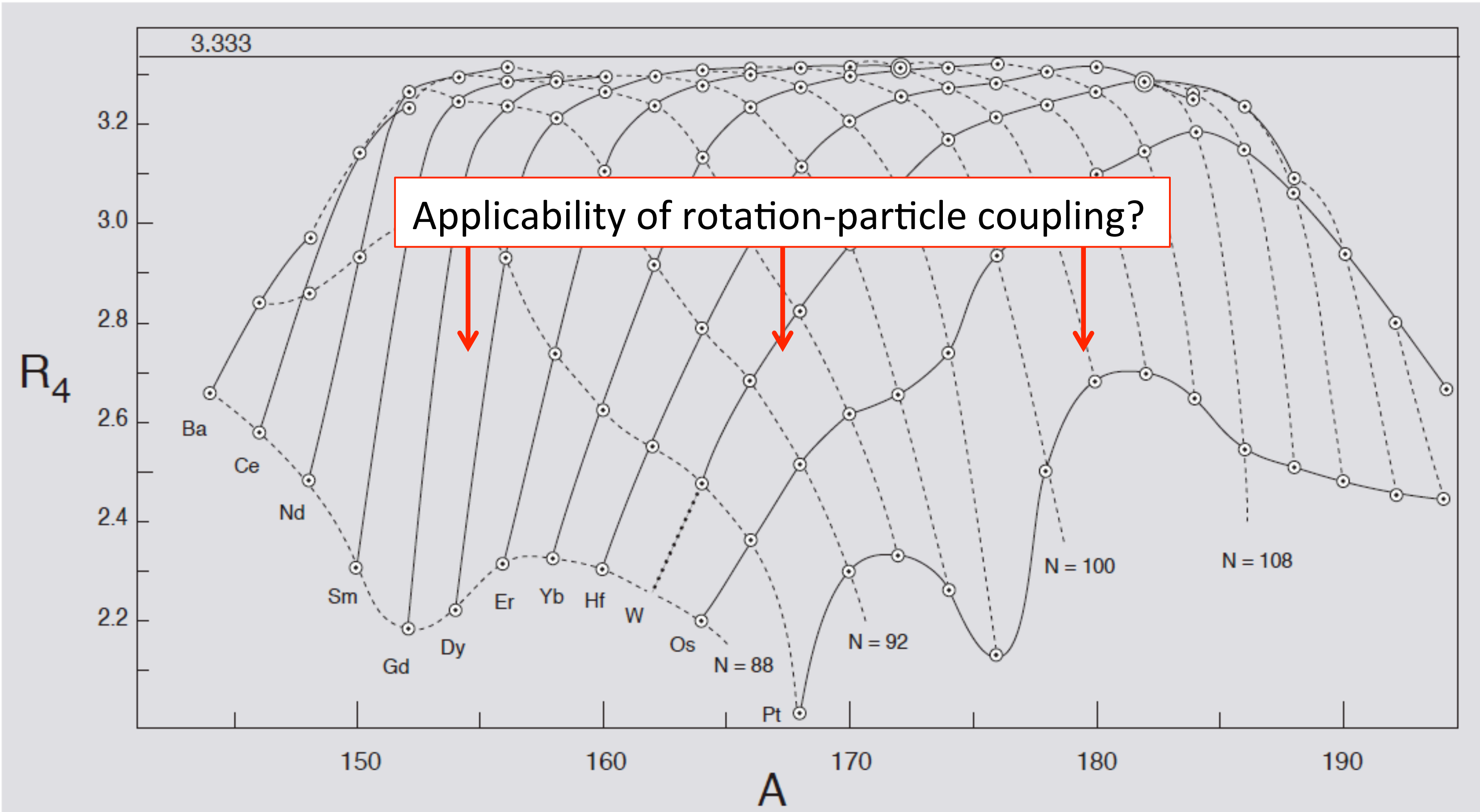
Rotation-Particle Coupling:
application to weakly deformed nuclei

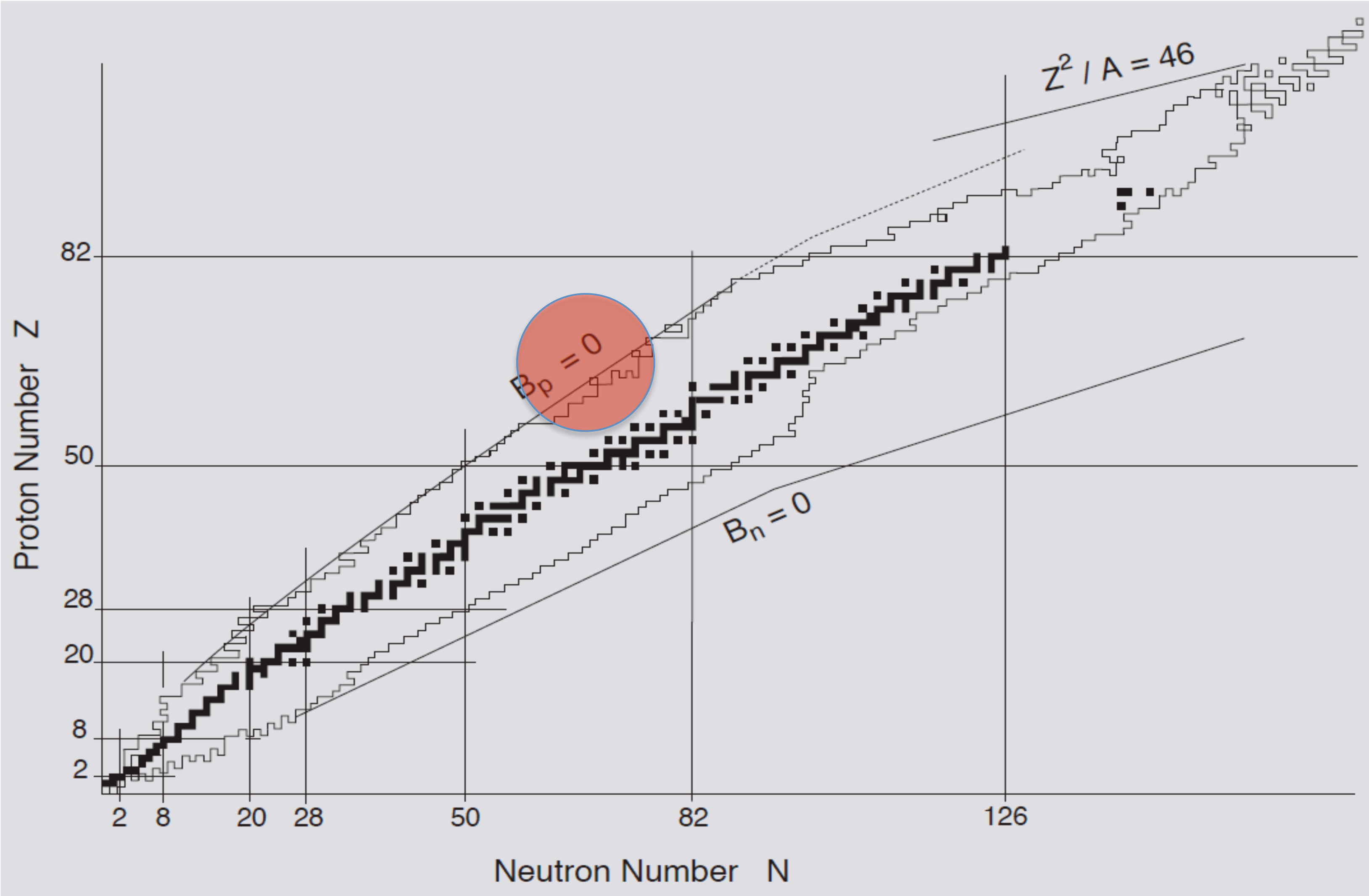
John L. Wood

What should be called a rotor?

