Status Report of E15 1st stage and Request for 2nd stage

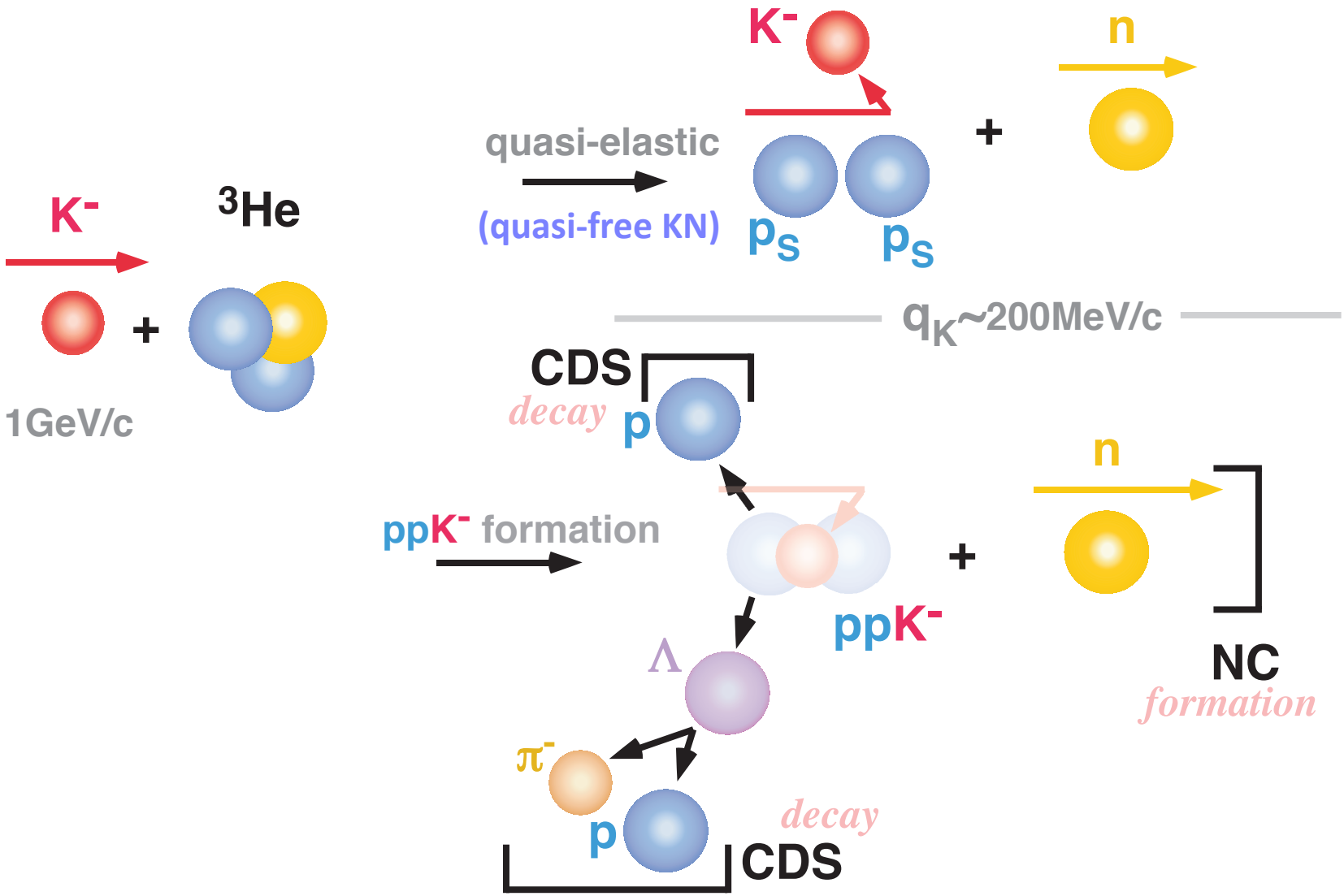
Search for "Kpp" state via ^{3}He(K$^-$,n) reaction

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

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

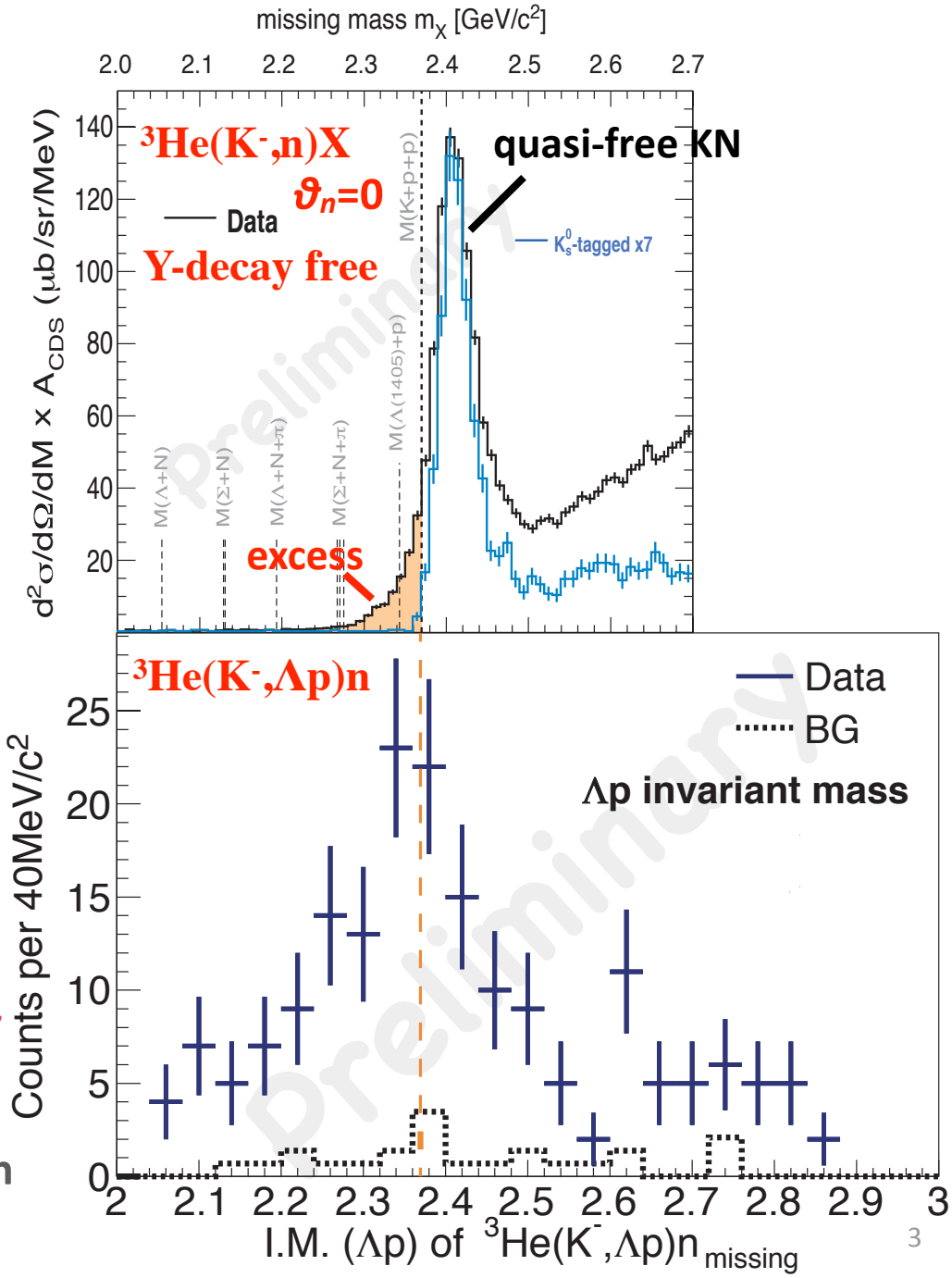
- excess below threshold
  background-free
- contribution from
  Λ(1405)n + p_S (2NA)
  may exist

Decay channel

exclusive

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

- excess exist
- cannot be Λ(1405)n + p_S (2NA), because F.S.= Λpn



Formation vs Decay

Formation channel

semi-inclusive

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

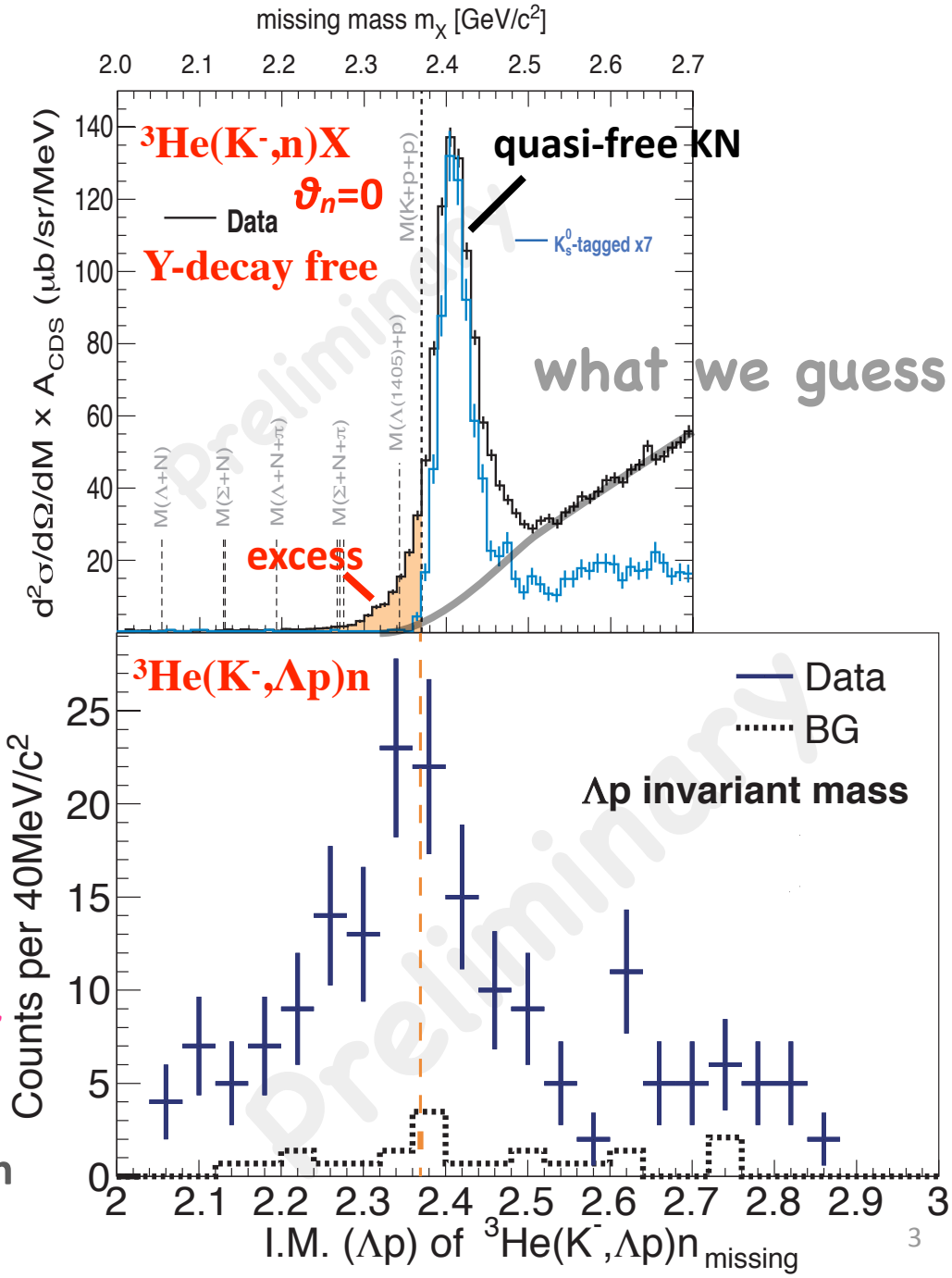
- excess below threshold
  background-free
- contribution from
  Λ(1405)n + p_S (2NA)
  may exist

