Recent result of an exclusive $^{3}\mathrm{He}(K^{-}, \Lambda p)n$ analysis to search for $\overline{K}NN$ bound state

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For the J-PARC E15 collaboration

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Outline

Kaonic Nuclei and $\overline{K}NN$ bound state

◆ **Kaonic nuclei**

  ► **What's this?**

  • **Bound state of anti-kaon and nucleus**

    » **As a consequence of attractive $\overline{K}N$ interaction in $I = 0$**

    » **High-density matter could be realized.**

  ► **What's interest?**

  • **$\overline{K}N$ interaction in the sub-threshold region**

    » **Cannot be provided by $\overline{K}N$ scattering experiments**

◆ **$\overline{K}NN$ bound state**

  • **The simplest kaonic nucleus**

    » **So-called K^-pp bound state**

  • **B.E. is expected to be several tens MeV.**

# Recent status of K^-pp bound state

◆ **There are many Theoretical/Experimental results.**

▶ **From theoretical calculations**
- **Kpp bound state can exist**
  - » **B.E. and width are widely distributed.**
    - ▪ **E-dep.** / **E-indep.** of KbarN interaction

▶ **From experiments**
- **Some experiments reported the bound state.**
  - » **B.E. and width are not consistent**
- **However, some experiments reported NO bound state.**
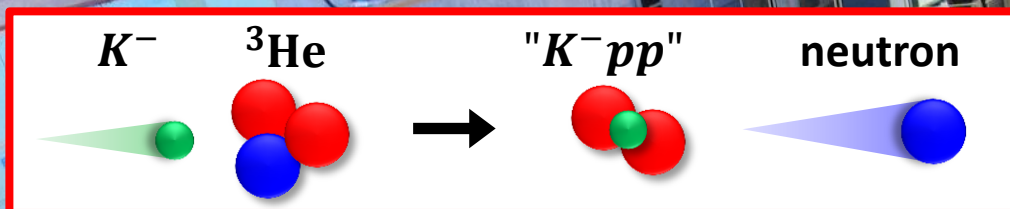 - » **Experiment using different reaction is desired.**
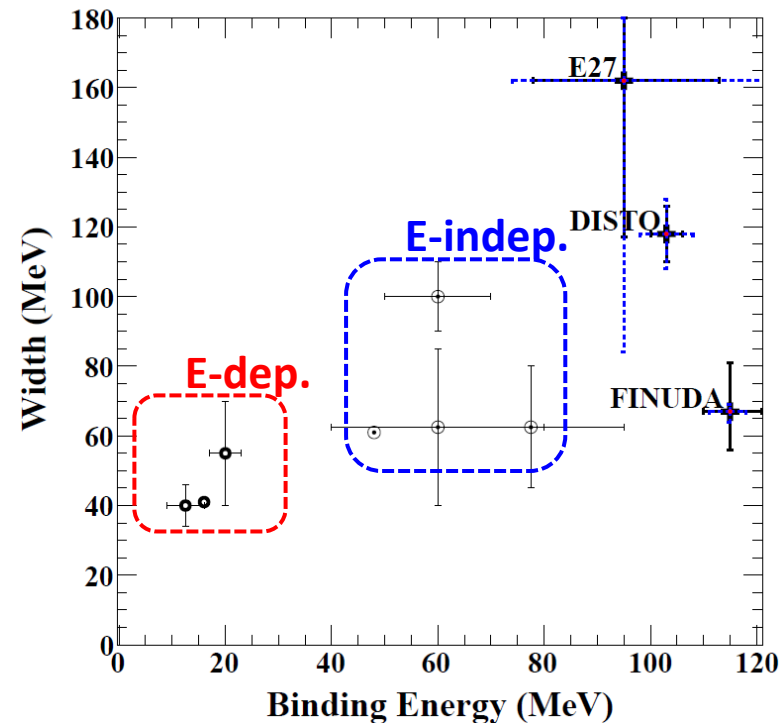
K^-pp **is still subject to refined experiments.**
We investigate K^-pp **bound state via the** $(\text{in-flight } K^-, n)$ **reaction.**

