Lifetime measurements in exotic nuclei at Lohengrin

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Università degli Studi di Milano and INFN

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Collaboration

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The Institut Laue-Langevin in Grenoble

NEUTRONS FOR SOCIETY

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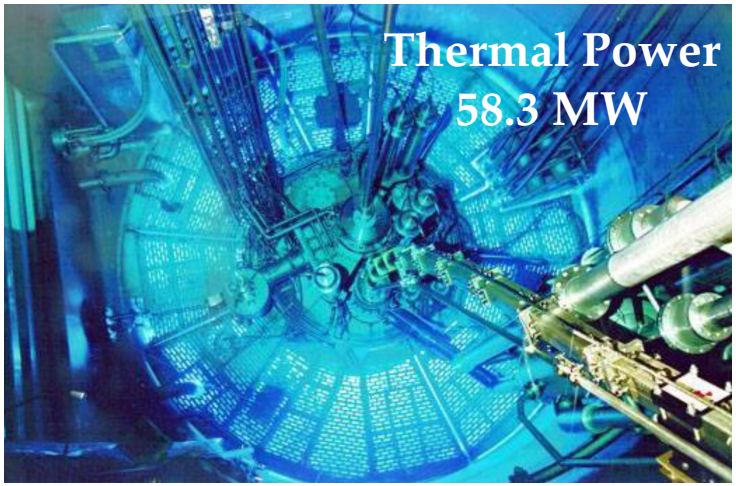
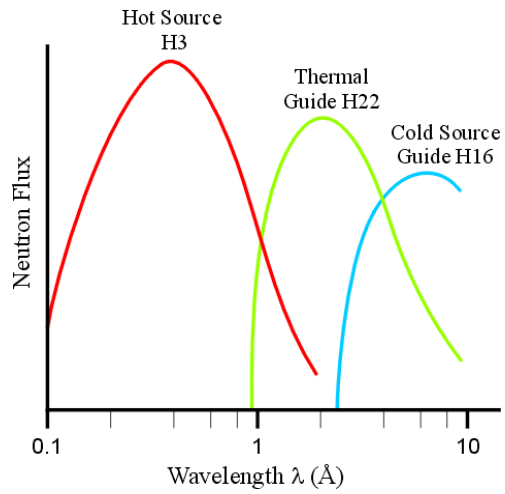
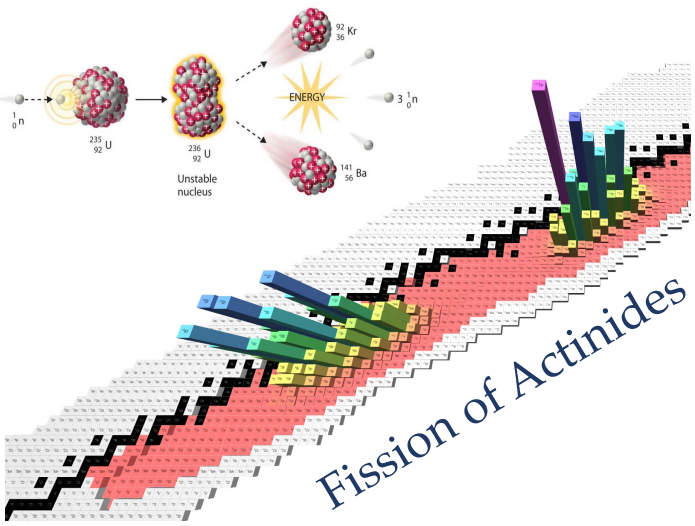
HIGH FLUX REACTOR

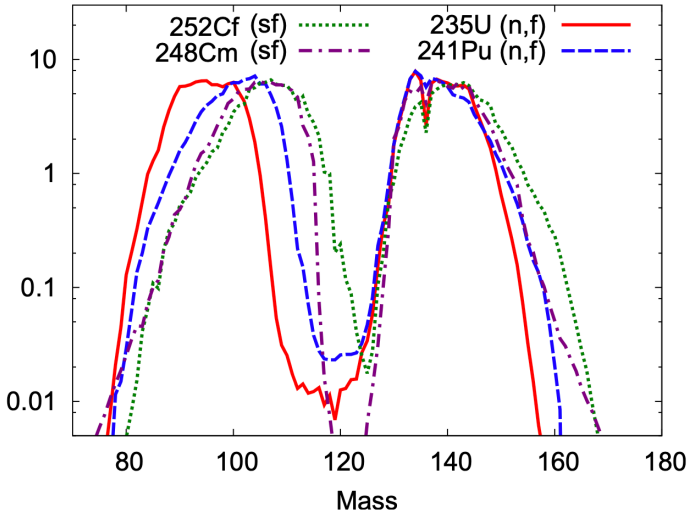


~10^{15} neutrons/s/cm^2

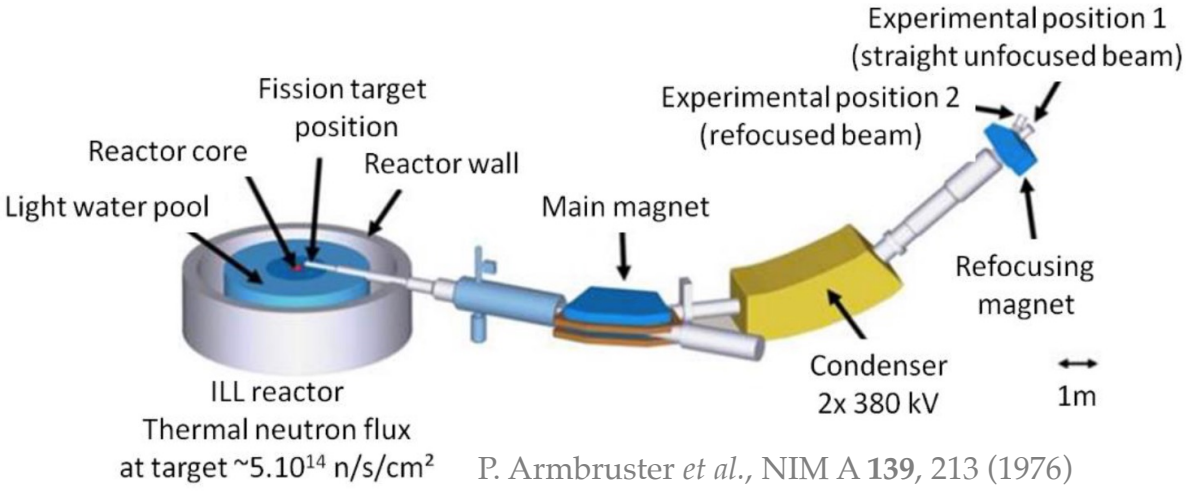
NEUTRON-INDUCED FISSIONS



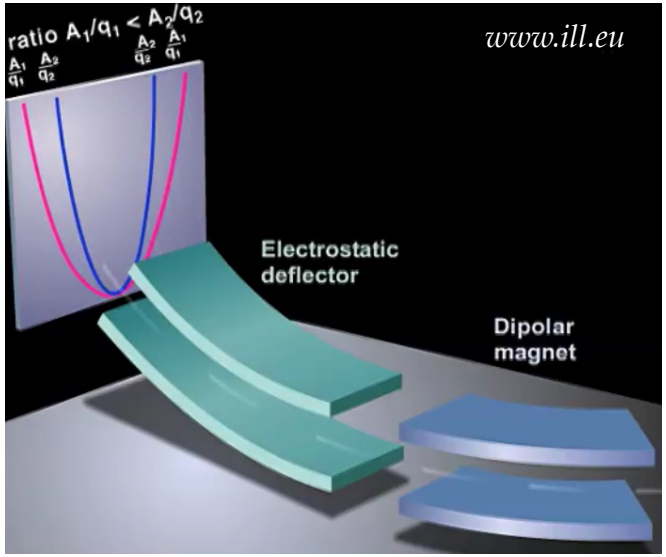




THE LOHENGRIN SPECTROMETER

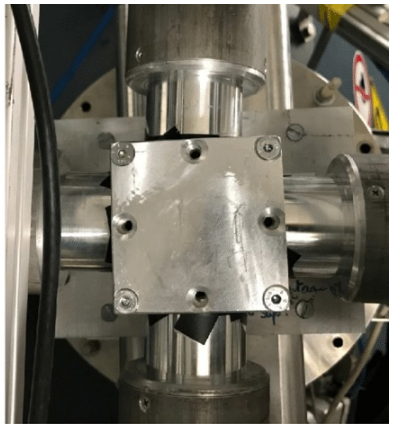


P. Armbruster *et al.*, NIM A **139**, 213 (1976)



$$q\mathcal{E} = \frac{Av^2}{r_{con}} \qquad qvB = \frac{Av^2}{r_{mag}}$$

THE FOCAL PLANE DETECTORS



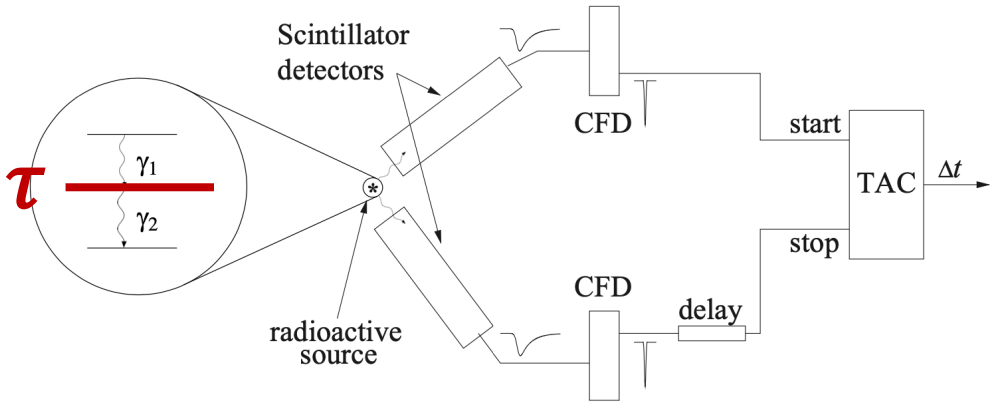
J.-M. Régis et al., NIM A **955,** 163258 (2020)

- 1 Ionization chamber (2 sections)
- Clover HPGe (high energy resolution)
- 4 $LaBr_3$ (fast timing)

