Review of shell-model results in ^{100}Sn region

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27-31.03.2017

Several shell-model studies in ^{100}Sn region:

- Stability of shell gaps N=Z=50 and single-particle structure of ^{101}Sn

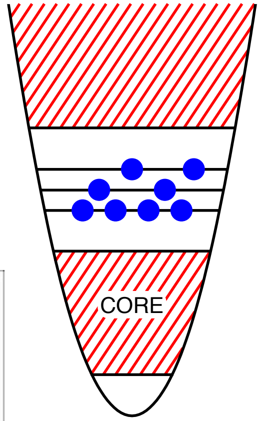
1. Core-excited states, spin-gap isomers
2. The puzzle of B(E2) transitions
3. Superallowed GT decay of ^{100}Sn

- Proton-neutron pair correlations in N~Z systems

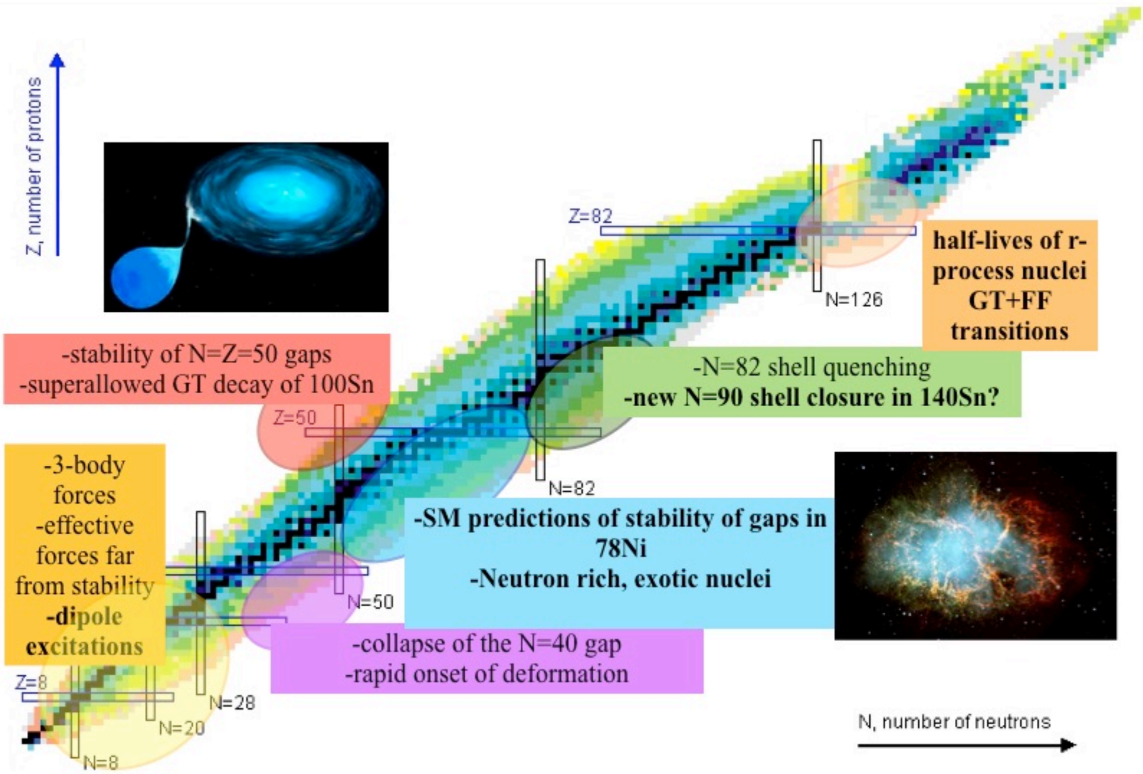
1. Collectivity in light Xe isotopes

SM studies: generalities

- SM relies on the possibility of diagonalizing the Hamiltonian matrix and constraining (empirically) the effective interaction

