A mechanism for shape coexistence-

under construction

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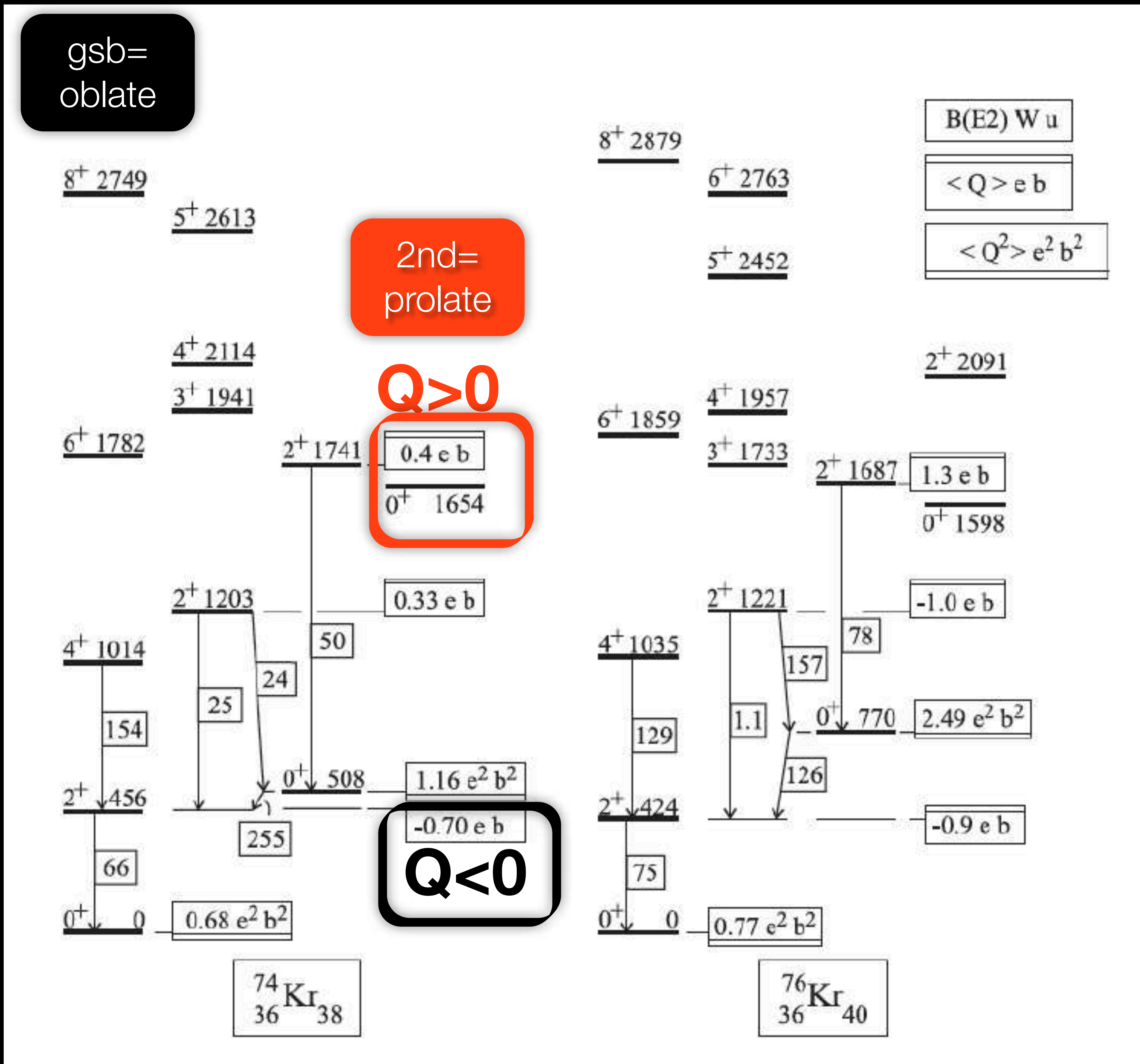
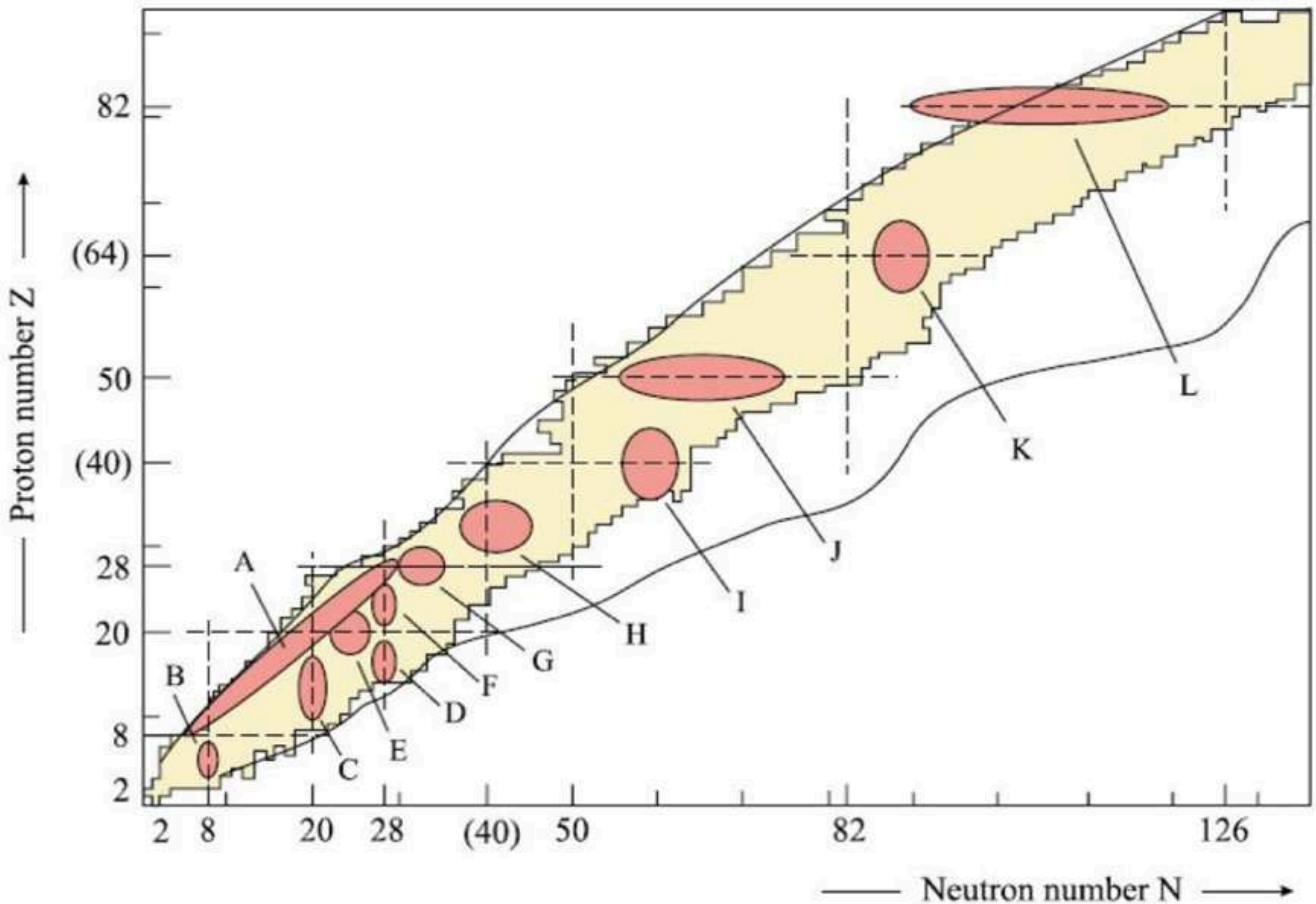
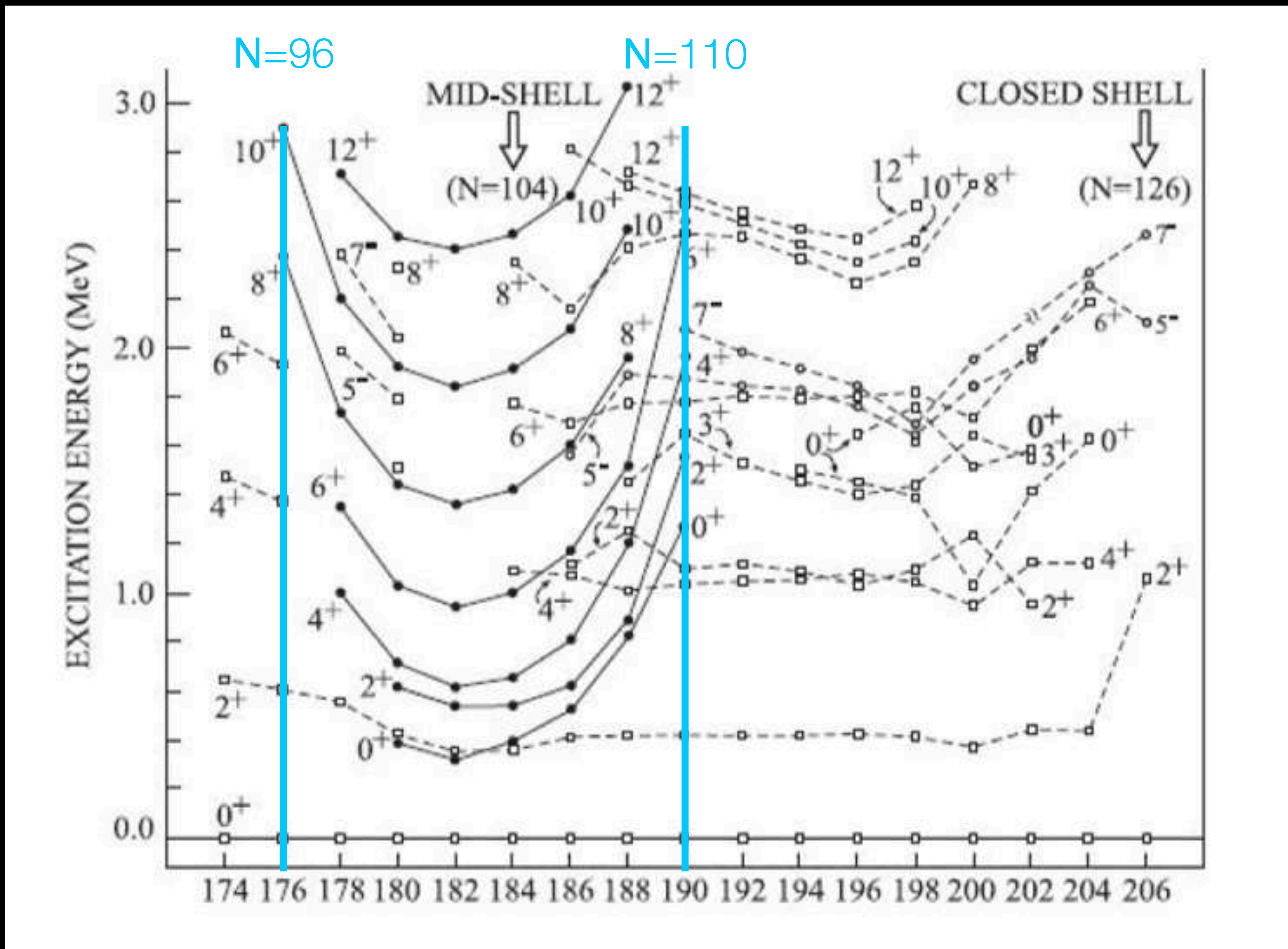