γ decay from isomeric states

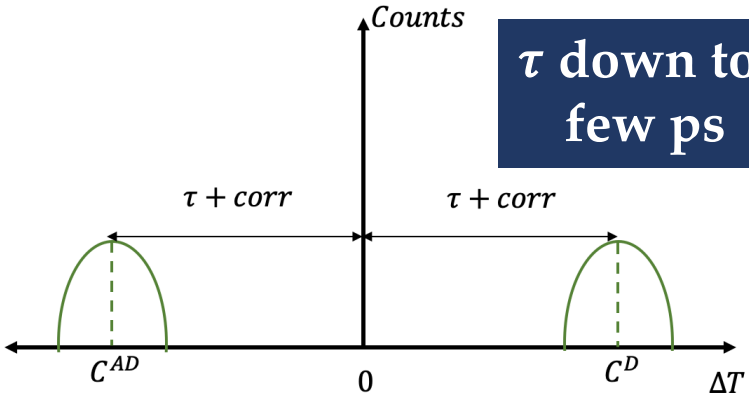
Subnanosecond lifetimes with fast-timing techniques

FAST TIMING



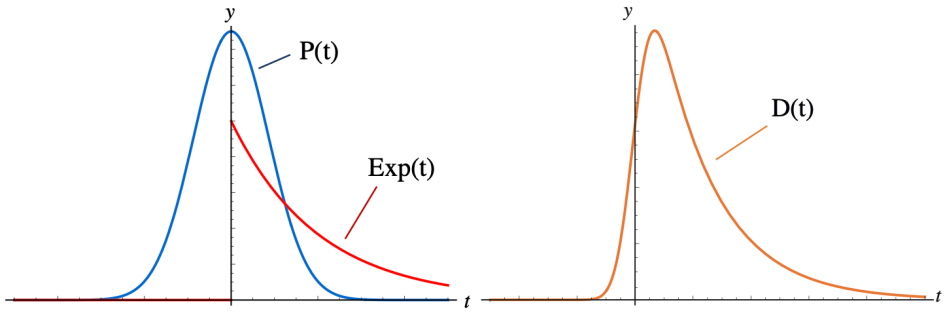
GENERALIZED CENTROID DIFFERENCE

J.-M. Régis et al., NIM A **955,** 163258 (2020)



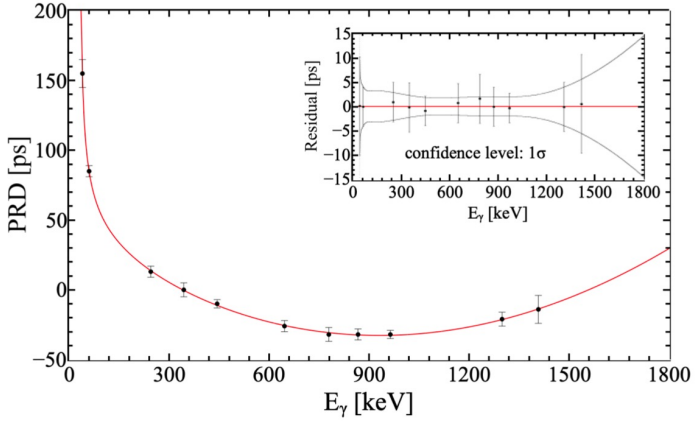
τ down to few ps

SLOPE METHOD



τ ~ hundreds ps or more

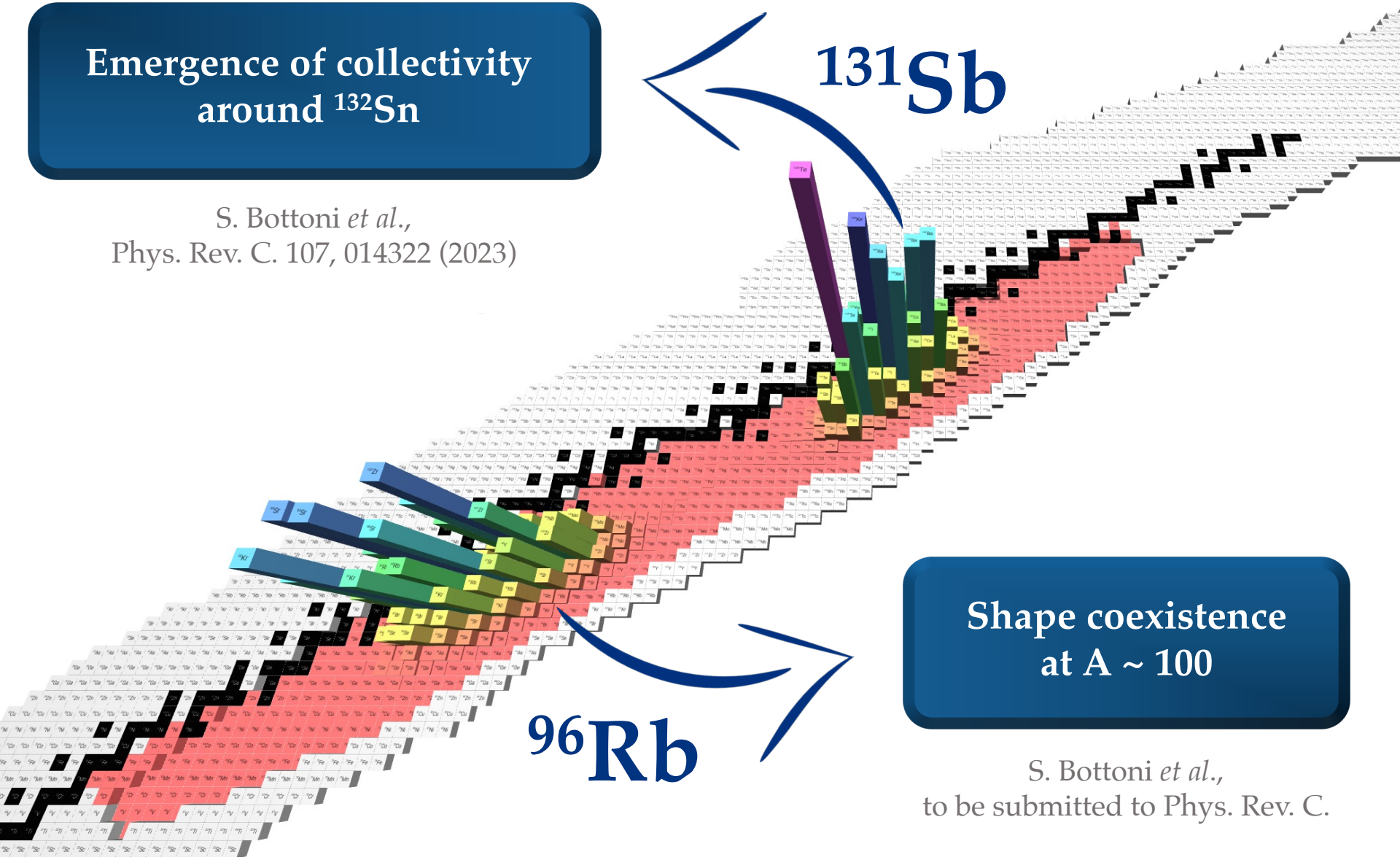
$$\Delta C = PRD(E_{start}, E_{stop}) + 2\tau$$



