K1.8BR Beam-time Plan and Analysis Status of E15-1st

Search for "K⁻pp" state via ^{3}He(K⁻,n) reaction @ p_K = 1 GeV/c

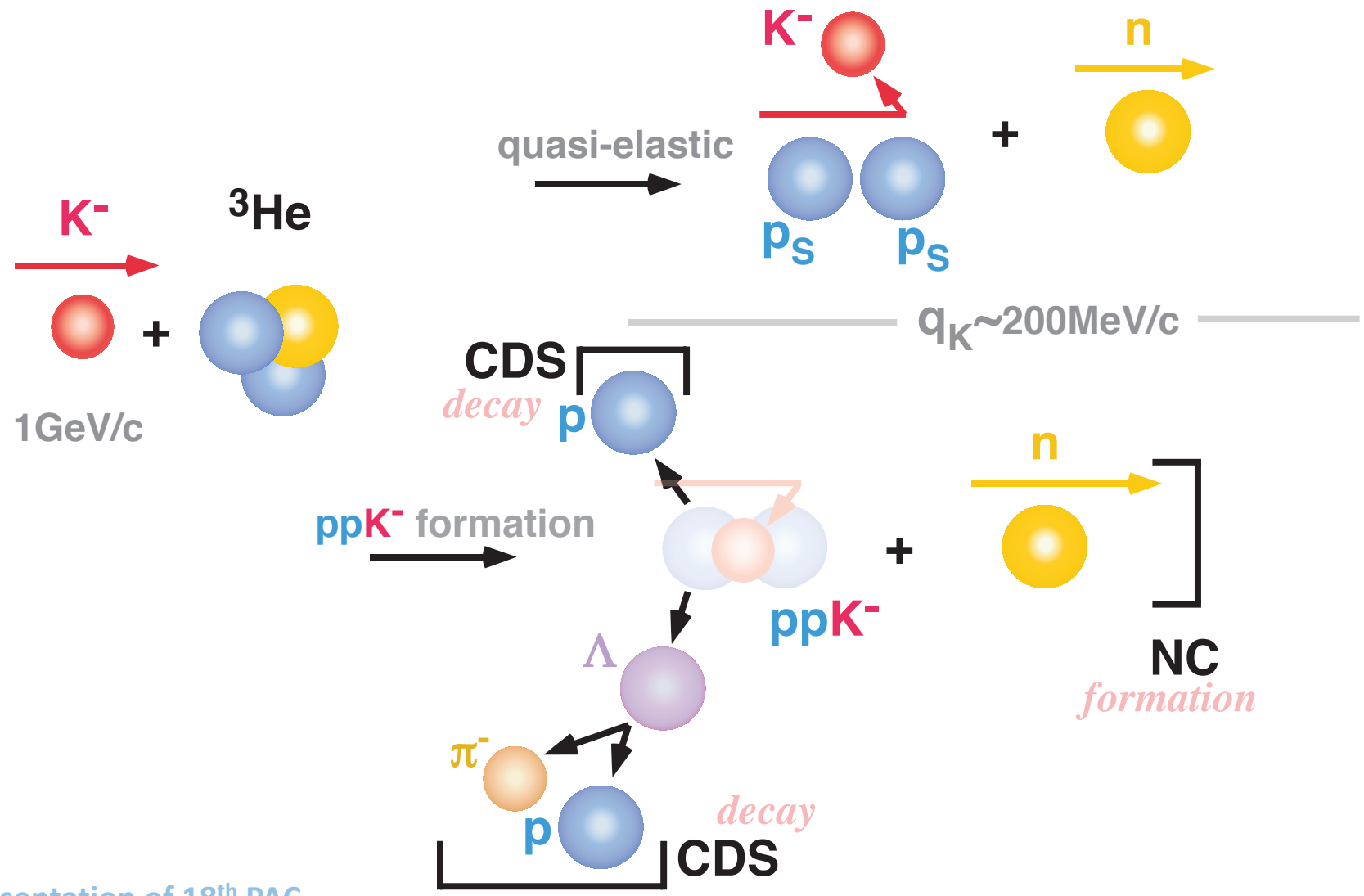
M.Iwasaki

for J-PARC E15 Collaboration

E15: "K⁻pp" search via ^{3}He(K⁻,n) @p_K=1GeV/c

for efficient "ppK" formation { *without 2NA background*

Formation & Decay { *Y decay can be rejected*



Formation vs Decay

Formation channel

semi-inclusive

$K^- + {}^3He \rightarrow n + X\ (\theta_n=0)$

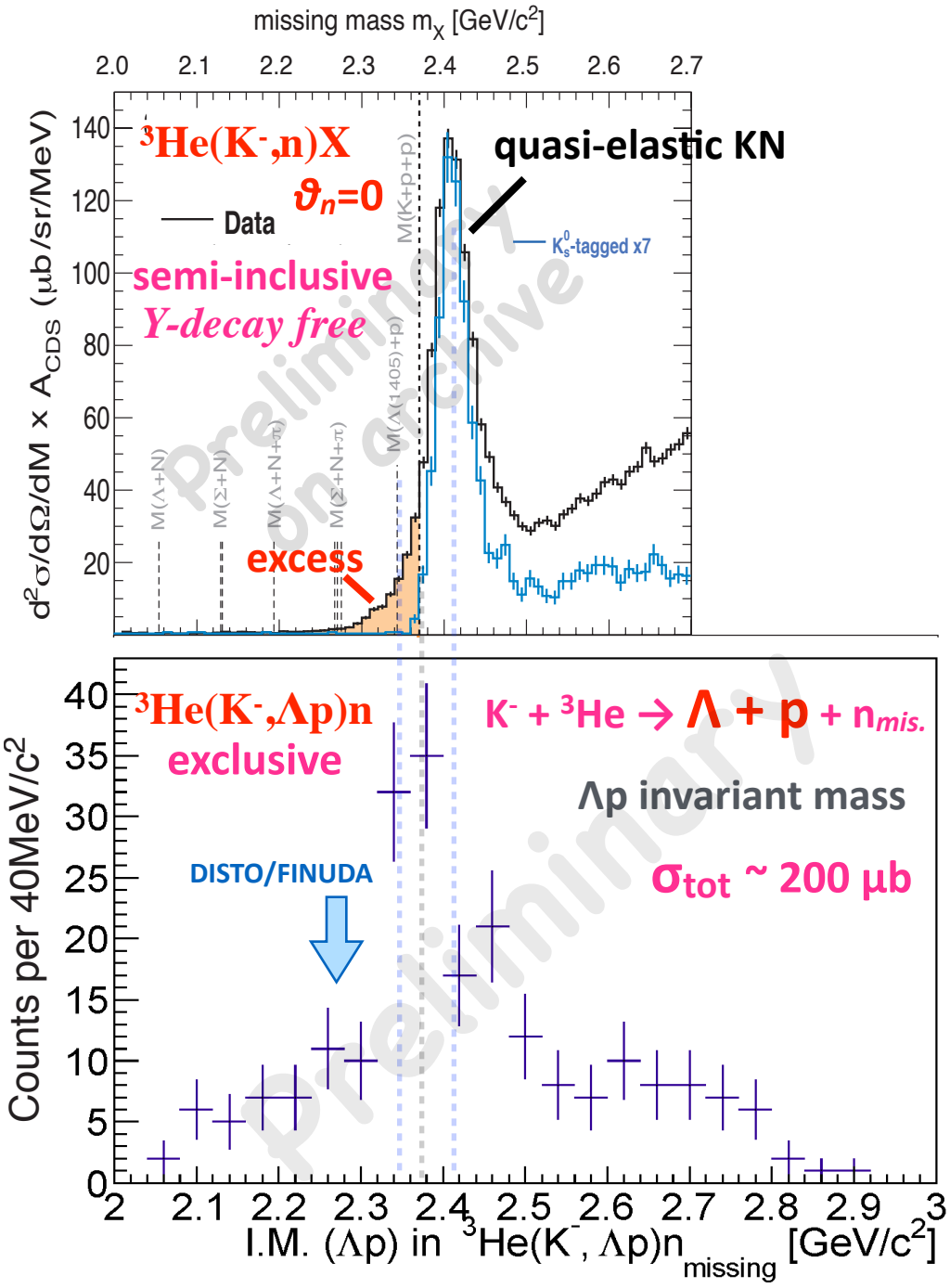
- excess below threshold
  background-free
- contribution from
  $\Lambda(1405)n + p_S$ (2NA)
  may exist

Decay channel

exclusive

$K^- + {}^3He \rightarrow \Lambda + p + n_{mis.}$

- excess exist near threshold
- cannot be $\Lambda(1405)n + p_S$ (2NA), because F.S.= $\Lambda p n$
- contamination $\Sigma^0 < 20\%$



E15 2nd stage

May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	140 k/spill	88 h	5.1 x 10^9

x10

E15 2nd: 50x10^9 kaons on target

The goal of the E15 2nd

1. confirm the spectral shape of the Λp invariant-mass by the exclusive measurement of ^{3}He(K^-,Λp)$n_{mis.}$
2. explore the neutron spectrum at θ_{lab}=0 with aid of kinematically complete measurement of ^{3}He(K^-,Λpn)
3. extend study on other channel, like ^{3}He(K^-,Σπpn)

➢ to extract more information on the $K^{bar}N$ interaction

Approved Beam-time at 18th-PAC

Beam-time Plan @ K1.8BR

1 GeV/c K^- yield = 140 k/spill (=Run49c) *previously achieved value*

May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	140 k/spill	88 h	5.1 x 10^9

1. Commissioning run
   - **~1 day**
2. Calibration run with H2-target
   - **~4 days** → $p(K^-,K^0)n_{forward}$: ~5×10^3 *corrected*
3. E31 pilot run with D2-target
   - $14*10^9$ kaons on target = **~10 days**
4. E15 2nd-stage production run with ^{3}He-target
   - $50*10^9$ kaons on target = **~40 days**

--- Report from 18th PAC ---

"The beam request of the 2nd stage is reasonable and necessary to further study the K-pp system, and supports the beam request."

K1.8BR Beam-time Plan

--- under updated situation ---

Expected K- yield in Feb.-Mar., 2015

--- based on Run#49c condition ---

	Primary-beam intensity	Secondary-kaon intensity	Kaons on target / day (w/ tgt selection)
May, 2013 (Run#49c)	***24 kW (30 Tppp, 6s)***	***140 k/spill***	***1.4 x 10^9/day***

previously achieved value

** production target: Au 50% loss, spill length: 2s, spill duty factor: ~45%, K/pi ratio: ~1/2*

** ~70% of beam kaons hit the fiducial volume of ^{3}He target*

- **f_{T1} ~ 0.8 [T1 optics modification]**
- **f_{spill} ~ 0.67 [space cycle 6s→9s (2.93s flat-top)]**

