A Possible Observation of Λnn Continuum Structure and a Bound ΣNN State using the (e,e'K^+) Reaction

Update on E12-17-003 Experiment
Data Taken: October 31 to November 26 2018
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Jefferson Lab
EXPLORING THE NATURE OF MATTER

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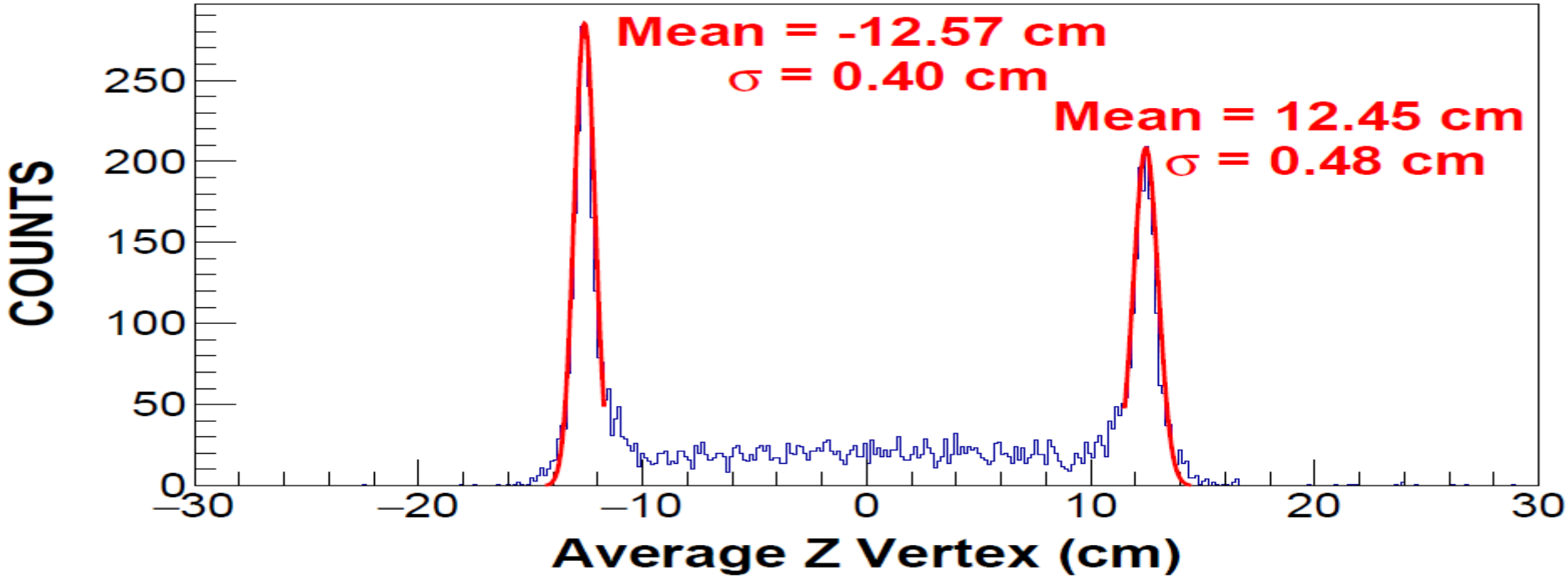
Physics Motivation:

- The YN and YY interactions are difficult to produce as compared to NN interactions.
- Limited data exists for the YN interaction.
- Λn interaction data does not exist.
- Significant charge symmetry breaking is reported in case of A = 4 isospin mirror pair of hypernuclei.
- The HypHI experiment indicated the existence of either a resonance or the bound state.

E12-17-003: Opportunity to Search for the Possible Λnn Resonance

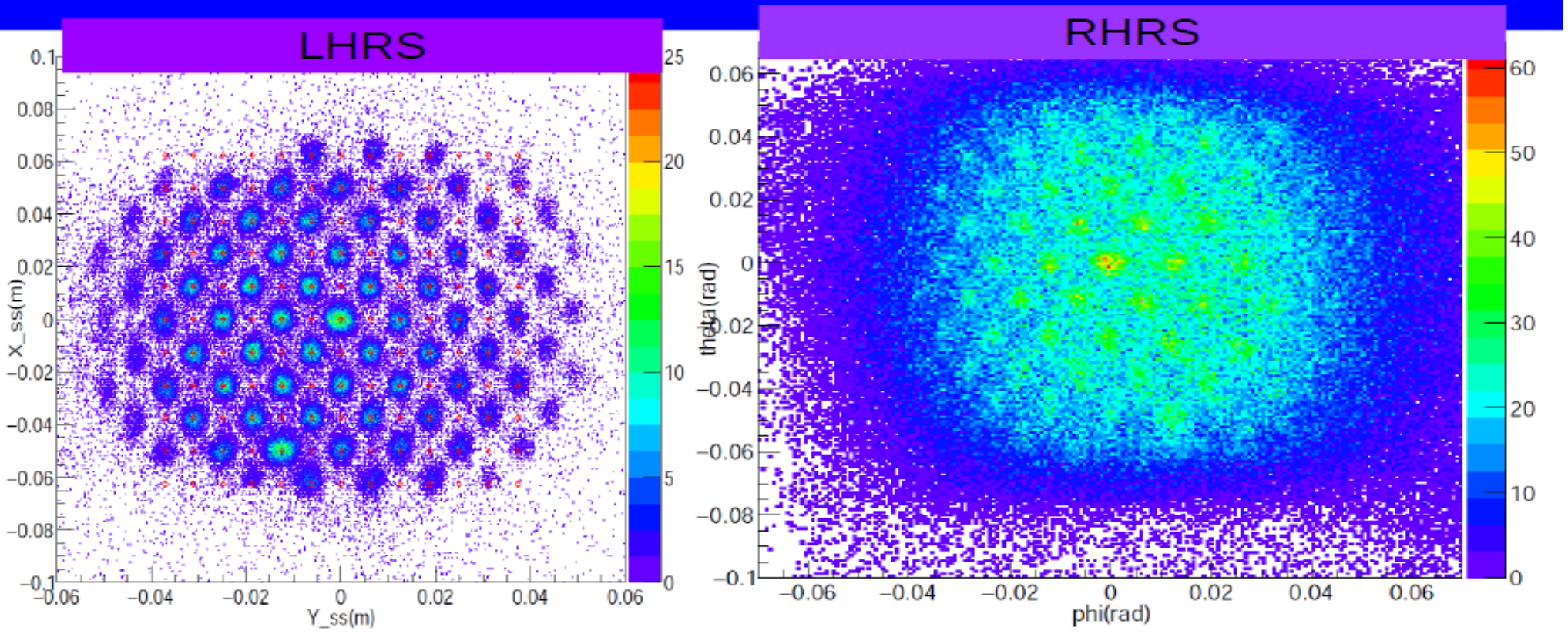
- Hall A with tritium target aimed to search for the Λnn resonance or the bound state as indicated by HypHI experiment. However, the available system was not ideal for this experiment.
- The electron arm was at very large angle $\theta_{e'} = 13.2^{\circ}$ produces large $Q^2 = 0.5(GeV/c)^2$ which results low production yield.
- The path length for the hadron arm was too large (~ 26 m) which limits the K^+ survival rate ~ 10 %.
- The $\vec{q}(\Lambda)$ was too high ~ 400 MeV/c which can give very small value of $d\sigma/d\Omega$.
- The available aerogel detectors were too old, can not detect all of the charge particles (kaons) passing through them.

