日本物理学会　第71回年次大会
March 19-22, 2016 @ 東北学院大学

J-PARC K1.8BRビームラインに於ける $^{3}\mathrm{He}(K^{-},n)$ 反応を用いた $\bar{K}NN$ 束縛状態の探索

Takumi Yamaga
Research Center for Nuclear Physics, Osaka university

For the J-PARC E15 collaboration

March 21, 2016

Outline

- Introduction
  - Kaonic nuclei
  - Recent status of $K^{-}pp$ bound state
- Experiment and analysis
  - Setup of J-PARC E15 experiment
  - Analysis procedure
- E15 – 2nd
- Summary

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

Kaonic nuclei

What's this?

- Bound state of anti-kaon and nucleus
  - As a consequence of attractive $\bar{K}N$ interaction in $I = 0$

What's interest?

- $\bar{K}N$ interaction in the sub-threshold region
  - Cannot be provided by $\bar{K}N$ scattering experiments
- High-density matter could be realized.

$\bar{K}NN$ bound state

- The simplest kaonic nucleus
  - So-called $K^{-}pp$ bound state

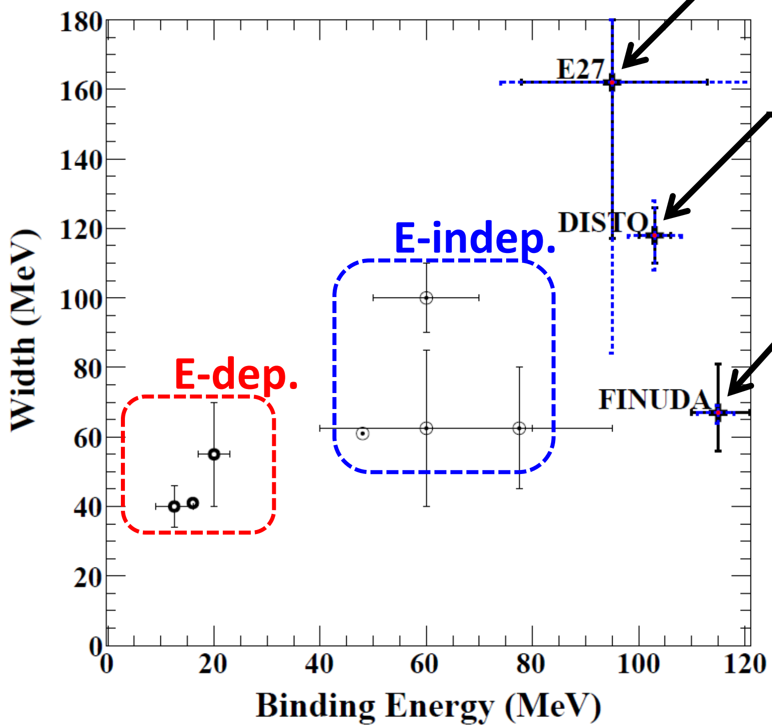
Recent status of $K^- pp$ bound state

◆ Recent results

▶ Theoretical calc.

KbarN interaction model

E-dep. / E-indep.



▶ Experiments

Reports structure / ***NO structure***

J-PARC E27
$d(\pi^+, K^+)X$

DISTO
$pp \to \Lambda p K^+$

FINUDA
$(stopped\ K^-, \Lambda p)$

LEPS
$p(\gamma, \pi^- K^+)X$

HADES
$pp \to \Lambda p K^+$

$K^- pp$ is still subject to refined experiments.

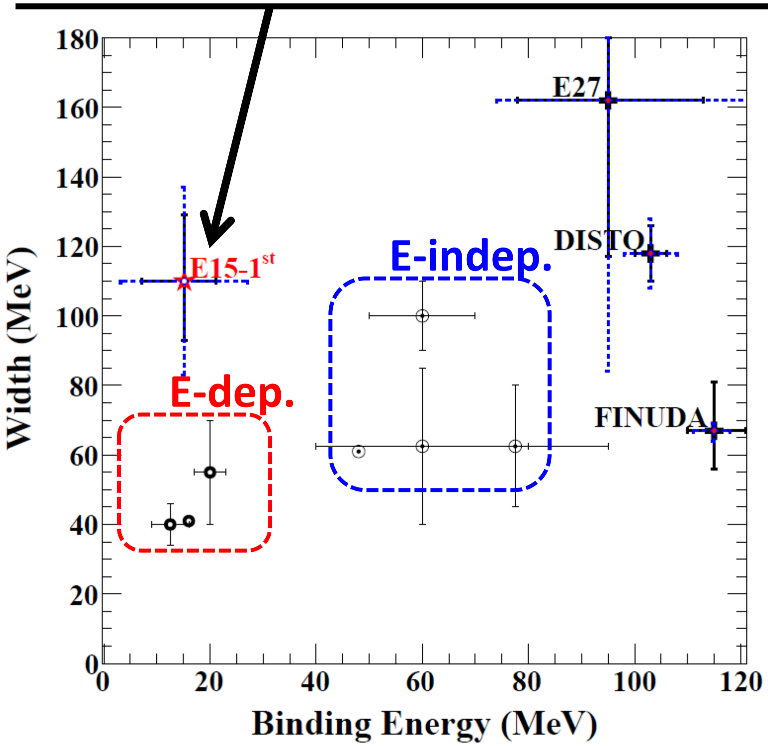
J-PARC E15
Using (in-flight K^-, n) reaction

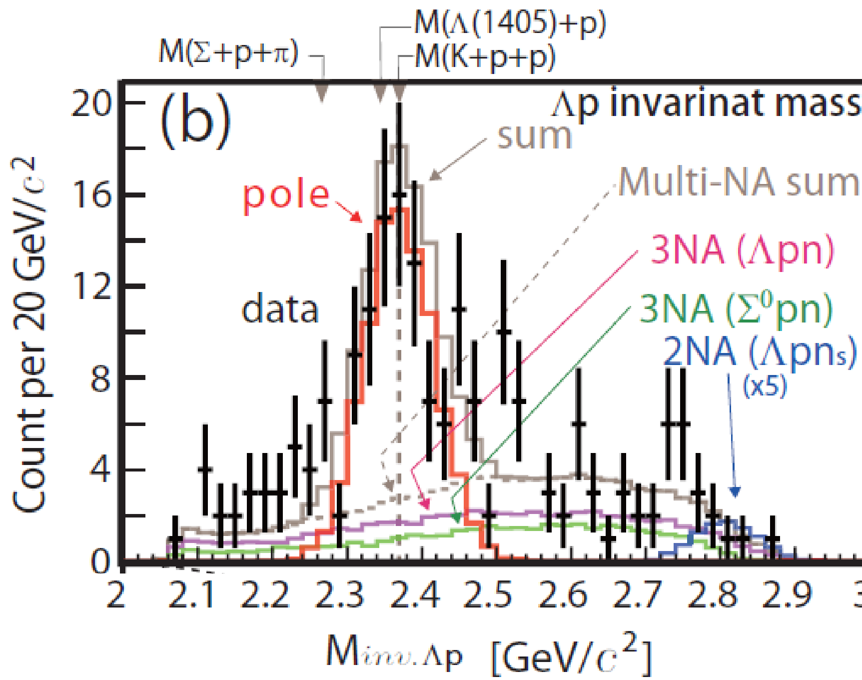
Recent status of $K^{-}pp$ bound state

◆ Recent results including E15

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]
(Accepted by PTEP)

