

High-K isomers in exotic nuclei

- **high-K isomerism**
- **K-mixing mechanisms**
- **n-rich rare earths at RIKEN:** ^{172m}Dy , $^{160m^2}\text{Sm}$
- **isomeric fission**

Phil Walker
University of Surrey, UK

Isomer prediction: Soddy, *Nature* 99 (1917) 433

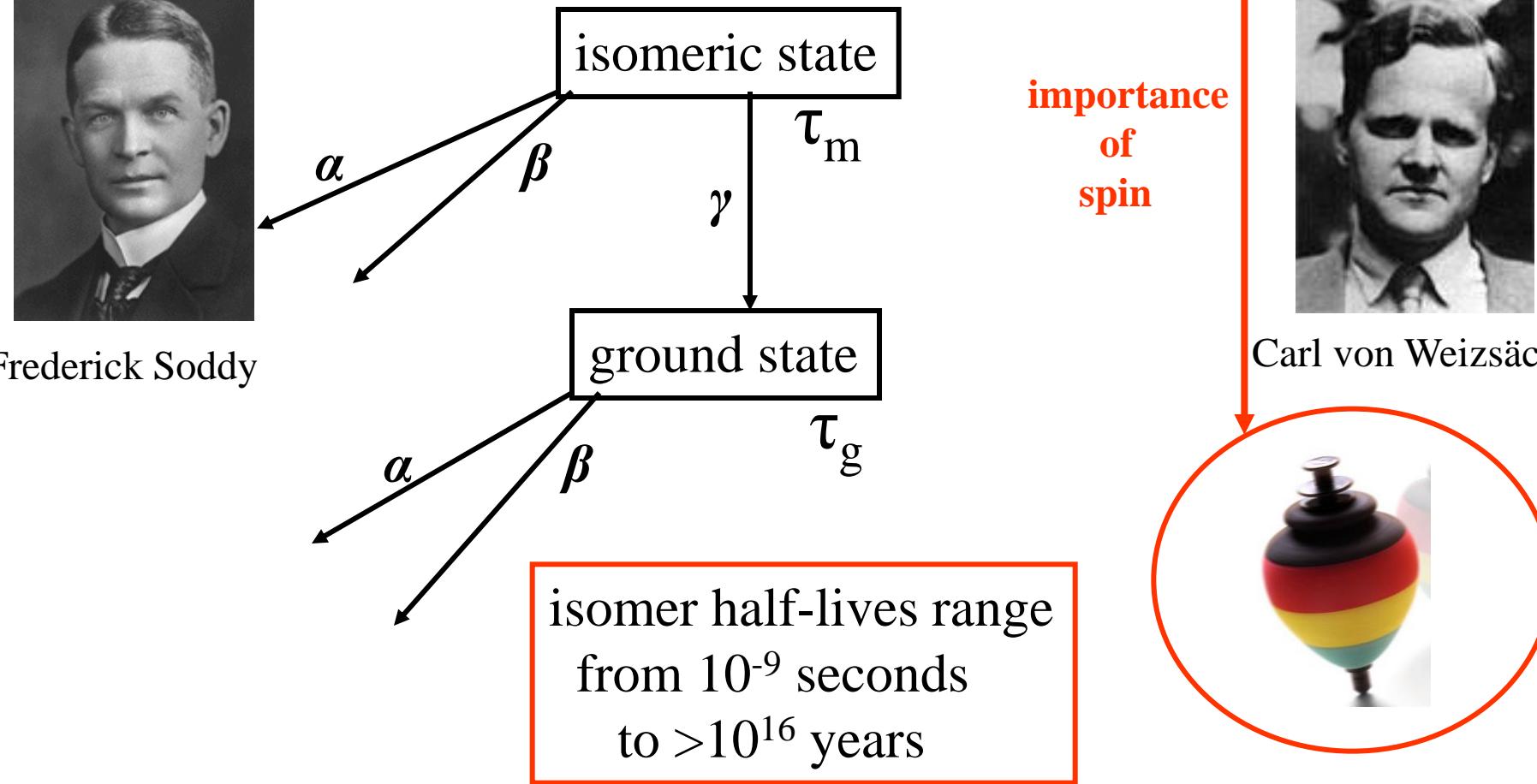
“We can have isotopes with identity of atomic weight, as well as of chemical character, which are different in their stability and mode of breaking up.”



99 years

explanation:
von Weizsäcker,
Naturwissenschaften
24 (1936) 813

spin doctor at age 24



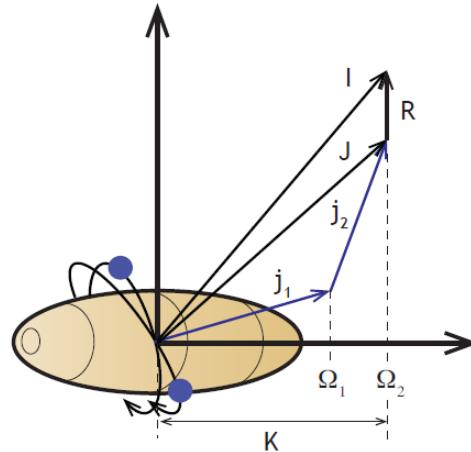
importance
of
spin



Carl von Weizsäcker

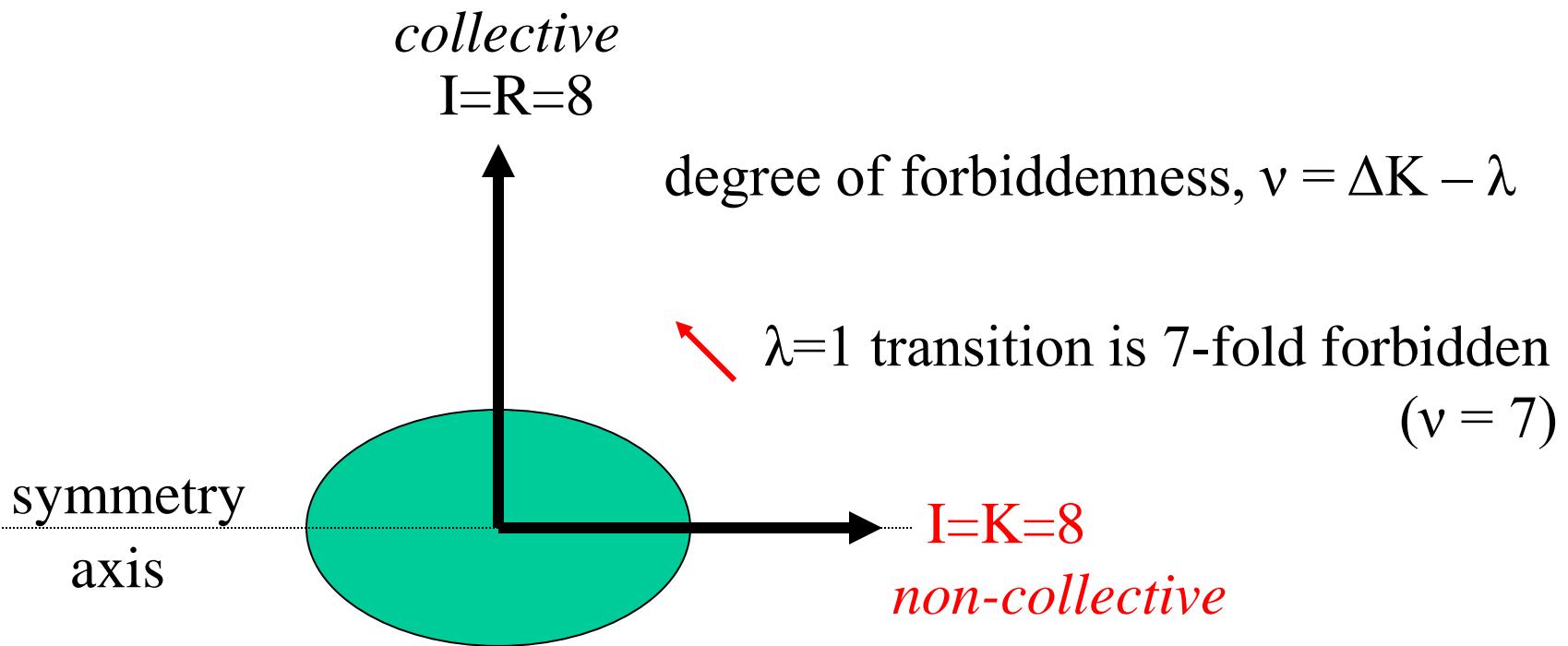


K-isomer issues



- quasiparticle structure => *understanding the nuclear potential*
- windows on shape coexistence => *e.g. ^{188}Pb high- K rotation*
- **decay rates => *K-mixing mechanisms, enhanced stability at the limits of binding***
- exploitation => *decay to excited states far from stability*
- astrophysics => *n-rich nuclei and the r-process path*

