Spin-isospin responses of deformed neutron-rich nuclei

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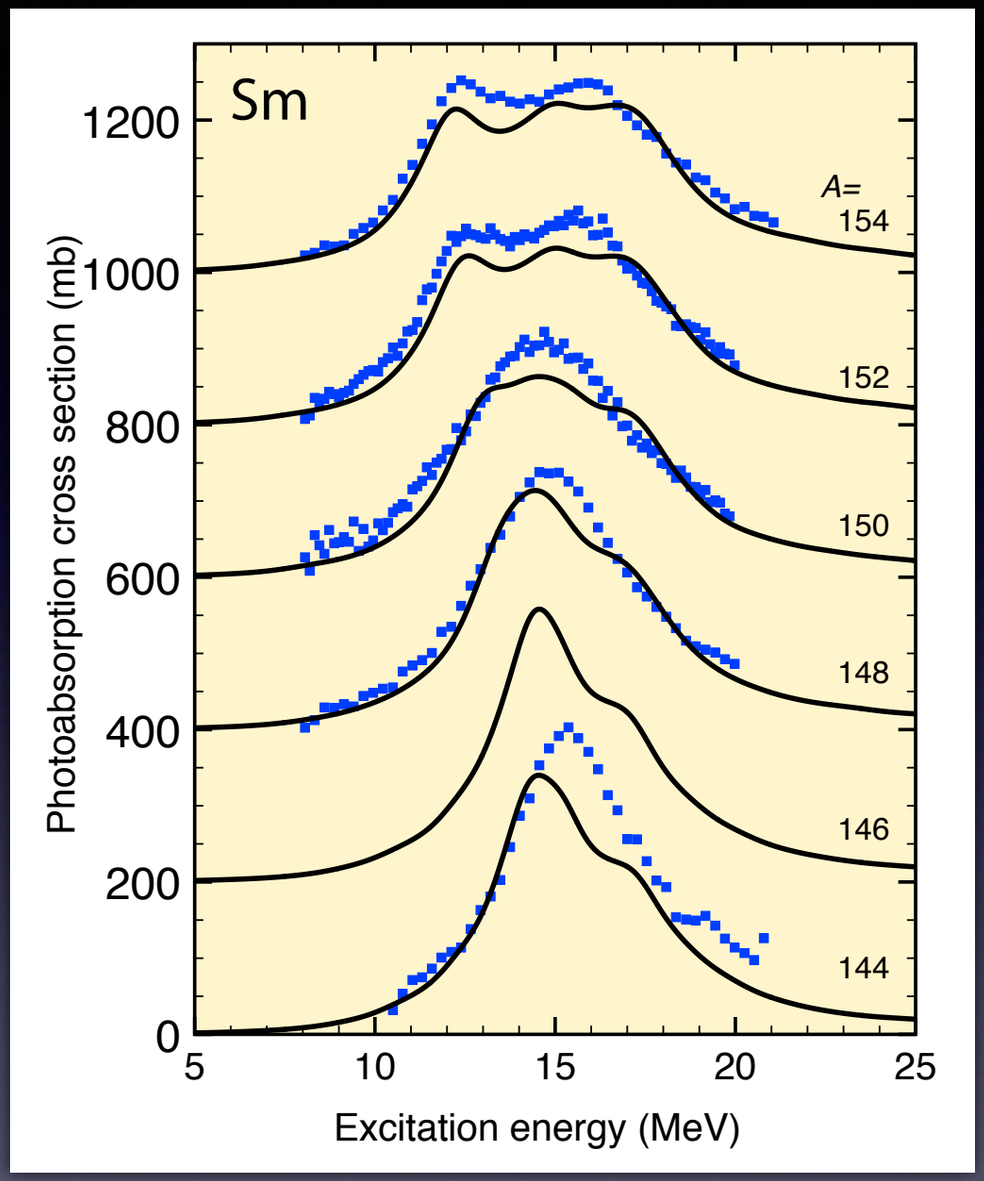
Kenichi Yoshida

Vibration in deformed nuclei

- ✓Low-frequency K=0^+ and 2^+ modes; beta- and gamma-vibrations

- ✓K-splitting of giant dipole resonance



KY, T. Nakatsukasa, PRC83(2011)021304

What can we see in charge-exchange modes?
How about an effect of neutron excess?

Roles of neutron excess:

quest for collective modes unique in neutron-rich nuclei

✓ Strongly collective GTGR?

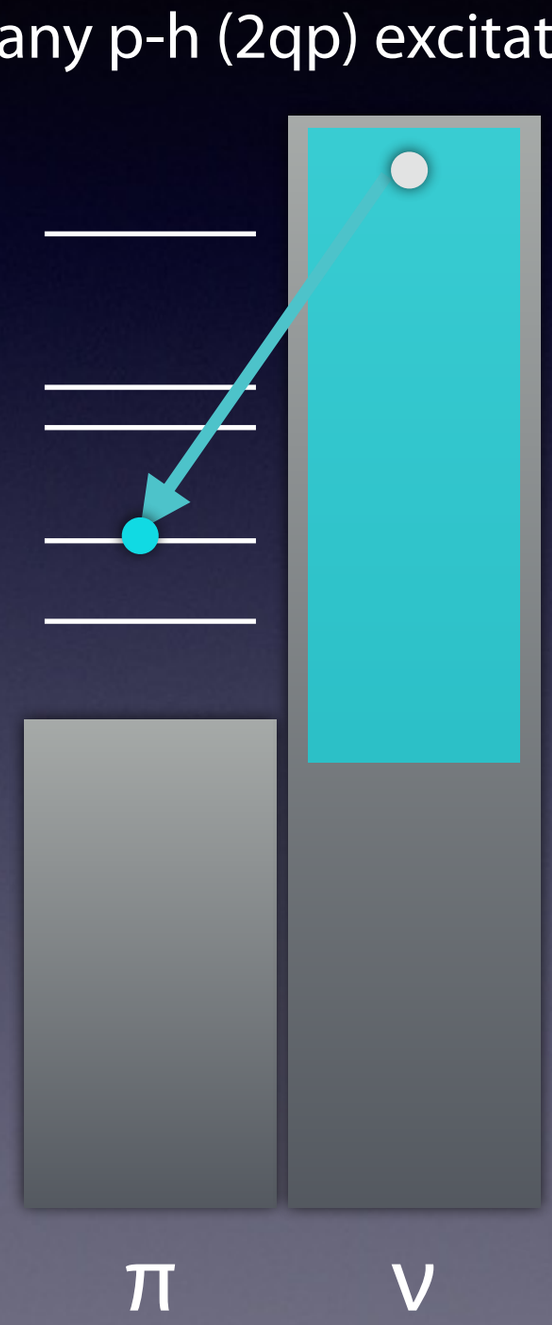
carrying large strength

$$S_- - S_+ = 3(N - Z)$$

✓ "Super allowed" GTGR?

only in light nuclei close to the neutron drip line?

