Xi-Nucleus interaction from the 1st evidence of Xi^{-} - ^{14}N system

(HNP2015@Kurabi, Thailand)

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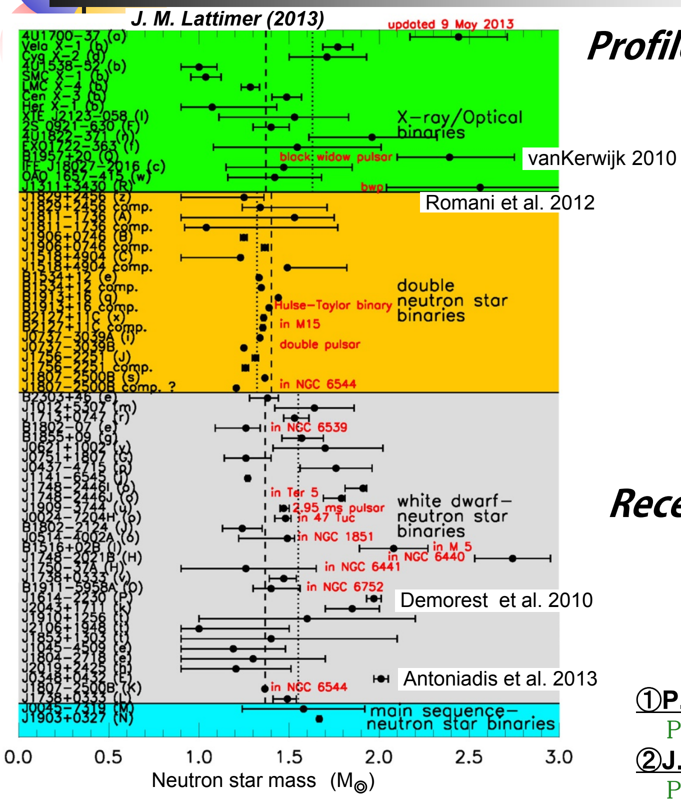
Outline

1. Introduction….neutron star & Y*N*, YY interaction
2. Present knowledge on S=-2 system, eps. Xi-*N*.
3. Coming E07 experiment @ J-PARC
   and The ***KISO event*** showing
   a deeply-bound Ξ-*N* system
4. Summary

1. *Introduction*



Profile and structure of Neutron Stars **(NSs)**

Mass	(1~2)M⊙
Radius	(10~20)km
Temperature	~10^{6} K [surface]
	~10^{8} K [internal]
Pressure	(10^{29}~10^{31}) atm [center]
Density	~10^{6} g/cc [surface]
	~10^{15}g/cc [center]

cf. ~10^{14}g/cc for ^{12}**C**, 5.5 g/cc for earth, 1.5 g/cc for sun.

Recent topics of NS

- *Observation of heavy NS* (~2M⊙)
- *Hope to measure radius and mass of NS, coincidently.*
- *Detection of fast cooling of NS*

①**P. B. Demorest et al., Nature 467 (2010) 1081**
PSR J1614−2230 (NS−WD binary), 1.97 ± 0.04 M⊙

②**J. Antoniadis et al., Science 340 (2013) 448**
PSR J0348+0432 (NS−WD binary), 2.01 ± 0.04 M⊙

Hyperons in NS

1) Hyperons will be mixed in NS.

* Density ρ becomes large
  - ➔ chemical potential of neutron becomes large
  - ➔ *YN*-mixing ($\Lambda \Leftrightarrow$ n, $\Sigma^- \Leftrightarrow$ n + e-)

start at $\rho_t(\Lambda) \sim 5\rho_0$ ($\rho_0 \sim 0.17 fm^{-3}$)

if *YN* interaction is attractive, ρ_t is decreasing to **(2 ~ 3)**ρ_0.

2) Necessity of "Extra Repulsion" in hypernuclear system.

* $\rho > \rho_t(\Lambda)$ ➔ "softening" of EOS by increasing hyperons
  - ➔ keeping heavy mass of NS becomes hard.

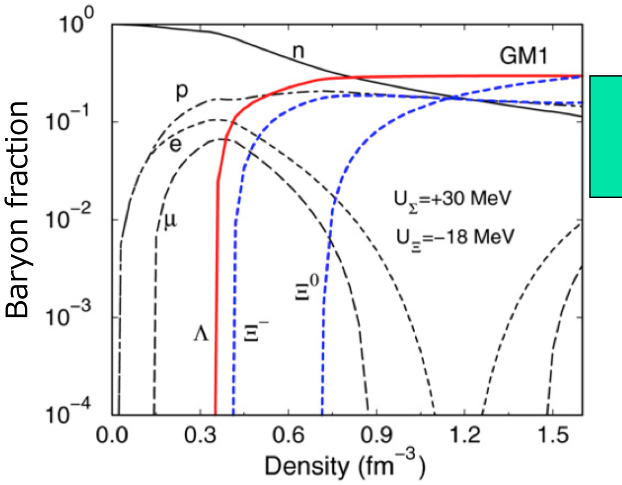
Introduction of three body force into hypernuclear system makes ρ_t rebound to ~$4\rho_0$.

Interaction

== *YN* interaction ==

Σ^--nucleus potential is strongly repulsive.

[KEK-PS E438 P. K. Saha et al., Phys. Rev. C 70 (2004), 044613.]

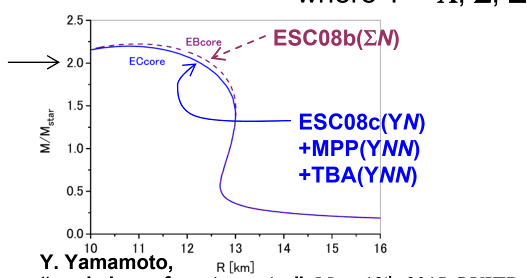


J.Schaffner-Bielich, N.P. **A 804** (2008) 309-321
「Hypernuclear physics for neutron stars」

Discovery of heavy NS (~$2M_\odot$)

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.

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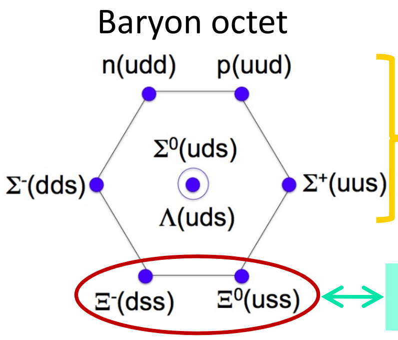
It is necessary for more rich information of *YN* & YY int.

