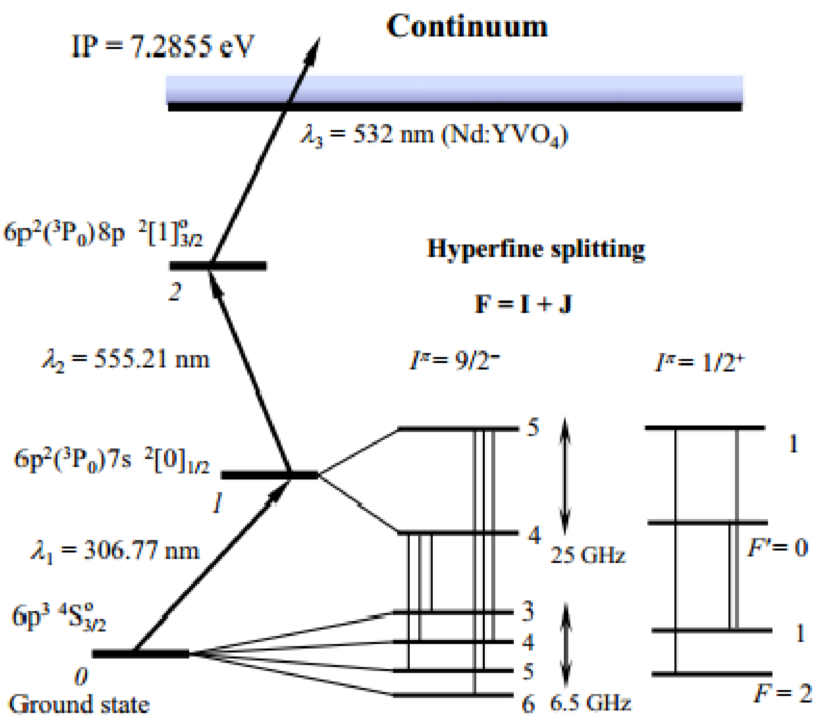
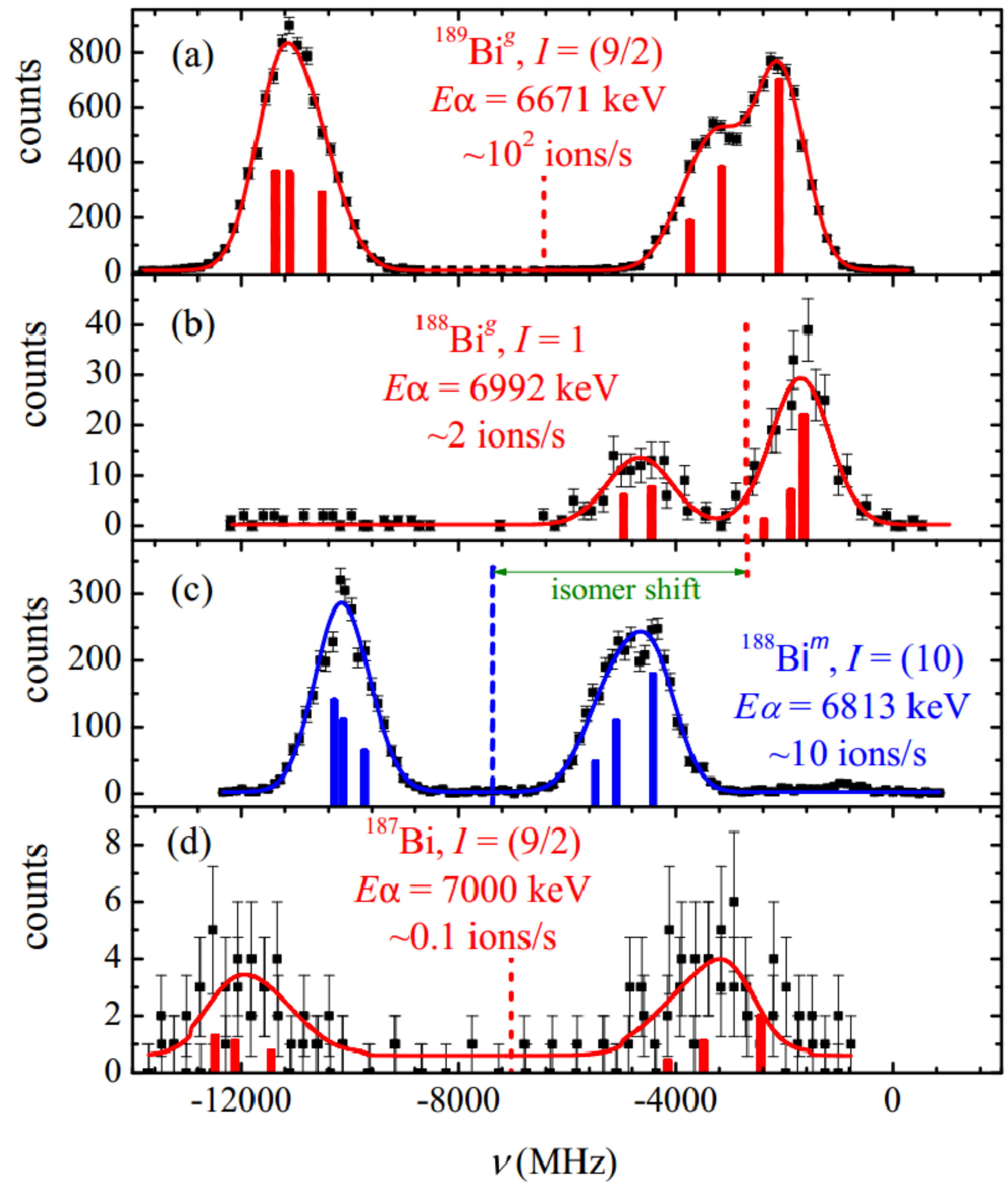
Эксперименты с лазерным ионным источником (ISOLDE, CERN; *Windmill-ISOLTRAP-RILIS-IDS collaboration*)

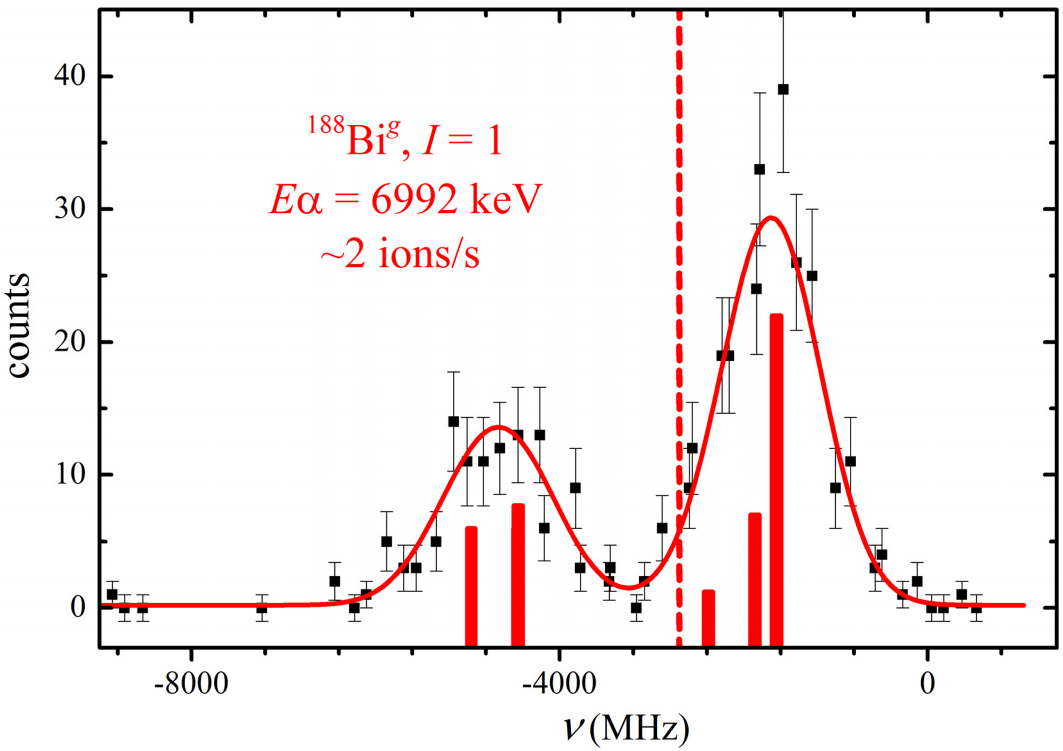
А. Е. Барзах, П. Л. Молканов, В. Н. Пантелеев,
М. Д. Селиверстов, Д. В. Федоров

