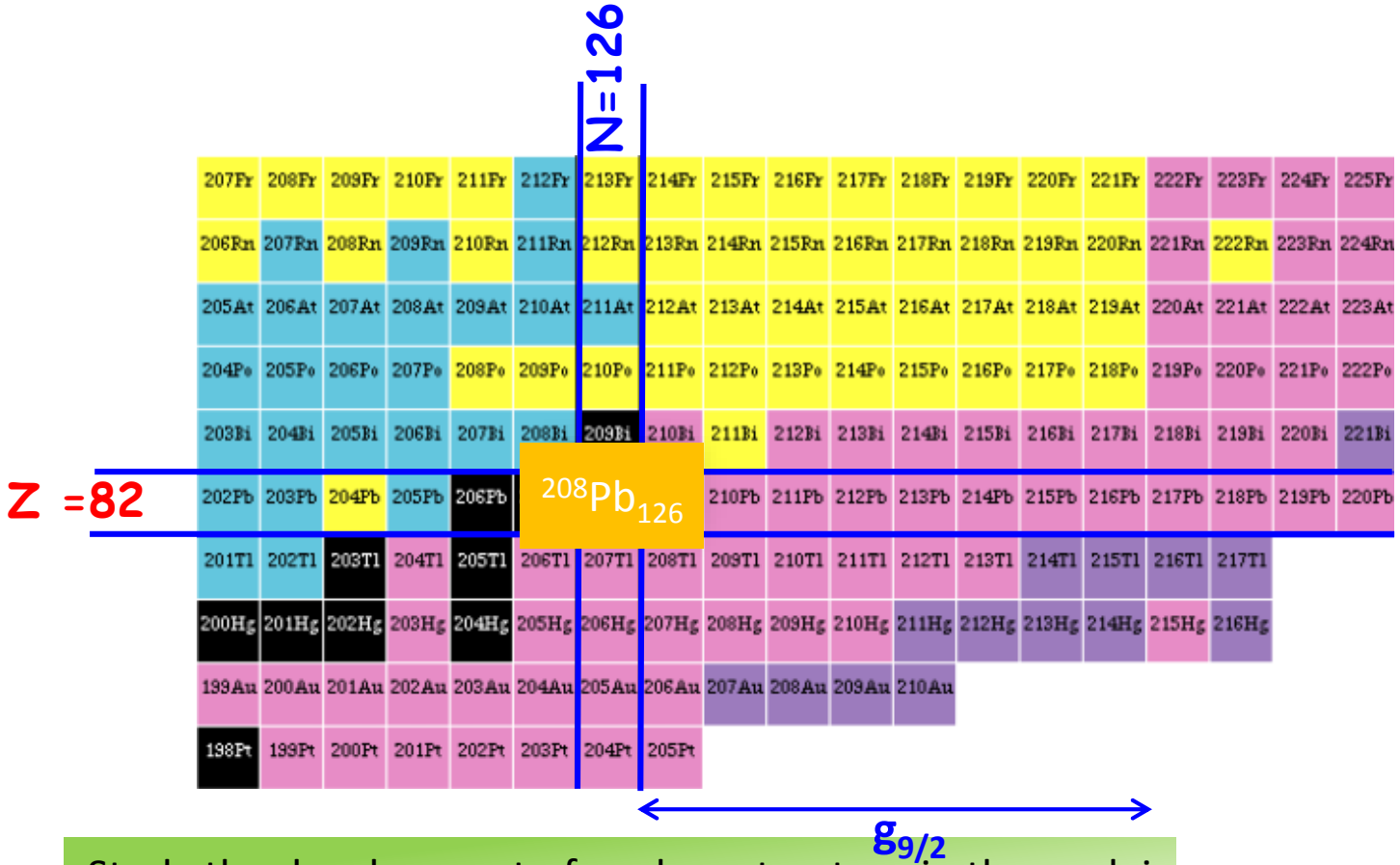
STATUS REPORT IS584

β-decay study of neutron-rich Tl and Pb isotopes

A. Gottardo, E. Rapisarda

11 shifts assigned in 2013

Nuclear structure beyond ^{208}Pb



Study the development of nuclear structure in the nuclei beyond N=126

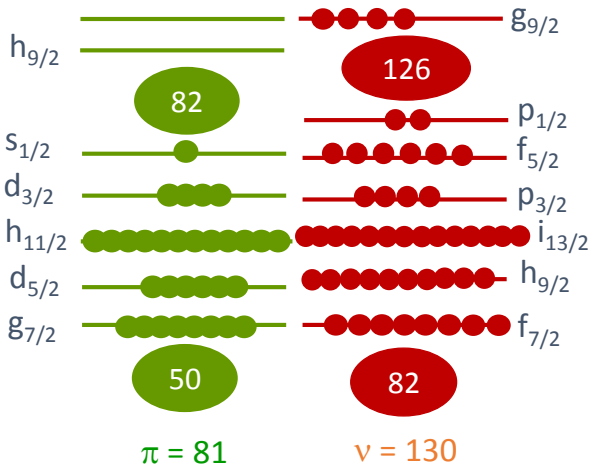
- What the position of the $d_{3/2}$ and $s_{1/2}$ proton orbitals?
- Can we explain with shell model what we observe ?

The region around Z=82 and N=126

The region around ^{208}Pb has been very difficult to populate experimentally due to its large A and Z.

