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Laser spectroscopy of neutron-deficient Hg

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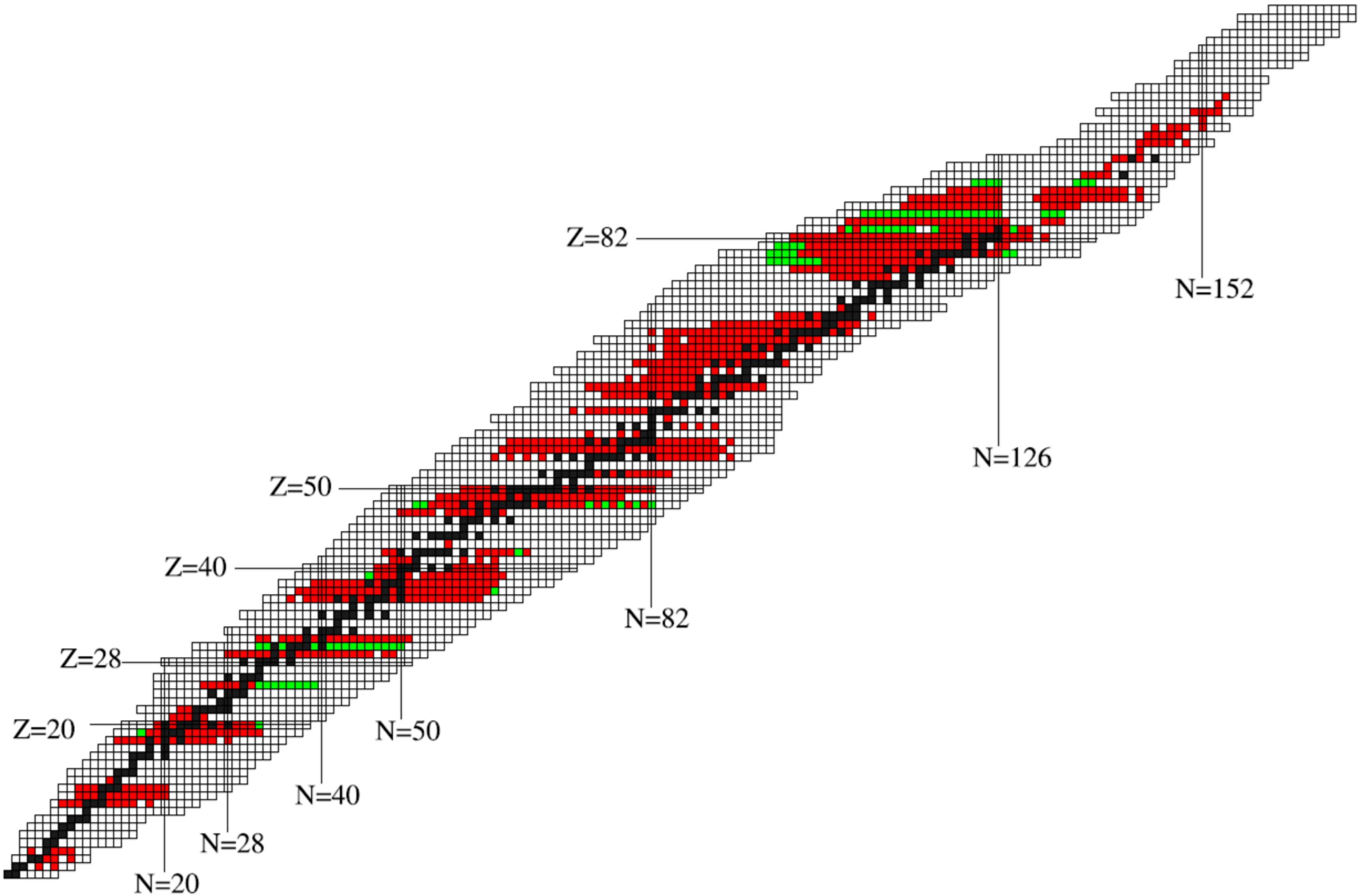
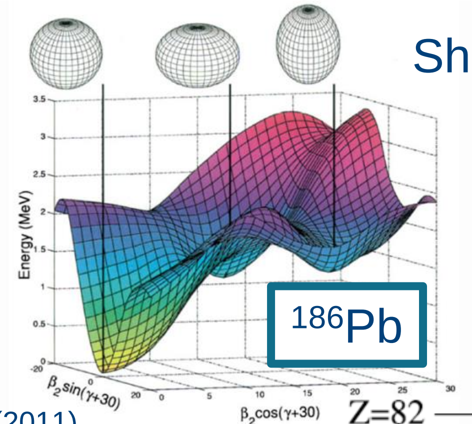
Outline

- Introduction
- Experiment
- Results
- Comparison to theory
- Conclusions and outlook

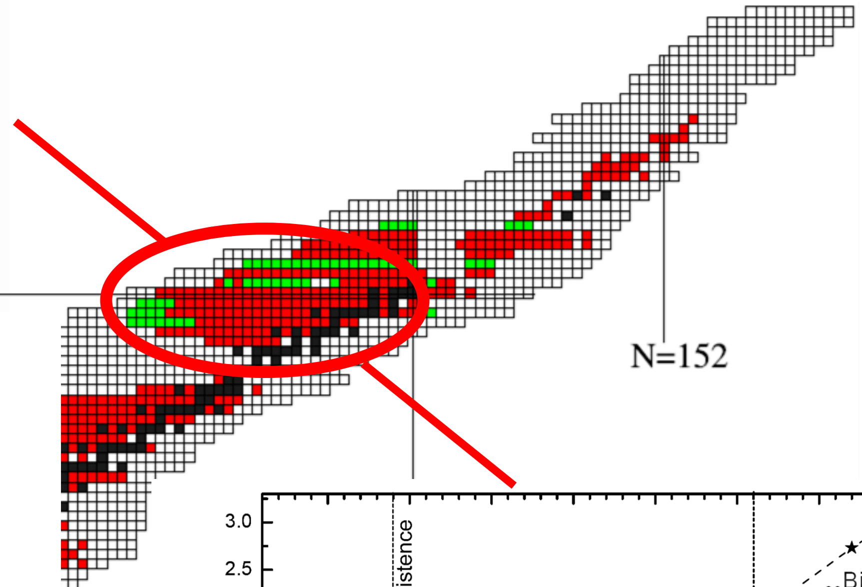


P. Campbell et al. Progress in Particle and Nuclear Physics 3596 (2015),

Shape coexistence



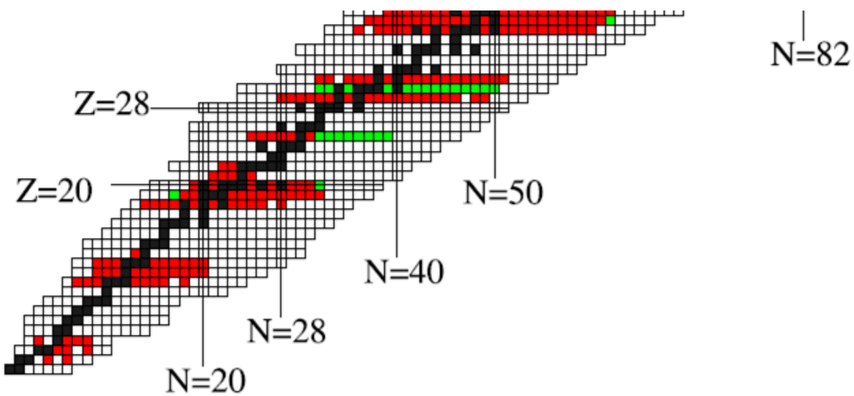
Heyde and Wood, Rev Mod Phys (2011)