IS and hfs for neutron-deficient Bi isotopes





Spin of $^{188}Bi^{g}$



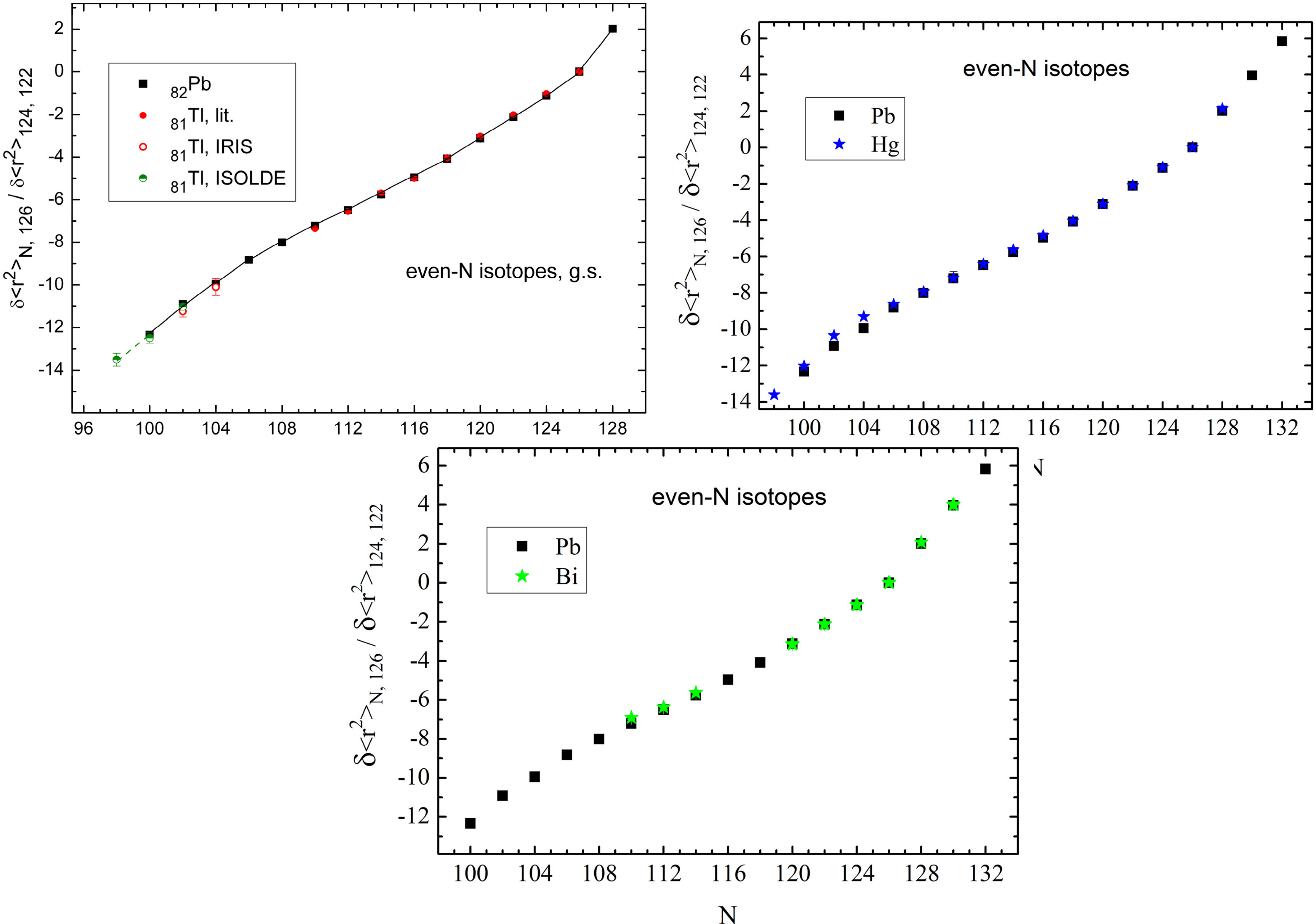
Due to limited resolution, for the spin determination the "integration method" was used.

The ratio of areas under each resolved peak:

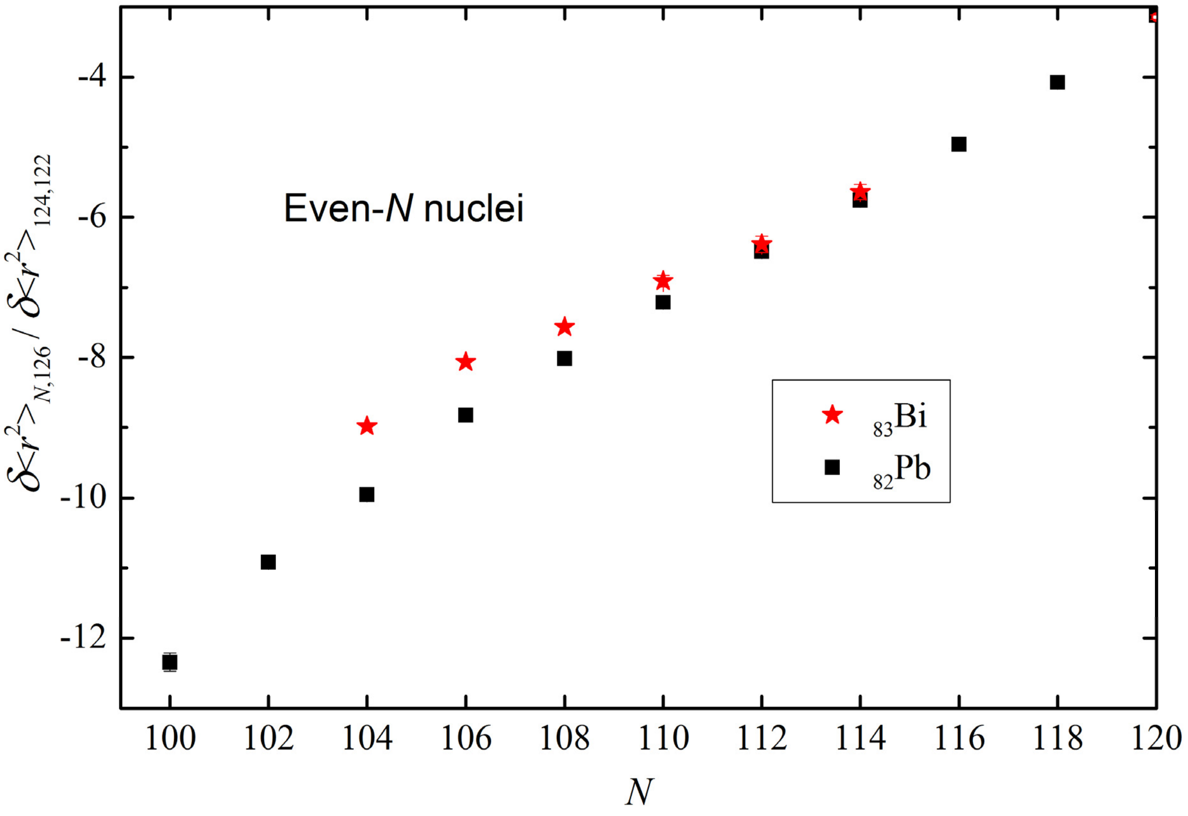
r_{theor} = (I+1)/I . r_{theor} = 2 at I = 1
r_{theor} = 1.5 at I = 2
r_{theor} = 1.67 at I = 3 etc.

The weighted mean value, r_{expt} = 2.00(12), for the six hfs spectra available for $^{188}Bi^{g}$ indicates a strong preference for an I = 1 assignment.

