The Value of Perspective

Approaching nuclei through multiple perspectives and diverse models: Patterns, symmetries, interactions

(Apologies for two slides from Tokyo)

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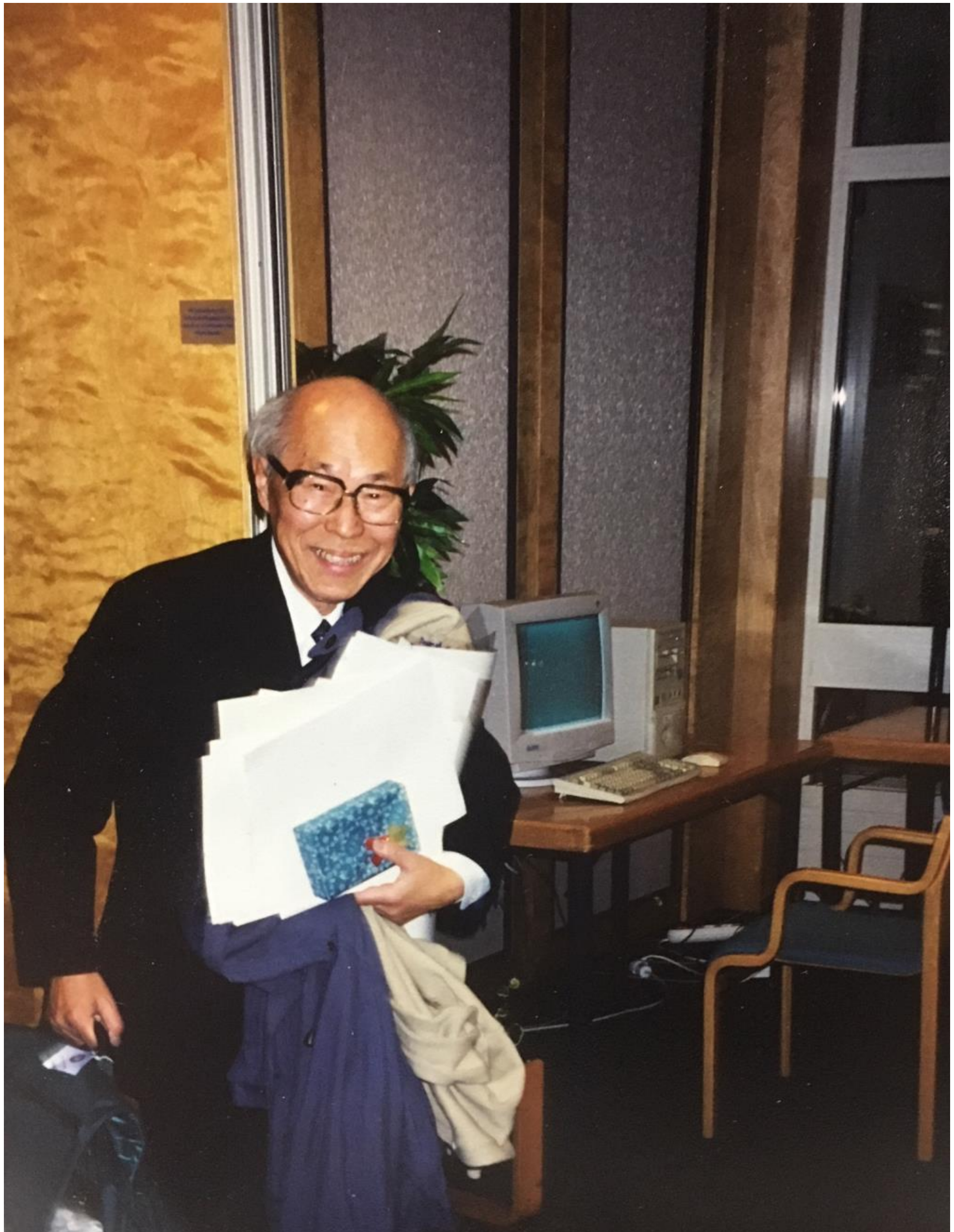
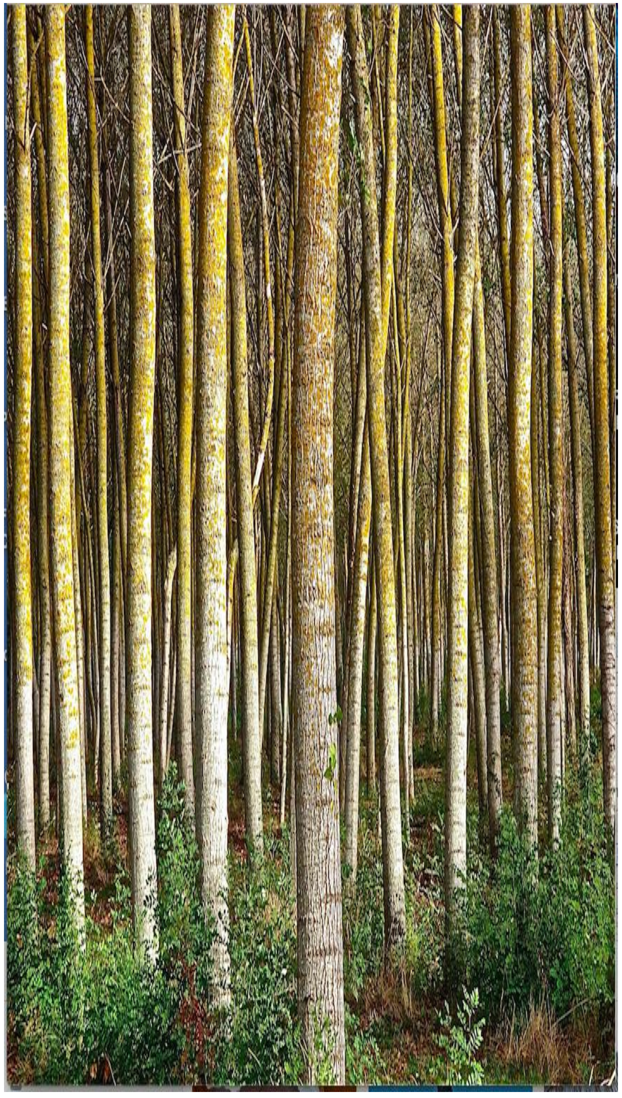
International Symposium on Simplicity, Symmetry, and Beauty of Atomic Nuclei, in honor of Professor Akito Arima's 88 year-old Birthday

