# Core-breaking and octupole low-spin states in $^{207}$Tl

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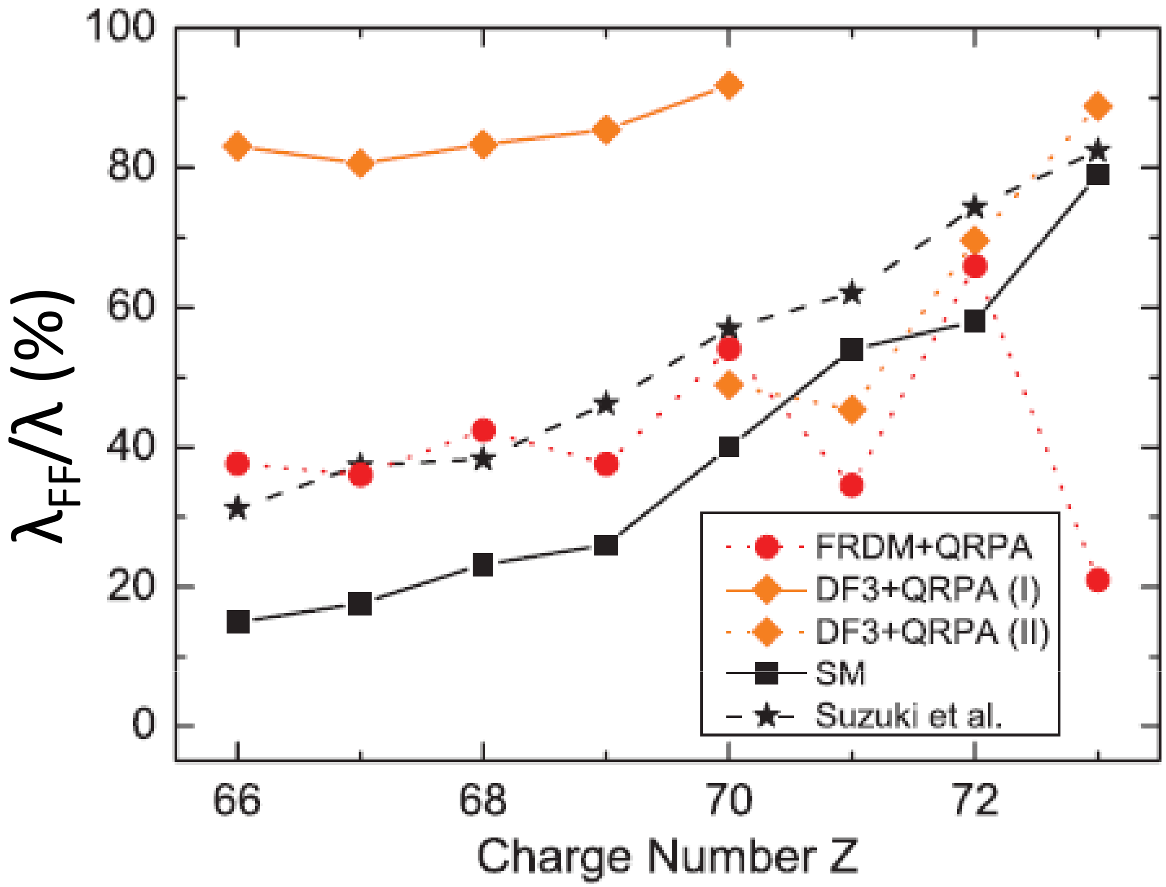
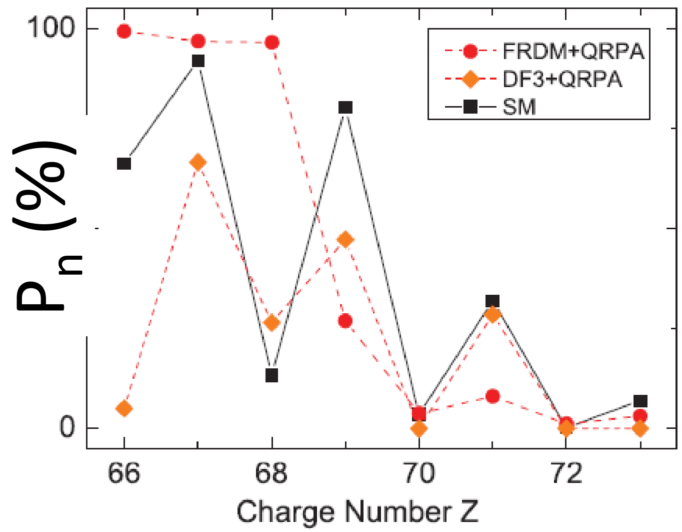
# What do we know?

| | | | | |
|---|---|---|---|---|
| **208Pb**<br>Core | **209Pb**<br>Yrast<br>+ ~3 | **210Pb**<br>Yrast<br>+ ~4 | **211Pb**<br>see<br>Benzoni | **212Pb**<br>see<br>Benzoni |
| **207Tl**<br>g.s. ½+<br>Yrast~35/2 | 208Tl<br>g.s. (5+) | 209Tl<br>gs.(1/2+) | 210Tl<br>g.s. (5+) | 211Tl |
| **206Hg**<br>Yrast till<br>(13-) | 207Hg<br>gs.(9/2+) | | | |
| **205Au**<br>yrast | | | | |
| **204Pt**<br>yrast | | | | |
| **203Ir**<br>yrast | | | | |

Decay of 207Hg:
core-excitations => size of shell gap
coupling of 3- (structure of 3- ?)
ideal for studying fist-forbidden transitions;
crucial for heavy nuclei r-process;

Beta-decay studies (into 208Pb, 209Pb, 207Tl) performed at least 30 years ago
Only structure discussion (not decay)




Q. Zhi, E. Caurier, J.J. Cuenca-Garcia, K. Langanke, G. Martinez-Pinedo, K. Sieja, Phys. Rev. C 87, 025803 (2013)

# Shell model space

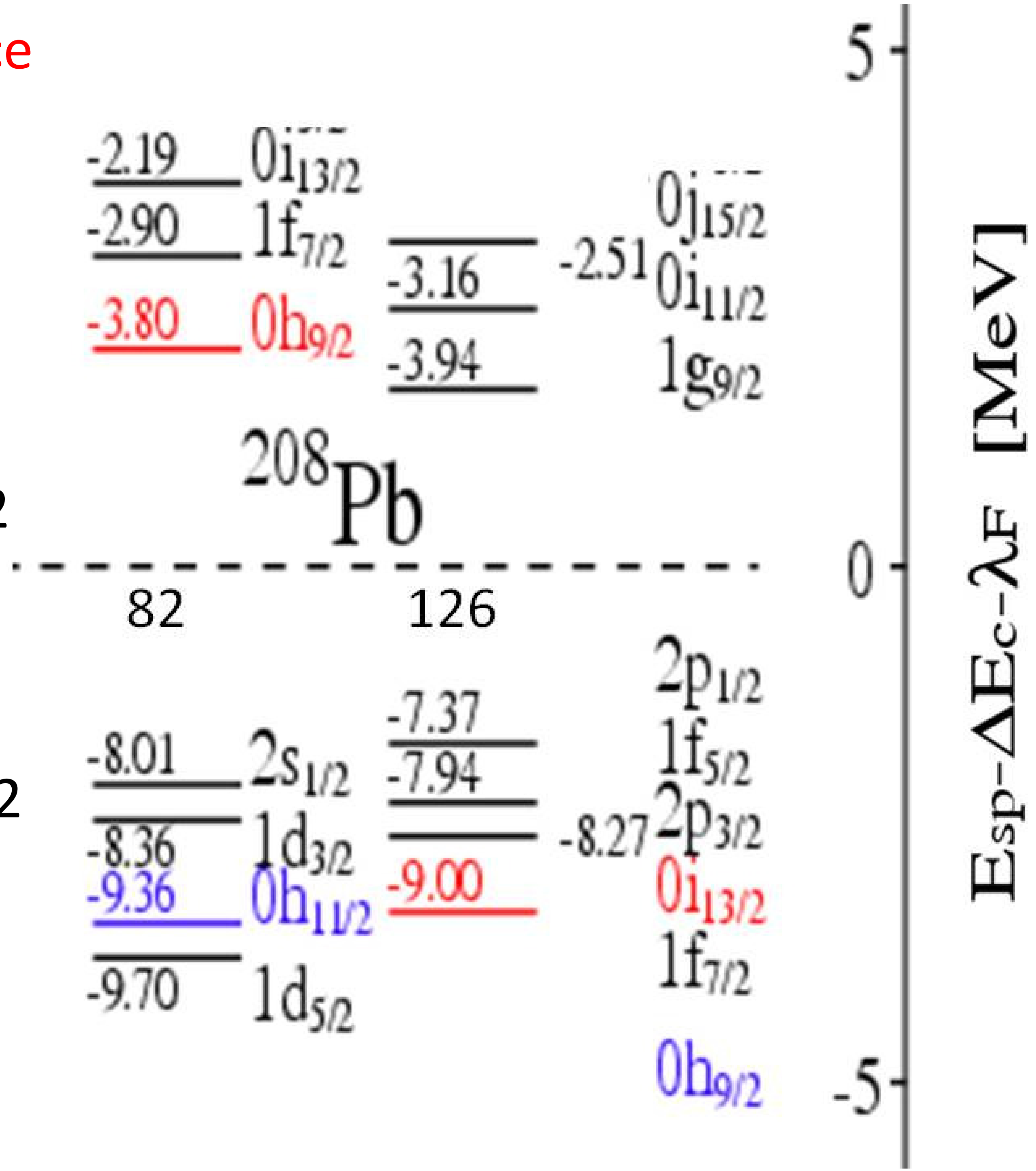
Allowed GT:

