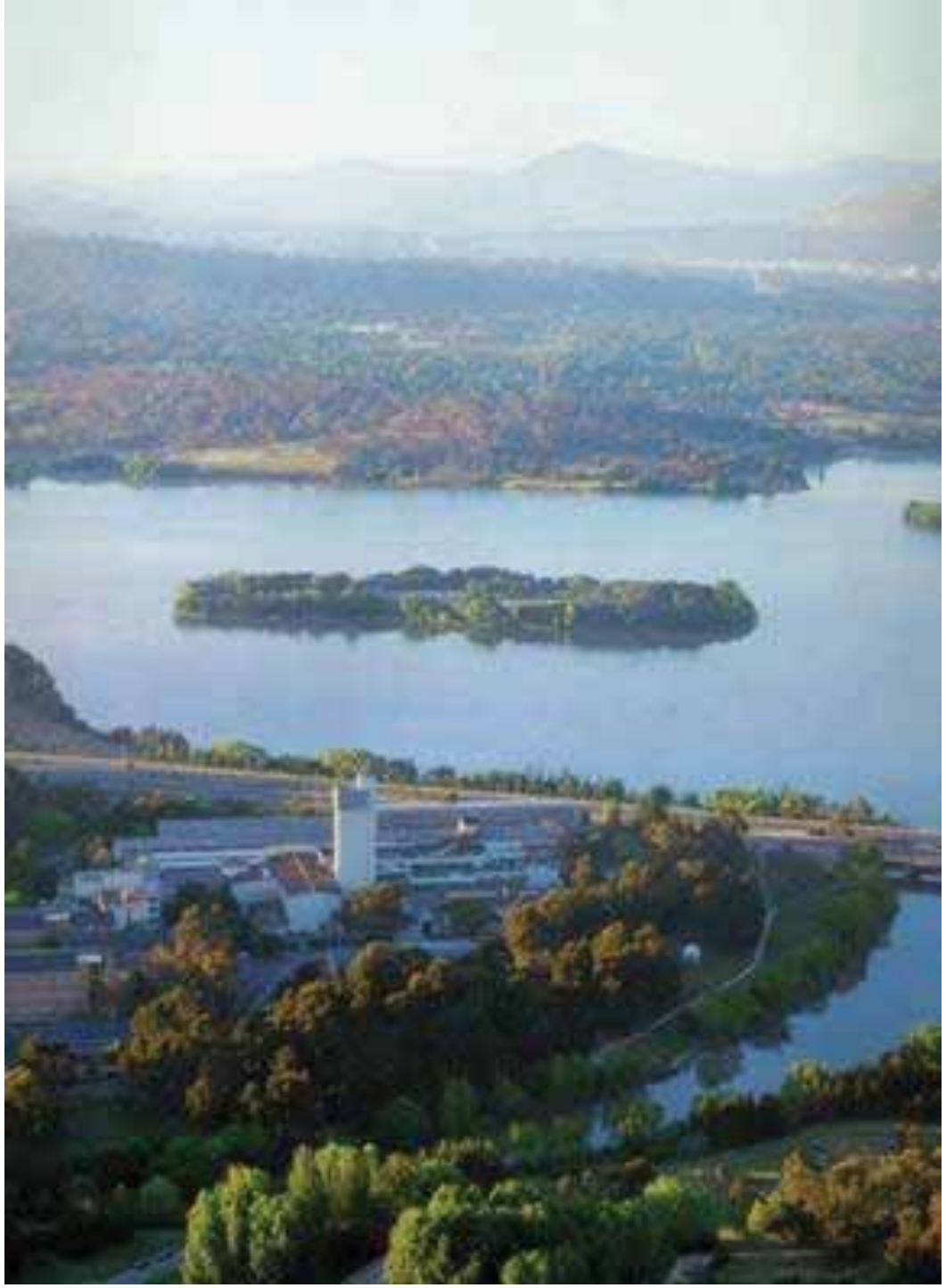
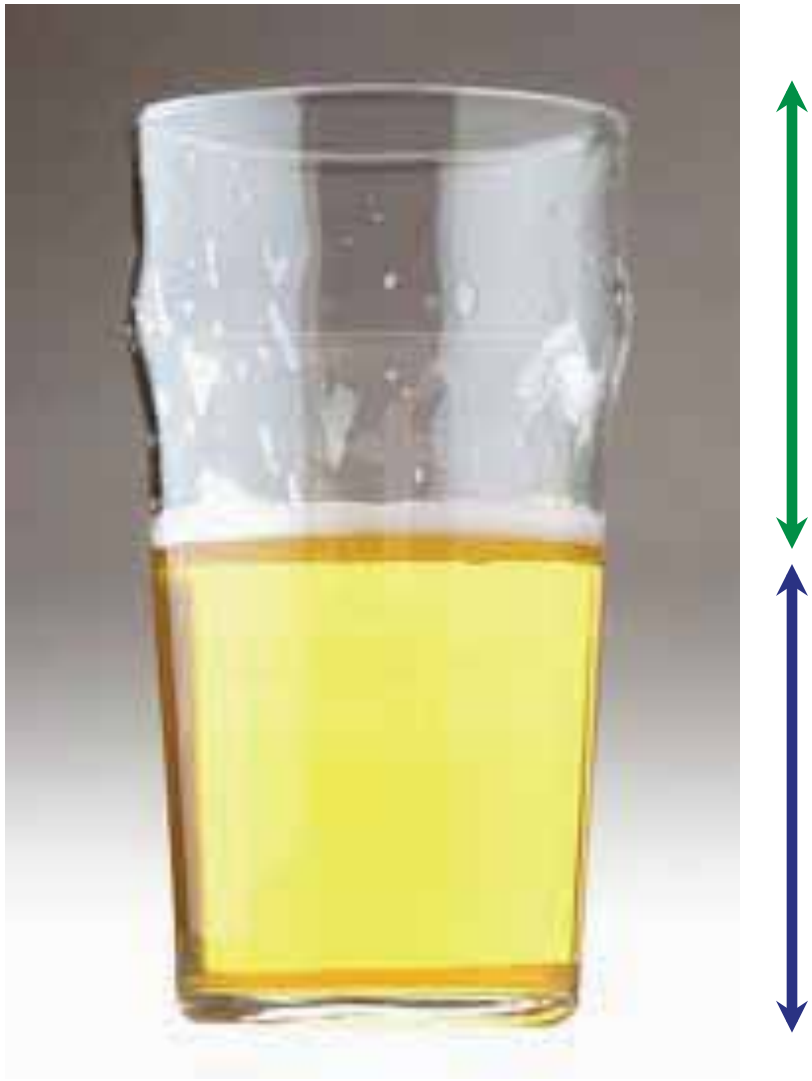


Research possibilities with CARIBU beams and associated measurement methods

Greg Lane

THE AUSTRALIAN NATIONAL UNIVERSITY

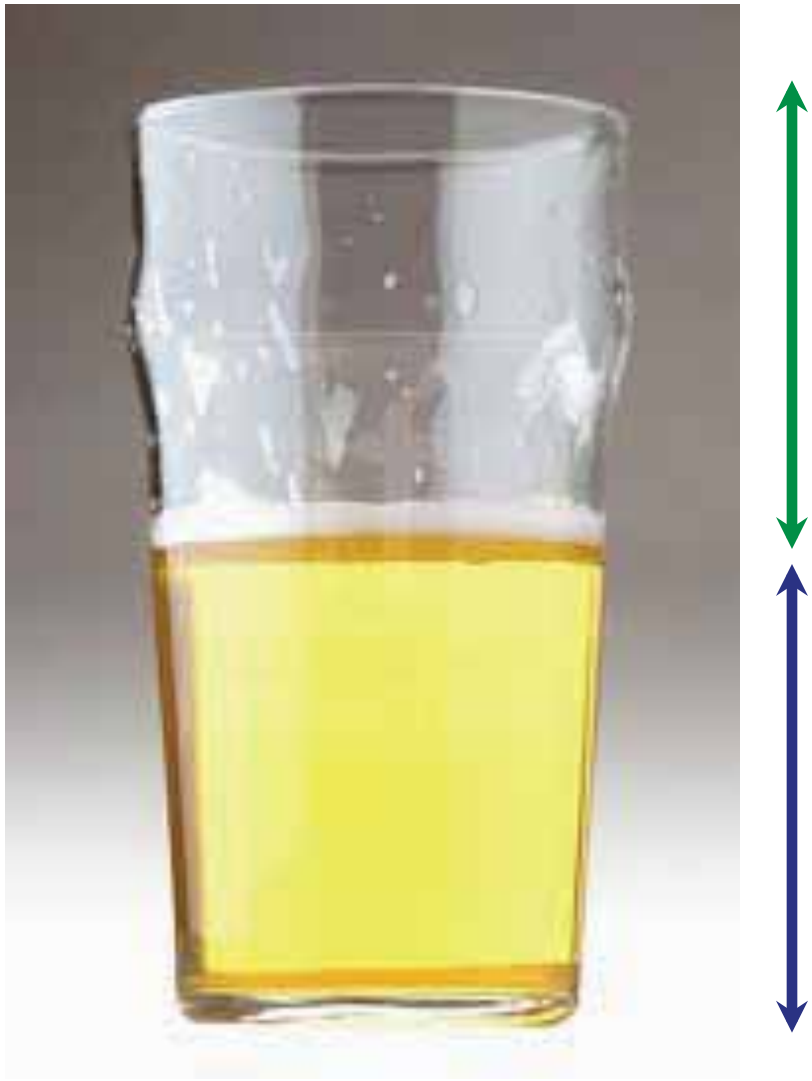
The "joy" of being the next to last speaker



"Half-empty"

"Half-full"

