Exotic rotations and seniority isomers in Nd nuclei

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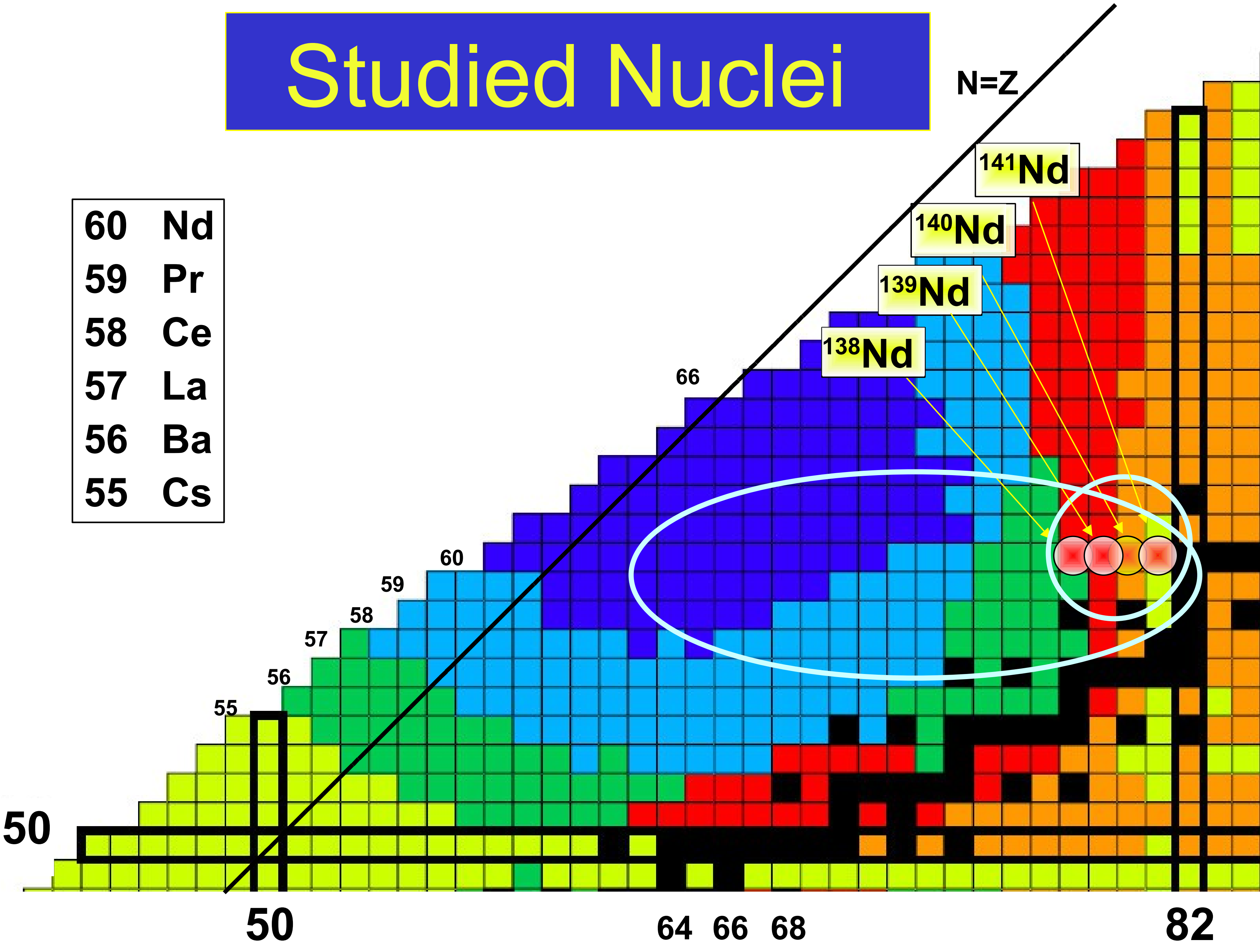
1. Exotic rotations - GASP, Legnaro (Italy)
   - Euroball, Strasbourg (France)
   - Jurogam+RITU, Jyvaskyla (Finland)

2. Seniority isomers - Jurogam+RITU, Jyvaskyla (Finland)

Studied Nuclei



CNS calculations for ^{138}Nd : high spins !

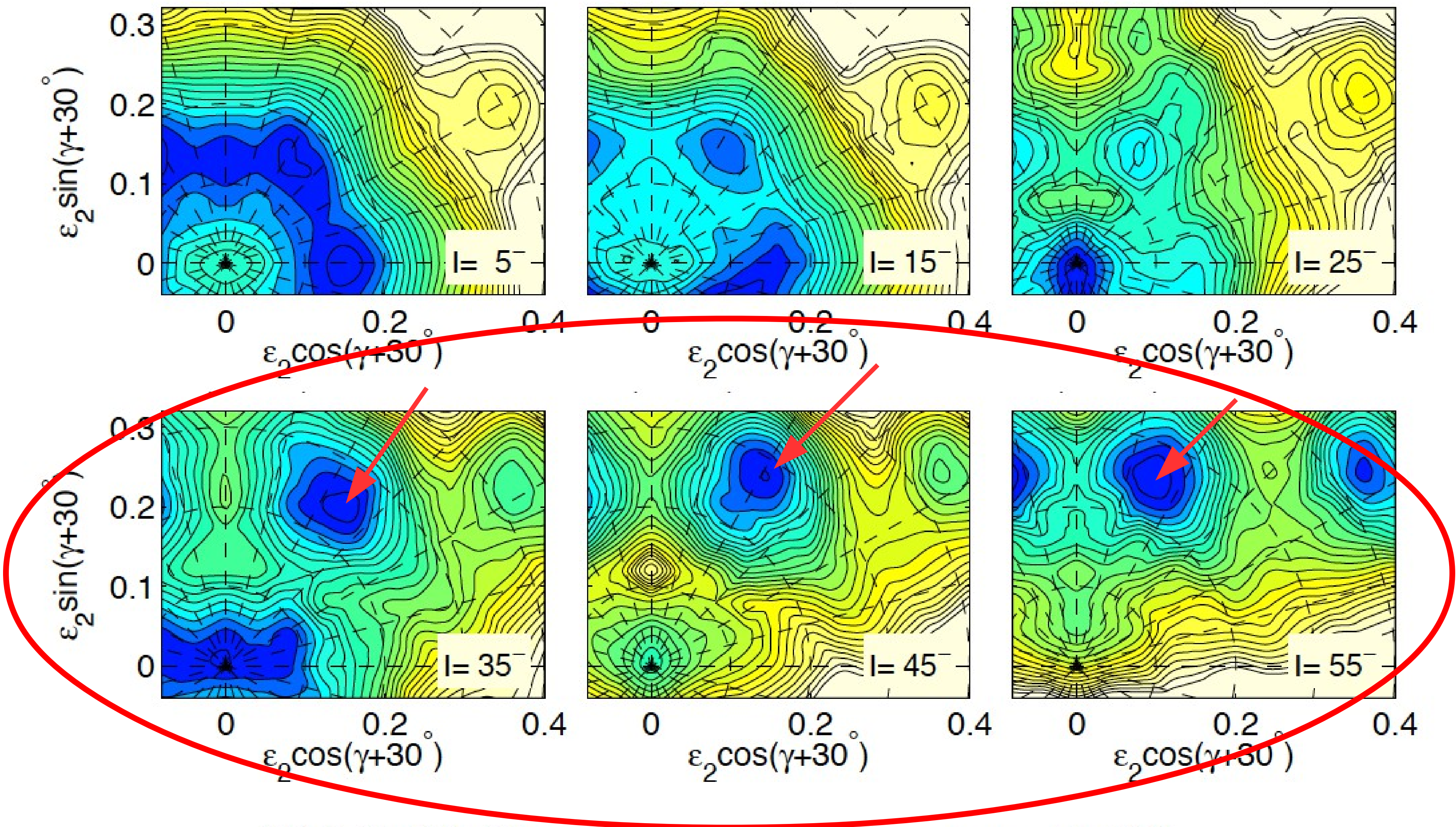


FIG. 3: The PES of the configuration $\pi_p = -, \alpha_p = 1, \pi_n = +, \alpha_n = 0$ for ^{138}Nd.