J-PARC E15 experiment

Search for K^-pp bound state via the $(\text{in-flight } K^-, n)$ reaction

K^- ^{3}He → "K^-pp" neutron

Neutron counter
Charge veto counter

Flight length : 15 m

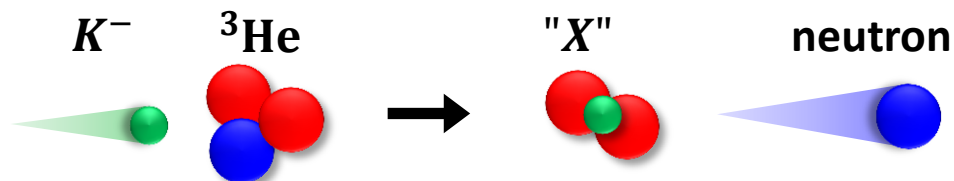Beam sweeping magnet

CDS

Beam spectrometer

5

Analysis overview

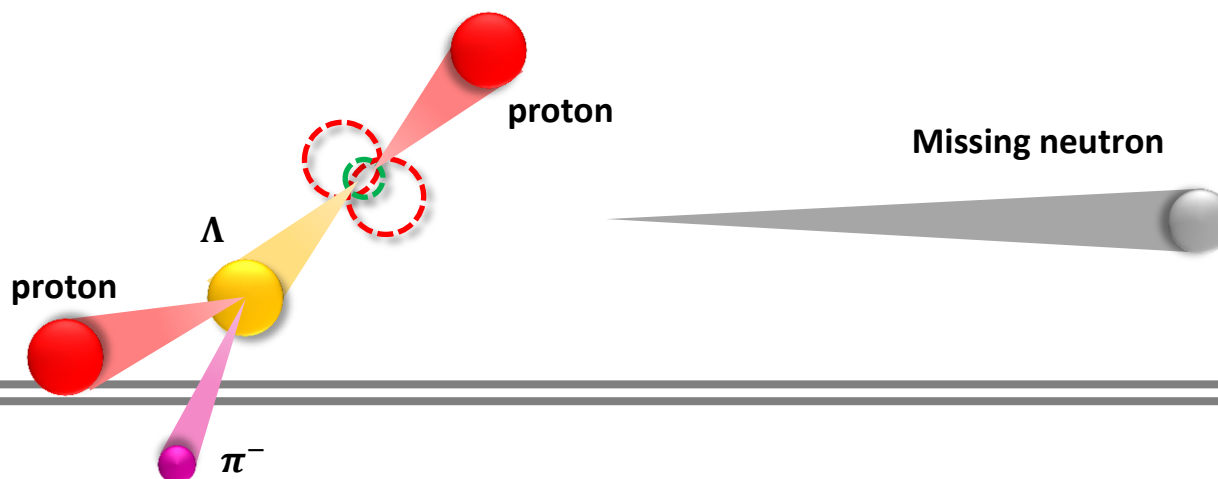◆ **Formation channel**

- T. Hashimoto, et al, PTEP, 2015, 061D01

▶ $\mathbf{^3He}(K^-, n)"X"$ **missing mass spectroscopy**

K^- ^{3}He   "X"   **neutron**

◆ **Decay channel (Exclusive channel)**

- Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

▶ Λp **invariant mass spectroscopy in** $\mathbf{^3He}(K^-, \Lambda p)"n"$ **reaction**

proton

Missing neutron

Λ

proton

π^-

Result of semi-inclusive analysis

T. Hashimoto, et al, PTEP, **2015**, 061D01
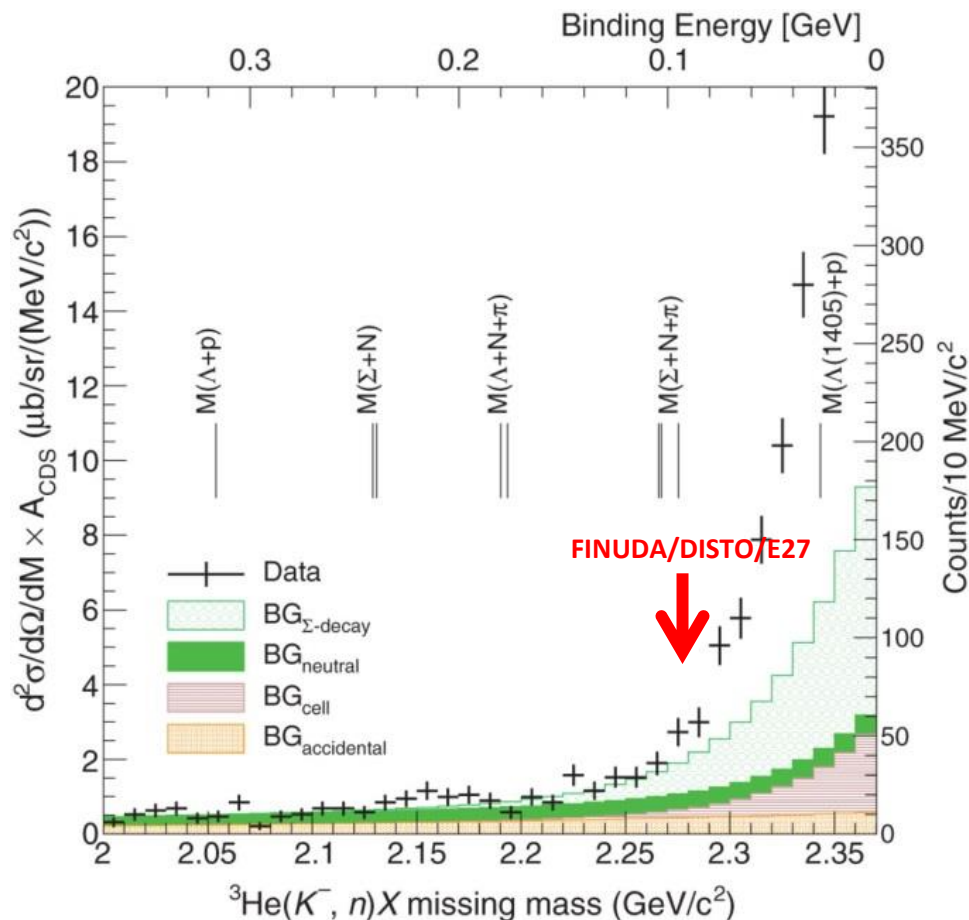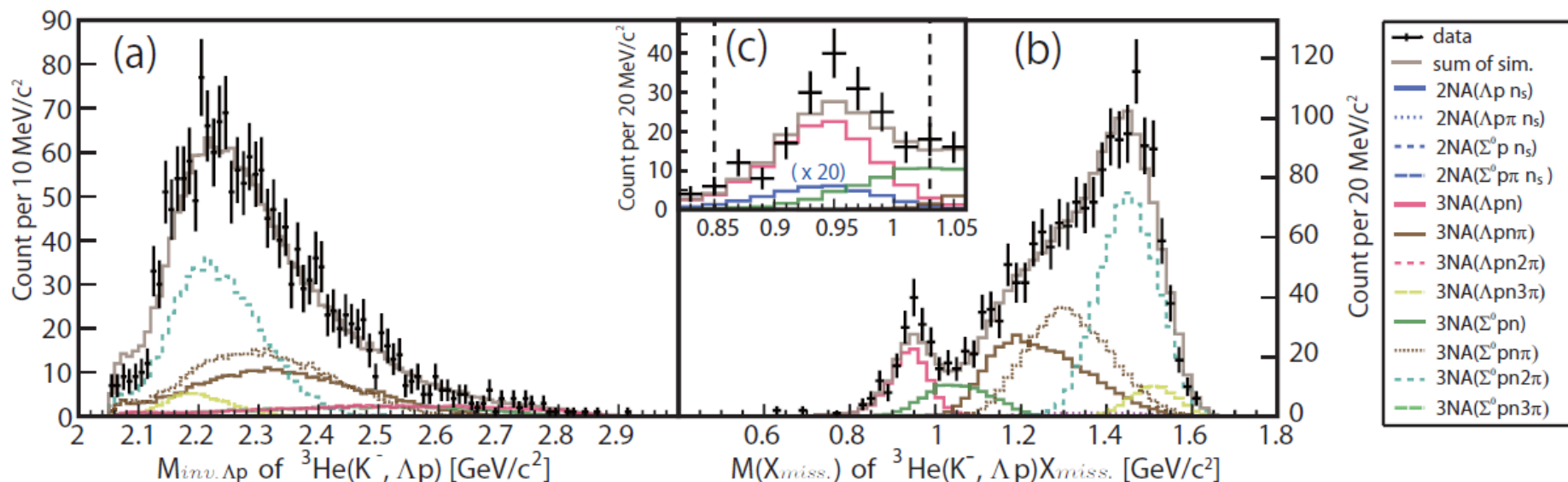

