ISOMERS Pb-Po-Rn-Fr...

1] Technicalities: lifetimes/widths/strengths..
2] Building blocks...
3] Signatures of structure: seniority isomers, K-isomers
4] Triple shape coexistence - ^{188}Pb example

Four Case Studies

Case I: ^{209}Fr - maybe

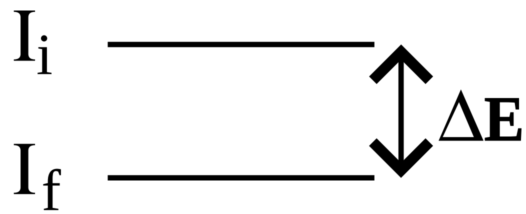
Case II: ^{212}Rn - E3 transitions; signatures
- Empirical Shell Model View
- Deformed Independent Particle Model View

Case III: ^{190,192,194,194}Pb - 11^- isomers; E3 strengths
- oblate deformation

Case IV: ^{189}Pb - $\nu i_{13/2}^{-3}$ isomer ?
- residual interactions/ non-maximal coupling

τ ... and the meaning of life...

$\lambda \geq I_i - I_f$



$\tau \sim 1 / \{ |\langle f|T_\lambda|i\rangle|^2 \times \Delta E^{(2\lambda+1)} \}$ ***von Weizsacker 1936*

structure dependent — difficult to calculate for forbidden transitions

partly structure dependent
partly random — difficult to predict ΔE accurately

low energy
small matrix element
high multipolarity...

nowhere to go...

Play School

τ (not $T_{1/2}$) - the "natural" unit

$$\Gamma.\tau = 0.658\text{x}10^{-15} \text{ eV.s}$$

$$\Gamma = \Gamma\gamma_1 + \Gamma_{e_1} + \Gamma\gamma_2 + \Gamma_{e_2} + \ldots$$

$$= (1 + \alpha_1{}^{T})\Gamma\gamma_1 + (1 + \alpha_2{}^{T})\Gamma\gamma_2 + \ldots$$

Weisskopf unit (eV)

$$\Gamma_W(E1) = 6.748 \times 10^{-2} A^{2/3} E\gamma^3$$

$$\Gamma_W(E2) = 4.792 \times 10^{-8} A^{4/3} E\gamma^5$$

$$\Gamma_W(M1) = 2.072 \times 10^{-2} E\gamma^3$$

$$\Gamma_W(M2) = 1.472 \times 10^{-8} A^{2/3} E\gamma^5$$

$$\Gamma_W(E3) = 2.333 \times 10^{-14} A^2 E\gamma^7$$

Play School

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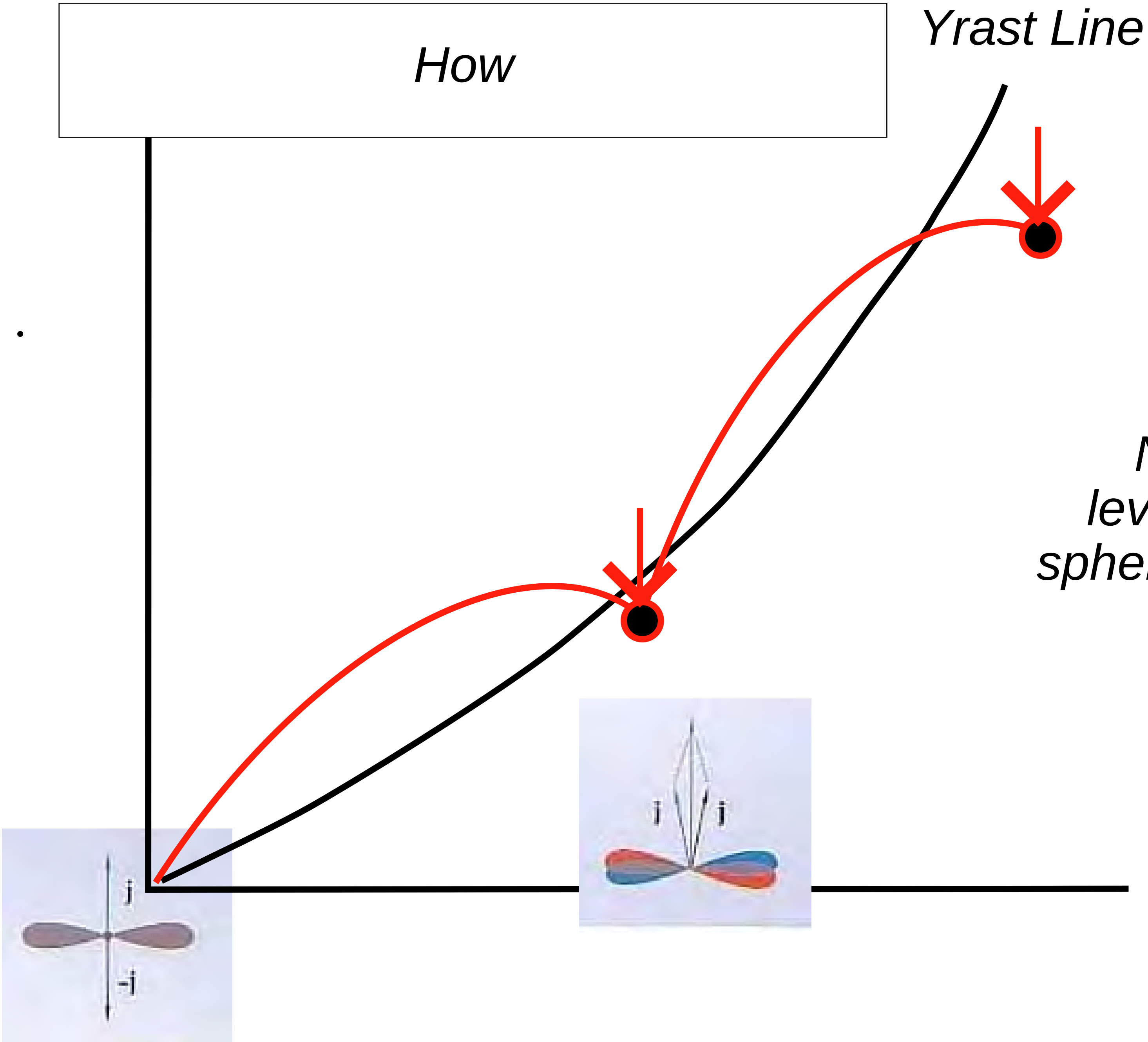
typical lifetimes:(Pb 500 keV)

10^{-6} W.u.	E1	23 ns
1 W.u.	E2	0.4 ns
0.1 W.u	M1	0.002 ns
< 1 W.u.	M2	> 32 ns
10 W.u.	E3	8.6 μs

a long lifetime does not imply hindrance

How

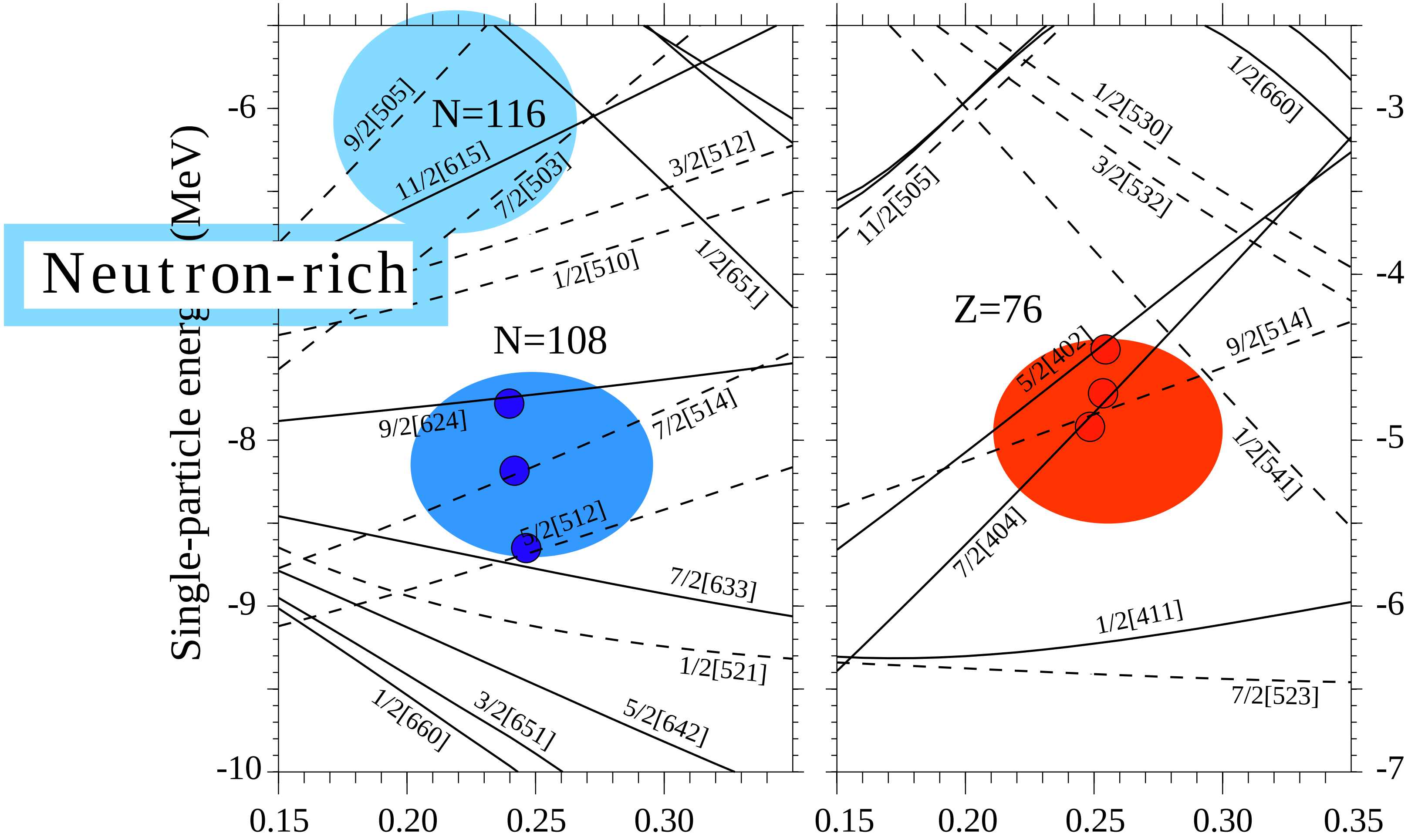


Residual
spin-spin
j or K

Non-uniform
levels -shell gaps
spherical or deformed

High-j or
High-K

Z~ 76; N ~104 favoured region for high-K



$$\mathbf{K} = \nu\, |\Omega_1 + \Omega_2 + \Omega_3 \ldots|^2 + \pi\, |\Omega_1 + \Omega_2 + \Omega_3 \ldots|$$

$$\sim 9/2 + 7/2 + 5/2 \ldots + 7/2 + 9/2 + 5/2 \ldots = 21$$

Higk-K Intrinsic states cost less energy than rotation

Z = 72
N ~ 104

common deformed building blocks

^{178}Hf exp.

the 31-year isomer

align high-Ω orbitals

8^-	ν	$9/2^+[624] \times 7/2^-[514]$
8^-	π	$9/2^-[514] \times 7/2^+[404]$

→ 16^+ →

8^- 1147
8^- 1479

16^+ 2626 keV
cf: 2447 keV

lower because of residual interaction →

Z = 72
N ~ 104

common deformed building blocks

align high-Ω orbitals

8^-	ν	$9/2^+[624] \times 7/2^-[514]$
8^-	π	$9/2^-[514] \times 7/2^+[404]$

→ **16^+** →

^{178}Hf exp.

the 31-year isomer

8^- 1147
8^- 1479

16^+ 2626 keV
cf: 2447 keV

Z ~ 82-
N ~ 124

common spherical building blocks

align high-j orbitals

^{212}Po exp.

the 65 sec. isomer

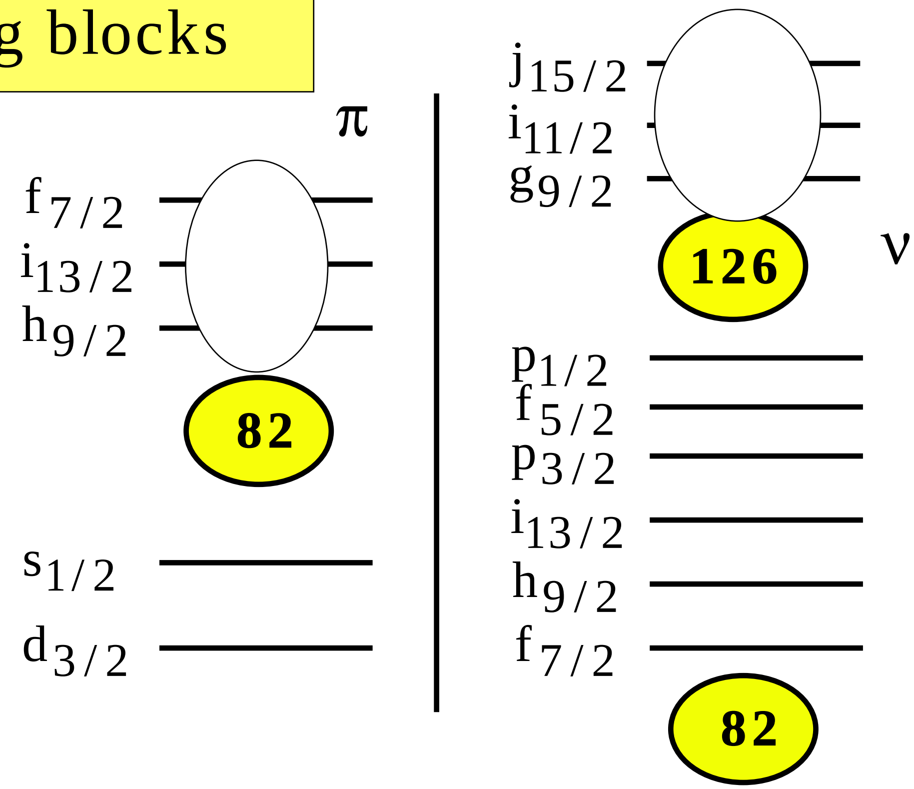
e.g.

8^+	π	$h_{9/2}^2$
10^+	ν	$g_{9/2} i_{11/2}$

→ **18^+**

8^+ 1476
10^+ 1834

18^+ 3310 keV
cf: 2922 keV



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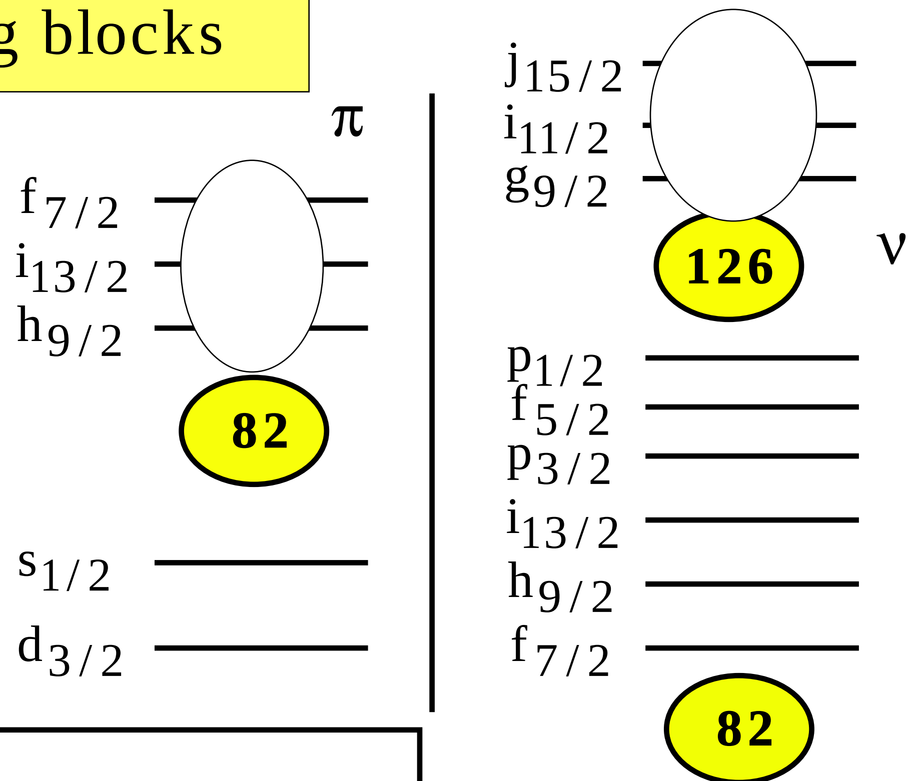


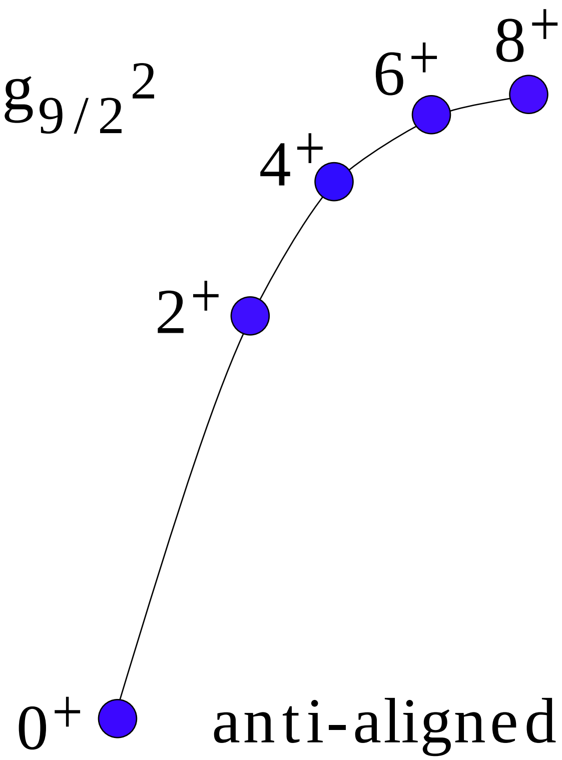
11^- $\pi\, h_{9/2} i_{13/2}$, 12^+ $\nu\, i_{13/2}{}^{-2}$ ....

many factors...

Low transitions energies - low orbitals + favourable interactions,
large configuration changes, K-hindrance, etc. etc.

e.g.

j^n multiplets - two (or more) identical particles in single j-shell



aligned: $j_{max} = 2j-1$

(a) low 8^+ to 6^+ energy gap

(b) B(E2) dependent on shell filling

"seniority-2" [isolated shell]

$B(E2) \propto (2\Omega - 2n)^2 \longrightarrow 0$ at n=5

[shell degeneracy $2\Omega = 2j+1$]

"quasiparticles" [mixed shells]

$B(E2) \propto (u^2 - v^2)^2 \times e_{eff}{}^2 \longrightarrow 0$ at u=v

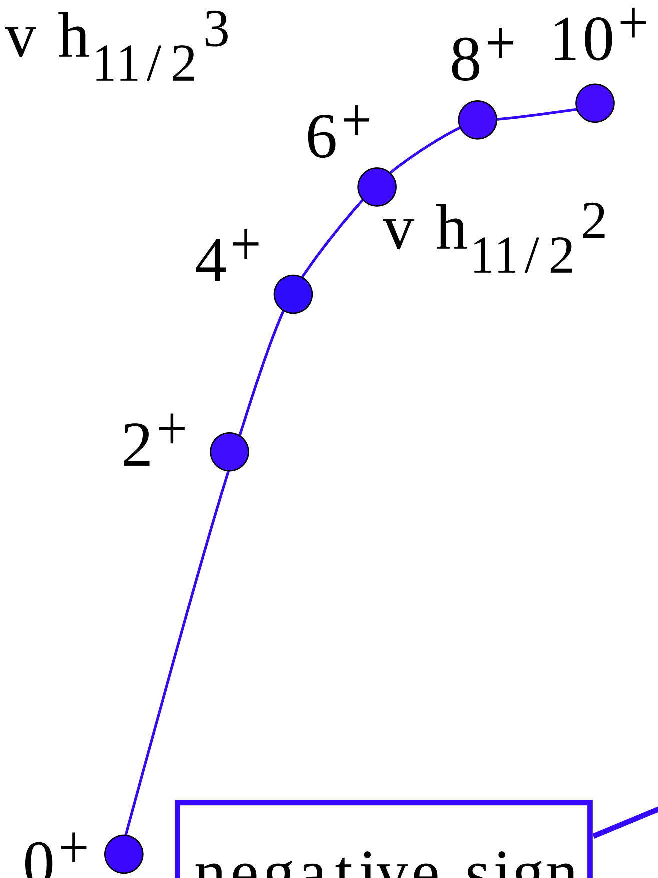
[occupation prob. u, v]

anti-aligned;
(additional depression from pairing)

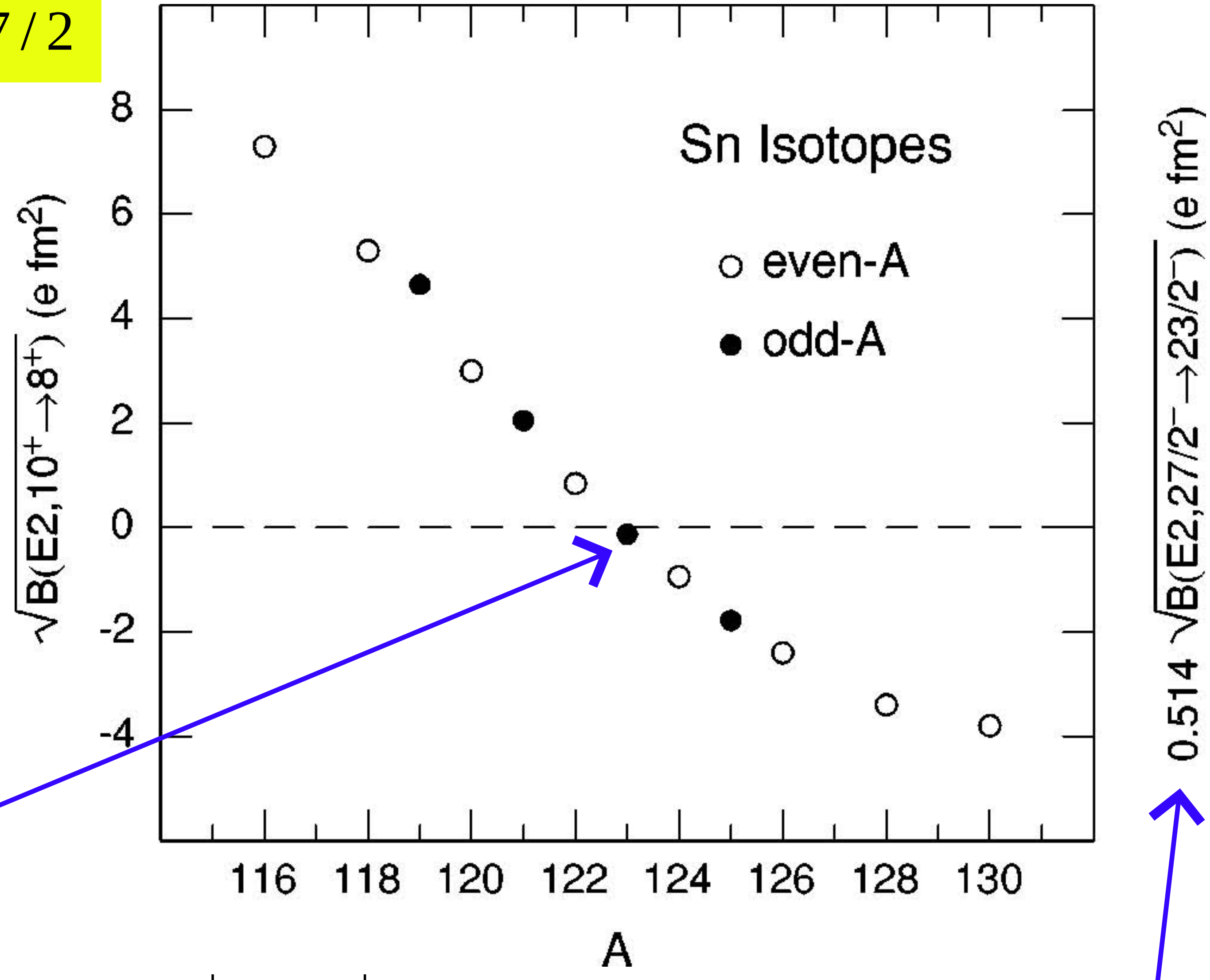
signature of shells

Zhang et al PRC 62 (2000) 057305: 10^+ and $27/2^-$ isomers

m = 11/2+9/2+7/2 =27/2



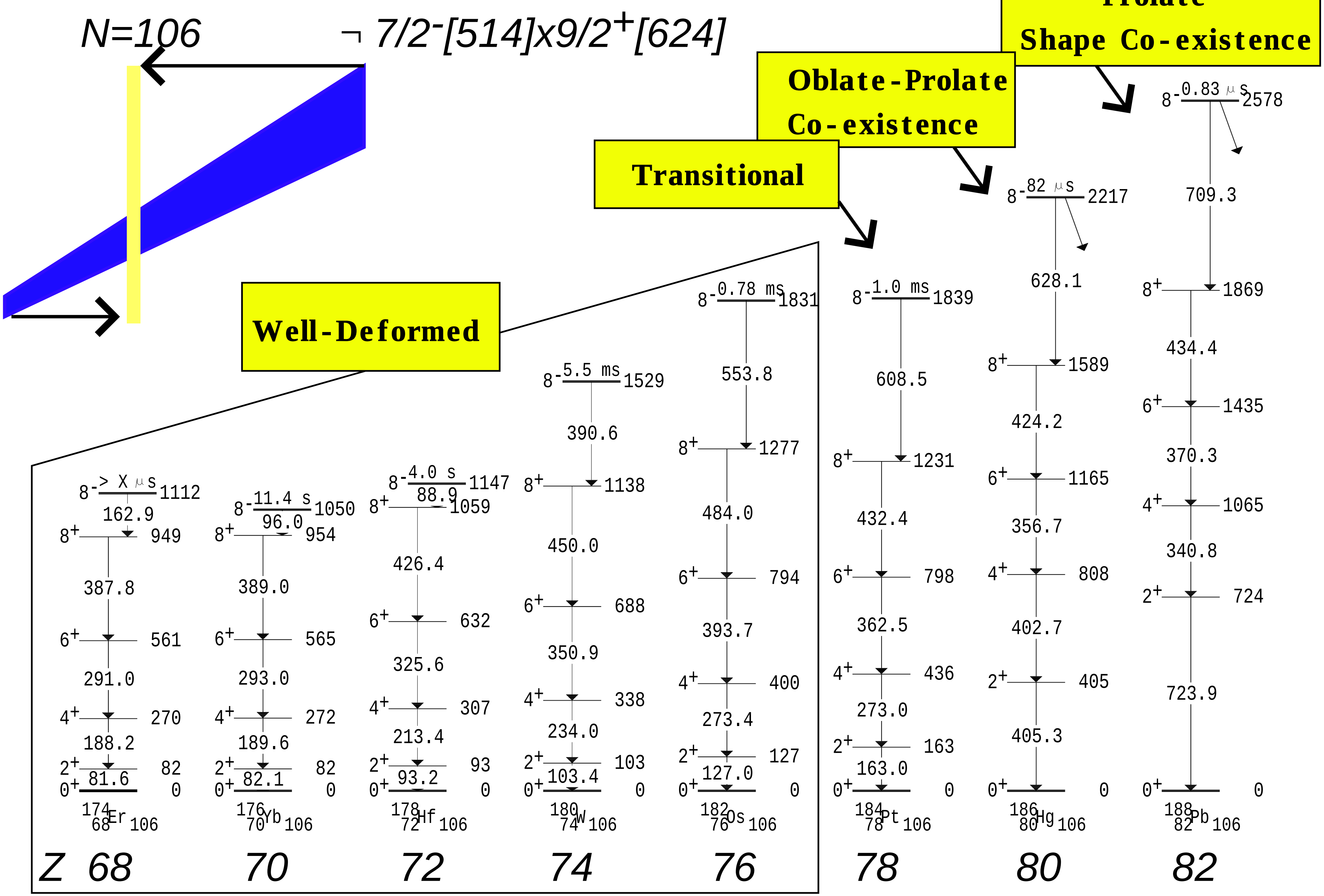
negative sign assumed



10^+ to 8^+ compared to $27/2^-$ to $23/2^-$
[adjusted for $\nu=3/\nu=2$ geometric factors]