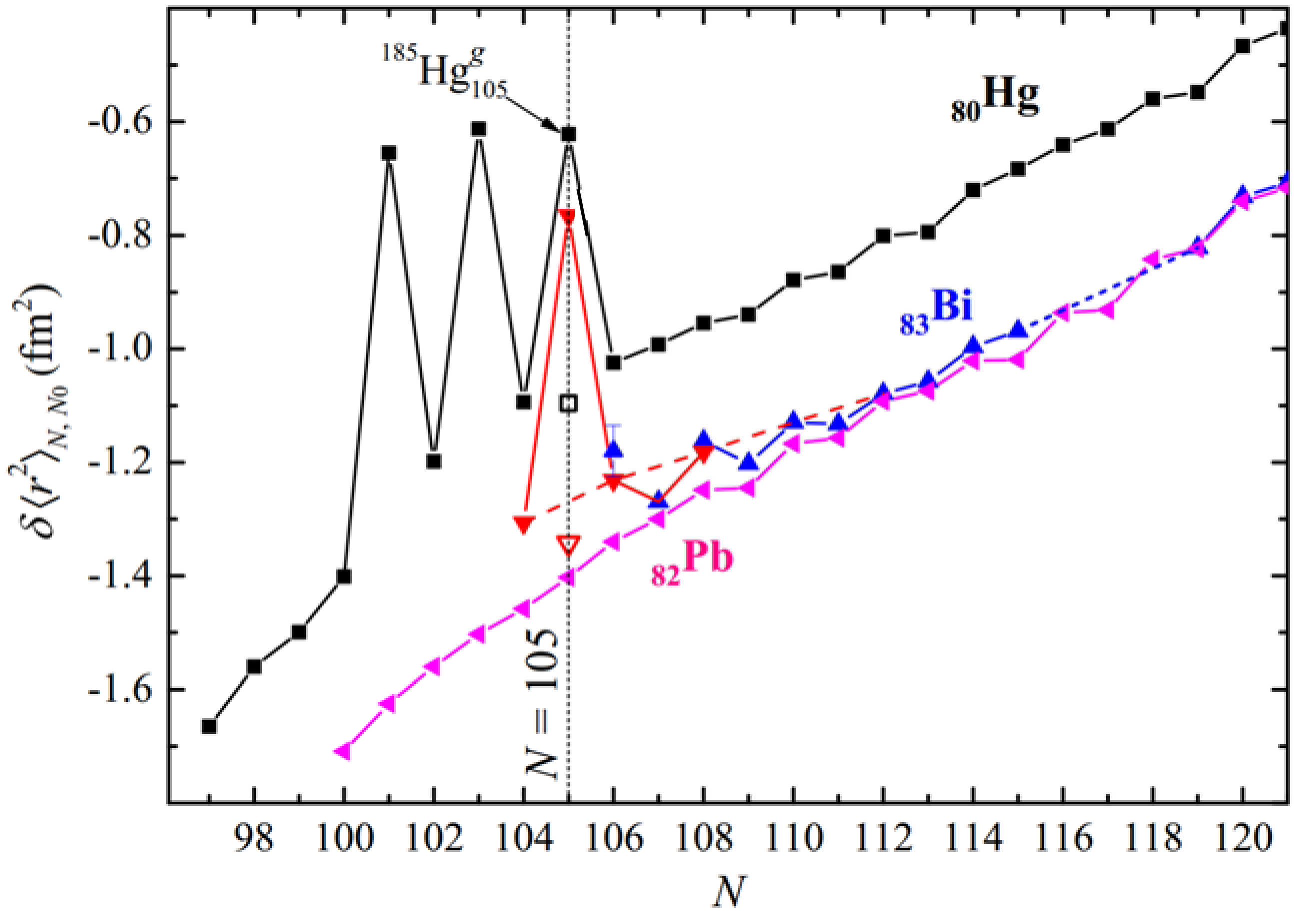
Relative radii: universal Pb trend



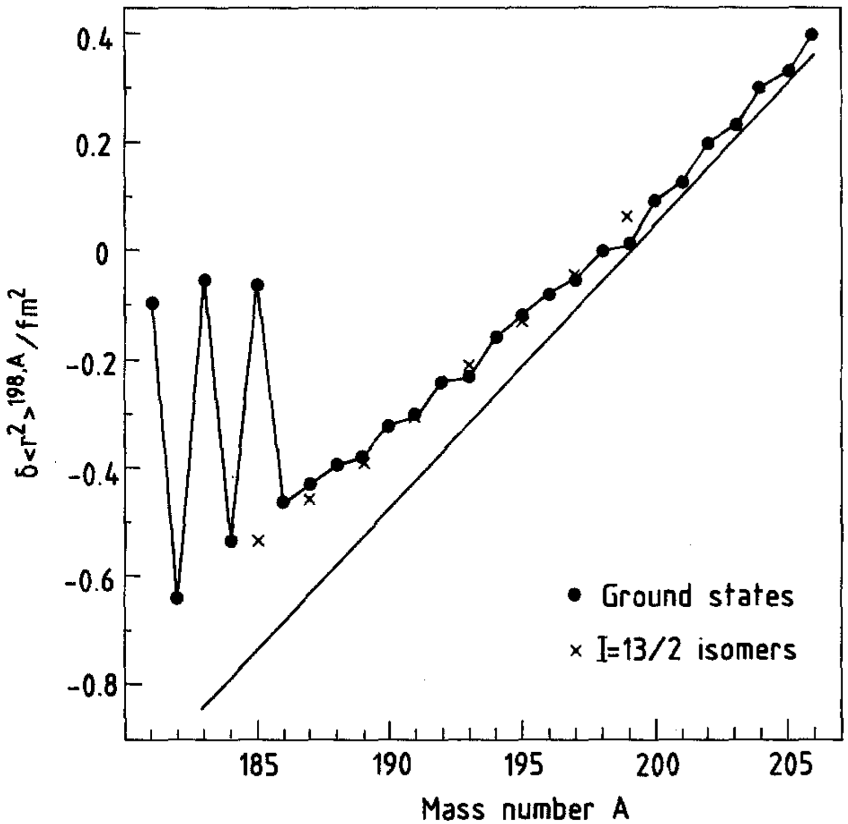
Relative radii: deviation from universal Pb trend

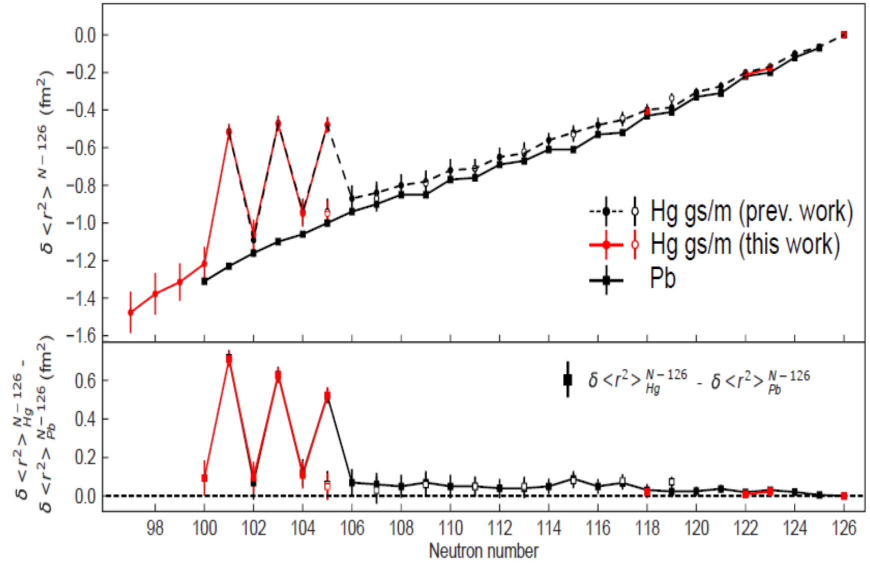


Shape staggering: Bi



Shape staggering: Hg





"One of the most remarkable discoveries in nuclear structure physics in the last 50 years".
K. Heyde and J. L. Wood, Phys. Scripta 91, 083008 (2016)

Shape staggering: $^{188}Bi^{g}$, magnetic and quadrupole moments

$\mu_{exp}(^{188}\text{Bi}; I = 1) = 0.994(21)\ \mu_N$

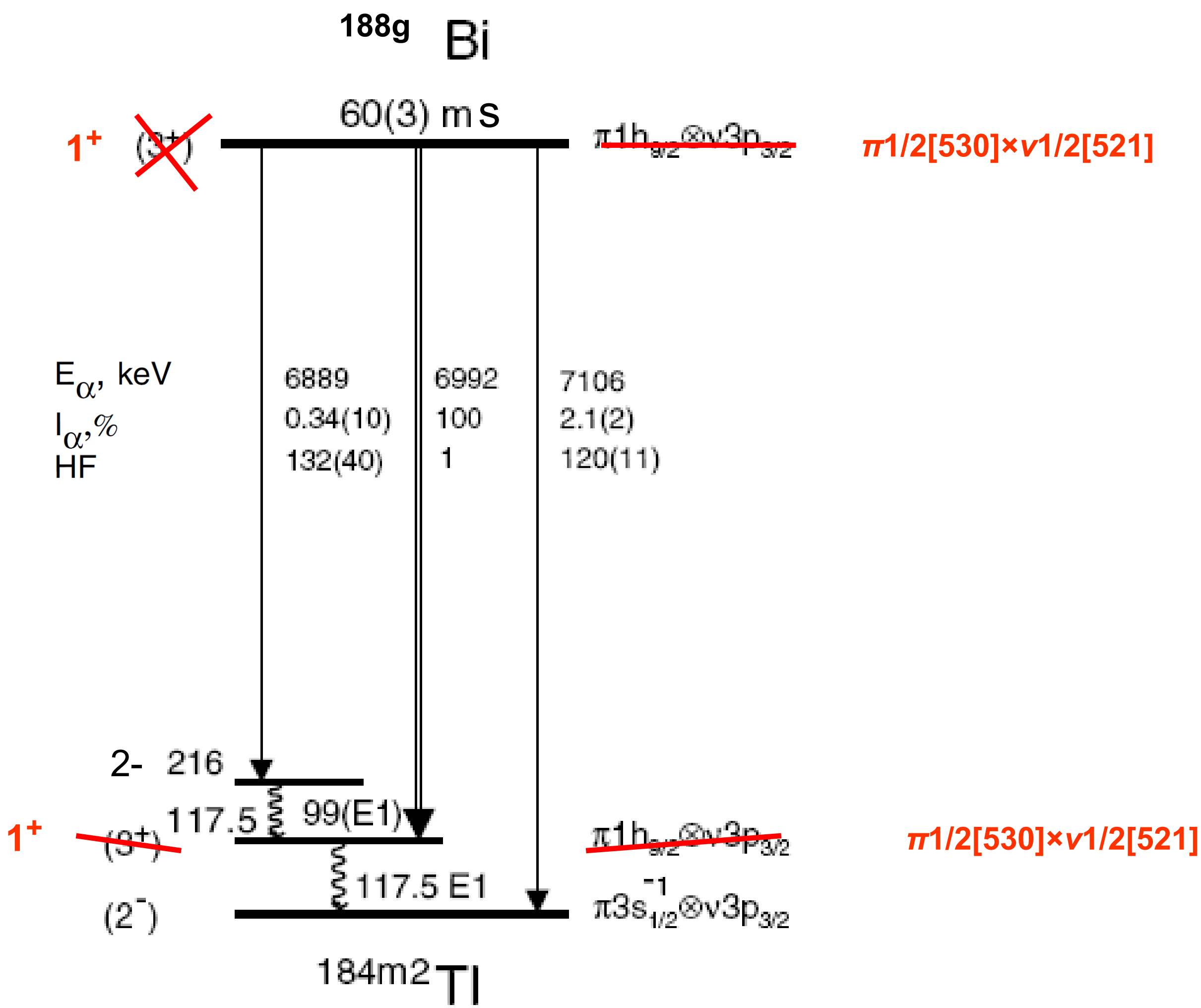
Configuration with proper magnetic moment:
$\mu_{theor}(\{\pi 1/2[530] \times \nu 1/2[521]\}_1) = 1.0(2)\ \mu_N$

neutron orbital 1/2[521] is exactly the same that determines the strong prolate deformation in $^{181, 183, 185}$Hg; ^{185}Hg has the same neutron number (N = 105) as ^{188}Bi.