Lifetime measurements in exotic nuclei

Emergence of collectivity around ^{132}Sn

S. Bottoni *et al.*,
Phys. Rev. C. 107, 014322 (2023)



Shape coexistence at A ~ 100

S. Bottoni *et al.*,
to be submitted to Phys. Rev. C.

Emergence of collectivity around ^{132}Sn

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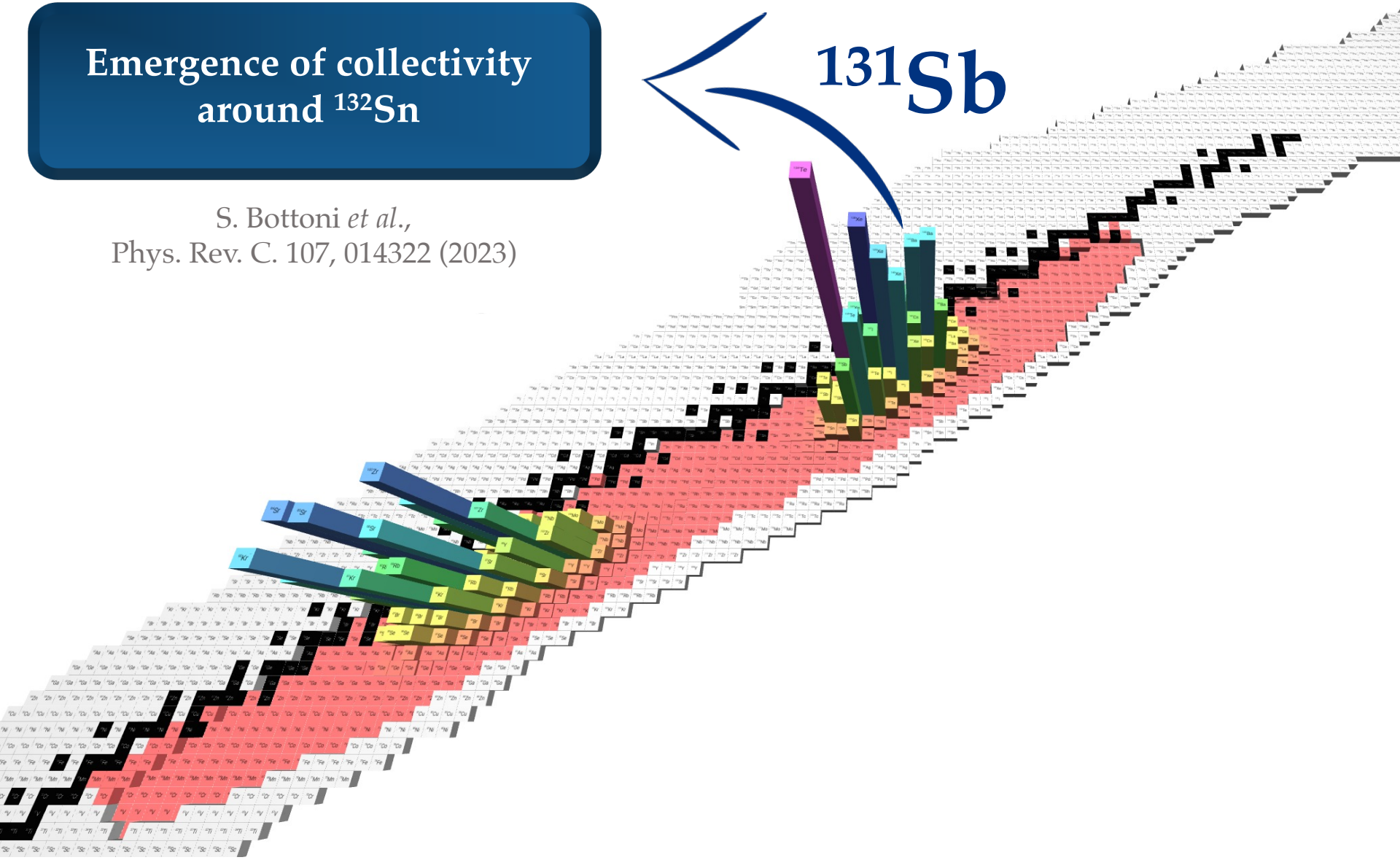
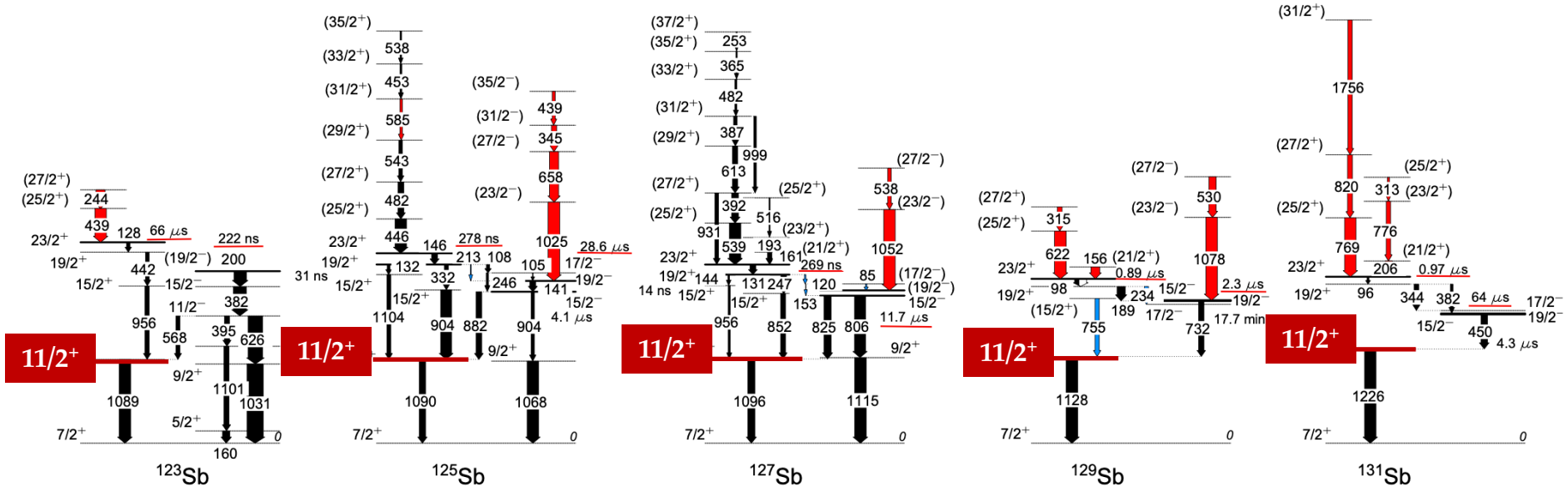
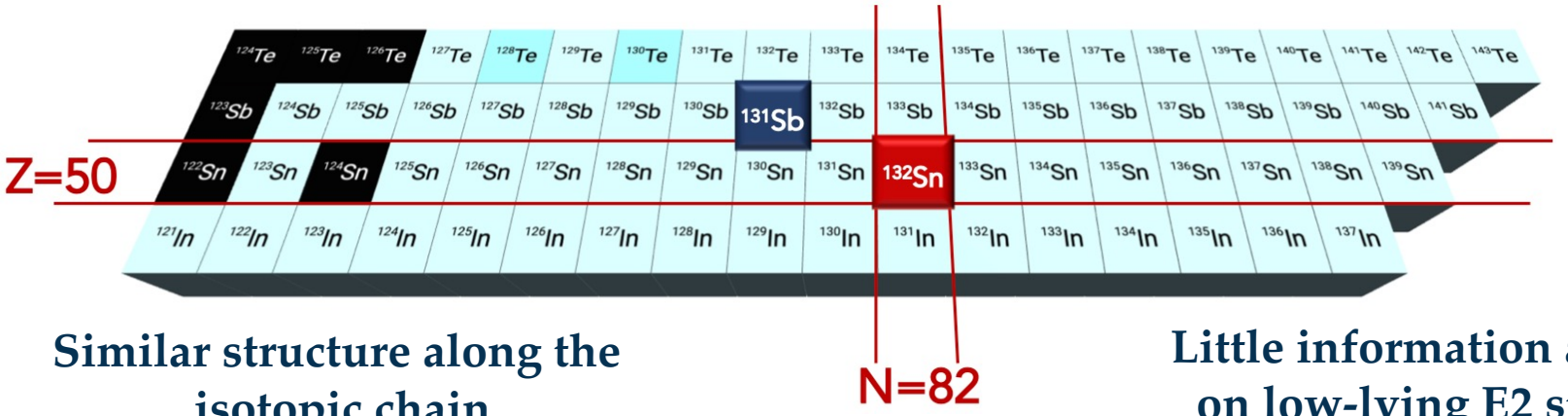


Emergence of collectivity around ^{132}Sn

S. Biswas *et al.*, Phys. Rev. C. **99,** 064302 (2019)





Similar structure along the isotopic chain

Little information available on low-lying E2 strength

Emergence of collectivity around ^{132}Sn

Adding and removing nucleons around doubly magic nuclei

AROUND ^{132}Sn

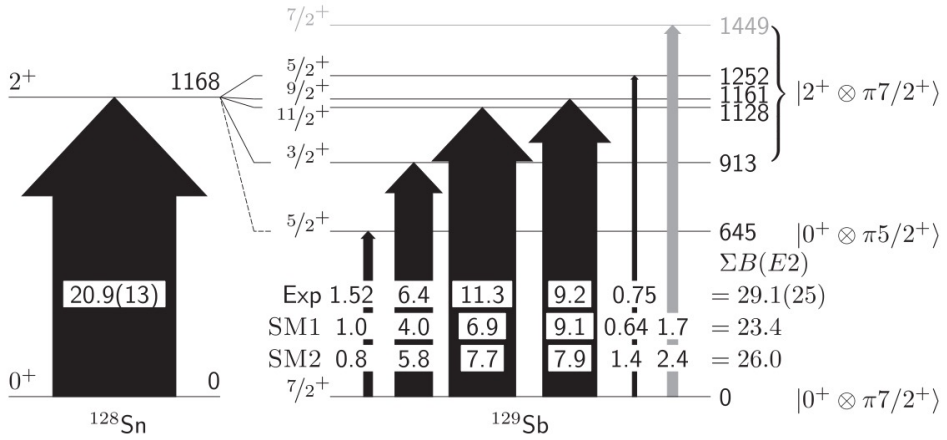
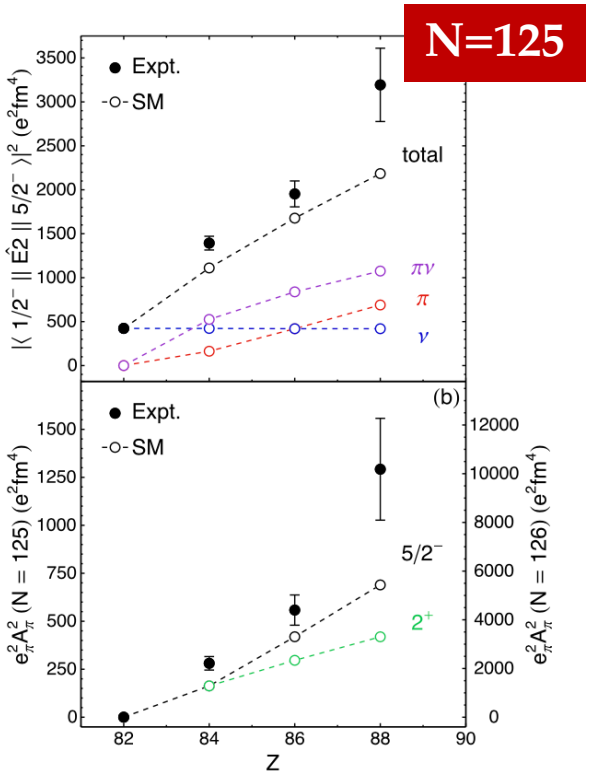


TABLE I. $B(E2)$ results of ^{129}Sb and comparison to shell-model calculations.

