Challenging theory in the nuclear landscape
A few pinchos from a Swedish smorgasbord with an experimental perspective

Bo Cederwall
KTH Royal Institute of Technology

International Workshop "Nuclear tapas: the shell model as a cornerstone of nuclear structure"

Honoring **Prof. Alfredo Poves**
on the occasion of his retirement

Pinchos en el menú del dia

- "Unexpected" appearance and disappearance of seniority symmetry

- pairing isospin modes at intermediate angular momentum in heavy N~Z systems

- What is the role of pairing on proton-decay rates?

- Shape coexistence and alpha-decay fine structure

N·H ELSEVIER

2 July 1998

PHYSICS LETTERS B

Physics Letters B 430 (1998) 203–208

Pairing and the structure of the *pf*-shell $N \sim Z$ nuclei

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Abstract

The influence of the isoscalar and isovector $L=0$ pairing components of the effective nucleon-nucleon interaction is evaluated for several isobaric chains, in the framework of full *pf* shell model calculations. We show that the combined effect of both isospin channels of the pairing force is responsible for the appearance of $T=1$ ground states in $N=Z$ odd-odd nuclei. However, no evidence is found relating them to the Wigner energy. We study the dependence of their contributions to the total energy on the rotational frequency in the deformed nucleus ^{48}Cr. Both decrease with increasing angular momentum and go to zero at the band termination. Below the backbending their net effect is a reduction of the moment of inertia, more than half of which comes from the proton-neutron channel.

PACS: 21.10.-k; 21.60.Cs; 27.40.+z

The Nuclear Shell Model Toward the Drip Lines

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NCNP 2011 Stockholm, June 2011

PHYSICAL REVIEW C
covering nuclear physics

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Nilsson-SU3 self-consistency in heavy $N = Z$ nuclei

A. P. Zuker, A. Poves, F. Nowacki, and S. M. Lenzi
Phys. Rev. C **92**, 024320 – Published 26 August 2015

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The shell model as a unified view of nuclear structure

E. Caurier, G. Martínez-Pinedo, F. Nowacki, A. Poves, and A. P. Zuker
Rev. Mod. Phys. **77**, 427 – Published 16 June 2005

IOP Publishing | Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. **43** (2016) 024010 (14pp) doi:10.1088/0954-3899/43/2/024010

Shape coexistence: the shell model view

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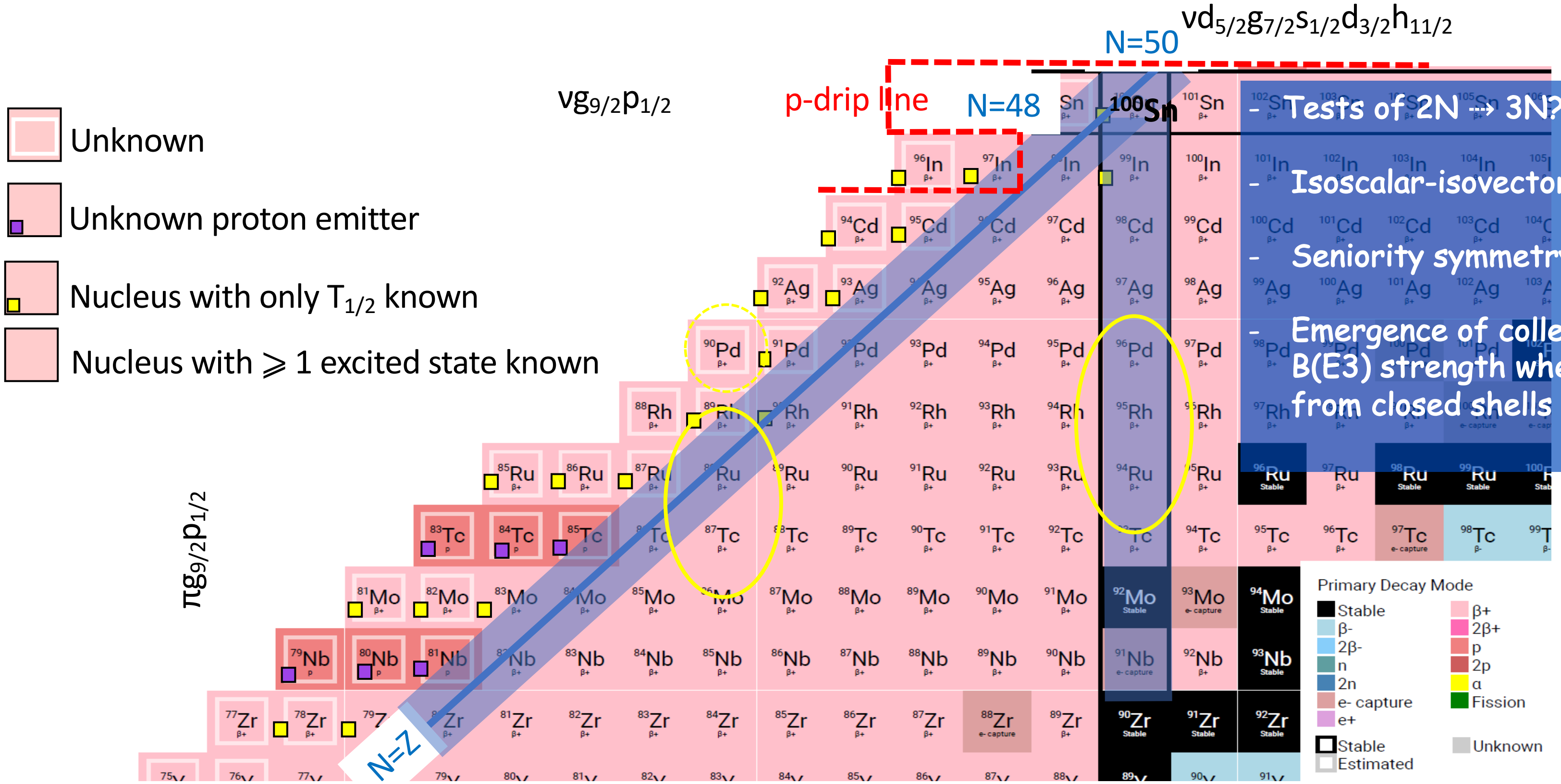
CrossMark

Abstract

We shall discuss the meaning of the 'nuclear shape' in the laboratory frame proper to the spherical shell model. A brief historical promenade will bring us from Elliott's SU3 breakthrough to today's large scale shell model calculations. A section is devoted to the algebraic model which extends drastically the field of applicability of Elliot's SU3, providing a precious heuristic guidance for the exploration of collectivity in the nuclear chart. Shape coexistence and shape mixing will be shown to occur as the result of the competition between the main actors in the nuclear dynamics; the spherical mean field, and the pairing and quadrupole–quadrupole interactions. These ideas will be illustrated with examples in magic nuclei (^{40}Ca and ^{68}Ni); neutron rich semi-magic (^{32}Mg, and ^{64}Cr); and in proton rich $N = Z$ (^{72}Kr).

Keywords: shell model, algebraic approaches, nuclear shapes

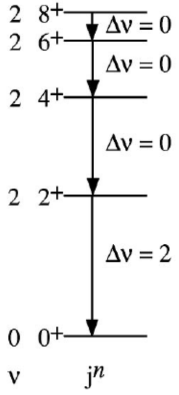
Interplay of seniority symmetry, isoscalar correlations and emergence of collectivity



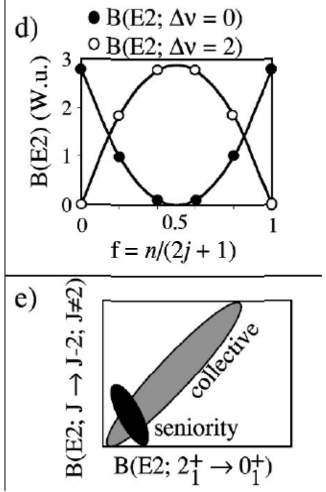
- Tests of 2N → 3N?
- Isoscalar-isovector pairing
- Seniority symmetry
- Emergence of collectivity; B(E2), B(E3) strength when departing from closed shells

Chart from M. Górska

Seniority symmetry
– manifestation of (isovector) 2N interactions in the nucleus



energy level multiplets

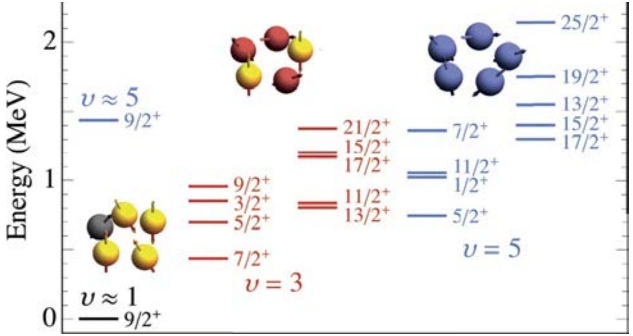


E2 transition strengths
(even-tensor operators)

Physics Letters B
Volume 816, 10 May 2021, 136183

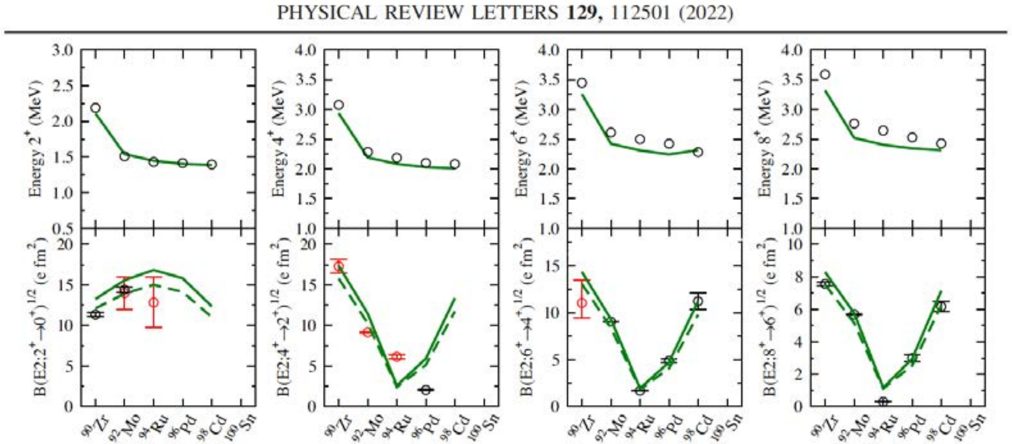
Manifestation of the Berry phase in the atomic nucleus ^{213}Pb