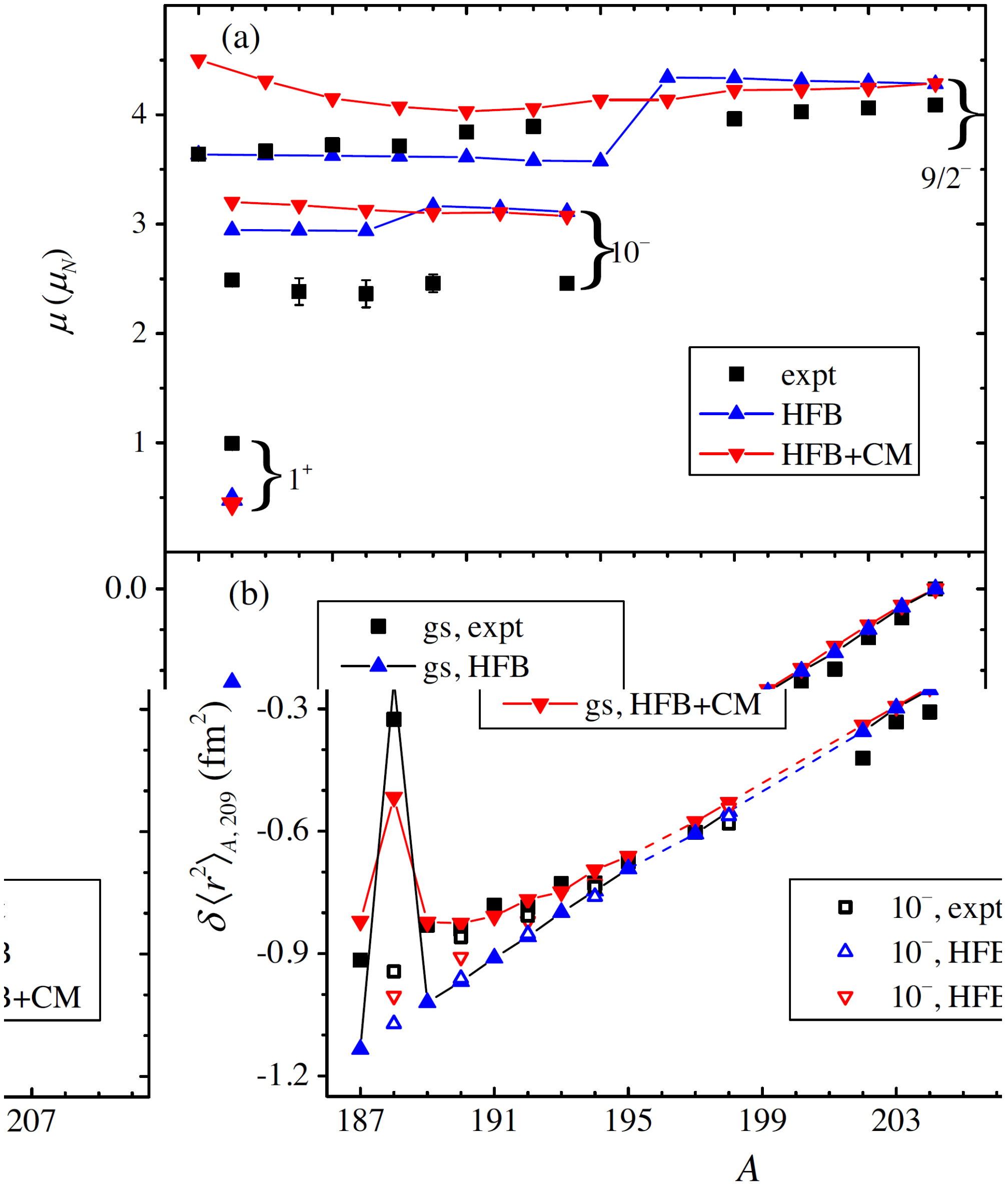
$Q_{exp}(^{188}\text{Bi}^{g}) = 0.85(37)$ b ⟹ β = +0.25(7)

$$Q_s = \frac{I\cdot(2I-1)}{(I+1)\cdot(2I+3)}\cdot\frac{3}{\sqrt{5\pi}}\cdot Z\cdot R_0^2\cdot\beta_Q\cdot\left(1+\frac{1}{7}\cdot\sqrt{\frac{20}{\pi}}\cdot\beta_Q+\ldots\right)$$

