HYP2003@Jlab

Production of neutron-rich Λ hypernuclei by the (π^-,K^+) double-charge-exchange reaction

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RIKEN, Tohoku Univ., Seoul National Univ.,

Contents:

Introduction:
Key reactions to produce a Λ hypernucleus

1. Usual reactions:

(π^+, K^+), (K^-, π^-),

(Stopped K^-, π^-)

2. Photon induced reactions:

ex: (e, e'K^+) reaction:

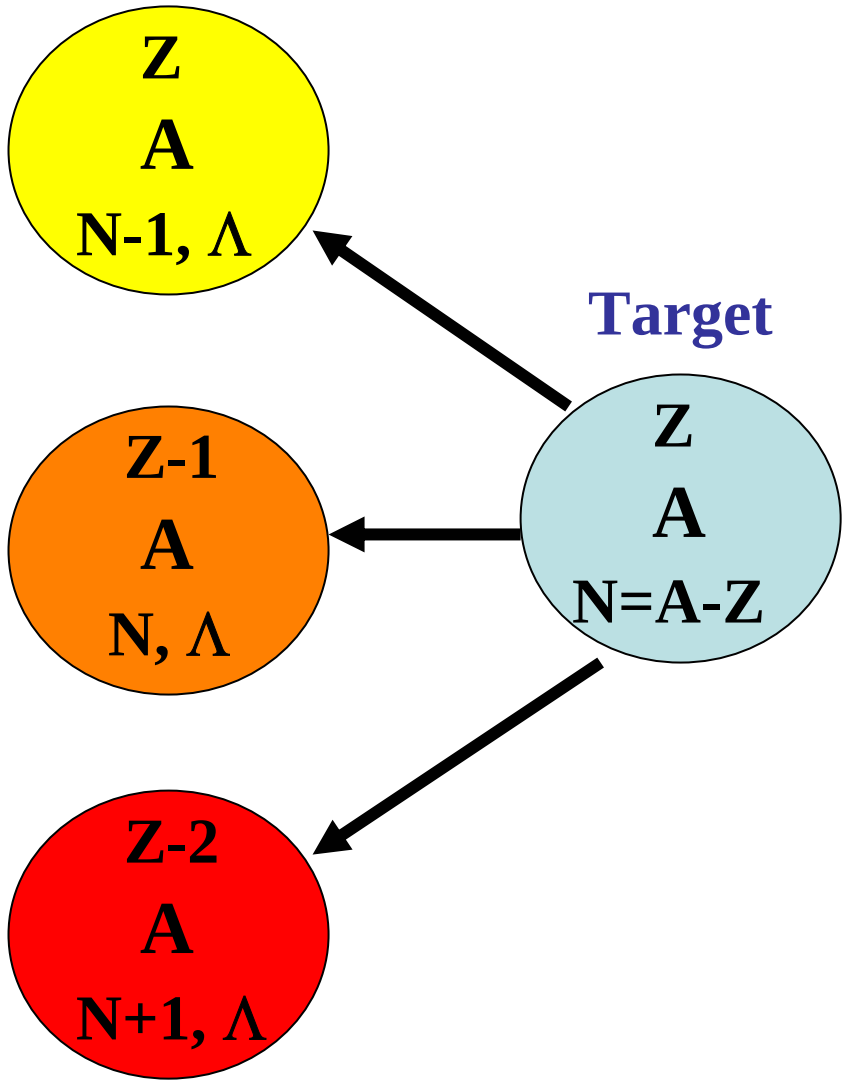
Recently: γ+n -->Λ+K^0 ($\pi^+\pi^-$)

3. DCX reactions:

(π^-, K^+), (K^-, π^+),

(Stopped K^-, π^+)

Ex: $^{7}_{\Lambda}$H from ^{7}Li(π^-,K^+)



Physics Motivations

1. Search for one neutron-rich Λ hypernucleus ($^{10}_{\Lambda}$Li) as a first step and to understand the reaction mechanism as well.

2. To understand the "Coherent Λ–Σ coupling" experimentally.

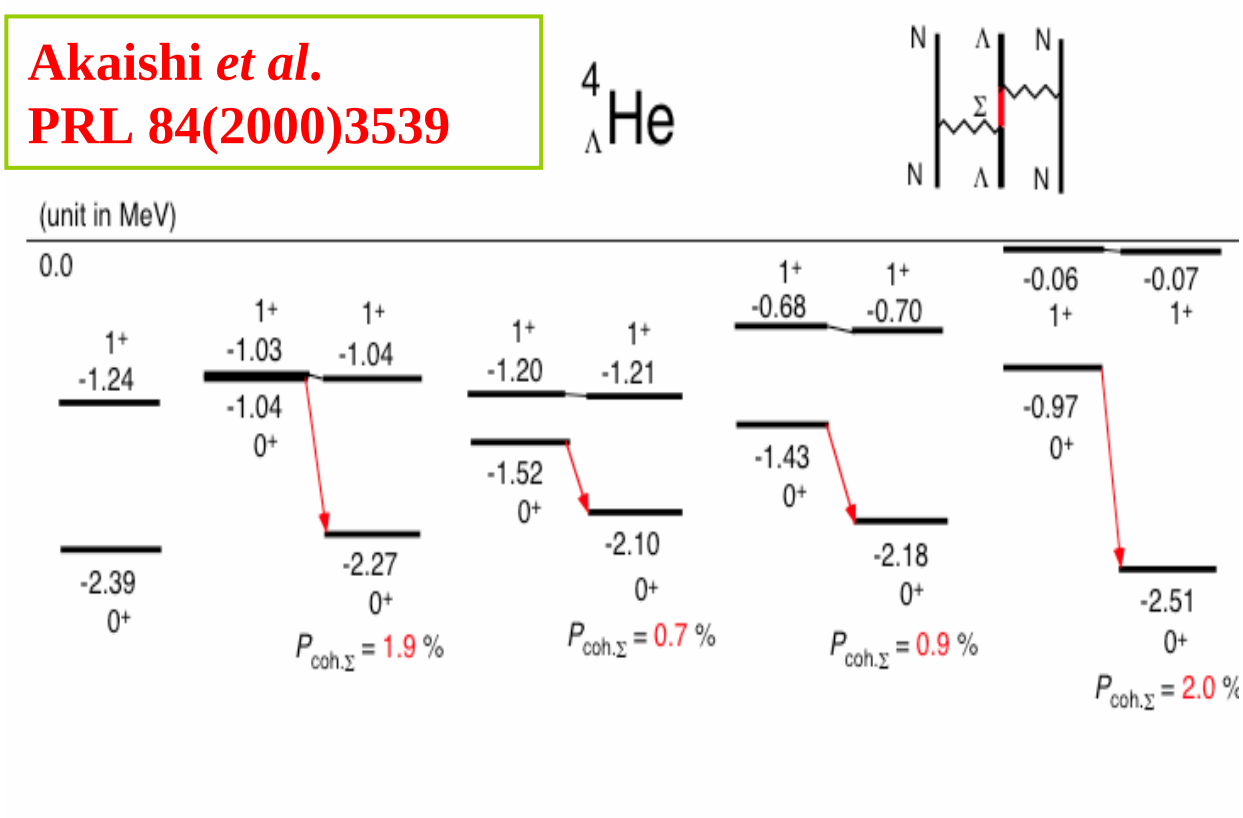
3. To produce a very exotic object like, $^{6}_{\Lambda}$H or even $^{7}_{\Lambda}$H in near future.

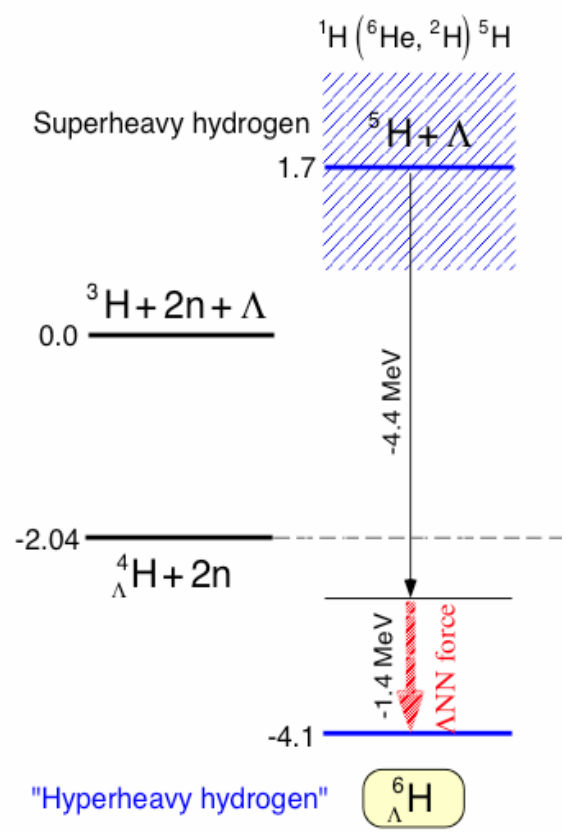
4. Fill up the strangeness (S) = -1 sector

5. Study of hypernucleus with large neutron access in connection with a halo nucleus

Coherent Λ–Σ Coupling and it's observation Experimentally

Akaishi *et al.*
PRL 84(2000)3539





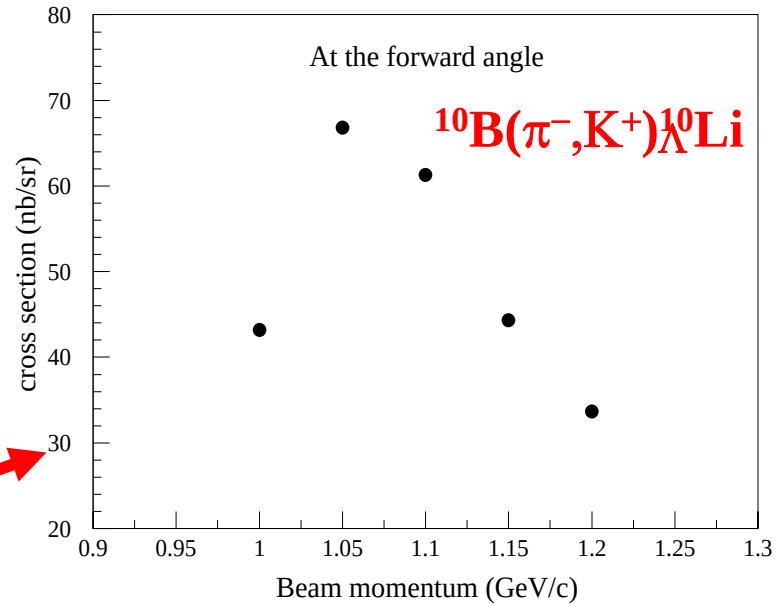
^{6}Li(π^-,K^+)$^{6}_{\Lambda}$H

Reaction mechanism and the theoretical calculation

Tretyakova, Akaishi et. al. (Private communication, 2002)

1. Single-step process:

By the $\pi^- p \rightarrow \Sigma^- K^+$ via a small admixture of the Σ^- state due to the $\Sigma^- p \leftrightarrow \Lambda n$ coupling.

