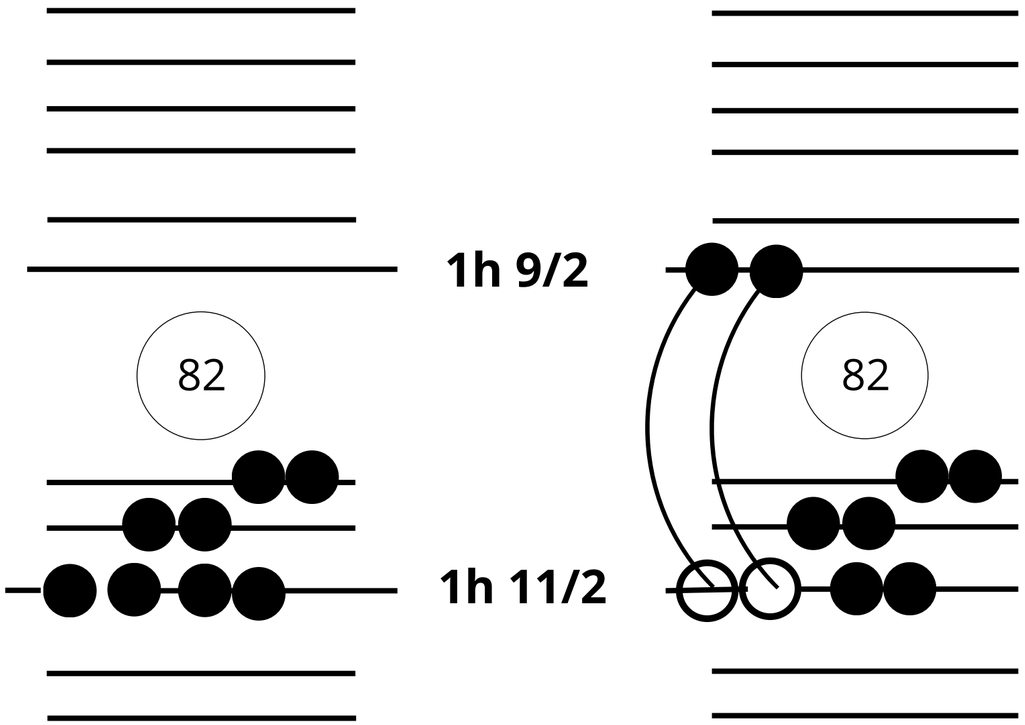
IBFM - CM

$Z = 78 \quad 79 \quad 80$

Pt	Au	Hg

$|Hg^{[N_b]}\rangle$

$|Hg^{[N_b+2]}\rangle$



Au

1p - 1h

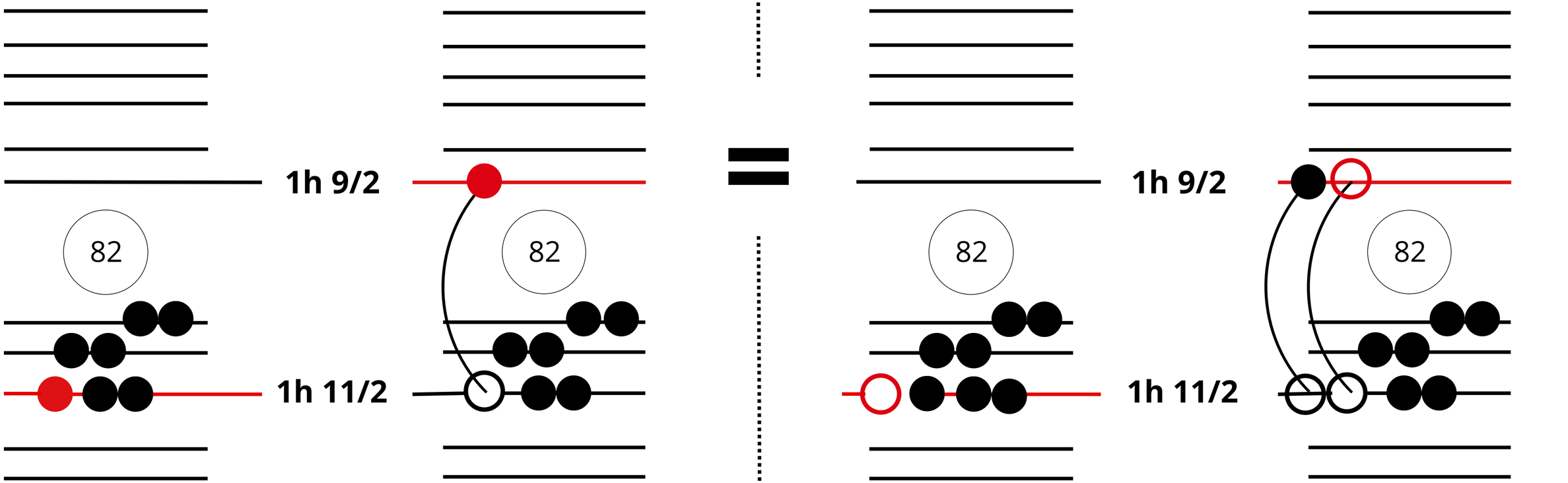
IBFM - CM

$Z =$ **78** **79** **80**

Pt	Au	Hg

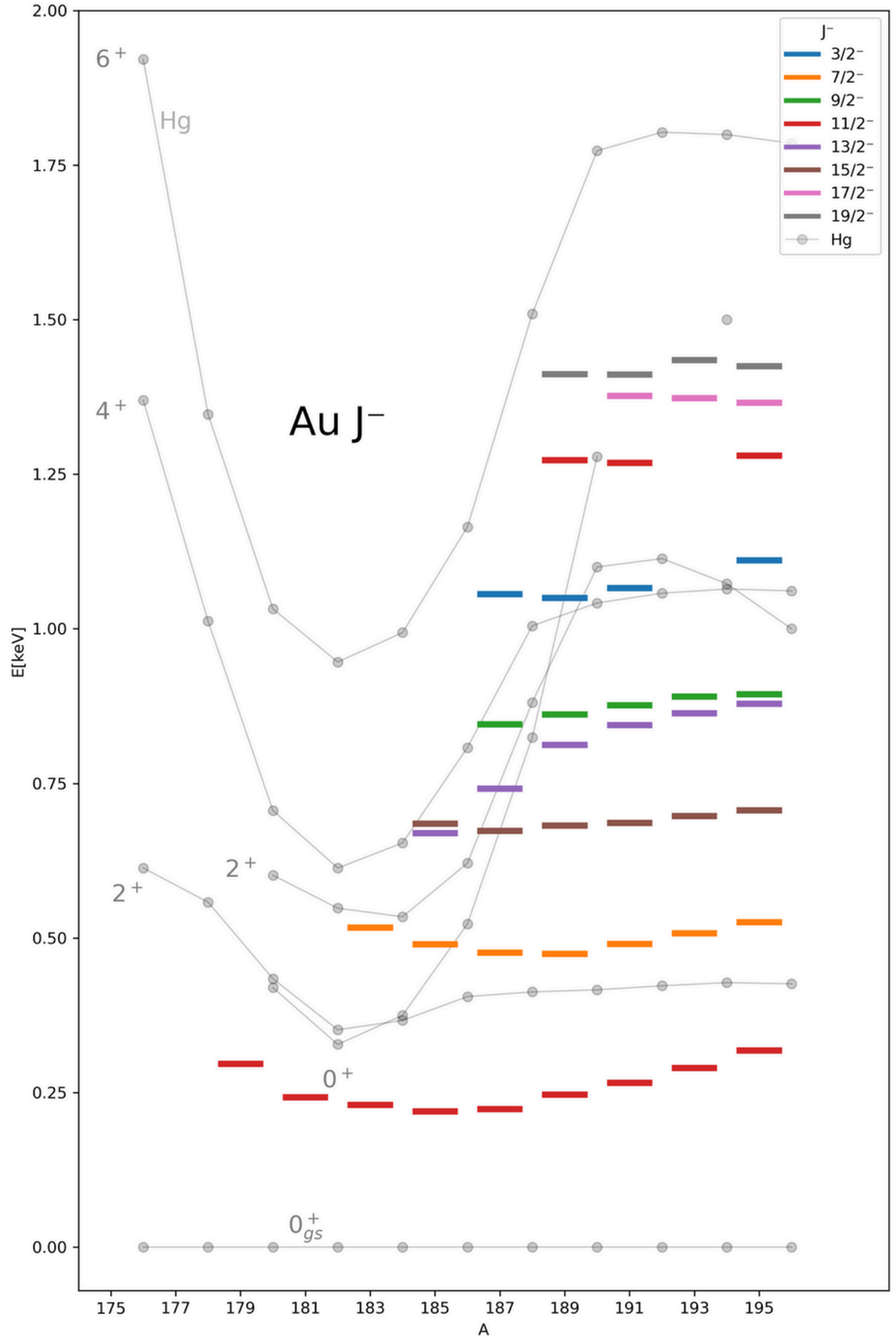
Regular *Intruder*

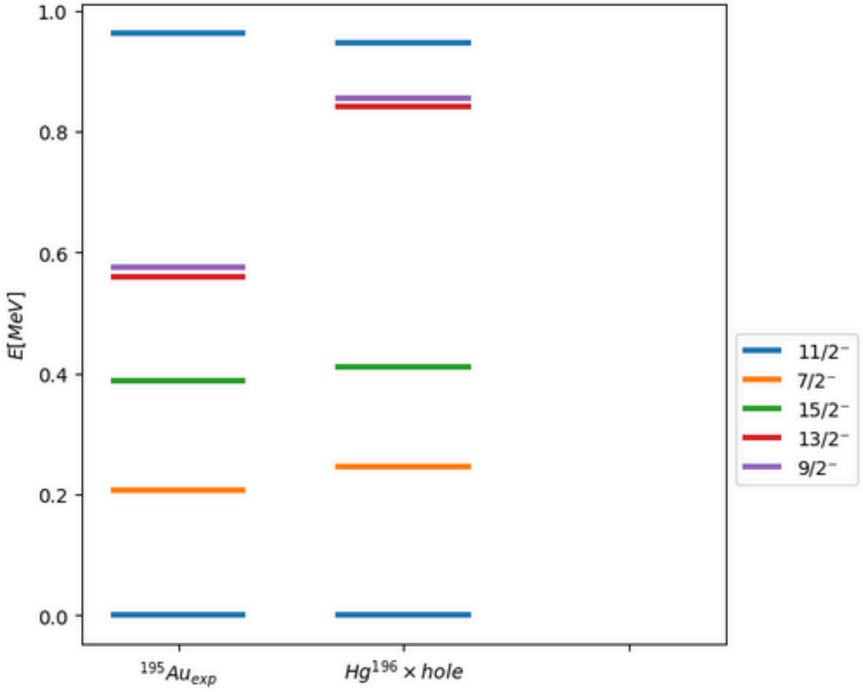
$|Hg^{[N_b]} \times \frac{11}{2}\pi^{-1}\rangle$ $|Hg^{[N_b+2]} \times \frac{9}{2}\pi^{-1}\rangle$



