An experimental search for strange multibaryonic states via (stopped K^-, YN) reactions

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Introduction -*Does deeply bound kaonic nuclear states with narrow widths exist ?*

-> No, they don't! They must be shallow and broad

-> Yes, they do.

1) T. Kishimoto (PRL **83** 4701 (1999))

BNL-AGS E930 (T. Kishimoto *et. al.,* 2001) with ^{16}O(in-flight K^-,n)

-> *narrow bound state(s)?*(NPA **754** 383c (2005))

KEK-PS E548 (T. Kishimoto *et. al.,* 2005) with ^{16}O(in-flight K^-,N) -> *no narrow sates !*

2) Y. Akaishi and T. Yamazaki (PRC **65** 044005 (2002), PLB **535** 70 (2002))

KEK-PS E471 (M. Iwasaki *et. al.*, 2002/2003) with ^{4}He(stopped K^-,N)

-> *observation of "strange tribaryons"* (nucl-ex/0310018,PLB **597** 263 (2004))

FINUDA (T. Bressani *et. al.*, 2003/2004) with $^{6/7}$Li/ ^{12}C(stopped K^-,Λp)

-> *evidence for deeply bound ppK$^-$ state*(PRL **94** 210323 (2005))

KEK-PS E549/570 (M. Iwasaki *et. al.*/R. S. Hayano *et. al.*, 2005) with

^{4}He(stopped K^-,N) -> *no narrow sates !* (PLB **659** 107 (2008))

Broad states? ***-> This talk***

Original aim of the Experiment

(semi-)Inclusive missing mass spectroscopy

of $(K_{bar}NNN)_{Z=0,T=1}$: S^0 / $(K_{bar}NNN)_{Z=1,T=0,1}$: S^+ via

$K^-_{stopped} + {}^4He$ -> $p + S^0_{T=1}$ ->M. Sato, PLB **659** 107

-> $n + S^+_{T=0,1}$ ->H. Yim, under preparation

$S^+_{T=0,1}$ -> $Y(\pi)NN$

$Y \to \pi N$

Very strict upper limits for narrow(Γ< ~40 MeV/c^2) states

Insensitive to broad (Γ> ~40 MeV/c^2) states

Semi-exclusive studies

Semi-exclusive missing mass spectroscopy via

This talk.

$K^-_{stopped} + {}^4He \rightarrow N + {}^3S^{0/+}_{T=0,1}$

(Y:Λ->arXiv:0711.4943)

$\quad {}^3S^{0/+}_{T=0,1} \rightarrow Y(\pi)NN$

Small statistics, but well resolved final states. Dibaryon?

