Recent results of the experiment to search for KbarNN bound state via the in-fight ^{3}He(K$^-$,N) reactions at J-PARC

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The J-PARC E15 Collaboration

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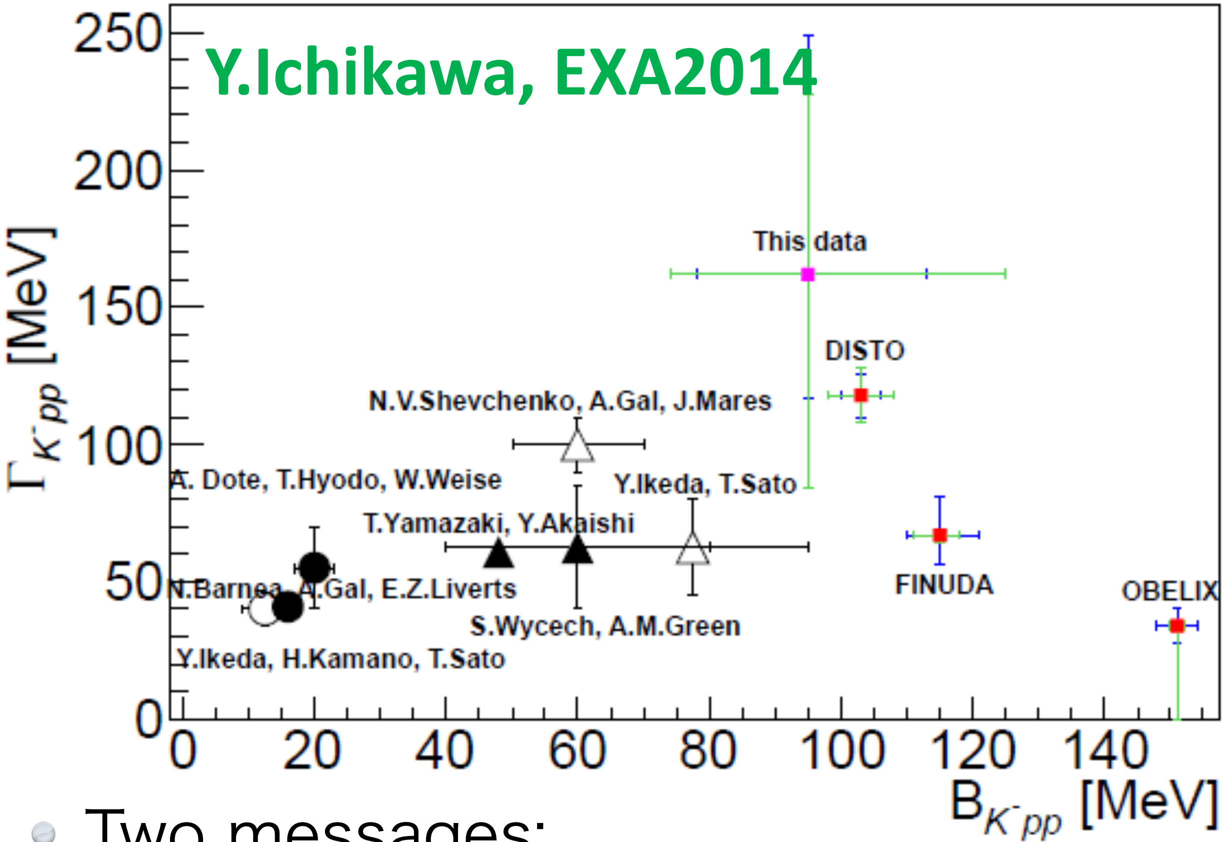
KbarNN bound state



No signal observed

(upper limit are claimed)

- HADES (p-p collisions)
- LEPS (photo- production)

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- Two messages:
  - Theoretically, existence for the KbarNN would be no question, due to strong KbarN attraction, but width would be wide, because of strong Kbar absorption on nucleon
  - However only deeply bound state has been observed

Still need experiment to clarify the situation

Goal for the E15 experiment at J-PARC

- To Searching for the S=-1 di-baryonic system, i.e KbarNN, in K- on 3He reaction for both
  - via measurement on ^{3}He(K-,n) reaction (inclusive analysis)

    Prog. Theor. Exp. Phys. 2015, 061D01
  - via measurement on ^{3}He(K-,n)Λp (exclusive analysis)

    To be submitted to Prog. Theor. Exp. Phys.

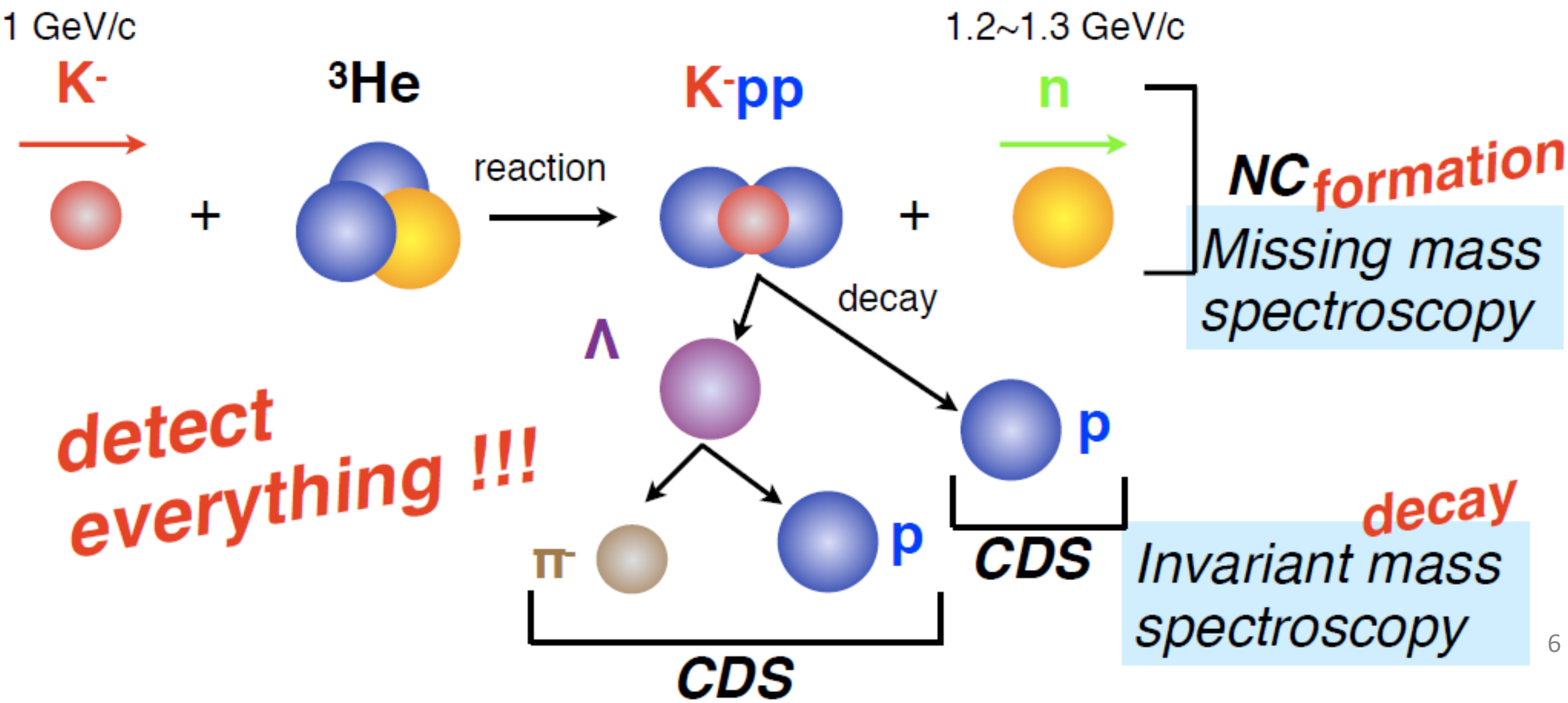
Status of the E15 Experiment

- Production run of ***~1% of the approved proposal*** was successfully carried out in 2013.

	Exp. Target	Primary-beam intensity	Secondary-kaon intensity	Duration	Kaons on target (w/ tgt selection)
May, 2013 (Run#49c)	E15[1st] *^3He*	*24 kW (30 Tppp, 6s)*	*140 k/spill*	*88 h*	*5.3 x 10^9*
Apr-May, 2015 (Run#62)	calibration *H_2*	*26.5 kW (33 Tppp, 6s)*	*130 k/spill*	*73 h*	*3.7 x 10^9*
Apr-May, 2015 (Run#62)	calibration *D_2*	*26.5 kW (33 Tppp, 6s)*	*130 k/spill*	*53 h*	*2.8 x 10^9*

** production target: Au 50% loss, spill length: 2s, spill duty factor: 35~45%, K/pi ratio: ~1/2*
** ~70% of beam kaons hit the fiducial volume of ^{3}He target*

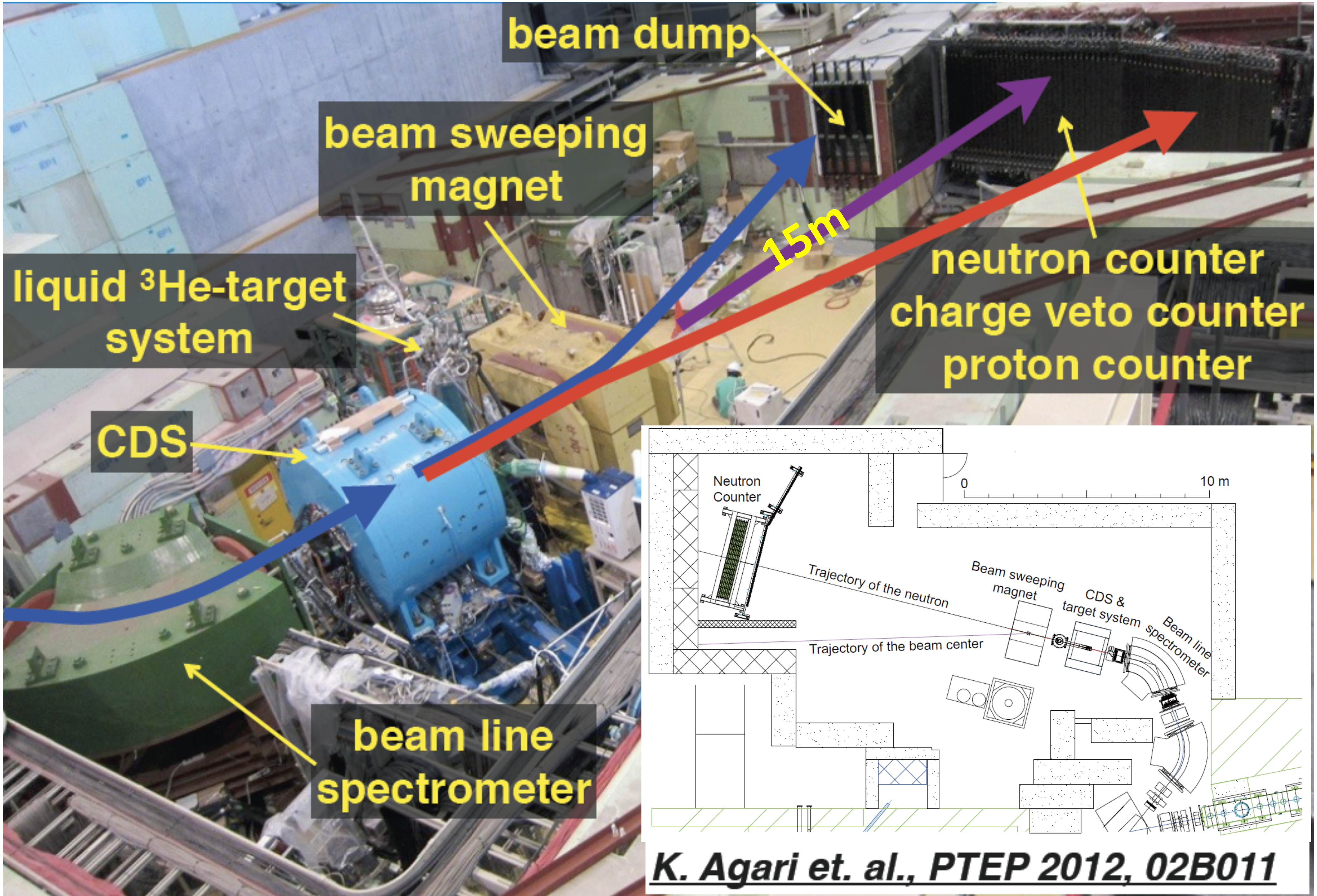
concept for the J-PARC E15 Experiment



- two-nucleon absorption
- hyperon decays

} CAN be discriminated kinematically

Apparatus for the Experiment



K. Agari et. al., PTEP 2012, 02B011

Formation Channel,
inclusive ^{3}He(K$^-$,n) reaction

PTEP

Prog. Theor. Exp. Phys. **2015**, 061D01 (11 pages)
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Letter

