Recent results of the $K^{bar}NN$ search via the in-flight $^{3}He(K^{-},n)$ reaction at J-PARC

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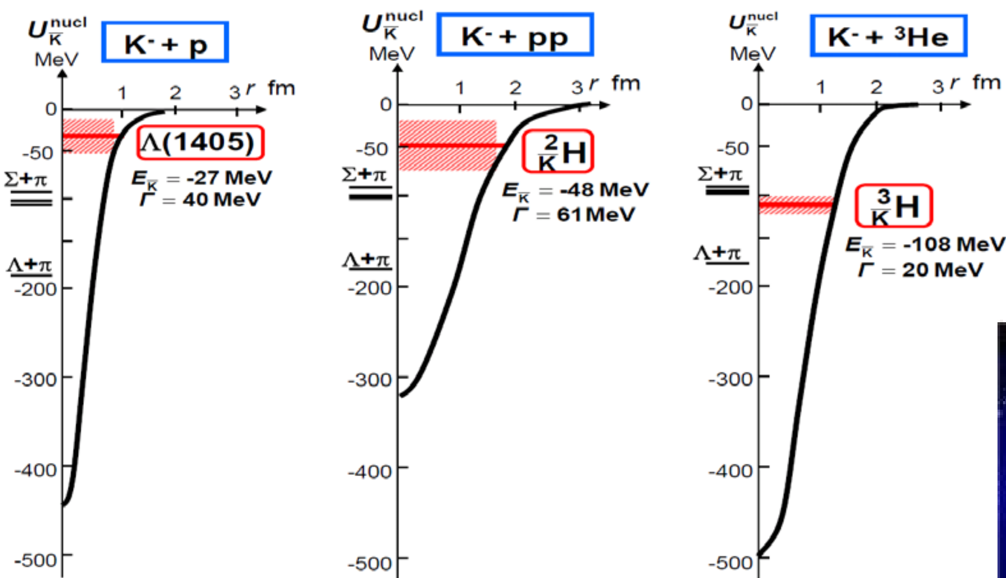
for the J-PARC E15 collaboration

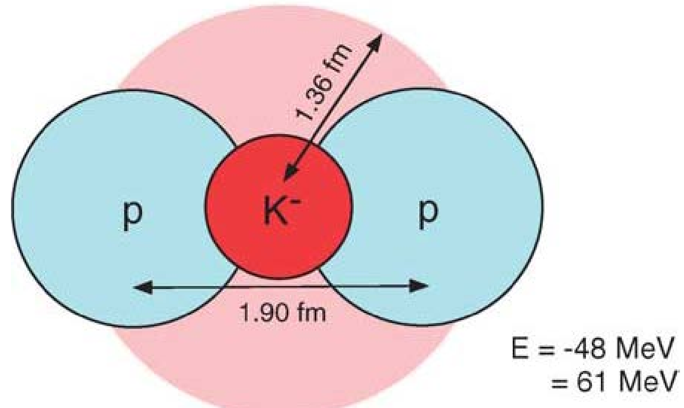
HYP2015, Sendai, Sep.7-12, 2015

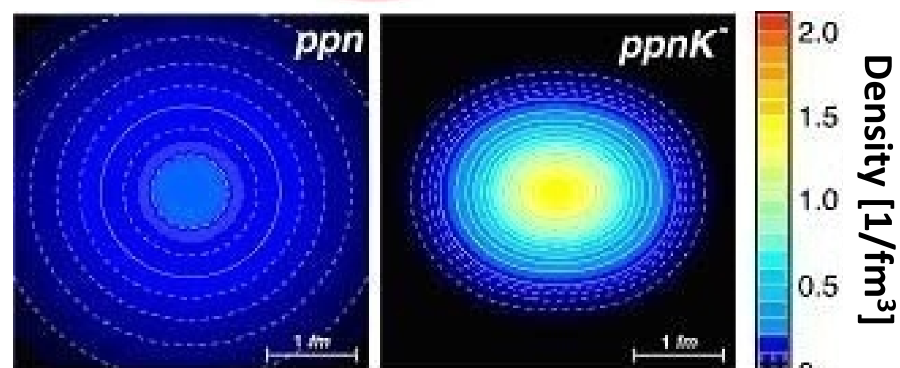
Kaonic Nuclei

Kaonic nucleus is a bound state of nucleus and anti-kaon ($K^{bar}NN$, $K^{bar}NNN$, $K^{bar}K^{bar}NN$, ...)



Y.Akaishi & T.Yamazaki, PLB535, 70(2002).





T.Yamazaki, A.Dote, Y.Akiaishi, PLB587, 167 (2004).

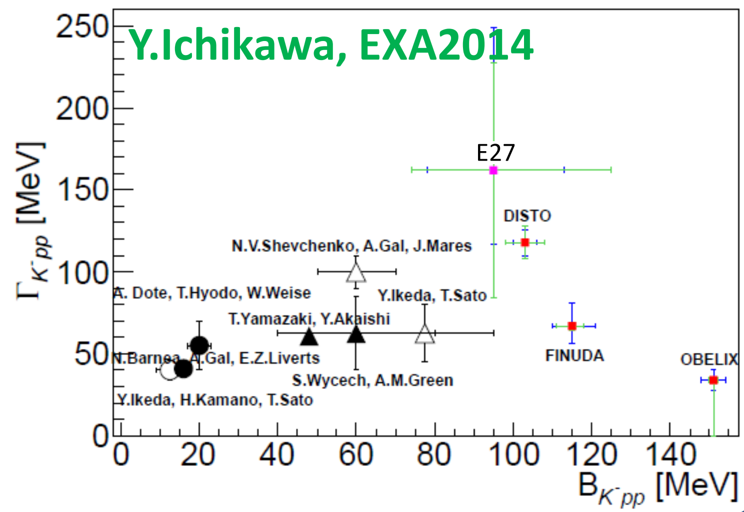
$K^{bar}NN$ Bound State

$K^{bar}NN$: the simplest K^{bar}-nuclear state

Calculated $K^- pp$ binding energies B and widths Γ (in MeV). **A.Gal, NPA914(2013)270**

	Chiral, energy dependent			Non-chiral, static calculations			
	var. [7]	var. [8]	Fad. [9]	var. [10]	Fad [11]	Fad [12]	var. [13]
B	16	17–23	9–16	48	50–70	60–95	40–80
Γ	41	40–70	34–46	61	90–110	45–80	40–85

[7] N. Barnea, A. Gal, E.Z. Liverts, Phys. Lett. B 712 (2012) 132.
[8] A. Doté, T. Hyodo, W. Weise, Nucl. Phys. A 804 (2008) 197;
A. Doté, T. Hyodo, W. Weise, Phys. Rev. C 79 (2009) 014003.
[9] Y. Ikeda, H. Kamano, T. Sato, Prog. Theor. Phys. 124 (2010) 533.
[10] T. Yamazaki, Y. Akaishi, Phys. Lett. B 535 (2002) 70.
[11] N.V. Shevchenko, A. Gal, J. Mareš, Phys. Rev. Lett. 98 (2007) 082301;
N.V. Shevchenko, A. Gal, J. Mareš, J. Revai, Phys. Rev. C 76 (2007) 044004.
[12] Y. Ikeda, T. Sato, Phys. Rev. C 76 (2007) 035203;
Y. Ikeda, T. Sato, Phys. Rev. C 79 (2009) 035201.
[13] S. Wycech, A.M. Green, Phys. Rev. C 79 (2009) 014001.

