Latest results of the $K^{bar}NN$ search via the (K^{-},N) reaction in J-PARC E15

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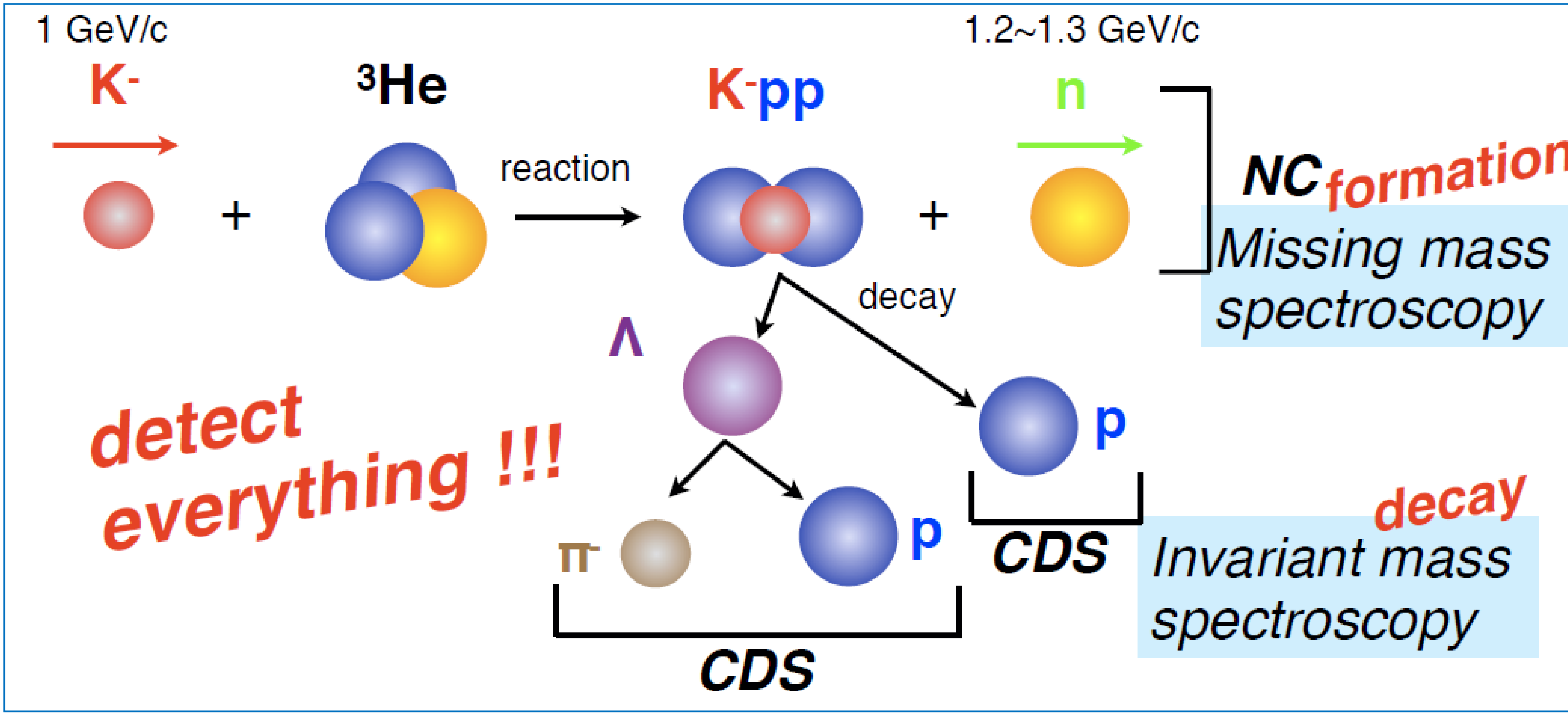
for the J-PARC E15 collaboration

ストレンジネス核物理の発展方向研究会 2015 8/3-5

J-PARC E15 Experiment

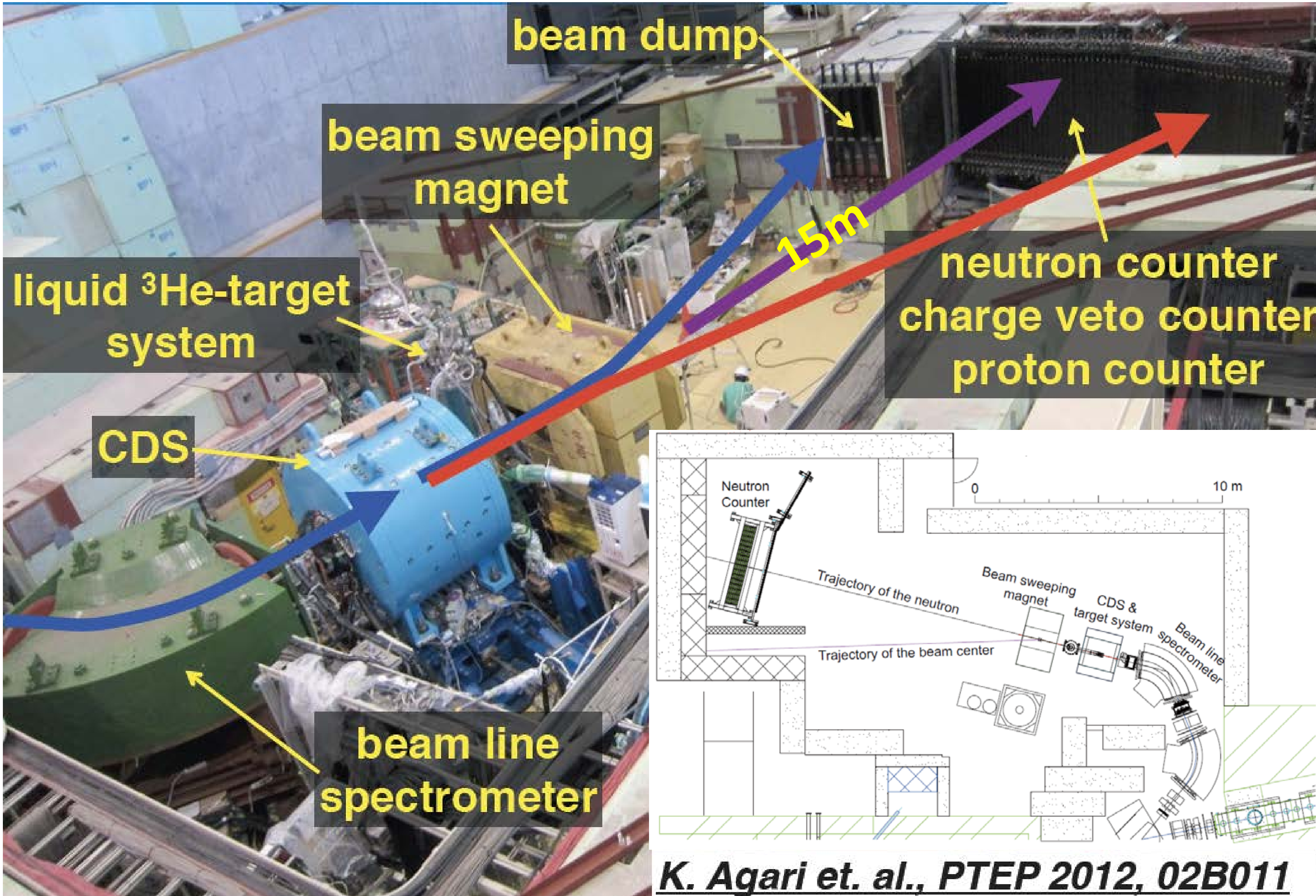
A search for the simplest kaonic nucleus, K^-pp, using ^{3}He(*in-flight* K^-,n) reaction



- two-nucleon absorption
- hyperon decays

CAN be discriminated kinematically

Experimental Setup



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

Status of the E15 Experiment

- Production run of ***~1% of the approved proposal*** was successfully carried out in 2013.
- **2nd physics run will be performed in the autumn of 2015**

	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	5.3×10^9
Apr-May, 2015 (Run#62)	calibration H_2	26.5 kW (33 Tppp, 6s)	130 k/spill	73 h	3.7×10^9
Apr-May, 2015 (Run#62)	calibration D_2	26.5 kW (33 Tppp, 6s)	130 k/spill	53 h	2.8×10^9
Autumn, 2015	E15 2nd ^3He	40 kW (50 Tppp, 6s)	200k/spill	26d	50×10^9

** 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 ^3He target*

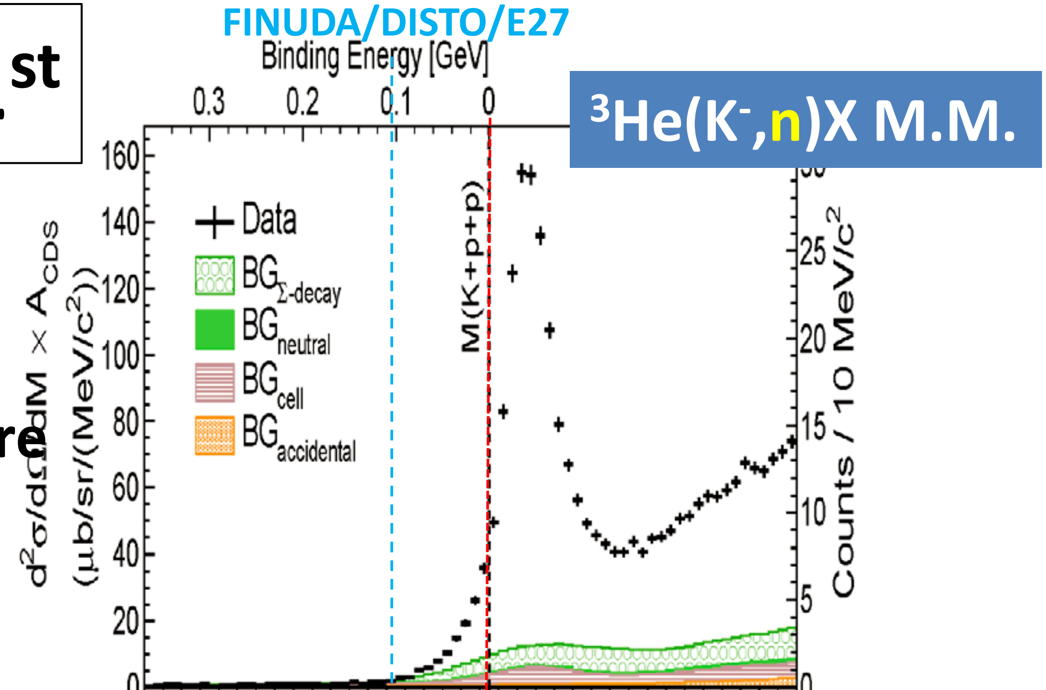
Summary of E15 1st

Formation Channel

Semi-Inclusive $^3He(K^-,n)X$

✓ **No significant bump structure** in the deeply bound region

✓ **Excess below the threshold**
2NA of Λ^*N?