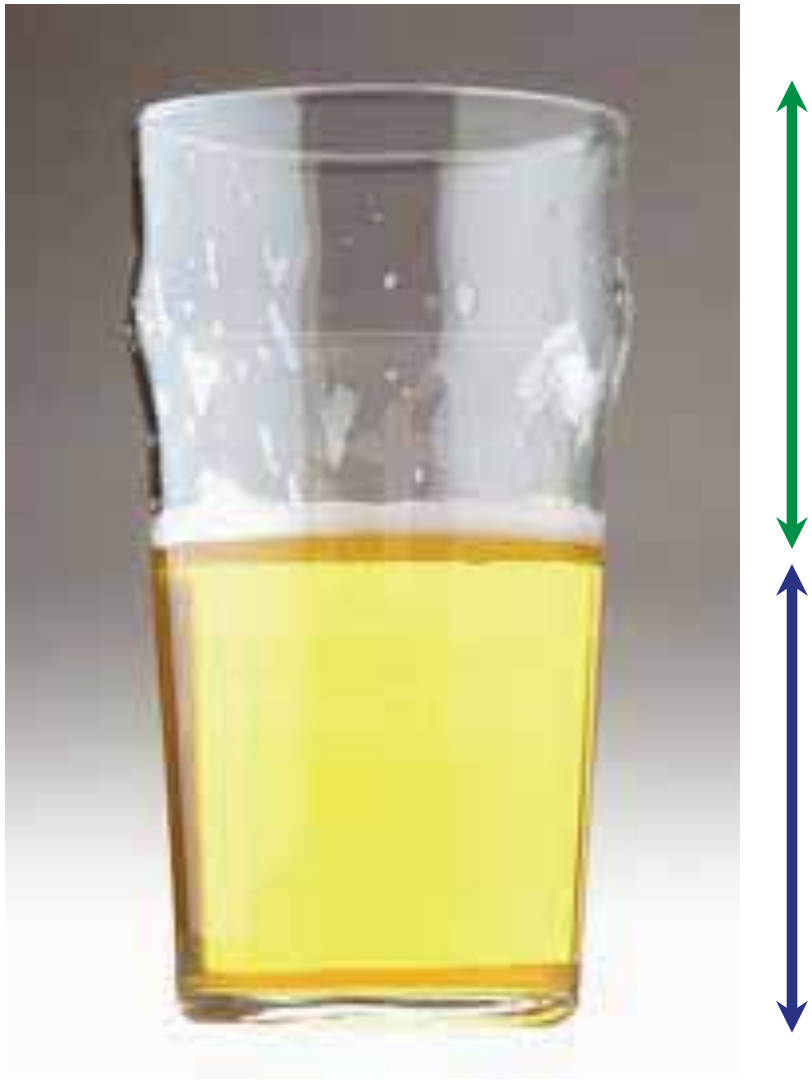
The "joy" of being the next to last speaker



"The optimist"

My ideas are obviously good, as they' ve all been covered already…

The "joy" of being the next to last speaker



"The pessimist"

Everyone has stolen my good ideas!

My original plan... discuss funded projects

We have had recent funding success with an Australian Research Council project specifically listing CARIBU

- TAS measurements aimed at nuclei important to decay heat and AFC's – IAEA priority lists
- Decay spectroscopy of nuclei relevant to r-process nucleosynthesis
- Collectivity of neutron-rich nuclei determined via direct lifetime measurements

All of these have been covered in some detail over the course of this meeting!

Total Absorption Spectroscopy

Speakers - Hill, Tain, Algora, Rykaczewski, Rubio, Schier, Karny, Firestone, Smith

Rationale – pandemonium, decay heat, reactor control etc

Methodology – overviews, specific detectors, related measurements (beta-delayed neutrons, fission fragment lifetimes)

Probably enough talks for now…

We (ANU) are a part of the group bringing the ANL TAGS detector back to life at CARIBU.

r-process nucleosynthesis

Speakers – Montes, Surman

- Mass measurements (CPT) and ground state lifetimes are likely to have the greatest impact.
- Our interest is from the nuclear structure side.
    - Serendipitous discoveries may be possible - Isomers in odd-odd nuclei? (Dracoulis, Kondev, Lane et al)

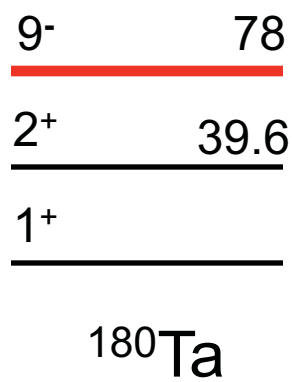
"Connections between high-K and low-K states in the s-process nucleus ^{176}Lu" – Dracoulis et al. PRC 81 (2010) 011301(R)

"Gamma- ray limits affecting the production and survival of ^{180}Ta in astrophysical processes" – Lane et al, in preparation.

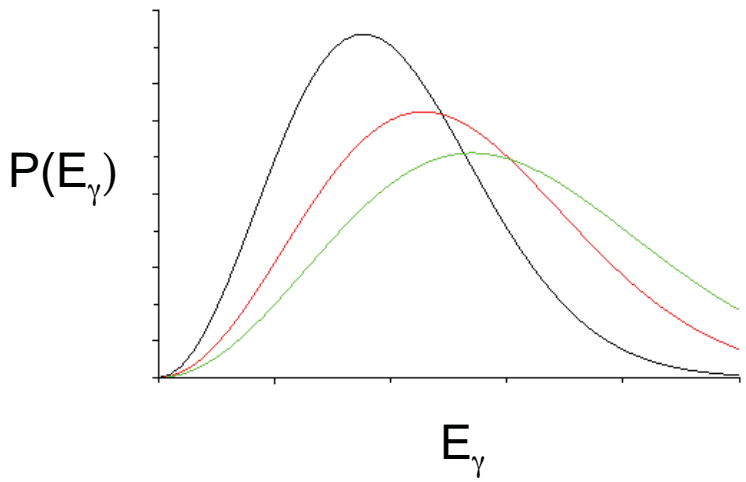
^{180}Ta – the only naturally occurring isomer

