

Search for Excited State of Σ Hypernucleus in the J-PARC E13 Experiment

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For the J-PARC E13 collaboration

A decorative graphic consisting of a large, wavy blue shape that resembles a liquid splash or a stylized wave, extending from the bottom left towards the right. To the right of this wave, there are two smaller, realistic-looking blue bubbles of different sizes, one above the other, with highlights and shadows giving them a three-dimensional appearance.



Introduction

Study of ΣN interaction

- ΣN interaction
 - Strong isospin dependency
 - Total isospin $t = 3/2$: repulsive, $t = 1/2$: attractive
- Σ - nucleus potential
 - Study to understand ΣN interaction

$$\frac{U_0^\Sigma + U_\tau^\Sigma (T_{\text{core}} \cdot t_\Sigma) / A_{\text{core}}}{}$$

A_{core} : Mass number of core nucleus

KEK-PS E438
C, Si, In, Bi(K^- , π^+)

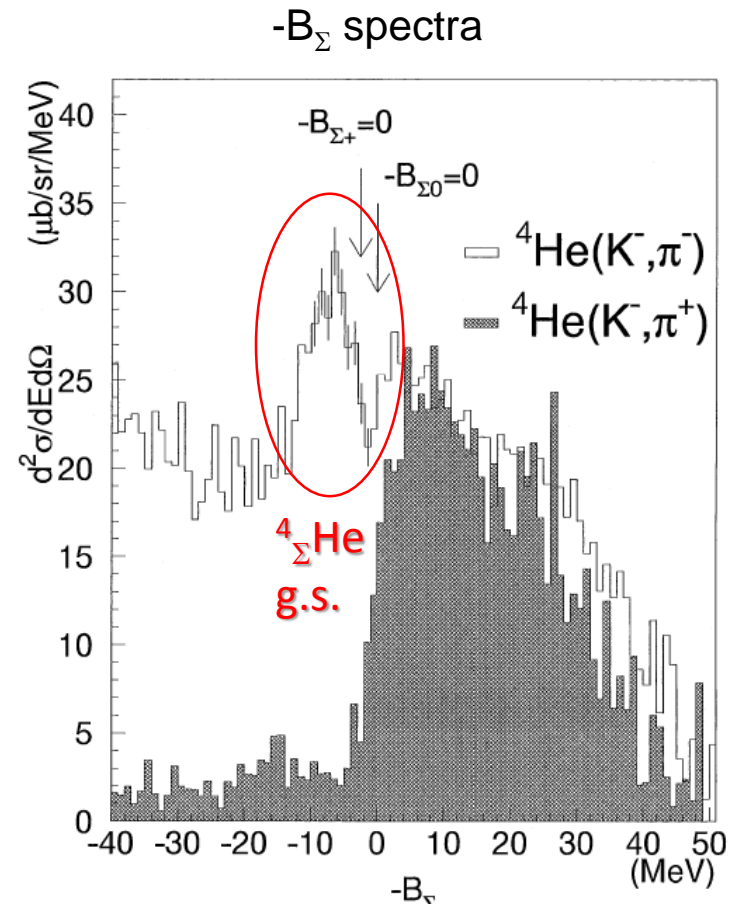
Isospin independent

Lane's term
Isospin dependent

- Understand the Lane's term
 - Appear in light ($A_{\text{core}} \leq 4$) nucleus

Observation of ${}^4_{\Sigma}\text{He}$ bound state

- KEK-PS E167
 - Bump structure in ${}^4\text{He}(\text{stopped } K^-, \pi^-)$ reaction
 - BNL-AGS E905
 - ${}^4\text{He}(K^-, \pi^-)$ reaction
 - ${}^4_{\Sigma}\text{He}$ ground state
 - $\Gamma = 7 \pm 0.7$ MeV
 - $-B_{\Sigma^+} = -4.4 \pm 0.3$ MeV
 - Other experiment
 - Other nuclei have no bound states
- ➔ Only bound state of ${}^4_{\Sigma}\text{He}$ hypernucleus was observed



T.Nagae *et al.*, Phys.Rev.Lett.
80(1998)1605.