Manifestation of shape coexistence

Islands of coexistence

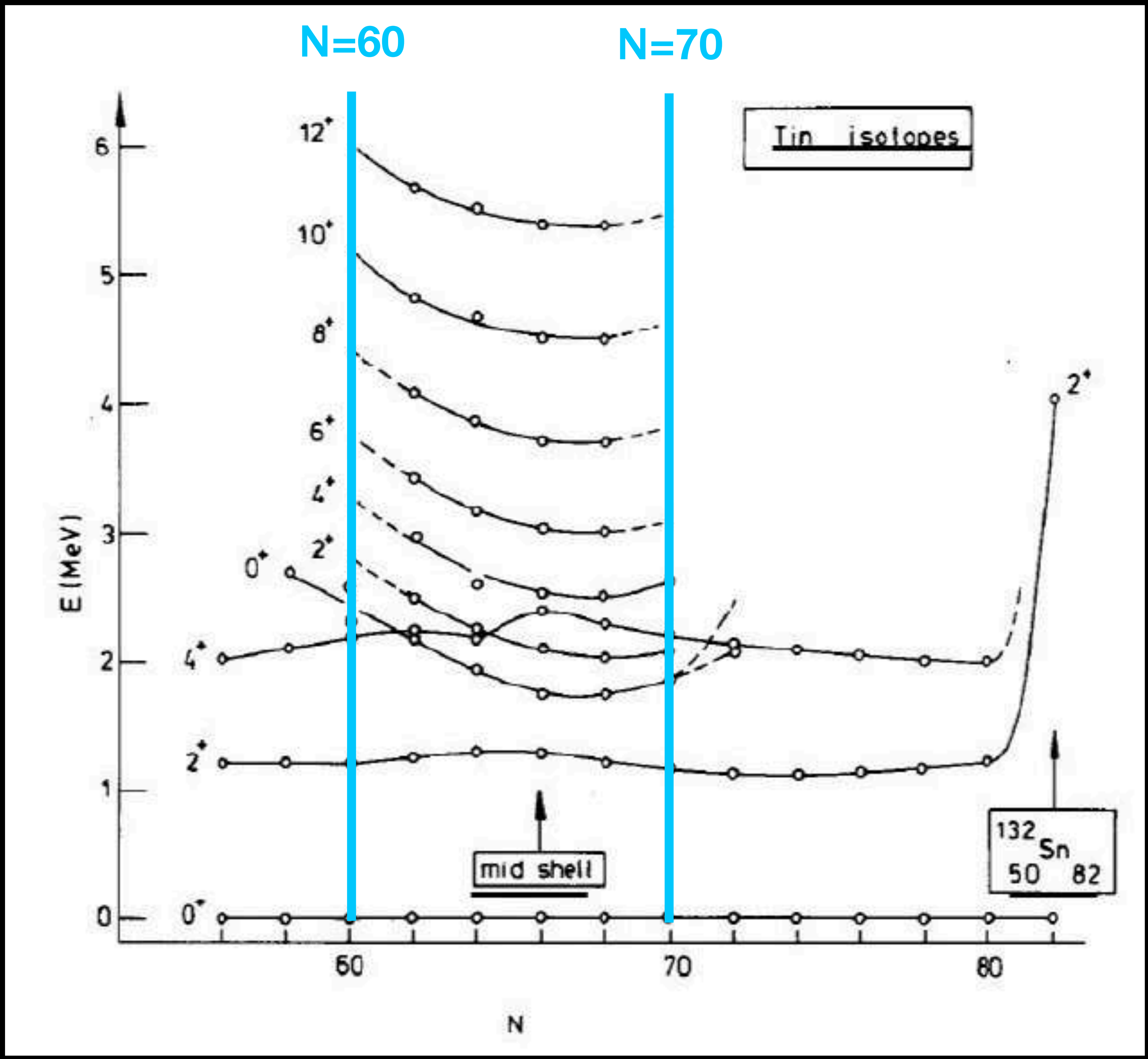


Hg isotopes



Why?

Sn isotopes



Why?

Shell model	Original Nilsson
$1g_{9/2}$	9/2[404]
	7/2[413]
	5/2[422]
	3/2[431]
	1/2[440]
$2p_{1/2}$	1/2[301]
$1f_{5/2}$	5/2[303]
	3/2[301]
	1/2[310]
$2p_{3/2}$	3/2[312]
	1/2[321]
$1f_{7/2}$	7/2[303]
	5/2[312]
	3/2[321]
	1/2[330]
$1d_{3/2}$	3/2[202]
	1/2[200]
$2s_{1/2}$	1/2[211]
$1d_{5/2}$	5/2[202]
	3/2[211]
	1/2[220]
$1p_{1/2}$	1/2[101]
$1p_{3/2}$	3/2[101]
	1/2[110]
$1s_{1/2}$	1/2[000]