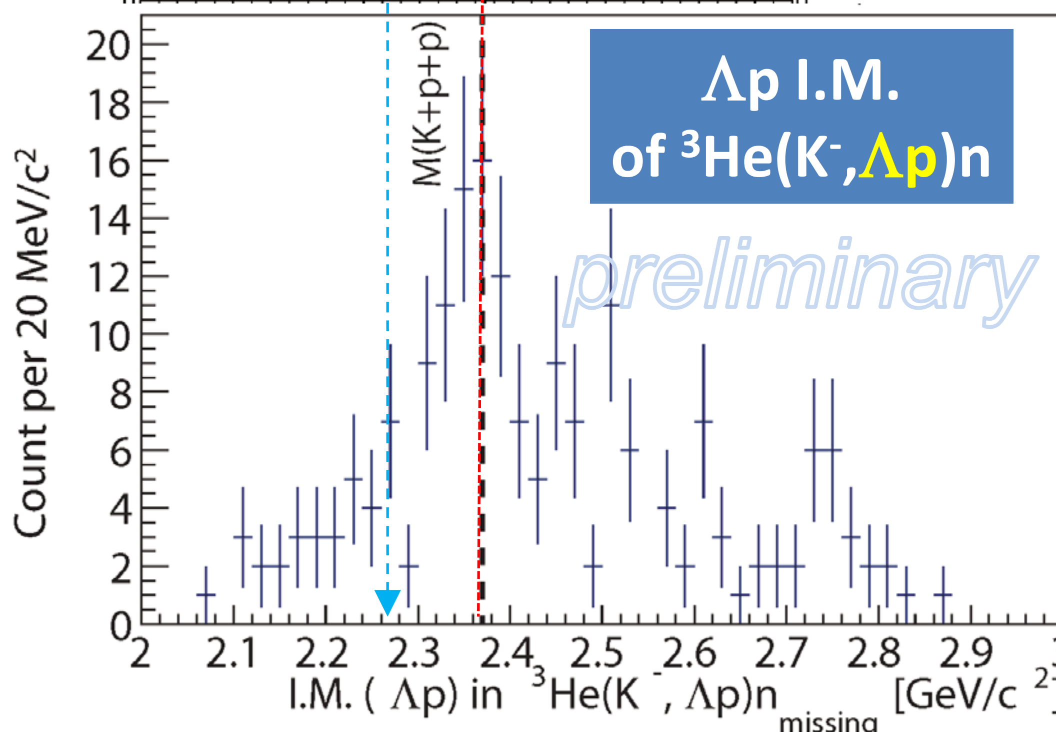


Decay Channel

Exclusive $^3He(K^-,\Lambda p)n$

✓ **Clear structure around the threshold**
multi-step? di-baryon???

✓ Cannot be from 2NA of Λ^*n
(final state = Λpn)



Formation Channel, Semi-Inclusive $^3He(K^-,n)X$

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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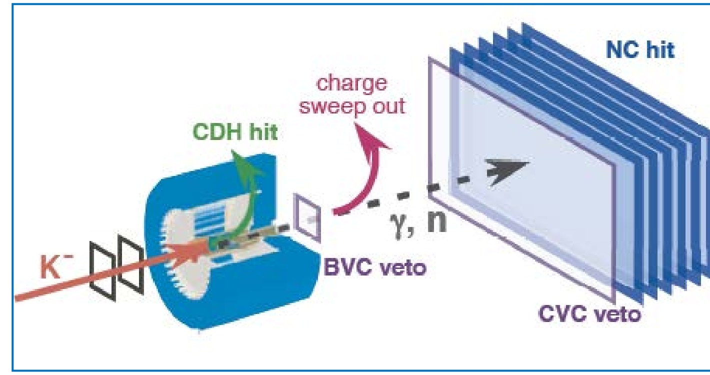
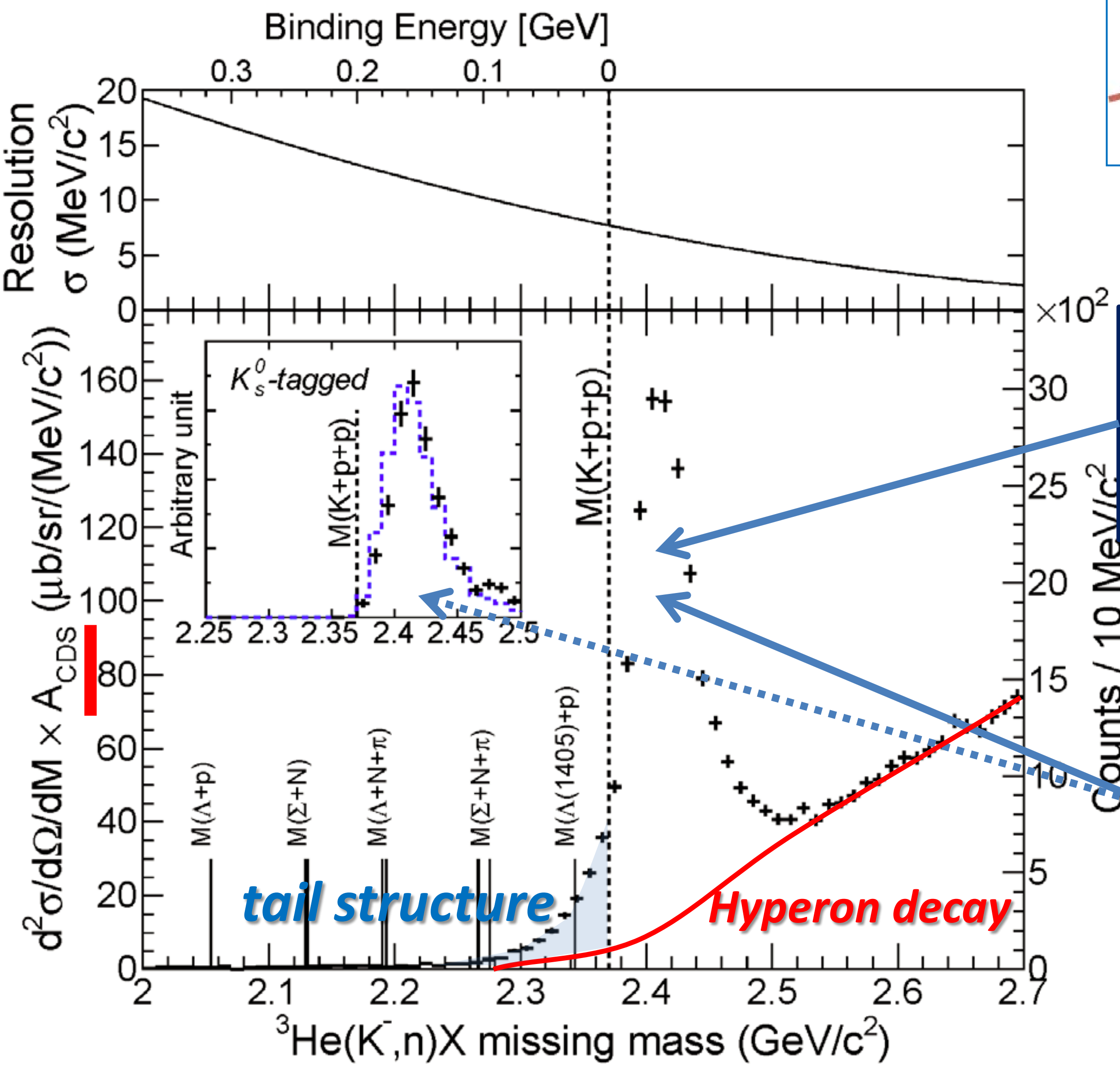
Semi-Inclusive Spectrum of ^{3}He(K$^-$,n)X





