Determining the Unknown Λn Interaction by Investigating the Λnn Resonance

Update on E12-17-003 Experiment

(Data Taken: October 31 to Nov. 26, 2018)

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Hall A Winter Collaboration Meeting
Jefferson Lab
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Jefferson Lab

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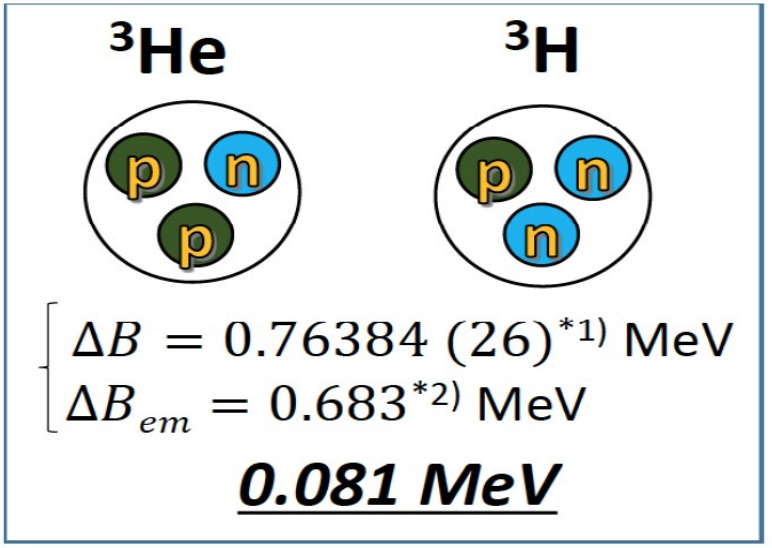
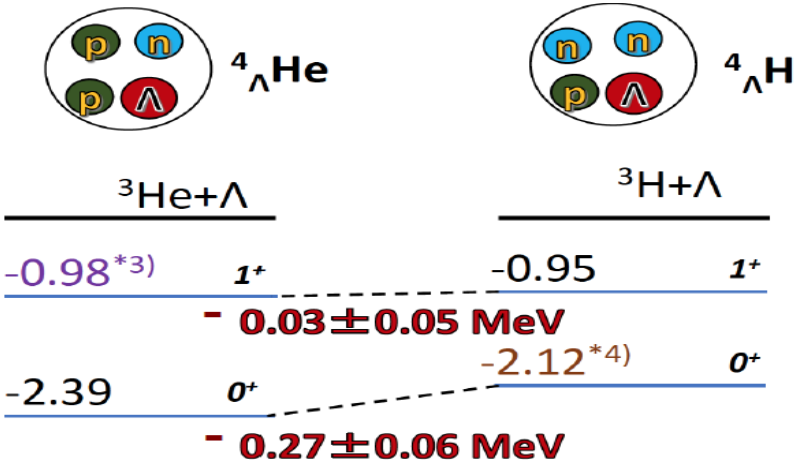
Physics Motivation

- Plenty of scattering data on the **NN** interaction exist, however, for **YN** and **YY** interactions the data are limited or do not exist. **Λ-n** has no data.
- The **Λ-n** interaction is treated to have the same properties as the **Λ-p** interaction.
- Significant charge symmetry breaking is reported in **Λ-N** interaction by a recent precise experiment.

N-N Interaction



Λ-N Interaction

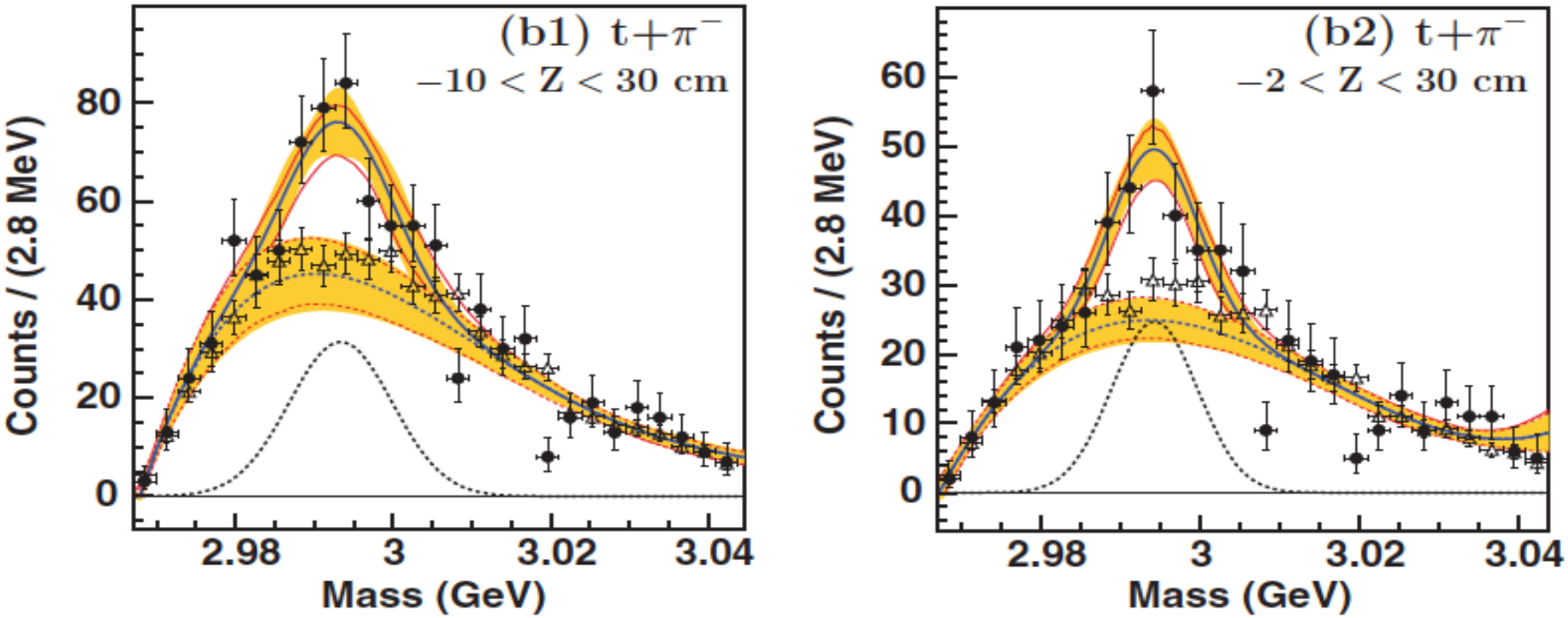


*1) J.H.E. Mattauch *et al.*, Nucl. Phys. **67**, 1 (1965).
*2) R.A. Brandenburg *et al.*, NPA **294**, 305 (1978).
*3) T.O. Yamamoto *et al.*, Phys. Rev. Lett. **115**, 222501 (2015).
*4) A. Esser *et al.*, Phys. Rev. Lett. **114** 232501 (2015).

- Experimental data on Λn interaction may shed light on the origin of CSB.

Physics Motivation Continue

^{6}Li (2A GeV) on ^{12}C target and study the invariant mass of final state particles



C. Rappold et al., Phys. Rev. C ***88****, 041001(R) (2013)*

- It was claimed to be a bound state.
- All the theoretical studies ruled out bound **Λnn** system.
- However, some theoretical studies indicated that **Λnn** resonance may likely exist and by measuring the binding energy and the natural width of such state, it is possible to extract the **Λ-n** interaction.

Physics Motivation Continue

Hall A with tritium target aimed to search for the possible ΛnnΛnn resonance or the bound state indicated by HypHI experiment. However, the system was not optimized for this experiment.