Search for the deeply bound $K^- pp$ state from the semi-inclusive forward-neutron spectrum in the in-flight K^- reaction on helium-3

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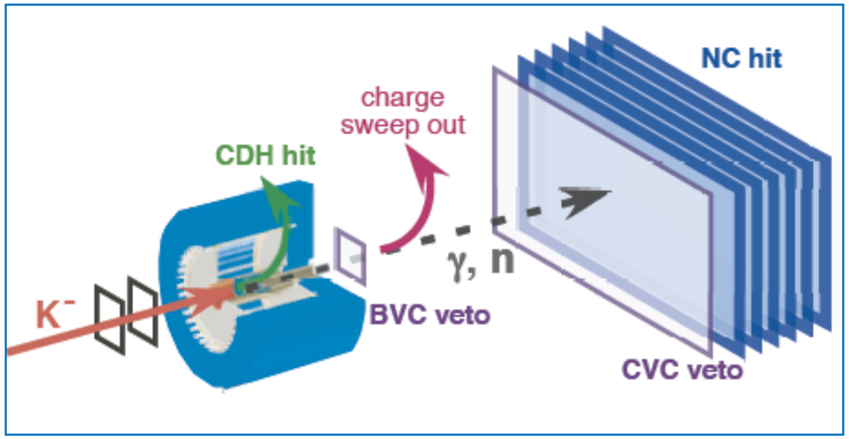
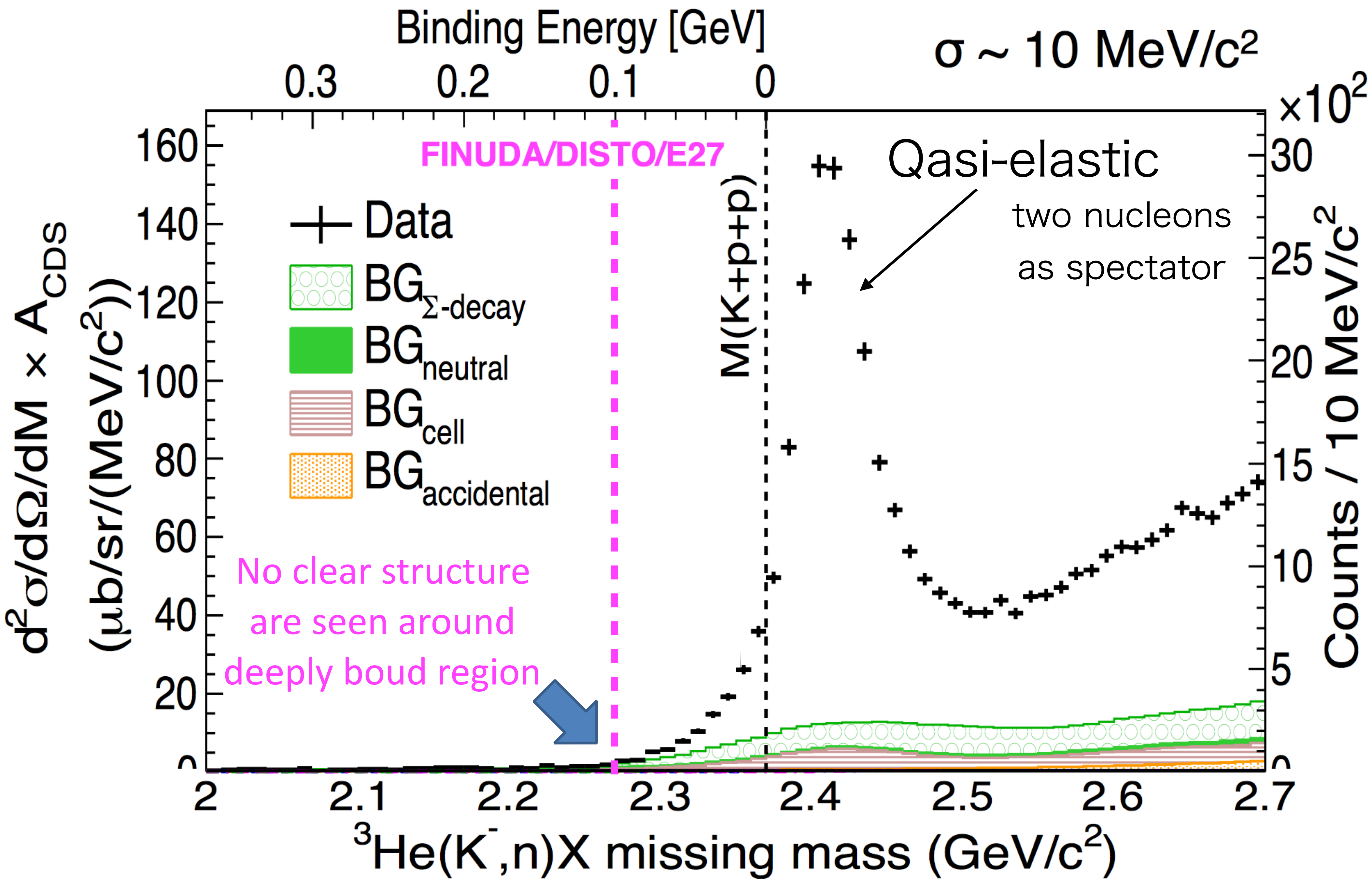
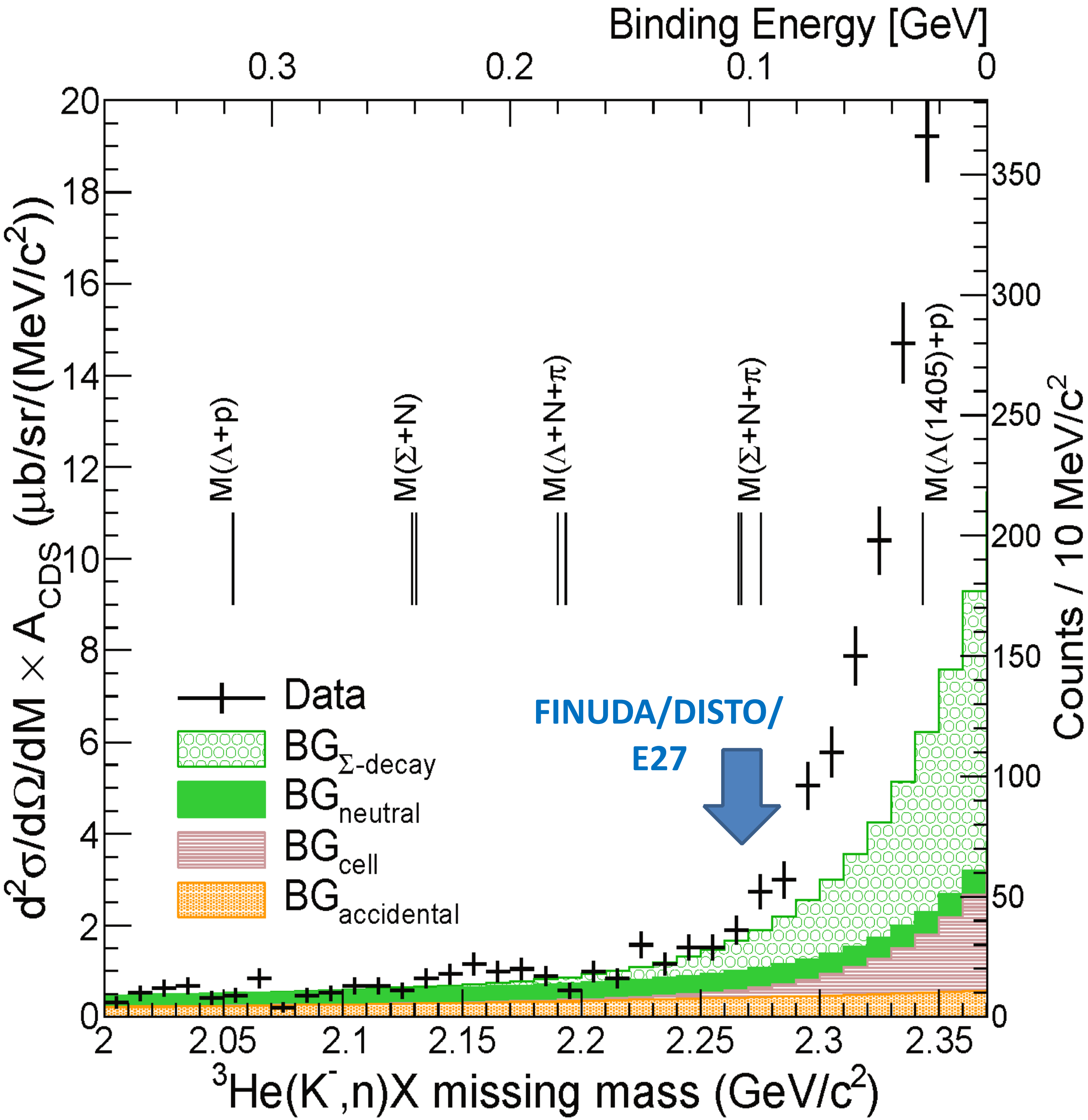
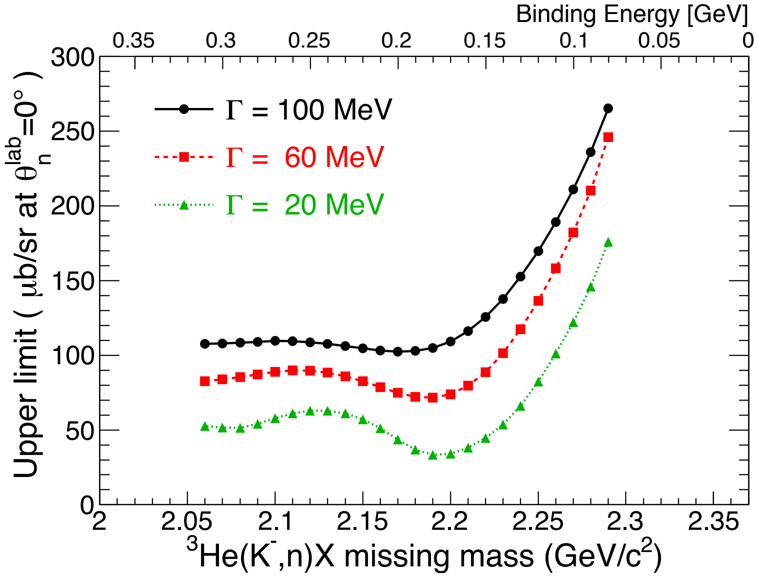