Excited states of Σ hypernucleus

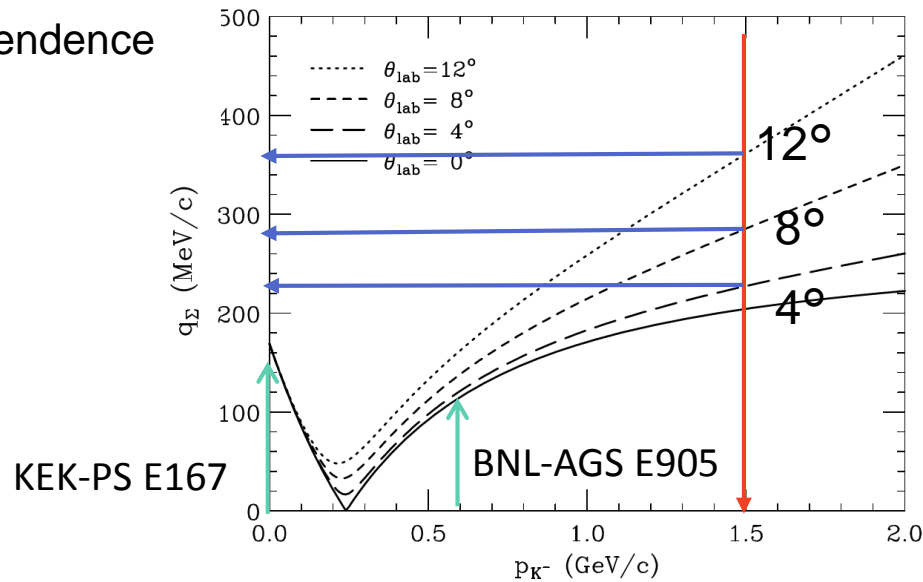
- More information of ΣN interaction

➔ Information of p-wave in ΣN interaction is needed

- Excited states of ${}^4_{\Sigma}\text{He}$
- High momentum (K^-, π^-) reaction

- Select Large Momentum transfer region (>200 MeV/c)

