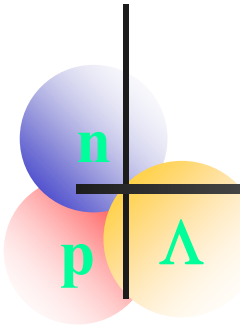
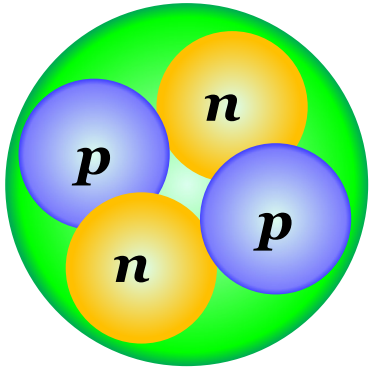


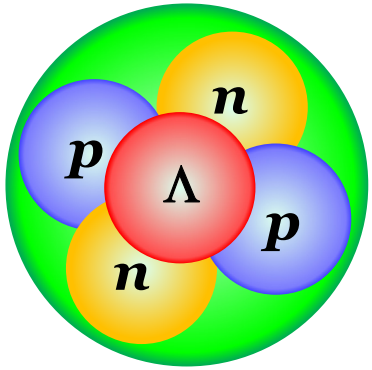
ダブルハイパー核実験用原子核乾板の神岡地下施設の鉛ブロック内での保管

仲澤　和馬
岐阜大学・物理学教室
2015年12月18日

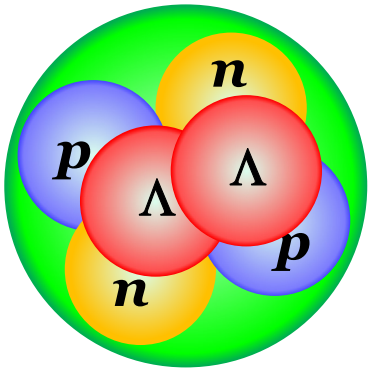
ダブルハイパー核
ストレンジネス(S) −2の原子核



^{4}He原子核

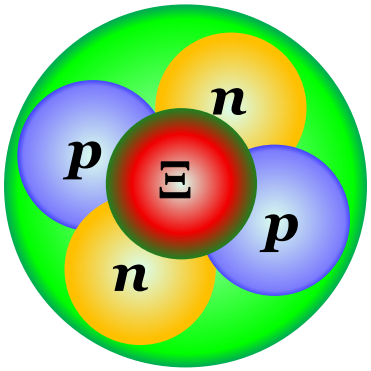


^{5}Heシングル Λ
ハイパー核



ダブル Λ
ハイパー核

Λ−Λ 相互作用



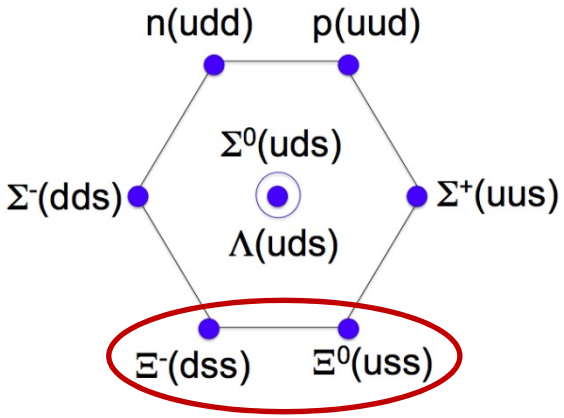
グザイ
ハイパー核

Ξ−*N* 相互作用

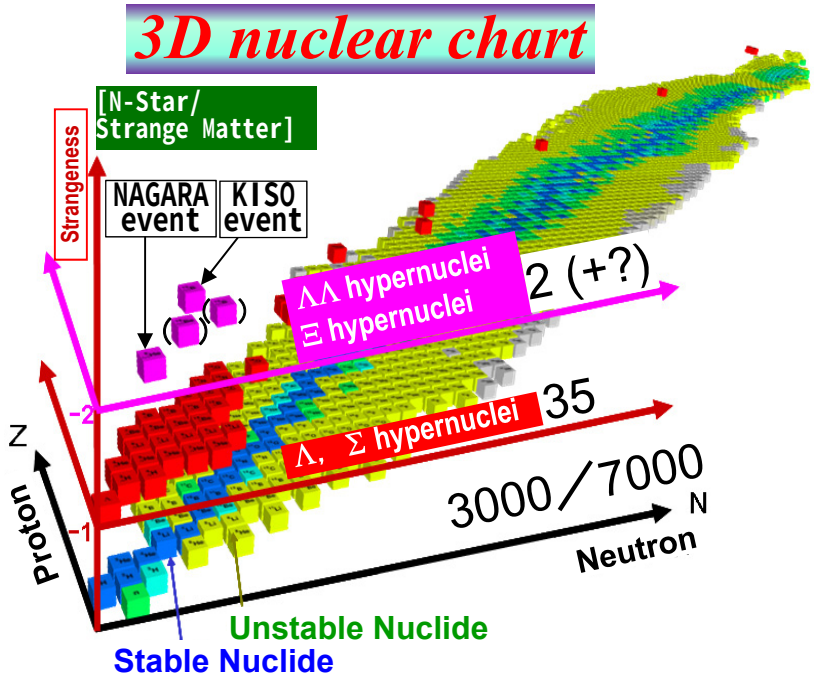
Motivation

Nuclear Phys. with S=-2

Baryon octet



∗ **Making a nuclear chart of double-hypernuclei**



In S=-2 sector,

➔ YY-mixing [ΛΛ⇔Ξ*N*⇔ΣΣ(⇔H)]

- m(Ξ*N*) – m(ΛΛ) = (23~28) MeV
- m(Σ*N*) – m(Λ*N*) = 80 MeV

Information of Λ-Λ and Ξ-*N* force,

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

and as guide for us to Multi-strangeness system,

e.g. Neutron Stars.