◆ $^3\text{He}(K^-, n)$"X" missing mass spectrum

- ► **Tail structure just below the threshold**
  - **Cannot be explained by any elementary processes**

- ► **NO structure in deeply bound region**
  - **Different from FINUDA/DISTO/E27 experiments**

Result of exclusive analysis

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

- ◆ Λp invariant/missing mass spectrum
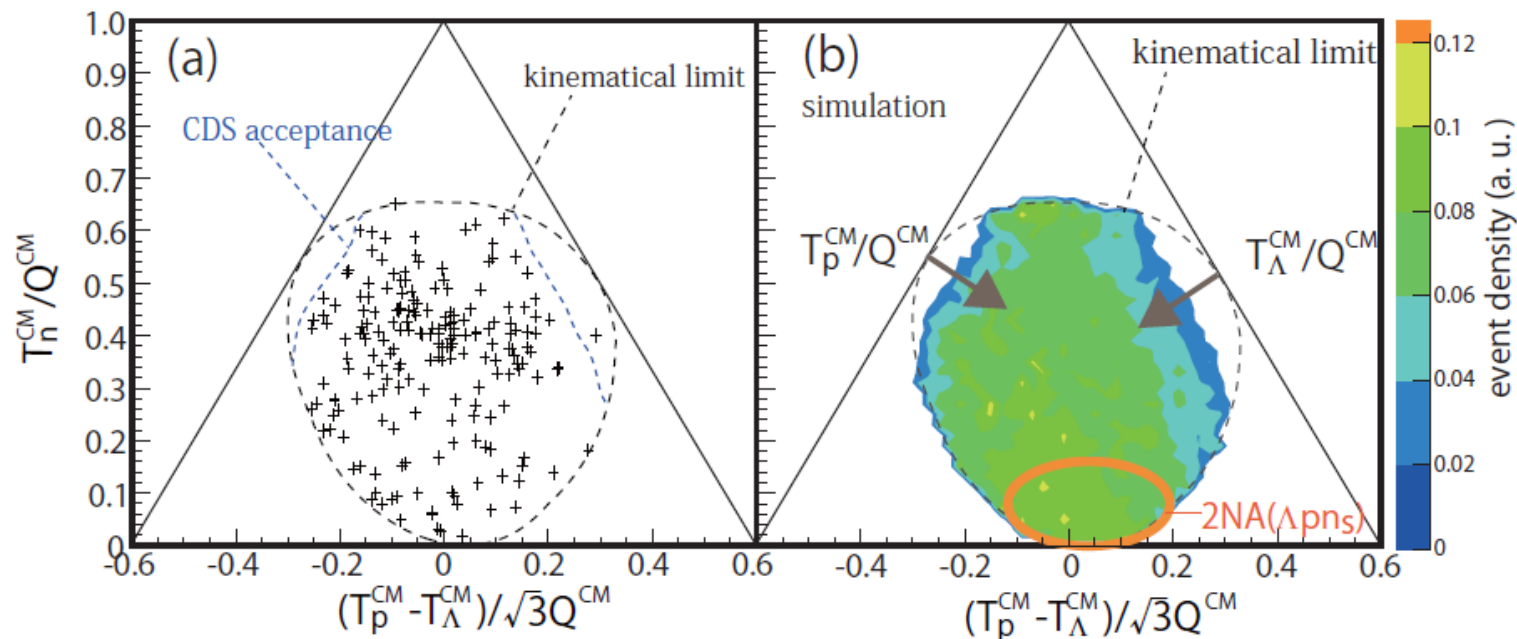 - ► Well reconstructed by MC simulation.
- ◆ In Λpn final state
  - ► 3NA processes are dominant.
    - 3NA(Λpn) : 3NA($\Sigma^0 pn$) : 2NA(Λpn) = 0.62 : 0.20 : 0.01