	Experiment			SM1			SM2		
I_i^π	E_x (keV)	$B(E2\uparrow)$ (W.u.)	$B(E2\downarrow)$ (W.u.)	E_x (keV)	$B(E2\uparrow)$ (W.u.)	$B(E2\downarrow)$ (W.u.)	E_x (keV)	$B(E2\uparrow)$ (W.u.)	$B(E2\downarrow)$ (W.u.)
$5/2_1^+$	645	1.52(25)	2.0(3)	937	1.0	1.4	781	0.80	1.1
$3/2_1^+$	913	6.4(7)	12.7(14)	1090	4.0	8.0	1204	5.8	11.6
$11/2_1^+$	1128	11.3(7)	7.5(5)	1172	6.9	4.6	1419	7.7	5.1
$9/2_1^+$	1161	9.2(8)	7.3(6)	1078	9.1	7.3	1417	7.9	6.3
$5/2_2^+$	1252	0.75(9)	1.00(12)	1245	0.64	0.85	1440	1.4	1.9
$7/2_2^+$				1449	1.7	1.7	1695	2.4	2.4
$\sum B(E2\uparrow)$		29.1(25)			23.4			26.0	

T. J. Gray *et al.*, Phys. Rev. Lett. **124,** 032502 (2020)

AROUND ^{208}Pb



M. S. M. Gerathy *et al.*, Phys. Lett. B **823,** 136738 (2021)

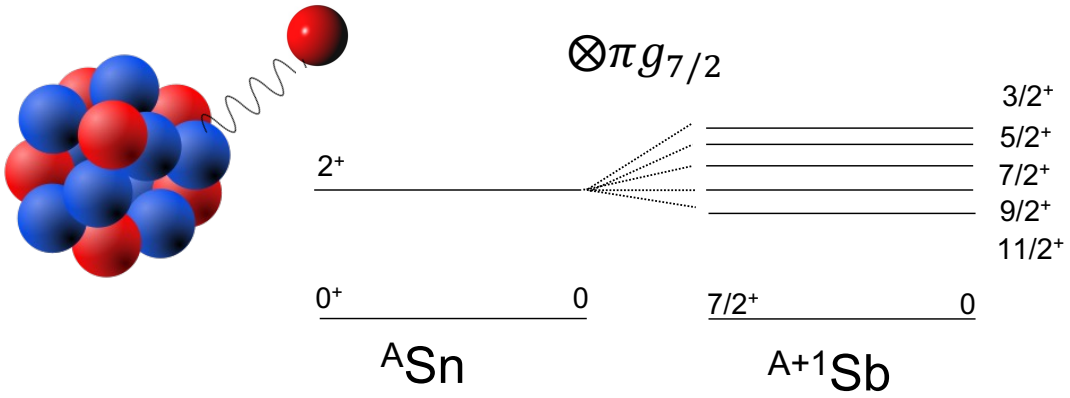
Increase of collectivity typically underestimated by SM calculations

Emergence of collectivity around ^{132}Sn

Do single nucleons act as spectators?

WEAK-COUPLING LIMIT

A. De-Shalit., Phys. Rev.. **122,** 1530 (1961)



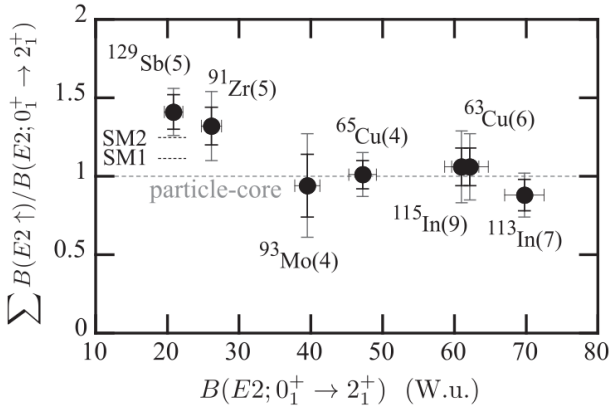
$$B\left(E2;\ J \rightarrow \frac{7}{2}\right) = B(E2;\ 2+ \rightarrow 0)$$

$$\sum_J B\left(E2;\ \frac{7}{2} \rightarrow J\right) = B(E2;\ 0 \rightarrow 2)$$

ELECTRIC QUADRUPOLE STRENGTH

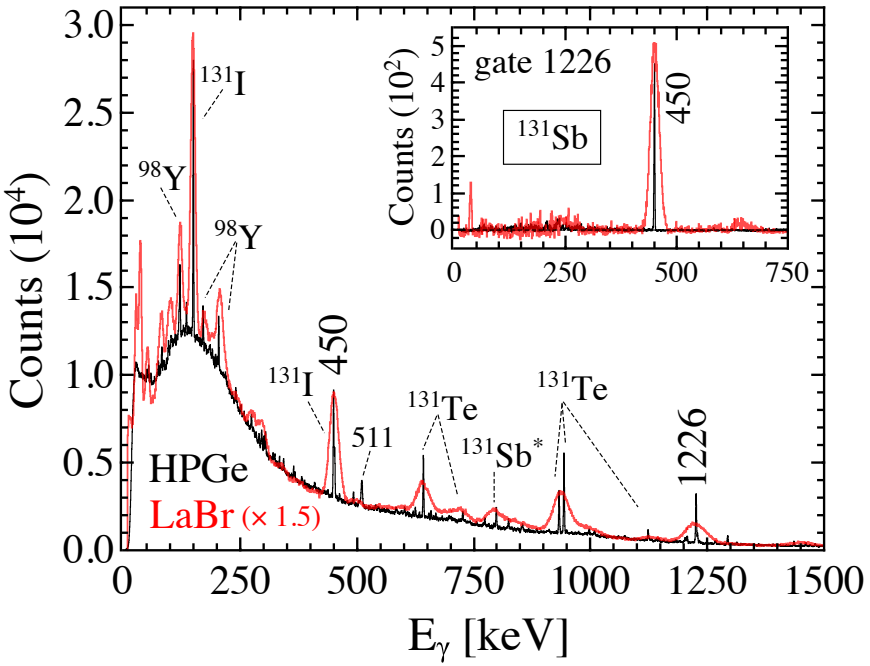
$$B\left(E2; J \rightarrow \frac{7^+}{2}\right) = \left(e_p \frac{A_p}{\sqrt{2J+1}}\right)^2 + \left(e_n \frac{A_n}{\sqrt{2J+1}}\right)^2 + 2e_p\, e_n \frac{A_p\, A_n}{(2J+1)}$$

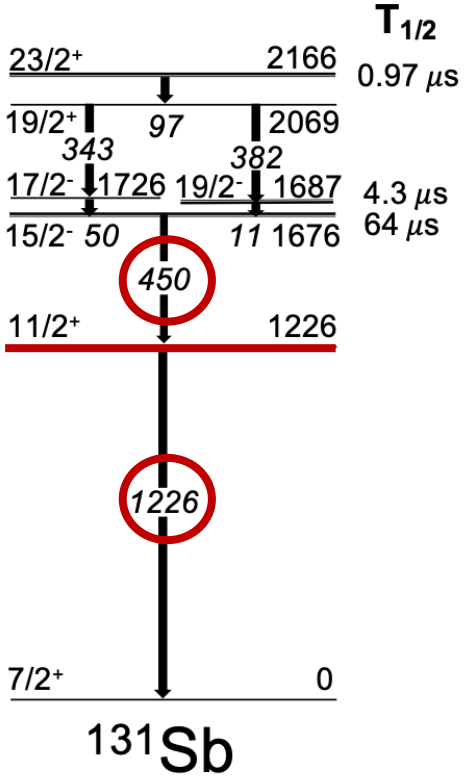
proton-neutron interference term



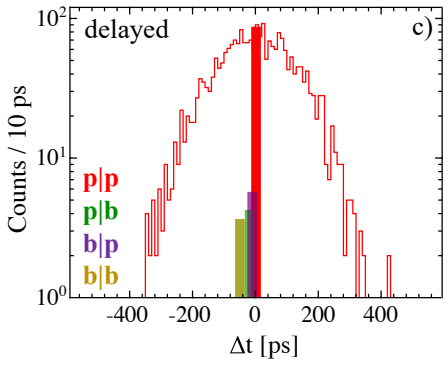
T. J. Gray *et al.*, Phys. Rev. Lett. **124,** 032502 (2020)

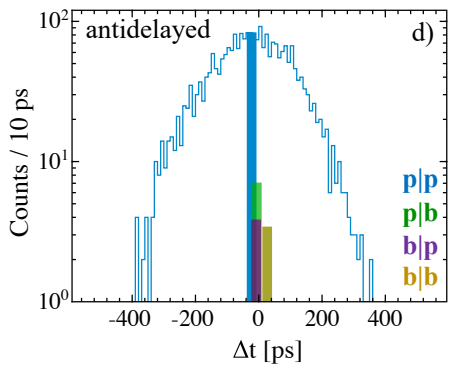
Emergence of collectivity around ^{132}Sn





LIFETIME MEASUREMENT



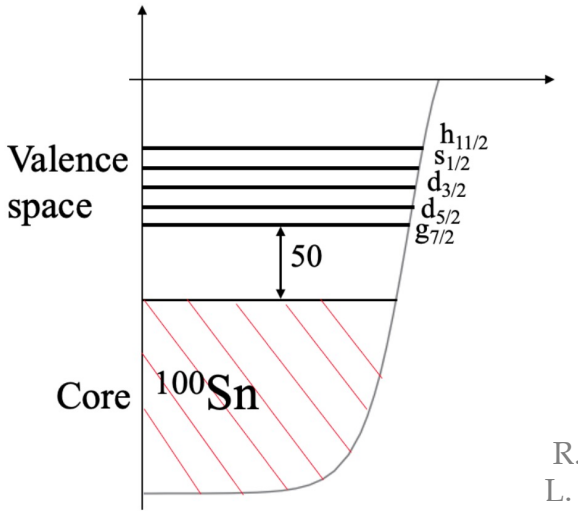


$T_{1/2}$ = 3(2) ps

At the limit of the experimental method

B(E2)= 1.5(9) W.u.