➔ For those information;

available sources are

double-Λ hypernucleus,

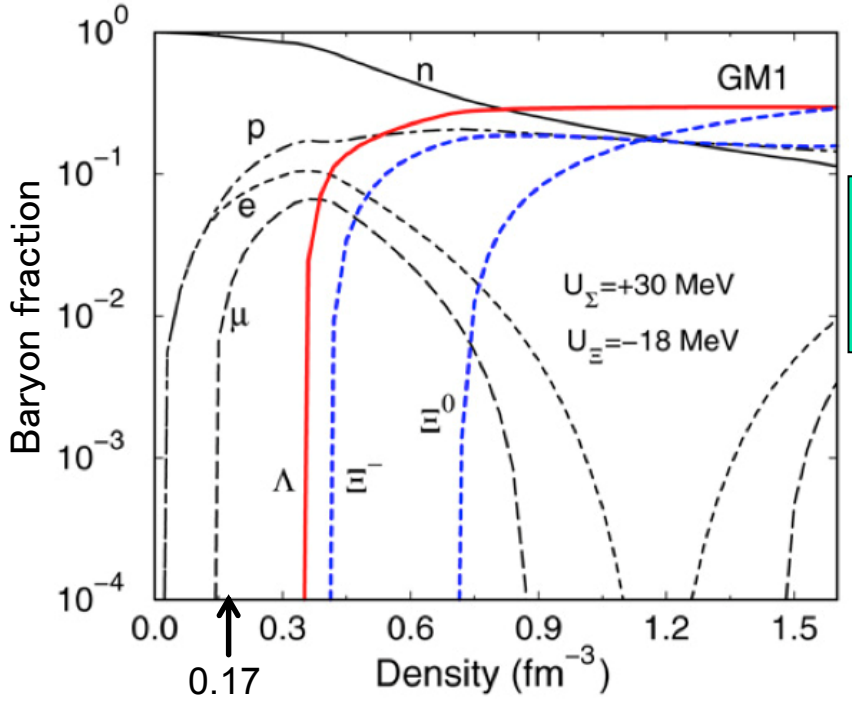
Ξ hypernucleus,

H-dibaryon

Motivation

== Y*N* interaction ==

$M_{NS} < 1.4M_{\odot}$



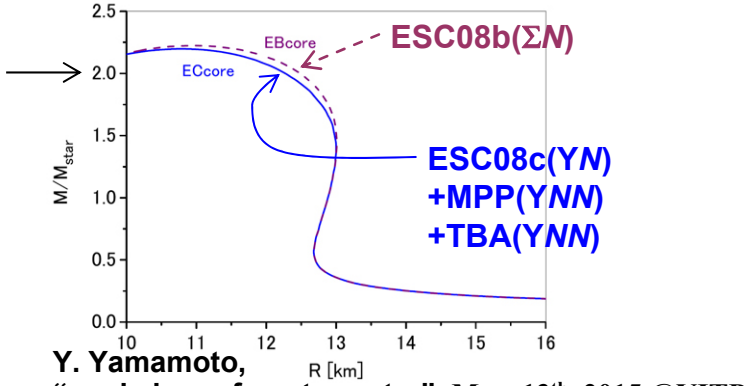
J.Schaffner-Bielich, N.P. **A 804** (2008) 309-321
「Hypernuclear physics for neutron stars」

Discovery of heavy NS ($\sim 2M_{\odot}$)

For extra repulsive forces,

1. Universal three body force.
   → flavor independent *!*

   NNN, Y*NN*, YY*N*, YYY int.,
   where Y = Λ, Σ, Ξ



Y. Yamamoto,
"workshop of neutron star", Mar. 13th, 2015 @YITP

2. Phase transition of
   baryon to quark matter.
3. ・・・

Many theorists present many theories.

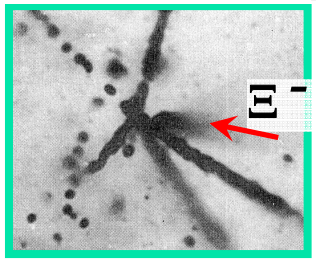
百家争鳴

It is necessary for more rich information of Y*N* & YY int.