I. Ragnarsson

CNS calculations for ^{138}Nd

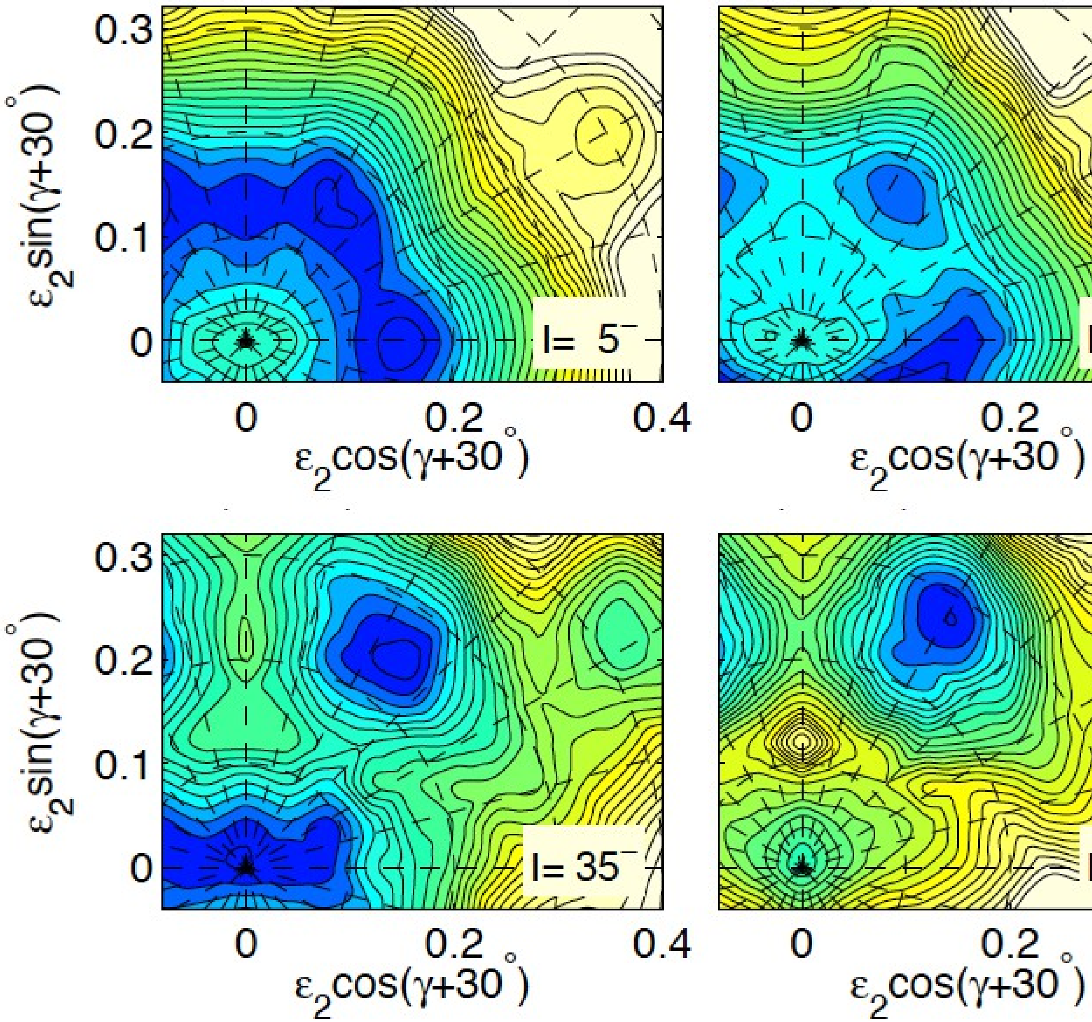
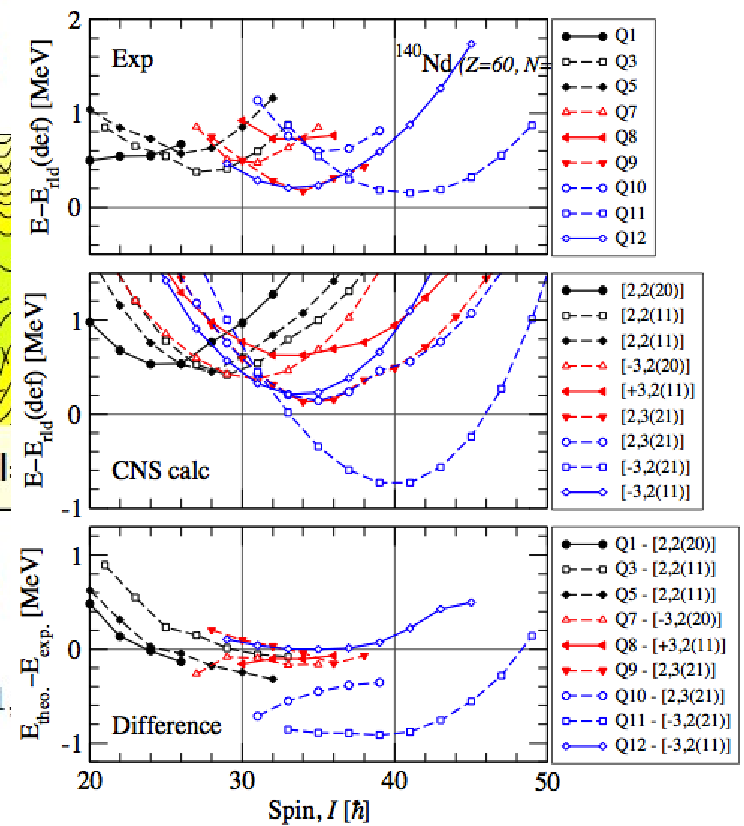
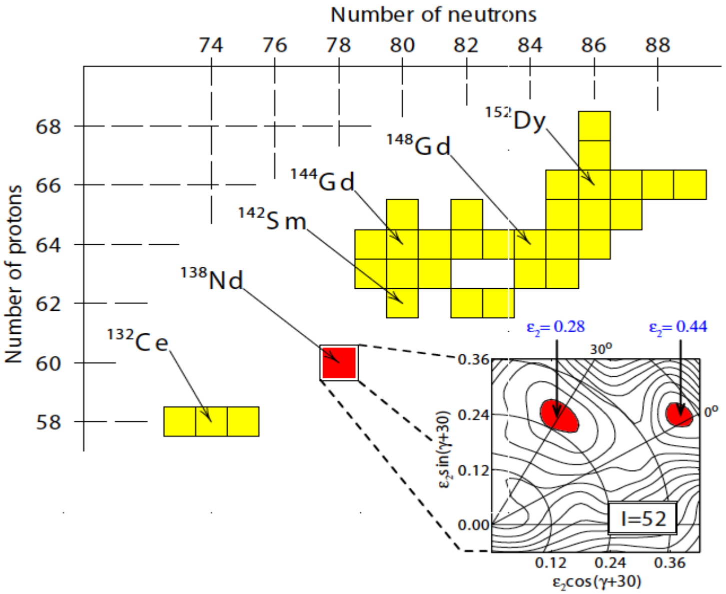


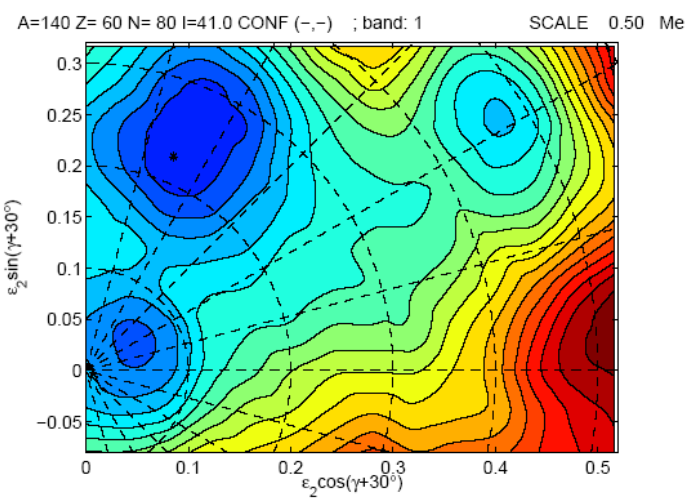
FIG. 3: The PES of the configuration $\pi_p = -, \alpha_p = 1,$

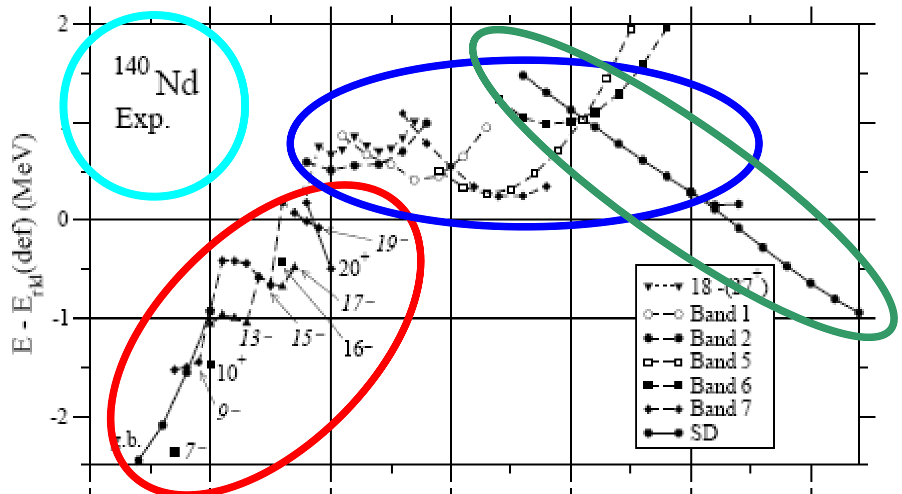


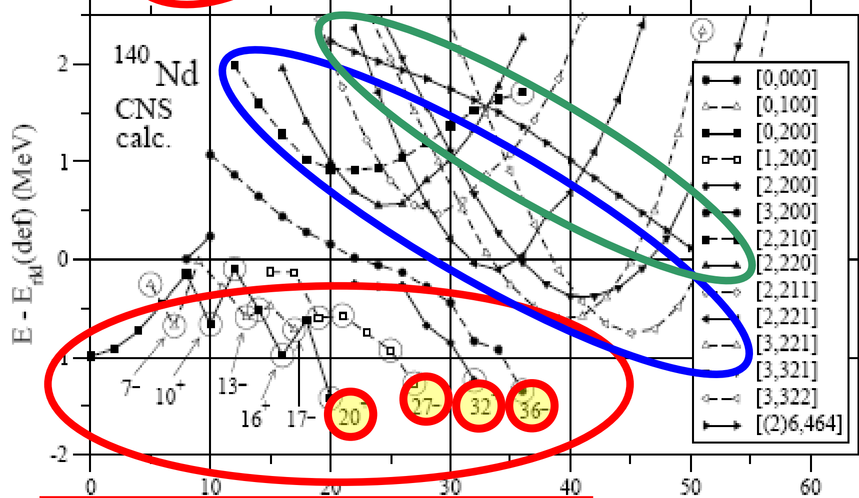
I. Ragnarsson

Stable triaxiality: ~ +30° for N<82









$[\ (d_{5/2}g_{7/2})^{-4}_{10+}\ \ (h_{11/2})^{-2}_{10+}\ ]_{20+}$

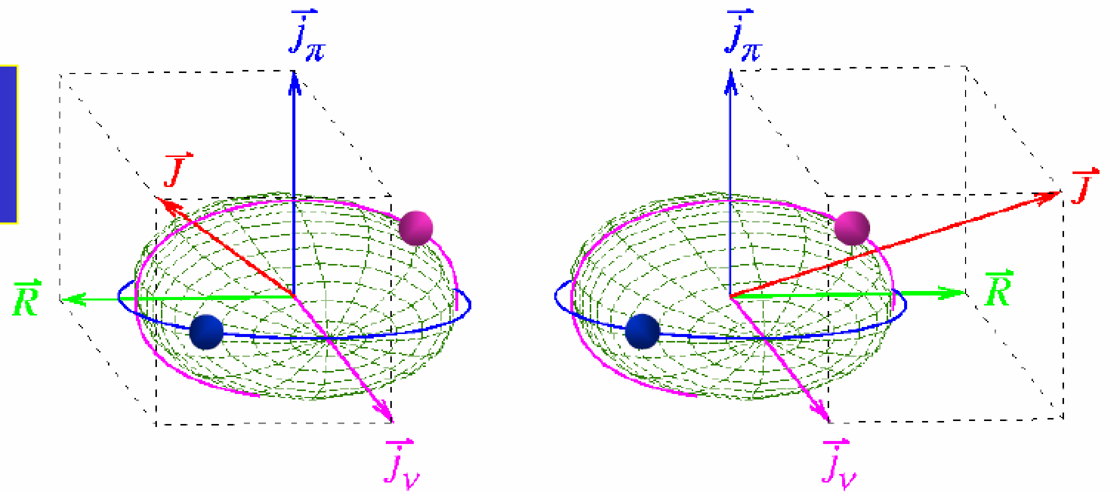
PRC 61 (1999); 69 (2004); 70 (2004); 72 (2005); 74 (2006); 84 (2011); 86 (2012); 87 (2013); 88 (2013); 88 (2013)R