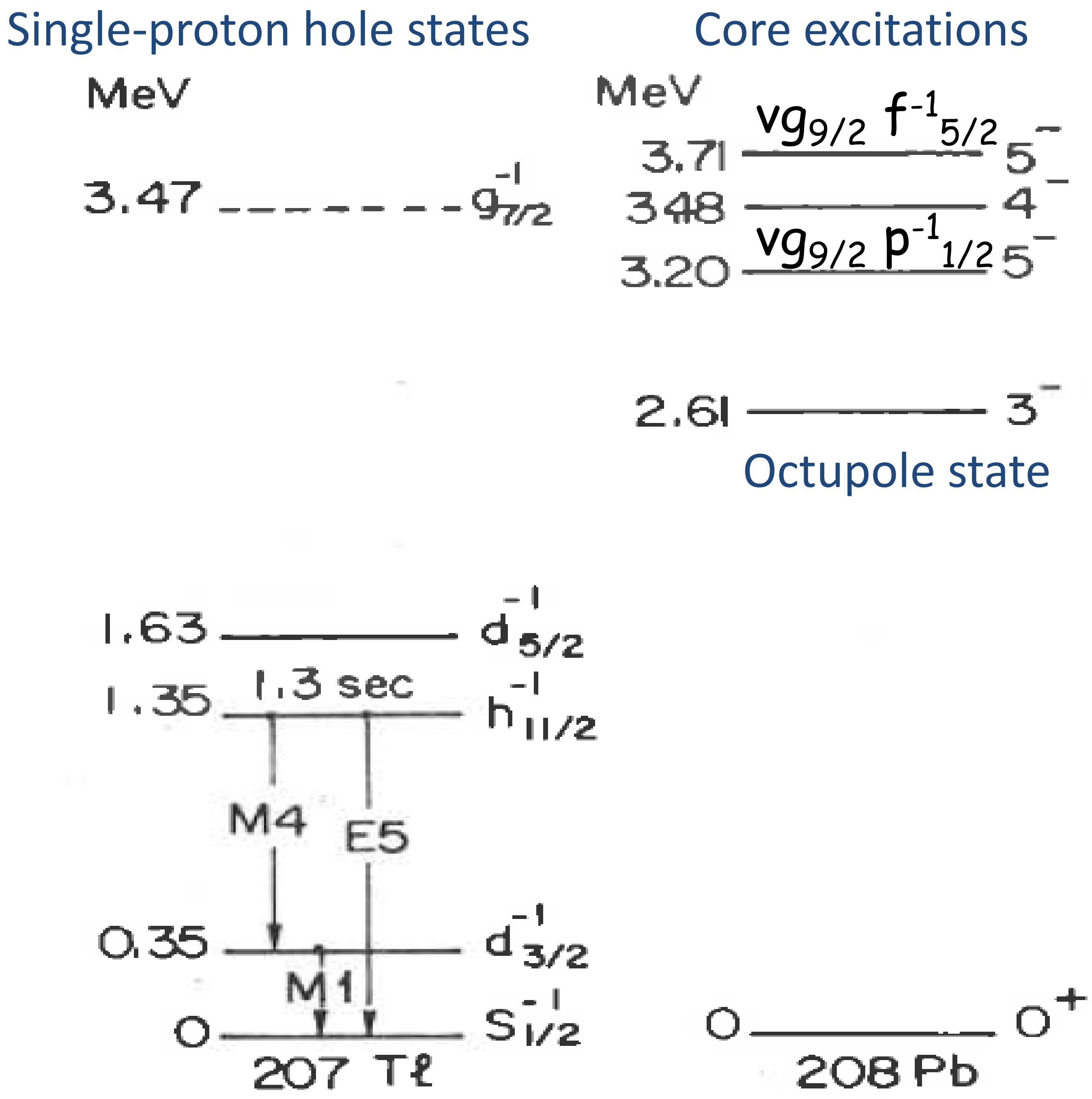
νh9/2 -> π h11/2

First-forbidden:

νp1/2->πd3/2

νi13/2 -> π h11/2

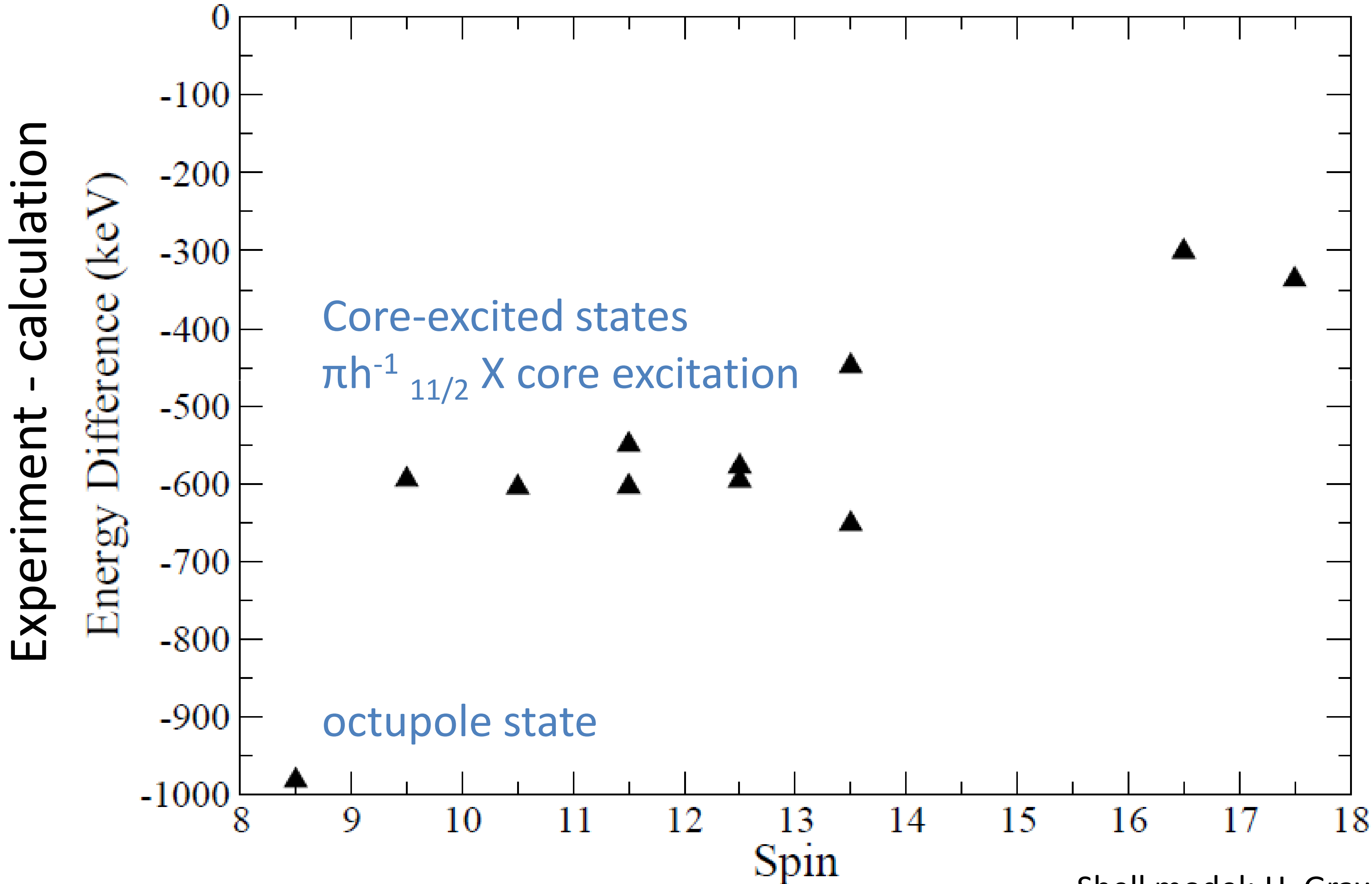




Single-proton hole states
Core excitations
MeV
MeV
3.47
$g_{7/2}^{-1}$
3.71
$\nu g_{9/2} f^{-1}_{5/2}$
$5^-$
3.48
$4^-$
3.20
$\nu g_{9/2} p^{-1}_{1/2}$
$5^-$
2.61
$3^-$
Octupole state
1.63
$d_{5/2}^{-1}$
1.35
1.3 sec
$h_{11/2}^{-1}$
M4
E5
0.35
$d_{3/2}^{-1}$
M1
0
$s_{1/2}^{-1}$
207 Tℓ
0
$0^+$
208 Pb