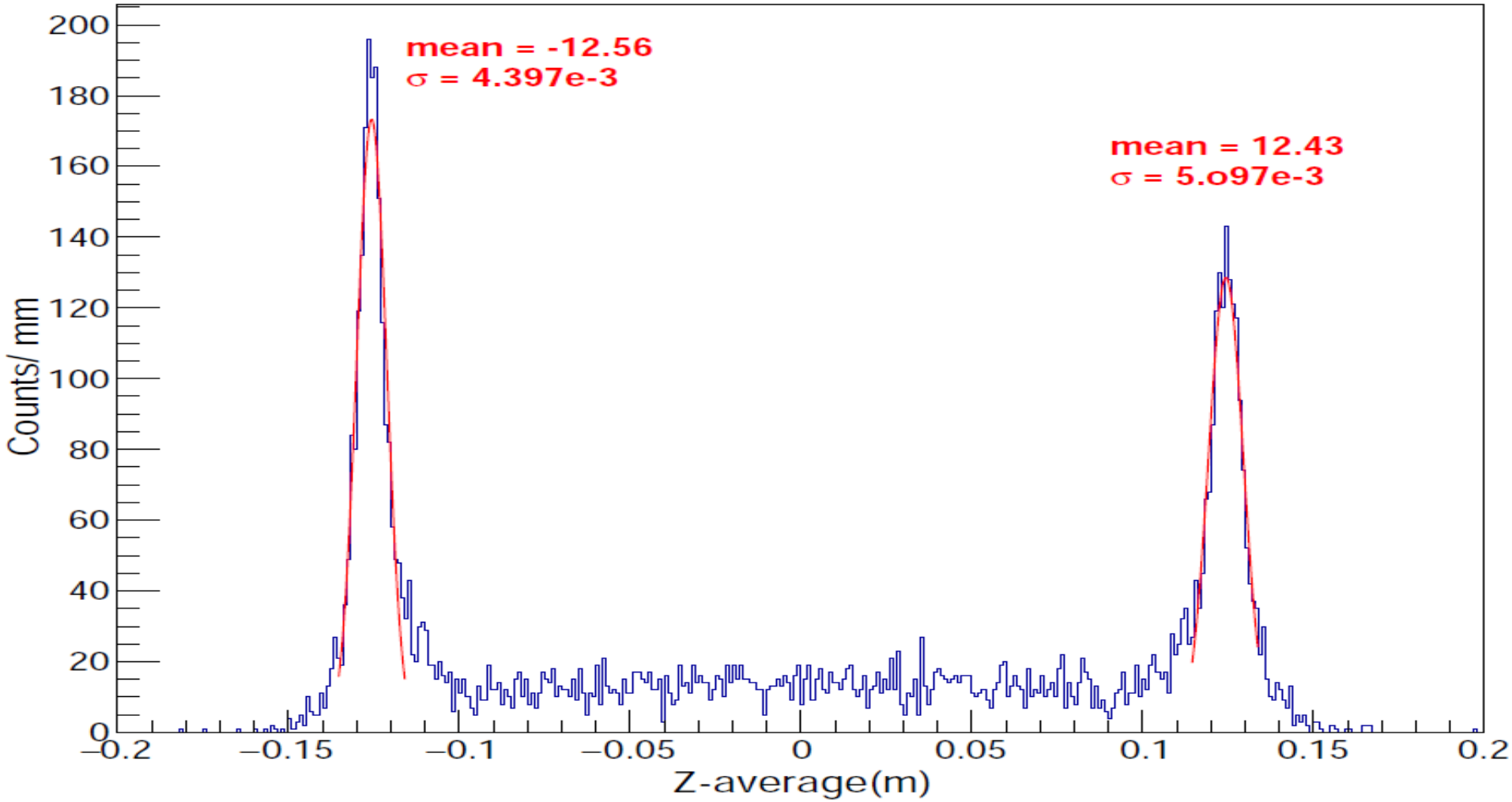
- The electron arm was at very large angle $\theta_{e'=13.2}^{\circ}$, produces large $Q^2 \sim 0.5 GeV/c^2$. Which gives the low production yield.
- The path length for the hadron arm is too large which limits the k^+ survival rate is only ~ 10% .
- The $\vec{q}(\Lambda)$ is too high ~ 400 MeV/c which gives very small $d\sigma/d\Omega$.
- Since we used the electro production, the cross-section is very small. So, in reality, the yield could be even smaller than what we expect.
- If the real state exist, it will give some signature which is very interesting.

First Part of the Analysis

About first half of 2019, analysis focused on the single arm trigger data.

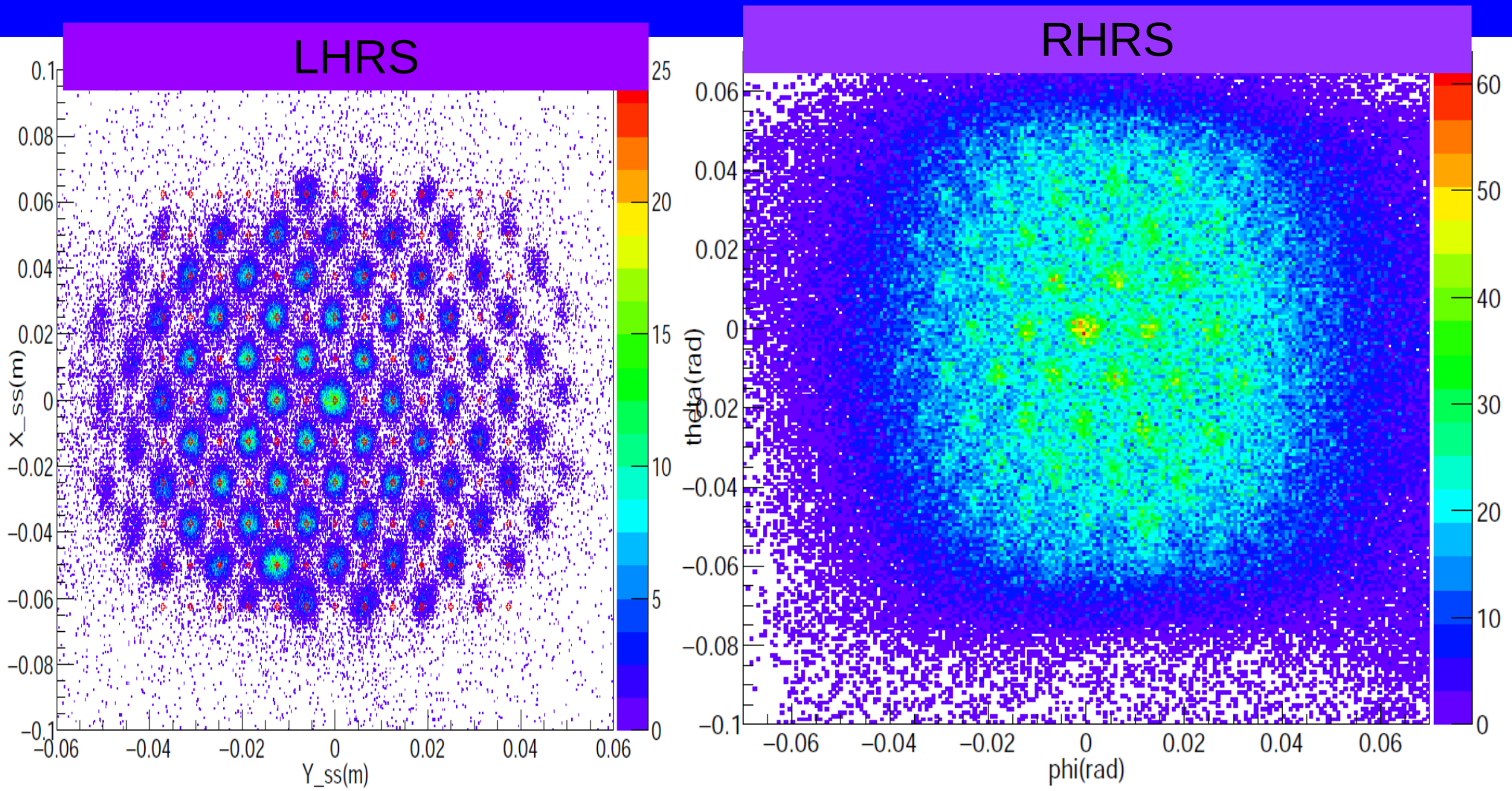
- Z vertex reconstruction is calibrated very well.
- The HRS angles are calibrated.
- PID is done.

Average Z Vertex for Hydrogen Data



- Achieved good Z-vertex resolution about σ ≈ 5 mm which satisfies the experimental requirement.

