Enhanced Collectivity of Gamma Vibration in Neutron-rich Dy isotopes with *N*=108-110

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in collaboration with
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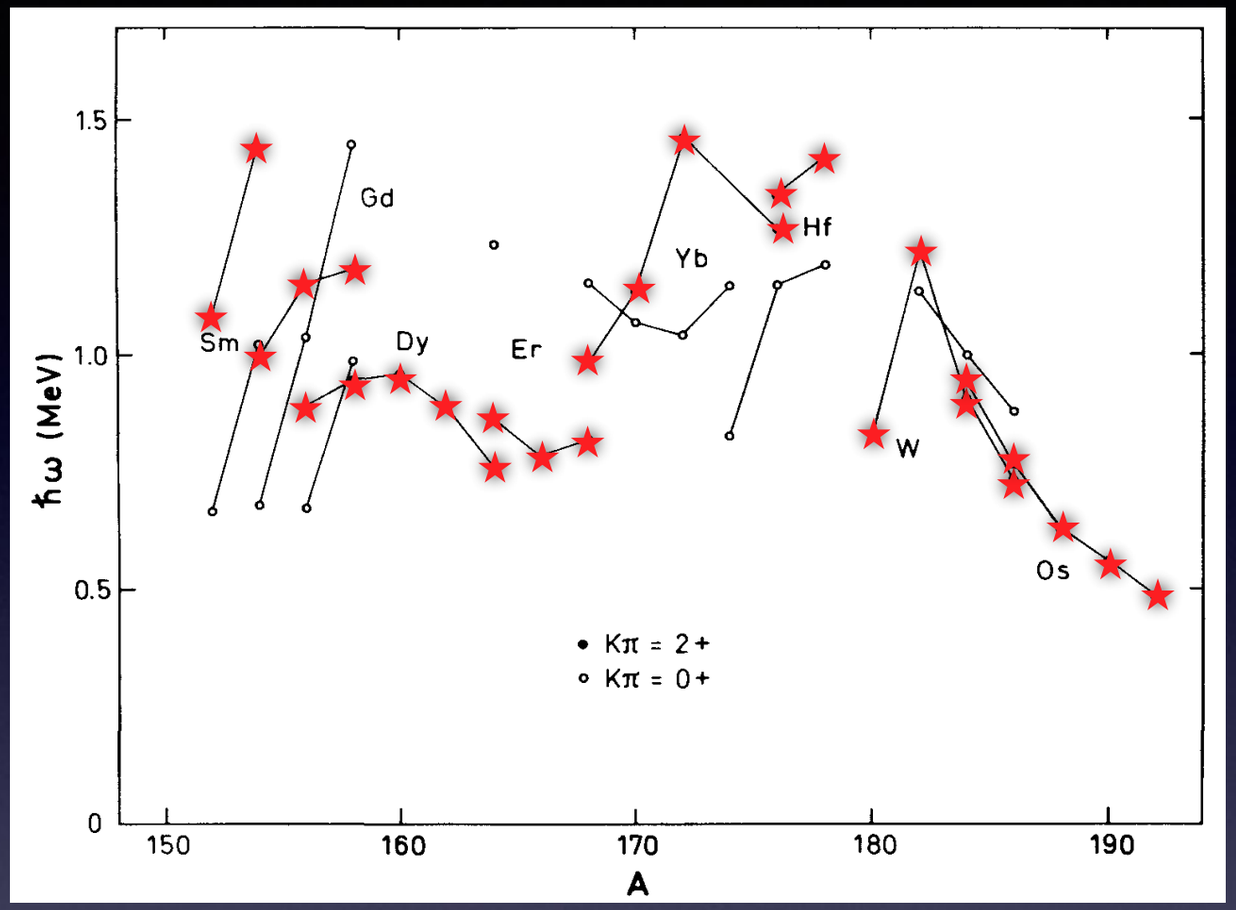
Gamma vibration

- ✓ Systematically appears in the even-even deformed nuclei
- ✓ Low-frequency quadrupole vibration along the γ direction
- ✓ Soft mode of the triaxial deformation



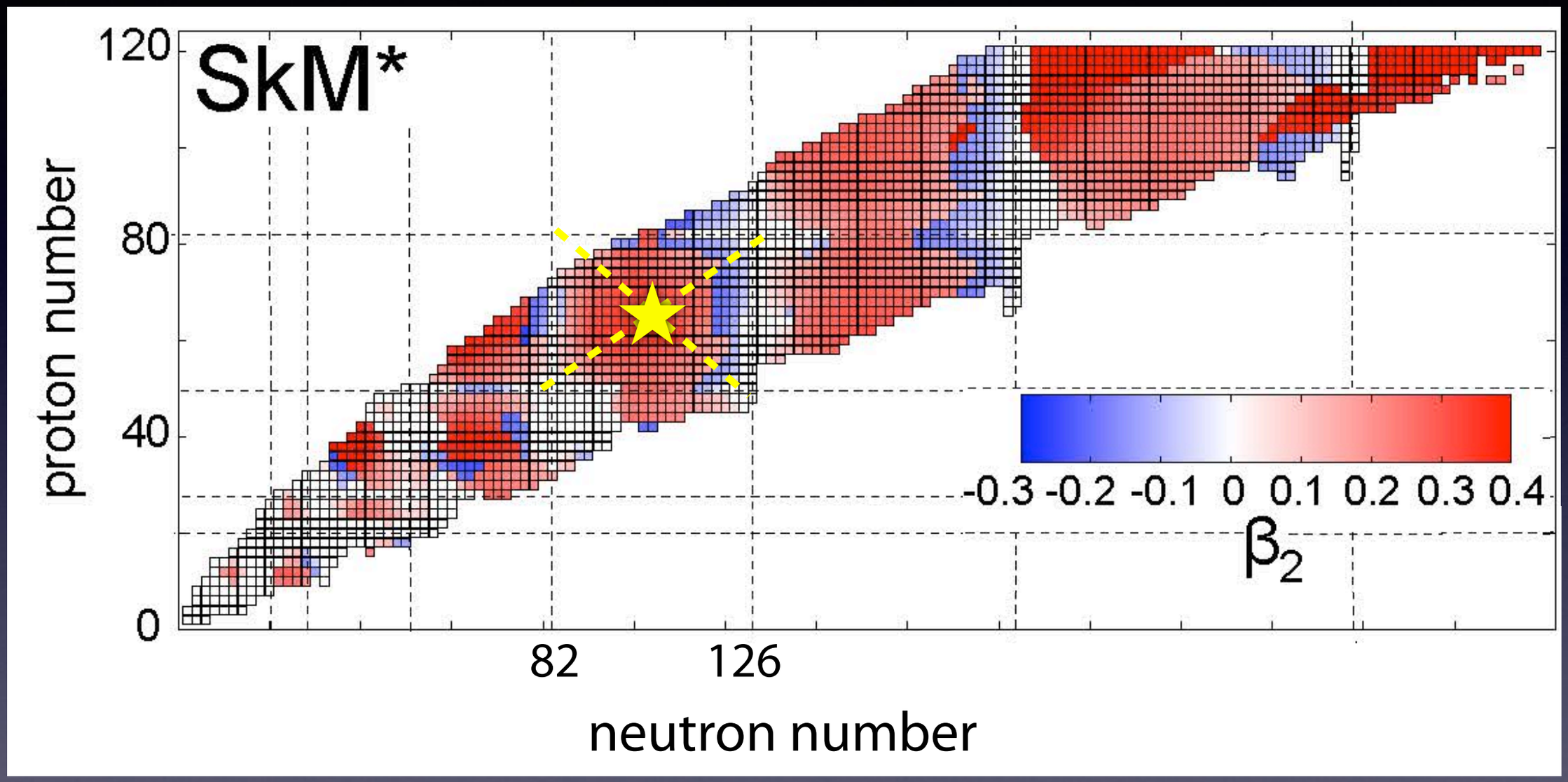
Bohr and Mottelson, Vol. 2

How about in neutron-rich deformed nuclei?