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





▶ **E15-1st experiment**

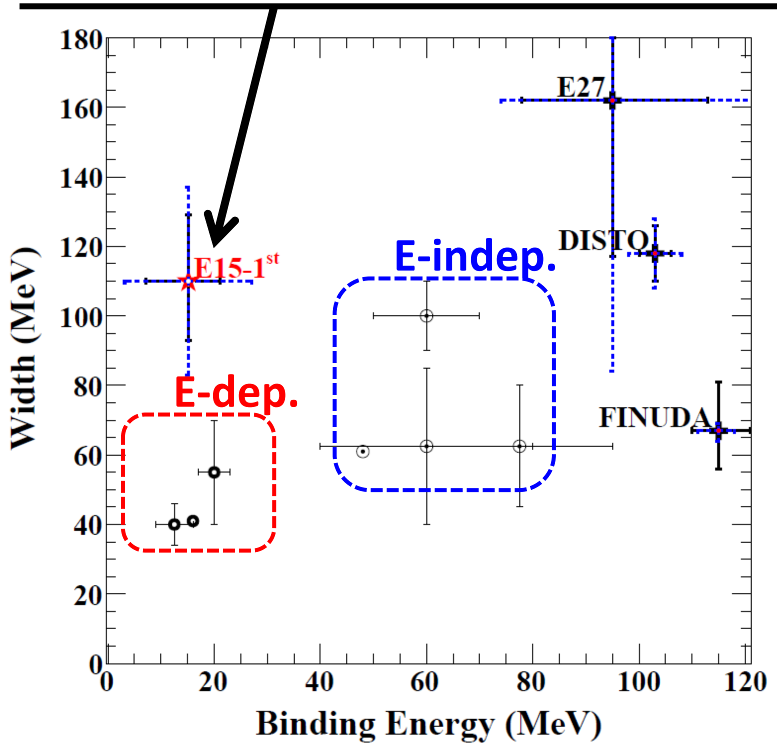
- **Λp invariant mass analysis in $^{3}\mathrm{He}(K^{-},\Lambda p)$"n"**
- **Assuming simple Breit-Wigner**

Recent status of $K^- pp$ bound state

◆ Recent results including E15

Y. Sada, et al, arXiv:1601.06876 [nucl-ex]
(Accepted by PTEP)

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



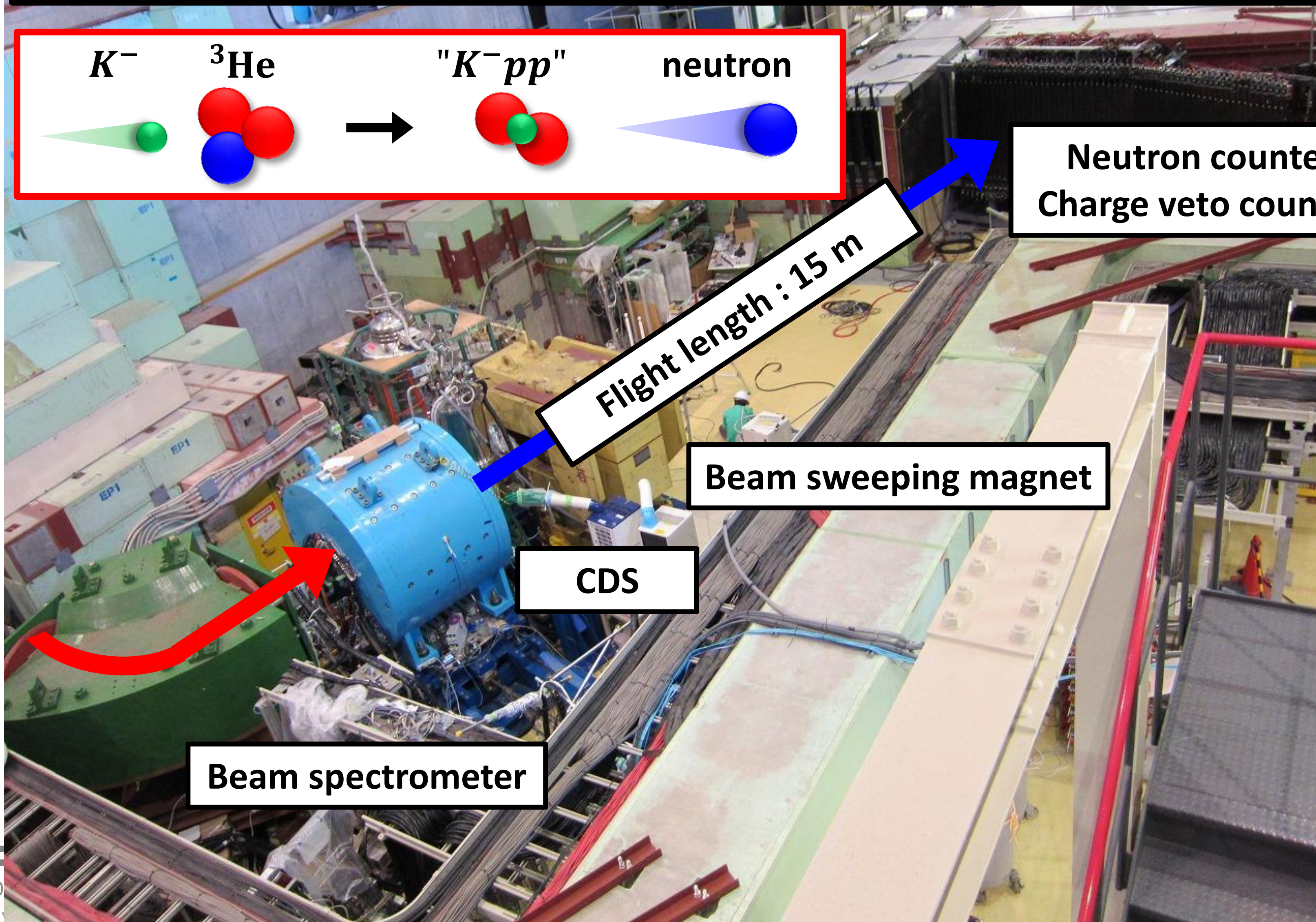
- ▶ **E15-1st experiment**
  - **Assuming 1-pole structure**
  - **Lack of statistics**

- ▶ **E15-2nd experiment**
  - **8-times more K^--beam**
  - **Special trigger condition**
    - » **Statistics becomes larger.**

More detail analysis can be performed.