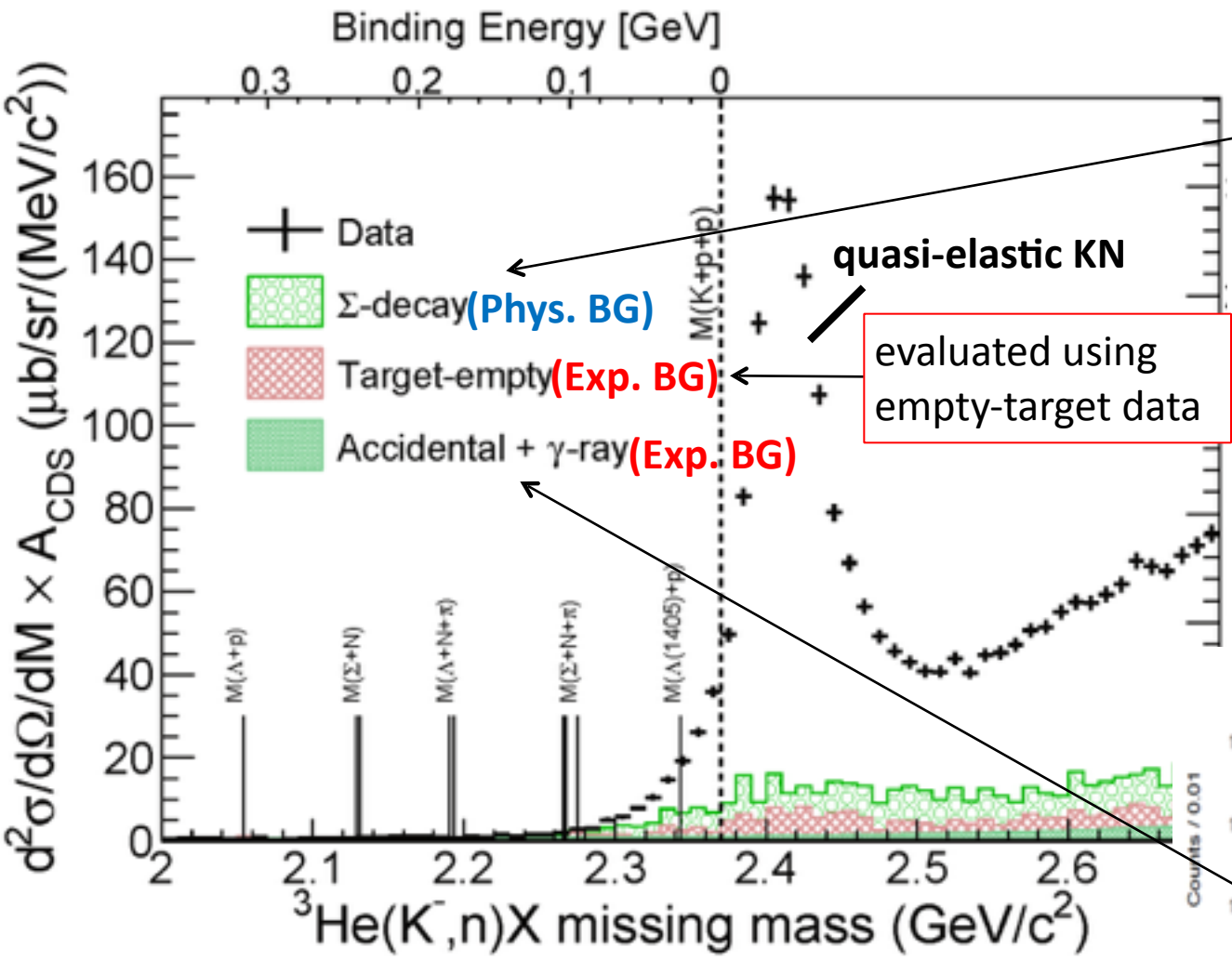
	Primary-beam intensity	Secondary-kaon intensity	Kaons on target / day (w/ tgt selection)
Feb.-Mar, 2015	***30 Tppp, 9s***	***110 k/spill***	***0.7 x 10^9/day***

"Updated" Beam-time Plan @ K1.8BR

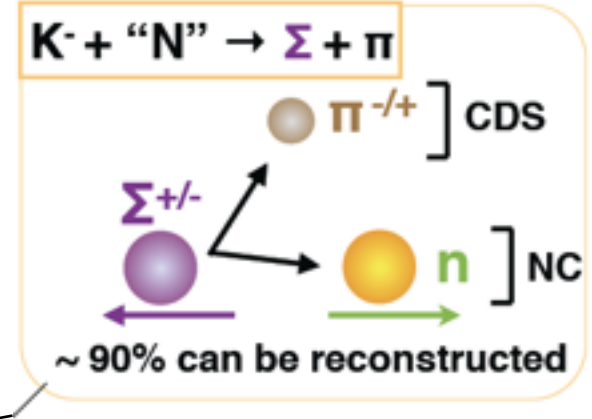
		Primary-beam intensity	Kaons on target	Duration	Objectives
Feb. - Mar., 2015	***Commissioning***	***30 Tppp, 9s***		***1 day***	***beam-line optimization***
Feb. - Mar., 2015	**Calibration (H2)**	30 Tppp, 9s	$4*10^9$	6 days	calibration of the NC [$p(K^-,K^0_S)n$: 5000 events]
- Jun., 2015	***E31-pilot (D2)***	***30 Tppp, 9s (30 Tppp, 6s)***	***$14*10^9$***	***20 days (13 days)***	$\Lambda(1405)\rightarrow\pi^+\Sigma^-$***: 750*** $\rightarrow\pi^-\Sigma^+$***: 120*** $\rightarrow\pi^0\Sigma^0$***: 33***
Oct. - Mar., 2016	**E15-2nd (^{3}He)**	60 Tppp, 6s ***50 kW (6s)!***	$50*10^9$	25 days	• $^3He(K^-,n)X$ + tagging • $^3He(K^-,\Lambda p)n$: 2,000 • $^3He(K^-,\Lambda pn)$: 100

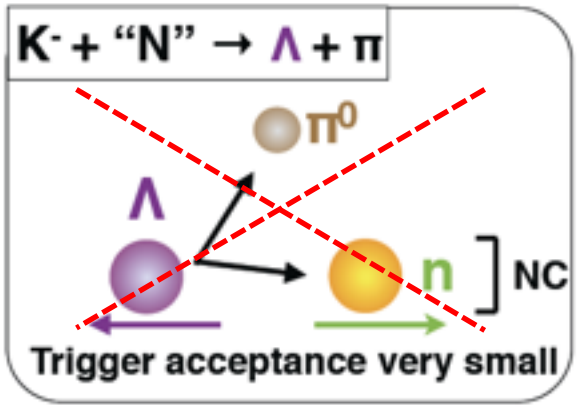
Analysis Status of E15-1st

Background Evaluation

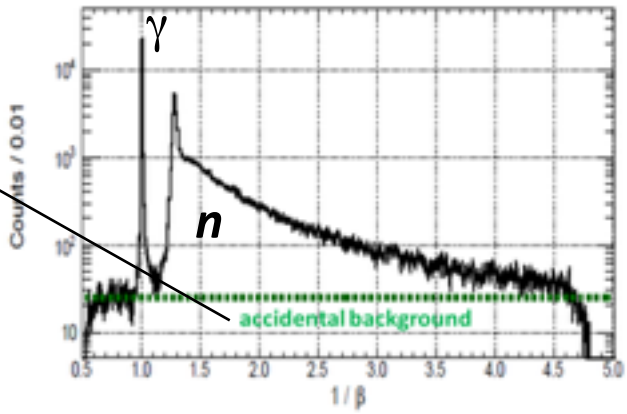


evaluated using empty-target data



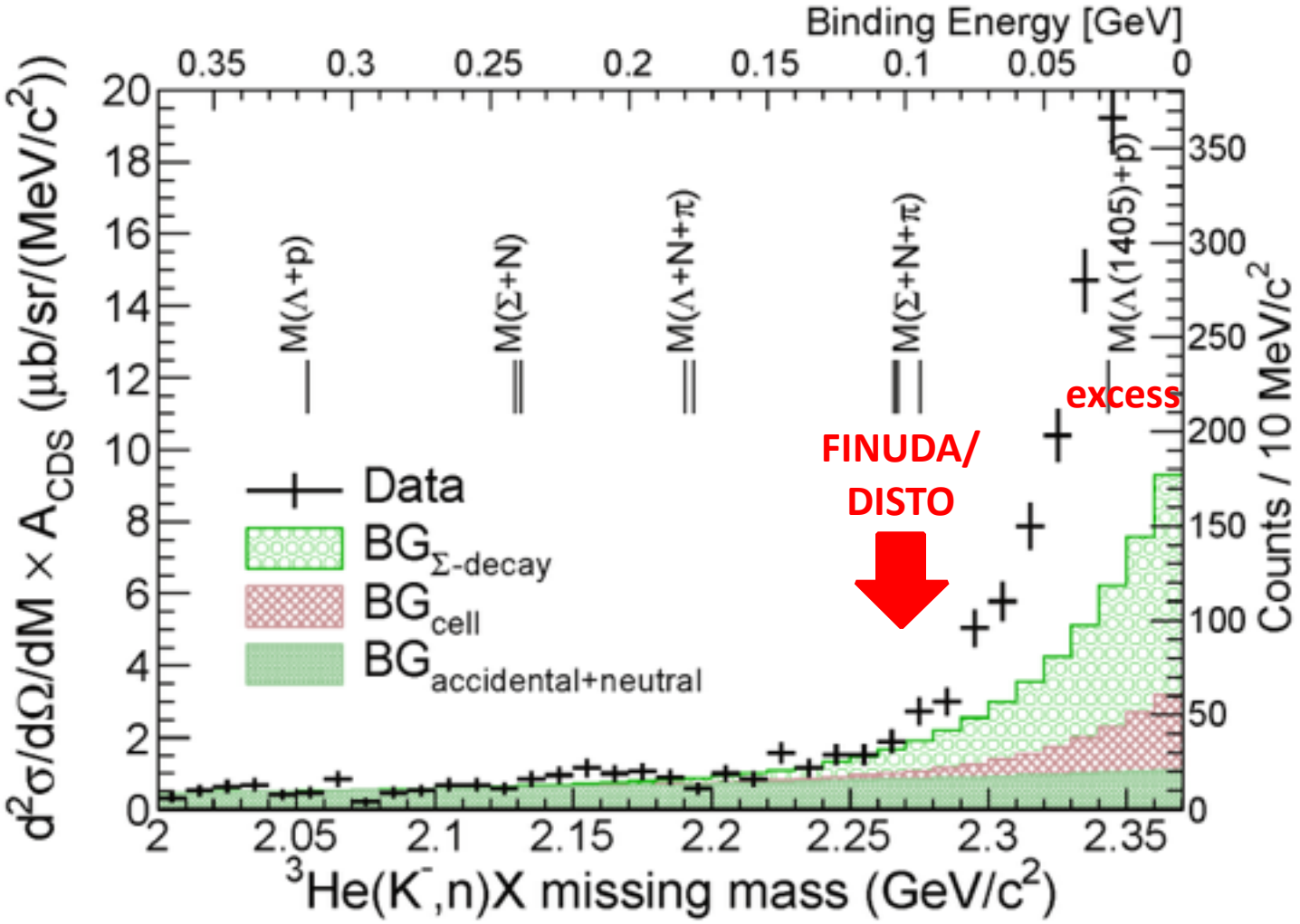


1/β distribution for γ/n



Spectrum below the Threshold

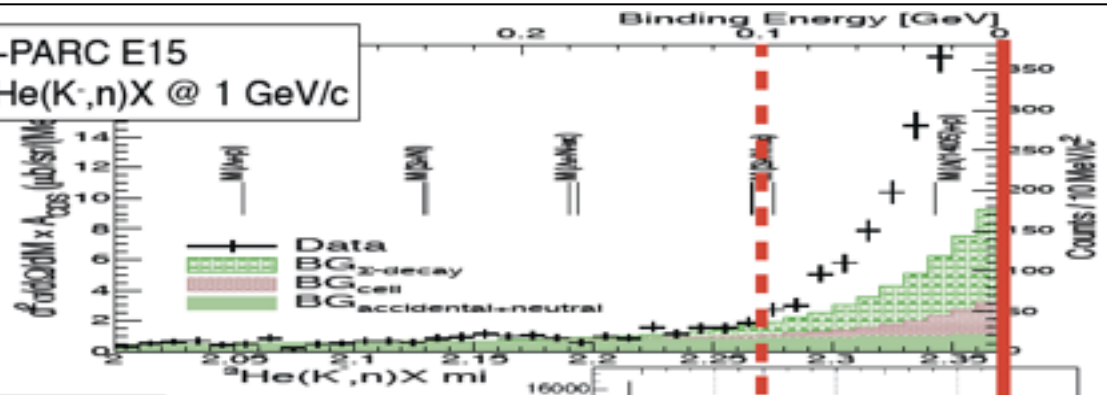
T.Hashimoto et al., arXiv:1408.5637, submitted to PLB



- **No significant structure in the deep-binding region**
- **Excess (tail) exist just below K^-pp threshold**