Emergence of collectivity around ^{132}Sn



CALCULATIONS

A. Gargano, G. De Gregorio

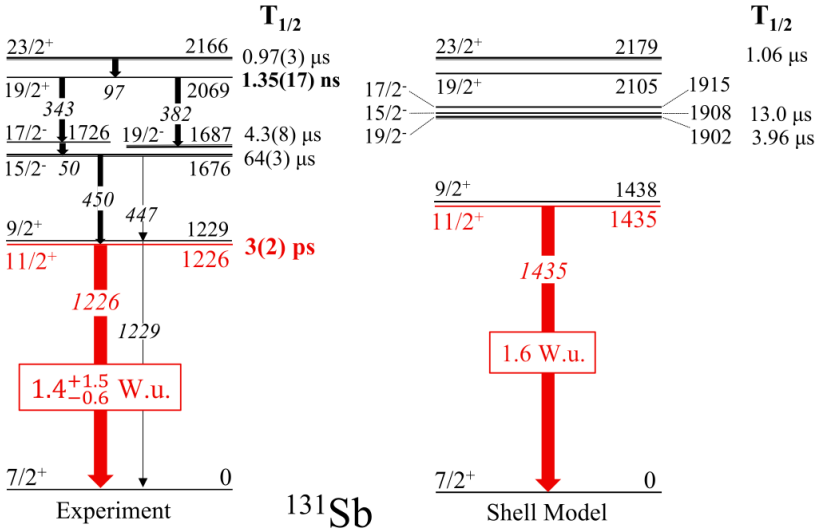
- KSHELL
- CD-Bonn NN potential
- TBME from V_{low-k}
- Q-box at third order

R. Machleidt, Phys. Rev. C 63, 024001 (2001)
L. Coraggio et al., Ann. Phys. 327, 2125 (2012)

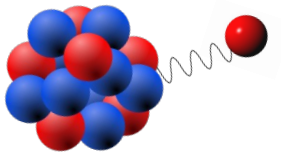
^{130}Sn

B(E2; $2^+ \rightarrow 0^+$) [W.u.]		
Exp	e_n=0.9	**e_n=0.67**
1.2(3)	2.2	**1.2**

RESULTS



Almost pure wave function



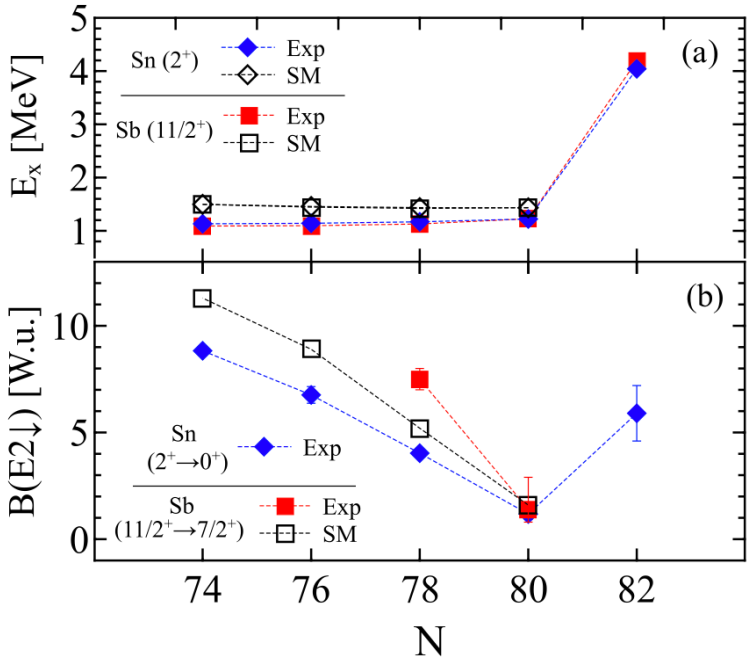
$\pi g_{7/2} \otimes 2^+$ (0.88)

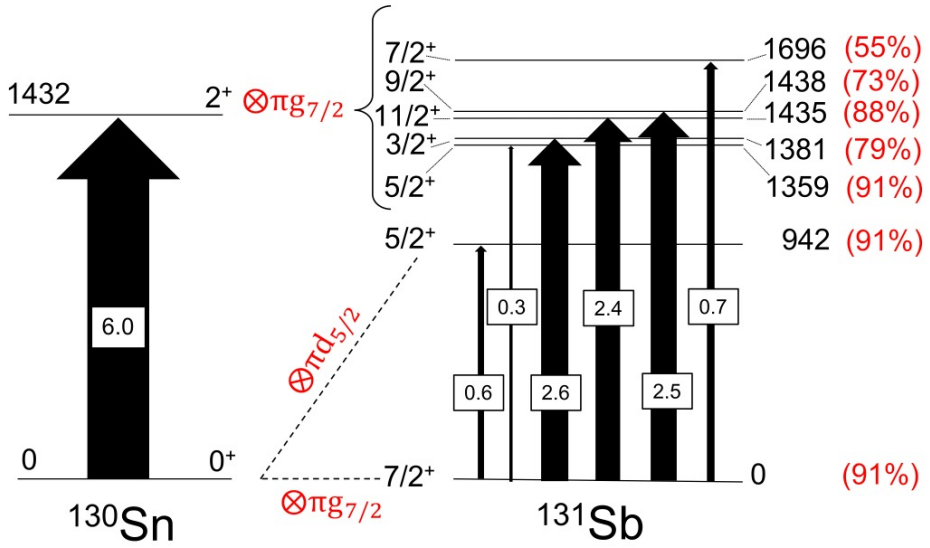
This supports the weak coupling approximation

B(E2) – ^{130}Sn= 1.2(3) W.u.

Emergence of collectivity around ^{132}Sn

ORIGIN OF COLLECTIVITY



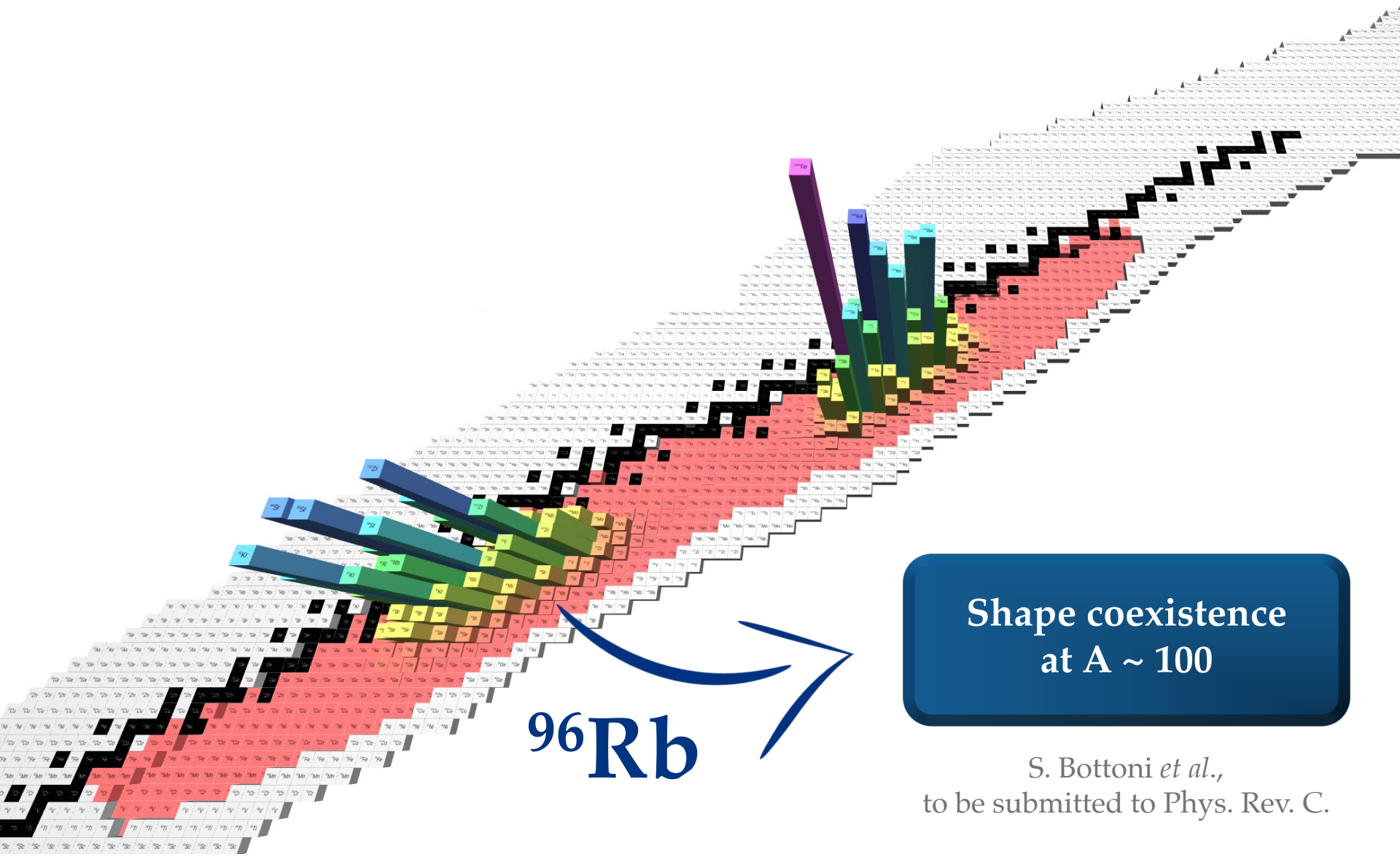


less fragmented wave function

equal proton and proton-neutron contribution

the SM prediction of the sum of the fragmented B(E2) strength is larger than the one of the core **already in ^{131}Sb**

Shape coexistence at A ~ 100

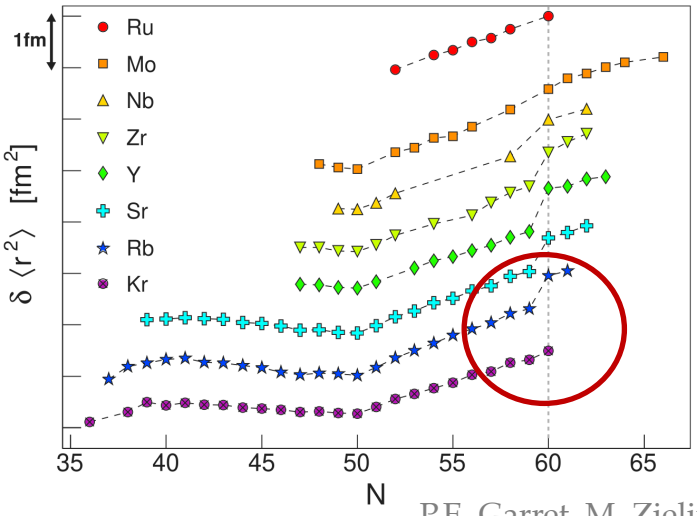


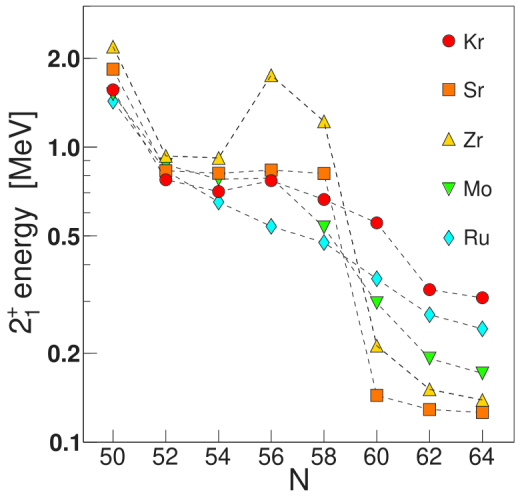
Shape coexistence at A ~ 100

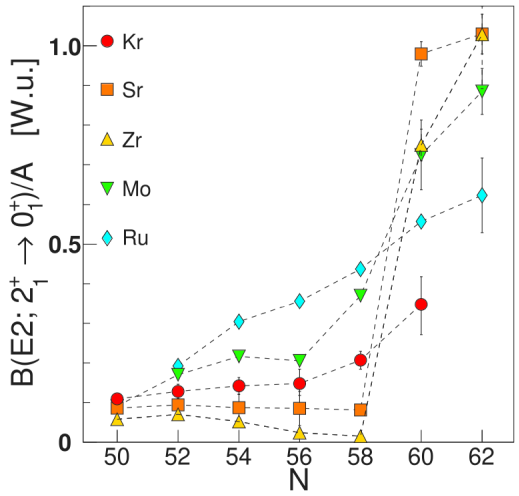
S. Bottoni *et al.*,
to be submitted to Phys. Rev. C.

