Isospin mixing at finite temperature in $^{80}$Zr

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Isospin Mixing

Isospin Mixing at $T > 0$ using GDR $\gamma$ decay

Preliminary results from $T = 2.2$ MeV

Possible measurements at SPES

Conclusions
The Isospin Mixing in the ground state

- The presence of the Coulomb interaction inside the nucleus causes a mixing between states with different isospin.
- The main contribution to the mixing is between states with \( \Delta I = 1 \).
- In a perturbative way the mixing probability in the nuclear ground state is defined as:

\[
\alpha^2 = \frac{|\langle I = 1 | H_c | I = 0 \rangle|^2}{\Delta E^2}
\]
A CN in an excited state has a finite lifetime $\tau$.

The lifetime can be so short to not allow a complete mixing.

At high excitation energy (and thus at short lifetime) the isospin symmetry is restored.

Lifetime implies a dynamical behavior of the isospin mixing phenomenon.
The Isospin Mixing at $T>0$

This **dynamical behavior** is described by the parameter $\alpha^2$, defined as:

$$\alpha^2 \approx \frac{\Gamma}{\Gamma_{CN}} \approx \frac{\tau_{CN}}{\tau_{MIX}}$$

- **Coulomb spreading width**
- **Compound nucleus decay width**
- **To be obtained from measurements**
- **Known from statistical decay**

The Isospin Mixing at $T>0$

Theoretical model describes the relation between $E^*$ and $\alpha^2$:

$$\alpha^2_{J=0+1} \sim \frac{\Gamma_{\text{IAS}}}{\Gamma_{\text{CN}}(T) + \Gamma_{\text{IVM}}}$$

- $\Gamma_{\text{IAS}}$ is the coulomb spreading width of the Isobaric Analog State. **FROM DATA**
- $\Gamma_{\text{IVM}}$ is the width of the monopole resonance at the energy of the IAS **PARAMETER**
- $\Gamma_{\text{CN}}$ is the decay width of the nucleus. **KNOWN FROM CN DECAY**

**AIM OF THE PROJECT**

Using this model with two or more measurements we can extrapolate the mixing at $T=0$, from the values at $T \neq 0$.

More measurements for the same $N=Z$ system are needed

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Why $^{80}\text{Zr}$?

- In $^{80}\text{Zr}$ the isospin mixing effects are not negligible
- The theoretical predictions depend on the nuclear interaction used

The Isospin Mixing at T>0

- In N=Z nuclei I=0
- In N=Z nuclei the electric dipole transitions in long-wavelength limit are forbidden in states with the same isospin.

\[ I_{\text{fin}} = I_{\text{in}} \pm 1 \]

GDR at Temperature > 0

Selection rule:
E1 decays correspond to change of isospin

The mixing increases the \( \gamma \) decay yield

The observed E1 strength is a signature of the mixing

\[ \alpha^2 = 2.50(\pm 1.0 - 0.7)\% \]
Experimental technique

We form a $I=0$ Compound Nucleus with a heavy ions fusion reaction

$$^{40}\text{Ca} + ^{40}\text{Ca} \rightarrow ^{80}\text{Zr}^*$$

From the data fit we can extract $\Gamma^\downarrow$ quantity

We form a $I\neq 0$ Compound Nucleus with a heavy ions fusion reaction

$$^{37}\text{Cl} + ^{44}\text{Ca} \rightarrow ^{81}\text{Rb}^*$$

- We can use this reaction to determine the GDR’s parameters.
- The GDR’s parameters (centroid, width, strength) are expected to be the same for both reactions.
Experimental technique

HECTOR + GARFIELD Detectors

\[ E_{\text{GDR}} = 16.2 \pm 0.17 \text{ MeV} \]
\[ \Gamma_{\text{GDR}} = 10.8 \pm 0.2 \text{ MeV} \]
\[ S_{\text{GDR}}(\%) = 90 \pm 3.5 \]

\[ \Gamma_{\downarrow} = 10 \pm 3 \text{ keV} \]