Observed double-Λ Hypernuclei in E176/E373 Hybrid Emulsion experiments

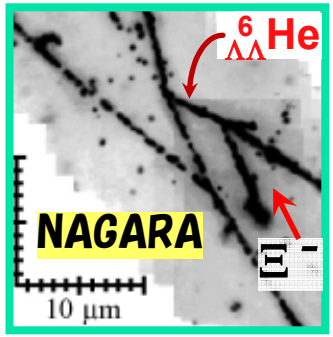
KEK-E176

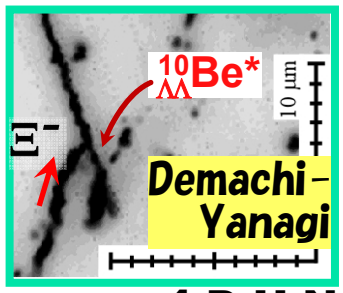
in ~80 Ξ⁻ stops

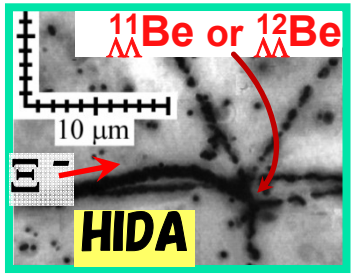


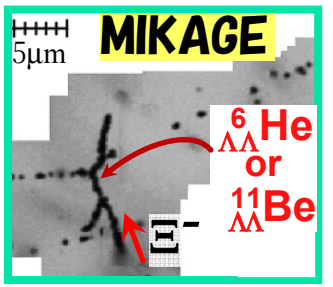
S.Aoki et al., NP. A828 (2009) 191-232

KEK-E373 ~10^3 Ξ⁻ stops









4 D.H.N in 7 samples by E373

J.K.Ahn et al., Phys. Rev. C88 (2013) 014003-1~10

ΛΛ bound energies

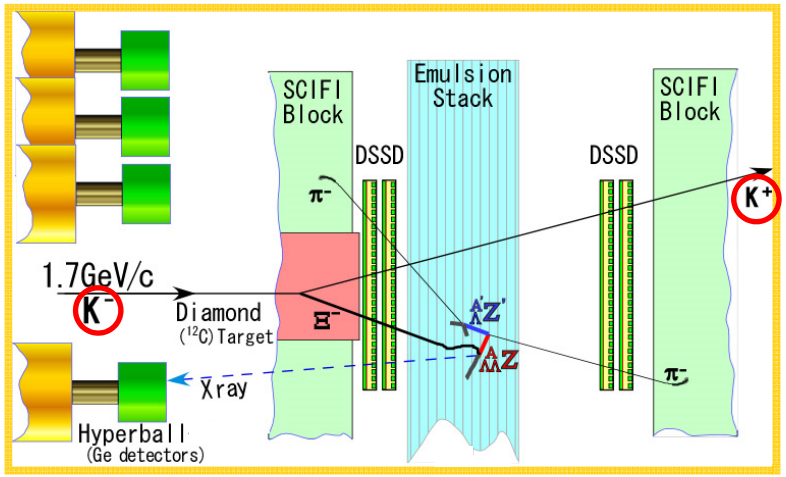
[1]Hiyama et al. PRL104(2010)212502 [2]Gal-Millener PLB701(2011)342

Event	$^{A}_{\Lambda\Lambda}Z$	Target	$B_{\Lambda\Lambda}$ [MeV]	$\Delta B_{\Lambda\Lambda}$ [MeV]	Cluster [1]	Shell [2]
NAGARA	$^{6}_{\Lambda\Lambda}$He	^{12}C	6.91±0.16	0.67±0.17	(6.91)	(6.91)
DEMACHIYANAGI	$^{10}_{\Lambda\Lambda}$Be ($^{10}_{\Lambda\Lambda}$Be*)	^{12}C	11.90±0.13	-1.52±0.15	11.88	
HIDA	$^{11}_{\Lambda\Lambda}$Be	^{16}O	20.83±1.27	2.61±1.34	18.23	18.40
	$^{12}_{\Lambda\Lambda}$Be	^{14}N	22.48±1.21	—		20.27
MIKAGE	$^{6}_{\Lambda\Lambda}$He	^{12}C	10.01±1.71	3.77±1.71		
	$^{11}_{\Lambda\Lambda}$Be	^{14}N	23.05±2.59	4.85±2.63		
E176	$^{13}_{\Lambda\Lambda}$B ($^{13}_{\Lambda}$C*)	^{14}N	23.3±0.7	0.6±0.8		23.21
Danysz et al.	$^{10}_{\Lambda\Lambda}$Be ($^{9}_{\Lambda}$Be*)	^{14}N	14.7±0.4	1.3±0.4	14.74(g.s.)	14.97(g.s.)

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

Strategy of E07 experiment at J-PARC

1.New Hybrid method



J-PARC

1. Pure K-beam
   (better 3.5 times than KEK-PS)
2. More emulsion volume (E373 x 3)
   [gel : **2.1** *t*]

10^3 (E373) ➔ 10^4 Ξ- stop events

1. ~10^2 double hypernuclei
2. X ray measurement from Ξ **atom**
   ➔ study of **Ξ-N interaction**

Automated track-following

2. *Overall-scanning*

Fully automatic detection of

3 vtx. event

like NAGARA and KISO event

10 times statistics of that with the hybrid method

(1/0.3): free from acceptance & tracking
X
4 : $\cdot p(K^-,K^+)\Xi^-$ in the emulsion
$\cdot n(K^-,K^0)\Xi^-$ reaction

