Searching for the possible Λnn resonance at Jlab

(E12-17-003)

Liguang Tang

Hampton University / JLAB

On behalf of the JLab Hypernuclear and Hall A collaborations

Publications

- "The cross-section measurement for the ^{3}H(e, $e'K^{+}$)$nn\Lambda$ 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 *ΛN* interact.
- However, the standing puzzles, *such as Charge-Symmetry-Breaking* (CSB) urges us to obtain more direct ***ΛN*** interaction data.
- *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 *Λnn* system (if it exists) may be unique to determine the unknown *Λn* 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

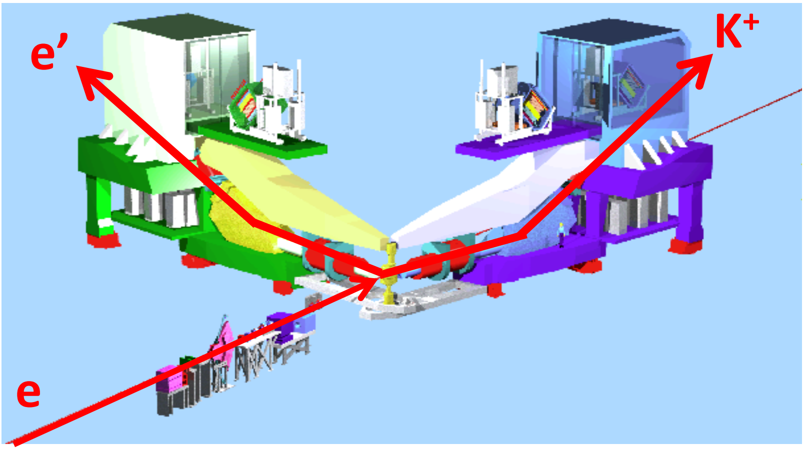
Advantages and Opportunity

- Production: $^{3}H(e, e'K^{+})(\Lambda nn)$ reaction. It is the best for searching the Λnn 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 $q_\Lambda \geq 400$ 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 GeV/c @13.2°