$^{188}Bi^{g}$: α decay



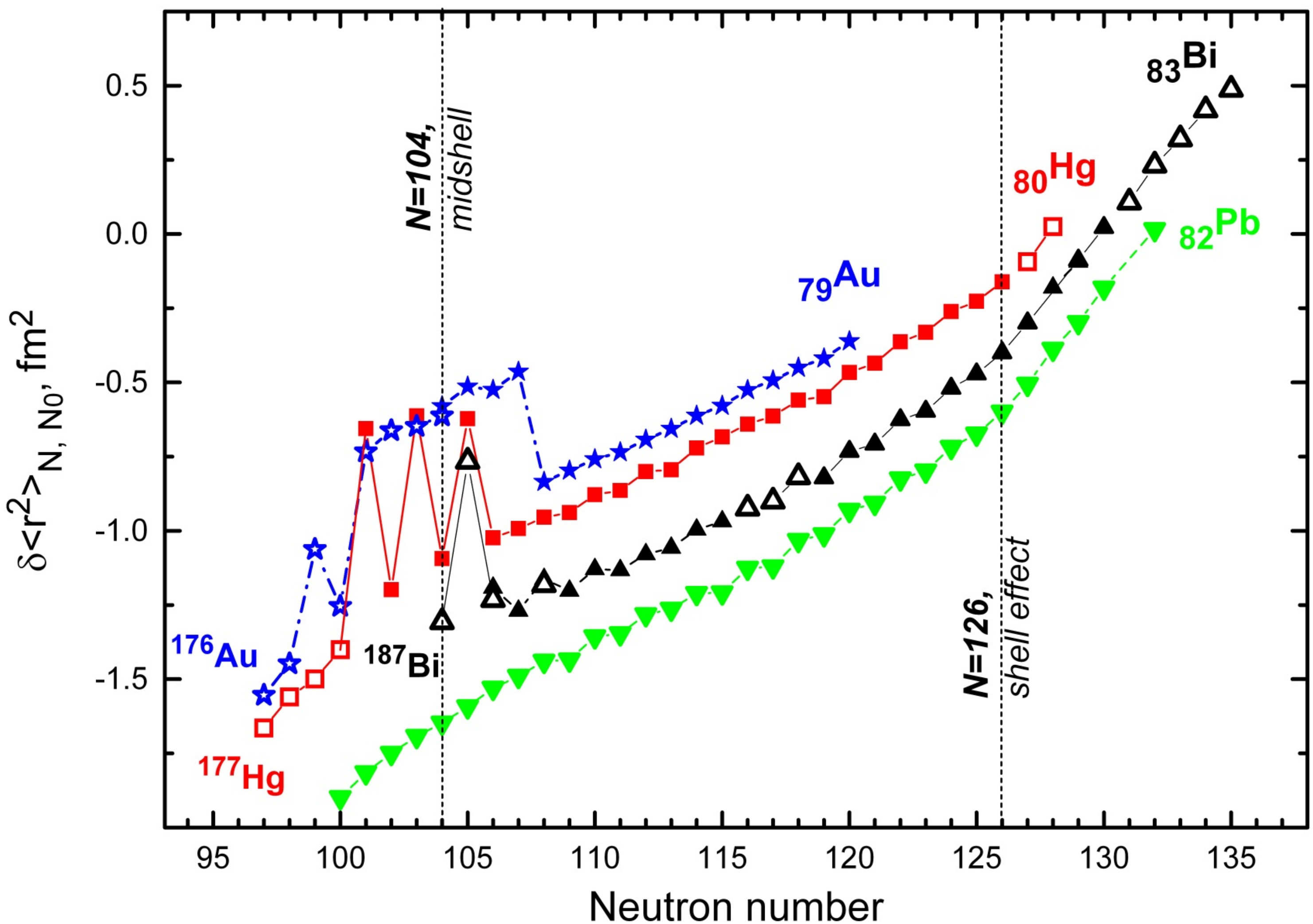
Shape staggering and OES in Bi: theory



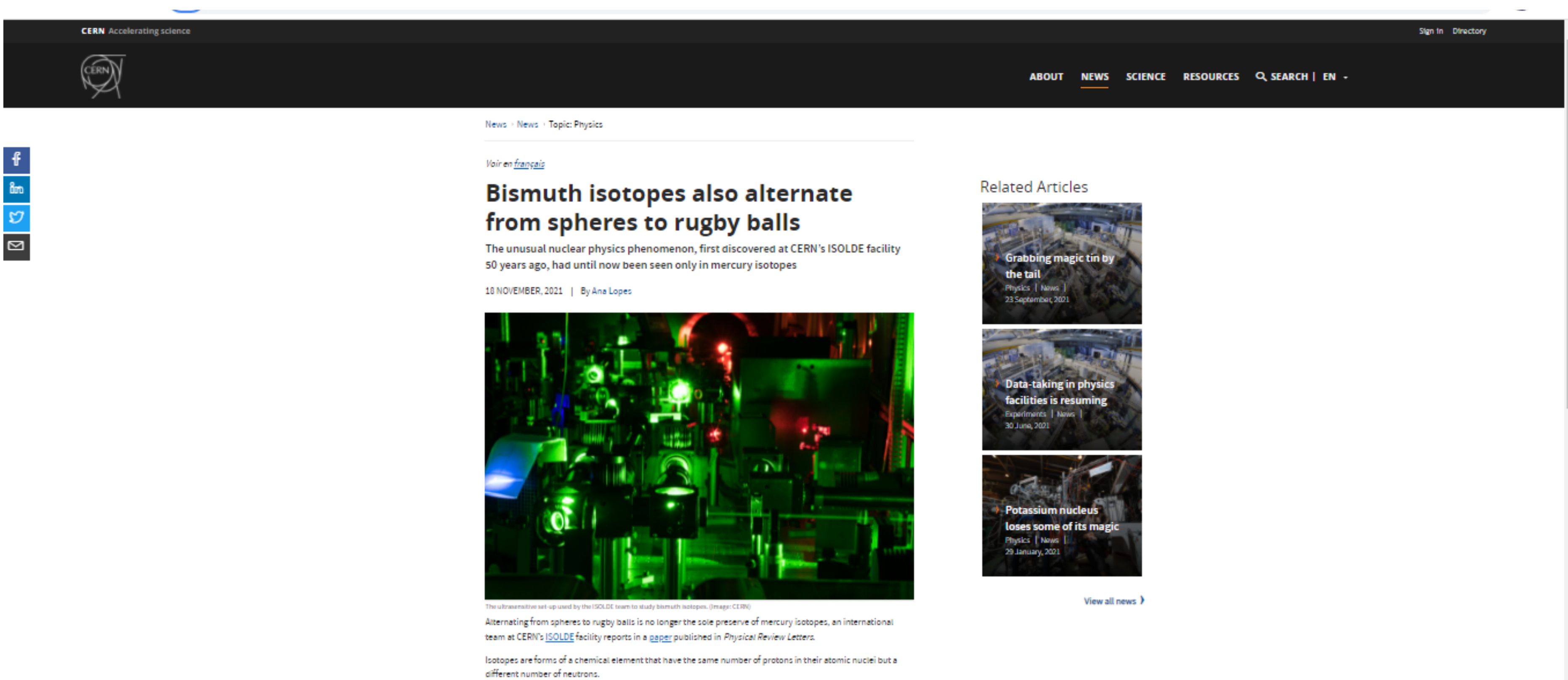
Phenomenological model of configuration mixing:

$$< \mathcal{O} >= \frac{\int_q \mathcal{O} \exp(-E/T) dq}{\int_q \exp(-E/T) dq}$$

Different patterns of shape evolution near midshell



Заметка на сайте CERN News


CERN Accelerating science

Sign in Directory

ABOUT NEWS SCIENCE RESOURCES SEARCH | EN

News › News › Topic: Physics

Voir en français

Bismuth isotopes also alternate from spheres to rugby balls

The unusual nuclear physics phenomenon, first discovered at CERN's ISOLDE facility 50 years ago, had until now been seen only in mercury isotopes

10 NOVEMBER, 2021 | By Ana Lopes

The ultrasensitive set-up used by the ISOLDE team to study bismuth isotopes. (Image: CERN)

Alternating from spheres to rugby balls is no longer the sole preserve of mercury isotopes, an international team at CERN's ISOLDE facility reports in a paper published in *Physical Review Letters*.

Isotopes are forms of a chemical element that have the same number of protons in their atomic nuclei but a different number of neutrons.

Related Articles

Grabbing magic tin by the tail
Physics | News | 23 September, 2021

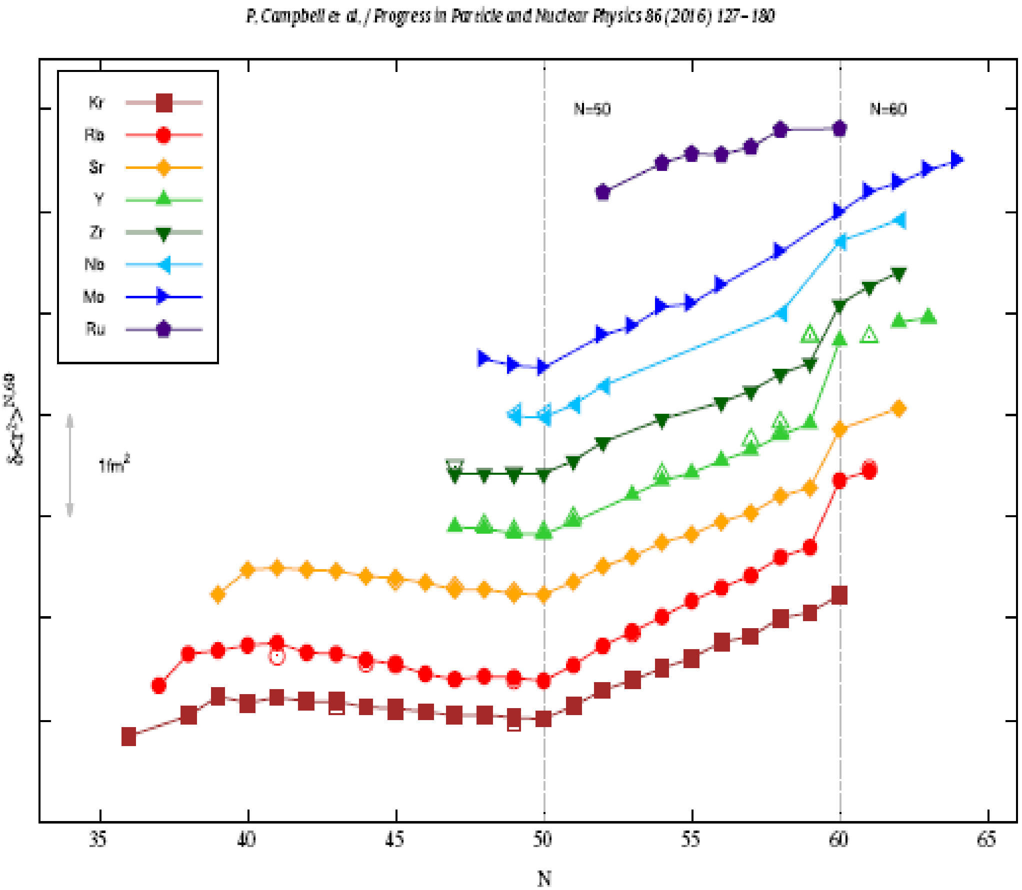
Data-taking in physics facilities is resuming
Experiments | News | 30 June, 2021

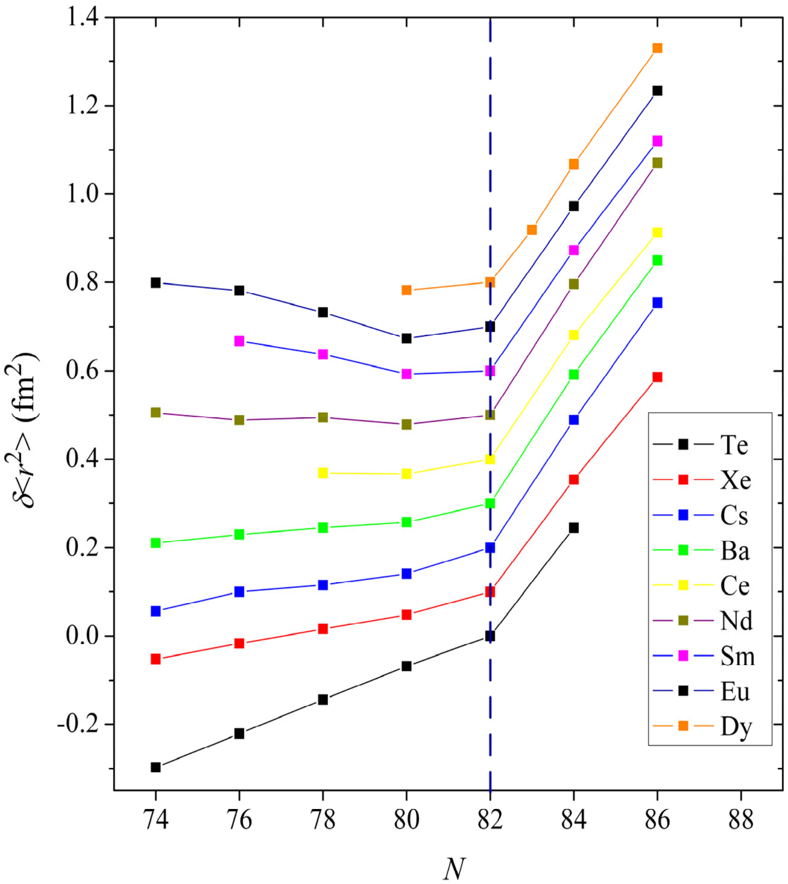
Potassium nucleus loses some of its magic
Physics | News | 29 January, 2021

View all news

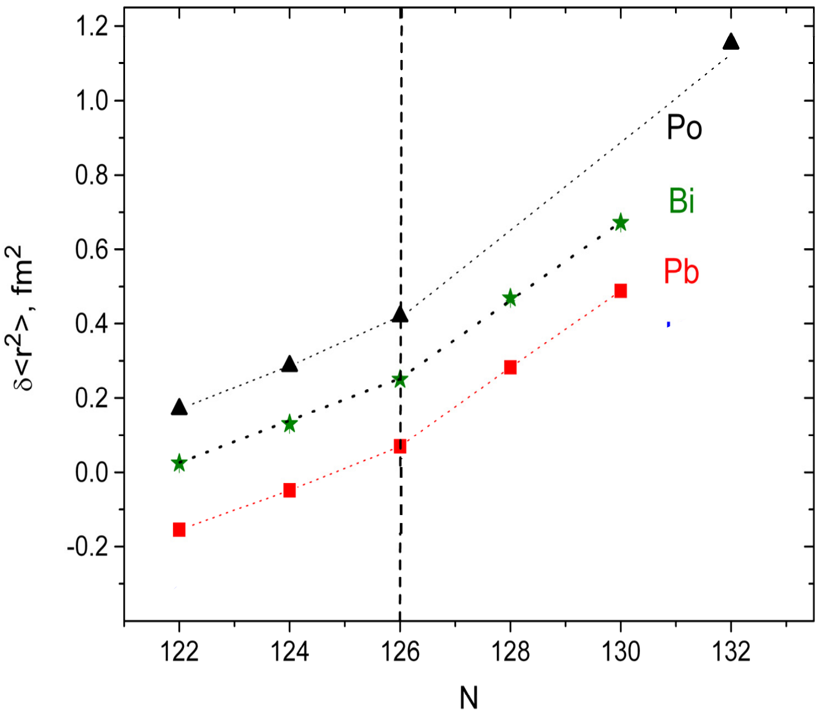
Barzakh A., … Fedorov D. V., ... Molkanov P., … Panteleev V., … Skripnikov L. V., … Zaitsevskii A. V., *Large Shape Staggering in Neutron-Deficient Bi Isotopes*, Phys. Rev. Lett. **127**, 192501 (2021).