J.J. Valiente-Dobón [a], A. Gottardo [a], G. Benzoni [b], A. Gadea [c], S. Lunardi [d, e], A. Algora [c], G. de Angelis [a], D. Bazzacco [e], J. Benlliure [f], P. Boutachkov [g], A. Bracco [b, h], A.M. Bruce [i], F. Camera [b, h], E. Casarejos [k], M.L. Cortés [g], F.C.L. Crespi [b], A. Corsi [b, h], C. Domingo-Pardo [g], M. Doncel [j], T. Engert [g], H. Geissel [g], J. Gerl [g], A. Goasduff [a], N. Goel [g], M. Górska [g], J. Grebosz [l], E. Gregor [g], T. Habermann [g], S. Klupp [m], I. Kojouharov [g], N. Kurz [g], S.M. Lenzi [d, e], S. Leoni [b, h], S. Mandal [n], R. Menegazzo [e], D. Mengoni [e], B. Million [b], A.I. Morales [b], D.R. Napoli [a], F. Naqvi [g, o], C. Nociforo [g], M. Pfützner [p], S. Pietri [g], Zs. Podolyák [q], A. Prochazka [g], F. Recchia [e], P.H. Regan [q], D. Rudolph [r], E. Sahin [a], H. Schaffner [g], A. Sharma [g], B. Sitar [s], D. Siwal [n], P. Strmen [s], I. Szarka [s], C.A. Ur [e], P.M. Walker [q, t], H. Weick [g], O. Wieland [b], H.-J. Wollersheim [g], P. Van Isacker [u]



J. J. Ressler, R. F. Casten et al., Phys. Rev. C 69, 034317 (2004)
G. Racah, Phys. Rev. 63, 367 (1943).
G. Racah, I. Talmi, Physica 18, 1097 (1952)
P Van Isacker J. Phys.: Conf. Ser. 322 012003 (2011)
J.J.Valiente-Dobón et al., Physics Letters B 816, 136183 (2021)
R.M. Pérez-Vidal et al., Physical Review Letters 129, 112501 (2022)

Seniority Symmetry in the $g_{9/2}$ subshell



DESPEC-FATIMA FAIR-0 experiment S480

Structure of the heaviest N=Z nuclei:

Seniority Transitions and EM Transition Rates in ^{94}Pd

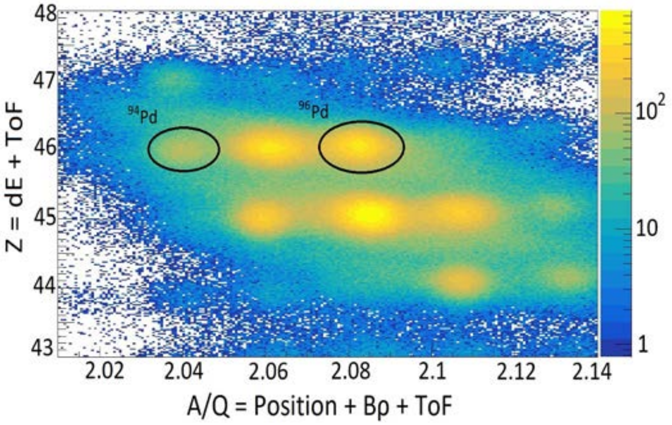
M. Górska, P.H. Regan, B. C., J. Jolie et al.

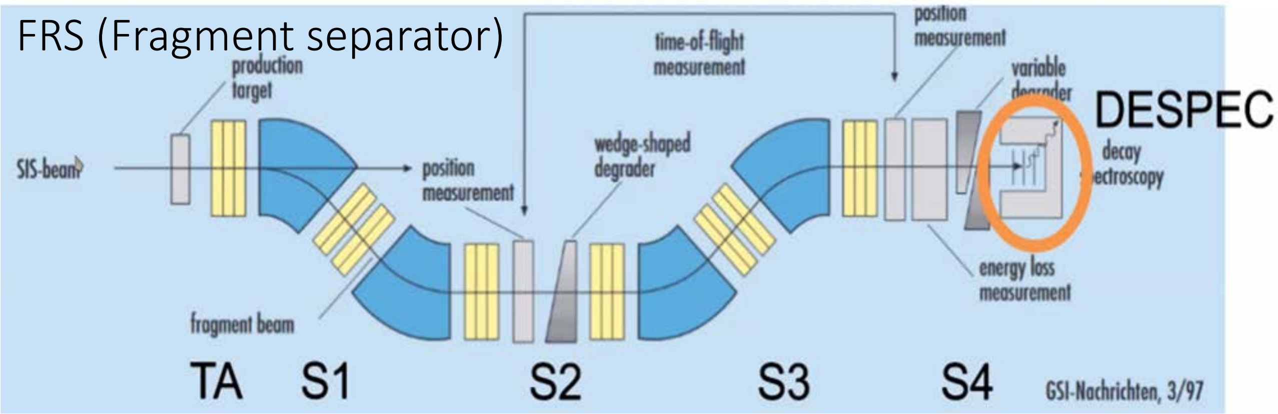
Primary objective, tagged (isomer) fast-timing spectroscopy:
Measure the B(E2:$8^+ \rightarrow 6^+$) in $^{94}Pd_{48}$ (T_z=+1) as test for p-n pairing vs seniority coupling
Here: β-p delayed and β delayed $\gamma\gamma$ (FATIMA) for ^{95}Pd -> $^{94}Ru_{50}$, $^{95}Rh_{50}$

A.K.Mistry et al. NIM A1033, 166662 (2022)

- ^{124}Xe primary beam (982 MeV/u) on a ^{9}Be target (4 g/cm^2)

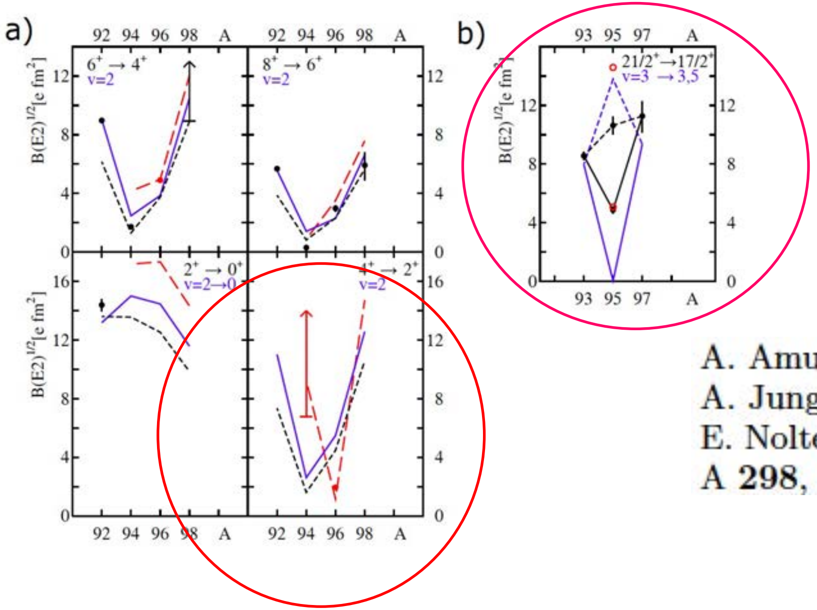
- Secondary beam - separated by magnets and identified by FRS detectors
  - TPCs - Position
  - Scintillators - Time of flight
  - MUSIC - Energy loss





Seniority Symmetry in the $\pi g_{9/2}$ shell

test of 2-body interactions (and if they are sufficient …)



LISE @ GANIL

H. Mach, A. Korgul,, M. Górska, H. Grawe, et al.,
Ultra fast timing lifetime measurements in ^{94}Ru and ^{96}Pd; the breakdown of the seniority scheme in N=50 isotones
Phys. Rev. C 95, 014313 (2017)

A. Amusa, R. D. Lawson, Z. Phys. A. **307**, 333 (1982).
A. Jungclaus *et al.*, Nucl. Phys. A **637**, 346 (1998).
E. Nolte, G. Korschinek and U. Heim, Phys. Lett. Z. Phys. A **298**, 191 (1980).

Seniority symmmetry breaking from subtle in-shell (fpg) mixing effects ^{96}Pd and ^{94}Ru?

PHYSICAL REVIEW C **105**, L031304 (2022)

Letter

S480 (FAIR-0)

Nature of seniority symmetry breaking in the semimagic nucleus ^{94}Ru

B. Das,[1,*] B. Cederwall,[1,†] C. Qi,[1] M. Górska,[2] P. H. Regan,[3,4] Ö. Aktas,[1] H. M. Albers,[2] A. Banerjee,[2] M. M. R. Chishti,[3] J. Gerl,[2] N. Hubbard,[2,5] S. Jazrawi,[3,4] J. Jolie,[6] A. K. Mistry,[2,5] M. Polettini,[7,8] A. Yaneva,[2,6] S. Alhomaidhi,[2,5] J. Zhao,[2] T. Arici,[2] S. Bagchi,[9] G. Benzoni,[8] P. Boutachkov,[2] T. Davinson,[10] T. Dickel,[2,11] E. Haettner,[2] O. Hall,[10] Ch. Hornung,[2] J. P. Hucka,[5] P. R. John,[5] I. Kojouharov,[2] R. Knöbel,[2] D. Kostyleva,[2] N. Kuzminchuk,[2] I. Mukha,[2] W. R. Plass,[2,11] B. S. Nara Singh,[12] J. Vasiljević,[1] S. Pietri,[2] Zs. Podolyák,[3] M. Rudigier,[5] H. Rösch,[5] E. Sahin,[2,5] H. Schaffner,[2] C. Scheidenberger,[2] F. Schirru,[2] A. Sharma,[13] R. Shearman,[4] Y. Tanaka,[2] J. Vesić,[14] H. Weick,[2] H. J. Wollersheim,[2] U. Ahmed,[5] A. Algora,[15,16] C. Appleton,[10] J. Benito,[17] A. Blazhev,[6] A. Bracco,[7,8] A. M. Bruce,[18] M. Brunet,[3] R. Canavan,[3,4] A. Esmaylzadeh,[6] L. M. Fraile,[17] G. Häfner,[19,6] H. Heggen,[2] D. Kahl,[10] V. Karayonchev,[6] R. Kern,[5] A. Korgul,[20] G. Kosir,[14] N. Kurz,[2] R. Lozeva,[19] M. Mikolajczuk,[20,2] P. Napiralla,[5] R. Page,[21] C. M. Petrache,[19] N. Pietralla,[5] J.-M. Régis,[6] P. Ruotsalainen,[22] L. Sexton,[10] V. Sanchez-Temble,[17] M. Si,[19] J. Vilhena,[23] V. Werner,[5] J. Wiederhold,[5] W. Witt,[5] P. J. Woods,[10] and G. Zimba[22]

TABLE I. Experimental mean lifetimes and $B(E2)$ strengths in ^{94}Ru in comparison with various shell model predictions. Experimental data except for $8^+ \rightarrow 6^+$ [41,45] are from the present work.

