Chirality and oblate rotation in nuclei: new achievements and perspectives

Orsay, CSNSM – C. P., B.F. Lv et al

Notre Dame, USA – S. Frauendorf

Lanzhou, IMP – S. Guo et al

Peking, University – J. Meng et al

Garching, Germany – Q.B. Chen

Jyväskylä, JYFL – P. Greenlees et al

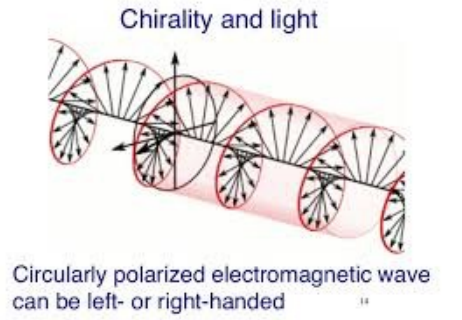
Stockholm, KTH – B. Cederwall et al

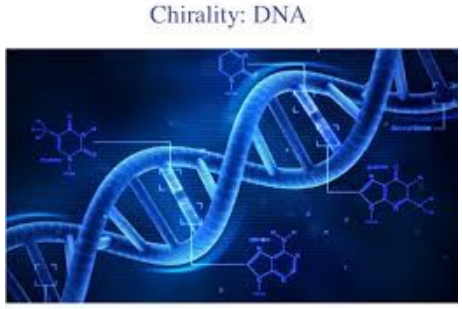
Vancouver, TRIUMF – C. Andreoiu et al

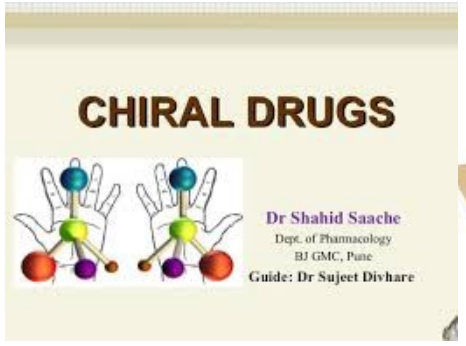
Warsaw, HIL – J. Srebrny et al

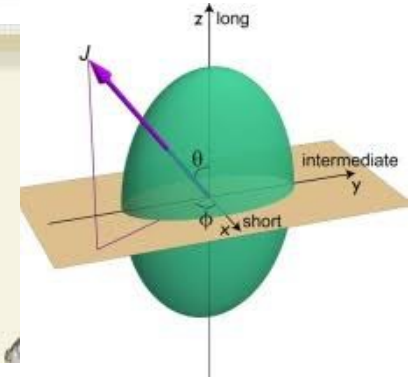
Debrecen, INR – J. Timar et al

Chirality under microscope

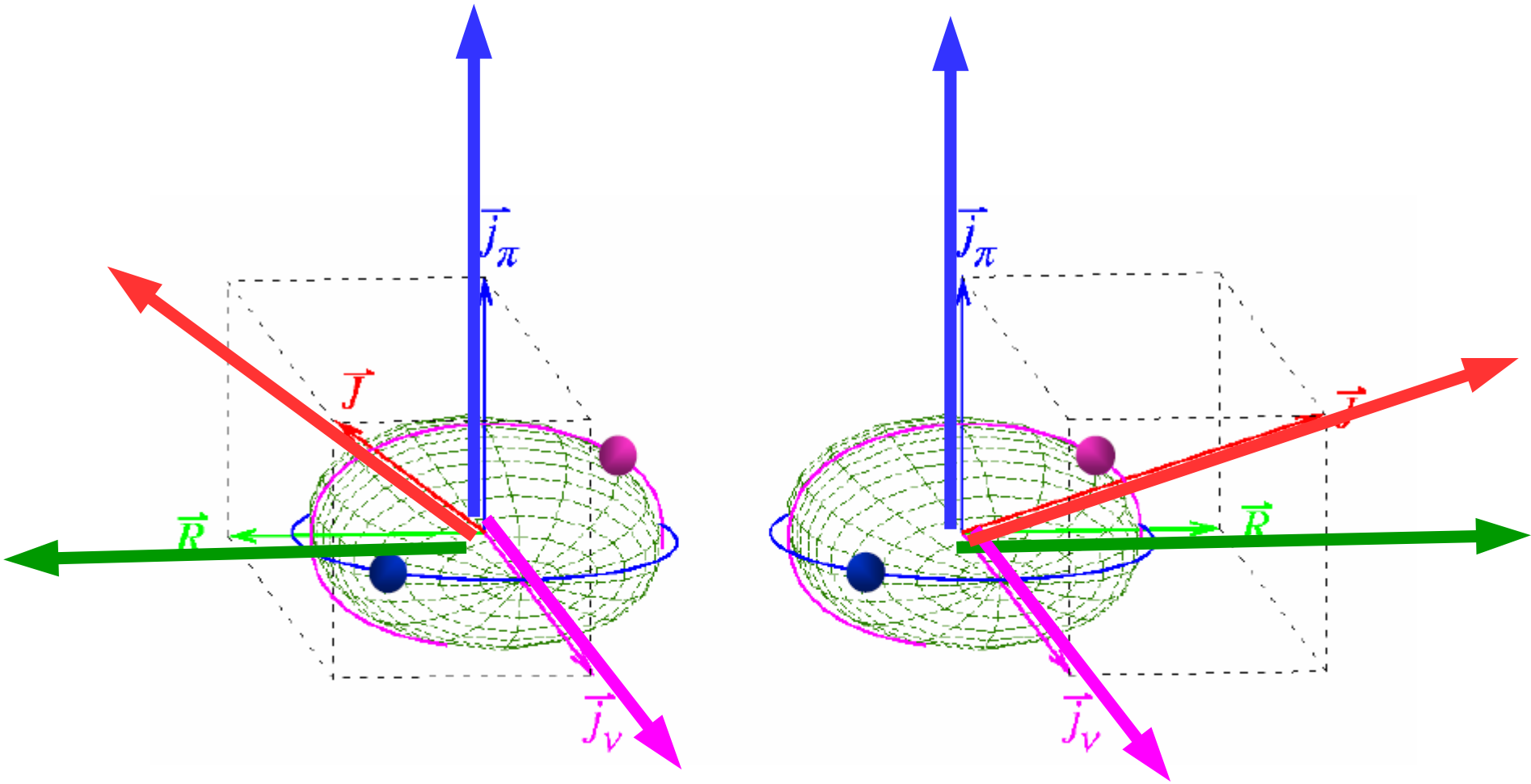




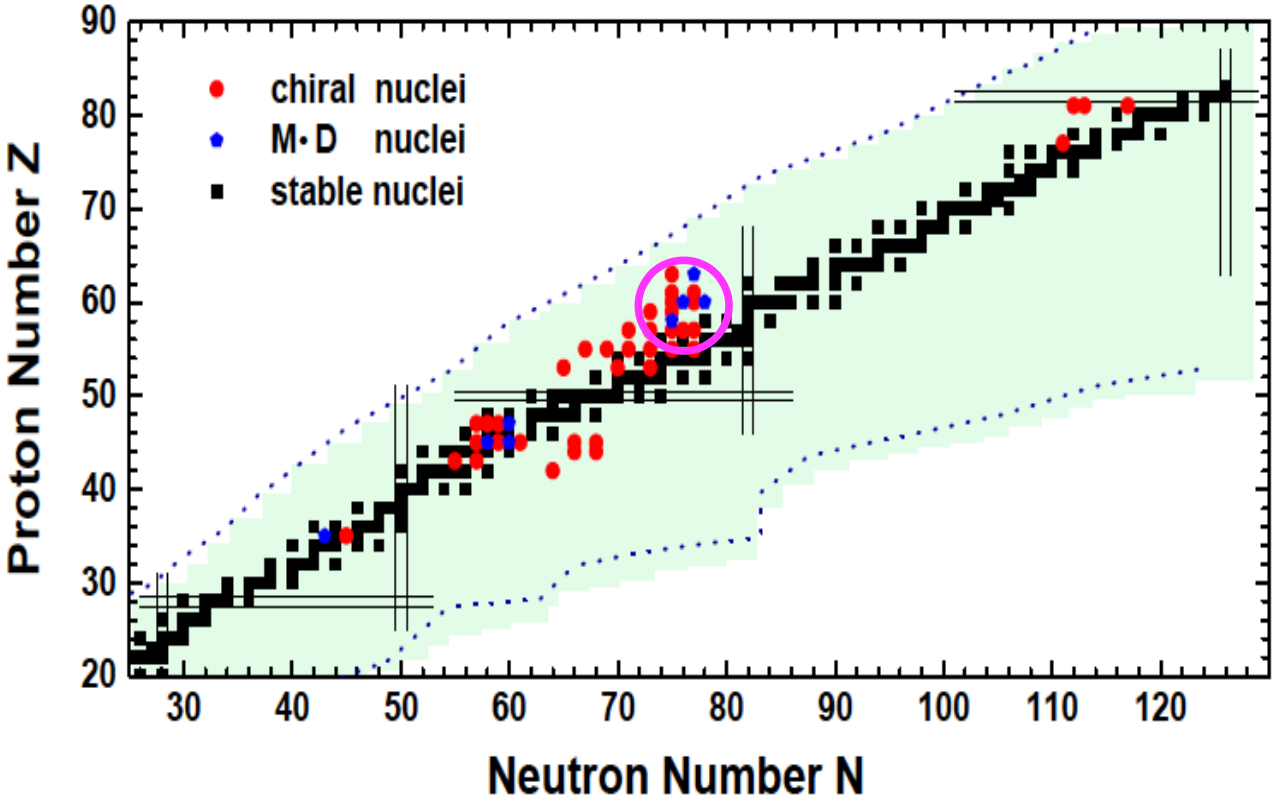




NEW :
Chirality in even-even nuclei

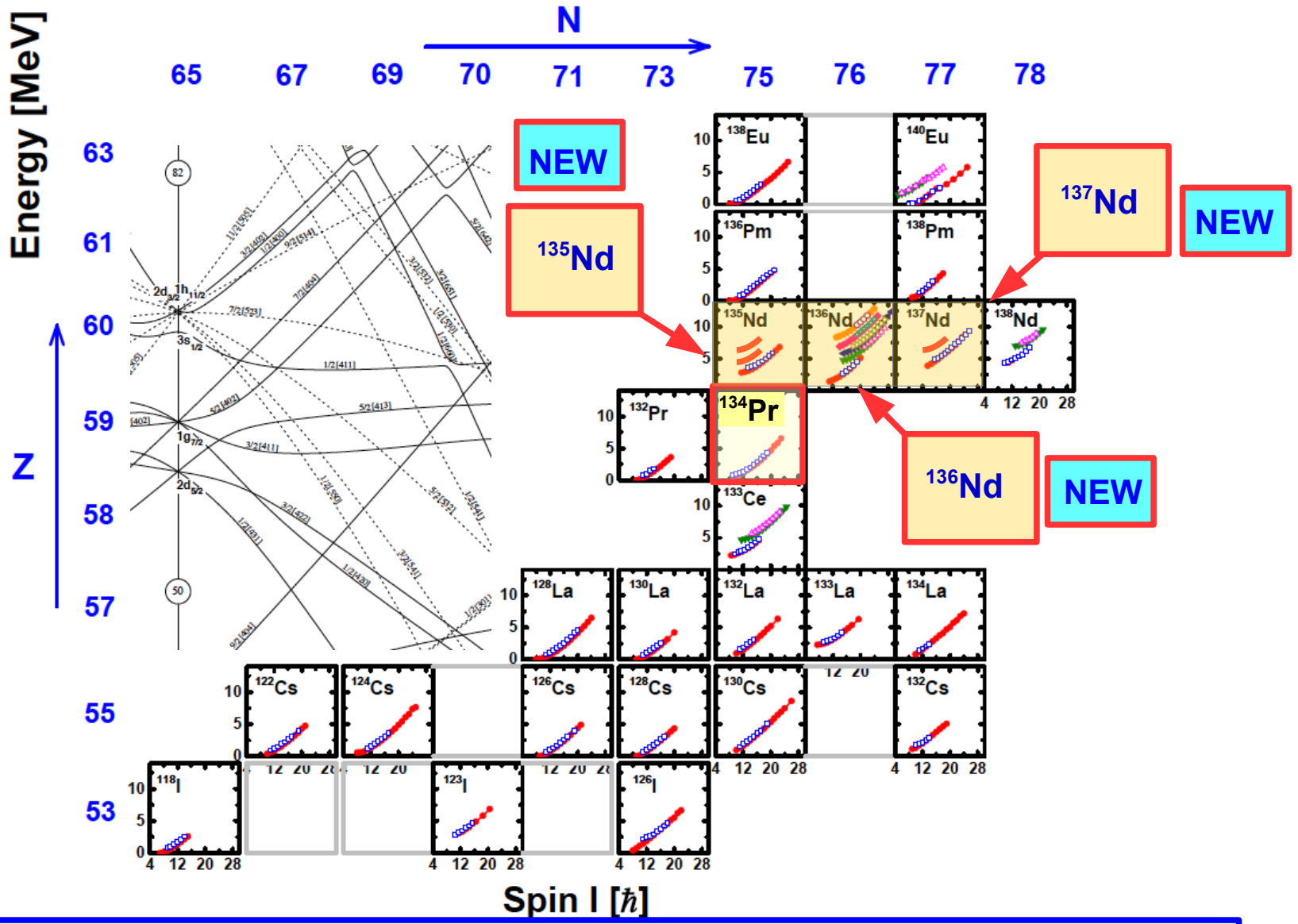


Chiral bands on the nuclear chart



B.W. Xiong, Y.Y. Wang, ADNDT 125 (2018) 193: Nuclear chiral bands data tables

New chiral bands in A=130 region



B.W. Xiong, Y.Y. Wang, ADNDT 125 (2018) 193: Nuclear chiral bands data tables

JUROGAM II + RITU, $^{40}Ar+^{100}Mo$
20 pnA, 1 week (October 2016)