$K^-_{stopped} + {}^4He \rightarrow {}^2S^{0/+}_{T=1/2,3/2} + N + N$

$\quad {}^2S^{0/+}_{T=1/2,3/2} \rightarrow YN$

Inclusive measurement for

$K^-_{stopped} + {}^4He \rightarrow {}^2S^0_{T=1/2} + d$

Semi-exclusive measurement for

$K^-_{stopped} + {}^4He \rightarrow {}^2S^0_{T=1/2} + d$

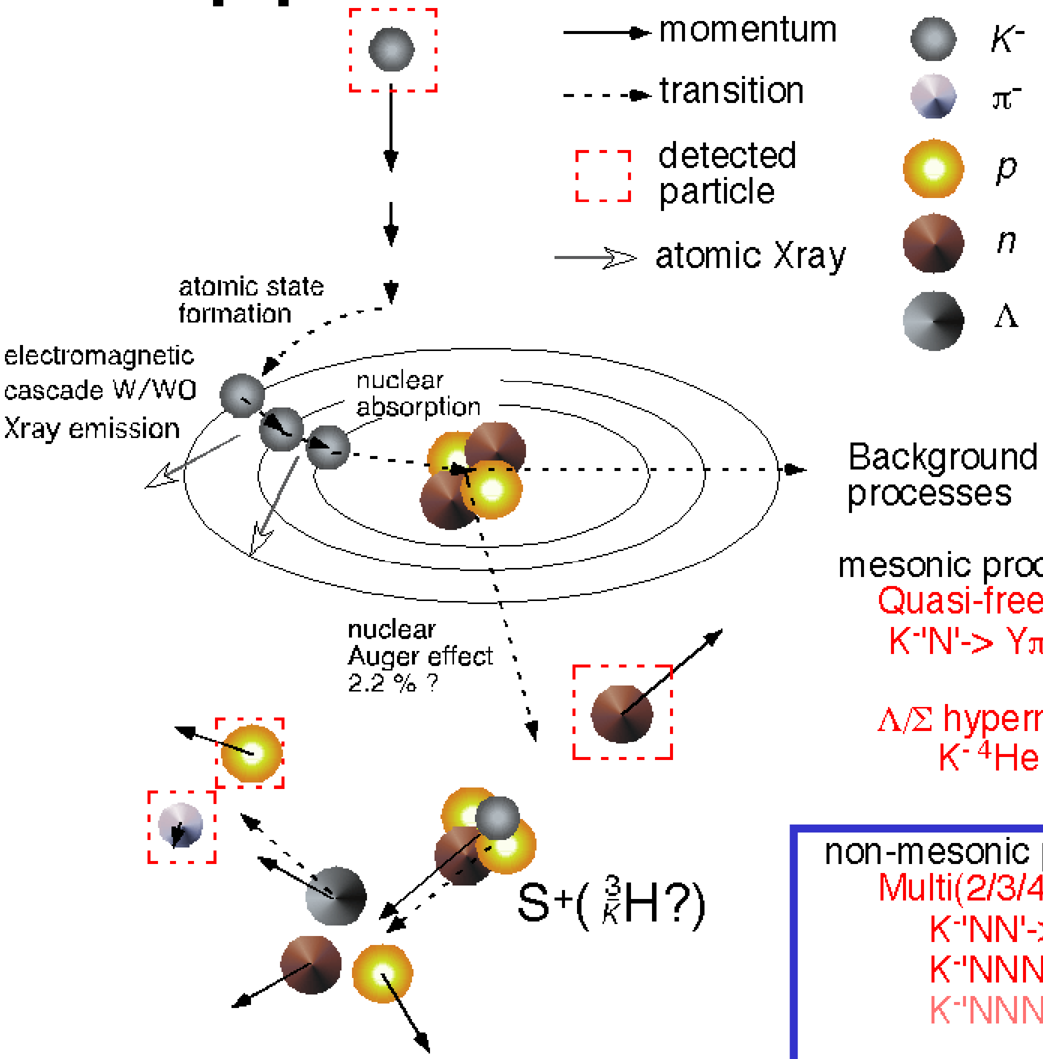
$\quad {}^2S^0_{T=1/2} \rightarrow Yn$

$\quad \rightarrow {}^3S^+_{T=0,1} + n$

$\quad {}^3S^+_{T=0,1} \rightarrow Yd$

Y:Λ->PRC **76** 068202

Stopped K^- Reaction on ^{4}He



mesonic processes ~ 80%

Quasi-free hyperon production ~ 70 %

K^-'N'-> Yπ

Λ/Σ hypernuclear formation ~ 3+5? %

K^- ^{4}He -> $^4_{\Lambda/\Sigma}$He π^-

-> $^4_\Lambda$H π^0

non-mesonic processes ~ 17%

Multi(2/3/4)-Nucleon Absorption

K^-'NN'-> YN (2NA)

K^-'NNN'-> YNN (3NA)

K^-'NNNN'-> YNNN (4NA)

Dibaryon production+ its non-mesonic decay?

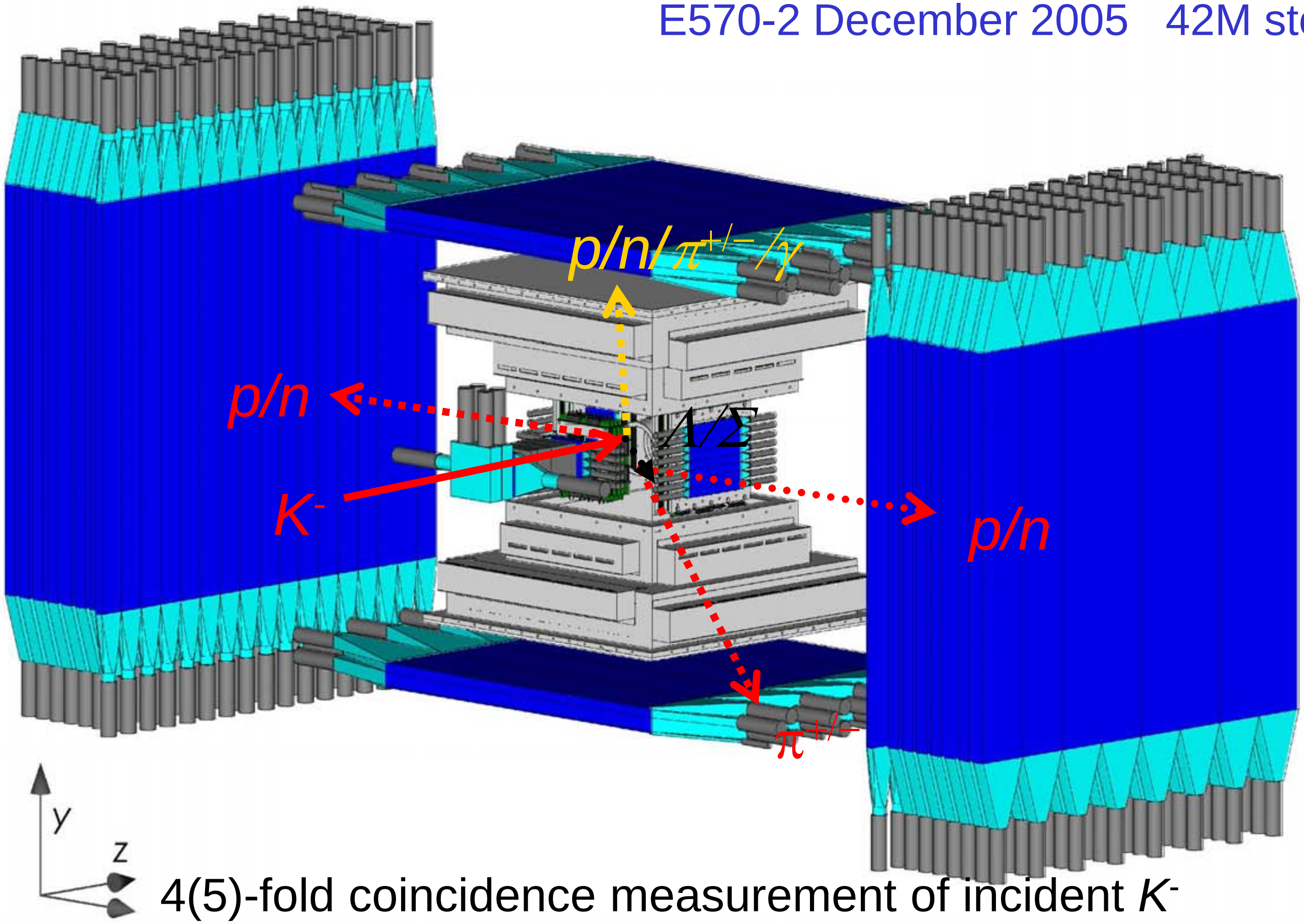
K^- ^{4}He -> XNN

X->YN

Only total capture Rate is known. Dynamical nature is speculative

Measurement

E549 June 2005 95M stopped K^-
E570-1 October 2005 108M stopped K^-
E570-2 December 2005 42M stopped K^-



