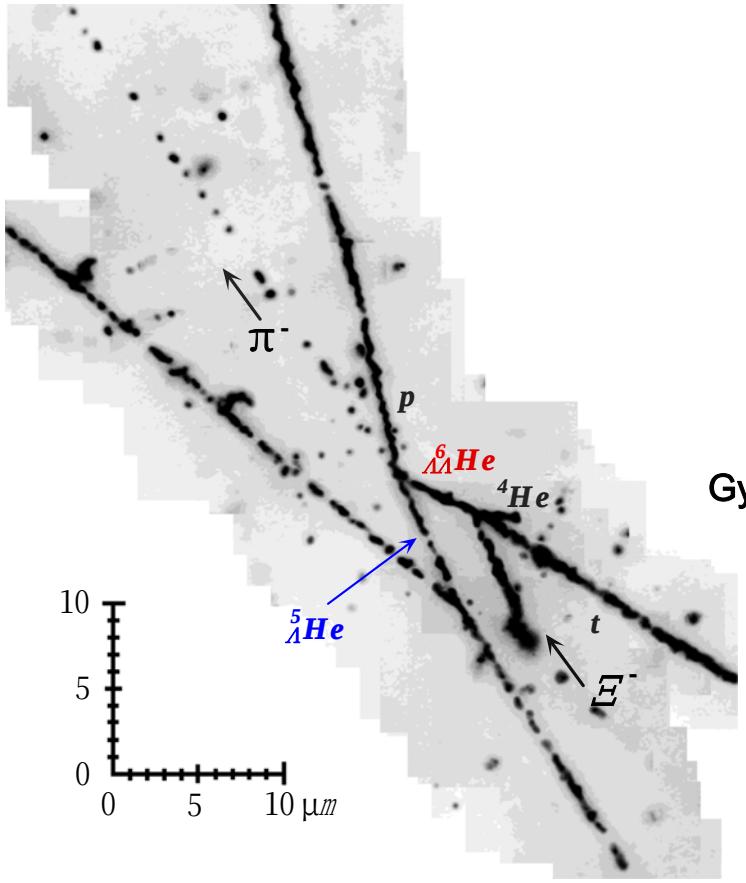
Jun.30,2006
J-PARC.PAC

Systematic Study of Double Strangeness System with an Emulsion-Counter Hybrid Method

NAGARA event (KEK-E373)



Kyoto: E.Hayata, M.Hayata, M.Hirose, K.Imai, S.Kamigaito, N.Saito, K.Tanida, M.Togawa, T.Tsunemi, C.J.Yoon

Gifu: M.Kawasaki, H.Nakamura, K.Nakazawa, K.T.Tint, T.Watanabe

Tohoku: K.Hosomi, T.Koike, Y.Ma, K.Shirotori, H.Tamura, M.Ukai

AMU: R.Hasan

BNL: R.E.Chrien

CIAE: Y.Y.Fu, C.P.Li, Z.M.Li, J.Zhou, S.H.Zhou, L.H.Zhu

Chonnam: J.Y.Kim

Dongshin: M.Y.Pac

Fukui: T.Yoshida

Gyeongsang: K.S.Chung, S.H.Kim, J.S.Song, C.S.Yoon

KEK: M.Ieiri, H.Noumi, M.Sekimoto, H.Takahashi

Nagoya: K.Hoshino, T.Kawai, B.D.Park, T.Sato, T.Watabe

NIRS: N.Yasuda

OsakaCity: K.Yamamoto

Pusan: J.K.Ahn, S.Y.Ryu

Toho: C.Fukushima, M.Kimura, S.Ogawa, H.Shibuya

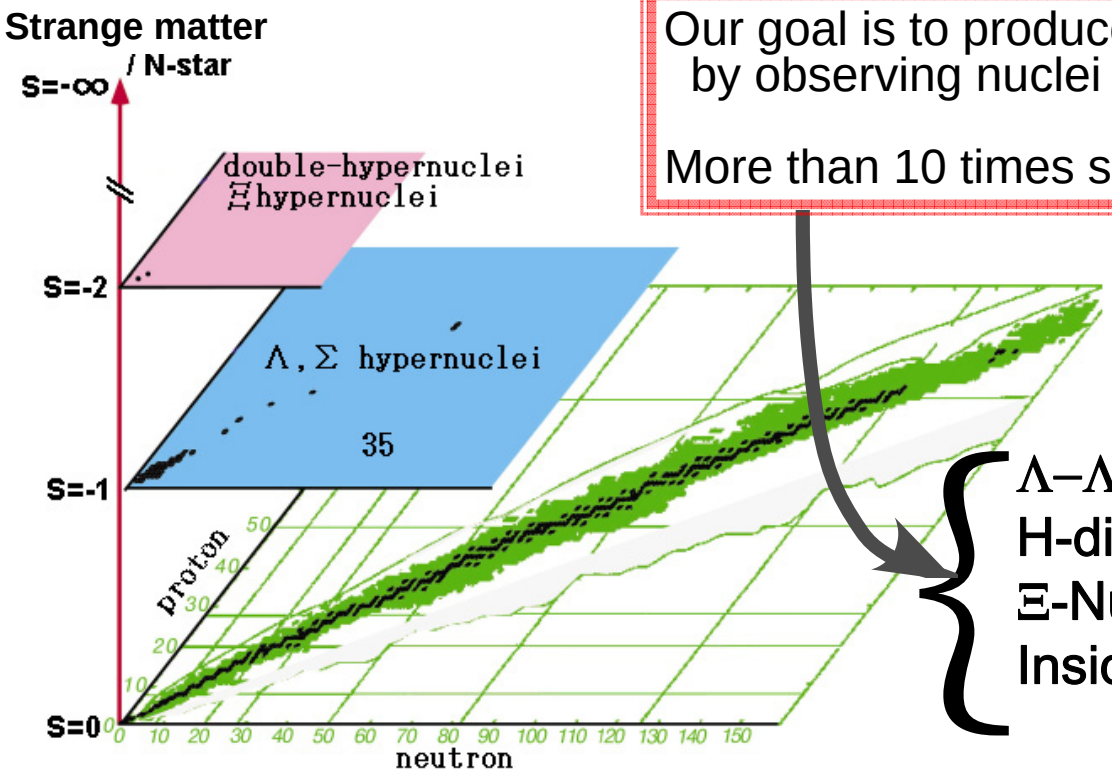
UCL: D.H.Davis, D.Tovee

U.Houston: Ed.Hungerfold

U.New-Mexico: B.Bassalleck

Motivation of the proposed experiment

* detection of 10^2 or more candidate events with S = –2,
→ Discovery of 10 or more nuclear species.