$I_i^\pi \rightarrow I_f^\pi$	τ (ps)	$B_{EX}(E2)$ (e^2fm^4)	$B_{SMLB}(E2)$ (e^2fm^4)	$B_{SDGN}(E2)$ (e^2fm^4)
$8^+ \rightarrow 6^+$	$102(4)\times10^6$	0.09(1)	2.0	0.77
$6^+ \rightarrow 4^+$	91(3)×10[illegible]	3.0(2)	6.1	17.3
$4^+ \rightarrow 2^+$	32(11)	103(24)	6.8	85.2
$2^+ \rightarrow 0^+$	$\leqslant 15$	$\geqslant 10$	225	295

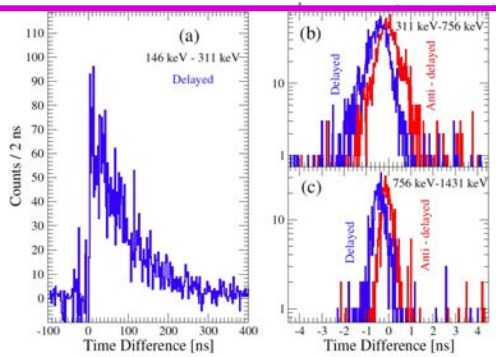
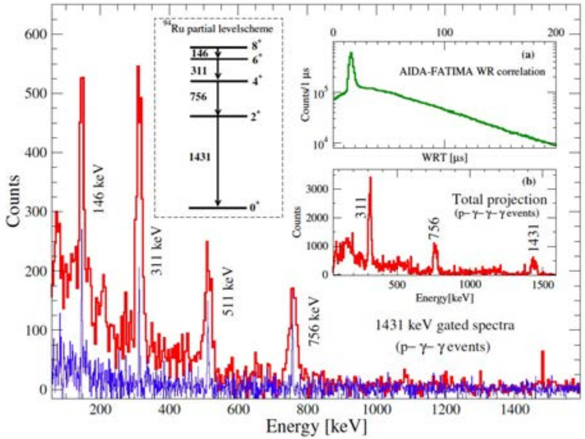
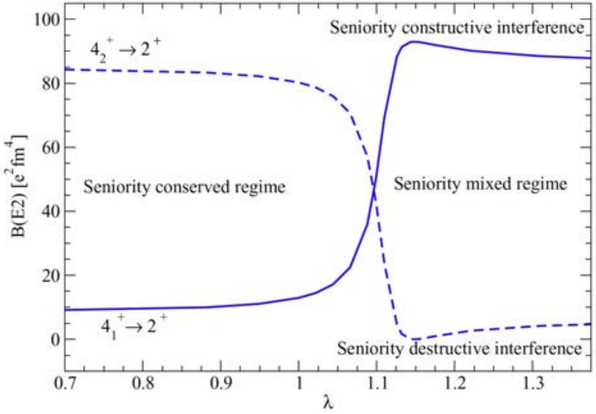


FIG. 3. (Color online) (a) The background subtracted delayed time distribution for the 146 keV-311 keV coincident transitions. The delayed and anti-delayed time distributions for (b) 311 keV - 756 keV transitions, and (c) 756 keV - 1431 keV transitions.

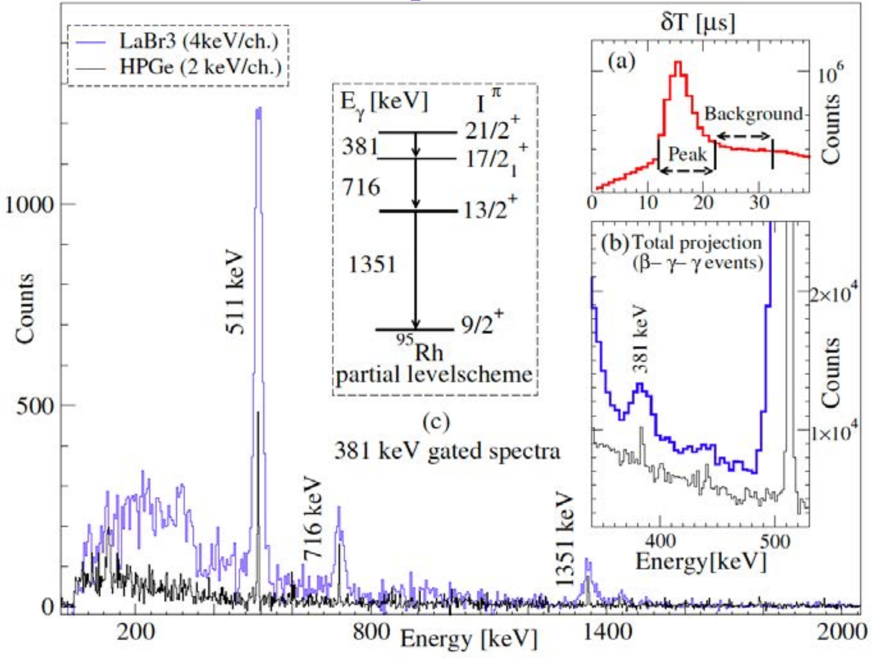




S480: ^{95}**Rh** (*exactly* at the πg9/2 midshell)

B. Das et al., in prep.

The observation of a strongly suppressed E2 strength for the $13/2^+ \rightarrow 9/2^+$ ground-state transition cannot be explained by SM calculations employing standard interactions and model spaces



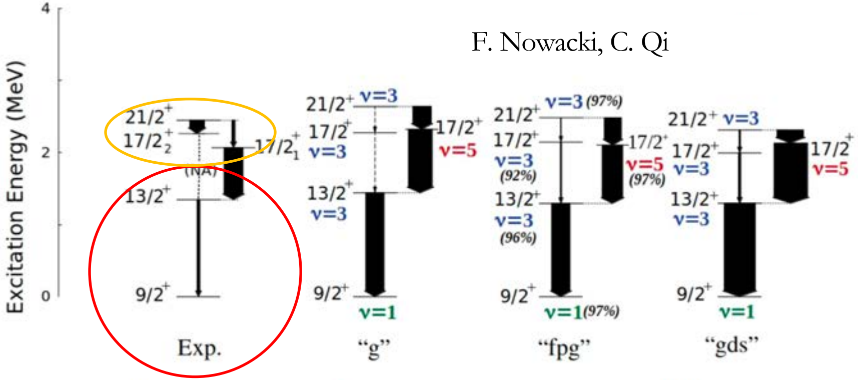


TABLE I. Experimental lifetimes and B(E2) strengths in ^{95}Rh. The lifetime value for the $21/2^+$ state is taken from Ref. [17]. The lifetime limit for the $17/2_1^+$ state was determined with 98% confidence level. See text for details.

$I_i^\pi \rightarrow I_f^\pi$	τ [ps]	$B_{exp.}(E2)$ $[e^2 fm^4]$
$21/2^+ \rightarrow 17/2_1^+$	$3.0(4) \times 10^3$	29.0(4.0)[8]
$21/2^+ \rightarrow 17/2_2^+$	$3.0(4) \times 10^3$	136(20)[8]
$17/2_1^+ \rightarrow 13/2^+$	≤ 28	≥ 154.7
$17/2_2^+ \rightarrow 13/2^+$		
$13/2^+ \rightarrow 9/2^+$	36(15)	$5.0^{+3.6}_{-1.6}$

TABLE II. Theoretical B(E2) strengths in ^{95}Rh calculated in different model spaces. The states are labeled by the dominant seniority component in the wave function. See text for details.

$I_i^\pi \rightarrow I_f^\pi$	$B_{gds}(E2)$ $[e^2 fm^4]$	$B_{fpg}(E2)$ $[e^2 fm^4]$	$B_g(E2)$ $[e^2 fm^4]$
$21/2^+ \rightarrow 17/2^+_{\nu=3}$	10.72	2.82	0.00
$21/2^+ \rightarrow 17/2^+_{\nu=5}$	177.09	158.14	172.00
$17/2^+_{\nu=3} \rightarrow 13/2^+$	18.41	10.88	0.00
$17/2^+_{\nu=5} \rightarrow 13/2^+$	232.37	189.49	208.70
$13/2^+ \rightarrow 9/2^+$	219.24	169.71	169.27

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Lifetime Measurements of Excited States in ^{172}Pt and the Variation of Quadrupole Transition Strength with Angular Momentum

B. Cederwall *et al.*
Phys. Rev. Lett. **121**, 022502 – Published 10 July 2018

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covering nuclear physics

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Decay spectroscopy of ^{171,172}Os and ^{171,172,174}Ir

W. Zhang *et al.*
Phys. Rev. C **107**, 014308 – Published 19 January 2023

SpringerLink

Regular Article – Experimental Physics | Open Access | Published: 20 February 2020

Evidence for octupole collectivity in ^{172}Pt

A. Ertoprak, B. Cederwall, [...]R. Wyss

The European Physical Journal A **56**, Article number: 65 (2020) | Cite this article