4(5)-fold coincidence measurement of incident K^- (+X)+back-to-back 2 nucleons+charged π

Momentum decision by track detection+TOF method for π/p/n

^{4}He(stopped K$^-$, ΛN) missing mass

Regardless of the medium states,

$K^-_{stopped} + {}^4He \rightarrow \Lambda + N + N + N + \pi$
$K^-_{stopped} + {}^4He \rightarrow \Lambda + N + N + N$
$K^-_{stopped} + {}^4He \rightarrow \Lambda + n + d$

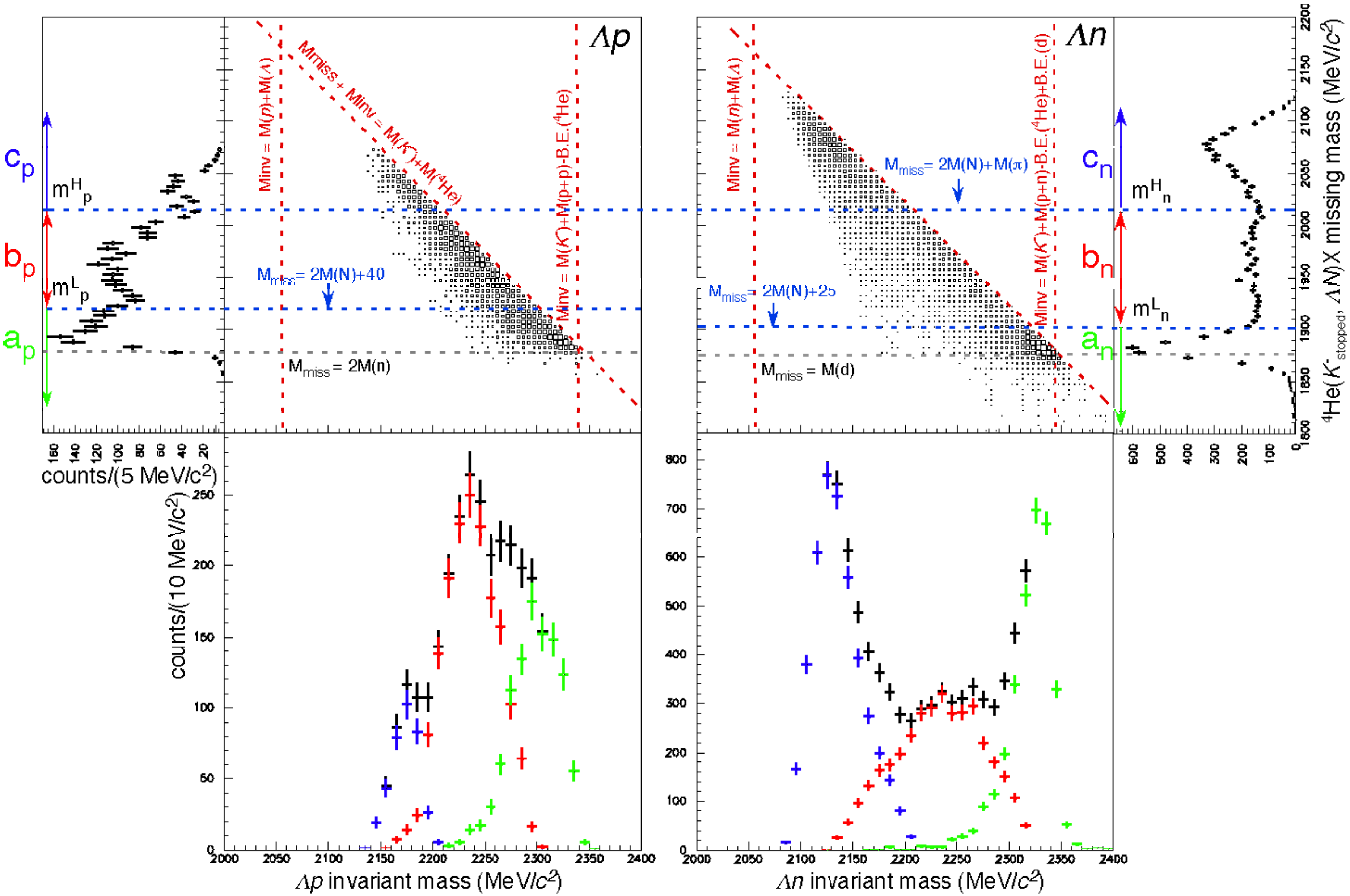
final states can be separated by

^{4}He($K^-_{stopped}$, ΛN) missing mass,