# $^{207}$Tl: yrast states

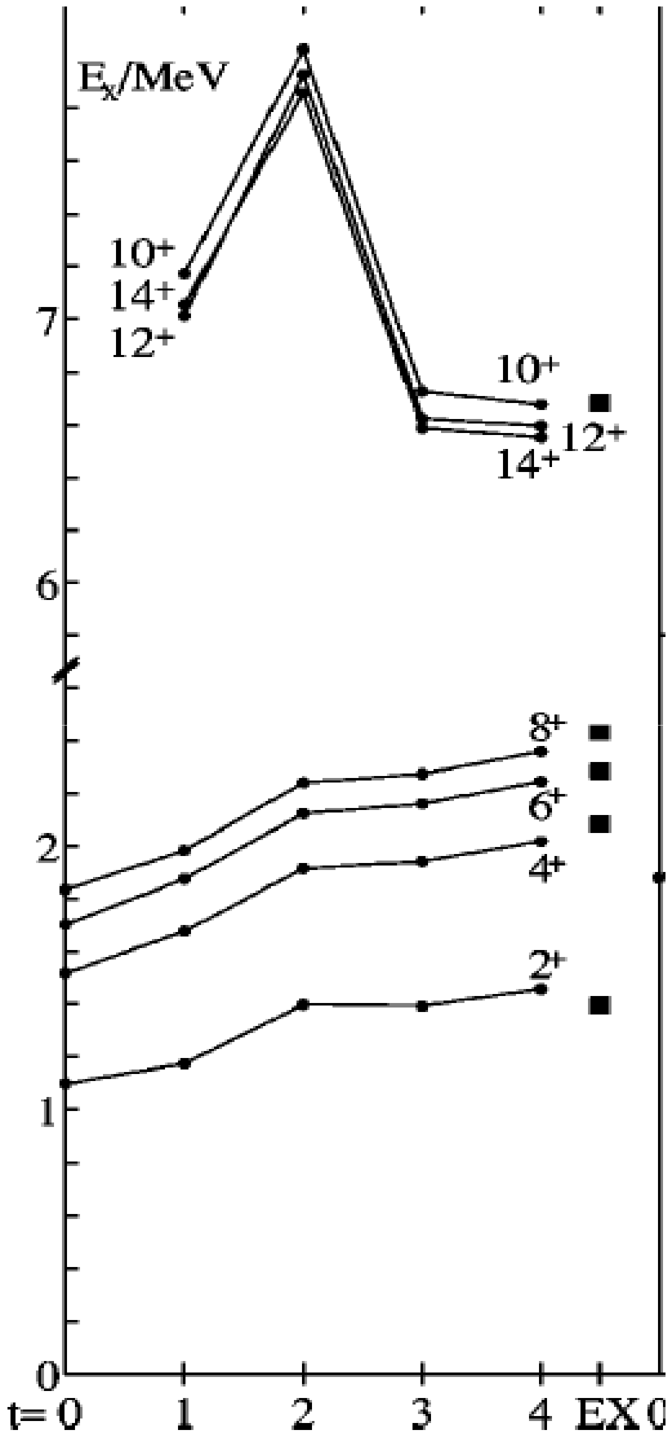
Yrast states populated in $^{208}$Pb+$^{208}$Pb at Gammasphere (to be published)




Shell model: H. Grawe

## $^{98}Cd$

t=number of core-excitations



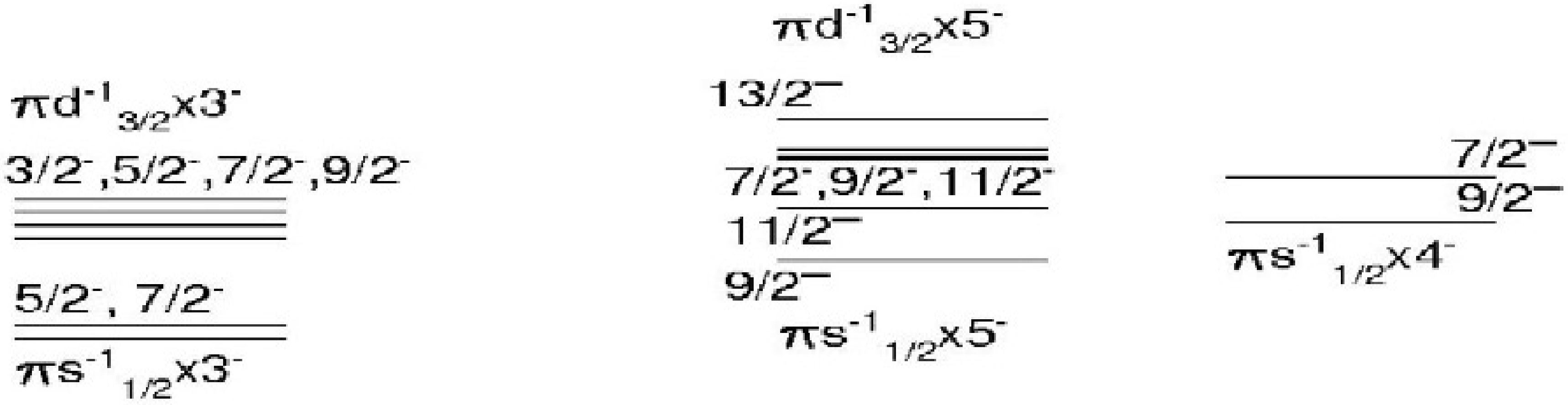

$^{207}Tl$ discrepancy:

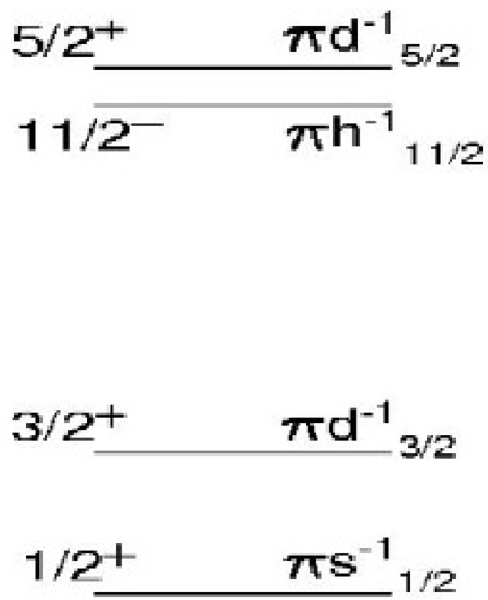
-from not considering t=3

-problem with interaction

A. Blazhev et al., Phys. Rev. C 69, 064304 (2004)

calculations by E. Caurier, F. Nowacki



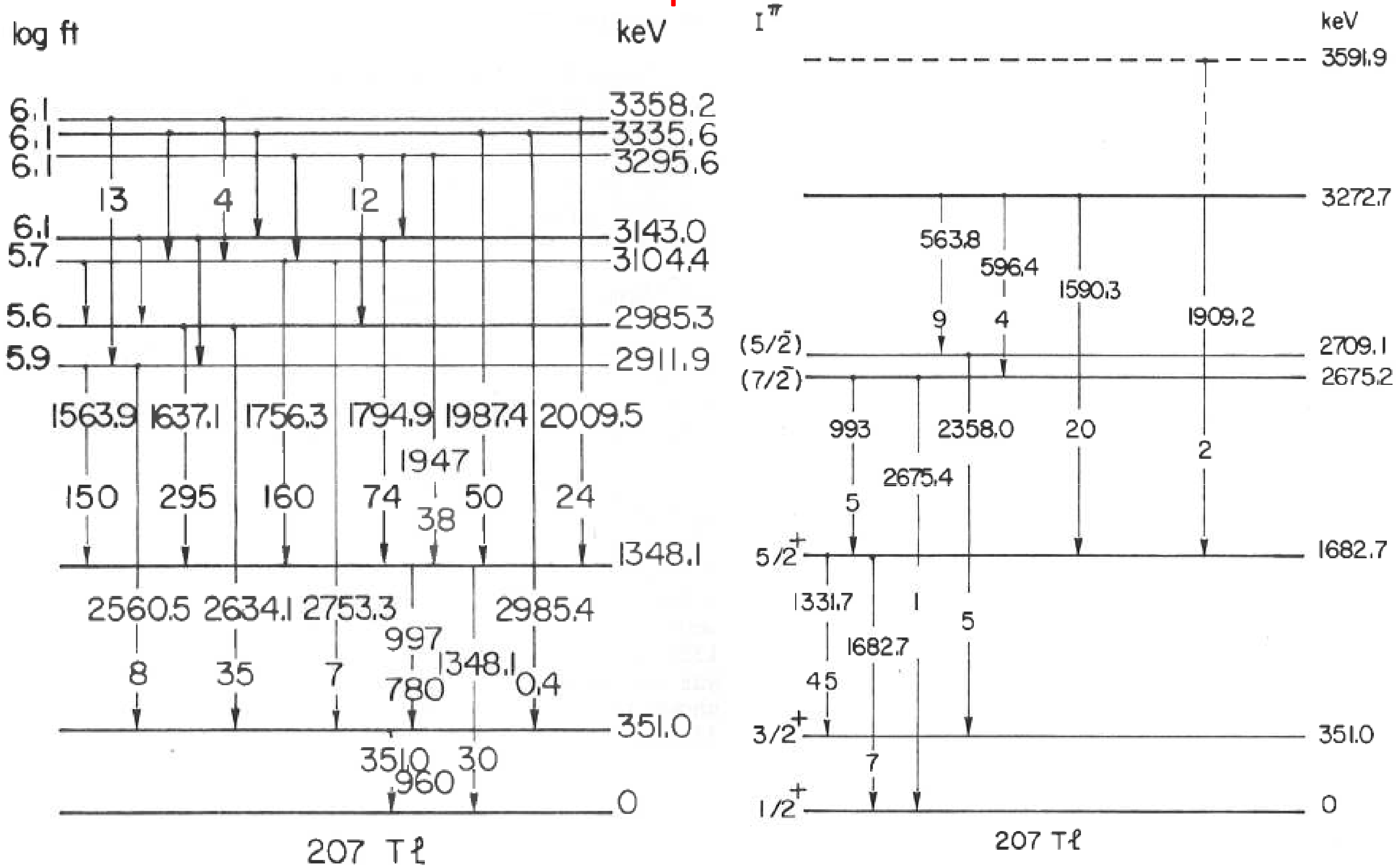




$^{207}$Tl

Shell model calculations: H. Grawe
excitation across N=126 and Z=82

(modified:
core-excitation -600 keV;
octupoles ‘by hand’)

# Former experiment




B. Jonson, O.B. Nielsen, J. Zylicz, CERN-81-09 (1981)
(Proc. Int. Conf. Nuclei far from stability, Helsingor, Denmark. Vol.2 p.640 (1981))

Nucl. Data Sheets 112, 707 (2011): ‘incomplete and unbalanced’; e.g.20% feeding to the g.s.