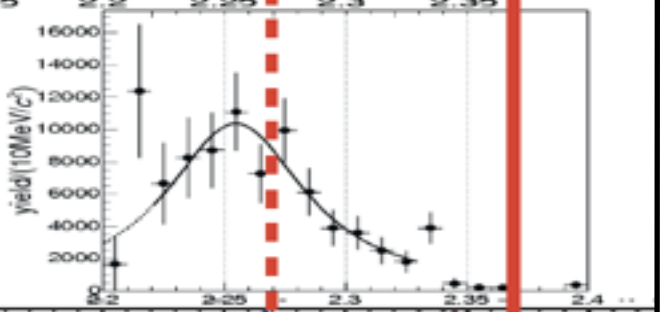
E15 and Other Experiments

J-PARC E15
^{3}He(K$^-$,n)X @ 1 GeV/c



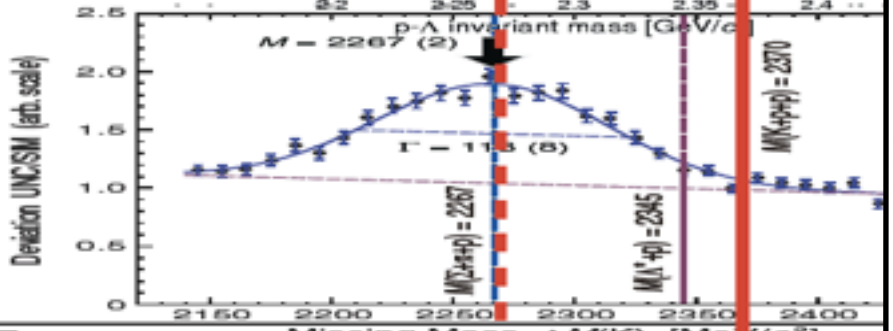
FINUDA
stopped K$^-$

PRL94(2005)212303



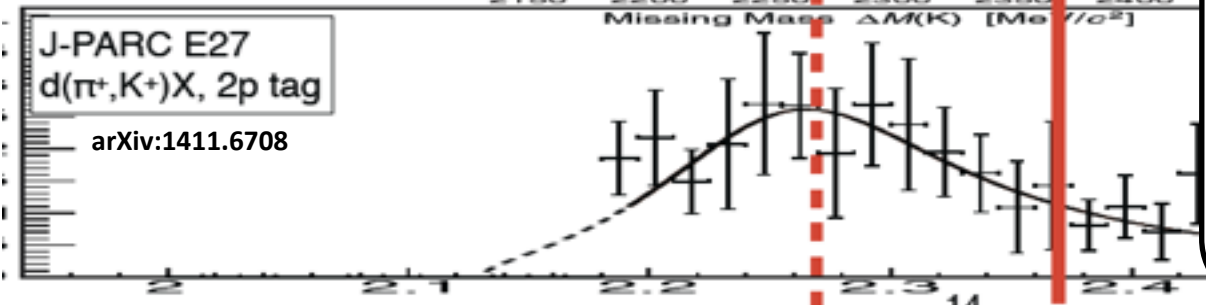
DISTO
pp→ΛpK$^+$

PRL104(2010)132502



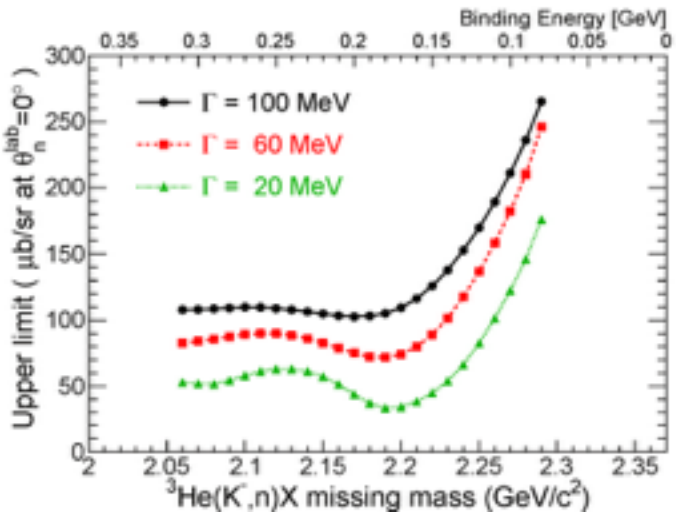
J-PARC E27
d(π$^+$,K$^+$)X, 2p tag

arXiv:1411.6708



U.L. evaluation with:

- K$^-$pp → Λp 100% (isotropic)
- K$^-$pp shape = Breit-Wigner



- **E15(K$^-$+^{3}He):**
  (UL) 0.5-5% of QF
- **FINUDA(stopped K$^-$):**
  ~0.1% of stopped K$^-$
- **DISTO(p+p @ 2.85GeV):**
  larger than Λ*
- **HADES (p+p @ 3.5 GeV):**
  (UL) 0.7-4.2 μb (Λ* ~ 10 μb)
- **LEPS(γ+d)**
  (UL) 1.5-26% of γN→K$^+$π$^-$Y

kinematically complete,
w/ 4-momenta conservation

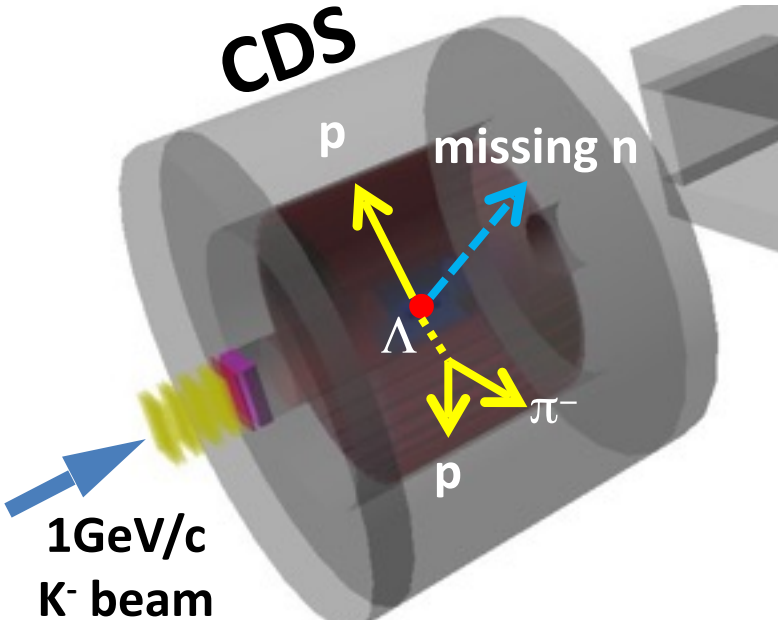
Decay Channel,
Exclusive ^{3}He(K^{-}, $p\pi^{-}(\Lambda)p$)n

- revised analysis!

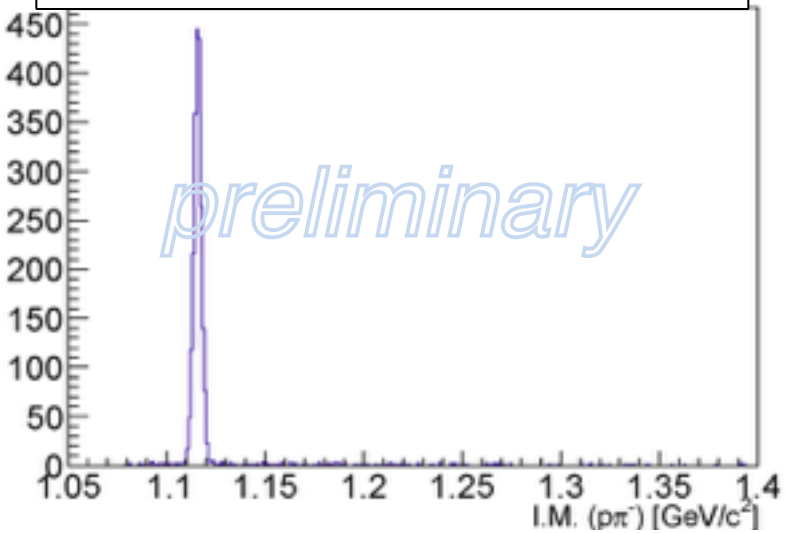
  $p\pi^{-}$ (=Λ) pair defined by probability

  to improve the Λ definition

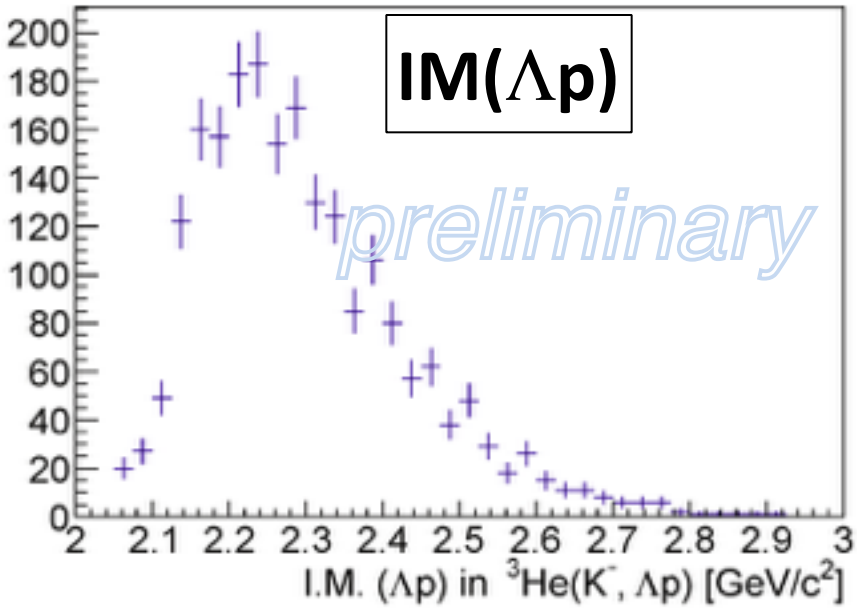
$^3He(K^-,pp\pi^-)X = {}^3He(K^-,\Lambda p)n_{mis.}$ events



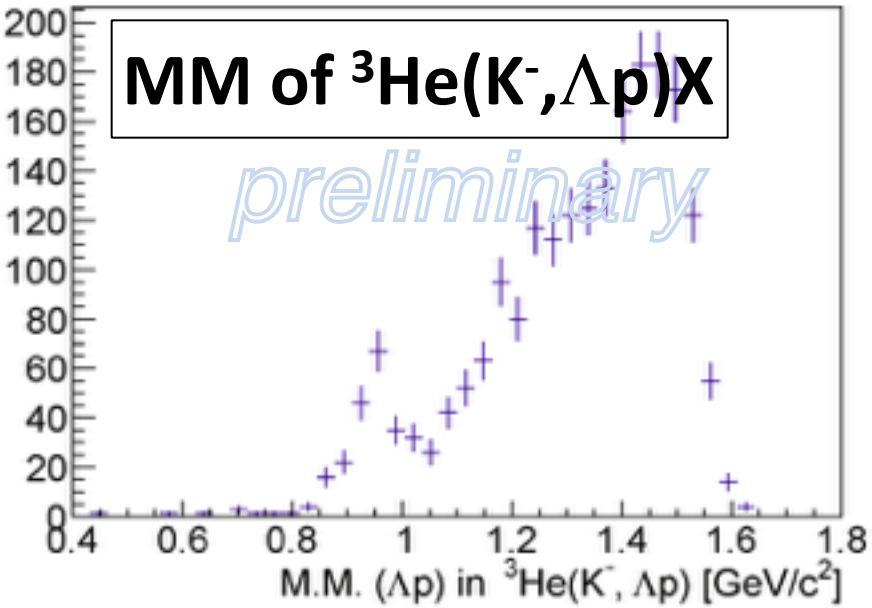
$\Lambda \rightarrow p\pi^-$ reconstruction



IM(Λp)