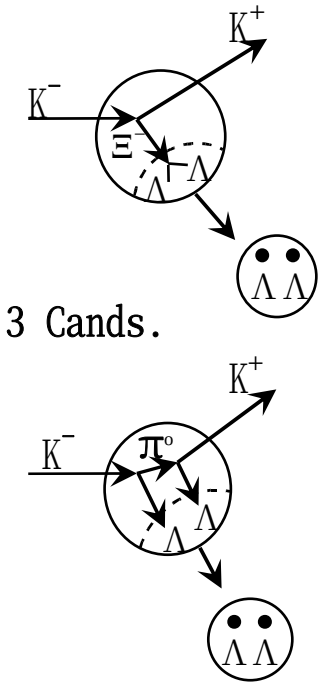
Our goal is to produce a S=-2 nuclear chart,
by observing nuclei with S=-2 as many as possible.

More than 10 times statistics than previous E373.

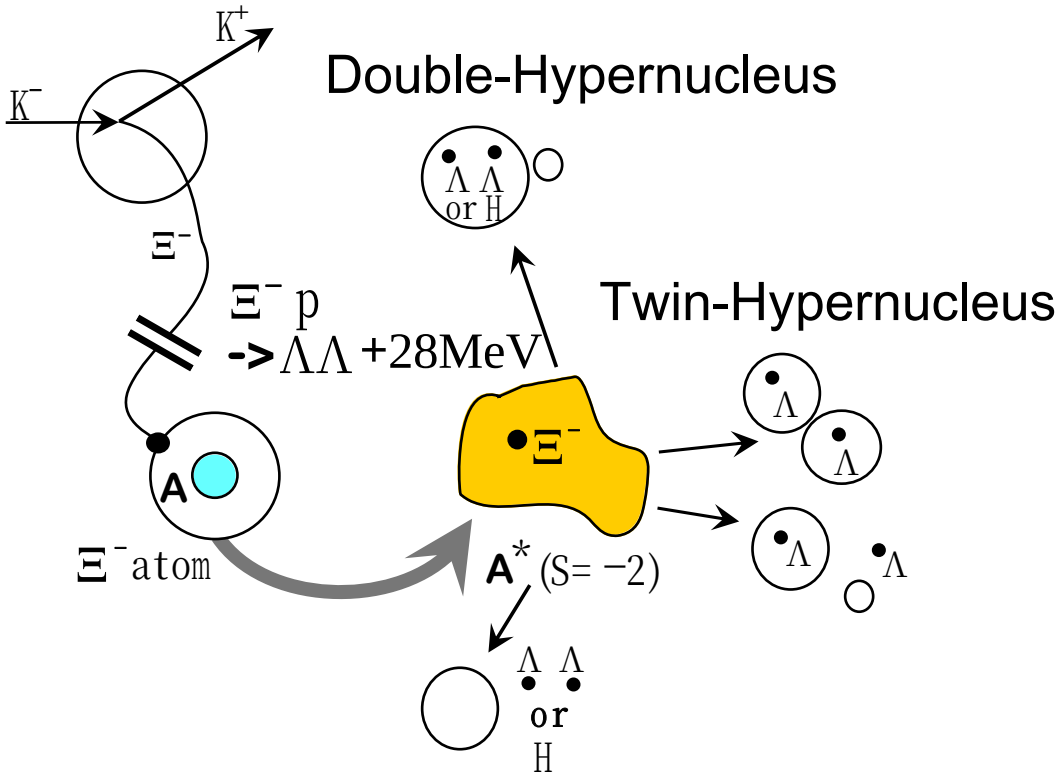
Λ–Λ Interaction,
H-dibaryon,
Ξ-Nucleus Interaction,
Inside Neutron Stars (Quark-star?)

How to produce S=-2 Systems

- **Direct process**



- **via Ξ atom (KEK-E373)**



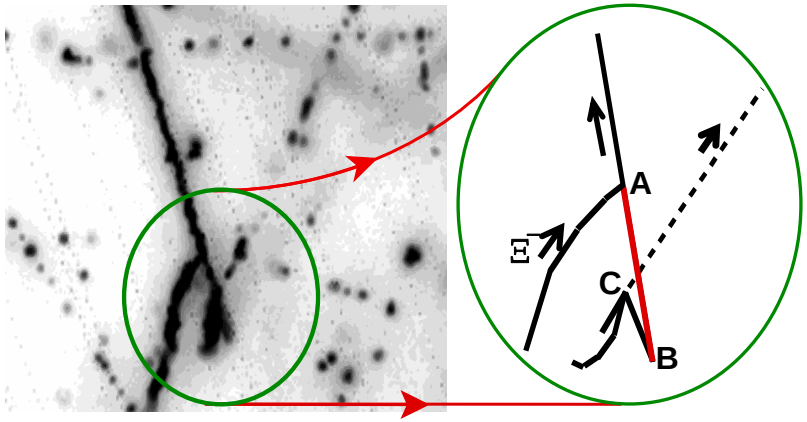
Double-Hypernuclei found by KEK-E373

- **47** single-hypernuclear events
  - ➔ ~ **600** events Ξ^- capture at rest
- 6 double-hypernuclei
- 2 twin-hypernuclei
- 1 Σ^-emission

