High resolution mass spectroscopy of hypernuclei with primary electron beams: Recent results and prospects

Contents

- Introduction
  - \((e,e'K+)\) reaction spectroscopy
  - Historical overview
- Search for \(nn\Lambda\)
  - Motivation, Setup, First data
- Spectroscopy of \(\Lambda K\) hypernuclei
  - Motivation, Setup
(e,e'K^+) reaction spectroscopy

\[ e(p_e) + p(p_p) \rightarrow e'(p_{e'}) + K^+(p_K) + \Lambda(p_\Lambda), \]

**High resolution Spectrometer**

- p to \( \Lambda \)
- **Absolute energy calibration**
- High quality e- beam

**High energy resolution**

\[ M^2_{HYP} = (E_e + M_l - E_{e'} - E_{K^+})^2 - (p_e - p_{e'} - p_{K^+})^2 \]

- JLab E05-115
- CH\(_2\) target

1115.683 ± 0.006 MeV
1192.642 ± 0.024 MeV
Continuous electron beam facility

- 12 GeV (max.)
- 100 μA
- 2-ns bunches
- Small Emittance (2 μm⋅mrad)
- Small Energy spread (ΔE/E 2×10⁻⁵)
Hypernuclear Projects


E89-009 (2000) : JLab Hall-C
Proof of Principle
$\Lambda, \Sigma, ^{12}\Lambda B$

$B_\Lambda^{(\text{g.s.)}} = 5.68 \pm 0.03 \pm 0.25 \text{ MeV}$

L.Tang et al., PRC90 (2014) 034320.

E01-011 (2005) : JLab Hall-C
Light hypernuclei
$\Lambda, \Sigma, ^7\Lambda Li, ^{12}\Lambda B, ^{28}\Lambda Al$

$B_\Lambda^{(\text{g.s.)}} = 11.4 \pm 0.5 \text{ MeV}$


E94-107 (2004-5) : JLab Hall-A
Light hypernuclei
$\Lambda, \Sigma, ^9\Lambda Li, ^{12}\Lambda B, ^{16}\Lambda N$

F.Cusanno et al., NPA835 (2010) 129.
F.Cusanno et al., PRL103 (2009) 202501.

E05-115 (2009) : JLab Hall-C
Light – Medium-heavy hypernuclei
$\Lambda, \Sigma, ^7\Lambda He, ^{10}\Lambda Be, ^{12}\Lambda B, ^{52}\Lambda V$

$B_\Lambda^{(\text{g.s.)}} = 11.53 \pm 0.03 \pm 0.11 \text{ MeV}$

Search for $nn\Lambda$ state

(JLab E12-17-003)
nnΛ state

- T=1 state
- Neutral
- Bound state exists or not?

**Experiment**

nnΛ → \(^3\)H+\(π^-\)

C. Rappold et al. (HyPhI Collaboration)

**Theory**

Bound nnΛ: cannot be reproduced

E. Hiyama et al., PRC 89 (2014) 061302.
A. Gal et al., PLB 736 (2014) 93.

Resonance nnΛ state ??

H. Kamada et al., EPJ Web Conf. 113 (2016) 07004.

Search for nnΛ state is important investigating Λn interaction.

⇒ \((e,e'K^+)\) reaction spectroscopy
nnΛ search (JLab E12-17-003)

Peak width & Λ binding energy is expected to be measured with ≃100 keV

Det. resolution ~2 MeV (FWHM)
Setup

\[
\begin{array}{|c|c|}
\hline
E_e & 4.319 \text{ (GeV)} \\
\hline
p_{e'} & 2.180 \text{ (GeV/c)} \\
\hline
p_K & 1.823 \text{ (GeV/c)} \\
\hline
\theta_{e'} & 13.2 \text{ (deg)} \\
\hline
\theta_K & 13.2 \text{ (deg)} \\
\hline
Q^2 & 0.13 \text{ (GeV}^2) \\
\hline
\end{array}
\]

Path ~ 23.4 m

(R)HRS Detectors

AC2
AC1
TOF2
GC
TOF1
VDCs
Tritium Target

- φ = 12.7 mm
- e⁻
- 0.082 g/cm² (40 TBq)
- 0.3 MPa at 40K
- 25 cm Length
- Al window

Figure taken from Dave’s slide (2015).
- We are taking data from Oct. 31 - Nov. 21 (Now!!)
- We took \( p(e,e'K^+)\Lambda \) data first 3 days.
- We are taking data with right condition
Spectroscopy of Medium-heavy hypernuclei

Spectroscopy of Medium-heavy $\Lambda K$ isotope
(JLab E12-15-008)
Isospin dependence of $\Lambda NN$ interaction

$\Lambda$ of $^{40,48}_{\Lambda K}$ with high precision
(L-)HRS

- Higher Yield
  - Forward angles
- Less Background
  - No acceptance at 0 deg

Re-use of E05-115
- High resolution
- Large Acceptance
- Short arm
- Good KID

We are preparing now. It will be run in 2020-2021!

New Charge Septum Magnet
Summary

**Λ hypernuclear spectroscopy with the (e,e’K+) reaction**
- High resolution, High precision, Absolute $B_Λ$
- CEBAF at JLab
- $^7_Λ$He, $^{10}_Λ$Be, and $^{12}_Λ$B (JLab E05-115 [Hall-C])

**nnΛ search (E12-17-003) at JLab Hall A**
- Study of the Λn interaction
- (e,e’K+) experiment with the tritium target.
- Kinematics & Detectors were checked with $p(e,e’K^+)Λ$ data
- The experiment is now running.

**High resolution spectroscopy of $ΛK$ hypernuclei**
- Study of the isospin dependence of the ΛNN interaction
- Design of a new Septum magnet is on going.
- The experiment will be run in 2020-2021