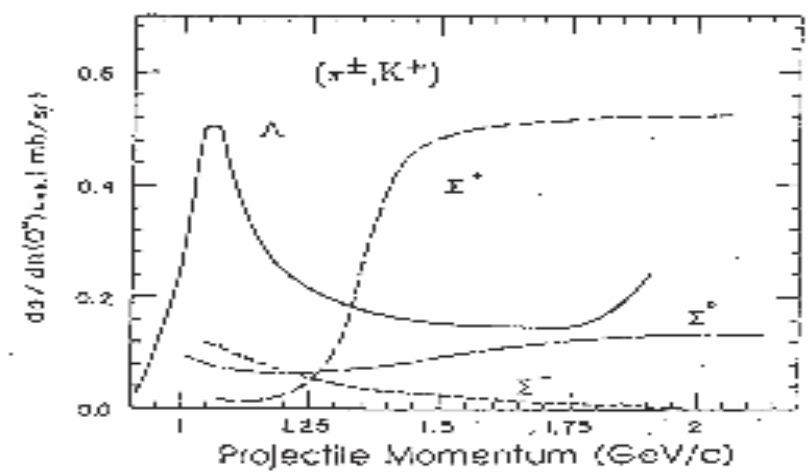


2. Two-step process:

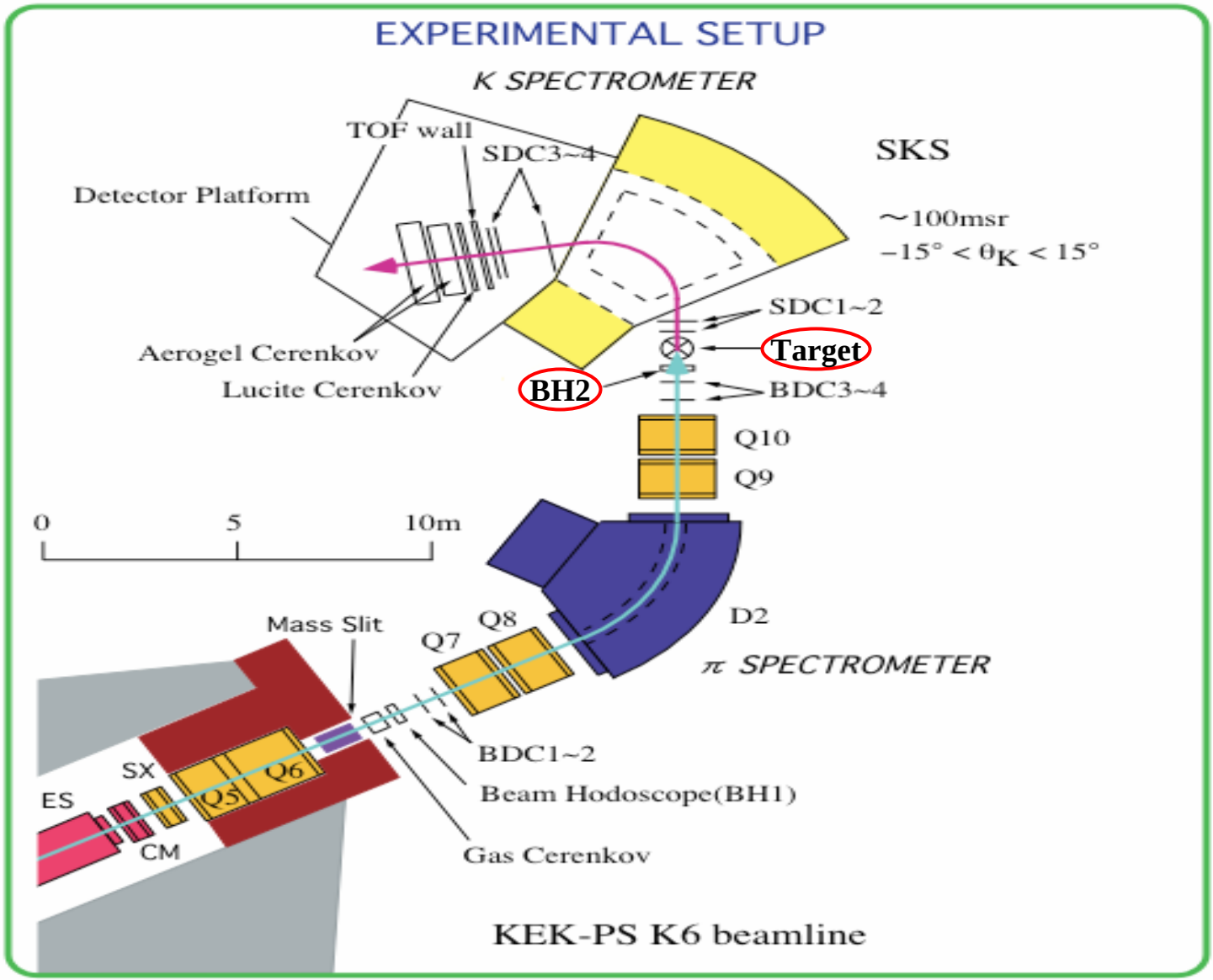
$\pi^- p \rightarrow K^0 \Lambda$; $K^0 p \rightarrow K^+ n$

$\pi^- p \rightarrow \pi^0 n$; $\pi^0 p \rightarrow K^+ \Lambda$

$\pi^- p \rightarrow \Sigma^- K^+$; $\Sigma^- p \rightarrow \Lambda + n$



Experimental setup of KEK-PS-E521

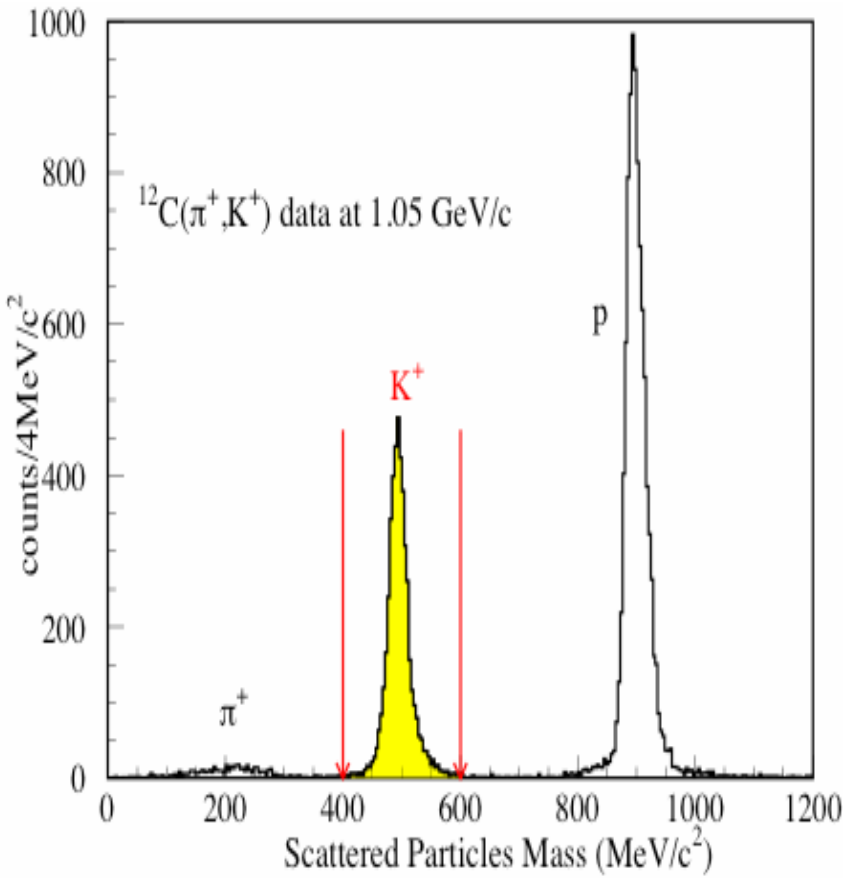


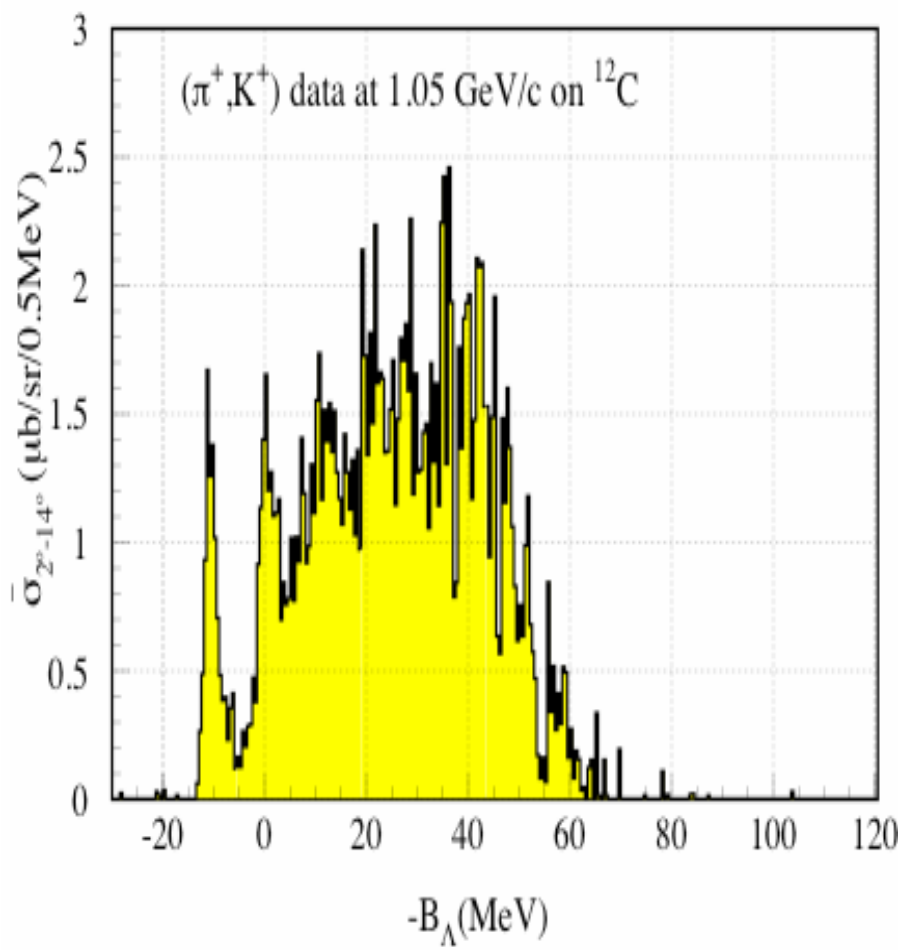
Data summary of KEK-PS-E521 (year02+year03)[15 +15 days]

Target	Beam Mom. [GeV/c]	SKS current [A]	Reaction	Irradiated π^+/π^- [x10^9]	Year
^{10}B	1.05	272	(π^-,K^+)	440	
^{10}B	1.20	395	(π^-,K^+)	460	
^{12}C	1.20	395	(π^+,K^+)	15	2002
^{12}C	1.05	272	(π^+,K^+)	16	
^{10}B	1.05	272	(π^+,K^+)	31	
^{10}B	1.20	395	(π^-,K^+)	700	2003
^{12}C	1.20	395	(π^+,K^+)	26	

Data by (π^+,K^+) reaction were mainly for calibration

$^{12}C(\pi^+,K^+)^{12}_{\Lambda}C$ spectrum at 1.05 GeV/c (for calibration)