$K^{\pi} = 8^{-}$ Isomer; Signature of prolate Deformation

Identification of ^{174}Er & 8- isomer in prolate Well



Triple shape co-existence - Isomers

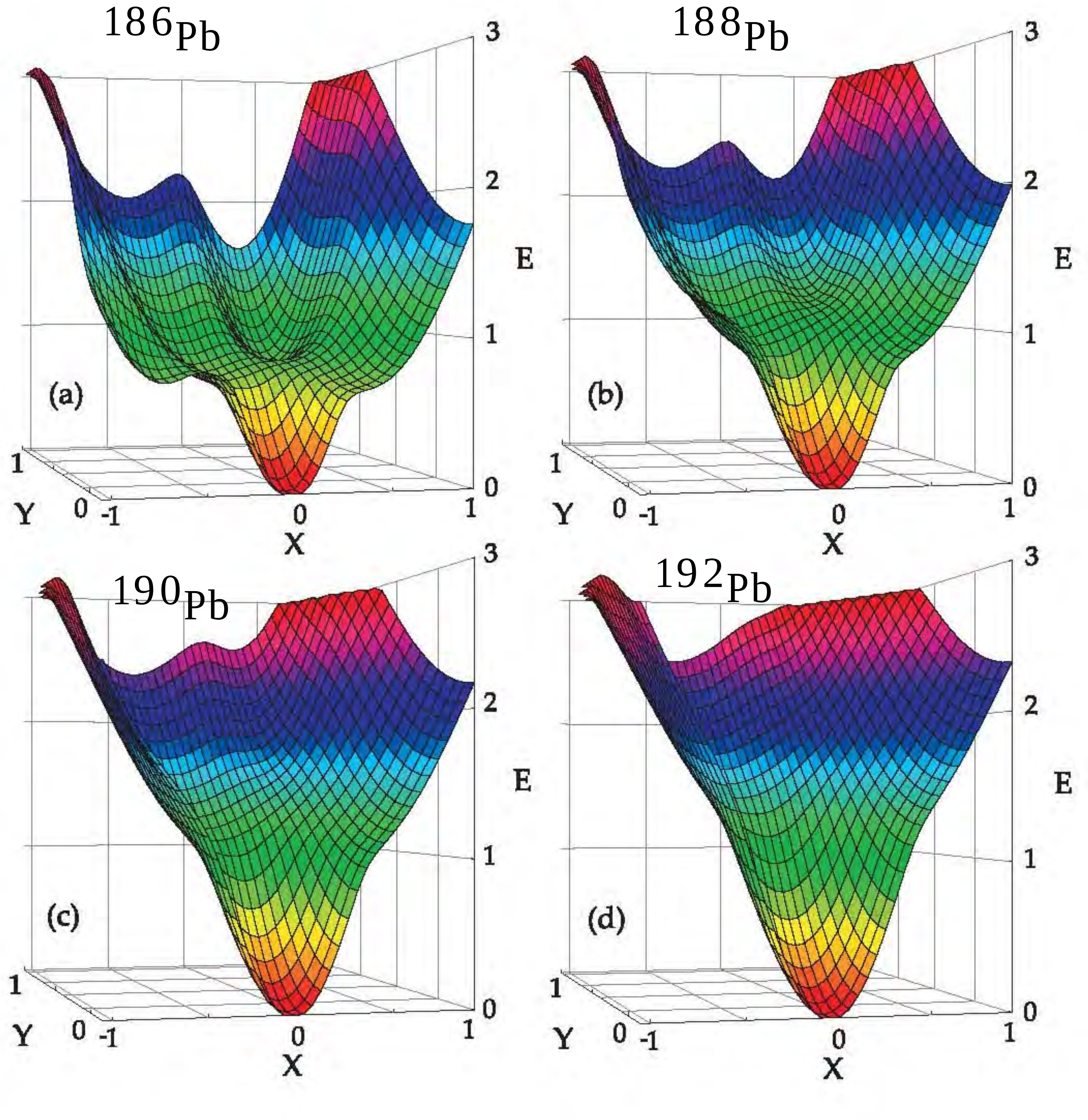
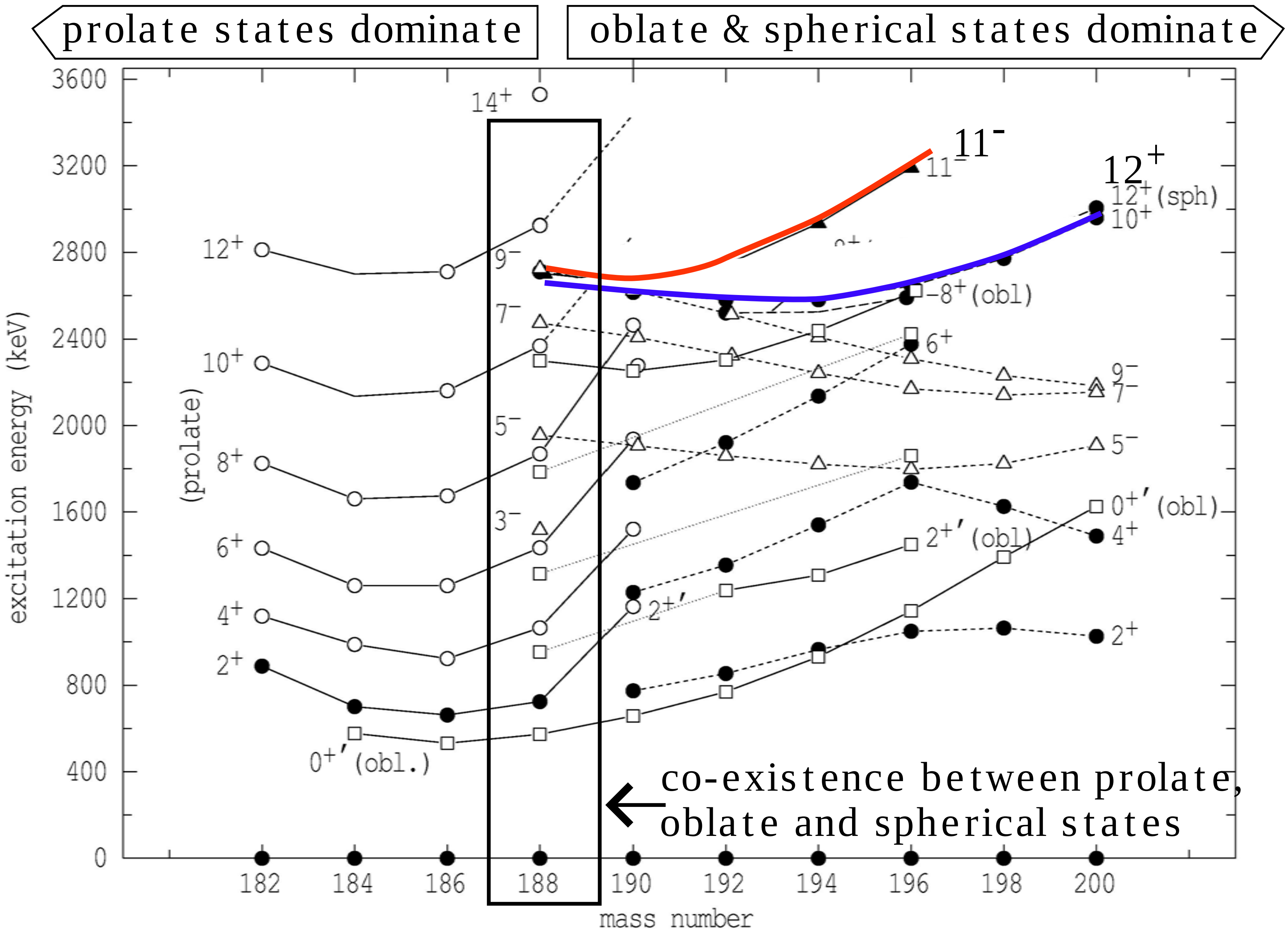


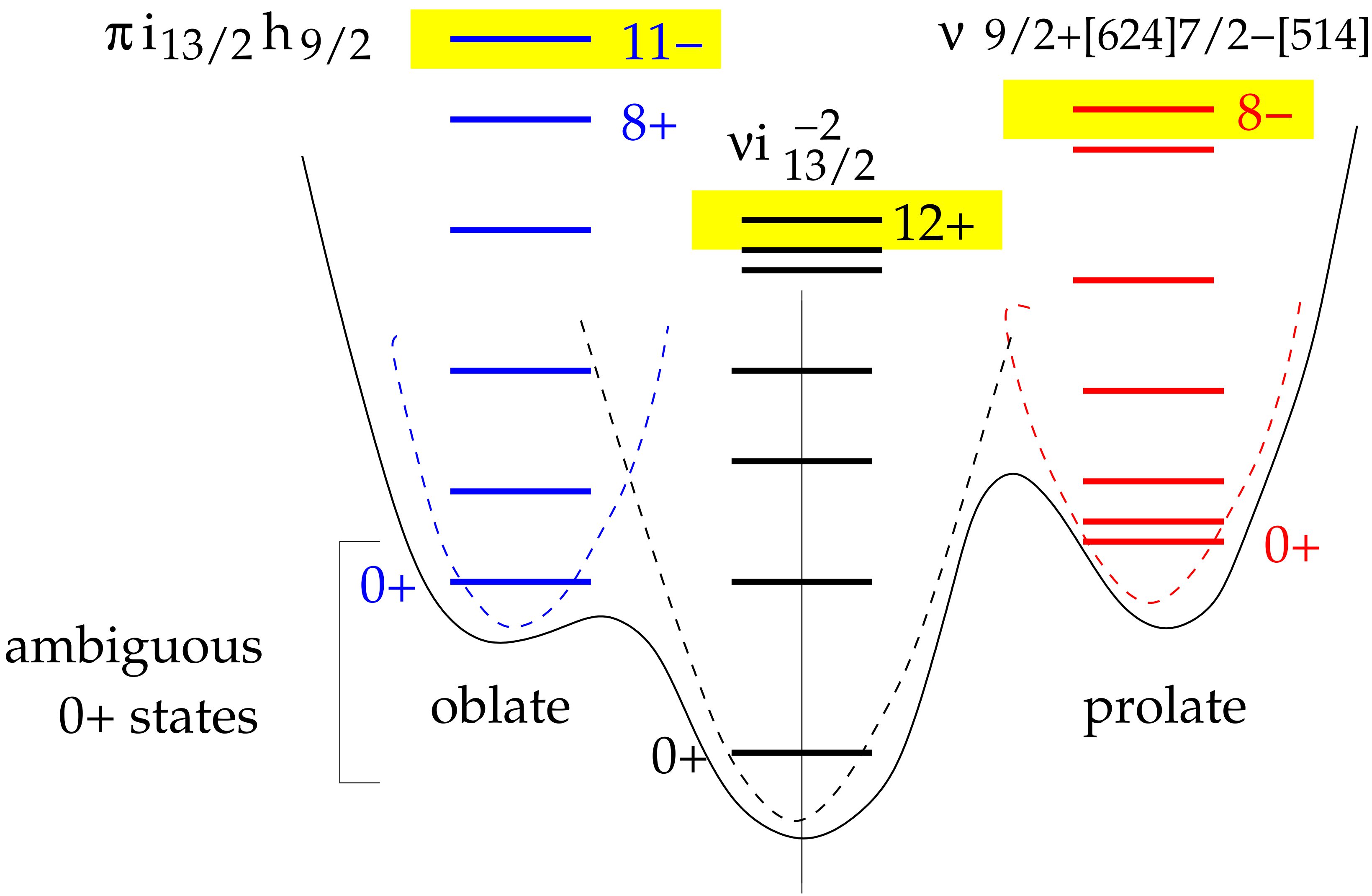
FIGURE 3.1: Energy surfaces for (a) ^{186}Pb, (b) ^{188}Pb, (c) ^{190}Pb, and (d) ^{192}Pb. On the horizontal axes, $X \equiv \beta \sin(\gamma + \pi/6)$, while $Y \equiv \beta \cos(\gamma + \pi/6)$. The vertical axis gives the energy in MeV. The figure is taken from [Fra04] and the parameters used to construct the surfaces were determined in [Fos03].

Pb Systematics



predicted Z=82 Triple Well

characteristic isomers in each: structure, spin and parity

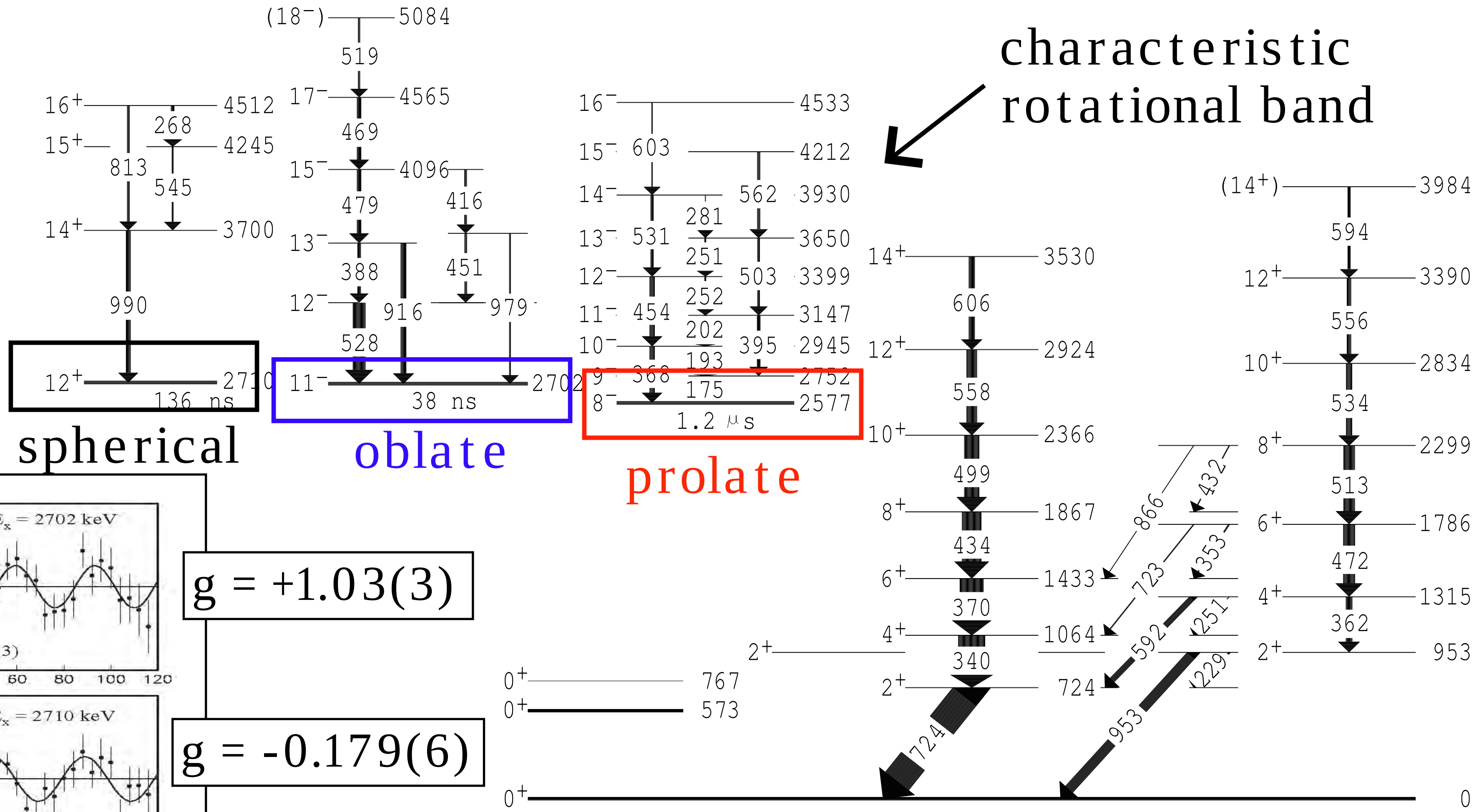


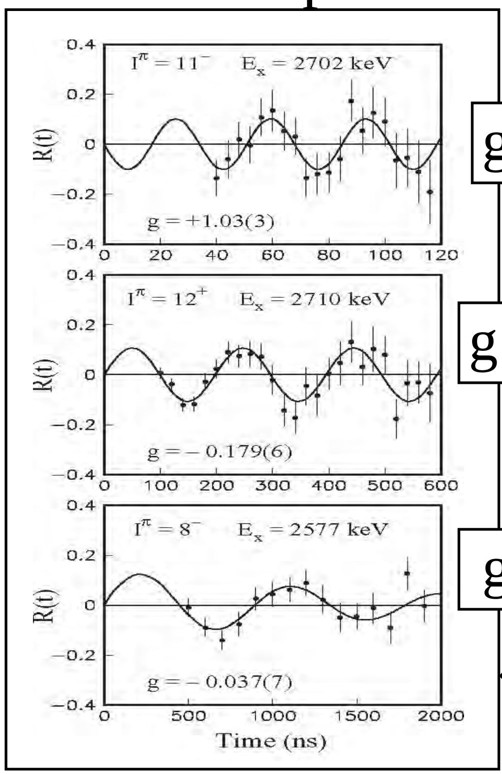
structures above isomers also distinctive

^{188}Pb spherical/oblate/prolate

GDD et al. , PRC 67, 05130(R) (2003); PRC 69, 054318 (2004)

characteristic rotational band





g = +1.03(3)

g = -0.179(6)

g = -0.037(7)

Ionescu-Bujor et al. PRC 81, 024323 (2010)

"g-factors of co-existing isomeric states in ^{188}Pb"

CASE - I: ^{209}Fr

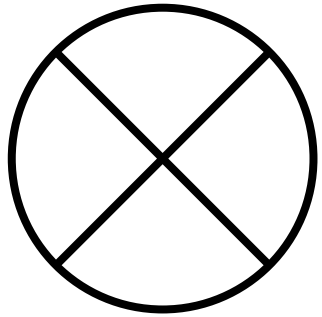
[5 valence protons; 4 neutron holes]

Case I: ^{209}Fr Z=87, N=122 , $i_{13/2}$ proton state?

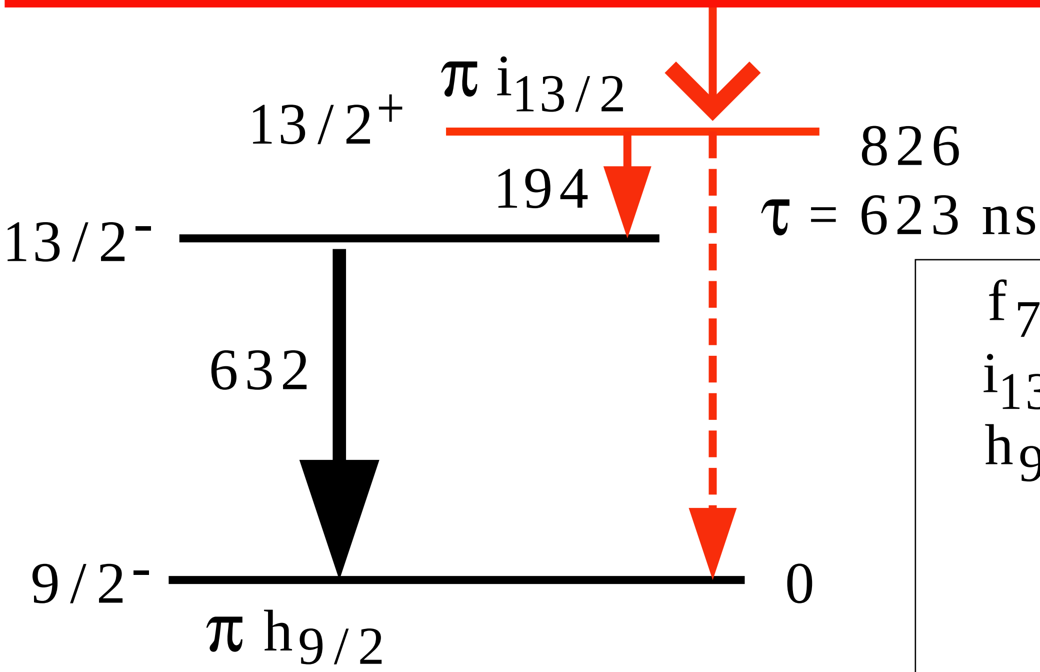
$\Gamma(E1,194) = 1 \times 10^{-9}$ eV

$\pi\, i_{13/2}$ to $h_{9/2}$ M2 ~ 0.2 W.u.