50

40

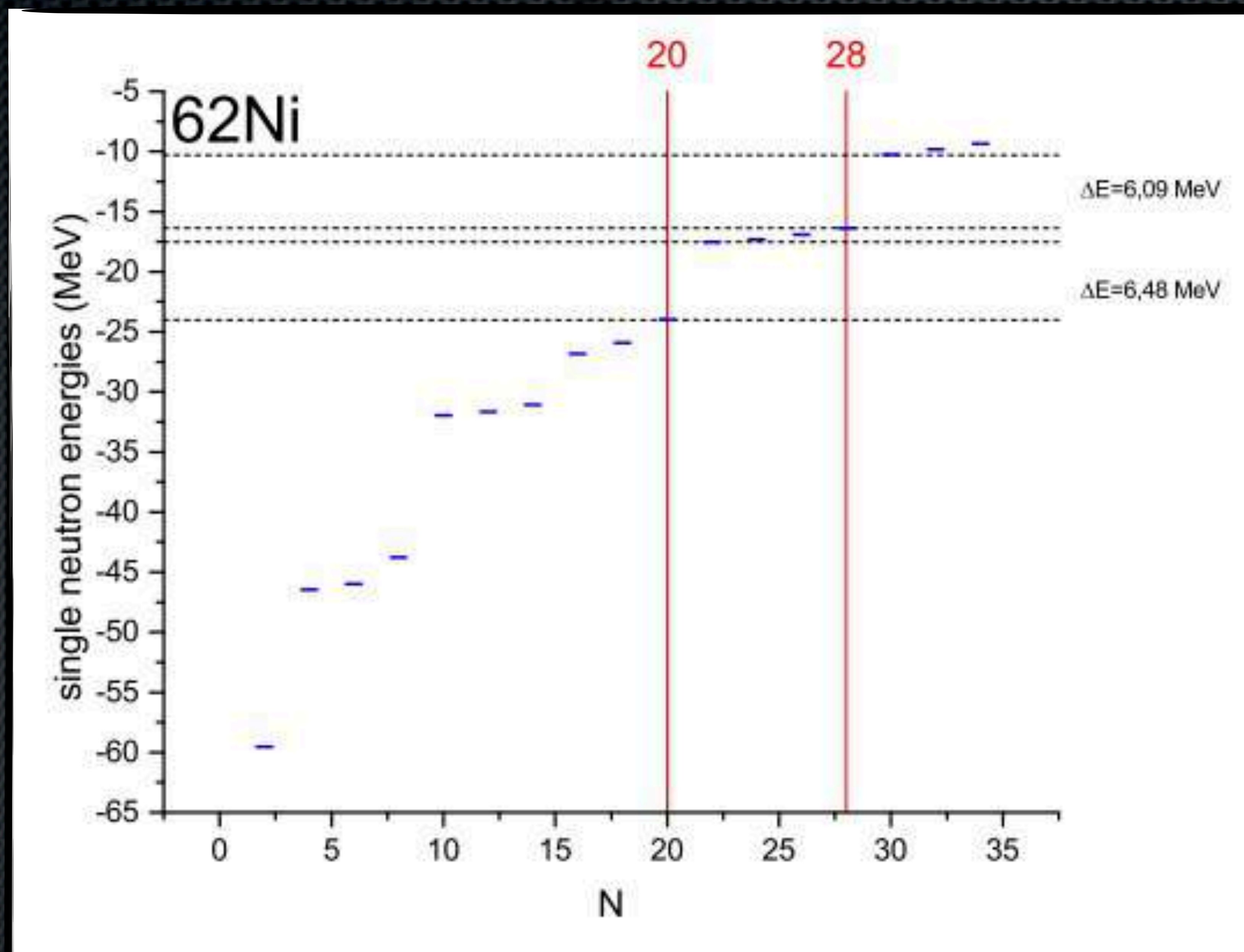
28

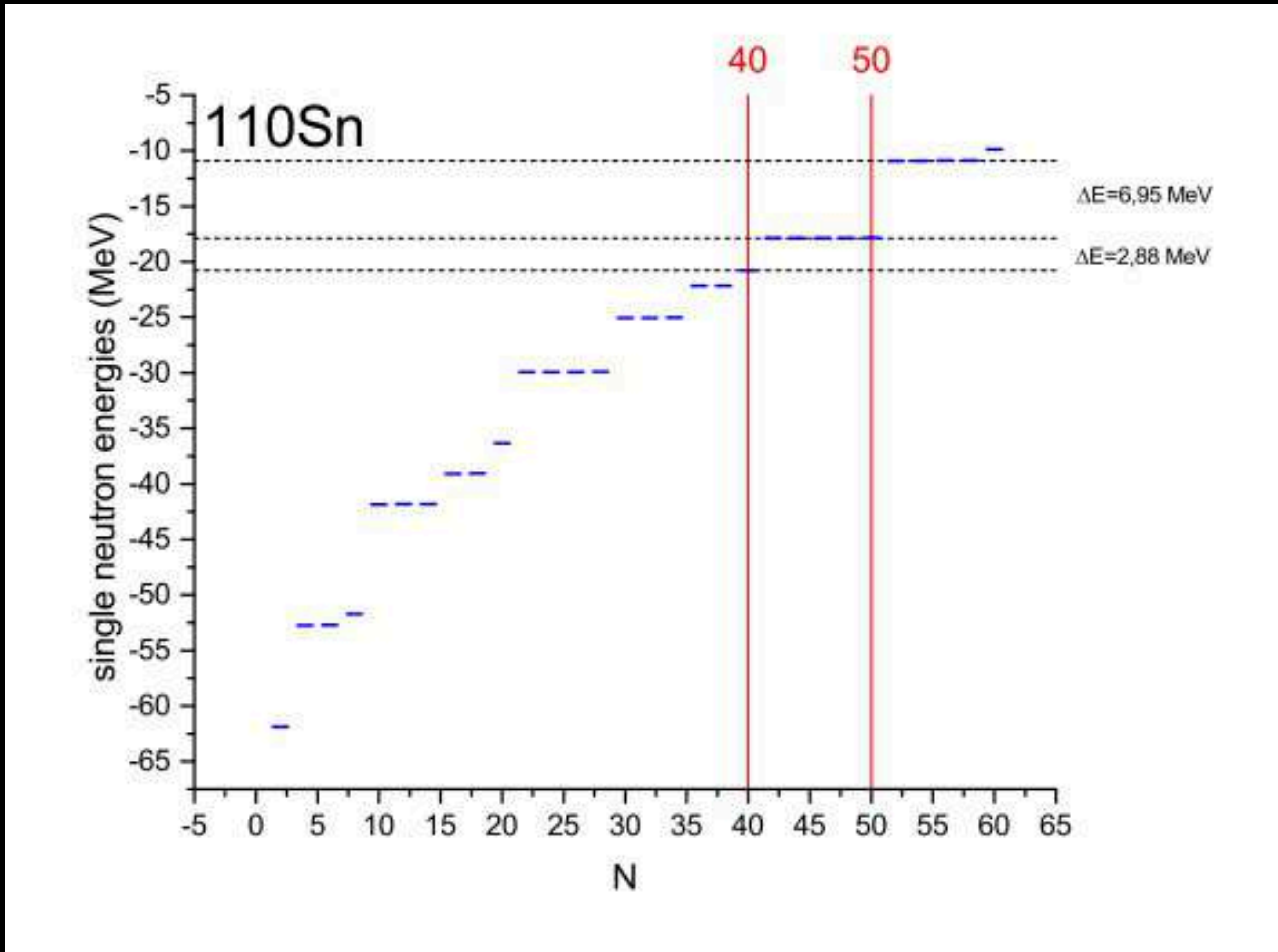
20

Nuclear Magic numbers

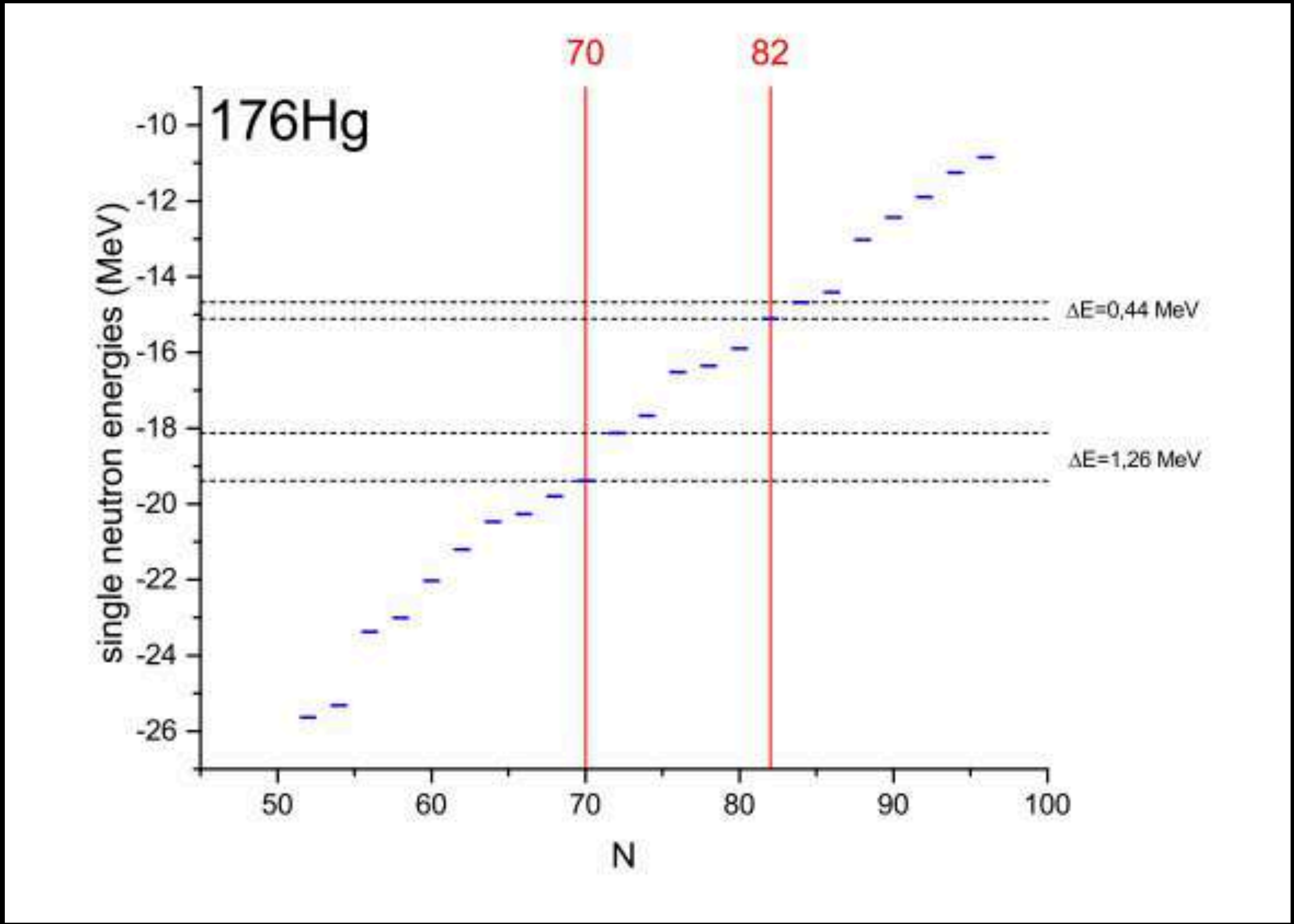
Selection rules of QQ interaction

Lowering of major energy gaps





110Sn
40
50
single neutron energies (MeV)
N
ΔE=6,95 MeV
ΔE=2,88 MeV
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65



70
82
176Hg
single neutron energies (MeV)
N
ΔE=0,44 MeV
ΔE=1,26 MeV
-10
-12
-14
-16
-18
-20
-22
-24
-26
50
60
70
80
90
100

Shell model	Original Nilsson
$1g_{9/2}$	9/2[404]
	7/2[413]
	5/2[422]
	3/2[431]
	1/2[440]
$2p_{1/2}$	1/2[301]
$1f_{5/2}$	5/2[303]
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	5/2[312]
	3/2[321]
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	1/2[200]
$2s_{1/2}$	1/2[211]
$1d_{5/2}$	5/2[202]
	3/2[211]
	1/2[220]
$1p_{1/2}$	1/2[101]
$1p_{3/2}$	3/2[101]
	1/2[110]
$1s_{1/2}$	1/2[000]