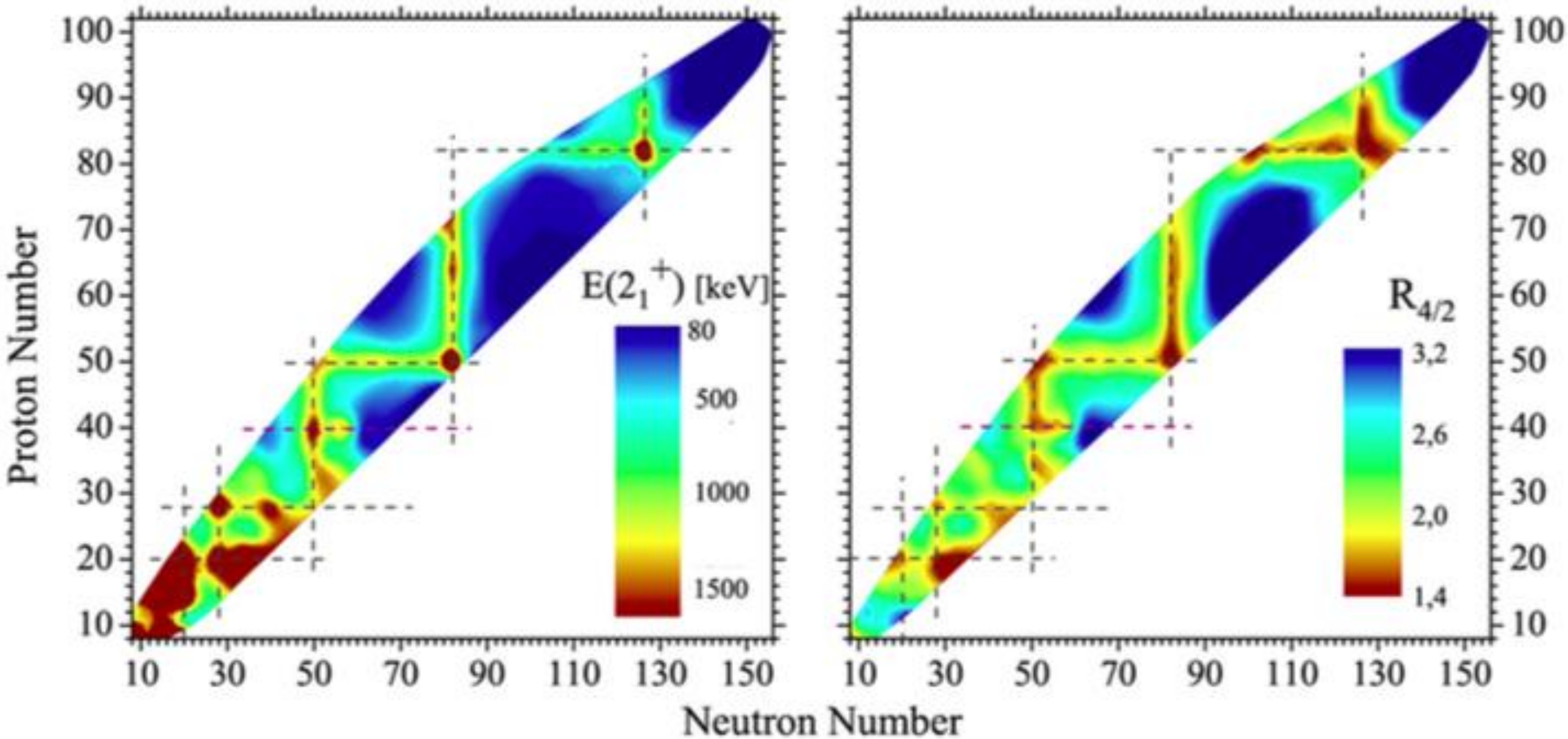
Shanghai, Sept. 26-28, 2018



Do you want to study the details of the trees?
Or the beauty and symmetry of the forest?
Or simplify to its essence



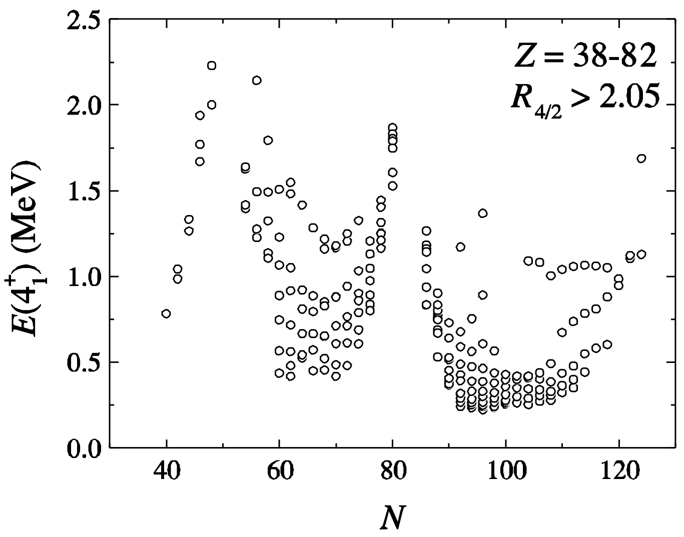
The Beauty and Elegance of Nuclear Structural Evolution

