Search for strange tribaryon states in the ^{4}He(stopped K^-, p) reaction

RIKEN

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for KEK-PS E549 collaboration

KEK-PS E549 collaboration

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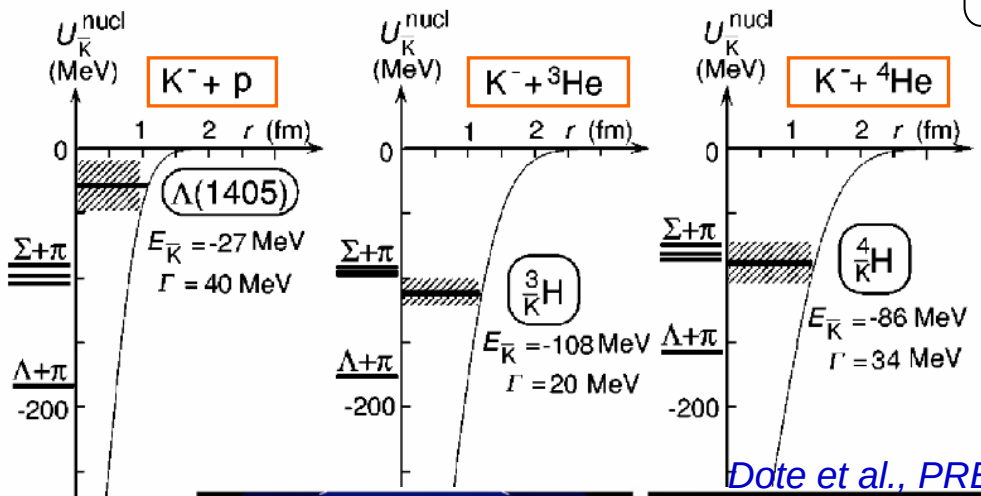
Embedding K⁻ in nuclei?

- $\bar{K}N$ potential by Akaishi & Yamazaki
  assuming $\Lambda(1405)$ to be a $K^- p$ bound state

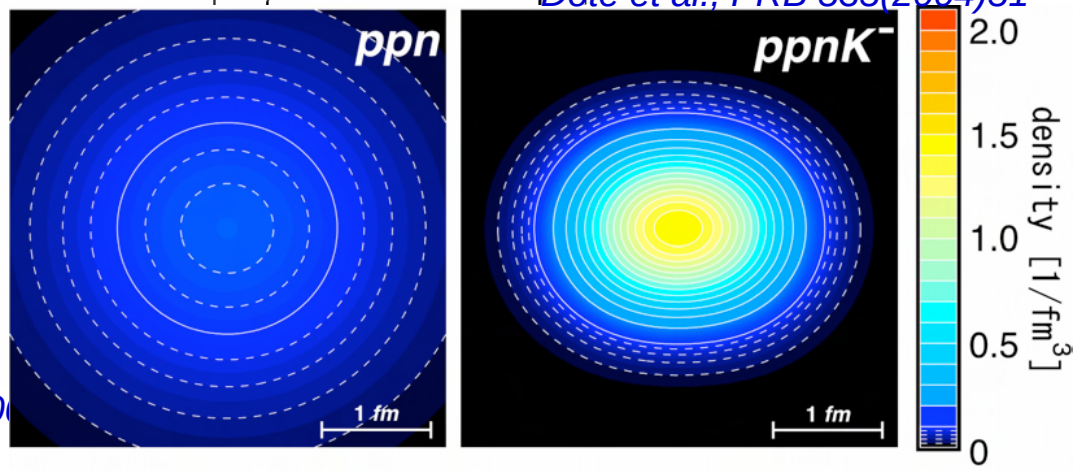
- mass & width of $\Lambda(1405)$
- kaonic hydrogen $2p \rightarrow 1s$ level shift
- KN scattering data

Strong attraction of $\bar{K}N$ I=0



Dote et al., PRC 65(20

Dote et al., PRB 535(2004)51



- Deep
  B. E. ~100 MeV
- Narrow
  Γ ~20 MeV
- Shrink
  High density?
  ~3 ρ_0

KEK-PS E471 results

✓ **Search ofr deeply-bound kaonic nuclear states**

Y. Akaishi & T. Yamazaki : PRC 65 (2002) 044005

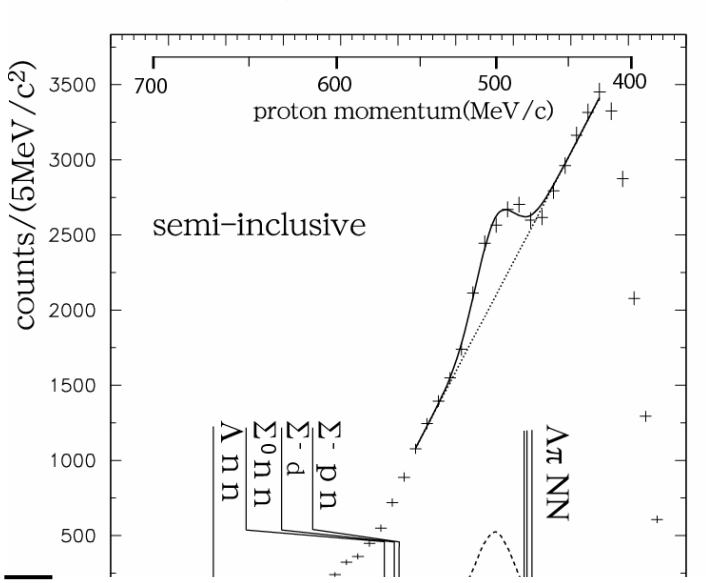
KEK-PS E471 experiment:

^{4}He(stopped K^-, p) : $S^0(3115)$ (B=3, S=-1, T=1)

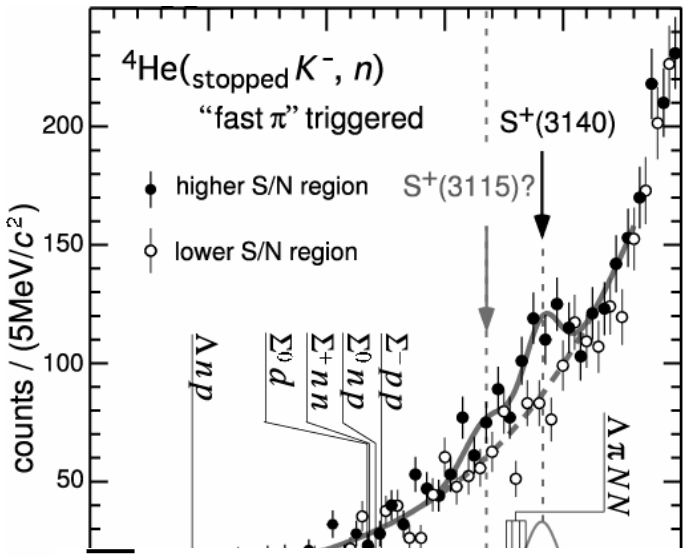
T. Suzuki *et al*: PLB 597 (2004) 263

^{4}He(stopped K^-, n) : $S^+(3140)$ (B=3, S=-1, T=0)

arXiv:nucl-ex 0310018 (Insufficient statistics)