Shape coexistence at A ~ 100

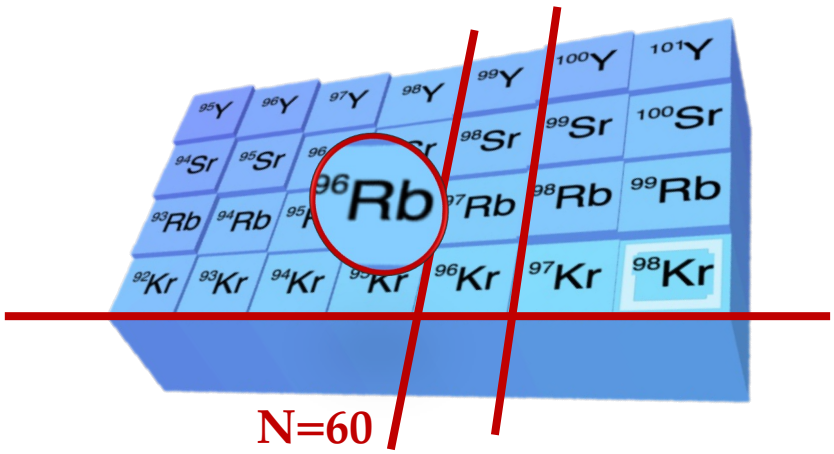
ISLAND OF DEFORMATION AT N=60

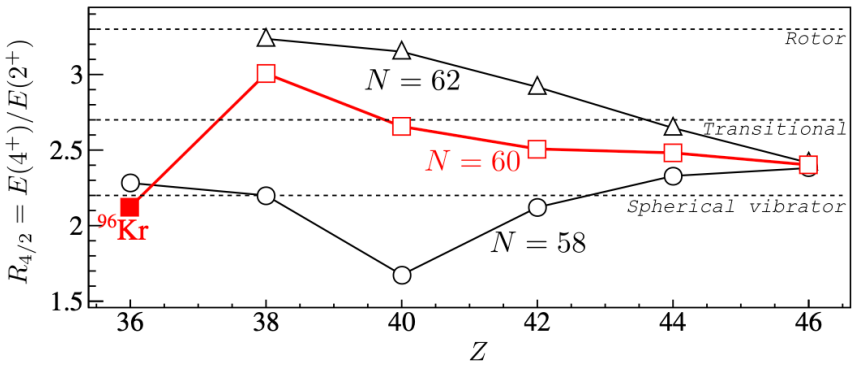






P.E. Garret, M. Zielińska, E. Clément, Progr. Nucl. Part. Phys. 124, 103931 (2022)



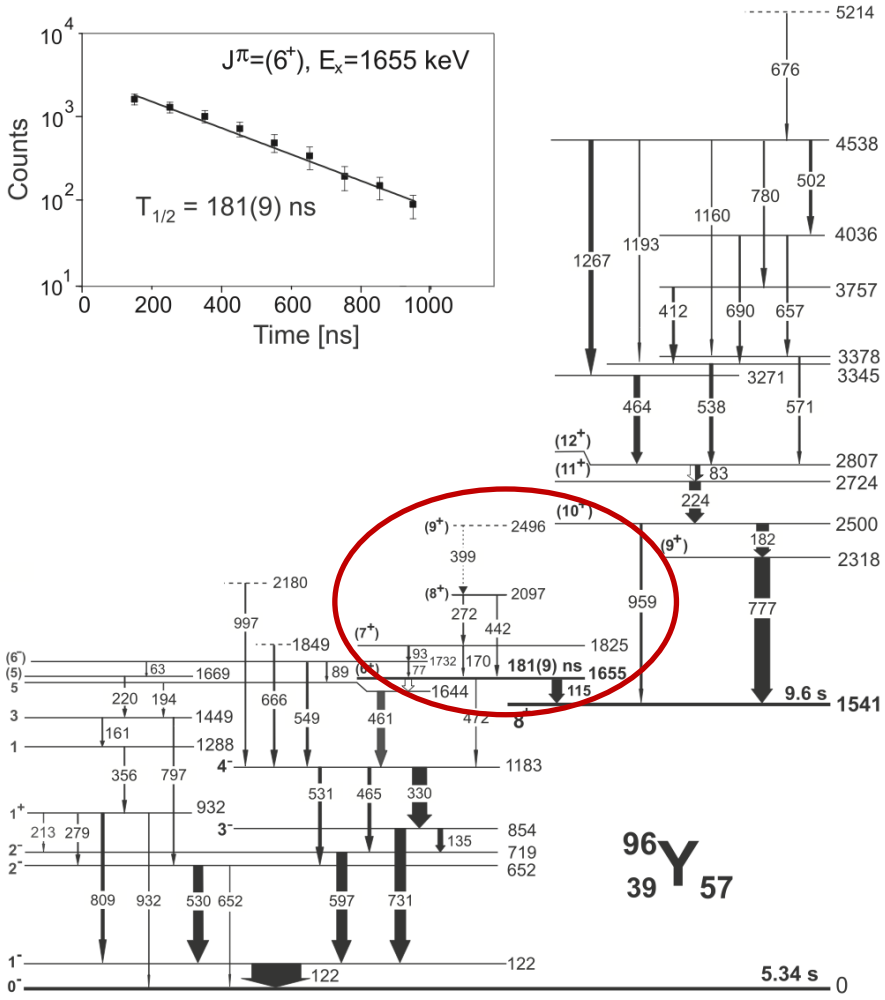


J. Dudouet *et al.*, Phys. Rev. Lett. 118, 162501 (2017)

Approaching N=60 at the low-Z border of the island of deformation

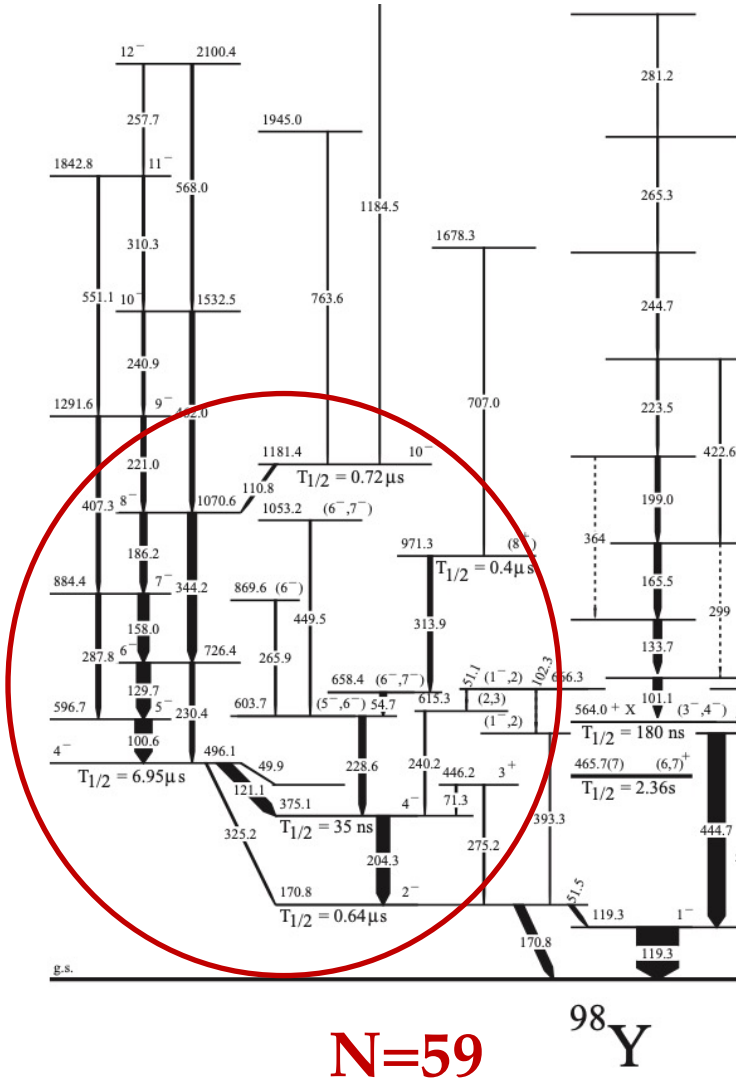
Shape coexistence at A ~ 100

THE Z=39 ISOTOPIC CHAIN



N=57

L. W. Iskra et al., Phys. Rev. C. 102, 054324 (2020)

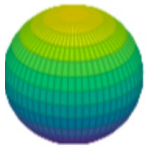


N=59

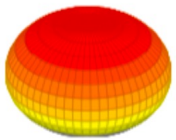
W. Urban et al., Phys. Rev. C. 96, 044333 (2017)

WHAT HAPPENS IN ^{96}Rb?