K-forbidden γ -ray transitions



angular momentum has both magnitude and direction!

transition-rate hindrance factors

$$F_W = T_{1/2}^\gamma / T_{1/2}^W$$

Weisskopf hindrance

$$\nu = \Delta K - \lambda$$

degree of K forbiddenness

$$f_\nu = (F_W)^{1/\nu}$$

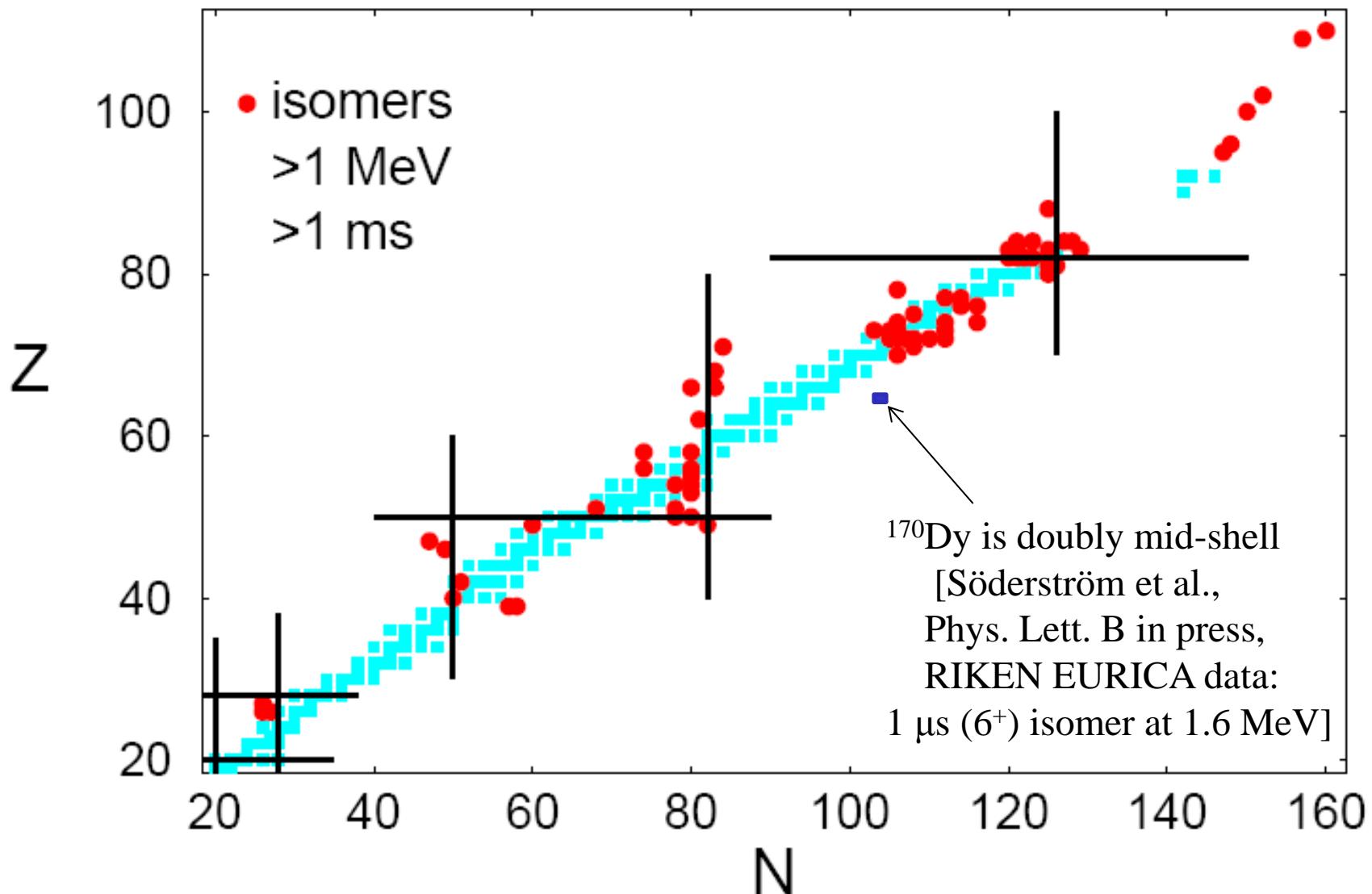
reduced hindrance
*(hindrance per degree of
 K forbiddenness)*

contains the physics

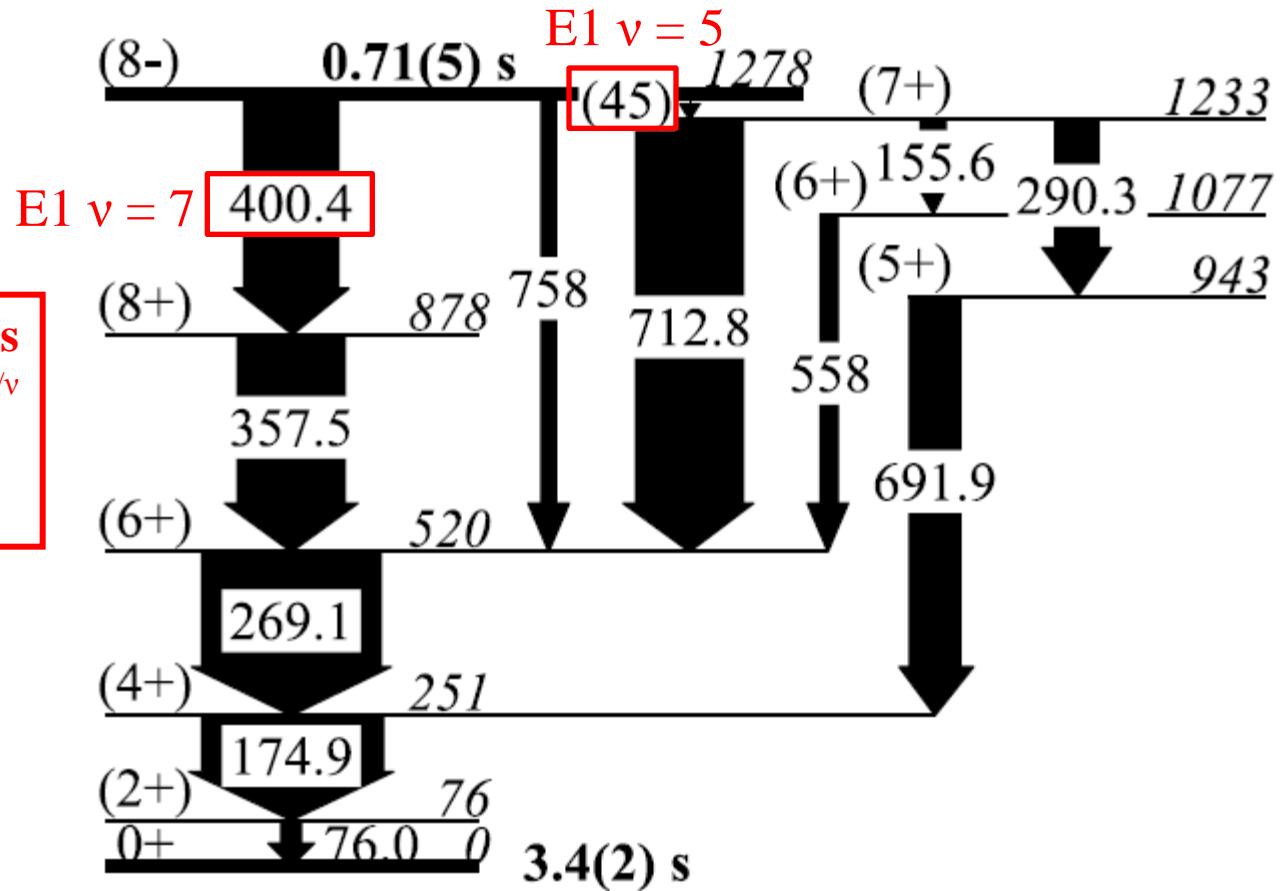
$f_\nu \Leftrightarrow$ broken axial symmetry: rotation (Coriolis)
non-axial shape (γ deformation)
random mixing (density of states)

