ЭКСПЕРИМЕНТЫ С ЛАЗЕРНЫМ ИОННЫМ ИСТОЧНИКОМ

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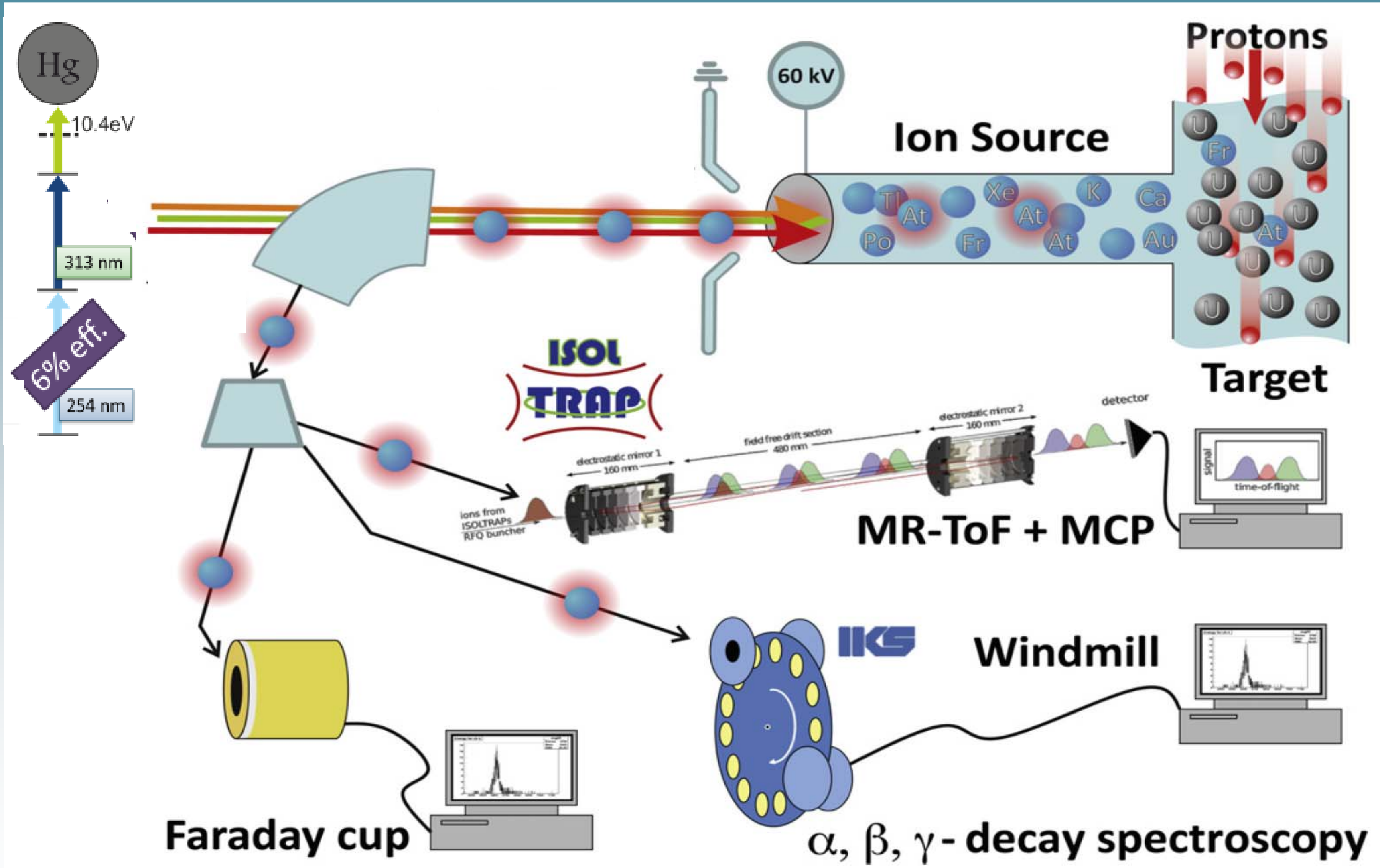
… … …

IS 456, 466, 511, 534, 598, 608

ISOLDE: in-source spectroscopy



B. A. Marsh et al., 20013 EMIS conference, NIM B317, p.550 (2013)

WM: A.N. Andreyev et al, Phys. Rev. Lett 105, 252502 (2010)

MR-ToF MS: R. N. Wolf et al, NIM, A686, 82 (2012)

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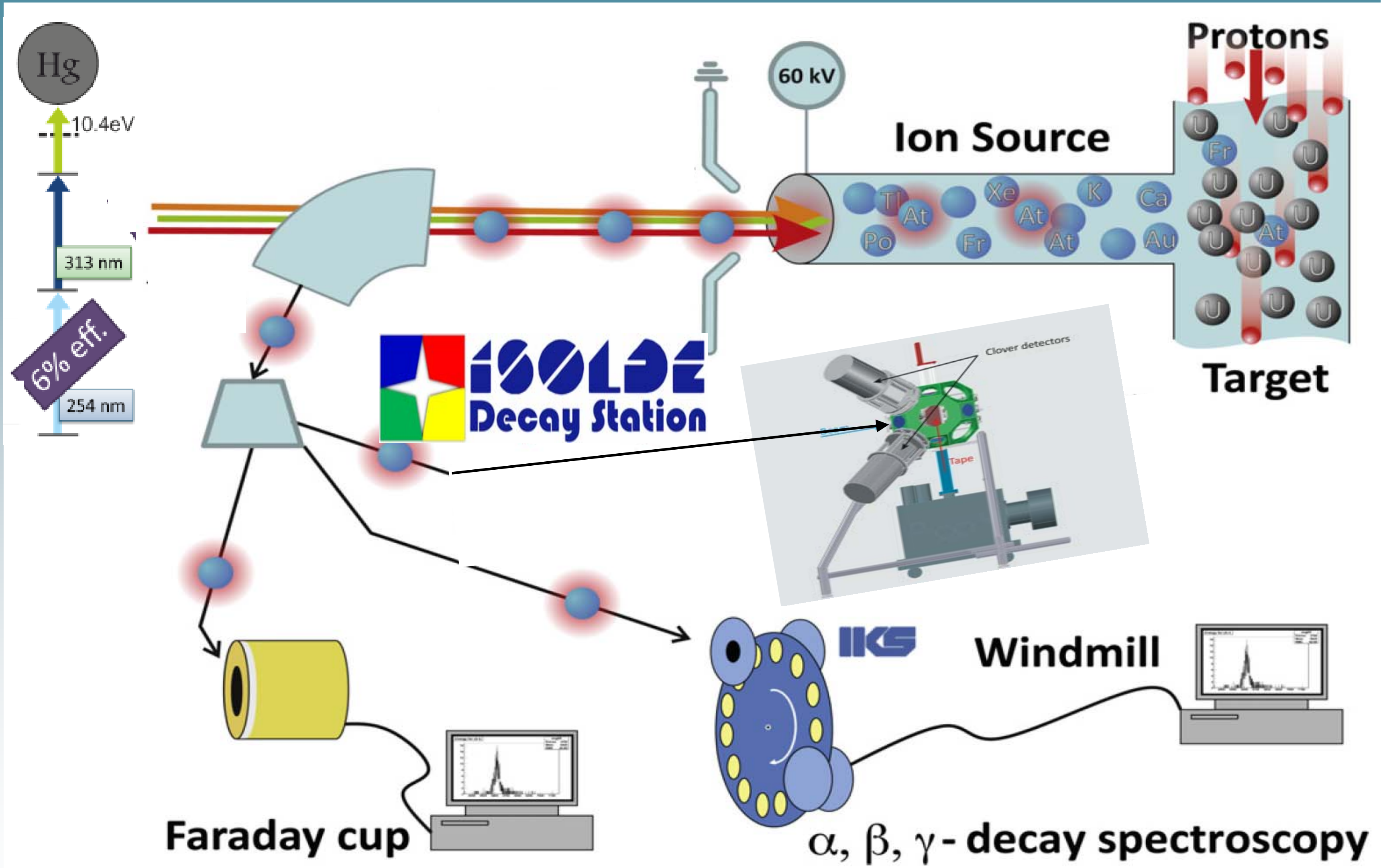

