

Nuclear Physics with double strangeness (S=-2)

KEK-E373 => AGS-E964> J-PARC

Λ Observation of a $\Lambda\Lambda^6\text{He}$ (KEK-E373)

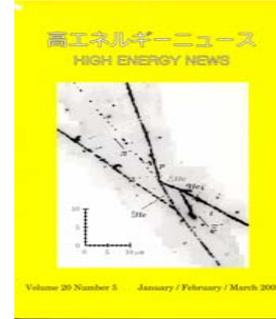
Success of Emulsion detector with micro-meter accuracy

NAGARA event

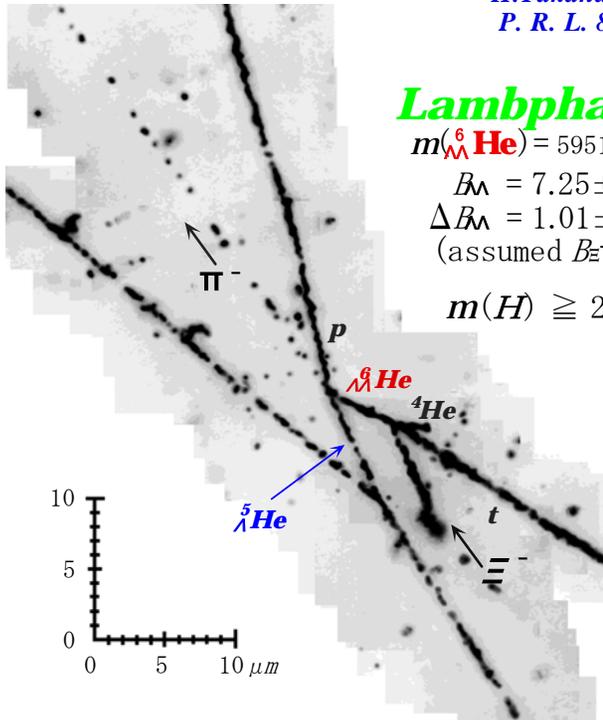
$\Lambda\Lambda^6\text{He}$ double-hypernucleus
Unique interpretation!!



H.Takahashi et al.,
P. R. L. 87, 212502(2001)



High Energy News
Vol.20 No.5 (2002)
KEK



Lambpha

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

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

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

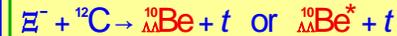
(assumed $B_{\Xi^-} = 0.13 \text{ MeV}$)

$$m(H) \geq 2223.7 \text{ MeV}/c^2$$

(90% C.L.)

Demachi-yanagi event

* two body case at point A

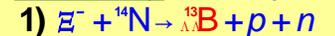


$$\Delta B_\Lambda : -1.14 \pm 0.19 \text{ or } +1.86 \pm 0.19 \text{ MeV}$$

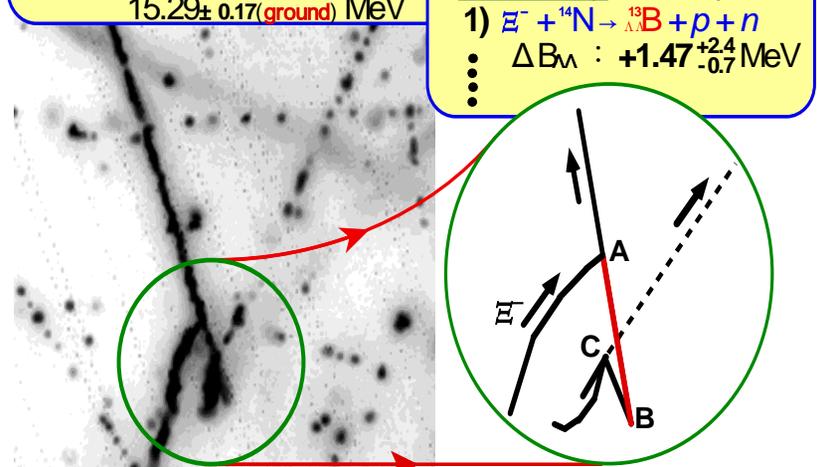
$$B_\Lambda : 12.29 \pm 0.17 \text{ (excited) MeV}$$