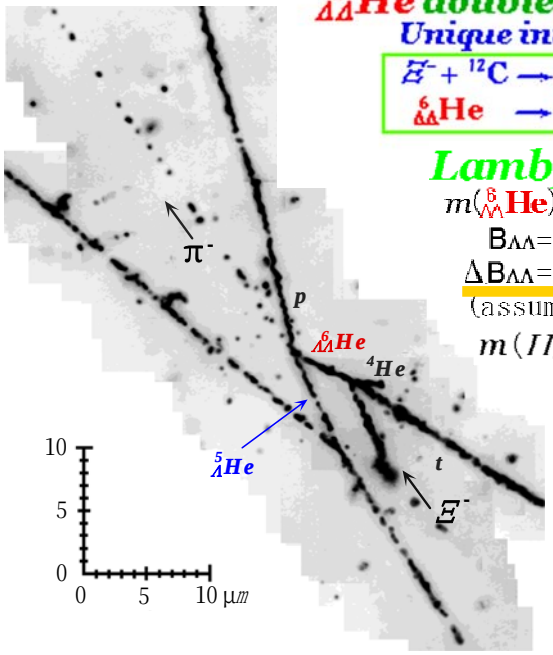
Demachi-yanagi event

* two body case at point A
$\Xi^- + {}^{12}C \rightarrow {}^{10}_{\Lambda\Lambda}Be + t$ or ${}^{10}_{\Lambda\Lambda}Be^* + t$

* three body case at point A
$\Xi^- + {}^{14}N \rightarrow {}^{13}_{\Lambda\Lambda}B + p + n$



NAGARA event



${}^{6}_{\Lambda\Lambda}He$ double-hypernucleus
Unique interpretation!!

$\Xi^- + {}^{12}C \rightarrow {}^{6}_{\Lambda\Lambda}He + {}^{4}He + t$
${}^{6}_{\Lambda\Lambda}He \rightarrow {}^{5}_{\Lambda}He + p + \pi^-$

Lambpha 87, 212502(2001)

$m({}^{6}_{\Lambda\Lambda}He) - 5951.82 + 0.54$MeV
$B_{\Lambda\Lambda} = 7.25 \pm 0.19^{+0.18}_{-0.11}$MeV
$\Delta B_{\Lambda\Lambda} = 1.01 \pm 0.20^{+0.18}_{-0.11}$MeV
(assumed $B_{\Xi^-} = 0.13$ MeV)
$m(H) \geq 2223.7$ MeV/c^2
(90% C.L.)

$\Delta B_{\Lambda\Lambda}$: $\Lambda\Lambda$ Interaction Energy

$$\Delta B_{\Lambda\Lambda} = B_{\Lambda\Lambda}({}_{\Lambda\Lambda}{}^{A}{}_{\Lambda}Z) - 2B_{\Lambda}({}^{A-1}{}_{\Lambda}Z)$$

Found

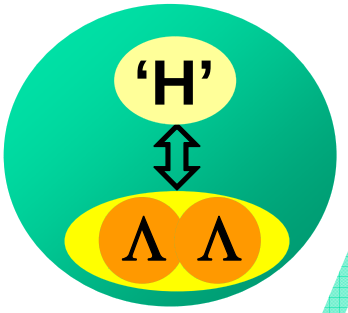
Weakly attractive $\Lambda\Lambda$ Interaction *!*