universality of emergence of the collective mode across the nuclear chart

Collectivity around $^{170}_{66}Dy_{104}$

Middle of the major shells between ^{132}Sn and ^{208}Pb

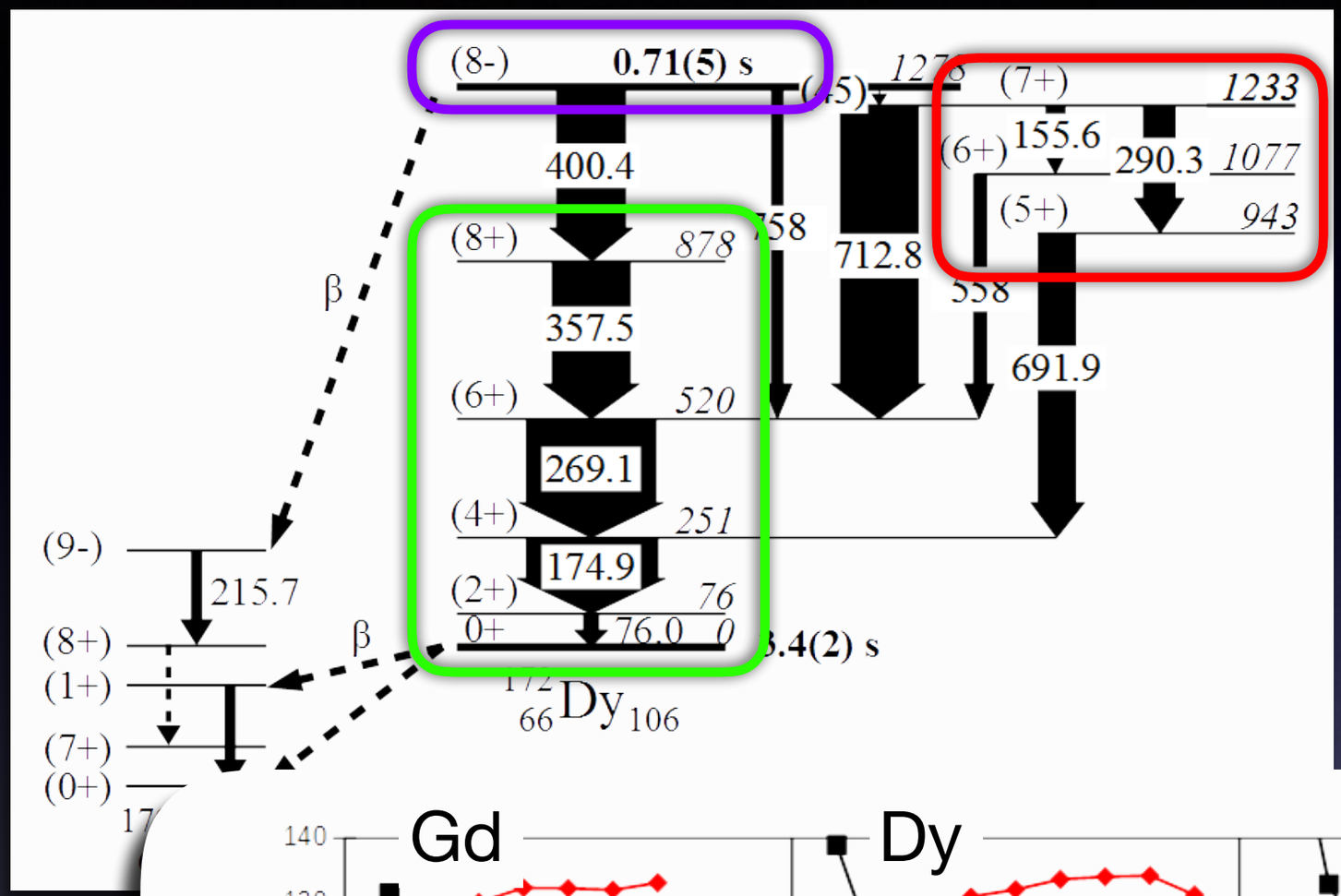


J. Erler et al., Nature 486(2012)509

- ✓ Effect of neutron excess on the occurrence of γ-vibration
- ✓ Shell structure in neutron-rich medium-heavy nuclei

Decay spectroscopy at RIKEN RIBF: EURICA

H. Watanabe *et al.*, PLB760(2016)641



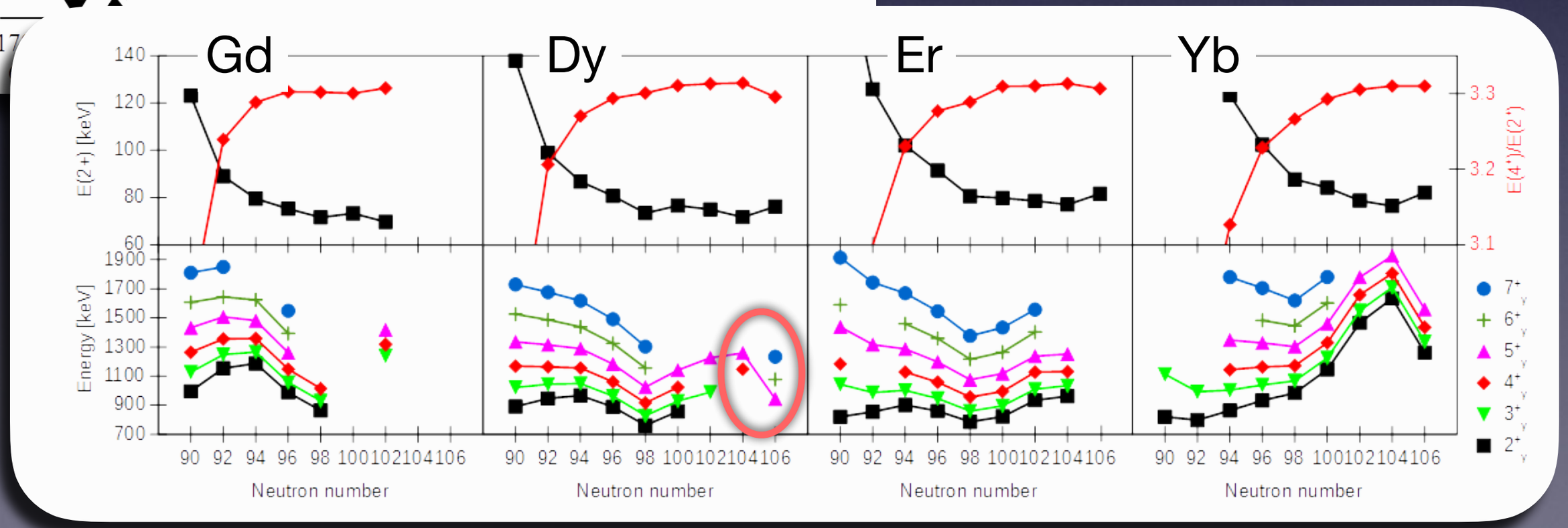
$^{172}Dy_{106}$

Long-lived isomeric state

Ground-state rotational band

Possible gamma band

Sudden decrease in the excitation energy at *N*=106



Nuclear DFT for collective vibration

w/ Skyrme + pairing energy-density functional

$$\mathcal{E}[\rho, \tilde{\rho}](\boldsymbol{r})$$

Hartree-Fock-Bogoliubov (HFB) like equation

J. Dobaczewski *et al.*, NPA422(1984)103

$$\begin{pmatrix} h^q(r\sigma) - \lambda^q & \tilde{h}^q(r\sigma) \\ \tilde{h}^q(r\sigma) & -(h(r\sigma) - \lambda^q) \end{pmatrix} \begin{pmatrix} \varphi^q_{1,\alpha}(r\sigma) \\ \varphi^q_{2,\alpha}(r\sigma) \end{pmatrix} = E_\alpha \begin{pmatrix} \varphi^q_{1,\alpha}(r\sigma) \\ \varphi^q_{2,\alpha}(r\sigma) \end{pmatrix}$$

$q = \nu,\ \pi$

"s.p." hamiltonian and pair potential: $h^q = \dfrac{\delta \mathcal{E}}{\delta \rho^q}, \qquad \tilde{h}^q = \dfrac{\delta \mathcal{E}}{\delta \tilde{\rho}^q}$

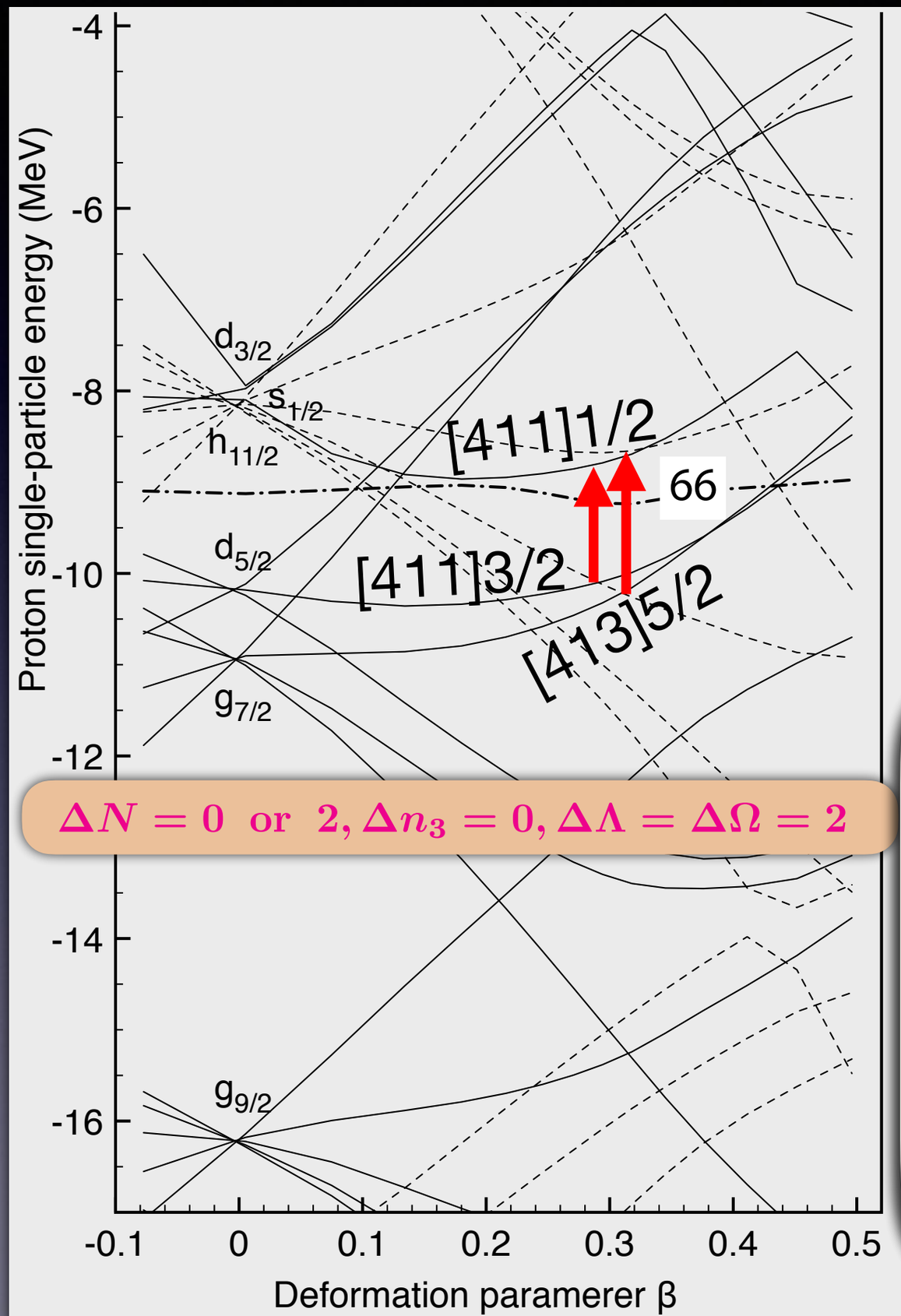
response to the weak external field $\hat{F}\ :\ \ v^{\mathrm{ext}}(r)e^{-i\omega t}$