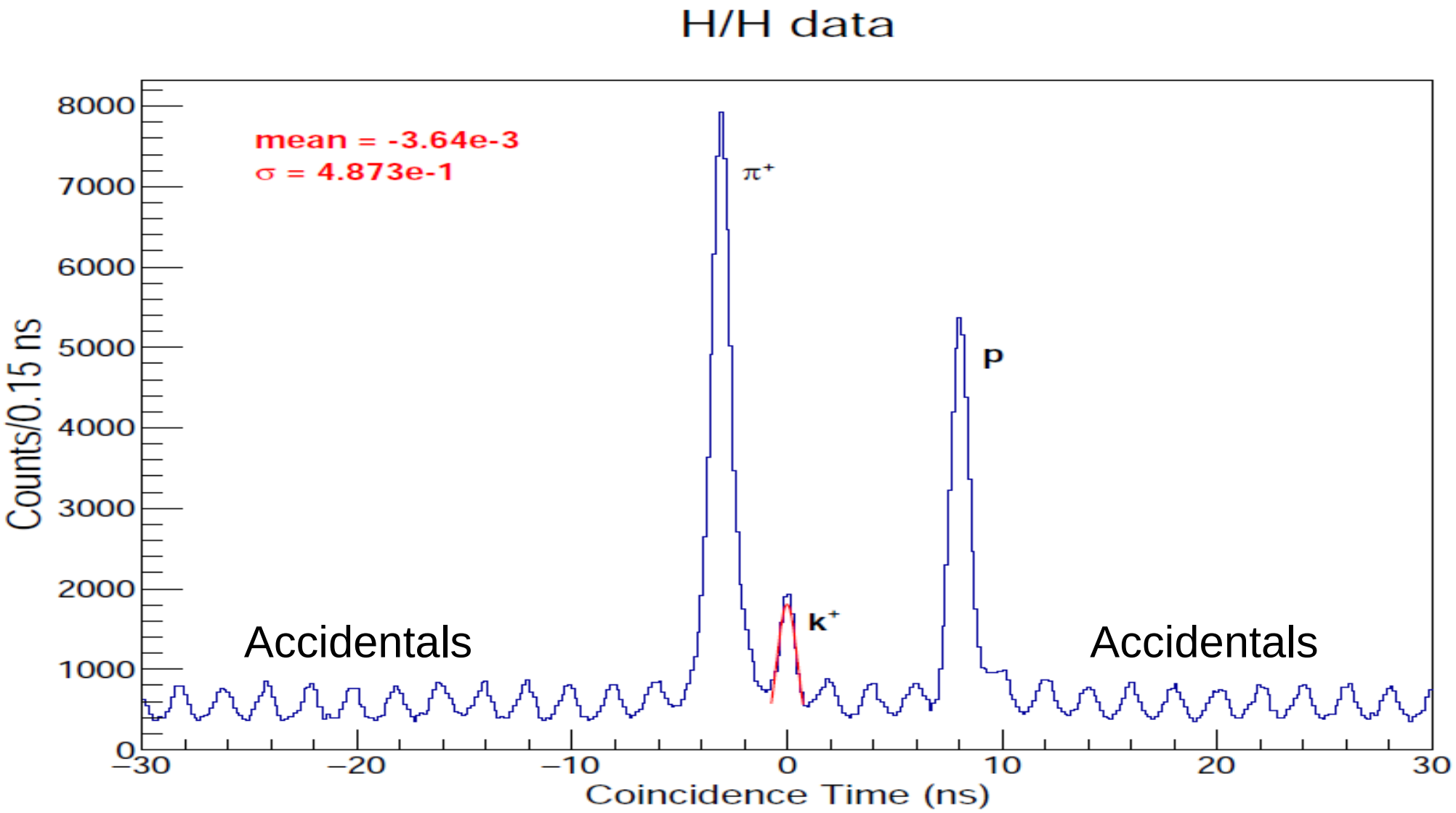
HRS Angle Reconstruction with Multi-C-foil target



Achieved acceptable angular resolution.

- In the dispersive plane σ ≈ 3 mrad
- In the non dispersive plane σ ≈ 2 mrad
- The RHRS has a lot of background as the hadrons are punching through the SS.

Coincidence Time Spectrum



- Kaons are cleanly separated from the rest of the hadrons.

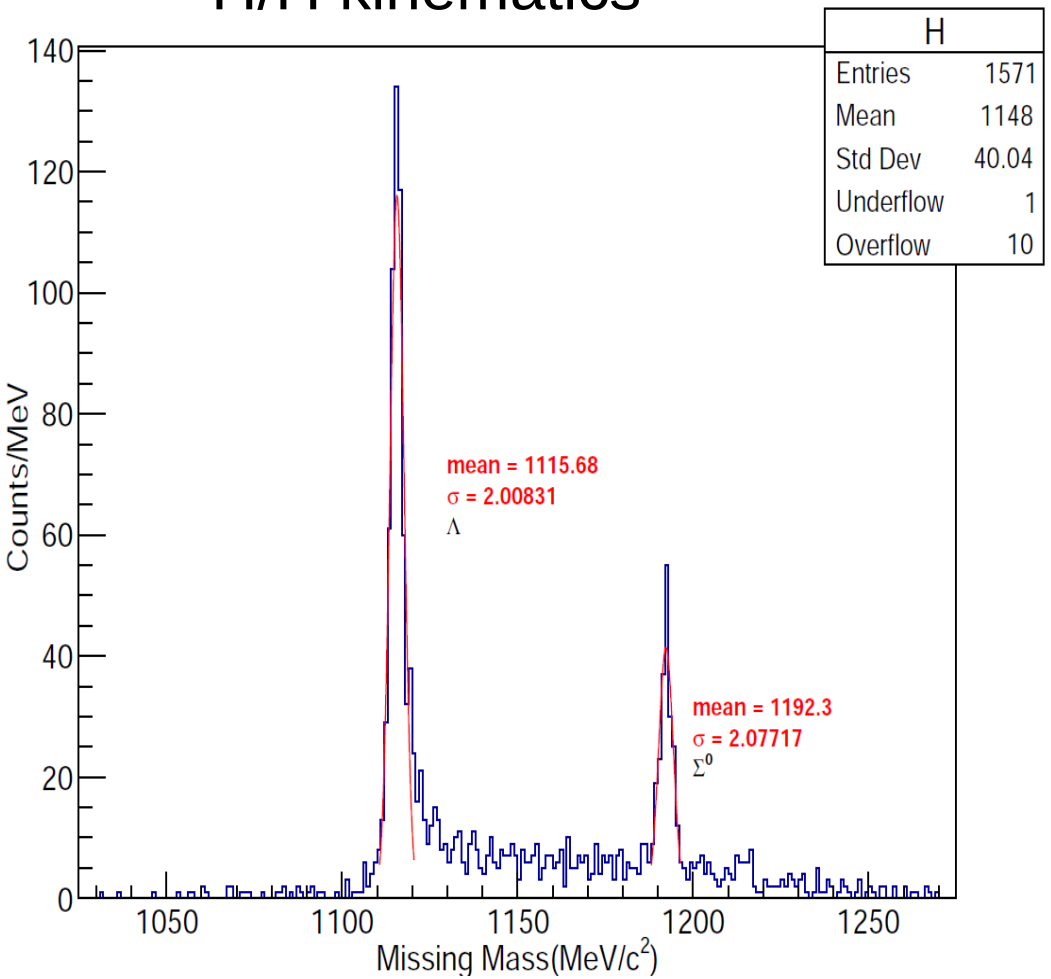
Second Part of the Analysis

The second half of 2019, analysis focused on the coincidence data

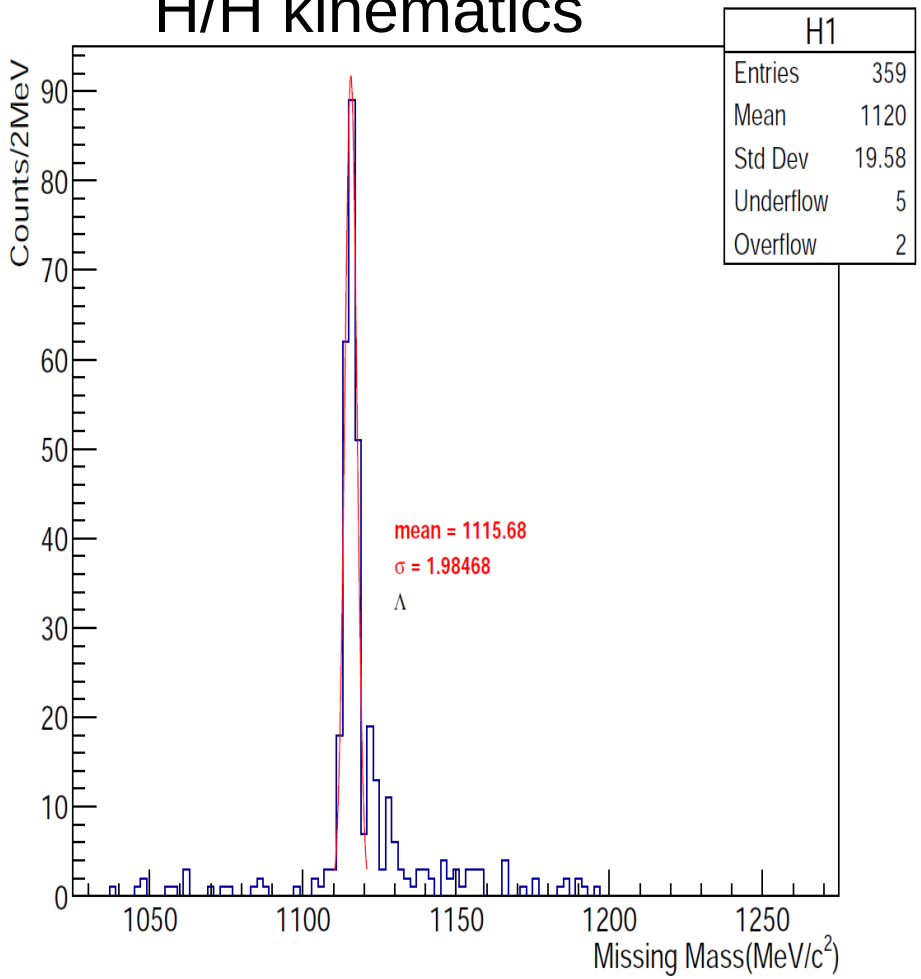
- The momentum matrices are tuned by using the known Λ and Σ^0 Masses.
- The resolution is limited to about 2 Mev in sigma which is far from the experimental requirement.
- VDC tracking problem on the right arm for the coincidence event is detected.
- Al data is included in tune.

