Aug.02-04,2004
NP04

Study of double-Λ hypernuclei

Phys. Dept., Gifu Univ.
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- Our goal
- Status of experiments
- Experiment at J-PARC
- Summary---statistics

Experimental motivation

Making a nuclear chart of double-hypernuclei

=> Information Λ-Λ force,

for understanding B-B int. in SU(3)$_f$

investigating Multi-strangeness system, “strange matter”

$$\begin{aligned}\Delta B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z) &= B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z) - 2B_{\Lambda}({}^{A-1}_{\Lambda}Z) \\ &= 2M({}^{A-1}_{\Lambda}Z) - M({}^{A-2}Z) - M({}^{A}_{\Lambda\Lambda}Z)\end{aligned}$$

Existence of the H-dibaryon → resonance?

$$M_H \geq 2m_\Lambda - B_{\Lambda\Lambda}$$

Coupling effect

$$|H>= \sqrt{\frac{1}{8}}|\Lambda\Lambda> + \sqrt{\frac{4}{8}}|N\Xi> - \sqrt{\frac{3}{8}}|\Sigma\Sigma>$$

Theoretical progress

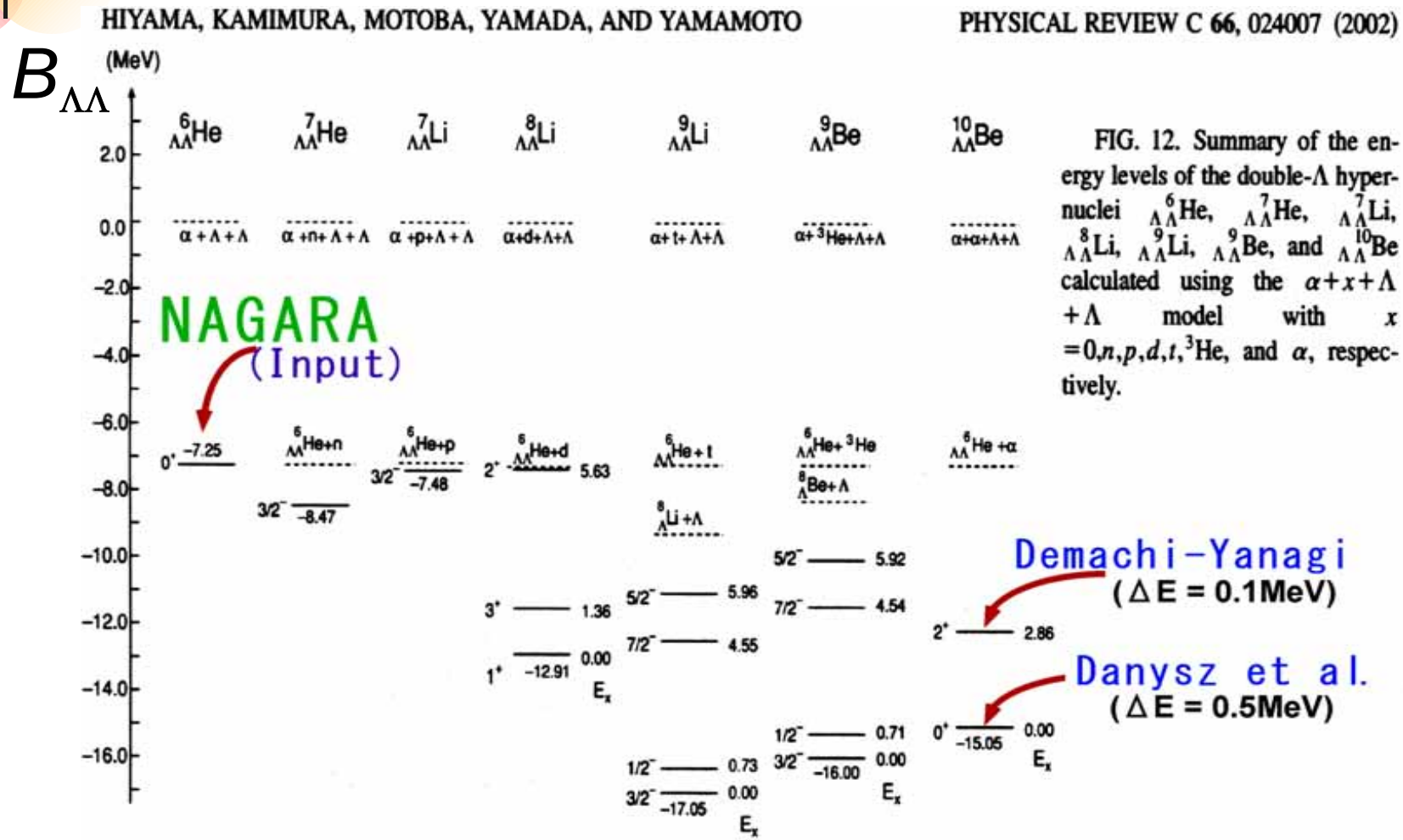


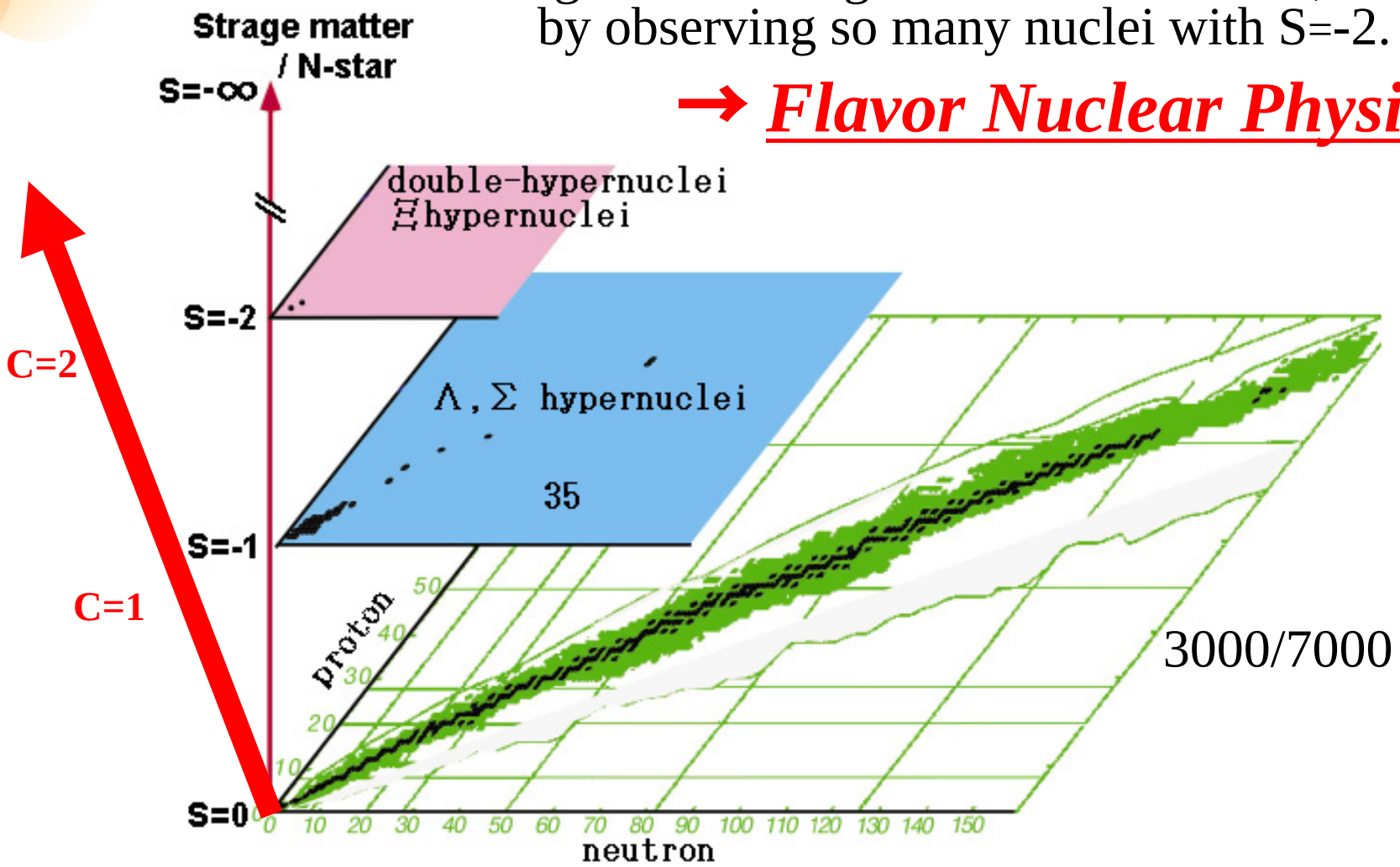