H. Sagawa *et al.*, PLB303(1993)215



Nuclear DFT for vibrational motion

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

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

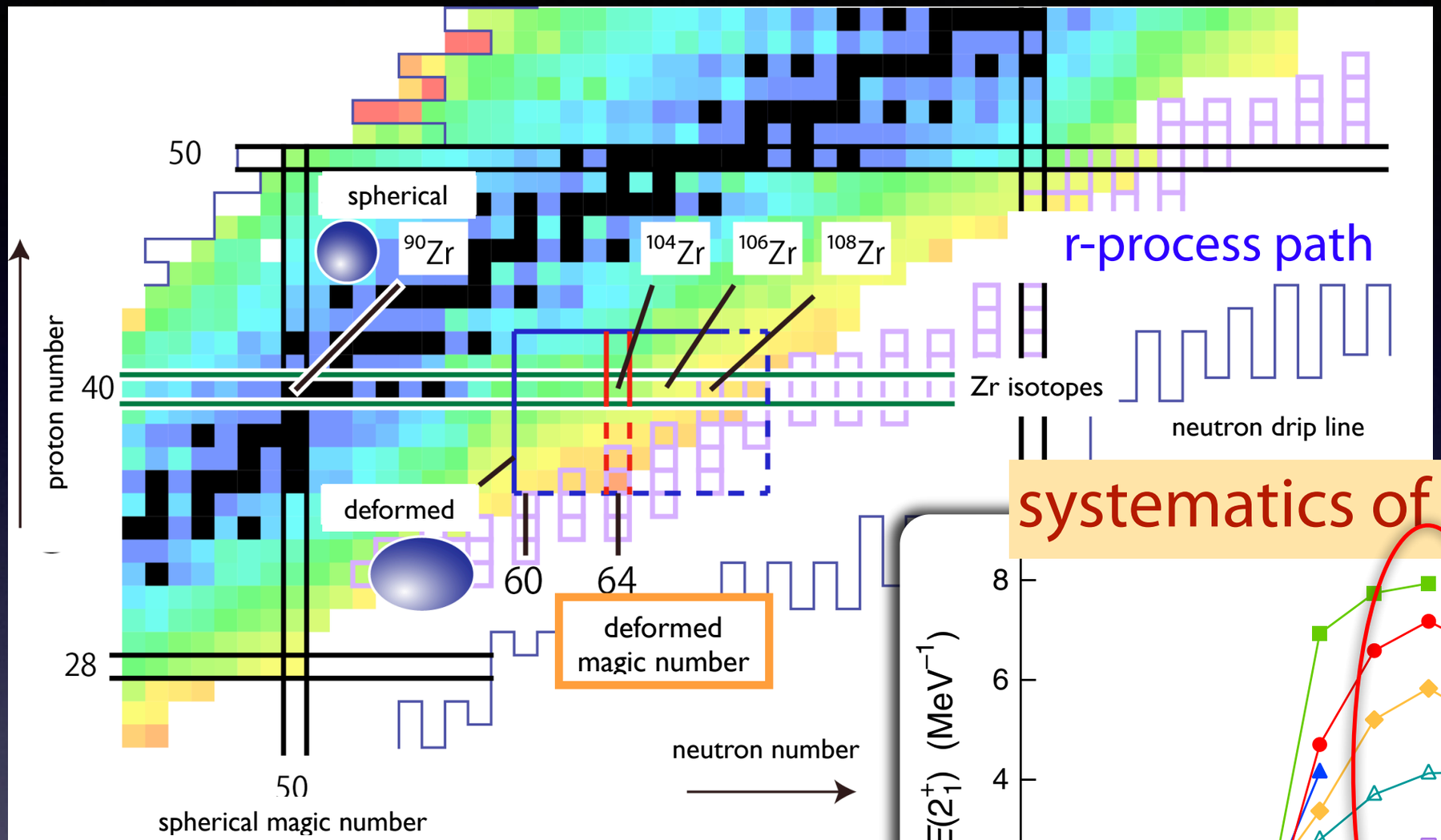
"s.p." hamiltonian and pair potential: $h^q = \dfrac{\delta \mathcal{E}}{\delta \rho^q}, \qquad \tilde{h}^q = \dfrac{\delta \mathcal{E}}{\delta \tilde{\rho}^q}$

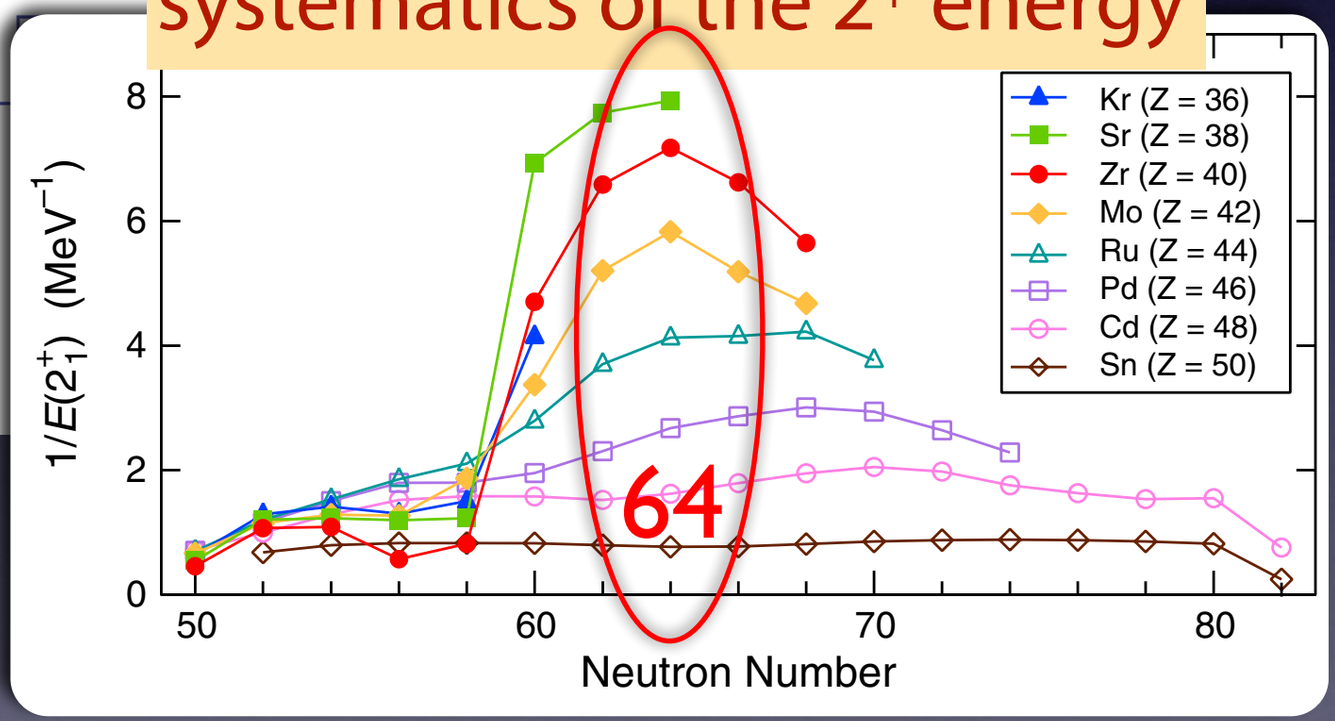
response to the weak external field $\hat{F}$: $v^{\mathrm{ext}}(r)e^{-i\omega t}$

