「多重ストレンジネスのバリオン間相互作用」（計画研究A01班）

Baryon-baryon interaction with multi-strangeness

A01班代表者 高橋俊行（KEK）

- Introduction
  - Neutron star & S=-2 B-B interaction
  - Present knowledge on S=-2 B-B int.
- Research project
  - Emulsion experiment
  - H-dibaryon search

研究組織
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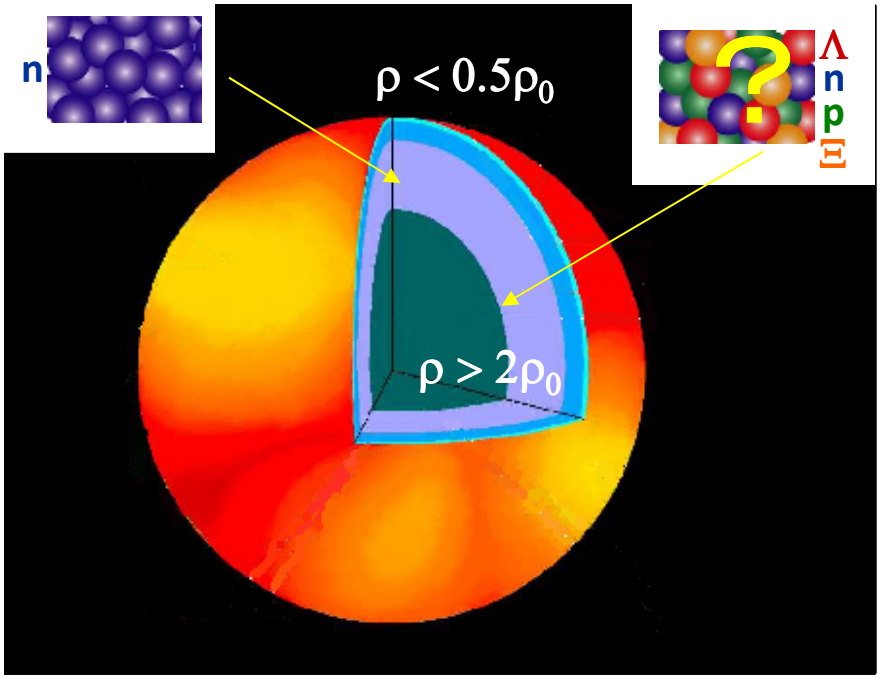
住浜水季、
谷田聖

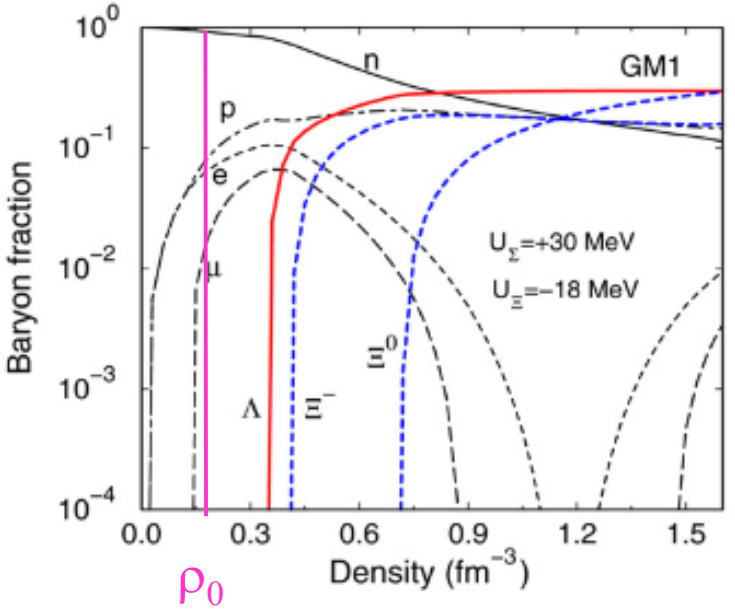
Strangeness in the Neutron Star



Hyperon Matter
should be appeared at high density

EOS should support $2M_{\odot}$

J.Schaffner-Bielich, NPA804(2008)309



$$\mu_Y = m_Y + \frac{k_F^2}{2m_Y} + U_Y(k_F)$$

↑

to be experimentally determined

Hyperon Potential & Interactions

Λ:

U_Λ = –30 MeV in normal (N~Z) matter at ρ_0

U_Λ ? in neutron-rich matter

Σ (Σ^+, Σ^0, Σ^-) :

ΣN int. is repulsive but how much?