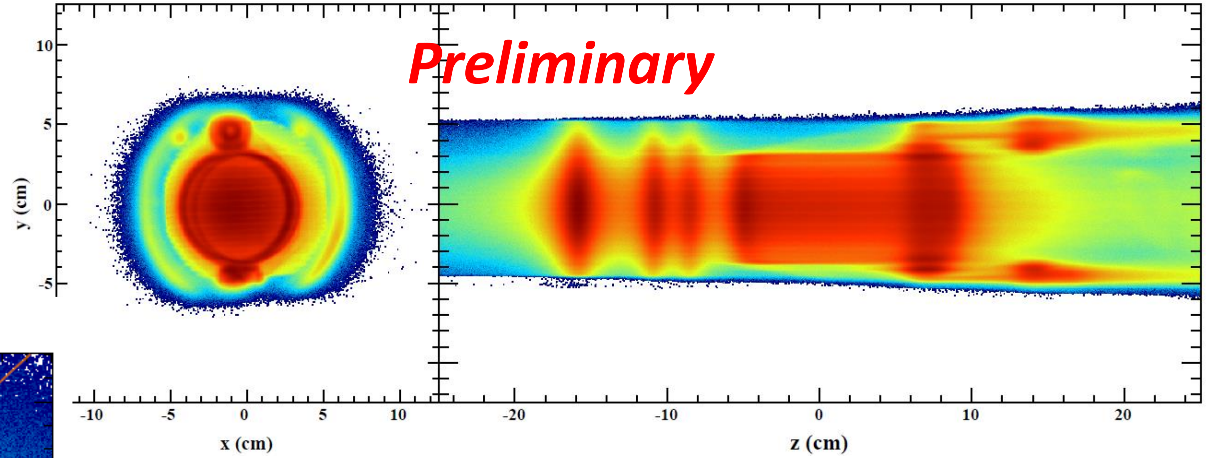
J-PARC E15 experiment

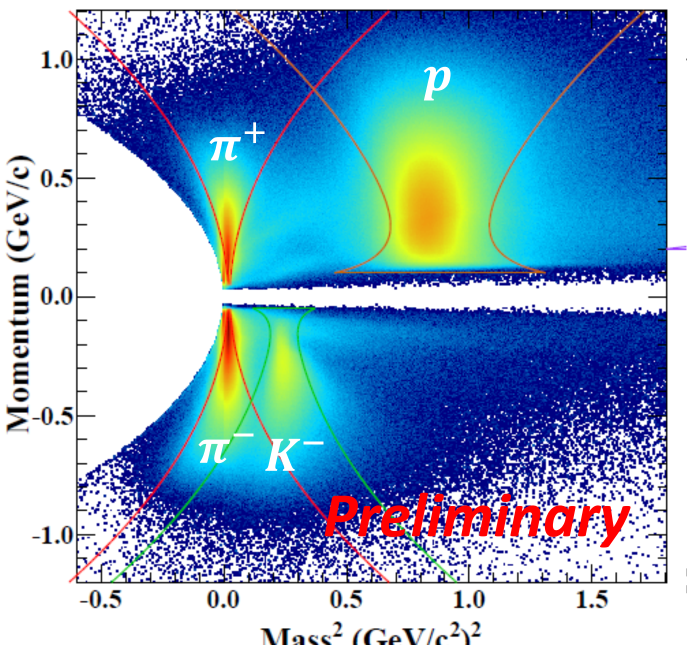
Search for $K^{-}pp$ bound state via the (in−flight K^{-}, n) reaction



