Correlations versus shell evolution in the Nuclear Shell Model

Frédéric Nowacki

Strasbourg-Madrid Shell-Model collaboration
Shell structure and correlations

- at stability
  - double magicity + superdeformed states: $^{16}$O, $^{40}$Ca, $^{56}$Ni

- far from stability
  - Vanishing of shell closure: $^{11}$Li, $^{32}$Mg, $^{42}$Si, $^{68}$Ni, $^{80}$Zr ...
  - New gaps: $^{24}$O, $^{54}$Ca ...

Interplay between
- Monopole field (spherical mean field)
- Multipole correlations (pairing, Q.Q, ...)

“Pairing plus Quadrupole propose, Monopole disposes”

A. Zuker, Coherent and Random Hamiltonians, CRN Preprint 1994

For the Monopole field itself,
interplay between
- single particle field
- two-body interaction (T=1, T=0)
Island of inversion at N=40: an old story

A. Poves

CR and FR around N=40

A new region of deformation.

A situation that reminds what is known at N=20 FFS.

\[ g(0^+ - 2^+) = 5.70 \]
\[ g(0^+ - 4^+) = 8.30 \]

\[ Q = -9.0 \text{ b}^2 \]
\[ B(\alpha) = 19.8 \text{ b}^2 \]

\[ \frac{E(4^+)}{E(2^+)} = 2.7 \]

\[ \frac{E(4^+)}{E(2^+)} = (3.2) (3.4) \]

in the sd-shell configurations.

\[ \text{CS} < 1\% \]
\[ \eta(d5/2) = 1.1 \]
Collectivity at $N = 40$ in neutron-rich $^{64}$Cr


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Onset of collectivity in neutron-rich Fe isotopes: Toward a new island of inversion?


1CEA Saclay, IRFU, Service de Physique Nucléaire, F-91191 Gif-sur-Yvette, France
2GANIL, CEA/DSM-CNRS/IN2P3, Bd Henri Becquerel, BP 55027, F-14076 Caen, France
3CNRS-CNRS-IN2P3, F-01405 Orsay, France
SM framework

Island of inversion around $^{64}$Cr

S. Lenzi, F. Nowacki, A. Poves and K. Sieja


LNPS interaction:

- based on realistic TBME
- new fit of the pf shell (KB3GR, E. Caurier)
- monopole corrections

Calculations:

- up to 14p-14h excitations across Z=28 and N=40 gaps
- up to $10^{10}$
- m-scheme code ANTOINE (non public version)
Triple coexistence in $^{68}$Ni

- at first approximation, $^{68}$Ni has a double closed shell structure for GS

- But low lying structure much more complex

- three (now four) coexisting $0^+$ states appear between 0 and $\sim 2.5$ MeV
at first approximation, $^{68}\text{Ni}$ has a double closed shell structure for GS

But low lying structure much more complex

three (now four) coexisting $0^+$ states appear between 0 and $\sim 2.5$ MeV
Shape transition at N=40

### Graph (a)

- **E(2^+)(MeV)**
- **Z**
- **N=40**

### Graph (b)

- **B(E2;2^+ -> 0^+)(e^2 fm^4)**
- **Z**

### Table

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>νg(9/2)</th>
<th>νd(5/2)</th>
<th>configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>⁶⁸Ni</td>
<td>0.98</td>
<td>0.10</td>
<td>0p0h(51%)</td>
</tr>
<tr>
<td>⁶⁶Fe</td>
<td>3.17</td>
<td>0.46</td>
<td>4p4h(26%)</td>
</tr>
<tr>
<td>⁶⁴Cr</td>
<td>3.41</td>
<td>0.76</td>
<td>6p6h(23%)</td>
</tr>
<tr>
<td>⁶²Ti</td>
<td>3.17</td>
<td>1.09</td>
<td>4p4h(48%)</td>
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</table>
Neutron effective single particle energies

- Reduction of the $\nu d_{3/2}-f_{7/2}$ gap with removing $d_{5/2}$ protons
- Proximity of the quasi-SU3 partner $p_{3/2}$

- Reduction of the $\nu f_{5/2}-g_{9/2}$ gap with removing $f_{7/2}$ protons
- Proximity of the quasi-SU3 partner $d_{5/2}$
Spin-Tensor decomposition