JUROGAM II

24 Clovers HPGe

15 Coaxial HPGe

39 BGO shields

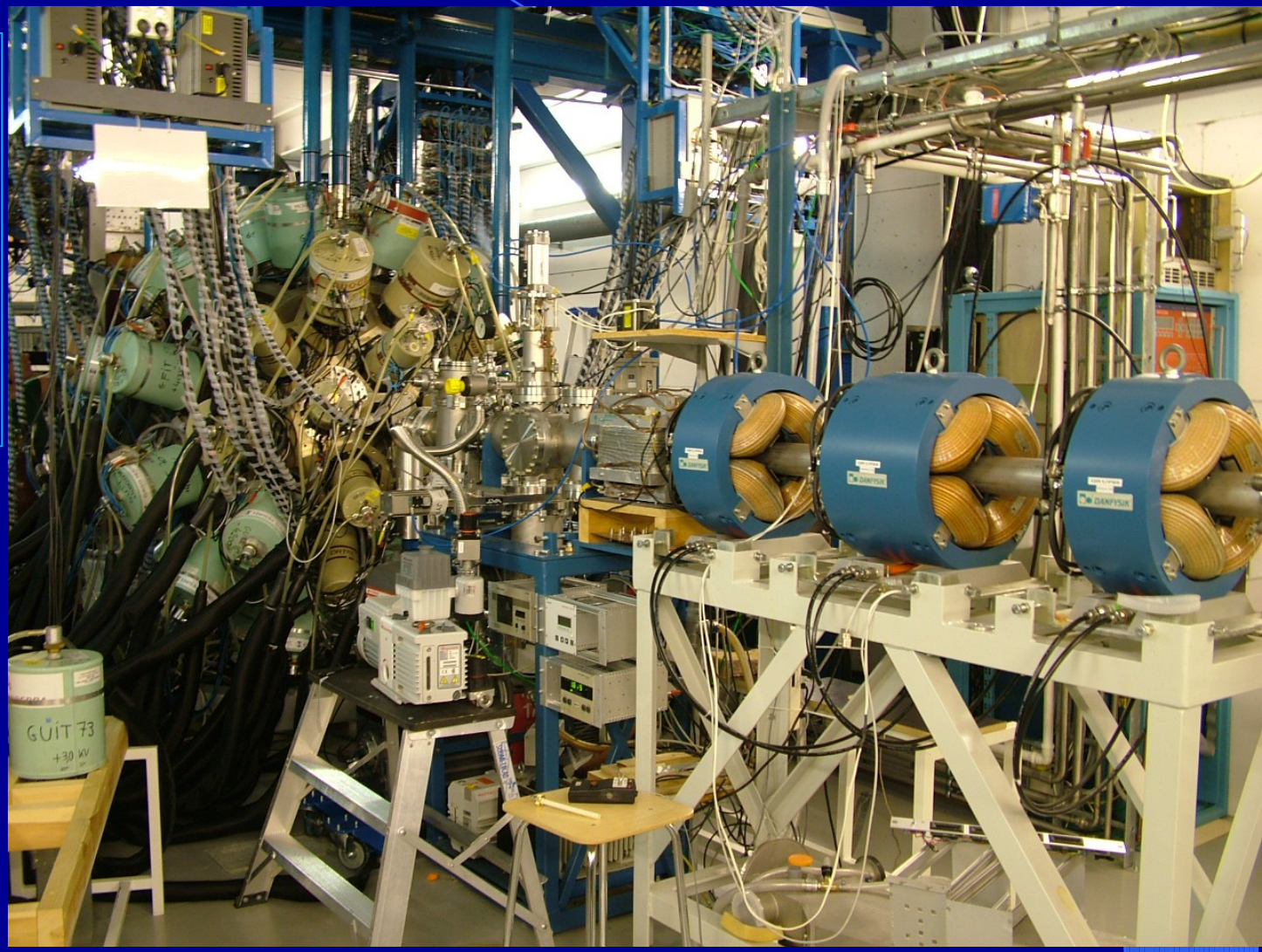
ε_{tot} = 4 %

RITU

QHDQHQV

500 ns transport time

20-50% transmission

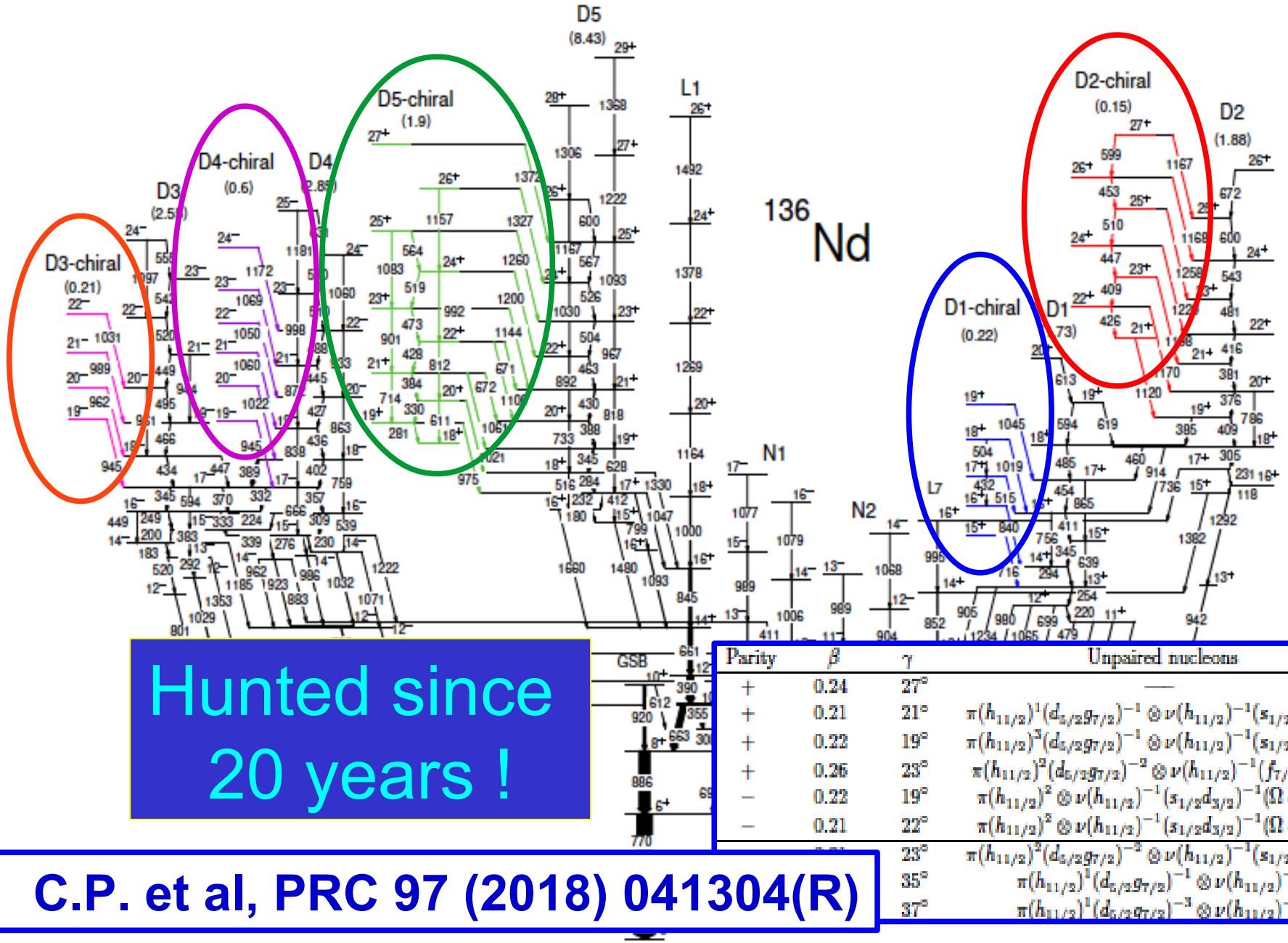


First observation of 4(6)-qp chiral bands in an even-even nucleus: 5 chiral doublets in ^{136}Nd

C.M. Petrache, B.F. Lv, A. Astier, E. Dupont, et al.

PRC 97, (2018) 041304(R)

Ultimate chirality : clear evidence in even-even nuclei



Parity	β	γ	Unpaired nucleons
+	0.24	27°	—
+	0.21	21°	$\pi(h_{11/2})^1(d_{5/2}g_{7/2})^{-1} \otimes \nu(h_{11/2})^{-1}(s_{1/2}d_{3/2})^{-1}$
+	0.22	19°	$\pi(h_{11/2})^3(d_{5/2}g_{7/2})^{-1} \otimes \nu(h_{11/2})^{-1}(s_{1/2}d_{3/2})^{-1}$
+	0.26	23°	$\pi(h_{11/2})^2(d_{5/2}g_{7/2})^{-2} \otimes \nu(h_{11/2})^{-1}(f_{7/2}h_{9/2})^{1}$
−	0.22	19°	$\pi(h_{11/2})^2 \otimes \nu(h_{11/2})^{-1}(s_{1/2}d_{3/2})^{-1}(\Omega \sim +\frac{3}{2})$
−	0.21	22°	$\pi(h_{11/2})^2 \otimes \nu(h_{11/2})^{-1}(s_{1/2}d_{3/2})^{-1}(\Omega \sim -\frac{3}{2})$
		23°	$\pi(h_{11/2})^2(d_{5/2}g_{7/2})^{-2} \otimes \nu(h_{11/2})^{-1}(s_{1/2}d_{3/2})^{-1}$
		35°	$\pi(h_{11/2})^1(d_{5/2}g_{7/2})^{-1} \otimes \nu(h_{11/2})^{-2}$
		37°	$\pi(h_{11/2})^1(d_{5/2}g_{7/2})^{-3} \otimes \nu(h_{11/2})^{-2}$

Hunted since 20 years !