$$15.29 \pm 0.17 \text{ (ground) MeV}$$

* three body case at point A



$$\Delta B_\Lambda : +1.47^{+2.4}_{-0.7} \text{ MeV}$$

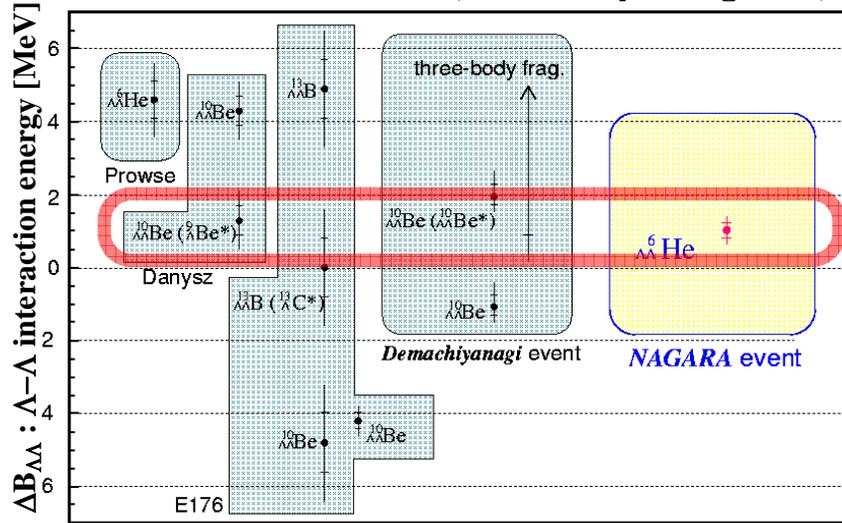


n
p
Λ

From KEK-E373 output to AGS-E964

KEK-E373 (Preliminary results)

- *) $\sim 10^3$ Ξ^- stopping events in nuclear emulsion.
- *) Observation of several double- Λ hypernuclei
=> **NAGARA event** (without any ambiguities).



ΛΛ interaction is attractive but weak

Theoretical calculation for light double hypernuclei

HIYAMA, KAMIMURA, MOTOKA, YAMADA, AND YAMAMOTO

PHYSICAL REVIEW C 66, 024007 (2002)

