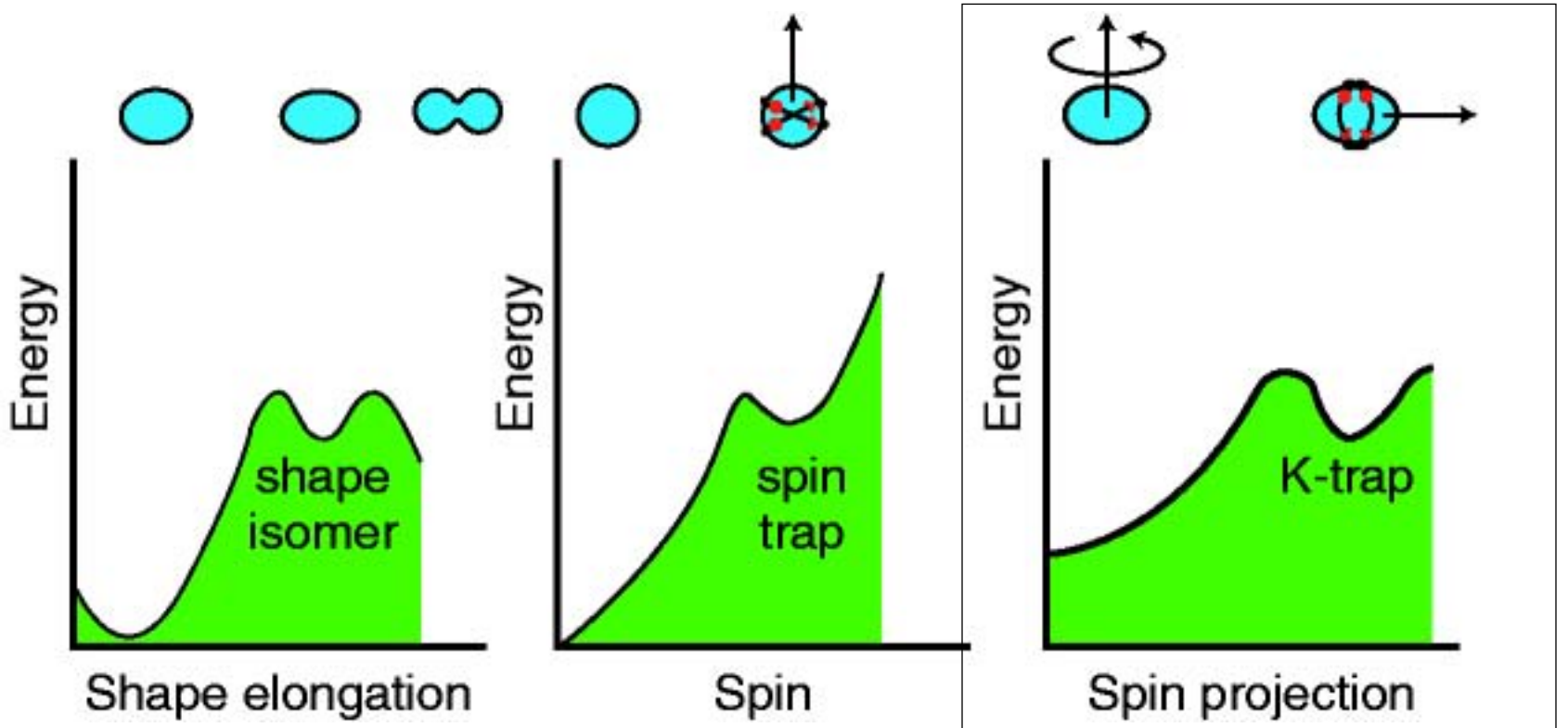
Isomerism

Soddy(19??)
Hahn (1921)
Gamow (1934)
Von Weizsacker(1936)



Walker & Dracoulis
Nature 399(2001)

K-isomers
since 1953

Dracoulis; Limits2004

some building blocks

Z = 72
N ~ 104

6^+ π $5/2^+[402] \times 7/2^+[404]$
6^+ ν $5/2^-[512] \times 7/2^-[514]$
8^- ν $9/2^+[624] \times 7/2^-[514]$
8^- π $9/2^-[514] \times 7/2^+[404]$
8^+ ν $9/2^+[624] \times 7/2^+[633]$

14^-

16^+ →

e.g. ^{178}Hf exp.

1147
1479

2626 keV
cf: 2447

higher-N

10^+ ν $9/2^+[624] \times 11/2^+[615]$
10^- ν $9/2^-[505] \times 11/2^+[615]$

18^+

favoured states at the yrast line →

high-Ω; high-K
equal numbers of
quasiprotons and quasiprotons

Dracoulis; Limits2004

Calculating Energies & Residual Interactions

Aberg
NPA 306(1978)89
schematic pairing

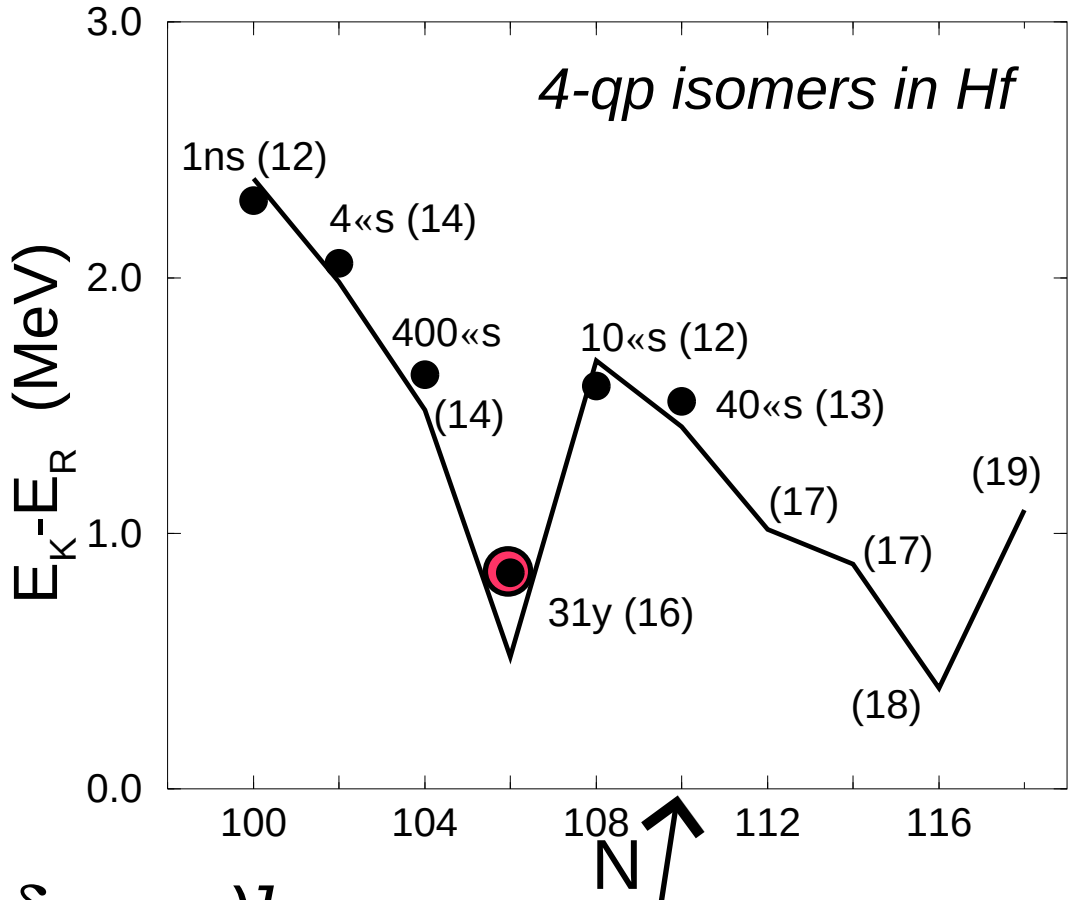
Fixed Deformation
Nilsson energies
Blocking; Fermi level and pairing gaps Self-Consistent;
Jain et al [NPA 591(1995)61
but with Lipkin-Nogami Pairing

$E_{residual}$
essentially a sum of empirical 2-particle (π–π π–ν ν–ν) splittings

$$K = | \Omega_1 \pm \Omega_2 \pm \ldots \Omega_n |$$

$$E_{res} \sim \sum [E_{\alpha_1\alpha_2}(GM) \, (1/2 - \delta_{\Sigma\alpha_1\alpha_2})]$$