- Lifetime measurements in ^{211,212,213}Tl
- Lifetime measurements in ^{218,219}Bi

  G. Benzoni et al., Phys. Lett. B715 (2012) 293
- Three high-spin isomers in ^{211}Pb and decay scheme — *G.J. Lane et al., Phys. Lett. B 606 (2005) 34*
- Isomeric states in ^{208}Hg and ^{210}Hg — *N. Al-Dahan et al., Phys. Rev. C80 (2009) 061302*; *A. Gottardo et al., Phys. Lett. B725 (2013) 292*
- Isomeric states in ^{212,214,216}Pb — *A. Gottardo et al., Phys. Rev. Lett. 109 (2012) 162502*
- Isomeric state in ^{209}Tl (95 ns) — *N. Al-Dahan et al., Phys. Rev. C80 (2009) 061302*
- Isomeric states in ^{211,213}Tl — *A. Gottardo et al., Phys. Rev. C. 109 (2019) 054326*



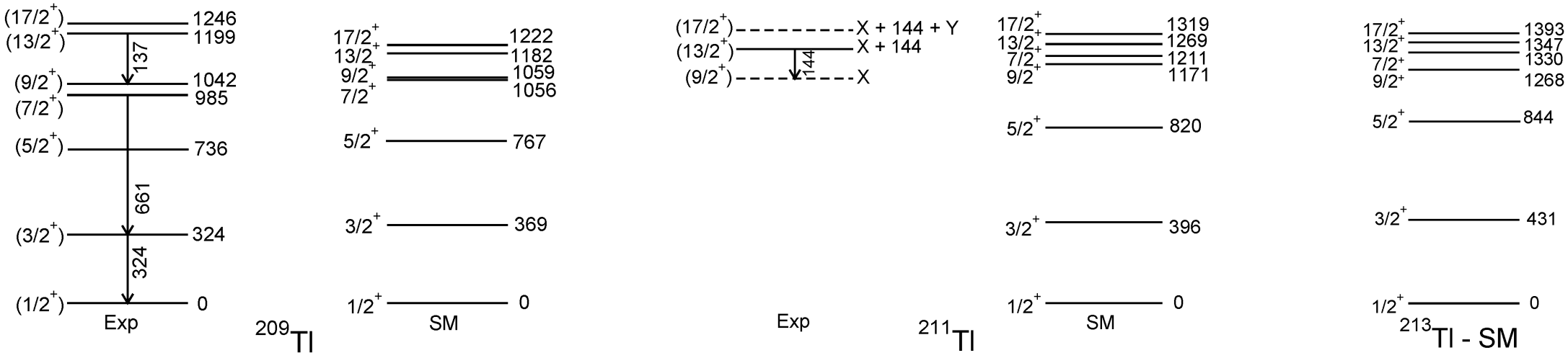
Seniority scheme

Experimental level scheme for $^{210\text{-}216}$Pb consistent with $\nu(g_{9/2})^n$ dominance
low-lying states in odd-mass Tl described as $\nu(g_{9/2})^2 \otimes \pi(s^{-1}_{1/2})$ or $\pi(d^{-1}_{3/2})$

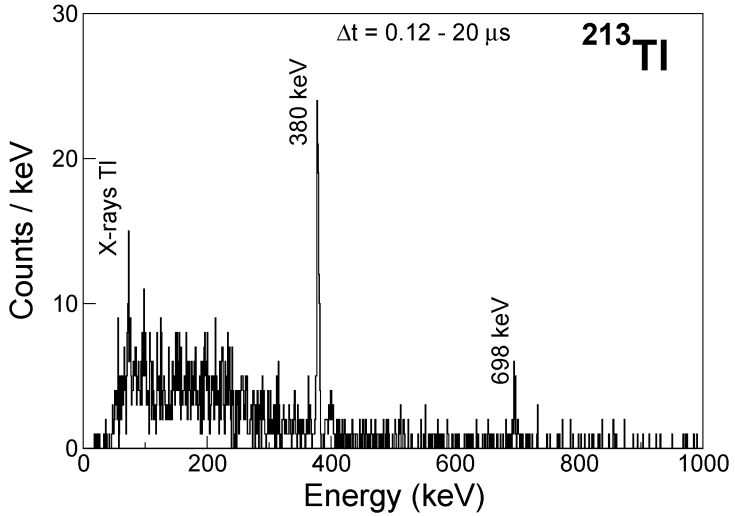
Inclusion of effective three-body forces is essential

A. Gottardo et al. PRL109, 162502 (2012)

Long-living isomer in ^{211,213}Tl ?