$\pi(g_{9/2})\nu(h_{11/2})$



spherical



deformed

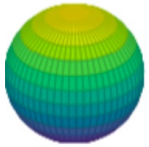
proposed $\beta_2 > 0.28$

J.A. Pinston et al., Phys. Rev. C. 71, 064327 (2005)

$\pi[431\,3/2] \times \nu[541\,3/2]K = 3^-$

J.A. Pinston et al., Phys. Rev. C. 71, 064327 (2005)

spherical



$Q_0 = 0.86(16)$

$\beta_2 = 0.10(2)$

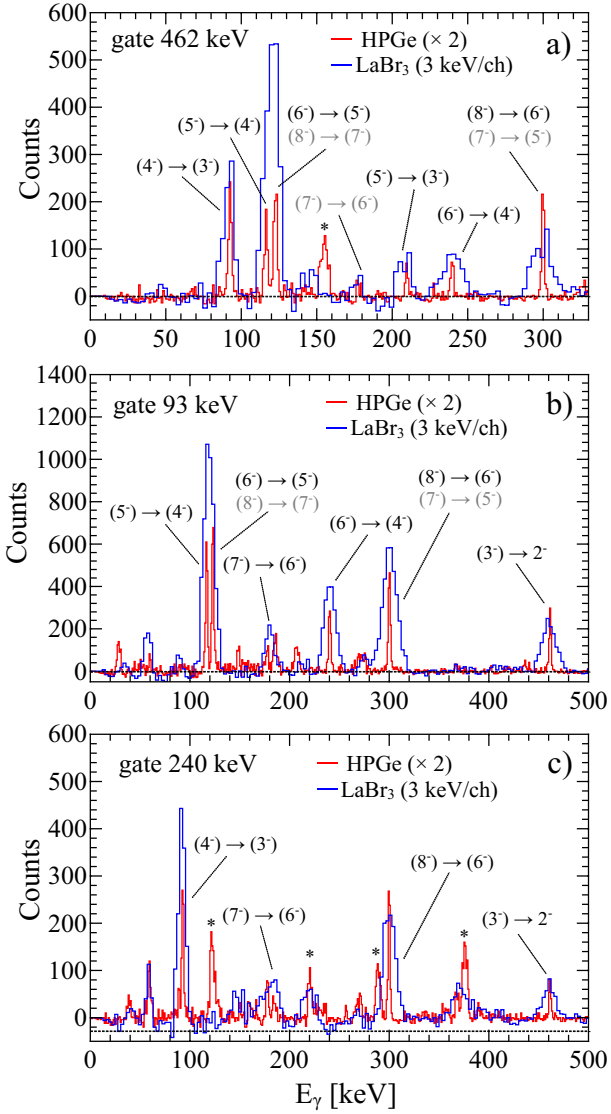
$\pi(f_{5/2})\nu(s_{1/2})$

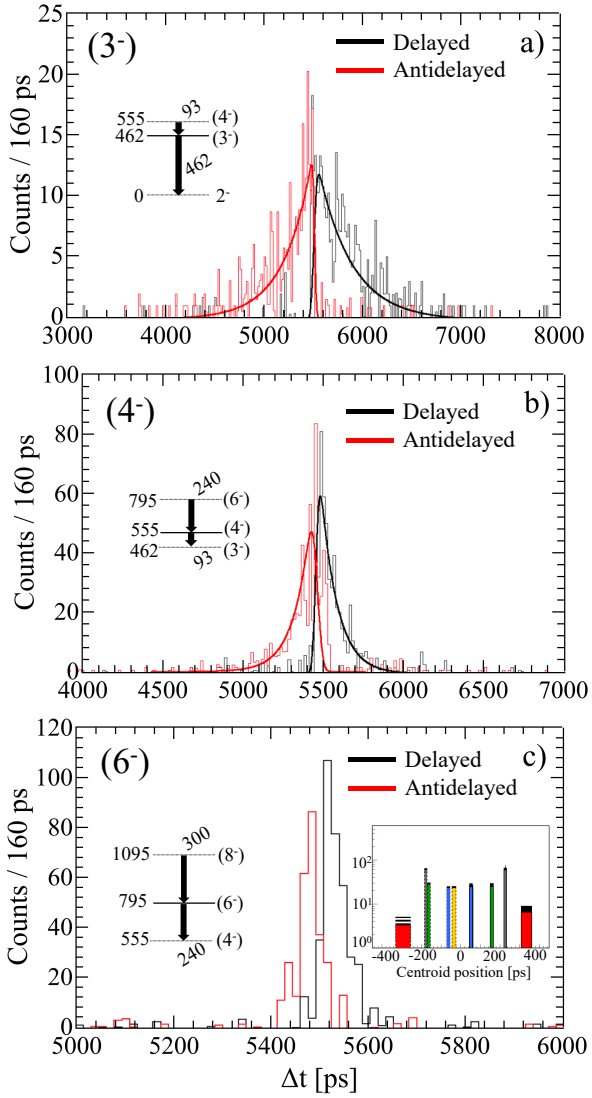
J. Genevey et al., Phys. Rev. C. 59, 82 (1999)

Can we probe and "quantify" shape coexistence and deformation ?

Shape coexistence at A ~ 100

LIFETIMES RESULTS



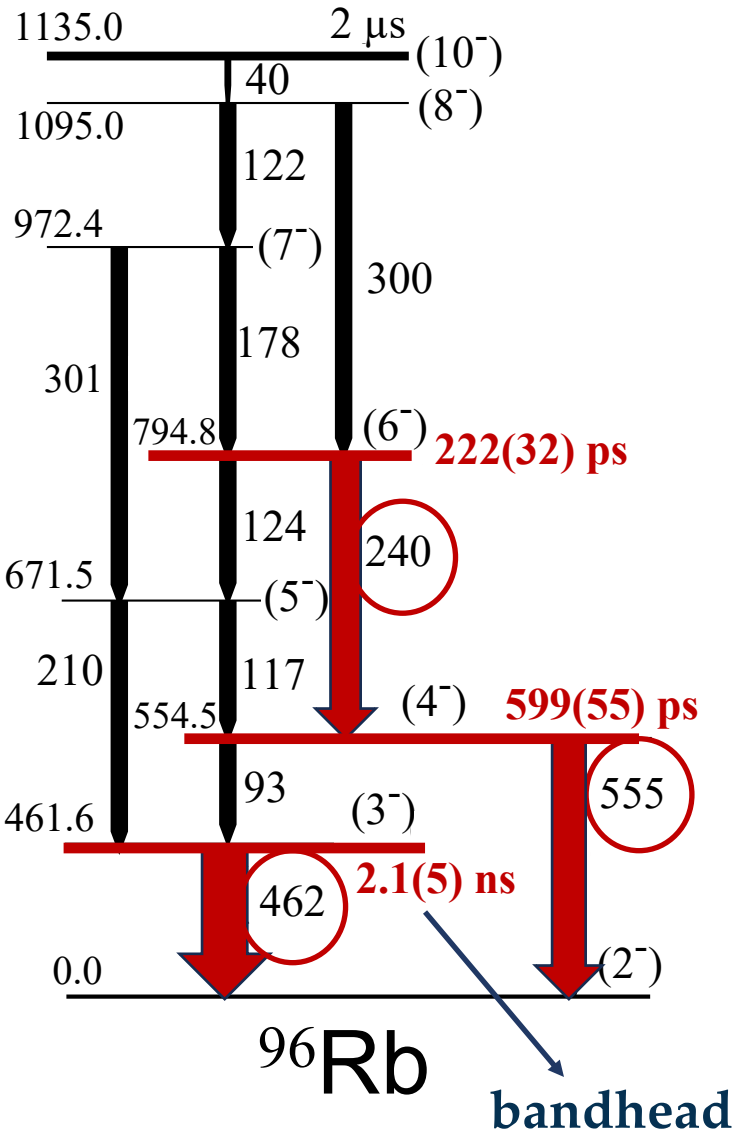


$T_{1/2}$ = 2.1(5) ns

$T_{1/2}$ = 599(55) ps

$T_{1/2}$ = 222(32) ps

TRANSITION PROBABILITIES



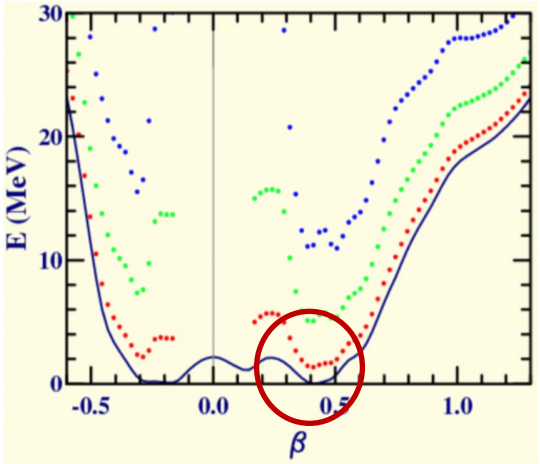
B(E2; 6⁻ → 4⁻)=64.3(96) W.u.

$$B(E2; J_i \rightarrow J_f) = \frac{5}{16\pi} e^2 Q_0^2 \langle J_i K 20 | J_f K \rangle^2$$

$$Q_0 = \frac{3}{\sqrt{5\pi}} R_{av}^2 Z \beta_2 \left(1 + \frac{2}{7}\sqrt{\frac{5}{\pi}}\beta_2 + \frac{1}{14\pi}\beta_2^2 + \cdots \right)$$

