Changing Shapes & Structures in Heavy Nuclei approaching the Proton Drip Line

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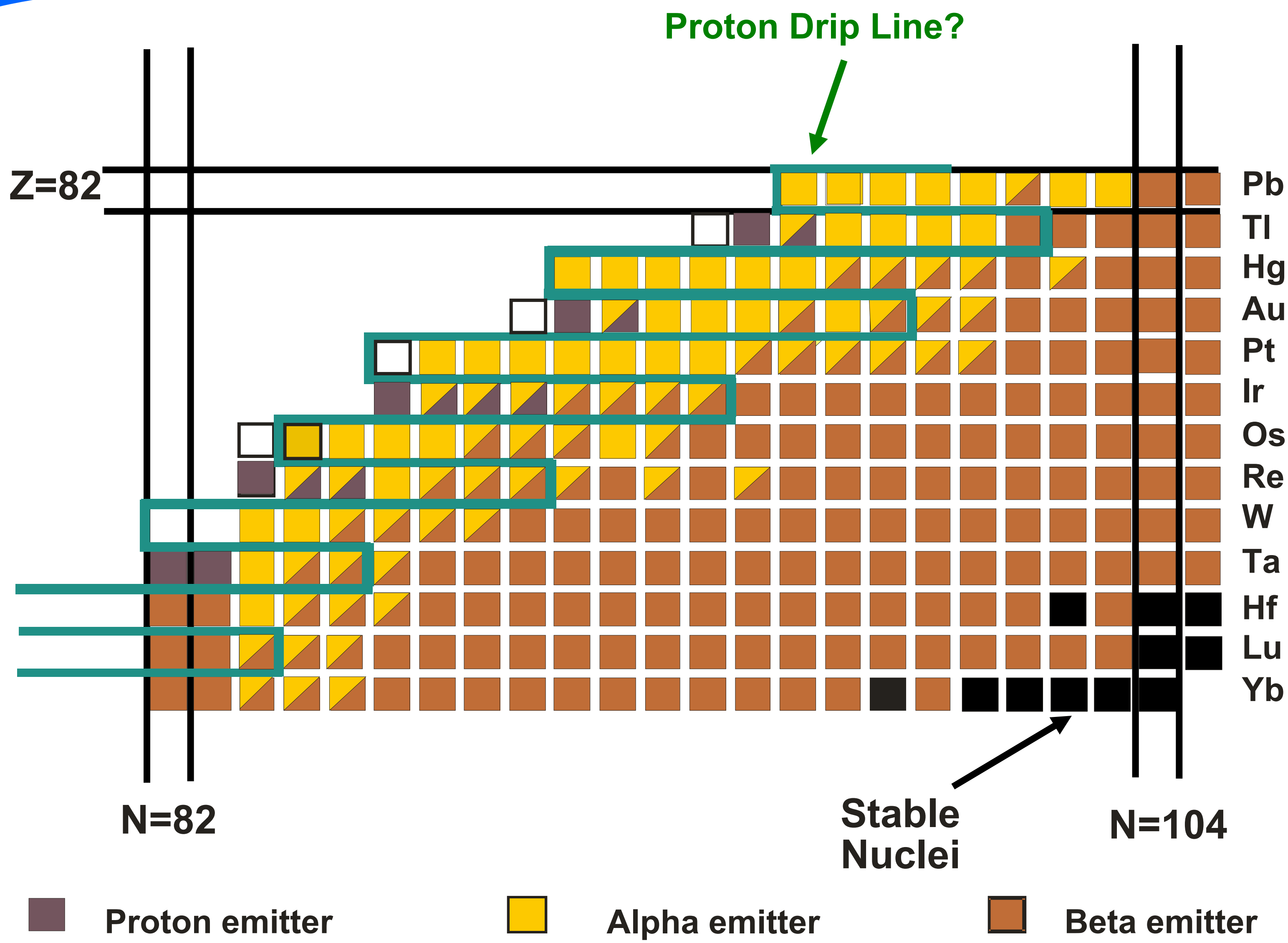
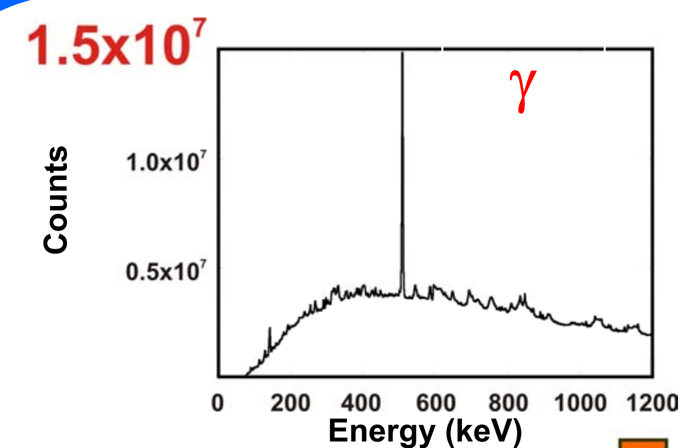
Changing structure of yrast bands in Pt and Os isotopes near N=82

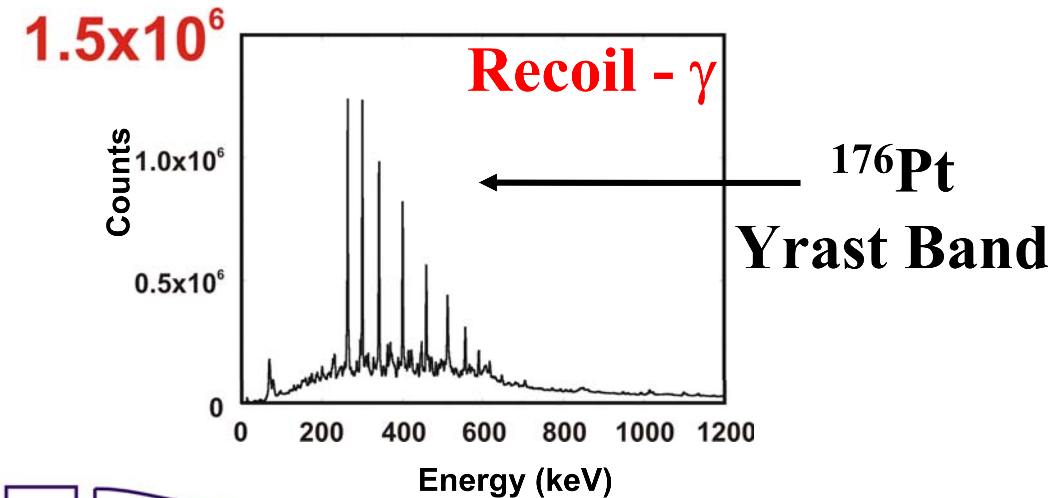
Transition from collective to single-particle structure in the light Re isotopes

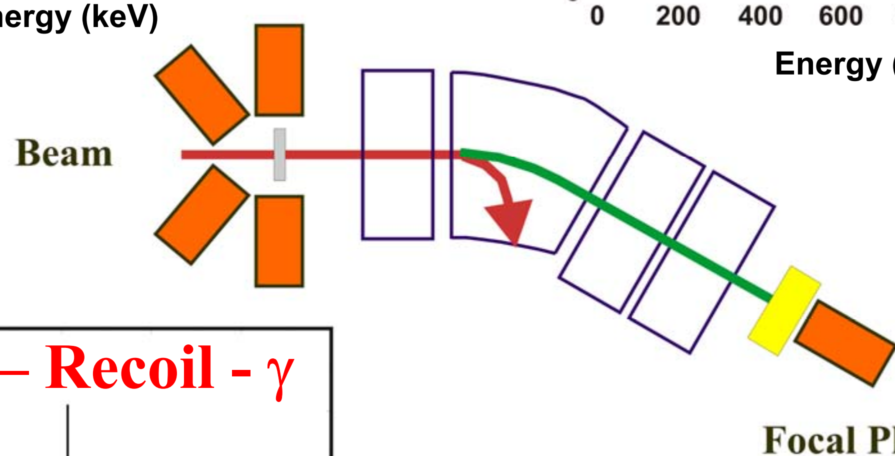
The new proton emitter ^{159}Re


Proton Drip Line?
Z=82
Pb
Tl
Hg
Au
Pt
Ir
Os
Re
W
Ta
Hf
Lu
Yb
N=82
Stable
Nuclei
N=104
Proton emitter
Alpha emitter
Beta emitter

The Recoil Decay Tagging Technique

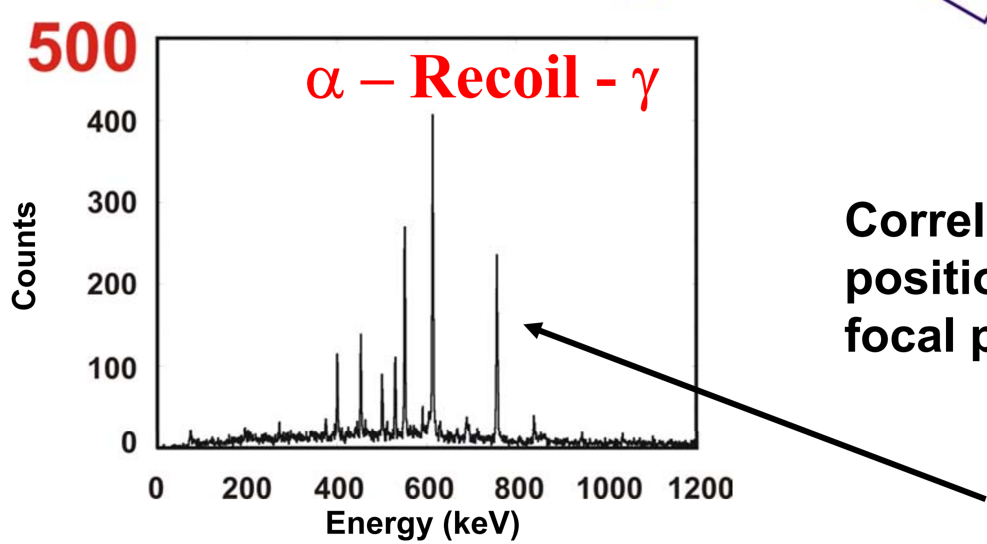






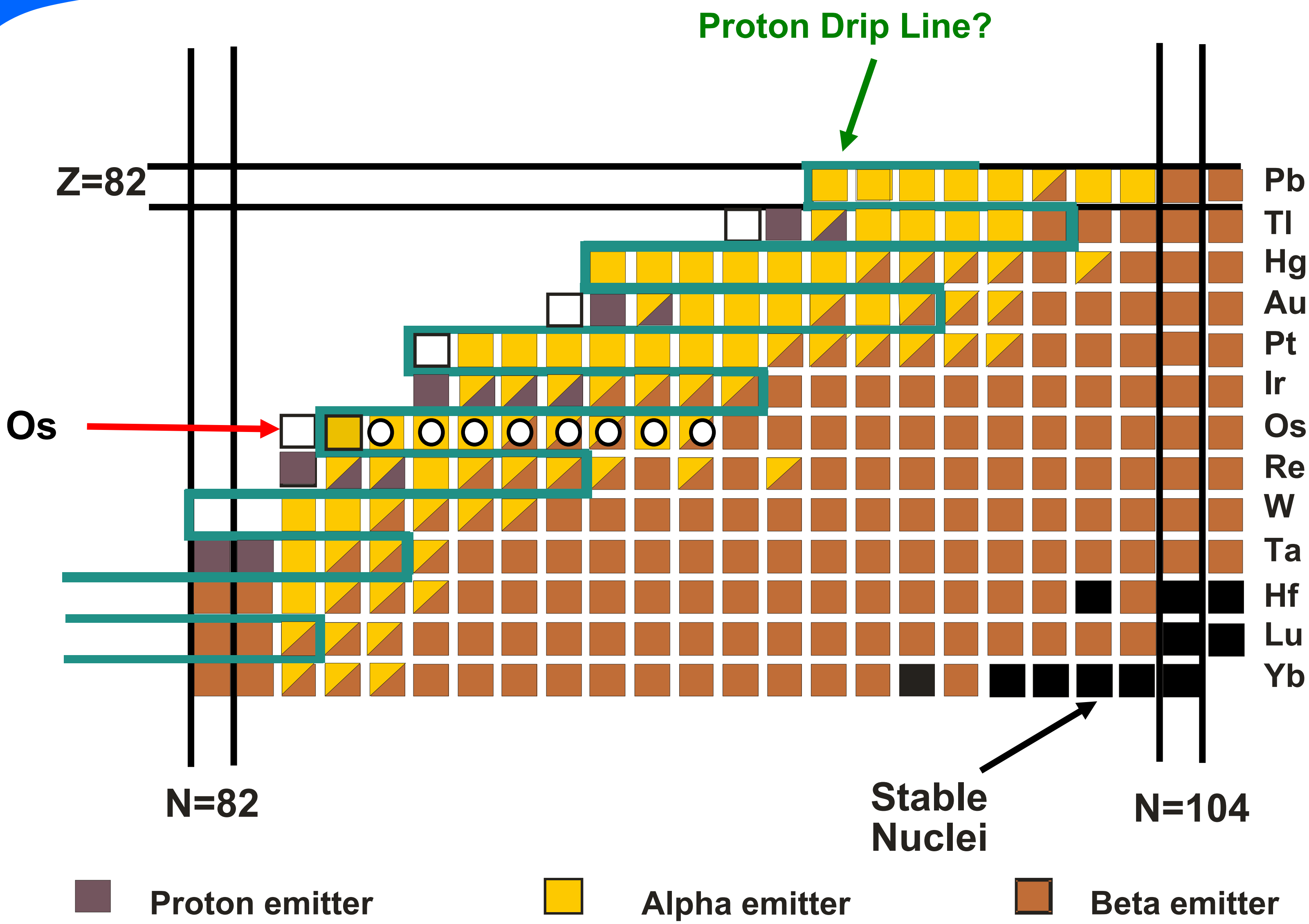
JUROGAM+RITU+GREAT
experiment at JYFL

J.Simpson, R. Julin *et al*.,



Correlate radiation detected at the target position with characteristic decays at the focal plane