50

20

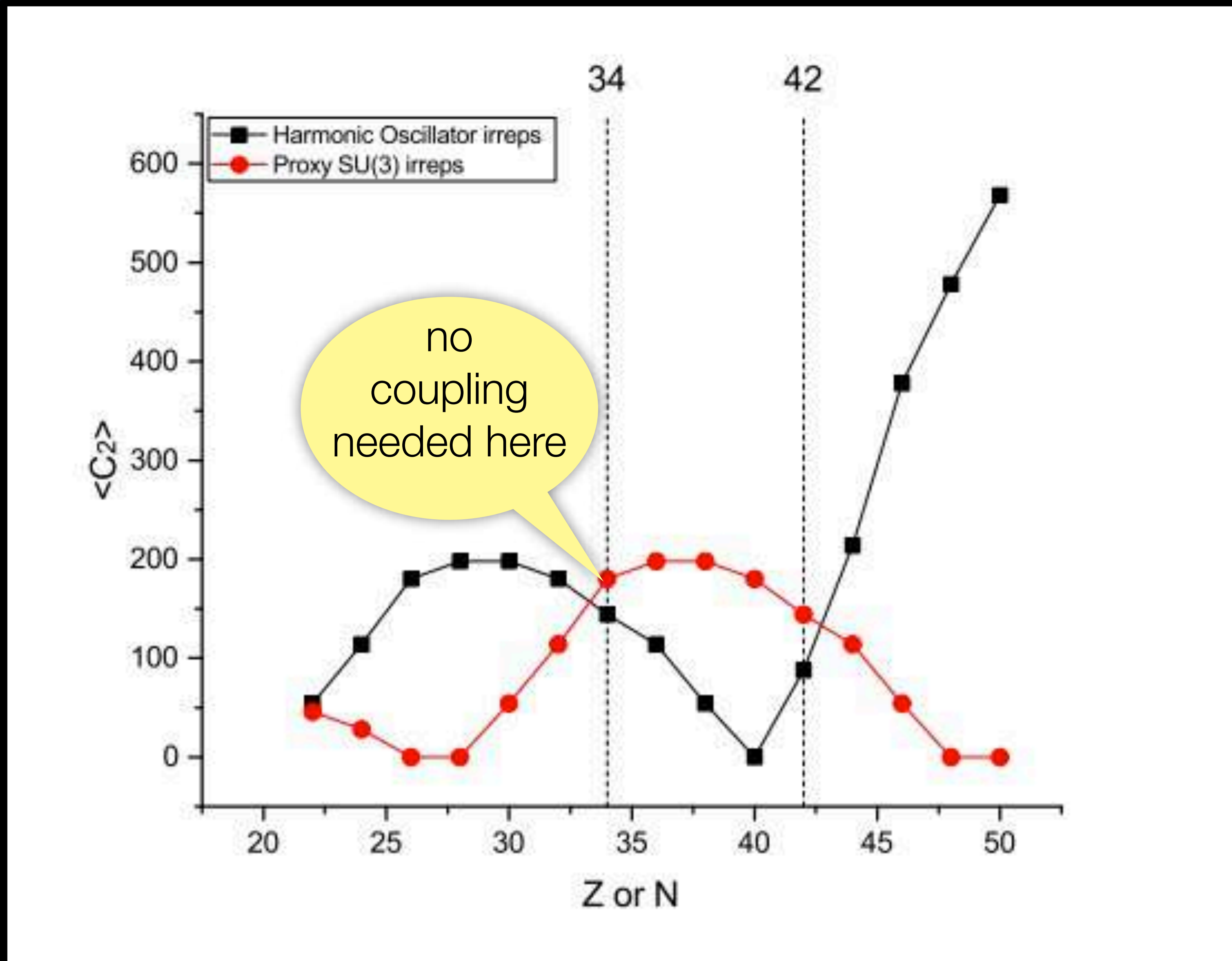
One super shell

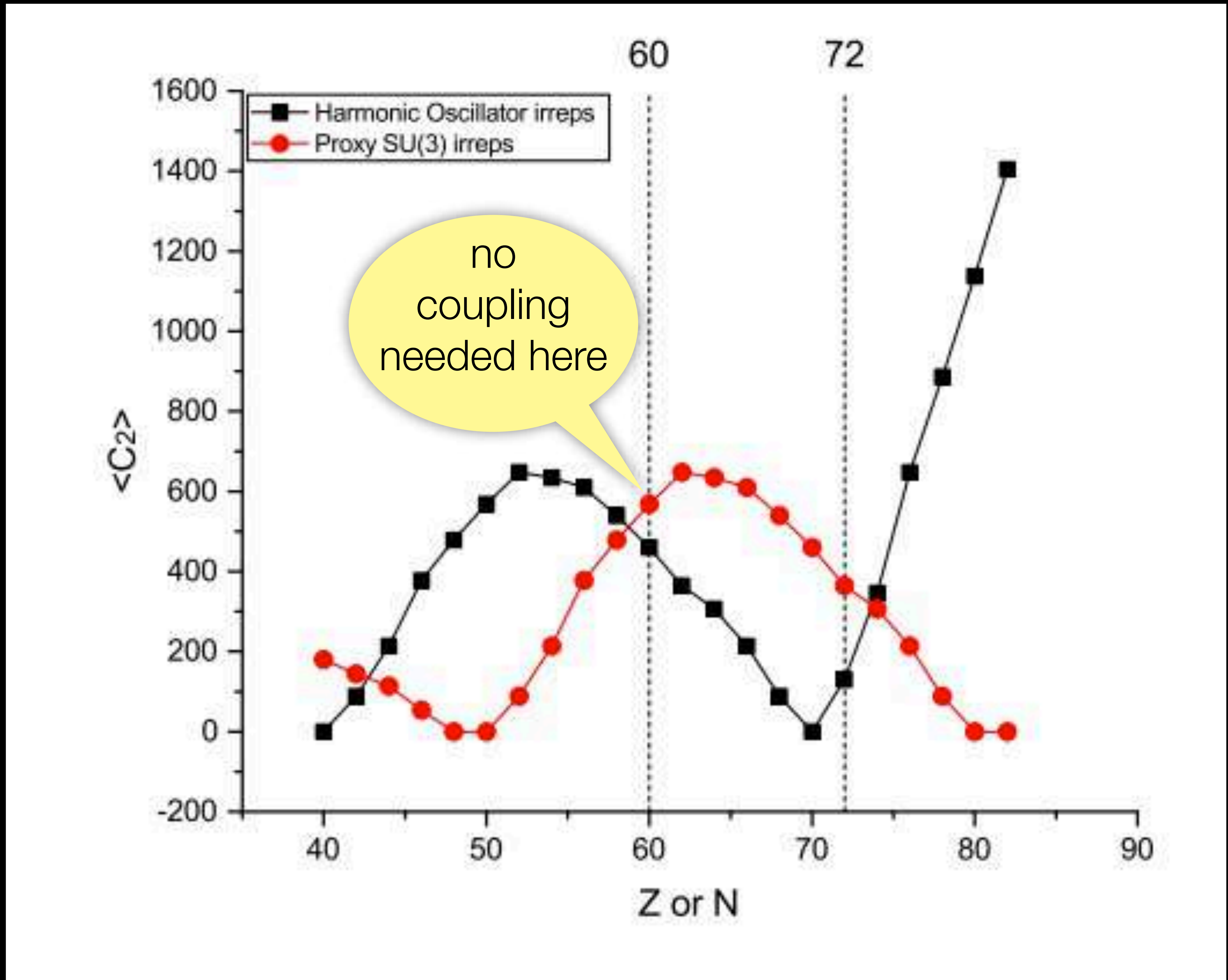
The collective quadrupole interaction