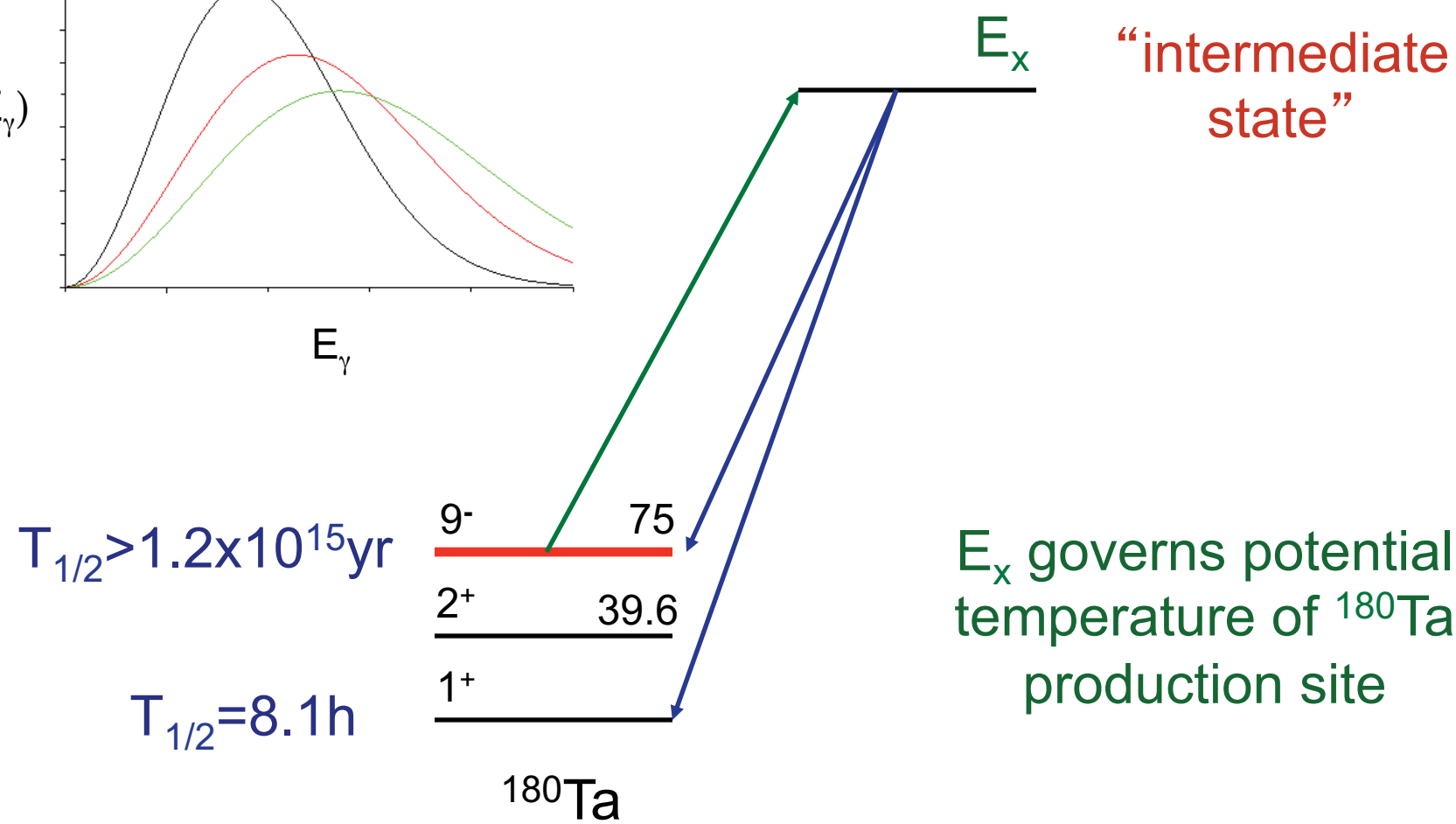
$T_{1/2}$>1.2x10^{15}yr

$T_{1/2}$=8.1h

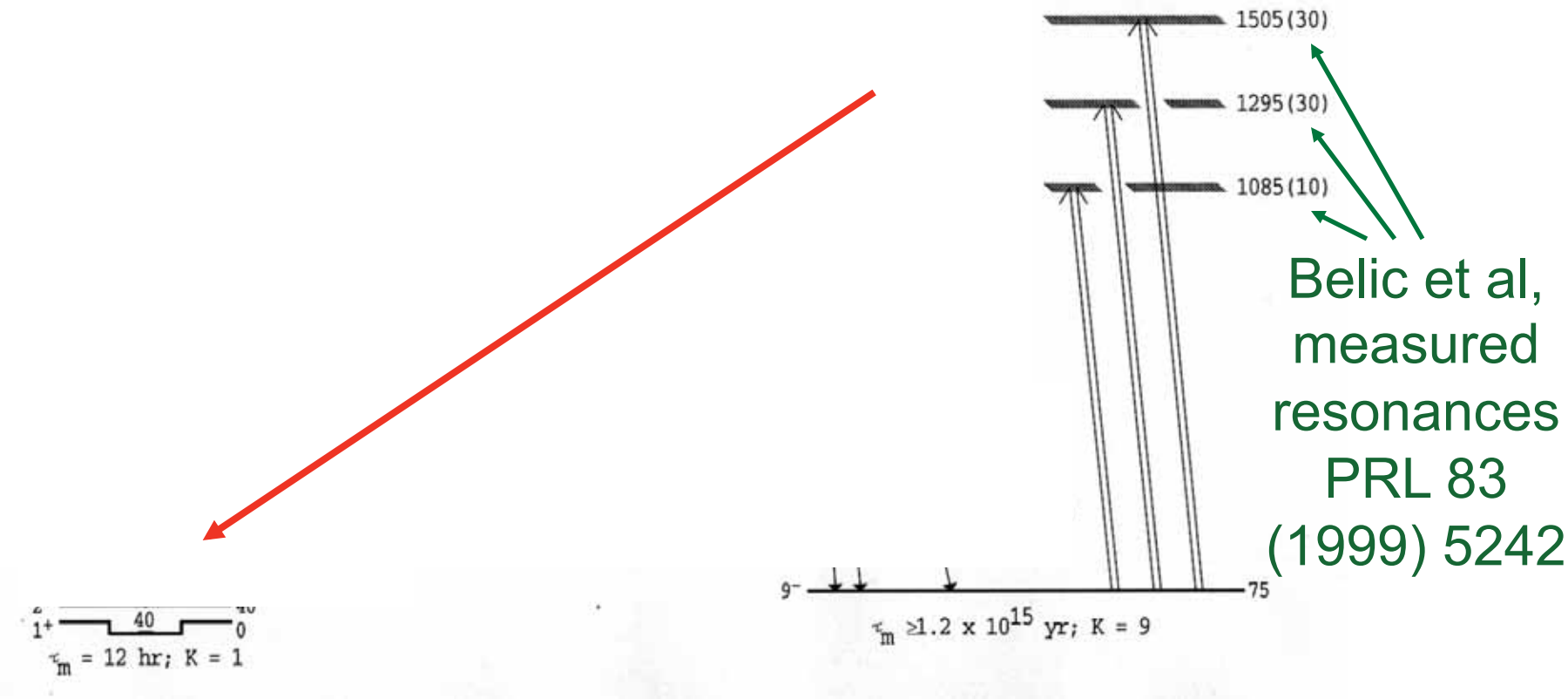


Can ^{180}Ta survive in the stellar environment?



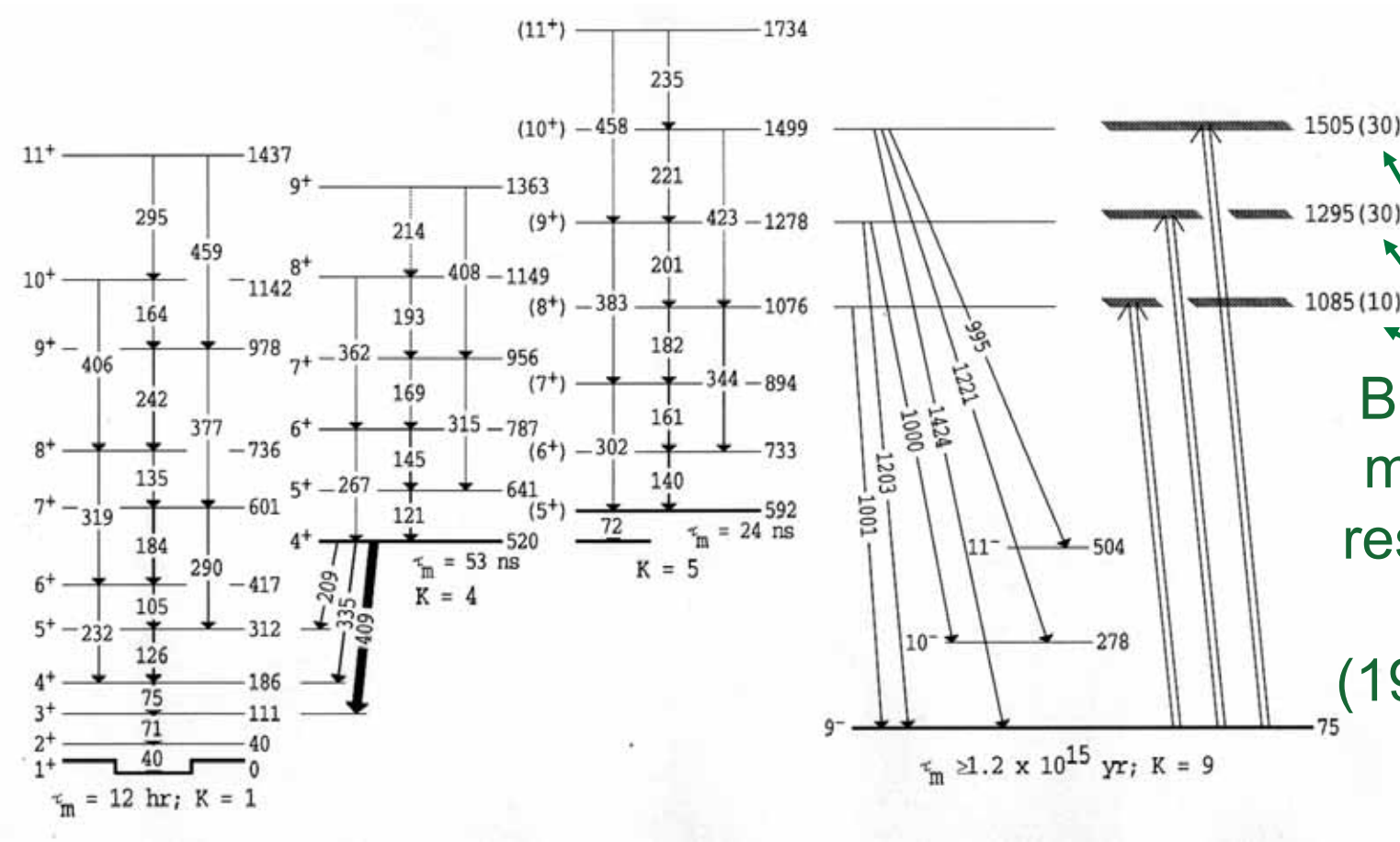


Possible "doorway" states in ^{180}Ta



Possible "doorway" states in ^{180}Ta

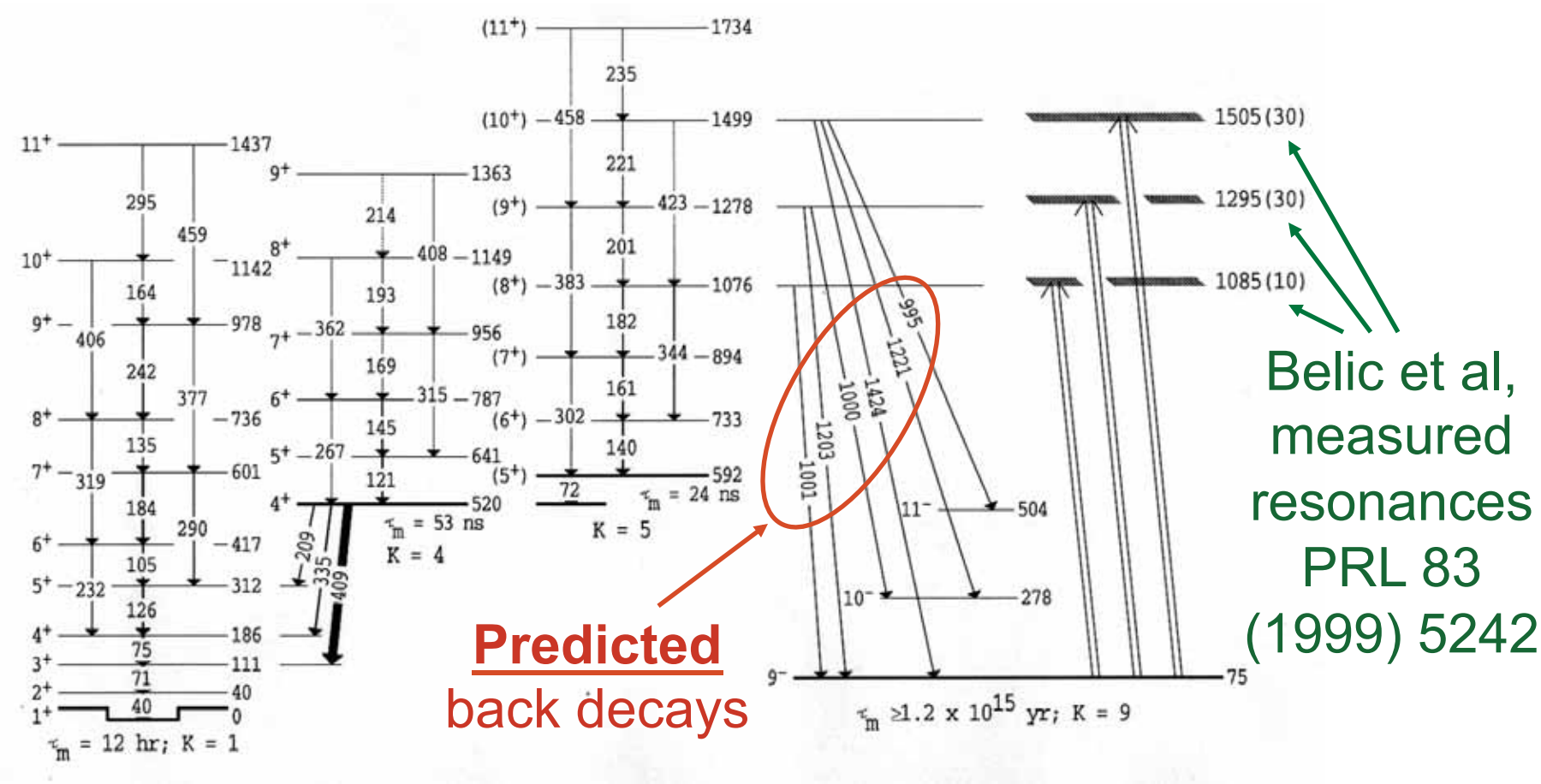
Walker, Dracoulis and Carroll, Phys. Rev. C 64 (2001) 061302(R)