Quasi Elastic

$K^- + {}^3He \rightarrow K^- + \mathbf{n} + p_s + p_s$

$d\sigma/d\Omega_{\theta=0deg} \sim 6mb/sr$

and

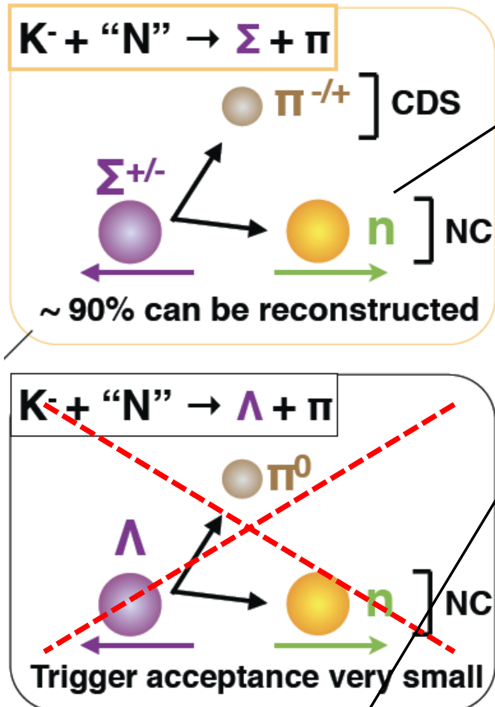
Charge-Exchange

$K^- + {}^3He \rightarrow K^0 + \mathbf{n} + d_s$

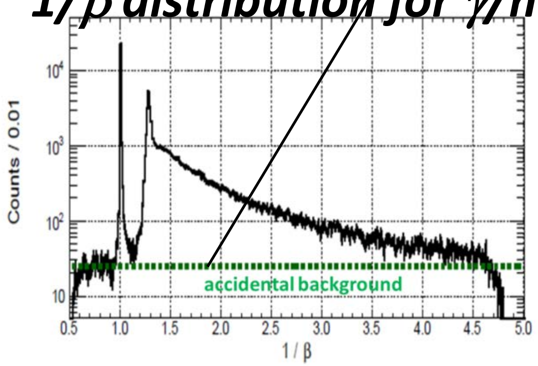
$K^0 \rightarrow \pi^+ + \pi^-$

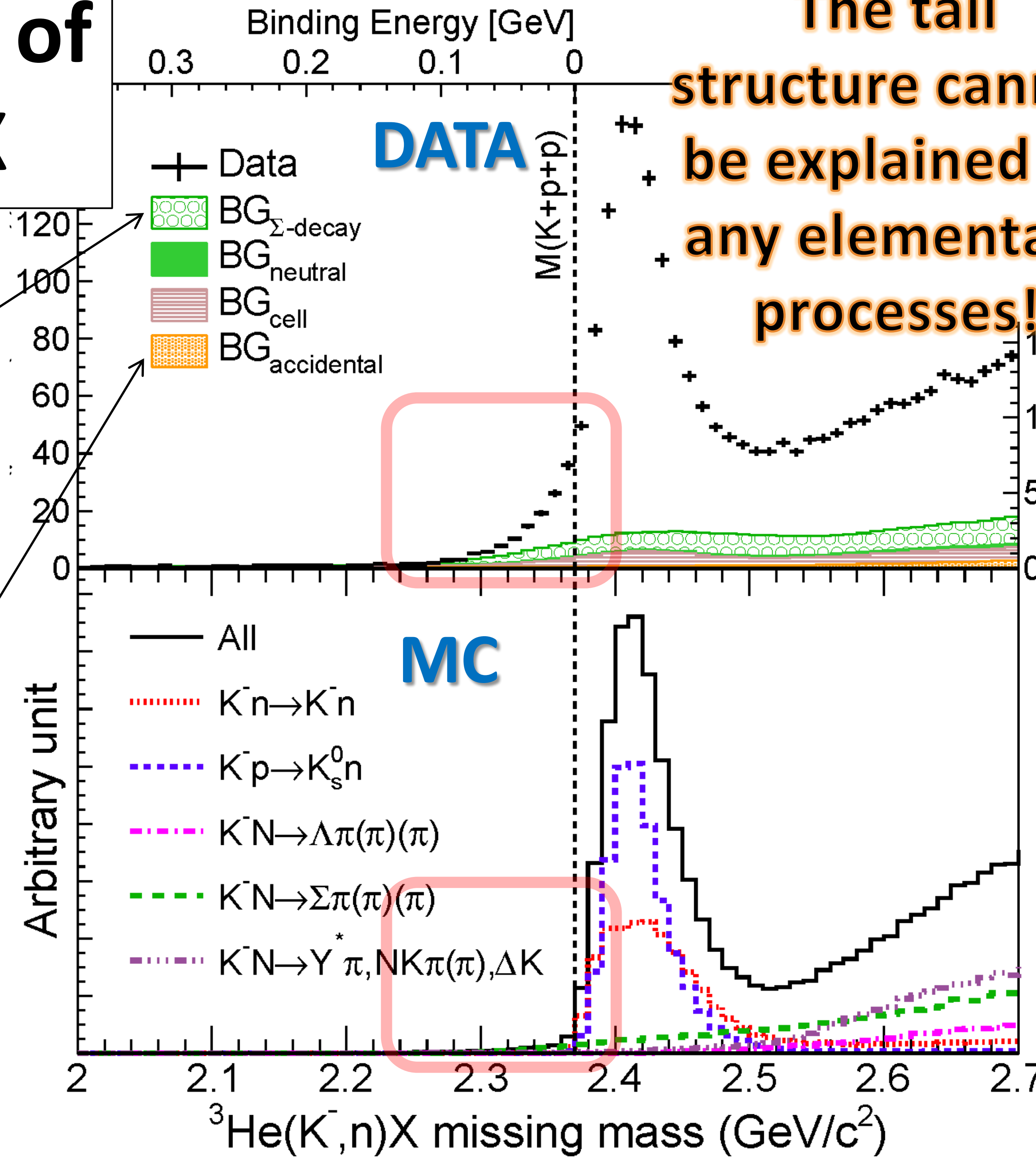
$d\sigma/d\Omega_{\theta=0deg} \sim 11mb/sr$

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



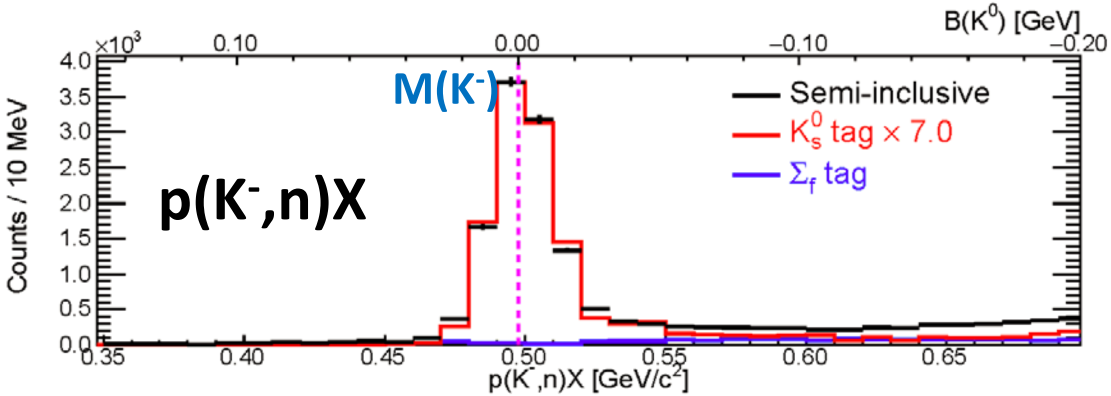
1/β distribution for γ/n





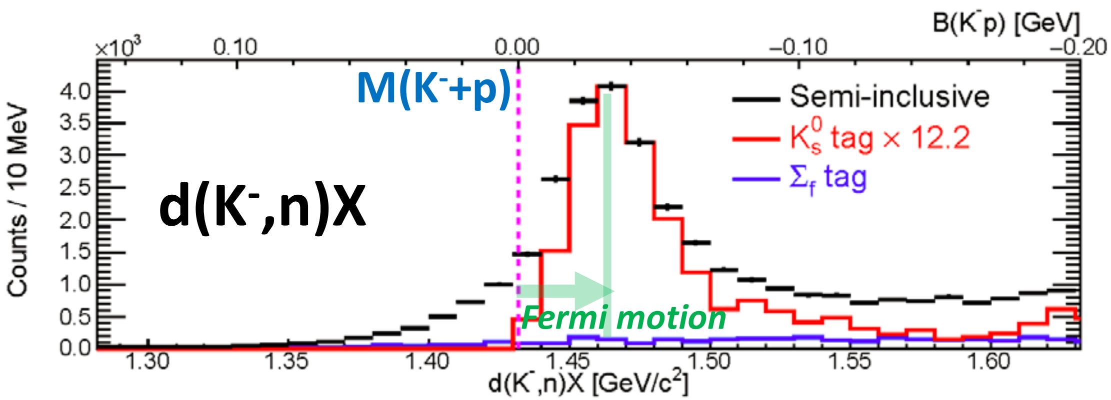
The tail structure cannot be explained by any elementary processes!

Subthreshold Excess?