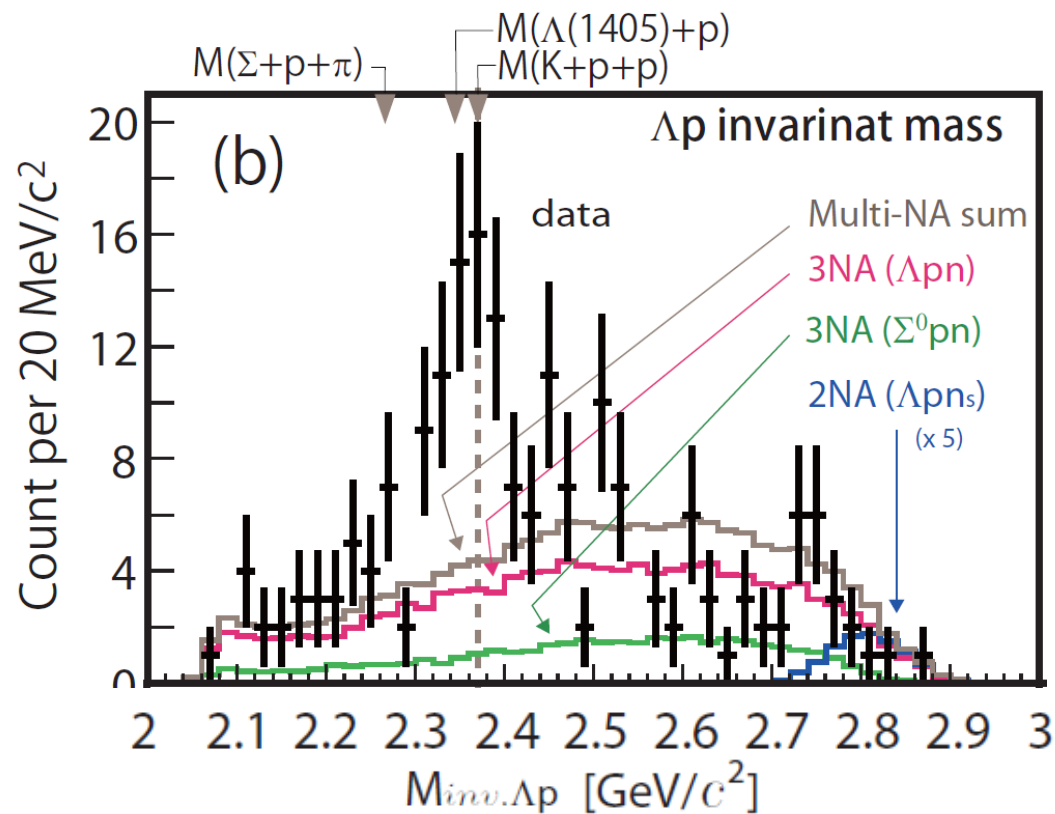# Result of exclusive analysis

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

◆ **In Λpn final state (Dalitz plot)**

▶ **Widely distributed in the phase space**

• **Contribution from 2NA processes is very small**

» **Consistent with global fitting result**

Result of exclusive analysis

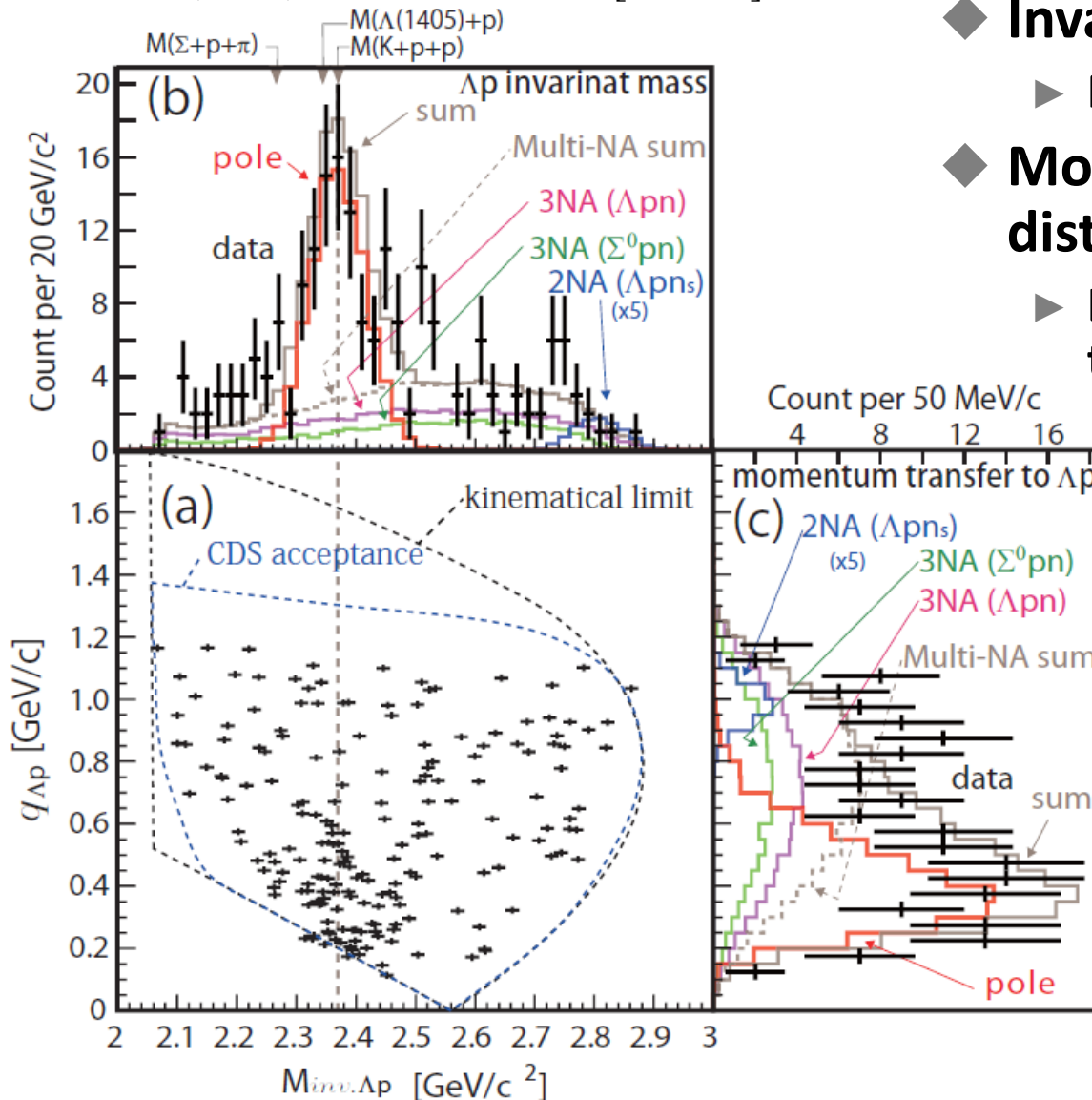Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

