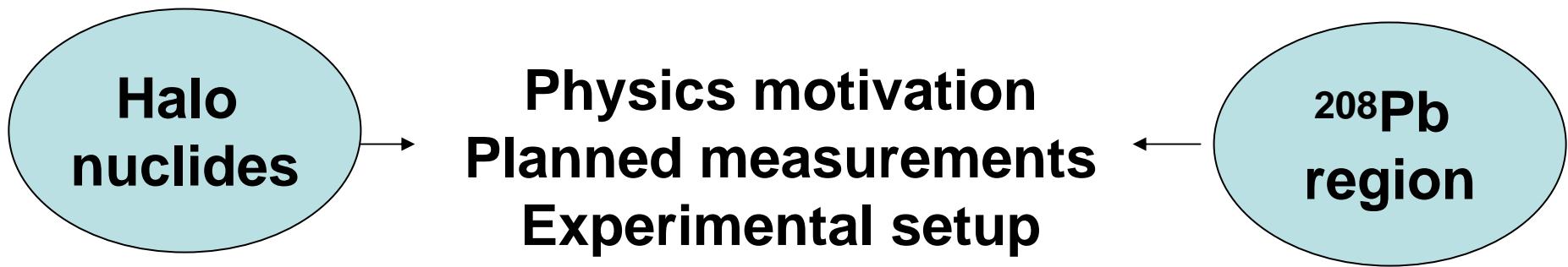
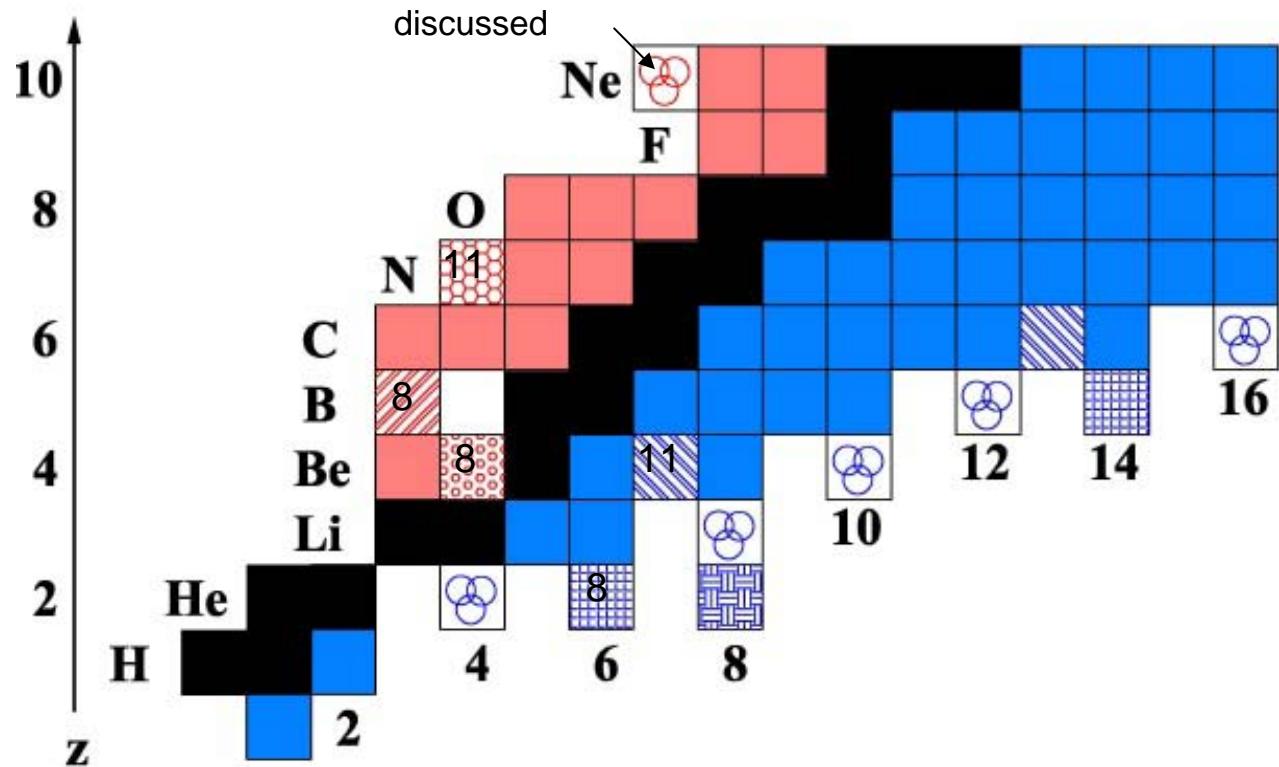


Masses of halo nuclides and decay-spectroscopy in the lead region: new developments at ISOLTRAP



Region of interest I

Halo nuclides
and
their masses



nuclide	half-live	mass uncert.	rel. uncert.	yield
^6He	0.8 s	0.8 keV	1.3e-7	5e7 (UCx)
^8He	0.12 s	7 keV	9e-7	5e5 (UCx)
^{11}Be	13.8 s	6 keV	6e-7	5e6 (UCx)
^{14}Be	4 ms	140 keV	1.0e-5	5 (UCx)
^{11}Li	9 ms	19 keV	2e-6	1-3e3 (Ta)

Motivation

Crucial for precise derivation of charge radii

Isotope shift = mass shift + field shift

$$\delta\nu^{A,A'} = K \times \frac{M' - M}{M' M} + F \times \delta\langle r^2 \rangle^{A,A'}$$

Recent results for the
charge radii of He isotopes:
(P. Müller et al., 2007)