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

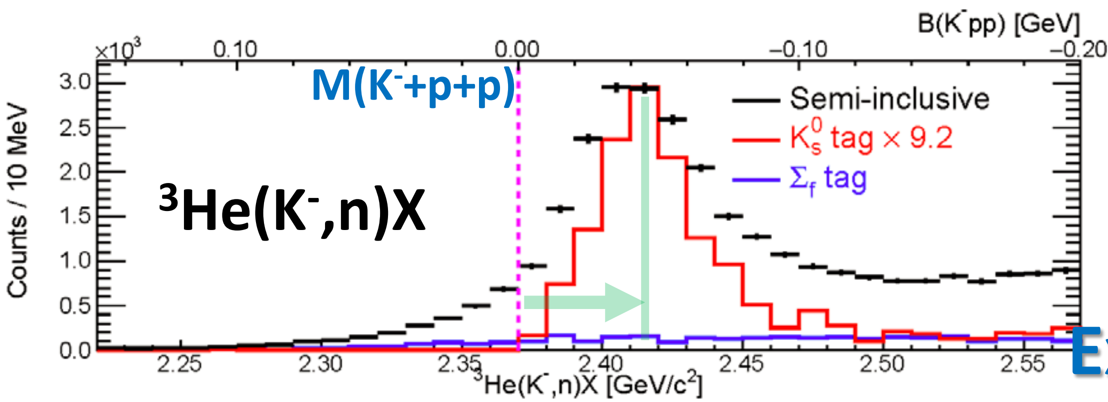
  well describes the spectrum



- $K^-d \rightarrow Y^*+n_{fw}$

  Y* production are seen as excess

  The main goal of E31

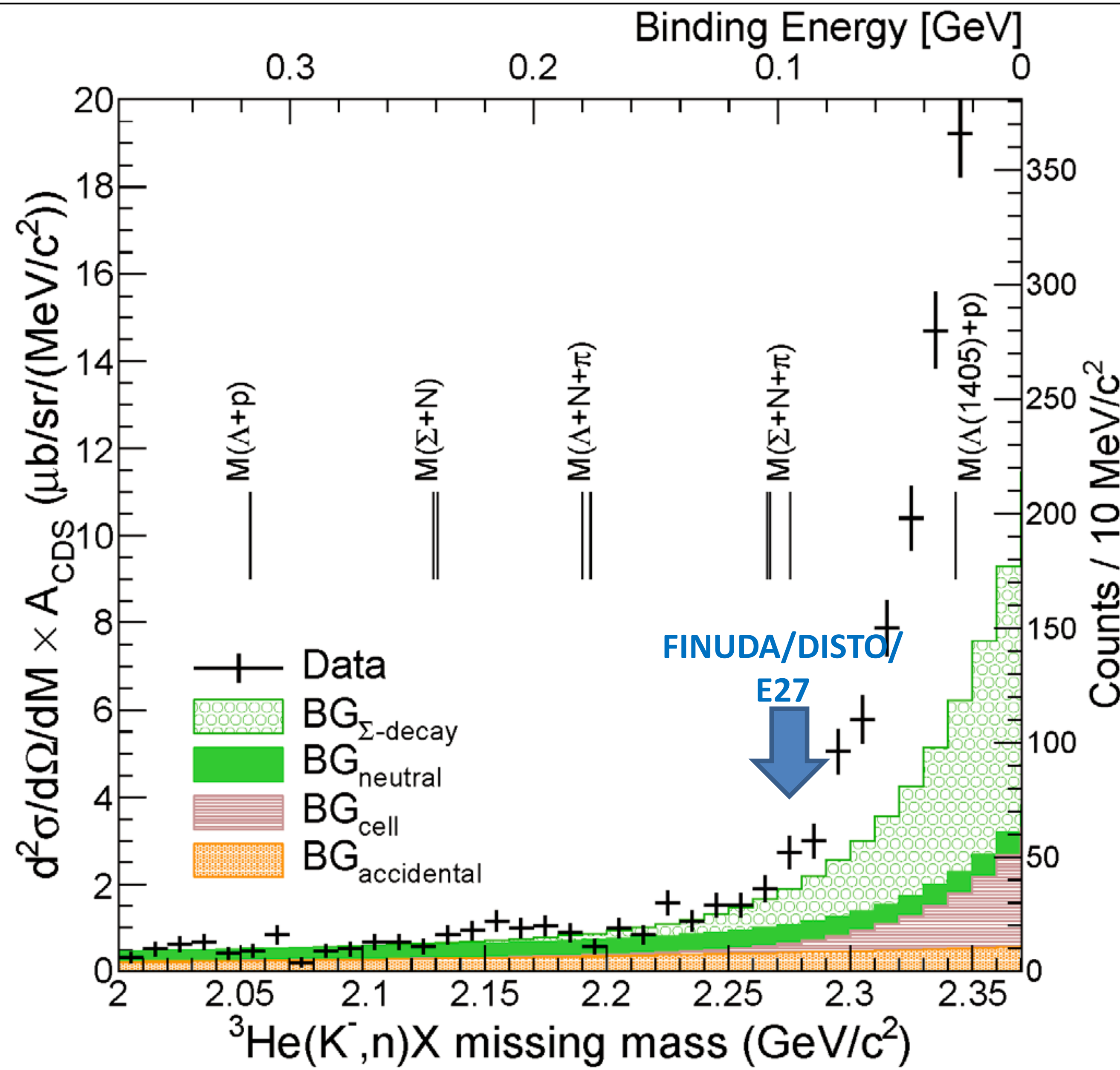


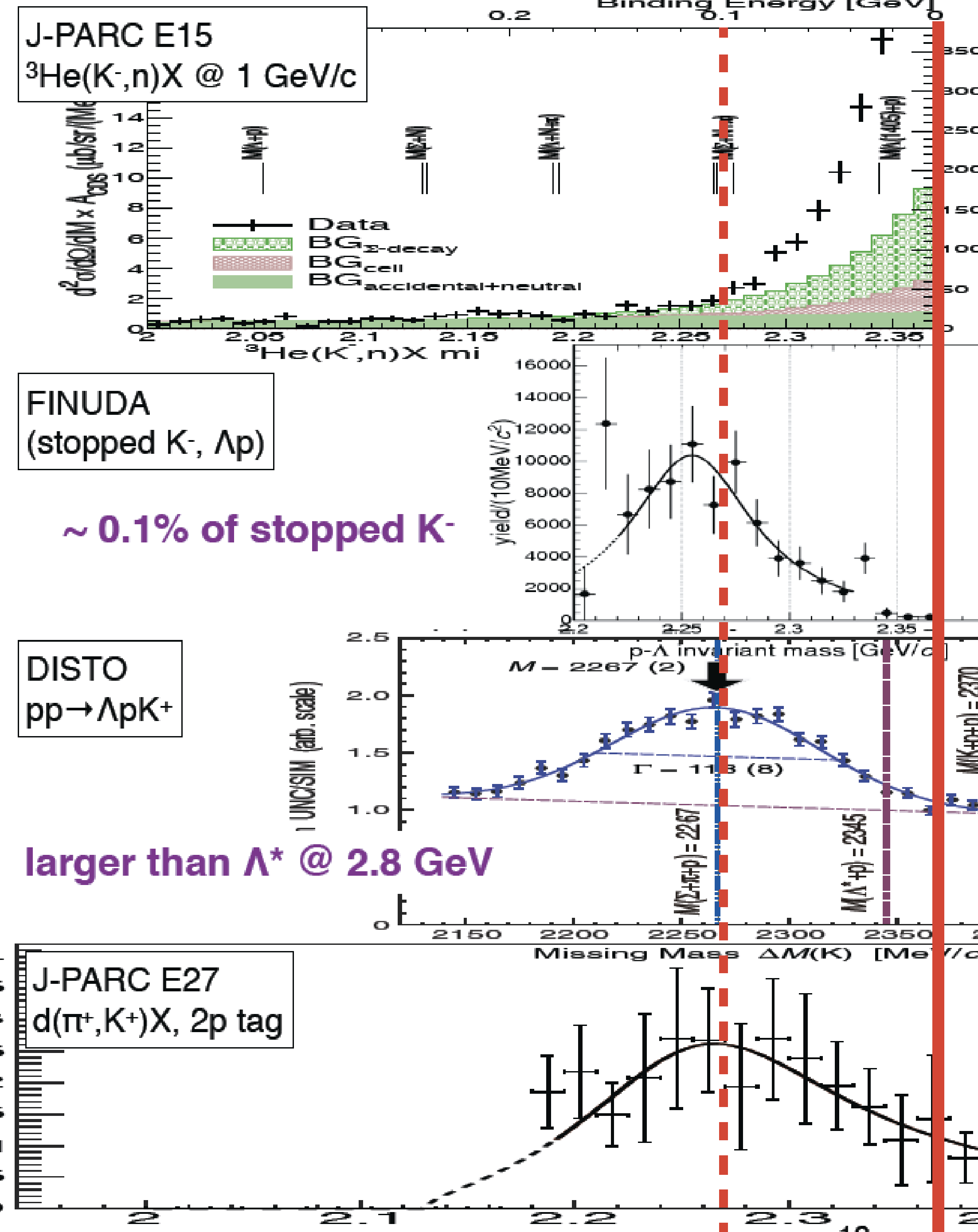
- $K^{-3}He \rightarrow Y^*N+n_{fw}$

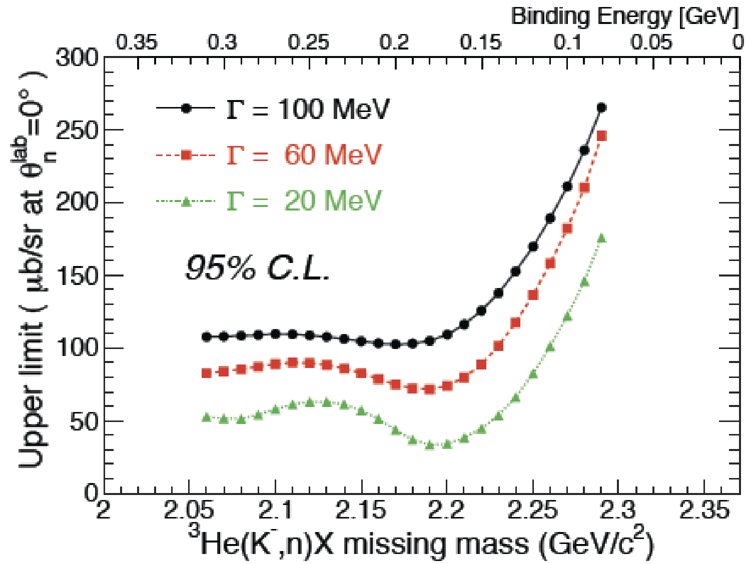
  Y* production and/or exotic production are seen as excess

Exclusive analysis is crucial!

Close-Up of the Deeply-Bound Region







Assumptions

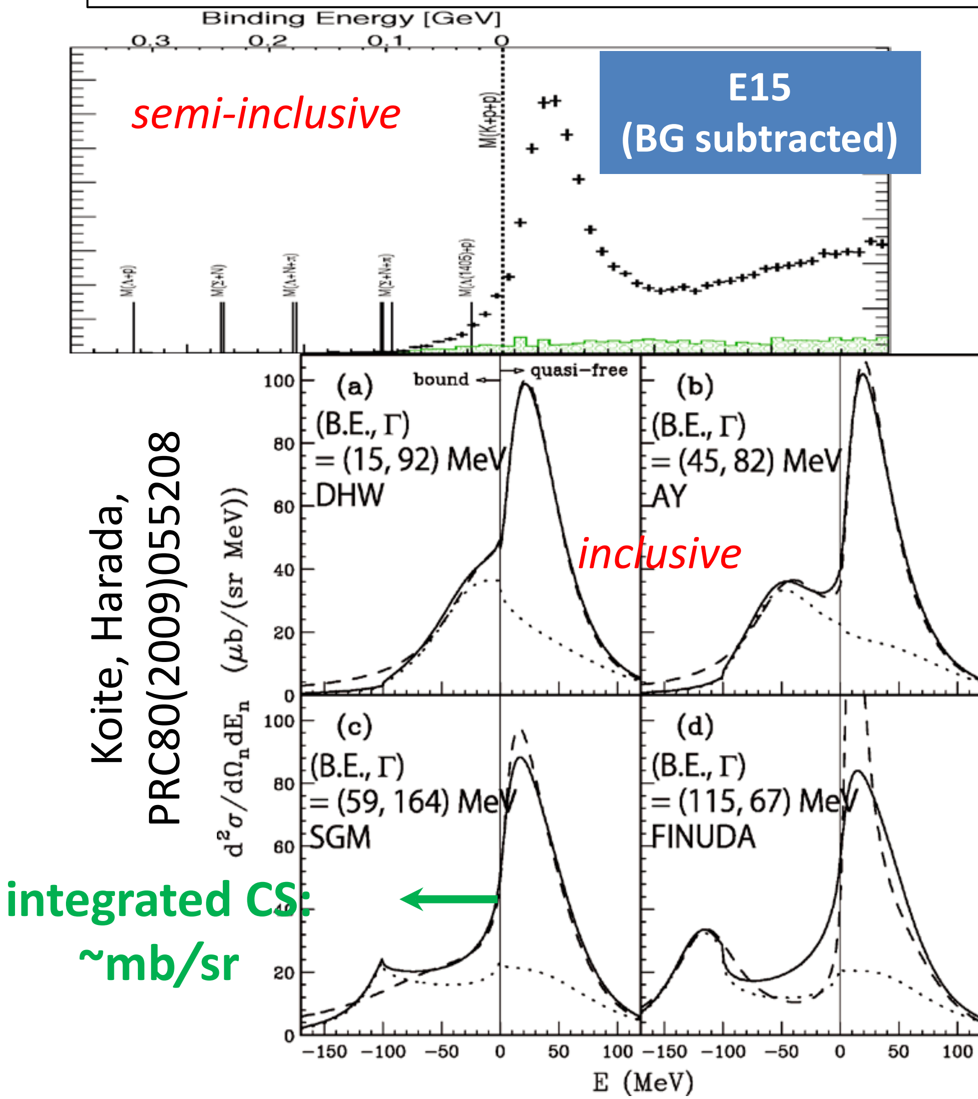
Intrinsic peak shape: Breit-Wigner
Decay mode: **K$^-$pp→Λp 100%** (isotropic decay)

