Quadrupole-octupole coupling and the onset of octupole collectivity

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CGS17, Grenoble, July 2023

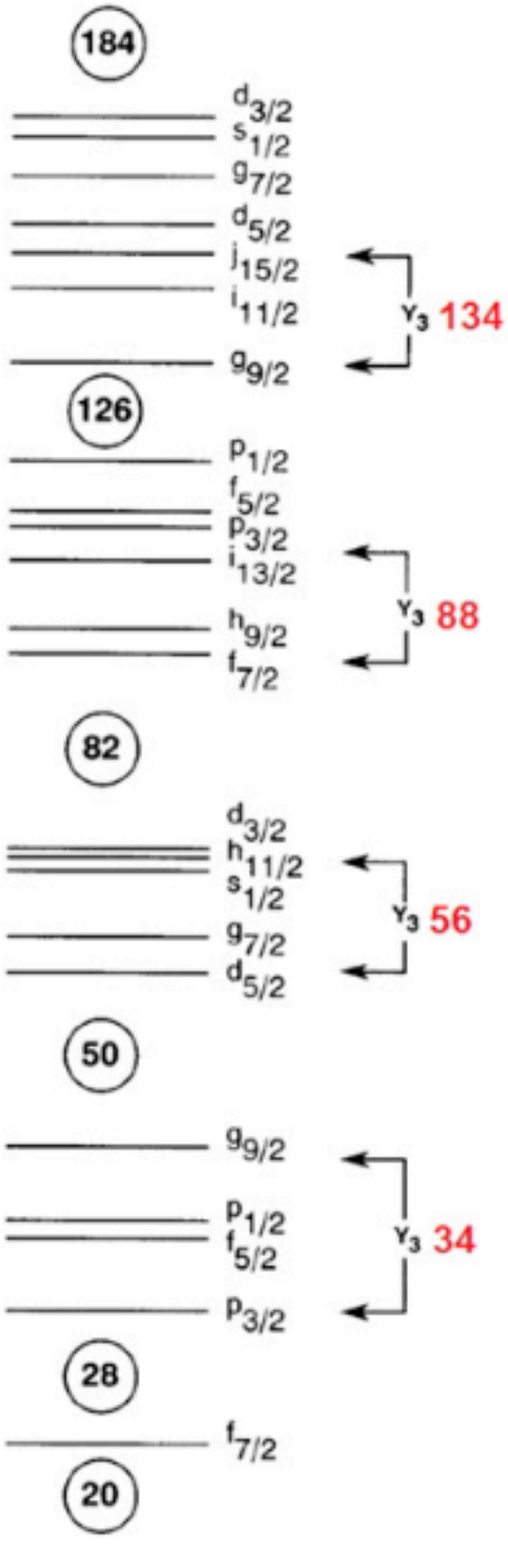
Contents

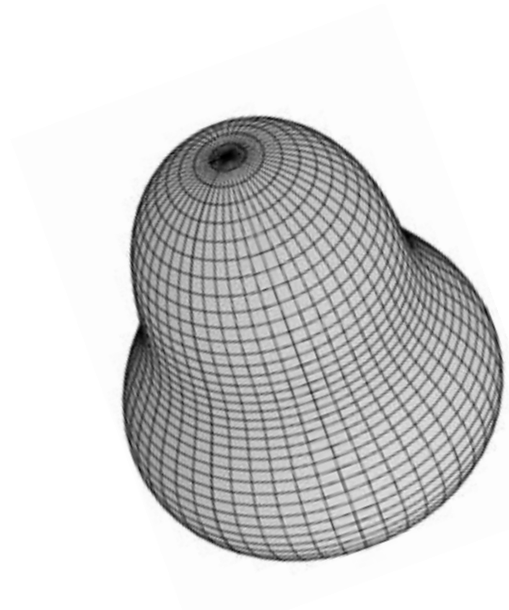
- Octupole deformation and IBM

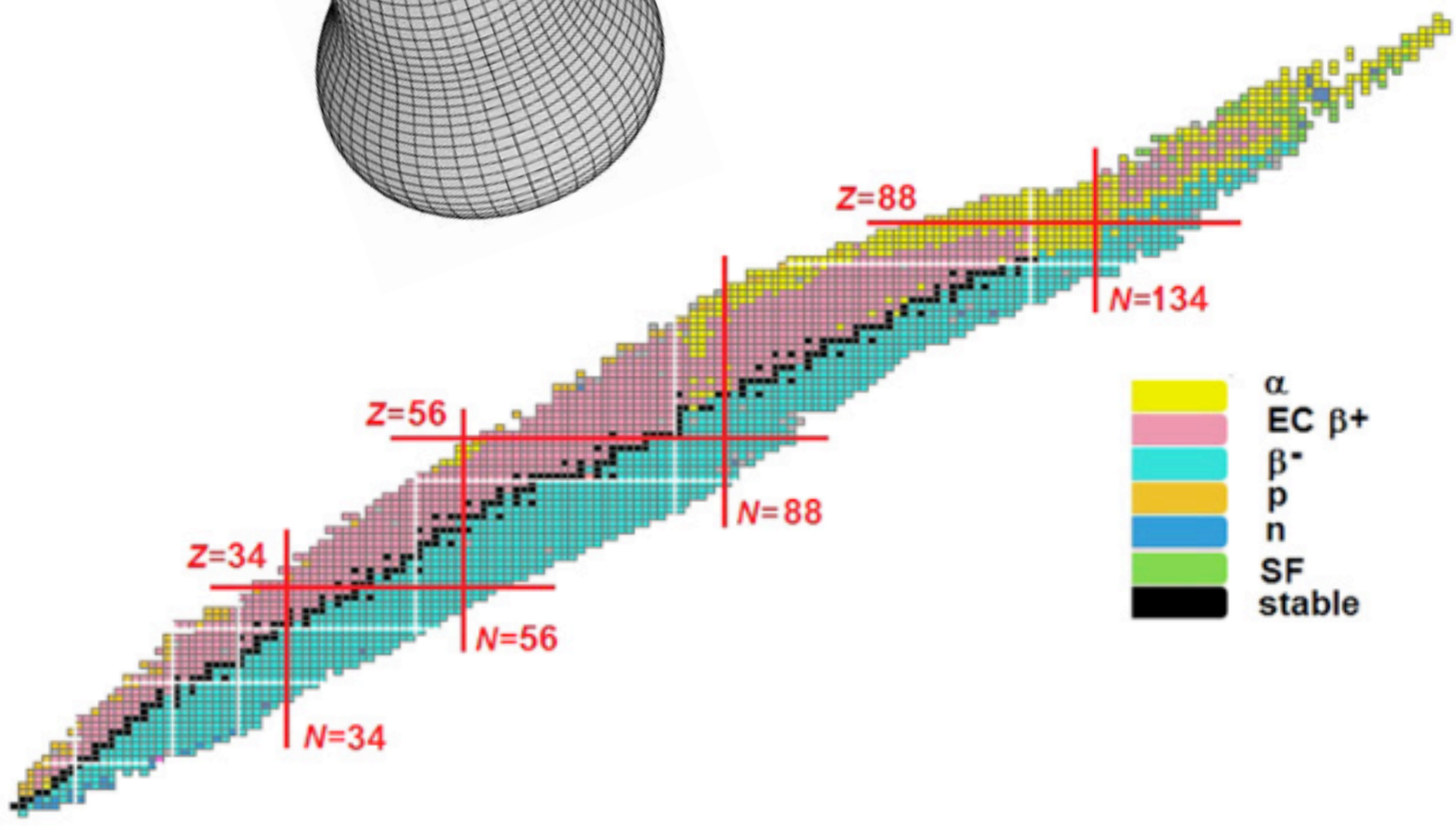
- Global study on octupole deformation

- A~100 nuclei, and shape coexistence in N~Z nuclei

Search for pear shapes







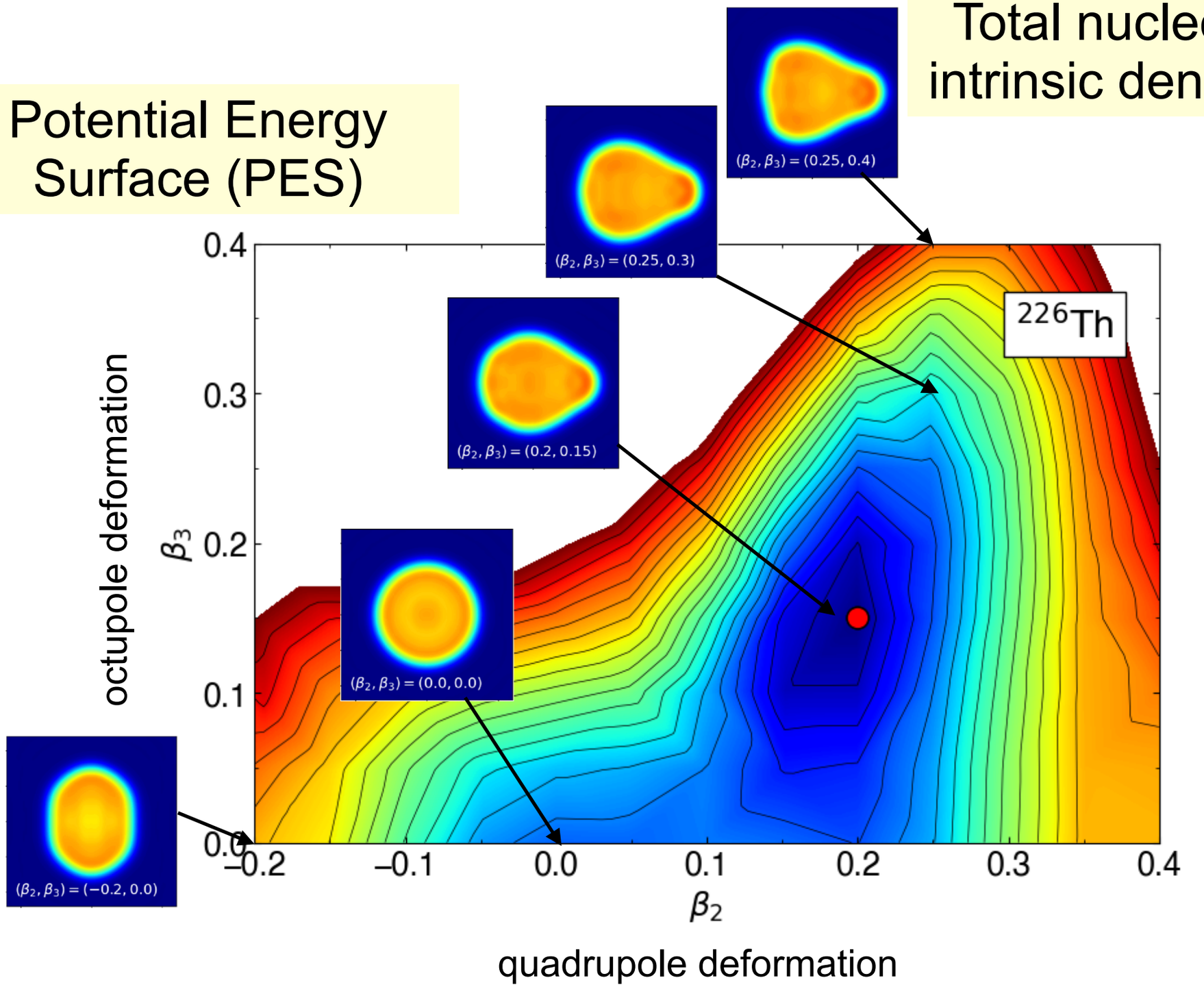
^{220}Rn, ^{224}Ra (CERN), ^{144,146}Ba (ANL), etc.

Butler, Nazarewicz, RMP (1996); Butler, JPG (2016)

Mean-field picture

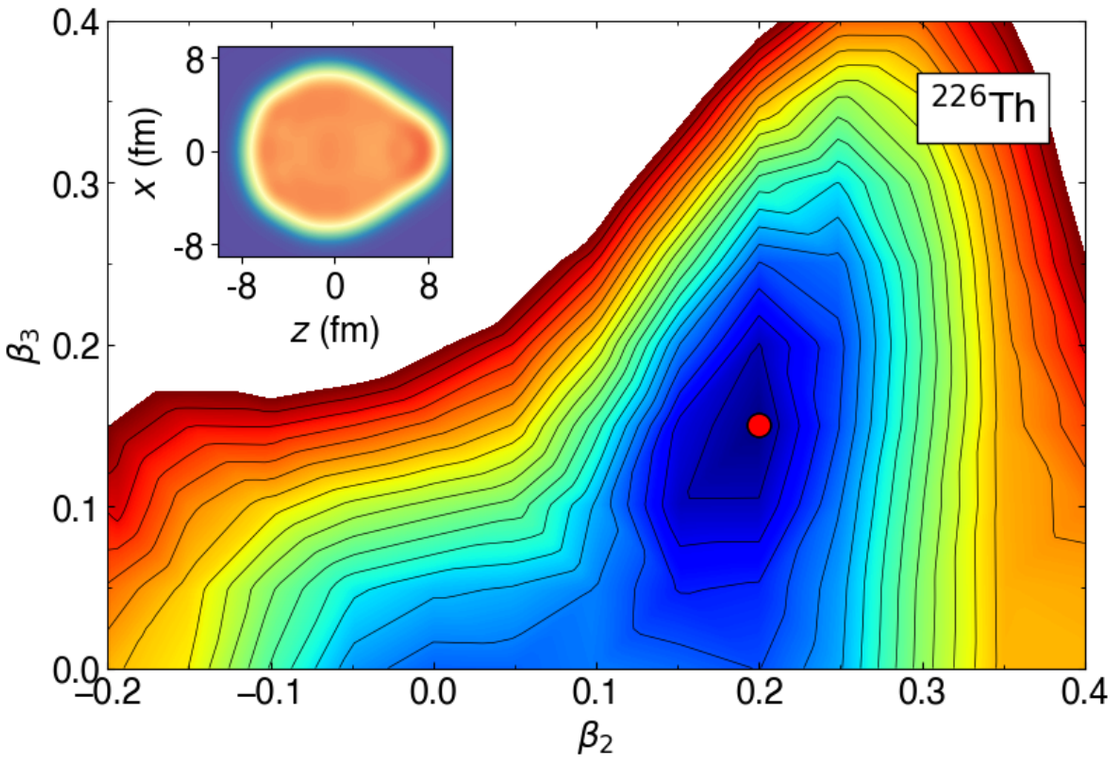
Potential Energy Surface (PES)