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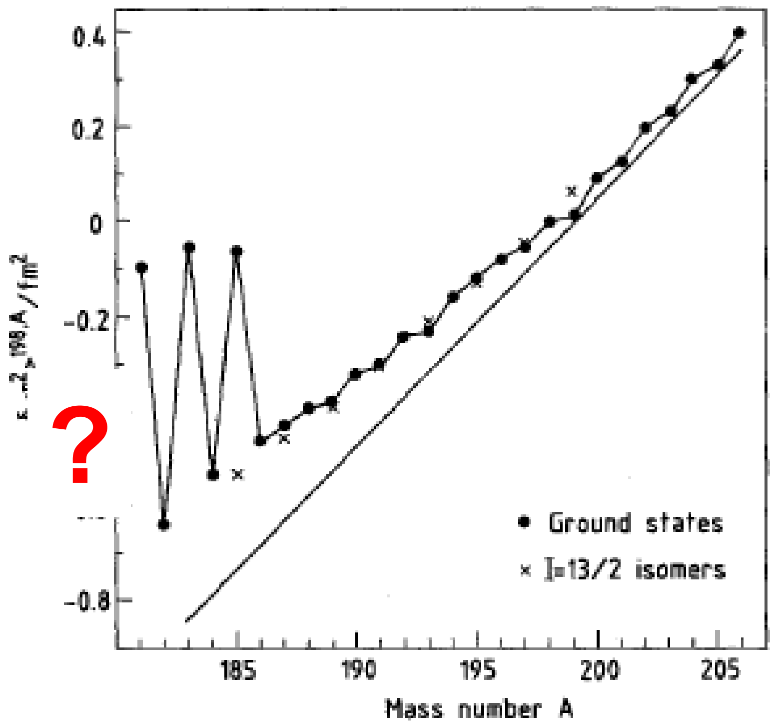
Hg: Shape staggering

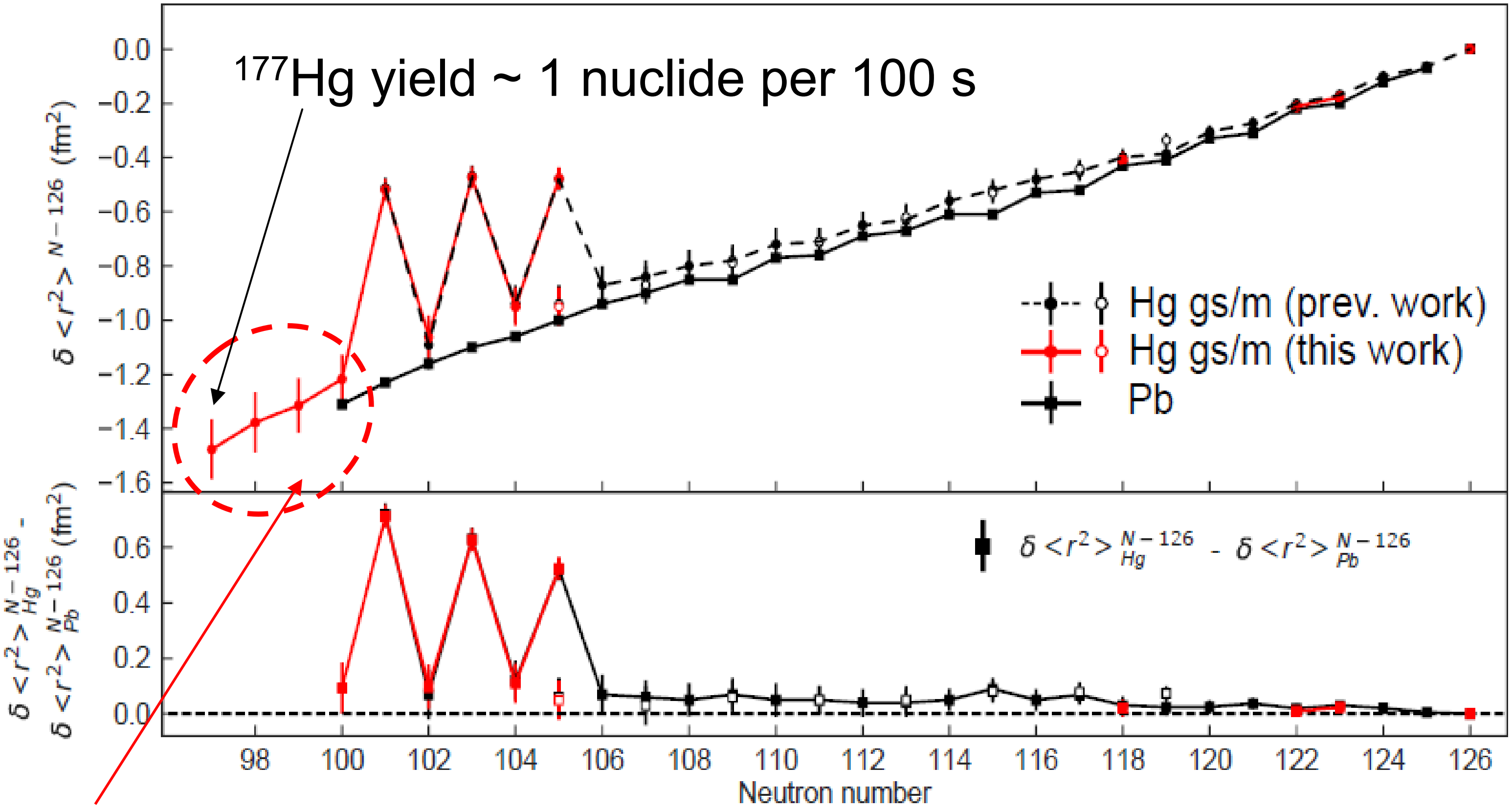


"The huge shape staggering in light Hg isotopes is one of the most remarkable discoveries in nuclear structure physics in the last 50 years".

