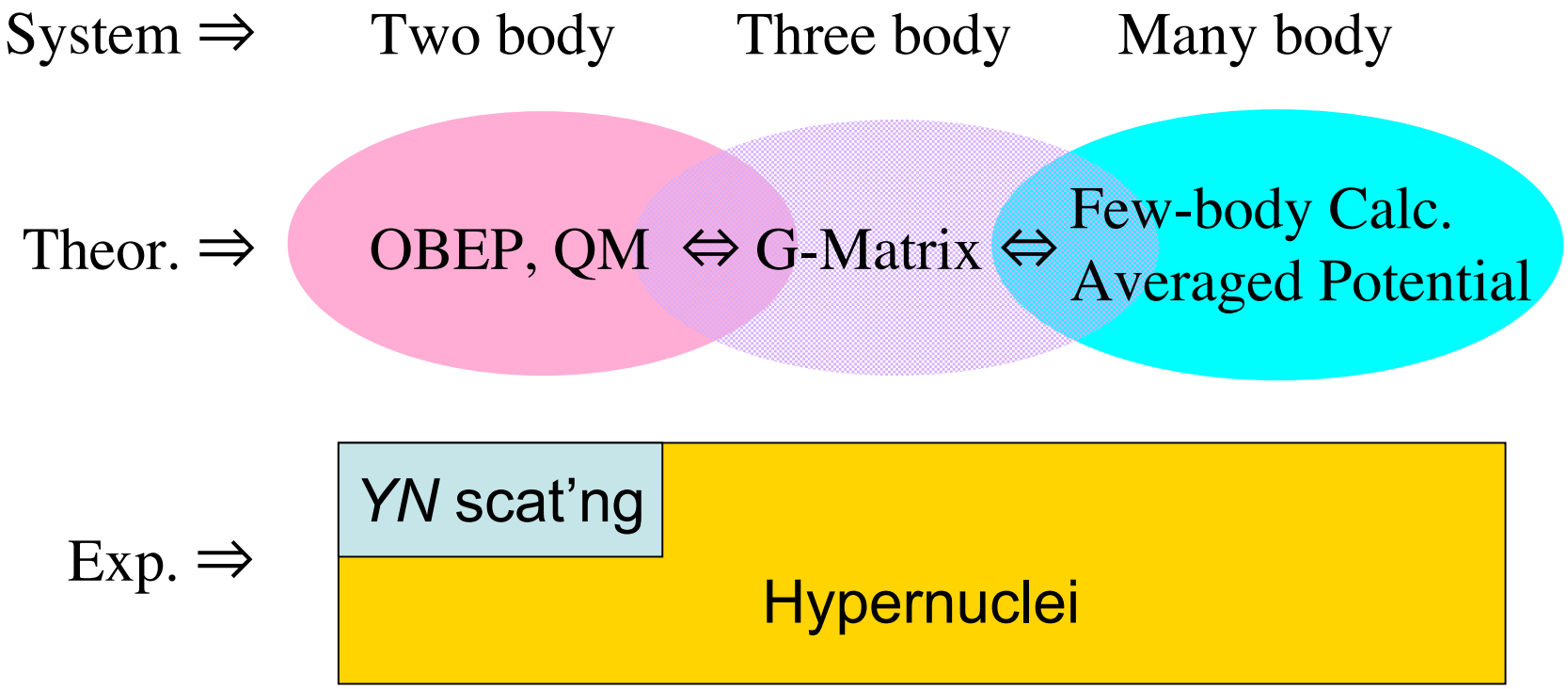
June 7-8, 2004
Seminar Hall, Bldg.4 KEK

KEK-PS External Review 2004
E438/E521

H. Noumi (KEK) for E438/E521

Importance of Hypernuclear Studies

⇒ In order to reveal *the Baryon-Baryon Interaction*



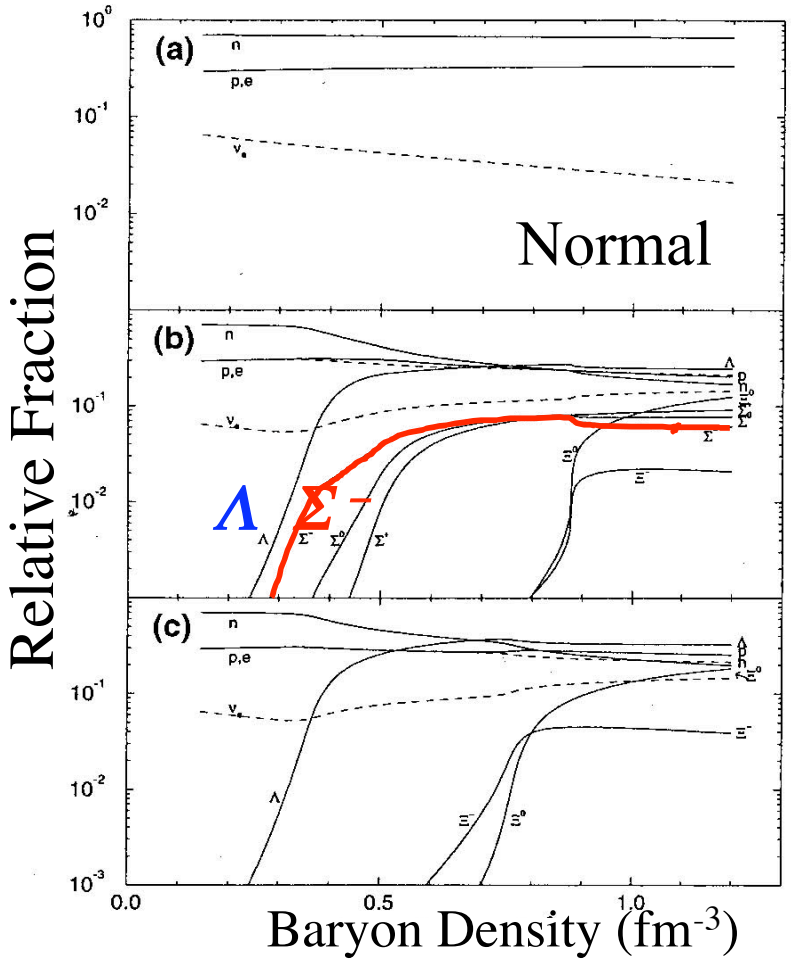
E438: Study of the Σ-Nucleus Potential

??Repulsive/Attractive? How Absorptive?

E521: Prod. of the neutron-rich Λ hypernuclei

Doorway to study the Λn Int.