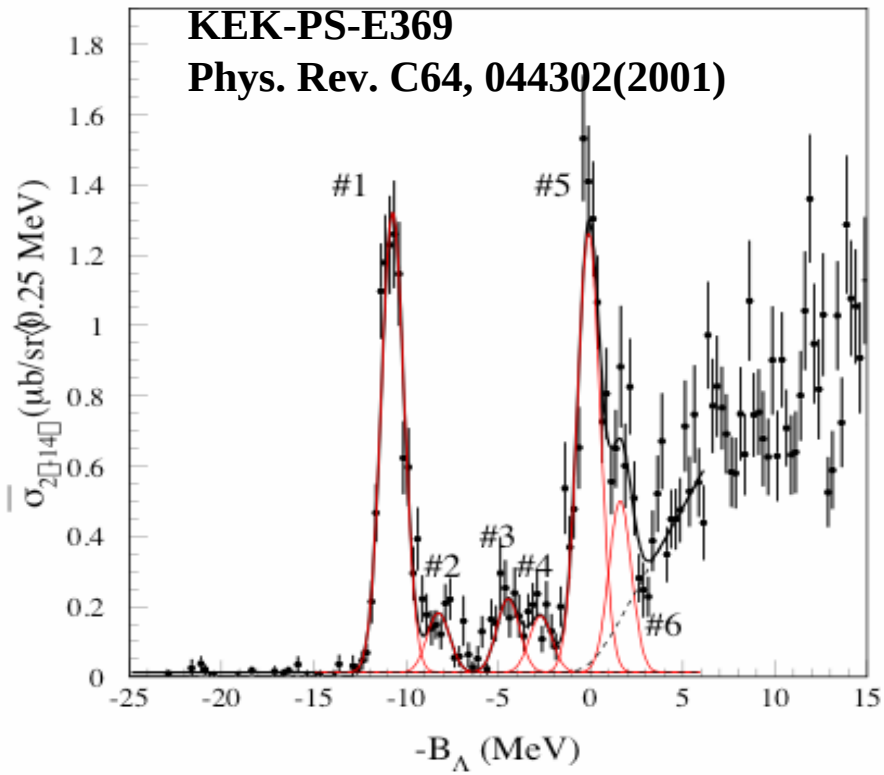


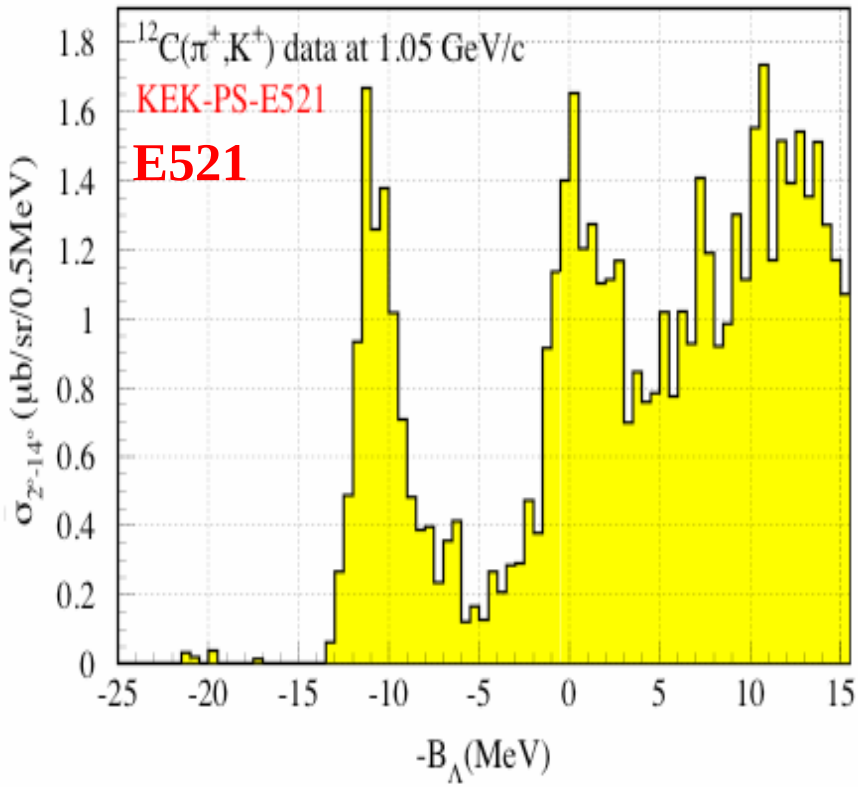
Comparison of $^{12}C(\pi^+,K^+)^{12}_{\Lambda}C$ spectrum at 1.05 GeV/c with previous experiment

Thin target (0.86 gm)
Resolution: 1.45 MeV (FWHM)
g.s. cross section : 8.07 μb/sr

Consistent!!

Thicker target (3.5 gm)
Resolution: 2.5 MeV (FWHM)
g.s. cross section: 8.2 μb/sr

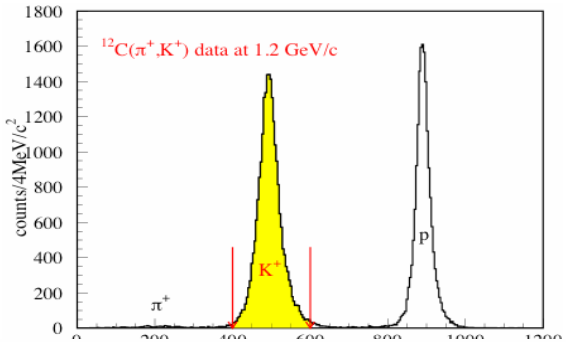


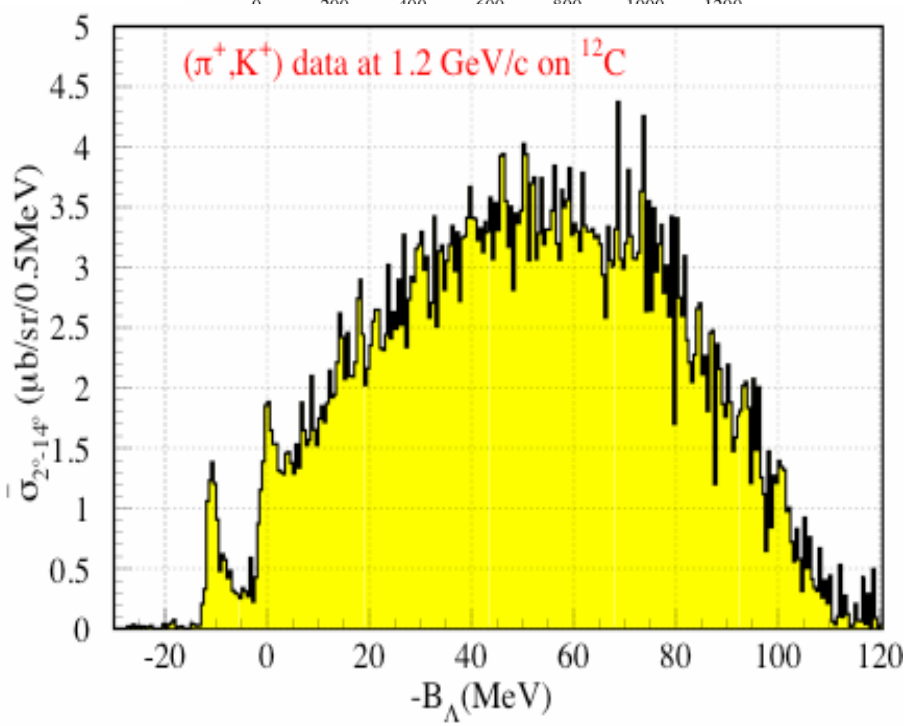


$^{12}C(\pi^+,K^+)^{12}C$ spectrum at 1.2 GeV/c

Λ

(for calibration)





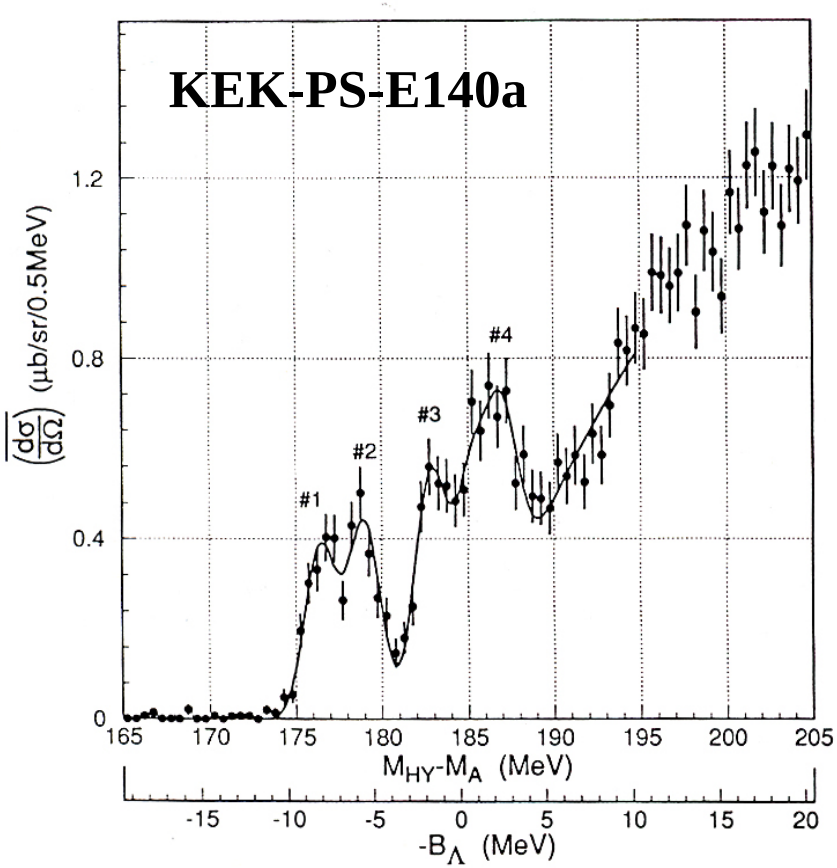
New Experimental information about Λ production at 1.2 GeV/c !!

