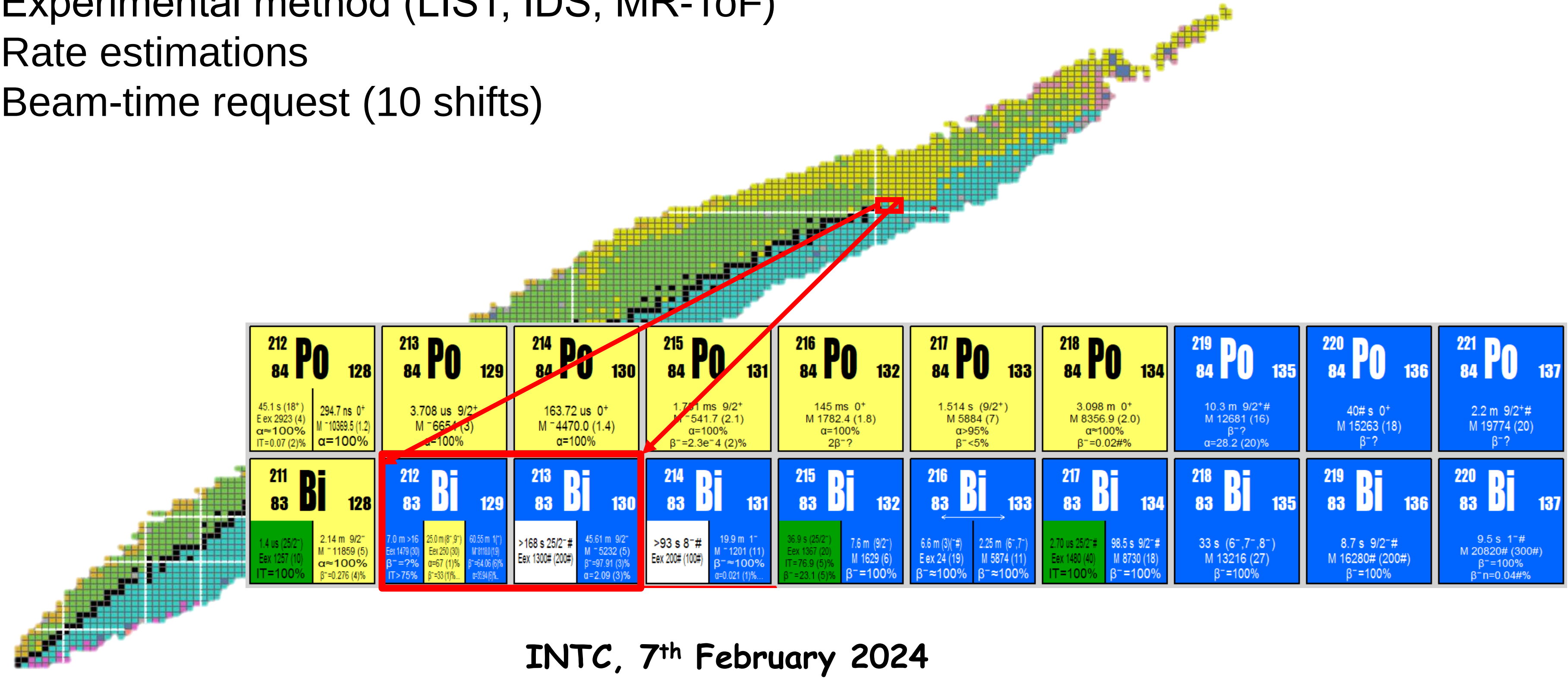
Nuclear and laser spectroscopy study of the neutron-rich ^{212,213}Bi isotopes with LIST

Andrei Andreyev
University of York
on behalf of York-Leuven-Bratislava-Bucharest...
+IDS-RILIS-ISOLTRAP Collaboration

Contents

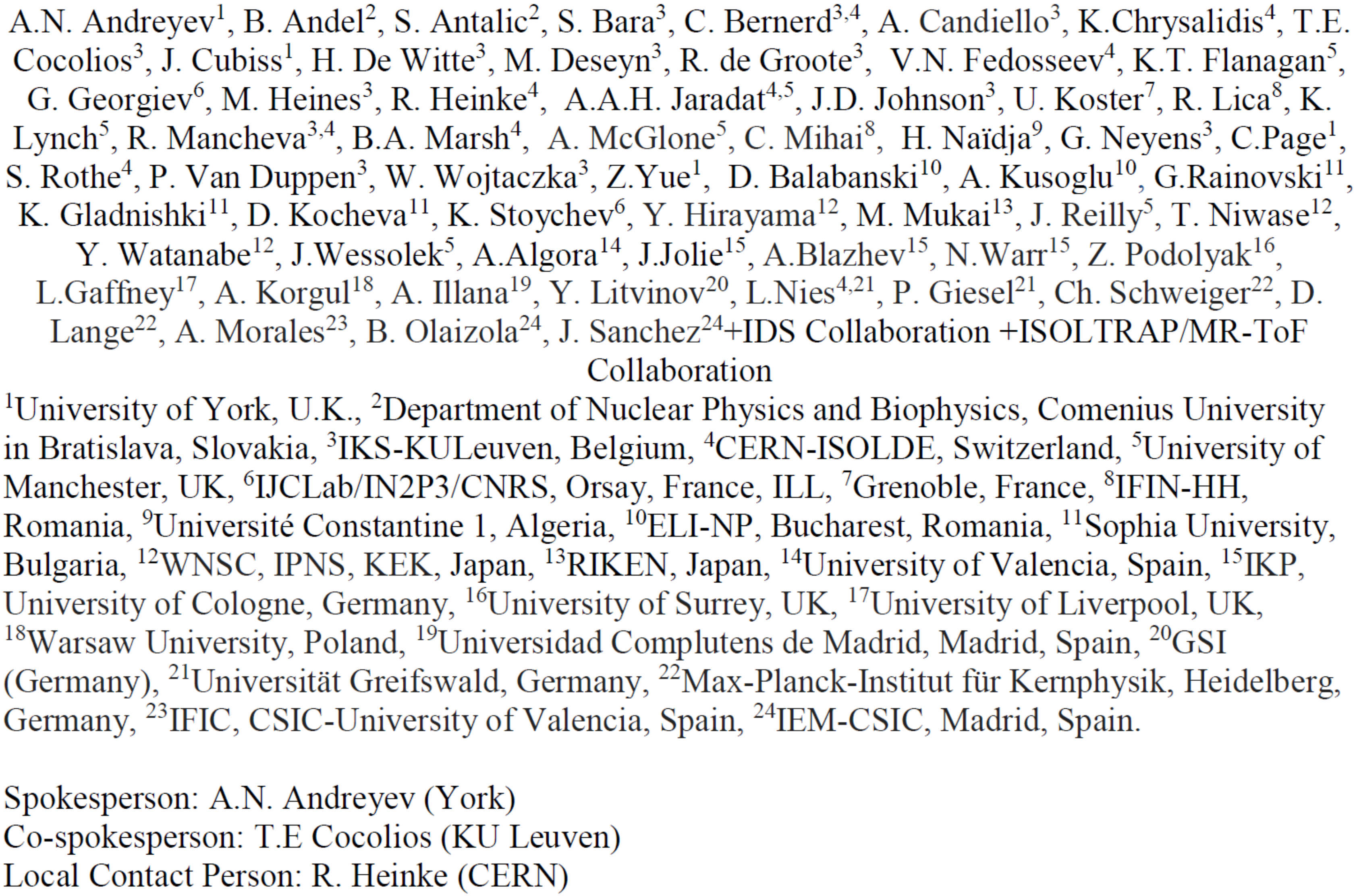
- Previous Bi studies by our collaboration (IS608, IS650)
- Outstanding questions and puzzles in the neutron-rich Bi isotopes
- Experimental method (LIST, IDS, MR-ToF)
- Rate estimations
- Beam-time request (10 shifts)



212 Po 84 128 45.1 s (18^+) E ex 2923 (4) α≈100% IT=0.07 (2)% 294.7 ns 0^+ M −10369.5 (1.2) α=100%	213 Po 84 129 3.708 us $9/2^+$ M −6654 (3) α=100%	214 Po 84 130 163.72 us 0^+ M −4470.0 (1.4) α=100%	215 Po 84 131 1.781 ms $9/2^+$ M −541.7 (2.1) α=100% β^-=2.3e−4 (2)%	216 Po 84 132 145 ms 0^+ M 1782.4 (1.8) α=100% 2β^-?	217 Po 84 133 1.514 s ($9/2^+$) M 5884 (7) α>95% β^-<5%	218 Po 84 134 3.098 m 0^+ M 8356.9 (2.0) α≈100% β^-=0.02#%	219 Po 84 135 10.3 m $9/2^+$# M 12681 (16) β^-? α=28.2 (20)%	220 Po 84 136 40# s 0^+ M 15263 (18) β^-?	221 Po 84 137 2.2 m $9/2^+$# M 19774 (20) β^-?
211 Bi 83 128 1.4 us ($25/2^-$) Eex 1257 (10) IT=100% 2.14 m $9/2^-$ M −11859 (5) α≈100% β^-=0.276 (4)%	212 Bi 83 129 7.0 m >16 Eex 1479 (30) β^-=?% IT>75% 25.0 m (8^-,9^-) Eex 250 (30) α=67 (1)% β^-=33 (1)%... 60.55 m $1(^-)$ M −8118.0 (1.9) β^-=64.06 (6)% α=35.94 (6)%...	213 Bi 83 130 >168 s $25/2^-$# Eex 1300# (200#) 45.61 m $9/2^-$ M −5232 (5) β^-=97.91 (3)% α=2.09 (3)%	214 Bi 83 131 >93 s 8^-# Eex 200# (100#) 19.9 m 1^- M −1201 (11) β^-≈100% α=0.021 (1)%...	215 Bi 83 132 36.9 s ($25/2^-$) Eex 1367 (20) IT=76.9 (5)% β^-=23.1 (5)% 7.6 m ($9/2^-$) M 1629 (6) β^-=100%	216 Bi 83 133 6.6 m (3)($^-$#) E ex 24 (19) β^-≈100% 2.25 m (6^-,7^-) M 5874 (11) β^-≈100%	217 Bi 83 134 2.70 us $25/2^-$# Eex 1480 (40) IT=100% 98.5 s $9/2^-$# M 8730 (18) β^-=100%	218 Bi 83 135 33 s (6^-,7^-,8^-) M 13216 (27) β^-=100%	219 Bi 83 136 8.7 s $9/2^-$# M 16280# (200#) β^-=100%	220 Bi 83 137 9.5 s 1^-# M 20820# (300#) β^-=100% β^-n=0.04#%

INTC, 7th February 2024

The Team (RILIS-IDS-ISOLTRAP Collaboration)