K. Heyde and J. L. Wood,
Phys. Scr. 91 (2016) 083008

G. Ulm, S.K. Bhattacherjee, P. Dabkiewicz, et al., Z. Phys. A 325, 247-259 (1986)

Hg: End of the shape staggering

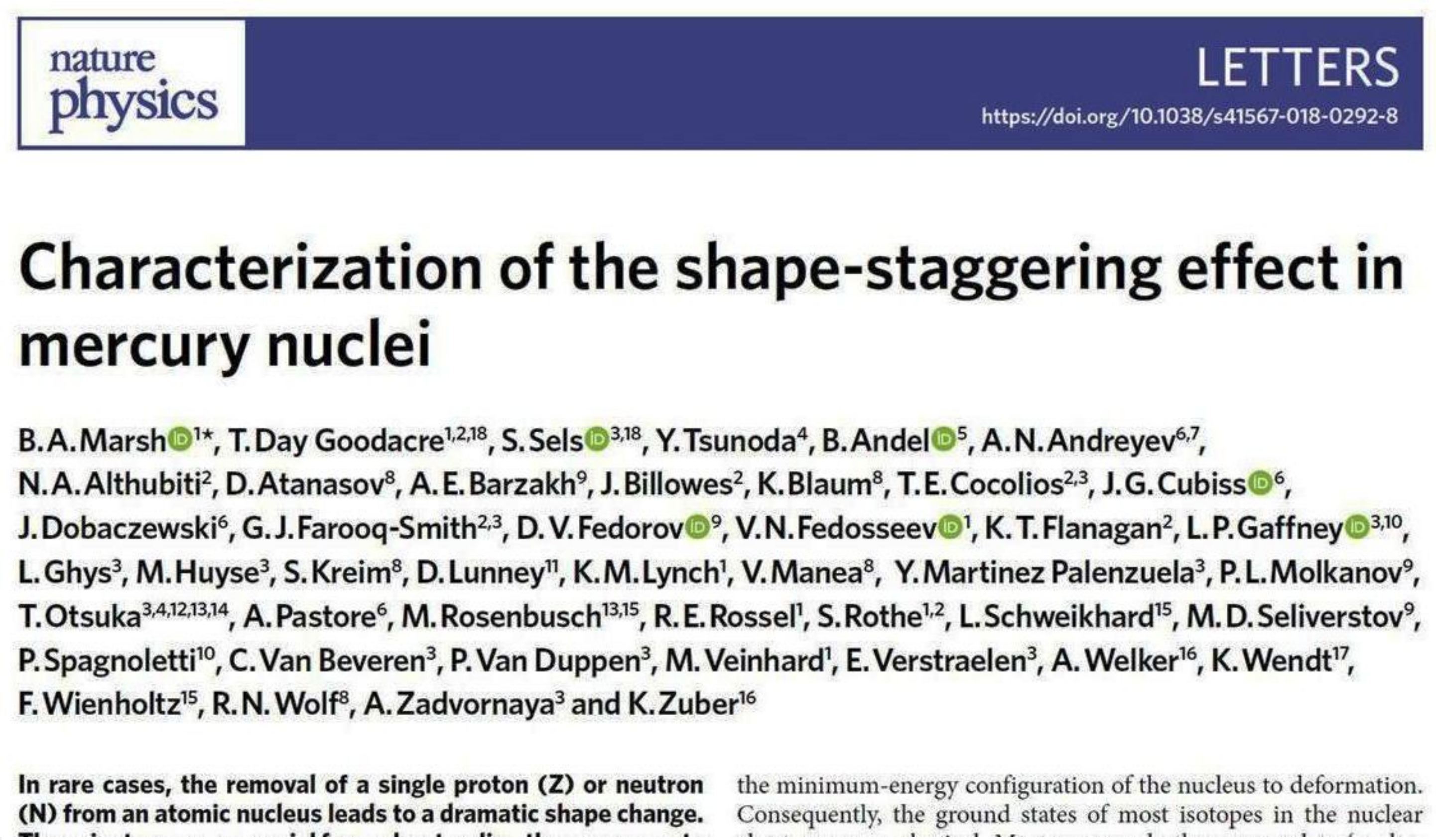


^{177}Hg yield ~ 1 nuclide per 100 s

End of the shape staggering!

New theoretical explanation of the shape evolution was proposed to describe our data

ISOLDE: End of the shape staggering



nature physics

LETTERS

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Characterization of the shape-staggering effect in mercury nuclei

B. A. Marsh[1]*, T. Day Goodacre[1,2,18], S. Sels[3,18], Y. Tsunoda[4], B. Andel[5], A. N. Andreyev[6,7], N. A. Althubiti[2], D. Atanasov[8], A. E. Barzakh[9], J. Billowes[2], K. Blaum[8], T. E. Cocolios[2,3], J. G. Cubiss[6], J. Dobaczewski[6], G. J. Farooq-Smith[2,3], D. V. Fedorov[9], V. N. Fedosseev[1], K. T. Flanagan[2], L. P. Gaffney[3,10], L. Ghys[3], M. Huyse[3], S. Kreim[8], D. Lunney[11], K. M. Lynch[1], V. Manea[8], Y. Martinez Palenzuela[3], P. L. Molkanov[9], T. Otsuka[3,4,12,13,14], A. Pastore[6], M. Rosenbusch[13,15], R. E. Rossel[1], S. Rothe[1,2], L. Schweikhard[15], M. D. Seliverstov[9], P. Spagnoletti[10], C. Van Beveren[3], P. Van Duppen[3], M. Veinhard[1], E. Verstraelen[3], A. Welker[16], K. Wendt[17], F. Wienholtz[15], R. N. Wolf[8], A. Zadvornaya[3] and K. Zuber[16]

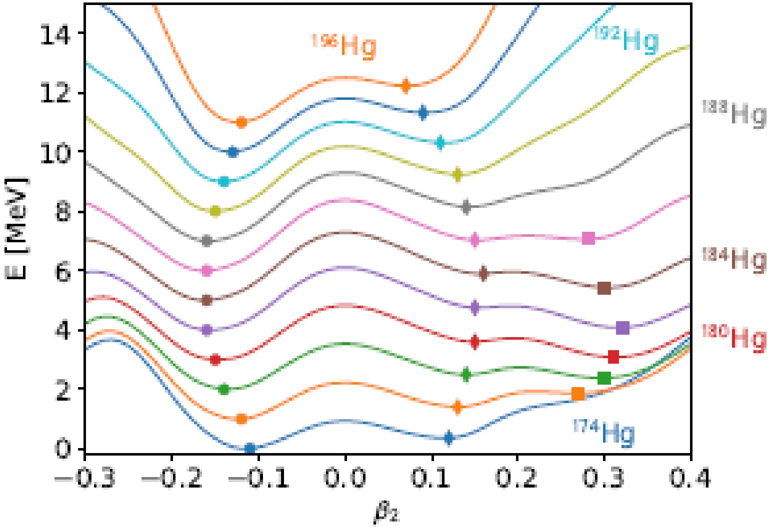
In rare cases, the removal of a single proton (Z) or neutron (N) from an atomic nucleus leads to a dramatic shape change.

the minimum-energy configuration of the nucleus to deformation. Consequently, the ground states of most isotopes in the nuclear