Shell effect in radii at N = 50, 82



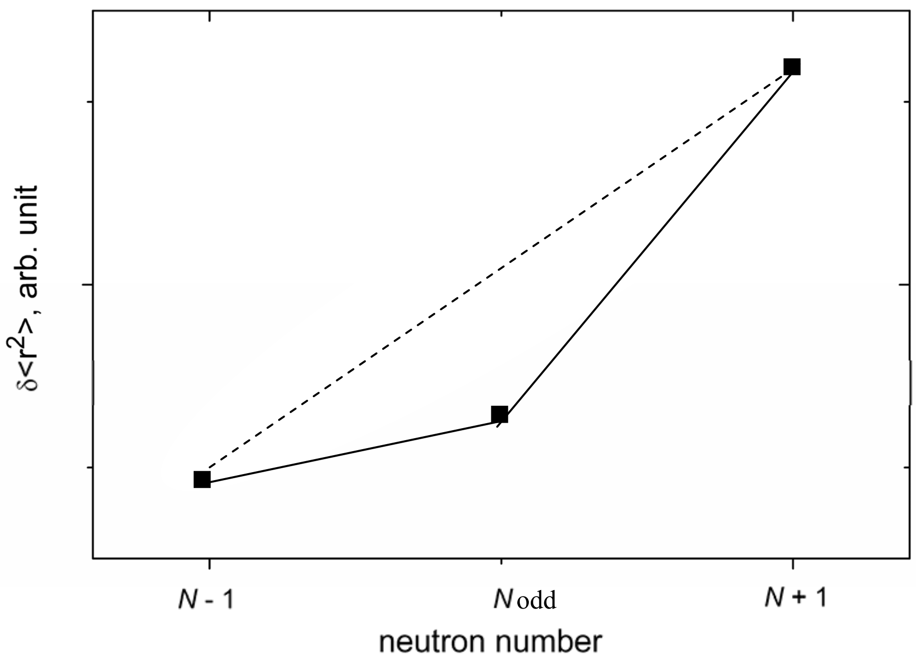


Shell effect in radii at $N = 126$ and odd-even staggering

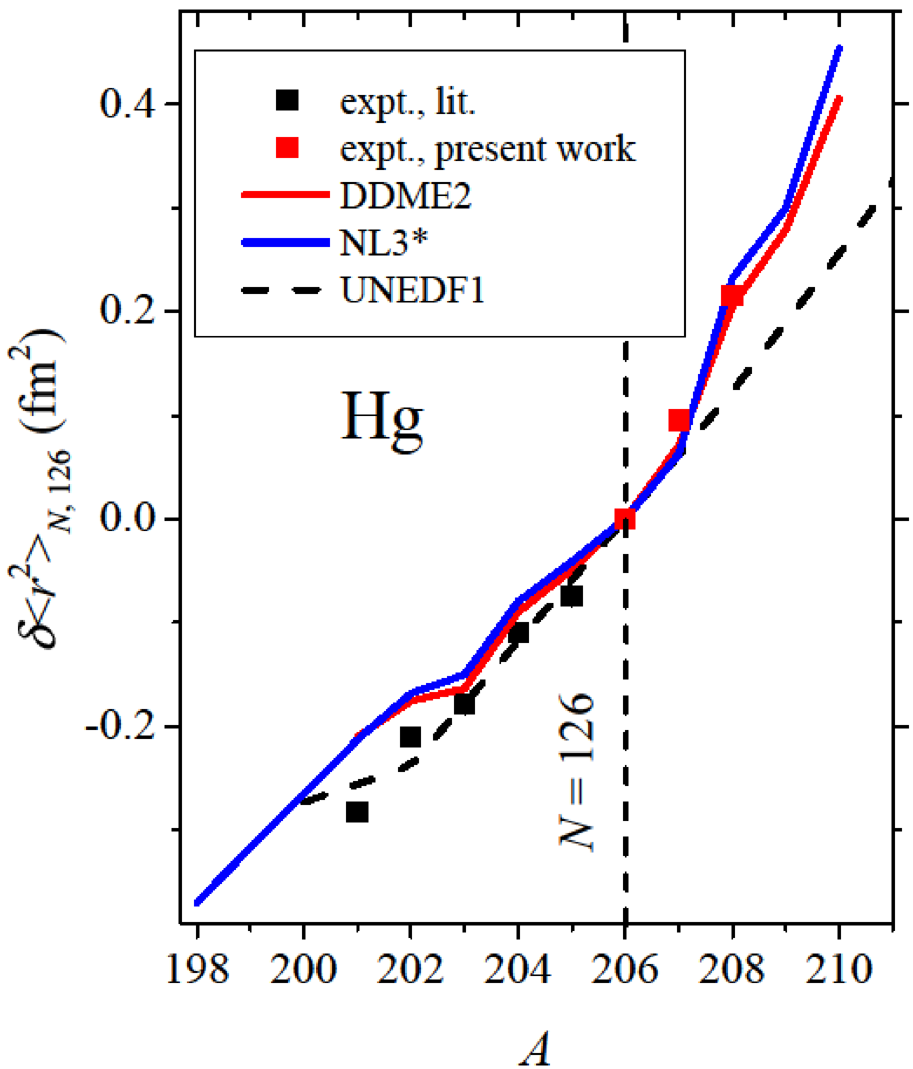


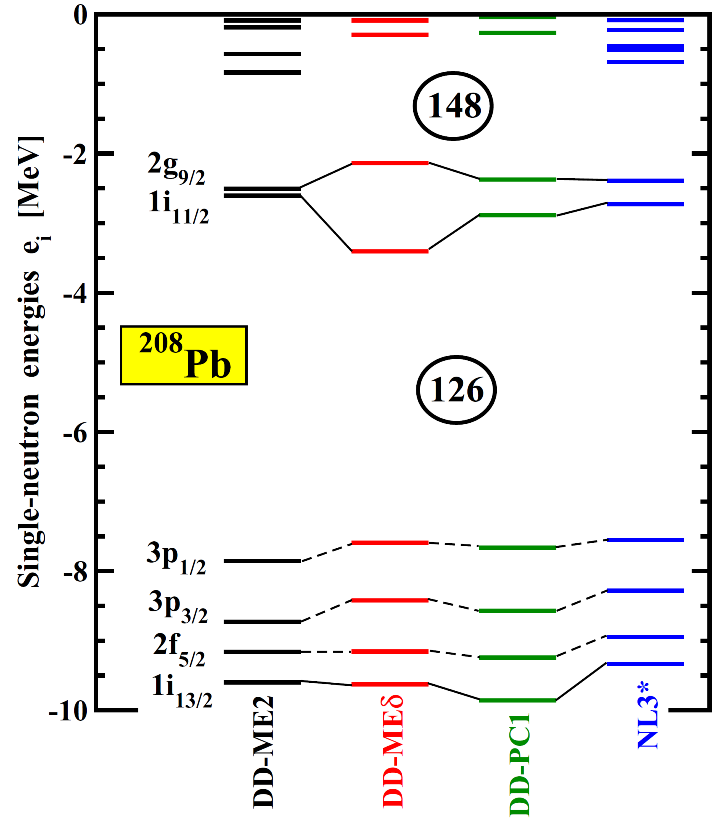
The shell effect in the changes of the nuclear mean-square charge radius $\delta\langle r^2\rangle$ — the kink in its isotopic trend at the magic neutron numbers — was found to be an universal feature of the $\delta<r^2>$ behavior