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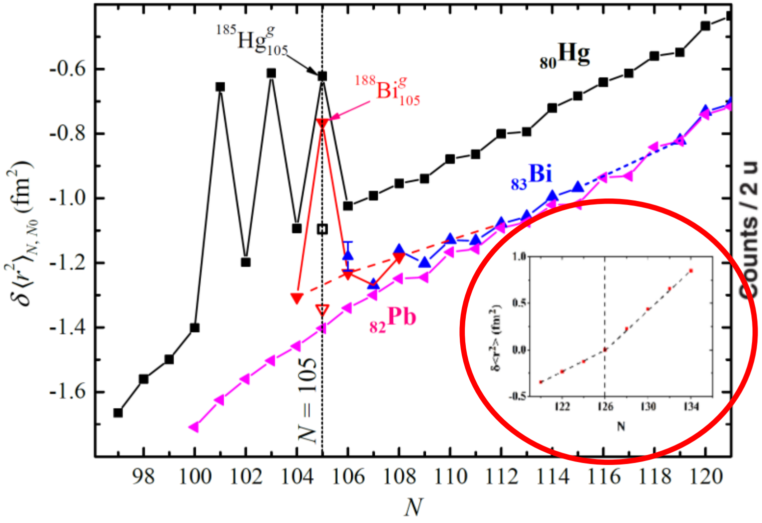
Spokesperson: A.N. Andreyev (York)
Co-spokesperson: T.E Cocolios (KU Leuven)
Local Contact Person: R. Heinke (CERN)

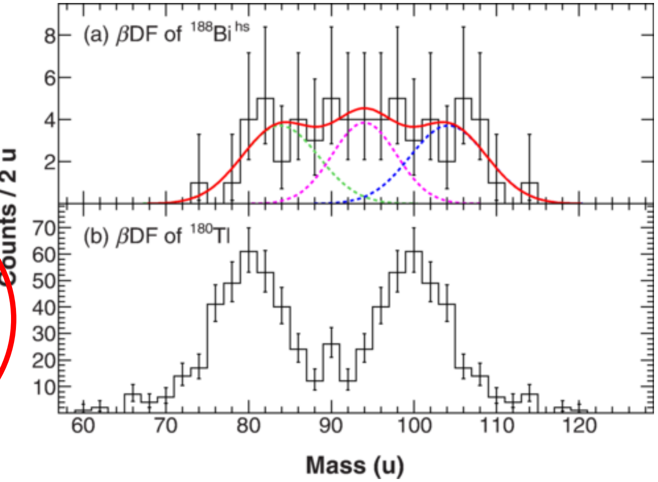
The CRIS team will provide and set-up the “injection-seeded” laser to obtain the “narrow-band” mode.

Selected latest results on Bi isotopes (IS608+IS650)

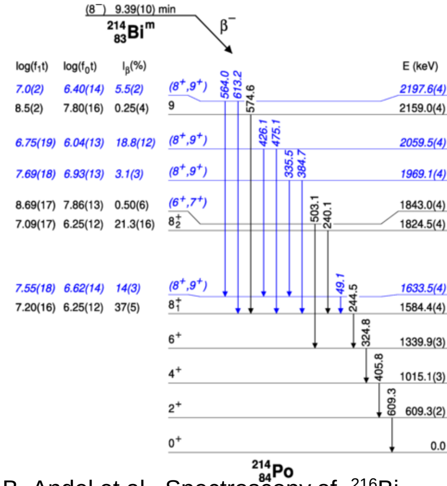
IS608 A.E. Barzakh et al., Shape staggering in gs of $^{187-189}$Bi
Phys. Rev. Lett. 127, 192501 (2021)



IS608 B. Andel et al., ^{188}Bi beta-delayed fission
Phys. Rev. C 102, 014319 (2020)

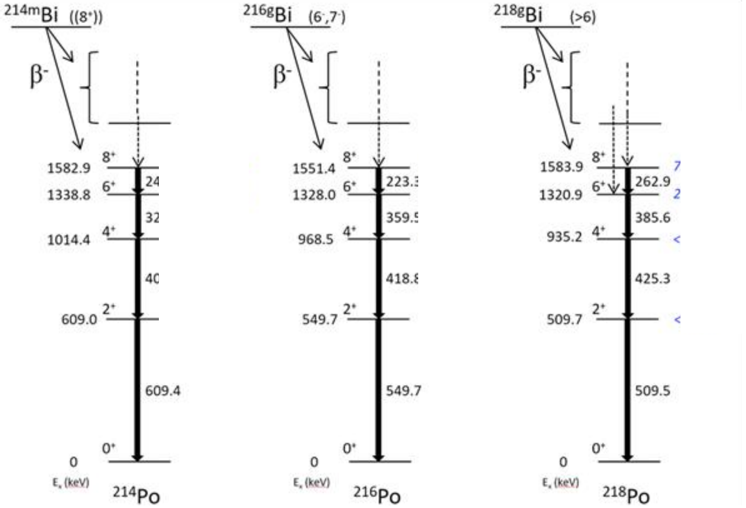


IS650 B. Andel et al., New isomer in ^{214}Bi
Phys. Rev. C 104, 054301 (2021)

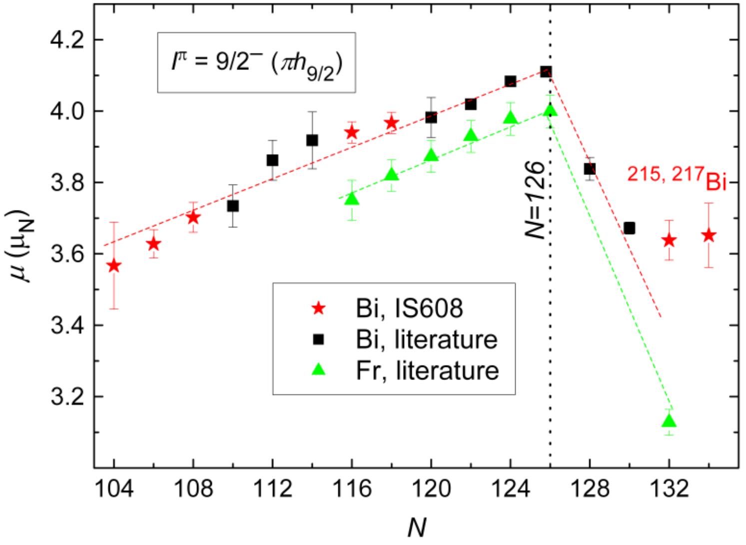


B. Andel et al., Spectroscopy of ^{216}Bi
Submitted to PRC, January 2024

IS650, fast timing, 8⁺ isomers; R.Lica in preparation
Provided rate measurements up to ^{218}Bi



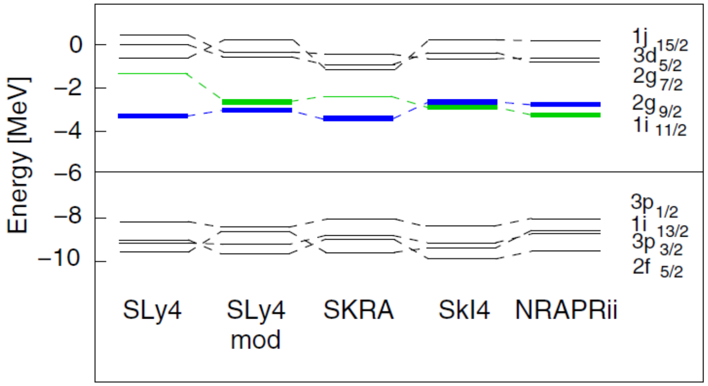
IS608, Anomaly of the gs 9/2⁻ magnetic moments in ^{215,217}Bi
In preparation

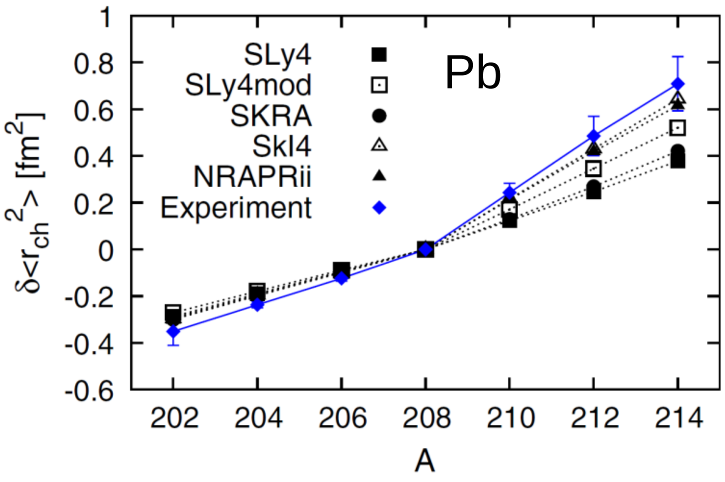


Goal: High-spin isomers ^{212m1,m2,213m}Bi and the N=126 kink problem

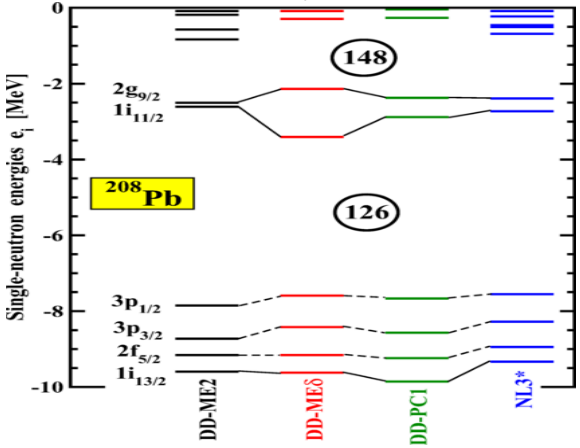
Properties of the high-spin isomers ^{212m1,m2,213m}Bi and their link to the Bi gs charge radii kink at N=126: is the position and occupation of the i11/2 neutron orbital relative to g9/2 a real culprit for the N=126 kink?

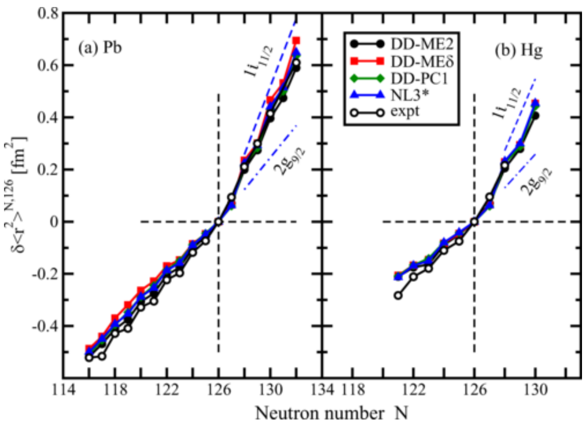
Skyrme, P.M. Goddard et al,PRL110 (2013)

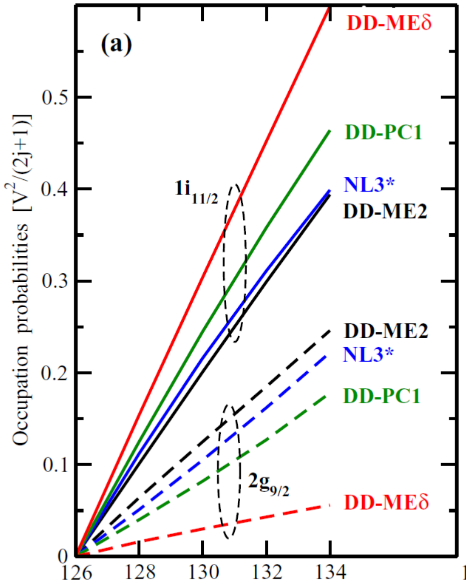




Relativistic, T. Day Goodacre et al,PRL126(2021)&PRC104(2021)