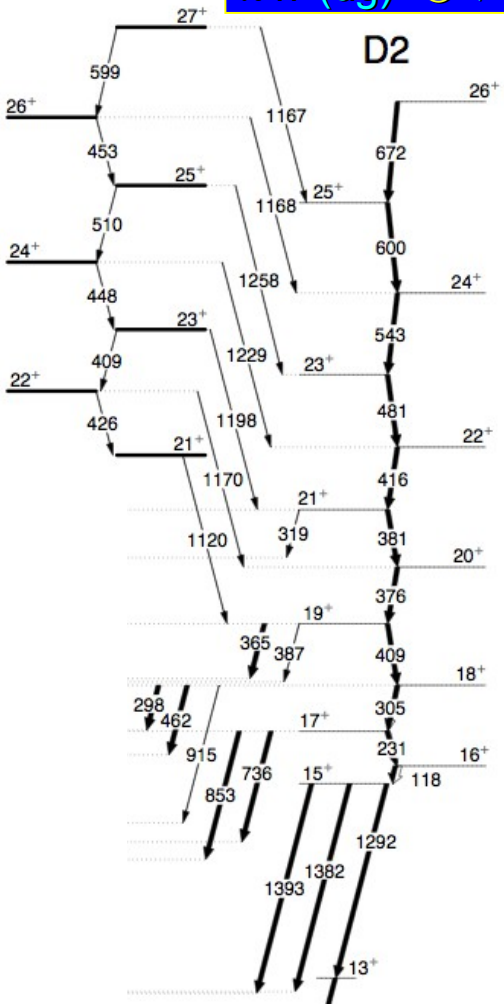
C.P. et al, PRC 97 (2018) 041304(R)

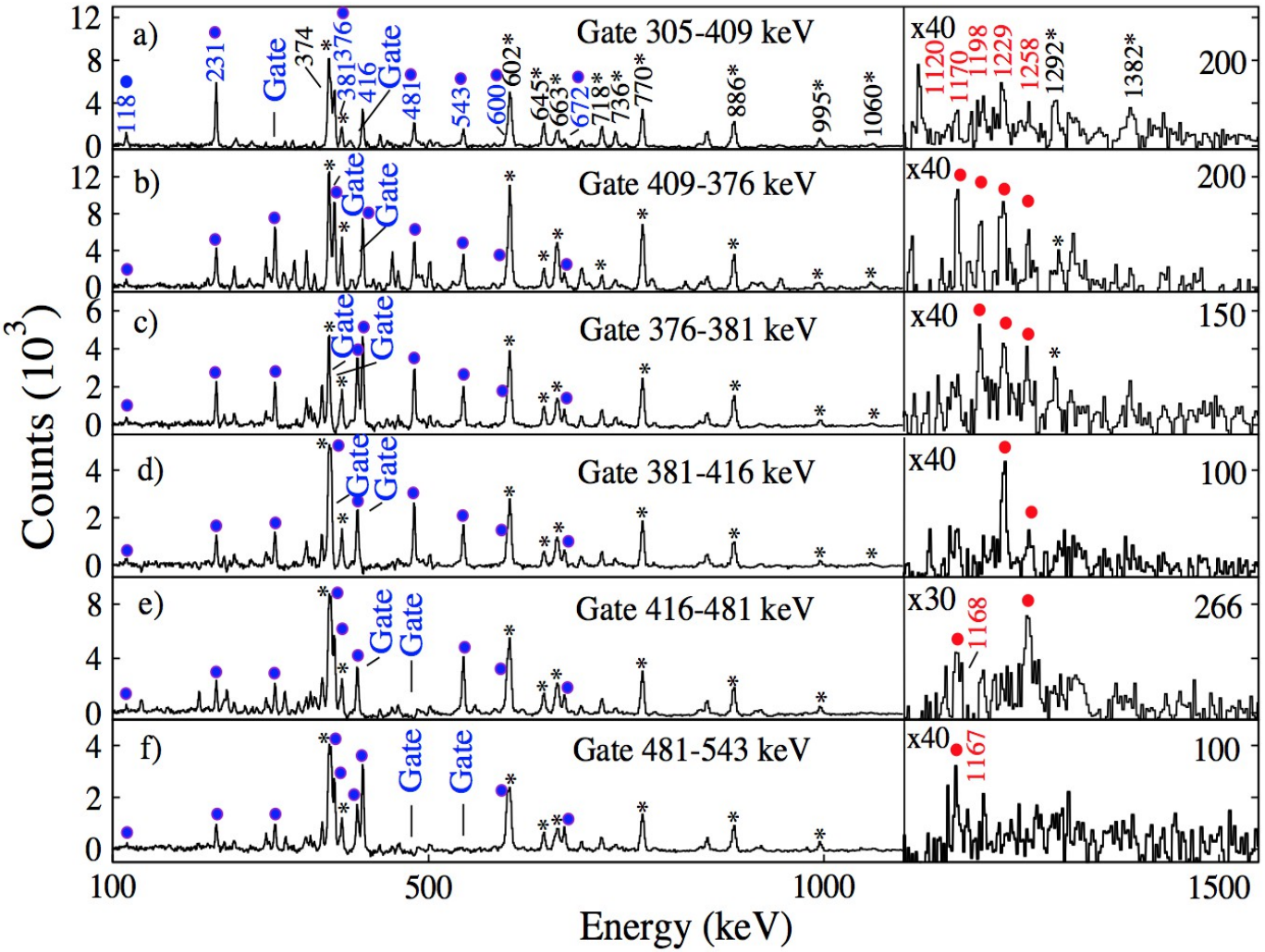
^{136}Nd – D2 chiral doublet

Chiral

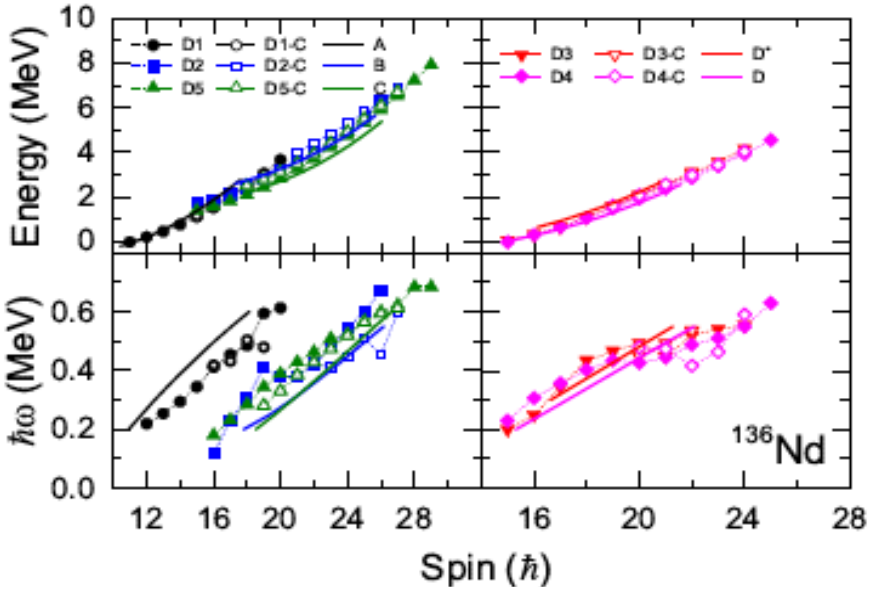
D2-chiral

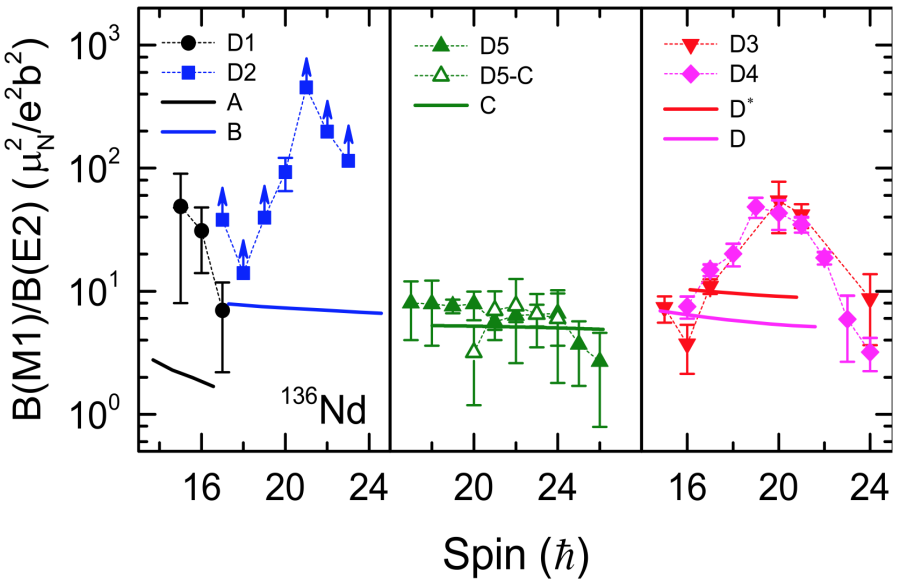
$\pi\, h^3 (dg)^{-1} \otimes \nu\, h^{-1}(sd)^{-1}$