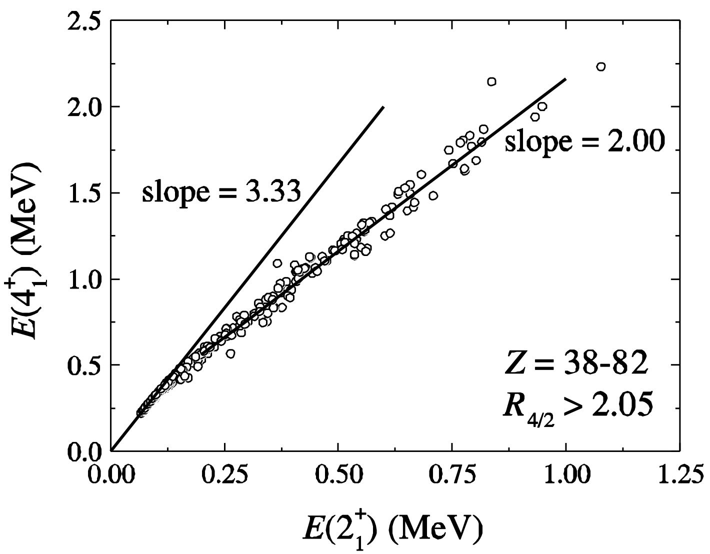


Chaos to order, emergent collectivity, symmetries

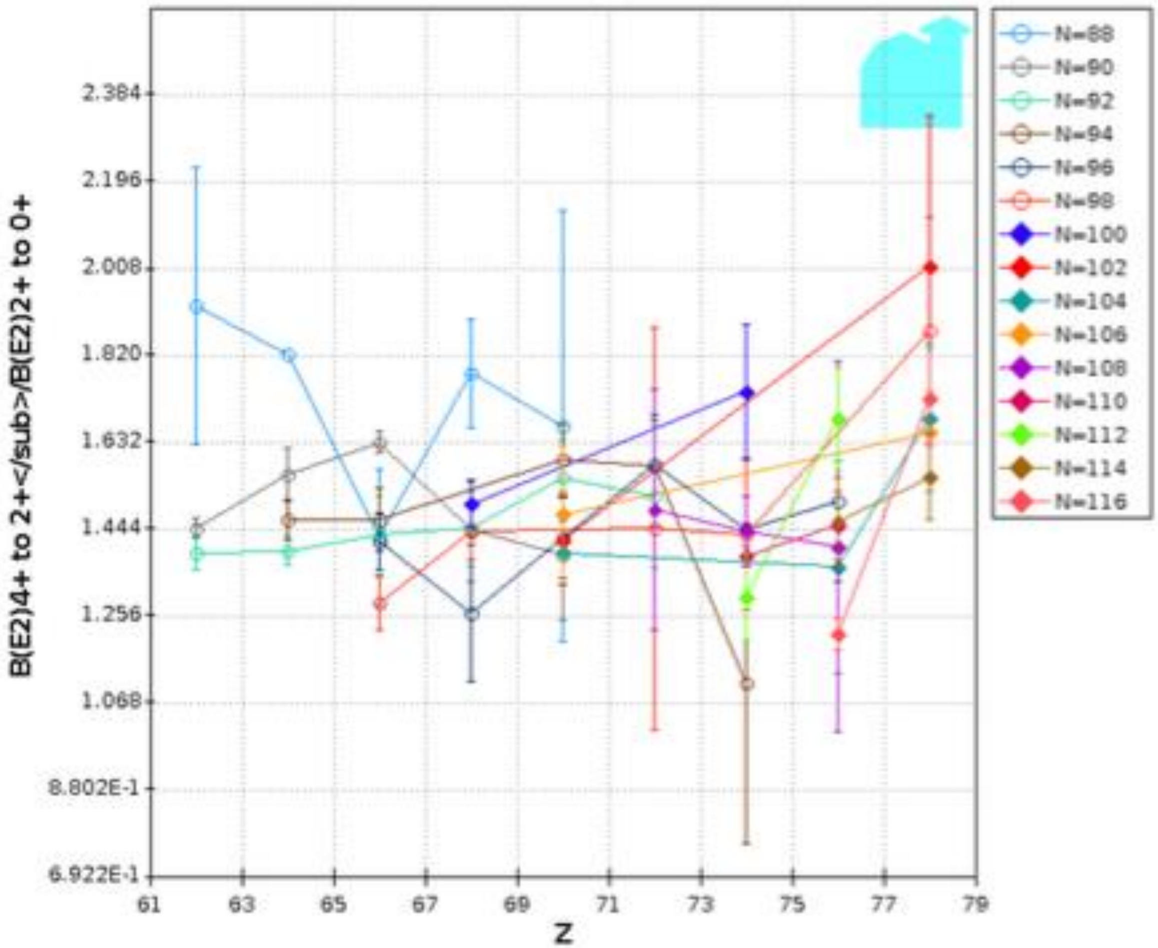
Thanks to R.Burcu Cakirli for figure

Structural evolution: Look at data from different perspectives



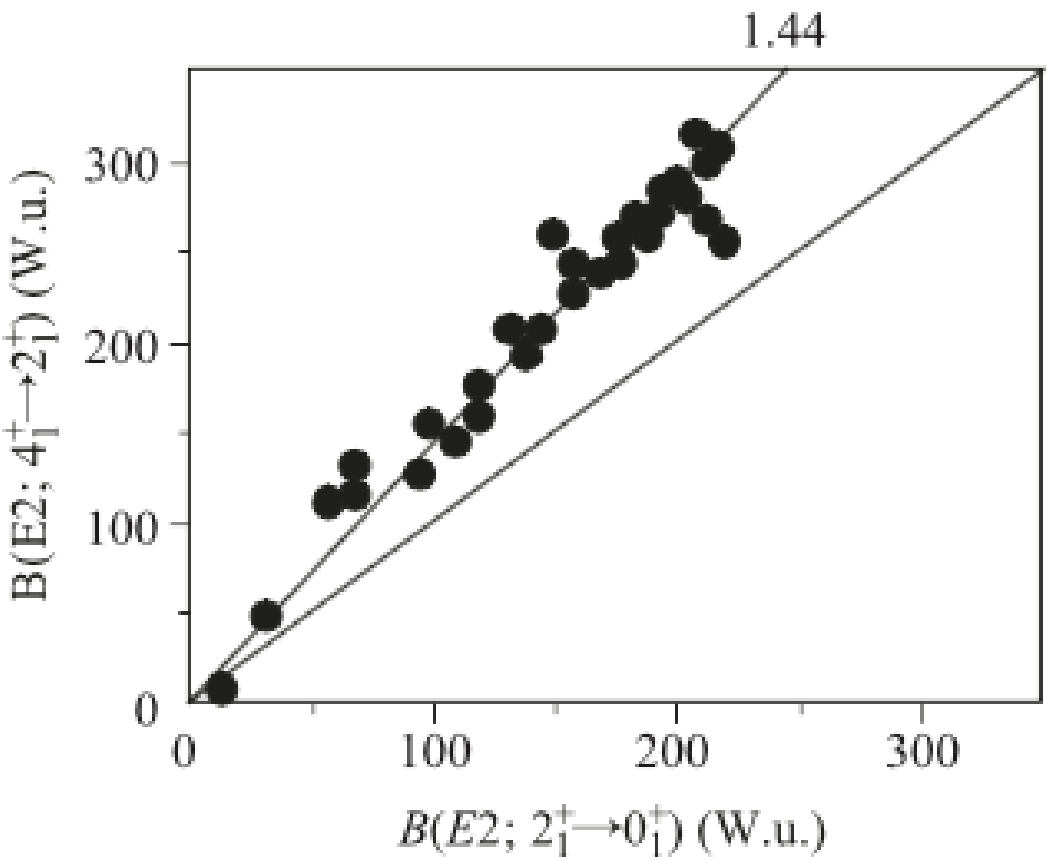


$B(E2: 4^+ -- 2^+)/B(E2: 2^+ -- 0^+)$



B(E2)4+ to 2+</sub>/B(E2)2+ to 0+
2.384
2.196
2.008
1.820
1.632
1.444
1.256
1.068
8.802E-1
6.922E-1
61
63
65
67
69
71
73
75
77
79
Z
N=88
N=90
N=92
N=94
N=96
N=98
N=100
N=102
N=104
N=106
N=108
N=110
N=112
N=114
N=116

B(E2) values: complex behavior across a shell. A different perspective shows a hidden regularity and some physics



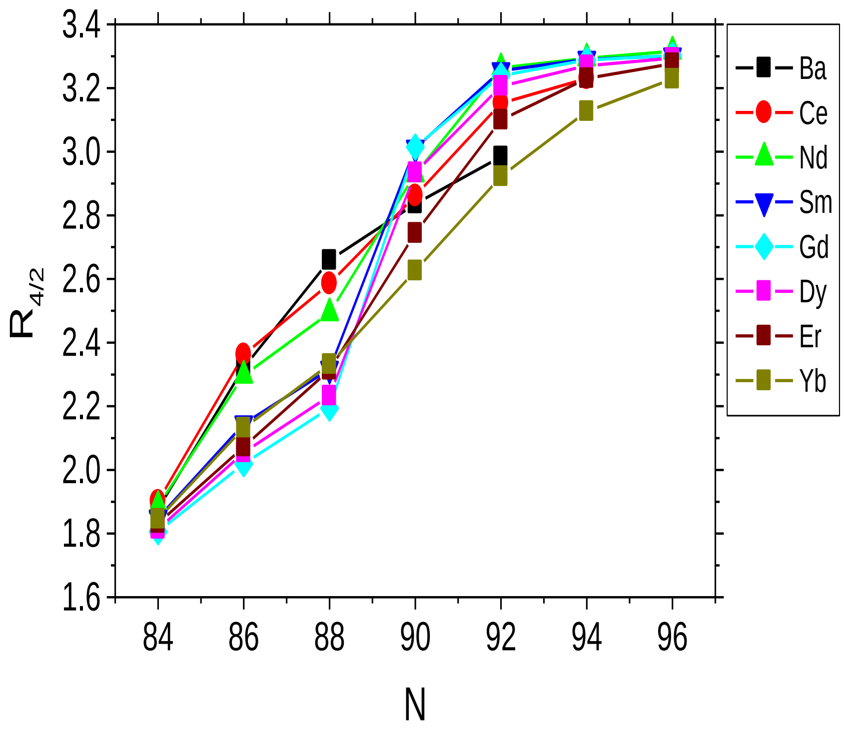
Not only regular but illustrates an interesting point?: Why is slope so constant across many structures?

SU(3) and O(6): ~1.43

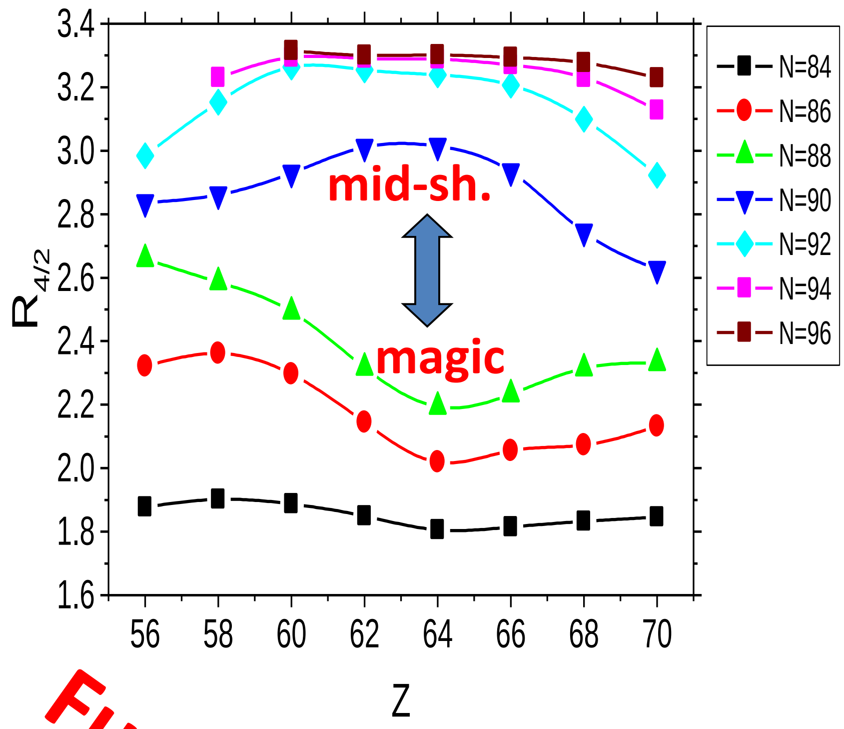
Geom. Vibrator: 2.00

But U(5): 2x(N-1)/N
For N = 4, this equals: 1.5 !