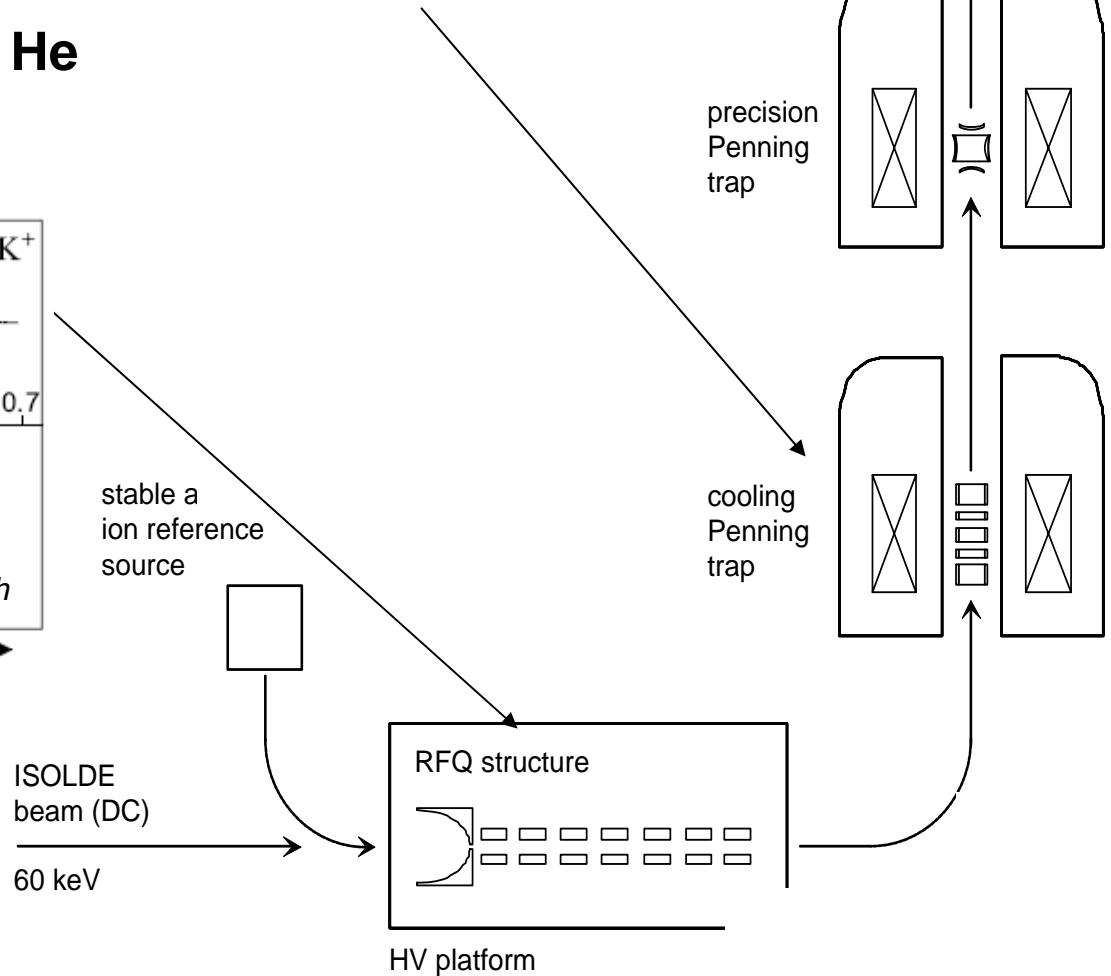
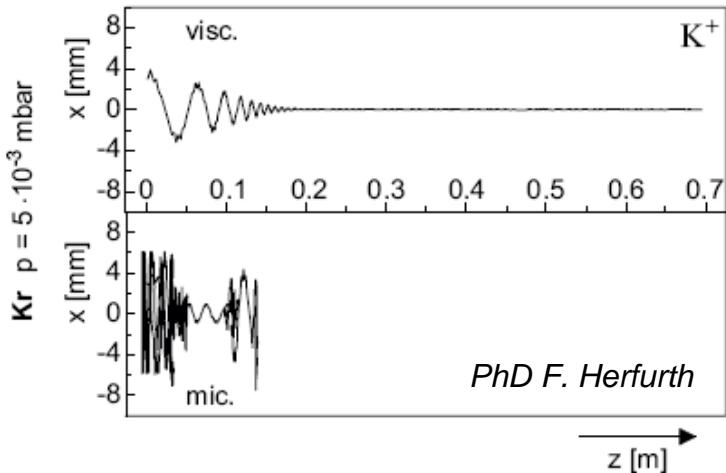
	⁶ He	⁸ He
Field Shift, MHz	-1.464(34)	-0.916(95)
RMS R _{CH} , fm	2.068(11)	1.929(26)
Total Uncertainty	0.5 %	1.3 %
- Statistical	0.1 %	0.6 %
- Systematic	0.3 %	0.6 %
- Nuclear Mass	0.2 %	1.0 %
- He-4: 1.676(8) fm	0.3 %	0.4 %

Modifications to the setup

Cooling with Ne instead of He
(to avoid resonant charge exchange)

Cooling with H₂ instead of He

(to avoid rf heating and
resonant charge exchange)