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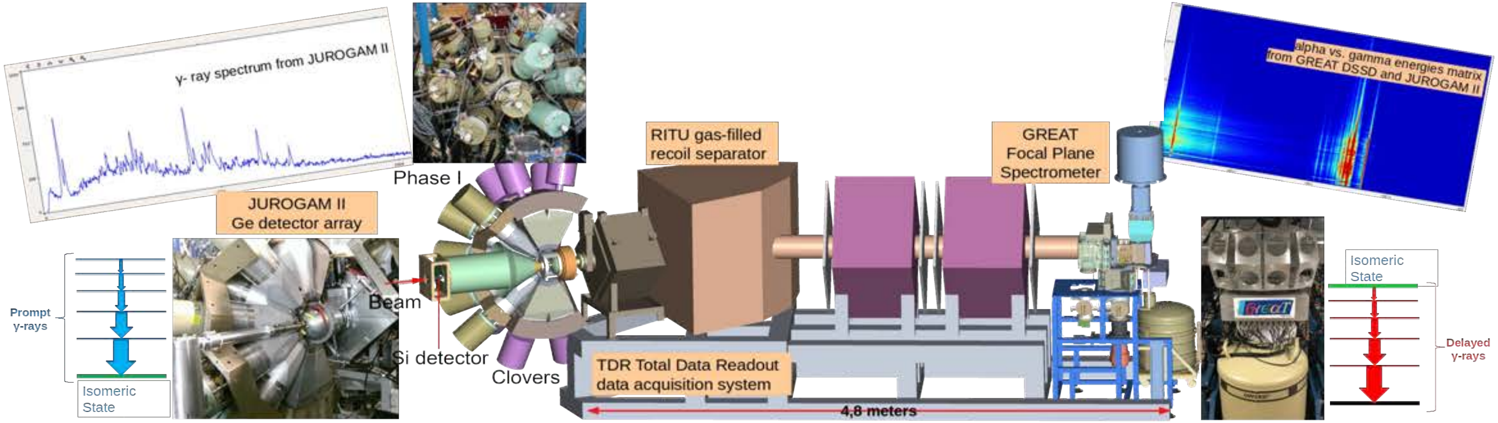
ELSEVIER — Physics Letters B
Volume 820, 10 September 2021, 136527

Lifetime measurements of excited states in ^{169,171,173}Os: Persistence of anomalous $B(E2)$ ratios in transitional rare earth nuclei in the presence of a decoupled $i_{13/2}$ valence neutron

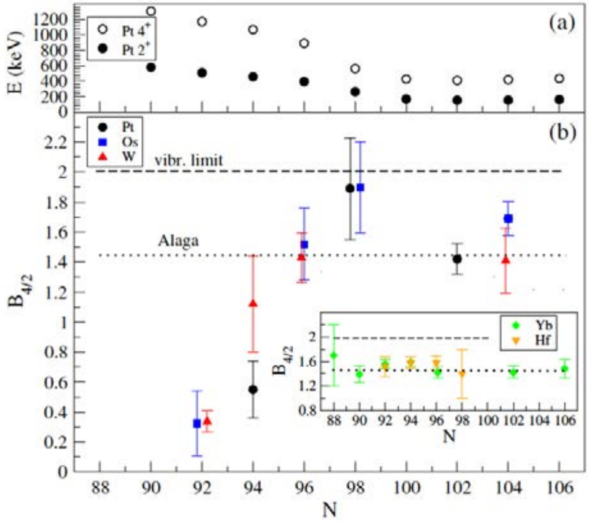
W. Zhang[a], B. Cederwall[a], M. Doncel[b,c], Ö. Aktas[a], A. Ertoprak[a,d], R. Liotta[a], C. Qi[a], T. Grahn[e], B.S. Nara Singh[f,g], D.M. Cullen[f], D. Hodge[f], M. Giles[f], S. Stolze[e], H. Badran[e], T. Braunroth[h], T. Calverley[e], D.M. Cox[e,i], Y.D. Fang[j] ... J.J. Valiente-Dobón[k]



PHYSICAL REVIEW LETTERS 121, 022502 (2018)

Lifetime Measurements of Excited States in ^{172}Pt and the Variation of Quadrupole Transition Strength with Angular Momentum

B. Cederwall,[1,*] M. Doncel,[2] Ö. Aktas,[1] A. Ertoprak,[1,3] R. Liotta,[1] C. Qi,[1] T. Grahn,[4] D. M Cullen,[5] D. Hodge,[5] M. Giles,[5] S. Stolze,[4] H. Badran,[4] T. Braunroth,[6] T. Calverley,[4] D. M. Cox,[4,†] Y. D. Fang,[7] P. T. Greenlees,[4] J. Hilton,[4] E. Ideguchi,[7] R. Julin,[4] S. Juutinen,[4] M. Kumar Raju,[7] H. Li,[8] H. Liu,[1] S. Matta,[1] V. Modamio,[9] J. Pakarinen,[4] P. Papadakis,[4,‡] J. Partanen,[4] C. M. Petrache,[10] P. Rahkila,[4] P. Ruotsalainen,[4] M. Sandzelius,[4] J. Sarén,[4] C. Scholey,[4] J. Sorri,[4,12,§] P. Subramaniam,[1] M. J. Taylor,[11] J. Uusitalo,[4] and J. J. Valiente-Dobón[12]



Physics Letters B 820 (2021) 136527

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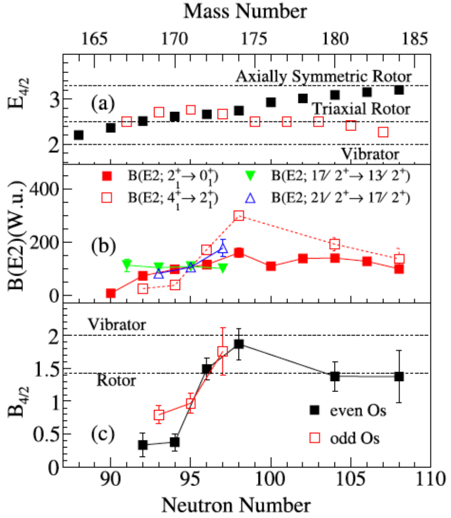
ELSEVIER

Lifetime measurements of excited states in ^{169,171,173}Os: Persistence of anomalous $B(E2)$ ratios in transitional rare earth nuclei in the presence of a decoupled $i_{13/2}$ valence neutron

W. Zhang[a,*], B. Cederwall[a], M. Doncel[b,c], Ö. Aktas[a], A. Ertoprak[a,d], R. Liotta[a], C. Qi[a], T. Grahn[e], B.S. Nara Singh[f,g], D.M. Cullen[f], D. Hodge[f], M. Giles[f], S. Stolze[e], H. Badran[e], T. Braunroth[h], T. Calverley[e], D.M. Cox[e,i], Y.D. Fang[j], P.T. Greenlees[e], J. Hilton[e], E. Ideguchi[j], R. Julin[e], S. Juutinen[e], M. Kumar Raju[j], H. Li[k], H. Liu[a], S. Matta[a], P. Subramaniam[a], V. Modamio[l], J. Pakarinen[e], P. Papadakis[e,m], J. Partanen[e], C.M. Petrache[n], P. Rahkila[e], P. Ruotsalainen[e], M. Sandzelius[e], J. Sarén[e], C. Scholey[e], J. Sorri[e,o], M.J. Taylor[p], J. Uusitalo[e], J.J. Valiente-Dobón[q]

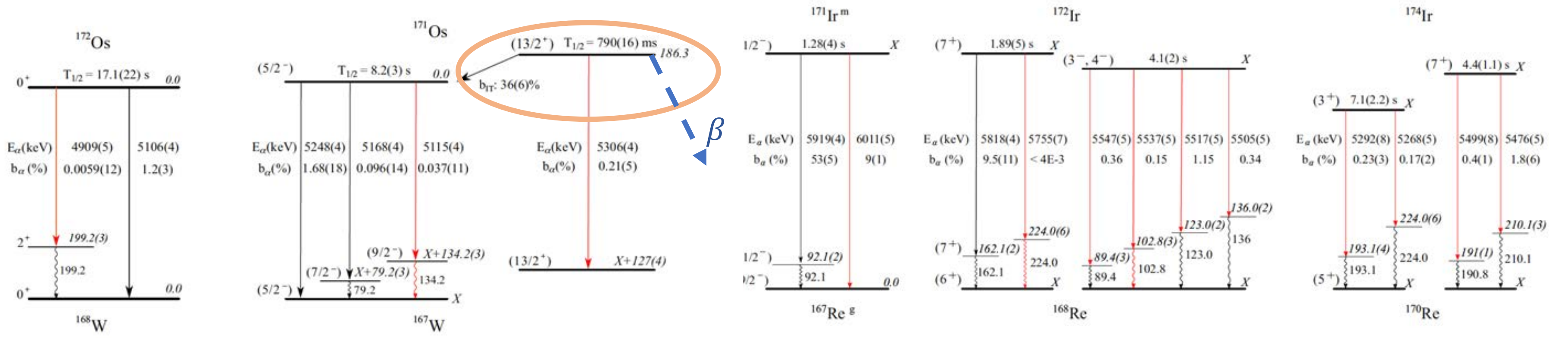


Phase transition between (unexpected) seniority-like and collective structure? SM calculations run out of steam. Can can we find a solution within the IBA approach (beyond Casten's simple formula)? See talk by Chong Qi

PHYSICAL REVIEW C **107**, 014308 (2023)

Decay spectroscopy of ^{171,172}Os and ^{171,172,174}Ir

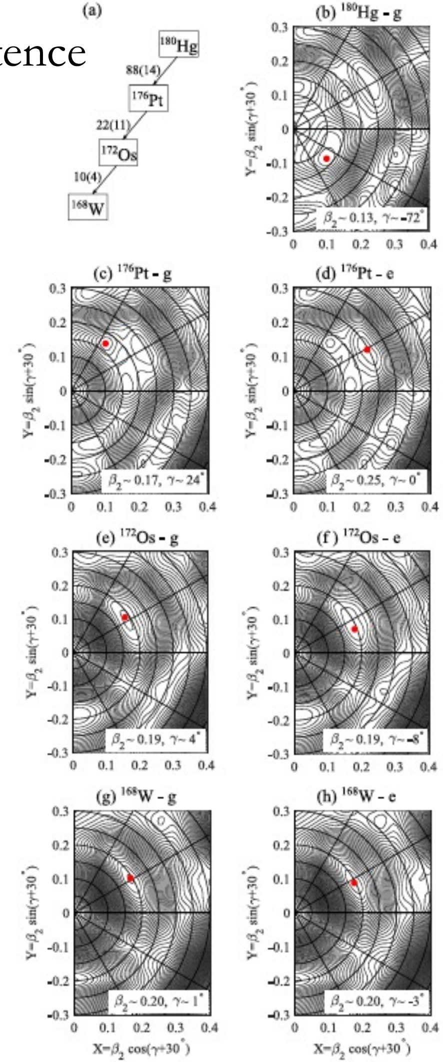
W. Zhang,[1] B. Cederwall,[1] M. Doncel,[2] Ö. Aktas,[1] A. Ertoprak,[1] C. Qi,[1] T. Grahn,[3] B. S. Nara Singh,[4] D. M. Cullen,[5] D. Hodge,[5] M. Giles,[5] S. Stolze,[3] K. Auranen,[3] H. Badran,[3] T. Braunroth,[6] T. Calverley,[3] D. M. Cox,[7] Y. D. Fang,[8,9] P. T. Greenlees,[3] J. Hilton,[3] E. Ideguchi,[8] R. Julin,[3] S. Juutinen,[3] M. Kumar Raju,[8,10] M. Leino,[3] H. Li,[1] H. Liu,[1] S. Matta,[1] P. Subramaniam,[1] V. Modamio,[11] J. Pakarinen,[3] P. Papadakis,[12] J. Partanen,[3] C. M. Petrache,[13] P. Rahkila,[3] P. Ruotsalainen,[3] M. Sandzelius,[3] J. Sarén,[3] C. Scholey,[3] J. Sorri,[3] M. J. Taylor,[3] J. Uusitalo,[3] and J. J. Valiente-Dobón[14]