Decay channel

exclusive

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

- excess exist
- cannot be Λ(1405)n + p_S (2NA), because F.S.= Λpn



Summary of E15 1st stage

- **E15 1st stage was successfully completed!**
  - Semi-inclusive channel
    - **^{3}He(K^-,n)** → **excess** below $\bar{K}$NN threshold
    - naively attractive & absorptive $\bar{K}$N to explain the excess
    - **excess = Λ(1405) + n + p_S (2NA) cannot be excluded**

      selective enhancement Λ(1405)n 2NA is required, which would be unnatural
  - Exclusive channel
    - **^{3}He(K^-,Λp)$n_{mis.}$** → **excess** around $\bar{K}$NN threshold
    - **excess cannot be Λ(1405) + n + p_S (2NA)**
    - statistics is very limited at the 1st stage

      one received doctor's title, four (*or five*) on their way...
- **We need definitely more data to investigate the $K^{bar}N$ interaction by exclusive analyses!**

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 the 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

Let’s discuss the rest material more in discussion base

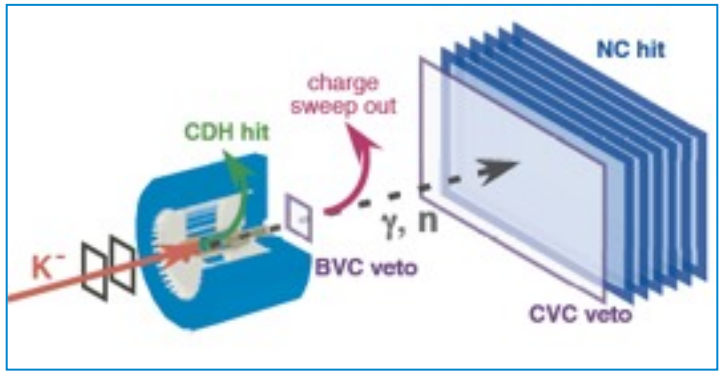
Formation channel

A member received a doctor's degree on this subject.