Average Z-Vertex for H data:



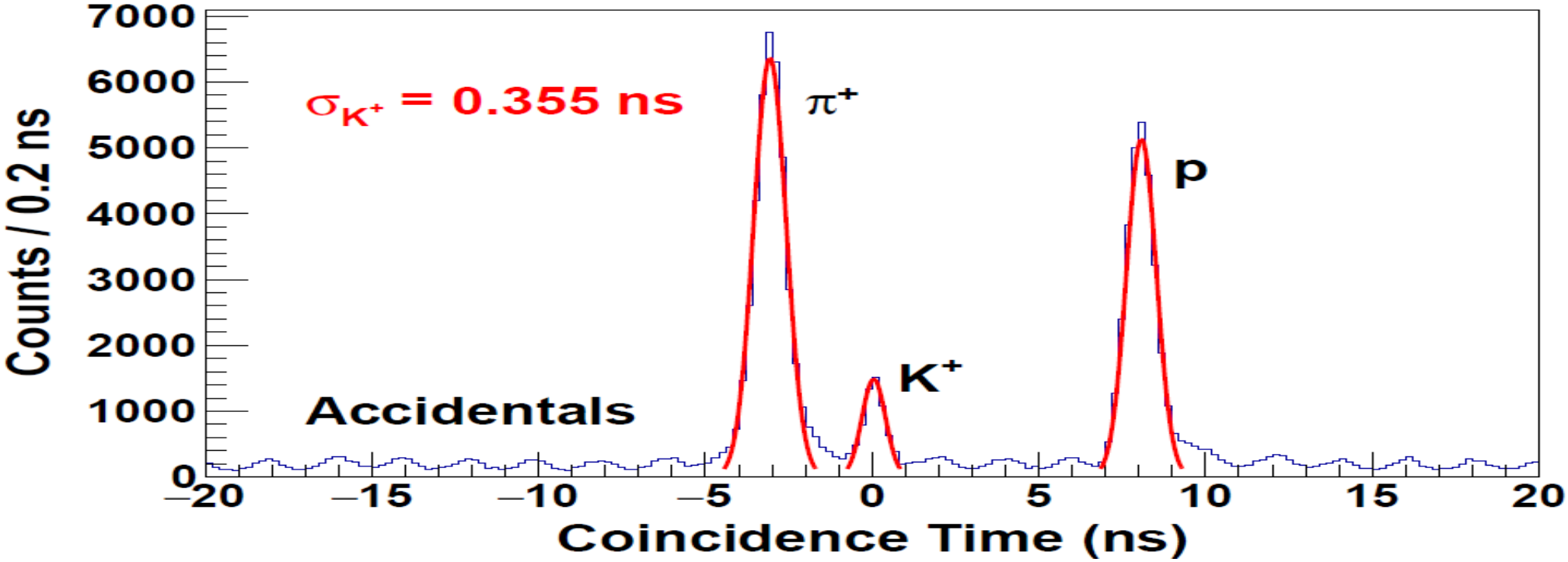
- Each of the z vertex was optimized with single arm trigger data and then averaged with the coincidence data.
- The z vertex resolution of about σ = 4.5 mm was achieved.
- To select the events from the gas region, z vertex ranging from -10 cm to 10 cm was selected.

HRS Angle Reconstruction with Multi-foil Target:



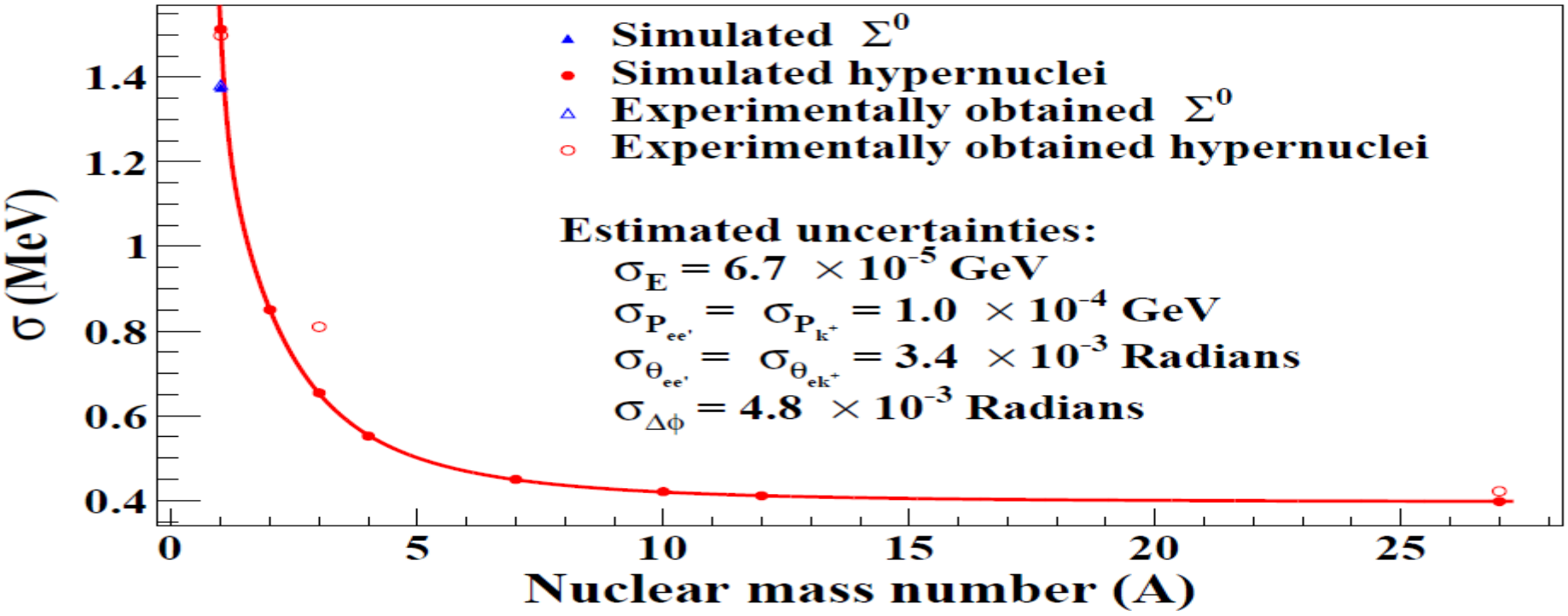
- Achieved acceptable angular resolution.
- The RHRS has more background as the hadrons are punching through the sieve slit and producing secondary hadrons .

Coincidence Time Spectrum:



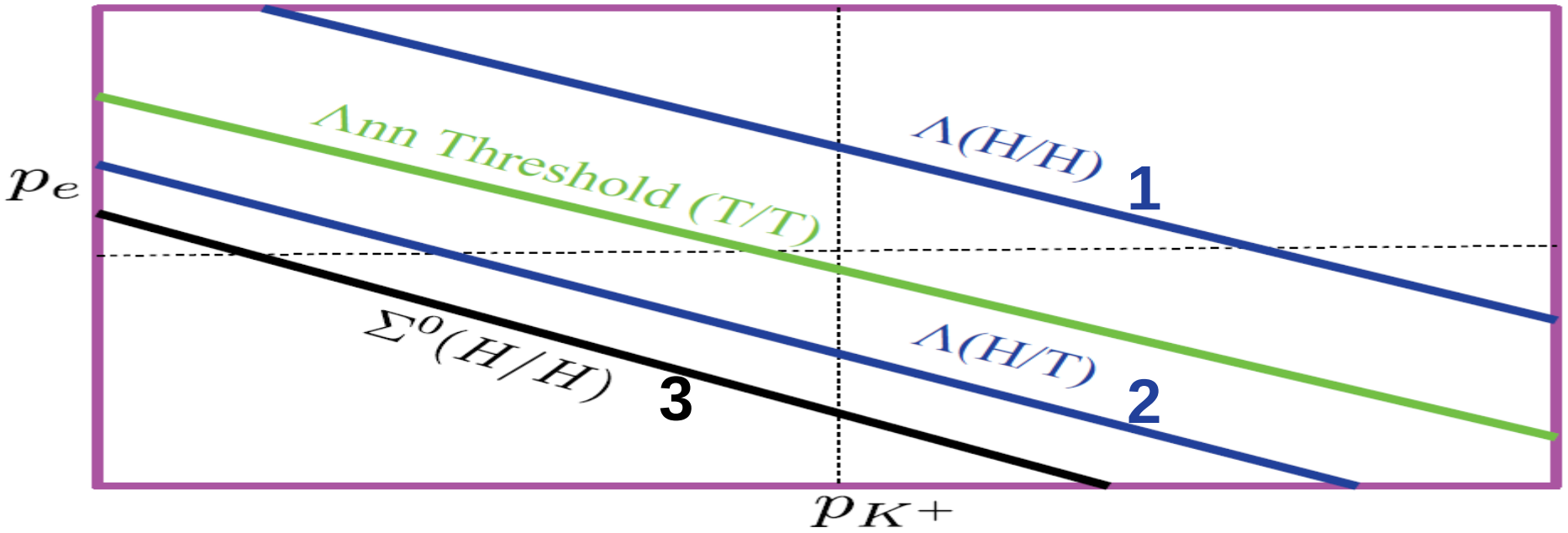
- The time resolution of about 355 ps was achieved for a 2 ns CEBAF beam bunch.
- The K^+ are cleanly separated from the rest of the hadrons.
- For physics analysis a coincidence time gate of ± 1ns was used to select the K^+.
- The accidentals are because the KID detectors can not reject all of the background particles.

