Enhanced proton-neutron interactions and emergent collectivity in nuclei

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

(NuPECC Long Range Plan 2010)

new coupling scheme

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Emergent collectivity in nuclei and enhanced proton-neutron interactions

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L. Amon Susam (Istanbul)

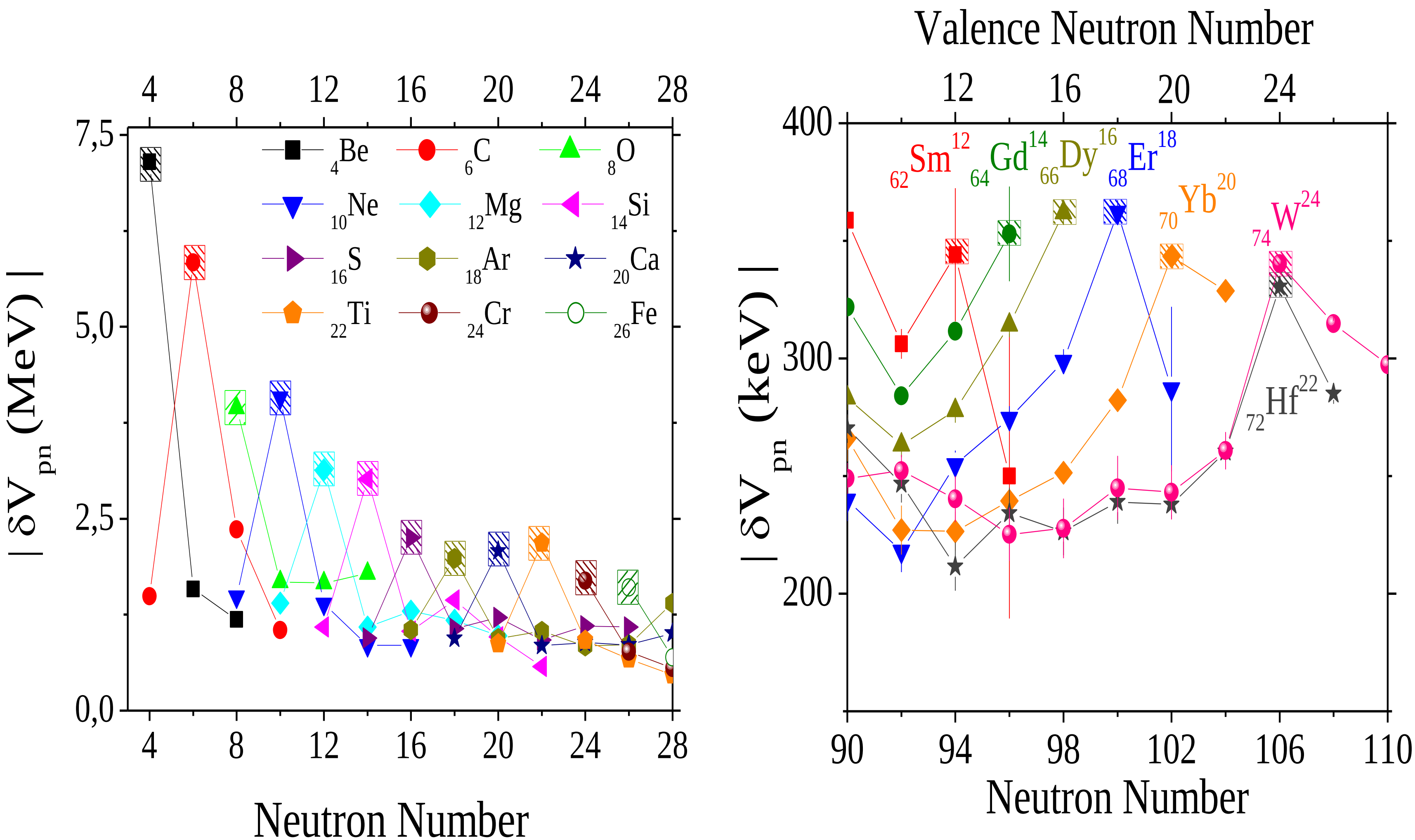
Starting point:

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[110] pairs

  $\Delta K\ [\Delta N\ \Delta n_z\ \Delta\Lambda]$

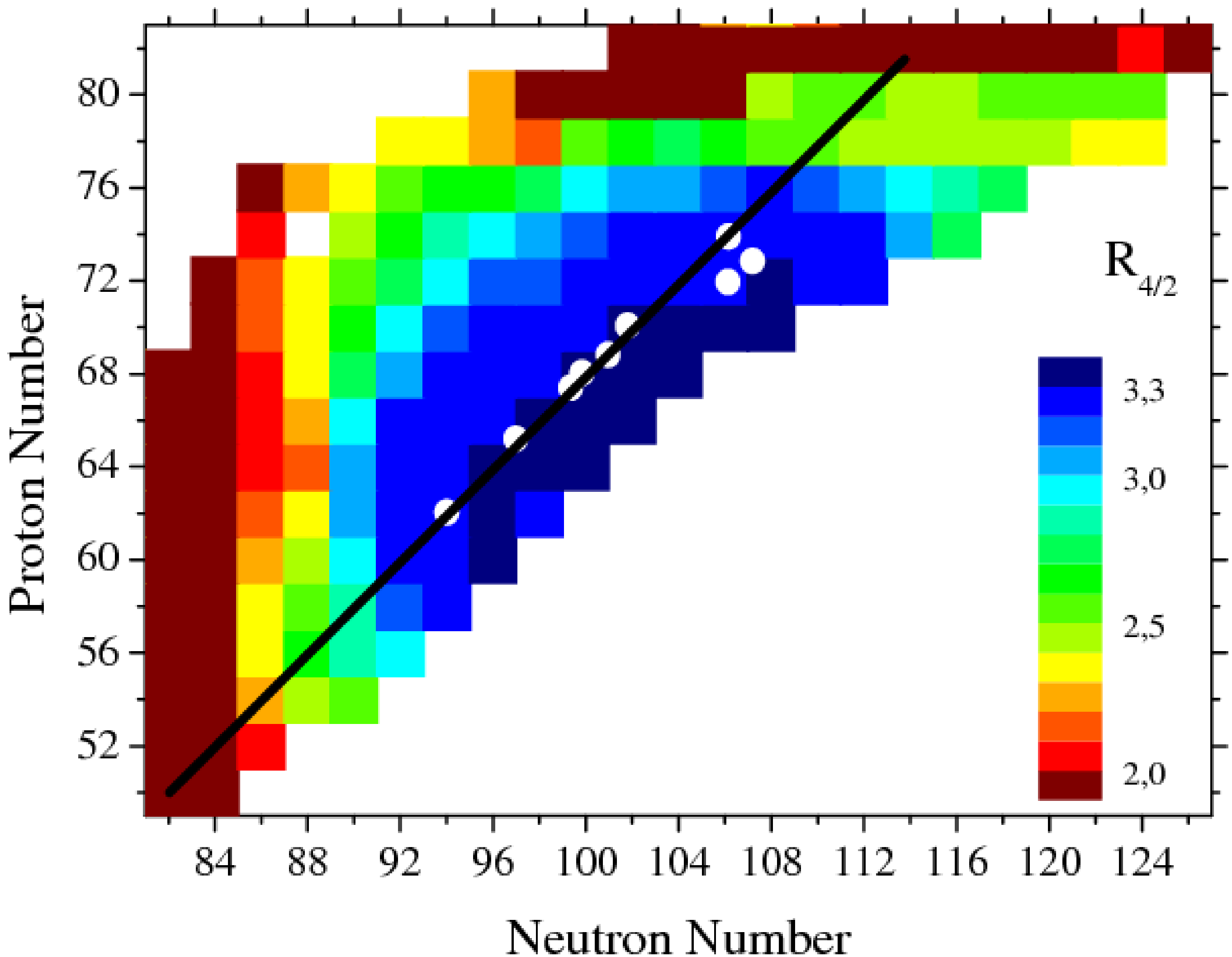
δVpn peaks

	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]
			$K[N\ N_z\ \Lambda]$	S=1

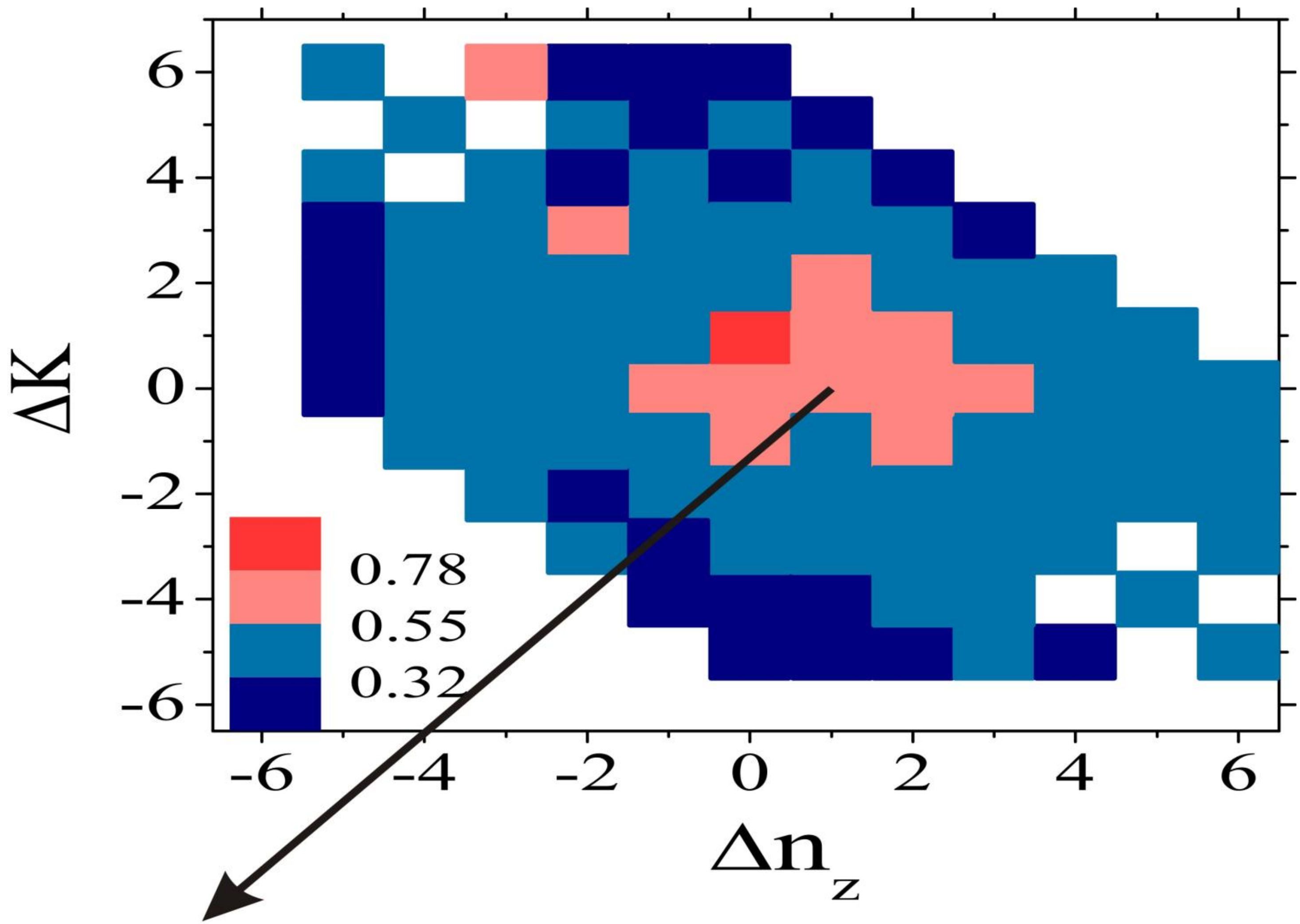
Rick Casten
Yale U.

