Determining the Unknown Λn Interaction by Investigating the Λnn Resonance

Update on E12-17-003 Experiment

(Data Taken: October 30 to Nov. 26, 2018)

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CEBAF center Jefferson Lab
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Jefferson Lab

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Physics Motivation

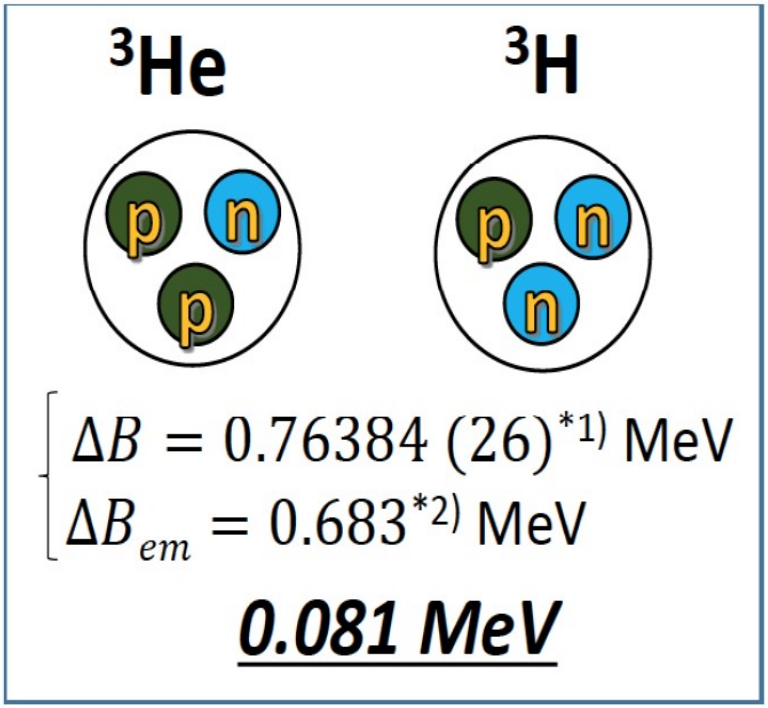
- Plenty of scattering data on the **NN** interaction exist, however, for **YN** and **YY** interactions the data are limited or do not exist. **Λ-n** has no data.

- Recent precise experimental results show that charge symmetry breaking (**CSB**) is much more significant in **Λ-N** interaction. Thus determining the unknown **Λ-n** interaction is critically important to understand the **CSB**.

- The **Λ-n** interaction is treated to have the same properties as the **Λ-p** interaction.

Charge Symmetry Breaking

N-N Interaction

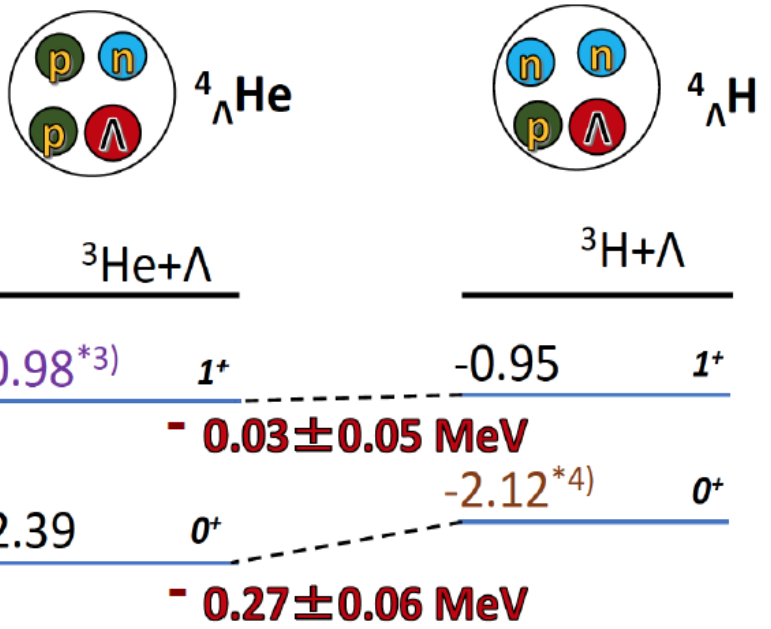


$$\Delta B = 0.76384\ (26)^{*1)}\ \text{MeV}$$
$$\Delta B_{em} = 0.683^{*2)}\ \text{MeV}$$

0.081 MeV

*1) J.H.E. Mattauch *et al.*, Nucl. Phys. **67**, 1 (1965).
*2) R.A. Brandenburg *et al.*, NPA **294**, 305 (1978).

Λ-N Interaction

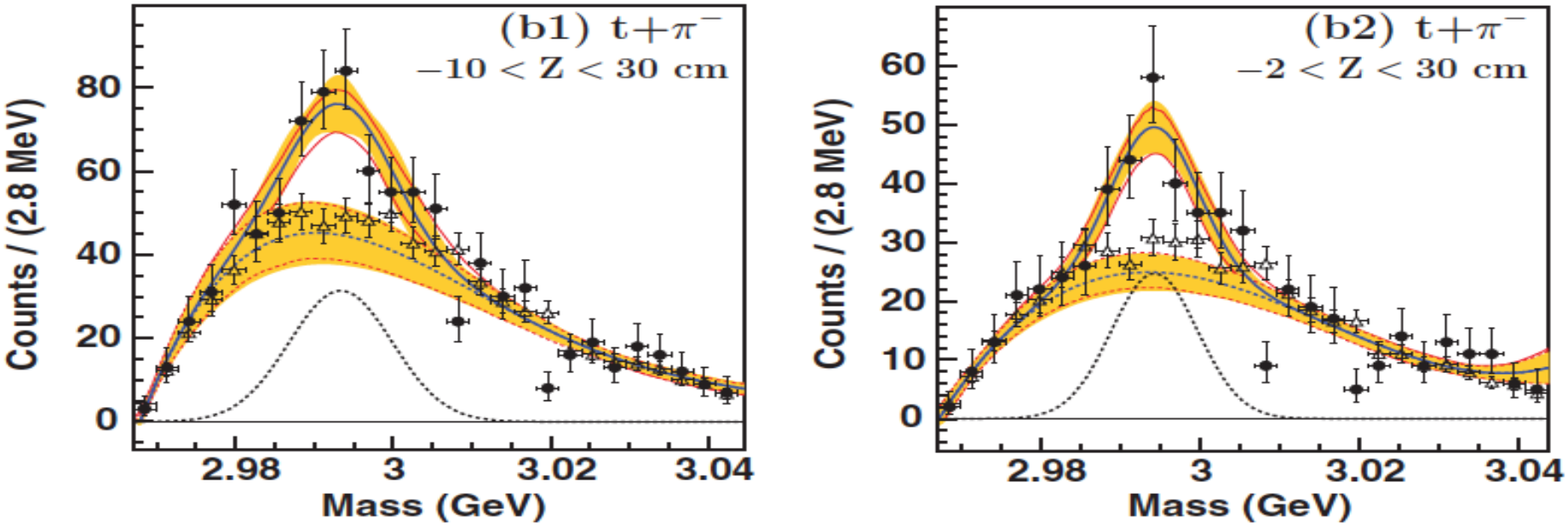


3) T.O. Yamamoto *et al.*, Phys. Rev. Lett. **115**, 222501 (2015).
4) A. Esser *et al.*, Phys. Rev. Lett. **114** 232501 (2015).

