Experimental study of *YN* interaction in the neutron rich environment produced via the ^{6}Li(π^{-}, K^{+})X reaction

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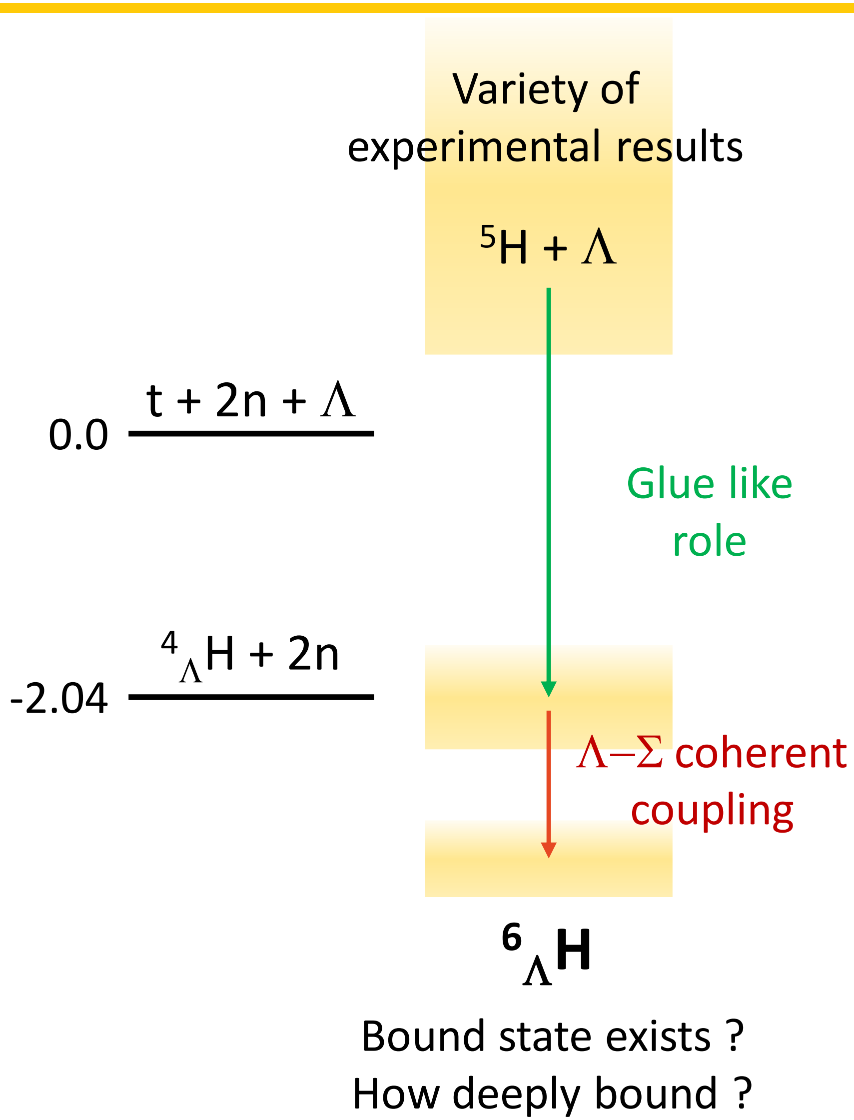
For the J-PARC E10 collaboration.

Outline

- Introduction
- J-PARC E10 experiment
- Latest analysis result
  - Improvement
  - Final spectra
- Discussion
- Summary

Physics motivation



Production of the extremely neutron-rich hypernuclei.

- The glue like role of the Λ particle in nuclei could stabilize the unbound ^{5}H system.
- Leading the understanding of the structure of nuclei, which close to the neutron-drip line.

Λ-Σ coupling in the neutron-excess environment.

- Key to explain the level structure of Λ hypernuclei. Especially, this is quite important in light system.
- The coupling effect is expected to be enhanced in the neutron-excess environment by summed up coherently.

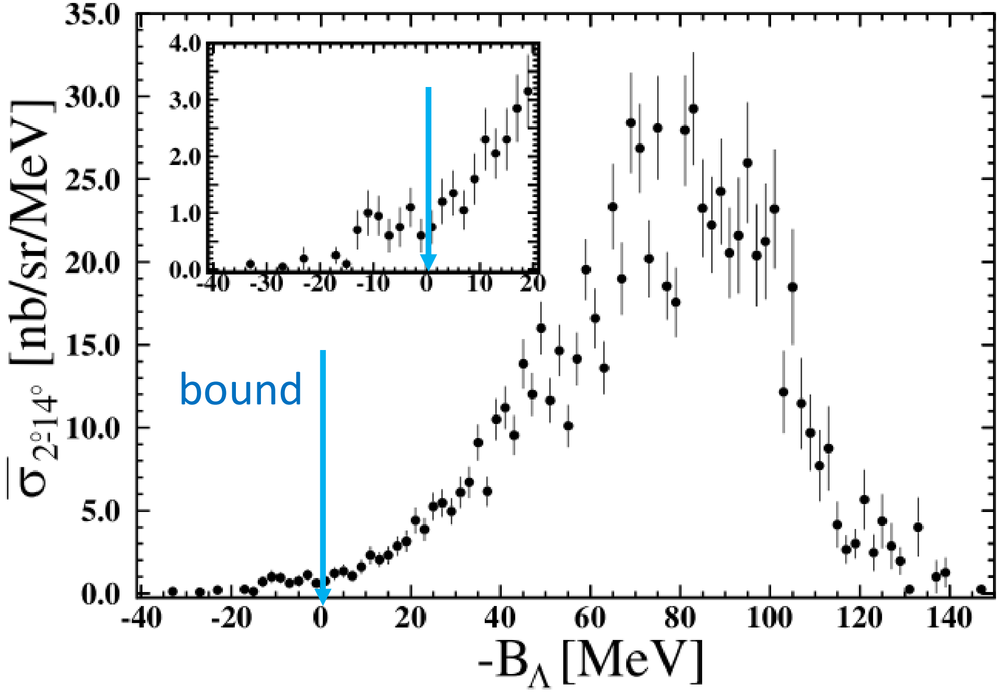
Production via the double-charge exchange reaction

The KEK-PS E521 experiment

$^{10}{}_{\Lambda}$Li production via the ^{10}B(π^-, K^+)X reaction at 1.05 and 1.20 GeV/c.