Missing Mass Before the VDC Tracking Problem

H/H kinematics



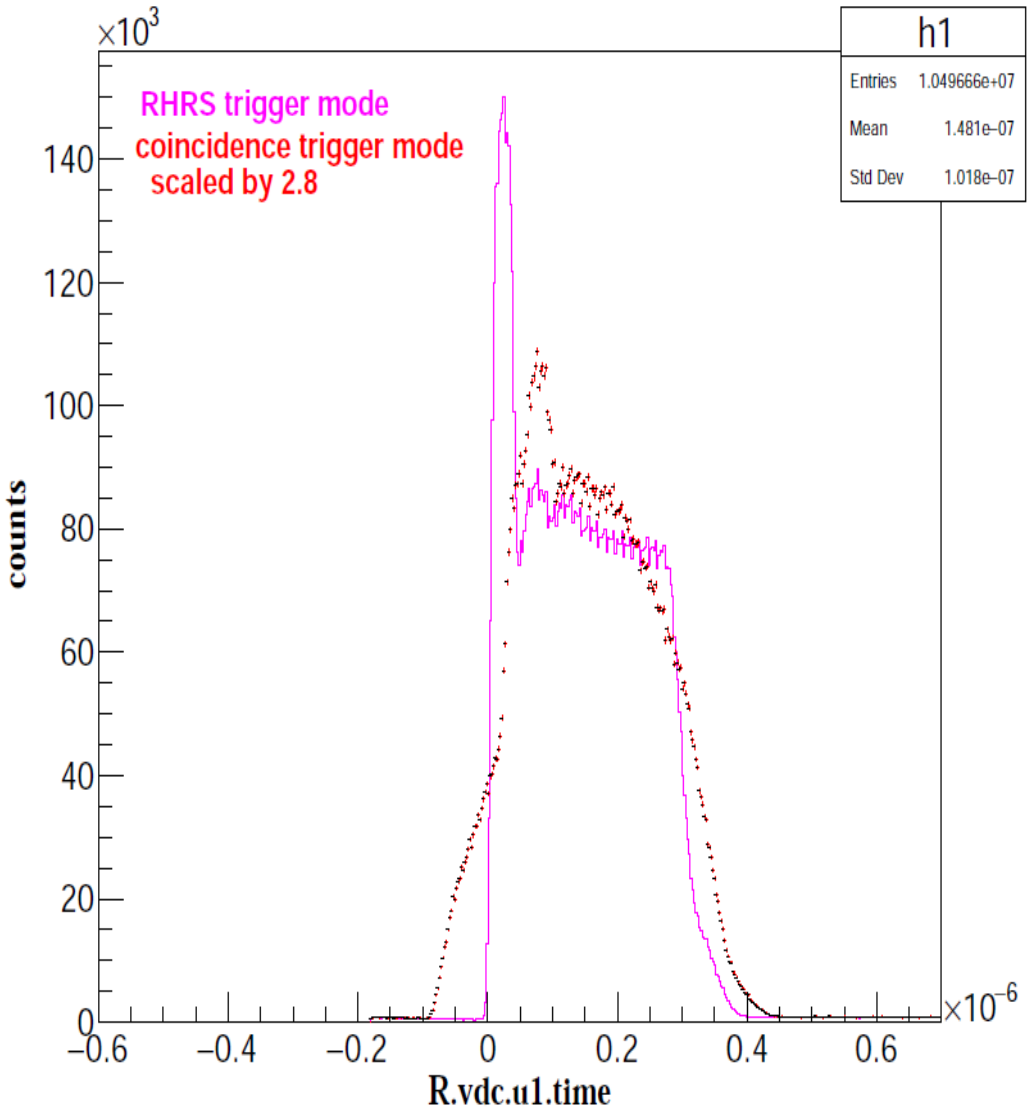
H/H kinematics



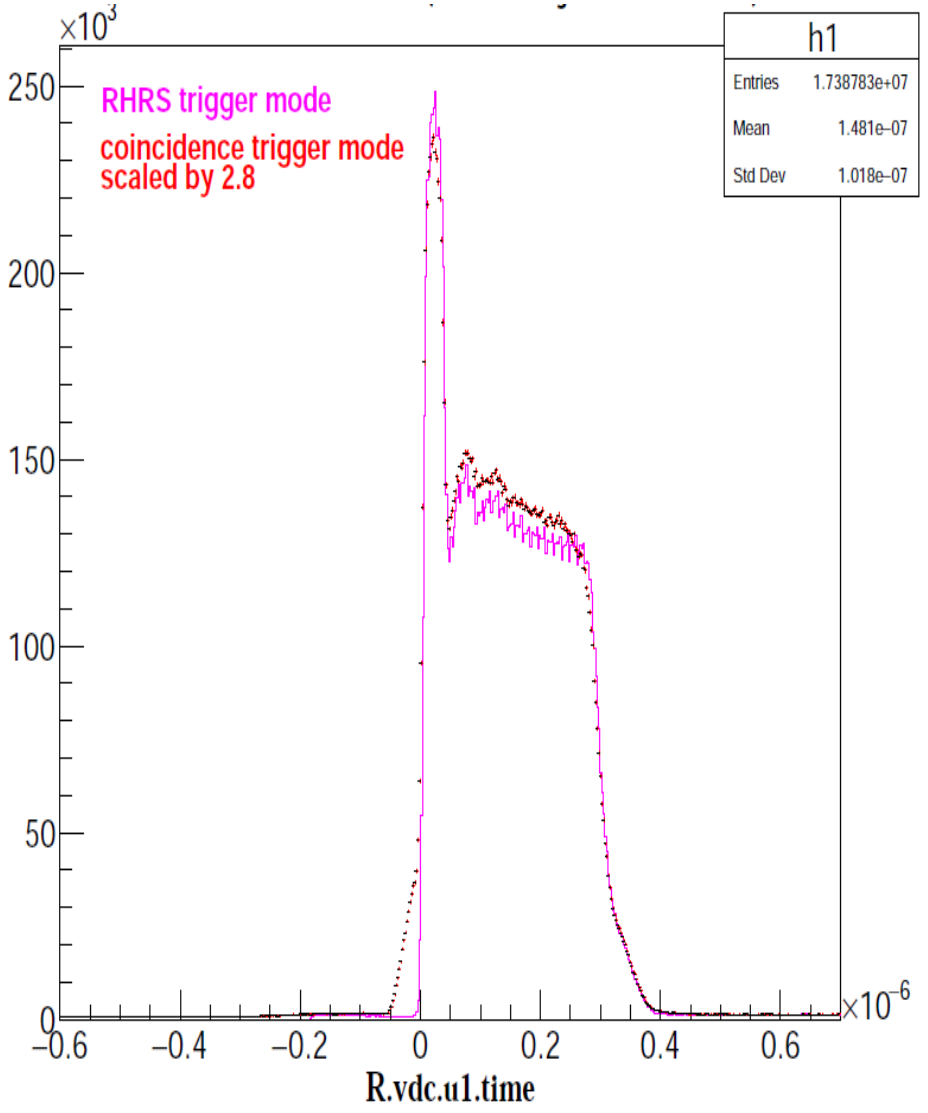
- The resolution is limited to about 2 Mev in sigma which is far from the experimental requirement.
- VDC tracking problem in the right arm for the coincidence events is detected.