Group-A02
(S=–1)

Ξ (Ξ^0 , Ξ^-) : Ξ nucleus is not well established

U_Ξ = –14 MeV ? ($^{12}_{\Xi}$Be) to be established

B_Ξ = –2.6 MeV ? (Ξ^-+^{14}N–>twin Λ-nucleus)

$\Lambda\Lambda$ interaction:

$\Delta B_{\Lambda\Lambda}$ = 0.67 ± 0.17 MeV from *NAGARA* event

systematic data (A-dependence)

Group-A01
(S=–2)

YY:

Ω^-N:

S=-2 Baryon-Baryon Interaction

Strong attraction in the flavor singlet channel

$$BB\ ^{(1)} = H = -\sqrt{\frac{1}{8}}\Lambda\Lambda + \sqrt{\frac{3}{8}}\Sigma\Sigma + \sqrt{\frac{4}{8}}\Xi N$$

No repulsive core

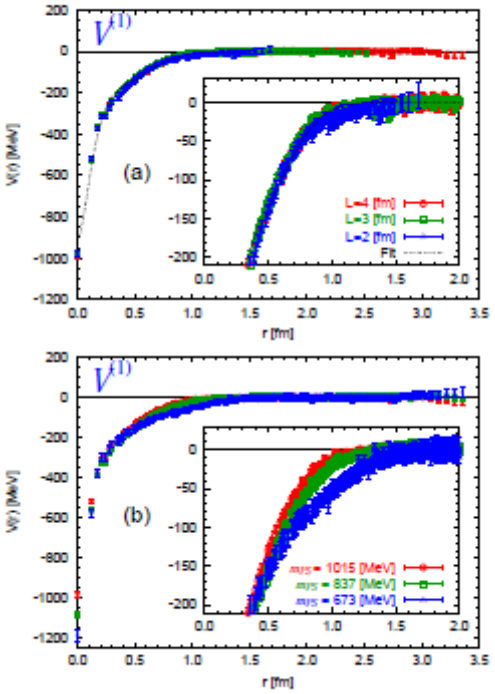
Recent L-QCD suggests the existence of bound or resonance *H* dibaryon

HAL: $SU(3)_f$ limit

30 - 40 MeV bound *H* from ($\Lambda\Lambda$-$\Sigma\Sigma$-ΞN)

NPQCD:

B^H_∞=16.6±2.1±4.6 MeV (m_π~ 389MeV)