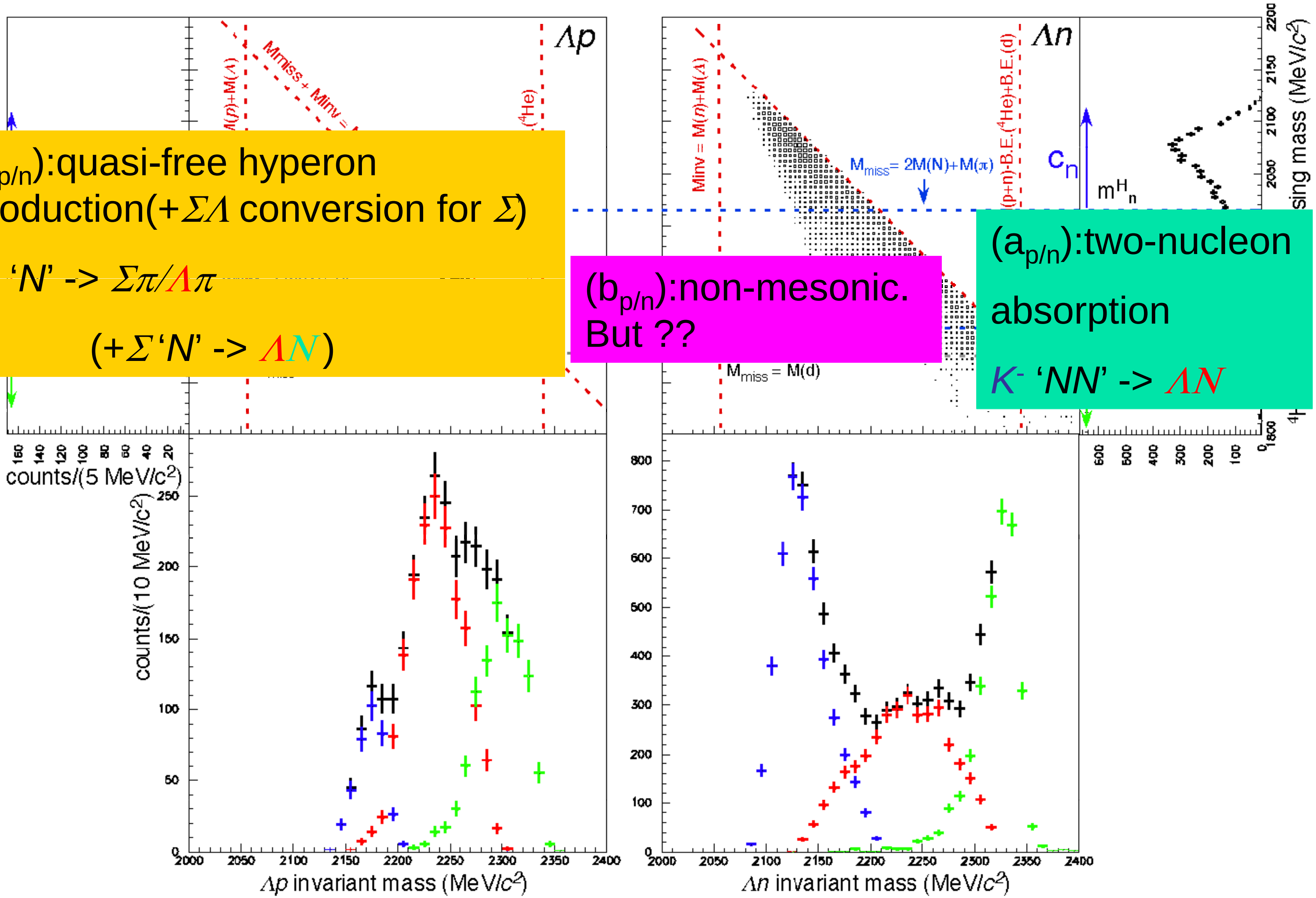
$$M_{NN^*} = \sqrt{(p_{init} - p_\Lambda - p_N)^2},$$

which is actually internal energy of nuclear residual.
Internal energy can give important information to interpret observed strength.

ΛN invariant mass VS ^{4}He(stopped K$^-$, ΛN) missing mass



ΛN invariant mass VS ^{4}He(stopped K$^-$, ΛN) missing mass



($c_{p/n}$):quasi-free hyperon production(+$\Sigma\Lambda$ conversion for Σ)

K^- ‘N’ -> $\Sigma\pi/\Lambda\pi$

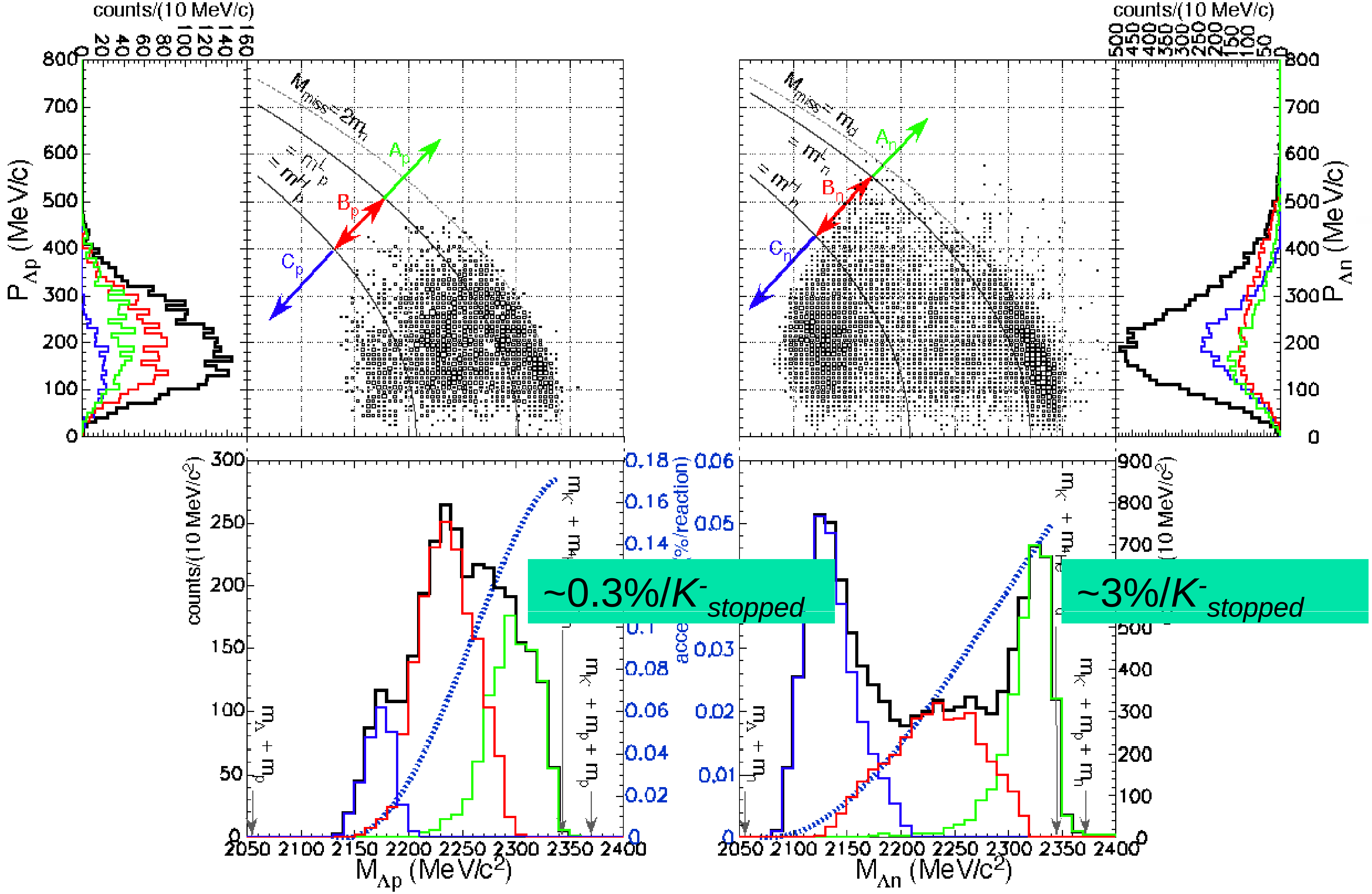
(+Σ ‘N’ -> ΛN)