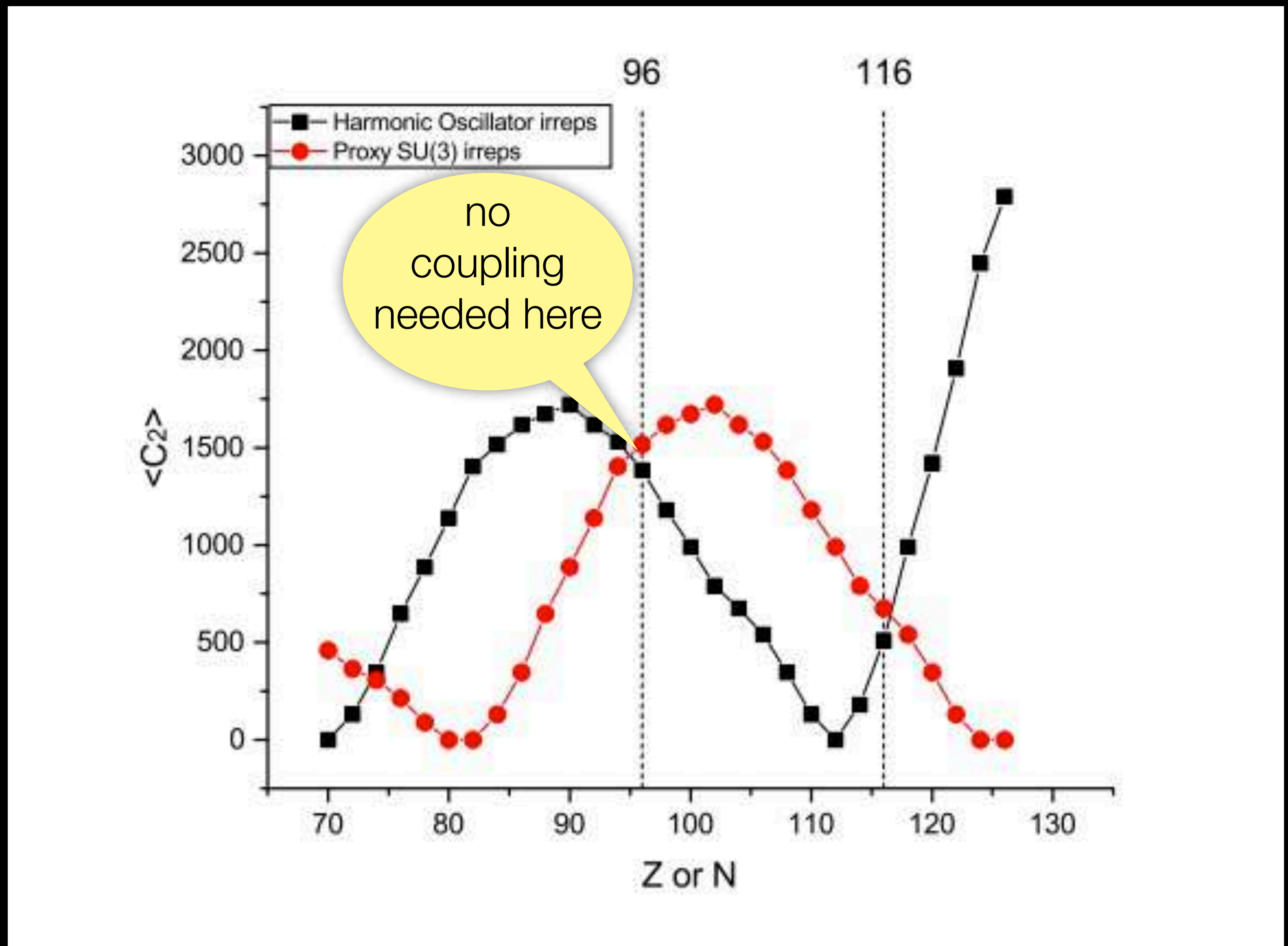
$$Q \cdot Q = 4C_2 - 3L^2,$$
$$C_2 = \lambda^2 + \mu^2 + \lambda\mu + 3(\lambda + \mu),$$
$$\beta^2 = \frac{4\pi}{5(A\bar{r^2})^2}(C_2 + 3)$$