- For A =4 isospin mirror pair of hypernuclei $^4_\Lambda He$ and $^4_\Lambda H$ there is significant charge symmetry breaking in the order of about 270 keV.
- Experimental data on Λn interaction may shed light on the origin of CSB.

Approach to Access Λn Interaction

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

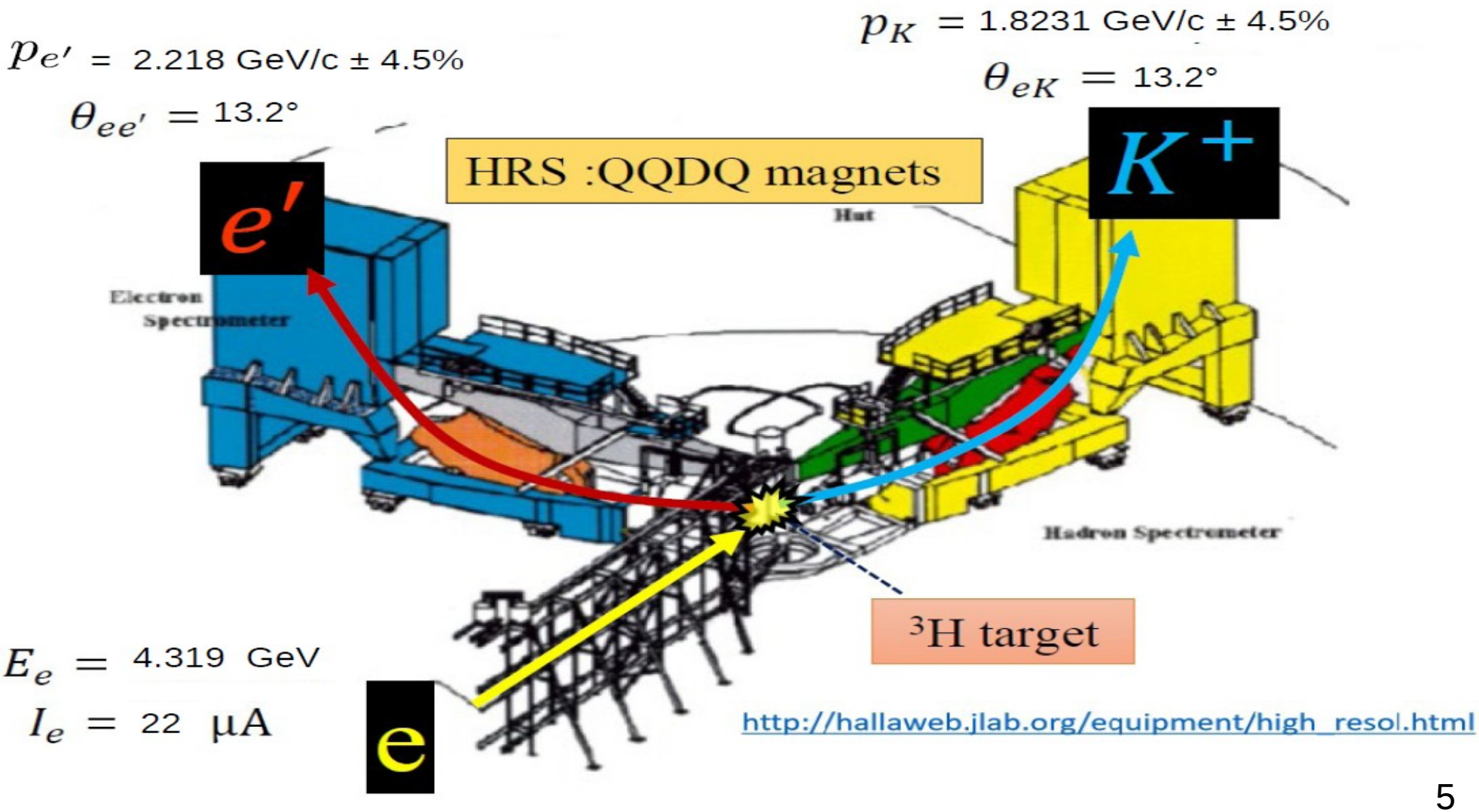


*C. Rappold et al., Phys. Rev. C **88**, 041001(R) (2013)*

- 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
- Hall A with tritium target aimed for this purpose; if it does exist and its binding energy and natural width are determined, we may for the first time provide direct experimental information which can be used for theoretical investigation on **Λ-n** interaction

Experimental Setup for E12-17-003

- The experiment, E12-17-003 was carried out from October 30 to November 25, 2018
- The ideal case for such experiment is to have a short spectrometer with large solid angle acceptance and a tritium target