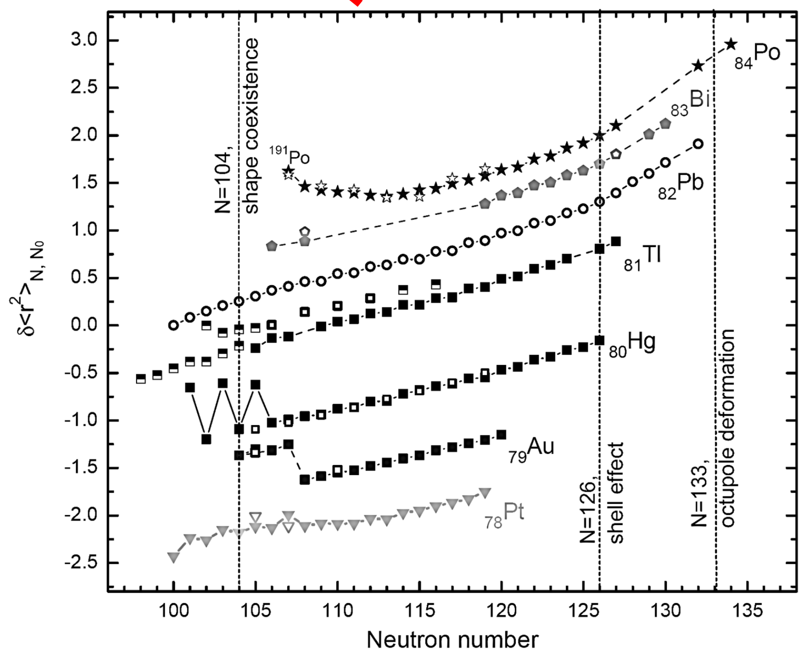


Different types of shape/deformation at low excitation energy

Interplay between:

- Stabilizing effect of closed shells
- Residual proton-neutron interaction





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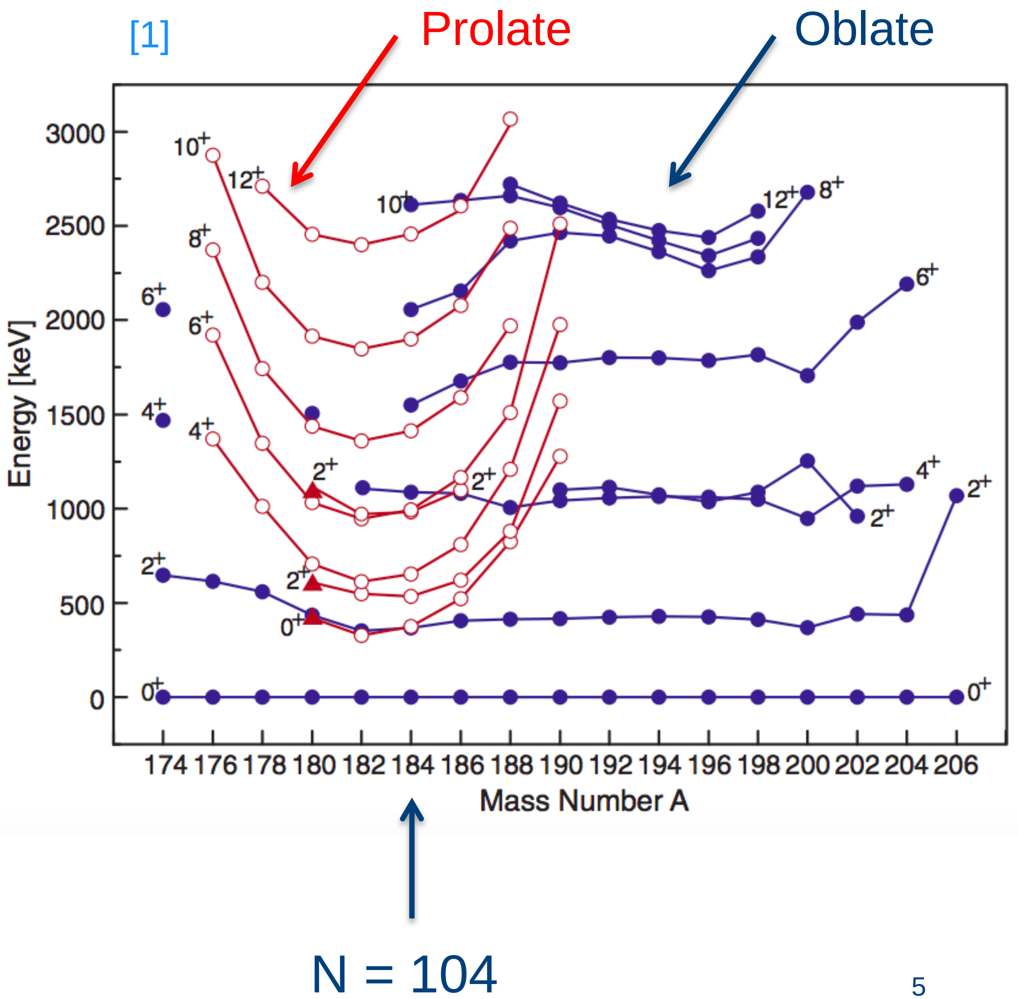
P. Campbell et al. Progress in Particle and Nuclear Physics 3596 (2015),

Level systematics in even-even Hg

[1]



Coexistence of different bands in Hg isotopes

Prolate intruder states comes down in energy towards minimum around *N=104* midshell region

Studied by multitude of techniques

- Coulex (cfr. Talk K. Wrzosek-Lipska)
- Gamma spec.
- Decay spec.
- ….

But direct measurement of ground-state charge radii differences and electromagnetic moments missing below *N=101*

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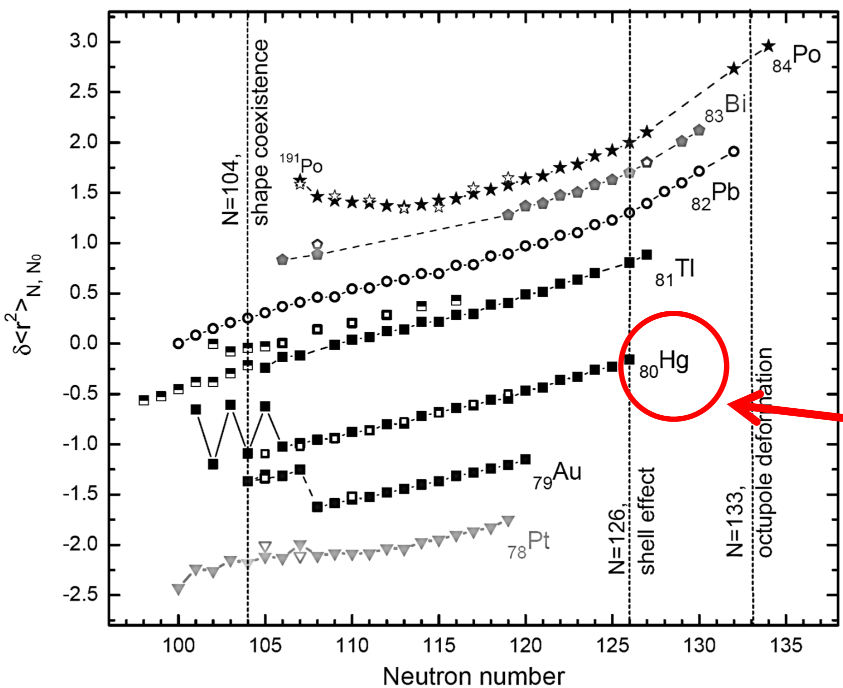
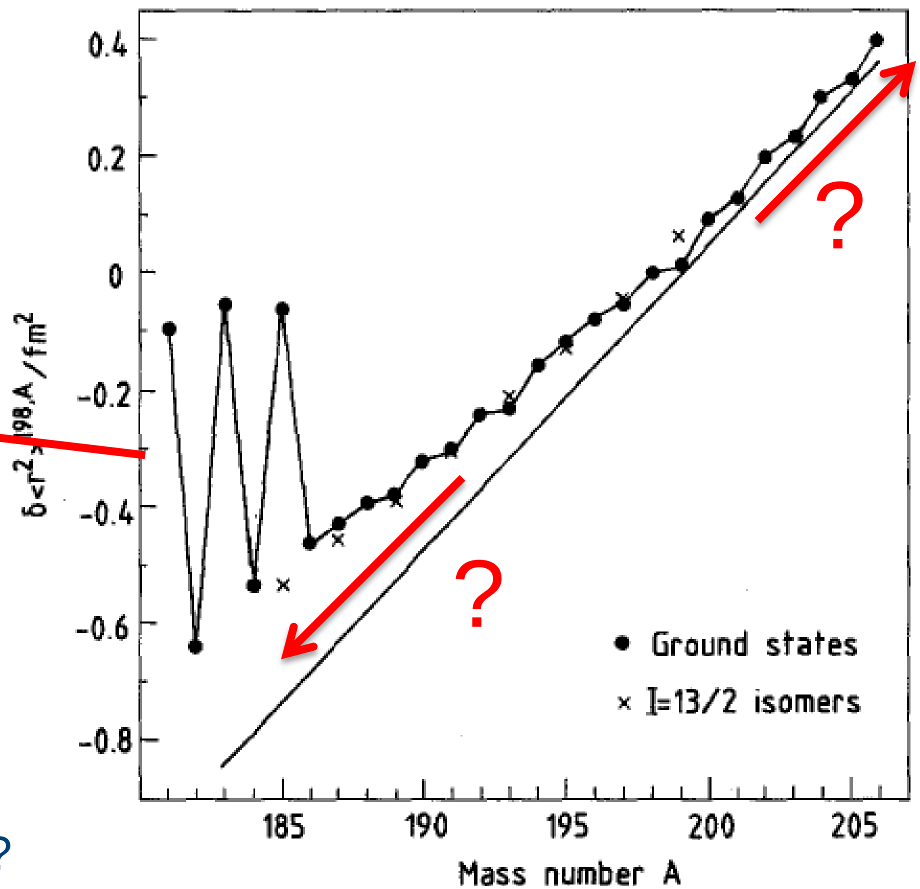
[1] J. Elseviers PRC 84 (2011)