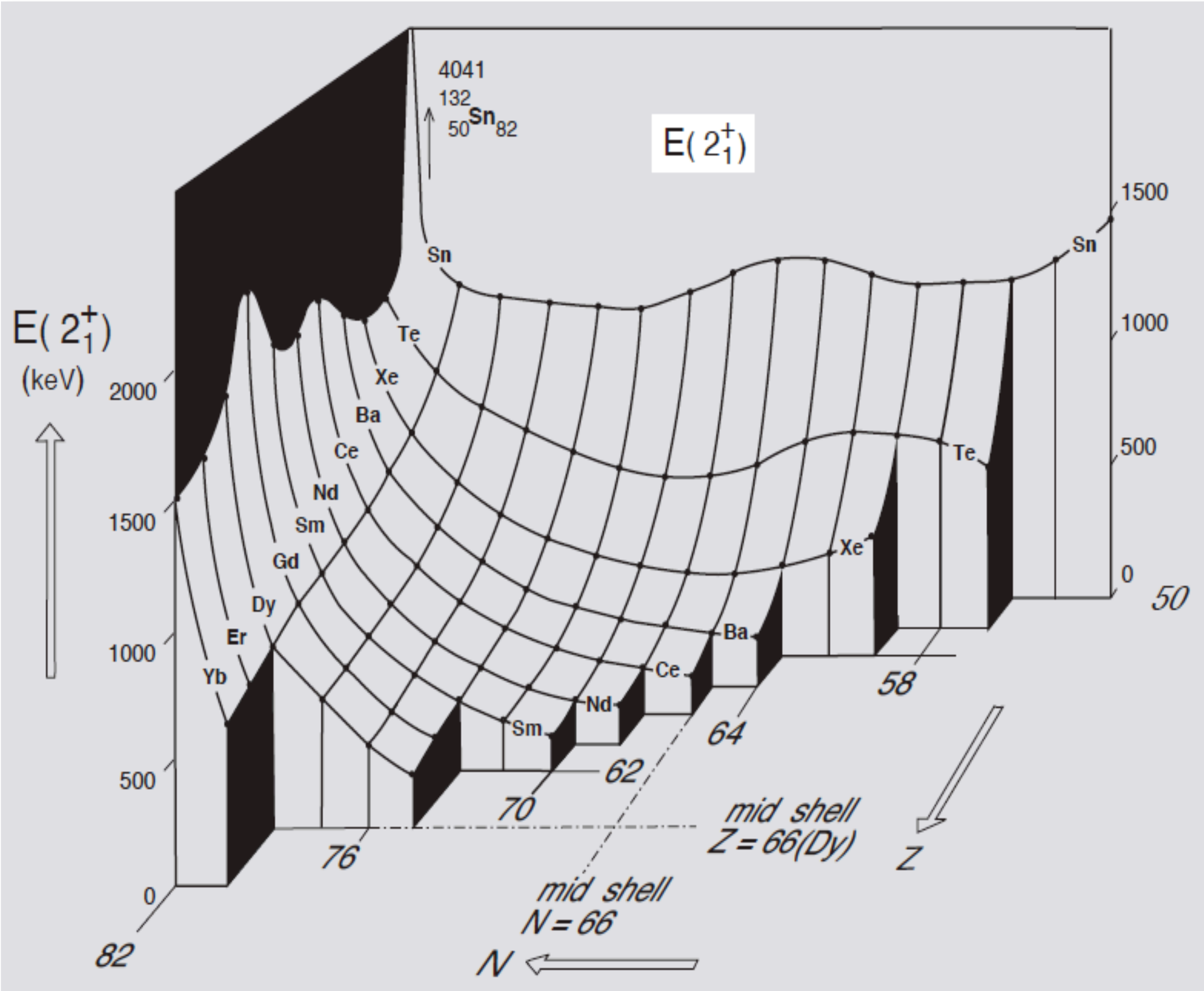


R&W Fig. 1.56

Deformed nuclei: Z ≥ 50, N ≤ 82

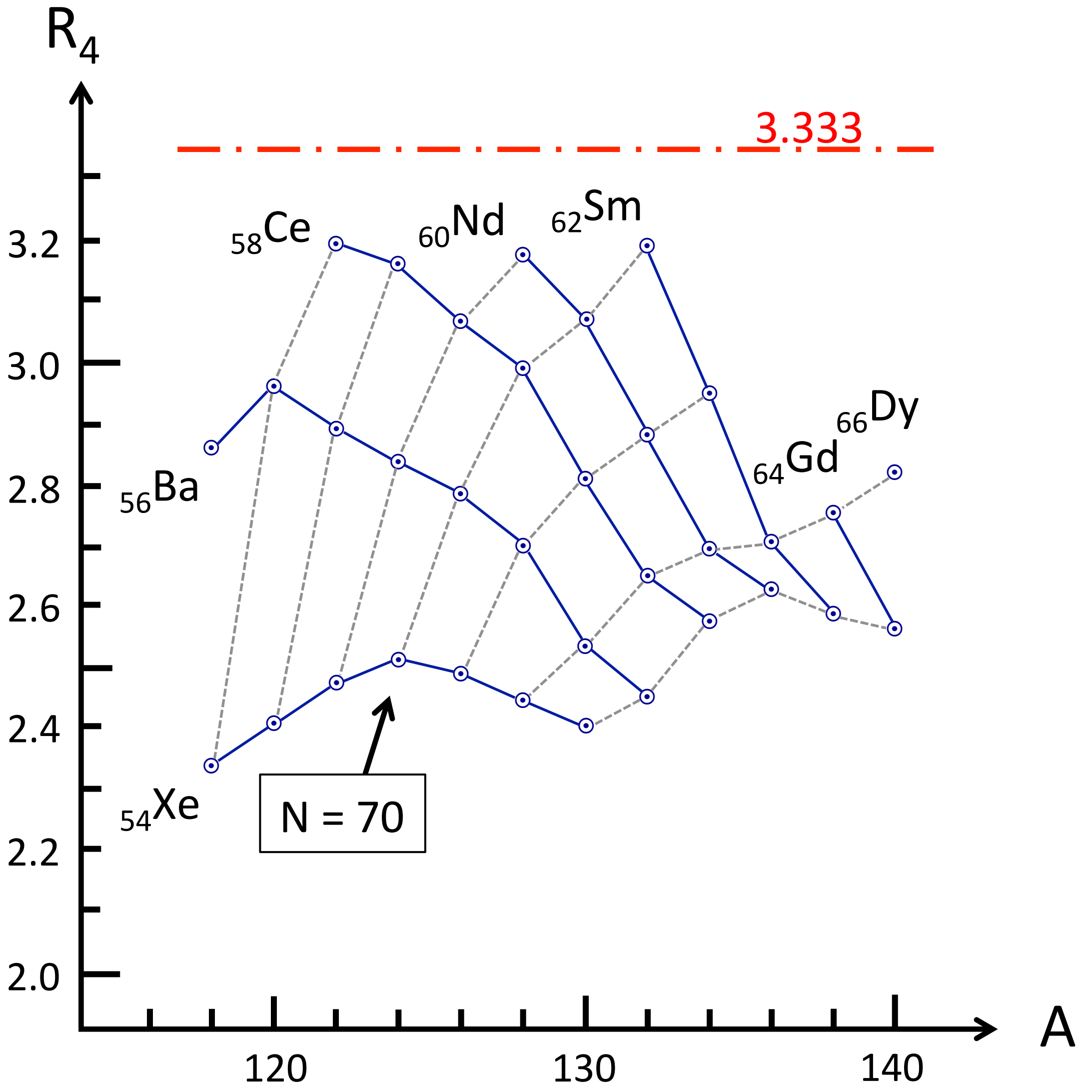


Systematic of $E(2_1^+)$ for $Z \geq 50$, $N \leq 82$



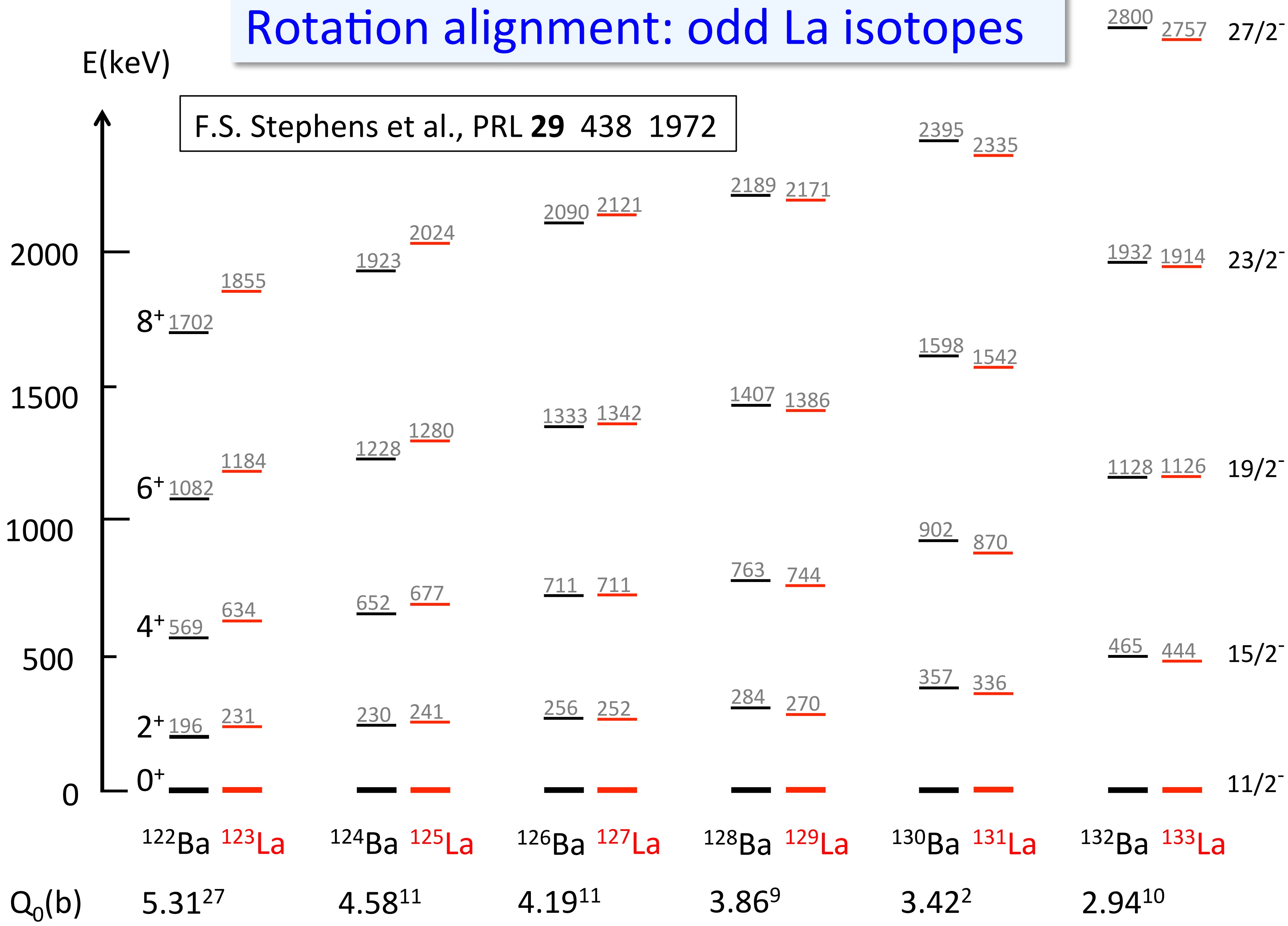
R&W Fig. 1.36

Deformed nuclei: $Z \geq 50$, $N \leq 82$

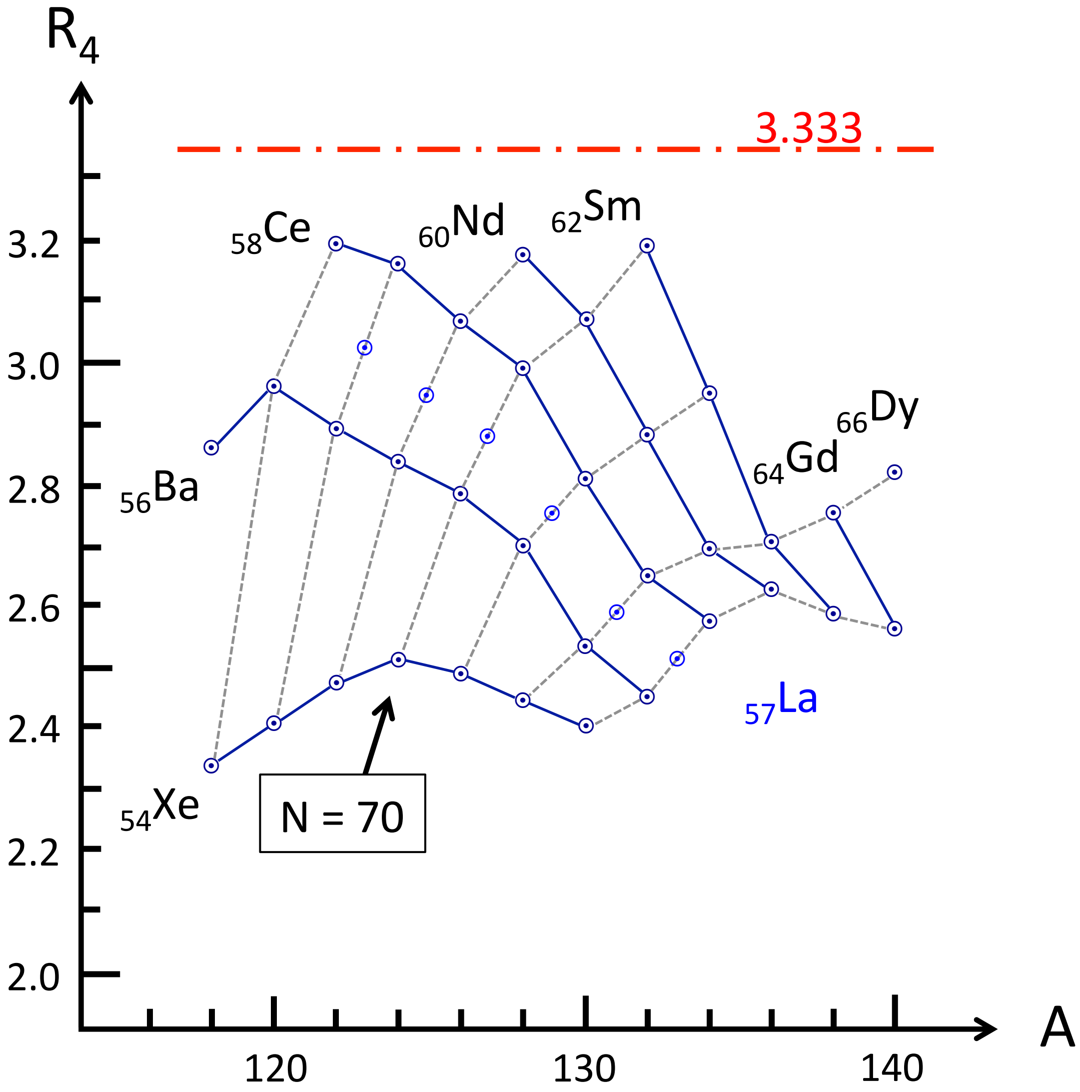


Rotation alignment: odd La isotopes

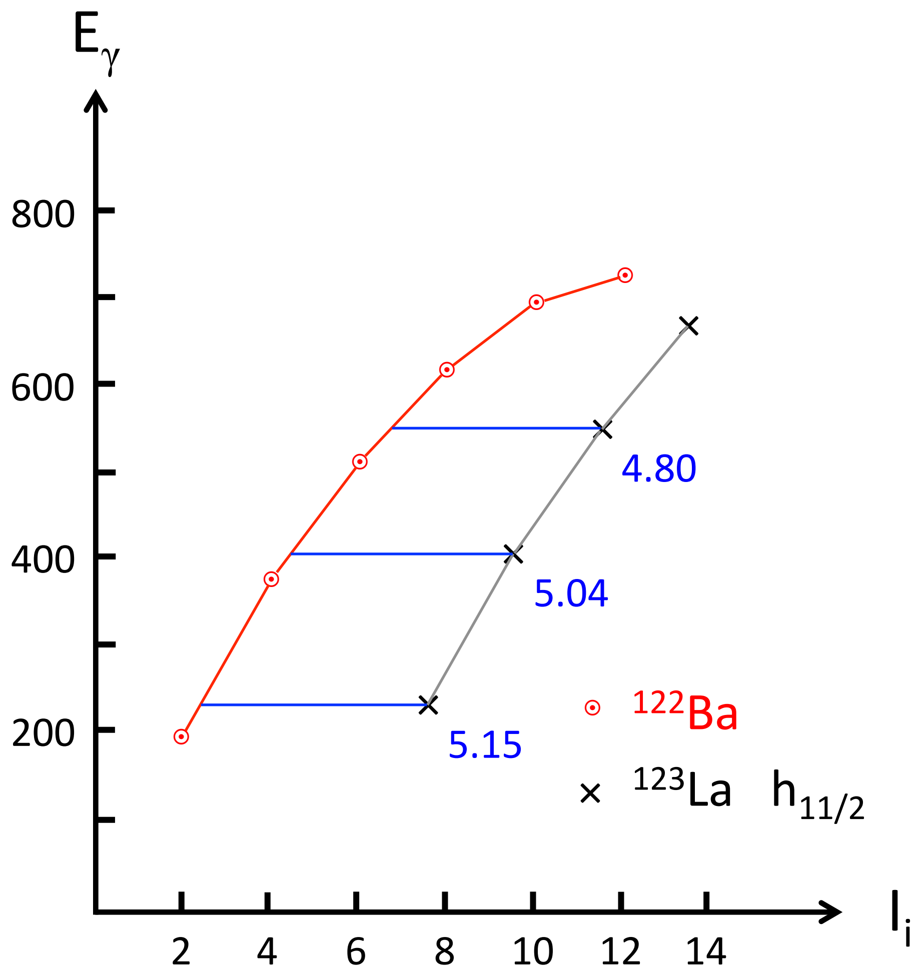
F.S. Stephens et al., PRL **29** 438 1972



Strongly deformed nuclei: Z ≥ 50, N ≤ 82



Rotation alignment: ^{123}La $h_{11/2}$



Full alignment for $h_{11/2}$ would be I_i = 5.50

The key concept for modeling deformed nuclei: the symmetric-top + Nilsson model

$$\hat{H} := \frac{\hbar^2 \hat{\mathbf{R}}^2}{2\Im} + \boxed{\hat{h}},$$

"coupling" = add Hamiltonians
(wave functions will be direct products)