Nuclear Phys. with S=-2

Main subject : *Study of hadron-hadron interaction*



- ***N*-*N* interaction**
  Continuous research has been made in experiment and theory for more than 50 years
- **Y-*N* interaction**, where Y = (Σ, Λ)
  Steadily progressing, *e.g.* γ-ray spectroscopy.

Next subject

In S=-2 sector,

➔ YY-mixing [ΛΛ⇔Ξ*N*⇔ΣΣ(⇔H)]

- m(ΞN) – m(ΛΛ) = (23~28) MeV
- m(ΣN) – m(Λ*N*) = 80 MeV

➔ For those information, uniquely available source;
double-Λ hypernucleus, Ξ hypernucleus,
(H-dibaryon)

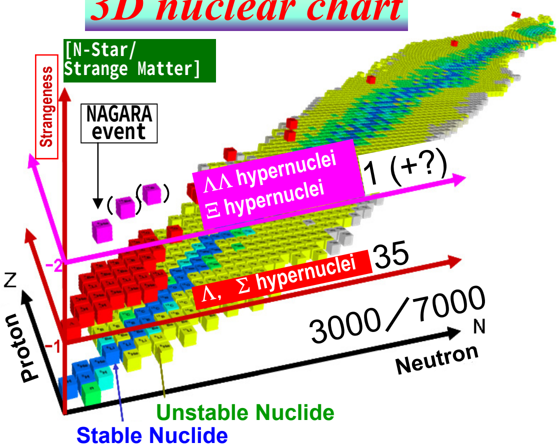
Nuclear Phys. with S=-2

∗ Making a nuclear chart of double-hypernuclei

=> **Information of Λ-Λ and Ξ-*N* force,** for understanding B-B int. in SU(3)*f*
guides us to Multi-strangeness system, "strange matter"

Key values of experiment: $B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z) = M({}^{A-2}Z) + 2M(\Lambda) - M({}^{A}_{\Lambda\Lambda}Z)$ **and** B_{Ξ^-}

3D nuclear chart



However, it is hard to carry out any Λ-Λ and **Ξ-*N*** scattering experiment due to their very short lives.

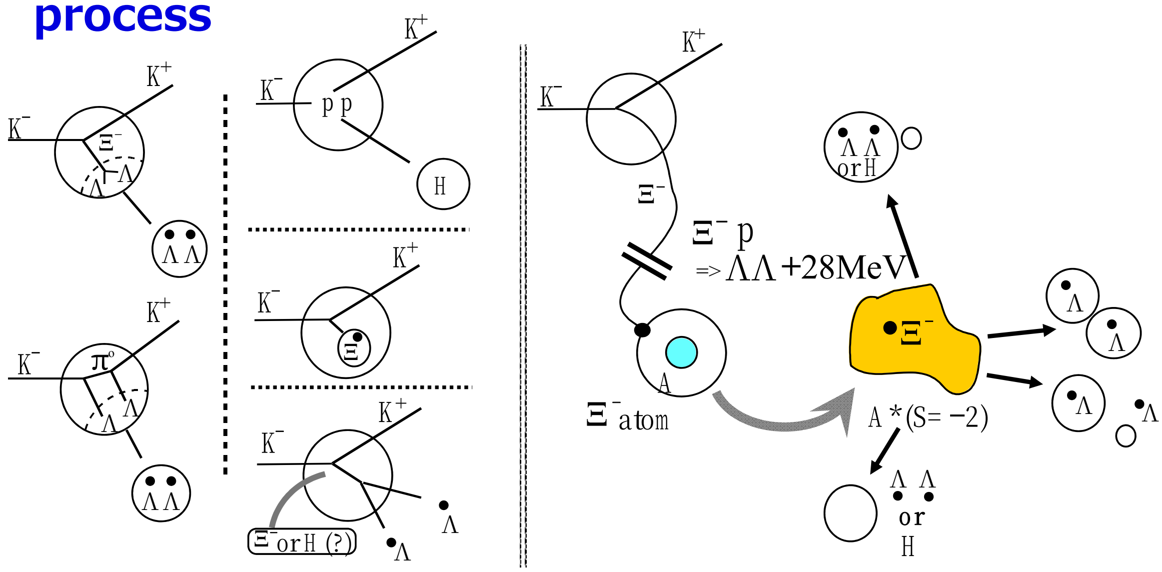
One of the most powerful methods for the detection of DHN

→ Emulsion experiment *!!*

system with nuclear emulsion

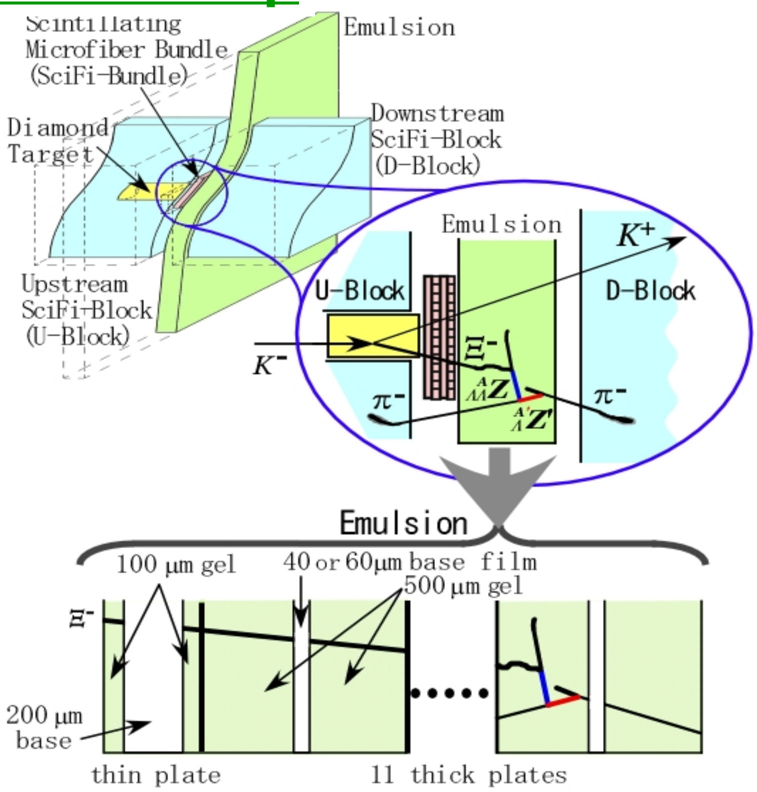
How to input double strangeness into nucleus