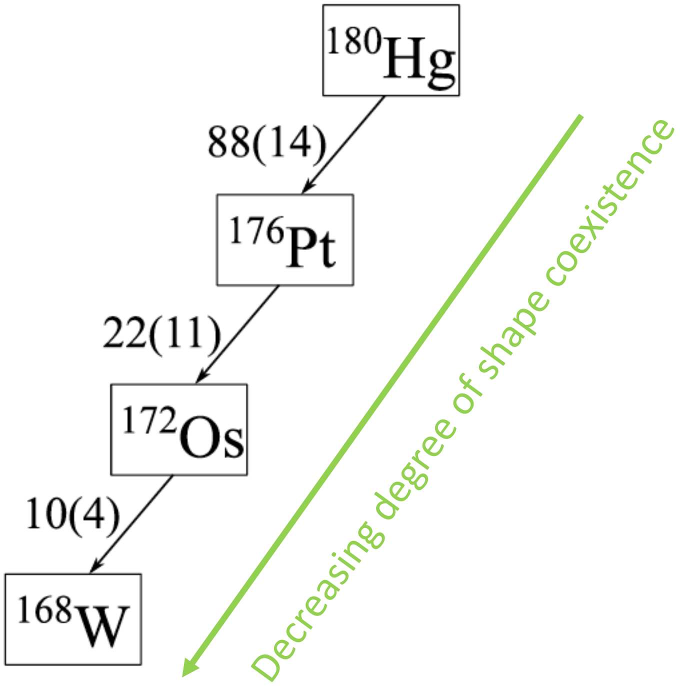
α-decay fine structure in the "classical" region of shape coexistence

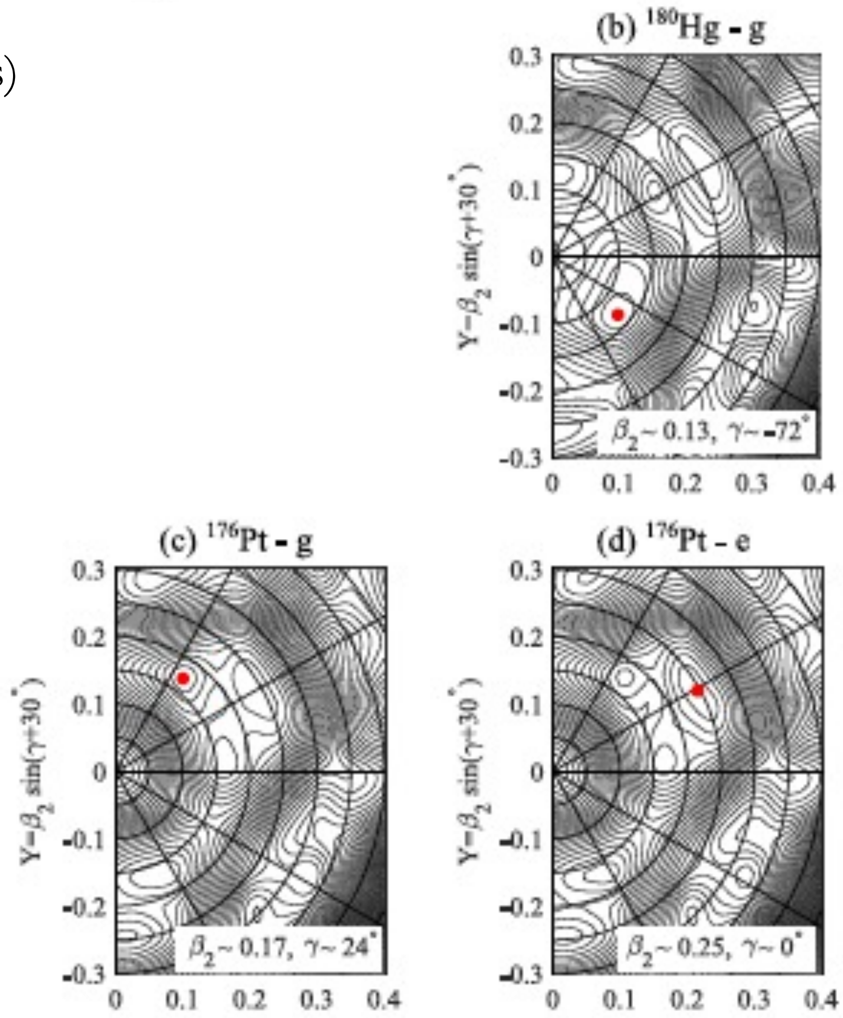
TABLE I. Measured α-decay energies, E_α (coincident E_γ, if observed), half-life values $T_{1/2}$, branching ratios b_α, formation probabilities $|RF_l(R)|^2$, reduced widths, relative hindrance factors (HF) (when possible) referenced to the α decay of ^{170}Os with $E_\alpha = 5.407$ MeV, tentative spin and parity assignments as proposed from this work or quoted from the earlier studies, and the deduced internal conversion coefficients as well as the multipolarities (when possible) for $^{171,172}Os$ and $^{171,172,174}Ir$.

Nucleus	J_i^π	$T_{1/2}$ (s)	E_α (keV)	b_α (%)	$\|RF_l(R)\|^2$ (fm^{-1})	δ^2 (keV)	HF	J_f^π	E_γ (keV)	α_k	Multipolarity
^{170}Os [17]	0^+	7.37(18)	5407(2)	9.5(10)	0.012(1)	117(12)	1	0^+			
^{172}Os	0^+	17.1(2.2)	5106(4)	1.2(3)	0.019(5)	182(51)	0.6(2)	0^+			
^{172}Os			4909(5)	0.0059(12)	0.0017(4)	17(4)	7(2)	2^+	199.2(3)		$E2$
^{171}Os	$(5/2^-)$ [28]	8.0(4)	5248(4)	1.68(18) [17]	0.011(1)	109(12)	1.1(1)	$(5/2^-)$ [17]			
^{171}Os			5168(4)	0.096(14)	0.0029(4)	28(4)	4.2(7)	$(7/2^-)$ [17]	79.2(3)	9.0(11)	$M1$
^{171}Os			5115(4)	0.037(11)	0.0021(6)	20(6)	6(2)	$(9/2^-)$	134.2(3)	0.39(8)	$E2$
^{171}Os	$(13/2^+)$ [28]	0.79(2)	5306(4)	0.21(5)	0.0076(18)	72(17)	1.6(4)	$(13/2^+)$			
^{171}Ir	$(11/2^-)$ [31]	1.28(4)	5919(4)	53(5) [31]	0.0067(6)	61(6)	1.9(3)	$(11/2^-)$ [31]	92.1(2)	5.1(4)	$M1$
^{171}Ir			6011(5)	9(1)[a]	0.0008(1)	7.8(9)	15(2)	$(9/2^-)$			
^{172}Ir	(7^+) [33]	1.89(5)	5818(4)	9.5(11) [33]	0.0020(2)	19(2)	6.2(9)	(7^+) [33]	162.1(2)	0.69(6)	$M1/E2$ [34]
^{172}Ir			5755(7)	<0.004					224.0(6)		
^{172}Ir	$(3^-, 4^-)$ [33]	4.1(2)	5547(5)	0.36(6)[b]					89.4(3)		$E1$[c]
^{172}Ir			5537(5)	0.15(3)[b]					102.8(3)		$E1$[c]
^{172}Ir			5517(5)	1.15(20)[b]					123.0(2)		$E1$ [34]
^{172}Ir			5505(5)	0.34(6)[b]					136.0(2)		$E1$[c]
^{174}Ir	(3^+) [34]	7.1(22)[d]	5292(8)	0.23(3)[e]					193.1(4)		$E2$[f]
^{174}Ir			5268(5)	0.17(2)[e]					224.0(6)		$E2$[f]
^{174}Ir	(7^+) [34]	4.4(1.1)[g]	5499(8)	0.4(1)[h]					191(1)		E1[i]
^{174}Ir			5476(5)	1.8(6)[h]					210.1(3)		E2[j]



HF(gs→2+)/HF(gs → gs)

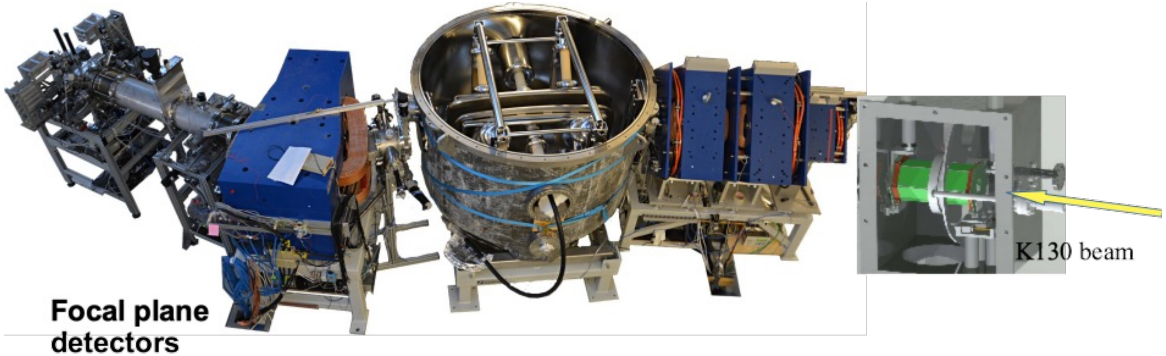


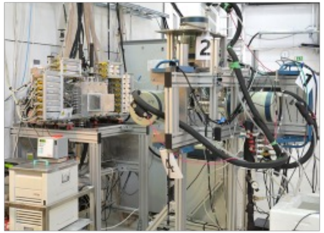


HFs seem to correlate qualitatively with predicted shape changes

Calculations of NME ?