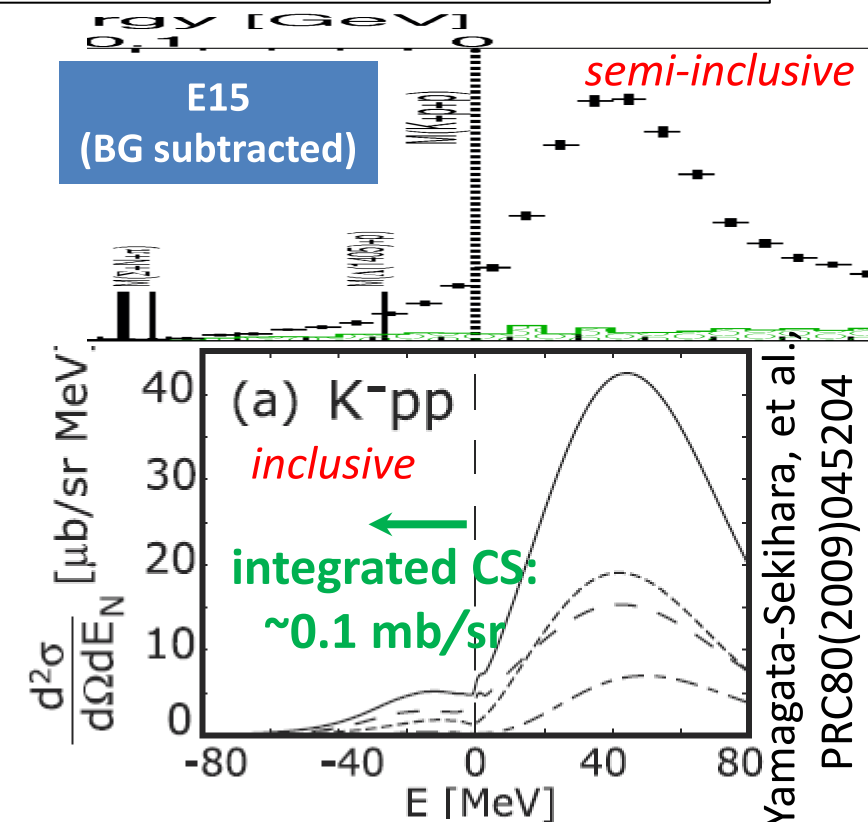
- **J-PARC E15 (U.L.)**
  30 ~ 300 μb/sr @ 0 deg.
  0.5 - 5% of quasi-elastic
  smaller than usual hypernucleus sticking

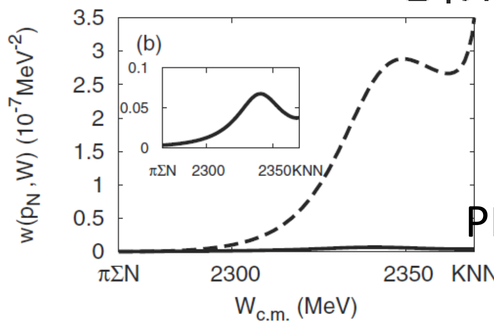
- **LEPS (γ+d) (U.L.)**
  1.5-26% of γN→K$^+$πY

- **HADES (pp @ 3.5 GeV)**
  0.7-4.2 μb (Λ* ~ 10 μb)

Theoretical Calculations







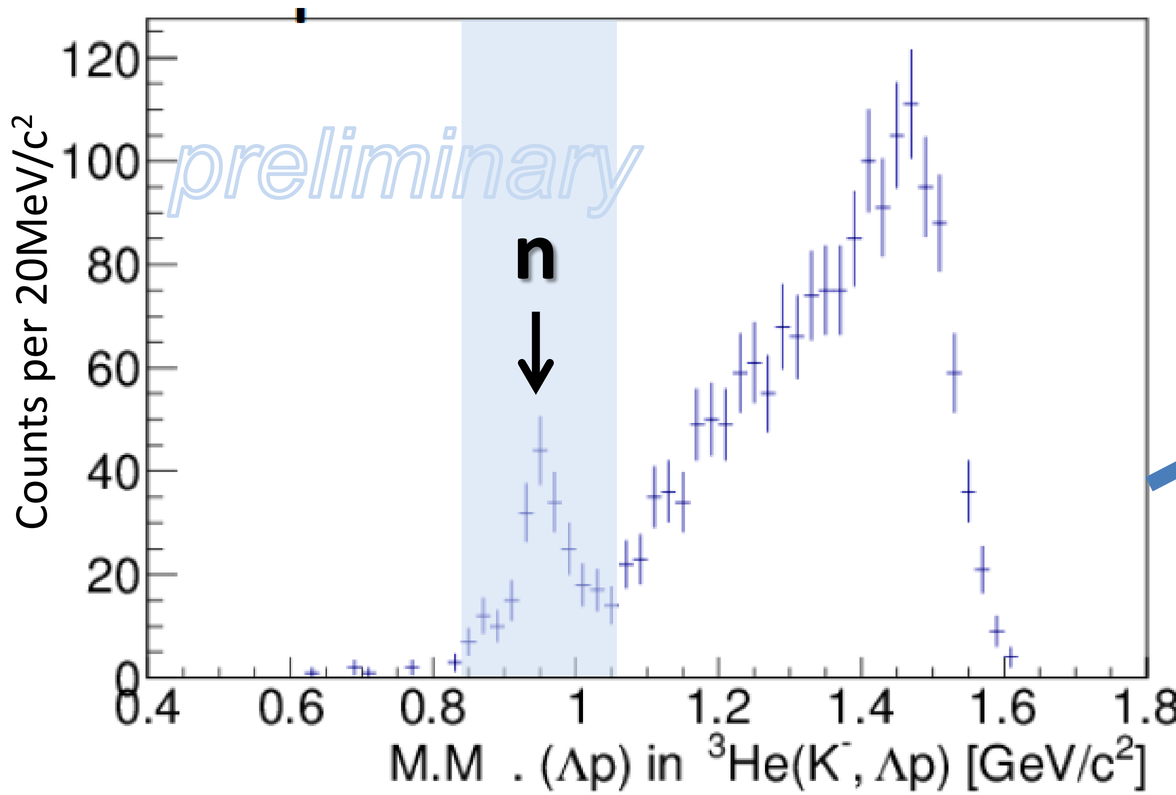
S.Ohnishi, et al.,
PRC88(2013)025204

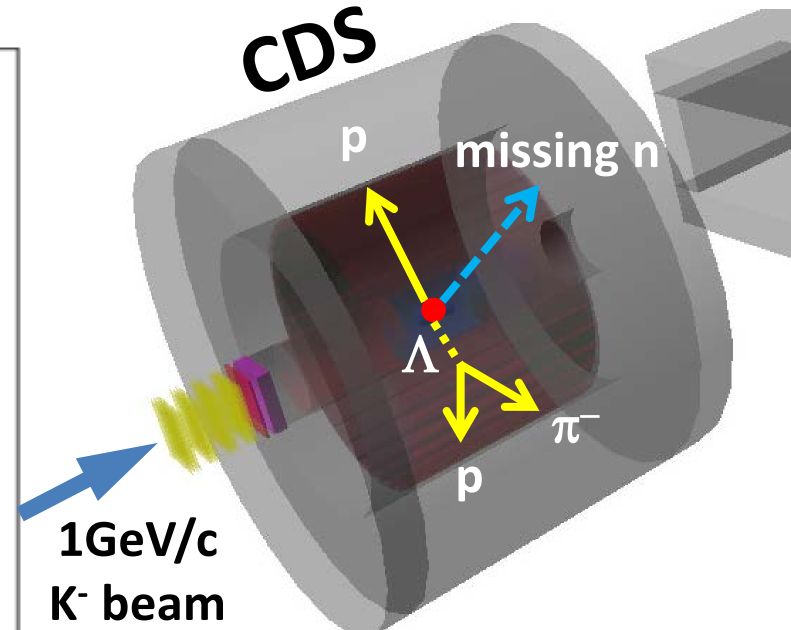
- CS is roughly consistent with KH
- **Exclusive πΣN measurement is an important key for further study**

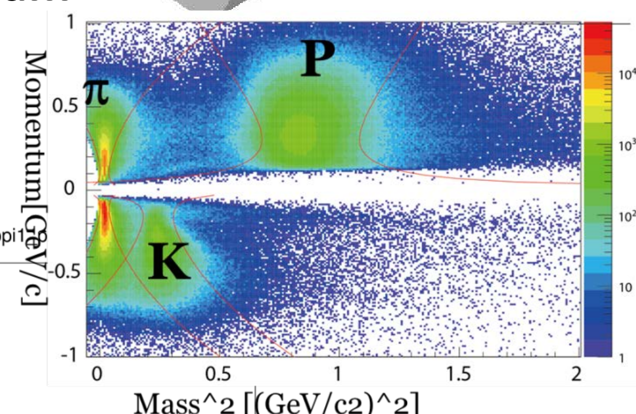
Decay Channel,
Exclusive $^3He(K^-,\Lambda p)n$