in the initial state or in the final state

nuclear chart with >1 MeV isomers

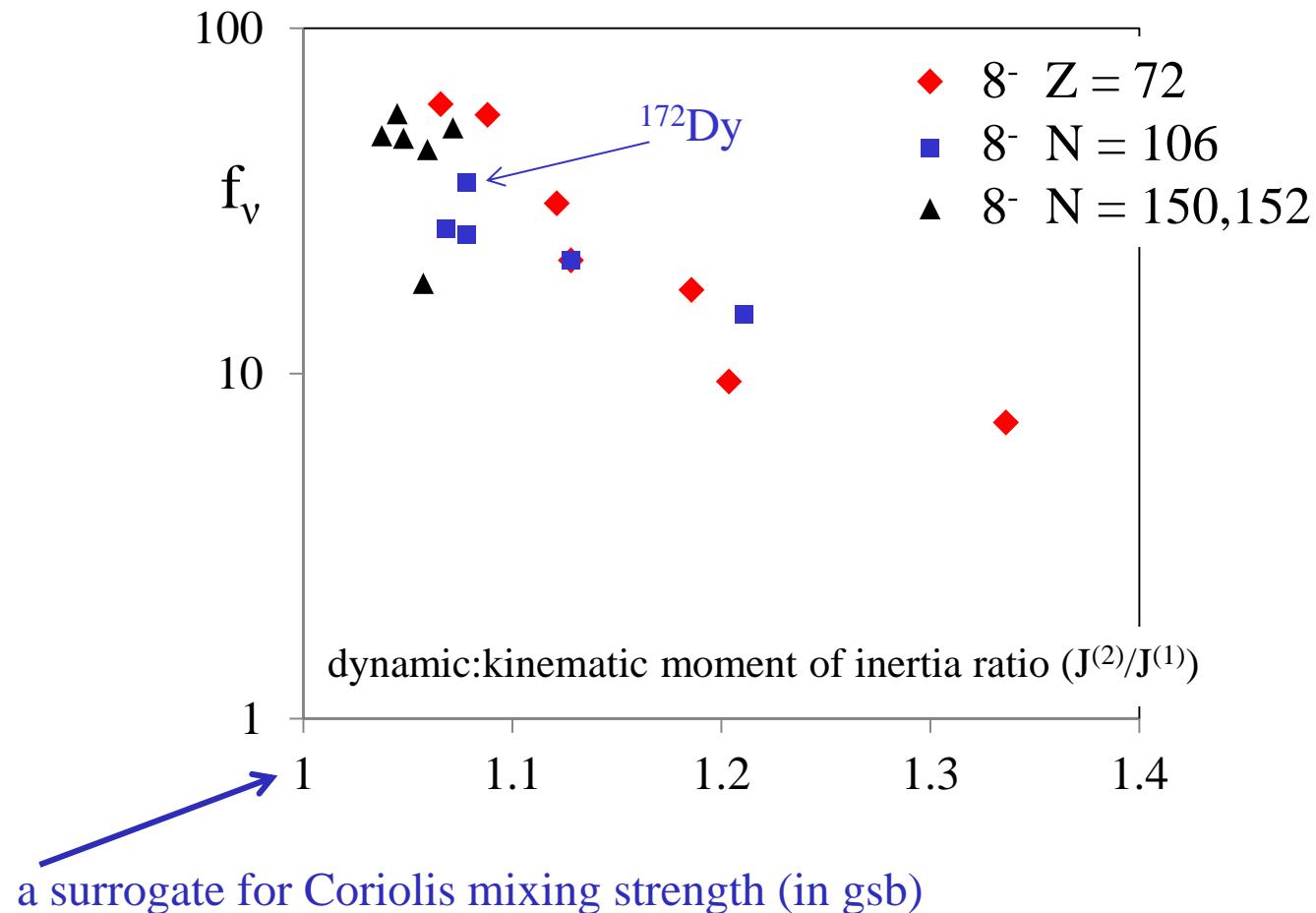


● ^{172}Dy RIKEN EURICA data



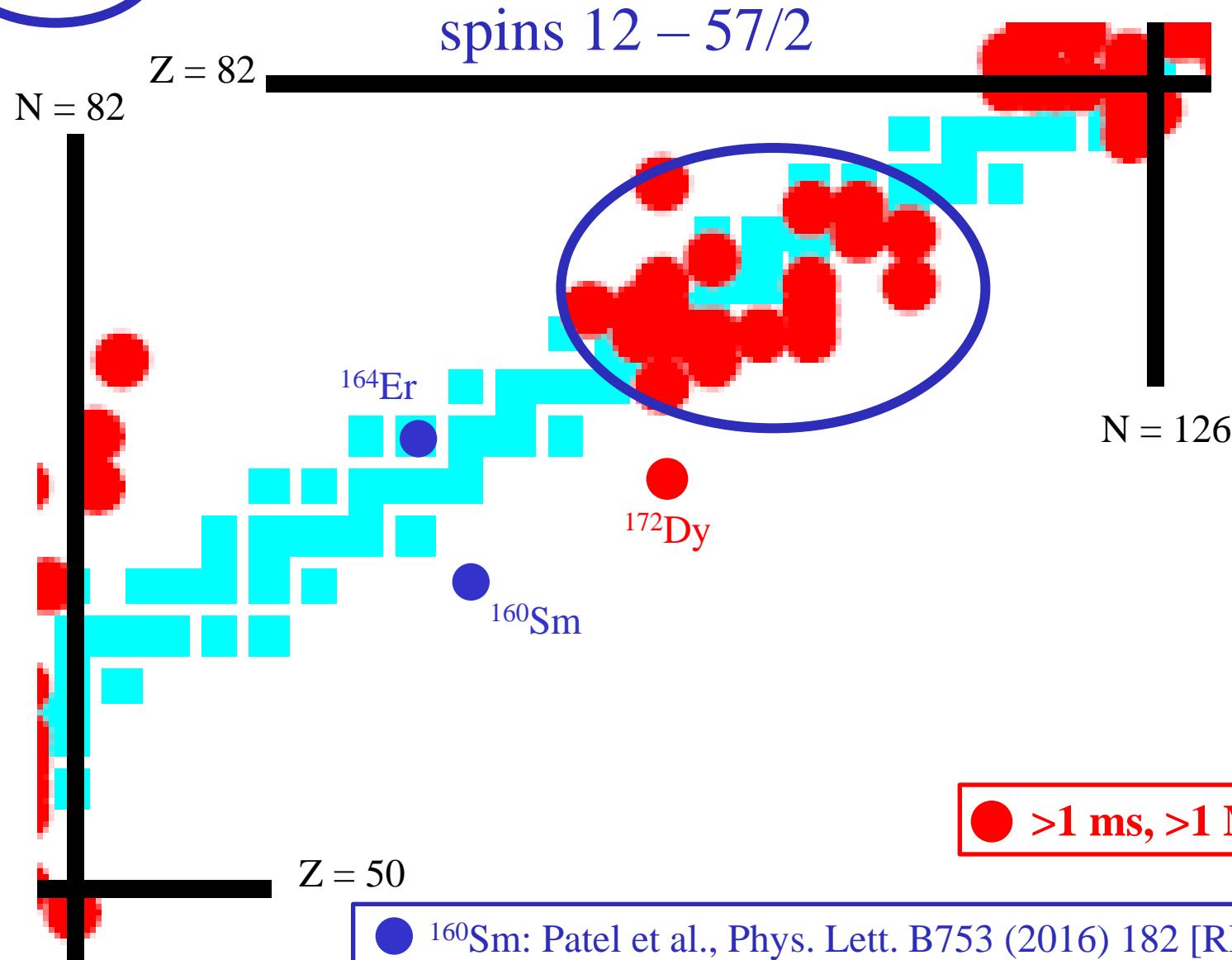
Watanabe et al., Phys. Lett. B760 (2016) 641