the Coherent ΛN–ΣN coupling



$V_\Lambda \sim V_\Sigma$

V_Σ : repulsive

Roles of Hyperons in Neutron Star Cores

based on the YN/YY int. from hypernuclei

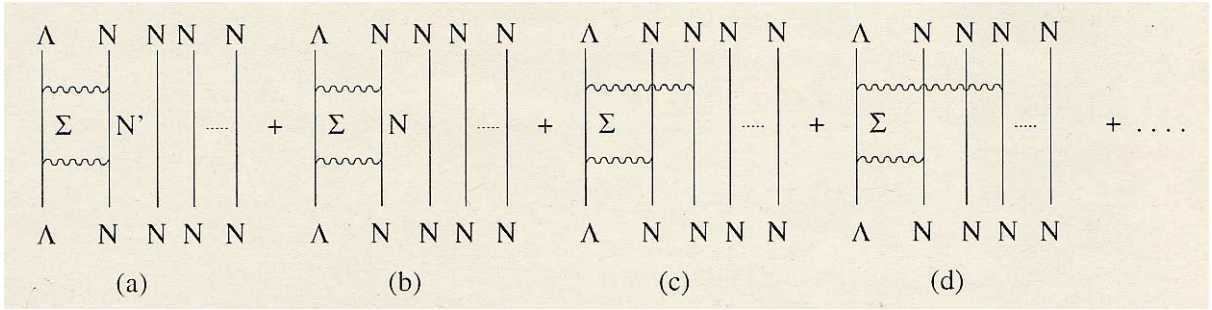
Maximal Mass<1.44M_{solar}

No Sigma Appears

S. Balberg and A. Gal, NPA625(1997)435

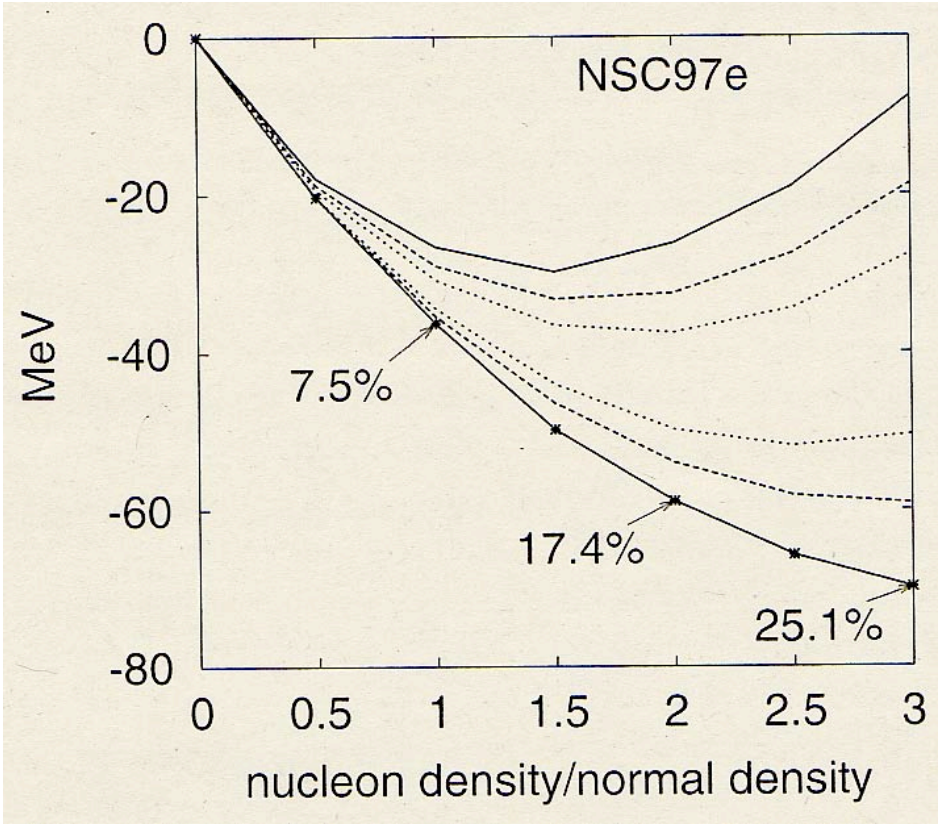
Role of the ΛN-ΣN coupling in Neutron Star Cores

S.Shinmura, K. S. Myint, T. Harada, and Y. Akaishi, J. Phys. G28(2002)L1



coherent $\Lambda \rightarrow \Sigma$
w/o exciting N
(b)~(d)…
No effect in T=0

Single-particle Λ potential in neutron matter ($T=\infty$)



p=0%
p=10%
p=20%

without coherent
ΛN-ΣN coupling

p=20%
p=10%
p=0%

with coherent
ΛN-ΣN coupling

P_{Σ^0} increases with ρ_N

E438

VOLUME 89, NUMBER 7 PHYSICAL REVIEW LETTERS 12 AUGUST 2002

Sigma-Nucleus Potential in $A = 28$

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(Received 16 December 2001; published 30 July 2002)

We have studied the (π^-, K^+) reaction on a silicon target to investigate the sigma-nucleus potential. The inclusive spectrum was measured at a beam momentum of 1.2 GeV/c with an energy resolution of 3.3 MeV (FWHM) by employing the superconducting kaon spectrometer system. The spectrum was compared with theoretical calculations within the framework of the distorted-wave impulse approximation, which demonstrates that a strongly repulsive sigma-nucleus potential with a nonzero size of the imaginary part reproduces the observed spectrum.

DOI: 10.1103/PhysRevLett.89.072301 PACS numbers: 21.80.+a, 13.75.Ev, 25.80.Hp, 25.80.Nv

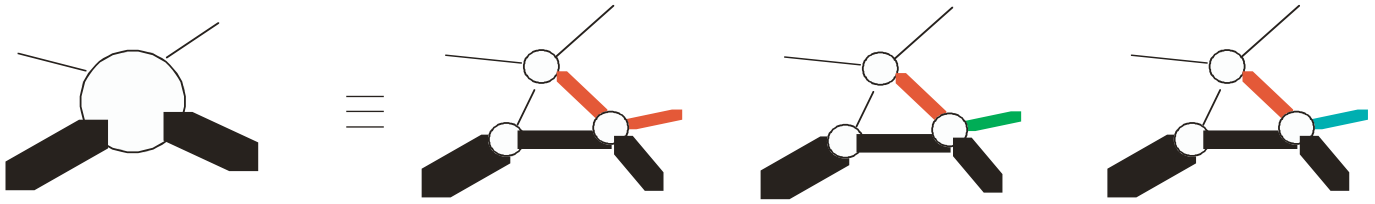
The sigma(Σ)-nucleus potential describe
of a Σ hyperon in the nuclear medium.
Σ-nucleus potential is still unclear becaus

Papers: published in PRL89(2002)072301
submitted to PRC/nucl-ex 0405031

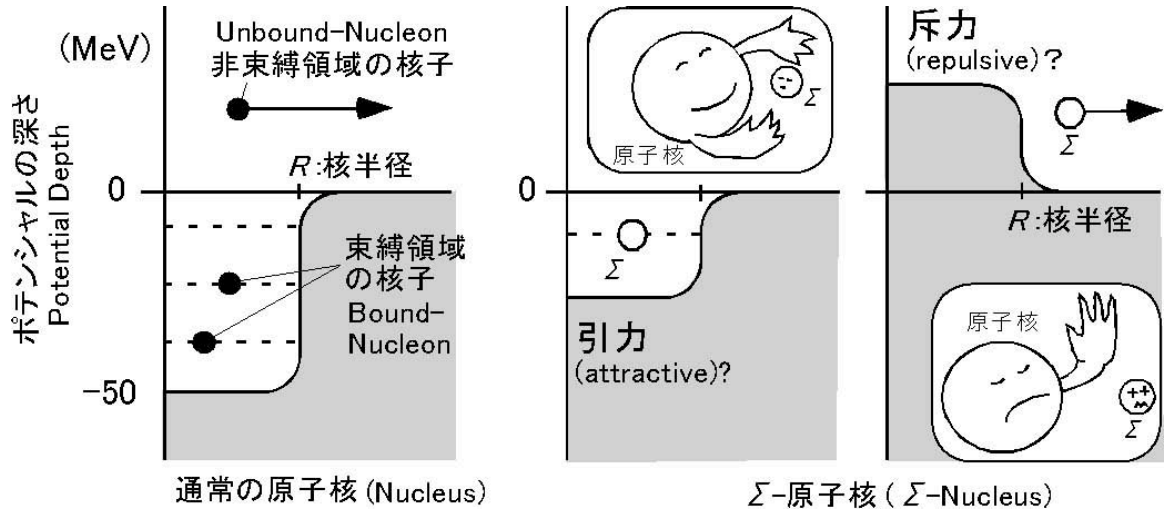
E438: Study of Σ-nucleus potential by the (π,K⁺) reaction on heavy nuclei

