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
Hall A/C summer Joint Collaboration Meeting
Jefferson Lab
July 16, 2020

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Jefferson Lab
EXPLORING THE NATURE OF MATTER

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Outlines:

- Physics motivation
- Single arm data analysis
- VDC tracking problem
- Coincidence data analysis
- Analysis result
- Summary

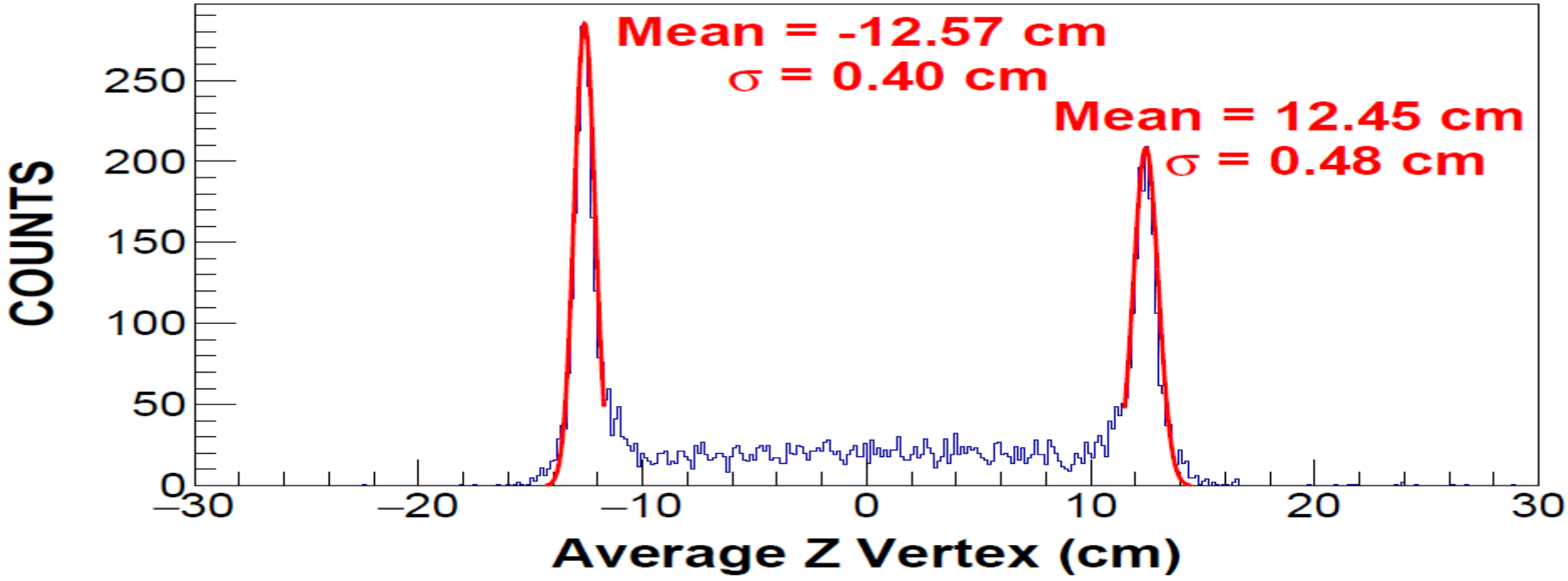
Physics Motivation:

- 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.

Hall A was not Optimized for the Experiment:

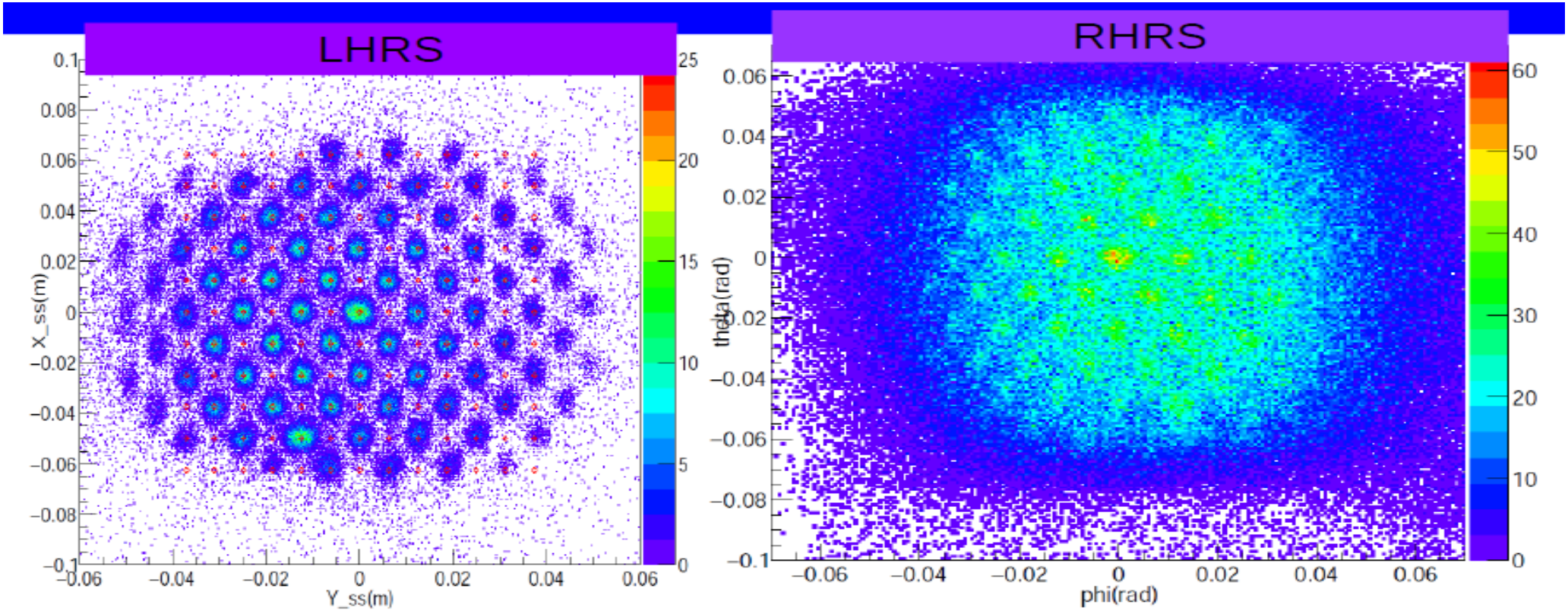
- Hall A with tritium target aimed to search for the Λnn resonance or the bound state as indicated by HypHI experiment. However, the system was not optimized for this experiment.
- The electron arm was at very large angle $\theta_{e'} = 13.2^{\circ}$, produces large $Q^2 = 0.5(GeV/c)^2$ which results low production yield.
- The path length for the hadron arm was too large (~ 26 m) which limits the K^+ survival rate ~ 10 %.
- The $\vec{q}(\Lambda)$ is too high ~ 400 MeV/c which gives very small value of $d\sigma/d\Omega$.
- The K^+ efficiency of the aerogel detector was very low.
- No cross-section information is available.