Simulation of A dependence of Missing Mass Resolution



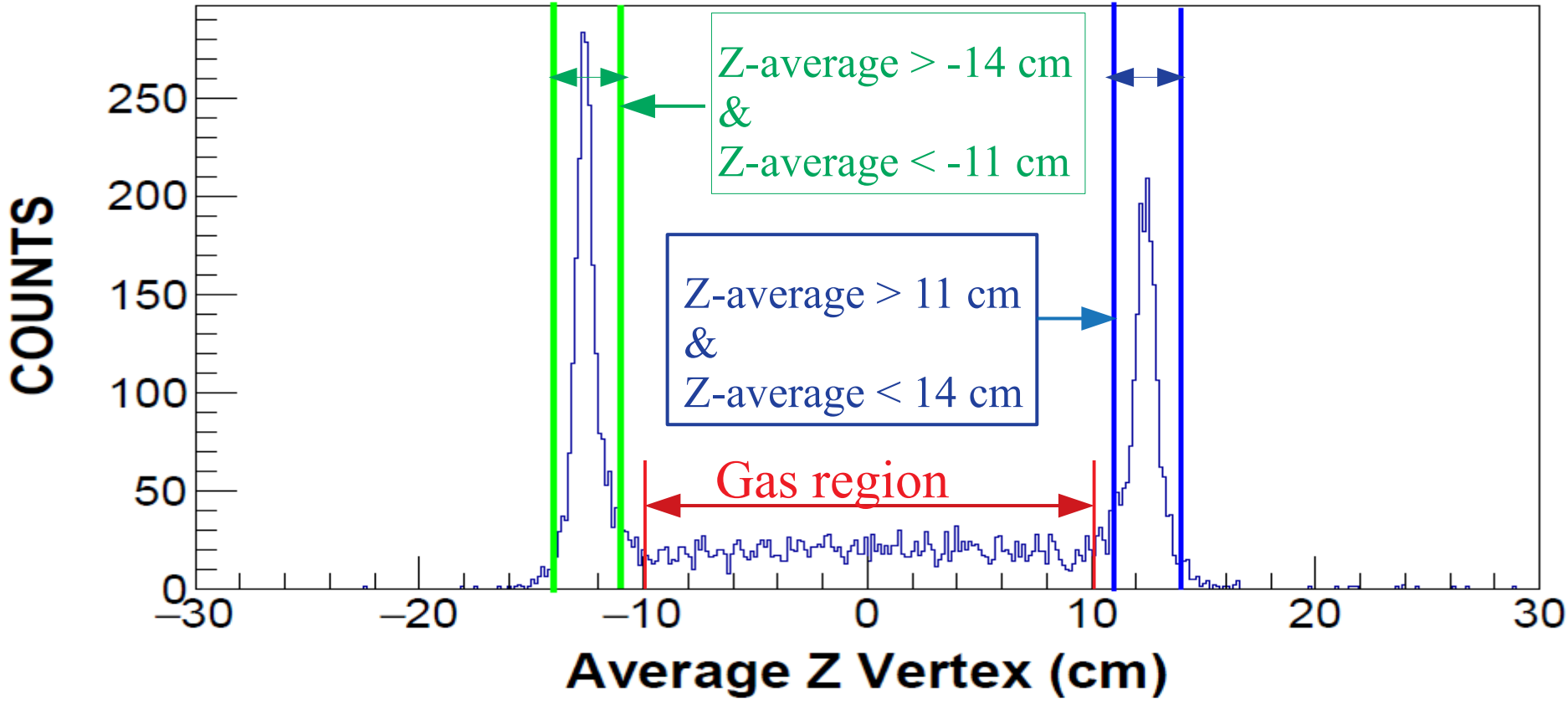
- With the estimated uncertainty contributions from beam energy, momenta from e' and K+ and scattering angles, the A dependence of missing mass resolution was simulated.
- The scattering angle uncertainty dominates for the A =1 system, while the energy and momentum uncertainties dominate for the system with A>7.
- For A = 3 system, all uncertainties evenly contribute.

Kinematic Space for e,e'K^+:



- The momentum calibration is the two dimensional correlation.
- There are only three data points to calibrate the momentum matrices.
- There is large kinematic gap between the two Λ correlation lines.
- The optics quality may not be uniform in the gap region.
- A heavy mass system (A ≥10) with negligible angular dependence need to be involved in matrix tune along with the Λ and Σ^0 masses.

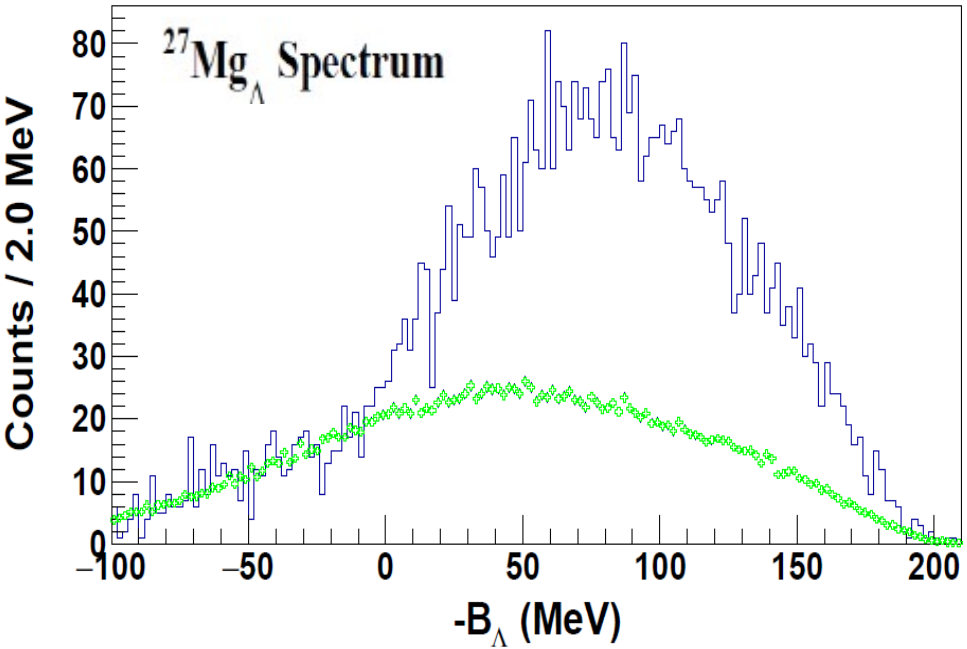
Al is Considered as Target :