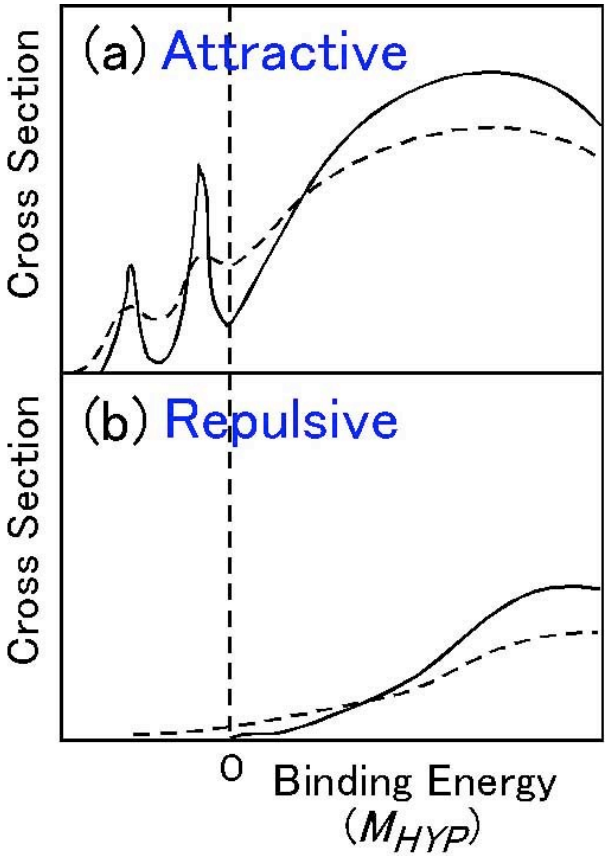
$U_\Sigma = V_\Sigma + i\,W_\Sigma$

No Σ-hypernuclear bound states, but ${}^{4}_{\Sigma}\mathrm{He}$



Inclusive spectrum tells the Σ potential…



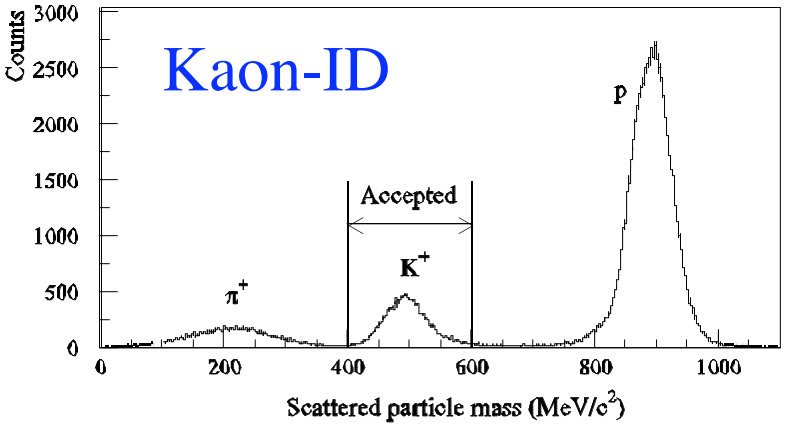


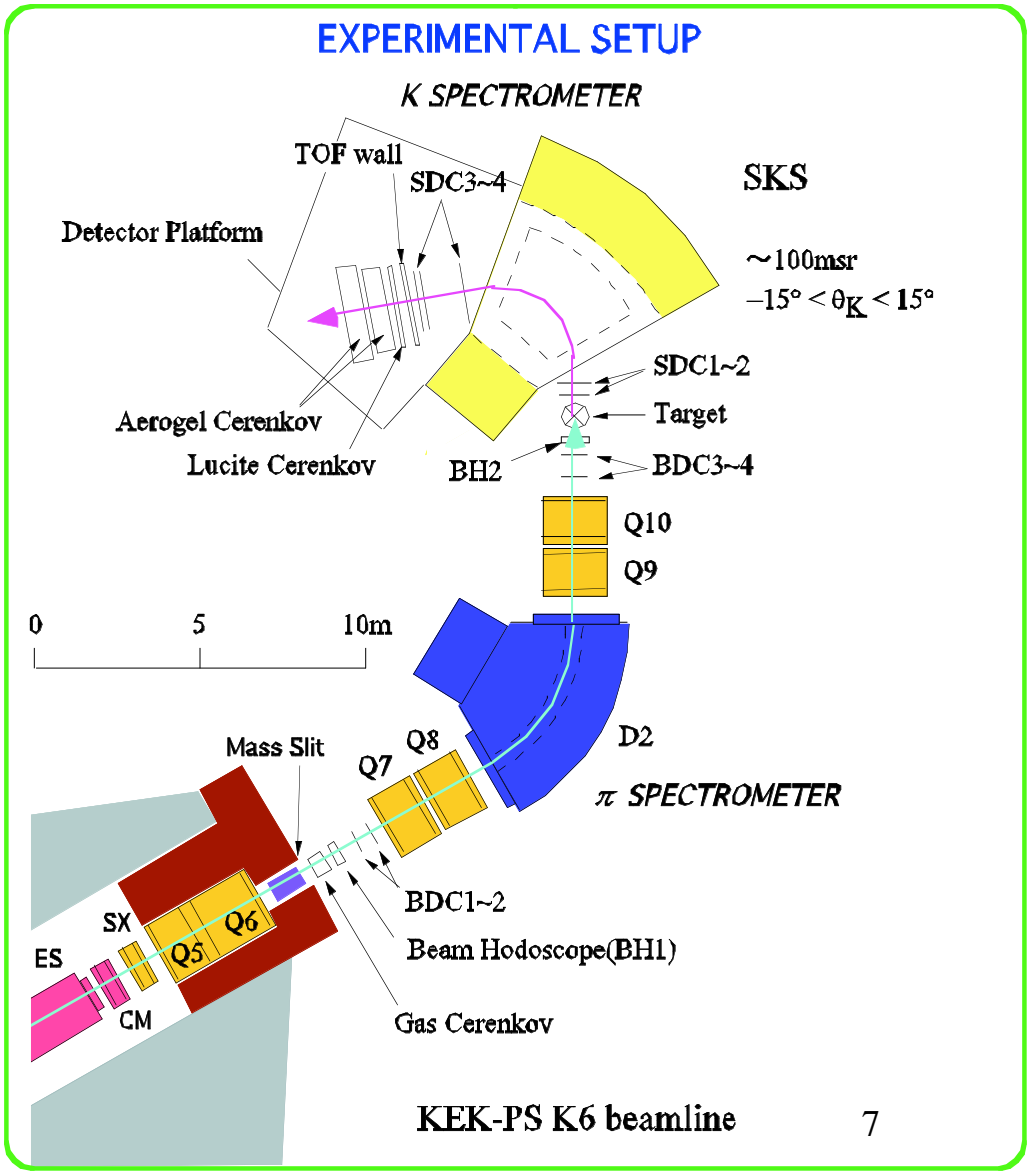
Inclusive (π^-,K^+) spectra at p_{beam}=1.2 GeV/c on CH_2, Si, Ni, In and Bi were measured at KEK-PS K6 with SKS in Oct. & Dec., 1999.

○Energy Resolutions
3.3~5.2 MeV (depend on t_{TGT})
maintain a sensitivity to W_Σ.

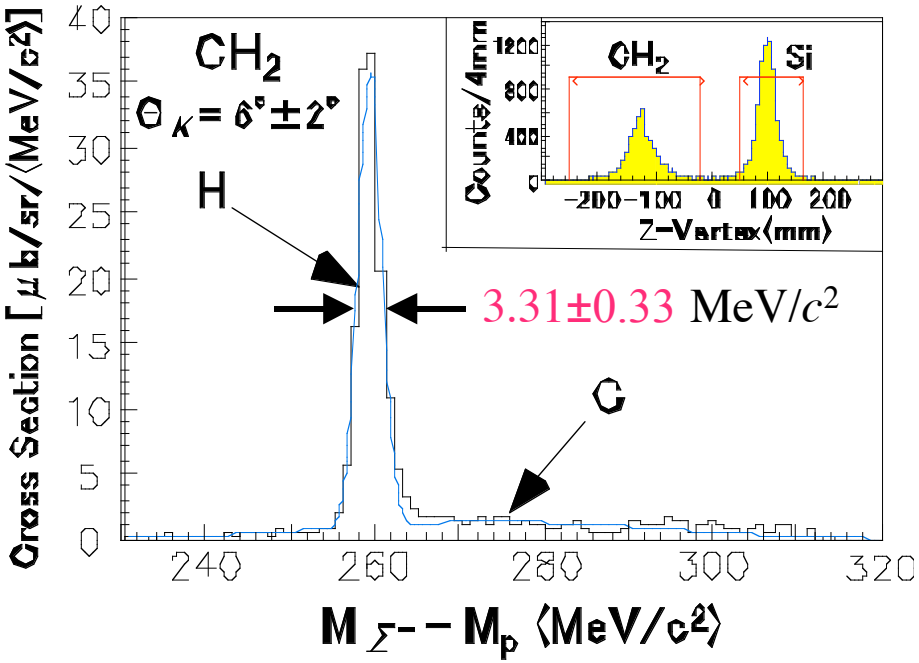
○Energy/Cross Section Scales
calibrated by $p(\pi^-,K^+)\Sigma^-$.