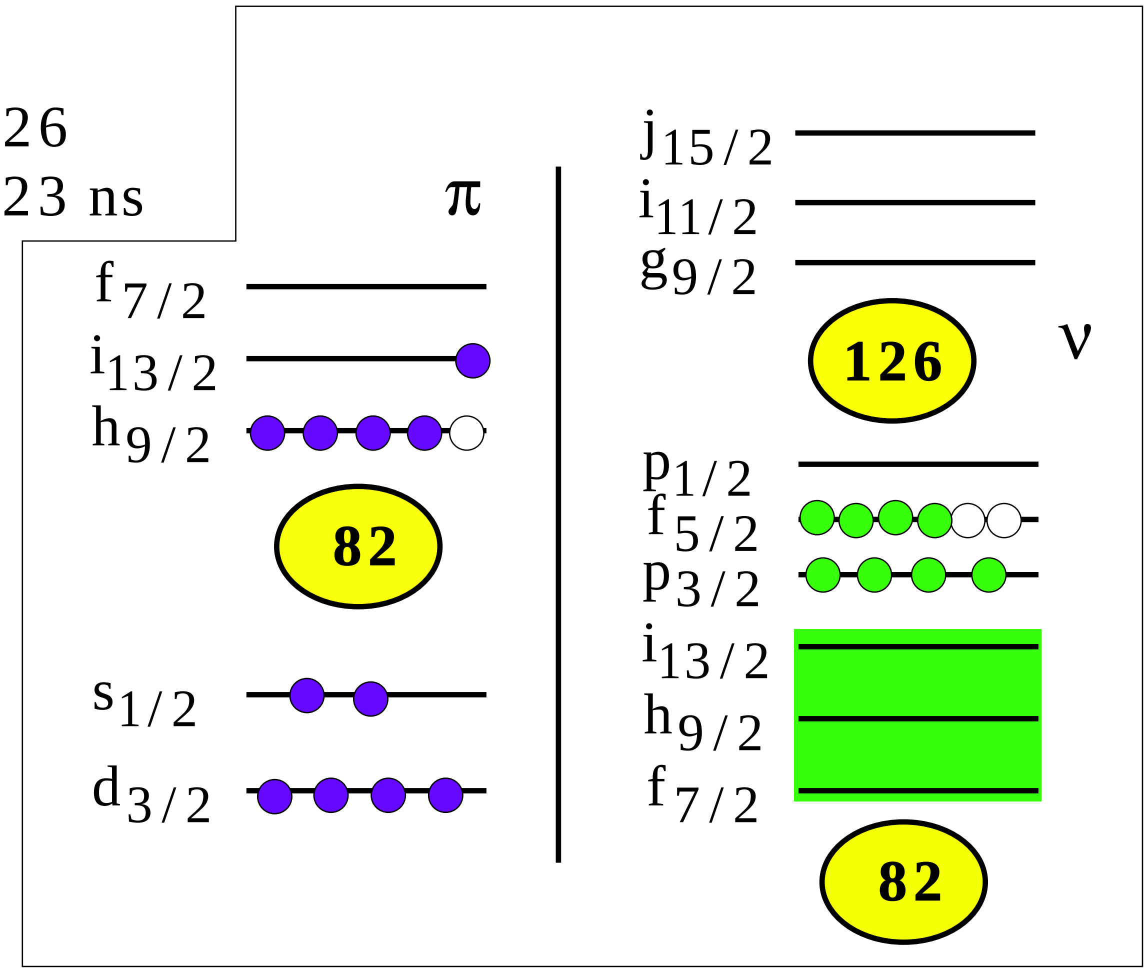
$\Gamma(M2,826) \sim 40 \times 10^{-9}$ eV; $\tau_\gamma = 17$ ns



M2 BRANCH SHOULD DOMINATE



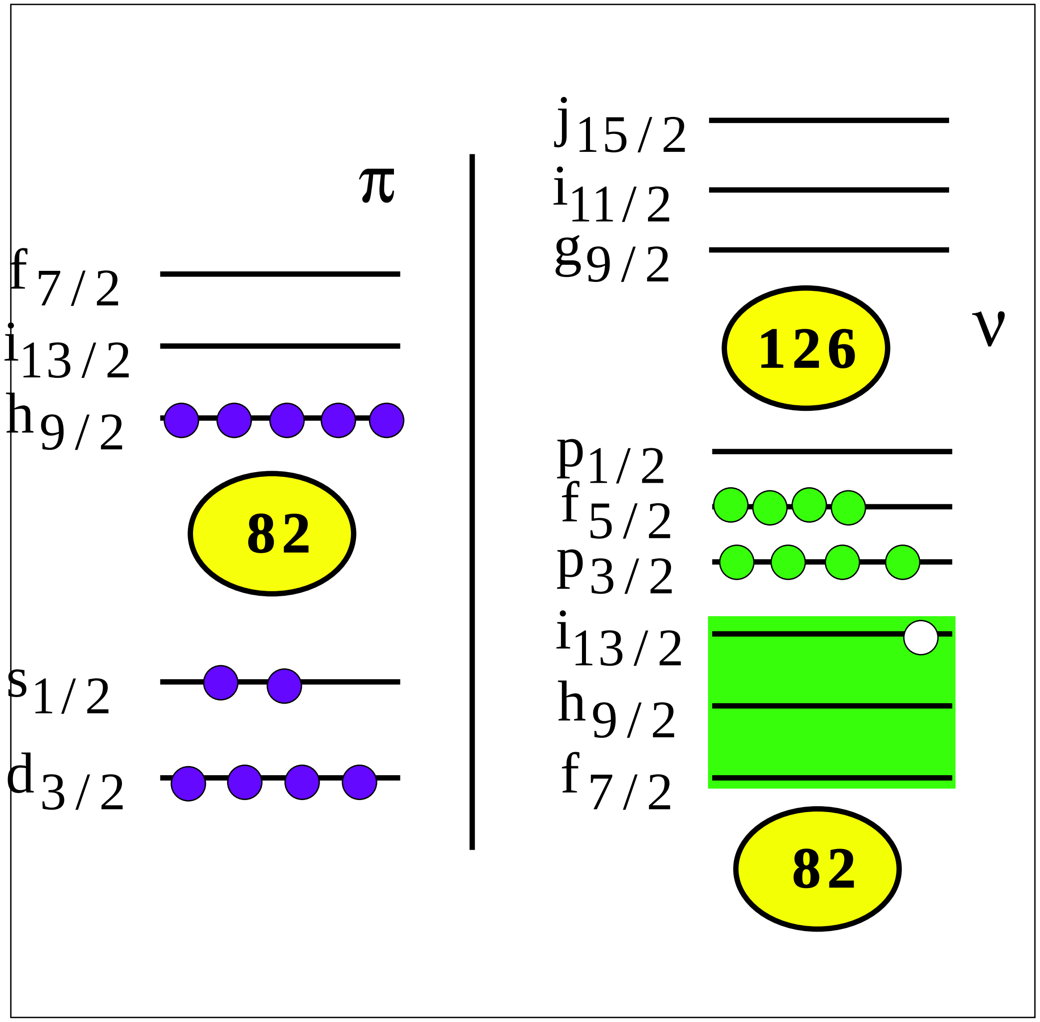
209 Fr
Meyer et al
Phys Rev C 73 (2006) 024307

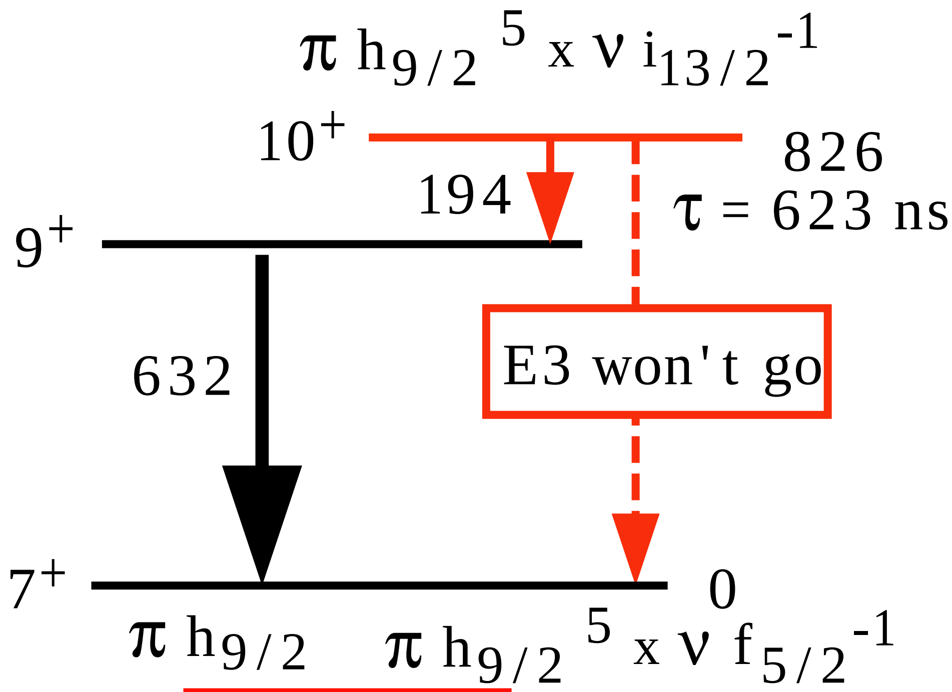


Case I: the drastic solution...

$\Gamma(E1,194) = 1 \times 10^{-9}$ eV

STRUCTURE IS IN ^{208}FR !!





^{208}Fr !

GDD et al
EPJA 40(2009)127

CASE - II: ^{212}Rn
[4 valence protons; 0 neutron holes plus neutron core excitations]
Signature E3 Transitions

See Phys Rev C-80-2009-05430
Phys Lett B 662-2008-19

Spherical levels and octupole coupling - E3 signatures

$$|\tilde{i}_{13/2}\rangle = \alpha\, i_{13/2} + \beta\, f_{7/2} \otimes 3^- + \gamma \ldots$$

← collective E3 admixtures

"type-A" E3 ~ 22 W.u.
(stretched)

$\pi\, i_{13/2} \rightarrow f_{7/2}$

or

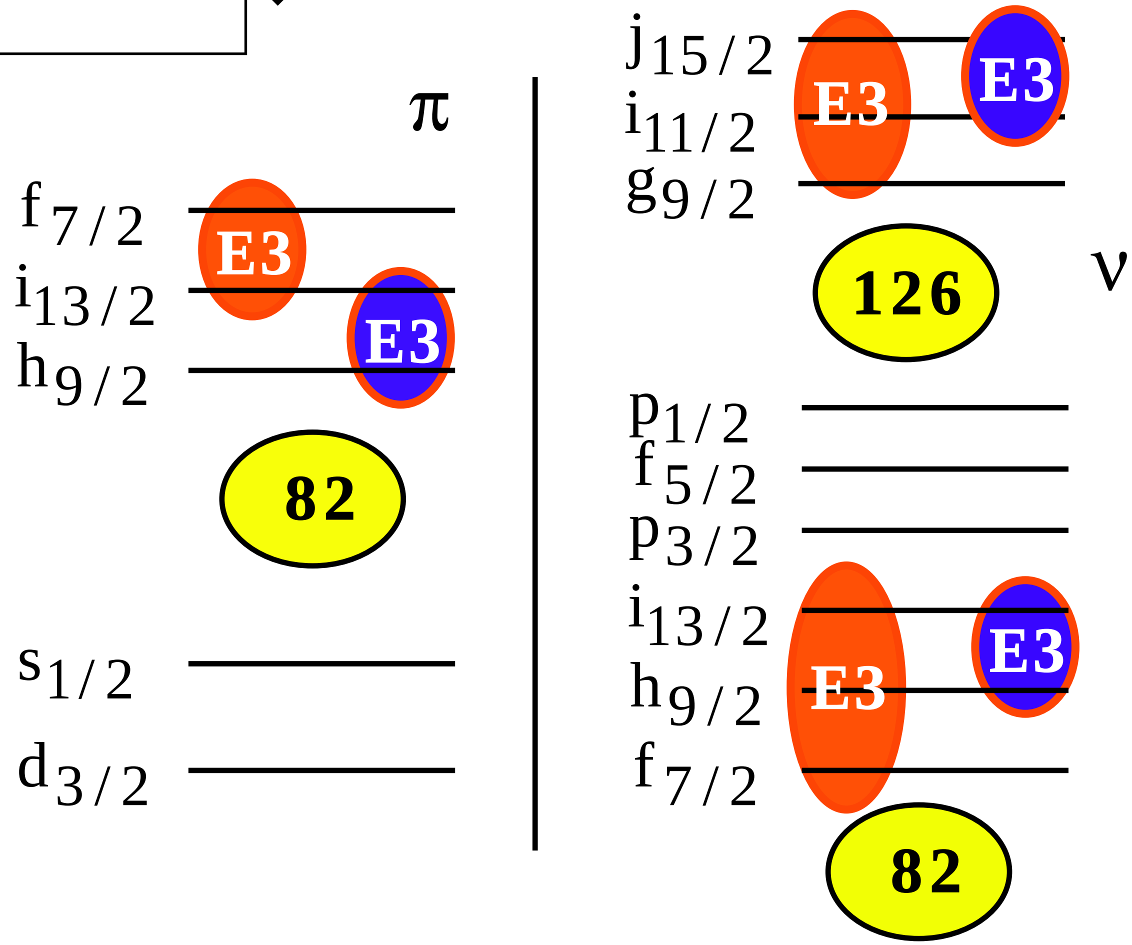
$\nu\, j_{15/2} \rightarrow g_{9/2}$

"type-B" E3 ~ 3 W.u.
(spin-flip)

$\pi\, i_{13/2} \rightarrow h_{9/2}$

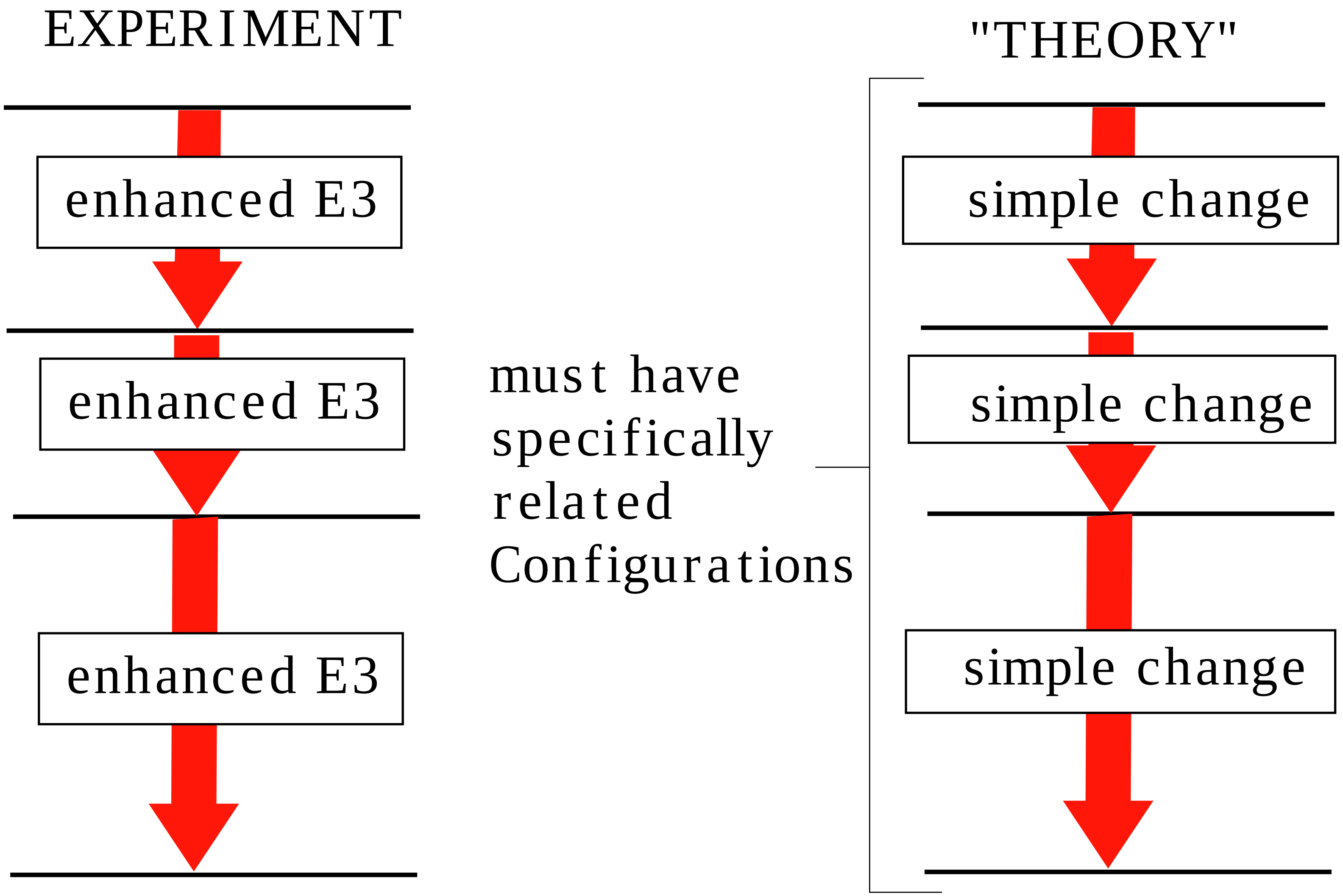
or

$\nu\, j_{15/2} \rightarrow i_{11/2}$



see Bergstrom and Fant, Phys. Scr. 31 (1985) 26 and many others

A simple proposition...



Low and High-Spin States (Isomers) in ^{212}Rn
Shell Model View
[Extremely Brief]

Semi-Empirical Shell-Model (ESM):
- Single-Particle Energies +
weighted sum of two-body interaction matrix elements

The shell-model Hamiltonian for a many-body system may be written as

$$H = \sum_i H_i + \sum_{i>j} H_{i,j}, \tag{1}$$

where H_i and $H_{i,j}$ are single-particle and two-body terms, respectively.

In terms of the excitation energy of a state Ψ, we can write:

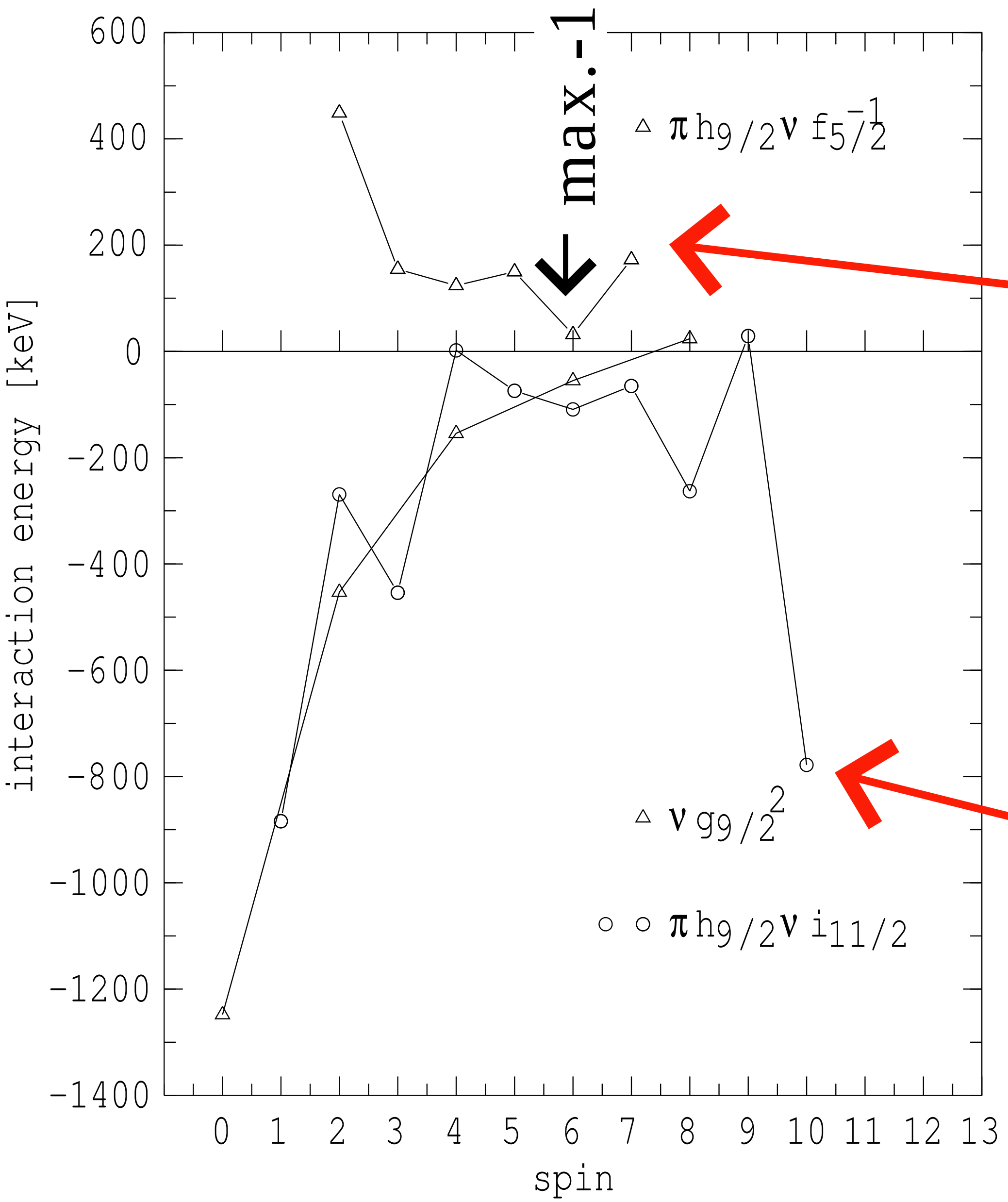
$$E_{\text{ex}}(\Psi) = \varepsilon_0 + \sum \langle j_a, j_b \rangle_J, \tag{2}$$

where ε_0 denotes the difference between the single-particle energy and the ground-state energy and $\langle j_a, j_b \rangle_J$ are the two-body residual interaction energies. In the present calculations interaction energies are taken from experiment where possible, and from theoretical models (Kuo and Herling [20]) where it is not. A full list of the interactions used in this work is tabulated in [21].

Blomqvist :
Proc Argonne Symposium, 1979 ANL/PHY-79-4, p155

See: Bayer et al, NPA 694 (2001) 3; NPA 650 (1999) 3; etc.

Typical residuals

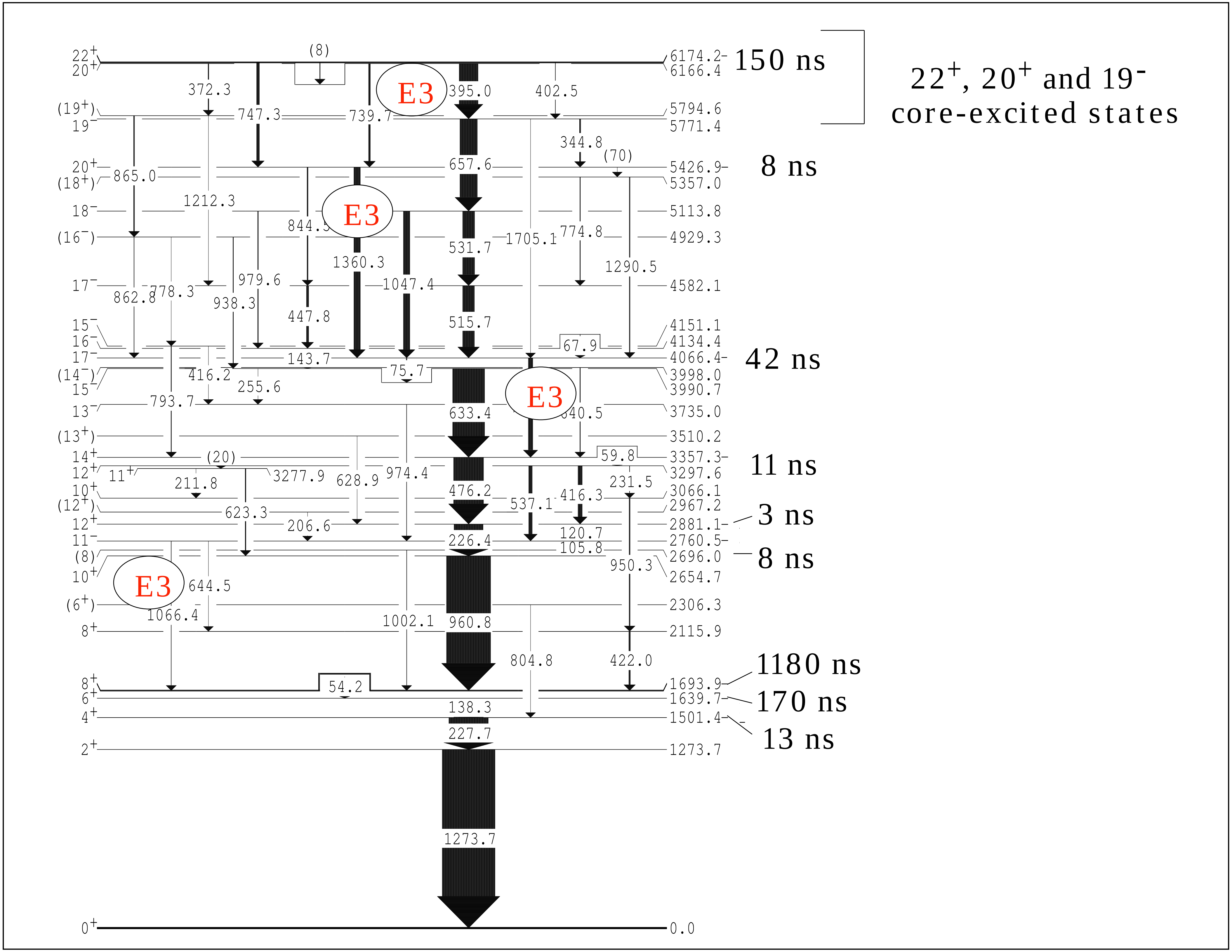


proton, neutron-hole

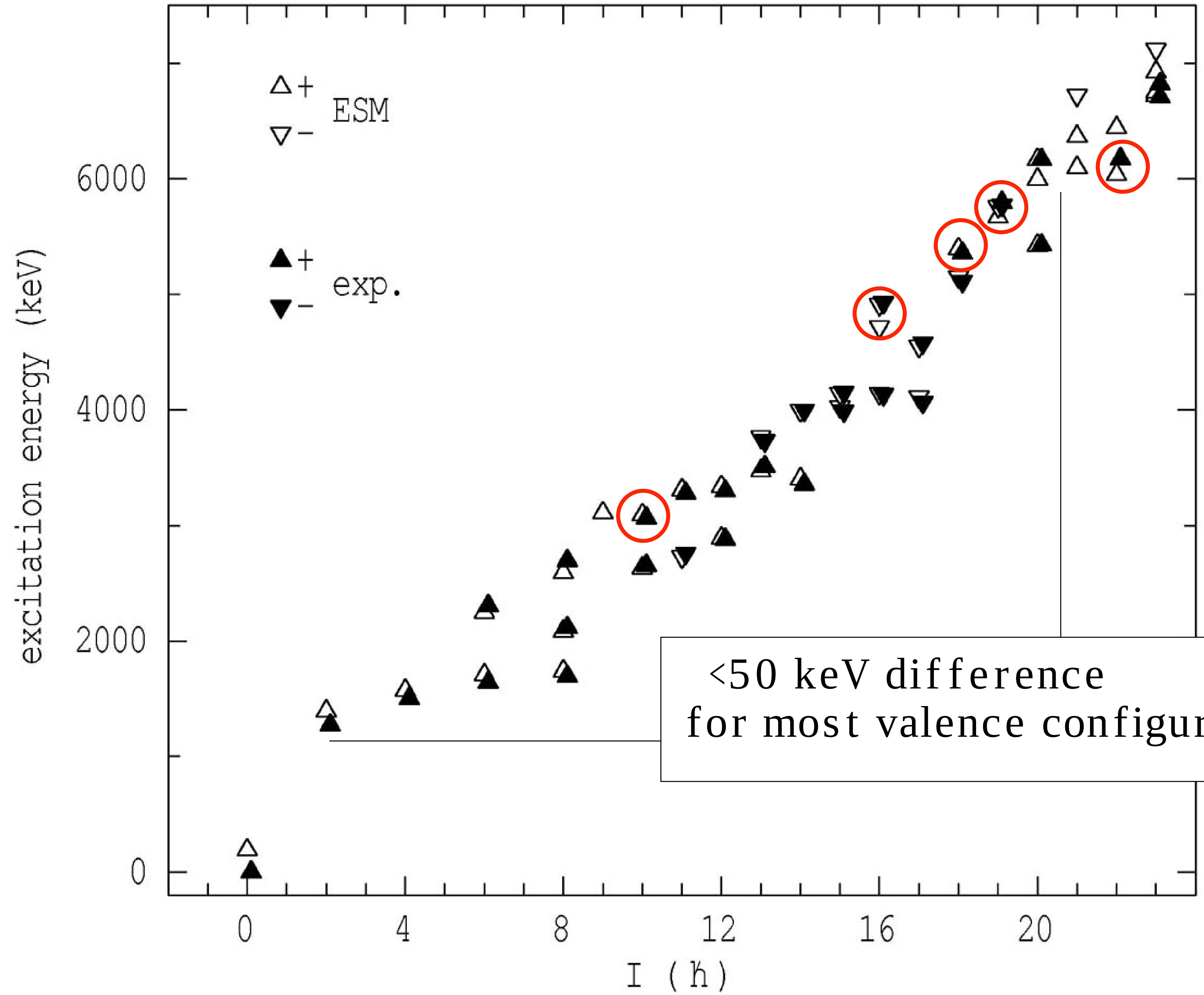
repulsive
for mutual alignment,
even for low-j neutron-hole

