Shell evolution of neutron-deficient Xe isotopes: Octupole and Quadrupole Correlations above $^{100}$Sn

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For the E730 Collaboration
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1. Physic motivation

- LIFETIMES OF EXCITED STATES IN $^{112}$Xe
  - Octupole correlation: $3^-$ and $5^-$ states
  - Quadrupole collectivity: $2^+$ and $4^+$ states
1. Physic motivation

★ Enhanced octupole due to the interaction of $d_{5/2}$ and $h_{11/2}$
$\Delta L = 3, \Delta J = 3$, inverse parity.

★ $Z$ or $N$ close 56, 88 and 136.

★ No $B(E3)$ have been measured in this region close to $N=Z$ beyond $^{114}Xe$.

★ Correlations predicted for both: protons and neutrons in region with $N=Z=56$.

★ Fermi surface in this region lies between the $d_{5/2}$ and $h_{11/2}$ orbitals.

★ Removing neutron from the $h_{11/2}$ orbital gradually decreases the 3-excitation energy and enhances the $B(E3)$ value for the Xe isotopes.
1.1 Physic motivation: Octupole

- Calculations using GCM (Generator-Coordinate Method) of the HFB (Hartree-Fock-Bogoliubov) self-consistent mean field theory with the Gogny force.

<table>
<thead>
<tr>
<th></th>
<th>$^{114}$Xe</th>
<th>$^{112}$Xe</th>
<th>$^{118}$Ba</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E (3⁻) (MeV)</strong></td>
<td>1.84/1.62</td>
<td>1.99/1.65</td>
<td>2.11</td>
</tr>
<tr>
<td><strong>B (E3, 3⁻ → 0⁺)\text{Theo (W.u.)}</strong></td>
<td>17</td>
<td>25</td>
<td>17.46</td>
</tr>
<tr>
<td><strong>B (E3, 3⁻ → 0⁺)\text{Exp (W.u.)}</strong></td>
<td>77(27)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Good agreement with excitation energy of the 3⁻ state.
- B (E3, 3⁻ → 0⁺) turns out to be too small in the case of $^{114}$Xe with a factor of ~ 4 times difference with the experimental value.
- We expect the B(E3) of $^{112}$Xe higher.
- Experimental data fundamental to shed light on the issue.
1.2 Physic motivation: Quadrupole

- Preserving collectivity approaching N=50 in the vicinity of N=Z.
- These findings constitute possible evidence for the importance of isoscalar n-p interactions for the development of nuclear collectivity.
- Nevertheless, lifetimes provides a better indication of collectivity.
- More spectroscopic data are needed. We have performed the first measurement of the B(E2)'s of the first excited states in $^{112}$Xe via their lifetime using the plunger technique.

2. Production Mechanism

• Fusion-Evaporation Reaction

Beam: $^{58}\text{Ni}$ → Target: $^{58}\text{Ni}$ → FUSION → Compound Nucleus: $^{116}\text{Ba}$ → $^{112}\text{Xe}$

- Beam energy of 250 MeV.
- The cross section was estimated to be a few hundred $\mu$barns.
- The channels with higher population in the reaction are $^{112}\text{Te}(4p)$, $^{109}\text{Sb}(\alpha 3p)$, $^{113}\text{I}(3p)$ and $^{110}\text{Te}(\alpha 2p)$ which constitute respectively 46%, 16%, 12% and 10% of the reaction products.
- Trigger: at least 1 neutron in coincidence with $\gamma$-rays is required, discriminated with PSA.
- This trigger eliminates already $\sim$85% of unwanted channels and suppress the background from the $\beta$-decay.
3. Experimental Setup

• GANIL

CAD drawing of the experimental set-up. From the left to right, the different detectors are drawn: NEDA+NEUTRON WALL, DIAMANT (placed in the target chamber) and AGATA.
3.1. Experimental Setup: Detectors

- GANIL

BC501A liquid scintillator with PSA capability


CAD drawing of the experimental set-up. From the left to right, the different detectors are drawn: NEDA+NEUTRON WALL, DIAMANT (placed in the target chamber) and AGATA.
3.1. Experimental Setup: Detectors

- **GANIL**

  \[ \text{Eff} = (30 \pm 6)\% \]