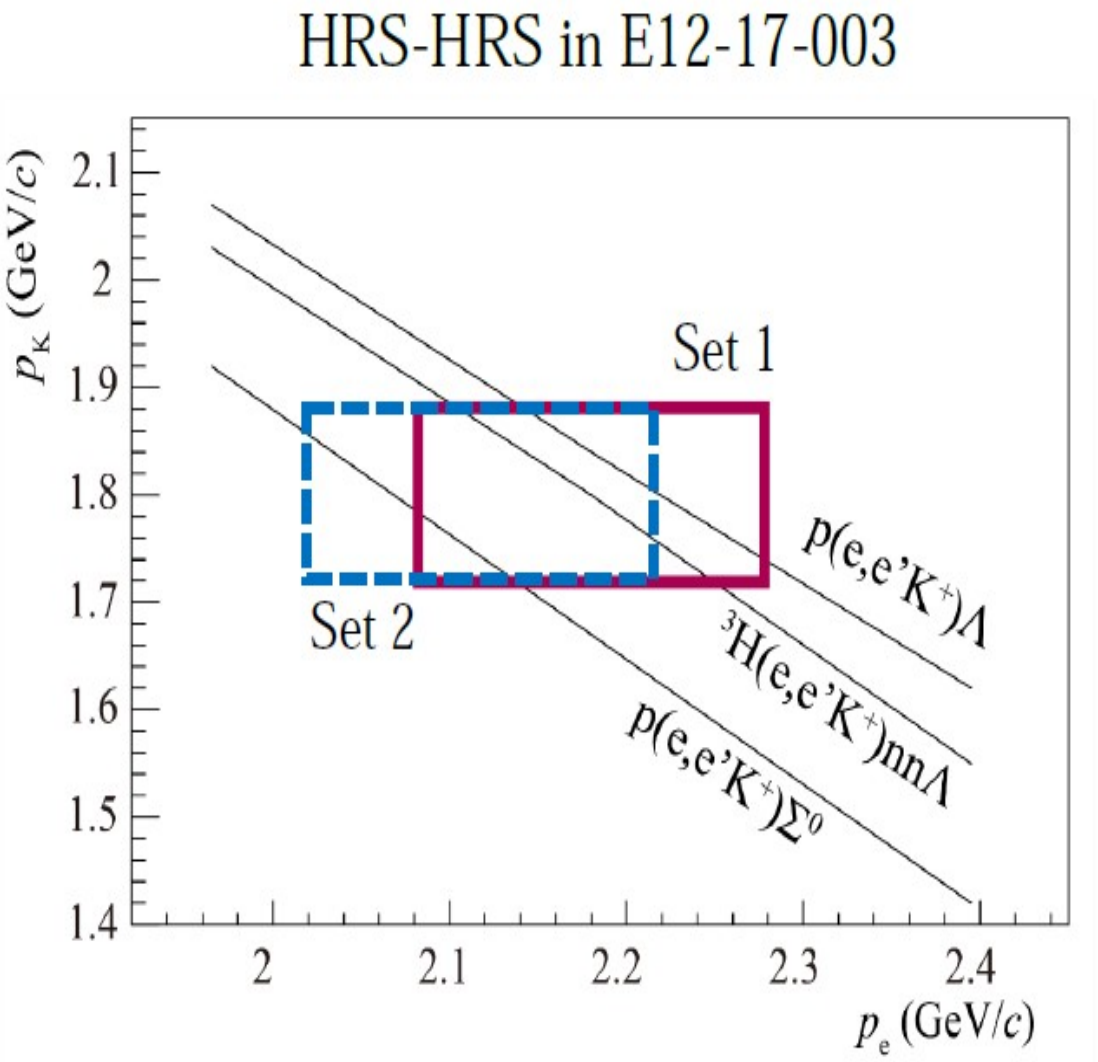


Kinematics for E-12-17-003

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



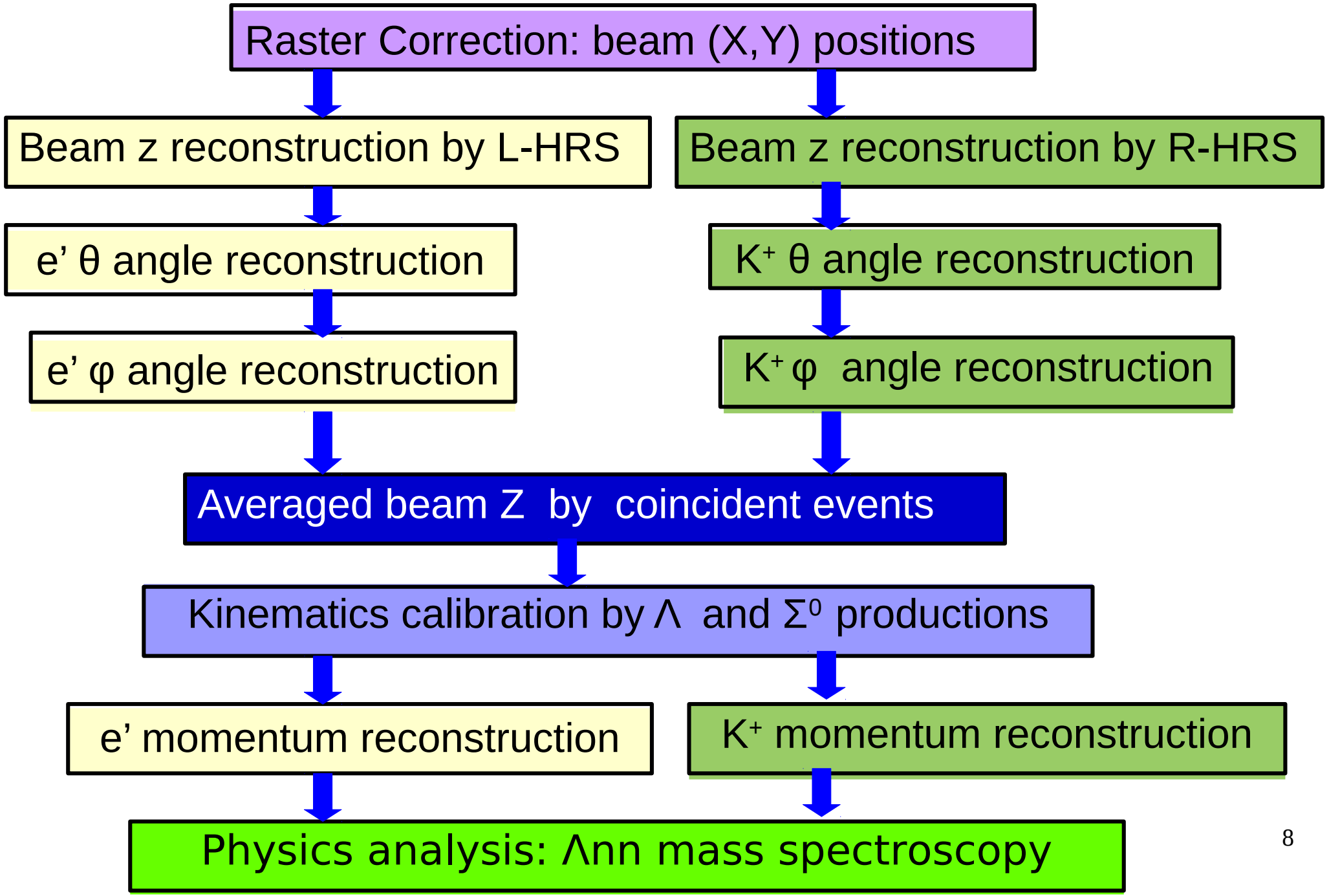
Took All Types of Data for the Analysis

1. Optics data
   Target: Multi-Carbon-foil w/ and w/o raster and with seive slits in
   Target: Thick-Al and dummy targets w/ and w/o raster
   Purpose: To optimize the various reconstructions(z-vertex, raster and angles in both of the arms)

2. Calibration data :
   Target: H (with H kinematics)
   Purpose: Kinematics calibration with known Λ and Σ^0 masses and for the determination of the absolute beam energy and spectrometer central momentum.