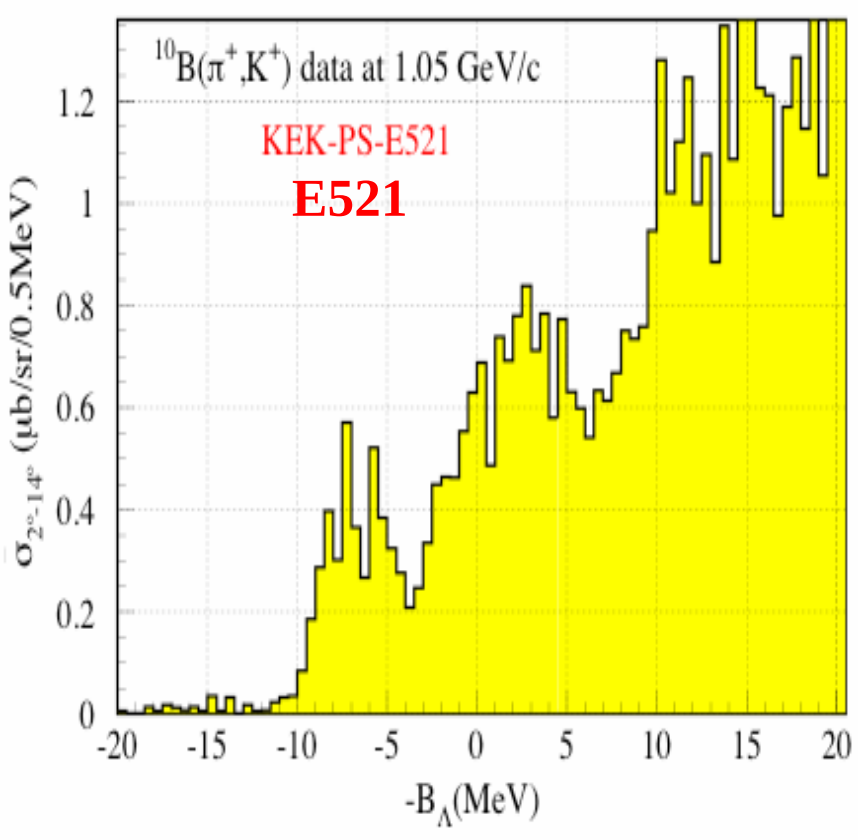
Ratio of g.s. cross section:
1.2 GeV/c to 1.05 GeV/c
(4-8 deg.)
0.92 ± 0.1

T. Motoba
(Private communication) 2002
(5 deg.) -> 0.82

$^{10}B(\pi^+,K^+)^{10}_{\Lambda}B$ spectrum at 1.05 GeV/c and comparison with previous data(for calibration)

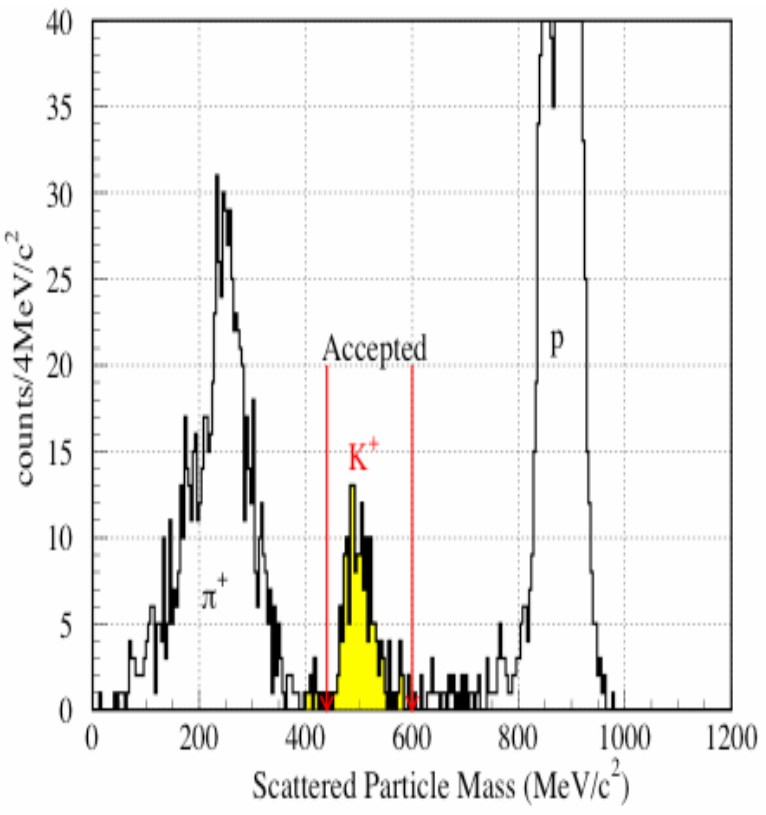
Consistent!!

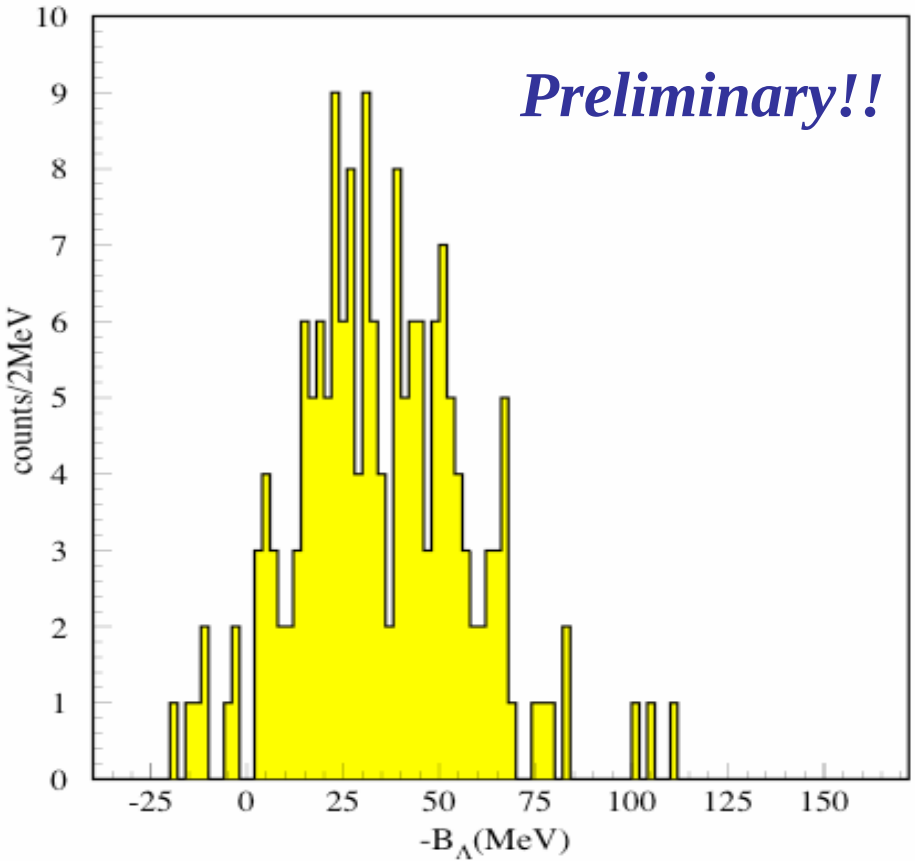




Analysis of $^{10}B(\pi^-,K^+)$ data at 1.05 GeV/c

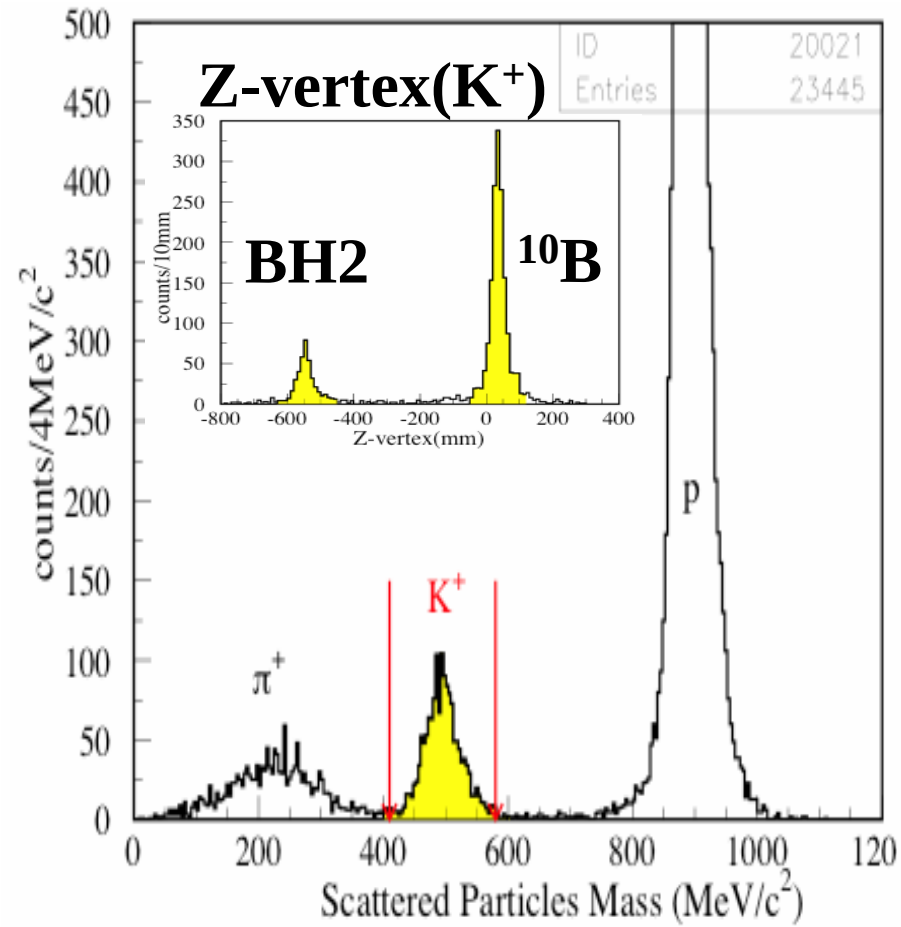
In the bound region, a maximum of 7 counts
~ 1 order less than the expectation!!