HAL

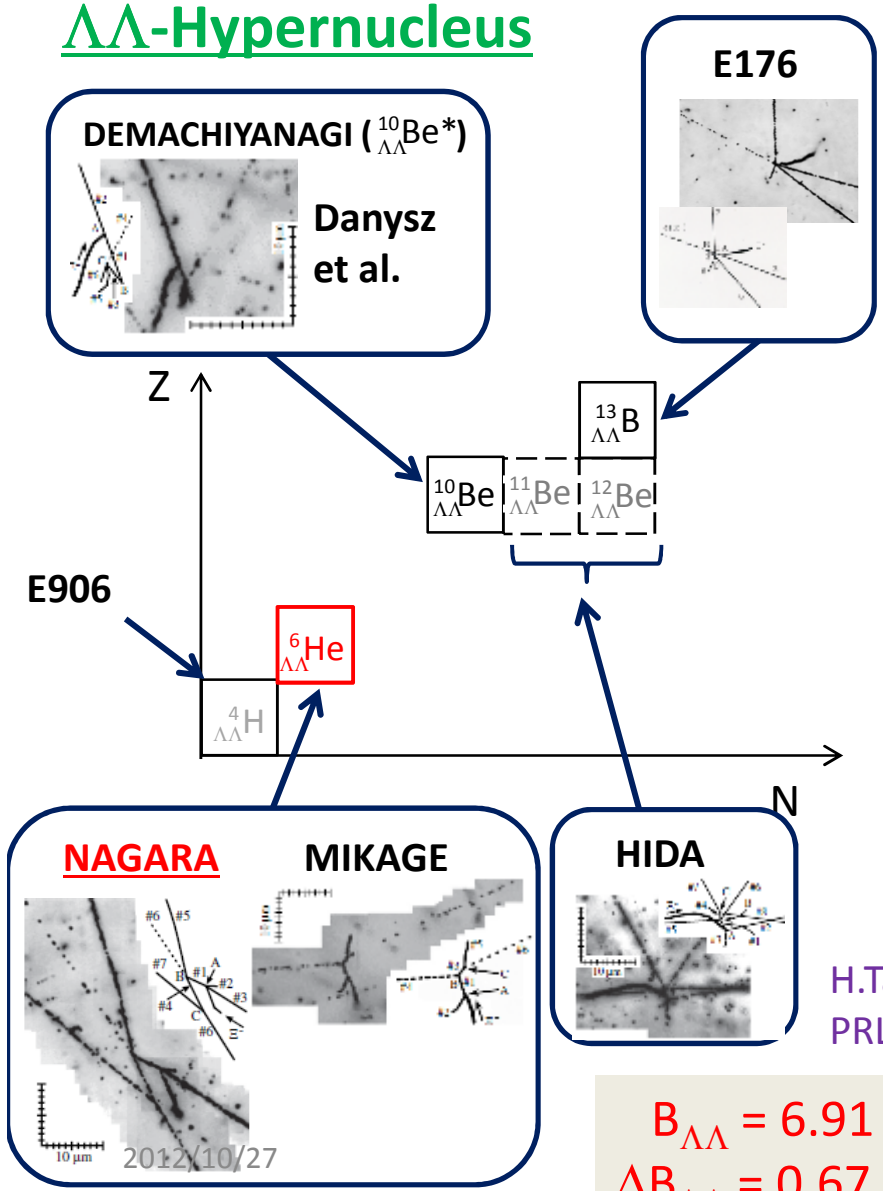
T.Inoue et al.

PRL106(2011)16002

Expermentally confirmation of the existance of *H*

Information on S=−2 System, so far (1)

ΛΛ-Hypernucleus

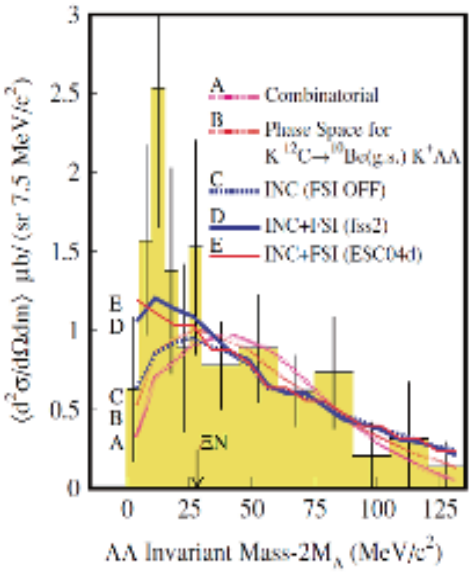


H-particle , ΛΛ-invariant mass

KEK-E522

Resonance *H* ?

C.J.Yoon et al.
PRC75(2007)022201(R)



Y. Nara et. al, Nucl. Phys. A 614(1997)433.
A. Ohnishi, et al, Nucl. Phys. A670(2000)297c, A684(2001)595, A691(2001),242c;Few-Body Syst. Suppl. 12 (2000), 367

$m_H \geqq 2223.7$ MeV/c^2
(7MeV window for bound *H*)

H.Takahashi et al.
PRL87 (2001) 212502

$B_{\Lambda\Lambda} = 6.91 \pm 0.16$ MeV
$\Delta B_{\Lambda\Lambda} = 0.67 \pm 0.17$ MeV

weakly attractive

Information on S=−2 System, so far (2)

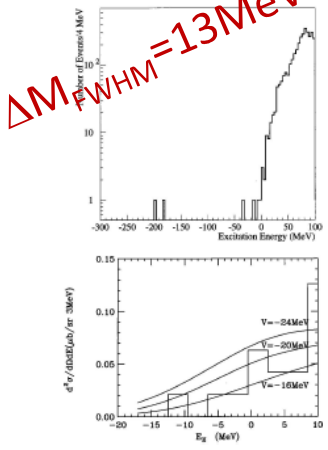
Ξ-Nucleus Missing mass spectroscopy of $^{12}C(K^-,K^+)^{12}_{\Xi}Be$