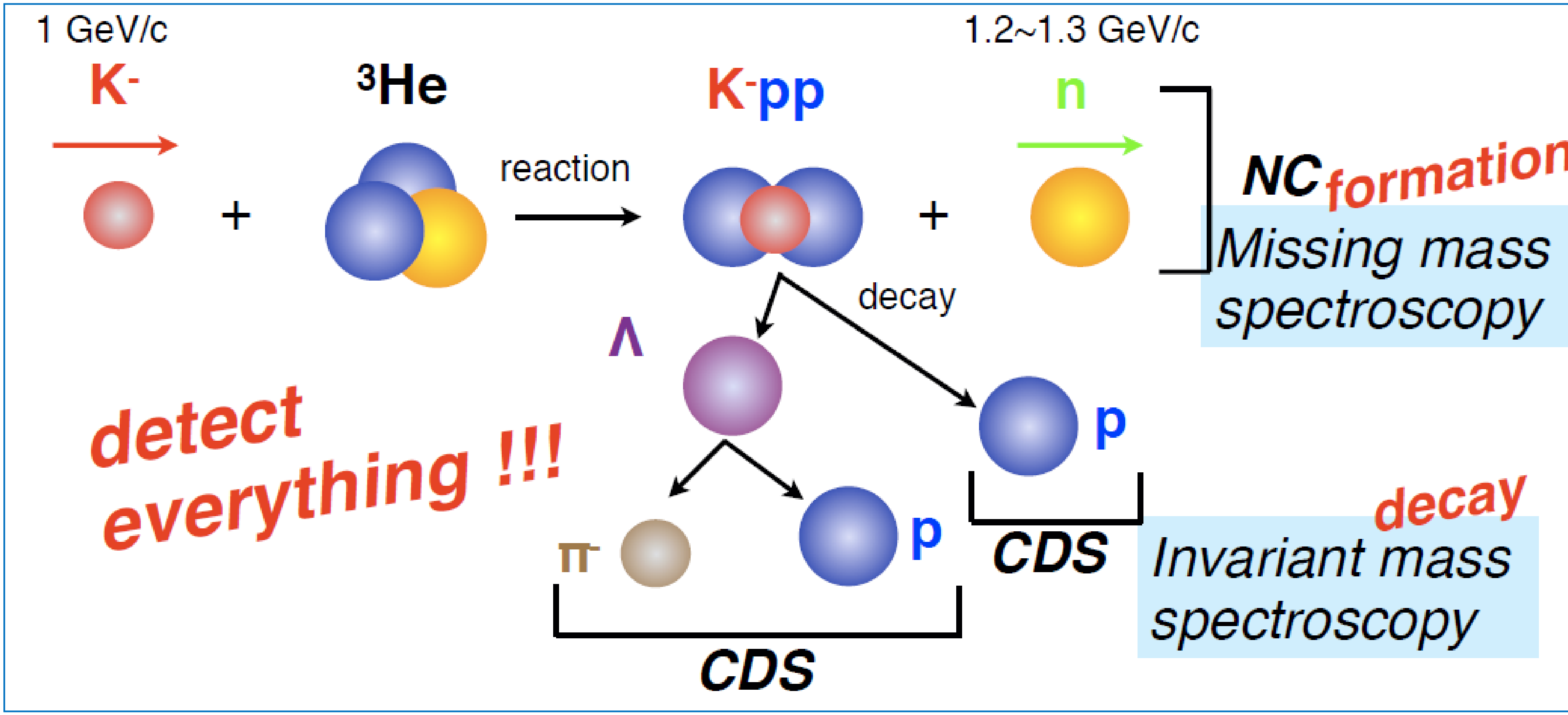


All theoretical studies predict existence of the $K^{bar}NN$

→ However, B.E. and Γ are controversial

J-PARC E15 Experiment

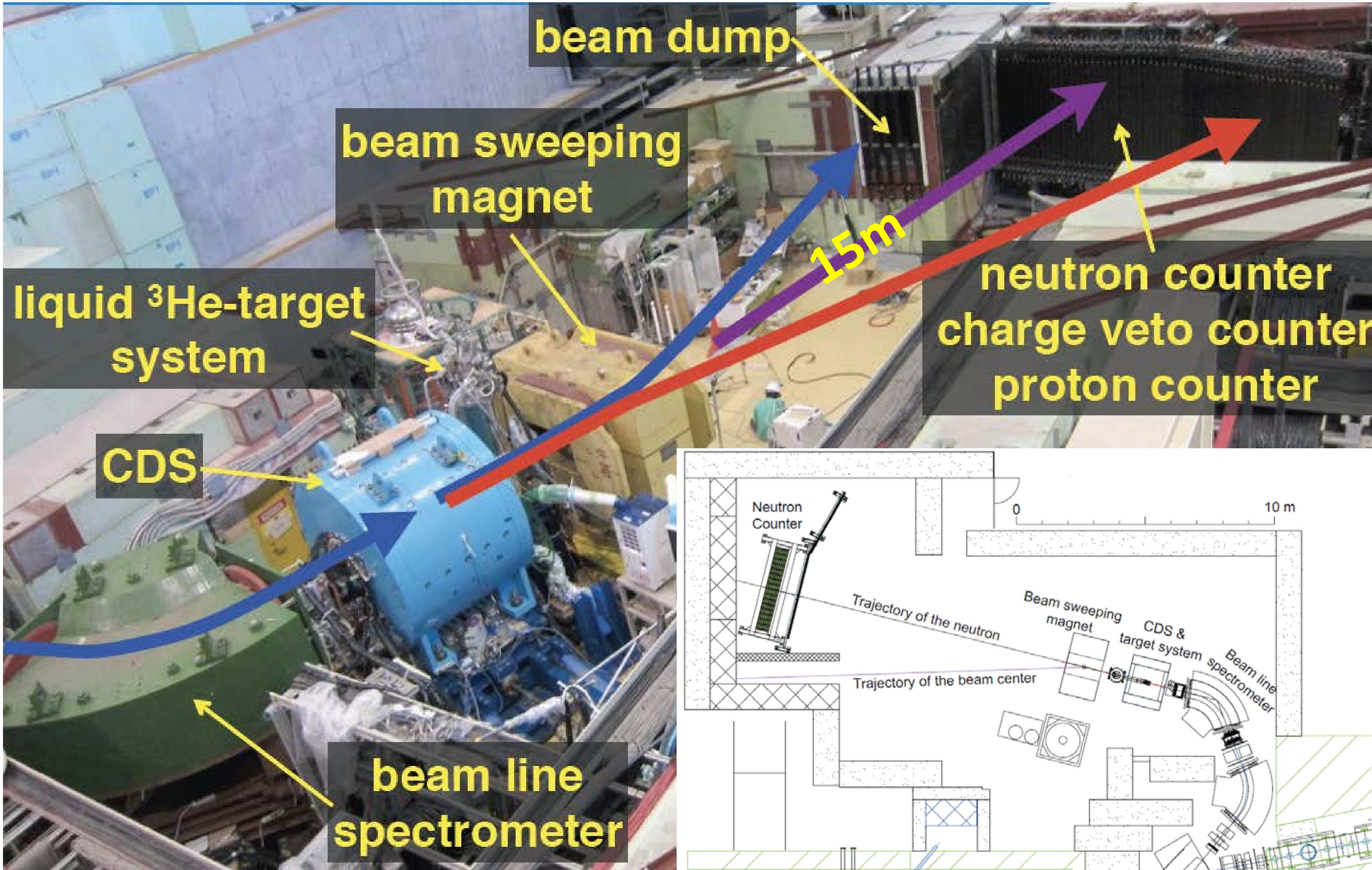
A search for the simplest kaonic nucleus, $K^{bar}NN$, using ^3He(*in-flight* K^-,n) reaction