$P_{e'}$ = 2.1000 GeV/c @13.2°

Producing both **Λ** and **Σ^0** for kinematics calibration

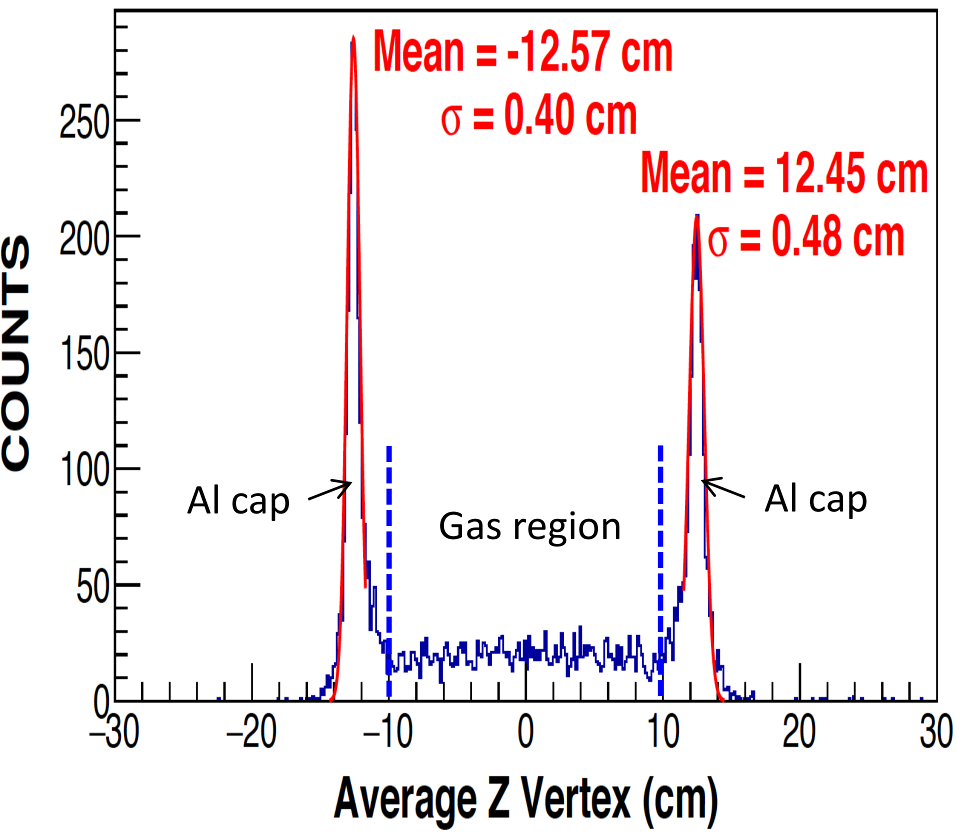
T Kinematics: T and H targets

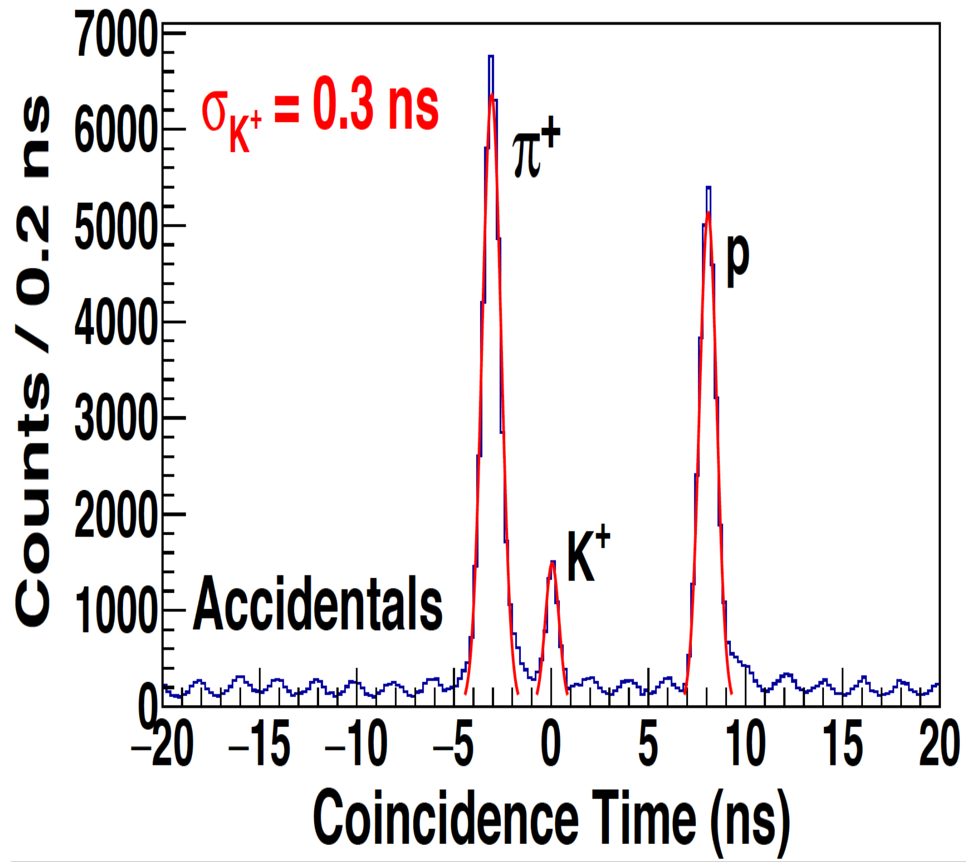
P_K = 1.8231 GeV/c @13.2°

$P_{e'}$ = 2.2180 GeV/c @13.2°

Obtain the ***Λnn*** mass spectroscopy from T_2 and reference **Λ** from H_2 targets

RESULTS – *Z-vertex & Coincidence time*



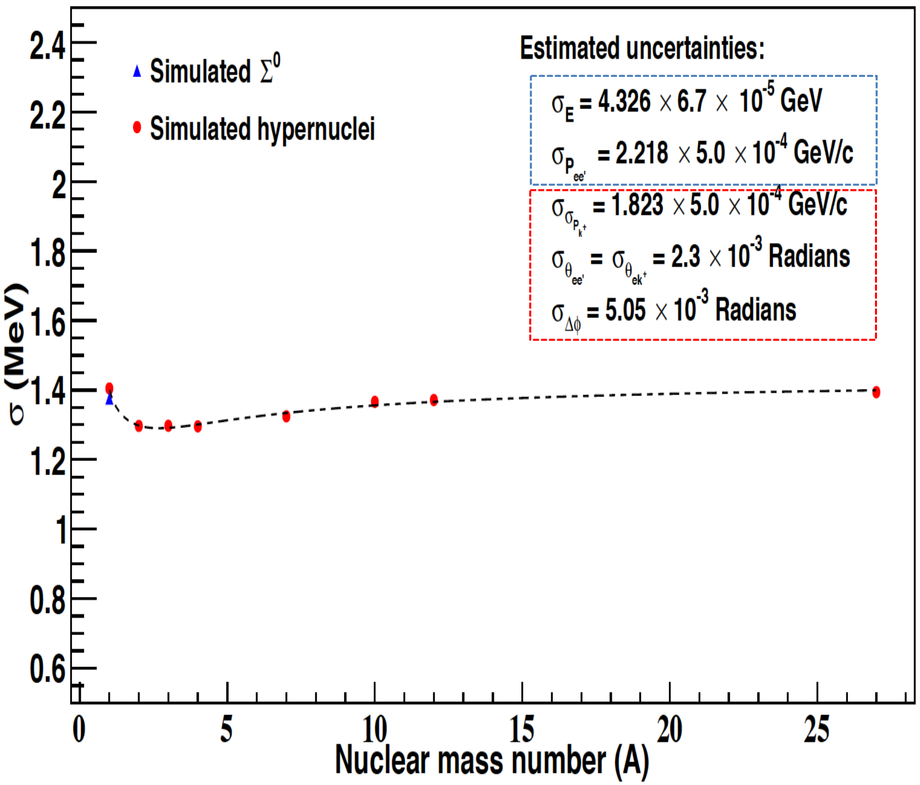


- ✓ 25 cm gas cell target
- ✓ Z-vertex resolution: $\sigma_Z \approx 4.5$ mm
- ✓ ± 10 cm vertex cut

