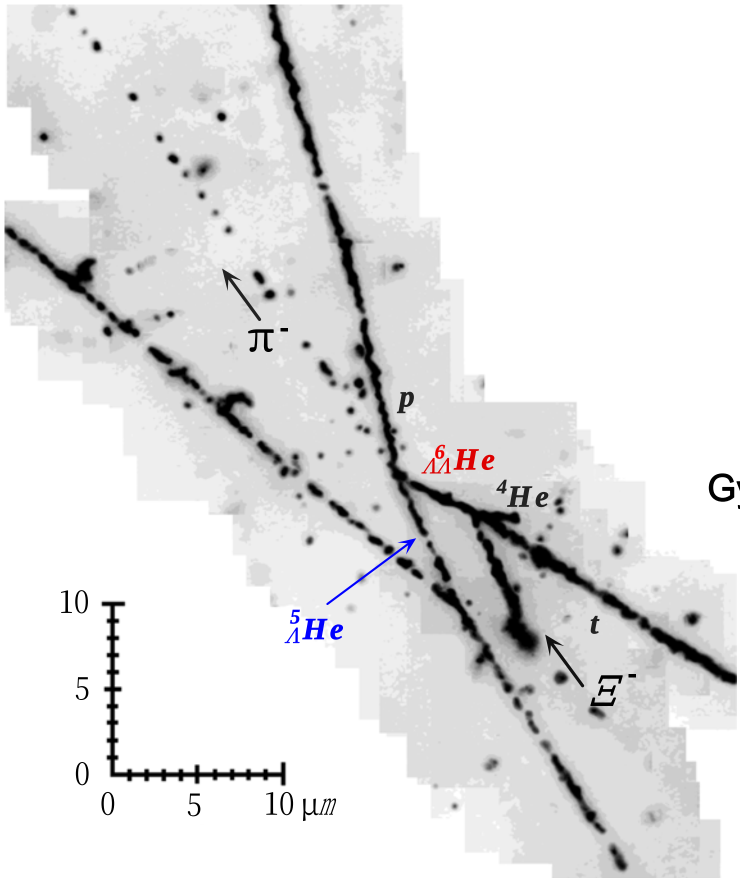
Jun.30,2006
J-PARC.PAC

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

NAGARA event (KEK-E373)



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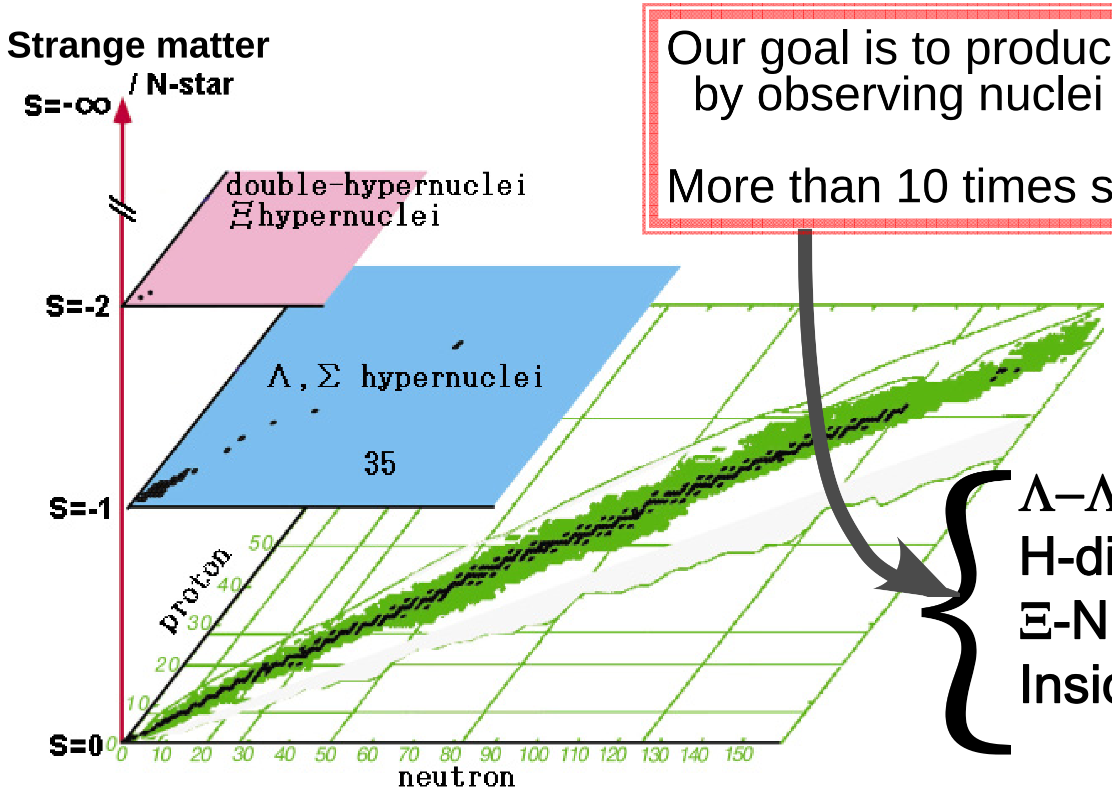
Motivation of the proposed experiment

* 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.