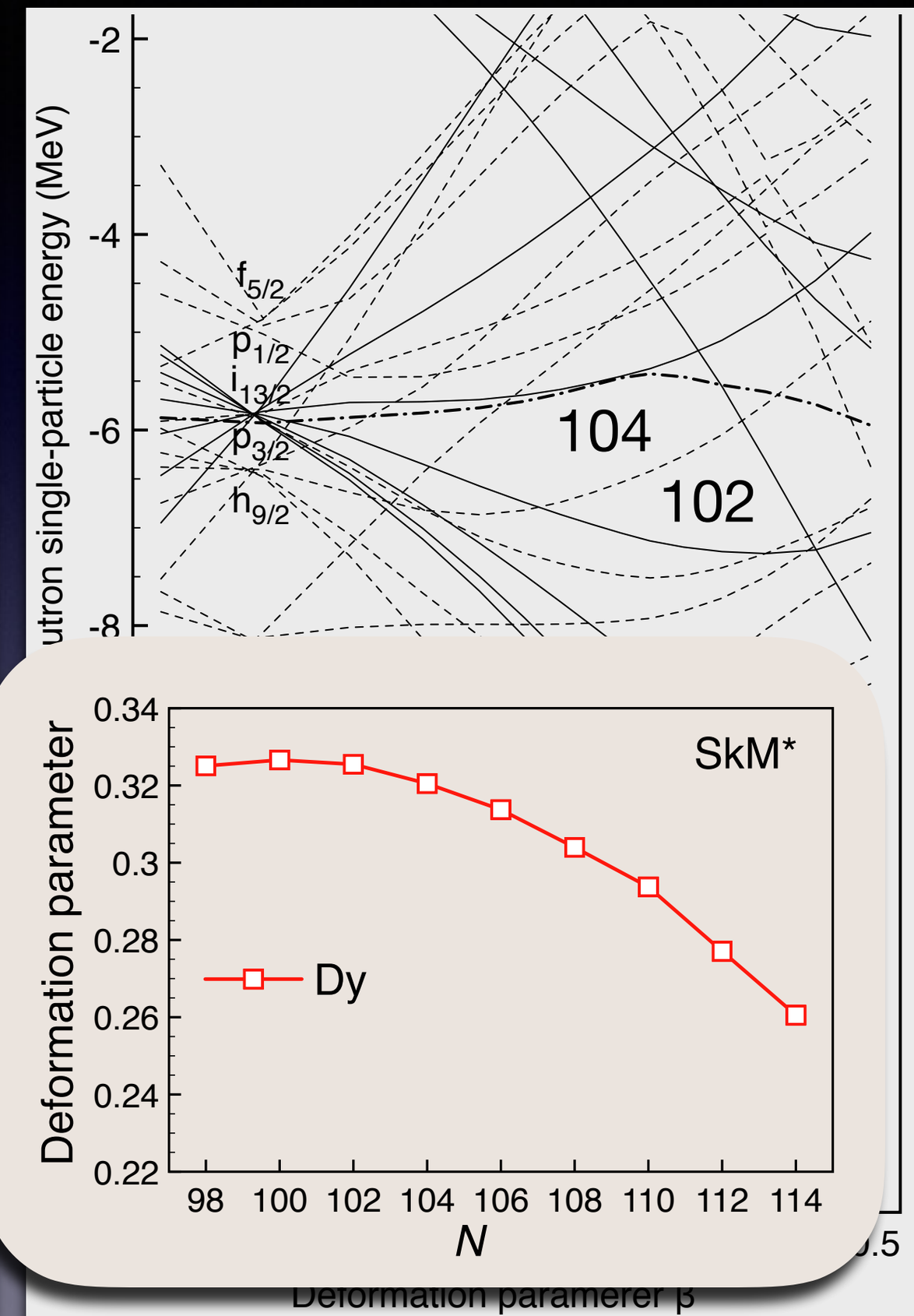
QRPA: $$\delta\rho_i(r) = \int dr' \chi_0^{ij}(r, r') \left[\frac{\delta^2 \mathcal{E}}{\delta\rho_j \delta\rho_k} \delta\rho_k(r') + v_j^{\mathrm{ext}}(r') \right]$$

transition matrix elements: $\langle \Psi_\lambda | \hat{F} | \Psi_0 \rangle = \int dr \delta\rho(r; \omega_\lambda) v^{\mathrm{ext}}(r)$