$$\gamma = \arctan\left(\frac{\sqrt{3}(\mu + 1)}{2\lambda + \mu + 3}\right)$$

- (λ,μ) are the quantum numbers of SU(3). They depend on the choice of magic numbers. β is the deformation and γ is the angle which distinguishes prolate from oblate.


34
42
Harmonic Oscillator irreps
Proxy SU(3) irreps
600
500
400
300
200
100
0
<C2>
20
25
30
35
40
45
50
Z or N
no coupling needed here


60
72
1600
1400
1200
1000
800
600
400
200
0
-200
<C2>
Harmonic Oscillator irreps
Proxy SU(3) irreps
no coupling needed here
40
50
60
70
80
90
Z or N


96
116
Harmonic Oscillator irreps
Proxy SU(3) irreps
3000
2500
2000
1500
1000
500
0
<C2>
no coupling needed here
70
80
90
100
110
120
130
Z or N

Z or N for shape coexistence

34-40
60-70
96-112
210-240

The 0+ states

no particle excitations

$$H = H_0 - \frac{\chi}{2} QQ,$$

$$0_2^+ = \frac{\chi}{2}(QQ_{nucl} - QQ_{ho}) - (N_{0,nucl} - N_{0,ho})$$

$$\frac{\chi}{2} = \frac{1\text{MeV}}{N_0}$$

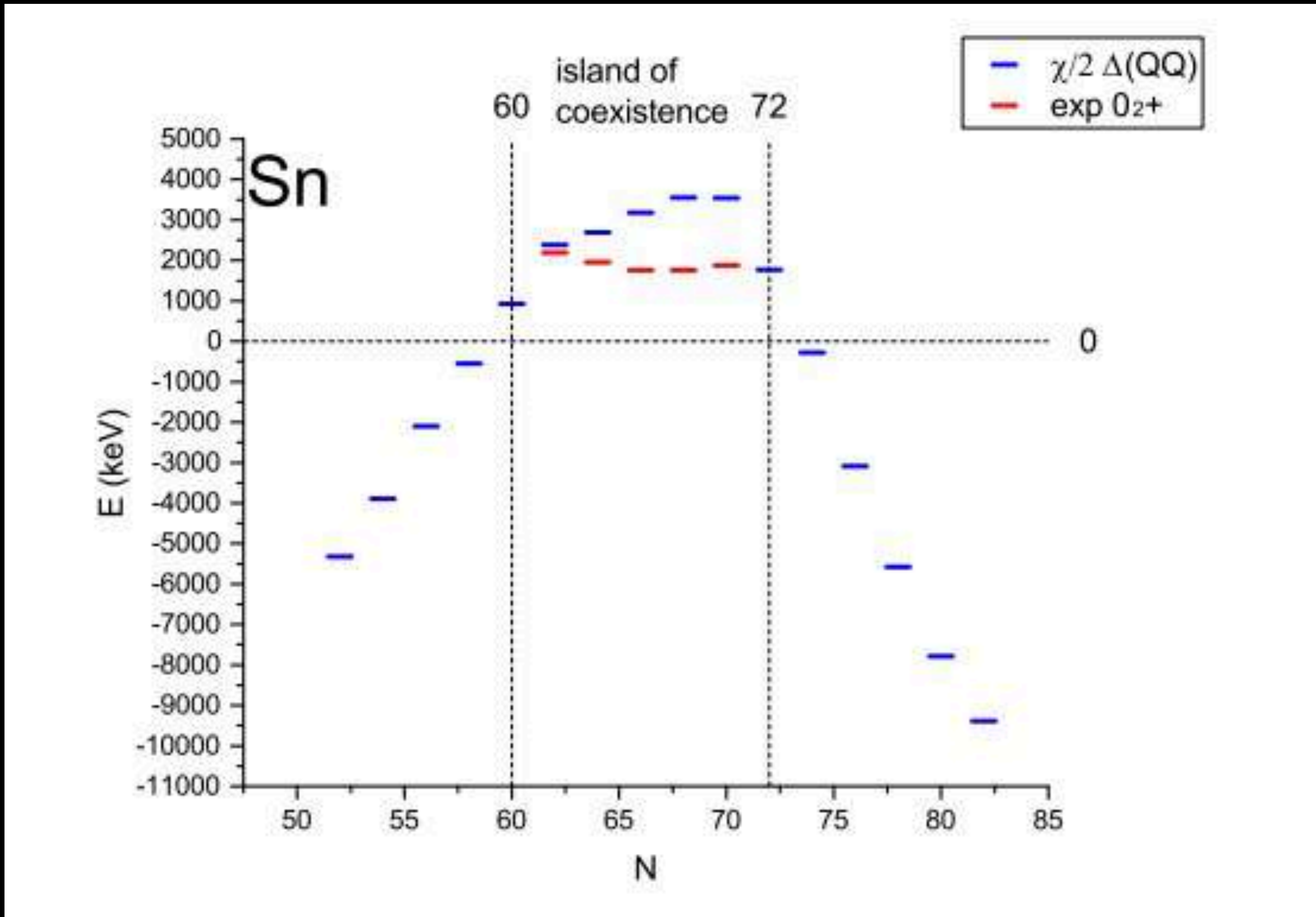
$$N_0 = \sum_{i=1}^{A}(n_i + \frac{3}{2})\hbar\omega_i,$$