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

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

Deformation of Zr isotopes in neutron-rich region





T. Sumikama *et al*., PRL106(2011)202501

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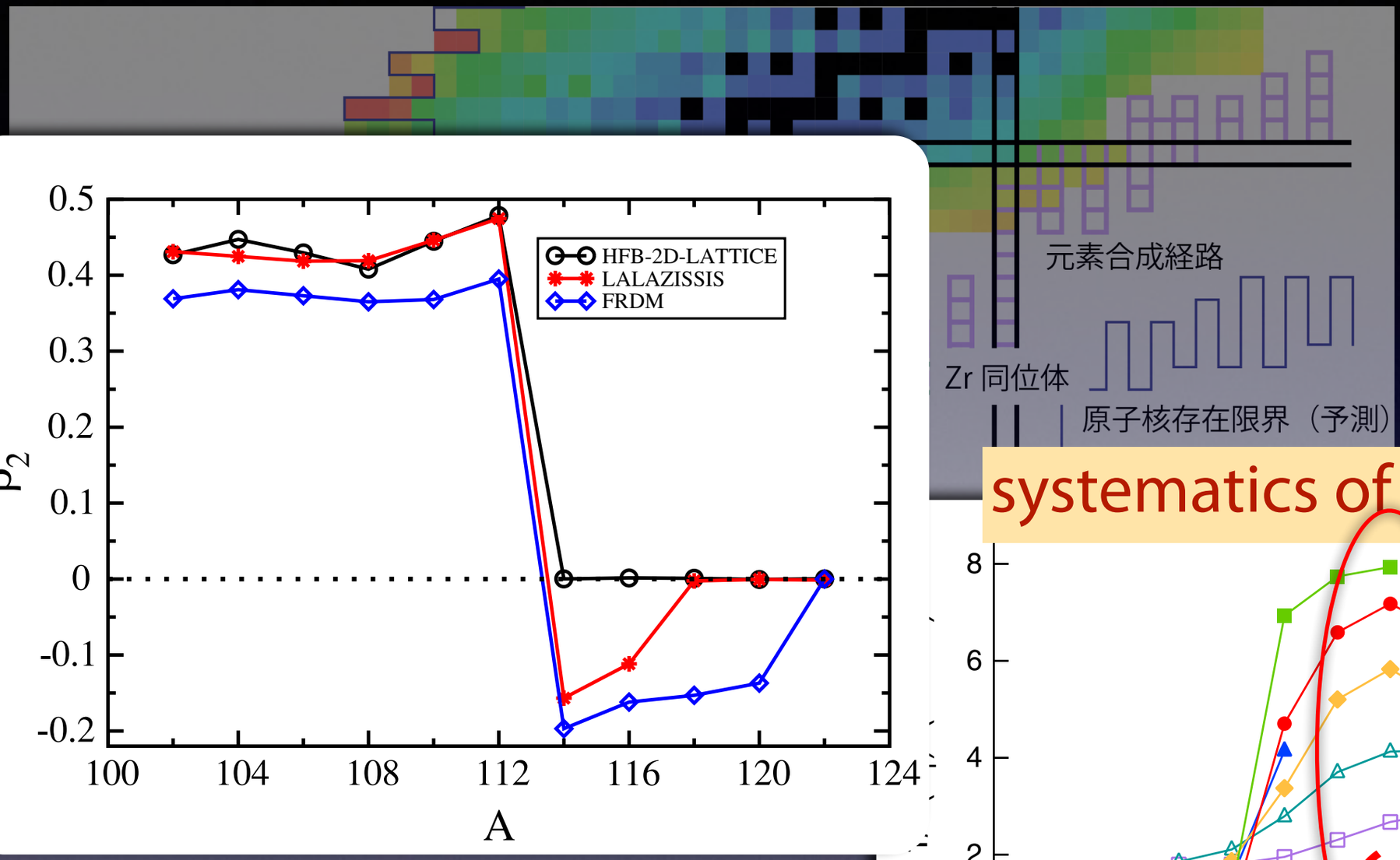
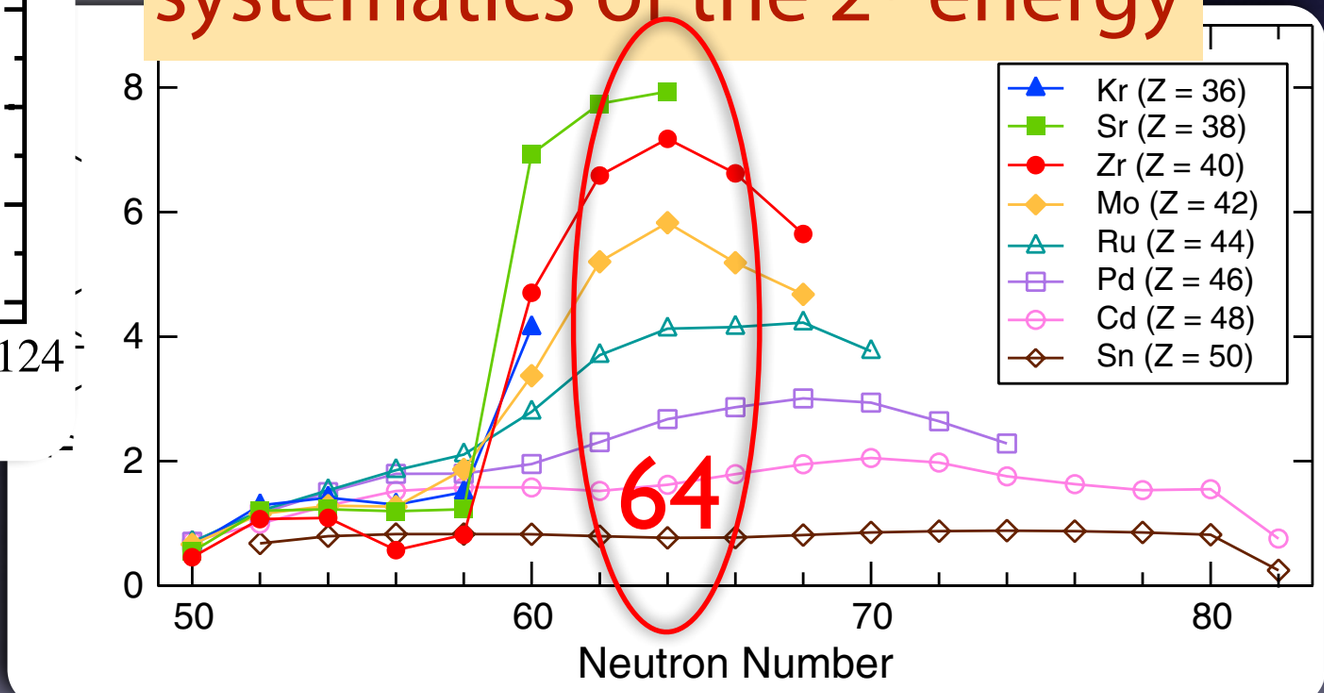