$$\boxed{\hat{h} := \frac{\hat{p}^2}{2M} + \tfrac{1}{2} M \left[\omega_\perp^2 (\bar{x}^2 + \bar{y}^2) + \omega_z^2 \bar{z}^2\right] + D \hat{\mathbf{l}}^2 + \xi \, \hat{\mathbf{l}} \cdot \hat{\mathbf{s}}.}$$

$$\hat{\mathbf{I}} := \hat{\mathbf{R}} + \hat{\mathbf{j}}$$

"coupling" = add spins/angular momenta

$$\hat{H} = \frac{\hbar^2 \hat{\mathbf{I}}^2}{2\Im} + \boxed{\hat{h}} + \frac{\hbar^2 \hat{\mathbf{j}}^2}{2\Im} \boxed{- \frac{\hbar^2}{\Im} \hat{\mathbf{I}} \cdot \hat{\mathbf{j}}}$$

FOCUS, THIS TALK

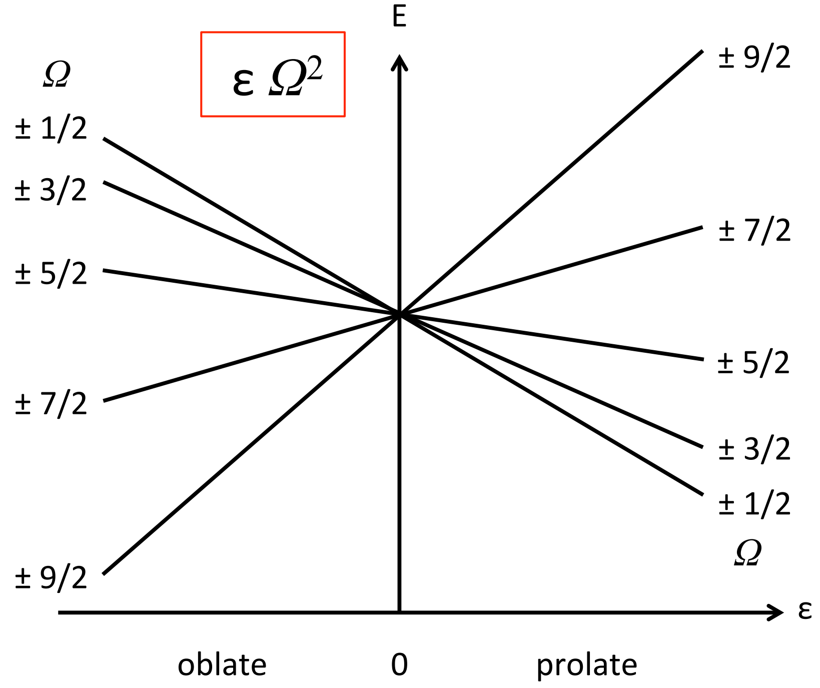
Competition between $E_{Nilsson}$ and E_{align}

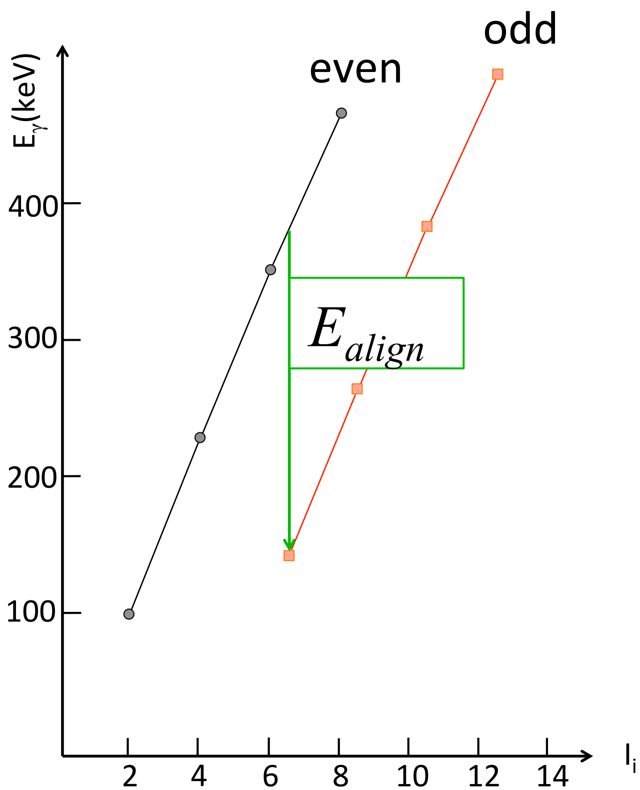
$$\hat{H} = \boxed{\frac{\hbar^2 \hat{\mathbf{I}}^2}{2\Im}} + \boxed{\hat{h}} + \frac{\hbar^2 \hat{\mathbf{j}}^2}{2\Im} \boxed{- \frac{\hbar^2}{\Im} \hat{\mathbf{I}} \cdot \hat{\mathbf{j}}}$$

$$E_I = E_0 + \boxed{A[I(I+1)]} + \boxed{\varepsilon\, \Omega^2} + \boxed{E_{align}}$$