^{176}Hg Yrast Band


Proton Drip Line?
Z=82
Pb
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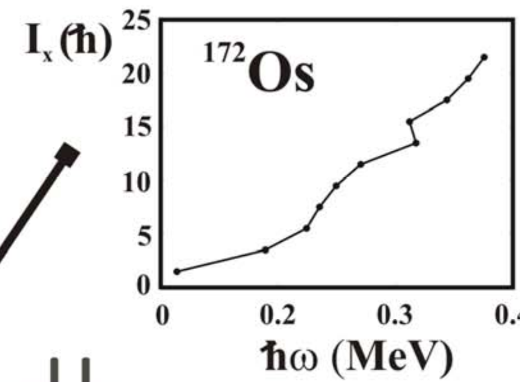
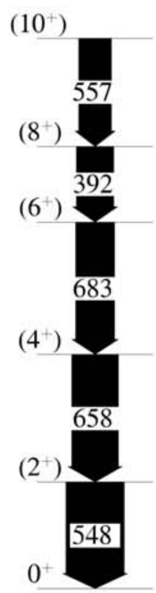
N=82
Stable Nuclei
N=104
Proton emitter
Alpha emitter
Beta emitter

The changing structure of Osmium isotopes approaching the N=82 shell gap

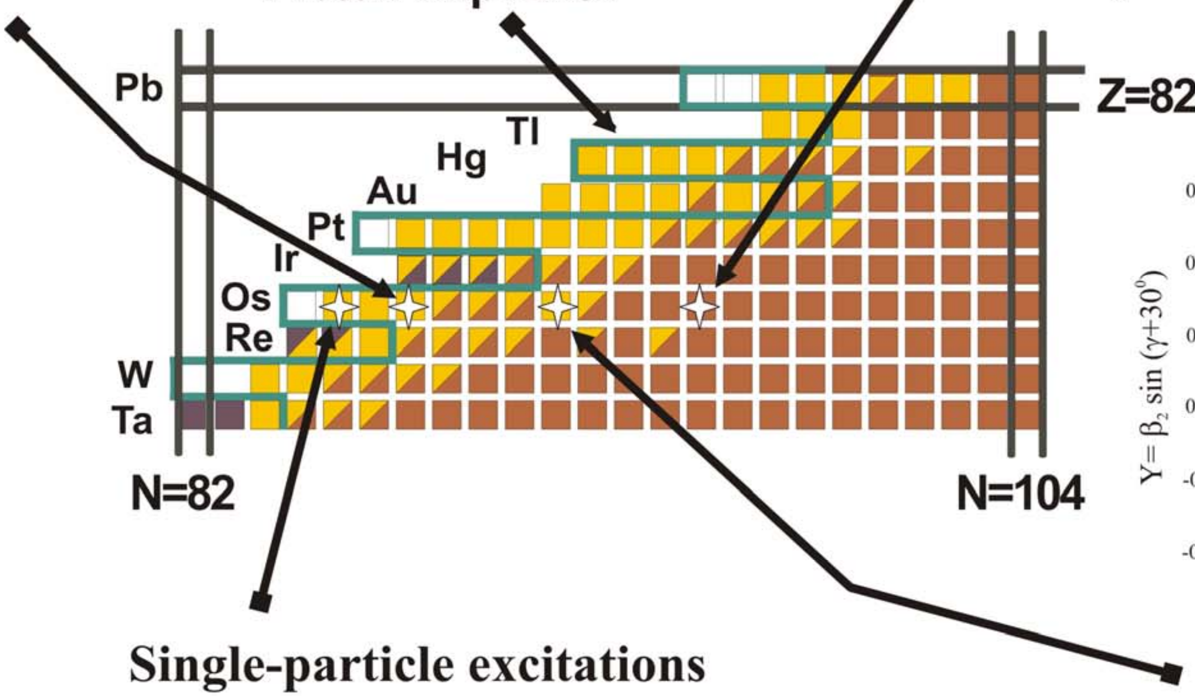
Shape coexistence

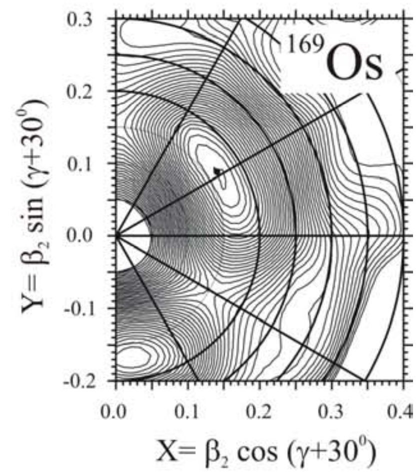


Vibrational nuclei



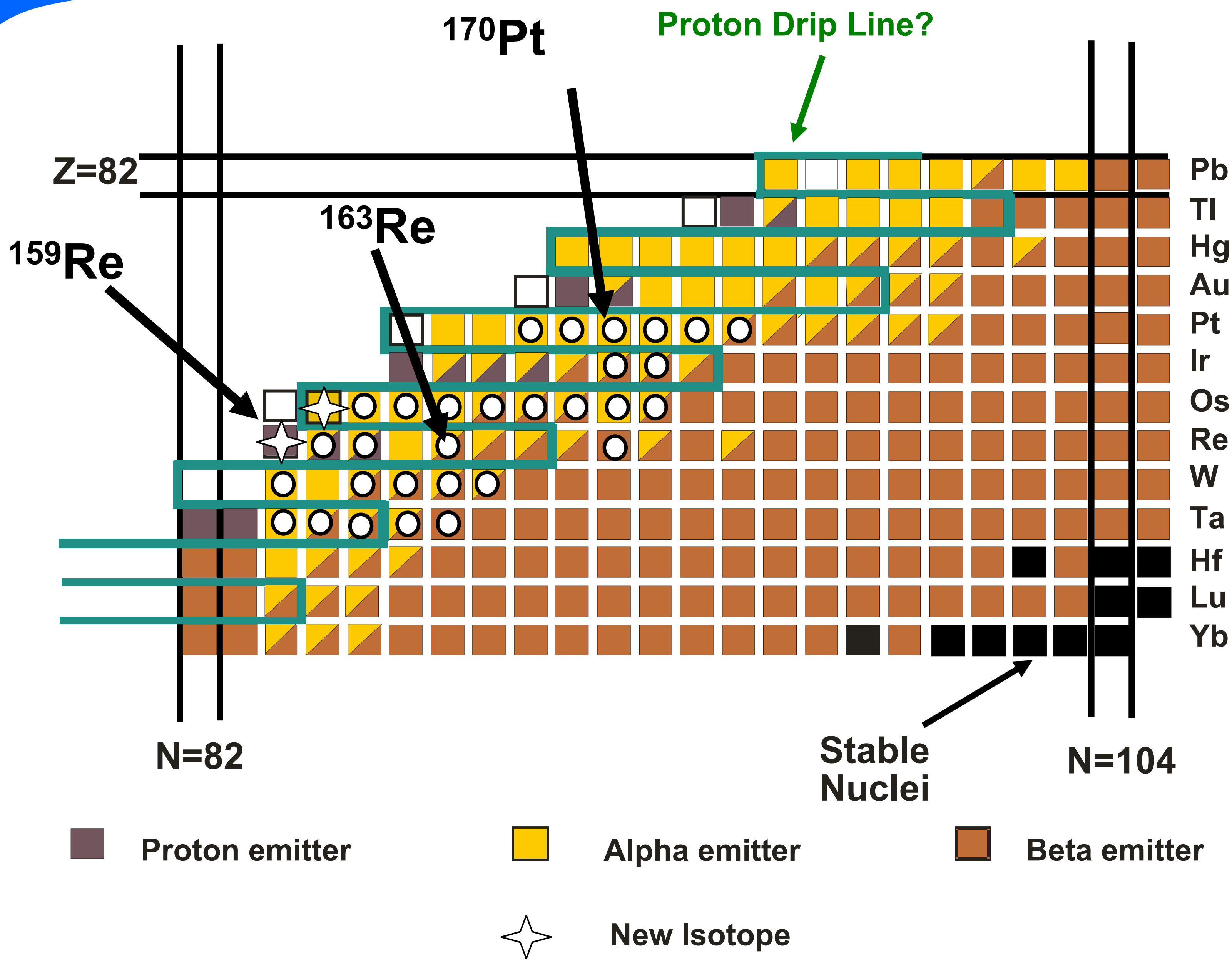
^{164}Os



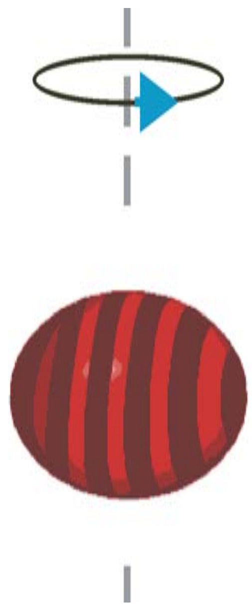


Single-particle excitations

Gamma-soft triaxial rotors

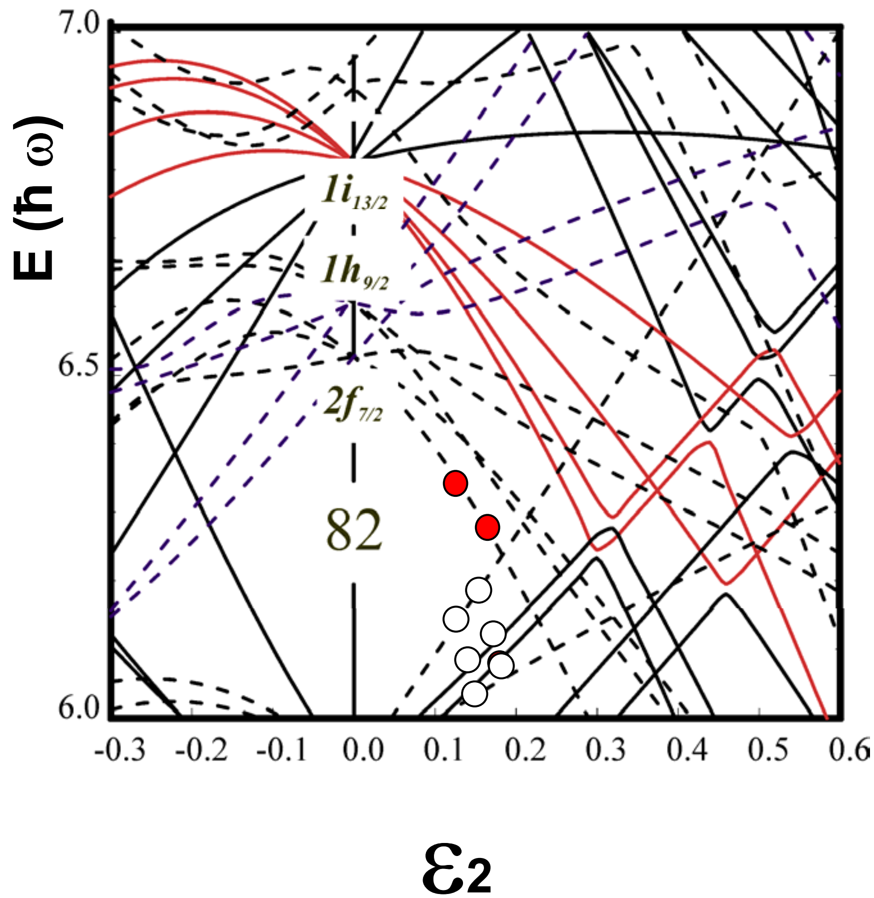


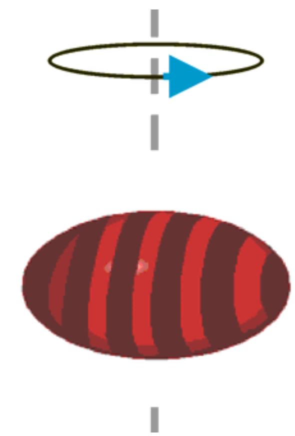
170Pt
Proton Drip Line?
Z=82
163Re
159Re
Pb
Tl
Hg
Au
Pt
Ir
Os
Re
W
Ta
Hf
Lu
Yb
N=82
Stable Nuclei
N=104
Proton emitter
Alpha emitter
Beta emitter
New Isotope



GROUND STATE

(Weakly Deformed)