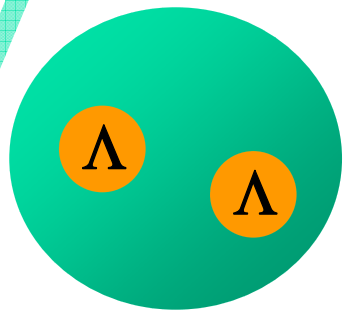
Hybrid Method ==> Reliable

$\Delta B_{\Lambda\Lambda}$ & nuclear structure

S=-2 nuclear system

$\Delta B_{\Lambda\Lambda}$
may **NOT depend** on **A**

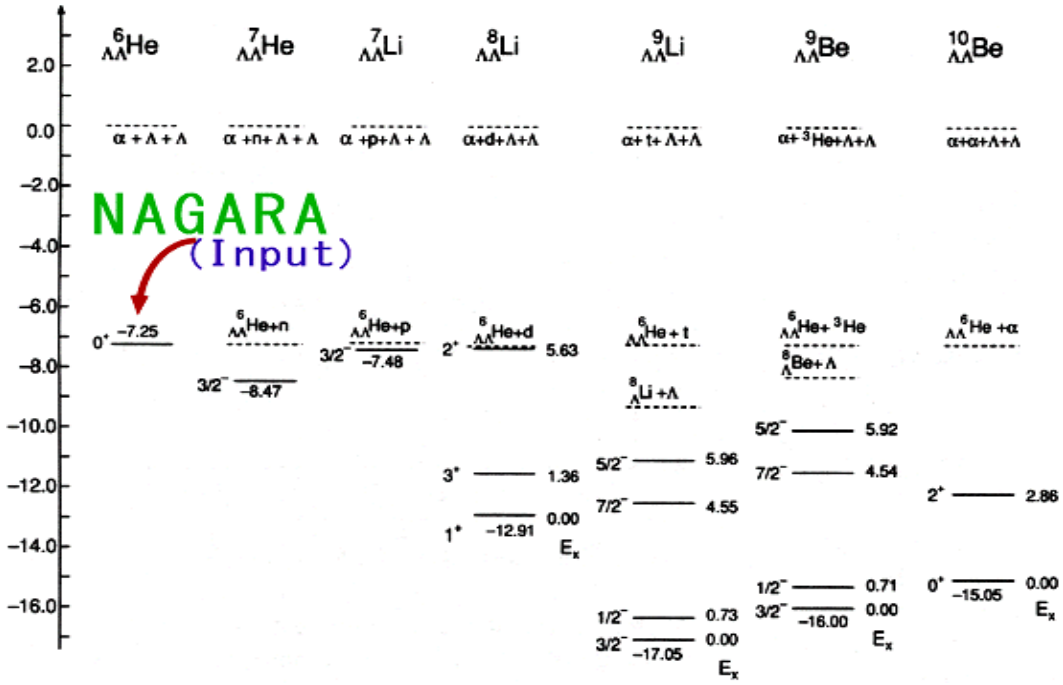




$\Delta B_{\Lambda\Lambda}$
depends on **A**

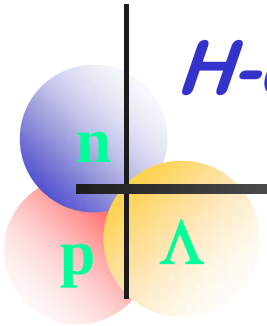
Theoretical prediction

HIYAMA, KAMIMURA, MOTOBA, YAMADA, AND YAMAMOTO
PHYSICAL REVIEW C 66, 024007 (2002)



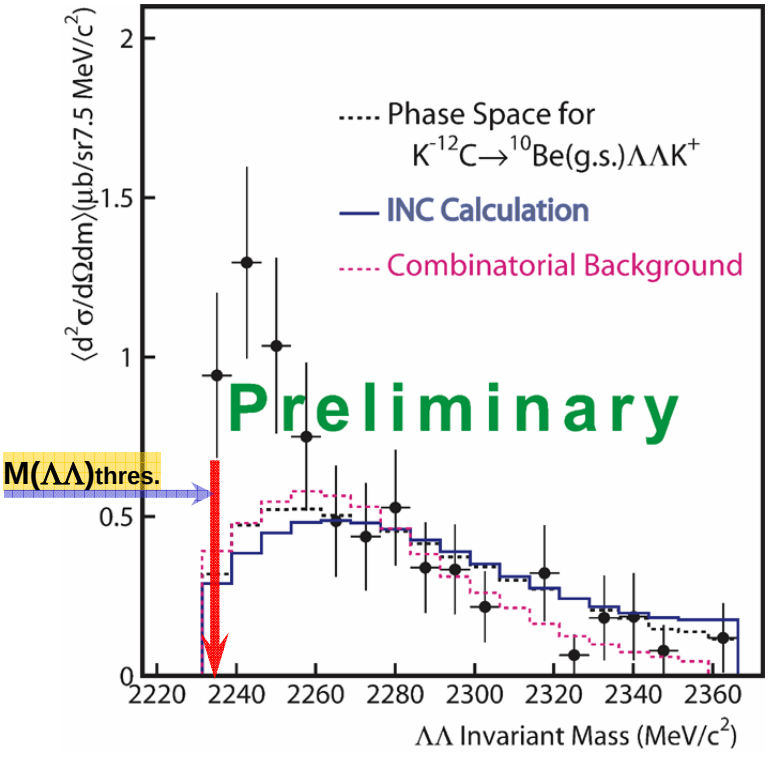
To determine ΛΛ interaction independent on the nuclear structure,
we need to measure **A-dependence** of $\Delta B_{\Lambda\Lambda}$.

H-dibaryon resonance (?) near the ΛΛ threshold



Recent result

KEK-PS E522

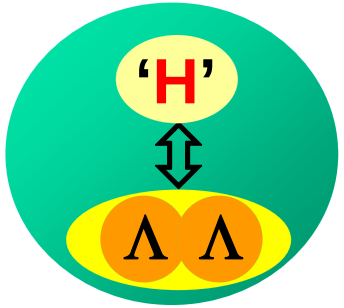


ΛΛ invariant mass

What is the ground state of S=-2 nuclei?

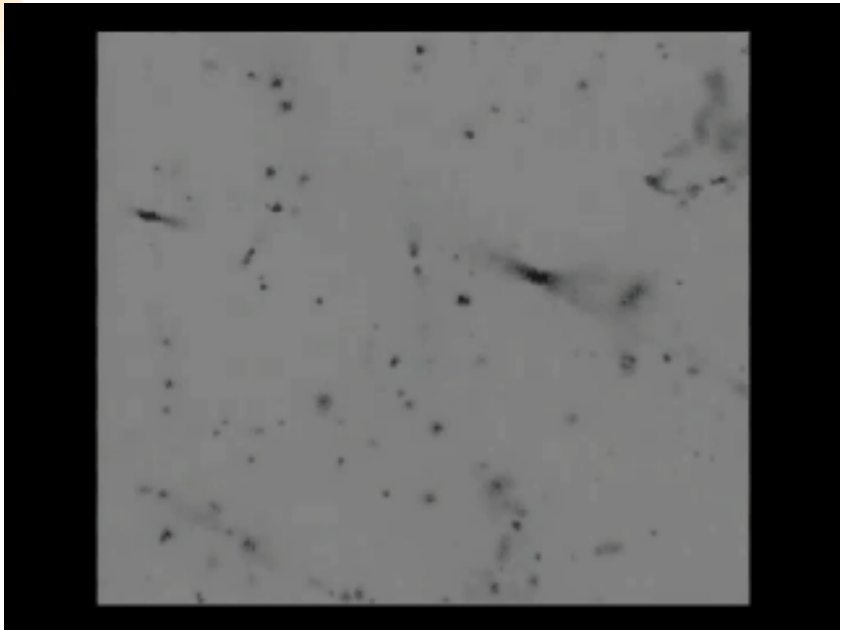
ΛΛ or H-dibaryon state or mixed in nuclei?