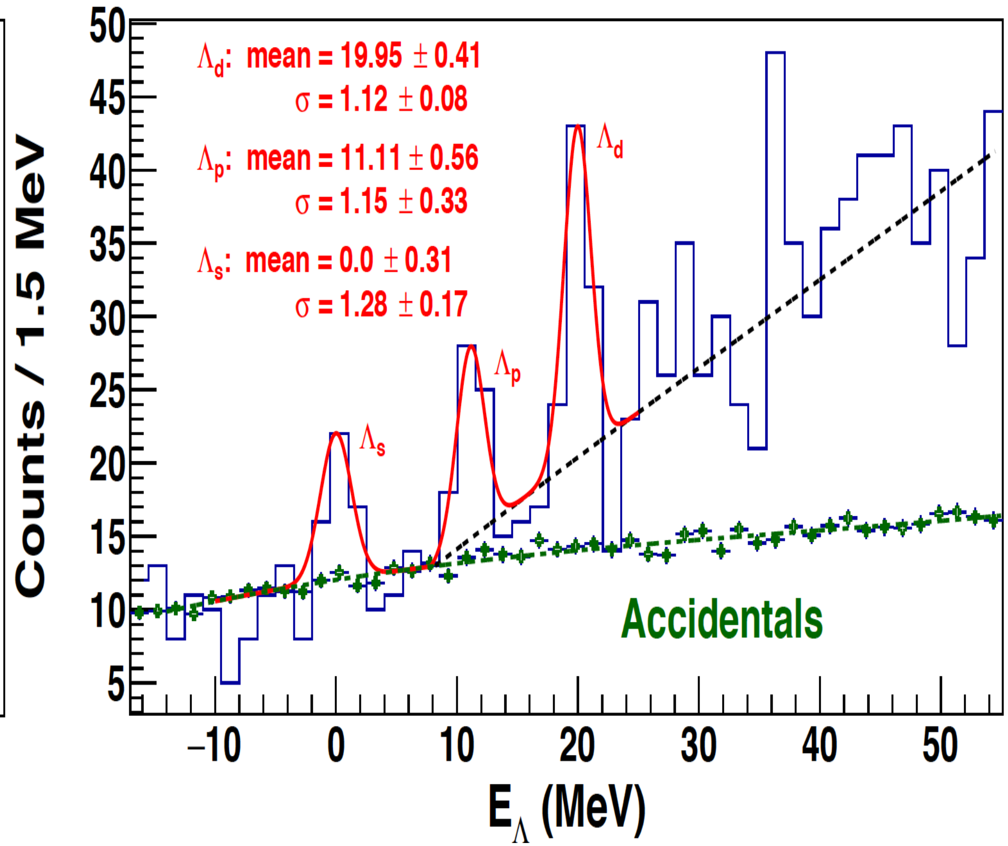
- ✓ Inefficiency of aerogel detectors
- ✓ Accidentals from π^+ and *p*.

RESULTS – *Energy Cal. & Momentum Matrix Opt.*

Simulation for expected resolution



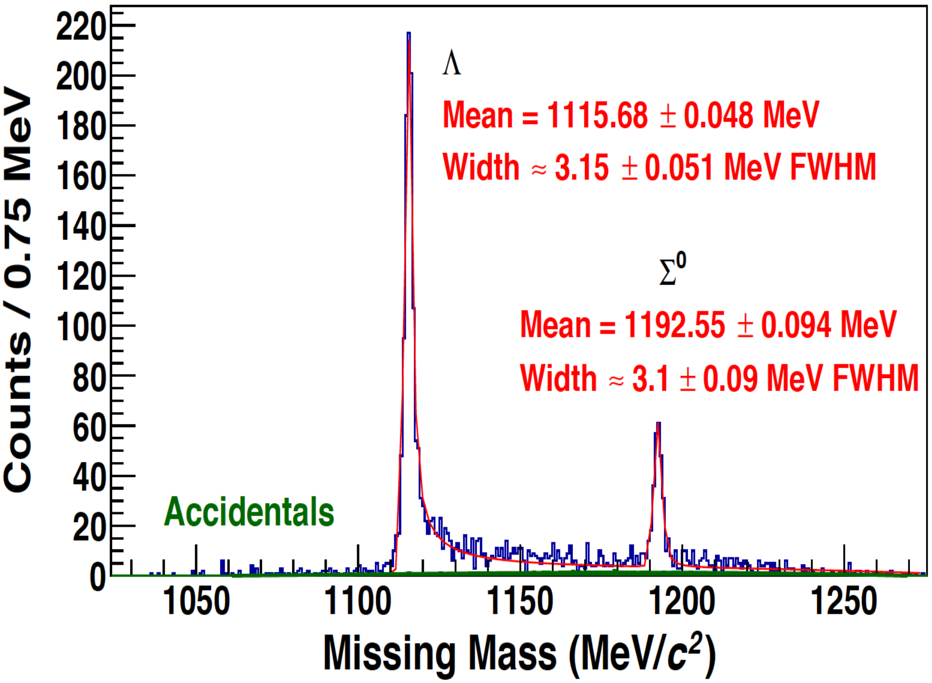
Matrix optimization involving $^{27}_{\Lambda}$Mg events