The (π^-, K^+) reaction is suitable to produce the hypernuclei with quite small cross section because of its back ground free property.

The production of the neutron-rich hypernucleus was observed, but no peak was seen.



Integrated cross section of bound region **11.3 ± 1.9 nb/sr**

[P. K. Saha, et al., PRL 94 (2005) 052502.]

J-PARC E10 experiment

J-PARC E10 Experiment

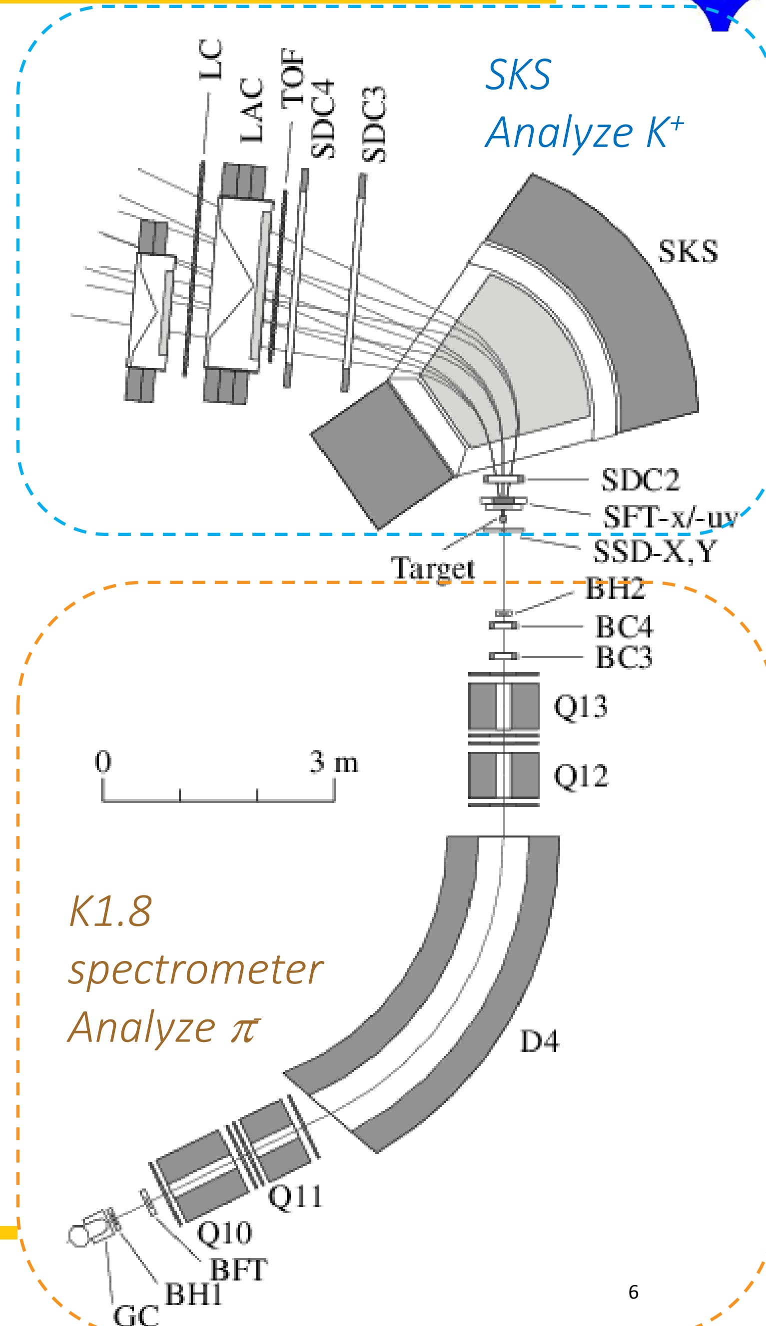
Missing mass spectroscopy at J-PARC K1.8 carried out in 2012 and 2013

The $^{6}Li(\pi^{-}, K^{+})X$ reaction @ 1.2 GeV/c
with ^{6}Li target (3.5 g/cm^2, 95.54% enriched).

Expected production cross section of $^{6}_{\Lambda}H$ hypernucleus.

- Order of nano barn. (From KEK-PS E521)

A large number of pion beams (3×10^{12}) using 10 M/spill beam (spill length = 2 s.)



Data summary

Data	Momentum (GeV/c)	Reaction	Target	Intensity (M pions/spill)	N_{pion}
$^{6}_{\Lambda}$H	1.2	(π^-, K^+)	^{6}Li	12	1.7×10^{12}
$^{12}_{\Lambda}$C	1.2	(π^+, K^+)	graphite	4	5.4×10^{10}
Σ^-	1.37	(π^-, K^+)	polyethylene	10	4.1×10^{10}
Σ^+	1.37	(π^+, K^+)	polyethylene	3.5	3.1×10^{9}
beam through	0.8, 0.9, 1.0, 1.2		none		

[R. Honda, Doctoral thesis.]

