

Enhanced proton-neutron interactions and emergent collectivity in nuclei

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and Dennis Bonatsos

INPP, NCSR Demokritos

How do regular and simple patterns emerge
in the structure of complex nuclei?

(NuPECC Long Range Plan 2010)

new coupling scheme

PHYSICAL REVIEW C **88**, 054309 (2013)

**Emergent collectivity in nuclei and enhanced
proton-neutron interactions**

D. Bonatsos, S. Karampagia,

R. B. Cakirli (Istanbul),

R. F. Casten (Yale), K. Blaum (MPI Heidelberg),

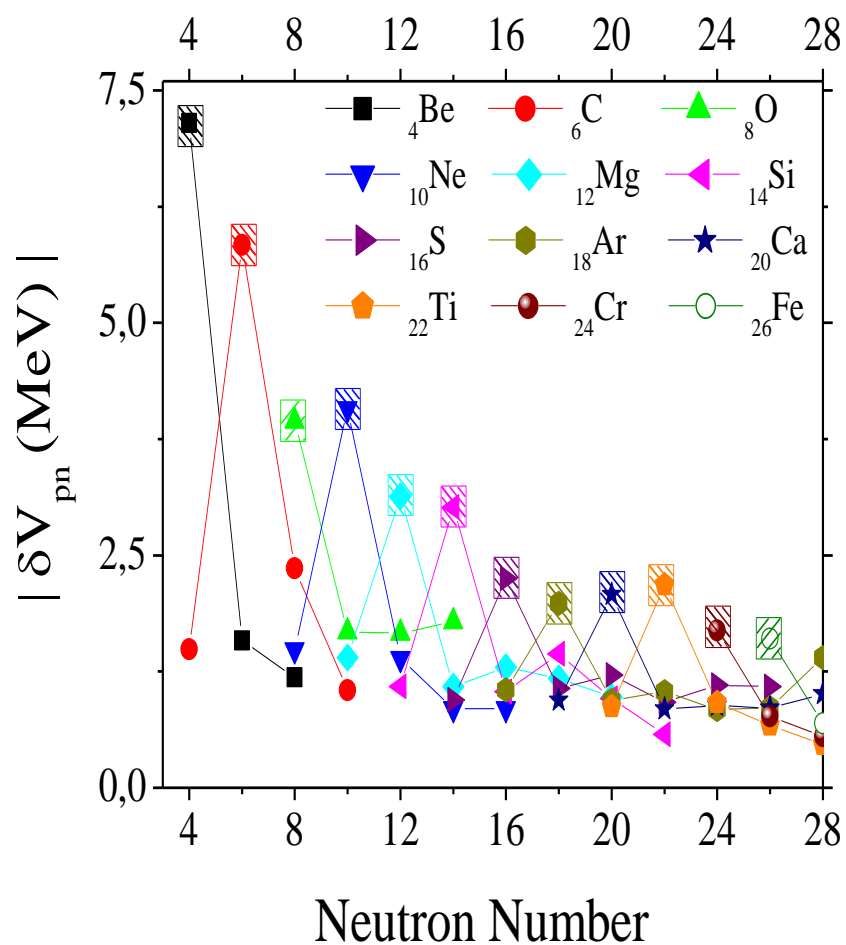
L. Amon Susam (Istanbul)

Starting point:

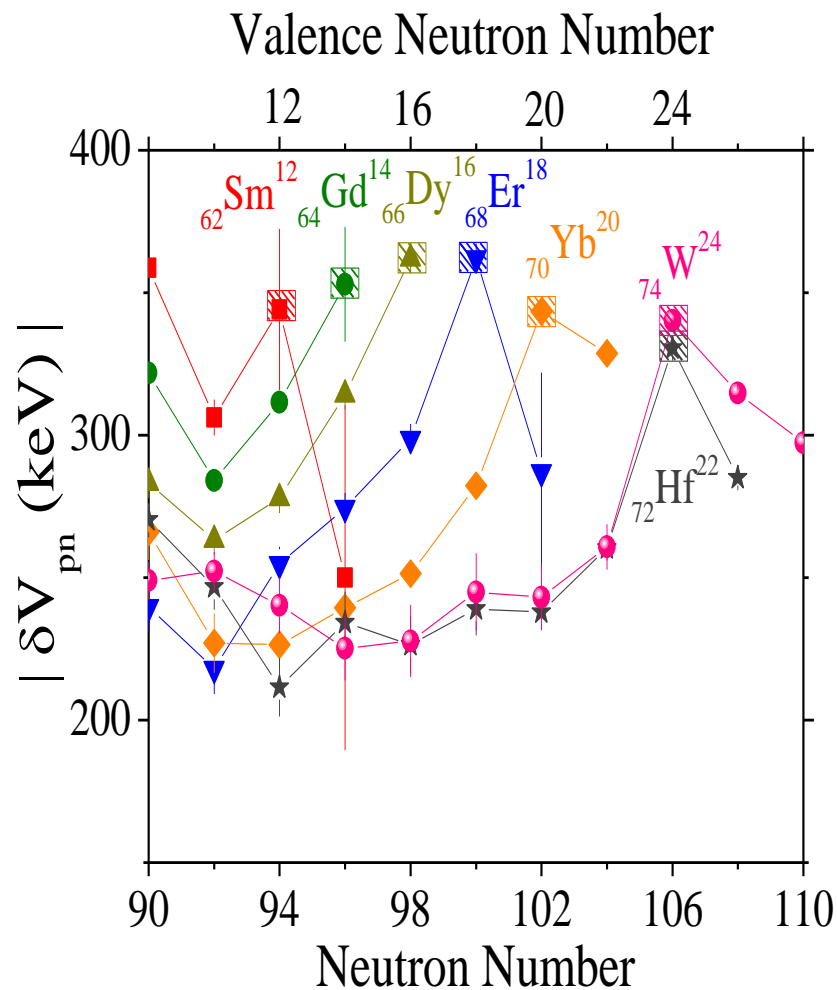
Athens, Dionyssos, October 2010

$$\delta V_{pn}(Z,N) = (B(Z,N) - B(Z,N-2) - B(Z-2,N) + B(Z-2,N-2)) / 4$$

light nuclei
spikes at N=Z



heavy nuclei
spikes at Nval=Zval



- Light nuclei
SU(4) Wigner supermultiplet
(T=1, S=0) and (T=0, S=1) pairs
- Heavy nuclei
Nilsson 0[1 10] pairs
 ΔK [ΔN Δn_z $\Delta \Lambda$]