Detector Performances

- **Vertex reconstruction**
  - Well performed

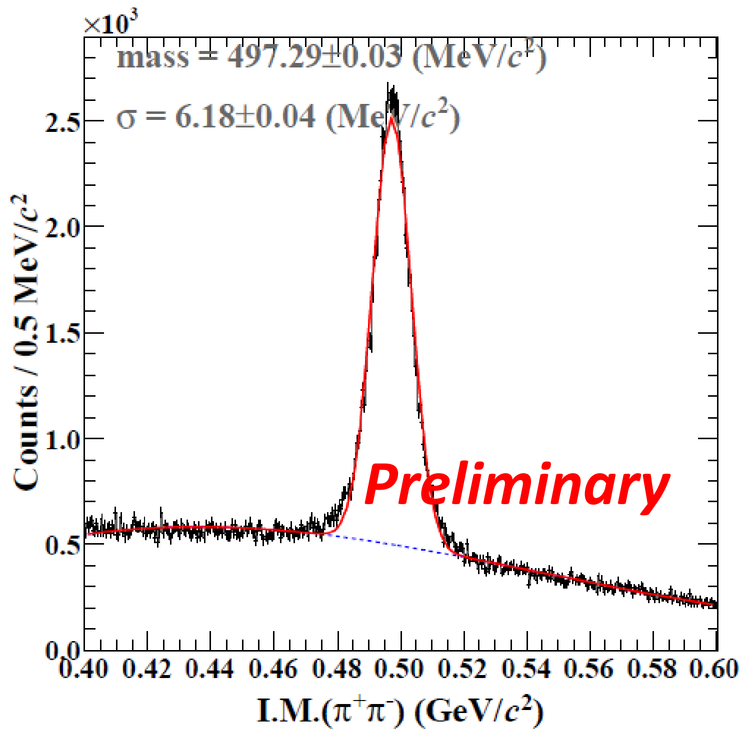


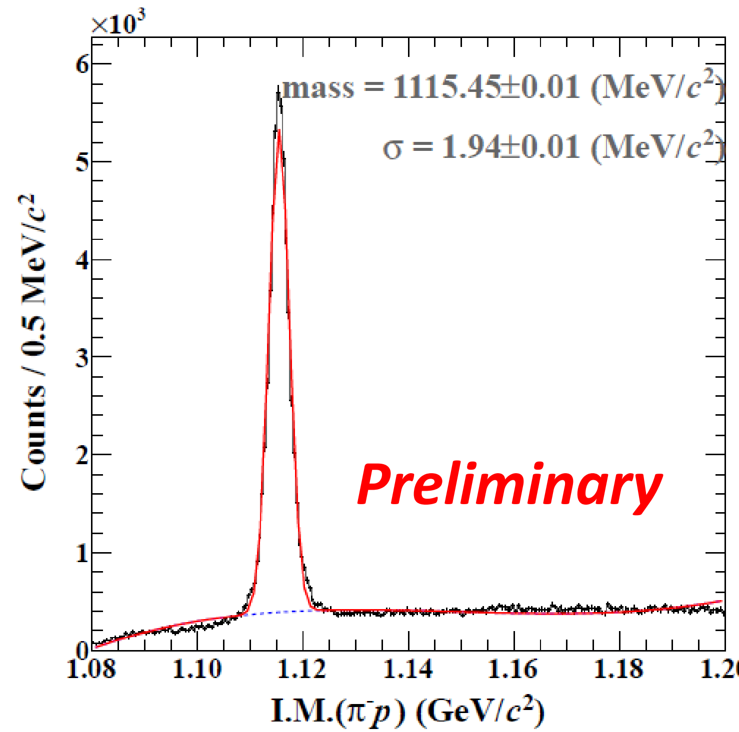


- **PID by CDS**
  - Each particles are clearly separated.
    - 2D PID function is applied.

Detector Performances

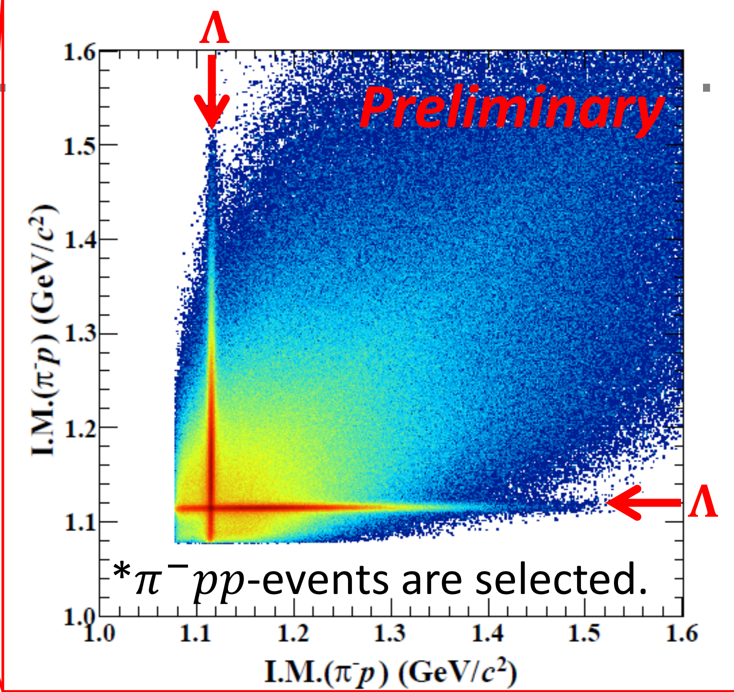
- K^0 and Λ reconstruction
  - Both particles are well reconstructed.
    - Mass position is almost same as the PDG value.