Triaxiality at high spins

Chiral Geometry in Nuclei

Mutually orthogonal coupling of three angular momenta in odd-odd nuclei

Chiral mode

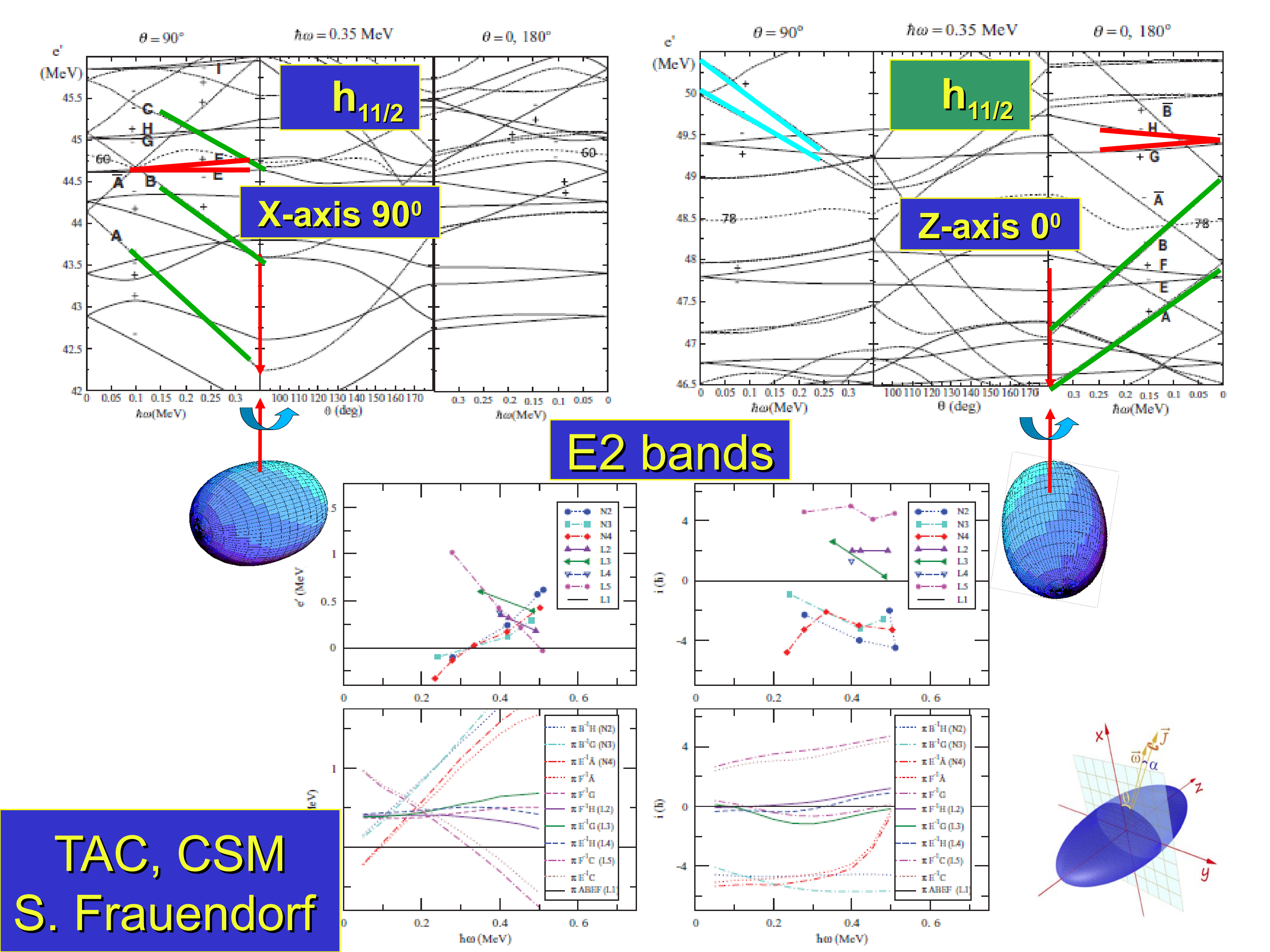


Wobbling mode

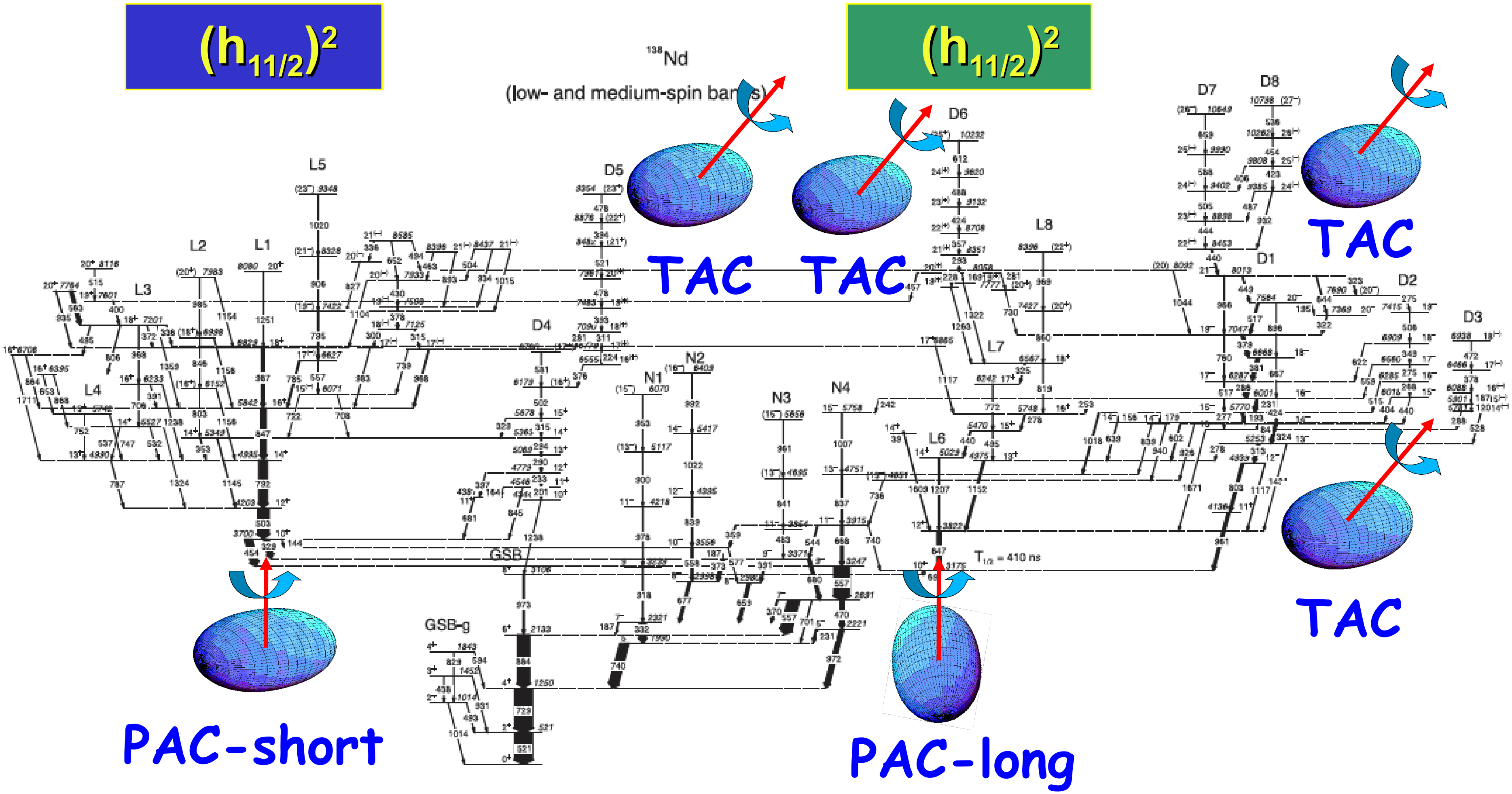
$$E(I, n_{\text{wobb}}) = \frac{I(I+1)}{2\mathcal{J}_x} + \hbar\omega_{\text{wobb}}\left(n_{\text{wobb}} + \frac{1}{2}\right)$$

$$\hbar\omega_{\text{wobb}} = \hbar\omega_{\text{rot}}\sqrt{\frac{(\mathcal{J}_x - \mathcal{J}_y)(\mathcal{J}_x - \mathcal{J}_z)}{\mathcal{J}_y \mathcal{J}_z}}$$

$$\hbar\omega_{\text{rot}} = \frac{I}{\mathcal{J}_x}$$

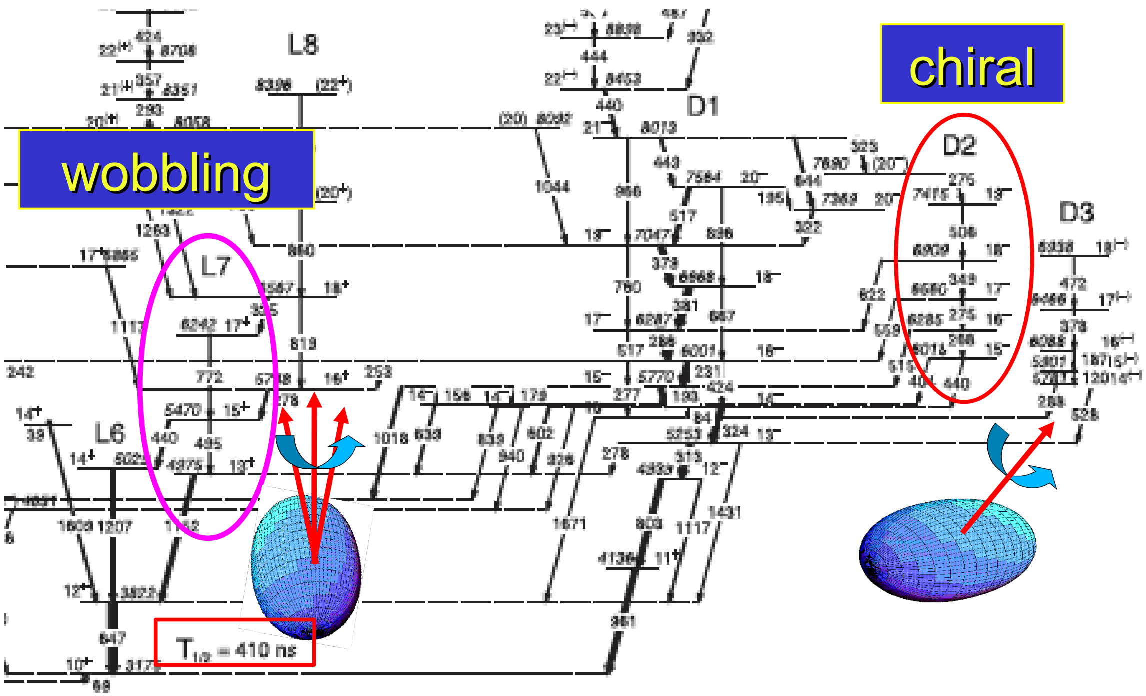

h11/2
X-axis 90°
θ = 90°
ħω = 0.35 MeV
θ = 0, 180°
e' (MeV)
ħω(MeV)
θ (deg)
h11/2
Z-axis 0°
E2 bands
TAC, CSM
S. Frauendorf

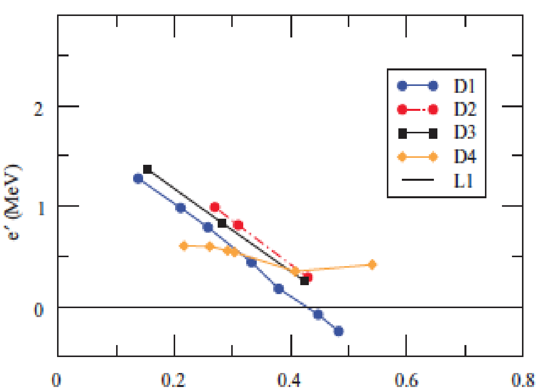
^{138}Nd – 21 bands at medium spins !