FIG. 12. Summary of the energy levels of the double-Λ hypernuclei ${}^{6}_{\Lambda\Lambda}$He, ${}^{7}_{\Lambda\Lambda}$He, ${}^{7}_{\Lambda\Lambda}$Li, ${}^{8}_{\Lambda\Lambda}$Li, ${}^{9}_{\Lambda\Lambda}$Li, ${}^{9}_{\Lambda\Lambda}$Be, and ${}^{10}_{\Lambda\Lambda}$Be calculated using the $\alpha+x+\Lambda+\Lambda$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

To know ΛΛ int. independent on the core structure,
we need to measure A-dependence of $B_{\Lambda\Lambda}$.

Nuclear Chart with Strangeness

Our goal is making a S=-2 nuclear chart,
by observing so many nuclei with S=-2.

→ ***Flavor Nuclear Physics***

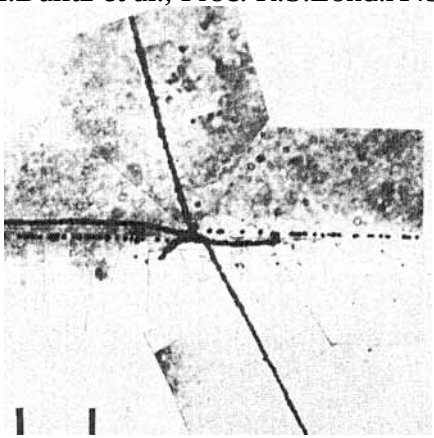


3000/7000

Status of experiments I

1963

M.Danysz et al., PRL.11(1963)29;
R.H.Dalitz et al., Proc. R.S.Lond.A436(1989)1



$^{10}_{\Lambda\Lambda}$**Be** in ~4 Ξstops

$\Delta B_{\Lambda\Lambda}$ = **4.3**±0.4 MeV

if a doughter $^{9}_{\Lambda}$Be is in excited

$\Delta B_{\Lambda\Lambda}$ = ~**1.3** MeV

1966

D.J.Prowse, PRL.17(1966)782

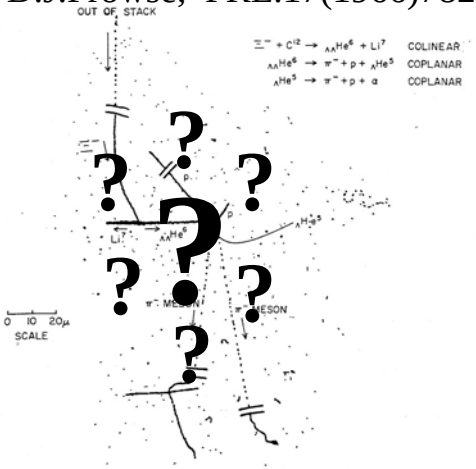


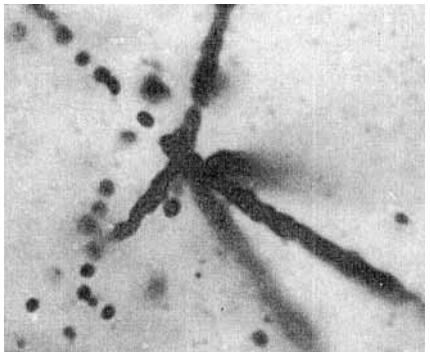
FIG. 1. Drawing of the event.