# Where can we do better?

Higher statistics:

- 207Hg beam intensity
- gamma detection efficiency

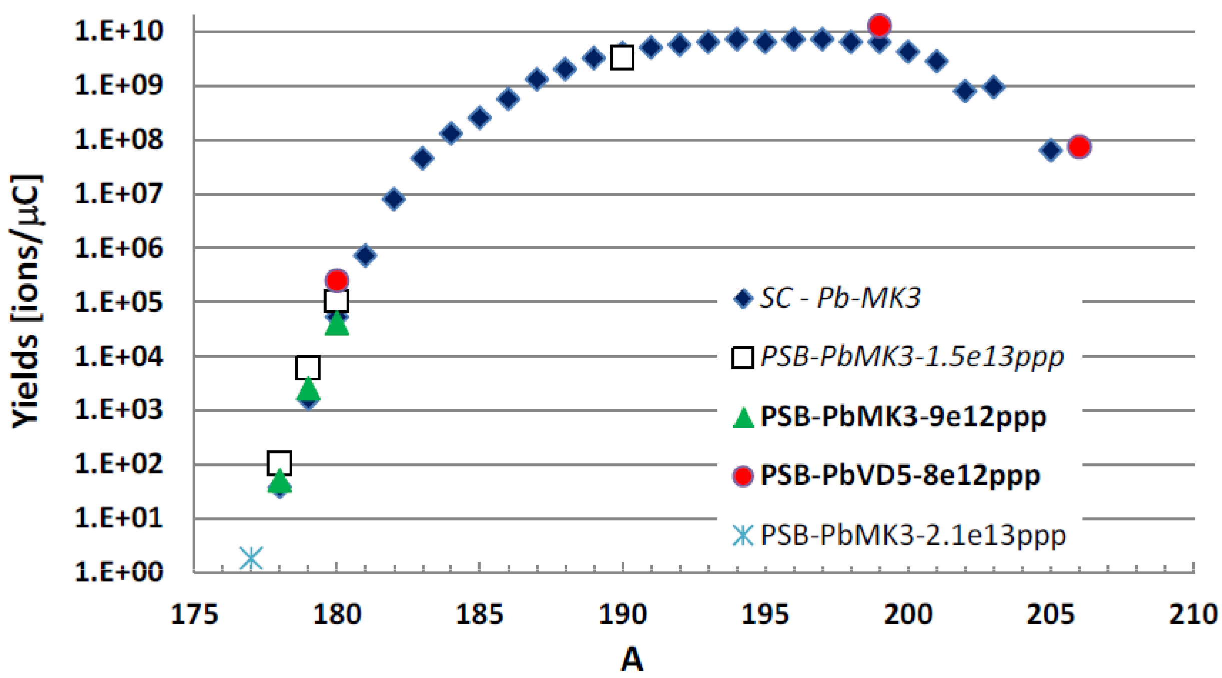
$\Rightarrow$spin-parity determination:

- angular correlation
- weak gammas
- log ft values

State-of-the-art shell model treatment

- structure
- reaction

# $^{207}Hg$ beam




T. Stora, EURISOL town meeting, Oct. 2012

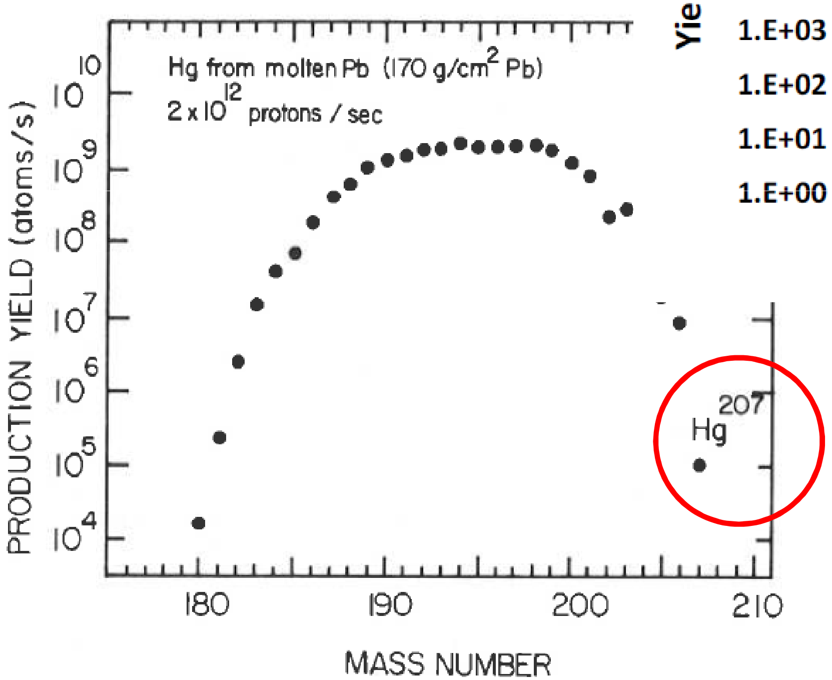
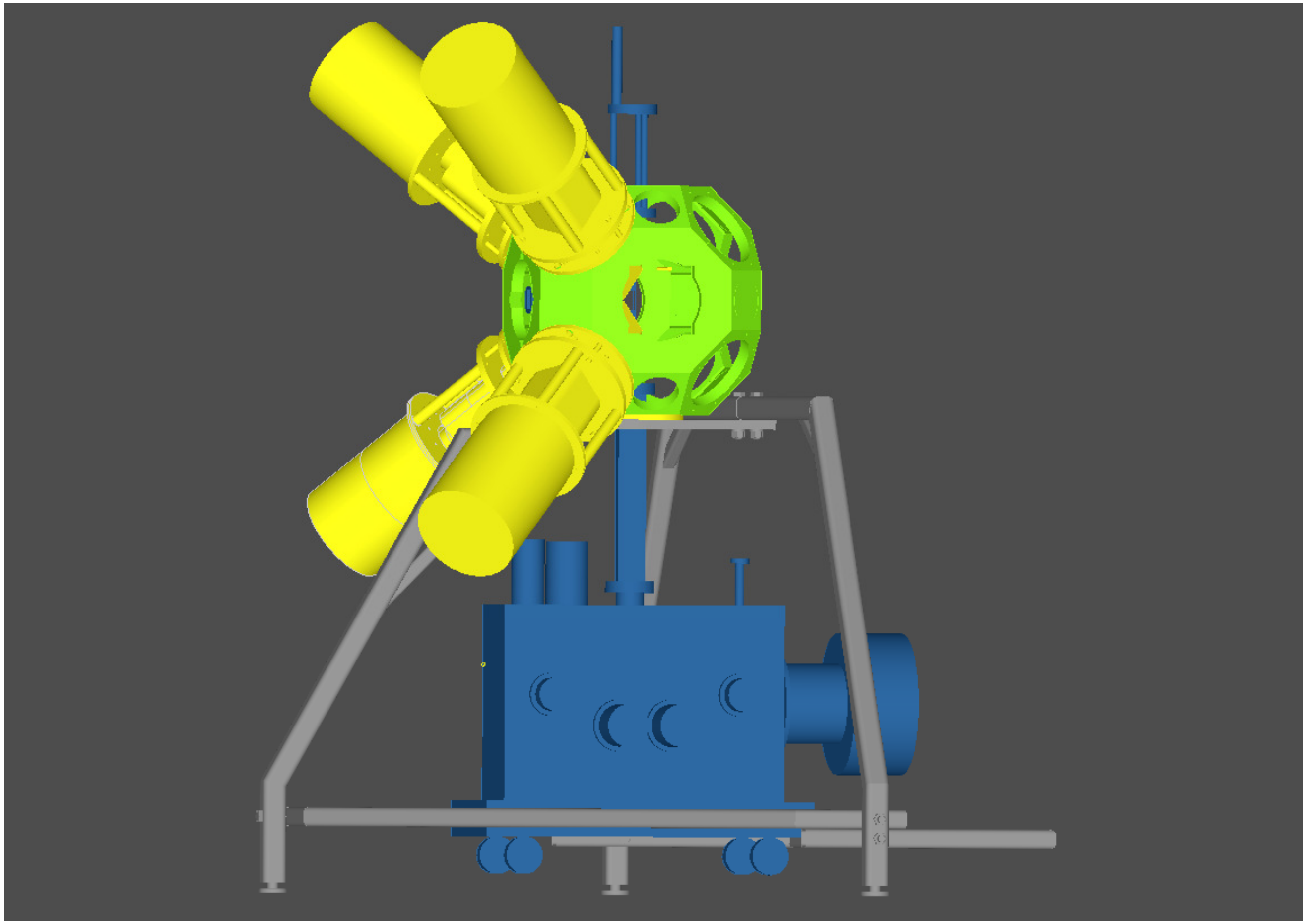



Fig. 1 Production yield in the ISOLDE facility of the mercury isotopes, including $^{206}Hg$ and $^{207}Hg$.