Odd-even staggering (OES) — another universal feature



Shell effect in radii: comparison with RMF





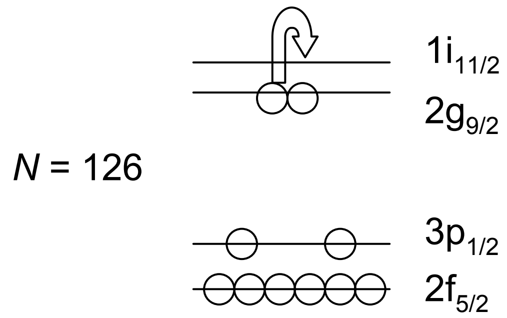
$I\,(^{207}Hg_{127}) = 9/2$

$\mu(^{207}Hg_{127}) = -1.37(2)\ \mu_N$

$\mu_{sp}(\nu g_{9/2}) = -1.3\ \mu_N$

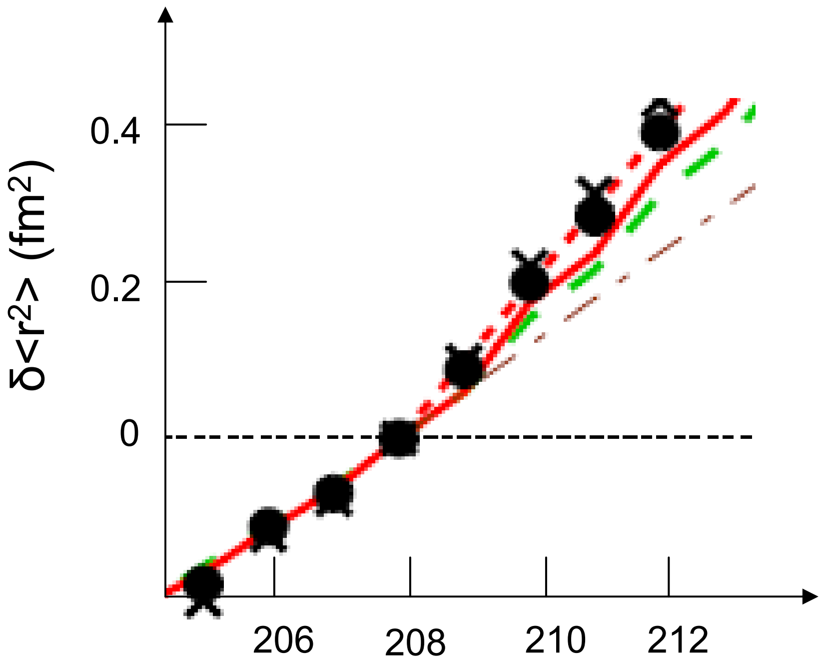
Shell effect in radii: theory

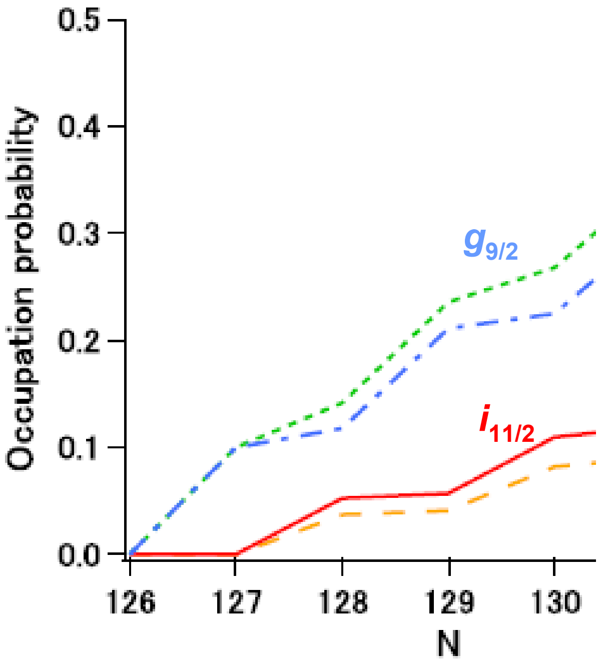
P. M. Goddard, P. D. Stevenson, and A. Rios, Phys. Rev. Lett. **110**, 032503 (2013):
The reproduction of the isotope shift in lead is determined by
the occupation of the $1i_{11/2}$ neutron orbital.



The increase of the $\nu i_{11/2}$-orbital occupancy in the RMF and modified HF approaches was shown to be connected with the decrease of the energy splitting between the $\nu g_{9/2}$ and $\nu i_{11/2}$ levels in contradiction with the experimental evidences

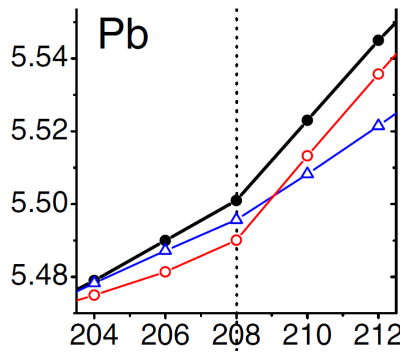
Shell effect in radii: comparison with NRMF

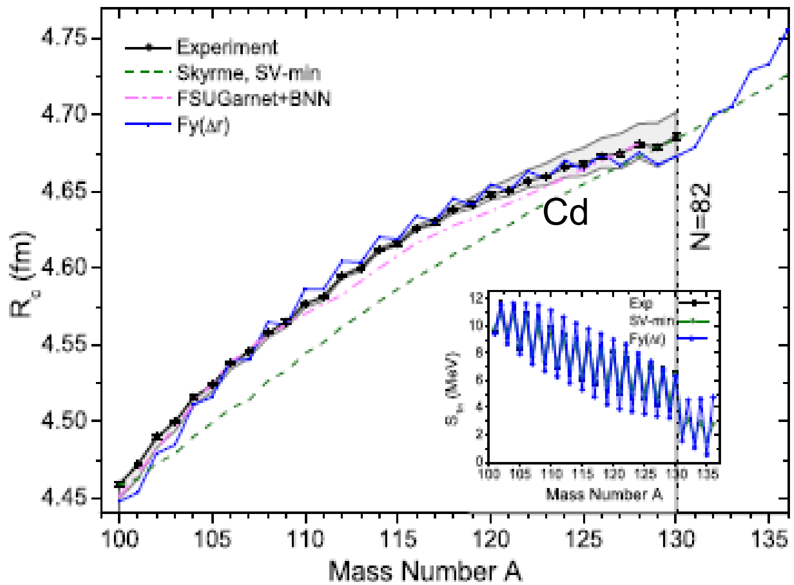


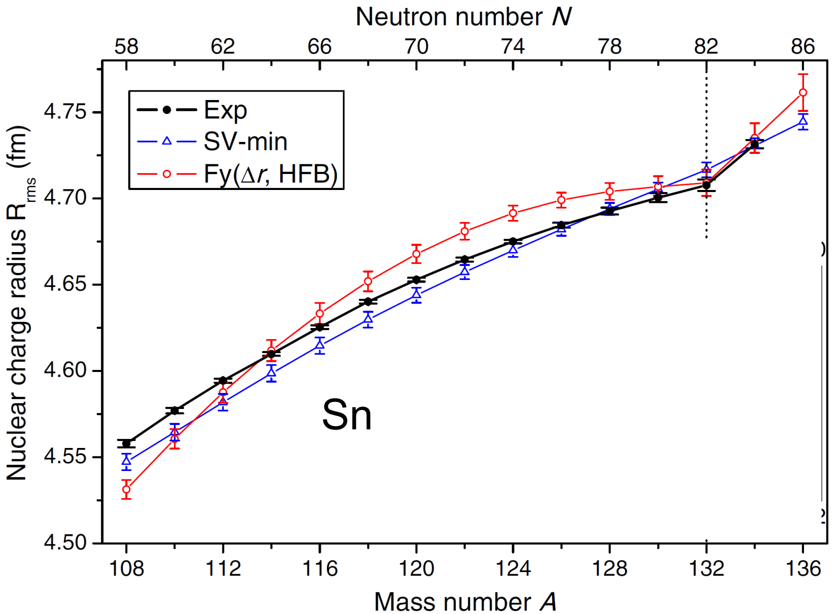


H. Nakada succeeded in reproducing the $\delta\langle r^2\rangle$ behavior for the Hg nuclei in the HFB calculations with with density-depended LS interaction based on 3N forces from effective field theory. The isotope shifts were described without the $ng_{9/2}$-$ni_{11/2}$ degeneracy.

Shell effect in radii: Fayans functional







M. Hammen et al., Phys. Rev. Lett. 121, 102501 (2018)
C. Gorges et al., Phys. Rev. Lett. 122, 192502 (2019)

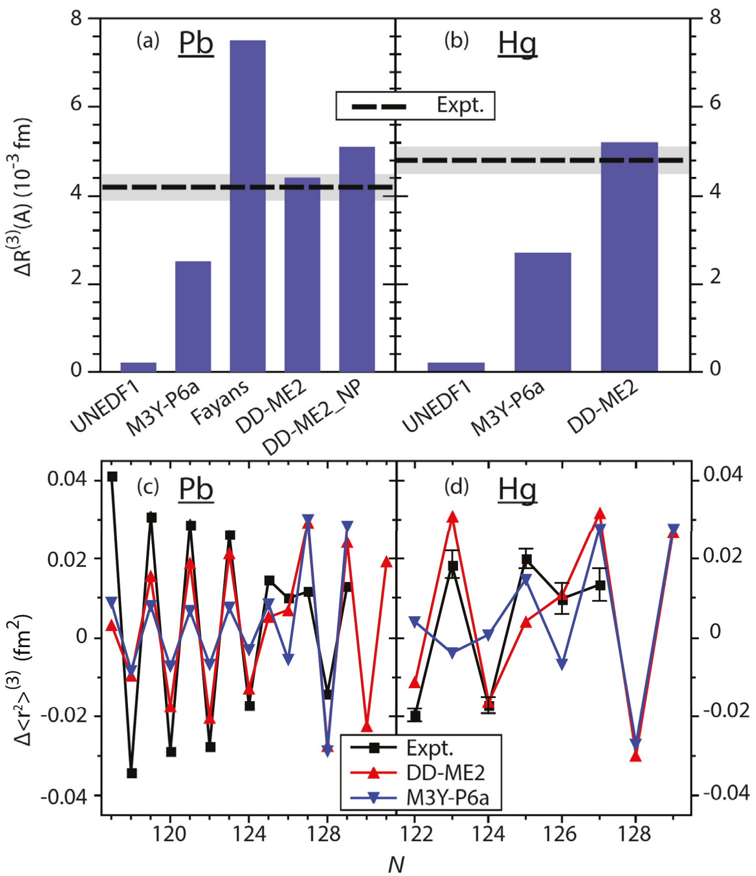
Energy density functional method based on the theory of finite Fermi systems. Fayans functional involves gradient terms in surface and pairing energies. They are responsible for the kink description.
S. A. Fayans, S. V. Tolokonnikov, E. L. Trykov, D. Zawischa, Nucl. Phys. A **676**, 49 (2000)
P.-G. Reinhard and W. Nazarewicz, Phys. Rev. C 95, 064328 (2017)