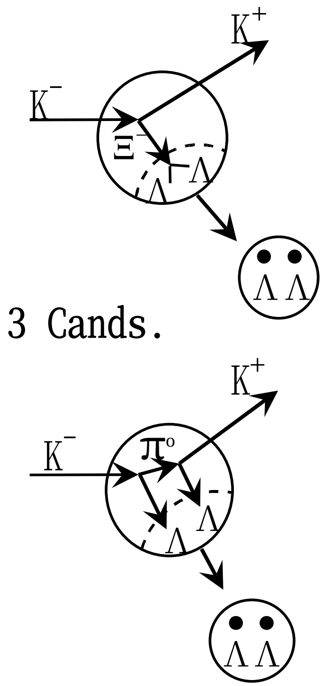
More than 10 times statistics than previous E373.



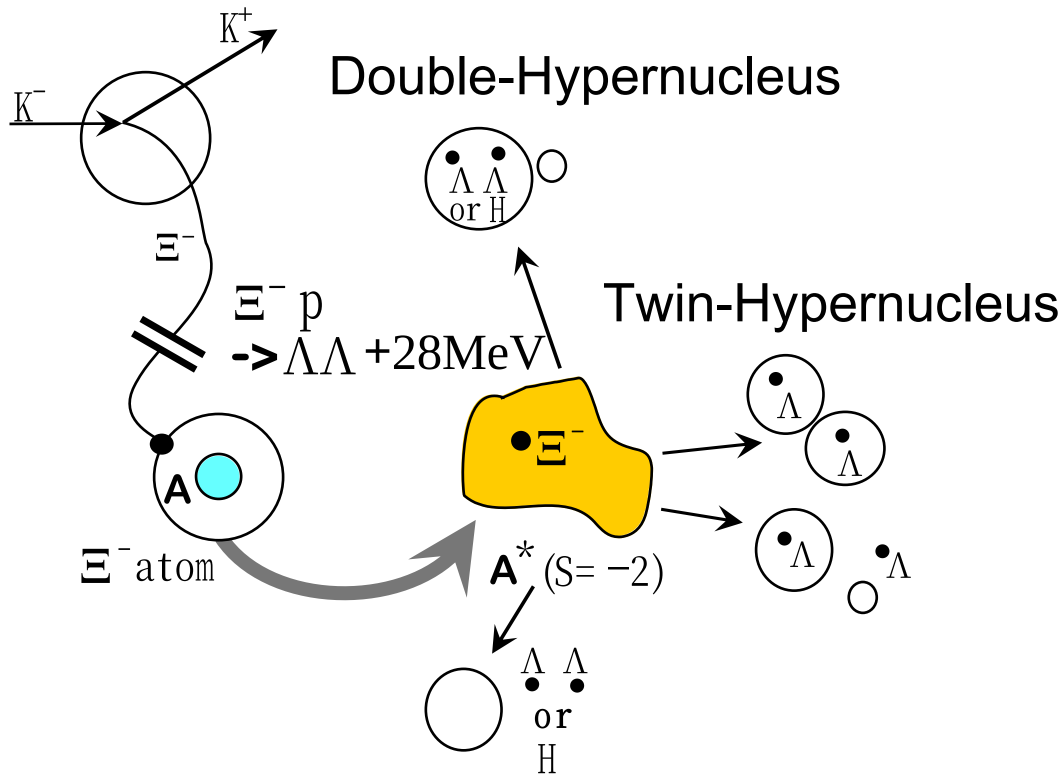
- Λ–Λ Interaction,
- H-dibaryon,
- Ξ-Nucleus Interaction,
- Inside Neutron Stars (Quark-star?)

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

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)

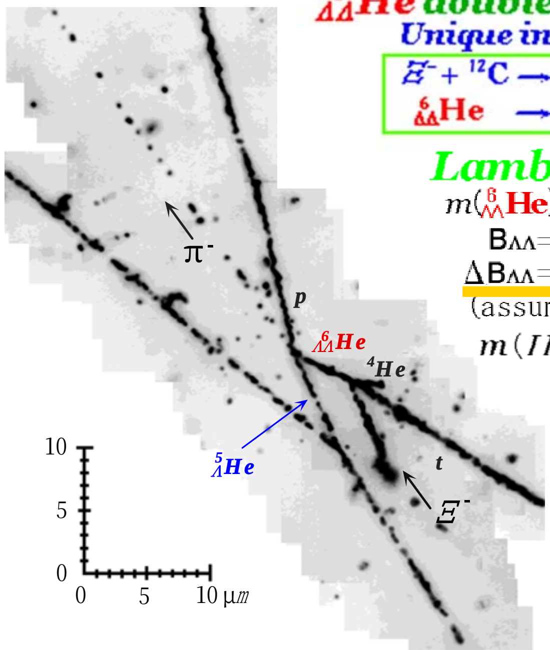
$m({}^{6}_{\Lambda\Lambda}He) = 5951.82 \pm 0.54$ MeV

$B_{\Lambda\Lambda} = 7.25 \pm 0.19^{+0.18}_{-0.11}$ MeV

$\Delta B_{\Lambda\Lambda} = 1.01 \pm 0.20^{+0.18}_{-0.11}$ MeV

(assumed B_{Ξ^-} = 0.13 MeV)