Raw TDC Spectrum

Before time jitter correction



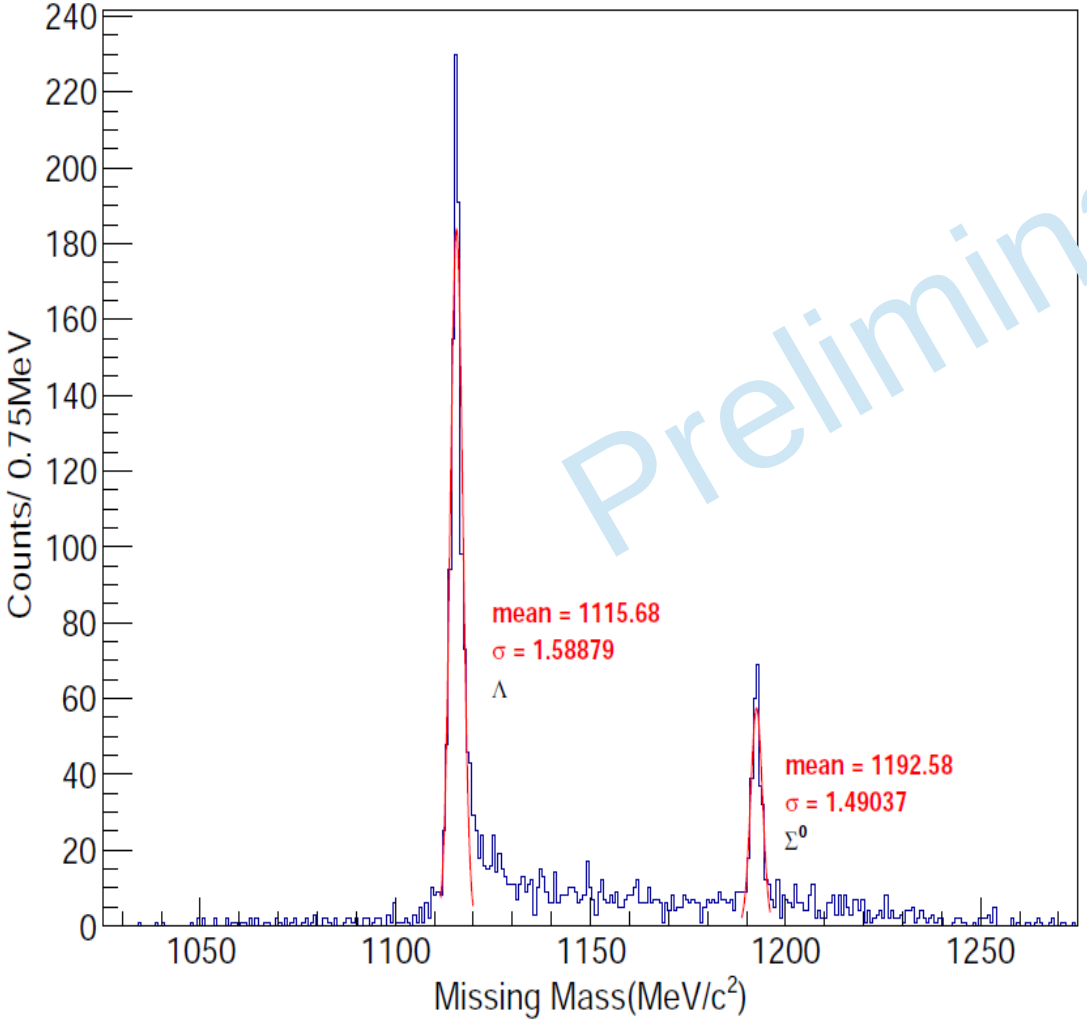
After time jitter correction



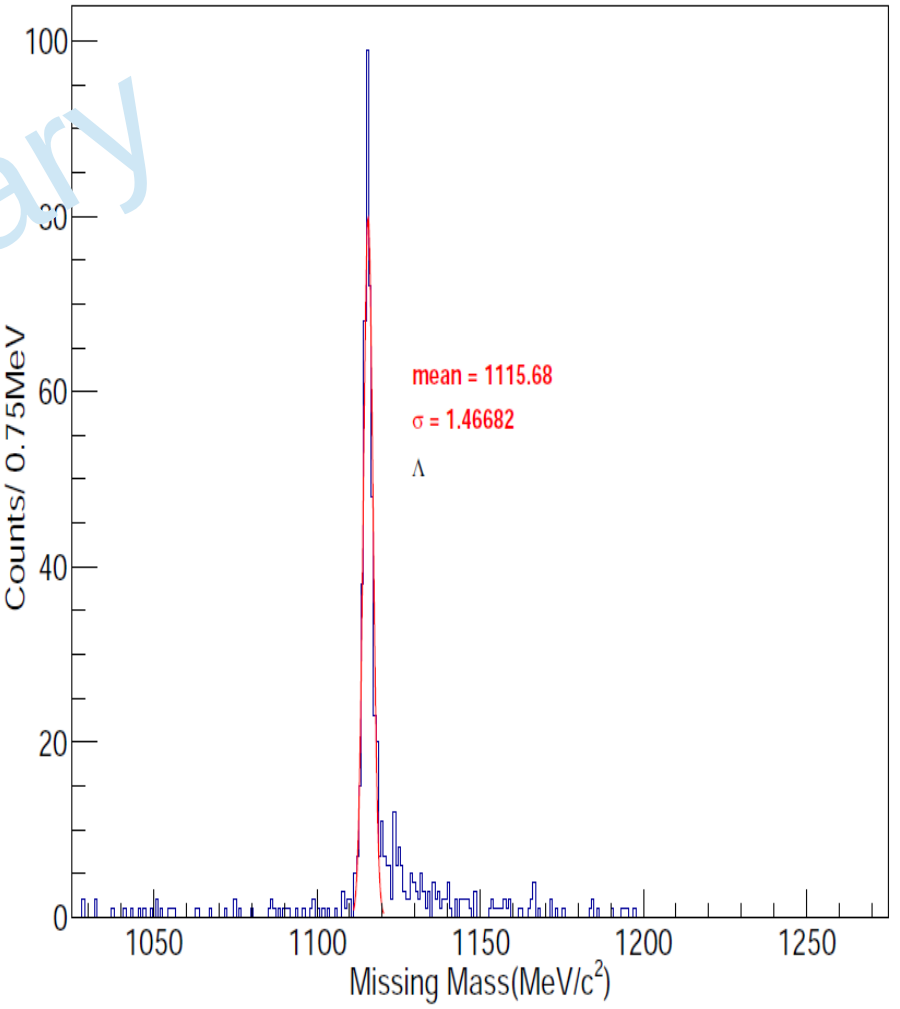
- Thanks to Dr. Ole Hansen for his great effort for solving the tracking issue.