Burcu Cakirli
Istanbul U.

R4/2=E(4)/E(2)

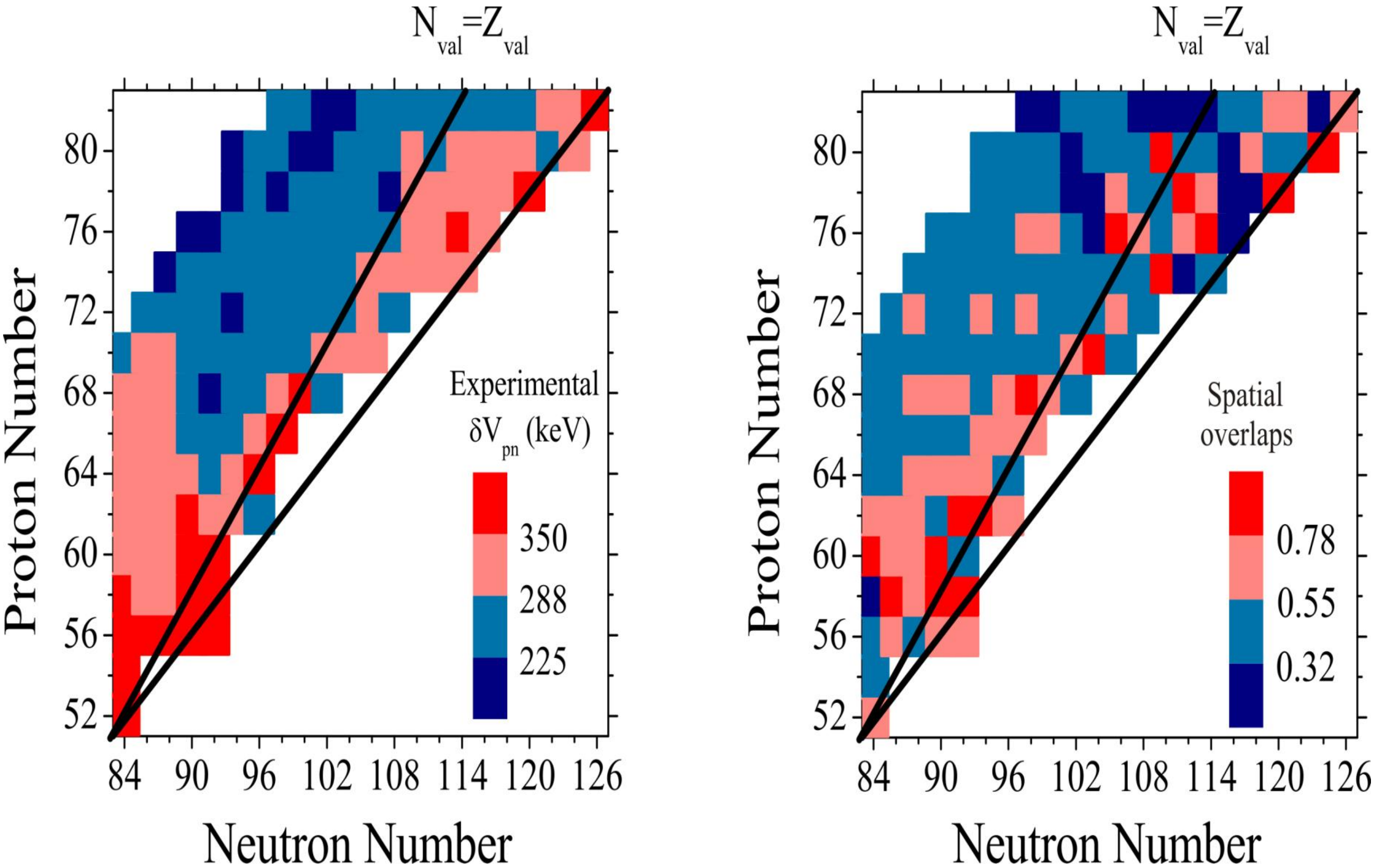

Proton Number
Neutron Number
$R_{4/2}$
3,3
3,0
2,5
2,0
52
56
60
64
68
72
76
80
84
88
92
96
100
104
108
112
116
120
124