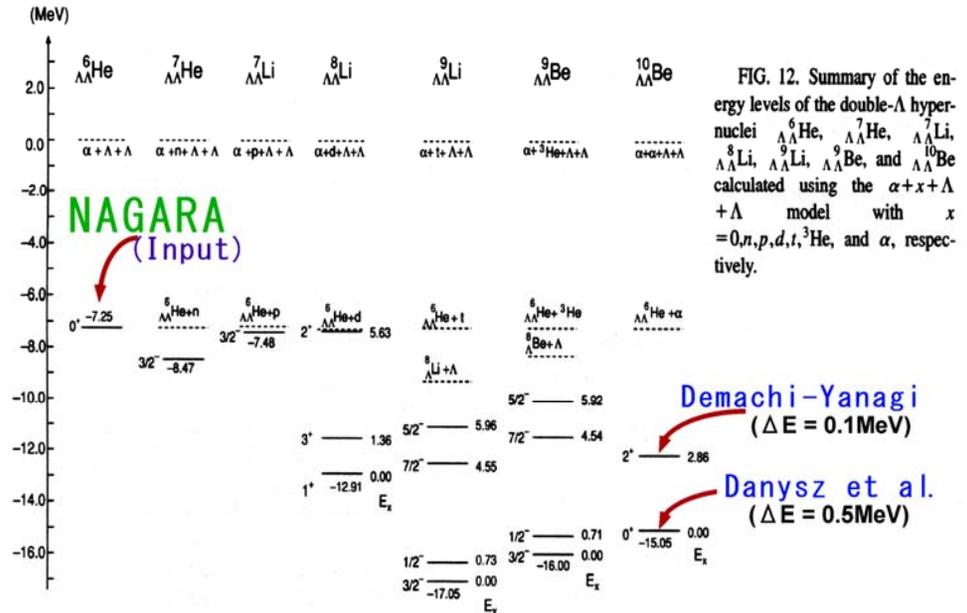
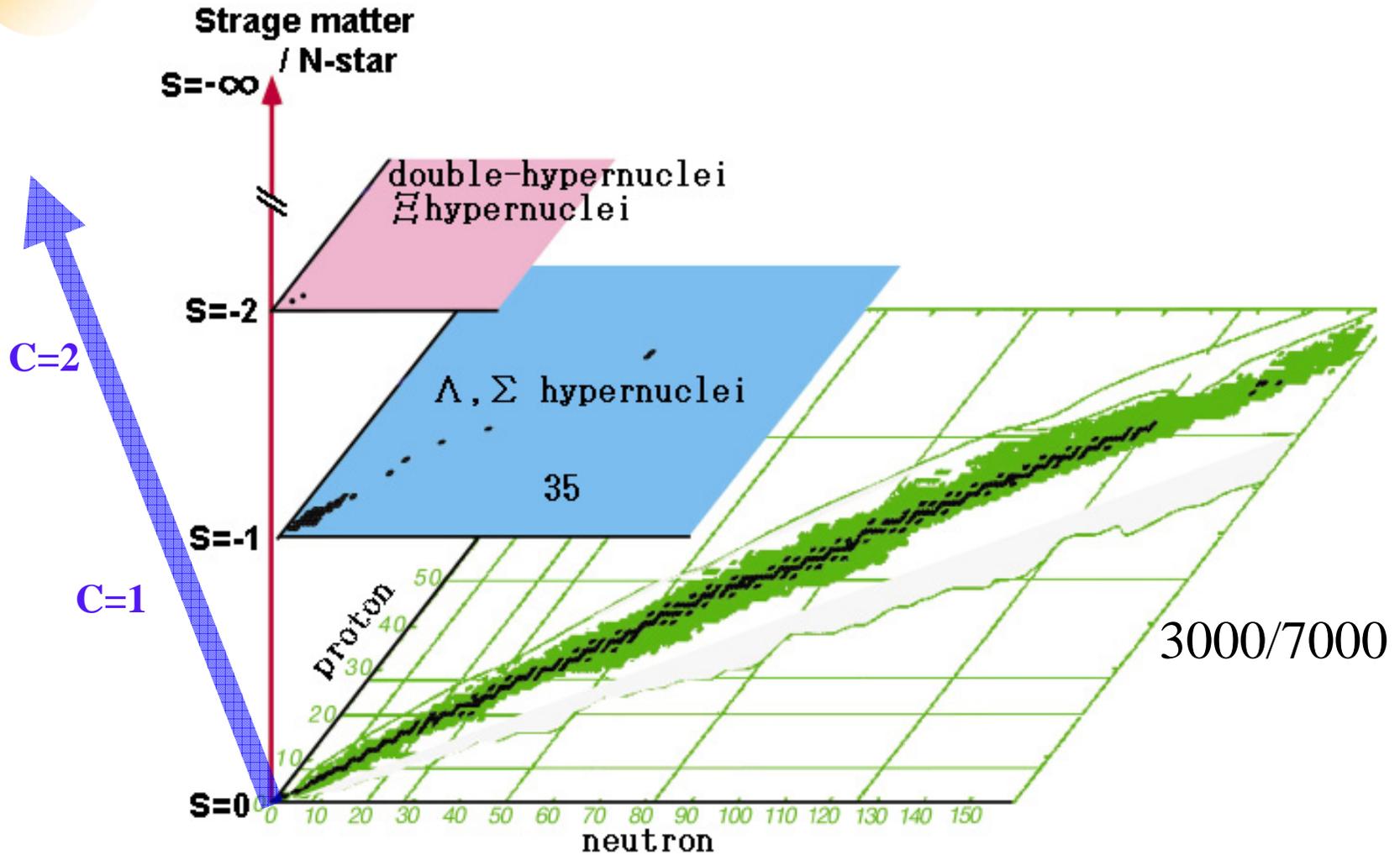


FIG. 12. Summary of the energy levels of the double- Λ hypernuclei ${}^6_{\Lambda\Lambda}\text{He}$, ${}^7_{\Lambda\Lambda}\text{He}$, ${}^7_{\Lambda\Lambda}\text{Li}$, ${}^8_{\Lambda\Lambda}\text{Li}$, ${}^9_{\Lambda\Lambda}\text{Li}$, ${}^9_{\Lambda\Lambda}\text{Be}$, and ${}^{10}_{\Lambda\Lambda}\text{Be}$ calculated using the $\alpha+x+\Lambda$ model with $x=0,n,p,d,t,{}^3\text{He}$, and α , respectively.