($b_{p/n}$):non-mesonic. But ??

($a_{p/n}$):two-nucleon absorption

K^- ‘NN’ -> ΛN

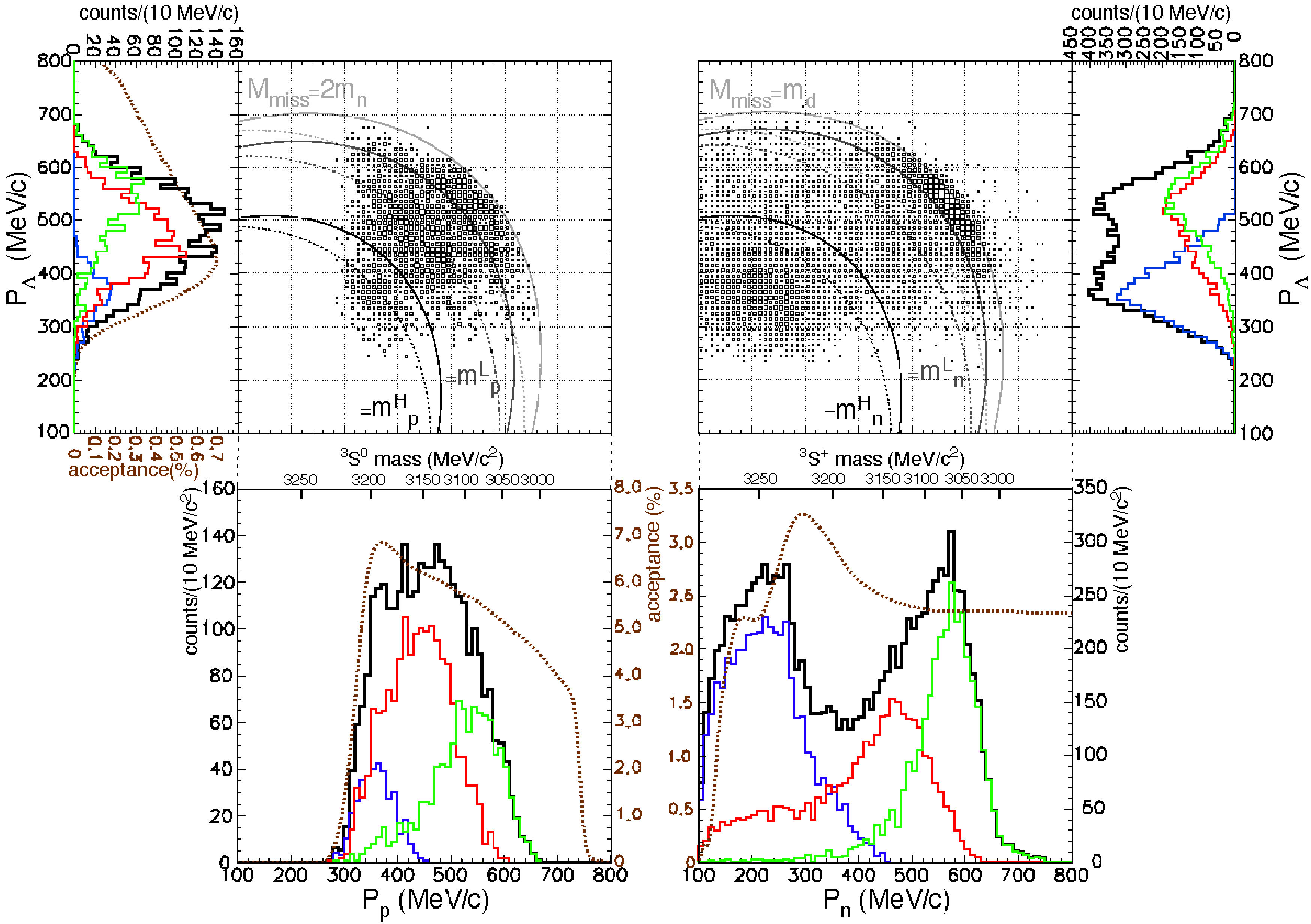
ΛN invariant mass VS ΛN total momentum



1. 'NN'$_{I=0,S=1}$ dominance of K^- '*NN*'$_{I,S}$ -> ΛN

2. More intense contribution of $B_{p/n}$

Λ momentum VS N momentum



($b_{p/n}$) -> Unresolved ***broad strength peaked at ~3140 MeV/c^2***.