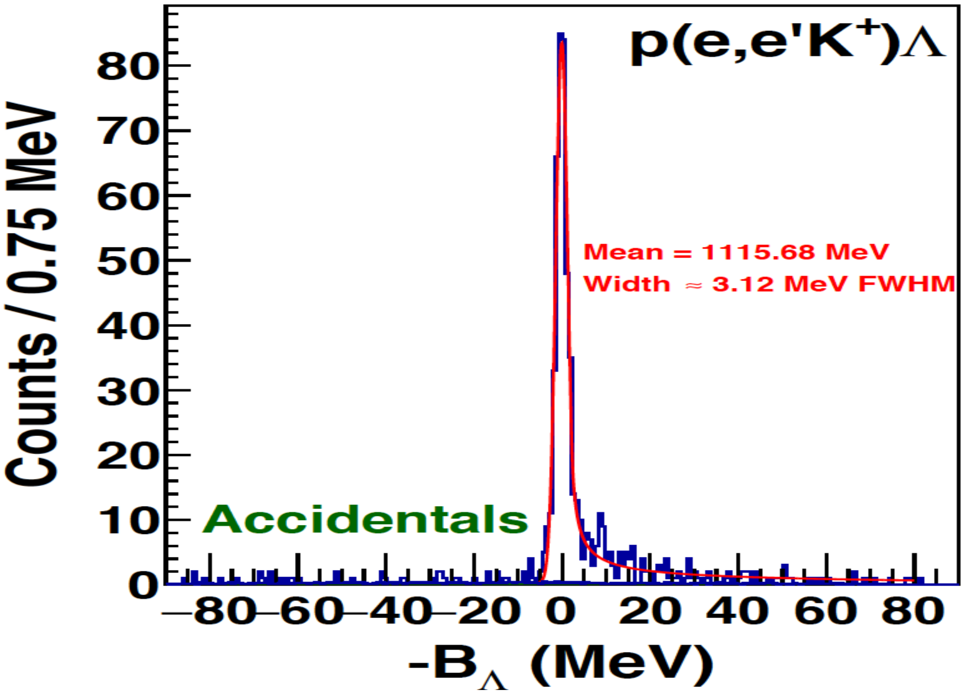
- ✧ Events from Λ and Σ^0 (H) and $^{27}_{\Lambda}$Mg (Al caps) for momentum matrix optimization
- ✧ Known mass of Λ and Σ^0 provides the absolute energy/ mass calibration
- ✧ Heavy $^{27}_{\Lambda}$Mg events improve the momentum matrix optimization