Average Z-Vertex for H data:



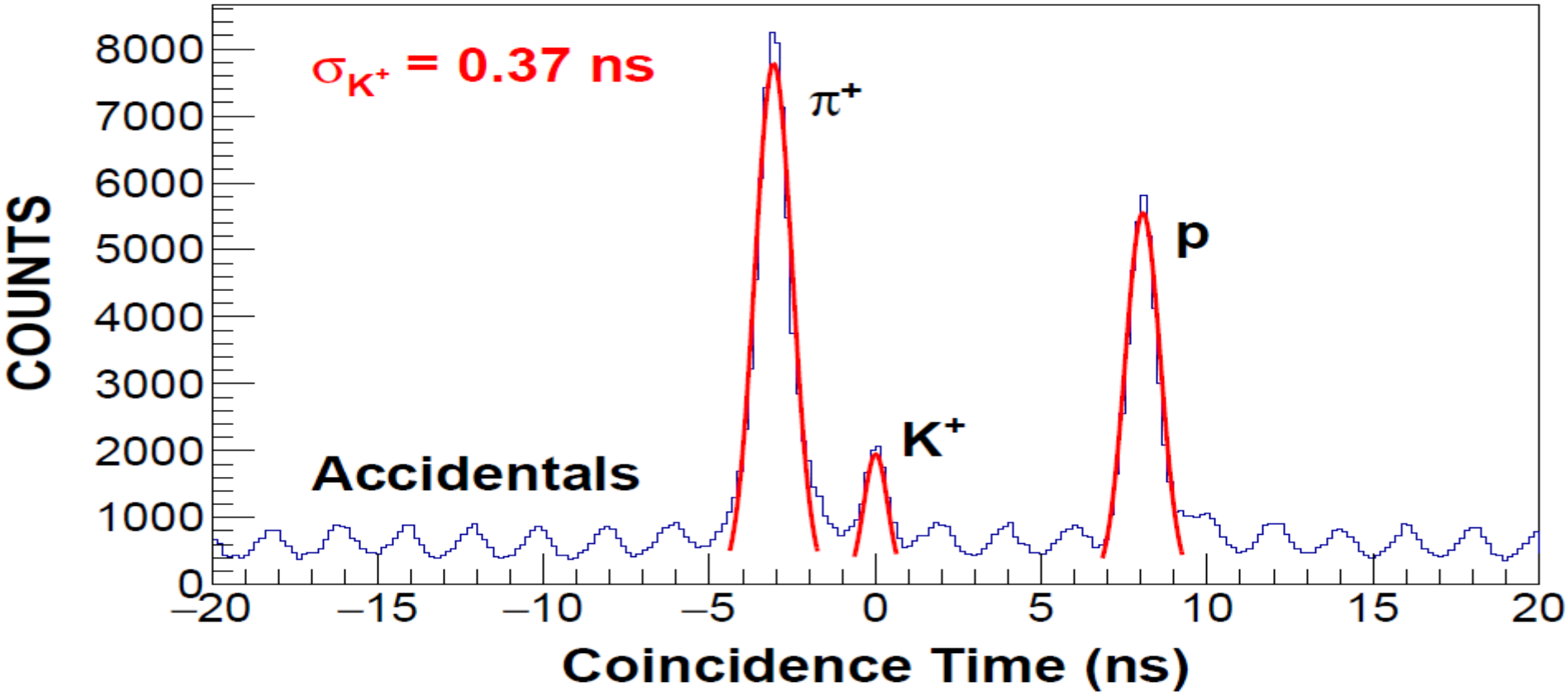
- Each of the z vertex was optimized with single arm trigger data and then averaged with the coincidence data.
- The z vertex resolution of about σ = 4.5 mm was achieved.
- To select the events from the gas region, z vertex ranging from -10 cm to 10 cm was selected.

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 .

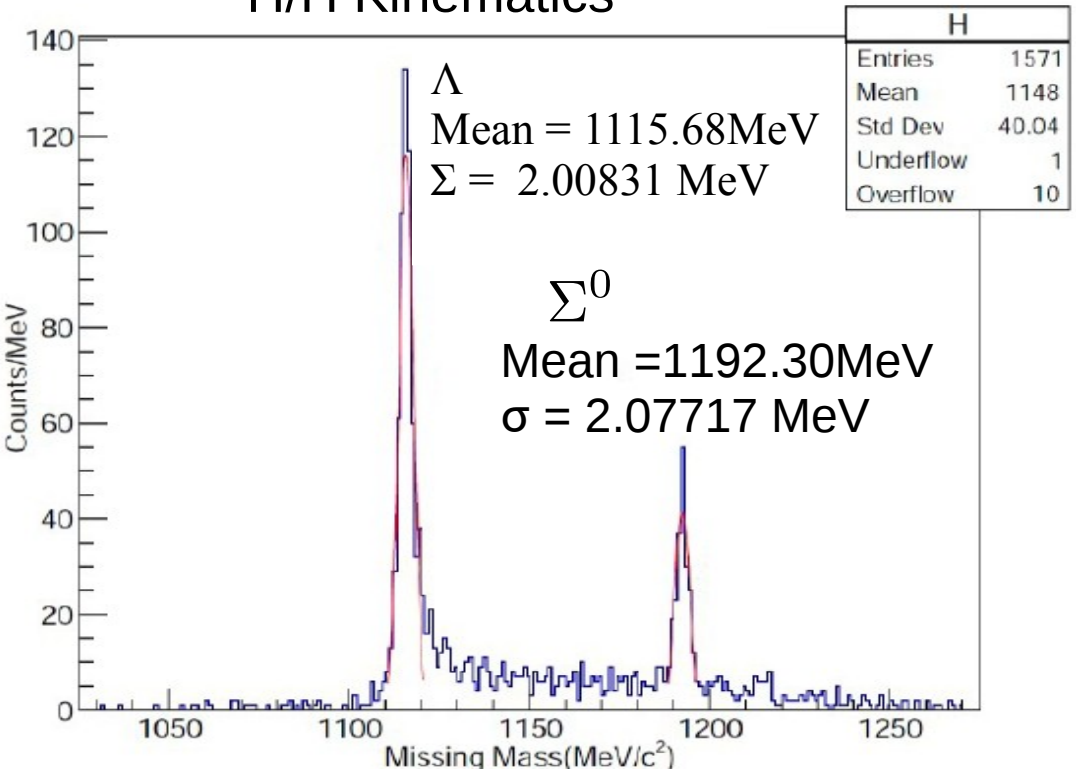
Coincidence Time Spectrum:



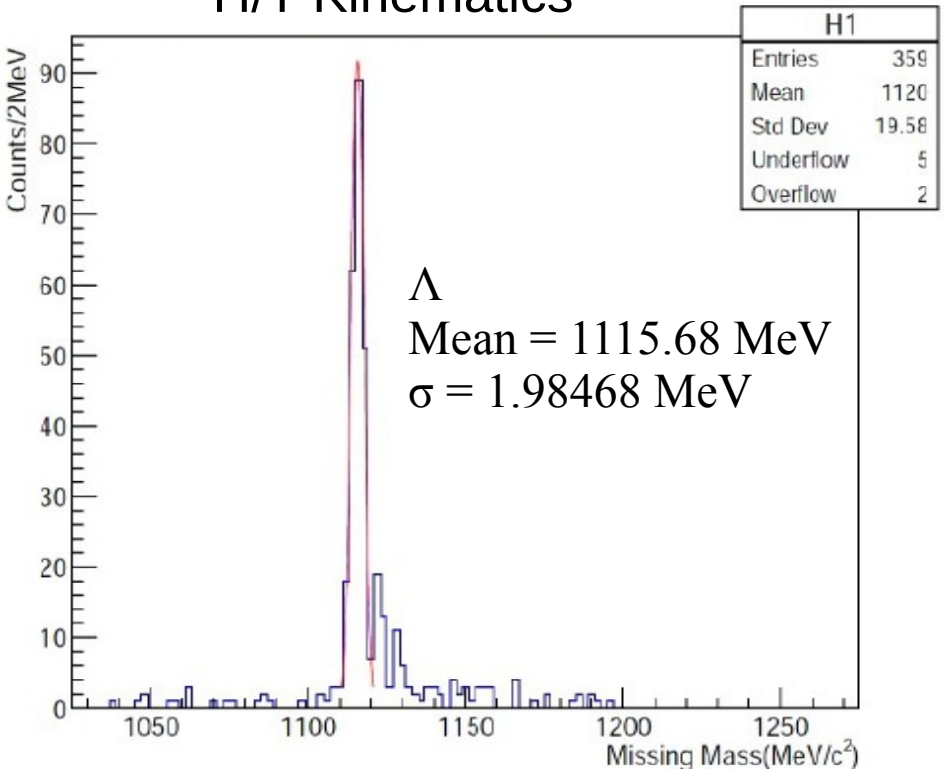
- The time resolution of about 370 ps was achieved for a 2 ns CEBAF beam bunch.
- The K^+ are cleanly separated from the rest of the hadrons.
- The accidentals are because of the inefficient KID detectors.

Missing Mass Before VDC Tracking Problem:

H/H Kinematics

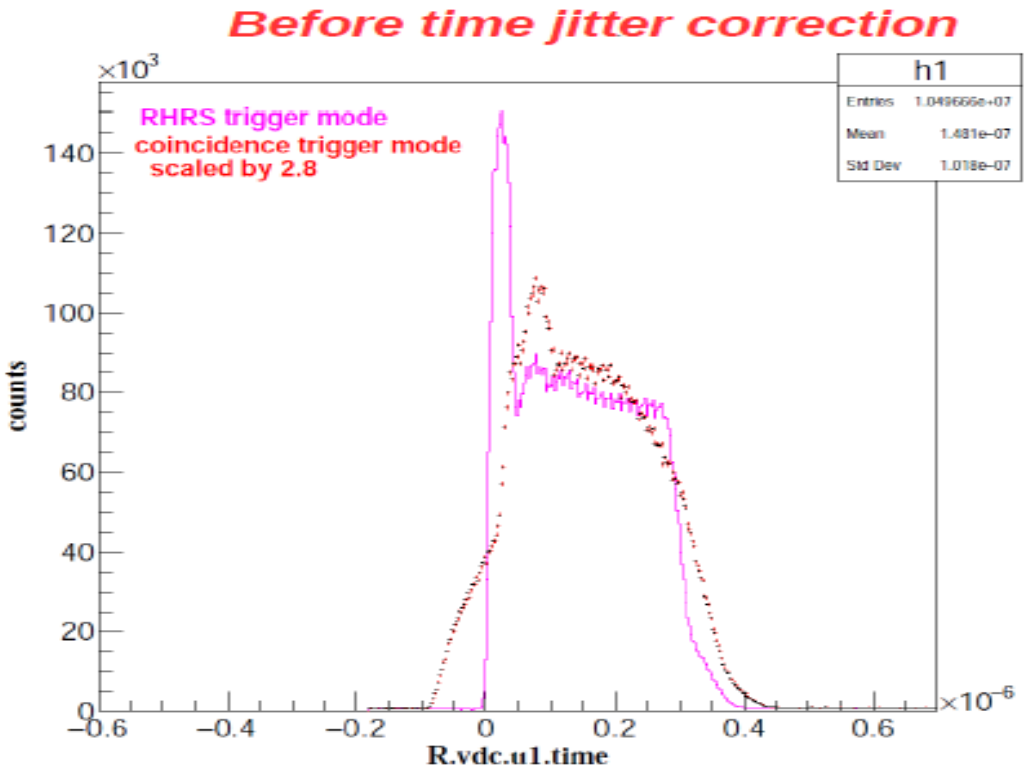


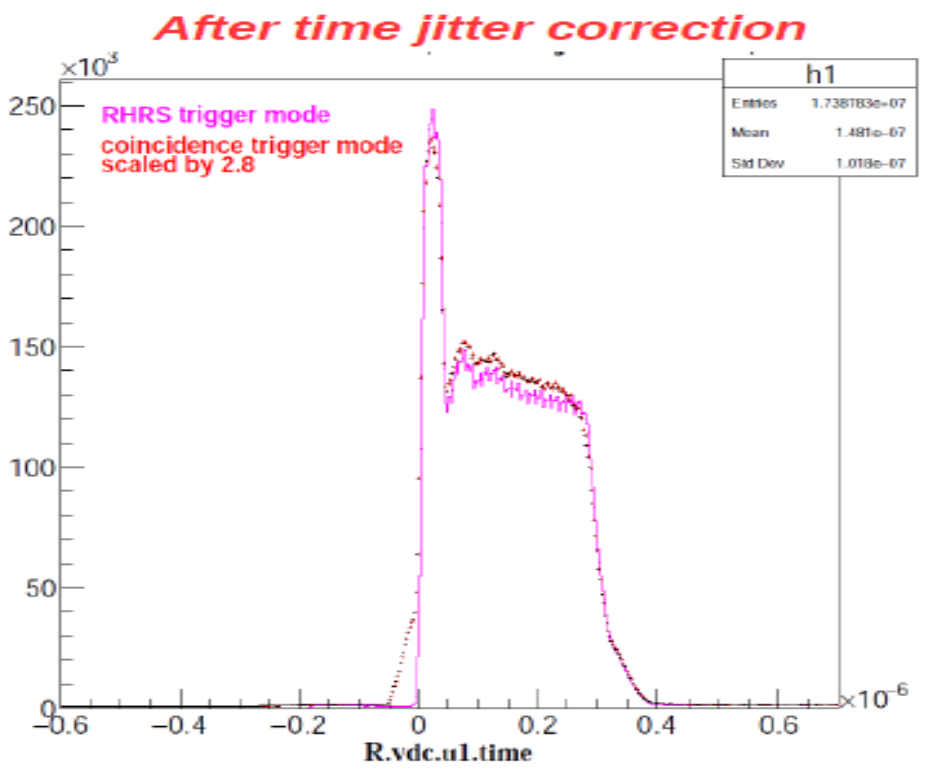
H/T Kinematics



- The resolution was limited to about 2 MeV is σ which was far from our requirement.
- The VDC tracking problem at the RHRS for the coincidence events was detected.

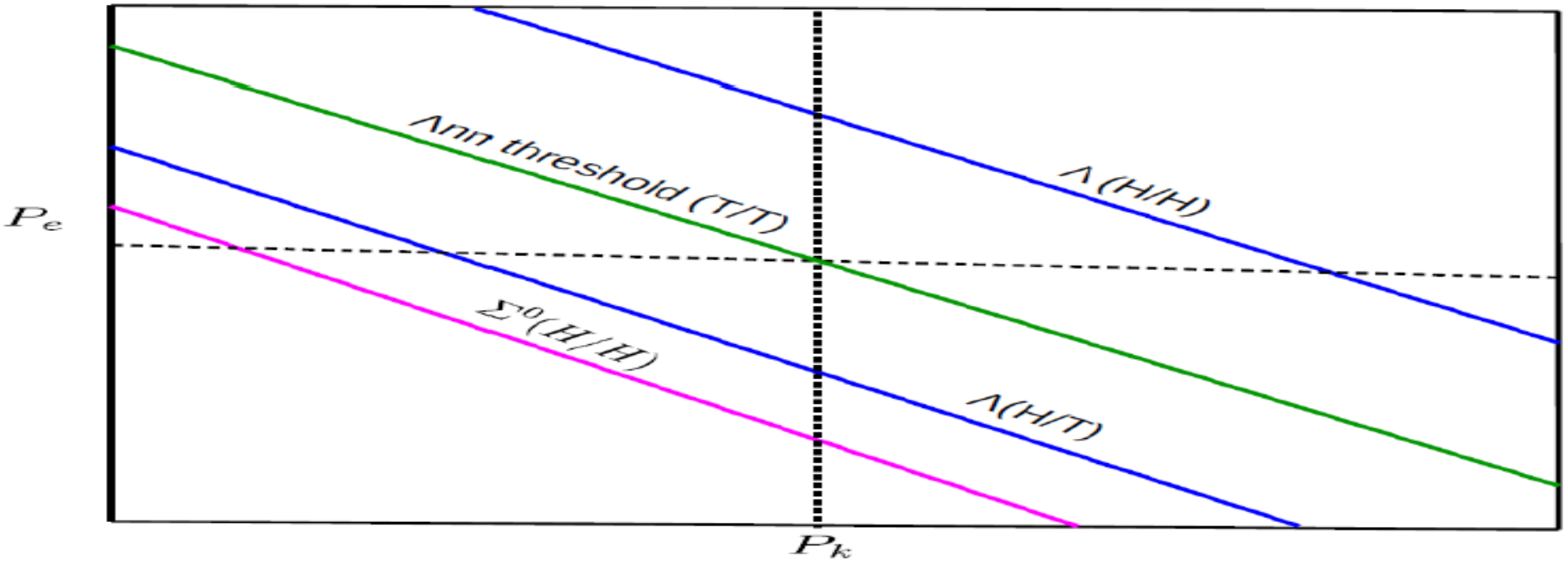
Raw TDC Spectrum





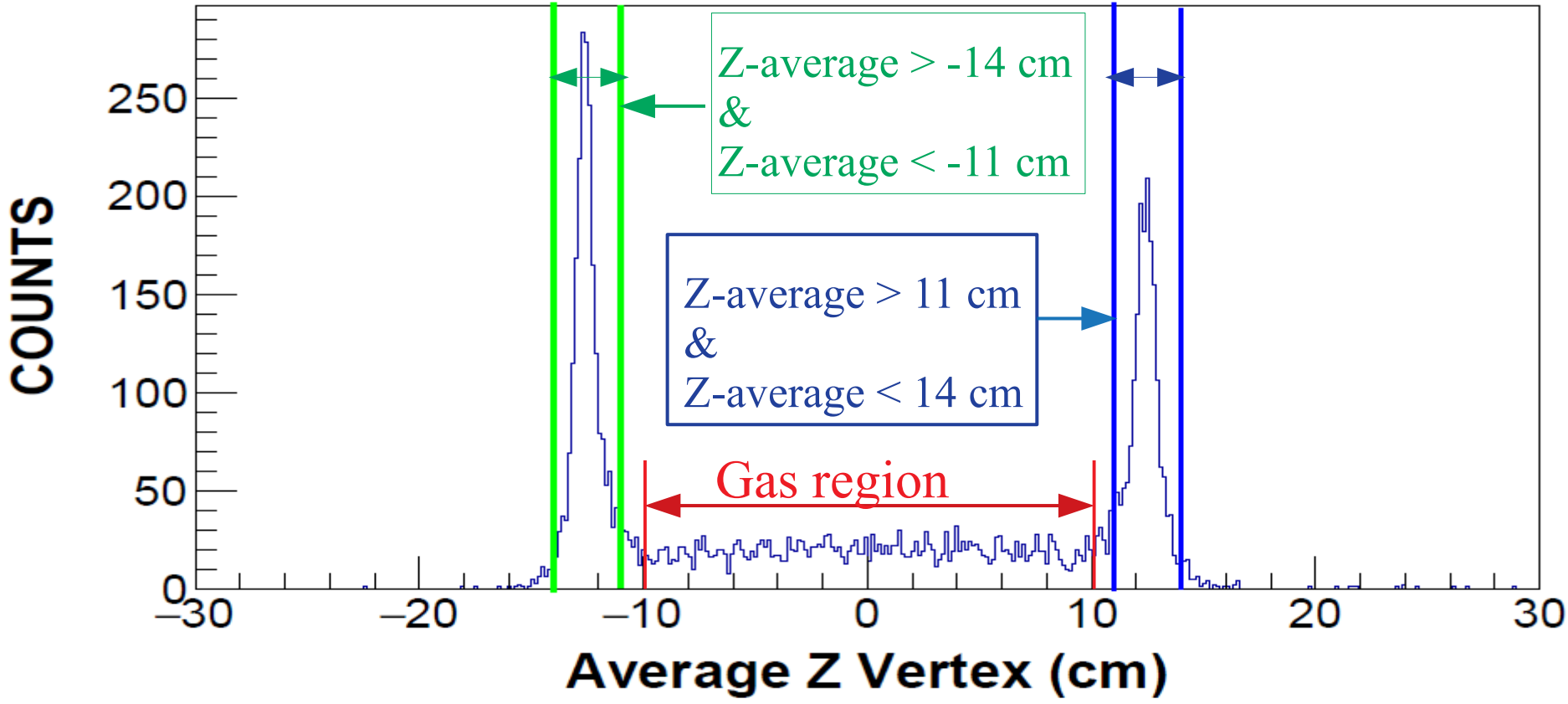
- After the time jitter correction, both the single and coincidence trigger mode spectrum are in agreement with each other.
- Thanks to Dr. Ole Hansen for his great effort to solve the tracking problem.