Nilsson model overlaps



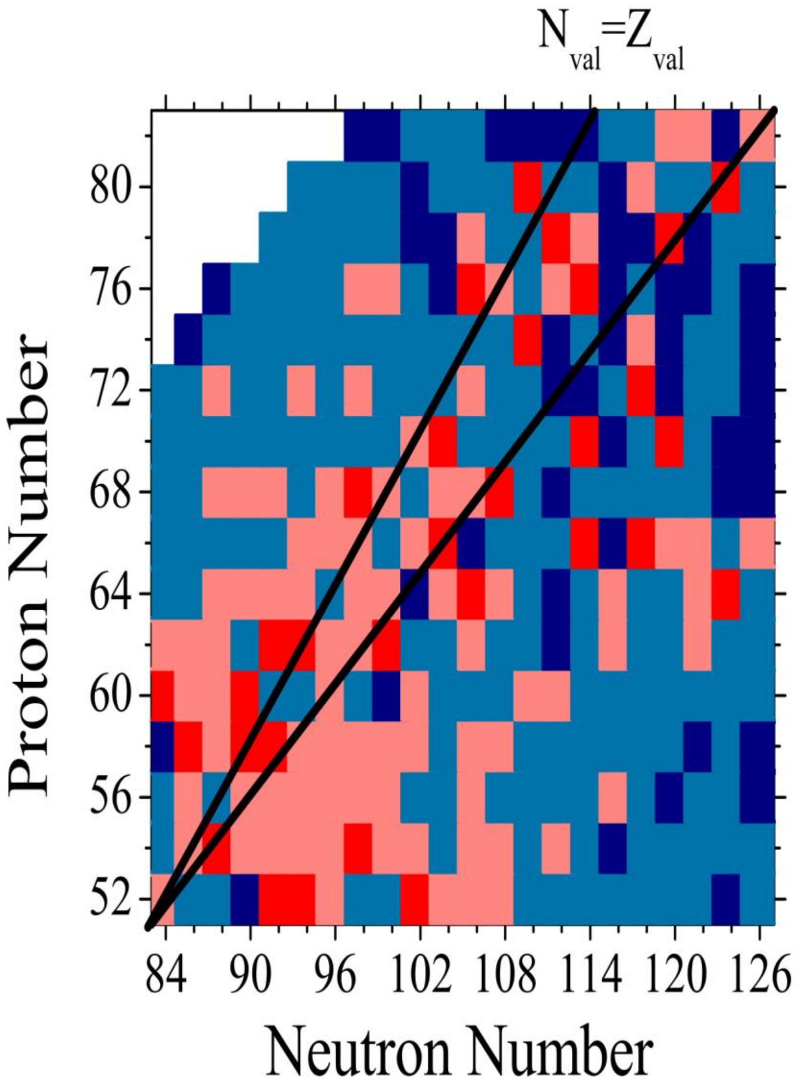
$\Delta K[\Delta N\ \Delta n_z\ \Delta\Lambda] = 0[110]$ pairs