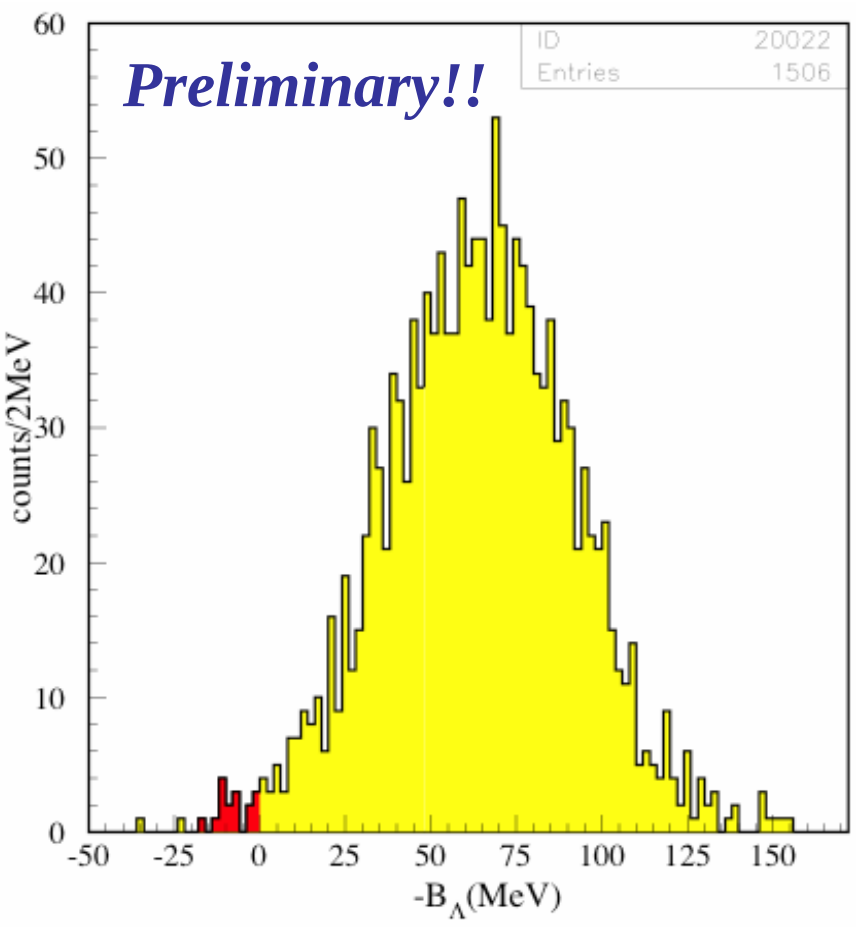




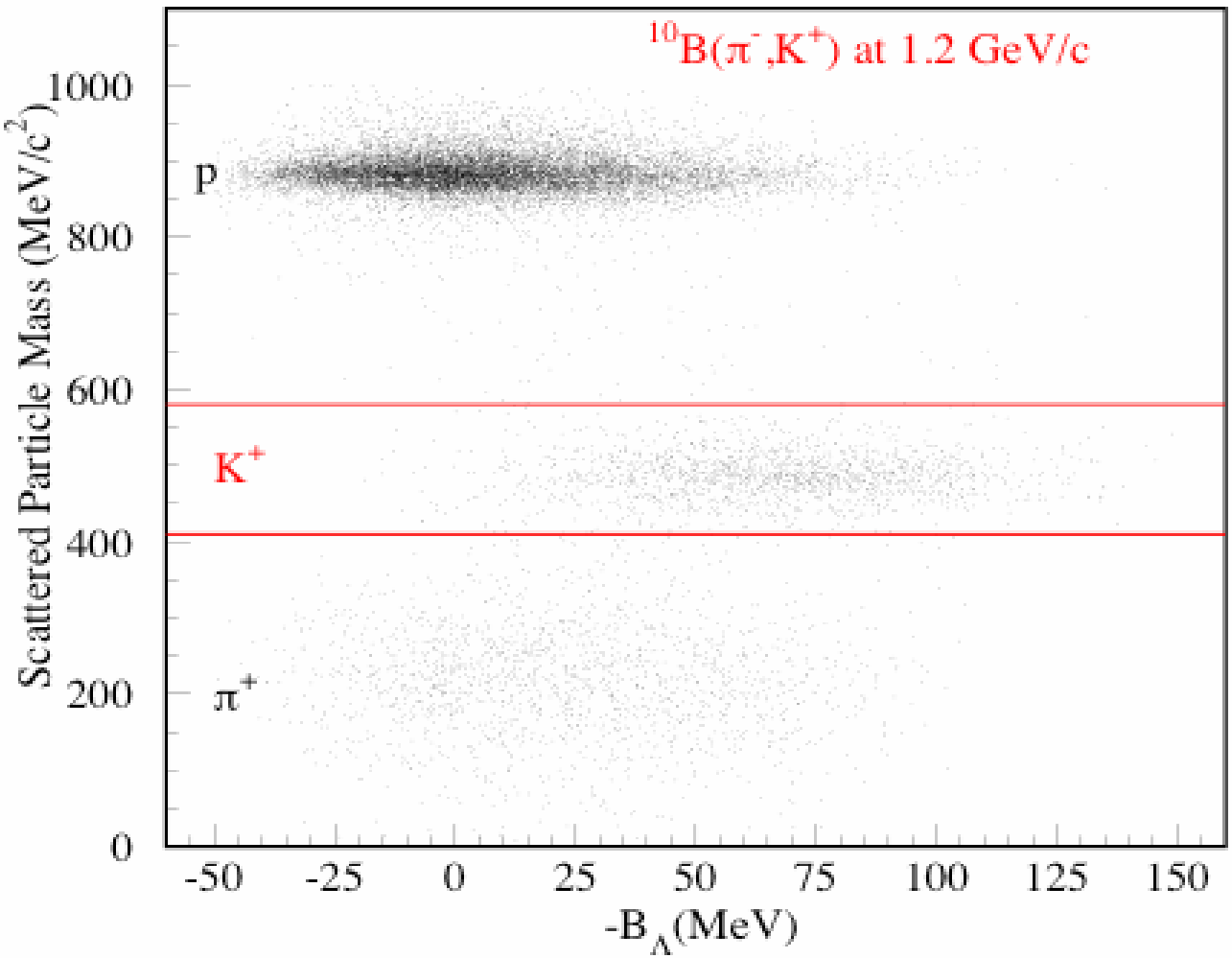
Analysis of $^{10}B(\pi^-,K^+)$ data at 1.2 GeV/c (Year02)

About 15 counts in the bound region
~ 2 times more than 1.05 GeV/c data !!





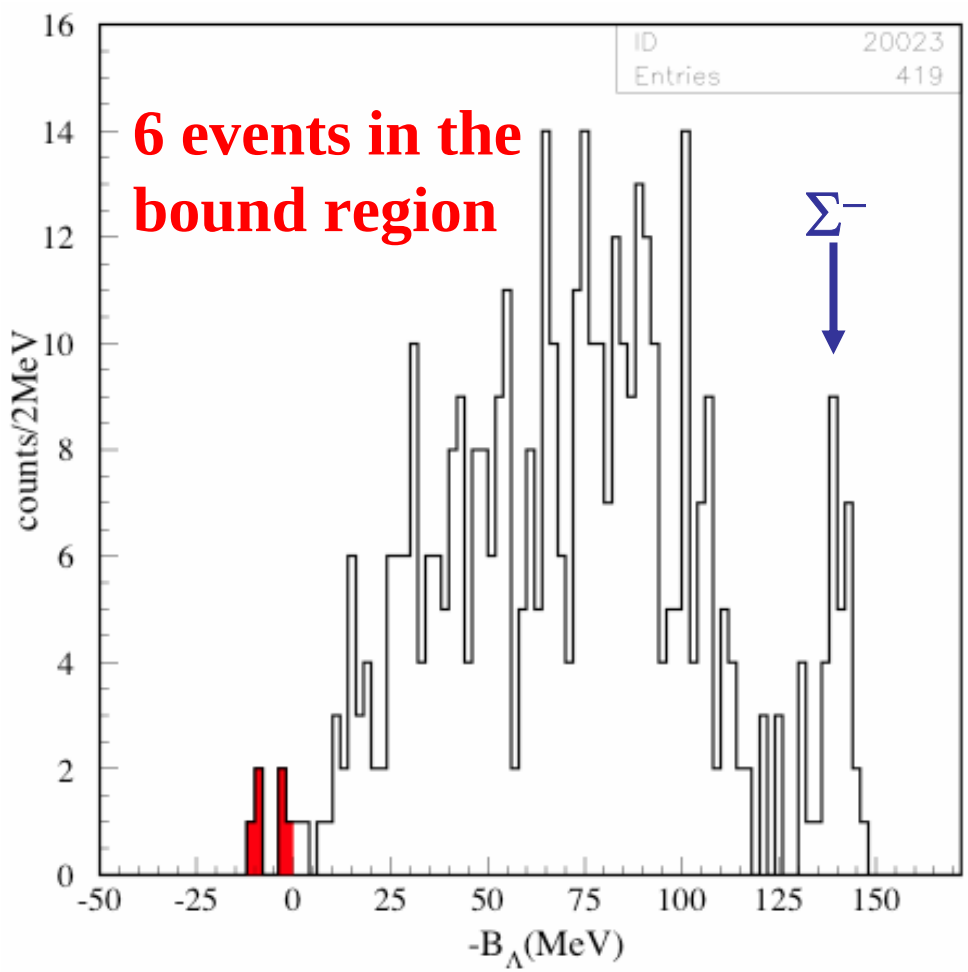
2D plot between $-B_\Lambda$ and Scattered particles



Selected K^+ are well separated from π^+ or p even in the bound region

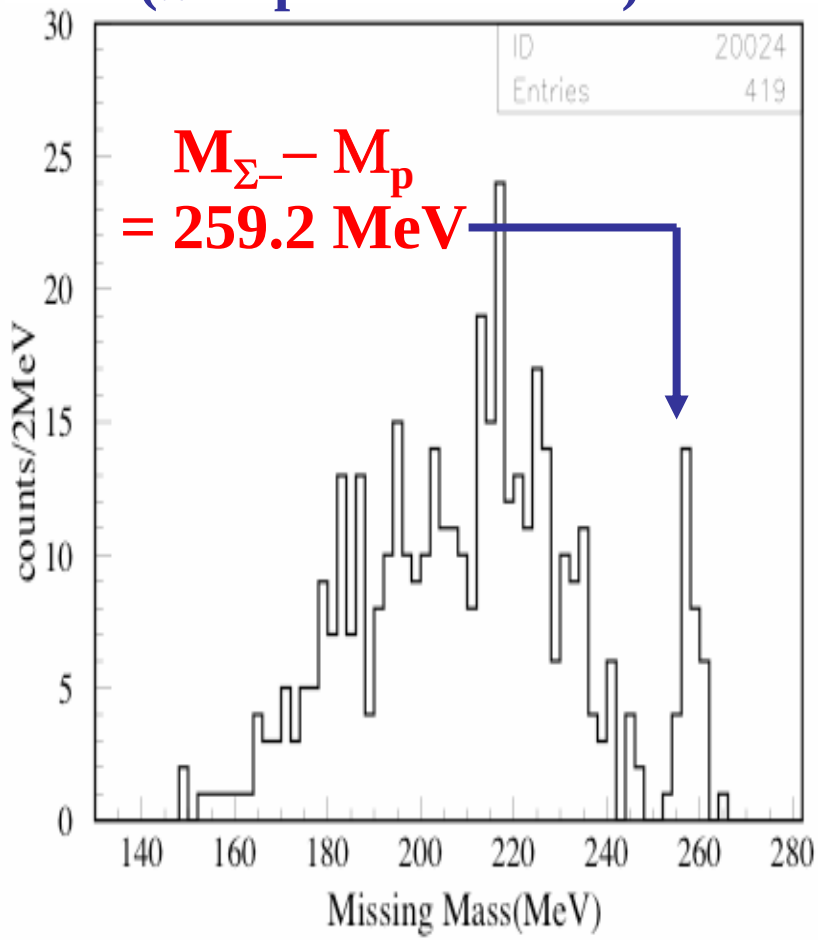
Analysis of BH2 counter events (Year02)