A. Blazkiewski *et al.*, PRC71(2005)054321

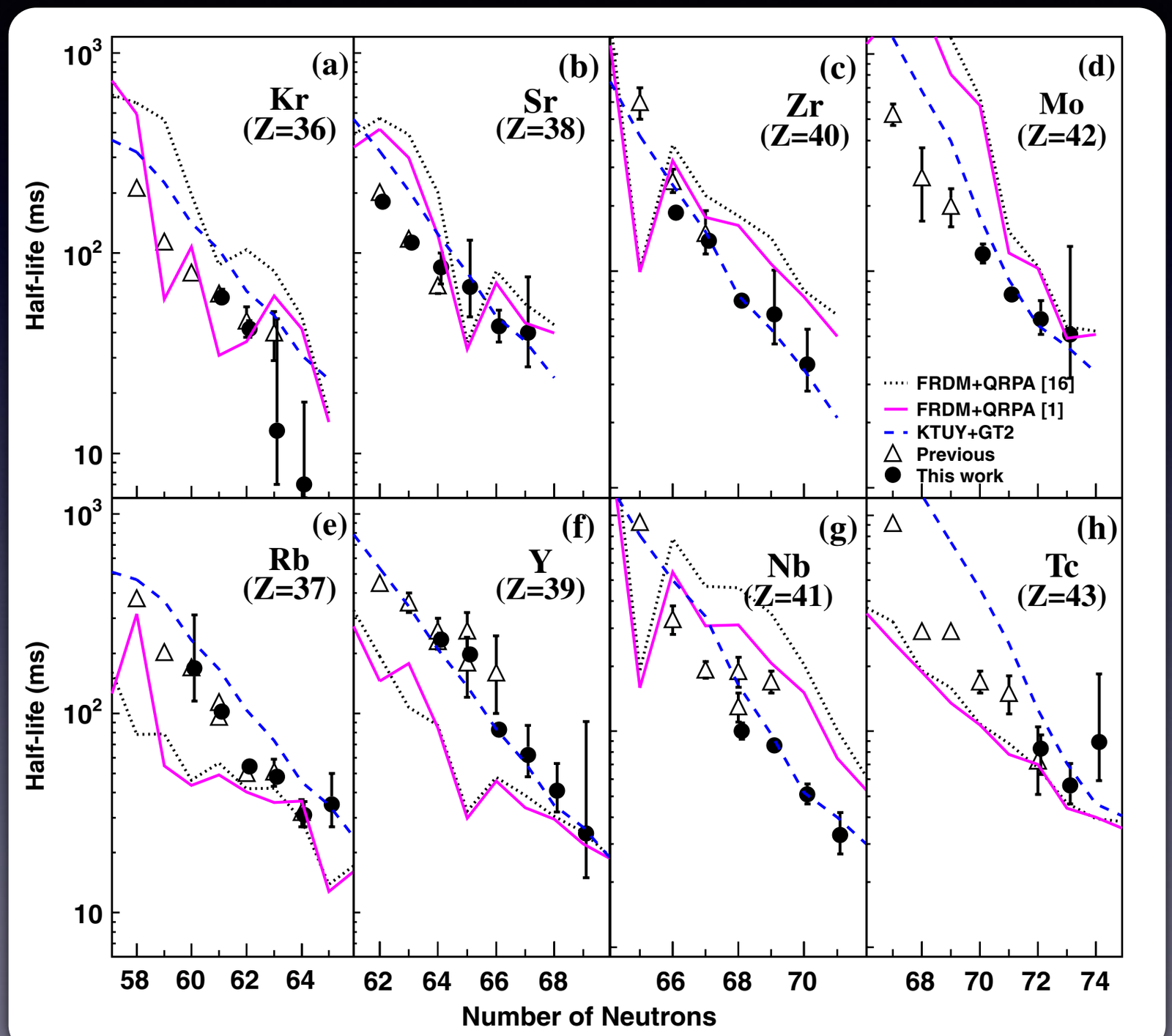
systematics of the 2^+ energy



T. Sumikama *et al.*, PRL106(2011)202501

β-decay half-lives in neutron-rich Zr isotopes

S. Nishimura *et al.*, PRL106(2011)052502



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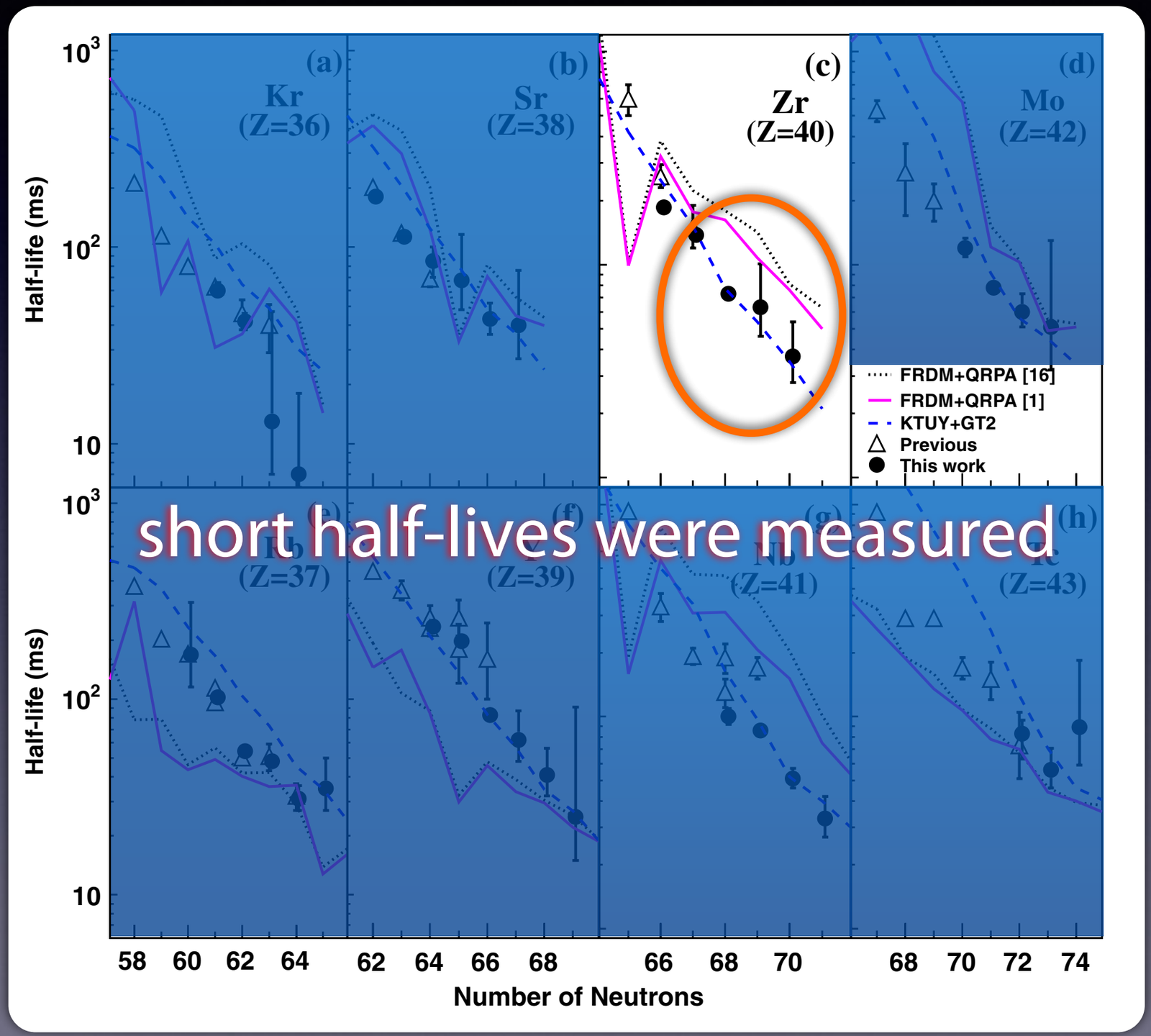
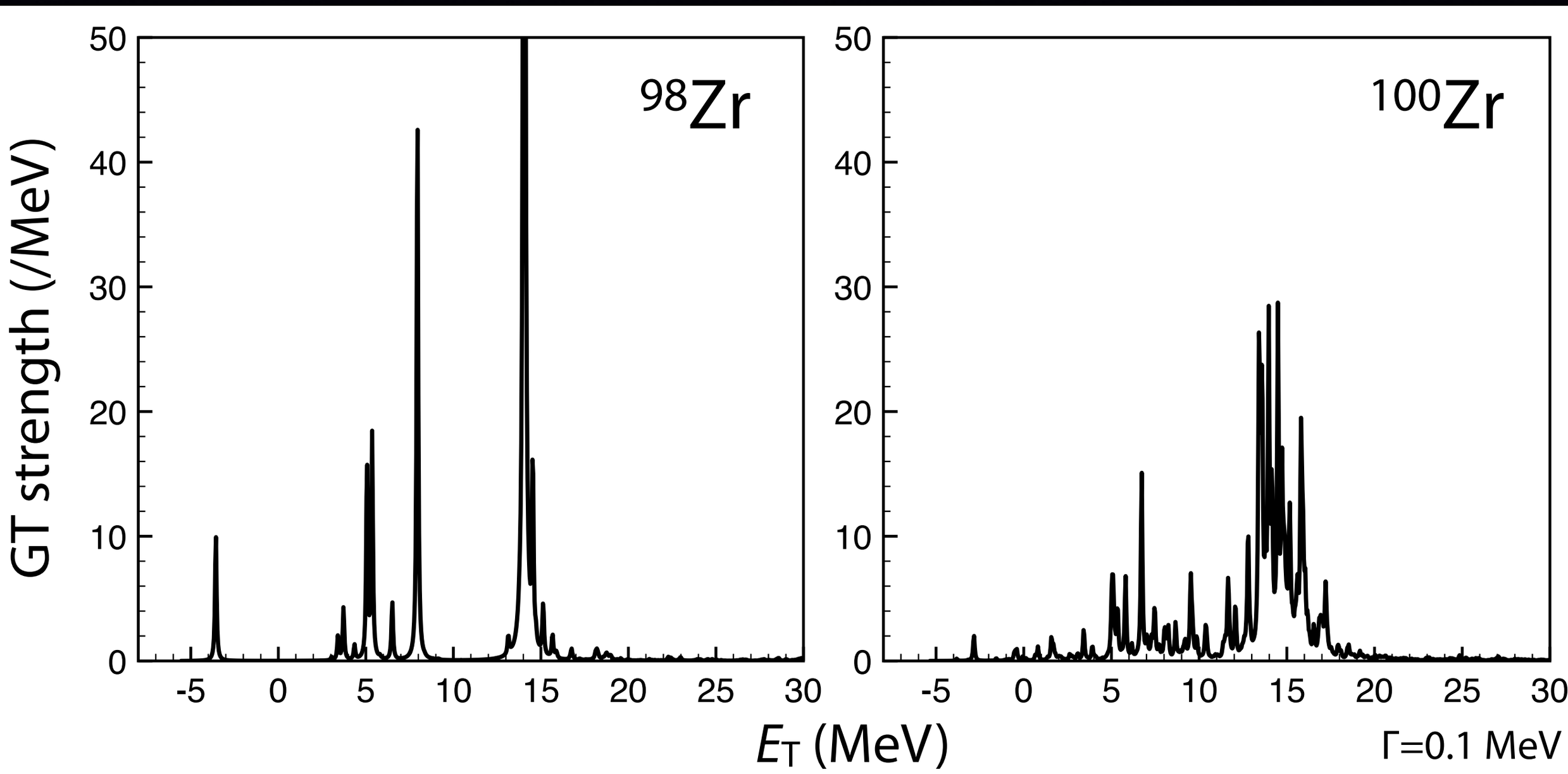