◆ Λp **invariant mass spectrum**

▶ **Peak structure around threshold was observed.**

Result of exclusive analysis

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

- ◆ **Invariant mass spectrum**
  - ▶ **Pole structure around threshold**
- ◆ **Momentum transfer distribution**
  - ▶ **Large events in Low momentum transfer region**

Result of exclusive analysis

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]

◆ **To explain the peak structure**

▶ **S-wave Breit-Wigner with Gaussian form-factor**

$$\frac{d^2\sigma_X}{dM_{inv.\Lambda p}dq_{\Lambda p}} \propto \rho_3(\Lambda pn) \times \frac{(\Gamma_X/2)^2}{(M_{inv.\Lambda p} - M_X)^2 + (\Gamma_X/2)^2} \times |\exp(-q_{\Lambda p}^2/2Q_X^2)|^2,$$
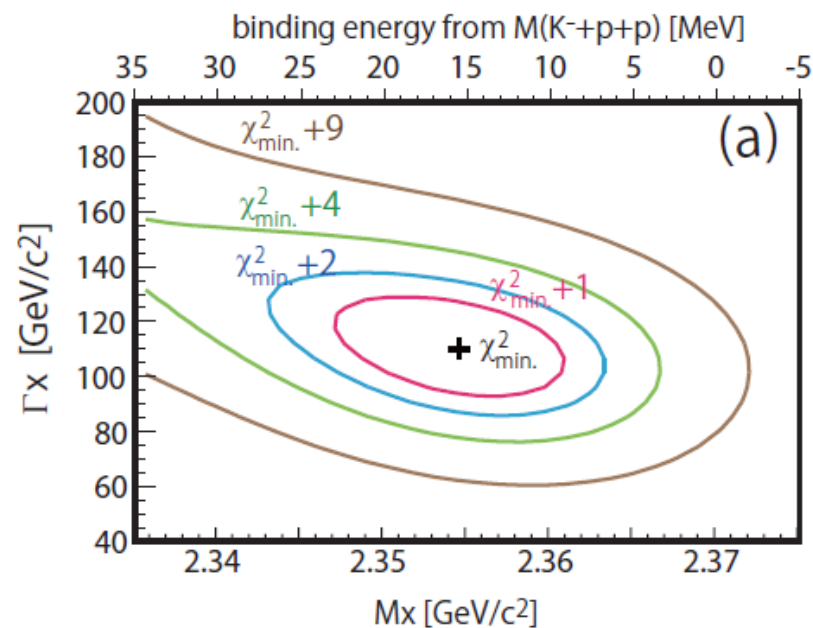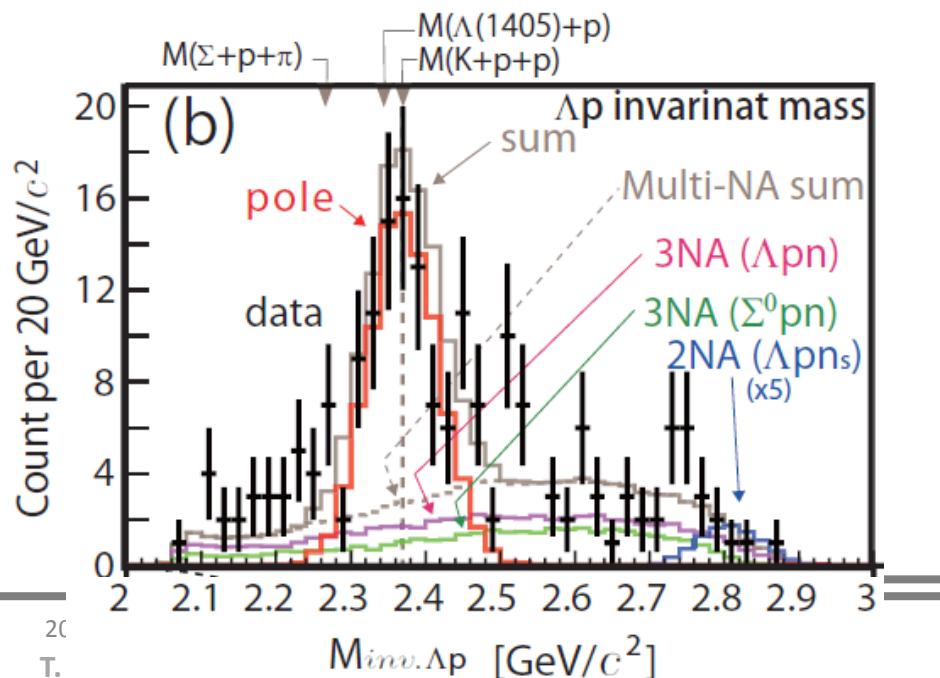
Mass (MeV/c^2)	Width (MeV/c^2)
$2355^{+8}_{-6}\,(stat.)^{\pm 12}\,(sys.)$	$110^{+19}_{-17}\,(stat.)^{\pm 27}\,(sys.)$