Production run

- Finally, the effective number of pions were 1.7×10^{12} in 13 days beam time using 10 - 12 M/spill beam.

$^{12}_{\Lambda}$C production

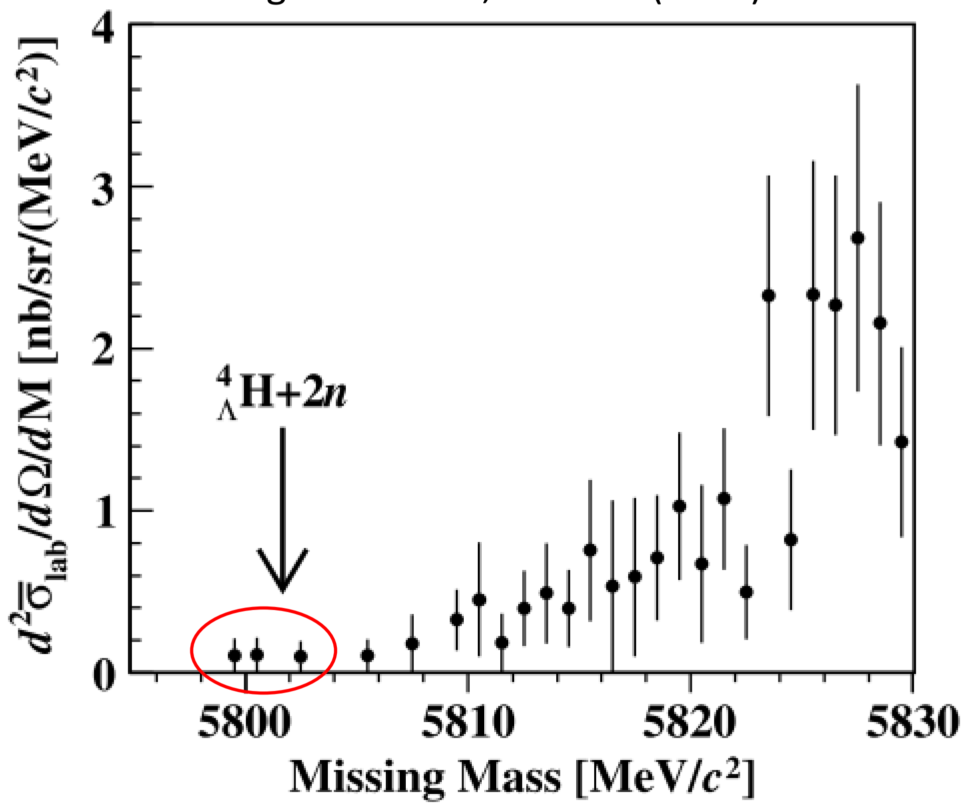
- Estimate missing-mass resolution and the mass uncertainty.

$\Sigma^{+/-}$ production

- Calibrate momentum.
- Confirm validity of our analysis by comparing with the past experimental data.

Last analysis result

H. Sugimura et al., PLB 729 (2014) 39-44



No peak structure.
Only 3 events around the $^4_\Lambda$H + 2n mass threshold.

Upper limit : 1.2 nb/sr (90% C.L.)

It was not concluded that these events were really whether signal or background.

Improvements in the latest analysis.

- Missing mass resolution
  - To set the narrower integral region if events are remained.
- Back ground level
  - To confirm these events are signal or background.

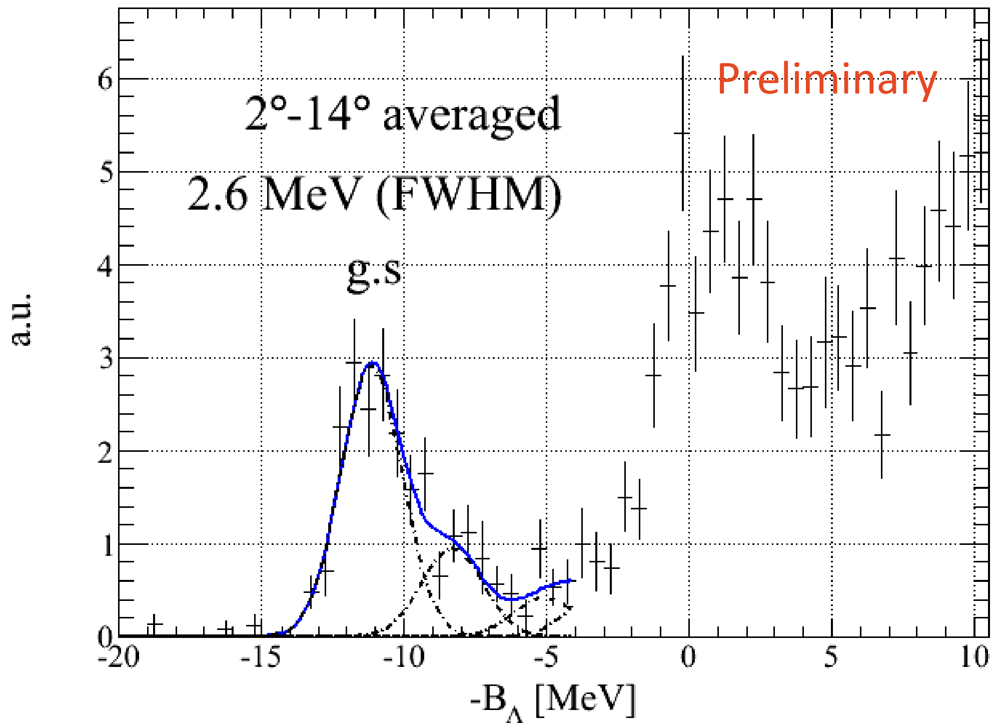
Latest analysis results

${}^{12}_{\Lambda}C/\Sigma^{+/-}$

$^{12}{}_{\Lambda}$C analysis

Reconsidered the momentum correction for each spectrometer to improve the momentum resolution.