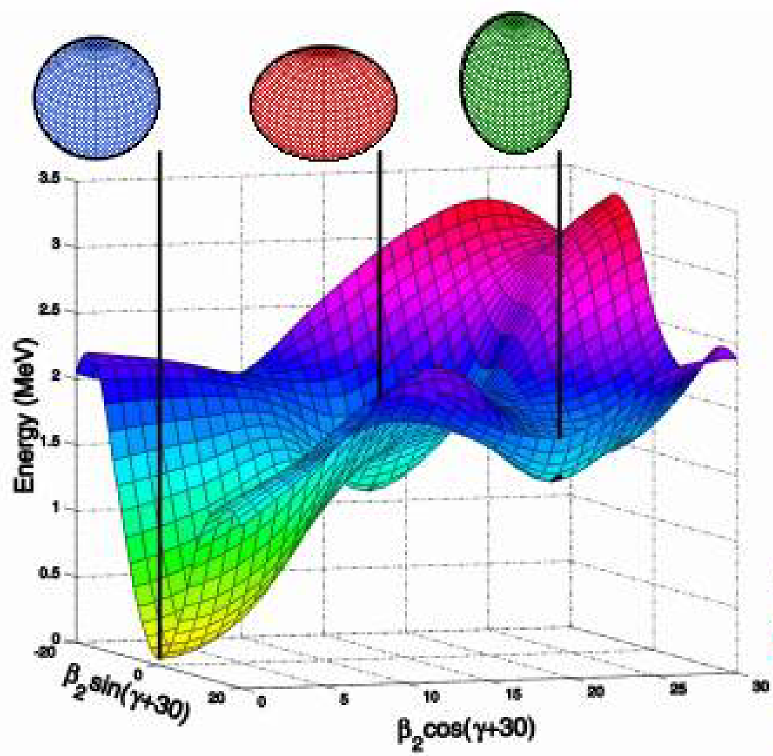
INTRUDER

(Well Deformed)

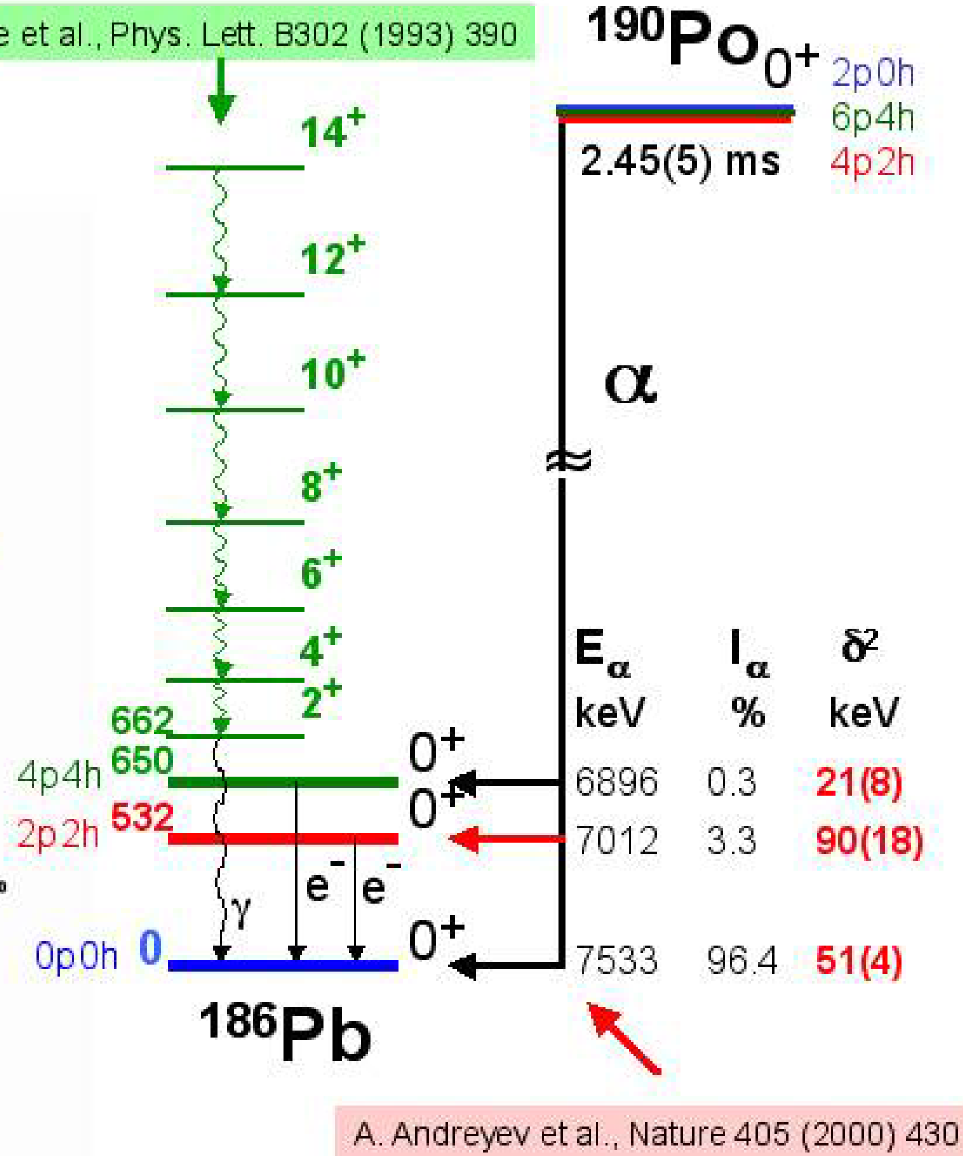
A phenomenon where nuclear configurations at similar excitation energies are built on very different deformations.

Shape coexistence is expected to occur in transitional regions between weakly and strongly deformed ground states

Different shapes, co-existing at low excitation energy

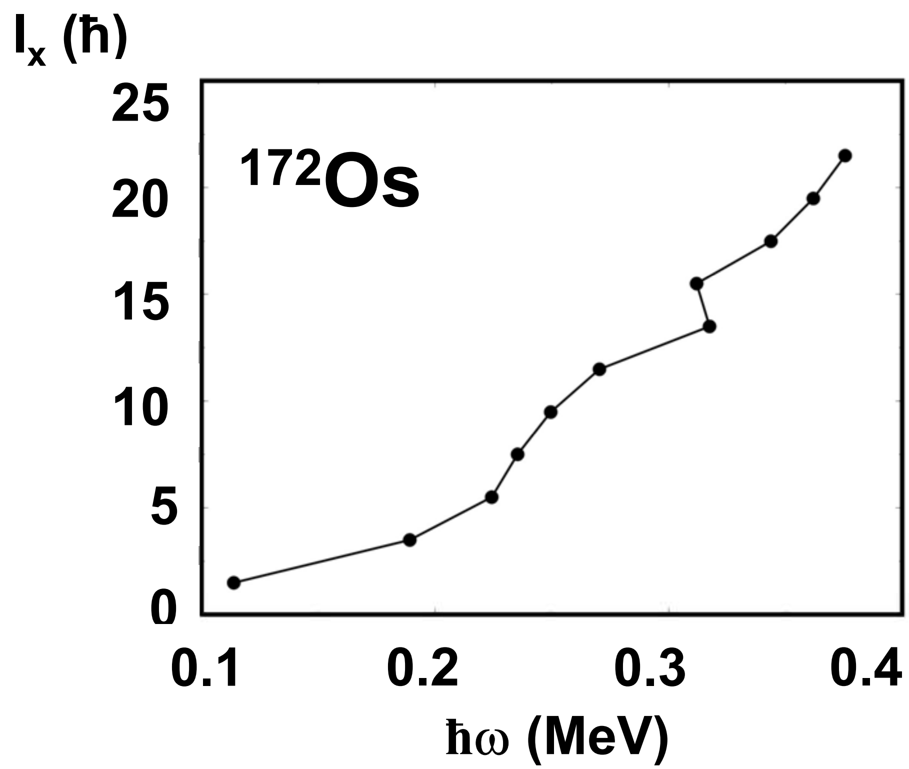


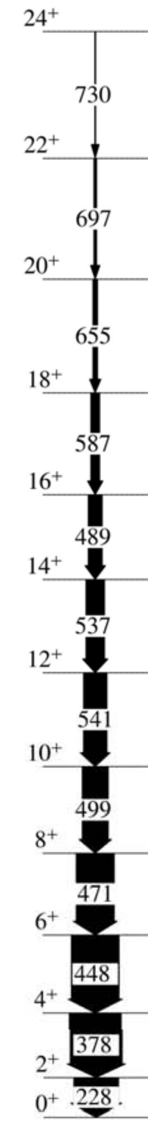
Potential Energy Surface for ^{186}Pb



Shape coexistence in the Os-Pt isotopes: mixed bands

Total Aligned Angular Momentum $I_x = \sqrt{I(I+1) - K^2}$





Experiments performed at ANU revealed irregular ground state band in ^{172}Os.

The results were interpreted in terms of a three band mixing scenario.

J.L. Durell *et al*., Phys. Lett. **B115** (1982) 367.

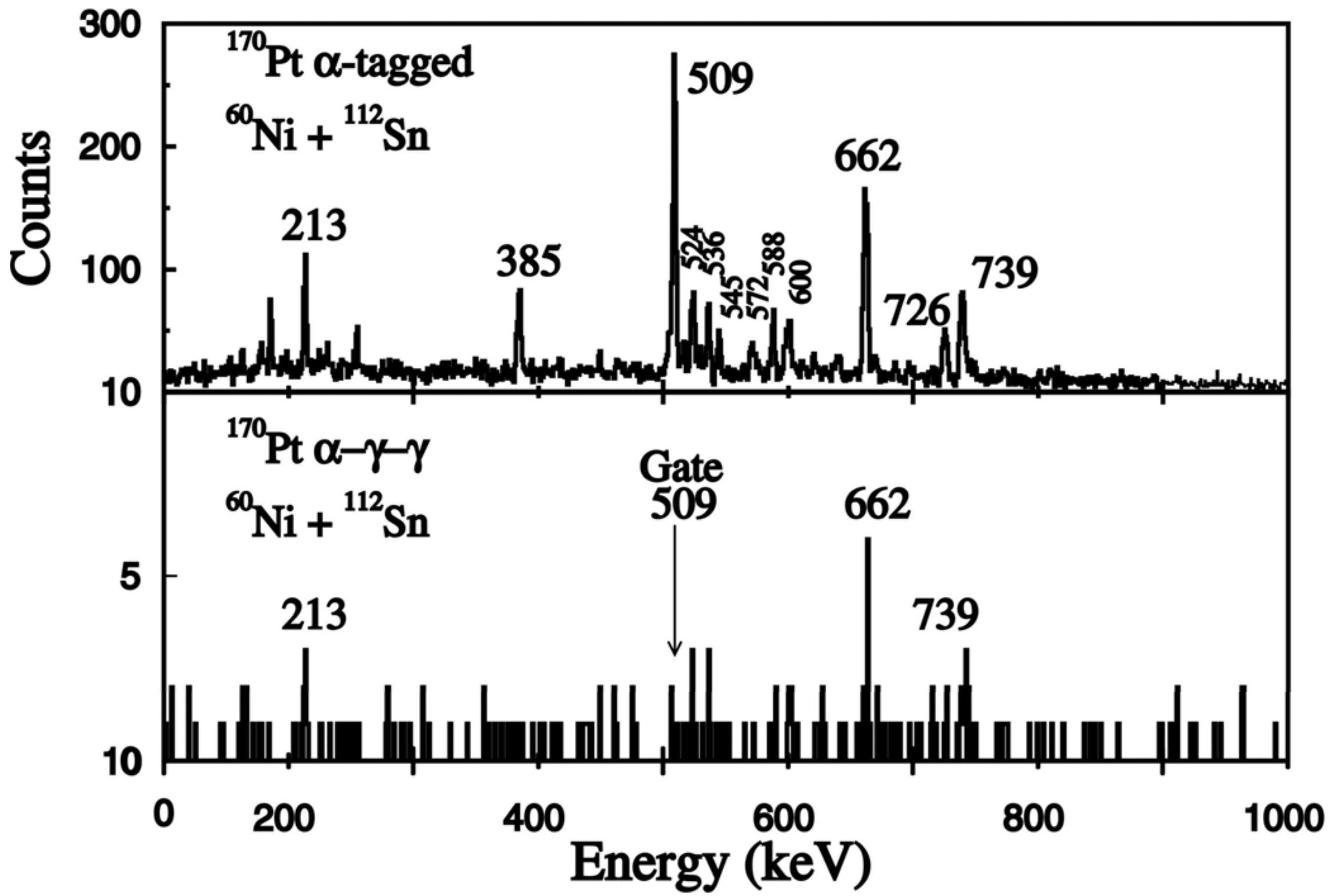
G. D. Dracoulis *et al*., Nucl. Phys. **A486** (1988) 414.

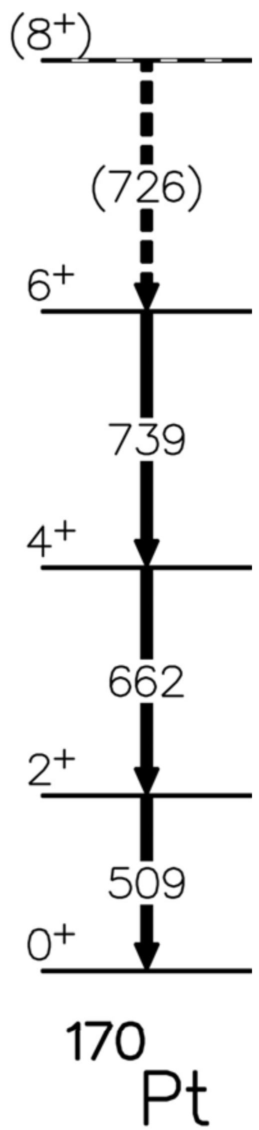
First observation of excited states in ^{170}Pt made with JUROSPHERE

S.L. King et al., Phys. Lett. B. 443 (1998) 82.

