Shape effects in E2 transition rates from $Z \approx 76$ high-spin isomers

- historical introduction
- structural changes along the yrast line
- K isomerism
- K-forbidden transition rates
- $N_p N_n$ dependence

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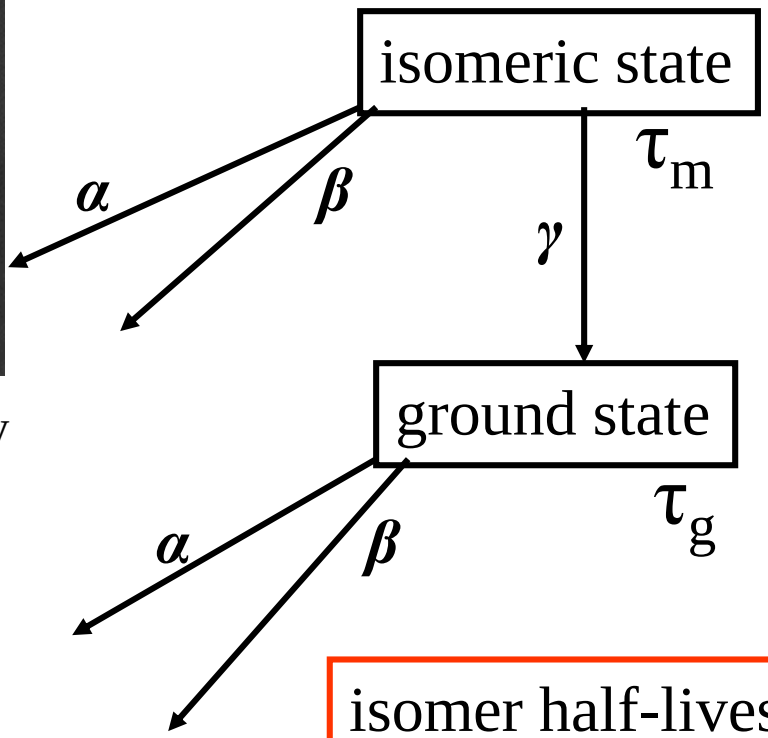
***Isomer prediction**: Soddy, Nature 99 (1917) 433*

"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."