AGS-E964 (statistics x 10)

- *) $\sim 10^4$ Ξ^- stopping events in nuclear emulsion.
- *) ~ 10 double- Λ hypernuclei (without any ambiguities).
=> making a **nuclear chart with S=-2**.
A-dependence of $\Delta B_{\Lambda\Lambda}$ in several nuclides.
- *) **X-ray measurement** from Ξ^- -atom, for the first time.
=> information of Ξ -N interaction.
- *) **funded \$2.5M** by JPN. Gov., already. (2003~2007)

Nuclear Chart with Strangeness



Nuclear Physics with double strangeness (S=-2)
KEK-E373 => AGS-E964> J-PARC

International collaboration
AGS-E964(BNL)

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

AGS-E964 collaborators (now)

USA: BNL R. E. Chrien, M. May, P. Pile, A. Rusek
CMU G. B. Franklin
Houston Ed. Hungerfold, K. J. Lan, Y. Cui, Song
New Mexico B. Bassalleck

CHINA: CIAE H. Guo, Z. Liu, S. Lu, J. Zhou

INDIA: AMU R. Hasan

JPN: Gifu K. Nakazawa
Kyoto H. Funahashi, K. Imai, N. Saito, M. Yosoi
OCU K. Yamamoto, T. Yoshida
Osaka E-C H. Hotchi
Riken K. Tanida
Toho S. Ogawa, H. Shibuya
Tohoku Y. Miura, H. Tamura, M. Ukai

KOREA: GNU J. S. Song, C. S. Yoon
PUSAN J. K. Ahn, S. J. Kim

MM: MANDALAY M. Thein, K. S. Myint
UK : UCL D. H. Davis, D. Tovee
+ Graduate students

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

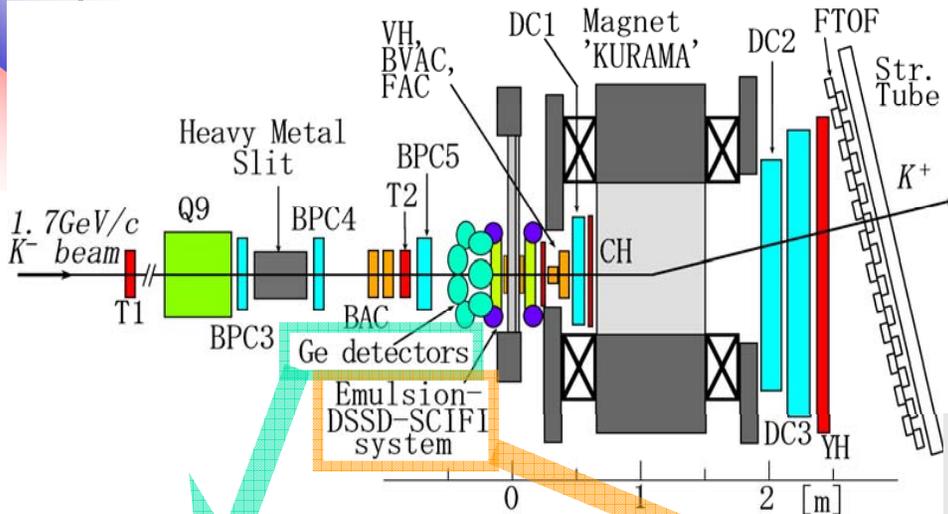
Beam : K⁻ (1.7GeV/c),
2 x 10⁵ K⁻/spill (4.1sec)
with **K⁻/π⁺>9 at D6-line**

Detectors : Nuclear Emulsion,
Double-sided Si strip Detector,
Ge-Detector (Hyperball),
KURAMA magnet