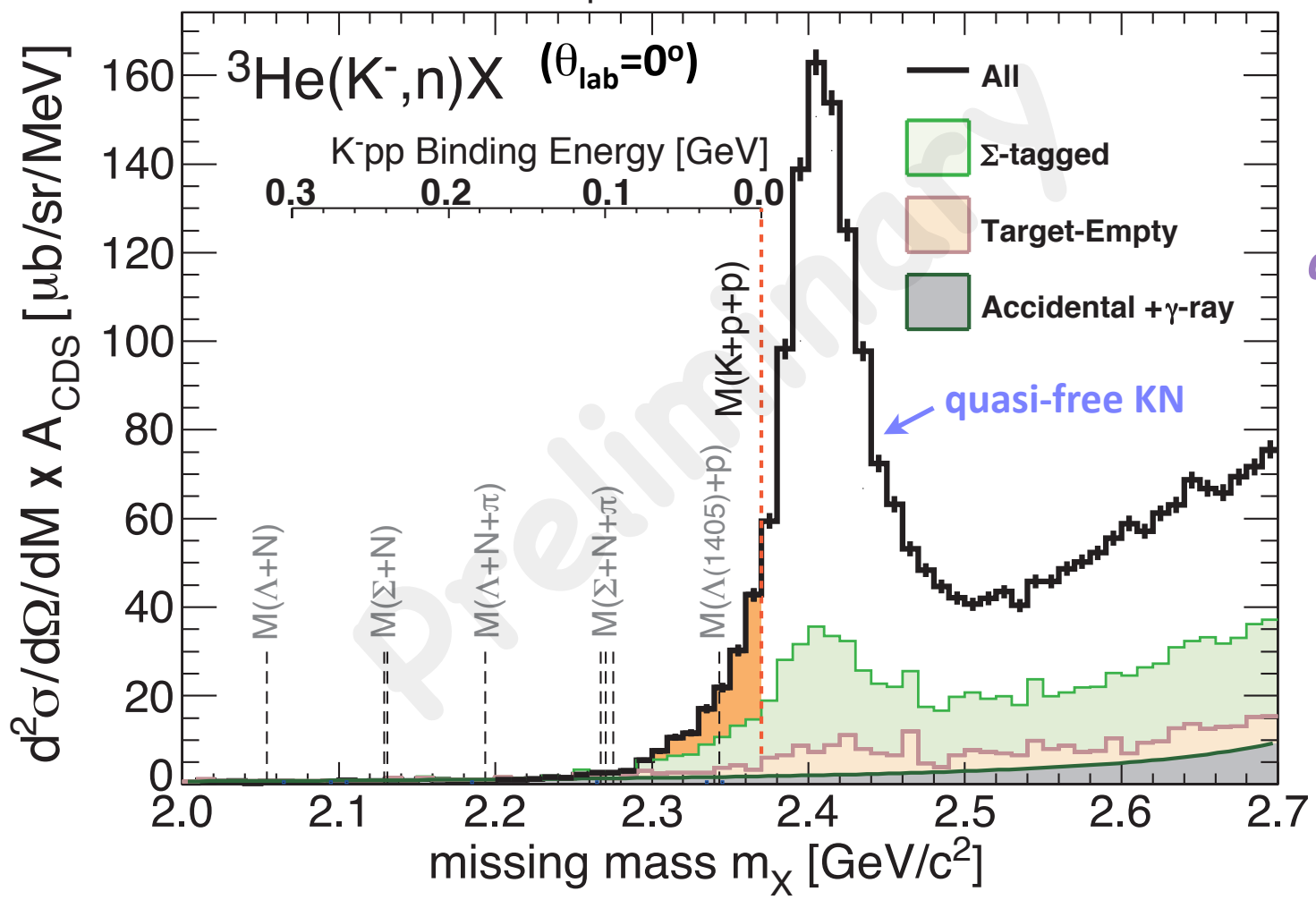
Formation channel

$d\sigma/d\Omega(\theta_{lab}=0^o)$ excess ~ 1 mb/sr

naively attractive & absorptive



semi-inclusive neutron spectrum

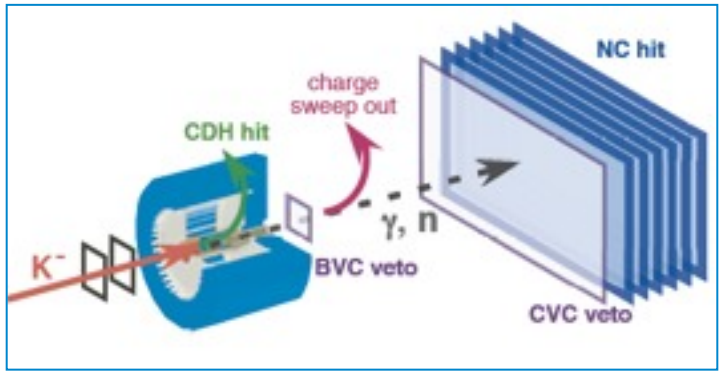


deep structure not seen as it is suggested by several experimental groups

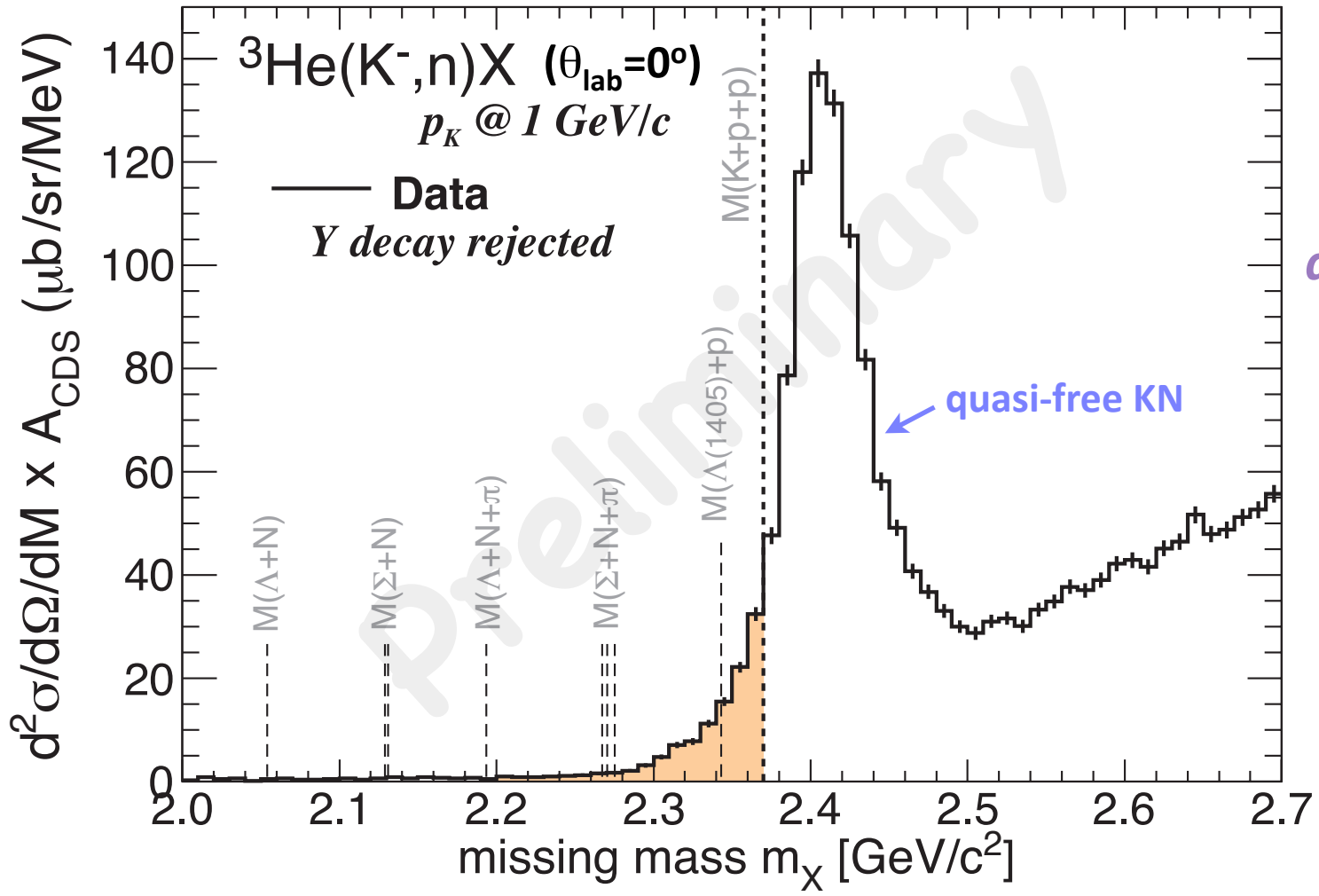
Formation channel

$d\sigma/d\Omega(\theta_{lab}=0^{o})$ excess ~ 1 mb/sr

naively attractive & absorptive



semi-inclusive neutron spectrum

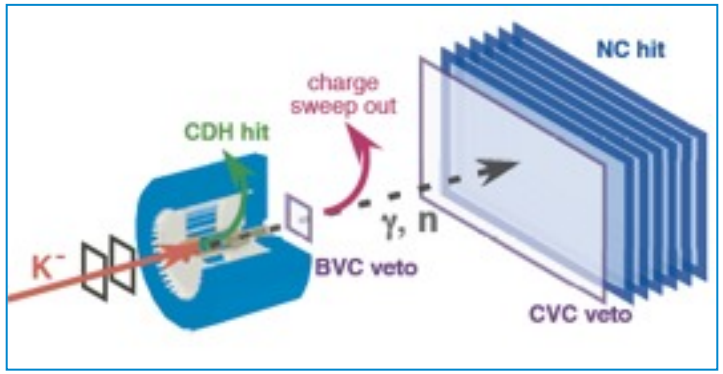


deep structure not seen as it is suggested by several experimental groups

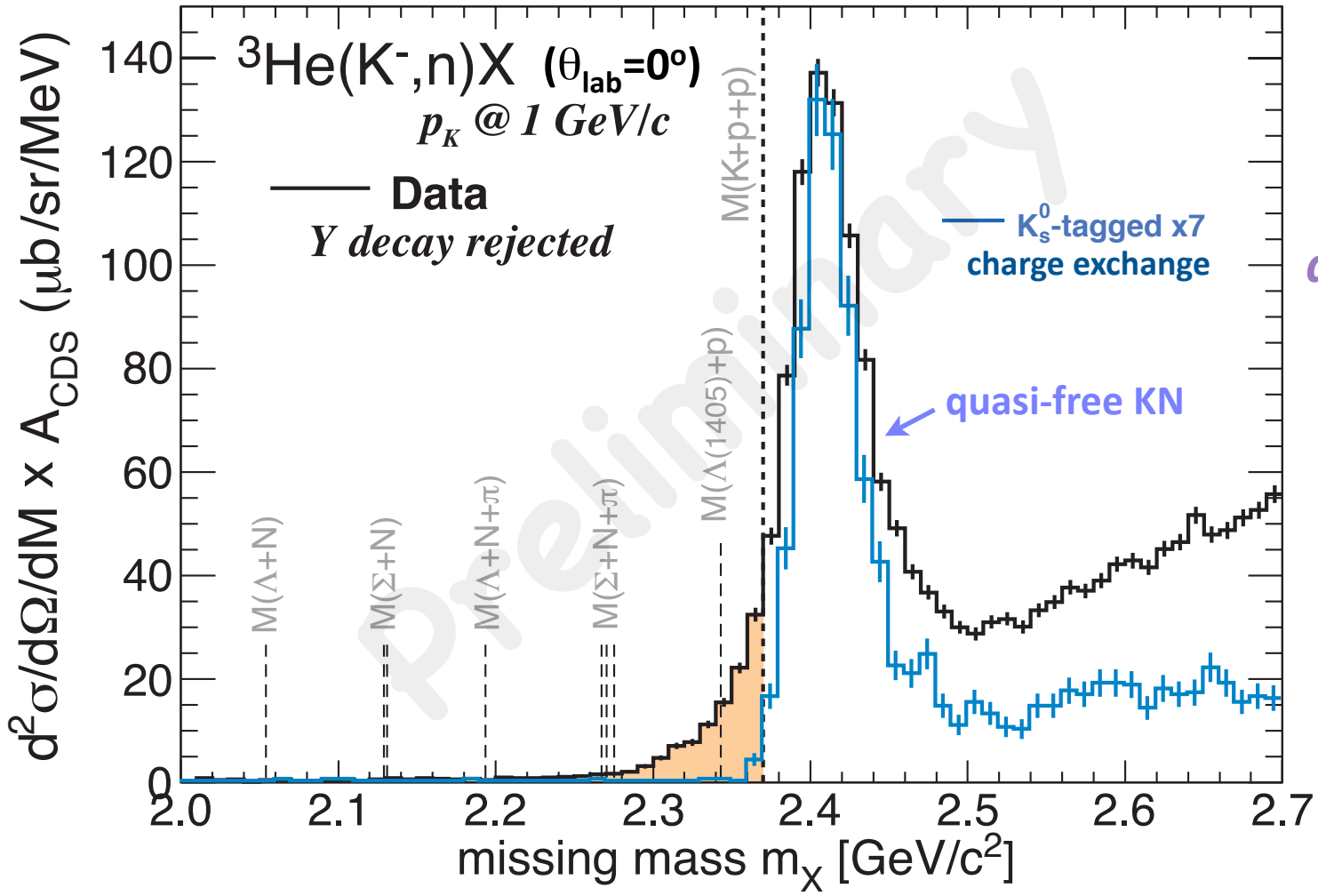
Formation channel

$d\sigma/d\Omega(\theta_{lab}=0^{o})$ excess ~ 1 mb/sr

naively attractive & absorptive

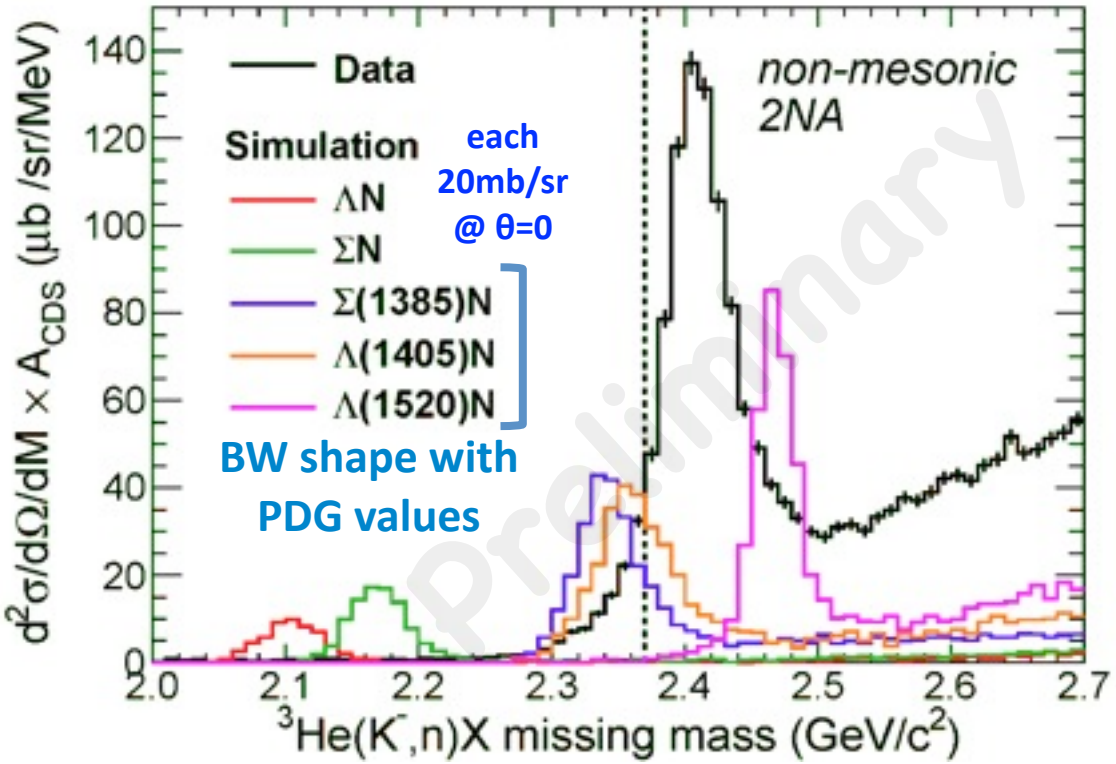


semi-inclusive neutron spectrum



deep structure not seen as it is suggested by several experimental groups

Formation channel: small 2NA (non-mesonic)



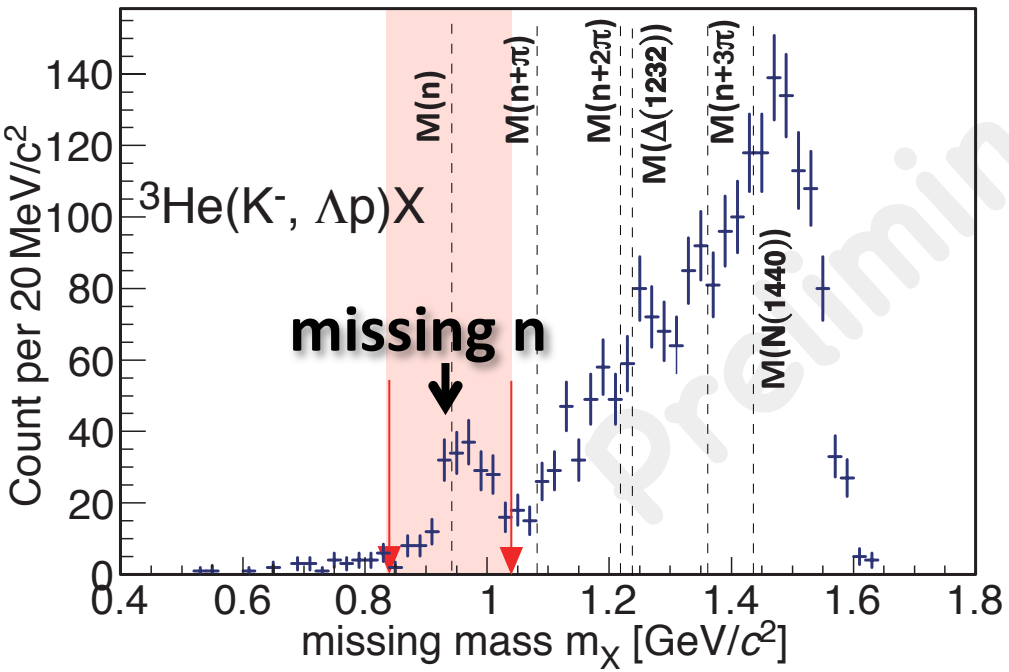
Y* mass spectra assumed B.W. with PDG mass & width