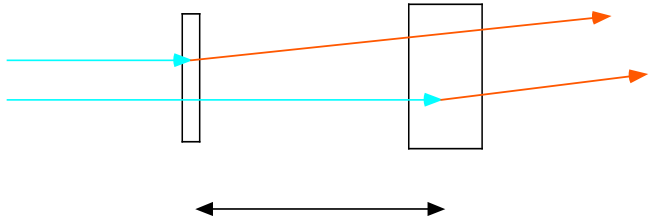
○Large Solid Angle
Wide Mom. Acceptance
covered by SKS.





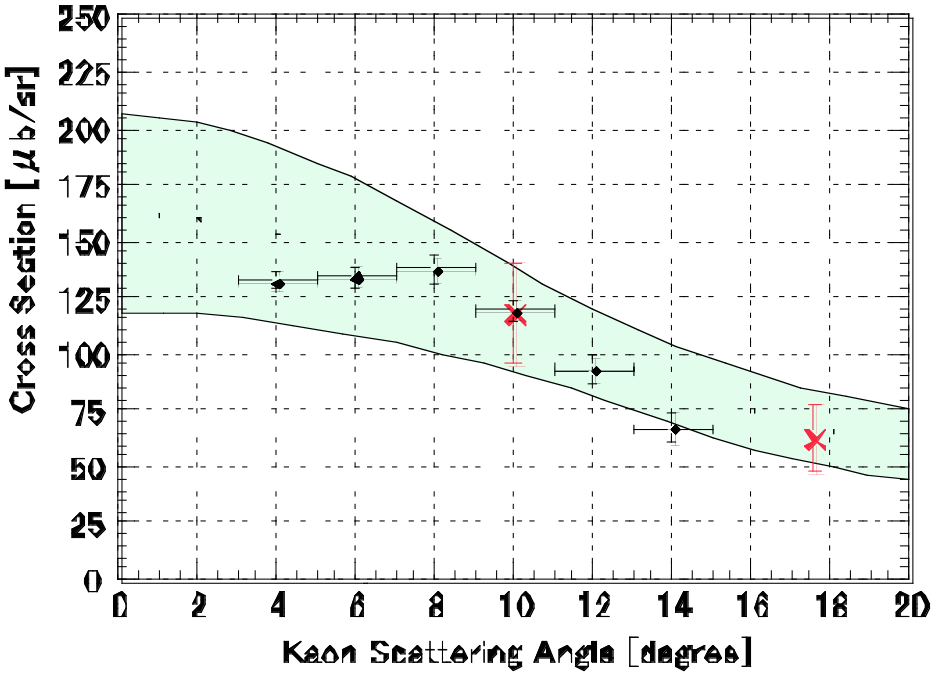
Energy Scale
Energy Resolution





Cross Section Scale

Angular Dist. of the $p(\pi,K^+)\Sigma^-$ Reaction



Present Data

Previous Data @ 1.225 GeV/c

(Curves: Error Boundary from the Legendre Poly. Fitting)

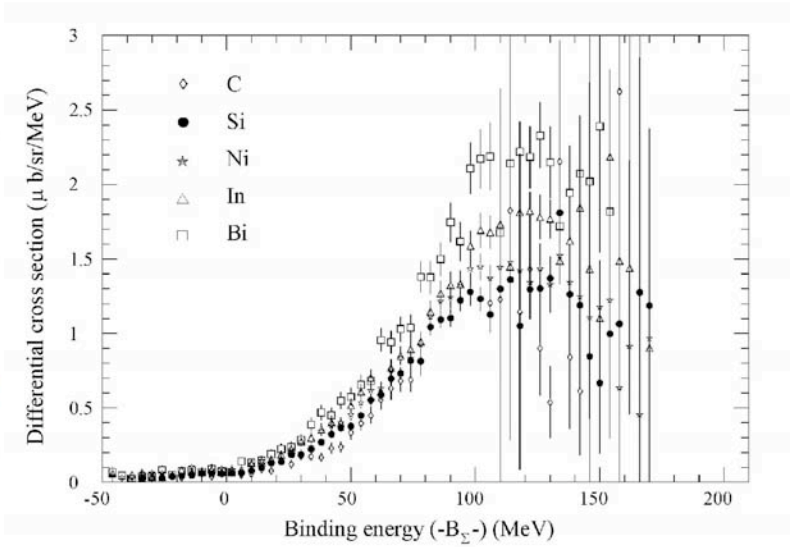
PR 183(1969)1142

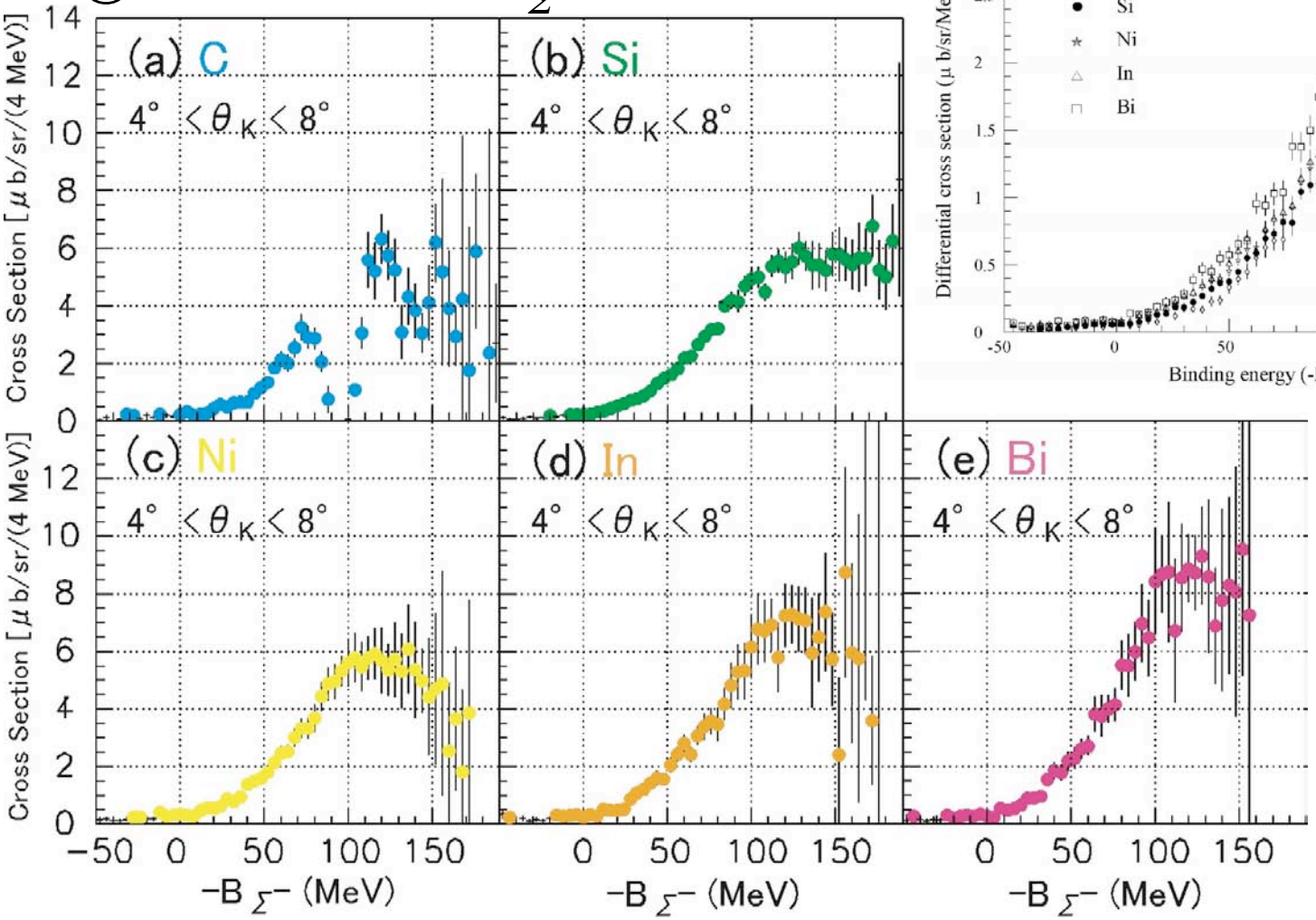
Measured Inclusive (π,K^+) Spectra on C, Si, Ni, In, & Bi