$^{12}{}_{\Lambda}$C spectrum with fitting functions



Gaussian fitting result.

Missing mass resolution

- 3.2 MeV (FWHM), (PLB result)

↓

- 2.6 ±0.2 MeV (FWHM), (Present)

$-B_{\Lambda}$ of the ground state

- −11.1 ± 0.2 (stat) MeV (Present)
- (−10.76 MeV, NPA 547(1992), 369c)

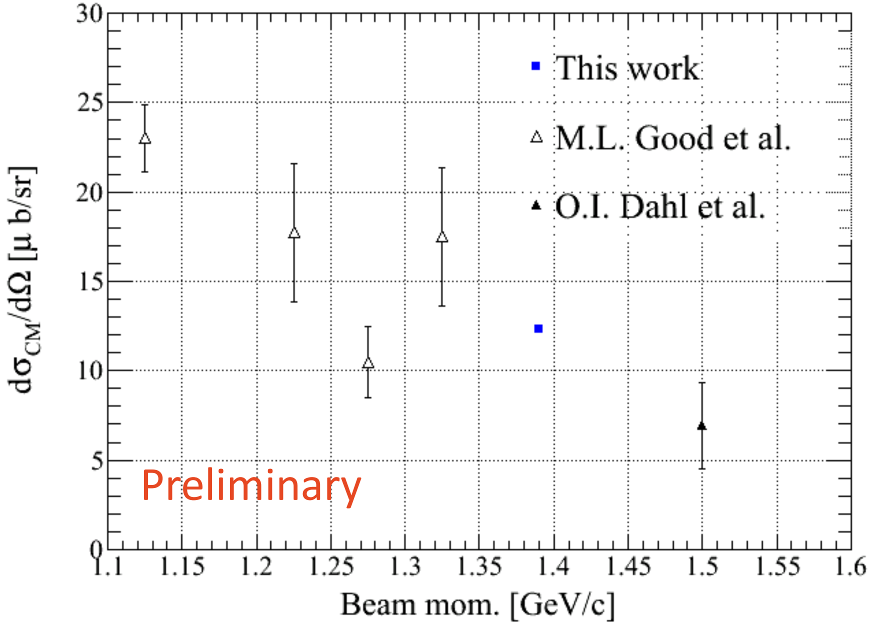
The mass uncertainty

- less than 1.0 MeV

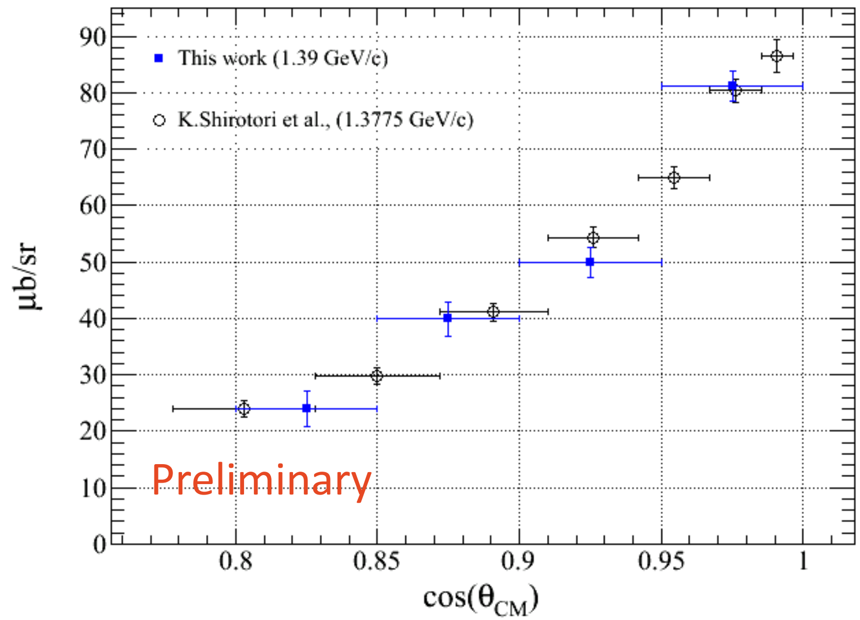
(Including systematic errors)

Σ^-/Σ^+ analysis

Momentum dependence of
Σ^- production (0.8 - 1.0 $\cos(\theta_{CM})$)



Angular distribution of
Σ^+ production (0.8 - 1.0 $\cos(\theta_{CM})$)