$^{12}C(\pi^-, K^+)$ kinematics



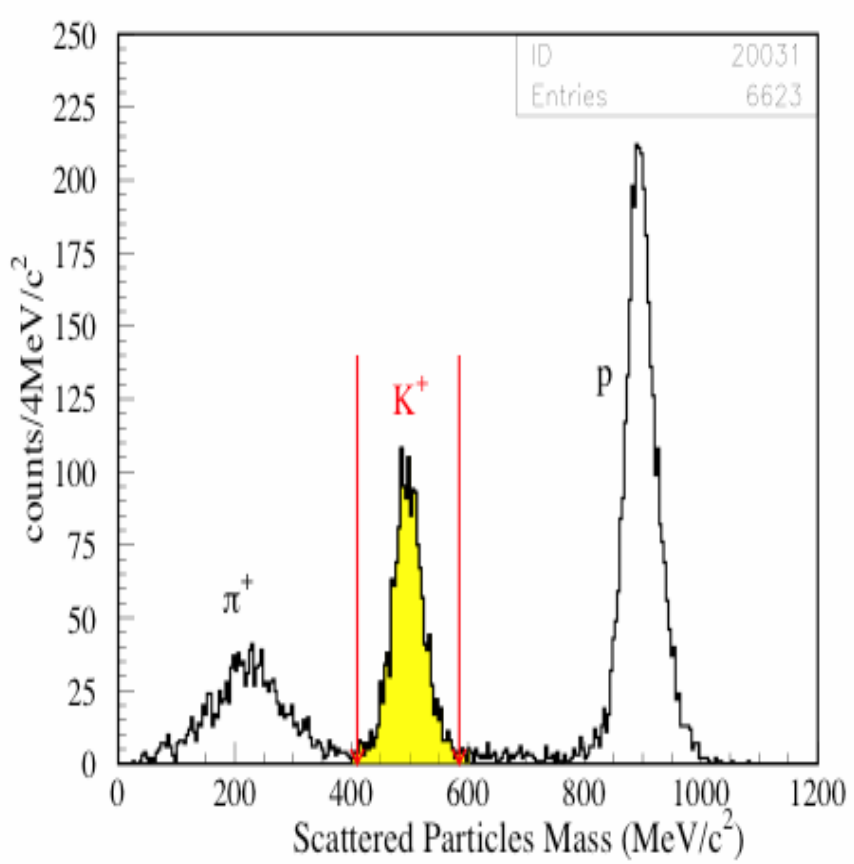
Elementary kinematics

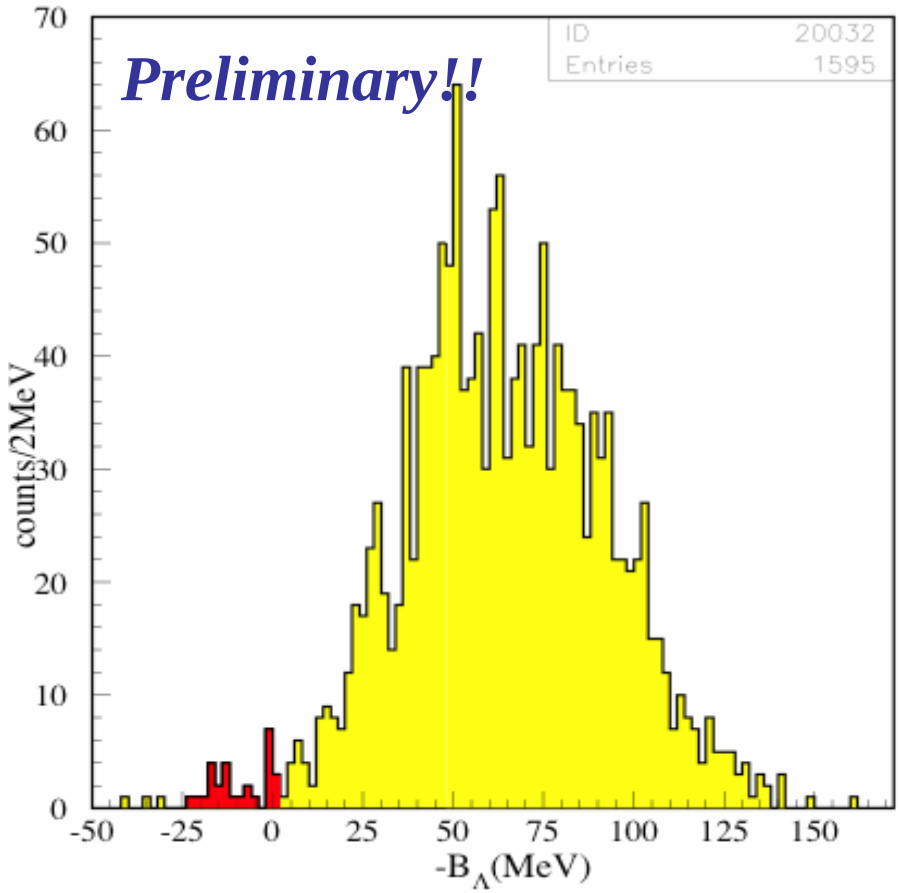
$(\pi^- + p \longrightarrow \Sigma^- + K^+)$



Analysis of $^{10}B(\pi^-,K^+)$ data at 1.2 GeV/c (Year03)

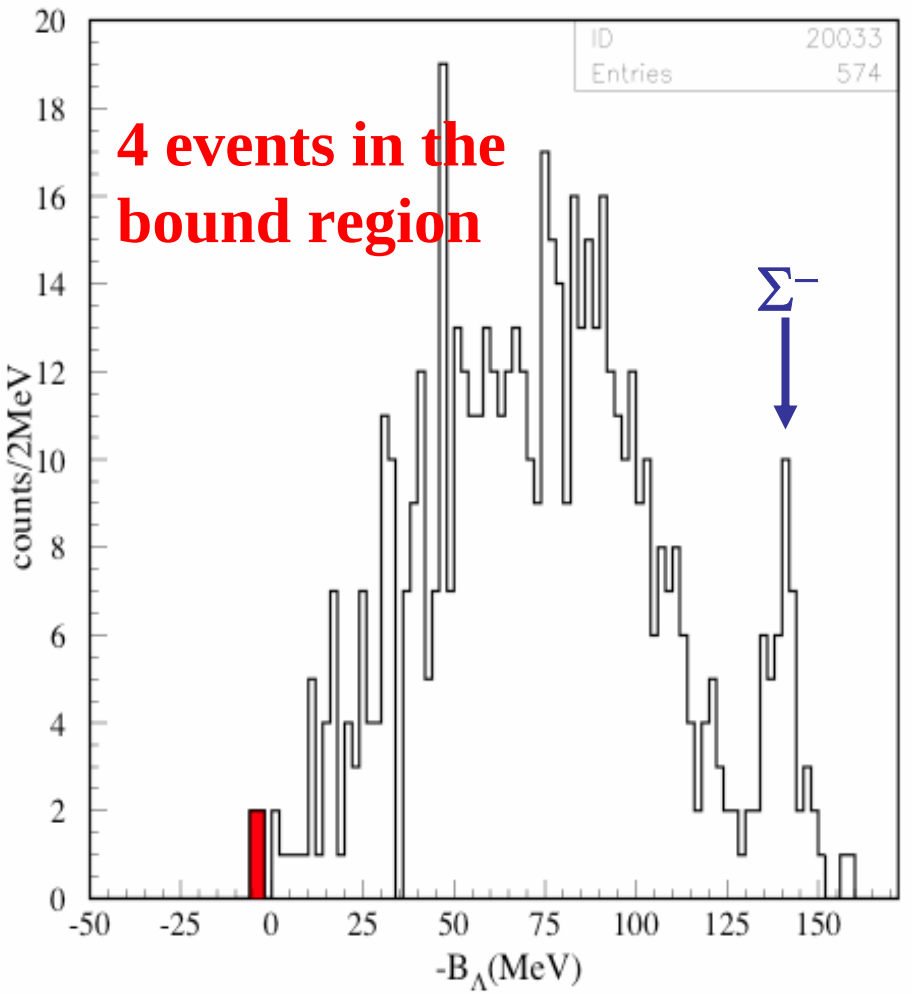
About 25 counts in the bound region
Quite consistent with year02 data!!





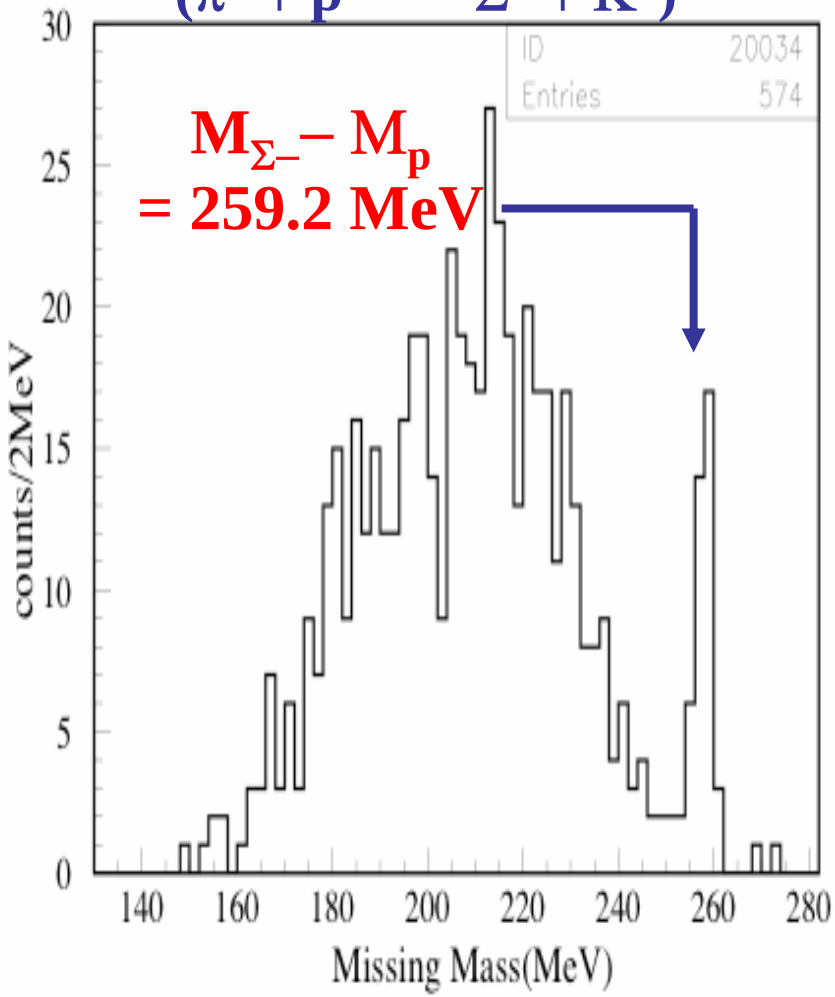
Analysis of BH2 counter events (Year03)