Discussion of a_p/a_n (2-nucleon absorption) components

Clear observation of "two"-nucleon absorption,

K^- '*pp*' $_{I=1,S=0}$ -> Λp (a_p~0.3%/$K^-_{stopped}$)

K^- '*pn*' $_{I=1,S=0/I=0,S=1}$ -> Λn (a_n ~3%/$K^-_{stopped}$)

Consequences

1. Significantly small branch on Λp(***I=0,S=1 dominance***).
2. ***only ~30%*** of known $\Lambda(\Sigma^0)$(*pnn*)(11.7 +-2.4)% (PRD **1** 1267 (1970)) final states!
3. ***Suppression*** of

$$(K^- [pp]_{I=1,S=0}) \to \Lambda p$$

decay mode of strongly bound K^-pp system.

Properties of b_p/b_n components

1. Presence of intense(~70% of ΛNNN final states) $(b_p)/(b_n)$ components.

2. (b_n) could be explained by the elastic re-scattering effect(PRC **74** 025206).

3. Much different (a_p):(b_p),(a_n):(b_n) intensity ratio.
-> simultaneous explanation of b_p and b_n by elastic re-scattering effect is almost impossible…

4. (b_p) cannot be explained by the re-scattering effect from the spectrum shape.
-> ***(b_p) is extremely peculiar.***

Interpretation of b_p component

Possible contibutions to component (b_p)…

1. Σ branch of "two"-nucleon absorption and successive $\Sigma\Lambda$ conversion process

K^- 'NN' -> Σp

Σ 'N' -> Λp

Possible contribution from

K^- 'pp' -> $\Sigma^0 p$

Σ^0 -> $\Lambda\gamma$

2. "three"-nucleon absorption cf. PRC 76 068202)

K^- 'NNN' -> ΛpN ← *Expected brach* is 0.1% order…

3. $^2S^+_{T=1/2}$ dibaryon (K^- [pp] $_{I=1,S=0}$) production and its Λp decay
(for ^{6}Li + ^{7}Li + ^{12}C, FINUDA collaboration, PRL **94** (2005) 212303)

$K^-_{stopped} + {}^4He$ -> $^2S^+_{T=1/2} + n + n$

$^2S^+_{T=1/2}$ -> $\Lambda + p$ ← Spin-isospin suppressed…

4. $^3S^0_{T=1}$ tribaryon production and its Λnn decay

$K^-_{stopped} + {}^4He$ -> $^3S^0_{T=1} + p$

$^3S^0_{T=1}$ -> $\Lambda + n + n$

Interpretation of b_n component

Possible contributions to component (b_n)…

1. Σ branch of "two"-nucleon absorption and successive ΣΛ conversion process

K^- 'NN' -> Σn

Σ 'N' -> Λn

Possible contribution from

K^- 'pn' -> $\Sigma^0 n$

$\Sigma^0 \rightarrow \Lambda\gamma$

Unseen on ΣN spectra.

2. Elastic re-scattering

K^- 'NN'(NN) -> Λn(NN) K^- 'NN'(NN) -> Λn(NN)