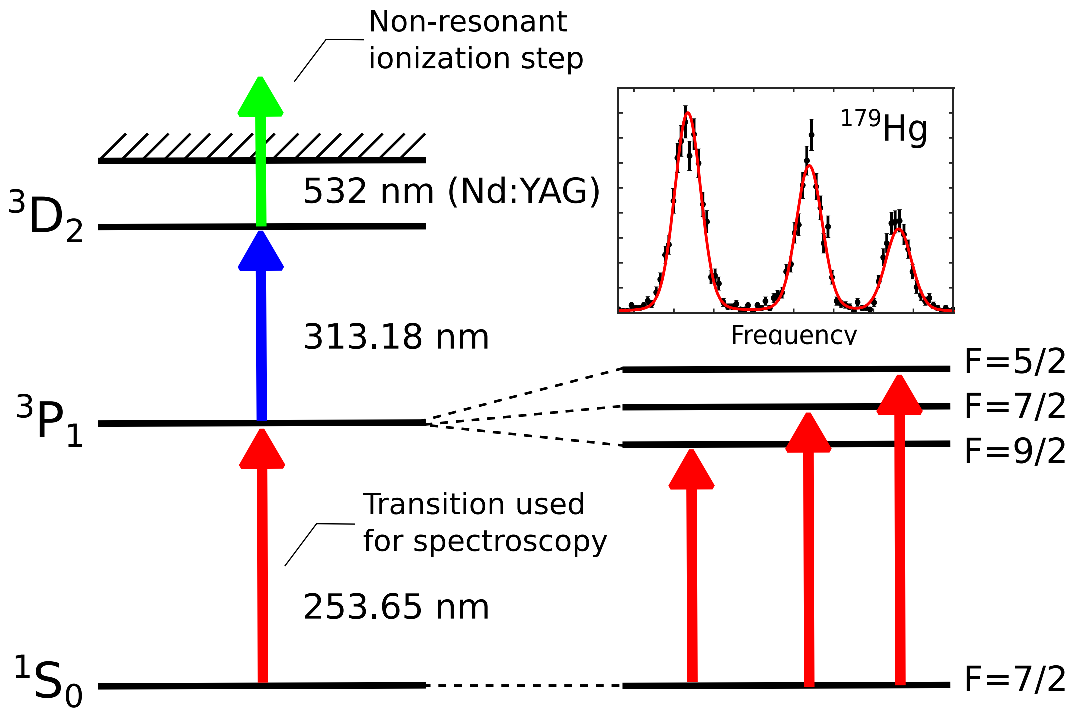
Charge radii differences





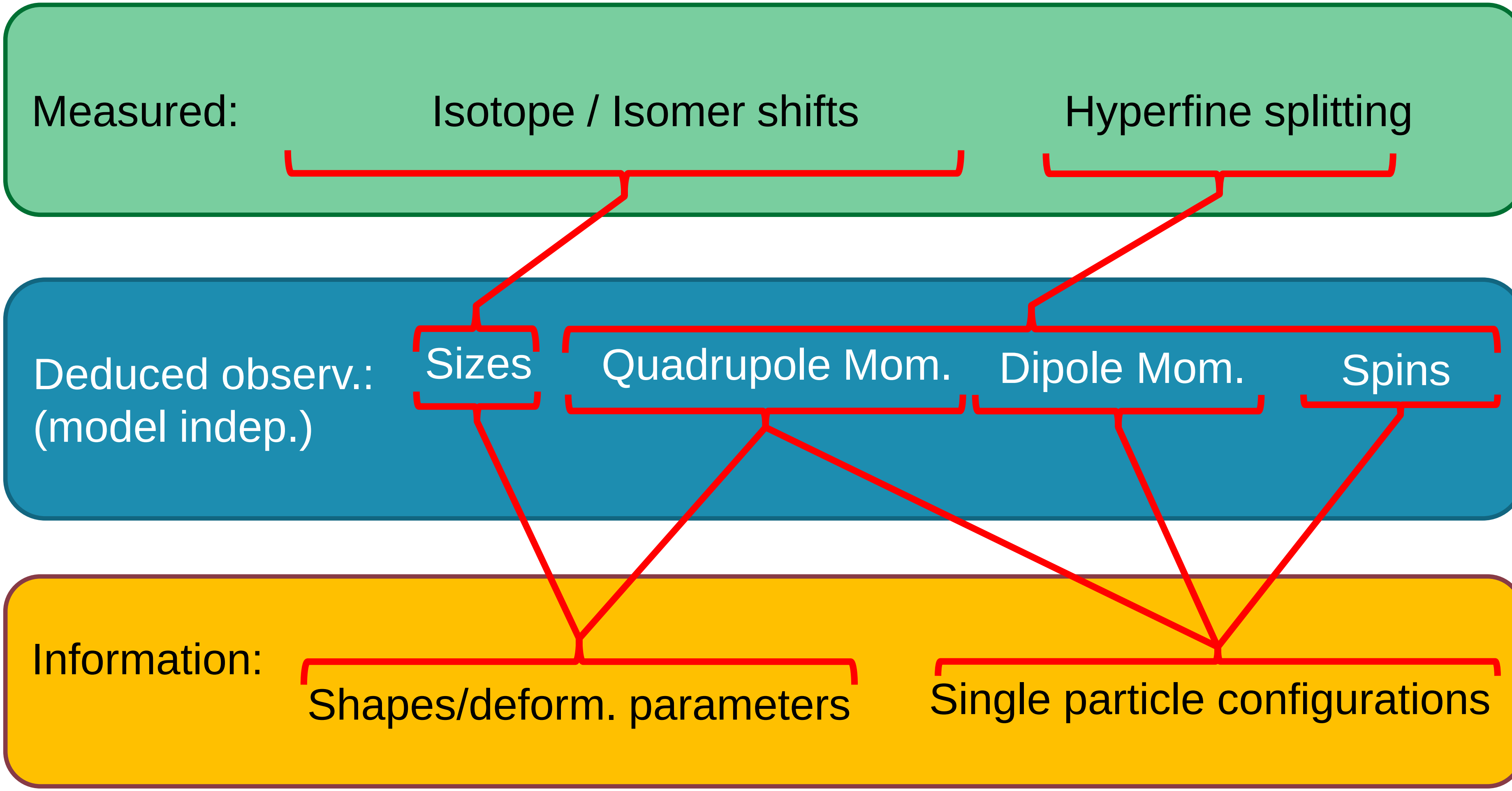
- Where does the shape staggering end?
  > Excellent tool to test precision of theoretical models
- Kink at N=126 like Pb,Bi,Po ?