$^{6}_{\Lambda\Lambda}$**He**

$\Delta B_{\Lambda\Lambda}$ = **4.6**±0.5 MeV

1991

S.Aoki et al, PTP.85(1991)1287



KEK-E176

$^{13}_{\Lambda\Lambda}$**B** in ~80 Ξstops

$\Delta B_{\Lambda\Lambda}$ = **4.9**$^{+0.7}_{-0.8}$ MeV

if a doughter $^{13}_{\Lambda}$C is in excited

$\Delta B_{\Lambda\Lambda}$ = ~**0** MeV

or $^{10}_{\Lambda\Lambda}$**Be**

$\Delta B_{\Lambda\Lambda}$ = **-4.8**$^{+0.7}_{-0.8}$ MeV

The existence of Double-Λ hypernucleus was confiermed

Status of experiments II

Double-Λ hypernuclei from E373

2001

NAGARA event

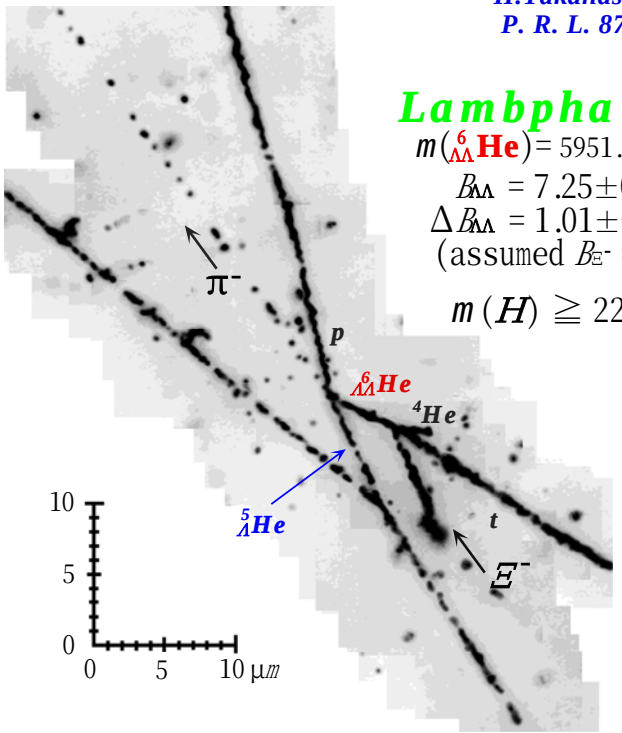
$^{6}_{\Lambda\Lambda}$He double-hypernucleus

Unique interpretation!!

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

${}^{6}_{\Lambda\Lambda}He \rightarrow {}^{5}_{\Lambda}He + p + \pi^-$

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



Lambpha

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

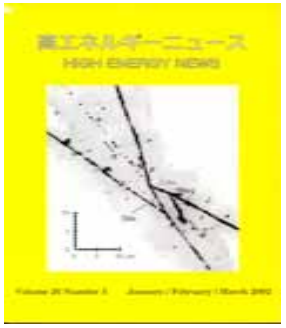
$B_{\Lambda\Lambda} = 7.25 \pm 0.19^{+0.18}_{-0.11}$ MeV

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

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

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

http://www.phys.ed.gifu-u.ac.jp/Topics/NAGARA-e.htm



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

Demachi-yanagi event

2001

*two body case at point A

$\Xi^- + {}^{12}C \rightarrow {}^{10}_{\Lambda\Lambda}Be + t$ or ${}^{10}_{\Lambda\Lambda}Be^{*} + t$

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

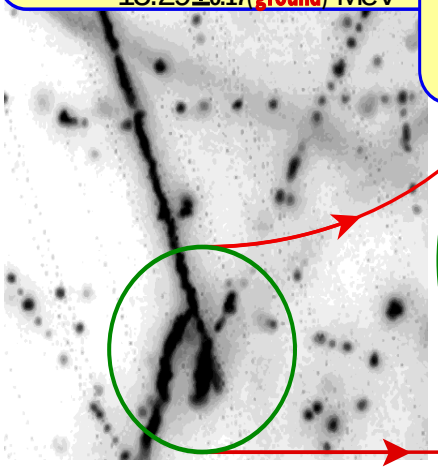
$B_{\Lambda\Lambda}$: 12.29±0.17(excited) MeV