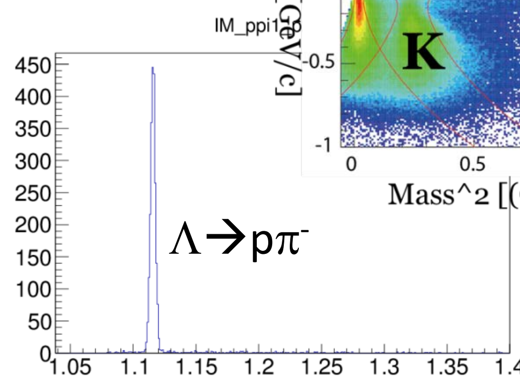
Y.Sada et al., paper in preparation

Exclusive ^{3}He(K$^-$,Λp)n events



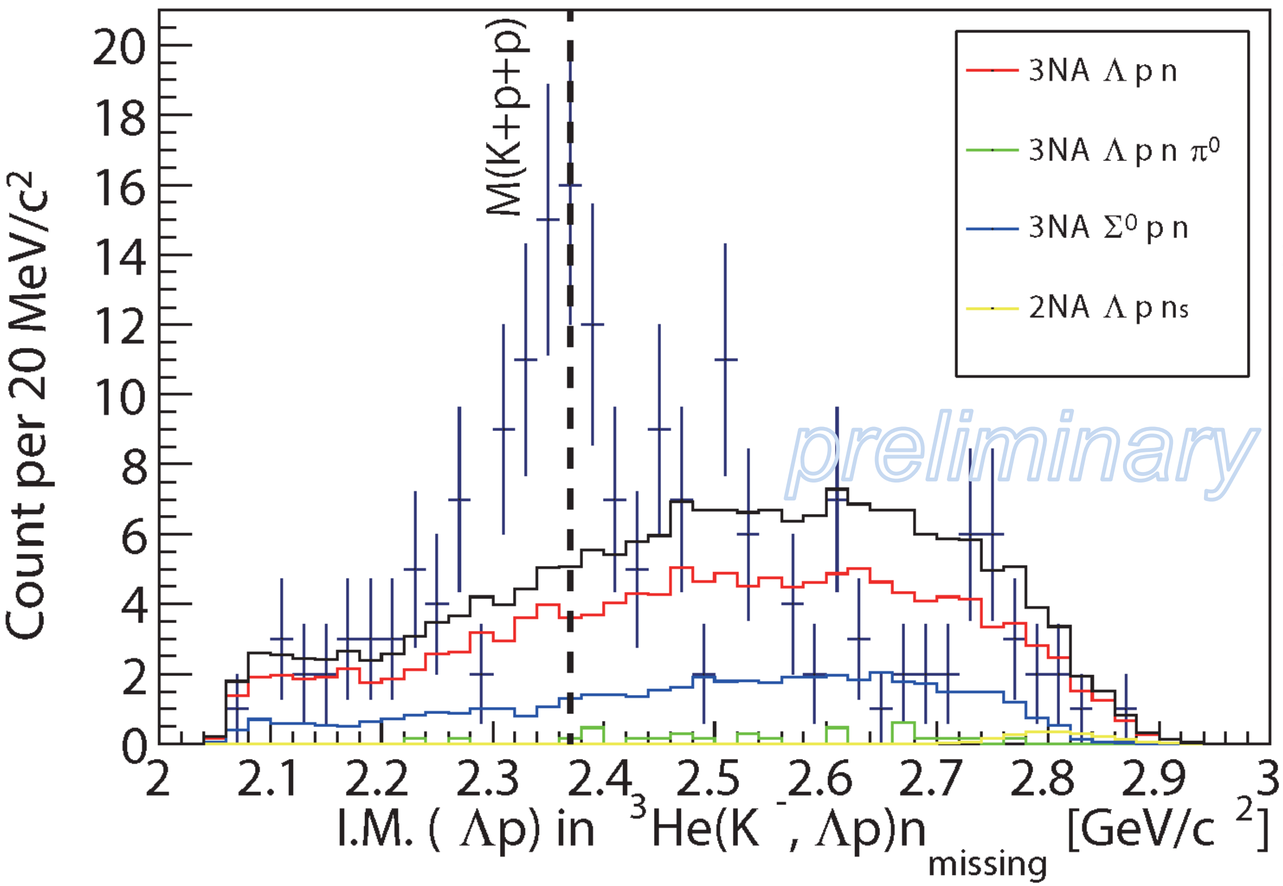


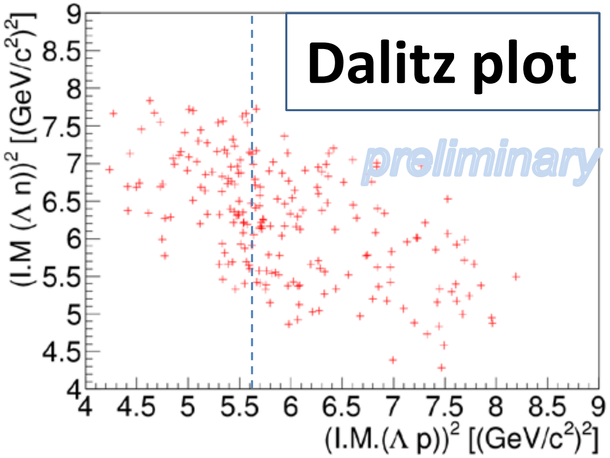




- K$^-$ ^{3}He→Λ(Σ^0)pn events can be identified exclusively
  - # of Λ(Σ^0)pn events: ~200
    - Σ^0pn contamination: ~20%

Exclusive $^3He(K^-,\Lambda p)n$ by 3NA





- The spectrum CANNOT be reproduced by only 3NA
- Clear structure is seen around the threshold

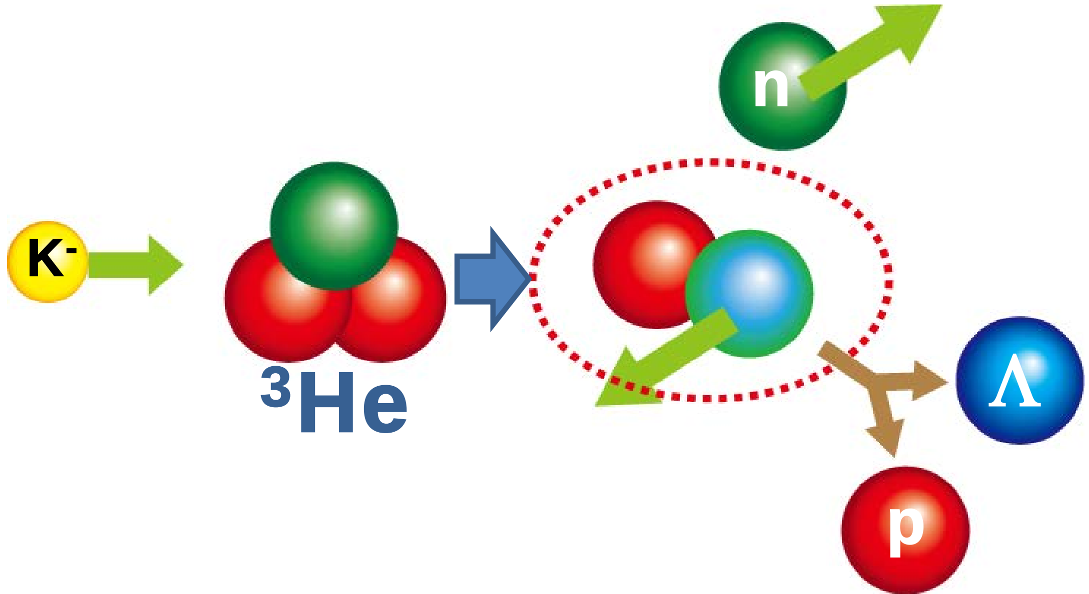
2-step Reactions?

- The spectrum CANNOT be reproduced by only 3NA
- **Attempt to reproduce the spectrum with 2-step reactions**

A) 2NA followed by Σ"N"$\rightarrow\Lambda$N conversion

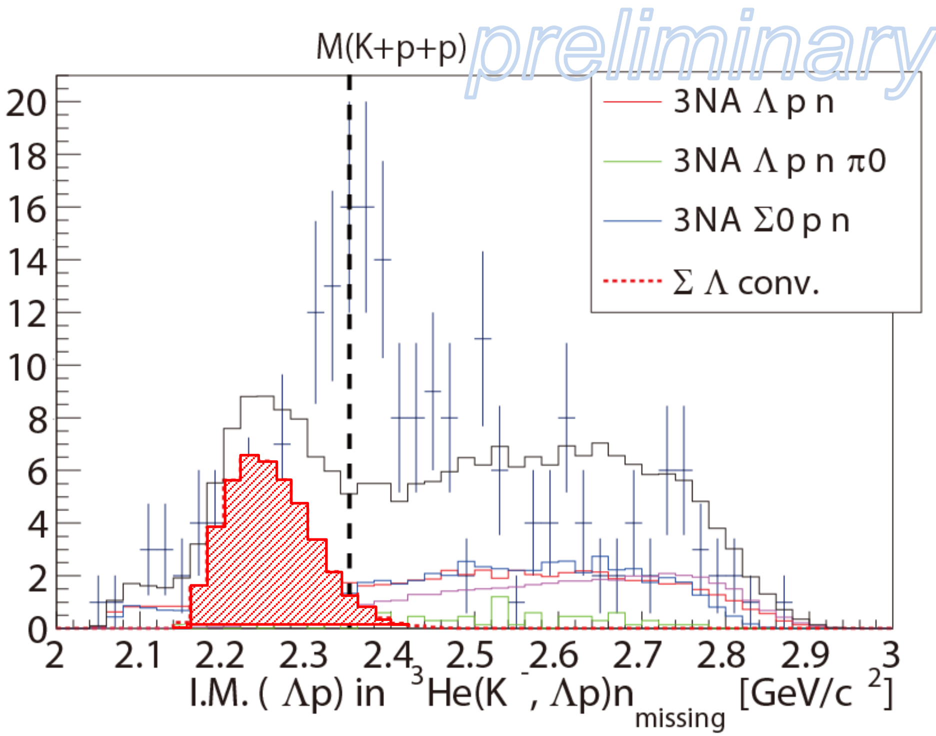
B) 2NA followed by $\Lambda(1405)$"N"$\rightarrow\Lambda$N conversion

C) KN$\rightarrow$KN followed by K"NN"$\rightarrow\Lambda$N

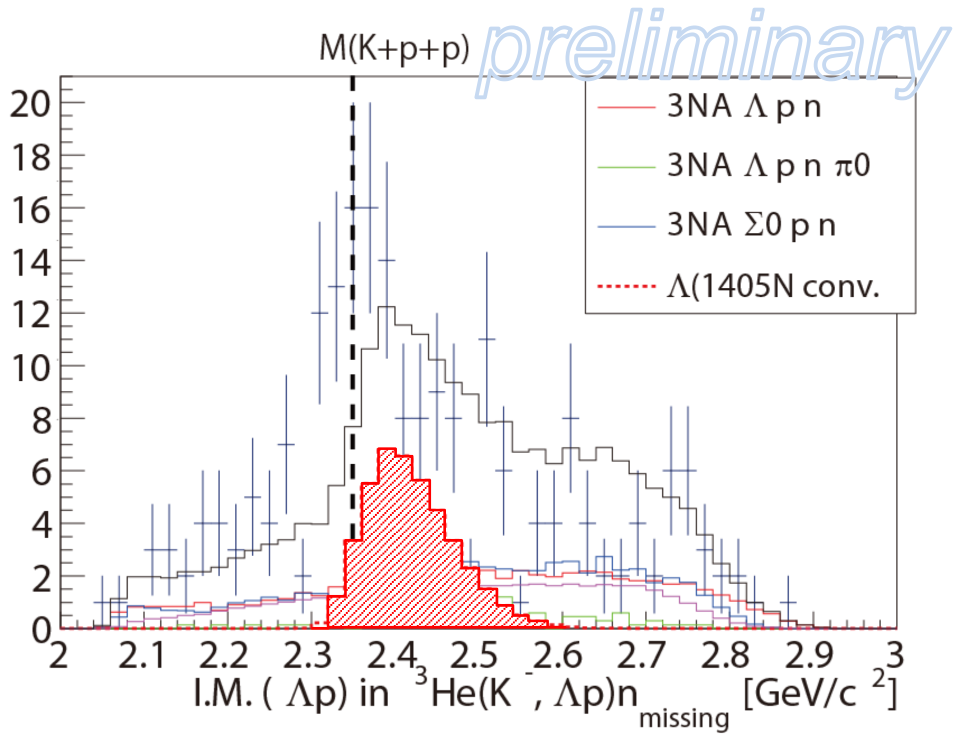


2-step Reactions? (Contn'd)