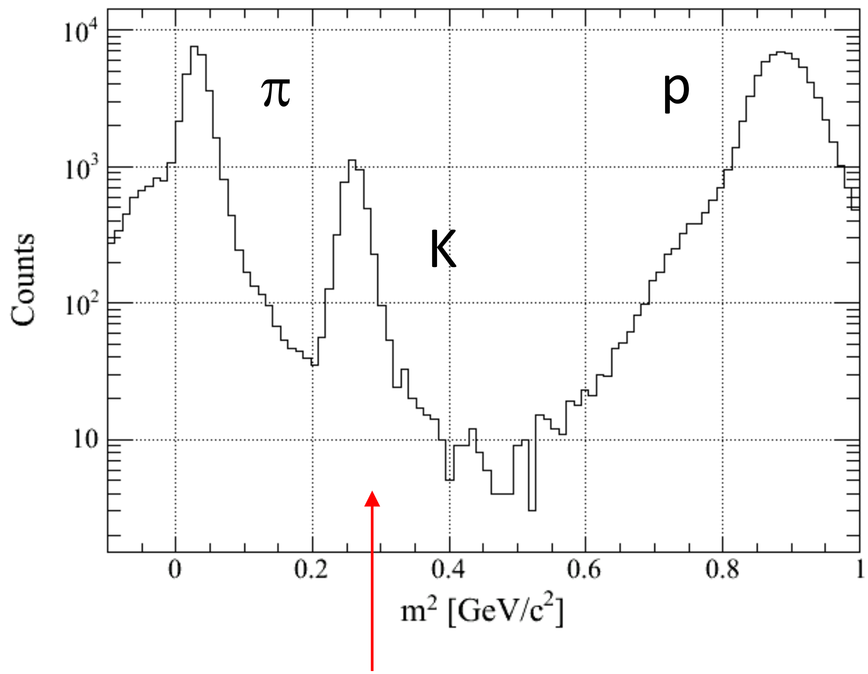


Good agreement with the past experimental data.

Latest analysis results
Background reduction

pion/proton contamination

m^2 distribution in production run



Back ground contamination

Pion/proton contaminate the kaon region **due to wrong timing information of time0 counter** caused by the quite high intensity beam condition.

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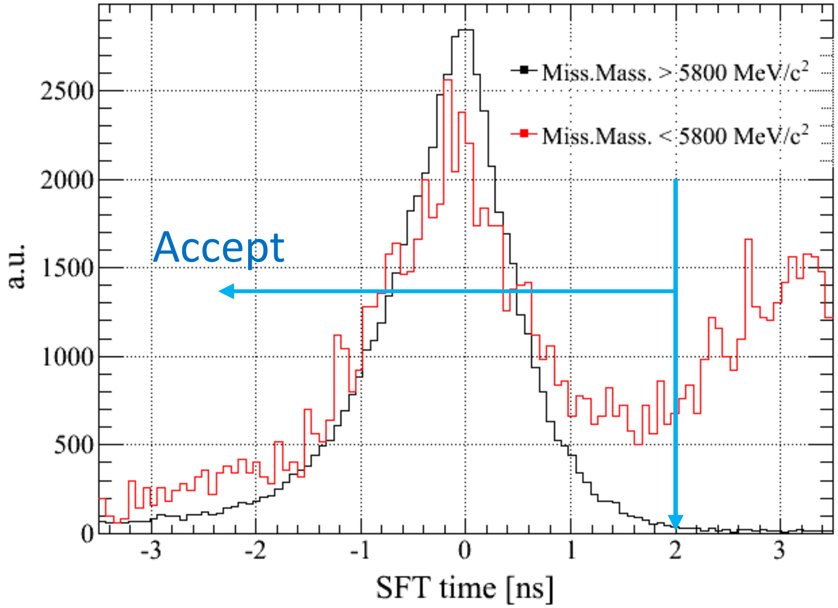
Reduce BG events using other information except for TOF timing information.

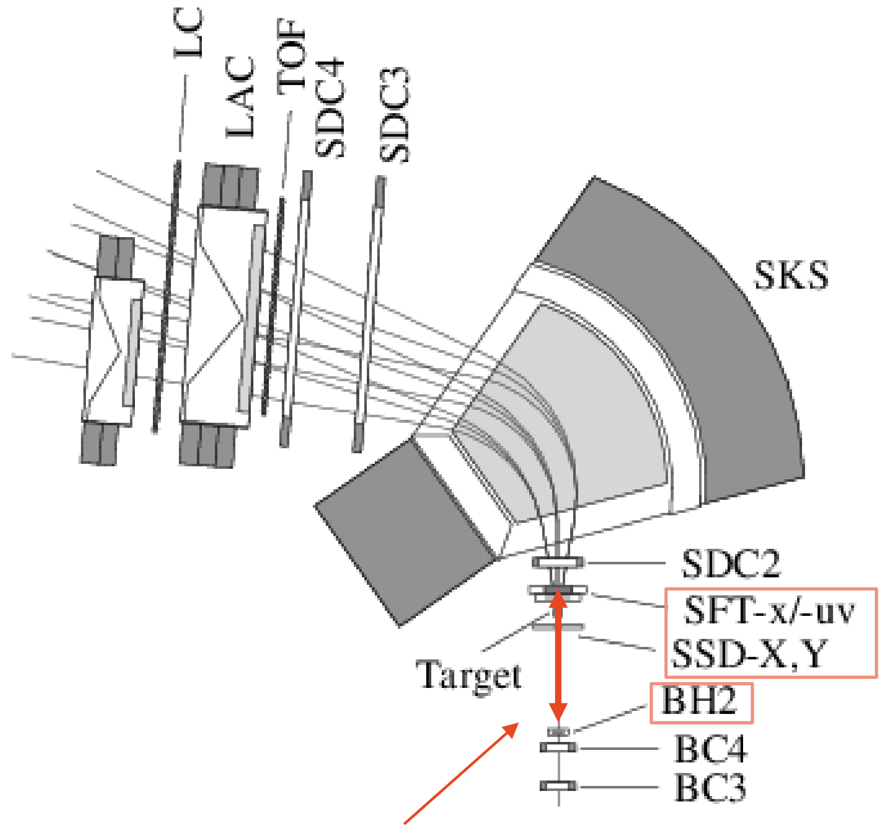
Reduce BG events using fiber tracker

Timing difference between BH2 and SFT



Since this is almost beam TOF between BH2 and SFT, it should make one peak.