δV_{pn} peaks

	Z	N	last protons	last neutrons
168Er	68	100	7/2[523]	7/2[633]
172Yb	70	102	1/2[411]	1/2[521]
178Hf	72	106	7/2[404]	7/2[514]
180W	74	106	7/2[404]	7/2[514]
			K[N Nz Λ]	S=1

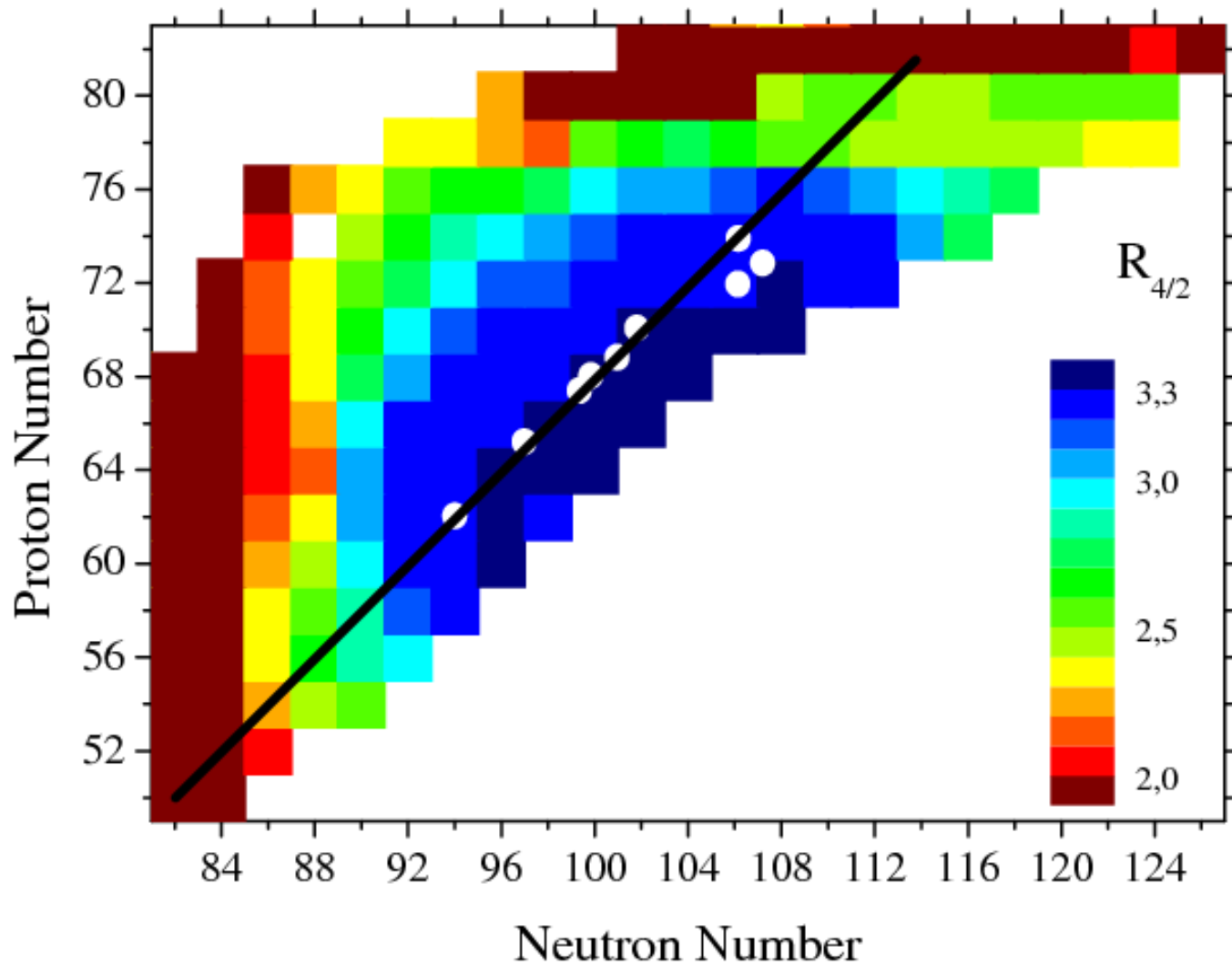
Rick Casten
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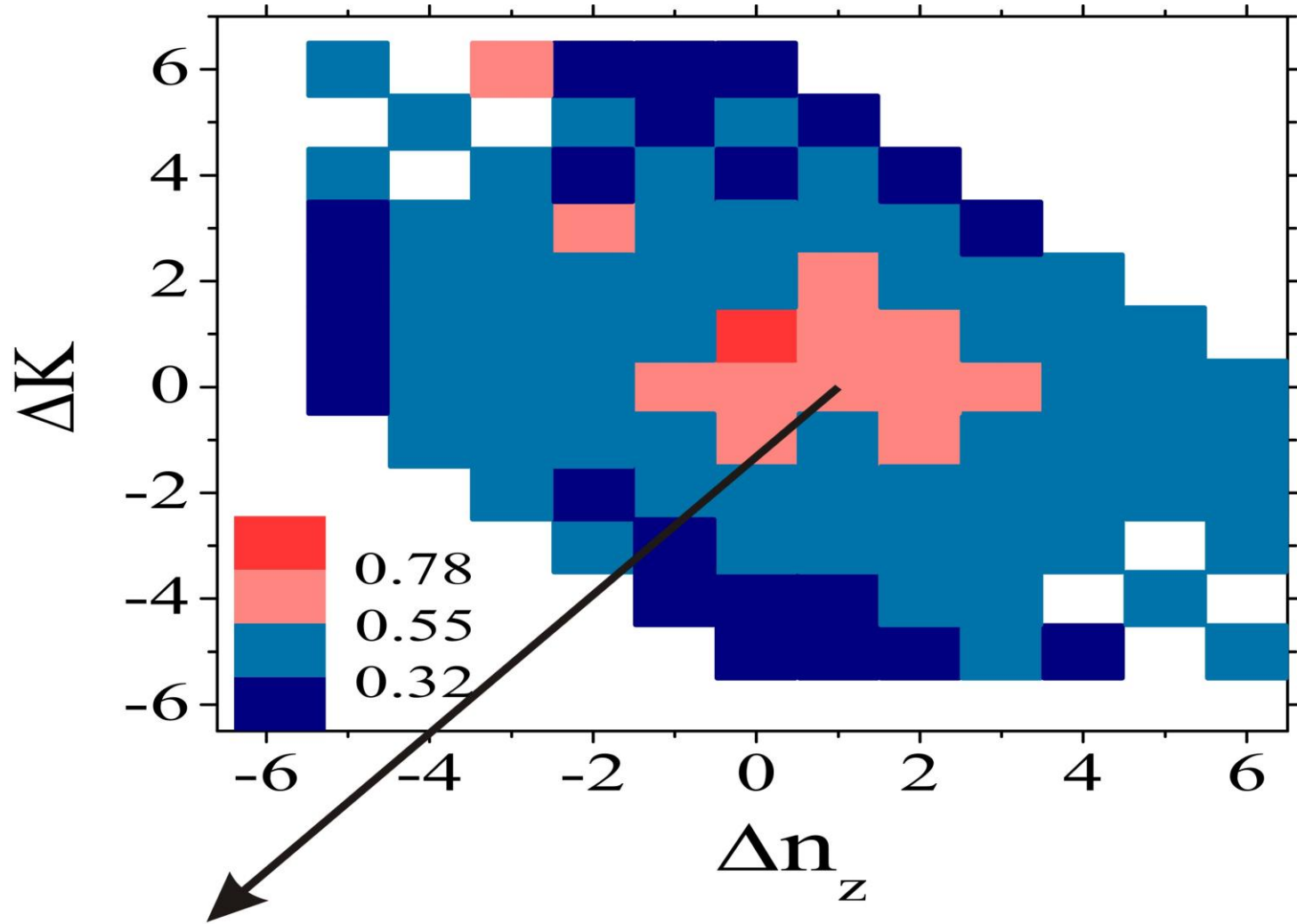
Burcu Cakirli
Istanbul U.