- 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*

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

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

J-PARC E15 Collaboration
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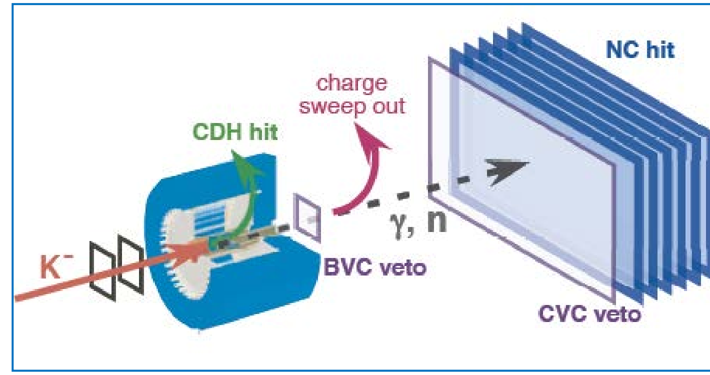
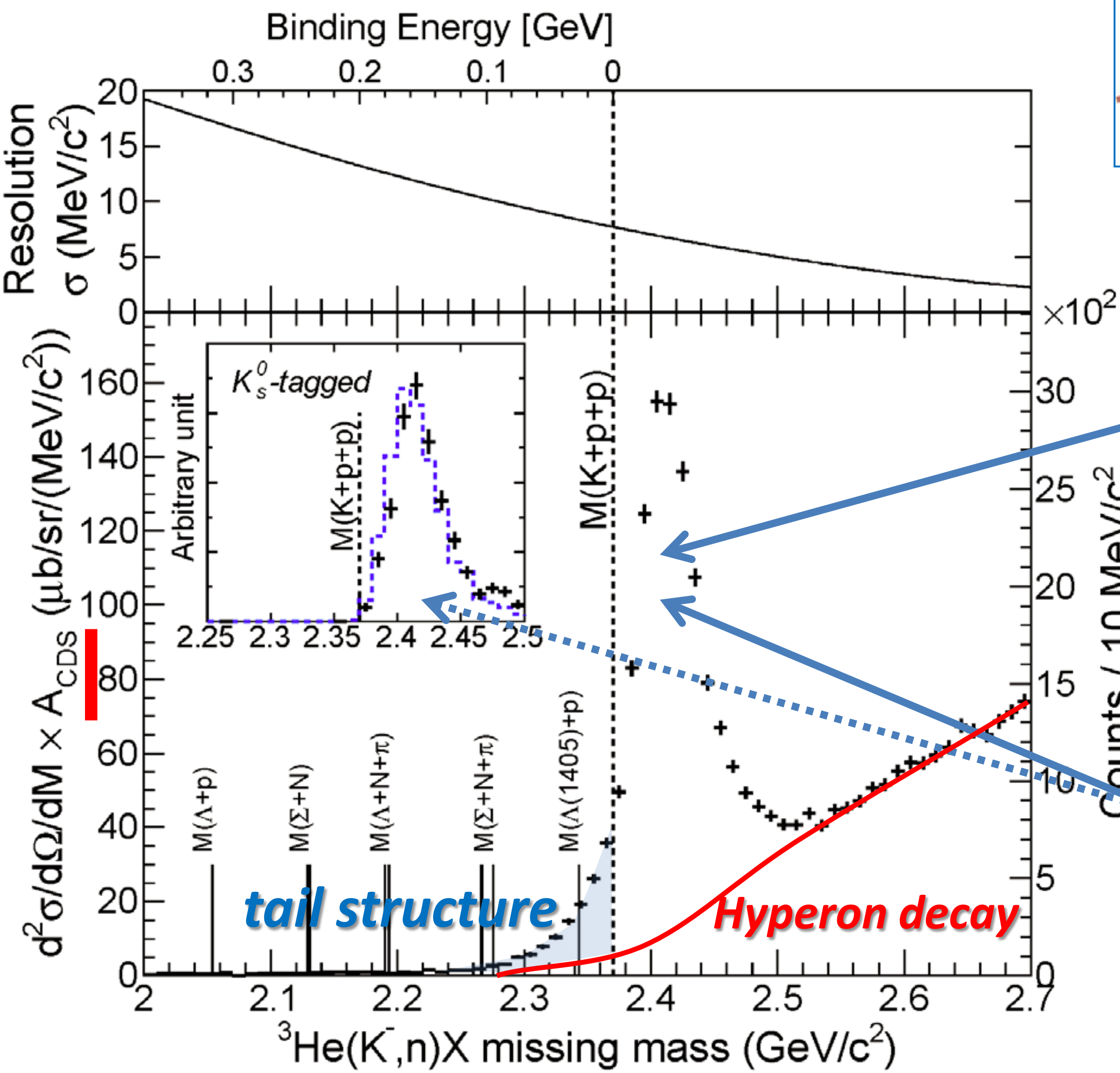
Semi-Inclusive Spectrum of $^3He(K^-,n)X$





Quasi Elastic

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

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

and

Charge-Exchange

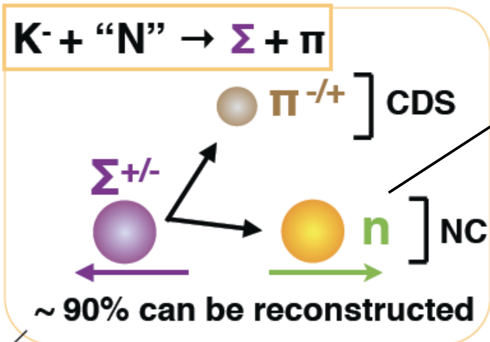
$K^- + {}^3He \rightarrow K^0 + \mathbf{n} + d_s$