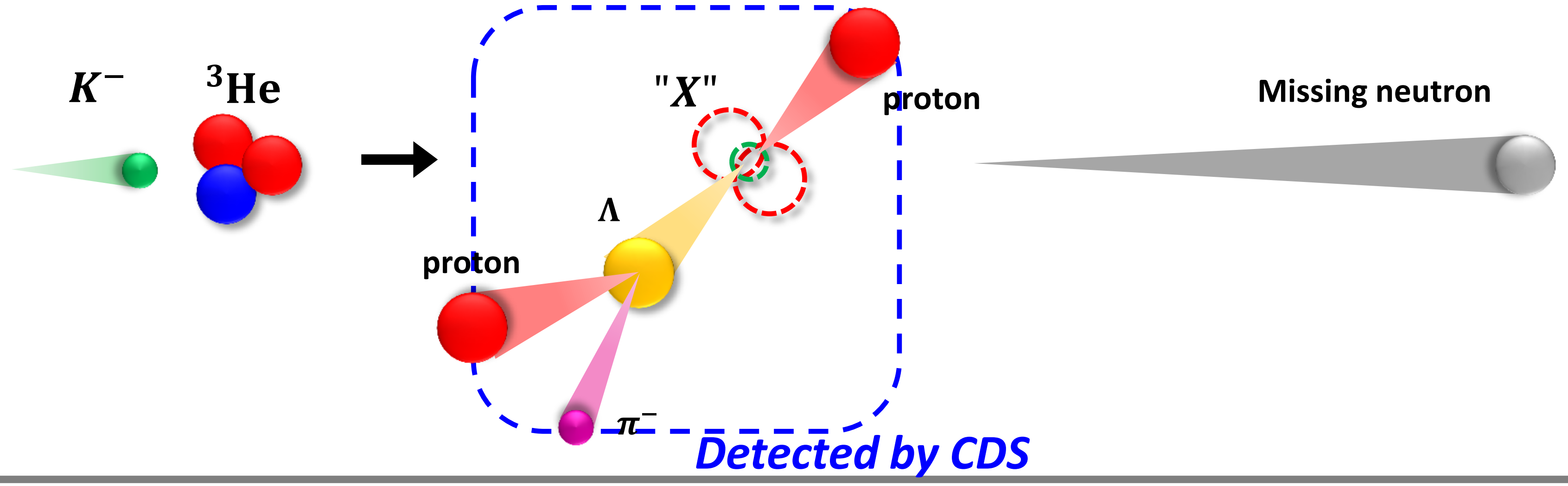




Analysis overview

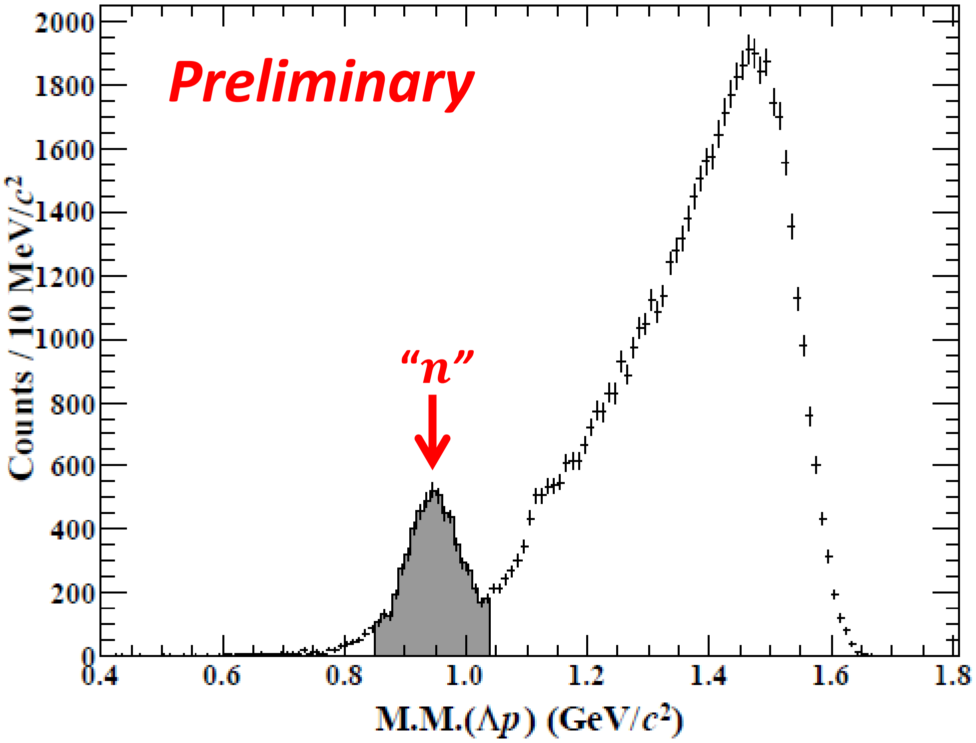
- Λp invariant mass analysis in $^3\mathrm{He}(K^-, \Lambda p)"n"$reaction
  - Event selection
    - Selecting $\pi^- pp$-events
    - Reconstructing Λ from $\pi^- p$-pair
    - "n"-tagging





Analysis overview

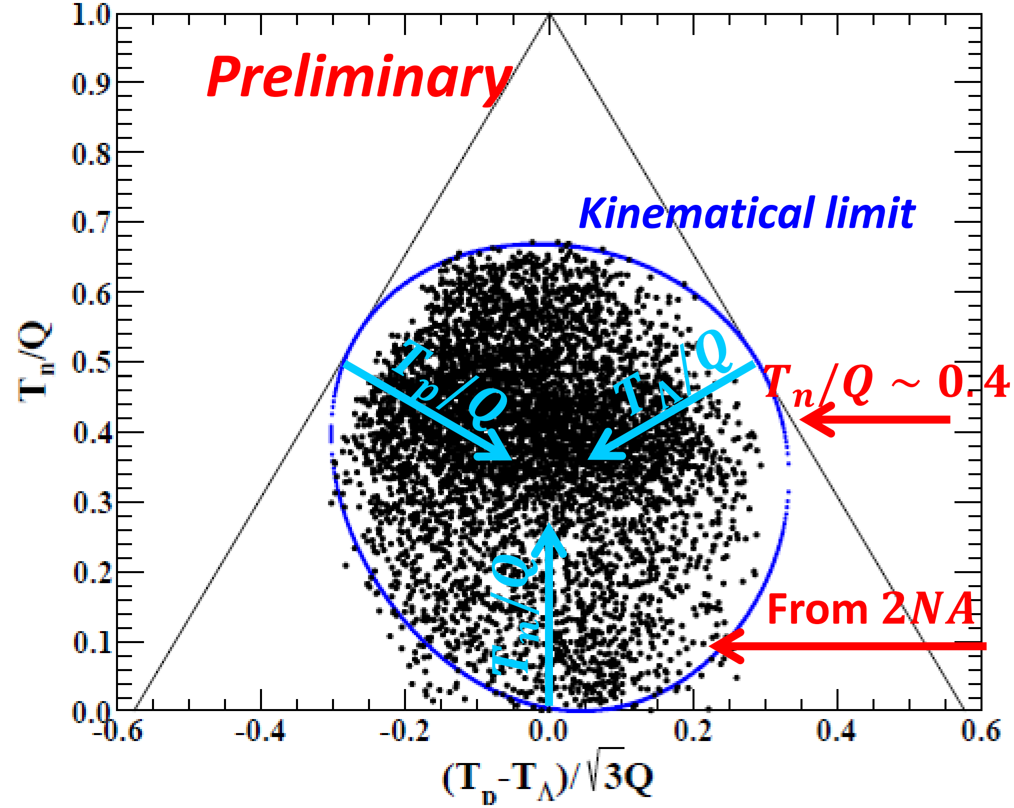
- Λp invariant mass analysis in $^3\mathrm{He}(K^-, \Lambda p)"n"$reaction
  - Event selection
    - Selecting $\pi^- pp$-events
    - Reconstructing Λ from $\pi^- p$-pair
    - "n"-tagging
      - » "n"-peak is clearly observed.



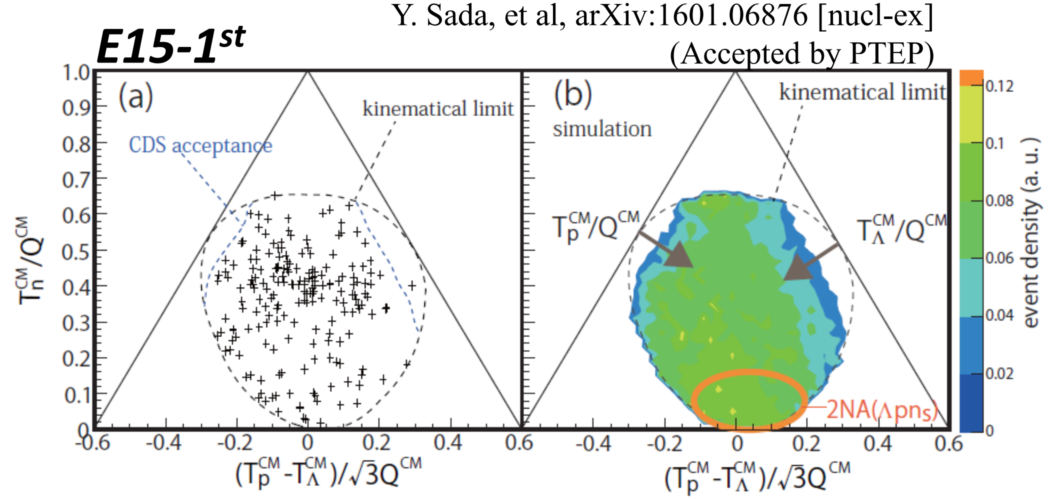
Analysis of Λp"n"

- **Dalitz plot**
  - Widely distributed in phase space
  - Locus around $T_n/Q \sim 0.4$ is observed.