$^{12}C(\pi^-, K^+)$ kinematics

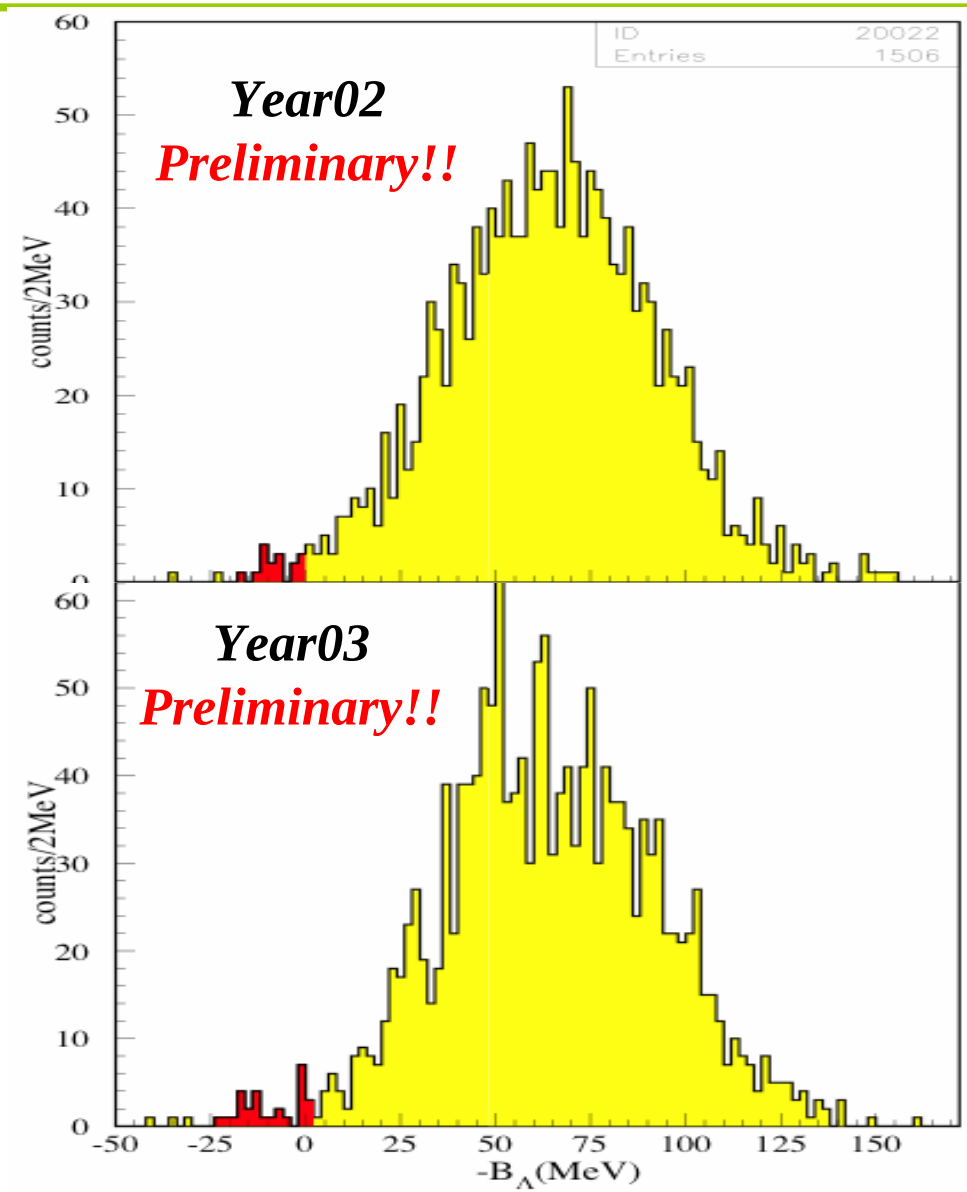


Elementary kinematics

$(\pi^- + p \longrightarrow \Sigma^- + K^+)$



Comparison of ^{10}B year02 and year03 spectra

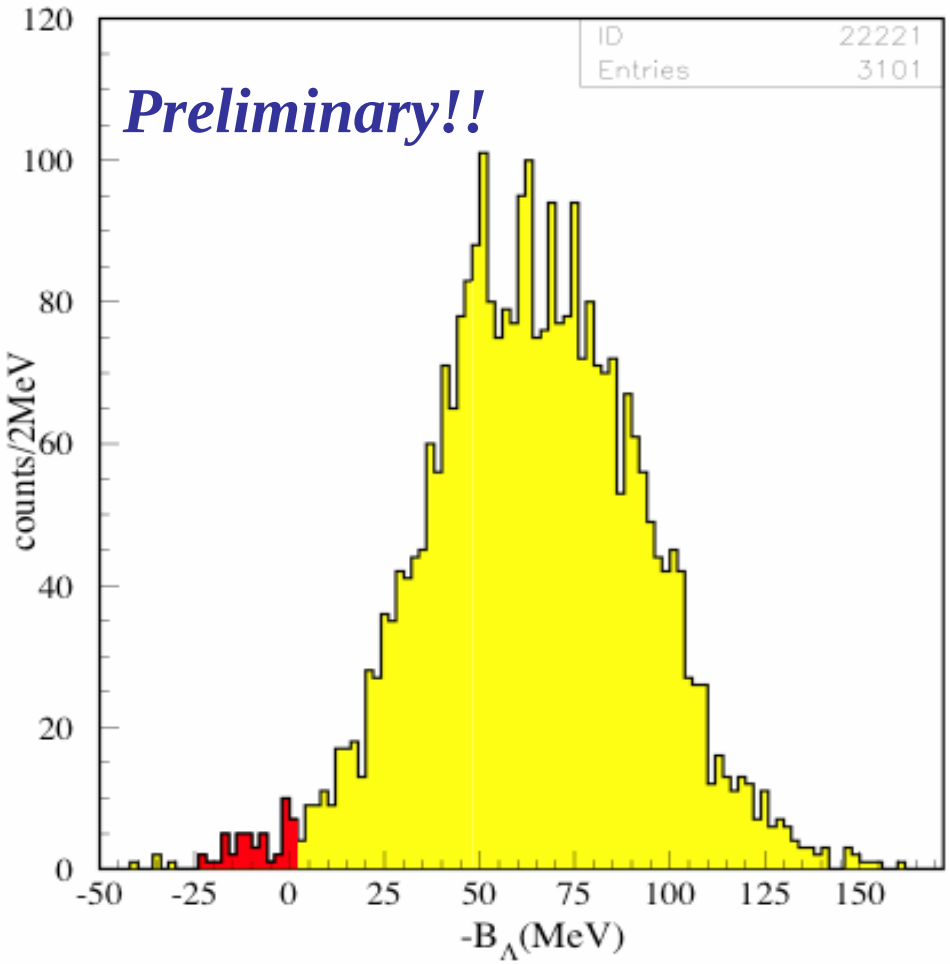


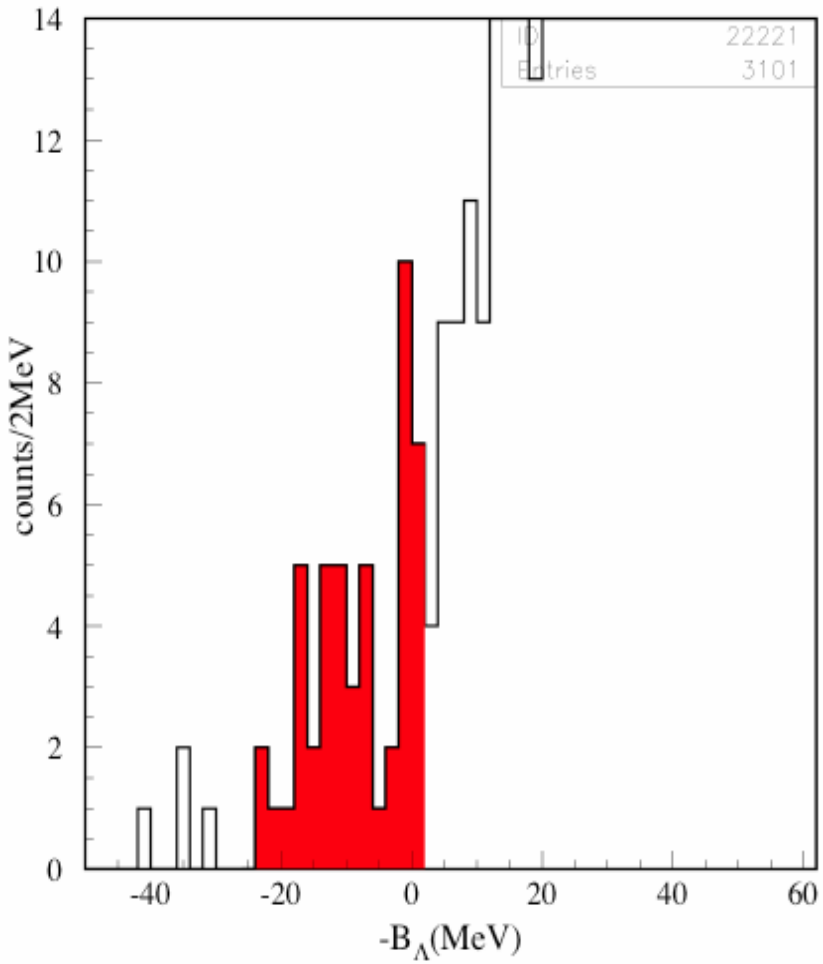
Look similar!!

Year03 data needs more fine tuning concerning the resolution

$^{10}B(\pi^-,K^+)$ spectrum with Year02+Year03

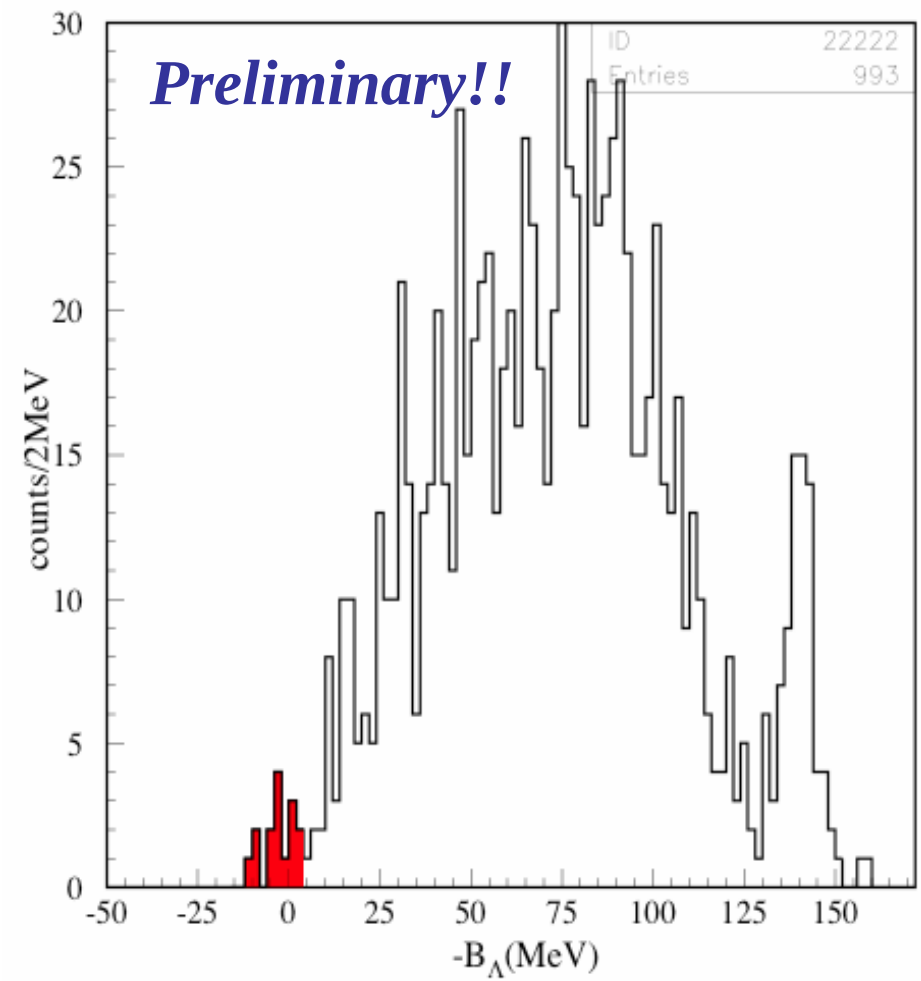
In total, about 40 counts in the bound region