Beam momentum dependence
of momentum transfer





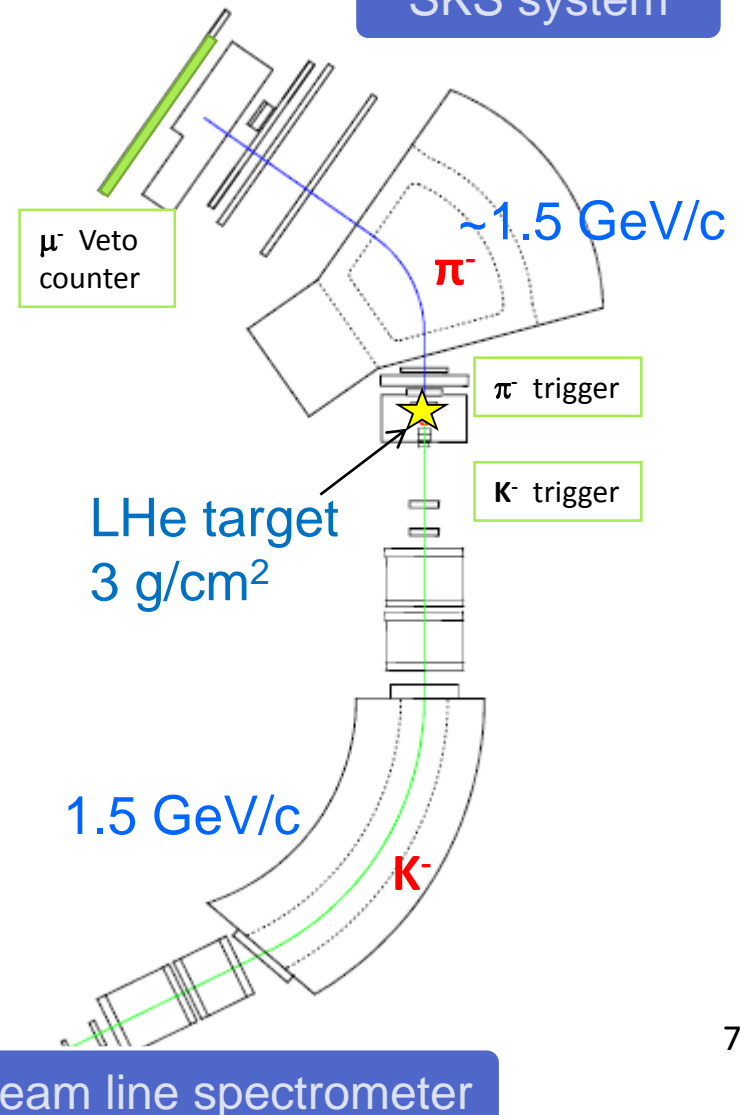
J-PARC E13 Experiment

J-PARC E13 Experiment

SKS system

J-PARC E13 experiment was carried out in K1.8 beam line in April 2015

- Purpose
 - Search for **excited states of Σ hypernucleus**
- Missing mass spectroscopy of ${}^4\text{He}(K^-, \pi^-)$ reaction
 - High momentum K^- beam : **1.5 GeV/c**
 - Liquid ${}^4\text{He}$ target : **3 g/cm²**
 - Scattering angle : **0 – 20 deg**
 - **2 – 14 deg** was used for now




Data summary

- K^- beam condition

Beam intensity	K-/pi- ratio	Total beam time
300 k/spill(2s)	~2	138 hours = 23 G kaon

- Data taking

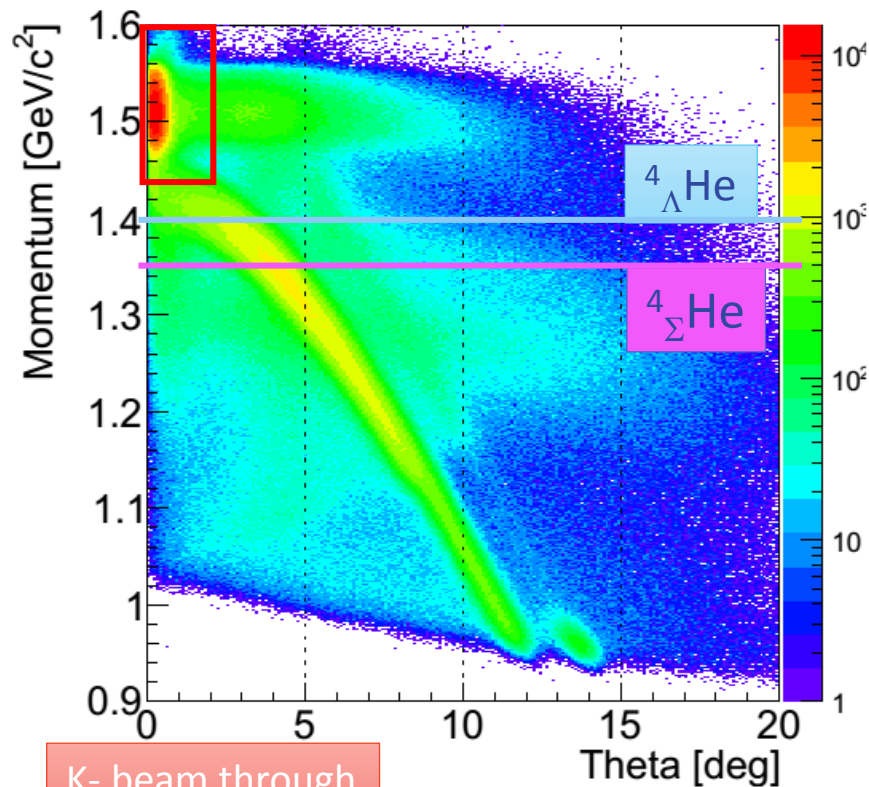
obtained data		Beam momenta [GeV/c]
^4He physics run		1.5
Calibration run	Sigma+ production	1.5, 1.8
	Beam through	1.2, 1.37, 1.5, 1.8
	Empty target	1.5