Laser spectroscopy

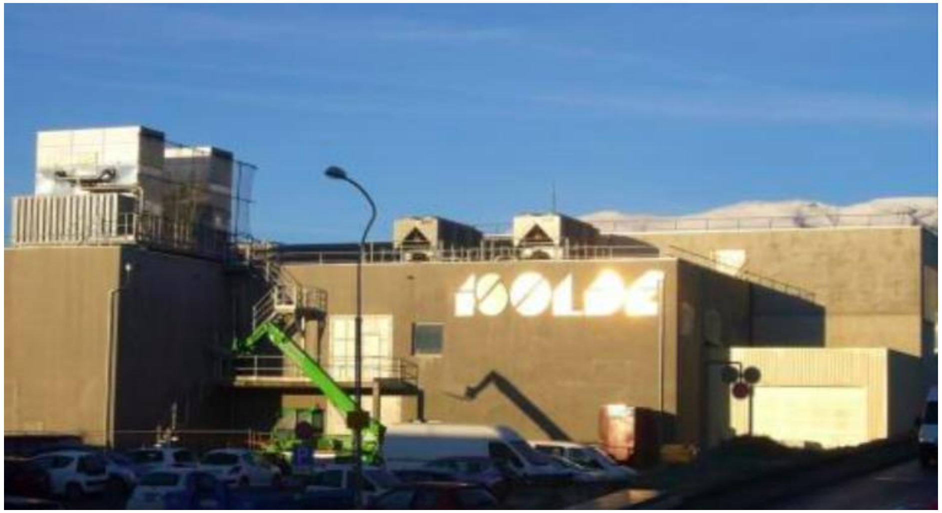


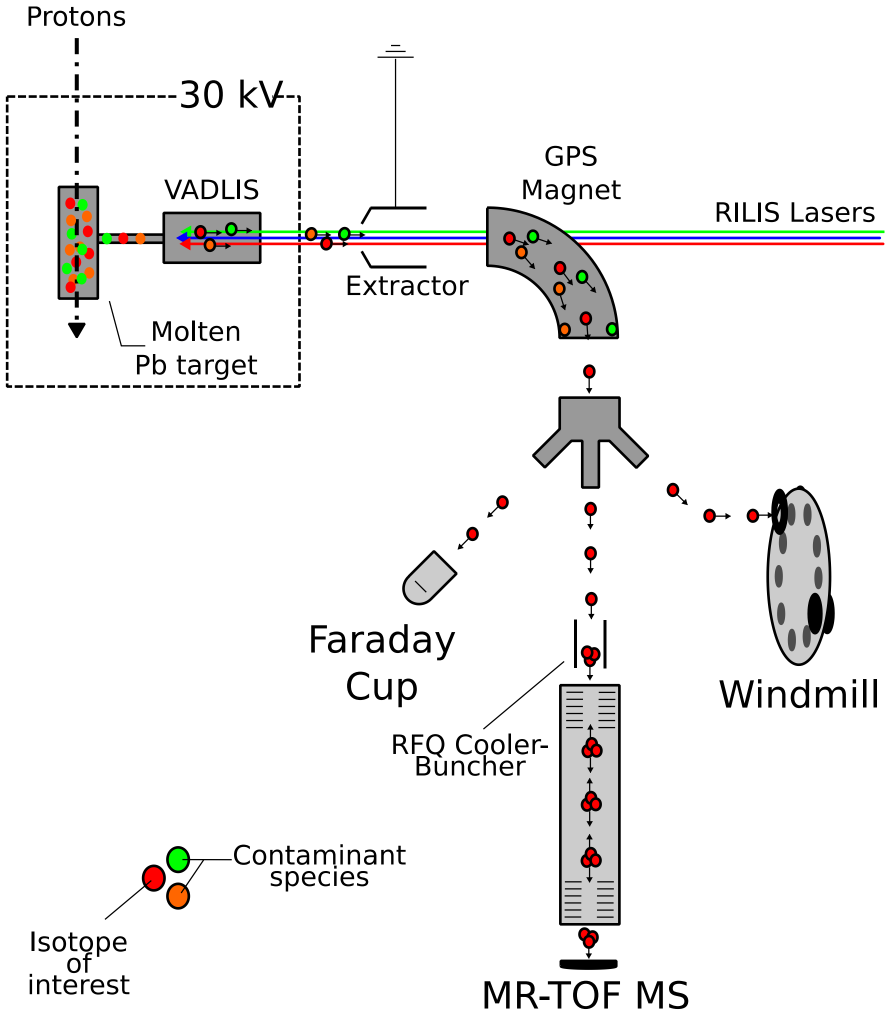
Isotope shift,
hyperfine parameters → $\delta\langle r^2\rangle^{A,A'}\ I, \mu, Q,$

Laser spectroscopy variables

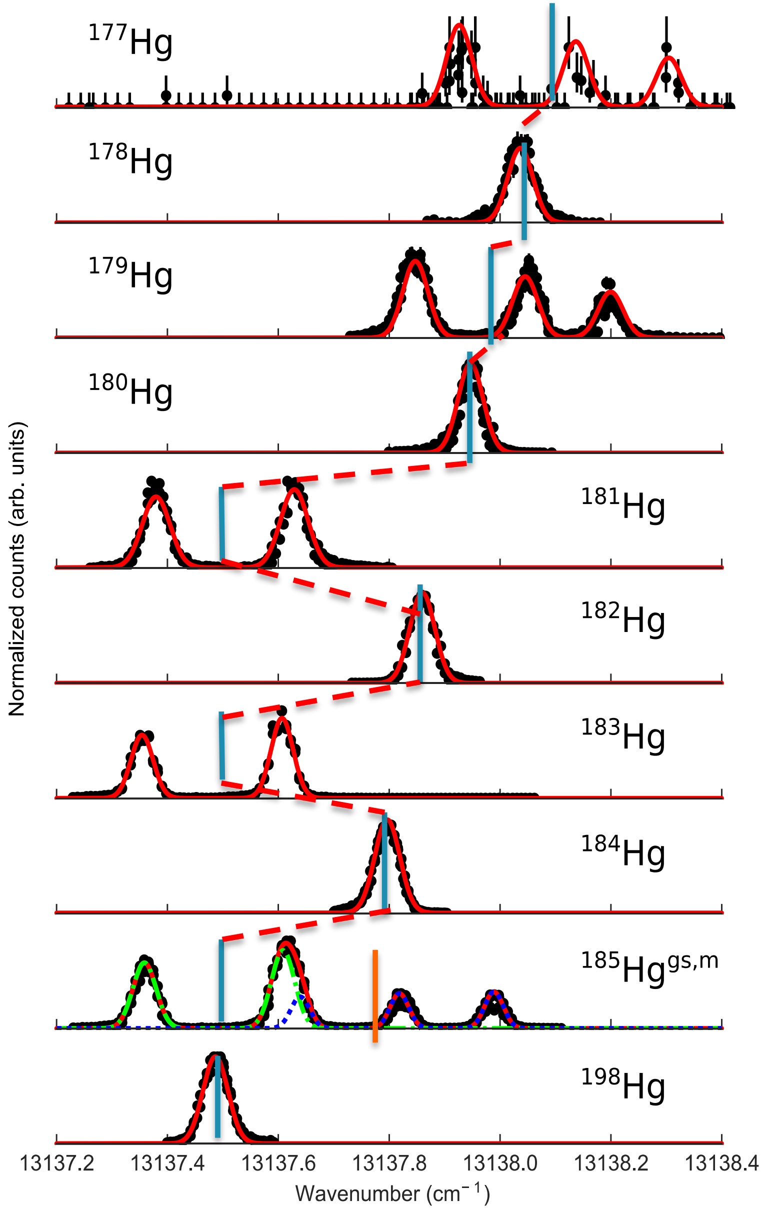


ISOLDE - CERN


ISOLDE


Protons
30 kV
VADLIS
Molten
Pb target
Extractor
GPS
Magnet
RILIS Lasers
Faraday
Cup
Windmill
RFQ Cooler-
Buncher
Contaminant
species
Isotope
of
interest
MR-TOF MS