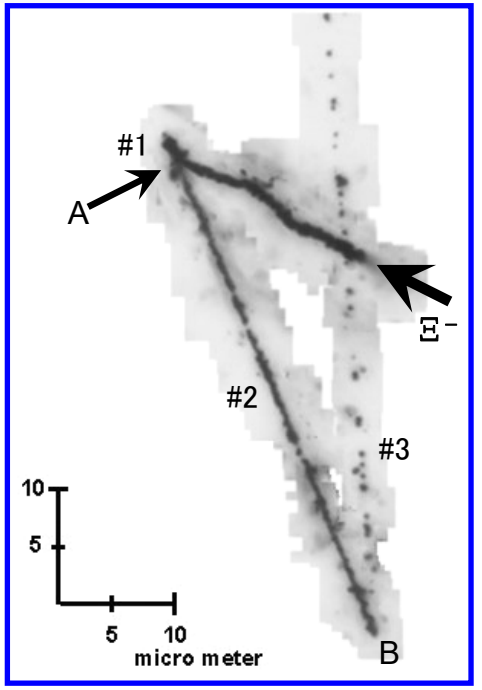
$|H\rangle = \sqrt{a}\,|\Lambda\Lambda\rangle + \sqrt{b}\,|\Xi N\rangle - \sqrt{c}\,|\Sigma\Sigma\rangle$



1. **A-dependence of $\Delta B_{\Lambda\Lambda}$**
2. **Decay branching ratio**
   [S=-2] => $\Sigma^- p$, Λn
3. **Higher statistics for ΛΛ spectrum is expected.**

First observation Σ-N weak decay of double strangeness nuclei





- $\Xi^- + (p) \rightarrow X \rightarrow \Sigma^- + p$

Decay mode ($X \Rightarrow \Sigma^- + p$) <····· Theoretical Prediction.

X : ΛΛ (~10^{-3})、H−dibaryon (several tens' %).

E373 data : *One event for the Decay* ($X_{[S=-2]} \Rightarrow \Sigma^- p$)

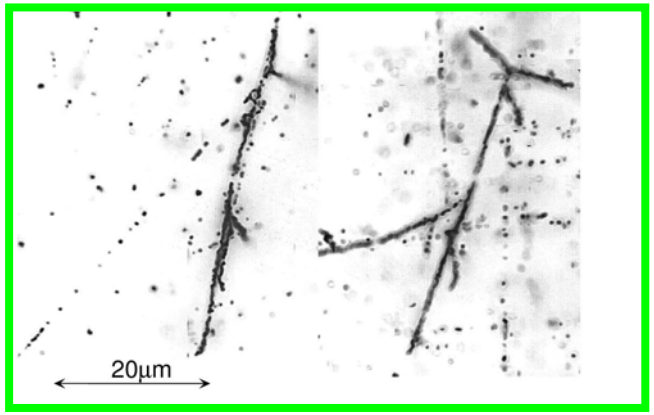
Proposed experiment can provide

$Br(X_{[S=-2]} \Rightarrow \Sigma^- p)$

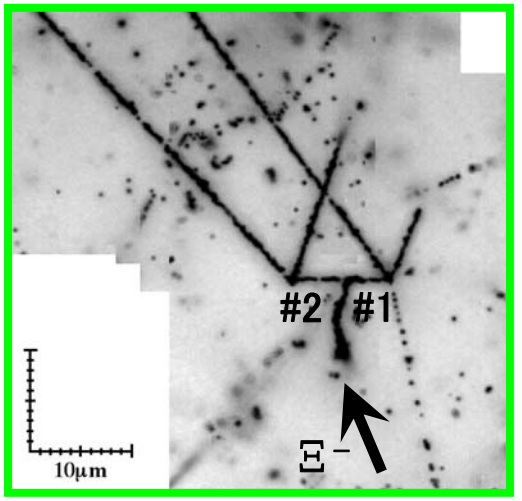
with more than 10 times higher statistics.

Ξ-nucleus potential

1) Level energy of Ξ⁻ hyperon in nucleus by twin-hypernuclei.



A.Ichikawa et al., Phys. Lett.B (2001)



2) The first measurement of Ξ⁻-atomic X rays
employing "Hyperball-J" (Ge detector array).

Energy shift -> Ξ- nucleus potential -> Ξ-N interaction

High accuracy ← P03 K. Tanida

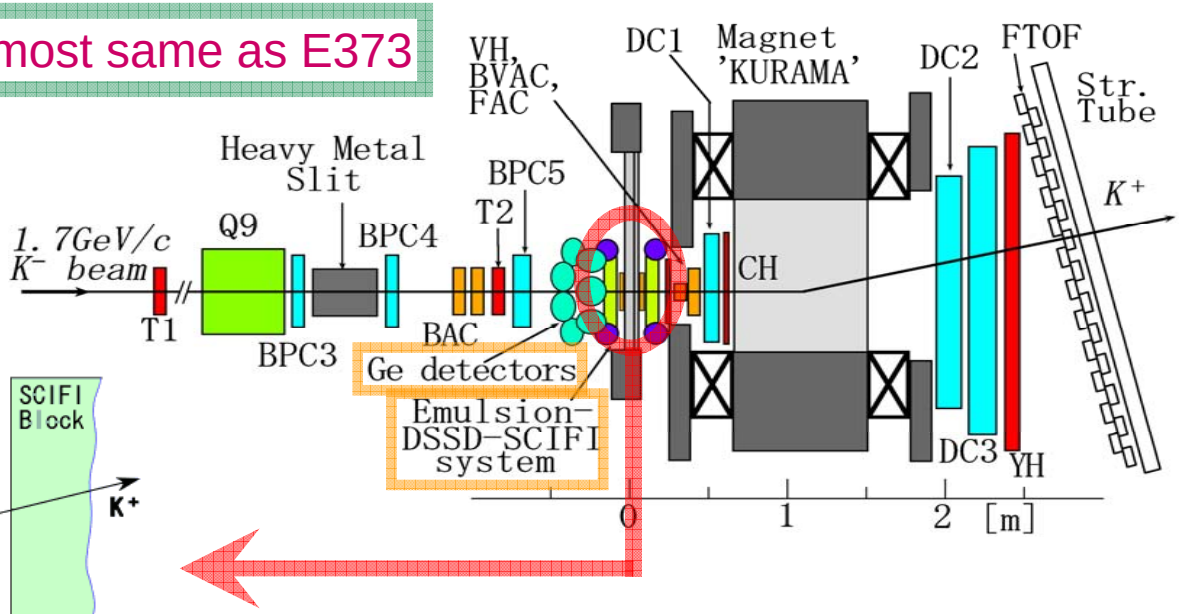
~ 0.2 keV (FWHM) < **Expected energy shift 0.3 – 3 keV (by Friedman, Gal)**