Analysis & Results

Measured particles by SKS system

Correlation plot between mom. and scat. angle



- Large amount of K- Beam through

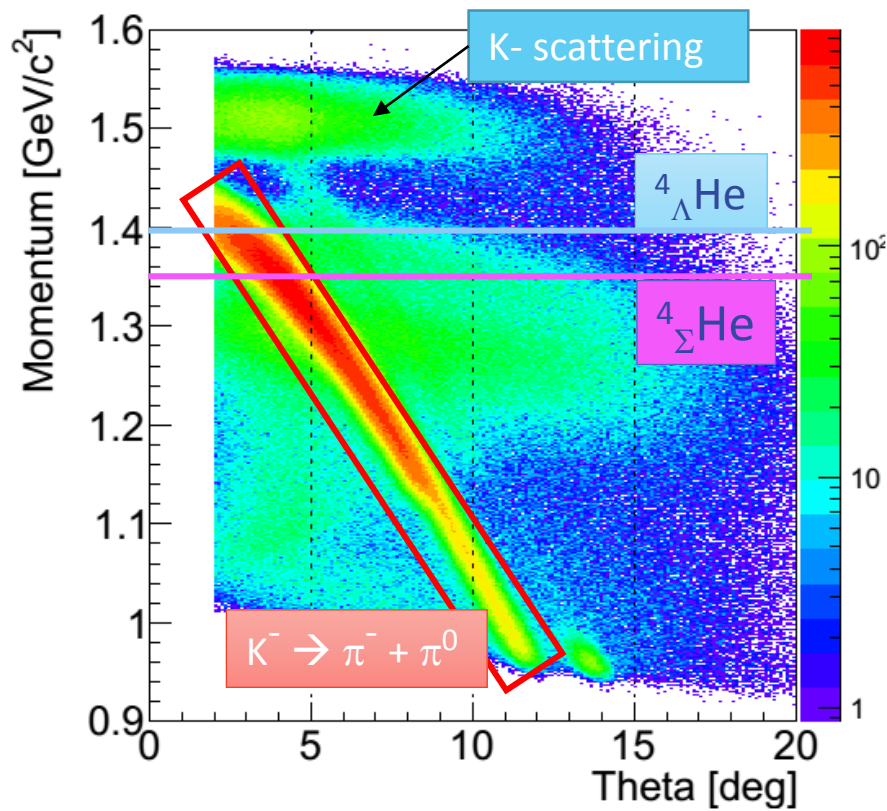
– BG Overlap

- Ground state region of ${}^4_{\Lambda}\text{He}$
- Ground state region of ${}^4_{\Sigma}\text{He}$