Shell evolution and nuclear forces,
N.A. Smirnova, B. Bally, K. Heyde, F. Nowacki, K. Sieja


\[(f_7^2-d_3^2)\] shell gap evolution between \(^{32}\text{Mg}\) and \(^{34}\text{Si}\)
Spin-Tensor decomposition

\[ V = \sum V_k = \sum U_k \cdot S_k \]

<table>
<thead>
<tr>
<th>( k )</th>
<th>( S )</th>
<th>( S' )</th>
<th>spin-tensor components</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>C=Central</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>( l )</td>
<td>ALS=antisymmetric spin-orbit</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>( l )</td>
<td>LS=spin-orbit</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>T=Tensor</td>
</tr>
</tbody>
</table>

Proton number

ESPE (MeV)
Spin-Tensor decomposition

Shell evolution and nuclear forces,
N.A. Smirnova, B. Bally, K. Heyde, F. Nowacki, K. Sieja


$(f_7^2 - d_3^2)$ shell gap evolution between $^{32}$Mg and $^{34}$Si

\[
\begin{array}{ccc}
\Delta (f_7^2 - d_3^2) \text{ filling } d_5^2 \\
\hline
G \text{ matrix} & SDPF-U & \text{diff.} \\
\text{Tot} & 1.57 & 1.17 & -0.40 \\
\text{Central} & 1.11 & 0.70 & -0.41 \\
\text{Vector} & -0.159 & -0.155 & 0.004 \\
\text{LS} & -0.049 & -0.12 & -0.071 \\
\text{ALS} & -0.11 & -0.035 & 0.075 \\
\text{Tensor} & 0.61 & 0.63 & 0.02 \\
\end{array}
\]

Proton number

ESPE (MeV)
Neutron rich $sd – pf$ nuclei

Silicium chain

- Reduction of $d_{5/2} - d_{3/2}$ $Z=14$ gap with filling $f_{7/2}$ neutron orbital
- Reduction of $p_{3/2} - p_{1/2}$ spin-orbit splitting with filling $s_{1/2}$ proton orbital
- Reduction of $f_{7/2} - p_{3/2}$ $N=28$ gap with filling $d_{3/2}$ neutron orbital

"Tensor mechanism"
Neutron rich $sd$ – $pf$ nuclei

Silicium chain

- Reduction of $d_{5/2} - d_{3/2}$, $Z=14$ gap with filling $f_{7/2}$ neutron orbital
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“Tensor mechanism”
Neutron rich $sd – pf$ nuclei

Silicium chain

- Reduction of $d_{5/2} - d_{3/2}$ $Z=14$ gap with filling $f_{7/2}$ neutron orbital
- Reduction of $p_{3/2} - p_{1/2}$ spin-orbit splitting

$\Delta (d_{3/2} - d_{5/2})$ filling $f_{7/2}$

<table>
<thead>
<tr>
<th></th>
<th>G matrix</th>
<th>SDPF-U</th>
<th>diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tot</td>
<td>-3.15</td>
<td>-2.38</td>
<td>+0.77</td>
</tr>
<tr>
<td>Central</td>
<td>0.24</td>
<td>-0.11</td>
<td>-0.35</td>
</tr>
<tr>
<td>Vector</td>
<td>-0.27</td>
<td>0.55</td>
<td>0.82</td>
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<tr>
<td>LS</td>
<td>-0.11</td>
<td>0.11</td>
<td>0.22</td>
</tr>
<tr>
<td>ALS</td>
<td>-0.16</td>
<td>0.44</td>
<td>0.60</td>
</tr>
<tr>
<td>Tensor</td>
<td>-2.65</td>
<td>-2.77</td>
<td>0.12</td>
</tr>
</tbody>
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Evidence for a spin–aligned neutron–proton paired phase from the level structure of $^{92}\text{Pd}$


doi:10.1038/nature09644
New proton-neutron coupling scheme in $^{92}$Pd?

Claim for transition from Cooper pairs to aligned p-n pairs.
New proton-neutron coupling scheme in $^{92}$Pd

- In $A=90-100$ region, spin-orbit is at play: strong $Z=50$ shell closure and the $g_{\frac{9}{2}}$ orbital deeply bound with respect to the remaining $gds$ orbitals.