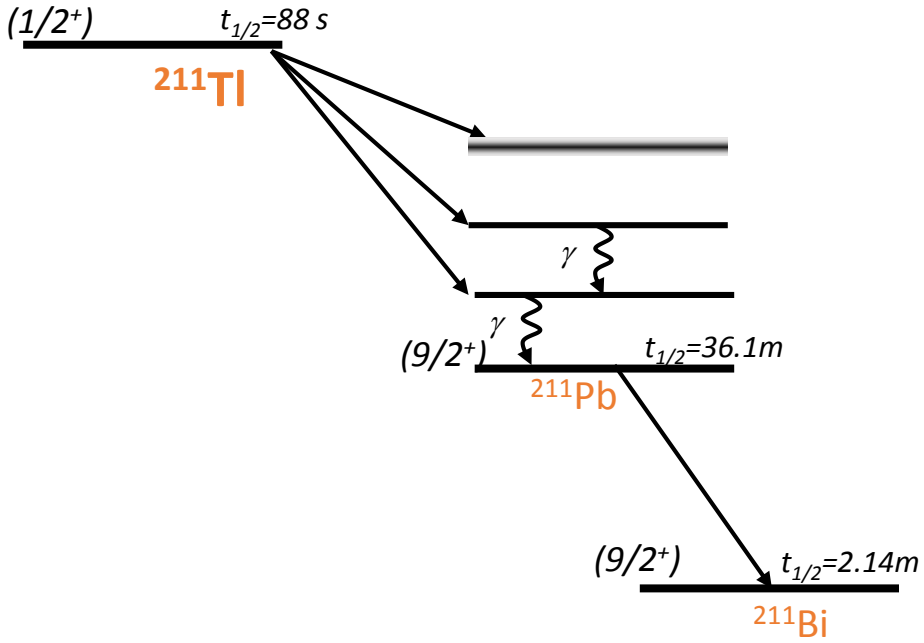


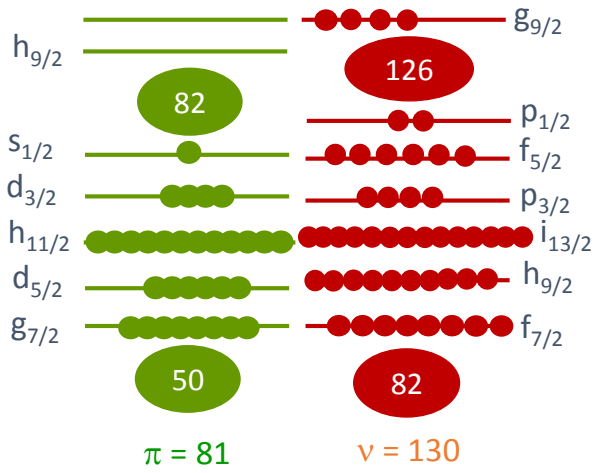
A. Gottardo et al., Phys. Rev. C. 109 (2019) 054326



- In ^{211}Tl maybe a long-living isomer due to a spin trap;
- In ^{213}Tl we do not understand what we observe: maybe a long-living isomer as well

Half-life of $^{211\text{-}213}$Tl





^{211}Tl $t_{1/2}$=88 s → *50% uncertainty*
^{212}Tl $t_{1/2}$=96 s → *50% uncertainty*
^{213}Tl $t_{1/2}$=46 s → *100% uncertainty*

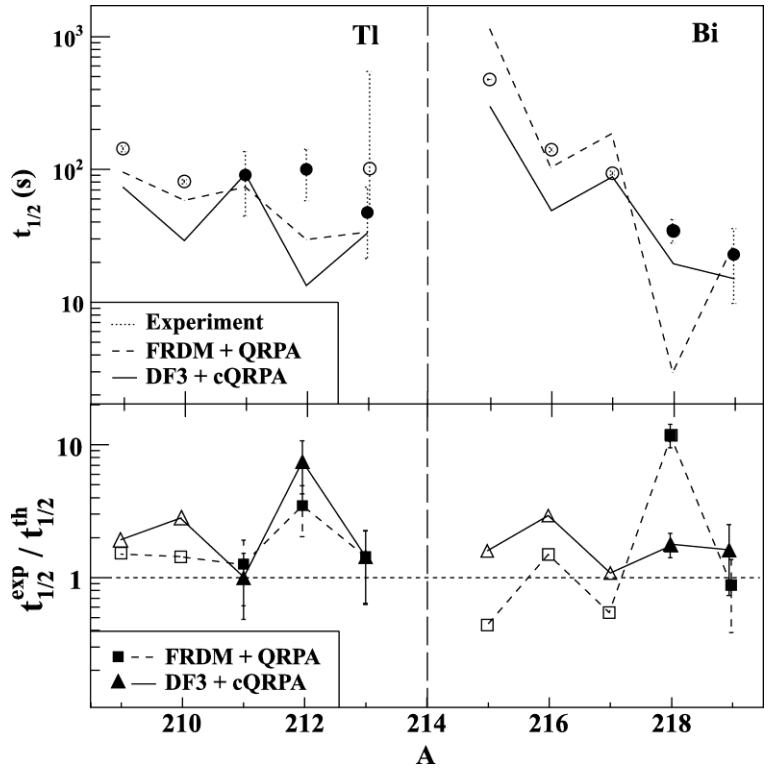
G. Benzoni et al., Phys. Lett. B715 (2012) 293

State-of-the-art models used in r-process calculations underestimate the experimental results