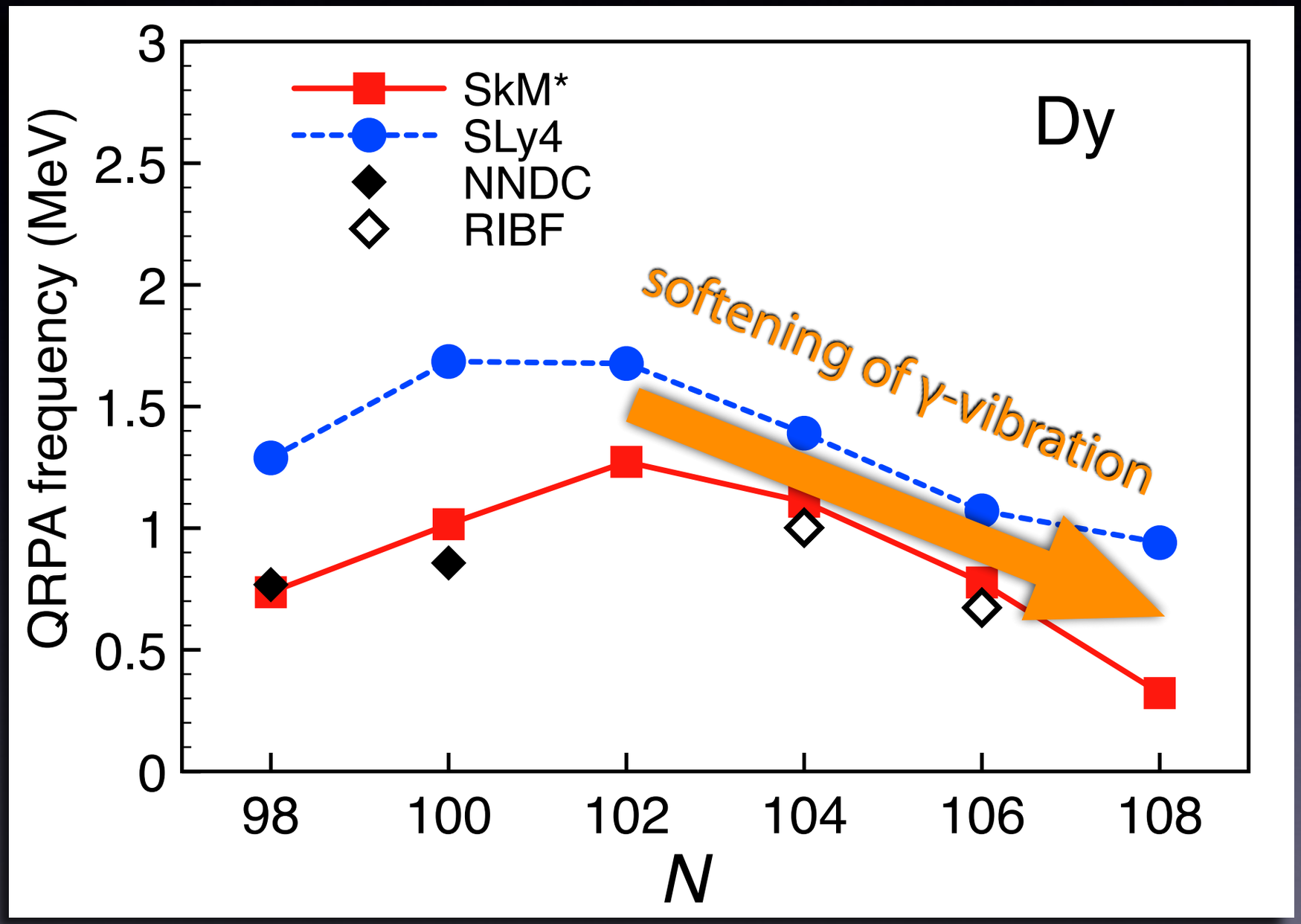
Single-particle energies in ^{172}Dy

SkM*





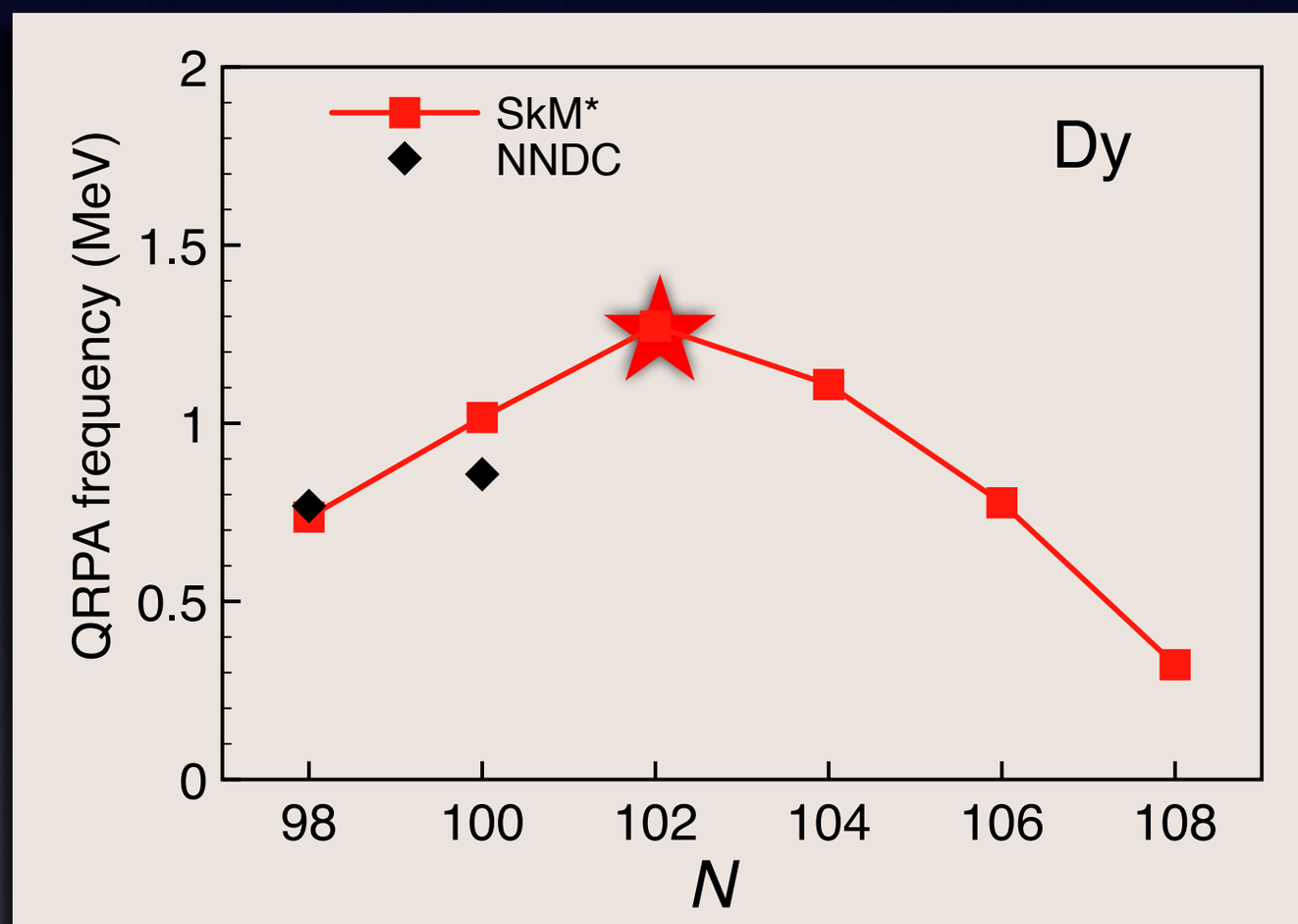
γ-vibration in the neutron-rich Dy isotopes