Belic et al, measured resonances PRL 83 (1999) 5242

Possible "doorway" states in ^{180}Ta

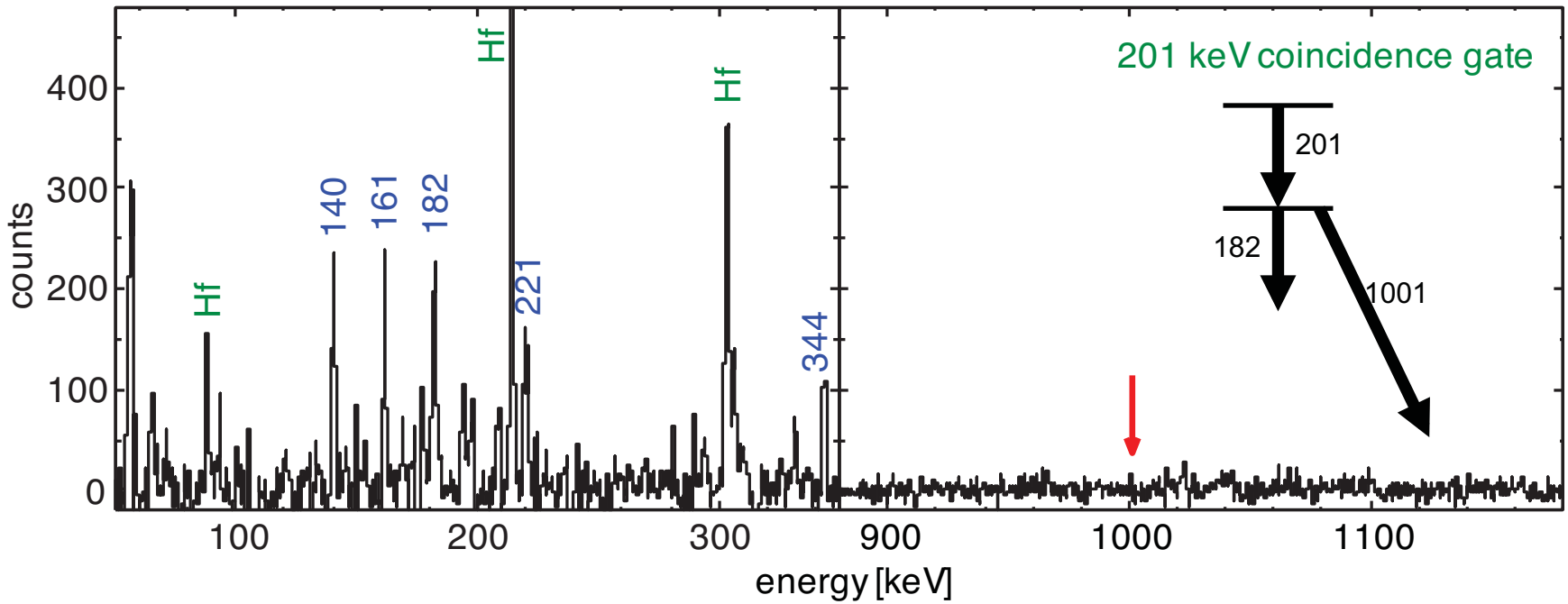
Walker, Dracoulis and Carroll, Phys. Rev. C 64 (2001) 061302(R)



Belic cross-sections define the transition strengths

$\Rightarrow$ all γ-ray strengths can be calculated

Search for back-decay transition in ^{180}Ta



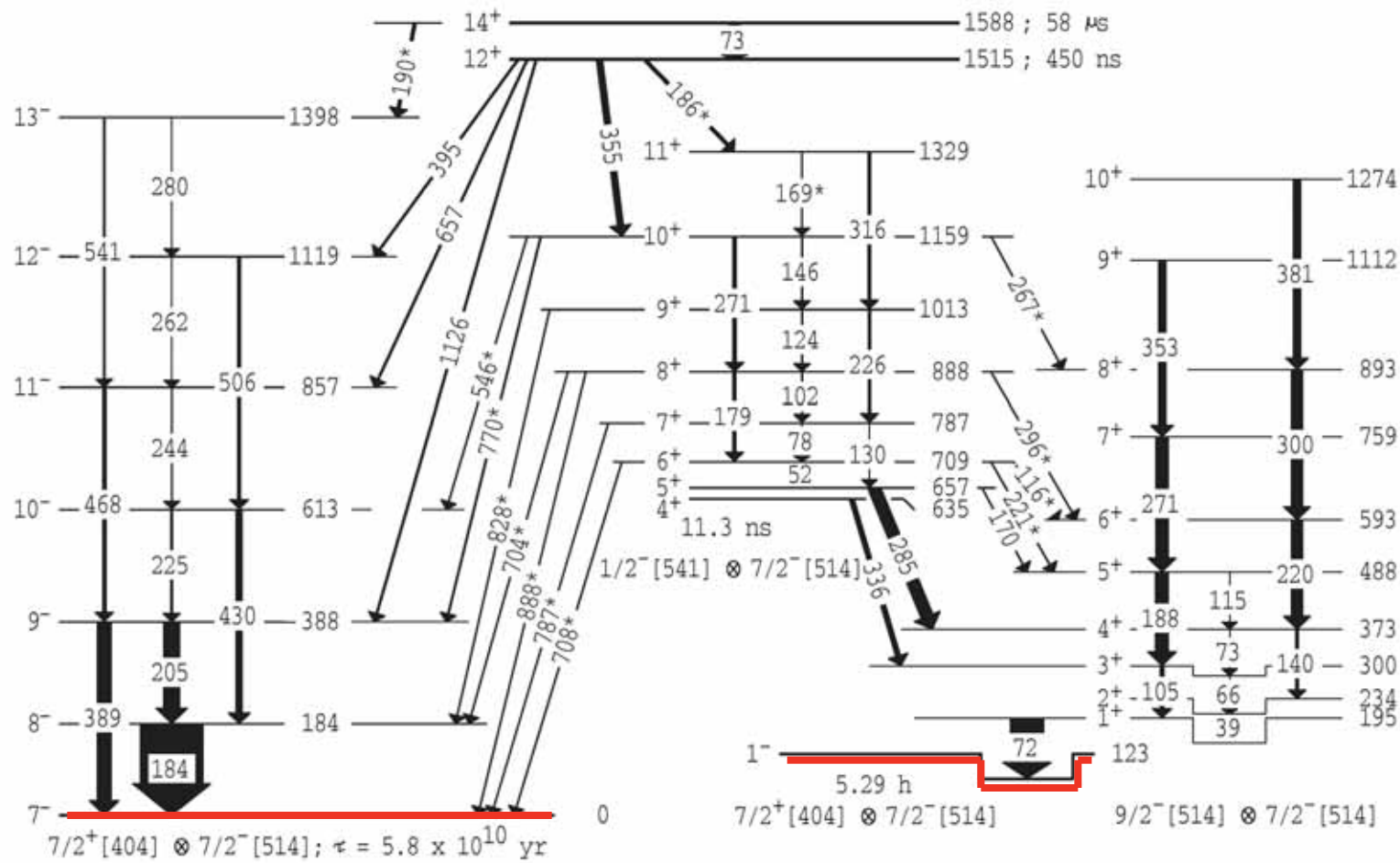
BR(1001/182) ≤ 0.28 vs 2.6 (predicted)

Where are the doorway states?
Can we calculate photoexcitation properly?