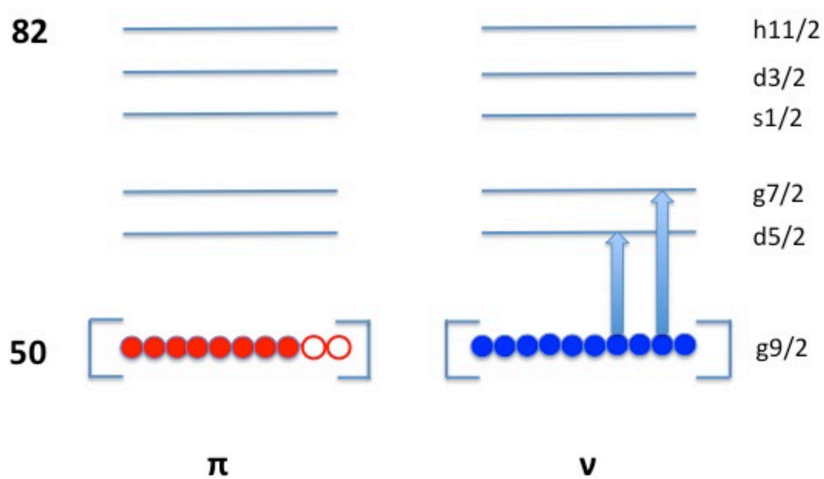


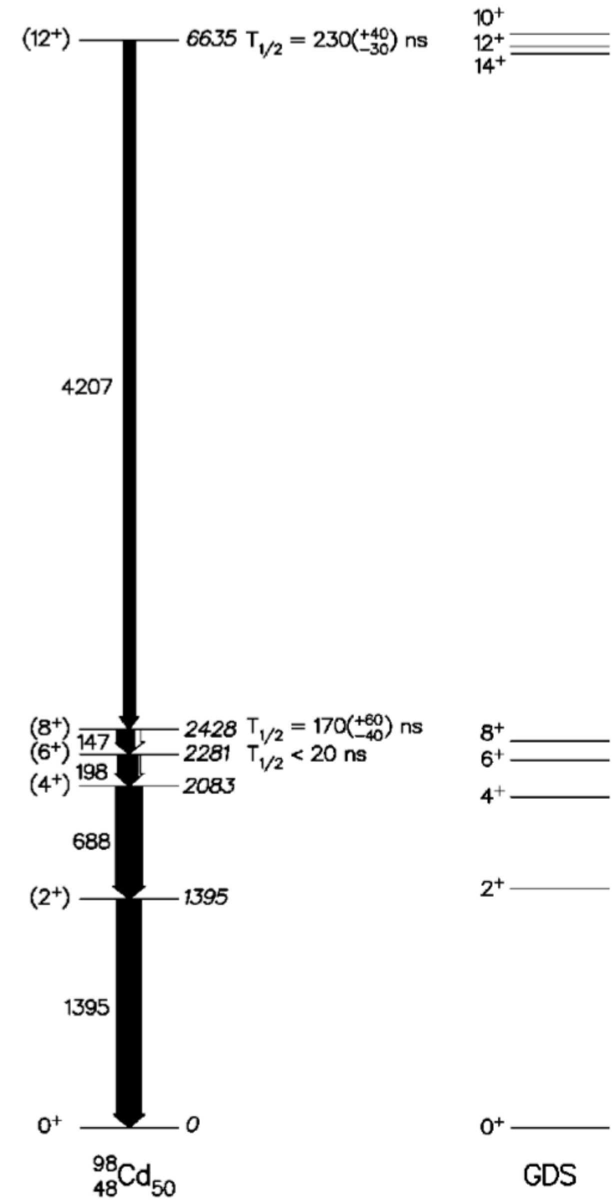
$$H_{eff}\Psi_{eff}=E\Psi_{eff}$$



Core-excited states: ^{98}Cd

A. Blazhev et al., Phys. Rev. C69, 064304, 2004



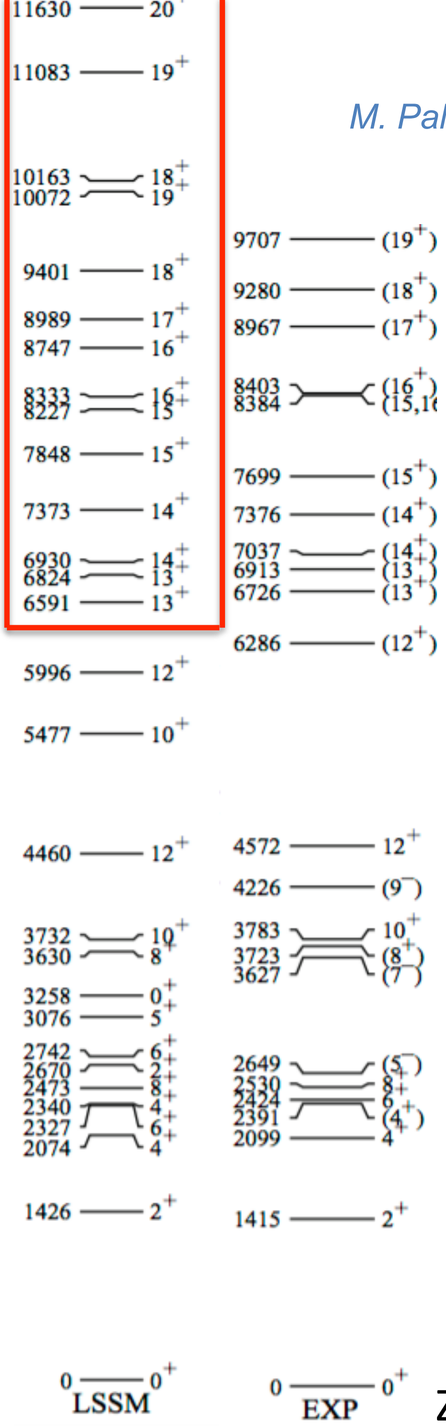


- Shell model calculations in *sdg* model space, up to 4p-4h excitations across the N=Z=50 gaps
- Clean constraint on the N=50 shell gap: 6.5MeV estimated from SM calculations

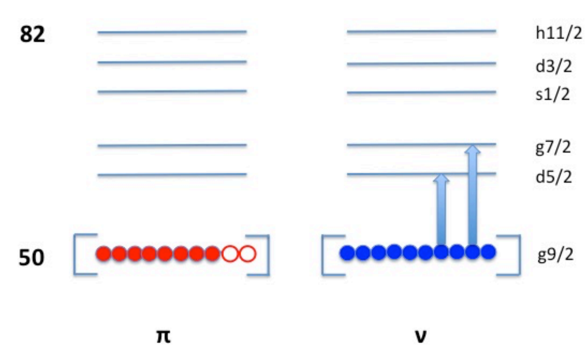
Core excited states: ^{96}Pd, ^{96}Ag

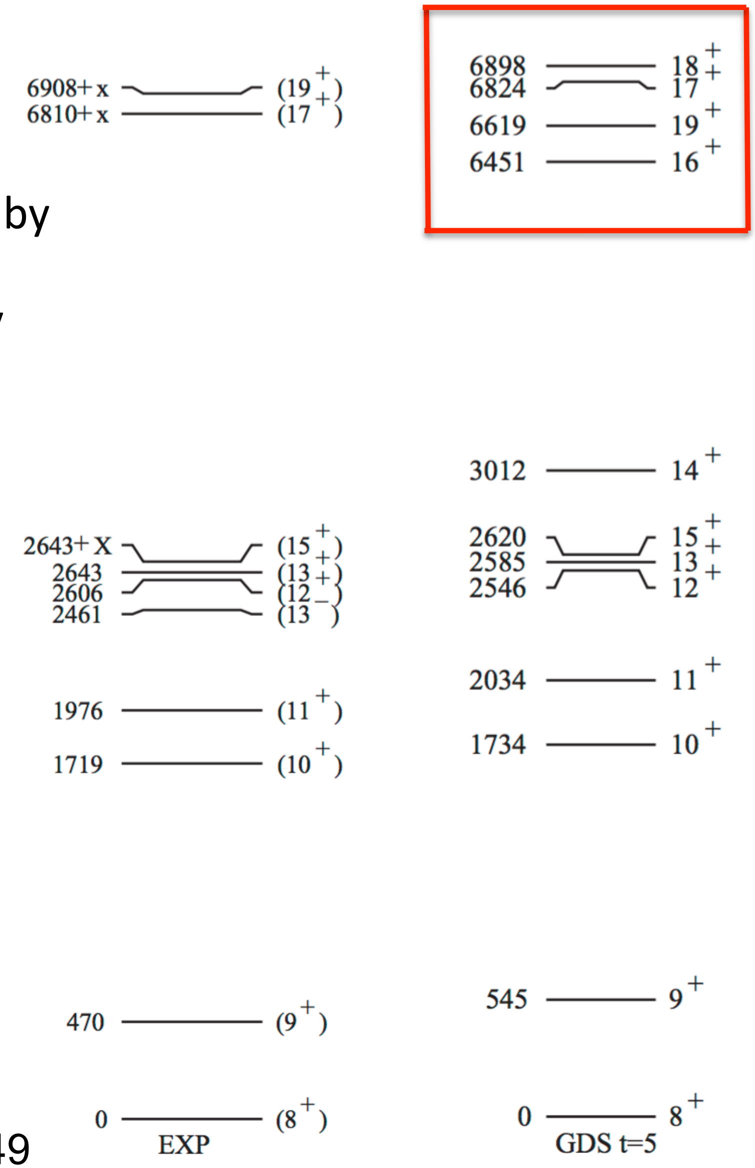
M. Palacz, J. Nyberg, H. Grawe, K. Sieja et al., Phys. Rev. C88, 014318, 2012

P. Boutachkov et al., Phys. Rev. C84, 044311, 2011



- High-spin states dominated by neutron-core excitations consistent with 6.5-6.7 MeV N=50 gap