A) 2NA followed by Σ"N"$\rightarrow\Lambda$N

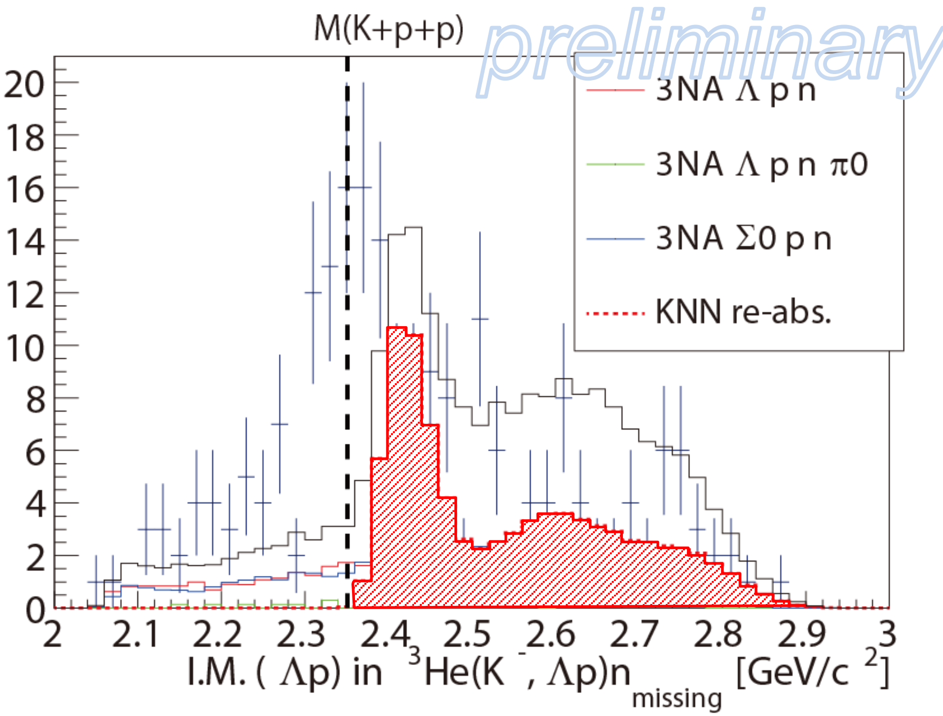


B) 2NA followed by Λ(1405)"N"$\rightarrow\Lambda$N

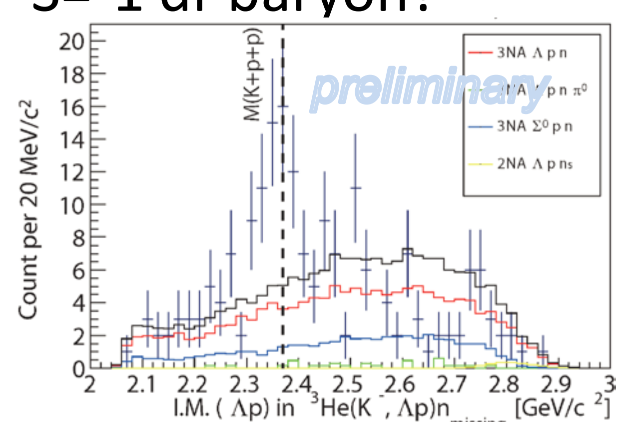


2-step Reactions? (Contn'd)

C) KN→KN followed by K"NN"→ ΛN

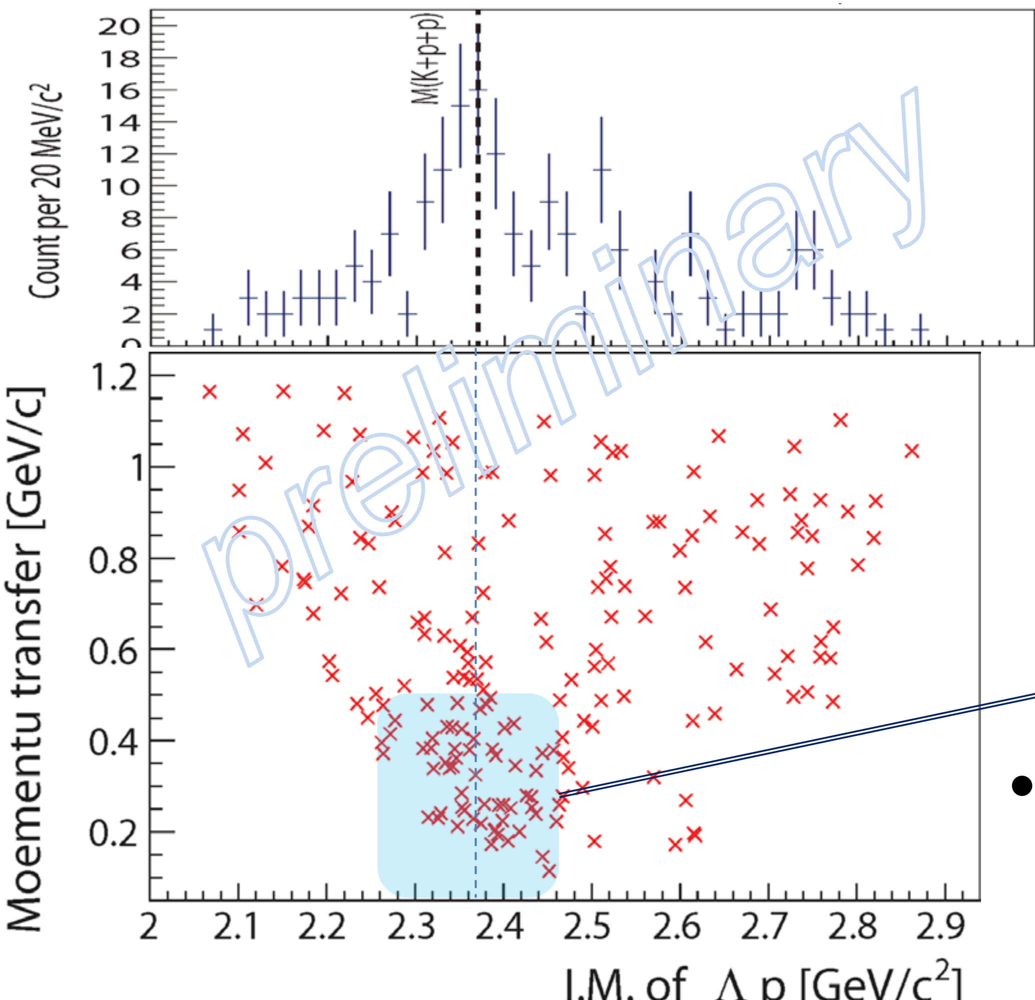


- **The structure is NOT explained by any 2-step reactions**
- Other possibilities
  - ~~K$^-$"pp" → Λp cusp?~~
    - too broad (~100MeV/c^2) if the structure is attributed to the cusp
  - S=-1 di-baryon?

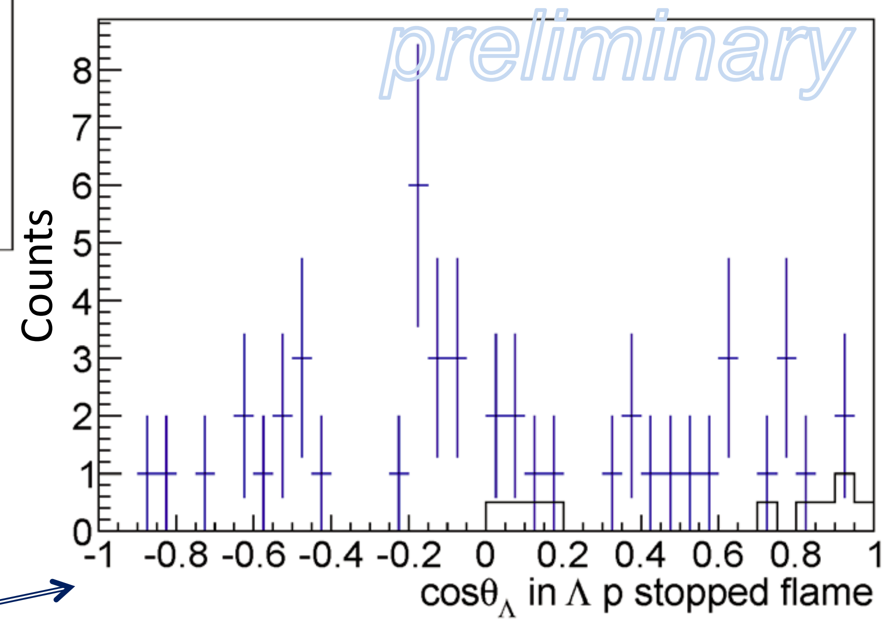


Kinematics of the Structure

Mom. Trans. of (K^-,n) vs. IM(Λp)

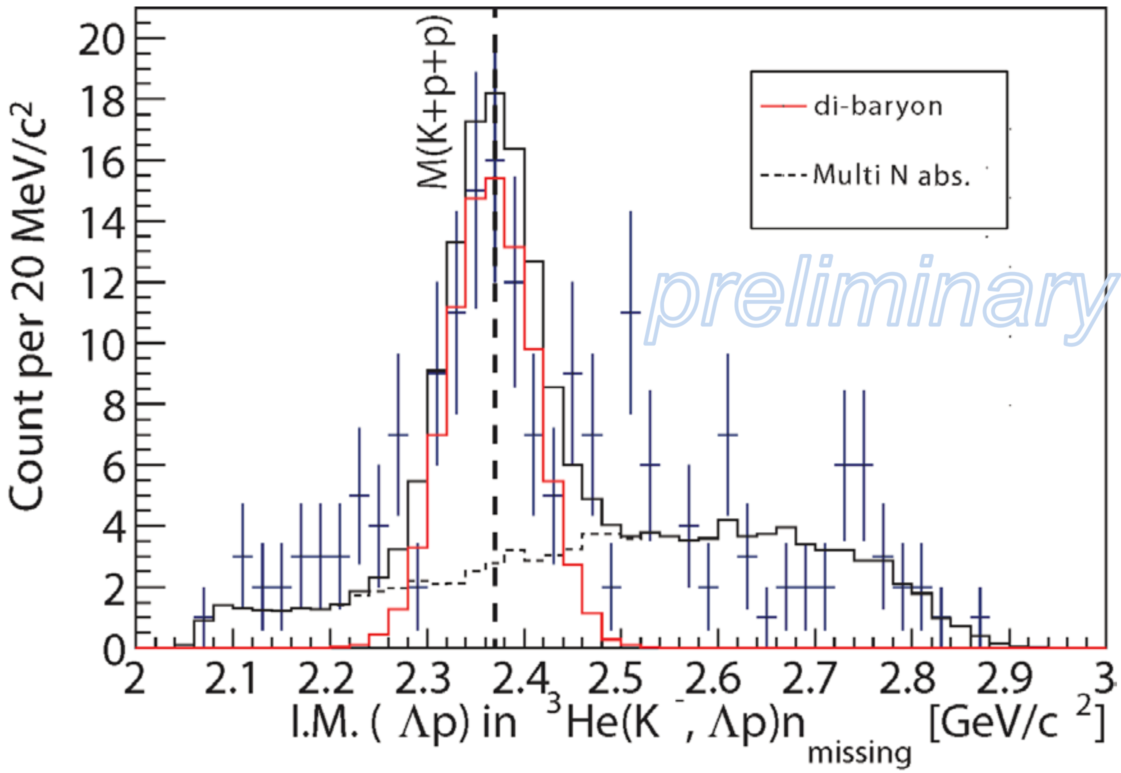


Λp decay-angle in CM

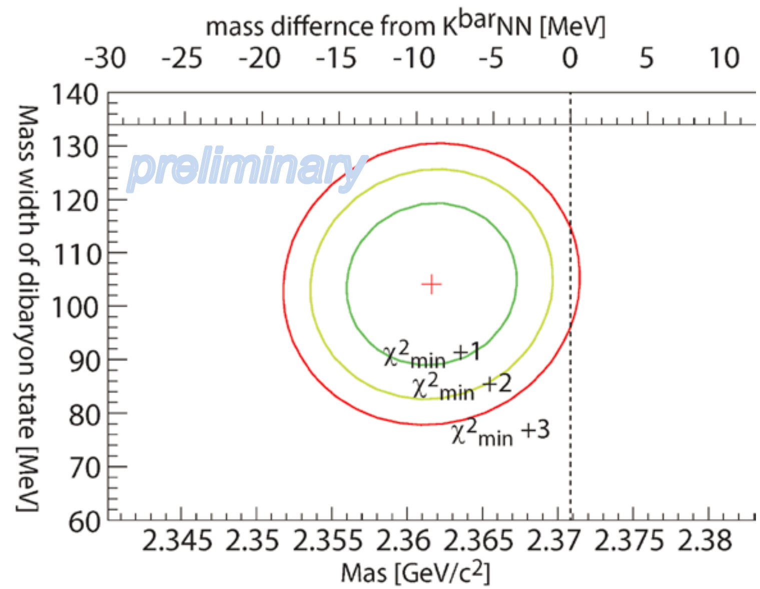


- low-momentum transfer seems to be enhanced around the threshold
- isotropic Λp decay?