B. Jonson, O.B. Nielsen, J. Zylicz, CERN-81-09 (1981)

(Proc. Int. Conf. Nuclei far from stability, Helsingor, Denmark. Vol.2 p.640 (1981))

# ISOLDE Decay Station

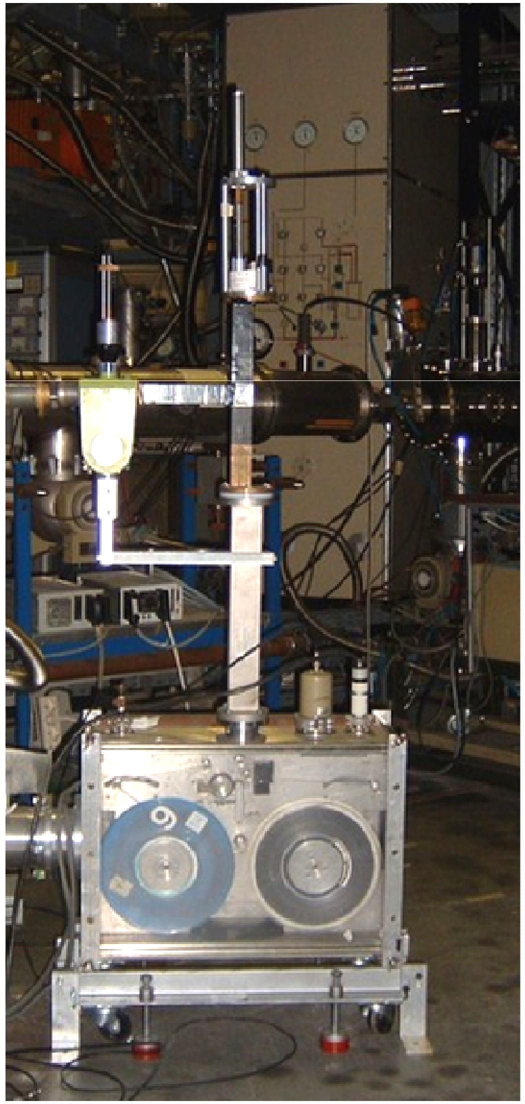


Frame from Osiris IFIN Bucharest

Tape station from KU Leuven

2 clovers from IFIN Bucharest

2 clovers from KU Leuven



# Yield calculations

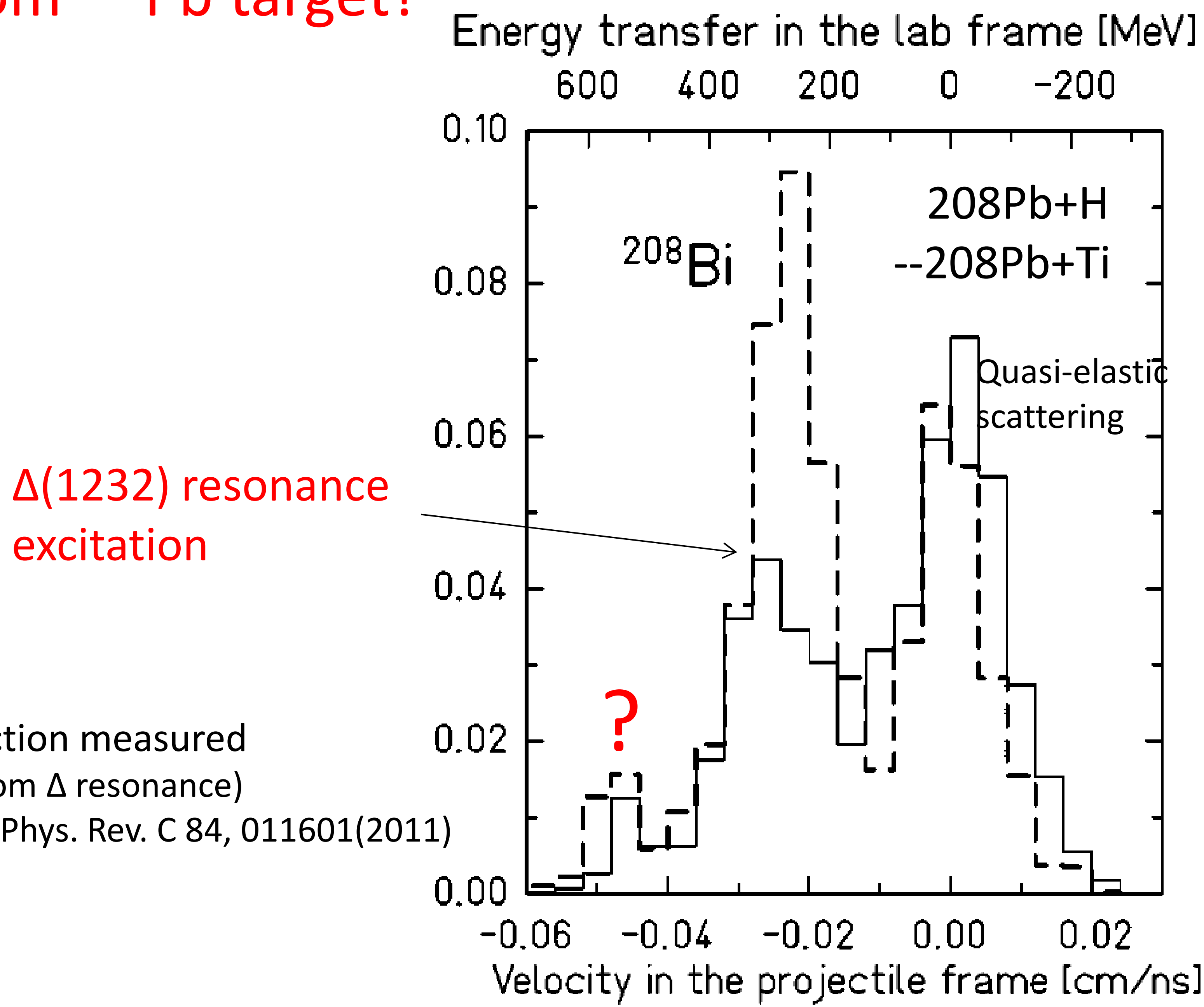
Beam: $^{207}$Hg +$^{207}$Pb (stable)
$^{207}$Hg yield: ~$10^6$ pps from target => ~$4x10^5$ pps on tape
(in the 1981 report: $10^5$ pps)

$^{207}$Hg (T1/2=2.9(2) min. -> $^{207}$Tl (T1/2=4.77(3) min -> $^{207}$Pb (stable)
Efficiency: gammas ~5%; beta ~60%
Beta-branch: $10^{-4}$ (needed!)

Beta-gamma-gamma rate: ~50 hour$^{-1}$

=> 15 shifts are requested +time to set up.