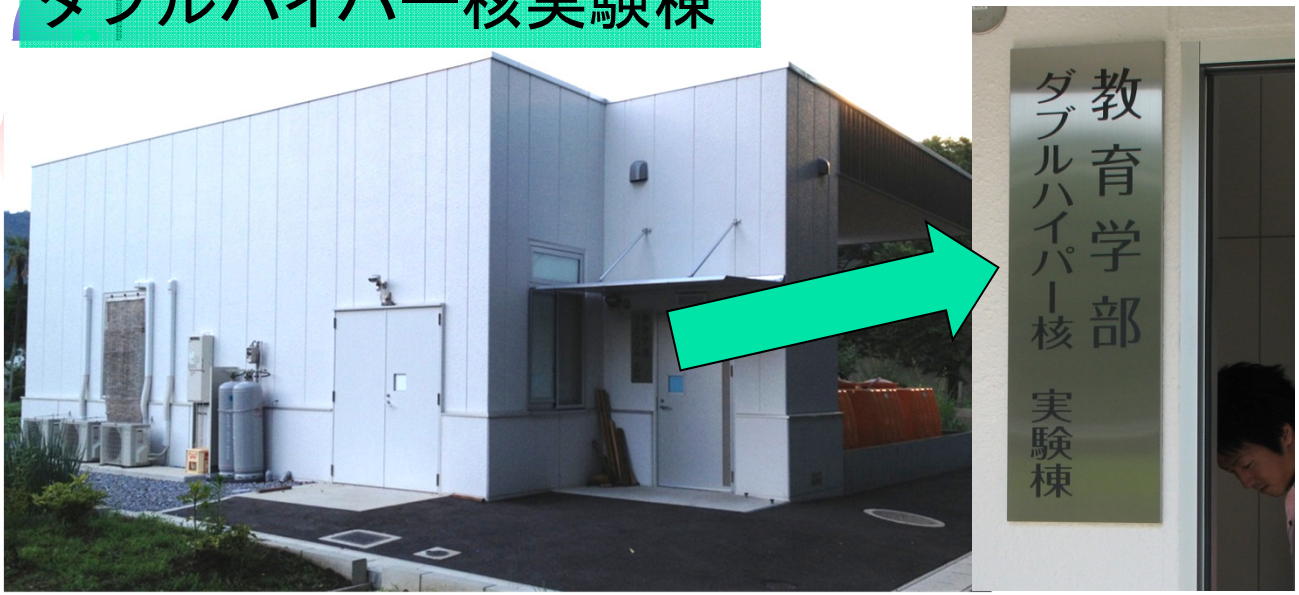
We expect to measure the mass of

~10^3 double-Λ hypernuclei

~10^2 Ξ hypernuclei

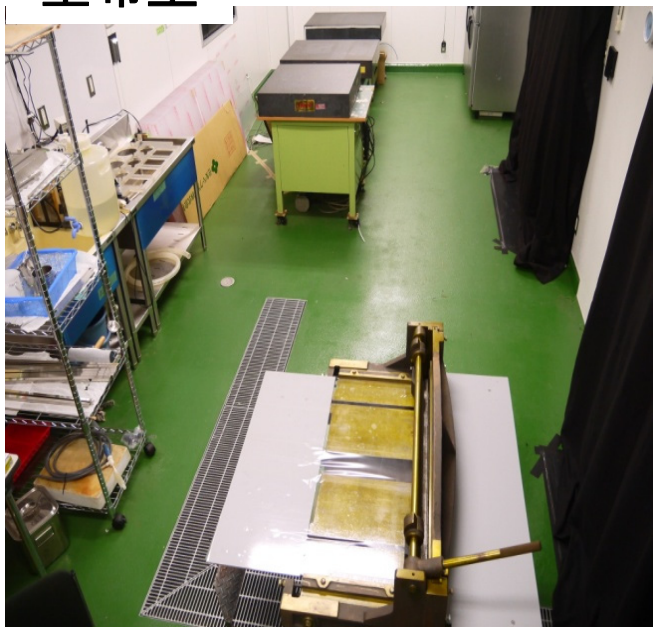
with A<16

ダブルハイパー核実験棟

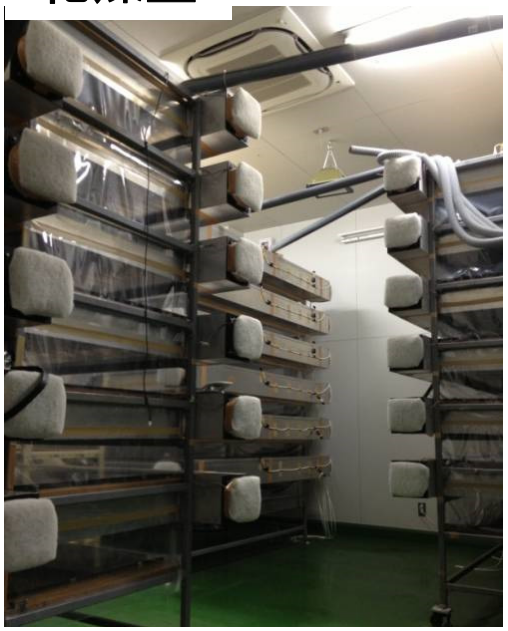


<塗布室>
Three flat stone bases,
Hot bath
Cutting machine
<乾燥室>
Temp **30 ℃** and R.H. **75%**.
<現像室>
1200 liters' chemical solutions
Total 100 m²