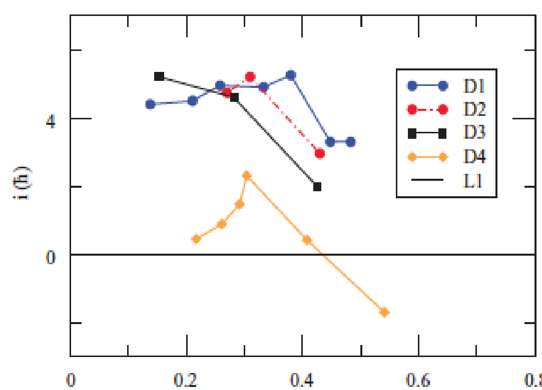


C. Petrache et al., PR C86, 044321 (2012)

^{138}Nd







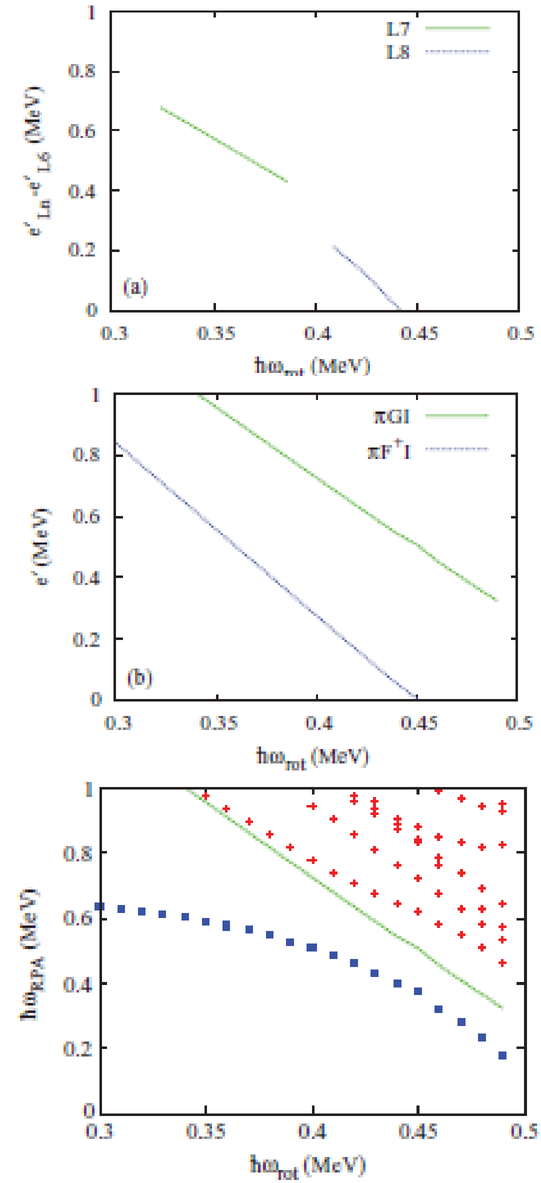


FIG. 18. (Color online) Calculated excitation energies of the RPA solutions built on the aligned $\nu 10$ configuration as functions of the rotational frequency in ^{138}Nd. Among them, the collective solution is emphasized by blue squares. Note that noncollective solutions are occasionally overlooked in the present algorithm, which however does not have any consequences for the discussion. The green dotted curve is the unperturbed πGI state.

C. Petrache et al., PR C86, 044321 (2012)

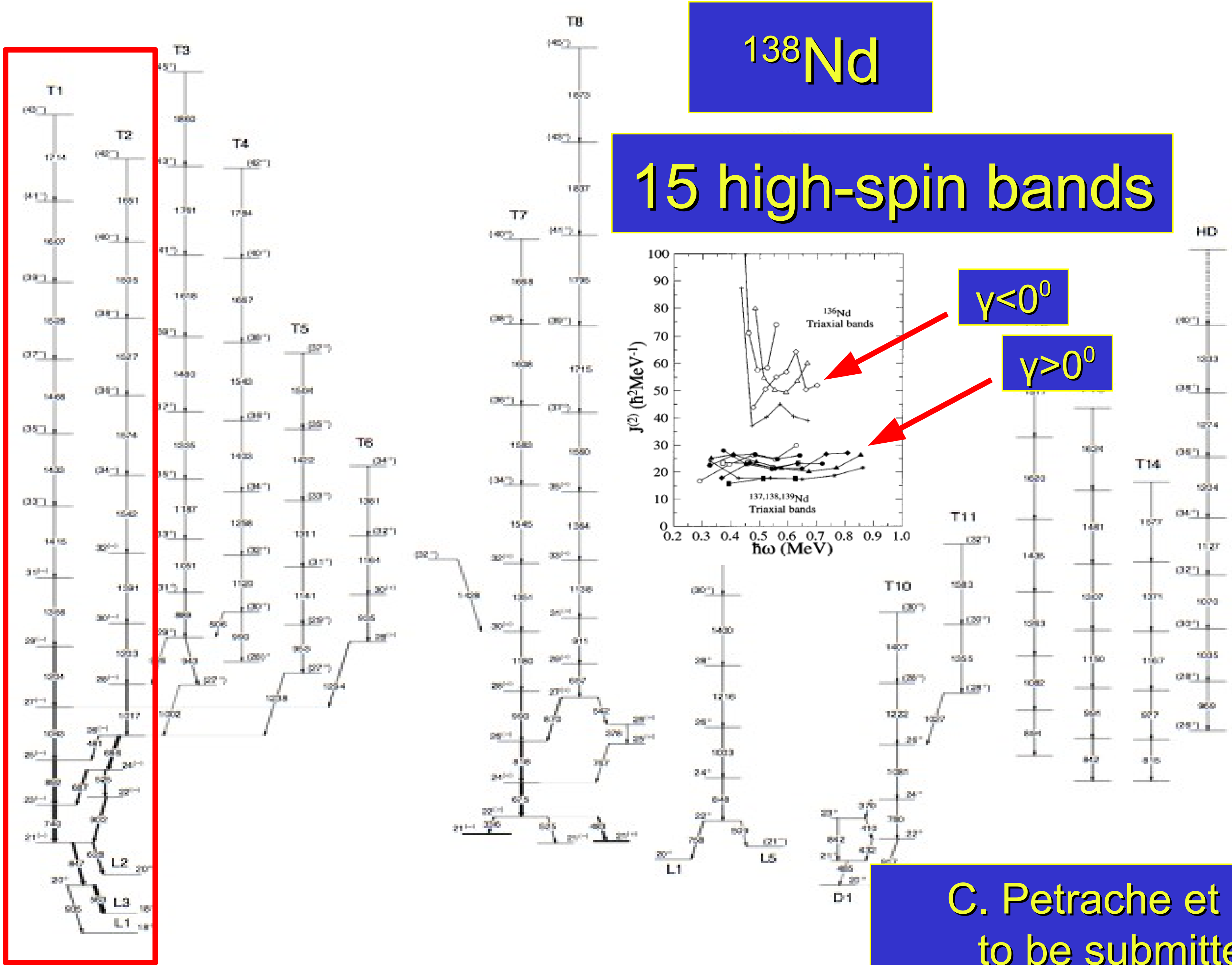
Configuration assignments for the 21 bands at low and medium spin of ^{138}Nd

TABLE IV. Configuration assignments to the low- and medium-spin bands of ^{138}Nd in terms of particle-hole excitations with respect to the $\pi ABEF = \pi 10$ reference configuration assigned to band L1 or the corresponding quasiproton vacuum for small finite pairing. The rotation axis is also indicated, which can be tilted (TAC) or parallel to a principal axis (PAC) of the intrinsic reference system of the nucleus. In the case of PAC, l and s indicate the long and short axes, respectively.

Band	Intensity (%)	Configuration	Rotation type	States	Comments
g band	100	$\pi 0 \otimes \nu 0$		2^+-8^+	
γ band		γ band		2^+-4^+	Decays to g band
N1	39	$\pi 0 \otimes \nu B^{-1} H \nu 10$	PAC-l	$5_1^- - 15^-$	Decays to g band
N2	14	$\pi B^{-1} H \pi 10 \otimes \nu 0$	PAC-s	$8_2^- - 16^-$	Decays to N1, N3, 8_1^-
N3	2	$\pi B^{-1} G \pi 10 \otimes \nu 0$	PAC-s	$9_2^- - 15^-$	Decays to N2, N4, 8_1^-
N4	89	$\pi E^{-1} \bar{A} \pi 10 \otimes \nu 0$	PAC-s	$7_2^- - 15^-$	Decays to N1, N3, GSB
8_1^-	17	$\pi F^{-1} \bar{A} \pi 10 \otimes \nu 0$	PAC-s	$8_1^-, 8_2^-$	Decays to N1
L1	64	$\pi 10 \otimes \nu 0$	PAC-s	10^+-20^+	Decays to N2, N3
L2	6	$\pi F^{-1} H \pi 10 \otimes \nu 0$ or $\pi E^{\dagger} F^{\dagger} \pi 10 \otimes \nu 0$	PAC-s	$14^+, 16^+, 18^+$	Decays to L1
L3	2	$\pi E^{-1} G \pi 10 \otimes \nu 0$ or $\pi F^{\dagger} H \pi 10 \otimes \nu 0$	PAC-s	14^+-20^+	Decays to L1, L4
L4	2	$\pi E^{-1} H \pi 10 \otimes \nu 0$	PAC-s	$13^+, 15^+$	Decays to L1, L3
L5	8	$\pi F^{-1} C \pi 10 \otimes \nu 0$ or $\pi 10 \otimes \nu h^2$	PAC-s	$15^{(-)}-23^{(-)}$	Decays to L1, D4
L6	24	$\pi 0 \otimes \nu 10$	PAC-l	10^+-14^+	Band head is isomeric
L7	11	wobbling or $\pi 0 \otimes \nu F^{-1} G \nu 10$ or $\pi G I \pi 0 \otimes \nu 10$	PAC-l	13^+-17^+	Decays to L6
L8	2	$\pi 0 \otimes \nu E^{-1} G \nu 10$ or $\pi F^{\dagger} I \pi 0 \otimes \nu 10$	PAC-l	16^+-22^+	Decays to L7
D1	21	$\pi F^{-1} \bar{A} \pi 10 \otimes \nu 10$	TAC	$13^- - 21^-$	Decays to N4, L8
D2	2	$\pi E^{-1} \bar{A} \pi 10 \otimes \nu 10$ or chiral	TAC	$15^- - 19^-$	Decays to D1
D3	1	$\pi B^{-1} G \pi 10 \otimes \nu 10$	TAC	$14^- - 18^-$	Decays to nonyrast $\pi = -$
D4	5	$\pi F^{-1} I \pi 10 \otimes \nu 0$ or $\pi F^{-1} \bar{A} \otimes \nu b^{-1} g$	TAC	10^+-17^+	Decays to L1 and GSB
D5	1	$\pi 10 \otimes \nu 10$	TAC	$16^{(+)}-23^{(+)}$	Decays to D4 and $\pi = -$
D6	4	$\pi F^{-1} I \pi 10 \otimes \nu 10$ or $\pi E^{-1} H \otimes \nu 10$	TAC	$19^{(+)}-(25^+)$	Decays to L7
D7	3	$\pi F^{-1} C \pi 10 \otimes \nu 10$	TAC	$22^{(-)}-(26^-)$	Decays to D1
D8	2	$\pi E^{-1} C \pi 10 \otimes \nu 10$	TAC	$24^{(-)}-(27^-)$	Decays to D7