- Direct process
- via Ξ atom



The E373 experiment @ KEK (K-,K+) reaction

E373 setup

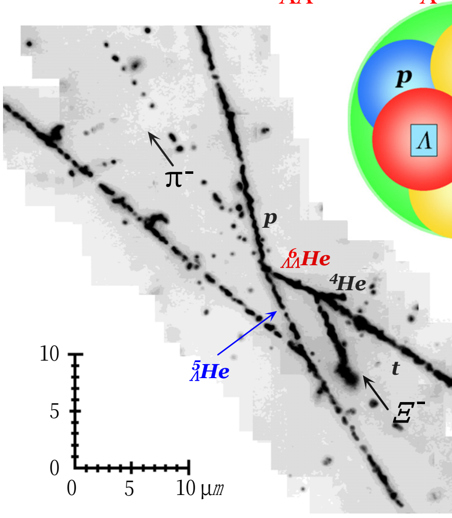


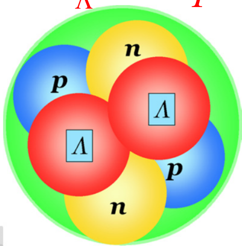
- p_{K-}=1.67 GeV/c
  ➔ Q.F. ‘p’(K-,K+)Ξ^-
- The target,
  ==> Diamond
- following Ξ^- cand. track,
  ➔ **~10^3** Ξ^- stopping.
  (estimated)

the *NAGARA* event

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

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





J.K. Ahn ,et al., Phys. Rev. C 88, 014003 (2013).

if we take into account B_{Ξ^-} = 0.13 MeV [atomic 3D : ^{12}C- Ξ^-]

$^6_{\Lambda\Lambda}$He $B_{\Lambda\Lambda}$ = 6.91 +/- 0.16 MeV, $\Delta B_{\Lambda\Lambda}$ = 0.67 +/- 0.17 MeV

cf. a previous paper ; H. Takahashi et al., PRL(2001) $B_{\Lambda\Lambda}$ = 7.25 +/- 0.19 MeV, $\Delta B_{\Lambda\Lambda}$ = 1.01 +/- 0.20 MeV

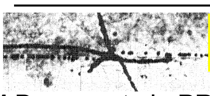
K.Nakazawa and H.Takahashi, PTP. Suppl.185 (2010) 335
J.K.Ahn et al., Phys. Rev. C88 (2013) 014003

$B_{\Lambda\Lambda}$ and $\Delta B_{\Lambda\Lambda}$

By checking consistency of $\Delta B_{\Lambda\Lambda}$ (NAGARA) within 3 STD.,

	$^A_{\Lambda\Lambda}$Z	Ξ^- Captured	$B_{\Lambda\Lambda}$ - B_{Ξ^-} [MeV]	$\Delta B_{\Lambda\Lambda}$ - B_{Ξ^-} [MeV]	Assumed level	$B_{\Lambda\Lambda}$ [MeV]	$\Delta B_{\Lambda\Lambda}$ [MeV]
NAGARA	$^6_{\Lambda\Lambda}$He	^{12}C	$B_{\Lambda\Lambda}$ = 6.79 + 0.91B_{Ξ^-} (+/- 0.16) $\Delta B_{\Lambda\Lambda}$ = 0.55 + 0.91B_{Ξ^-} (+/- 0.17) B_{Ξ^-} < 1.86		3D	6.91 +/- 0.16	0.67 +/- 0.17
MIKAGE	$^6_{\Lambda\Lambda}$He	^{12}C	9.88 +/- 1.71	3.64 +/- 1.71	3D	10.01 +/- 1.71	3.77 +/- 1.71
	$^{11}_{\Lambda\Lambda}$Be	^{14}N	21.95 +/- 2.67	3.73 +/- 2.71	3D	22.12 +/- 2.67	3.94 +/- 2.71
DEMACHI-YANAGI	$^{10}_{\Lambda\Lambda}$Be*	^{12}C	11.77 +/- 0.13	-1.65 +/- 0.15 *cf. Ex* = 2.8	3D	11.90 +/- 0.13	-1.52 +/- 0.15 *cf. Ex* = 2.8
HIDA	$^{11}_{\Lambda\Lambda}$Be	^{16}O	20.60 +/- 1.27	2.38 +/- 1.34	3D	20.83 +/- 1.27	2.61 +/- 1.34
	$^{12}_{\Lambda\Lambda}$Be	^{14}N	22.31 +/- 1.21	------	3D	22.48 +/- 1.21	------
E176	$^{13}_{\Lambda\Lambda}$B -> $^{13}_{\Lambda}$C*		*Ex* = 4.9 ------- S.Aoki et al., N.P. A828(2009)191	--------	3D	23.3 +/- 0.7	0.6 +/- 0.8
	$^{10}_{\Lambda\Lambda}$Be -> $^{9}_{\Lambda}$Be*		*Ex* = 3.0 -------	-------	Recon. at Decay	14.7 +/- 0.4	1.3 +/- 0.4

Λ-Λ interaction can be weakly attractive



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

Theoretical calculations:

\# 4-body Cluster …A=7-10 DoubleΛ. Hiyama *et al.*, PRC66 (2002) 024007

\# 5-body Cluster Structure…$^{11}_{\Lambda\Lambda}$Be. Hiyama *et al.*, PRL104 (2010) 212502

Our knowledge on Ξ-*N* interaction

Ξ-nucleus interaction can be studied via Ξ hyper-nucleus and Ξ atoms. However non conclusive measurement has been made, so far.

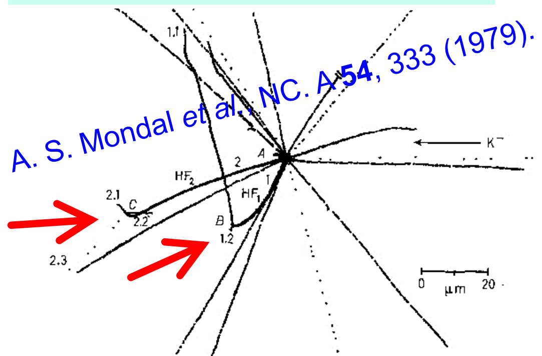
Our knowledge is very limited.

@ BNL, KEK
- Any peak structures for Ξ-nuclear state were not observed.
- Attractive potential on $^{12}_{\Xi}$Be was suggested to be ~14 MeV.
- Two events (E176) … *3D* atomic or nuclear *p* bound state?
- One event (E373) … consistent with the Ξ- capture in 3*D* orbit.