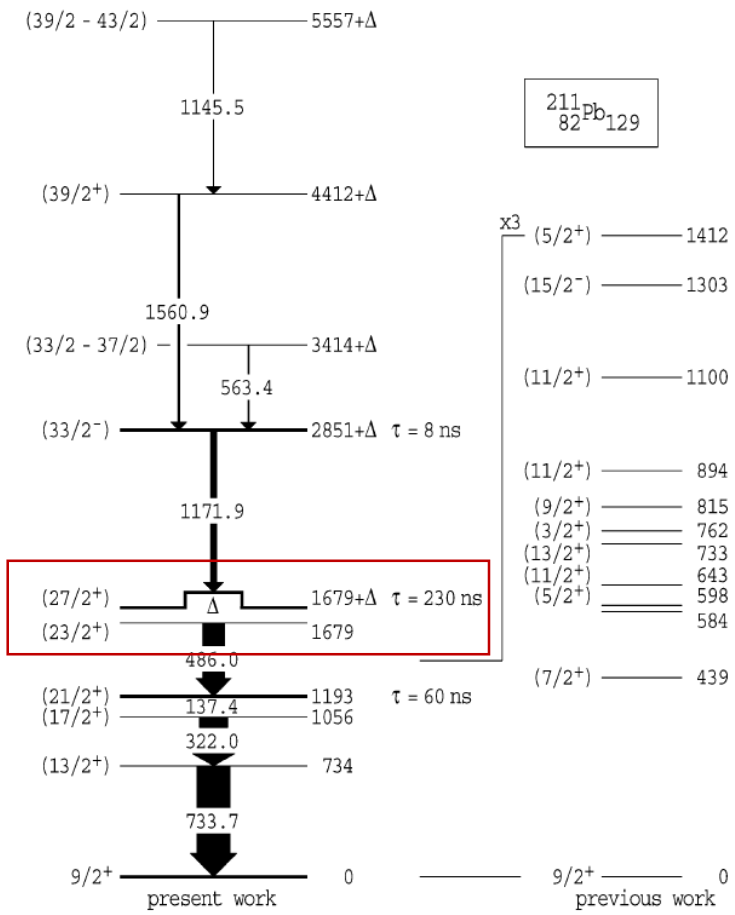
The β-decay would be dominated by high energy Gamow-Teller transitions from partially occupied neutron shells $3d_{5/2}$ or $4s_{1/2}$ above $g_{9/2}$

Low-lysing states in the daughter Pb can be populated and studied.

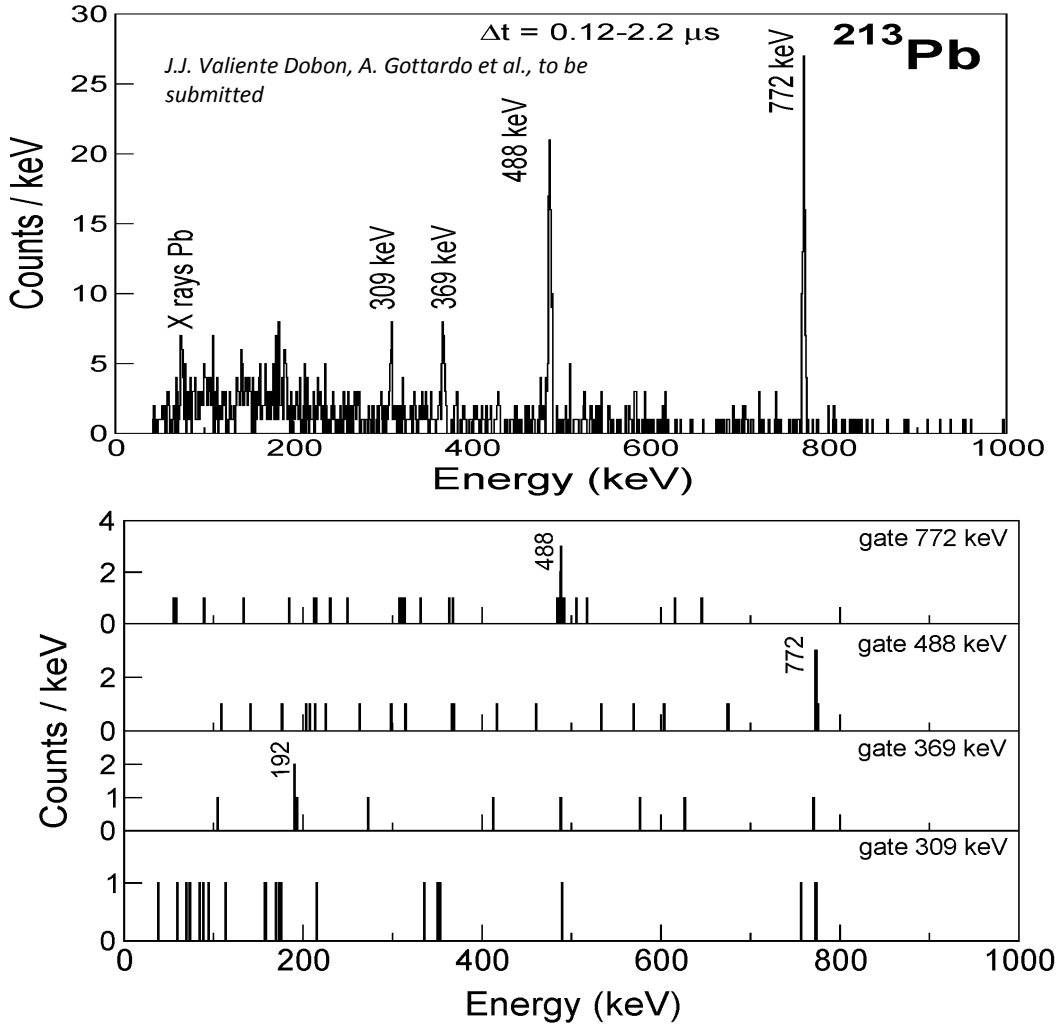
G. Benzoni et al., Phys. Lett. B715 (2012) 293



What is the situation in ^{213}Pb ?