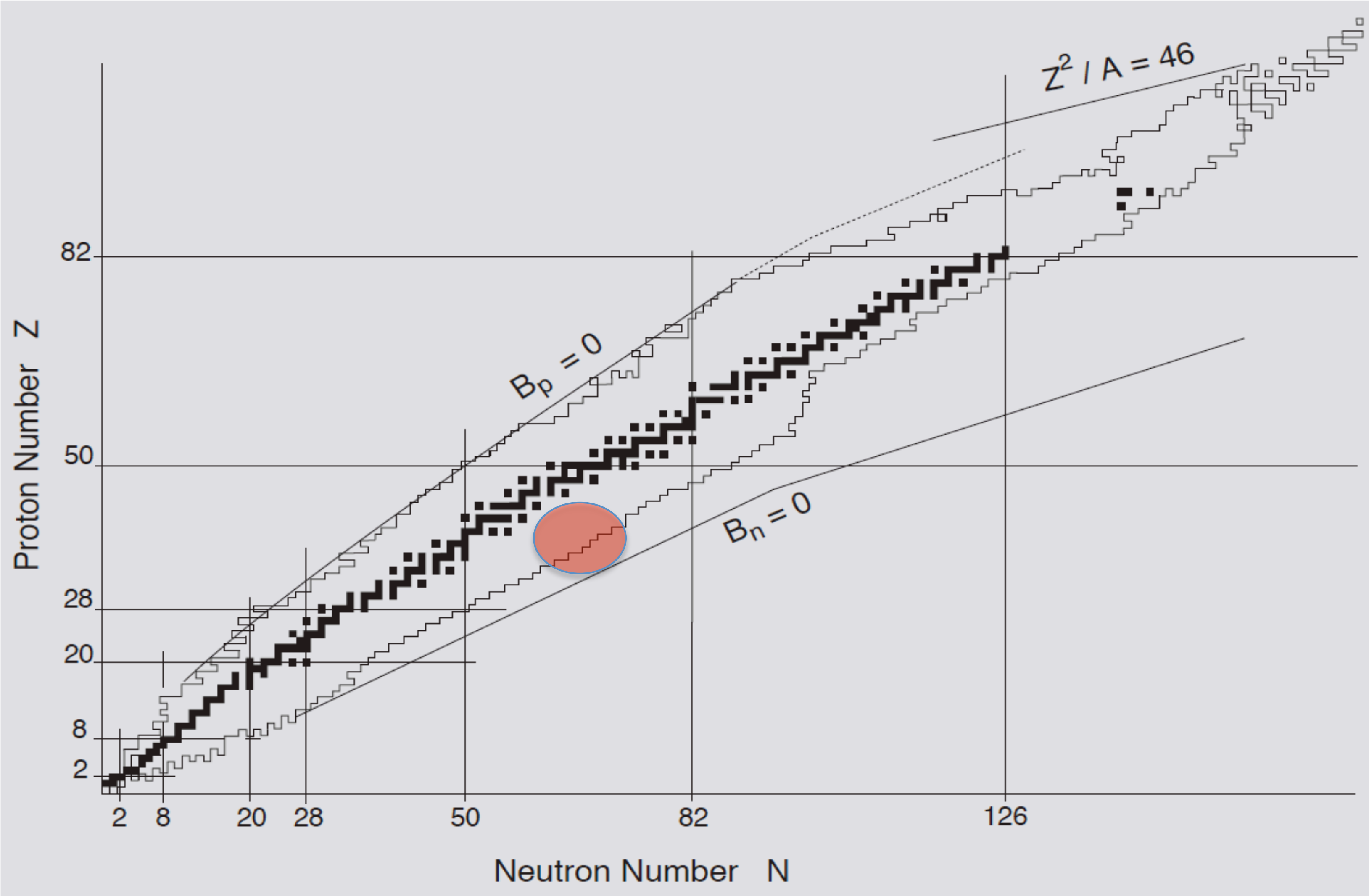
$\boxed{E_{Nilsson}}$

ε -- small
$\Im$ -- small, E_{align} large

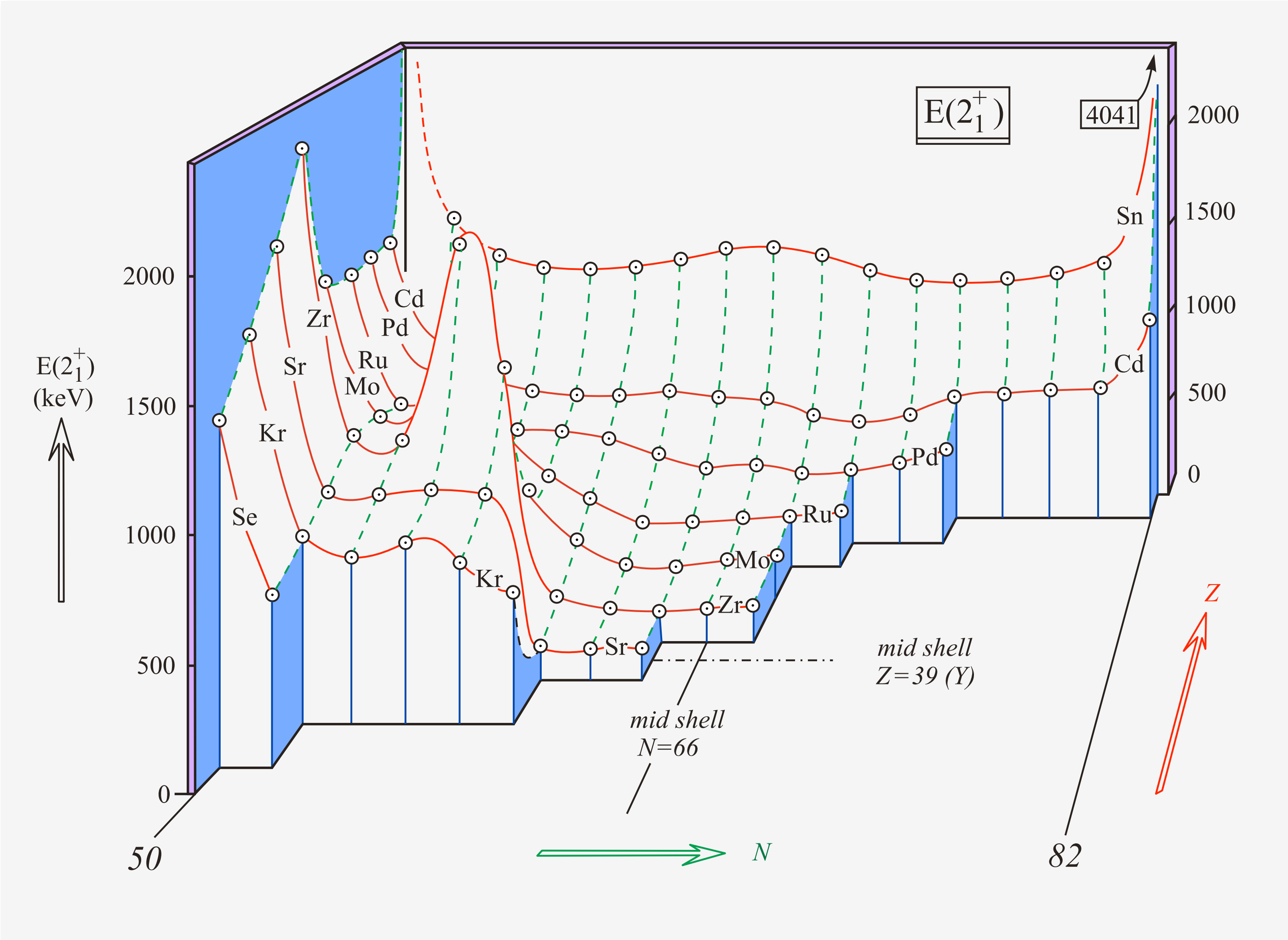




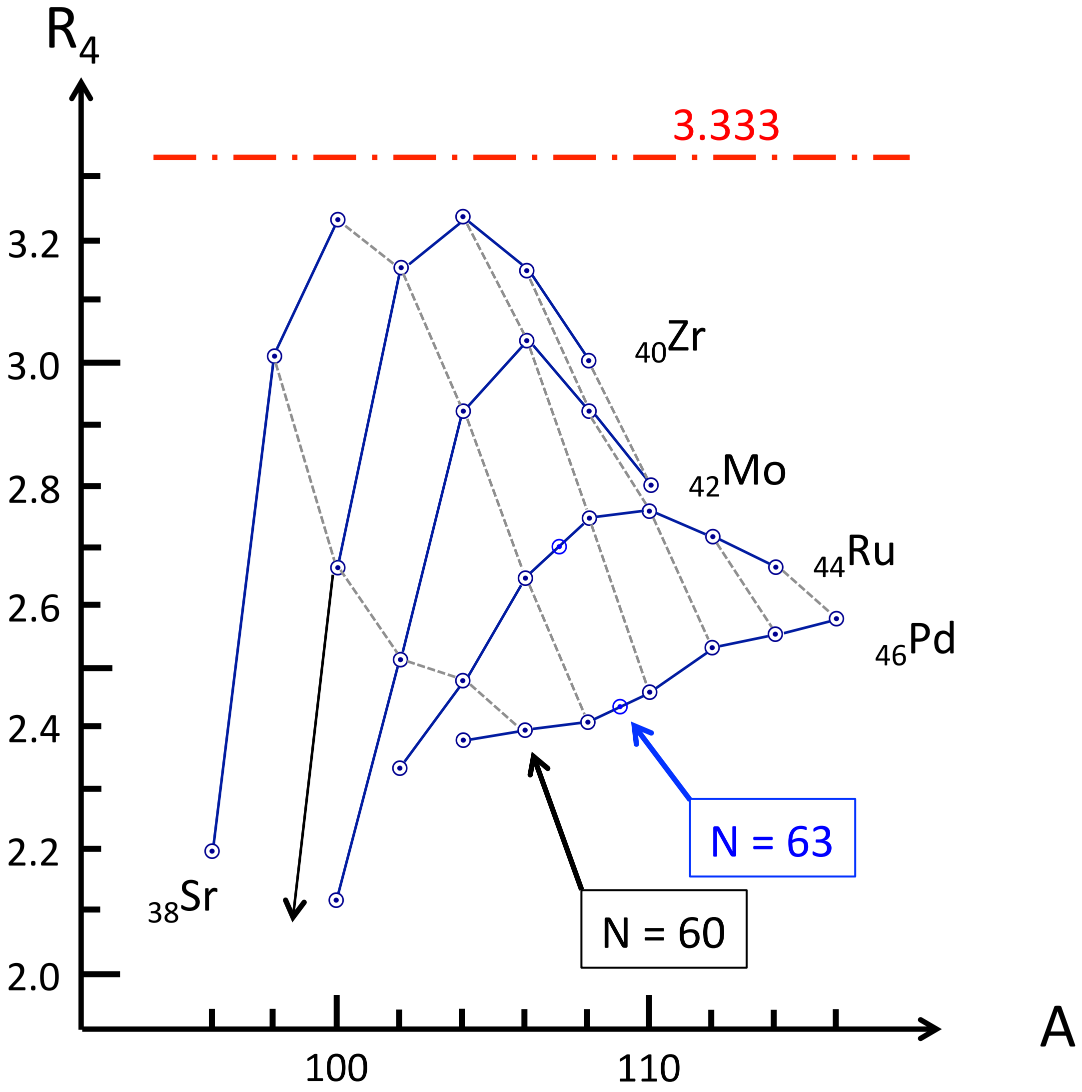
Deformed nuclei: Z ≥ 50, N ≤ 82



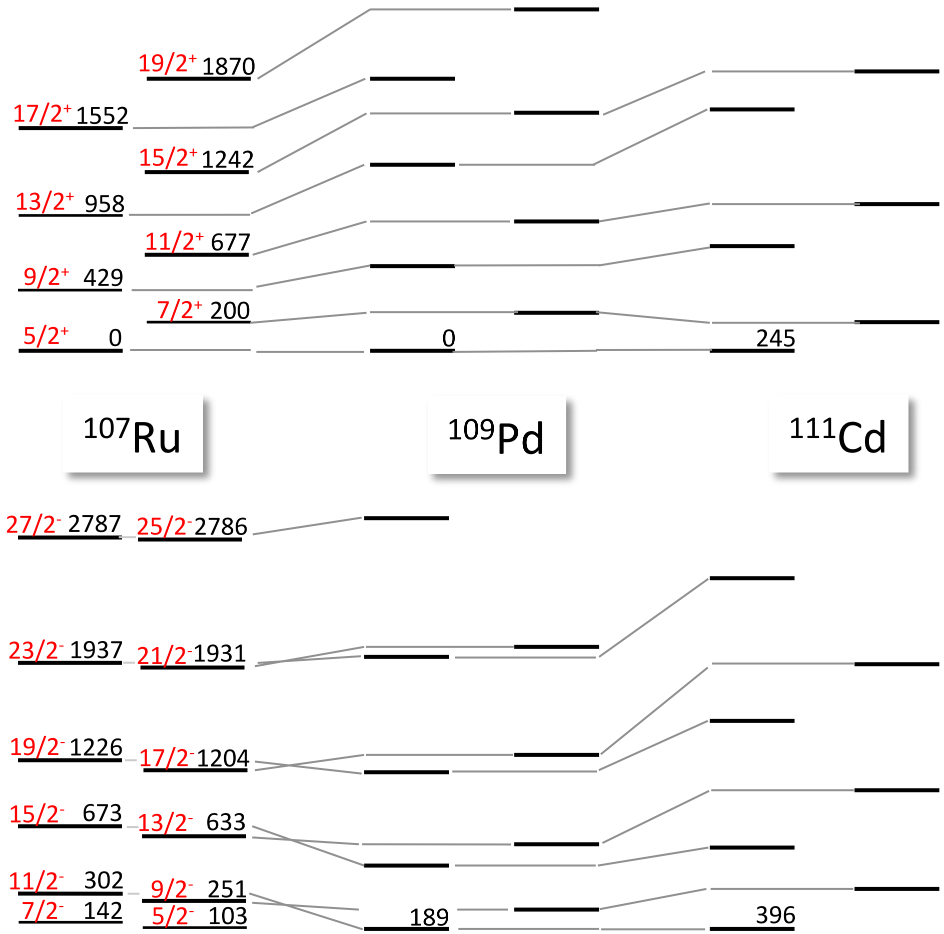
Systematic of $E(2_1^+)$ for N ≥ 50, Z ≤ 50