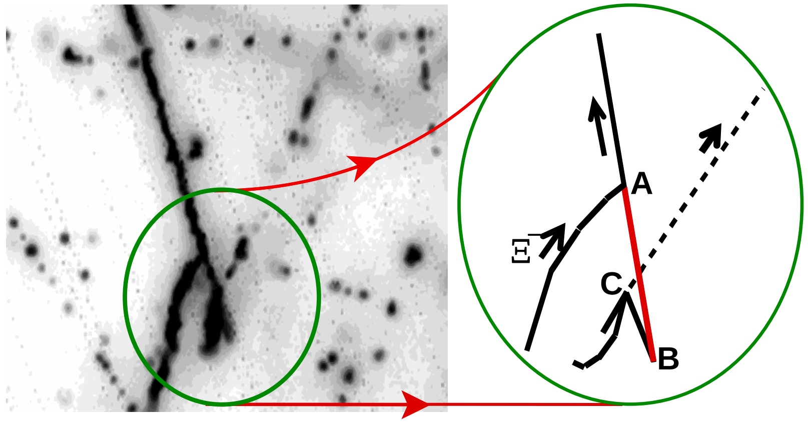
$m(H) \geq 2223.7$ MeV/c^2 (90% C.L.)



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
$\Xi^- + {}^{14}N \rightarrow {}^{13}_{\Lambda\Lambda}B + p + n$



ΔB$_{\Lambda\Lambda}$: ΛΛ Interaction Energy

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

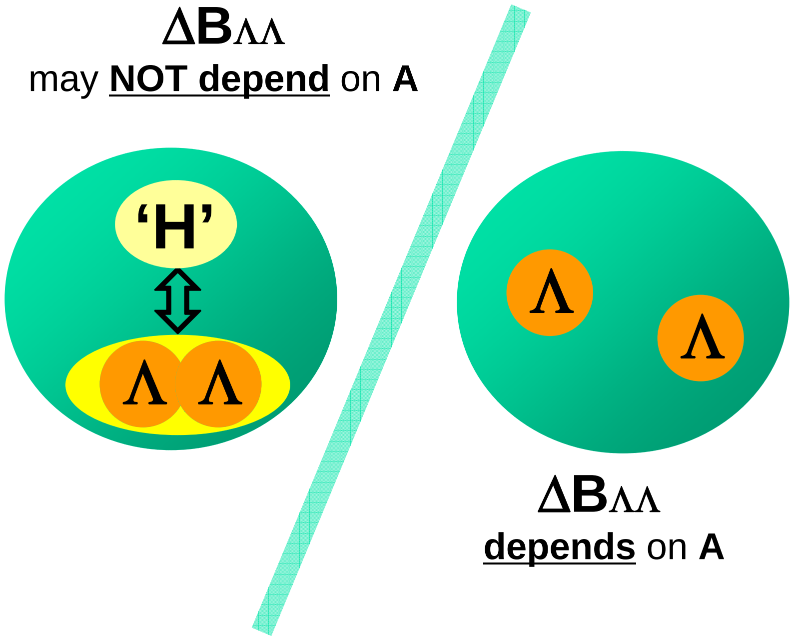
Found

Weakly attractive ΛΛ Interaction !

Hybrid Method ==> Reliable

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

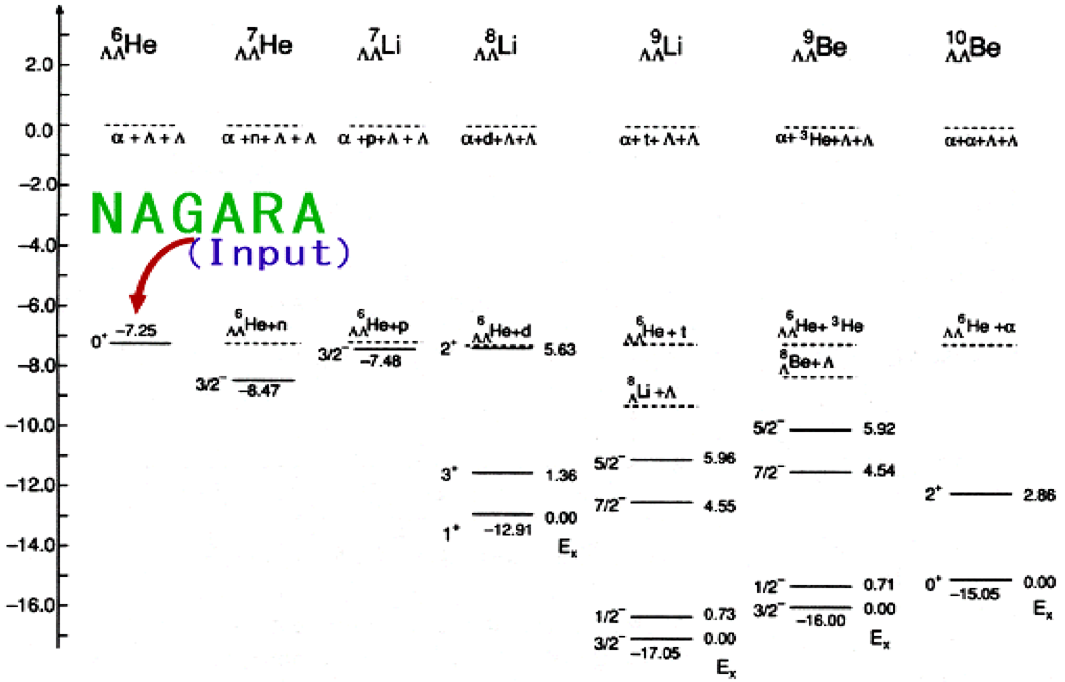
S=-2 nuclear system



Theoretical prediction

HIYAMA, KAMIMURA, MOTOBA, YAMADA, AND YAMAMOTO

PHYSICAL REVIEW C 66, 024007 (2002)