Nilsson model overlaps

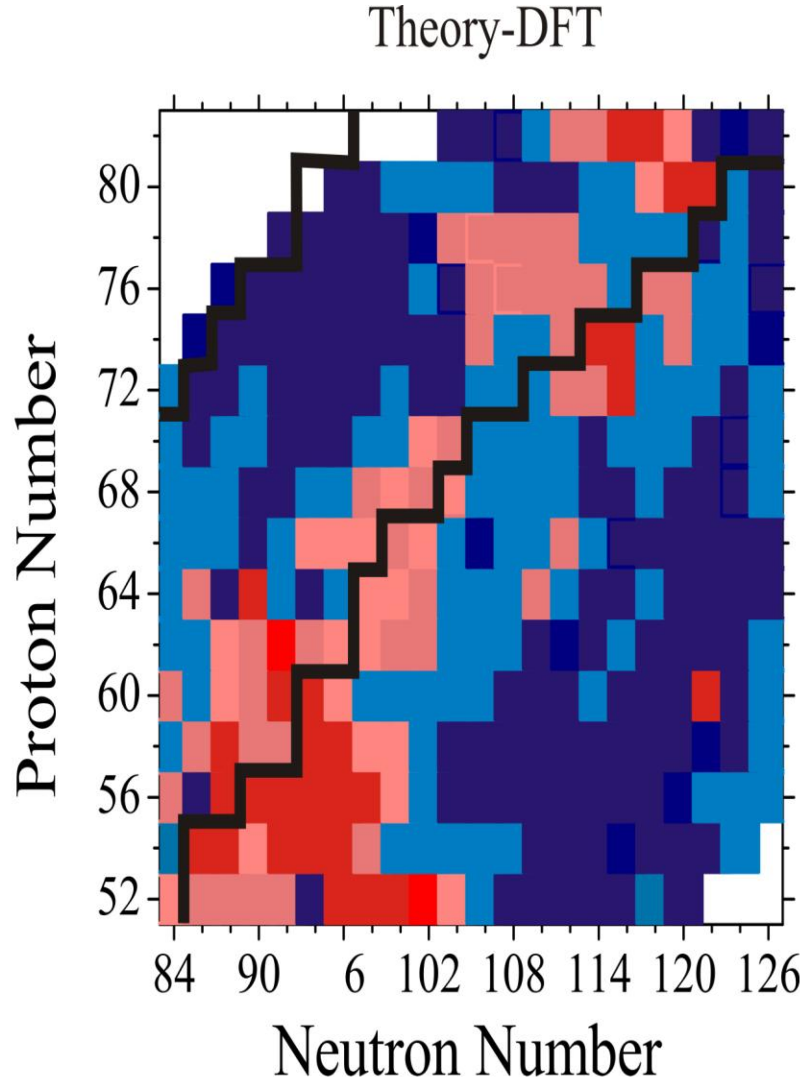


Nilsson

DFT



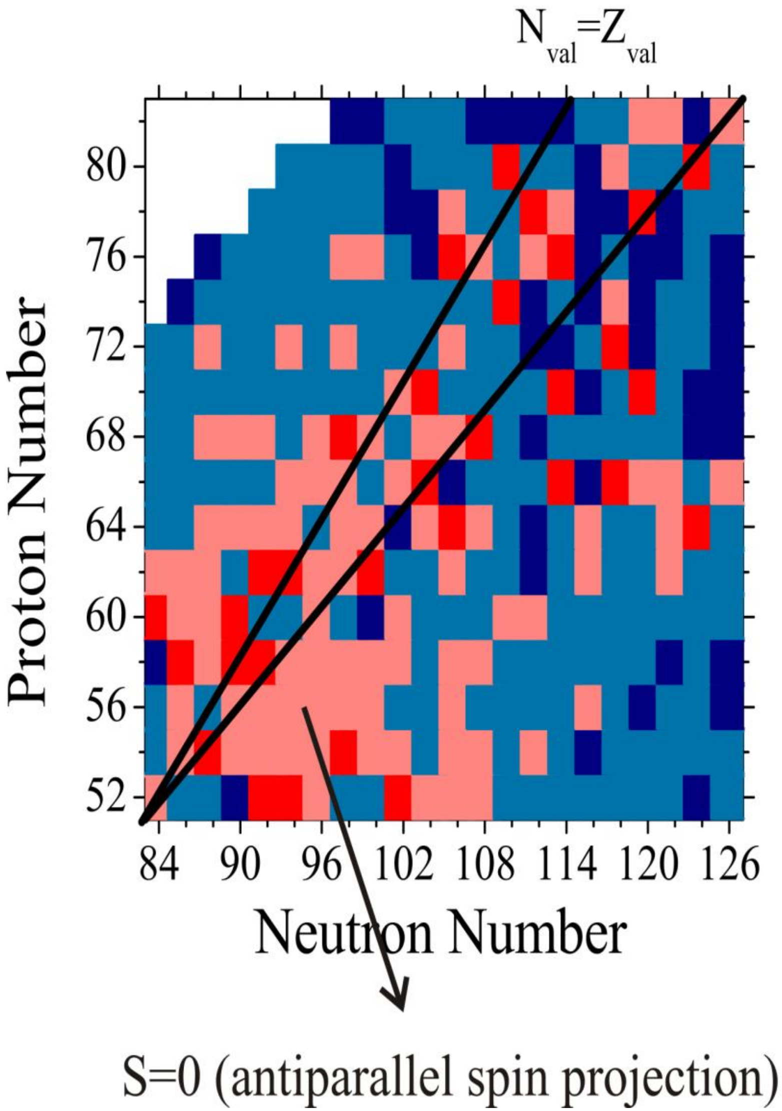
$N_{val}=Z_{val}$
Proton Number
80
76
72
68
64
60
56
52
84
90
96
102
108
114
120
126
Neutron Number

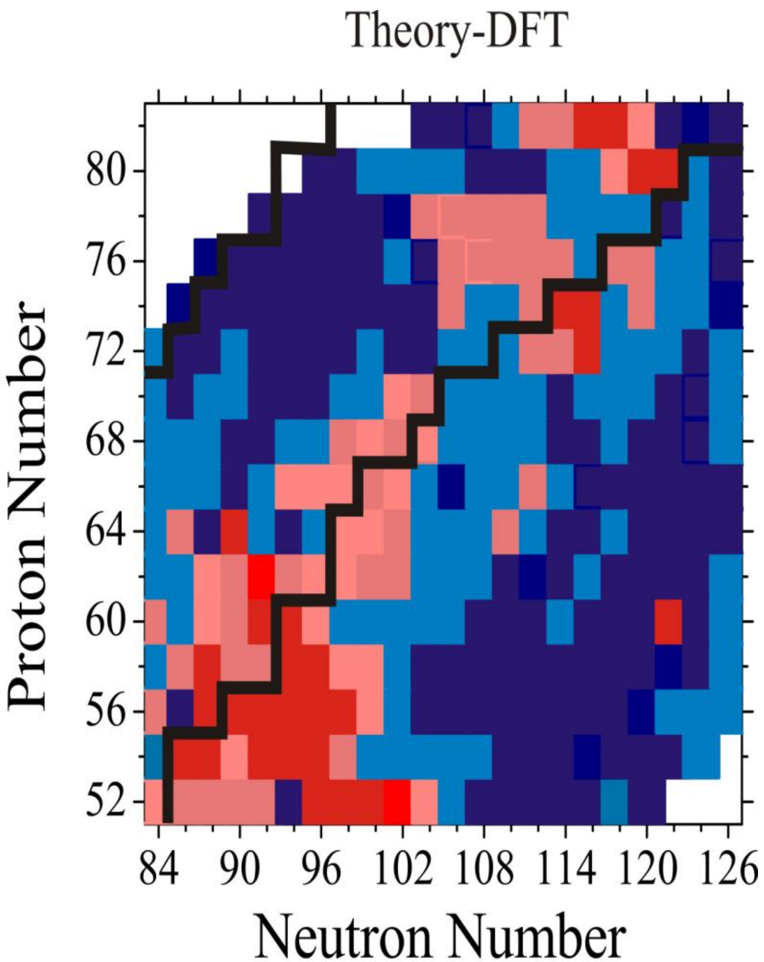


Theory-DFT
Proton Number
80
76
72
68
64
60
56
52
84
90
6
102
108
114
120
126
Neutron Number