Λ(n)-> Λn n(N)-> nN

3. $^2S^0_{T=1/2}$ dibaryon (K^- [pn] $_{I=0,S=1}$) production and its Λn decay

$K^-_{stopped} + {}^4He \rightarrow {}^2S^0_{T=1/2} + p + n$

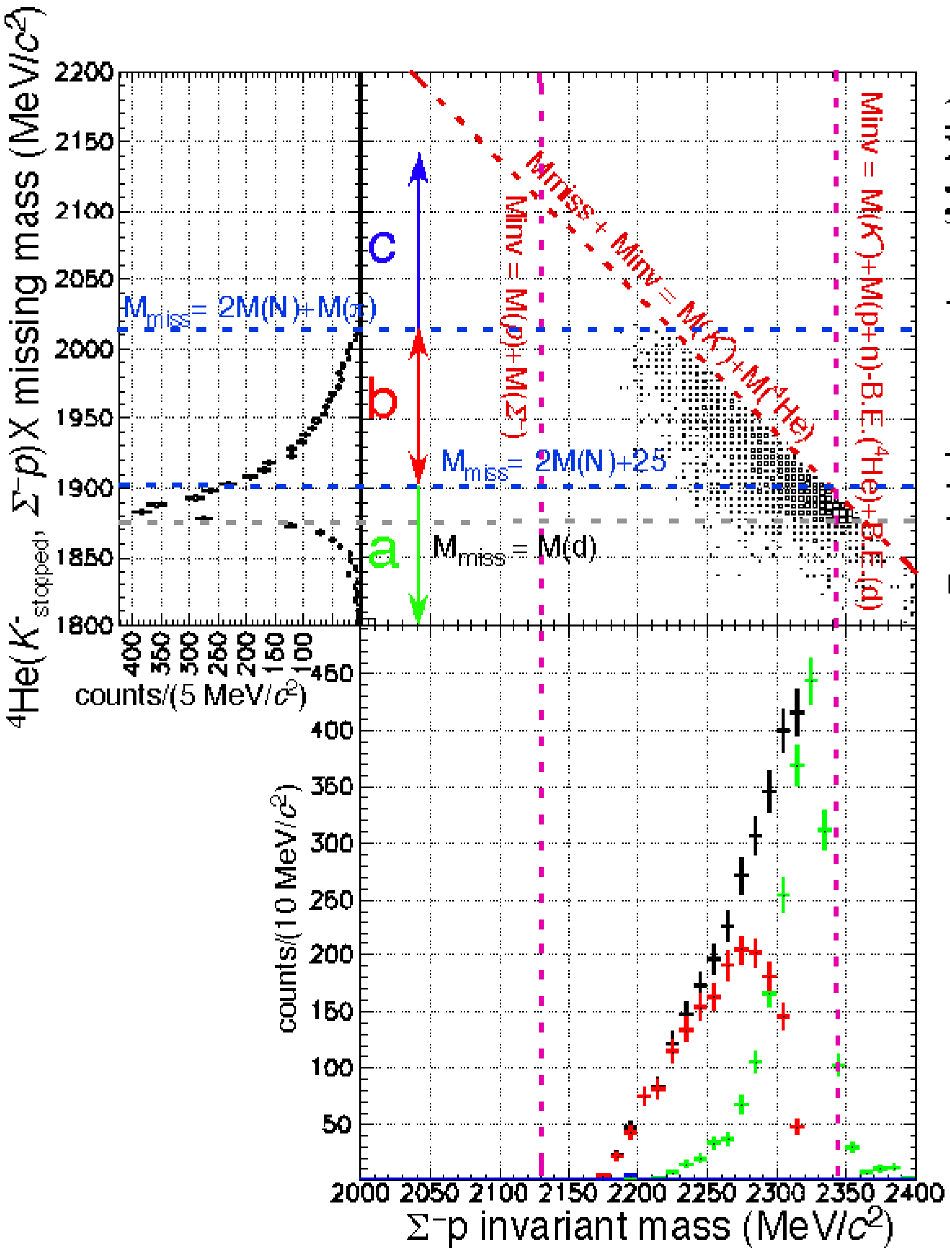
${}^2S^0_{T=1/2} \rightarrow \Lambda + n$

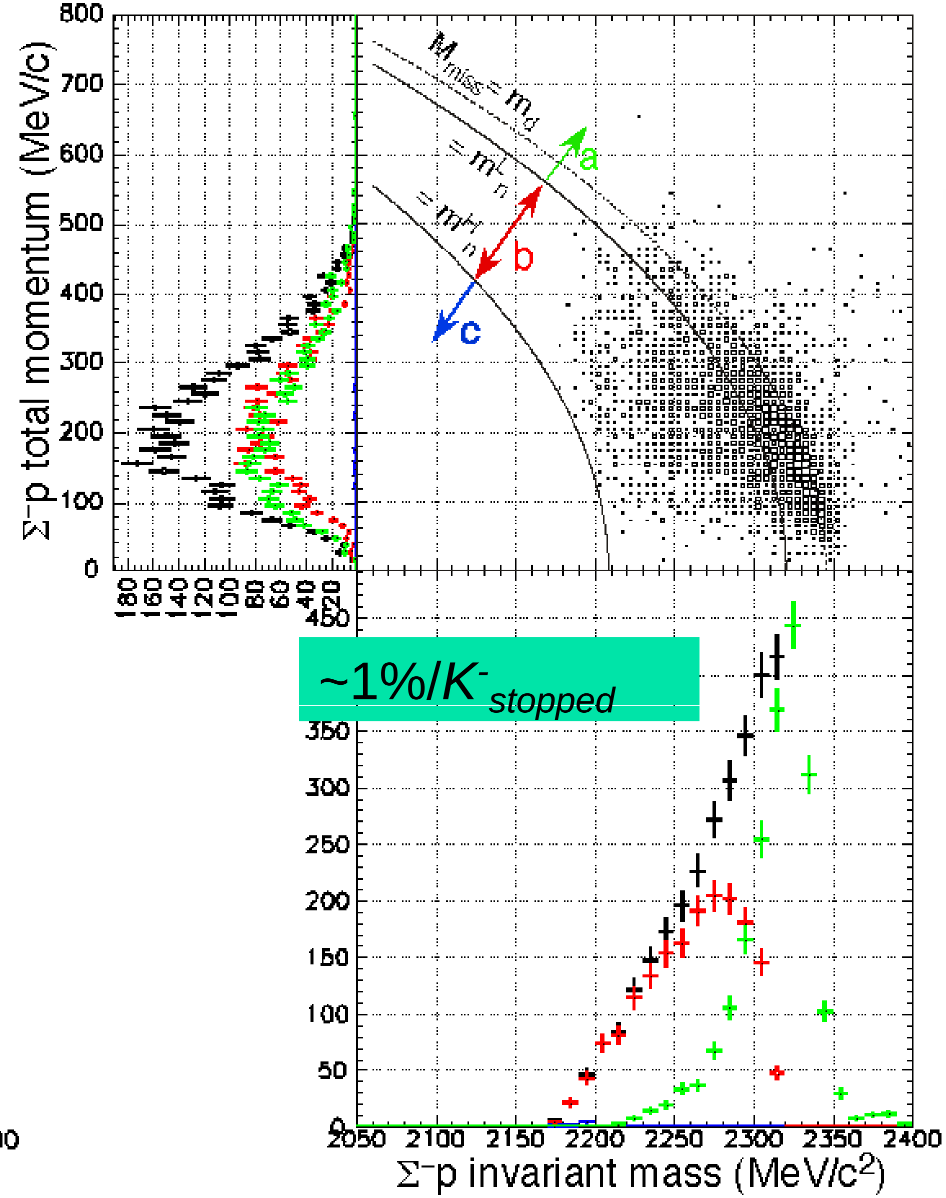
4. $^3S^+$ tribaryon production and its Λpn decay