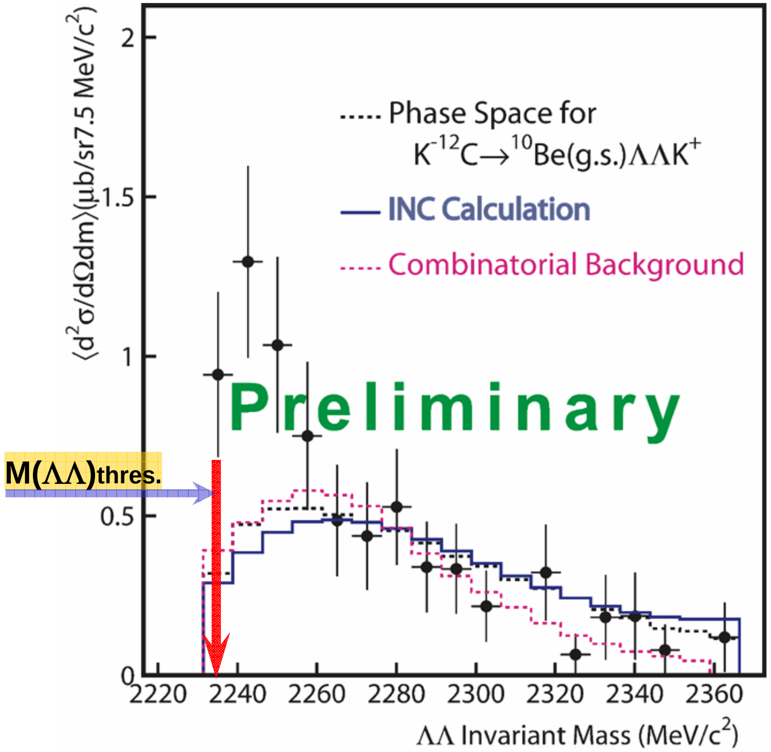


To determine ΛΛ interaction independent on the nuclear structure,
we need to measure **A-dependence** of $\Delta B_{\Lambda\Lambda}$.

H-dibaryon resonance (?) near the ΛΛ threshold

Recent result

KEK-PS E522

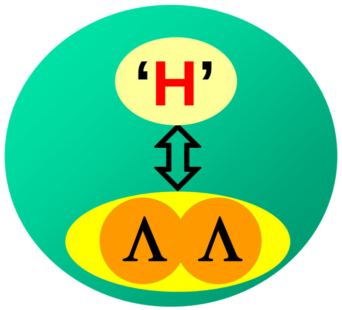


ΛΛ invariant mass

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

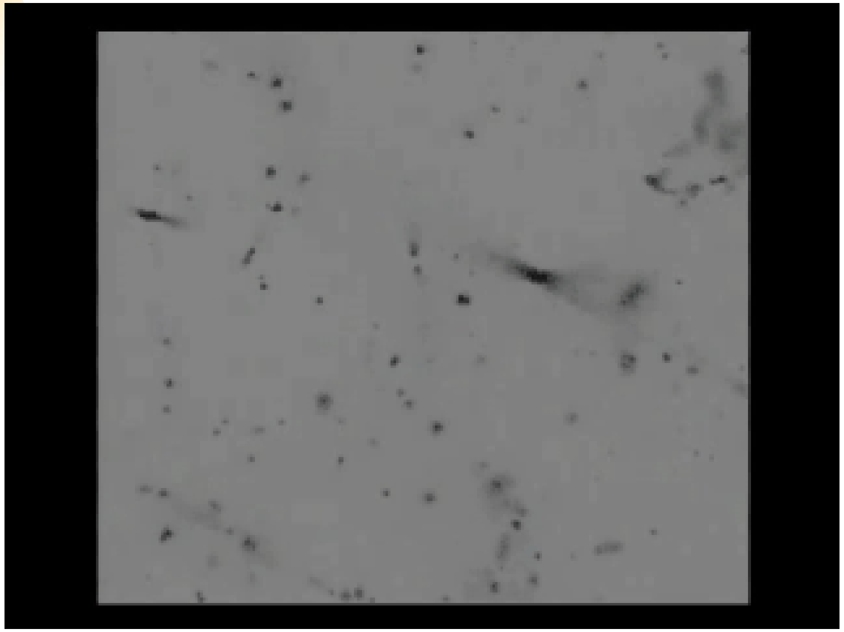
ΛΛ or H-dibaryon state or mixed in nuclei?