KNNN **(Z=0, B=3, I, I_Z>=1,-1>)?**



KNNN **(Z=1, B=3, I, I_Z>=0,0>)?**

Present experiment

Objective of inclusive proton spectroscopy in KEK-PS E549

Search for strange tribaryon states in the ^{4}He (*stopped* K^-, *p*) *reaction*

$$K^-_{stopped} + {}^4\mathrm{He} \rightarrow S^0_{T=1} + p$$
$$(\overline{KNNN}^{I=1,-1})$$

Improved resolution / higher statistics than those of E471

resolution x2 statistics x 20

- *Confirmation / study of* $S^0(3115)$ *E471*

  natural width of $S^0(3115)$ *:* $\Gamma < 21$ MeV

  precise formation branching ratio ~ 1 %/*stopped* K^-

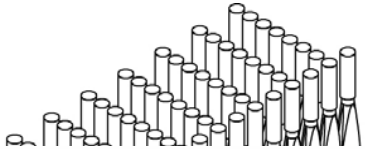
- *Search for other candidates of strange tribaryon states*

  Proton momentum acceptance enlarged

  Excited states of $S^0(3115)$*?*

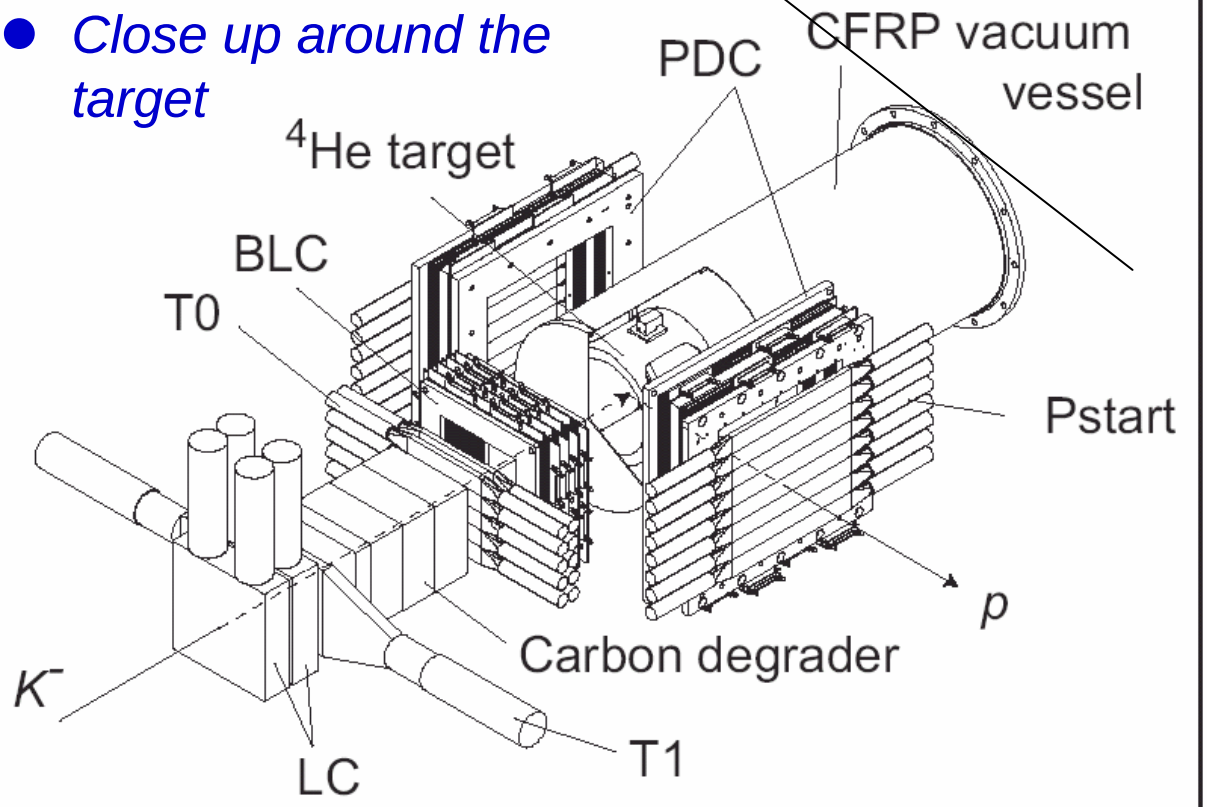
Experiment setup

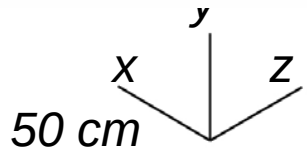
@KEK 12GeV PS K5 beam line



TOF stop

- *Close up around the target*





π^- / K- ratio : ~ 200
# of stopped K- : 1.0 x 10^8

BLC : beam tracking
T0 : beam timing

proton detection: (L & R arm)