ANALYSIS RESULTS – *Λ/Σ⁰ Spectrum*

H Kinematics



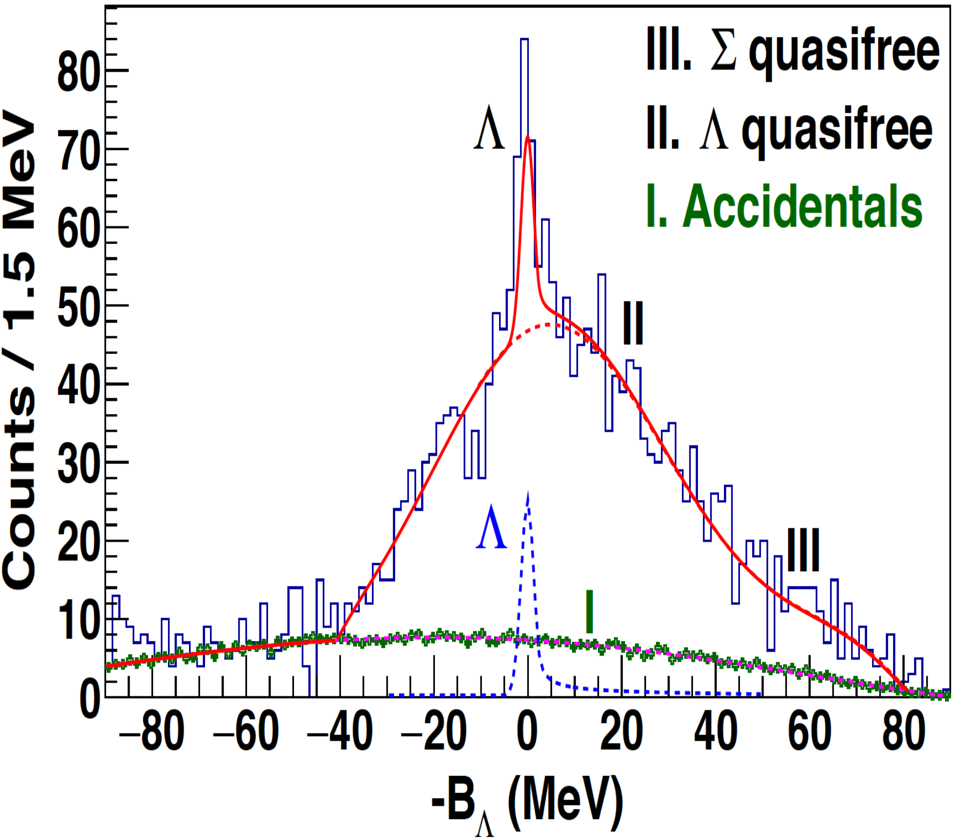
T Kinematics



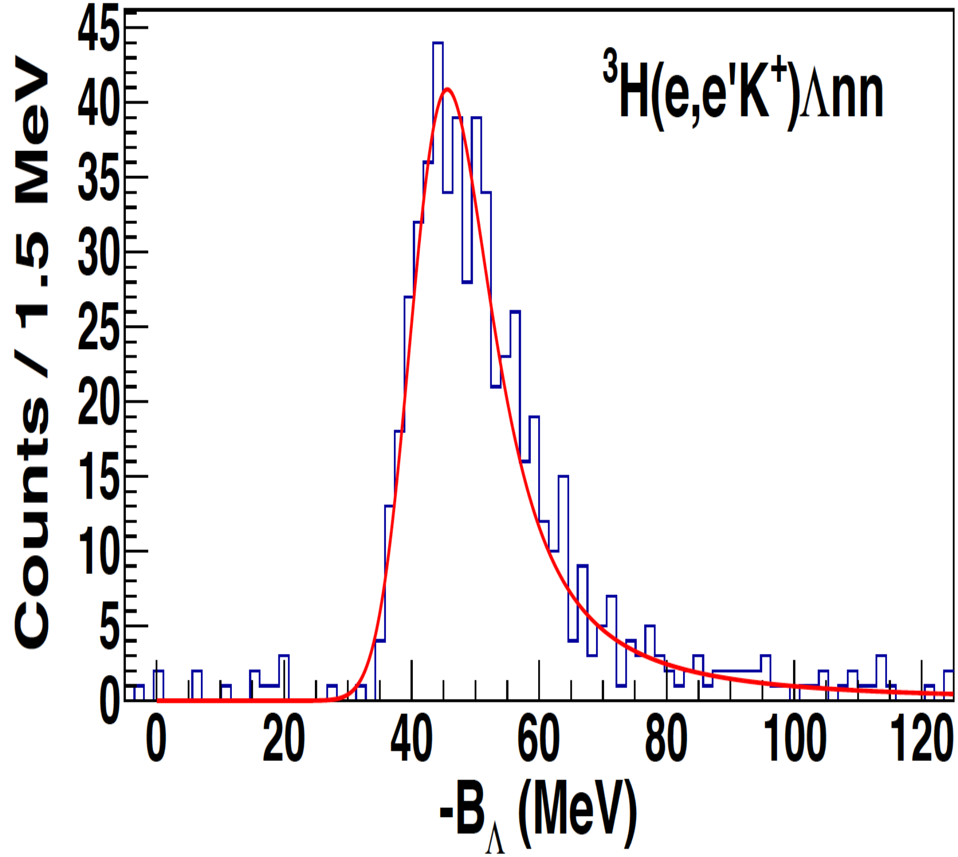
- ✧ Data collected under both H and T kinematic conditions
- ✧ Resolution reached to the optimum as the simulation indicated
- ✧ ΔM = 76.94 MeV/c^2 (nominal: 76.96 MeV/c^2)