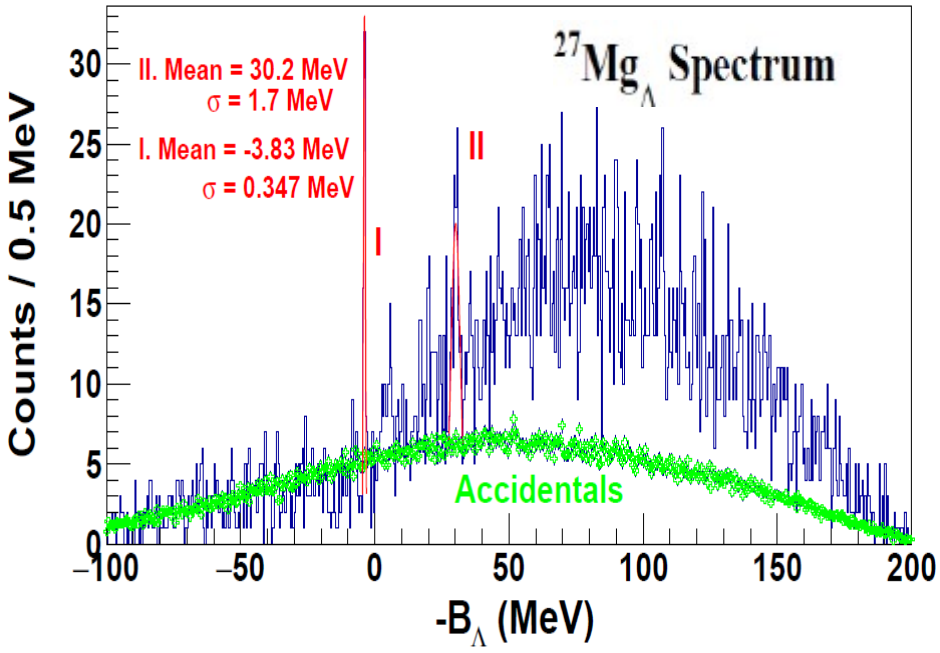
- Events from the region of beam entrance and beam exit Al windows were selected and combined together to form the $^{27}Mg_{\Lambda}$ hypernuclei.

Al Data Involved in Matrix tune Along with Λ and Σ^0 Masses:

Before Al involve in Tune



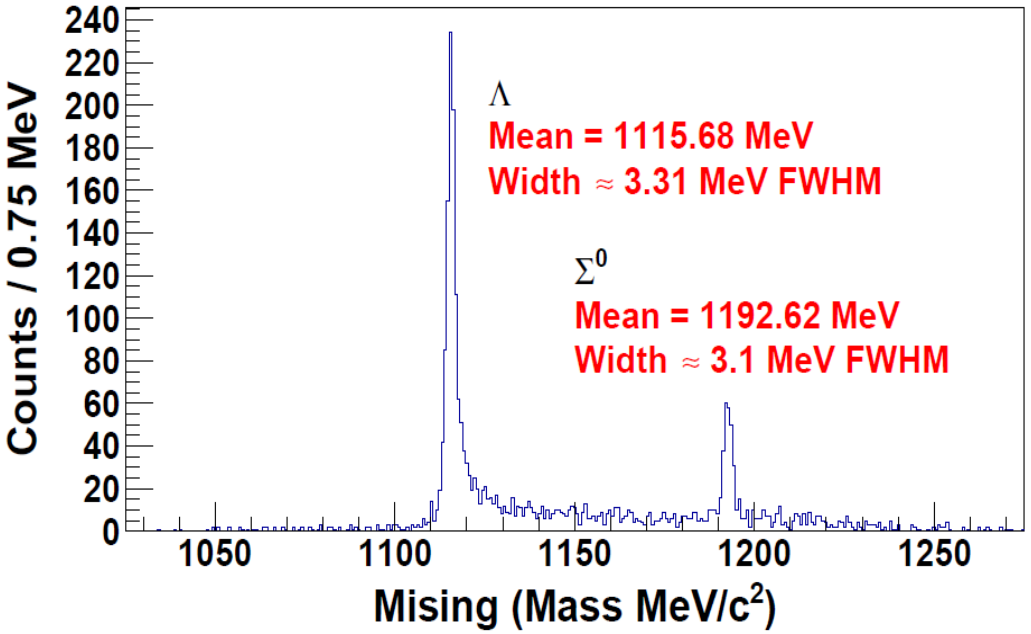
After Al involve in Tune



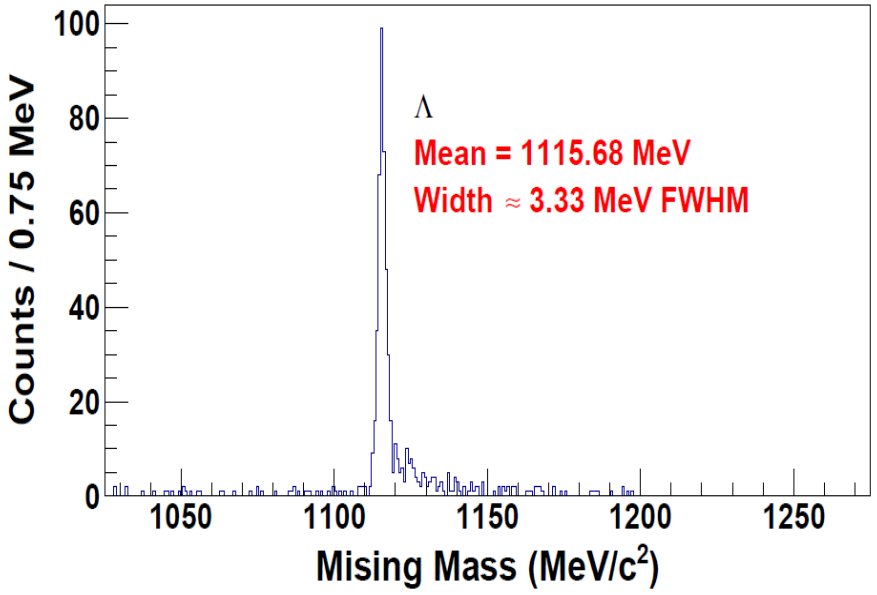
- After searching the first single state real peak, Al data was involved in tune with Λ and Σ^0 masses.
- The observed bound state is not a ground state.
- The resolution of the first Al peak agreed well with the simulation.