2qp isomers: E1, $\Delta K = 8$ reduced hindrances (with 10^4 factor)



cf. Walker et al., Phys. Rev. C49 (1994) 1718

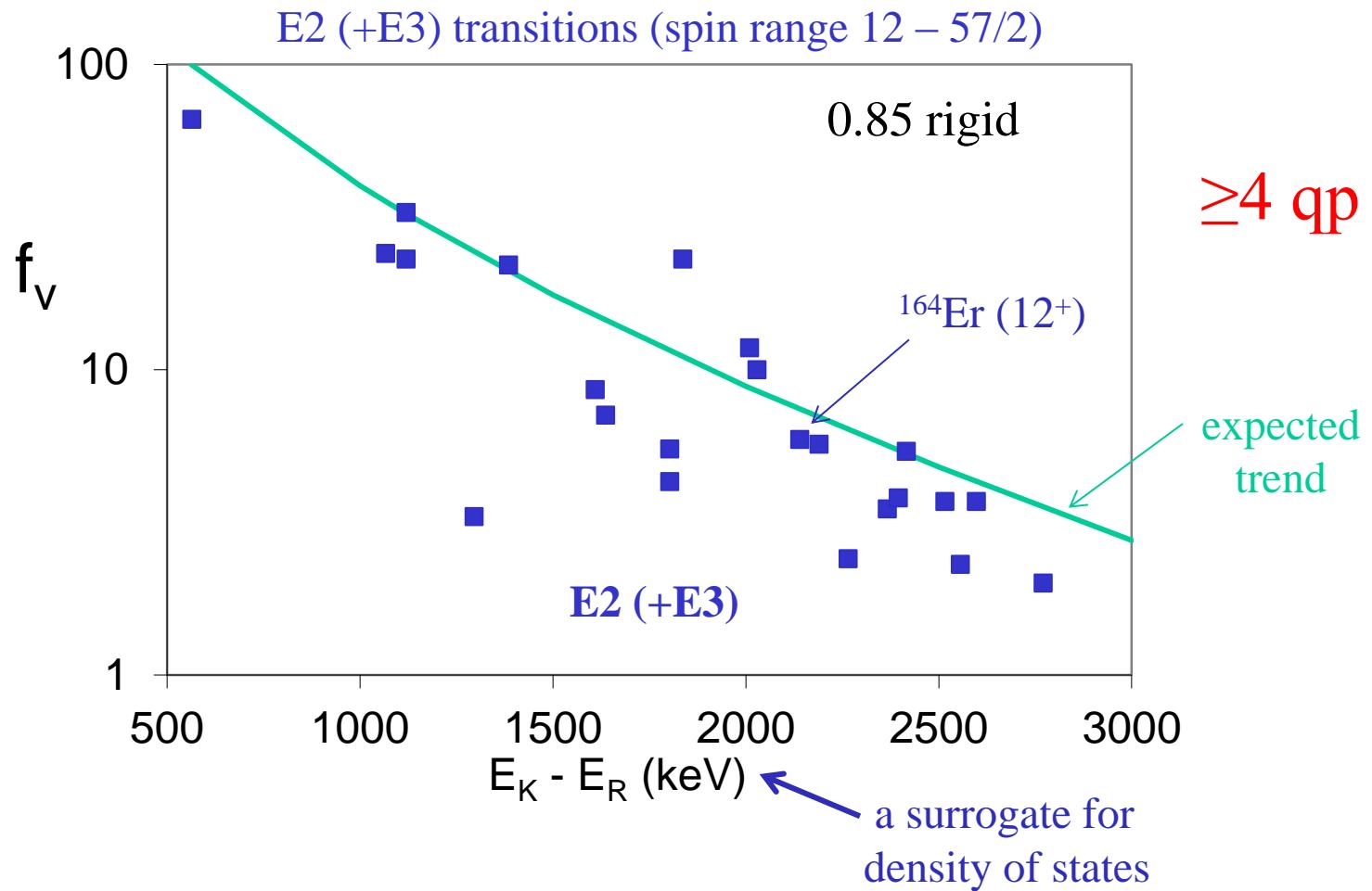
A~180 region of multi-quasiparticle isomers (≥ 4 qp)



● >1 ms, >1 MeV

- ^{160}Sm : Patel et al., Phys. Lett. B753 (2016) 182 [RIKEN]
- ^{164}Er : Swan et al., Phys. Rev. C86 (2012) 044307 [ANU]

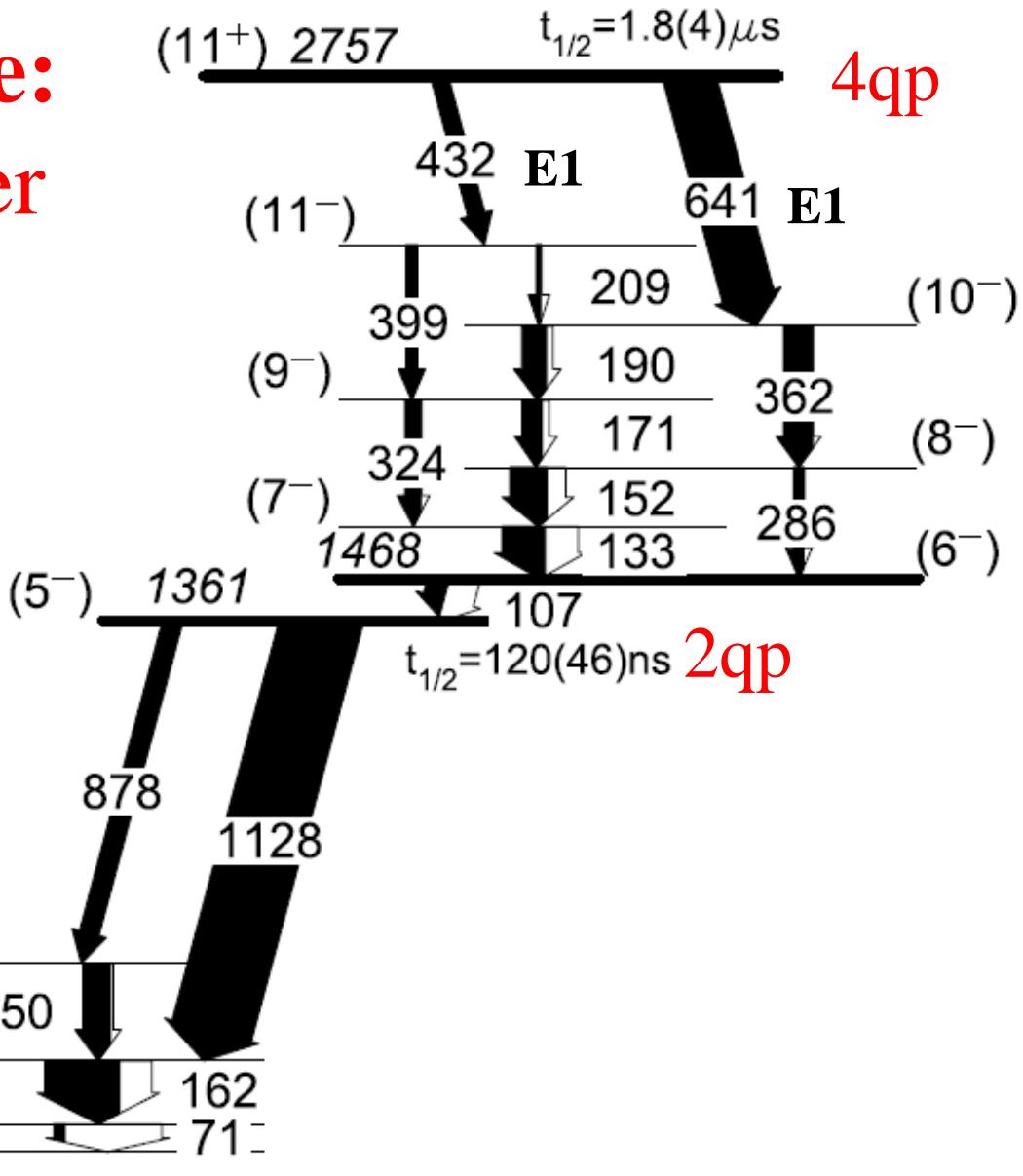
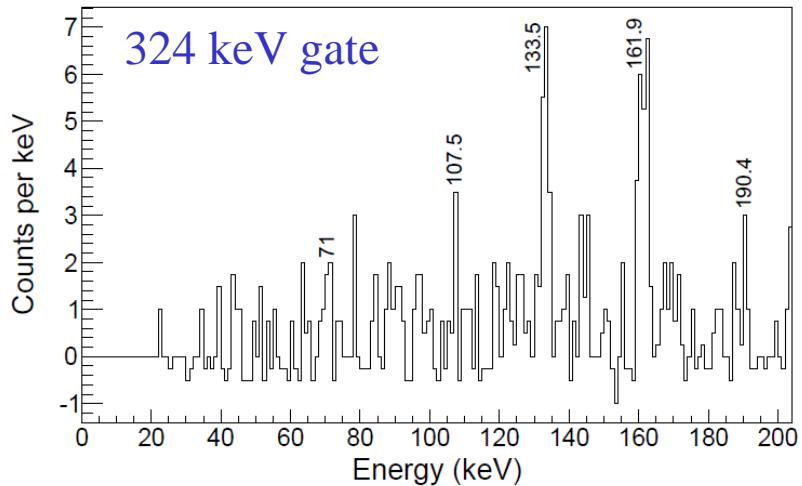
multi-quasiparticle reduced hindrance