100 years

***explanation**:*
von Weizsäcker, Naturwissenshaften 24 (1936) 813

Frederick Soddy



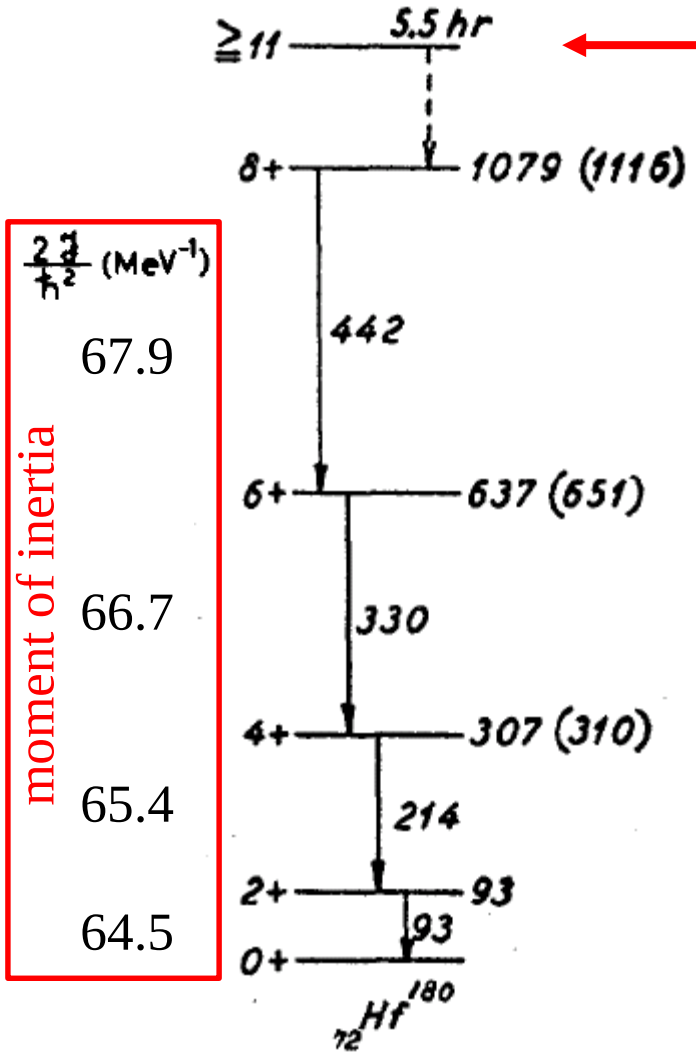
importance of spin

spin doctor at age 24

Carl von Weizsäcker

isomer half-lives range from 10^{-9} seconds to $>10^{16}$ years

^{180}Hf isomer decay: nuclear collective rotation



$I^{\pi} = 8^{-}$: broken-pair excitation

K quantum number not yet recognised

$E(I) = (\hbar^2/2\Im)\, I(I+1)$

$\Im \sim 1/3\ \Im_{rigid}$ => superfluidity

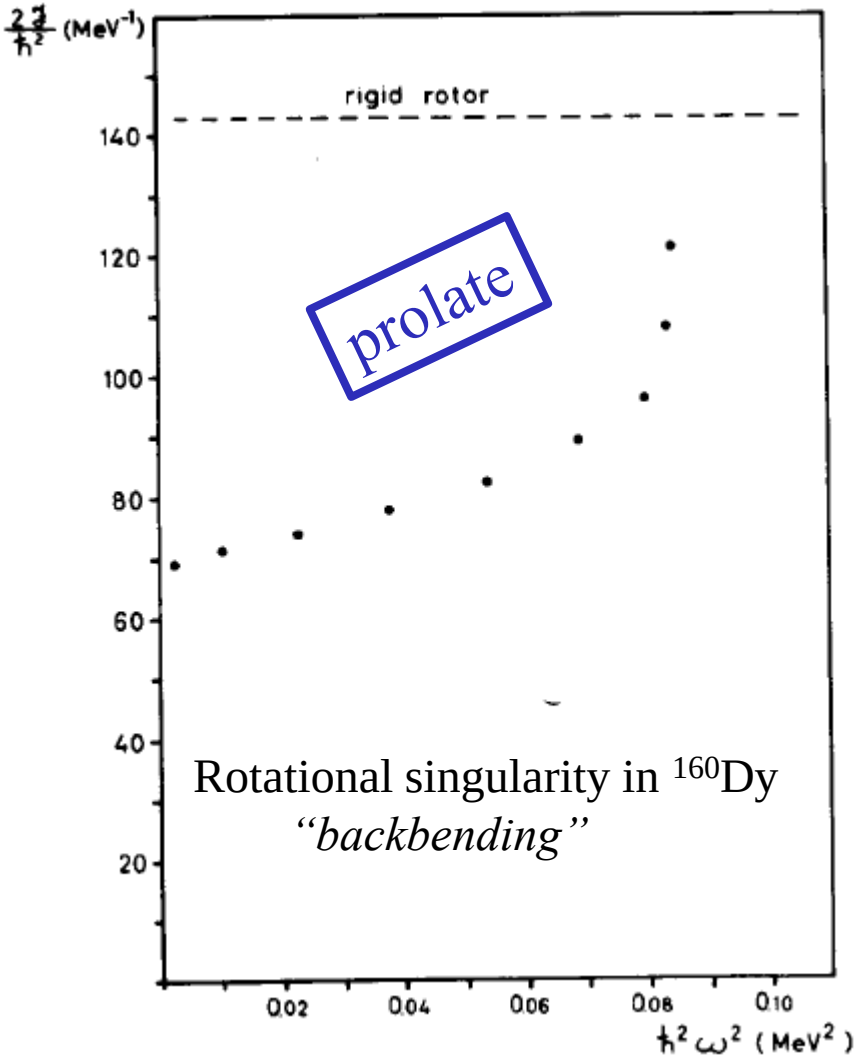
^{180}Hf: $E(4^+)/E(2^+) = 3.30$

perfect rotor: $E(4^+)/E(2^+) = 3.33$

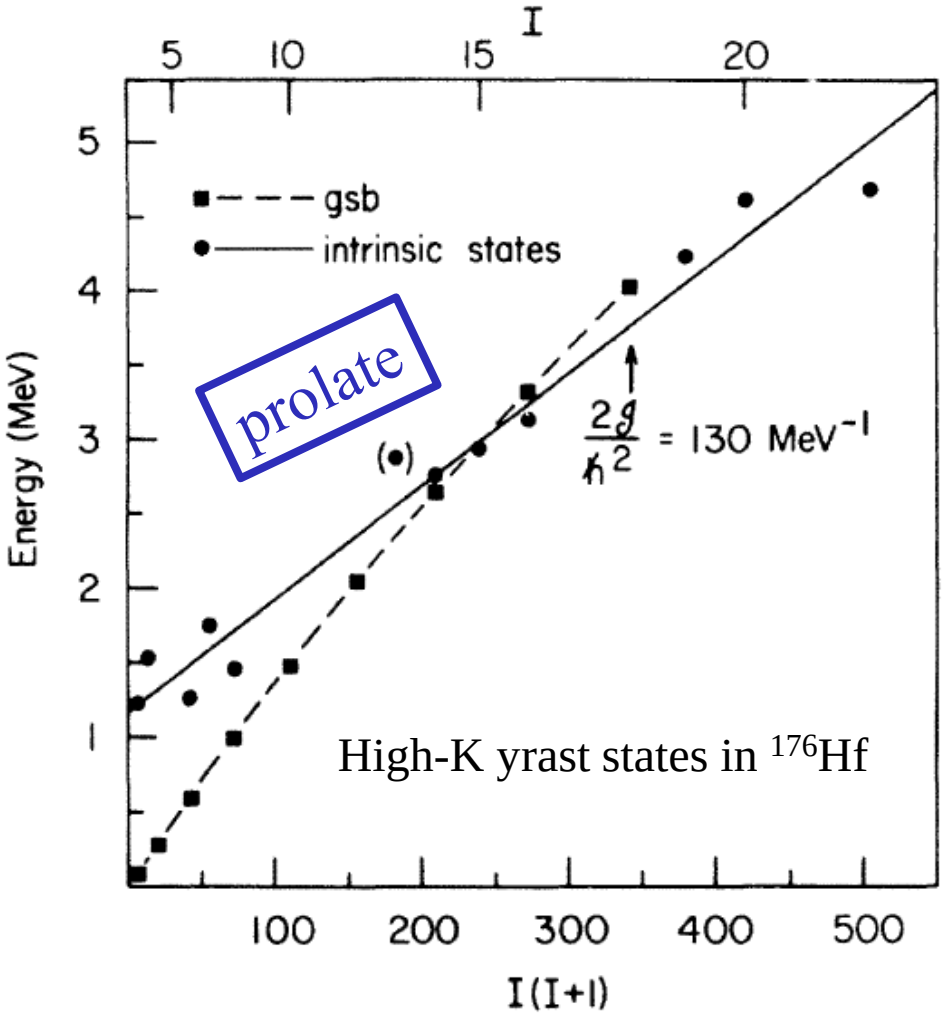
interplay between individual-particle and collective degrees of freedom

Bohr and Mottelson, Phys. Rev. 90 (1953) 717

structural changes along the yrast line:
rotation alignment in ^{160}Dy, deformation alignment in ^{176}Hf

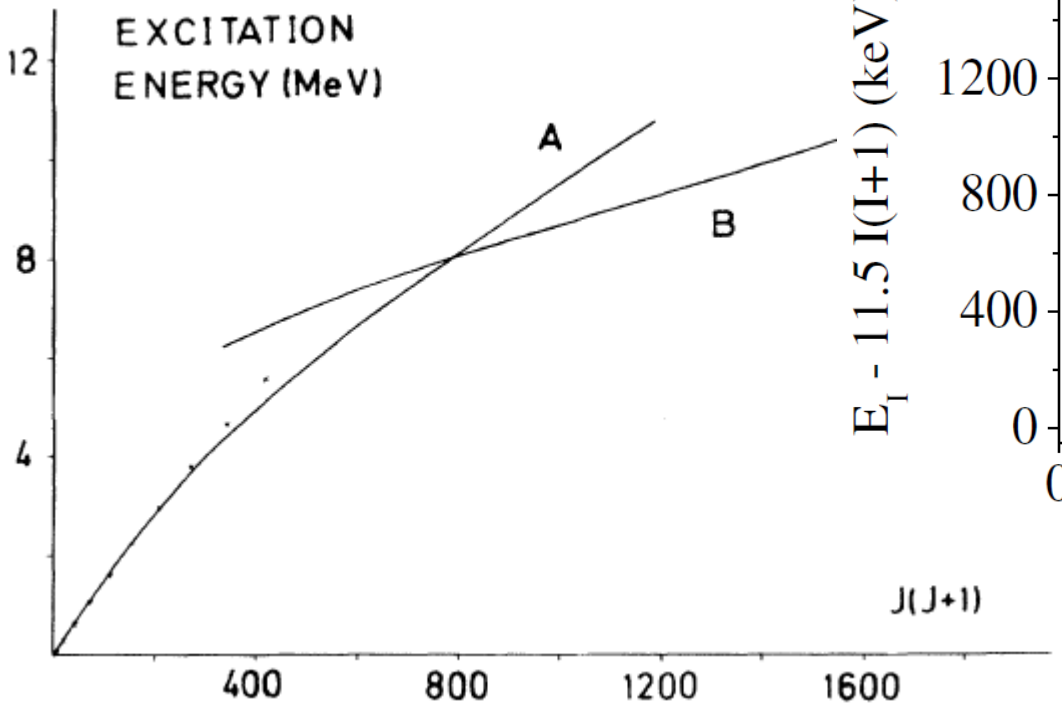


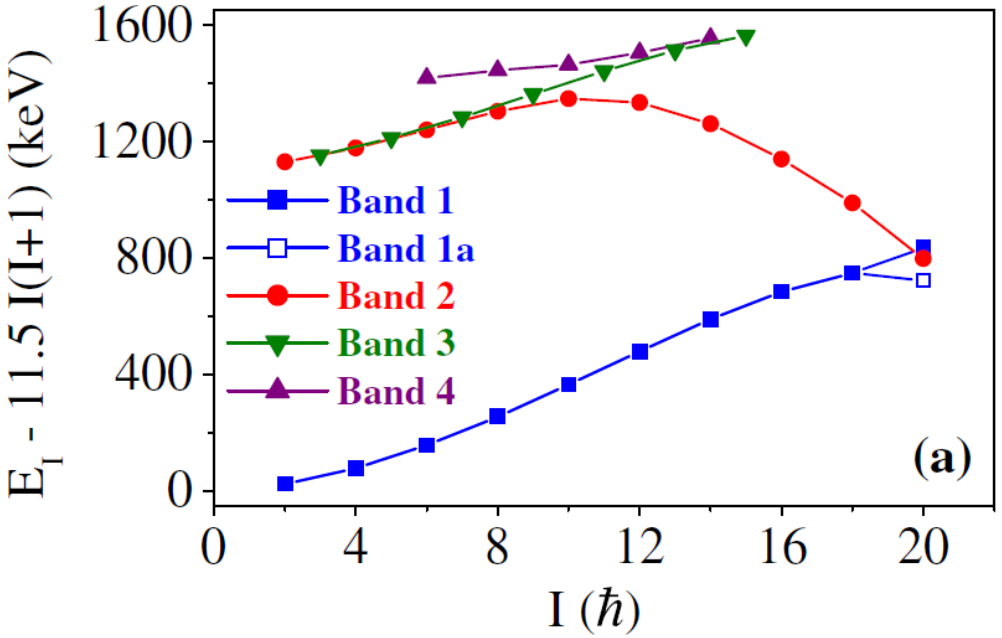
Johnson et al., Phys. Lett. B34 (1971) 605



Khoo et al., Phys. Rev. Lett. 37 (1976) 823

^{180}Hf prolate → oblate



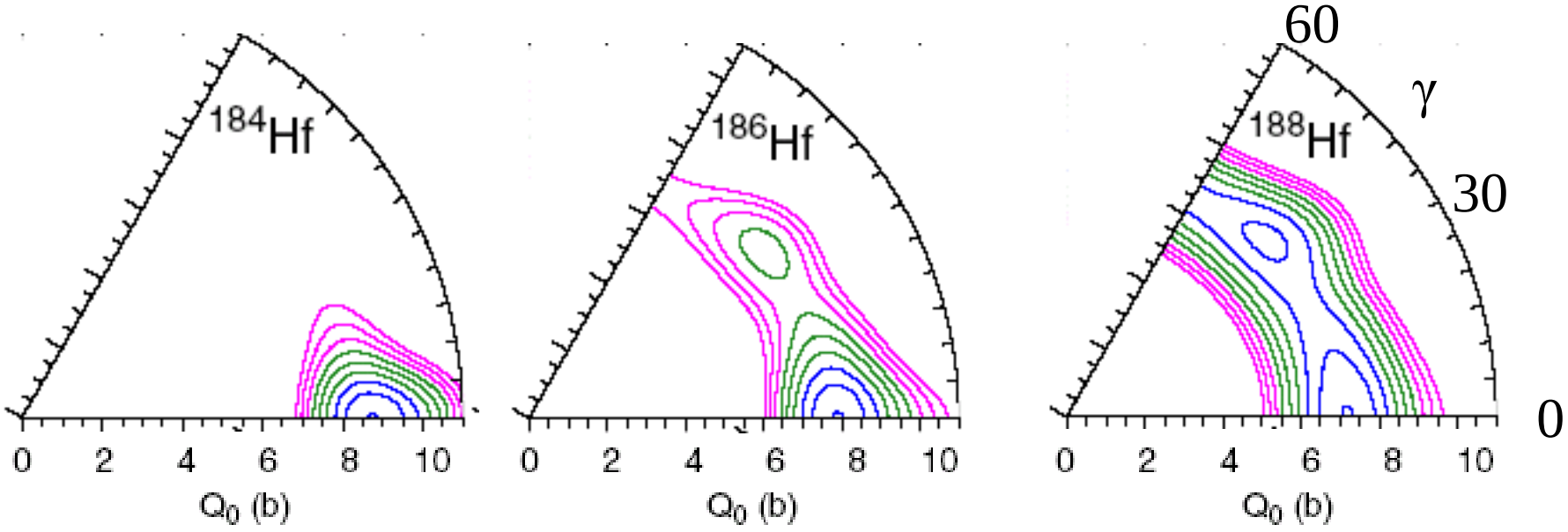


experiment (Gammasphere at ANL):
Tandel et al. PRL101 (2008) 182503

prediction (HFB):
Hilton and Mang PRL43 (1979) 1979

prolate → oblate with increasing N

n-rich hafnium ground states (HFB calculations)