$$R_{4/2} = E(4)/E(2)$$

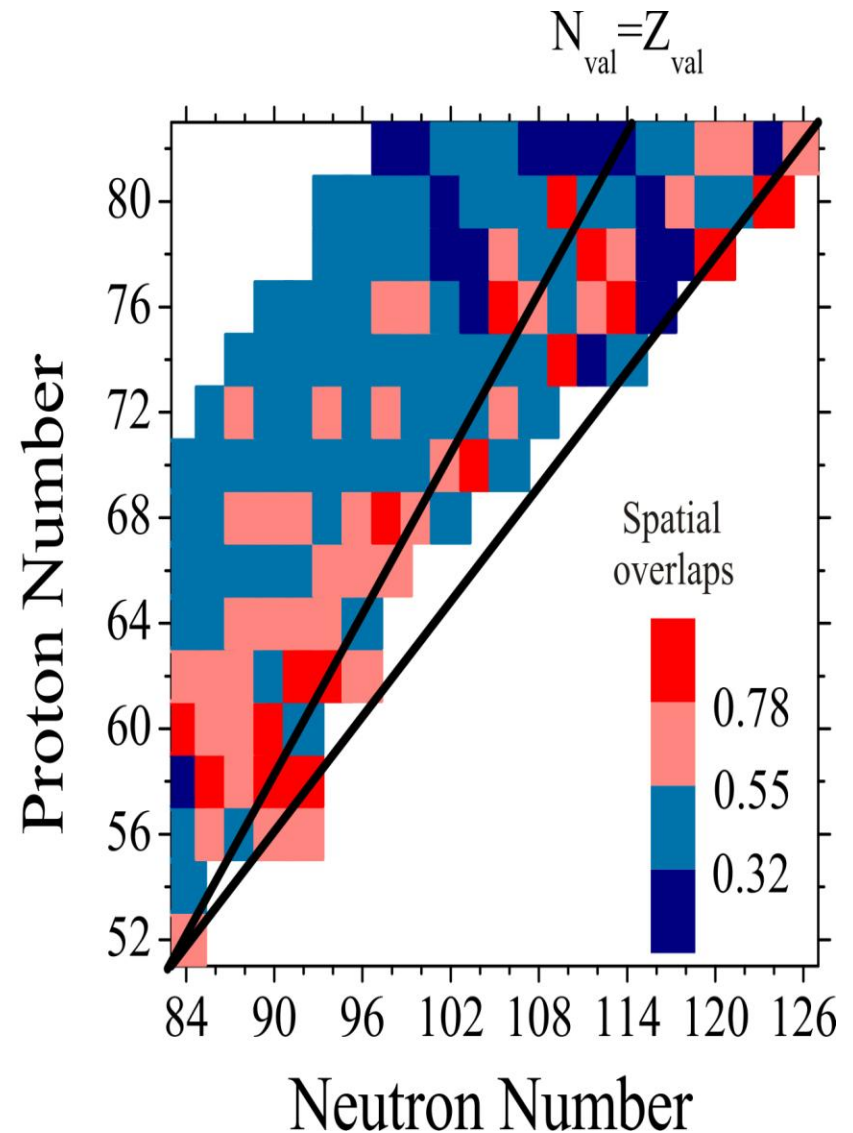
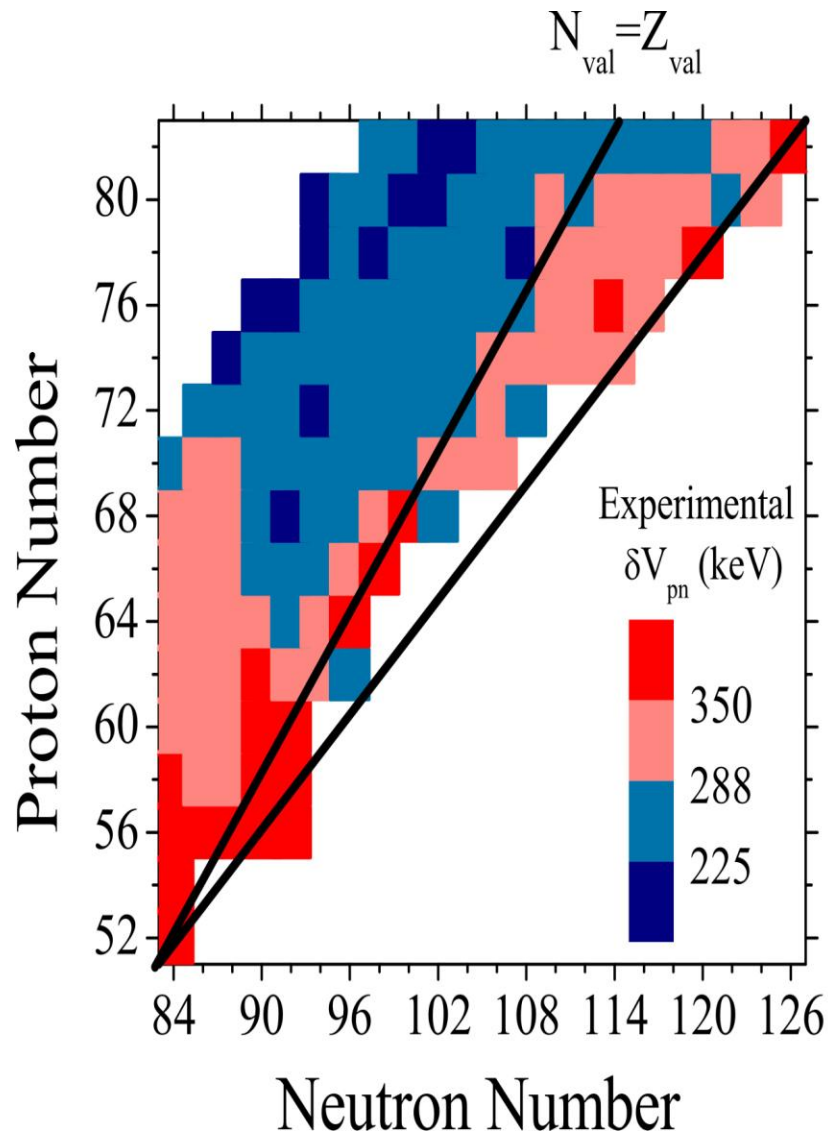