Walker & Xu, Phys. Scr. 91 (2016) 013010

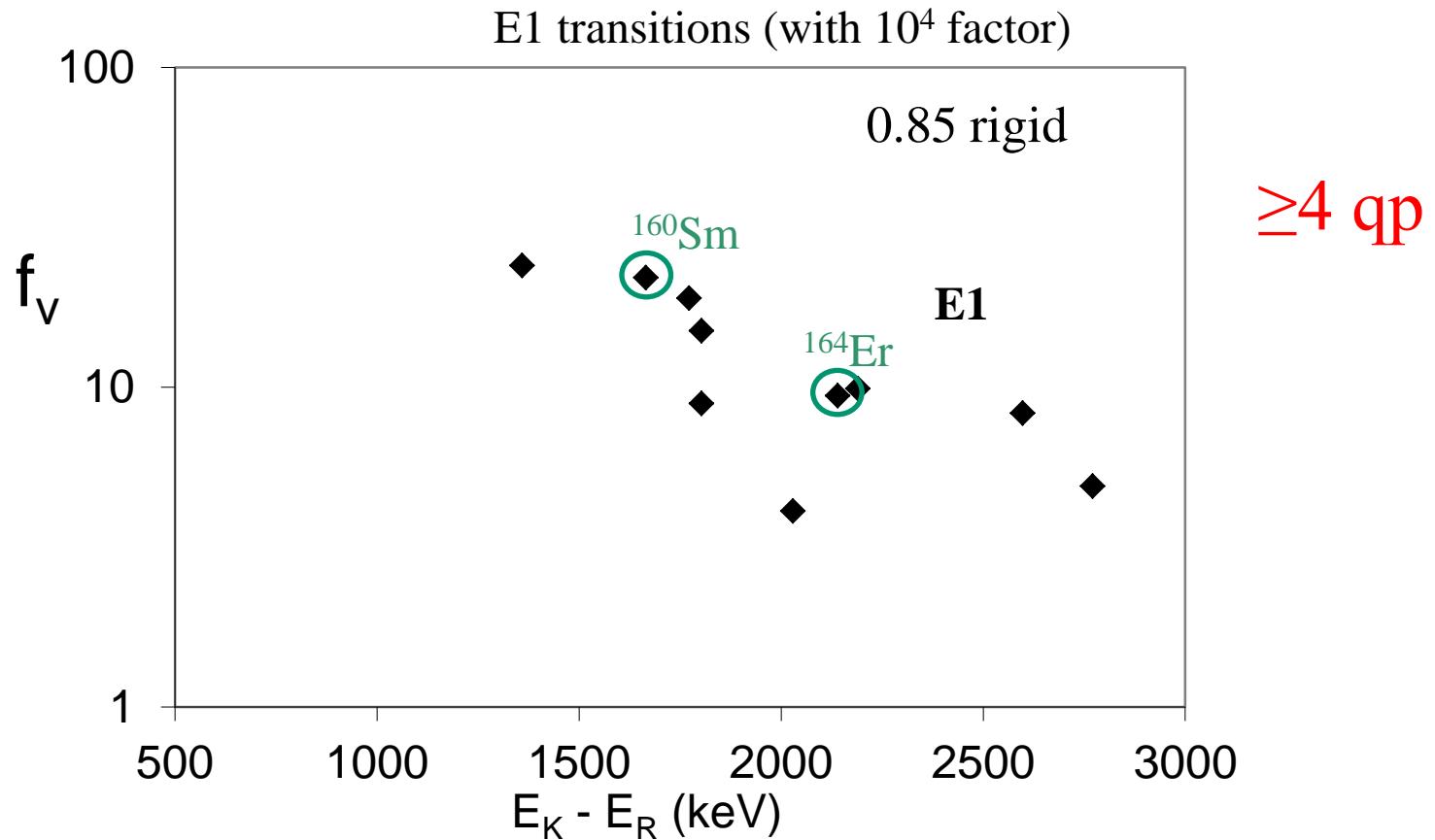
Dracoulis, Walker & Kondev, Rep. Prog. Phys. 79 (2016) 076301