The power of different perspectives



Onset of deformation



Onset of deformation

as a

quantum phase transition

mediated by a

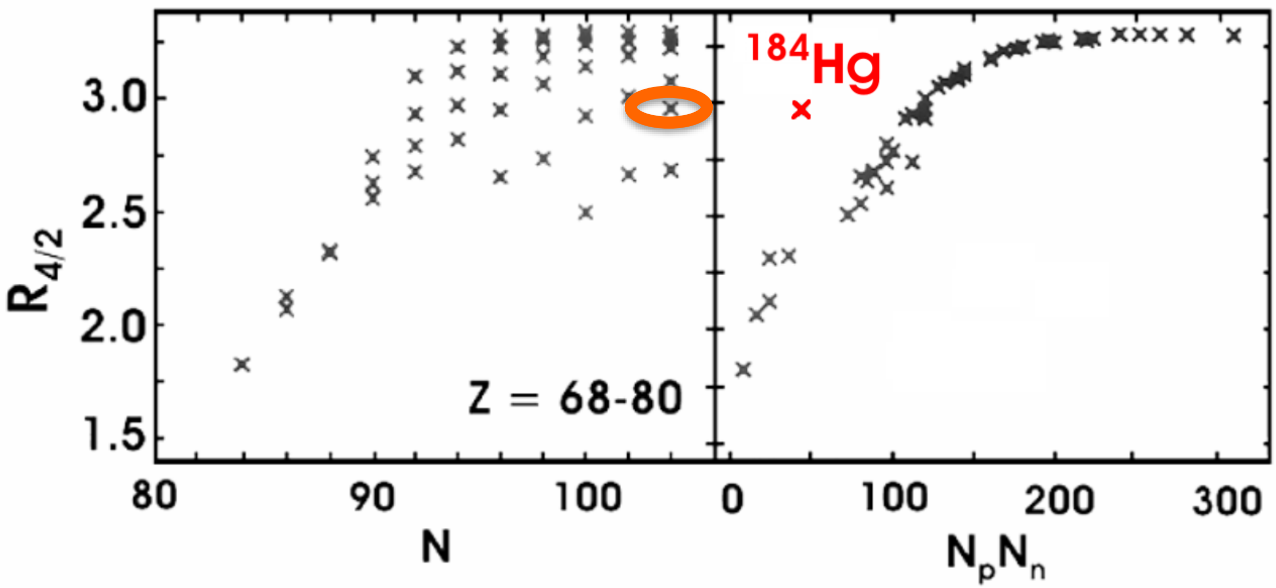
change in proton shell structure

driven by

the p-n interaction

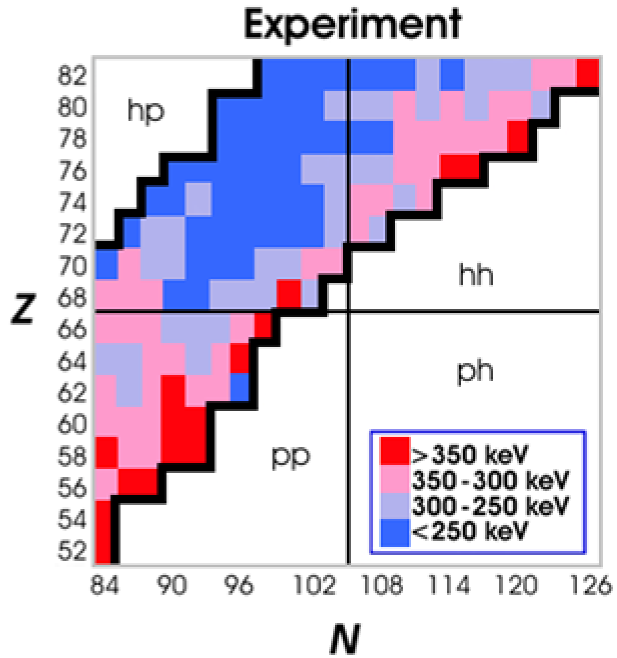
Further interpretation

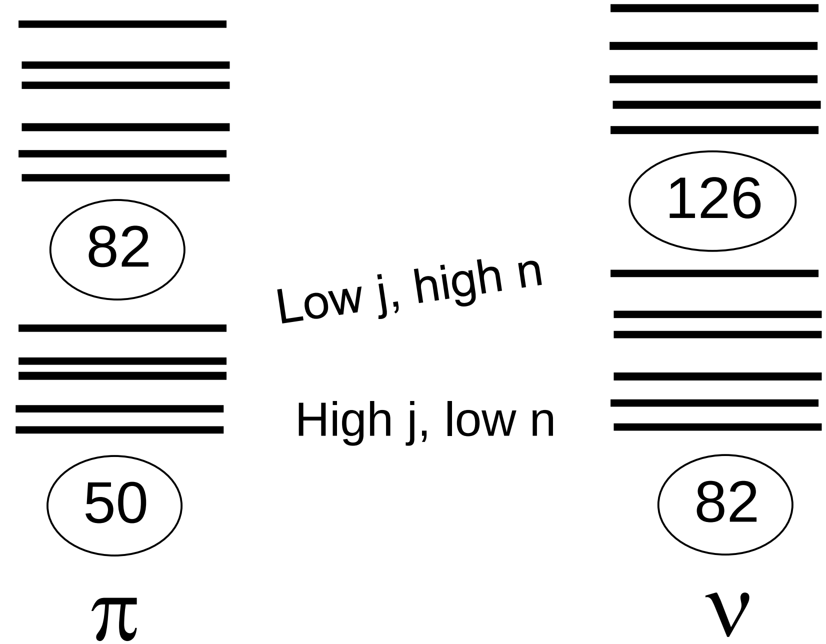
Different perspectives, one more example
Inspired by the p-n interaction



Which is the anomalous nucleus?