Missing Mass Spectrum:

H/H Kinematics

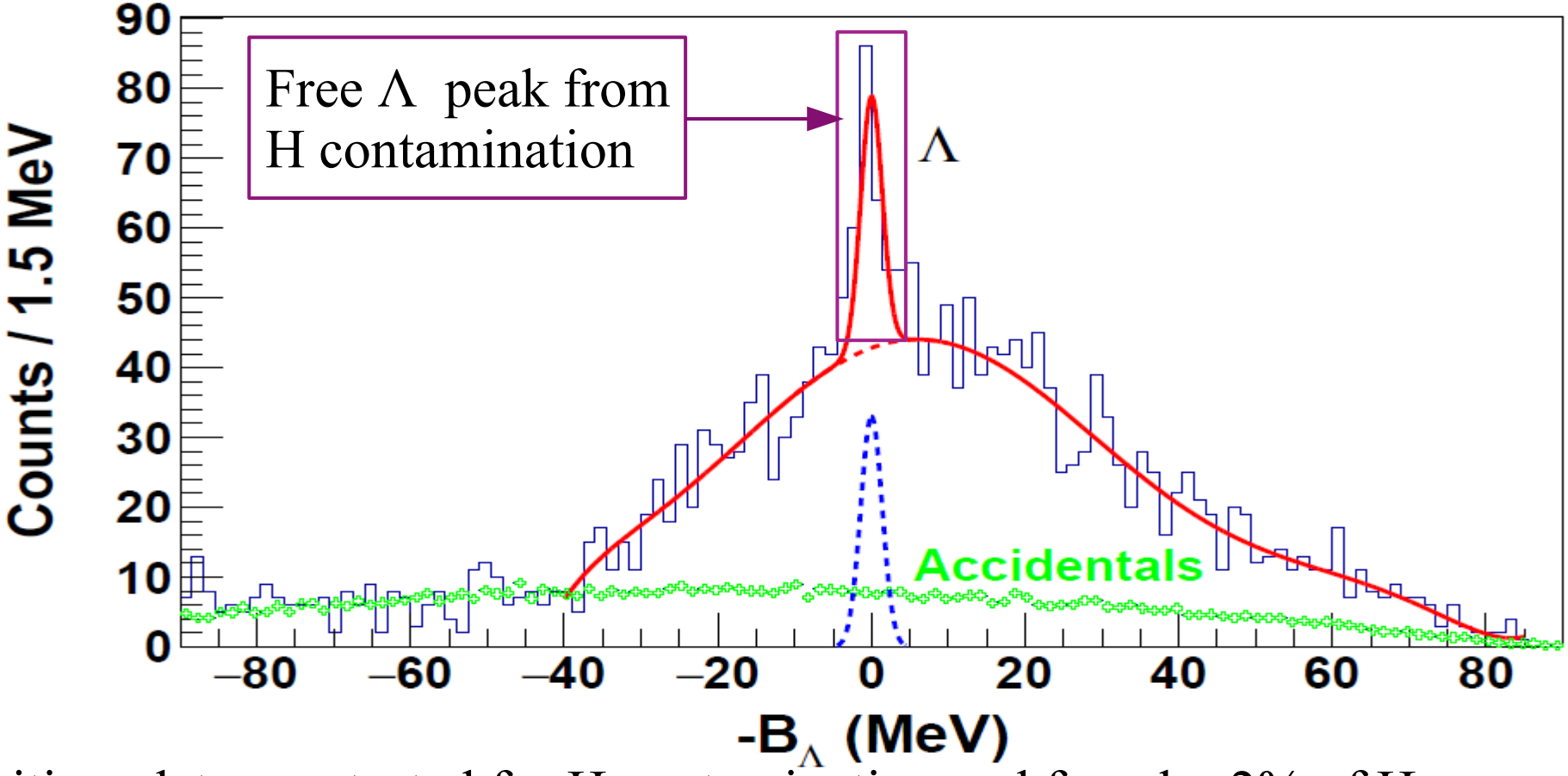


H/T Kinematics



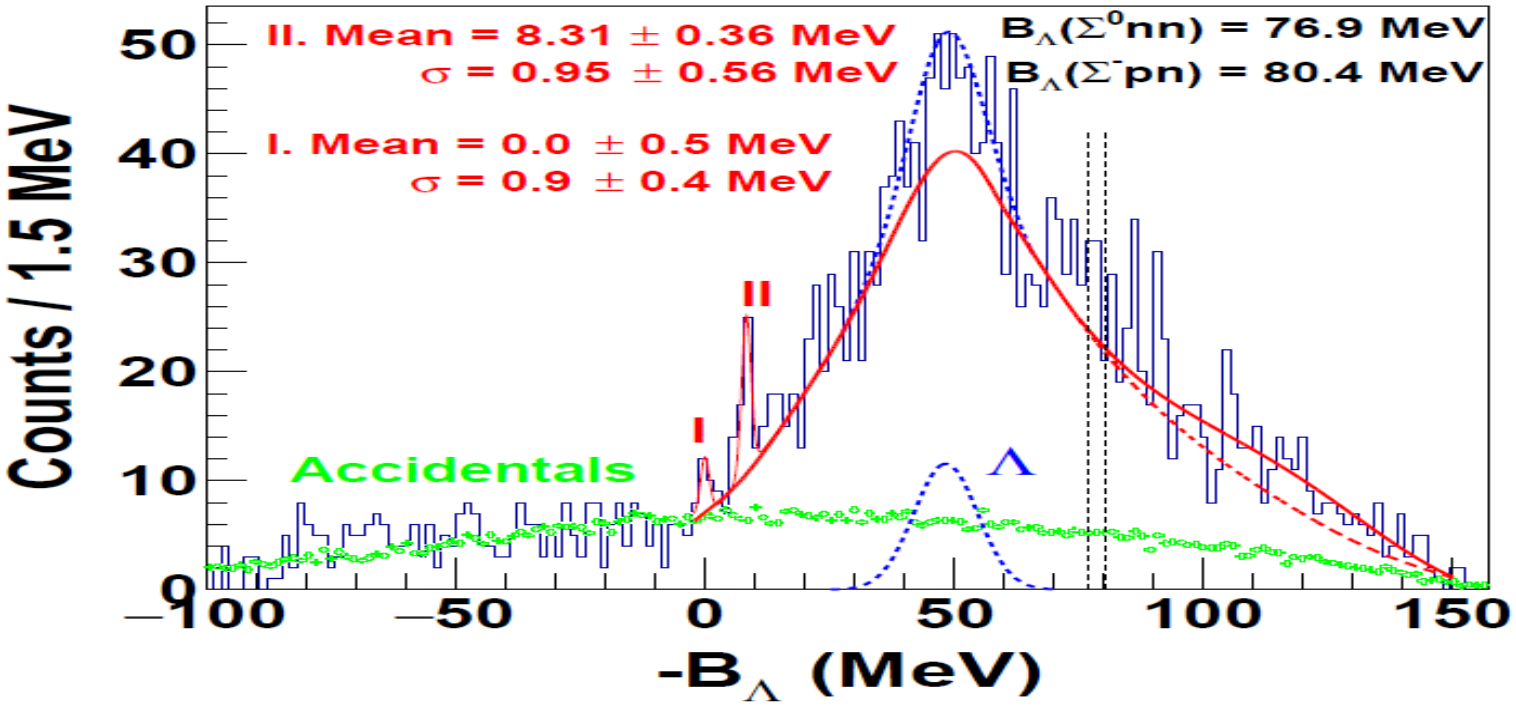
- These are the important data sets used for the absolute missing mass calibration.
- The Λ and Σ^0 landed at their known masses with a separation of 76.94 MeV/c^2 (Nominal = 76.96 MeV/c^2).