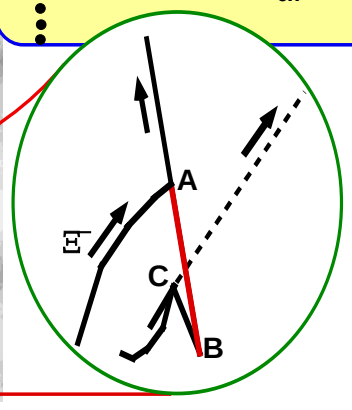
15.29±0.17(ground) MeV

*three body case at point A

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

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





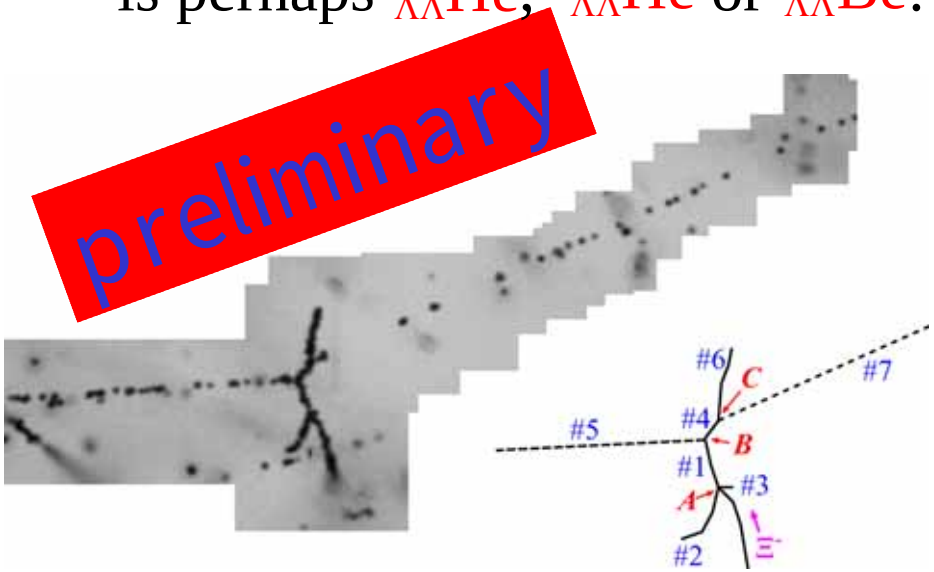
Status of experiments II

Double-Λ hypernuclei from E373

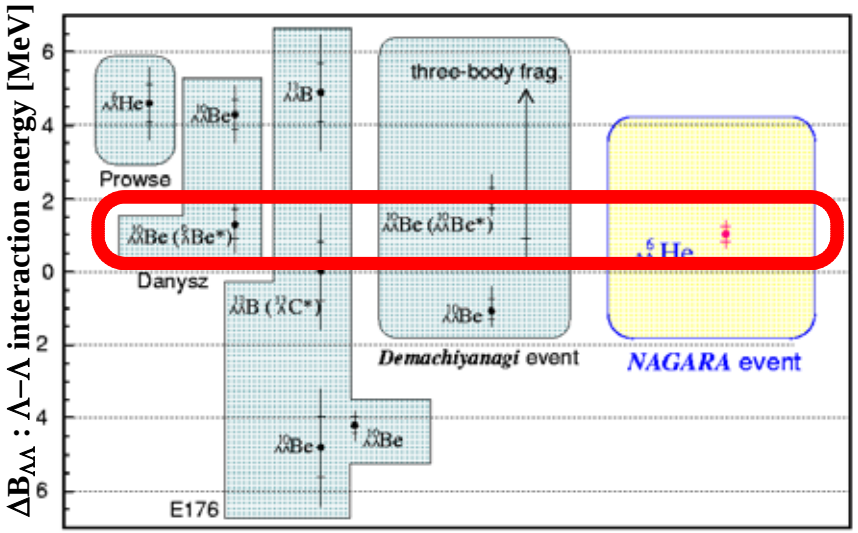
2002

3rd double-Λ hypernucleus

Nuclear species of the double-Λ is perhaps $^{6}_{\Lambda\Lambda}$He, $^{7}_{\Lambda\Lambda}$He or $^{11}_{\Lambda\Lambda}$Be.



Our knowledge for ΛΛ int. until now.



ΛΛ interaction is attractive but weak

Statistics of experiments via Ξ^- hyperon capture at rest

	Danysz, *et al.* 1963	E176 1991	95% finished E373 2004
# of Ξ^- stop	~4	~80	~10^3
Light nuclei with S=-2	1	1	~6
Twin single-Λ	0	2~3	2

Quite poor statistics until now.

BNL-E964 → J-PARC

Nuclear Physics with double strangeness (S=-2)

KEK-E373 => AGS-E964

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

Beam : K^- (1.7GeV/c),
4×10^5 K^-/spill
with **$K^-/\pi^- > 9$ at D6-line**

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

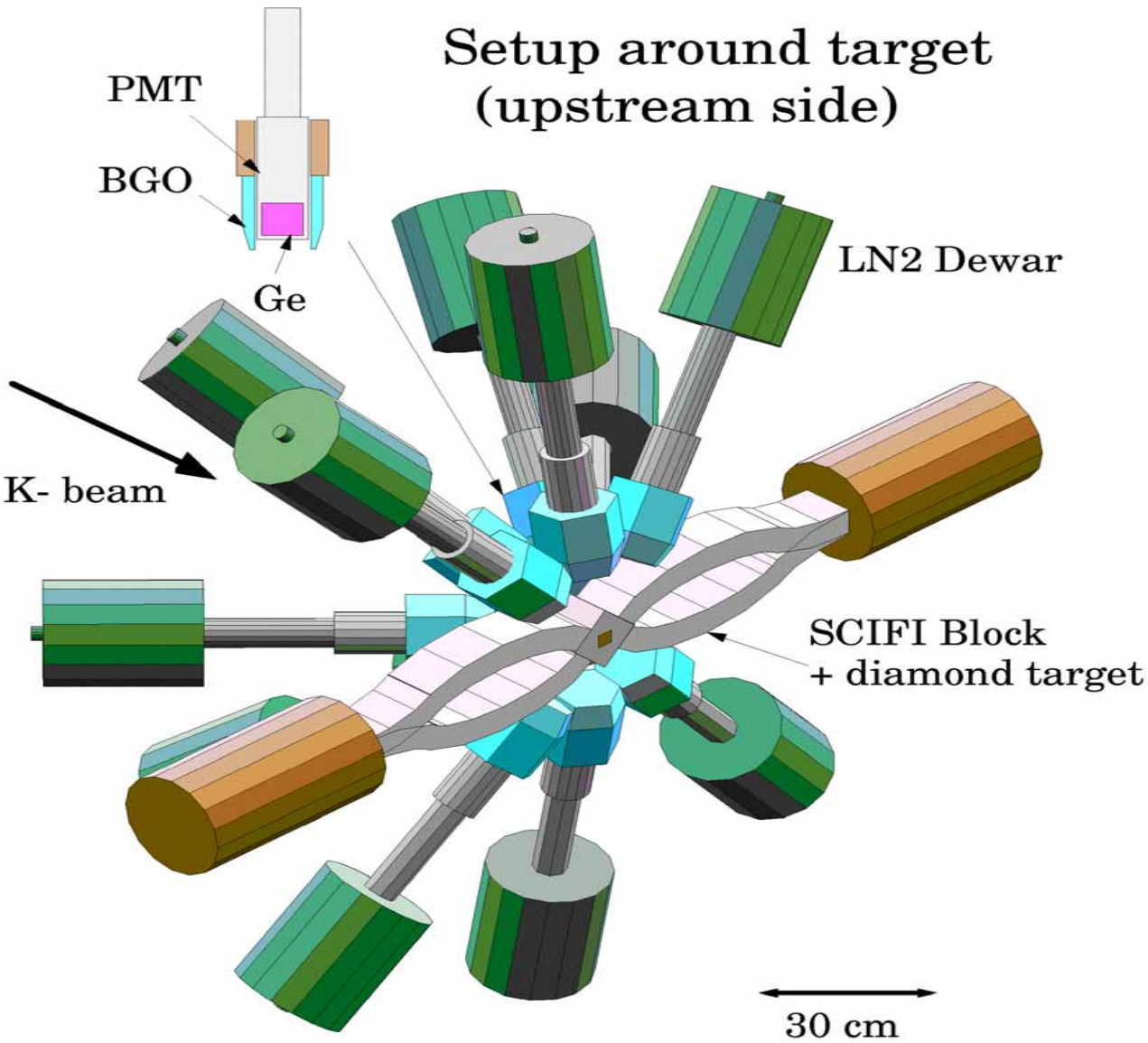
Time requested :
150 hours for detector tune
600 hours for beam exposure