Deformation effect on GTGR

SLy4

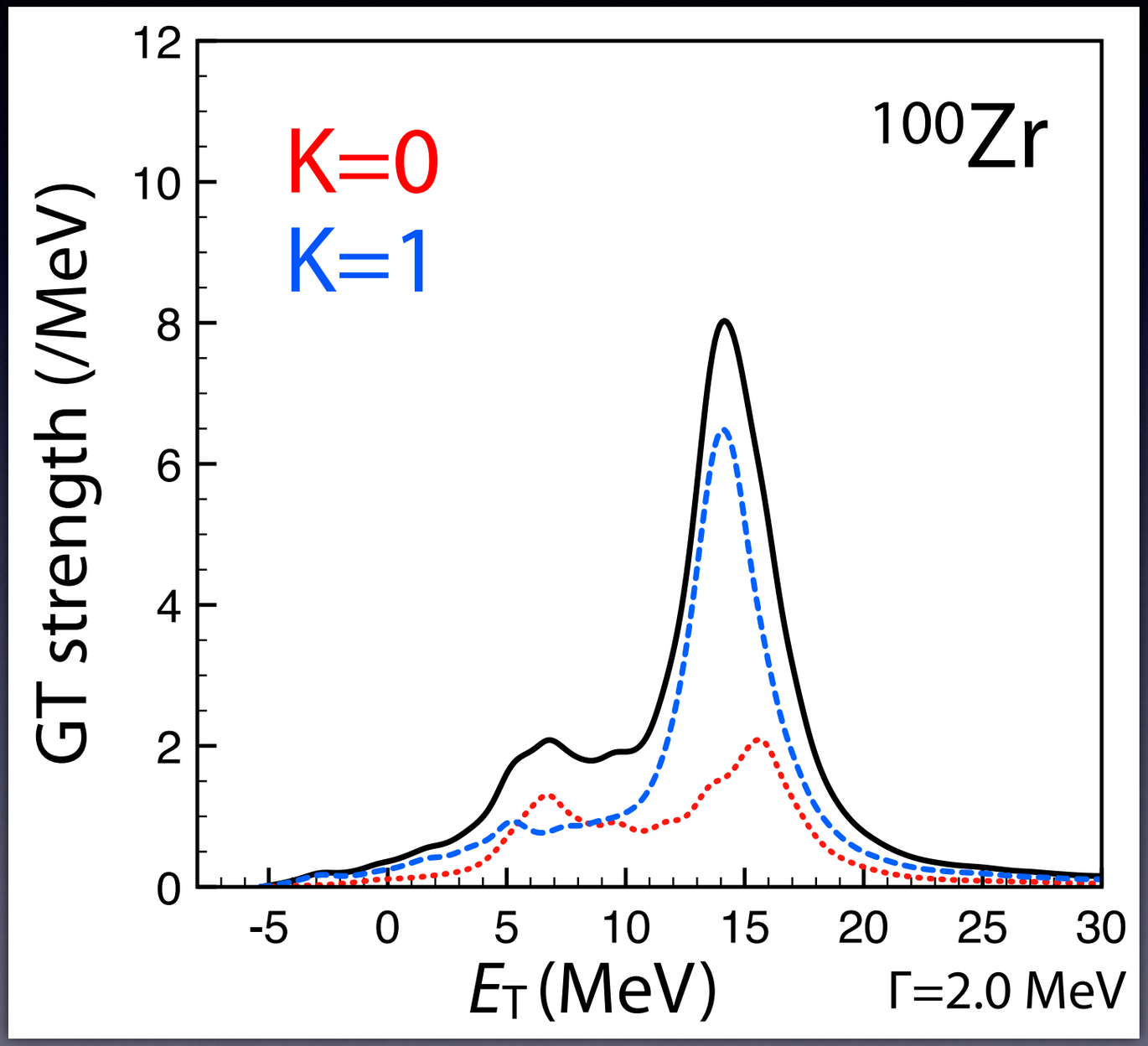
spherical

deformed (β=0.40)