Missing Mass with Hydrogen Data

H/H kinematics

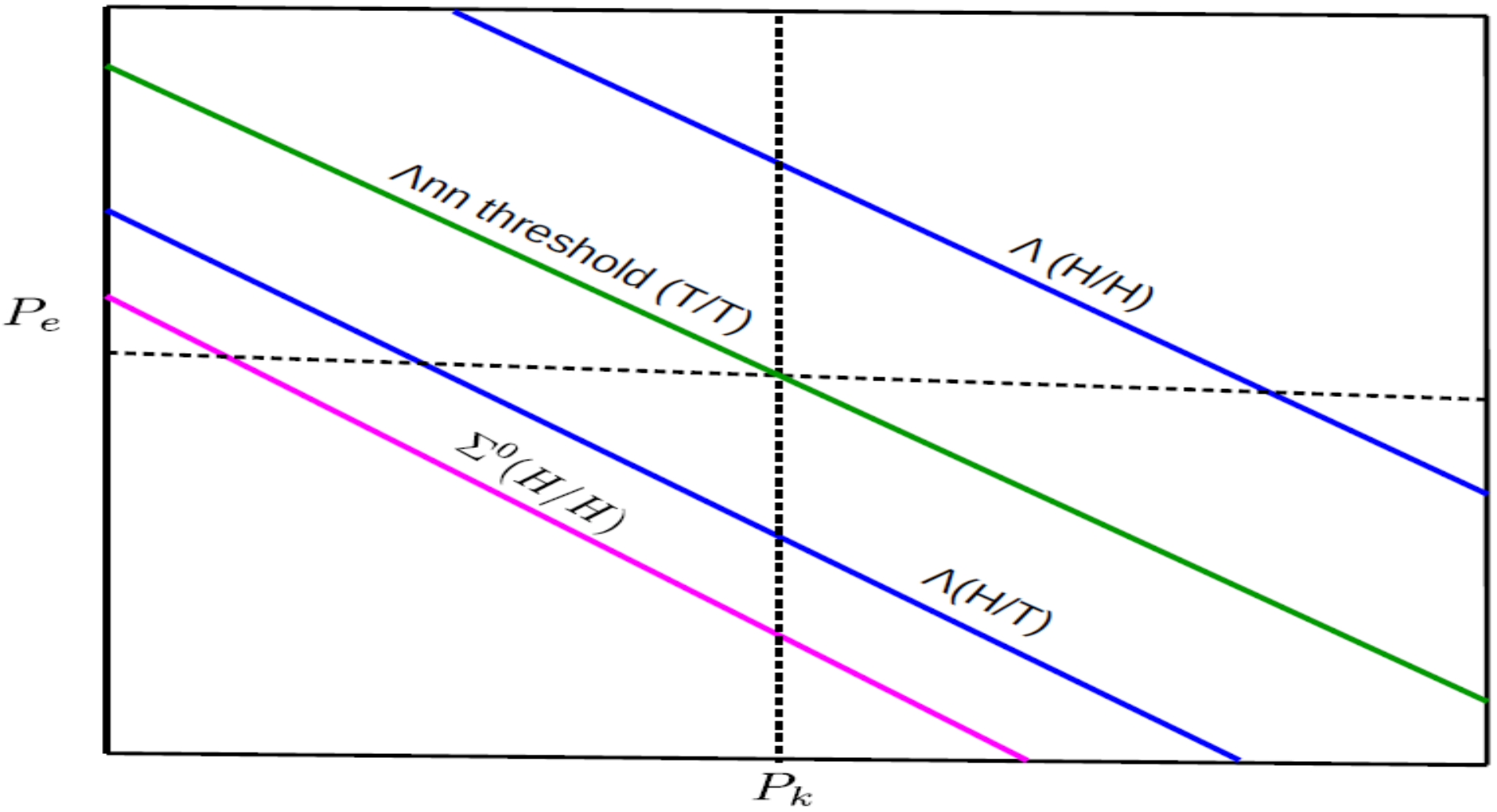


H/T kinematics



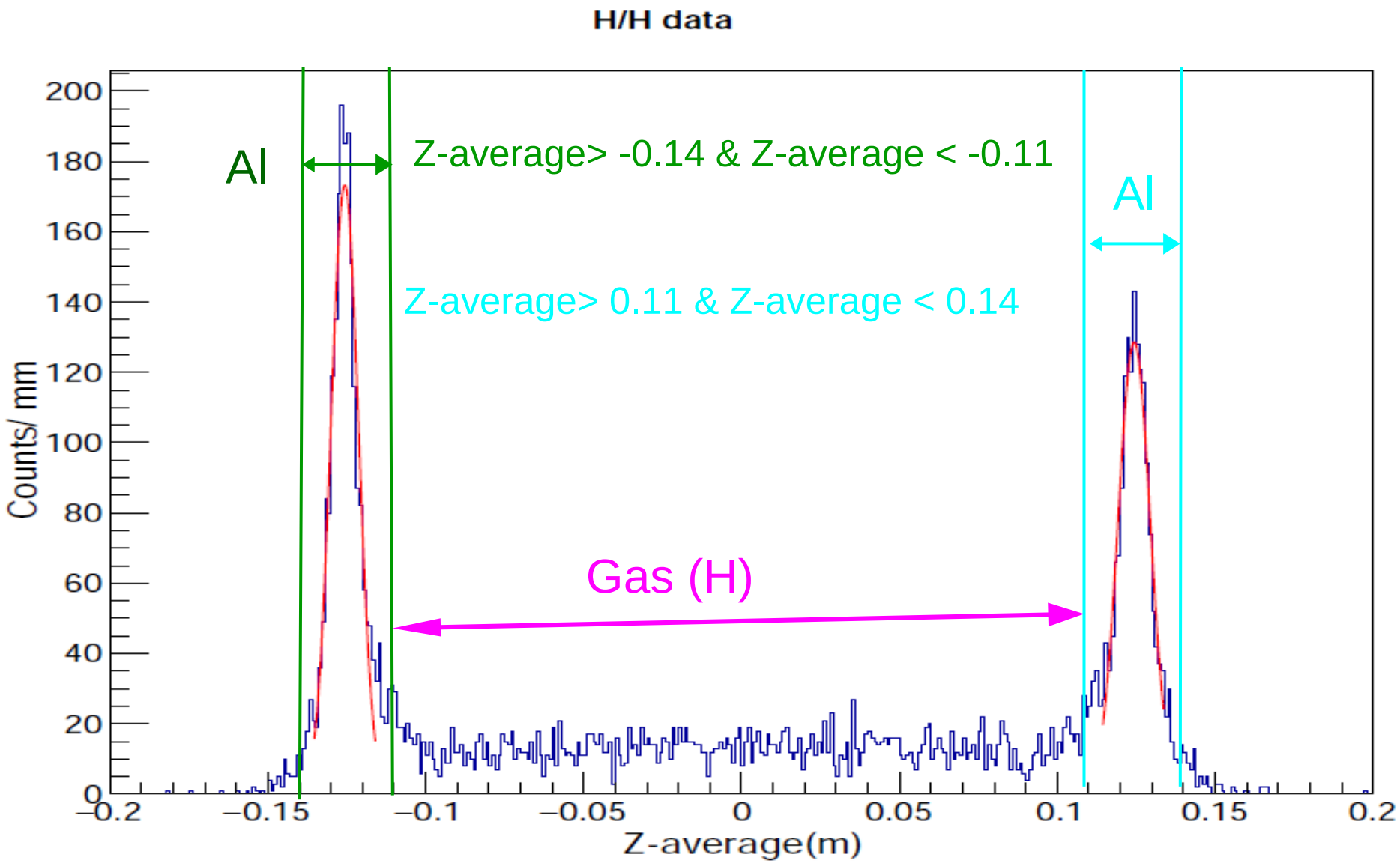
- Using the 3 data points, the momentum matrices are tuned and resolution is improved by about 25%.

Kinematics Space for ee'k



- The momentum calibration is the two dimensional correlation.
- We have only three data sample to optimize the momentum matrices.
- There is a large gap in the kinematics space between the two Λ lines.
- The quality of optics may not be uniform in the gap between.