Total nucleon intrinsic density

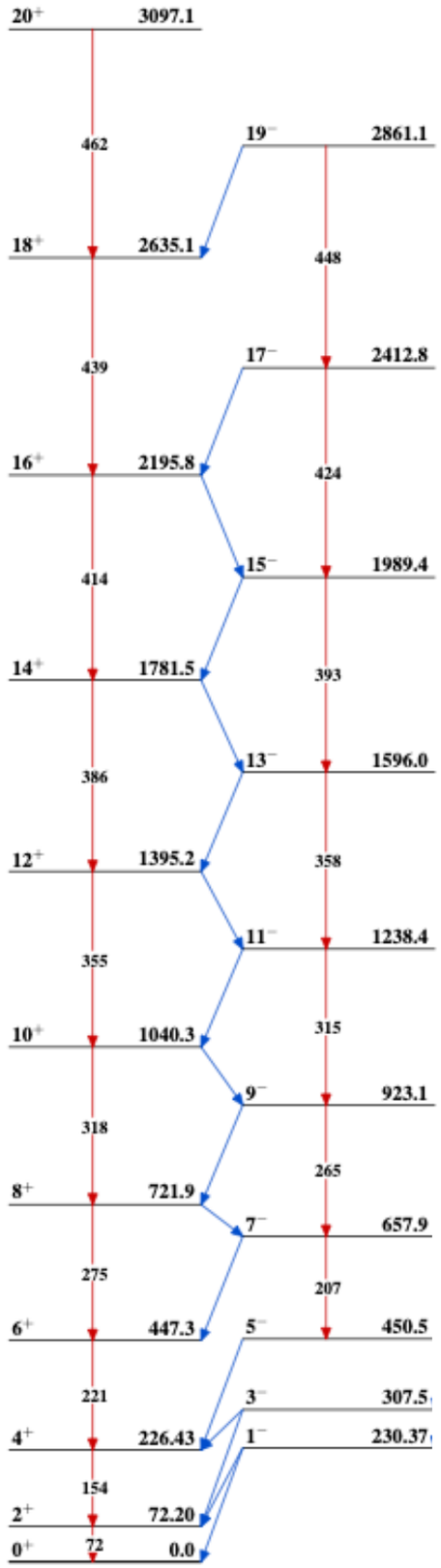


Computing energy spectra

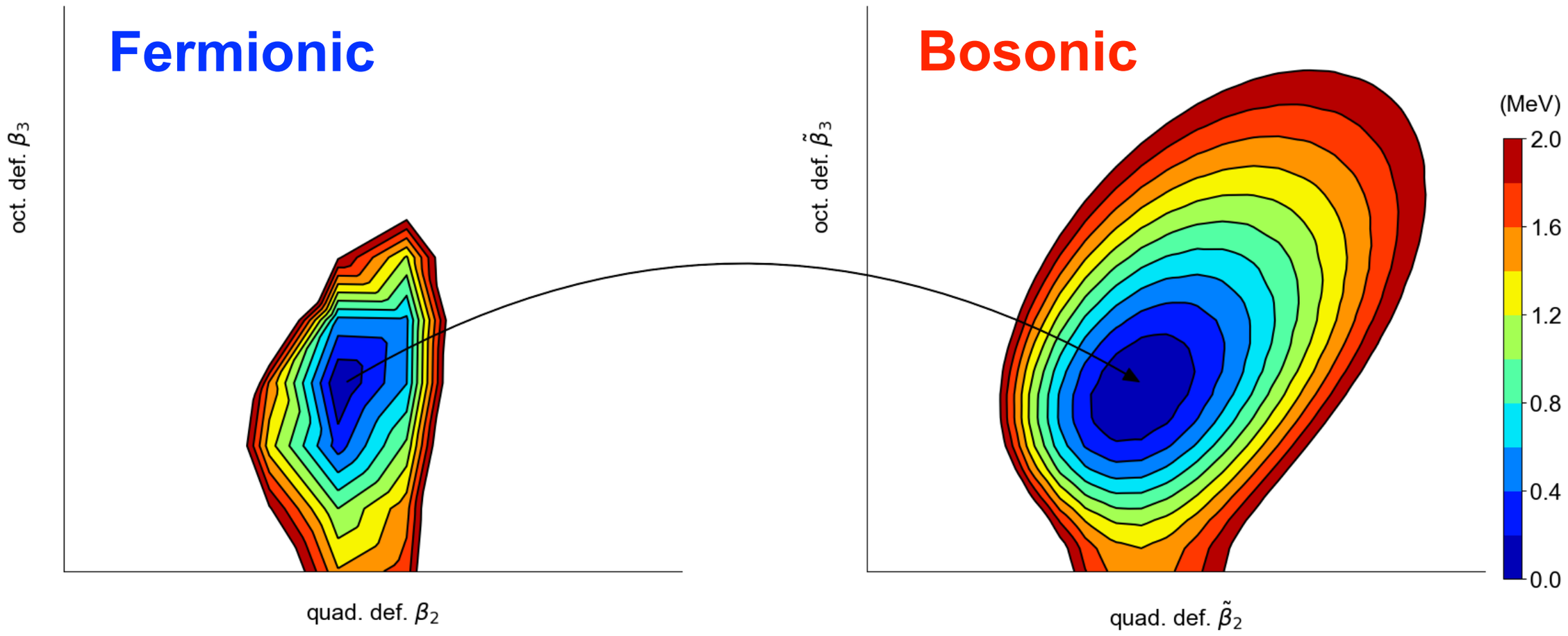
Intrinsic frame



Observables:
alternating parity band?
E1, E3?



Mean-field to IBM



- Mapping microscopic energy surface onto the IBM Hamiltonian
- Diagonalization of the mapped Hamiltonian -> energy spectra

KN et al. PRL (2008) ; PRC (2010)

Interacting Boson Model

Arima, Iachello (1975)

Building blocks:

s, d, f bosons ~ J=0+, 2+ and 3- collective nucleon pairs

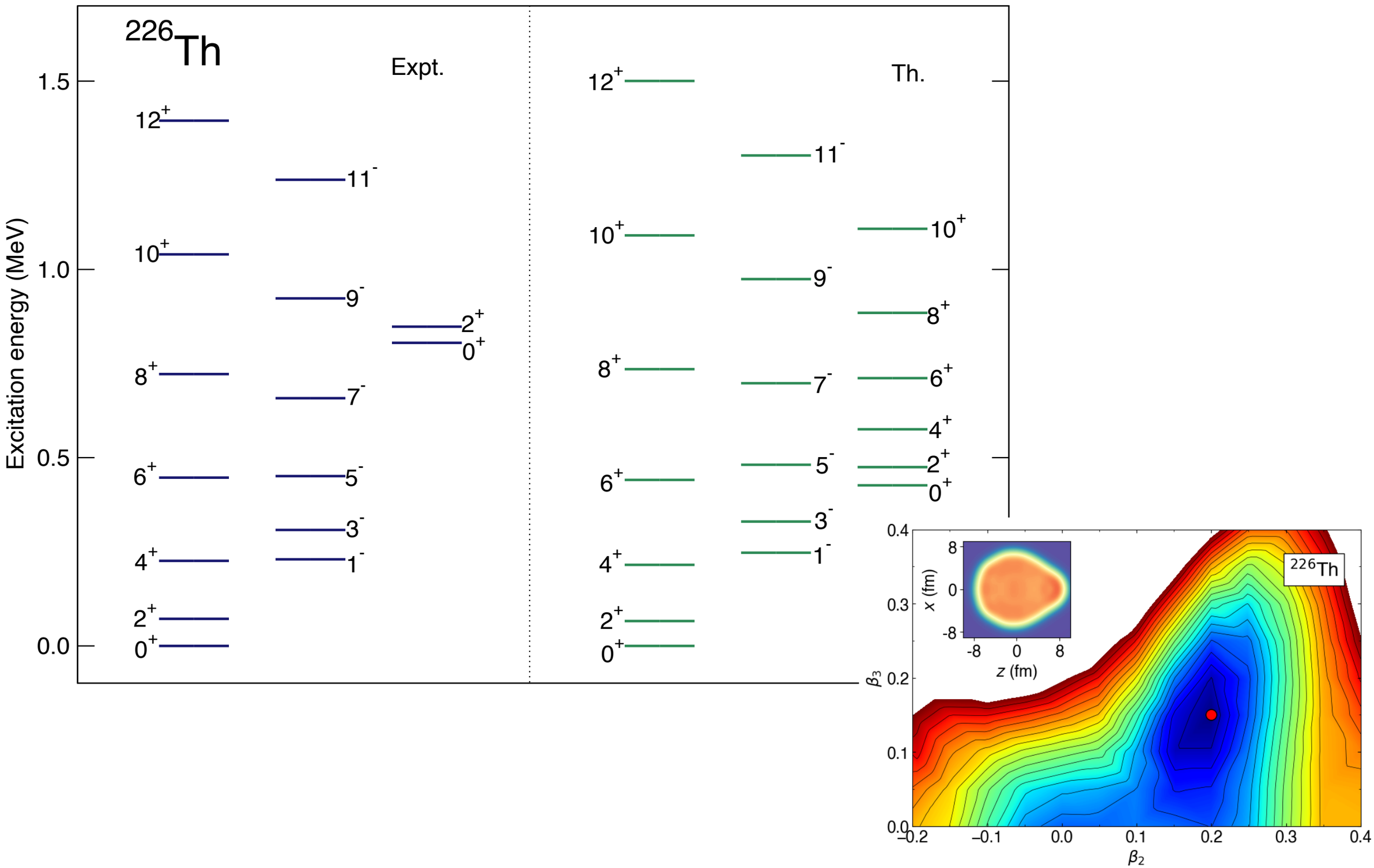
Hamiltonian: $$\boxed{H = H_{sd} + H_f + H_{sd-f}}$$

… determined by equating energy surfaces:

$$\boxed{E_{\mathrm{MF}}(\beta_{20}, \beta_{30}) \approx E_{\mathrm{IBM}}(\beta_{20}, \beta_{30})}$$

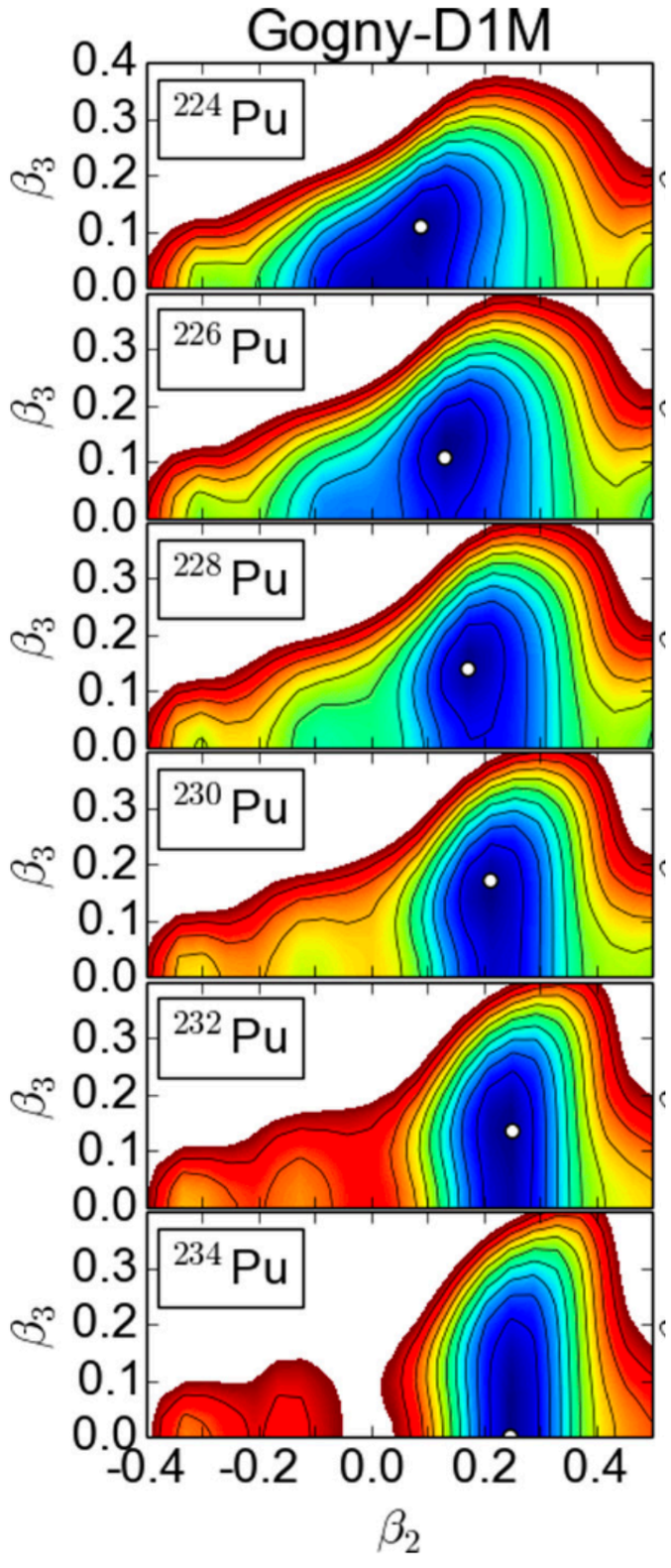
KN et al. PRC 88 (2013); PRC 89 (2014)