Regular Negative Parity Band

- Far from Midshell
- No mixing with the intruder configuration





$$|Hg^{[N]} \times \frac{11}{2}\pi^{-1}\rangle$$

$$[MeV]$$
$$A_j = -0.13$$
$$\Gamma_j = -2.00$$
$$\Lambda_j = -1.00$$

Preliminary result!

Next steps

- $\hat{H}_{-} = \hat{H}_{REG} + \hat{H}_{INT} + \hat{V}_{MIX}$
- $\hat{H}_{TOT} = \hat{H}_{-} + \hat{H}_{+}$

Conclusions

- **More experimental data available** in the lead-region midshell would help to do the shown analysis and understand the phenomenology.
- It seems to be possible describing shape coexistence in ***Au*** within the IBFM-CM framework by coupling a **proton hole to even-even *Hg*.**
- Regular (N) and intruder (N+2) bands come from **different single particle levels.**

New in IBFM-CM!

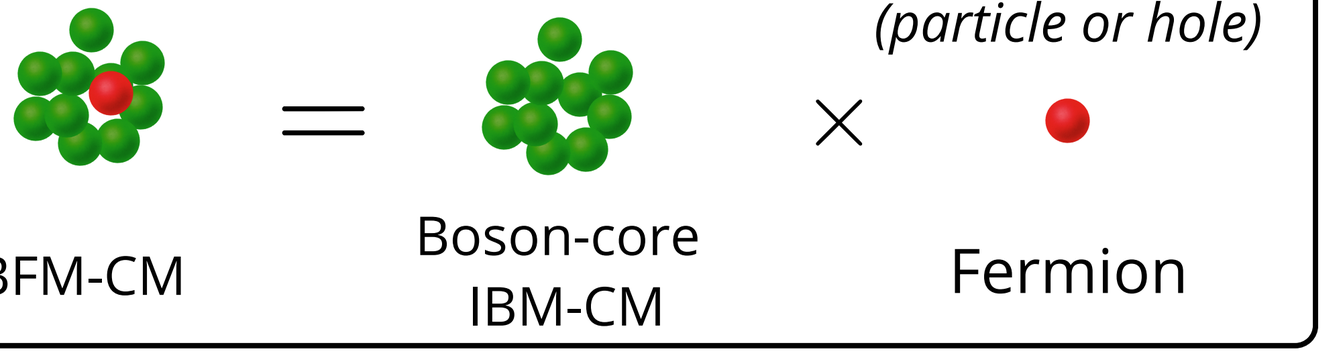
THAT'S ALL

THANKS FOR YOU ATTENTION!