Lane et al, in preparation

The "doorway" states have been found in ^{176}Lu

G. D. DRACOULIS *et al.* PHYSICAL REVIEW C **81**, 011301(R) (2010)

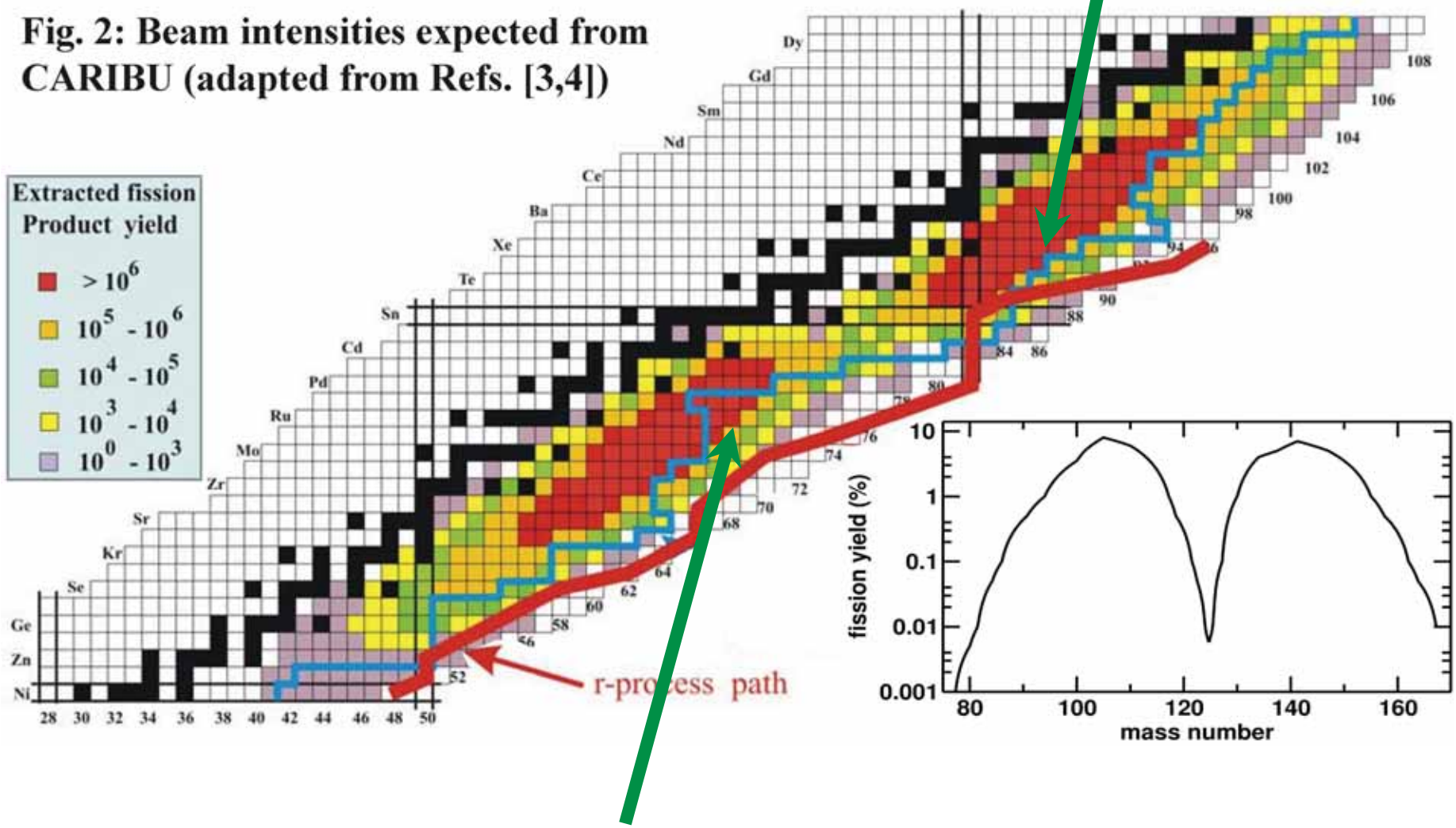


$K^{\pi}=7^{-}$ $\tau=6\times10^{10}$ yr

$K^{\pi}=1^{-}$ $\tau=5.3$ hr

Trends in collectivity

Octupole - Lister



Shape changes / large defms – Lister/Kondev/Bucher

Trends in collectivity

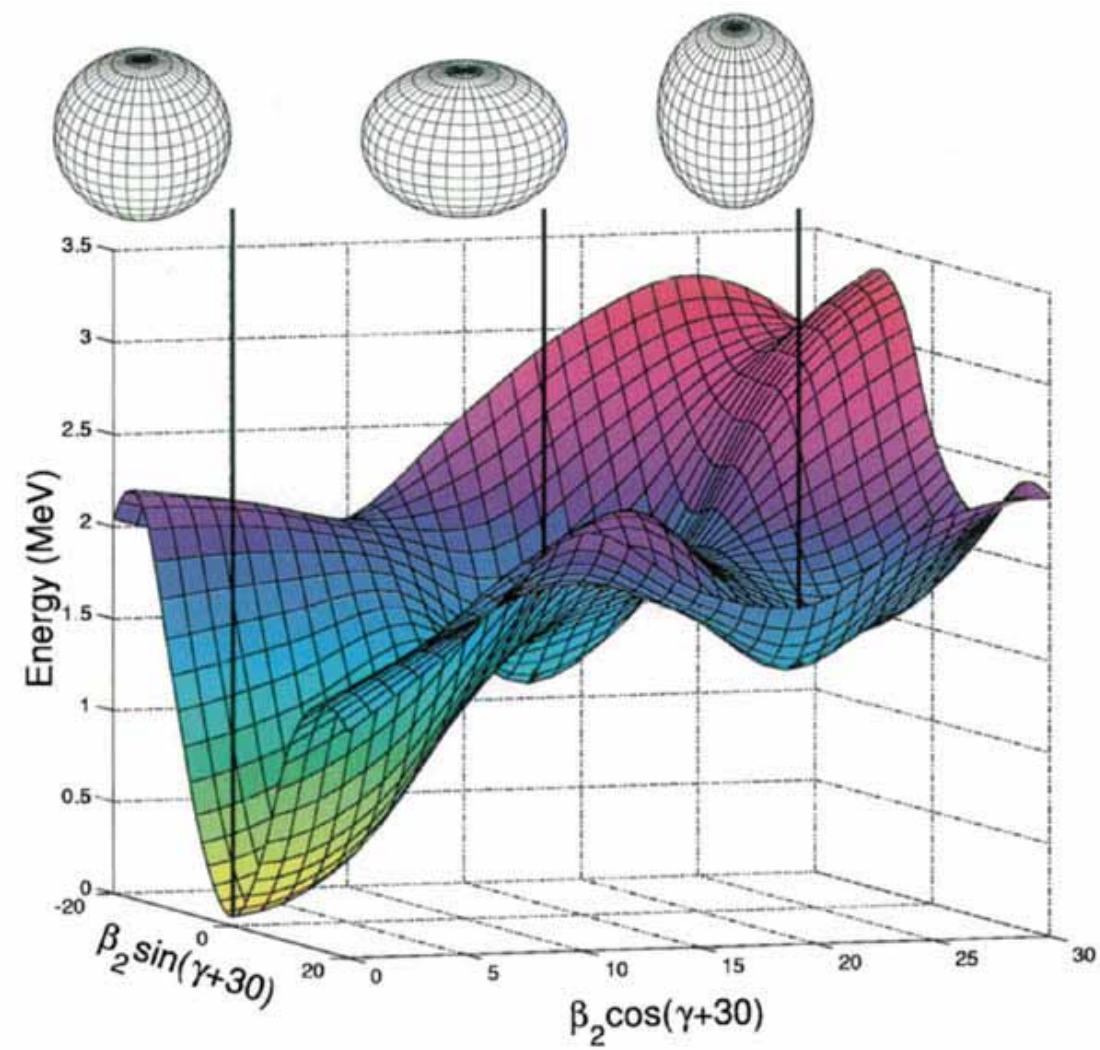
Shape transitions around A=110 (Sr/Mo/Ru) - Kondev

- Probe via direct lifetime measurements (LaBr)

Evidence for oblate rotation?

- Very little (firm) evidence
- Neighbourhood of ^{68,69}Se (Fischer, Lister, Jenkins)
- Neighbourhood of ^{131}La (not ground state, Paul et al)
- Large oblate deformations predicted – enough valence nucleons to make stable?
- Unique mqp states?
- Population in beta-decay?

How oblate is oblate?



"A triplet of differently shaped spin-zero states in the atomic nucleus, ^{186}Pb", A.N. Andreyev et al, Nature 405 (2000) 430.

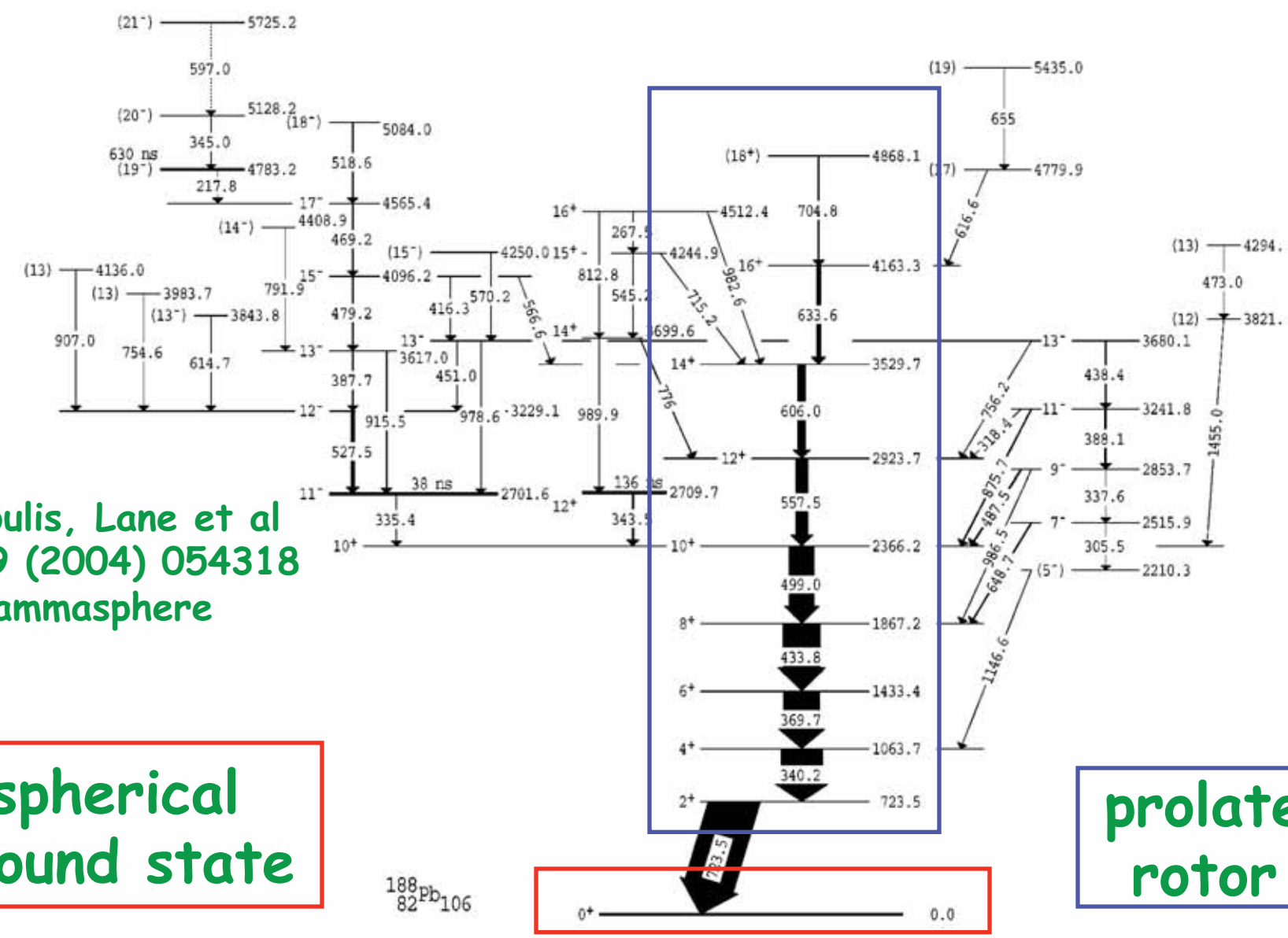
Shape coexistence in Hg/Pb region

Often named as the best example of nuclear shape coexistence.

But 0+ states do not tell you the shape!

Isomeric states with unique configurations can prove a shape is present.