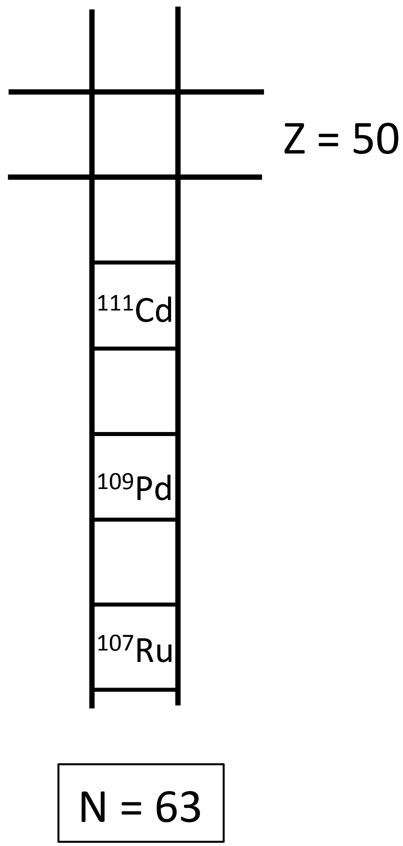


Deformed nuclei: $N \geq 50$, $Z \leq 50$



Rotor model:
applicable to nuclei with small deformations

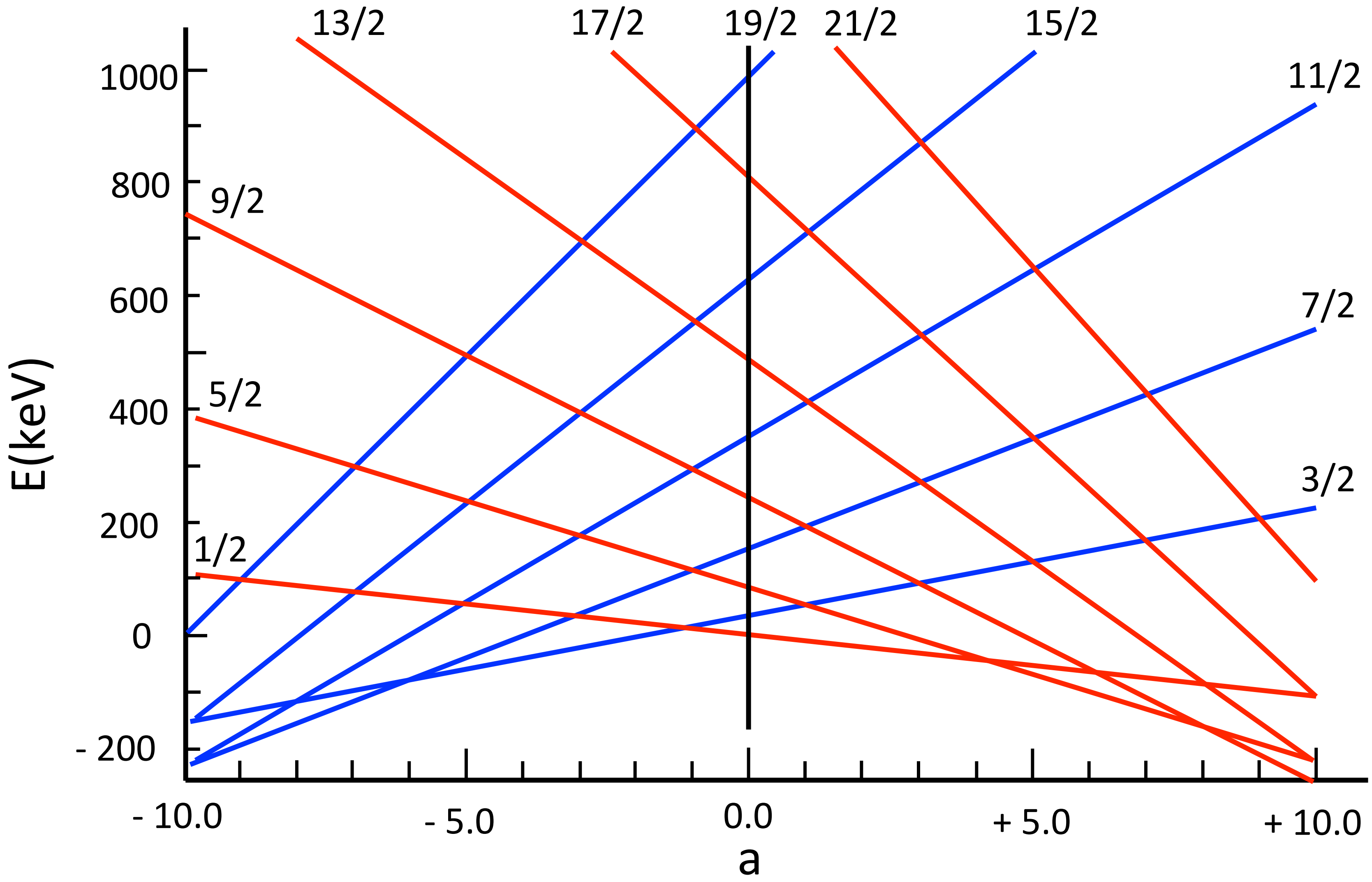




Quantum mechanics of particle-rotor coupling: K = ½ bands and "Coriolis" decoupling

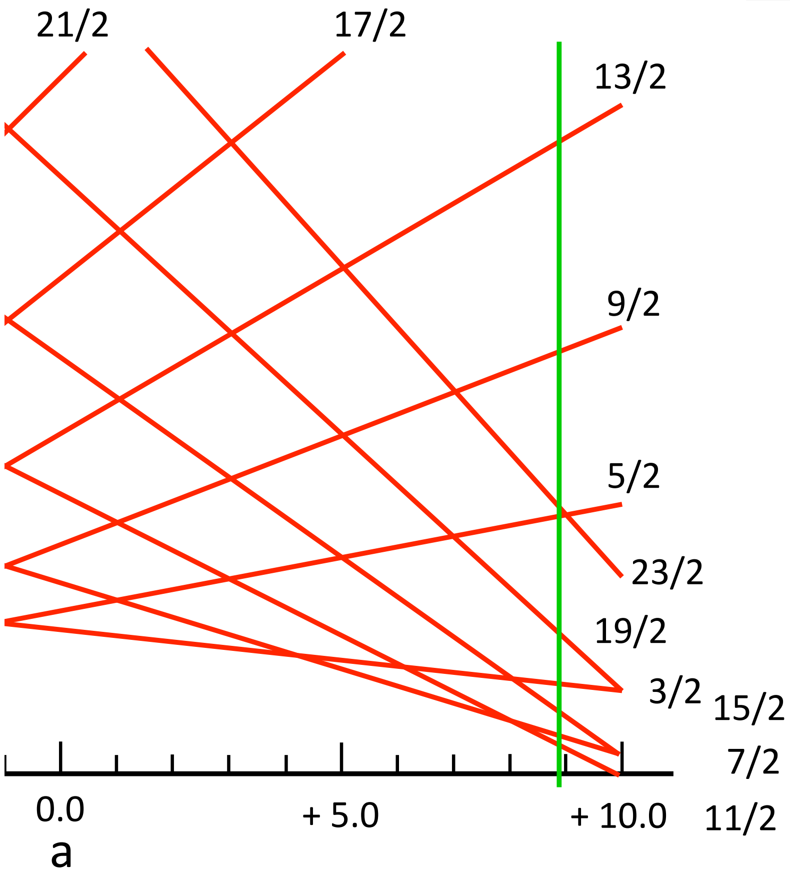
$$E_I = E_0 + A[I(I+1) + (-1)^{I+1/2}(I + 1/2)\, a\, \delta_{K,1/2}]$$