$K^-_{stopped} + {}^4He \rightarrow {}^3S^+ + n$

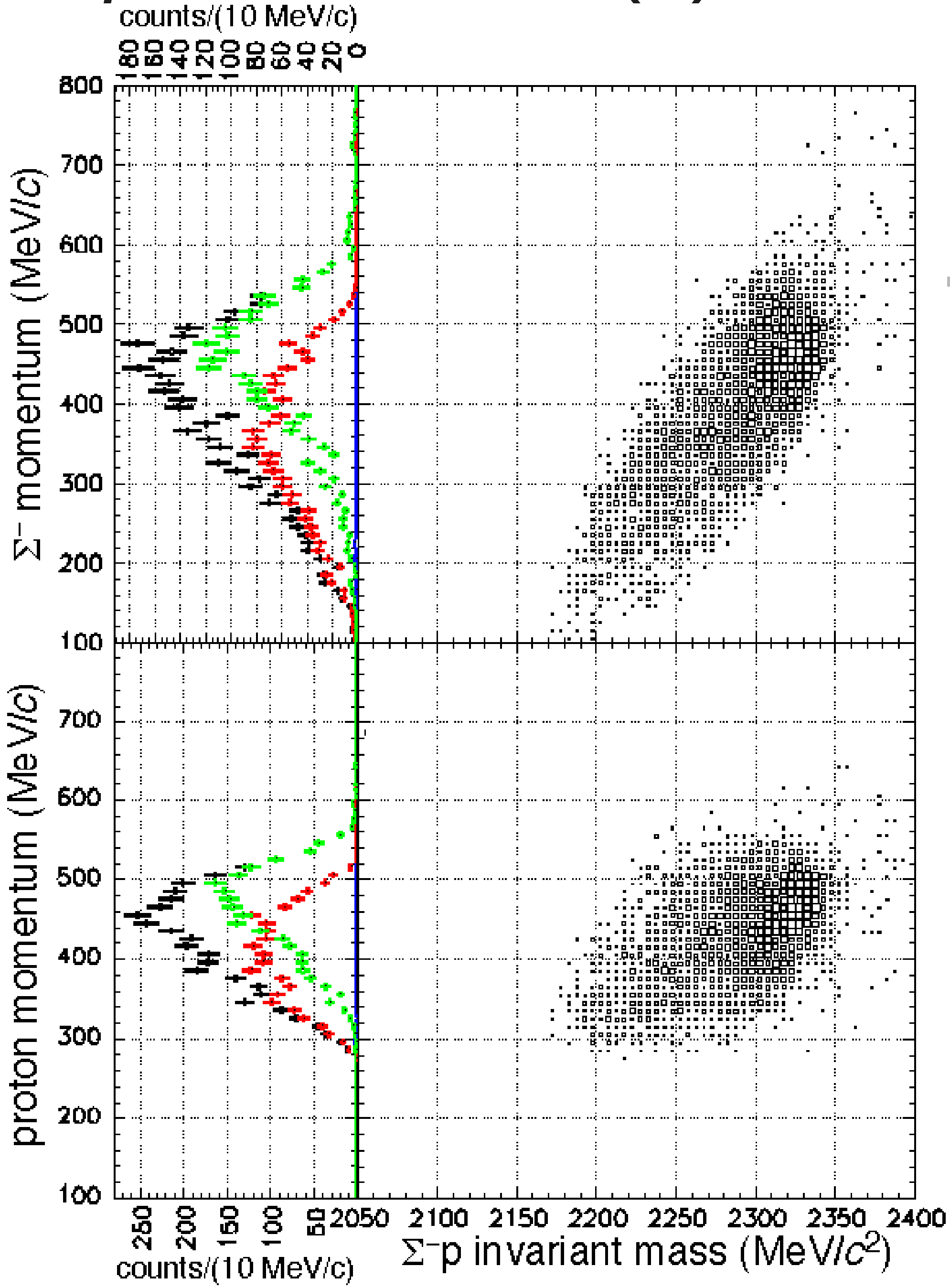
${}^3S^+ \rightarrow \Lambda + p + n$

$\Sigma^- p$ correlations (1)





$\Sigma^- p$ correlations (2)



2NA: ~1 % out of 3.6 +- 0.9 % of Σ^-ppn/Σ^-pd final state

Σ^- momentum distribution for non-2NA component is ***never explained by elastic re-scattering!!!***

$K^-_{stopped} + {}^4He$

$\rightarrow {}^2S^0_{T=1/2} (K^- [pn]_{I=0,S=1}) + p + n$

${}^2S^0_{T=1/2} \rightarrow \Sigma^- + p$

$\rightarrow {}^3S^0_{T=1} + p$

${}^3S^0_{T=1} \rightarrow \Sigma^- + pn/d$

Conclusions and prospects

1. The 2NA process accounts for ***only ~30%*** of non-mesonic Λ branch.

2. The K^- [*pp*] $_{I=1,S=0}$ hypothesis of Λp spectrum (FINUDA interpretation) is ***disfavored*** by observed spin-isospin property of the 2NA process at 0-energy.

3. The remaining ~70% could include the signal of non-mesonic decay of strange multibaryons.

4. Σp correlations suggest $^2S^0_{T=1/2}/^3S^0_{T=1}$ more strongly.

5. All suggested multibaryons have large width or as continuum.

6. Whole spectrum shapes will be examined after acceptance correction (now going on), to discuss the central masses.

7. The (K^-,N) experiments with A=3/4 targets (cf. J-PARC E15-> ***Dr Sakuma's talk***), by which Λ/Σ channels are ***exclusively*** studied in wide angular/momentum range, are awaited at J-PARC K1.8BR/K1.1.