New cooling parameters
Safety issues

Status and outlook I

**All necessary equipment at ISOLTRAP:
 H_2 , automatic valve, H_2 detector,**

Cooling simulations in progress

Safety inspection to be done

Tests with Li and He cooling to come

Measurements planned for early 2008: start with He

Region of interest II

n-rich mercury and thallium isotopes above N=126

208 83 Bi 125	209 83 Bi 126	210 83 Bi 127	211 83 Bi 128	212 83 Bi 129	213 83 Bi 130	214 83 Bi 131	215 83 Bi 132	216 83 Bi 133	217 83 Bi 134	218 83 Bi 135				
2.9 m 12 ⁺ β ⁻ =100% IT=100%	368 keV (5) M = 18258.5 (1.4) Abundance=100% α=100%	19 Eyr 9/2 ⁺ M = 18258.5 (1.4) Abundance=100% α=100%	57.5 ms 1 ⁺ β ⁻ =100% IT=100%	5824 fm β ⁻ =100% IT=100%	1.4 ns 9/2 ⁺ β ⁻ =100% IT=100%	7.6 m 15 β ⁻ =100% IT=100%	25.0 m 9/2 ⁺ β ⁻ =100% IT=100%	45.59 m 9/2 ⁺ M = 5231 (5) β ⁻ =97.91 (3%) α=2.09 (3%)	19.9 m 1 ⁺ M = 1200 (11) β ⁻ =100% α=0.021 (1%)	38.4 m 25/2 ⁺ M = 1347.2 (5) IT=2? β ⁻ =100%	7.6 m 9/2 ⁺ M = 1648 (15) β ⁻ =?	2.17 m 1 ⁺ # M = 5874 (11) β ⁻ =100%	97 s 9/2 ⁺ # M = 8820# (200#) β ⁻ =100%	33 s 1 ⁺ # M = 13340# (360#) β ⁻ =100%
207 82 Pb 125	208 82 Pb 126	209 82 Pb 127	210 82 Pb 128	211 82 Pb 129	212 82 Pb 130	213 82 Pb 131	214 82 Pb 132	215 82 Pb 133						
808 ms 12 ⁺ β ⁻ =100% IT=100%	stable 1/2 ⁺ M = 22415 (1.2) Abundance=100% α=100%	500 ns 10 ⁺ stable 0 ⁺ M = 21748.5 (1.2) Abundance=100% α=100%	3.253 h 9/2 ⁺ M = 17614.4 (1.7) β ⁻ =100% IT=100%	201 ns 4 ⁺ M = 12181.0 (1.7) β ⁻ =100% IT=100%	22.9 s 3 ⁺ M = 16038.0 (1.7) β ⁻ =100% IT=100%	36.1 m 9/2 ⁺ M = 10491.4 (2.7) β ⁻ =100% IT=100%	5.0 s 8 ⁺ M = 10540.0 (2.7) β ⁻ =100% IT=100%	10.64 m 0 ⁺ M = 26747.0 (2.7) β ⁻ =100% IT=100%	10.2 m 9/2 ⁺ M = 3184 (8) β ⁻ =100% IT=100%	26.8 m 0 ⁺ M = 181.3 (2.4) β ⁻ =100% IT=100%	2.45 m 5/2 ⁺ # M = 4480# (410#) β ⁻ =100%			
206 81 Tl 125	207 81 Tl 126	208 81 Tl 127	209 81 Tl 128	210 81 Tl 129	211 81 Tl 130	212 81 Tl 131								
3.74 m (12) β ⁻ =100% IT=100%	4.200 s 0 ⁺ M = 2225 (1.4) β ⁻ =100%	1.03 x 10 ² β ⁻ =100% IT=100%	4.77 m 1/2 ⁺ M = 21934 (5) β ⁻ =100%	3.053 m 5 (1) M = 16749.5 (2.0) β ⁻ =100%	2.161 m (1/2 ⁺) M = 13638 (8) β ⁻ =100%	1.30 m 5 (1) M = 9246 (12) β ⁻ =100% IT=0.009 (6%)	1# m 1/2# M = 6080# (200#) β ⁻ ?	30# s 5# M = 1650# (300#) β ⁻ ?						
205 80 Hg 125	206 80 Hg 126	207 80 Hg 127	208 80 Hg 128	209 80 Hg 129	210 80 Hg 130									
1.12 ms (32) β ⁻ =100% IT=100%	52 m 10 ⁺ M = 22287 (4) β ⁻ =100%	8.15 ms 4 ⁺ M = 20946 (20) β ⁻ =100%	2.9 m (9/2 ⁺) M = 16220 (150) β ⁻ =100%	42 m 0 ⁺ M = 13100# (300#) β ⁻ =100%	37 s 9/2# M = 8350# (200#) β ⁻ =100%	10# s 0 ⁺ M = 5110# (300#) β ⁻ ?								
204 79 Au 125	205 79 Au 126													
39.8 s (2) M = 20750# (200#) β ⁻ =100%	31 s 3/2 ⁺ M = 18750# (300#) β ⁻ =100%													

N=126

Problem: very large contamination from surface-ionized francium

Solution: use ISOLTRAP to purify the beam

Z=82

Physics motivation

Proximity of Z=82 and N=126 shell closures, but very little data available in this quadrant of the nuclear chart

Our observables:

Masses and beta-decay schemes of Hg and Tl isotopes

Will provide:

Test-ground for different mass formulas

Missing dV_{pn} values => interaction of the last two protons and neutrons

Input for the shell model: for the poorly known interaction between neutrons and proton-holes around Z=82 and N=126

Energies and evolution of single-particle levels around ^{208}Pb

Possibly evidence of new isomers and even new isotopes

Experimental setup

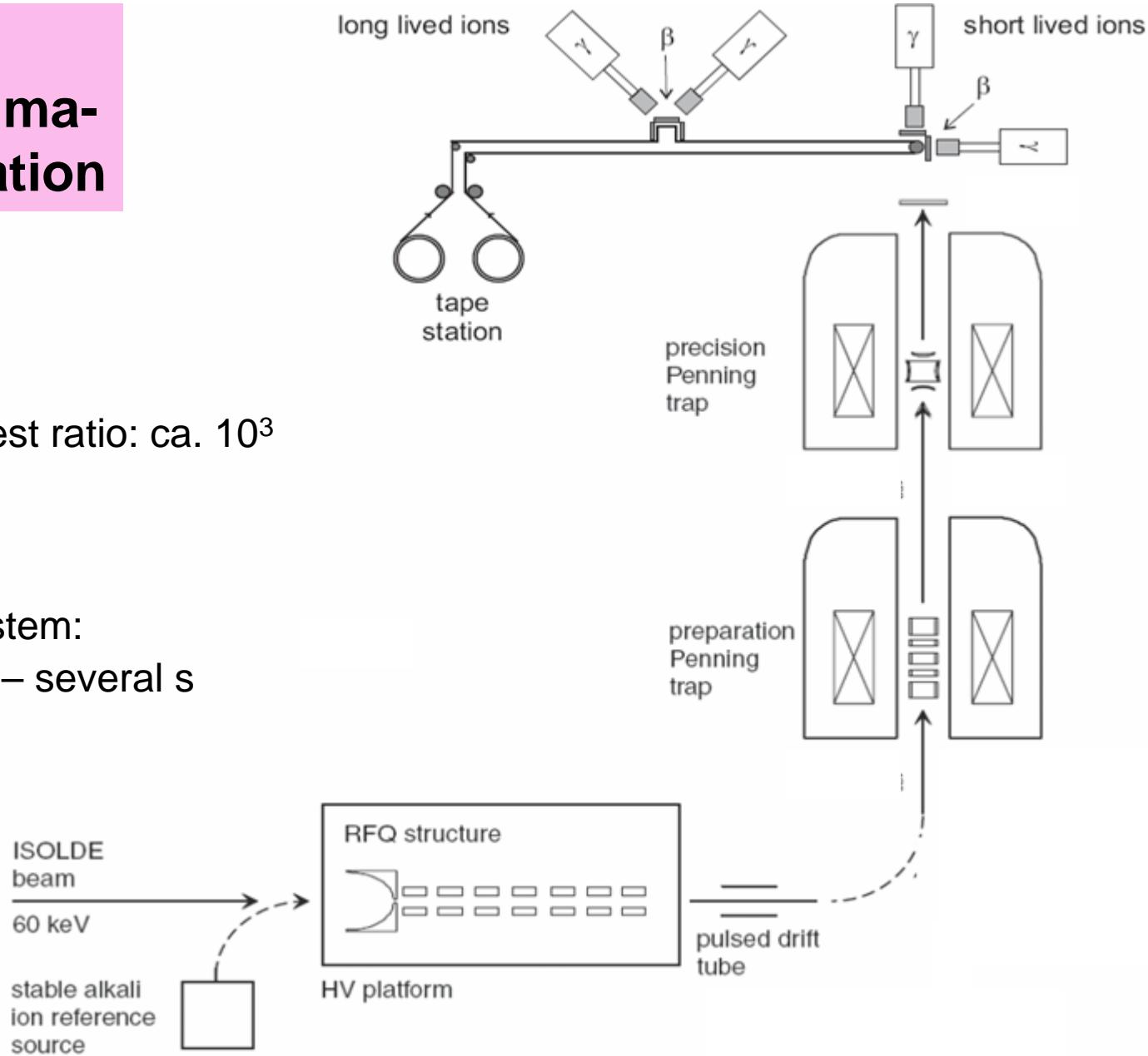
ISOLTRAP + beta- and gamma- decay tape station