$A = 10.0$ keV

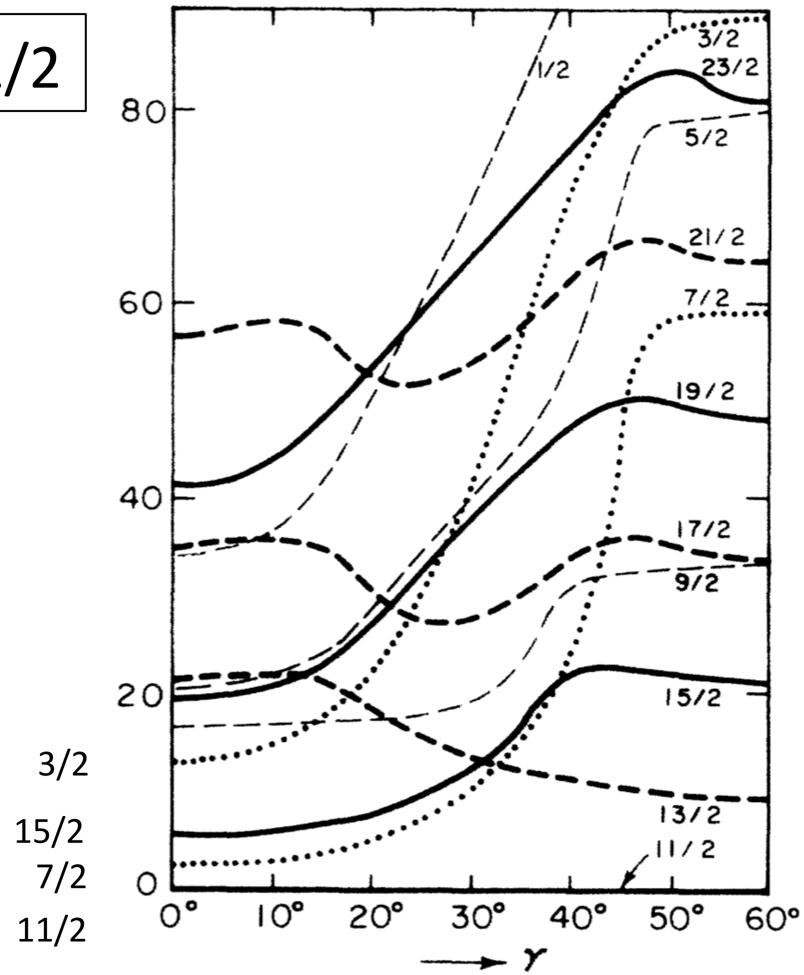


From axially symmetric decoupled to axially asymmetric decoupled

j = 11/2

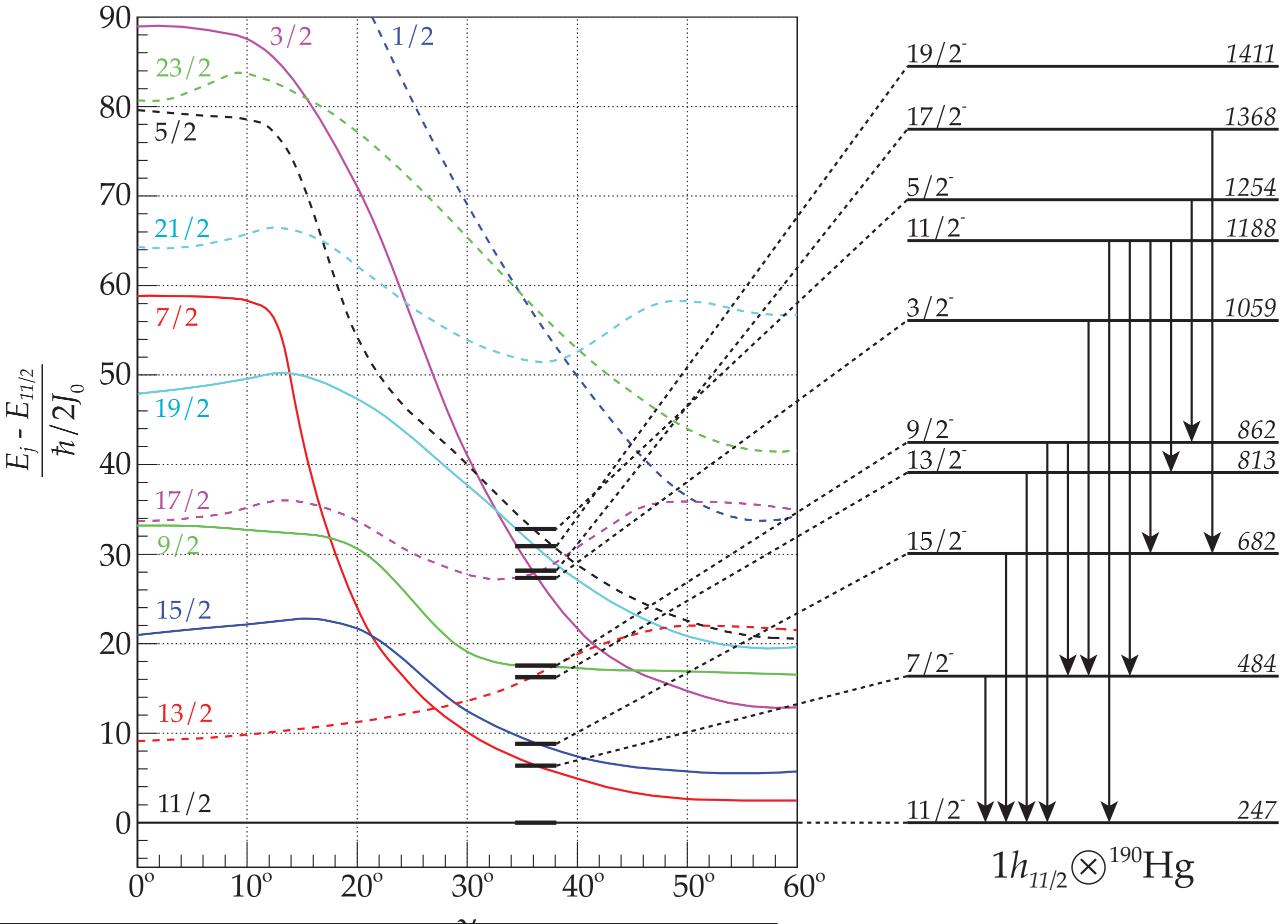


prolate



prolate oblate

Comparison of Meyer-ter-Vehn model with $\pi h_{11/2}^{-1} \times {}^{190}Hg$ in ${}^{189}Au$

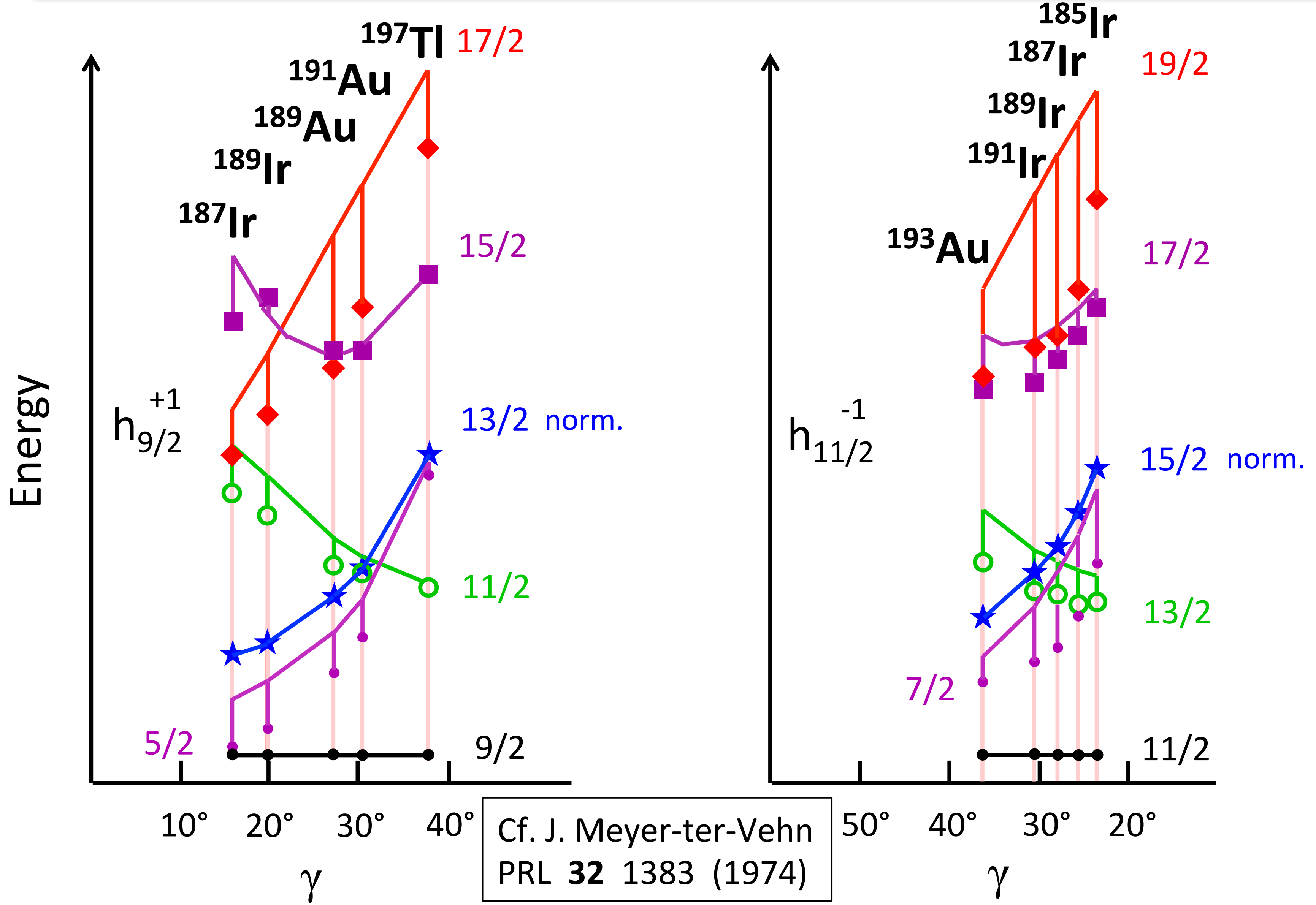


Cf. J. Meyer-ter-Vehn PRL **32** 1383 (1974)

Figure: courtesy M. Venhart

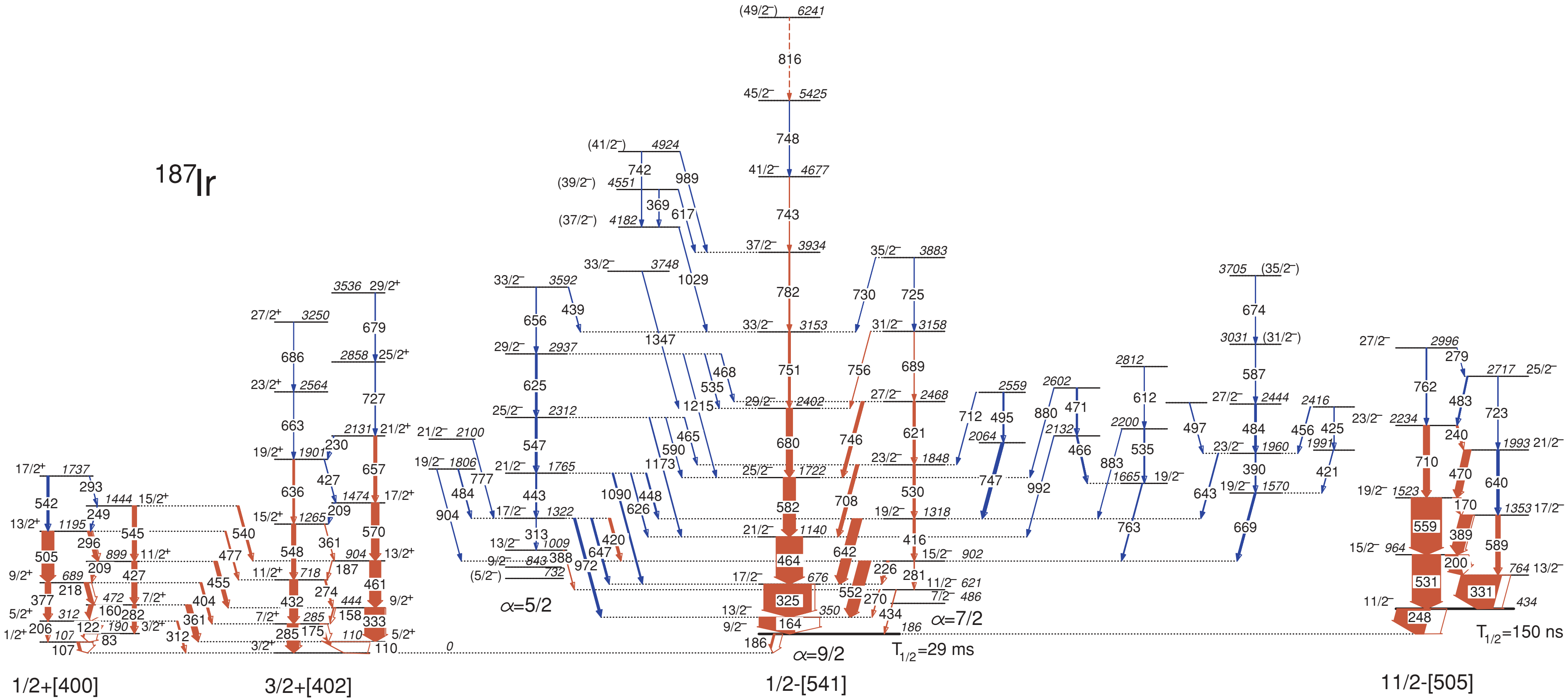
$\gamma \sim 36°$

Meyer-ter-Vehn model:
axial asymmetry deduced from energies



Cf. J. Meyer-ter-Vehn
PRL **32** 1383 (1974)