Semi-inclusive $^3He(K^-,n)$ at $\theta_n = 0$



Close-Up of the Deeply-Bound Region





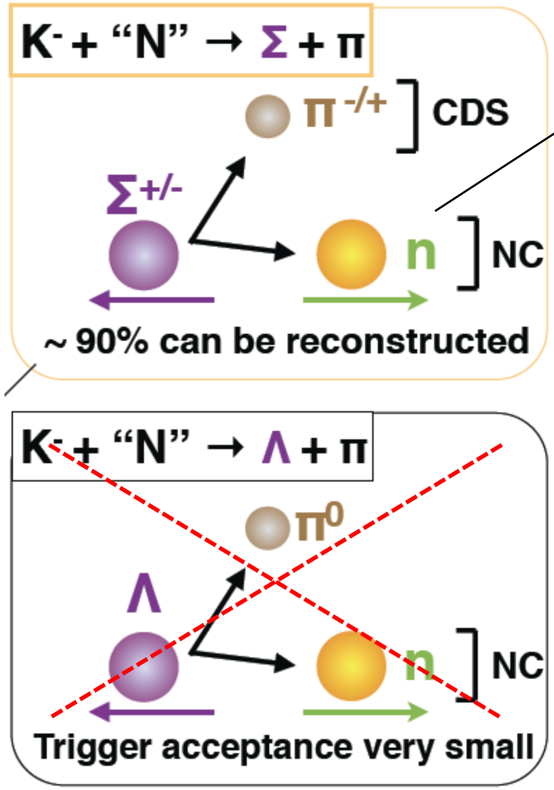
Intrinsic peak shape: Breit-Wigner
Decay mode: **$K^-pp \rightarrow \Lambda p$ 100%** (isotropic decay)

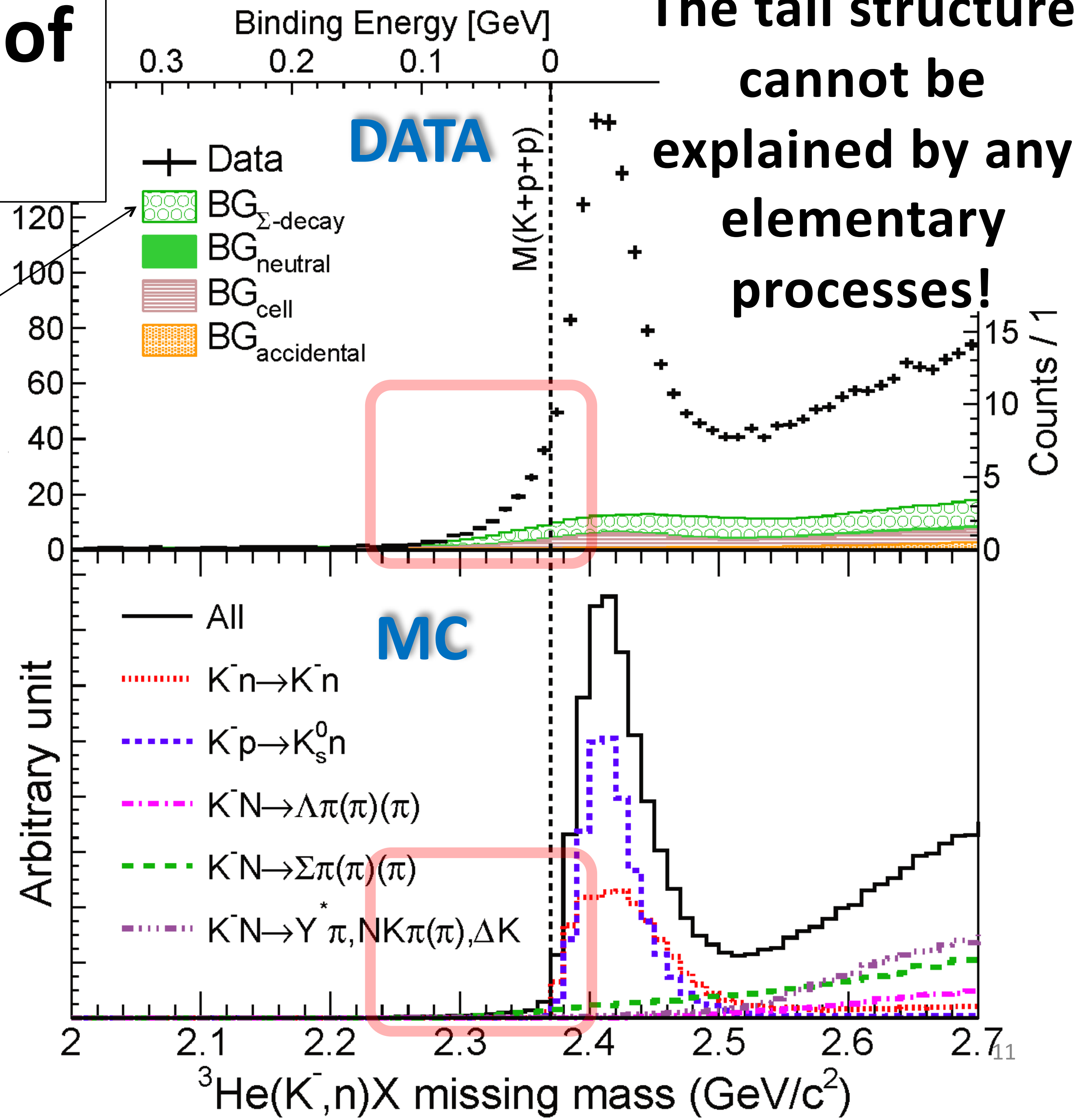
- **J-PARC E15 (U.L.)**
  30 ~ 300 μb/sr @ 0 deg.
  0.5 - 5% of quasi-elastic

smaller than usual hypernucleus sticking

- **LEPS (γ+d) (U.L.)**
  1.5-26% of $\gamma N \rightarrow K^+\pi^- Y$
- **HADES (pp @ 3.5 GeV) (U.L.)**
  0.7-4.2 μb (Λ* ~ 10 μb)

Comparison of $^3He(K^-,n)X$



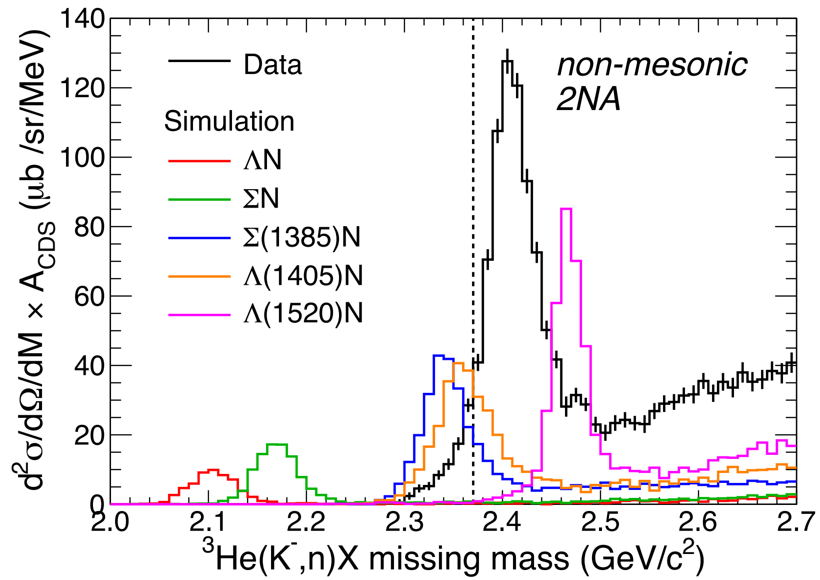


The tail structure cannot be explained by any elementary processes!

Indeed
tail structure
exists

Source of tail structure

- Of course, it will be able to explain by the attractive nature of KbarN potential and its absorption
- However, other possibilities are proposed.
  i.e. no-mesonic two nucleon absorption of Λ(1405)
- To explain the excess all by due to Λ(1405), we need to assume rather large Λ(1405) production cross section
  (~ 5mb!!!)

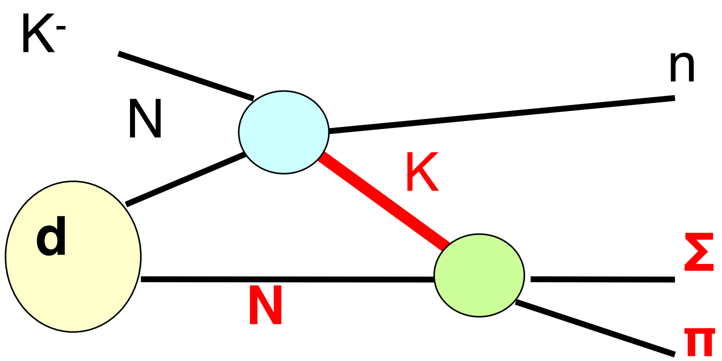


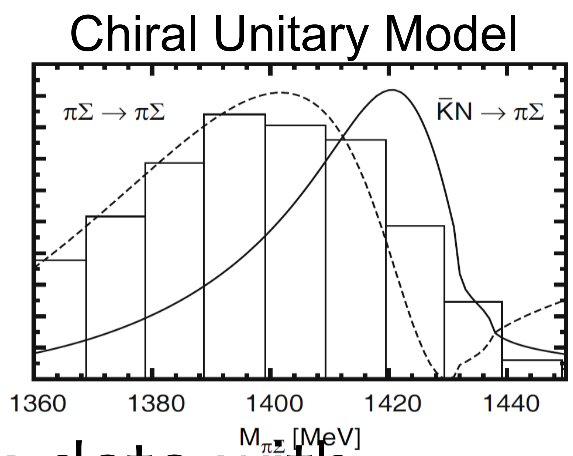
Probably, we need to understand the production of Λ(1405) on nucleus

indeed J-PARC E31 experiment!!