$Q_X = 400^{+60}_{-40}$ MeV/c

Result of E15 1st Data Analysis

◆ **Semi-inclusive analysis**

- $^3\text{He}(K^-, n)"X"$ missing mass spectrum

▶ **Excess below the threshold was observed.**

▶ **NO structure in deeply-bound region**

◆ **Exclusive analysis**

- Λp invariant mass spectrum

▶ **A peak structure was observed below $K^- pp$ threshold.**

Mass (MeV/c^2)	Width (MeV/c^2)
$2355^{+8}_{-6} \, (stat.)^{\pm 12} \, (sys.)$	$110^{+19}_{-17} \, (stat.)^{\pm 27} \, (sys.)$

- S=-1 di-baryon state?
- Y^*N unbound resonance?

More detail analysis with higher statistics should be done.
e.g. study of the momentum transfer dependence

Latest status of E15

◆ **E15 2nd Physics Run was performed.**

  ▶ **8-times more K^- beam than 1st physics run**

  ▶ **Modification of the DAQ system**

    » **Focusing on $^3\mathrm{He}(K^-, \Lambda p)"n"$ channel**

  About 50 times larger statistics of Λpn events is expected.

◆ **Calibration and Analysis are ongoing.**
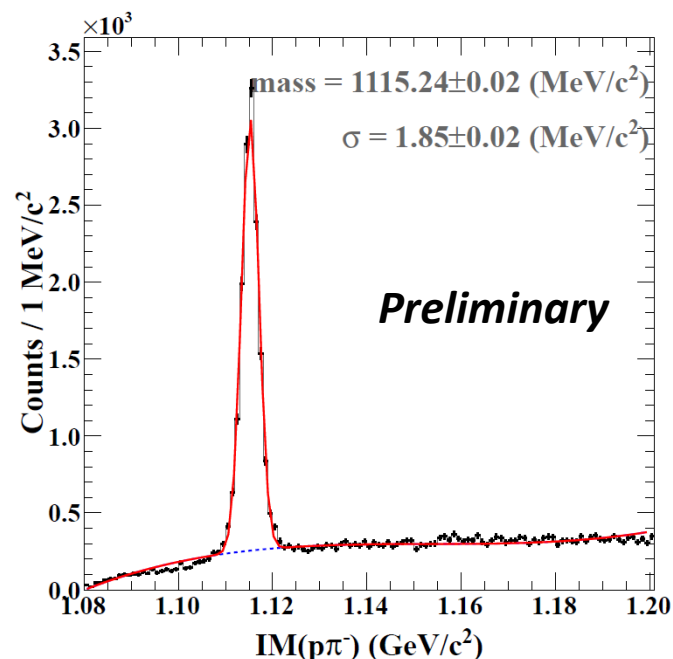
Latest status of E15
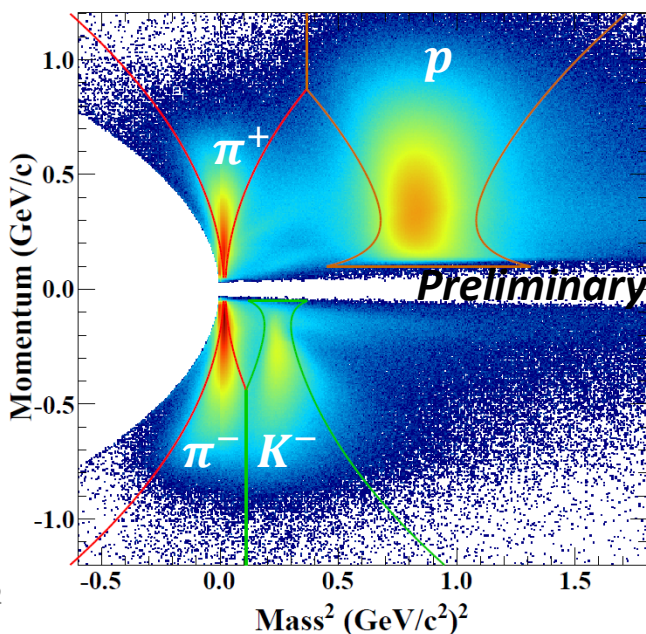
◆ **Detector performances in E15 2ⁿᵈ physics run**