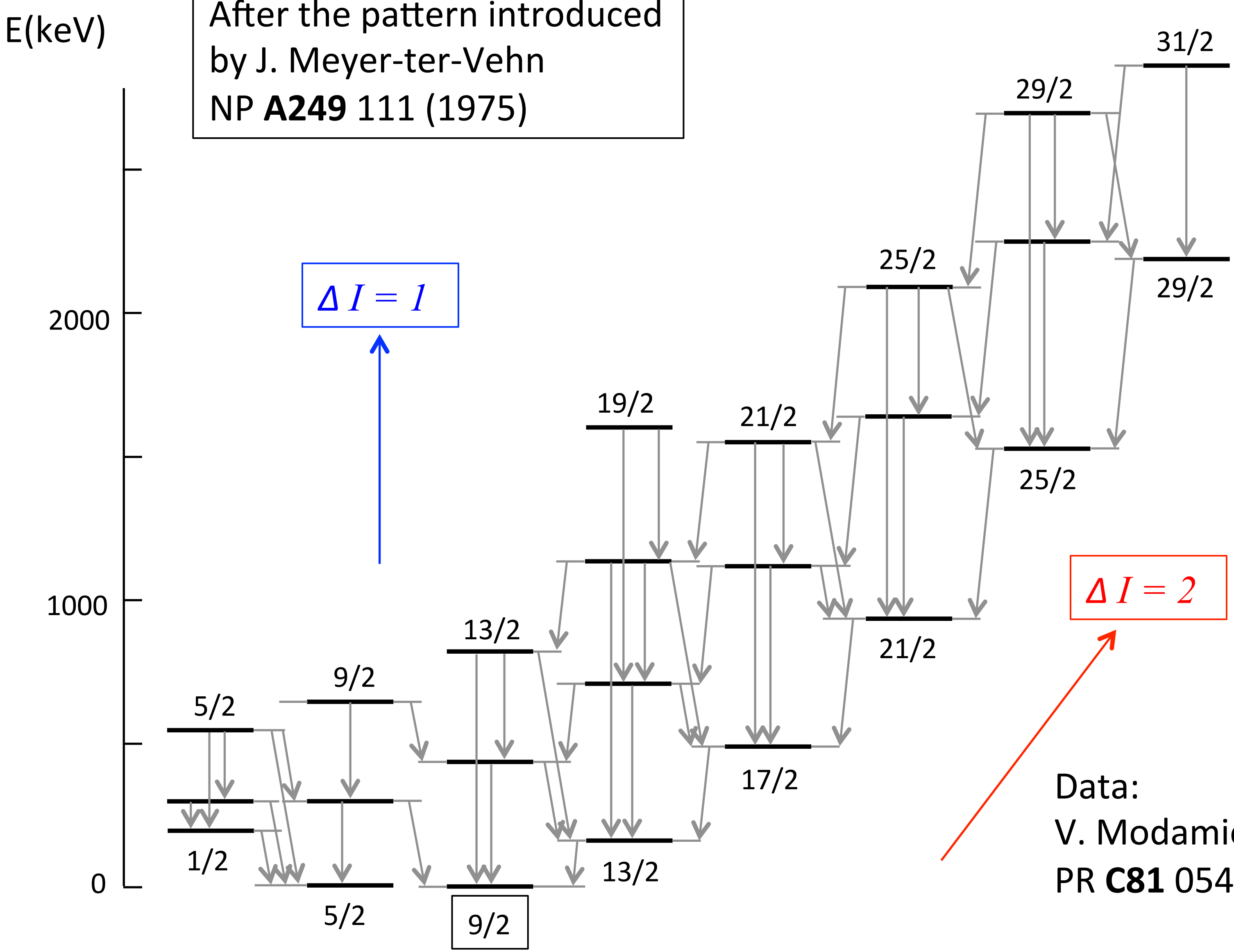
V. Modamio et al., PR C81 054304 (2010)



^{187}Ir:

bands associated with $h_{9/2}$

After the pattern introduced by J. Meyer-ter-Vehn NP **A249** 111 (1975)



Data:
V. Modamio et al.
PR **C81** 054304 (2010)

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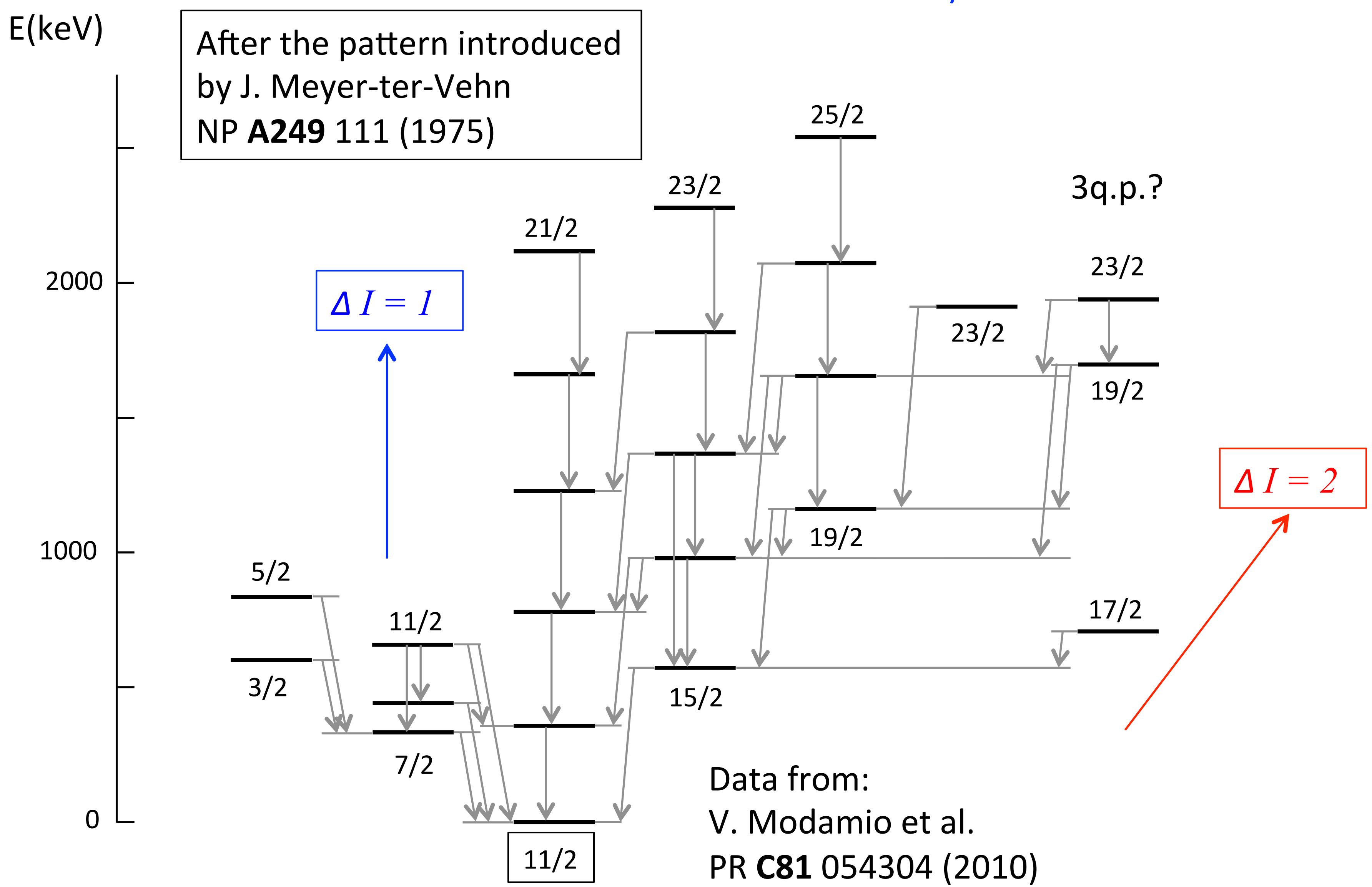
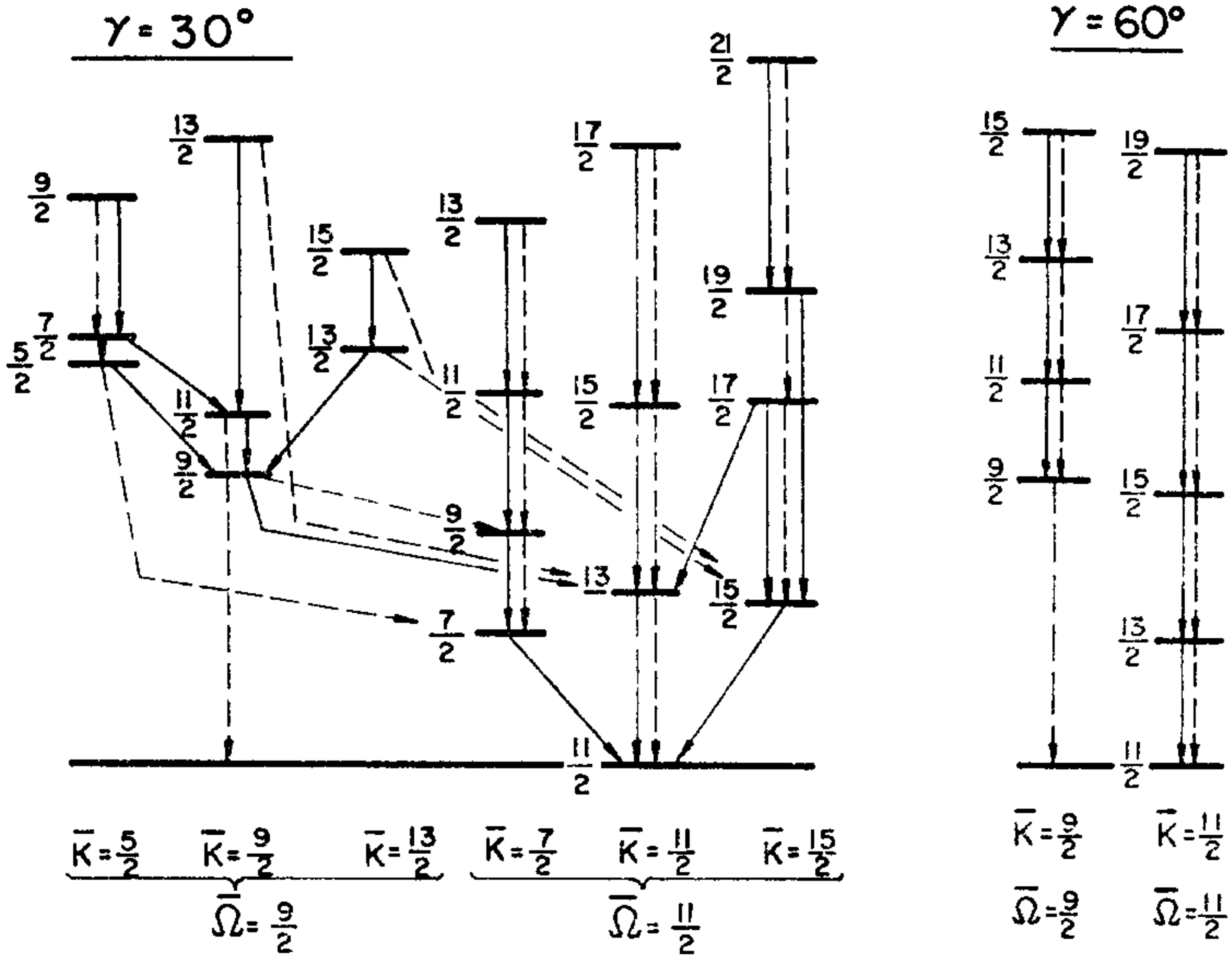