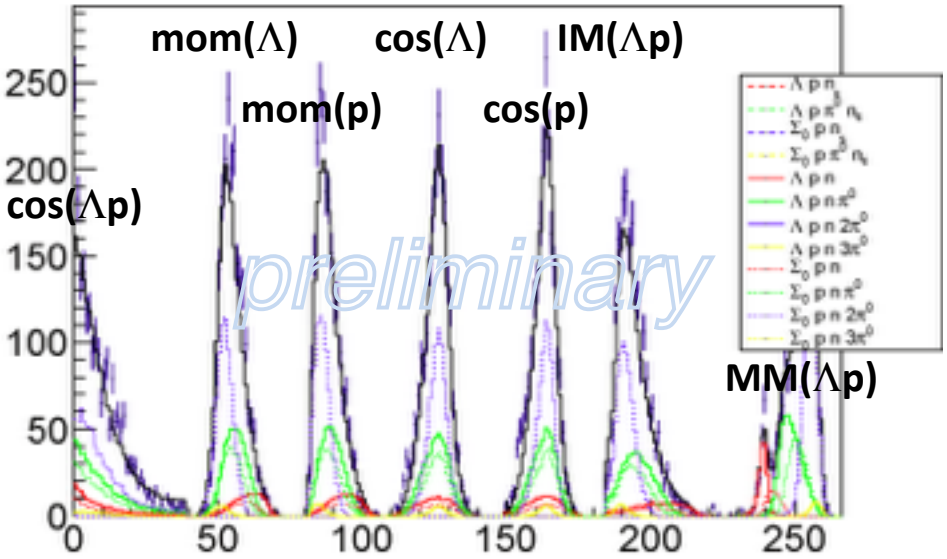
MM of $^3He(K^-,\Lambda p)X$



Global Fitting

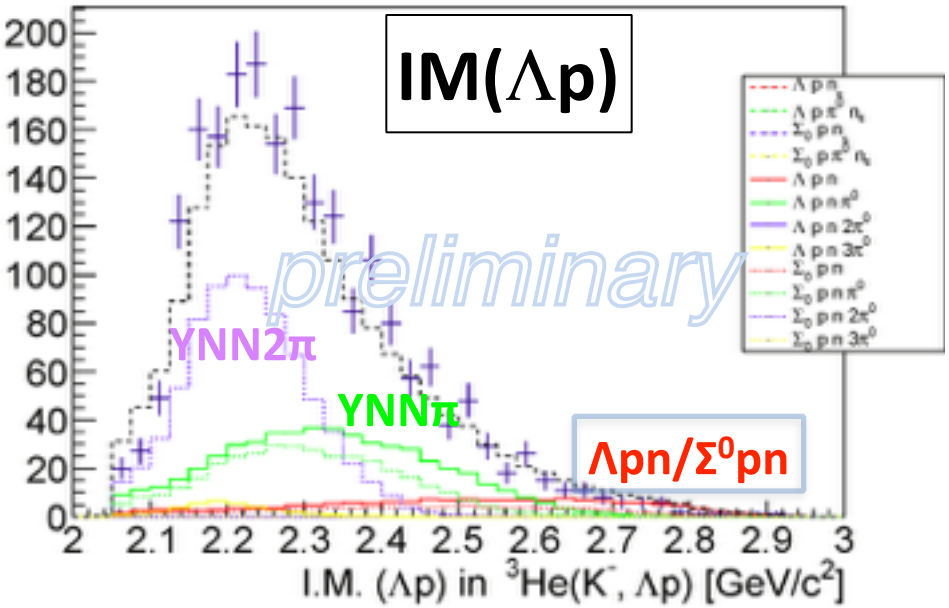
to see rough contributions

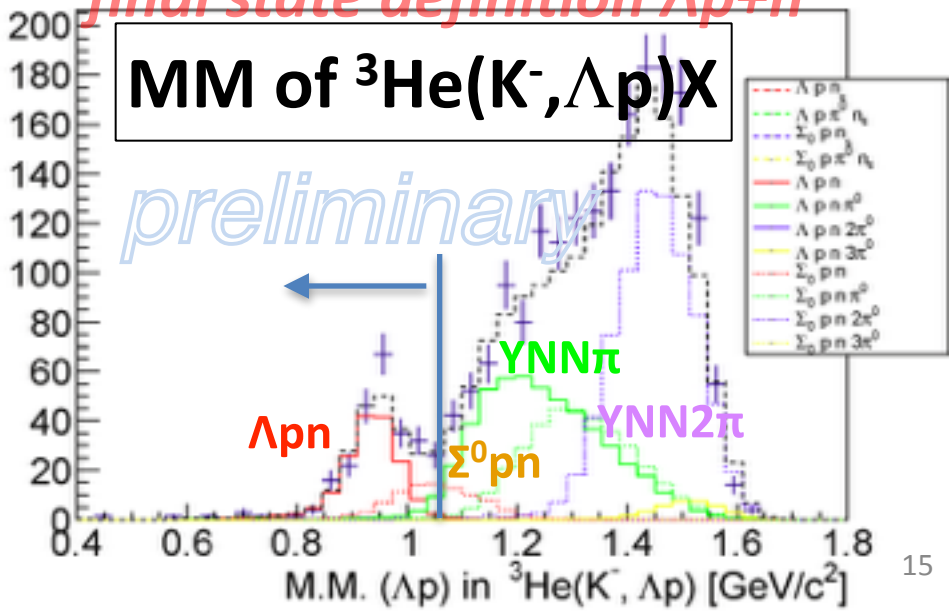
- 2NA and 3NA processes are taken into account
- $\chi 2$ / NDF = 605/ 254
- missing-neutron events: 220
  - Λpn:68%, $\Sigma^0 pn$:23%, $\Lambda pn\pi^0$:7%



not all the Λp events are of interest

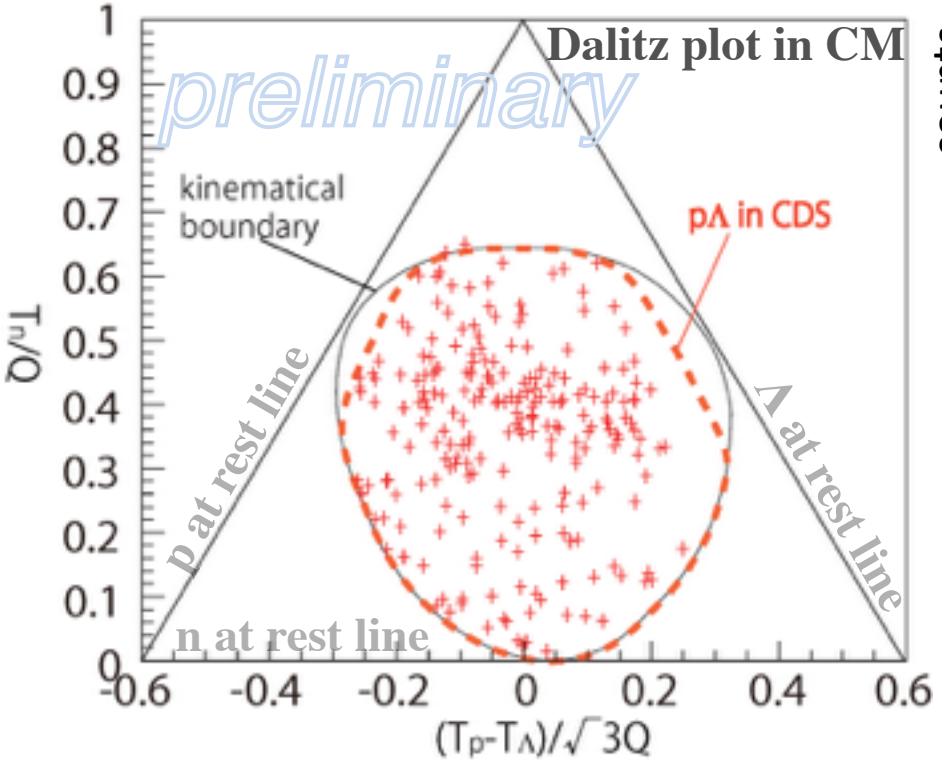
final state definition Λp+n

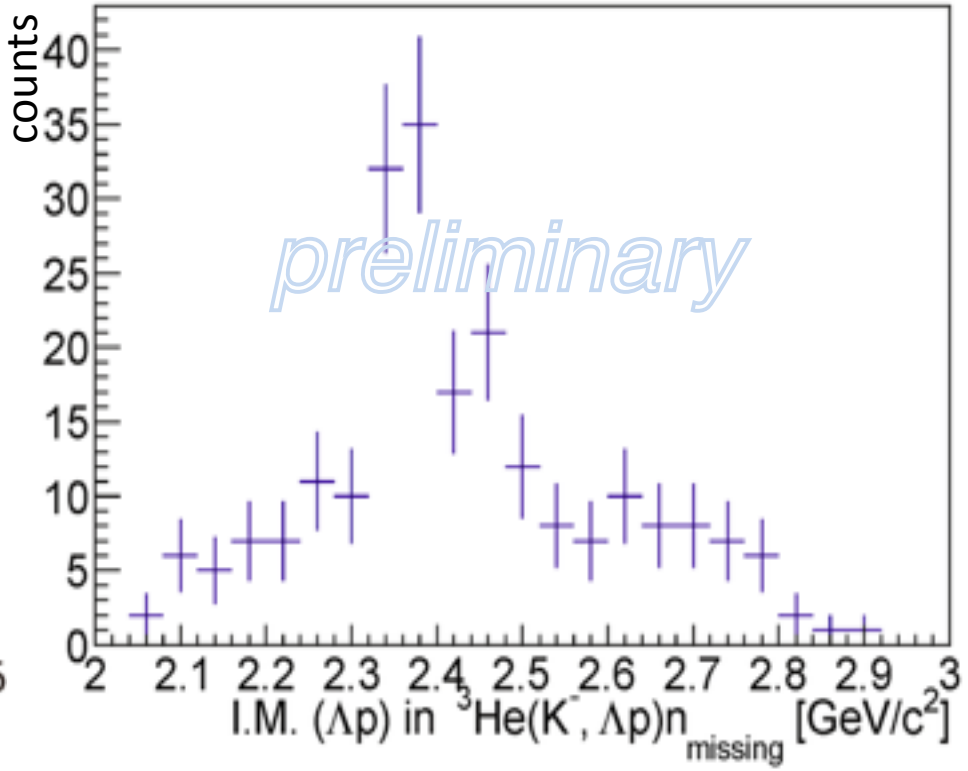




^{3}He(K$^-$,Λp)n Events

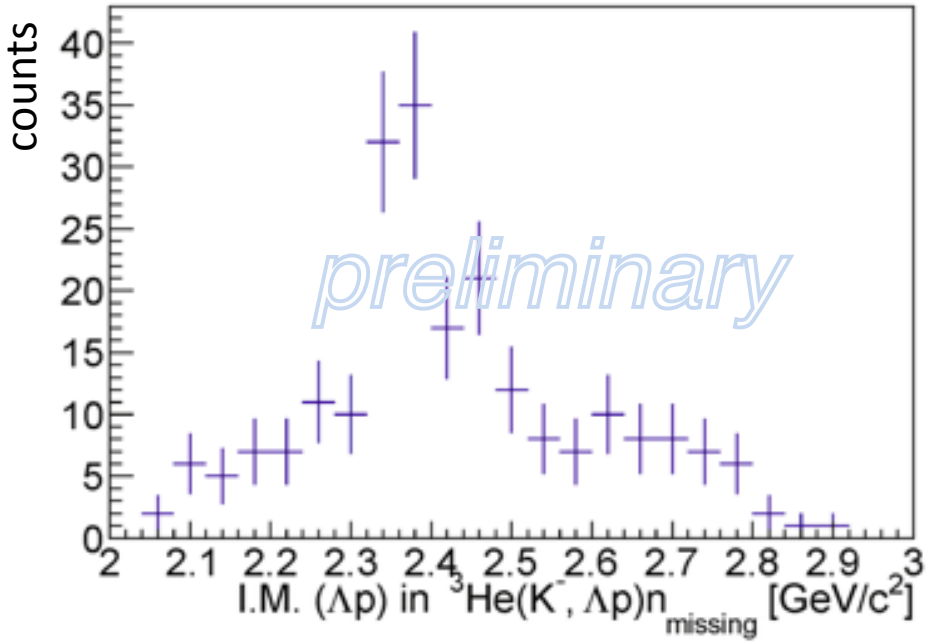
kinematically complete, w/ 4-momenta conservation