Nilsson

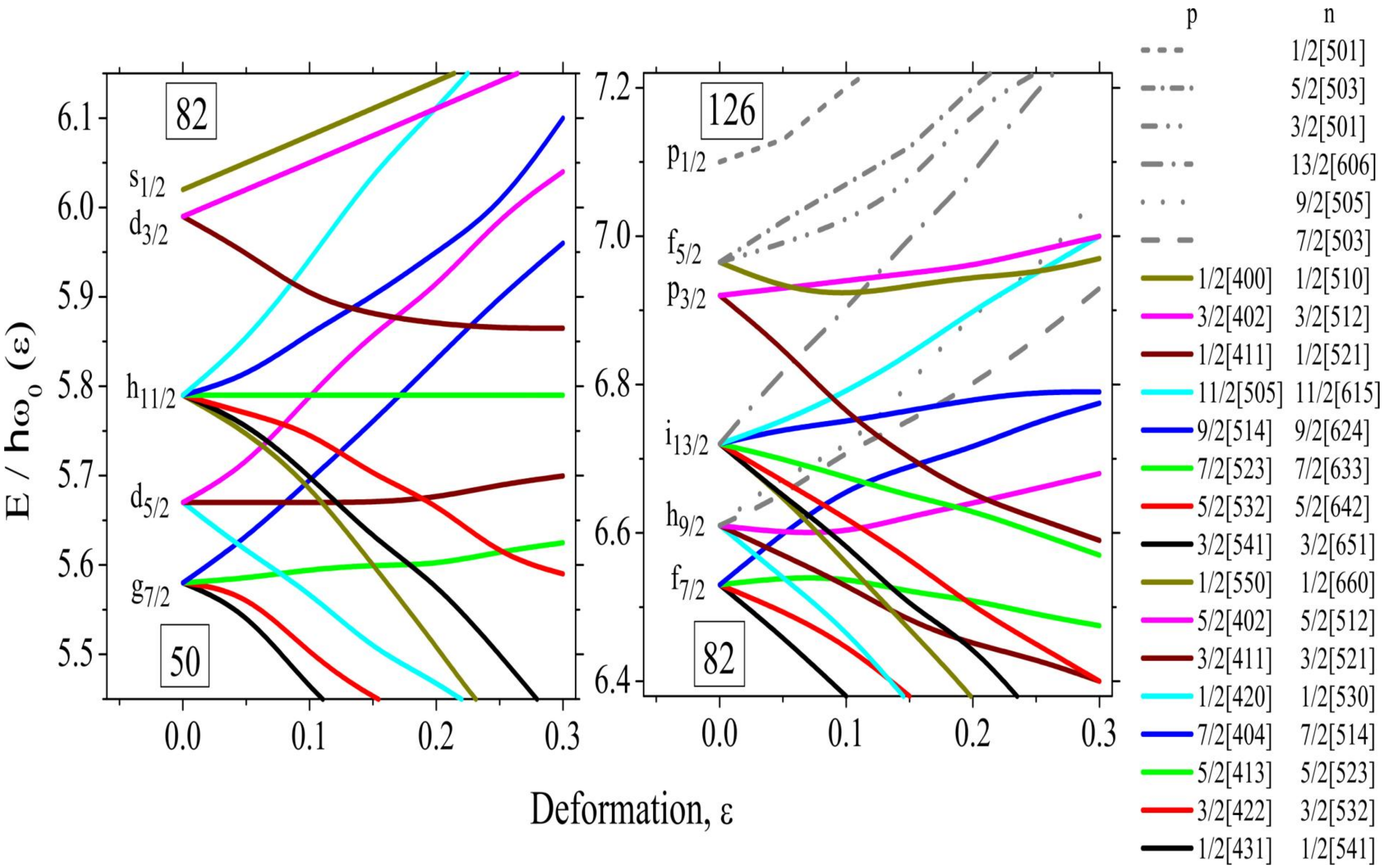
DFT


N$_{val}$=Z$_{val}$
Proton Number
52
56
60
64
68
72
76
80
84
90
96
102
108
114
120
126
Neutron Number
S=0 (antiparallel spin projection)

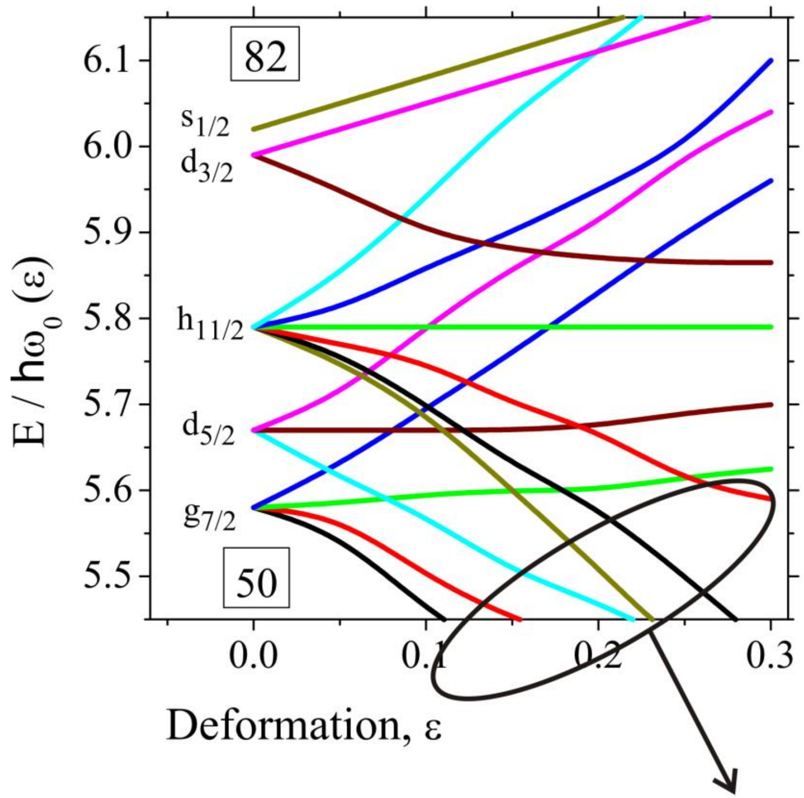

Theory-DFT
Proton Number
52
56
60
64
68
72
76
80
84
90
96
102
108
114
120
126
Neutron Number