P. K. Saha et al., nucl-ex0405031/submitted to PRC

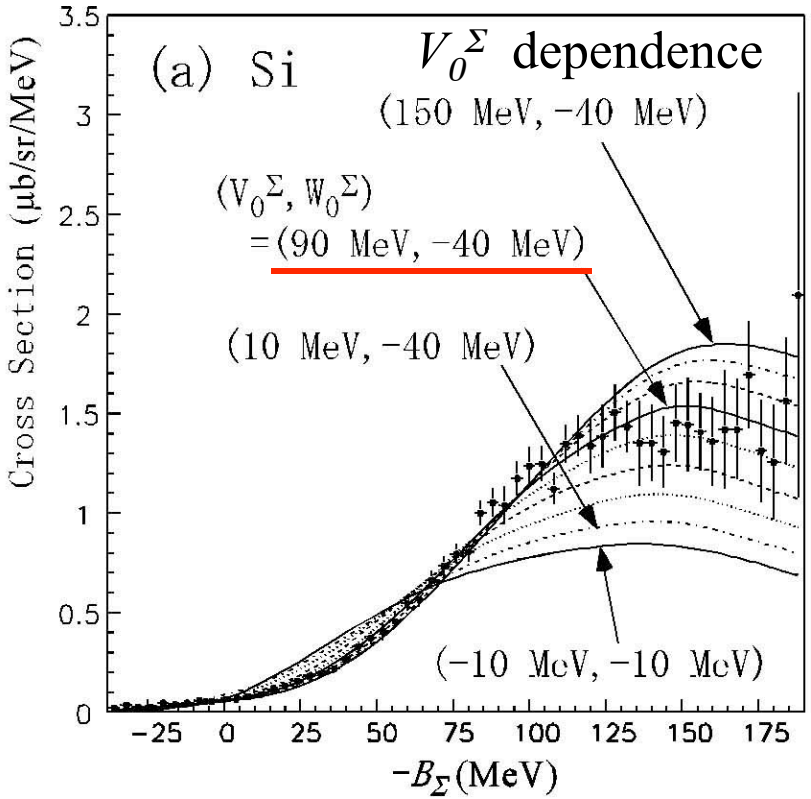
P. K. Saha, PhD thesis, KEK-Rep.2001-17

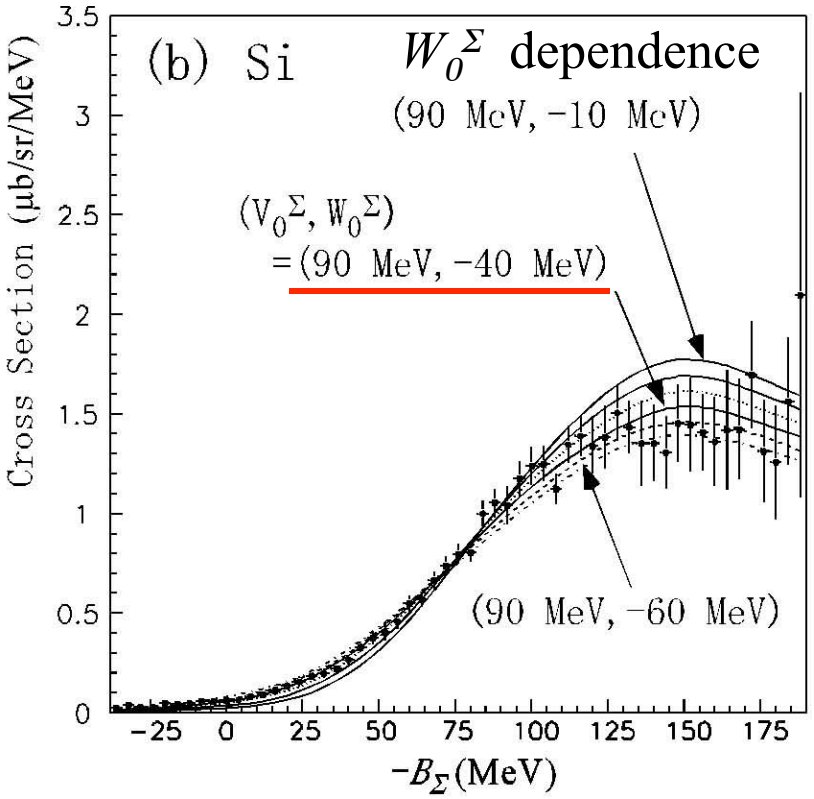
- ◯ Similar Shape
- ◯ No peak in $-B_\Sigma-$ <0 MeV
- ◯ Maximum @ $-B_\Sigma-$ >120 MeV



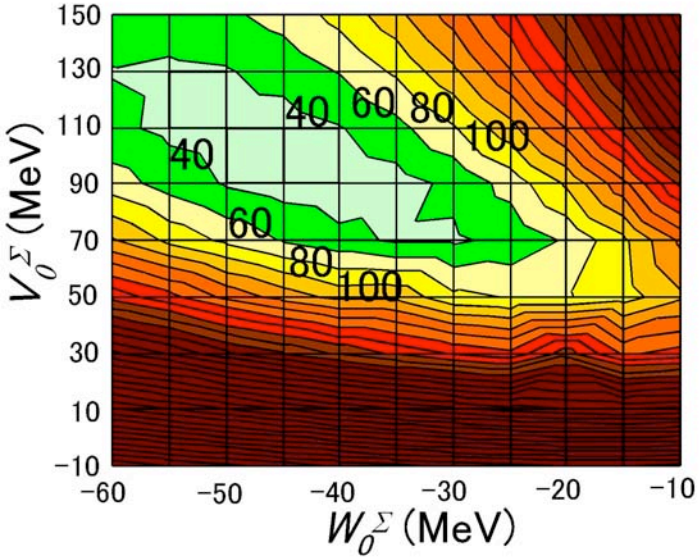


Compared with DWIA Cal. - Fitting Results -





χ^2 dist. (dof=56)