Identify deviant behavior





Empirical valence p-n interactions

$\delta\ V_{pn}$

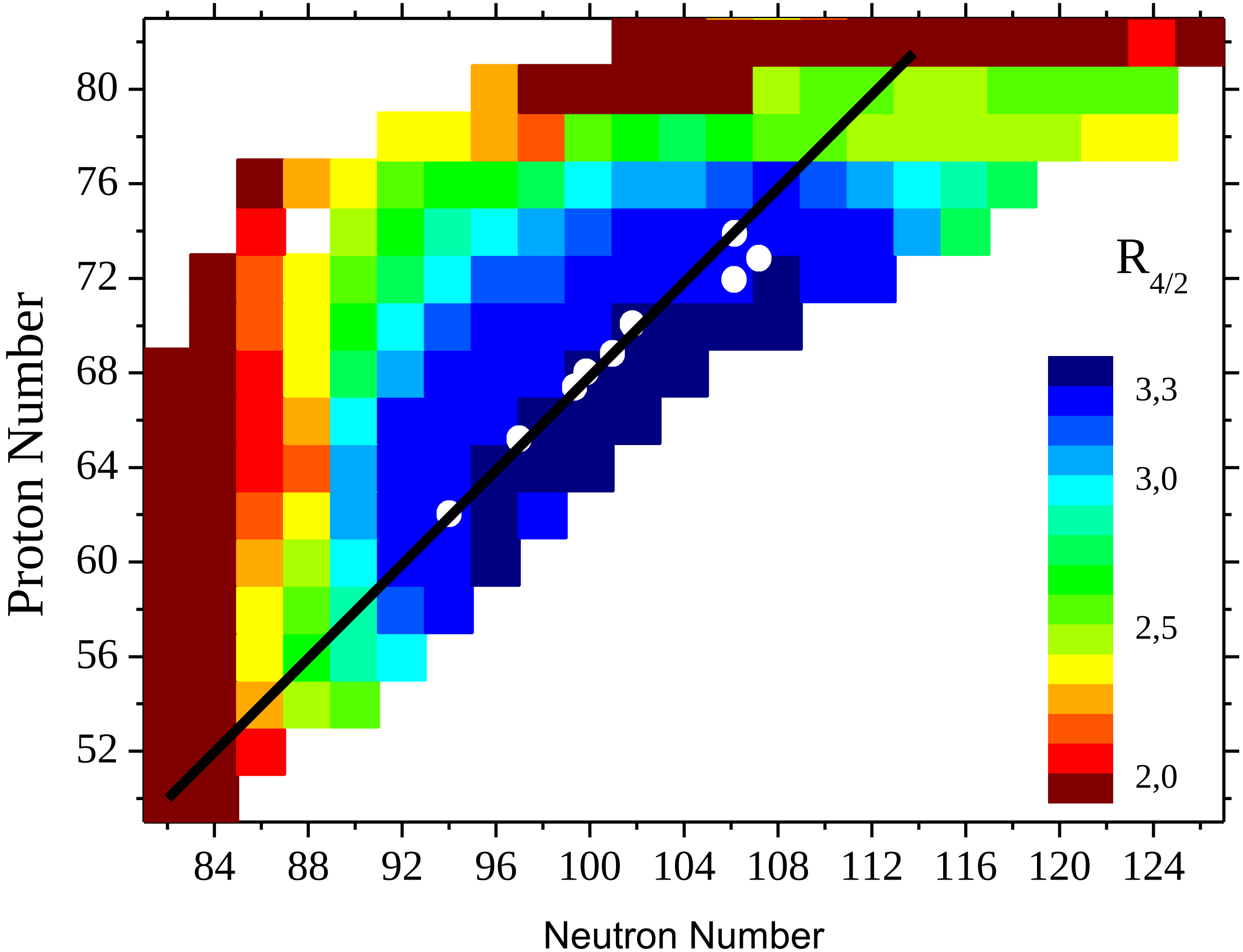
Double difference of masses

Empirical p-n interaction strengths indeed strongest along diagonal.

Empirical p-n interaction strengths stronger in like regions than unlike regions.

Locus of collectivity

Collectivity and maxima in δV_{pn}: Essential role of the p-n interaction



Nuclear Astrophysics / Nucleosynthesis

n-capture cross sections in keV energy range key, especially for unstable nuclei

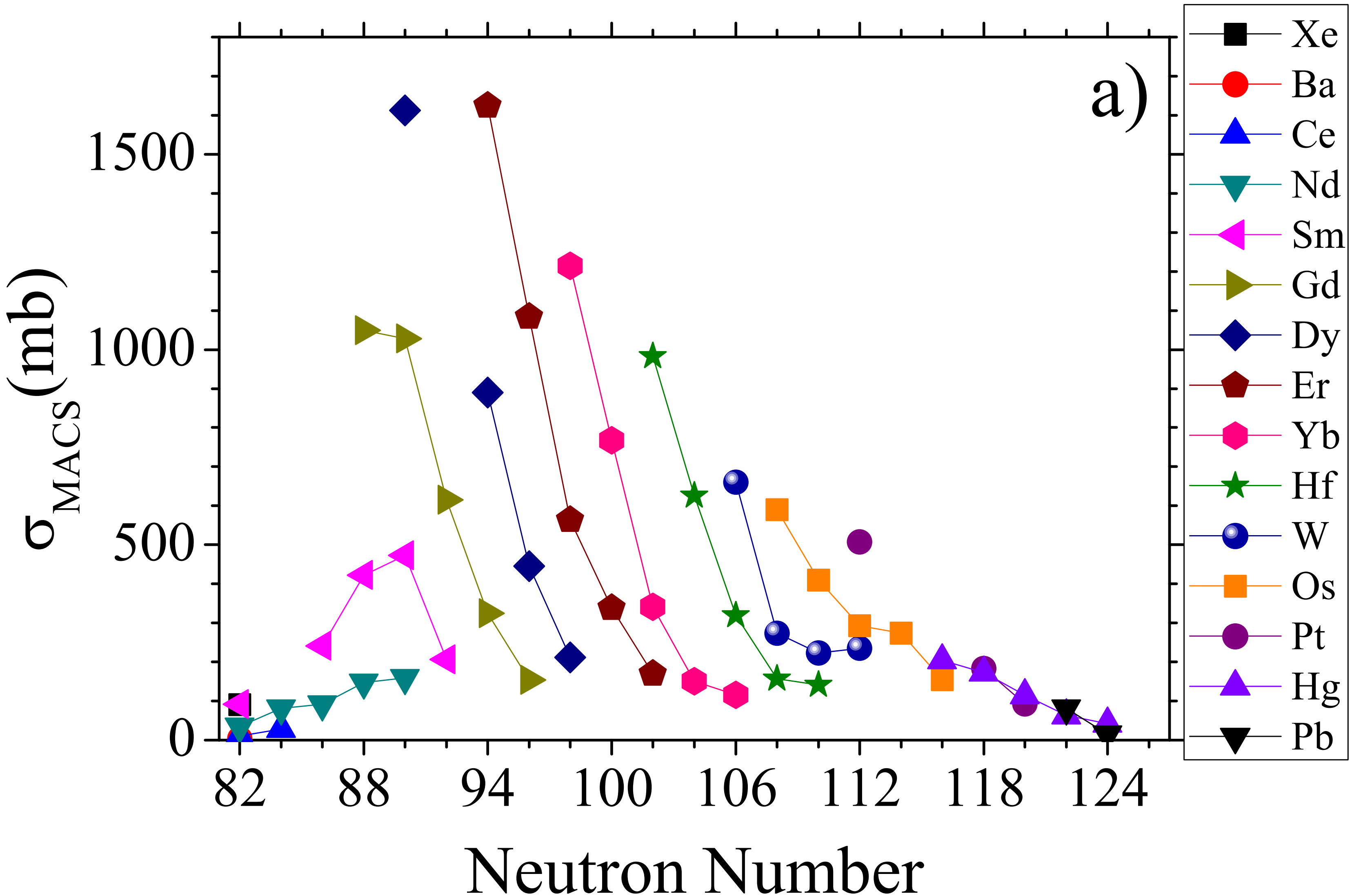
Problem: Difficult to measure
Difficult and uncertain to predict

Is there another way?