Many γ rays are apparent in the ^{170}Pt α - γ spectrum.

Need coincidences to order γ rays in level scheme.

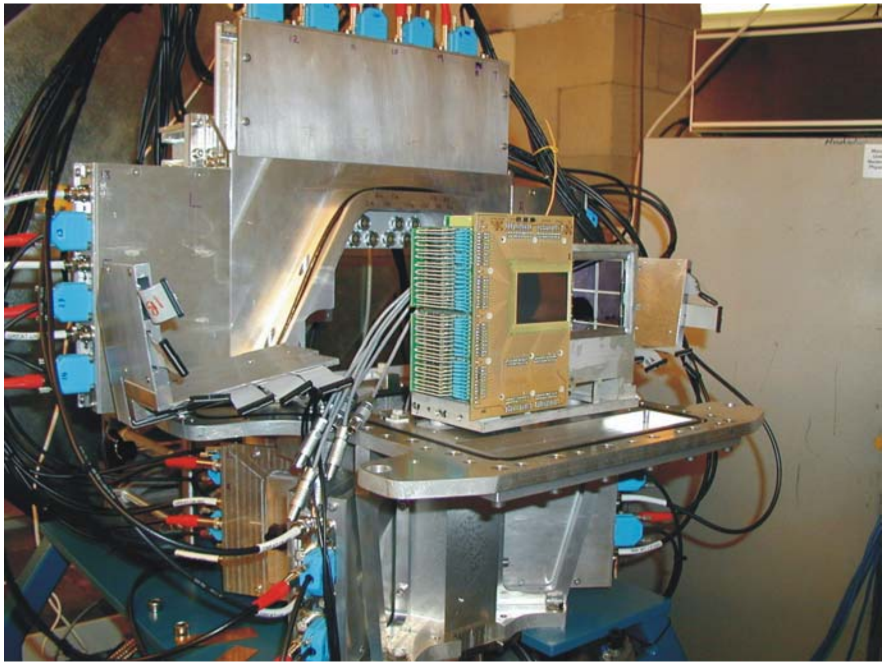


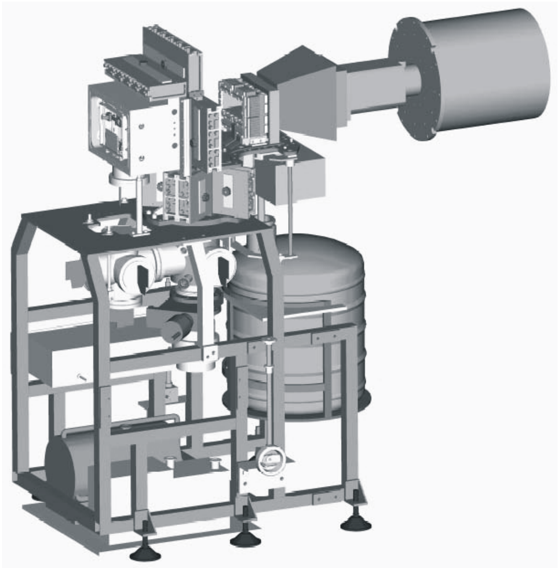


The GREAT focal plane spectrometer

- 200 Channels DSSD (2 x 6cm x 4cm)
- 28 PIN Diode detectors
- Segmented Planar Ge (12cm x 6cm)
- Segmented Clover Ge (4 x 70% Crystals)
- Gas detector (MWPC)

- Position of recoils/alphas
- e^- detection
- β & Low energy γ
- γ
- TOF & DE/E





http://npg.dl.ac.uk/GREAT

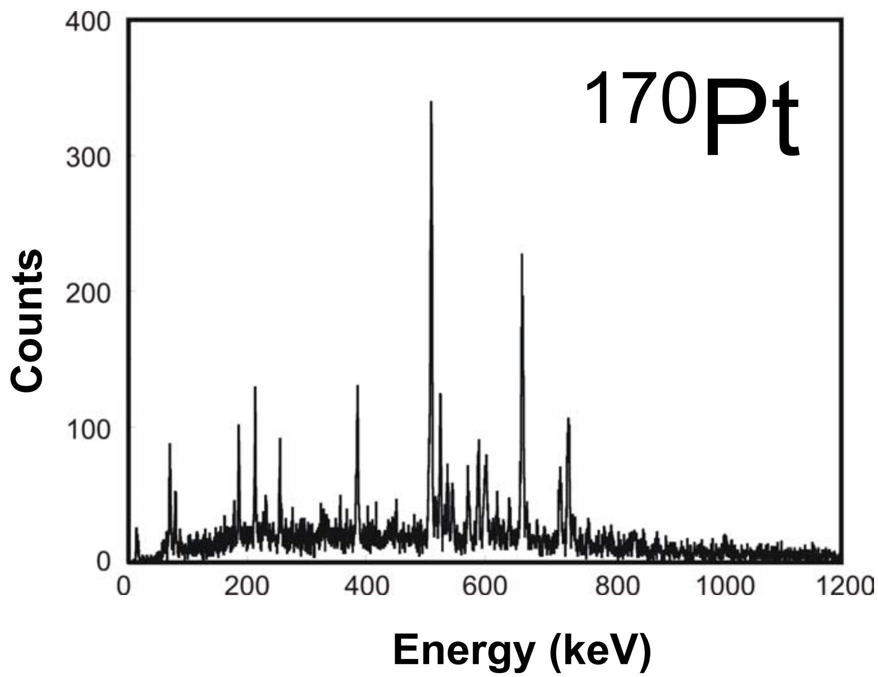
$^{60}Ni + ^{112}Sn \rightarrow ^{172}Pt^*$ (E_{beam}=266 MeV)

Beam current = 5.5 pnA

Seven day experiment.

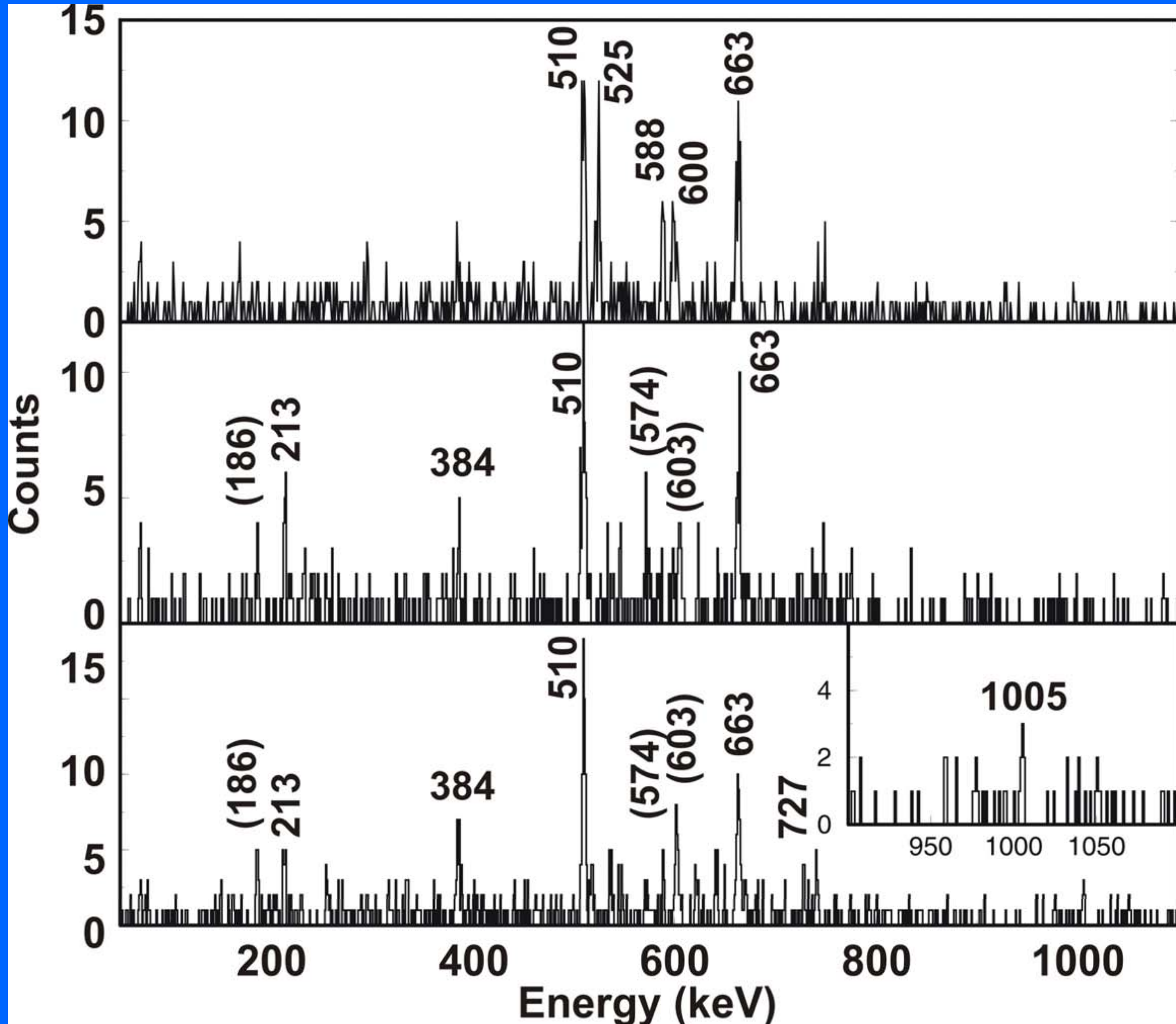
GREAT spectrometer (DSSD / PIN diodes)

JUROGAM array
(43 Ge detectors)