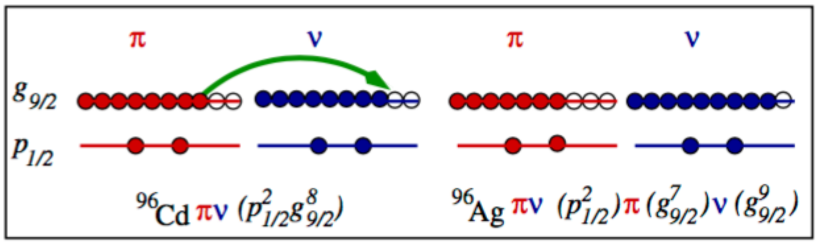


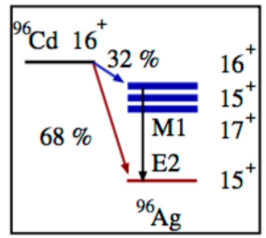
Z=46, N=50

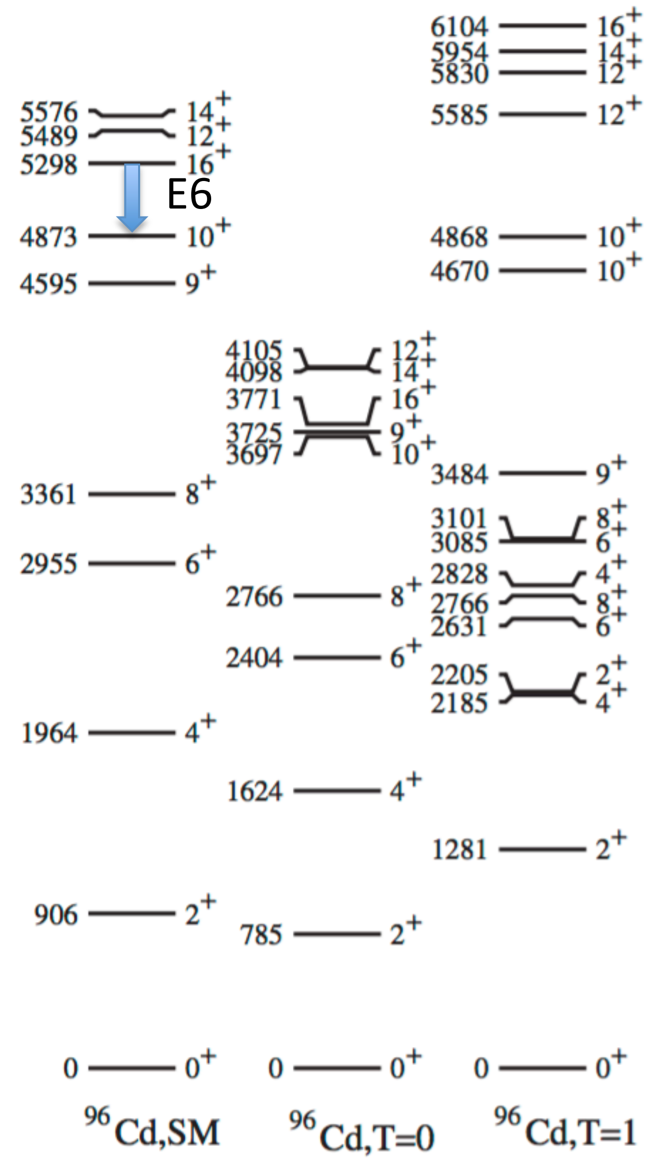
Z=47, N=49

Spin-gap 16^{+} isomer in ^{96}Cd and T=0 interaction

B. S. Nara Singh et al. Phys. Rev. Lett. 107, 172502 , 2011



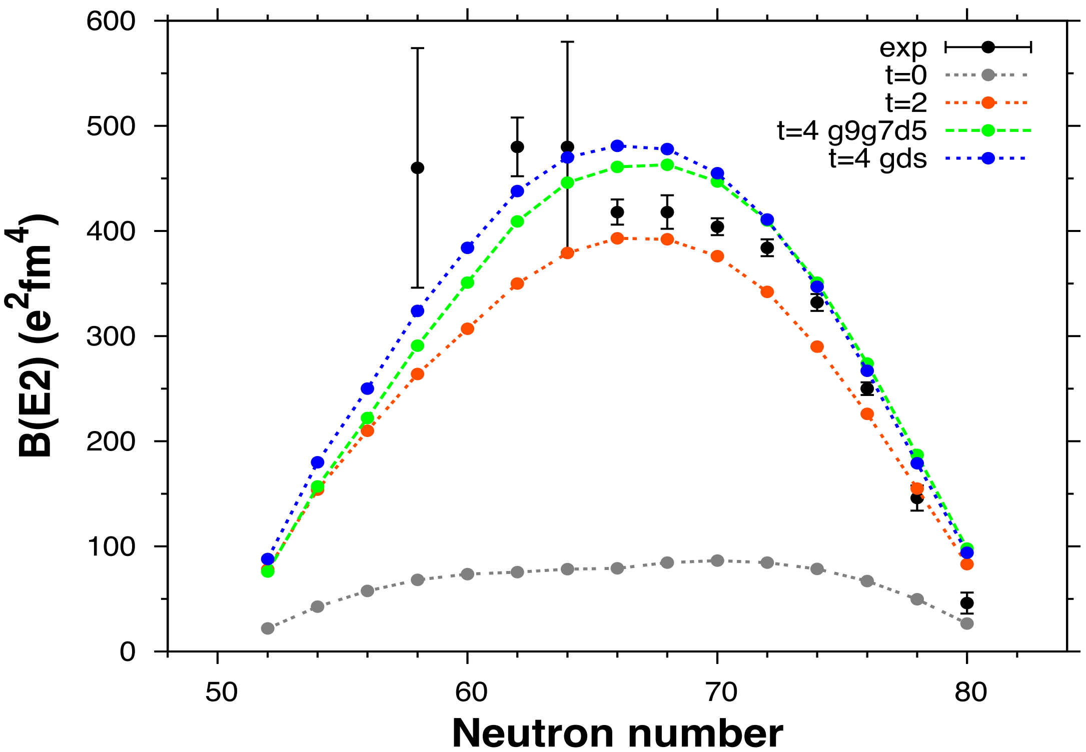


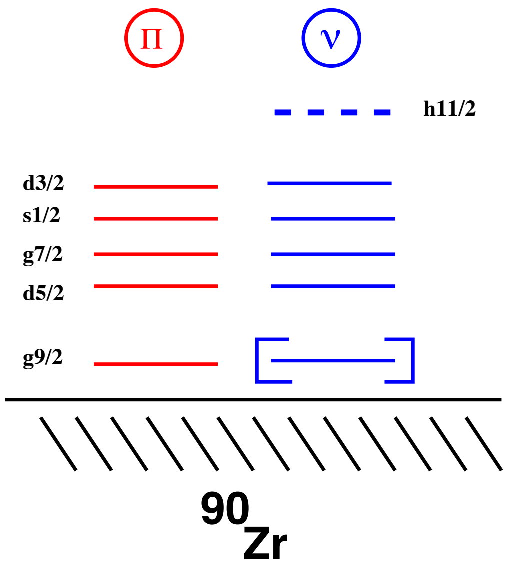


- ❑ Long-standing shell-model prediction of the spin-gap isomer *Phys. Rev. C28, 958, 1983* confirmed in experiment and in modern large- scale shell-model calculations with core excitations