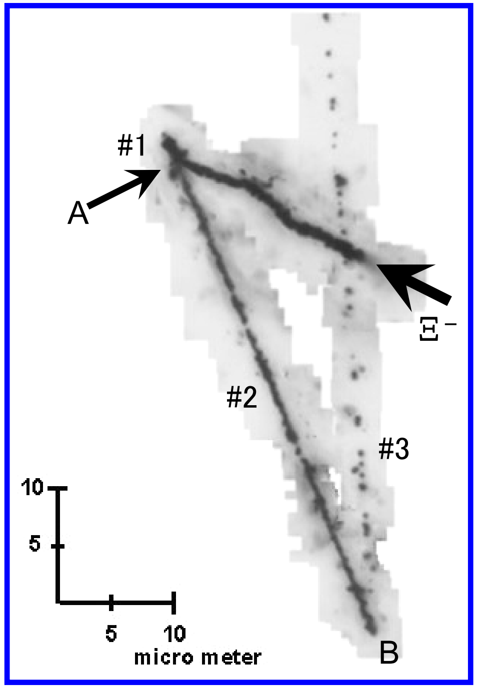
$|H\rangle = \sqrt{a}\,|\Lambda\Lambda\rangle + \sqrt{b}\,|\Xi N\rangle - \sqrt{c}\,|\Sigma\Sigma\rangle$



1. **A-dependence of $\Delta B_{\Lambda\Lambda}$**
2. **Decay branching ratio**
   [S=-2] => Σ^-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** => $\Sigma^- + p$) <……. **Theoretical Prediction.**

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

E373 data : ***One event*** *for the Decay* (**X**[S= -2] => $\Sigma^- p$)

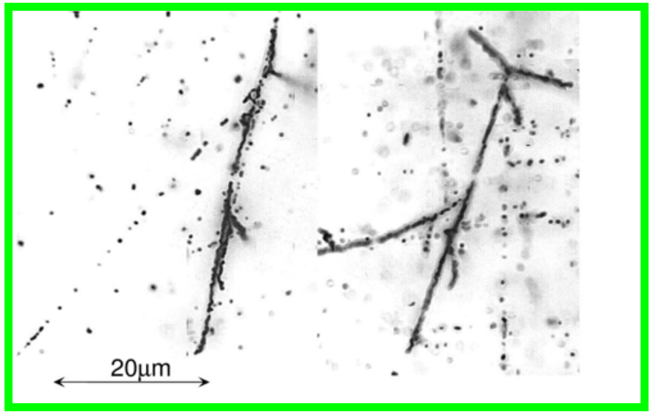
Proposed experiment can provide

Br(**X**[S= -2] => $\Sigma^- p$)

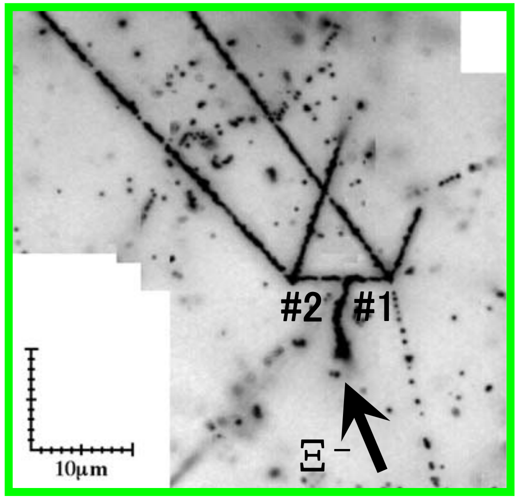
with more than 10 times higher statistics.

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

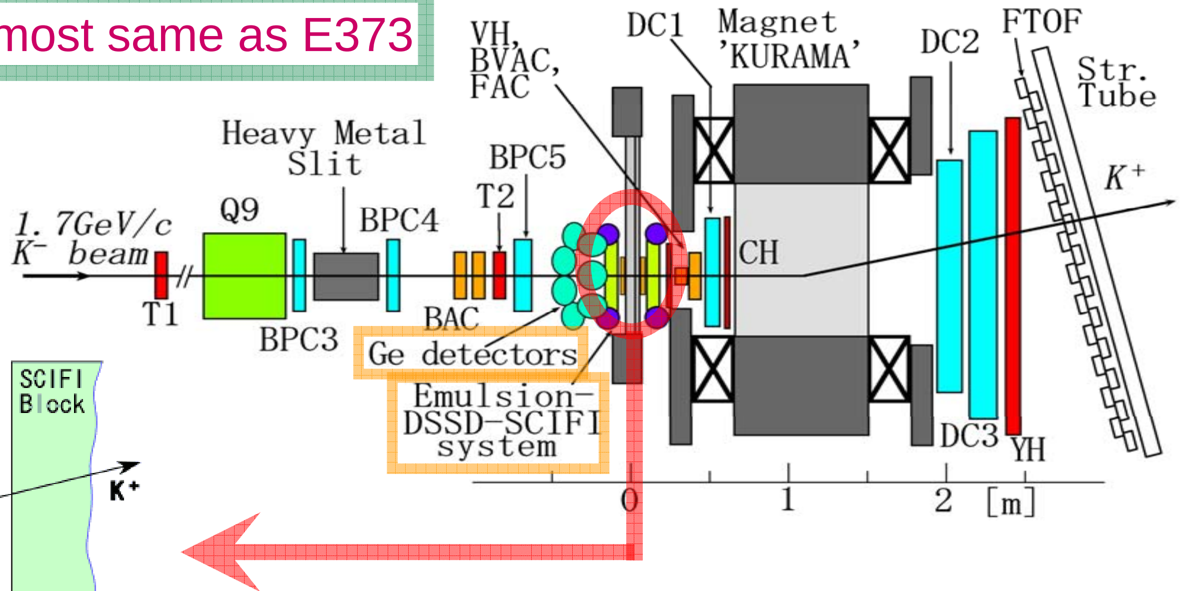
~ 0.2 keV (FWHM) < Expected energy shift 0.3 – 3 keV (by Friedman, Gal)