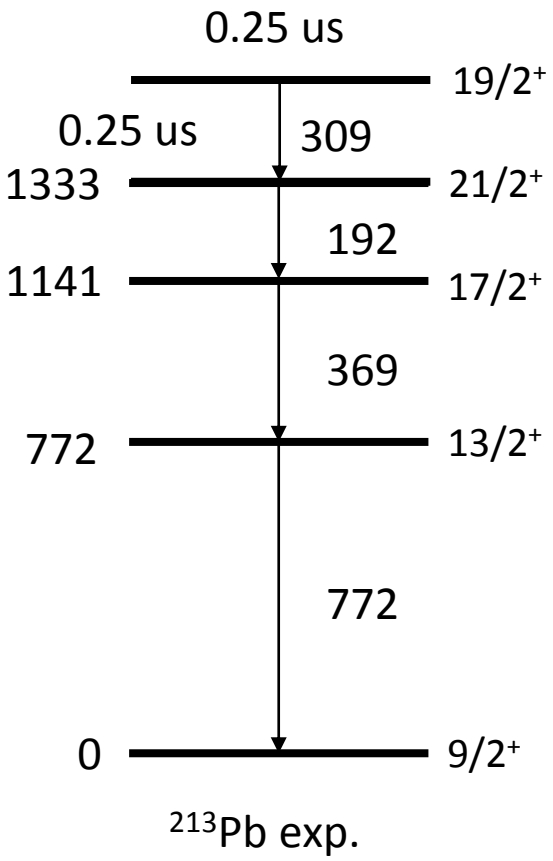
G.J. Lane et al., Phys. Lett. B 606 (2005) 34



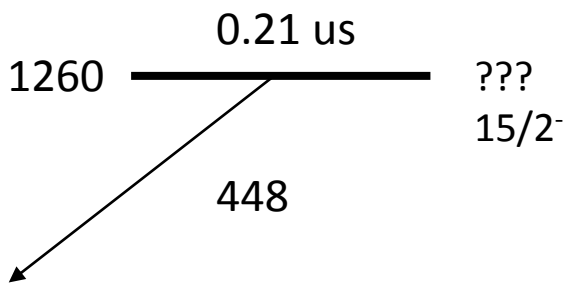
A. I. Morales et al. Phys. Rev. C 89, 014324 (2014): 675 keV line from 213Tl decay

- No experimental evidence of short-lived isomeric decay;
- If $(27/2)^+$ moves below $(23/2)^+$ → SPIN TRAP → Long living isomers in ^{213}Pb ???
- Observed structure is at variance with ^{211}Pb

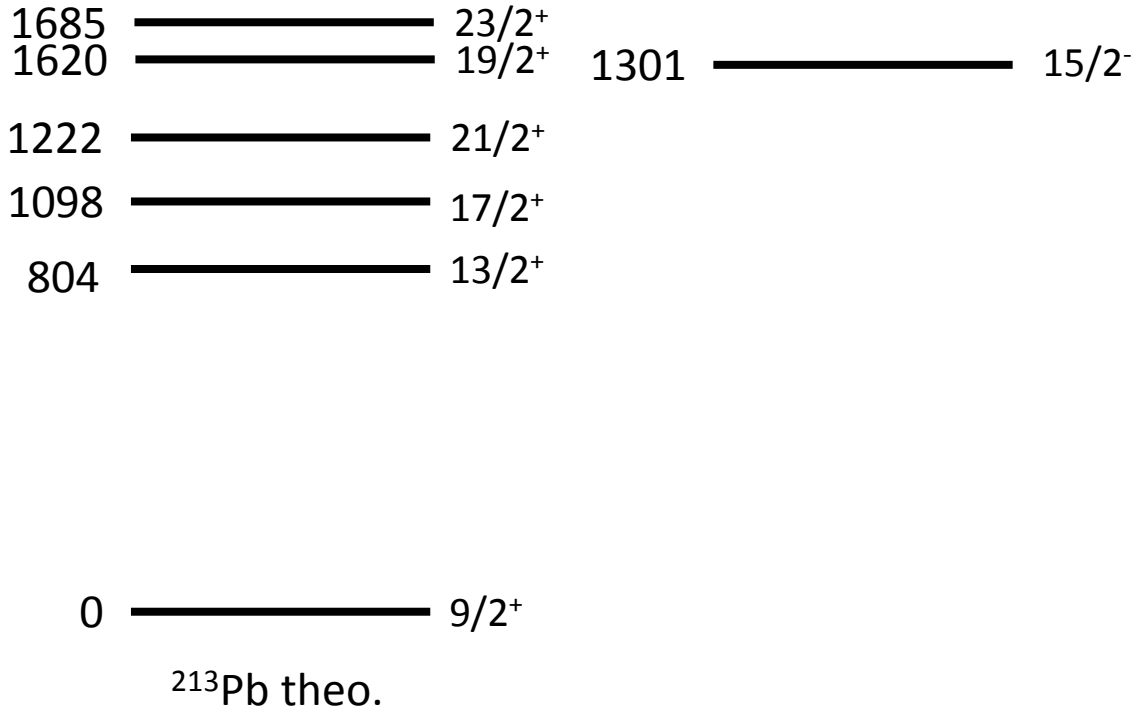
^{213}Pb: a possible level scheme



^{213}Pb exp.