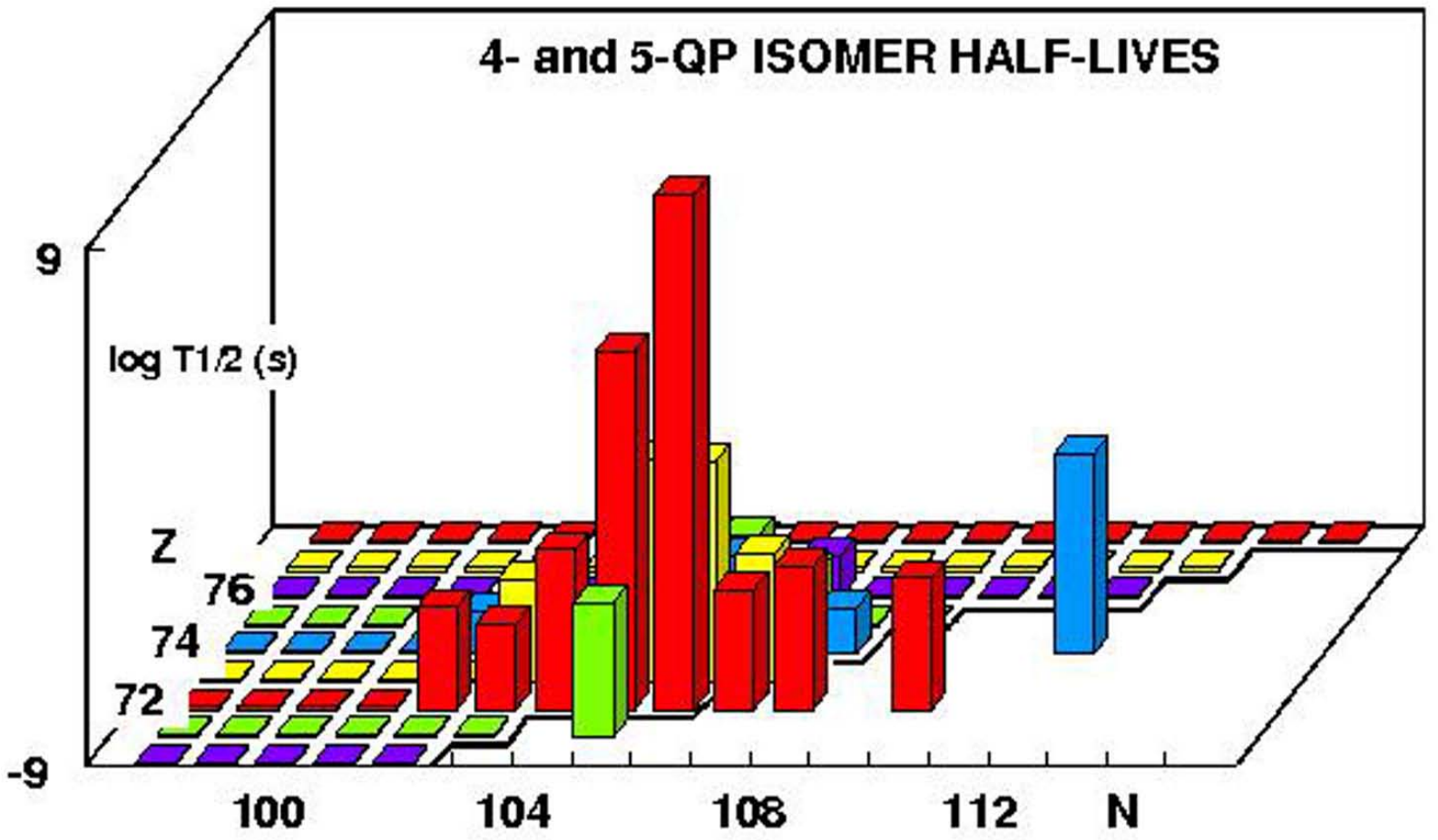
usually interested in K_{max} ...



Walker &Dracoulis, Hyp. Int.

Dracoulis; Limits2004

can classify strength but can't predict τ



hindrance $F = \tau\gamma / \tau_W$

forbiddenness $\nu = \Delta K - \lambda$

reduced hindrance $f = F^{1/\nu}$

E2 usually ~ 100

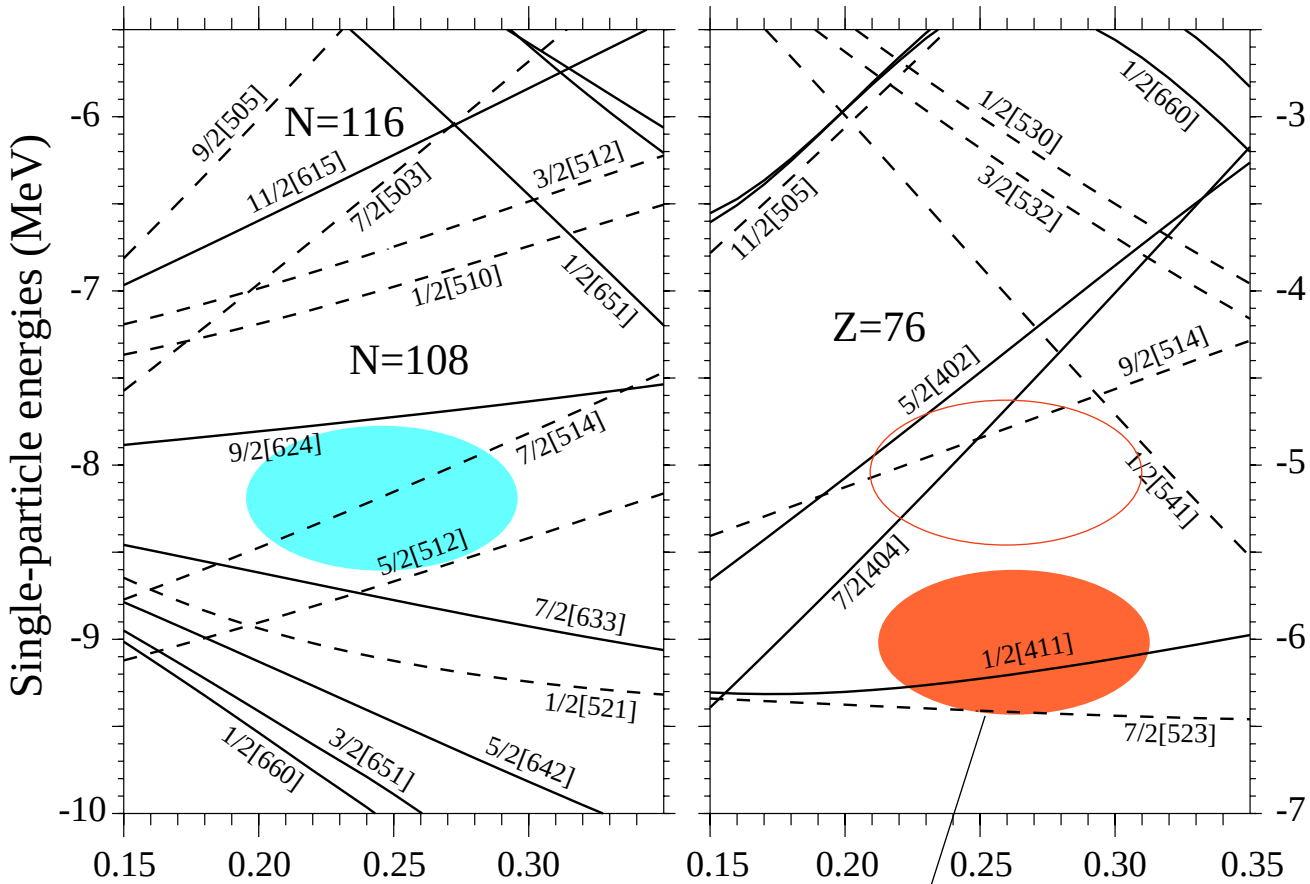
if f < 20 ; explain

f > 300 is unlikely

multipolarity ?

Dracoulis; Limits2004

but going down in Z...-qualitative change



low-Ω orbital at proton Fermi surface $1/2^{+}[411]$

(with hindsight) possible implications

- *high-K states may be non-yrast*
- *ν^4 configurations will compete with "balanced" configurations, such as $\nu^2\ \pi^2$.. etc..*
- *states with non-maximum K-coupling , such as K-1 (e.g opposite coupling of the 1/2+[411] proton), may be significant*