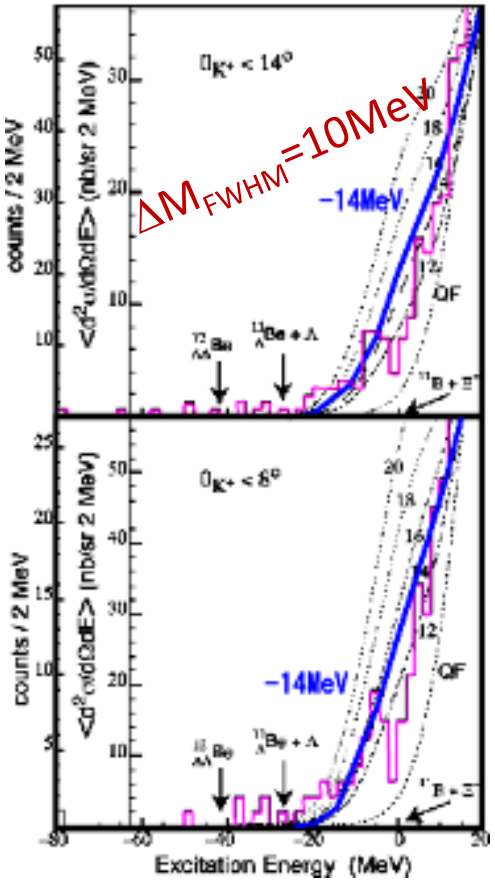
No clear peak was observed...,

Spectrum shape suggests attractive potential for Ξ.

KEK E224

T.Fukuda et. al,
PRC58(1998)1306





BNL AGS E885

U_{Ξ}=-14 MeV

P.Khaustov et. al,
PRC61(2000)054603

−20 < E < 0 MeV	89±14 nb/sr θ< 8° 42± 5 nb/sr θ<14°

Twin Λ hypernuclei from Ξ⁻ capture

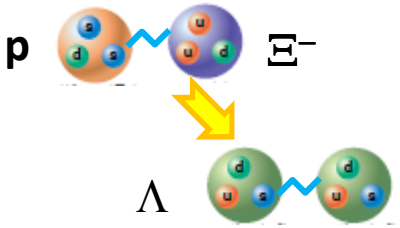
A.Ichikawa et. al, Phys.Lett.B500(2001)37

$\Xi^- + {}^{14}N \rightarrow {}^{5}_{\Lambda}He + {}^{5}_{\Lambda}He + {}^{4}He + n$

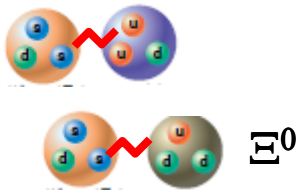
B_{Ξ}=−2.6±1.2 MeV

A01 Bryon-baryon interaction with multi-straneness

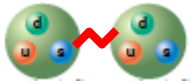
ΞN→ΛΛ Int.



ΞN Int.



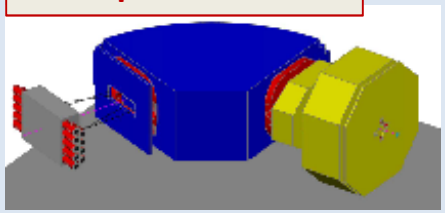
ΛΛ Int.



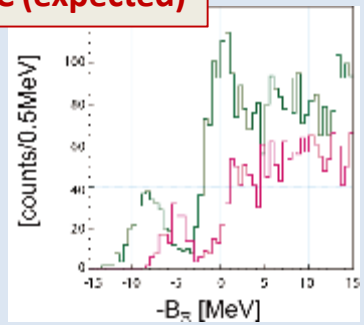
High density region of EOS

Spectroscopy of Ξ-Nucleus

S-2S Spectrometer



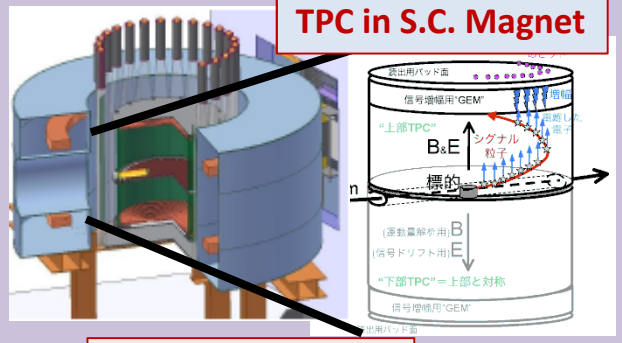
$^{12}_{\Xi}$C (expected)