Put together two perspectives

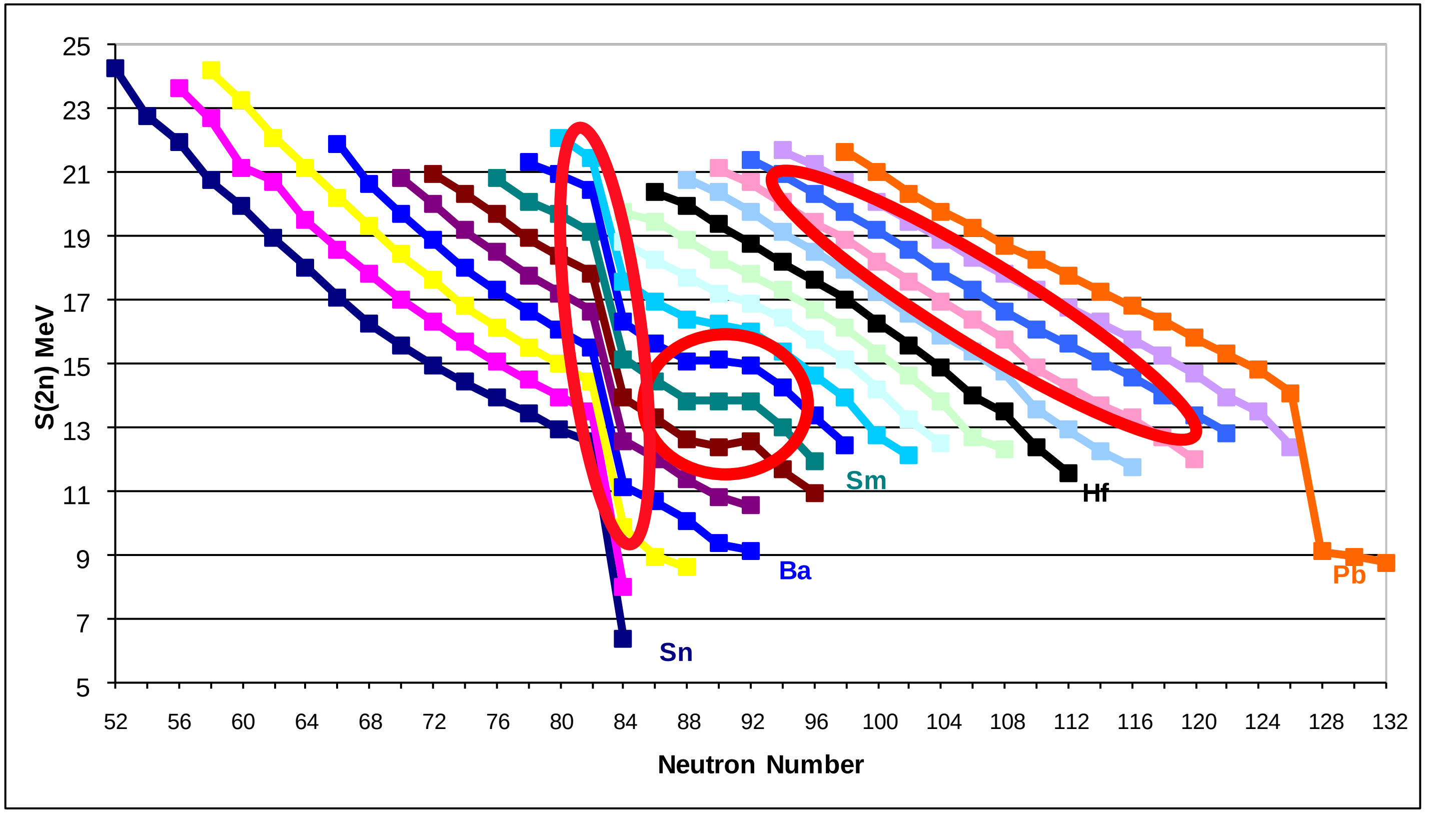
N-capture cross sections

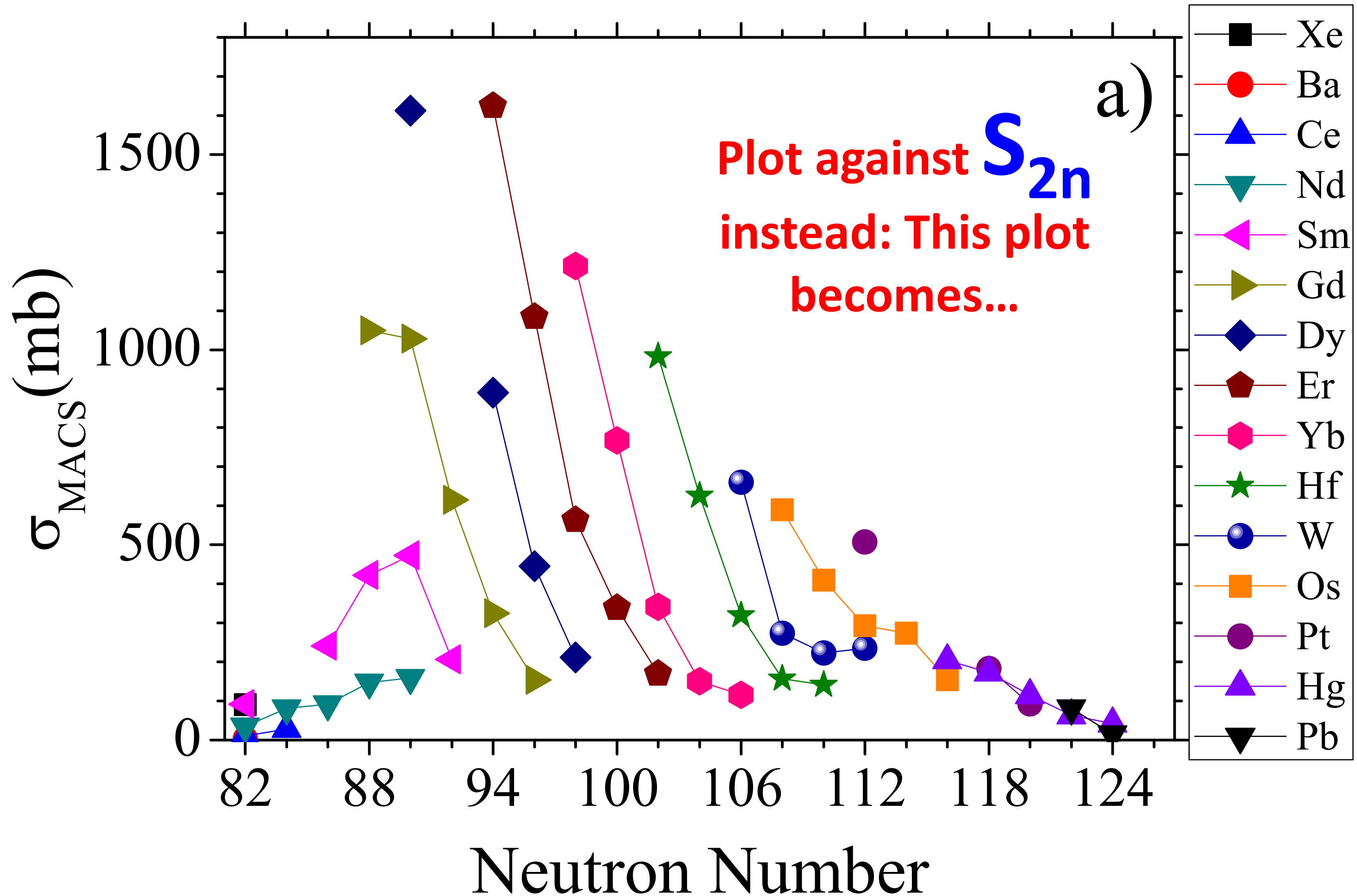
Rare earth region, 30 keV



Try a different perspective

Look at two neutron separation energies

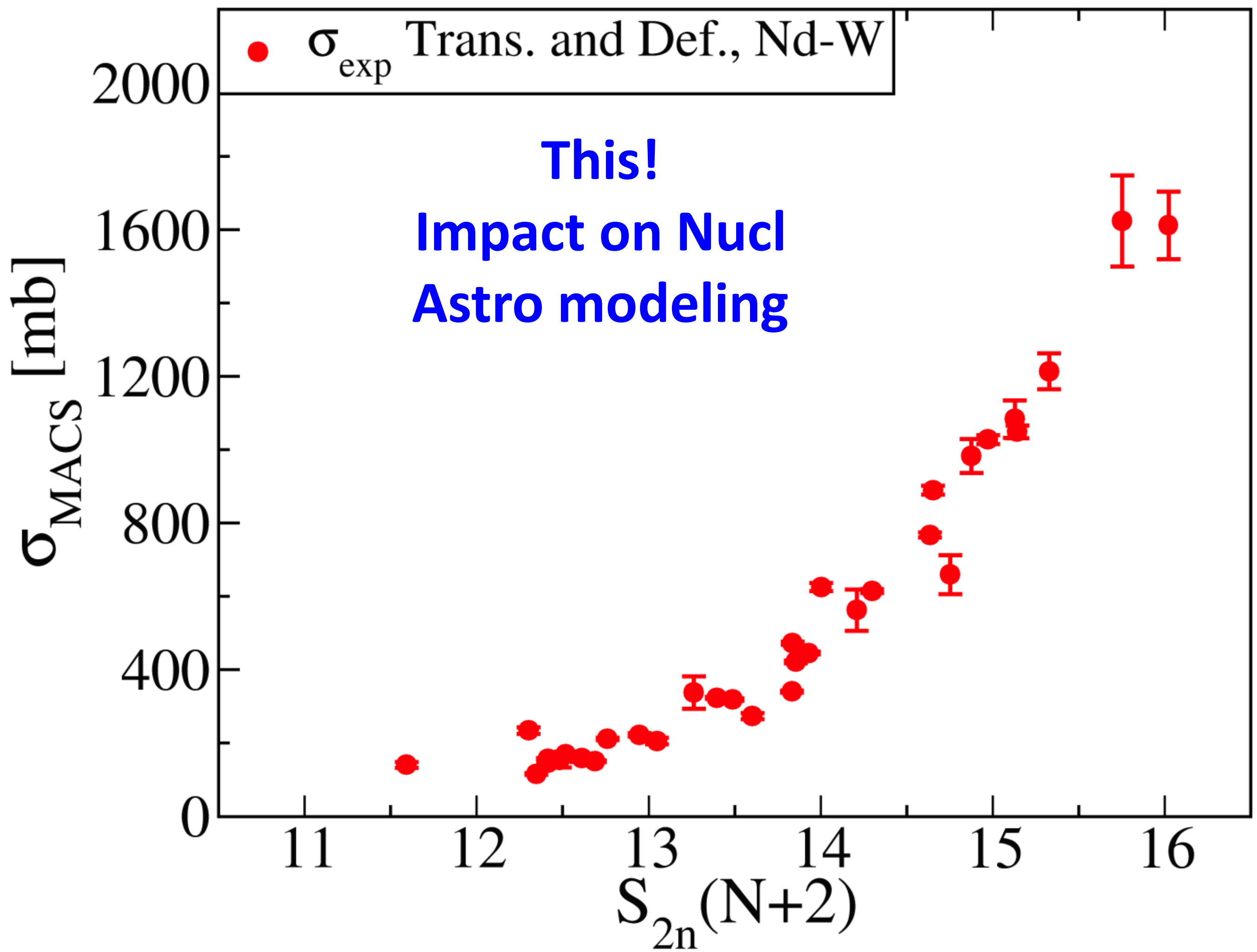




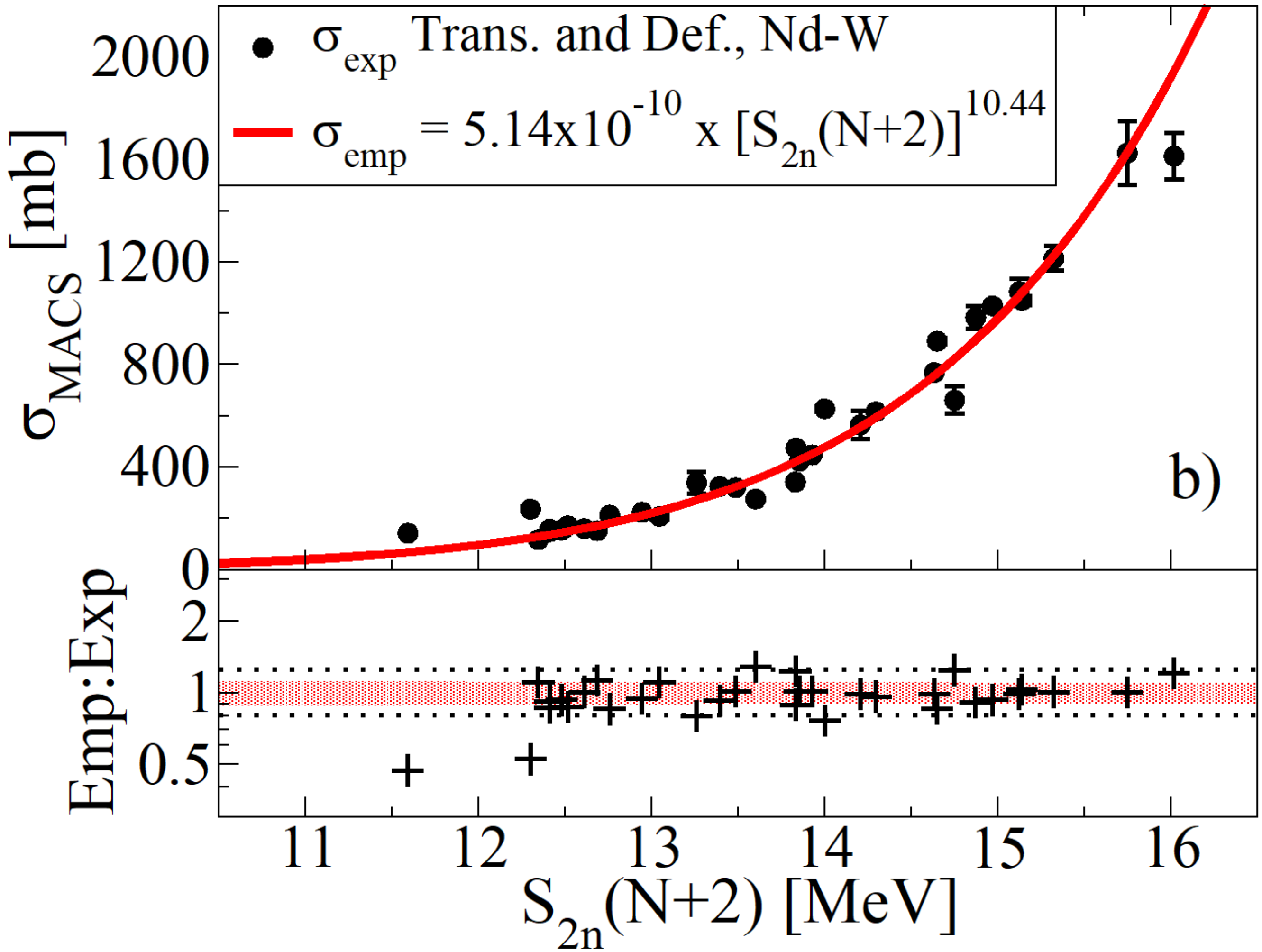
a)
Plot against S_{2n} instead: This plot becomes...
σ_{MACS}(mb)
Neutron Number
0
500
1000
1500
82
88
94
100
106
112
118
124
Xe
Ba
Ce
Nd
Sm
Gd
Dy
Er
Yb
Hf
W
Os
Pt
Hg
Pb

Neutron capture MACS at 30 keV vs. S_{2n} (N + 2)

Bring together 3 physicists, one who knows cross sections and two who know masses:



Use these correlations to predict unknown cross sections



$$\Delta\sigma = [S2n\ (N+2)]^{9.44}\{(4.33\times10^{-21})\ [S_{2n}\ (N+2)]^{2} - (6.89\times10^{-20})\ S_{2n}(N+2) + 6.89\times10^{-19}\}^{1/2}$$