ANALYSIS RESULTS – *H Contamination in T*

T data analyzed assuming H target

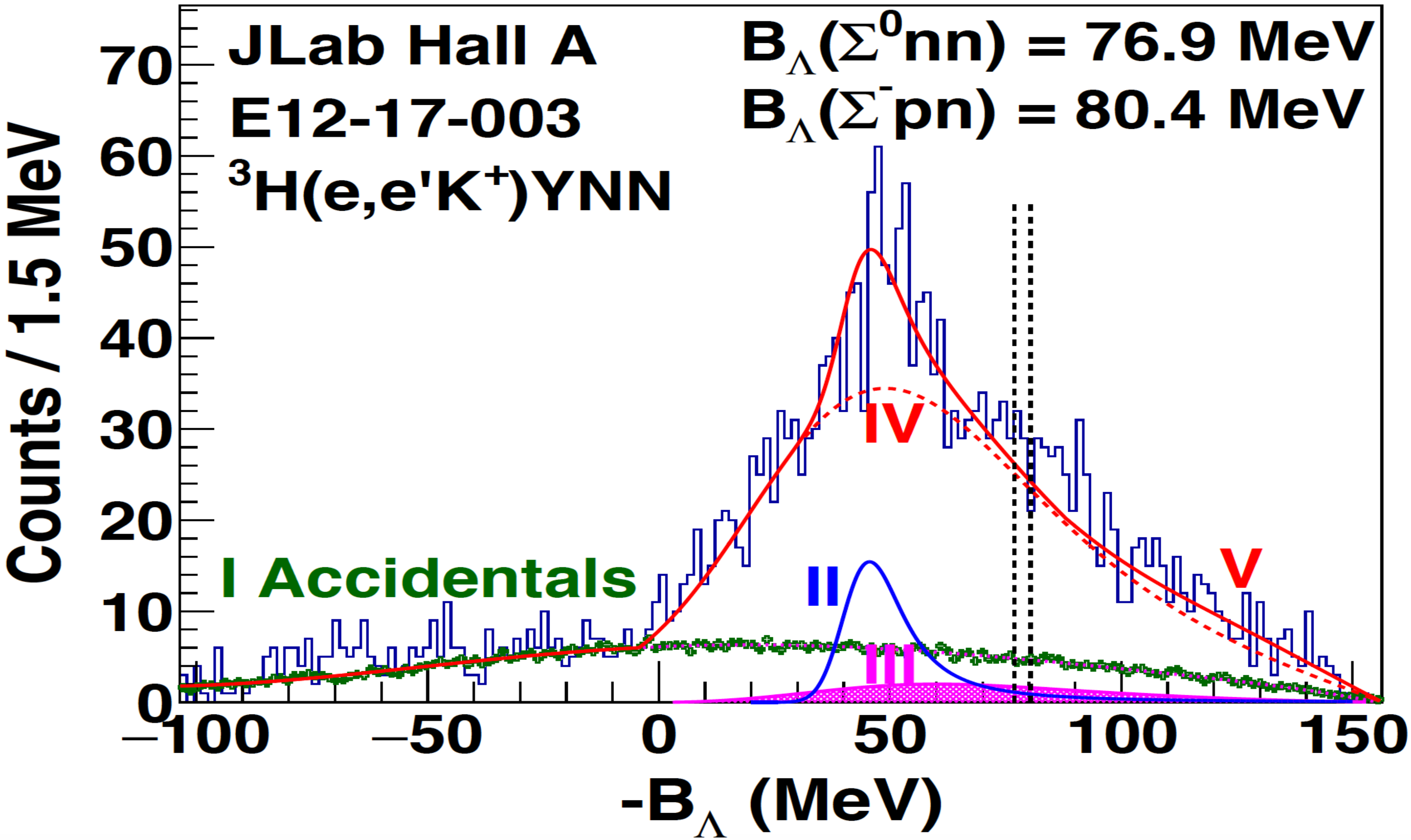


H data analyzed assuming T target



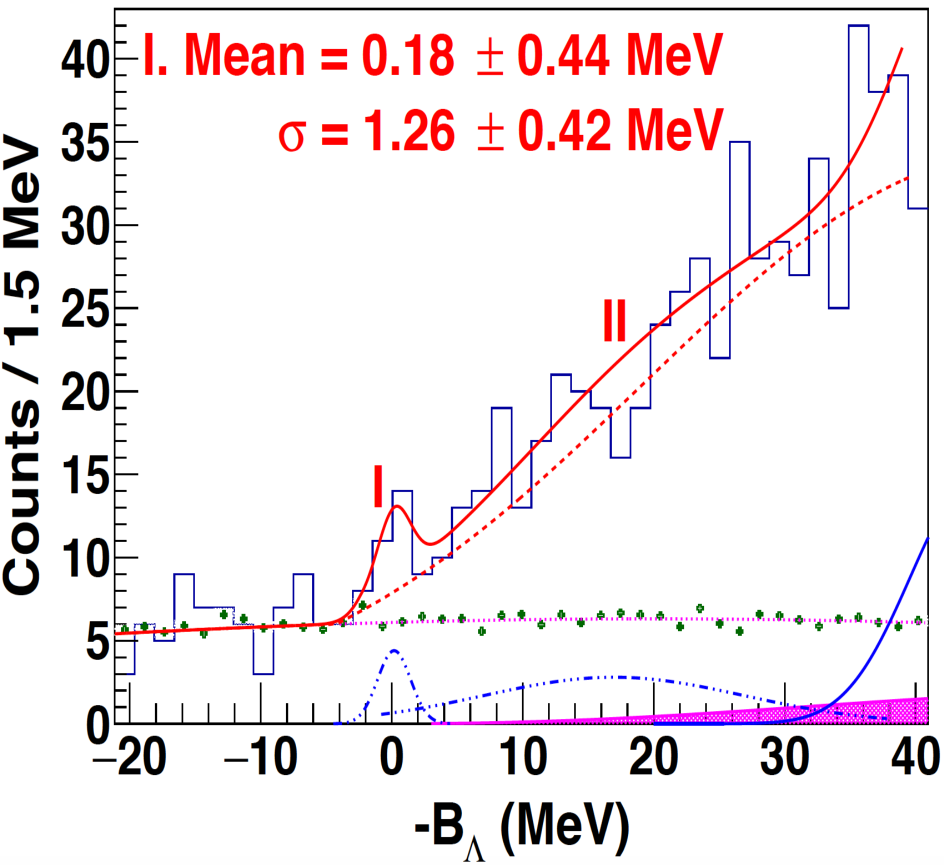
- T data analyzed with the H kinematics
- ~158 counts of free Λ, correspond to ≈ 3% H contamination
- Expect a free Λ peak in the *Λnn* spectrum with large width

