Spectroscopic Study of the Intruder S-wave in $^{12}$Be via Transfer Reaction

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The halo nucleus $^{11}\text{Be}$

- Neutron loosely bound $S_n=0.504$ MeV
- Larger radius $\text{rms}=2.91$ fm
- $^{10}\text{Be}$ core + 1 valance n

PRL 108, 192701 (2012), $^{10}\text{Be}(d,p)$ $S\sim0.71(5)$

PLB 461, 22-27 (1999) $^{11}\text{Be}(p,d)$ $S\sim16\%$

PRL 84, 35(2000) $^{11}\text{Be}$ 1n removal $S\sim22\%$

Nearly 100% intruder state in $^{11}\text{Be}_{\text{g.s.}}$
$^{12}\text{Be} \sim ^{11}\text{Be} + n$

Intruder state or Normal state

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The structure of nucleus $^{12}$Be

- **disappearance** of conventional magic number: N=8
- **Isomeric state**: $0^+_2$ 331(12) ns

Two decay modes:
- E2 decay: 130 keV and 2.11 MeV gamma-rays 17(2)%
- E0 decay: internal conversion: negligible
  - $e^+e^-$ pair **creation** 511 keV gamma 83(2)%

<table>
<thead>
<tr>
<th></th>
<th>$0_1^+$ G.S</th>
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<td>Knock-out reaction</td>
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<td>S=0.48</td>
<td>S=0.44</td>
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<td>Transfer reaction</td>
<td>S=0.28 (0.17)</td>
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<td>S=0.73 (0.51)</td>
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</table>

- **Normal**: Normal state is dominant
- **Intruder**: Intruder state is dominant
- **Uncertain**: no d-wave, could not make sure

**Experiments**

- **Great difference**
- **$0_2^+$ Mix with $2^+$ state**
Main goal:

Investigate the intruder s-wave strength in the ground state and low-lying excited state of $^{12}\text{Be}$ via the $d(^{11}\text{Be},p)$ transfer reaction at 20-30 MeV/u.

20-30 MeV/u:

1. $S_f$ is independent of the incident energy in large energy range
2. Reduce the effect of complicated reaction mechanism
3. Beam production rate times reaction cross sections
New ideas

- **Decrease the background**
  Coincident measurement of $^{10-12}\text{Be}$ and light-charged particles

- **Remove the effect of proton in CD2 target**
  Compare the elastic scattering data of $^{11}\text{Be}+p$ to $^{11}\text{Be}+d$ to get the proton content in CD$_2$ target.

- **New technique to separate $0_2^+$, measure Smaller angles data**
  Implantation-decay-detect gamma( stop and decay)

- **Measure the elastic scattering Channel** in the same experiment
Experimental Setup

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Elastic scattering data of $^{11}\text{Be} + p$ and $^{11}\text{Be} + d$

To extract Optical Potential for the entrance channel of transfer reaction
"11Be elastic and breakup on protons"

PID on the zero degree telescope

Energy spectrum for $^{11}$Be

Cut $^{11}$Be on Tele0

Core excitation is important

Provision by A.M. Moro

CDCC $\rightarrow$ considering the effect of breakup channels

XCDCC $\rightarrow$ considering the effect of core excitation
11Be elastic and inelastic scattering on deuteron

Global JLM potential can reproduce the Angular distribution of 11Be+d breakup calculation for breakup of 11Be +d

Energy spectrum for 11Be

PID on the zero degree telescope

Provide by D.Y.Pang

Provide by A.M.Moro


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September 17th, 2015
Experimental result of transfer reaction
Experimental result of $^{11}\text{Be}(d,p)^{12}\text{Be}$

PID on the zero degree telescope

Energy spectrum for $^{12}\text{Be}$

Kinematic loci for protons in coincidence with $^{12}\text{Be}$ on Tele0

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Isomeric state (E0 decay was used)

\[ \begin{align*}
1^- & : 2.68 \text{ MeV} \\
0^+ & : 2.24 \text{ MeV} \quad \text{T1/2} = 331 \text{ ns} \\
2^+ & : 2.1 \text{ MeV} \\
0^+ & : \text{g.s.} \\
\end{align*} \]

\( E0: 83\% \)\n\( 511 \text{ keV} \)

\( E2: 17\% \)
\( 130 \text{ keV and } 2100 \text{ keV} \)

Experimental result of $^{11}\text{Be}(d,p)^{12}\text{Be}$

Angular distribution of $^{11}\text{Be}(d,p)^{12}\text{Be}(\text{g.s.})$ \quad $\gamma$ spectrum in coincidence with $^{12}\text{Be}$ on Tele0

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<th>Energy (MeV)</th>
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<th>DWBA</th>
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<tr>
<td>27</td>
<td>$0.20^{+0.03}_{-0.03}$</td>
<td>$0.14^{+0.02}_{-0.02}$</td>
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<tr>
<td>27</td>
<td>$0.41^{+0.11}_{-0.12}$</td>
<td>$0.24^{+0.07}_{-0.07}$</td>
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Error: 68% confidence

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### Experimental result of $^{11}\text{Be}(d,p)^{12}\text{Be}$

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<tr>
<td>Our result</td>
<td>S=0.14 (0.17)</td>
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<td>S=0.28 (0.41)</td>
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- **Result**
  - Consistent with another transfer experimental results within error bar
  - Isomeric state: Determine the s-wave SF from Direct measurement

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• O.P. for $^{11}\text{Be}+d$ is extracted from the same experiment
  Global OP including $^{11}\text{Be}$ density can reproduce angular distribution
  Core excitation of $^{11}\text{Be}$ is important
  the effect of H percent in CD$_2$ target are removed

• New experimental technical to detect isomeric state
  implant----stop-----decay
  get the angular distributions in smaller C.M system

• ADWA method is used to extract the s-wave SF
  G.S : $S_f = 0.20^{+0.04}_{-0.04}$, confirm transfer experimental results
  Isomeric state: $S_f = 0.41^{+0.08}_{-0.08}$, determined from direct measurement

• More theoretical calculations to explain our results

Intruder state  or  Normal state
Collaborators

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Osaka University, Japan
Aoi, Ong Hooi Jin, Eiji Ideguchi, Tetsuya, Mana, Suzuki, Tran Trong

RIKEN, Japan
Jenny Lee, Wu Jin, Liu Hongna, Wen Chao

Beihang University, China
Pang Danyang

Universidad de Sevilla, Spain
A.M. Moro

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Thank you for attention!