MARA@JYFL (K130 cyclotron)





Micron BB20 DSSD
Area: 128 × 48 mm^2
Strip pitch: 0.67 mm

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Observation of the proton emitter ${}^{116}_{57}\mathrm{La}_{59}$

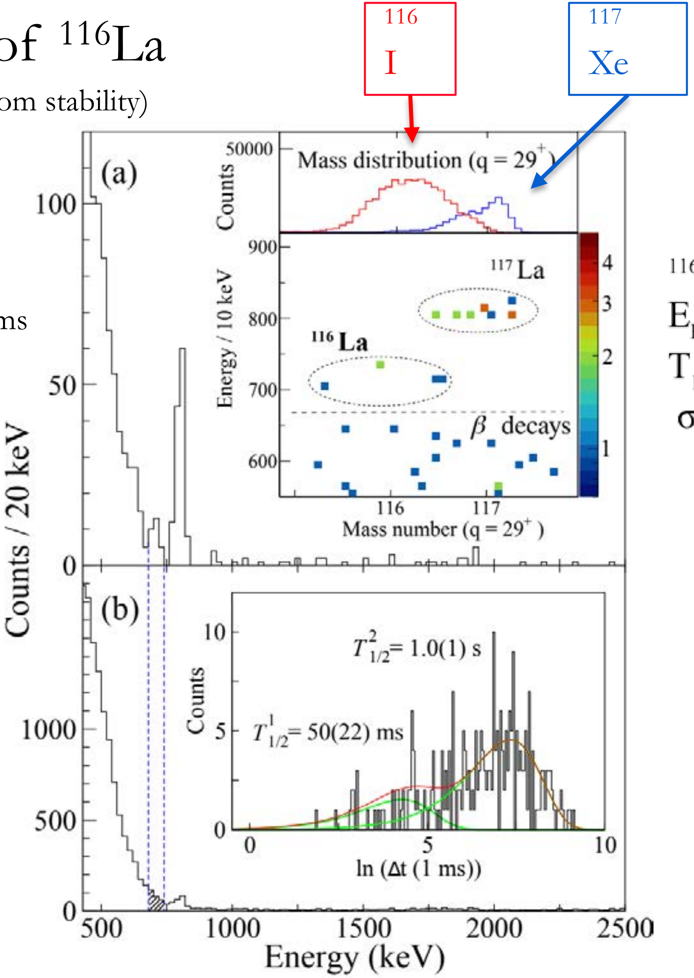
Wei Zhang, Bo Cederwall, Özge Aktas, Xiaoyu Liu, Aysegül Ertoprak, Ayse Nyberg, Kalle Auranen, Betool Alayed, Hussam Badran, Helen Boston, Maria Doncel, Ulrika Forsberg, Tuomas Grahn, Paul T. Greenlees, Song Guo, Jacob Heery, Joshua Hilton, David Jenkins, Rauno Julin, Sakari Juutinen, Minna Luoma, Olavi Neuvonen, Joonas Ojala, Robert D. Page, Janne Pakarinen, Jari Partanen, Edward S. Paul, Costel Petrache, Panu Rahkila, Panu Ruotsalainen, Mikael Sandzelius, Jan Sarén, Stuart Szwec, Holly

Identification of ^{116}La

(T_Z=1   22 neutrons from stability)

Tcorr max (recoil – ptoton) = 100 ms

Tcorr max (recoil – ptoton) = 10 s

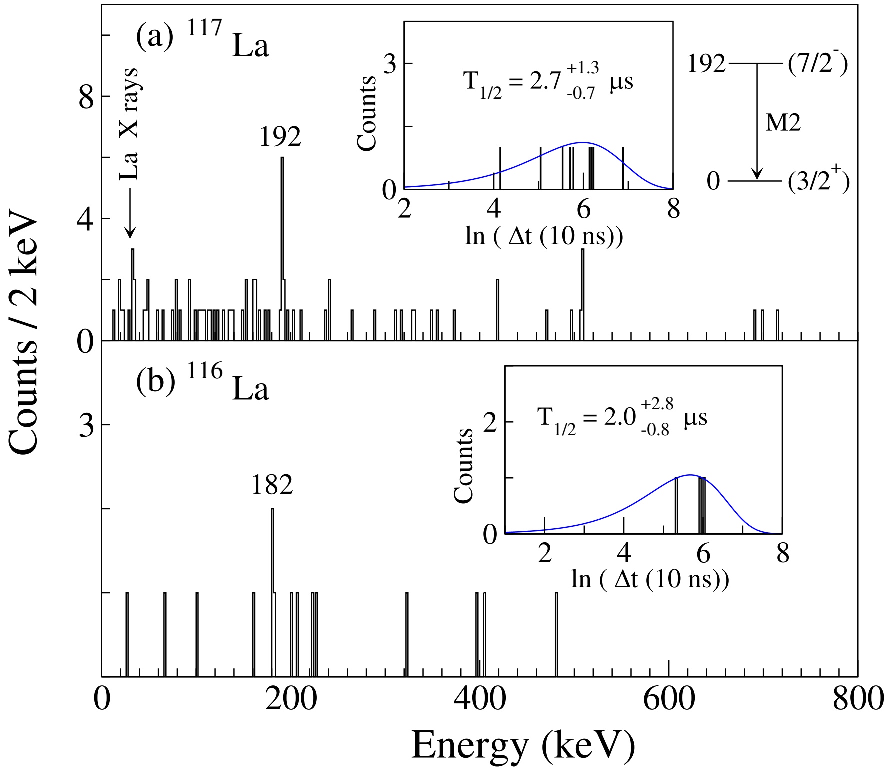


^{116}La:

$E_p = 718(9)$ keV

$T_{1/2} = 40^{+32}_{-14}$ ms

$\sigma \sim 8$ nb



γ-ray energies detected within 8 μs of a recoil implantation into the DSSD and followed by a proton decay (^{117}La/^{116}La) in the same quasipixel.

Insets: logarithmic time distributioons and lifetime determination using the maximum likelihood method

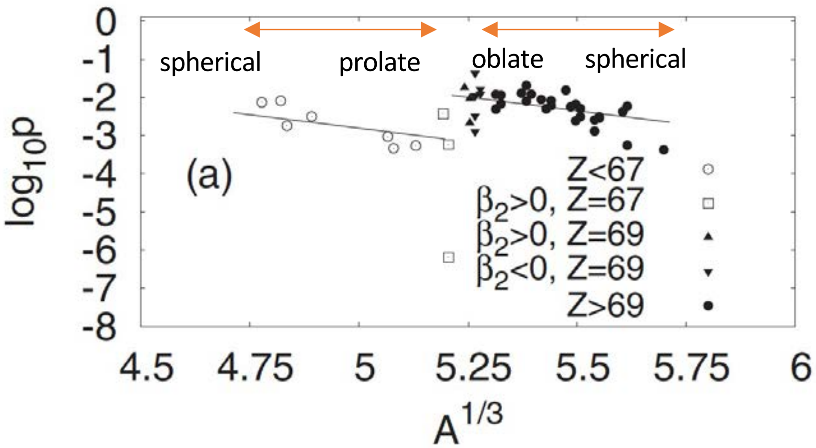
”Microscopic” description of proton decay*

$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma_l} = \frac{\ln 2}{v} \left| \frac{H_l^+(\chi,\rho)}{RF_l(R)} \right|^2$$

where $F_l(R)$ is the formation amplitude

and the penetrability can be written $P_l(R) = \frac{kR}{|H_l^+(R)|^2}$

Deformation parameters taken from
P. Möller, R. J. Nix, W. D. Myers, and W. Swiatecki, At. Data Nucl. Data Tables 59, 185 (1995)

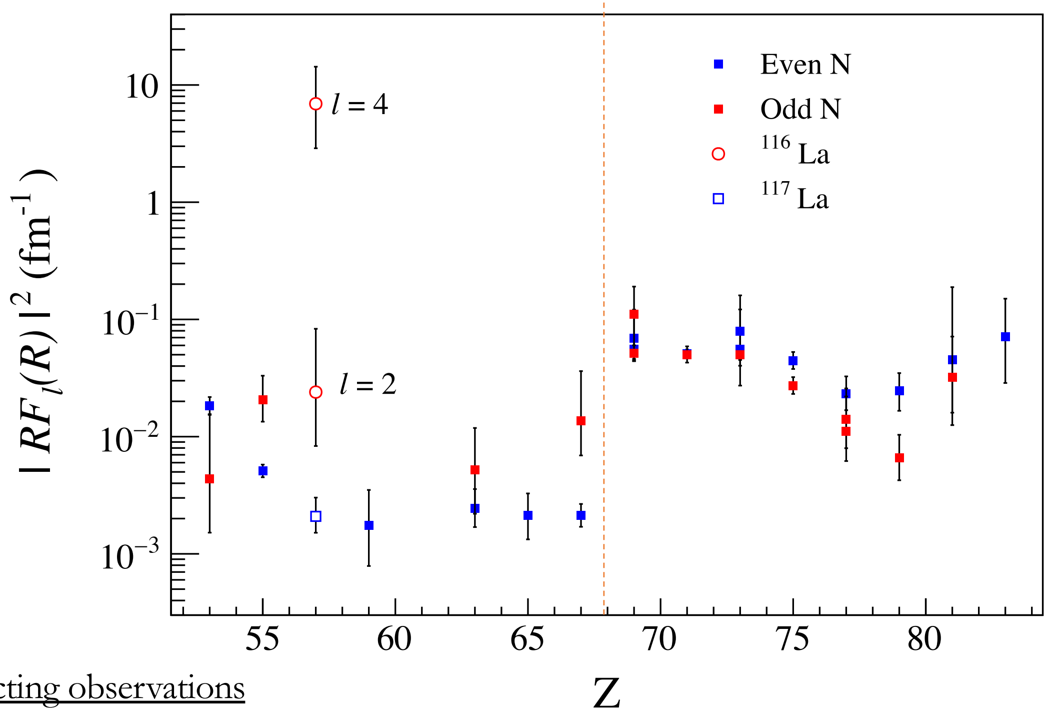


* D. S. Delion and A. Dumitrescu, Universal proton emission systematics, Phys. Rev. C 103, 054325 (2021)
D. S. Delion., R.J. Liotta and R. Wyss, Effects of formation properties in one-proton radioactivity, Phys. Rev. C 85, 011303(R) (2012)
D. S. Delion., R.J. Liotta and R. Wyss, Systematics of proton emission, Phys. Rev. Lett. 96, 072501 (2006)
C. Qi, F.R. Xu, R.J. Liotta and R. Wyss, Universal decay law in charged-particle emission and exotic cluster radioactivity. Phys. Rev. Lett. 103, 072501 (2009).