- Level schemes of $A \sim 90$ nuclei to be described within $g_{\frac{9}{2}}$ orbital.

- Regular level spacing and constant BE2's.

- Wave function analysis lead to condensate of $(pn)^J=9^+$ pairs.

<table>
<thead>
<tr>
<th>Shell Model</th>
<th>Exp.</th>
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<tbody>
<tr>
<td>$10^+$</td>
<td>4072</td>
</tr>
<tr>
<td>$8^+$</td>
<td>3127</td>
</tr>
<tr>
<td>$6^+$</td>
<td>2466</td>
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<tr>
<td>$6^+$</td>
<td>2535</td>
</tr>
<tr>
<td>$4^+$</td>
<td>1708</td>
</tr>
<tr>
<td>$4^+$</td>
<td>1786</td>
</tr>
<tr>
<td>$2^+$</td>
<td>878</td>
</tr>
<tr>
<td>$2^+$</td>
<td>874</td>
</tr>
<tr>
<td>$0^+$</td>
<td>0</td>
</tr>
<tr>
<td>$0^+$</td>
<td>0</td>
</tr>
</tbody>
</table>
How to assess (pn) condensate regime

1) build \((j_{p1}j_{n1})^{N}_{J=2j}\) objects

2) diagonalise \((J = 2j; T = 0)\) single matrix element for given system

- take the overlap with effective wave function
- take the expectation value of pair counting operator
- first two methods give \(\sim\) results, and provide relative estimate
- counting pairs provides absolute estimate
calculations with effective $g_{9/2}^\text{eff}$ (Chong et al.) and JUN45 (Otsuka et al.) interactions

- striking similarity of computed spectra

- regular level spacing and constant BE2’s

- BUT quantitative differences between wave functions and underlying physics

- 29% of $(g_{9/2}^\text{eff})^{12}$ configuration left in the full space calculation

- vanishing Q’s in $r3g$
- large and constant in $g_{9/2}$
**Table:** correlated JT=90 pairs content in the yrast band of in $^{92}$Pd.

| $J^\pi$ | $\langle con|\psi_{92Pd}\rangle$ | $\langle con|\psi_{92Pd}\rangle$ |
|---------|-----------------|-----------------|
|         | g$_{9/2}$ | r$_{3g}$       |
| 0$^+$   | 0.83      | 0.45            |
| 2$^+$   | 0.87      | 0.48            |
| 4$^+$   | 0.91      | 0.58            |
| 6$^+$   | 0.87      | 0.62            |
| 6$^+$   | 0.73      | 0.57            |
| 8$^+$   | 0.86      | 0.69            |
| 10$^+$  | 0.35      | 0.34            |
| 24$^+$  | 1.00      | 0.99            |

```
10^+     4072
  330
  8^+     3127
   298
  6^+     2466
   345
  4^+     1708
   325
  2^+     878
   239
  0^+     0

10^+     4071
  335
  8^+     3217
   316
  6^+     2535
   364
  4^+     1786
   382
  2^+     874
   304
  0^+     0
```

EGAN 2011 workshop, June 26-30, 2011
**Table:** Number of correlated JT=90 pairs in the yrast band of $^{92}\text{Pd}$.

<table>
<thead>
<tr>
<th>$J^\pi$</th>
<th>$N_{\text{pair}}$</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$g_9/2$</td>
<td>2.26</td>
<td>1.34</td>
</tr>
<tr>
<td>0$^+$</td>
<td>2.32</td>
<td>1.48</td>
</tr>
<tr>
<td>2$^+$</td>
<td>2.35</td>
<td>1.65</td>
</tr>
<tr>
<td>4$^+$</td>
<td>2.38</td>
<td>1.69</td>
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<td>1.69</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>24$^+$</td>
<td>3.87</td>
<td>3.87</td>
</tr>
</tbody>
</table>

Diagram showing energy levels and transition energies for $^{92}\text{Pd}$.
Table: Number of correlated JT=90 pairs in the yrast band of $^{92}\text{Pd}$.