Dracoulis; Limits2004

816 MeV ^{136}Xe on 6 mg/cm^2 targets of ^{176}Lu ^{175}Lu ^{174}Yb with GAMMASPHERE at Argonne

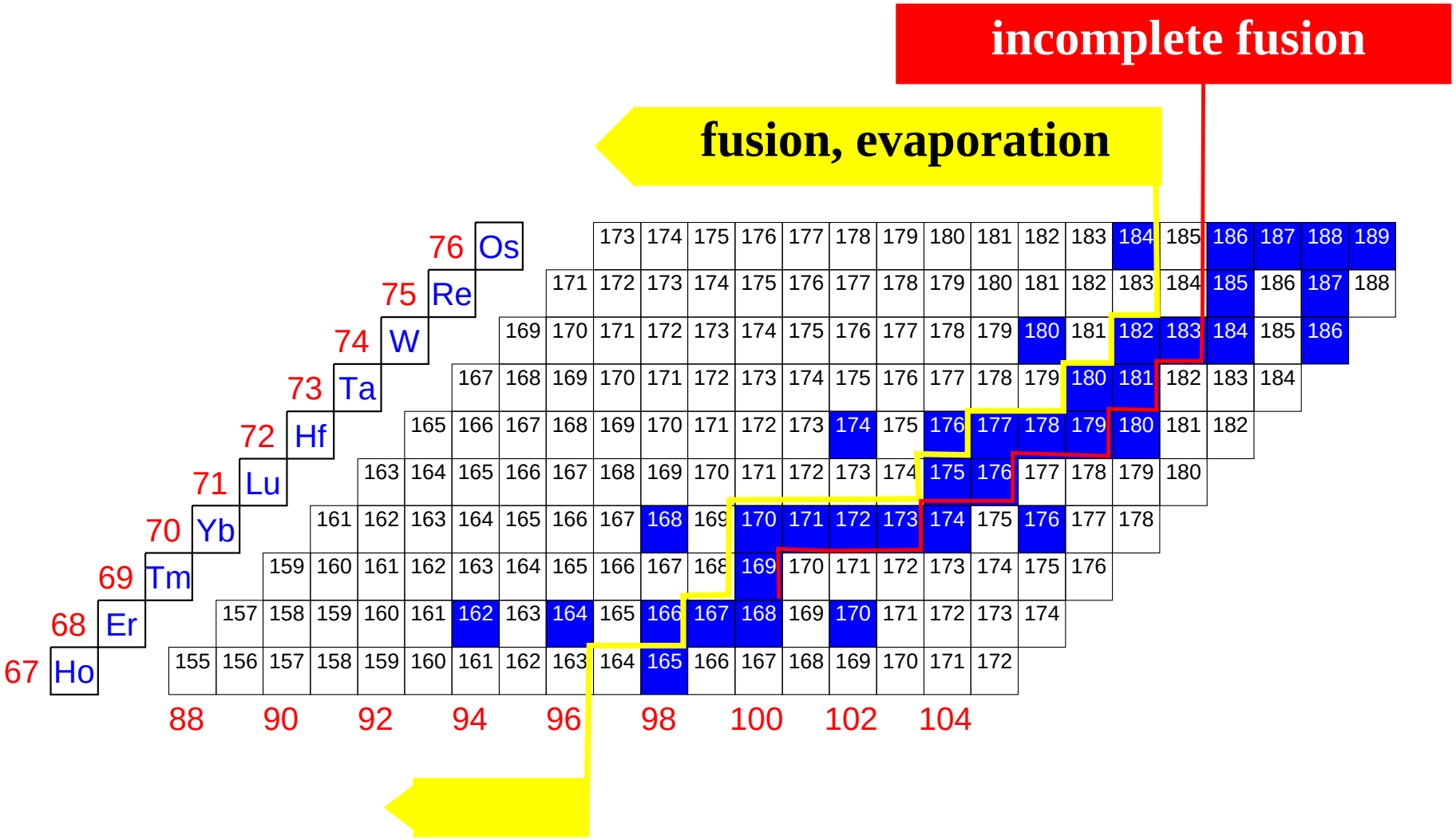
main population

	102	104	106	108	110					
76										Os
75										Re
74	176 +3p-3n	177 +3p-2n	178 +3p-1n	179 +3p	180 +3p1n	181 +3p2n	182 +3p3n	183 +3p4n	184	W
73	175 +2p-3n	176 +2p-2n	177 +2p-1n	178 +2p	179 +2p1n	180 +2p2n	181 +2p3n	182 +2p4n	183	Ta
72	174 +1p-3n	175 +1p-2n	176 +1p-1n	177 +1p	178 +1p1n	179 +1p2n	180 +1p3n	181 +1p4n	182	Hf
71	173 -3n	174 -2n	175 -1n	^{176}Lu	177 +1n	178 +2n	179 +3n	180 +4n	181	Lu
70	172 -1p-3n	173 -1p-2n	174 -1p-1n	175 -1p	176 -1p+1n	177 -1p+2n	178 -1p+3n	179 -1p+4n	180	Yb

fgk

Dracoulis; Limits2004

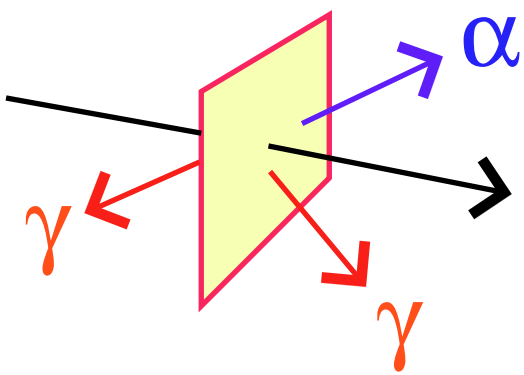
Heavy Ion Fusion with stable nuclei ; Z,N limit