3. Production data:
   Targets: H,He and T (with T kinematics)
   Purpose: To check the effect of H and He contamination and for the physics purpose

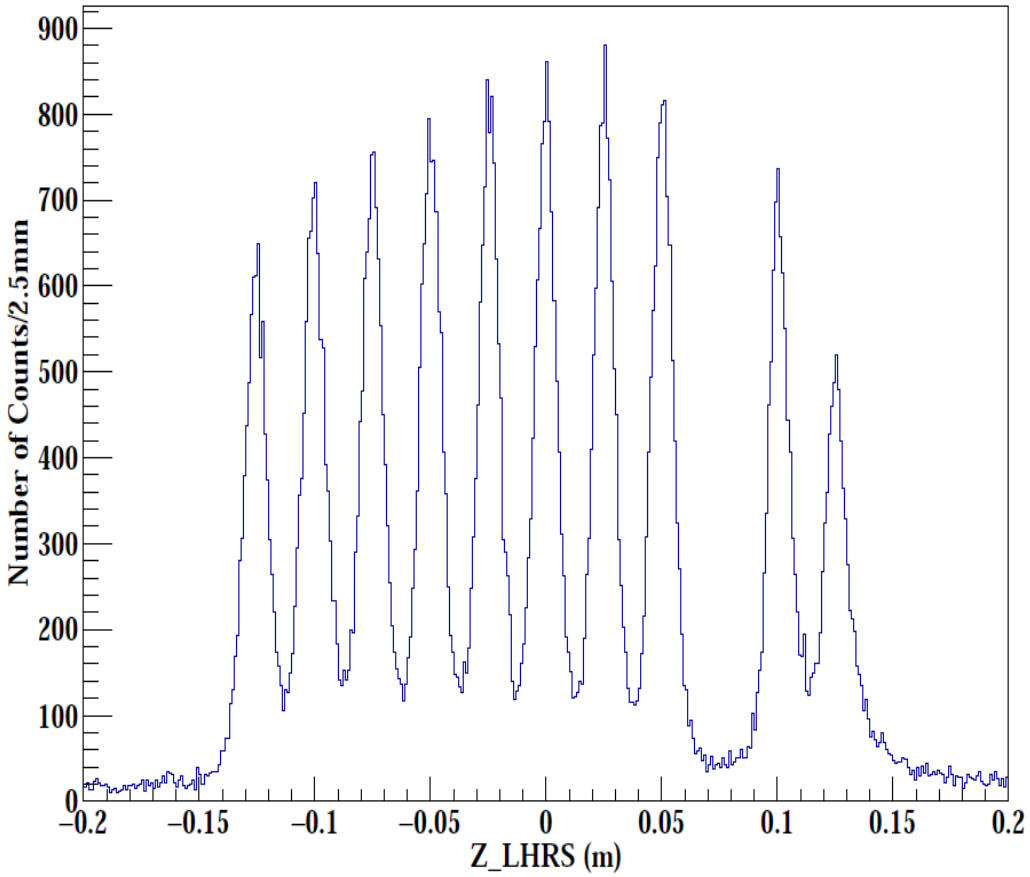
Analysis: Detailed Optimizations



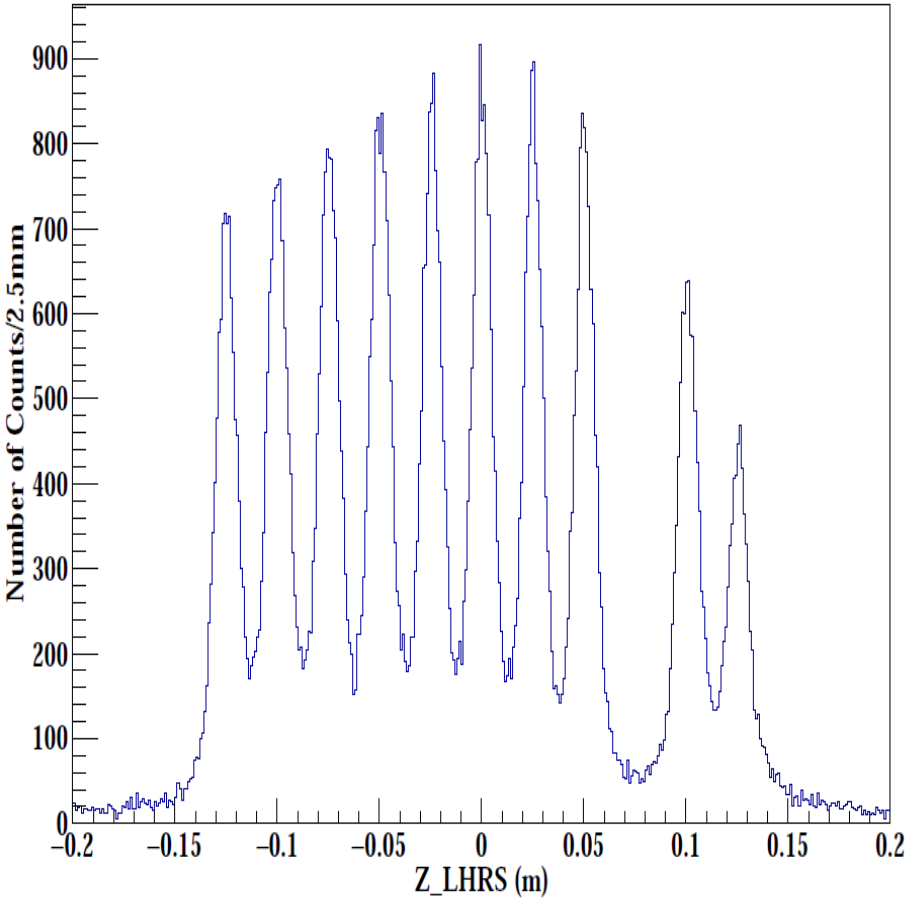
Current Analysis

1. a. LHRS Z-Vertex Reconstruction

Multi-C-foil target with raster off



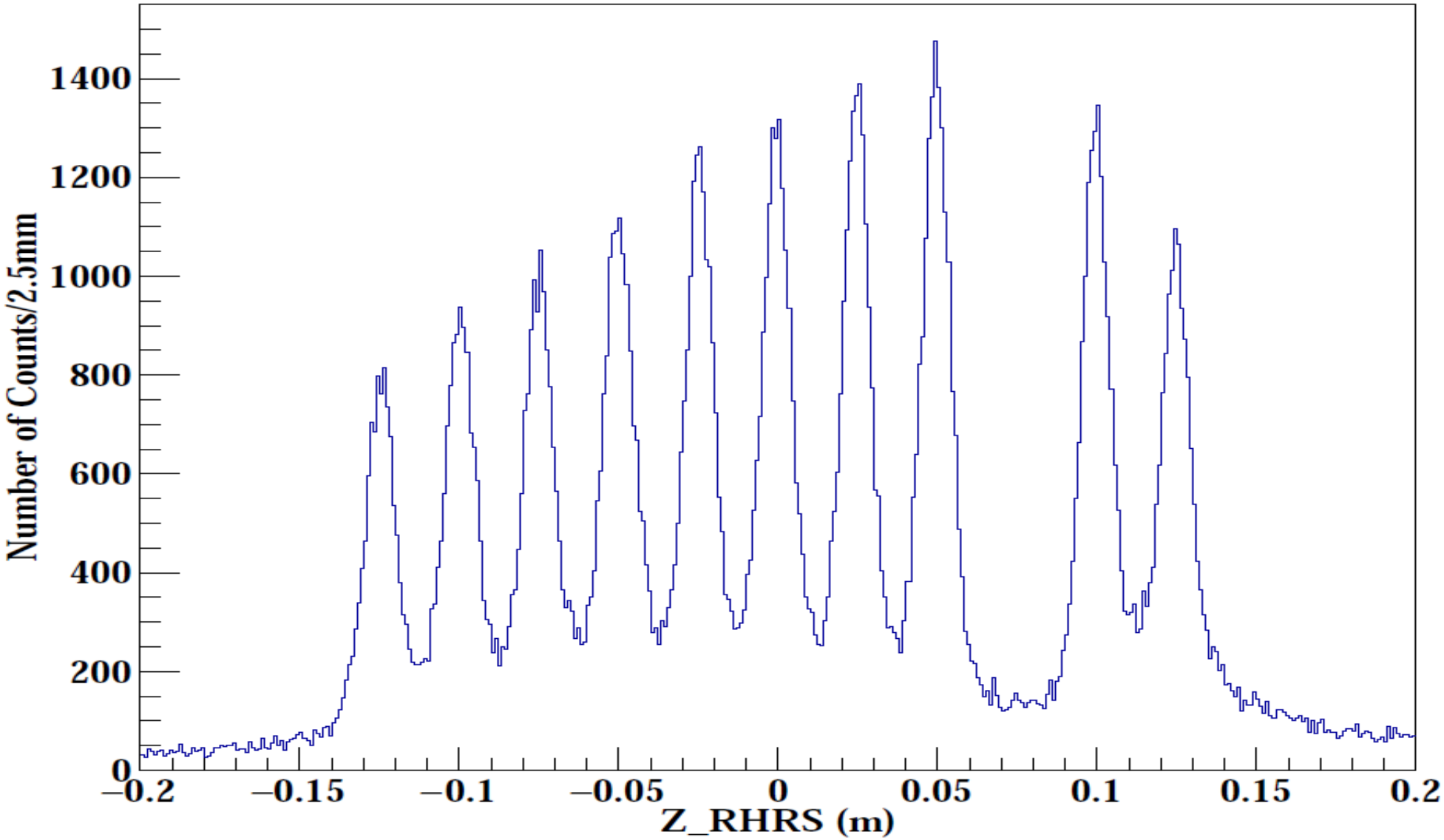