^{160}Sm level scheme: decay of 4qp isomer



RIKEN EURICA data

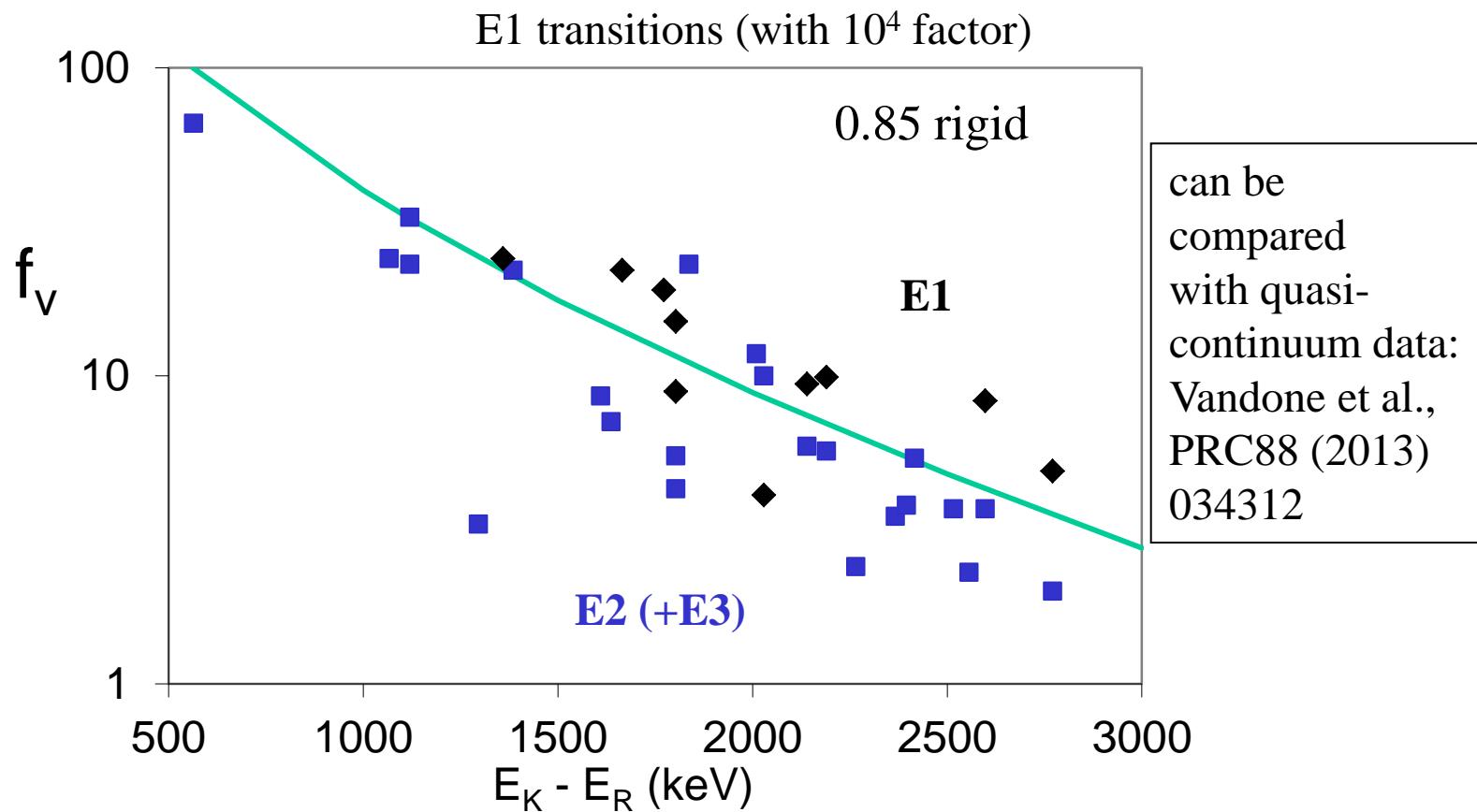
multi-quasiparticle reduced hindrance



^{160}Sm : Patel et al., Phys. Lett. B753 (2016) 182 [RIKEN]

^{164}Er : Swan et al., Phys. Rev. C86 (2012) 044307 [ANU]

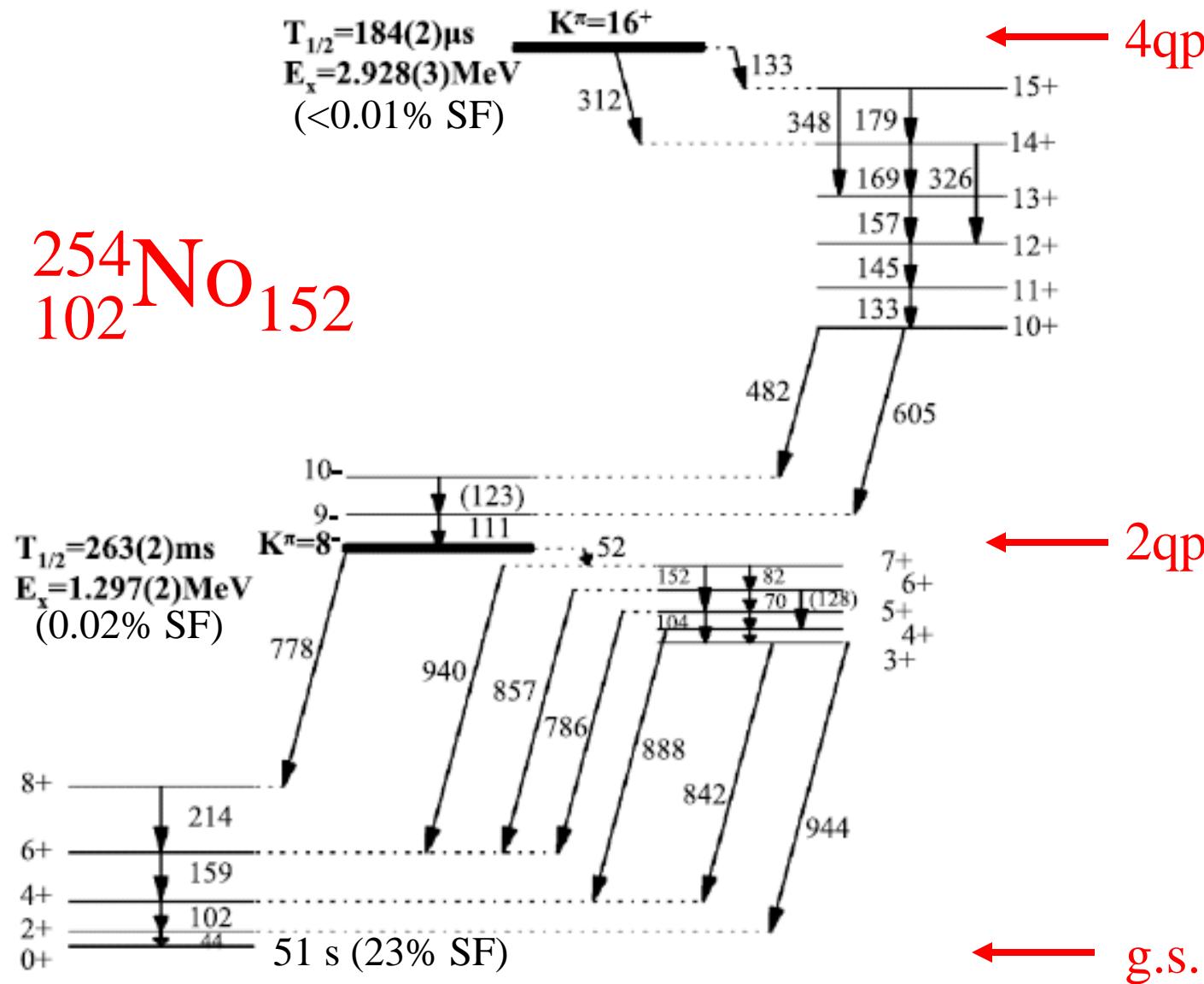
multi-quasiparticle reduced hindrance



^{160}Sm : Patel et al., Phys. Lett. B753 (2016) 182 [RIKEN]

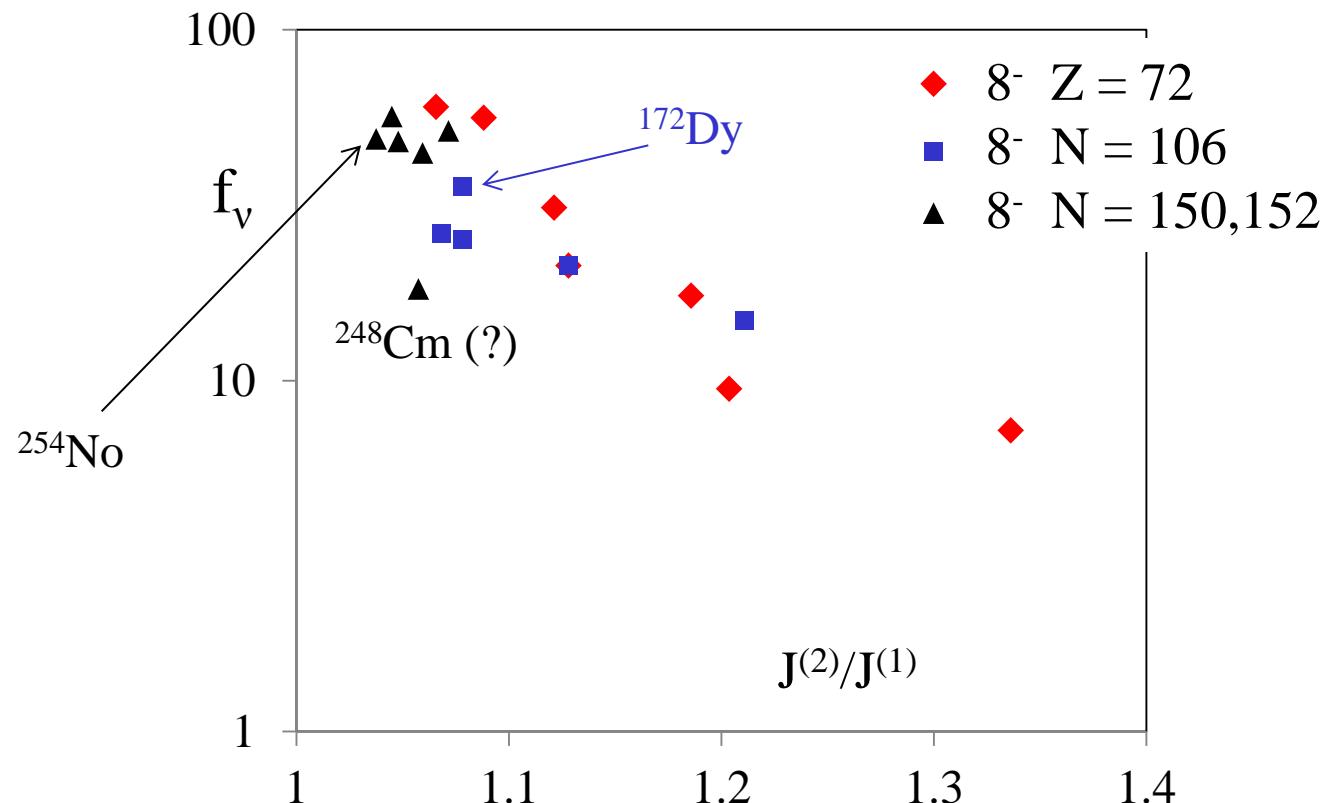
^{164}Er : Swan et al., Phys. Rev. C86 (2012) 044307 [ANU]