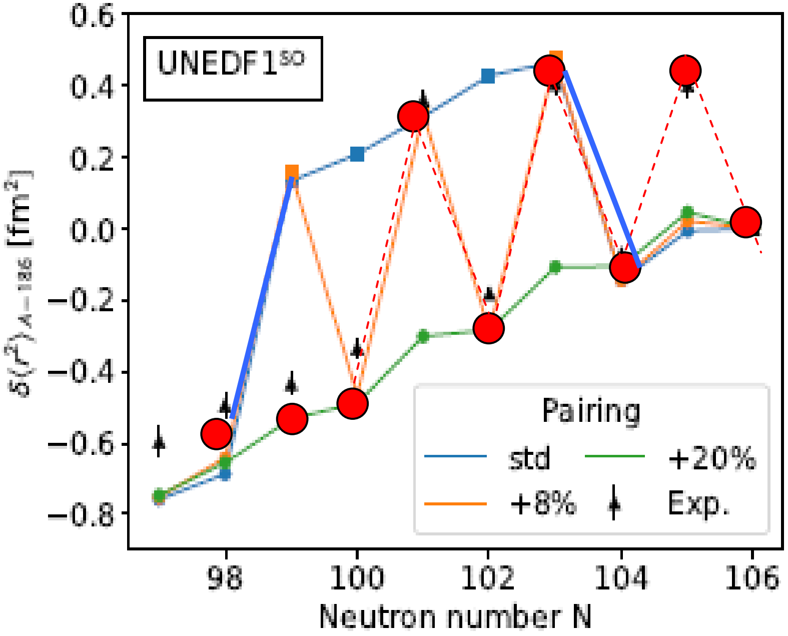
Shape staggering: Theory, HF

Nuclear Density Functional Theory (DFT)

Potential Energy Surface

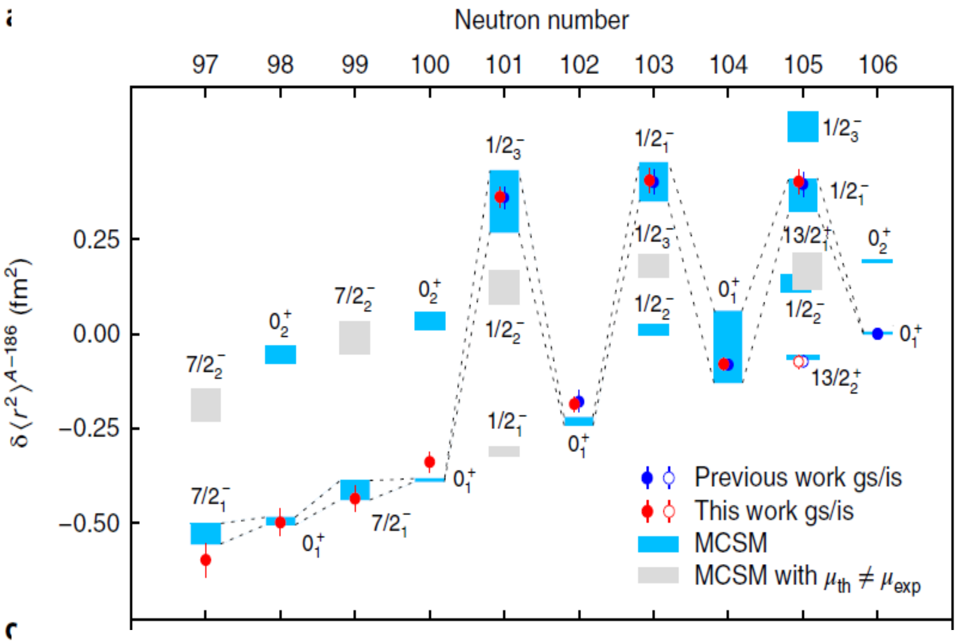


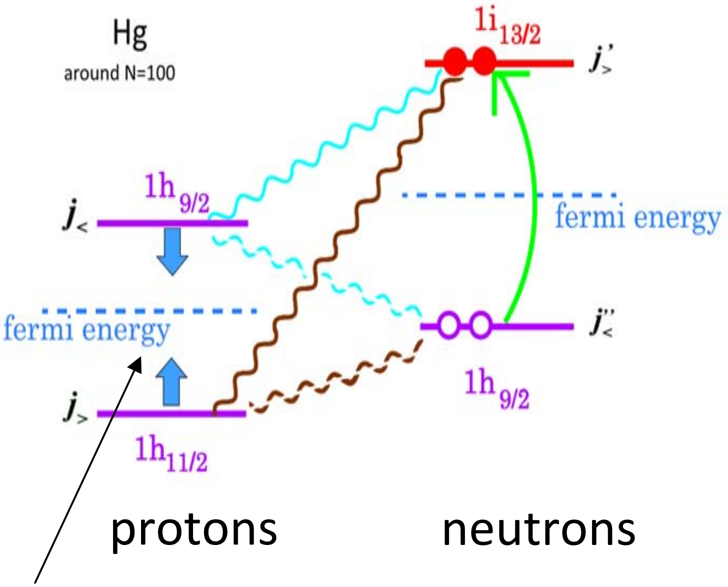
Circles: oblate, diamonds : weekly prolate,
Squares: strongly prolate minima



Wrong I and μ!

Shape staggering: Theory, MCSM





change of spin-orbit splitting due to the n-p tensor forces

Q, μ and $\delta<r^2>$ values are reproduced by the theory

α- and β-decay studies with the laser ion source

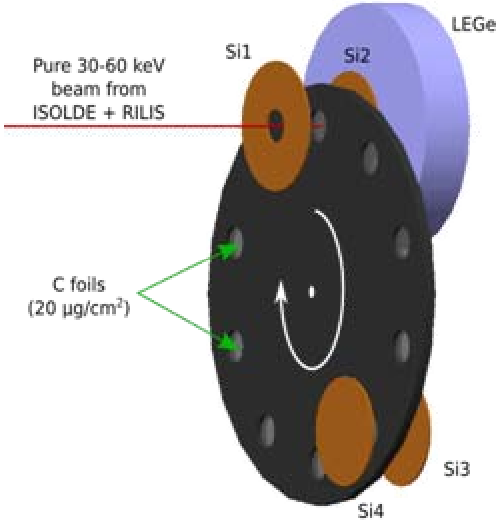
Main information:

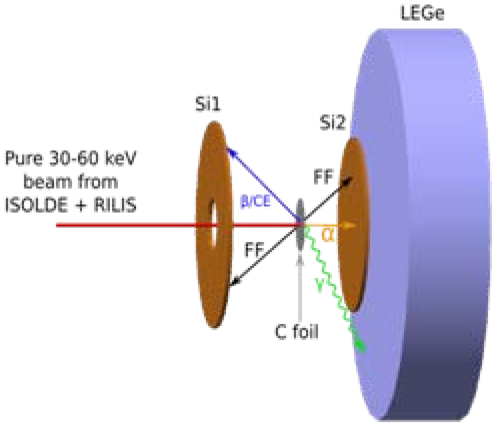
I, $\delta\langle r^2\rangle$, μ, Q

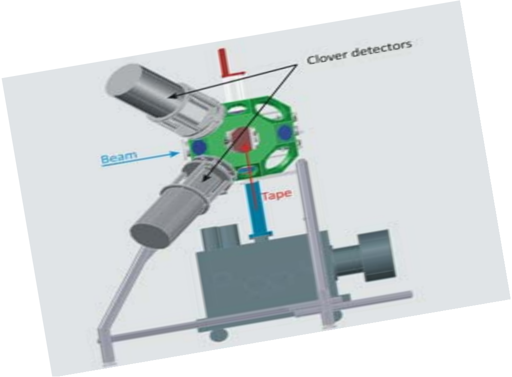
Additional information:

$T_{1/2}$
E_α, b_α, b_β
Q_α (masses)
α-γ, γ-γ coincidence
levels, E_γ
hindrance factors
transition multipolarities
conversion coefficients
E0 transitions
partial decay schemes
(isomer selectivity)