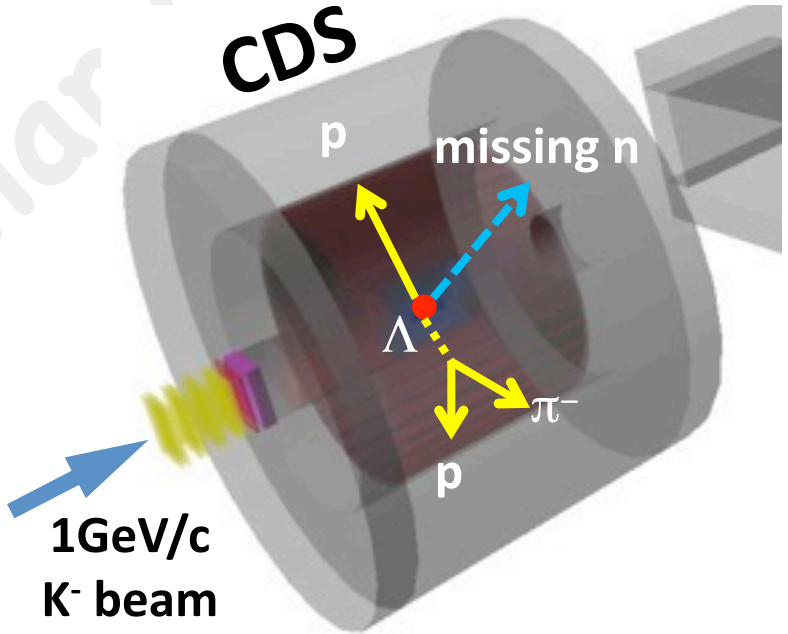
- **ΛN/ΣN 2NA branches are negligibly small**
- **excess by Λ(1405)n + p_S (2NA) cannot be excluded**
- **small q_K ~200 MeV/c equally prefers Σ(1385)/Λ(1405)/Λ(1520)**
  - **rather large Cross Section ~5mb/sr needed**
  - **if large Λ(1520)n exist, why no hint of Λ(1520)n?**

Decay channel

Another member preparing thesis for doctor's degree on this subject.

Decay channel - for exclusive $^3He(K^-,\Lambda p)n_{mis.}$



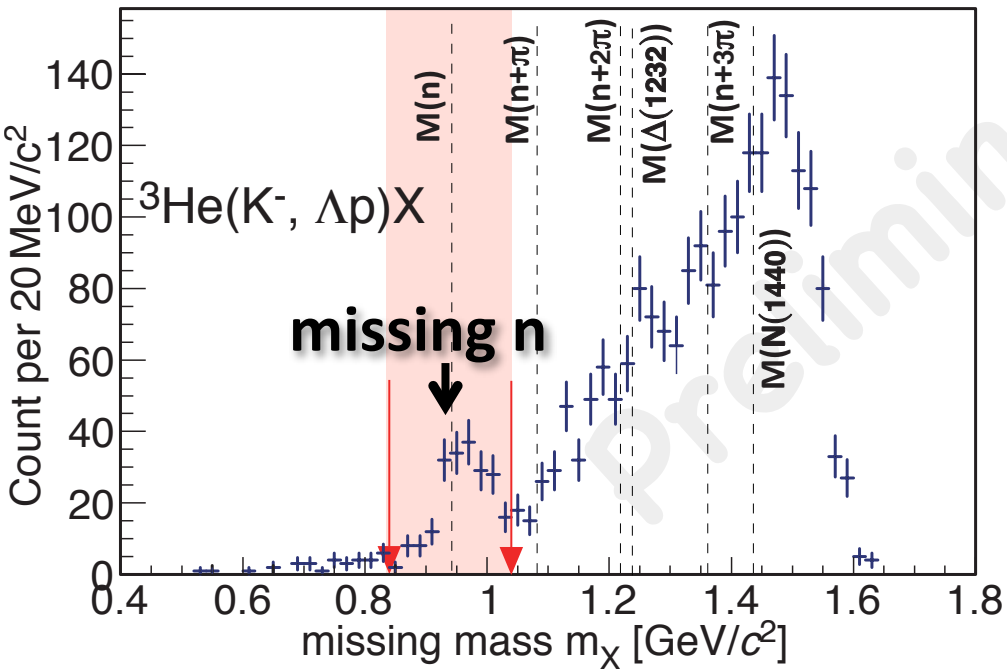


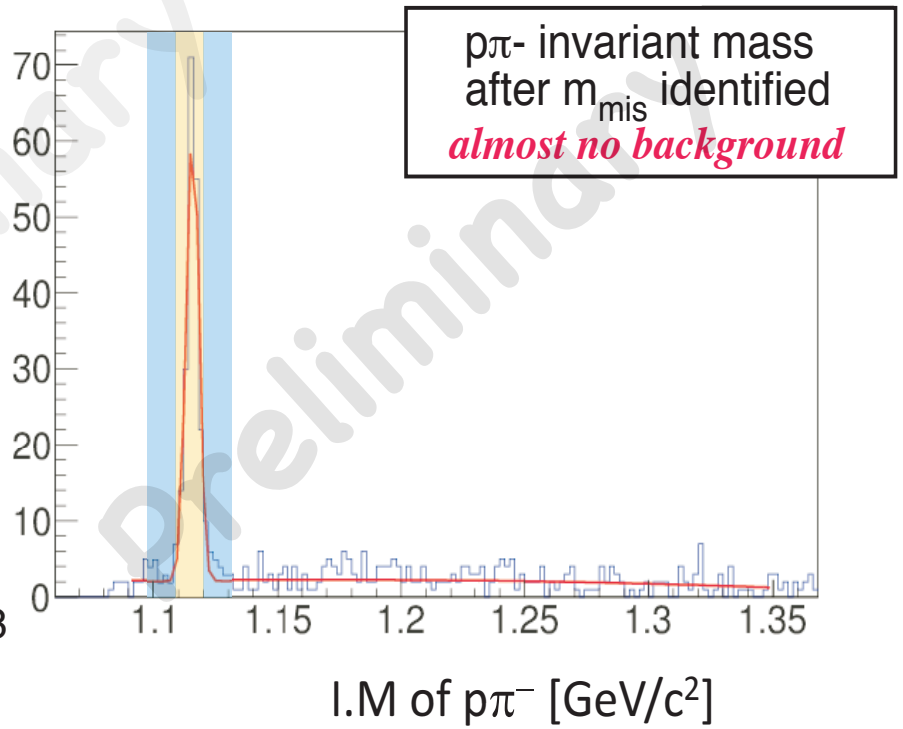
$Br(\Sigma^0pn)/\{Br(\Lambda pn) + Br(\Sigma^0pn)\} < 20\%$

from fitting with simulation

- **$K^{-3}He \rightarrow \Lambda(\Sigma^0)pn$ events identified**
  - # of $\Lambda(\Sigma^0)pn$ events: ~190
    - Σ^0pn contamination: ~20%

Decay channel - for exclusive ^{3}He(K$^-$,Λp)n$_{mis.}$





Br(Σ^{0}pn)/{Br(Λpn) + Br(Σ^{0}pn)} < 20%

from fitting with simulation

- **K$^-$^{3}He→Λ(Σ^0)pn events identified**
  - # of Λ(Σ^0)pn events: ~190
    - Σ^{0}pn contamination: ~20%

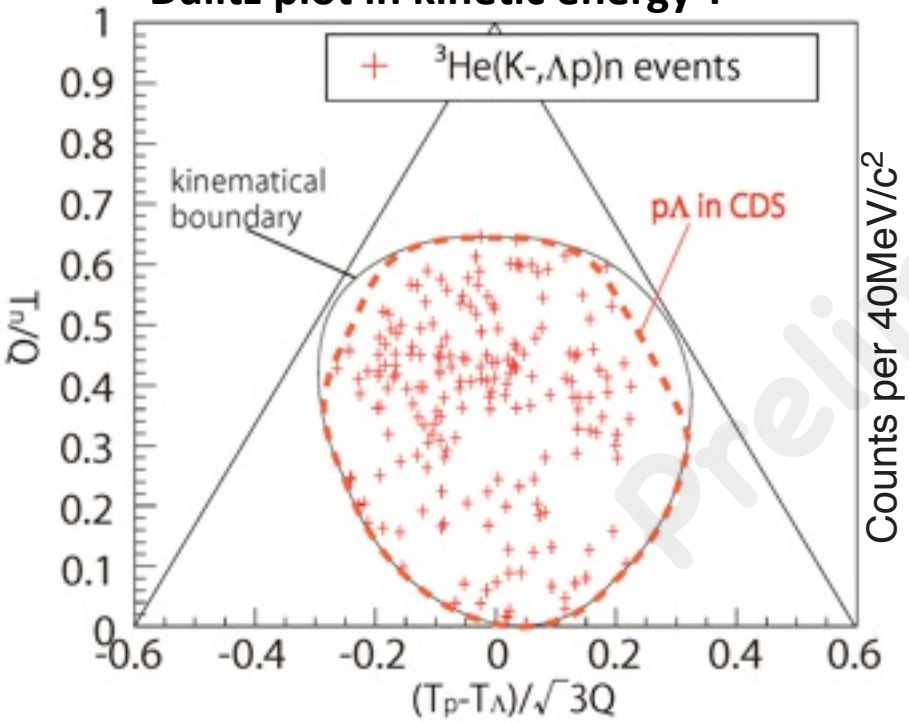
Decay channel

Events are scattered over 3 body phase-space

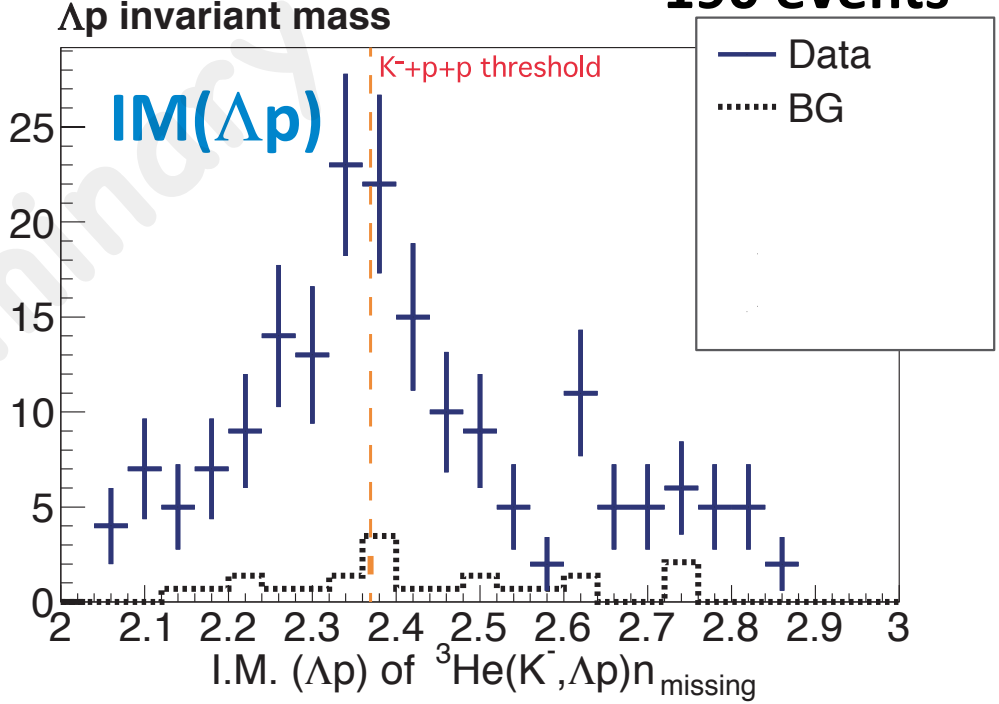
$K^-+{}^3He \to \Lambda+p+n$

~190 events

Dalitz plot in kinetic energy T



Λp invariant mass



- **total CS : ~210 μb** **(~ 0.1% of total cross section of $K^-{}^3He$)**

  assuming CS proportional to phase-space

  - **another excess seen near the threshold**
  - **cannot be Λ(1405)n + p_S (2NA), because of Λpn F.S.**
  - **is 3NA exist beyond 2NA?**