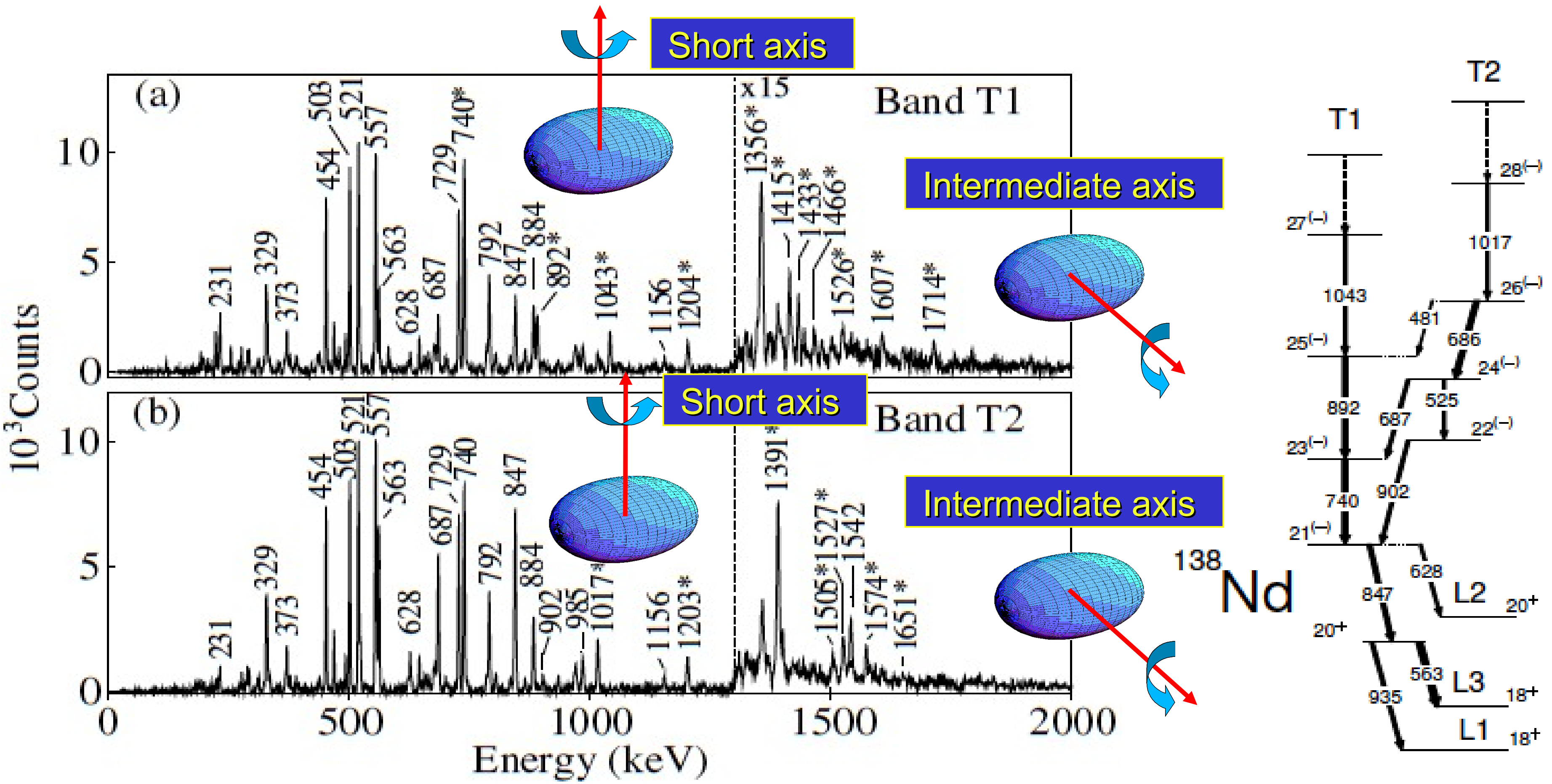
^{138}Nd

15 high-spin bands



C. Petrache et al., to be submitted

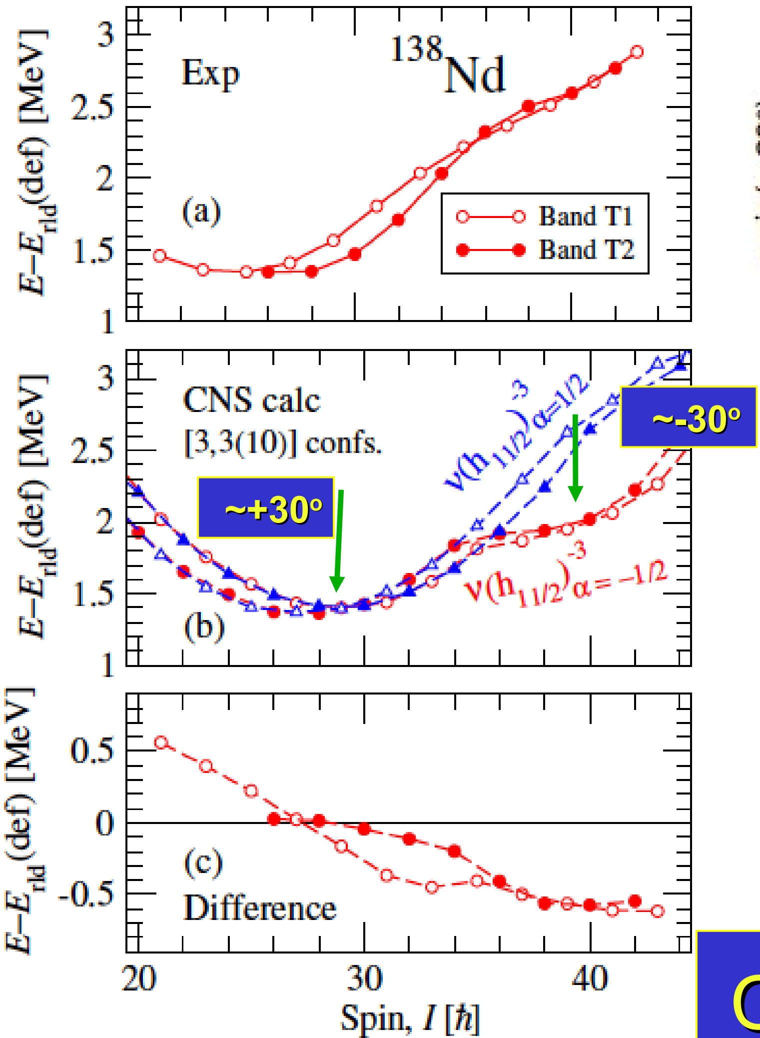
Switch of rotation from short to intermediate axis at high spin in ^{138}Nd

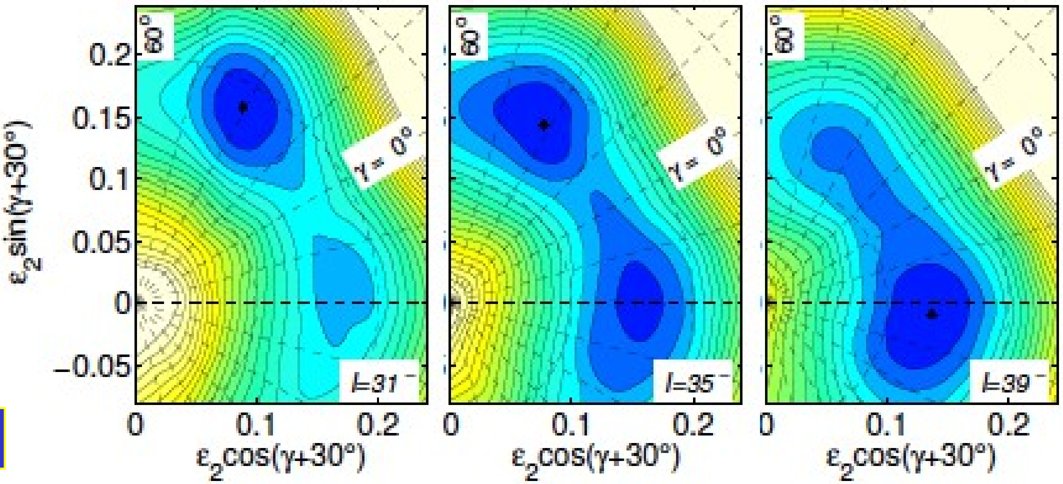


C. Petrache et al., PRC(R) 2013

Existence of triaxial shapes with γ > 0° and γ < 0°

CNS calculations for ^{138}Nd – I. Ragnarsson

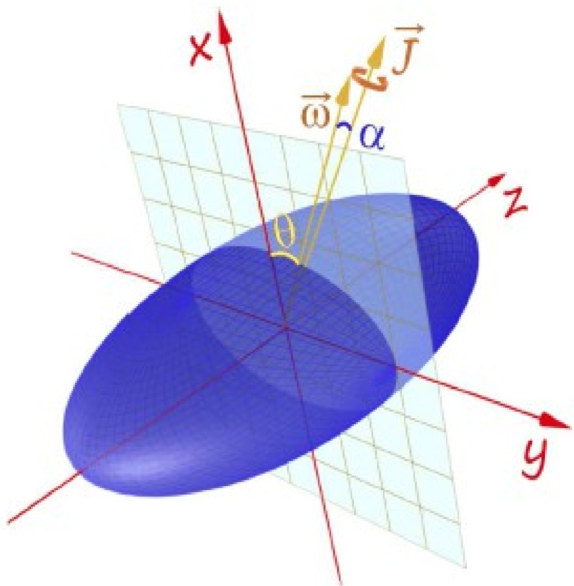


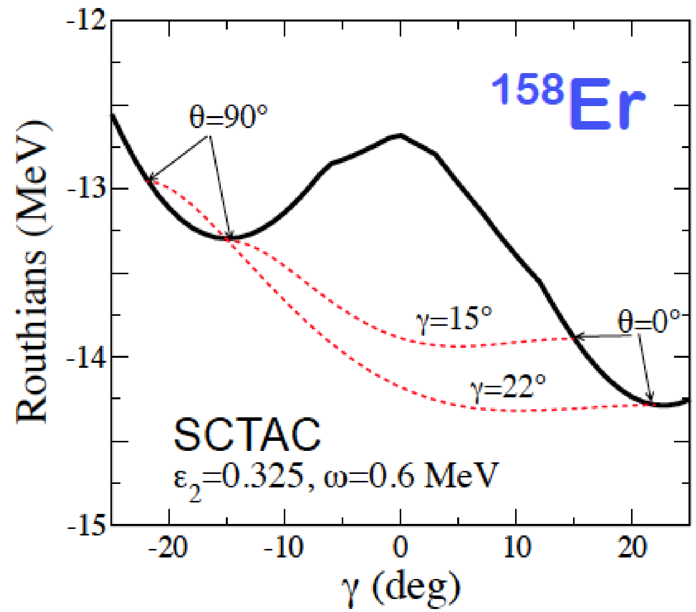


Calculated potential energy surfaces in the (ε_2,γ)-plane, illustrating the shape change around I = 35 for the [3,3(10)] configuration assigned to the T1 band. The contour line separation is 0.25 MeV.