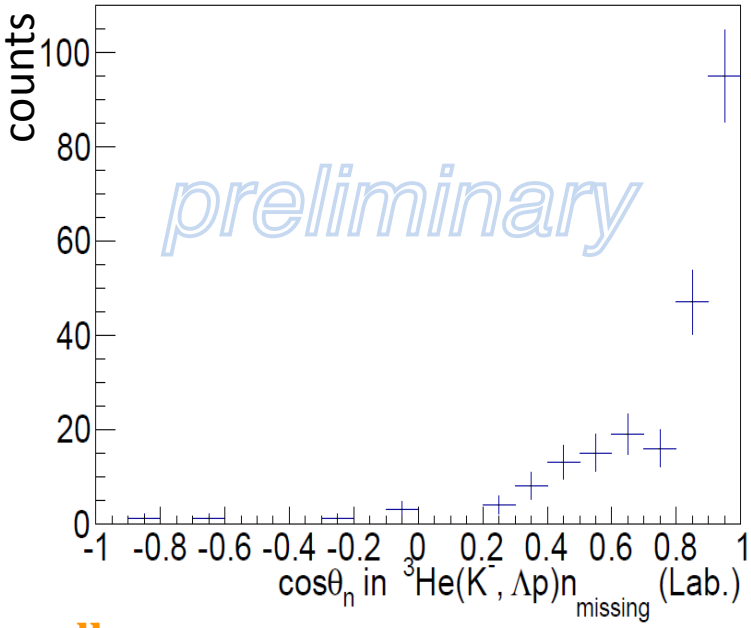


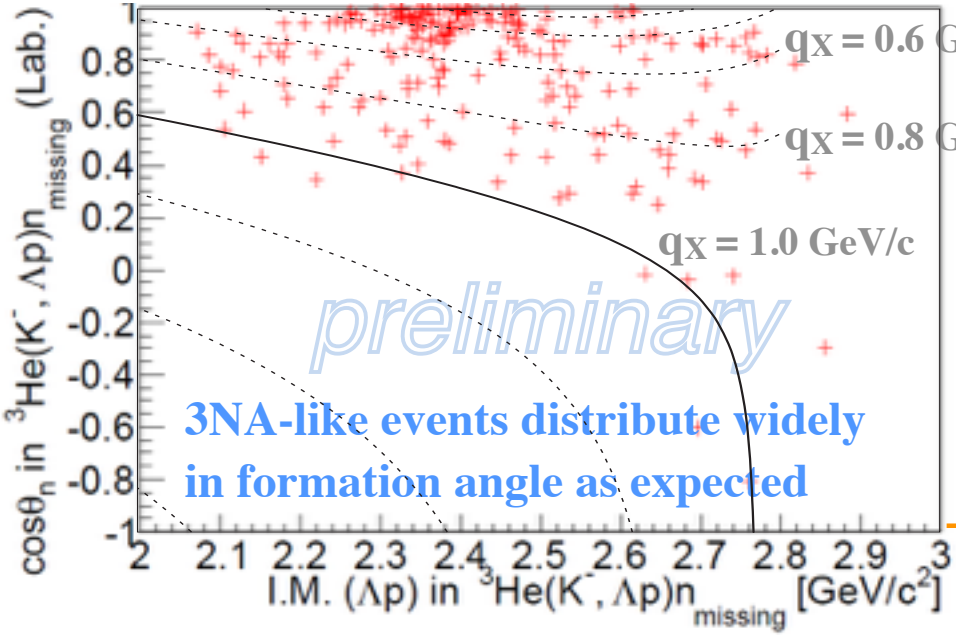


- structure found near K$^-$pp threshold
- 2NA reaction K$^-$+^{3}He → Λ+p+n$_s$ seem to be very weak
- 3NA reaction K$^-$+^{3}He → Λ+p+n exist, but weak as well
- 2NA Λ(1405) production excluded; Λ(1405)+n+p$_s$ (2NA)

Angular distribution of the excess







— smaller q_X

— larger q_X

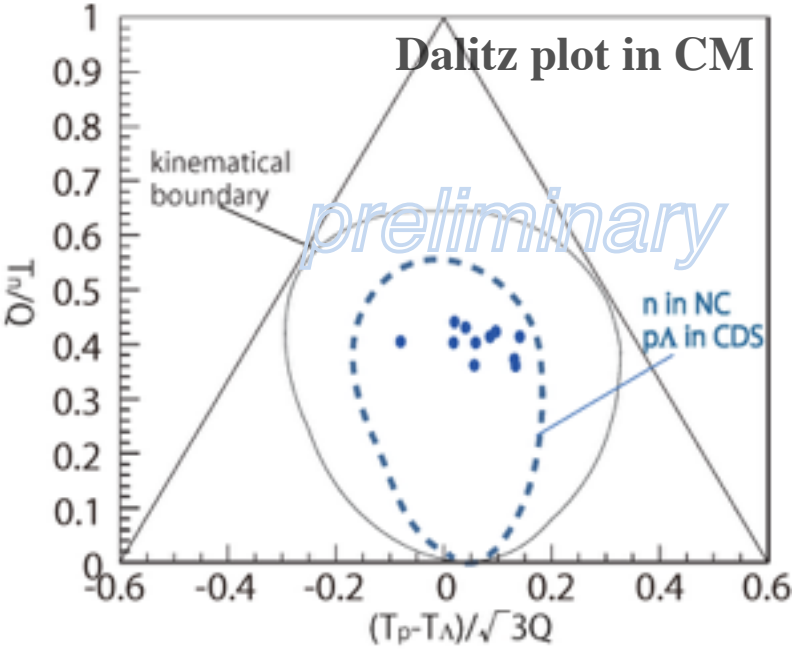
Forward neutron

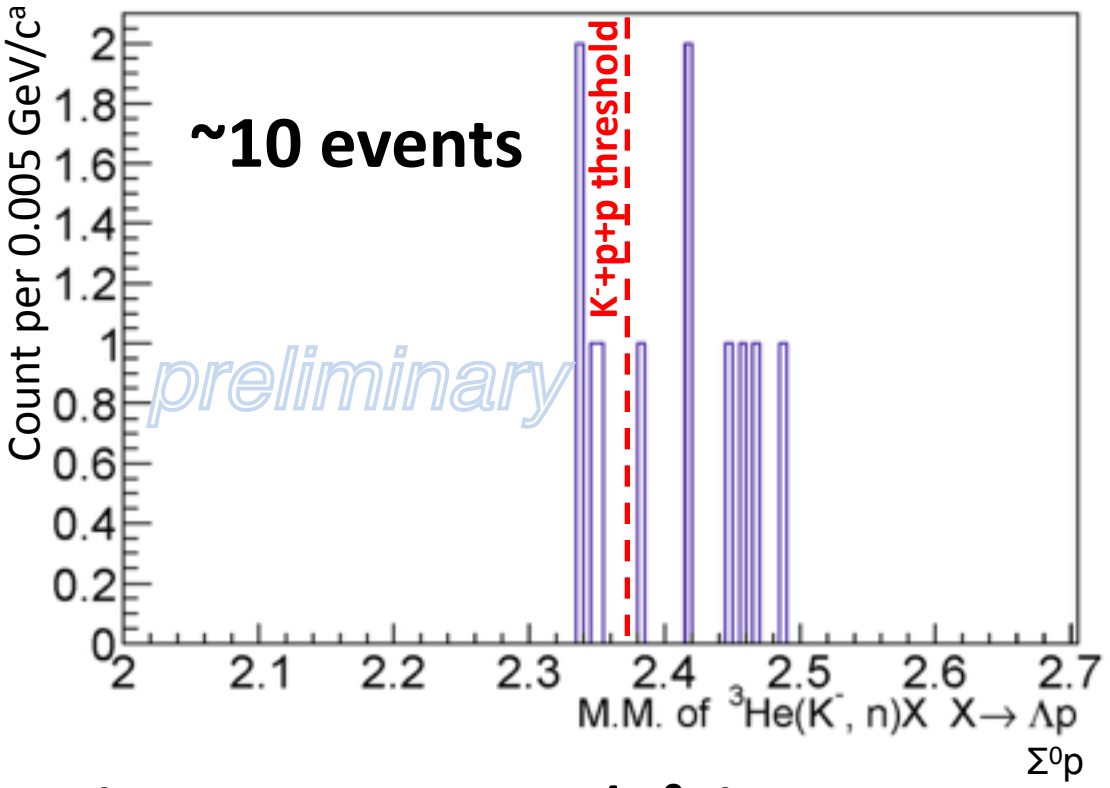
II

Low momentum transfer preferred

Kinematically-complete ^{3}He(K^-, Λpn)

redundant w/ 4-momenta conservation





- Formation neutron selectively (no effect from Λp / Σ^0p)
- 3NA largely suppressed (consistent with $n_{mis.}$ events)
- more data awaited

Summary

- **K1.8BR beam-time plan:**
  - Before the summer of 2015 [30 Tppp, 9s] *~ 24 kW*
    - **Commissioning: 1 day**
    - **Calibration (H2): 6 days**
    - **E31 pilot-run (D2): 20 days (13 days @ 6s)**
  - Before the end of JFY2015 [60 Tppp, 6s] *50 kW!*
    - **E15-2nd (^{3}He): 25 days**

- **Analysis status of E15-1st**
  - Inclusive (K^-,n)X: submitted to PLB
  - Exclusive (K^-,Λp)n: will be finalized soon

The J-PARC E15 Collaboration

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(*) Spokesperson
($) Co-Spokesperson

Thank you for attention!

Backup

^{3}He(K$^-$, n): hint in exclusive ^{3}He(K$^-$,$\pi^+\pi^-$pn)n

Blue: in CDS / Red: in NC

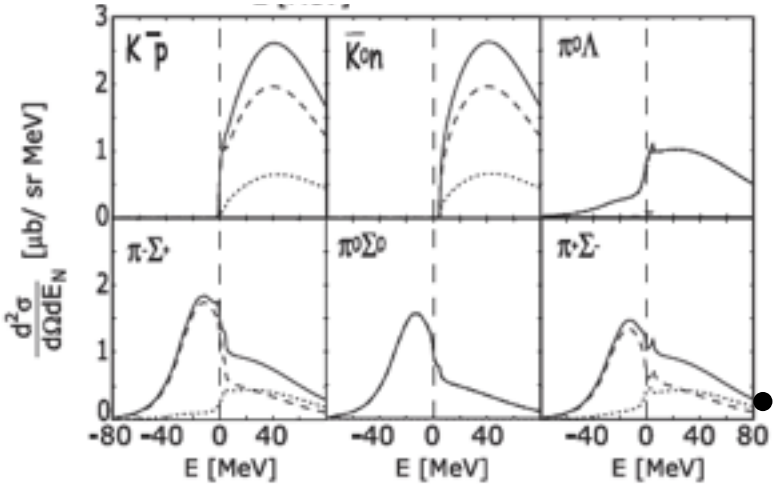
$K^- + {}^3He \rightarrow \Sigma^{+-} + \pi^{-+} + p + n$