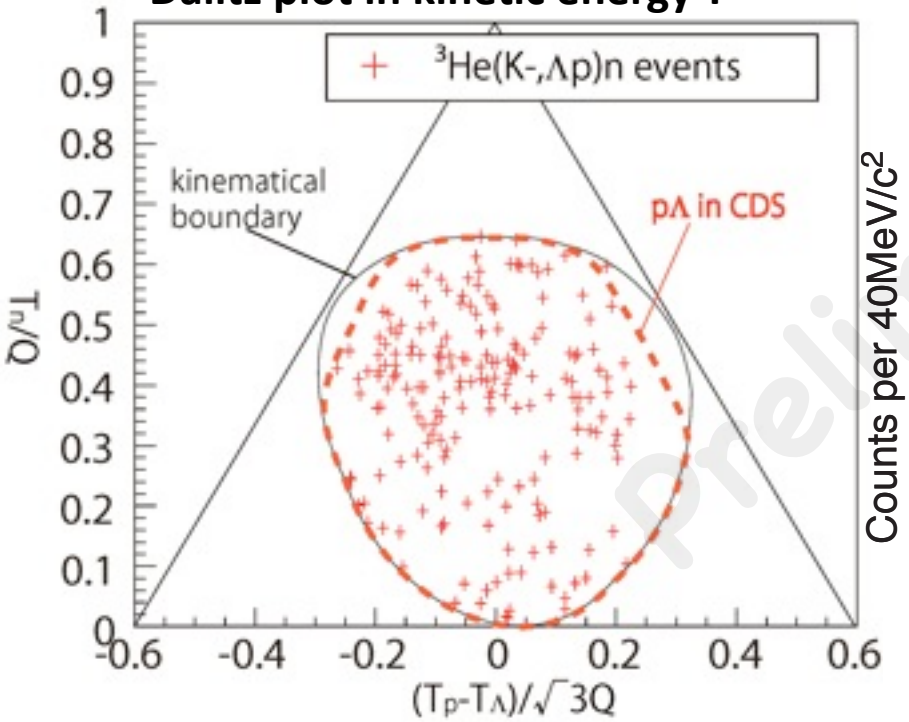
Decay channel

Events are scattered over 3 body phase-space

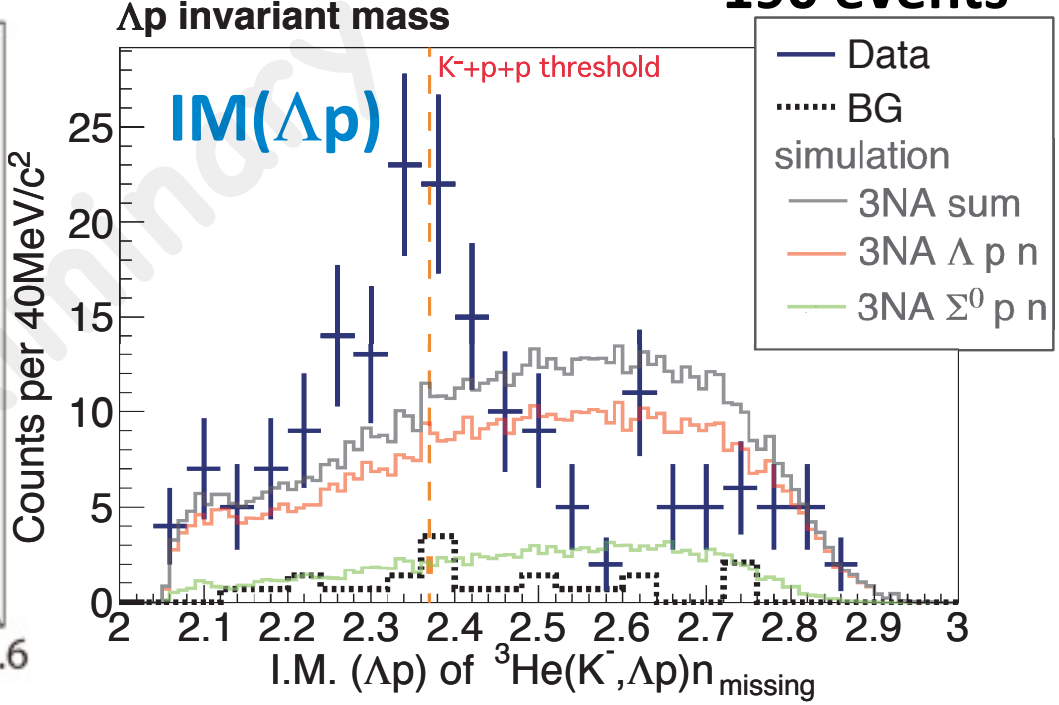
$K^-+{}^3He \to \Lambda+p+n$

~190 events

Dalitz plot in kinetic energy T



Λp invariant mass



- **total CS : ~210 μb** (~ 0.1% of total cross section of $K^{-3}He$)
  assuming CS proportional to phase-space
  - another excess seen near the threshold
  - cannot be Λ(1405)n + p_S (2NA), because of Λpn F.S.
  - is 3NA exist beyond 2NA?

Formation channel

+

Decay channel

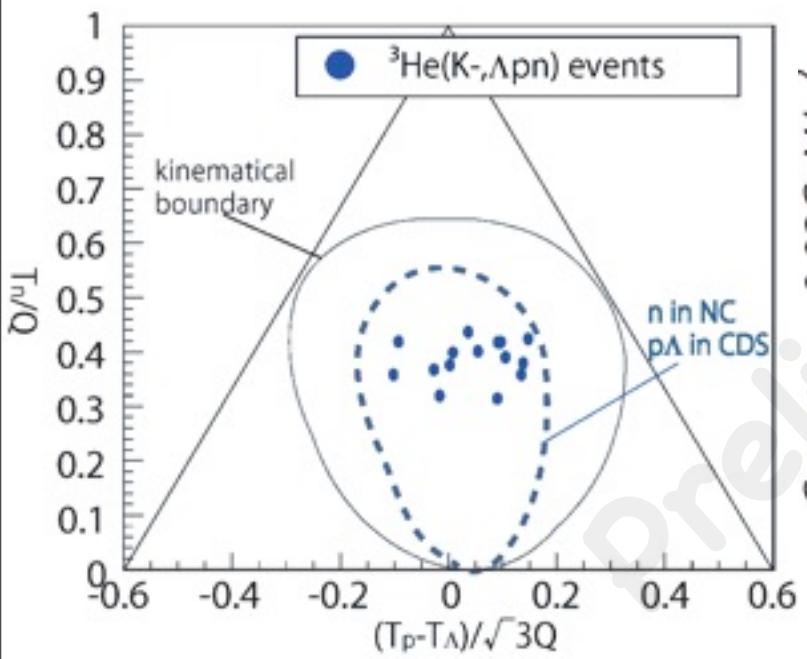
=

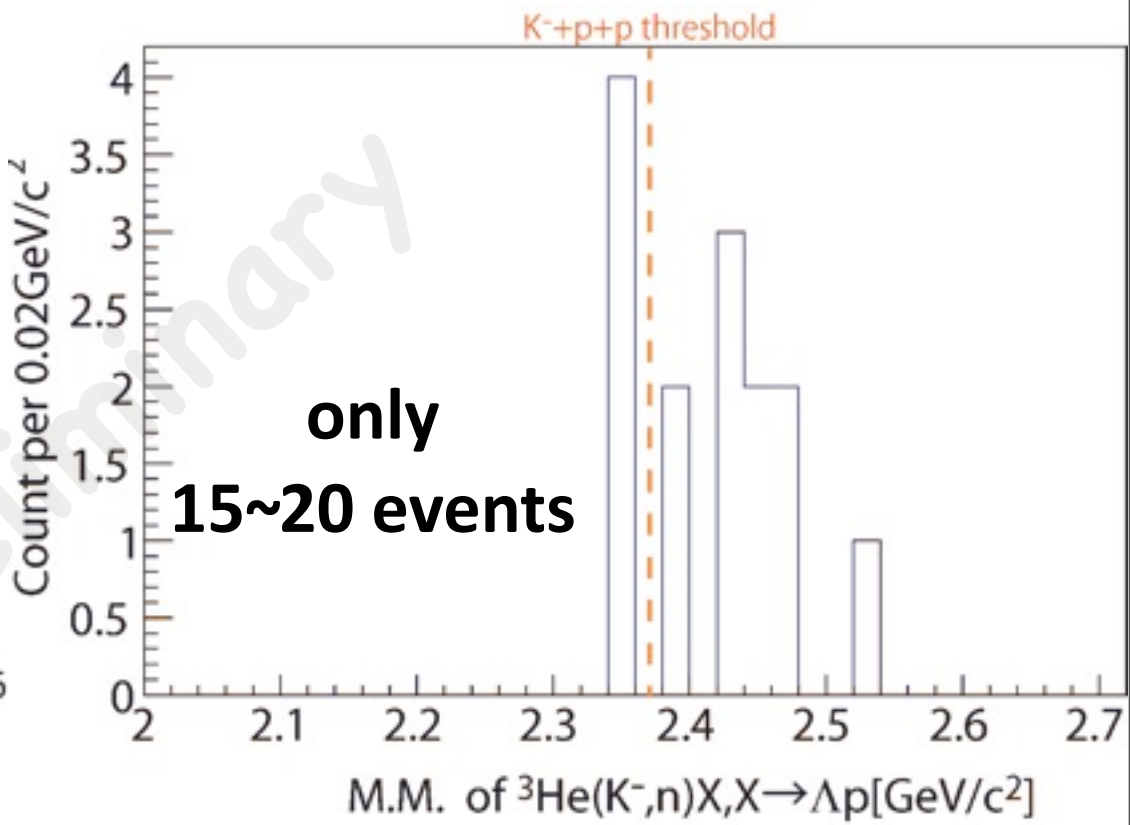
Exclusive analysis

with redundancy check by full kinematics

limited in statistics, though

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





- **Consistent with previous analysis**
- **To study, x100 (at least x10) beam is required**
- **will extend exclusive analysis on other final state (F.S.)**