Multi-C-foil target with raster on



- Achieved good Z-vertex resolution for both about σ ≈ 5.2 mm
- Conformed good raster correction

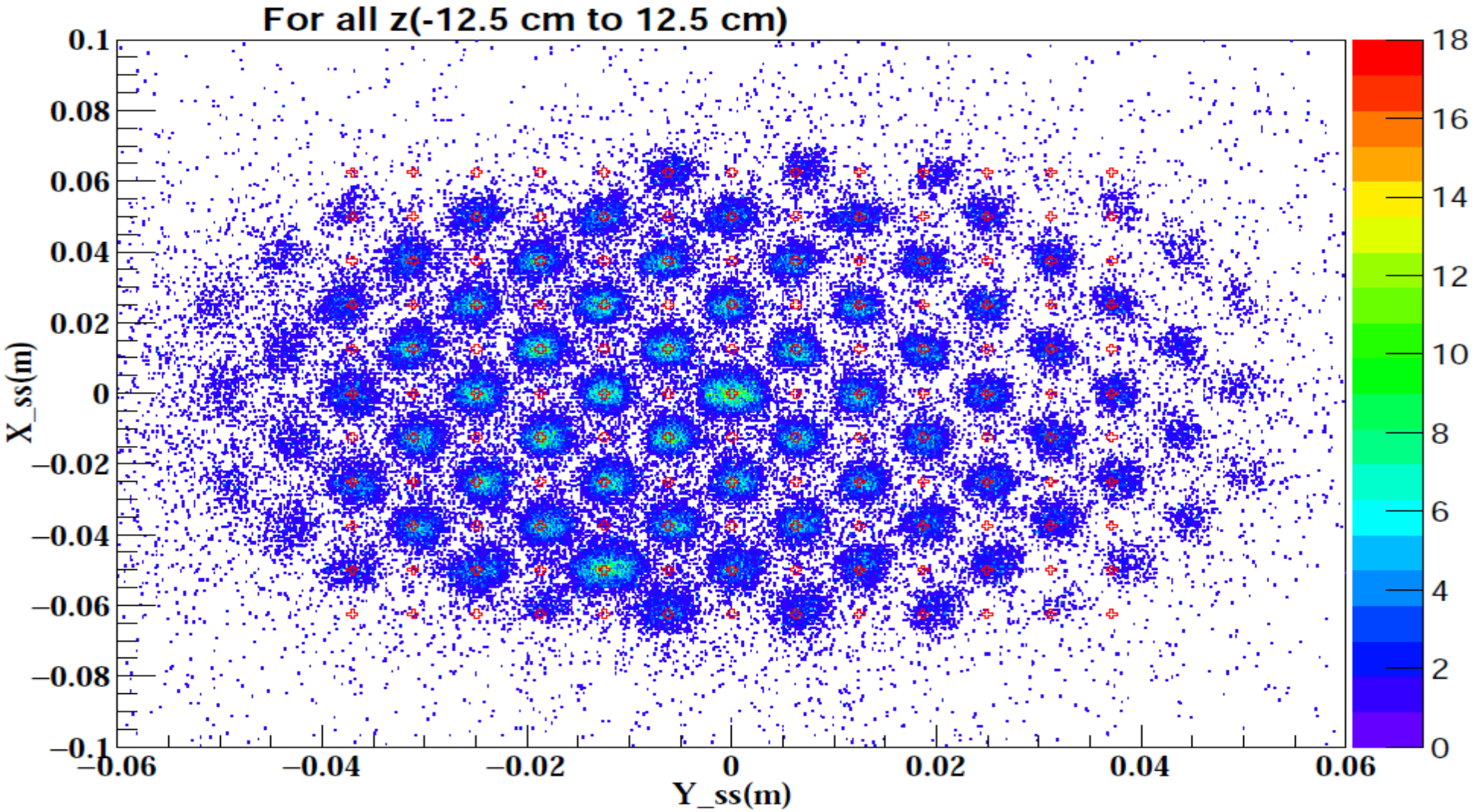
1. b. RHRS Z-Vertex Reconstruction

Multi-C-foil target with raster off



- RHRS Z-vertex has the same resolution as LHRS that is σ ≈ 5.2 mm

2. LHRS Angle Reconstruction



Achieved good angular resolution.