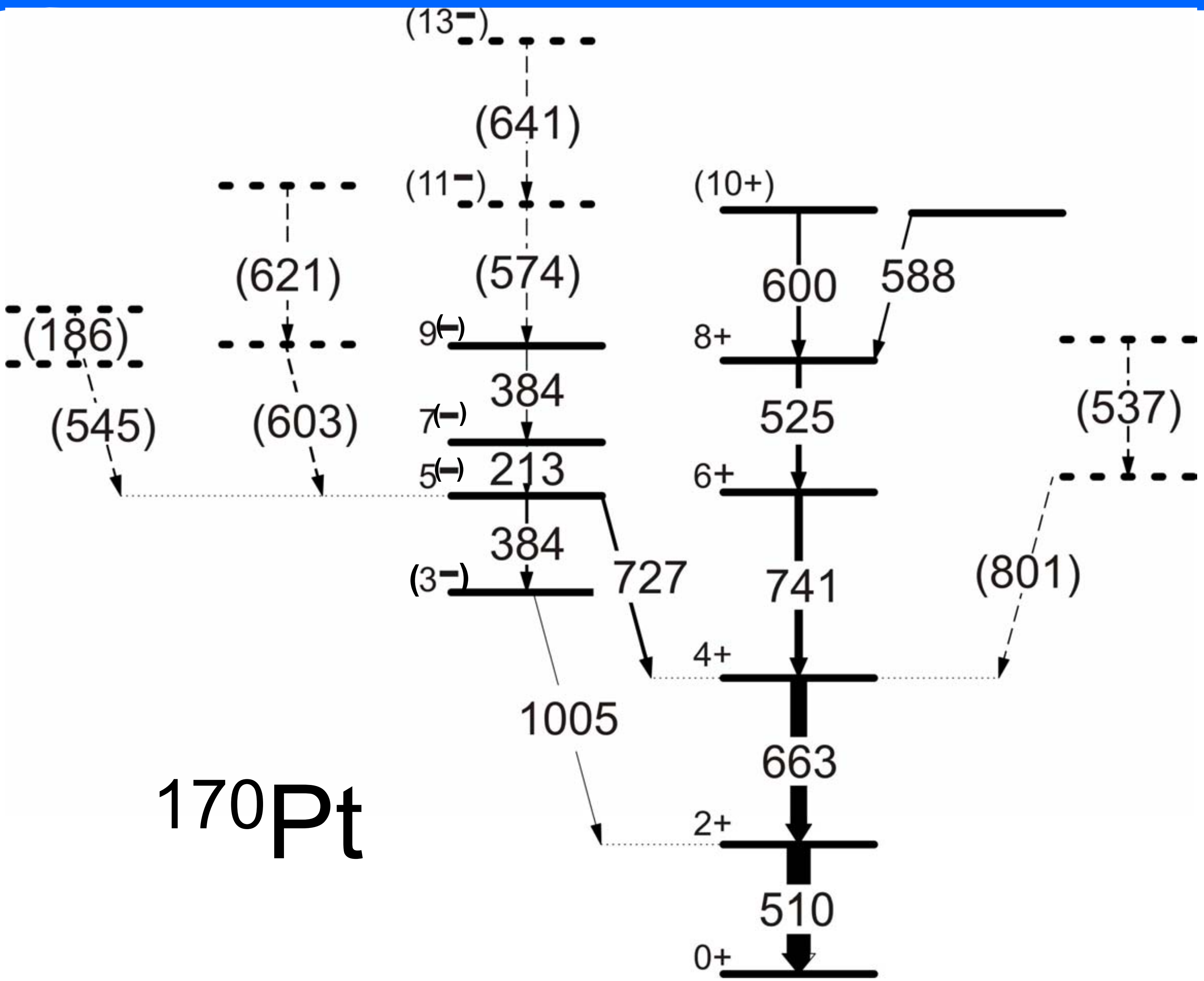


Rates

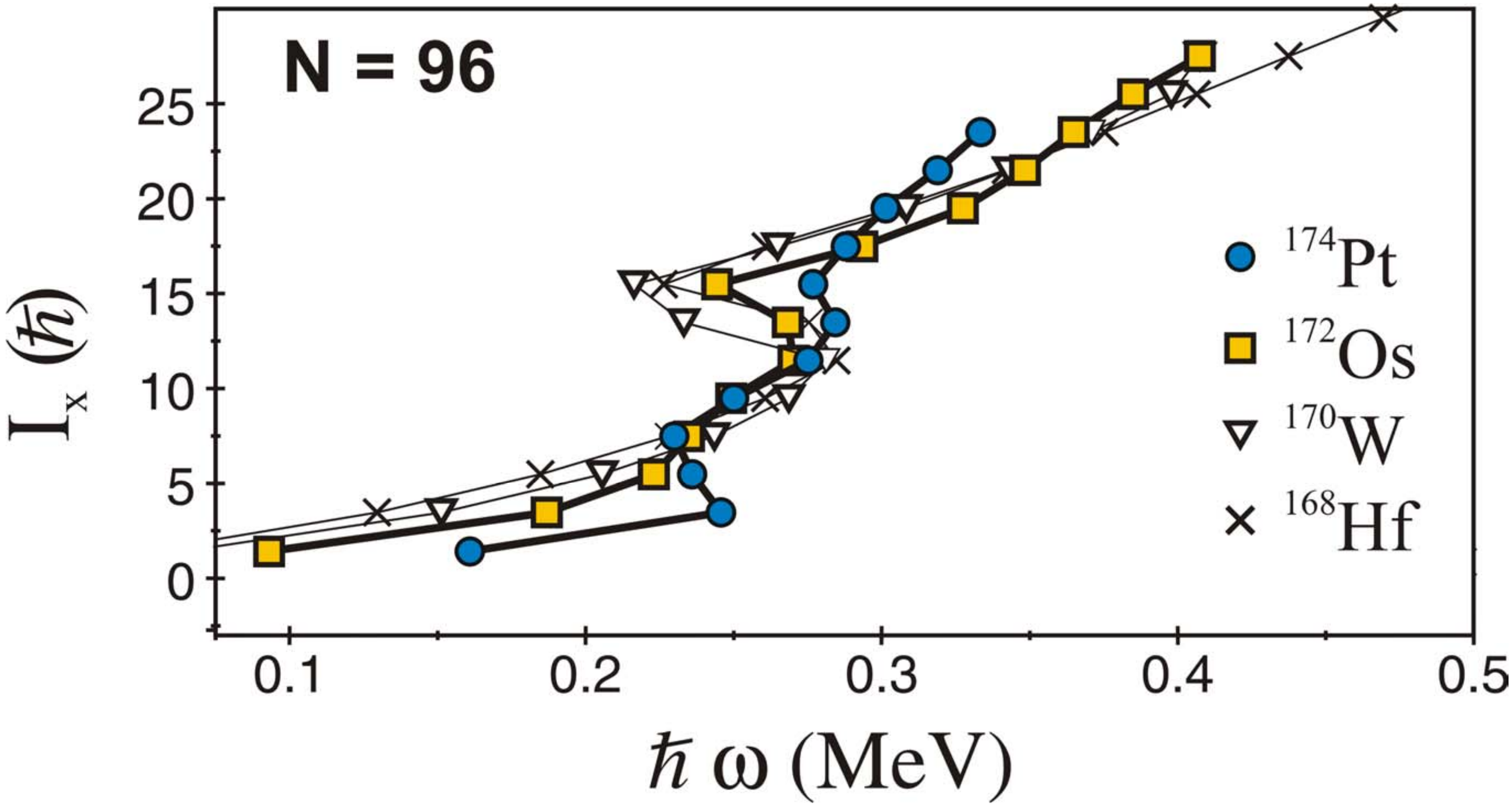
Ge (Singles) ~ 4 kHz
Recoil implants ~ 360 Hz



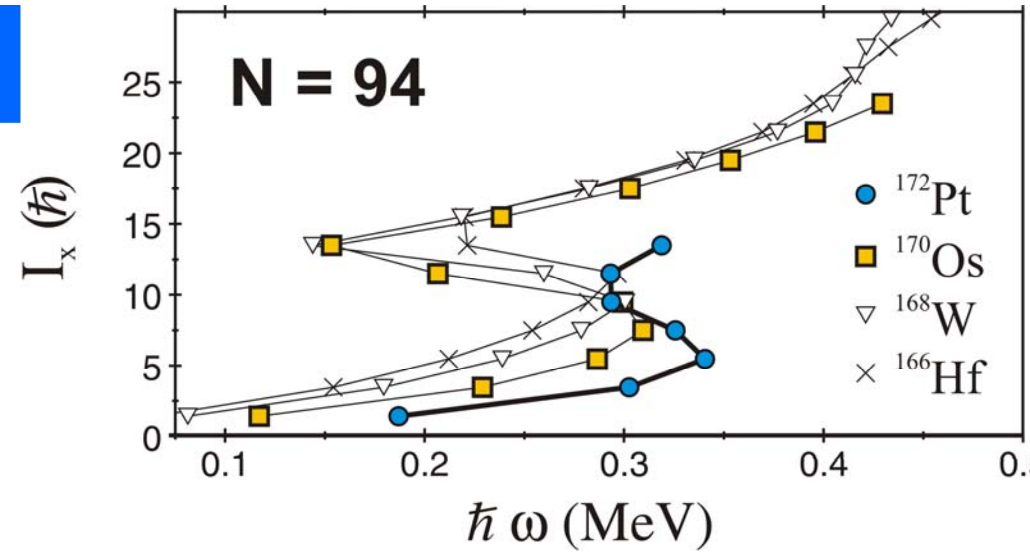
Gate
741 keV
727 keV
384 keV
^{170}Pt
510
525
588
600
663
(186)
213
384
(574)
(603)
727
1005
Counts
Energy (keV)

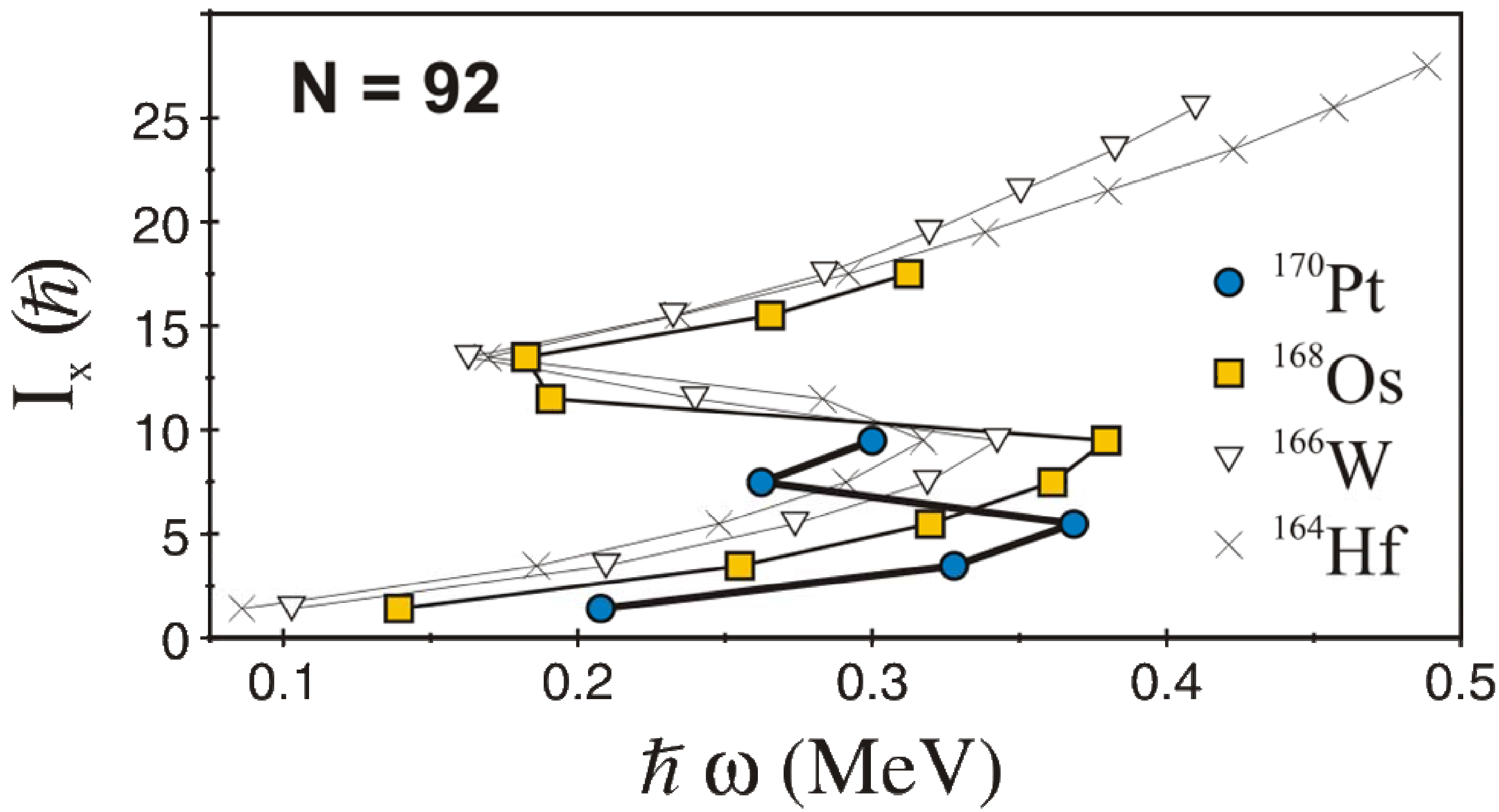

(13−)
(641)
(11−)
(10+)
(621)
(574)
600
588
(186)
9(−)
8+
384
525
(537)
(545)
(603)
7(−)
5(−)
213
6+
384
727
741
(801)
(3−)
4+
1005
663
2+
510
0+

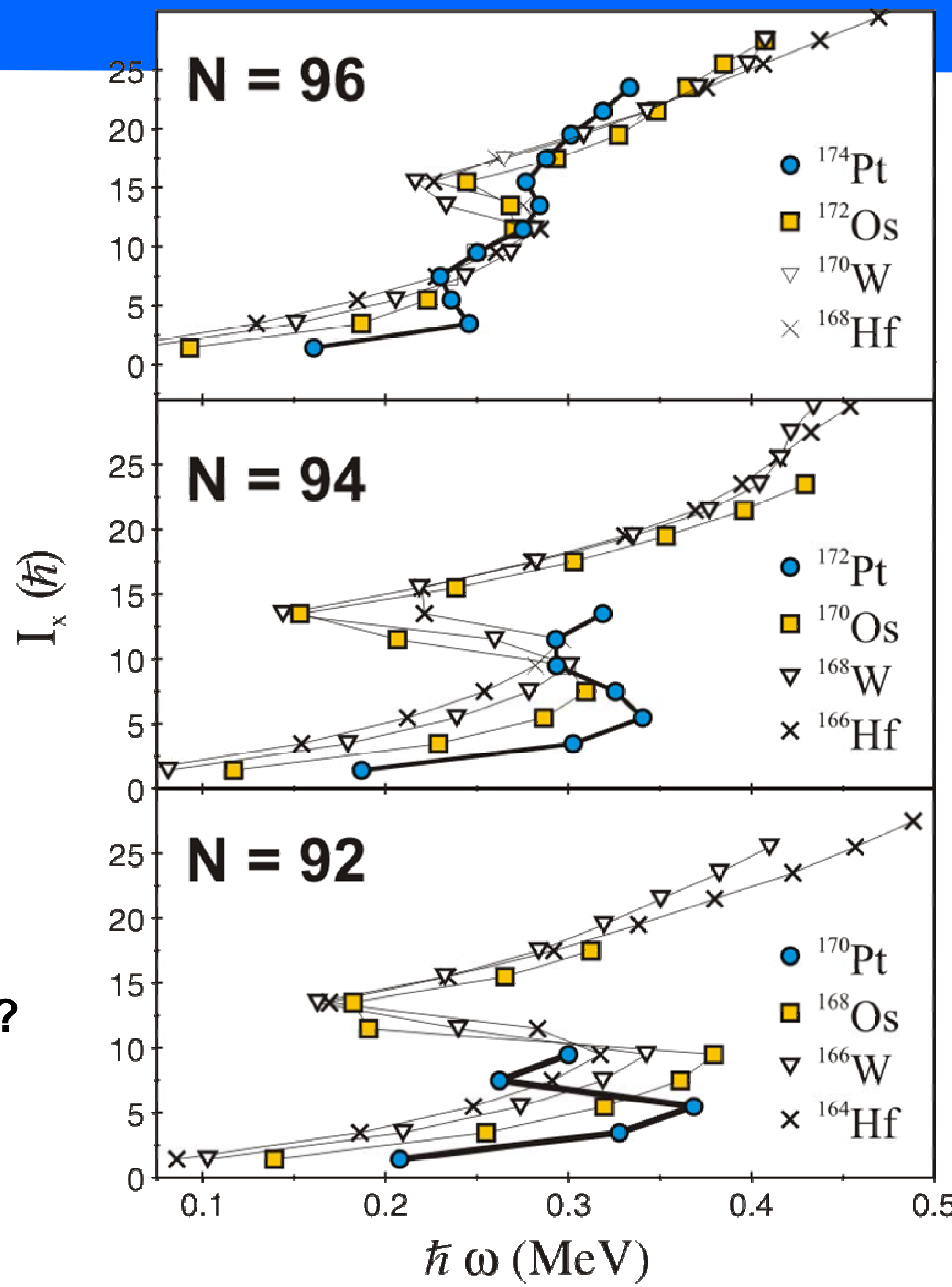
^{170}Pt



^{174}Pt – J. TM. Goon et al., Phys. Rev. C **70**, (2004) 014309.
^{172}Os -J.L.Durell, Phys. Lett. **B115**, (1982) 367.