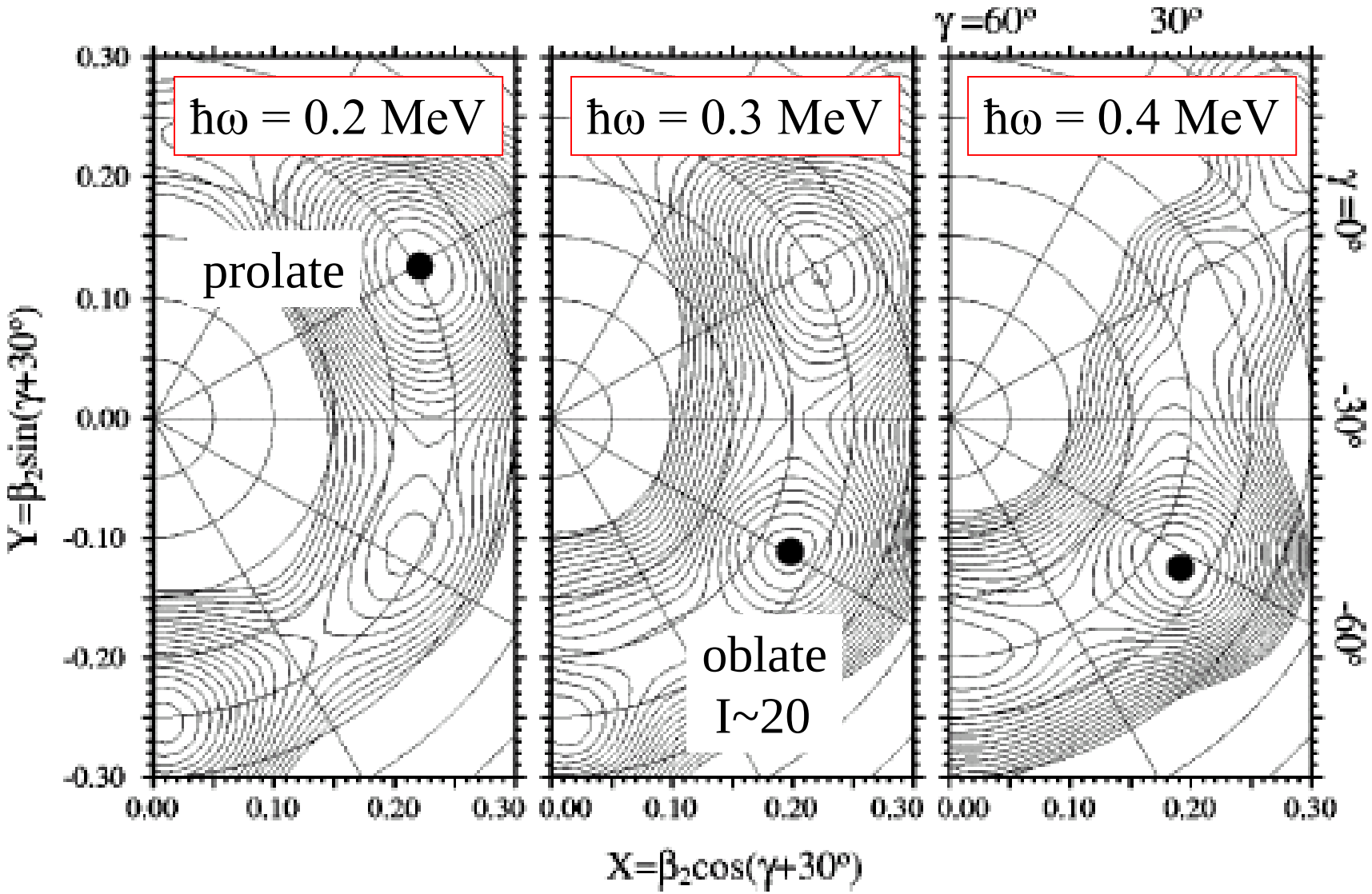


N = 112 N = 114 N = 116

*Robledo et al., J. Phys. G**36**, 115104 (2009)*

total Routhian surfaces (TRS): $^{182}Hf_{110}$

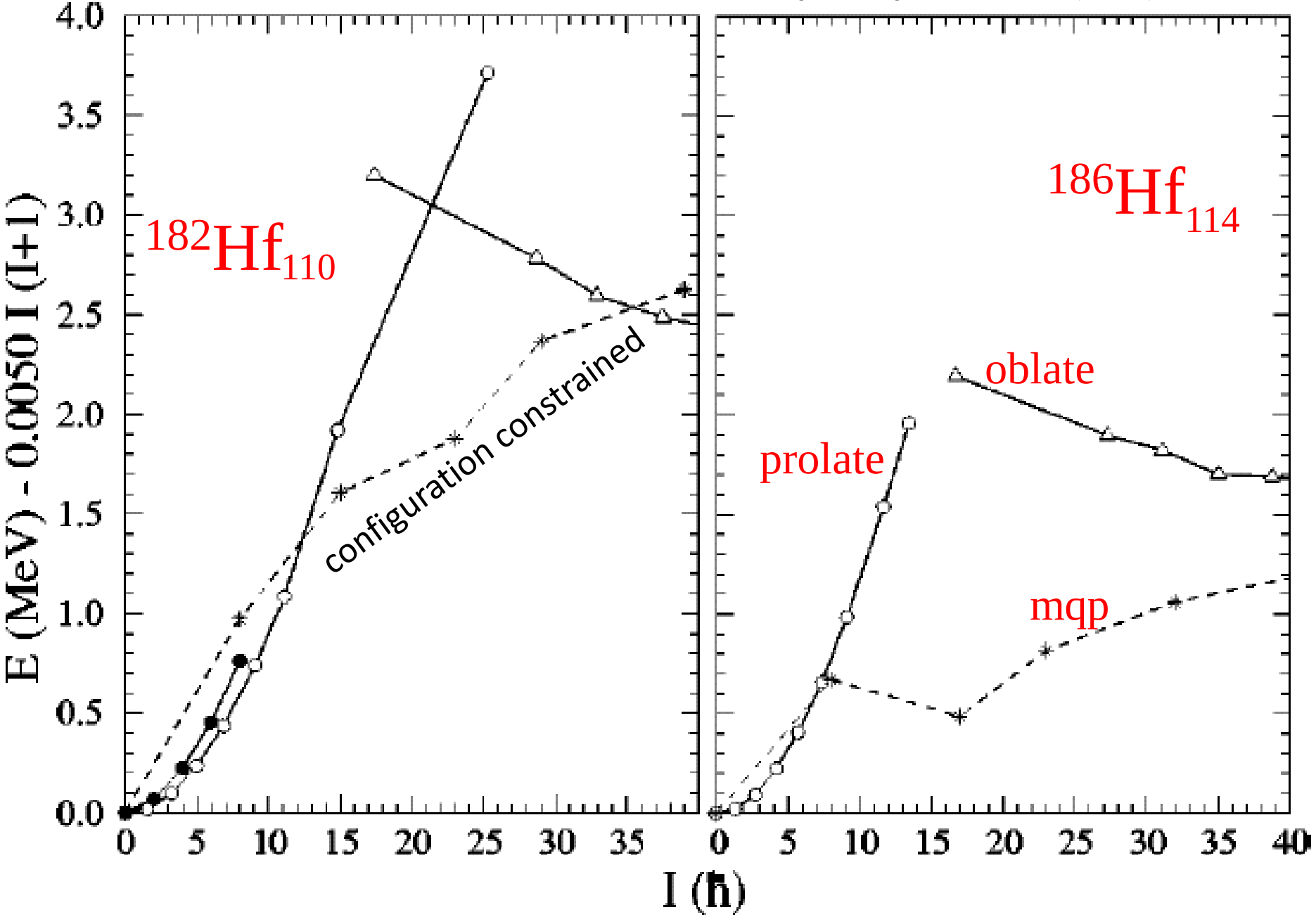
Xu, Walker and Wyss, Phys. Rev. C62 (2000) 014301