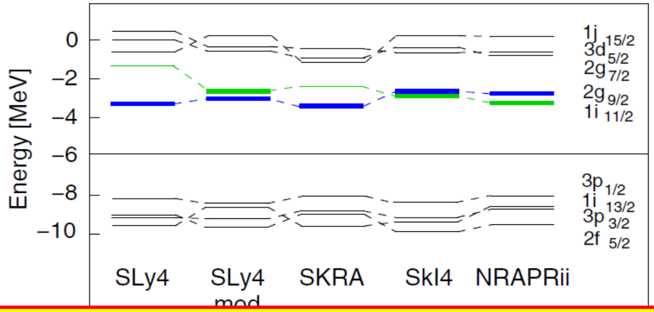


It seems the models in which **the i11/2 neutron orbital is below g9/2** (or very close to it) reproduce the kink better**, due to enhanced population of the i11/2 orbital. In particular, this is a common property of relativistic approaches.**

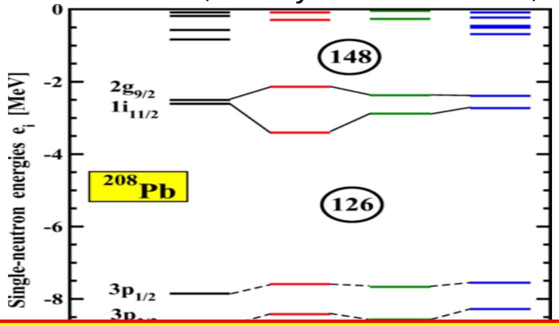
Goal: High-spin isomers ^{212m1,m2,213m}Bi and the N=126 kink problem

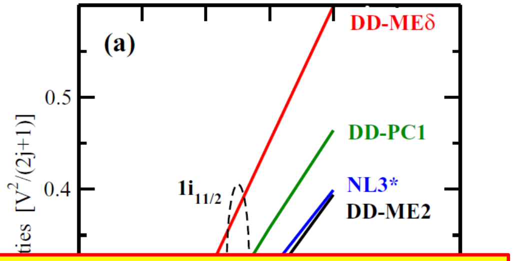
Properties of the high-spin isomers ^{212m1,m2,213m}Bi and their link to the kink in Bi gs charge radii at N=126: is the position and occupation of the i11/2 neutron orbital a real culprit for the N=126 kink?

Skyrme, P.M. Goddard et al,PRL110 (2013)



Relativistic, T. Day Goodacre et al, PRC104,054322(2021)



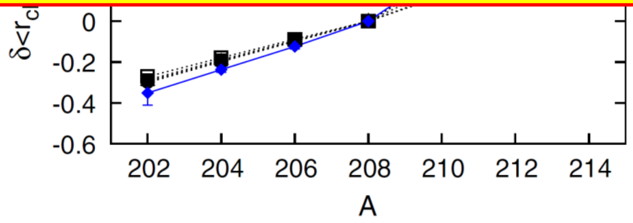


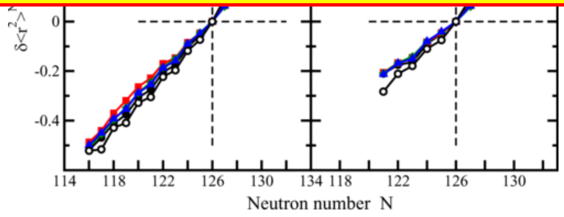
This effect can be probed by charge radii of high-spin isomers in ^{212m2,213m}Bi, whose configuration **presumably includes an i11/2 neutron**:

^{212m2}Bi [πh9/2×((νg9/2)^{2}×**νi11/2**)]18⁻,

^{213m}Bi [πh9/2× (νg9/2×**νi11/2**)]25/2⁻,

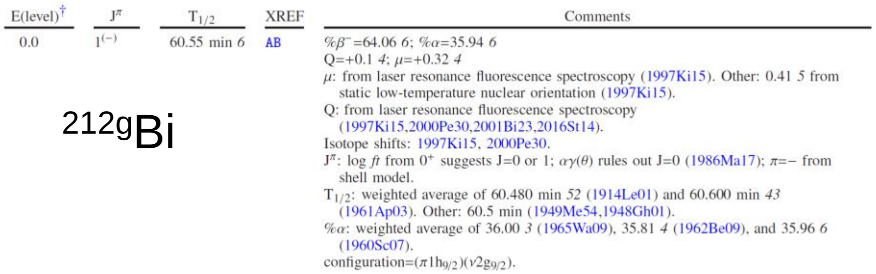
relative to their gs's or ^{212m1}Bi [πh9/2×νg9/2)]8⁻,9⁻, which have no i11/2 neutrons.





It seems the models in which **the i11/2 neutron orbital is below g9/2** (or very close to it) reproduce the kink better**, due to enhanced population of the i11/2 orbital. This is a common property of relativistic approaches.**

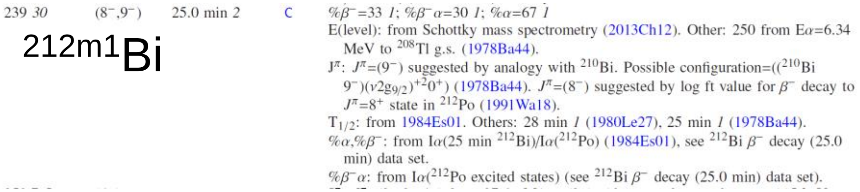
^{212g,m1,m2}Bi (N=129)



E(level)†	J^π	$T_{1/2}$	XREF	Comments
0.0	$1^{(-)}$	60.55 min 6	AB	$\%\beta^-$=64.06 6; $\%\alpha$=35.94 6 Q=+0.1 4; μ=+0.32 4 μ: from laser resonance fluorescence spectroscopy (1997Ki15). Other: 0.41 5 from static low-temperature nuclear orientation (1997Ki15). Q: from laser resonance fluorescence spectroscopy (1997Ki15,2000Pe30,2001Bi23,2016St14). Isotope shifts: 1997Ki15, 2000Pe30. J^π: log ft from 0^+ suggests J=0 or 1; $\alpha\gamma(\theta)$ rules out J=0 (1986Ma17); π=− from shell model. $T_{1/2}$: weighted average of 60.480 min 52 (1914Le01) and 60.600 min 43 (1961Ap03). Other: 60.5 min (1949Me54,1948Gh01). $\%\alpha$: weighted average of 36.00 3 (1965Wa09), 35.81 4 (1962Be09), and 35.96 6 (1960Sc07). configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.

^{212g}Bi

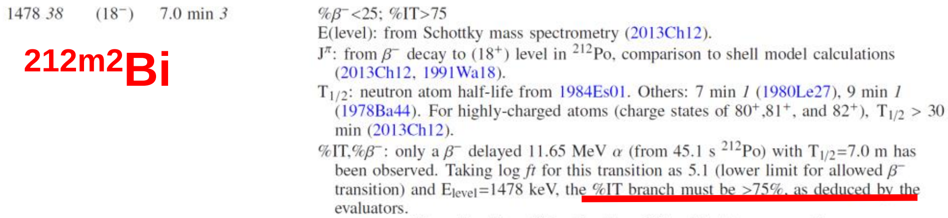
configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.



E(level)	J^π	$T_{1/2}$	XREF	Comments
239 30	$(8^-,9^-)$	25.0 min 2	C	$\%\beta^-$=33 1; $\%\beta^-\alpha$=30 1; $\%\alpha$=67 1 E(level): from Schottky mass spectrometry (2013Ch12). Other: 250 from Eα=6.34 MeV to ^{208}Tl g.s. (1978Ba44). J^π: $J^\pi=(9^-)$ suggested by analogy with ^{210}Bi. Possible configuration=$((^{210}\mathrm{Bi}\ 9^-)(\nu 2g_{9/2})^{+2}0^+)$ (1978Ba44). $J^\pi=(8^-)$ suggested by log ft value for β^- decay to $J^\pi=8^+$ state in ^{212}Po (1991Wa18). $T_{1/2}$: from 1984Es01. Others: 28 min 1 (1980Le27), 25 min 1 (1978Ba44). $\%\alpha,\%\beta^-$: from Iα(25 min ^{212}Bi)/Iα(^{212}Po) (1984Es01), see ^{212}Bi β^- decay (25.0 min) data set. $\%\beta^-\alpha$: from Iα(^{212}Po excited states) (see ^{212}Bi β^- decay (25.0 min) data set).

^{212m1}Bi

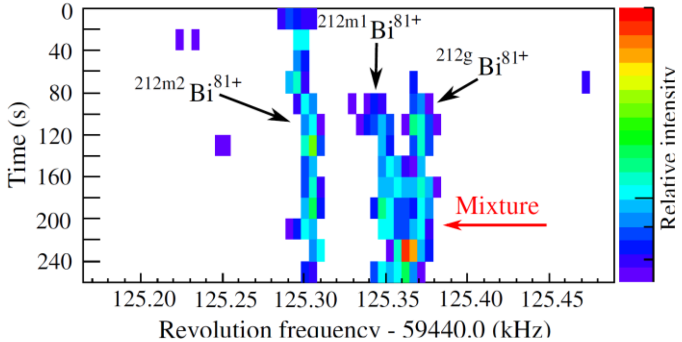
$((^{210}\mathrm{B}\ 9^-)(\nu 2g_{9/2})^{+2}0^+)$ (1978Ba44).

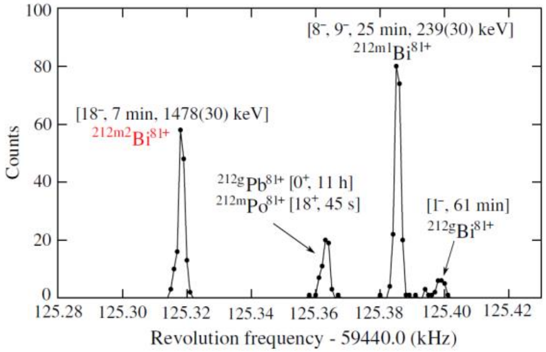


E(level)	J^π	$T_{1/2}$	Comments
1478 38	(18^-)	7.0 min 3	$\%\beta^-$<25; %IT>75 E(level): from Schottky mass spectrometry (2013Ch12). J^π: from β^- decay to (18^+) level in ^{212}Po, comparison to shell model calculations (2013Ch12, 1991Wa18). $T_{1/2}$: neutron atom half-life from 1984Es01. Others: 7 min 1 (1980Le27), 9 min 1 (1978Ba44). For highly-charged atoms (charge states of 80^+,81^+, and 82^+), $T_{1/2}$ > 30 min (2013Ch12). %IT,$\%\beta^-$: only a β^- delayed 11.65 MeV α (from 45.1 s ^{212}Po) with $T_{1/2}$=7.0 m has been observed. Taking log ft for this transition as 5.1 (lower limit for allowed β^- transition) and E_{level}=1478 keV, the %IT branch must be >75%, as deduced by the evaluators.