(K-, K+) trigger

$10^4 \Xi^-$ stopping events

We requested Beam time on
FY2006

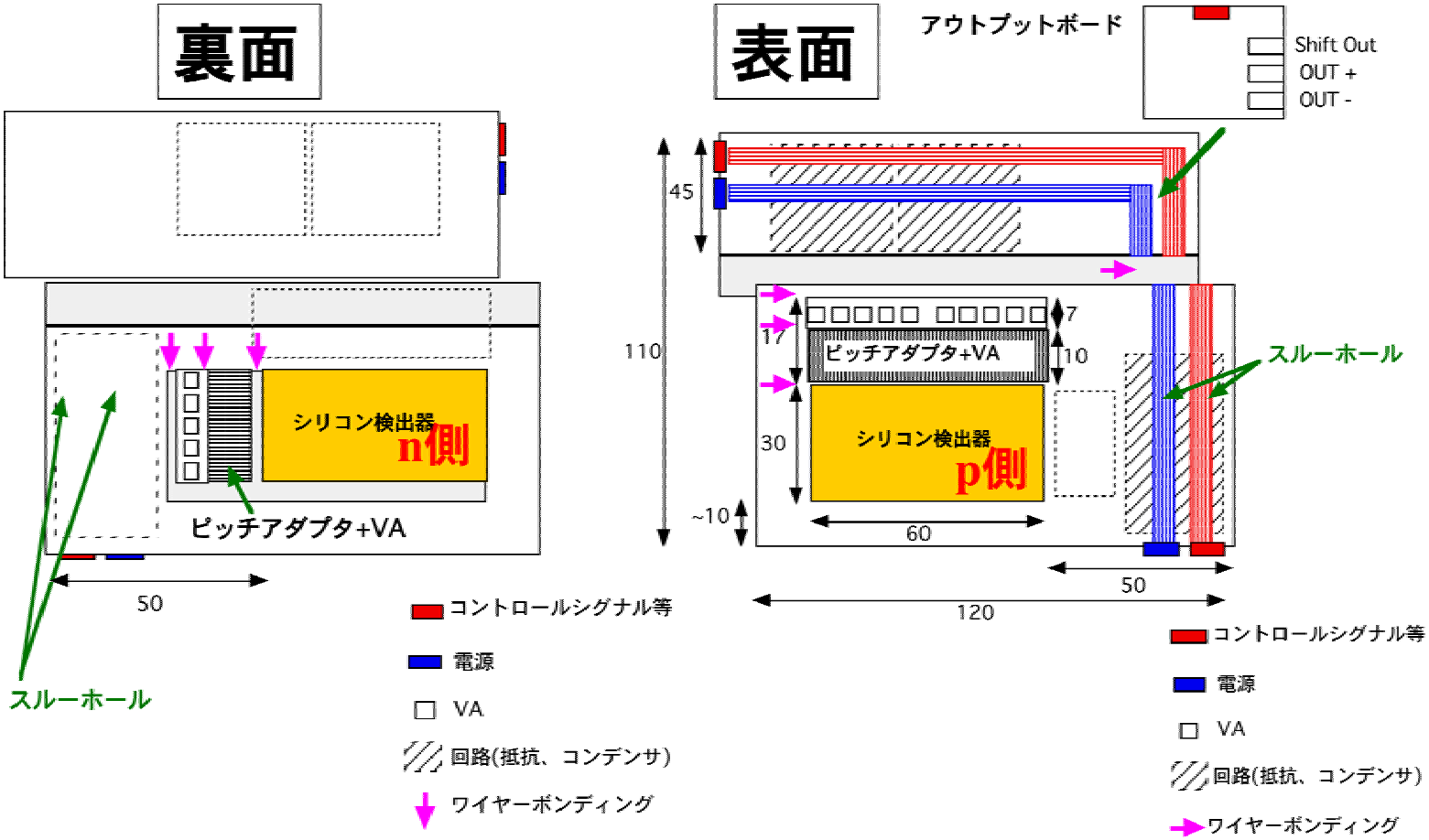
Ge detector for Ξ-atomic X-ray



Double-Sided Si Detector

全体像

基板はBTレジンで1.2mmの厚さ



Development of Automatic Scanning

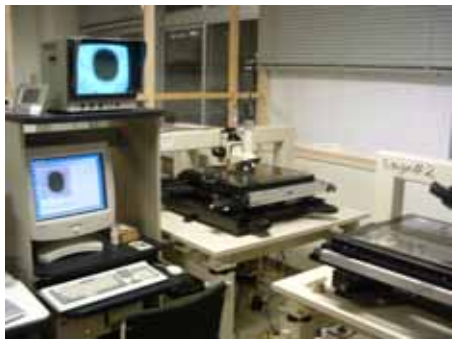
○KEK-E373

- stage drive : step-by-step
- image capture : 30Hz

⇨ **1.5~2.0** sec / one view

Images are shown:

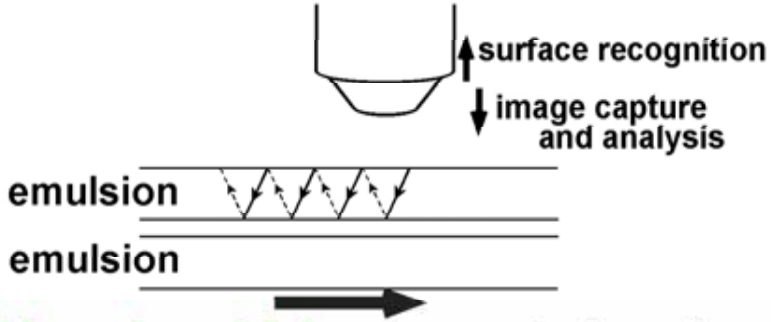
1. **Surface** detection
   => **Grid** measurement
   for position calib.
2. **Track scanning**