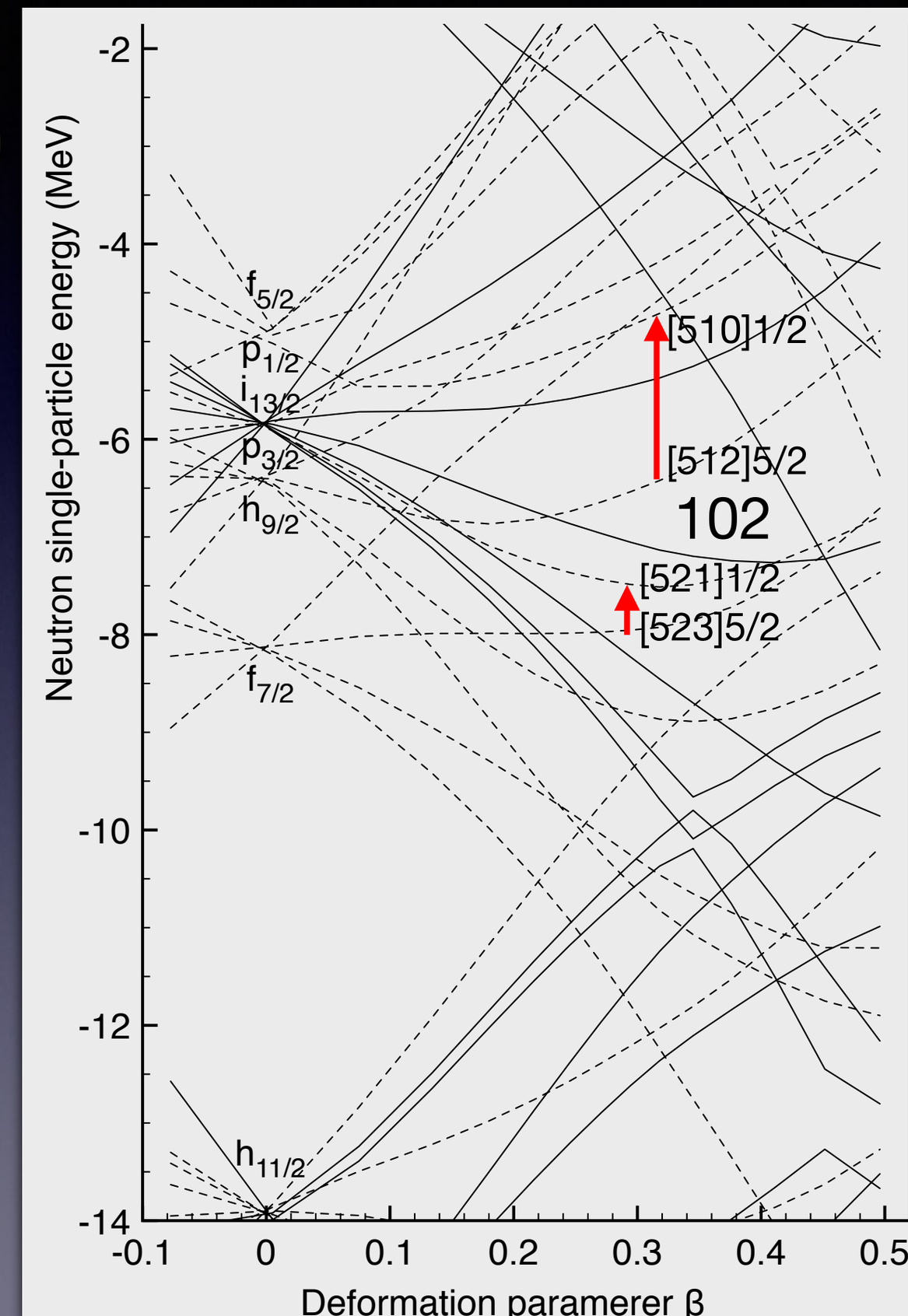


Microscopic structure of the γ-vibration: isotopic dependence

@*N*=102

$$\Delta N = 0 \text{ or } 2, \Delta n_3 = 0, \Delta\Lambda = \Delta\Omega = 2$$

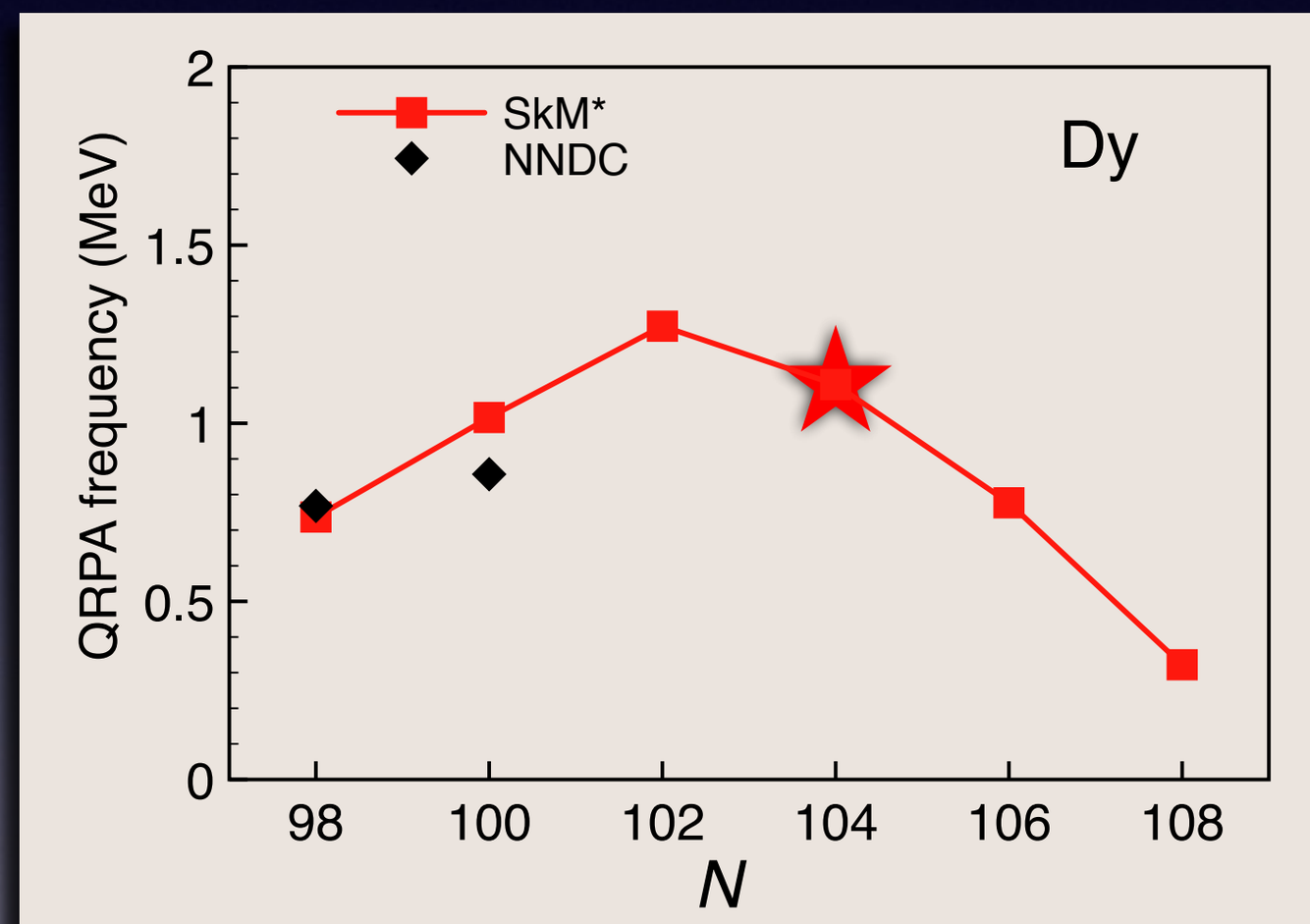


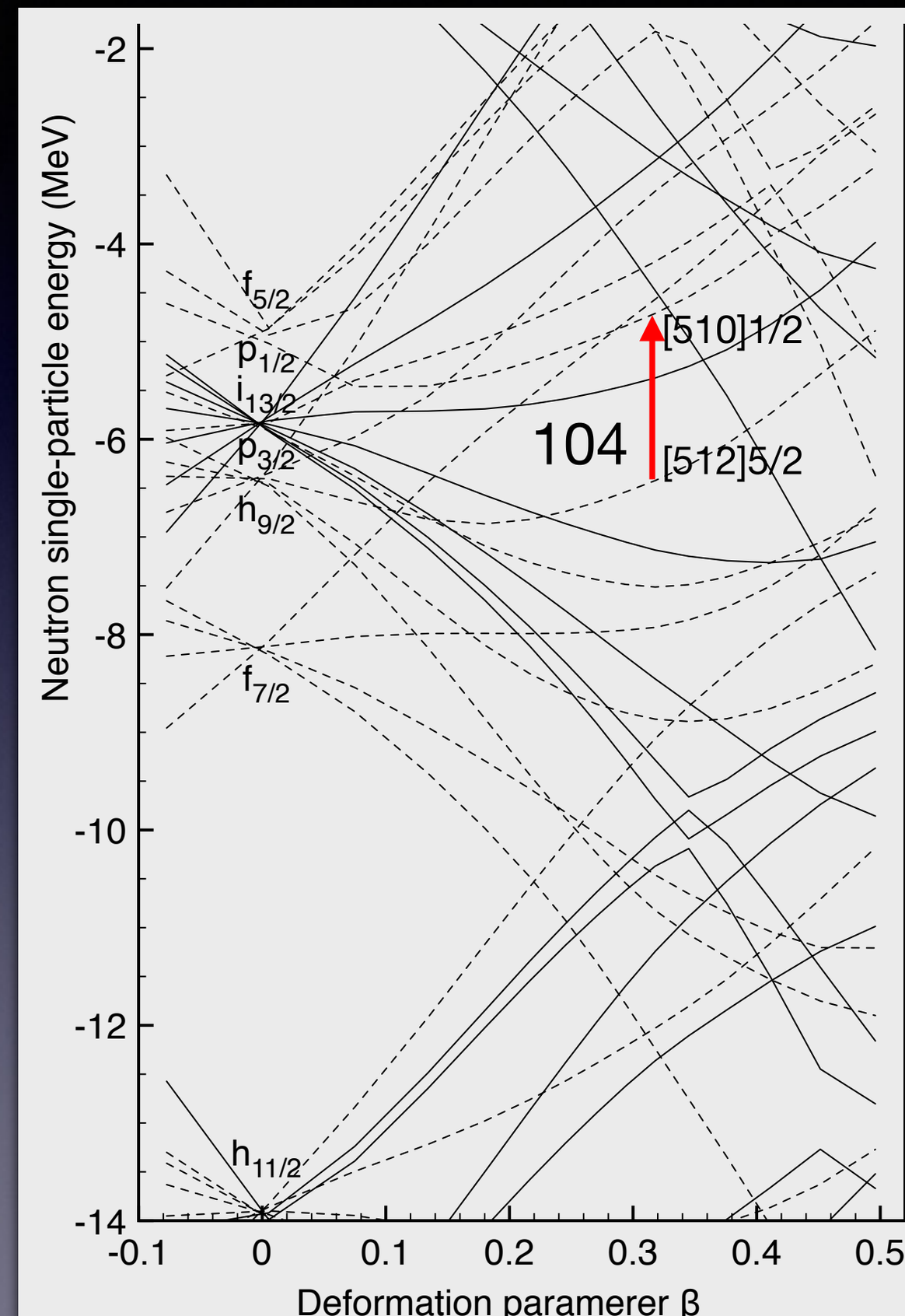


Microscopic structure of the γ-vibration: isotopic dependence

@N=104

$$\Delta N = 0 \text{ or } 2, \Delta n_3 = 0, \Delta\Lambda = \Delta\Omega = 2$$

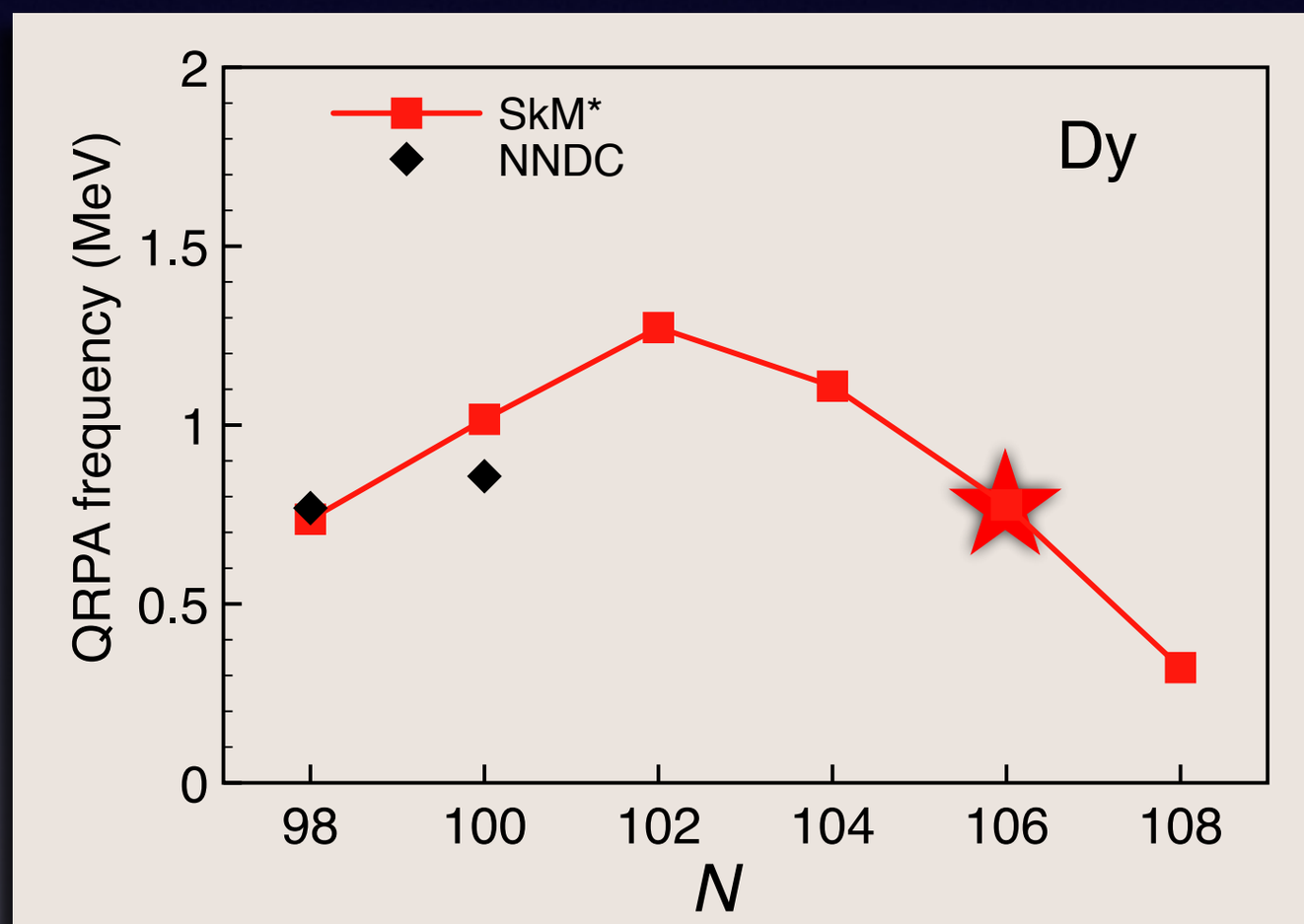


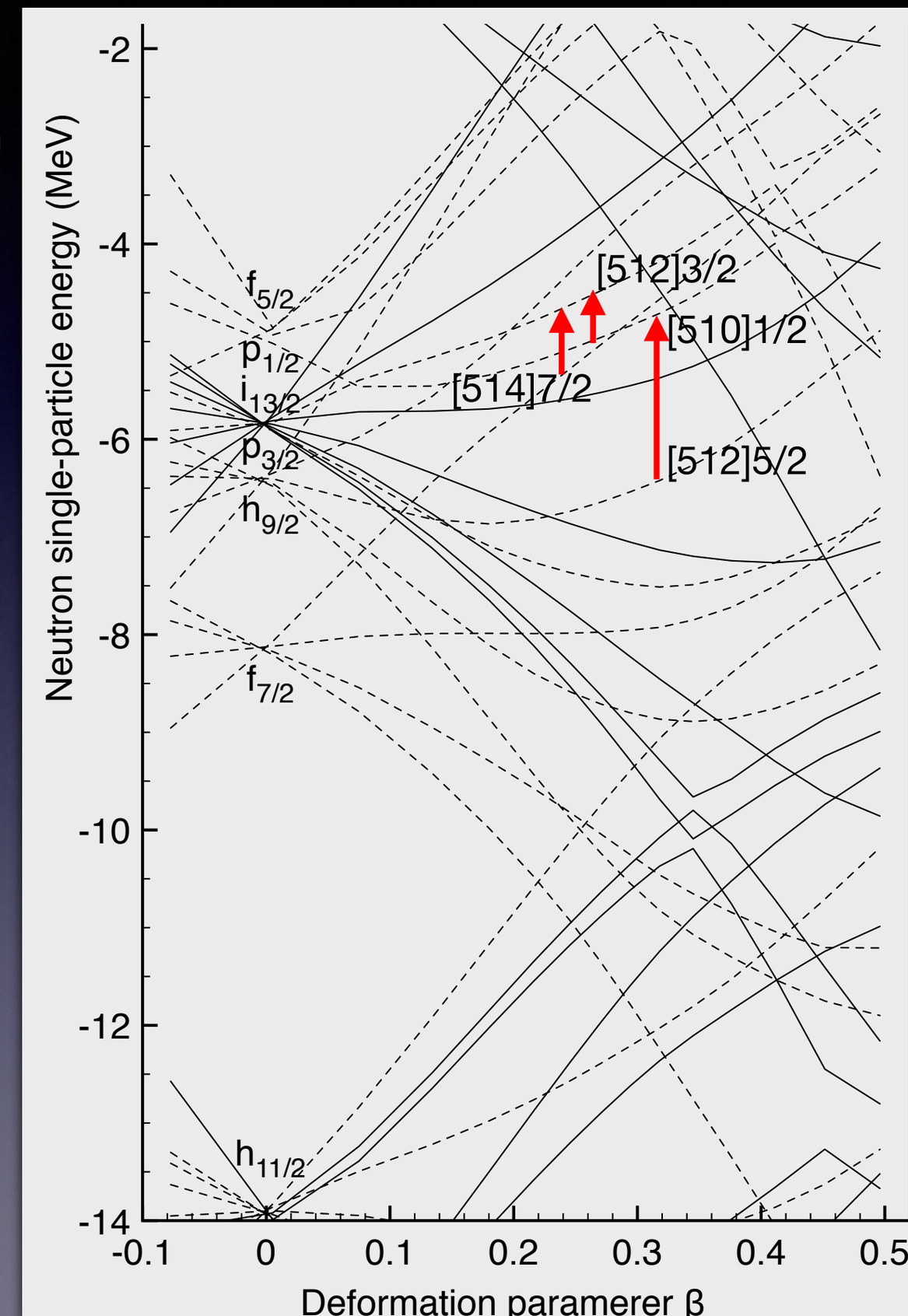