^{212m2}Bi

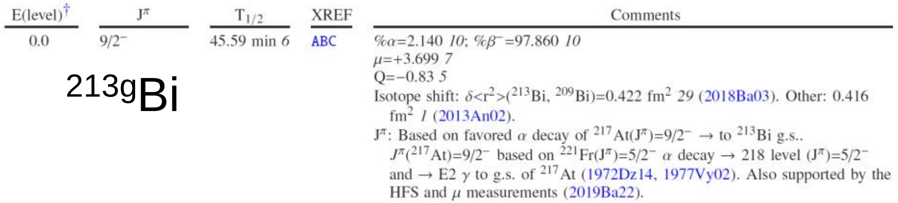
^{212m2}Bi [πh9/2×((νg9/2)^2×**νi11/2**)]18$^-$ **???**





L. Chen et al., PRL **110**, 122502 (2013)

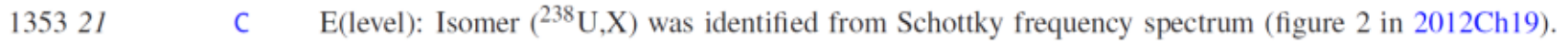
^{213g,m}Bi (N=130)



E(level)†	J^π	$T_{1/2}$	XREF	Comments
0.0	$9/2^-$	45.59 min 6	ABC	$\%\alpha$=2.140 10; $\%\beta^-$=97.860 10 μ=+3.699 7 Q=−0.83 5 Isotope shift: $\delta\langle r^2\rangle(^{213}\mathrm{Bi},\ ^{209}\mathrm{Bi})$=0.422 fm^2 29 (2018Ba03). Other: 0.416 fm^2 1 (2013An02). J^π: Based on favored α decay of ^{217}At(J^π)=$9/2^-$ → to ^{213}Bi g.s.. J^π(^{217}At)=$9/2^-$ based on ^{221}Fr(J^π)=$5/2^-$ α decay → 218 level (J^π)=$5/2^-$ and → E2 γ to g.s. of ^{217}At (1972Dz14, 1977Vy02). Also supported by the HFS and μ measurements (2019Ba22).

^{213g}Bi

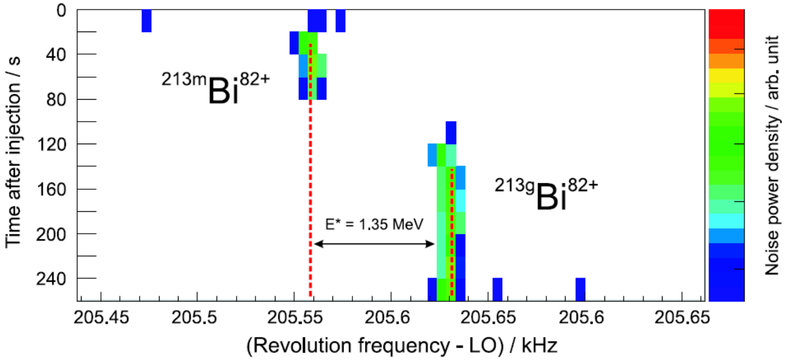
Configuration: $\pi\ (h^{+1}_{9/2})$.



E(level)	XREF	Comments
1353 21	C	E(level): Isomer (^{238}U,X) was identified from Schottky frequency spectrum (figure 2 in 2012Ch19).

^{213m}Bi

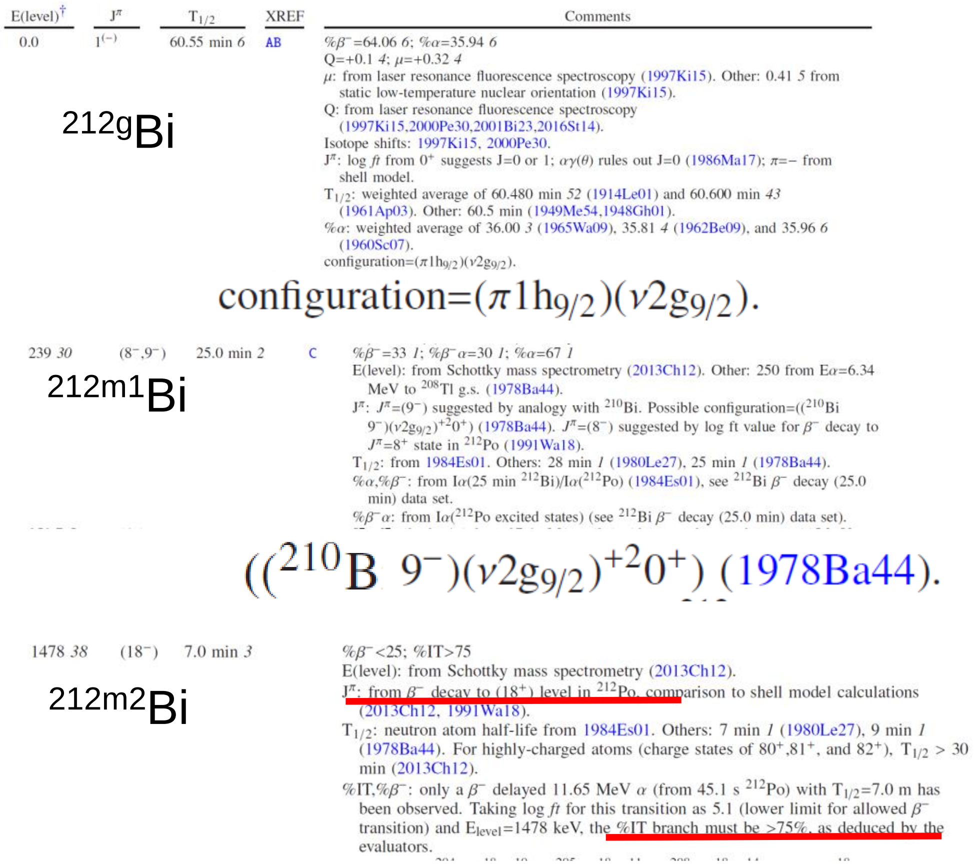
L. Chen et al., Nuclear Physics A 882 (2012) 71–89



^{213m}Bi [πh9/2× (νg9/2×**νi11/2**)]25/2$^-$ **???**

^{212g,m1,m2}Bi (N=129)

^{213g,m}Bi (N=130)



E(level)†	Jπ	$T_{1/2}$	XREF	Comments
0.0	$1^{(-)}$	60.55 min *6*	AB	%β^-=64.06 *6*; %α=35.94 *6* Q=+0.1 *4*; μ=+0.32 *4* μ: from laser resonance fluorescence spectroscopy (1997Ki15). Other: 0.41 *5* from static low-temperature nuclear orientation (1997Ki15). Q: from laser resonance fluorescence spectroscopy (1997Ki15,2000Pe30,2001Bi23,2016St14). Isotope shifts: 1997Ki15, 2000Pe30. Jπ: log *ft* from 0^+ suggests J=0 or 1; $\alpha\gamma(\theta)$ rules out J=0 (1986Ma17); π=− from shell model. $T_{1/2}$: weighted average of 60.480 min *52* (1914Le01) and 60.600 min *43* (1961Ap03). Other: 60.5 min (1949Me54,1948Gh01). %α: weighted average of 36.00 *3* (1965Wa09), 35.81 *4* (1962Be09), and 35.96 *6* (1960Sc07). configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.
239 *30*	$(8^-,9^-)$	25.0 min *2*	C	%β^-=33 *1*; %$\beta^-\alpha$=30 *1*; %α=67 *1* E(level): from Schottky mass spectrometry (2013Ch12). Other: 250 from Eα=6.34 MeV to ^{208}Tl g.s. (1978Ba44). Jπ: Jπ=(9^-) suggested by analogy with ^{210}Bi. Possible configuration=((^{210}Bi 9^-)$(\nu 2g_{9/2})^{+2}0^+$) (1978Ba44). Jπ=(8^-) suggested by log ft value for β^- decay to Jπ=8^+ state in ^{212}Po (1991Wa18). $T_{1/2}$: from 1984Es01. Others: 28 min *1* (1980Le27), 25 min *1* (1978Ba44). %α,%β^-: from Iα(25 min ^{212}Bi)/Iα(^{212}Po) (1984Es01), see ^{212}Bi β^- decay (25.0 min) data set. %$\beta^-\alpha$: from Iα(^{212}Po excited states) (see ^{212}Bi β^- decay (25.0 min) data set).
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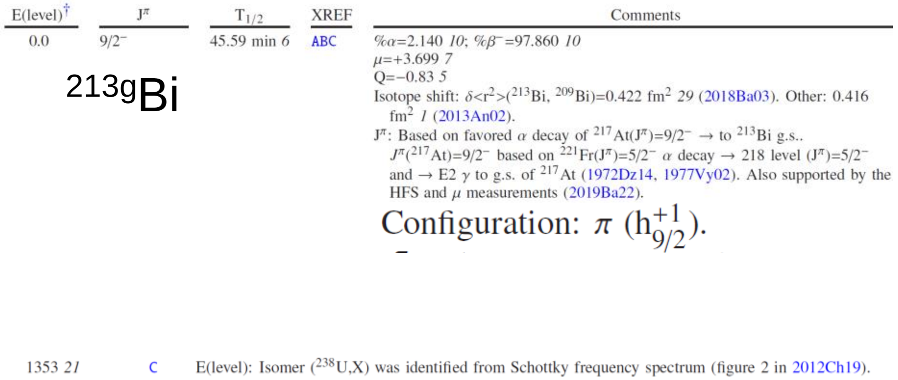
^{212g}Bi

configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.

^{212m1}Bi

((^{210}B 9^-)$(\nu 2g_{9/2})^{+2}0^+$) (1978Ba44).

^{212m2}Bi



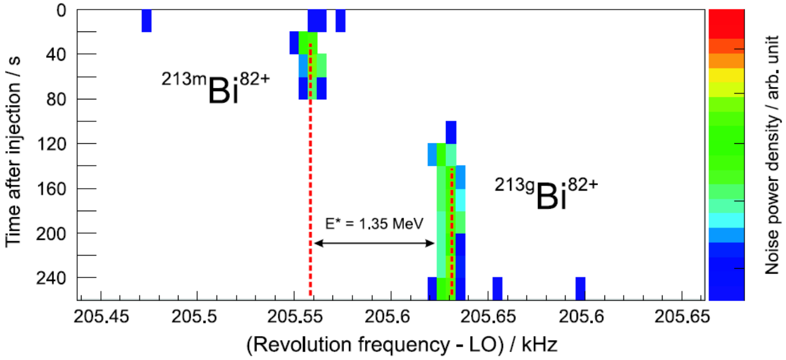
E(level)†	Jπ	$T_{1/2}$	XREF	Comments
0.0	$9/2^-$	45.59 min *6*	ABC	%α=2.140 *10*; %β^-=97.860 *10* μ=+3.699 *7* Q=−0.83 *5* Isotope shift: $\delta\langle r^2\rangle$(^{213}Bi, ^{209}Bi)=0.422 fm^2 *29* (2018Ba03). Other: 0.416 fm^2 *1* (2013An02). Jπ: Based on favored α decay of ^{217}At(Jπ)=$9/2^-$ → to ^{213}Bi g.s.. Jπ(^{217}At)=$9/2^-$ based on ^{221}Fr(Jπ)=$5/2^-$ α decay → 218 level (Jπ)=$5/2^-$ and → E2 γ to g.s. of ^{217}At (1972Dz14, 1977Vy02). Also supported by the HFS and μ measurements (2019Ba22).
1353 *21*			C	E(level): Isomer (^{238}U,X) was identified from Schottky frequency spectrum (figure 2 in 2012Ch19).

^{213g}Bi

Configuration: $\pi\ (h^{+1}_{9/2})$.