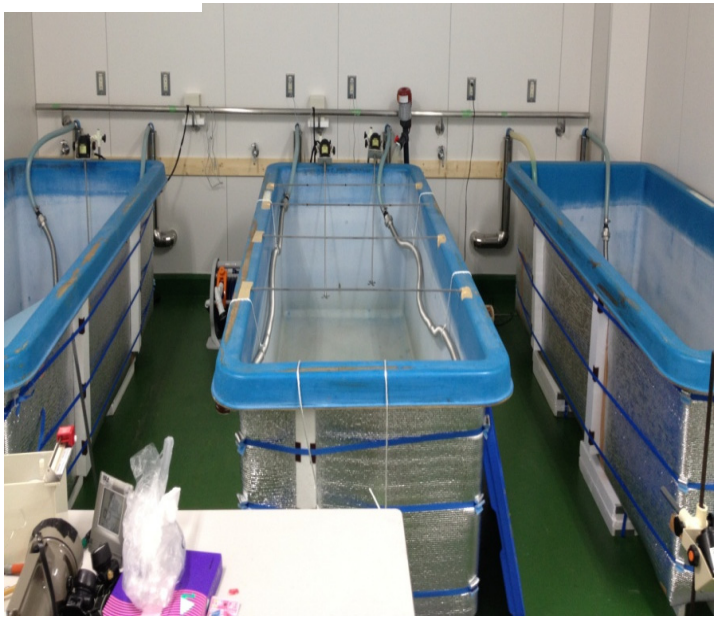
塗布室



乾燥室

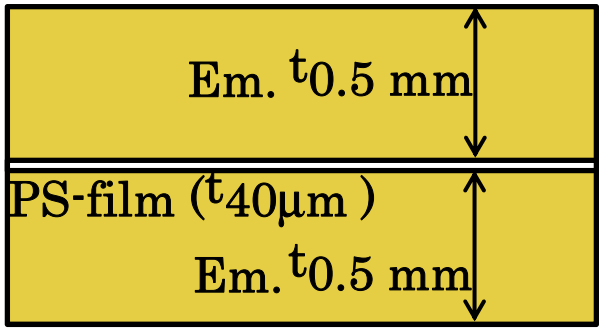


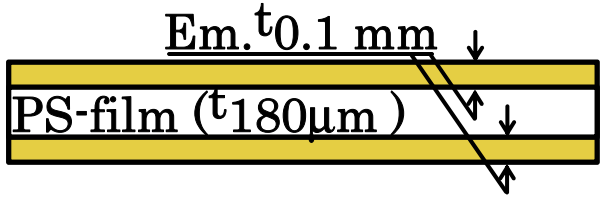
現像室



Mass production from Dec. 06, 2013 to May 18, 2014

Size:
345 x 350 mm²





2.1*t* gels ➔ **1380** plates **240** plates

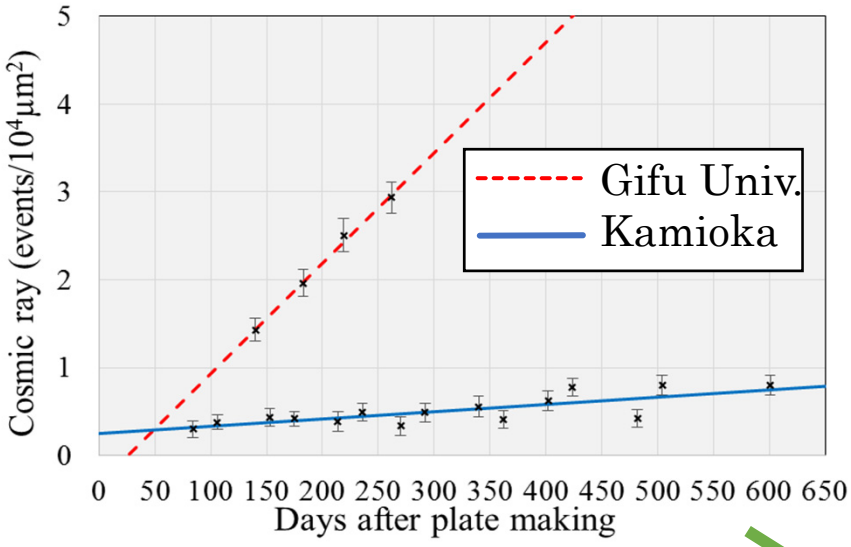
Stocked in the Kamioka mine

Spot cooler keeps temp. at 15~17 ºC. It is monitored via internet.

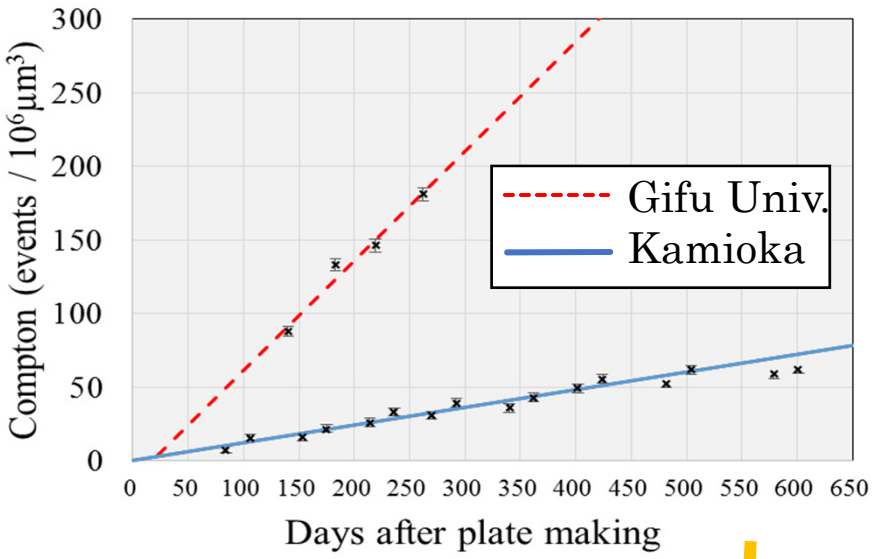
Box made of Lead wall
(t10 cm, 60 cm×60 cm×240 cm)
to avoid ……
1. Cosmic radiation
2. γ-ray from air