Regarding Ξ-*N* potential, ~~~

Woods-Saxon well depth of Xi-Nucleus potential

K- interaction ➔ Two $_{\Lambda}$A were prod. two step prod. can not be omitted.



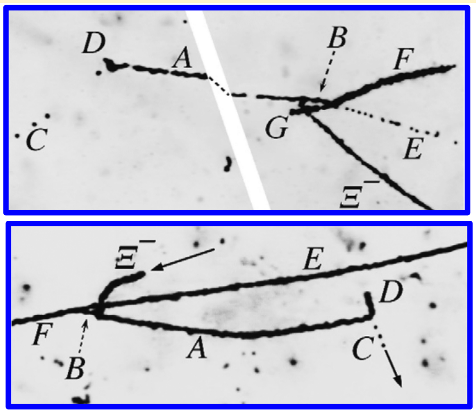
1) D. H. Wilkinson *et al.*, PRL. **3**, 397 (1959); 2) A.Bechdolff *et al.*, PL. **26B**, 174 (1968); 3) J. Catala *et al.*, Proc. of Int. Conf. on Hyp. Phys., Argonne, 1969 (unpub.), Vol. 2, p.758; 4) A. S. Mondal *et al.*, NC. A **54**, 333 (1979).

V_0^{Ξ} = -24+/- 4 MeV

C. B. Dover and A. Gal, Ann. Phys. (N.Y.) **146**, 309 **(1983)**.

E176 @ KEK-PS

Ξ- stopping ➔ Twin $_{\Lambda}$A pair prod.
The first observations of **clearly identified Ξ- bound systems**.



1) S. Aoki *et al.*, Prog. Theor. Phys. **89**, 493 (1993);
2) S. Aoki *et al.*, Phys. Lett. B **355**, 45 (1995).

V_0^{Ξ} = -(16~17) MeV by Ξ-^{12}C

Y. Yamamoto, Few-Body Syst., Suppl. **9**, 145 (1995); K. Nakazawa, T. Sasaki, and Y. Yamamoto, in *Proc. Hyp. Phys.*, Genshikaku Kenkyu **41**, No. 6, 75 **(1997)**.

Woods-Saxon well depth of Xi-Nucleus potential

E224 @ KEK-PS

^{12}C(K–, K+) int.
➔ Missing mass spectrum

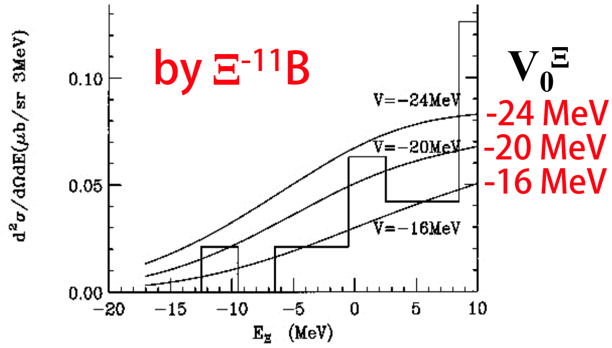


FIG. 4. Expanded view of the missing-mass spectrum around the bound region as a function of the excitation energy (E_{Ξ}) of Ξ^- in $^{12}_{\Xi}$Be. See text concerning the solid lines.

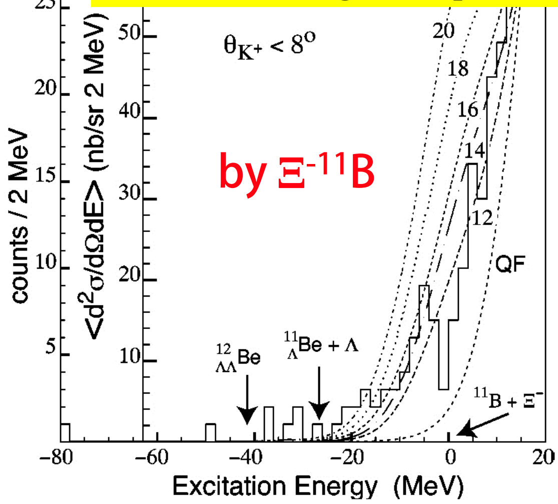
1) J. K. Ahn *et al.*, Phys. Lett. B **378**, 53 (1996).

$V_0^{\Xi} > -20$ MeV

T. Fukuda *et al.*, PR. C 58, 1308 **(1998)**.

E885 @ BNL-AGS

^{12}C(K–, K+) int.
➔ Missing mass spectrum



··· reasonable agreement between the data and theory is achieved by assuming a Ξ-nucleus potential well depth V_0^{Ξ} of **about -14 MeV** within the Woods-Saxon prescription.

P. Khaustov *et al.*, PR. C 61, 054603 **(2000)**.

Short Summary for Woods-Saxon well depth of Xi-Nucleus potential

1983	V_0^{Ξ} = -24+/- 4 MeV	**K$^-$ interaction**
1997	V_0^{Ξ} = -(16~17) MeV	**Ξ^- bound system (Ξ^{-12}C)**
1998	V_0^{Ξ} > -20 MeV	**Missing mass spectrum**
2000	V_0^{Ξ} ~ -14 MeV **[?]**	**Missing mass spectrum**

@ J-PARC (coming soon)

- E07 … ~10^3 double-Λ hypernuclei and ~10^2 Ξ-nucleus
- E03 & E07 … X-ray measurement from Ξ atoms.
- E05 …… High reso. spectr. of Ξ hypernuclei.

3. *The E07 experiment and the KISO event*

To obtain rich information about ΛΛ & Ξ*N* interaction. !!

K.Imai[a], K.Nakazawa[b], H.Tamura[c], S.Ahmad[d], J.K.Ahn[e], B.Bassalleck[f], R.E.Chrien[g], H.Ekawa[i], Y.Y.Fu[j], S.Fukunaga[k], Y.Han[f], R.Hasan[d], S.Hasegawa[a], E.Hayata[i], M.Hirose[i], K.Hoshino[b], K.Hosomi[a], S.Hwang[a], M.Ieiri[l], H.Ito[b], K.Ito[m], K.Itonaga[b], T.Kawai[m], J.H.Kim[n], S.Kinbara[b], R.Kiuchi[o], T.Koike[c], H.S.Lee[e], J.Y.Lee[o], C.Li[j], Z.M.Li[j], K.Miwa[c], H.Noumi[p], S.Ogawa[k], S.Y.Ryu[e], H.Sako[a], S.Sato[a], T.Sato[m], M.Sekimoto[l], H.Shibuya[k], K.Shirotori[p], M.K.Soe[q], H.Sugimura[a], M.Sumihama[b], H.Takahashi[l], T.Takahashi[l], K.Tanida[o], A.M.M.Theint[q], K.T.Tint[r], A.Tokiyasu[p], M.Ukai[c], T.Watabe[m], T.Yamamoto[c], N.Yasuda[s], C.S.Yoon[n], J.Yoshida[b], T.Yoshida[s], D.H.Zhang[t], J.Zhou[j], S.H.Zhou[j], and L.H.Zhu[j]