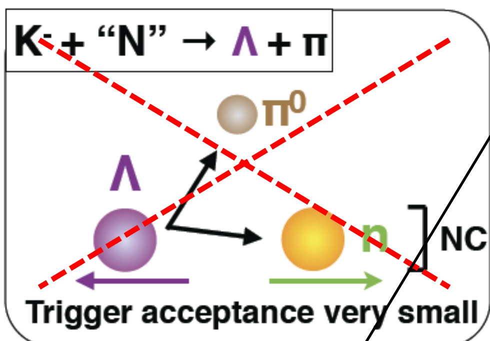
$K^0 \rightarrow \pi^+ + \pi^-$

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

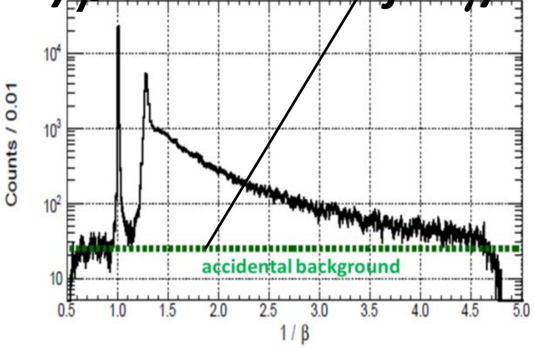
Comparison of $^3He(K^-,n)X$

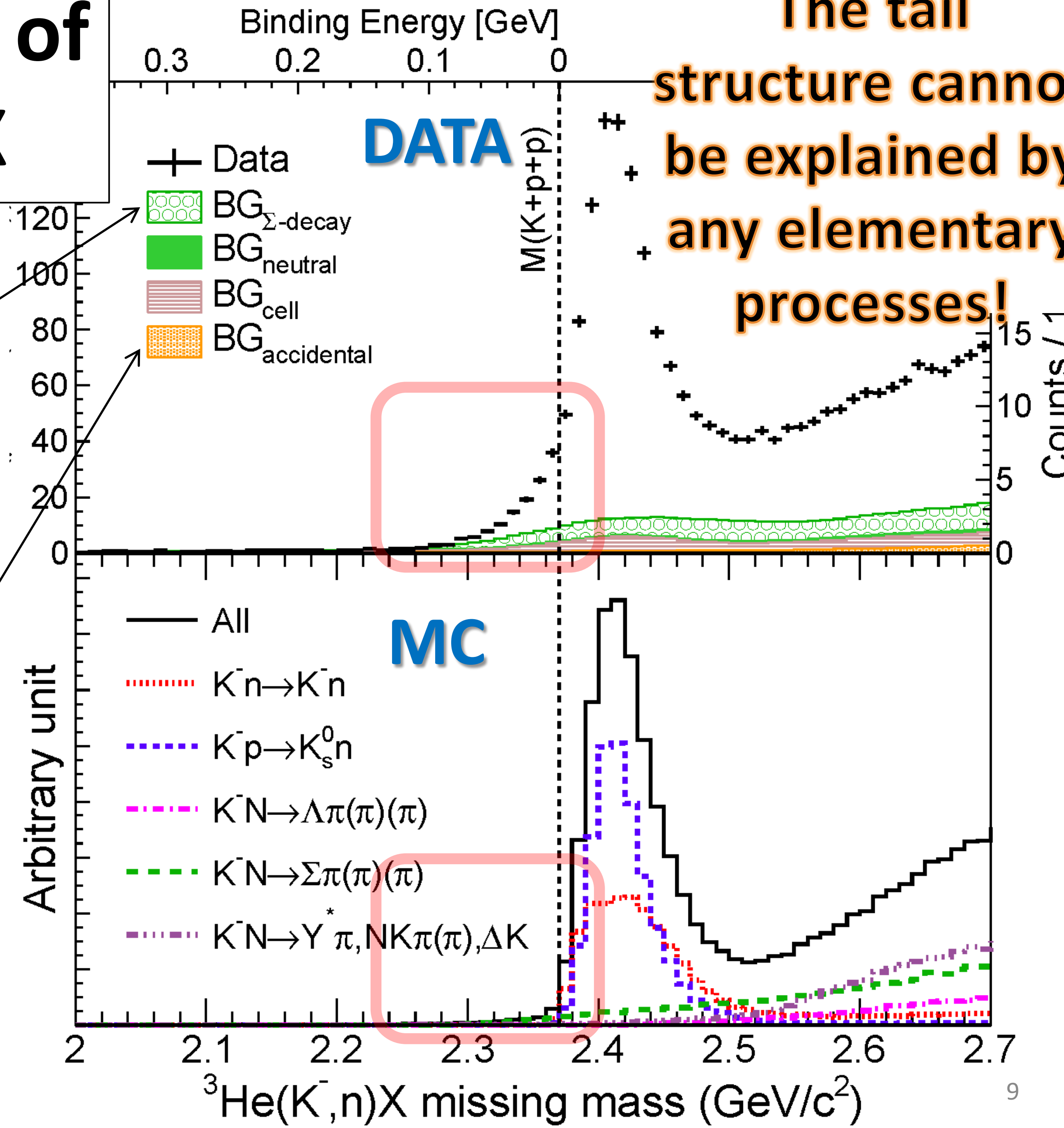
The tail structure cannot be explained by any elementary processes!



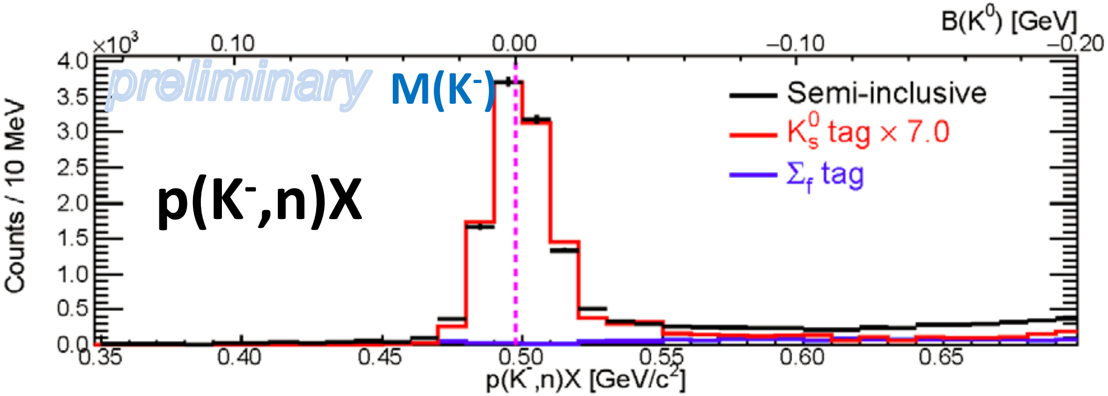


1/β distribution for γ/n



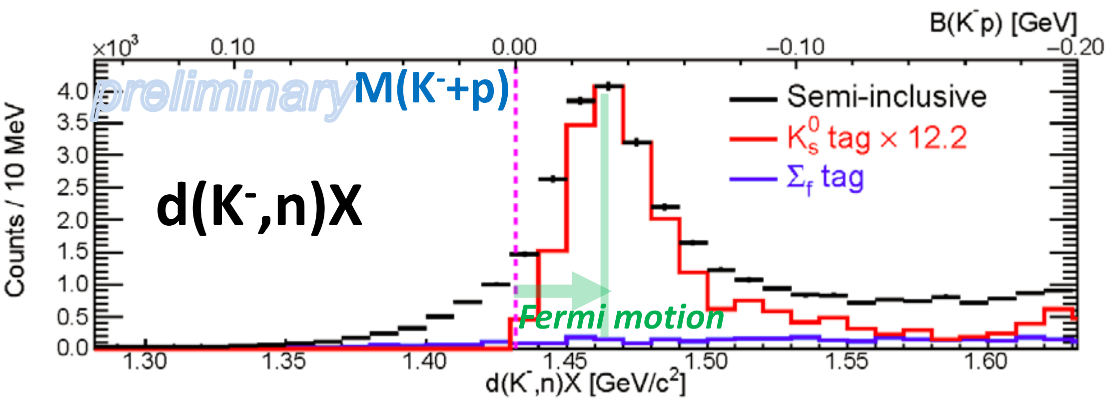


Subthreshold Excess?



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

  well describes the spectrum



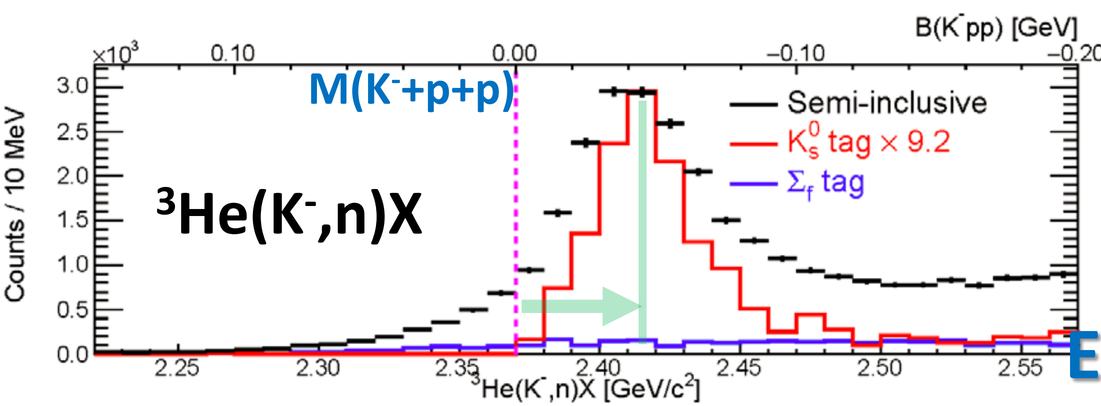
- $K^-d \rightarrow [K^-p] + n_{fw}$

  Y*

  sub-threshold excess is seen

  The main goal of E31

  → Inoue's Talk (5a-2, 9/8)