Nilsson model overlaps

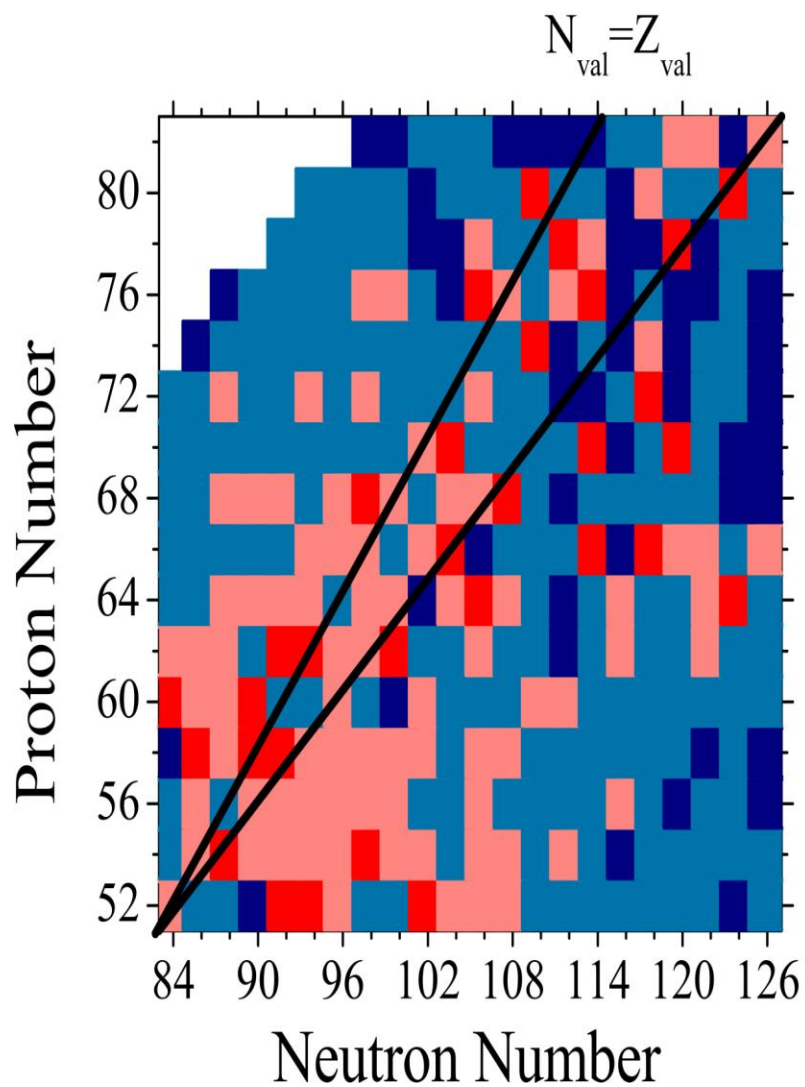


$\Delta K[\Delta N \ \Delta n_z \ \Delta \Lambda] = 0[110]$ pairs

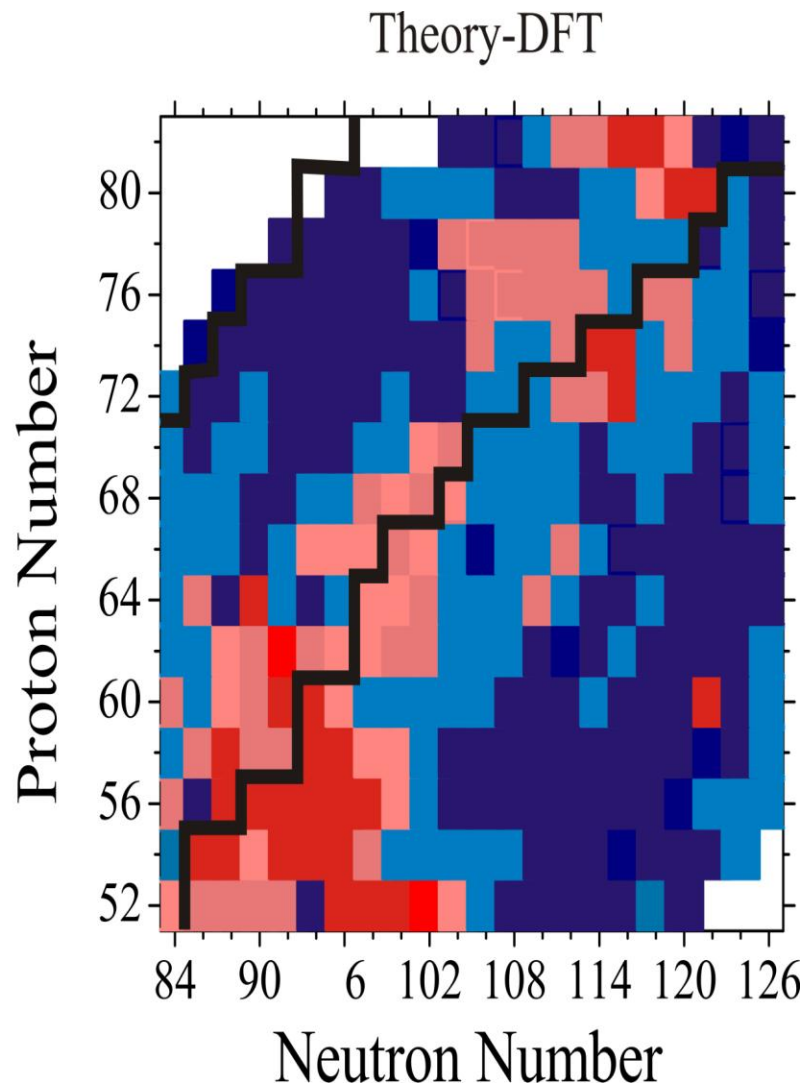
Nilsson model overlaps



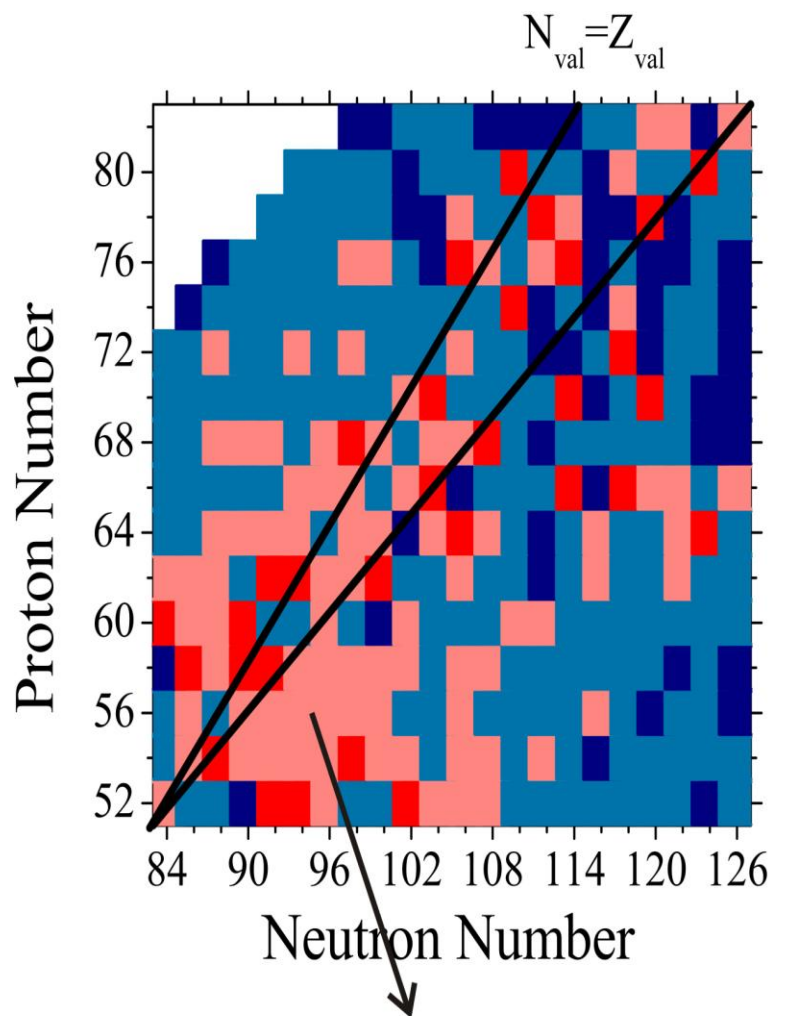
Nilsson



DFT

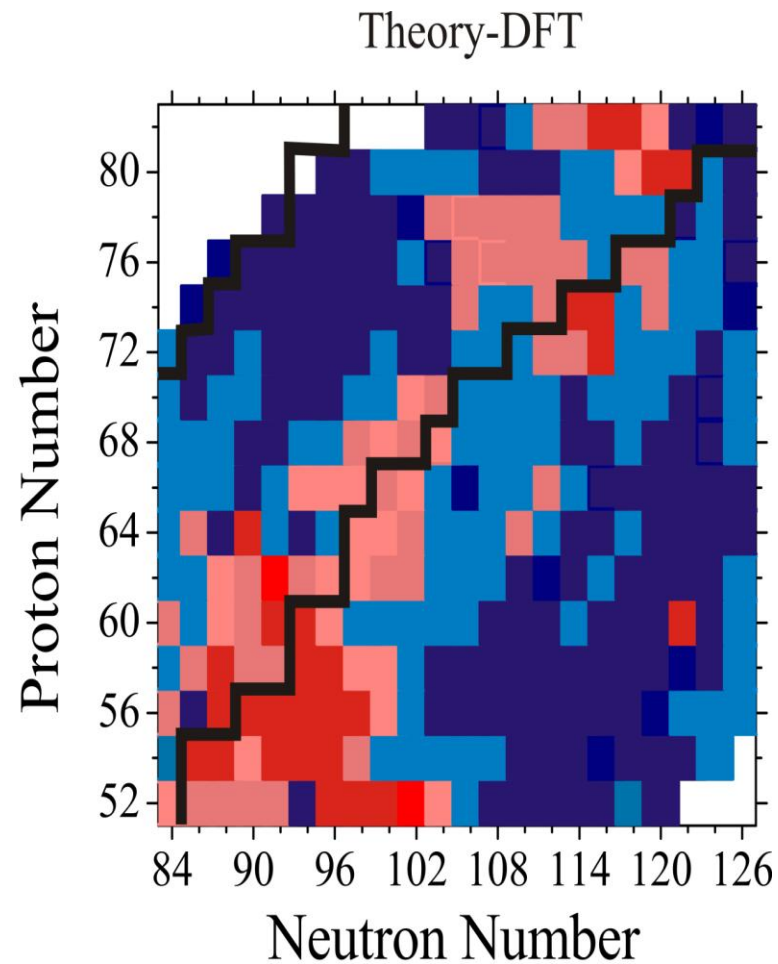


Nilsson

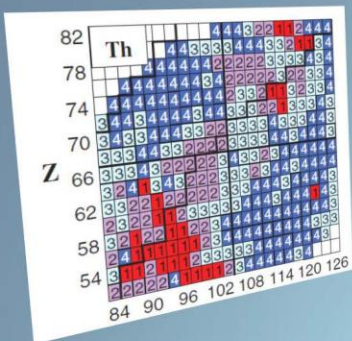


S=0 (antiparallel spin projection)

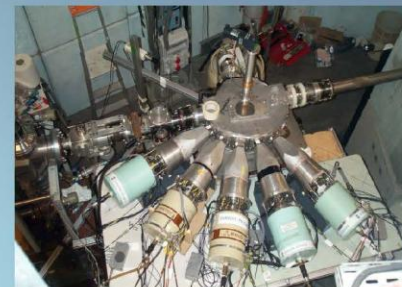
DFT



Mario Valentinov Stoitsov (1953-2011)



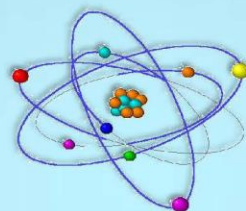
XX International School on Nuclear Physics, Neutron Physics and Applications September 16 - 22, 2013 Varna, Bulgaria