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CAD drawing of the experimental set-up. From the left to right, the different detectors are drawn: NEDA+NEUTRON WALL, DIAMANT (placed in the target chamber) and AGATA.
3.2. Experimental Setup: Plunger

Target: $^{58}$Ni 1 mg/cm$^2$

Degrader: $^{197}$Au 5 mg/cm$^2$

CSNSM “OUPS” plunger

$\gamma \approx E_{\gamma} - (1 - \frac{v_{rec}}{c} \cos \theta)$

$I(t) + I'(t) = N_0 e^{-(x/v_{rec})/\tau}$

Beam

Variable distance

Distances ranging from 10 to 1500 μm

Simulation done by J. Ljungvall

Stopper

Degrader

Simulation done by J. Ljungvall

A. Dewald et al, Progress in Particle and Nuclear Physics 67 (2012) 786–839
4. Analysis Status

AGATA
DATA
PROCESSING

In each detector the event is recorded as a set of 36+2 sampled waveforms.

Energy Calibration
Time Alignment
Cross-talk correction
Dead/Unstable segment correction

Re-calibrations
Neutron damage correction
Global Time alignment

Global reference frame
Event validation
TimeStamp window

OFT tracking algorithm used

Read-in the data from the disk

Differential Cross-talk correction
Pulse Shape Analysis Grid
search type: Adaptive

Merging AGATA & Complementary Det.
Coincidence window

Write-out the data from the disk
4. Analysis Status

AGATA DATA PROCESSING

ONLINE

Raw data
AGATA detectors
LOCAL Level Processing
Crystal Producer
Preprocessing Filter
PSA Filter
PostPSA Filter
GLOBAL Level Processing
Event Builder
Complementary Det.
Event Merger
Tracking Filter
Consumer

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OFF tracking algorithm used
4. Analysis Status

AGATA: POSTPSA  Neutron Damage and Energy Corrections

PSA Data
After ND corr
After Energy corr
4. Analysis Status

- **GLOBAL TIME ALIGNMENT**

Before GTA

After GTA
4. Analysis Status

- **GLOBAL TIME ALIGNMENT**

<table>
<thead>
<tr>
<th>Before GTA</th>
<th>After GTA</th>
</tr>
</thead>
</table>

![Graph showing data before and after GTA alignment]
4. Analysis Status

- Time Align of DIAMANT
4. Analysis Status

- **DIAMANT GATES**

Energy vs PID for channel 8 of board 100
4. Analysis Status

- **NEDA+NW GATES**

Energy vs Charge Comparison PSA for channel 10 of board 142

4. Analysis Status

- **NEDA+NW GATES**

Time Of Flight vs Charge Comparison PSA for channel 10 of board 142
4. Analysis Status

- Neutron scattering

DeltaTDistance_tot

\[ \Delta \text{ToF (ns)} \]

\[ \text{Dist [mm]} \]
We can see after the proper gates, with the 2n2p particle identification, the principal transitions online.
4.1 Online Analysis Result

Sum of distances: 20, 30 and 40 μm
4.1 Online Analysis Result

- Example of online Lifetime

2⁺ lifetime. Gated on the fast decay of the 4⁺

\[ T_{1/2} \sim 14 \text{ ps} \]

\[ \tau \sim 20 \text{ ps (}^{114}\text{Xe} \ 2^+ \rightarrow 0^+ \tau = 23\text{ps)} \]

380 \( \mu \text{m} \) distance

on-going 700 \( \mu \text{m} \) distance

200 \( \mu \text{m to be measured} \)
5. Summary

- Experimental study of octupole and quadrupole correlations in $^{112}$Xe
- Experiment performed at GANIL using the AGATA+NW+NEDA+DIAMANT+plunger Set-up
- Post-PSA corrections in AGATA
- Time Alignment of detectors
- Particle gates in DIAMANT
- Neutron gates in NEDA and NW
- Neutron efficiency
- Ongoing Analysis. Actual step: Event Merger
THANK YOU FOR YOUR ATTENTION
ACKNOWLEDGE THE GANIL COLLEAGUES,
SPECIALY THE ACCELERATORS TEAM.
THANK YOU TO THE AGATA, NEDA-NW, DIAMANT
AND THE “OUPS” PLUNGER
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