Microscopic structure of the γ-vibration: isotopic dependence

@*N*=106

$$\Delta N = 0 \text{ or } 2, \Delta n_3 = 0, \Delta\Lambda = \Delta\Omega = 2$$

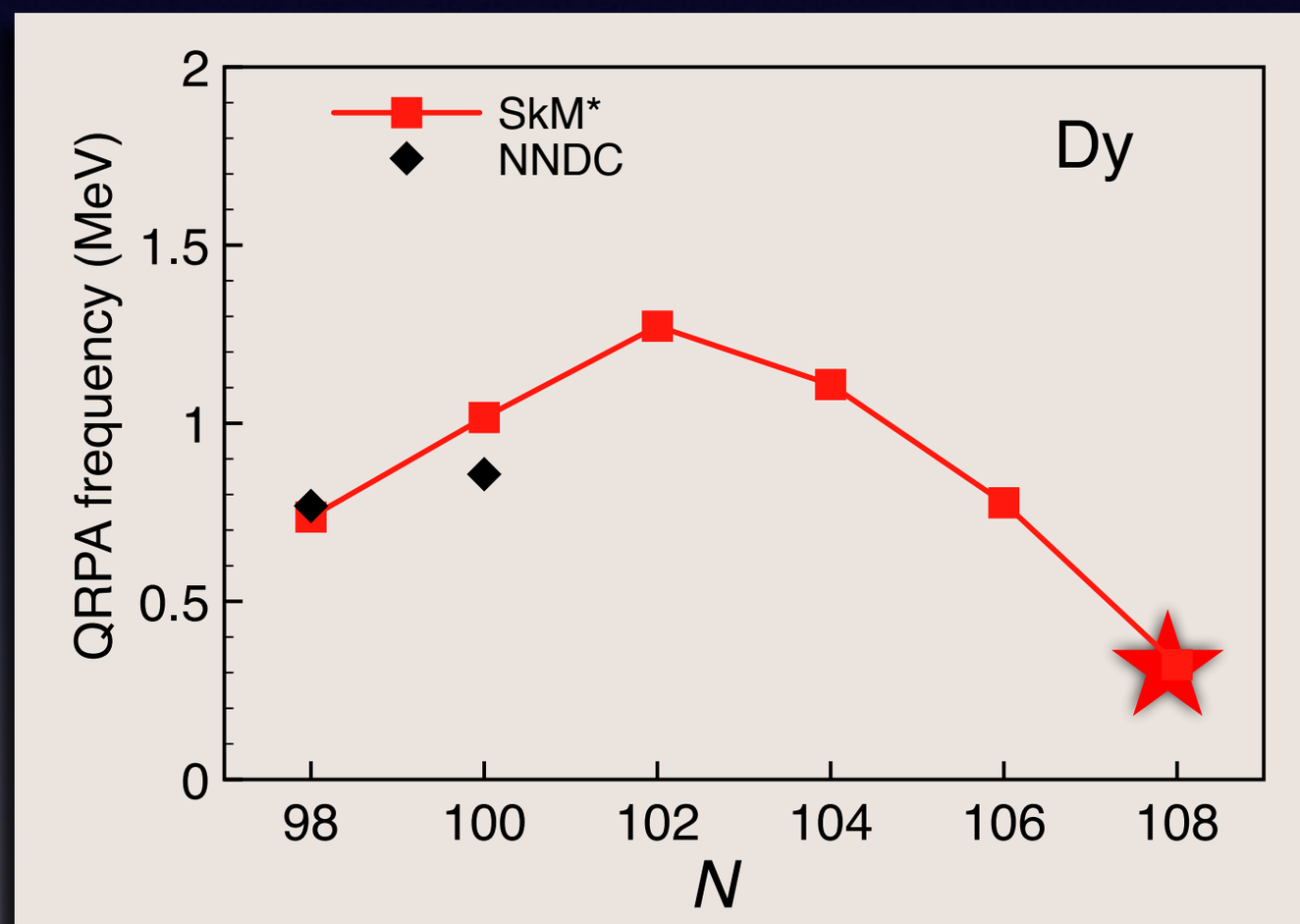


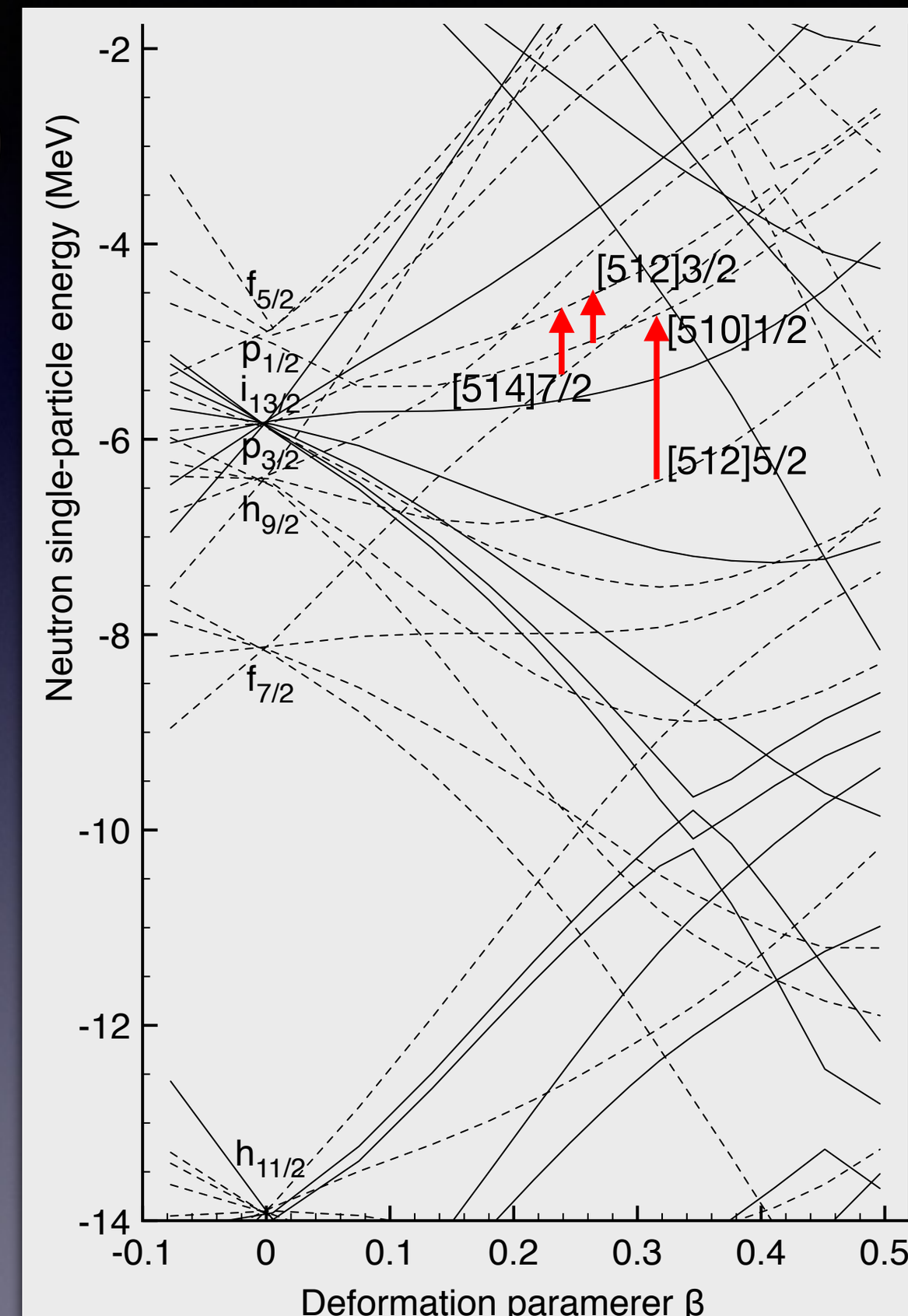


Microscopic structure of the γ-vibration: isotopic dependence

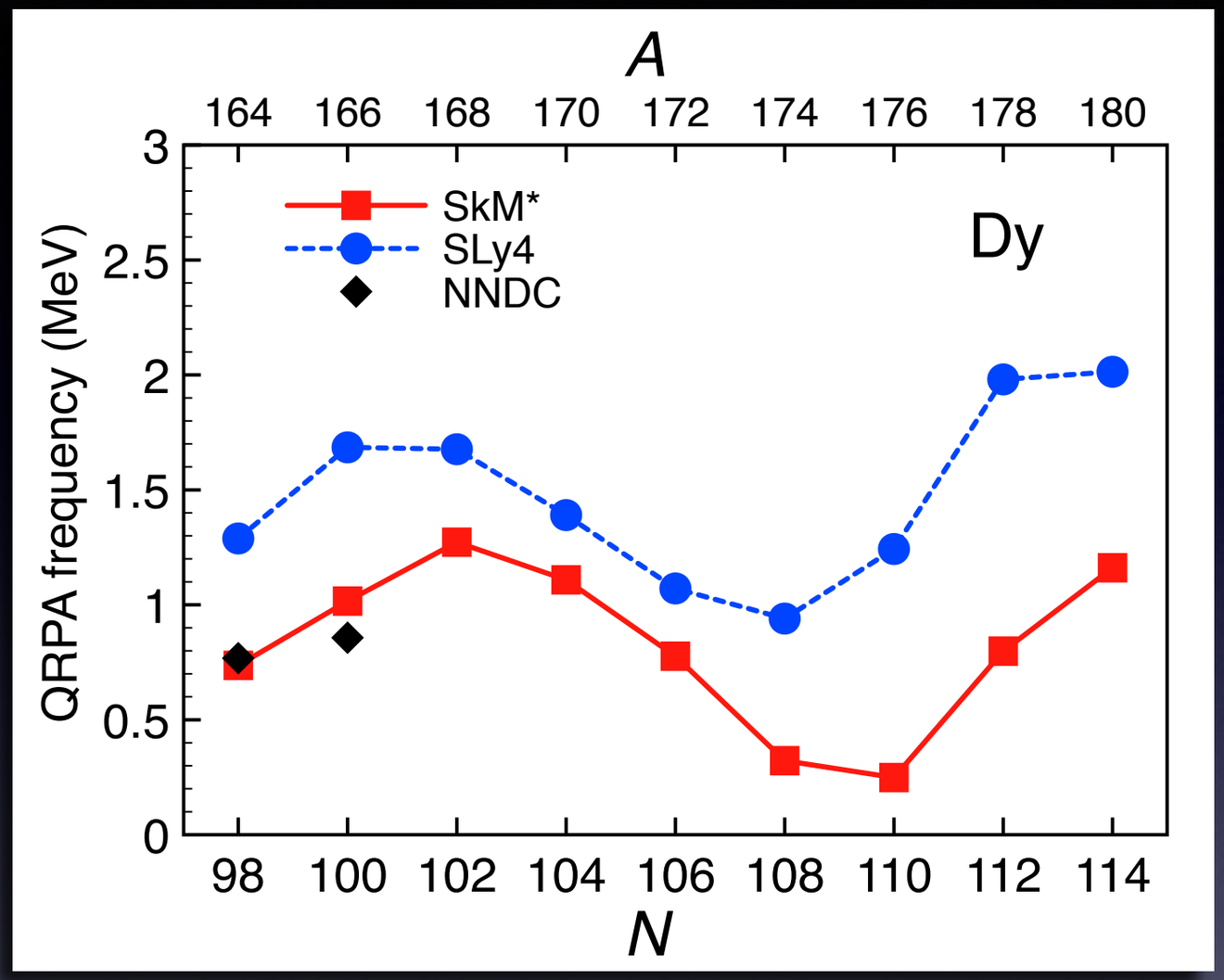
@*N*=108

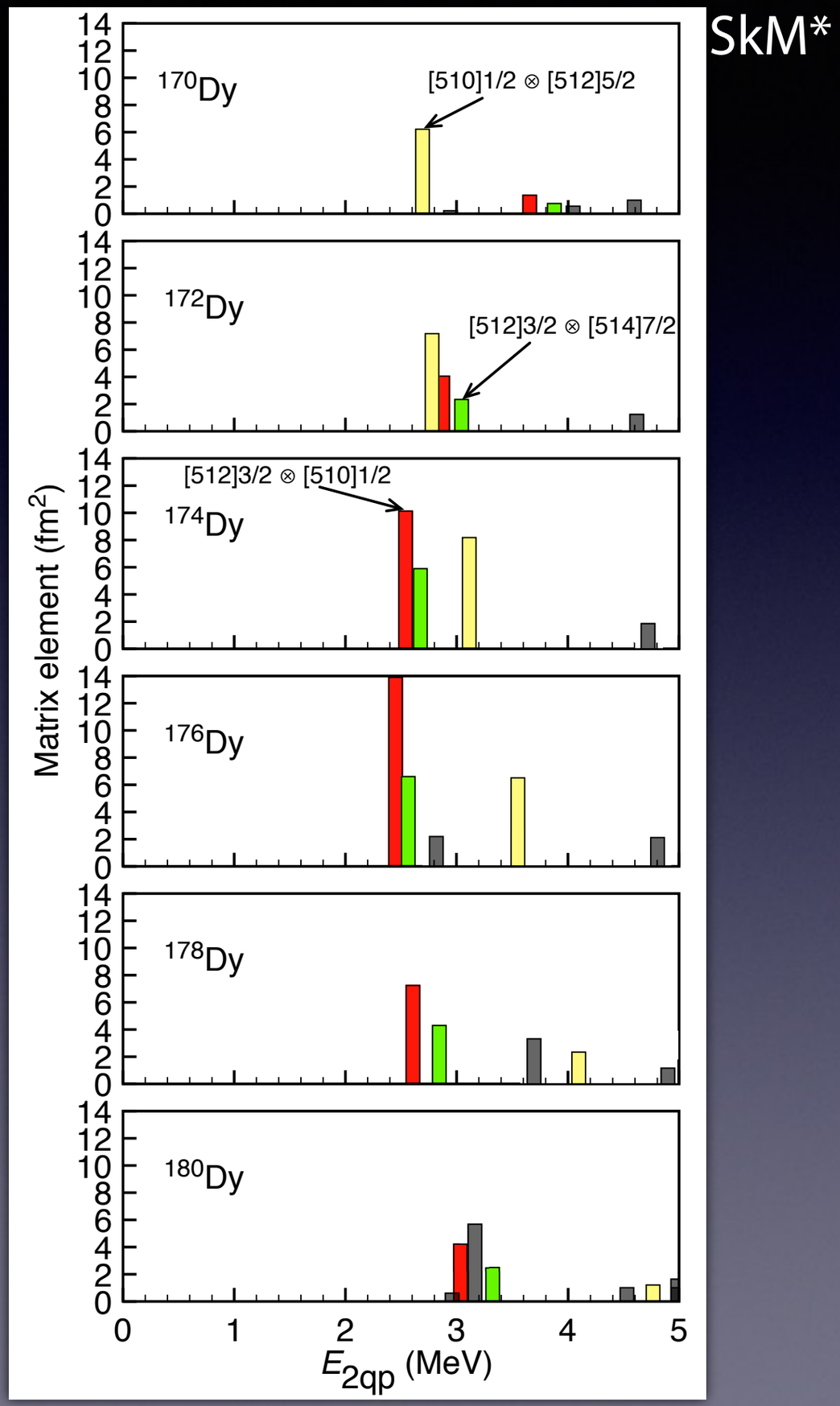
$$\Delta N = 0 \text{ or } 2, \Delta n_3 = 0, \Delta\Lambda = \Delta\Omega = 2$$





Strong collectivity of the γ-vibration around N=108-110