Fragmentation of strengths

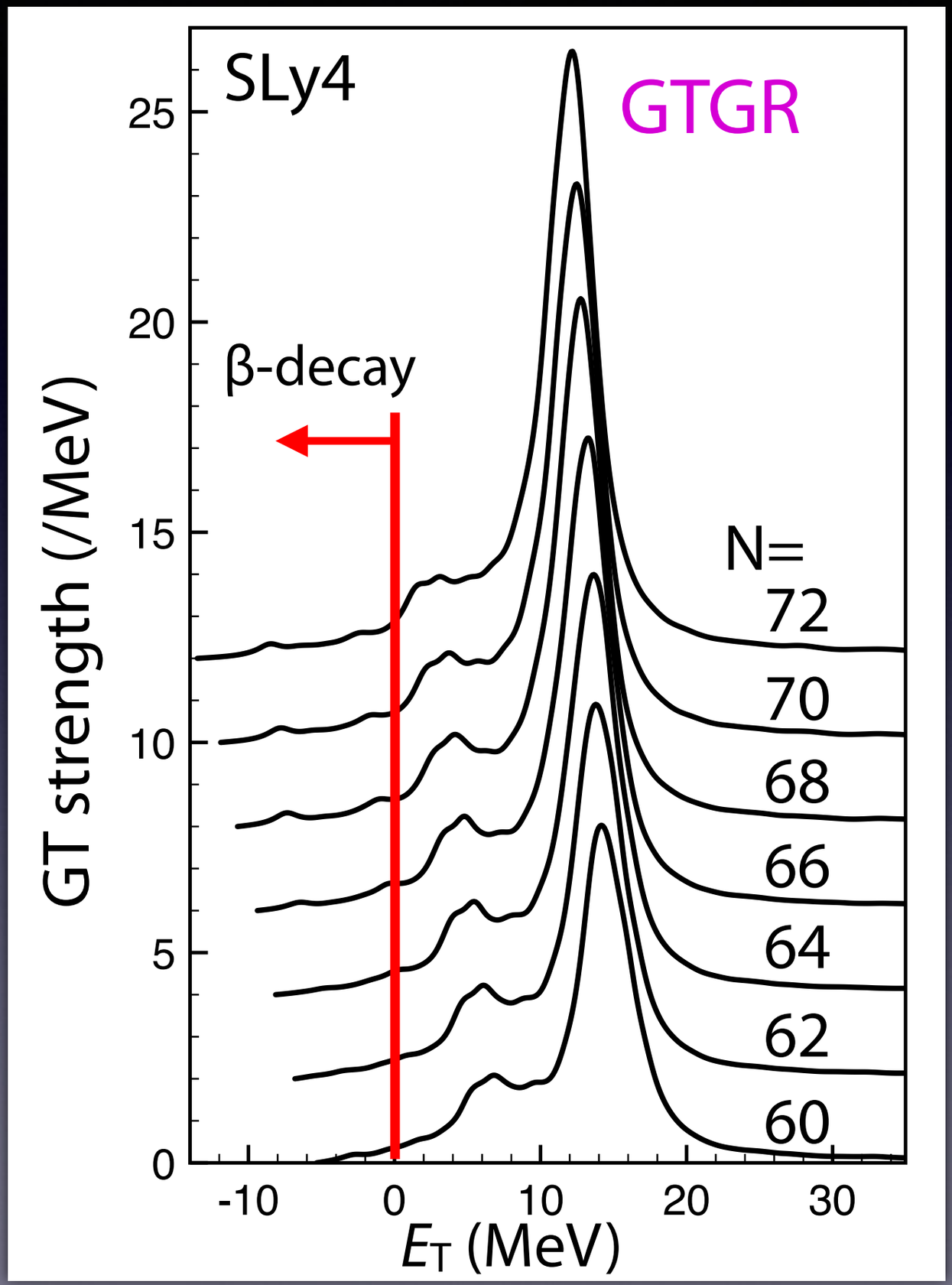
Deformation effect on GTGR



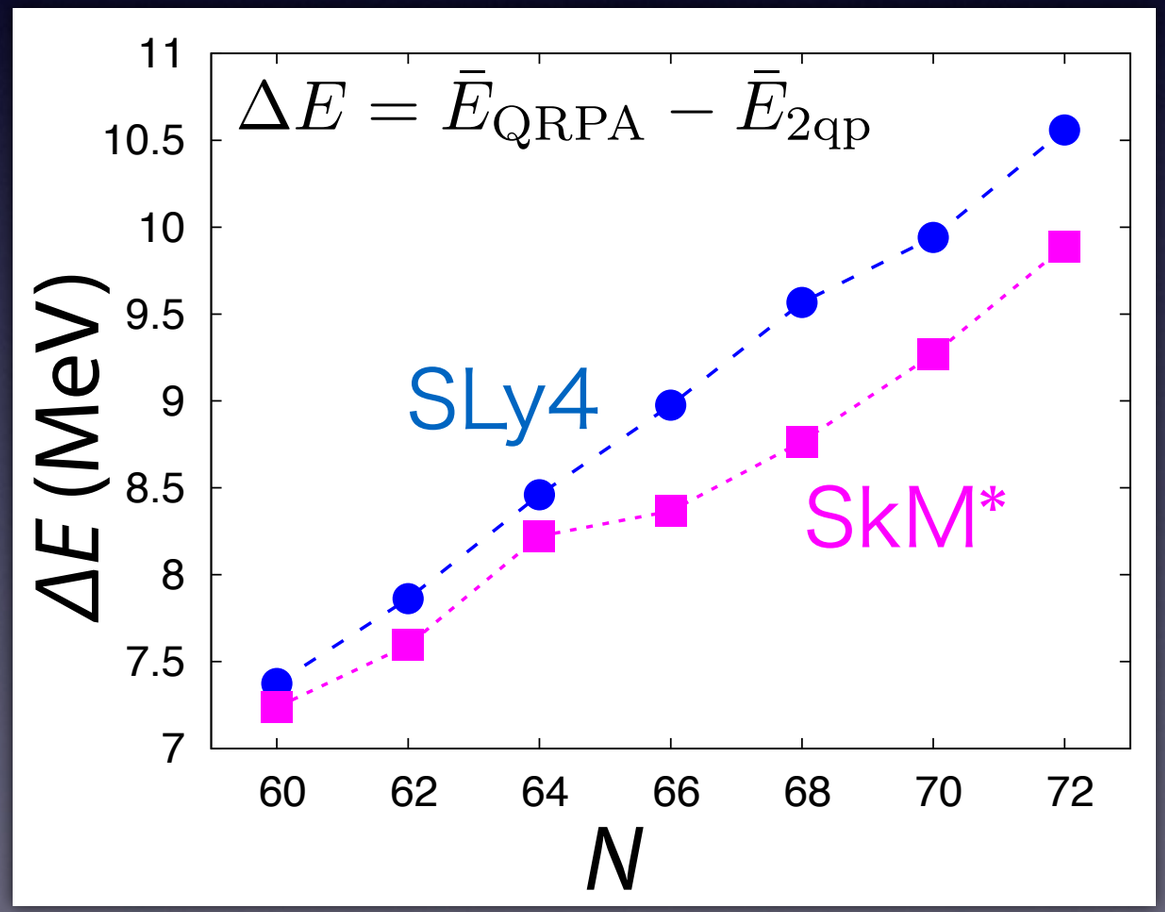
- ✓ K-splitting is small
- ✓ fragmentation due to deformed shell structure