Triple shape coexistence in ^{188}Pb

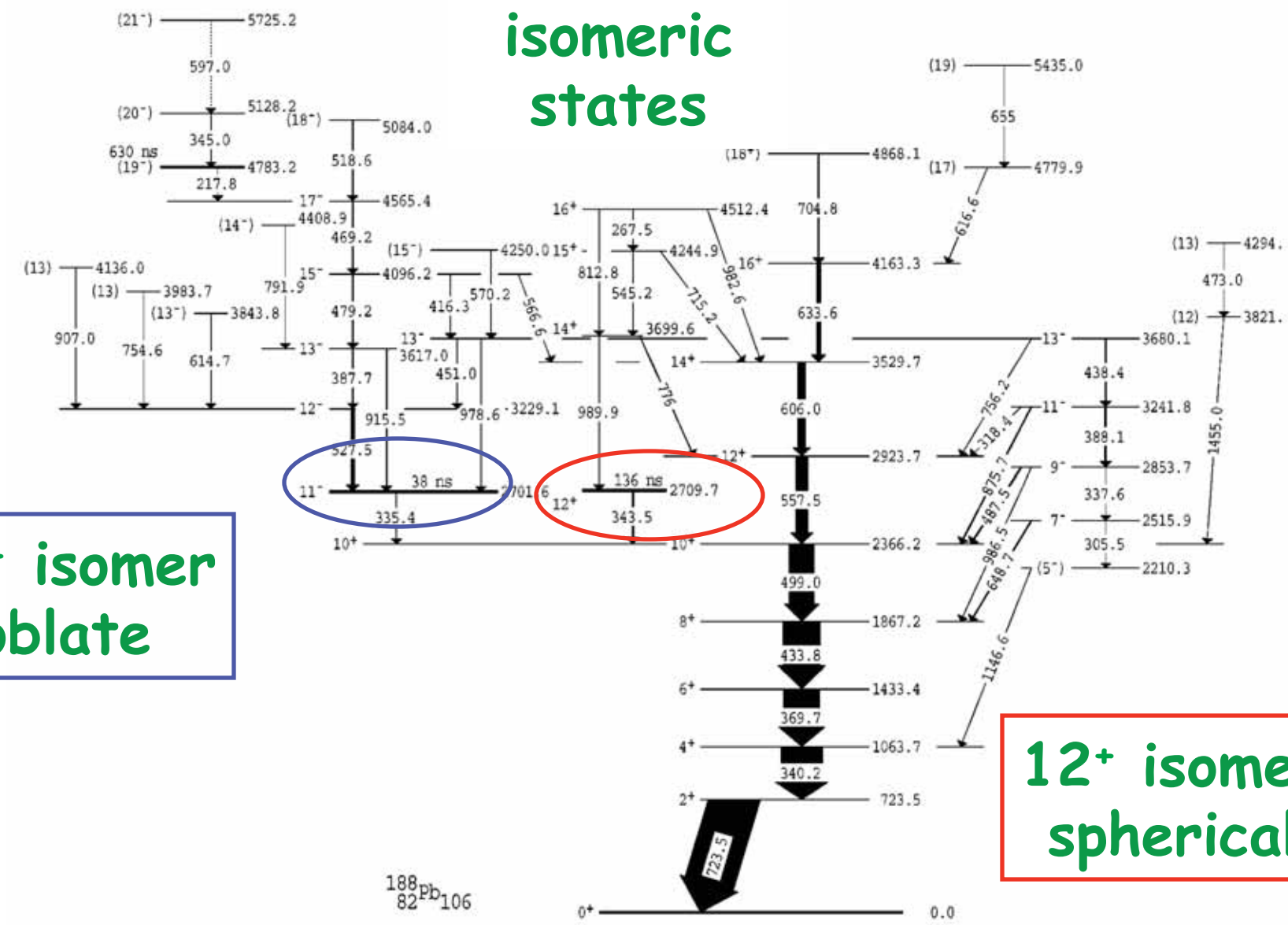


Dracoulis, Lane et al
PRC 69 (2004) 054318
Gammasphere

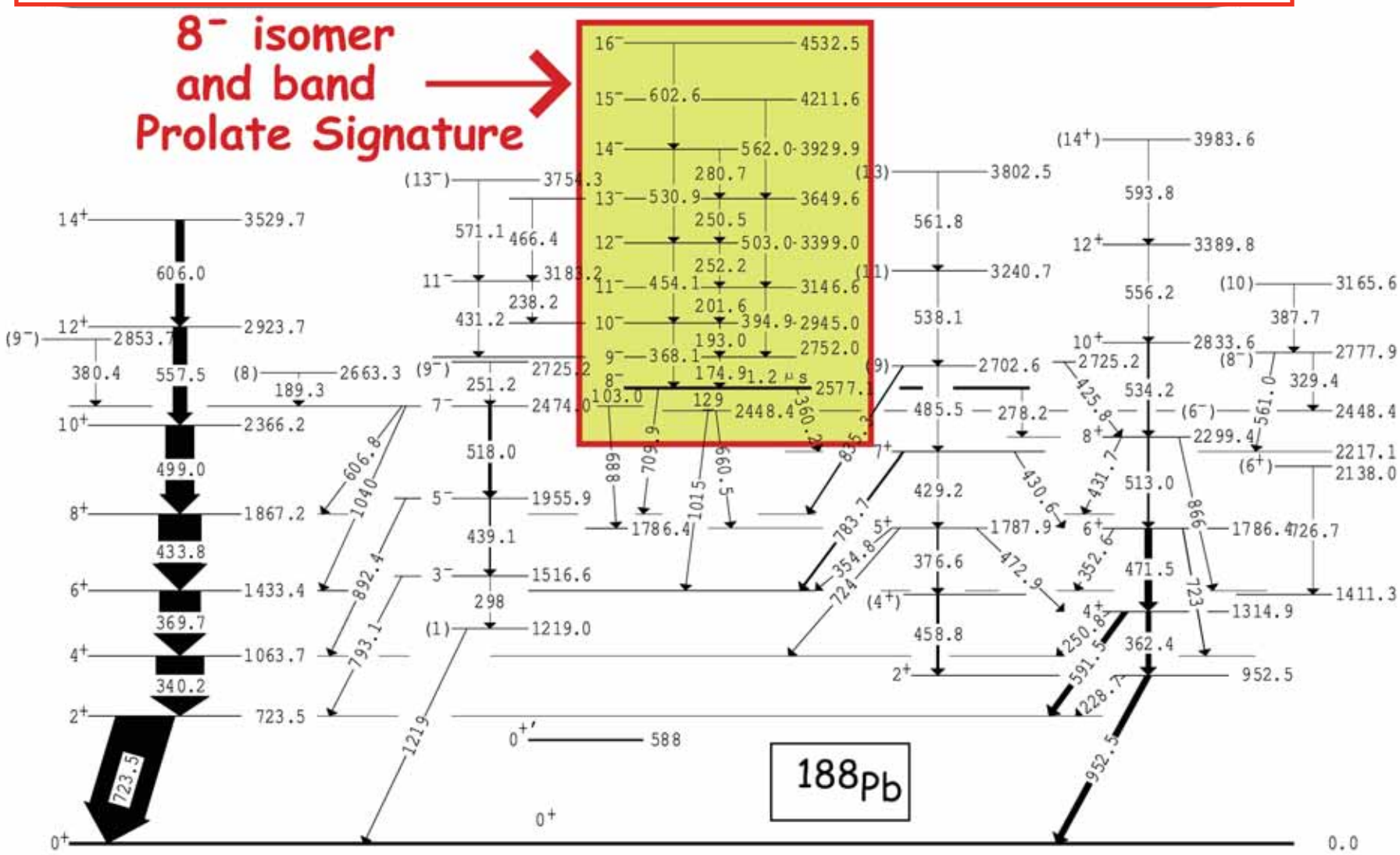
spherical ground state

prolate rotor

Triple shape coexistence in ^{188}Pb



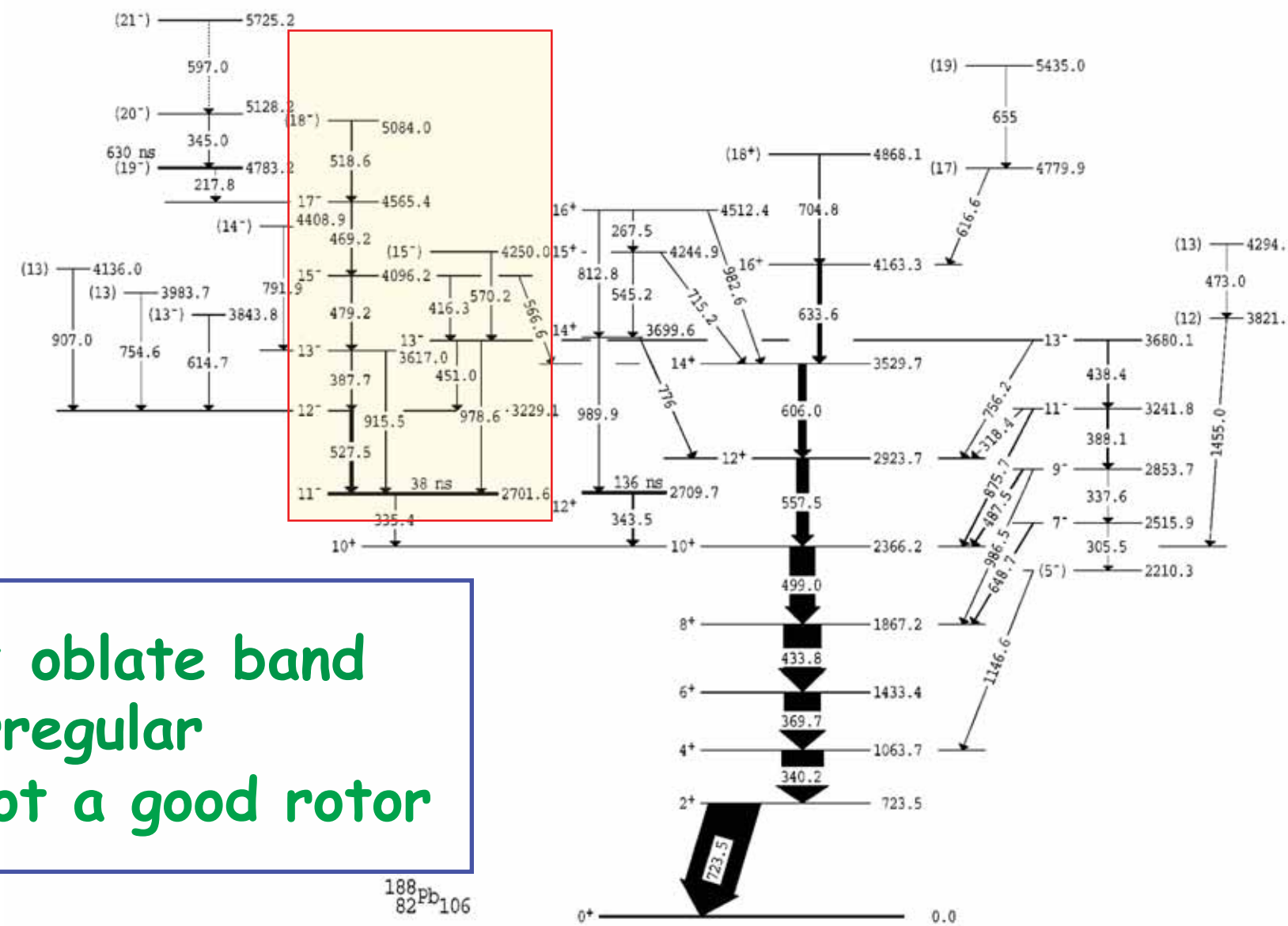
Triple shape coexistence in ^{188}Pb



Phys Rev C 69 (2004) 054318

Gate on delayed transitions below 8- isomer

Triple shape coexistence in ^{188}Pb



11^- oblate band

- irregular
- not a good rotor

Trends in collectivity

A=110 region (Sr/Mo/Ru) Kondev

- Isomers / MQP states (Kondev)
- J^{π} unique to oblate shape?
- Large oblate deformations predicted – good rotors?

Caveat: Population in beta-decay?

Probe via direct lifetime measurements (LaBr)