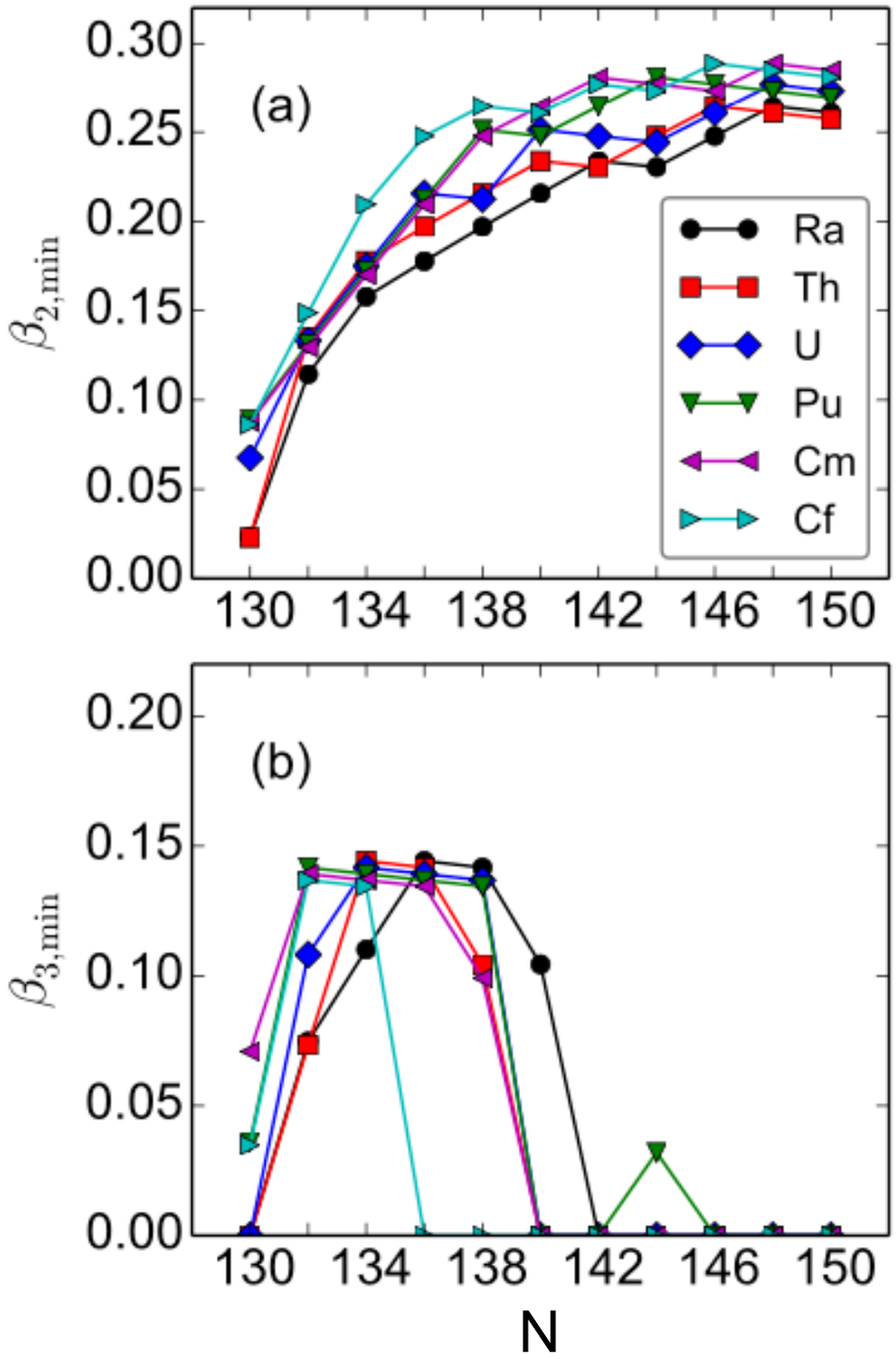
$K = 0^+$ and 0^- bands



Global study

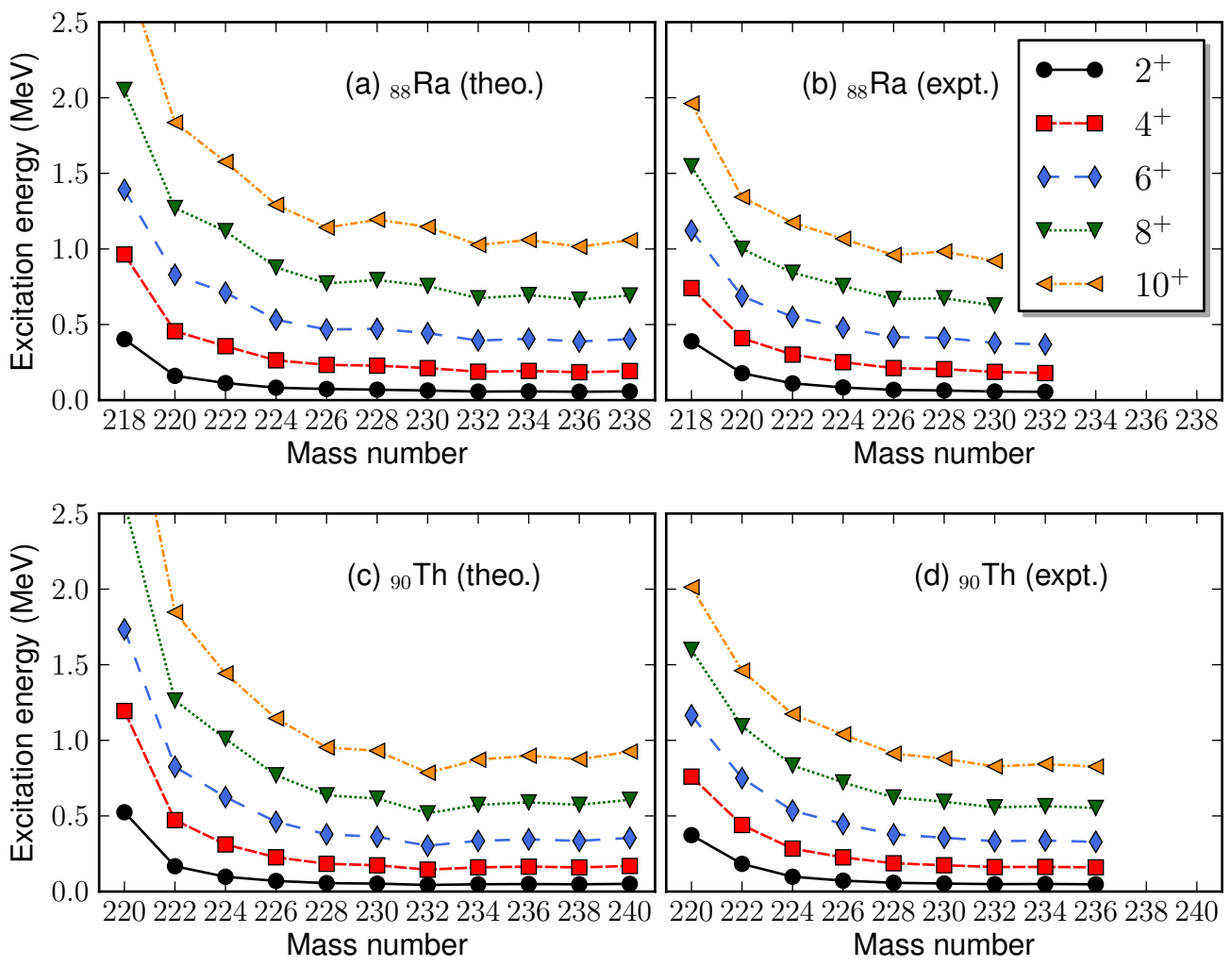
Actinides

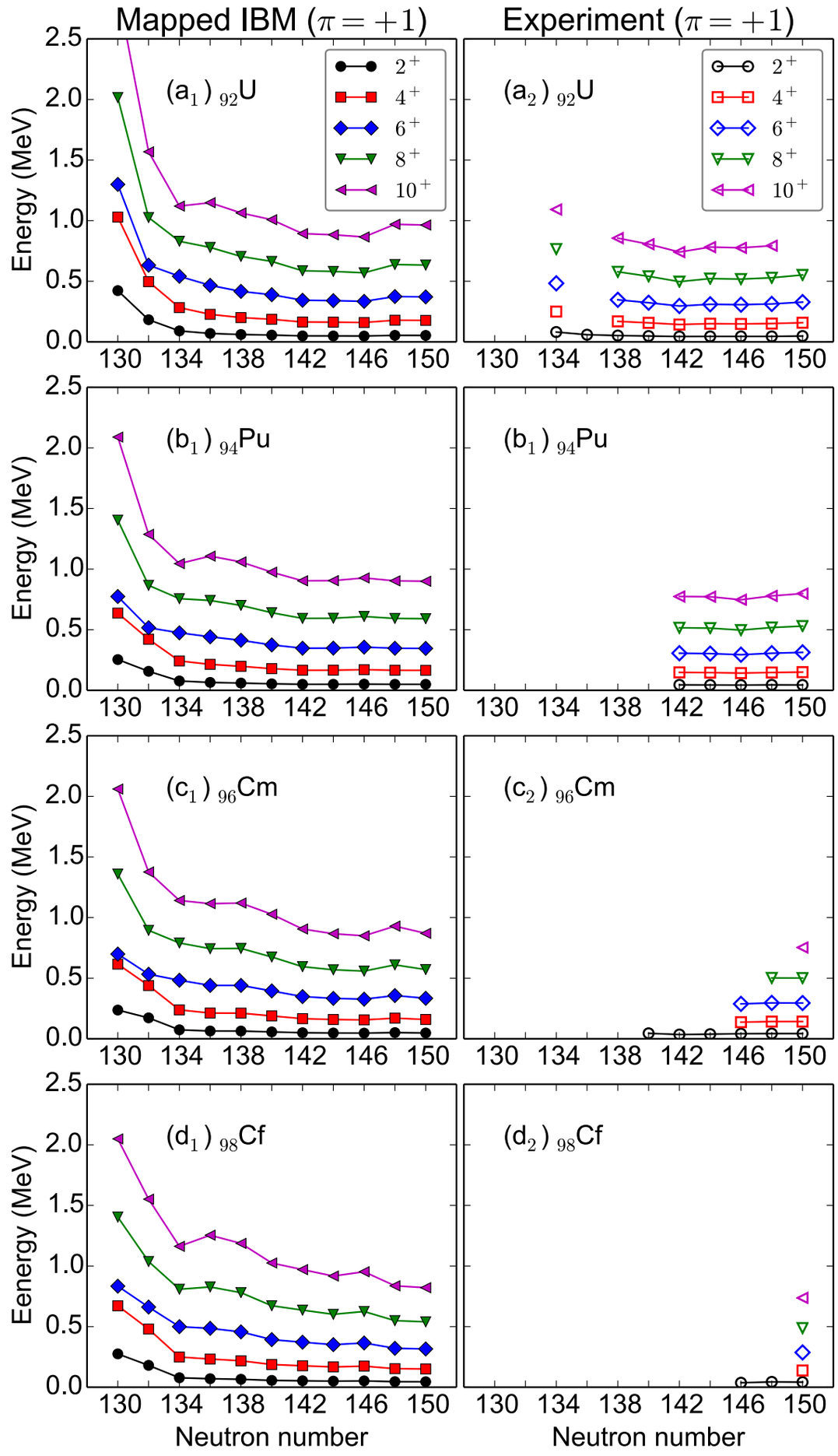




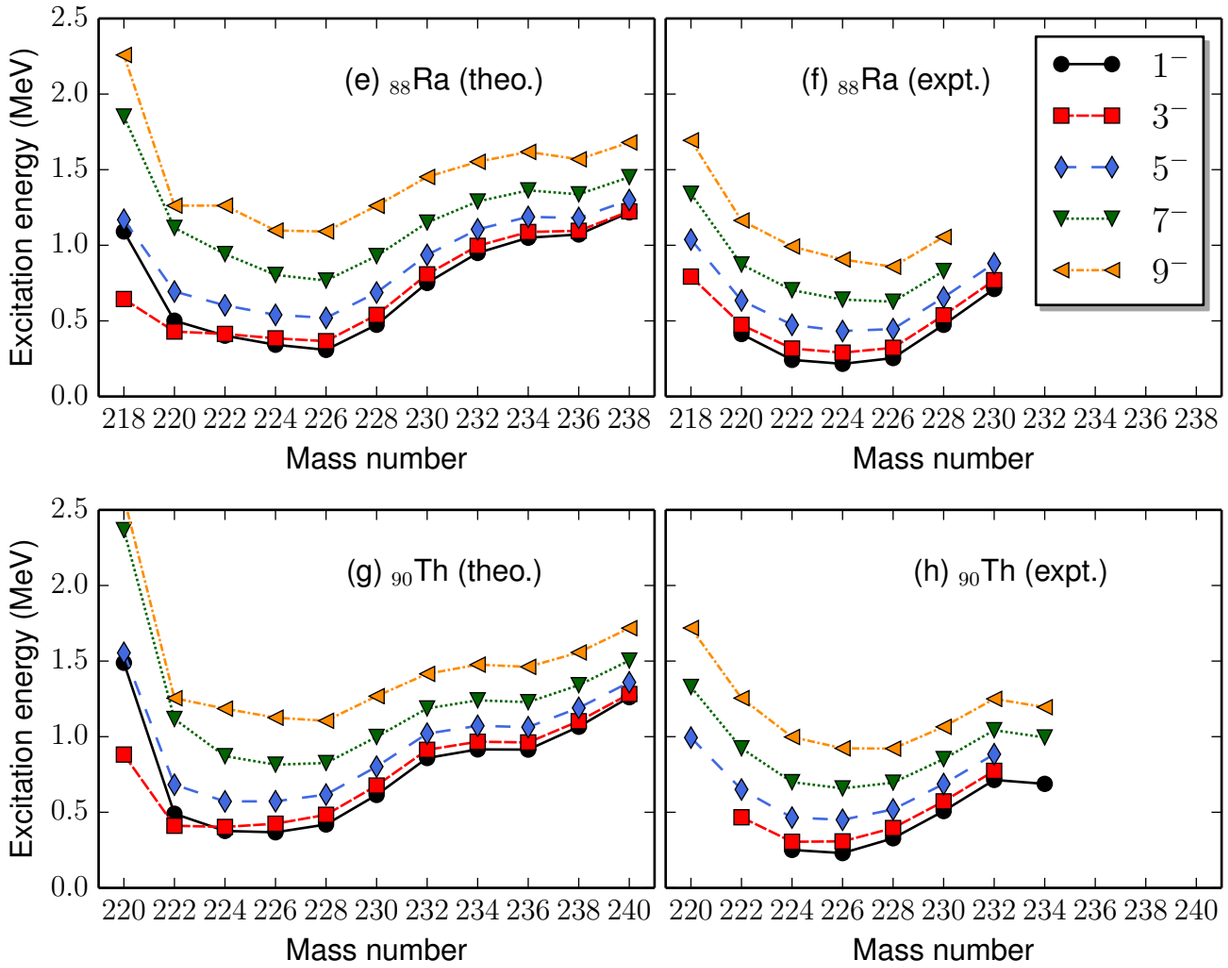
KN et al. PRC 102 (2020); PRC 103 (2021)