Further analysis is in progress



Y. Sada, et al, arXiv:1601.06876 [nucl-ex]
(Accepted by PTEP)



Summary

- **We performed 2nd physics run to investigate $K^{-}pp$ bound state with high statistics data.**

- **Preliminary analysis results**
  - **MM(Λp) spectrum**
    - **"n"-peak is clearly observed.**
    - **We can select Λp"n" events clearly.**
  - **Analysis of Λp"n" (Dalitz plot)**
    - **Data points are widely distributed in phase space.**
    - **Locus around $T_n/Q \sim 0.4$ is observed.**

Thank you for your attention

~ The E15 collaboration ~

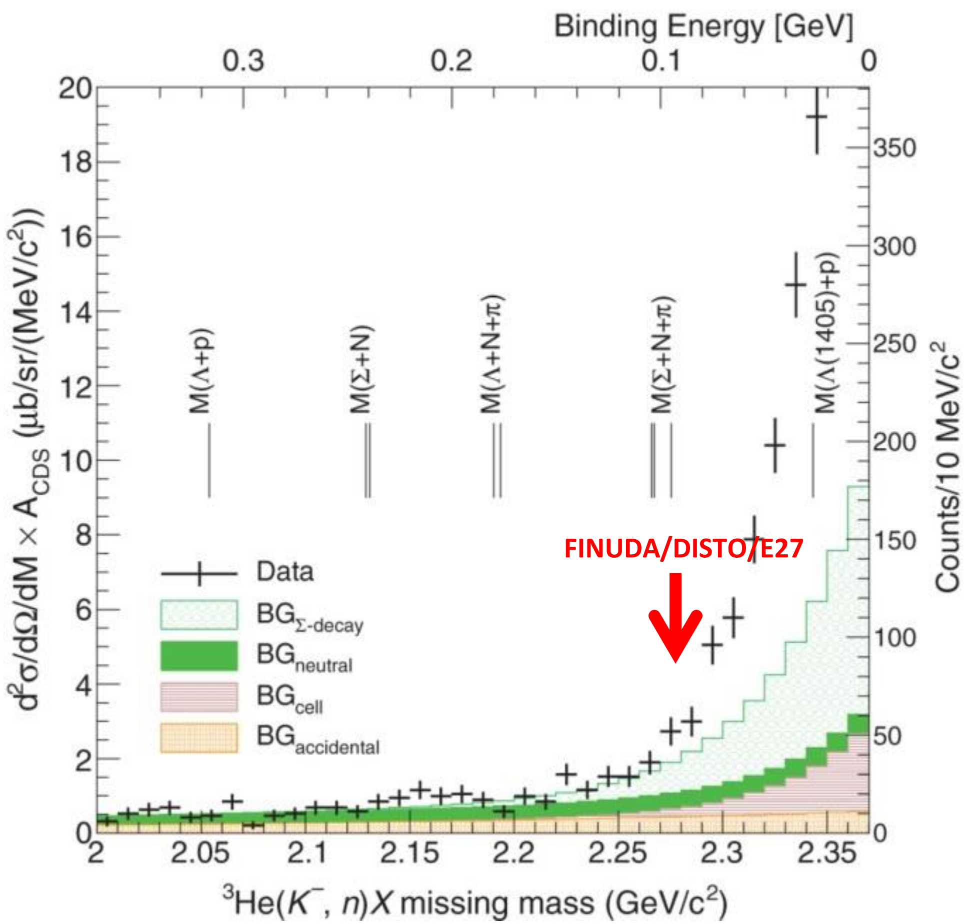
S. Ajimura[a], G. Beer[b], C. Berucci[e], H. Bhang[c], M. Bragadireanu[d], P. Buehler[e], L. Busso[f,g], M. Cargnelli[e], S. Choi[c], C. Curceanu[h], S. Enomoto[n], D. Faso[f,g], H. Fujioka[j], Y. Fujiwara[k], T. Fukuda[l], C. Guaraldo[h], T. Hashimoto[m], R. S. Hayano[k], T. Hiraiwa[a], M. Iio[n], M. Iliescu[h], K. Inoue[a], Y. Ishiguro[j], T. Ishikawa[k], S. Ishimoto[n], T. Ishiwatari[e], K. Itahashi[m], M. Iwai[n], M. Iwasaki[o,m*], K. Kanno[k], K. Kato[j], Y. Kato[m], S. Kawasaki[i], P. Kienle[p], T. Kim[o], H. Kou[o], Y. Ma[m], J. Marton[e], Y. Matsuda[q], Y. Mizoi[l], O. Morra[f], T. Nagae[j†], H. Noumi[a], H. Ohnishi[m,a], S. Okada[m], H. Outa[m], K. Piscicchia[h], A. Romero Vidal[h], Y. Sada[a], A. Sakaguchi[i], F. Sakuma[m], M. Sato[m], A. Scordo[h], M. Sekimoto[n], H. Shi[h], K. Shirotori[a], D. Sirghi[h,d], F. Sirghi[h,d], K. Suzuki[e], S. Suzuki[n], T. Suzuki[k], K. Tanida[u], H. Tatsuno[v], M. Tokuda[o], D. Tomono[a], A. Toyoda[n], K. Tsukada[r], O. Vazquez Doce[h,s], E. Widmann[e], B. K. Wuenschek[e], T. Yamaga[i], T. Yamazaki[k,m], H. Yim[t], Q. Zhang[m], and J. Zmeskal[e]

(J-PARC E15 Collaboration)

(a) *Research Center for Nuclear Physics (RCNP), Osaka University, Osaka, 567-0047, Japan*
(b) *Department of Physics and Astronomy, University of Victoria, Victoria BC V8W 3P6, Canada*
(c) *Department of Physics, Seoul National University, Seoul, 151-742, South Korea*
(d) *National Institute of Physics and Nuclear Engineering - IFIN HH, Romania*
(e) *Stefan-Meyer-Institut für subatomare Physik, A-1090 Vienna, Austria*
(f) *INFN Sezione di Torino, Torino, Italy*
(g) *Dipartimento di Fisica Generale, Universita' di Torino, Torino, Italy*
(h) *Laboratori Nazionali di Frascati dell' INFN, I-00044 Frascati, Italy*
(i) *Department of Physics, Osaka University, Osaka, 560-0043, Japan*
(j) *Department of Physics, Kyoto University, Kyoto, 606-8502, Japan*
(k) *Department of Physics, The University of Tokyo, Tokyo, 113-0033, Japan*
(l) *Laboratory of Physics, Osaka Electro-Communication University, Osaka, 572-8530, Japan*
(m) *RIKEN Nishina Center, RIKEN, Wako, 351-0198, Japan*
(n) *High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801, Japan*
(o) *Department of Physics, Tokyo Institute of Technology, Tokyo, 152-8551, Japan*
(p) *Technische Universität München, D-85748, Garching, Germany*
(q) *Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, 153-8902, Japan*
(r) *Department of Physics, Tohoku University, Sendai, 980-8578, Japan*
(s) *Excellence Cluster Universe, Technische Universität München, D-85748, Garching, Germany*
(t) *Korea Institute of Radiological and Medical Sciences (KIRAMS), Seoul, 139-706, South Korea*
(u) *ASRC, Japan Atomic Energy Agency, Ibaraki 319-1195, Japan*
(v) *Department of Chemical Physics, Lund University, Lund, 221 00, Sweden*