$\Sigma^{+-} \rightarrow n + \pi^{+-}$

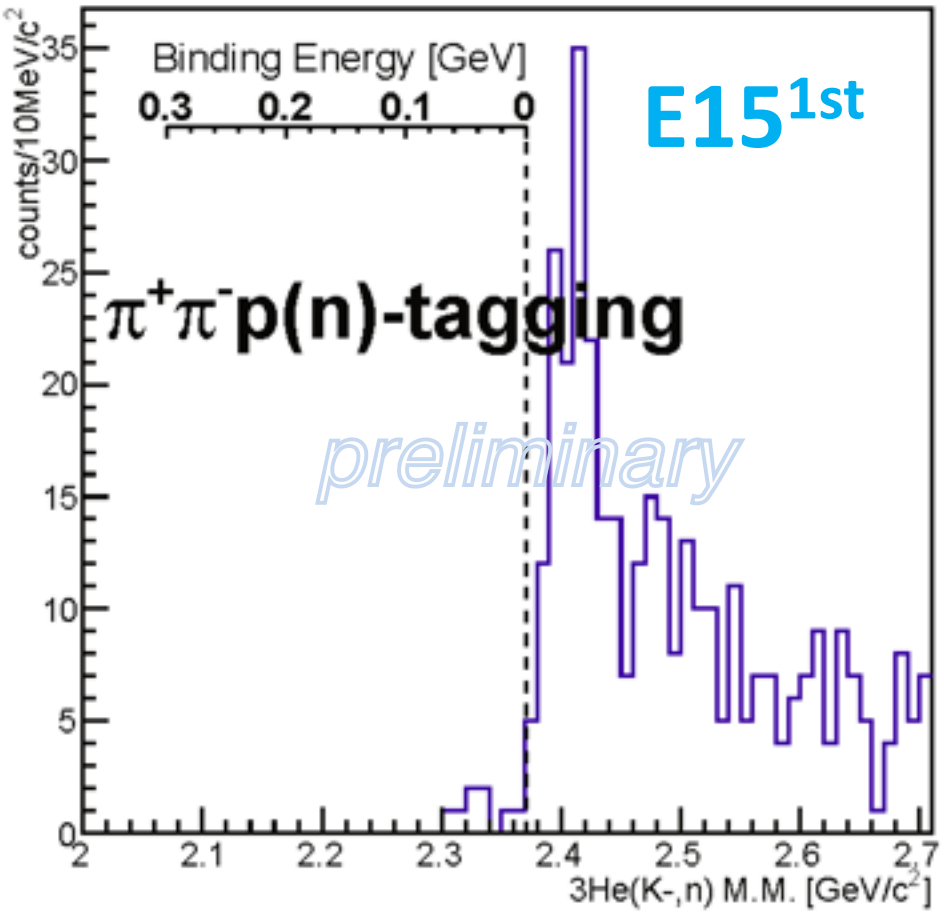
or

$K^- + {}^3He \rightarrow \Sigma^{+-} + \pi^{-+} + p + n$

$\Sigma^{+-} \rightarrow n + \pi^{+-}$

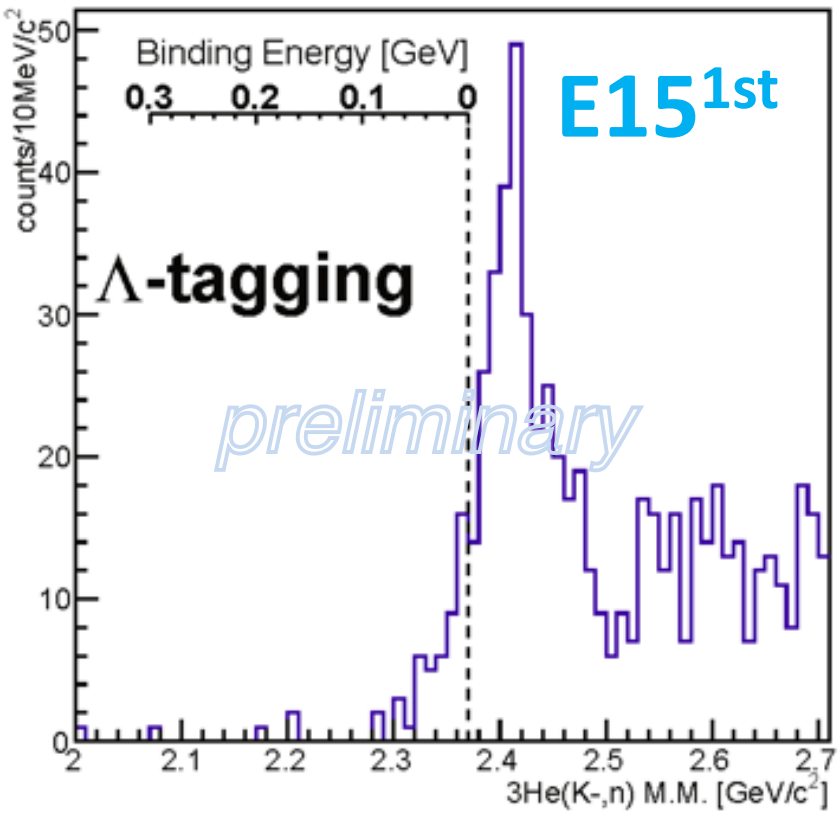


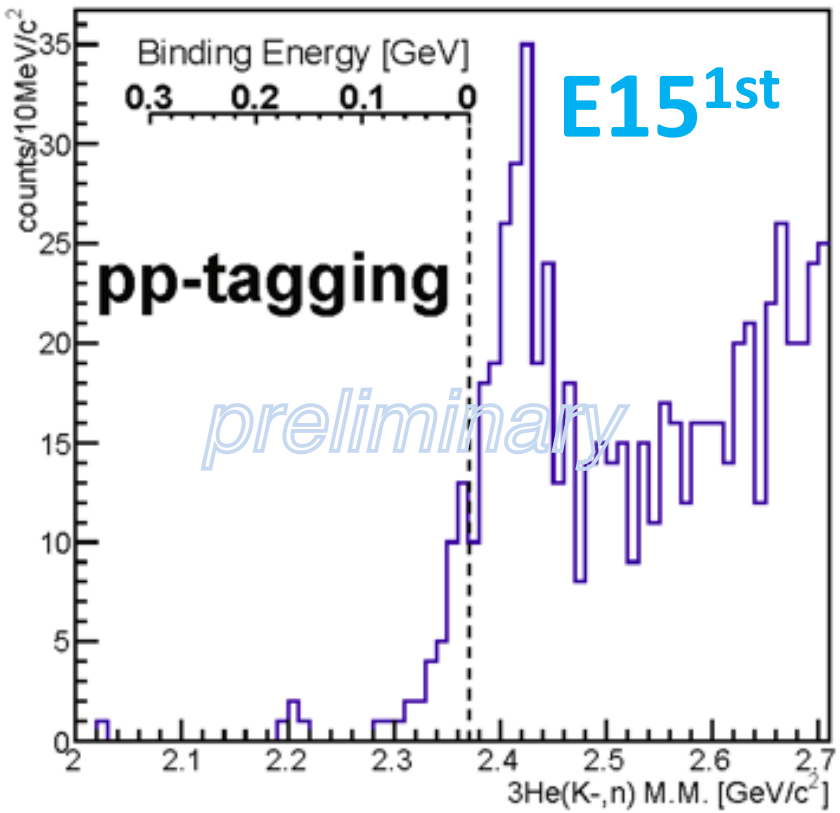
J. Yamagata-Sekihara et. al., Phys. Rev. C 80, 045204 (2009)



- **Very low statistics, but some structure in the binding region?**

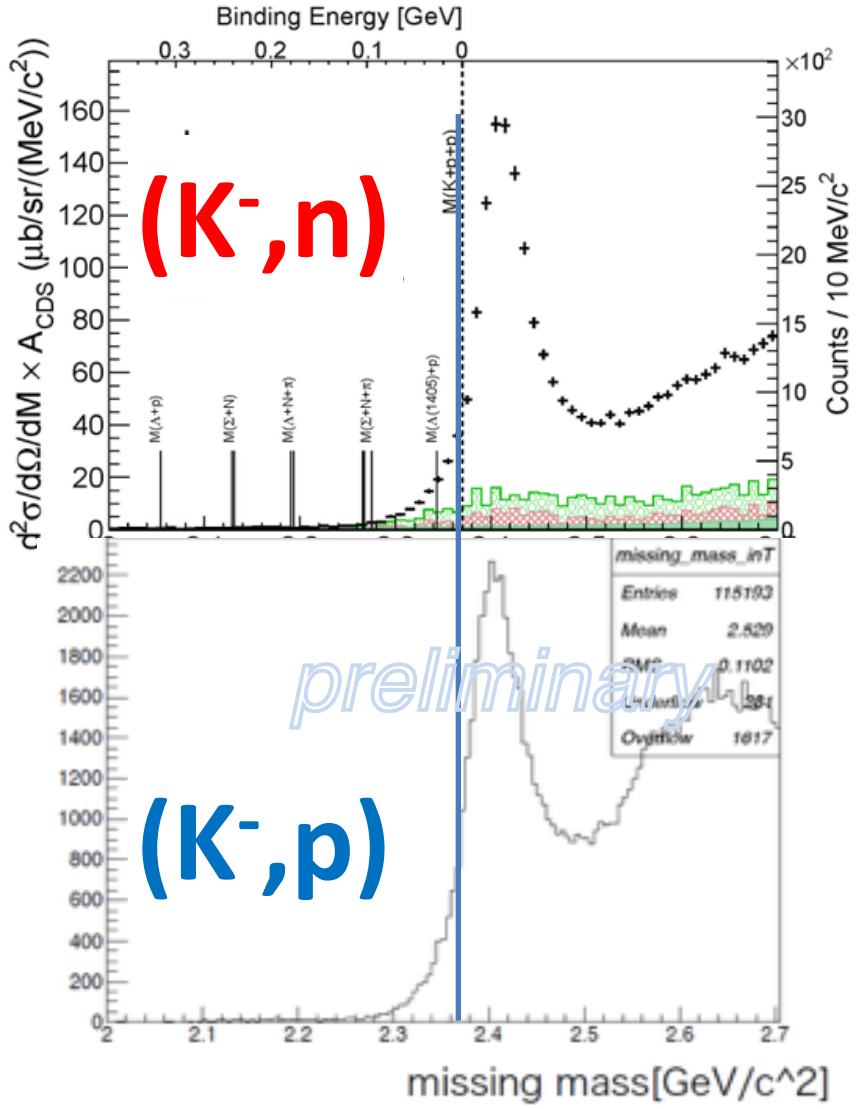
^{3}He(K$^-$, n): hints in Λ/pp-tagging

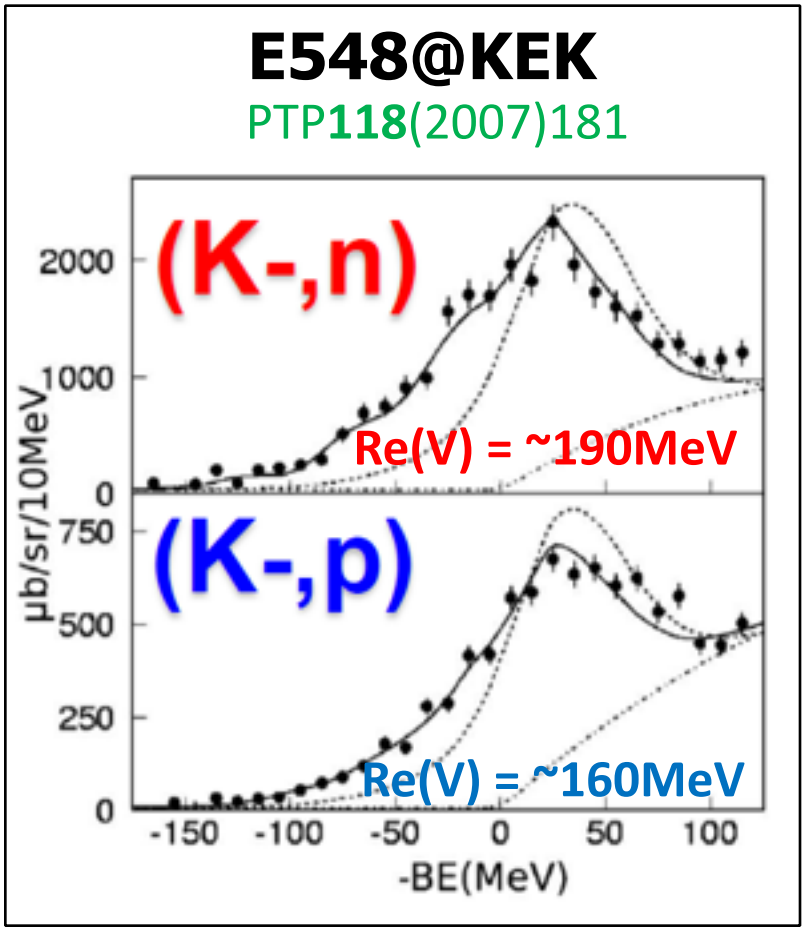




- **tagging method would address the origin of the sub-threshold excess**

Semi-Inclusive ^{3}He(K$^-$,n/p)X M.M. spectrum





- ^{3}He(K$^-$,p) spectrum looks similar to (K$^-$,n)

$p(K^-,K^0_S)n_{forward}$ yield (n in NC acc.)