Dracoulis; Limits2004

neutron-rich nuclei via incomplete-fusion

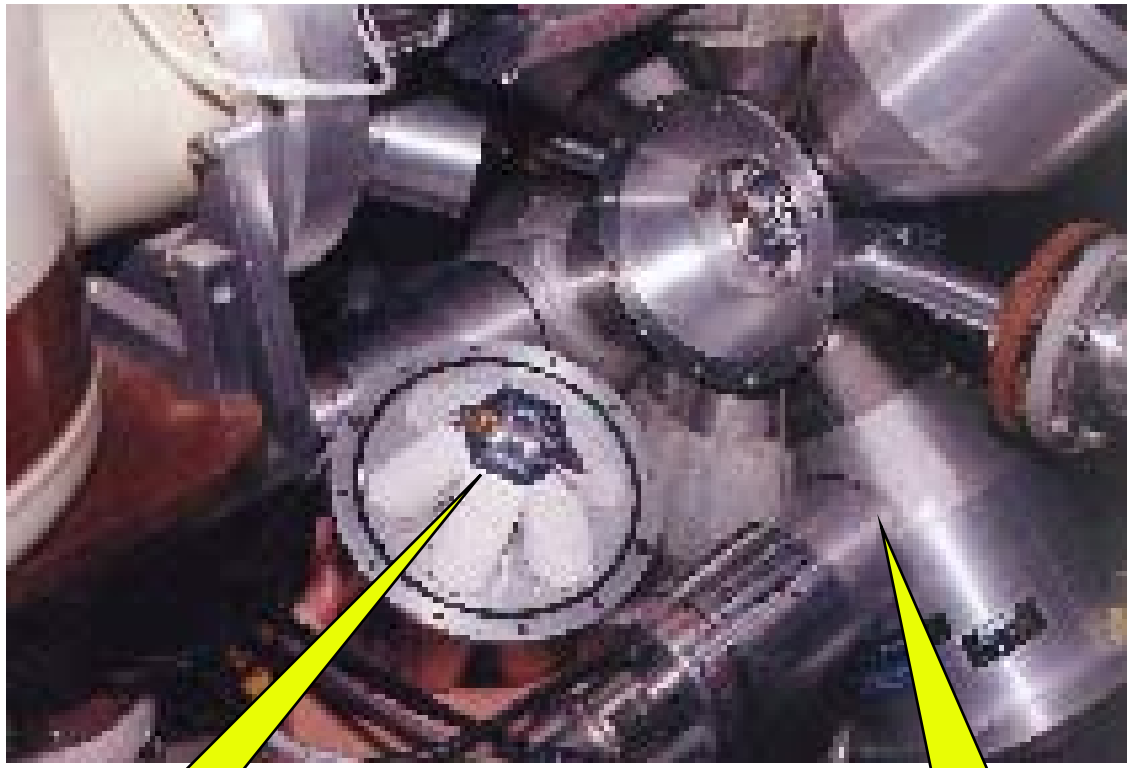
the poor man's RIB



$^{176}Yb\ (^{11}B,\alpha 3n)^{180}Ta$

$^{176}Yb\ (^{9}Be,\alpha 3n)^{178}Hf$

$^{176}Yb\ (^{7}Li\ ,\alpha 2n)^{177}\ Lu$

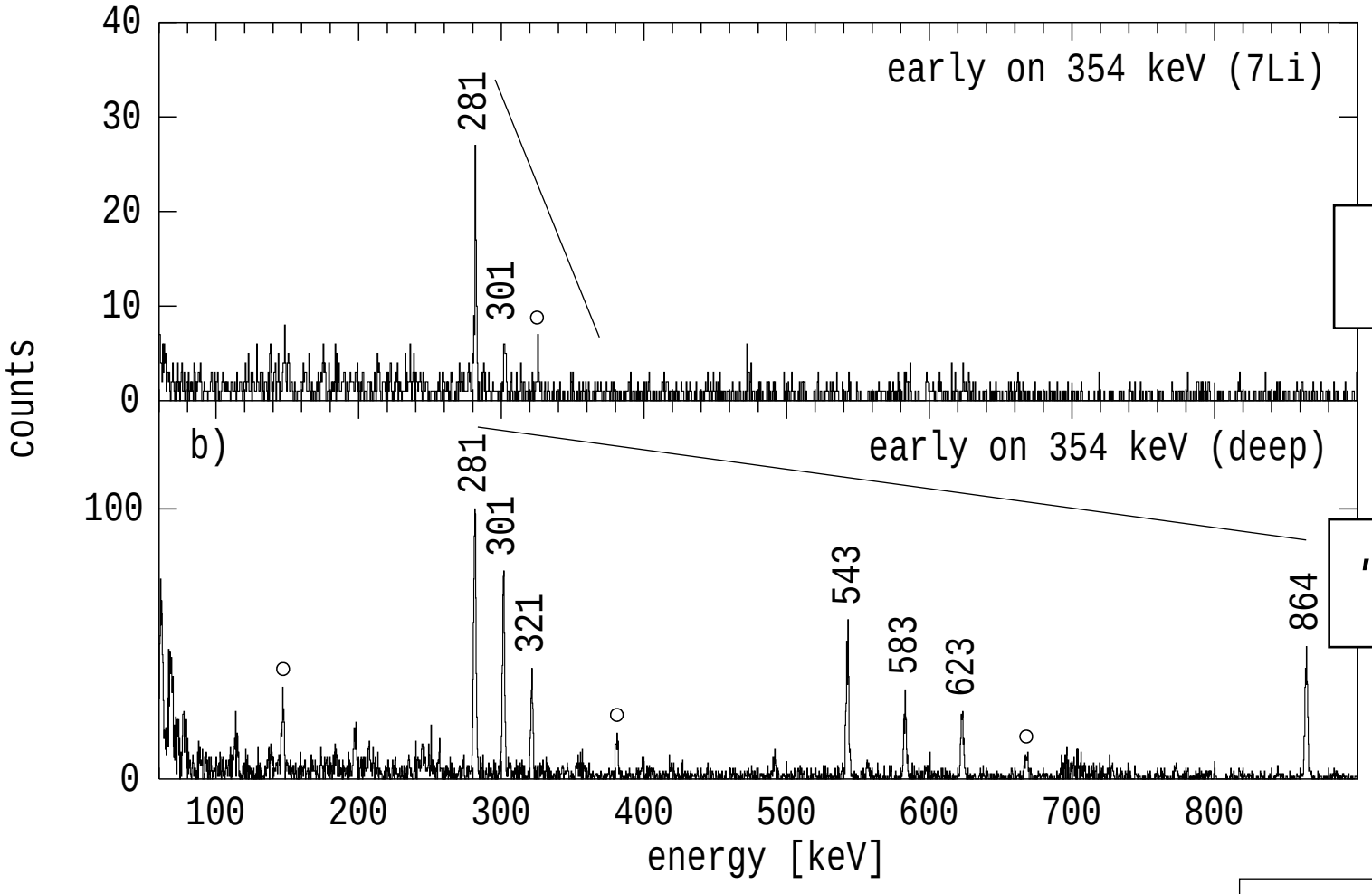


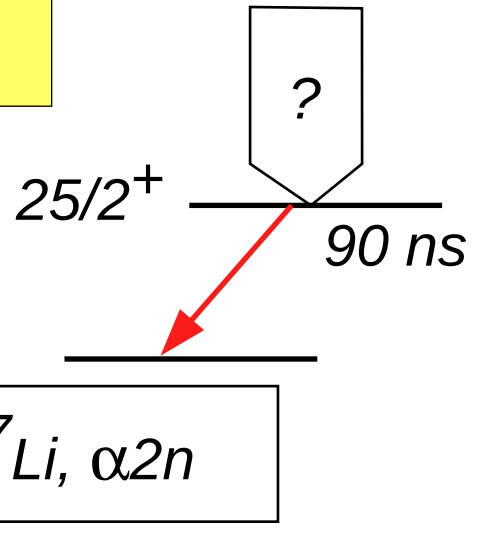
14-element fast/slow plastic

Compton-suppressed Ge

Dracoulis; Limits2004

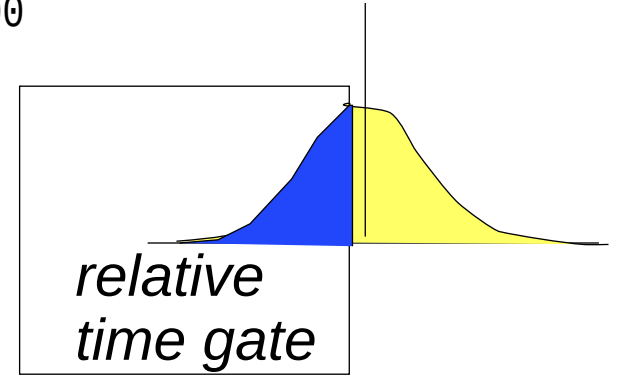
cross bombardment - spin input - ^{177}Lu





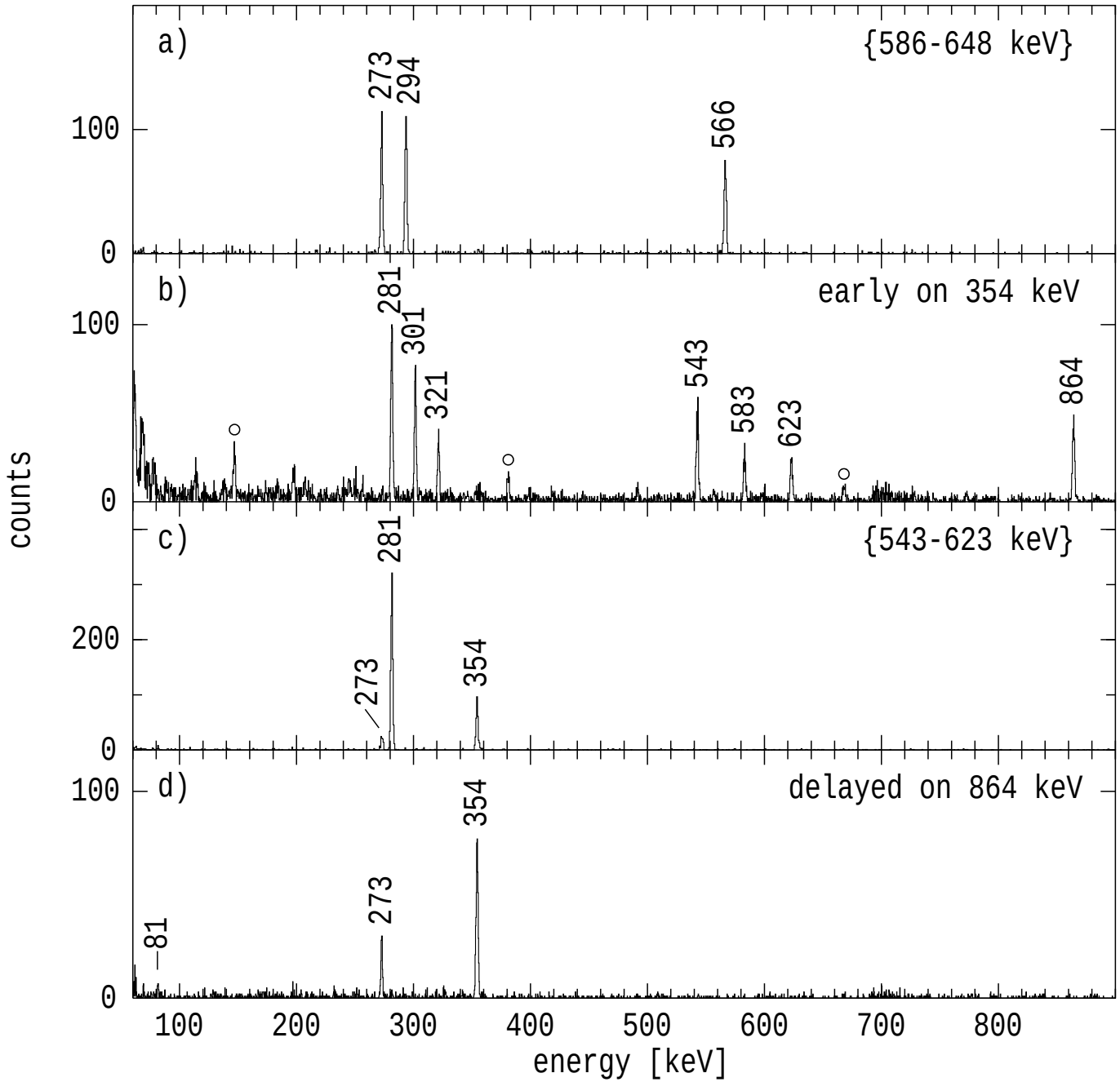
"deep-inelastic"