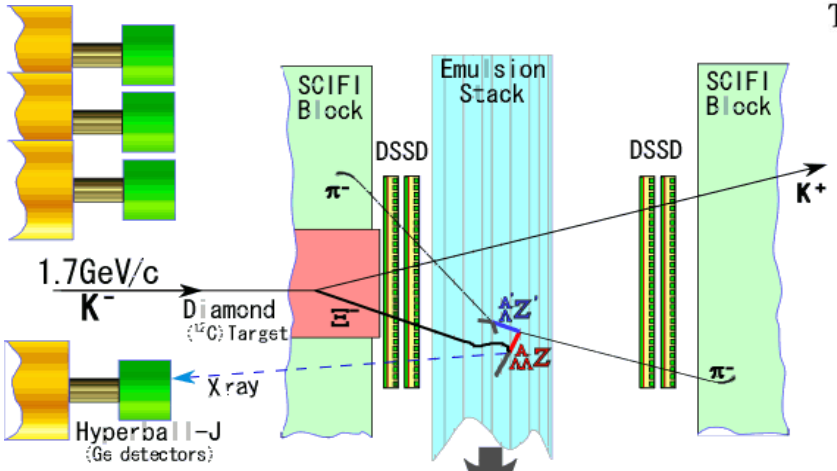
Very low background

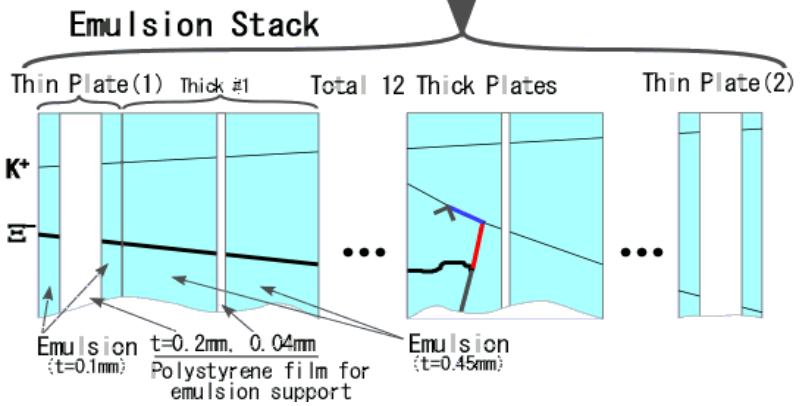
Clean Ξ⁻ stopping events identified in emulsion.

Setup of the proposed experiment

Almost same as E373







Beam : K^- (1.7GeV/c),

3×10^5 K^-/spill with **$K^-/\pi^- > 6$**

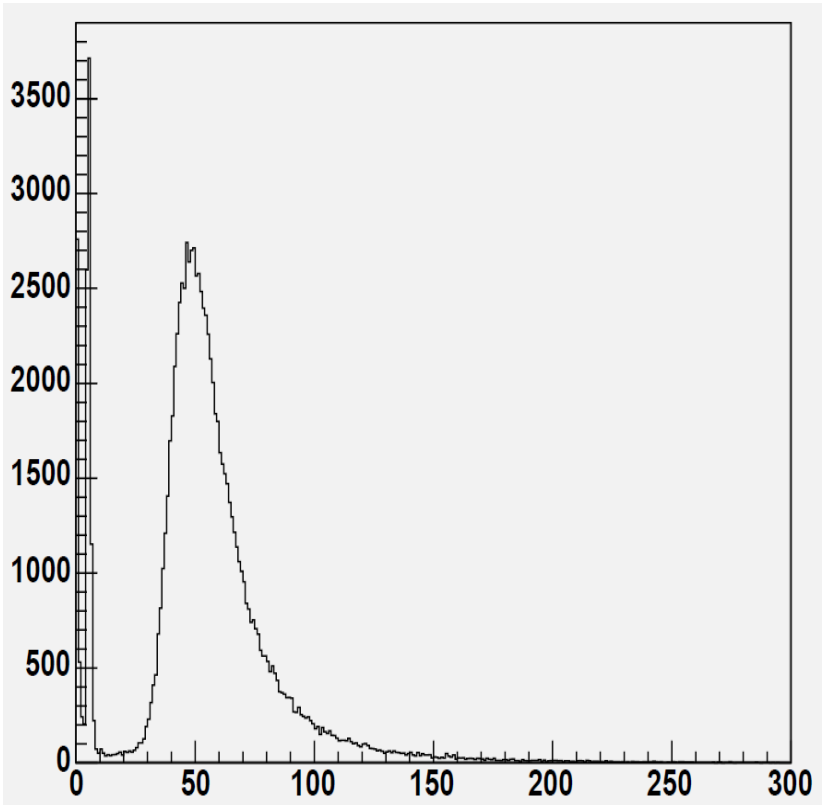
at **K1.8 beam-line** **(~20% of 9μA)**

Trigger : **(K-, K+)**

=> 10^4 Ξ^- stopping events

(more than 10 times higher stat. than E373)

Development #1
Double-sided Si Strip Detector (DSSD)



Silicon; 32 x 64mm area, 300μm thick
50μm strip pitch -> 16μm resolution
readout; VA-chip

Energy spectrum for β-ray (^{90}Sr)
Equivalent electron noise; 600~1000
S/N;23~34 for MIPS