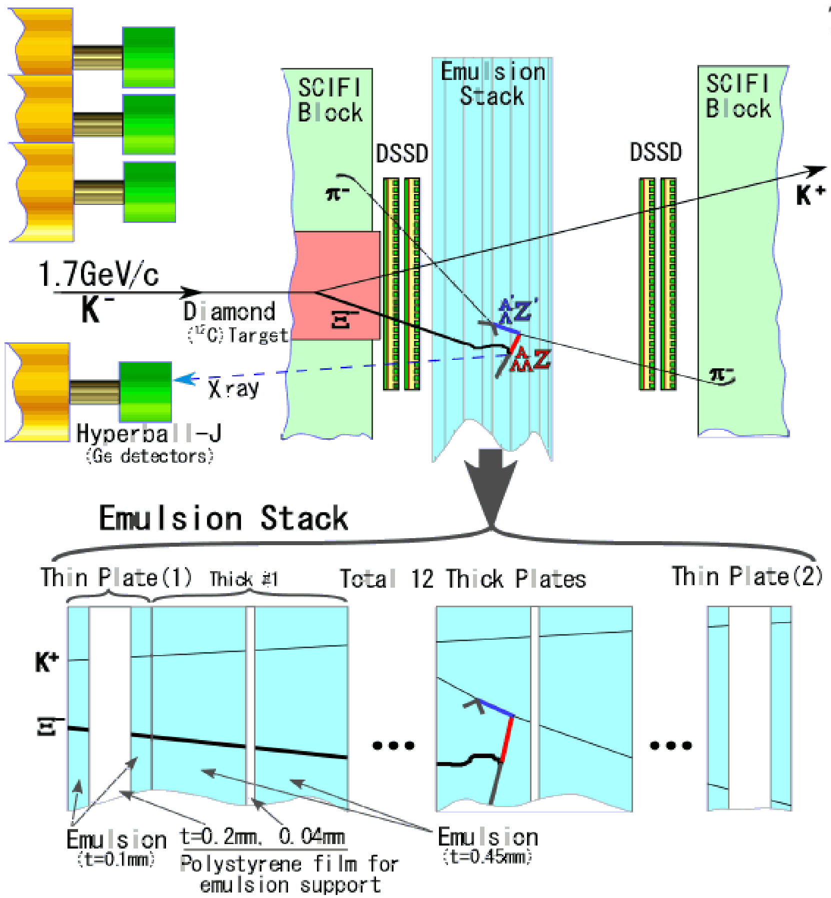
Very low background

Clean Ξ⁻ stopping events identified in emulsion.

Setup of the proposed experiment

Almost same as E373





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

3 x 10^5 K^-/spill with **K^-/π^- > 6**

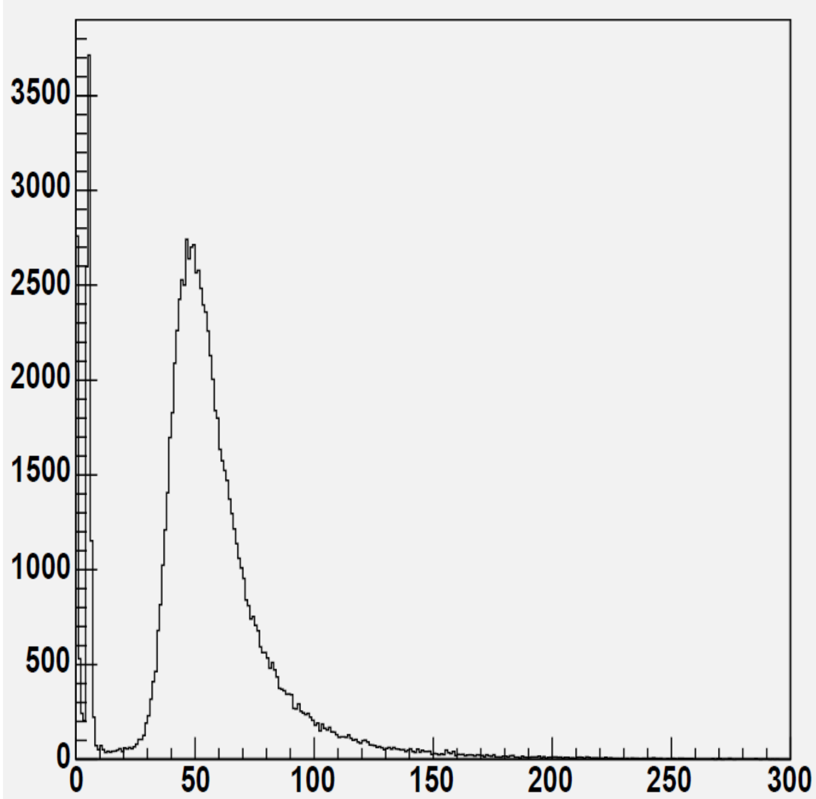
at **K1.8 beam-line** (~20% of 9μA)