◎AGS-E964(BNL)

- stage drive : Non-Stop
- image capture : 100Hz

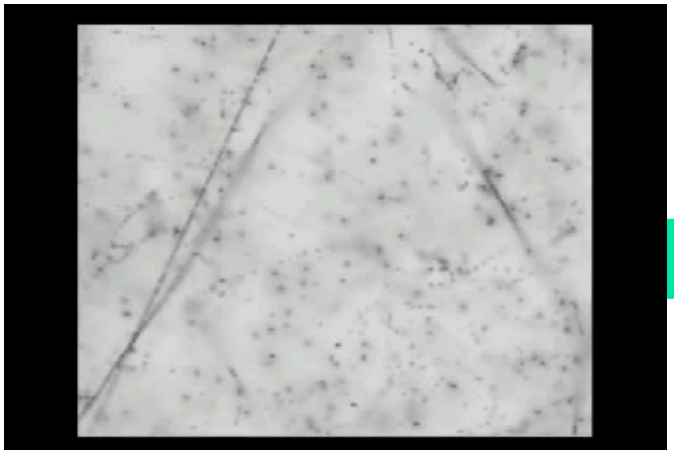
⇨ **~0.2** sec / one view
(designed value)



Non-stop driving : speed~1mm/sec

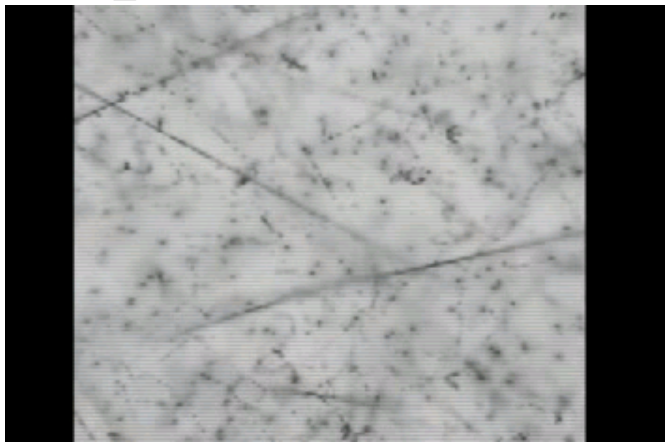
Current system

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



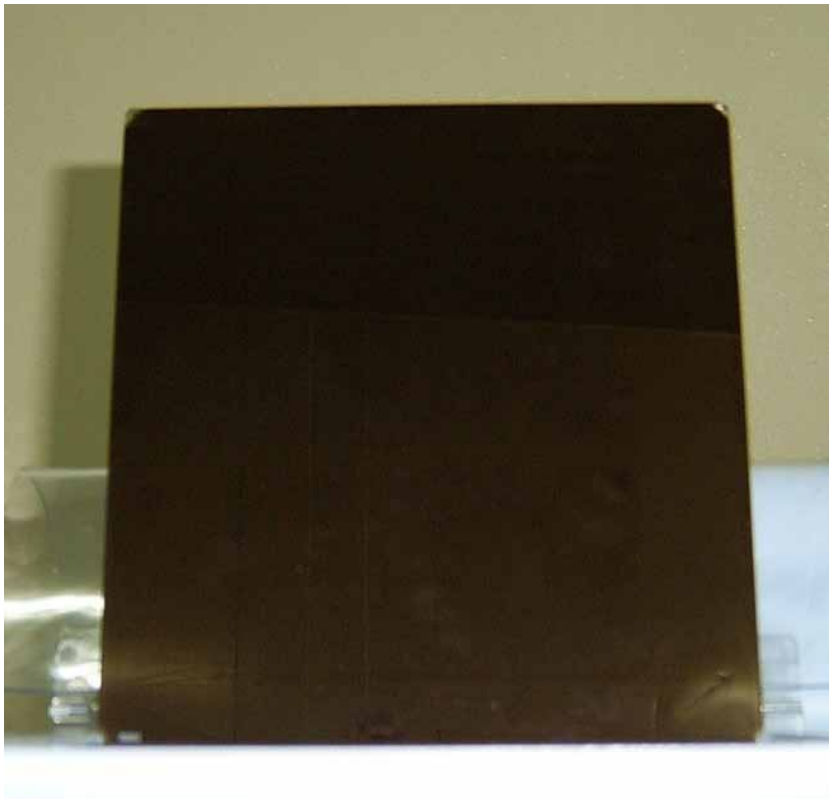
Developing system

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



Development of grid printing to get better position accuracy

Fabrication of sample mask from Korean Collaborators



Size of mask : 15x15cm^2

Area of hole marks : 15 x 7.5cm^2 (half below)

Base : Quartz crystal (3.2mm thick)

Coated material : Chrome (10 μm thick)

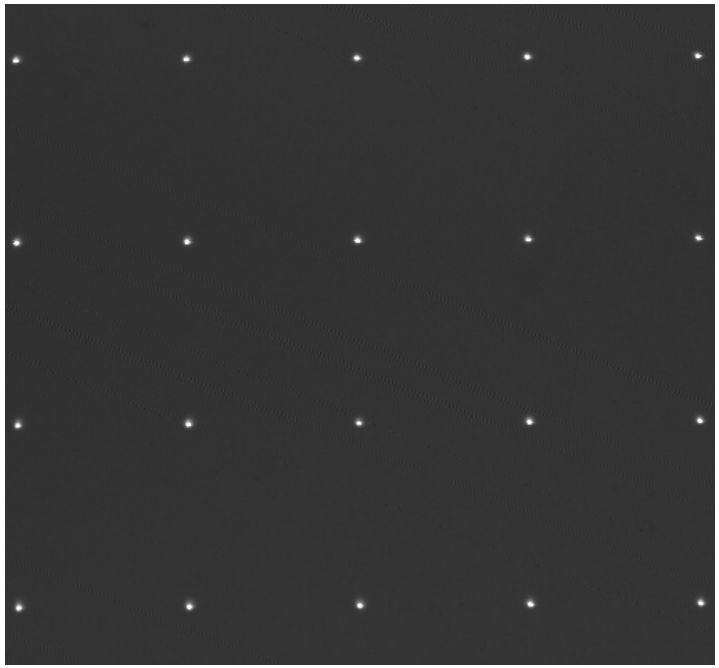
Gap distance of each marks :