➔ Reject theta < 2

Measured particles by SKS system

Correlation plot between mom. and scat. angle



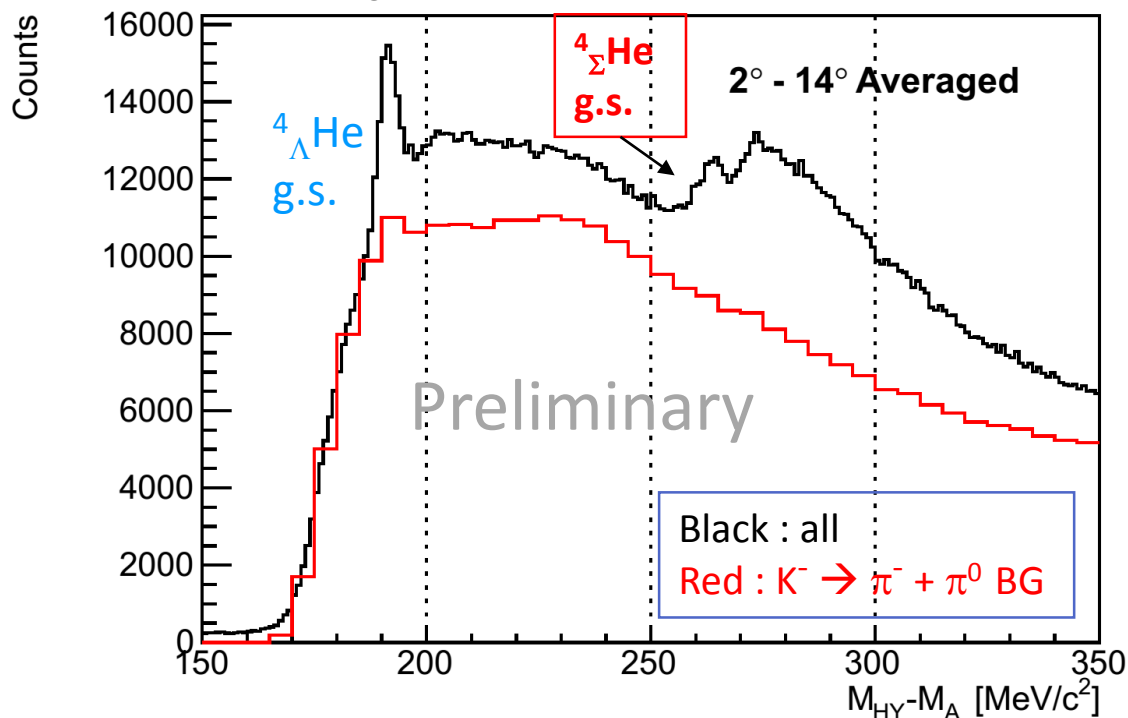
• Background

- K- scattering
 - No overlap
- $K^- \rightarrow \mu^- + \bar{\nu}$
 - Rejected in trigger level
- $K^- \rightarrow \pi^- + \pi^0$
 - **Main background**

➔ BG shape of $K^- \rightarrow \pi^- + \pi^0$ mode is estimated

- Count base of missing mass spectrum of ${}^4\text{He}(\text{K}^-, \pi^-)$ reaction
 - Observed ground state of ${}^4_{\Lambda}\text{He}$ and ${}^4_{\Sigma}\text{He}$