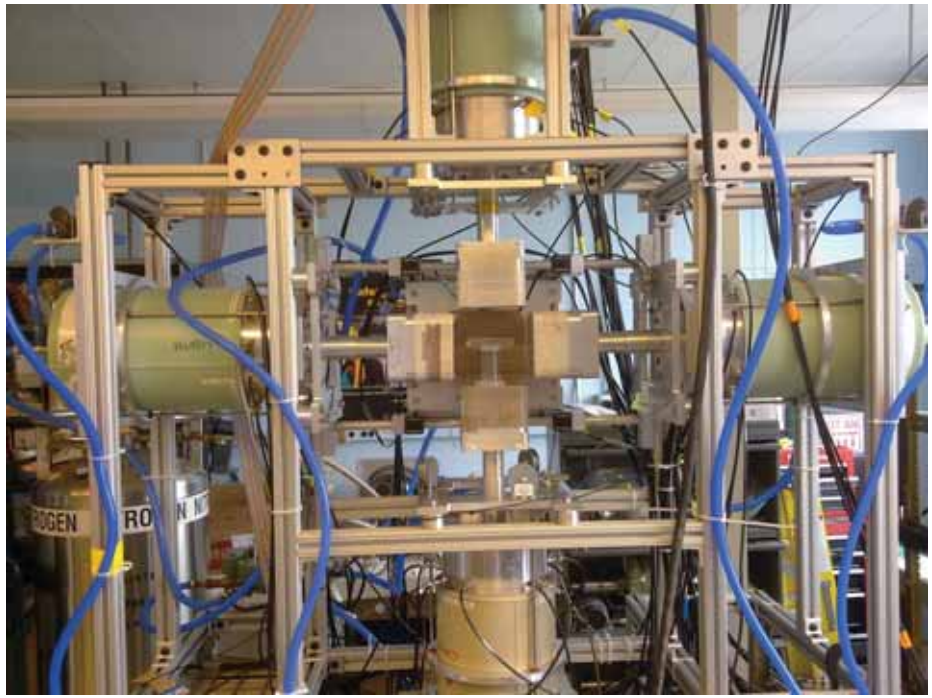
We have funding for some LaBr detectors (2 to 4).
We plan to use them in Canberra with chopped heavy ion beams and a magnetic solenoidal separator to select cascades below isomers and/or after beta-decay.

They could be made available for use with CARIBU.

X-array

Darek Seweryniak (Thu am)

- 4 “normal” clovers – four 60x60mm HPGe
- 1 “super” clover – four 70x70mm HPGe
- box arrangement
- high efficiency / close geometry

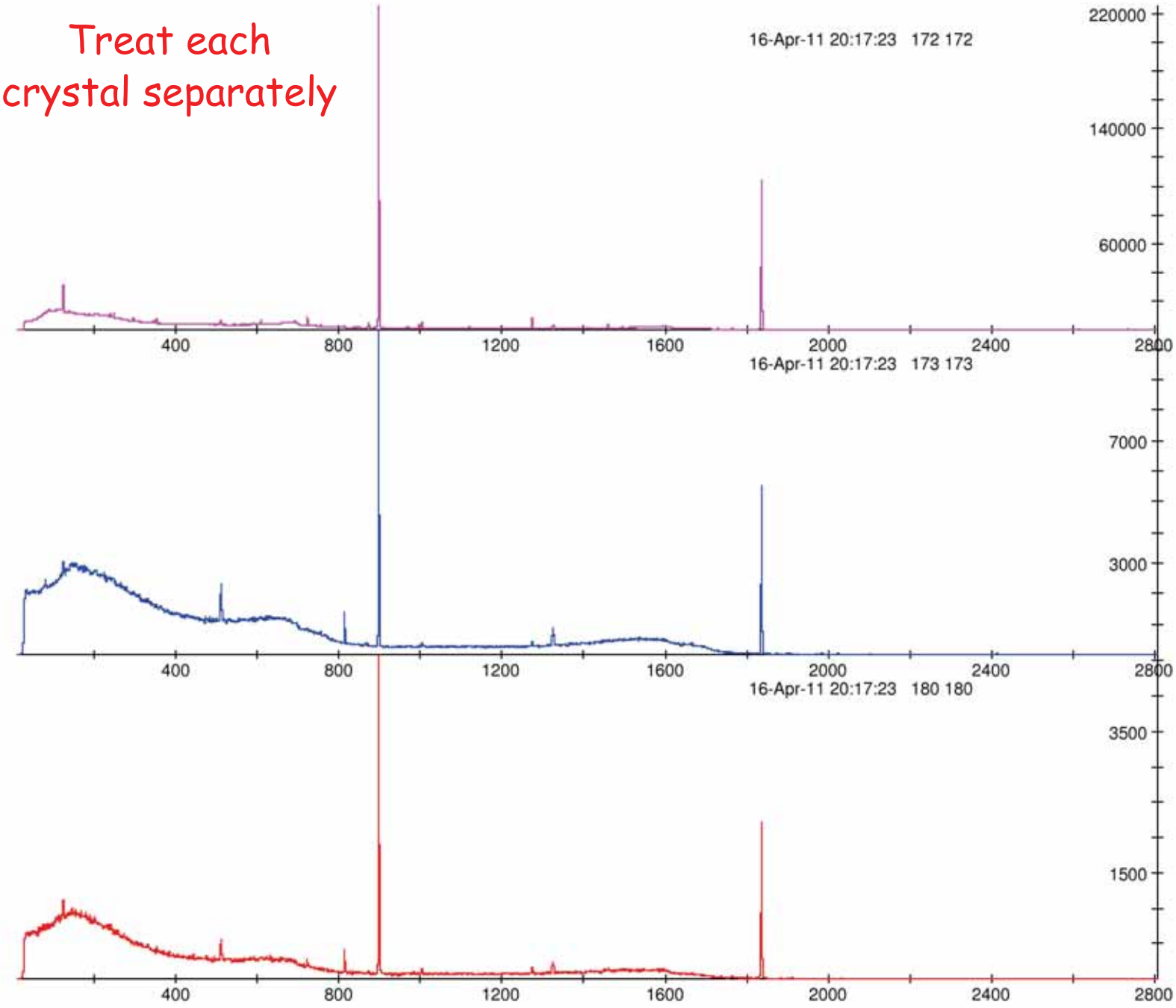


Paul Garret (Fri pm) discussed background suppression with the 8pi array (TRIUMF) and Mike Carpenter asked about Compton suppression…

I spent some time over the last week playing with the X-array with Kim Lister, Partha Chowdhury and Michael Smith…