Beam-time Plan @ K1.8BR

1 GeV/c K^- yield = 100 k/spill (=f_{24GeV}*f_{T1}*Run49c)

f_{24GeV} ~ 0.9 [MR 30→24GeV], f_{T1} ~ 0.8 [T1 modification]

1. Commissioning run
   - **~1 day**
2. Calibration run with H2-target
   - **~4 days** → **$p(K^-,K^0)n_{forward}$: ~2×10^4**
3. E31 pilot run with D2-target
   - 14*10^9 kaons on target = **~14 days**
4. E15 2nd-stage production run with ^{3}He-target
   - 50*10^9 kaons on target = **~56 days**

Conclusion

- **We accomplished the E15 1st stage.**
  - 5x10^9 kaons on target (in May, 2013)
  - The aims of the E15^{1st} were successfully achieved
  - Fruitful results have been obtained

- **We request x10 beam-time as 2nd stage.**
  - 50x10^9 kaons on target
  - study observed excess given in the E15 1st stage
  - extend exclusive analysis to other final states

The J-PARC E15 Collaboration

http://ag.riken.jp/J-PARC/collaboration/

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

(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) Laboratori Nazionali di Frascati dell' INFN, I-00044 Frascati, Italy
(e) National Institute of Physics and Nuclear Engineering - IFIN HH, Romania
(f) Stefan-Meyer-Institut für subatomare Physik, A-1090 Vienna, Austria
(g) INFN Sezione di Torino, Torino, Italy
(h) Dipartimento di Fisica Generale, Universita' di Torino, Torino, 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) Department of Physics, Tokyo Institute of Technology, Tokyo, 152-8551, Japan
(n) RIKEN Nishina Center, RIKEN, Wako, 351-0198, Japan
(o) High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801, 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

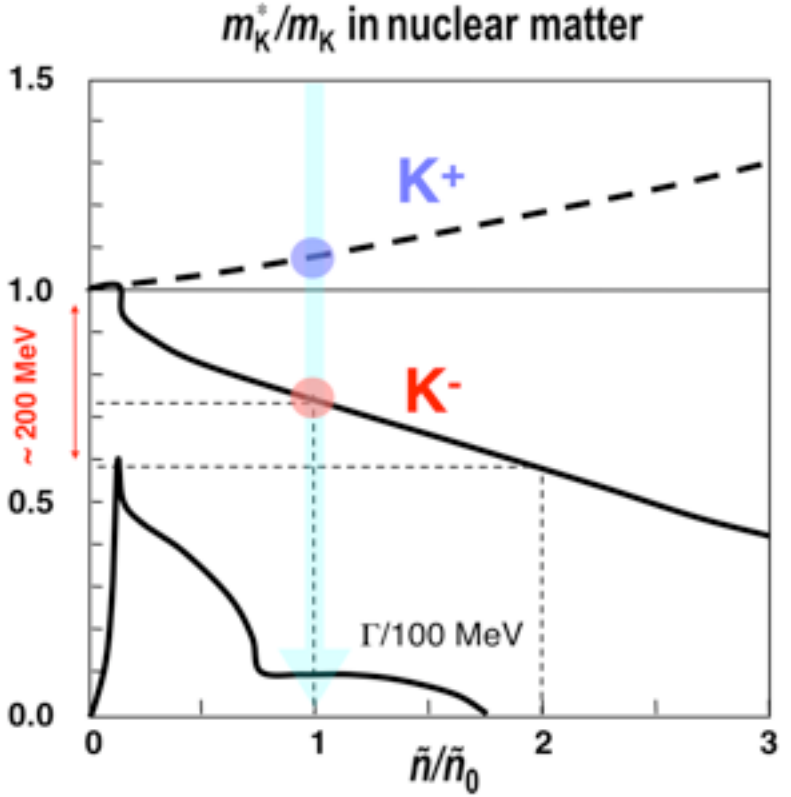
(*) Spokesperson
($) Co-Spokesperson

backup

Embedding K^- in nucleus

Motivation of J-PARC E15

- understand $\bar{K}N$ interaction below threshold
- K mass modification / high density matter?



T. Waas, N. Kaiser & W. Weise, Phys. Lett. B379 (1996) 34.

$\Lambda(1405)$ as K^-p bound state?

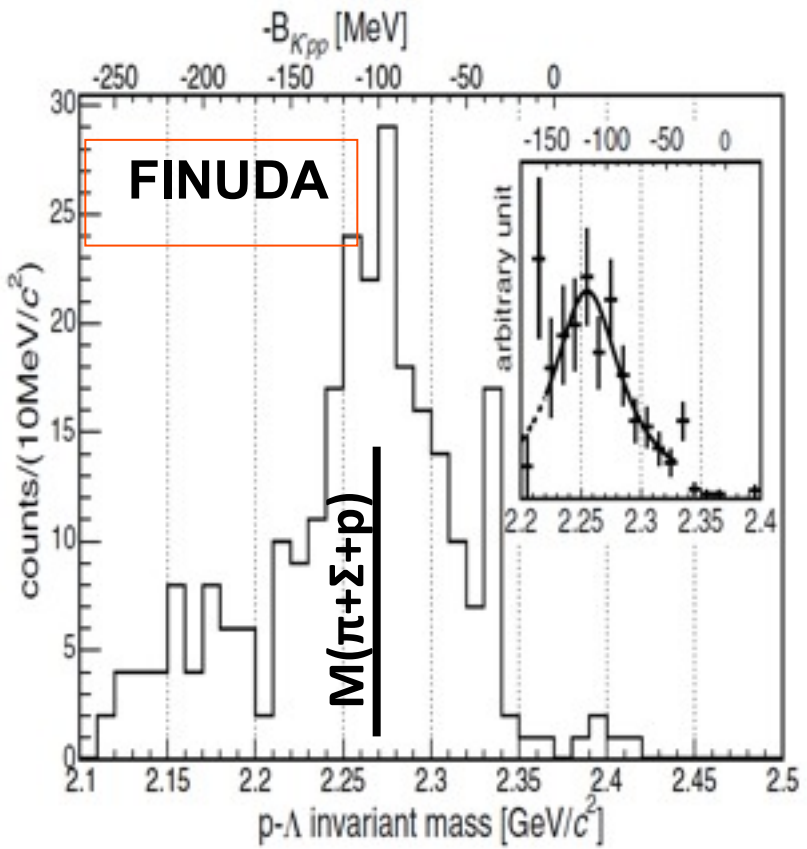
K^- bound state in nuclei?

high density nuclear matter?

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

“Kpp” candidates in Λp invariant mass

“Λp” invariant mass @ K⁻ at rest



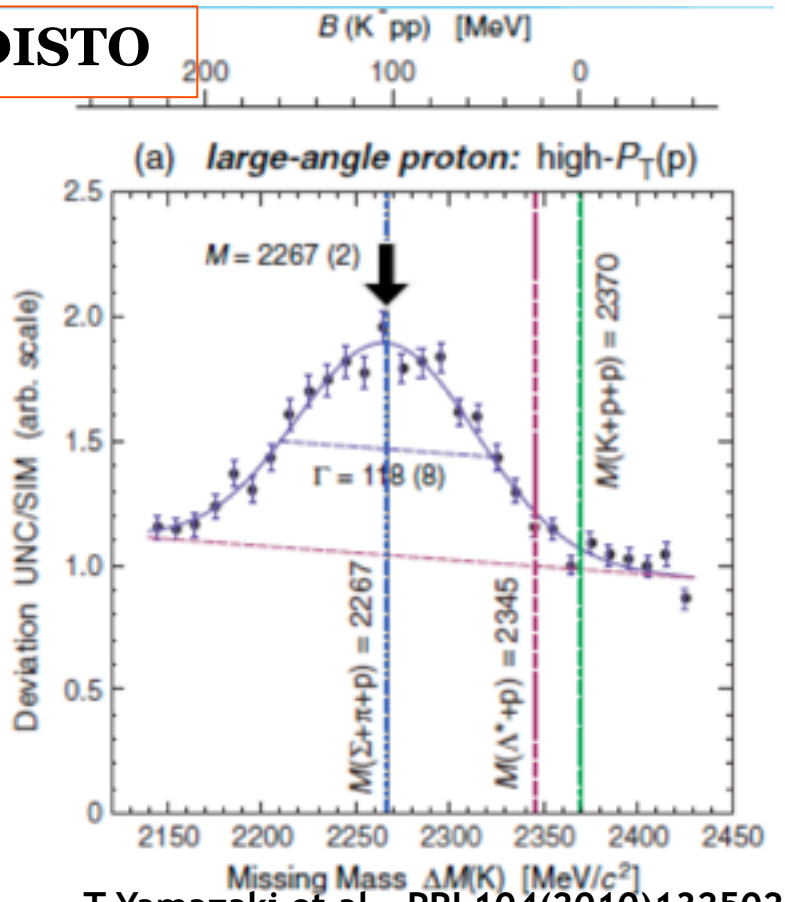
B_K = 115±6±4 MeV

Γ_K = 67±14±3 MeV

(M_{ppK}=2255±6±4 MeV)

p (p, K⁺) Λp @ T = 2.85 GeV

DISTO



T.Yamazaki et al., PRL104(2010)132502

M_x=2267±3±5 MeV !

(B_K = 103±3±5 MeV)

Γ_x=118±8±10 MeV !