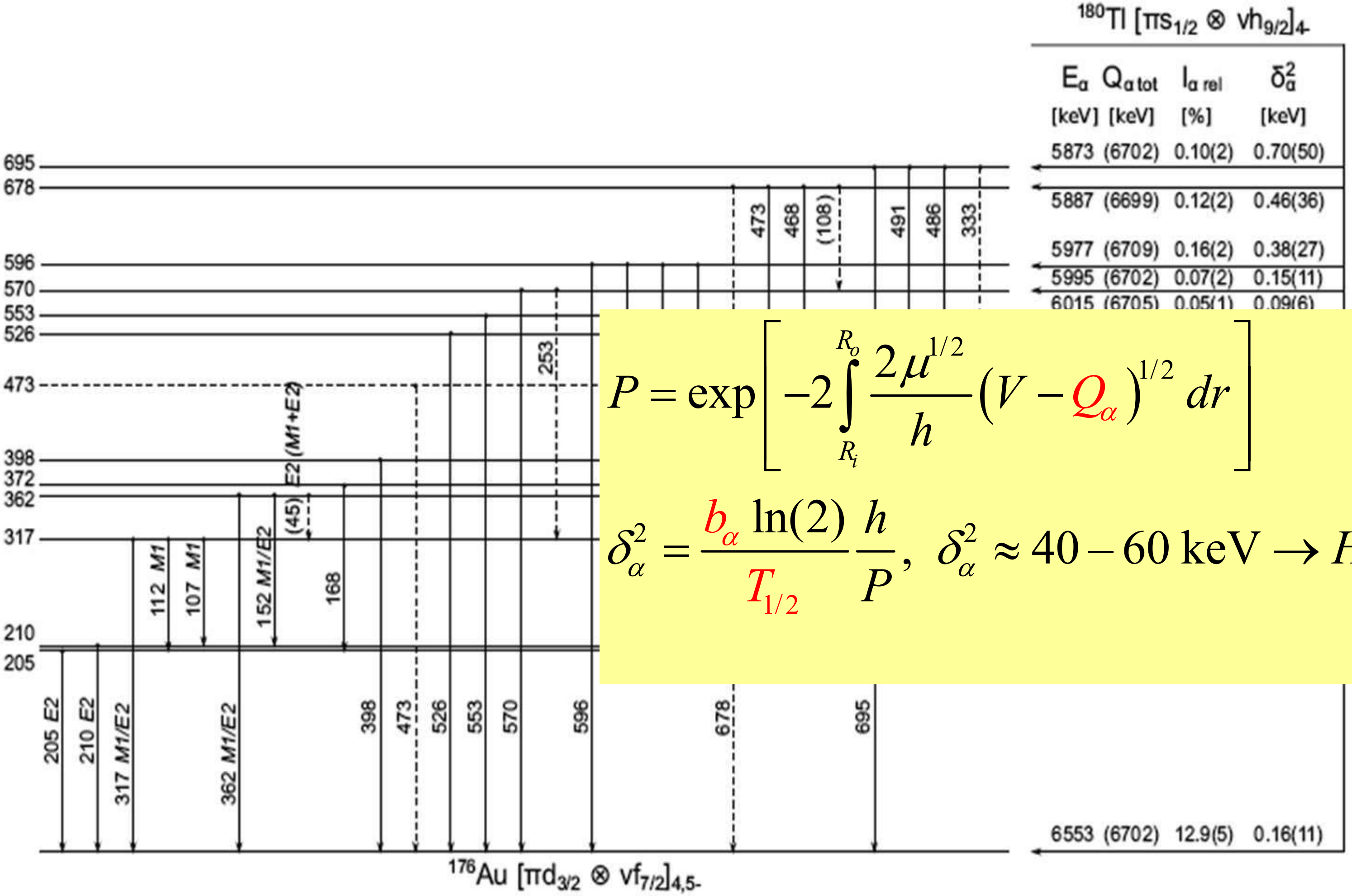
Windmill station







Large hindrance of α decay $^{180}\mathrm{Tl}^{g} \rightarrow {}^{176}\mathrm{Au}^{g}$



E_α [keV]	$Q_{\alpha\,tot}$ [keV]	$I_{\alpha\,rel}$ [%]	δ_α^2 [keV]
5873	(6702)	0.10(2)	0.70(50)
5887	(6699)	0.12(2)	0.46(36)
5977	(6709)	0.16(2)	0.38(27)
5995	(6702)	0.07(2)	0.15(11)
6015	(6705)	0.05(1)	0.09(6)
6553	(6702)	12.9(5)	0.16(11)

$$P = \exp\left[-2\int_{R_i}^{R_o} \frac{2\mu^{1/2}}{h}\left(V - Q_\alpha\right)^{1/2} dr\right]$$

$$\delta_\alpha^2 = \frac{b_\alpha \ln(2)}{T_{1/2}}\,\frac{h}{P},\quad \delta_\alpha^2 \approx 40-60\ \mathrm{keV} \rightarrow HF \approx 1$$

B. Andel *et al.*, Phys. Rev. C 96, 054327 (2017)

Large hindrance of α decay $^{180}Tl^{g} \rightarrow {}^{176}Au^{g}$

^{178}Tl		^{180}Tl		^{182}Tl	
E_α (keV)	δ^2(keV)	E_α (keV)	δ^2 (keV)	E_α (keV)	δ^2 (keV)
6862(10)	**0.30(15)**	**6553(7)**	**0.16(11)**	6406	0.043(25)
6693(10)	13.0(17)	6354(7)	2.9(19)	6360(6)	0.048(28)
6595(10)	10.2(24)	6348(7)	0.27(18)	6165(6)	1.13(66)

Strongly hindered gs→gs decay (δ^2~0.1keV; HF~500) at the same spin and deformation! Large hindrance is due to the change of both proton, $s_{1/2} \rightarrow d_{3/2}$, and neutron, $h_{9/2} \rightarrow f_{7/2}$, configurations (confirmed by our μ measurements).

^{176}Au

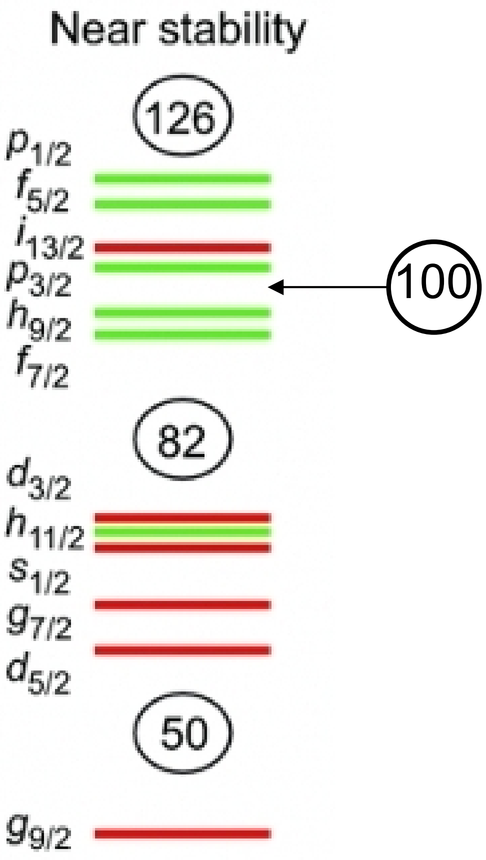
Configuration	I	$\mu_{add}(\mu_N)$	$\mu_{exp}(\mu_N)$
$\boldsymbol{\pi d_{3/2} \otimes \nu f_{7/2}}$	**4**	**–0.84**	**–0.834(9)**
$\pi d_{3/2} \otimes h_{9/2}$	4	0.66	-0.834(9)

^{180}Tl

Configuration	I	$\mu_{add}(\mu_N)$	$\mu_{exp}(\mu_N)$
$\boldsymbol{\pi s_{1/2} \otimes \nu h_{9/2}}$	**4**	**–0.58**	**–0.564(23)**
$\pi s_{1/2} \otimes \nu f_{7/2}$	4	0.70	–0.564(23)

Why does neutron in ^{176}Au occupy $f_{7/2}$ instead of expected $h_{9/2}$ orbital?