Assuming a Breit-Wigner

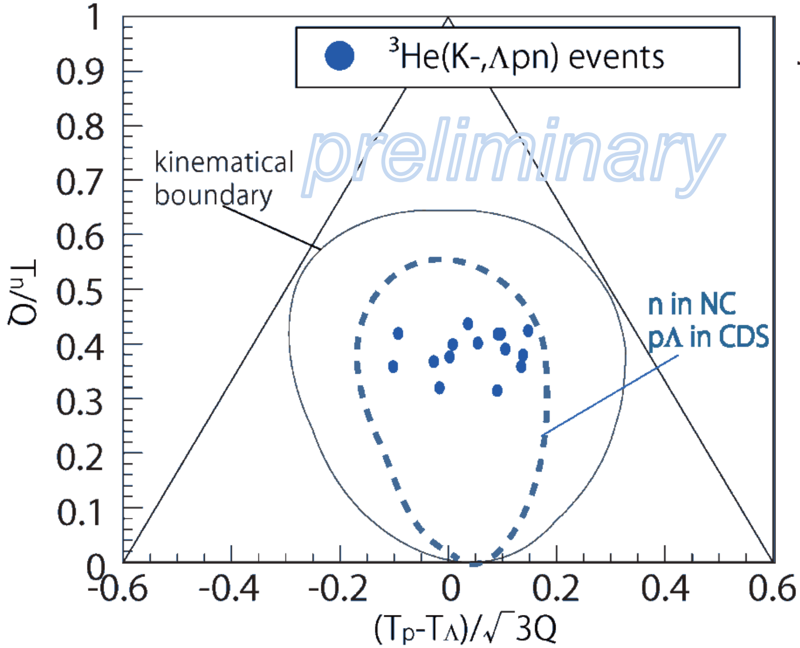


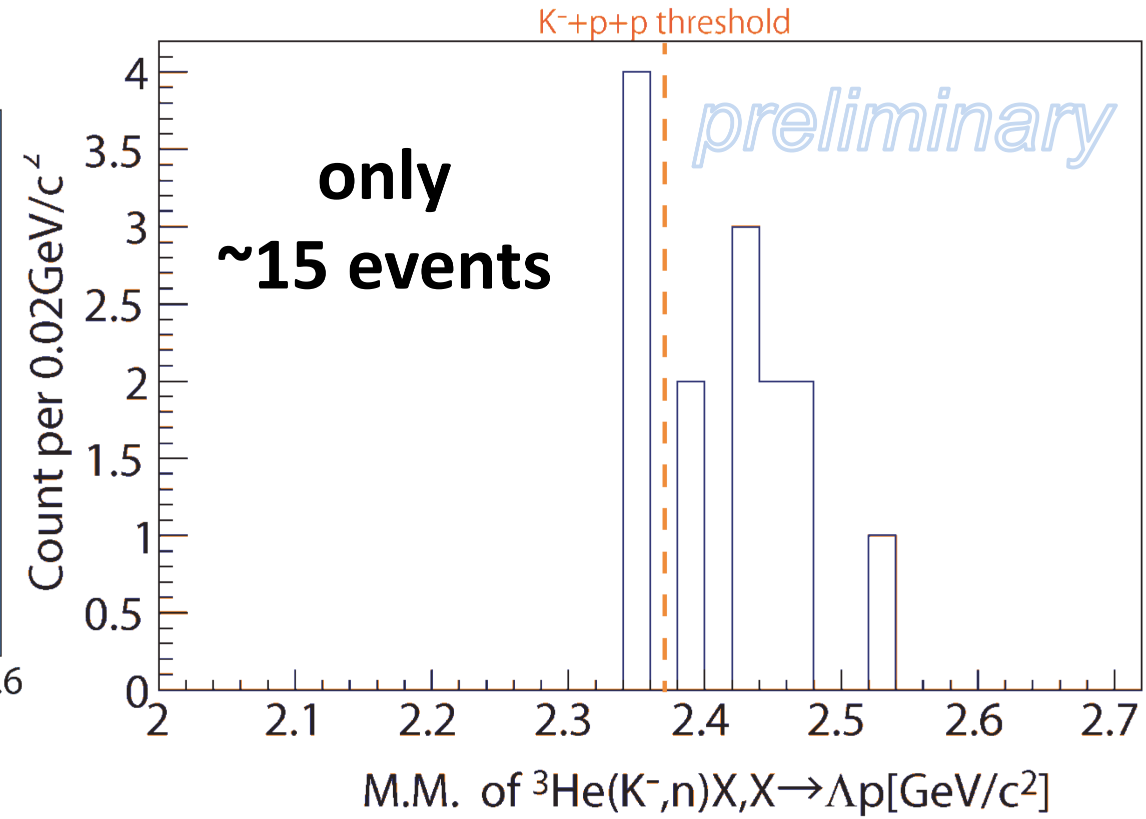
$\chi 2$/NDF=62.3 /49



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

Kinematically-complete measurement of $^{3}He(K^{-}, \Lambda pn)$





- Minimum momentum transfer of the $^{3}He(K^{-},n)$ reaction

  → would enhance the S=-1 di-baryon production
- **x100 beam time is required**

Summary

● Deeply-bound region

The bump-structure, which was reported by FINUDA/DISTO/E27, has NOT been observed

● Around the threshold

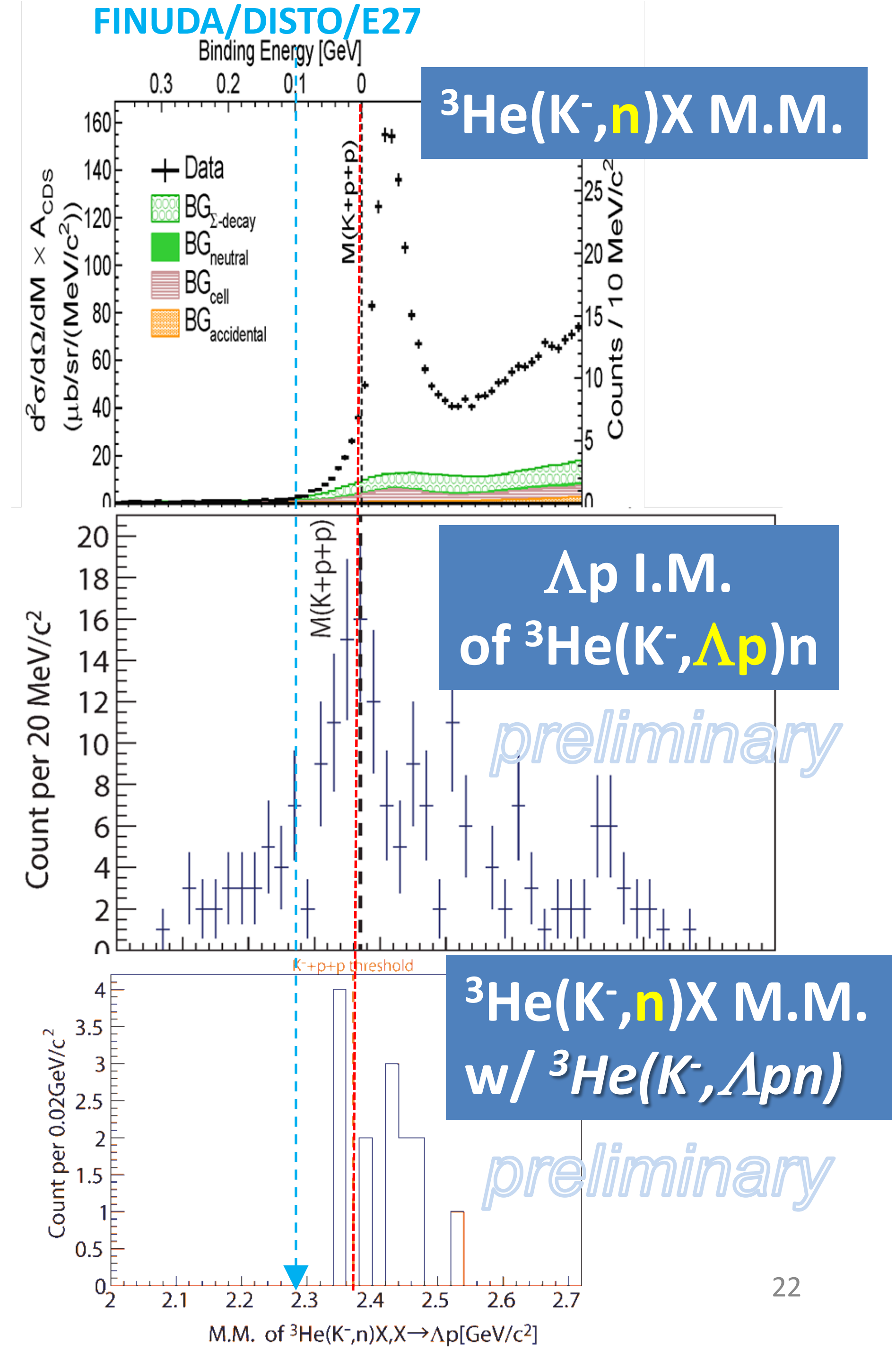
Some structure has been seen both in formation- and decay-channel

- Hint of S=-1 di-baryon state?

□ Reaction dependence?

$K^{bar}NN$ formation strongly depends on reaction channel?

- ➢ γ/π/K/p induced reaction?
- ➢ momentum transfer?



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