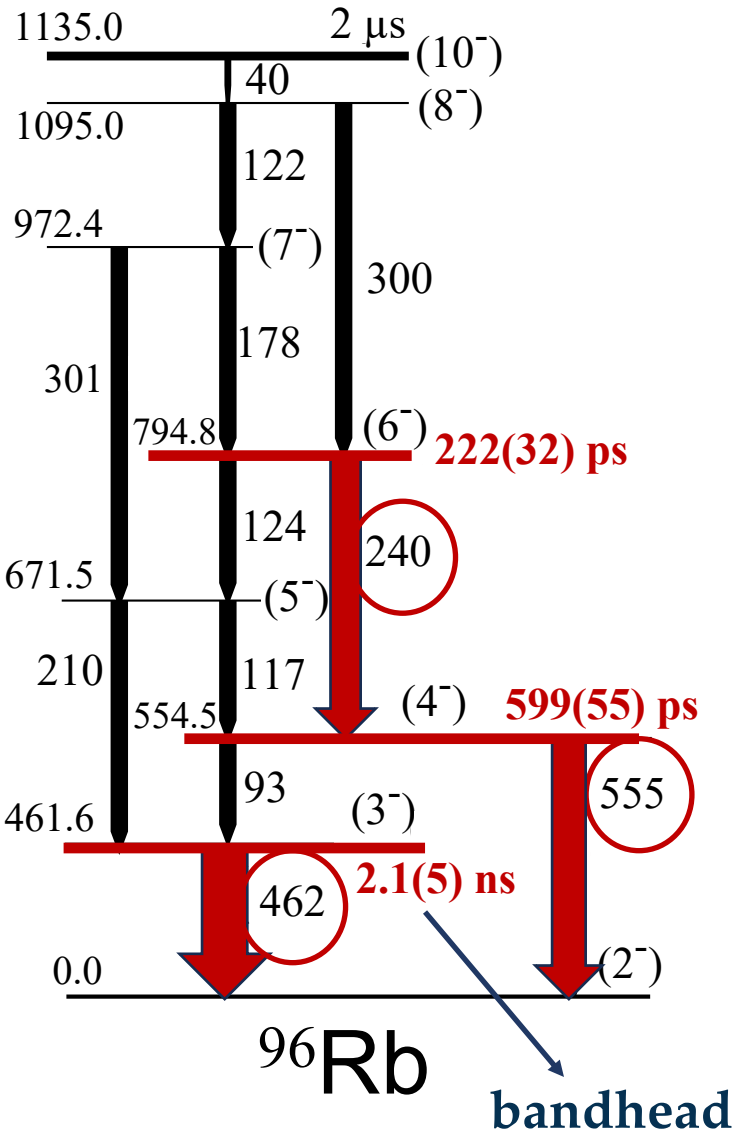
β_2=0.40(3)

HFB with DS1 Gogny



J. Berger, M. Girod, D. Gogny, Comp. Phys. Comm. 63, 365 (1991)

TRANSITION PROBABILITIES



Extraband transitions

$B(E2; 4^- \rightarrow 2^-) = 4.2(9) \times 10^{-2}$ W.u.

Limits on the 462 keV

$B(M1; 3^- \rightarrow 2^-) = 9.0(20) \times 10^{-5}$ W.u.

$B(E2; 3^- \rightarrow 2^-) = 4.0(10) \times 10^{-1}$ W.u.

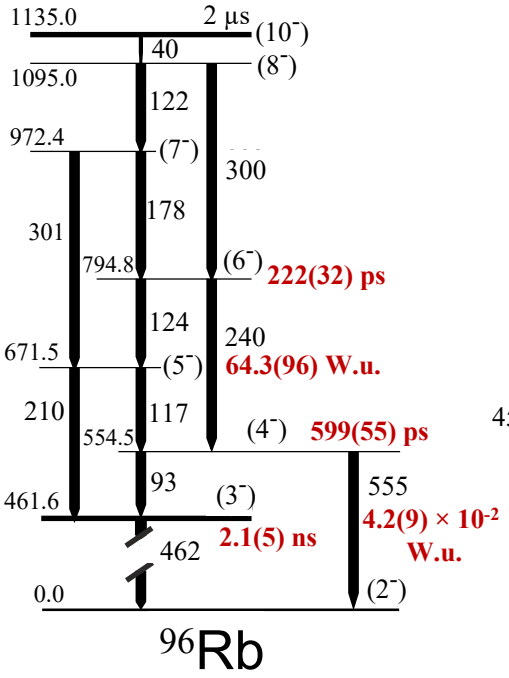
→ **Hindrance possibly due to shape change**

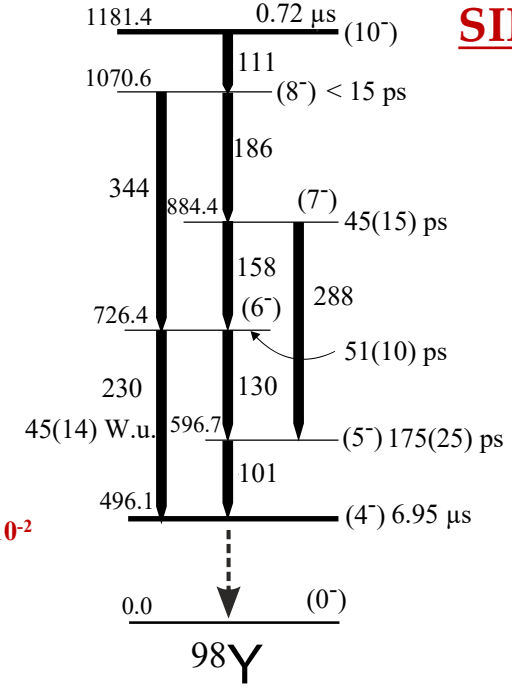
S. Leoni's talk (Ni, Se, Sn...)

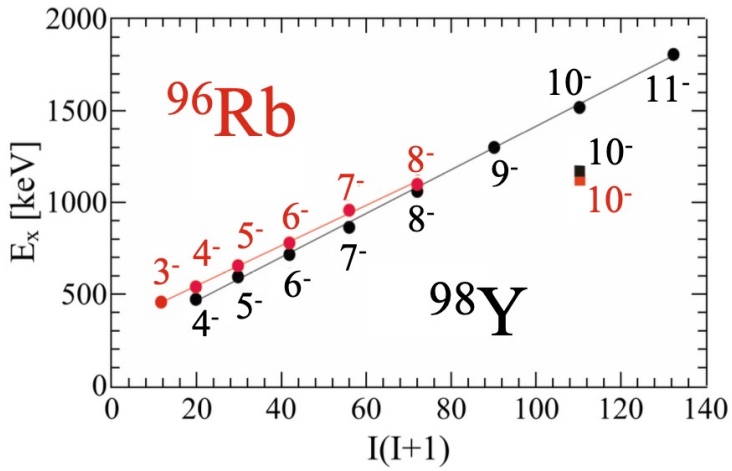
S. Leoni et al., Phys. Rev. Lett. 118, 162502 (2017)

N. Marginean et al., Phys. Rev. Lett. 125, 102502 (2020)

Shape coexistence at A ~ 100







SIMILARITIES BETWEEN ^{96}Rb AND ^{98}Y

- Spherical 10^- isomer
- Same band deformation
- Same moment of inertia
- Similar decay retardation

Same orbitals involved in spherical and deformed structures

Unique feature in the nuclide chart

J.A. Pinston et al., Phys. Rev. C. 71, 064327 (2005)

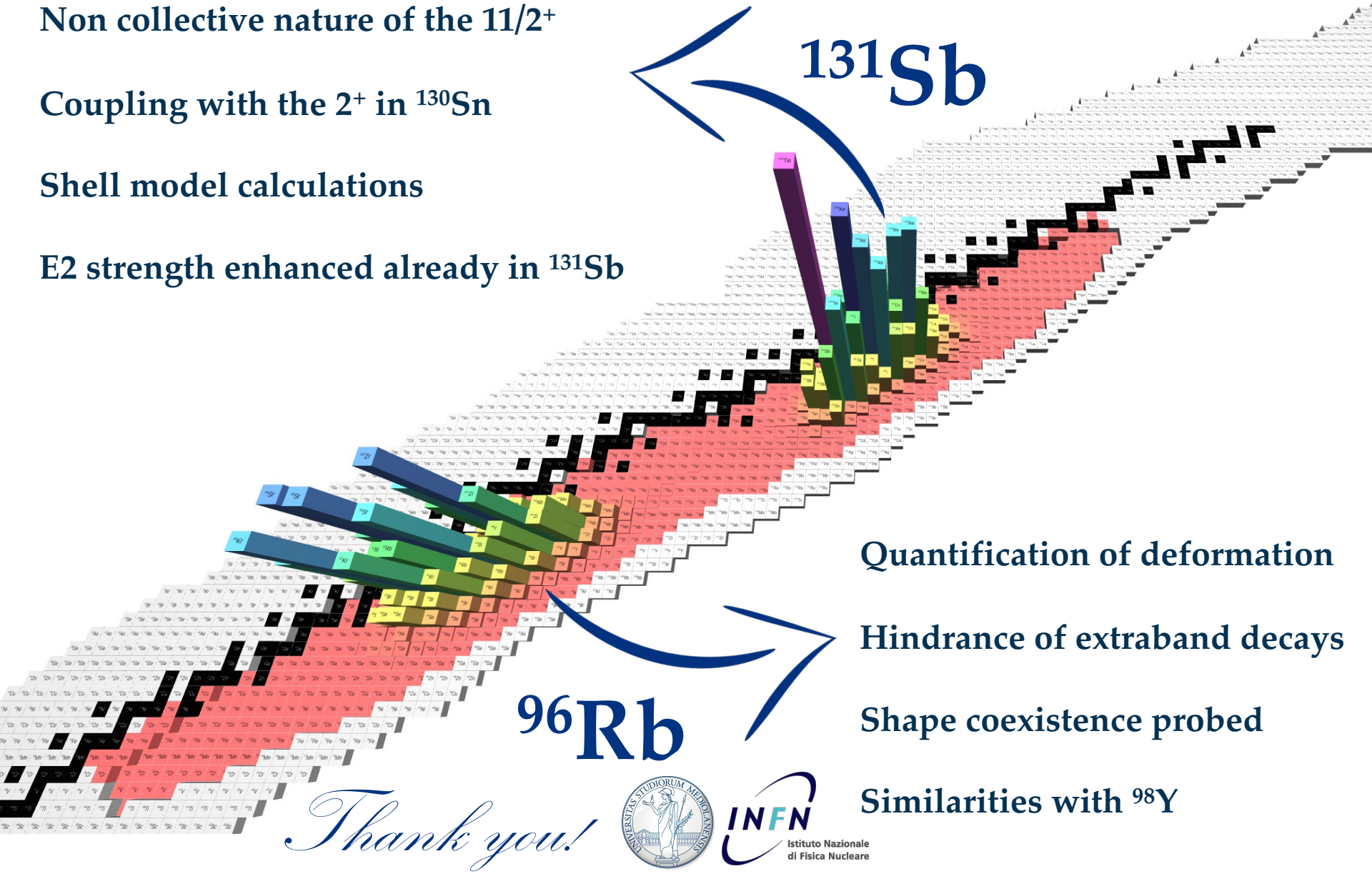
Conclusions

Non collective nature of the $11/2^+$

Coupling with the 2^+ in ^{130}Sn

Shell model calculations

E2 strength enhanced already in ^{131}Sb



Quantification of deformation

Hindrance of extraband decays

Shape coexistence probed

Similarities with ^{98}Y

Thank you!