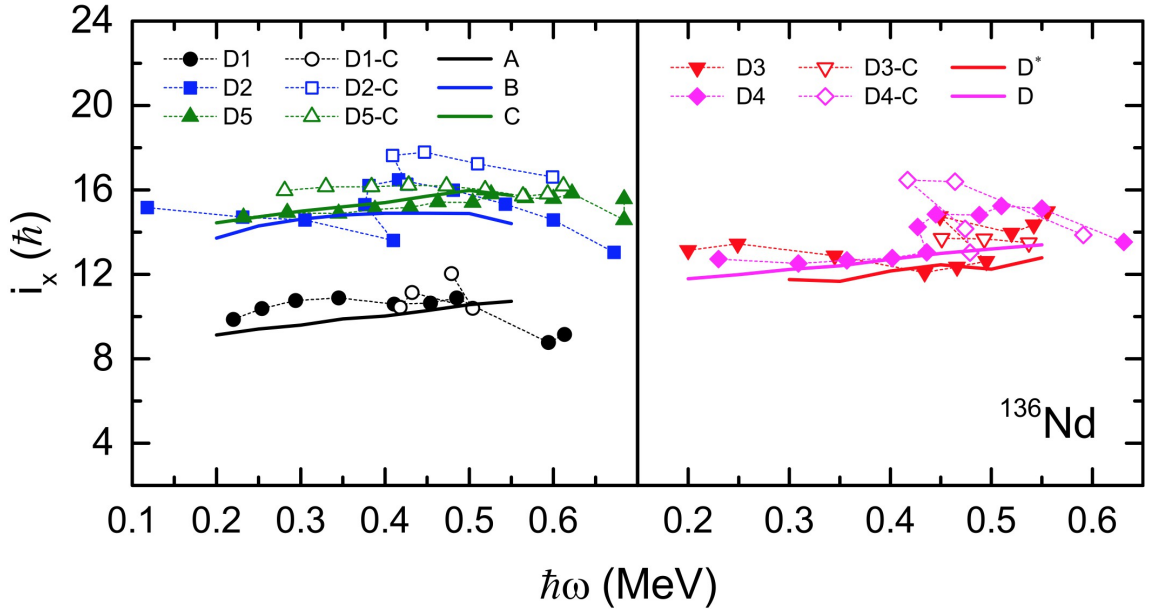




^{136}Nd – TAC-CDFT calculations





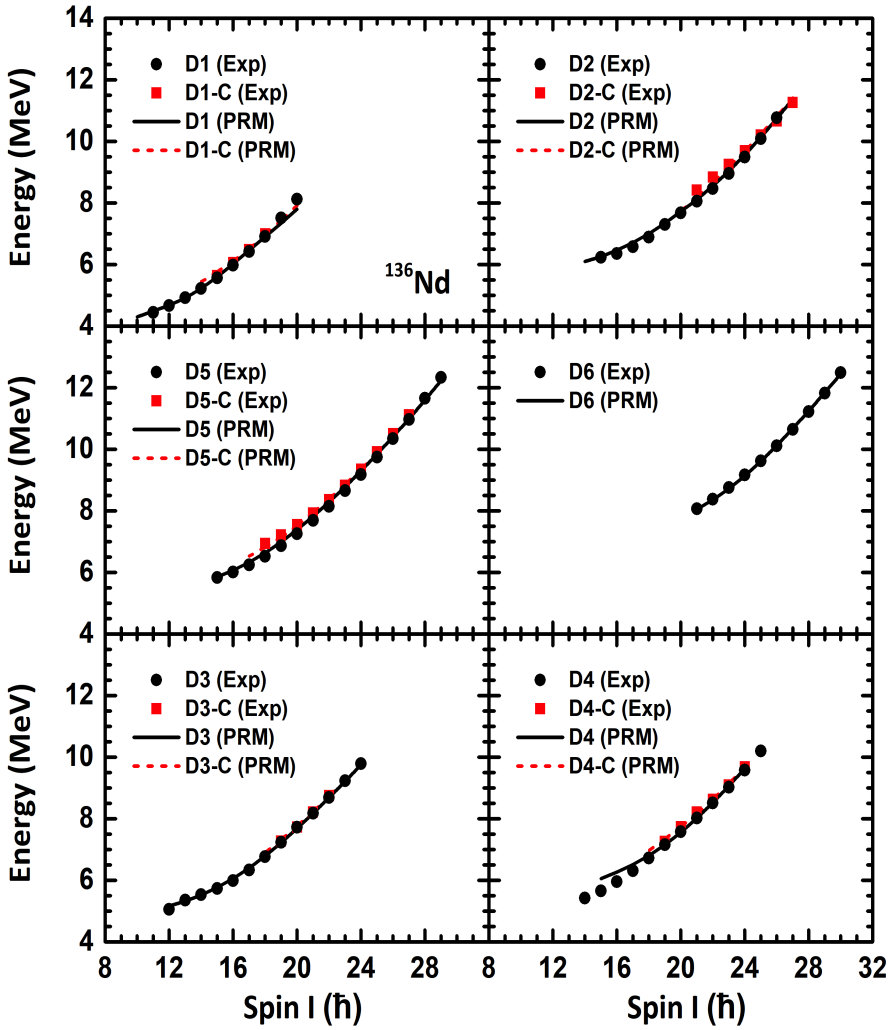


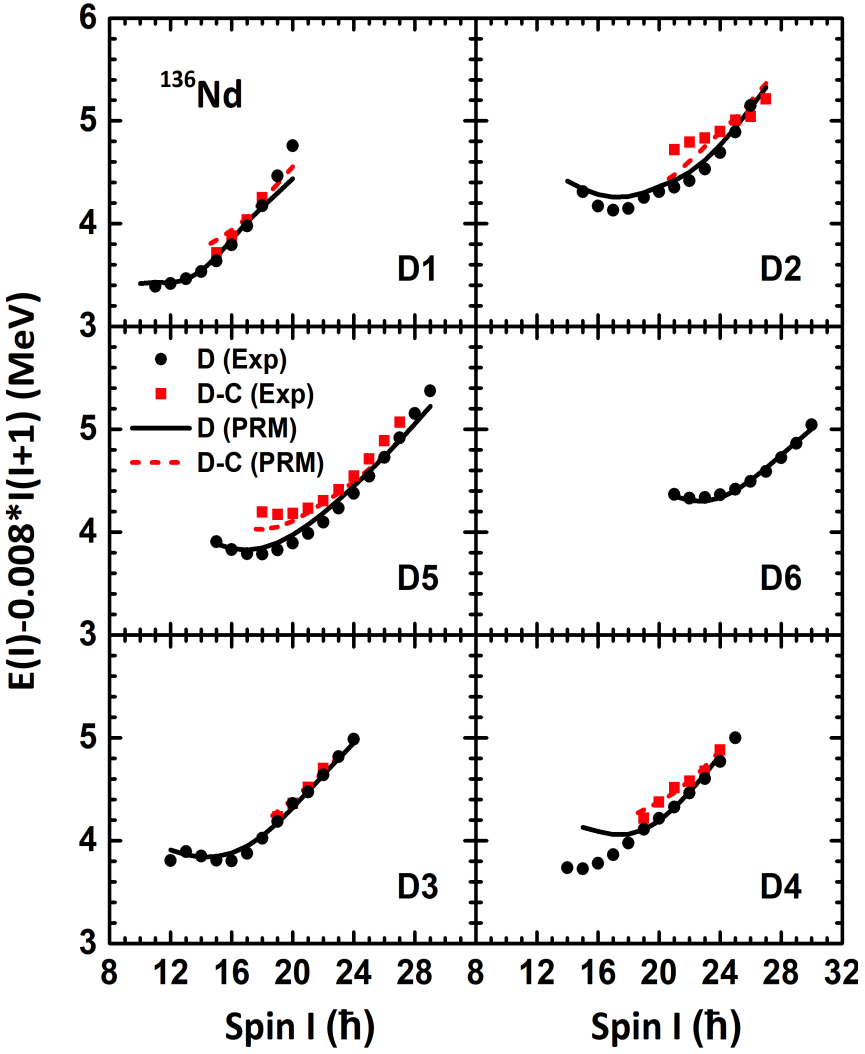
PTRM calculations for the 5 chiral bands of ^{136}Nd

Q.B. Chen, B.F. Lv, C.M. Petrache, J. Meng

PLB 782, 744 (2018)