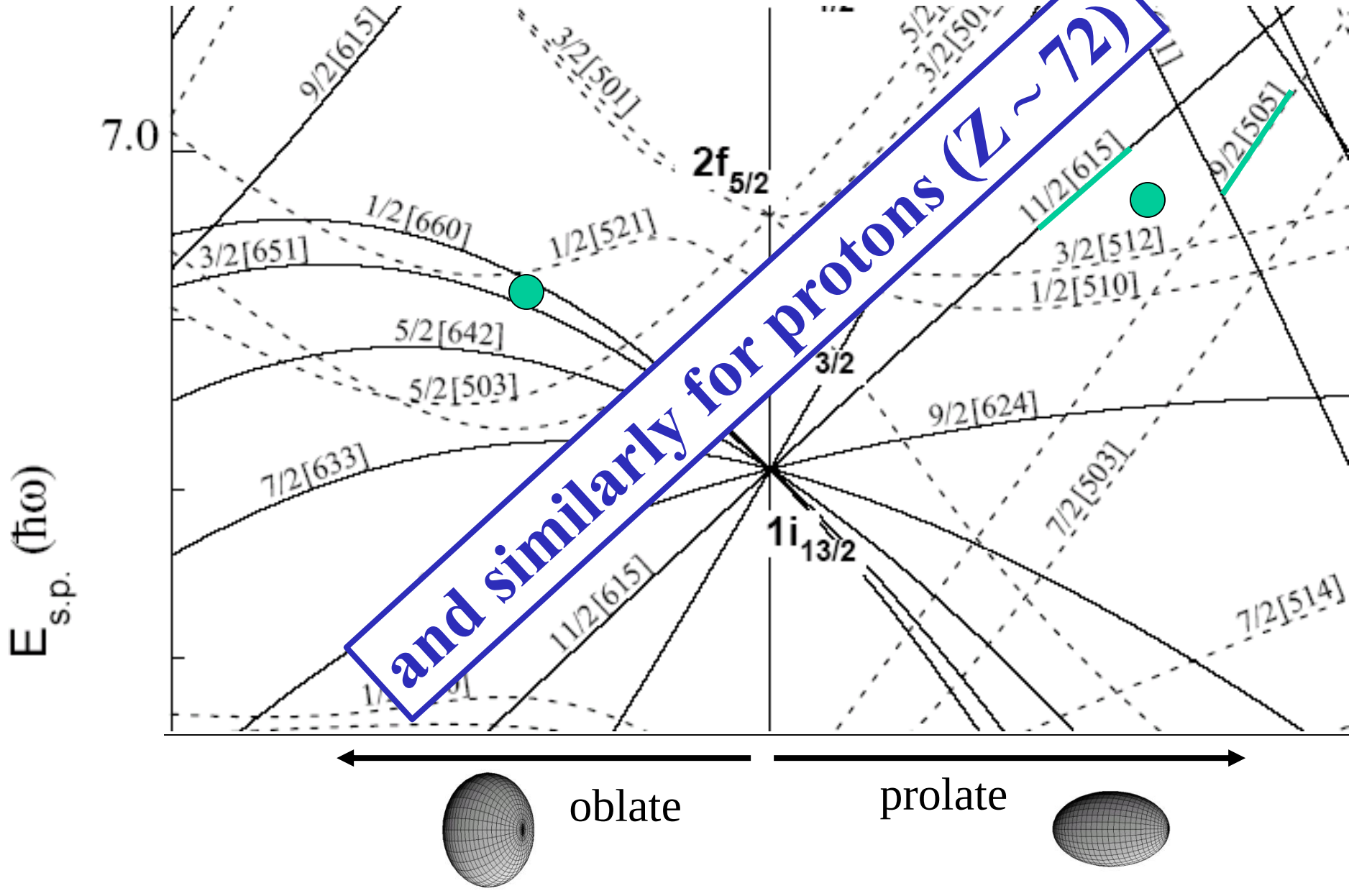
cf. Hilton and Mang's "giant backbending": PRL43 (1979) 1979

TRS calculations

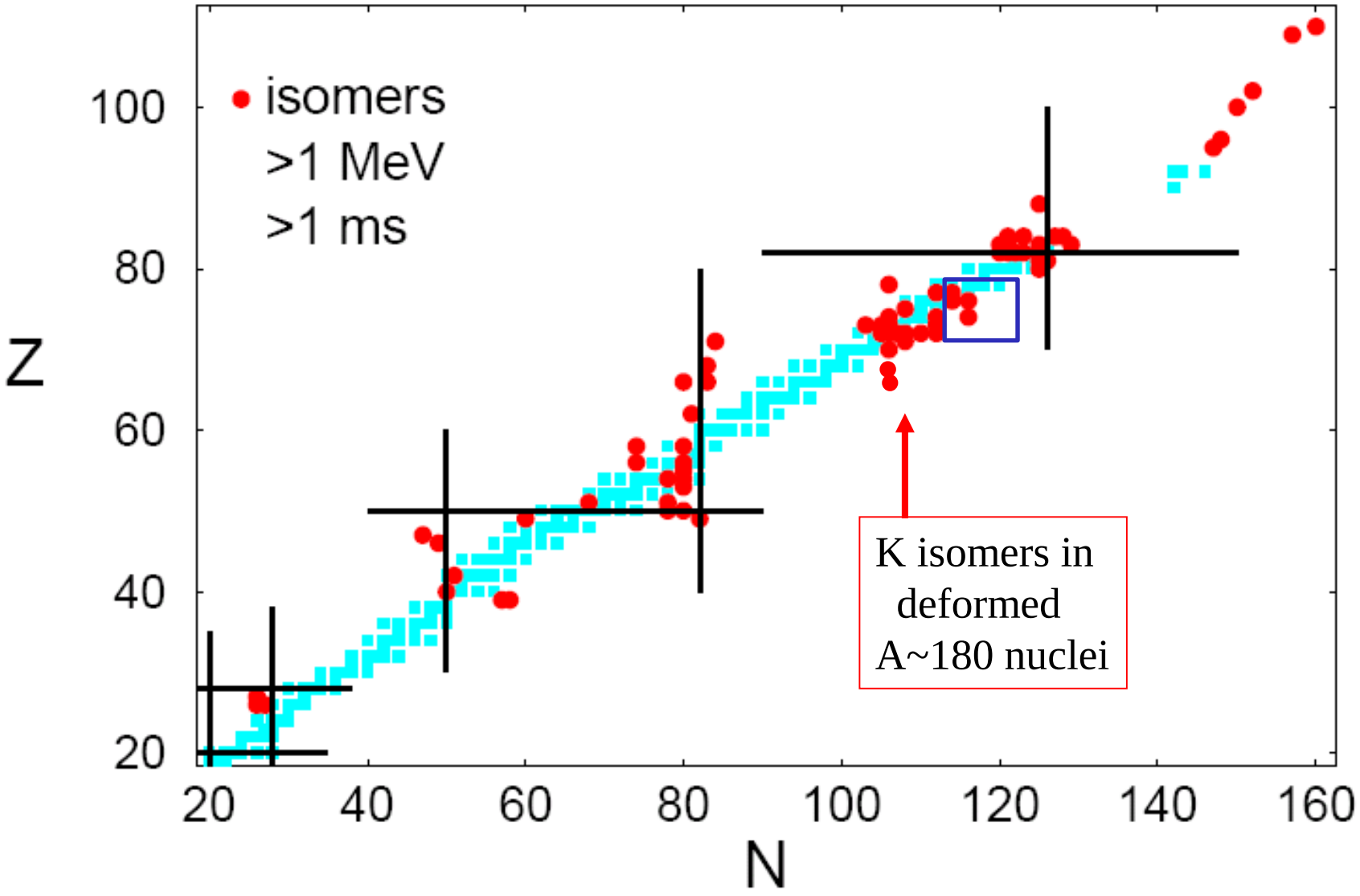
Xu, Walker and Wyss, Phys. Rev. C62 (2000) 014301



Nilsson single-particle diagram ● N = 116 (^{188}Hf, ^{190}W, ^{192}Os)

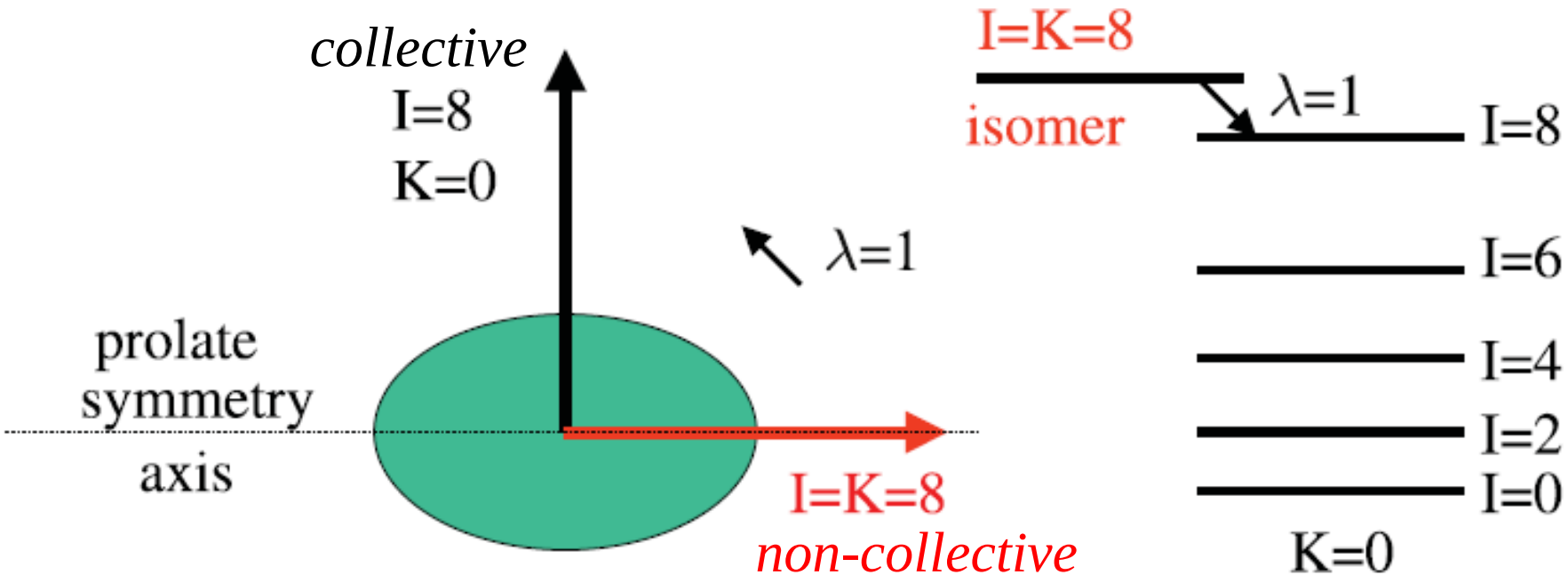


nuclear chart with >1 MeV isomers



adapted from Walker and Dracoulis, Nature 399 (1999) 35

K-forbidden γ-ray transitions



degree of forbiddenness, $\nu = \Delta K - \lambda$

=> $\lambda=1$ transition is 7-fold K-forbidden ($\nu = 7$)