Missing mass spectrum of ${}^4\text{He}(\text{K}^-, \pi^-)$ reaction

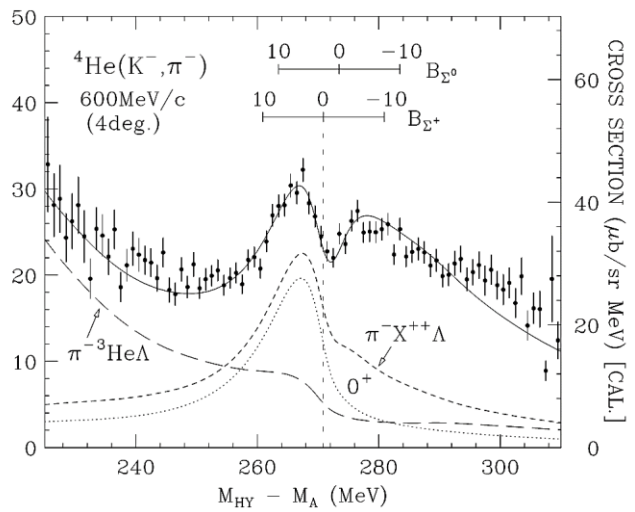
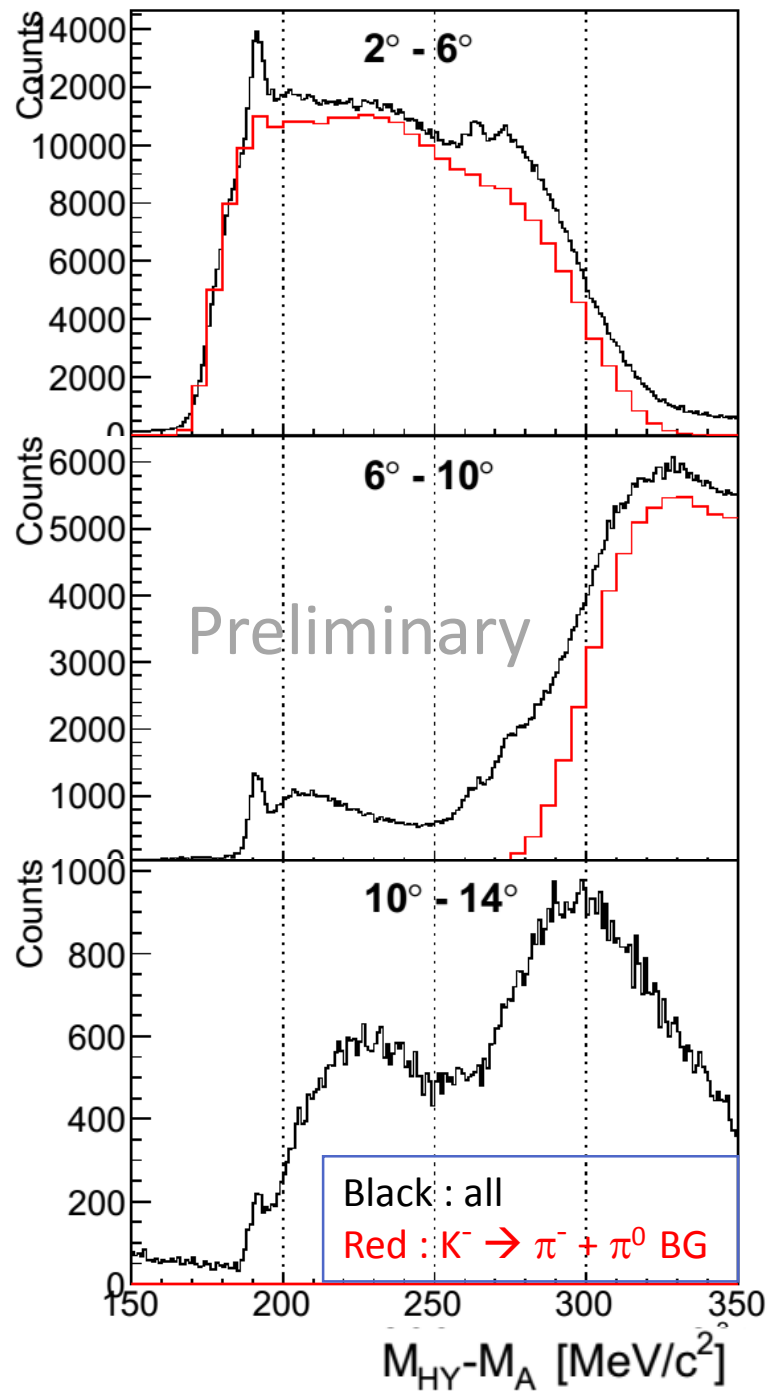


${}^4_{\Lambda}\text{He}$ ground state
FWHM 6 MeV/c^2

Future plan

- Acceptance correction
- Horizontal uncertainty
- Complete BG reproduction

Results Discussion



Obtained missing mass spectrum in BNL results
Harada *et al.*, PRL 81.5287

- Angular dependence of missing mass spectrum
 - 2 – 6 deg
 - ➔ Shape is similar to the result of BNL-AGS E905
 - Over 6 deg
 - New information of ΣN interaction

Summary

- Study of ΣN interaction
 - Understand Lane's term in light nuclei
- J-PARC E13 experiment
 - Search for the excited states of $^4_{\Sigma}\text{He}$
 - (K $^-$, π^-) reaction at 1.5 GeV/c
- Results
 - Missing mass spectrum of $^4\text{He}(K^-, \pi^-)$ reaction
 - Observed ground state of $^4_{\Lambda}\text{He}$ and $^4_{\Sigma}\text{He}$
 - Angular dependence (2 – 14 deg) were obtained
 - Similar to the result of previous experiment in 2 – 6 deg
 - New information over 6 deg
- Future plan
 - Background simulation for subtraction