N = 94
I_x ($\hbar$)
$\hbar\omega$ (MeV)
^{172}Pt
^{170}Os
^{168}W
^{166}Hf

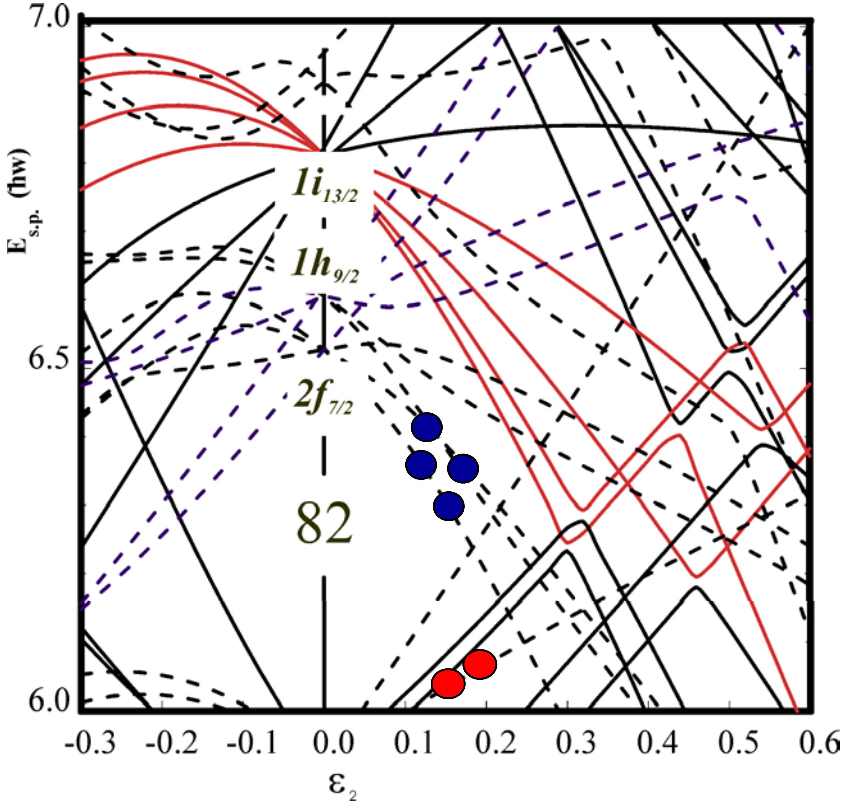

N = 92
I_x ($\hbar$)
$\hbar\omega$ (MeV)
^{170}Pt
^{168}Os
^{166}W
^{164}Hf

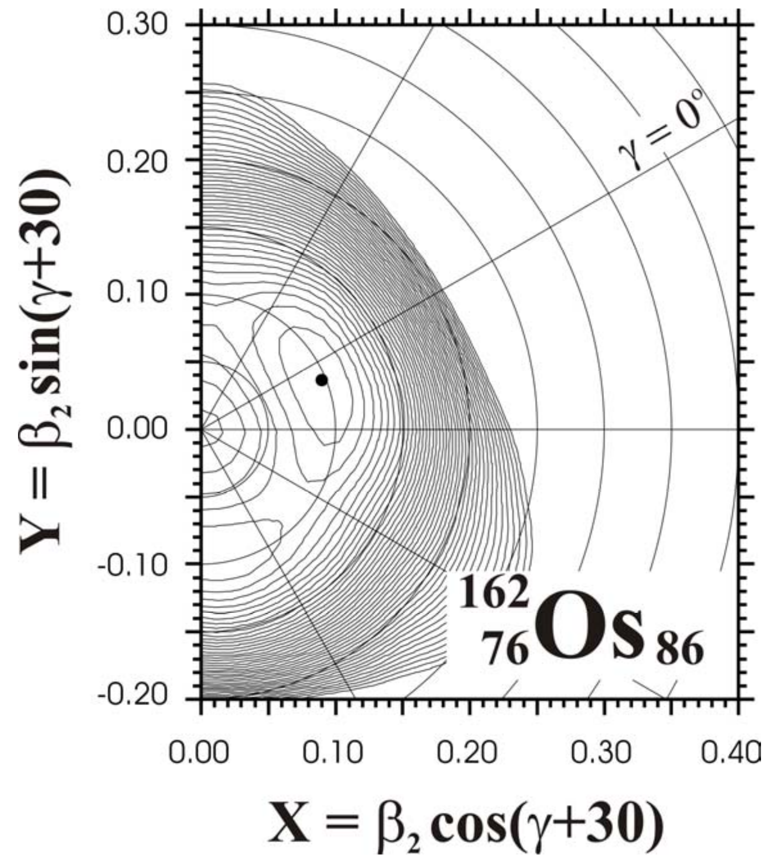


What is happening to the yrast states in ^{170}Pt ?

How is the structure changing?

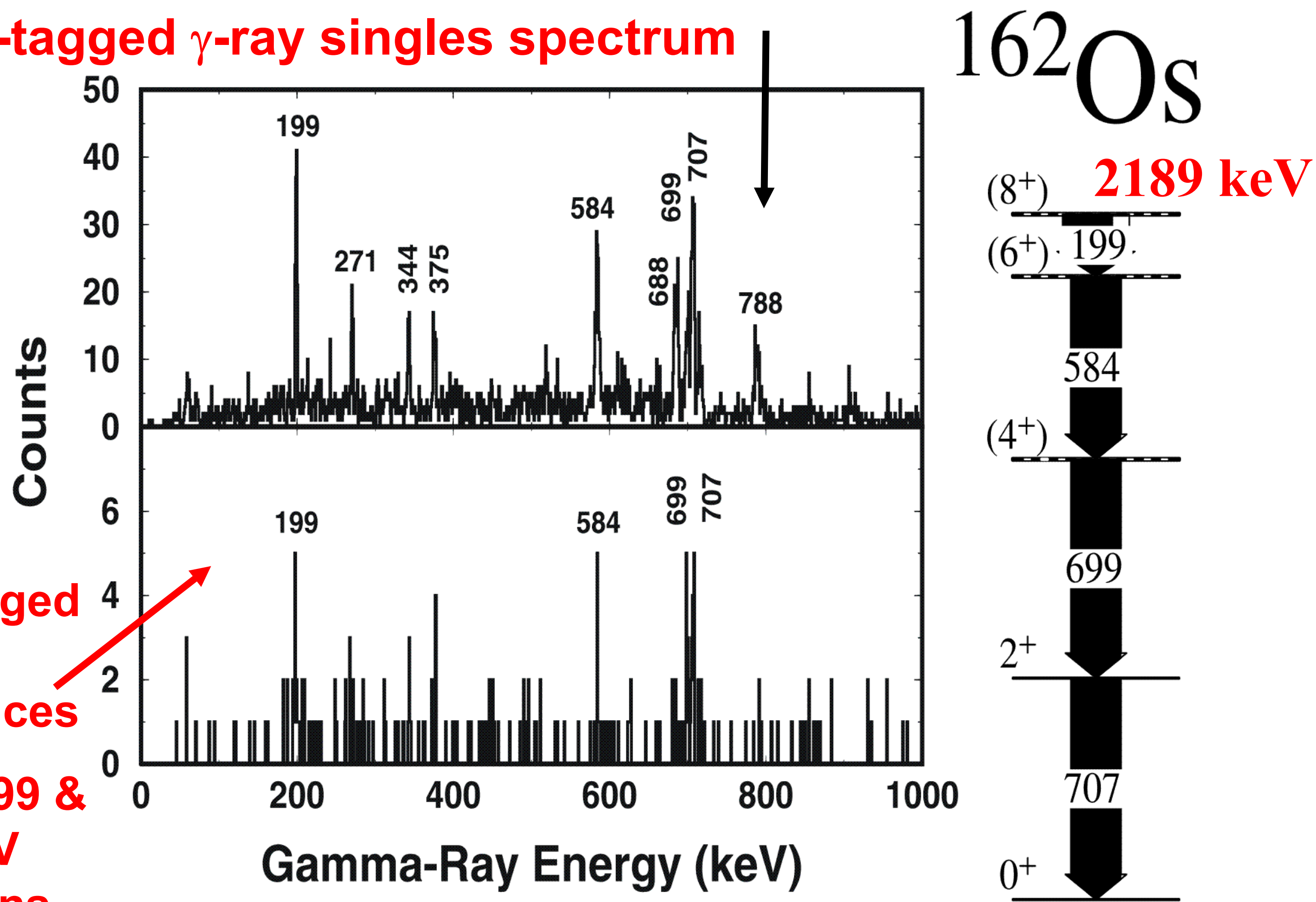
The low spin yrast structure is expected to be based on configurations involving the neutron $f_{7/2}$ and $h_{9/2}$ orbitals.





TRS calculations predict near-spherical shapes (β_2 = 0.09).