Emulsion condition after plate making

●Cosmic rays



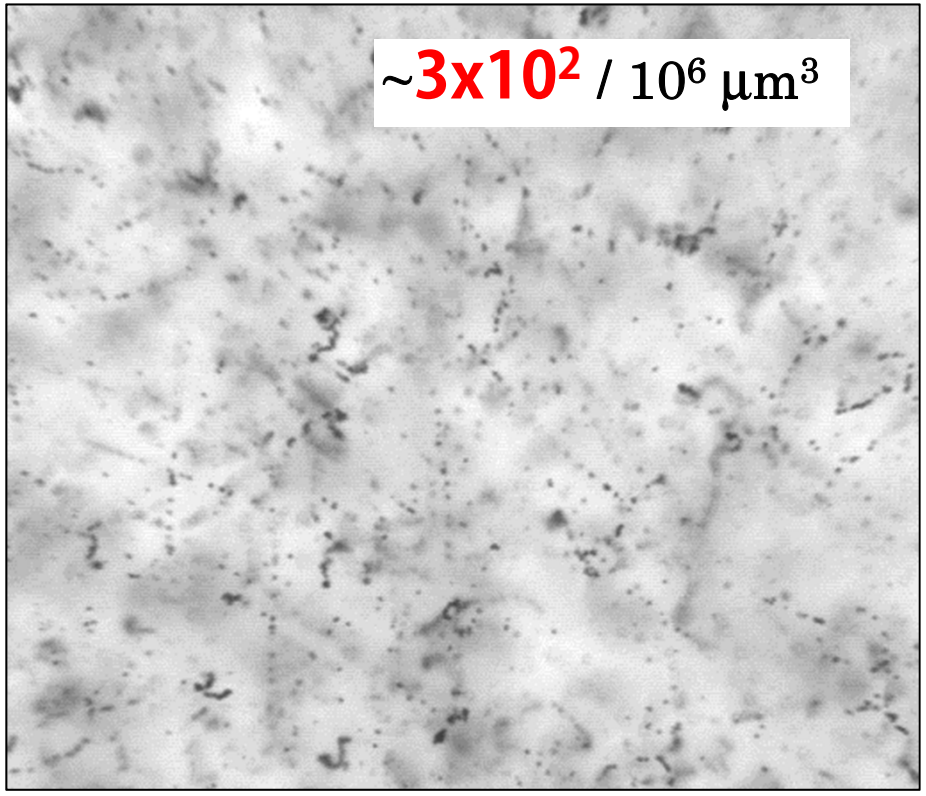
●Compton electron



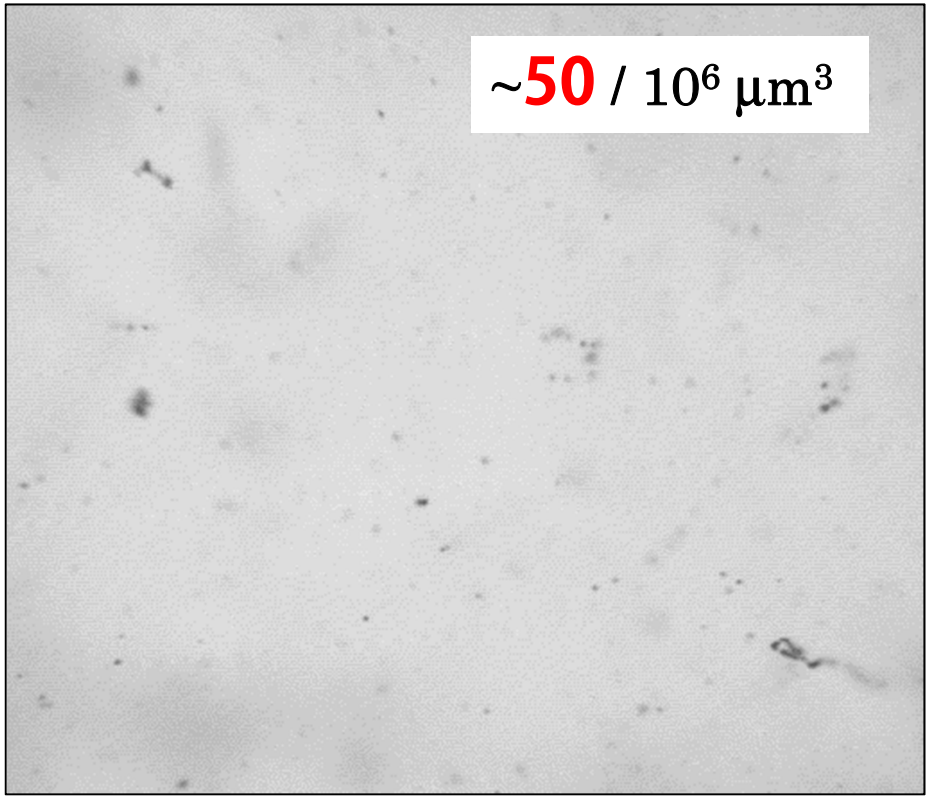
Location (day)		Cosmic ray (tracks/10^4μm^2・day)	Compton (electrons/10^6μm^3・day)
Refrigerator in Gifu Univ.		12.5 (±1.7)×10^{-3}	0.75 (±0.05)
Lead box at SK.	E07 (Jan. 2014～)	0.82 (±0.29)×10^{-3}	0.12 (±0.01)
	E373 (1999～2000)	0.45 (±0.05)×10^{-3}	0.14 (±0.01)