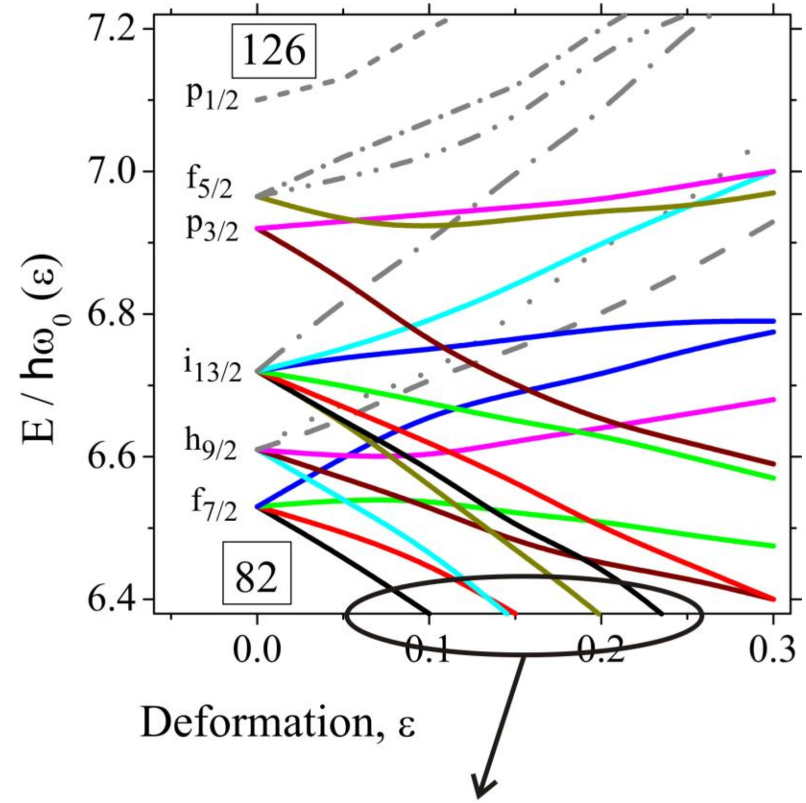
Mario Valentinov Stoitsov (1953-2011)

Nilsson level scheme



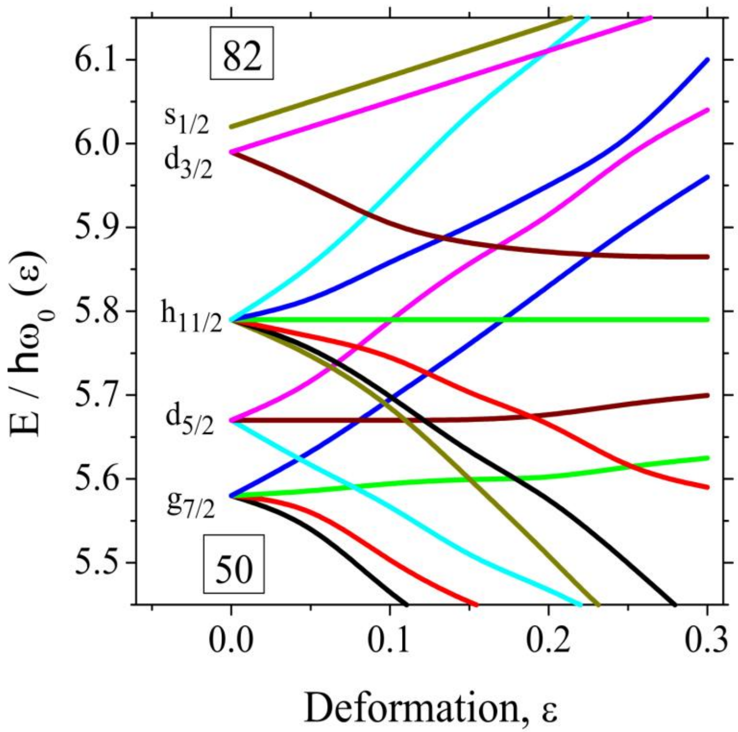
^{154}Sm: 12 valence protons
10 valence neutrons





12 valence protons sit in the (24,0) irrep of U(15) $\otimes$ 10 valence neutrons sit in the (30,4) irrep of U(21)