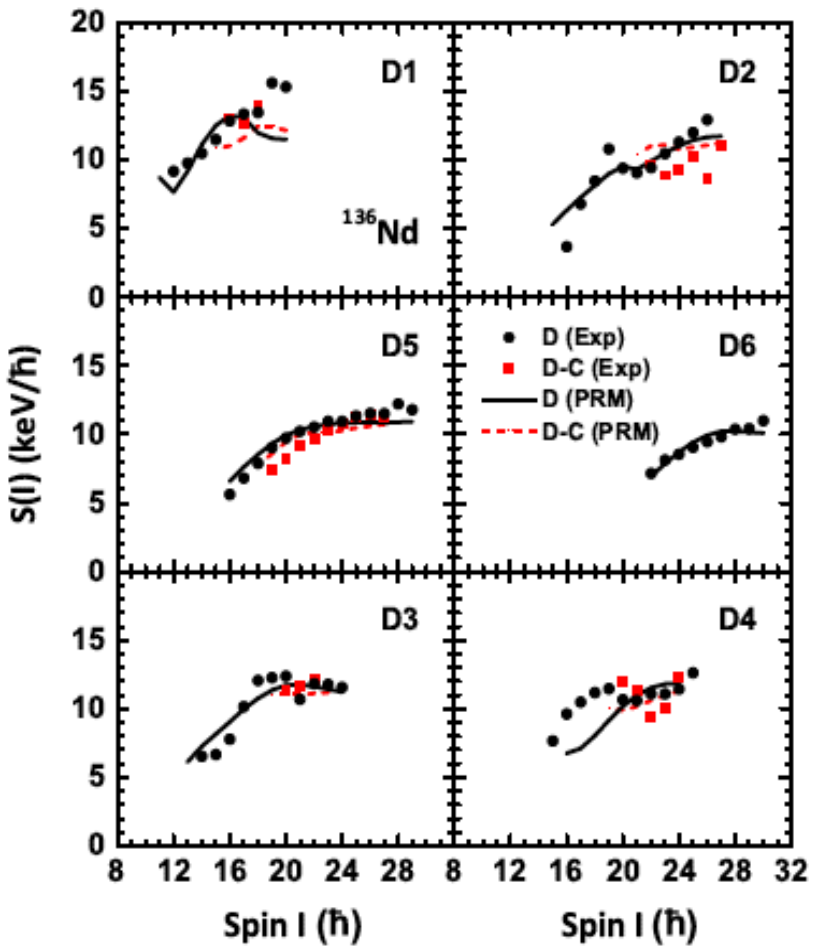
Multi-j PTRM calculations

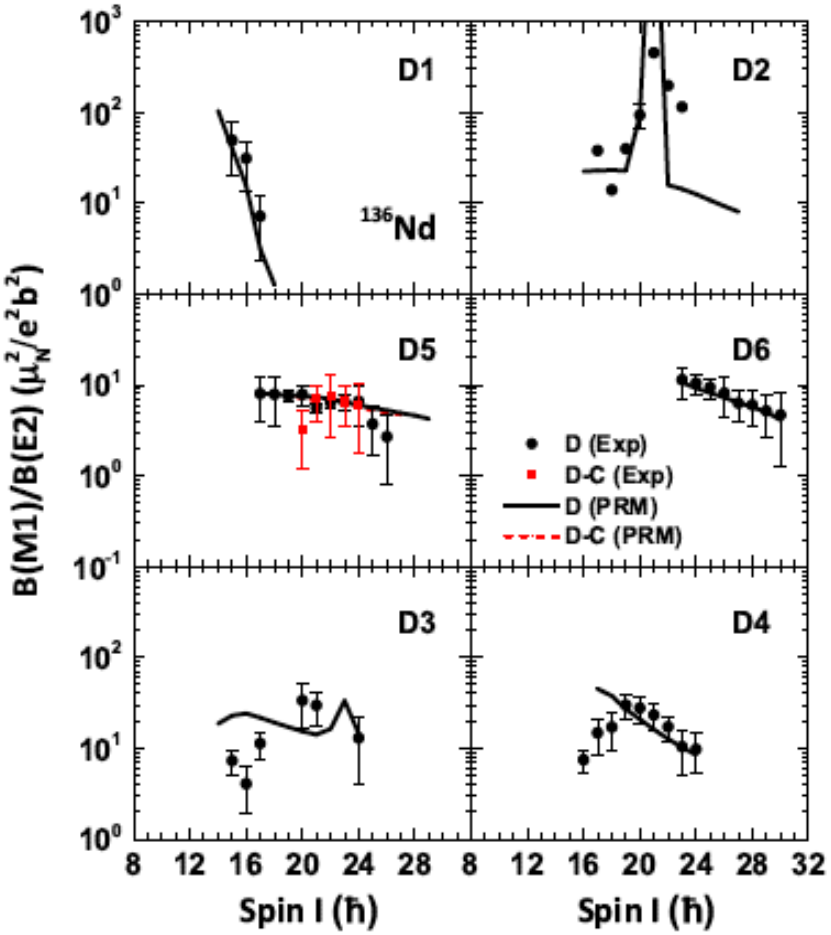




Multi-j PTRM calculations

$$S(I) = [E(I) - E(I-1)] / 2I$$

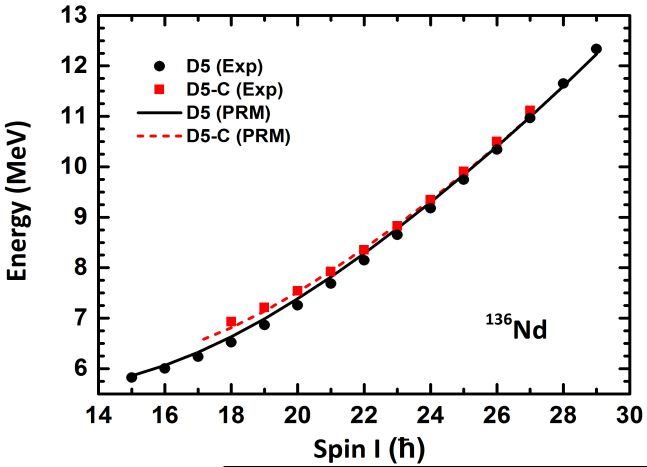


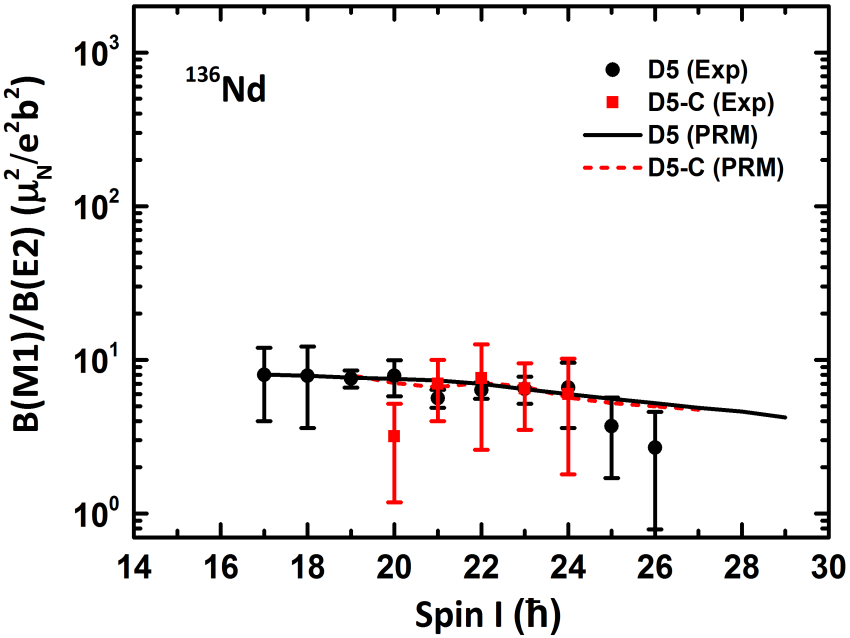


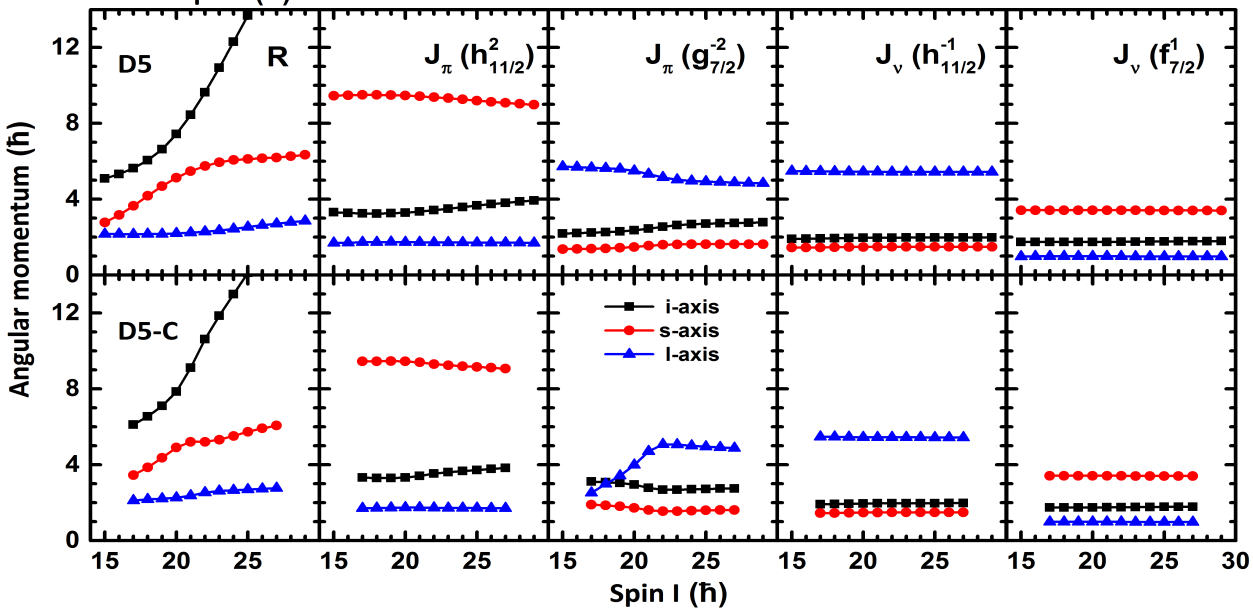
^{136}Nd – chiral doublet D5

Numerical details

- Configuration: $\pi\,(1h_{11/2})^{2}\,(1g_{7/2})^{-2}\,\nu\,(1h_{11/2})^{-1}\,(1f_{7/2})^{1}$
- Deformation: ($\beta = 0.26$, γ=23.0°)
- Irr. MOI: $\Im = 40$ MeV
- Coriolis attenuation factor: 0.93







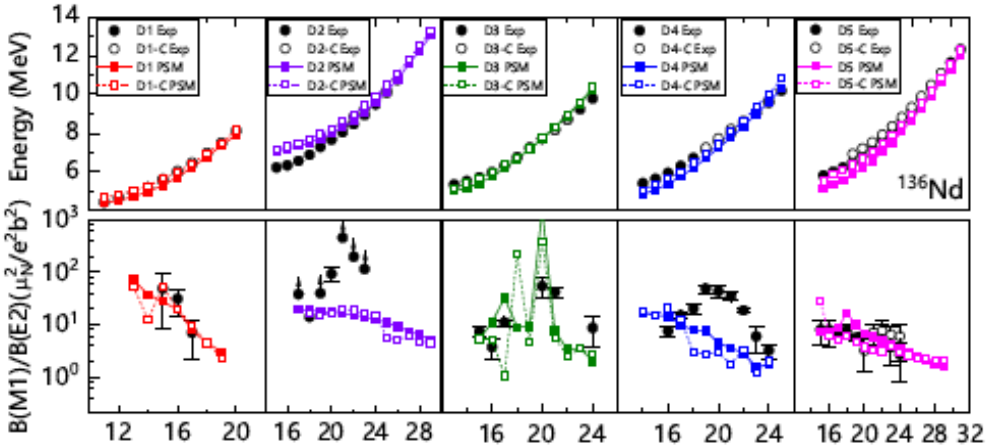
TPSM calculations for the 5 chiral bands of ^{136}Nd

Y.K. Wang, F.Q. Chen, P.W. Zhao, S.Q. Zhang, J. Meng

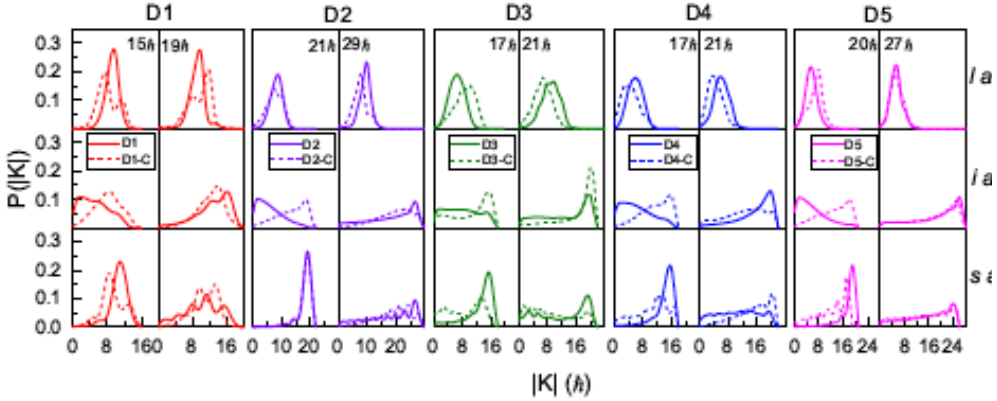
PRC 99 (2019) 054303

Multi-qp configurations

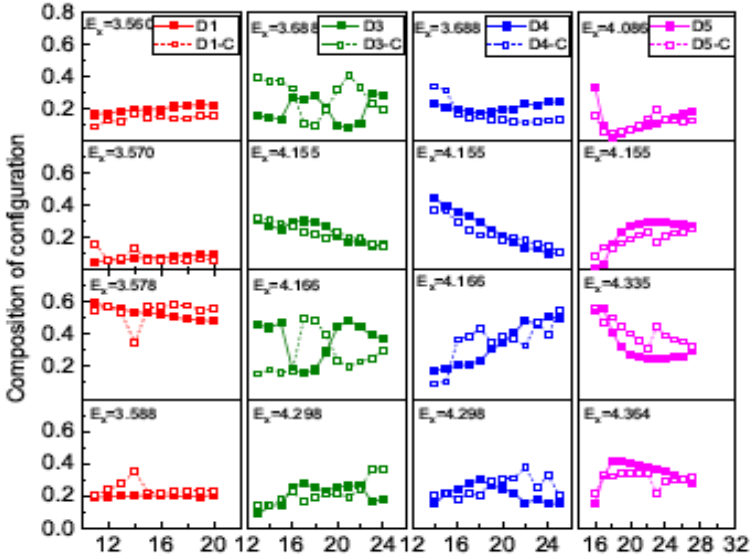
$$\{|\Phi_0\rangle, \hat{\beta}^\dagger_{\nu_i}\hat{\beta}^\dagger_{\nu_j}|\Phi_0\rangle, \hat{\beta}^\dagger_{\pi_i}\hat{\beta}^\dagger_{\pi_j}|\Phi_0\rangle, \hat{\beta}^\dagger_{\pi_i}\hat{\beta}^\dagger_{\pi_j}\hat{\beta}^\dagger_{\nu_k}\hat{\beta}^\dagger_{\nu_l}|\Phi_0\rangle,$$
$$\hat{\beta}^\dagger_{\nu_i}\hat{\beta}^\dagger_{\nu_j}\hat{\beta}^\dagger_{\nu_k}\hat{\beta}^\dagger_{\nu_l}|\Phi_0\rangle, \hat{\beta}^\dagger_{\pi_i}\hat{\beta}^\dagger_{\pi_j}\hat{\beta}^\dagger_{\pi_k}\hat{\beta}^\dagger_{\pi_l}|\Phi_0\rangle,$$
$$\hat{\beta}^\dagger_{\nu_i}\hat{\beta}^\dagger_{\nu_j}\hat{\beta}^\dagger_{\nu_k}\hat{\beta}^\dagger_{\nu_l}\hat{\beta}^\dagger_{\nu_m}\hat{\beta}^\dagger_{\nu_n}|\Phi_0\rangle, \hat{\beta}^\dagger_{\pi_i}\hat{\beta}^\dagger_{\pi_j}\hat{\beta}^\dagger_{\pi_k}\hat{\beta}^\dagger_{\pi_l}\hat{\beta}^\dagger_{\pi_m}\hat{\beta}^\dagger_{\pi_n}|\Phi_0\rangle,$$
$$\hat{\beta}^\dagger_{\pi_i}\hat{\beta}^\dagger_{\pi_j}\hat{\beta}^\dagger_{\nu_k}\hat{\beta}^\dagger_{\nu_l}\hat{\beta}^\dagger_{\nu_m}\hat{\beta}^\dagger_{\nu_n}|\Phi_0\rangle, \hat{\beta}^\dagger_{\nu_i}\hat{\beta}^\dagger_{\nu_j}\hat{\beta}^\dagger_{\pi_k}\hat{\beta}^\dagger_{\pi_l}\hat{\beta}^\dagger_{\pi_m}\hat{\beta}^\dagger_{\pi_n}|\Phi_0\rangle\},$$



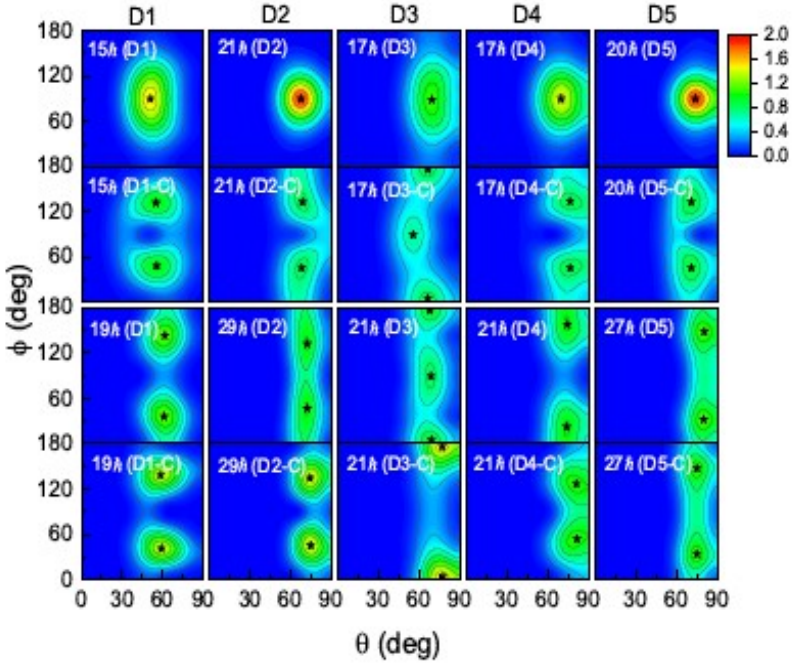
K plot



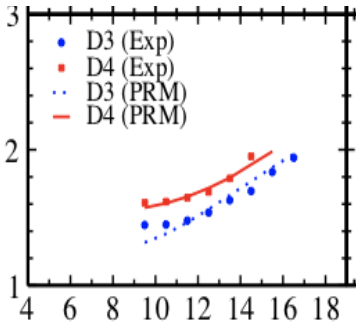
Composition of configurations



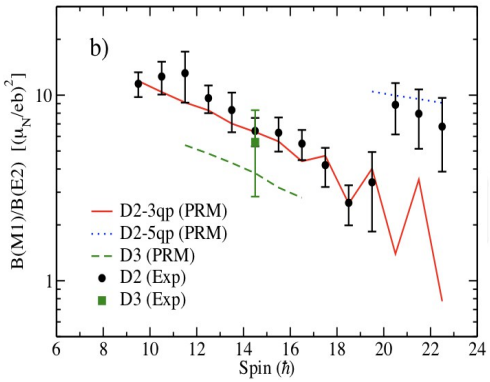
Azimuthal plot

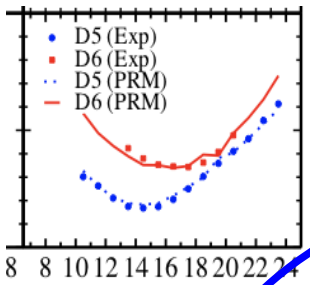


MχD in ^{135}Nd

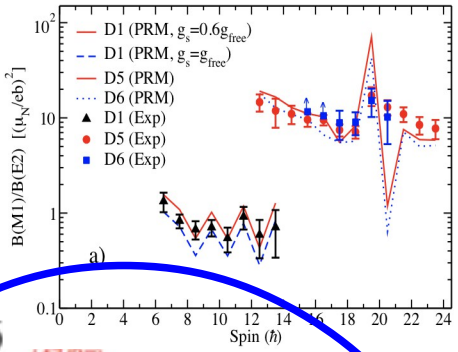


$\nu\ (h_{11/2})^{-1}\pi(g_{7/2}h_{11/2})$





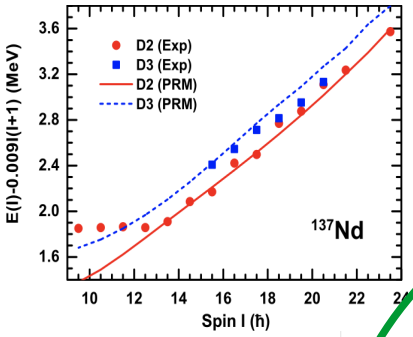
$\nu\ (h_{11/2})^{-1}\pi(h_{11/2})^{2}$



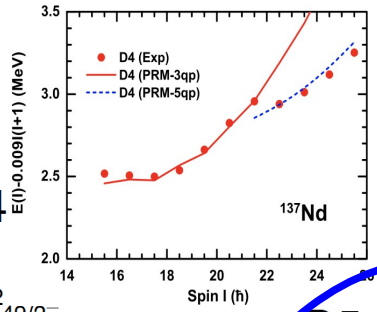
B.F. Lv, C. P. et al, submitted

MχD in ^{137}Nd

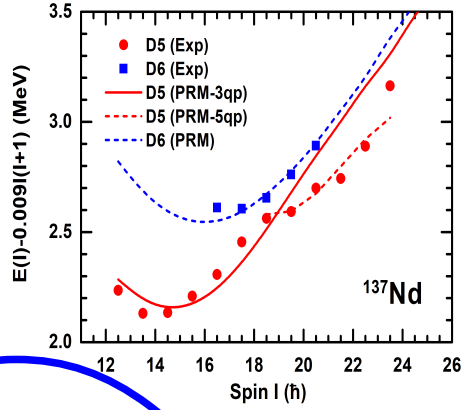
$\nu\,(h_{11/2})^{-1}\pi(g_{7/2}h_{11/2})$