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

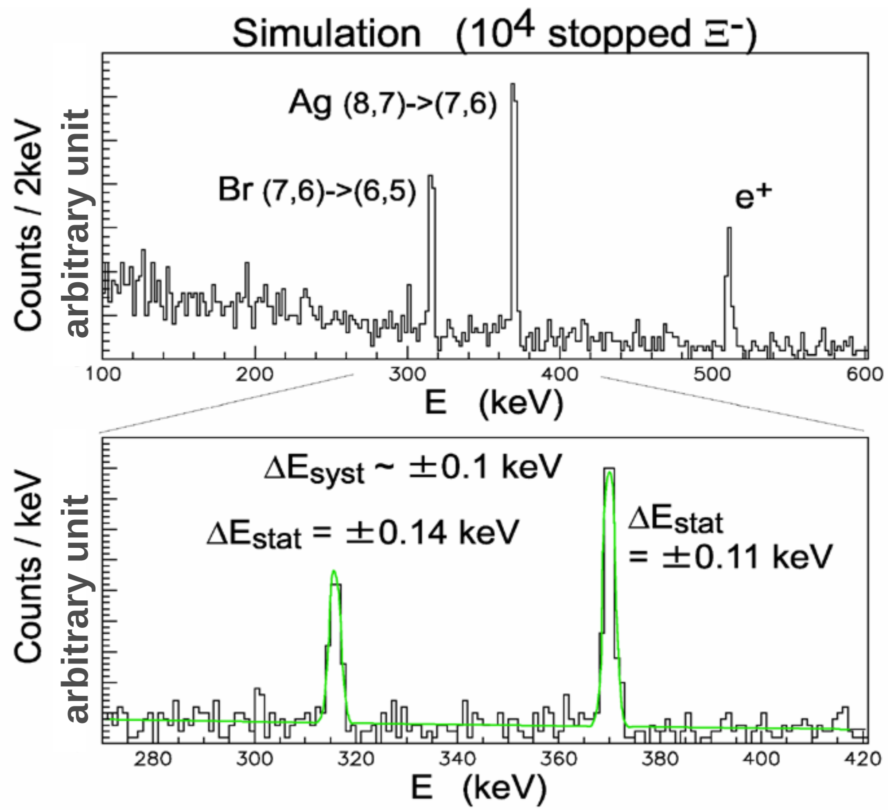
PS-T594 : + Track connection (DSSD ⇔ Emulsion)
using the last beam at KEK-PS, on mid March
+ Analysis is going-on.