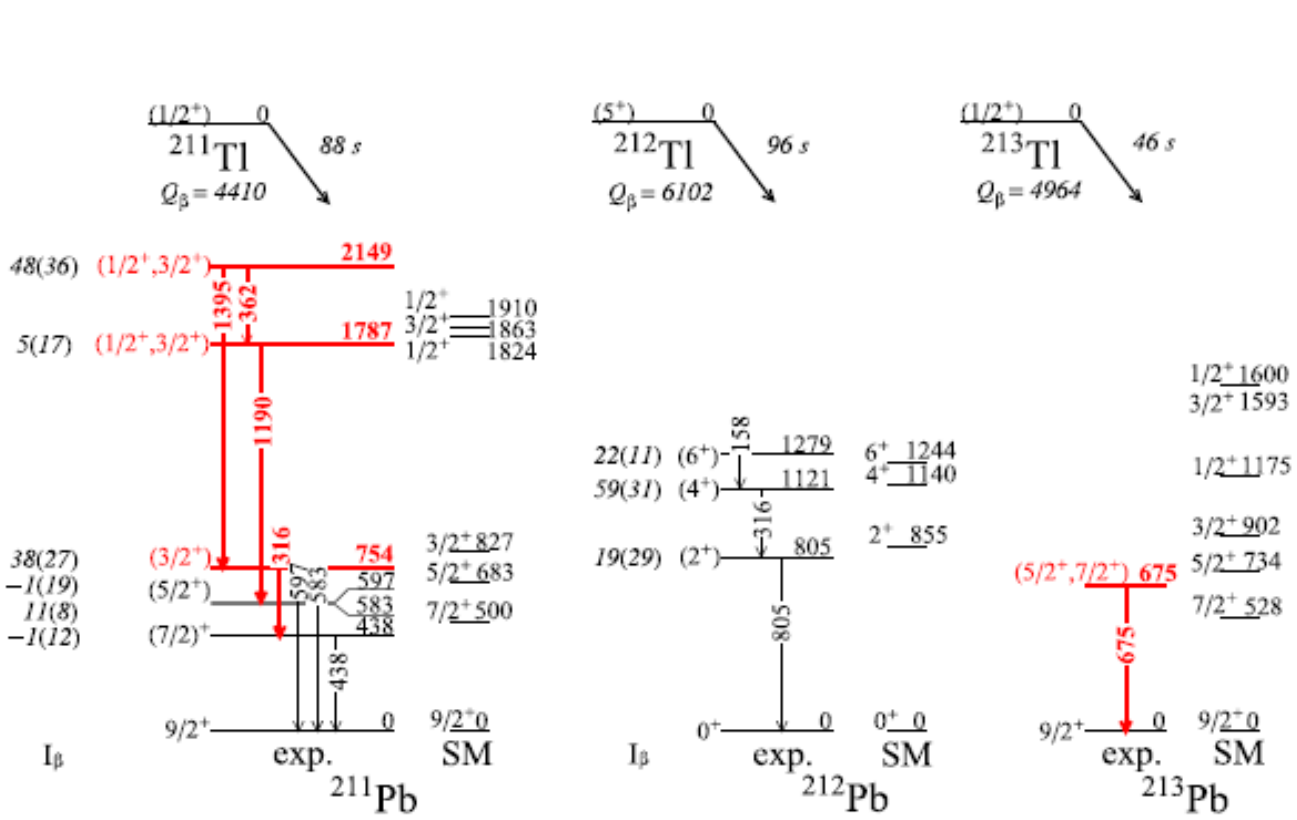
J.J. Valiente Dobon, A. Gottardo et al., to be submitted