- In the dispersive plane σ ≈ 3 mrad
- In the non dispersive plane σ ≈ 2 mrad
- RHRS angle Reconstruction is in progress

Definition of Best Cut

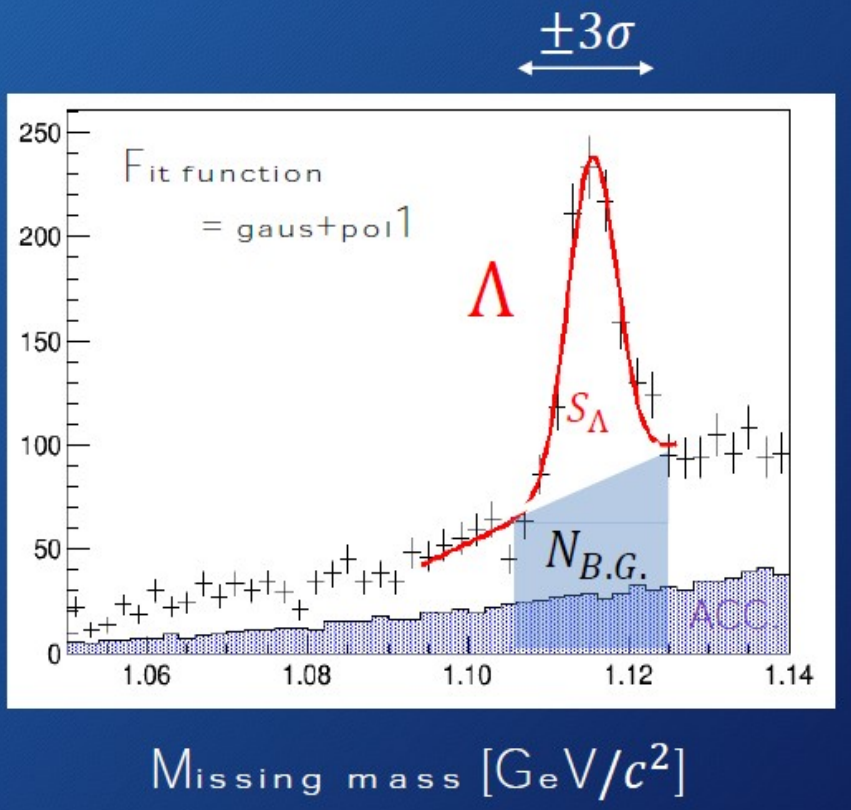
Tuning AC cut with missing mass

2

tuning AC cut: Maximum point of peak significance (P.S.) with Λ peak

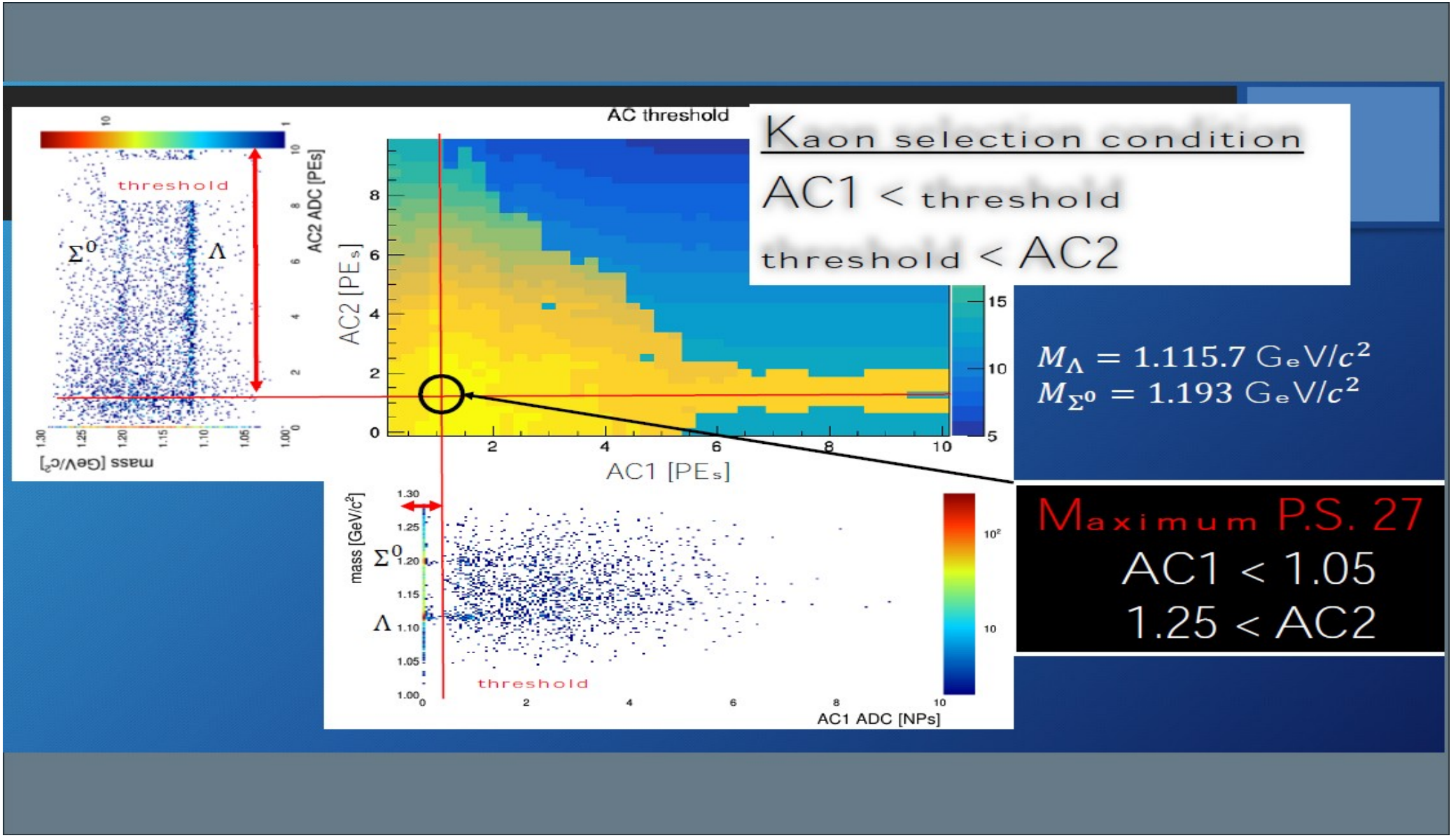
$$\mathrm{P.S.} = \sqrt{S^2_{\Lambda,\Sigma^0}/(N_{B.G} + S_{\Lambda,\Sigma^0})}$$

S_Λ : Getting by fitting (gaus + pol1)
$N_{B.G.}$: Total events below S_Λ ($\pm 3\sigma$)



Analysis done by Kosuke Itabashi(Tohoku University, Japan)