proton, neutron

strongly-attractive
for mutual alignment


150 ns
22+, 20+ and 19- core-excited states
8 ns
42 ns
11 ns
3 ns
8 ns
1180 ns
170 ns
13 ns
E3
E3
E3
E3
22+
20+
(19+)
19-
20+
(18+)
18-
(16-)
17-
15-
16-
17-
(14-)
15-
13-
(13+)
14+
12+
11+
10+
(12+)
12+
11-
(8)
10+
(6+)
8+
8+
6+
4+
2+
0+
6174.2
6166.4
5794.6
5771.4
5426.9
5357.0
5113.8
4929.3
4582.1
4151.1
4134.4
4066.4
3998.0
3990.7
3735.0
3510.2
3357.3
3297.6
3277.9
3066.1
2967.2
2881.1
2760.5
2696.0
2654.7
2306.3
2115.9
1693.9
1639.7
1501.4
1273.7
0.0
(8)
372.3
747.3
739.7
395.0
402.5
344.8
(70)
657.6
865.0
1212.3
844.5
1705.1
774.8
531.7
1360.3
1290.5
979.6
1047.4
862.8
778.3
938.3
447.8
515.7
67.9
143.7
416.2
75.7
255.6
793.7
633.4
640.5
(20)
59.8
211.8
628.9
974.4
231.5
476.2
416.3
537.1
623.3
206.6
120.7
226.4
105.8
950.3
644.5
1066.4
1002.1
960.8
804.8
422.0
54.2
138.3
227.7
1273.7

^{212}Rn Z=86, N= 126 - Experiment and ESM - low



<50 keV difference
for most valence configurations

Strengths (sampler)

within multiplet E2

J^{π}		E(keV)	σλ	W.u.	type
22^{+}	20^{+}_{2}	7.6	E2	4(1)	$\pi[h^{3}i]\ \nu\ p^{-1}g$ multiplet
	20^{+}_{1}	747	E2	$3.6(7)\times10^{-5}$	core-excited to valence
	19^{-}_{1}	403	E3	44(11)	core-excited to core-excited; $\pi\ \tilde{i}_{13/2}$ to $\tilde{f}_{7/2}$ type-A
20^{+}_{1}	18^{+}	70	E2	2.7(5)	valence multiplet
	17^{-}_{2}	845	E3	37(8)	valence to valence; $\pi\ \tilde{i}_{13/2}$ to $\tilde{f}_{7/2}$
	17^{-}_{1}	1360	E3	7(1)	valence to valence; $\pi\ \tilde{i}_{13/2}$ to $\tilde{h}_{9/2}$ type-B

Maximum-J ;
Single (I), Double (II), Triple(III) -
Neutron Core Excitations

valence protons

π [$h^3 f$] $_{17^-}$

π [$h^2 i^2$] $_{20^+}$

I

+ ν [p^{-1} g] $_{5^-}$
ν [p^{-1} i] $_{6^-}$
ν [p^{-1} j] $_{8^+}$

~28h

ν [f^{-1} g] $_{7^-}$
....

~30h

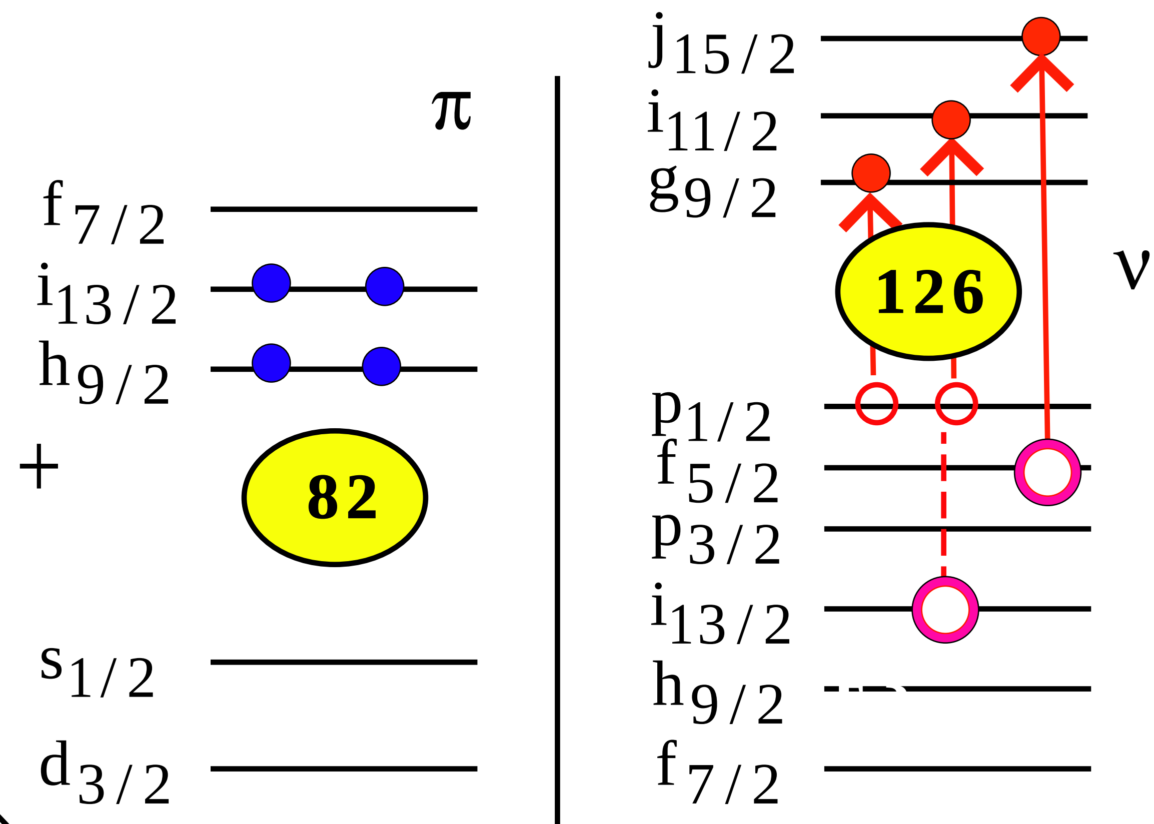
II

+ ν [p^{-2} gi] $_{10^+}$
ν [$p^{-2} j^2$] $_{14^+}$
ν [$p^{-1} f^{-1}$ gj] $_{16^-}$

~36h

ν [$p^{-1} i^{-1}$ i j] ....$_{20^+}$

~40h

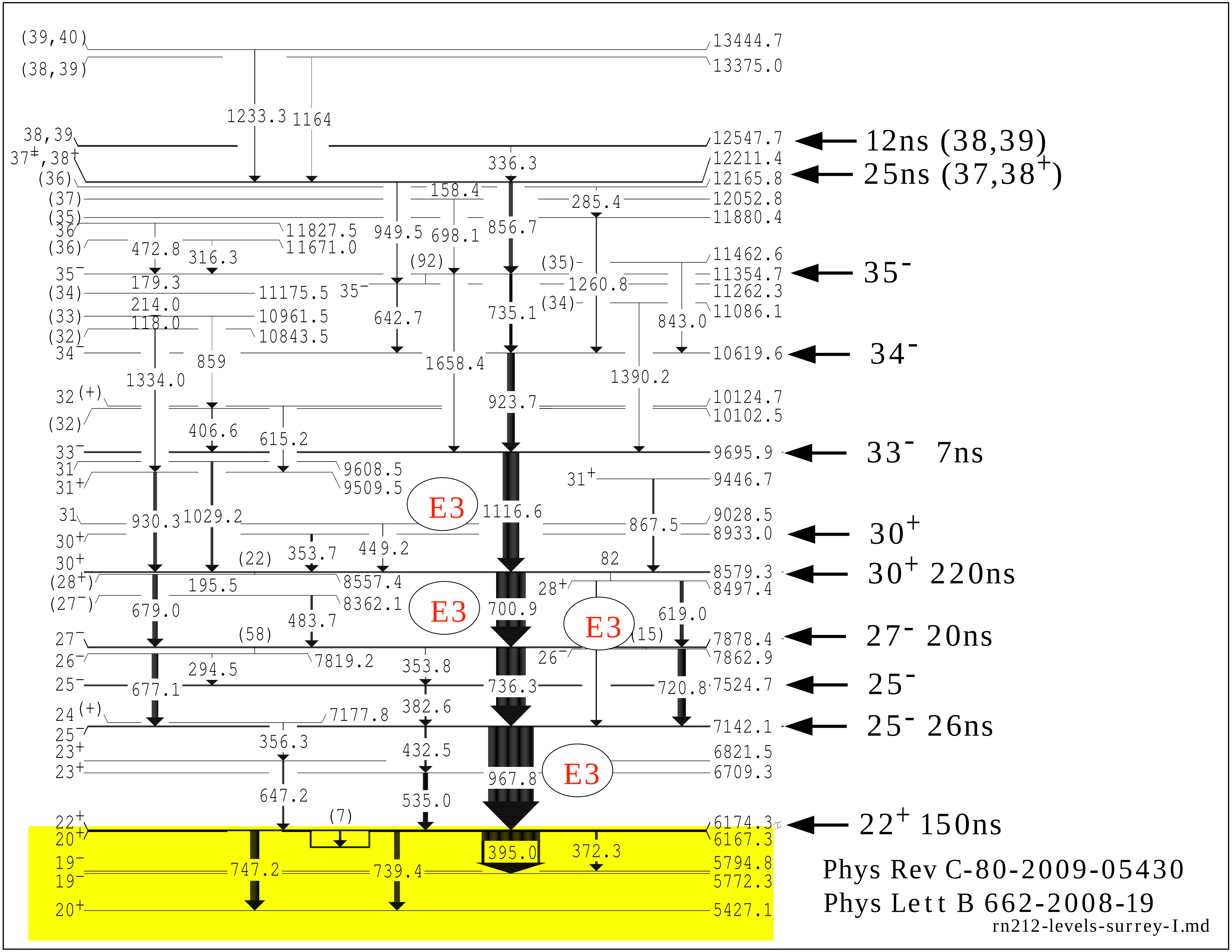


Mutual Alignment of high-j neutron holes/proton-particles - repulsive interaction

III

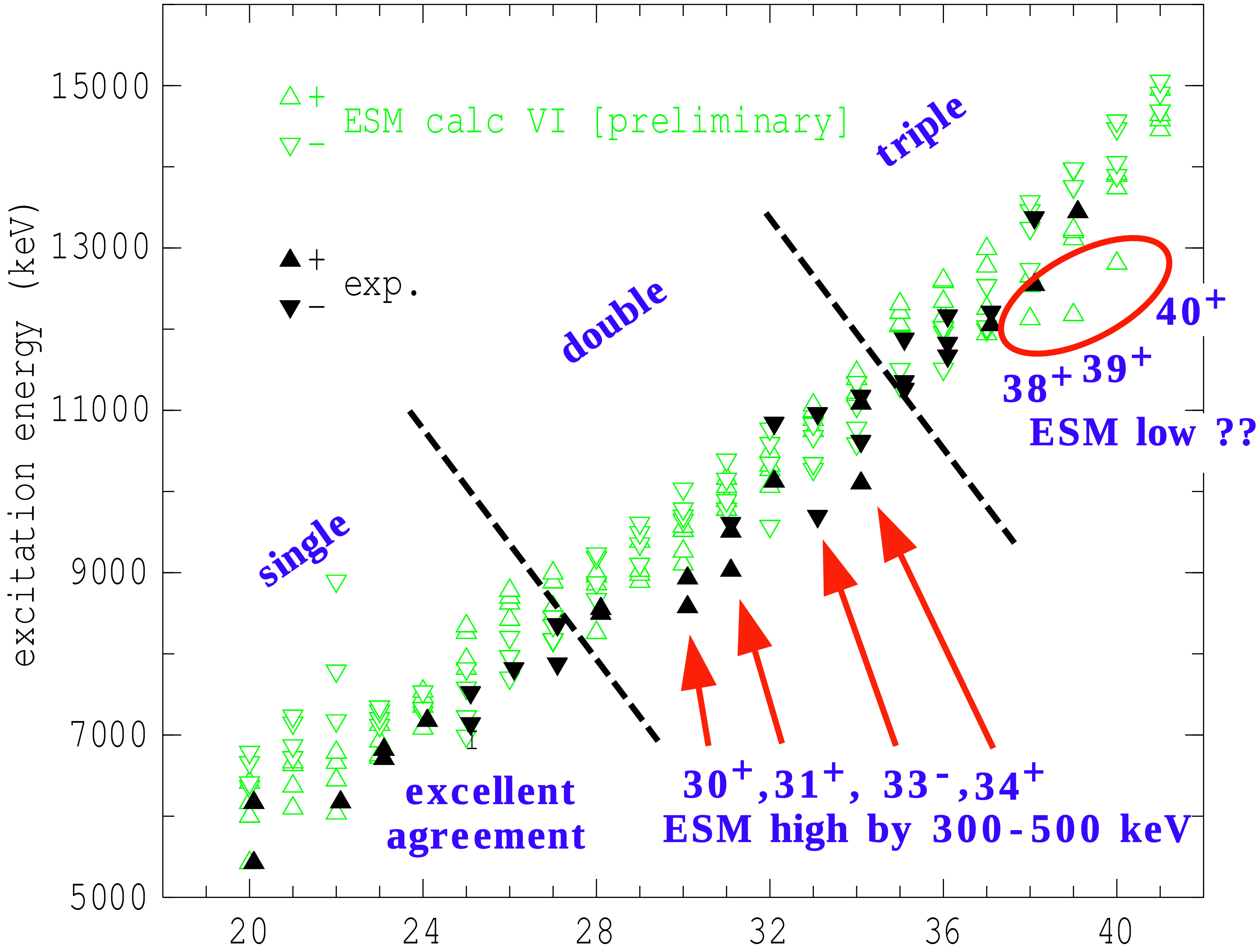
+ ν [$p^{-2} f^{-1}$ gij] ....$_{20^+}$

~40h



(39,40)
13444.7
(38,39)
13375.0
1233.3
1164
38,39
12547.7
12ns (38,39)
37±,38+
12211.4
336.3
(36)
12165.8
25ns (37,38+)
(37)
12052.8
158.4
285.4
(35)
11880.4
36
11827.5
(36)
11671.0
472.8
316.3
949.5
698.1
856.7
(92)
(35)-
11462.6
35−
11354.7
35-
179.3
1260.8
(34)
11175.5
35−
11262.3
214.0
(34)-
11086.1
(33)
10961.5
642.7
735.1
843.0
118.0
(32)
10843.5
34−
10619.6
34-
859
1658.4
1334.0
1390.2
32 (+)
10124.7
923.7
(32)
10102.5
406.6
615.2
33−
9695.9
33- 7ns
31
9608.5
31+
9509.5
31+
9446.7
E3
1116.6
31
930.3
1029.2
867.5
9028.5
30+
8933.0
30+
353.7
449.2
30+
(22)
82
8579.3
30+ 220ns
(28+)
8557.4
195.5
28+
8497.4
(27−)
8362.1
679.0
E3
700.9
E3
619.0
483.7
27−
(58)
(15)
7878.4
27- 20ns
26−
7819.2
26−
7862.9
294.5
353.8
25−
677.1
736.3
720.8
7524.7
25-
24 (+)
7177.8
382.6
25−
7142.1
25- 26ns
356.3
432.5
23+
6821.5
23+
E3
6709.3
967.8
647.2
535.0
22+
(7)
6174.3
22+ 150ns
20+
6167.3
395.0
372.3
19−
5794.8
747.2
739.4
19−
5772.3
20+
5427.1
Phys Rev C-80-2009-05430
Phys Lett B 662-2008-19
rn212-levels-surrey-I.md

^{212}Rn Z=86, N= 126 - Experiment and ESM - preliminary



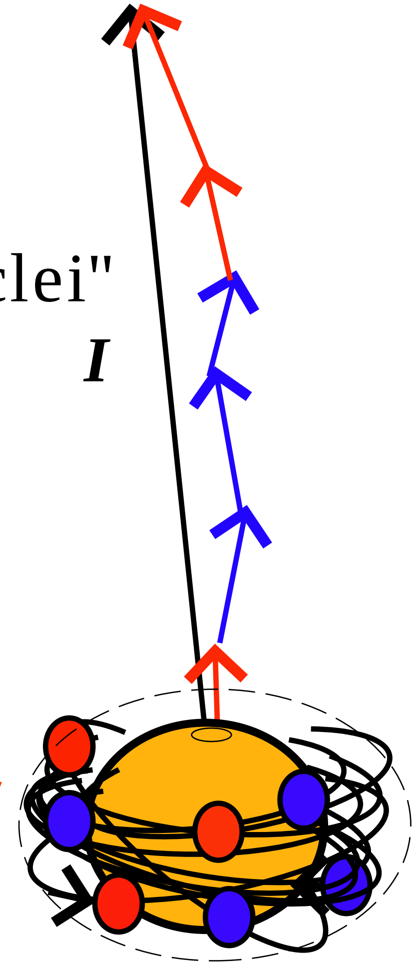
Deformed View (DIPM)

Induced Deformation

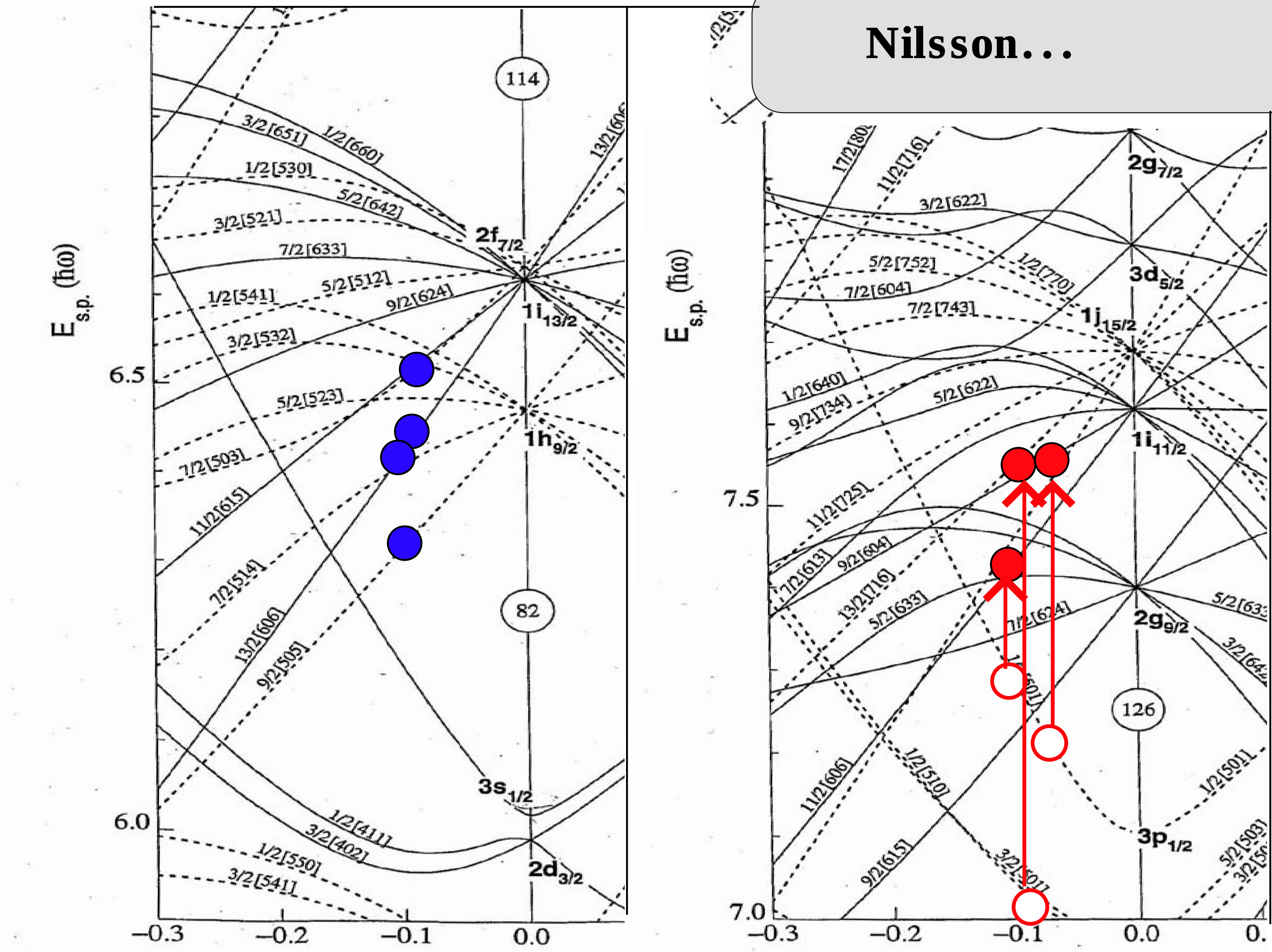
"New Era of High-Spin Studies in Trans-lead Nuclei"

Deformed Independent Particle Model (DIPM)
Matsuyanagi et al Nucl Phys A 307 (1978) 253

aligned high-spin states
equatorial nucleons congregate
- oblate deformation ?