ISOLTRAP:

Current limit on
isobar/beam-of-interest ratio: ca. 10^3

Efficiency: ca. 15%

Time spent in the system:
several hundred ms – several s



Status and outlook II

Tape-system (from GSI) already existing,
and tested at ISOLDE

Vacuum chambers for measurements
on short-lived ions almost complete

Ion optics machined

Parts still missing:
tape-transport system
Beta-scintillators
Detector support

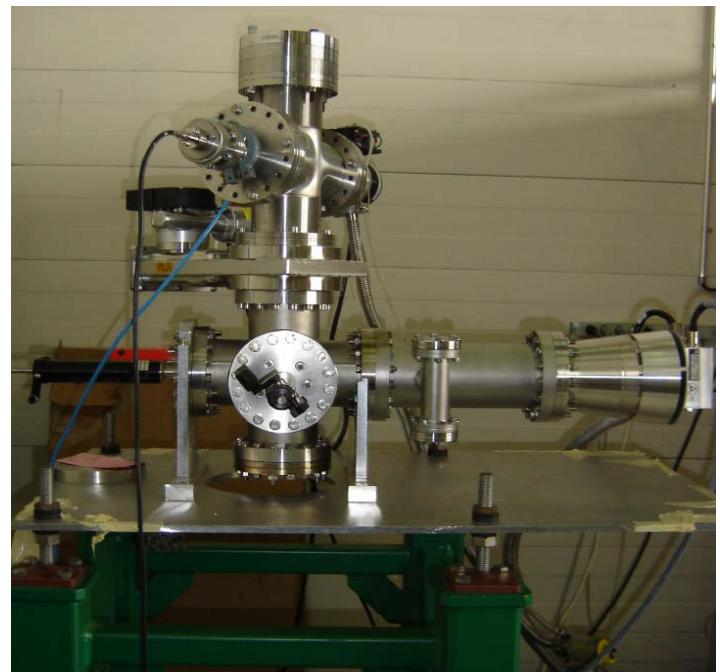


Next year: Installation at ISOLTRAP

A proposal was accepted in May and
measurements are planned for 2008:

19 shifts for mass measurements and decay
studies on $^{207-210}\text{Hg}$

3 shifts for production and contamination tests on
 $^{208-214}\text{Tl}$



Collaborators:

The ISOLTRAP team:

CERN–Greifswald–GSI–Heidelberg–Mainz–MSU–Orsay

S. Naimi, D. Beck, K. Blaum, M. Breitenfeldt,
S. George, F. Herfurth, A. Herlert, A. Kellerbauer, H.-J. Kluge,
D. Lunney, D. Neidherr, S. Schwarz, L. Schweikhard

Other teams presently involved in the decay spectroscopy project:
CERN–Leuven–Madrid–Orsay–Valencia

A. Agora, L.M. Fraile, G. Georgiev, M. Huyse, K. Riisager, B.
Rubio, P. Van Duppen

Thanks for your attention

Questions?

Reference nuclei: ${}^4\text{He}$, ${}^7\text{Li}$

Expected uncertainty: stat& systematic

Targets & ion sources

PSB data

Isotope	Yield (ions/ μ C)	Target	Target thickn. (g/cm 2)	Ion Source
^6He	2.6E+06	CaO (CaO powder)	5	MK7
	4.6E+06	CeO _x (CeOx fibers)	14	MK7
	3.0E+06	MgO (MgO powder)	2.5	MK7
	1.9E+06	La ₂ O ₃ (La2O3 powder)	64	MK7
	4.0E+05	SrO (SrO powder)	18	MK7
	2.8E+06	TiO ₂ (TiOx fibers)	7.3	MK7
	4.7E+07	UC _x (UC2/graphite)	54	MK7
	5.2E+05	ZrO ₂ (ZrO2 fibers)	8	MK7
	2.1E+07	ThC _x (ThC2/graphite)	57	MK7
^8He	1.1E+04	CaO (CaO powder)	5	MK7
	2.4E+04	CeO _x (CeOx fibers)	14	MK7
	4.7E+05	UC _x (UC2/graphite)	54	MK7
	1.8E+03	ZrO ₂ (ZrO2 fibers)	8	MK7
	6.0E+03	TiO ₂ (TiOx fibers)	7.3	MK7
	1.2E+04	MgO (MgO powder)	2.5	MK7