Peak Significance of AC Cut Dependence

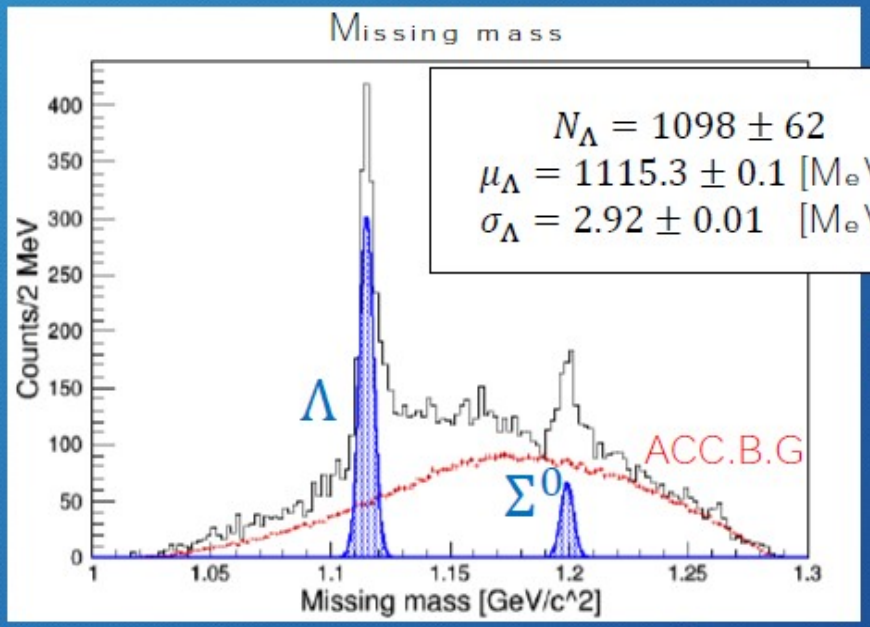


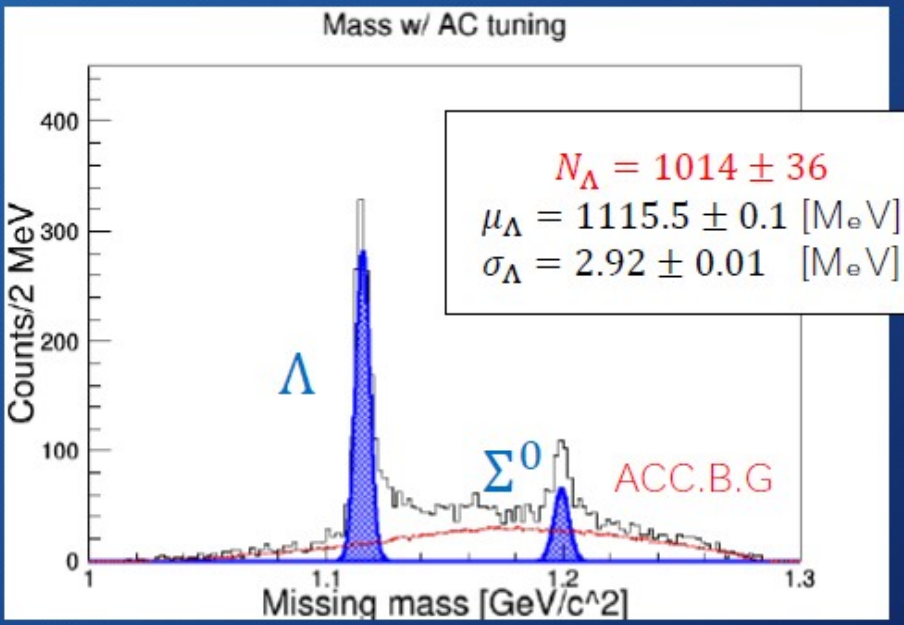
Analysis done by Kosuke Itabashi(Tohoku University, Japan)