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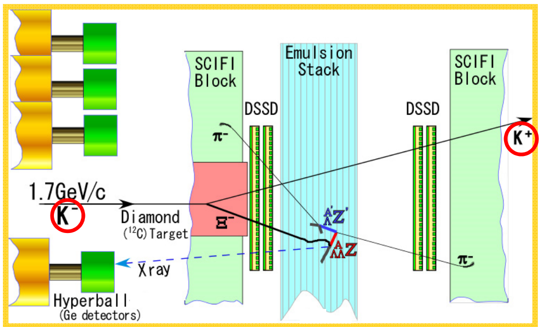
[g]*Brookhaven National Laboratory, USA,*
[h]*University Colledge of London, UK,*
[i]*Department of Physics, Kyoto University, Japan,*
[j]*CIAE, China Institute of Atomic Energy (CIAE), China,*
[k]*Department of Physics, Toho University, Japan,*
[l]*KEK, High Energy Accelerator Research Organization, Japan,*
[m]*Department of Physics, Nagoya University, Japan,*
[n]*Gyeongsang Nat'l University, Korea,*
[o]*Seoul National University, Korea,*
[p]*Research Center for Nuclear Physics (RCNP), Japan,*
[q]*Mandalay University, Myanmar,*
[r]*Yadanabon University, Myanmar,*
[s]*University of Fukui, Japan,*
[t]*Shanxi Normal University, China.*

JPN:9／KOR:3／MYM:2／CHN:2／USA:2／UK:1／IND:1

••••••••20 Univ.•Inst.

Strategy of E07@J-PARC

1.New Hybrid method



J-PARC

1. Pure K-beam
   (better 3.5 times than KEK-PS)
2. More emulsion volume (x 3)

10^3 (E373) ➔ 10^4 Ξ− stop events

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

Automated track-following

2. *Overall-scanning*

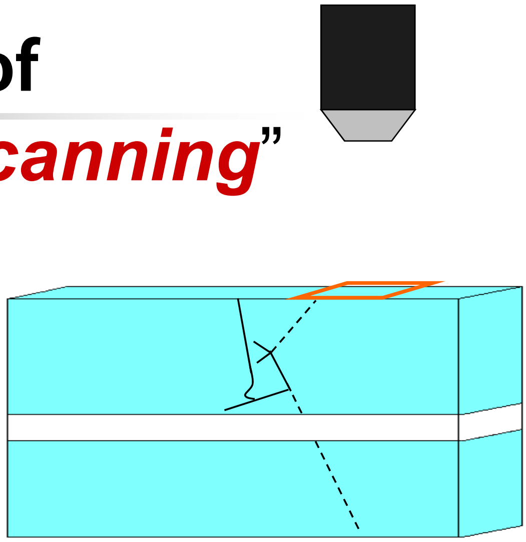
Fully automatic detection of
3 vtx. event
like NAGARA event, KISO event

10 times statistics of that with the hybrid method

(1/0.3): free from acceptance & tracking
X
4 :・*p* (K−,K+)Ξ− in the emulsion
・*n* (K−,K0)Ξ− reaction

Measurement of the mass of
~10^3 double hypernuclei
~10^2 Xi hypernuclei
with A<16

Development of "*Overall-scanning*"

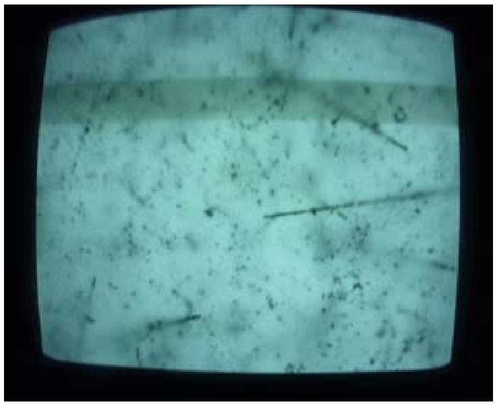


Primary motivation;
fast detection of α decay vertices of natural isotopes to calibrate range-energy relation.

① *fast image capture*

Developed system with CCD camera

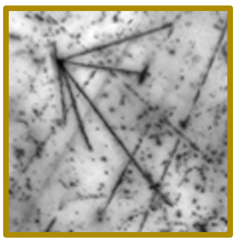
OS : Win2000 sp4
CPU : 3.0 GHz
1.57GB RAM
Camera : 100Hz (CCD)
Obj. lens : x 50
emulsion : 500μm
area : 0.1x0.08mm^2
# of image : ~100/cycle
Time : 5min. /cycle
➔ 3sec/cycle
[~ hard limit]



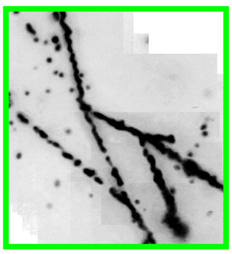
Development of "*Overall-scanning*"

② *fast image processing* for event detection

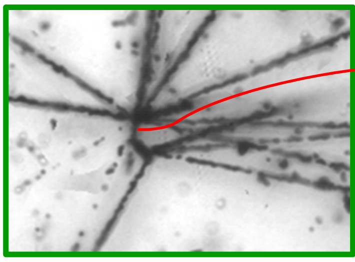
α decay **VTX**

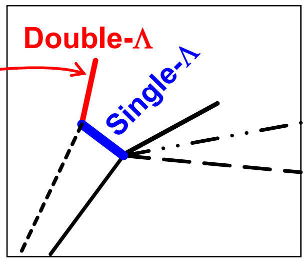


3 vertices

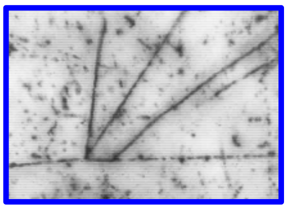


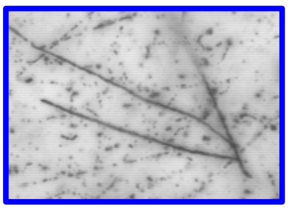
NAGARA event
was detected by this method





2 vertices (single-Λ cand.)