TOF wall :
path ~1.6 m for p

Drift chamber

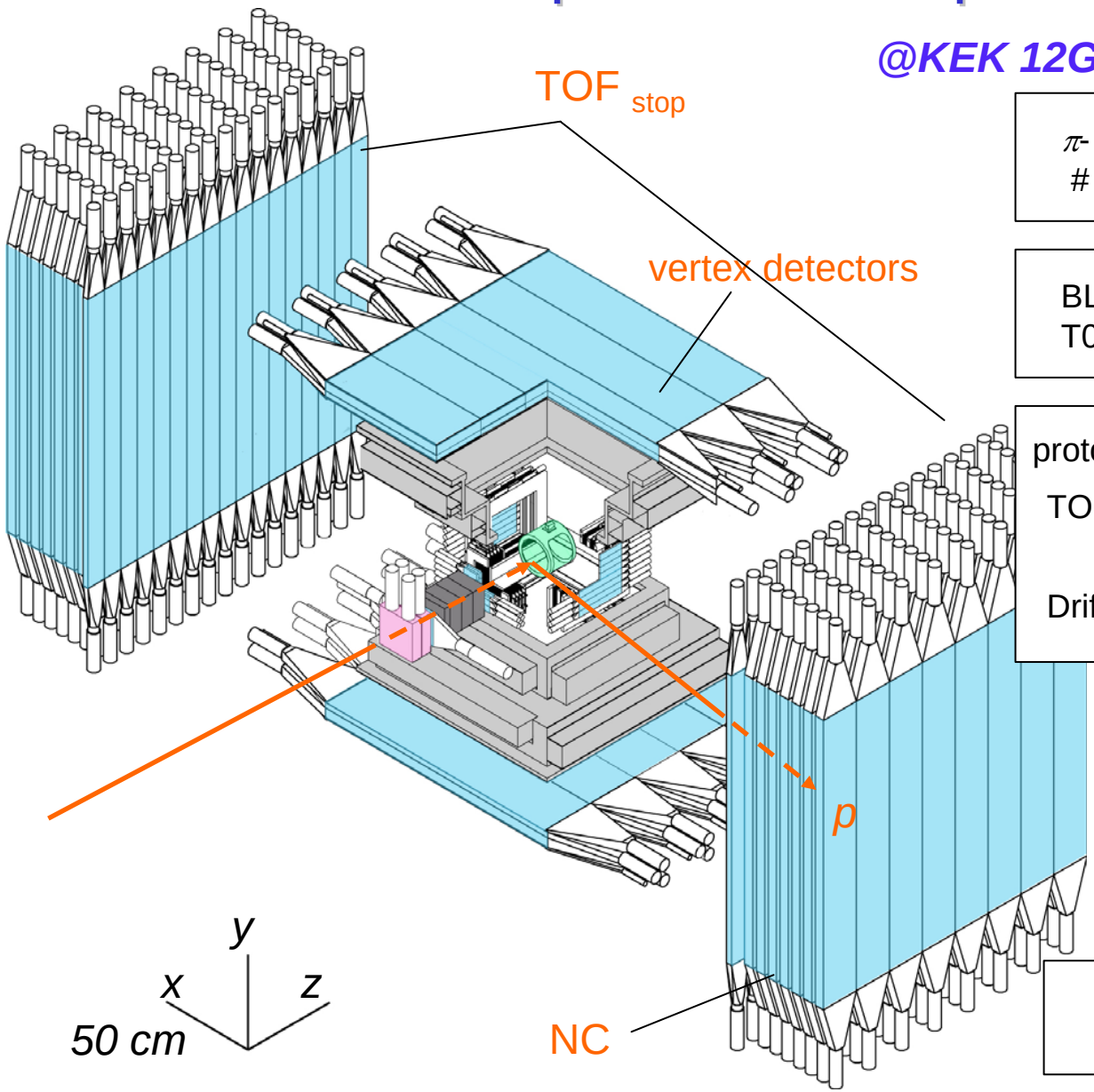
Vertex detectors
Drift chamber (VDC) +
Scinti. Counters (TC)

NC

Trigger : (*inclusive*)
(K) x (TOF counters)

Experiment setup

@KEK 12GeV PS K5 beam line



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Trigger : (*inclusive*)
(K) x (TOF counters)

Data Analysis

Detector performance

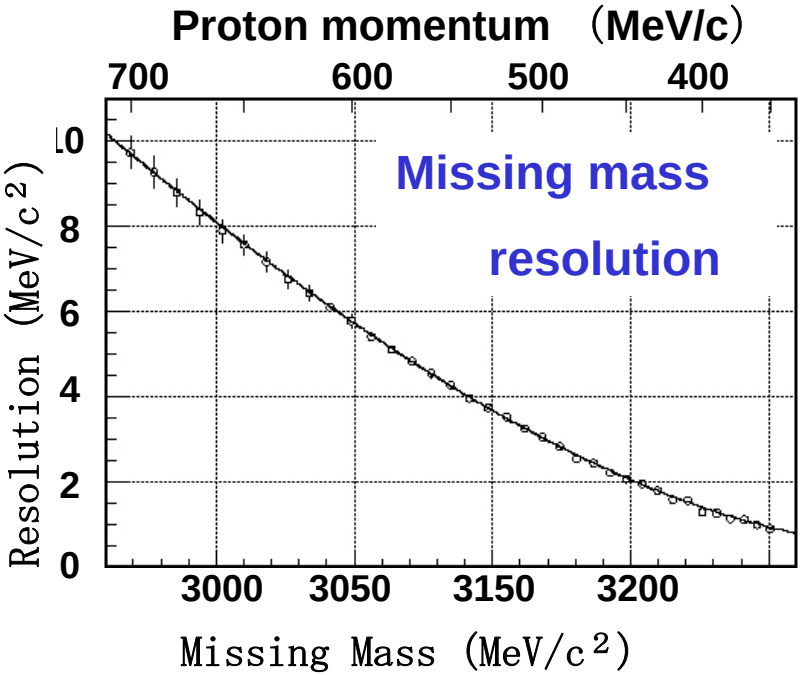
- ✓ **Check of TOF resolution:**
  long-lived metastable state of kaonic helium-4 atom (τ_{meta} ~ 59 ns)