transition-rate hindrance factors

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

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

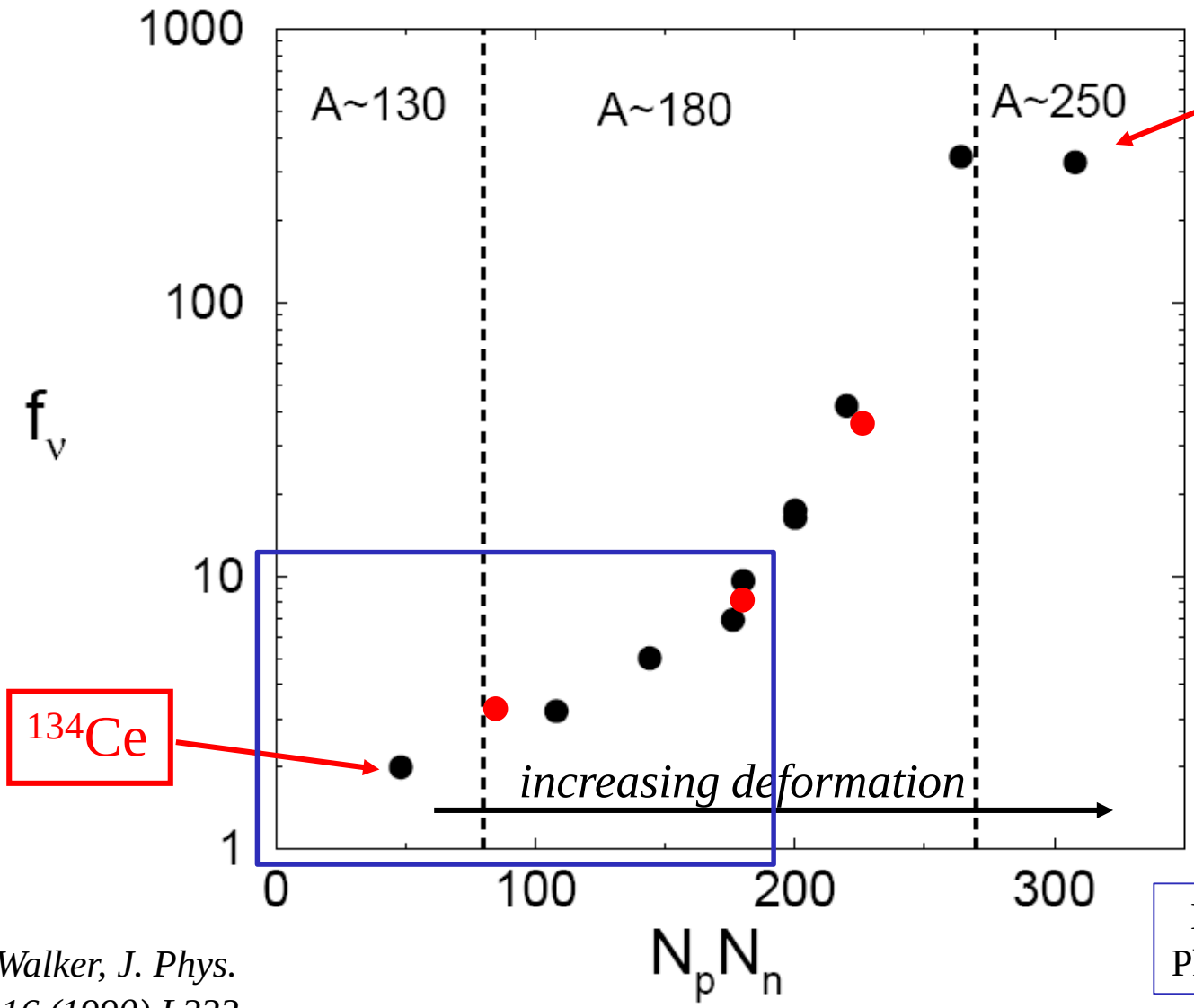
f_ν <=> broken axial symmetry: rotation (Coriolis)
non-axial shape (γ deformation)
random mixing (level density)

in the initial state and/or in the final state

Walker & Xu, Phys. Scr. 91 (2016) 013010; Walker, Phys. Scr. 92 (2017) 054001
Dracoulis, Walker & Kondev, Rep. Prog. Phys. 79 (2016) 076301

2-qp E2 reduced hindrances

even-even nuclides, $K^{\pi} = 6^{+}, 8^{+}, 10^{+}$ isomers



^{244}Cm

^{134}Ce

^{162}Dy: Swan et al., Phys. Rev. C83 (2011) 034322

^{180}Hf: Tandel et al., Phys. Rev. C94 (2016) 064304

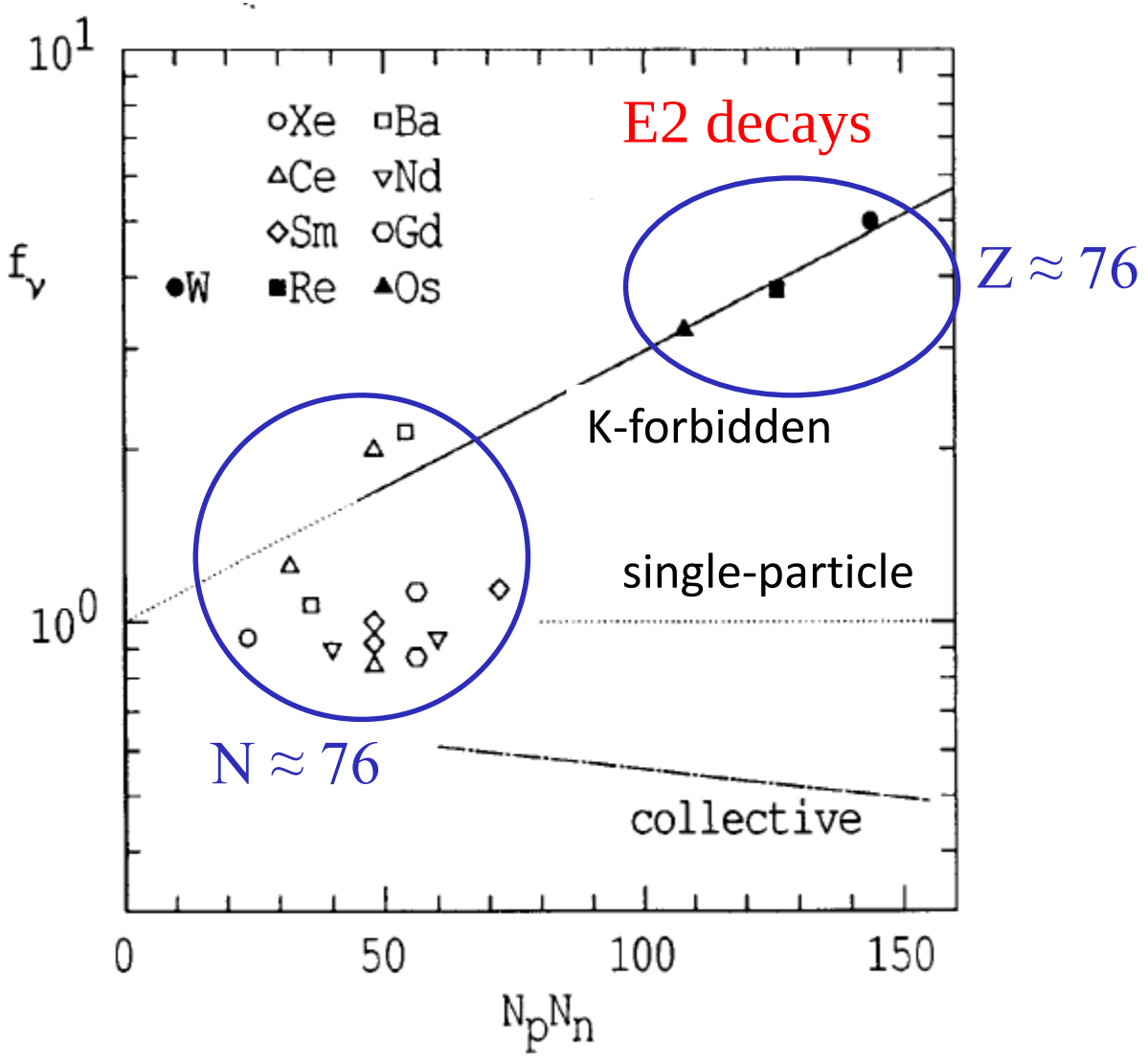
^{190}W: Lane et al., Phys. Rev C82 (2010) 051304(R)