^{213m}Bi

L. Chen et al., Nuclear Physics A 882 (2012) 71–89



^{212m2}Bi [πh9/2×((vg9/2)^2×**vi11/2**)]18$^-$ **???**

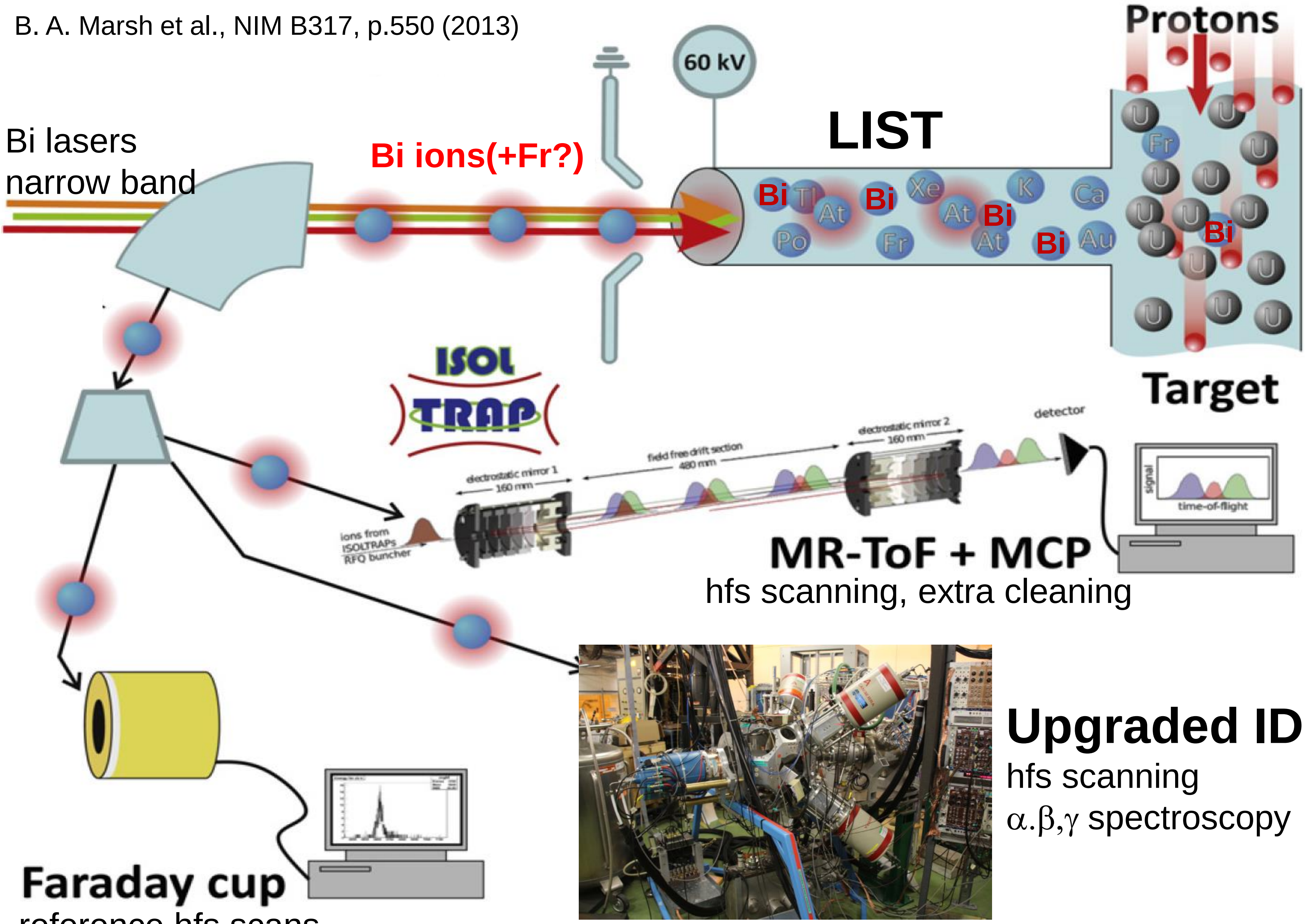
^{213m}Bi [πh9/2× (vg9/2×**vi11/2**)]25/2$^-$ **???**

Task 1: We will perform **hfs scanning for ^{212m2,213m}Bi** with LIST in narrowband mode (procedure confirmed for Po/Ac's in our 2022 campaigns). Some scanning can be done with MR-ToF (for longest-lived cases, if IDS is not enough**)**. **Deduced magnetic moments will help to confirm/establish the configurations. Also radii will be determined.**

Task 2: Decay properties of high-spin isomers are poorly known, some studied 40-50 years ago. We can now do it much better with the versatile IDS system, e.g. to **search for the IT decay from 18$^-$ to 8/9$^-$ (or even to the gs) in ^{212m2}Bi**, and/or to **measure for the 1st time the half-life and decay path of ^{213m}Bi**.

The Method: In-source laser spectroscopy+IDS+MR-ToF

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



Bi lasers
narrow band

Bi ions(+Fr?)

LIST

Target

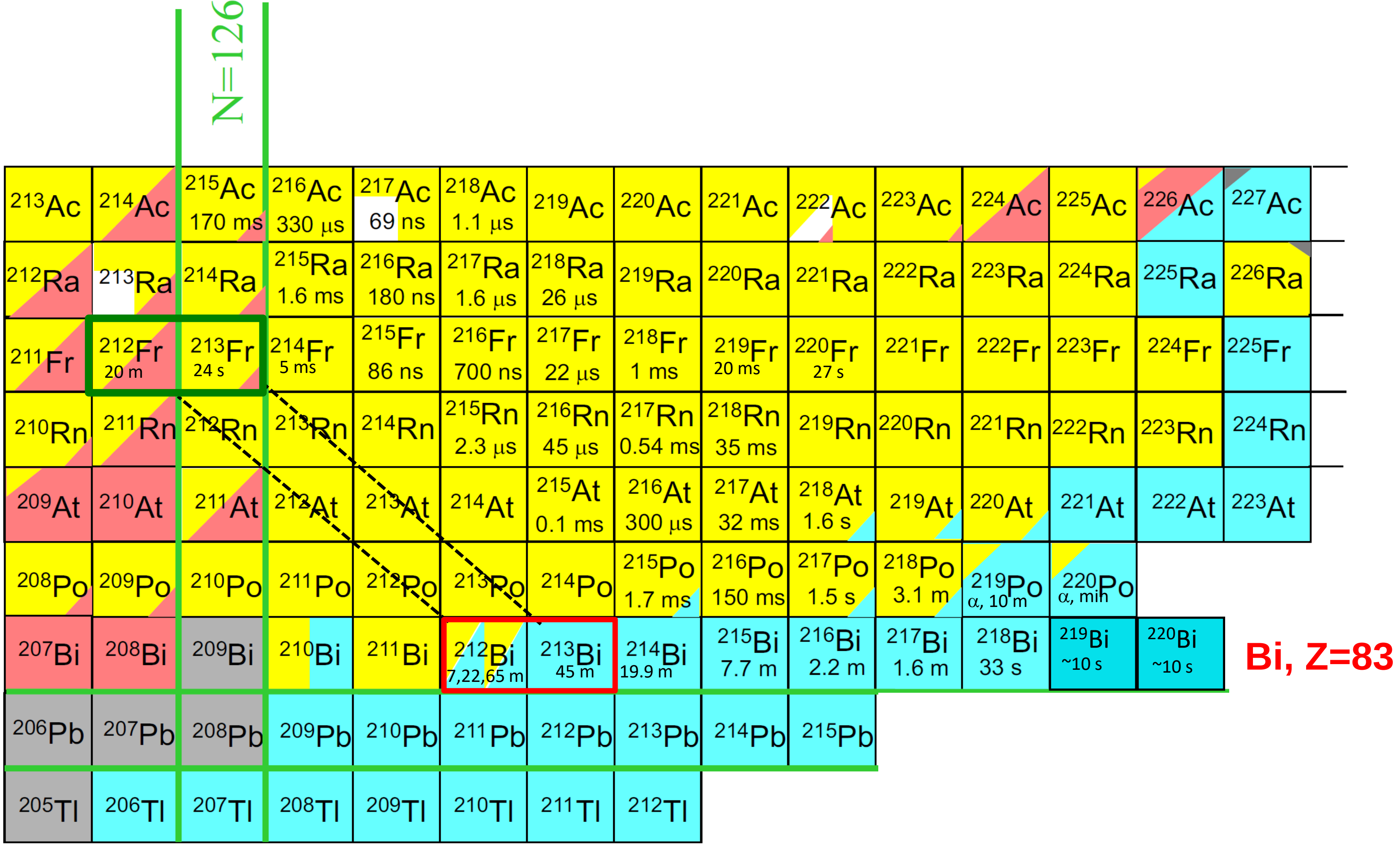
MR-ToF + MCP
hfs scanning, extra cleaning

Upgraded IDS
hfs scanning
α.β,γ spectroscopy

Faraday cup
reference hfs scans

Why LIST? -Fr contamination

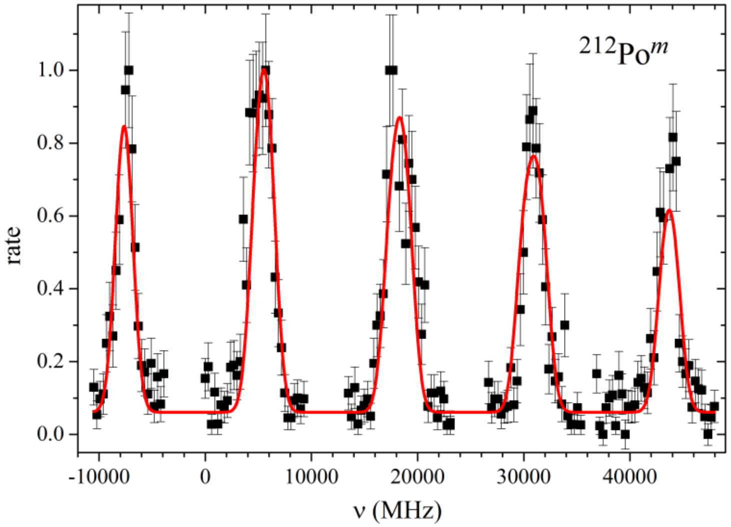
- Long-lived, strongly-produced Fr contaminants only at A=212,213
- The LIST operation in this region is now confirmed by several experiments, e.g. our recent $^{207\text{-}209}$Tl study (Z. Yue et al., PLB 849,138452, February 2024)