Hyperfine spectra



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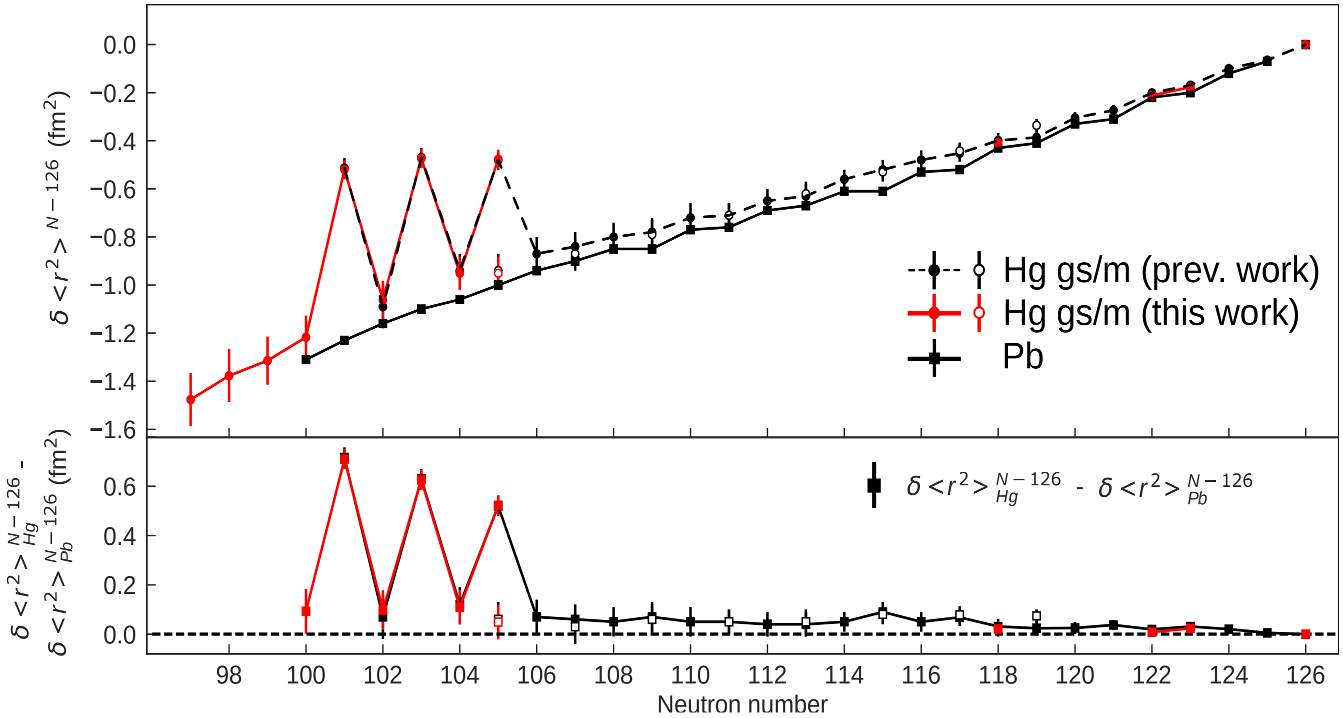
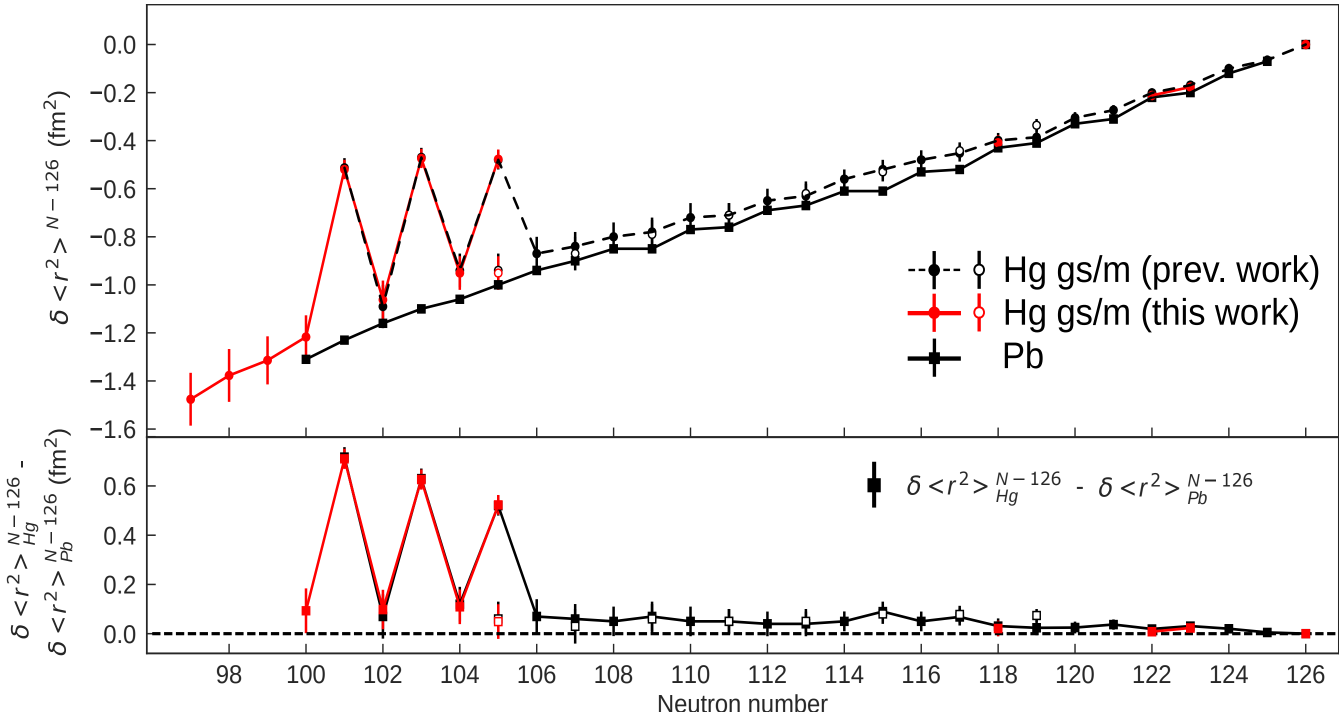
results



Charge radii results

- End point of shape staggering observed
- kink at N=126 present as well
- Agreement with previously measured values

results



Isotope	Spin I^π	μ (μ_N)	Q_s (b)
^{177}Hg	(7/2$^-$)	-1.025(40)	0.57(83)
	(9/2$^-$)	-1.056(40)	1.21(91)
^{179}Hg	(7/2$^-$)	-0.948(20)	0.76(28)
	(9/2$^-$)	-0.960(20)	1.45(31)
^{181}Hg	1/2$^-$	0.515(4)	-
		0.513(9)	-
^{183}Hg	1/2$^-$	0.521(6)	-
		0.527(1)	-
^{185}Hg	1/2$^-$	0.51(1)	-
		0.513(2)	-
^{185m}Hg	13/2$^+$	-1.01(1)	-0.15(41)
		-1.017(9)	0.19(32)

moments :