All spectra are of ^{88}Y (898, 1836 keV)x

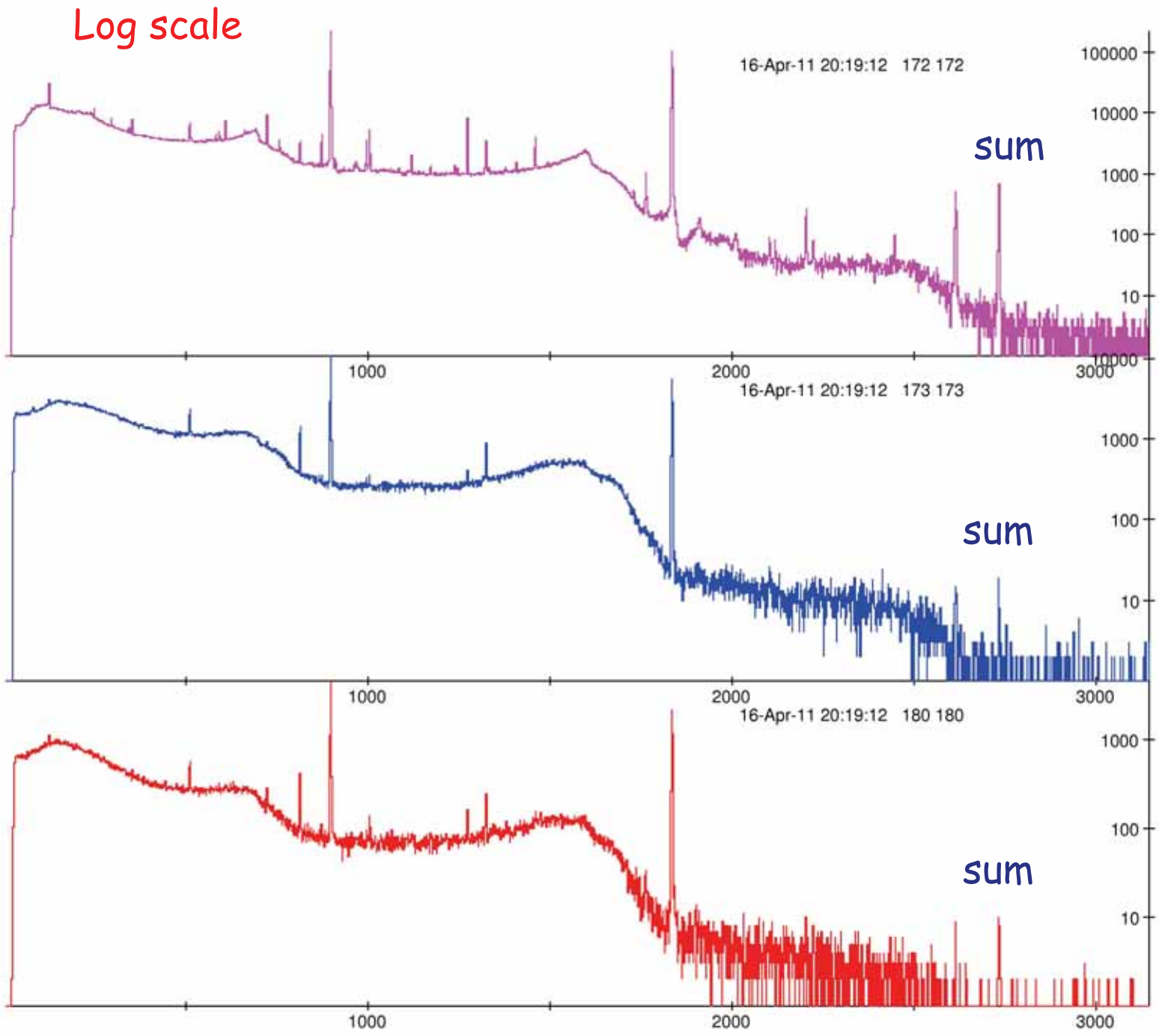
Treat each crystal separately



Single hits

Double hits

Triple & quad hits



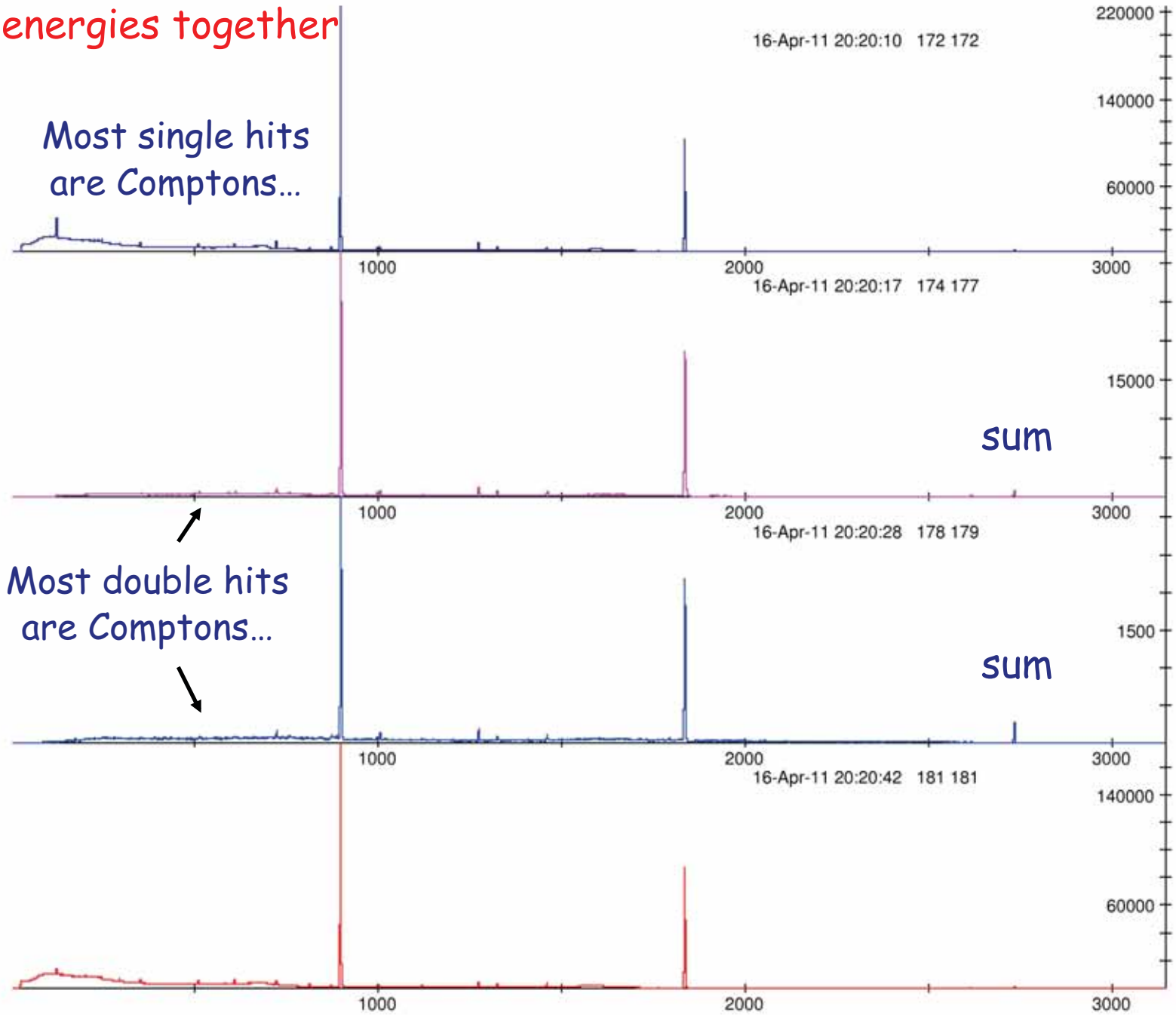
Single hits

Double hits

Triple & quad hits

Add crystal energies together

Most single hits are Comptons…



Most double hits are Comptons…

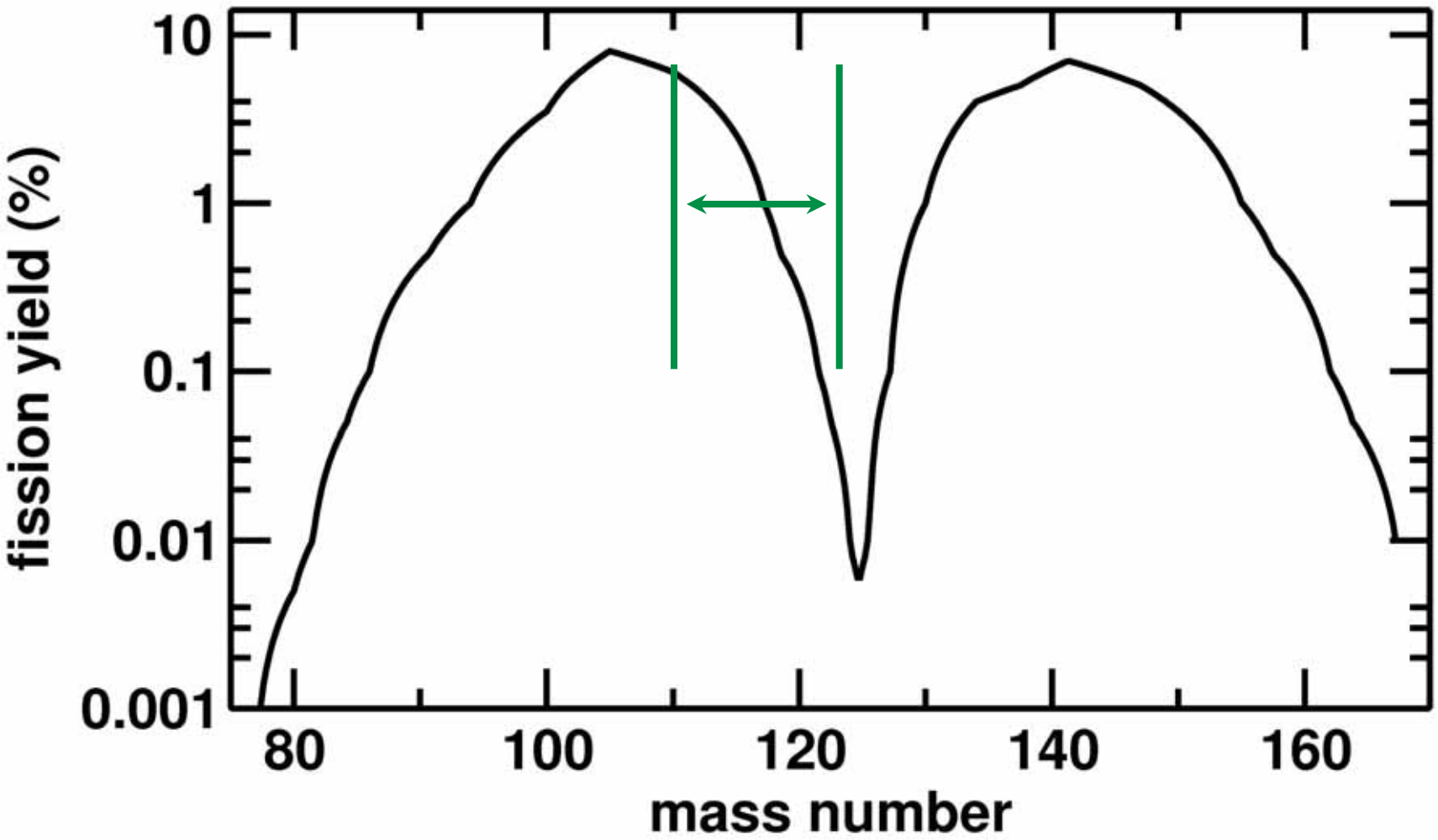
Single hits

Double hits (horiz/vert)

Double hits (diagonal)

3 or 4 hits

The CARIBU sweet spot…



- Uniform extraction is a great boon… but
- A = 110 to 120 might be the sweet spot (Firestone/Kondev)

Pessimism or Optimism?

Pessimism or Optimism?

The glass is filling…

Pessimism or Optimism?

The glass is filling…

Realism