Result of semi-inclusive analysis

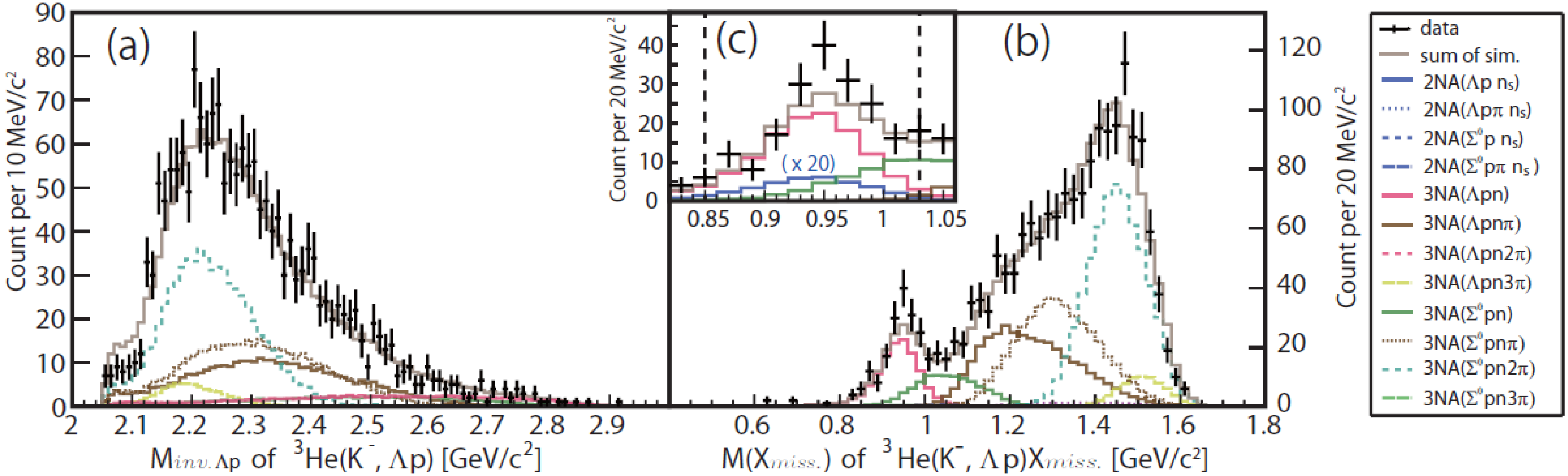
T. Hashimoto, et al, PTEP, **2015**, 061D01



- $^3\mathrm{He}(K^-, n)"X"$ **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

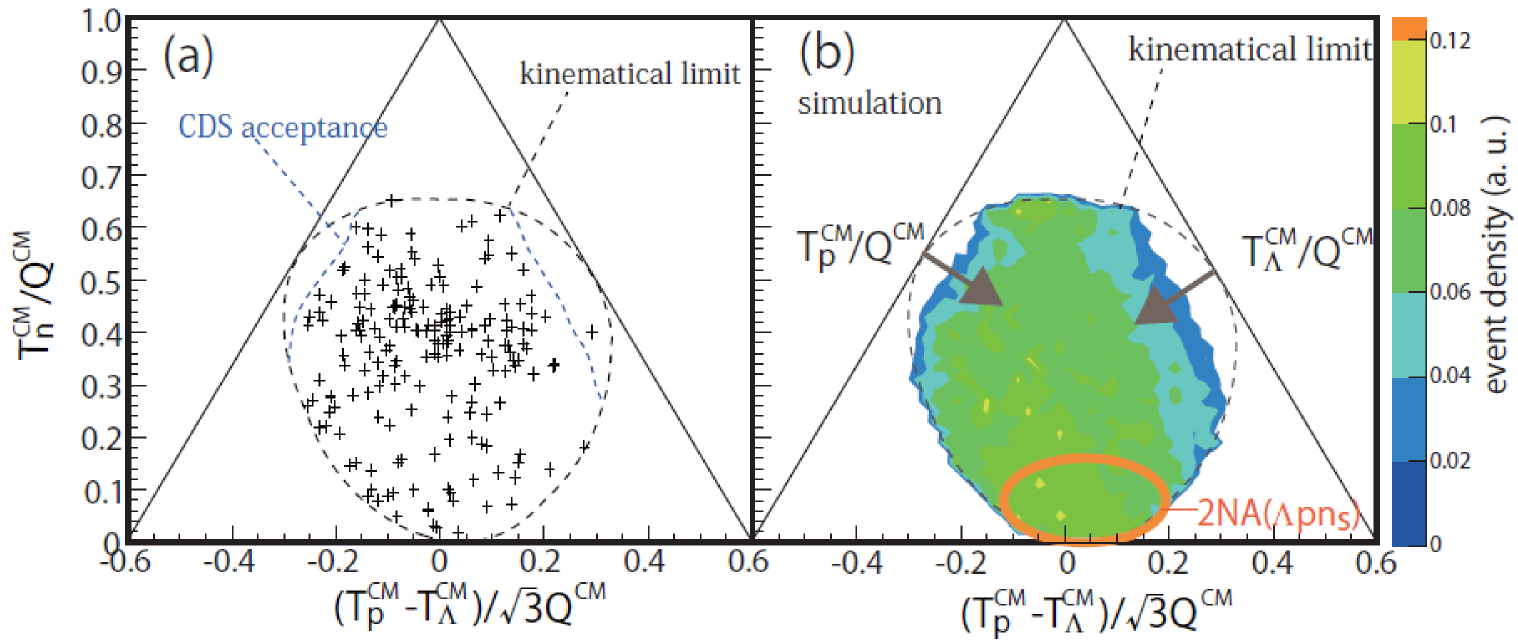
Y. Sada, et al, arXiv:1601.06876 [nucl-ex]