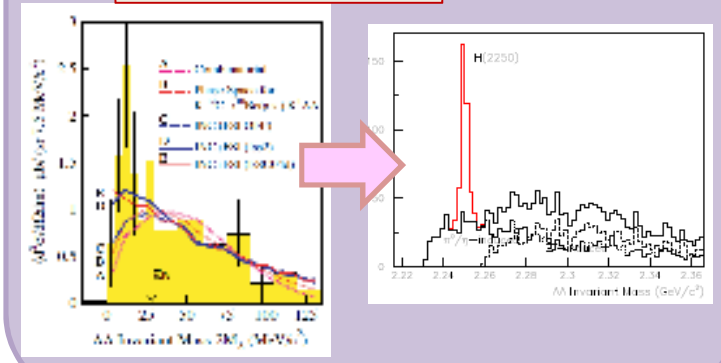
永江（特別推進）

ΛΛ coreretion with L.A. Hyperon Spectrometer

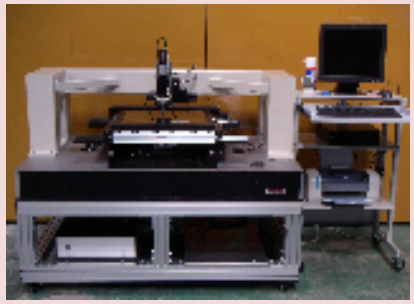
TPC in S.C. Magnet

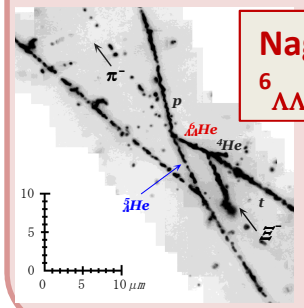


ΛΛ Invariant mass



Emulsion Exp.
＋Automatic Scaninng

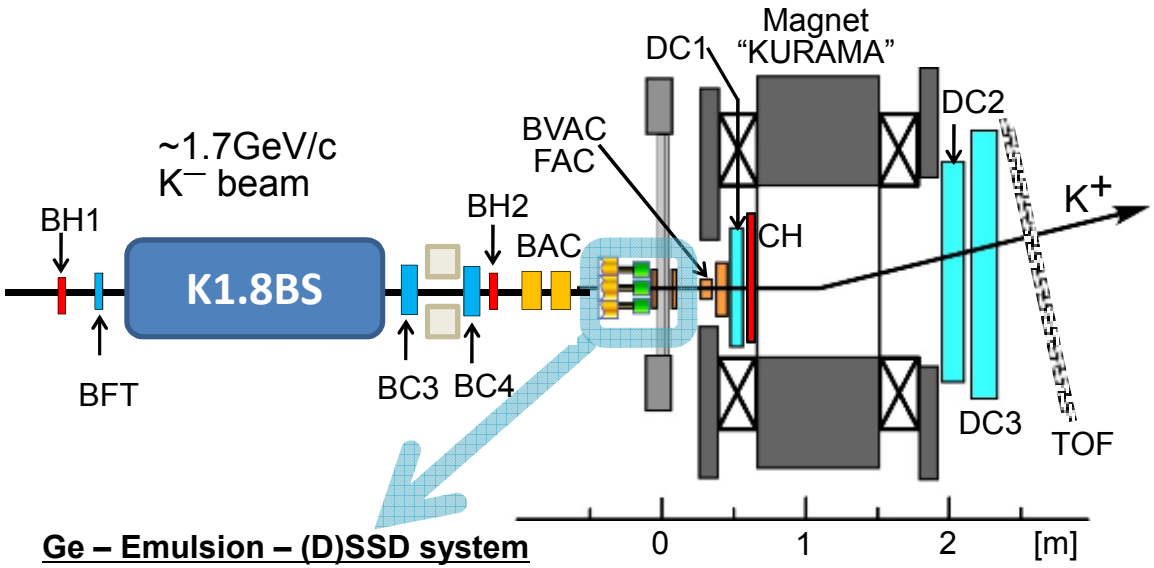




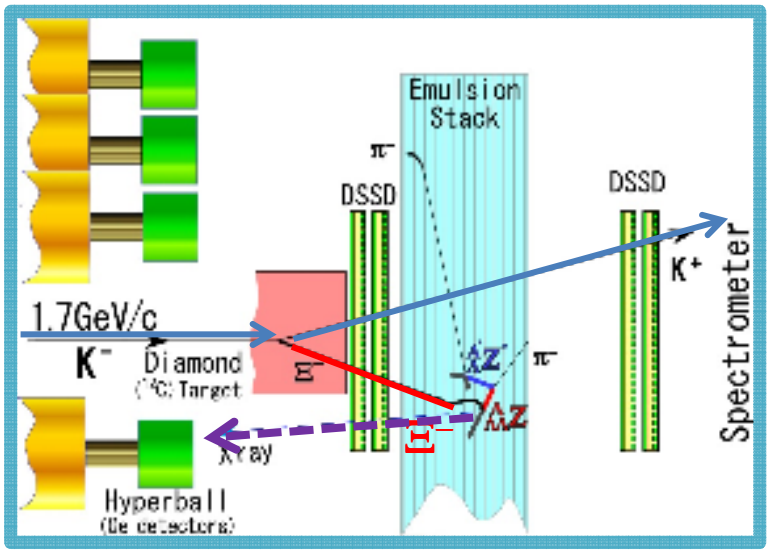
Nagara Event
$^{6}_{\Lambda\Lambda}$He

Study on S=-2 System by Emulsion-Counter Hybrid Method (J-PARC E07)

K.Nakazawa (Gifu), K.Imai(JAEA), H.Tamura(Tohoku)