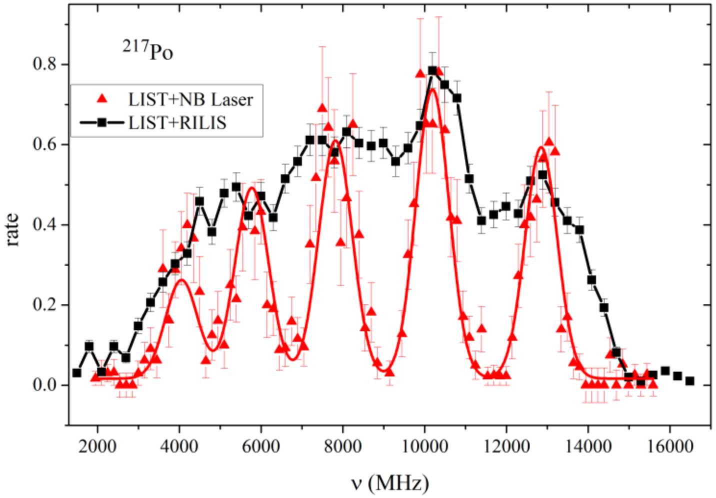
^{213}Ac	^{214}Ac	^{215}Ac 170 ms	^{216}Ac 330 µs	^{217}Ac 69 ns	^{218}Ac 1.1 µs	^{219}Ac	^{220}Ac	^{221}Ac	^{222}Ac	^{223}Ac	^{224}Ac	^{225}Ac	^{226}Ac	^{227}Ac
^{212}Ra	^{213}Ra	^{214}Ra	^{215}Ra 1.6 ms	^{216}Ra 180 ns	^{217}Ra 1.6 µs	^{218}Ra 26 µs	^{219}Ra	^{220}Ra	^{221}Ra	^{222}Ra	^{223}Ra	^{224}Ra	^{225}Ra	^{226}Ra
^{211}Fr	^{212}Fr 20 m	^{213}Fr 24 s	^{214}Fr 5 ms	^{215}Fr 86 ns	^{216}Fr 700 ns	^{217}Fr 22 µs	^{218}Fr 1 ms	^{219}Fr 20 ms	^{220}Fr 27 s	^{221}Fr	^{222}Fr	^{223}Fr	^{224}Fr	^{225}Fr
^{210}Rn	^{211}Rn	^{212}Rn	^{213}Rn	^{214}Rn	^{215}Rn 2.3 µs	^{216}Rn 45 µs	^{217}Rn 0.54 ms	^{218}Rn 35 ms	^{219}Rn	^{220}Rn	^{221}Rn	^{222}Rn	^{223}Rn	^{224}Rn
^{209}At	^{210}At	^{211}At	^{212}At	^{213}At	^{214}At	^{215}At 0.1 ms	^{216}At 300 µs	^{217}At 32 ms	^{218}At 1.6 s	^{219}At	^{220}At	^{221}At	^{222}At	^{223}At
^{208}Po	^{209}Po	^{210}Po	^{211}Po	^{212}Po	^{213}Po	^{214}Po	^{215}Po 1.7 ms	^{216}Po 150 ms	^{217}Po 1.5 s	^{218}Po 3.1 m	^{219}Po α, 10 m	^{220}Po α, min		
^{207}Bi	^{208}Bi	^{209}Bi	^{210}Bi	^{211}Bi	^{212}Bi 7,22,65 m	^{213}Bi 45 m	^{214}Bi 19.9 m	^{215}Bi 7.7 m	^{216}Bi 2.2 m	^{217}Bi 1.6 m	^{218}Bi 33 s	^{219}Bi ~10 s	^{220}Bi ~10 s	
^{206}Pb	^{207}Pb	^{208}Pb	^{209}Pb	^{210}Pb	^{211}Pb	^{212}Pb	^{213}Pb	^{214}Pb	^{215}Pb					
^{205}Tl	^{206}Tl	^{207}Tl	^{208}Tl	^{209}Tl	^{210}Tl	^{211}Tl	^{212}Tl							

Examples of **narrow-band** scanning for ^{212m,217}Po (April 2022) and simulations for ^{212g,m1,m2}Bi

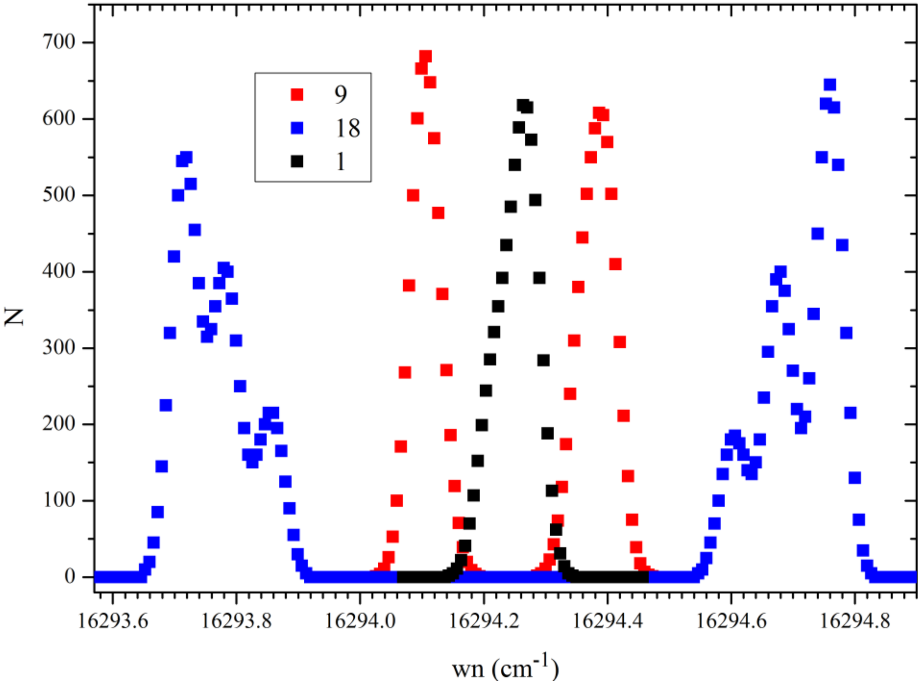
CRIS “injection-seeded” narrowband laser (April 2022)



^{217}Po, usual LIST vs NB LIST



Simulations for ^{212g,m1,m2}Bi



Long scans, ~200 laser steps are needed

Beam request

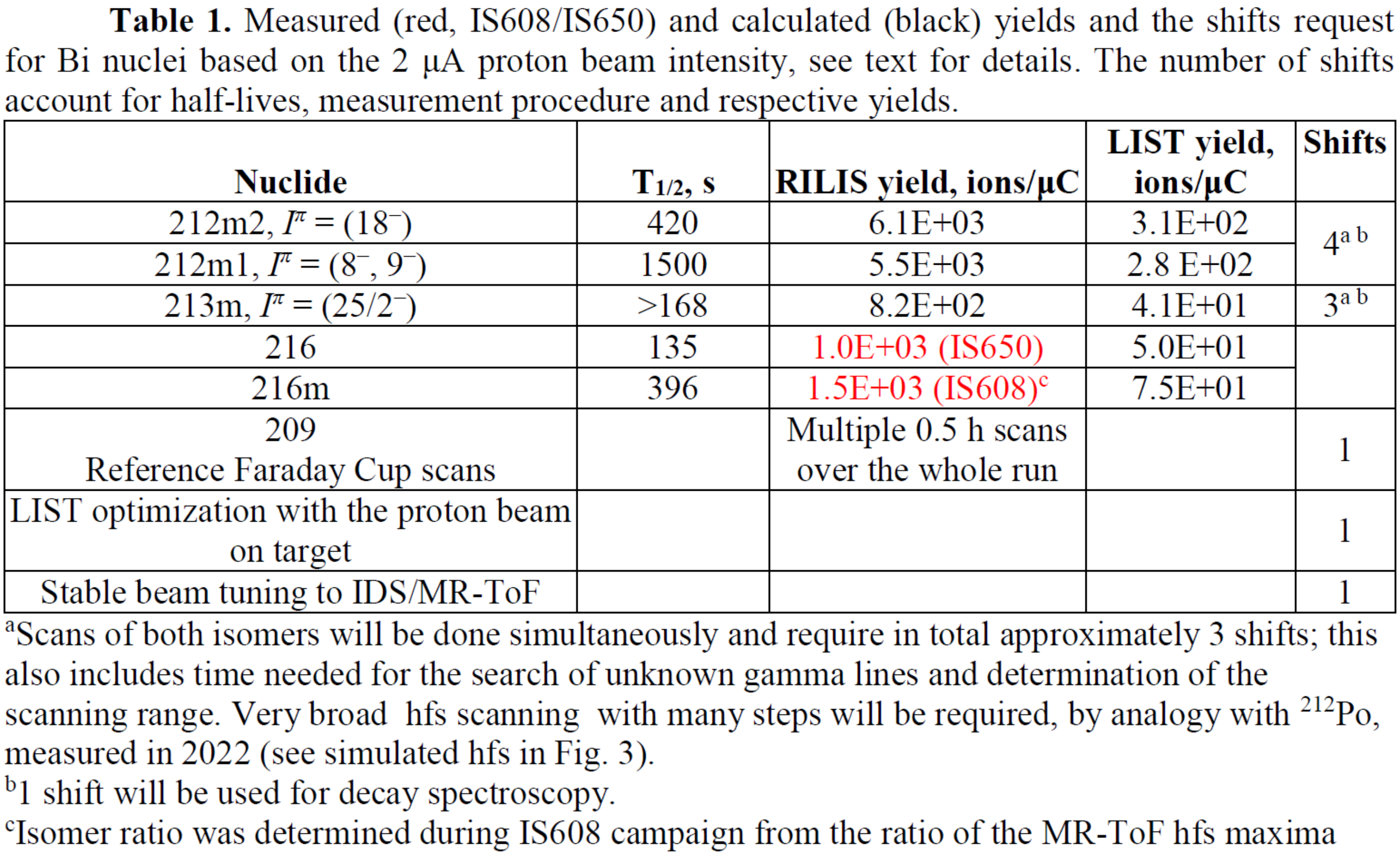


Table 1. Measured (red, IS608/IS650) and calculated (black) yields and the shifts request for Bi nuclei based on the 2 µA proton beam intensity, see text for details. The number of shifts account for half-lives, measurement procedure and respective yields.

Nuclide	$T_{1/2}$, s	RILIS yield, ions/µC	LIST yield, ions/µC	Shifts
212m2, $I^\pi = (18^-)$	420	6.1E+03	3.1E+02	4[a b]
212m1, $I^\pi = (8^-, 9^-)$	1500	5.5E+03	2.8 E+02	
213m, $I^\pi = (25/2^-)$	>168	8.2E+02	4.1E+01	3[a b]
216	135	1.0E+03 (IS650)	5.0E+01	
216m	396	1.5E+03 (IS608)[c]	7.5E+01	
209 Reference Faraday Cup scans		Multiple 0.5 h scans over the whole run		1
LIST optimization with the proton beam on target				1
Stable beam tuning to IDS/MR-ToF				1

[a] Scans of both isomers will be done simultaneously and require in total approximately 3 shifts; this also includes time needed for the search of unknown gamma lines and determination of the scanning range. Very broad hfs scanning with many steps will be required, by analogy with ^{212}Po, measured in 2022 (see simulated hfs in Fig. 3).

[b] 1 shift will be used for decay spectroscopy.

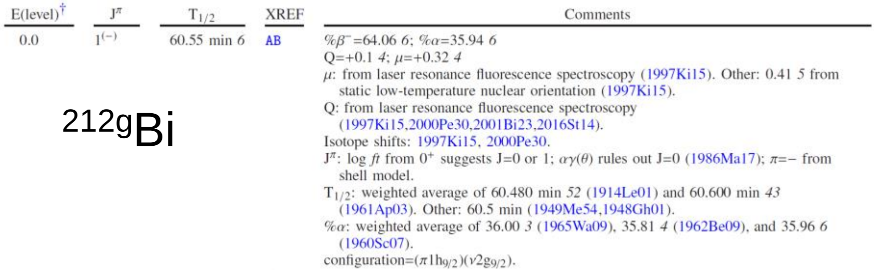
[c] Isomer ratio was determined during IS608 campaign from the ratio of the MR-ToF hfs maxima

In total, 10 shifts requested for hfs/IS, nuclear spectroscopy and reference measurements for ^{212,213}Bi

If the proposal is accepted, it will also "save" 2 shifts for G.Georgiev's LoI239 requesting the same Bi isotopes for the g-factor measurements in daughter Po

Thank you!