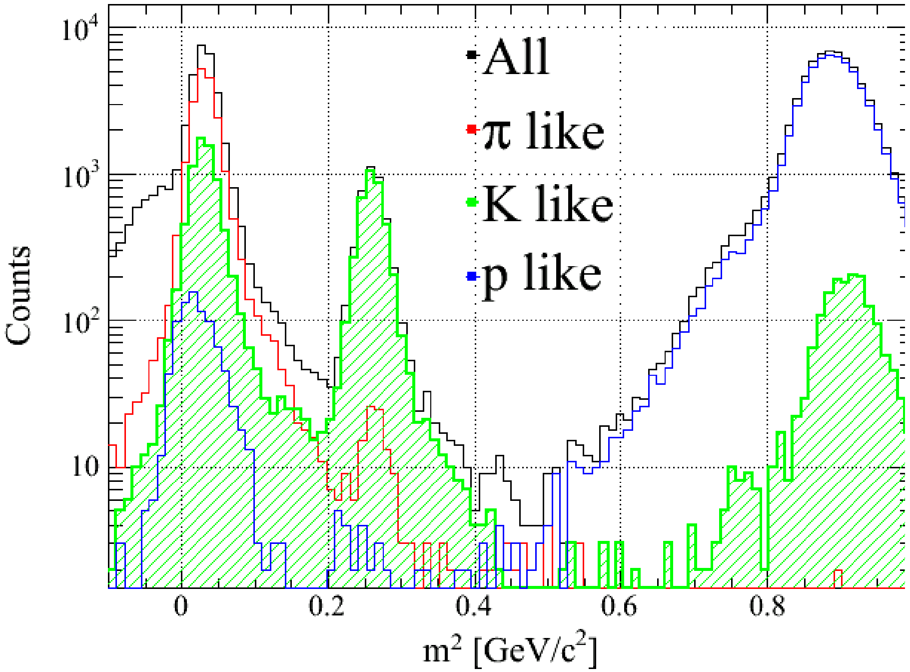
2nd peak over 2 ns was made due to the wrong BH2 timing.



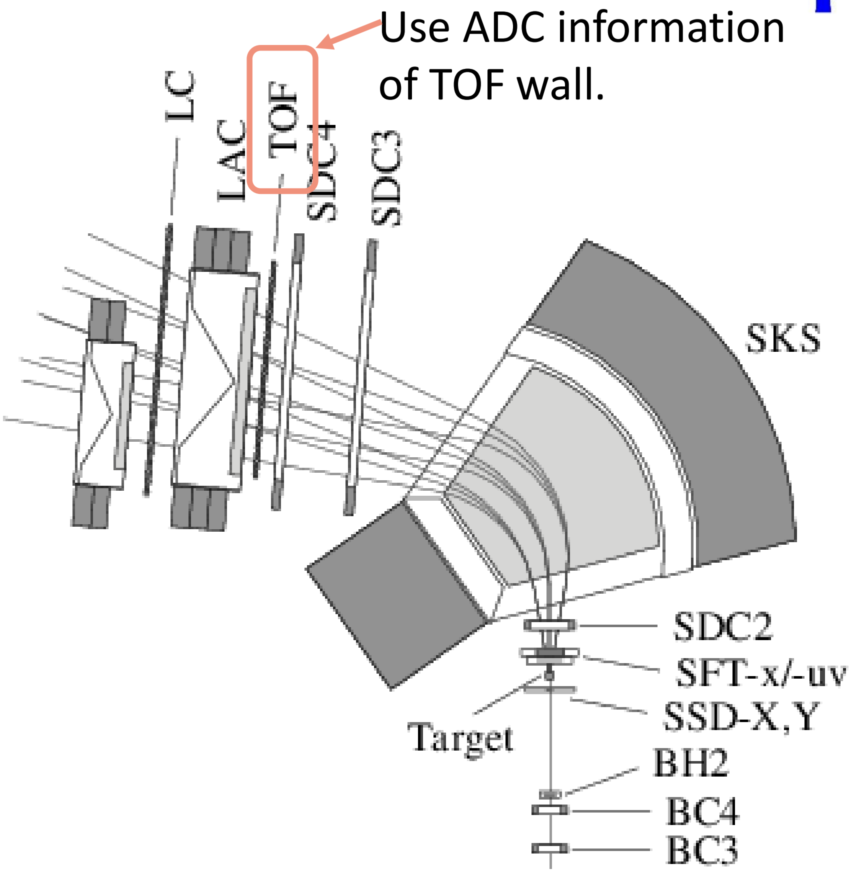
Timing information
between the time0 counter and the fiber tracker.

Reduce BG events using TOF ADC

Particle identification using
TOF ADC information



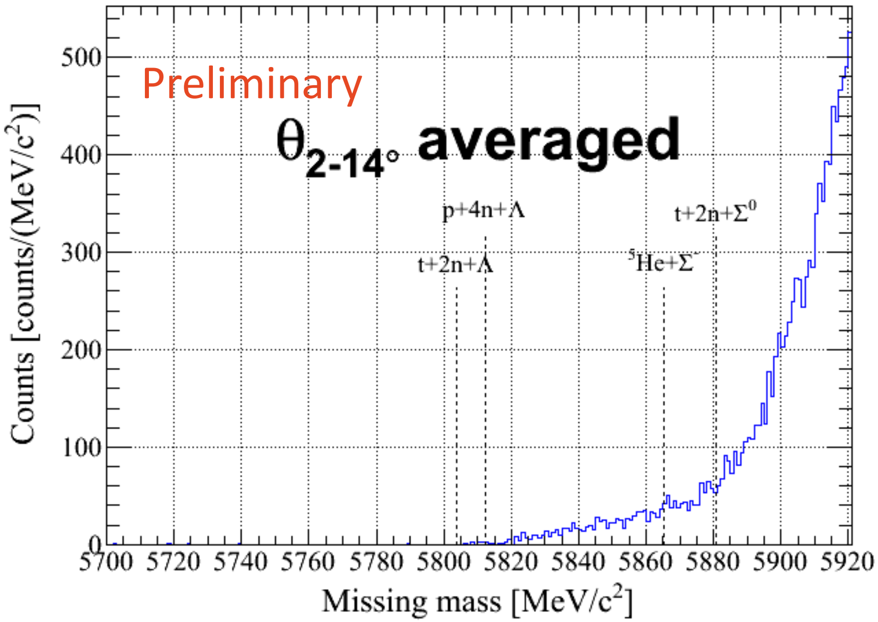
Events except for K like were rejected.