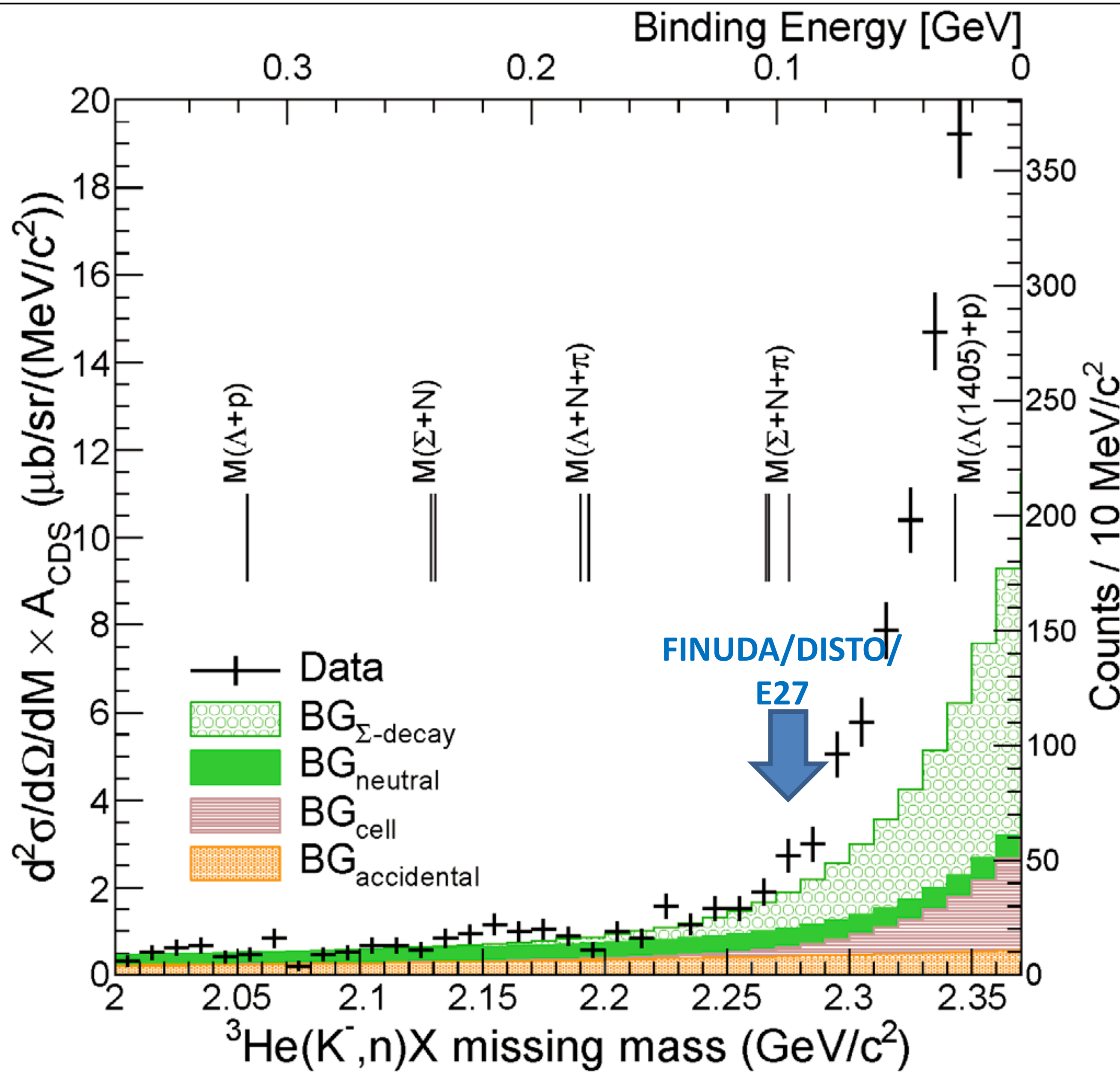
- $K^{-3}He \rightarrow [K^-pp] + n_{fw}$