magn 177-179-185m Hg : ≈ - 1

181-183-185 Hg : ≈ +0.5

quad 177-179-185m Hg : small

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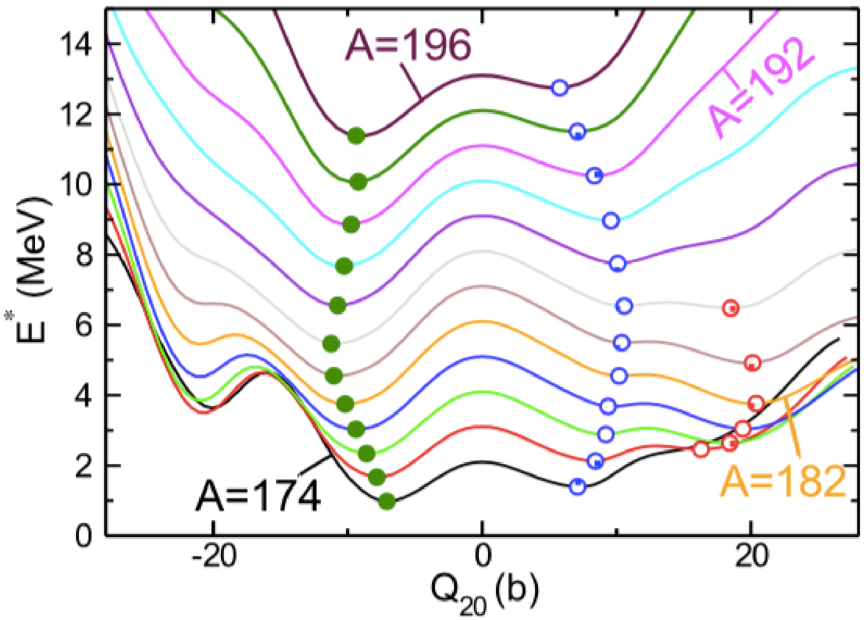
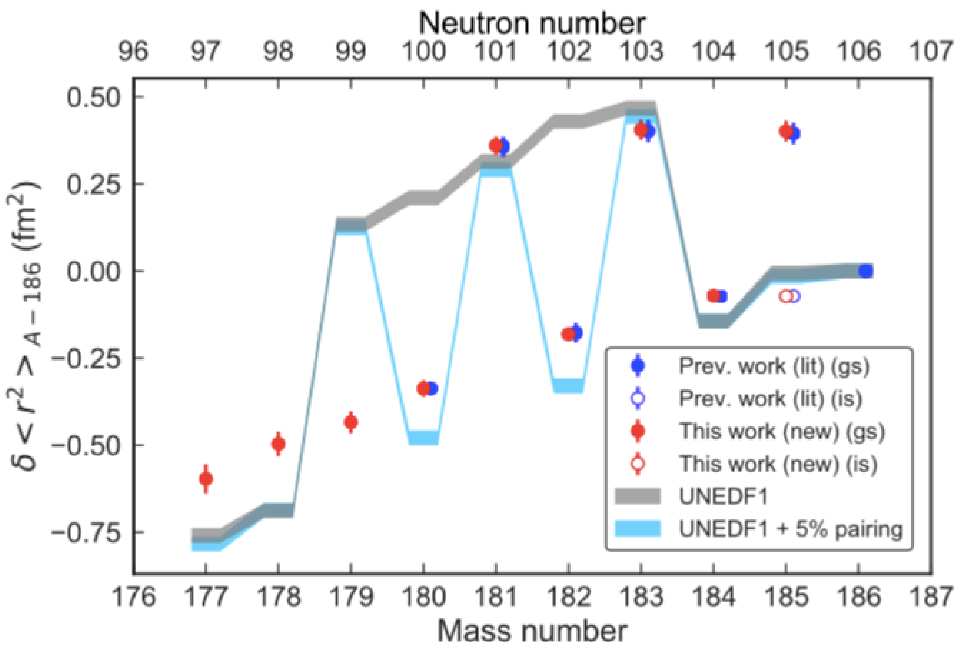
Shape staggering comparison to DFT

Potential Energy surface



Charge radii



Skyrme functional UNEDF1so [1]

→ Adjusted to global properties of nuclear chart

→ Fine tuned SO and pairing to reproduce No spectroscopy

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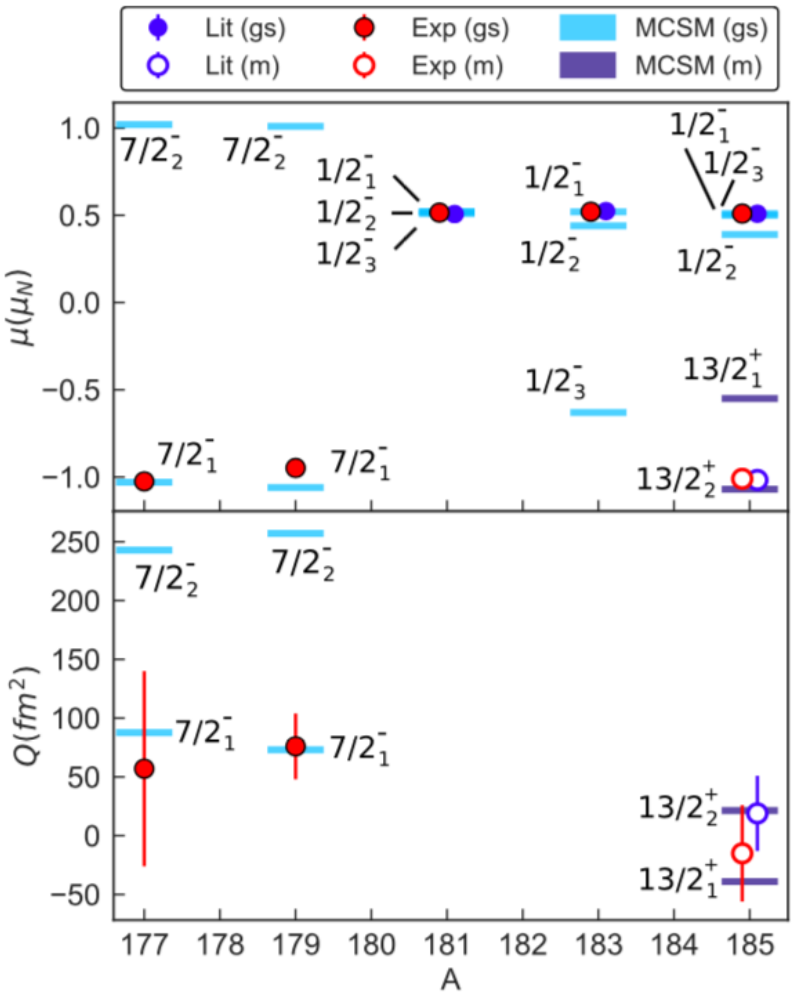
Calc: J. Dobaczewski, A. Pastore – Univ.York

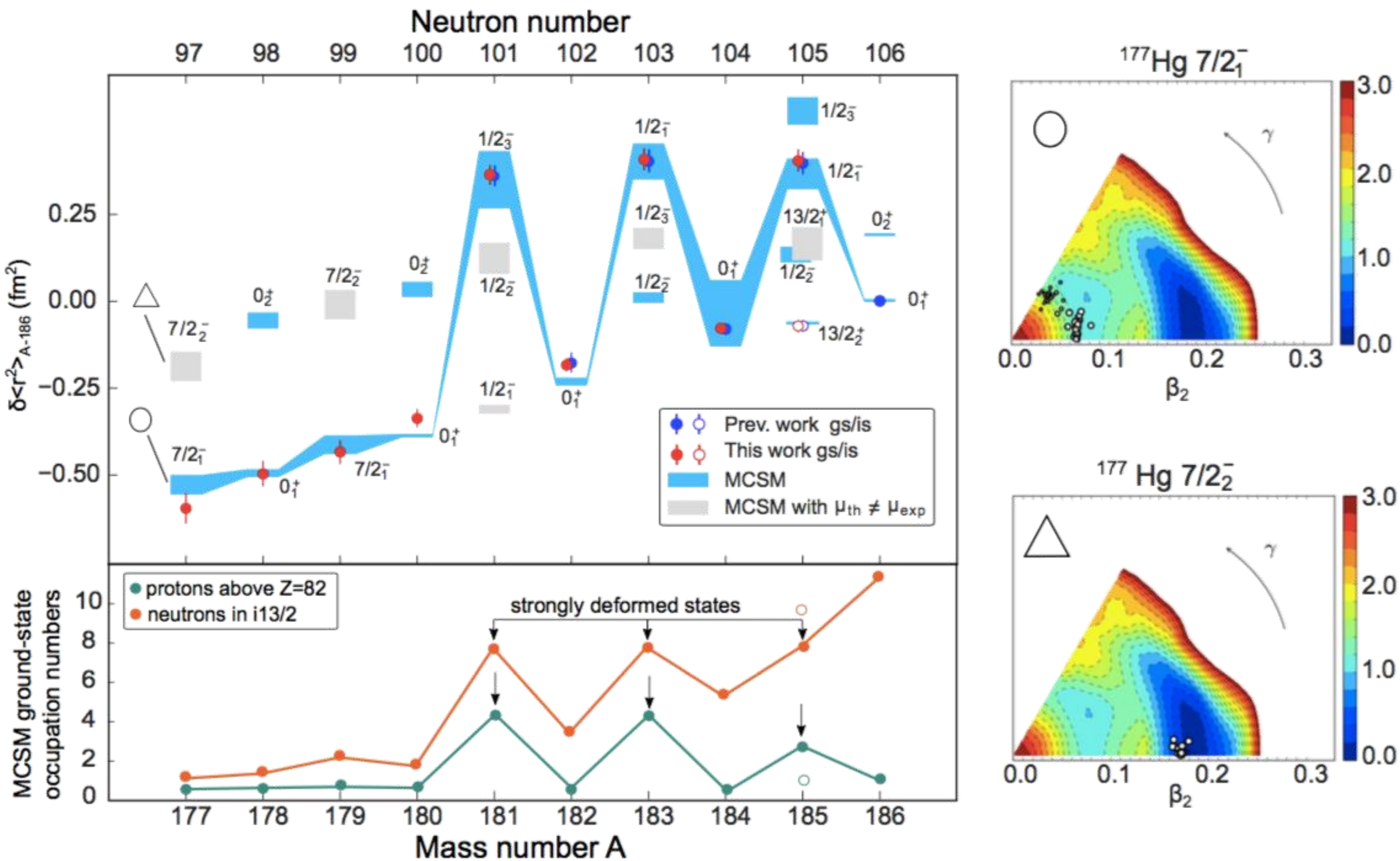
[1] PRC 89, 034309 (2014)