Time requested :
100 hours for detector tune
100 hours for beam tune
1100 hours for beam exposure

We requested Beam time on
FY2006

Setup around the target (E964)



Volume of nuclear emulsion

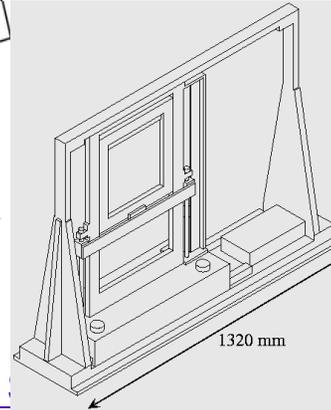
70 liters (E373) => **210 liters**

Track scanning method

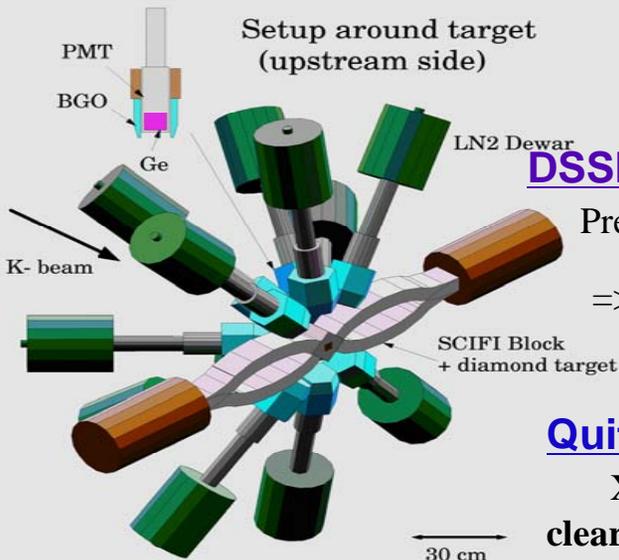
Automated + Interactive (E373)
=> **Fully Automated (speed x 4)**

Emulsion Mover

- Controlled with PC
- Move emulsion during spills
- Keep track density to $1 \times 10^6/\text{cm}^2$



Setup around target (upstream side)

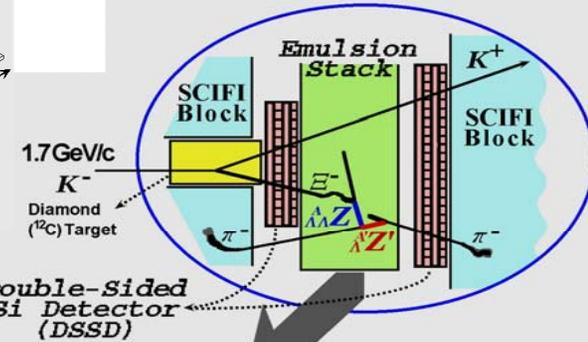


DSSD(Double-Sided)

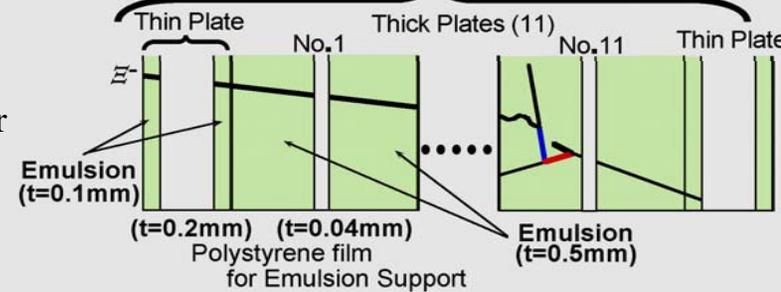
Precise prediction of Ξ^- tracks on the first emulsion plate.
=> Reduction in background tracks which are picked up in the first plate.

Quite low background

X-ray data are only analyzed for clear Ξ^- stopping events which are identified by nuclear emulsion.