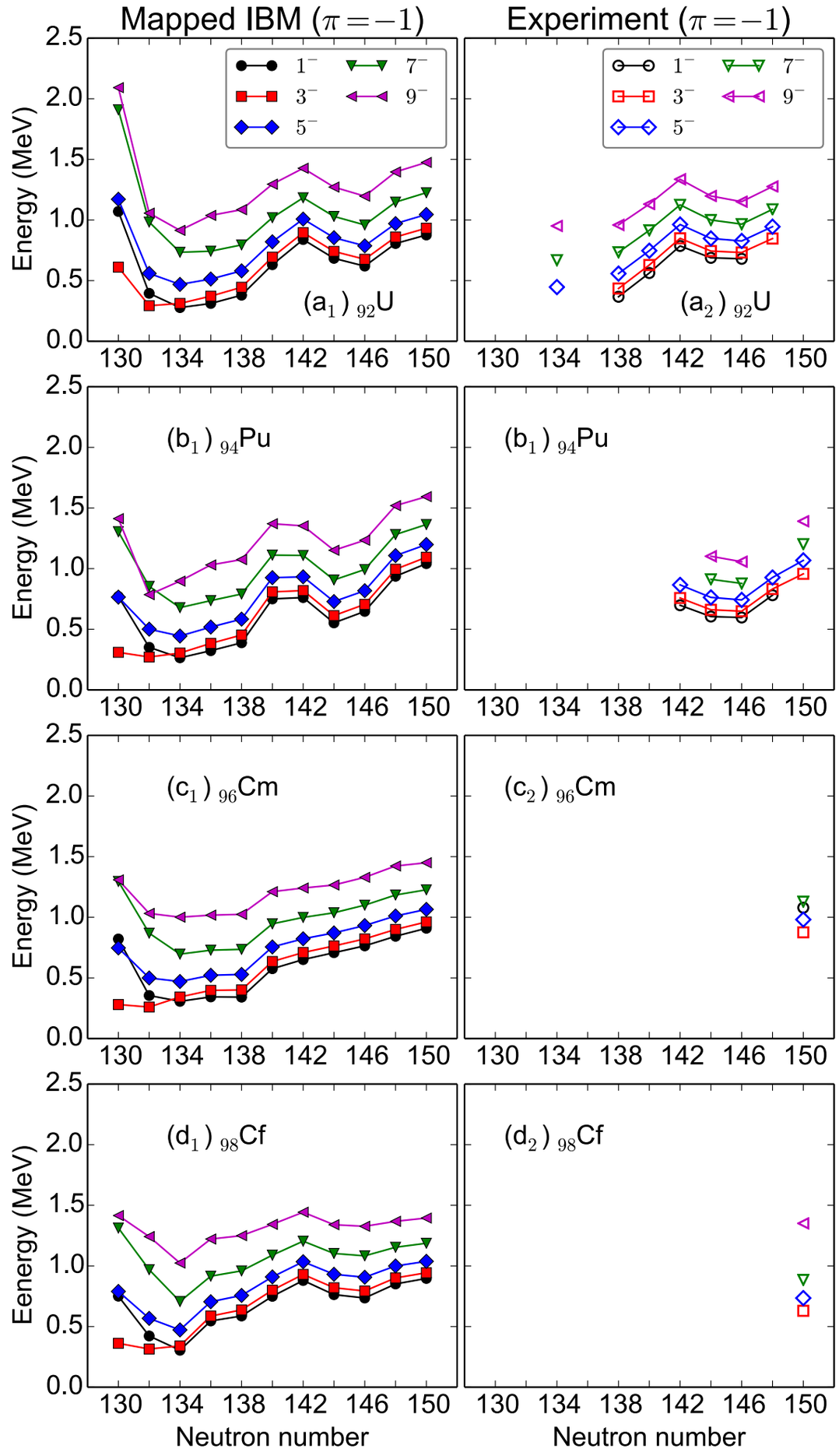
Positive parity



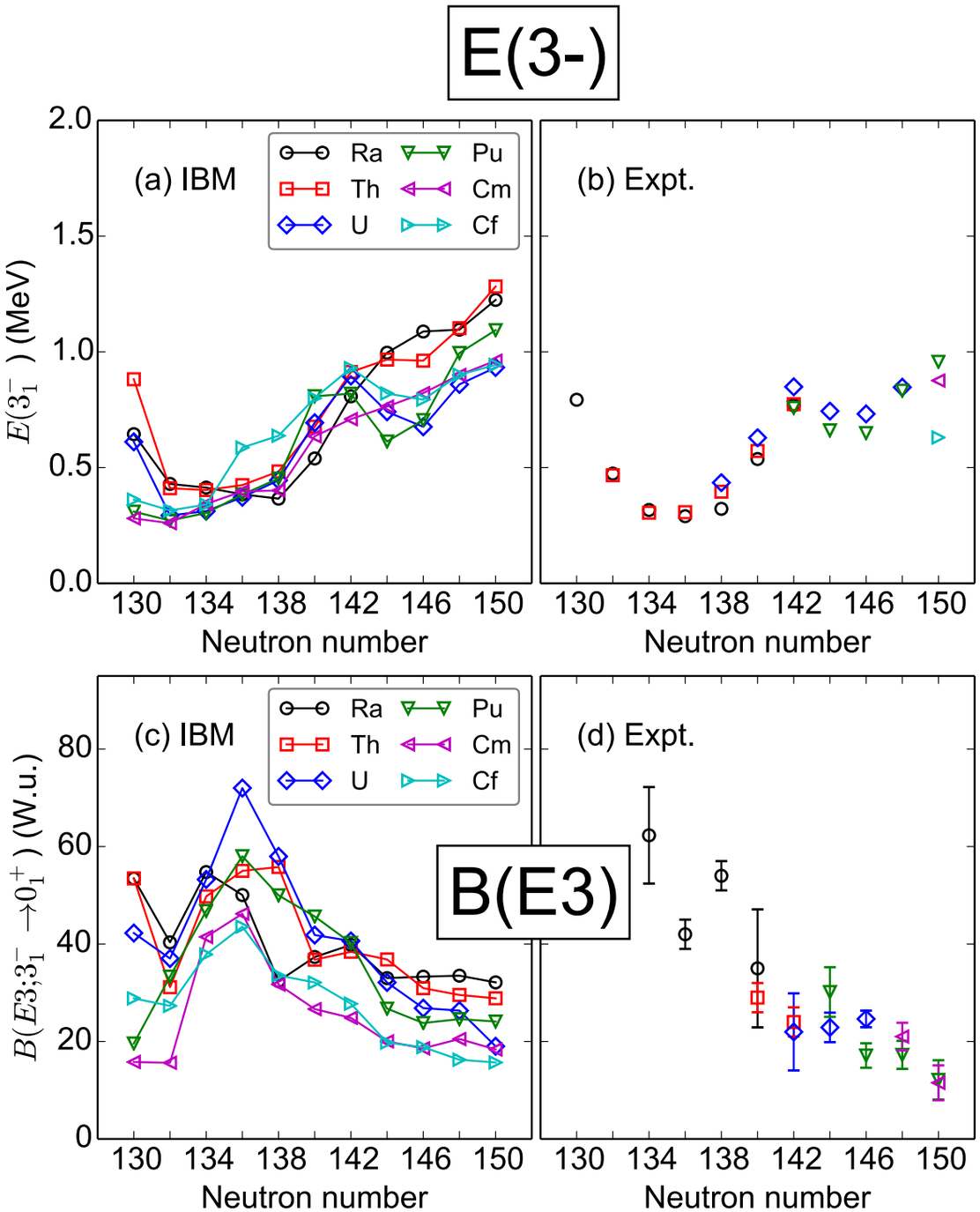


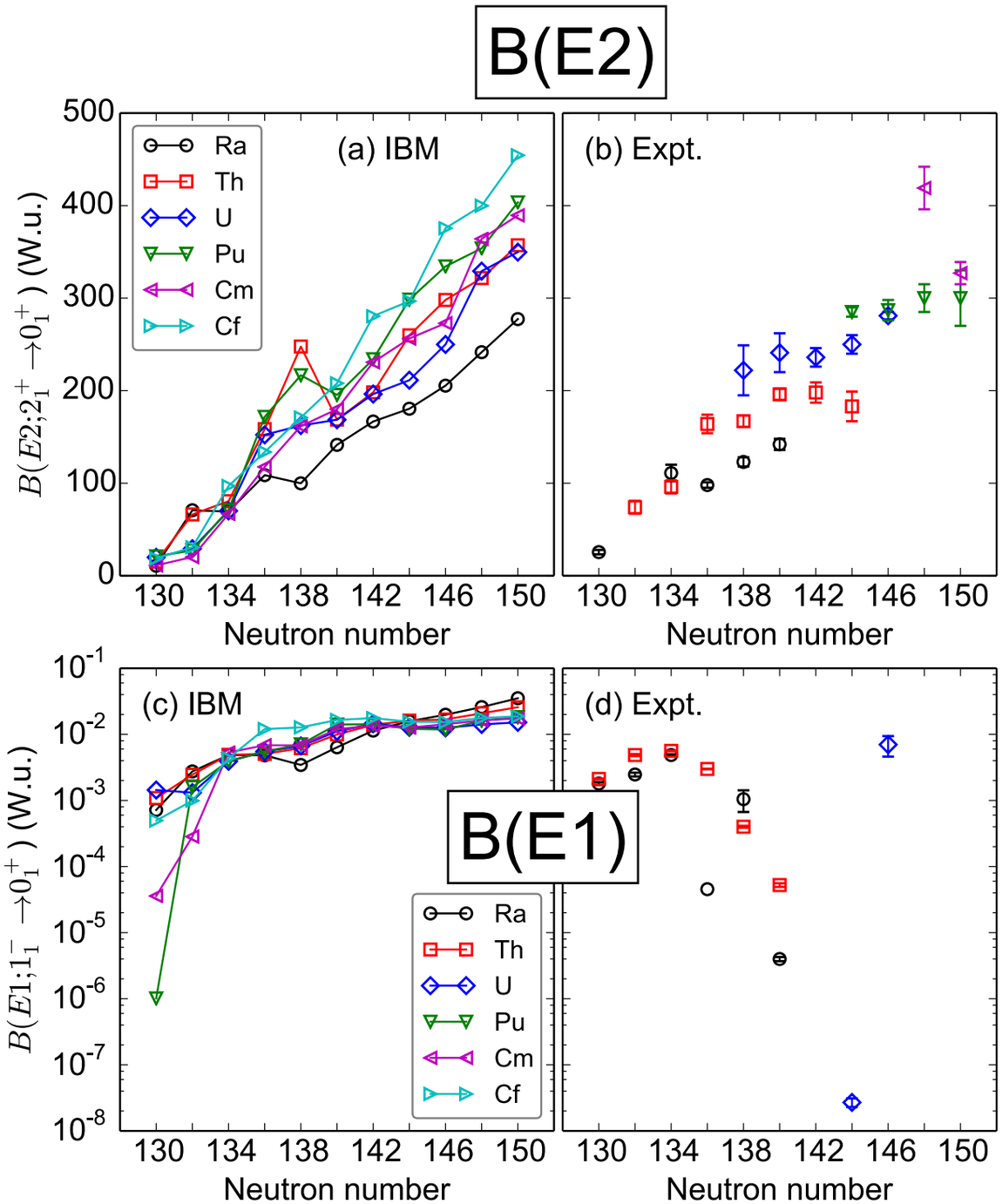
Negative parity



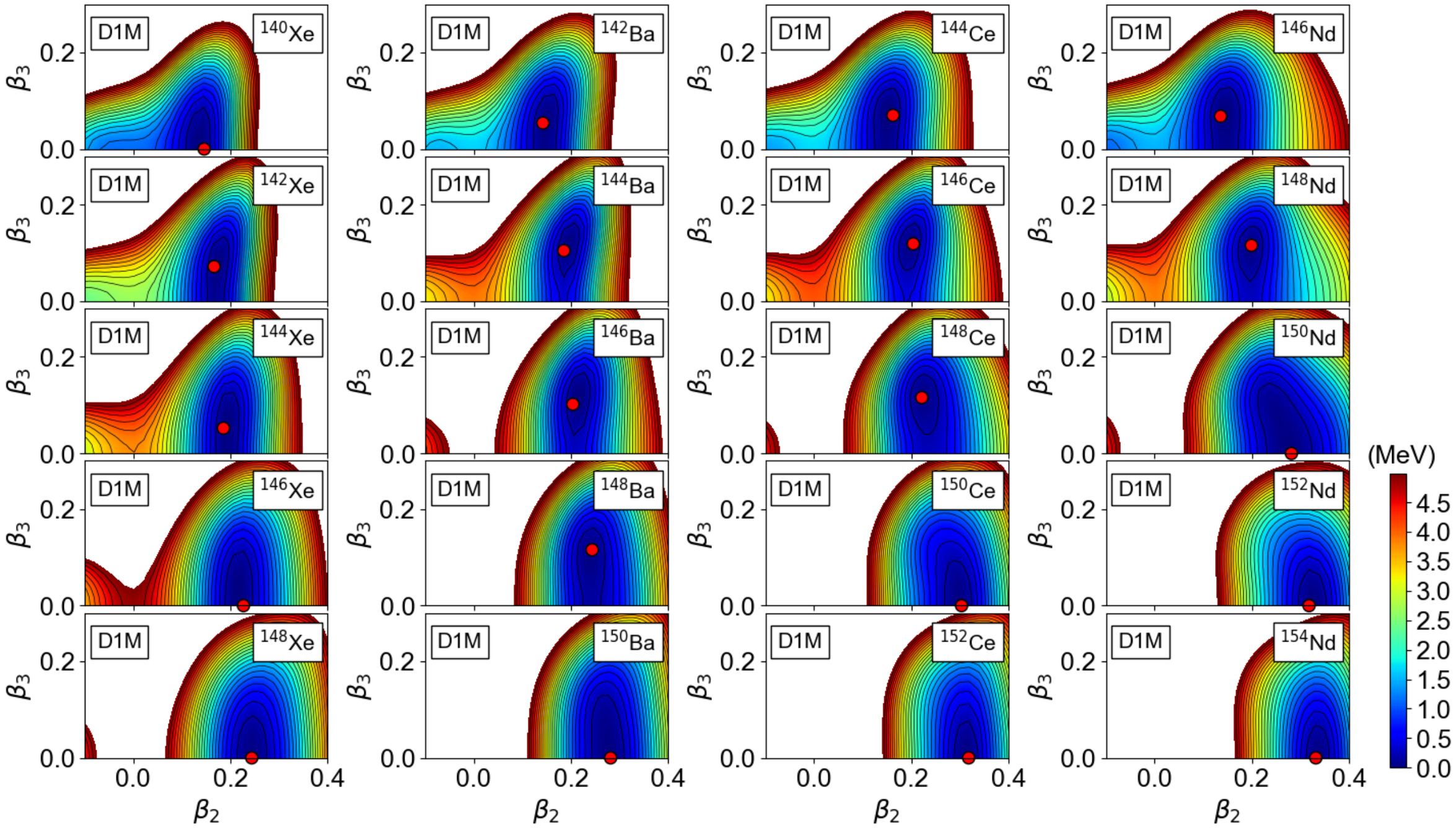


Transitions





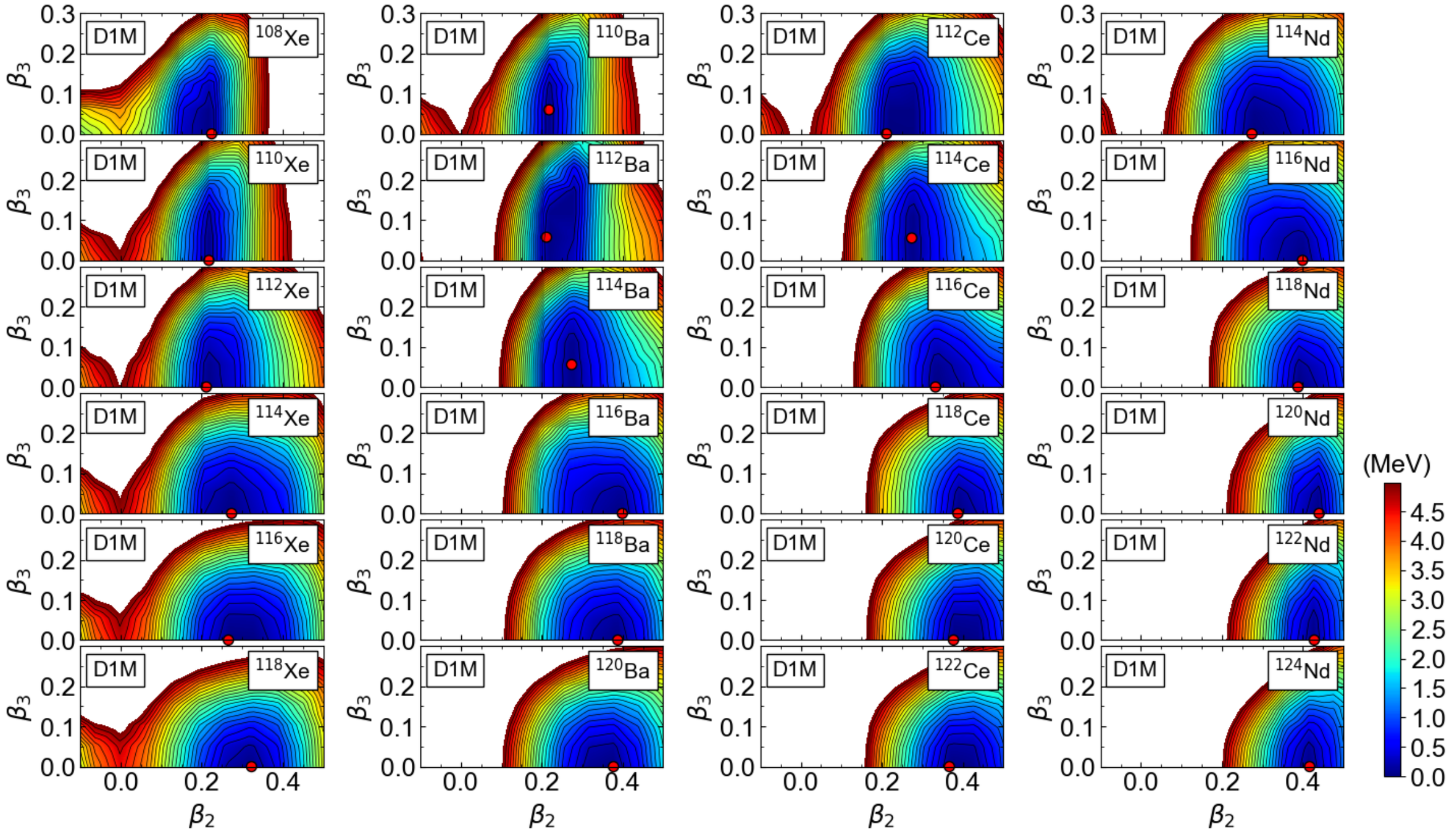
Neutron-rich lanthanides



IBM-Gogny

KN et al. PRC 104 (2021) 044324

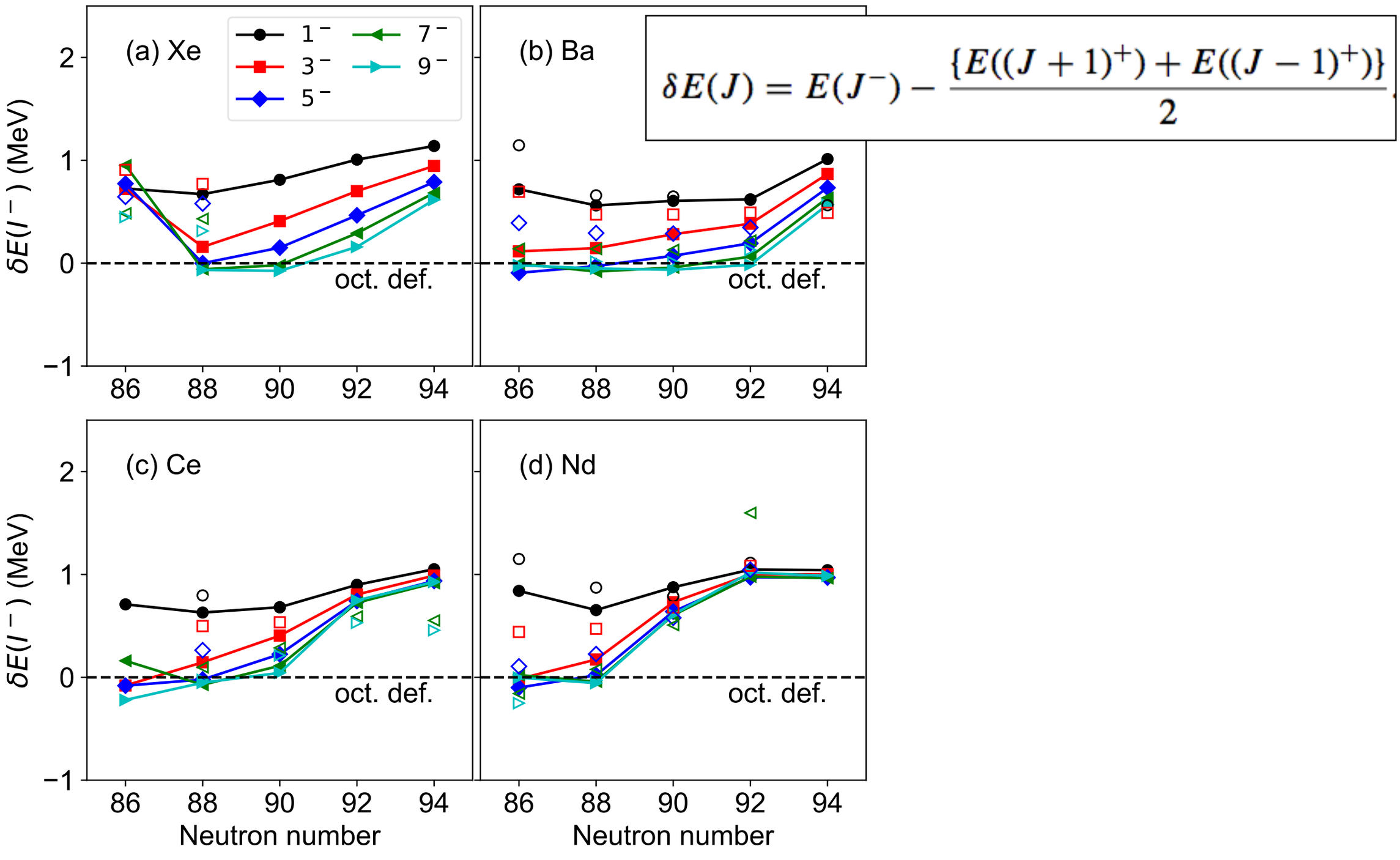