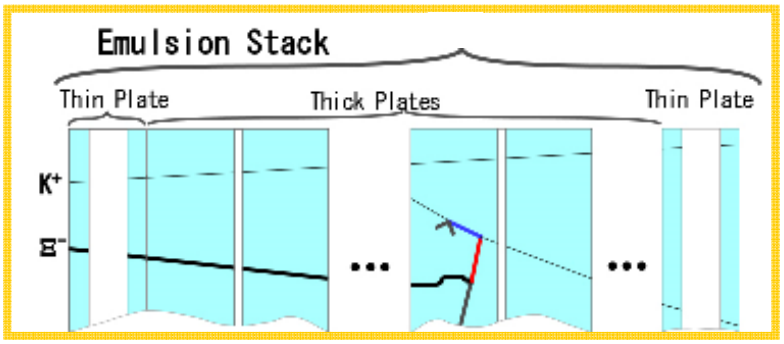
Ge – Emulsion – (D)SSD system

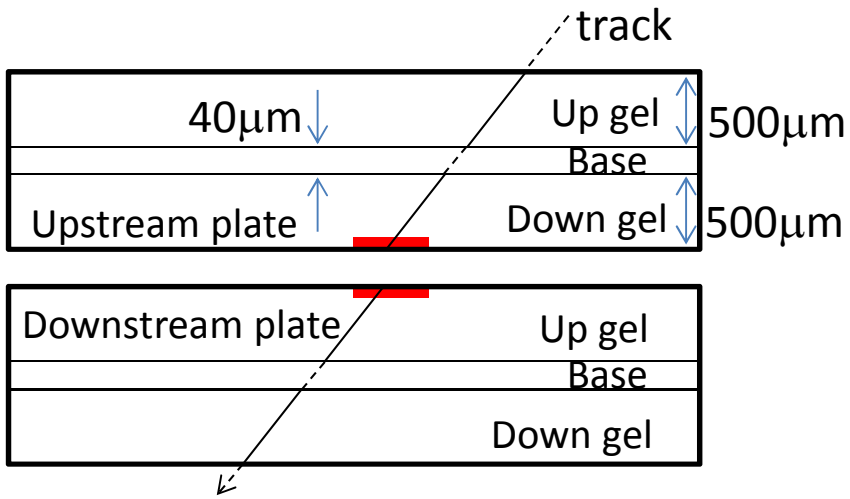


1. New hybrid method
   Ξ^- stop :10^3 (E373) → 10^4
   - Automatic tracking of Ξ^- to find absorption point
     → Detailed analysis by eye **10^2 ΛΛ-nucleus**
   - X-ray measurements with Ξ^- stop in emulsion
     30-50 X-rays (Ag/Br)
2. Overall scan
   - Find 3-vertexes events
     10^3 ΛΛ-nucleus

New hybrid method
— Automatic tracking of Ξ^- —

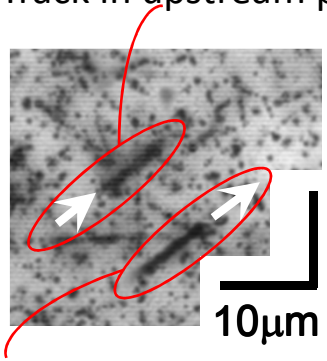
Ms. Umehara etc (Gifu Univ.)