Targets & ion sources

PSB data

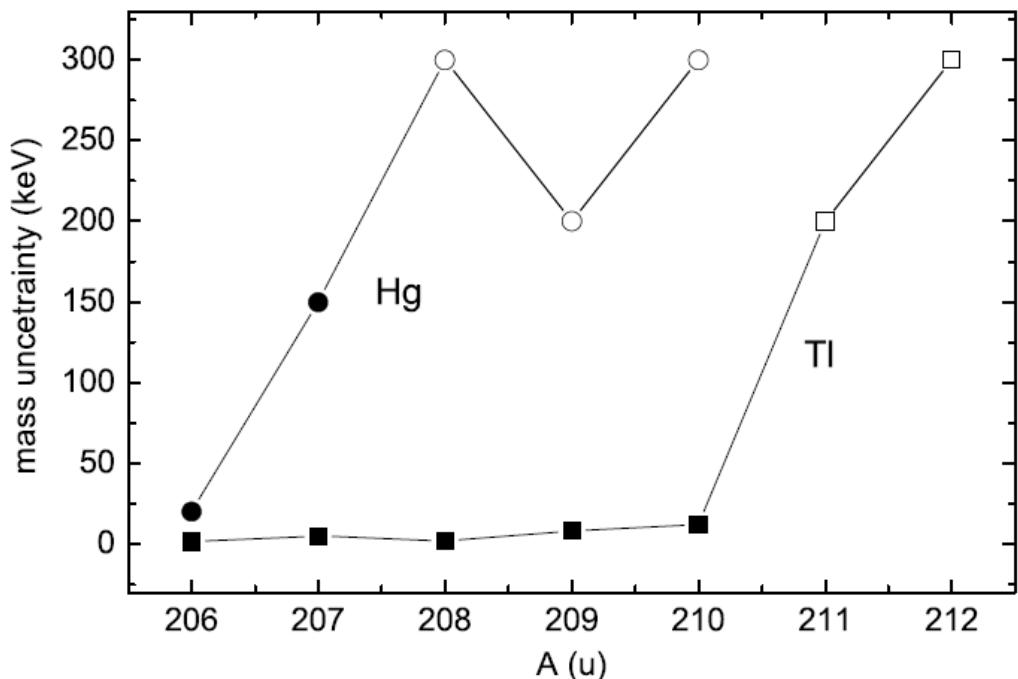
Isotope	Yield (ions/ μ C)	Target	Target thickn. (g/cm 2)	Ion Source
^{7}Be	1.4E+10	UC _x (UC2/graphite)	52	RILIS
	2.0E+12	C (Irradiated graphite from PSI)		RILIS
^{10}Be	6.0E+09	UC _x (UC2/graphite)	52	RILIS
	4.9E+08	Ta (thin Ta foil)	9.9	RILIS
	2.0E+12	C (Irradiated graphite from PSI)		RILIS
^{11}Be	7.0E+06	UC _x (UC2/graphite)	52	RILIS
	3.4E+06	Ta (thin Ta foil)	9.9	RILIS
^{12}Be	1.5E+03	UC _x (UC2/graphite)	52	RILIS
	7.0E+03	Ta (thin Ta foil)	9.9	RILIS
^{14}Be	4.0E+00	UC _x (UC2/graphite)	52	RILIS
	6.1E+00	Ta (thin Ta foil)	9.9	RILIS

Targets & ion sources

PSB data

Isotope	Yield (ions/ μ C)	Target	Target thickn. (g/cm ²)	Ion Source	Isotope
⁸ Li	5.8E+08	PSB	Ta (thin Ta foil)	8.8	WSI
⁹ Li	1.7E+07	PSB	Ta (thin Ta foil)	8.8	WSI
¹¹ Li	7.0E+03	PSB	Ta (thin Ta foil)	8.8	WSI
	5.0E+02	PSB	Ta (Ta foil rolls)	111	WSI
	2.5E+03	PSB	Ta (Ta foil discs)	149	WSI

Knowledge in the region



Masses

No direct measurements

G. Audi, A.H. Wapstra, and C. Thibault.
Nuclear Physics A, 729:337, 2003

Structure data

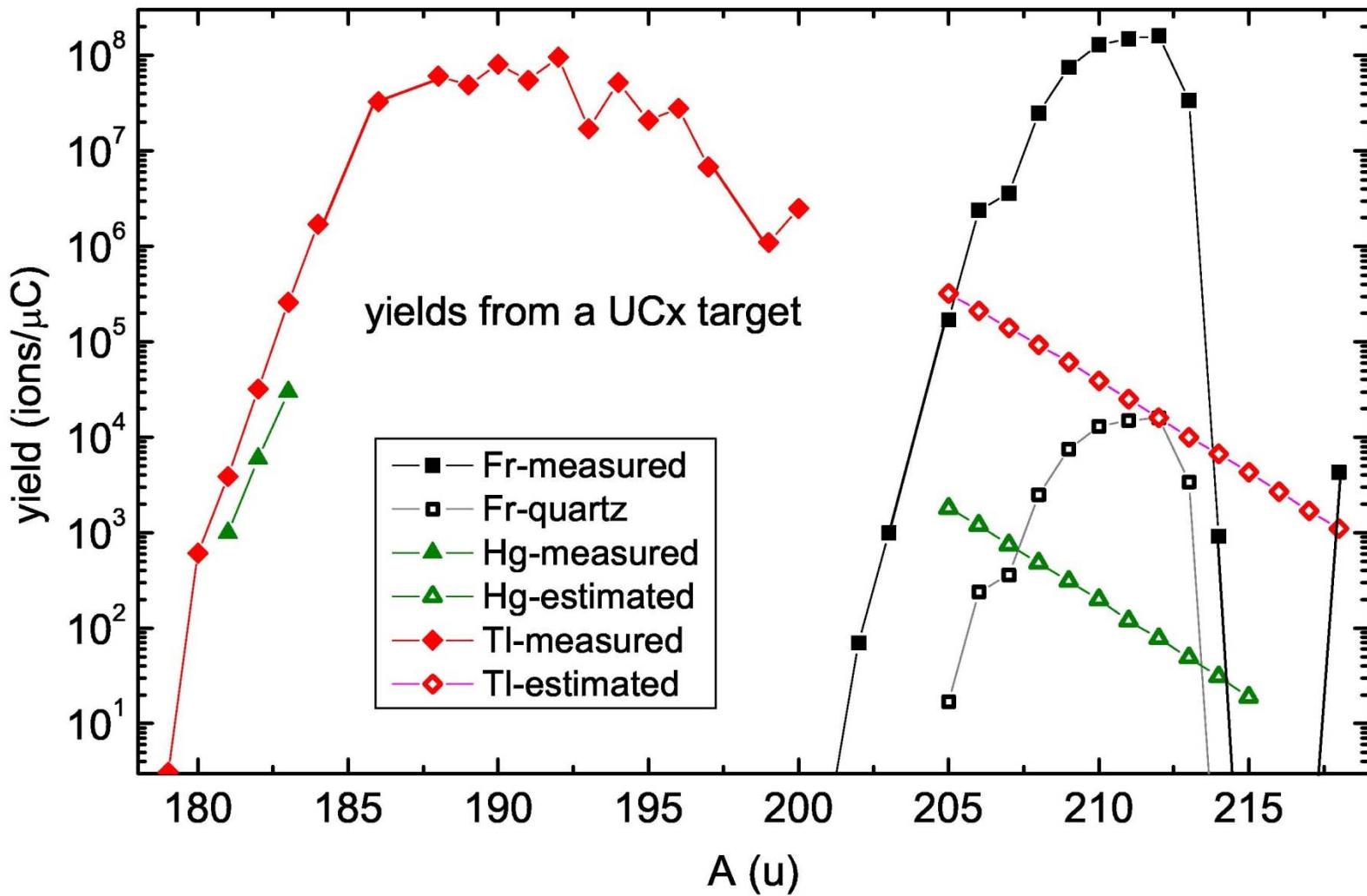
		124	126	128	130	132
Pb	82	206 207 208	209 $\alpha, \beta, 9/2^+$	210 $\alpha, \beta, 0^+$	211 $\alpha, 9/2^+$	212 $\alpha, 0^+$
Tl	81	205 206 $\alpha, \beta, 0^-$	207 $\alpha, \beta, 1/2^+$	208 $\alpha, \beta, 5^+$	209 $\alpha, (1/2^+)$	210 $\alpha, 5^{\#}$ 211 $1/2^{\#}$ 212