Λ(1405) production on deuterium

- The aim of the E31 experiment is to produce Λ(1405) via d(K-,n) reaction
  - advantage for the reaction:
    →we can access KN reaction below KN threshold
    (direct production of Λ(1405) is possible)

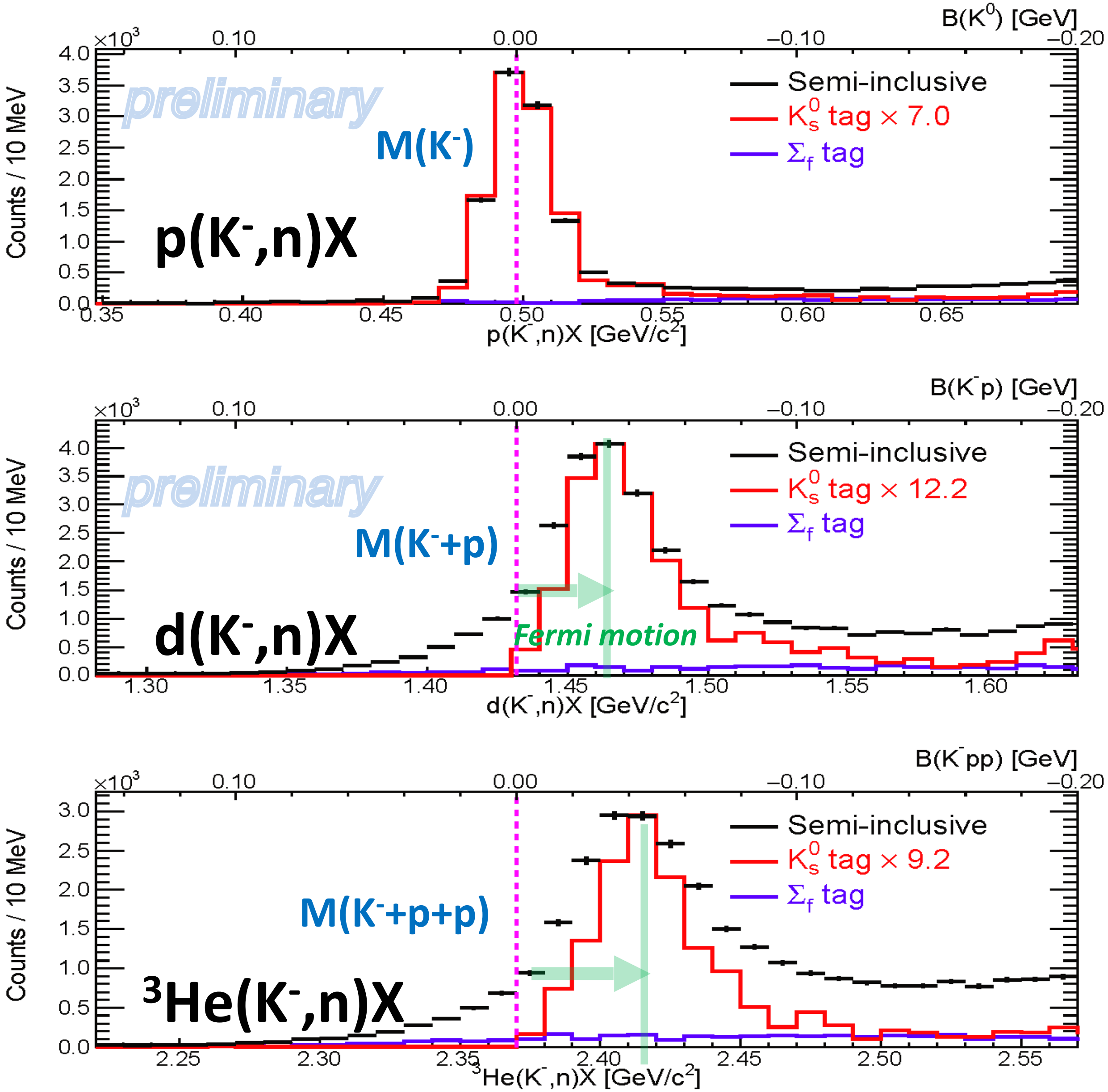




D. Jido et al., NPA725(03)181

- In 2014, the E15 experiment took data with hydrogen and deuterium for calibration purpose.
- This data can be used as feasibility test for the Λ(1405) production on nucleus (this case for deuteron)

(K-,n) reaction on different target



- $K^-p \rightarrow K^0 + n_{fw}$

well describes the spectrum

- $K^-d \rightarrow [K^-p] + n_{fw}$

Y*

sub-threshold excess is seen

The main goal of E31

- $K^{-3}He \rightarrow [K^-pp] + n_{fw}$

Y*N

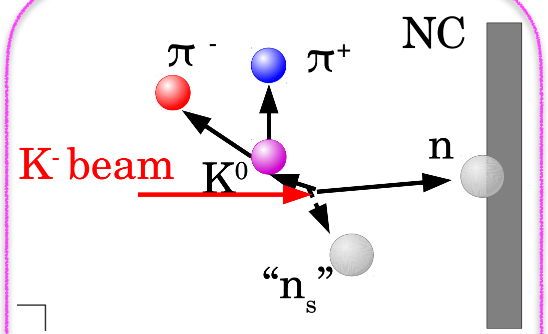
sub-threshold excess is seen

Excess seen both d and 3He

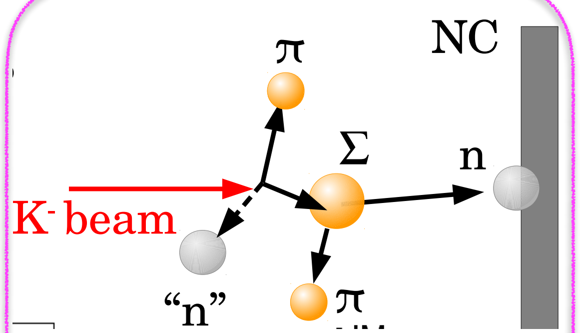
Understanding of the Λ(1405) contribution in d(K-n) spectra may give us the answer to the sub-threshold excess on 3He(K-,n) data

One step further

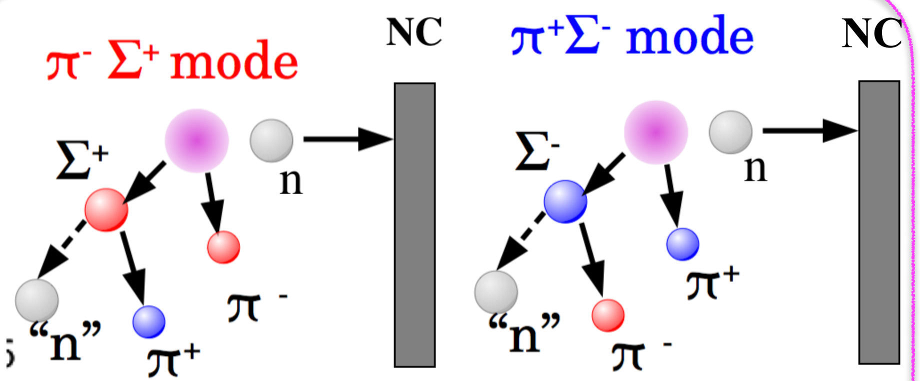
- Focusing on the analysis for d(K-,n) reaction data.
- Events with only “$\pi^+\pi^-$n n” in final state are selected
  - one neutron detected via NC
  - the other identified by missing mass analysis
- In the sample, contribution from following reaction are expected



quasi-free
backward K0



Forward
Σ production



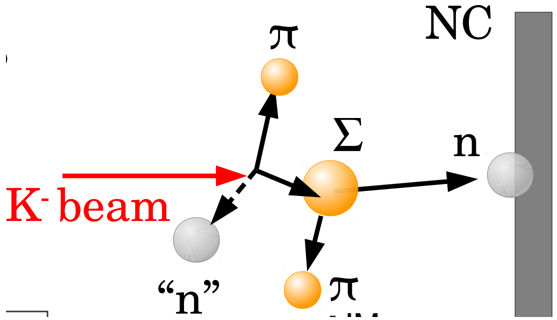
backword $\pi\Sigma$ production

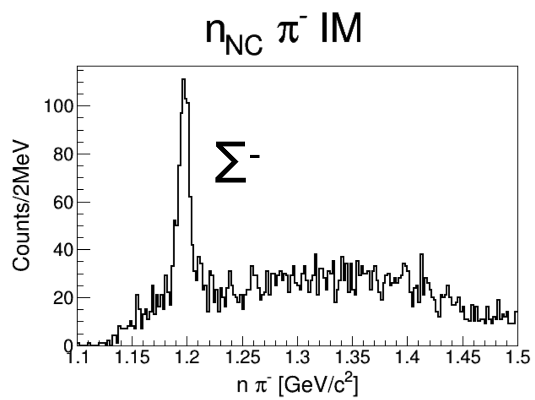
Background

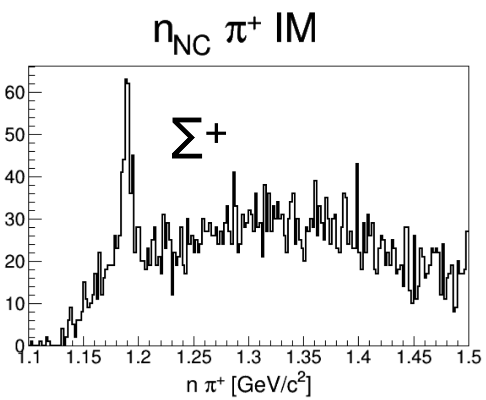
signal !!!

Toward d(K-,n)$\pi\Sigma$ reaction

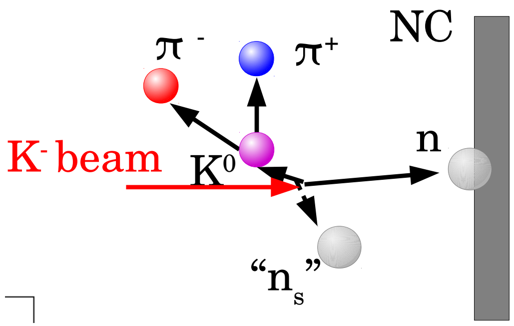
- Forward $\Sigma^{\pm}$ produced events will be identified invariant mass analysis on forward neutron and pion in CDC