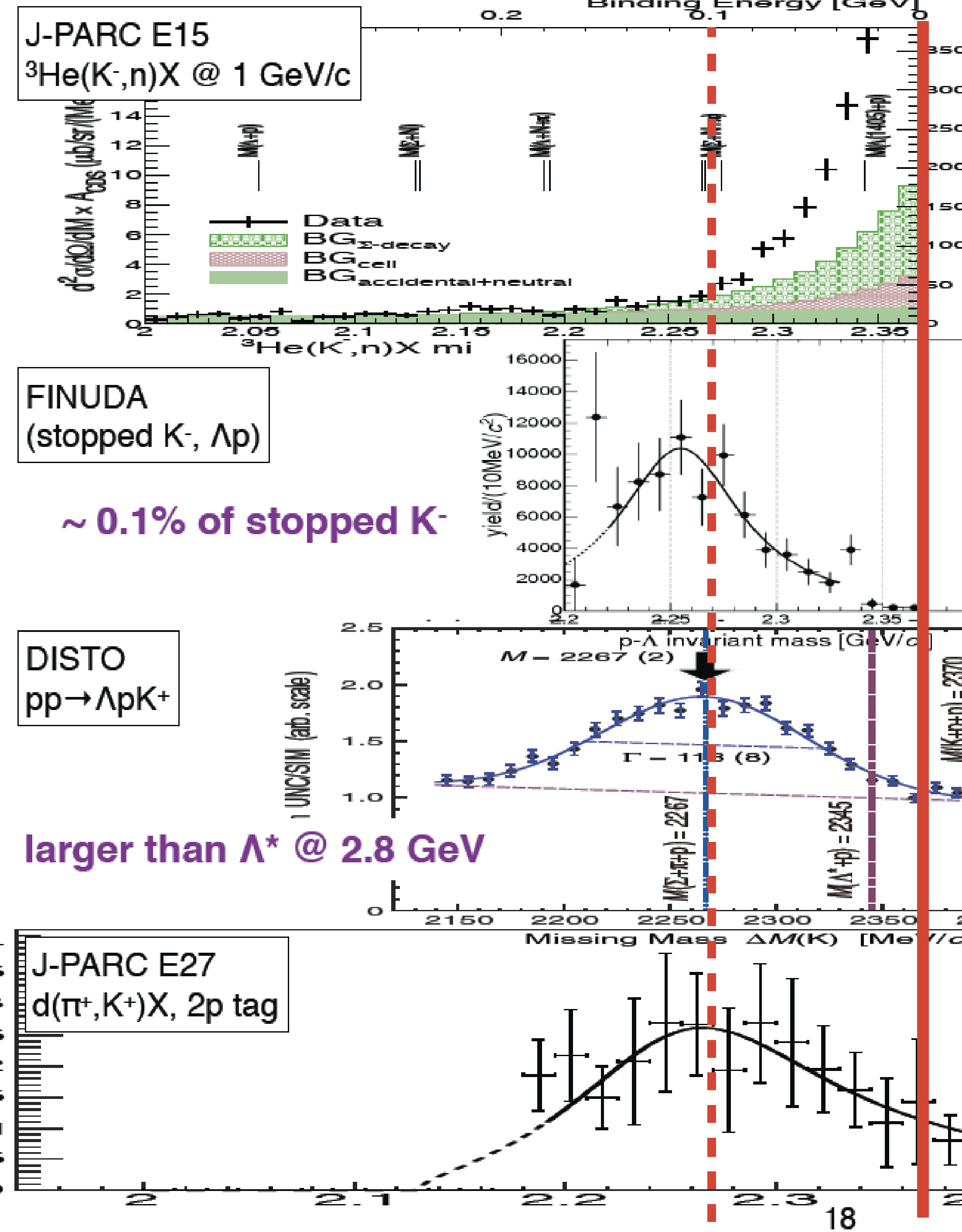
  Y*N

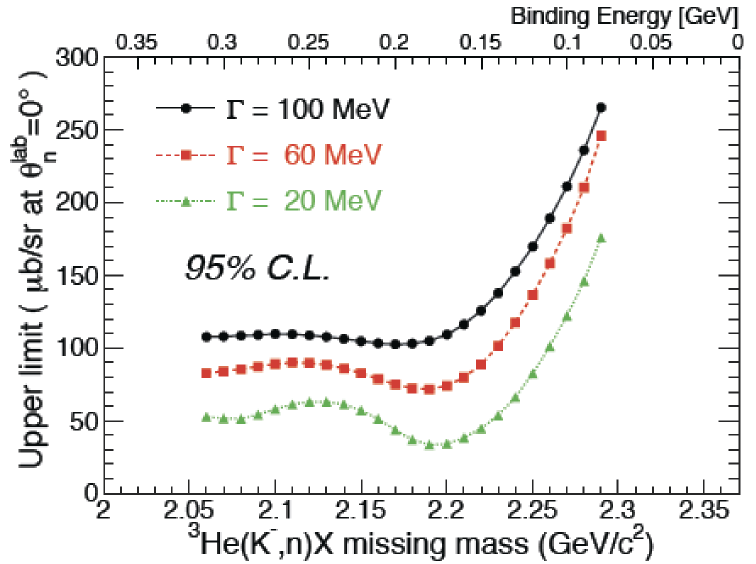
  sub-threshold excess is seen

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

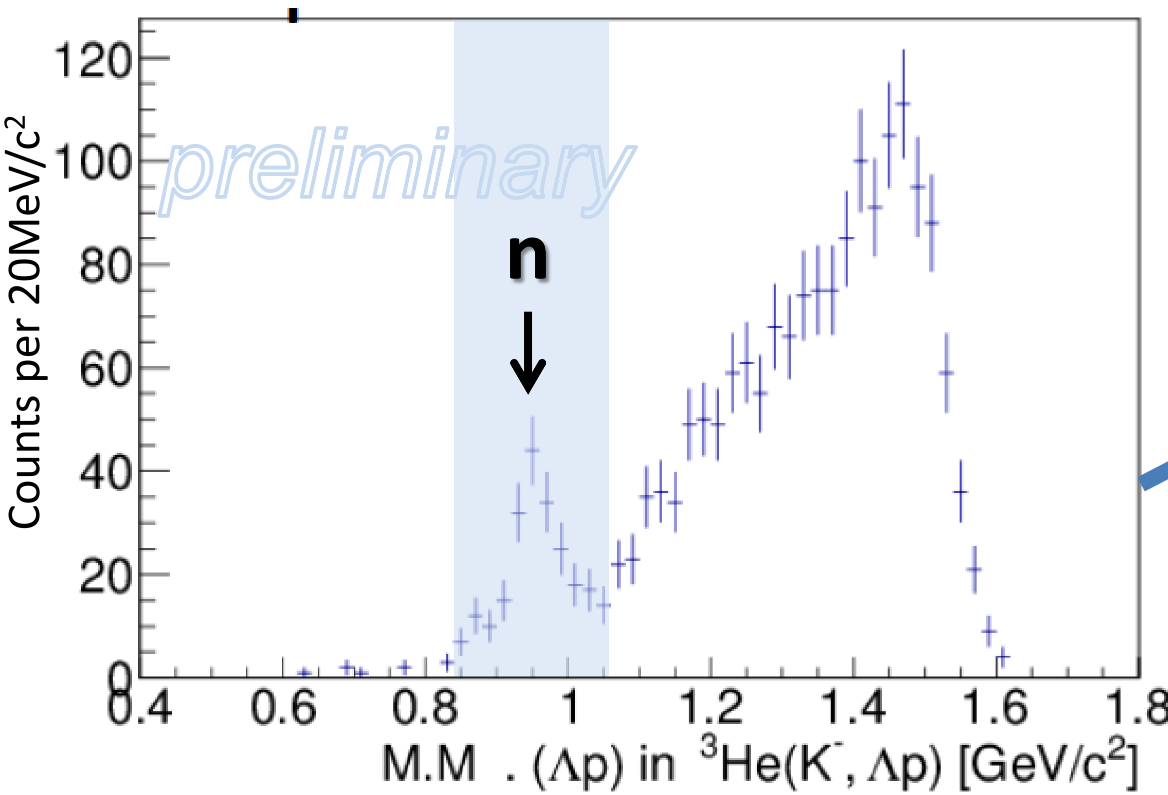
- **LEPS (γ+d) (U.L.)**
  1.5-26% of γN→K^{+}πY

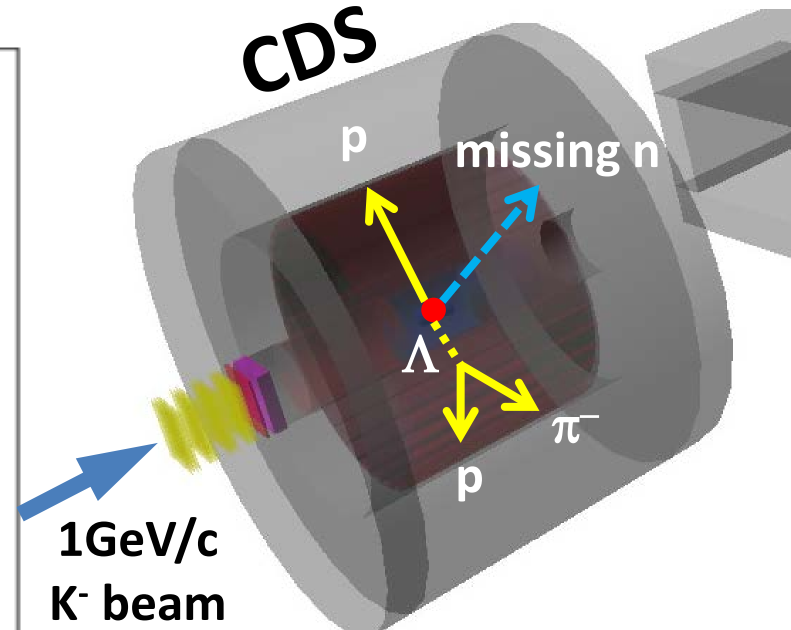
- **HADES (pp @ 3.5 GeV)**
  0.7-4.2 μb (Λ* ~ 10 μb)

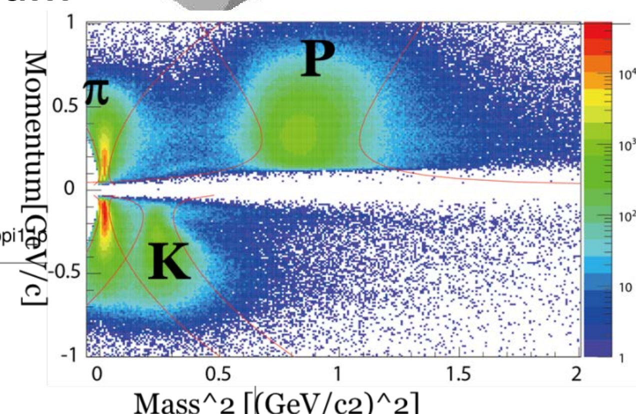
Decay Channel,
Exclusive $^{3}He(K^{-},\Lambda p)n$

