Electron capture of $^8$B into highly excited states in $^8$Be.  INTC: P-482


Spokespersons: T. Nilsson thomas.nilsson@chalmers.se
O. Tengblad olof.tengblad@csic.es
Contact person: R. Lica razvan.lica@cern.ch
Halo Nuclei

- Weakly bound (easy to break-up)
- Easy to polarise (large B(E1) low energy strength)
- Suffer lower Coulomb barrier
- Higher transfer probability

→ good cases to be studied in Reaction experiments

As was done for $^{11}\text{Li}$, $^{11}\text{Be}$, $^6\text{He}$

IS616@HIE-ISOLDE, D. Pietro et.al., Reaction mechanisms in collisions induced by a $^8\text{B}$ beam close to the barrier: effects of halo structure on reaction dynamics

The $^8\text{B}$ proton halo is not as extended as the neutron halos (p-wave & Coulomb barrier)

Reaction experiments; Coulomb dissociation at higher energy, or proton capture on $^7\text{Be}$, are good at probing the structure at larger distances from the core.

A complementary approach is $\beta$-deacy

- In beta decay we probe the complete wave function,
- we are sensitive to the structure at smaller distances,
- we can identify the largest part of the beta-strength
20 years ago: $^6\text{He}$ a 2n halo $\rightarrow$ localized decay in the 2n-halo $\rightarrow$ d + alpha

First observation of beta-delayed deuteron emission
ISOLDE-3: IP-42
24h for 147 coincidencies $\rightarrow$ branching $2.8 \times 10^{-6}$

$^8\text{B}$ as p-halo nuclei $\rightarrow$ $^7\text{Be} + p$

Here the situation is the opposite: we localize the main strength of the decay to the core and the halo-p constitutes the non-decaying spectator;

$$\mathcal{O} \mid c + h \rangle = \mathcal{O}(\mid c \rangle \mid h \rangle) = (\mathcal{O} \mid c \rangle) \mid h \rangle + c \langle \mathcal{O} \mid h \rangle$$

The decay through the $1^+$ level is described by the first term thus the strength can be estimated from the known decay of the $^7\text{Be}$ core nucleus.

T. Nilsson et al., Hyperfine Int. 129 (2000) 67

The region of interest enclosed in violet and the decay products red-rings
The $1^+$ at 17.640 MeV accessible only via EC

$E_p = 337$ keV

$\beta^-$

$\beta^+$

$^{8}$B: Decay modes

$^{8}$B Predominantly $\beta^+$ decay via 3.03 MeV state $\rightarrow$ 2 alphas

$^{4}$He $\rightarrow$ $^{4}$He

The high-lying, isospin-mixed, $2^+$ doublet is allowed $\rightarrow$ 2 alphas

$^{7}$Li $+$ $p$
The decay of $^8\text{B}$ into the $16.626$ MeV state has been observed several times. The decay (mainly EC) into the $16.922$ MeV state, however, was first seen in our JYFL experiment.

Expected ratio of decay rates assuming zero GT strength to T=1 component

$$\frac{r_{16.9}}{r_{16.6}} = 2.4 \times 10^{-2}$$

Consistent with the 5 to 180 events seen

Measurement of the beta-feeding to both members of the $2^+$ doublet will allow to determine the Gamow-Teller and Fermi matrix elements of BOTH states for the first time.
β-delayed proton emission

The 1+ at 17.640 MeV accessible only via EC

17.2551
7Li + p
17.640 1+; 1
EC
17.9798 2+; 1
8B

16.0052 2+; 1
8Li
11.4 4+; 0

Spectrum in Anti-coincidence with alphas

Search for 337 keV proton branch

Counts/10 keV


IGISOL data

To look for the 337-keV proton hidden in alpha & beta response is a very challenging task;

Theoretical branching ratio based on the p-halo spectator + 7Be core - decay $2.3 \times 10^{-8}$