The Path to Symmetry

Regularity out of chaos

→ Patterns

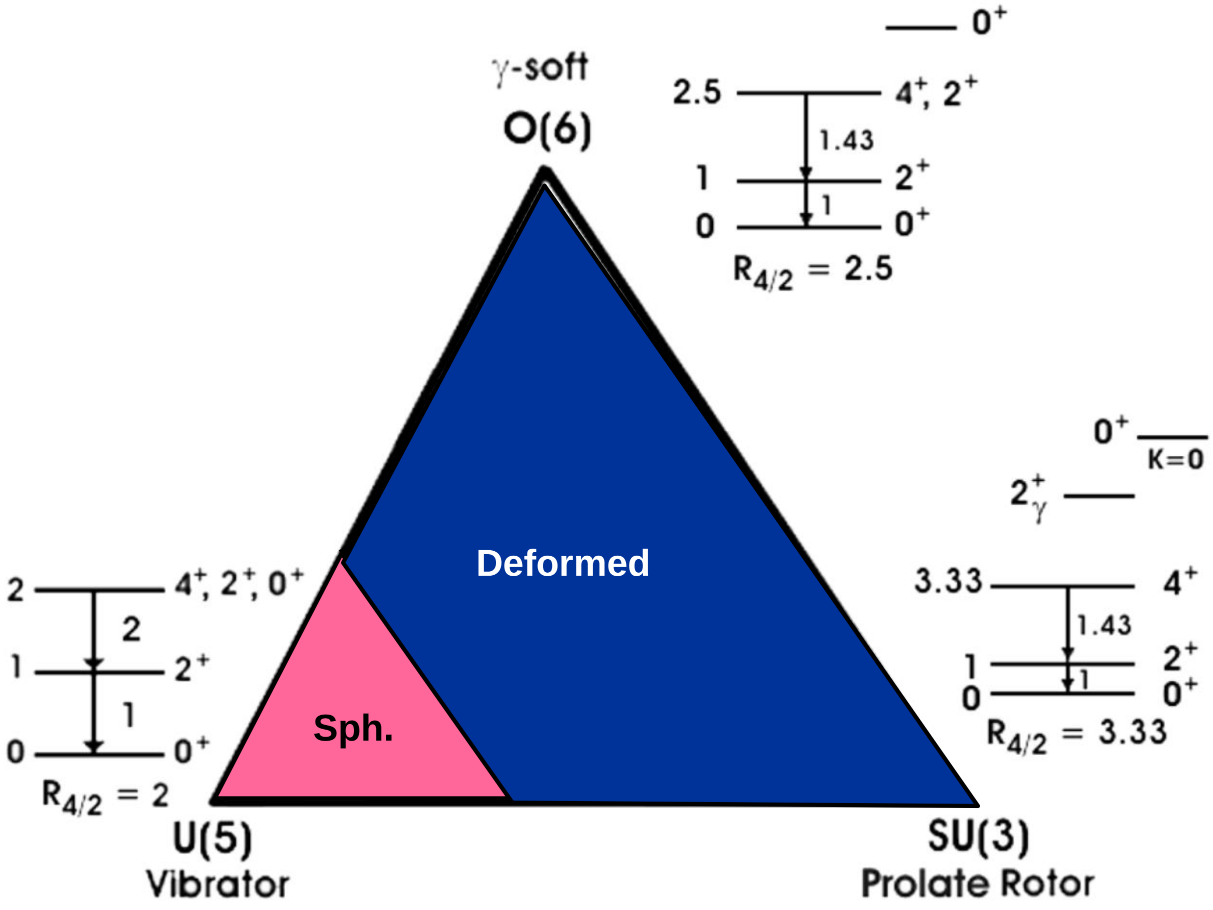
→ Simple interpretations

→ Geometry

→ Symmetries – Quantum numbers

→ Algebra

The IBM, not too shabby!!



The value and challenge of alternate perspectives in comparing models with the data

Comparing models

All give similar predictions ! Why?

Pure bands: Sep. Intr, Rot DoF

Eff. mixing through γ using Davydov

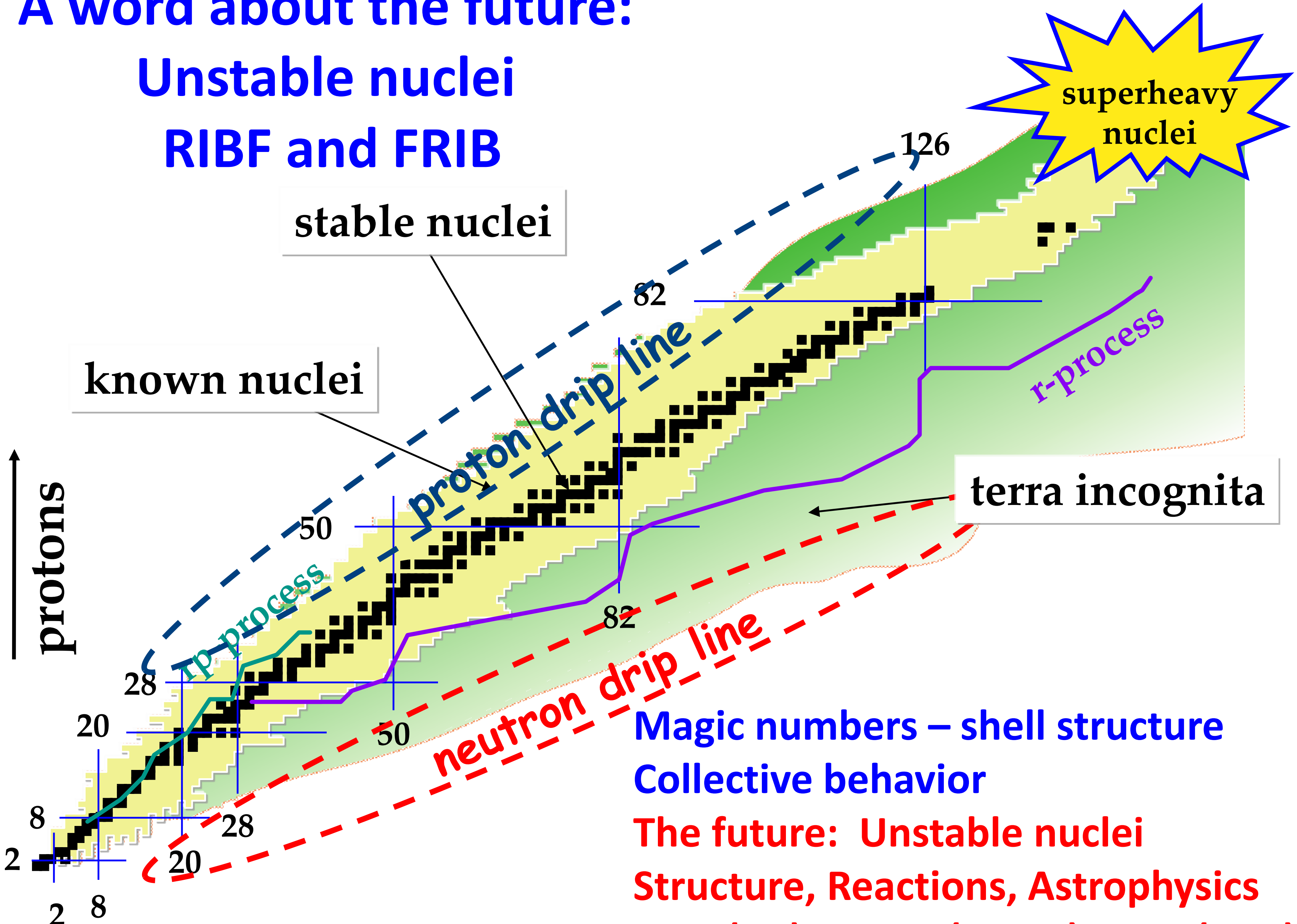
K mixing IBA

No mixing. Finite N

γ To Grd Rel. B(E2)s

$J_{initial}$	J_{final}	^{168}Er-EXP	Alaga	Zg=0.035	CQF	Proxy	PDS
2_g	0^+	56.2(11)	70	56.9	54	52.9	64.3
	2^+	100	100	100	100	100	100
	4^+	7.3(4)	5	7.6	8	8.5	6.3
3_g	2^+	100	100	100	100	100	100
	4^+	62.6(14)	40	62.9	69	73	49.3
4_g	2^+	19.3(4)	34	20.2	18	16.4	28.1
	4^+	100	100	100	100	100	100
	6^+	13.1(12)	8.6	16	16	18.7	12.5
5_g	4^+	100	100	100	100	100	100
	6^+	123(14)	57.1	117	125	147.7	79.6
6_g	4^+	11.2(10)	26.9	11	9	7.4	20.3
	6^+	100	100	100	100	100	100
	8^+	37.6(72)	10.6	23.6	20	27.9	18

A word about the future:
Unstable nuclei
RIBF and FRIB



From FRIB

Magic numbers – shell structure

Collective behavior

The future: Unstable nuclei

Structure, Reactions, Astrophysics

FRIB (US), RIKEN (Japan), FAIR (Ger.)

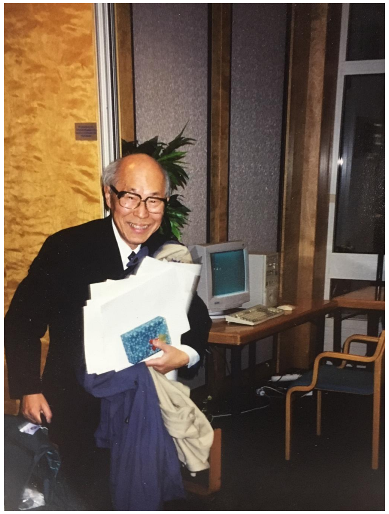
Conclusions / Congratulations, Akito

Different perspectives, simple patterns, symmetries: Have revealed so much about nuclei, influenced generations.

Do not look at nuclei (or other systems) only through your favorite paradigm, or model.

The IBM: Inspiration for half of Akito's life.

Congratulations, Akito
What an amazing career, and life !!



BACKUPS

Ditto – semi-log plot