Neutron-deficient lanthanides



IBM-Gogny

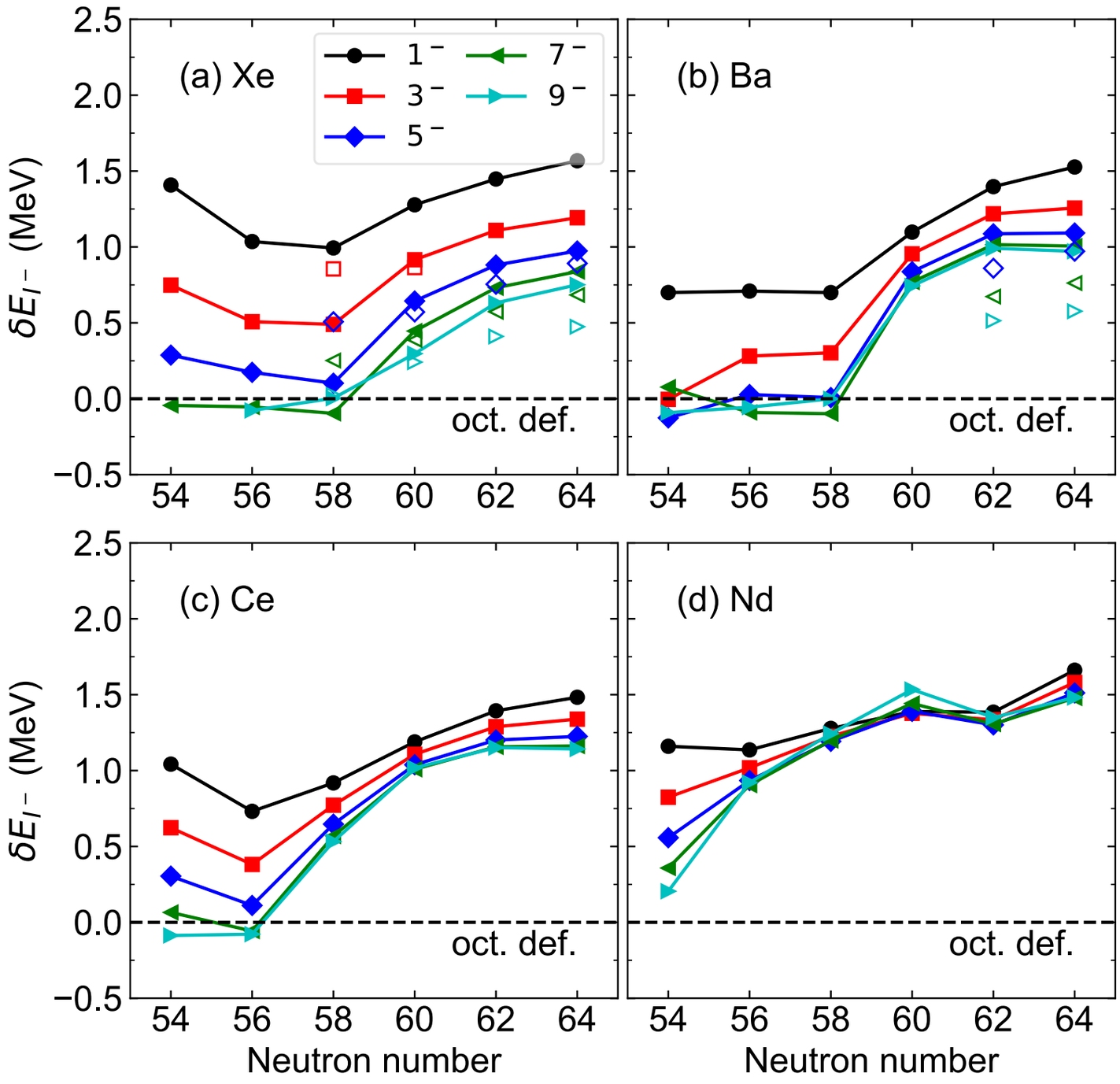
KN et al. PRC 104 (2021) 054320

A criteria for octupole collectivity

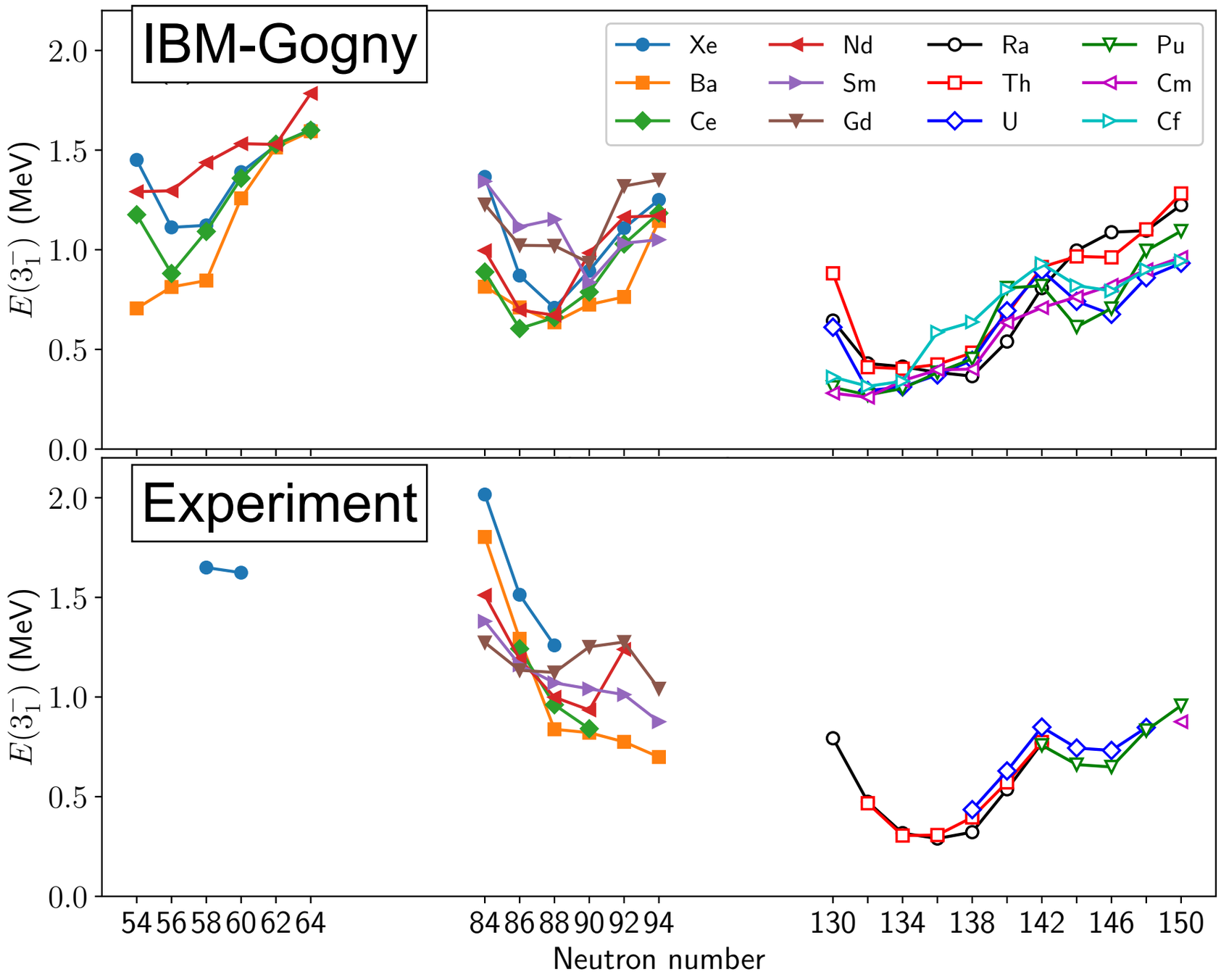


$$\delta E(J) = E(J^-) - \frac{\{E((J+1)^+) + E((J-1)^+)\}}{2}$$

A criteria for octupole collectivity

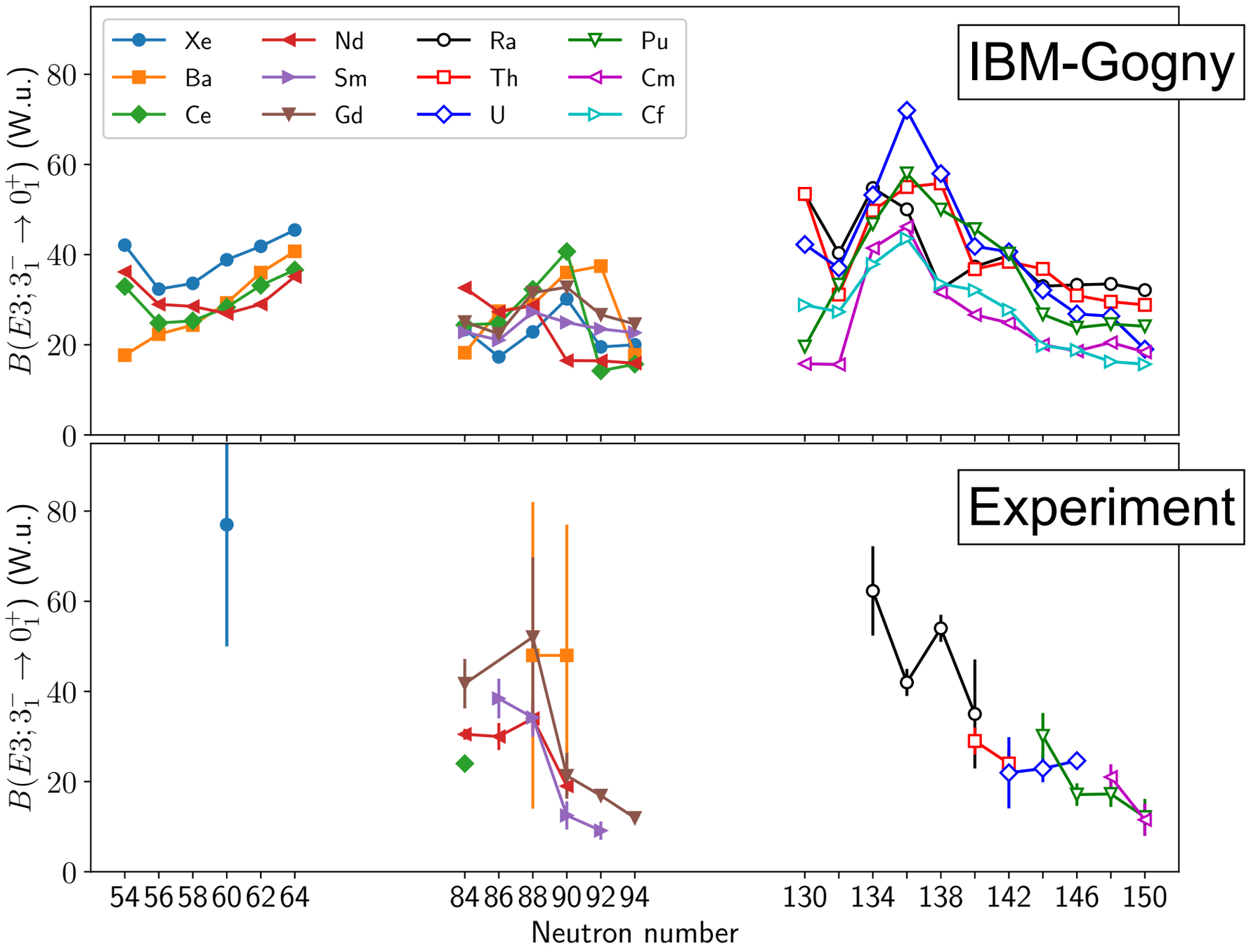


E(3-) systematics



KN, IJMPE (2023)