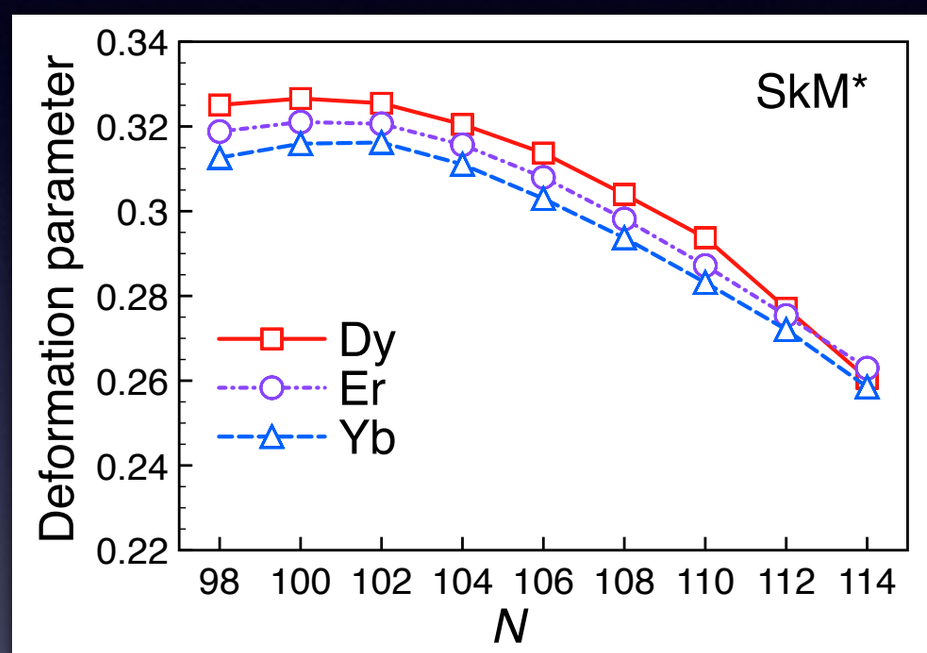
2qp matrix elements constructing the γ-vib.

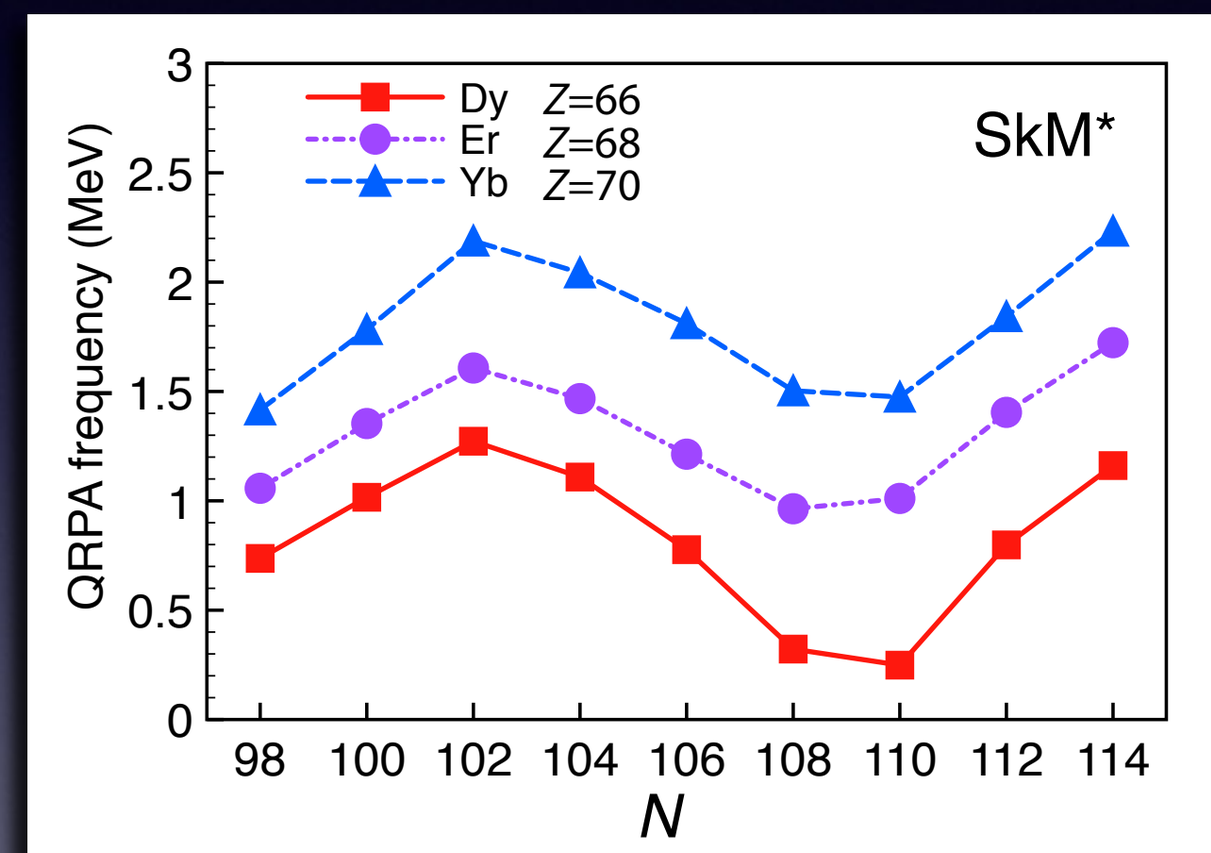
$$\langle i|\hat{F}^{q}_{\lambda K}|0\rangle = \sum_{\alpha\beta} M^{q,i}_{\alpha\beta}$$

Summary

arXiv:1607.07111

- ✓ A sudden decrease in the excitation energy of the γ-vibration at *N*=106 was observed at RIBF for neutron-rich Dy isotopes.
- ✓ The EDF-based QRPA calculations with the SkM* and SLy4 functionals reproduce well the measurement.
- ✓ The two-quasiparticle excitations of ν[512]3/2⊗ν[510]1/2, ν[510]1/2⊗ν[512]5/2, and ν[512]3/2⊗ν[514]7/2 play a major role in generating the collective γ-vibration.
- ✓ The strong collectivity at N = 108-110 is expected as the Fermi level of neutrons lies just among the orbitals that play an important role in generating the collectivity around N = 106.


SkM*
Dy
Er
Yb
Deformation parameter
0.34
0.32
0.3
0.28
0.26
0.24
0.22
98
100
102
104
106
108
110
112
114
N


Dy Z=66
Er Z=68
Yb Z=70
SkM*
QRPA frequency (MeV)
3
2.5
2
1.5
1
0.5
0
98
100
102
104
106
108
110
112
114
N