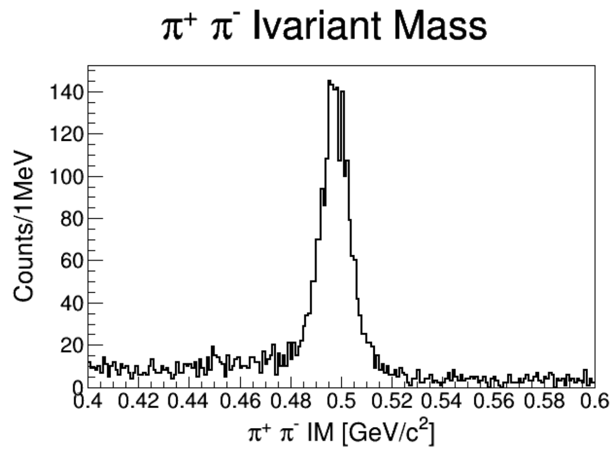






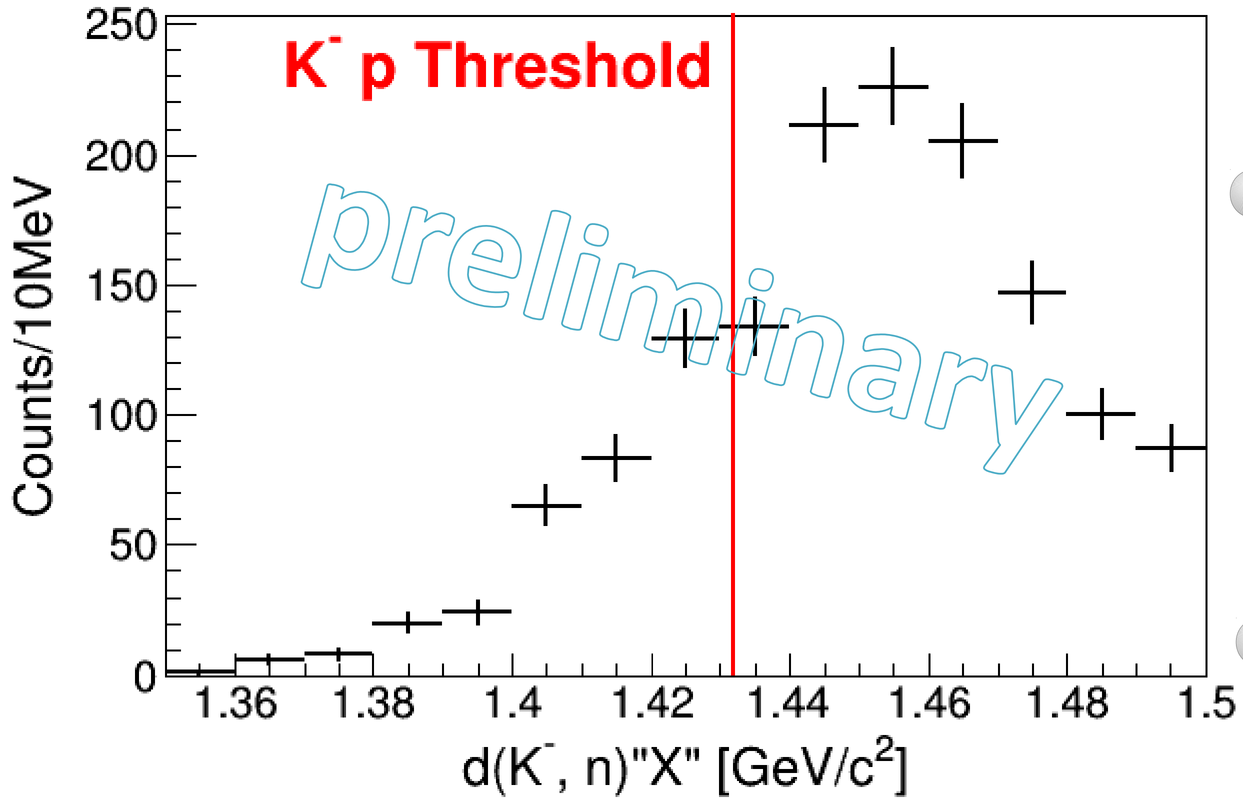
- backward K^0 produced, charge exchange reaction, will be identified vis invariant mass analysis with $\pi\pi$

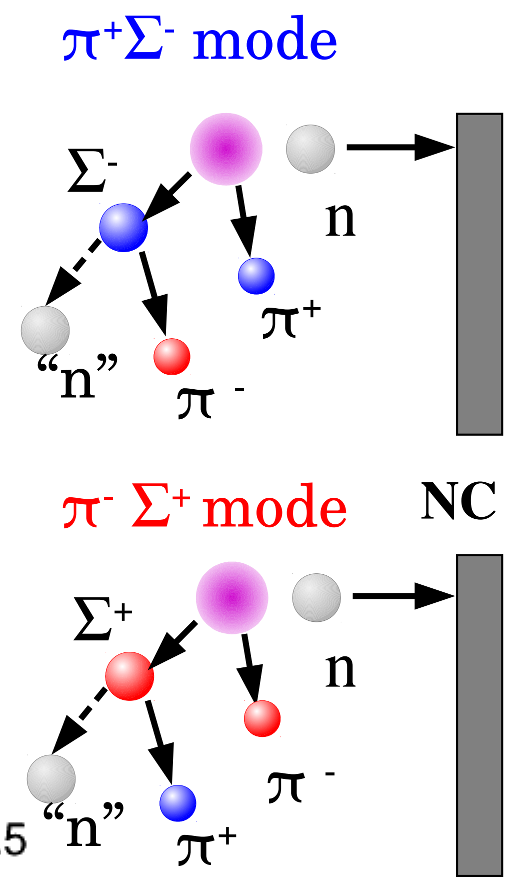




Those contribution are removed from final data sample

d(K$^-$, n)"X$_{\pi^\mp\Sigma^\pm}$" Spectrum





No separation btw. 2 charged modes
No acceptance correction

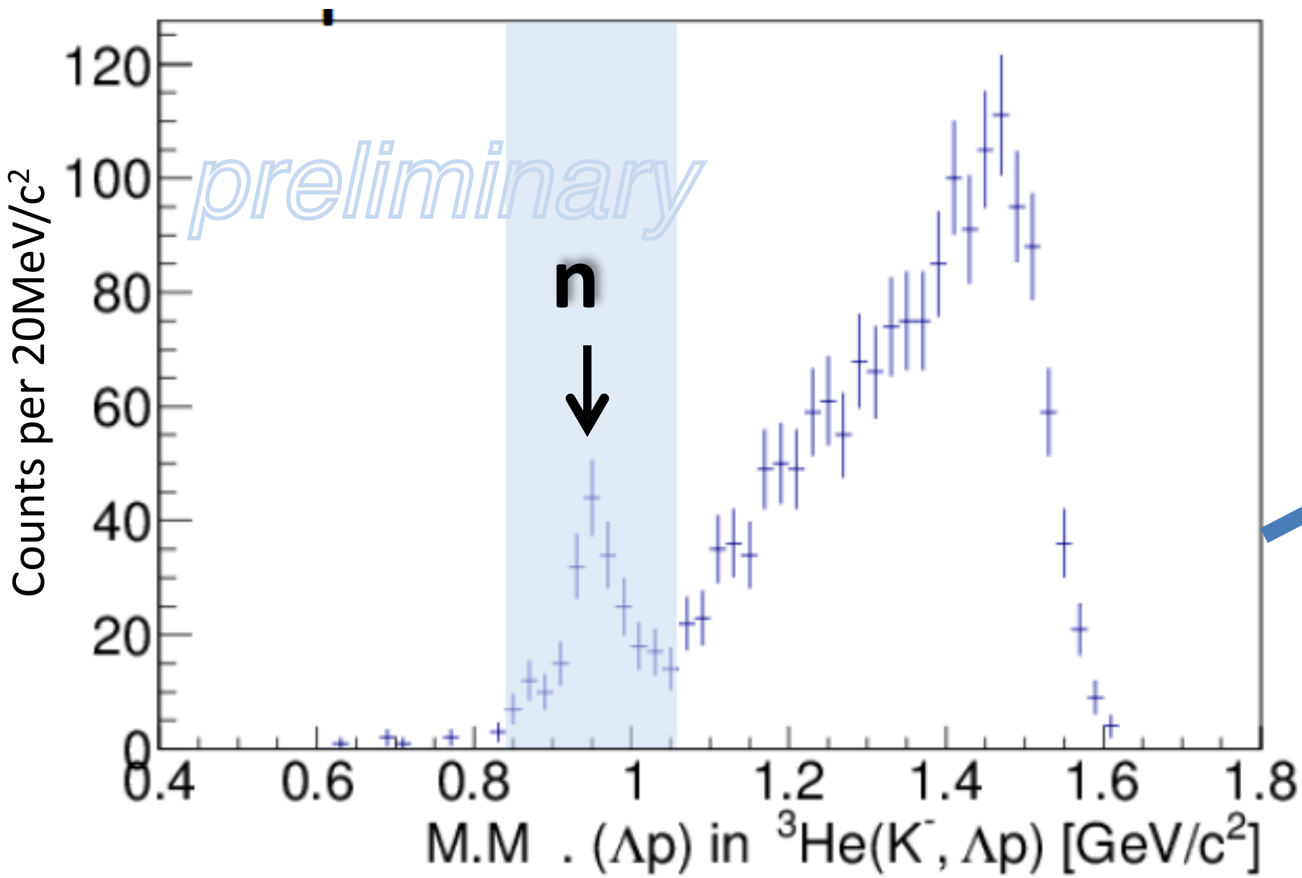
Significant amount of backward $\pi\Sigma$ production event exist below threshold energy

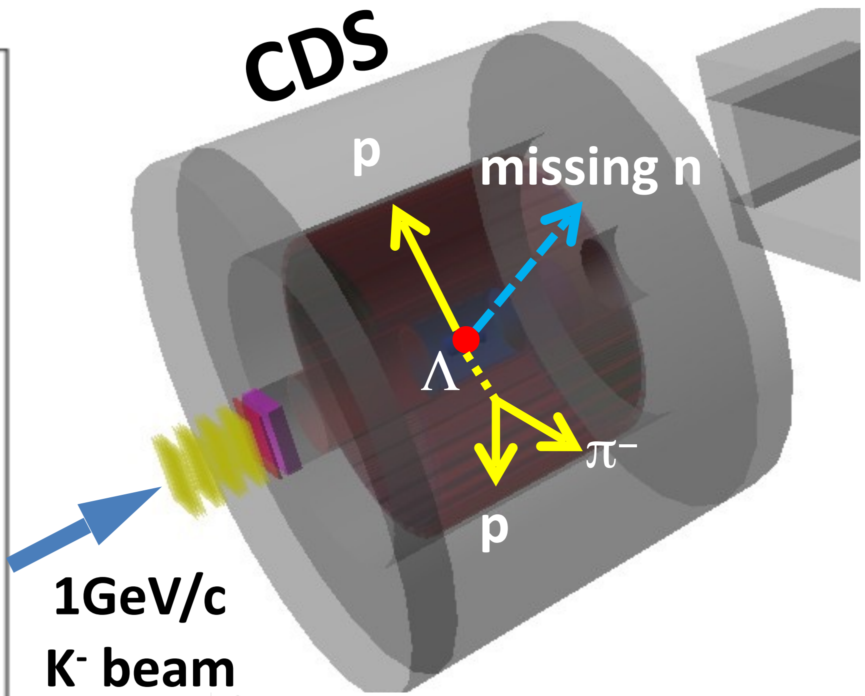
→ understanding of the structure will shed light on the sub-threshold enhancement in 3He(K-,n) reaction

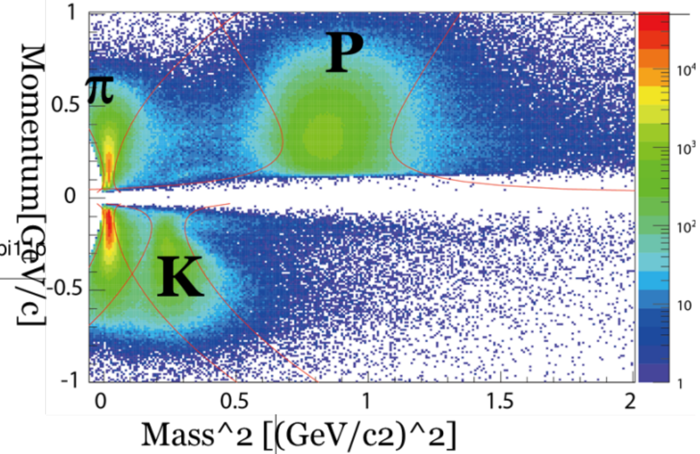
Decay Channel,
Exclusive $^{3}He(K^{-},\Lambda p)n$