Electromagnetic moments

Comparison to MCSM



Shape staggering comparison to MCSM



^{132}Sn as fixed core

→ 30 protons and 17-24 neutrons all interacting *NN,PP* [1] *PN* [2],

First for such a heavy system

Calc: T. Otsuka, Y. Tsunod

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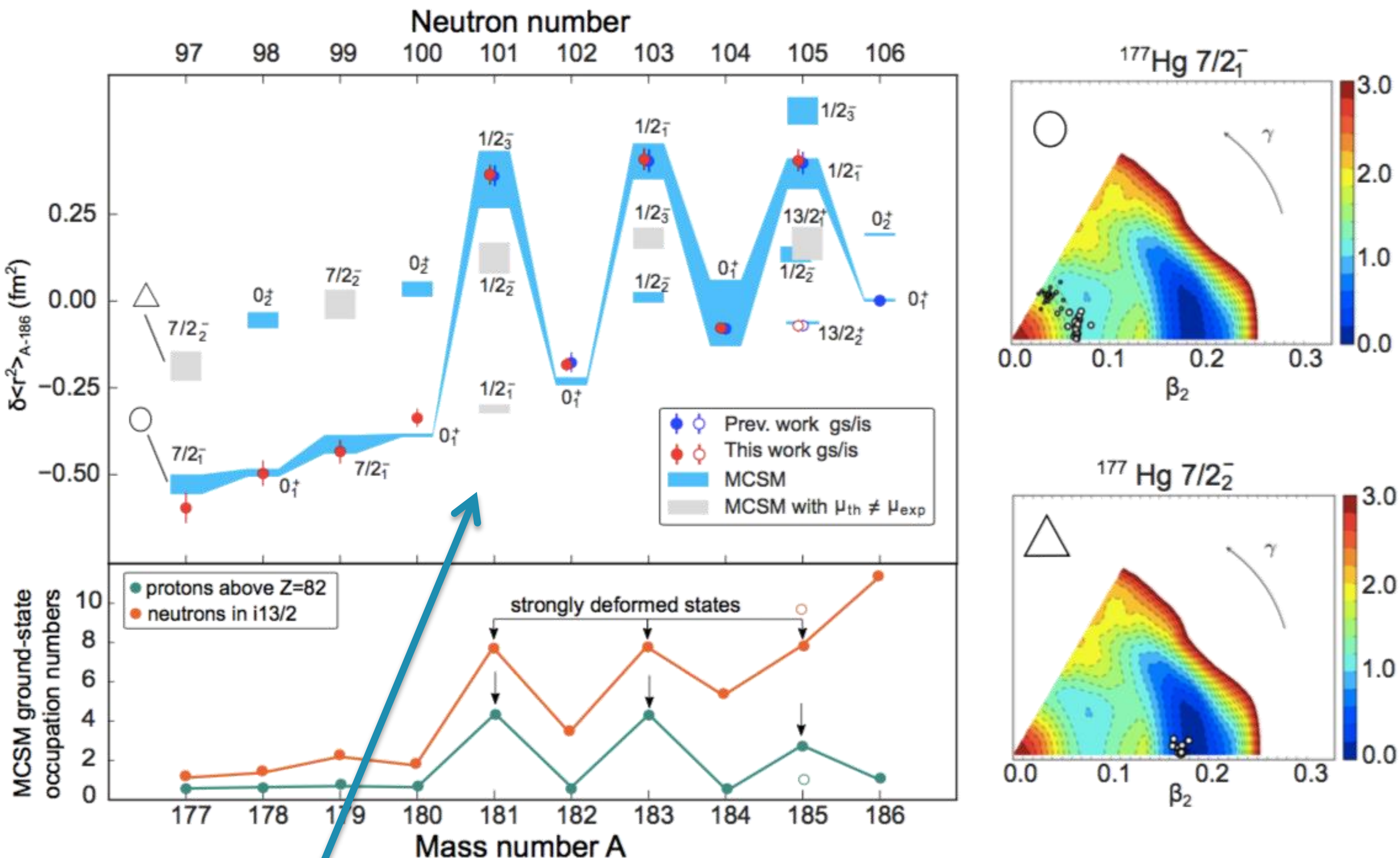
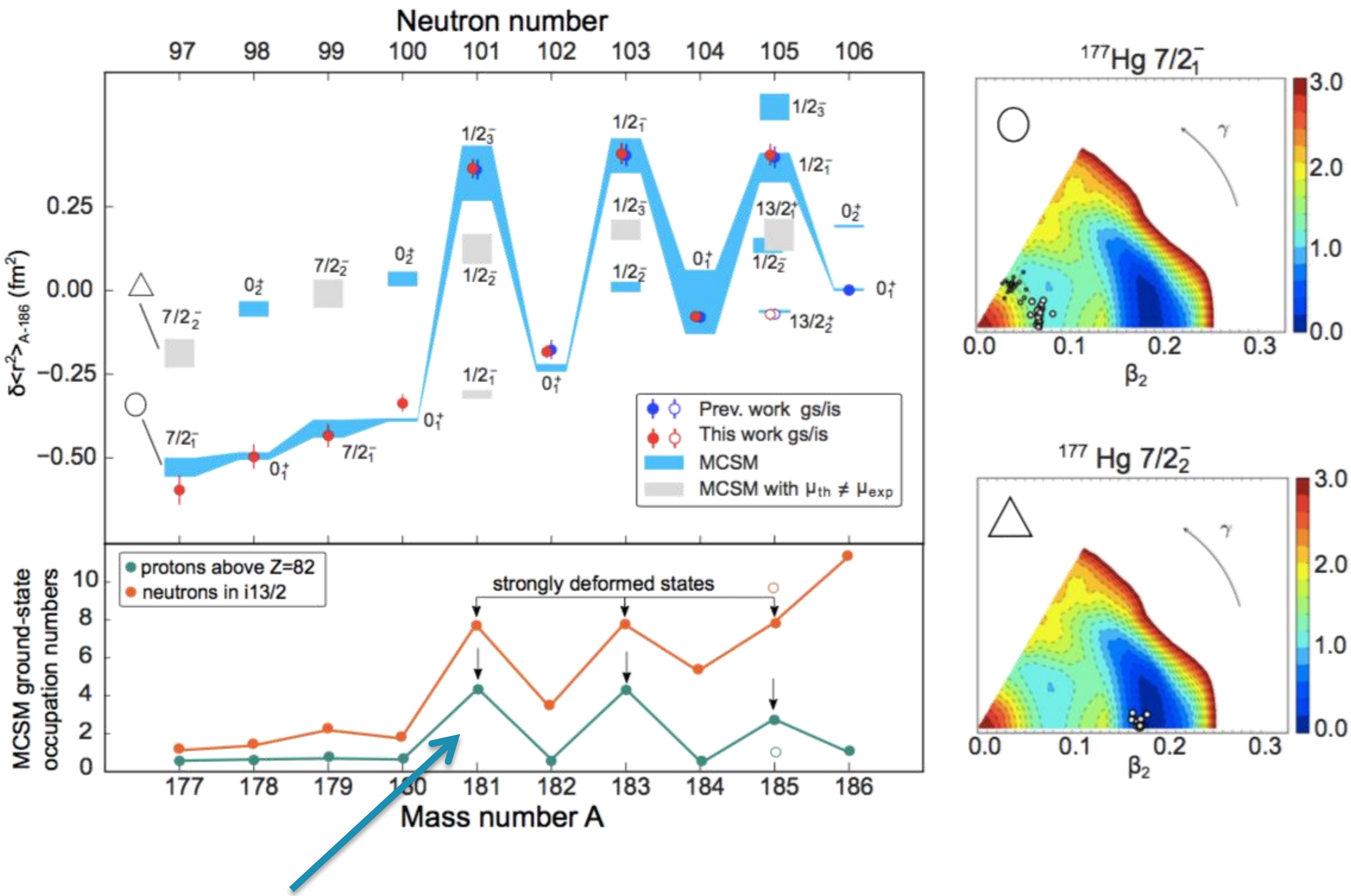
Shape staggering comparison to theory



Charge radii differences, staggering strength and location well reproduced!
In all but ^{181}Hg and ^{185m}Hg, state with correct $d\langle r^2\rangle$ = g.s.