W.S. Potential Params

	U_Σ	U_{Si}
z(fm)	0.67	0.537
c(fm)	3.3	3.82
V0(MeV)		-54.5

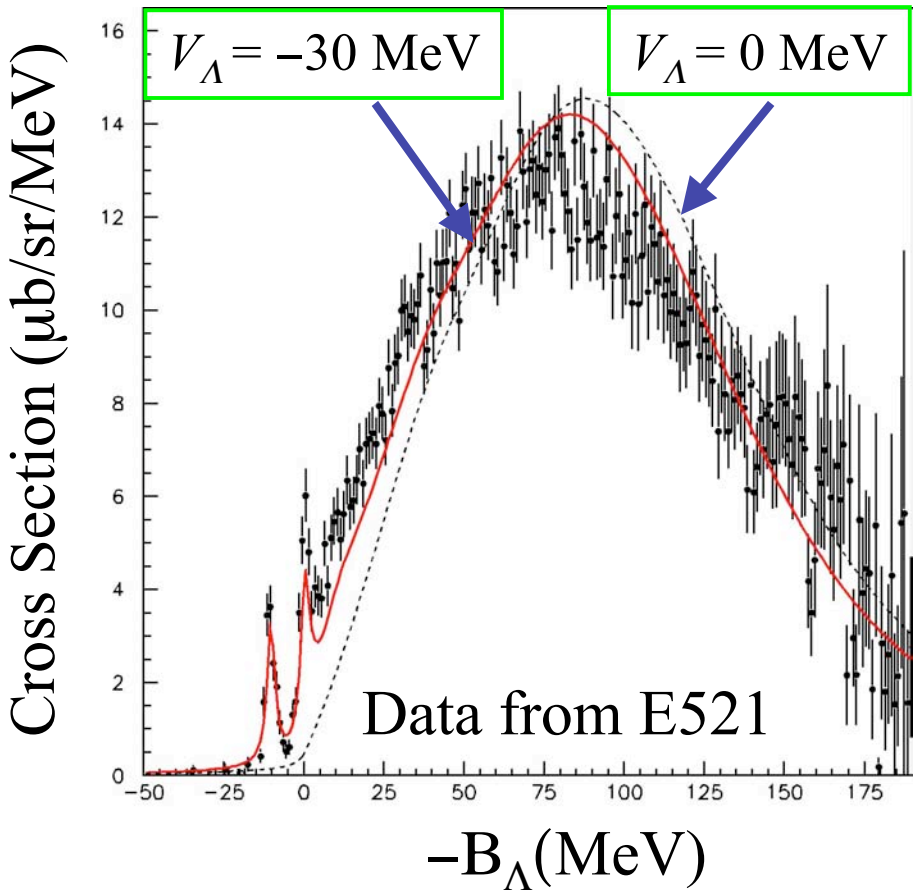
DWIA application to…

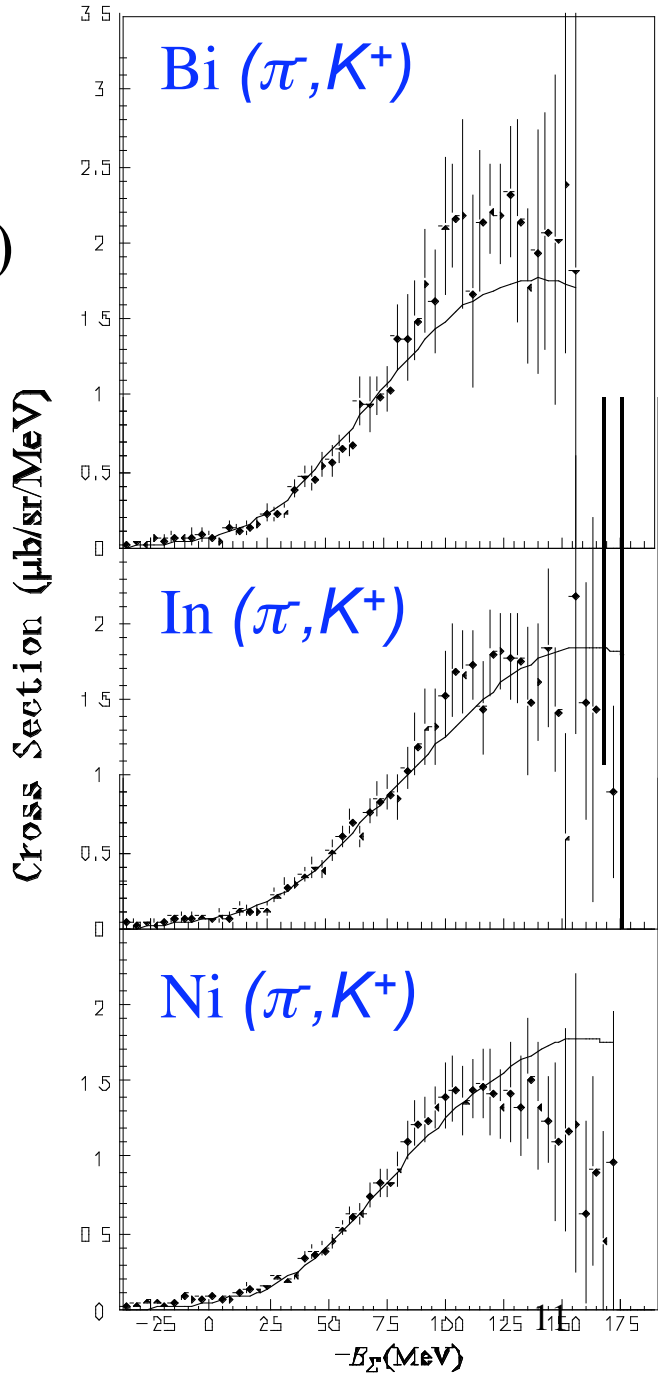
Ni, In, Bi(π^-,K^+)

w/ (V_0^Σ, W_0^Σ) = (90 MeV, -40 MeV)

^{12}C (π^+,K^+) at θ_K = 6°K2°

p_π=1.2 GeV/c





Concluding Remarks of E438

1. Inclusive (π^-,K^+) spectra on CH_2, Si, Ni, In, & Bi were measured with a good resolution (3~5 MeV in FWHM).
   - 1.1 The measured spectra show a similar shape.
   - 1.2 No peak structure in the bound region
   - 1.3 The maximum at $-B_{\Sigma^-}$ >120 MeV

2. The measured spectra on Si, Ni, In, & Bi were compared to calculated ones within the framework of the DWIA.
   - 2.1 A repulsive Σ^--nucleus potential with a non-zero size of the imaginary part was required to reproduce the measured (π^-,K^+) spectra in shape.
   - 2.2 This framework was successfully applied to reproduce the ($\pi^\pm$,$K^\pm$) spectrum on C.

E521

Draft: preparation for publication

Neutron-rich Λ hypernuclear production by the (π^-, K^+) double charge-exchange reaction

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[10]*RIKEN, Wako, Saitama 351-0198, Japan*

In order to produce a neutron-rich Λ hypernucleus for the first time, we carried out an experiment by utilizing the (π^-, K^+) double charge-exchange reaction on a ^{10}B target. We observed the production of a $^{10}_{\Lambda}$Li hypernucleus, but the production rate is found to be smaller than expected from a theoretical calculation based on a two-step mechanism with the meson charge-exchange.

PACS numbers:

I. INTRODUCTION

Studies of Λ hypernuclei have been extensively done by using the (K^-, π^-) or (π^+, K^+) reaction on various targets [1–4], which give information concerning the ΛN process via a Σ^- admixture in the Λ hypernuclear state due to the $\Sigma^- p \leftrightarrow \Lambda n$ coupling. Recently, there has been a theoretical calculation concerning both mechanisms on some light nuclear targets, where the two-step mechanism is found to be more dominant as compared to the single-

E521: Production of neutron-rich Λ hypernuclei by the (π^-,K^+) double-charge-exchange reaction

A pilot experiment for spectroscopic studies of
the neutron-rich Λ hypernuclei via the (π^-,K^+) reaction

Production cross section/ Background (sensitivity)
⇒ Understanding of the Reaction Mechanism