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<th>$r_3g$</th>
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<th>$g_9$</th>
<th>$r_3g$</th>
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<tbody>
<tr>
<td>$0^+$</td>
<td>2.26</td>
<td>1.34</td>
<td>2.26</td>
<td>1.34</td>
<td>2.32</td>
<td>1.48</td>
</tr>
<tr>
<td>$2^+$</td>
<td>2.32</td>
<td>1.48</td>
<td>2.35</td>
<td>1.65</td>
<td>2.38</td>
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<td>$4^+$</td>
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<td>2.38</td>
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</tr>
<tr>
<td>$6^+$</td>
<td>2.38</td>
<td>1.69</td>
<td>2.38</td>
<td>1.69</td>
<td>2.38</td>
<td>1.69</td>
</tr>
<tr>
<td>$8^+$</td>
<td>2.38</td>
<td>1.69</td>
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<td>2.38</td>
<td>1.69</td>
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<tr>
<td>$10^+$</td>
<td>2.38</td>
<td>1.69</td>
<td>2.38</td>
<td>1.69</td>
<td>2.38</td>
<td>1.69</td>
</tr>
<tr>
<td>$24^+$</td>
<td>3.87</td>
<td>3.87</td>
<td>3.87</td>
<td>3.87</td>
<td>3.87</td>
<td>3.87</td>
</tr>
</tbody>
</table>

Overestimation with $[(a^\dagger a^\dagger)^{J_{T_0}} (aa)^{J_{T_0}}]^{00}$ operator

$N_{p_0}^{J_0 T_0} = \beta_{J_0} \sum J \alpha_{J,J_0} [(a^\dagger a^\dagger)^{J_{T_0}} (aa)^{J_{T_0}}]^{00}$

$\alpha_{J,J_0} = -\frac{2J_0+1}{\sum J (2J+1)}$ for $J \neq J_0$

$\alpha_{J_0,J_0} = \frac{\sum J \neq J_0 (2J+1)}{\sum J (2J+1)}$

$\beta_{J_0} = \frac{\sum J (2J+1)}{\sum J \neq J_0 (2J+1)}$
**JT=90 pairs content**

**Table:** Number of correlated JT=90 pairs in the yrast band of $^{92}$Pd.

<table>
<thead>
<tr>
<th>$J^\pi$</th>
<th>$N_{pair}$</th>
<th>$N_{pair}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$g_9/2$</td>
<td>$r_3g$</td>
</tr>
<tr>
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<tr>
<td>$10^+$</td>
<td>2.38</td>
<td>1.69</td>
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<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$24^+$</td>
<td>3.87</td>
<td>3.87</td>
</tr>
</tbody>
</table>

---

*Diagram showing levels and energies for $^{92}$Pd.*

**sm g9**:

- $10^+$ at 4072
- $8^+$ at 330
- $6^+$ at 298
- $4^+$ at 2466
- $2^+$ at 878
- $0^+$ at 0

**exp.**:

- $10^+$ at 4071
- $8^+$ at 335
- $6^+$ at 3217
- $4^+$ at 2535
- $2^+$ at 874
- $0^+$ at 0

**sm f5p3p1g9**:

- $10^+$ at 4071
- $8^+$ at 335
- $6^+$ at 3217
- $4^+$ at 2535
- $2^+$ at 874
- $0^+$ at 0
Table: Number of correlated JT=90 pairs in the yrast band of $^{92}$Pd.

<table>
<thead>
<tr>
<th>$J^\pi$</th>
<th>$N_{pair}^{g_9/2}$</th>
<th>$N_{pair}^{r3g}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0$^+$</td>
<td>2.26</td>
<td>1.34</td>
</tr>
<tr>
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<tr>
<td>10$^+$</td>
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<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24$^+$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With JUN45 interaction in $r3g$ space:
- Weak content of $J = 9T = 0$ (pn) pairs
- Seniority zero component (35%) larger than condensate component (20%)!
**Case of $^{52}\text{Fe}$ (mate of $^{96}\text{Cd}$)**