- Achieved resolution of Λ and Σ^0 agreed with the simulation.
- Systematic uncertainty for the missing mass (binding energy) found ~ 100 keV.

H Contamination Test:



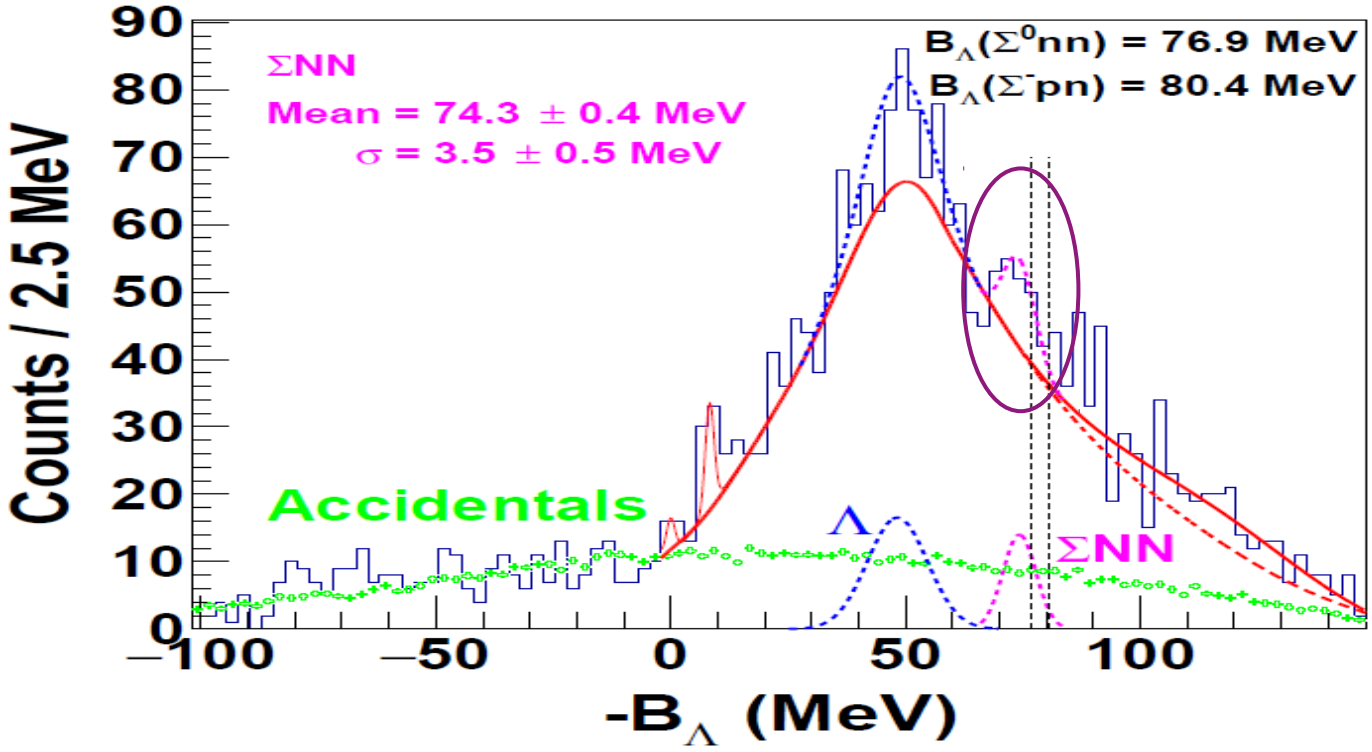
- Tritium data was tested for H contamination and found ~ 2% of H was present in the Tritium gas which is consistent with other tritium experiments.