K isomers at normal deformation in superheavy nuclei



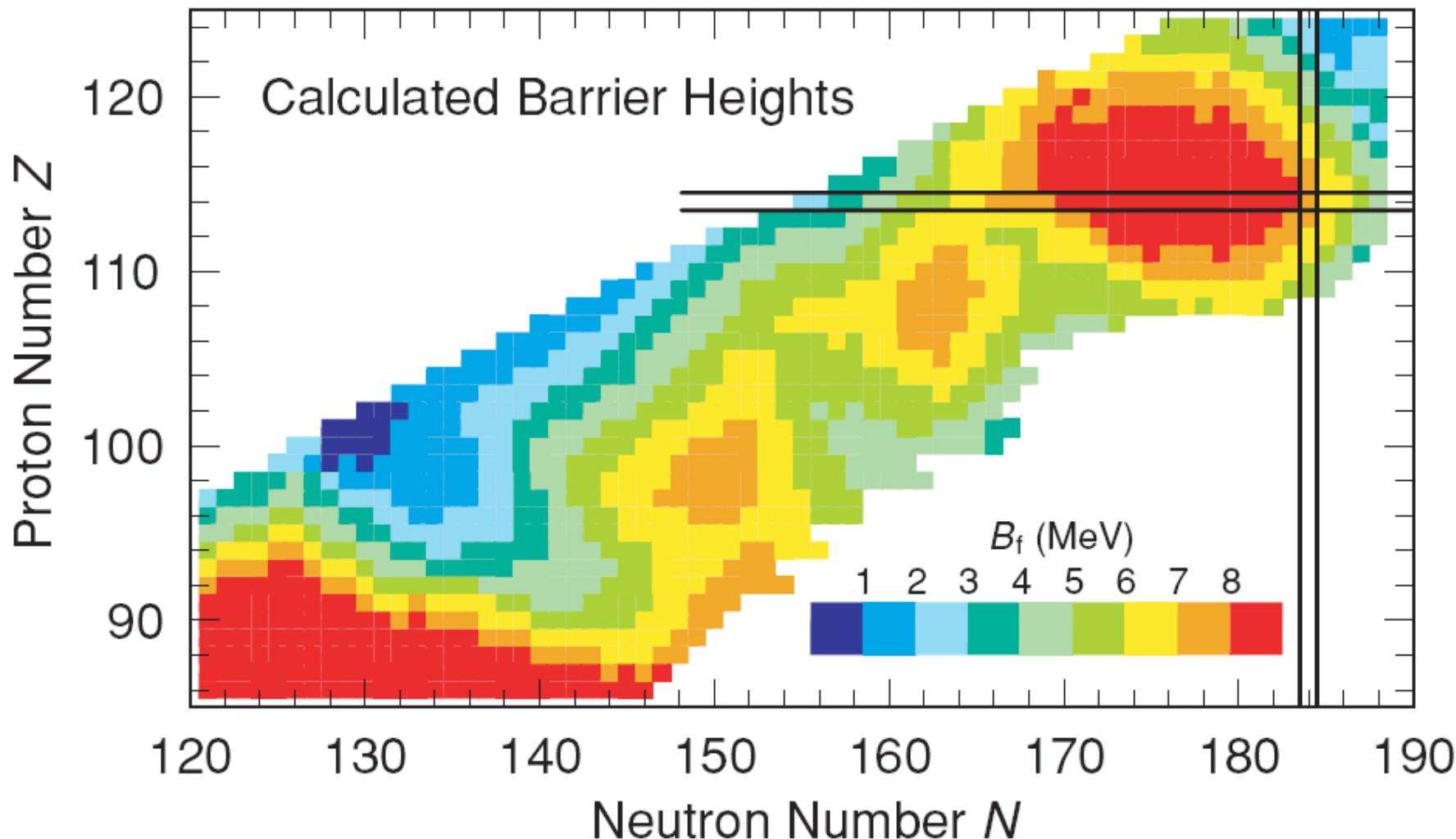
Clark et al. PLB690 (2010) 19 (LBNL data); Hessberger et al., EPJA43 (2010) 55 (GSI data)

2qp isomers: E1, $\Delta K = 8$ reduced hindrances (with 10^4 factor)



Results are especially sensitive to changes in the ground-state energy. A 1 MeV change in this energy will give rise to a change in the calculated half-life of six orders of magnitude.

FISSION



fissioning K isomer in ^{250}No

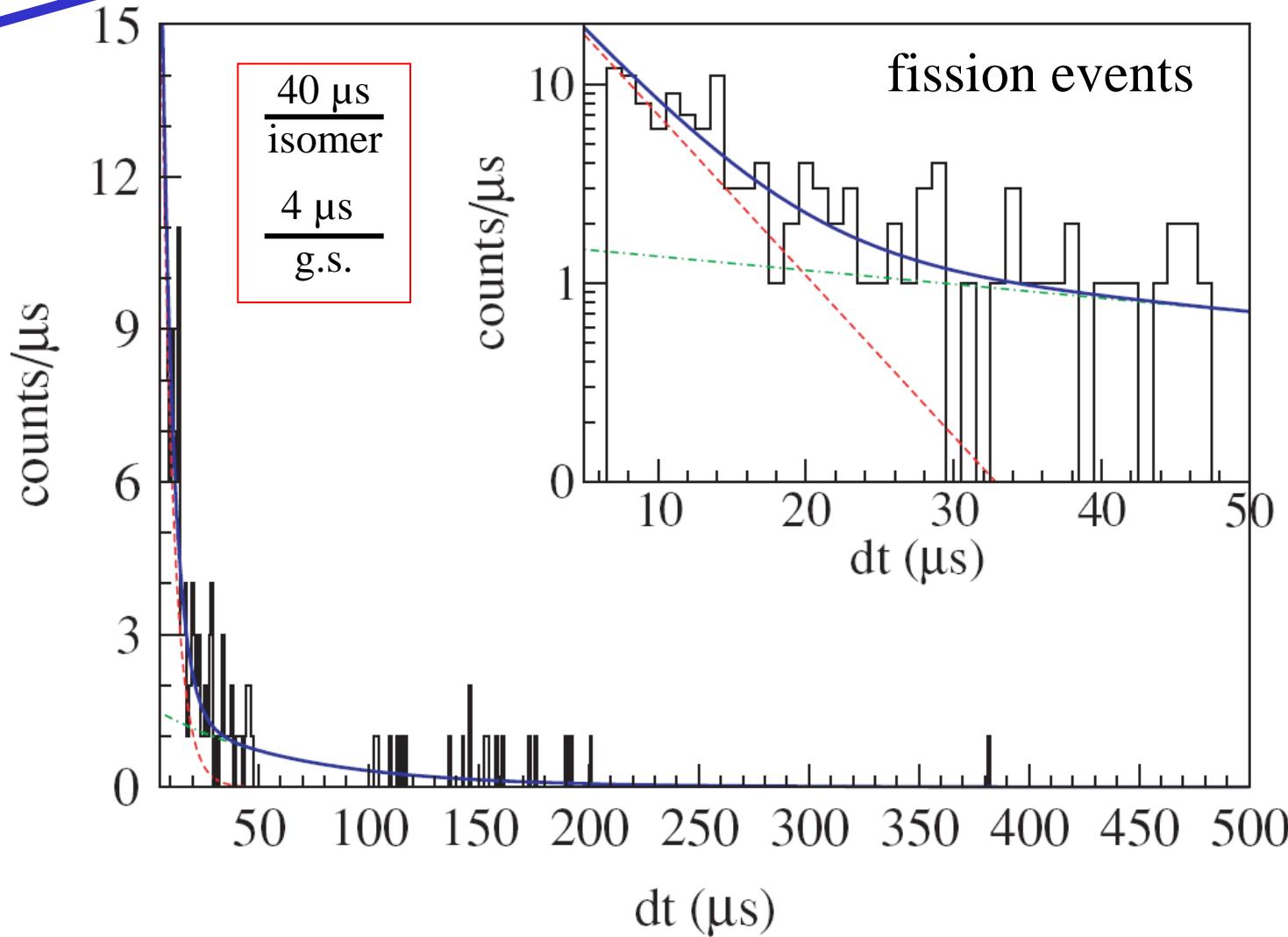
PHYSICAL REVIEW C 74, 014316 (2006)

Peterson et al.