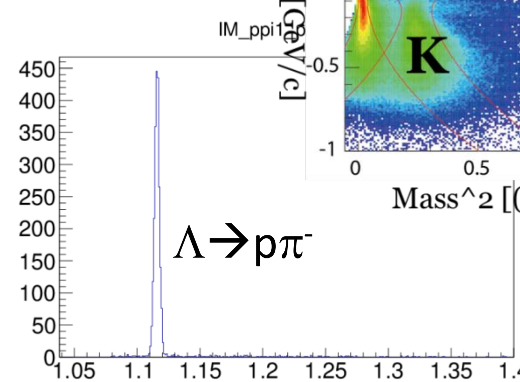
Y.Sada et al., paper in preparation

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



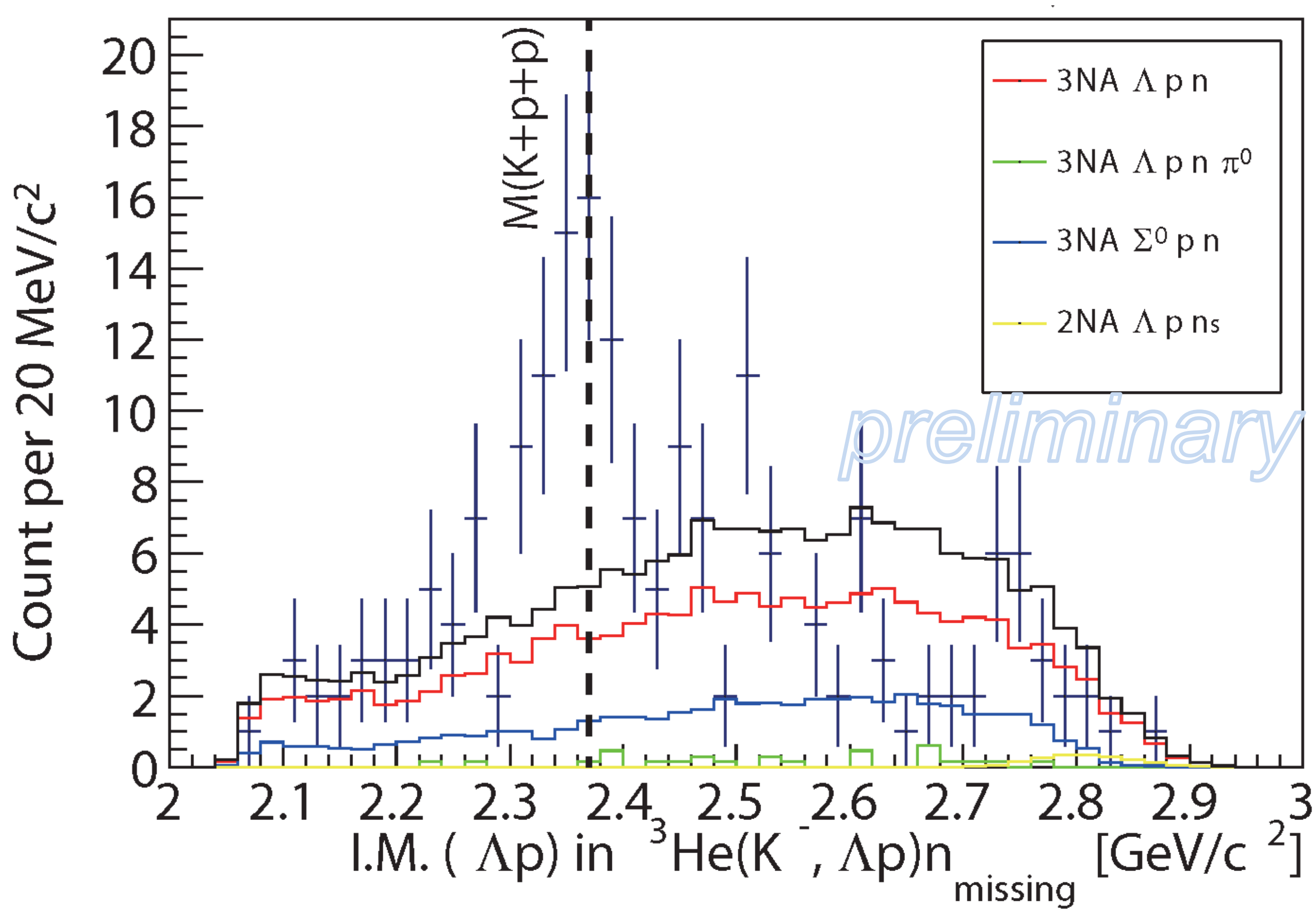






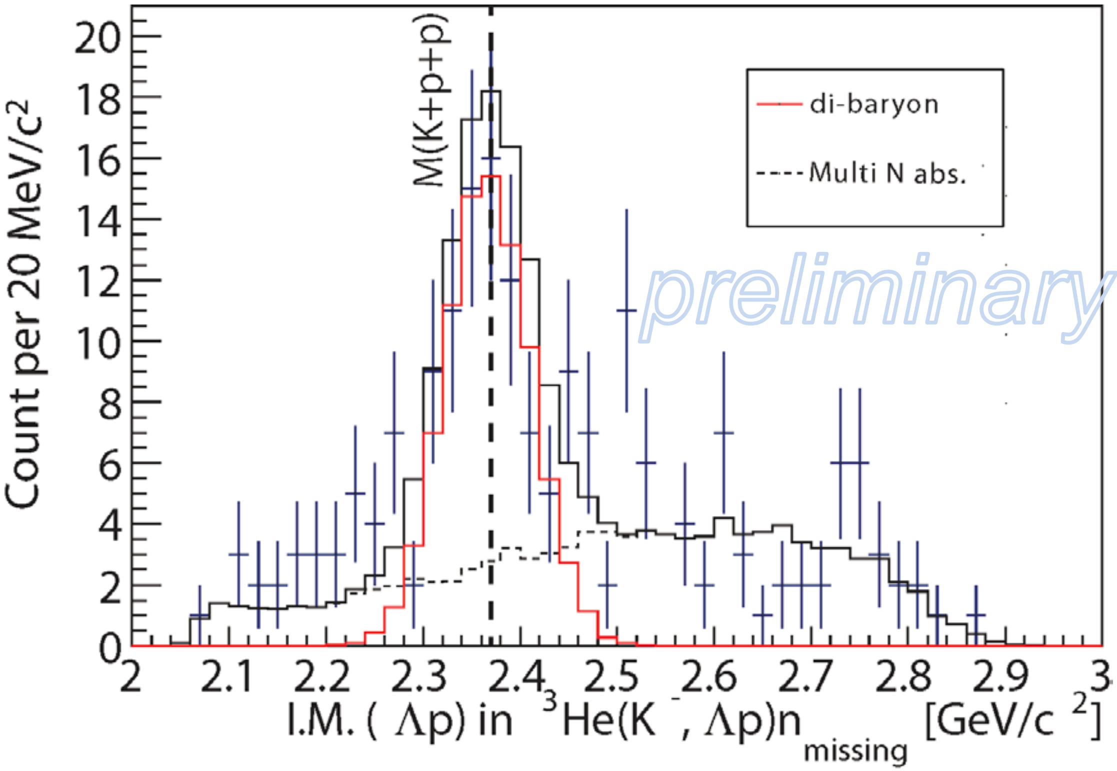
- $K^{-3}He \rightarrow \Lambda(\Sigma^0)pn$ events can be identified exclusively
  - # of $\Lambda(\Sigma^0)pn$ events: ~200
    - $\Sigma^0 pn$ contamination: ~20%