Alpha-tagged γ-ray singles spectrum

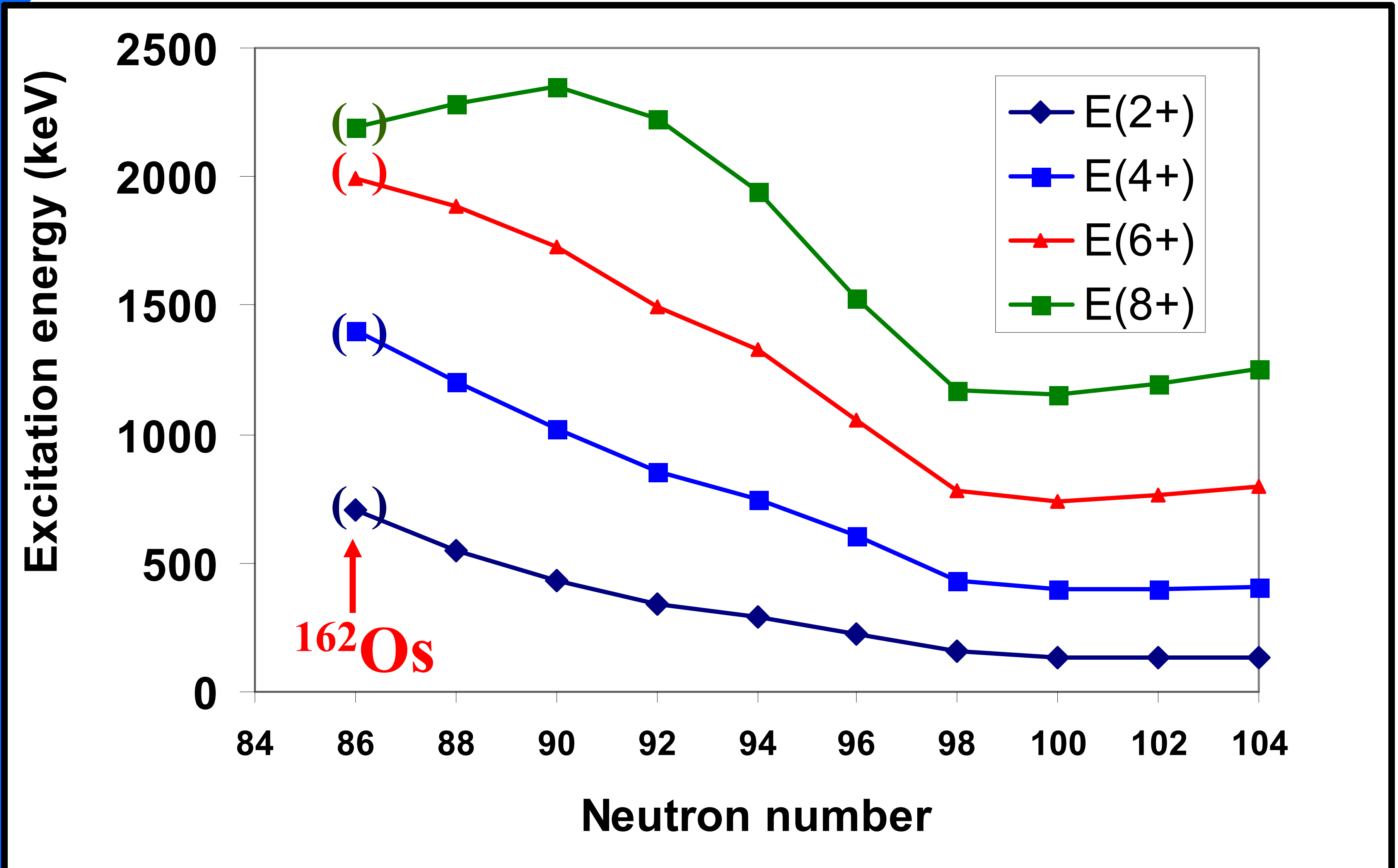


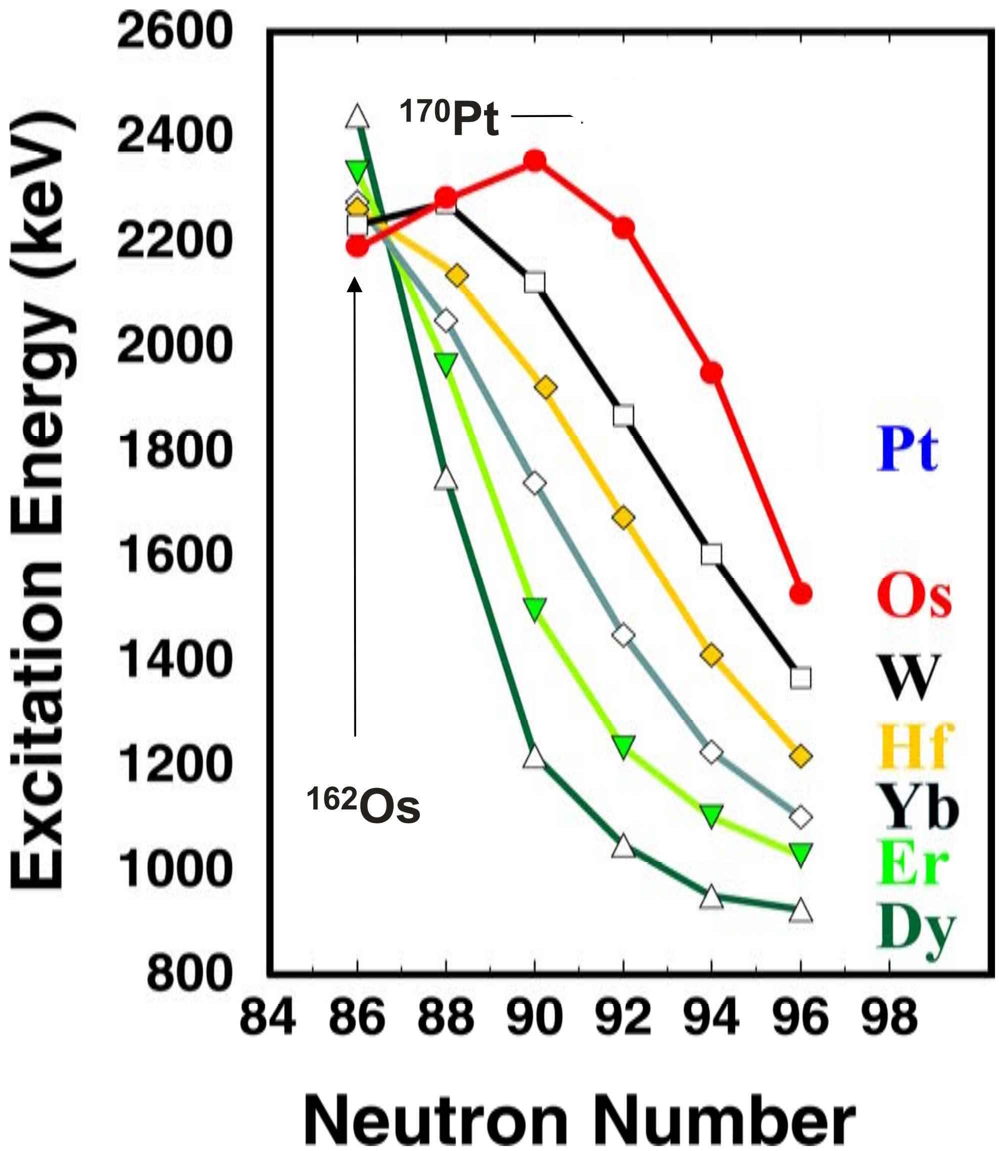
Alpha-tagged γ- γ coincidences

(Sum of 199 & 707 keV transitions

Cross section estimated from experimental alpha yield as σ ~400 nb

Level excitation energies for Osmium Isotopes





Above N = 86, lower-Z isotones have lower 8+ energies.

There is an inversion to this trend for N ≤ 86.

8^+ States are lowered in excitation energy at higher neutron numbers for nuclei nearest to the closed proton shell.

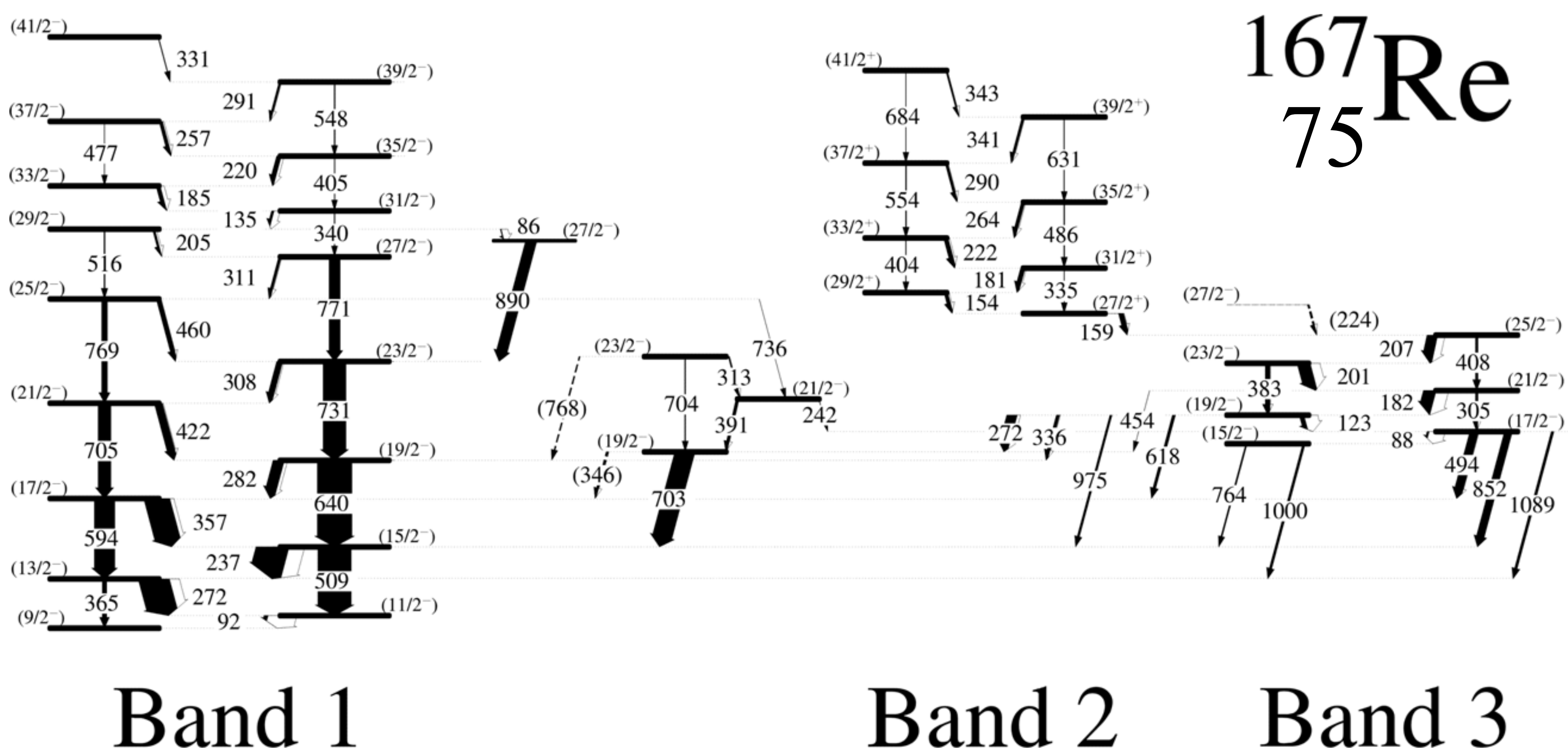
Similar trend observed for the N=84 isotones.
C.T. Zhang *et al*., Phys. Rev. C54, (1996) R1.

Lowering of neutron $h_{9/2}$ states

Conclusions for the Pt isotopes

- Yrast band in ^{172}Pt indicates that intruder configurations may be important in ^{172}Pt.
- The relative position of the neutron $h_{9/2}$ states are changing near N=82.
- The character of the yrast band in ^{170}Pt might reflect the single-neutron structure more than (proton) intruder scenario.

II From collective to single-particle configurations in the Re isotopes

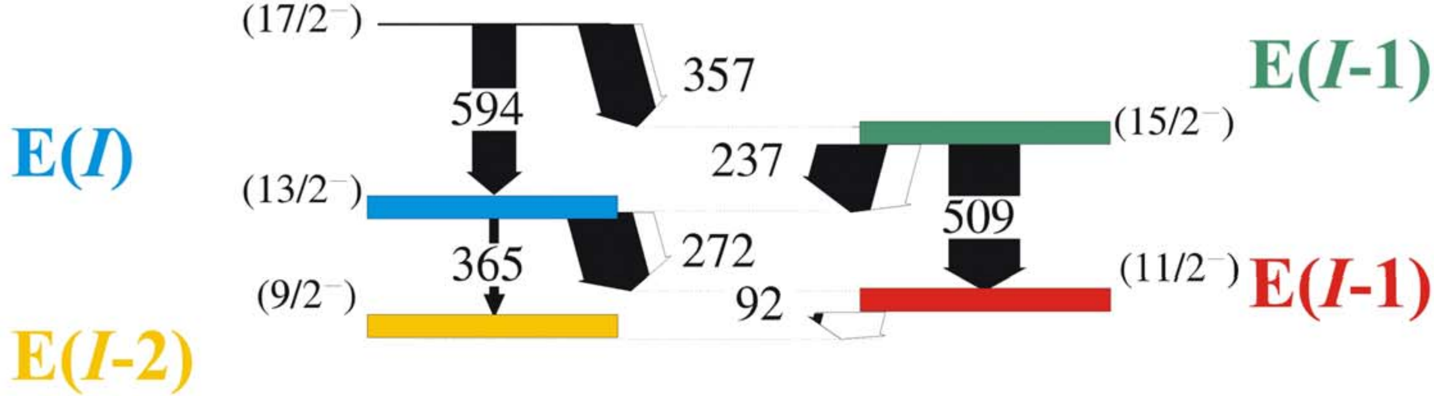


JUROSPHERE Experiment - from recoil-$\gamma\gamma$ coincidence matrix

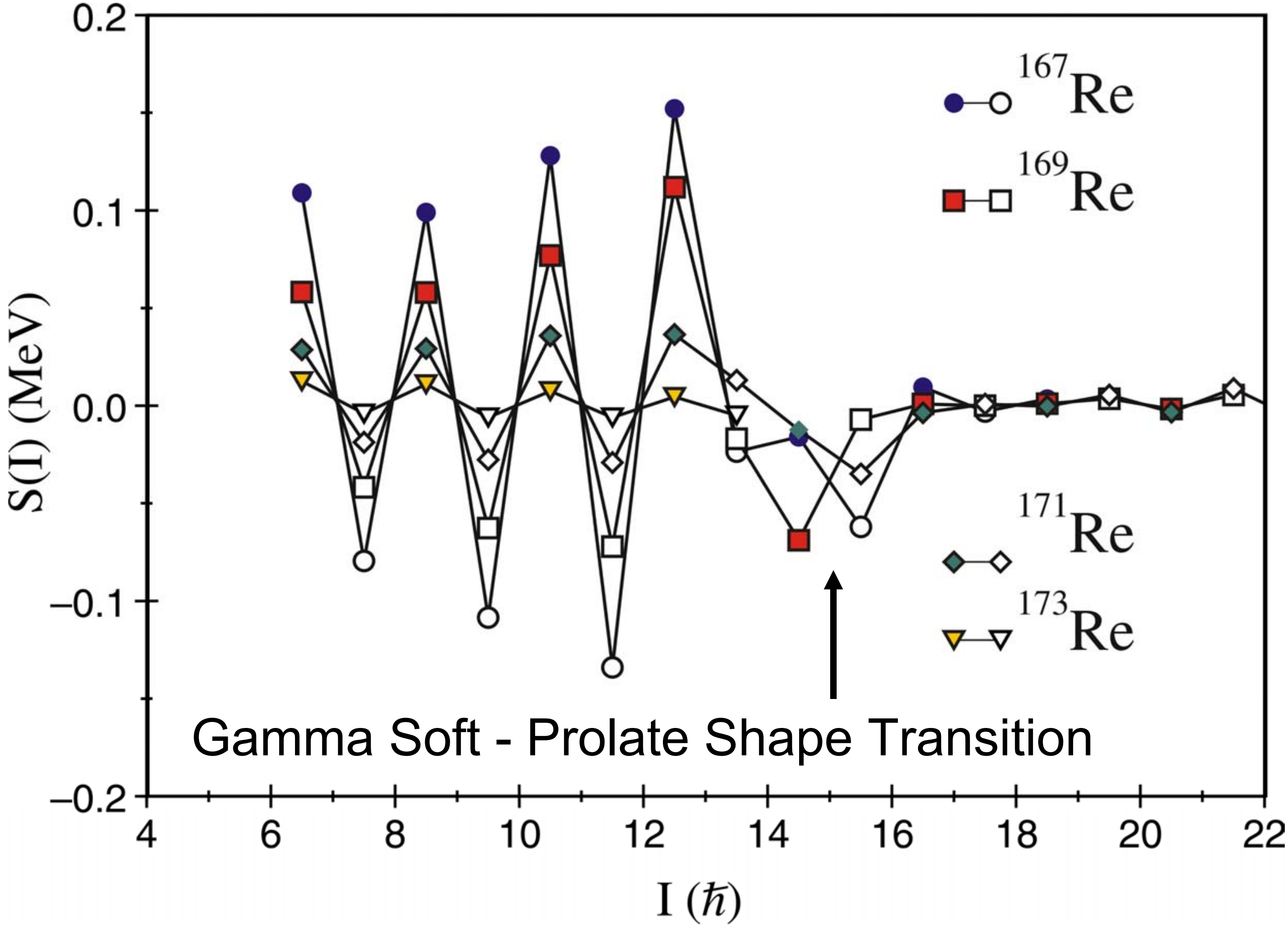
D.T. Joss et al., Phys. Rev. C68 (2003) 4303