A. Corsi et al. PRC 84, 041304(R) (2011)
Measurements and Analysis

AGATA – HECTOR$^+$ array @ LNL

4 AGATA Clusters (12 capsules)
6 LaBr$_3$:Ce (3.5” x 8”)
1 LaBr$_3$:Ce (3 x 3”)

With AGATA we measure the evaporation residues to tune statistical model.
AGATA – HECTOR+ array @ LNL

4 AGATA Clusters (12 capsules)
6 LaBr$_3$:Ce (3.5” x 8”)
1 LaBr$_3$:Ce (3 x 3”)

- With HECTOR+ we have a good time selection to reject eliminate neutron contribution and background
- Time resolution $\approx$ 1.8 ns
- Good efficiency for high energy gamma rays

[Graphs showing time vs. counts for $^{37}$Cl + $^{44}$Ca and $^{40}$Ca + $^{40}$Ca, with a note indicating neutrons.]
Measurements and Analysis

**Evaluation of the different angular momentum distributions for different triggers for $^{80}$Zr for statistical code**

CN Cross Section: $\langle J \rangle = 26 \hbar$, st.dev = 9 $\hbar$

<table>
<thead>
<tr>
<th>$M_\gamma$</th>
<th>$\langle J \rangle (\hbar)$</th>
<th>St.dev($\hbar$)</th>
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</thead>
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<tr>
<td>2</td>
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<td>7.7</td>
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<td>$1\text{AGATA} &amp; 1\text{LaBr}$</td>
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<tr>
<td>3</td>
<td>32</td>
<td>7</td>
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<td>3</td>
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</tr>
<tr>
<td>4</td>
<td>34</td>
<td>6.8</td>
</tr>
<tr>
<td>$2\text{AGATA} &amp; 2\text{LaBr}$</td>
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</tr>
</tbody>
</table>

- Spin distribution is an input for the statistical model
- The mean values of the angular momentum distributions increase with the fold request
Measurements and Analysis

Comparison between experimental and simulated residue intensity in $^{80}$Zr decay

The statistical model reproduce well the reaction
Measurements and Analysis

$^{81}\text{Rb} - \text{HECTOR}^+$

$^{80}\text{Zr} - \text{HECTOR}^+$

$E_{\text{GDR}} = 16.4 \pm 0.2 \text{ MeV}$

$\Gamma_{\text{GDR}} = 7.0 \pm 0.4 \text{ MeV}$

$S_{\text{GDR}} (%) = 88 \pm 2$

Preliminary fit result $\rightarrow \Gamma_{\downarrow} = 12 \pm 3 \text{ keV}$
For the measurement of isospin mixing we need a combination of target and projectile with N=Z

With radioactive beams it could be possible to produce new hot nuclei, in order to do a systematic study of isospin mixing at different Z and different temperature

Possible beams: $^{34}\text{Cl}$, $^{26}\text{Al}$, $^{38}\text{Kr}$, $^{44}\text{Ti}$
Possible nuclei: $^{74}\text{Rb}$, $^{66}\text{As}$, $^{79}\text{Y}$, $^{82}\text{Mo}$

For this measurement we need:

- High beam intensity
- Large temperature window in the fusion
- Detectors with a good efficiency at high energy ($\text{LaBr}_3$)
- Detectors for the identification of residues
Conclusions and Perspectives

Conclusions:

- We studied Isospin mixing at $T > 0$ with GDR $\gamma$-decay
  - two dataset are available $T=2.2$ and $3$ MeV on $^{80}$Zr
- Using theoretical help it is possible to extract the $T=0$ mixing from measured mixing at $T>0$
- Preliminary analysis shows for the two dataset:
  - consistent GDR parameters for $^{81}$Rb
  - the same value of Coulomb spreading width ($T^\downarrow$) within error bar

Future:

- Improve the fit technique in order to have small error bars in the parameters
- Compare the theoretical model with experimental $\alpha^2$ data
- Extract an experimental value of isospin mixing at $T=0$ in $^{80}$Zr
- Find new nuclei to use this technique
Thank you for your attention