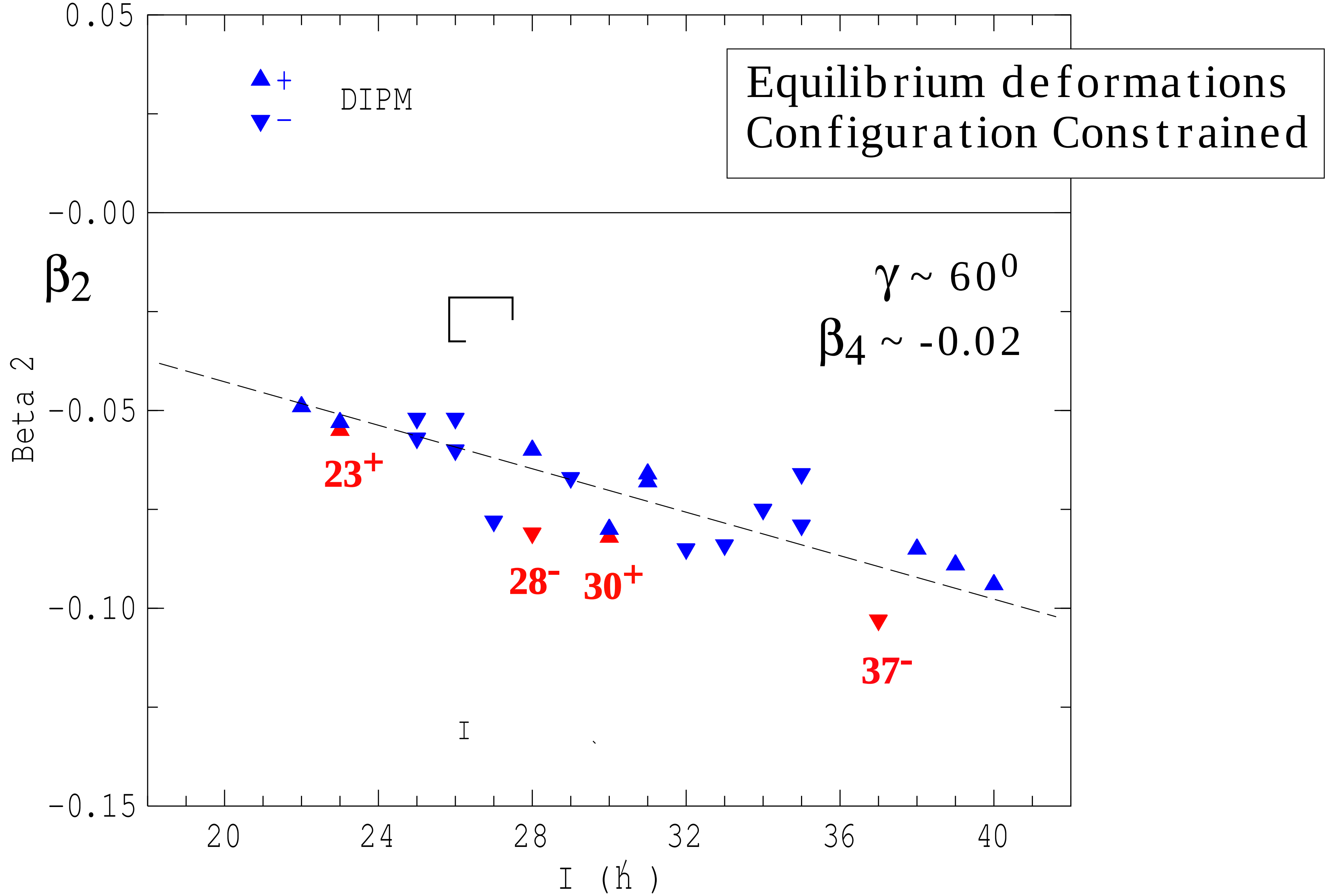
Nilsson...



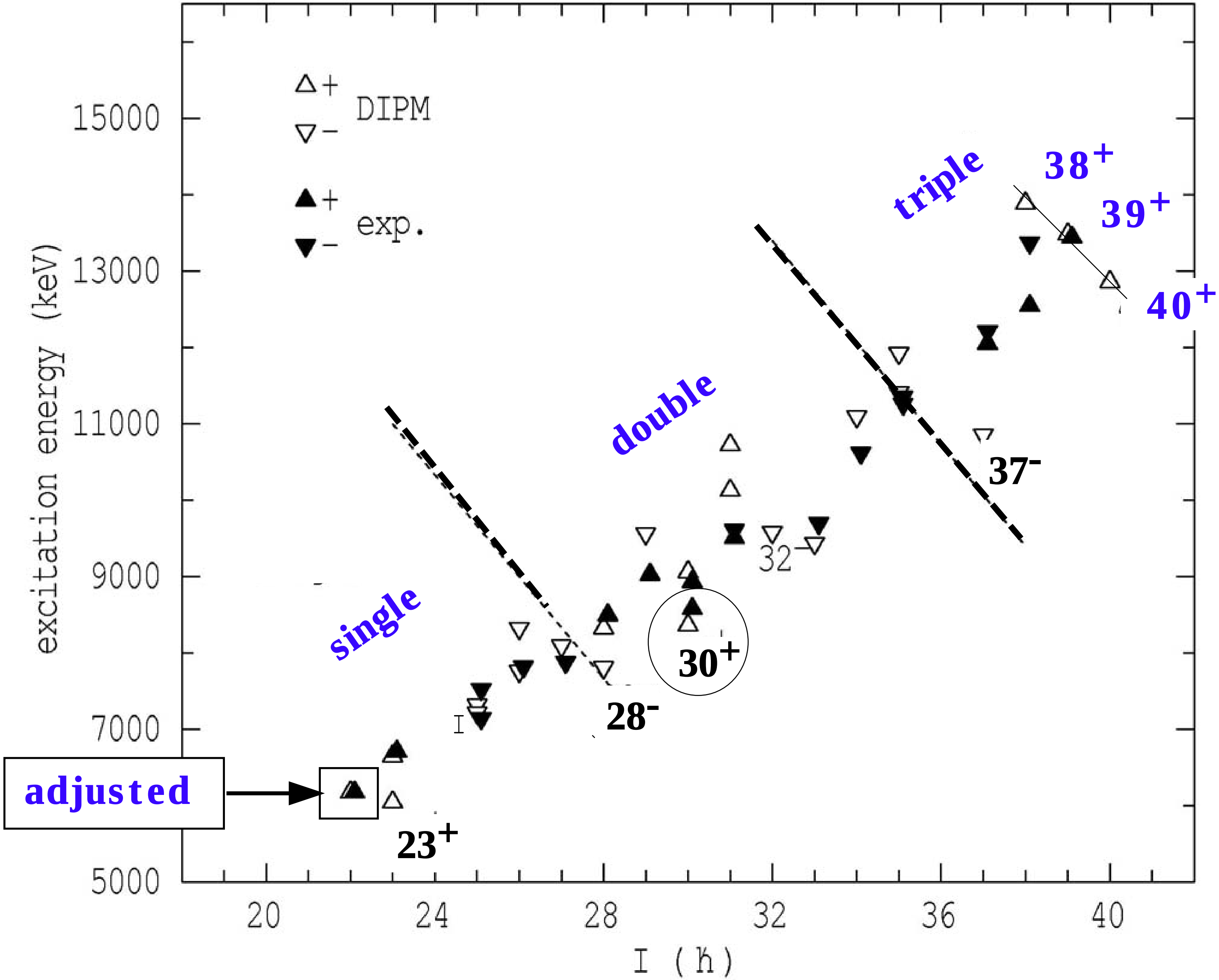
Protons.

Neutrons.

DIPM - predicted deformations (Xu,Liu)



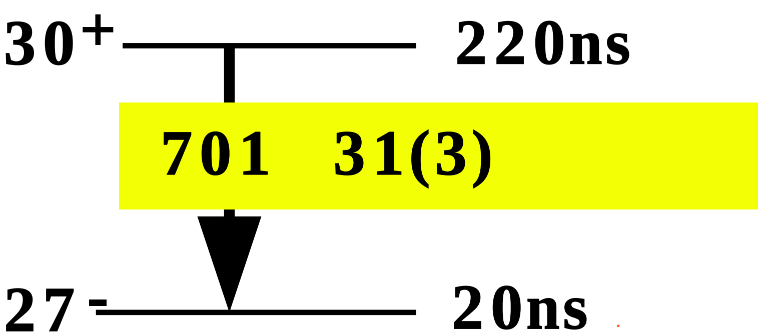
^{212}Rn Z=86, N= 126 - Experiment and DIPM



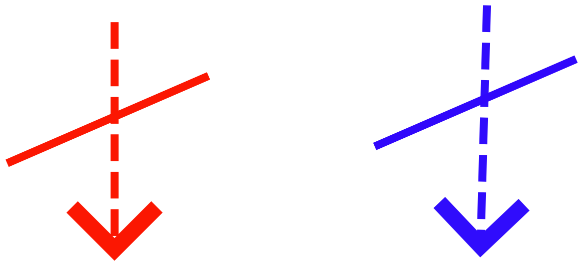
DIPM Configuration assignments do not match E3 transitions

DIPM Assignment - Matsuyanagi et al., Andersson et al; deVoight review...

Strong E3 not Possible

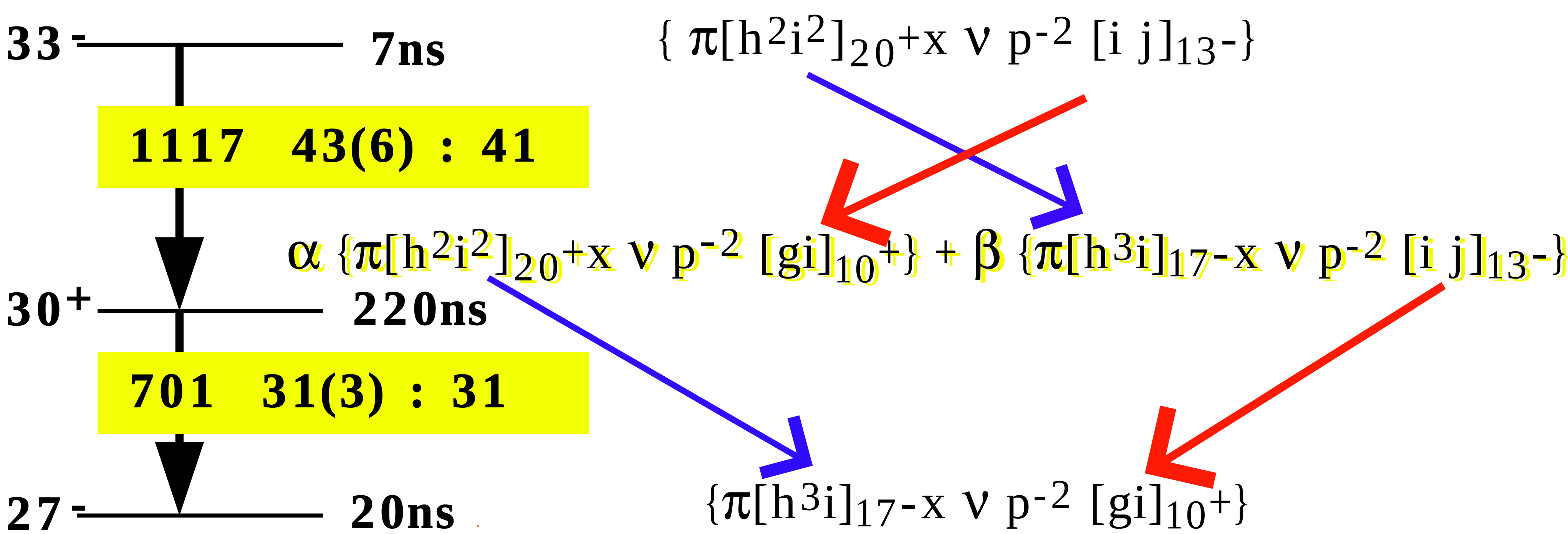


$\pi[h^2 fi]_{18}\text{-}x\ \nu\ p^{-2}\ [gj]_{12}\text{-}$



$\{\pi[h^3 i]_{17}\text{-}x\ \nu\ p^{-2}\ [gi]_{10}+\}$

Multiple - Particle - Octupole - Coupling: MPOC

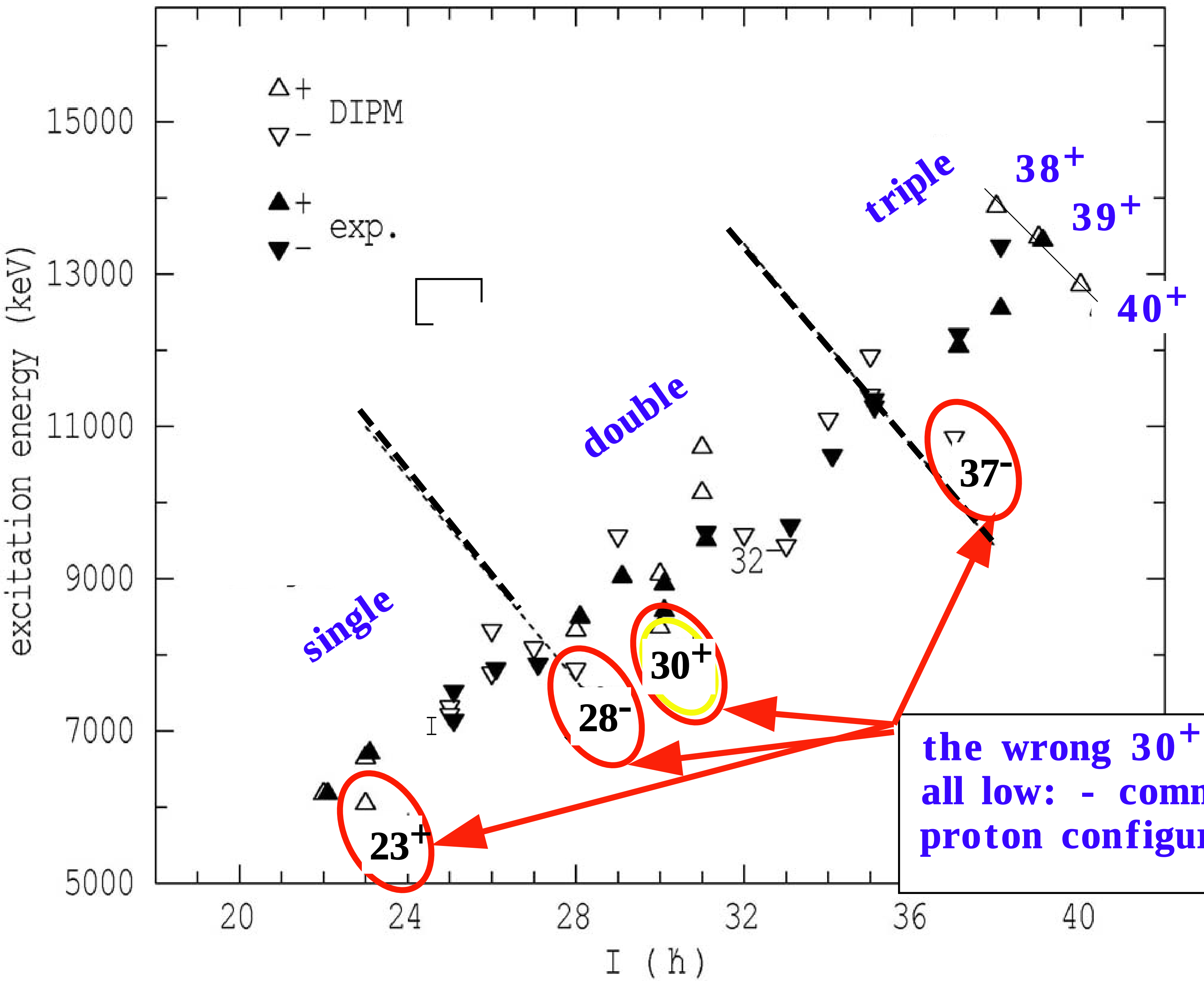


Poletti et al NPA 448 (1986) 189

Dracoulis et al PLB 246 (1990) 31

"Automatic" mixing
Constructive Interference

^{212}Rn Z=86, N= 126 - Experiment and DIPM - preliminary



the wrong 30+, and all low: - common proton configuration

Why is 18^- too low in DIPM?

23^+ $\pi\,(h^2 fi)_{18^-} \times \nu(p^{-1}g)_{5^-}$

28^- $\pi\,(h^2 fi)_{18^-} \times \nu(p^{-2}gi)_{10^+}$

30^+ $\pi\,(h^2 fi)_{18^-} \times \nu(p^{-2}gi)_{10^+}$ ← the original problem

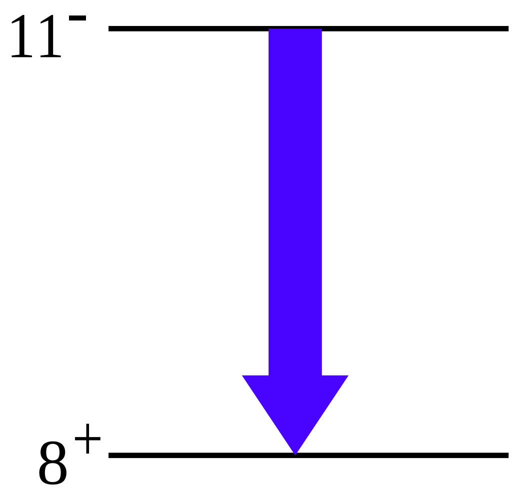
37^- $\pi\,(h^2 fi)_{18^-} \times \nu(p^{-2}f^{-1}gij)_{19^+}$

CASE III; Pb-Po, 11^-

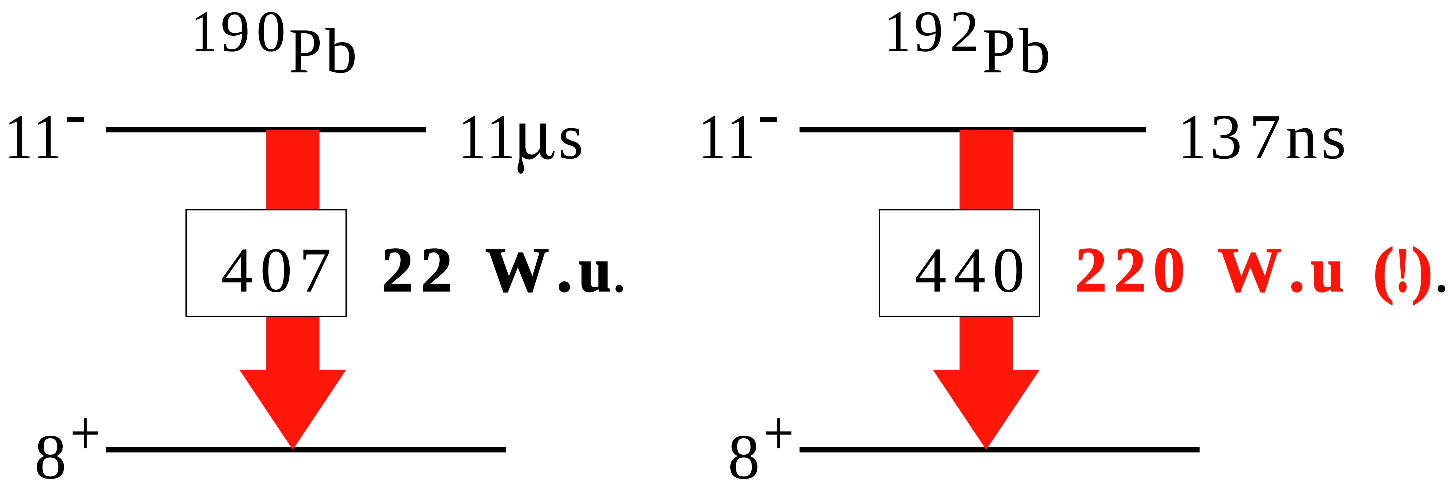
11^- to 8^+ E3 ; naive expectation

$\pi\,[\,i_{13/2}h_{9/2}\,]_{11^-}$ to $[\,h_{9/2}{}^2]_{8^+}$

"type-B" E3 ~ 3 W.u.
(spin-flip)



11^- to 8^+ E3 ; emerging reality



Dracoulis et al
PLB 432 (1998)37

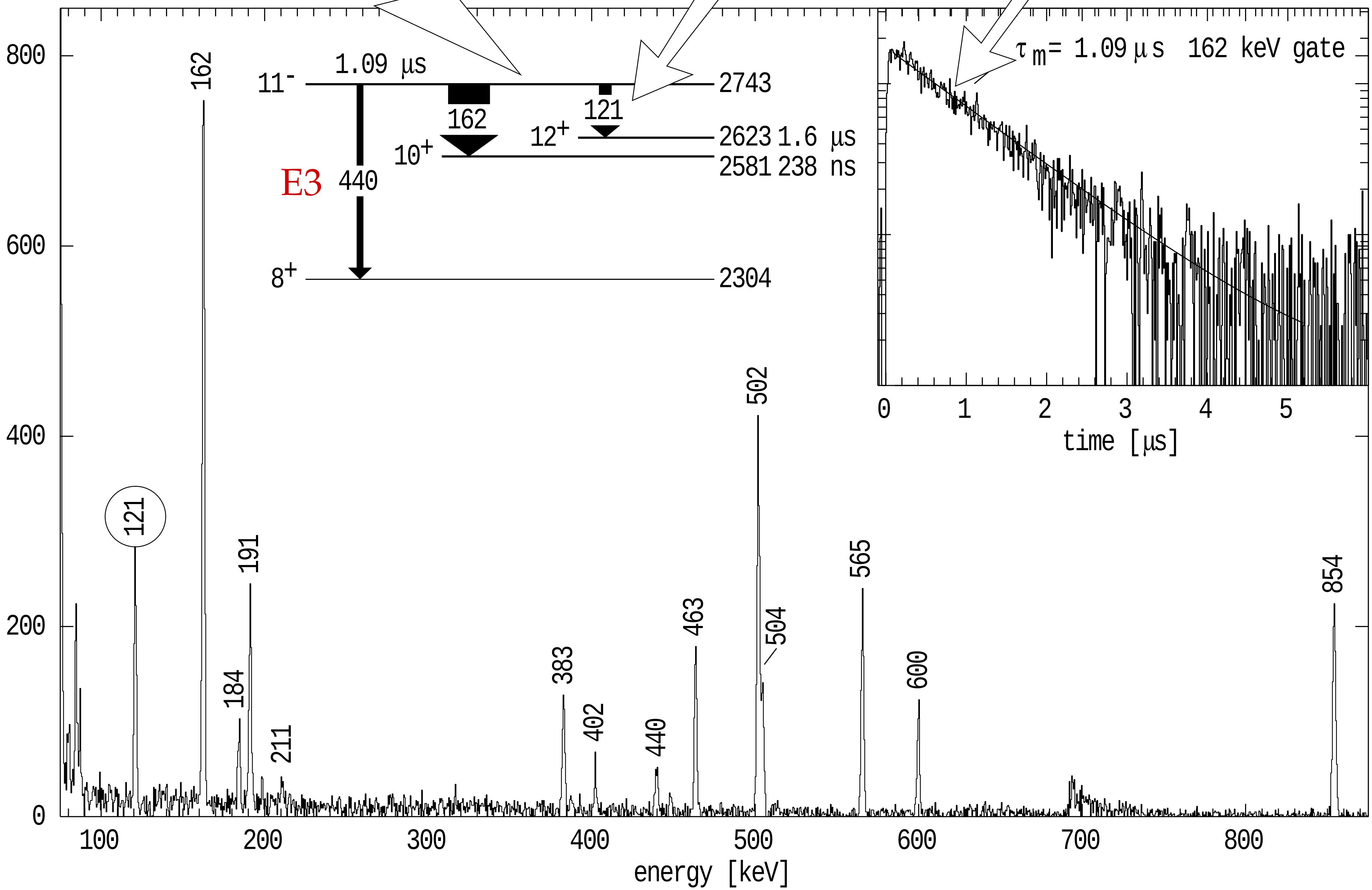
Literature
values of Lifetime and
Branching

Pb-192 11- state

delayed lines; gated on feed to 11-

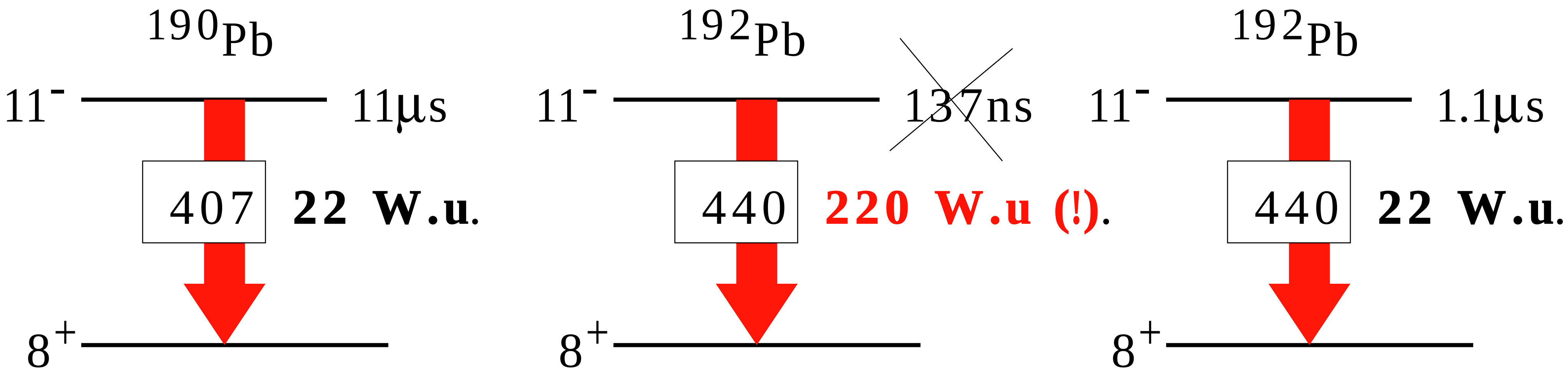
new branch

new lifetime



GDD et al PRC, Rapid Comm.