Determining the staggering parameter

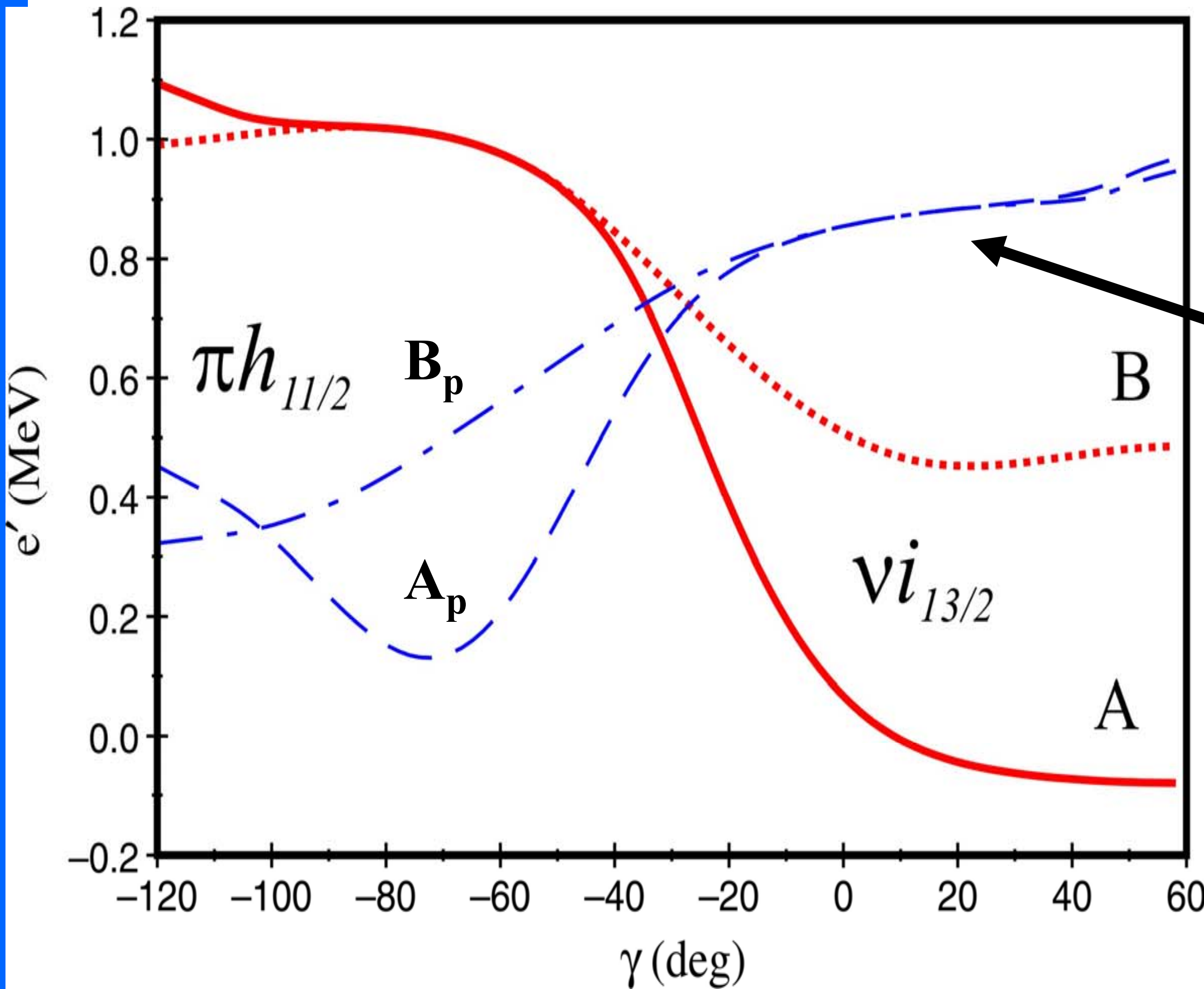
$$S(I) = E(I) - E(I\text{-}1) - 1/2[E(I\text{+}1)\text{-}E(I)\text{+}E(I\text{-}1)\text{-}E(I\text{-}2)]$$



Staggering in the [514]9/2$^-$ bands of odd-A Re isotopes

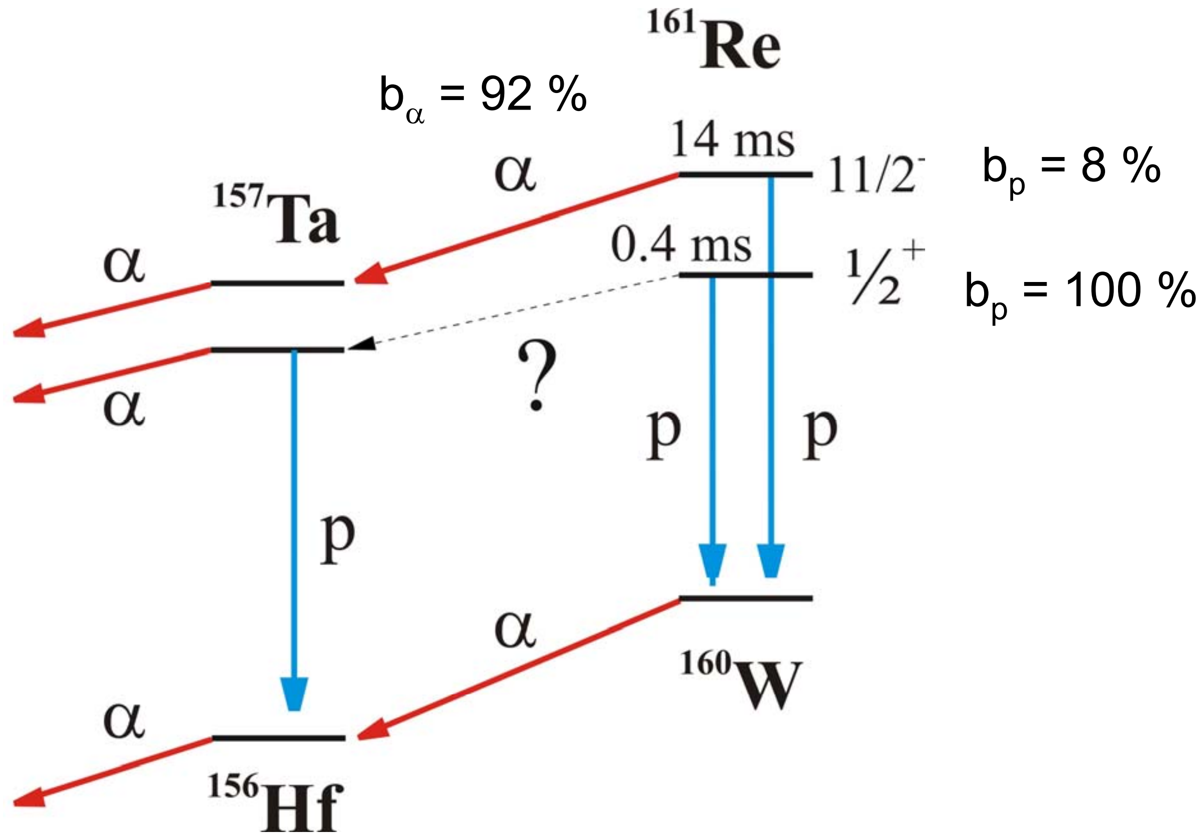


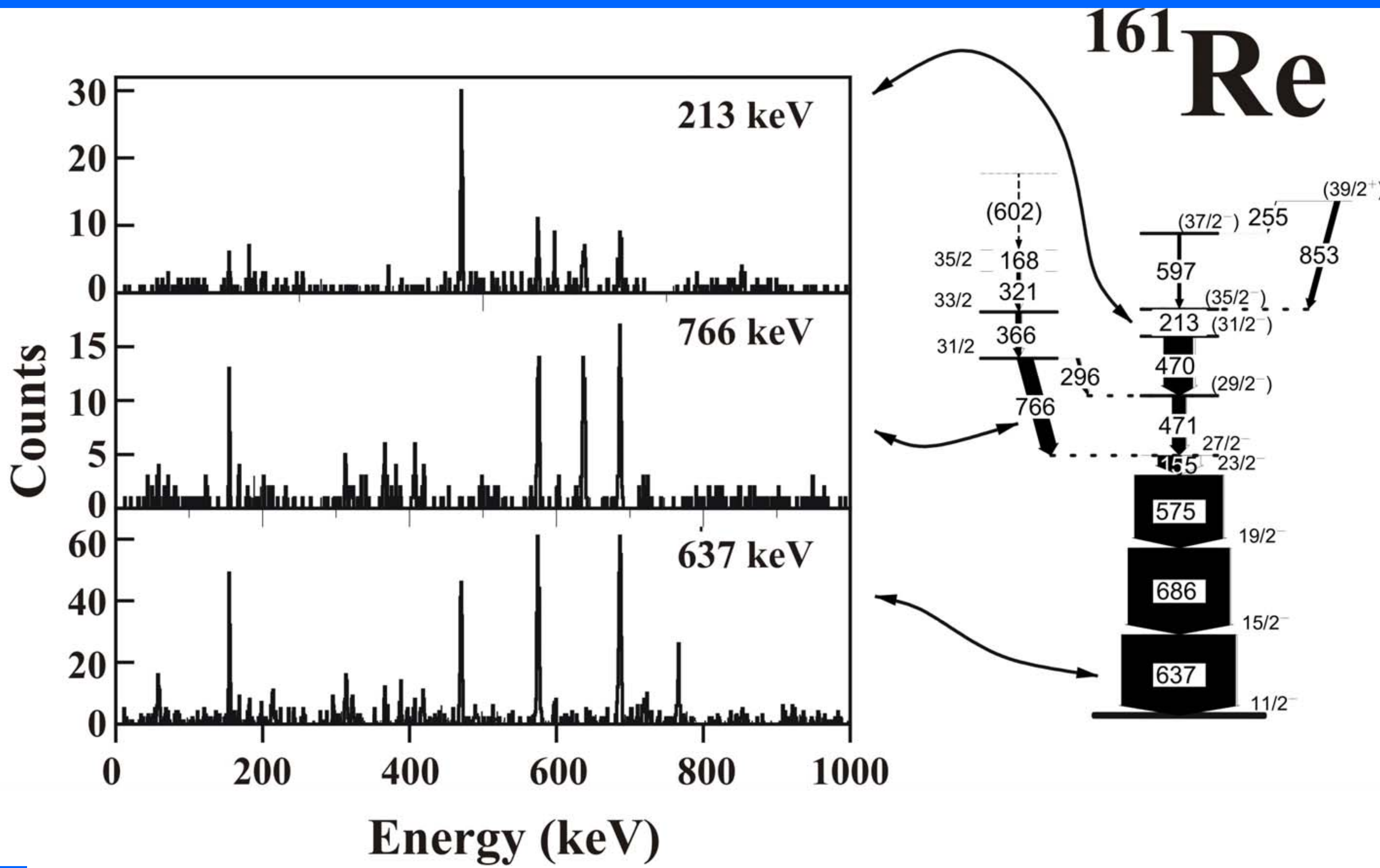
Cranked Shell Model Calculations



Signature splitting vanishes at prolate deformations

RDT of the proton emitter ^{161}Re





K. Lagergren *et al*., Submitted to Physical Review C.

Summary

•The exploitation of large γ-ray spectrometers with selective tagging techniques has allowed investigations of nuclei close to the proton drip line.

• Opportunity to chart the underlying and changing structure of the sub-lead region approaching the proton drip line and the closed neutron shell (N=82).

• Exciting possibilities with new instrumentation and tagging techniques in the future!

Thanks to

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