E15 1st stage

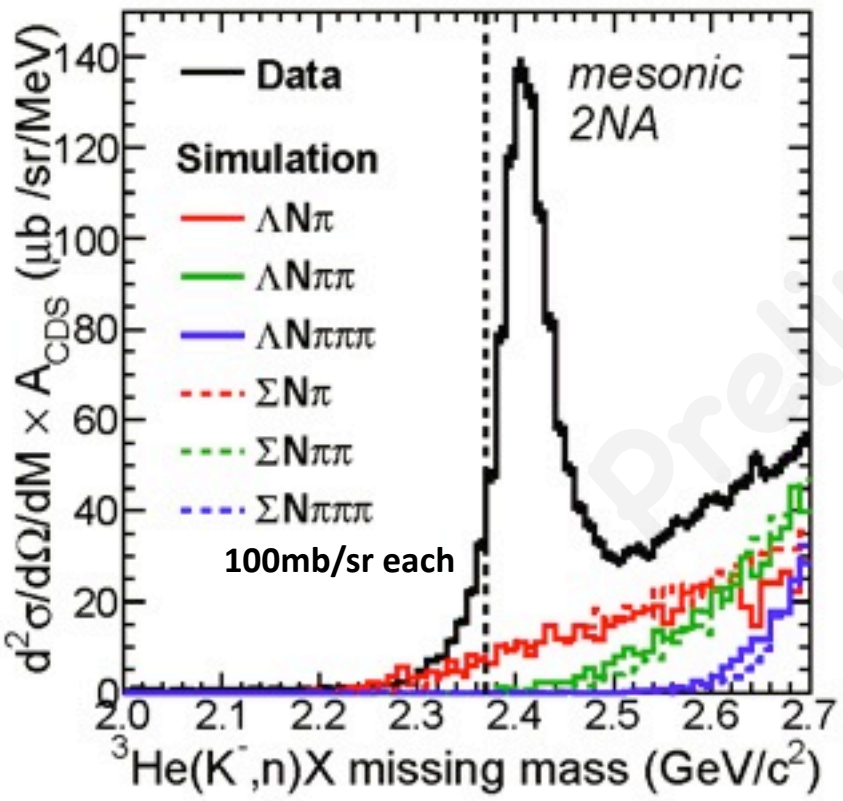
- Took half of scheduled ~15/30kW*week
  - ~1% of the approved proposal (270kW*4weeks)

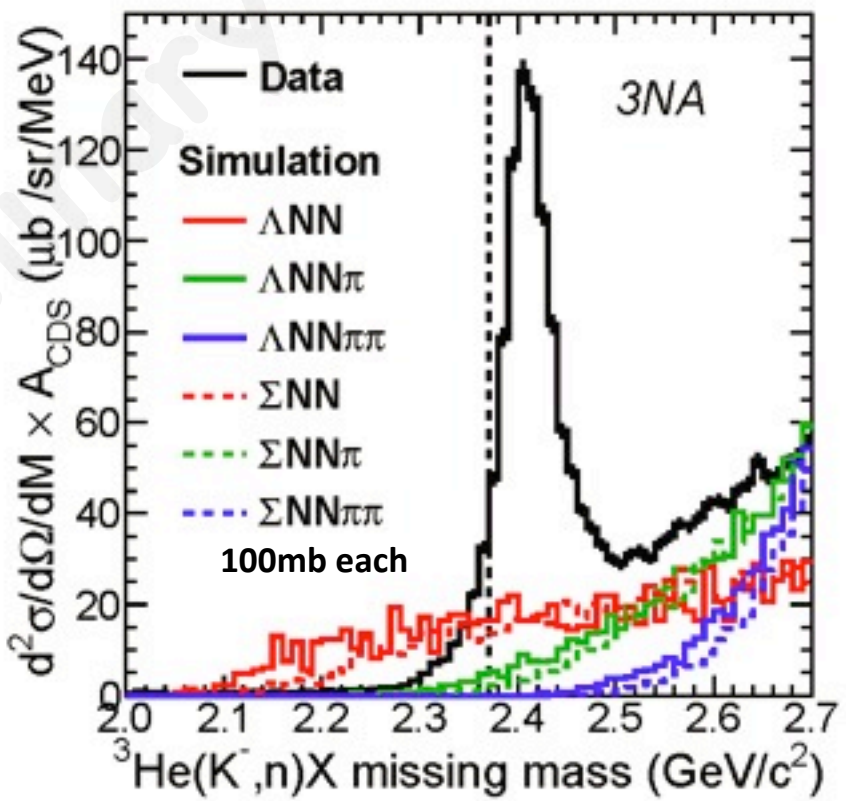
	Primary-beam intensity	Secondary-kaon intensity	Duration	Kaons on target (w/ tgt selection)
March, 2013 (Run#47)	14.5 kW (18 Tppp, 6s)	80 k/spill	30 h	1.1×10^9
May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	140 k/spill	88 h	5.1×10^9

** 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*

- All detector systems worked well as designed.
  - presented in the previous (17th) PAC meeting

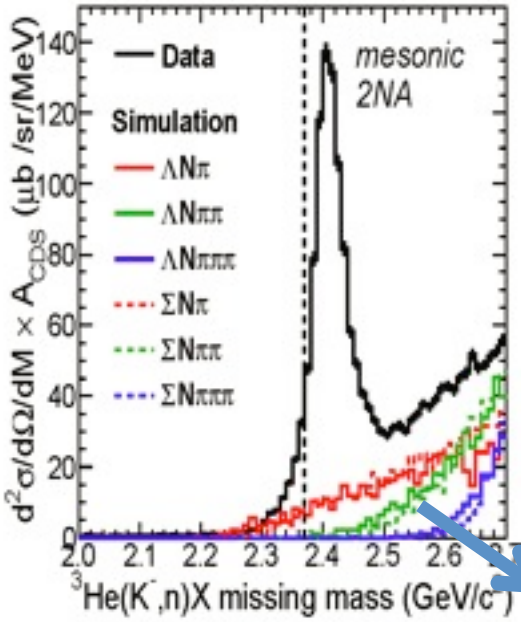
Formation channel: mesonic-2NA / 3NA also small

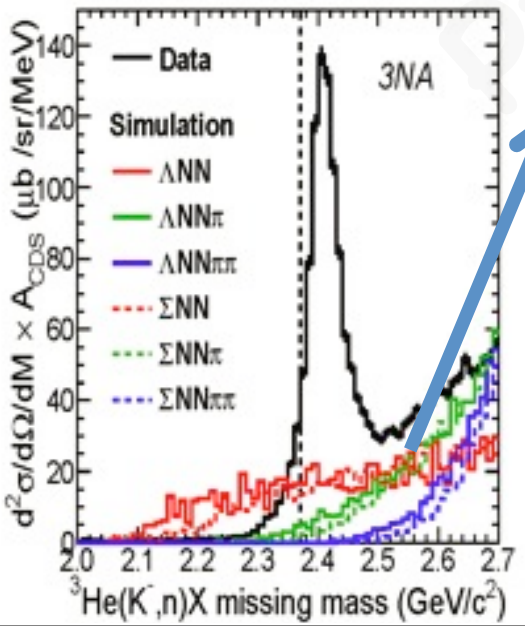


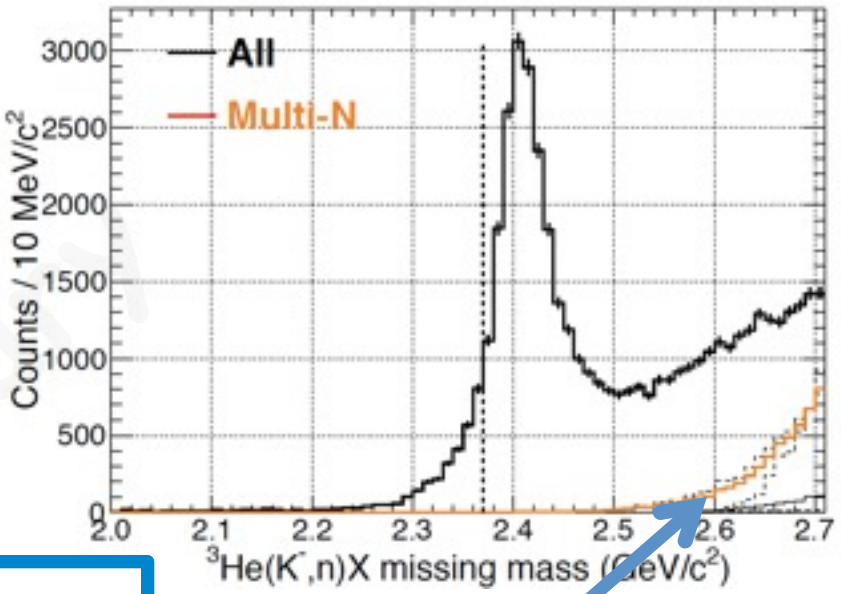


- sum of Ynπ/YNN is estimated to be below 5mb/sr
- **contributions in the binding region are negligible**

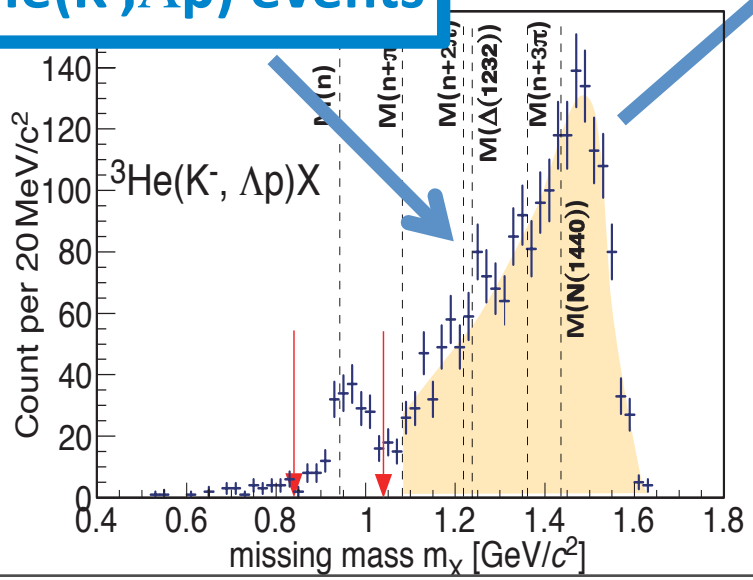
^{3}He(K$^-$,n): mesonic-2NA & 3NA?