fig. updated from Walker, Nucl. Phys. A834 (2010) 22c

N_pN_n scheme of Casten: Phys. Lett. B152 (1985) 145

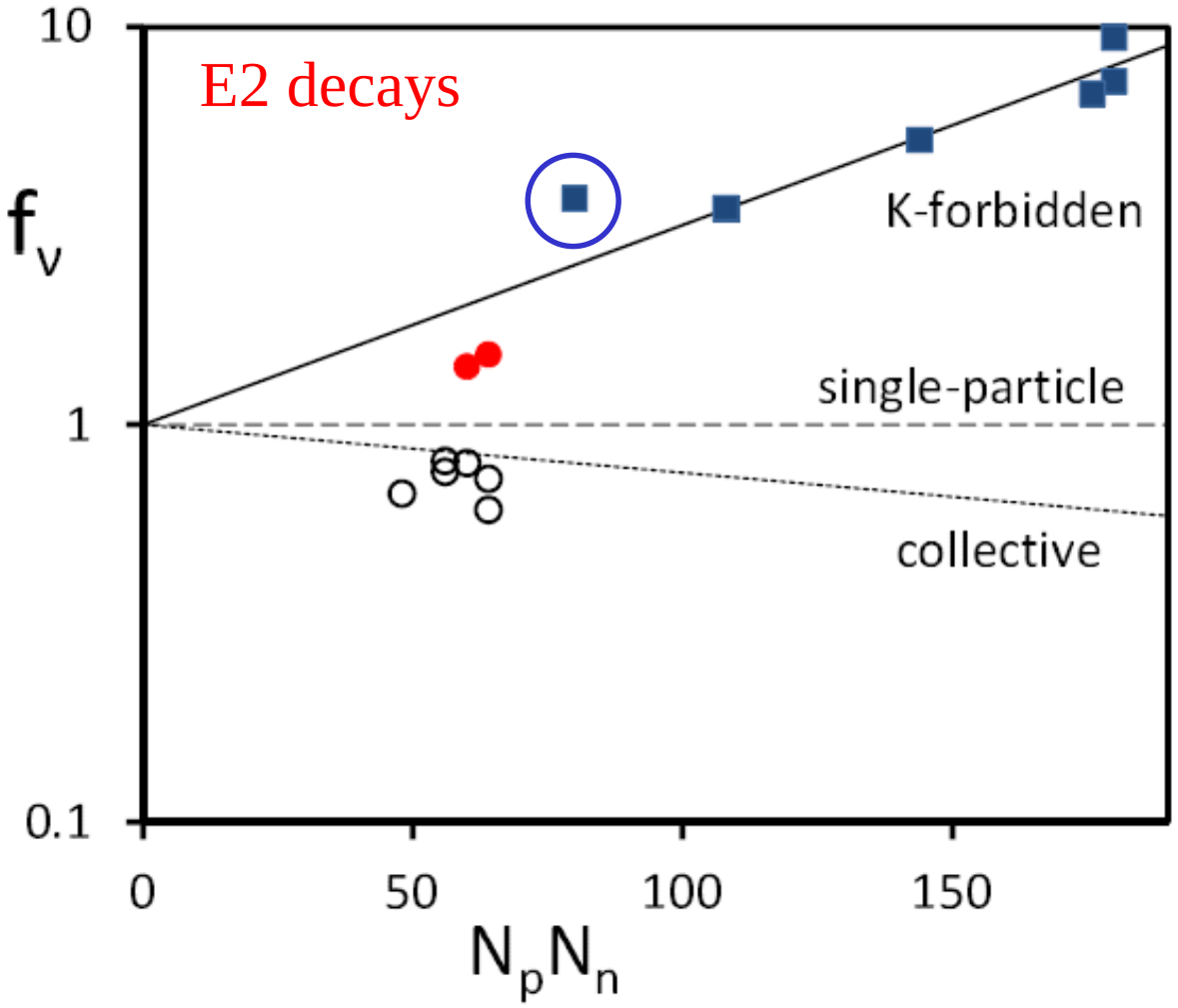
Walker, J. Phys. G16 (1990) L233

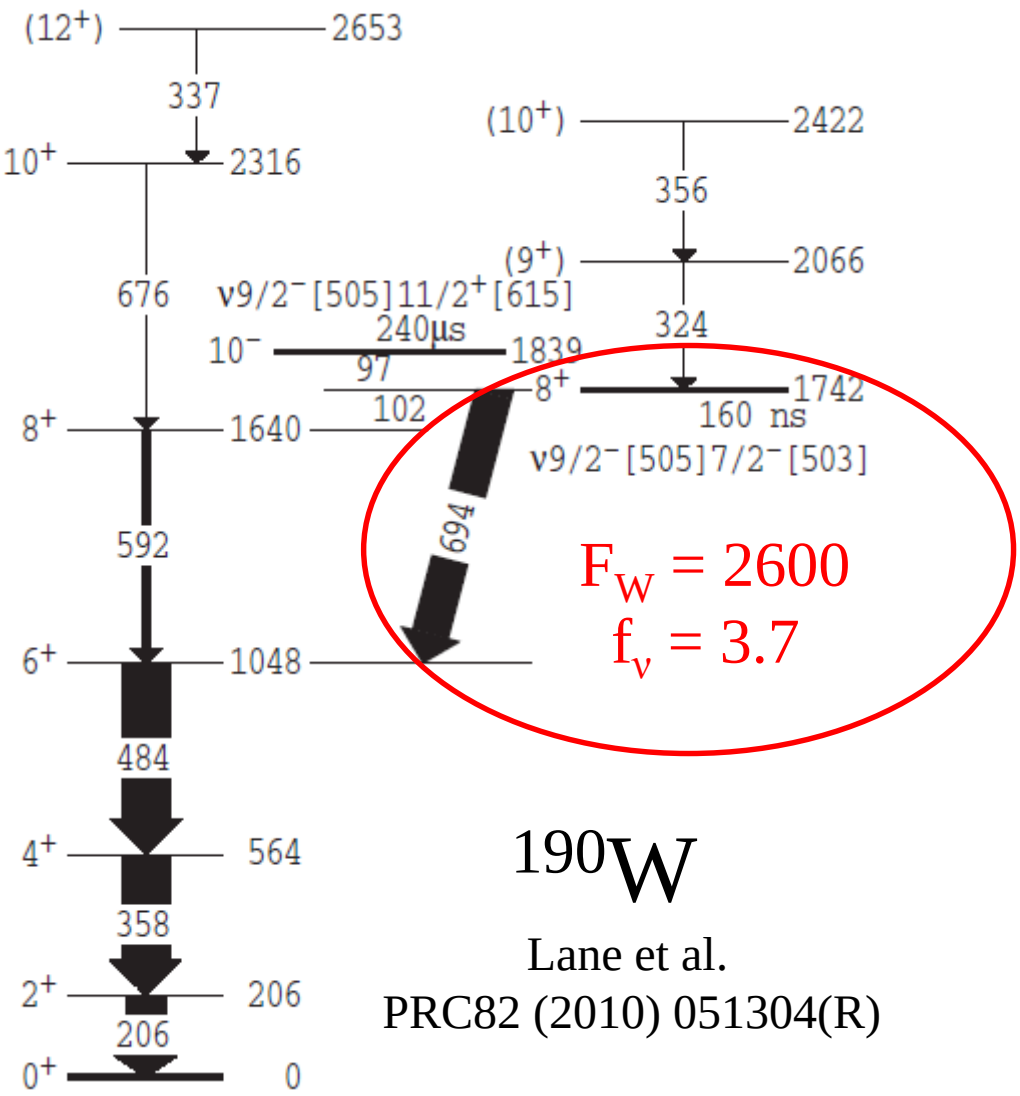
low N_pN_n values in the N ≈ 76 region



Walker and Schiffer, Z. Phys. A338 (1991) 239

low N_pN_n values in the $Z \approx 76$ region



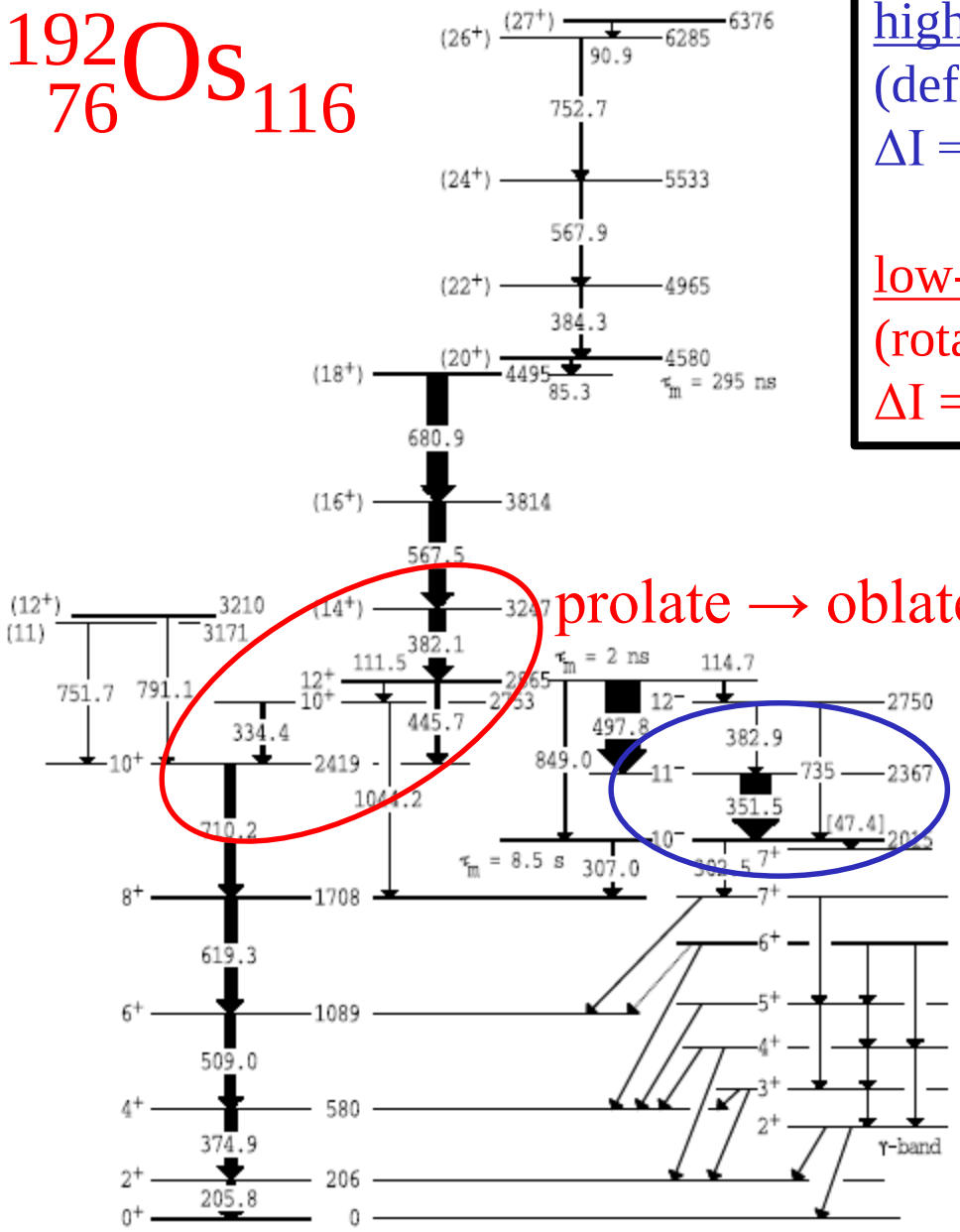


^{190}W

Lane et al.
PRC82 (2010) 051304(R)