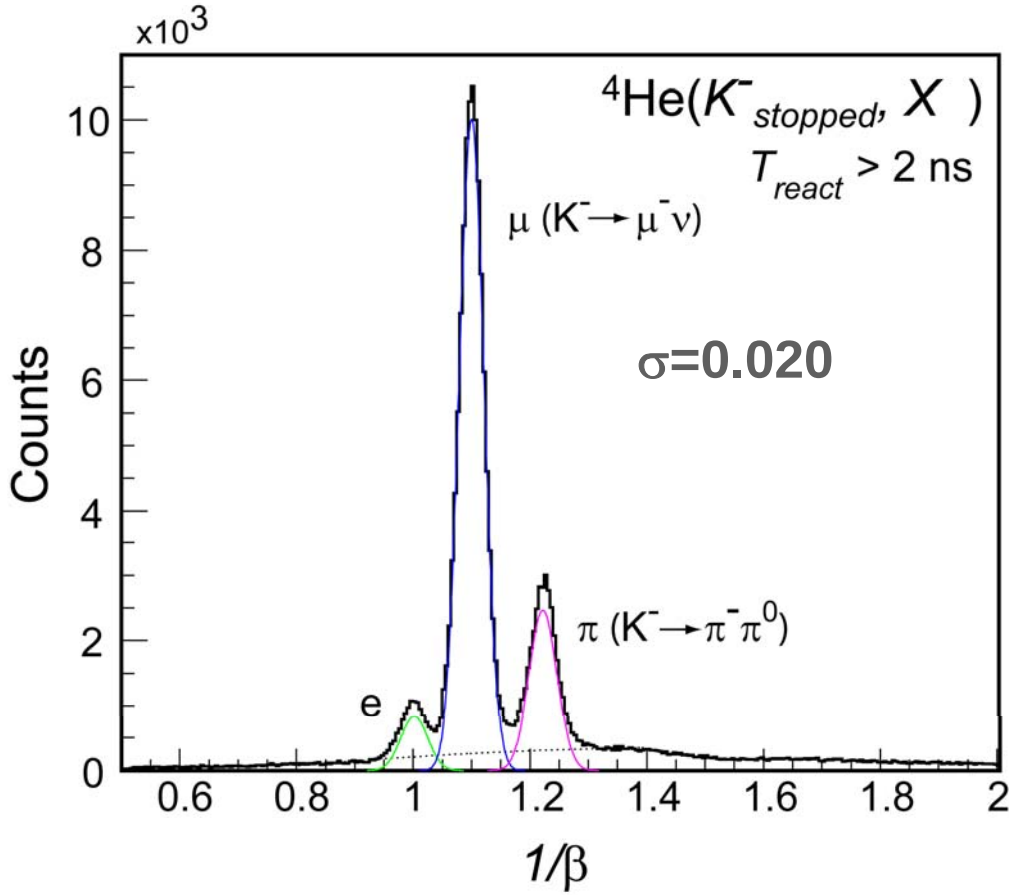
(T. Yamazaki et al., PRL 63(1989) 1590)