x: 99.6 μm, x: 99.3 μm

Hole size : 0.89 μm ϕ

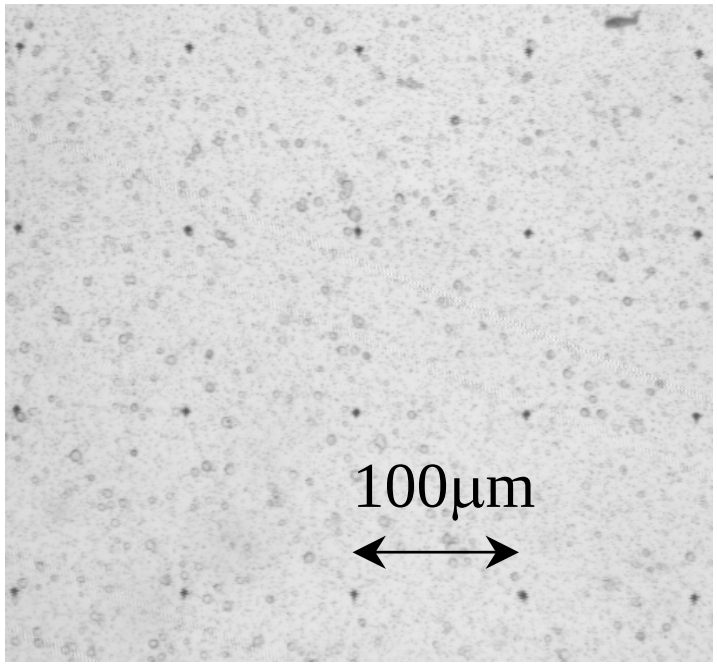
We will have precise calibration points

Mask holes



by ×20 obj. lens

Exposed image in X-ray film



by ×20 obj. lens

Exposure time : 1 sec

UV wave length : 255 nm

Distance from source to trget : 30cm

preliminary

New Hybrid-Emulsion Experiment at J-PARC

- Ξ^- production

10 times larger statistics than BNL-E964

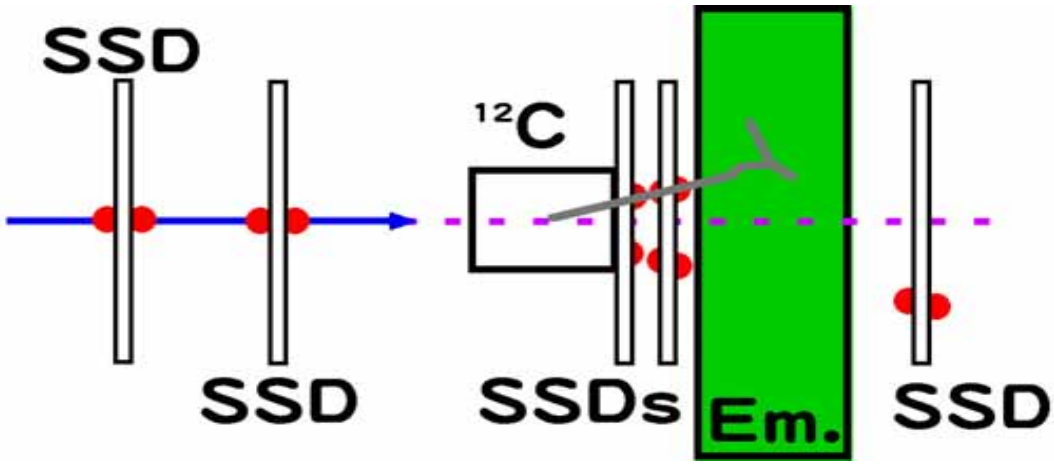
$K^- + p \rightarrow \Xi^- + K^+$
$\Xi^- + K^+ + \pi^0$
$\Xi^- + K^0 + \pi^+$
$K^- + n \rightarrow \Xi^- + K^0$
$\Xi^- + K^0 + \pi^0$
$\Xi^- + K^+ + \pi^-$

Quasi-free (K^-, K^+) reaction (no K^+ tracking x 2)

x2.5 ($\sigma_{\Xi^- prod.}$)

K^- +(p,n) ➔ X : 3.5times
& Em.: ✕3

Outline : No K^+ tagging → no spectrometer magnet
Trigger ・・・ **K^--^{12}C reaction ✕ X-ray(F→D)**



New Hybrid-Emulsion Experiment at J-PARC

To get ～10^3 double-Λ hypernucleus
via ～10^5 Ξ^- stopping events

Information:
- nuclear chart of S=-2 nuclei
- γ-ray from double-Λ hypernuclei

Developments :
- Hyperball
- fully automated scanning system
- nuclear emulsion itself → next speaker (**M. Natsume**)
- ・・・・・・

- proposal will be submitted.