Kinematic Space for ee'K$^+$:



- The momentum calibration is the two dimensional correlation.
- There are only three data point 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.
- The Al data was involved in matrix tune which has negligible angular dependence.

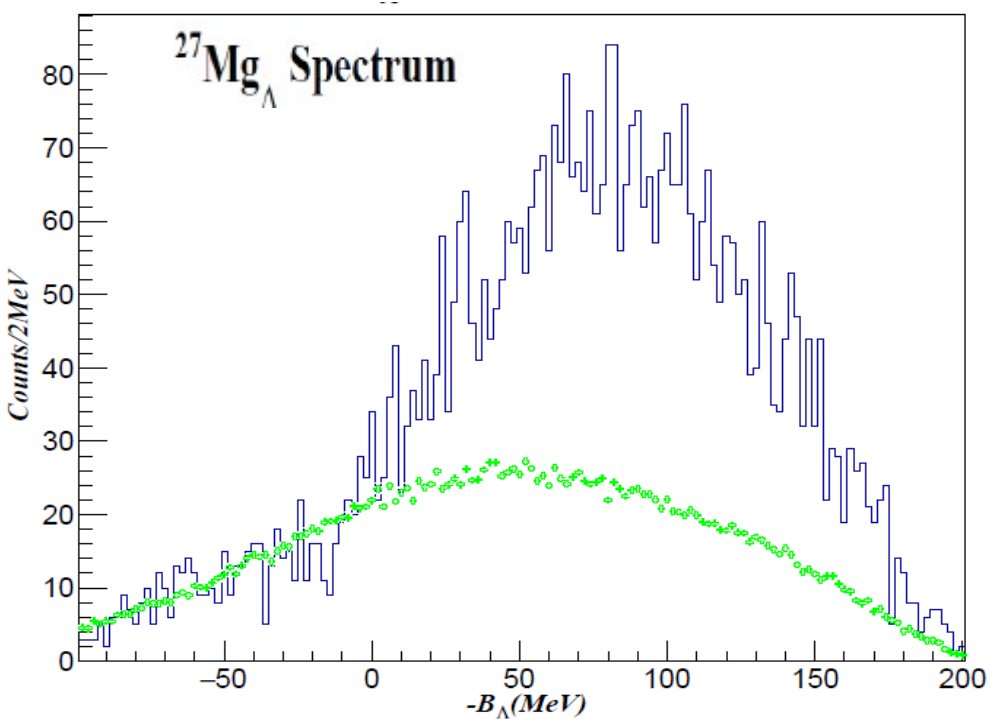
Al is Considered as Target:



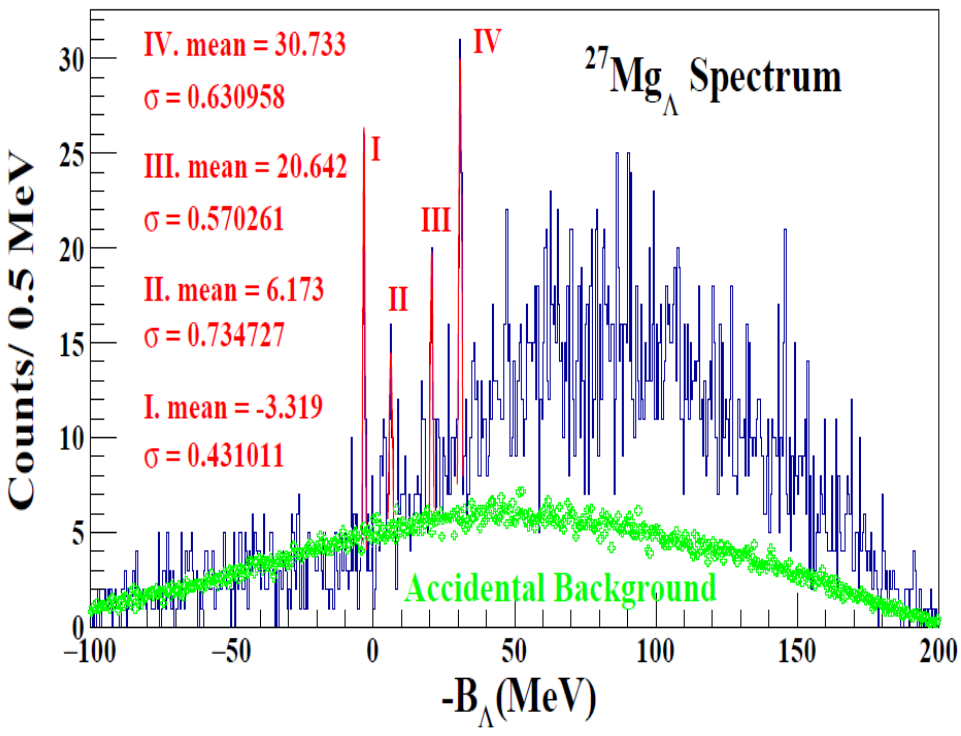
- Al region is selected from both beam entrance and beam exit window and combined together for matrix tune.