B(E3) systematics



KN, IJMPE (2023)

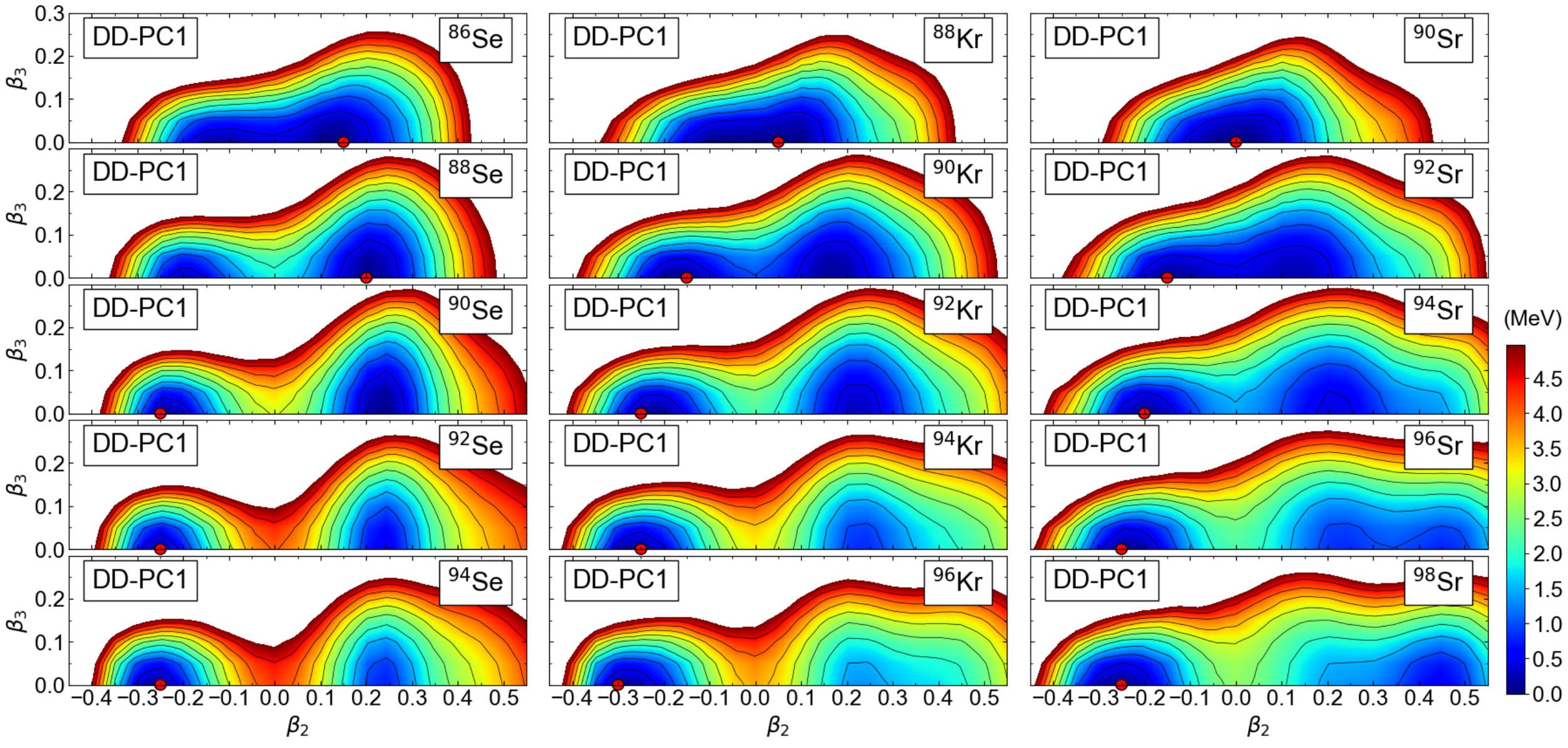
Challenging regions

PHYSICAL REVIEW C **105**, 054318 (2022)

IBM-RMF

Octupole correlations in collective excitations of neutron-rich $N \approx 56$ nuclei

Kosuke Nomura *



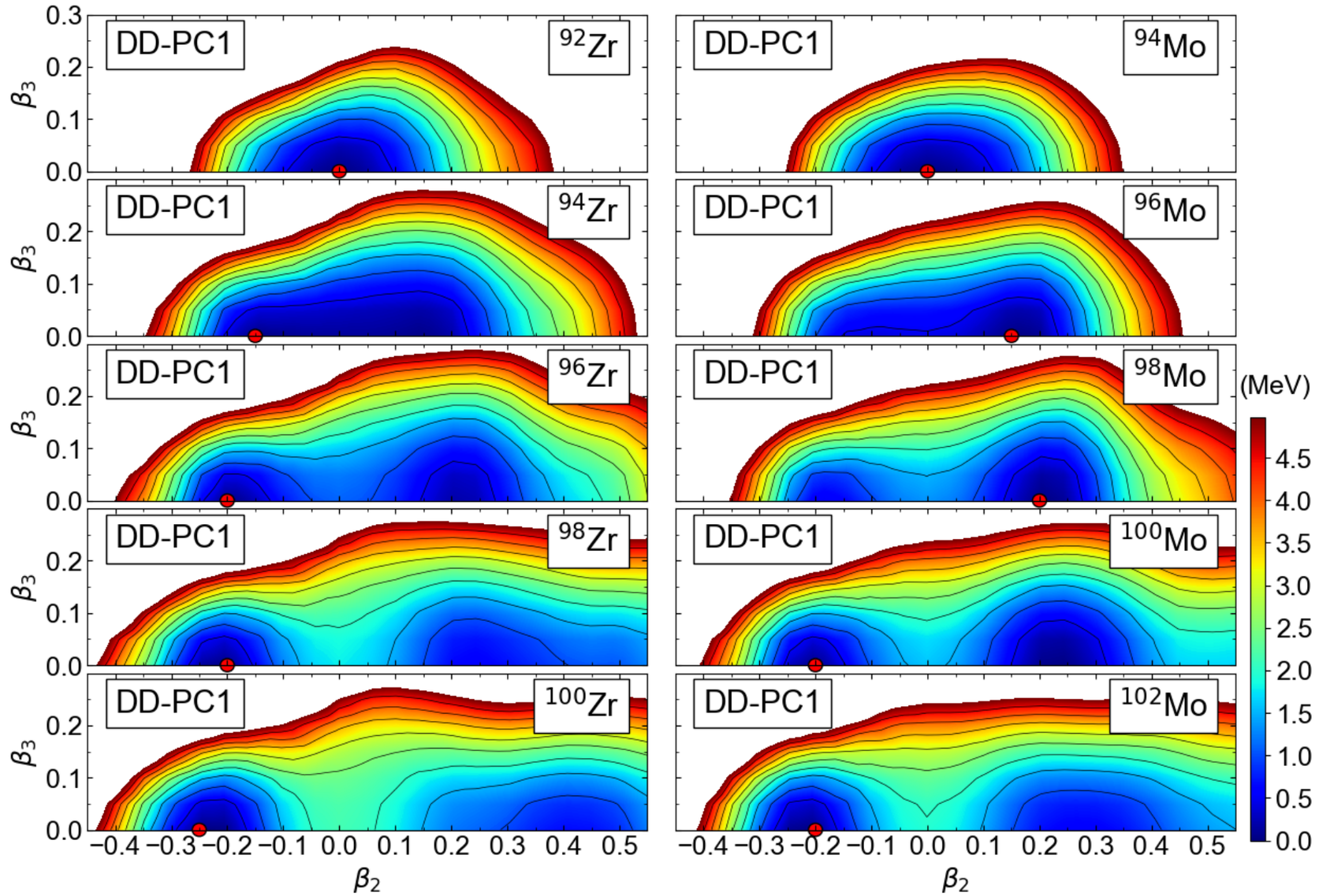
… no octupole minimum, β_3 soft for Se and Kr

PHYSICAL REVIEW C **105**, 054318 (2022)