Emulsion Stack



Development of Automatic Scanning

○ KEK-E373

- stage drive : step-by-step
 - image capture : 30Hz
- ⇒ 1.5~2.0 sec / one view

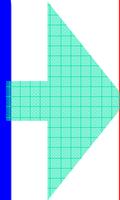
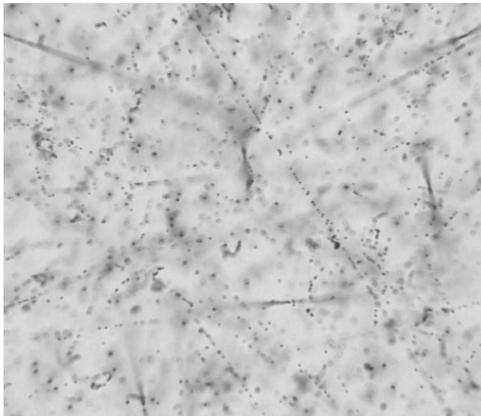
Images are shown:

1. Surface detection
=> Grid measurement
for position calib.
2. Track scanning



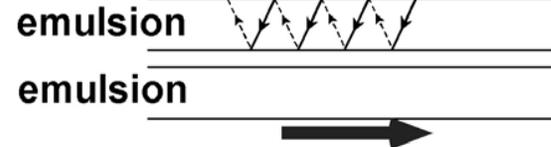
Current system

Surface & Grid : 22 sec.
Track_scan : 15 sec.



◎ AGS-E964(BNL)

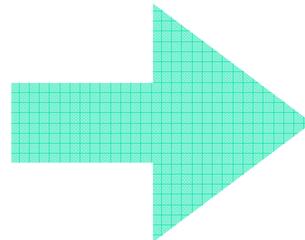
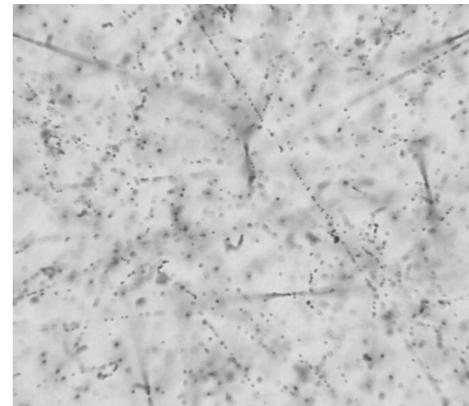
- stage drive : Non-Stop
 - image capture : 100Hz
- ⇒ ~0.2 sec / one view
(designed value)



Non-stop driving : speed~1mm/sec

Developing system

Surface & Grid : 9 sec.
Track_Scan : 6 sec.



E964 experiment

Nuclear Physics with double strangeness ($S=-2$)

RHIC/AGS
Ann. Users' meeting
May.11,2004.
K. NAKAZAWA
Gifu / Japan

KEK-E373 => AGS-E964> J-PARC

AGS-E964 (statistics **X10** of the past experiments)

- *) **International collaboration** (USA/China/India/JPN/Korea/Myanmar/UK)
- *) **$\sim 10^4$ Ξ^- stopping events** in nuclear emulsion.
- *) **~ 10 double- Λ hypernuclei (without any ambiguities).**
=> making **nuclear chart with $S=-2$.**
A-dependence of $\Delta B_{\Lambda\Lambda}$ in several nuclides.
- *) **X-ray measurement** from Ξ^- -atom, for the first time.
=> information of Ξ -N interaction.
- *) **funded \$2.5M** by JPN. Gov., already. (2003~2007)

However, the rearrangement of the beamlines are being planned for future fixed target programs and **decommissioning of D-line** is discussed.

To J-PARC (50GeV proton accelerator : JHF)

Initial PLAN : 2007 for the first beam.

PROBLEM : **Buried cultural property was excavated.**
Goshawk (endangered species) was found.

Start shall be delayed.

KEK-PS shutdown (2005? for M.E. Physics).

- *) **E964** leads the community of hypernuclear physics to significant activities at J-PARC.

n

p

Λ

Near Future Condition of Hadron Beams

2005(?)

2009 (?)

KEK-PS
 Θ^+ experiment
with SKS [$\Delta E < 1.5 \text{ MeV}$]
(K.Imai)

Shutdown
for J-PARC

**Desert of H.B. for
M.E. Phys?**

AGS is the Unique
possible tool for M.E.
Phys. with H.B.?

J-PARC
1st Beam