Table 1 Calculated proton formation probabilities and spectroscopic factors for the ground-state proton emitters.

Emitter	l_p	Q_p (keV)	$T^p_{1/2}$(exp)	$\|RF_l(R)\|^2(fm^{-1})$	Orbit	$T^{th}_{1/2}$(WKB)	S_{exp} (%)
$^{108}_{53}$I	2	605(13)	5.3(2.2) s	$0.004^{+0.011}_{-0.003}$	$2d_{5/2}$	89^{+95}_{-45} ms	$1.7^{+4.2}_{-1.1}$
$^{109}_{53}$I	2	827(5)	93.5(5) μs	0.018(3)	$2d_{5/2}$	6.2(11) μs	6.6(12)
$^{112}_{55}$Cs	2	823(7)	0.5(1) ms	$0.021^{+0.012}_{-0.008}$	$2d_{5/2}$	41^{+12}_{-9}μs	8^{+5}_{-3}
$^{113}_{55}$Cs	2	976(3)	16.7(7) μs	0.005(1)	$2d_{5/2}$	0.33(3) μs	2.0(3)
$^{116}_{57}$La	2	734(9)	84^{+86}_{-50} ms	$0.023^{+0.06}_{-0.015}$	$2d_{5/2}$	$8.6^{+4.2}_{-2.6}$ ms	10^{+28}_{-6}
$^{117}_{57}$La	2	825(5)	23.1(3.6) ms	$0.0021^{+0.0009}_{-0.0006}$	$2d_{5/2}$	$0.21^{+0.05}_{-0.03}$ ms	$0.9^{+0.4}_{-0.3}$
$^{121}_{59}$Pr	2	900(10)	10^{+6}_{-3} ms	$0.0018^{+0.0017}_{-0.001}$	$2d_{5/2}$	84^{+33}_{-24}μs	$0.8^{+0.8}_{-0.5}$
$^{130}_{63}$Eu	2	1039(15)	$0.90^{+0.49}_{-0.29}$ ms	$0.005^{+0.007}_{-0.003}$	$2d_{5/2}$	26^{+14}_{-9}μs	3^{+4}_{-2}
$^{131}_{63}$Eu	2	959(9)	$21.4^{+1.8}_{-1.7}$ ms	$0.0025^{+0.0011}_{-0.0008}$	$2d_{5/2}$	0.3(1) ms	$1.4^{+0.6}_{-0.5}$
$^{135}_{65}$Tb	3	1200(7)	$0.94^{+0.33}_{-0.22}$ ms	$0.0021^{+0.0012}_{-0.0008}$	$1h_{11/2}$	7.6(14) ms	> 100
$^{140}_{67}$Ho	3	1106(10)	6(3) ms	$0.014^{+0.022}_{-0.007}$	$1h_{11/2}$	320^{+110}_{-80} ms	> 100
$^{141}_{67}$Ho	3	1190(8)	4.1(1) ms	$0.0021^{+0.0006}_{-0.0004}$	$1h_{11/2}$	32(7) ms	> 100
$^{144}_{69}$Tm	5	1725(16)	$2.7^{+1.7}_{-0.7}$μs	$0.11^{+0.08}_{-0.06}$	$1h_{11/2}$	$2.9^{+0.8}_{-0.6}$μs	- 100
$^{145}_{69}$Tm	5	1753(7)	3.46(32) μs	$0.056^{+0.012}_{-0.01}$	$1h_{11/2}$	1.8(2) μs	53(11)
$^{146}_{69}$Tm	5	1210(4)	117.6(64) ms	$0.051^{+0.009}_{-0.007}$	$1h_{11/2}$	67(7) ms	57^{+10}_{-8}
$^{147}_{69}$Tm	5	1073(5)	3.78(1.27) s	$0.069^{+0.052}_{-0.025}$	$1h_{11/2}$	3.0(5) s	80^{+60}_{-30}
$^{150}_{71}$Lu	5	1283(3)	64.0(56) ms	0.05(1)	$1h_{11/2}$	38(3) ms	60(10)
$^{151}_{71}$Lu	5	1253(3)	127.1(18) ms	0.051(5)	$1h_{11/2}$	77(6) ms	61(6)
$^{155}_{73}$Ta	5	1468(15)	$2.9^{+1.5}_{-1.1}$ ms	$0.056^{+0.065}_{-0.029}$	$1h_{11/2}$	$2.0^{+0.7}_{-0.5}$ ms	69^{+82}_{-36}
$^{156}_{73}$Ta	2	1032(5)	149(8) ms	$0.05^{+0.013}_{-0.01}$	$2d_{3/2}$	70^{+13}_{-11} ms	47^{+12}_{-9}
$^{157}_{73}$Ta	0	947(7)	300(105) ms	$0.08^{+0.08}_{-0.035}$	$3s_{1/2}$	170(50) ms	56^{+56}_{-25}
$^{160}_{75}$Re	2	1287(6)	687(11) μs	0.027(5)	$2d_{3/2}$	0.18(3) ms	26(5)
$^{161}_{75}$Re	0	1214(6)	0.440(2) ms	0.045(7)	$3s_{1/2}$	0.14(3) ms	32(6)
$^{164}_{77}$Ir	5	1844(9)	113^{+62}_{-30}μs	$0.014^{+0.008}_{-0.006}$	$1h_{11/2}$	$21.5^{+3.2}_{-2.8}$μs	20(10)
$^{166}_{77}$Ir	2	1168(7)	152(71) ms	$0.011^{+0.015}_{-0.005}$	$2d_{3/2}$	18(4) ms	12^{+15}_{-6}
$^{167}_{77}$Ir	0	1096(6)	110(15) ms	$0.023^{+0.01}_{-0.006}$	$3s_{1/2}$	20^{+5}_{-4} ms	18^{+8}_{-5}
$^{170}_{79}$Au	2	1488(12)	321^{+67}_{-58}μs	0.007(3)	$2d_{3/2}$	23(6) μs	7^{+4}_{-3}
$^{171}_{79}$Au	0	1464(10)	$24.5^{+4.7}_{-3.1}$*mus*	$0.025^{+0.01}_{-0.008}$	$3s_{1/2}$	$4.9^{+1.2}_{-1}$μs	20^{+8}_{-6}
$^{176}_{81}$Tl	0	1282(18)	$5.2^{+3.0}_{-1.4}$ ms	$0.032^{+0.039}_{-0.019}$	$3s_{1/2}$	$1.5^{+1.0}_{-0.6}$ ms	29^{+35}_{-18}
$^{177}_{81}$Tl	0	1180(20)	67(37) ms	$0.05^{+0.14}_{-0.03}$	$3s_{1/2}$	28^{+24}_{-13} ms	41^{+130}_{-26}
$^{185}_{83}$Bi	0	1624(16)	$3.0^{+2.5}_{-1.1}$μs	$0.07^{+0.08}_{-0.03}$	$3s_{1/2}$	2.0(7) μs	64^{+72}_{-38}

The experimental Q_p values (including the recoil and electron screening corrections[68]), the partial proton emission half-lives, $T^p_{1/2}$, and the emitted angular momentum l_p (used for the formation probability calculation), as well as the specified spherical orbitals (for the calculation of half-lives, $T^{th}_{1/2}$) are taken from refs. [29,49-51], apart from the results for ^{116,117}La obtained in the present work. The theoretical half-lives, $T^{th}_{1/2}$, are calculated within the WKB approximation using the Becchetti-Greenless optical model parameters[69] and the experimental spectroscopic factors are determined as ratios of calculated and measured half-lives, $S_{exp} = T^{th}_{1/2}/T^p_{1/2}$. For the odd-odd proton emitters, it is assumed that the valence neutron remains the same configuration in the parent and daughter nuclei. Experimental uncertainties in the half-lives and Q-values have been taken into account when calculating the error bars of the formation probabilities and spectroscopic factors.



Two seemingly conflicting observations

- The emission probabilities in the odd-odd proton emitters ^{112}Cs, ^{116}La, ^{140}Ho appear to be enhanced compared with the respective neighboring isotopes ^{113}Cs, ^{117}La, ^{141}Ho closer to stability

At the same time:

- Proton-decay Q value differences:

Q(^{112}Cs) – Q(^{113}Cs) = -153(8) keV

Q(116La) – Q(^{117}La) = -90(10) keV

Q(^{140}Ho) – Q(^{141}Ho) = -83(11) keV

D. S. Delion and A. Dumitrescu, Universal proton emission systematics,
Phys. Rev. C 103, 054325 (2021)
D. S. Delion., R.J. Liotta and R. Wyss, Effects of formation properties in one-proton radioactivity,
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Phys. Rev. Lett. 103, 072501 (2009).

PHYSICAL REVIEW C **71**, 054303 (2005)

Nuclear pairing: Surface or bulk?