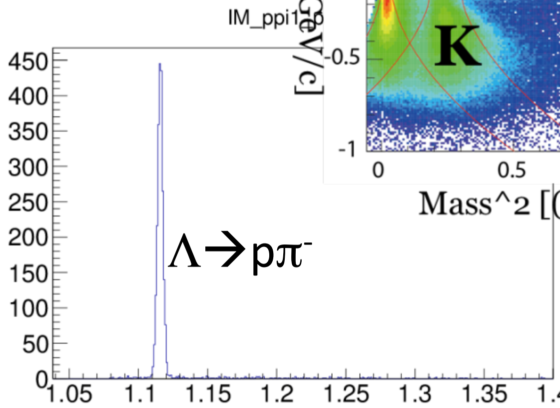
Y.Sada et al., paper in preparation

Exclusive ^{3}He(K$^-$,Λp)n events



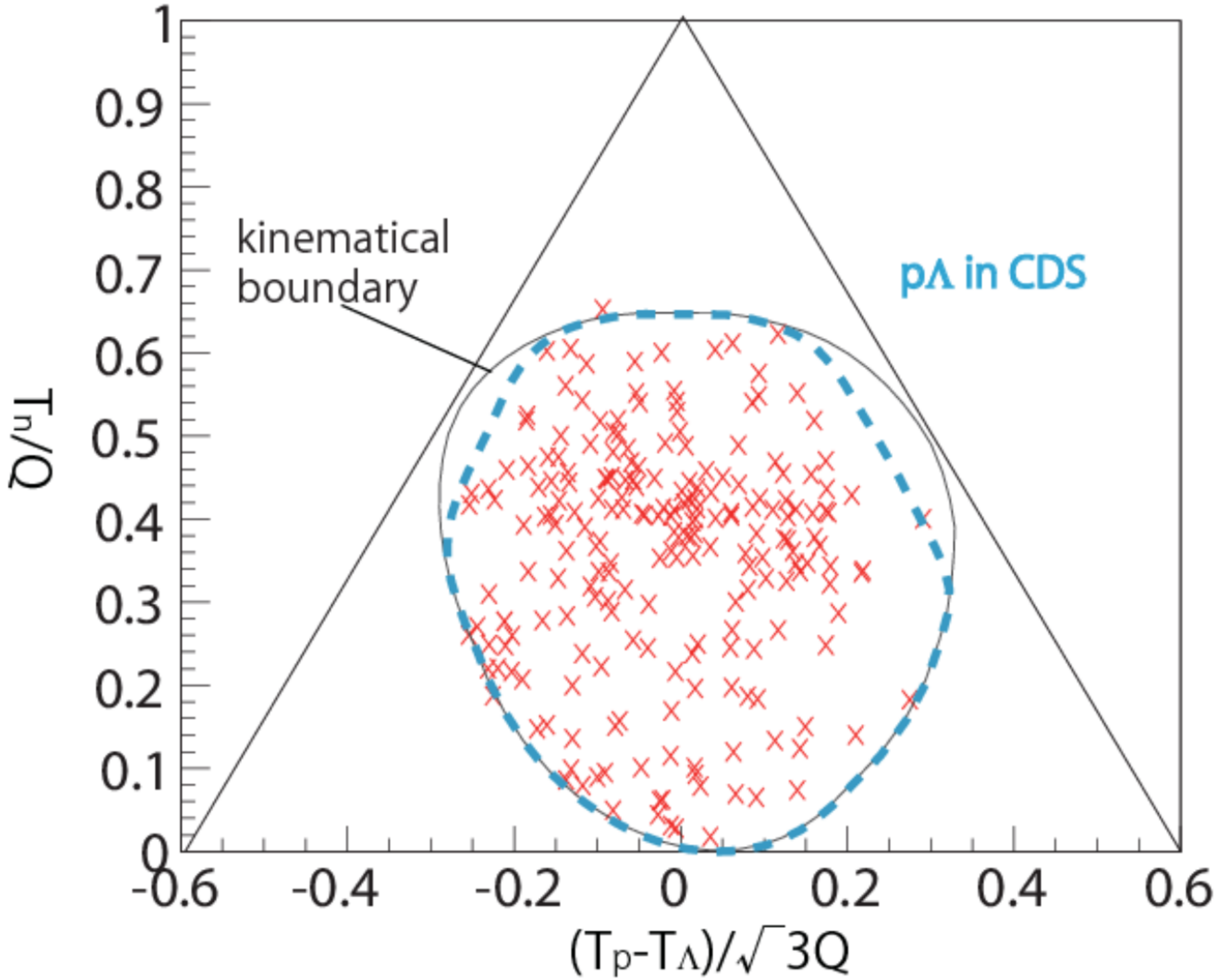




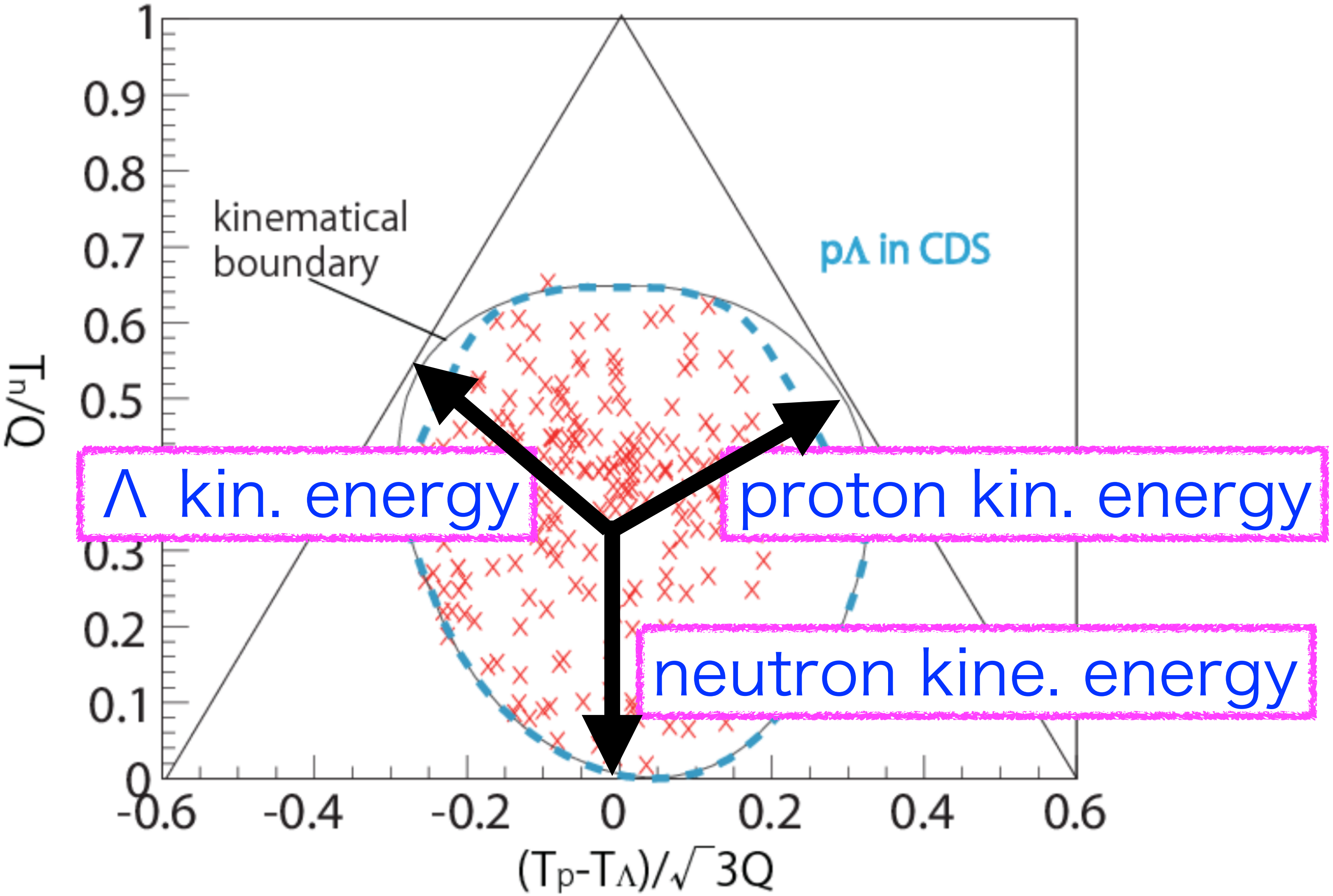


- $K^{-3}He \rightarrow \Lambda(\Sigma^0)pn$ events can be identified exclusively
  - \# of $\Lambda(\Sigma^0)pn$ events: ~200
    - $\Sigma^0 pn$ contamination: ~20%

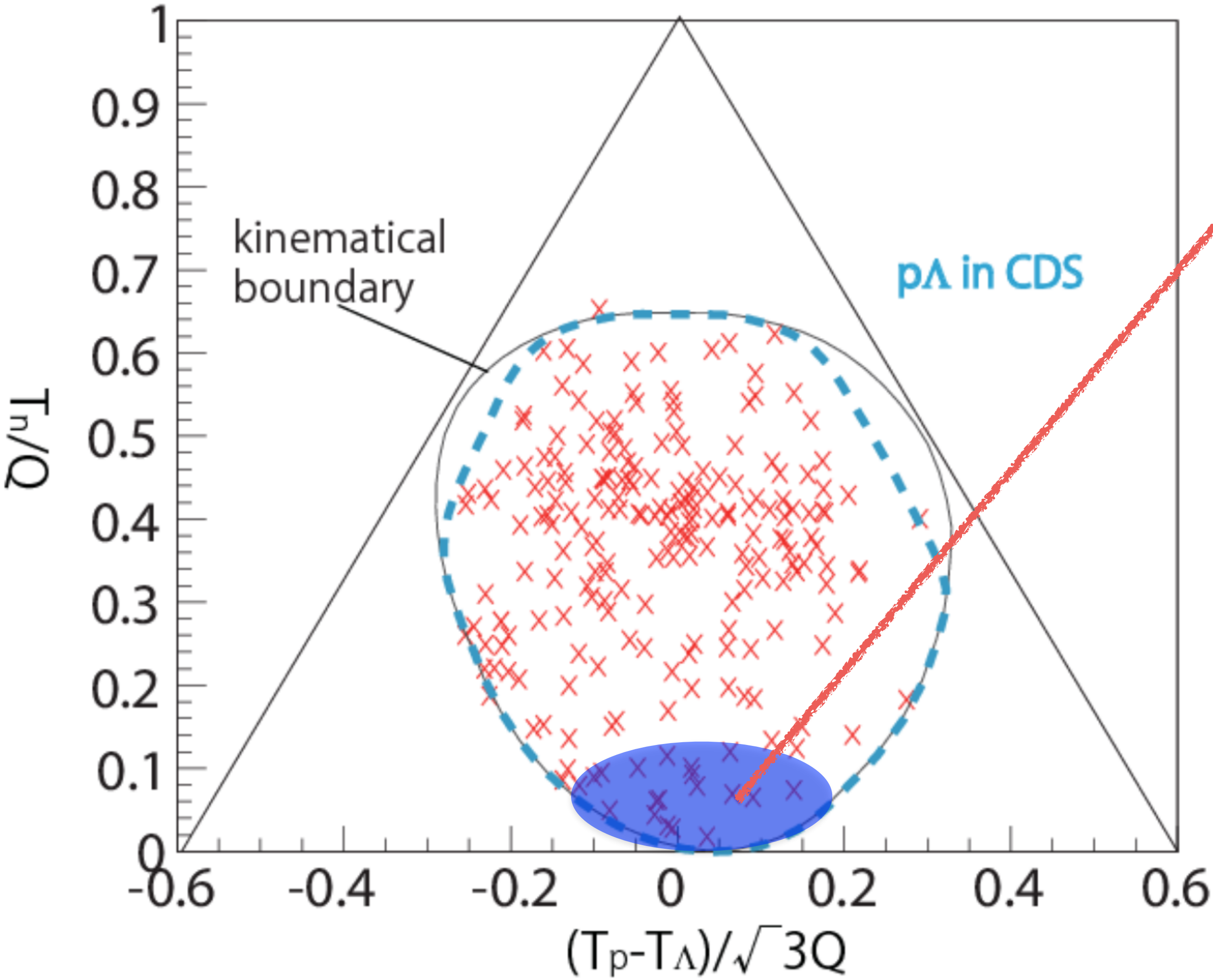
Kinematical distribution of Λpn final state