- ❑ Important role of the T=0 p-n interaction in the creation of isomer

B(E2) values of tins: reminder

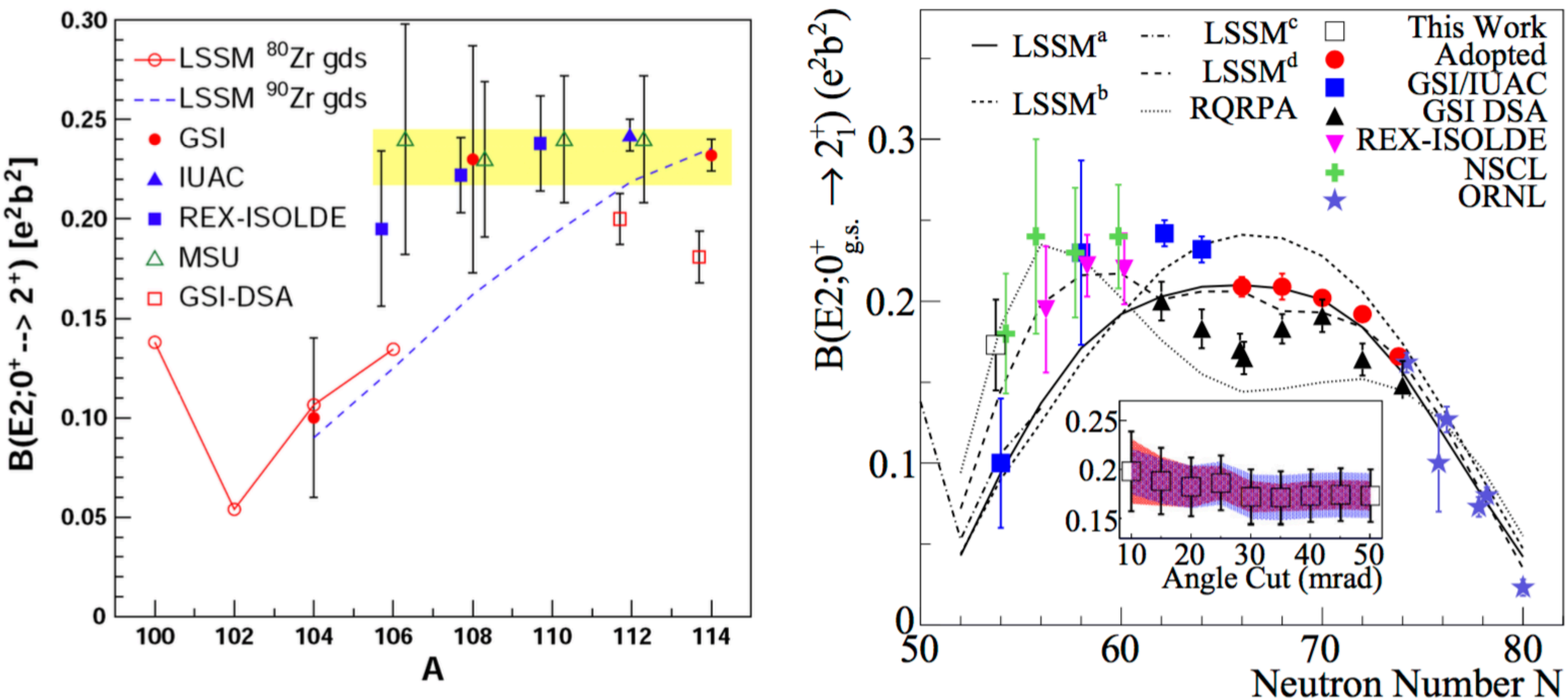




- Full space diagonalization possible
- Not applicable for light tins

A. Banu et al., Phys. Rev. C72, 06135(R), 2005

B(E2) transitions in light tins



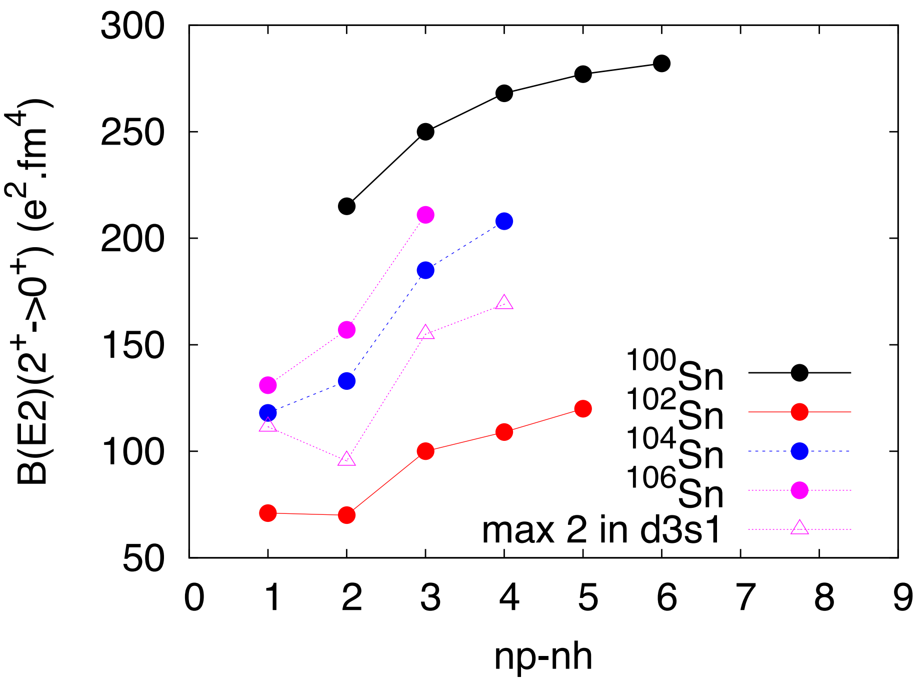
G. Guastalla et al., Phys. Rev. Lett. 110, 172501, 2013

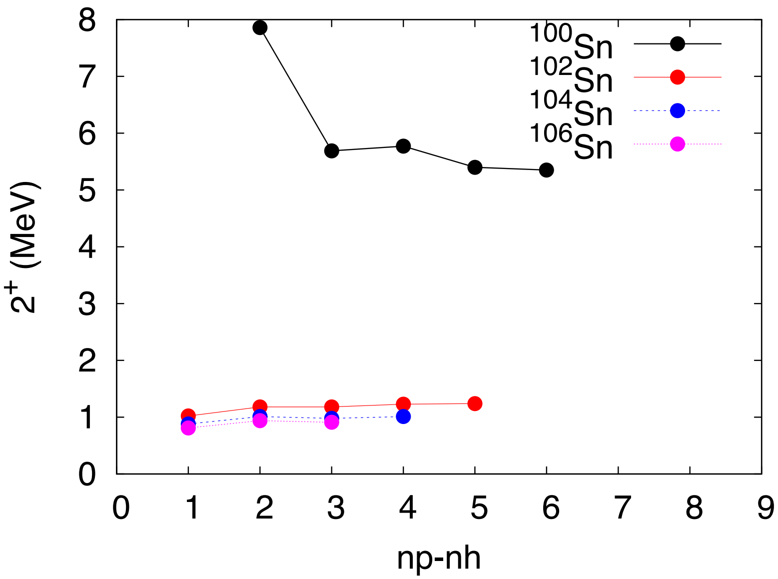
P. Doornebal et al., Phys. Rev. C90, 063102(R), 2014

What is the true pattern of transitions in tins ?

B(E2) transitions in light tins

- What is sure: Core-excitations are necessary for light tins
- SM calculations are suffering from computing limitations for the lightest tins



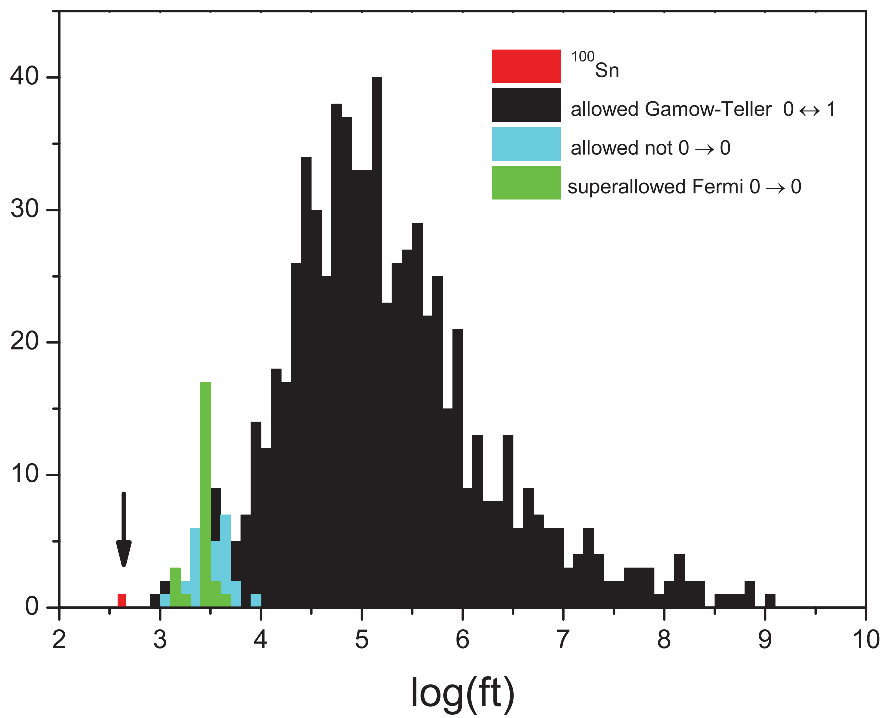


Where is the 2^+ of ^{100}Sn located ?