gated on 355 keV γ-ray below 90ns isomer
selecting γ-rays above



Dracoulis; Limits2004

prompt and early-delayed gates - ^{177}Lu



branch from 33/2+ isomer to 23/2- band

between the 33/2+ isomer & the 25/2+ isomer

within the 25/2+ band

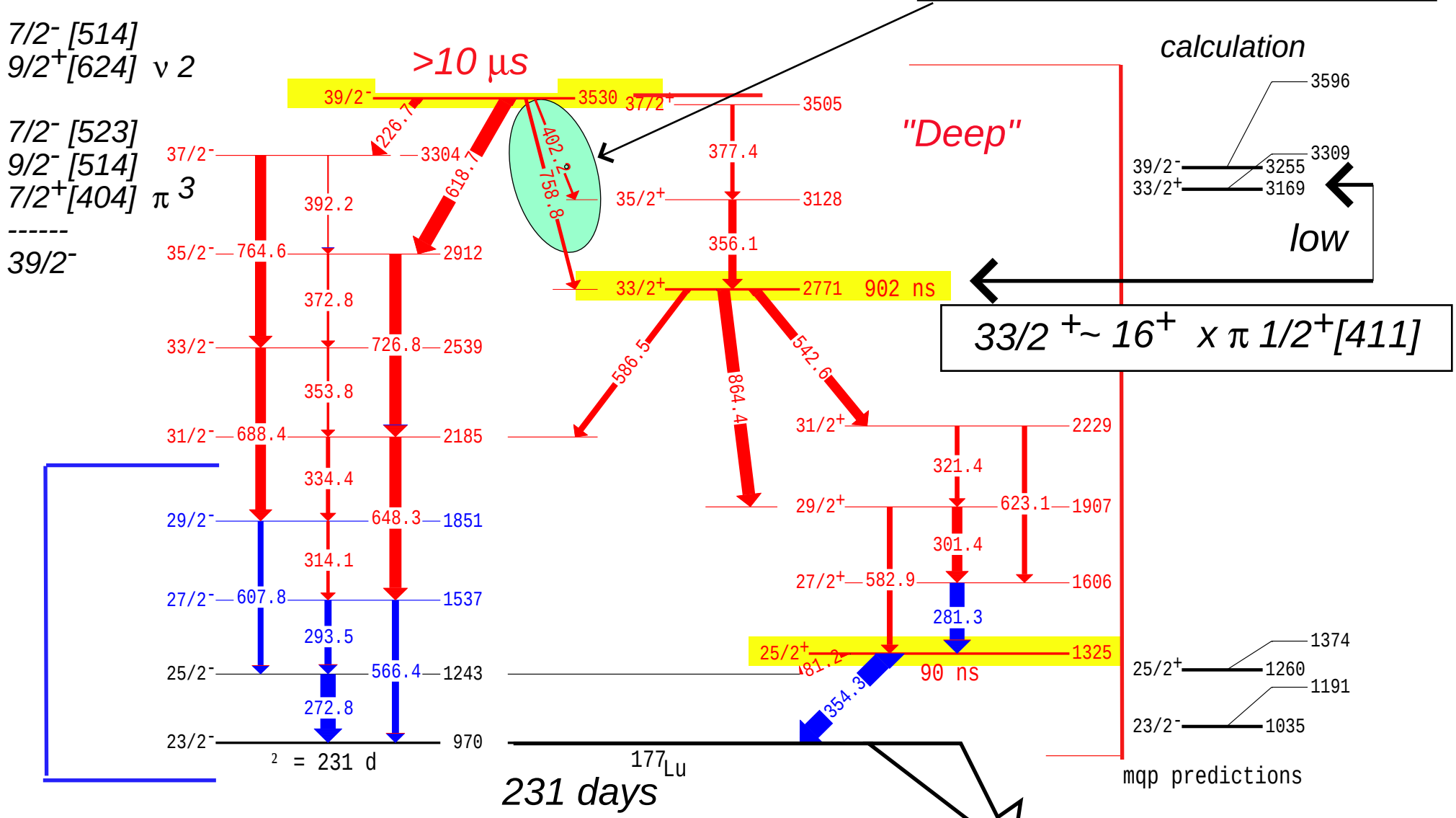
below the the 25/2+ isomer

Dracoulis; Limits2004

^{177}Lu

the K = 39/2- yrast isomer

E3 is not K-forbidden

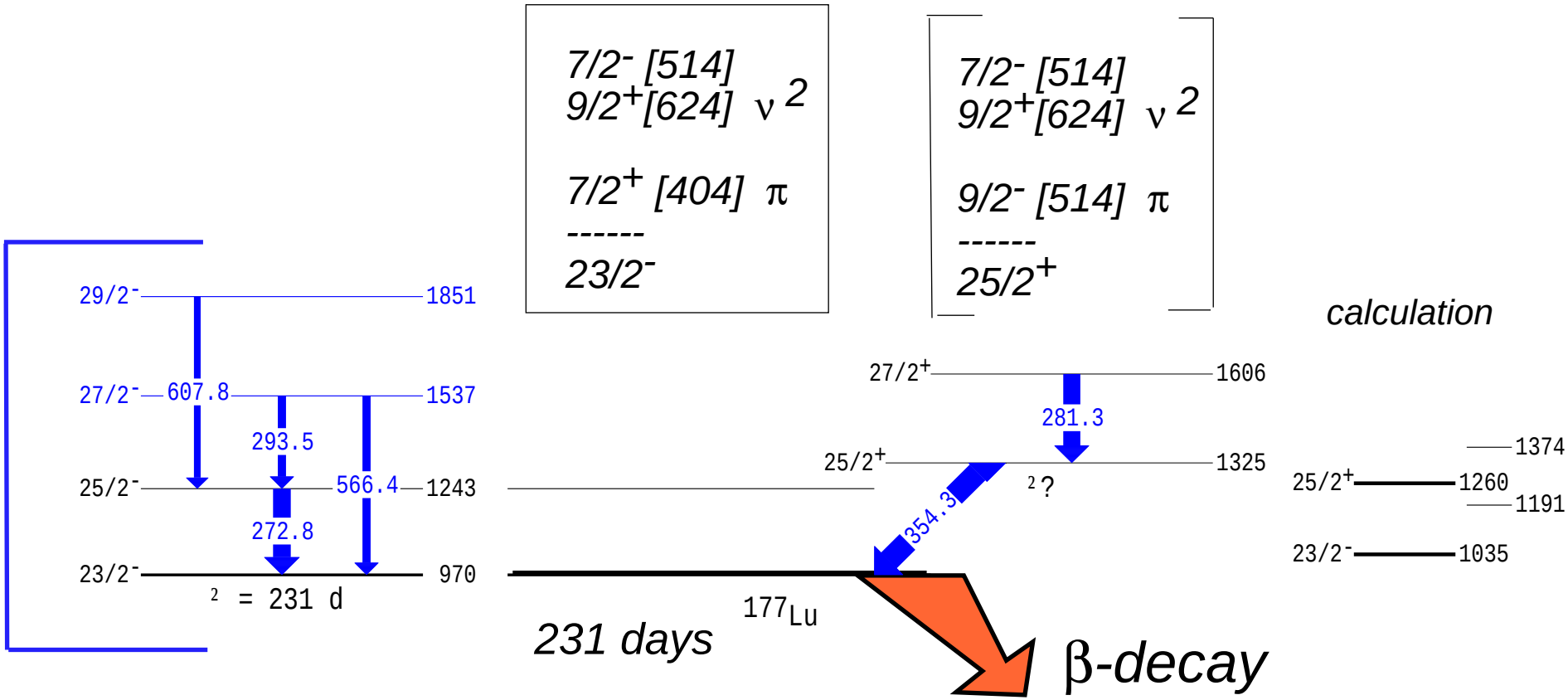


Dracoulis et al Phys Lett B 584(2004)22

71 1061z11

Dracoulis; Limits2004

^{177}Lu from incomplete fusion



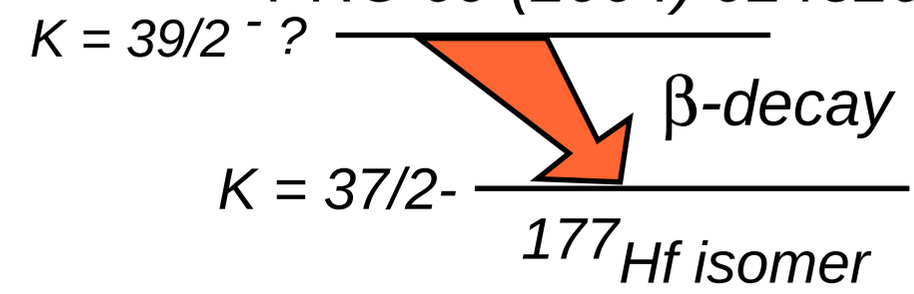
α–γ–γ–time coincidences 4p particle-detector array;
37 MeV 7Li ; angular momentum in 6-13 h - breakup-compound

^{176}Yb(^{7}Li,α2n) McGoram ANU PhD; to be published

Dracoulis; Limits2004

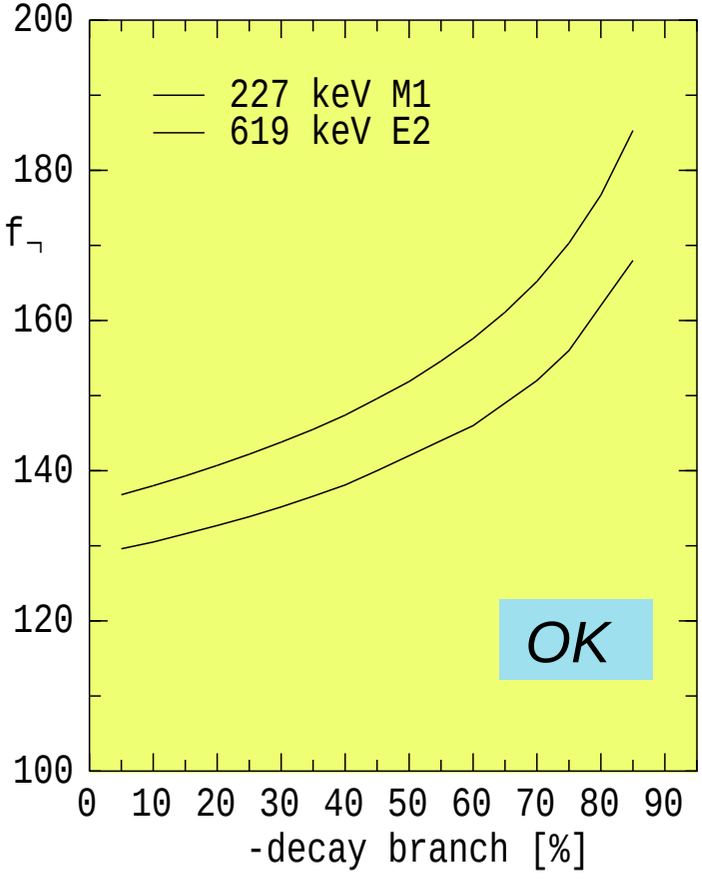
^{177}Lu - 7 min β-decay ?

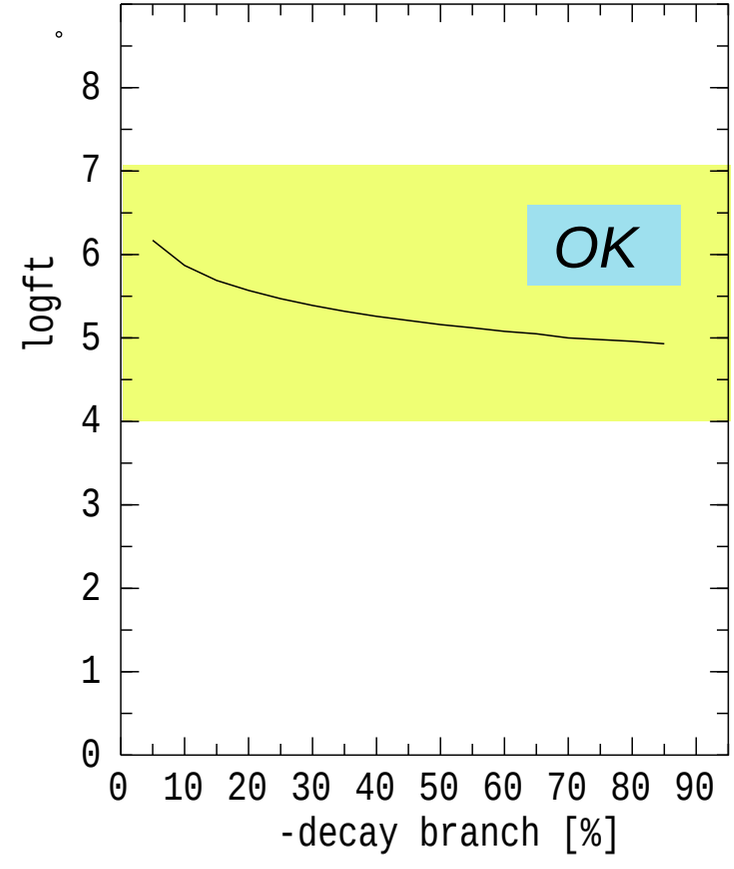
Al-Garni et al
PRC 69 (2004) 024320



Q_β - logft & strength of internal γ-ray branches

Dracoulis et al Phys Lett B 584(2004)22





not OK
for τ = 7 min.
759 keV E3
(39/2- to 33/2+)
is 10^{-9} W.u.

expect τ = 10 ms !

to be measured....