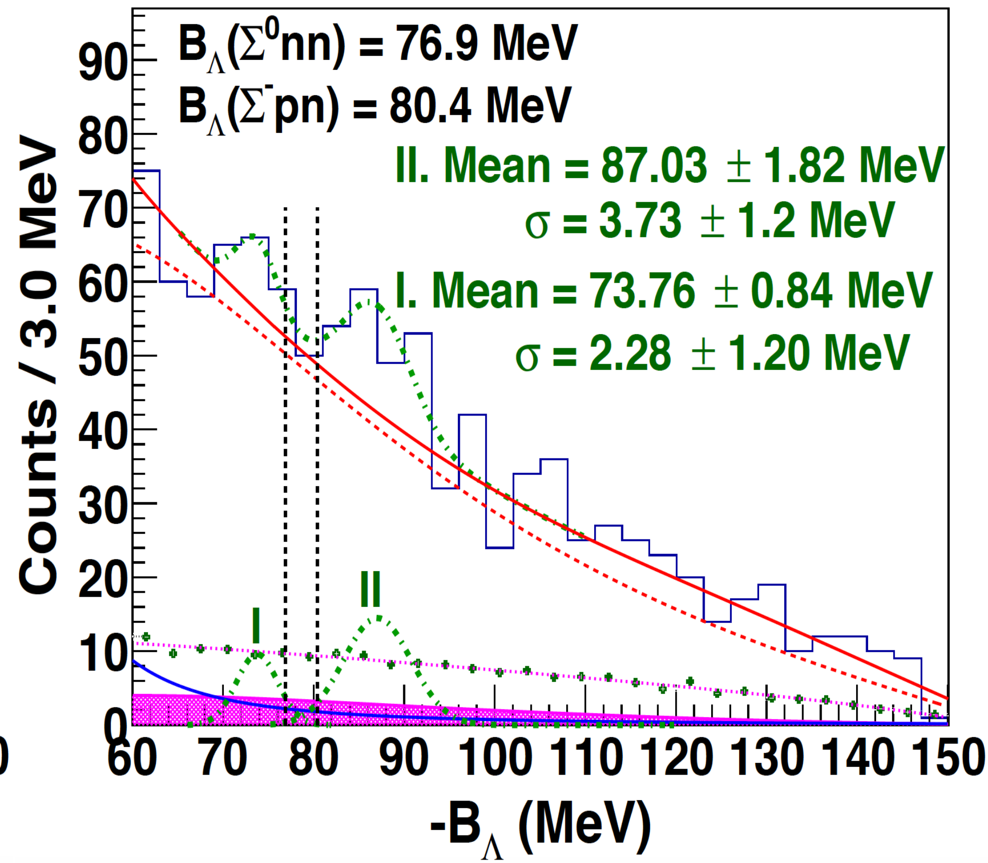
RESULTS – Λnn Spectrum



Although no definite identifications could be made, enhancements at both the Λnn and ΣNN thresholds are highly interesting