nature

Superallowed Gamow-Teller decay of ^{100}Sn

C. Hinke et al., Nature 341, 486, 2012



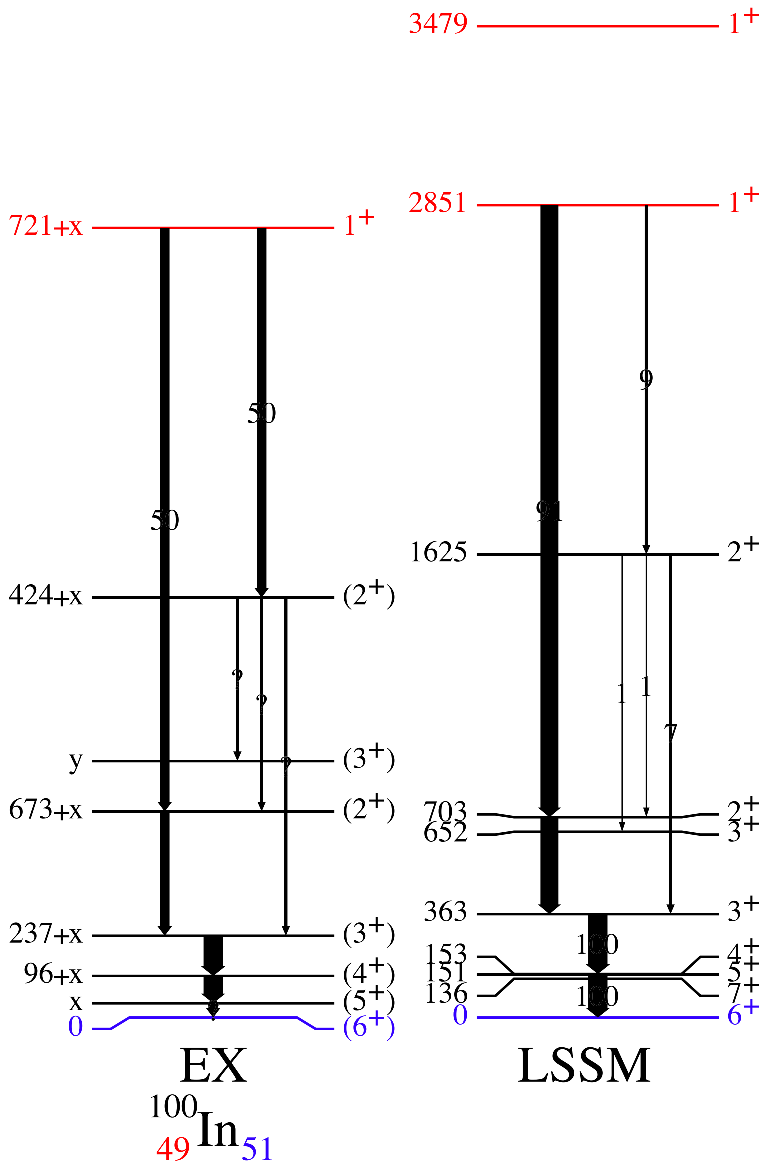
- ❑ Fastest GT decay ever observed
- ❑ B(GT)=9.1(3.0)
- ❑ Log (ft)=2.62(0.13)
- ❑ Single-particle limit:

B(GT)=10 (with 0.75 quenching)

$$B_{GT}^{ESPM} = \frac{4\ell}{2\ell+1} \cdot \left(1 - \frac{N_{\nu g7/2}}{8}\right) \cdot N_{\pi g9/2}$$

Experiment: RISING GSI

Superallowed Gamow-Teller of ^{100}Sn

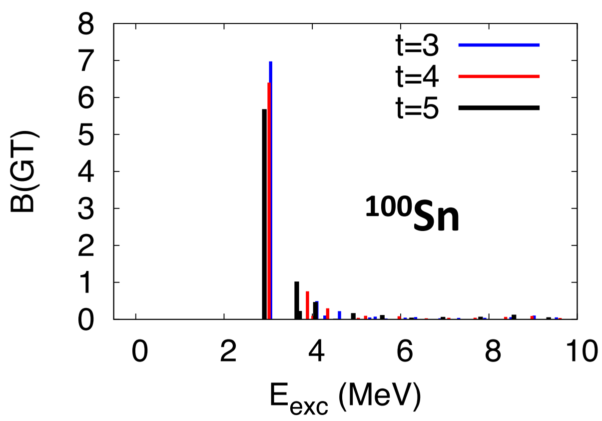


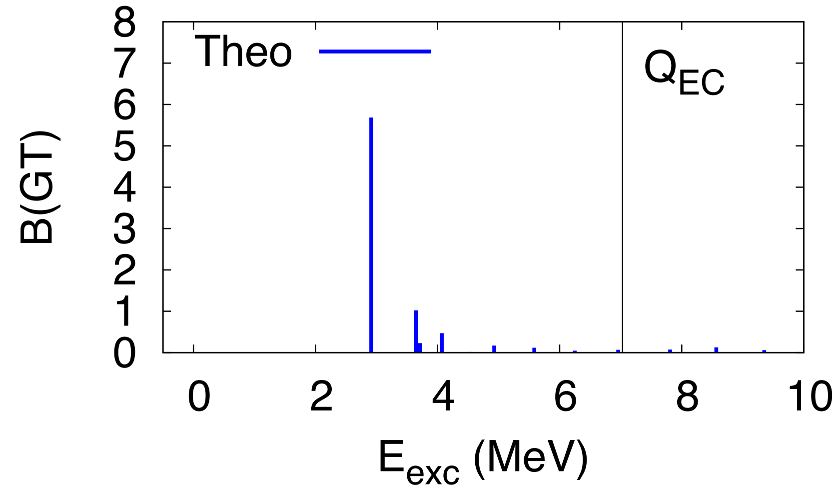
- Shell model calculations in *sdg* model space, up to 5p-5h excitations across the N=Z=50 gaps
- Shell model strength in the Q-window:
  B(GT)=7.82
- To the first 1$^+$
  B(GT)=5.68 (69% of the strength)
- Pure wave-functions:

$$\pi g_{9/2}^{10} \otimes \nu g_{7/2}^{0} \ (82\%)$$

$$\pi g_{9/2}^{9} \otimes \nu g_{7/2}^{1} \ (54\%)$$

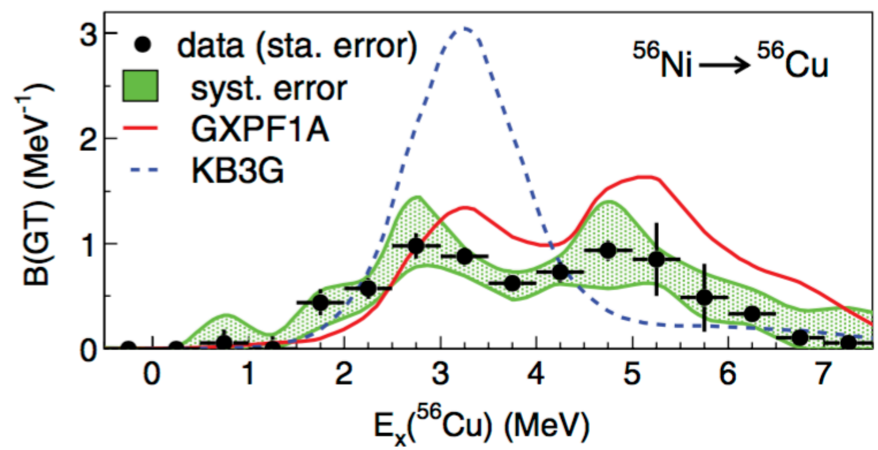
Superallowed Gamow-Teller of ^{100}Sn





- ❑ Correlations reduce the B(GT) sum rule

	^{94}Ru	^{96}Pd	^{98}Cd	^{102}Sn
0p-0h	7.11	10.66	14.22	16.02
2p-2h	4.36	7.68	11.30	12.15
4p-4h	3.44	6.64	10.36	10.95
5p-5h	2.21	5.44	10.18	
6p-6h	1.77			



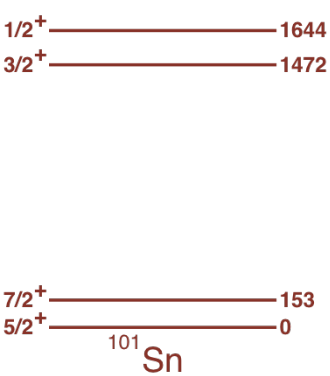
- ❑ 82% of closed shell in ^{100}Sn predicted in SM vs 50-60% in ^{56}Ni

Superallowed Gamow-Teller of ^{100}Sn

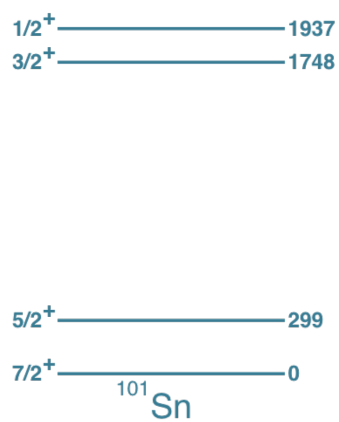
- The gaps N=Z=50 were constrained from earlier studies (e.g. ^{98}Cd)
- SM reproduced well ^{100}In structure
- GT appears sensitive to the $d_{5/2}g_{7/2}$- the rest of the shell splitting

What is the single-particle structure of ^{101}Sn ?