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Main Topics

- ✓ Nuclear excitations at various energies
- ✓ Nuclei at high angular moments and temperature
- ✓ Structure and reactions far from stability
- ✓ Symmetries and collective phenomena
- ✓ Methods for lifetime measurements
- ✓ Astrophysical aspects of nuclear structure
- ✓ Neutron nuclear physics
- ✓ Nuclear data
- ✓ Advanced methods in nuclear waste treatment
- ✓ Nuclear methods for applications

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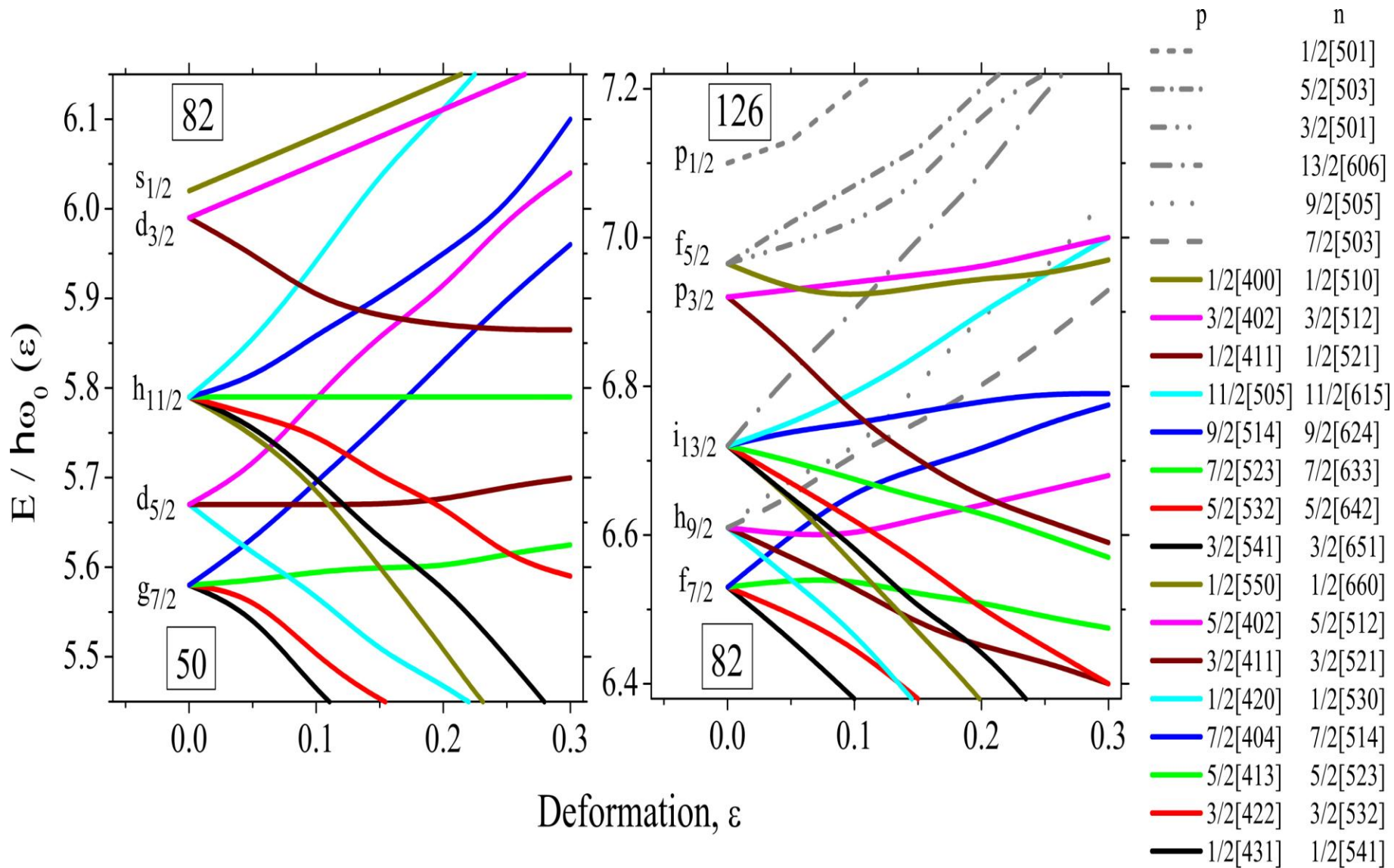
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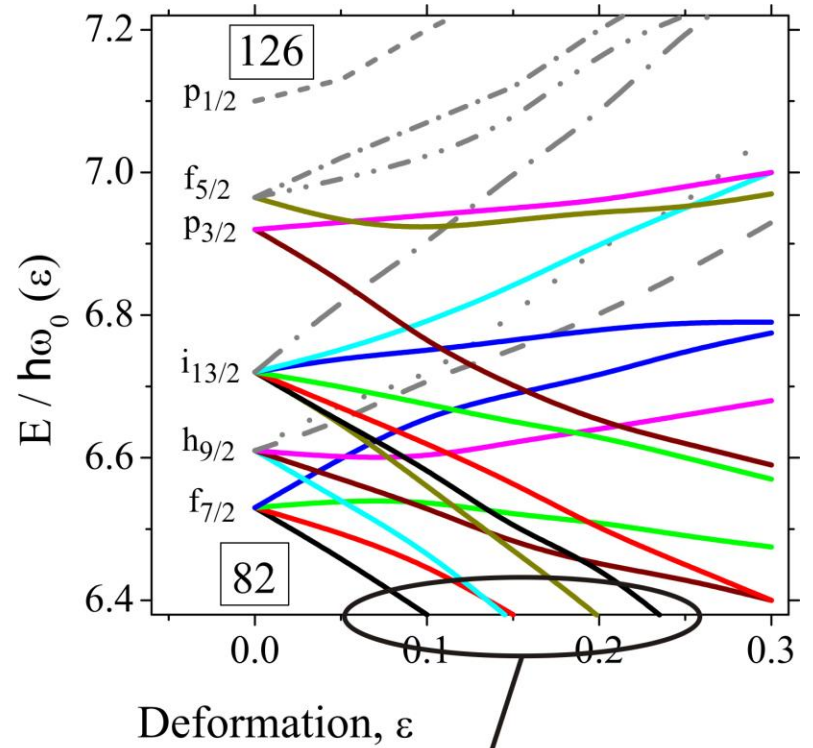
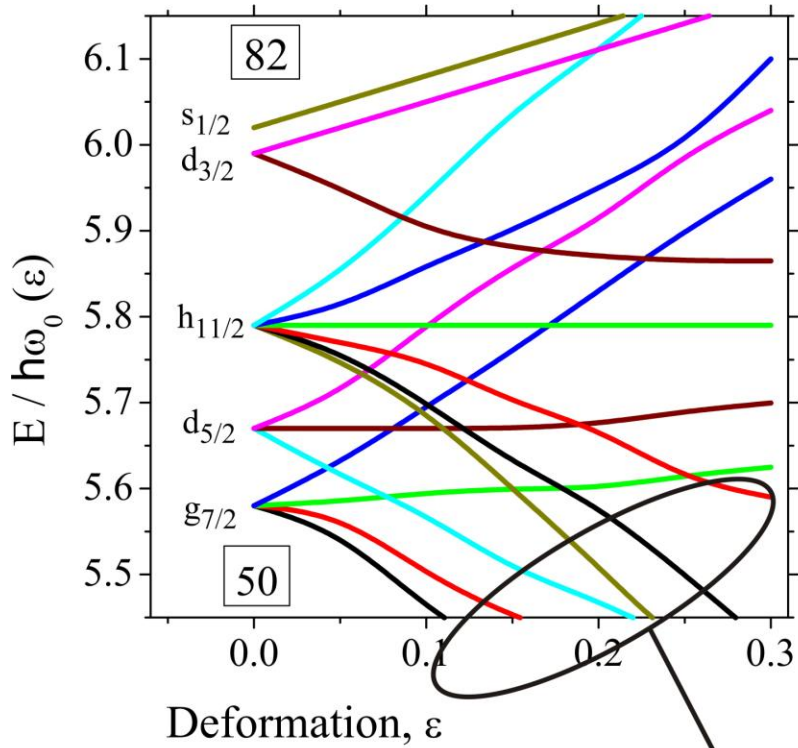
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Nilsson level scheme