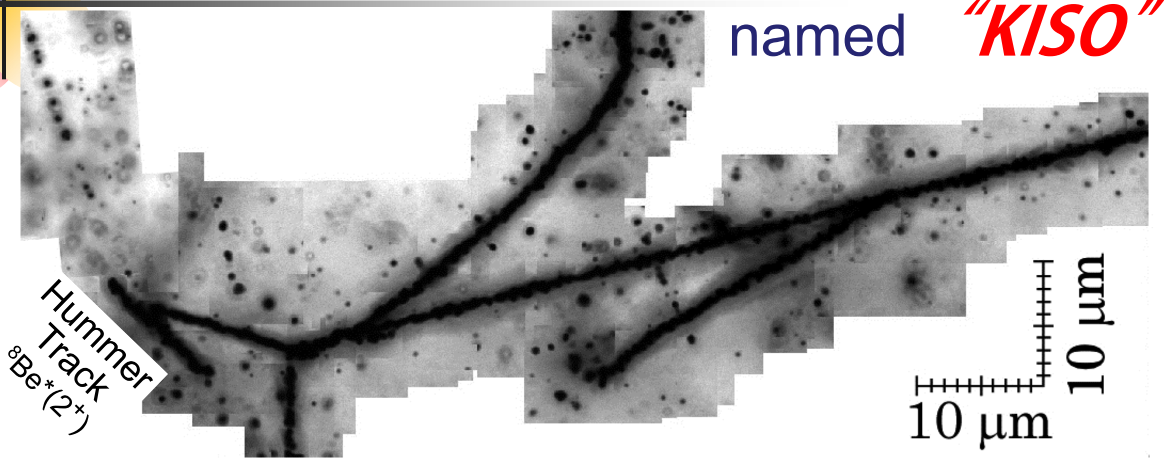




●●●●●● more

Until April. 2013,
***8 M* images under test operation** (1.46 cm^3)
using E373 emulsion (**55 liters**)

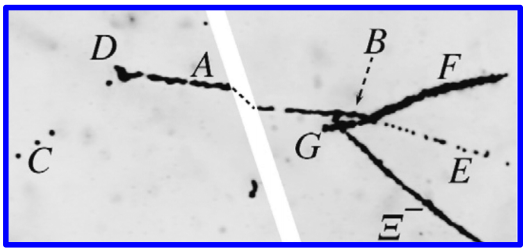
An event by the "*Overall-scanning*", named "*KISO*"



Emitted back-to-back direction

➔ Topology seems to be consistent with the past events of twin hypernuclei (E176).

Results of KEK-E176: S.Aoki et al., NP. A828 (2009) 191-232



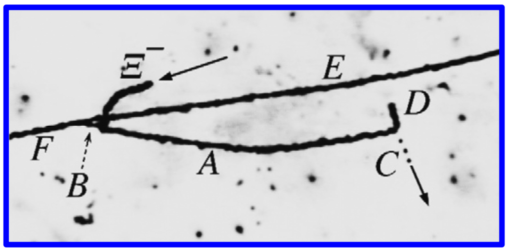
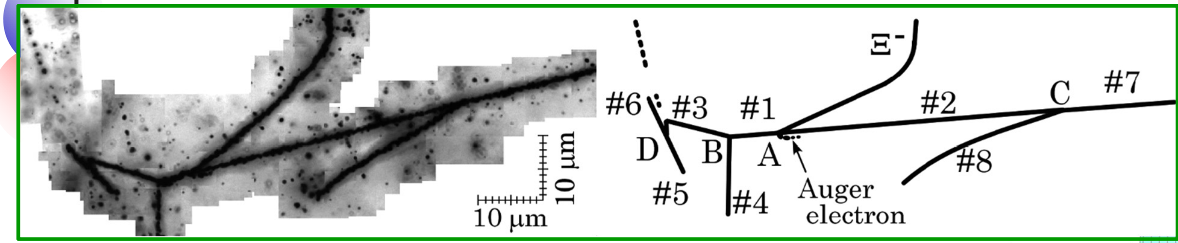
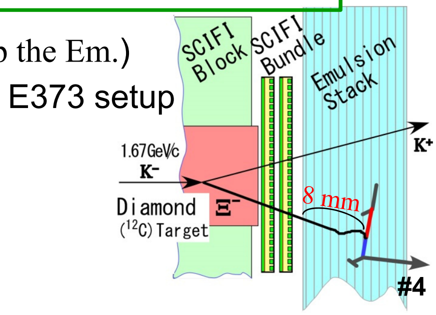


Image of the *KISO* event

Outline of the *KISO* event





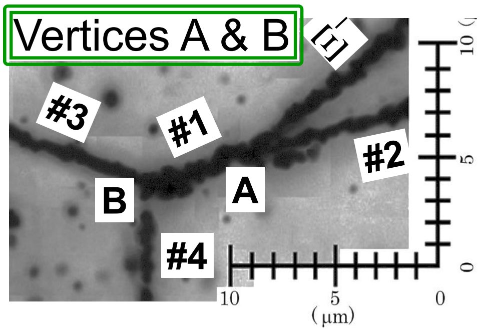
1) Ξ- hyperon can be produced in the target (8 mm from top the Em.)

2) **Auger electron** ➔ make the capture point clear.

3) MIPS track from the decay point **D**.

4) TK #4 ➔ went out of the emulsion stack.

5) Consistent with Ξ- capture reaction occurred on **C**, **N** or **O**.

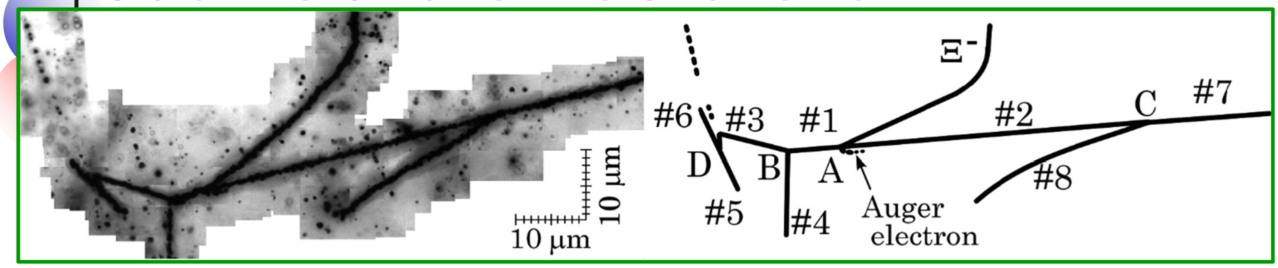


[1] The charge of #2 should be 2 or more.