Data from:
V. Modamio et al.
PR **C81** 054304 (2010)

Single j coupled to triaxial rotor:

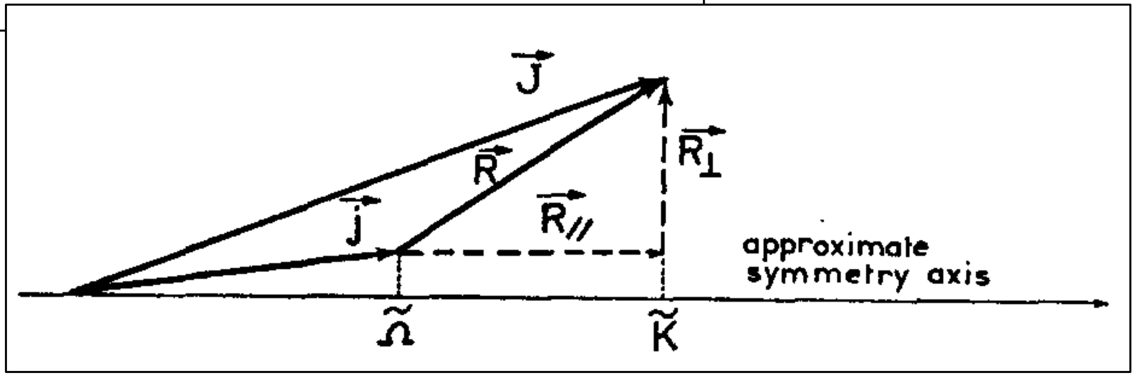
J. Meyer-ter-Vehn, NP **A249** 111 (1975)



Data from: I. Wiedenhöver et al., NP **A582** 77 (1995)
but pattern not recognized

^{125}Xe

$h_{11/2}$



7/2
5/2 896
$\tilde{K}$ = 5/2

$\tilde{\Omega}$ = 5/2

19/2 2508
19/2 2465
$\tilde{K}$ = 19/2
17/2 2175
15/2 1883
15/2 1660
13/2 1573
$\tilde{K}$ = 15/2
11/2 1341
9/2 887
11/2 920
$\tilde{K}$ = 11/2
7/2 266
$\tilde{K}$ = 7/2

$\tilde{\Omega}$ = 7/2

17/2 2255
19/2
21/2 2385
$\tilde{K}$ = 21/2
15/2 1586
17/2 1580
$\tilde{K}$ = 17/2
11/2 1024
5/2 762
$\tilde{K}$ = 5/2
13/2 894
$\tilde{K}$ = 13/2
9/2 253
$\tilde{K}$ = 9/2

$\tilde{\Omega}$ = 9/2

25/2 3055
27/2 3100
$\tilde{K}$ = 27/2
23/2 2811
19/2 2653
21/2
21/2 2167
23/2 2216
$\tilde{K}$ = 23/2
19/2 2006
17/2 1859
15/2 1310
17/2 1388
19/2 1441
$\tilde{K}$ = 19/2
7/2 608
$\tilde{K}$ = 7/2
13/2 737
15/2 797
$\tilde{K}$ = 15/2
11/2 311
$\tilde{K}$ = 11/2

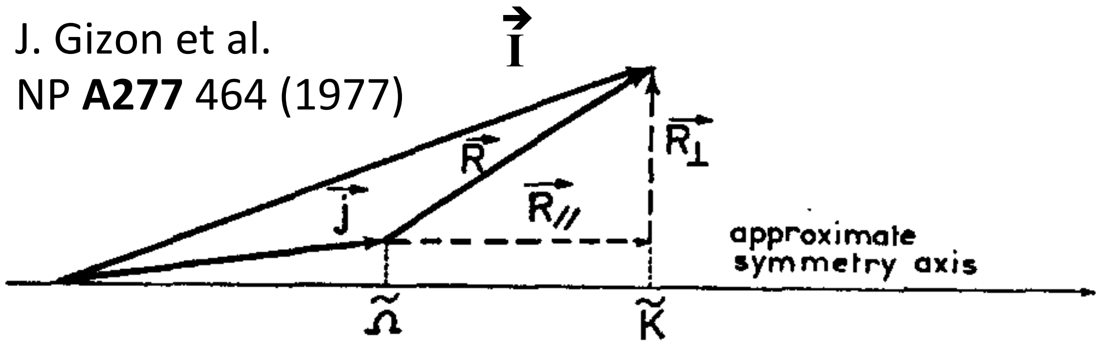
$\tilde{\Omega}$ = 11/2

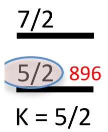
Data from: I. Wiedenhöver et al., NP **A582** 77 (1995)
but pattern not recognized

^{125}Xe

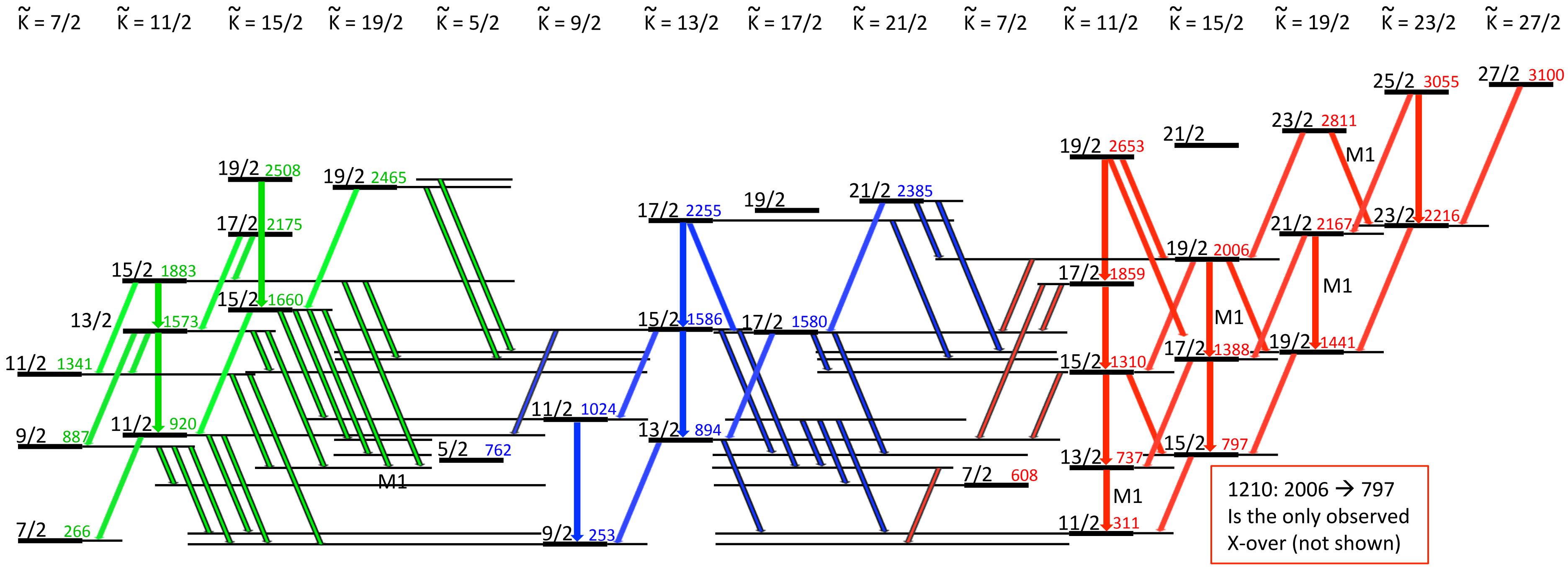
$h_{11/2}$

J. Gizon et al.
NP **A277** 464 (1977)





$\tilde{\Omega}$ = 5/2

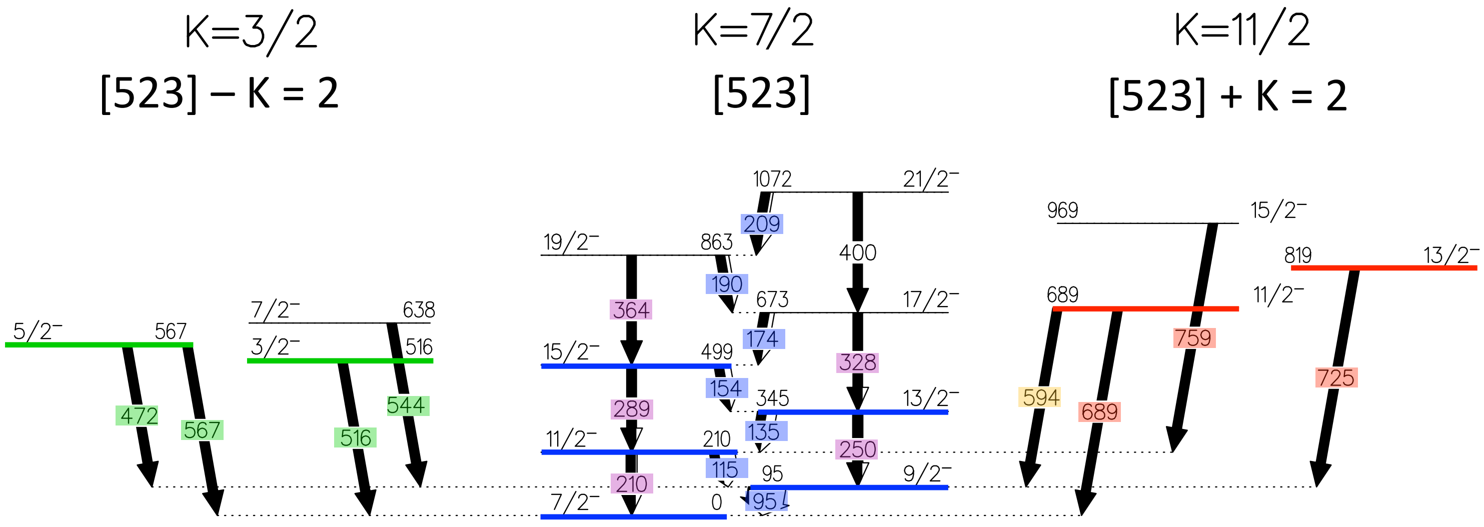


$\tilde{\Omega}$ = 7/2

$\tilde{\Omega}$ = 9/2

$\tilde{\Omega}$ = 11/2

"γ vibrations" of the prolate spheroid:
do not appear to be simple— "asymmetric" E2 MEs



J. Iwanicki, M. Zielińska et al., JP **G29** 743 2003

^{165}Ho