C. Petrache et al., PRC(R) 2013

SCTAC calculations for ^{158}Er



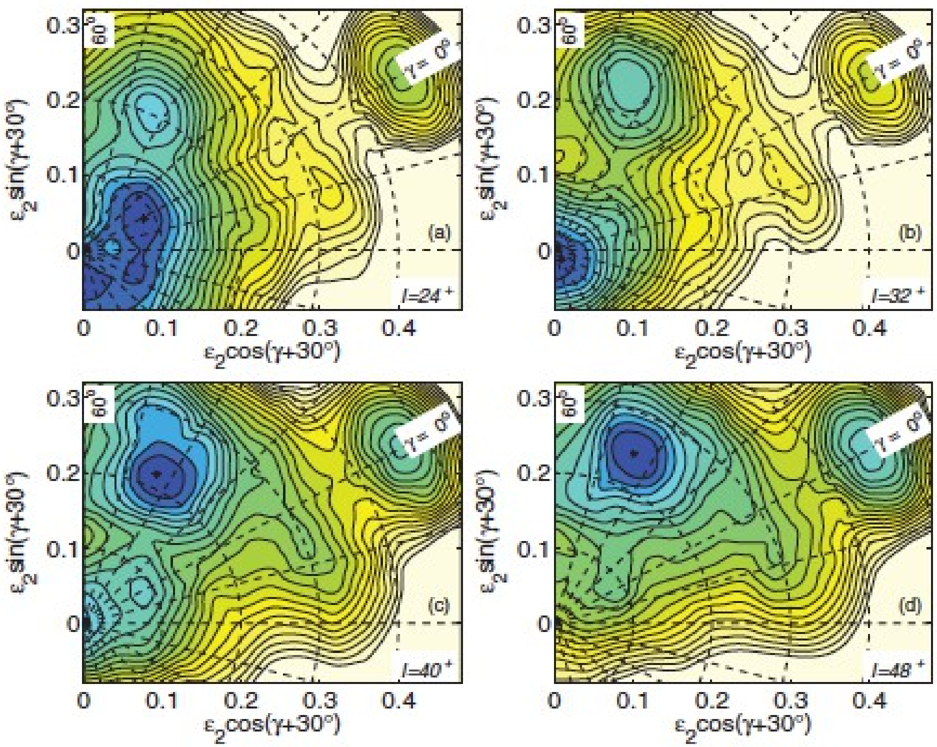


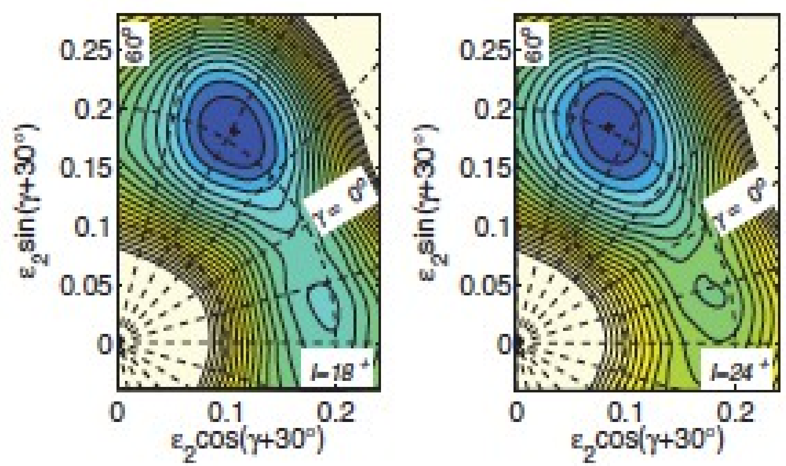
minimum that represents a TSD band. We have thus clarified a long-standing question pertaining to the nature of positive- and negative-γ bands associated with the same intrinsic shape in the PAC approach: the rotation of a well-deformed, slightly triaxial configuration can be either about a short or medium axis, but not about both.

Y. Shi et al., PRL 108, 092501 (2012)

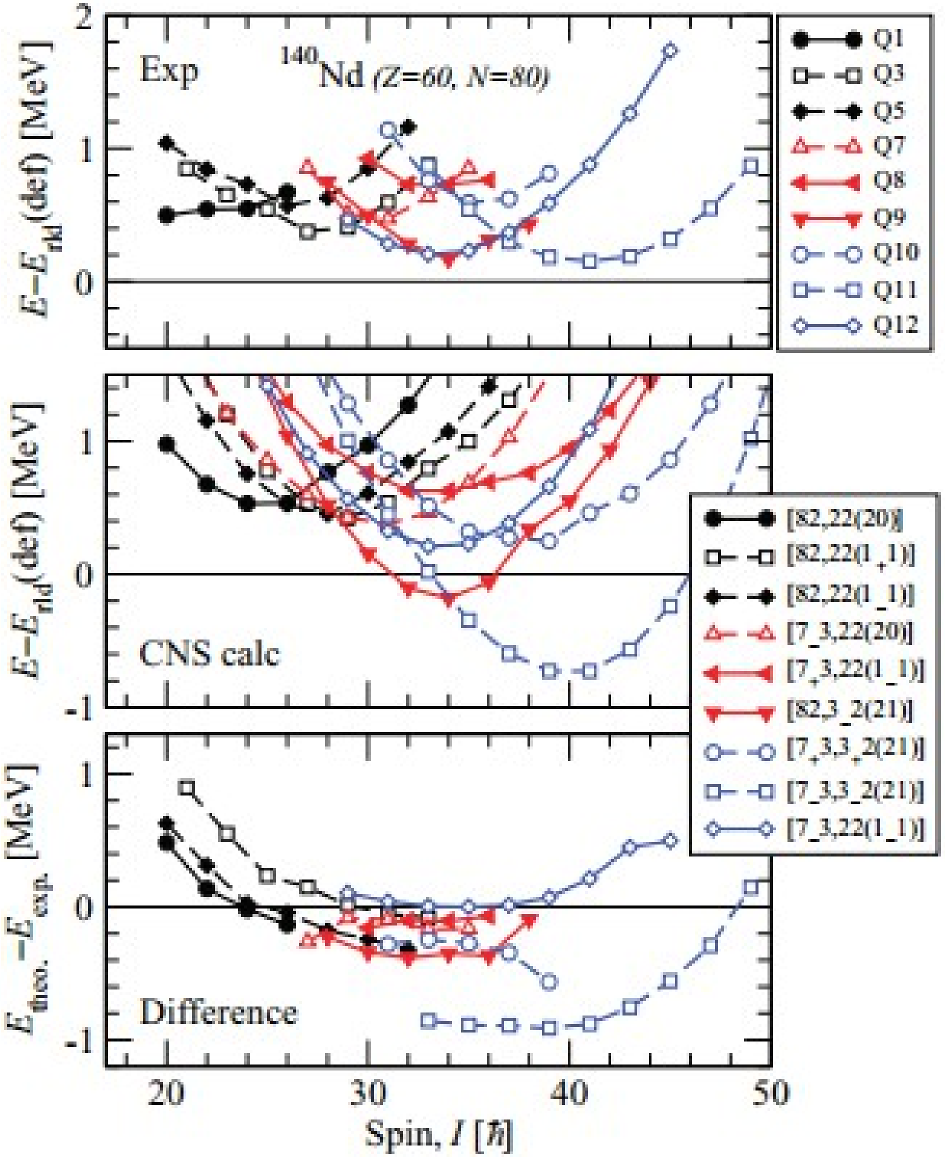
Existence of stable triaxial shape at high spins in Lanthanides with N < 82 : ^{140}Nd

CNS calculations for ^{140}Nd for $(I,\pi)=(\text{even},+)$ and for the [82,22(20)] configuration of band Q1

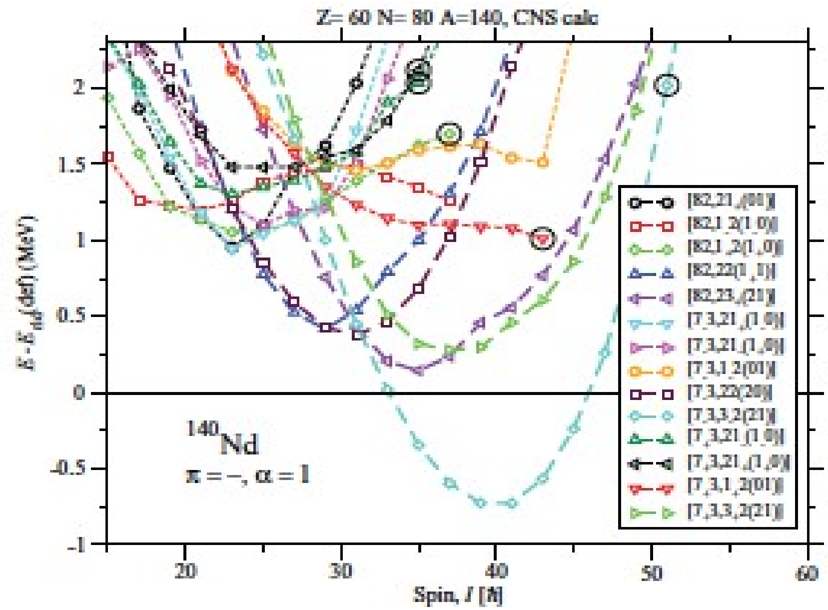




Comparison CNS - experiment for ^{140}Nd



Energies relative to a axially deformed rotating liquid drop



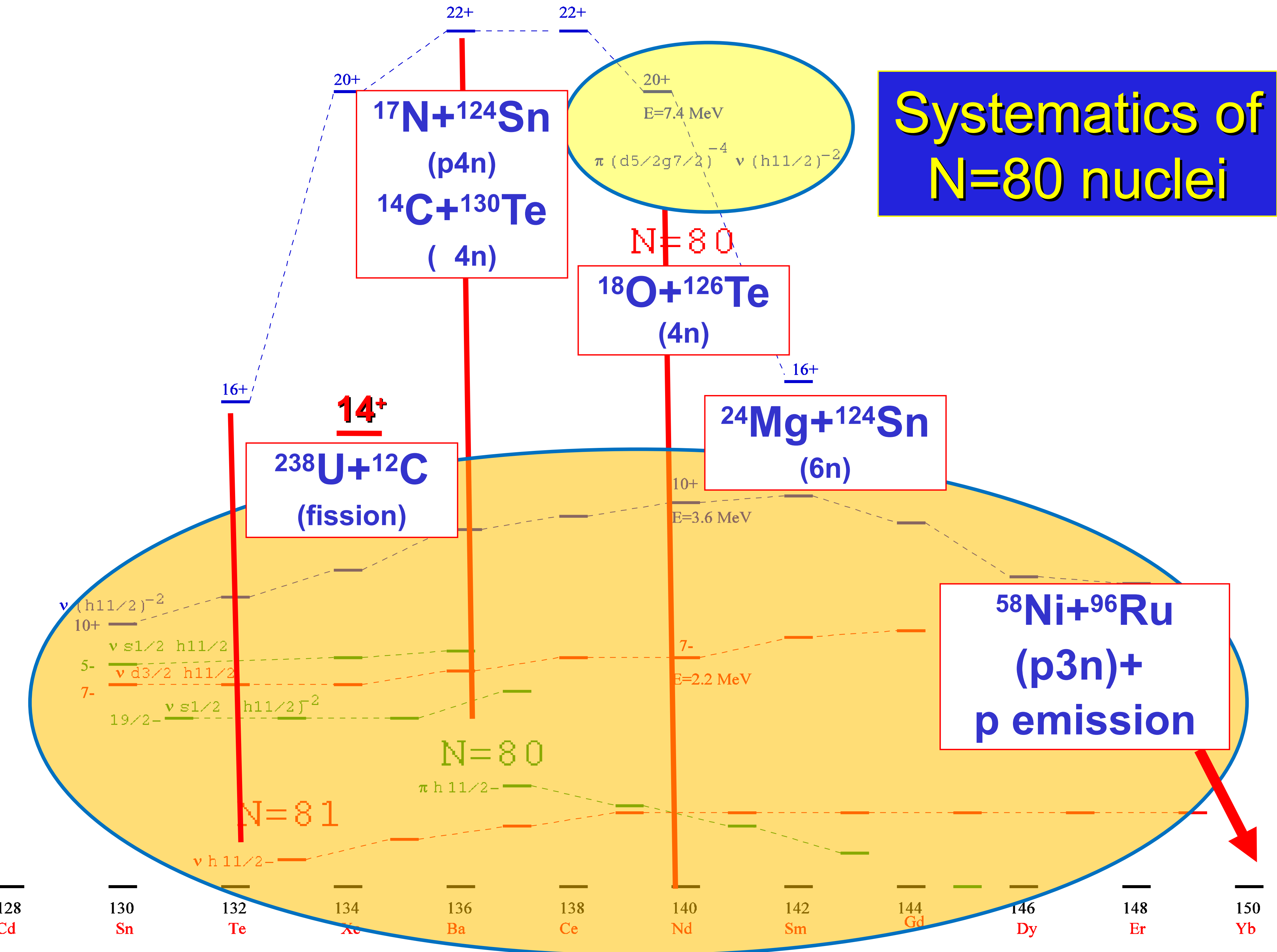
Leguillon et al, PRC 88, 014323 (2013)