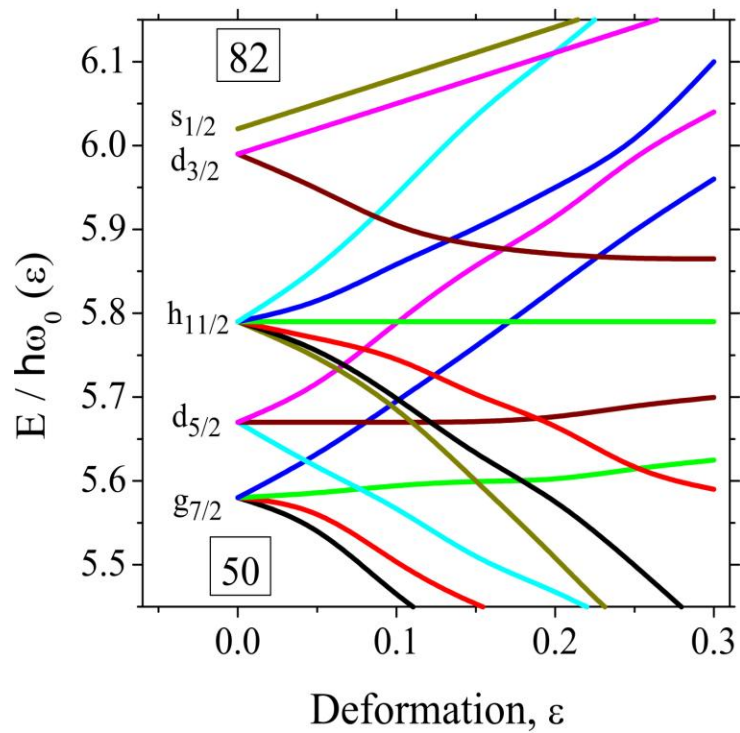
^{154}Sm : 12 valence protons
10 valence neutrons



12 valence protons
sit in the (24,0) irrep of U(15)

10 valence neutrons
sit in the (30,4) irrep of U(21)

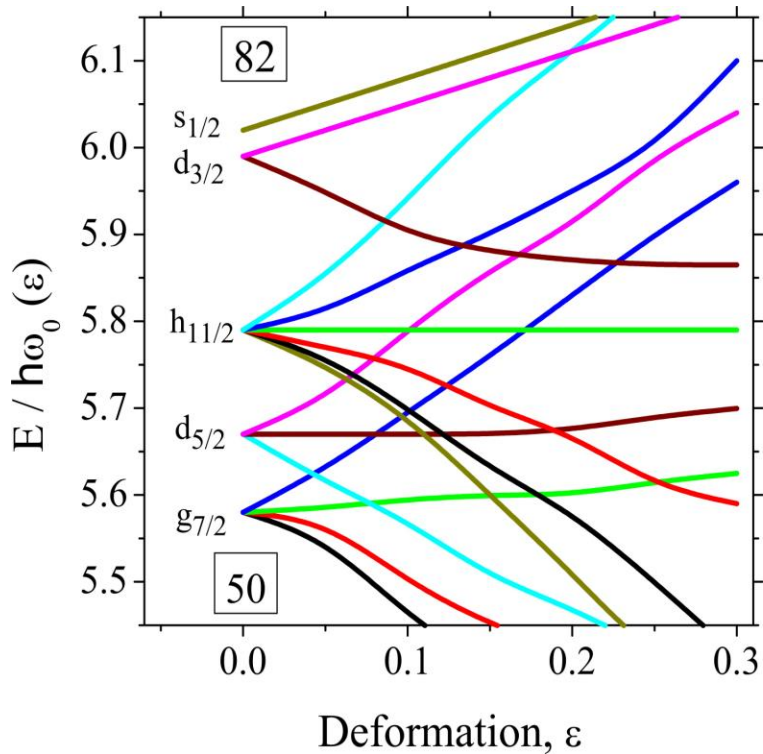
(54,4) irrep for all valence nucleons



0[110] partners

left out

50-82	50-82	sdg	sdg
3s1/2	1/2[411]	3s1/2	1/2[411]
2d3/2	1/2[400]	2d3/2	1/2[400]
	3/2[402]		3/2[402]
2d5/2	1/2[431]	2d5/2	1/2[431]
	3/2[422]		3/2[422]
	5/2[413]		5/2[413]
1g7/2	1/2[420]	1g7/2	1/2[420]
	3/2[411]		3/2[411]
	5/2[402]		5/2[402]
	7/2[404]		7/2[404]
1h11/2	1/2[550]	1g9/2	1/2[440]
	3/2[541]		3/2[431]
	5/2[532]		5/2[422]
	7/2[523]		7/2[413]
	9/2[514]		9/2[404]
	11/2[505]		