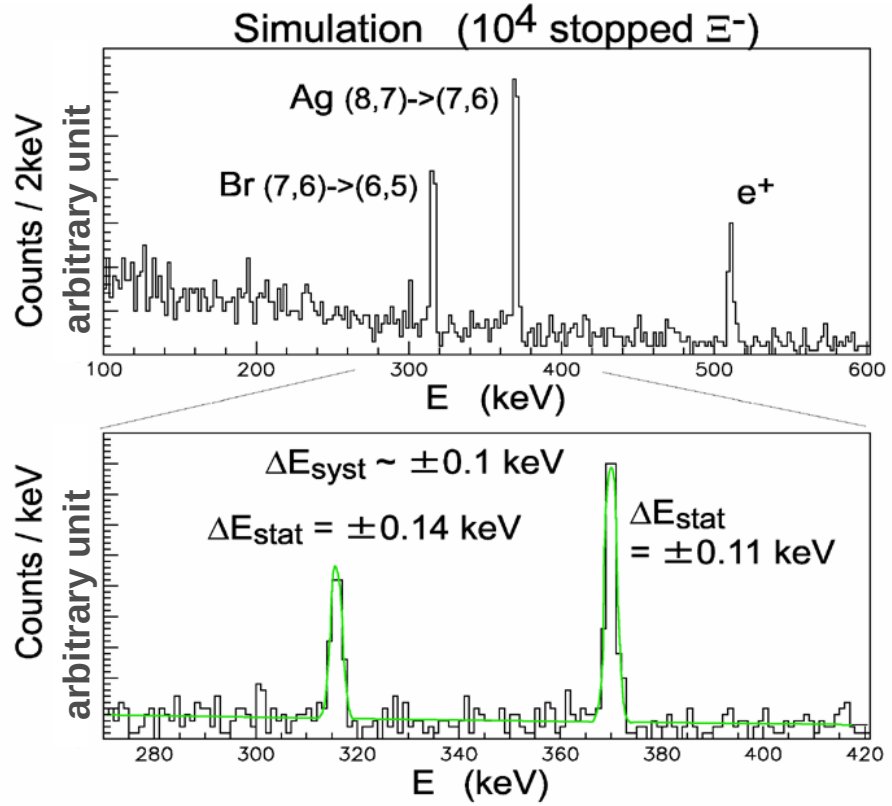
PS-T594 : + Track connection (DSSD ⇔ Emulsion)
using the last beam at KEK-PS, on mid March
+ Analysis is going-on.