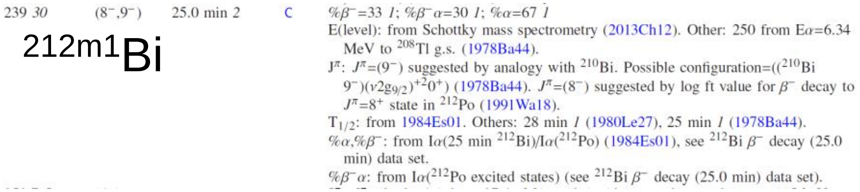
^{212g,m1,m2}Bi (N=129)



E(level)[†]	J^π	$T_{1/2}$	XREF	Comments
0.0	$1^{(-)}$	60.55 min *6*	AB	$\%\beta^-$=64.06 *6*; $\%\alpha$=35.94 *6* Q=+0.1 *4*; μ=+0.32 *4* μ: from laser resonance fluorescence spectroscopy (1997Ki15). Other: 0.41 *5* from static low-temperature nuclear orientation (1997Ki15). Q: from laser resonance fluorescence spectroscopy (1997Ki15,2000Pe30,2001Bi23,2016St14). Isotope shifts: 1997Ki15, 2000Pe30. J^π: log *ft* from 0^+ suggests J=0 or 1; $\alpha\gamma(\theta)$ rules out J=0 (1986Ma17); π=− from shell model. $T_{1/2}$: weighted average of 60.480 min *52* (1914Le01) and 60.600 min *43* (1961Ap03). Other: 60.5 min (1949Me54,1948Gh01). $\%\alpha$: weighted average of 36.00 *3* (1965Wa09), 35.81 *4* (1962Be09), and 35.96 *6* (1960Sc07). configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.

^{212g}Bi

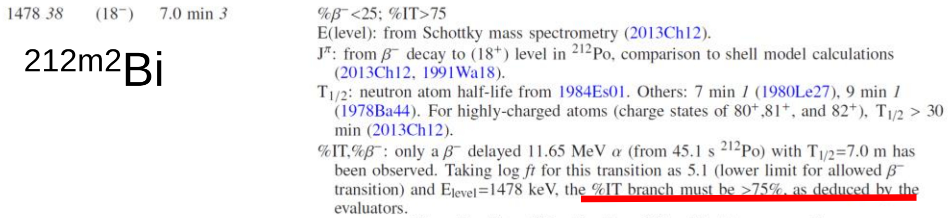
configuration=$(\pi 1h_{9/2})(\nu 2g_{9/2})$.



E(level)	J^π	$T_{1/2}$	XREF	Comments
239 *30*	$(8^-,9^-)$	25.0 min *2*	C	$\%\beta^-$=33 *1*; $\%\beta^-\alpha$=30 *1*; $\%\alpha$=67 *1* E(level): from Schottky mass spectrometry (2013Ch12). Other: 250 from Eα=6.34 MeV to ^{208}Tl g.s. (1978Ba44). J^π: J^π=(9^-) suggested by analogy with ^{210}Bi. Possible configuration=((^{210}Bi 9^-)$(\nu 2g_{9/2})^{+2}0^+$) (1978Ba44). J^π=(8^-) suggested by log ft value for β^- decay to J^π=8^+ state in ^{212}Po (1991Wa18). $T_{1/2}$: from 1984Es01. Others: 28 min *1* (1980Le27), 25 min *1* (1978Ba44). $\%\alpha$,$\%\beta^-$: from Iα(25 min ^{212}Bi)/Iα(^{212}Po) (1984Es01), see ^{212}Bi β^- decay (25.0 min) data set. $\%\beta^-\alpha$: from Iα(^{212}Po excited states) (see ^{212}Bi β^- decay (25.0 min) data set).

^{212m1}Bi

((^{210}B 9^-)$(\nu 2g_{9/2})^{+2}0^+$) (1978Ba44).



E(level)	J^π	$T_{1/2}$	XREF	Comments
1478 *38*	(18^-)	7.0 min *3*		$\%\beta^-$<25; %IT>75 E(level): from Schottky mass spectrometry (2013Ch12). J^π: from β^- decay to (18^+) level in ^{212}Po, comparison to shell model calculations (2013Ch12, 1991Wa18). $T_{1/2}$: neutron atom half-life from 1984Es01. Others: 7 min *1* (1980Le27), 9 min *1* (1978Ba44). For highly-charged atoms (charge states of 80^+,81^+, and 82^+), $T_{1/2}$ > 30 min (2013Ch12). %IT,$\%\beta^-$: only a β^- delayed 11.65 MeV α (from 45.1 s ^{212}Po) with $T_{1/2}$=7.0 m has been observed. Taking log *ft* for this transition as 5.1 (lower limit for allowed β^- transition) and E_{level}=1478 keV, the %IT branch must be >75%, as deduced by the evaluators.

^{212m2}Bi

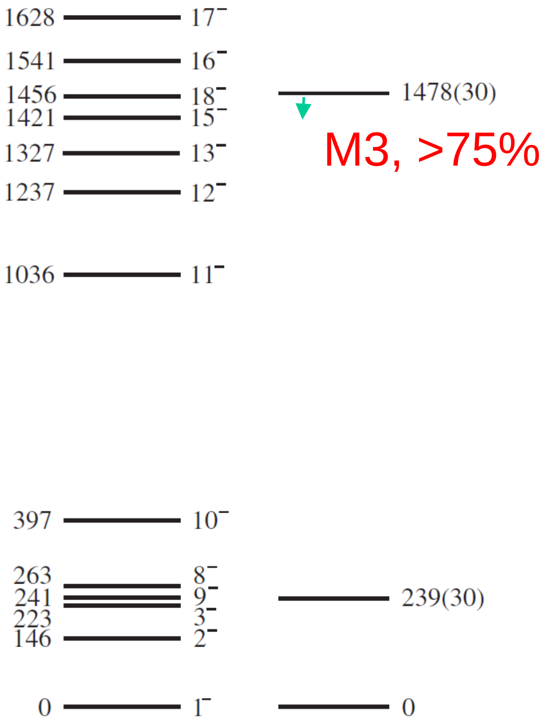
^{212m2}Bi [πh9/2×((νg9/2)^2×**νi11/2**)]18^- **???**

TABLE I. ^{212}Bi isomers studied in the ESR.

	I^π_{calc}	E_{calc}[a] (keV)	E^{new}_{calc} (keV)	E^{ESR}_{exp} (keV)	E_{exp}[b] (keV)
*m*1	8^-, 9^-	303, 281	263, 241	239(30)	250(30)
*m*2	18^-	1496	1456	1478(30)	>1910

[a] Calculated by Warburton [5].
[b] Literature excitation energies [4,9].

L. Chen et al., PRL **110**, 122502 (2013)



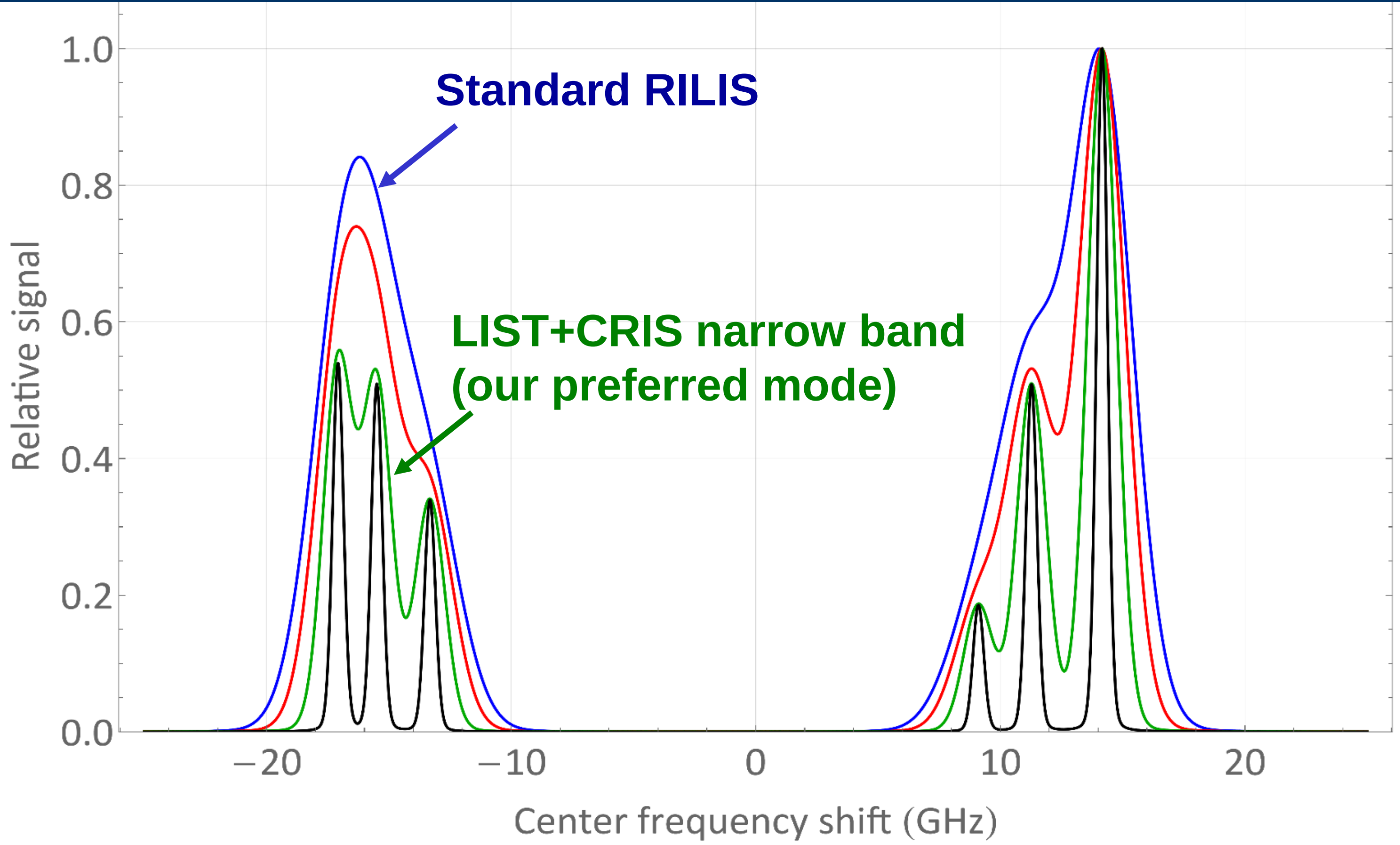
M3, >75% IT

FIG. 3. Partial level scheme for ^{212}Bi, showing the calculated energies of the yrast states on the left, together with a few non-yrast states (8^-, 16^-, and 17^-) that are discussed in the text. On the right are the observed isomers with their energies measured in the present work.

energies is given in Table I. The maximally aligned $\pi h_{9/2}$, $\nu i_{11/2}(g_{9/2})^2$ configuration for the 18^- state is calculated to have 98% purity.