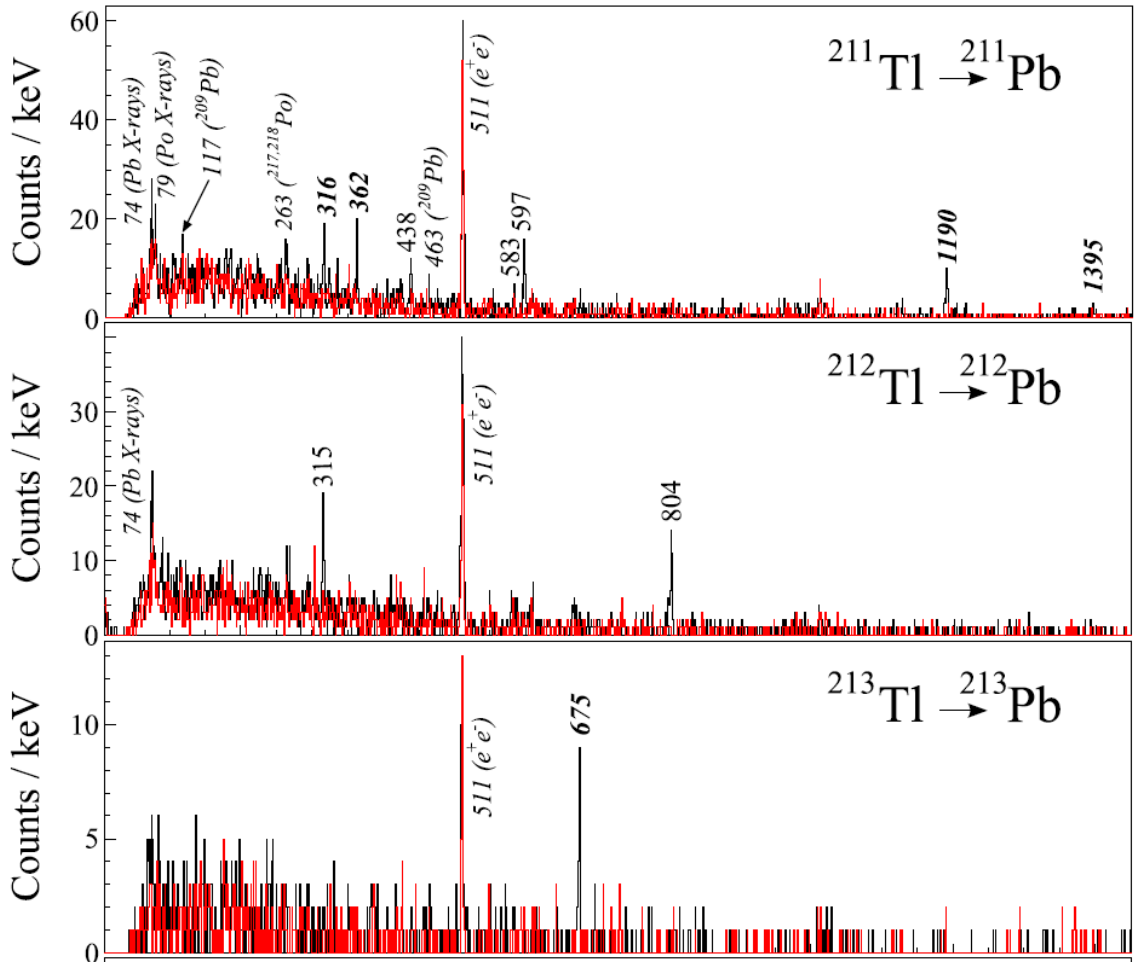


^{213}Pb theo.

$^{211\text{-}213}$Pb: low spins from beta decay

A. I. Morales et al. Phys. Rev. C 89, 014324 (2014)





Proposed experiment

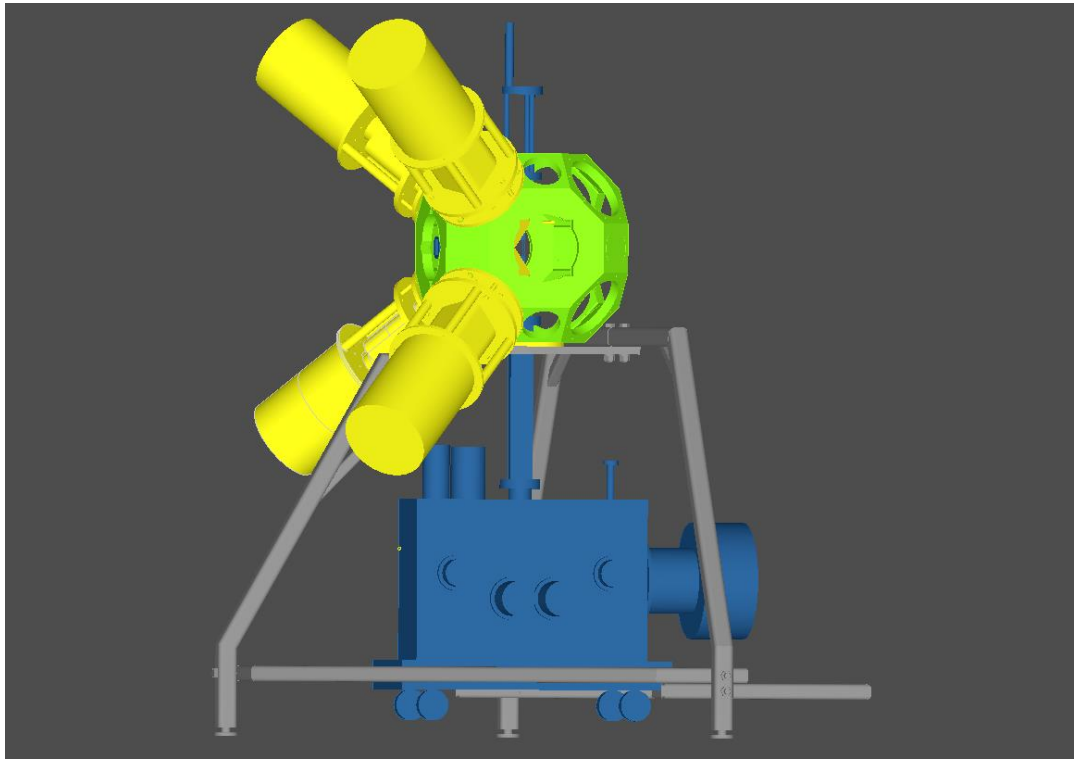
Laser Spectroscopy

AIM identify long-living isomers in ^{211,213}Tl and ^{213}Pb

Decay Spectroscopy

AIM

- decay scheme in $^{211\text{-}215}$Pb by β-decay Tl
- lifetime of $^{211\text{-}215}$Tl with 10% uncertainity



4 Clovers
1 Miniball Triple cluster:

Total γ detection efficiency is about 8-9% at 1.3MeV

Total β detection efficiency is about 60%

Beam Time Approval

UC_x Target + quartz transfer line + LIST target

- Laser Ionization: RILIS (27% and 7% for Tl and Pb respectively)
- Expected strong Fr and Ra contamination
  - HRS mass separator mandatory
  - Pulsed-release technique
  - We request therefore:

2 shifts for tuning the laser to Pb and Tl
4 shifts for laser - spectroscopy

Isotope	Rate on tape /s	Time	Expected n. counts
^{211}Tl	540	1 shift	$1 \cdot 10^5$
^{212}Tl	225	1 shift	$6 \cdot 10^4$
^{213}Tl	90	1 shift	$3 \cdot 10^4$
^{214}Tl	36	3 shifts	$3 \cdot 10^4$
^{215}Tl	12	6 shifts	$2 \cdot 10^4$
^{213}Pb	250	3 shifts	$2 \cdot 10^5$
^{215}Pb Reference	47 (*)		