Systematics of the GT strength distribution

KY, PTEP2013, 113D02



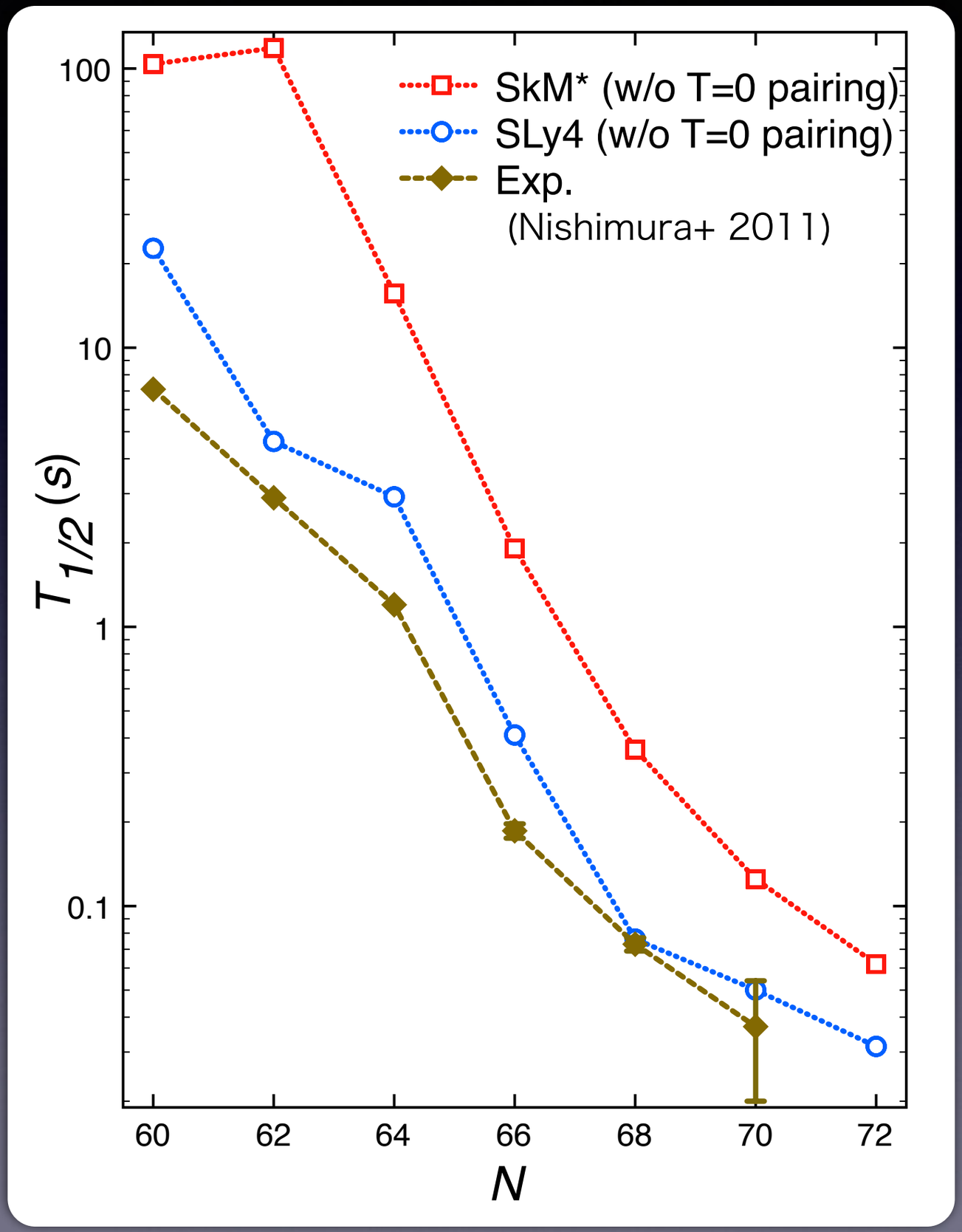
Strong collectivity of GTGR



$$\bar{E} = \frac{\int_0^\infty \omega S(\omega) d\omega}{\int_0^\infty S(\omega) d\omega}$$

Beta-decay half-lives of Zr isotopes

KY, PTEP2013, 113D02



✓Fermi's golden rule

N. B. Gove, M. J. Martin,
At. Data Nucl. Data Tables 10(1971)205

✓Fermi and Gamow-Teller strengths included

✓SkM* produces longer half-lives

primarily due to a small Q-value

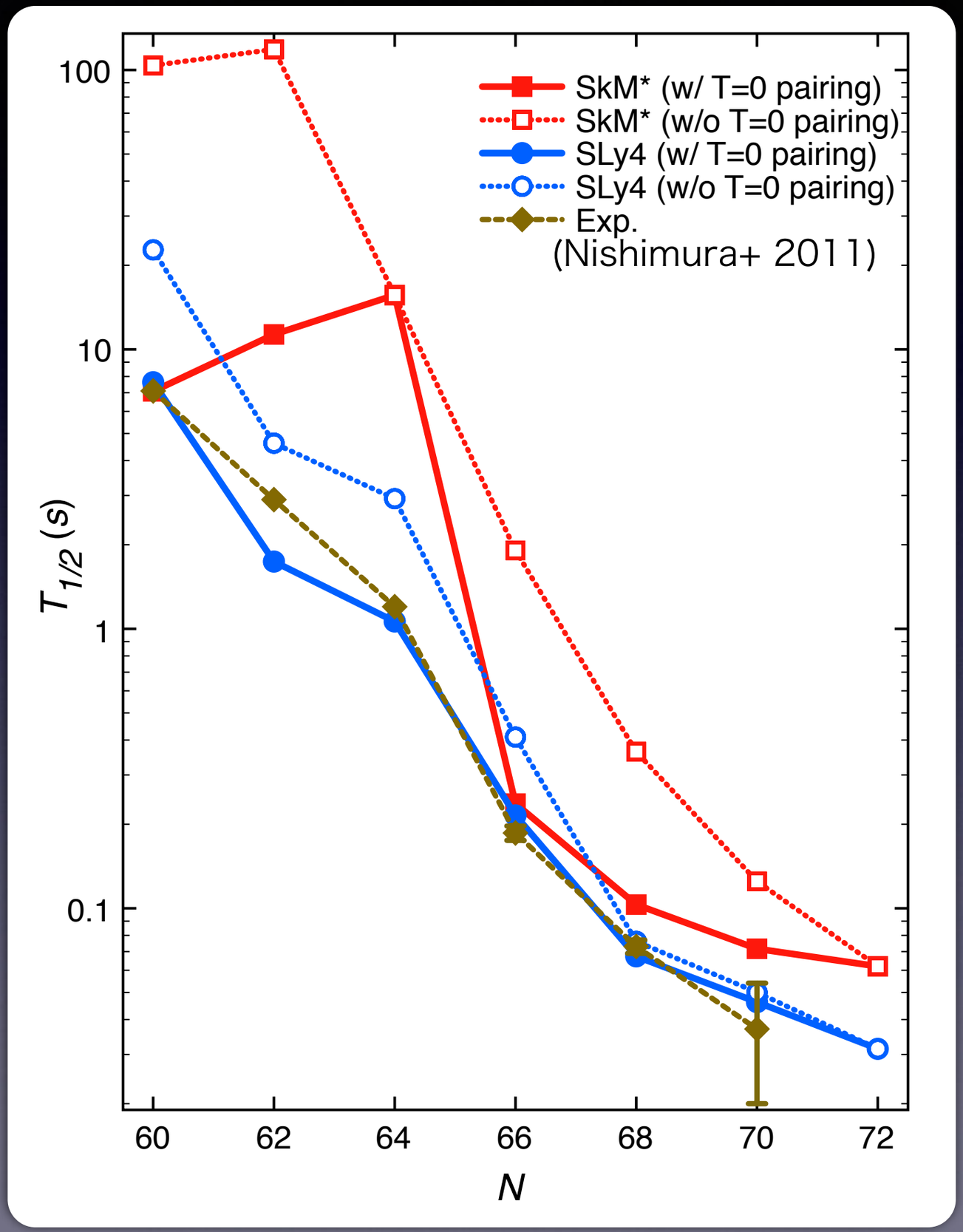
Q-value calculated approximately

$$Q_{\beta^-} = \Delta M_{\mathrm{n-H}} + B(A, Z+1) - B(A, Z)$$
$$\simeq \Delta M_{\mathrm{n-H}} + \lambda_\nu - \lambda_\pi - E_0$$
$$E_0 = \min[E_\nu + E_\pi]$$

cf. J. Engel *et al.*, PRC60(1999)014302

Beta-decay half-lives of Zr isotopes w/ T=0 pairing int.