Dracoulis et al. Phys. Lett. B720 (2013) 330
(Gammasphere data)

$^{192}_{76}Os_{116}$



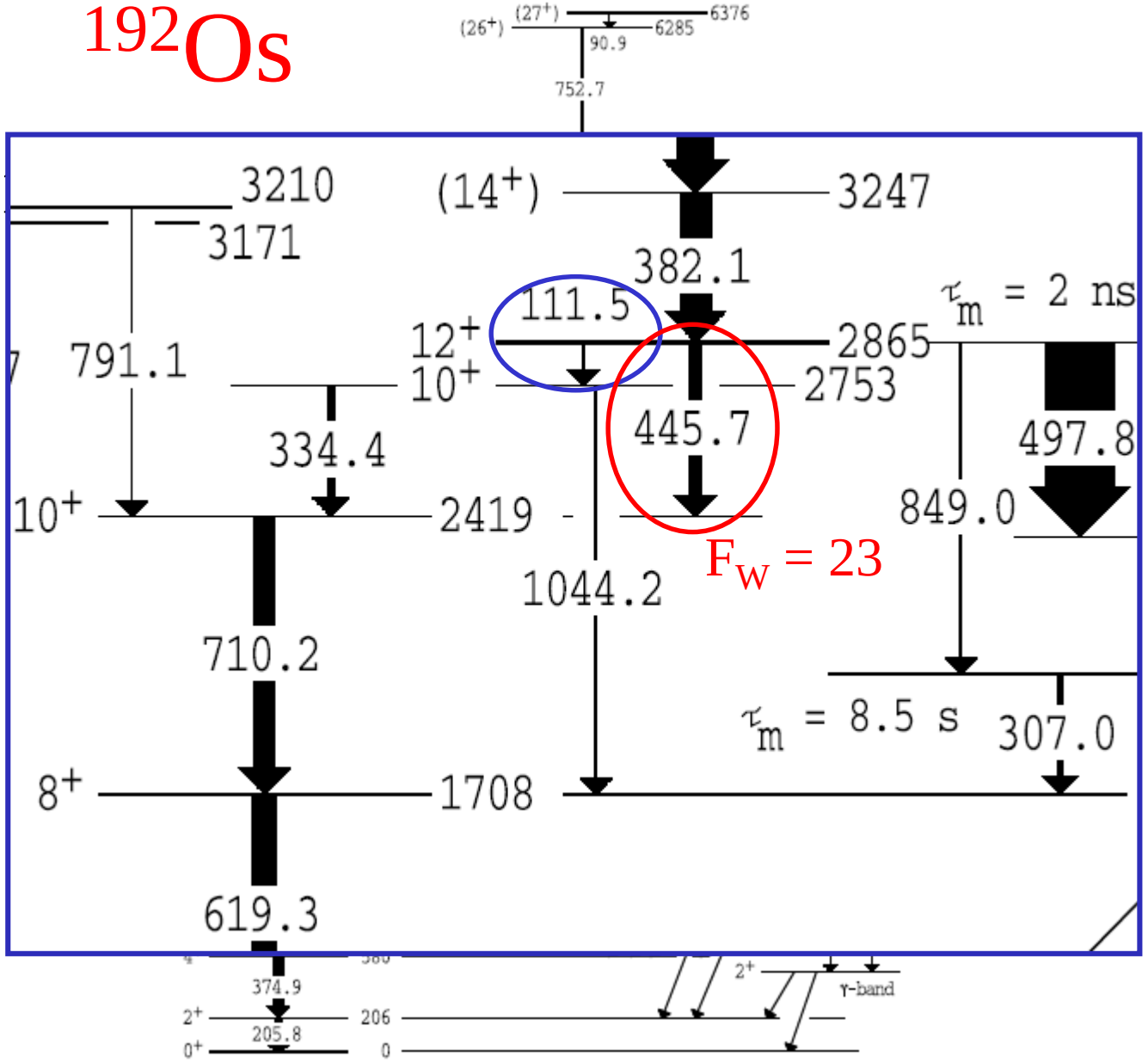
prolate → oblate bandcrossing

high-K

high-K bands:
(deformation aligned)
ΔI = 1 sequences

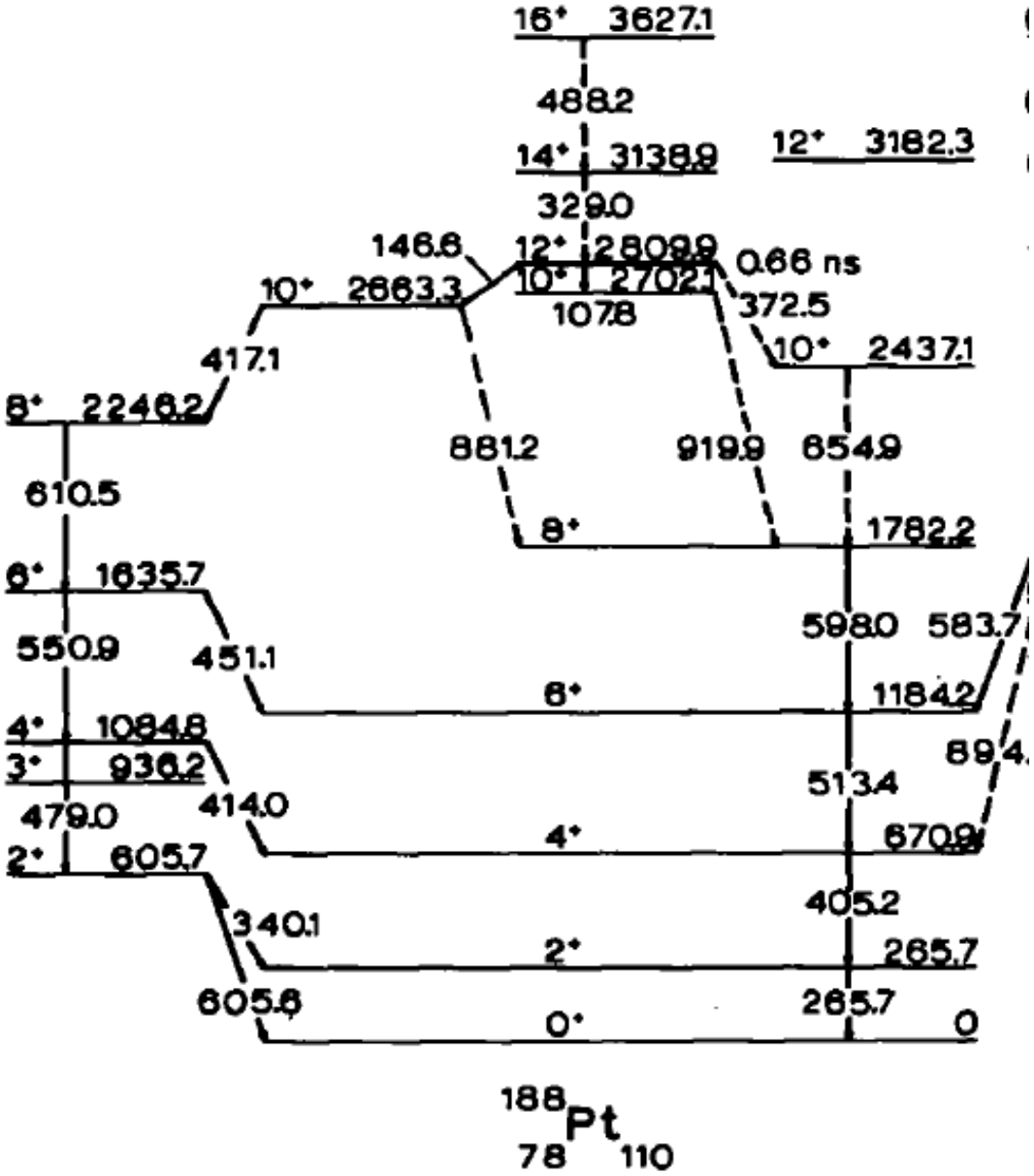
low-K bands:
(rotation aligned)
ΔI = 2 sequences

^{192}Os



Dracoulis et al. Phys. Lett. B720 (2013) 330
(Gammasphere data)