11^- to 8^+ E3 ; emerging reality



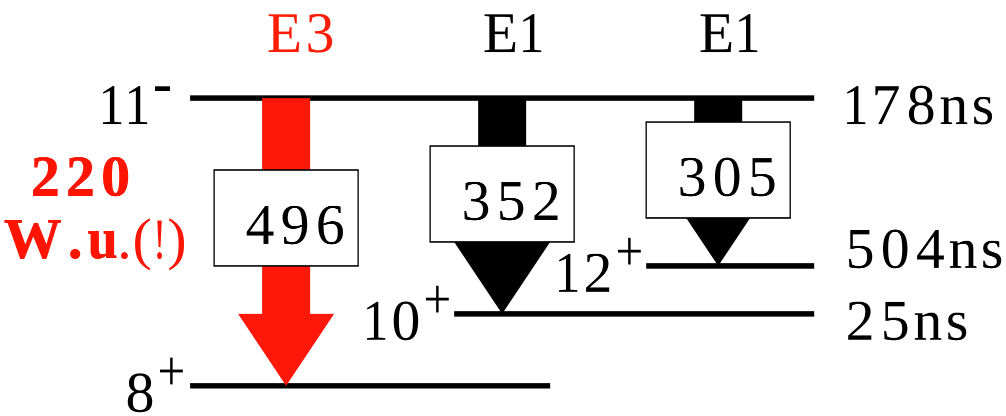
Dracoulis et al
PLB 432 (1998)37

Literature
values of ~~Lifetime~~ and
~~Branching~~

Dracoulis et al
PRC 63 (2001)
061302

"type-A" E3 ~ 20 W.u

11^- to 8^+ E3 ; ^{194}Pb

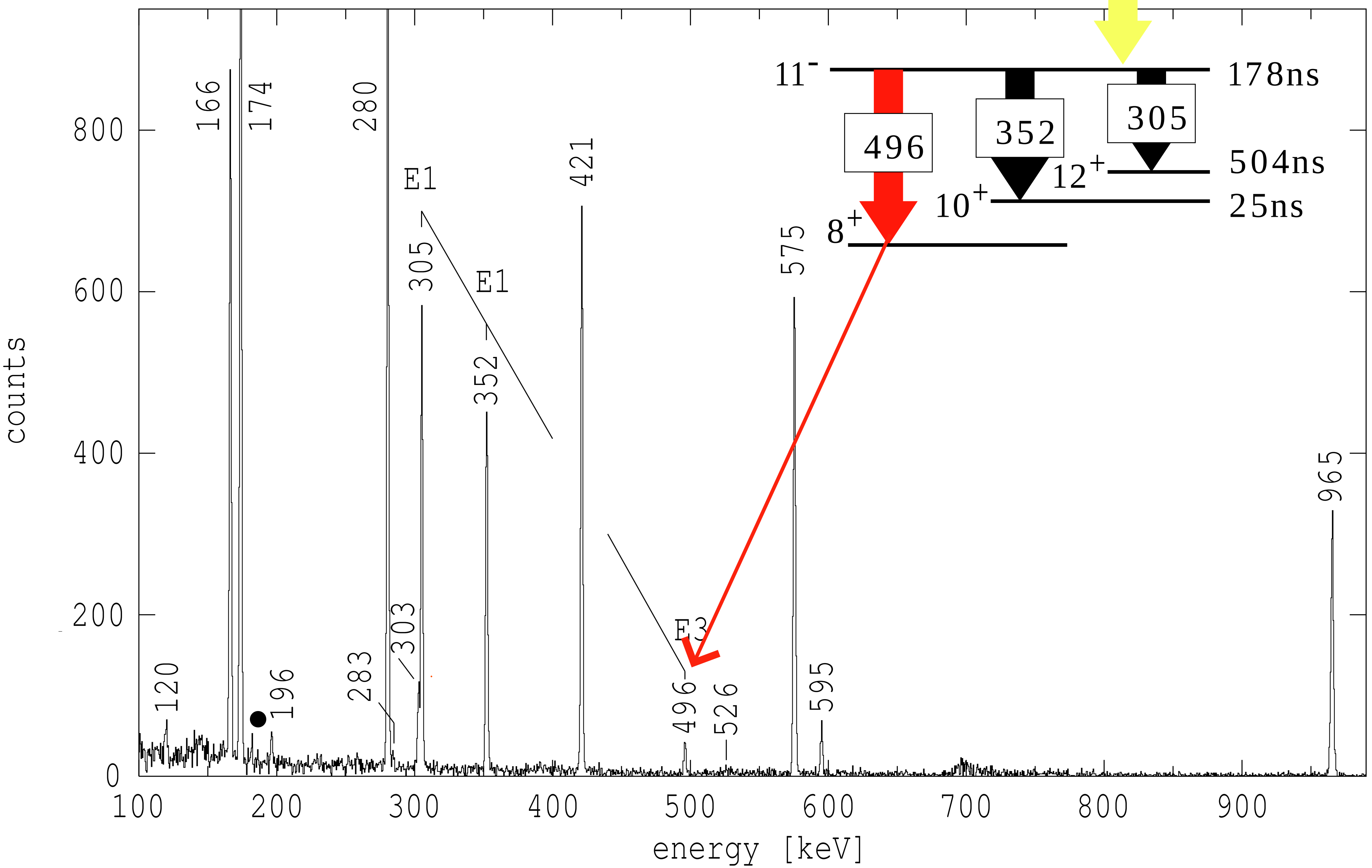


Iγ (496) = Iγ(352) = Iγ(305) ?

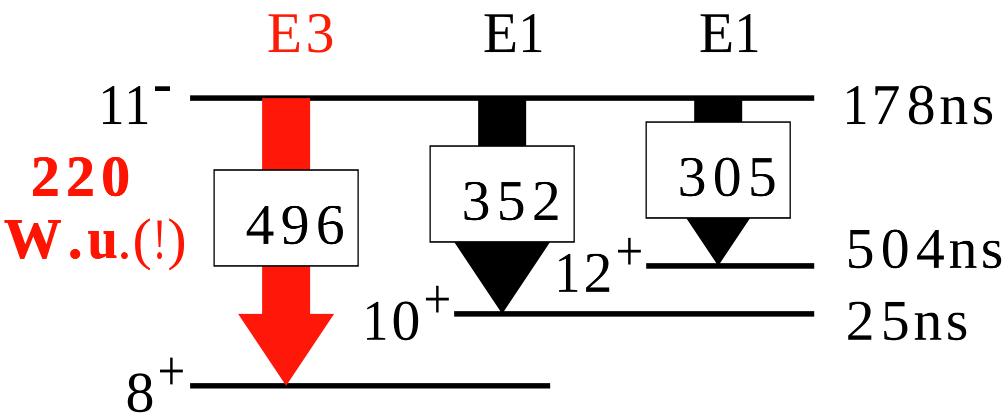
Van Ruyven et al (1986)
Fant et al (1991)
Kaci et al (2002)

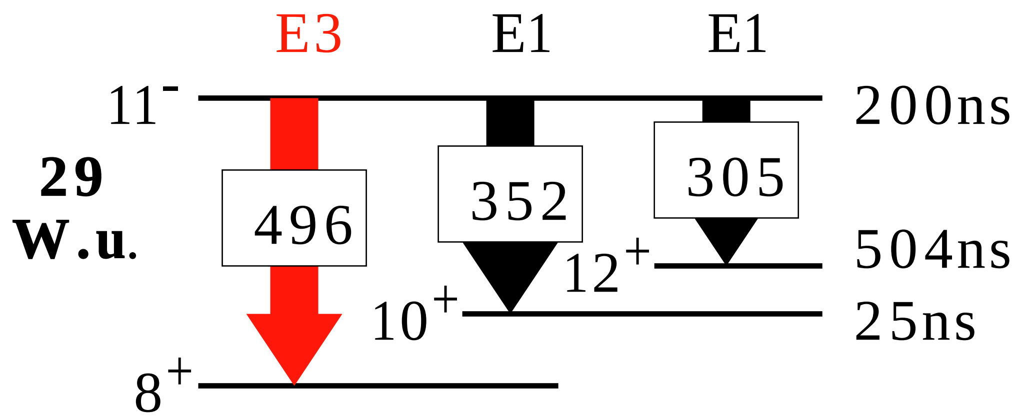
11⁻ Isomer decay ¹⁹⁴Pb

γ-ray gates above plus time gate



11⁻ to 8⁺ E3 ; ^{194}Pb





Iγ (496) = Iγ(352) = Iγ(305) ?

Iγ (496) << Iγ(352) = Iγ(305) ?

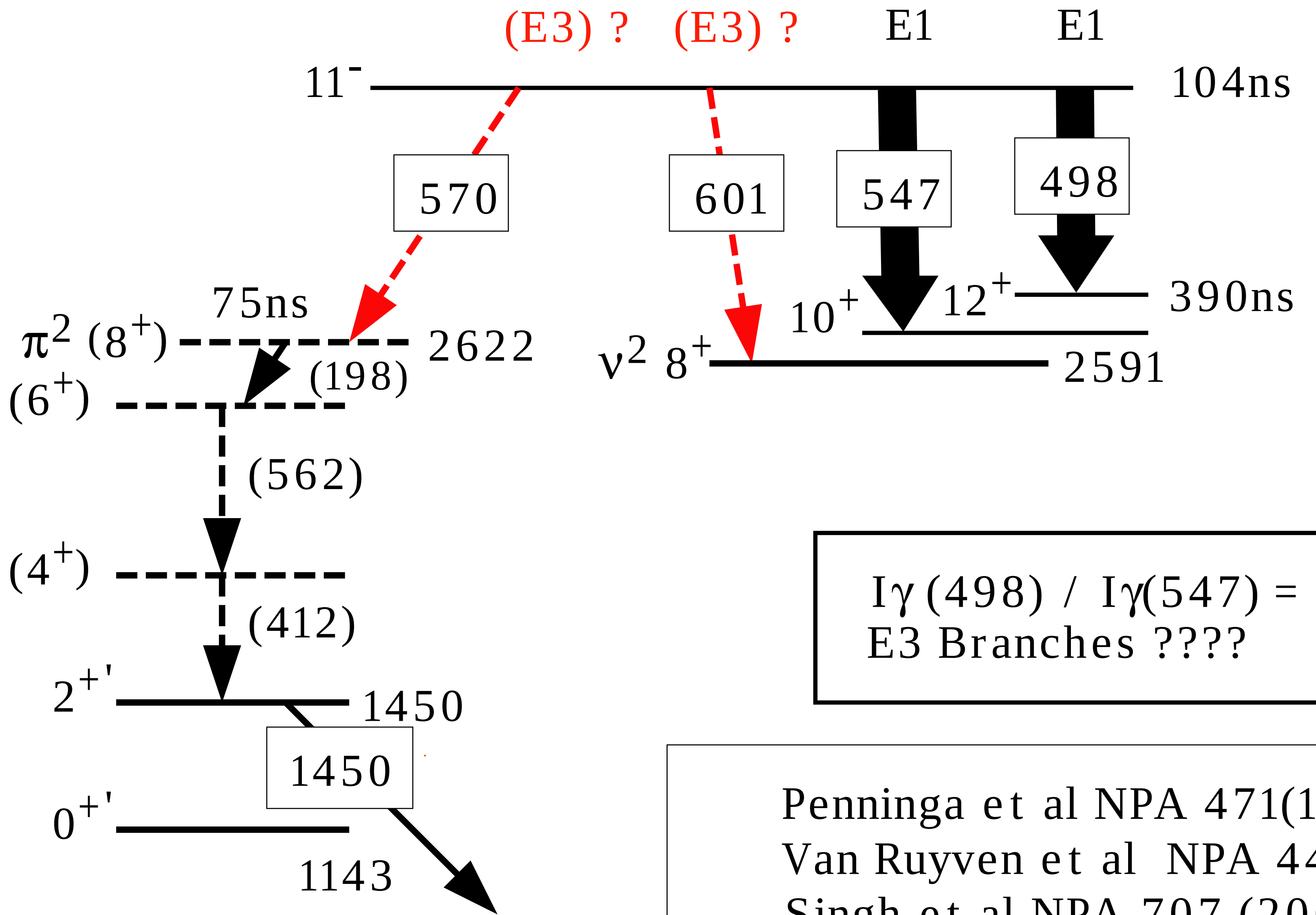
Van Ruyven et al (1986)
Fant et al (1991)
Kaci et al (2002)

"type-A" E3 ~ 20 W.u

...to be published

11$^-$ to 8$^+$ E3 ; ^{196}Pb challenge

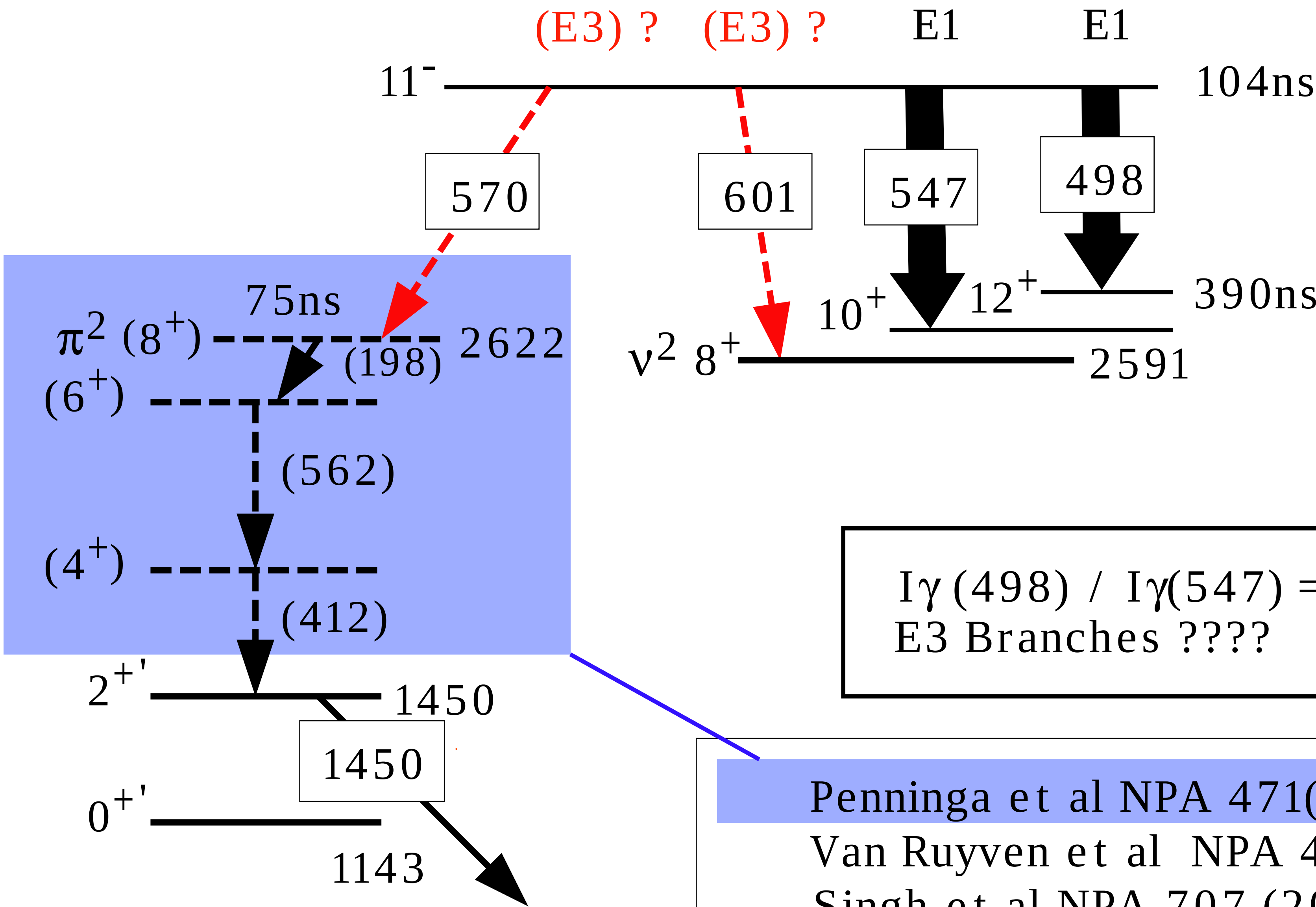
short-τ = weak branch



Iγ (498) / Iγ(547) = ????
E3 Branches ????

Penninga et al NPA 471(1987)535
Van Ruyven et al NPA 449(1986)
Singh et al NPA 707 (2002) 3

11^- to 8^+ E3 ; ^{196}Pb challenge

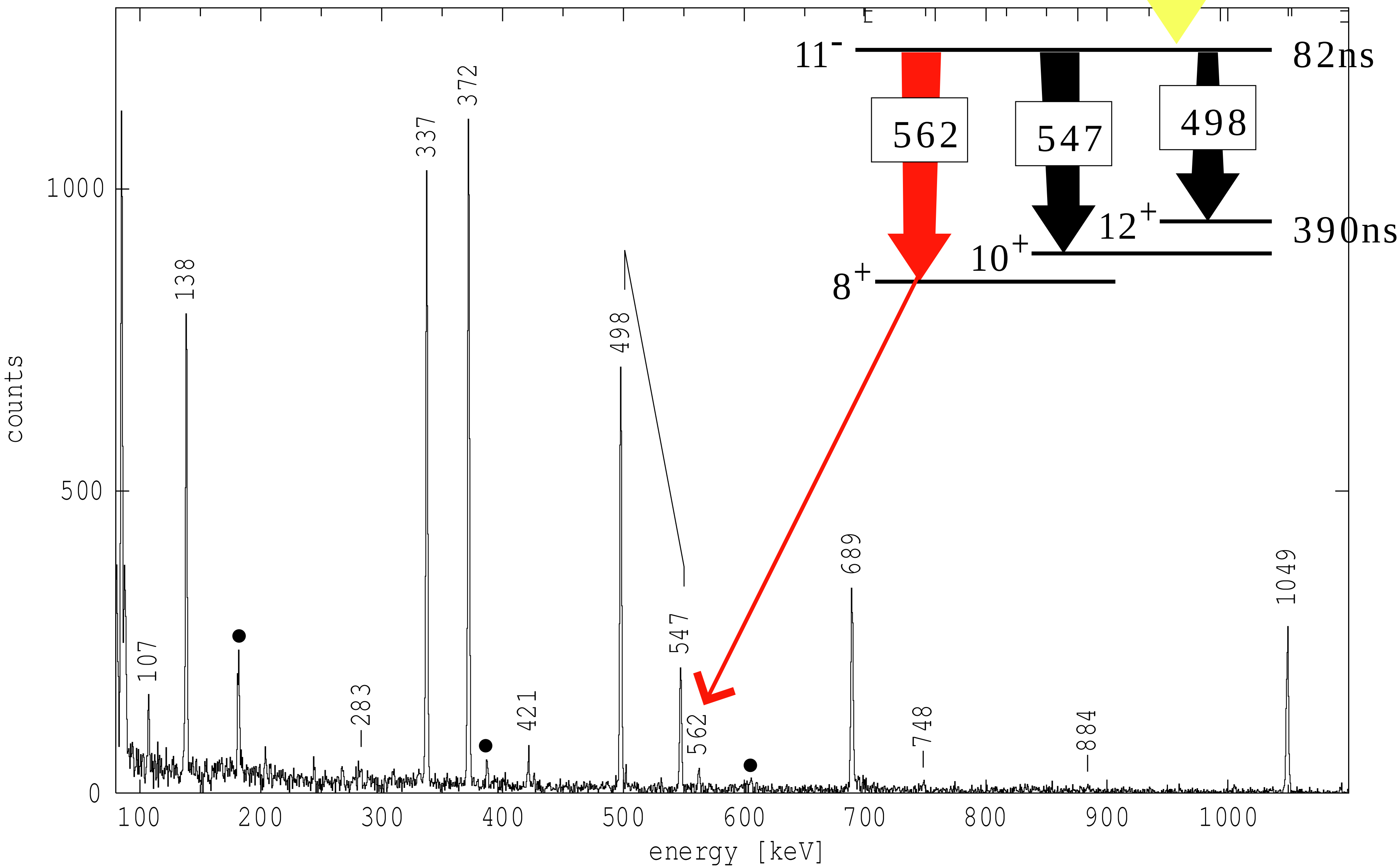


Iγ (498) / Iγ(547) = ????
E3 Branches ????

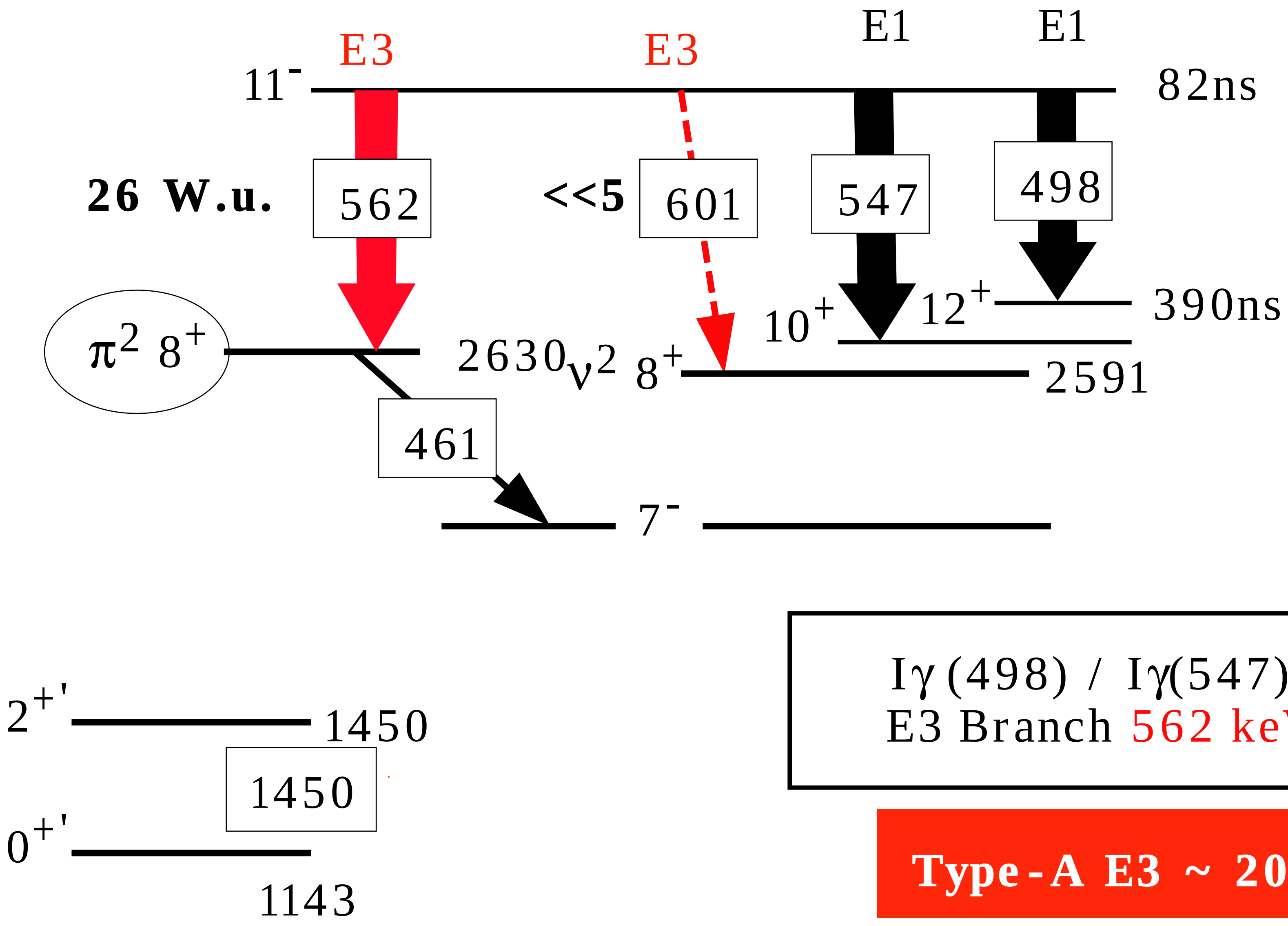
Penninga et al NPA 471(1987)535
Van Ruyven et al NPA 449(1986)
Singh et al NPA 707 (2002) 3

11^- Isomer decay ^{196}Pb

γ-ray gates above plus time gate



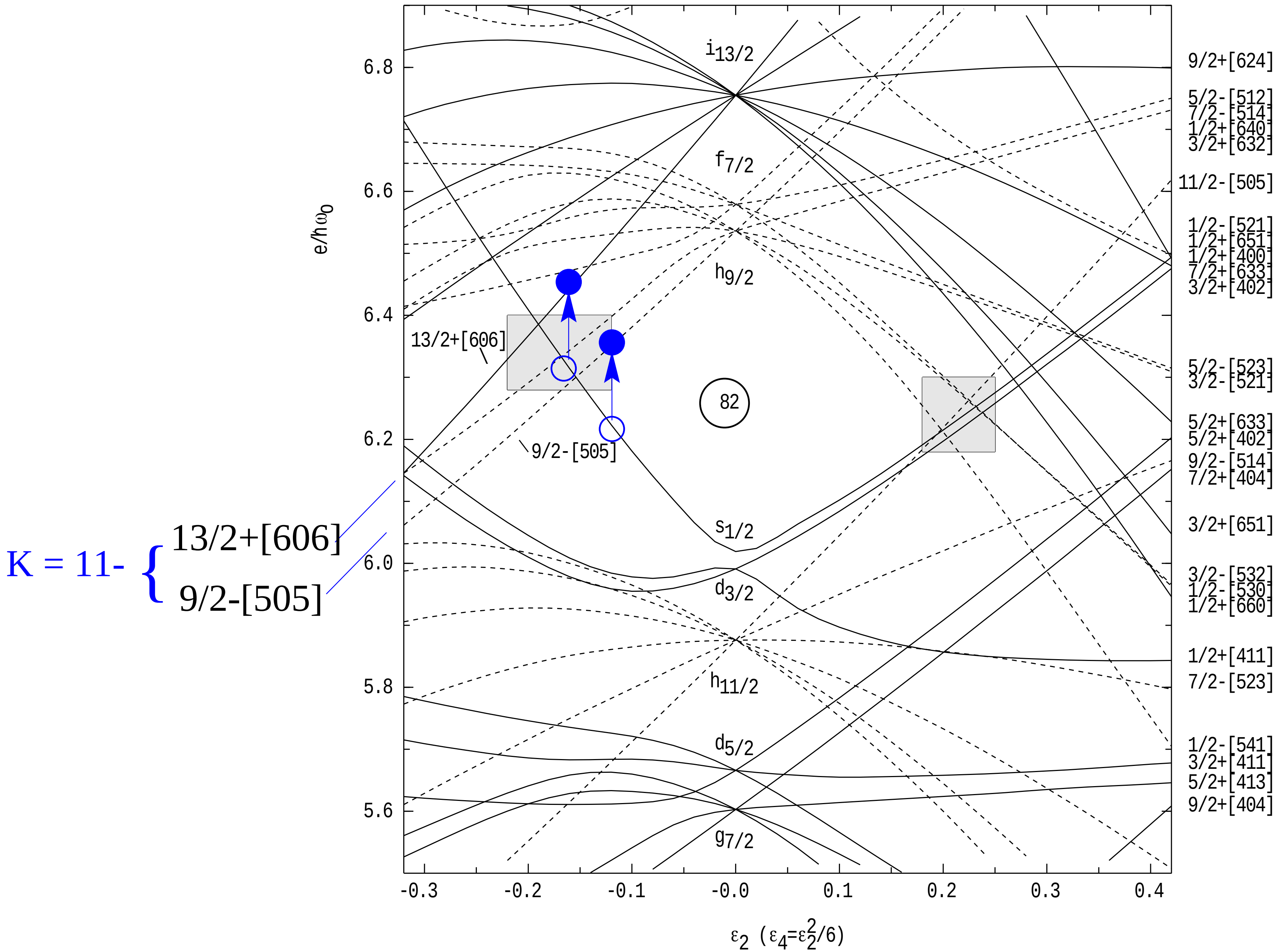
11^- to 8^+ E3 ; ^{196}Pb solution ?