# $^{208}$Hg from $^{208}$Pb target?

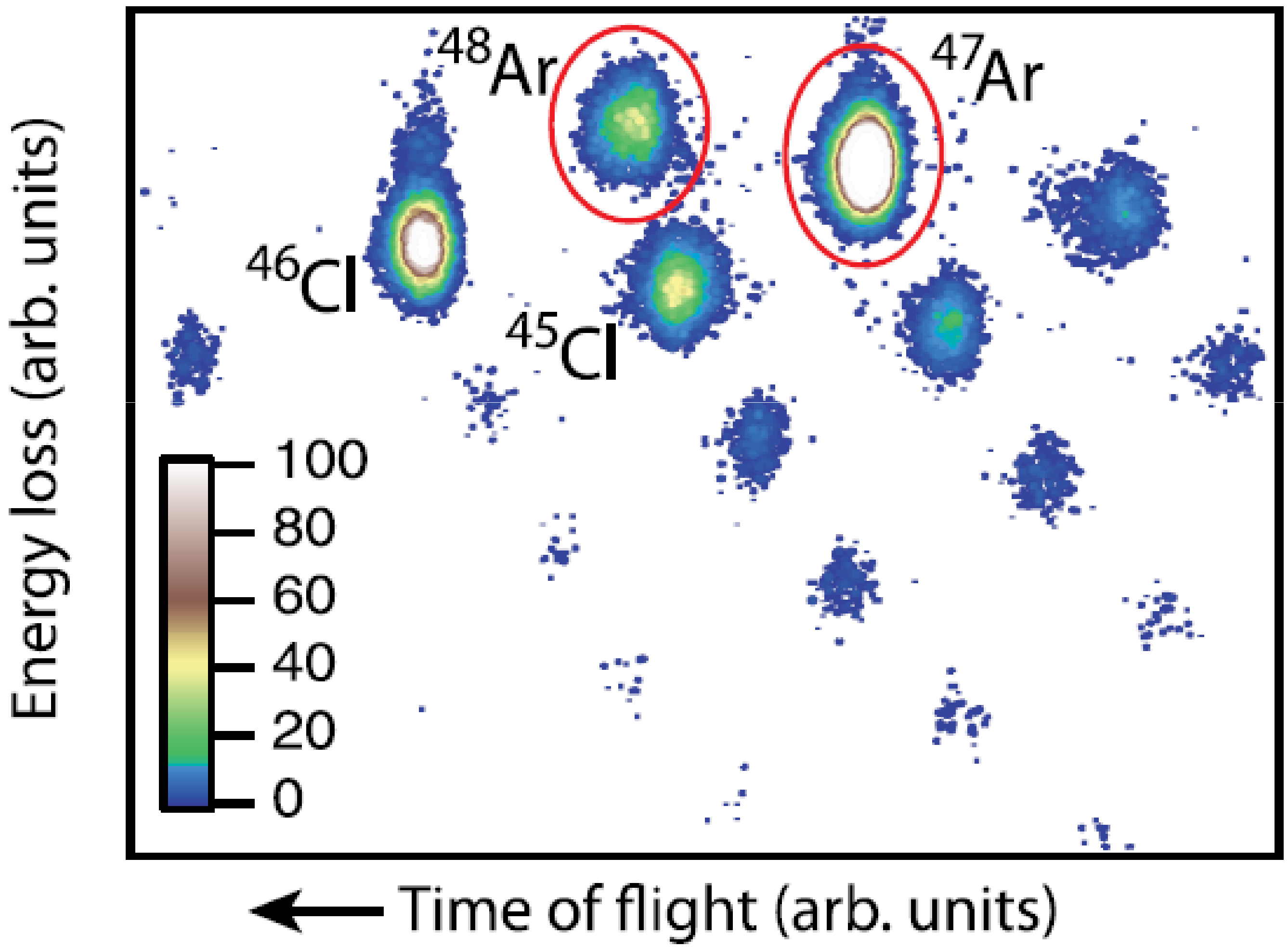



207Hg cross section measured
in 208Pb+9Be (from Δ resonance)
A. Morales et al., Phys. Rev. C 84, 011601(2011)

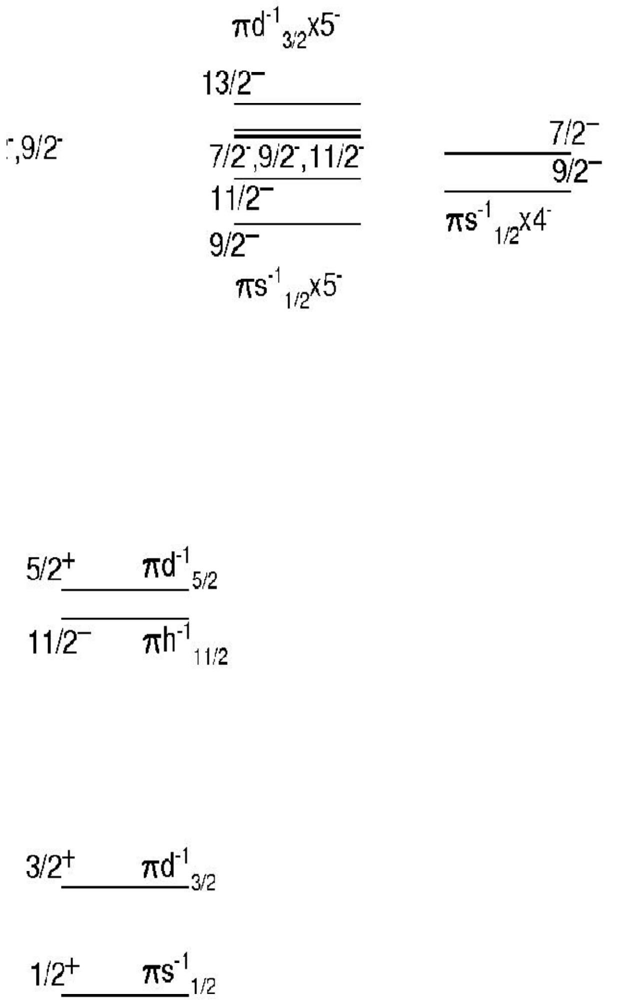
A. Kelic et al., Phys. Rev. C 70, 064608 (2004)

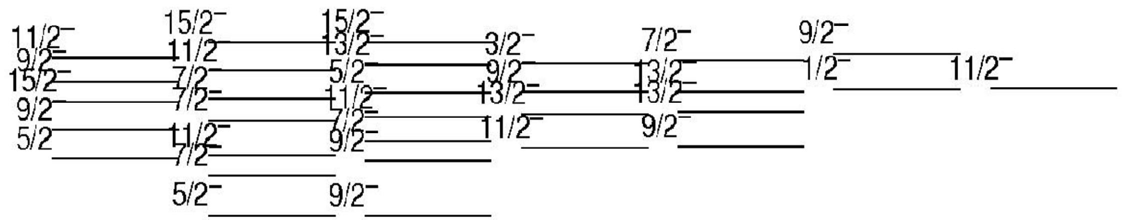
End

48Ca (140 MeV/u) +9Be -> 46Ar
Z=20 -> Z=18

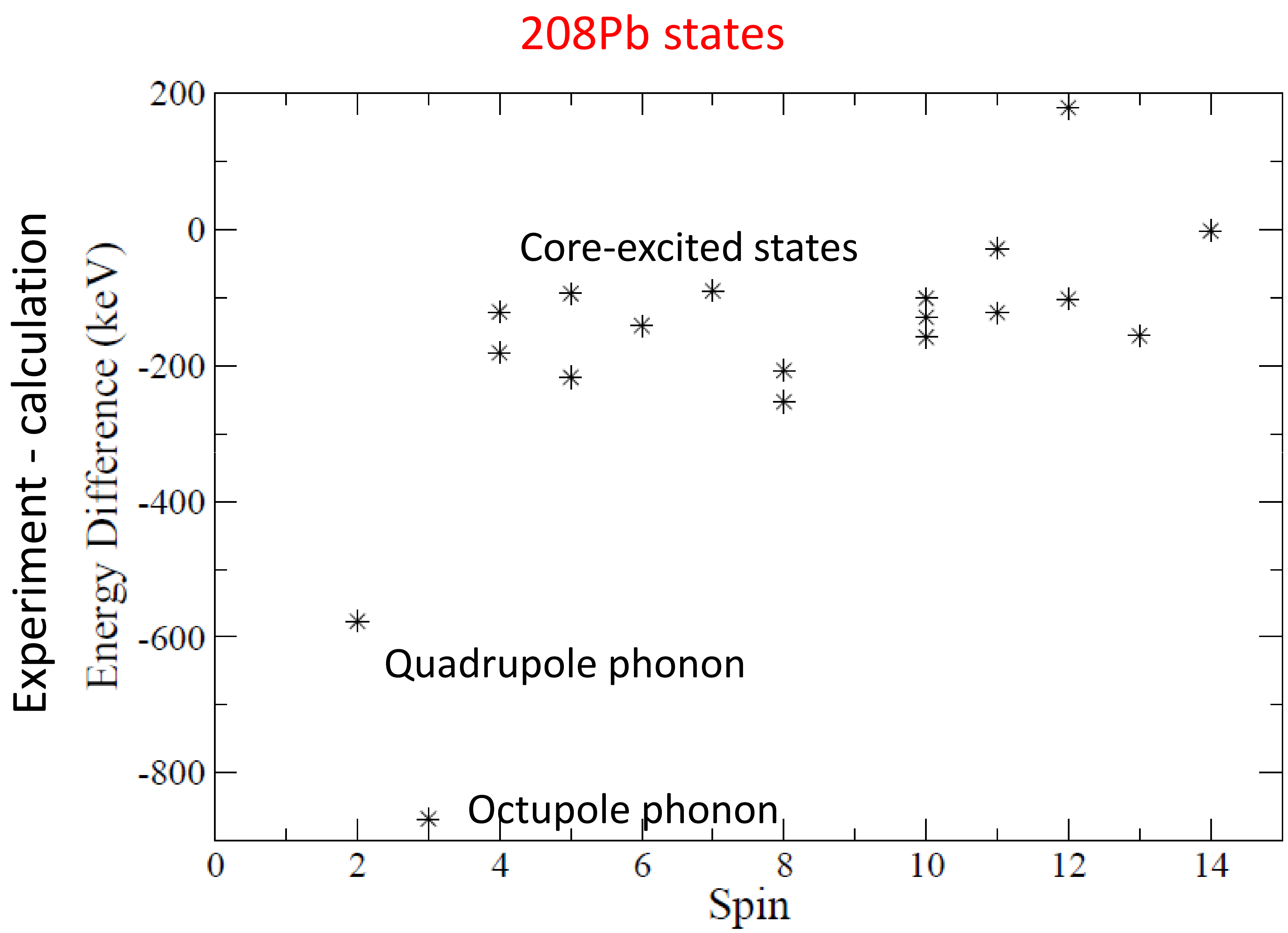



R. Winkler et al., Phys. Rev. Lett. 108, 182501 (2012)




Shell model: H. Grawe


208Pb states
Experiment - calculation
Energy Difference (keV)
200
0
-200
-400
-600
-800
0
2
4
6
8
10
12
14
Spin
Core-excited states
Quadrupole phonon
Octupole phonon