ANEXOS

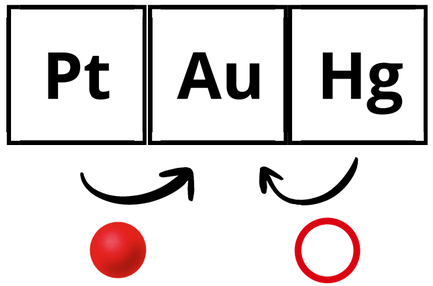
The Interacting Boson-Fermion Model with Configuration-Mixing

Odd Nuclei = *Even Nuclei* × *Unpaired Nucleon (particle or hole)*

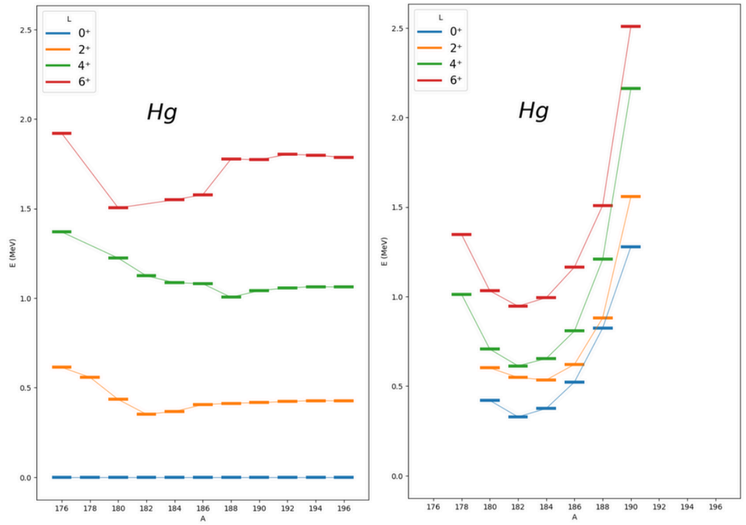


IBFM-CM = Boson-core IBM-CM × Fermion

$Z =$ **78** **79** **80**

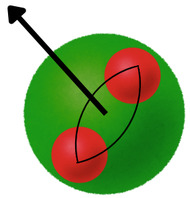


$[N_b]$ $[N_b + 2]$



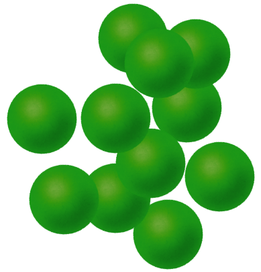
- The fermion determinates g.s. angular momentum
- Intruder boson w.f. described by 2p-2h

The Interacting Boson-Fermion Model - CM



$$L = 0 \rightarrow |s\rangle = s^{\dagger}|0\rangle$$

$$L = 2 \rightarrow |d\rangle = d^{\dagger}|0\rangle$$

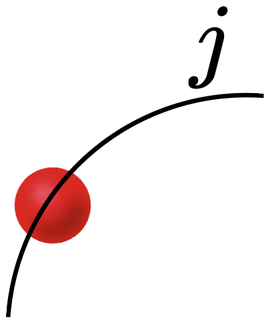


Boson Hamiltonian (EQC)

$$\hat{H}_B = \hat{n}_d - \hat{Q}^{\chi} \cdot \hat{Q}^{\chi}$$

IBM Configuration Mixing

$$\hat{H}_{B_{CM}} = \hat{H}_B^{[N]} + (\hat{H}_B^{[N+2]} + \Delta_{GAP}) + w_{MIX}$$