Gifu Univ. M2　Hiroki ITO

●Pictures of the emulsion plates



Refrigerator in **Gifu Univ. : 400days**



Lead box in **Kamioka mine : 424days**

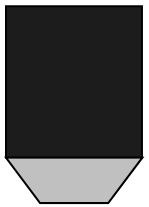
Back ground of Compton electrons **in E373**

max. ~130 / 10⁶ μm³

B.G. is closing the max. value on **Jul. 2016**

Gifu Univ. M2　Hiroki ITO

Development of "*Overall-scanning*"



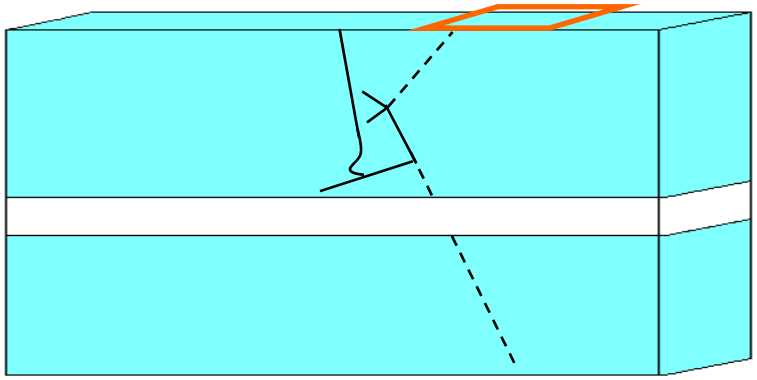
Primary motivation;

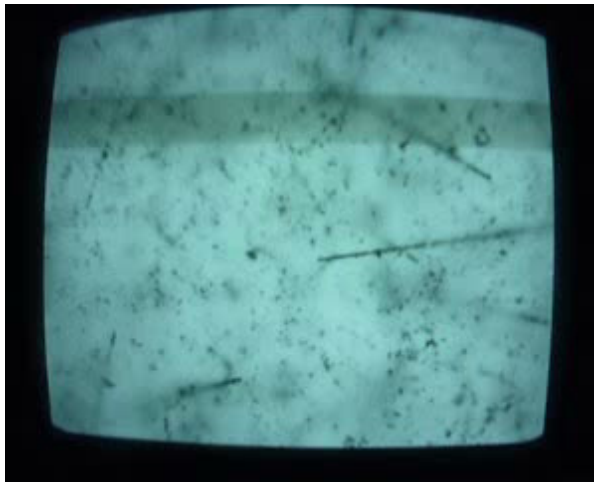
fast detection of α decay vertices of natural isotopes to calibrate range-energy relation.

① *fast image capture*

Developed system with CCD camera

OS : Win2000 sp4
CPU : 3.0 GHz
1.57GB RAM
Camera : 100Hz (CCD)
Obj. lens : x 50
emulsion : 0.5mm
area : 0.1x0.08mm^2
# of image : ~100/cycle
Time : 5 min. /cycle
➔ 3sec/cycle
[~ hard limit]

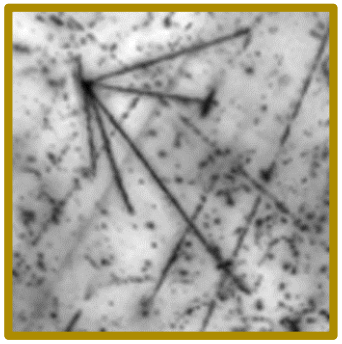




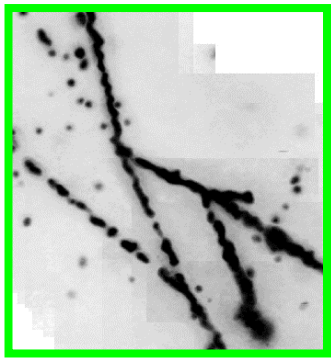
Development of "*Overall-scanning*"

② *fast image processing* for event detection

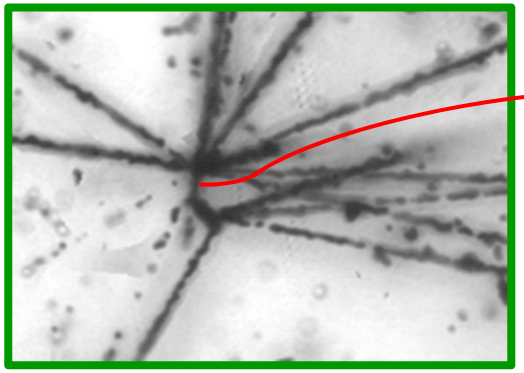
α decay VTX

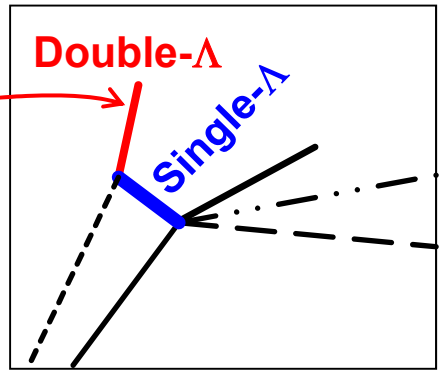


3 vertices

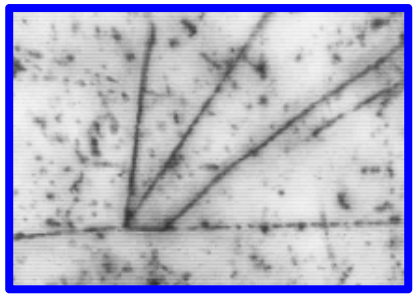


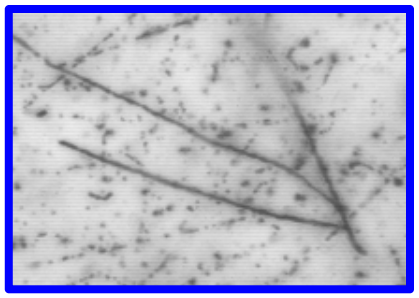
NAGARA event
was detected by this method





2 vertices (single-Λ cand.)