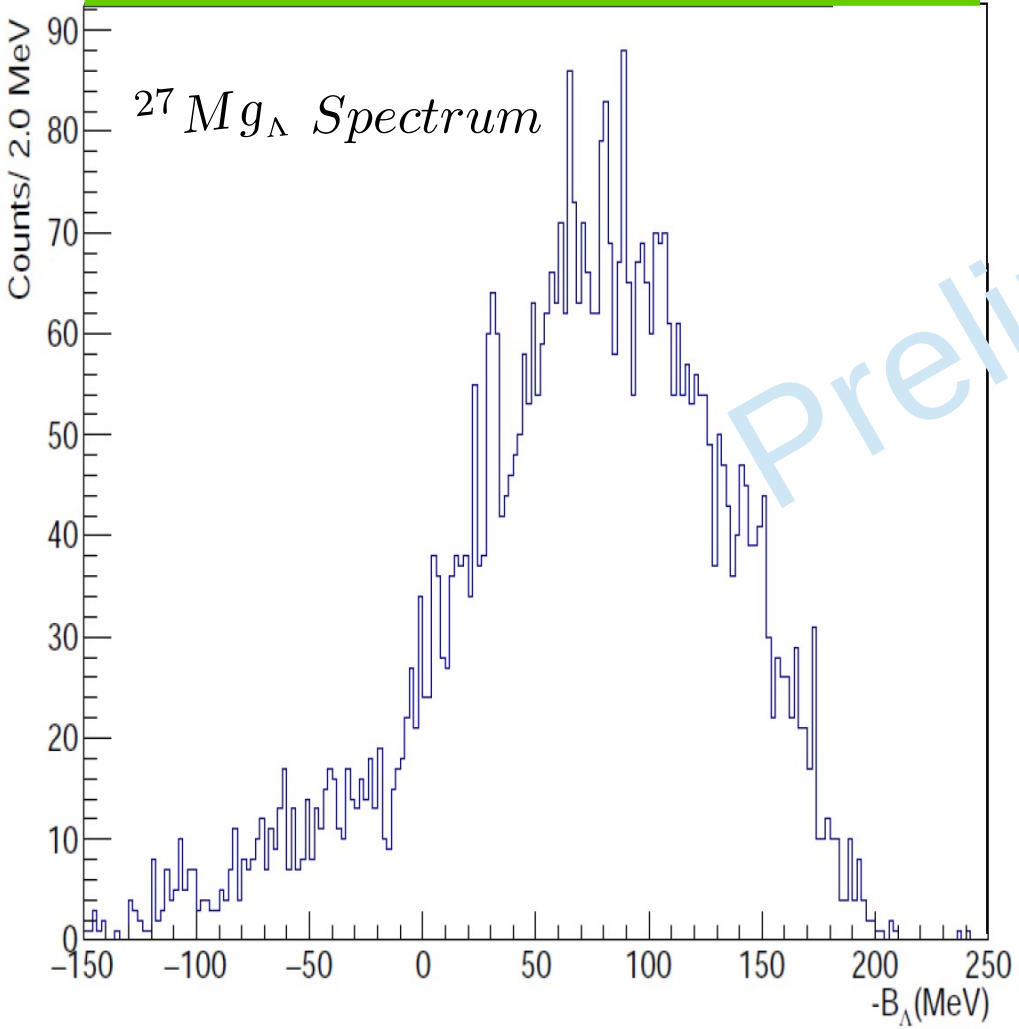
Al is Considered as Target



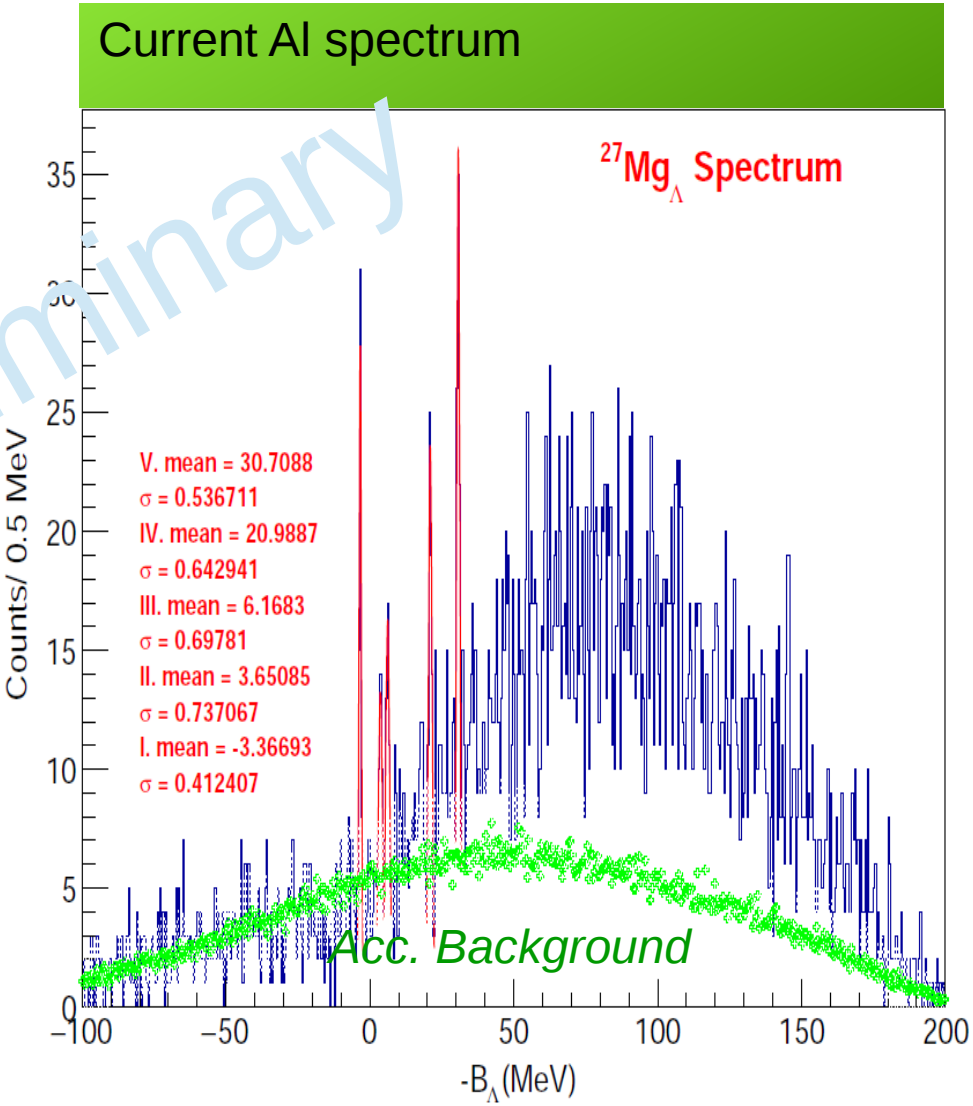
- Al region is selected from both side of the target cell and combined together for tune.

Al Data Included in tune along with Λ and Σ^0 Masses

Before involving the Al data in tune

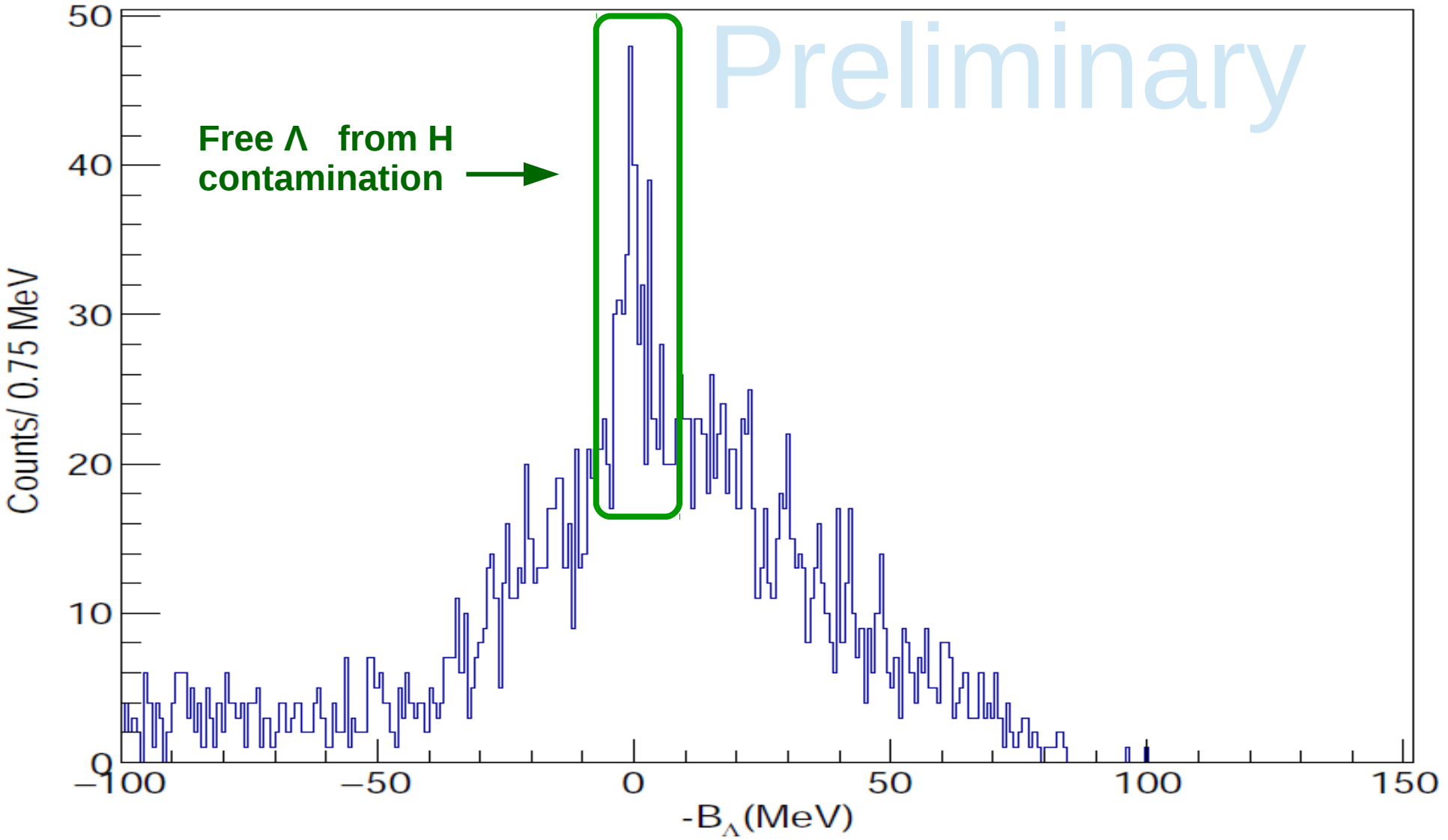


Current Al spectrum



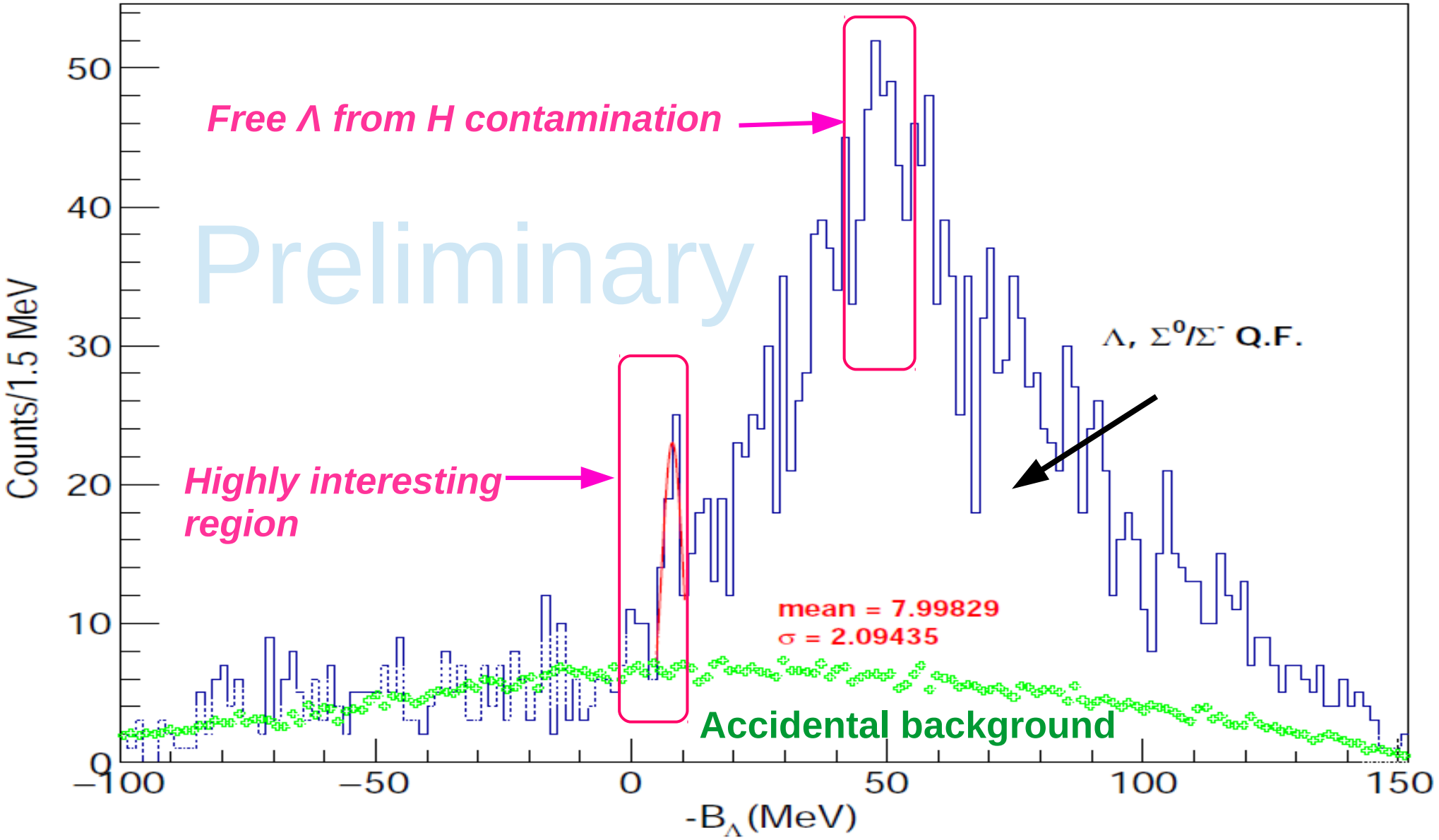
- After searching the first single state real peak, Al data is included in tune along with the Λ and Σ^0 Masses.
- Other peaks are gradually involved in tune one by one.