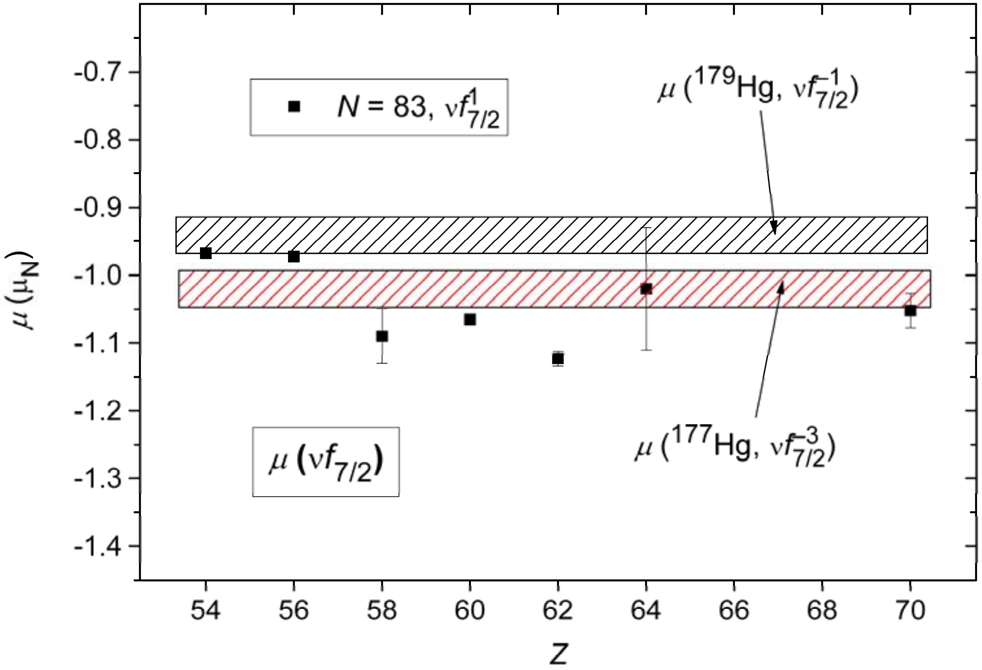
Nuclear shells below *N* = 100



All N = 83 (85) nuclei are of $vf_{7/2}$ configuration: spin, parity, μ (from $_{54}Xe_{83}$ to $_{70}Yb_{83}$)

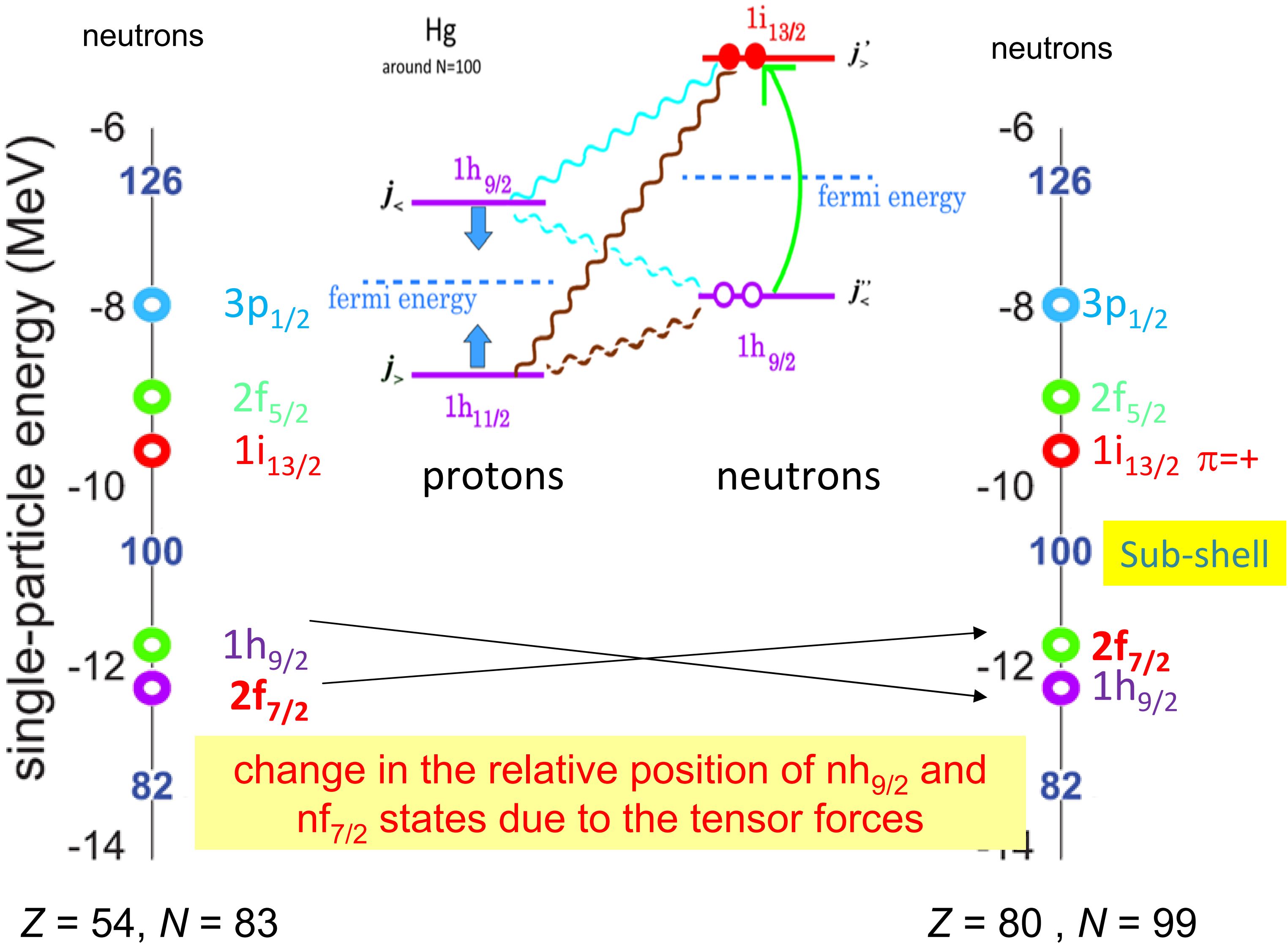
N = 99: $^{181}Pb_{99}$, 9/2—, $vh_{9/2}$

$^{179,177}Hg_{99,97}$, 7/2— and μ coincides with μ(*N* = 83)
Q corresponds to hole states in $f_{7/2}$ shell



S. Sels *et al.*, In-source laser resonance-ionization spectroscopy of neutron-deficient $^{177\text{-}185}$Hg isotopes (accepted by Phys. Rev. C)