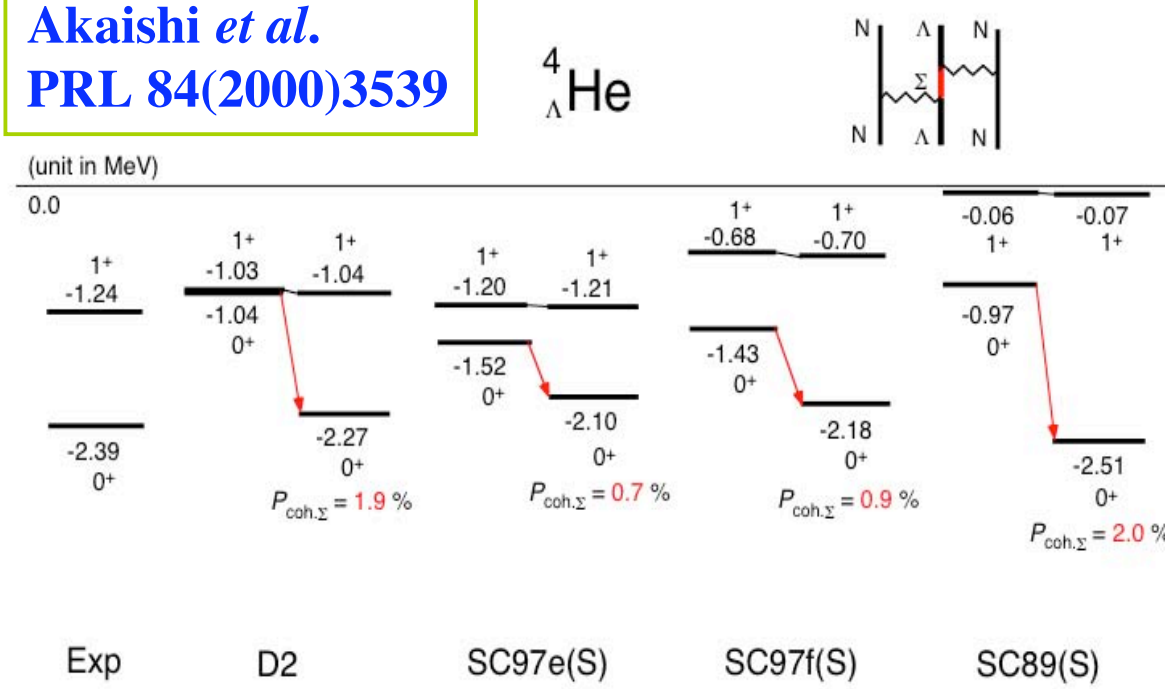
If it is promising,
one can study…

the *Λn* interaction

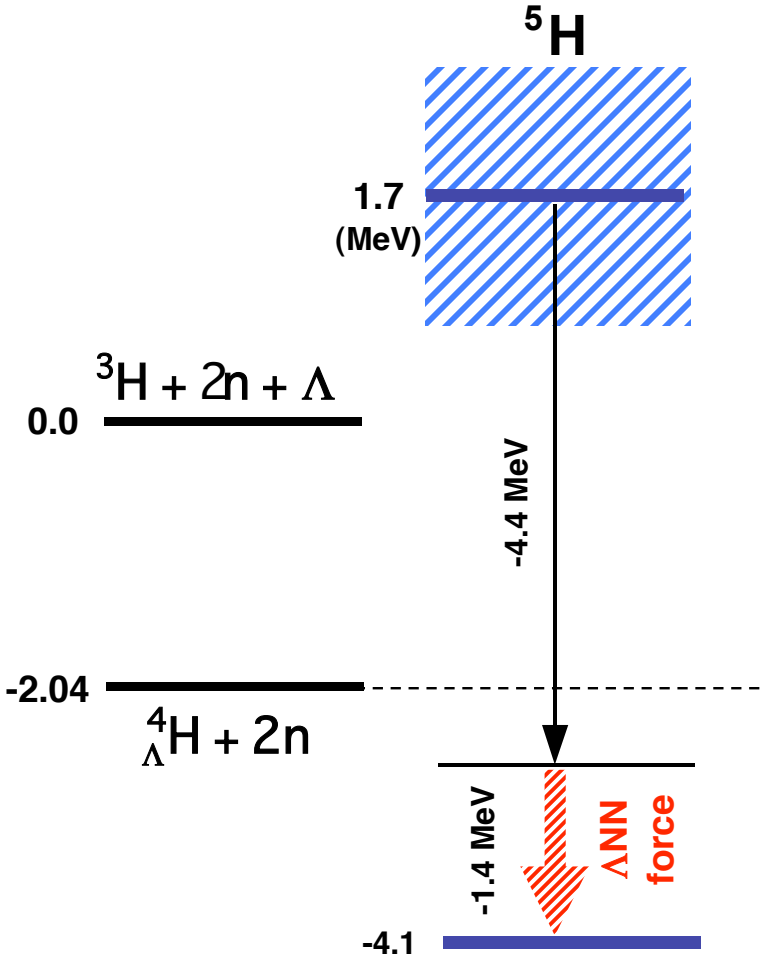
the Coherent
Λ–Σ coupling

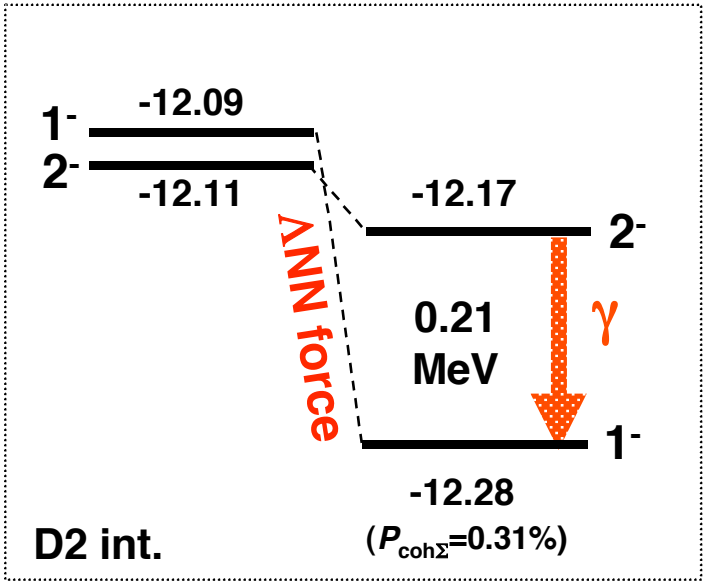
… exploring largely
neutron-excess
Λ hypernuclei

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



Superheavy hydrogen





$^{10}_{\Lambda}$Li

^{6}Li (π^-, K^+) $^{6}_{\Lambda}$H

"Hyperheavy hydrogen"

Reaction mechanism and the theoretical calculation

Tretyakova, Akaishi et al.

1. Single-step process:

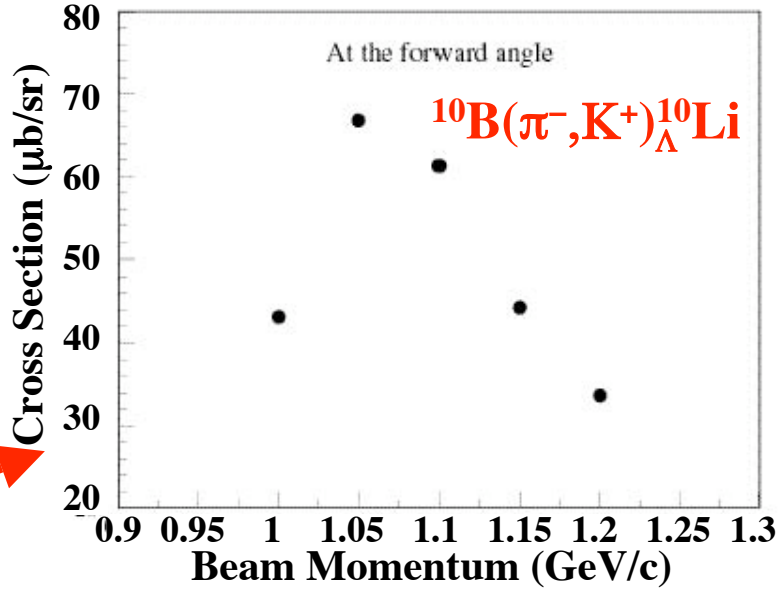
By the $\pi^- p \rightarrow \Sigma^- K^+$ via a small admixture of the Σ^- state due to the $\Sigma^- p \leftrightarrow \Lambda n$ coupling.