Kinematical distribution of Λpn final state



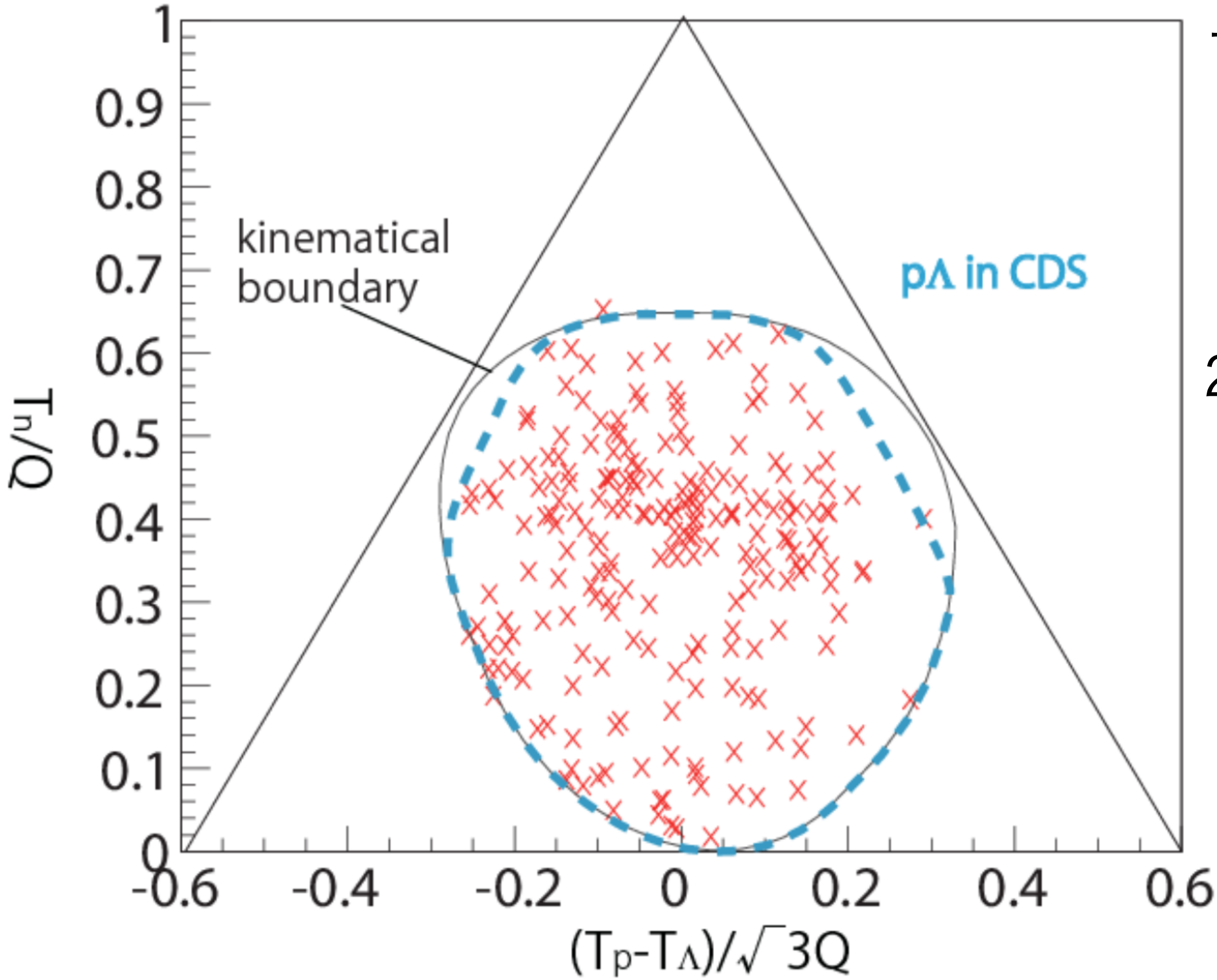
Kinematical distribution of Λpn final state



neutron spectator event (2NA) will be appeared here!

we have good acceptance for neutron spectator 2NA events

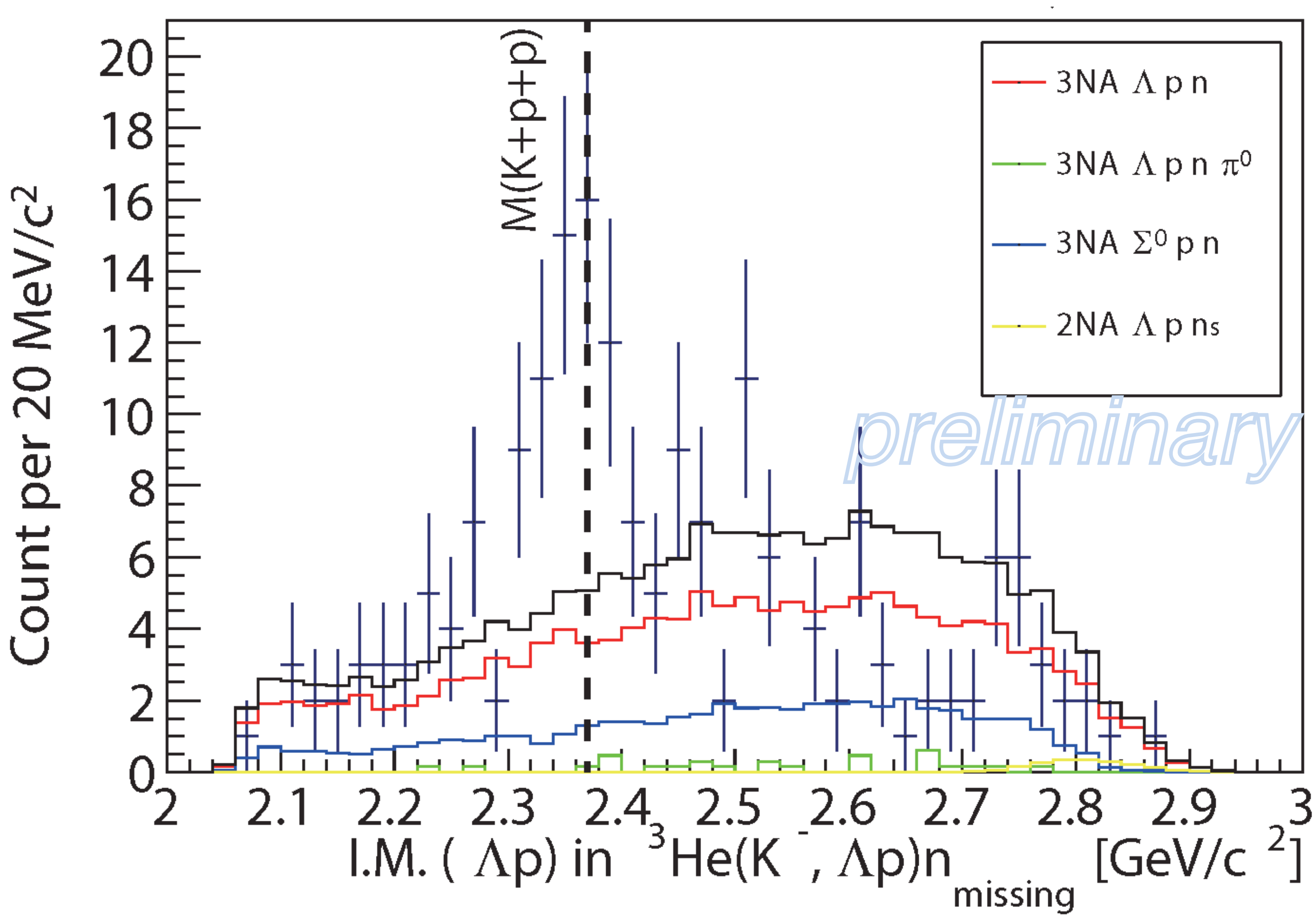
Kinematical distribution of Λpn final state



1) event widely distributed
   -> energy for kaon is equally distributed to 3 nucleons
2) 2NA absorption is not observed clearly (it was major contribution in kaon at rest)