Iγ (498) / Iγ(547) = 3
E3 Branch 562 keV

Type-A E3 ~ 20 W.u.

GDD et al PRC 72-2005-064319



K = 11-
13/2+[606]
9/2-[505]
e/hω0
ε2 (ε4=ε2²/6)
82
i13/2
f7/2
h9/2
s1/2
d3/2
h11/2
d5/2
g7/2
13/2+[606]
9/2-[505]
9/2+[624]
5/2-[512]
7/2-[514]
1/2+[640]
3/2+[632]
11/2-[505]
1/2-[521]
1/2+[651]
1/2+[400]
7/2+[633]
3/2+[402]
5/2-[523]
3/2-[521]
5/2+[633]
5/2+[402]
9/2-[514]
7/2+[404]
3/2+[651]
3/2-[532]
1/2-[530]
1/2+[660]
1/2+[411]
7/2-[523]
1/2-[541]
3/2+[411]
5/2+[413]
9/2+[404]

potential-mixing with oblate deformation

lowest $7/2^-$ proton orbital changes from $h_{9/2}$ to $f_{7/2}$

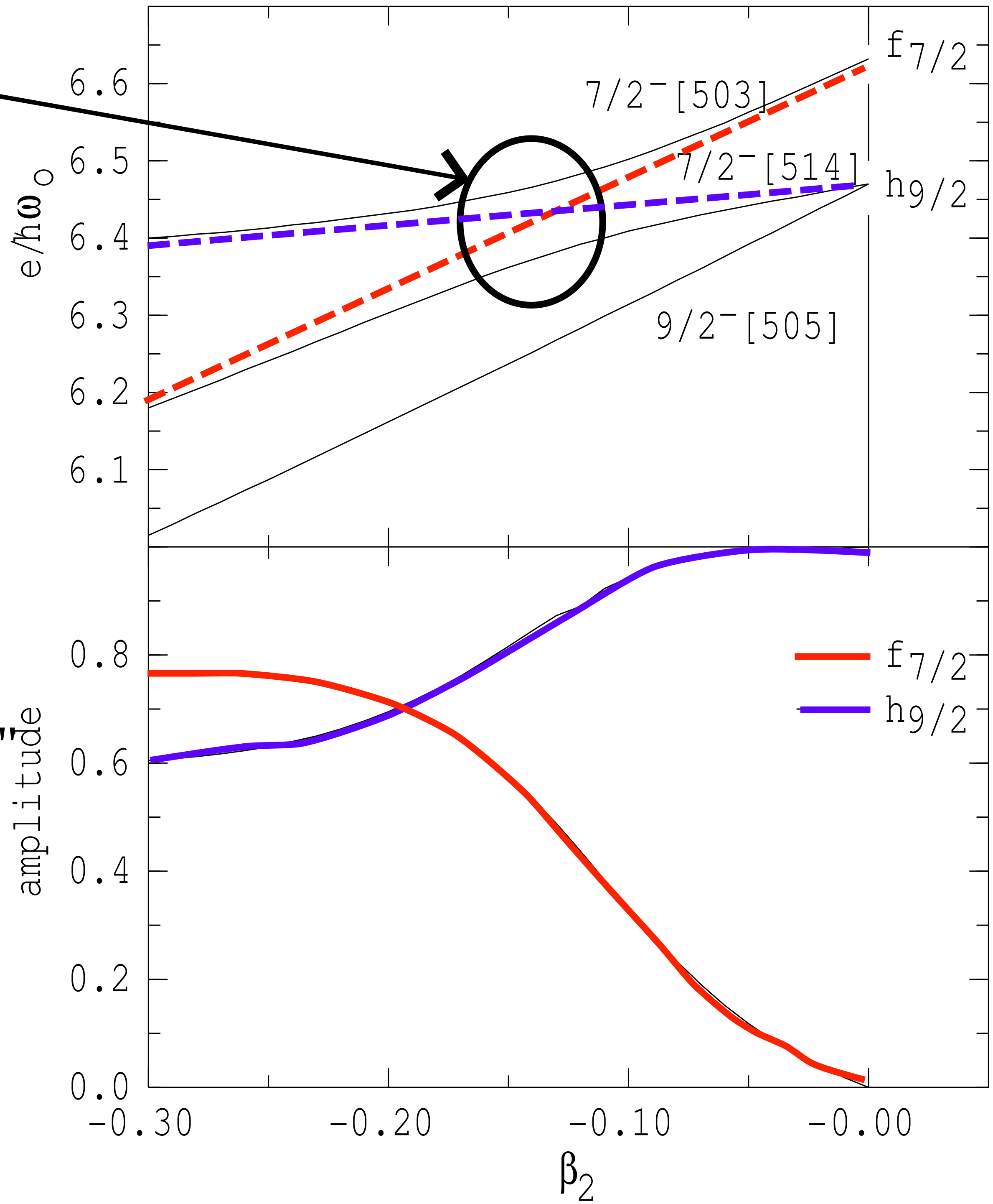
$|11^-\rangle$

$9/2^-[505]$ **i** $13/2^+[606]$

fast E3

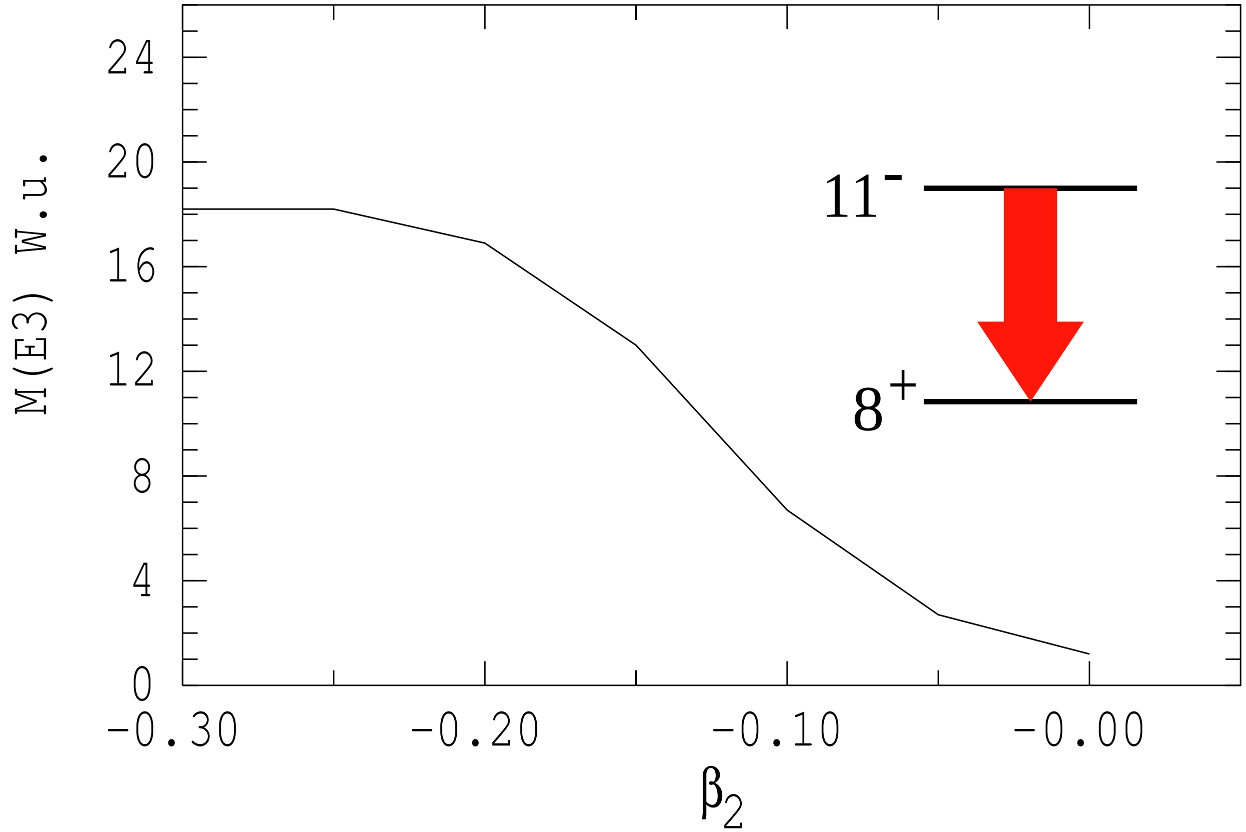
$9/2^-[505]$ **"f"** "$7/2^-[514]$"

$|8^+\rangle$



approximate dependence on oblate deformation

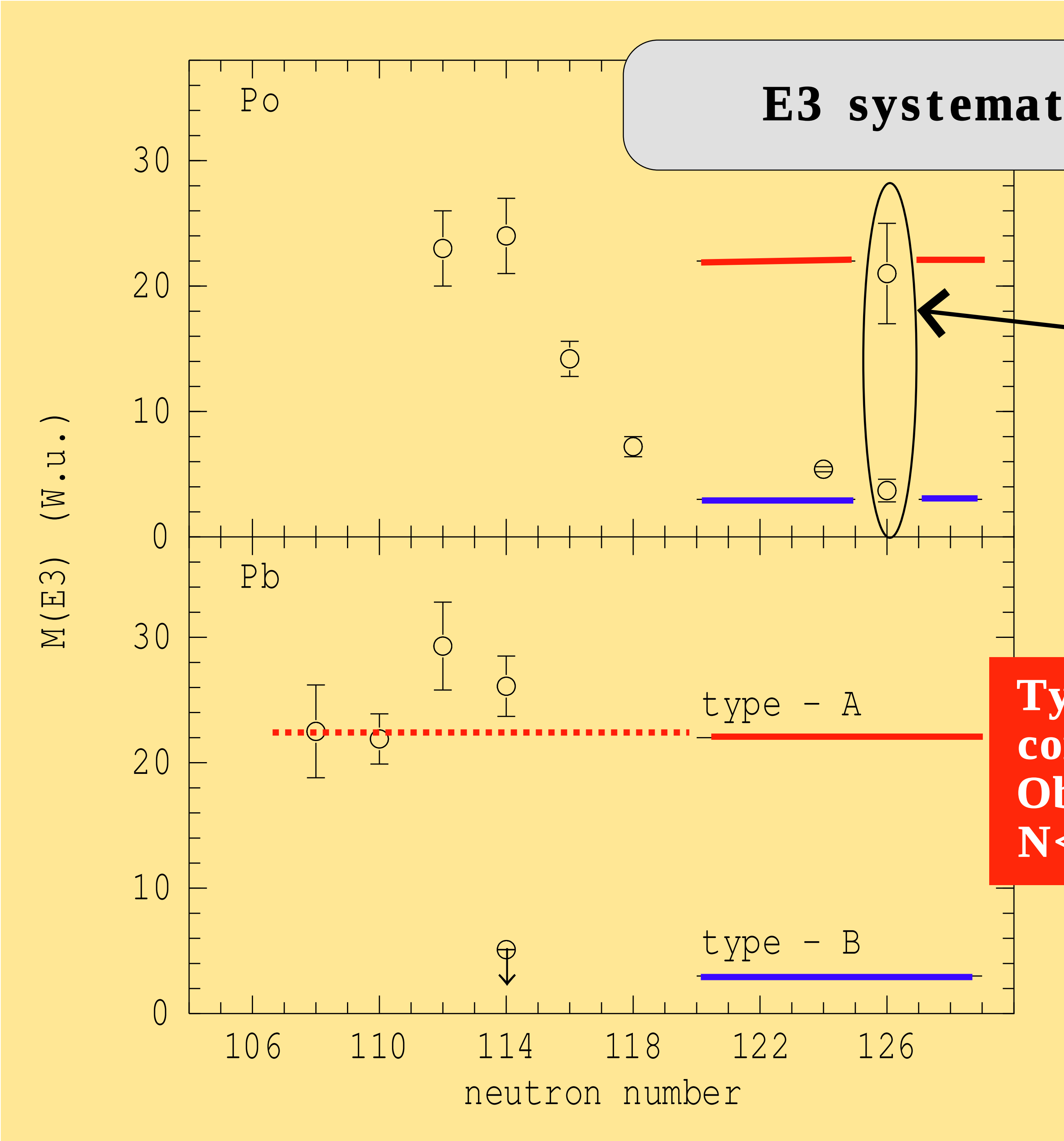
Taking calculated amplitudes α and β of h9/2 and f7/2 configuration in "7/2-[514]" orbital in typical Nilsson Potential



$$B(E3, 11^- \text{ to } 8^+) \sim \{\alpha\, U(...) \sqrt{B(E3;\, i_{13/2} \text{ to } h_{9/2})} + \beta\, U(...) \sqrt{B(E3;\, i_{13/2} \text{ to } f_{7/2})}\ \}^2$$

$$M(E3, 11^- \text{ to } 8^+) = \{\alpha\ 0.632 \sqrt{\mathbf{3}} + \beta\ 1.0 \sqrt{\mathbf{22}}\ \}^2 \text{ W.u.}$$

E3 systematics ; Pb-Po

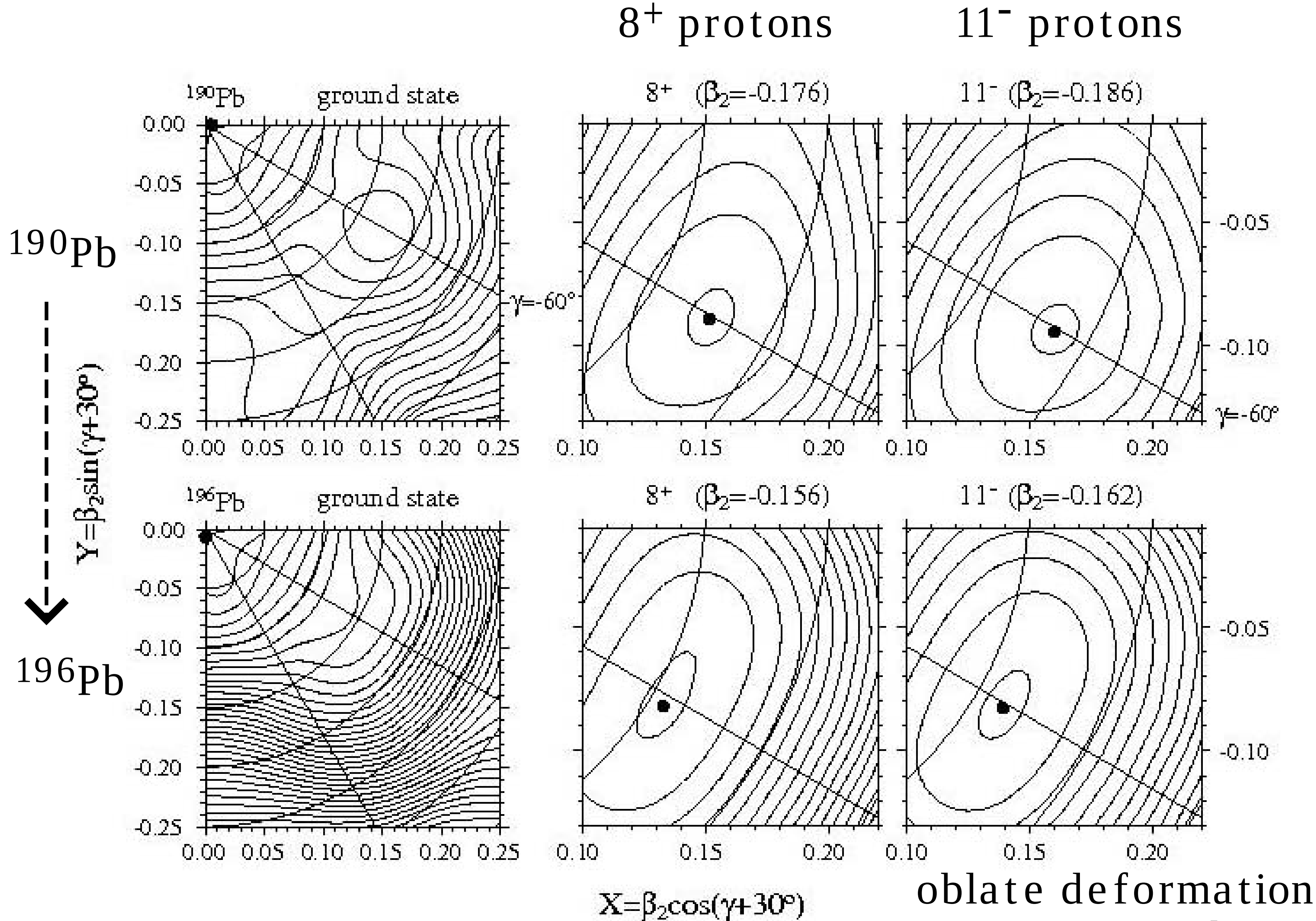


N=126 reproduced by shell model with octupole coupling Stuchbery et al. NPA 555 (1993)355

Type-A E3 ~ 22 W.u. consistent with ~constant Oblate deformation N< 116 ?

to be published...