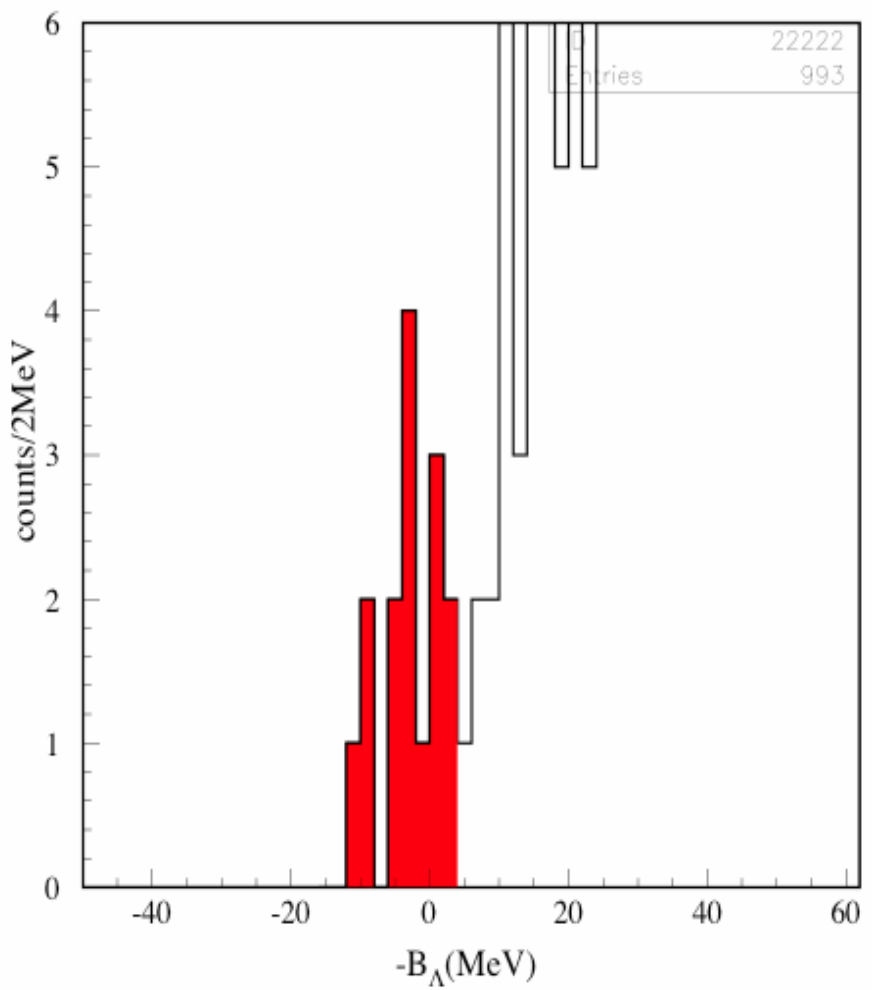




$^{12}C(\pi^-,K^+)$ spectrum from BH2 counter with Year02+Year03

In total, 10 counts in the bound region with no backgrounds!!





Experimental results (*Very Preliminary !!*)

Production rate of (π^-,K^+) reaction as compared to the (π^+,K^+) reaction(bound region)

Beam mom. (GeV/c)	Target	Reaction	Ratio
1.05	^{12}C	(π^+,K^+)	1
1.20	^{12}C	(π^+,K^+)	0.92±0.1(g.s)
1.20	^{12}C	(π^-,K^+)	0.89×10^{-3}
1.05	^{10}B	(π^+,K^+)	1
1.20	^{10}B	(π^+,K^+)	no data
1.20	^{10}B	(π^-,K^+)	1.24×10^{-3}

$$\frac{(\pi^-,K^+)}{(\pi^+,K^+)} \sim 10^{-3}$$

Summary and discussion

This is the first time we tried to produce neutron-rich Λ hypernuclei by the (π^-,K^+) double-charge-exchange reaction.

The preliminary results are already very interesting although no significant discrete peak because of limited statistics.

We are gradually getting information concerning the reaction mechanism and the present result would be very important for some theoretical inputs.

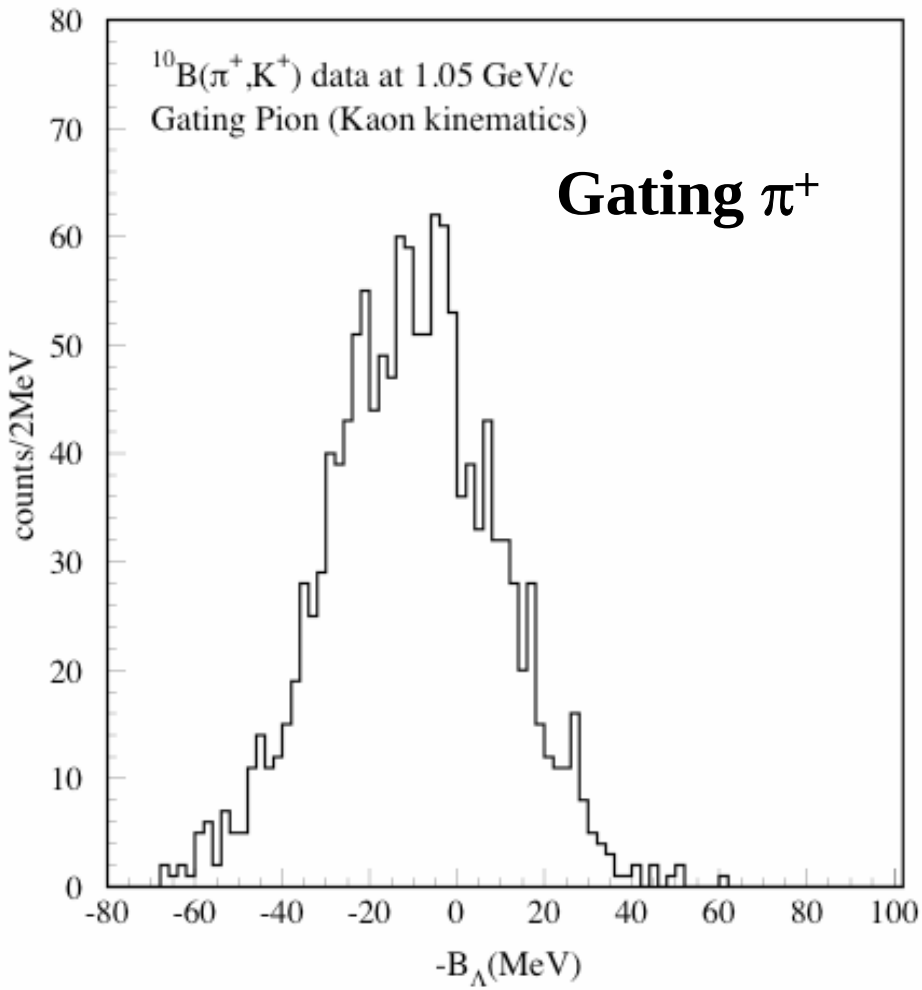
$\pi^-p \rightarrow \Sigma^- K^+$; $\Sigma^- p \rightarrow \Lambda + n$ process may have significant contribution!!

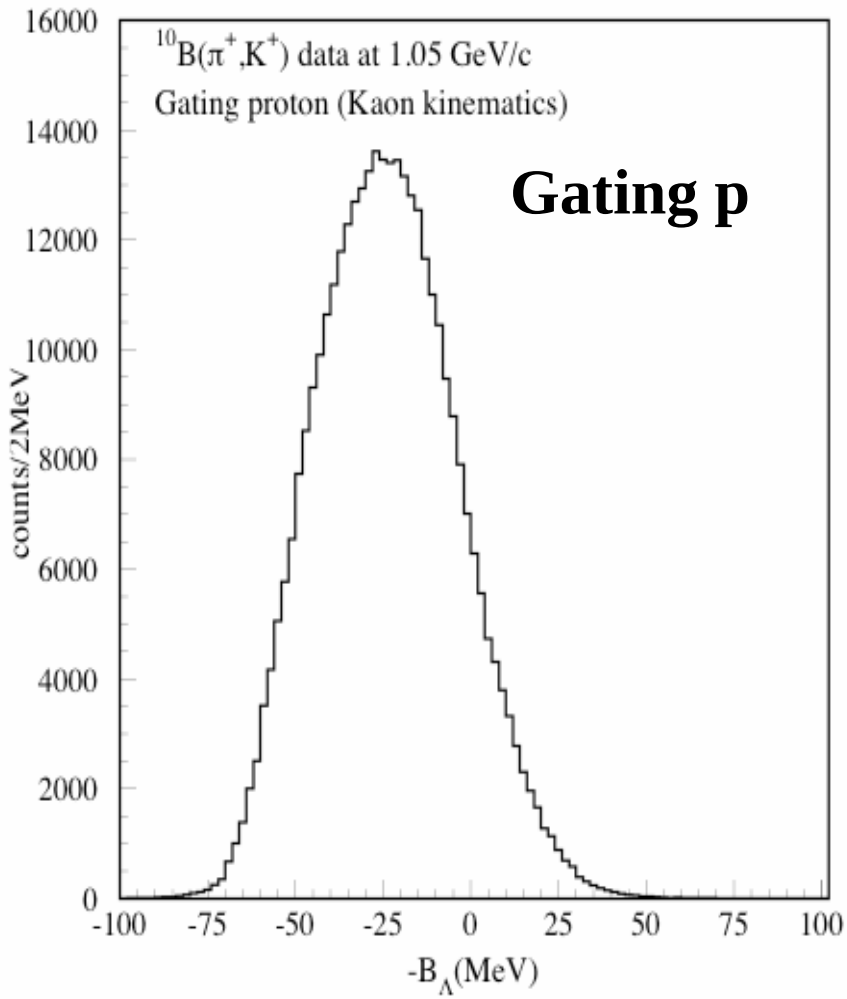
Detail calculations including structures of some several light Species are in progress by Akaishi group.

Please come to look at our poster by W. Imoto

$^{10}B(\pi^-,K^+)$ spectrum gating pion or kaon

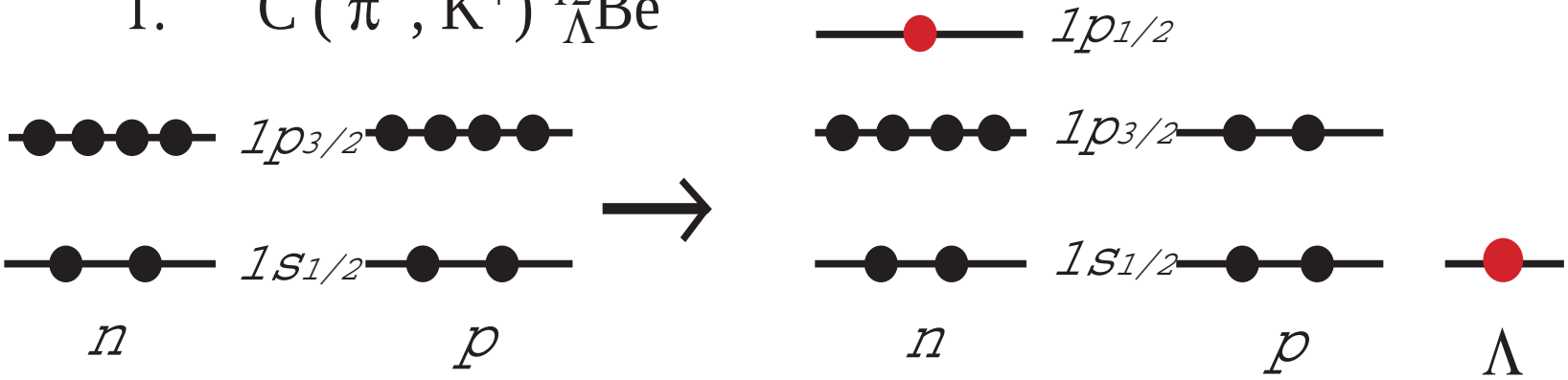
Year02 data





A demonstration about the reaction mechanism

1. $^{12}C\,(\pi^-, K^+)\,{}^{12}_{\Lambda}Be$



2. $^{10}B\,(\pi^-, K^+)\,{}^{10}_{\Lambda}Li$