IBM-RMF

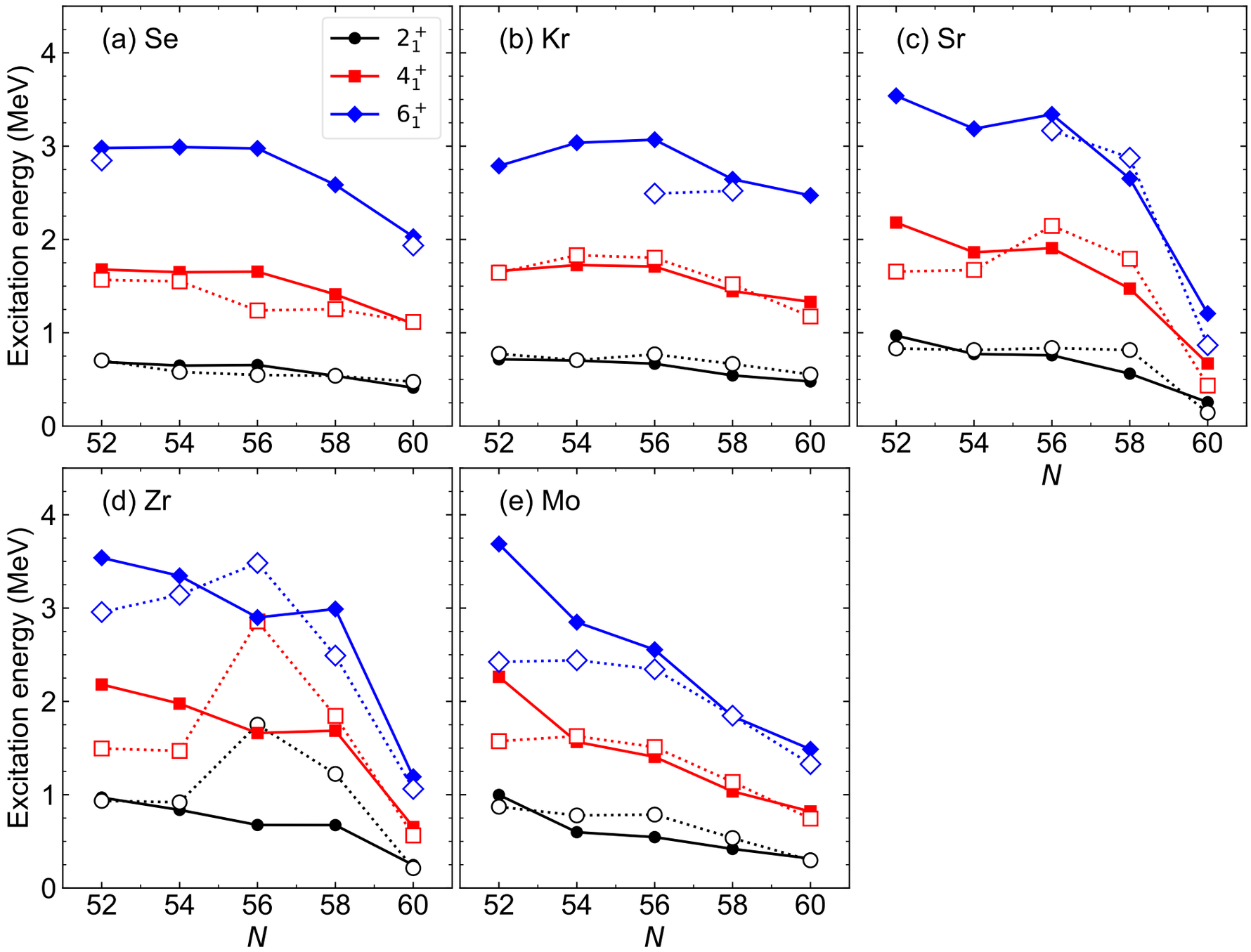
Octupole correlations in collective excitations of neutron-rich $N \approx 56$ nuclei

Kosuke Nomura *

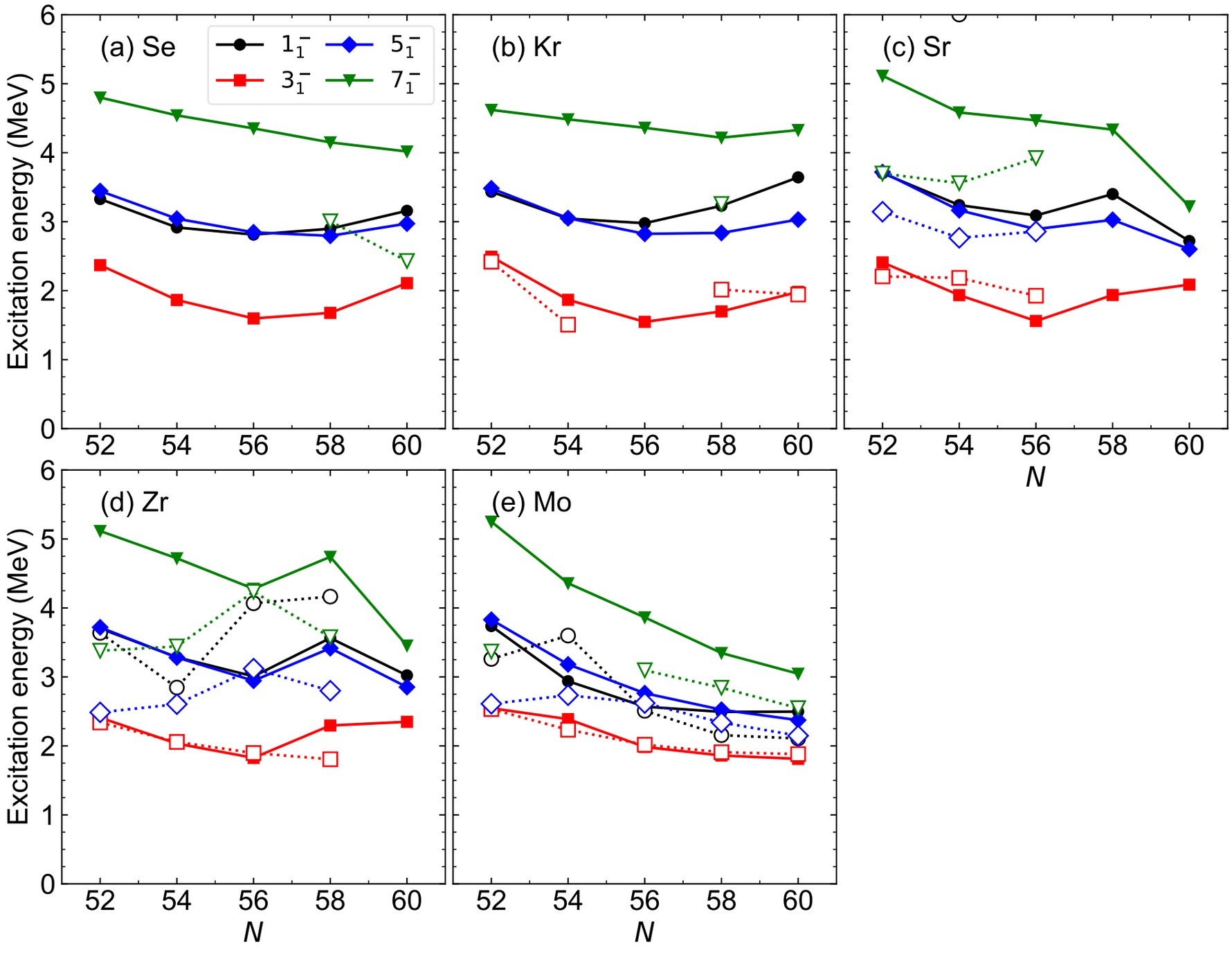


… no octupole minimum, soft in quadrupole

Positive parity levels



Negative parity levels



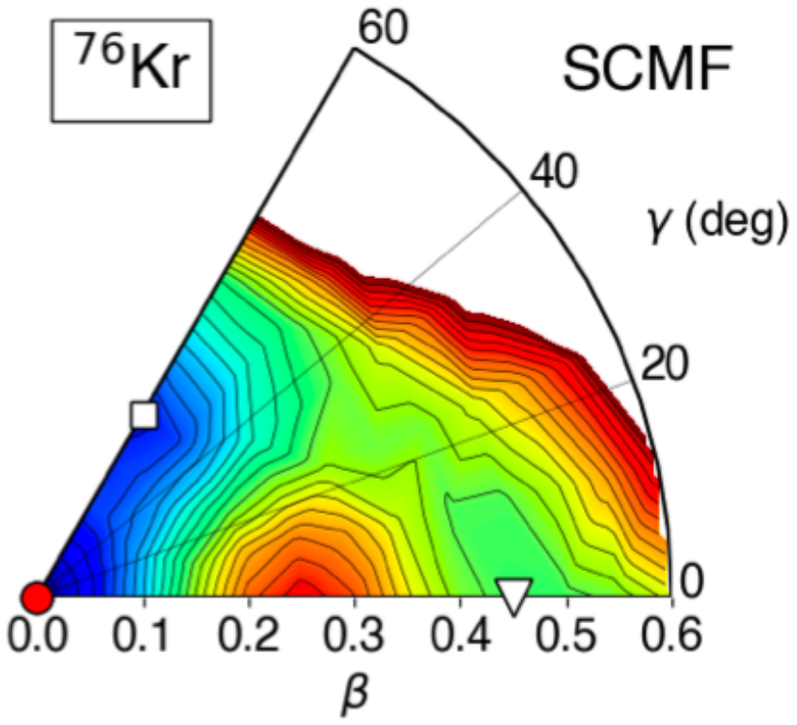
Shape coexistence in N~Z nuclei

PHYSICAL REVIEW C **106**, 024330 (2022)

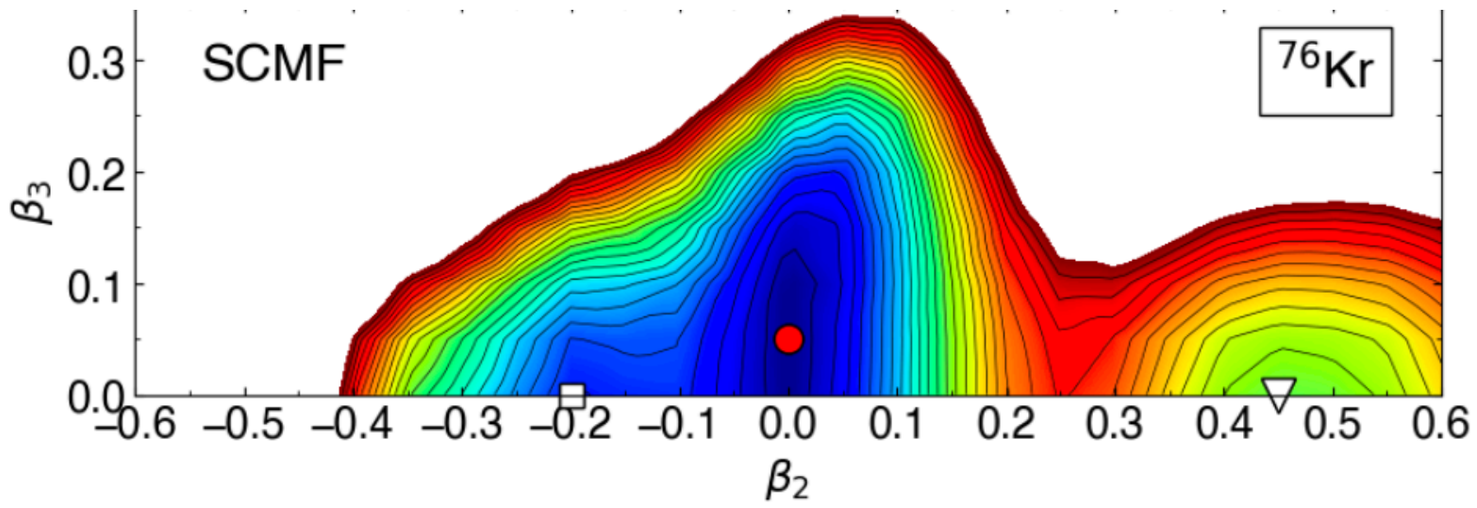
Effect of configuration mixing on quadrupole and octupole collective states of transitional nuclei

Kosuke Nomura

$\beta_2 - \gamma$ (triaxial quadrupole)

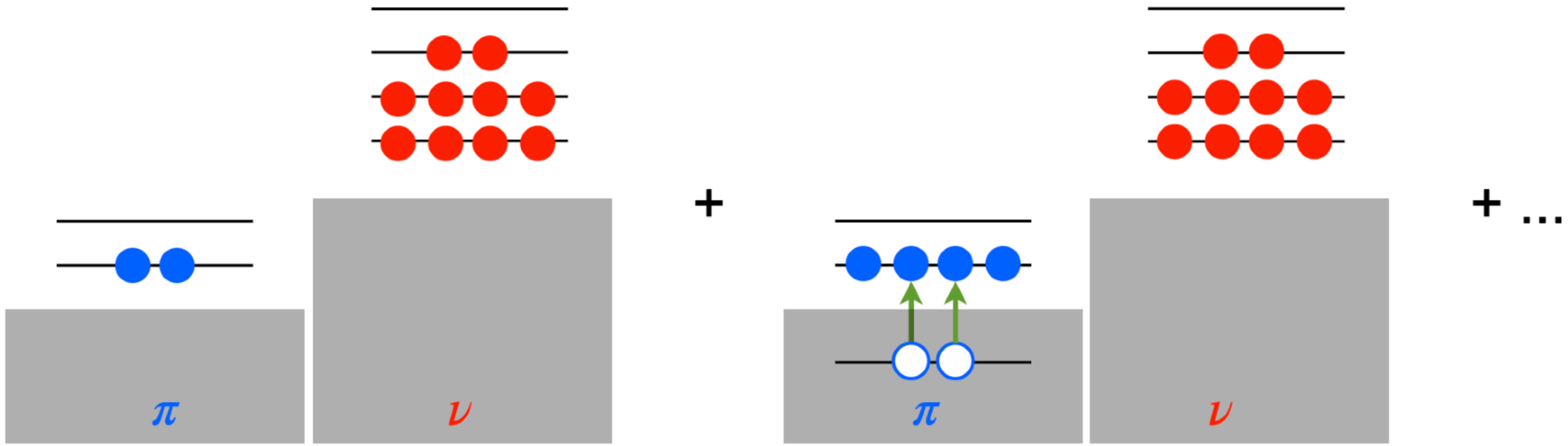


$\beta_2 - \beta_3$ (axial quadrupole - octupole)



IBM with configuration mixing

Duval, Barrett (1981)



0p-0h (N bosons)

2p-2h (N+2 bosons)