▶ **Reaction vertex is well reconstructed**
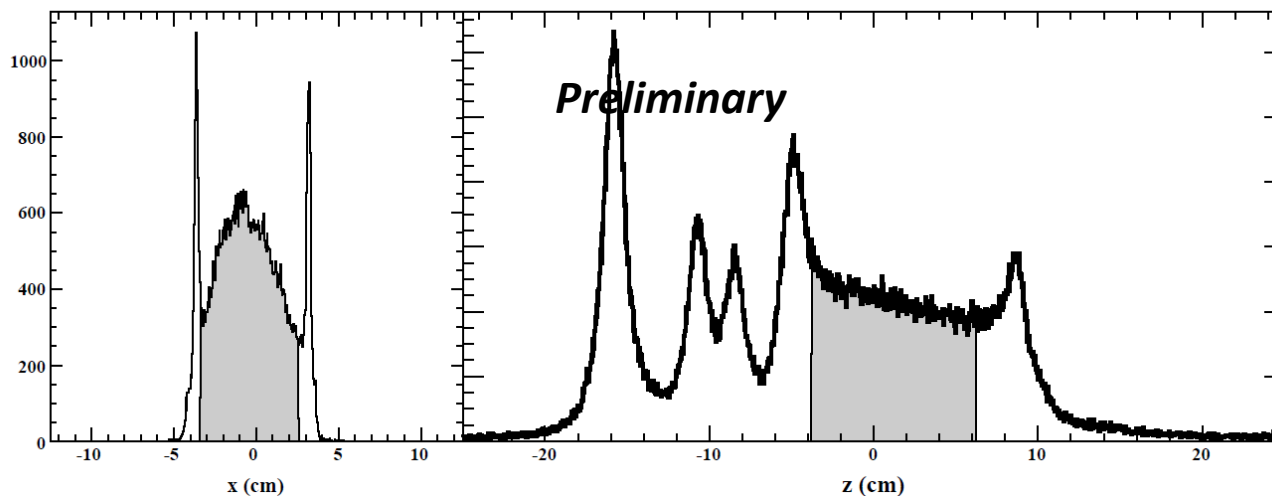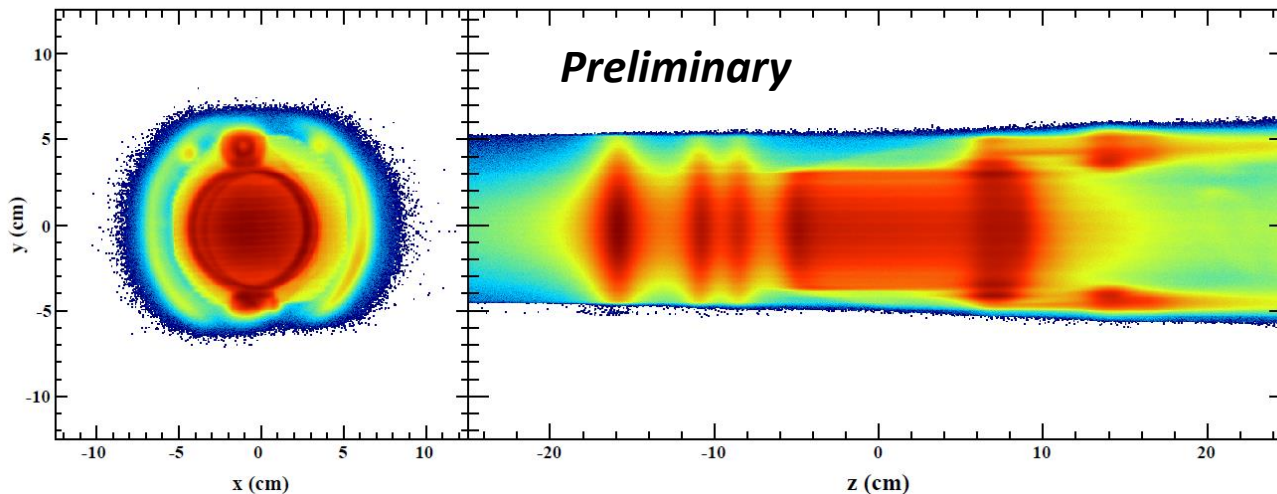
Latest status of E15