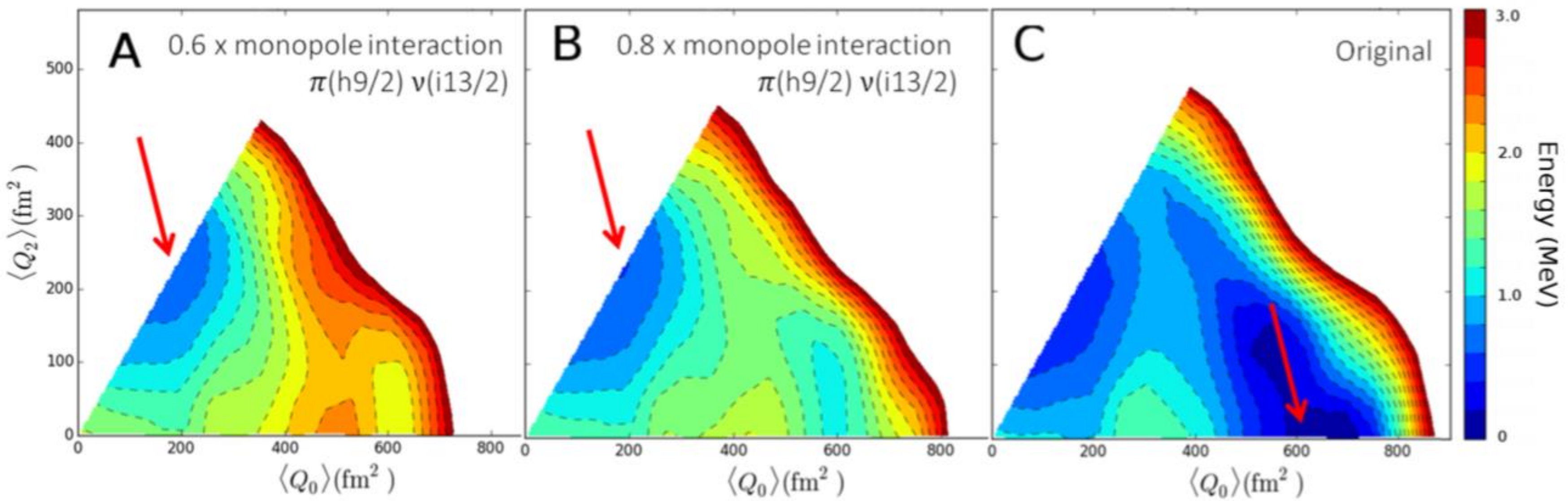
Calc: T. Otsuka, Y. Tsunoda et al

Shape staggering comparison to theory



Particular occupation numbers of $n(i_{13/2})$ and $p(h_{9/2})$ important

Effect of reducing monopole interaction



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Shape staggering mechanism

Combined action of monopole energy, which stands out compared to others between *n*($i_{13/2}$) and *p*($h_{9/2}$) and due to:

- Large radial overlap of wavefunctions
- Attractive tensor force between $j_>$ - $j_<$'

$$E_{\mathrm{mon}} = f(j_p, j_n) n_\pi(j_p) n_\nu(j_n)$$

And quadrupole interaction, bringing down the *deformed* state in energy to near-degeneracy with *spherical* state

Cfr. Similar to Type II shell evolution where SPE's are adjusted due to occupation numbers of *p* and *n* orbitals

Small addition in pairing energy between even/odd-A isotopes dictates the ground state shape

Conclusion

Experiment: Hg laser spectroscopy at ISOLDE

* Determined end-point of shape staggering
* Measured electromagnetic moments

Comparison to theory:

* DFT – interplay of shape coexistence, pairing and blocking
* MCSM:
  – $n(i_{13/2})$ $p(h_{9/2})$ interaction responsible
  – Related to Type II shell evolution

Outlook..

Extending to different measurements and observables

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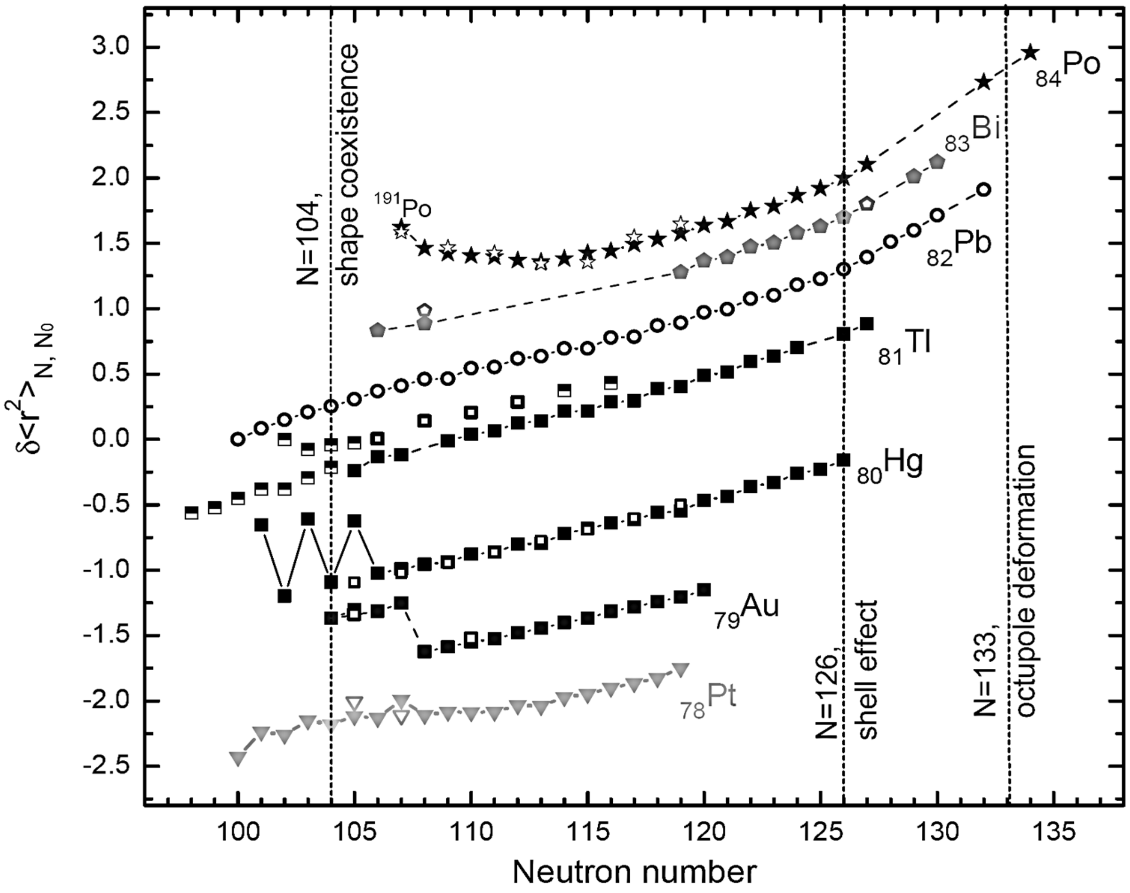
Outlook



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