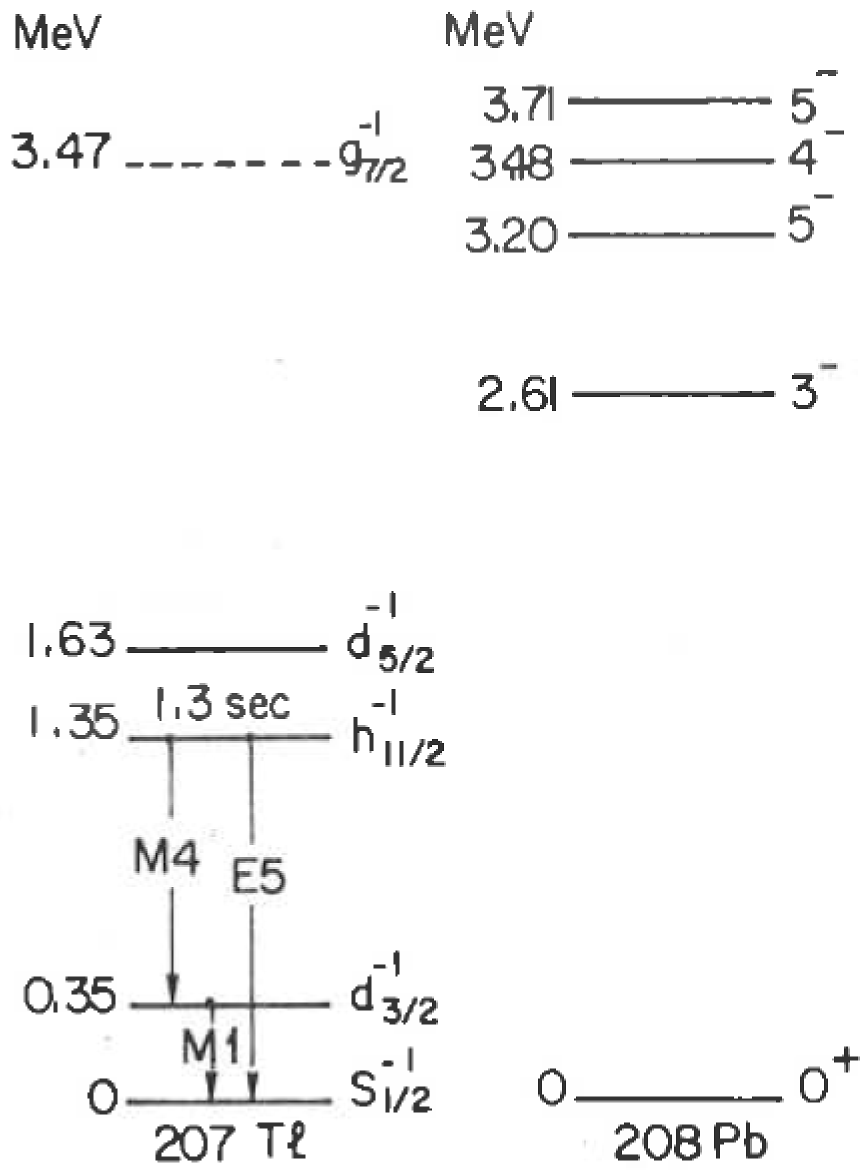
## $^{207}$Tl levels

| $E_{level}$[#] | $J^{\pi}$[@] | $T_{1/2}$[@] | $E_{level}$[#] | $J^{\pi}$[@] | $T_{1/2}$[@] | $E_{level}$[#] | $J^{\pi}$[@] | $T_{1/2}$[@] |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 1/2+ | 4.77 min *3* | 2708.8 *3* | | | 3272.5 *3* | (7/2,9/2+) | |
| 350.87 *19* | 3/2+ | 30 ps *7* | 2911.7 *3* | (7/2,9/2) | | 3295.5 *3* | (7/2,9/2) | |
| 1348.04 *21* | 11/2- | 1.33 s *11* | 2985.1 *3* | (7/2,9/2) | | 3335.9 *3* | (7/2,9/2) | |
| 1682.49 *21* | 5/2+ | | 3104.3 *3* | (7/2,9/2) | | 3357.5 *4* | (7/2,9/2,11/2) | |
| 2675.64 *25* | (5/2+) | | 3142.9 *4* | (7/2,9/2,11/2) | | 3591.7? *4* | (7/2,9/2+) | |

[#] From a least-squares fit to Eγ.
[@] From the adopted levels.

## $\beta^-$ Radiations

Level scheme in 1981JoZW is incomplete and unbalanced. The Iβ from the parent (9/2+) g.s. to the 3/2+ excited 350.86-keV state is 19.9%, which contradicts the β-decay selection rules. Therefore, the log ft values are not given by the evaluators.



MeV
3.47
$g^{-1}_{7/2}$
1.63
$d^{-1}_{5/2}$
1.35
1.3 sec
$h^{-1}_{11/2}$
M4
E5
0.35
$d^{-1}_{3/2}$
M1
0
$s^{-1}_{1/2}$
207 Tℓ
MeV
3.71
$5^-$
3.48
$4^-$
3.20
$5^-$
2.61
$3^-$
0
$0^+$
208 Pb

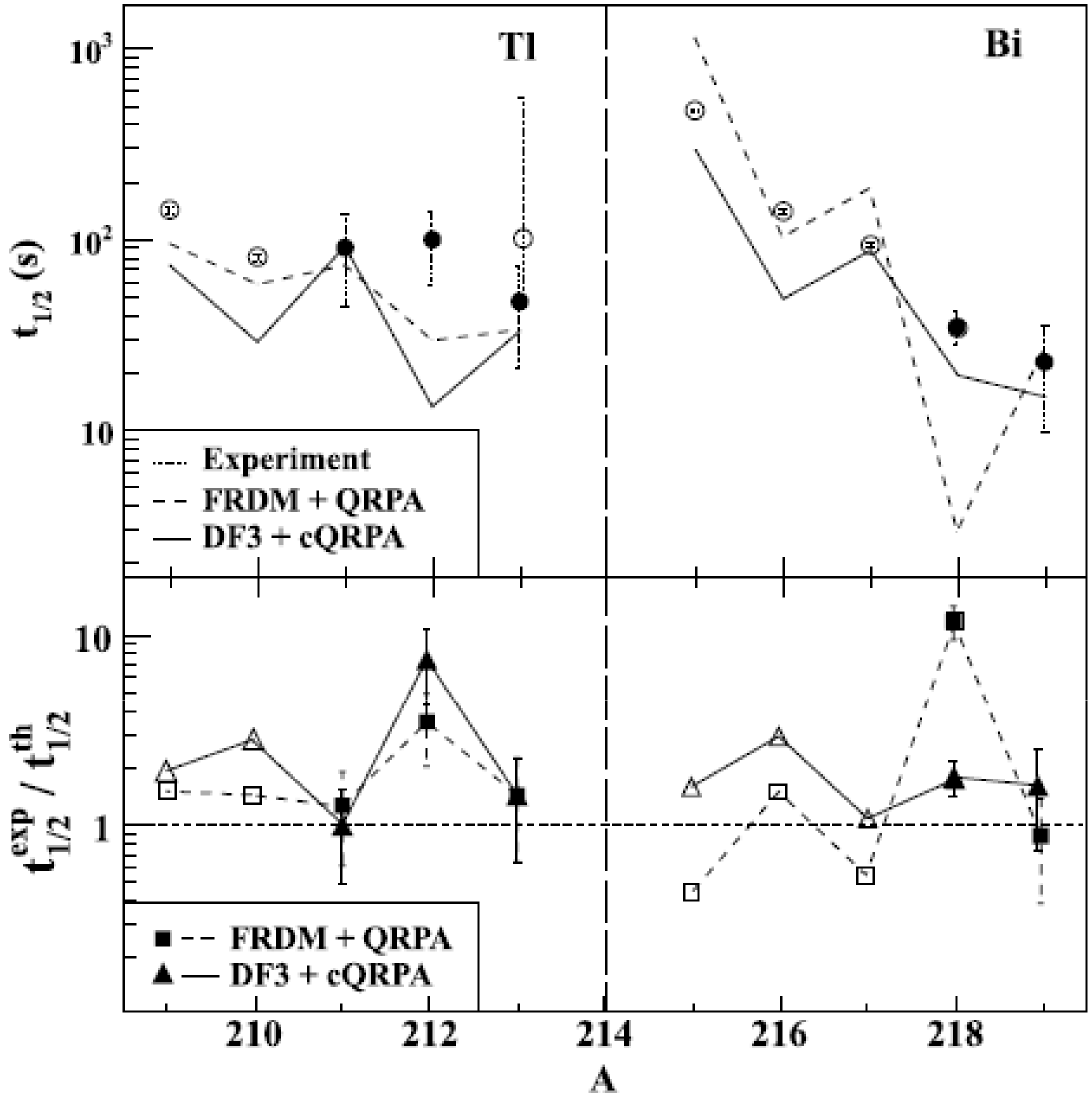



**Fig. 4.** Comparison with theoretical predictions. In the upper row the half-lives are given as function of mass number A for Tl (left) and Bi (right) isotopes. Open circles refer to previously known data while filled ones to the current analysis. The lower panels show the comparison in terms of ratio between experimental and theoretical values. The predictions shown by squares are obtained using the FRDM + QRPA approach while the ones shown with triangles by the DF3 + cQRPA one. (See text for discussion.)