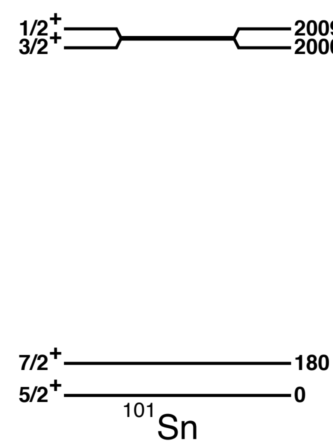
B(GT)=5.01



B(GT)=5.02



B(GT)=5.68

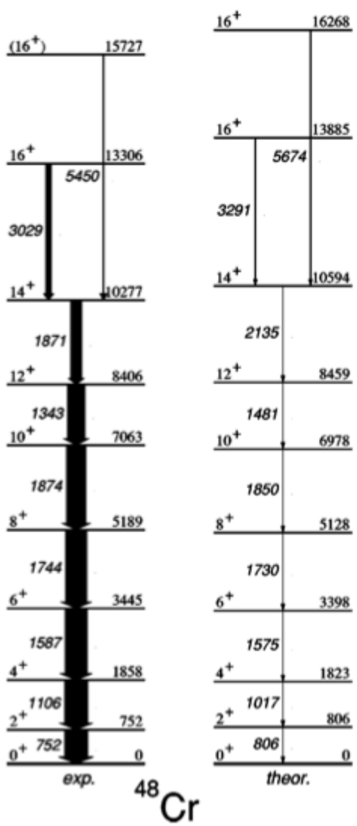


Collectivity in light Xe isotopes

PRL 99, 022501 (2007) PHYSICAL REVIEW LETTERS week ending 13 JULY 2007

Identification of Excited States in the $T_z = 1$ Nucleus ^{110}Xe: Evidence for Enhanced Collectivity near the $N = Z = 50$ Double Shell Closure

M. Sandzelius,[1] B. Hadinia,[1] B. Cederwall,[1,*] K. Andgren,[1] E. Ganioğlu,[2] I. G. Darby,[3] M. R. Dimmock,[3] S. Eeckhaudt,[4] T. Grahn,[4,†] P. T. Greenlees,[4] E. Ideguchi,[5] P. M. Jones,[4] D. T. Joss,[3] R. Julin,[4] S. Juutinen,[4] A. Khaplanov,[1] M. Leino,[4] L. Nelson,[3] M. Niikura,[5] M. Nyman,[4] R. D. Page,[3] J. Pakarinen,[4,†] E. S. Paul,[3] M. Petri,[3] P. Rahkila,[4] J. Sarén,[4] C. Scholey,[4] J. Sorri,[4] J. Uusitalo,[4] R. Wadsworth,[6] and R. Wyss[1]



Known rotors in the proximity of the closed shells:

sd-shell ^{24}Mg N=Z=4

pf-shell ^{48}Cr N=Z=4

sdg-shell ^{108}Xe N=Z=4 ?

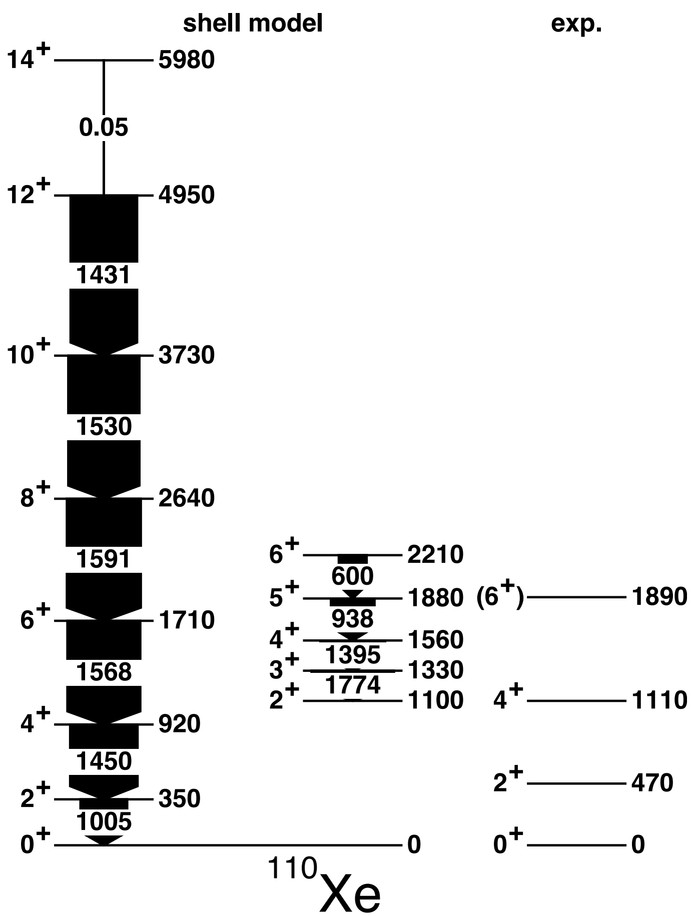
The proposed mechanism behind the light cases was a realizations of the approximate SU(3) symmetry scheme

« This unusual feature is suggested to be an effect of enhanced collectivity, possibly arising from isoscalar n-p interactions becoming increasingly important close to the N = Z line »

Collectivity in light Xenon isotopes

E. Caurier, F. Nowacki, A. Poves and K. Sieja, Phys. Rev. C82, 064304, 2010

- Shell Model calculations in *g7d5s1d3h11* model space with GCN5082 interaction



Experiment: Phys. Rev. Lett. 99, 022501, 2007

J	E^*	E_γ	$B(E2)$	Q_{spec}	Q_0 from $B(E2)$	Q_0 from Q_{spec}	β
2^+	0.35	0.35	1005	−62	225	217	0.17
4^+	0.92	0.57	1450	−78	226	215	0.17
6^+	1.71	0.79	1568	−83	224	208	0.17
8^+	2.64	0.93	1591	−87	220	207	0.17
10^+	3.73	1.09	1530	−86	213	198	0.17
12^+	4.95	1.22	1431	−85	204	191	0.16
14^+	5.98	1.03	0.05	−126			
16^+	6.63	0.65	111	−125			
18^+	7.51	0.88	1184	−130			
20^+	8.51	1.00	1043	−134			

^{110}Xe

J	E^*	E_γ	$B(E2)$	Q_{spec}	Q_0 from $B(E2)$	Q_0 from Q_{spec}	β
2_2^+	1.10			+61		214	0.17
3^+	1.33	0.23	1774	−1.3			
4_2^+	1.56	0.23	1395	−38	219	261	0.18
5^+	1.88	0.32	938	−54	217	234	0.17
6_2^+	2.21	0.33	600	−74	209	259	0.18