Seniority isomers in nuclei around the N=82 shell closure

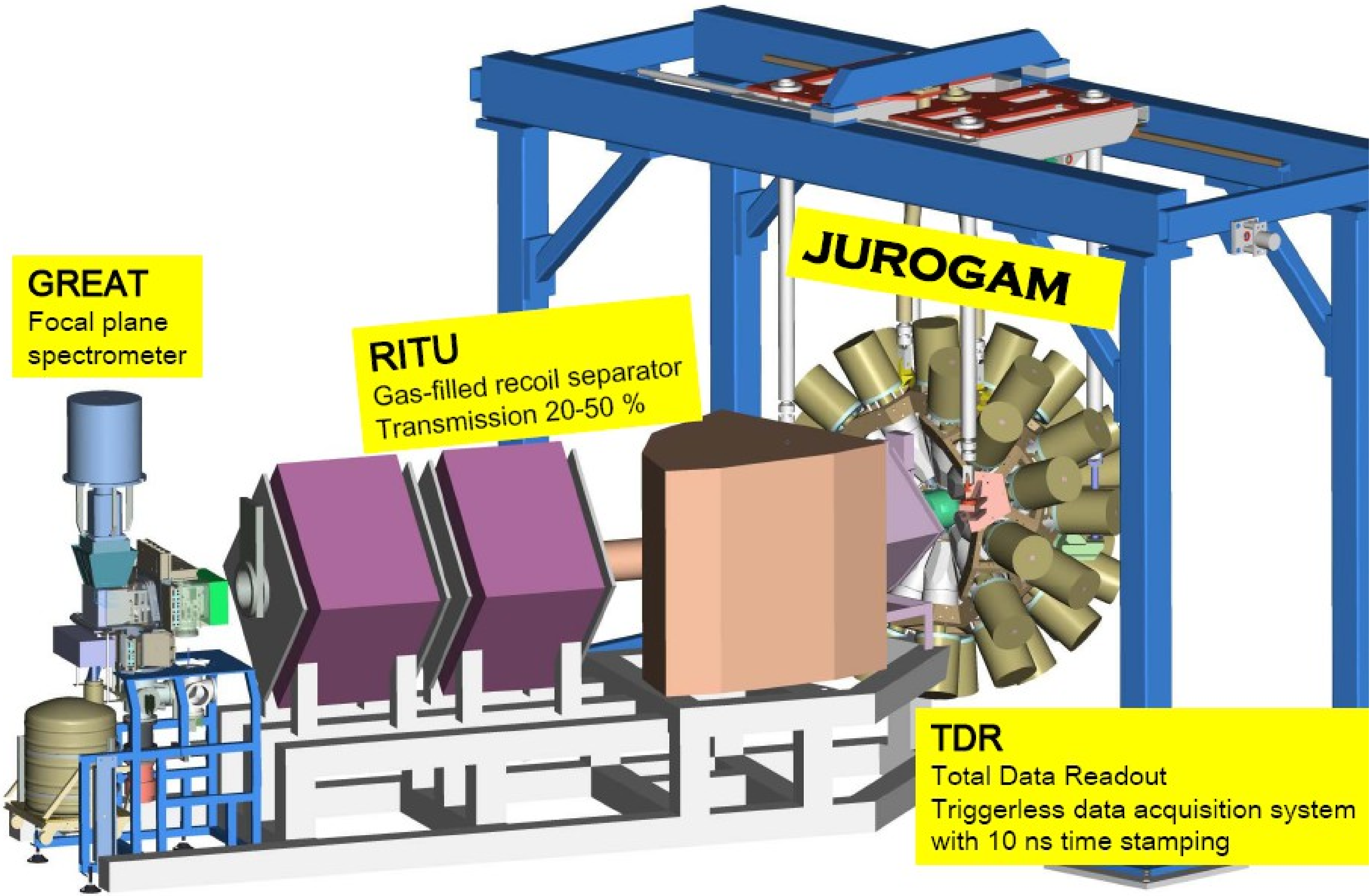
Why study of isomers ?

- Constraints for matrix elements of effective residual interactions used in the shell-model calculations
- Improve the predictive power of effective interactions for neutron-rich nuclei

Systematics of N=80 nuclei



JUROGAM+RITU at Jyväskylä (^{48}Ca + ^{96}Zr)



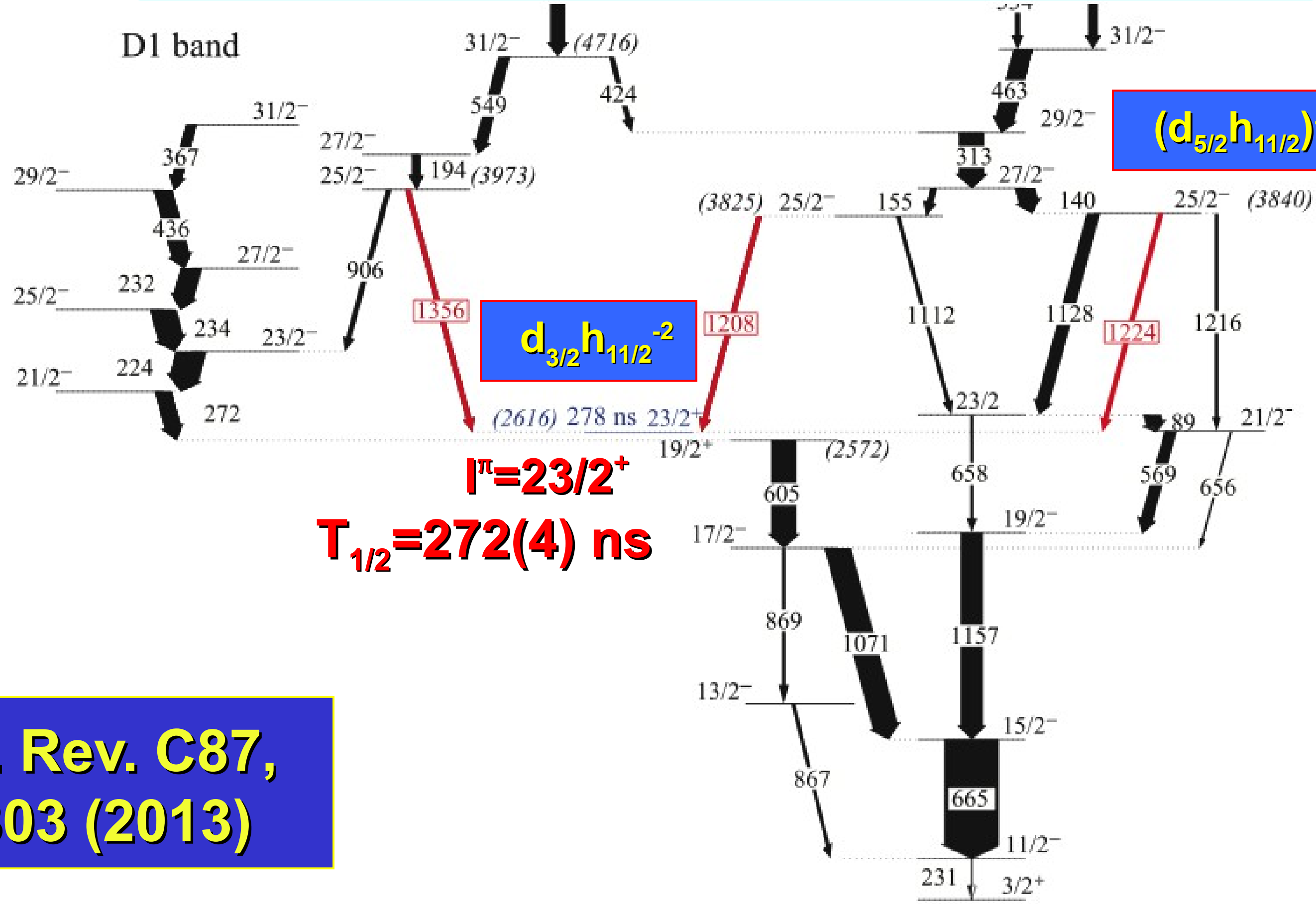
Ga

Isomers in nuclei close to N=82

Level scheme of ^{139}Nd

JUROGAM II + RITU

Prompt γ-rays + recoil selection



$(d_{5/2}h_{11/2})^{-2}$ $(s_{1/2}/d_{3/2})h_{11/2}^{-2}$

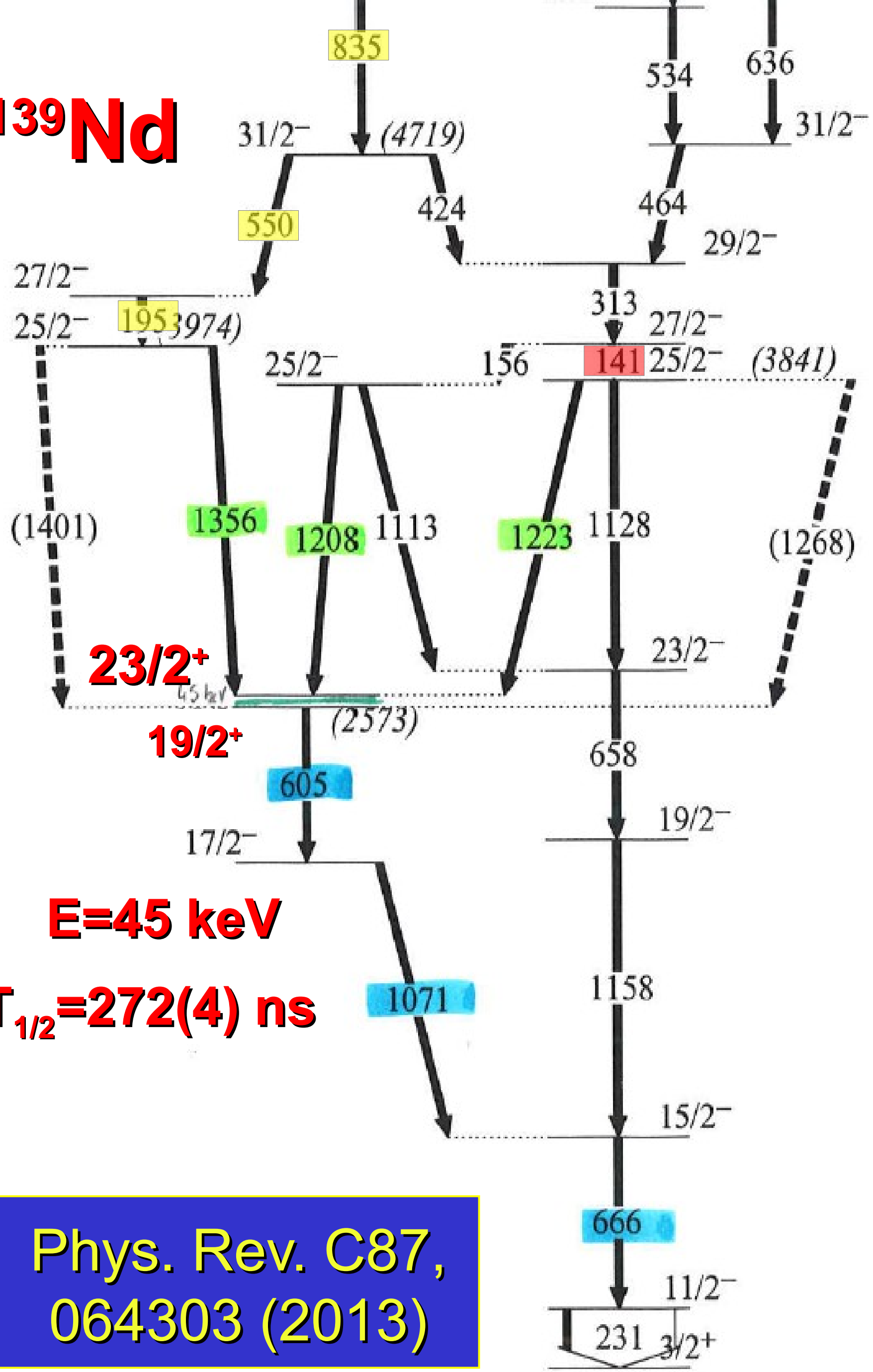
$d_{3/2}h_{11/2}^{-2}$

$I^{\pi}=23/2^{+}$

$T_{1/2}=272(4)$ ns

Phys. Rev. C87, 064303 (2013)