Do we really need PI-LIST mode?

Simulations for ^{209}Bi (R. Heinke)



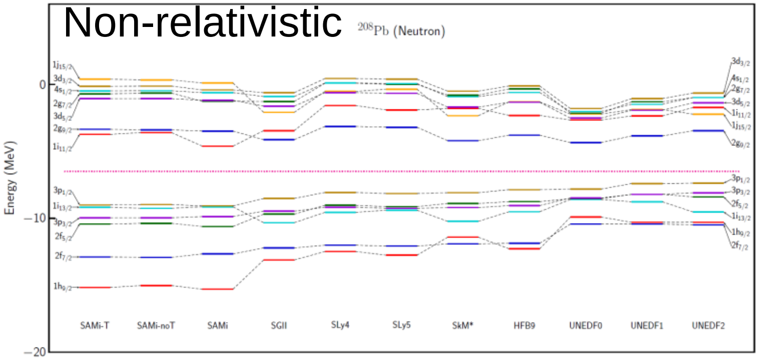
- **Blue:** Standard in-source spectroscopy + dual etalon laser (~2.9GHz)
- **Red:** LIST collinear mode + dual etalon laser (~2.2GHz) – The better resolution comes from the fact that the LIST only probes atoms flying towards the laser into the LIST. There will be a shift against the other modes.
- **Green: LIST collinear mode + CRIS narrowband laser (~1.4GHz) – our preferred mode of operation here**
- **Black:** PI-LIST mode + CRIS narrowband laser (~0.5GHz)

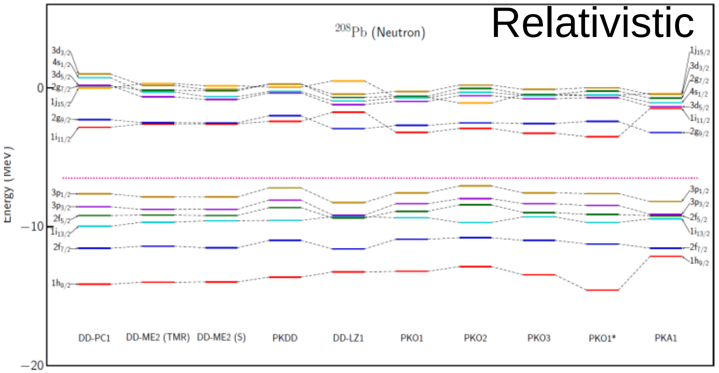
Conclusion: no significant improvement with PI-LIST, thus we might not use it at all (TAC asked on PI-LIST intensity reduction)

Physics Motivation and goals of the proposal
Goal 1: The N=126 kink problem

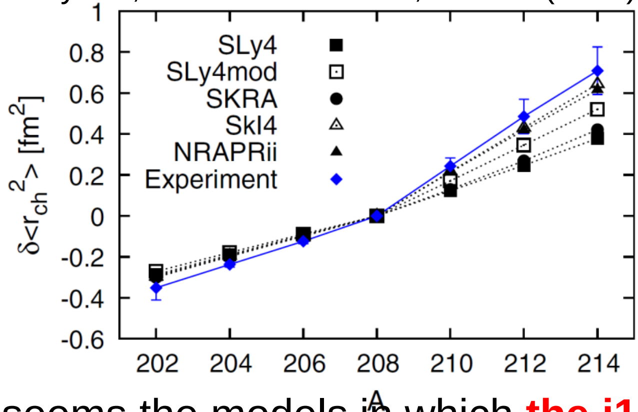
Goal 1. Properties of the high-spin isomers ^{212m1,m2,213m}Bi and their possible link to the kink in Bi ground state charge radii at N=126: is the population of the i11/2 neutron orbital a real culprit for the N=126 kink?

T. Naito et al., RIKEN, arXiv:2209.028572v2

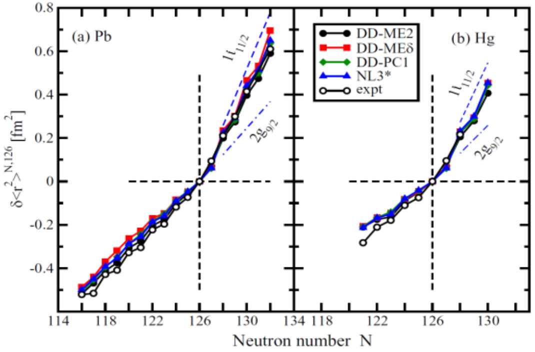


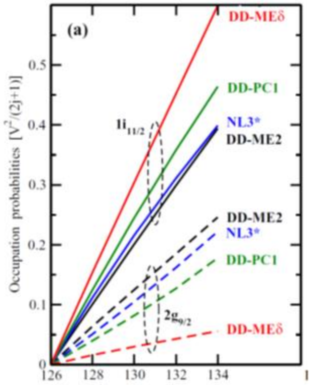


Skyrme, P.M. Goddard et al,PRL110 (2013)



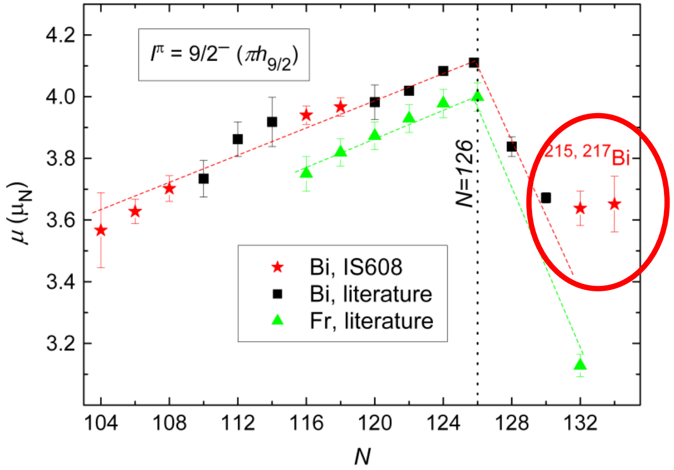
T. Day Goodacre et al, PRC104,054322(2021)

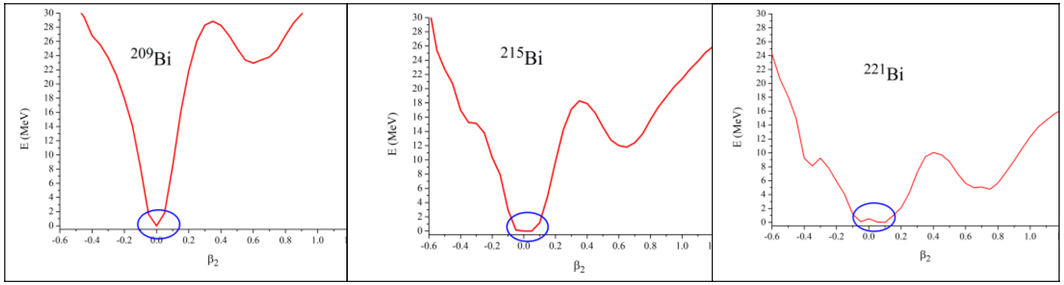




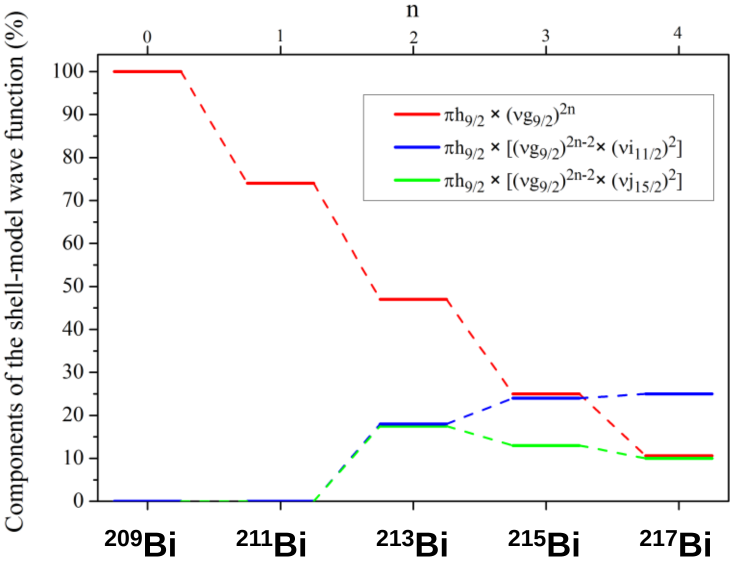
It seems the models in which **the i11/2 neutron orbital is below g9/2** (or very close to it) reproduce the kink better**, due to enhanced population of the former orbital.** If so, this effect can be probed by charge radii of high-spin isomers in ^{212,213}Bi, whose configuration does include an i11/2 neutron: ^{212m2}Bi $[\pi h9/2\times((\nu g9/2)^2\times\nu i11/2)]18-$, ^{213m}Bi $[\pi h9/2\times(\nu g9/2\times\nu i11/2)]25/2-$, relative to their gs's or ^{212m1}Bi, with less or no i11/2 neutrons (e.g. ^{212m1}Bi $[\pi h9/2\times\nu g9/2]8-,9-$).

Anomalous 9/2⁻ gs magnetic moment systematics in ^{215,217}Bi: evidence for deformation/configuration mixing?

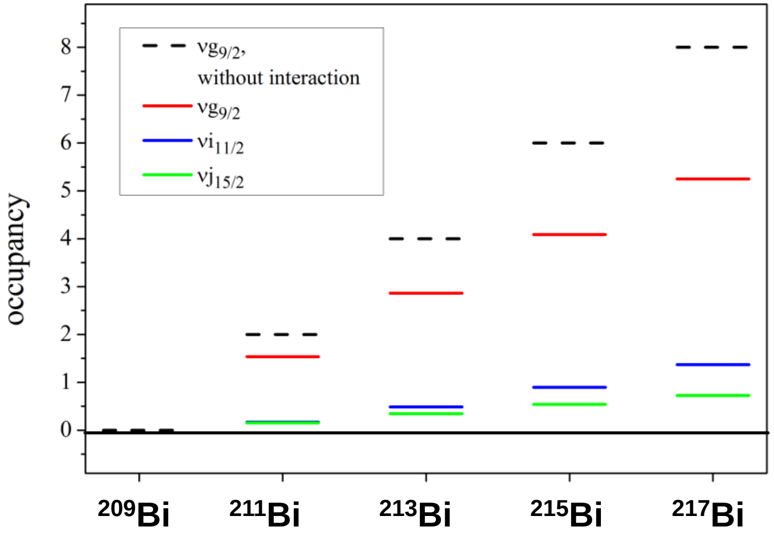




PES for ^{209,215,221}Bi calculated in HFB approach with Gogny forces D1S. A clear change of the PES minimum can be noticed by moving to heavier isotopes – deformation effects due to configuration mixing in the gs, via occupation of the high-j neutron orbitals?



The shell-model wave function components for the 9/2⁻ gs of the even-N Bi isotopes. Only components with the weight larger than 10% are shown (H. Naïdja)



The neutron shells occupancies for the 9/2⁻ gs of the even-N Bi isotopes. Black dashed lines correspond to artificial situation with sequential g9/2 shell filling, while red/blue/green lines correspond to the inclusion of the effective interaction. (H. Naïdja)