M. Pfützner et al. *Physics Letters B*, 444:32, 1998.

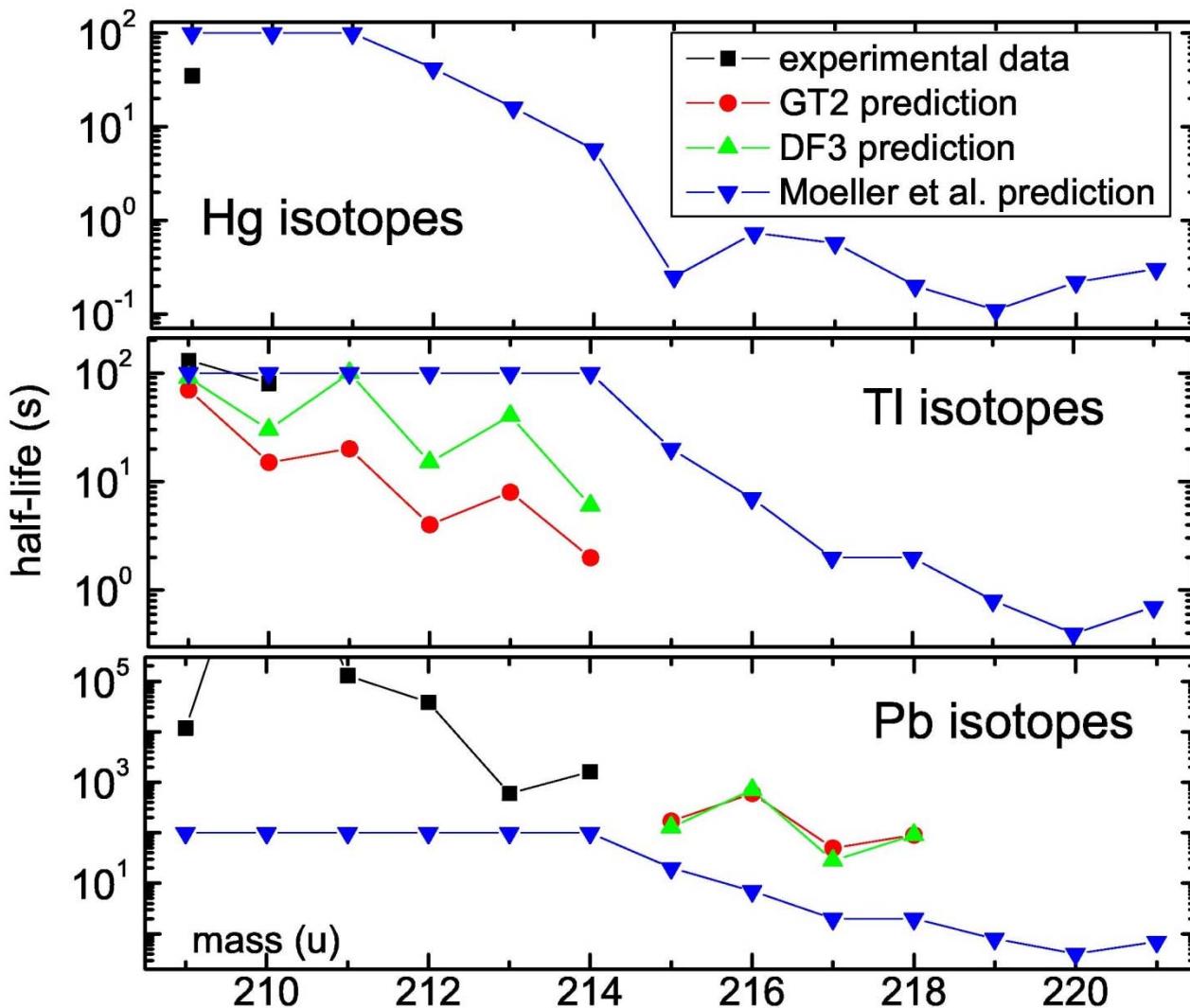
L. Zhang et al. *European Physical Journal A*, 16:299, 2003.

