Newly completed JLab experiment (E12-17-003): Determine the unknown Λn interaction by investigating the possible Λnn resonance

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Publications

- "The cross-section measurement for the ³H(*e*, *e'K*⁺)*nn*∧ reaction", K. N. Suzuki, T. Gogami, B. Pandey, K. Itabashi, S. Nagao, K. Okuyama, *et al.*, Prog. Theor. Exp. Phys. **2022** 013D01.
- "Spectroscopic study of a possible Λnn resonance and a pair of ΣNN states using the (e, e'K⁺) reaction with a tritium target", B. Pandey, L. Tang , T. Gogami, K. N. Suzuki, K. Itabashi, S. Nagao, et al., Phys Rev. C 105, L051001 (2022).

INTRODUCTION

- Experimental data from study of hypernuclei have so far made significant contributions in acquiring indirect or supplemental information on the AN interact.
- However, the standing puzzles, such as Charge-Symmetry-Breaking
 (CSB) urges us to obtain more direct **//N** interaction data.
- \land Λp scattering data does exists but limited. Λn data: **NONE!** Λn interaction has been treated the same as Λp interaction.
- Suggested by the HypHI result, the possible neutral Ann system (if it exists) may be unique to determine the unknown An interaction experimentally. This was the motivation of the JLab experiment E12-17-003.
 - * Iraj R. Afnan and Benjamin F. Gibson, Phys. Rev. C 92, 054608 (2015)

THE JLAB EXPERIMENT E12-17-003

Advantages and Opportunity

- Production: ³H(e, e'K⁺)(Ann) reaction. It is the best for searching the Ann state by precision mass spectroscopy.
- Tritium target already exists in JLab Hall A for four other approved experiments, providing a unique opportunity.

Disadvantages and Unfortunates

- → The existing standard HRS-HRS configuration was not optimized for the $(e,e'K^+)$ reaction, $-Q^2 \approx 0.5$ (GeV/c)² and $q_A \ge 400$ MeV/c.
- No knowledge of the photo-production cross section available and the available beam time was limited.
- Available detector system has only limited power to reject the background π^+ and p.

EXPERIMENT E12-17-003 IN HALL A



HRS path-length: 26 meters L-HRS: Scattered electrons (e') R-HRS: Reaction kaons (K⁺) Beam Energy: 4.319 GeV Cylindrical gas target: 25 cm

Data were collected with two different kinematic conditions:

H Kinematics: H target $P_K = 1.8231 \text{ GeV/c} @ 13.2^\circ$ $P_{e'} = 2.1000 \text{ GeV/c} @ 13.2^\circ$ Producing both Λ and Σ⁰ for kinematics calibration **T Kinematics: T and H targets** $P_{K} = 1.8231 \text{ GeV/c} @ 13.2^{\circ}$ $P_{e'} = 2.2180 \text{ GeV/c} @ 13.2^{\circ}$ Obtain the **Ann** mass spectroscopy from T₂ and reference **A** from H₂ targets

DIFFERENCE OF THE TWO KINEMATICS

H Kinematics

T Kinematics



Using the known masses of Λ and Σ^0 to ensure high precision on the absolute missing mass scale (systematic uncertainty of the binding energy of the Λnn resonance)

ANALYSIS RESULTS – Z-vertex & Coincidence time



- ✓ 25 cm gas cell target
 ✓ Z-vertex resolution: σ_Z ≈ 4.5 mm
 ✓ ± 10 cm vertex cut
- ✓ Inefficiency of aerogel detectors ✓ Accidentals from π^+ and p.

ANALYSIS RESULTS – Energy Cal. & Momentum Matrix Opt.



- \Leftrightarrow Events from Λ and Σ⁰ (H) and 2⁷ Mg (Al caps) for momentum matrix optimization
- \diamond Known mass of Λ and Σ^0 provides the absolute energy/ mass calibration
- Heavy ²⁷ Mg events improve the momentum matrix optimization

ANALYSIS RESULTS – Λ/Σ^0 Spectrum



- Data collected under both H and T kinematic conditions
- ♦ Resolution reached to the optimum as the simulation indicated
- $\Rightarrow \Delta M = 76.94 \text{ MeV/c}^2 \text{ (nominal: 76.96 MeV/c}^2\text{)}$

ANALYSIS RESULTS – H Contamination in T



- ♦ T data analyzed with the H kinematics
- ♦ ~158 counts of free Λ, correspond to ≈ 3% H contamination
- \diamond Expect a free Λ peak in the Λnn spectrum with large width

ANALYSIS RESULTS – *Ann* **Spectrum**



Although no definite identifications could be made, enhancements at both the Λ nn and Σ NN thresholds are highly interesting

ANALYSIS RESULTS – Possible YNN Resonances



- Possible Ann resonance: $-B_{\Lambda} = 0.18 \pm 0.44 \text{ (stat)} \pm 0.4 \text{ (sys)}$ $\Gamma/2 = 0.35 \pm 0.42 \text{ (stat)} \pm 0.5 \text{ (sys)}$
- Significance: ~2.2. If real, cross section ≈ 10 nb/sr)
- Possible bound $\Sigma^0 nn$ state (1st): - $B_{\Sigma 0nn} = -3.14 \pm 0.84$ (stat) ± 0.4 (sys)
- 2nd peak is about 13 MeV away
- Cross sections $(1^{st}/2^{nd}) \approx 20/45 \text{ nb/sr}$

SUMMARY

- ♦ E12-17-003 has proven the uniqueness of using the (e,e'K⁺) reaction at JLab.
- The experiment had possible observation of the Λnn resonance and a bound (A = 3) ΣNN state.
- Obtained statistics is too
 low to allow a definitive
 identification, information
 is not precise enough to
 determine the Λn and Λ-Σ
 interactions.



♦ The new proposal was conditionally approved.