KY, PTEP2013, 113D02



✓Strength of T=0 pairing determined at N=60

SLy4

✓reproduces well the observed isotopic dependence with T=0 pairing

✓Effect of the T=0 pairing is small beyond N=68

SkM*

✓gives a strong deformed gap at N=64

Deformed gap at N=72

✓pairing correlations inactive

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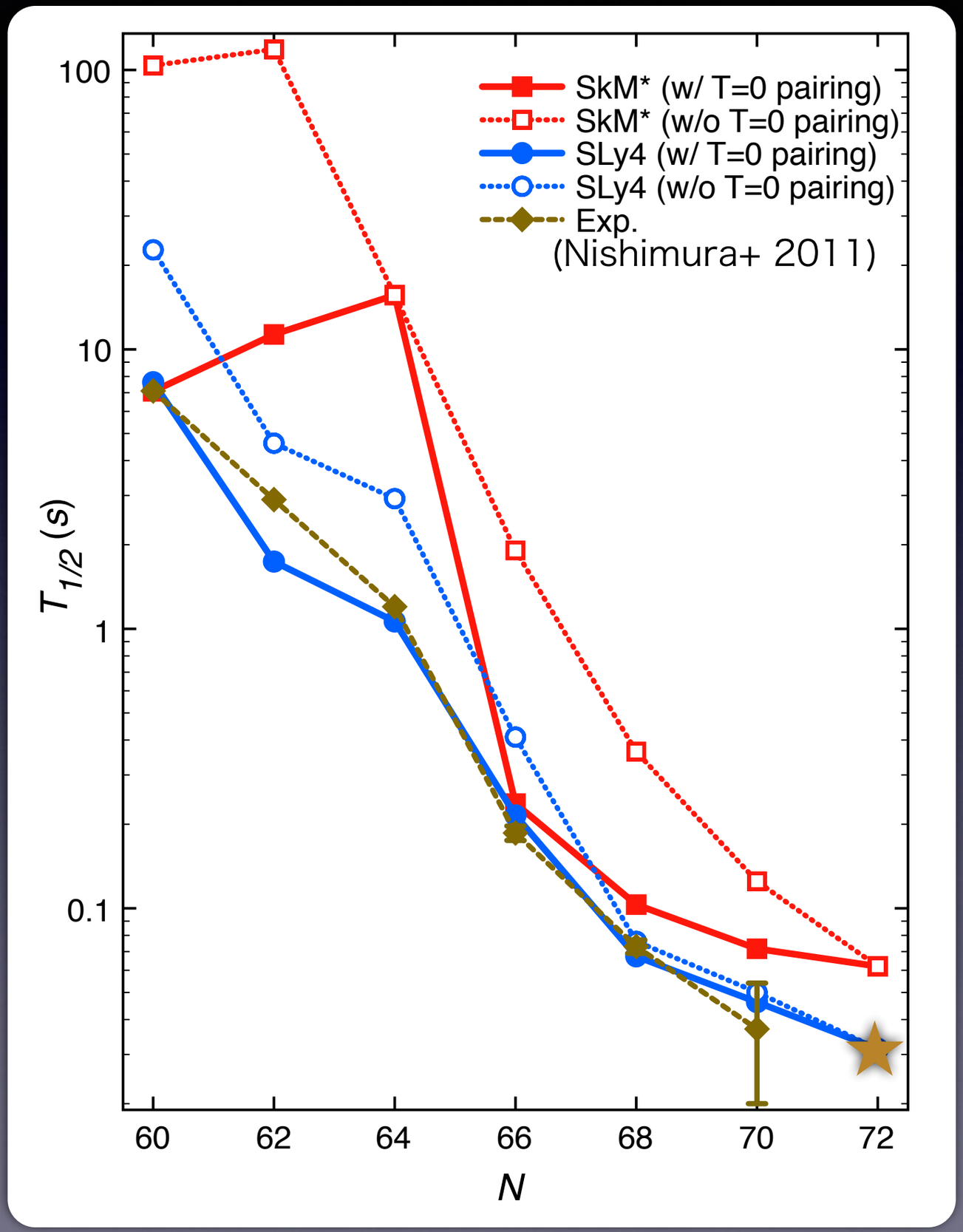

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Deformed gap at N=72

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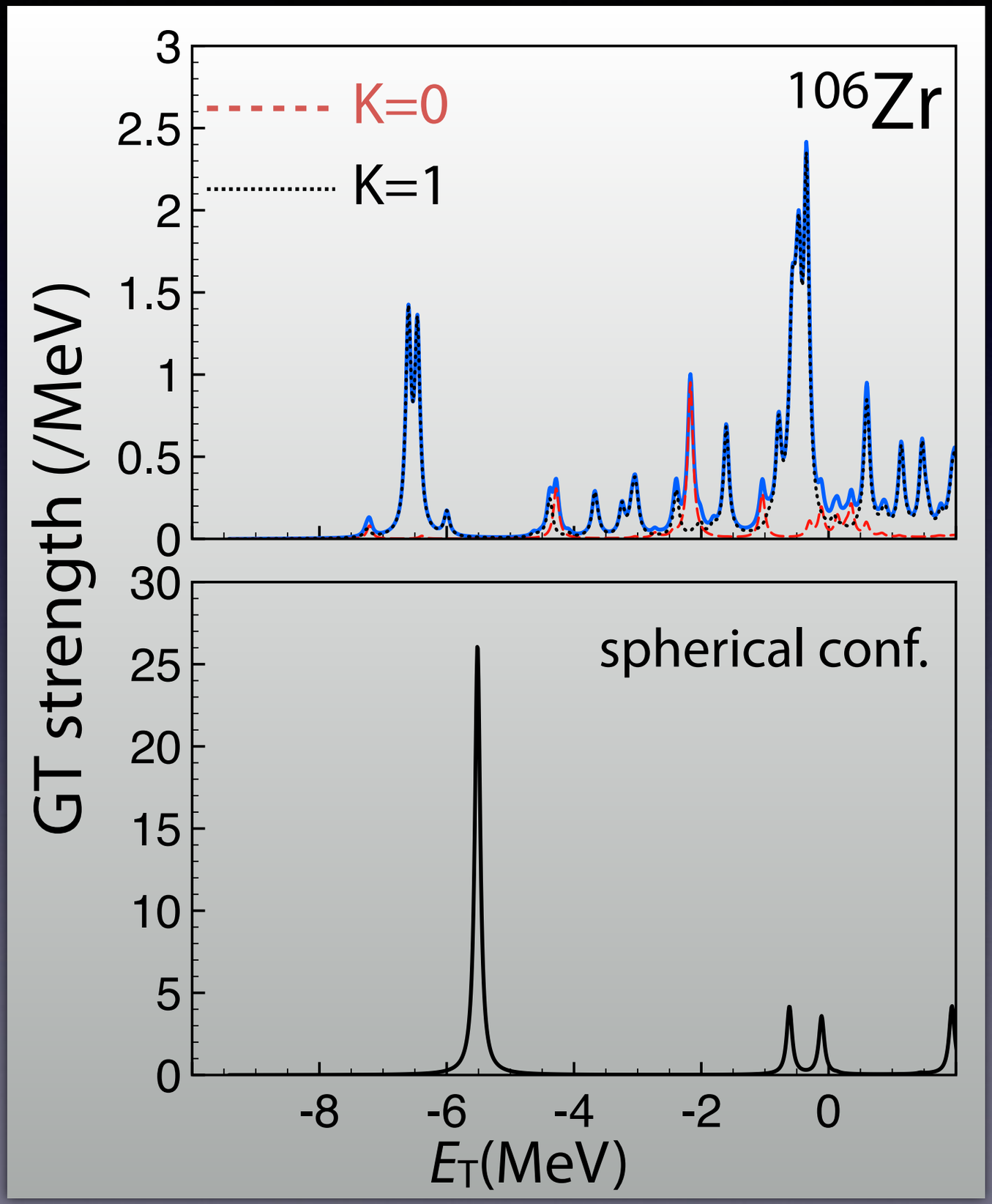
(Lorusso, Nishimura+ 2015)

Deformation effect:
low-lying GT strengths relevant to beta-decay



Fragmentation due to deformation

Deformed QRPA
takes account effectively the phonon coupling: $2^+ \otimes 1^+$

quadrupole def. ~
condensation of 2^+ phonon

For spherical nuclei,
the PVC should be considered explicitly

Summary

Nuclear DFT applied for spin-isospin response

Deformation: fragmentation of the GT strength distribution

both GTGR and low-lying states

preferable for evaluation of β-decay rate in the QRPA

β-decay rate of deformed neutron-rich Zr isotopes well described

Neutron excess: strong collectivity of GTGR

enhanced strength and large energy shift