a few % of stopped K^- *on* ^{4}He

→ *free decay*

- ✓ **Delayed timing selection ($\tau_K >> \tau_Y$)**



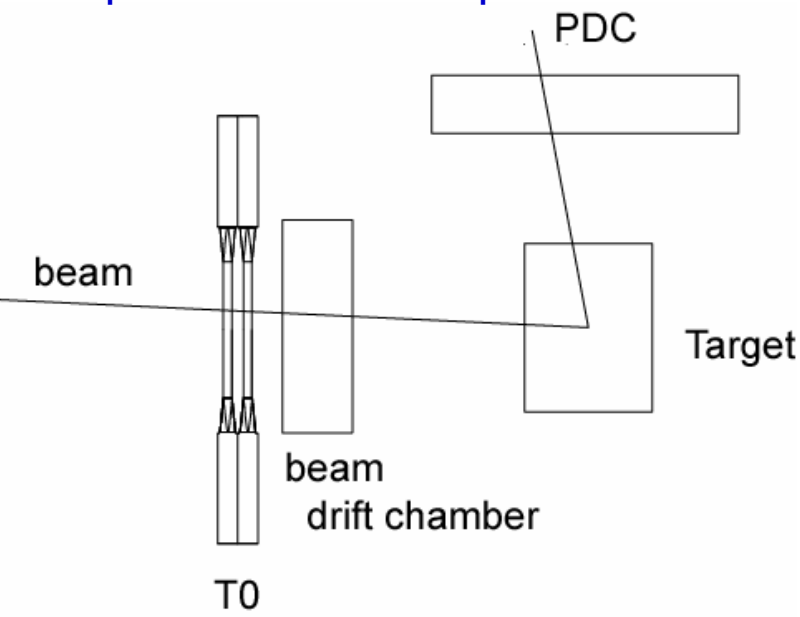


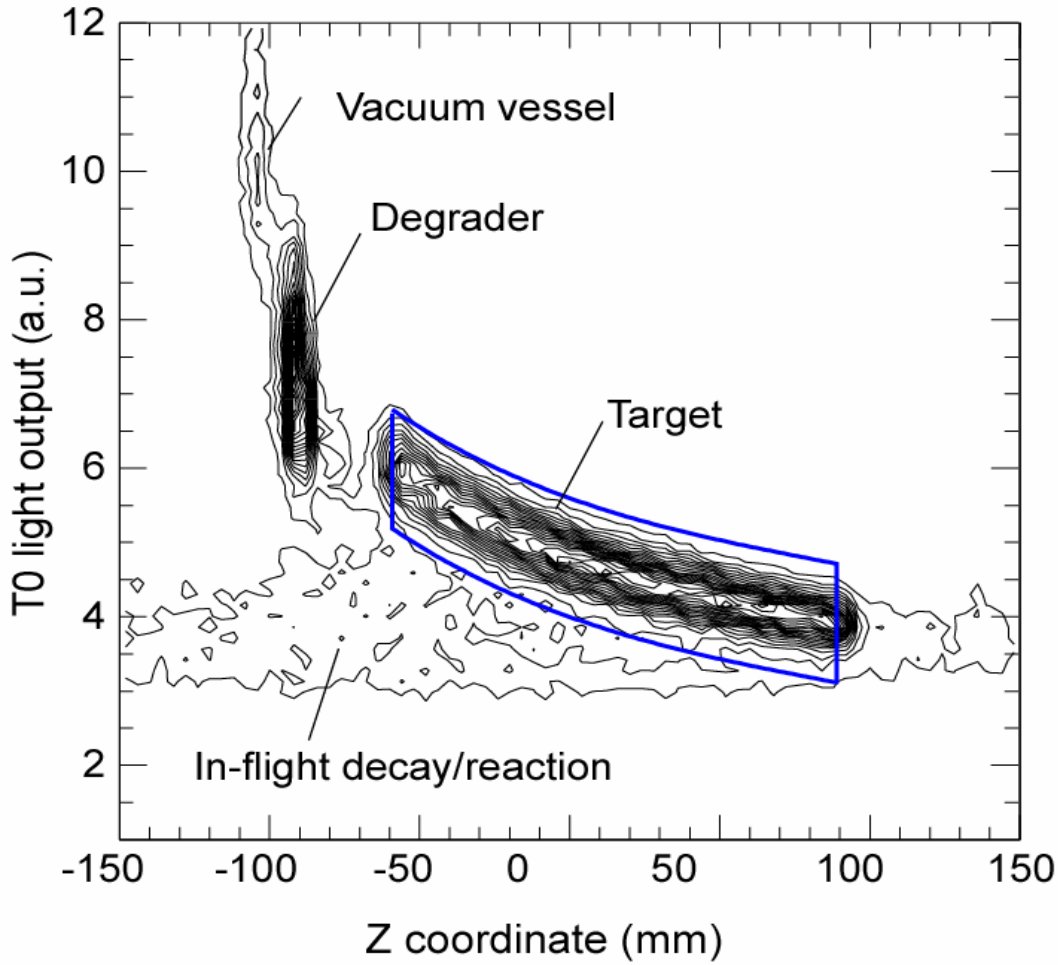
Stopped K^- selection

- *stopped* K^- : T0 light output VS Z (beam axis) reaction vertex

  to reject in-flight reaction/decay events inside ^{4}He

Top view of the setup





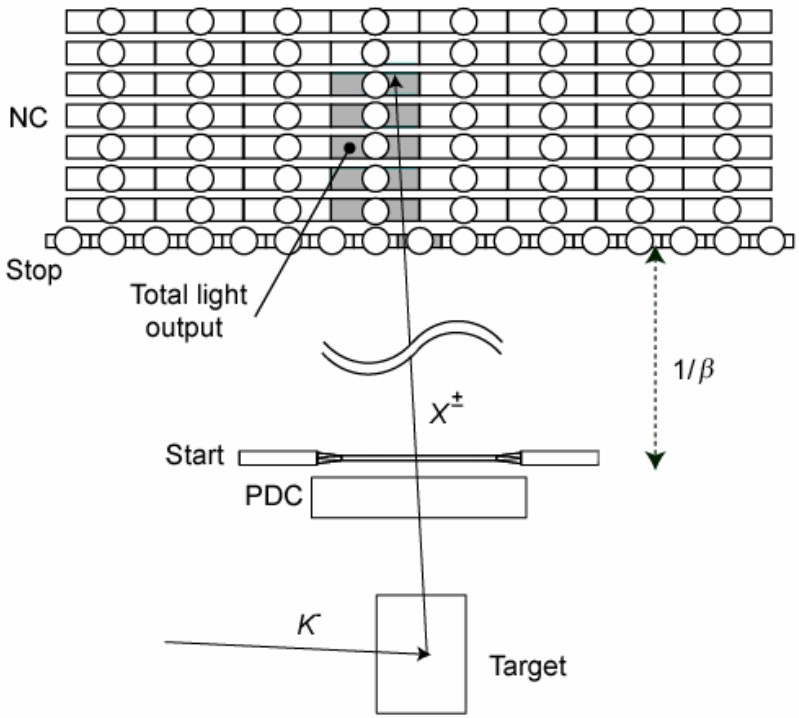
Clear stopped/ in-flight separation

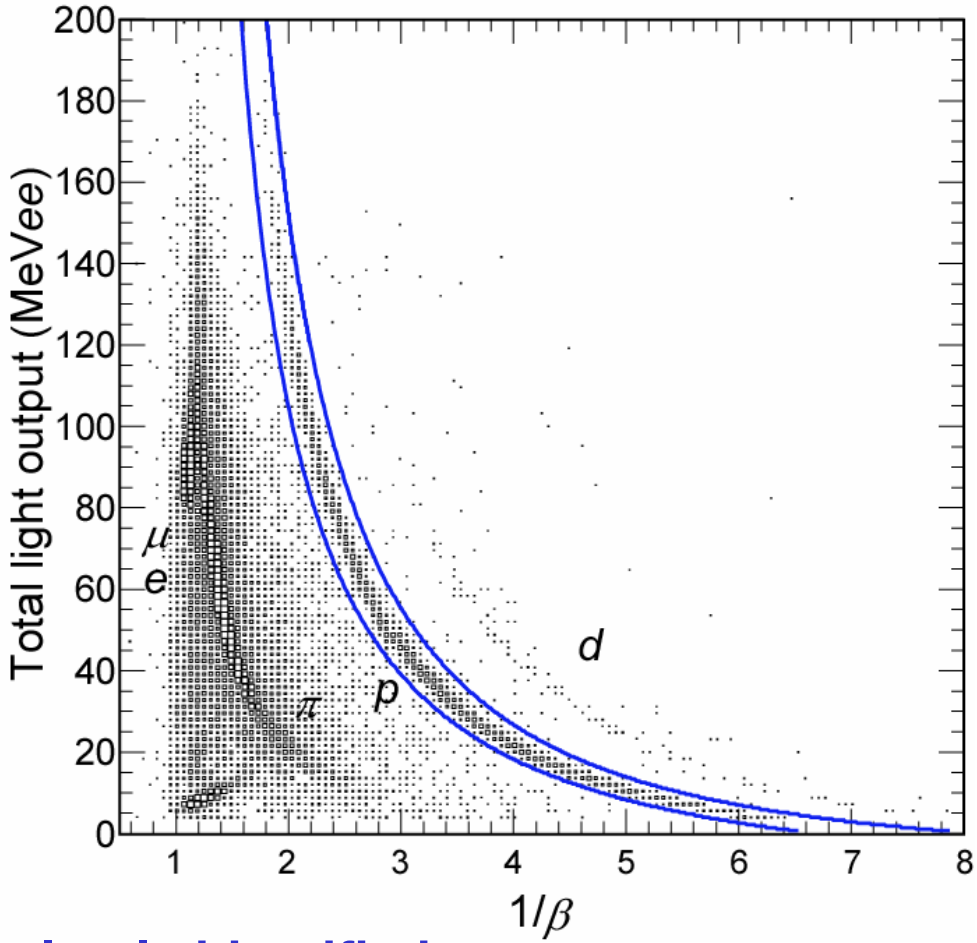
Proton identification

Particle identification from ^{4}He (stopped K^-, $X^{\pm}$)

- *Proton* : $1/\beta$ VS Total light output (TOF_{stop} + NC)