Fine grain emulsion crystal to get better position resolution at J-PARC

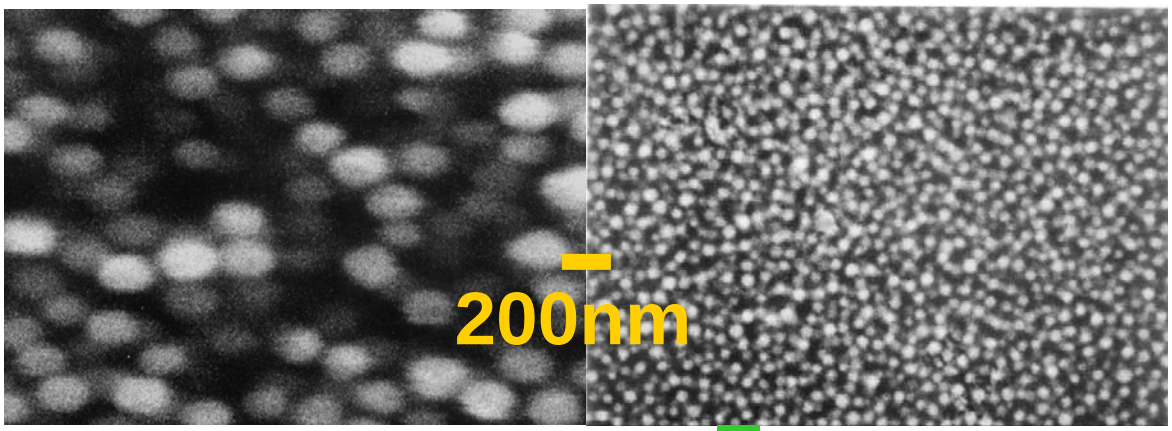
SEM Micrographs of AgBr Grains

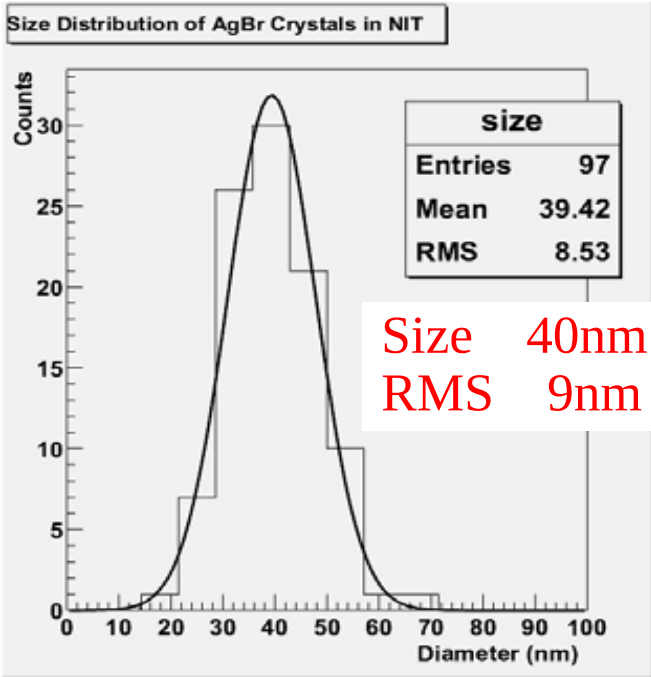
SEM : scanning electron microscope

E373 emulsion (ET-7C,D)

NIT(Nano Image Tracker developed by Nagoya

Size of AgBr Grains



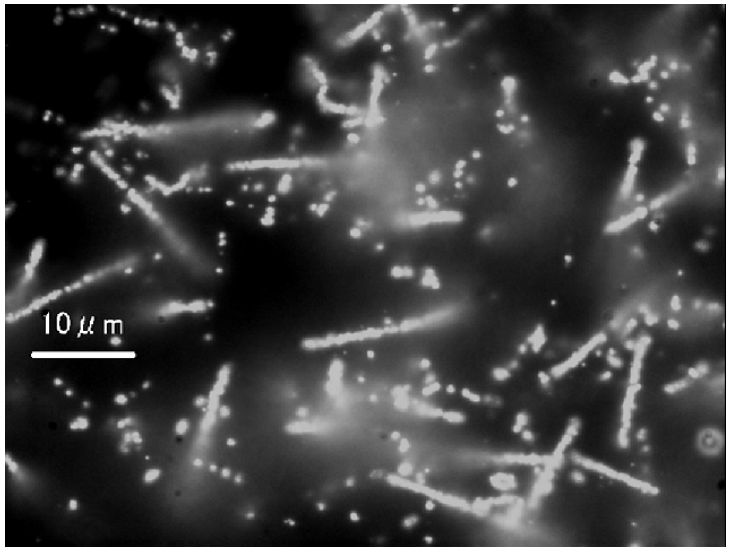


Fine grain emulsion crystal to get better position resolution at J-PARC

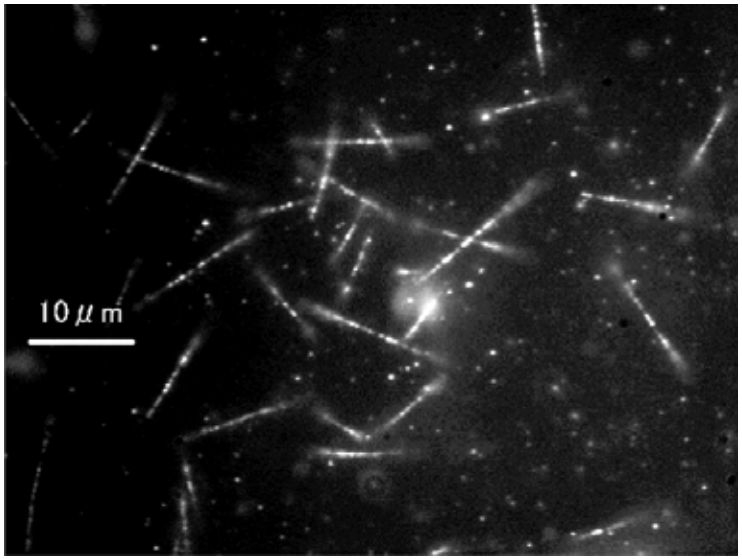
Tracks due to 5MeV α - particles

Dark Field Image of Light Microscope

ordinal emulsion



NIT



Development

1) density 2.8(g/cc) → 3.5(g/cc)

or 2) size : 40nm → 70~80[?]nm

Pions & fast protons without beam tracks → **Higher dense exposure**

Summary

Comparison of yields

Roughly estimated outcome

Experiment	KEK -E176	KEK -E373	BNL -E964	J-PARC
K^-/beam	1/4	1/5	0.9	0.9
# of K^- beams	1×10^9	1×10^{10}	1×10^{11}	3×10^{11}
(per spill)	3×10^3	$1\sim2\times10^4$	4×10^5	$1\sim2\times10^6$
Beam time (hr.)	~1000	1500	750	1500 ~3000
Trigger	(K^-,K^+)	(K^-,K^+)	(K^-,K^+)	(K^-, X)
# of Ξ^- stops	80	10^3	10^4	10^5
Em. Volume (ℓ)	30	70 210	600	
# of detected nuclei with S=-2	1	~10	$\sim10^2$	$\sim10^3$
		95% fin.	FY2006?	future