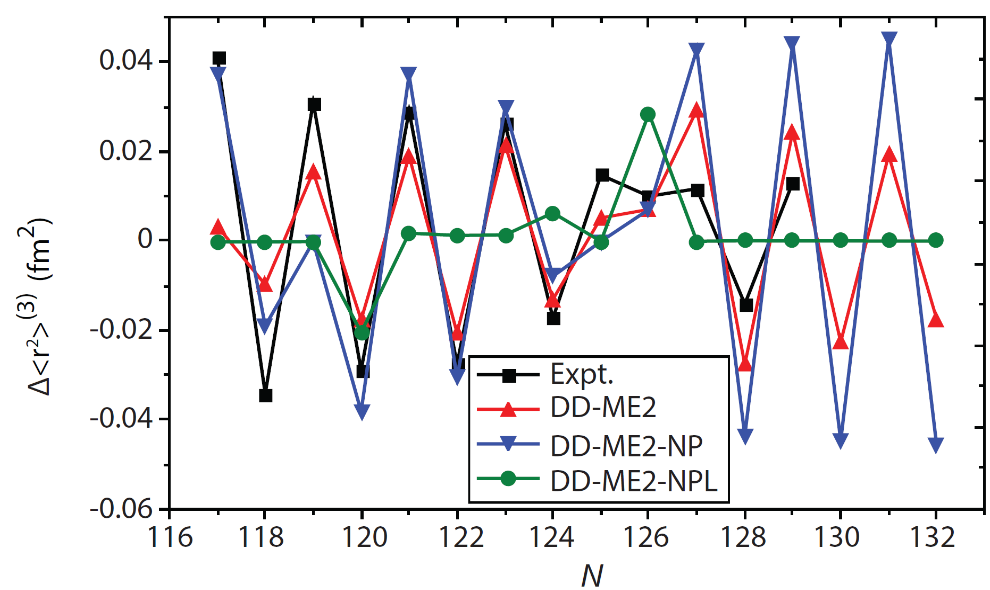
Shell effect in radii: comparison of theoretical approaches

OES indicator: $$\Delta\langle r^2\rangle^{(3)}(N) = \tfrac{1}{2}[\langle r^2\rangle(N-1) + \langle r^2\rangle(N+1) - 2\langle r^2\rangle(N)]$$

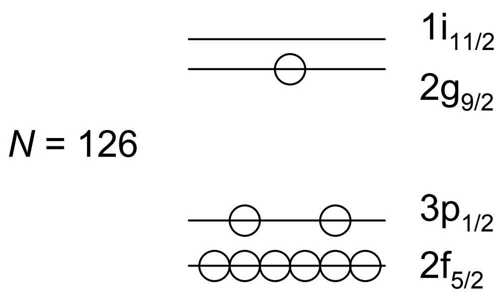
kink indicator: $$\Delta R^{(3)}(A) = \frac{1}{2}[R(A-2) + R(A+2) - 2R(A)],$$

where $R(A) = \langle r^2\rangle^{1/2}(A)$

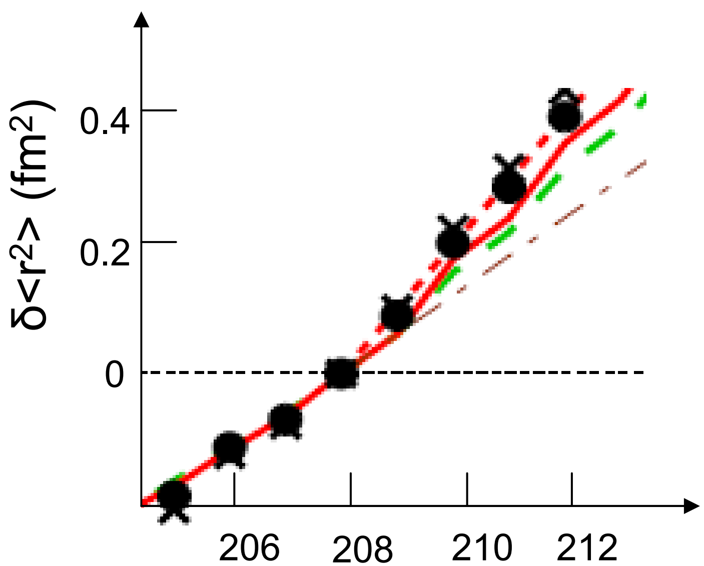


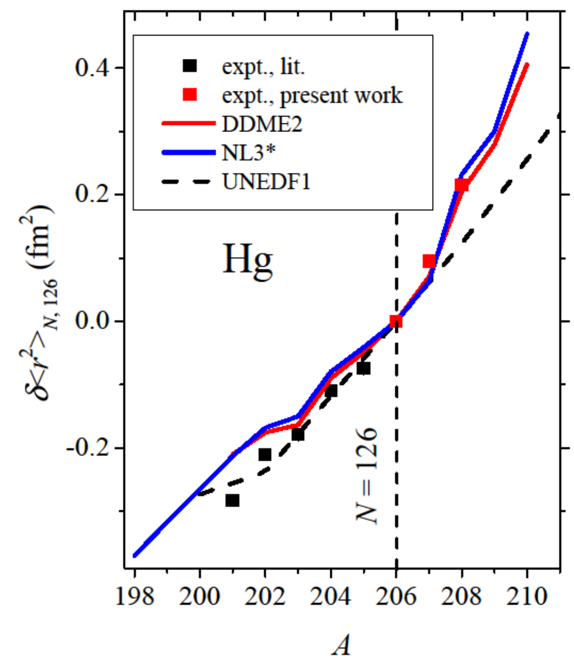


Shell effect in radii: odd-*N* nuclei



For *N* = 127 the occupancy of the $n1i_{11/2}$ state is equal to zero (pairing is absent). Correspondingly, all models with the kink explanation by the increase of this occupancy predict $\xi_{odd} \sim 1$ in contradiction with experiment





1. Ядерная спектроскопия $^{176,177,179}Au$: схемы распада, времена жизни, факторы задержки альфа распада, схемы уровней дочерних ядер и т. д.
2. α- и β-распад $^{183}Tl^{m}$: деформированные возбужденные состояния в сферическом ^{179}Au.
3. Ядерная спектроскопия ^{214}Bi: обнаружен новый долгоживущий изомер, существенно расширена схема уровней дочернего ^{214}Po, проверка продвинутых shell-model расчетов.
4. Времена жизни возбужденных уровней ^{214}Po
5. Анализ выходов изотопов золота из урановой мишени на установке ISOLDE.
6. Атомные расчеты аномалии стс в золоте и градиента электрического поля электронов на ядре висмута (для квадрупольного момента ядра)
7. Изомерно-селективная ядерная спектроскопия вблизи дважды магического ^{132}Sn
8. Запаздывающее деление ^{178}Au

1. Barzakh A., … Fedorov D. V., ... Molkanov P., … Panteleev V., … Skripnikov L. V., … Zaitsevskii A. V., *Large Shape Staggering in Neutron-Deficient Bi Isotopes*, Phys. Rev. Lett. 127, 192501 (2021).

2. T. Day Goodacre, A. V. Afanasjev, A. E. Barzakh, ... D. V. Fedorov, ... P. L. Molkanov, ... M. D. Seliverstov, et al., *Laser Spectroscopy of Neutron-Rich ^{207,208}Hg Isotopes: Illuminating the Kink and Odd-Even Staggering in Charge Radii across the N = 126 Shell Closure*, Phys. Rev. Lett. **126**, 032502 (2021).

3. T. Day Goodacre, A. V. Afanasjev, A. E. Barzakh, … D. V. Fedorov, … P. L. Molkanov, … M. D. Seliverstov, et al. *Charge radii, moments, and masses of mercury isotopes across the N = 126 shell closure*, Phys. Rev. C **104**, 054322 (2021).

4. Yu. A. Demidov, E. A. Konovalova, R. T. Imanbaeva, M. G. Kozlov , and A. E. Barzakh, *Atomic calculations of the hyperfine-structure anomaly in gold*, Phys. Rev. A **103**, 032824 (2021).

5. L. V. Skripnikov, A. V. Oleynichenko, A. V. Zaitsevskii, D. E. Maison, and A. E. Barzakh, *Relativistic Fock space coupled-cluster study of bismuth electronic structure to extract the Bi nuclear quadrupole moment*, Phys. Rev. C **104**, 034316 (2021).

6. R. D. Harding, A. N. Andreyev, A. E. Barzakh, … D. V. Fedorov, … P. L. Molkanov, … M. D. Seliverstov et al., *Laser-assisted nuclear decay spectroscopy of ^{176,177,179}Au*, Phys. Rev. C **104**, 024326 (2021).

7. B. Andel, … A. Barzakh, … D. V. Fedorov, … P. Molkanov, … M. D. Seliverstov, … (IDS Collaboration), *New β-decaying state in ^{214}Bi***,** Phys. Rev. C **104**, 054301 (2021).