6

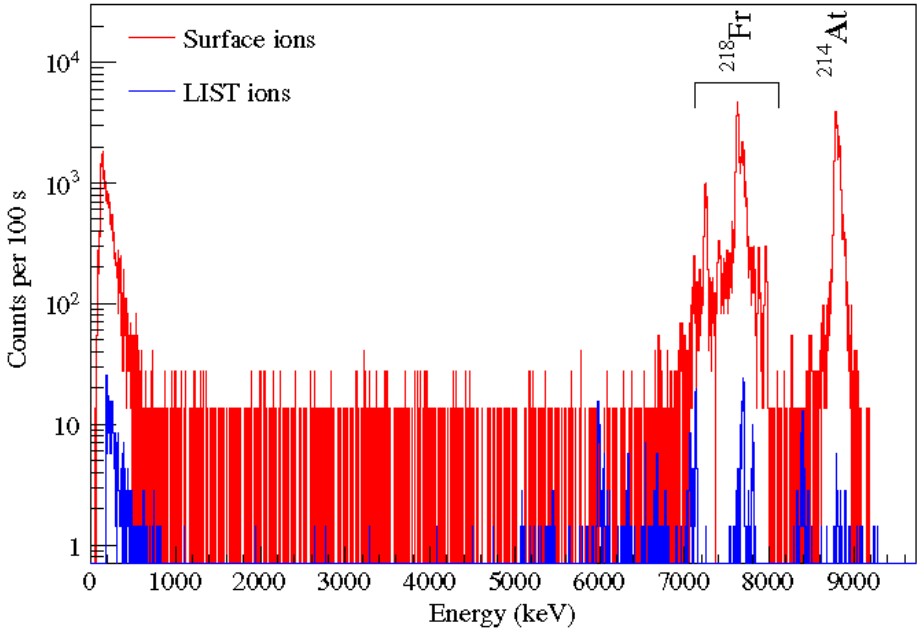
NOT approuved

(*) H. De Witte et al., Phys. Rev. C87 (2013) 067303

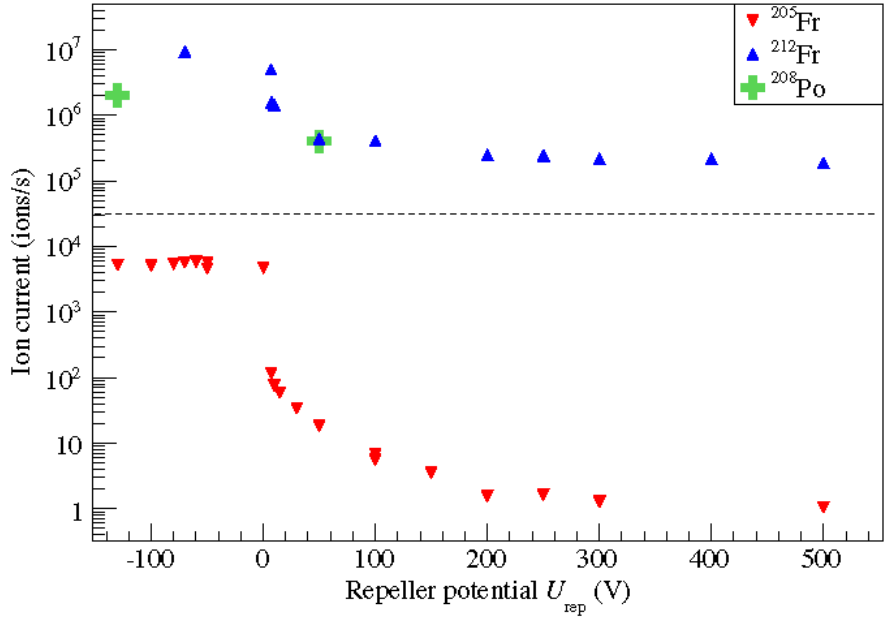
The Committee decided that authors should perform first the measurements with 211-213Tl and 213Pb, as well as the isomer search for 211,213Tl and 213Pb, and test the production of 214,215Tl. Based on the production rates for 214,215Tl, they should come-up with an addendum once the first part is completed. The committee recommended for the approval of the Research Board 11 shifts for the studies of 211-213Tl and 213Pb and yield tests of 214,215Tl.

What has been done for Fr, Ra suppression

D. A. Fink et al., Phys. Rev. X 5, 011018 (2015)



Fr present only in trace in LIST mode at A=218



At A=212 the situation is more challanging: only a factor 70 suppression, but possibility of further suppression with the mass separator (50 eV acceptance)

TAC report

This will require development before scheduling.
The LIST has shown 10E6 suppression for Na. However, the degree of suppression has been observed to change with isotope online with UC target. The reason for this is still not completely understood. Double repeller list may suppress e-impact ionization.
This is a TISD candidate for LIST test. Test required for Tl transmission through quartz line. In addition a technical development is needed to produce a LIST incorporating a quartz line.
After LS2 LIST available on HRS. Could this be enough to cut isobars ?

Could molecular beams be an option? (only if suppression is not enough/not enough Tl laser ionization)
Tl(I) iodide. IP 8.5eV. Boiling Point 824C
Could be tested offline. However, note that this will likely result in RaF (among others) as a contaminant.

Collaboration

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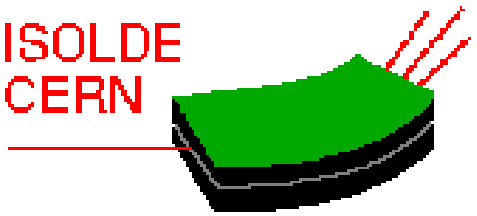

A. I. Morales et al. Phys. Rev. C 89, 014324 (2014)