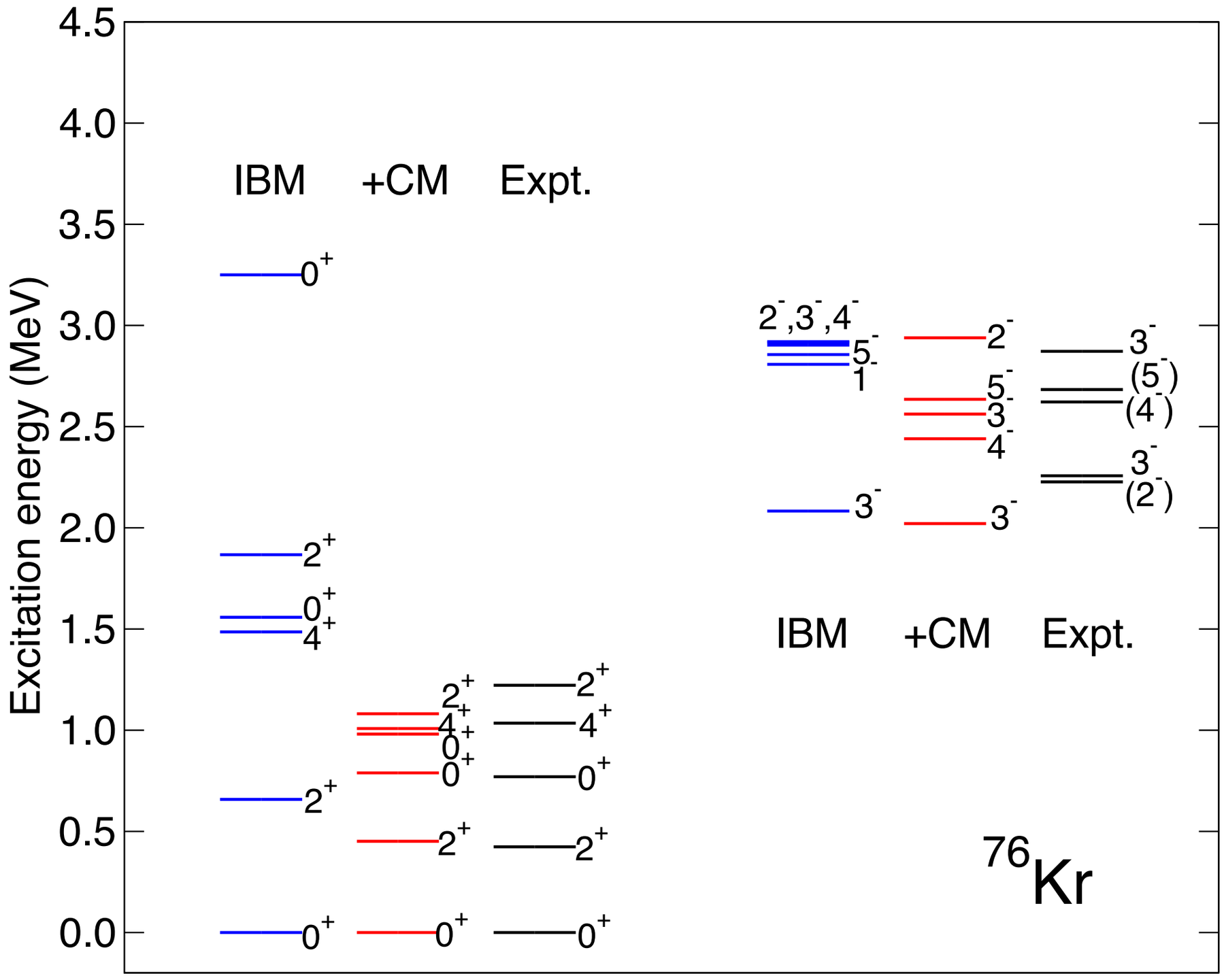
$$\hat{H} = \hat{H}_{sdf}(N) + \left[\hat{H}_{sdf}(N+2) + \Delta\right] + \hat{V}_{mix}(N, N+2)$$

Δ : energy to promote a boson

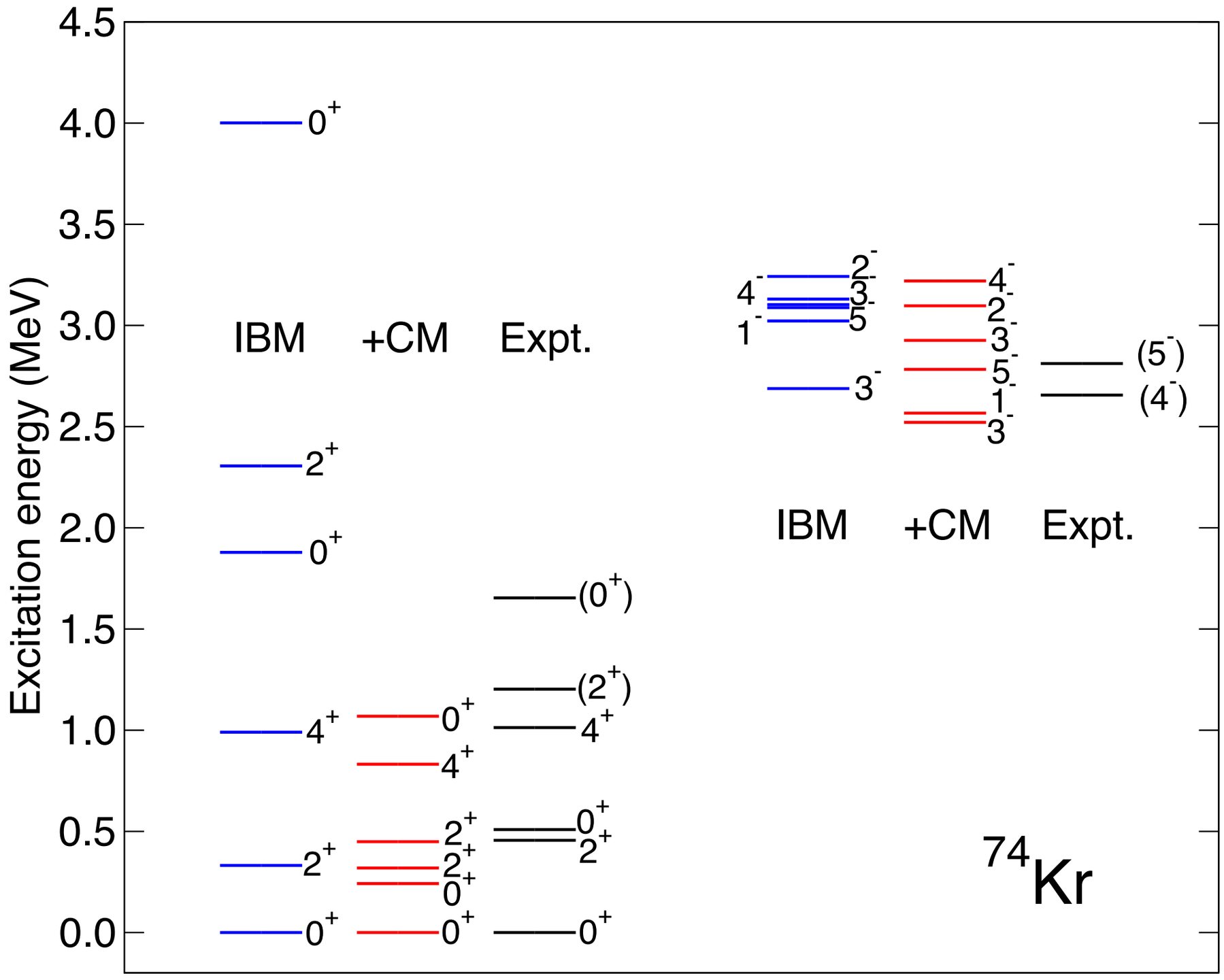
$\hat{V}_{mix}$: Mixing N - (N+2) spaces

Hilbert space: $[(sdf)^N \oplus (sdf)^{N+2}]$

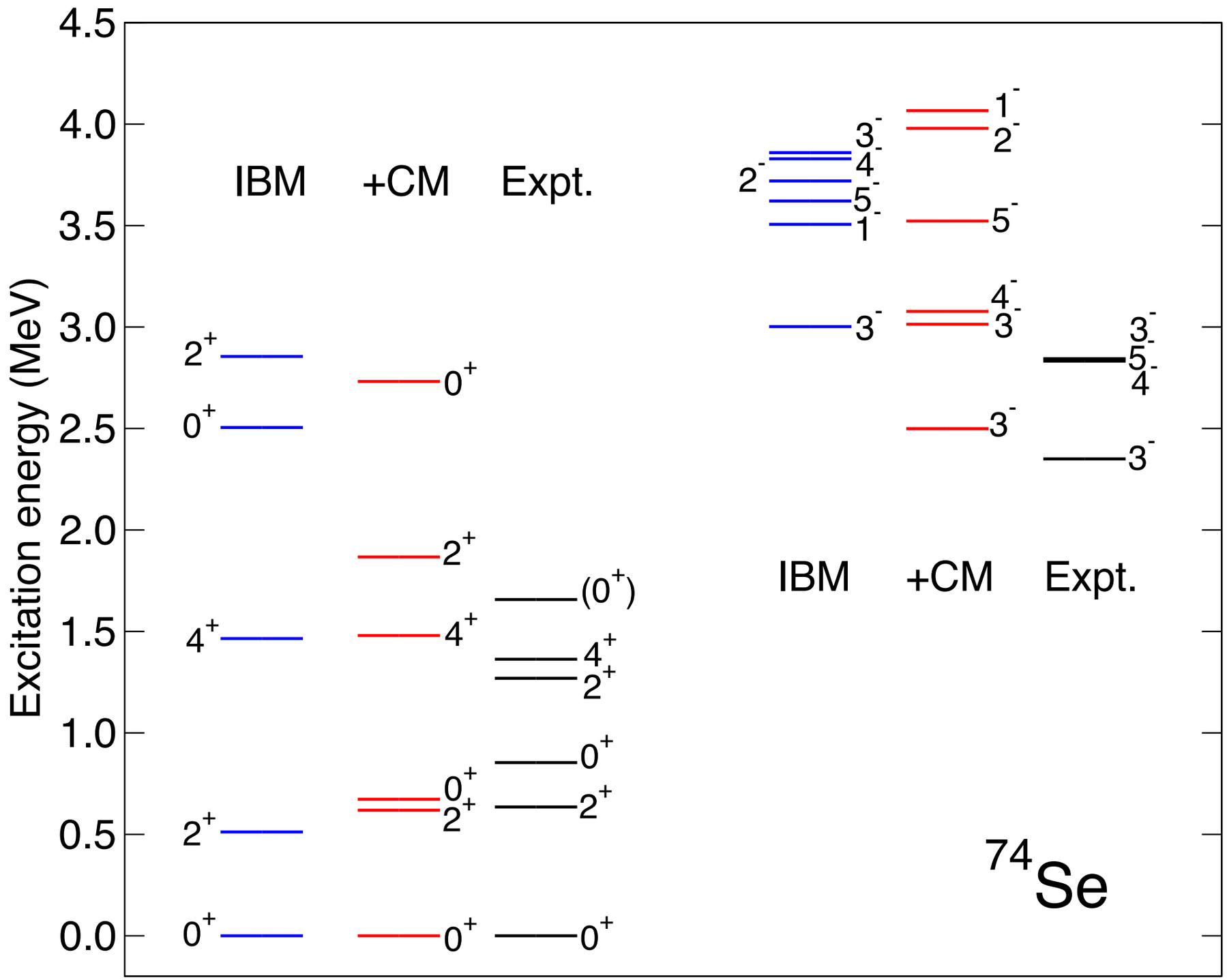
Effect of configuration mixing



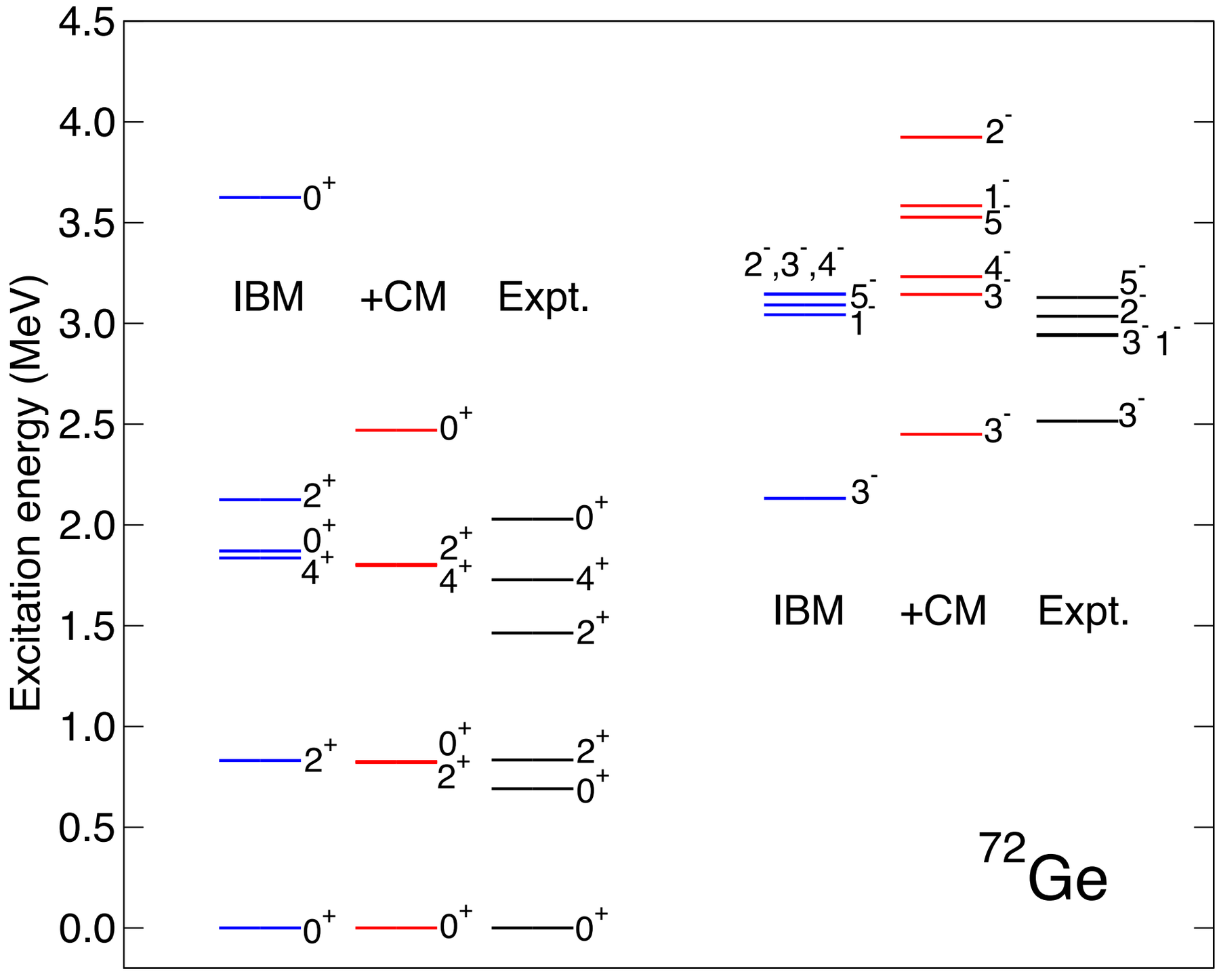
Effect of configuration mixing



Effect of configuration mixing



Effect of configuration mixing



Related studies

PHYSICAL REVIEW C **97**, 024317 (2018)

Signatures of octupole correlations in neutron-rich odd-mass barium isotopes

K. Nomura, T. Nikšić, and D. Vretenar

particle-boson coupling for odd-A nuclei

PHYSICAL REVIEW C **103**, 054301 (2021)

Microscopic description of octupole collective excitations near $N = 56$ and $N = 88$

K. Nomura,[1,*] L. Lotina,[1] T. Nikšić,[1] and D. Vretenar[1,2]

Analysis using the Bohr Hamiltonian

Summary

- Identified regions of pear shapes. Universal phenomena?
- Coupling with other degrees of freedom, e.g., triaxial
- Further investigations needed for the A~100 region

Thank you