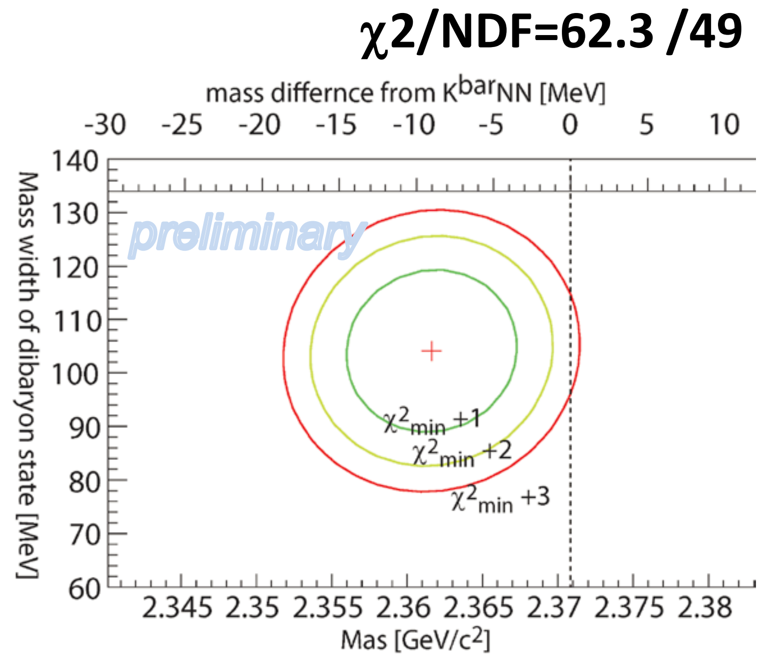
Exclusive $^3He(K^-,\Lambda p)n$ by 3NA



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

Assuming a Breit-Wigner

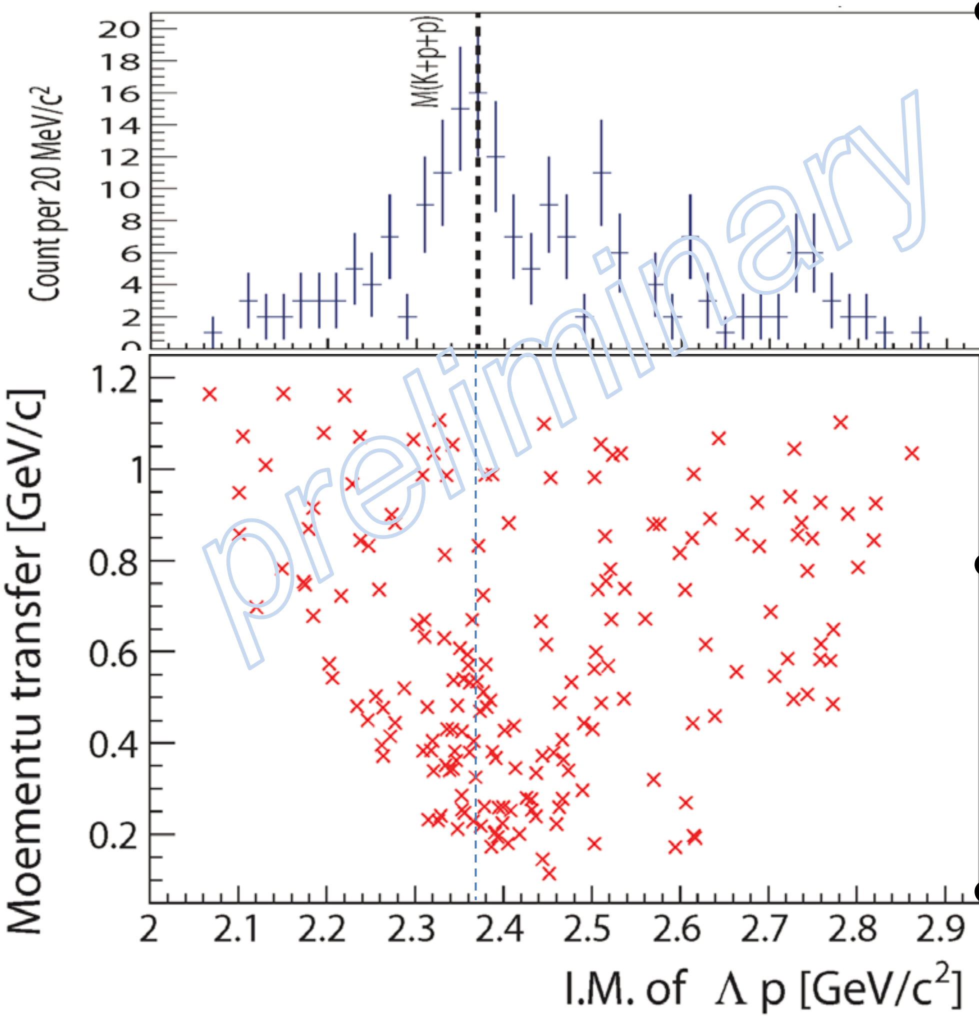




- χ^2-test with a Breit-Wigenr and 3NAs
  - assumption: isotropic Λp decay
  - parameters: Mass, Width, and Yield

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 $X \rightarrow \Lambda p$?

(further study is in progress…)

Summary

- **Deeply-bound region**

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

- **Around the threshold**

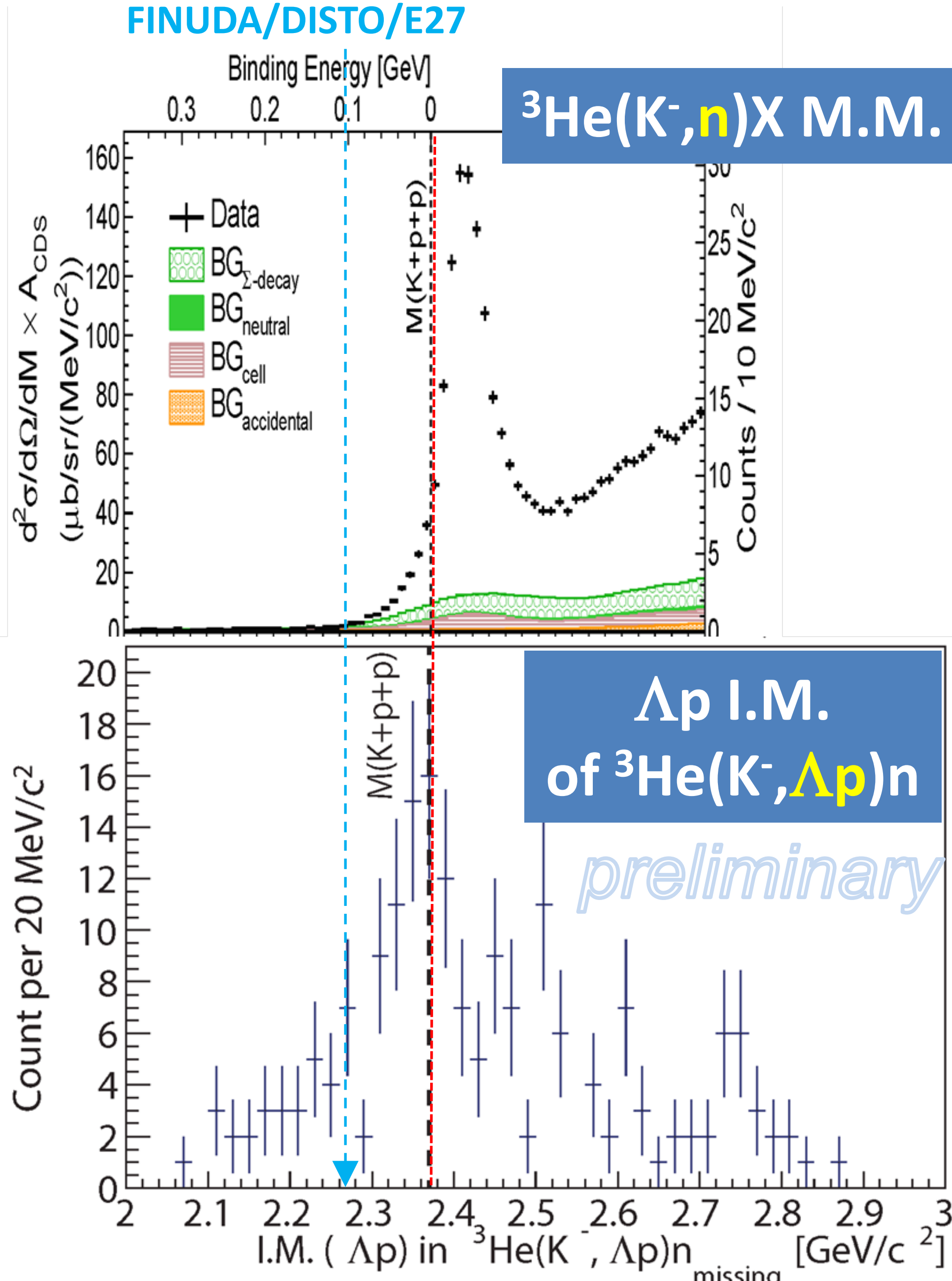
Structure has been seen both in formation- and decay-channel

  - Contribution of Y*?
  - 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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