- 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

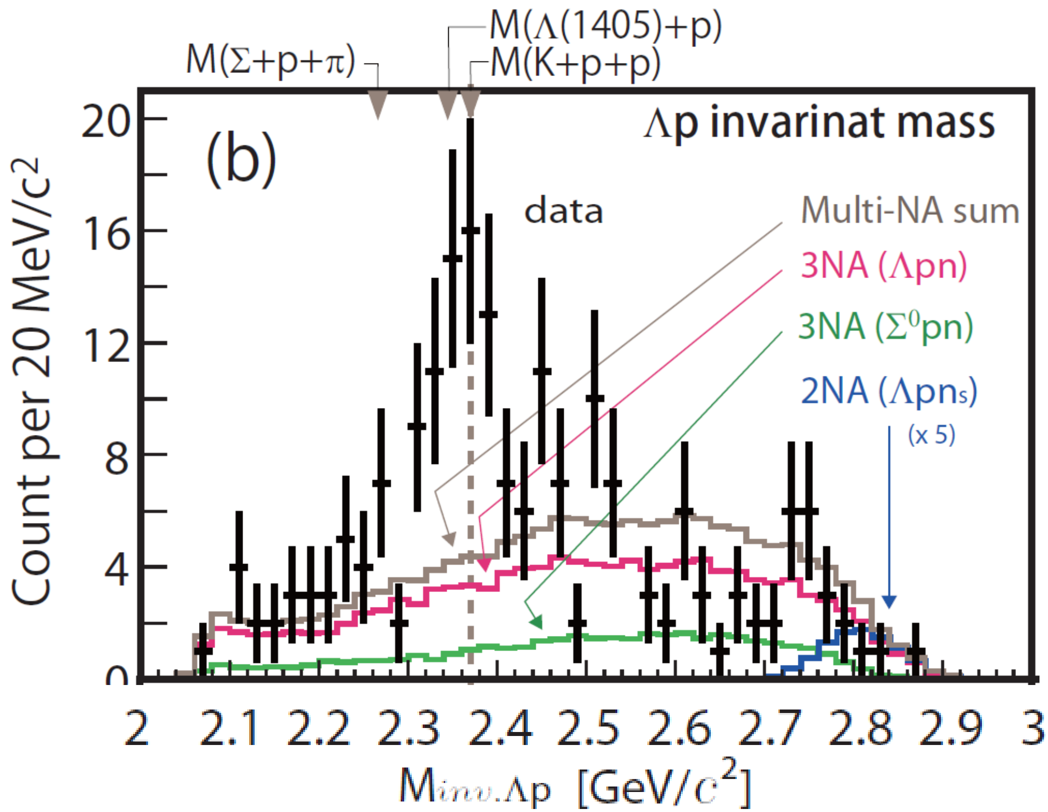
Y. Sada, et al, arXiv:1601.06876 [nucl-ex]



- **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

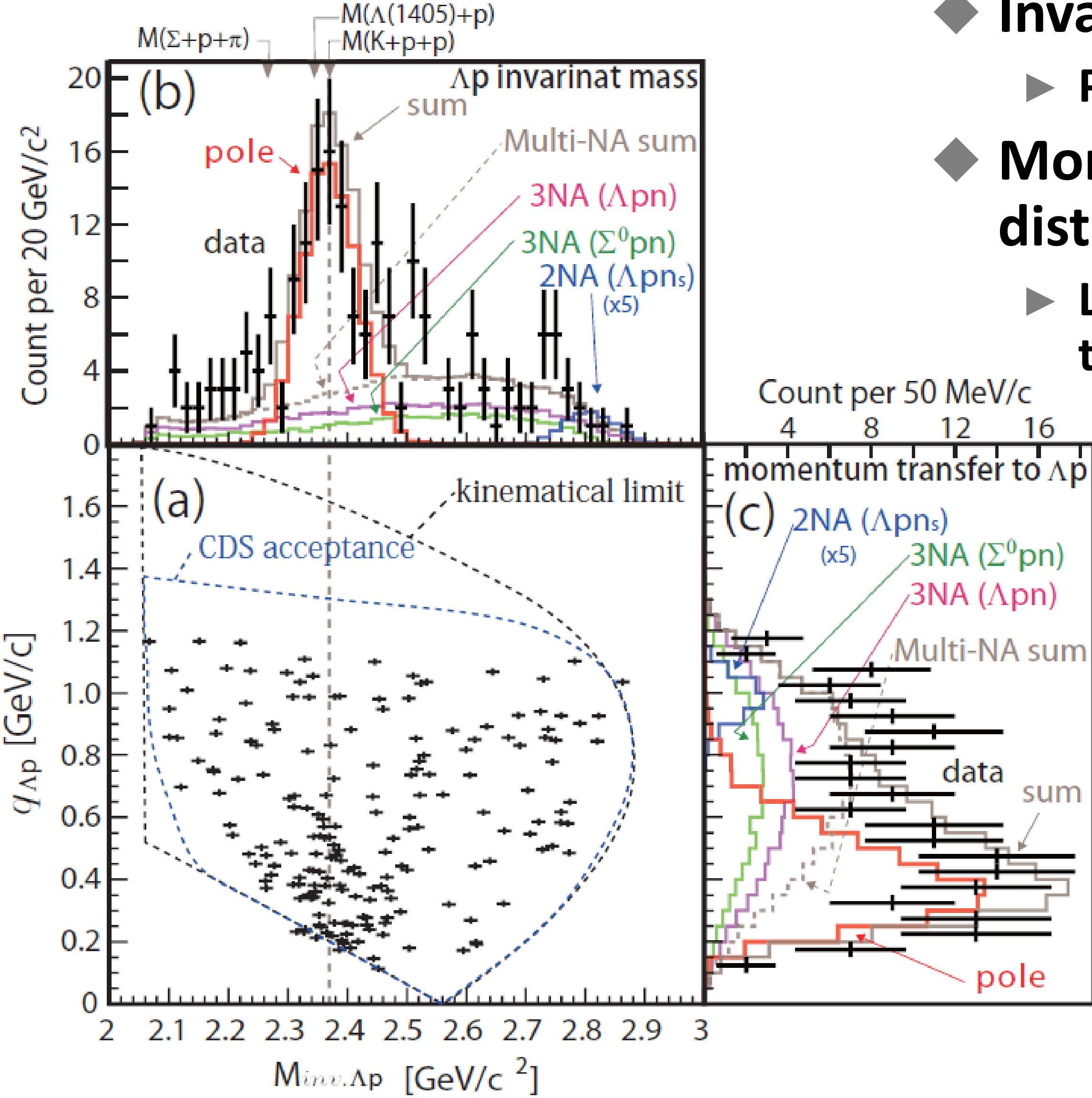
Y. Sada, et al, arXiv:1601.06876 [nucl-ex]



- $\boldsymbol{\Lambda p}$ **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)
$2355^{+8}_{-6}\,(stat.)^{\pm 12}\,(sys.)$	$110^{+19}_{-17}\,(stat.)^{\pm 27}\,(sys.)$

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