- $N_t = 5.8*10^{23}$ /cm^2
  - $\rho = 70.85*10^{-3}$ g/cm^3
  - l = 13.67 cm
- **$N_K = 1.1*10^5$ /spill/9s** *[run#49c * 0.8]*
- $\sigma = 3.92*10^{-27}$ cm^2 (= 7.84 mb * 0.5) *[past measurement]*
- ε(decay*(CDS*NC acc)) = $5.4*10^{-3}$ *[Monte-Carlo]*
- ε(beam ana) = 0.65
- ε(loss) = 0.97
- ε(fiducial selection) = 0.70
- ε(trig*DAQ) = 0.80
- ε(analysis) = 0.90

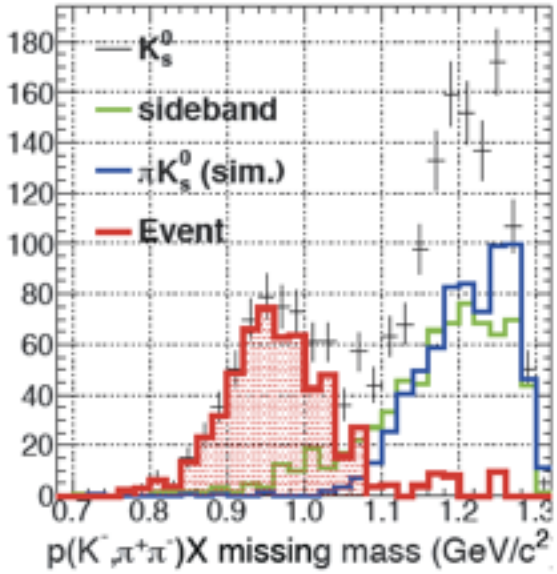
[Run#49c condition]

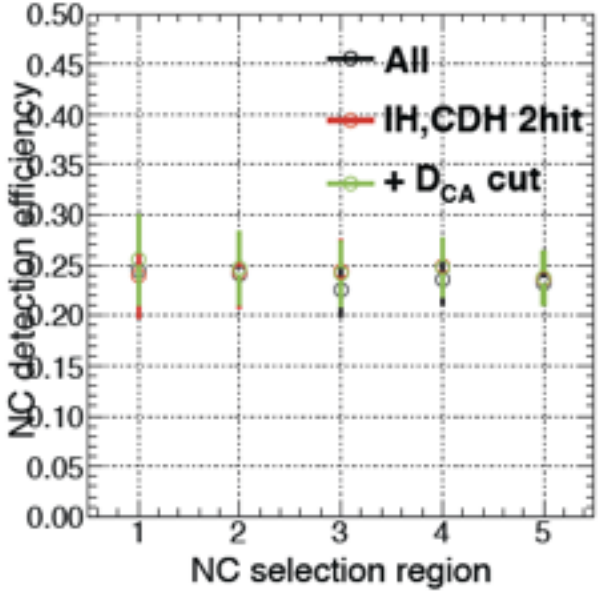
- **K*CDH2 pre-scale = 1/5** *[~ run#49c / 0.8]*

expected error:
K^0_S in CDS w/ NC acc. ~ 3400
K^0_S & n detection ~ 800
→ NC eff. ~ 0.23 +/- 0.007(stat.)

→ $3.4x10^3$ per 4 days (w/o NC eff.)

Neutron detection efficiency



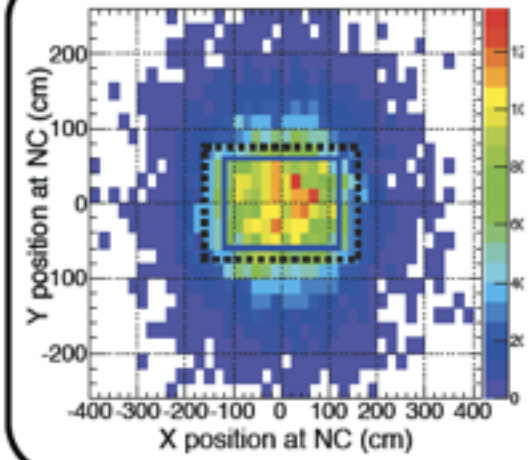


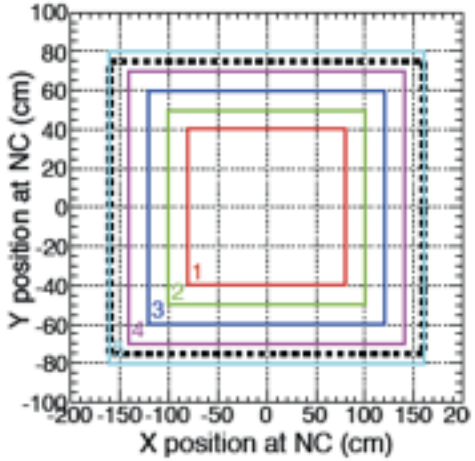
$$K^- + {}^3\mathrm{He} \rightarrow K^0_s + n + d_s$$
$$K^0_s \rightarrow \pi^+ + \pi^-.$$

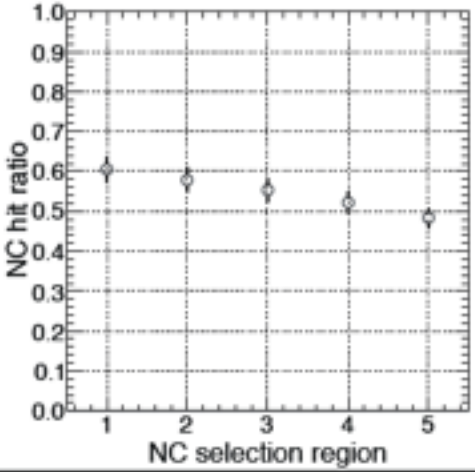
exclusive analysis with KxCDH^{2hit} trigger data

estimate neutron flux on the NC from missing momentum

ε(NC) = 23+/-4%







Simulation

bad resolution of missing mom.
↑
Fermi mom.

d(K⁻,n)Λ(1405) yield

Table I: Yield estimation

E31 status report, May, 2014

Beam Intensity **1.1x10⁵**	~~1.4x10⁵~~ ppp	24 kW primary beam
D_2 Target (Fiducial Vol.)	10 cm	Density: 0.169 g/cm²
Efficiency		
Beam tracking	0.63	Select single tracks
Fiducial cut for the beam size	0.70	
CDS tracking	0.92	*[Run#49c condition]*
Neutron detection	0.23	
Data Acquisition	0.815	
NC solid angle	22 msr	
Decay mode/ Cross section [3]	Mode ID efficiency	Yield/~~10 days~~ **20 days**
$\pi^+\Sigma^-$/ 220 μb	0.2	750
$\pi^-\Sigma^+$/ 97 μb *[prediction]*	0.07	120
$\pi^0\Sigma^0$/ 128 μb	0.015	33

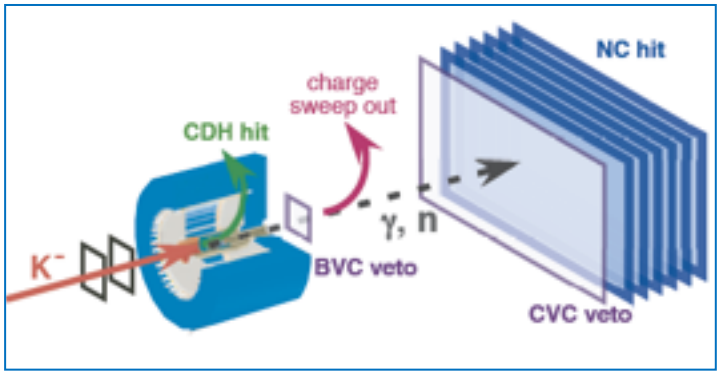
Typical Trigger Condition in 1GeV/c K^- + ^{3}He @ Run#49c [24 kW (30 Tppp)]

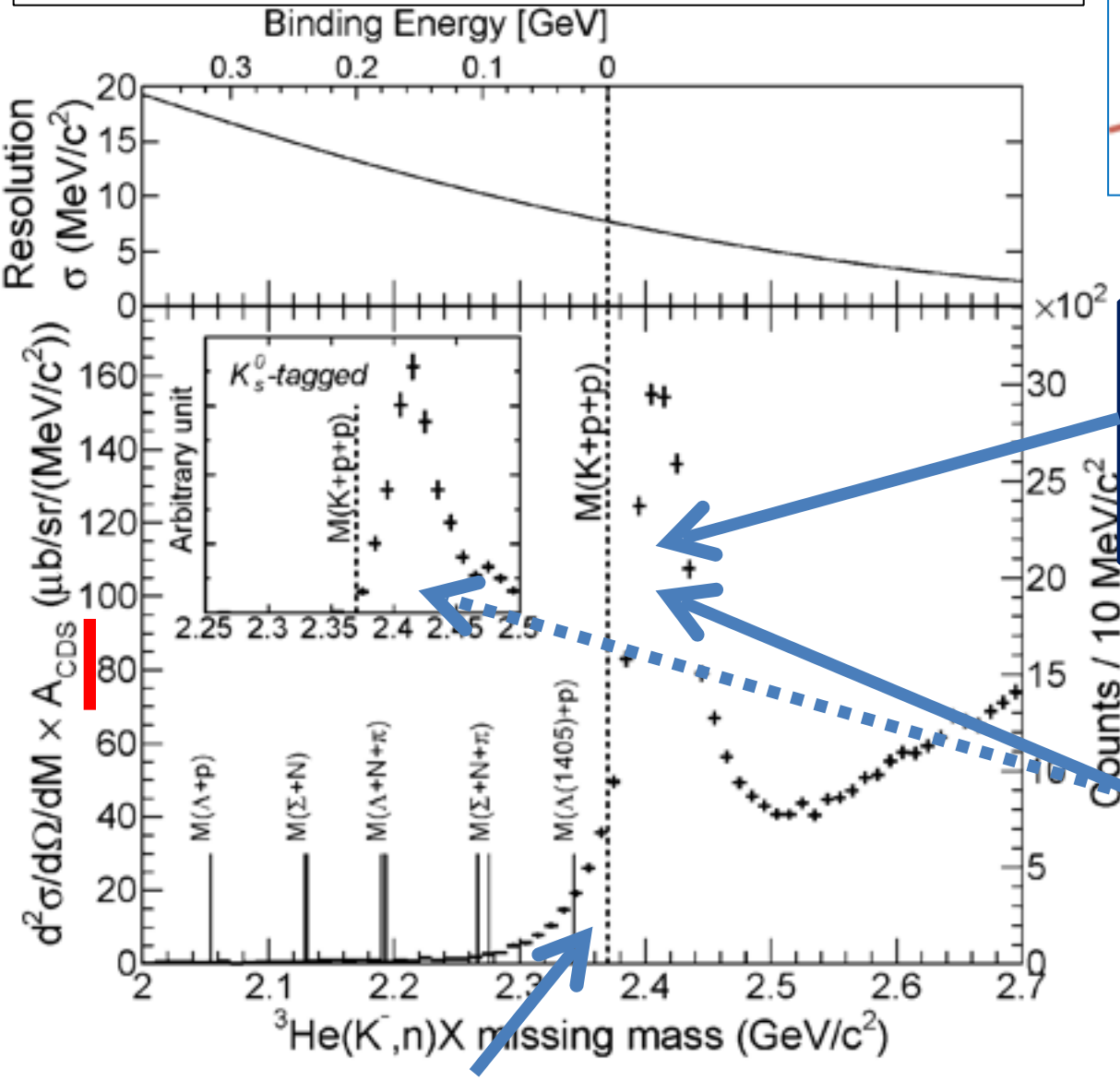
Table 2.11: Summary of trigger conditions.

	request / spill	pre-scale factor	accept / spill	main usage
BHD⊗T0	610k	50k	10	monitor AC&DEF
K_{beam}	145k	7k	17	normarisation
K_{beam}⊗CDH^{1hit}	48k	70	70	
K_{beam}⊗CDH^{2hit}	21k	7	280	Λp events
K_{beam}⊗CDH^{1hit}⊗Neutral	230	1	170	(K^-, n)
K_{beam}⊗CDH^{1hit}⊗Charged	130	1	100	(K^-, p)
π_{beam} ⊗ $\overline{\text{BVC}}$⊗Neutral	480	10	40	NC calibration
K_{beam} ⊗ $\overline{\text{BVC}}$⊗Neutral	850	10	70	
Total	8.5k		680	(1^{st} accept ~ 6.9k)