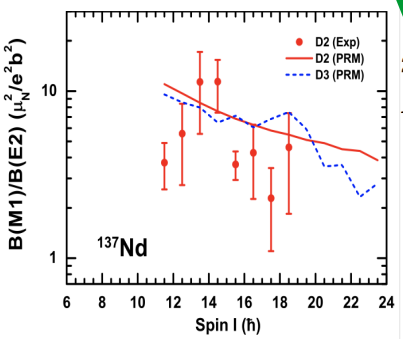


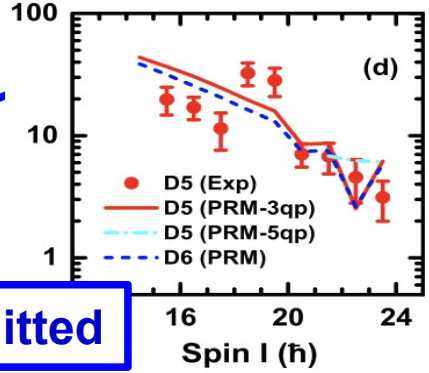
$\nu\,(h_{11/2})^{-3}$



$\nu\,(h_{11/2})^{-1}\pi(h_{11/2})^{2}$







C.P., B.F. Lv, et al, submitted

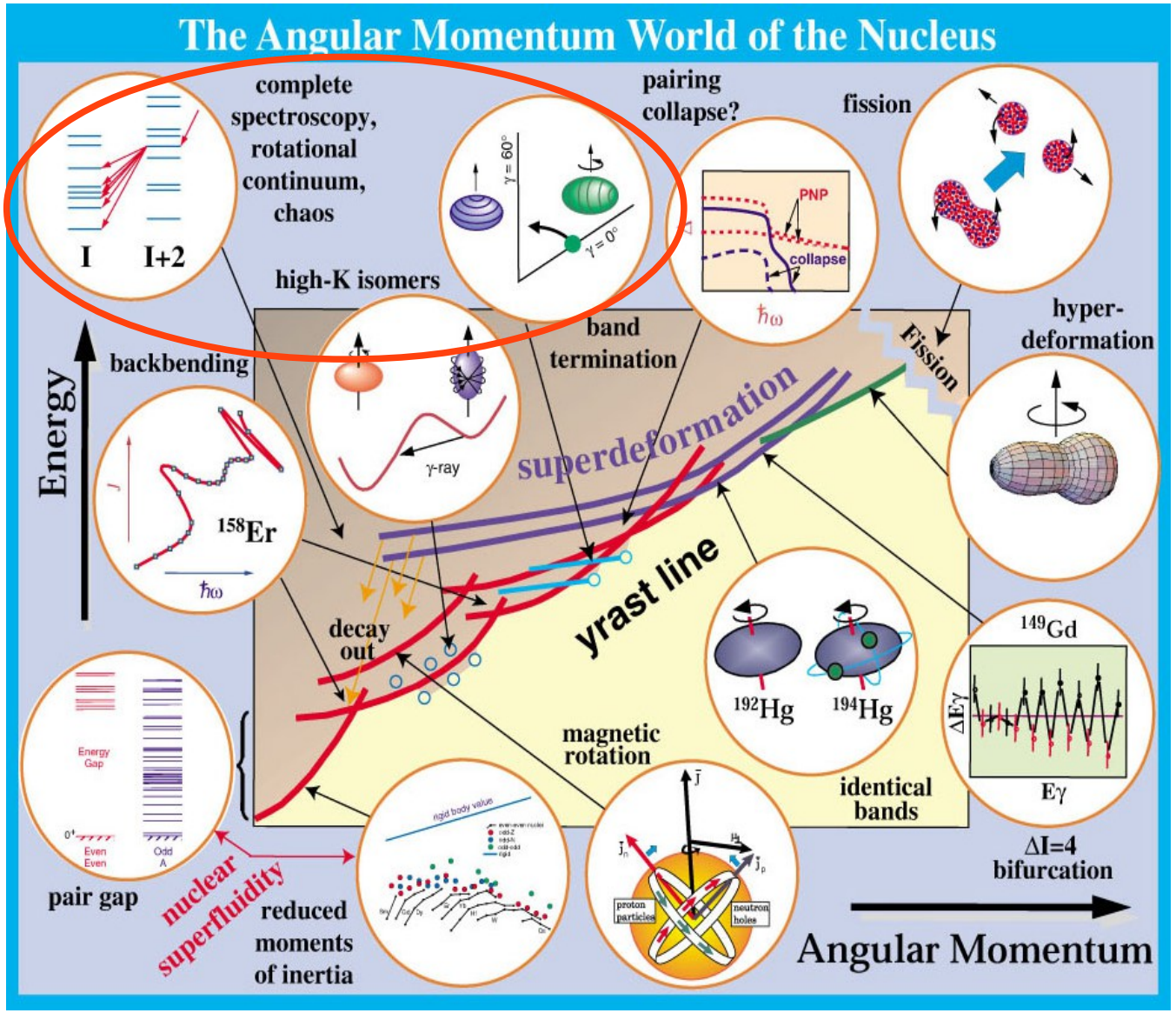
Conclusions, perspectives on chirality

→ First observation of chiral rotation in even-even nuclei ^{136}Nd – based on 4-qp and 6-qp configurations.

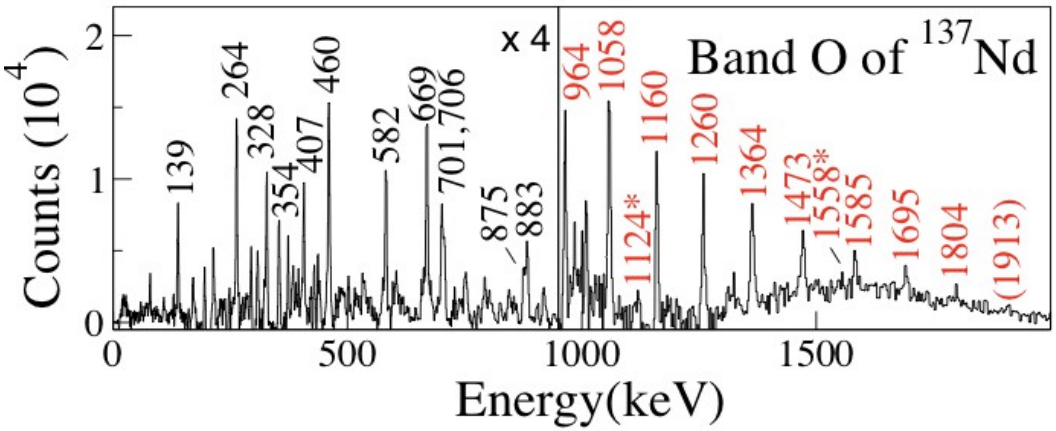
→ New chiral bands in ^{135}Nd and ^{137}Nd

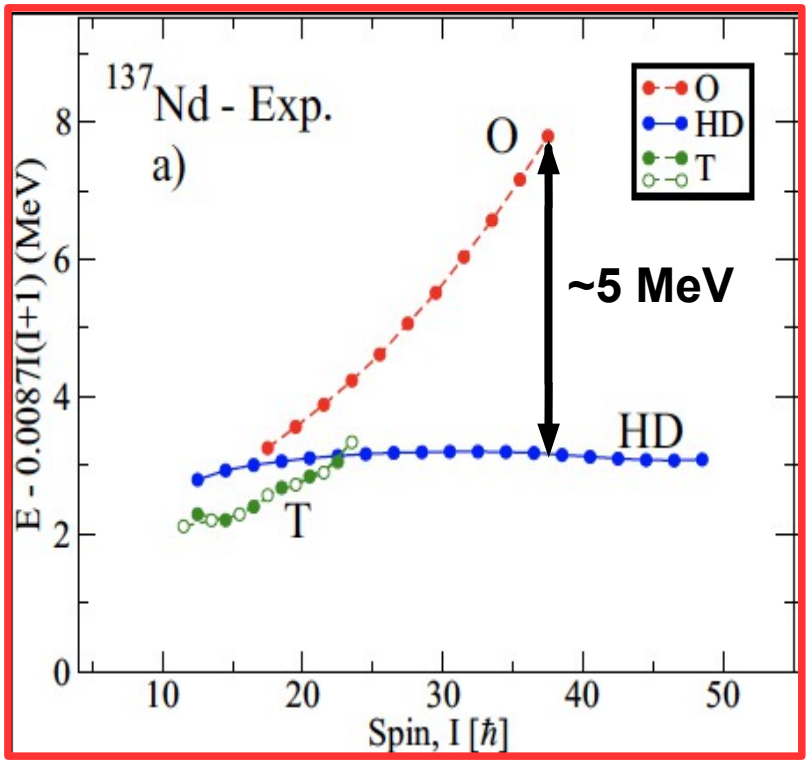
→ New precise experimental data and further theoretical work are needed in the neighboring Lanthanides, which remain a fertile field for the study of exotic excitation modes in triaxial nuclei.