Dracoulis; Limits2004

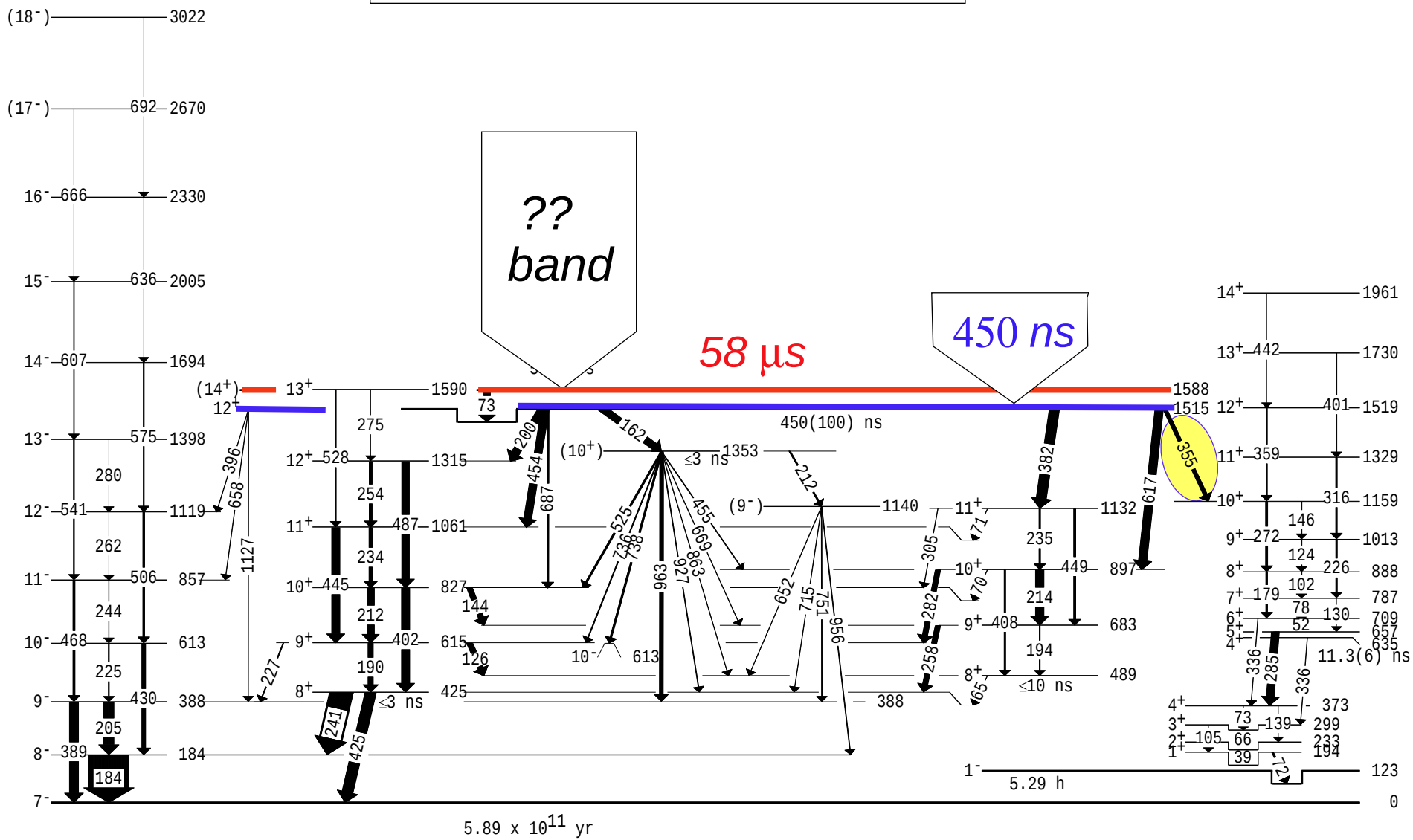
level schemes for

^{175}Lu (show and tell)

^{176}Lu ; ^{179}Ta (chance degeneracies)