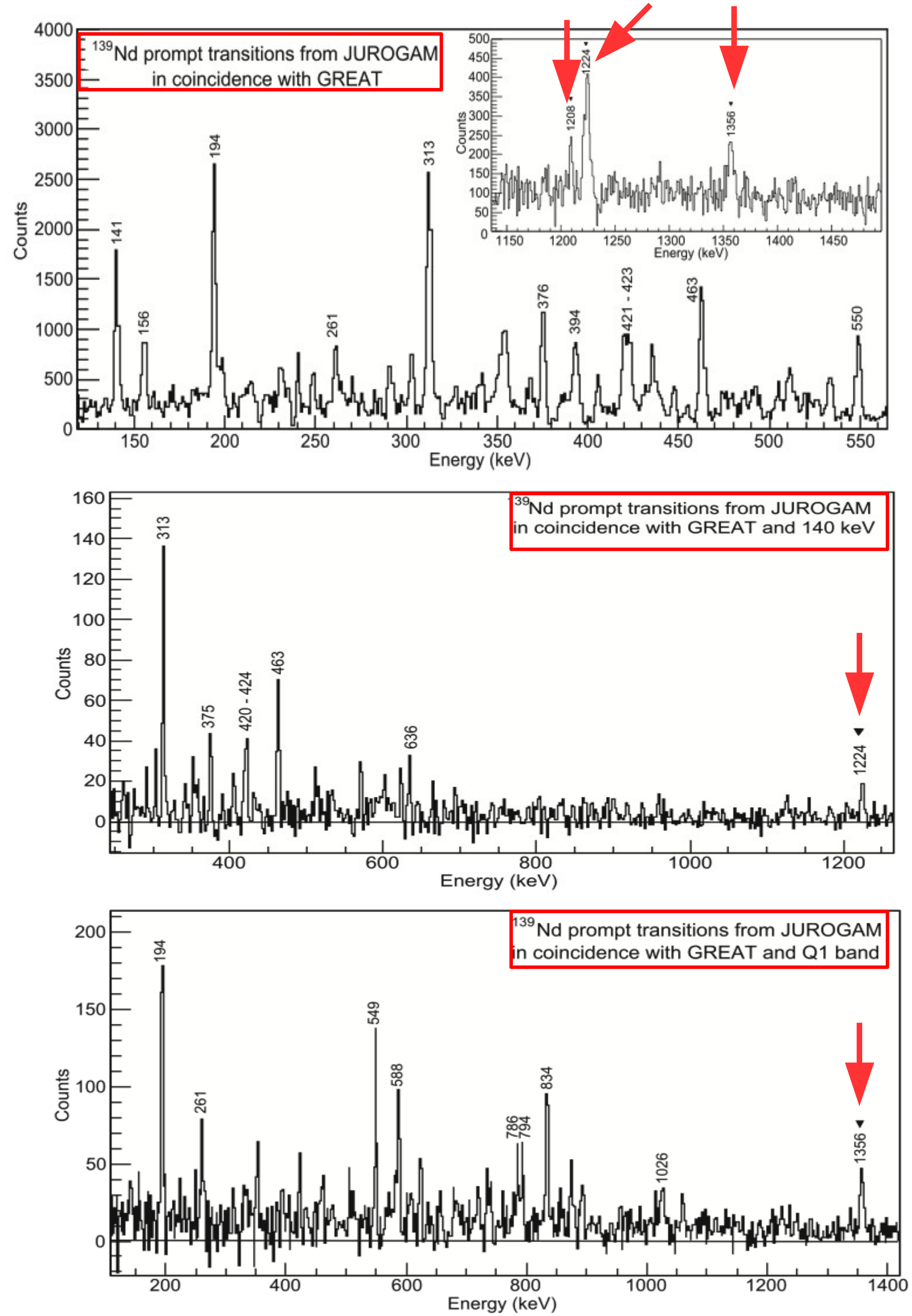
^{139}Nd



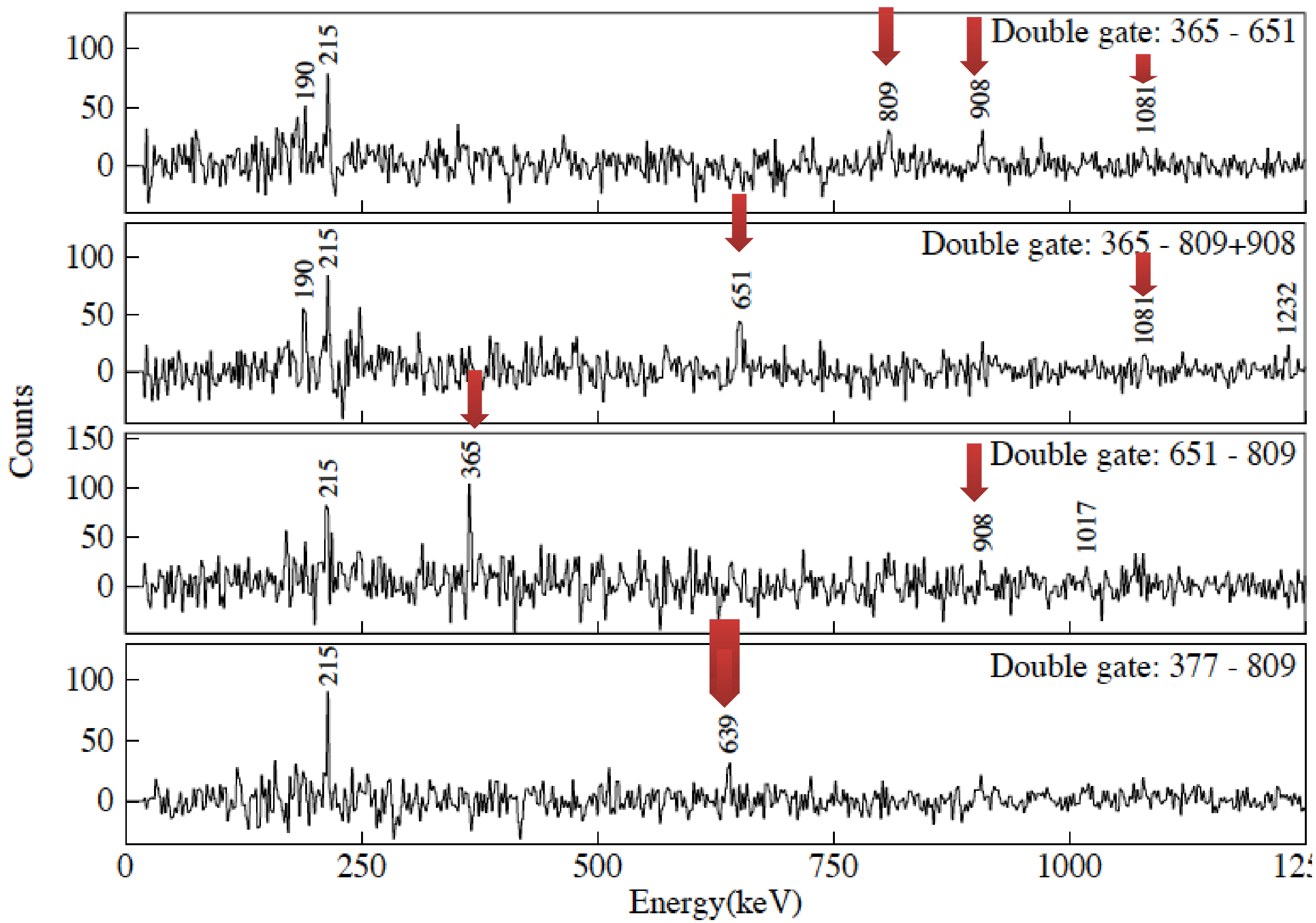
E=45 keV

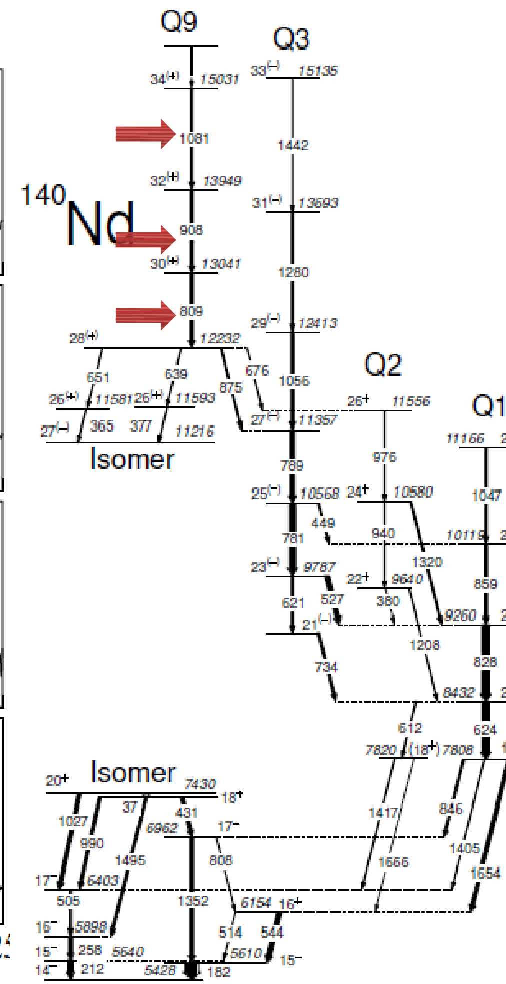
$T_{1/2}$=272(4) ns

Phys. Rev. C87, 064303 (2013)



Prompt coincidence spectra between transitions above the 27⁻ isomer





Collaboration

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Notre Dame University – S. Frauendorf

Fukuoka University – M. Matsuzaki

University of Jyväskylä – P. Greenlees et al.

University of Padova – S. Lunardi et al.