AC Cut Result

Λ, Σ^0 missing mass by using tuning AC cut

4



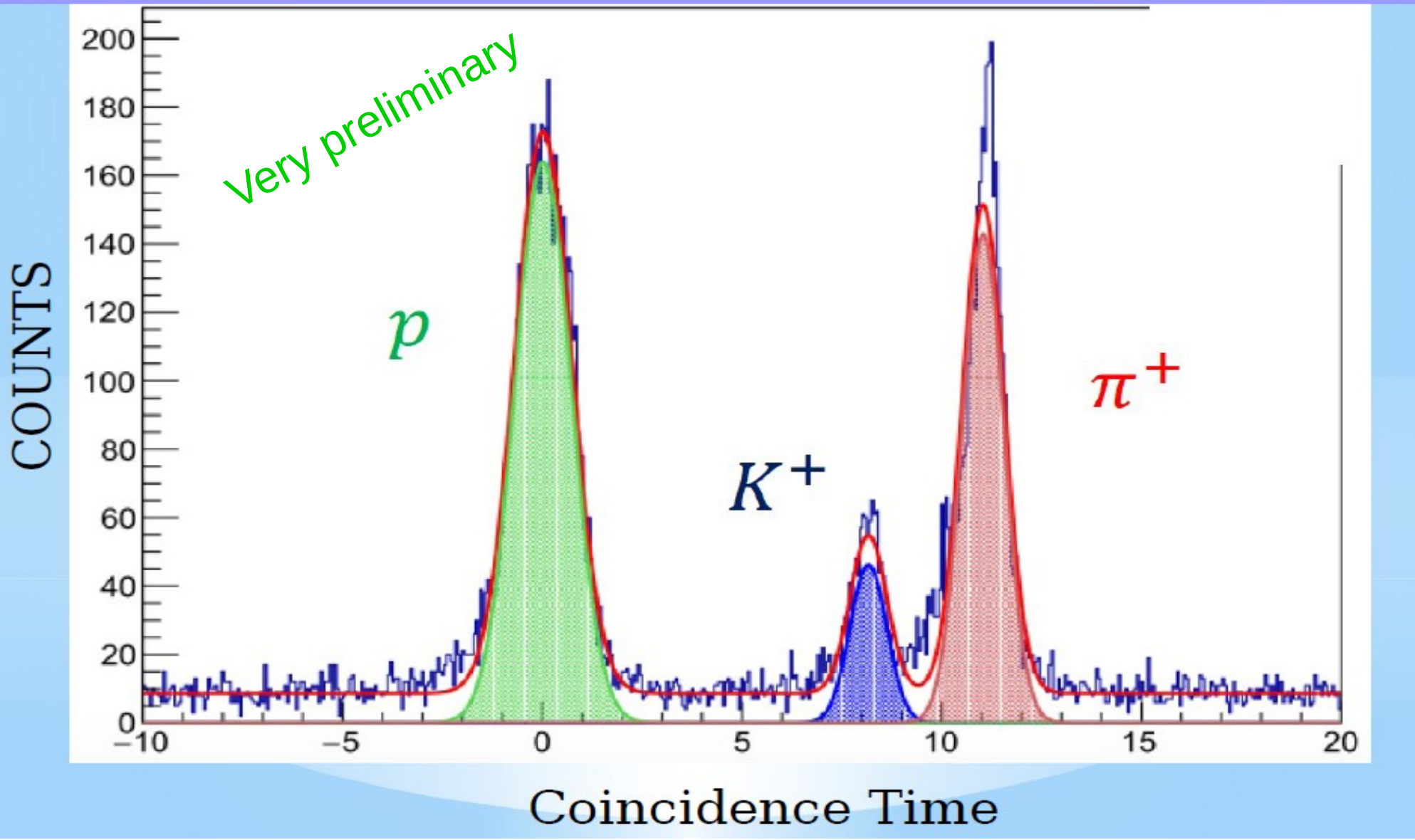


$\Lambda + \Sigma^0$ events: 1100 → 1000

Λ Peak significance: 23 → 27

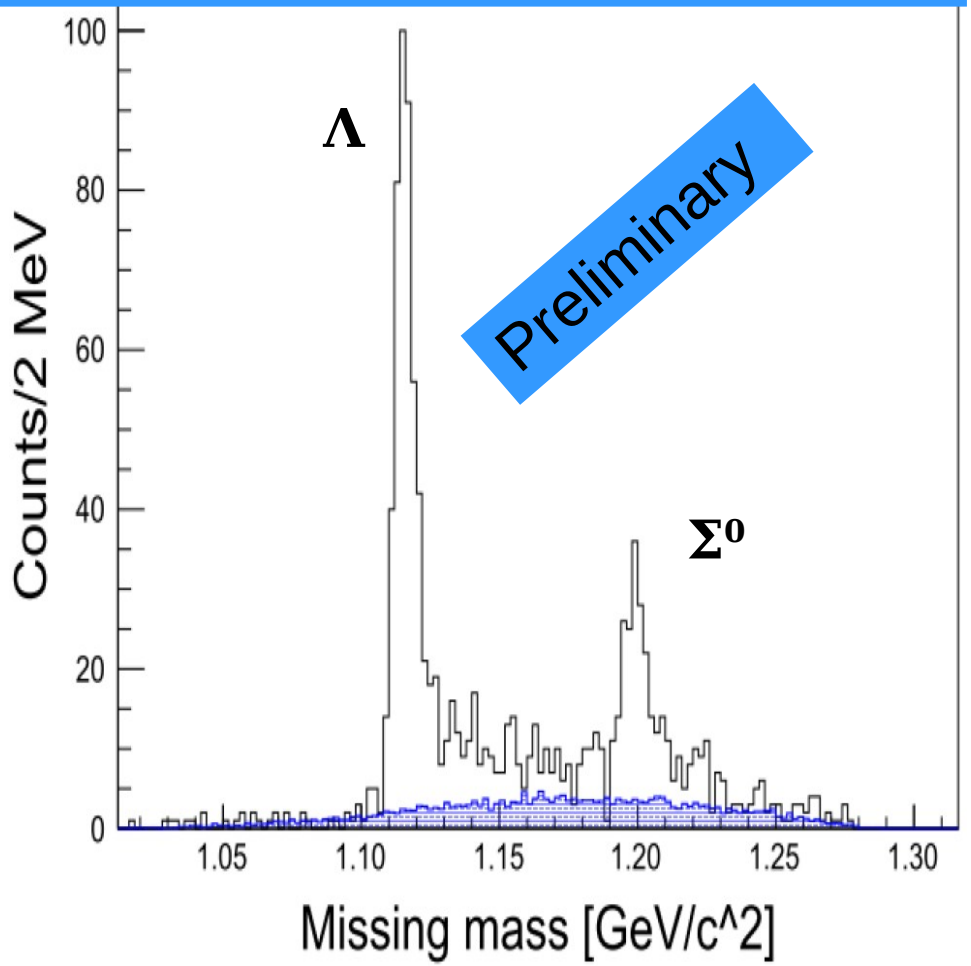
Analysis done by Kosuke Itabashi(Tohoku University, Japan)

Quick Online Analysis

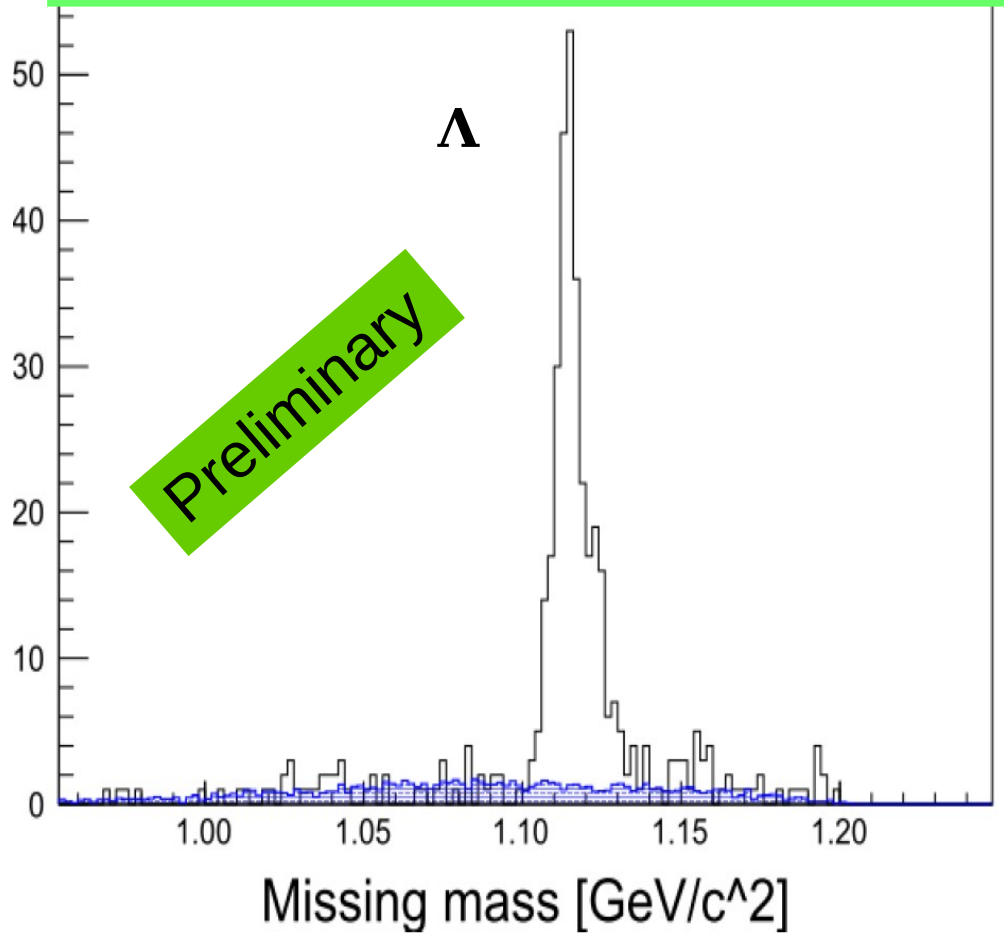


Quick Online Analysis Continue

Target: H
Kinematics: H



Target: H
Kinematics: T



- The online spectroscopy has a significant mass shift and energy resolution is poor as the system is not calibrated yet

Conclusions

- Recent precise experimental results show that charge symmetry breaking (**CSB**) is much more significant in **Λ-N** interaction
- From the GSI experiment, there is an indication 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 experiment E12-17-003 ($ee'K^+$) was carried out successfully in hall A with tritium target in November 2018.
- The preliminary results shows that the experiment is going in to the right direction
- The detailed analysis is in progress.

Thank You