^{176}Lu -partial

chance degeneracy

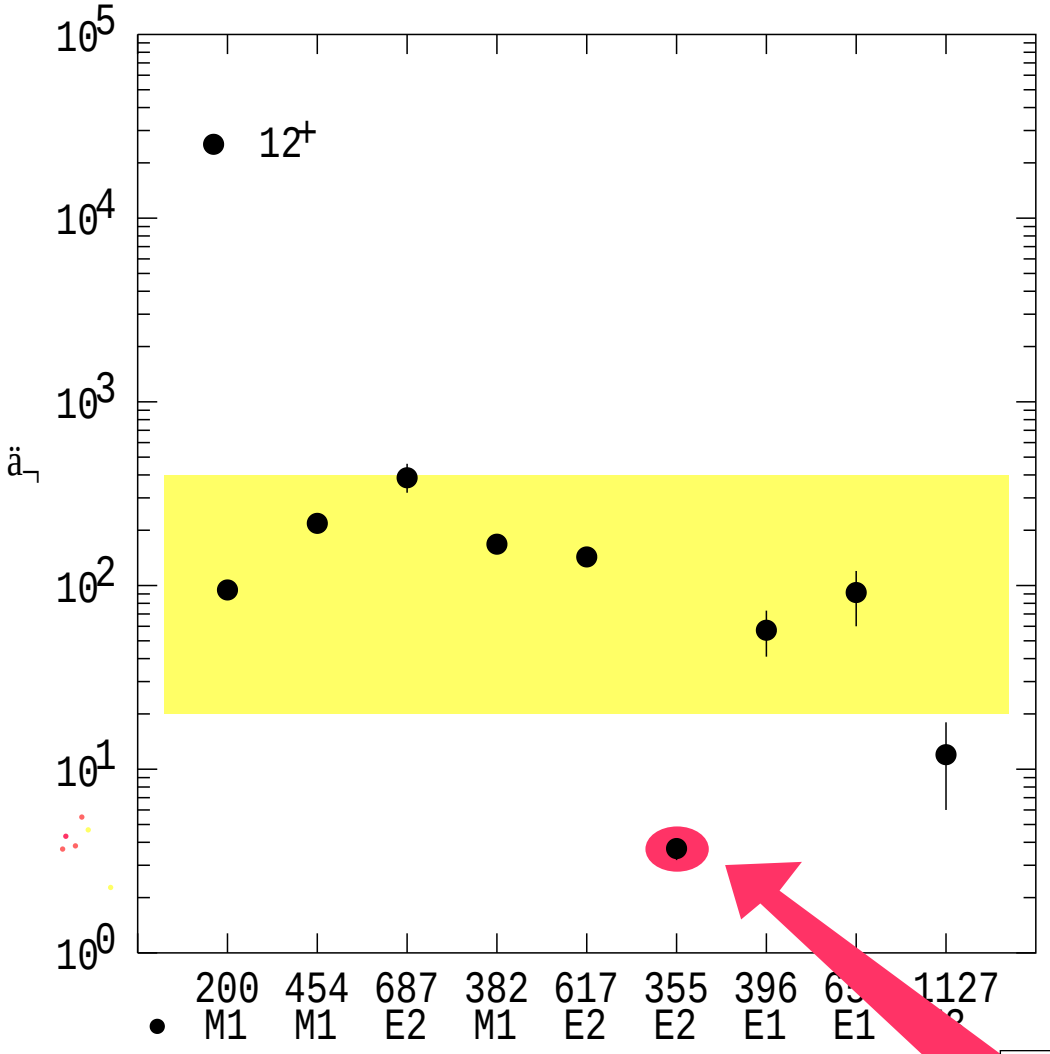


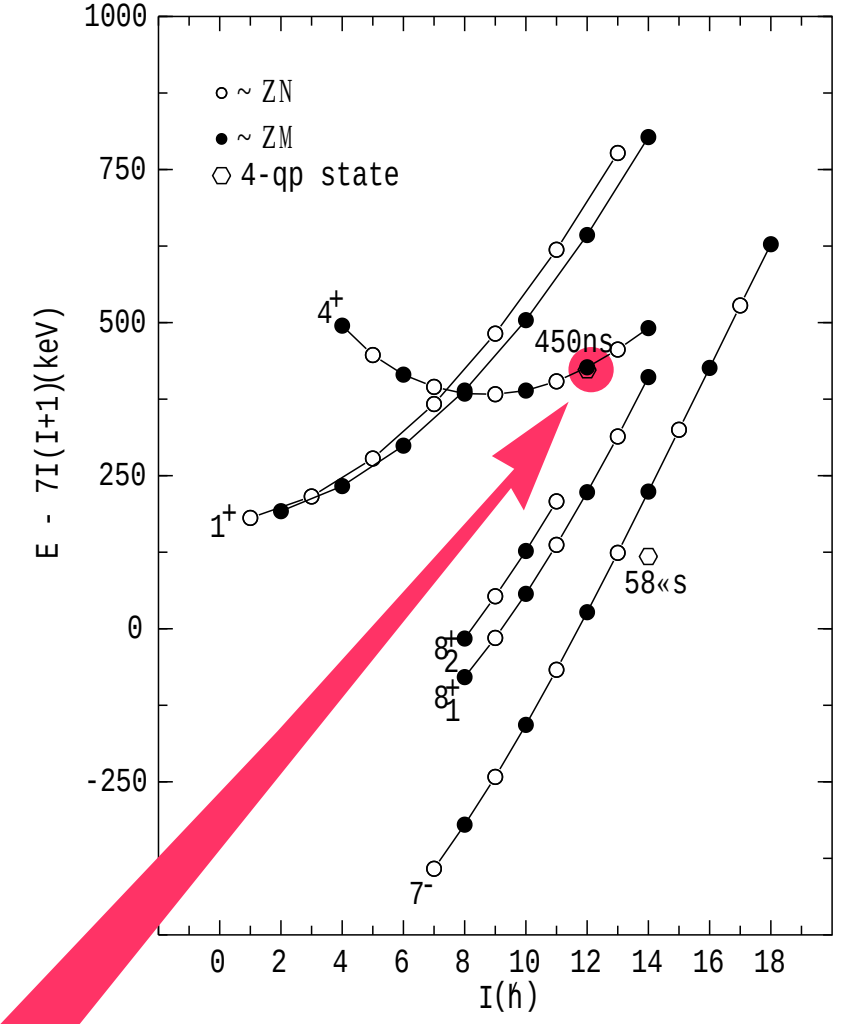
McGoram et al PRC 62 (2000) 031301

Dracoulis; Limits2004

Lu

anomalous hindrances - ^{176}Lu



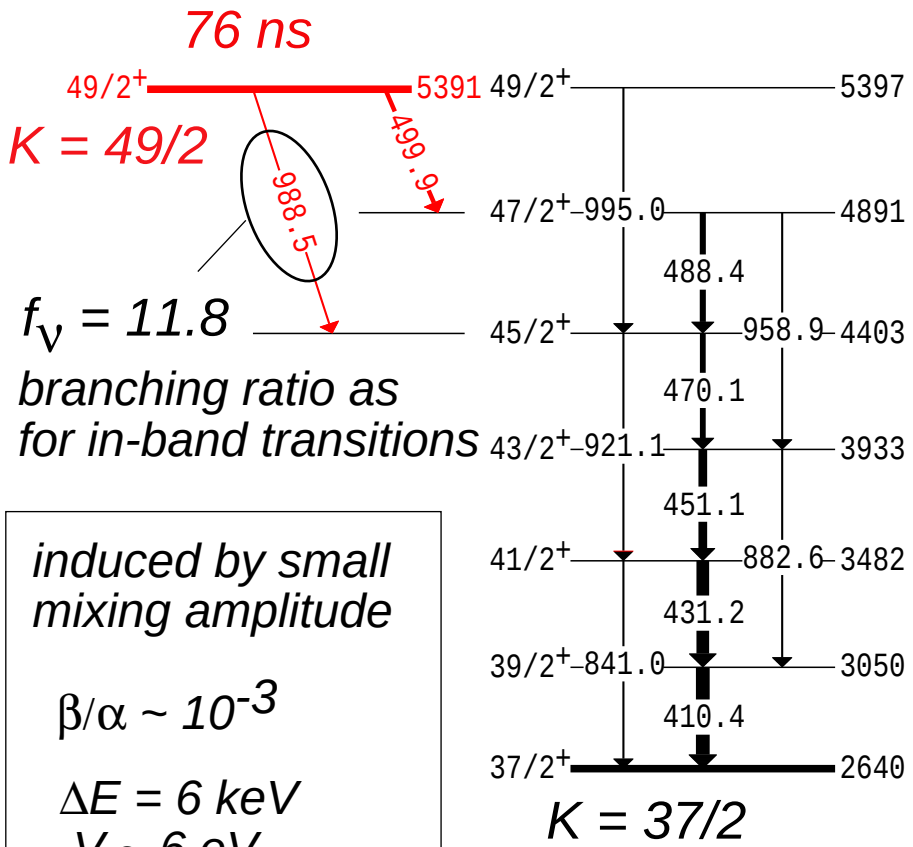


$f_\nu = 4 \quad \Delta K = 8 \quad \nu = 6$

Dracoulis; Limits2004

Lu

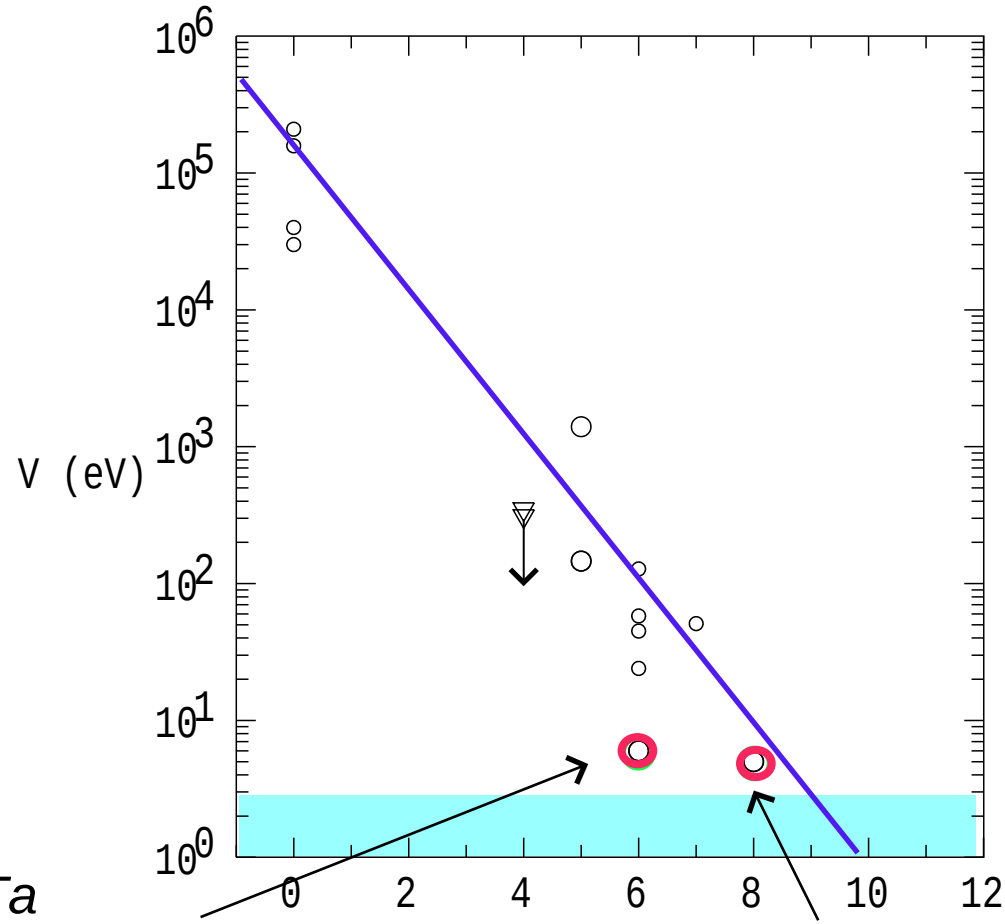
Interaction Matrix elements
from chance degeneracy



induced by small mixing amplitude

$\beta/\alpha \sim 10^{-3}$

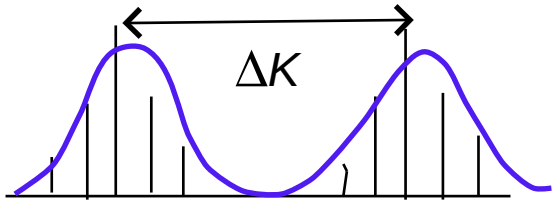
ΔE = 6 keV
$V \sim 6$ eV



^{179}Ta

Kondev et al EPJA 2004

^{176}Lu



gaussian overlap in K-space
implies exponential

see Saitoh et al NPA 660(1990) 121 and others

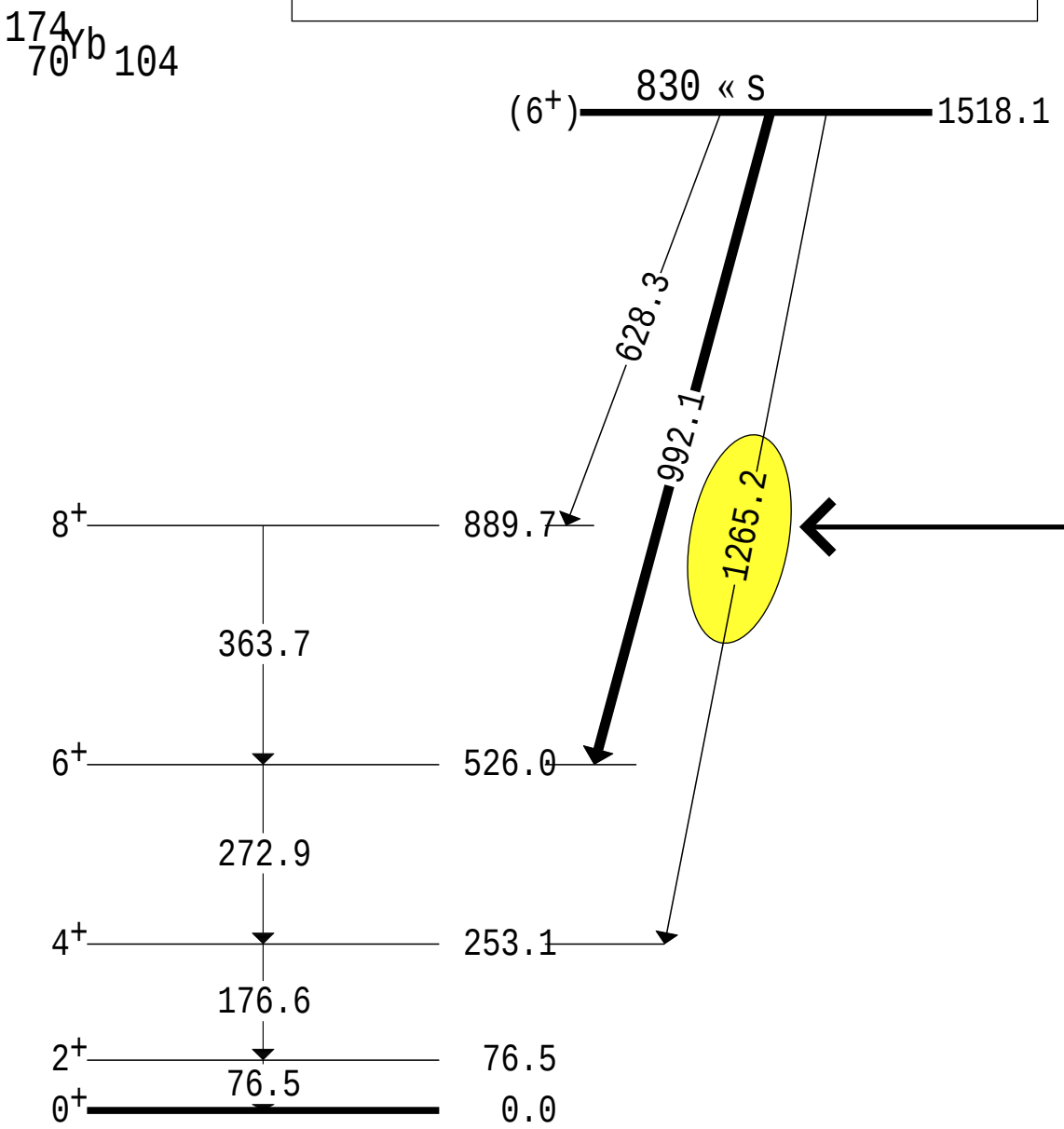
Dracoulis; Limits2004

Lu

^{174}Yb(6^{+} and up; hindrances)