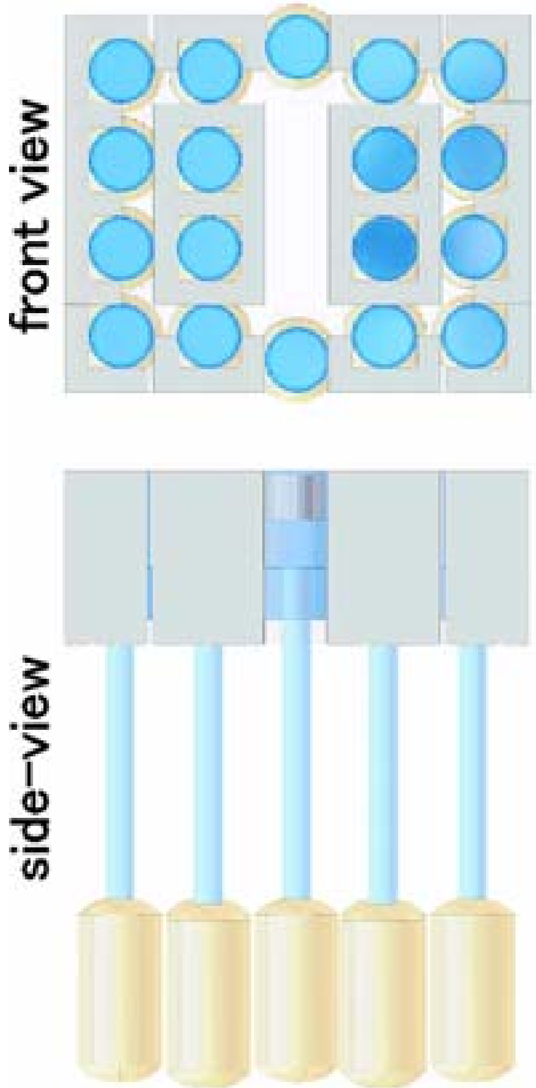
Development #2
Upgraded Hyperball-J

K.Tanida
H.Tamura

- *Peak efficiency : ×2
- * Very low background

Ξ^- atomic X-ray





Development #3
Emulsion scanning system

New system

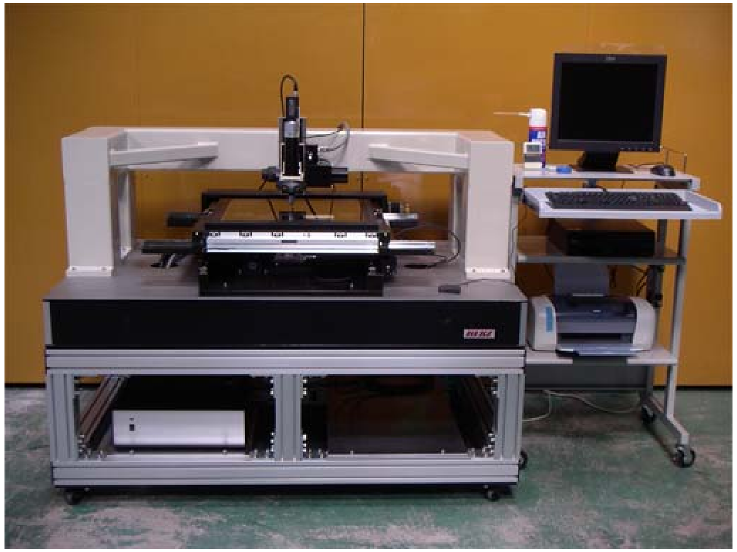
Area : **35×35** cm^2 ➔ **40×40** cm^2

Light : Halogen Lamp ➔Ultra High-bright **LED**

speed : ×2

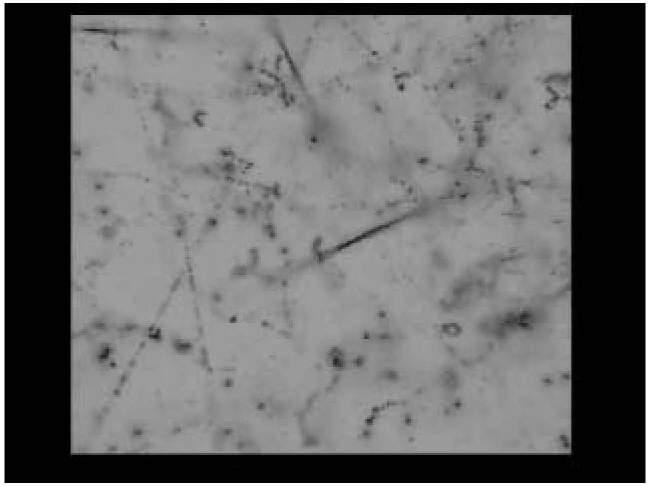
tracking eff. : × 1.5

# 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

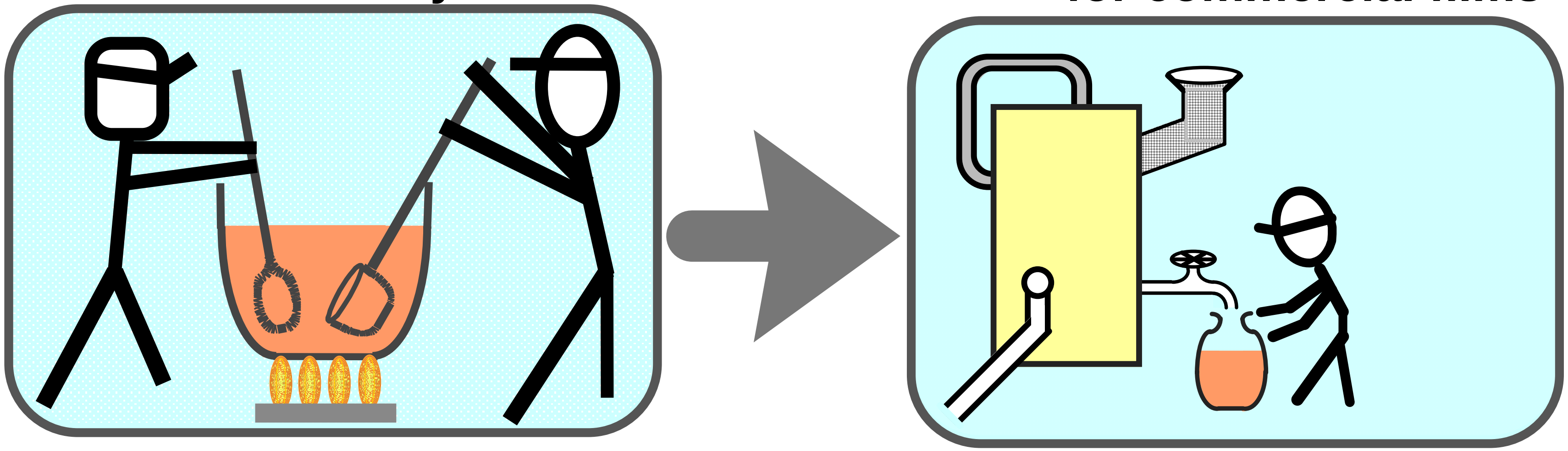
New method of Emulsion gel. production

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 $\Lambda\Lambda$ interaction and structure of S=-2 nuclei.

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

=> measure A-dependence of $\Delta B_{\Lambda\Lambda}$ & Σ–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 **S**i **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$^-$/π^- **> 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