Collectivity in light Xe isotopes

Large-scale SM calculations:

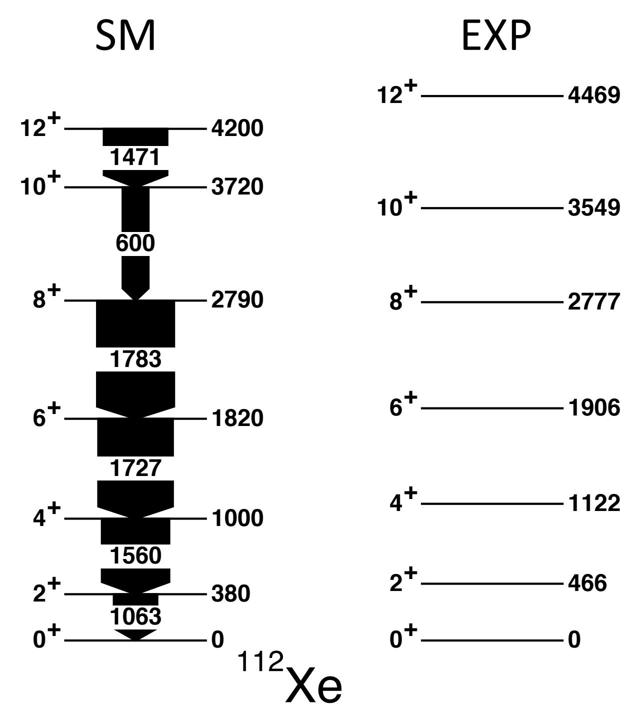
- ❑ ^{112}Xe: dim. 9.324.751.339 in the *g7d5s1d3h11* model space
- ❑ 2p-2h in ^{110}Xe 5.10^{9}
- ❑ 2p-2h in ^{112}Xe 17.888.383.122 (out of reach)

J	E^*	E_{exp}	$B(E2)$	Q_{spec}	Q_0 from $B(E2)$	Q_0 from Q_{spec}	β
2^+	0.38	0.46	1063	−62	217	231	0.17
4^+	1.00	1.12	1560	−75	206	236	0.17
6^+	1.82	1.91	1727	−76	190	236	0.17
8^+	2.79	2.78	1783	−74	176	232	0.17
10^+	3.72	3.55	600	−97			
12^+	4.20	4.47	1471	−118			

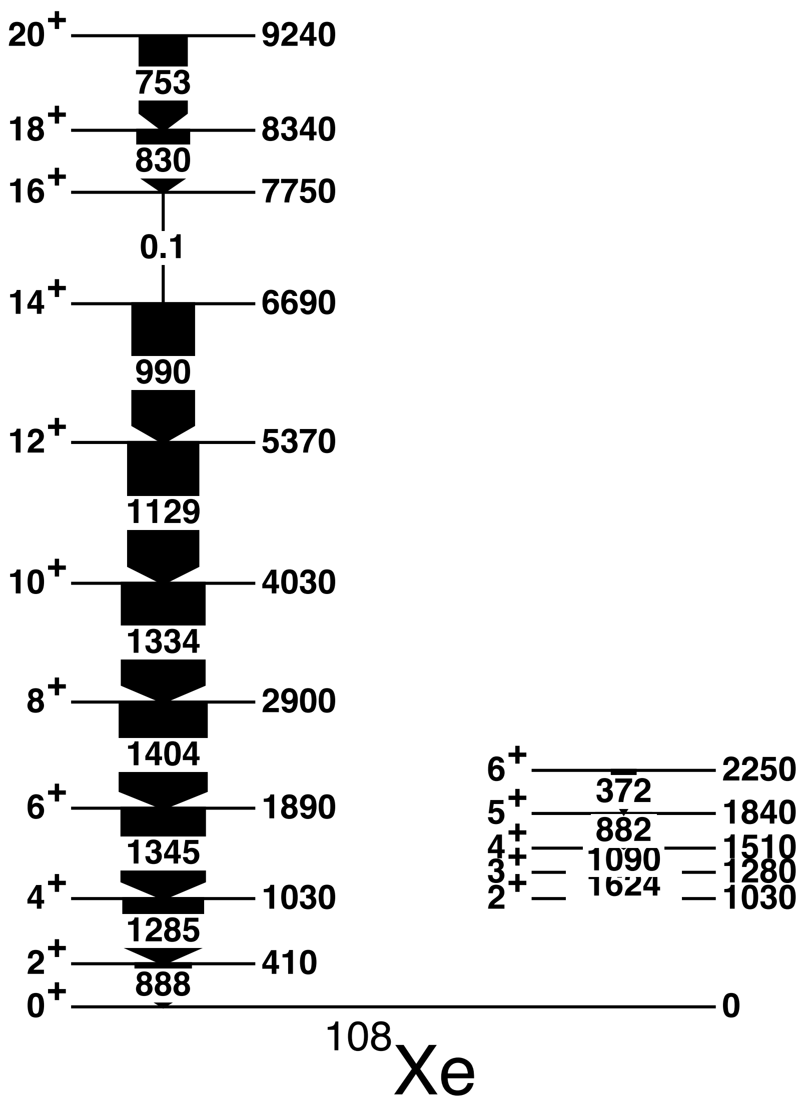
^{112}Xe

Is ^{100}Sn a good closed core?

^{108}Xe	Number of promoted particles	Effect on Q_2
1p-1h	0.25	15%
2p-2h	0.5	19%
^{110}Xe		
1p-1h	0.22	17%
2p-2h	0.5	21%
^{112}Xe		
1p-1h	0.25	20%



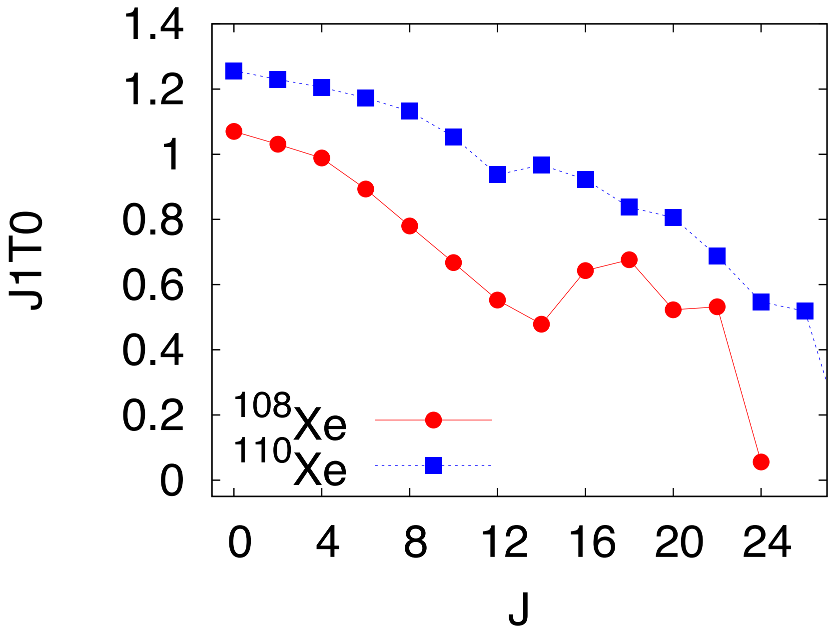
Collectivity in Xe isotopes: the N=Z case