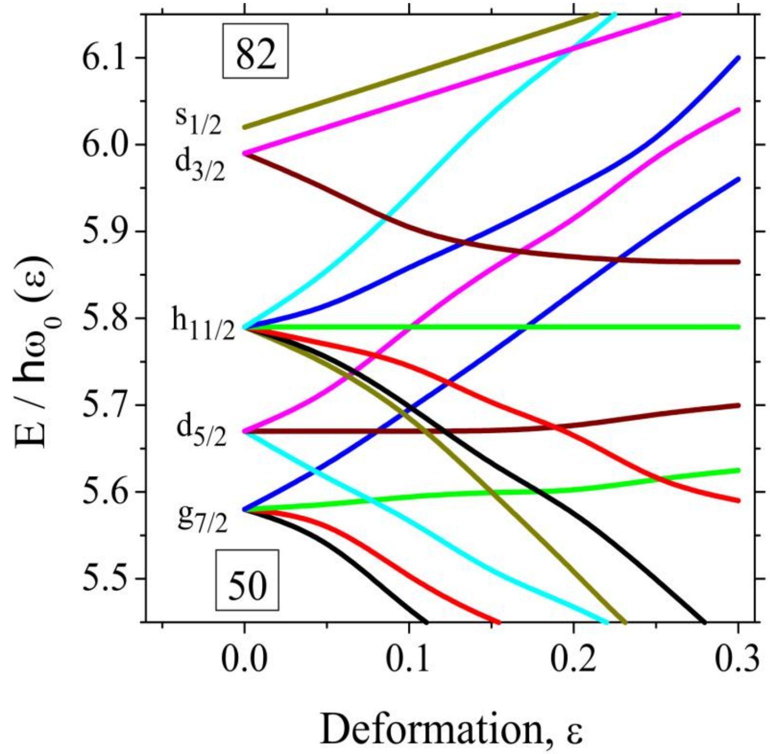
(54,4) irrep for all valence nucleons



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] 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

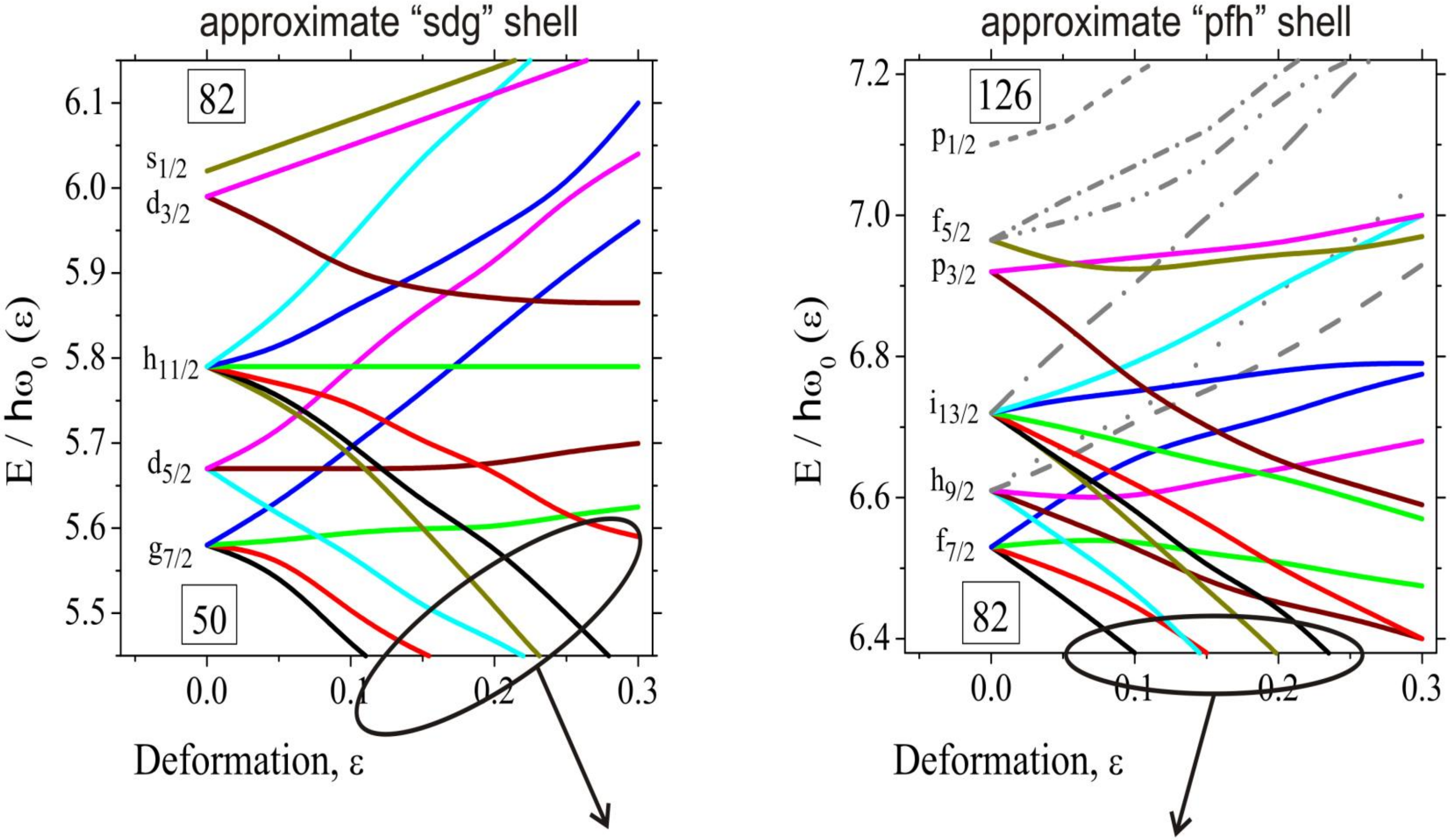
nz changes by 1

K, Λ, Σ same

left out

50-82 shell mapped onto an sdg shell with U(15)>SU(3)

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



12 valence protons in the [222222] irrep of U(15) × 10 valence neutrons in the [22222] irrep of U(21) ⊃

(24,0) most leading SU(3) irrep of U(15) × (30,4) most leading SU(3) irrep of U(21) ⊃

SU(3) irreps labelled (λ,μ)

(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)>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