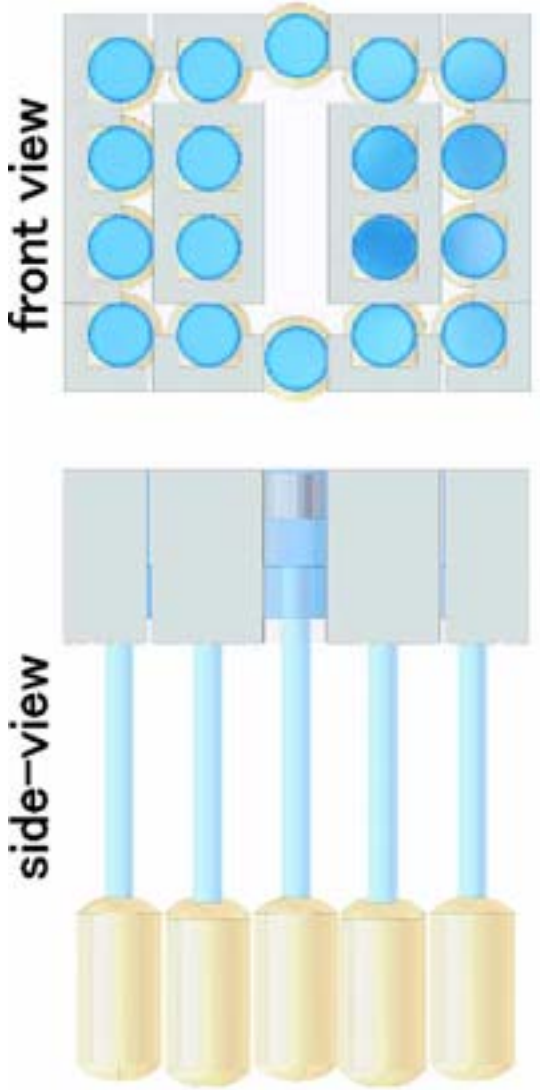
Development #2
Upgraded Hyperball-J

K.Tanida
H.Tamura

*Peak efficiency : ×2
* Very low background

Ξ^- atomic X-ray

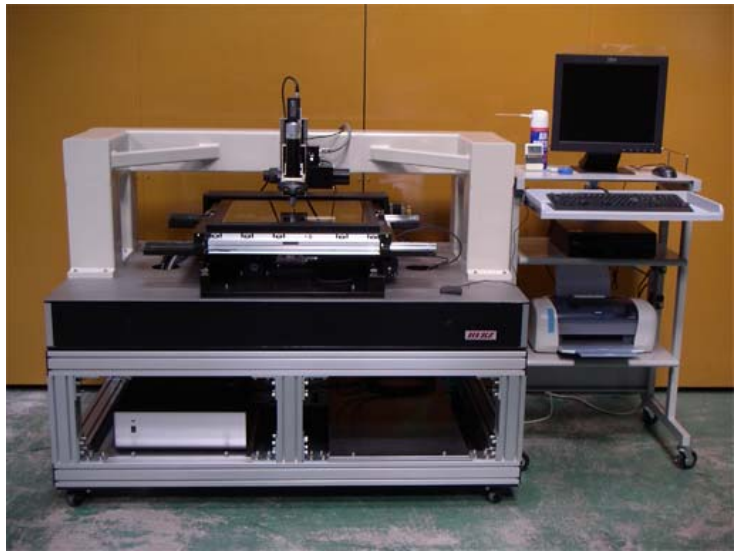




Development #3
Emulsion scanning system

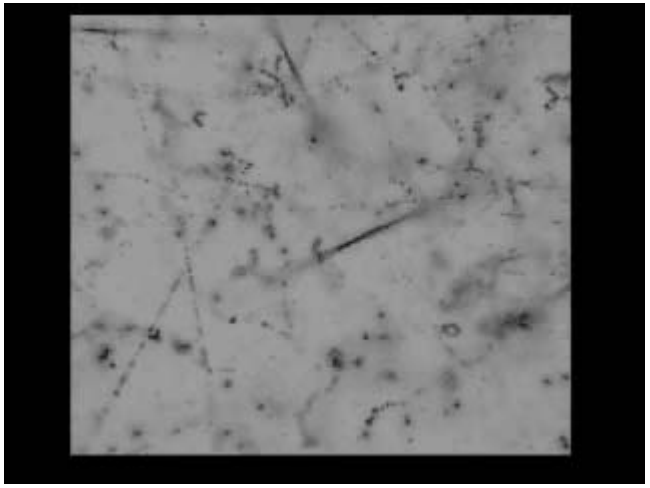
New system

Area : 35×35 cm^2 ➔ 40×40 cm^2
Light : Halogen Lamp ➔Ultra High-bright LED
speed : × 2
tracking eff. : × 1.5
# of System : 6 (old, E373) ➔7 (new) + 3 (old)



Old system

New system



Scanning for this experiment : **more speed-up** [× **6** than old system]
(1) Develop scanning algorism (2) **Optimize the area for scanning**

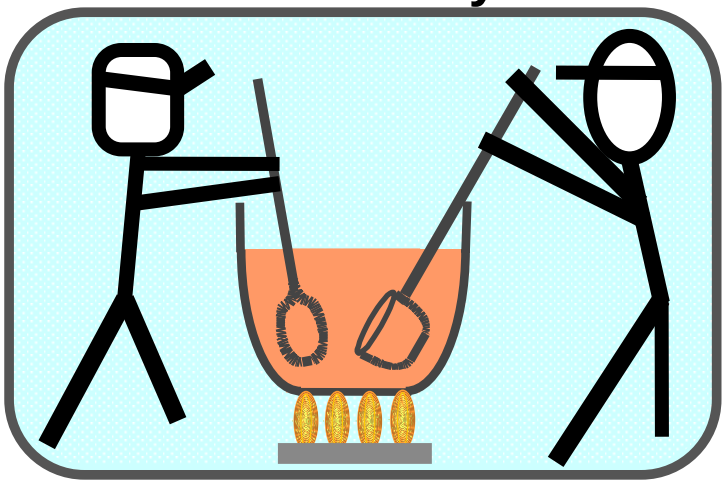
Development #4
Production method of emulsion

New method of Emulsion gel. production

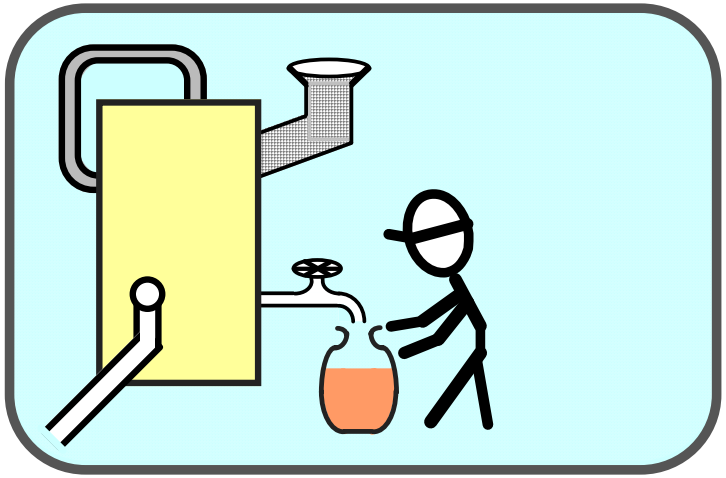
For the proposed exp., amount of emulsion gel => 2.6 tons

Fuji-film needs one year or more by conventional way.

Conventional way by hand

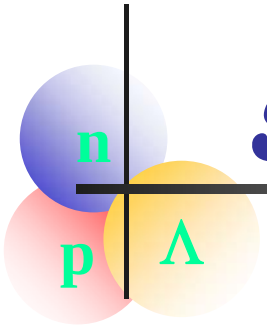


Using the production lines for commercial films



Tested by particle beams with good results.
Half of necessary emulsion has been made!

Emulsion cost will be saved
50%



Summary

Physics

1) S=-2 nuclear chart by **~10^2 $_{\Lambda\Lambda}Z$** via **10^4 Ξ^--stopping events.**

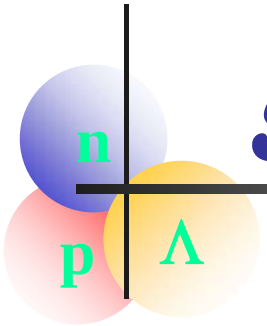
=> **$\Delta B_{\Lambda\Lambda}$ of several nuclides** will provide definitive information on ΛΛ interaction and structure of S=-2 nuclei.

2) H-dibaryon state in S=-2 system ?

=> measure **A-dependence of $\Delta B_{\Lambda\Lambda}$** & **$\Sigma^-$decay mode of $_{\Lambda\Lambda}Z$.**

3) Ξ^--nucleus potential

=> detection of **twin hypernuclei**
=> First measurement of **X-ray** of **Ξ^-atom**



Summary

Readiness of the Experiment ('Kakenhi / Tokubetsu-Suishin' : $3M)

+ **DSSD** (**D**ouble-sided **Si** **S**trip **D**etector)
+ **Scanning system** (**6**=>**10** systems : high speed and better efficiency)
+ **Emulsion** (50%)
+ **Hyperball-J** (other budgets)

Requested **Beam and Time** (K-, K+) trigger

3 x 10^5 K^-/spill with $K^-/\pi^- > 6$ at **K1.8 beam-line** (**~20%** of 9μA)
150 hours for detector tuning and **600 hours** for beam exposure

Detector : DSSD, Emulsion, Hyperball, KURAMA spectrometer, etc.

Almost Ready