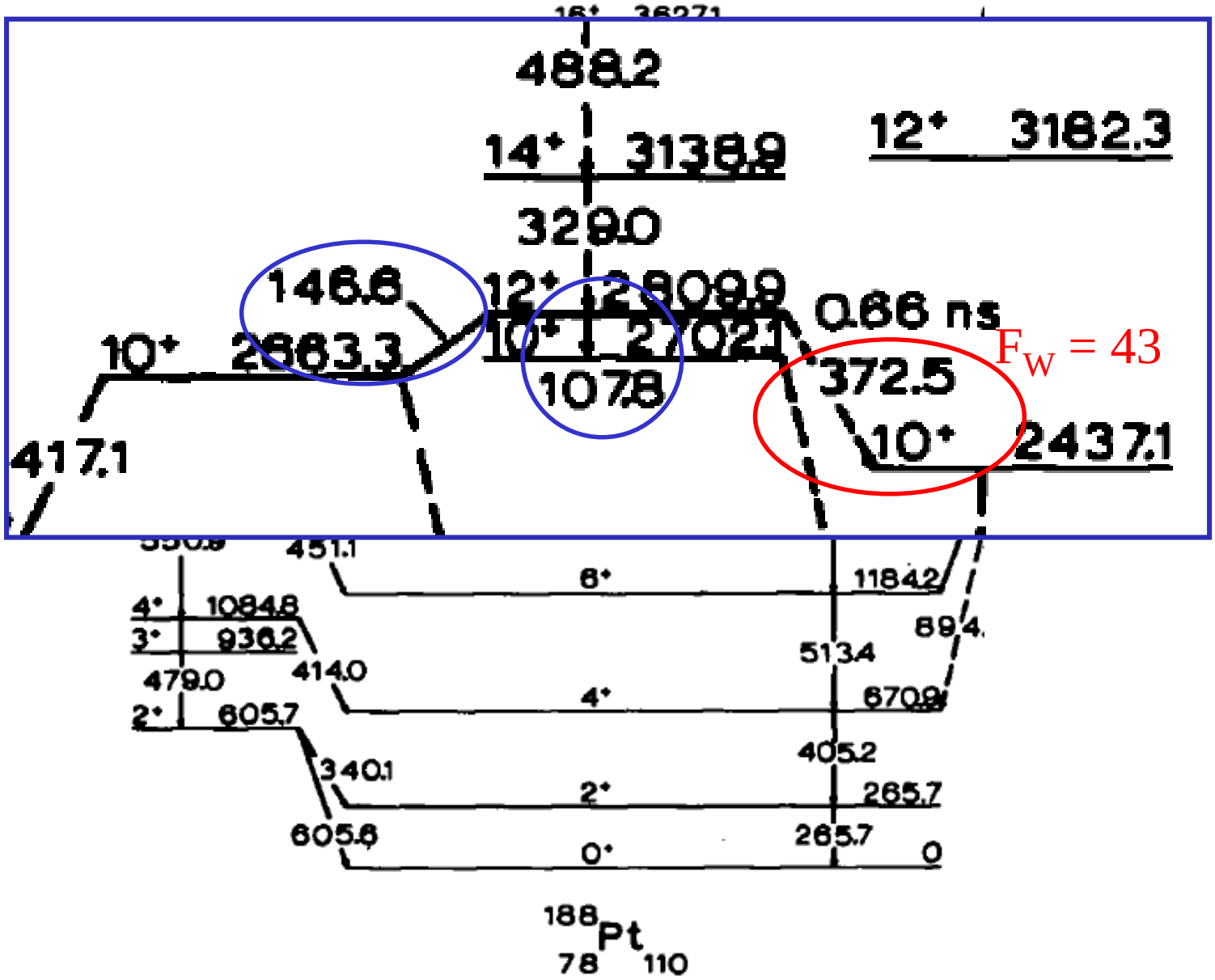
^{188}Pt



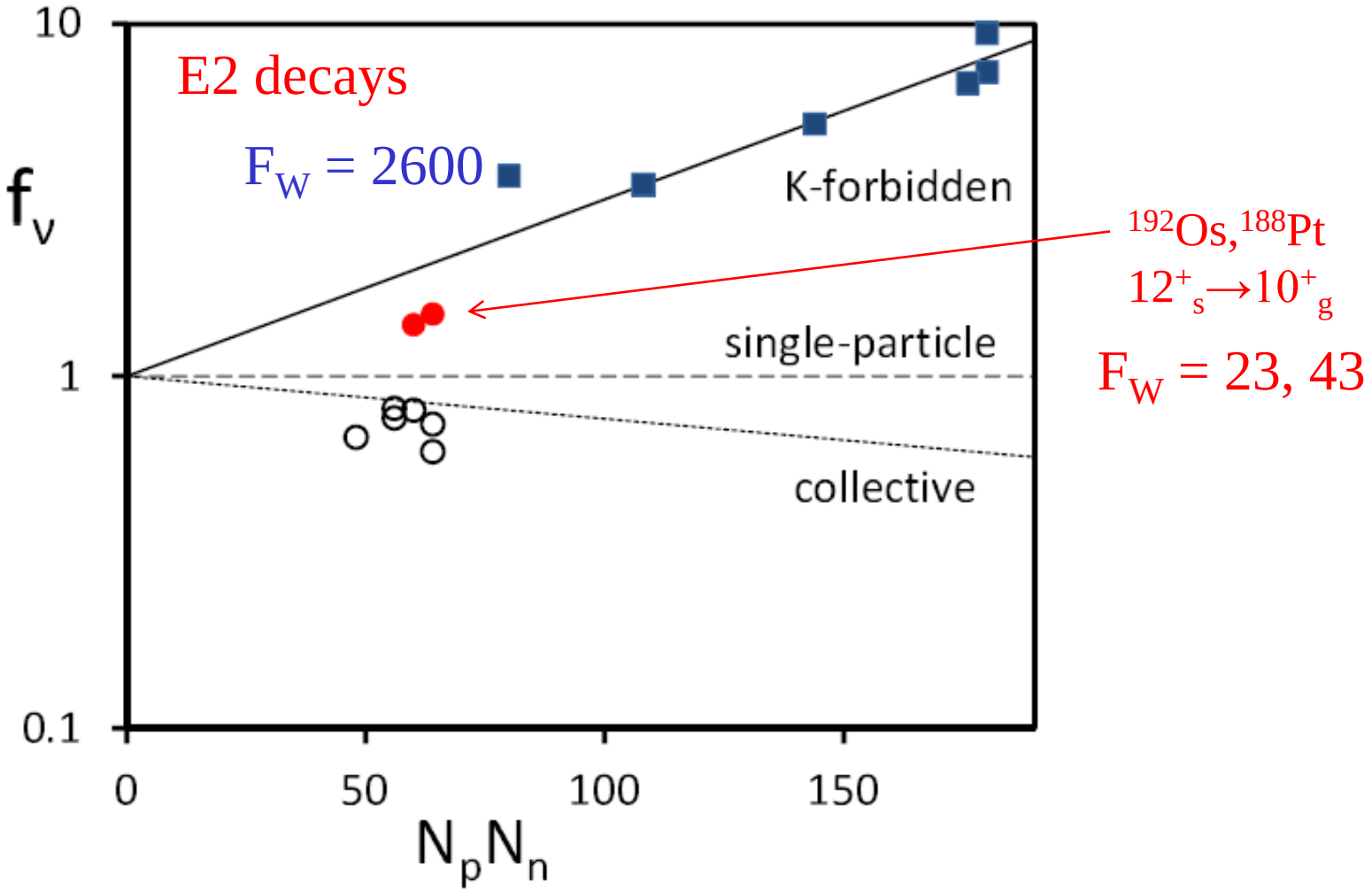
Richter et al., Nucl. Phys. A319 (1979) 221

^{188}Pt

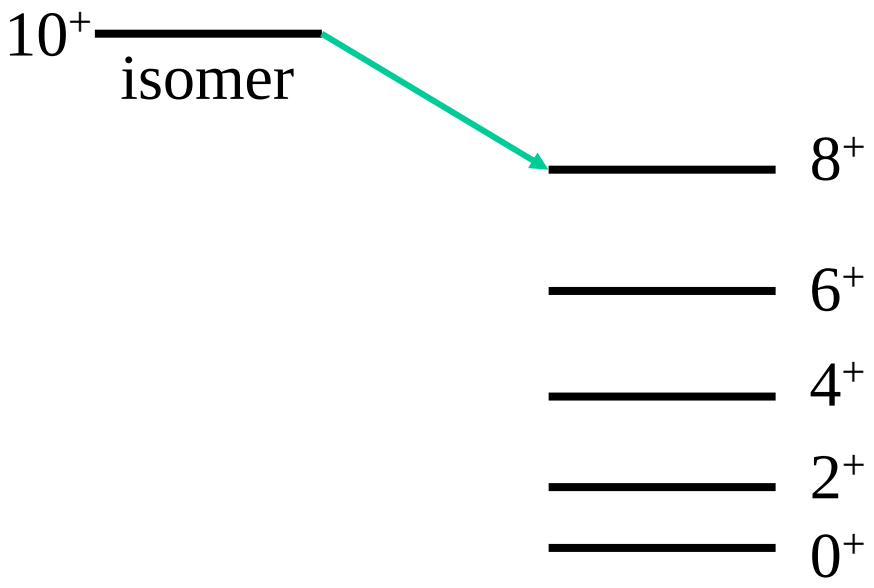
Richter et al., Nucl. Phys. A319 (1979) 221



low N_pN_n values in the $Z \approx 76$ region



oblate shape isomer or prolate K isomer?



Summary:

n-rich A ≈ 170-190 region

- E2 reduced hindrance & N_pN_n dependence
- Different angular-momentum orientations: ***K isomers***
- Different shapes: oblate→prolate ***shape isomers***
- Examples: ^{192}Os,^{188}Pt (^{190}Pt)
- Future measurements with mass-separated beams

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