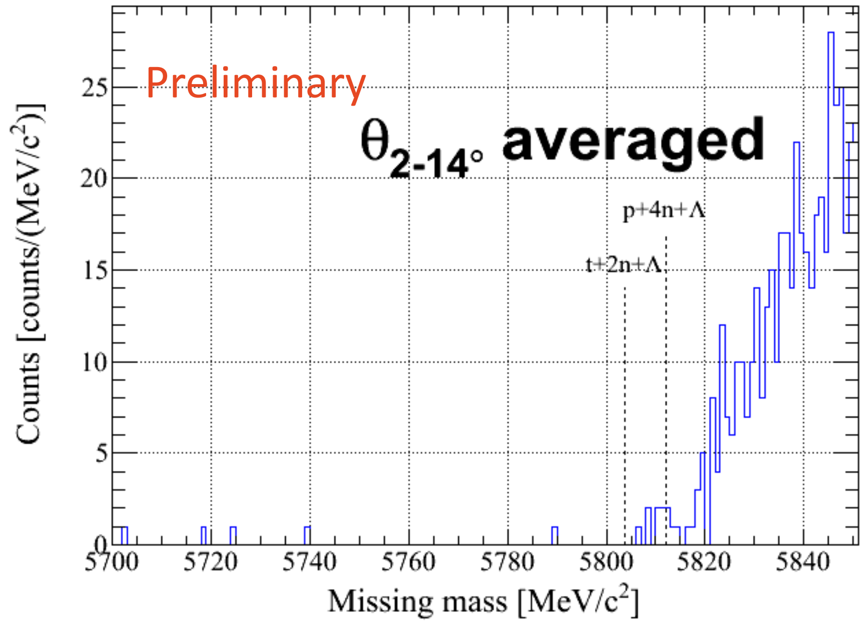
Latest analysis results
Final spectrum

Count base missing-mass spectrum

Count base missing-mass spectrum of ^{6}Li(π^-, K^+)X reaction



Count base missing-mass spectrum of ^{6}Li(π^-, K^+)X reaction (Zoom up)



Back ground level

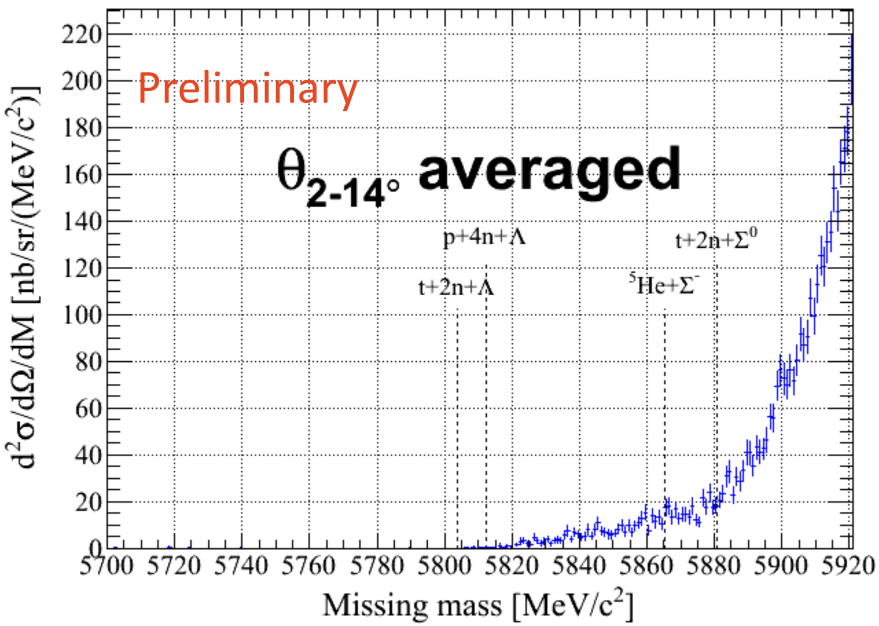
0.39 counts/(MeV/c^2) (PLB result)