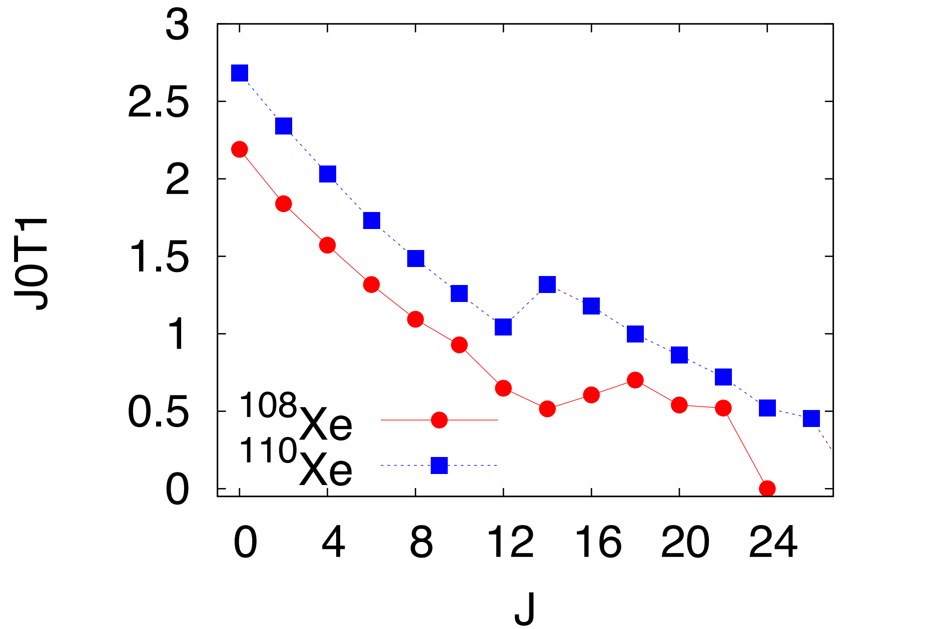
J	E^*	E_γ	$B(E2)$	Q_{spec}	Q_0 from $B(E2)$	Q_0 from Q_{spec}	β
2^+	0.41	0.41	888	−57	200	211	0.16
4^+	1.03	0.62	1285	−71	195	210	0.16
6^+	1.89	0.86	1345	−65	163	208	0.16
8^+	2.90	1.01	1404	−64	154	206	0.16
10^+	4.03	1.13	1334	−67	160	198	0.15
12^+	5.37	1.34	1129	−71	175	182	0.15
14^+	6.69	1.32	990	−79	176	168	0.14
16^+	7.75	1.06	0.1	−137			
18^+	8.34	0.59	830	−140			
20^+	9.24	0.90	753	−143			

J	E^*	E_γ	$B(E2)$	Q_{spec}	Q_0 from Q_{spec}	β
2_2^+	1.03			+59	196	0.16
3^+	1.28	0.25	1624	−1.3		
4_2^+	1.51	0.23	1090	−38	265	0.18
5^+	1.84	0.33	882	−51	220	0.17
6_2^+	2.25	0.41	372	−83	290	0.19

T=0 vs T=1 pairing in Xe isotopes



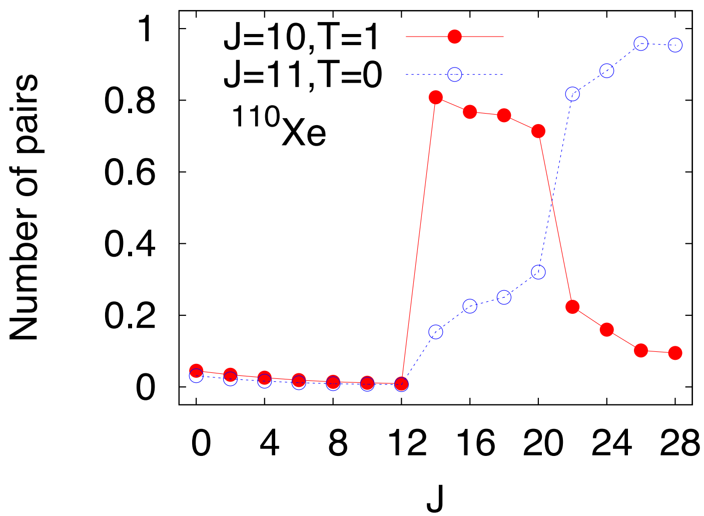
Number of p-n pairs (J=1, T=0)

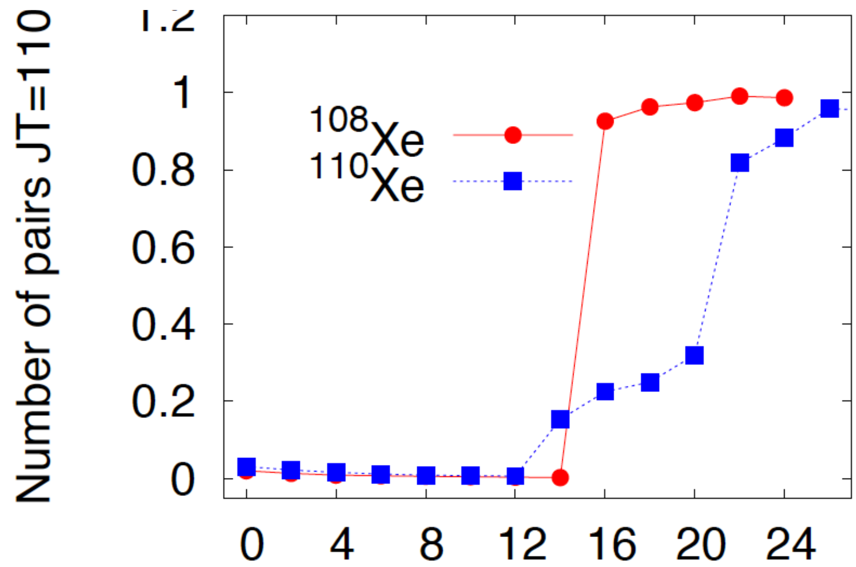


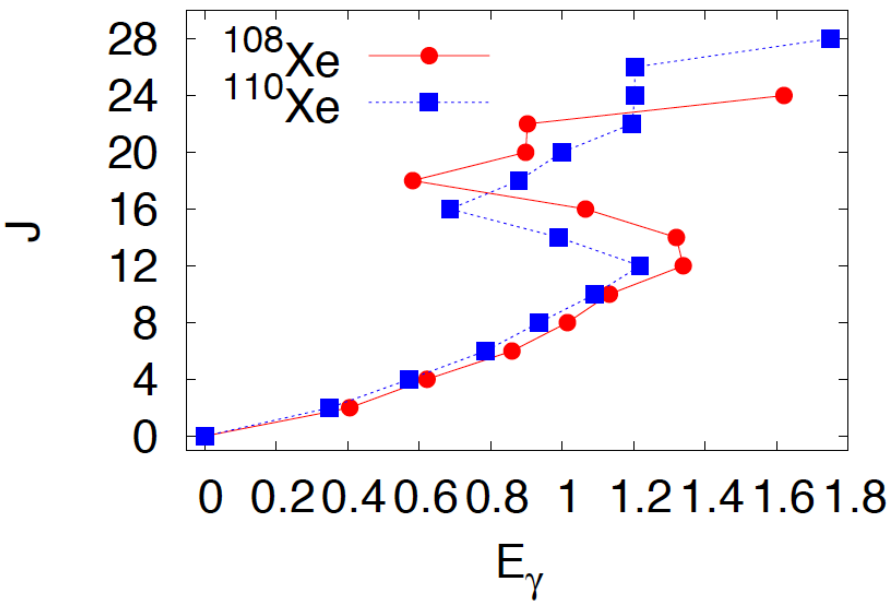
Number of p-p, p-n, n-n pairs (J=0, T=1

- ❑ No evidence for g.s. condensates
- ❑ Pair content decreasing with spin

Backbending and pair alignement







- Backbend takes place at J=14 in both nuclei
- Two-step process in ^{110}Xe

Conclusions

New, more precise data are welcome to revive the theoretical progress and interest in the ^{100}Sn region. The questions remain to be addressed experimentally:

- ❑ *What is the true pattern of transitions in tins ?*
- ❑ *Where is the 2^{+} of ^{100}Sn located ?*
- ❑ *What is the single-particle structure of ^{101}Sn ?*