Top view of the setup

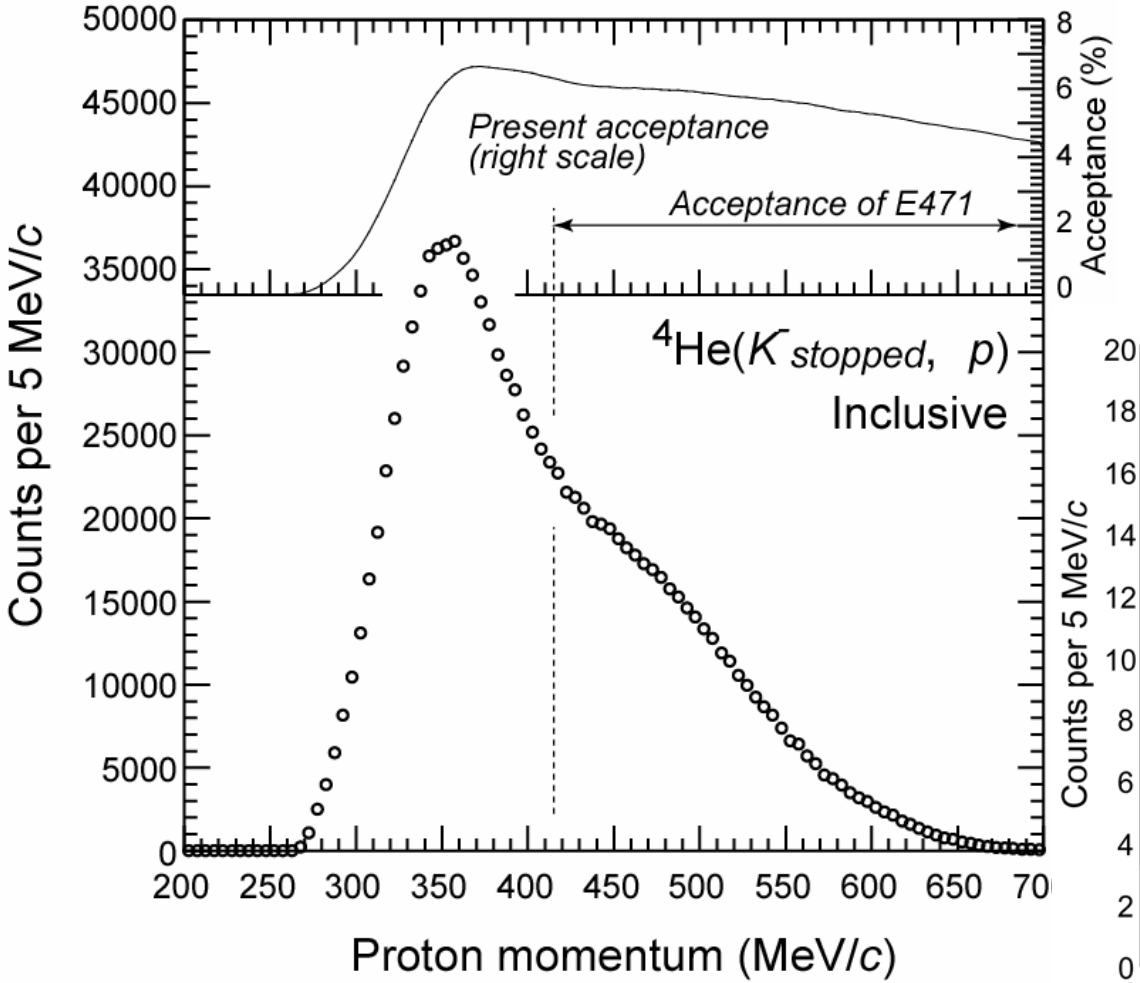




^{4}He(stopped K^-, p) events are clearly identified.

Momentum spectrum

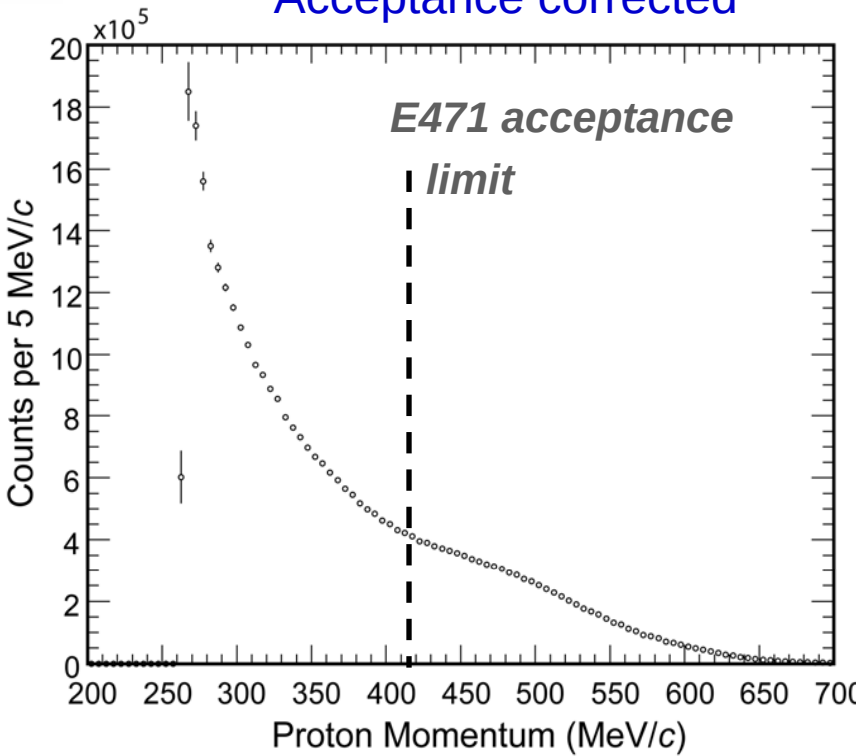
Inclusive proton momentum spectrum by ^{4}He(stopped K^-, p)



Very high statistics

(N_{proton} >1 M)

Acceptance corrected



Missing mass spectrum

Inclusive ^{4}He(stopped K^-, p)