Tritium Data is Tested for Hydrogen Contamination



- The clear peak at the threshold region shows presence of H in the tritium gas.

Λnn Spectrum



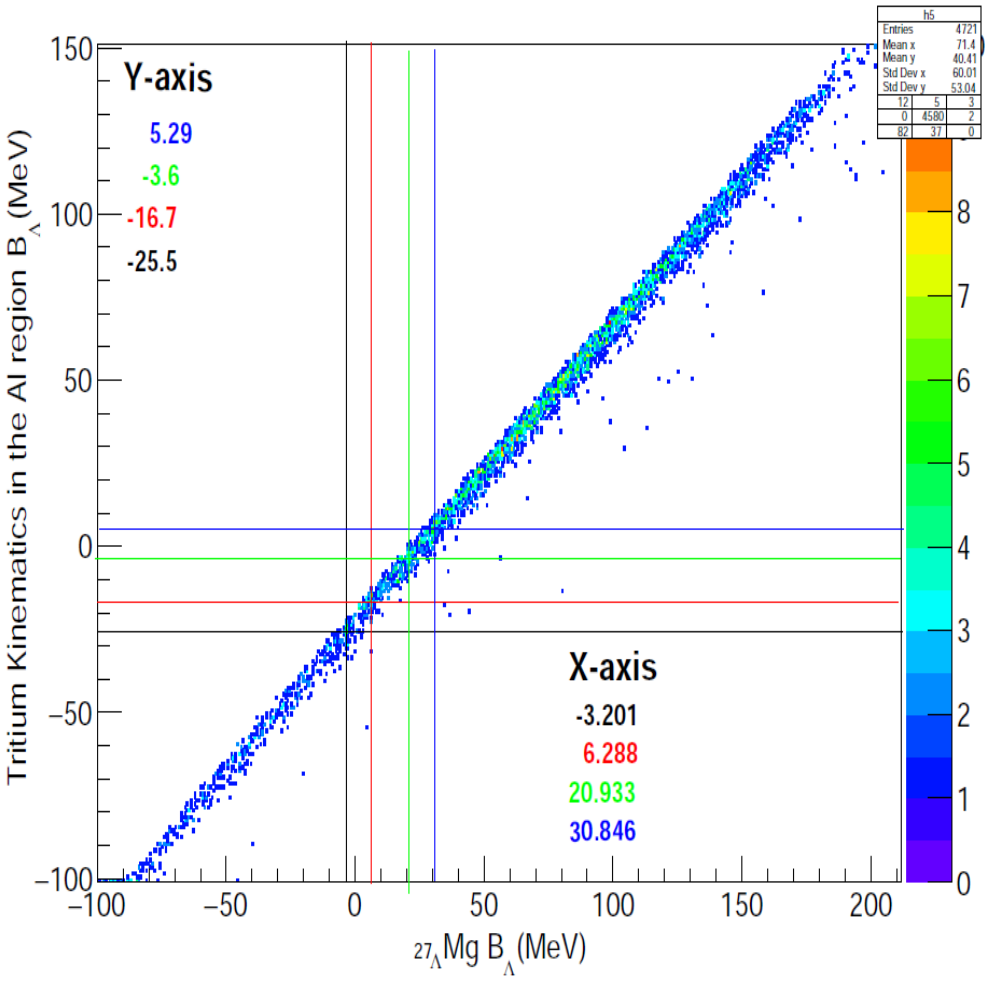
- Even for the low statistics there is a clear signature right above the threshold region.

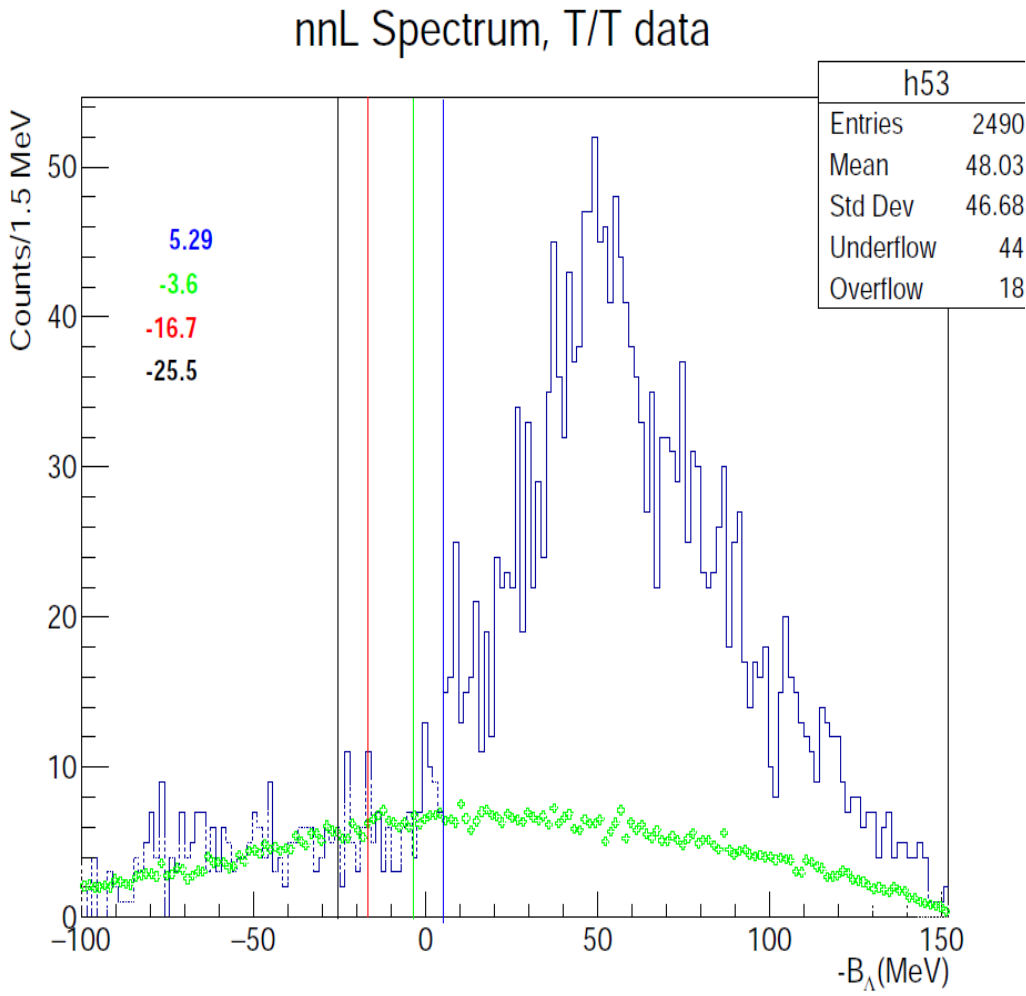
Conclusions

- Recent precise experimental results show that charge symmetry breaking (**CSB**) is much more significant in **Λ-N** interaction
- HypHI experiment indicated the existence of either **Λnn** resonance or a bound state exist.
- The ee'K^+ doing at Jlab is the best way to conform whether such state exist or not.
- The preliminary results shows some extremely interesting structures.
- The detailed and careful analysis is in progress.

Thank you

Backup





- If the peaks in the Al spectrum's are artificial or mathematical, there should be corresponding peaks in the nnL spectrum.

Backup

Kinematics for E-12-17-003

The data were taken with two different kinematics with fixed beam energy of 4.319 GeV and fixed HRS angles, 13.2° for each arm

1. H kinematics:
Target: H
PK = 1.8231 GeV/c
Pe' = 2.1000 GeV/c

2. T kinematics:
Target: T, H and He
PK = 1.8231 GeV/c
Pe' = 2.2180 GeV/c