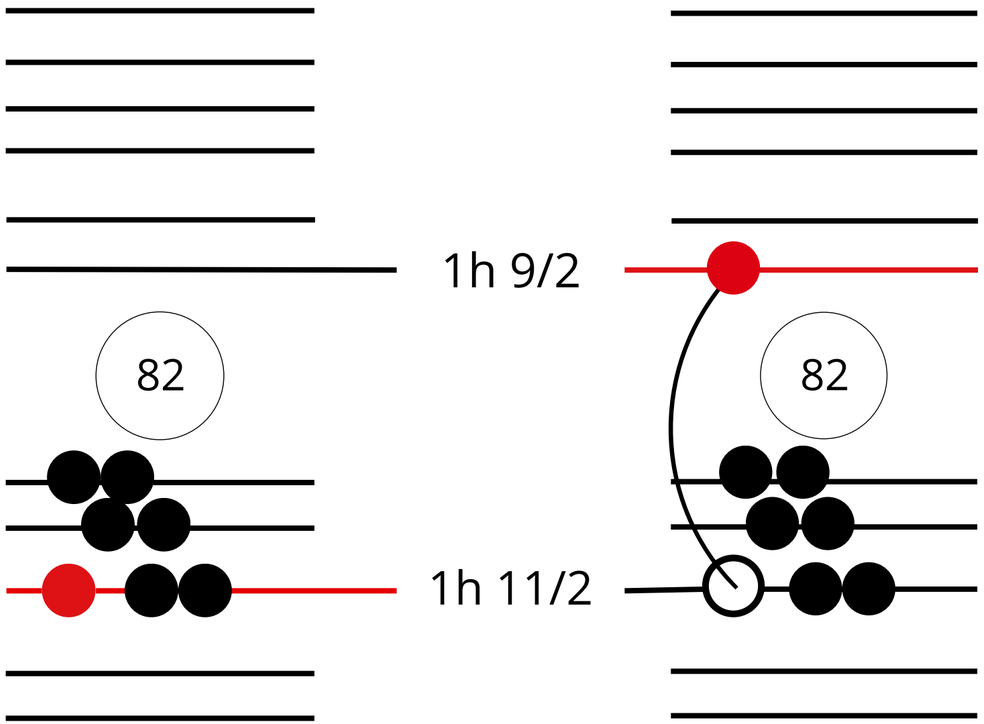
$$|j\rangle = a_j^{\dagger}|0\rangle$$

Fermion Hamiltonian

$$\hat{H}_F = [a_j^{\dagger} \times \tilde{a}_j]^{(0)}$$

1 particle - 1 hole

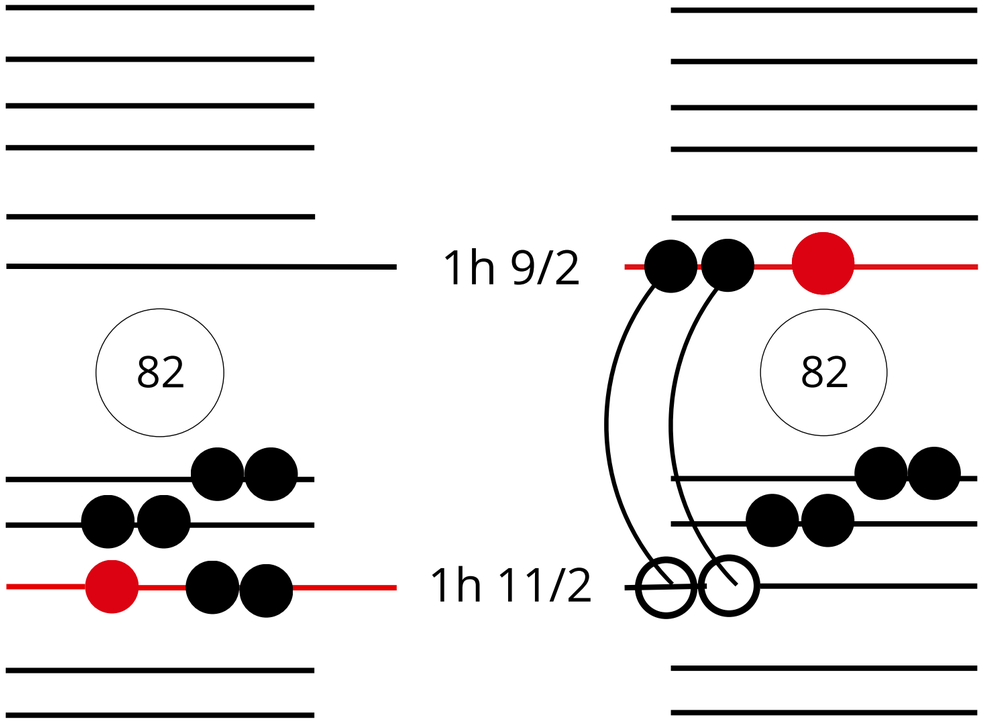
Au



Band-head Spin ⟶ *Unpaired Proton* ●

IBFM - CM

Pt x particle



Band-head Spin ⟶ *Coupled Fermion*

⇧ Valence particles

⬇

- ⇧ Correlated System
- ⇧ Pairing Energy
- ⇧ Deformation