R. Firestone et al. *Table of Isotopes: 1999 update*. 1999.

Yields



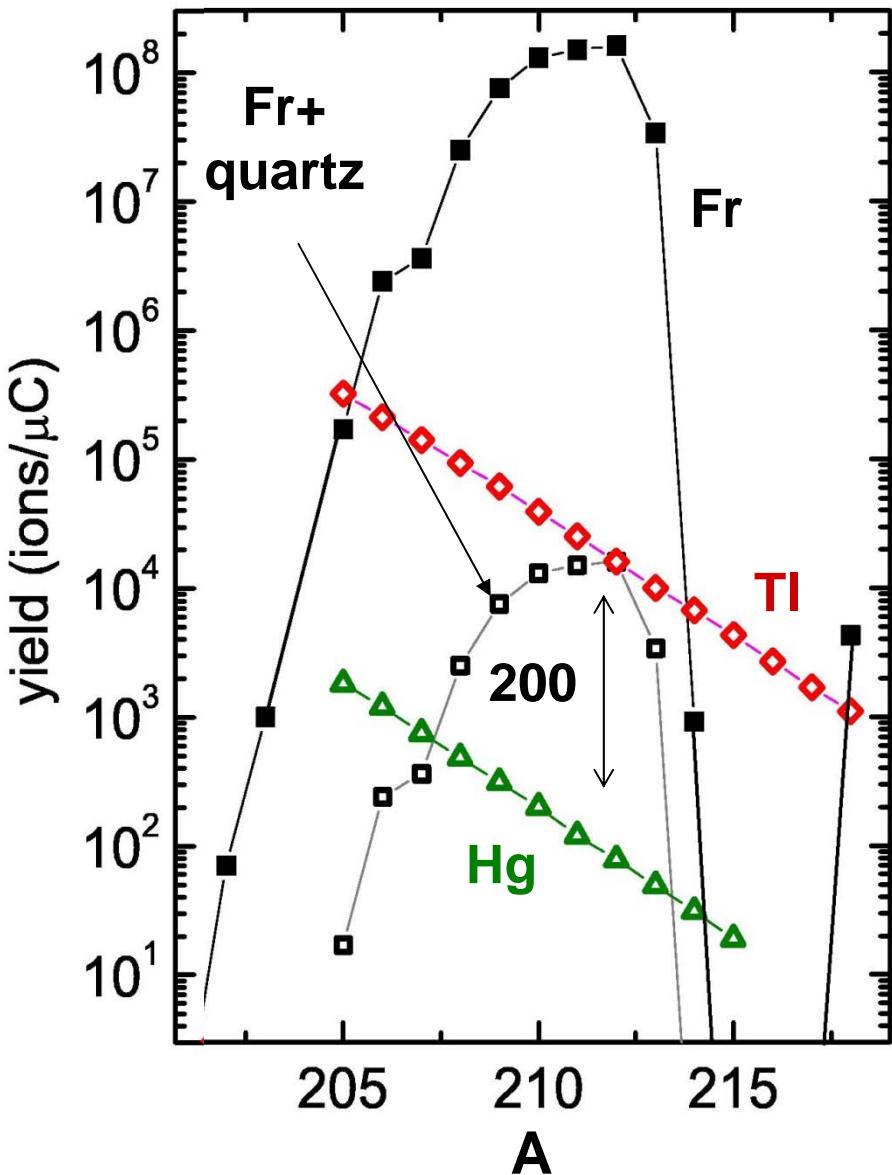
Expected half-lives



P. Möller et al. *Atomic Data and Nuclear Data Tables*, 66:131, 1997.

I.N. Borzov. *Physical Review C*, 67:025802, 2003.

Expected yields



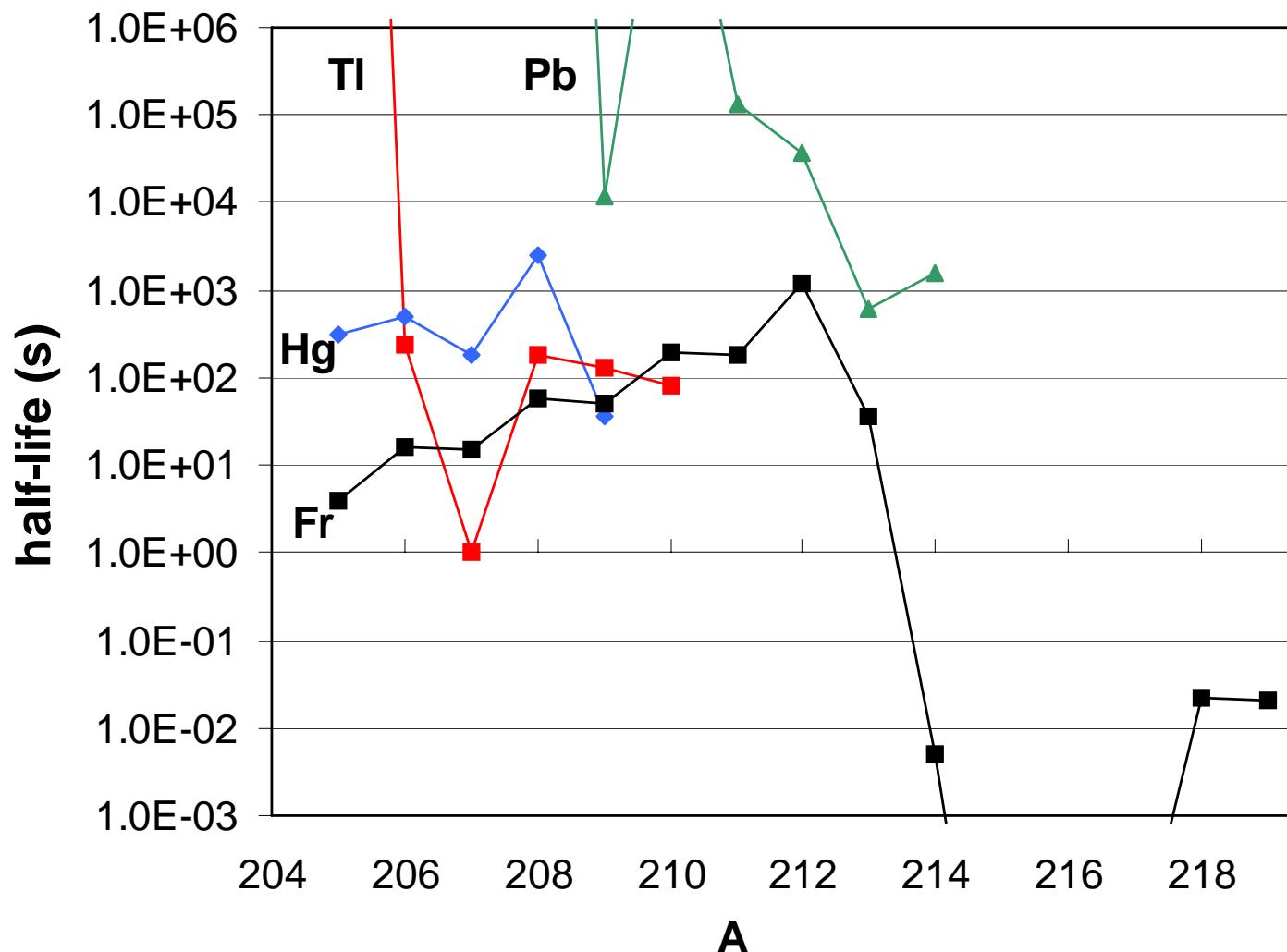
Actinide target
Laser ionization:
 $\varepsilon(\text{Hg}) > 1\%$
 $\varepsilon(\text{TI}) = 27\%$

Estimates based on:
Known yields on less n-rich
Hg and TI (ISOLDE database)