ANALYSIS RESULTS – Possible Y*NN* Resonances



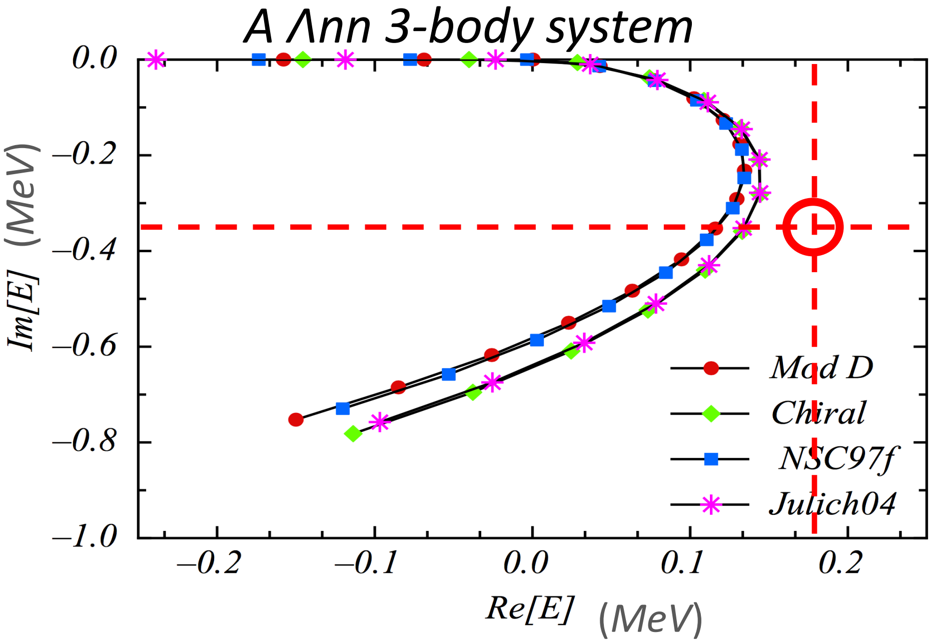


- Possible *Λnn* resonance:
  $-B_{\Lambda} = 0.18 \pm 0.44$ (*stat*) ± 0.4 (*sys*)
  $\Gamma/2 = 0.35 \pm 0.42$ (*stat*) ± 0.5 (*sys*)
- Significance: ~2.2. If real, cross section ≈ 10 nb/sr)

- Possible bound Σ^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 (1st/2nd) ≈ 20/45 nb/sr

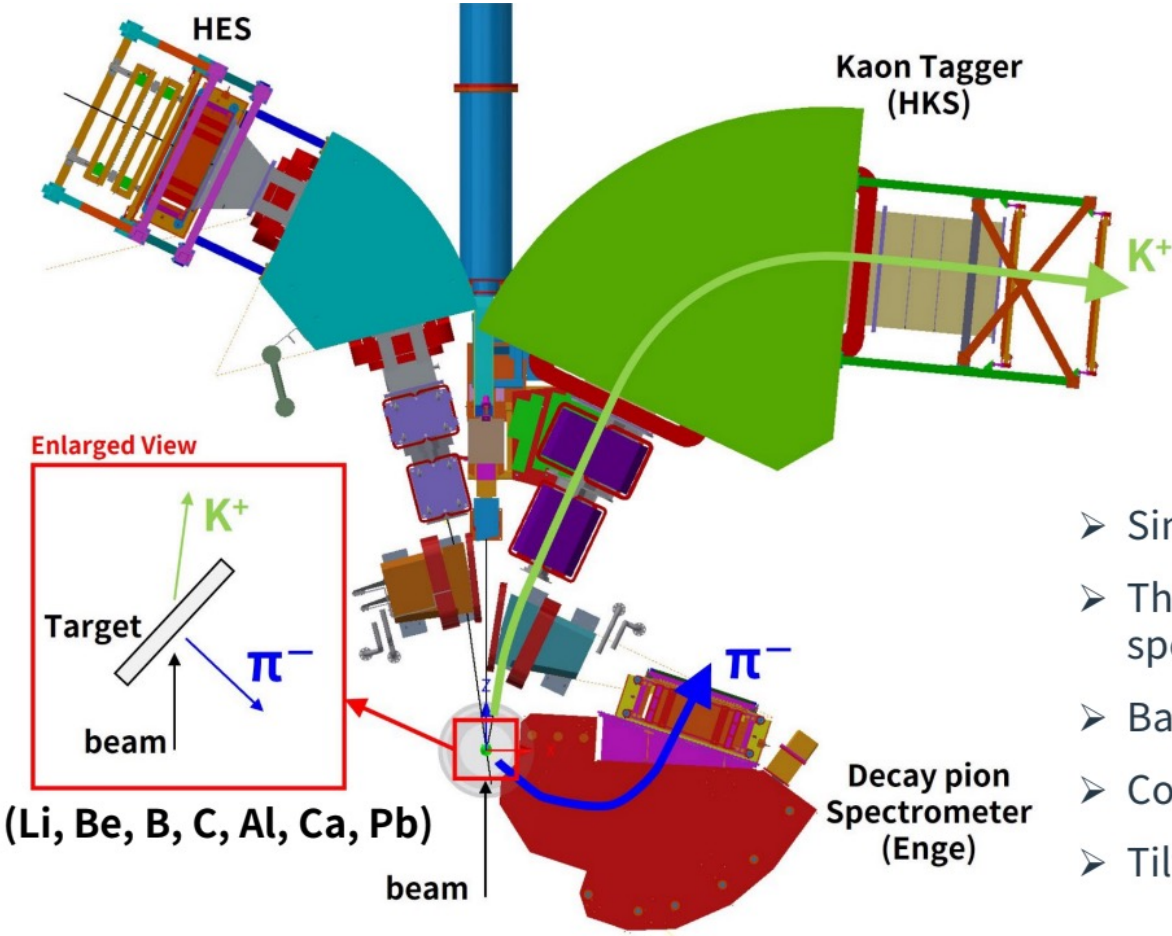
SUMMARY

- 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.*



SUMMARY

✧ *Future possibility*:
Decay pion spectroscopy, run in parallel with the (e, e'K+) experiments (E12-15-008 and E12-20-013) in 2026



- LOI submitted to PAC51 (2023)
- Proposal to PAC52 (2024)

- Similar concept to MAMI exp.
- Third spectrometer (Enge) as a decay-pion spectrometer
- Background suppression by tagged K^+
- Coincidence measurement of "π^-, K^+"
- Tilted targets

SUMMARY

✧ *Simulated decay pion momentum spectrum*