Lifetime Measurement in $^{103,104}$Rh with RDDS Method in Inverse Kinematics: A Test for Nuclear Chirality

Suzuki Tomokazu
Research Center for Nuclear Physics, Osaka University


$^1$ Department of Physics, Tohoku University, Japan
$^2$ St. Kliment Oridiski University of Sofia, Bulgaria
$^3$ SUNY at Stony Brook, NY, USA
$^4$ Argonne National Laboratory, IL, USA
$^5$ University of Tennessee, TN, USA
$^6$ University of Cologne, Germany
$^7$ Cyclotron and RI Center, Tohoku University, Japan
$^8$ ATOMKI, Hungary
$^9$ NSCL, MI, USA
$^{10}$ University of York, UK

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Introduction

- **Criteria for Nuclear Chirality**
  - Nearly degenerate $\Delta I = 1$ twin bands with the same parity
  - $B(E2 : I \rightarrow I - 2)_{\text{in,out}}$ and $B(M1 : I \rightarrow I - 1)_{\text{in,out}}$
    values are the same or similar between both bands.


- The Best Configuration for mass 100 region
  - \( \pi g_{9/2}^{\frac{-1}{2}} \otimes \nu h_{11/2} \)
  1. **shortest axis** of the triaxial shape \( j_n \); neutron-particle in a high-\( j_n \) shell
  2. **longest axis** of the triaxial shape \( j_p \); proton-holll in a high-\( j_n \) shell
  3. **intermidiate axis** of the triaxial shape \( R \); core rotation

Figure from T. Koike et. al. Phys. Rev. Lett. 93 172502 (2004)
Chiral candidates in the mass 100 region

The doublet bands are built on
- $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}$ configuration for odd-odd nuclei
- $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}^2$ configuration for odd-A nuclei (broken pair of neutron)

The energy degeneracy gets better from $^{102}\text{Rh}$ to $^{104}\text{Rh}$ and then gets less to $^{106}\text{Rh}$.
- The degeneracy is only 2-keV at the best in $^{104}\text{Rh}$. 

From:
- C. Vamman et. al. Private Communication
Chiral candidates in $^{103,104}$Rh

$^{103}$Rh and $^{105}$Rh

$^{103}$Rh

$^{105}$Rh

*The $^{105}$Rh was reported TAC calculation*  

**Coincidence Recoil Distance Doppler Shift Method (RDDS)**

\[
\frac{dn_i}{dt} = -\lambda_i n_i(t) + \sum_h \lambda_h n_h(t) b_{hi}
\]

\[
\tau_i = \frac{-N_{ij}(t) + b_{ij} \sum_h N_{hi}(t)}{\frac{dN_{ij}(t)}{dt}}
\]

\[
\tau_i = \frac{I_{s,u}^{BA}(x)}{I_{s,s}^{BA}(x + \Delta x) - I_{s,s}^{BA}(x - \Delta x)} \frac{2\Delta x}{v}
\]

\[
\tau_i = \frac{I_{s,u}^{CA}(x) - \alpha I_{s,u}^{CB}(x)}{I_{s,s}^{CA}(x + \Delta x) - I_{s,s}^{CA}(x - \Delta x)} \frac{2\Delta x}{v}, \quad \alpha = \frac{I_{s}^{CA}}{I_{s}^{CB}}
\]

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GAMMASPHERE GSFMA169

Lifetime measurement of candidate chiral members in the $A \sim 100$ region

- Recoil Distance Doppler Shift Method (RDDS)
  - GAMMASPHERE Ge detectors array
  - Cologne university plunger device
- Inverse Kinematics Reaction (Large recoil velocity $\beta \sim 0.05$)
  - Reaction $^{11}\text{B}(^{96}\text{Zr},x\text{n})^{104,103}\text{Rh}$ ($x=3,4$)
  - Beam $E(^{96}\text{Zr}) = 330\text{MeV}$ (from ATLAS accelerator at ANL)

**Trigger** $\gamma-\gamma$
7 distances (8,15,23,35,50,75,100 $\mu$m)

<table>
<thead>
<tr>
<th>Front ring angle</th>
<th>N_{det}</th>
<th>Back ring angle</th>
<th>N_{det}</th>
</tr>
</thead>
<tbody>
<tr>
<td>121.72°</td>
<td>5</td>
<td>129.93°</td>
<td>10</td>
</tr>
<tr>
<td>35.26°</td>
<td>8</td>
<td>145.45°</td>
<td>10</td>
</tr>
<tr>
<td>50.07°</td>
<td>10</td>
<td>162.73°</td>
<td>5</td>
</tr>
<tr>
<td>58.28°</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

84 $\gamma-\gamma$ matrices are created ring by ring for each distances.
Experiment result of $^{103}$Rh and calculated values of $^{105}$Rh


<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Spin</th>
<th>$\omega$</th>
<th>TAC for $^{105}$Rh</th>
<th>Exp. for $^{103}$Rh</th>
</tr>
</thead>
<tbody>
<tr>
<td>3631</td>
<td>$25/2^+$</td>
<td>0.25</td>
<td>0.09 $B(E2)$ 2.28 $B(M1)$ 0.077(14) 2.3(4)</td>
<td></td>
</tr>
<tr>
<td>3940</td>
<td>$27/2^+$</td>
<td>0.30</td>
<td>0.09 $B(E2)$ 2.16 $B(M1)$ 0.14(3) 1.8(2)</td>
<td></td>
</tr>
<tr>
<td>4322</td>
<td>$29/2^+$</td>
<td>0.35</td>
<td>0.09 $B(E2)$ 2.03 $B(M1)$ 0.11(4) 1.2(4)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\omega$</th>
<th>planar</th>
<th>aplanar</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>-4.297</td>
<td>-4.297</td>
</tr>
<tr>
<td>0.60</td>
<td>-5.971</td>
<td>-5.976</td>
</tr>
<tr>
<td>0.65</td>
<td>-7.064</td>
<td>-7.102</td>
</tr>
<tr>
<td>0.70</td>
<td>-8.206</td>
<td>-8.295</td>
</tr>
<tr>
<td>0.75</td>
<td>-9.397</td>
<td>-9.552</td>
</tr>
</tbody>
</table>
The $B(M1)/B(E2)$ staggering has been observed in the previous experiment.
- This is suspected for chiral selection rule if the staggering is caused by $B(M1)$ values. C. Vamman et. al. Phys. Rev. Lett. 92 (2004) 032501.
- However, the staggering is caused by $B(E2)$ staggering.
- The behavior of $B(E2)$ staggering is cannot be understood and needs theoretical interpretations.
Summary

- The lifetime of chiral candidates member in the $^{103,104}$Rh isotopes are measured.
  - RDDS, GAMMASPHERE

- $^{103}$Rh
  - Three lifetimes related to chiral doublets are extracted.
  - The experimental results are compared to TAC calculations for $^{105}$Rh.
  - TAC calculation indicates chiral doublet in the $\omega \geq 0.55$ region
  - Three levels ($0.25 \geq \omega \geq 0.35$) were consisted with TAC calculations for $^{105}$Rh.

- $^{104}$Rh
  - Four lifetimes are extracted.
  - The reported $B(M1)/B(E2)$ seems staggering from $B(E2)$.
  - In $B(E2)$ needs theoretical explanation.