Shell swap



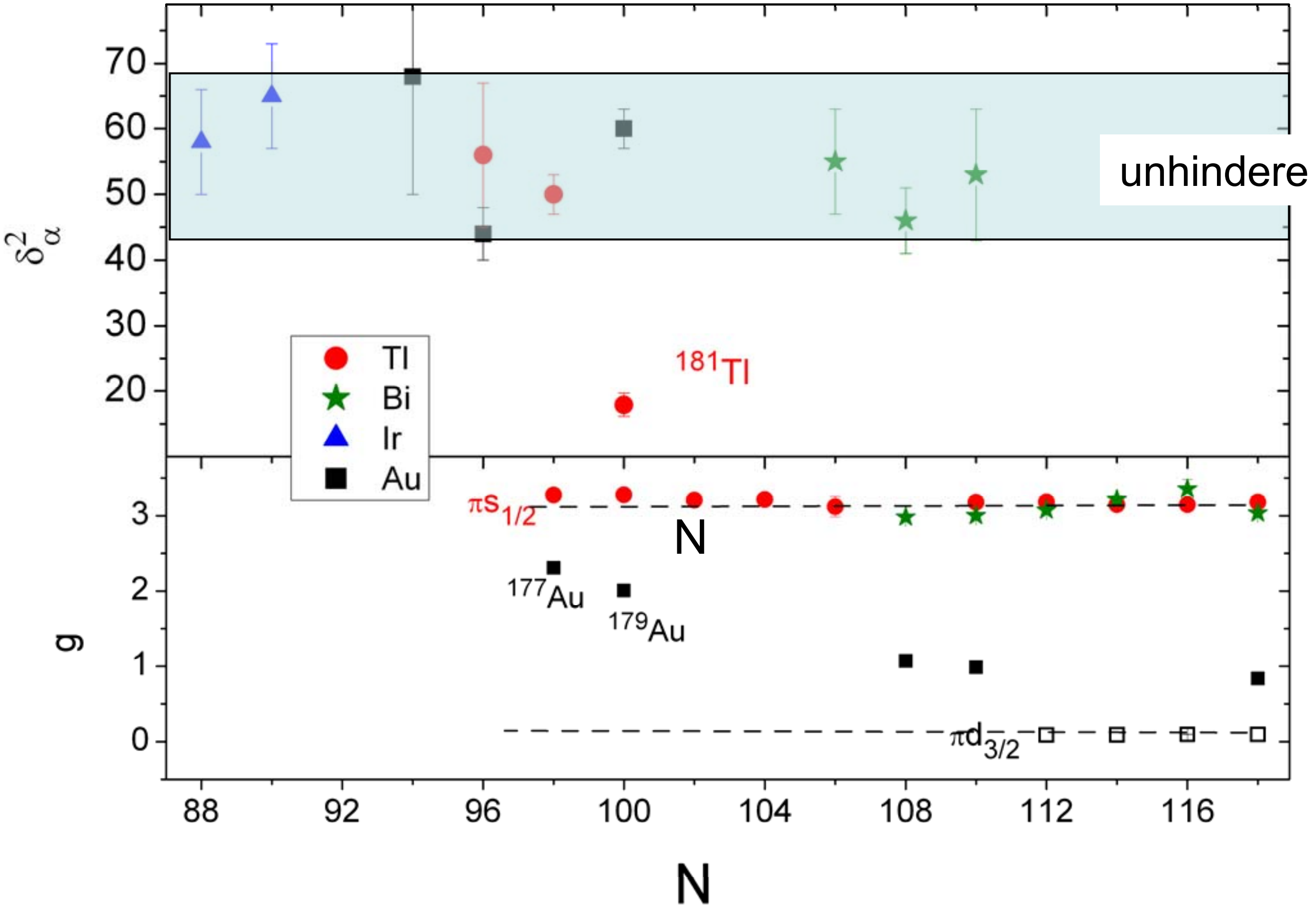
Sub-shell

change in the relative position of $nh_{9/2}$ and $nf_{7/2}$ states due to the tensor forces

T Otsuka and Y Tsunoda J. Phys. G: 43 (2016) 024009

Hindrance factors and μ for $1/2^+$ nuclei

reduced width for $1/2^+ \rightarrow 1/2^+$ α decay

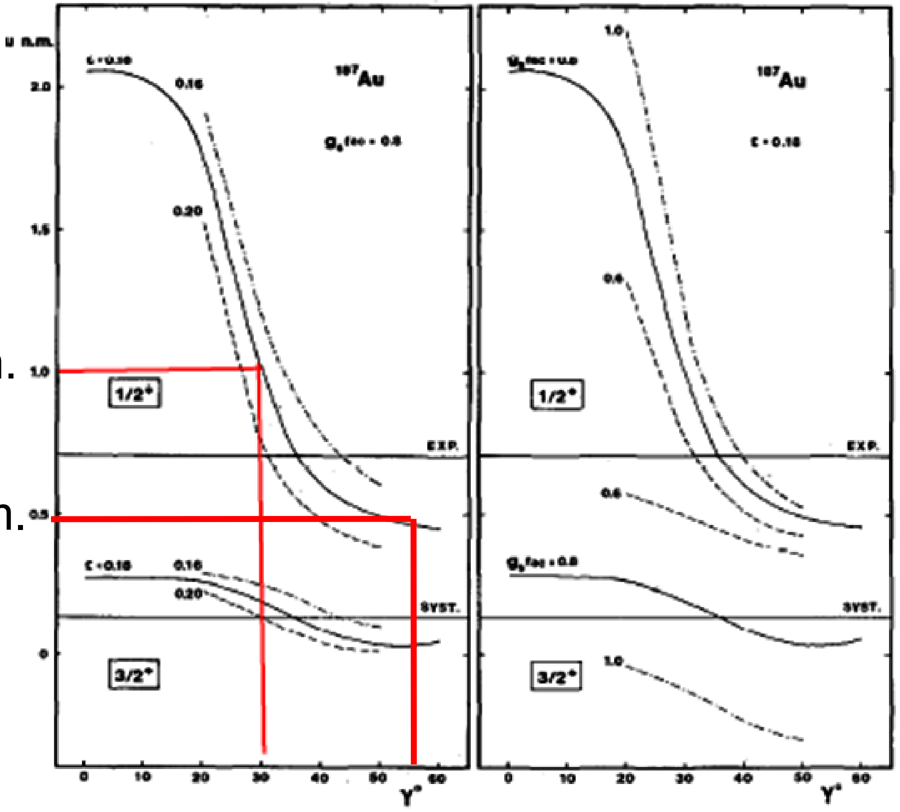


unhindered $1/2^+ \rightarrow 1/2^+$ decay

g factors

J. Cubiss et al., Phys. Lett. B 786 (2018) 355

Nonaxiality in $^{177, 179}$Au

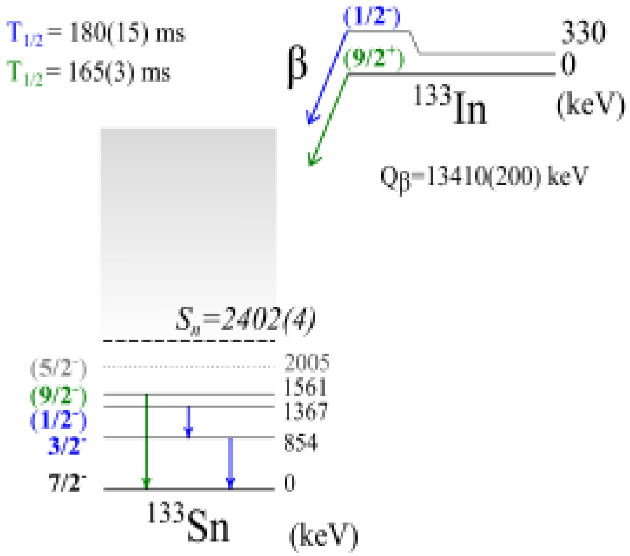


$^{177,\ 179}$Au, μ ~ 1n.m.