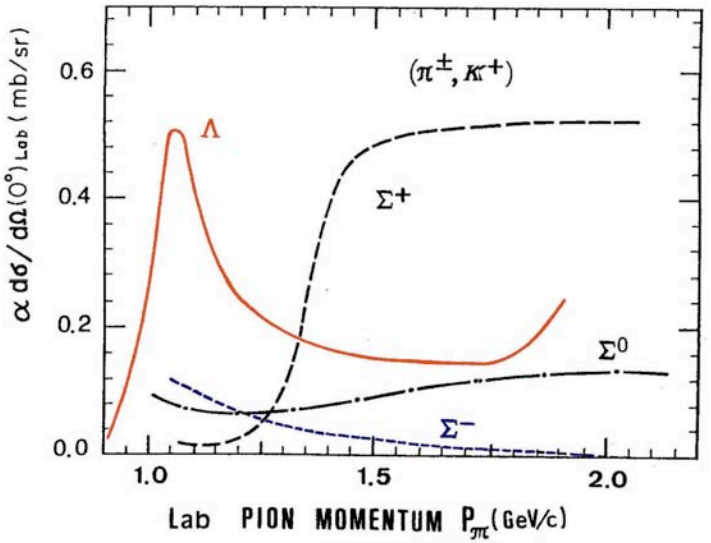
2. Two-step process:

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

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

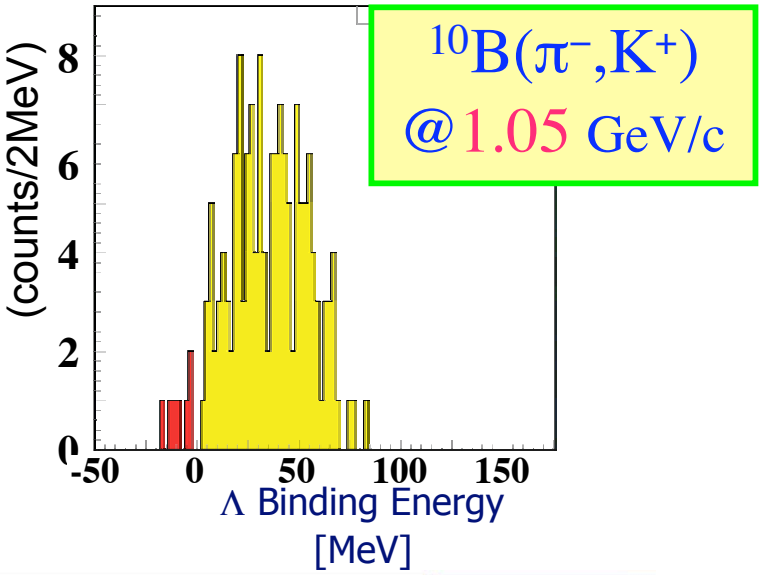
$\pi^- p \rightarrow \Sigma^- K^+$; $\Sigma^- p \rightarrow \Lambda + n$

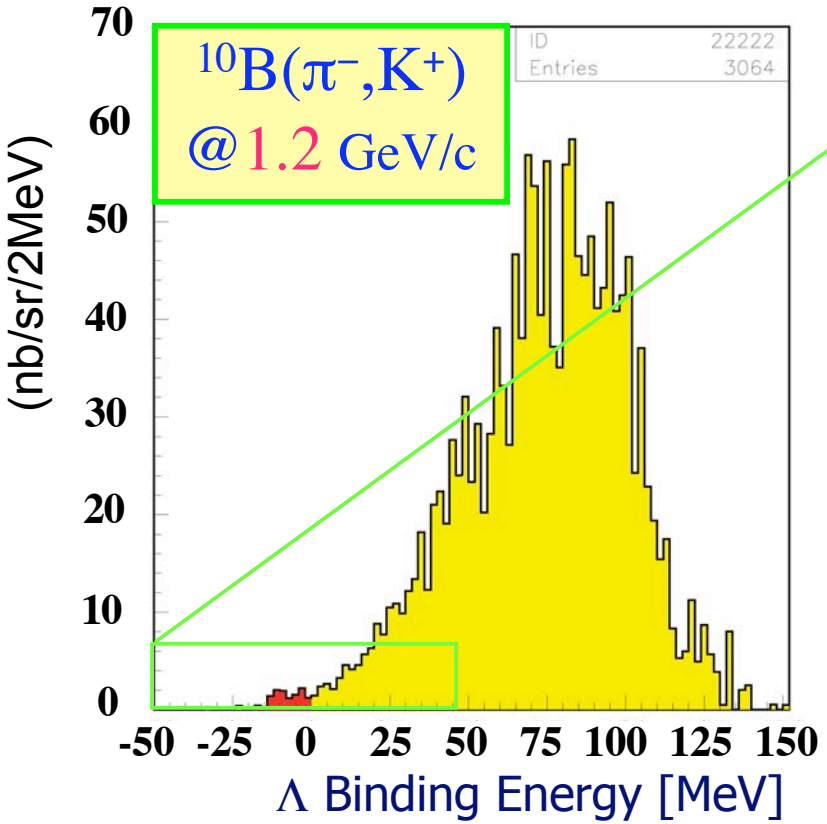


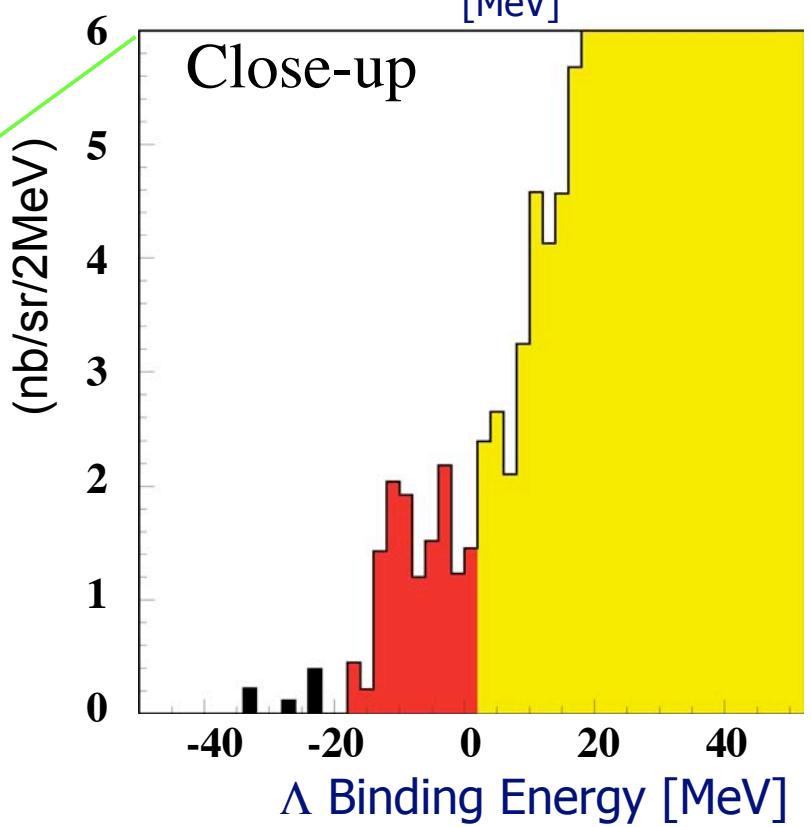


Experiemntal Results

- Background-Free
- $^{10}_{\Lambda}$Li Observed Clearly







Ratio of the Λ production cross section
(π^-,K^+) to (π^+,K^+)

Beam mom. (GeV/c)	Target	Reaction	Cross section(μb/sr) $-15<-B_\Lambda<0.$	Ratio
1.05	^{12}C	(π^+,K^+)	16.0	1
1.20	^{12}C	(π^+,K^+)	18.0	1.1
1.20	^{12}C	(π^-,K^+)	0.007	0.43×10^{-3}
1.05	^{10}B	(π^+,K^+)	7.80	1
1.20	^{10}B	(π^+,K^+)	no data	
1.20	^{10}B	(π^-,K^+)	0.0122	1.56×10^{-3}

Summary of $^{10}_{\Lambda}$Li experiment

- We have observed $^{10}_{\Lambda}$Li bound state for the first time.
- No distinct peak → statistics and/or nuclear structure
- Cross section
  - ~ 10^{-3} as compared to (π^+,K^+) reaction (having a good sensitivity)
  - ~ twice larger @ 1.2 GeV/c than @1.05 GeV/c
  - about <u>one order smaller</u> than a theoretical estimate with a two-step meson charge-exchange process
    --> a Σ^- production, Σ^-p -> Λn process may contribute

To J-PARC

At present at KEK,
no plan for extensions/new proposals concerning E438/E521

→ J-PARC (LoI-08/09)

On-going experiments at KEK-PS (till shutdown)

E548 (T. Kishimoto et al.) @ K2
E549 (M. Iwasaki et al.) @ K5
E559 (K. Imai et al.) @ K6
…

Other Activities (including potential activities)

at J-Lab., FINUDA, SPring8, RCNP, JAERI, …

R&D works for J-PARC experiments (spectrometers, detectors…)

LoI-06, 08, 09, 10, 21 (Strangeness Nuclear Physics)

J-PARC is strongly awaited.