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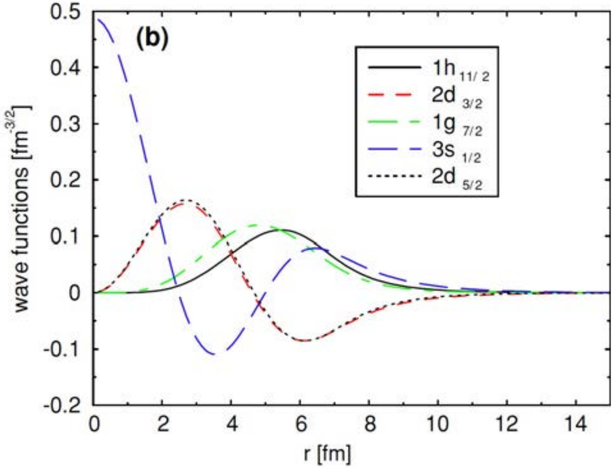
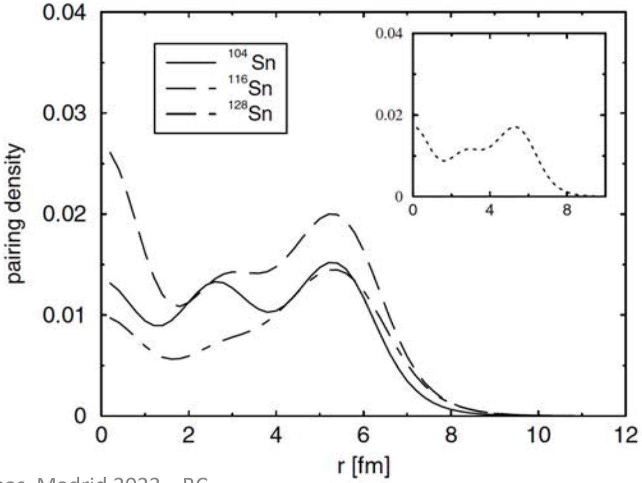
(Received 5 January 2005; published 11 May 2005)

HFB





Spatial dependence of the pairing gap in superfluid nuclei

E. Vigezzi[*], F.Barranco[†], R. A. Broglia[*,**], A. Pastore[*] and G. Potel[*]

[*] INFN, Sezione di Milano and Dipartimento di Fisica, Università di Milano, Via Celoria 16, 20133 Milano, Italy.
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AIP Conference Proceedings **1120**, 92 (2009)

HF + RPA

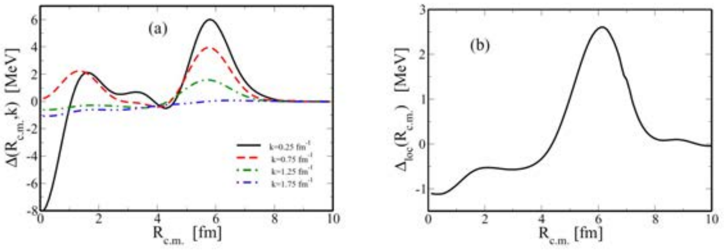

FIGURE 3. (a) Pairing field as a function of the position of the center of mass for different values of the relative momentum k, for the Argonne plus induced interaction $v_{Arg+ind}$. Going from top to bottom, the curves refer to values of k going from $k = 0.25$ fm^{-1} to $k = 1.75$ fm^{-1}, in steps of 0.5 fm^{-1}. (b) Pairing field obtained with the semiclassical approximation.

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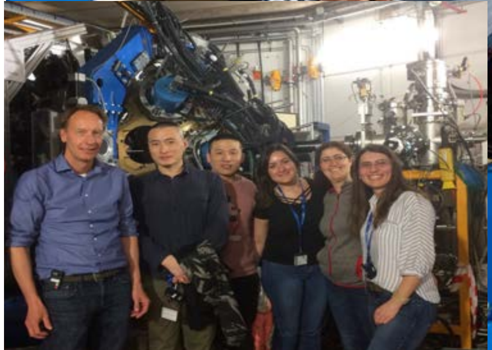
AGATA Phase I @ GANIL, Caen, France



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Evidence for enhanced neutron-proton correlations from the level structure of the $N = Z + 1$ nucleus $^{87}_{43}\mathrm{Tc}_{44}$

X. Liu *et al.*
Phys. Rev. C **104**, L021302 – Published 20 August 2021

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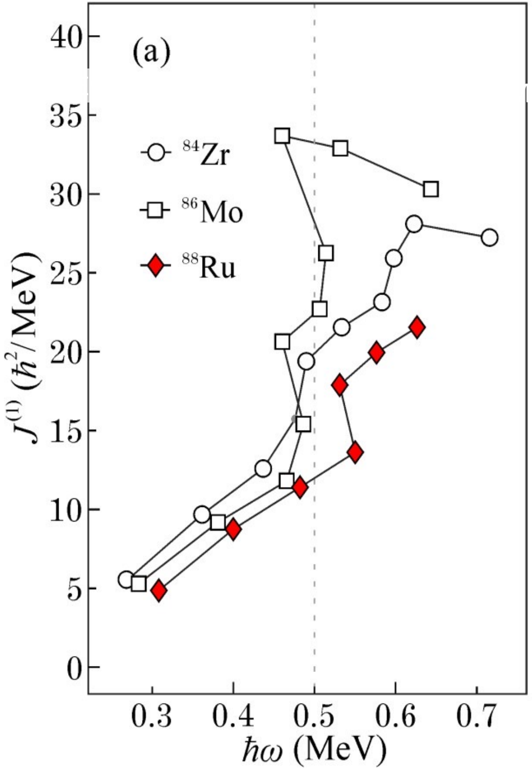
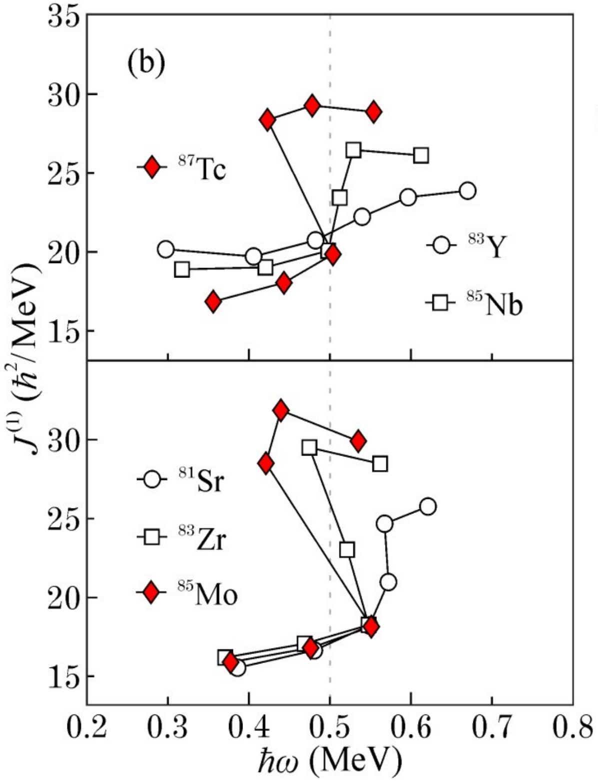
Evidence for spherical-oblate shape coexistence in $^{87}\mathrm{Tc}$

X. Liu *et al.*
Phys. Rev. C **106**, 034304 – Published 9 September 2022

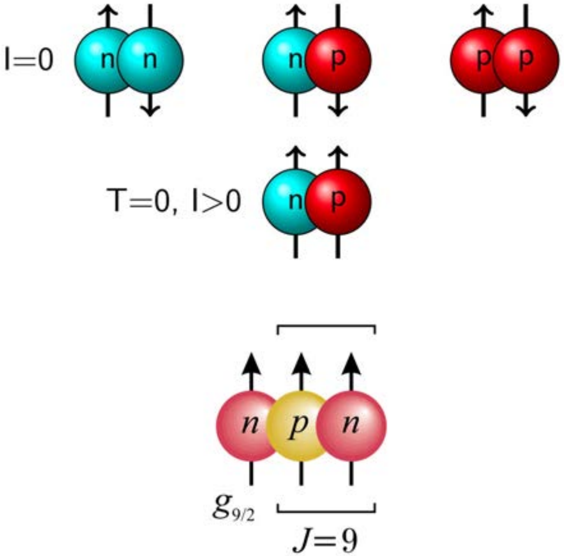
Pairing isospin modes in deformed N~Z nuclei at intermediate angular momentum – odd-even vs even-even



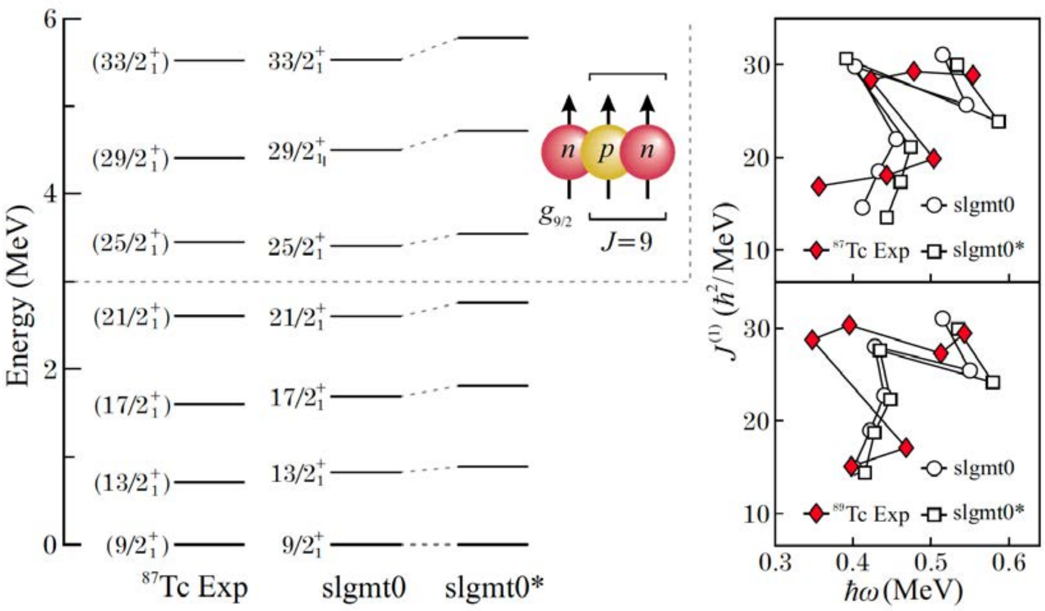
B. Cederwall et al, PRL 124 062501 (2020)



X. Liu et al, PRC 104 L021302 (2021)



Pairing isospin modes in deformed N~Z nuclei at intermediate angular momentum - odd-even (T_Z=1/2) nuclei



X. Liu et al, PRC 104 L021302 (2021)

Odd-mass N~Z (T_Z=1/2) nuclei:

- Spin-dependent "effective 3-N" interaction favors T=0 np pairs after alignment of first (isovector) pair?
- Increase of structural difference between 1qp and 3qp configuration reduces interaction strength in the band crossing?

Thank You