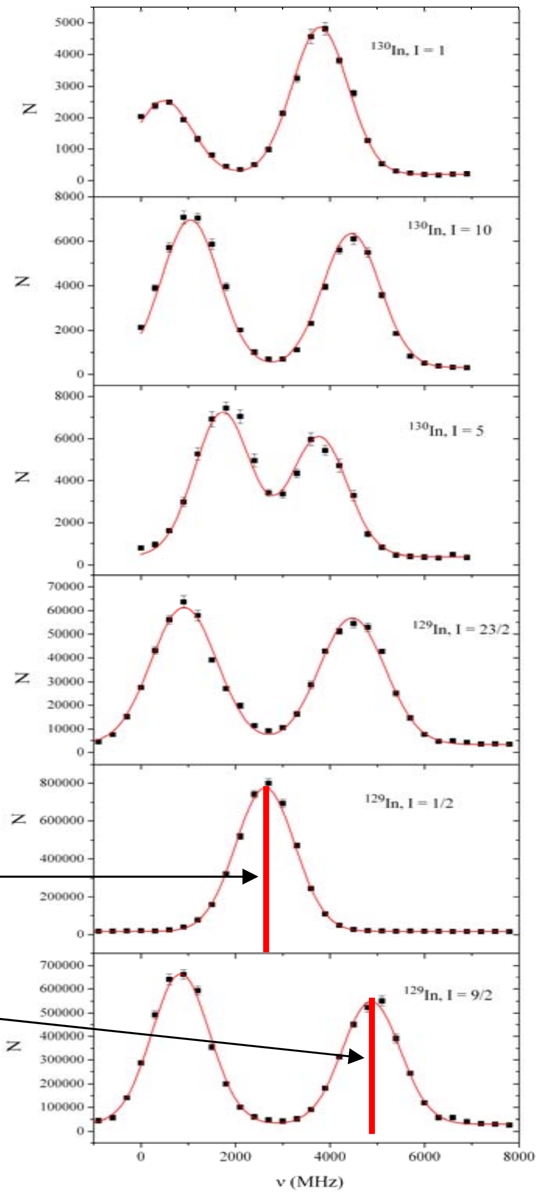
$^{187,\ 189}$Au, μ ~ 0.5n.m.

Thus, the structures of 1/2^{+} states in parent ^{181}Tl and daughter ^{177}Au are different: spherical $s_{1/2}$ state in ^{181}Tl and nonaxially deformed mixture of $s_{1/2}$ and $d_{3/2}$ states in ^{177}Au → hindrance of the α decay

Isomer-selective Indium photoionization



Low-lying states in ^{133}Sn

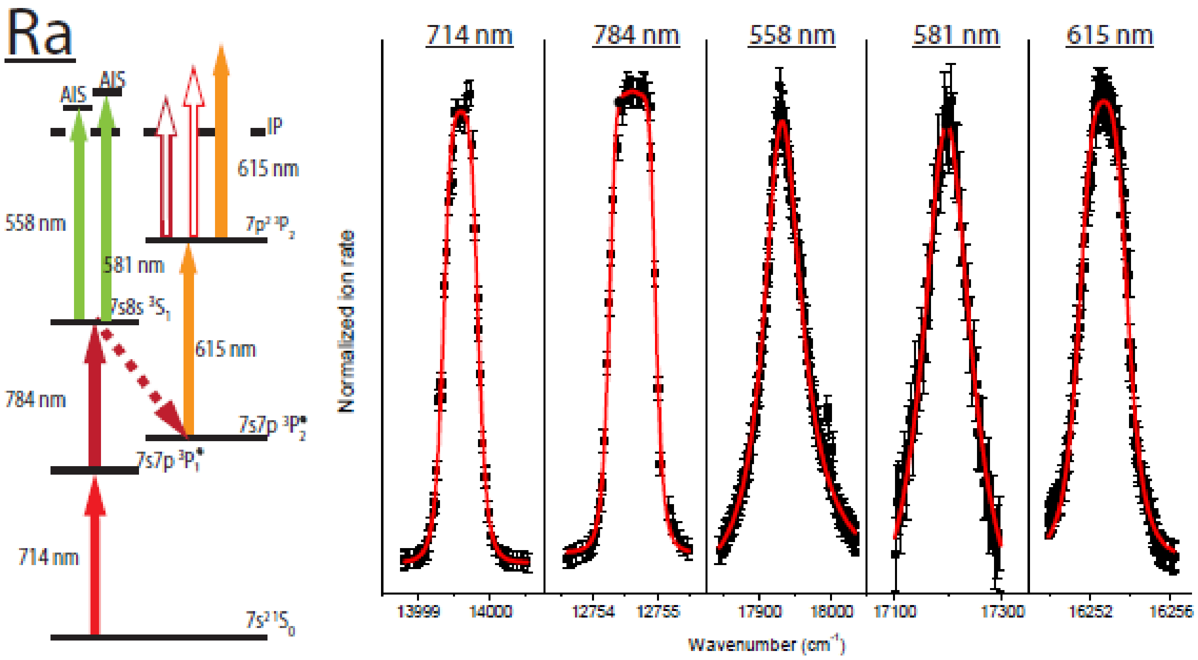


pure *I* = 1/2 isomer

pure *I* = 9/2 isomer

M. Piersa *et al.*, Acta Phys. Polon., B49 (2018) 523;
Phys. Rev. C (accepted)

New efficient ionization scheme for Ra



T. Day Goodacre *et al.,* Spectrochim. Acta, **B150**, 99 (2018)**;**
K. M. Lynch *et al.,* Phys. Rev. C **97**, 024309 (2018).

Laser ion source: summary (2018)

1. Измерены изотопические сдвиги и сверхтонкое расщепление (μ, Q, $\delta\langle r^2\rangle$) для 15 изотопов (изомеров) $_{80}$Hg на переходе 253.7 nm. Продемонстрировано исчезновение эффекта shape staggering при A<181.
2. Изомерно-селективная фотоионизация в лазерном ионном источнике позволяет получить большой объем ядерно-спектроскопической информации ($T_{1/2}$, E_α, b_α, b_β, α-γ, γ -γ coincidence, conversion coefficients, partial decay schemes и т. д.) без дополнительных затрат времени. Из полученных результатов отметим:
    1. Большой фактор задержки α распада $^{180}\mathrm{Tl} \rightarrow {}^{176}\mathrm{Au}$, а также анализ спинов и моментов соседних изотопов Hg указывает на изменение оболочечной структуры (shell swap).
    2. Сопоставление фактора задержки α распада $^{181}\mathrm{Tl} \rightarrow {}^{177}\mathrm{Au}$ со спинами и магнитными моментами этих ядер позволяет сделать вывод о неаксиальной деформации $^{177,\,179}$Au.