↓

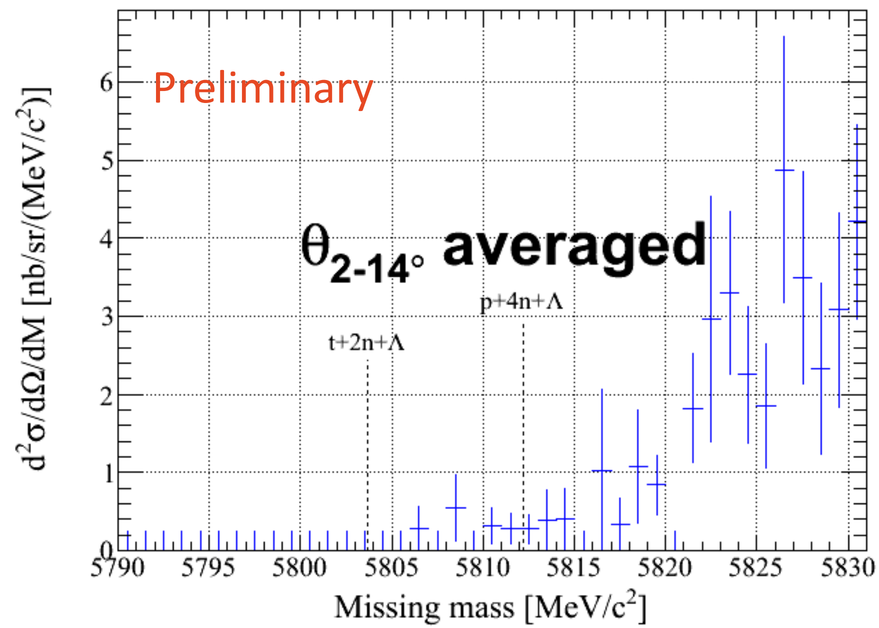
0.05 counst/(MeV/c^2) (Present)

Production cross section of ^{6}Li(π^-, K$^+$)X reaction

Production cross section of ^{6}Li(π^-, K^+)X reaction



Production cross section of ^{6}Li(π^-, K^+)X reaction (Zoom up)



No event was remained below the t+2n+Λ threshold

Upper limit

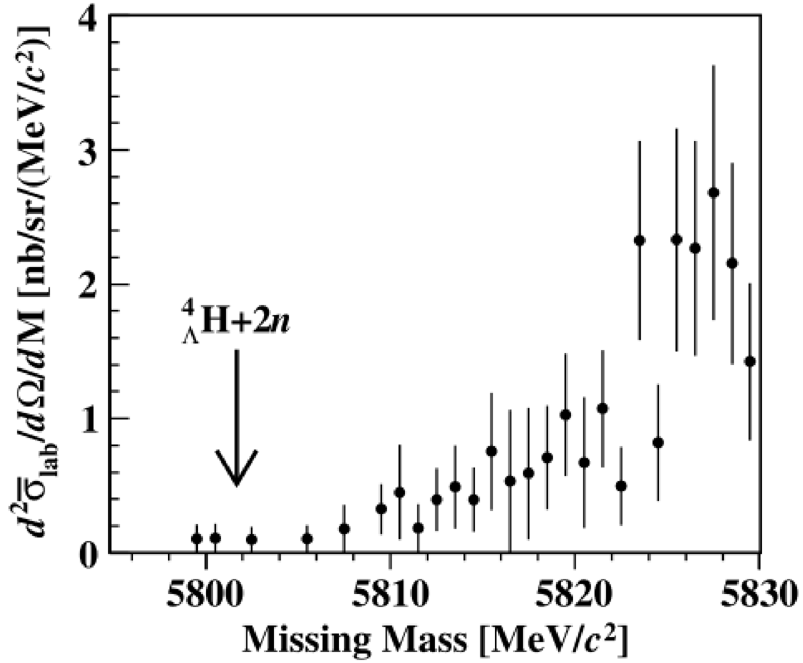
1.2 nb/sr (90% C.L.) (PLB result)

↓

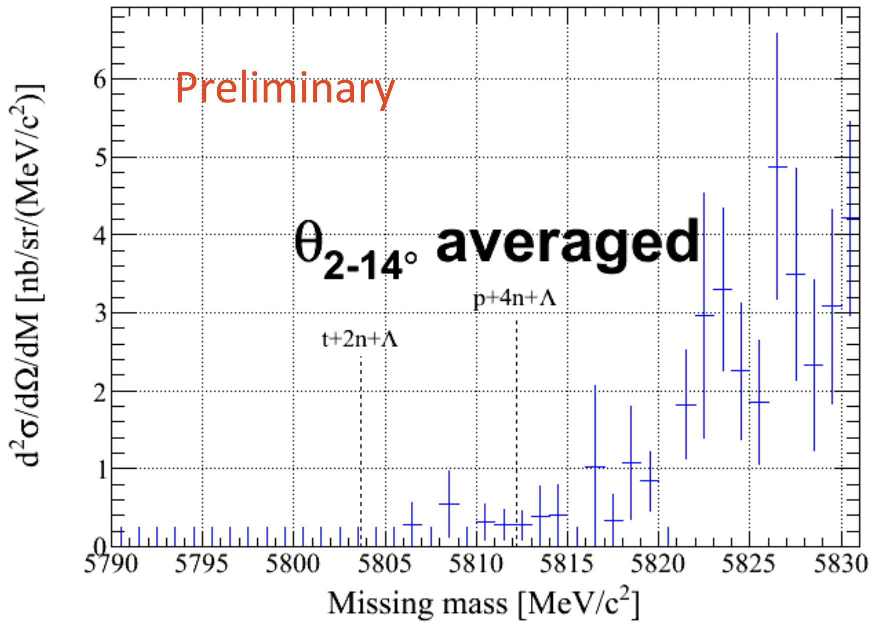
0.56 nb/sr (90% C.L.) (Present)

Discussion

PLB result



Present result



- Three events around $^{4}_{\Lambda}$H + 2n threshold were seems to be background.
- The present upper limit was 10 times smaller than our expectation. Quite difficult to produce the $^{6}_{\Lambda}$H hyperncleus by this experimental method.
- On the other hand, several events were seen between t + 2n + Λ and p + 4n + Λ threshold. Some excited states may exist, but at least 10 times statistics is necessary to observe them.