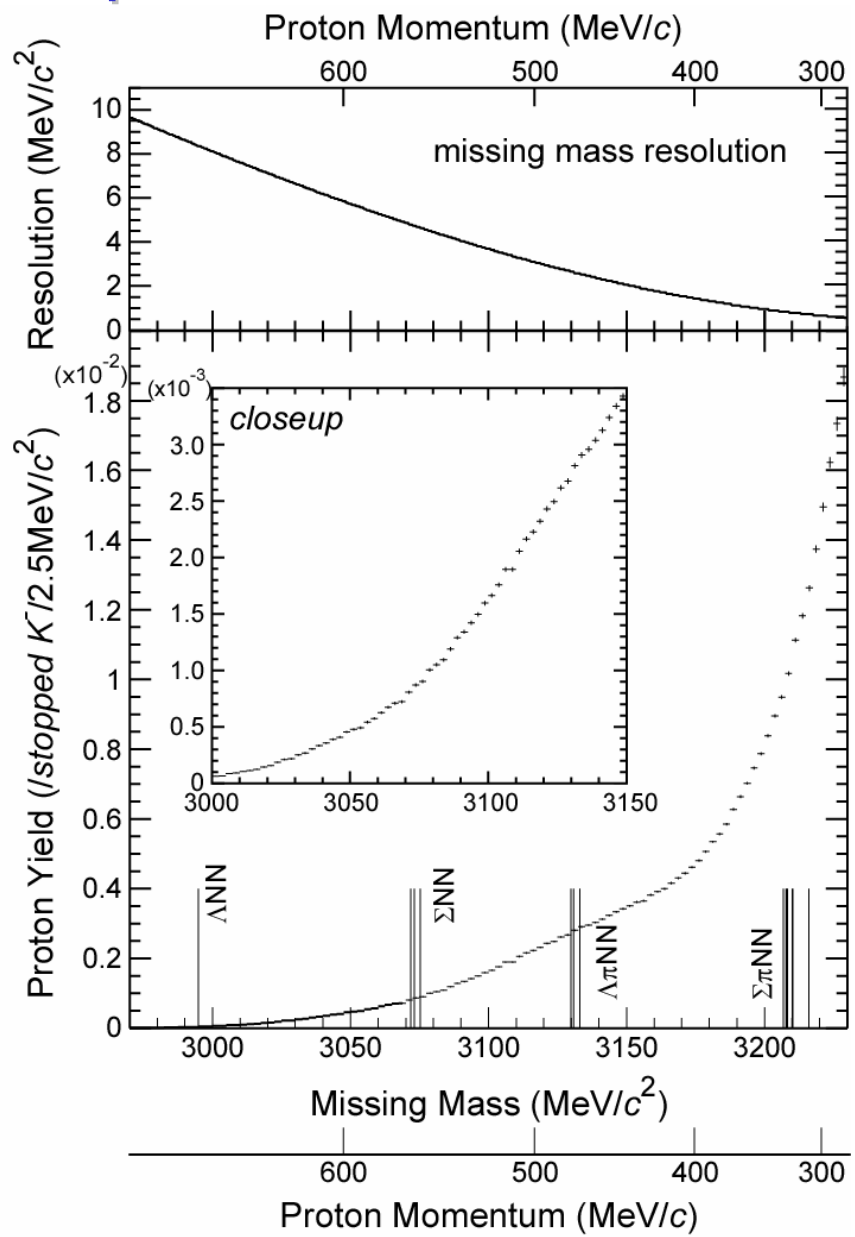
Acceptance corrected

Vertical axis : normalized by # of stopped K-

(σ_{syst} : 14.4 %)

Newly searched : MM > 3160 MeV/c^2

No peak structure was observed.



Coincidence momentum spectra

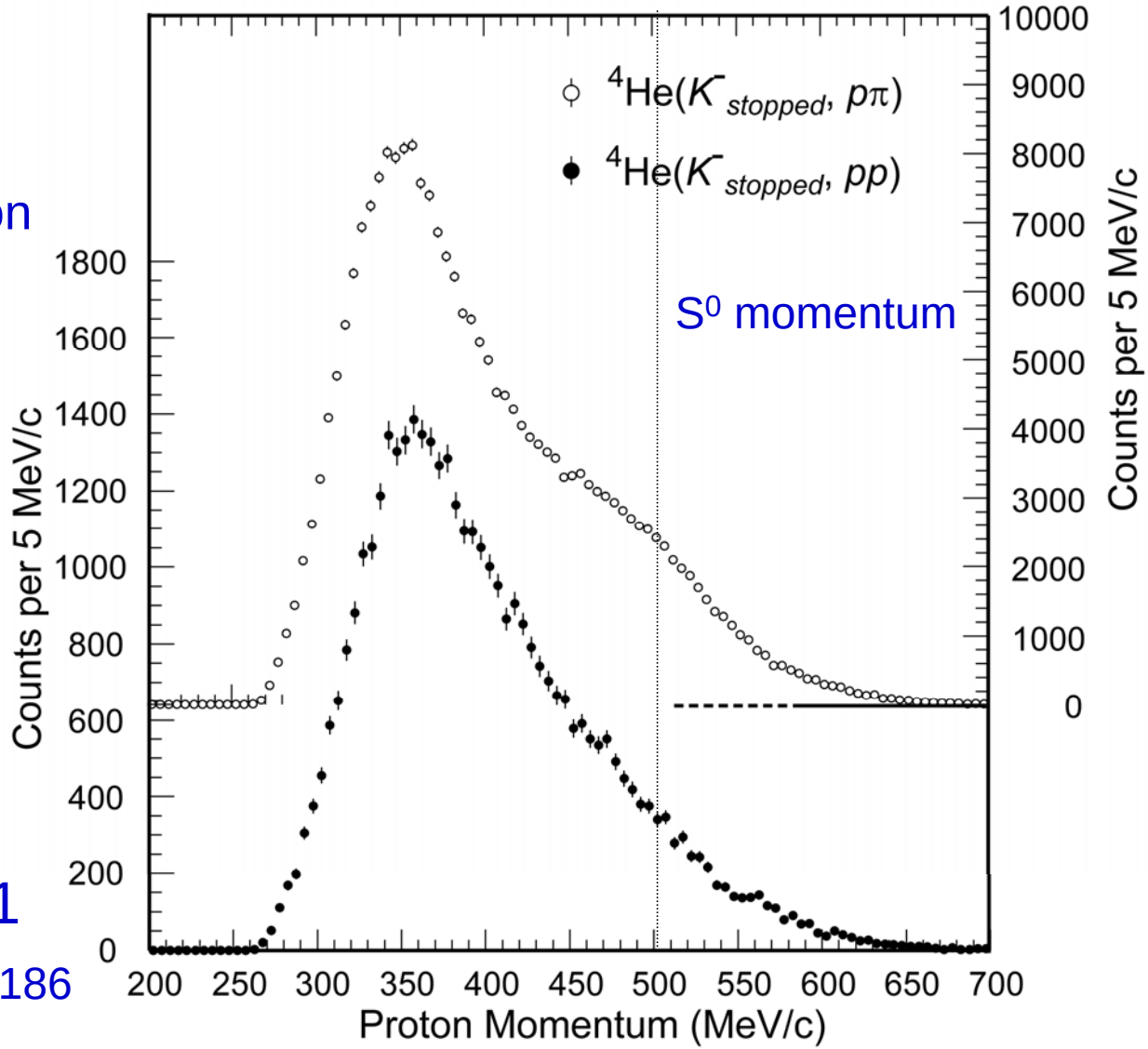
For a direct comparison
with E471

Same triggering condition
^{4}He(stopped K, pX)

No peak
in P_p =300-700MeV/c
(including S^0(3115))

Inconsistent with E471

M. Iwasaki. NPA 804(2008)186



Upper limit for formation branching ratio of strange tribaryon states (1)

Fitting function :

Peak : Voigtian (A, Γ, σ, m) (conbolution of Lorentzian and Gaussian)