**Table:** correlated JT=$70$ pairs content in the yrast band of in $^{52}\text{Fe}$.

| $J^\pi$ | $\langle \text{cond}|\Psi_{^{52}\text{Fe}}\rangle$ | $\langle \text{cond}|\Psi_{^{52}\text{Fe}}\rangle$ | $f_{7/2}$ | $fp$ |
|---------|---------------------------------|---------------------------------|---------|-------|
| $0^+$   | 0.99                            | 0.99                            | 0.99    | 0.66  |
| $2^+$   | 0.99                            | 0.99                            | 0.99    | 0.66  |
| $4^+$   | 0.99                            | 0.99                            | 0.99    | 0.66  |
| $6^+$   | 0.98                            | 0.98                            | 0.98    | 0.54  |
| $8^+$   | 0.99                            | 0.99                            | 0.99    | 0.75  |
| $10^+$  | 0.99                            | 0.99                            | 0.99    | 0.81  |
| $12^+$  | 1.00                            | 1.00                            | 1.00    | 0.81  |

**Diagram:**

- **sm f7**:
  - $12^+$ at 9426
  - $10^+$ at 8190
  - $8^+$ at 6370
  - $6^+$ at 4332
  - $4^+$ at 2392
  - $2^+$ at 850

- **exp.**:
  - $10^+$ at 7381
  - $12^+$ at 6820
  - $8^+$ at 6360
  - $6^+$ at 4325
  - $4^+$ at 2384
  - $2^+$ at 850

- **sm fp**:
  - $10^+$ at 7687
  - $12^+$ at 7638
  - $8^+$ at 6663
  - $6^+$ at 4647
  - $4^+$ at 2731
  - $2^+$ at 983

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Case of $^{52}\text{Fe}$ (mate of $^{96}\text{Cd}$)

**Table:** correlated JT=70 pairs content in the yrast band of $^{52}\text{Fe}$.

| $J^\pi$ | $\langle \text{cond}|\Psi_{^{52}\text{Fe}}\rangle$ | $f_{7/2}$ |
|--------|----------------------------------|---------|
|    0$^+$   | 0.99                             |         |
|    2$^+$   | 0.99                             |         |
|    4$^+$   | 0.99                             |         |
|    6$^+$   | 0.98                             |         |
|    8$^+$   | 0.99                             |         |
|   10$^+$   | 0.99                             |         |
|   12$^+$   | 0.81                             |         |

- Rotor regime for low-lying states
- Same conclusion holds for $^{96}\text{Cd}$
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. Eeckhautd,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. Khablanov,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. Wyss¹

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²Science Faculty, Physics Department, Istanbul University, 34459 Istanbul, Turkey
³Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom
⁴Department of Physics, University of Jyväskylä, FIN-40014 Jyväskylä, Finland
⁵Center for Nuclear Study, University of Tokyo, Wako, Saitama 351-0198, Japan
⁶Department of Physics, University of York, Heslington, York Y010 5DD, United Kingdom

(Received 30 January 2007; published 11 July 2007)

Gamma-ray transitions have been identified for the first time in the extremely neutron-deficient ($N = Z + 2$) nucleus $^{110}$Xe, and the energies of the three lowest excited states in the ground-state band have been deduced. The results establish a breaking of the normal trend of increasing first excited $2^+$ and $4^+$ level energies as a function of the decreasing neutron number as the $N = 50$ major shell gap is approached for the neutron-deficient Xe isotopes. 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.
Deformation in light Xenon isotopes

Identification of Excited States

M. Sandzelius,1 B. Hadinia,1 B. J. L. Gilbert,1 T. Grahn,4,† P. T. Greenlees,4 E. Thuneberg,4 L. Nelson,3 M. Niikura,5 M. Nyrén,6

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Gamma-ray transition intensities have been measured for the 20 (Z + 2) nucleus ^{110}Xe, and the level energies have been deduced. The results provide evidence for enhanced collectivity due to isoscalar n-p interactions for the neutron-deficient Xe isotopes in the mass region 110 ≤ A ≤ 136. Data are from the present work and Refs. [23,30].

claim for enhanced collectivity due to isoscalar n-p interactions

FIG. 3 (color online). Energies of 2^+_1 (squares) and 4^+_1 (circles) states plotted versus neutron number N for even-even Xe isotopes in the mass region 110 ≤ A ≤ 136. Data are from the present work and Refs. [23,30].
In A=100 region, spin-orbit is at play: strong Z=50 shell closure and the $g_{9/2}$ orbital deeply bound with respect to the remaining $gds$ orbitals.