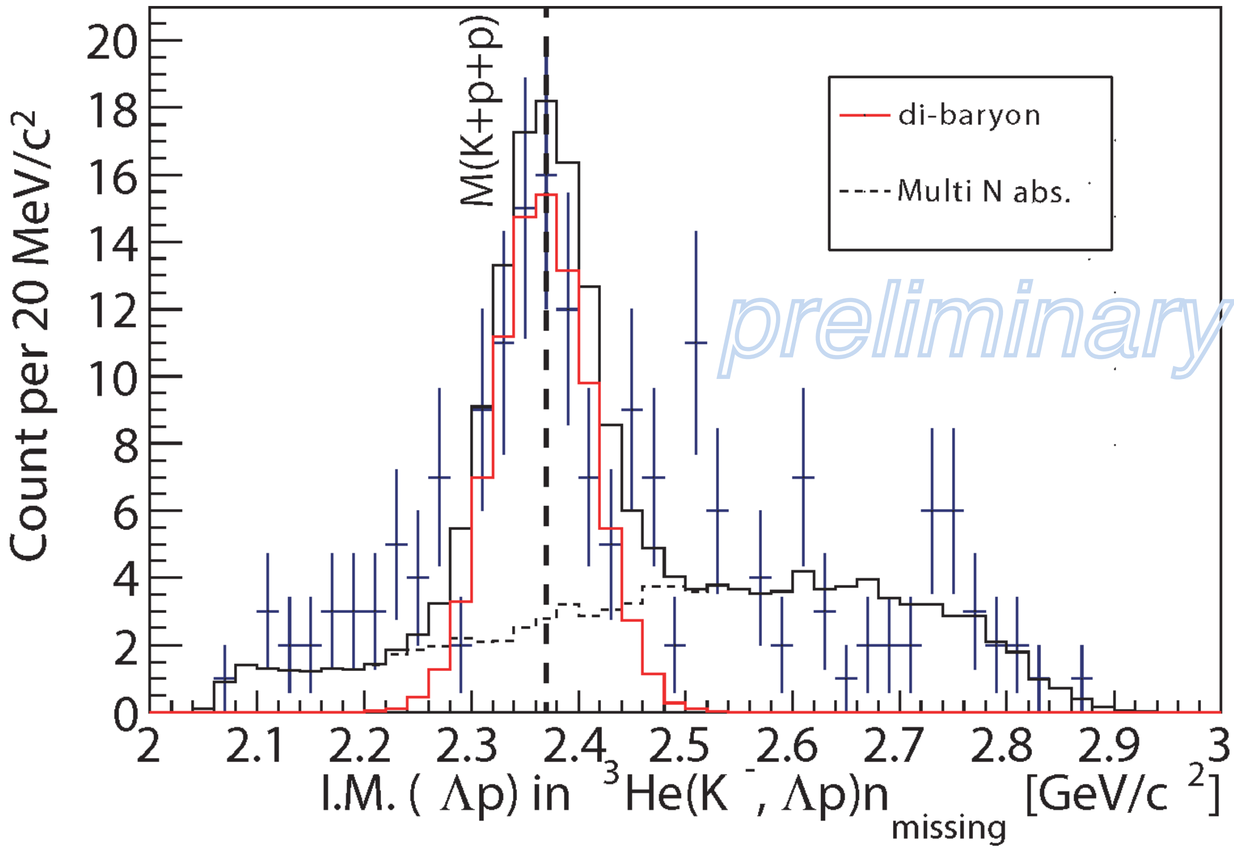
check invariant mass of Λp

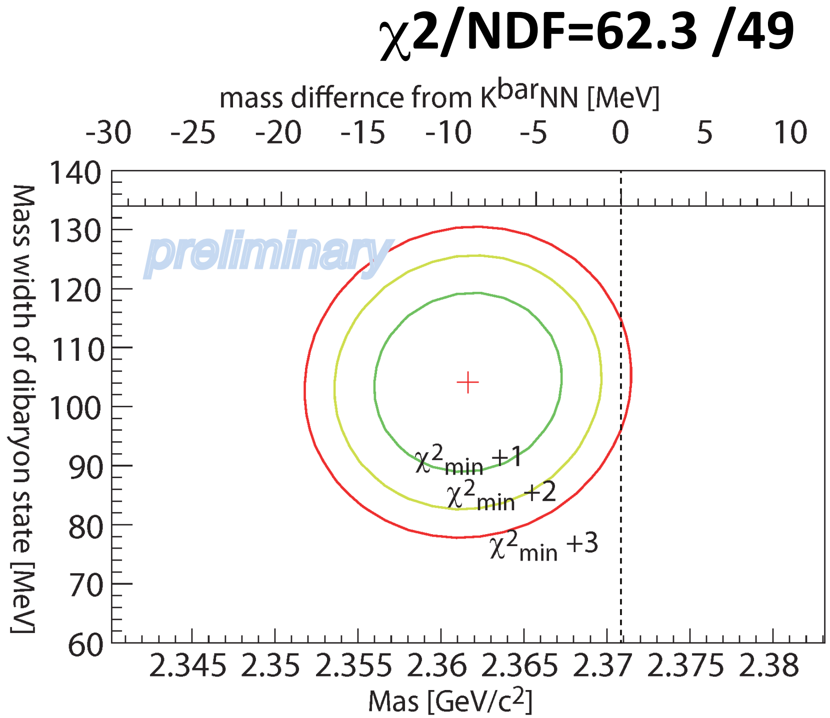
Exclusive ^{3}He(K$^-$,Λp)n by 3NA



- The spectrum CANNOT be reproduced by only 3NA
- contribution from 2NA seems minor
- Clear structure is seen around the threshold

Assuming a Breit-Wigner

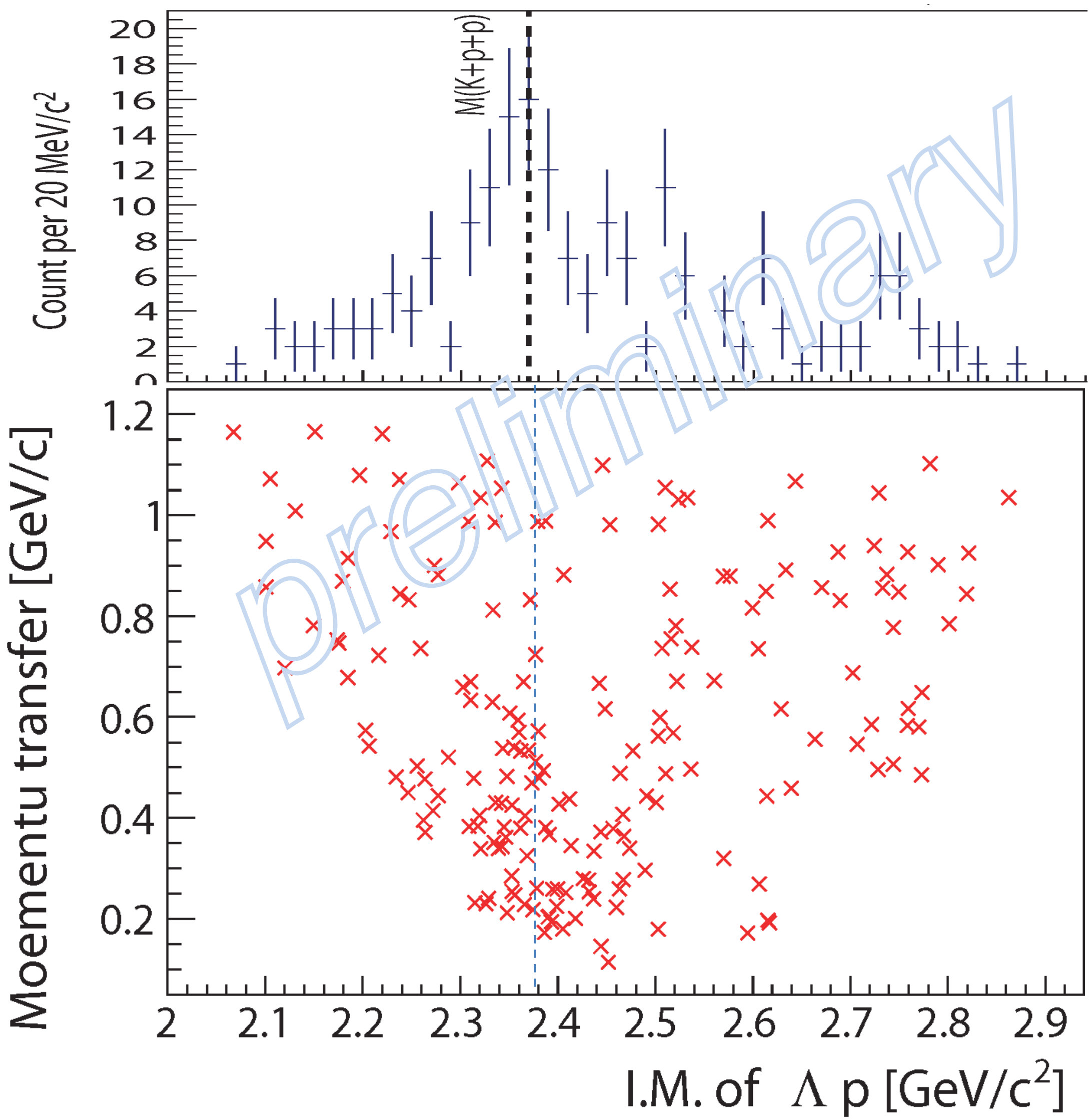




- χ^2-test with a Breit-Wigenr and 3NAs
  - assumption: isotropic Λp decay
  - parameters: Mass, Width, and Yield

Momentum Transfer of (K⁻,n)

Mom. Trans. of (K⁻,n) vs. IM(Λp)



- **low-momentum transfer seems to be enhanced around the threshold**

possible candidates

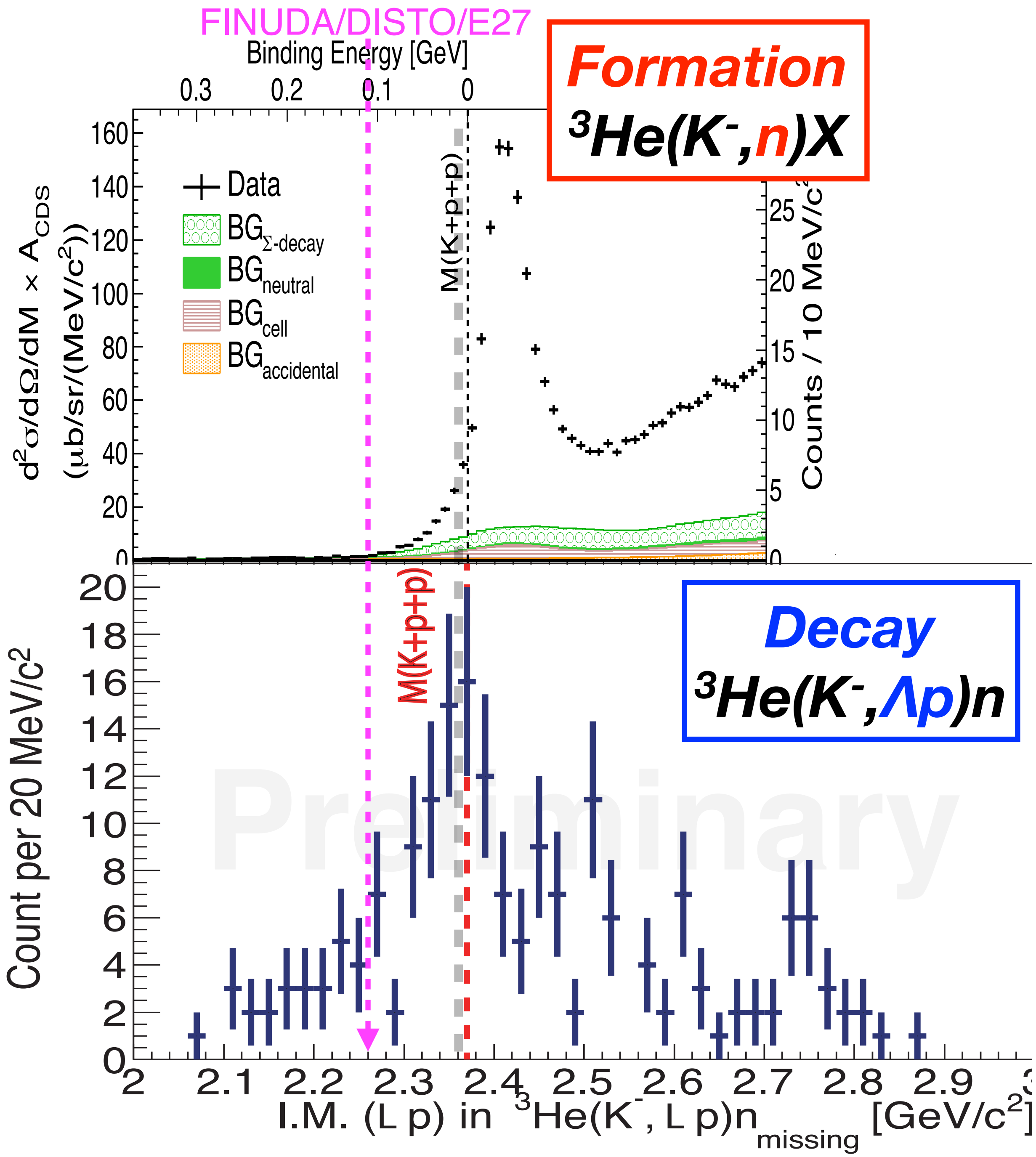
- Λ(1405) production in 2NA followed by $\Lambda^* p_s \rightarrow \Lambda p$?
- S=-1 di-baryon state of $X \rightarrow \Lambda p$?

Inclusive analysis
and
Exclusive analysis

Summary of results for the E15-1st

- **Around the threshold**
  - Some excess exist in both formation- and decay-channel
    - S=-1 di-baryon state?
    - explained by Λ(1405)?

- **Deeply-bound region**
  - bump-structure reported by FINUDA/DISTO/E27, has **NOT** been seen with the current statistics.
  - cross section strongly depend on the reaction?



Summary

- 1st physics results are coming out
  - Inclusive analysis: 3He (K-,n)
    - no significant structure in deeply bound region
    - some enhancement are found around the threshold
  - Exclusive analysis: 3He (K-,n)Λp
    - data suggest that 3NA absorption process will be major contribution in the reaction (2NA, i.e. one spectator nucleon, are somehow suppressed?)
    - Peak(bump?) structure are seen on Λp invariant mass
-> is this a candidate for S=-1 dibaryon? or something?
  - d(K-,n)πΣ analysis is in progress
    - It may show us a hint about Λ(1405) production on nucleus

Summary

- E15-2nd data taking will be start very soon (from 10/Nov)
  - we will accumulate 10 times more statistics than E15-1st data. This data allowed us
    - detail investigation for the enhancement found near K-NN threshold
  - E31, Λ(1405) via d(K^-,n), will be ready to taking data
    - to understand production cross section, iso-spin dependence of line shape etc.