[2] The charge of #1 should be ≦ 5.

[3] Hummer track : ^{8}He, ^{8}Li or ^{8}B ➔ ^{8}Be*(2$^+$).

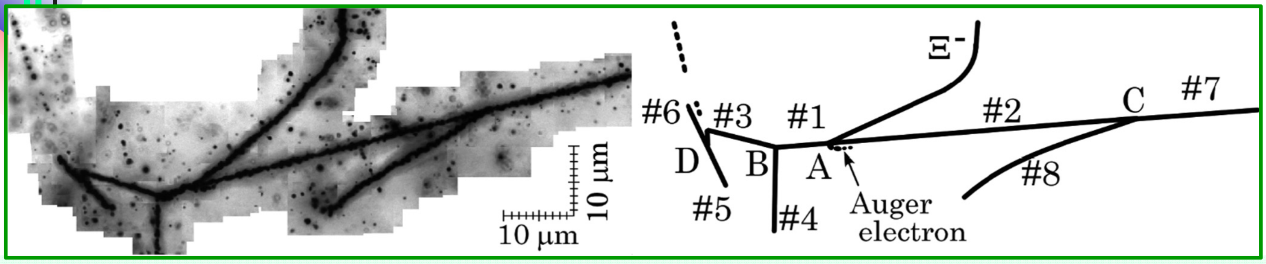
Outline of the *KISO* event



Ranges and angles

vtx	track	range (μm)	theta (deg.)	phi (deg.)	comments
A	#1	8.0 ± 0.3	133.0 ± 3.0	13.2 ± 3.2	Single-hypernucleus 77.1 ± 0.3 μm : B ~ C
	#2	69.1 ± 0.5	40.4 ± 0.9	193.1 ± 1.2	
B	#3	13.3 ± 0.4	102.3 ± 2.3	340.4 ± 1.6	
	#4	> 4990.7	145.0 ± 0.9	85.4 ± 1.3	Out of the emulsion stack
D	#5	6.7 ± 0.3	49.6 ± 4.2	132.6 ± 4.3	α from ^{8}Be
	#6	5.8 ± 0.3	131.0 ± 4.5	318.9 ± 4.7	α from ^{8}Be
C	#7	2492.0 ± 3.9	43.1 ± 1.3	191.8 ± 1.5	
	#8	37.3 ± 0.7	131.9 ± 1.3	29.2 ± 1.3	

＊Event interpretation and the energy of B_{Ξ^-}



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) $+ n$,

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

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

ex.

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

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

Measurement error : 0.09 MeV

Mass (${}^{10}_{\Lambda}Be$, ${}^{5}_{\Lambda}He$, Ξ^-) error : 0.23 MeV

The case of production of ${}^{10}_{\Lambda}Be$ in excited state

$B_{\Xi^-} = M(\Xi^- + {}^{14}N) - E({}^{10}_{\Lambda}Be) - E({}^{5}_{\Lambda}He)$

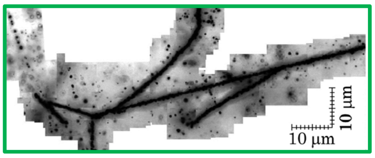


Table 8. Excitation energies of ${}^{10}_{\Lambda}Be$ calculated by cluster (Hiyama & Yamamoto) and shell (Millener) models. The B_{Ξ^-} value for the ground state, g.s., is 4.378 ± 0.250 MeV, determined by our experiment.

State	Hiyama & Yamamoto (cluster model) [28] (MeV)	Expected B_{Ξ^-} (MeV)	Millener (shell model) [29] (MeV)	Expected B_{Ξ^-} (MeV)
g.s.	0 (1^-)	4.38	0 (1^-)	4.378
	0.08 (2^-_1)	4.30	0.110 (2^-)	4.268
1st	2.36 (2^-_2)	2.02	2.482 (2^-)	1.896
	2.41 (3^-)	1.97	2.585 (3^-)	1.793
2nd	3.07 (0^+)	1.31	3.202 (0^-)	1.176
	3.27 (1^+)	1.11	3.228 (1^-)	1.150
3rd	–	–	6.433 (3^-)	Ξ^- unbound
			6.509 (4^-)	

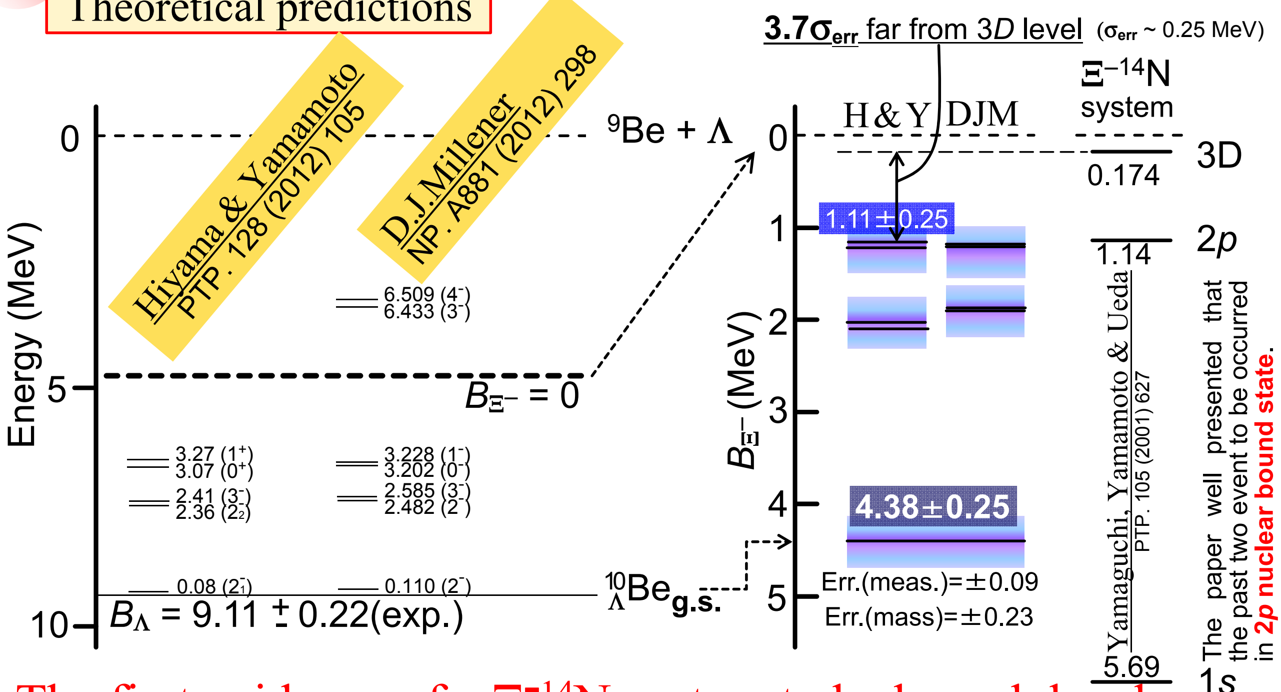
[28] E. Hiyama and Y. Yamamoto, PTP **128**, 105 (2012)
[29] D. J. Millener, Nucl. Phys. A **881**, 298 (2012)

the *KISO* event

$\Xi^- + {}^{14}N \rightarrow {}^{10}_{\Lambda}Be + {}^{5}_{\Lambda}He$ uniquely identified!!