◆ **Detector performances in E15 2nd physics run**

▶ **Reaction vertex is well reconstructed**

▶ **Particle identification with CDS is well performed.**

- Λ peak is clearly observed in I.M.($\pi^- p$) spectrum
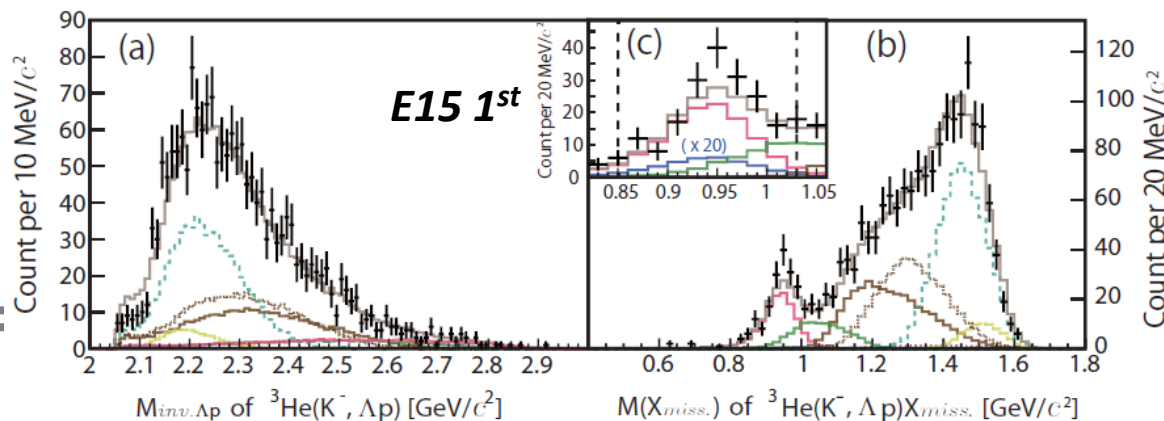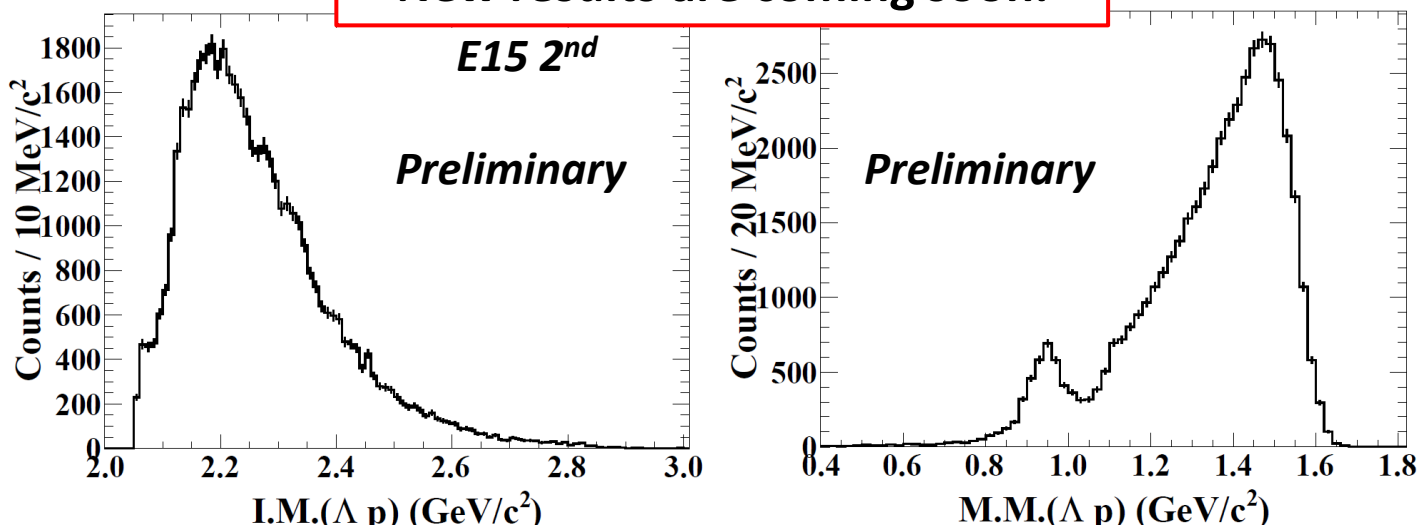
All Detectors worked well in E15 2nd physics run.

Latest status of E15

◆ **Exclusive analysis of $^3\text{He}(K^-, \Lambda p)$ events**

▶ **Missing neutron is clearly observed.**

New results are coming soon.

Summary

◆ **Results of E15 1st**

  ▶ **Semi-inclusive analysis**

  • **Excess below the threshold was observed.**

  • **NO structure in deeply-bound region**

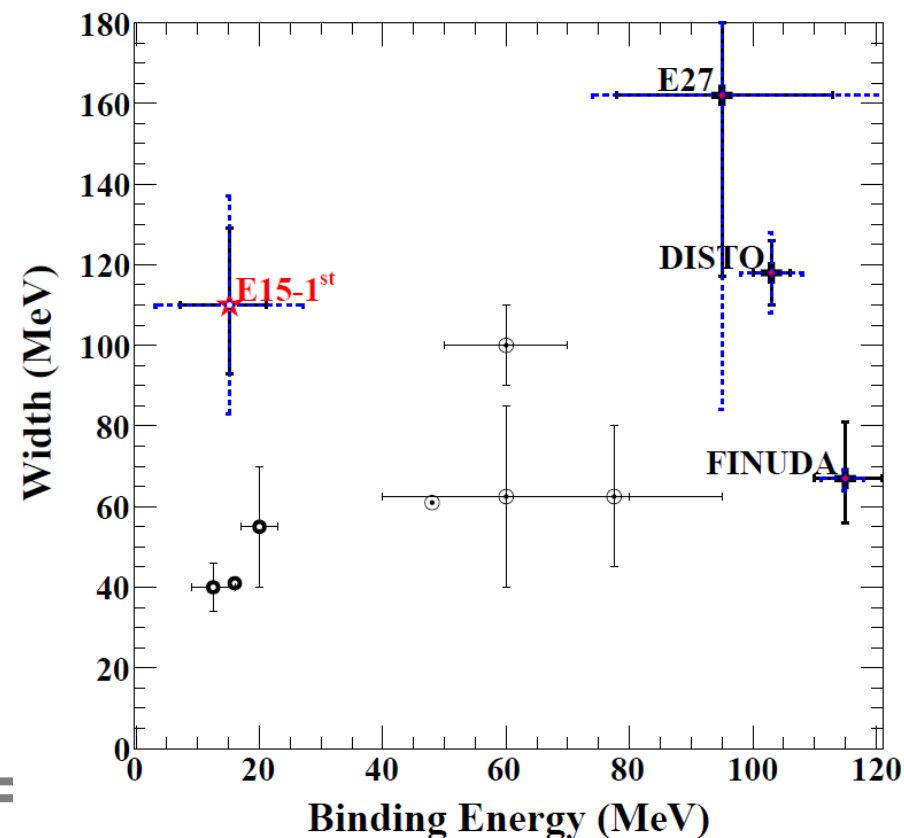 ▶ **Exclusive analysis**

  • **A peak structure was observed below K^-pp threshold.**

    » $S = -1$ di-baryon state?

    » Y^*N unbound resonance?

◆ **E15 2nd physics run was performed.**

  ▶ **Analysis is ongoing and new results are coming soon.**

Mass (MeV/c^2)	Width (MeV/c^2)
$2355^{+8}_{-6}\,(stat.)^{\pm12}\,(sys.)$	$110^{+19}_{-17}\,(stat.)^{\pm27}\,(sys.)$

Thank you for your attention

∼ The E15 collaboration ∼

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