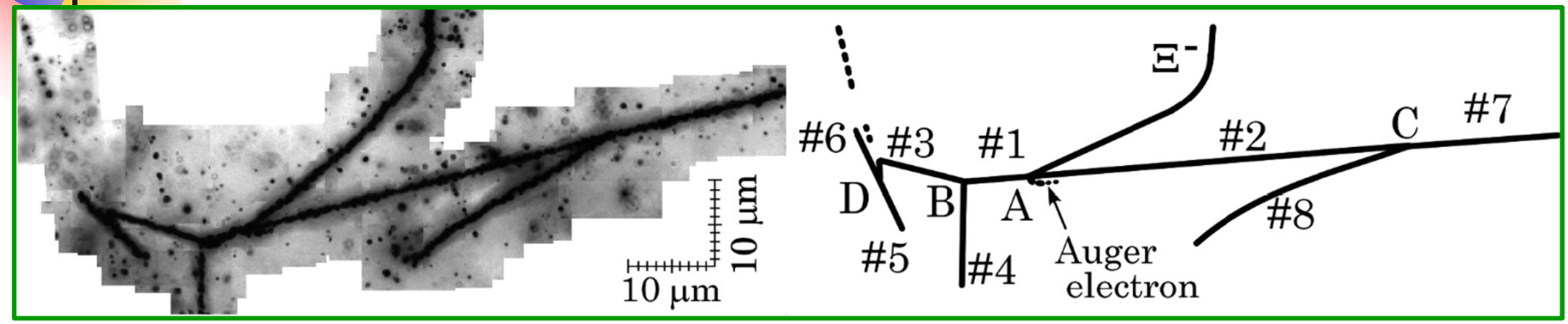


Until April. 2013,
***8 M* images** under test operation (1.46 cm³)
using E373 emulsion (**55 liters**)

, , , , , ,
more

＊The first evidence of Ξ^--^{14}N deeply bound system

K. Nakazawa et al., PTEP. 2015 033D02 (11 pages)



Process of the *KISO* event

$\Xi^- + {}^{14}N \rightarrow {}^{10}_{\Lambda}Be$ (#1) + ${}^{5}_{\Lambda}He$ (#2),

${}^{10}_{\Lambda}Be \rightarrow {}^{8}Li$ (#3) + p (#4) + n,

${}^{8}Li \rightarrow {}^{8}Be^*(2^+) + e^- (+ \bar{\nu}_e)$

ex. ${}^{8}Be^*(2^+) \rightarrow 2\alpha$ (#5 & # 6)

${}^{5}_{\Lambda}He \rightarrow p$(#7) + d(#8) + $2n$

B_{Ξ^-} = **4.38 +/- 0.25** MeV (by Mom. balance [#1 and #2])

if ${}^{10}_{\Lambda}Be$ is in excited production, B_{Ξ^-} = **1.11** +/- 0.25 MeV

cf. **0.17** MeV (atomic 3D level for ^{14}N)

Ξハイパー核(KISO event)発見の新聞報道（中日新聞2015年1月19日：朝刊3面）

New scanning system for the E07emulsion

Vertex Picker (VP) for Overall scanning in full EM volume

Fast image capture by Obj. x20 ➔ image processing ➔

Picked up vertices are checked by Obj. x50

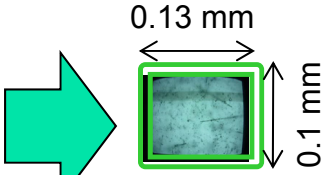


Image processing

with *piezo* stage

×300 faster !!

	Old	VP	
Obj. Lens	× 50 (NA. 0.9)	× 20 (NA. 0.35)	➔ × 50
Camera	100Hz XC_HR300	800Hz HXC20	
Pixel	512 × 440 pixel	2039 × 357 pixel	
Area	130 mm × 110 mm	1.1 mm × 0.20 mm	
Rate(Hz)	0.3	5	
	4 sets	3 sets	

Human check 3 VTX. in well contrasted images

In Myanmar Universities:

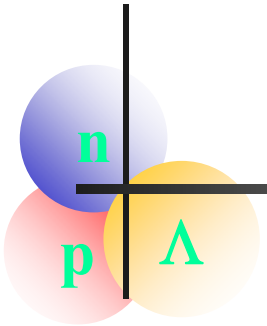
by more than 10 Graduate Stu.

Images with 3 VTX. are taken by bj.×100

Event analyses by the image

Physics by, ~10^3 D.H.N

At present, we are able to detect **(1~2) x 10^2 single-Λ hypernuclei in a week.**



E07 Exposure plan at J-PARC

1. **Beam test exposure** has been successfully performed in **Oct. 2015.**
2. **Spectrometer magnet** will be installed in **Mar. 2016.**
3. **Beam line** construction **from Apr. to Mar. 2016.**
4. **First run** will be **Jun. 2016.** **(<10% of all)**
5. **Second run** will be started in **Feb. 2017.**