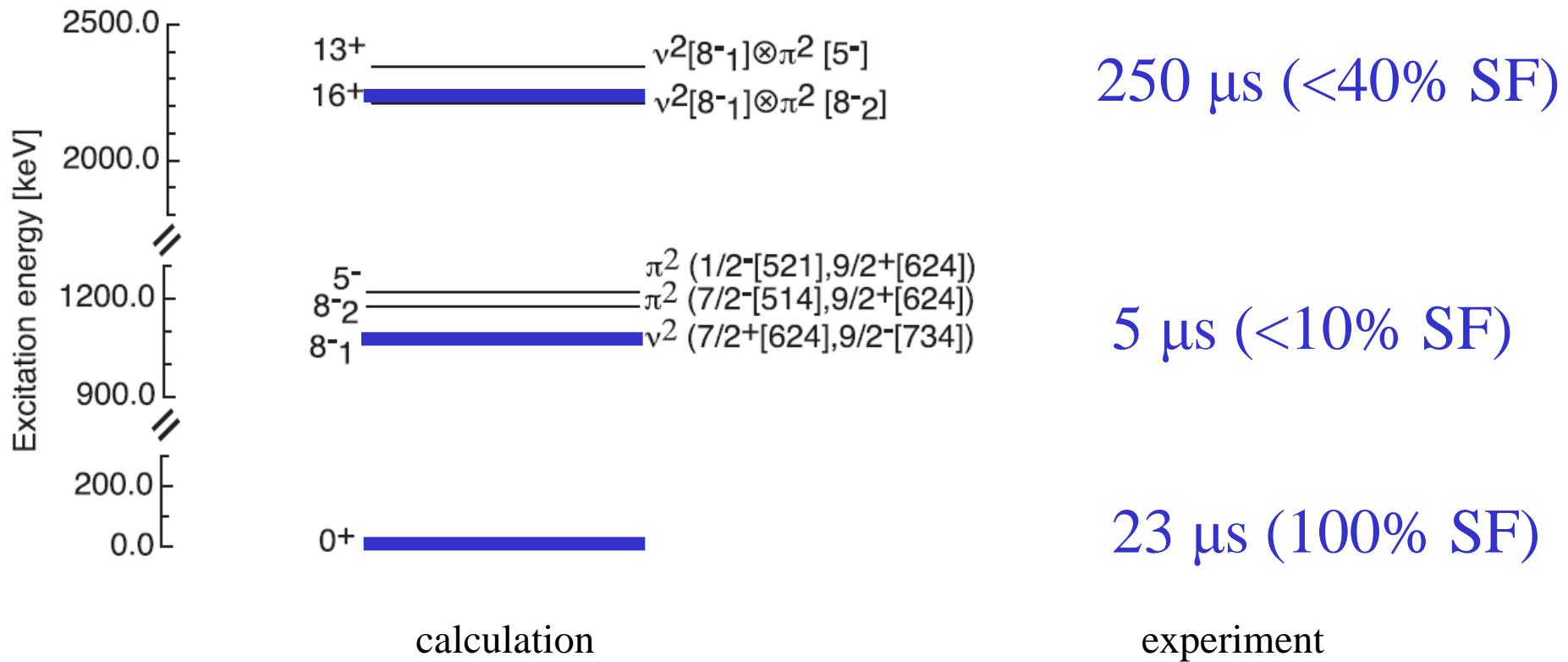
ANL data

Decay modes of ^{250}No

normal deformation

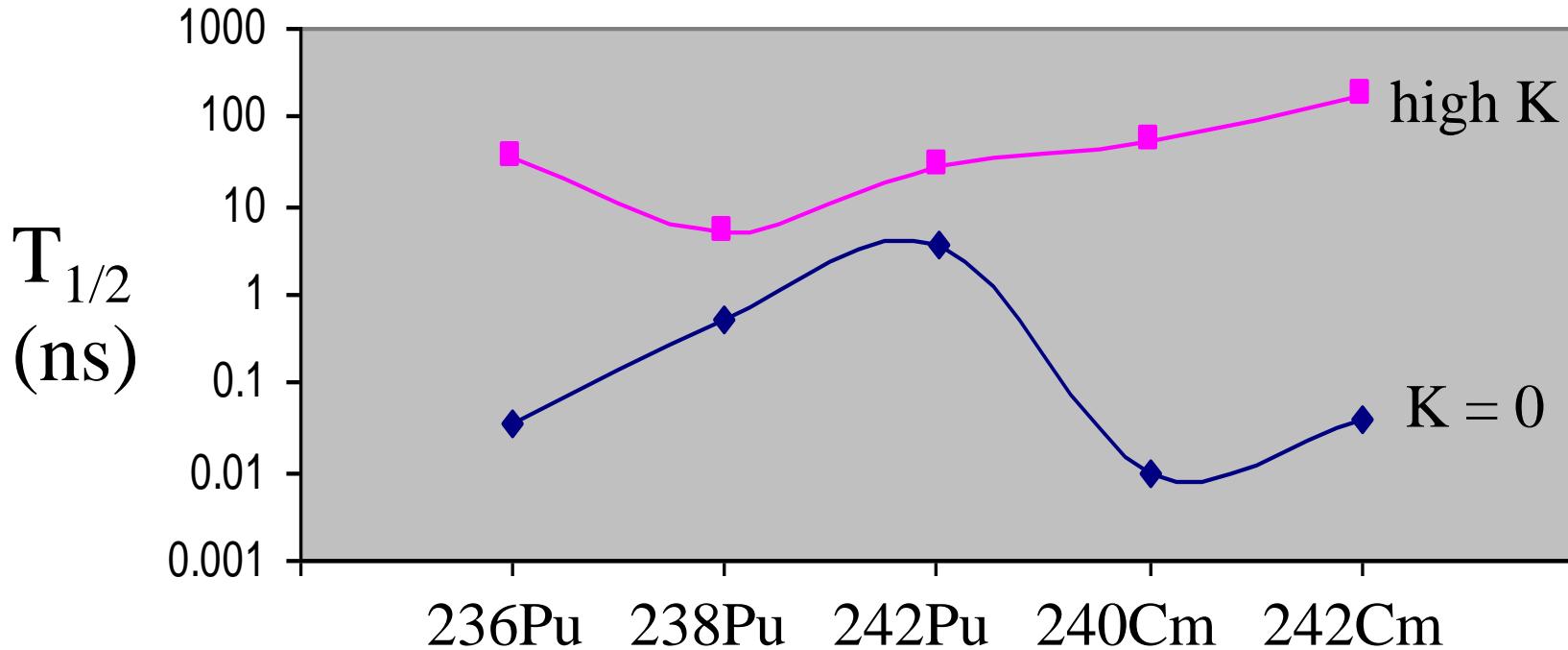


now also ^{254}Rf



superdeformation

fission isomers (even-even nuclides)



*data from Bjørnholm and Lynn,
Rev. Mod. Phys. 52 (1980) 725*

Summary – high-K isomers in exotic nuclei

- **A ~ 170: K-mixing mechanisms**
 ^{172m}Dy , $^{160m^2}\text{Sm}$: f_ν values
- **A ~ 250: fission inhibition from high-K isomers**

See also:

Hiroshi Watanabe (11:00 Friday)
Recent results from EURICA at RIBF