Dracoulis; Limits2004

^{174}Yb



10^{-10} s.p.u.

non-yrast
but long-lived
- very hindered
transitions

f_ν = 322
is it really E2 ?
non-Alaga

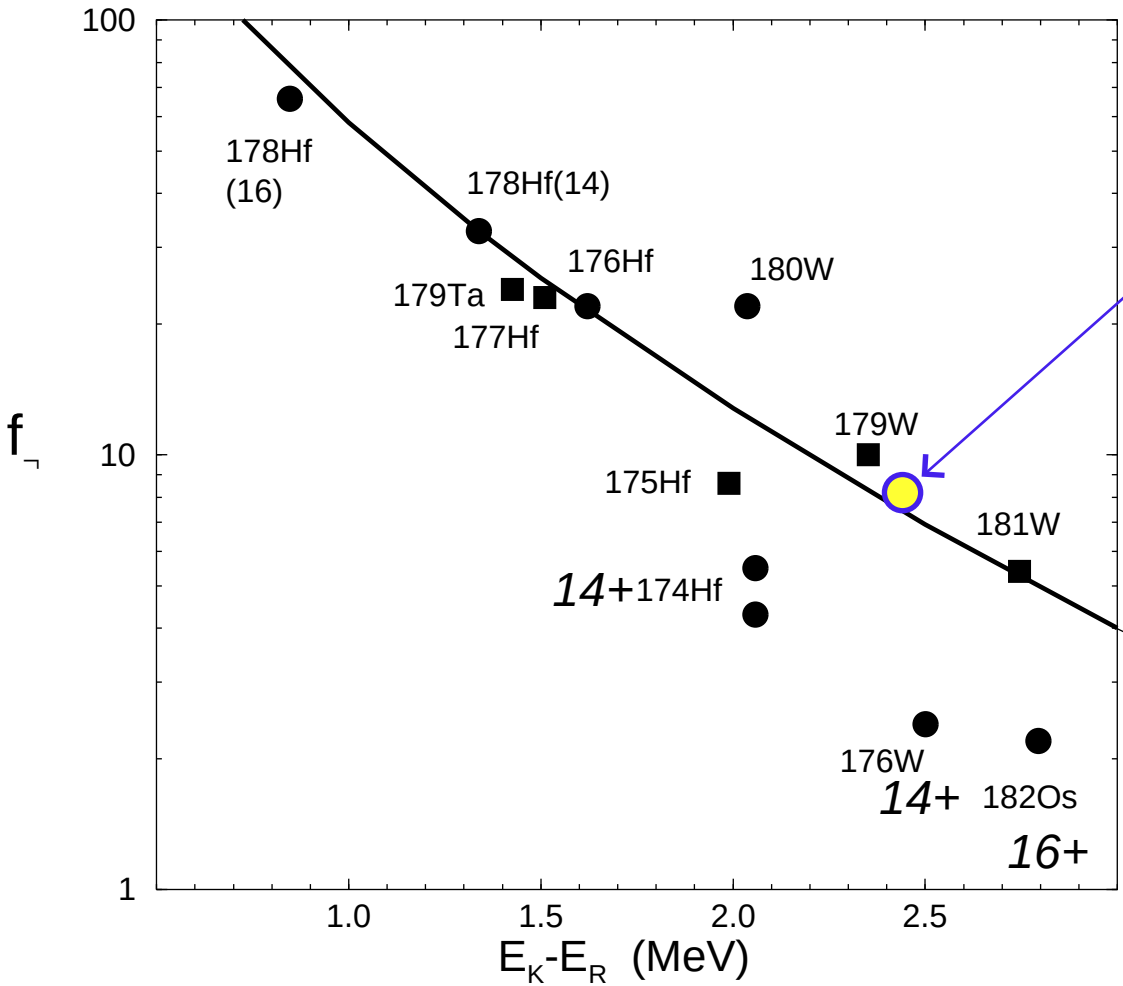
is it really 6^+ ?

β-*decay*
(d,pγ)

Dracoulis; Limits2004

hindrance away from the yrast line ?

for ΔK >= 6, E2 and E3 4-qp states



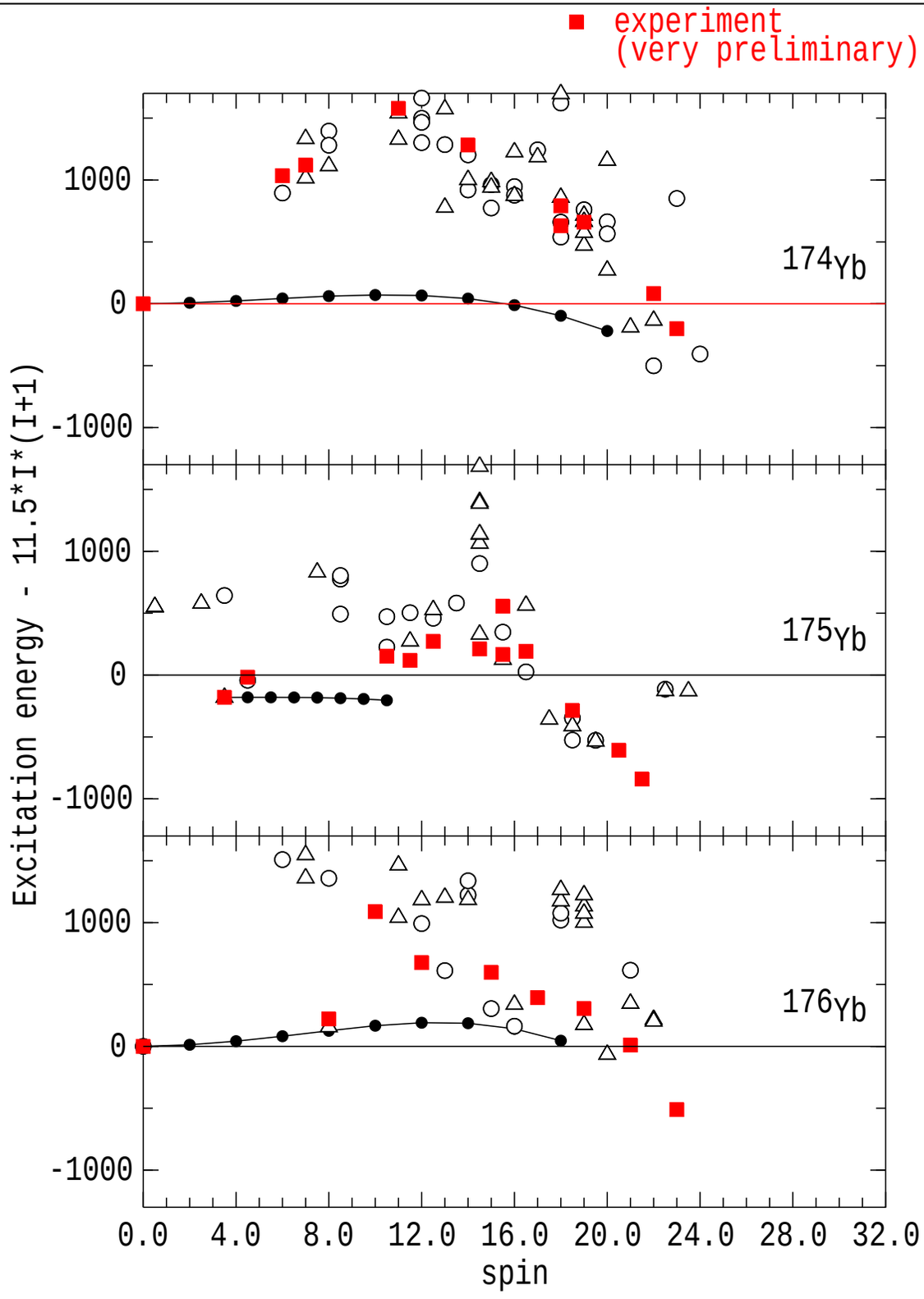
14+ ν4 state in 174Yb

Walker et al;
PLB 408 (1997)42
based on density-of-states formulation of
Vigezzi et al NPA 520

$$f_\nu = F_\nu \exp\left[\frac{-3}{\nu} \sqrt{\frac{\pi^2}{6} g_0 \Delta E} \right]$$

roughly... but many even lower points - specific mixing

Dracoulis; Limits2004



preliminary comparison

assignments in progress
a) total conversion
b) branching
c) transition strengths from τ or implied limits;

but, so far lacking one-to-one agreement for spin&parity

Dracoulis; Limits2004

some problems and prospects

- *Proper treatment of residual interactions in Multi-quasiparticle cases. That is, self consistently account for state-dependent occupation probabilities*

- *Tie down the position of single-particle orbitals away from the Fermi surface. A problem in configuration assignment but one of the promises implied by identifying multi-quasiparticle states*

experimental challenges

- *Isotopic assignment; Identifying structures above very long-lived states is like identifying new nuclei*

- *Spin-parity assignments !*

- *prospects for probing configuration purity away from the yrast line*

There are plenty of K-Isomers out there.

God bless them

Dracoulis; Limits2004