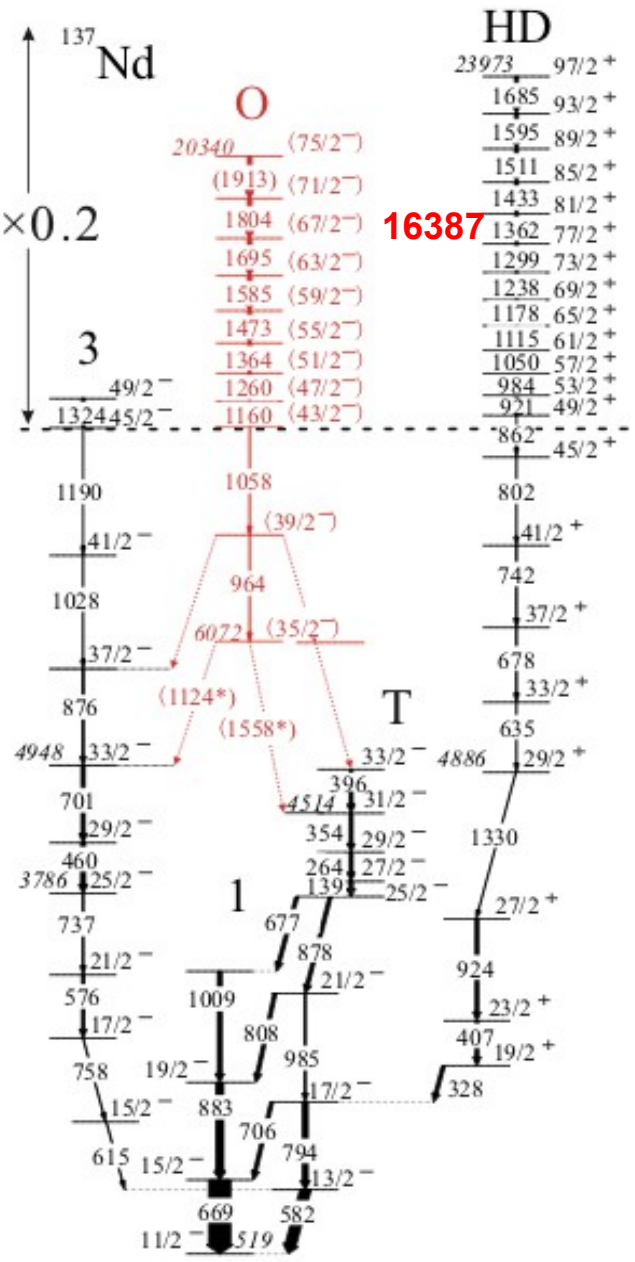
Rotation of oblate nuclei at very high spins



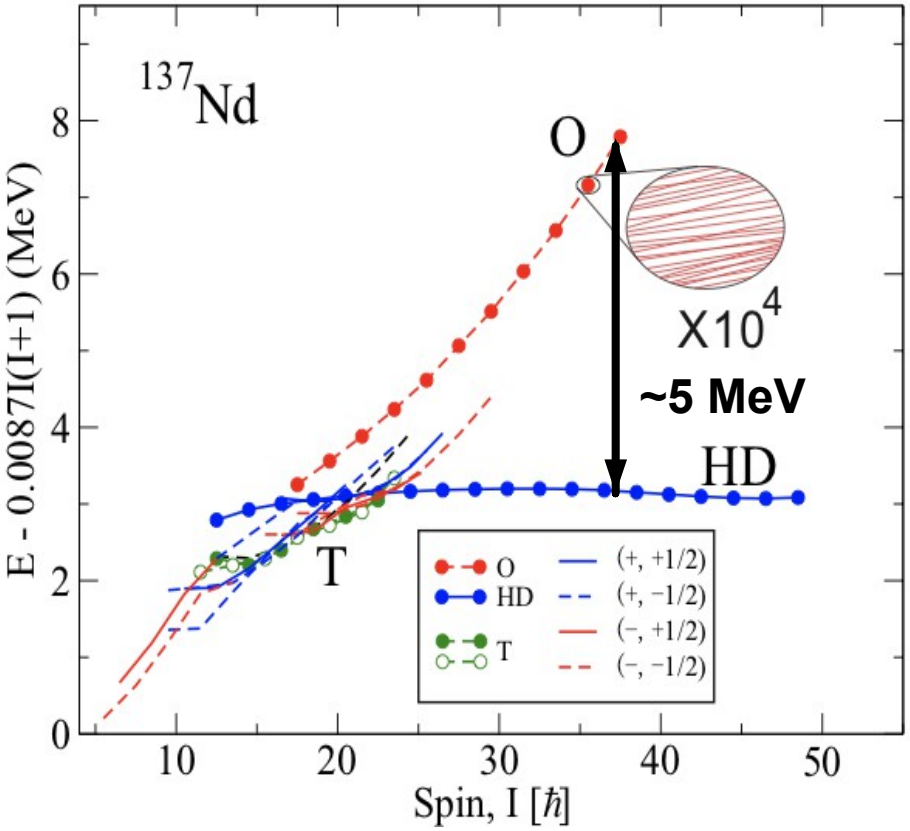
Oblate rotation at very high spins : survival in the see of chaos !

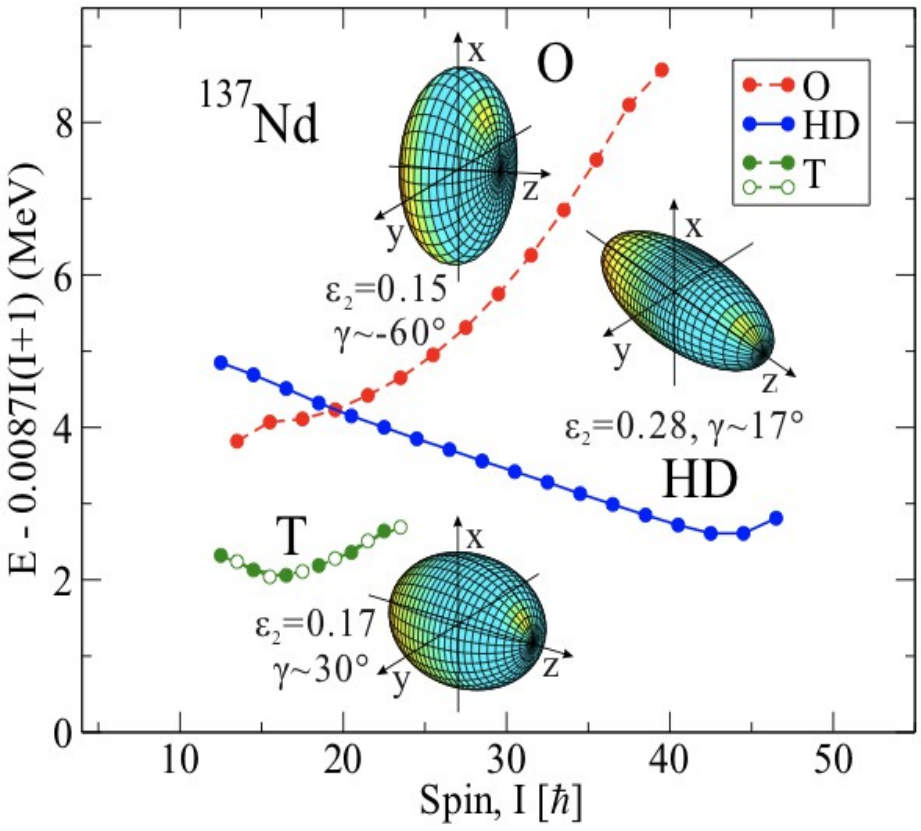




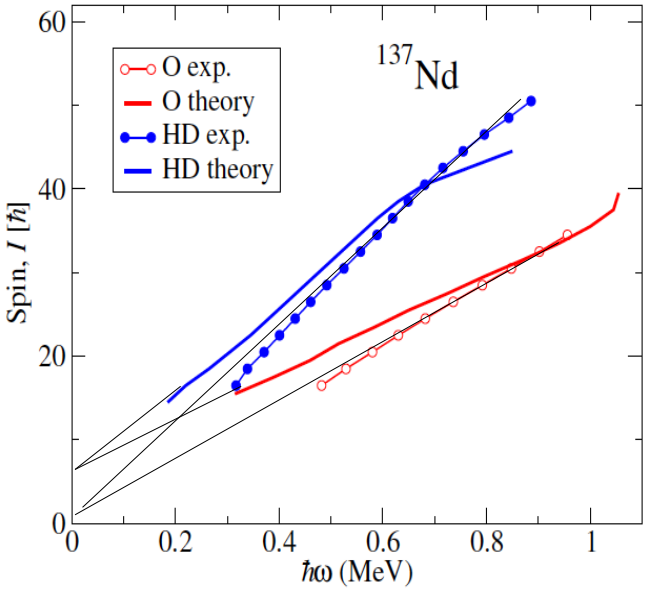


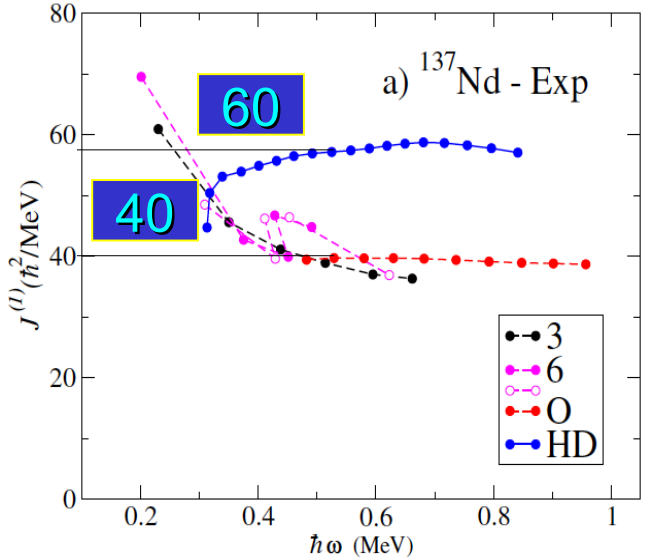
Collective rotation of oblate nuclei at very high spins

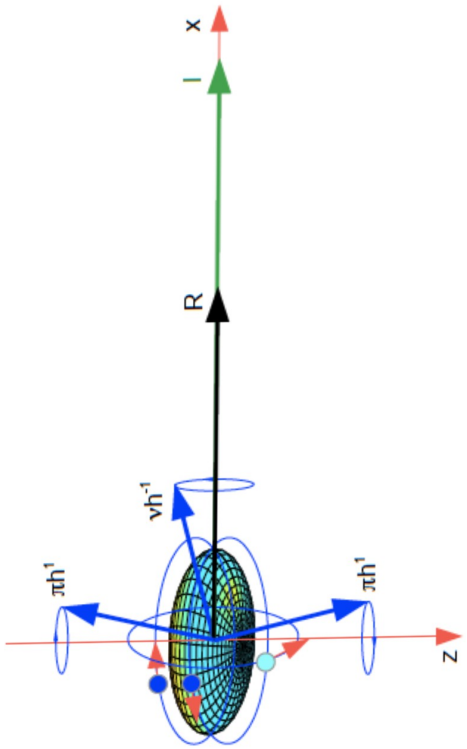


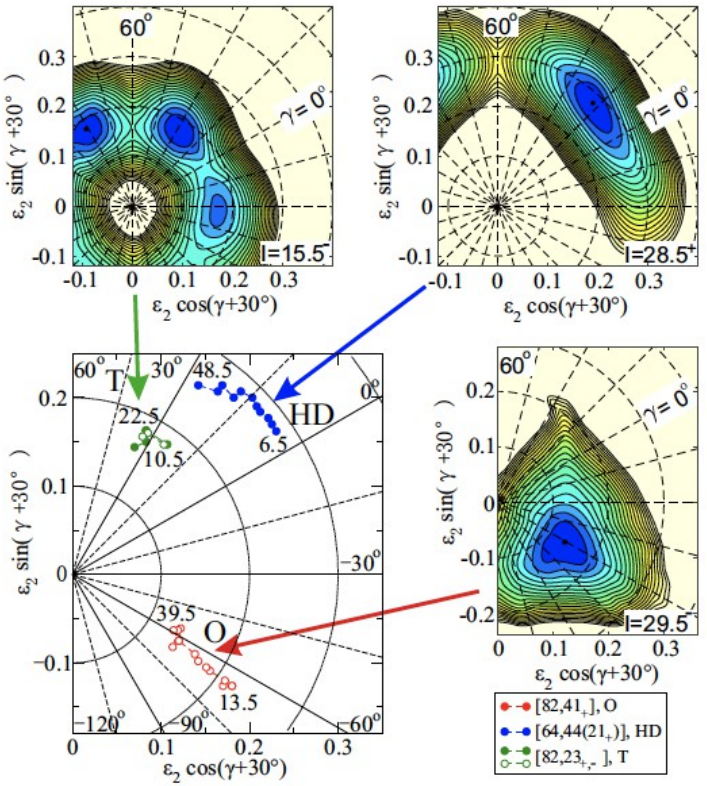


Oblate rotation at very high spins : survival in the see of chaos !