The natural valence space beyond $^{100}$Sn is made of $g_{7/2}$, $d_{5/2}$, $d_{3/2}$, $s_{1/2}$, and $h_{11/2}$ orbitals.

But at N=Z, $h_{11/2}$ is higher and the other orbitals close to each other.

One recovers a pseudo-fp space where SU3 symmetry scheme available.
Deformation in light Xenon isotopes

In the A=100 region, spin-orbit interactions are significant because of the strong Z=50 shell closure. The g_{9/2} orbital is deeply bound with respect to the remaining g_{7/2}, d_{5/2}, d_{3/2}, s_{1/2}, and h_{11/2} orbitals.

At N=Z, h_{11/2} is higher and the other orbitals are close to each other, leading to a pseudo-fp space where SU3 symmetry is available.

The image includes a diagram of the Shells model expansion for 100Sn, showing the occupation of orbitals up to 14^+ with energies up to 5980 MeV.

The observed energies (exp.) are compared with the shell model predictions (shell model exp.).
Deformation in light Xenon isotopes

In $A=100$ region, spin-orbit is at play: strong $Z=50$ shell closure and the $g_{\frac{9}{2}}$ orbital deeply bound with respect to the remaining $gds$ orbitals.

The natural valence space beyond $^{100}$Sn is made of $g_{\frac{7}{2}}$, $d_{\frac{5}{2}}$, $d_{\frac{3}{2}}$, $s_{\frac{1}{2}}$, and $h_{\frac{11}{2}}$ orbitals.

But at $N=Z$, $h_{\frac{11}{2}}$ is higher and the other orbitals close to each other.

One recovers a pseudo-fp space where SU3 symmetry scheme available.
A case of extreme triaxiality: $^{110}\text{Xe}$


<table>
<thead>
<tr>
<th>J</th>
<th>E*</th>
<th>$E_\gamma$</th>
<th>BE2</th>
<th>$Q_{sp}$</th>
<th>$Q_0$ (BE2)</th>
<th>$Q_0$ (Qsp)</th>
<th>$\beta$</th>
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</thead>
<tbody>
<tr>
<td>2^+</td>
<td>0.35</td>
<td>0.35</td>
<td>1005</td>
<td>-62</td>
<td>225</td>
<td>217</td>
<td>0.16</td>
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<tr>
<td>4^+</td>
<td>0.92</td>
<td>0.57</td>
<td>1450</td>
<td>-78</td>
<td>226</td>
<td>215</td>
<td>0.16</td>
</tr>
<tr>
<td>6^+</td>
<td>1.71</td>
<td>0.79</td>
<td>1568</td>
<td>-83</td>
<td>224</td>
<td>208</td>
<td>0.16</td>
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<tr>
<td>8^+</td>
<td>2.64</td>
<td>0.94</td>
<td>1591</td>
<td>-87</td>
<td>220</td>
<td>207</td>
<td>0.16</td>
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<tr>
<td>10^+</td>
<td>3.73</td>
<td>1.09</td>
<td>1530</td>
<td>-86</td>
<td>213</td>
<td>198</td>
<td>0.15</td>
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<tr>
<td>12^+</td>
<td>4.95</td>
<td>1.22</td>
<td>1431</td>
<td>-85</td>
<td>204</td>
<td>191</td>
<td>0.15</td>
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<tr>
<td>14^+</td>
<td>5.98</td>
<td>0.99</td>
<td>0.05</td>
<td>-126</td>
<td>1</td>
<td>279</td>
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<tr>
<td>16^+</td>
<td>6.63</td>
<td>0.69</td>
<td>111</td>
<td>-125</td>
<td>56</td>
<td>273</td>
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<tr>
<td>18^+</td>
<td>7.51</td>
<td>0.88</td>
<td>1184</td>
<td>-130</td>
<td>183</td>
<td>282</td>
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<tr>
<td>20^+</td>
<td>8.51</td>
<td>1.00</td>
<td>1043</td>
<td>-134</td>
<td>172</td>
<td>288</td>
<td></td>
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<tr>
<td>$2^+_2$</td>
<td>1.10</td>
<td></td>
<td></td>
<td>+61</td>
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<tr>
<td>$3^+$</td>
<td>1.33</td>
<td>0.23</td>
<td>1774</td>
<td>-1.3</td>
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<tr>
<td>$4^+_2$</td>
<td>1.56</td>
<td>0.23</td>
<td>1395</td>
<td>-38</td>
<td>219</td>
<td>261</td>
<td>0.18</td>
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<tr>
<td>$5^+$</td>
<td>1.88</td>
<td>0.32</td>
<td>938</td>
<td>-54</td>
<td>217</td>
<td>234</td>
<td>0.17</td>
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<td>$6^+_2$</td>
<td>2.21</td>
<td>0.33</td>
<td>600</td>
<td>-74</td>
<td>209</td>
<td>259</td>
<td>0.17</td>
</tr>
</tbody>
</table>