Cross-section codes
Silverberg-Tsao and EPAX

Measured suppression factor
for the quartz transfer line

Known half-lives

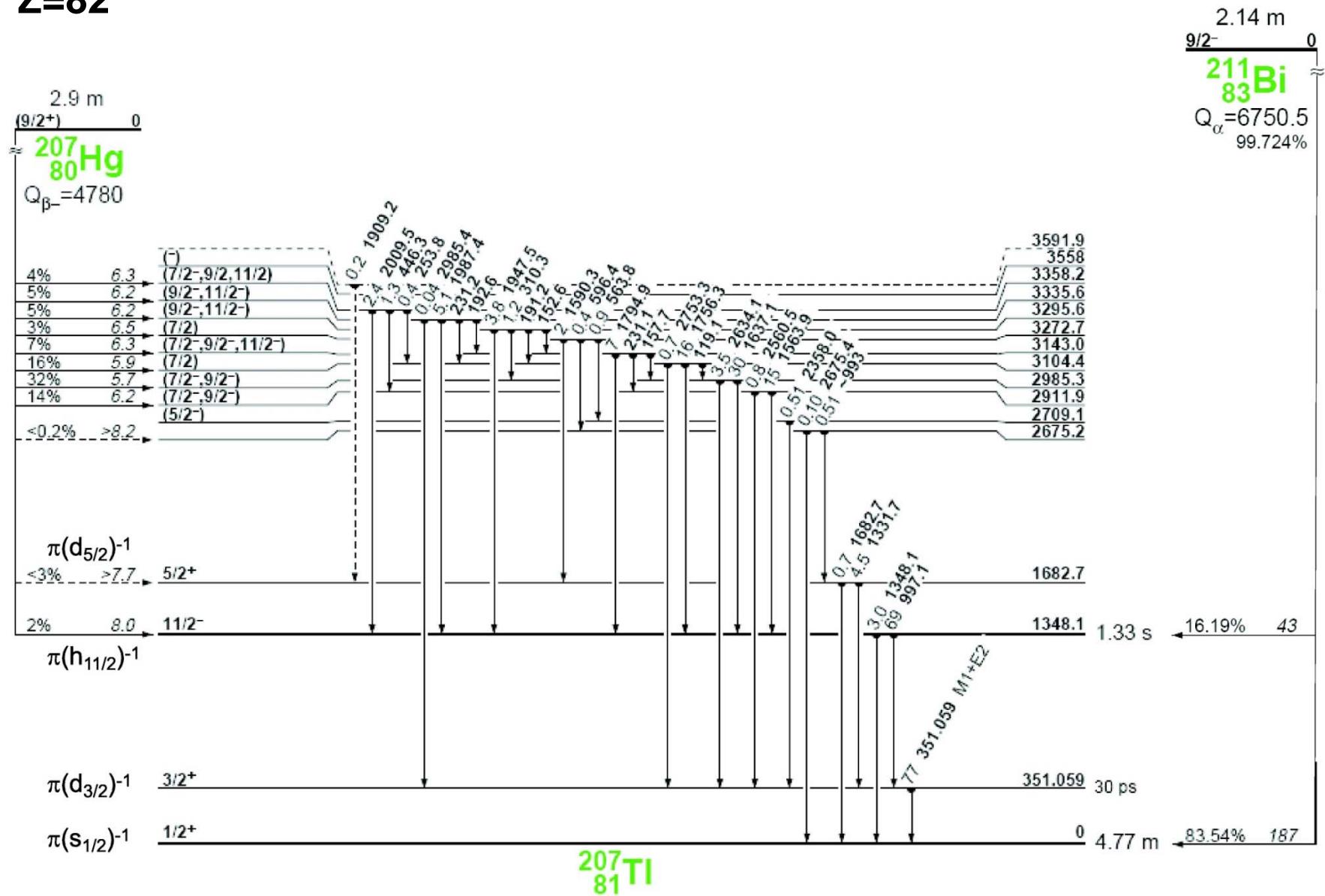


R. Firestone et al. *Table of Isotopes: 1999 update*. 1999.

G. Audi, A.H. Wapstra, and C. Thibault. *Nuclear Physics A*, 729:337, 2003

207TI level-scheme

Z=82



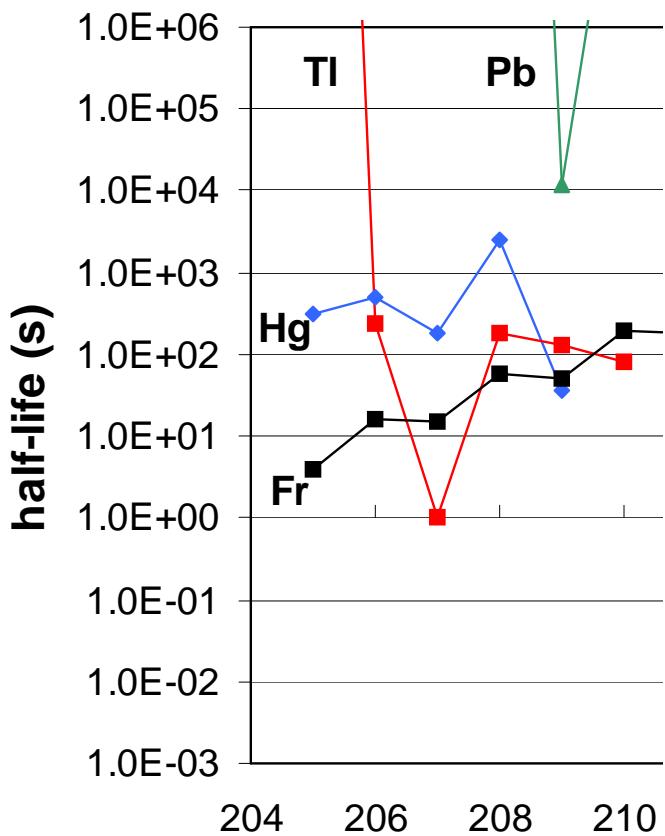
Properties of n-rich Tl isotopes

A	N	I^π	$t_{1/2}$ g.s./isomer	level scheme from α -decay	level scheme from β -decay
206	125	0^-	3.7 min / 4.2 min	+	+
207	126	$1/2^+$	1.3 s / 4.8 min	+	+
208	127	5^+	3.1 min	+	+
209	128	$(1/2^+)$	2.2 min	+	-*
210	129	(5^+) syst.	1.3 min	-	-
211	130	$(1/2+)$ syst.	> 300 ns	-	-
212	131	-	> 300 ns	-	-

Properties of n-rich Pb isotopes

A	N	I^π	$t_{1/2}$ g.s./isomer	level scheme from α -decay	level scheme from β -decay
206	125	0^-	3.7 min/ 4.2 min	+	+
207	126	$1/2^+$	1.3 s/ 4.8 min	+	+
208	127	5^+	3.1 min	+	+
209	128	$(1/2^+)$	2.2 min	+	-*
210	129	(5^+) syst.	1.3 min	-	-
211	130	$(1/2^+)$ syst.	> 300 ns	-	-
212	131	-	> 300 ns	-	-

Build-up of radioactivity



Beta-activity from decay of ^{207}TI ,
After implantation of 20 bunches of ^{207}Hg