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

Before Al involve in Tune



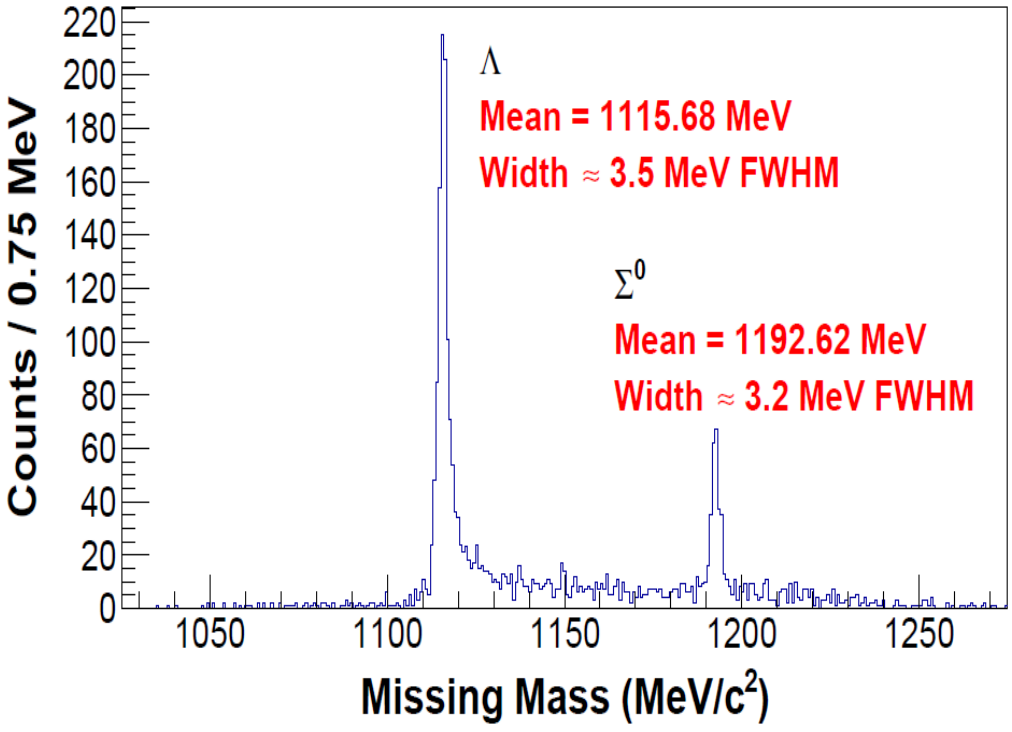
After Al involve in Tune



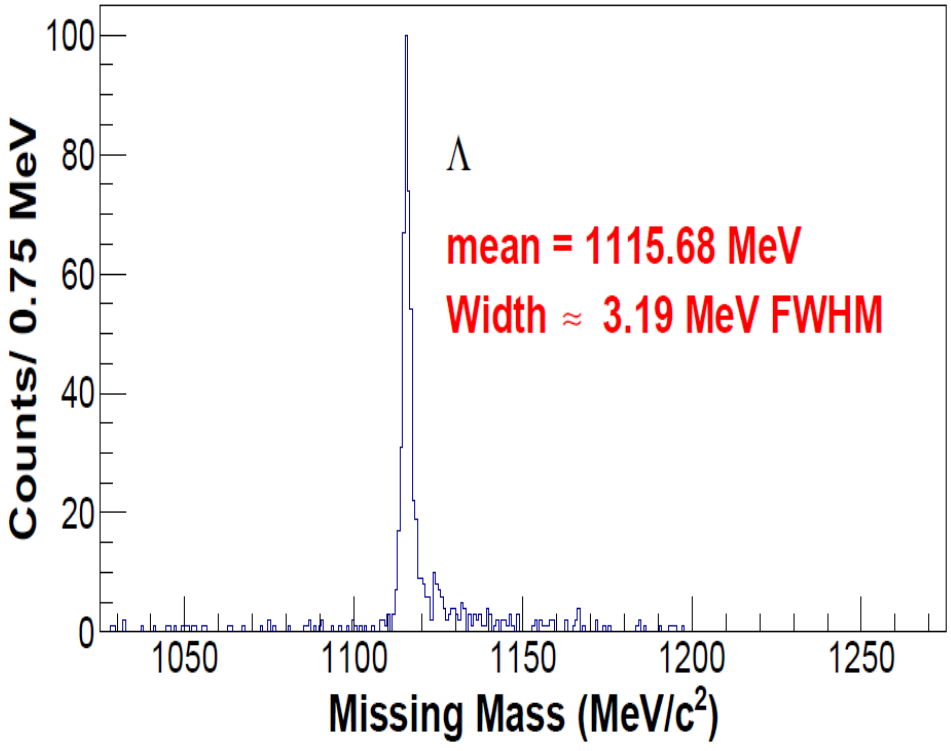
- After searching the first single state real peak, Al data was involved in tune with Λ and Σ^0 masses.
- Other peaks are gradually involve in tune one by one.

Missing Mass Spectrum:

H/H Kinematics

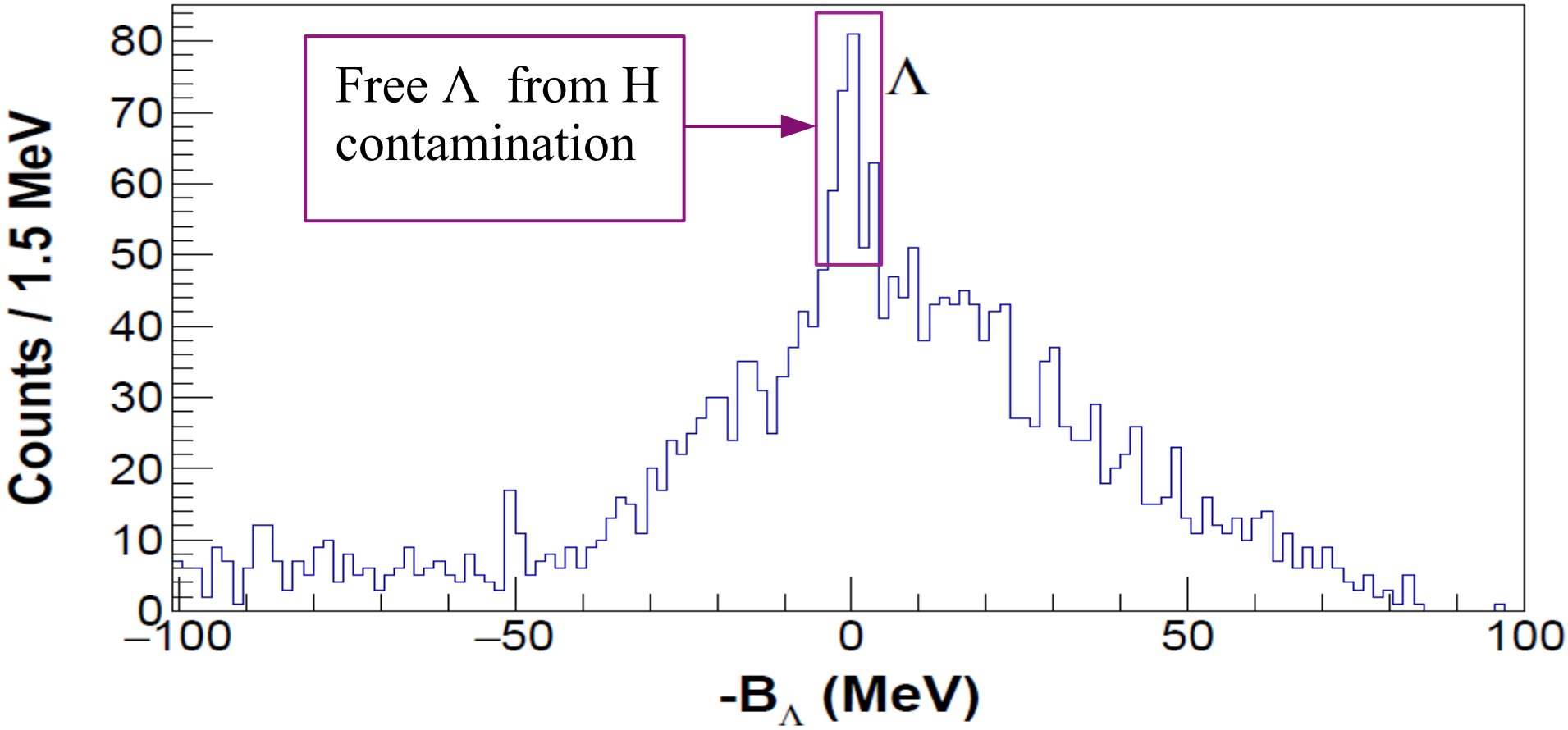


H/T Kinematics



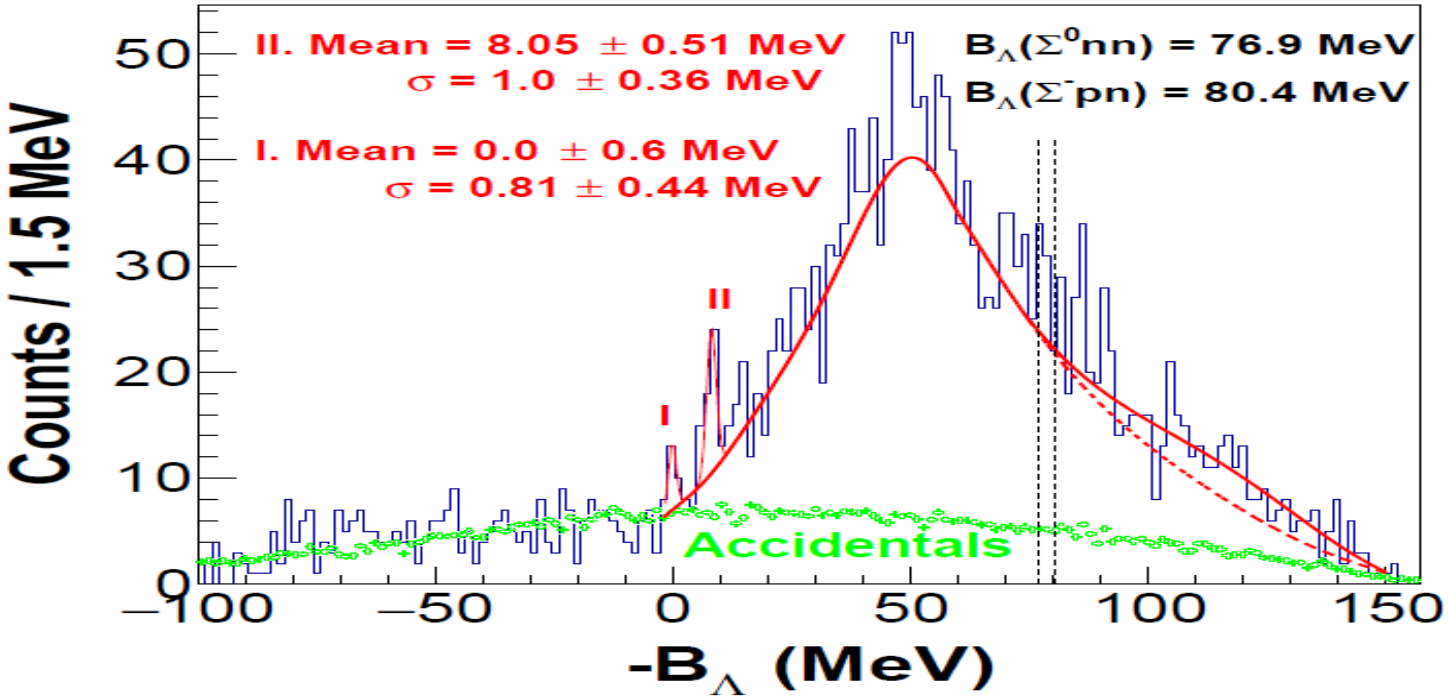
- The Λ and Σ^0 landed at their known masses with a separation of 76.94 MeV/c^2 (Nominal = 76.96 MeV/c^2).

H Contamination Test:



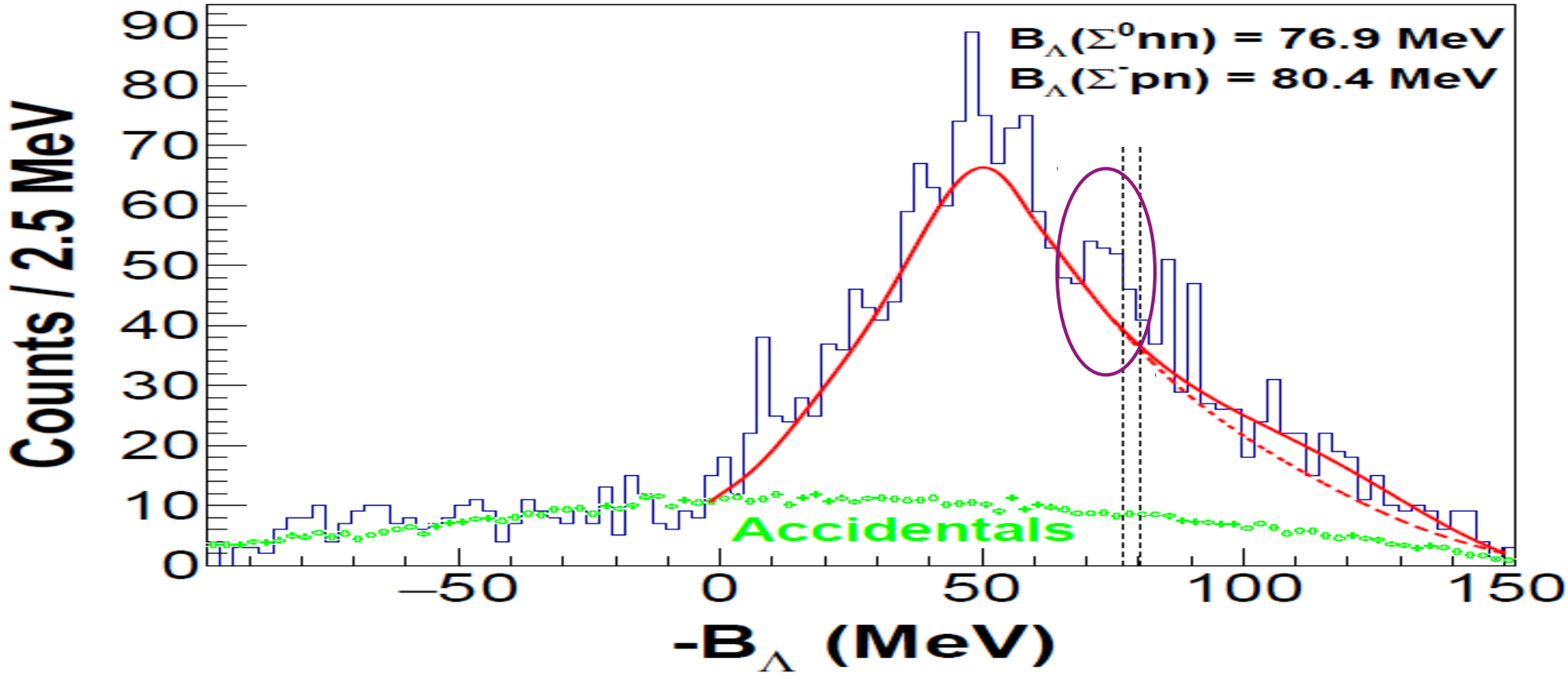
- Tritium data was tested for H contamination and found ~ 2% of H was present in the Tritium gas which is consistent with other tritium experiments.

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



- The first peak which is the possible resonance was expected, however, the statistics is very small to make a definite identification.
- The peak at the higher excitation was not expected, therefore, its origin is unclear.

Mass Spectroscopy with Higher Bins:



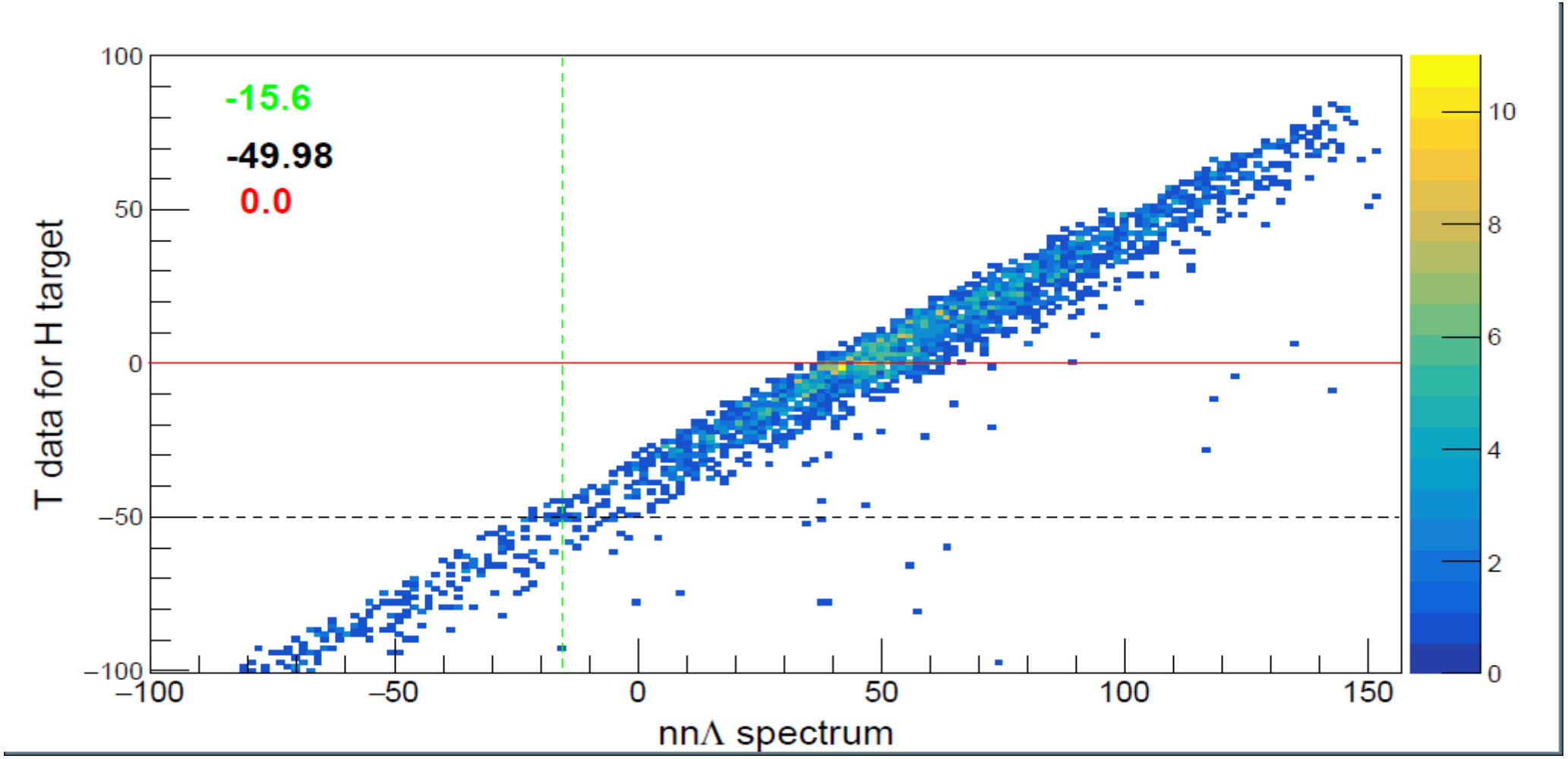
- The enhancement at the Σ bound region was predicted before and is a possible bound Σ hypernuclei.

Conclusions:

- The experiment demonstrated that by using the tritium target and the (e e'K^+) reaction, it is possible to observe the 3 body final state Λnn 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 0.55 MeV.
- However, due to low statistics the precision does not permit sufficient constrain in determination of the Λ-n Interaction.

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