$$0_2^+ = \frac{\chi}{2}\Delta(QQ) - \Delta N_0.$$

$$\hbar\omega_i = \frac{\hbar\omega}{N},$$

$$\hbar\omega = \frac{41MeV}{A^{1/3}}.$$

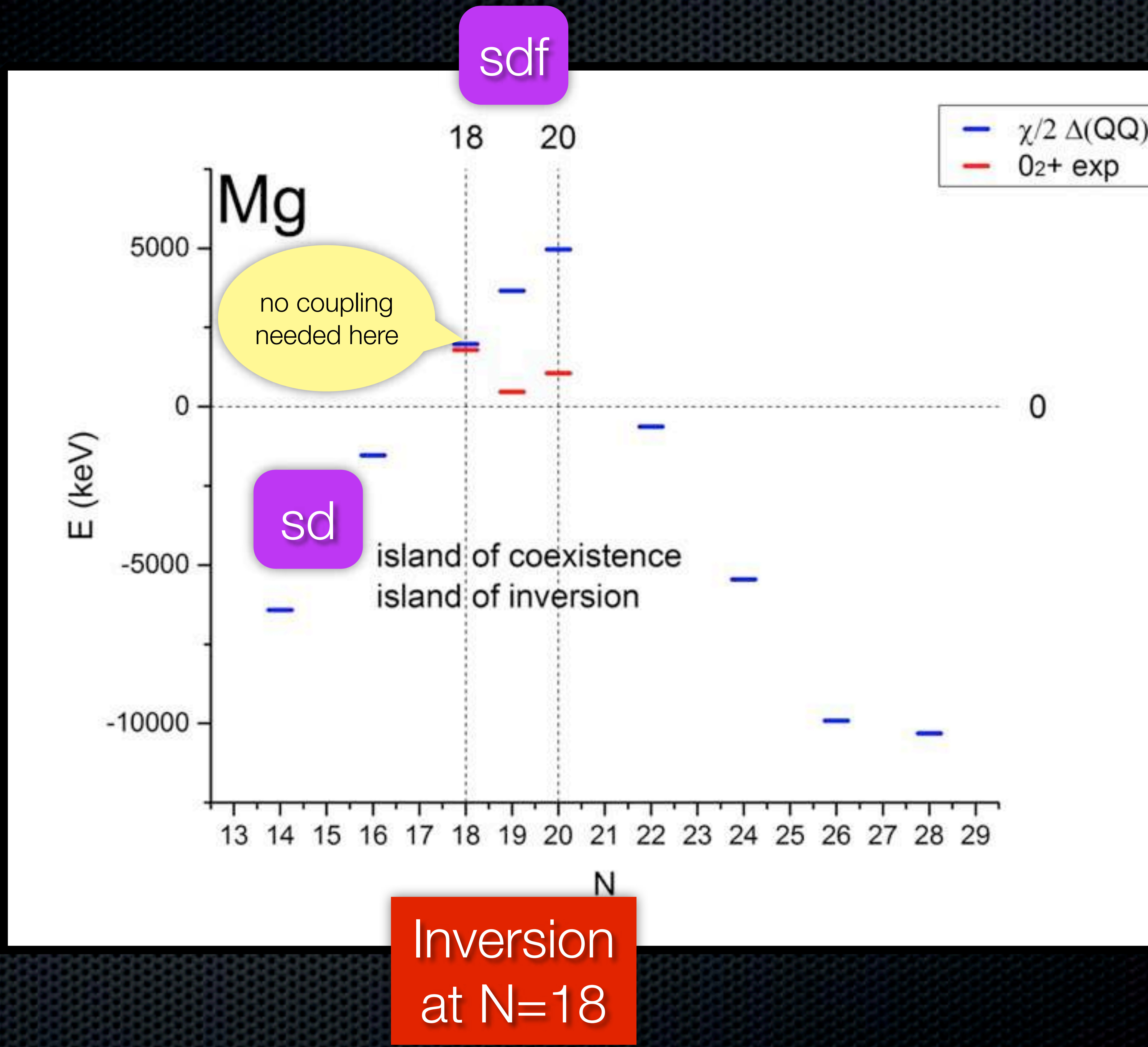
Before the coupling of 40-70, 50-82 shells



Below 28

Table 1 Magic numbers 14-28 consist of Nilsson orbitals which have a Proxy SU(3) symmetry. The Nilsson orbitals $1/2[330], 3/2[321], 5/2[312]$ different only by one quantum in the z axis with the $1/2[220], 3/2[211], 5/2[202]$ respectively. Such orbitals have differences of quantum numbers $\Delta K[\Delta N \Delta n_z \Delta \Lambda] = 0[110]$. By excluding the 7/2[303] orbital and replacing the rest $1f_{7/2}$ orbitals with their 0[110] counterparts of the $1d_{5/2}$, the 14-28 has a restored SU(3) symmetry. The 14-28 shell appears in the isotopes of the $N \sim 20$ island of inversion. This shell is also useful for the explanation of shape coexistence in the Mg region.

shell model	$K[Nn_z\Lambda]$	0[110] counterparts	algebra	magic numbers
$1f_{7/2}$	7/2[303]	X		28
	5/2[312]	5/2[202]		26
	3/2[321]	3/2[211]		
	1/2[330]	1/2[220]		
$1d_{3/2}$	3/2[202]		U(6)	
	1/2[200]			
$2s_{1/2}$	1/2[211]			
$1d_{5/2}$	5/2[202]	X		14
	3/2[211]	3/2[101]	U(3)	12
	1/2[220]	1/2[110]		
$1p_{1/2}$	1/2[101]			
$1p_{3/2}$	3/2[101]	X		6
	1/2[110]	1/2[000]	U(1)	4
$1s_{1/2}$	1/2[000]		U(1)	2


sdf
18
20
χ/2 Δ(QQ)
02+ exp
Mg
5000
no coupling
needed here
0
0
E (keV)
sd
island of coexistence
island of inversion
-5000
-10000
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
N
Inversion
at N=18

Conclusions

- The mechanism involves **no particle excitations**.
- The 0_2+ state is always the less deformed, coupled configuration.
- The 0_1+ state comes from the uncoupled nuclear shell, except from the island of inversion, where the 0_1+ state comes from the uncoupled harmonic oscillator shell.
- In nuclei with $C_{2proxy} \simeq C_{2ho}$,$\chi/2\Delta(QQ) \simeq 0_2+$. In the rest nuclei coupling of the two shells has to be done.
- Inversion of states occurs in nuclei which traditionally follow the harmonic oscillator magic numbers and they exhibit shape coexistence. The inversion is presented in the isotopes with shape coexistence.

Done

- The mechanism predicts that shape coexistence occurs in islands.
- The candidate nuclei for shape coexistence are predicted without parameters.

Have to be done

- Pairing interaction has to be introduced in the Proxy SU(3) symmetry. Pairing acquires a **9-(λ,μ)** symbol.
- The coupling of the shells acquires a **9-(λ,μ)** symbol. A code has to be constructed for large SU(3) irreps.
- The islands of coexistence have to be predicted after the 9-(λ,μ) symbol.
- The 0_2+ states have to be predicted after the 9-(λ,μ) symbol.

Thank you