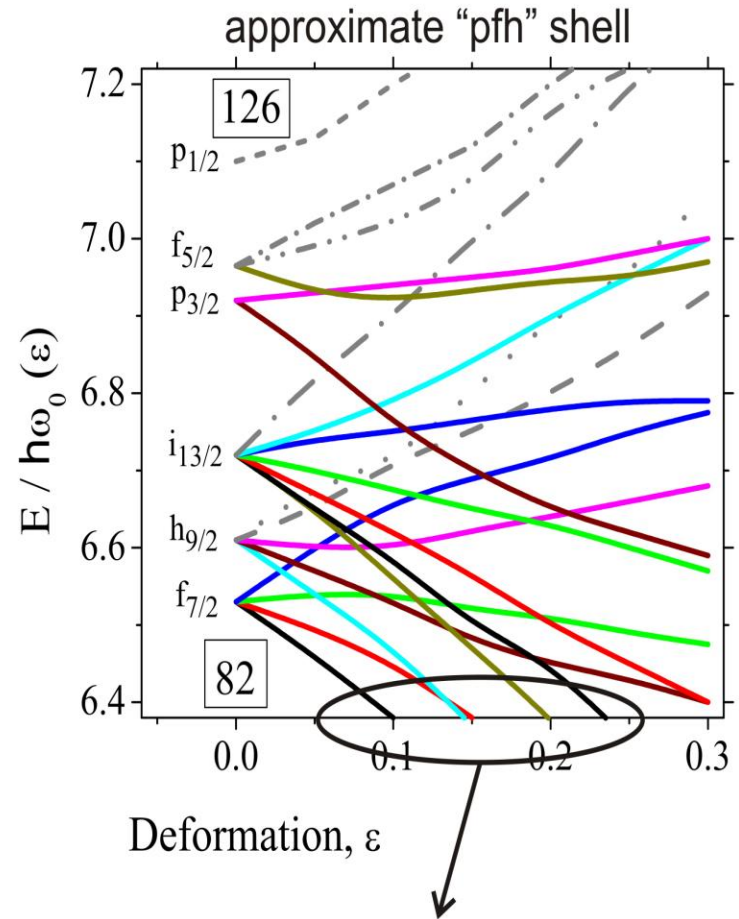
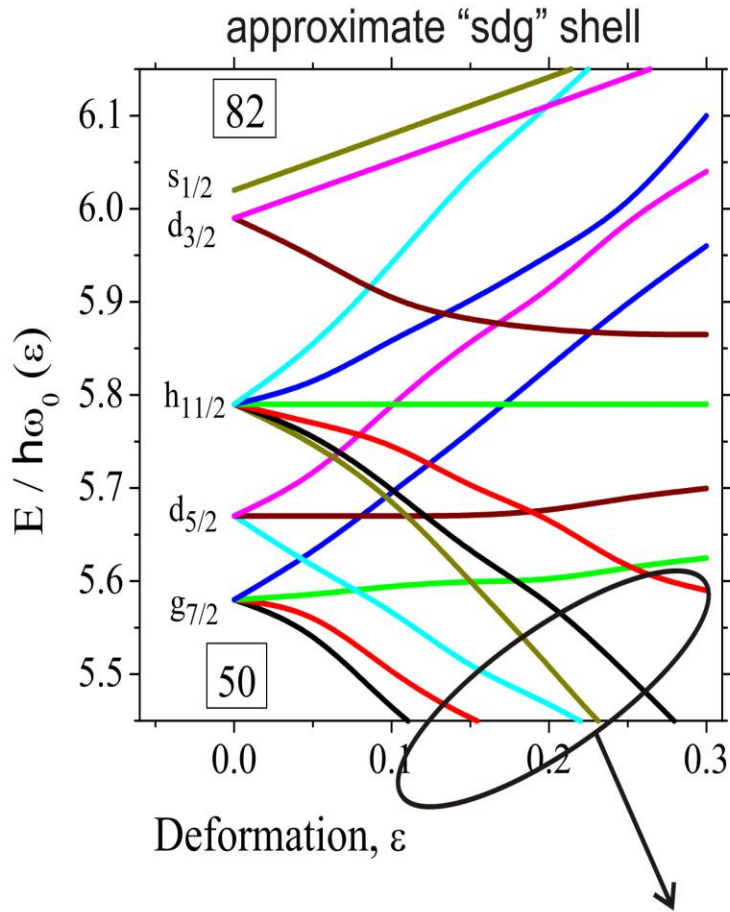
0[110] counterparts
 parity changes
 N changes by 1
 nz changes by 1
 K, Λ , Σ same

left out

50-82 shell mapped onto an
 sdg shell with $U(15) \supset SU(3)$

50-82	50-82	sdg	sdg
3s1/2	1/2[411]	3s1/2	1/2[411]
2d3/2	1/2[400]	2d3/2	1/2[400]
	3/2[402]		3/2[402]
2d5/2	1/2[431]	2d5/2	1/2[431]
	3/2[422]		3/2[422]
	5/2[413]		5/2[413]
1g7/2	1/2[420]	1g7/2	1/2[420]
	3/2[411]		3/2[411]
	5/2[402]		5/2[402]
	7/2[404]		7/2[404]
1h11/2	1/2[550]	1g9/2	1/2[440]
	3/2[541]		3/2[431]
	5/2[532]		5/2[422]
	7/2[523]		7/2[413]
	9/2[514]		9/2[404]
	11/2[505]		

^{154}Sm : 12 valence protons
10 valence neutrons



12 valence protons in the [222222] irrep of U(15)

(24,0) most leading SU(3) irrep of U(15)

SU(3) irreps labelled (λ, μ)

× 10 valence neutrons in the [22222] irrep of U(21) >

× (30,4) most leading SU(3) irrep of U(21) >

(54,4) irrep for all valence nucleons

He was very happy that there are still theorists for whom theory is not just massively computational but, as he said, “has some brains behind it” rather than just running some massive black box code on a supercomputer. Of course, such approaches are also valuable (supercomputer, that is – we know, Mario’s DFT for example) but they should not be the only thing.

(APS DNP Meeting, Newport News, VA, 26-10-2013)

- New coupling scheme
for symmetry based calculations
- Different kinds of pairing
[($T=1, S=0$), ($S=1, T=0$)]
favored at different regions
of the nuclear chart

R.B. Cakirli: IUPAP Young Scientist Prize 2013

Reductions $U(N) \supset SU(3)$

$N=10, 15, 21, 28$

N. Minkov (INRNE, Sofia)

I. Assimakis (NTUA)

Hamiltonian

non-diagonal third, fourth order terms

conserving $SU(3)$

breaking β, γ degeneracy

7th Workshop on Shape-Phase Transitions and Critical Point Symmetries in Nuclei

March 10-13, 2014

Sevilla, Spain



NUBA-1, Adrasan-Antalya 15-22 September 2014



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*"Nuclear Structure Challenged
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D. Bucurescu (IFIN, Bucharest)	D. Karamanis (Darmstadt)
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