G. Benzoni et al., Phys. Lett. B 715, 293 (2012)

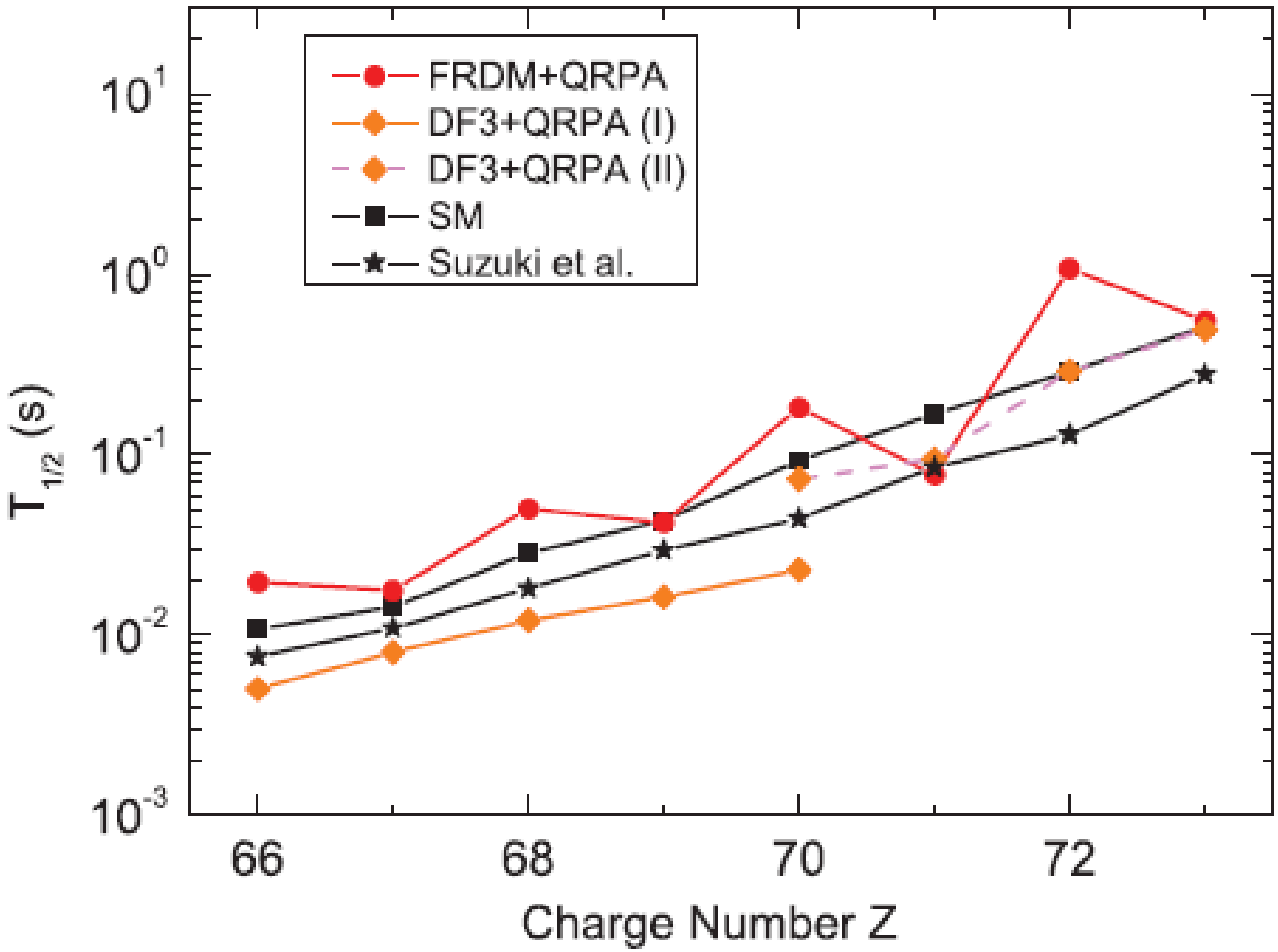
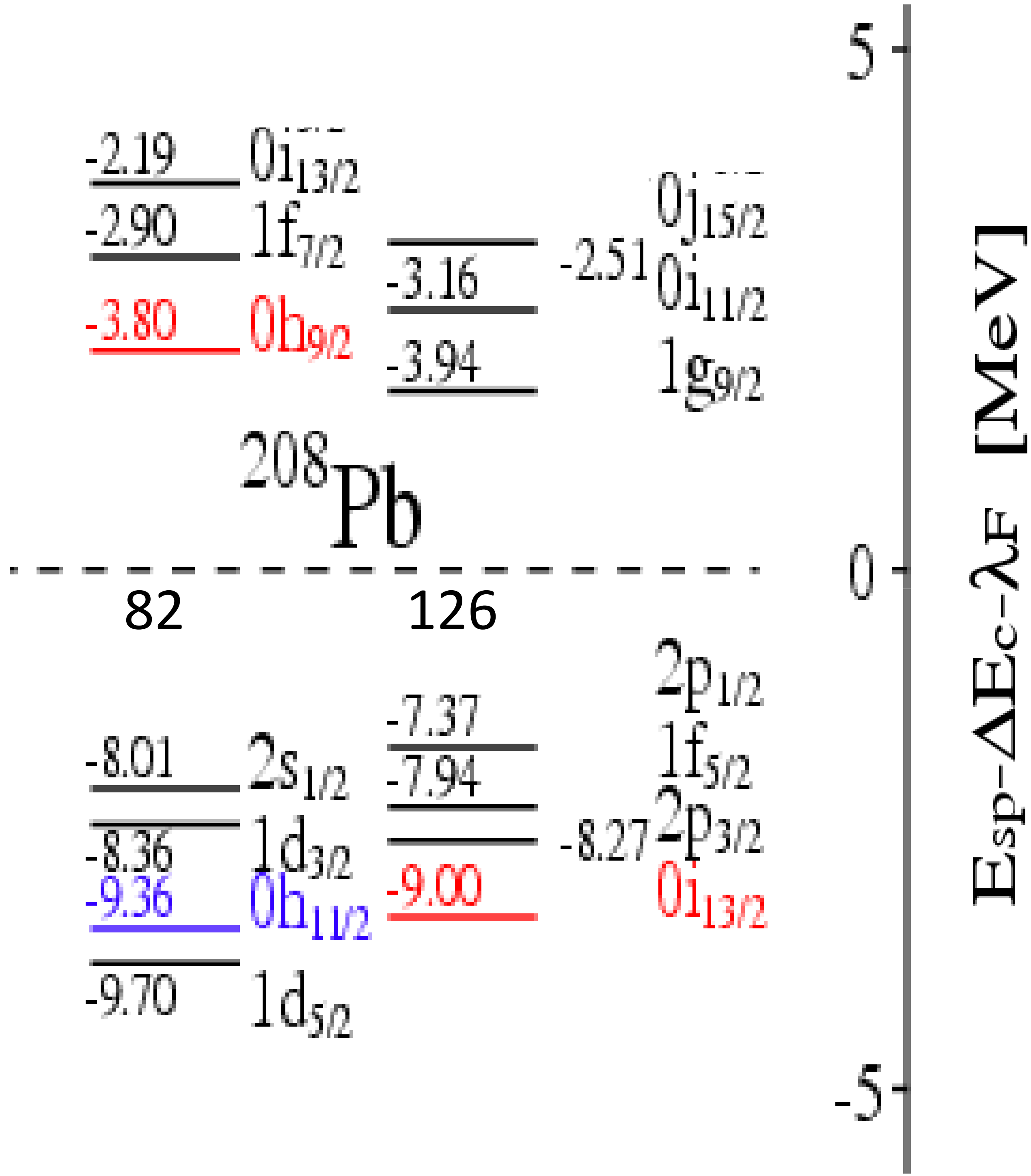



FIG. 14. (Color online) Comparison of half-lives of the $N = 126$ isotones as calculated in the FRDM + QRPA, DF3 + QRPA(I) [20], DF3 + QRPA(II) [60], and the present shell model approaches [59].

Q. Zhi, E. Caurier, J.J. Cuenca-Garcia, K. Langanke, G. Martinez-Pinedo, K. Sieja, Phys. Rev. C 87, 025803 (2013)



-2.19
$0i_{13/2}$
-2.90
$1f_{7/2}$
-3.80
$0h_{9/2}$
$0j_{15/2}$
-2.51
$0i_{11/2}$
-3.16
-3.94
$1g_{9/2}$
$^{208}$Pb
82
126
$2p_{1/2}$
-7.37
$1f_{5/2}$
-7.94
-8.27
$2p_{3/2}$
-9.00
$0i_{13/2}$
-8.01
$2s_{1/2}$
-8.36
$1d_{3/2}$
-9.36
$0h_{11/2}$
-9.70
$1d_{5/2}$
5
0
-5
$E_{sp}-\Delta E_c-\lambda_F$ [MeV]