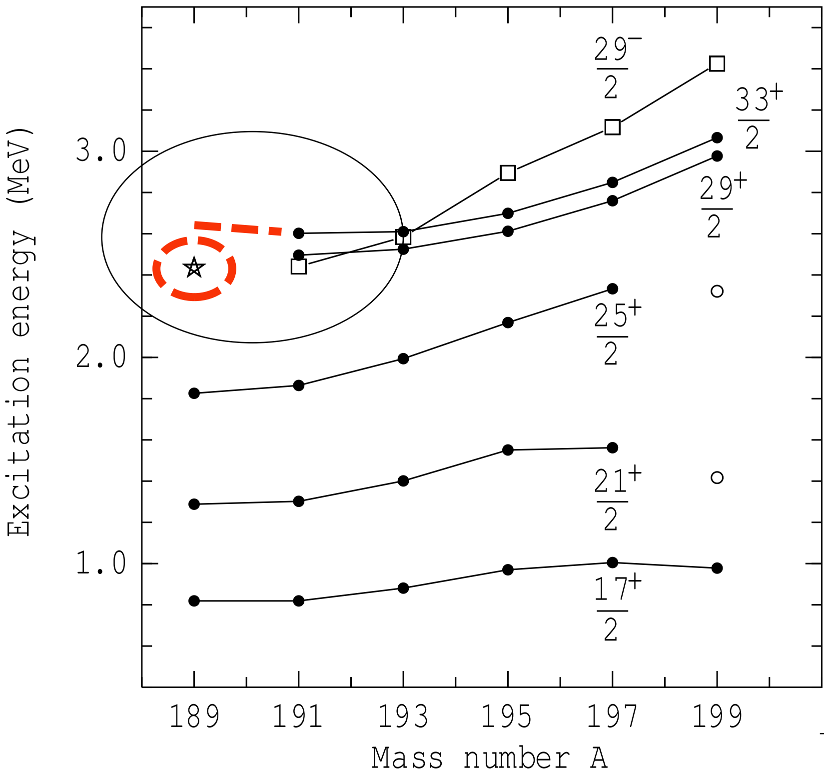
PES - configuration constrained



oblate deformation persists in Pb

CASE IV; ^{189}Pb isomer

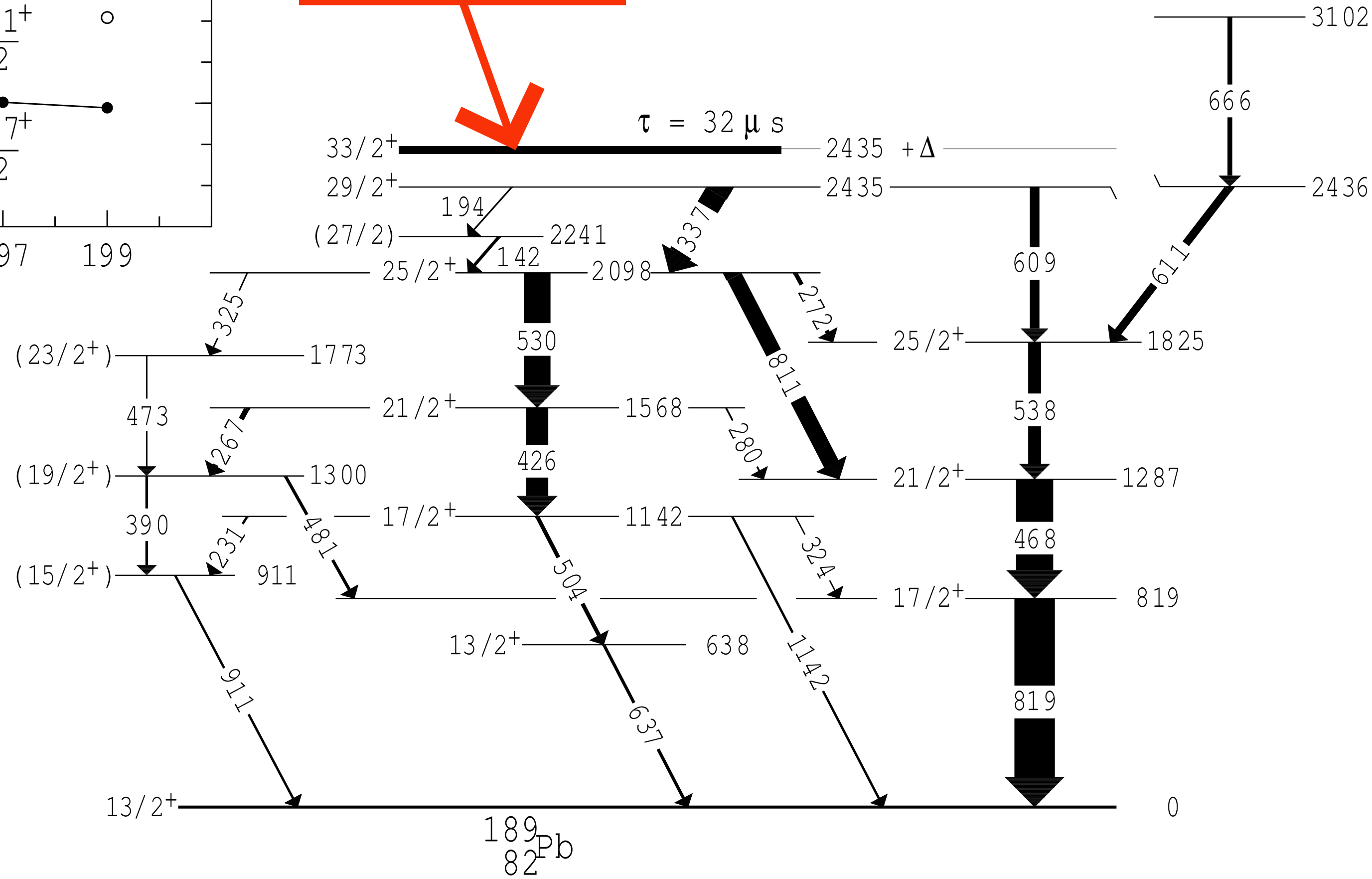
^{189}Pb: neutron $i_{13/2}^{-3}$



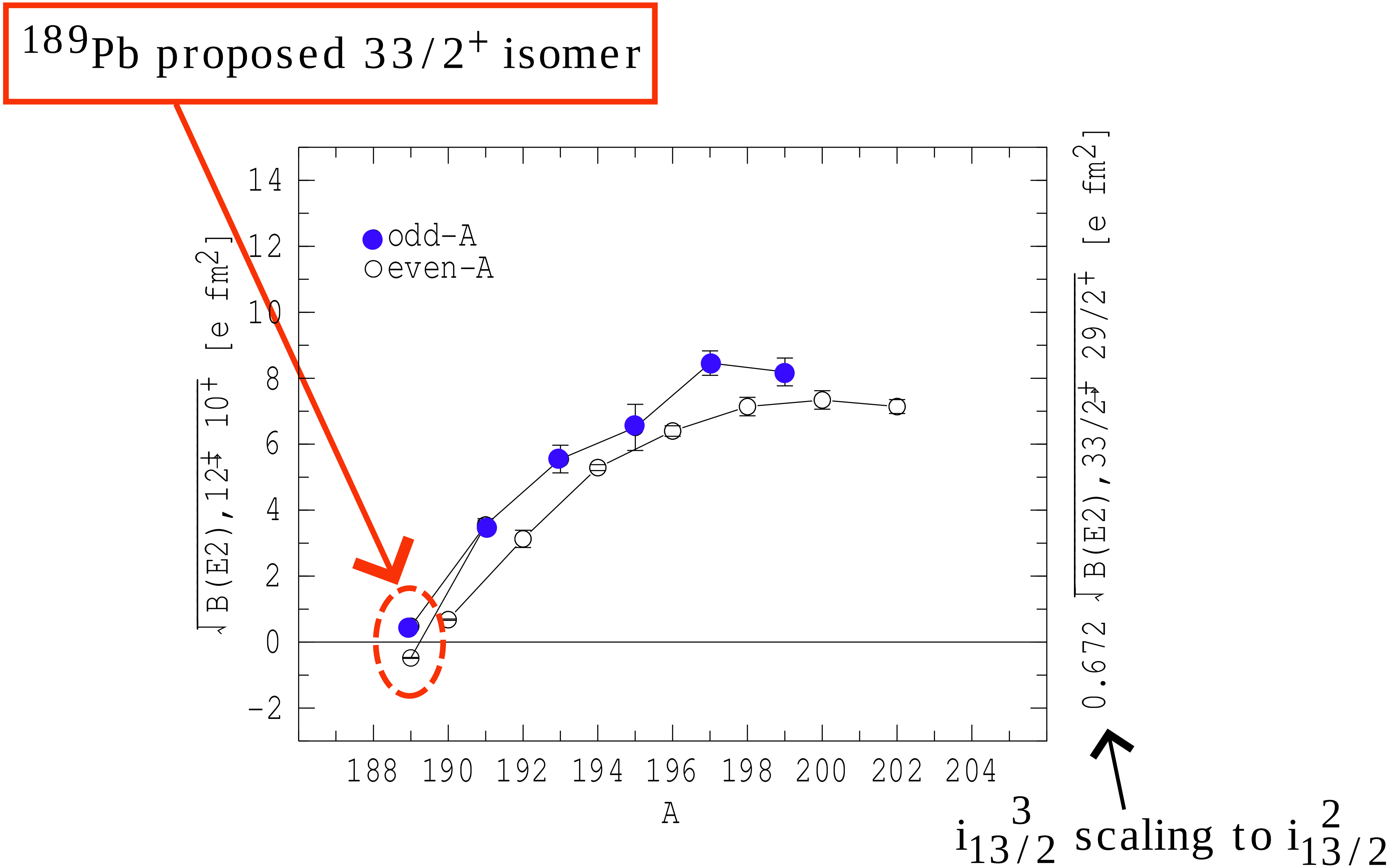
Baxter et al,
Phys Rev. C 71, 054302 (2005)

Tentative $J^{\pi} = 33/2^{+}$ assignment with unobserved E2 transition

τ = 32 μs



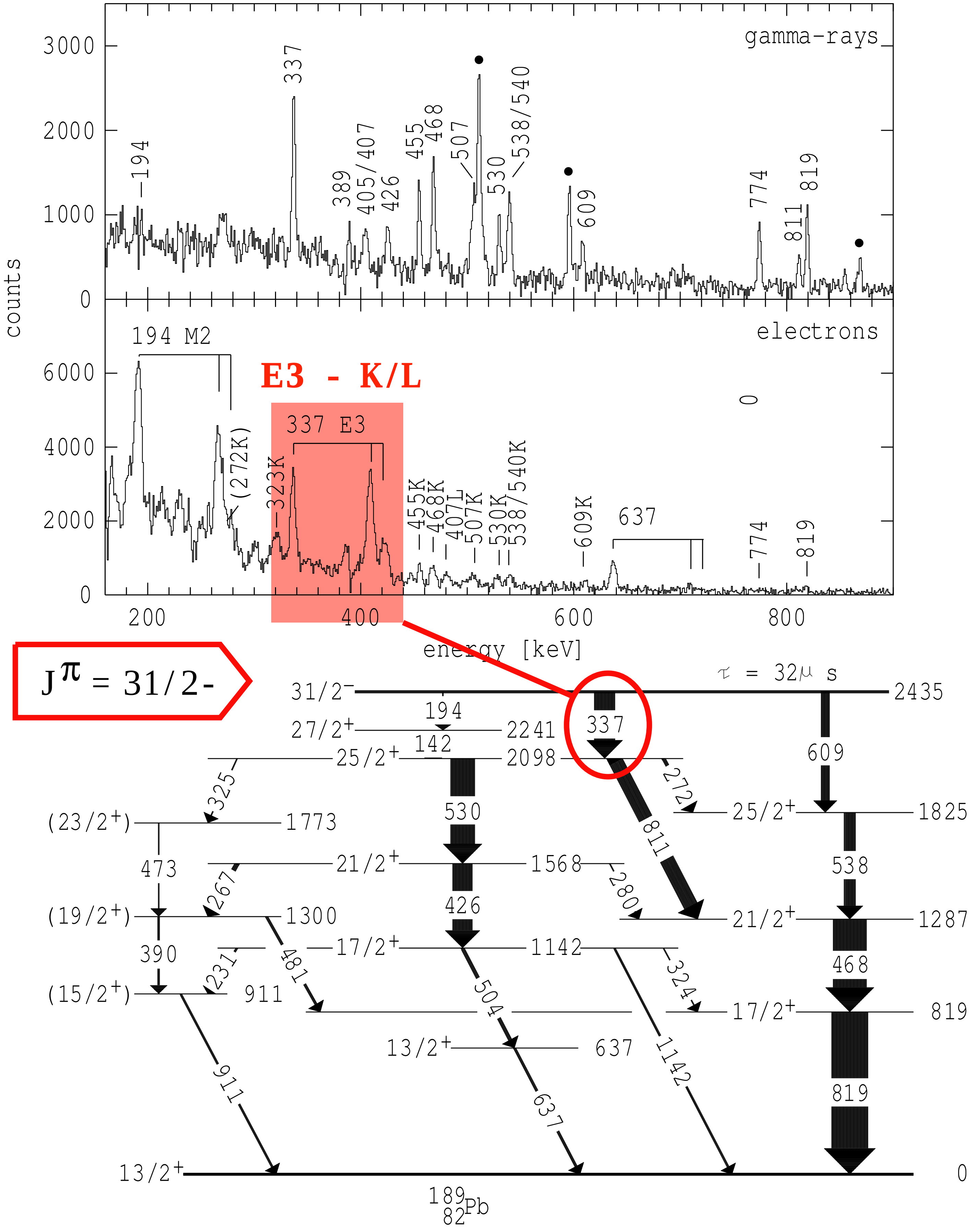
B(E2) mid-shell cancellation...



Solenogam test; ^{189}Pb 32 μs Isomer

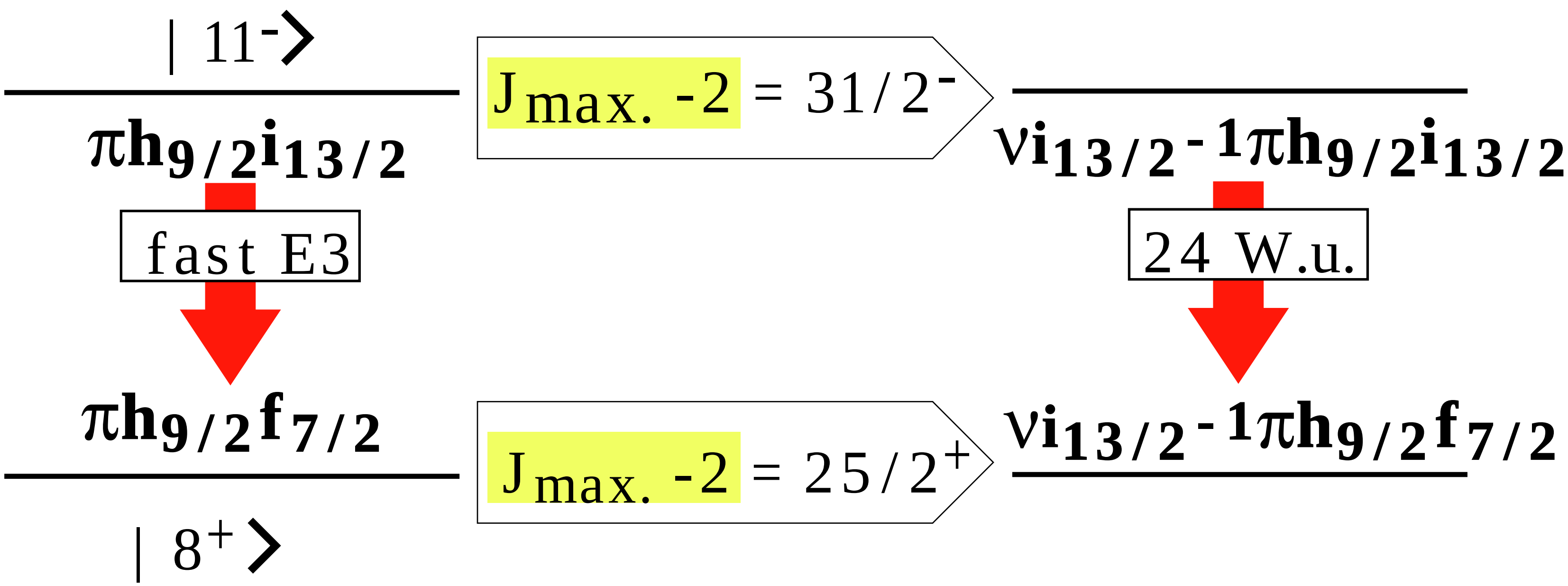
Characterisation as a Shears-mode bandhead

GDD, Lane, Kibedi. Nieminen. Phys Rev C 79,01302(R) (2009).



Configuration

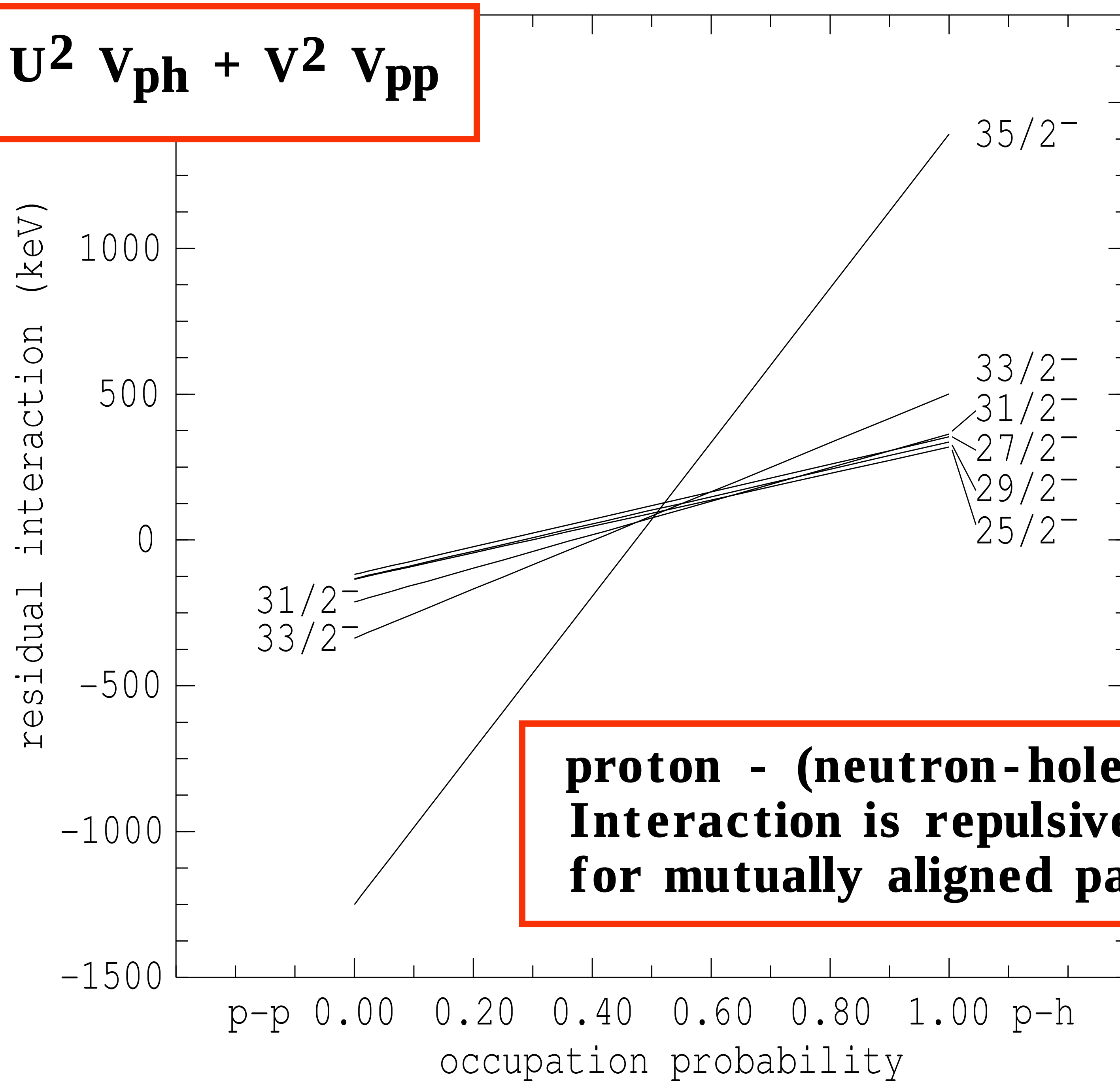
naive expectation:
Maximum coupling of
11^- core and $i_{13/2}$ neutron hole $J^\pi = 35/2^-$



Non-Maximal Coupling -
balance of residual interactions

Residual Interactions: Particles/Holes

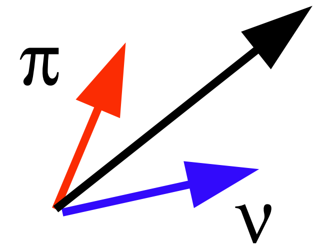
$$V_{eff.} = U^2 \, V_{ph} + V^2 \, V_{pp}$$

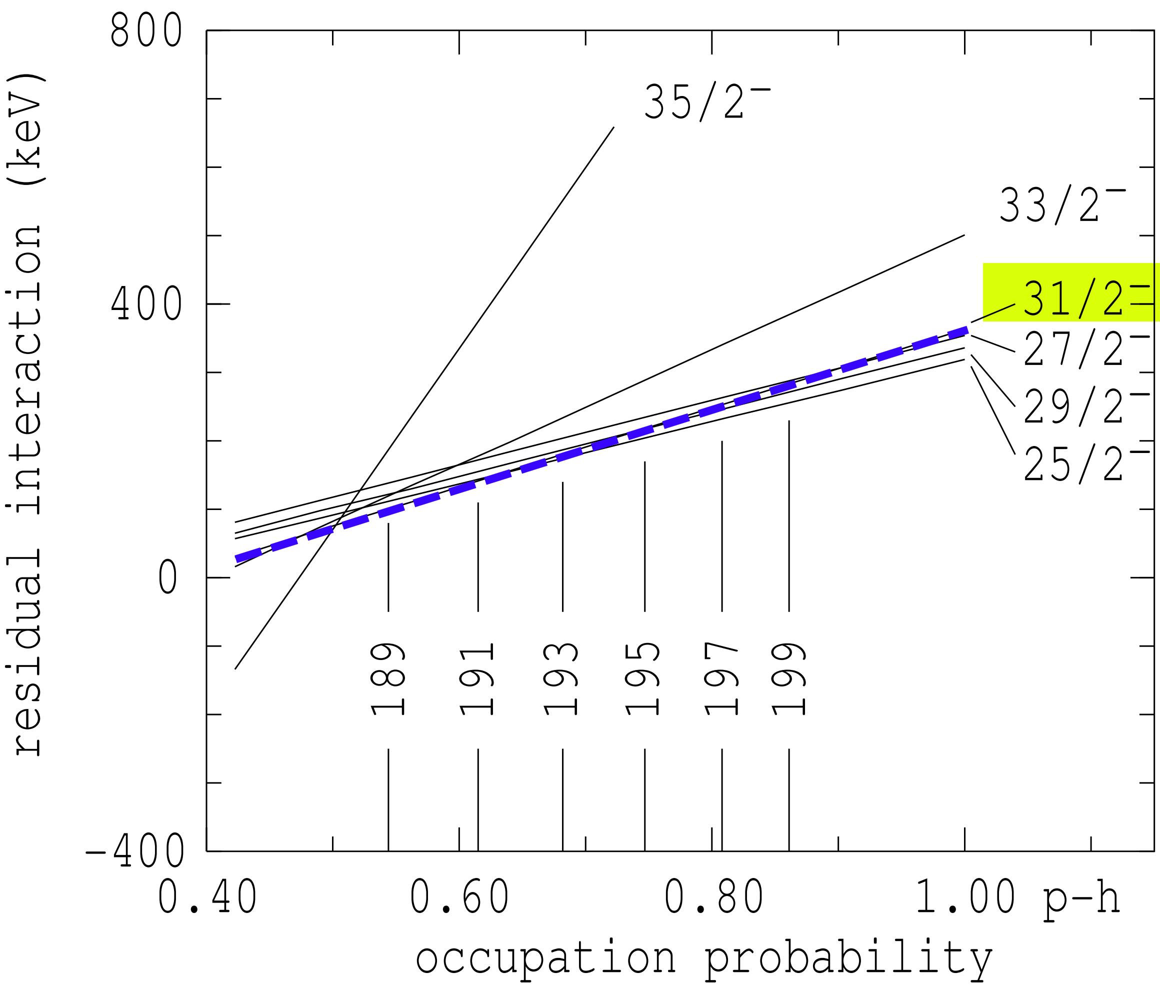


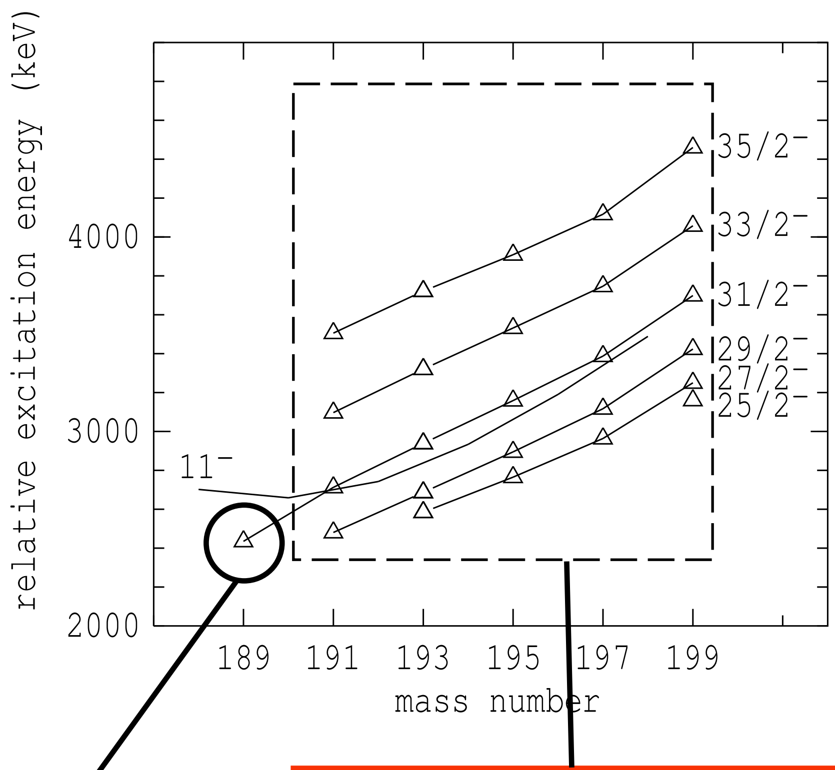
proton - (neutron-hole)
Interaction is repulsive
for mutually aligned particles

Residual Interactions: Detail/shears

$\pi\ [h_{9/2} i_{13/2}]_{11^-} \otimes \nu\ i_{13/2}$







shears bands...

31/2⁻ Isomer

pb189-vII-detail.md

Final Comments...

Isomers are a useful and important tool in Nuclear Structure

The detail matters

Expectation is not the same as Measurement

A Plea:

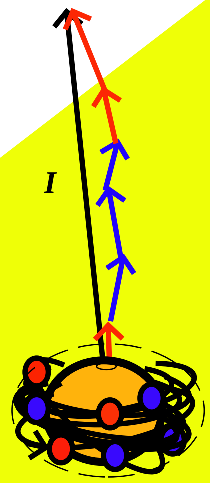
Don't ignore what has gone before

---

a thought for the day

Isomers have a life of their own

Dafni et al. PRL 55 (1985) 1271
Quadrupole Moment.. $63/2^-$ isomer in ^{211}Rn
"Absence of Core Deformations at Very High Spins"



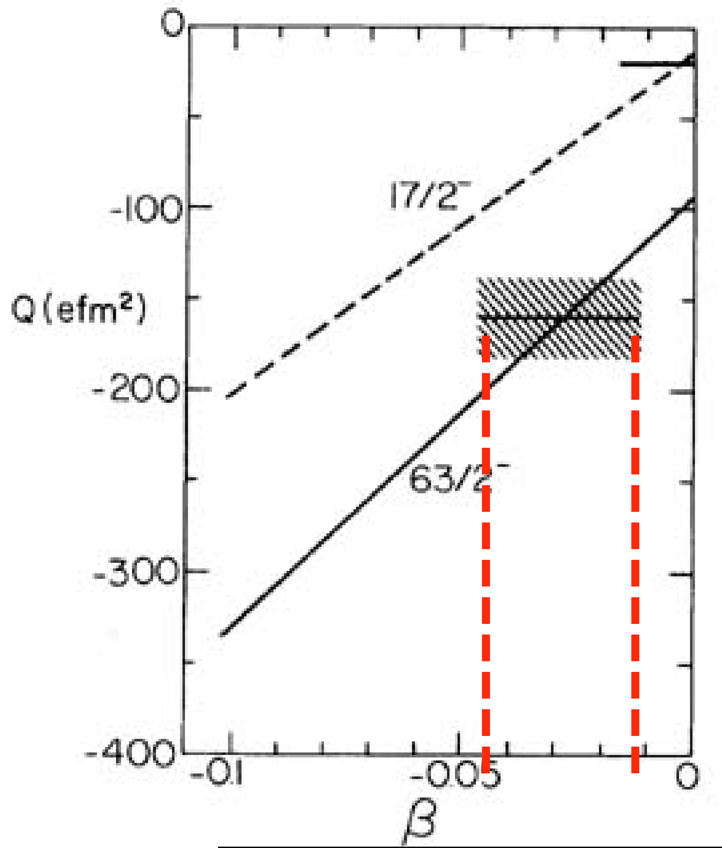
^{211}Rn $(63/2^-)$ = ^{212}Rn (30^+) + ν $(3/2^-)$
Spherical (eff. charges)
Q(shell) = -186

$\Sigma_\iota Q_{sp}$

Single Particle Moments (e.fm^2)

$\pi h_{9/2}$	-43
$\pi \iota_{13/2}$	-62
$\nu f_{5/2}$	+20
$\nu g_{9/2}$	-29
$\nu i_{11/2}$	-28
$\nu j_{15/2}$	-42

$|Q_{exp}|$ = 160(22)



X
Deformed (no eff. charges)
$Q = f(I) Q_0 = f(I)(Q_I + Q_{core})$
$Q_{core} \propto Z_{core} R^2 (\beta + 0.36\beta^2)$

$\beta \sim 0.027(10)$

Also, see Sagawa&Arima PLB 202 (1988) 15