B_{Ξ^-} = **4.38 +/- 0.25** MeV (by Mom. balance for ${}^{10}_{\Lambda}Be$ and ${}^{5}_{\Lambda}He$)

Theoretical predictions



The first evidence of a $\Xi^{-14}N$ system to be bound deeply.

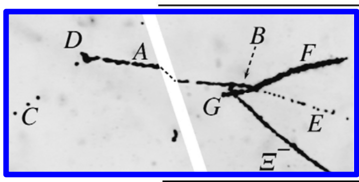
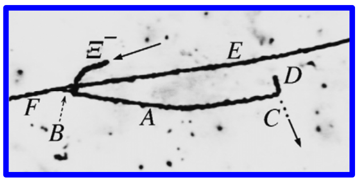
Comarison of E176 events with theoretical prediction

Table 9. Theoretical prediction of B_{Ξ^-} values for the Ξ^--^{12}C and Ξ^--^{14}N systems using **Coulomb and Ehime potentials.**

State	$B_{\Xi^-}[\Xi^- - {}^{12}C]$ (MeV)	$B_{\Xi^-}[\Xi^- - {}^{14}N]$ (MeV)
1*s*	4.77	5.93
2*p*	0.58	1.14
3*D*	0.126	0.174
2*s*	0.40	0.54
3*p*	0.19	0.28

M.Yamaguchi, K. Tominaga, Y. Yamamoto, and T. Ueda, PTP **105**, 627 (2001)

E176 results; S.Aoki et al., NP. A828 (2009) 191-232
Ξ^- binding energy (MeV) in nucleus : ^{12}C [**most probable**]

Event	${}^4_\Lambda H + {}^9_\Lambda Be$
	0.82 ± 0.17 -0.23 ± 0.17 (${}^4_\Lambda H^* + {}^9_\Lambda Be$) ($\chi^2 = 0.4$)
	3.89 ± 0.14 0.82 ± 0.14 (${}^4_\Lambda H + {}^9_\Lambda Be^*$) 2.84 ± 0.15 (${}^4_\Lambda H^* + {}^9_\Lambda Be$) -0.19 ± 0.15 (${}^4_\Lambda H^* + {}^9_\Lambda Be^*$) ($\chi^2 = 1.3$)

Good agreement
with
a theoretical prediction
in the case of
Ξ^- - ^{12}C system

Published at

K. Nakazawa et al.,
Prog. Theor. Exp. Phys. 2015, 033D02
DOI : 10.1093/ptep/ptv008

4. Summary

1. We have performed experiments to study **S=-2 systems with the nuclear emulsion** at KEK.
2. To get more rich information about S=-2 systems, which is quite important to understand **the EOS of neutron stars** and **baryon octet scheme**, we are developing fully automated and fast scanning method, "***Overall scanning***" for the emulsion.
3. During test operation of the system, a clear evidence of a deeply bound Ξ-^{14}N system has been detected and uniquely identified, **$\Xi^- + {}^{14}N \rightarrow {}^{10}_{\Lambda}Be + {}^{5}_{\Lambda}He$**, in the emulsion of 1.46 cm^3 volume among 55 liters.
4. The detected event, named "***KISO***", presents a deeply bound Ξ-^{14}N system with **Ξ^- binding energy of 4.38 +/- 0.25 MeV**, which is no longer the atomic 3*D* state (0.17 MeV for Ξ- atom on ^{14}N). Theoretical predictions for Coulomb-assisted nuclear bound state for **Ξ^--^{12}C** and **Ξ^--^{14}N** agree the results of not only KISO, but also two events presented by the E176 experiment.
5. It was understood that **Ξ*N* interaction** will be **attractive*!!*** To understand **A-dependence of ΛΛ int.** and **ΞN interaction more in detail**, we will continue development of "***overall scanning***" method to be applied in the E07 experiment, of which beam exposure can be accomplished in Early 2016 (?).

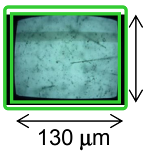
New scanning system for the E07emulsion

Introduced by Dr. J. Yoshida Jul.11th

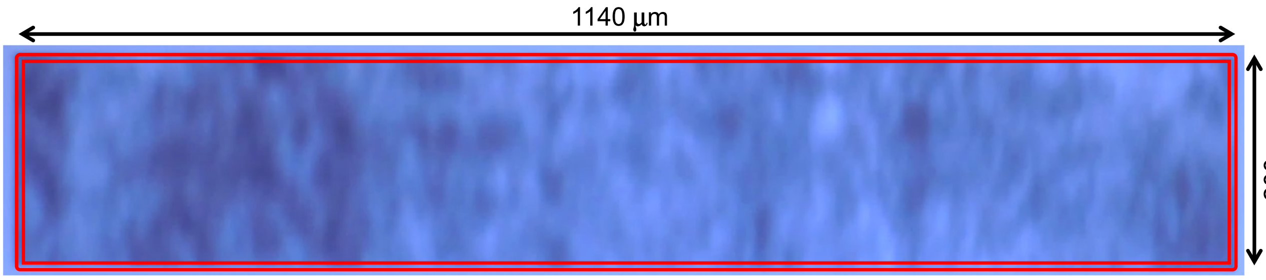
with piezo stage

×300 faster !!

Present system



	Present	New
Obj. Lens	×50 (NA. 0.9)	×20 (NA. 0.35)
Camera	100Hz XC_HR300	800Hz HXC20
Pixel	512×440 pixel	2039×357 pixel
Area	130 mm×110 mm	1140 mm×200 mm
Rate(Hz)	0.3	5
	4 sets	3 sets



Images of all of the emulsion can be obtained in a few years.