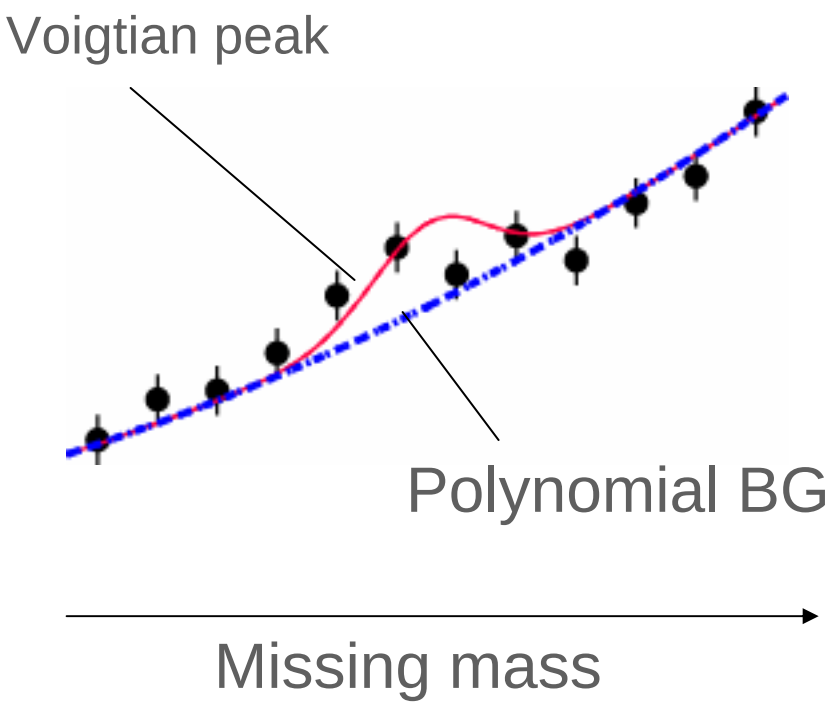
A : peak intensity
σ : experimental resolution
Γ : width
m : center

} fixed

Mass : 3000 –3200 MeV/c2

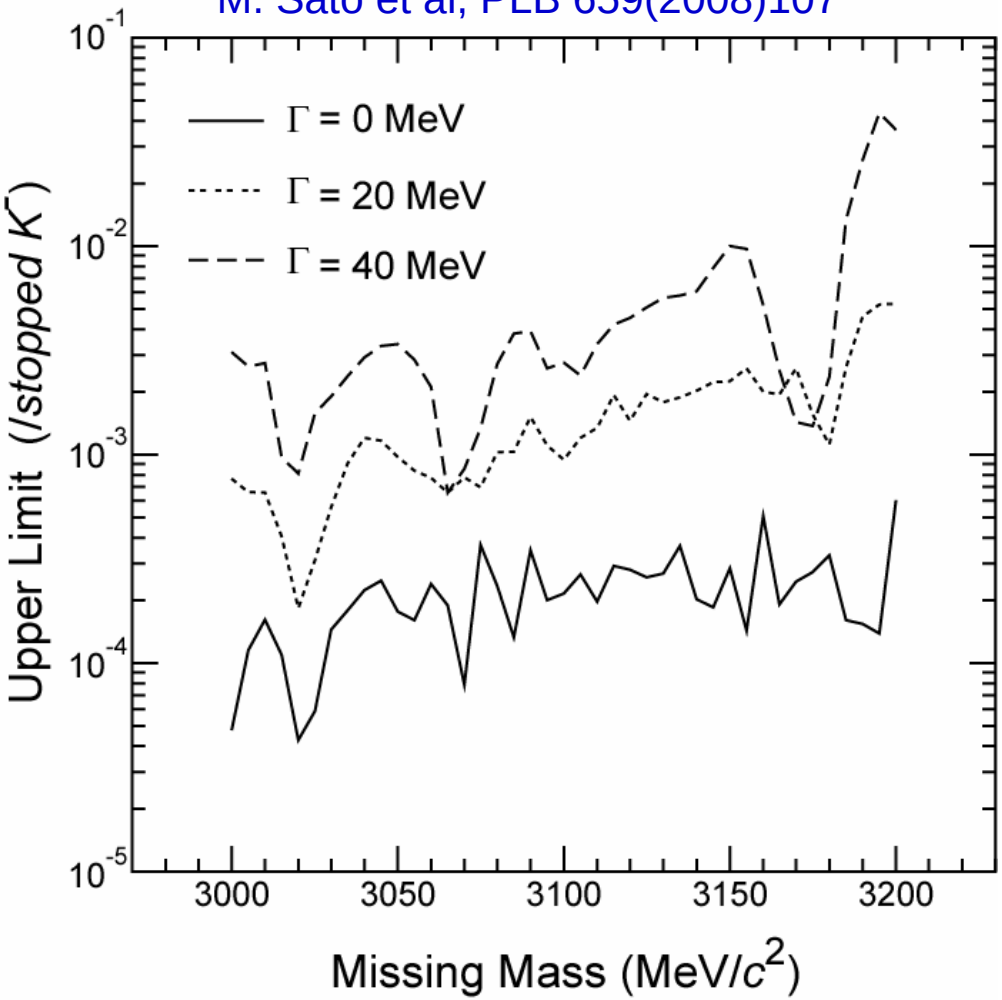
width : 0, 20, 40 MeV/c2

Fit results : A+ δA



Upper limit for formation branching ratio of strange tribaryon states (2)

M. Sato et al, PLB 659(2008)107



Upper limits of formation branching ratio (/stopped K-) w/ 95 % C.L.

Γ = 0 MeV : (0.4 ~ 6) x10^{-4}

Γ = 20 MeV : (0.2 ~ 6) x10^{-3}

Γ = 40 MeV : (0.06 ~ 5) x10^{-2}

Large formation branching ratio (~1 %) was excluded for narrow strange tribaryon states (including $\overline{K}NNN^{I,Iz=1,-1}$).

Conclusion

- An experimental search for strange tribaryon states using the ^{4}He(stopped K^-, p) reaction was performed at KEK.
- Very high statistics by the inclusive spectroscopy
- No narrow structure was observed in the proton missing mass spectrum.
- Upper limits for the formation branching ratio of strange tribaryon states with a narrow width ($\Gamma < 40$ MeV) were derived.

$\Gamma = 0$ MeV : $(0.4 \sim 6) \times 10^{-4}$

$\Gamma = 20$ MeV : $(0.2 \sim 6) \times 10^{-3}$

$\Gamma = 40$ MeV : $(0.06 \sim 5) \times 10^{-2}$

END