Experimental upper limit from IGISOL $2.6 \times 10^{-5}$

Lacking 3 order of magnitude in sensitivity

The Background is primarily from

- Multiple scattering of beta particles
- Cosmic muons (observed in beam-off run)
The average yield of $^8$B in the JYFL experiment was 200/s. Recent target development at ISOLDE has succeeded in producing a substantially higher yield:

**Online measurements: #513**

- Coincidence measurement of $\alpha$ and $\gamma$ (from $\beta^+$ annihilation)
- In addition: $\beta^+$ and $\gamma$ activity with tape station

<table>
<thead>
<tr>
<th>Target</th>
<th>TaF$^+$</th>
<th>TaF$_4^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>#499</td>
<td>0.6 pA</td>
<td>0</td>
</tr>
<tr>
<td>#513</td>
<td>190 nA</td>
<td>1.6 µA</td>
</tr>
</tbody>
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- Yield of $^8$BF$_2^+$ of $2.8 \times 10^4$ 1/µC

C. Seiffert, contribution to the ISOLDE workshop 2015

This now allows to tackle the above two challenges in the $^8$B decay @ ISOLDE
Experimental set-up @ IDS

4x particle $\Delta E$-$E$ telescopes + 1x PAD in the bottom for further $\beta$ coverage
- $\Delta E$: DSSDs 2x40 $\mu$m + 2x60 $\mu$m
- E: PADs 1500 $\mu$m

Highly segmented 1024 pixels of 3x3 mm
→ high many particle coincidence efficiency, high $\beta$-efficiency
Experimental sensitivity (p-branch)

By analyzing the $^{16}$N data of IS605 (2016);
- the cosmic background rate is sufficiently low,
- the beta rate in the 40 and 60 micron DSSDs is low
- Using the VETO condition we should reach a few $10^{-7}$ sensitivity in 6 shifts Not enough! →
The 17.640-MeV state is fed by EC (electron capture) → lack of a coincident charged particle to gate on → rely on other techniques;

1) Thinner Si detector 20 µm → minimize the beta and myon response
2) Thick Si surrounding → Anti-coincidence requirement will cut down unwanted events from the region of interest
3) Add magnetic separation?

- Thin 20 µm Small sized SiSB to reduce the noise level and better energy resolution
- close proximity to the C-foil
- Thick pad detectors acting as anti-coincidence veto
The purpose of this experiment is to determine the beta strength to highly exited states in $^8$Be;

→ explore the Halo wave function over the full radial range
→ identify the unobserved $^8$B delayed proton emission

We ask for 15 shifts distributed over 2 runs:

6 shifts: Measurement using DSSD + pad telescopes
Based on the IGISOL data we should observe
~500 decays through the 16.9-MeV member of the $2^+$ doublet

Time to analyse the background before the 2nd experiment

9 shifts: Measurement using optimized set-up for detecting the 337 keV proton
to reach a sensitivity of $10^{-8}$

Estimated beam time request is based upon an implantation rate of $4.2 \times 10^4$ ions/s
( TAC: Yield $3e4$ as BF$^+$, re-use existing target. Beam 1.6 $\mu$A Transmission 85% )
Recent β-decay studies by the collaboration

Data taking completed, under analysis

**IS605** $^{16}N$

**IS577** $^{31}Ar$


Completed experiment

**IS541** $^{11}Be$


**IS507** $^{20-21}Mg$


**IS476** $^{31}Ar$


n-halo in beta decay @ ISOLDE

6He: First observation of beta-delayed deuteron emission

17F: Beta-decay to the proton halo state in $^{17}$F

11Li: Evidence of a new state in $^{11}$Be observed in in the $^{11}$Li decay

11Be: $^{11}$Be($\beta$p), a quasi-free neutron decay?

Halo-nuclei at ISOLDE
T. Nilsson, G. Nyman and K. Riisager

Journal of Physics G: Nuclear and Particle Physics
ISOLDE Decay Station for decay studies of interest in astrophysics and exotic nuclei
Hans O U Fynbo¹, Oliver Kirsebom² and Olof Tengblad³
https://doi.org/10.1088/1361-6471/aa5e09