One could extract the $\gamma$ from:

$$\frac{BE2(2^+_\gamma \rightarrow 2^+_1)}{BE2(2^+_\gamma \rightarrow 0^+_1)} = \gamma = 20^\circ$$

Notice $Q(2^+_\gamma) = -Q(2^+_\text{Yrast})$ and $Q(3^+) \sim 0$ as results from $3K^2 - J(J+1)$ for $K=2$ and $J=3$.

Comments about $h_{11/2}$ influence:

- reduced M. I.: $E(2^+) = 0.19$
- slight increase of coll.: $BE2(2^+) = 1110$
- no backbending
- reduced triaxiality $\gamma = 12^\circ$
- better $J(J+1)$
- magnetic moments consistent with rot. model up to $J=20$
A case of extreme triaxiality: $^{110}\text{Xe}$


One could extract the $\gamma$ from:

$$\gamma = 20^\circ$$

$Q(2^+_\text{Yrast})$ and $Q(2^+_2)$ results from $3K^2 - J(J+1)$ for $K=2$ and $J=3$

$h_{11/2}$ influence

M. I. : $E(2^+) = 0.19$

Slight increase of coll. : $^1110$

No backbending

Reduced triaxiality $\gamma = 12^\circ$

Better $J(J+1)$ magnetic moments consistent with model up to $J=20$
Backbend plots
Alignment properties in $^{108}$Xe

The graph shows the number of $J=11$, $T=0$ pairs as a function of angular momentum $J$. The data are represented by two lines:

- A black line with squares, labeled $(r4)^6(h_{11/2})^2$.
- A red line with circles, labeled yrast.

The x-axis represents $J$ values, ranging from 0 to 24, and the y-axis represents the number of $J=11$, $T=0$ pairs, ranging from 0 to 0.8.
Alignment properties in $^{110}\text{Xe}$

The graph shows the number of JT-aligned pairs as a function of angular momentum ($J$) for two different alignment properties: $J=11, T=0$ (black circles) and $J=10, T=1$ (red squares). The number of aligned pairs increases with increasing $J$ for both cases, but the $J=11, T=0$ case shows a sharper rise and a subsequent sharper drop compared to the $J=10, T=1$ case.
Isovector pairing properties

The diagram shows the number of J=0 T=1 pairs for two isotopes of xenon: $^{108}$Xe and $^{110}$Xe. The number decreases as J increases, with $^{108}$Xe showing a slightly higher pair density compared to $^{110}$Xe.
Isoscalar pairing properties

![Graph showing number of J=1 T=0 pairs for \(^{108}\text{Xe}\) and \(^{110}\text{Xe}\)](image-url)
Summary

- Monopole drift develops in all regions but the interplay between correlations (pairing + quadrupole) and spherical mean-field (monopole field) determines the physics. It can vary from:
  - island of deformation at N=20 and N=40
  - deformation at Z=14, N=28 for $^{42}$Si and shell weakening at Z=28, N=50 for $^{78}$Ni
- Spin-Tensor analysis of the effective interaction in sd-pf show mainly central and tensor components effects
- Quadrupole energies can be huge and understood in terms of symmetries
- As well as in lighter systems, in mid-mass nuclei (like Xenon isotopes) isoscalar correlations in $N \sim Z$ nuclei appear to be weak for low-lying states
- In $A \sim 90$ region for $^{92}$Pd and $^{96}$Cd do not show condensate regime in LSSM
Summary

Thanks to:

- E. Caurier, K. Sieja, A. Zuker
- A. Poves
- H. Grawe, S. Lenzi, O. Sorlin