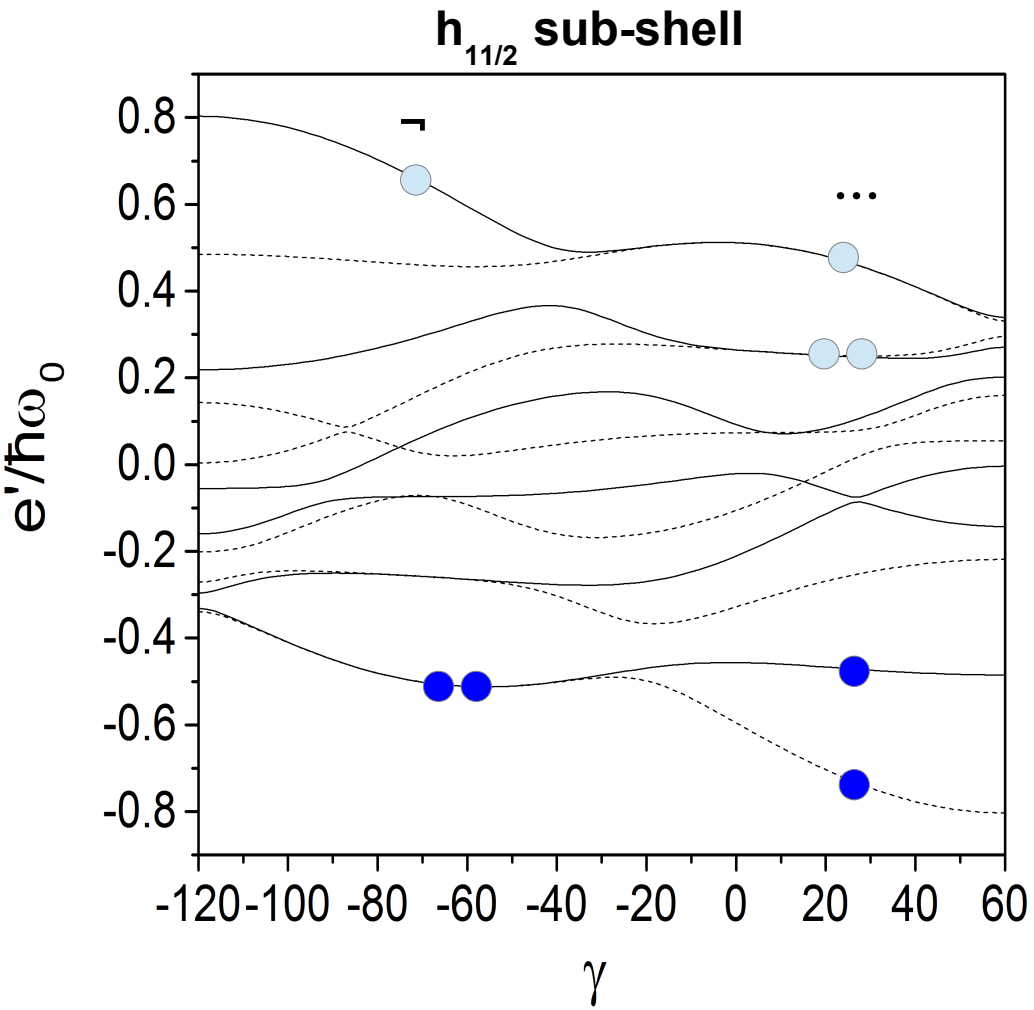


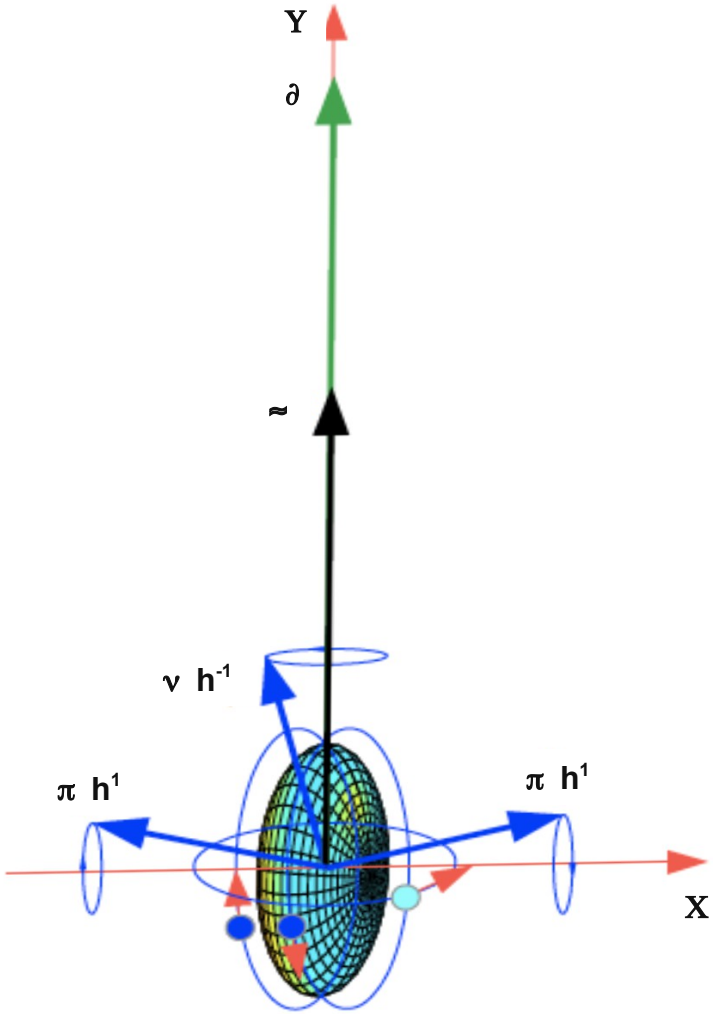




CNS calculations

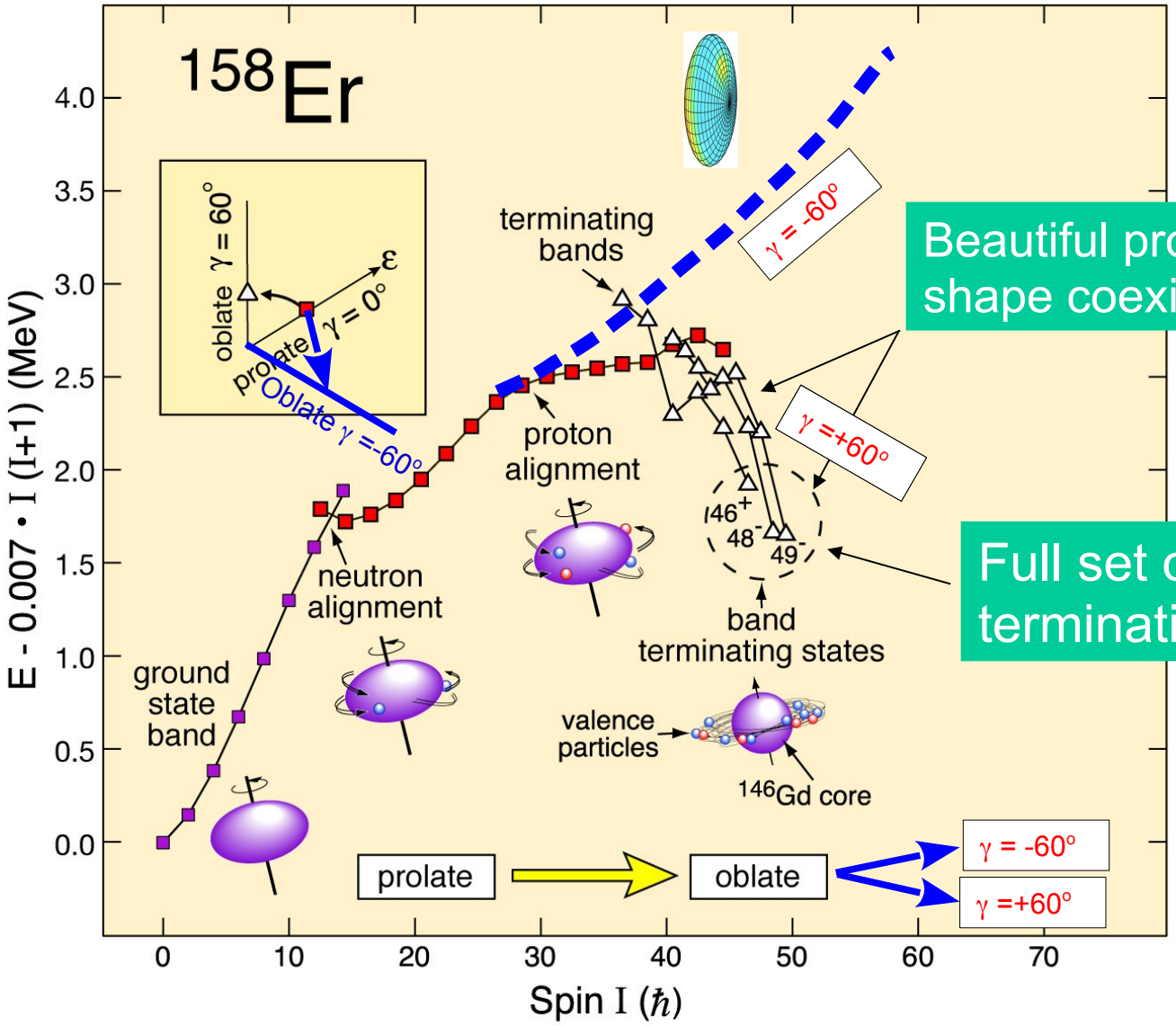
Oblate rotation at very high spins : survival in the sea of chaos !





Along the Yrast Line ^{158}Er – circa mid 90's

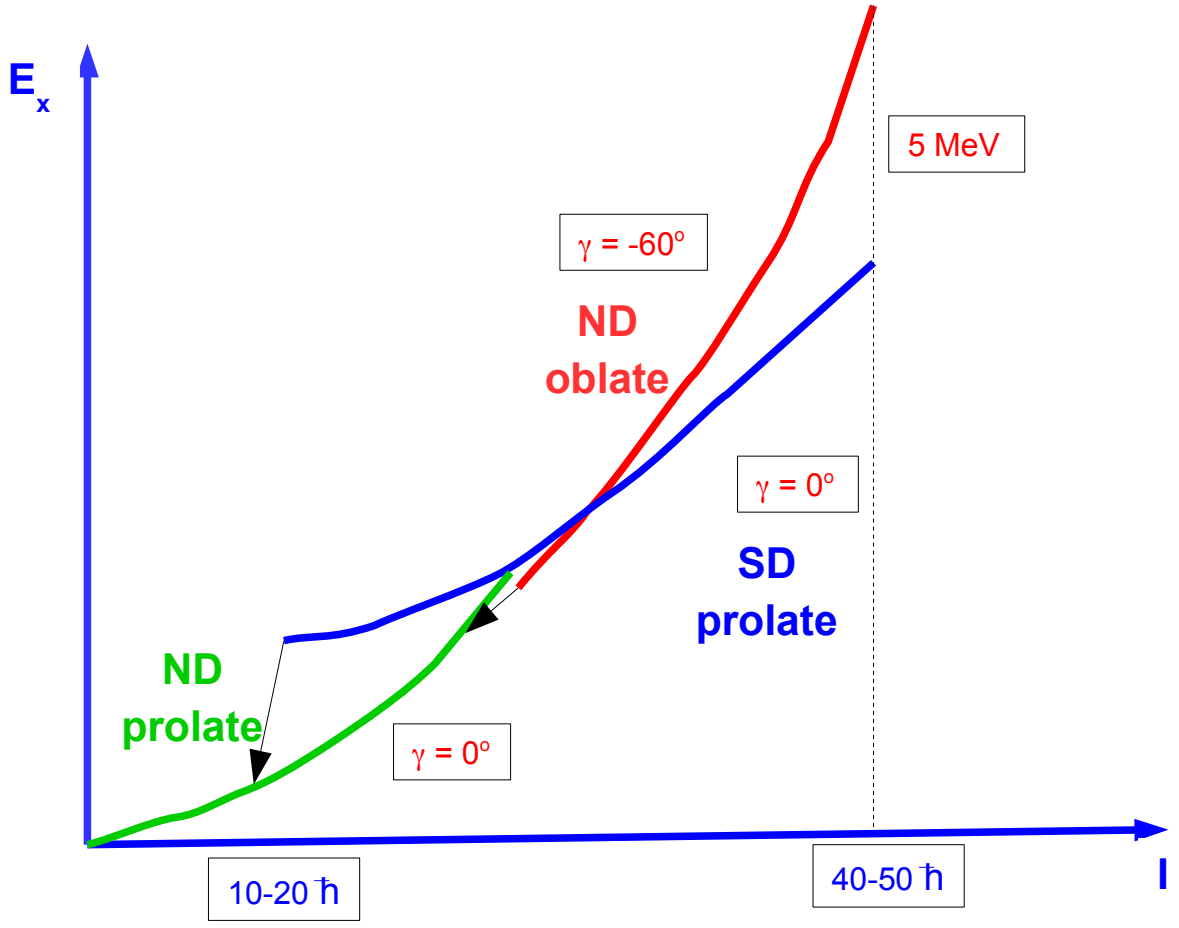
After another expt at Daresbury with EUROGAM 1



Beautiful prolate-oblate shape coexistence

Full set of favored terminations!

Survival in a sea of chaos !



Conclusions, perspectives

- New type of collective rotation at the highest spins : rotation of an oblate nucleus with antimagnetic configuration.
- Oblate rotation at the highest spins in other nuclei ?
- New experiments to firmly link the band to low-lying states and lifetime measurements to support the decreasing deformation at high spins.

Thank you !