Doctor thesis, T. Hashimoto, The University of Tokyo, 2014.3

Semi-Inclusive Spectrum





Quasi Elastic

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

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

and

Charge-Exchange

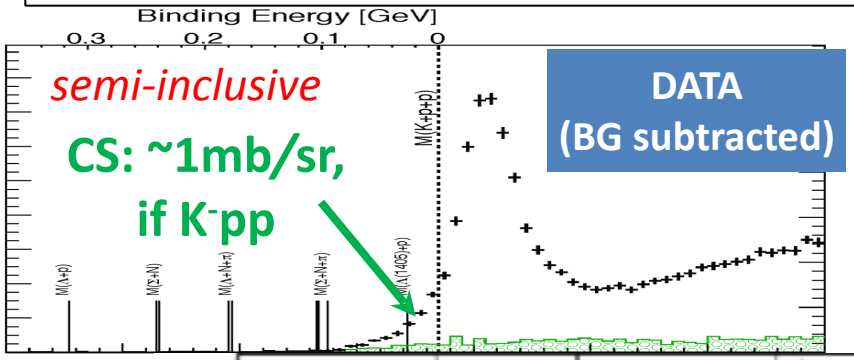
$K^- + {}^3He \rightarrow K^0 + n + d_s$

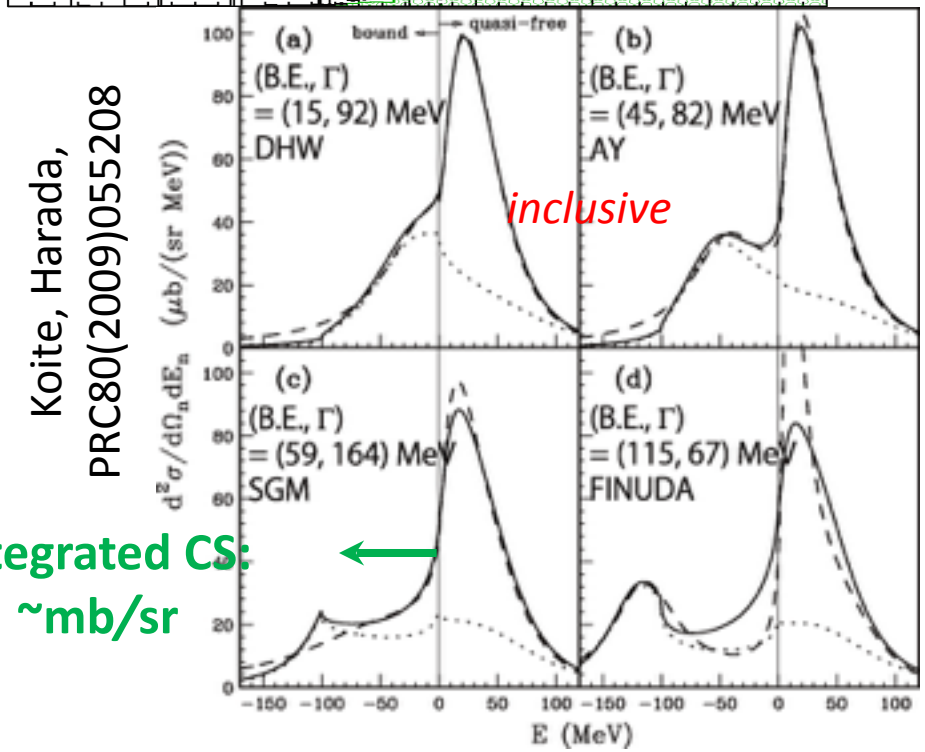
$K^0 \rightarrow \pi^+ + \pi^-$

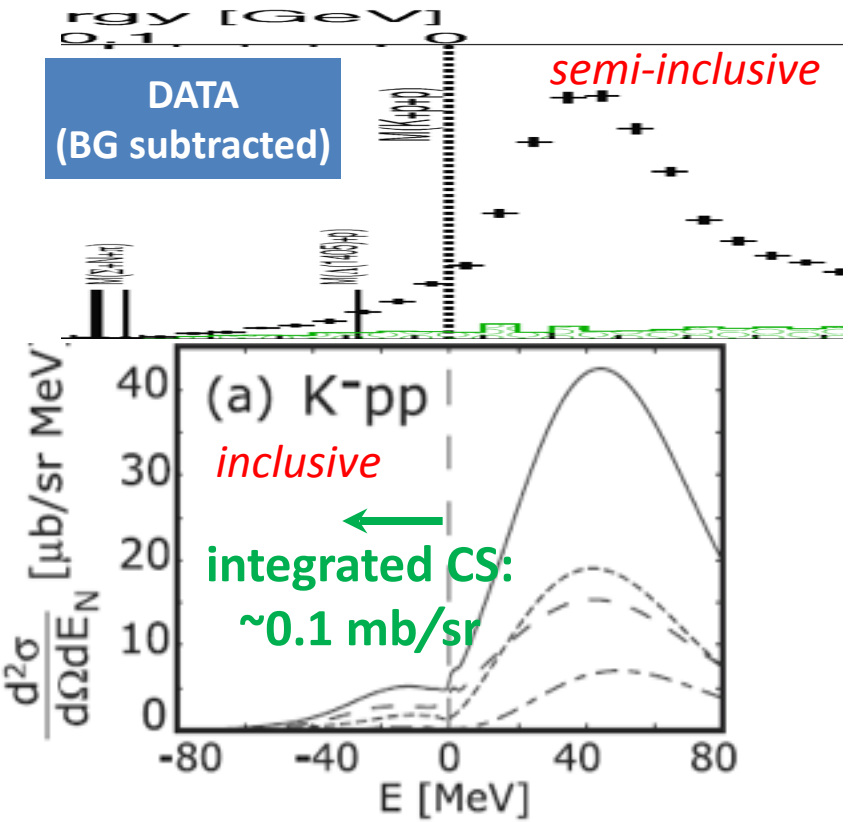
$d\sigma/d\Omega_{\theta=0deg}$ ~ 11mb/sr

The tail structure is not due to "the detector resolution"

E15 and Theoretical Spectra







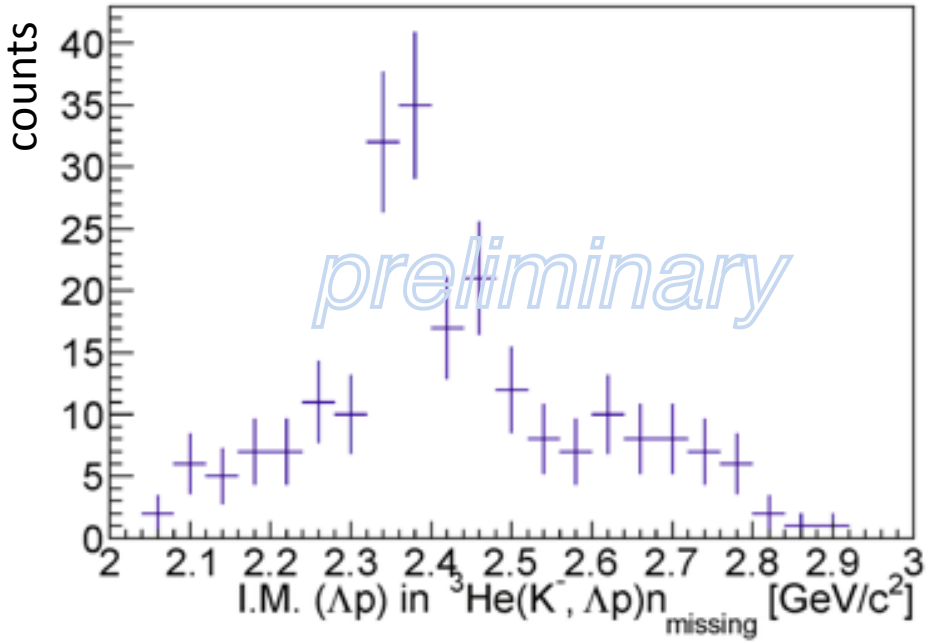
Yamagata-Sekihara, et al.,
PRC80(2009)045204

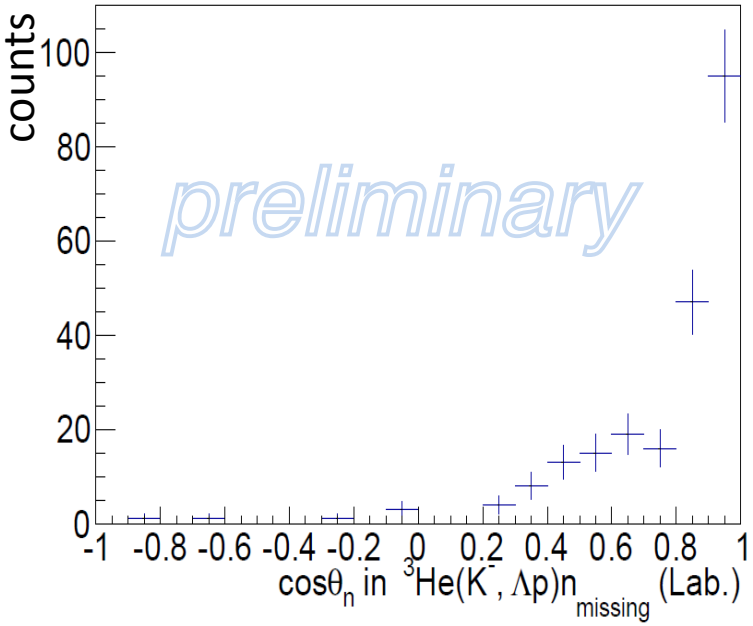
- CS is roughly consistent with KH
- Loosely-bound K-pp state ???

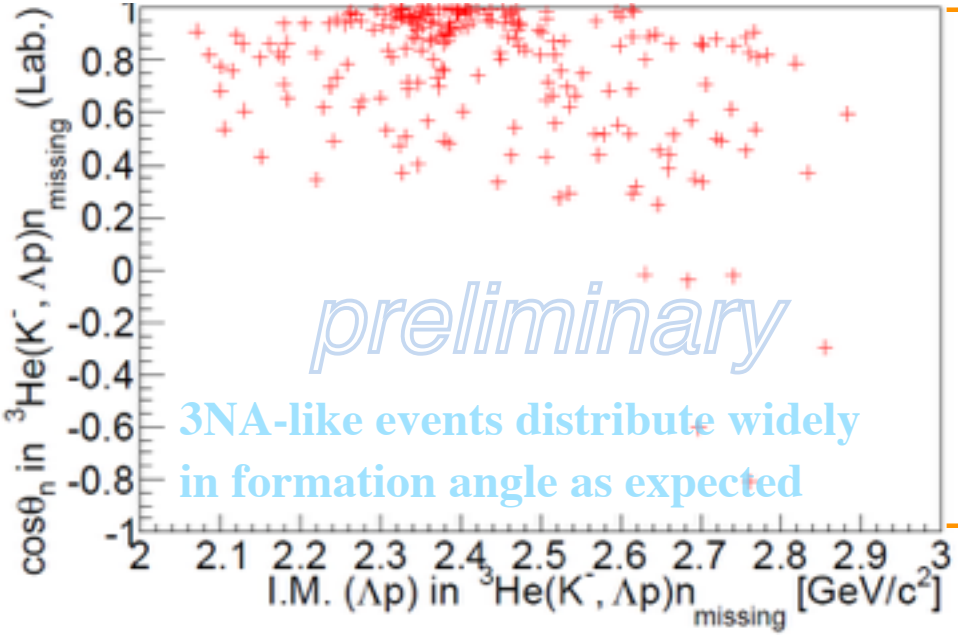
BUT

2NA of Λ(1405)n+p$_s$ cannot be excluded

Angular distribution of the excess







— smaller q

— larger q

Forward neutron

II

Low momentum transfer preferred