self-consistent to ^{3}He(K$^-$,Λp) events

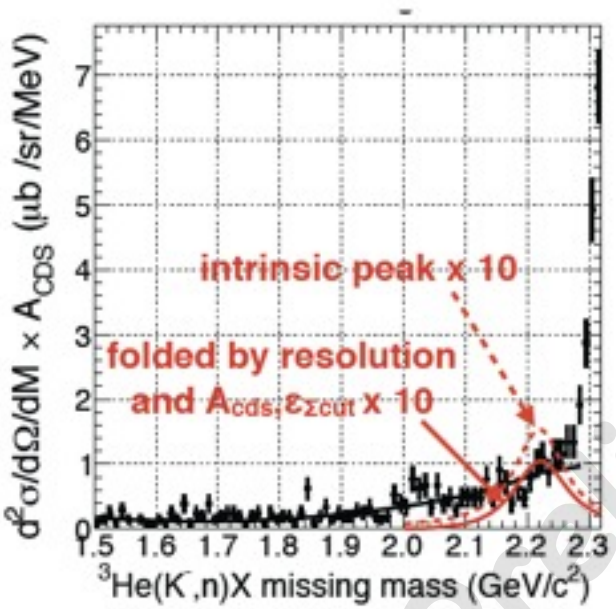


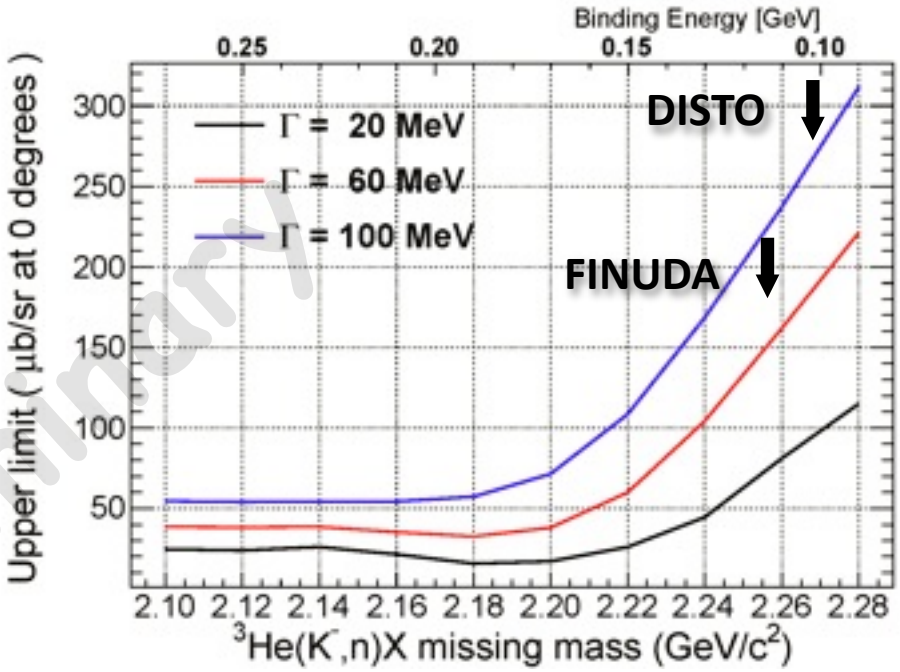
mesonic-2NA & 3NA reactions

- $K^- + {}^3He \rightarrow \pi + Y^{(*)} + N + N_s$
- $K^- + {}^3He \rightarrow Y^{(*)} + N + N$

contributions in the binding region are negligible!

Upper limit of Cross Section by formation channel



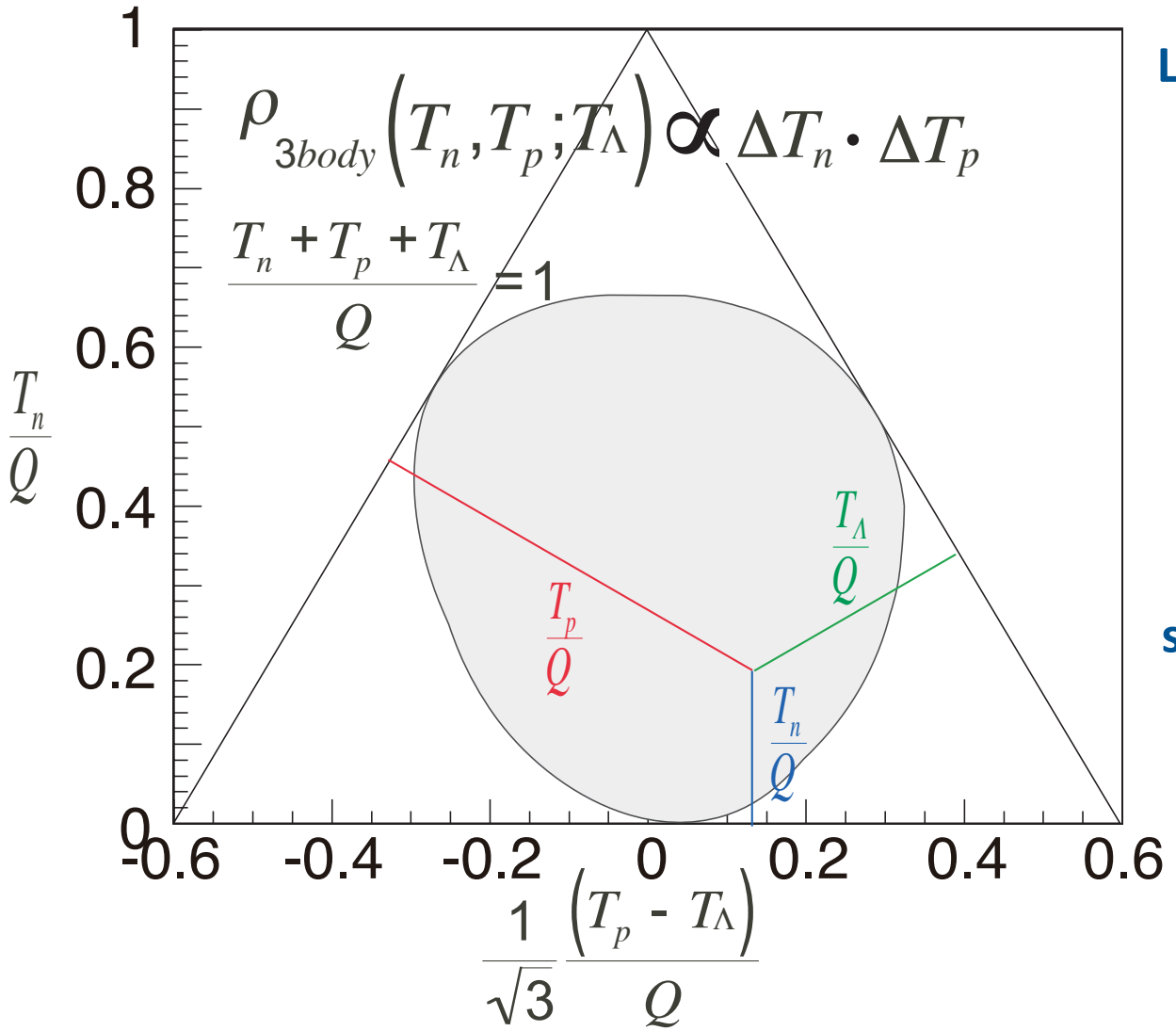


- **No clear structure was found in B.E. ~ 100 MeV/c²**
- $d\sigma/d\Omega(\theta_{lab}=0^o)$ upper limit ~0.3 mb/sr (95% C.L.)

	B.E. (MeV)	Γ (MeV)	95% C.L. (mb/sr)
FINUDA	115	67	~0.2
DISTO	103	118	~0.3

Dalitz plot

in CM kinetic energy T



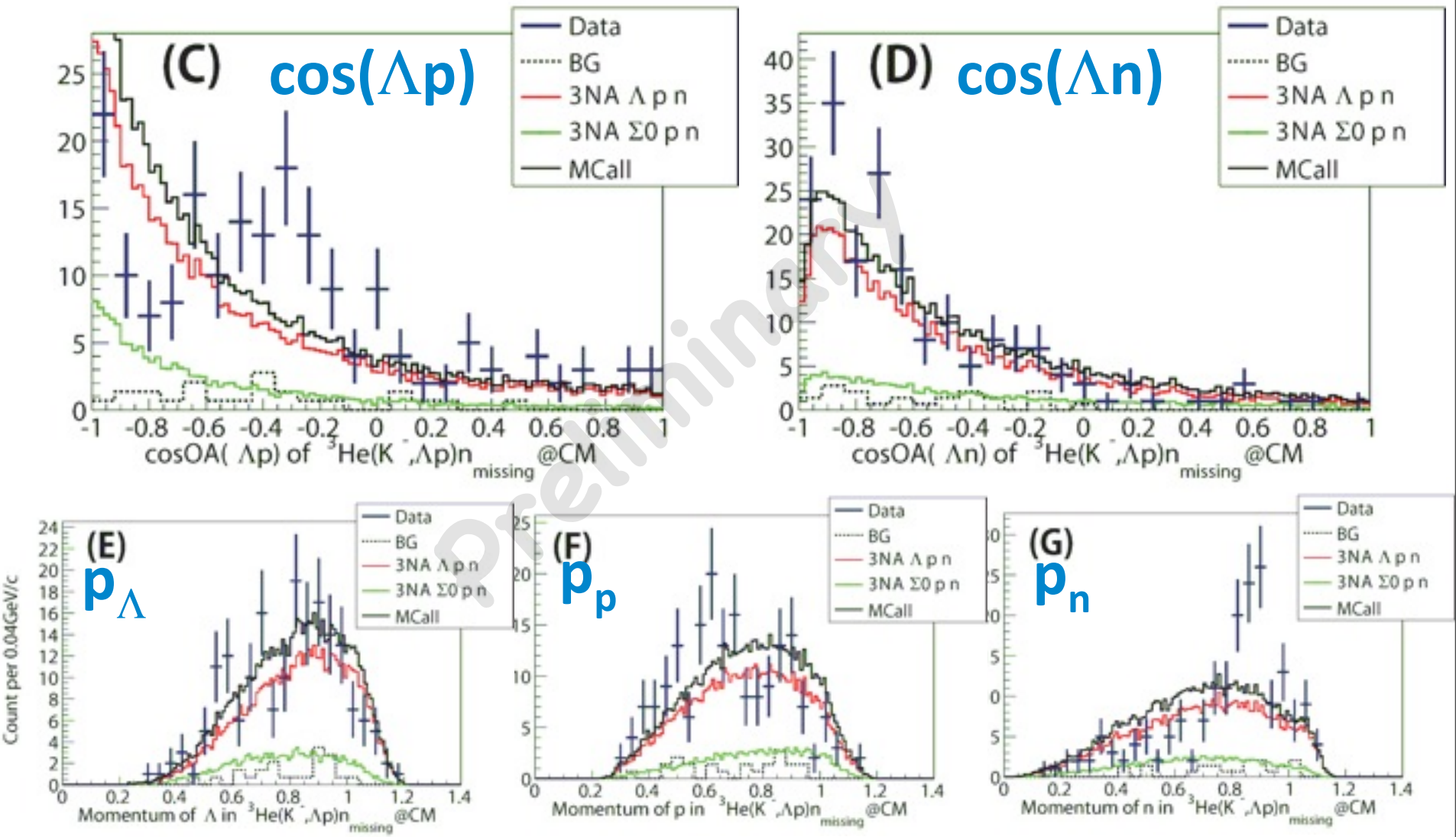
Lorentz invariant 3-body phase space is proportional to

$\Delta T_1 \times \Delta T_2$

easy to see kinematics

symmetric representation

^{3}He(K$^-$,Λp)n: Comparison with Phase-Space



- **data cannot be reproduced by the phase-space?**

Achievement of the E15 1st

4 objectivities of E15^{1st} @ 13th PAC meeting, Jan.2012

1. **^{3}He(K^{-}, n) spectrum** below the K^{bar}NN threshold
   - significant excess below the threshold
   - No clear structure in B.E ~ 100 MeV/c^{2}
2. Hint of signal in **Λ+p+n final states**
   - widely distributes over the phase-space?
   - excess around the threshold?
3. Investigation of the **background processes**
   - absence of K^{-}NN→ΛN/ΣN 2NA reactions
4. Realistic beam-time for **the E15 full experiment**.
   - more than x 100 beam-time compared to E15^{1st}