Three-body forces in two-neutron decay experiments: $^{26}$O

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Overview

* Motivation
* Neutron-rich oxygen isotopes

* Experimental
  ★ MoNA/Sweeper setup
  ★ 2n decay of $^{26}\text{O}$

* $^{26}\text{O}$ decay energy
* $^{26}\text{O}$ half-life

* 3NF status and needs
Neutron Dripline

Edge of nuclear landscape

Neutron Dripline

- Neutron - unbound states
  - Nuclear structure/Shell evolution/3NF
  - Halo Structures
  - 2n Decay (n-n correlations)
Neutron Dripline

Oxygen: 8 protons + 16 neutrons
Fluorine: 9 protons + ≥ 22 neutrons

Why?
Spectroscopy of n-rich oxygen isotopes

Z. Elekes et al., PRL 98 (2007) 102502
A. Schiller et al., PRL 99 (2007) 112501
C.R. Hoffman et al., PLB 672 (2009) 17
C.R. Hoffman et al., PRC83 (2011) 031303
K. Tshoo et al., PRL 109 (2012) 022501
C.R. Hoffman et al., PRL 100 (2008) 152501
C. Caesar et al., arXiv:1209.0156
26O: Bound or Unbound?

- 26O largely unconstrained
- Theoretical predictions of the S(2n) vary from -5 to +5 MeV
- Experimental data needed for comparing to theory
**26O experiment**

- **Production target**: 1316 mg/cm²

- **Al wedge**

- **K1200**
  - 48Ca
  - 140 MeV/u

- **K500**

- **A1900 fragment separator**

- **Final focus**

- **Coupled Cyclotrons**

- **Be**
26O experiment
Previous MoNA Experiment: Hoffman et al. PRL 2008
Measured g.s. of $^{25}$O @ 770 keV

Current work: Presence of low-energy neutrons

Dashed-lines CSM predictions
Volya & Zelevinsky PRL 2005
Ground state of $^{26}\text{O}$


Cross Talk: Single neutron interacting twice (false 2n signal).

26\text{O} unbound by < 200 keV

Causality cuts:
- $\Delta v = 7$ cm/ns
- $\Delta d = 25$ cm
$^{26}\text{O}$: Bound or Unbound?

- $^{26}\text{O}$ unbound by $<200$ keV
- $^{26}\text{O}$ unbound by $<50$ keV

C. Caesar, PRC 88 (2013) 034313
26O and Three-body forces

- Otsuka et al. PRL. 105, 032501 (2010).
- Cipollone et al. PRL 111, 062501 (2013).
- IM-SRG In-medium similarity renormalization group
- C. Caesar, PRC 88 (2013) 034313
- Coupled-cluster

Shell model

Self-consistent Green’s function

$^{26}\text{O}$ and Three-body forces

C. Caesar, PRC 88 (2013) 034313

Otsuka et al. PRL. 105, 032501 (2010).


Cipollone et al. PRL 111, 062501 (2013).

Self-consistent Green’s function

Shell model

In-medium similarity renormalization group

Coupled-cluster
2n radioactivity

- Pfutzner et al. (2012): $T_{1/2} > 10^{-14}$ s (10 fs)
  - Emission of particle from atomic nucleus
  - K-shell vacancy half-life of carbon atom $2 \times 10^{-14}$ s
  - Width (G) is 0.03 eV, which is about room temp
- Cerny & Hardy (1977): $T_{1/2} > 10^{-12}$ s (1 ps)
- IUPAC, discovery of element: $T_{1/2} > 10^{-14}$ s (10 fs)
  - Around the time for nucleus to acquire outer electrons

Grigorenko et al. PRC 84, 021303(R) (2011)
**R³B-LAND results**

Lifetime limit: $t < 5.7$ ns

2σ limit = 11.8 ns

2σ limit

$E_{\text{rel}} < 120$ keV

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Half-life measurement


increased lifetime = reduced velocity neutrons

\[ V_{\text{rel}} = V_n - V_{\text{frag}} \]

Increased lifetime = reduced velocity neutrons

Lifetime: \( T_{1/2} = 4.5^{+1.1}_{-1.5} \) (stat.) \( \pm 3 \) (syst) ps

82% C.L. for possible finite two-neutron radioactivity lifetime

Unbinned maximum likelihood technique
New Lifetime calculations

Realistic energy limit
$E_T < 1$ keV

Improve $E_{\text{decay}}$ constraints

$^{26}_{8}\text{O}_{18}$ true $2n$ decay

L.V. Grigorenko, I.G. Mukha, and M.V. Zhukov, PRL (2013)
Status + Needs

Experiment
1. Improve the $^{26}$O constraints on decay energy and half-life
2. Measure $^{28}$O!!!!

Theory
1. Optimized 2N vs 3N
2. Reliable $^{28}$O predictions
3. $^{26}$O – width/half-life
Thanks

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