Mass Spectroscopy of ${}^{3}_{n}\Lambda$:



- The first peak is possible to be the expected resonance. However, the statistics is very low.
- For the first peak, the cross section and the statistical significance are found ~ 1.3 nb/sr and ~ 2.1 respectively.
- The peak at the higher excitation was not expected, therefore, its origin is unclear.
- For the 2nd peak, cross section & significance are found ~ 3.66 nb/sr and ~4.5 respectively.

Mass Spectroscopy with Higher Bins:



- The enhancement at the Σ bound region was predicted before and is a possible bound Σ hypernuclei.
- For the ΣNN peak, the cross section and statistical significance are found ~ 8.03 nb/sr
- and ~ 3.1 respectively.

Conclusions:

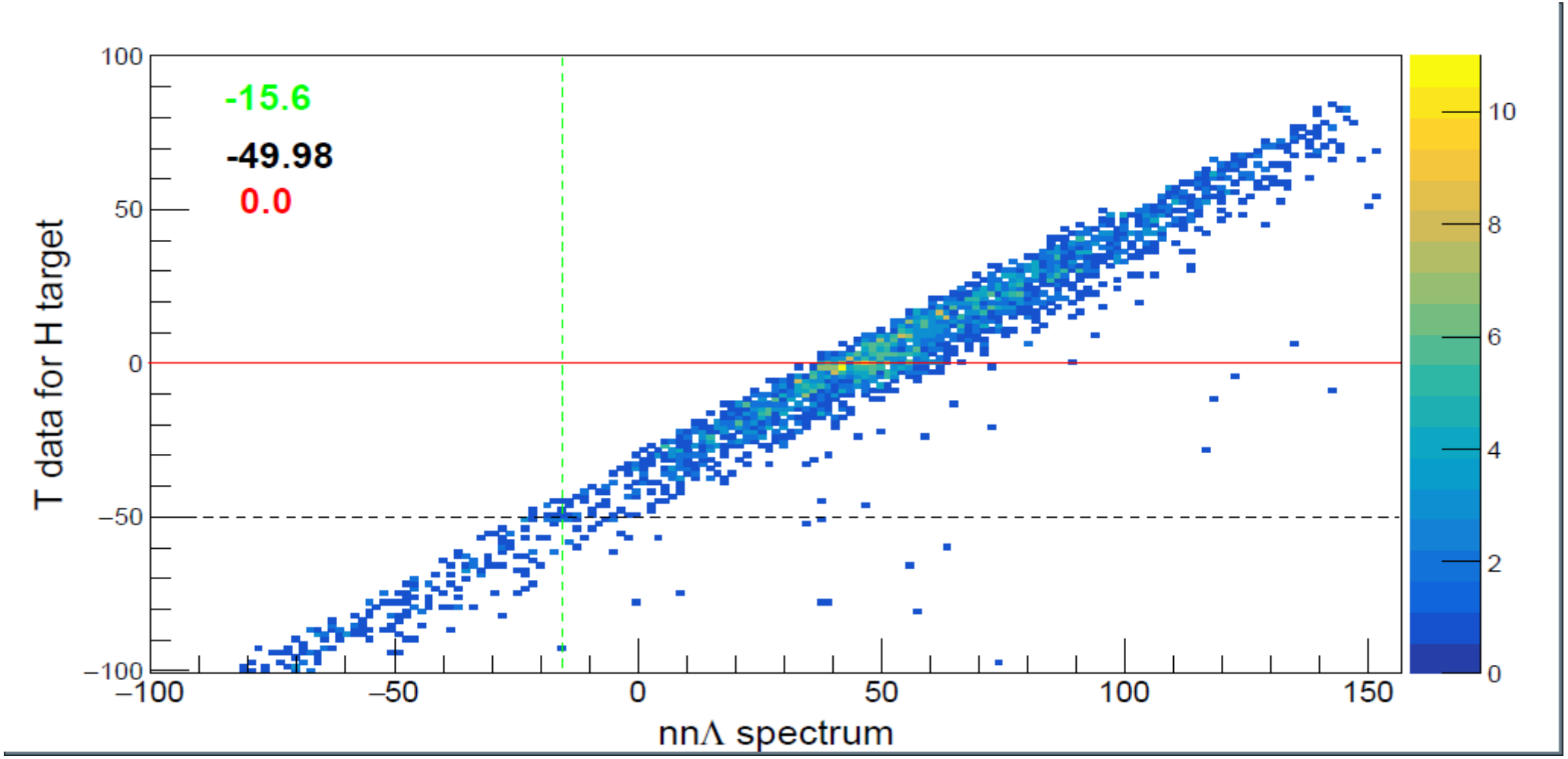
- The experiment demonstrated that by using the tritium target and the (e,e'K^+) reaction, it is possible to observe the 3 body Λnn final state and ΣNN interaction. However, Hall A system need to be optimized for higher statistics.
- From this experiment two resonance states of ${}^{3}_{\Lambda}n$ and one bound state of ${}^{3}_{\Sigma}n$ were observed. However, to make a definite identification, higher statistics are required.
- A simulation predicted the intrinsic missing mass resolution of A = 3 resonance to be σ = 0.66 MeV. Thus, the natural width is about 0.6 MeV.
- However, if these states are real, the dominant large statistical uncertainty (+/- 0.5 MeV) does not give sufficient constrain in determination of the Λ-n Interaction.

Acknowledgement

- Hall A Collaboration
- HKS Collaboration and spokes persons of the experiment
- Tritium Group students and postdocs
- Hall A technical staffs and Target group
- Accelerator Staff

Thank you

Backup:


-15.6
-49.98
0.0
T data for H target
nnΛ spectrum
100
50
0
−50
−100
−100
−50
0
50
100
150
10
8
6
4
2
0