E373 style

Track in upstream plate

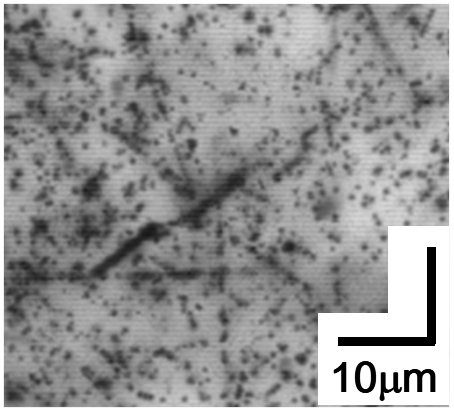


in downstream plate

Alignment accuracy ~20μm
need human assistance

Position alignment
with beam pattern

Plate of a section

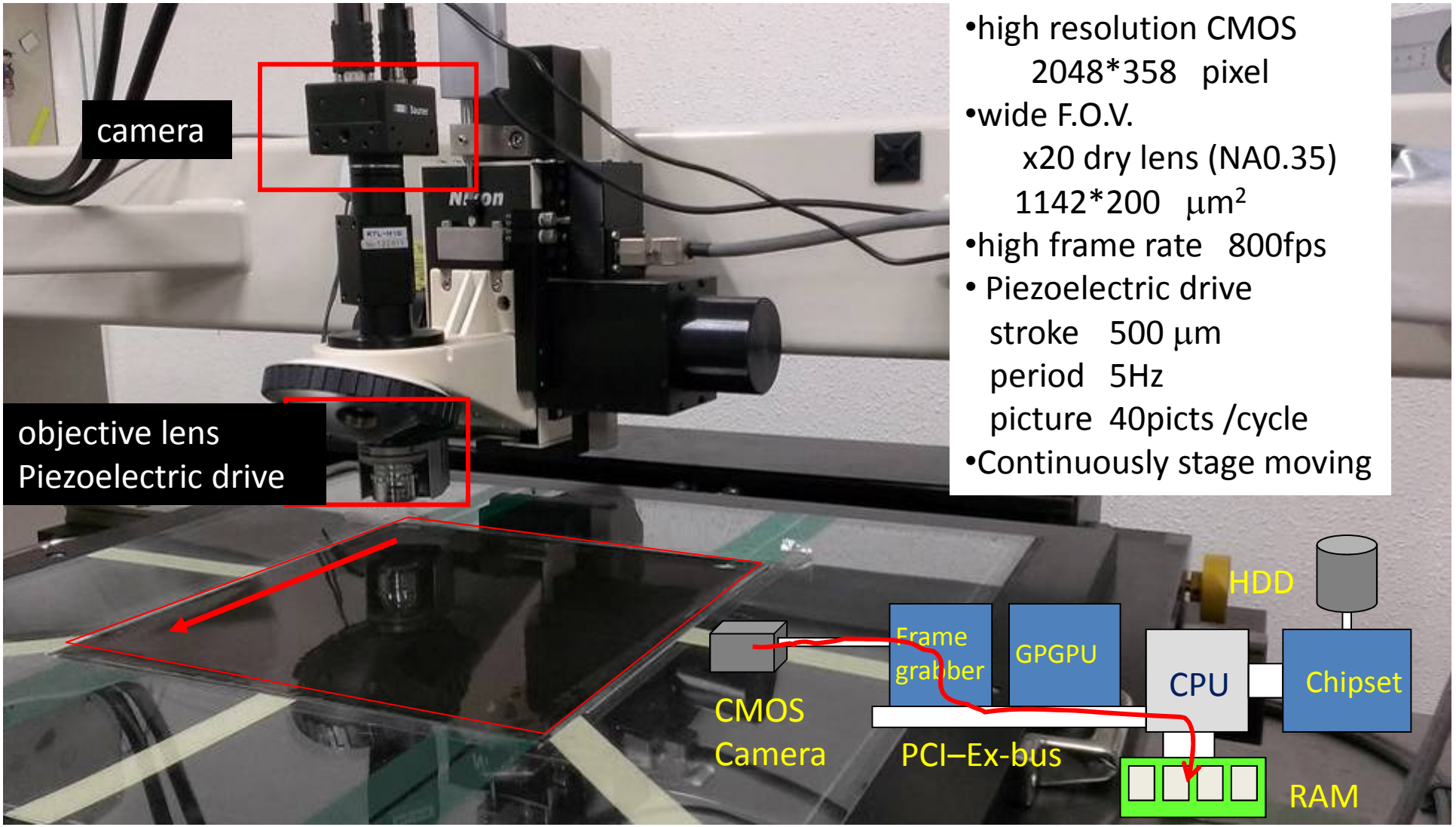


Accuracy of ~2μm has been achieved.
Automatic tracking is possible !!

Overall scanning

Dr. Yoshida (Gifu Univ.)

Two devices (#7, 8) were constructed (hardware)



Overall scanning using E373 emulsion

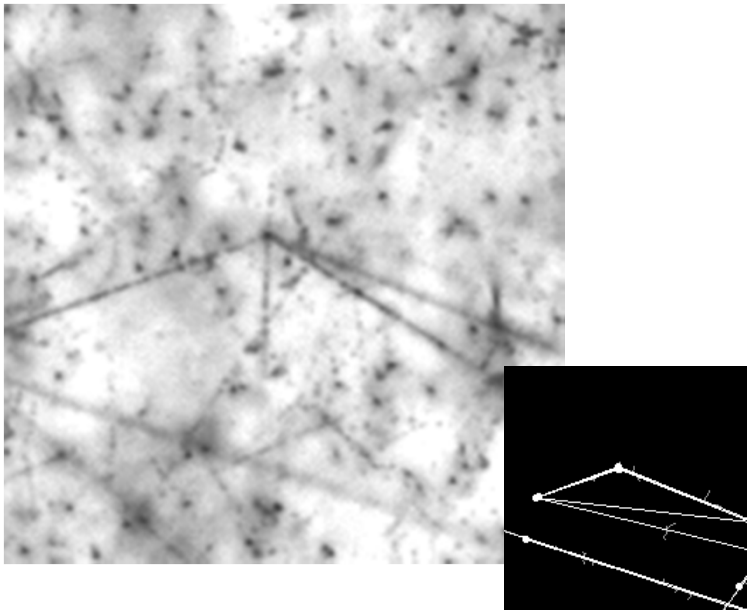
Dr. Yoshida (Gifu Univ.)

- Designed speed: 10mm*10mm*0.9mm / 2min ⇒ ~40 hours/plate
- Scanning started from Aug. 8 with 1/60 speed : 81.3cm^2*0.9mm
- Sample of 2.2mm * 10mm * 0.9mm :

Categorization by eye check

detected candidates: 3496

- vertex: 361
  - Alpha decay : 32
  - Beam Interaction: 329
  - Hyper?: 6
- noise: 3135
  - crossing-over : ~2900
  - Double counting: ~200



Efficiency: reasonable
need to improve S/N

Search for *H*-Dibaryon with a Large Acceptance Hyperon Spectrometer (J-PARC E42)

J.K.Ahn (Pusan Univ.)

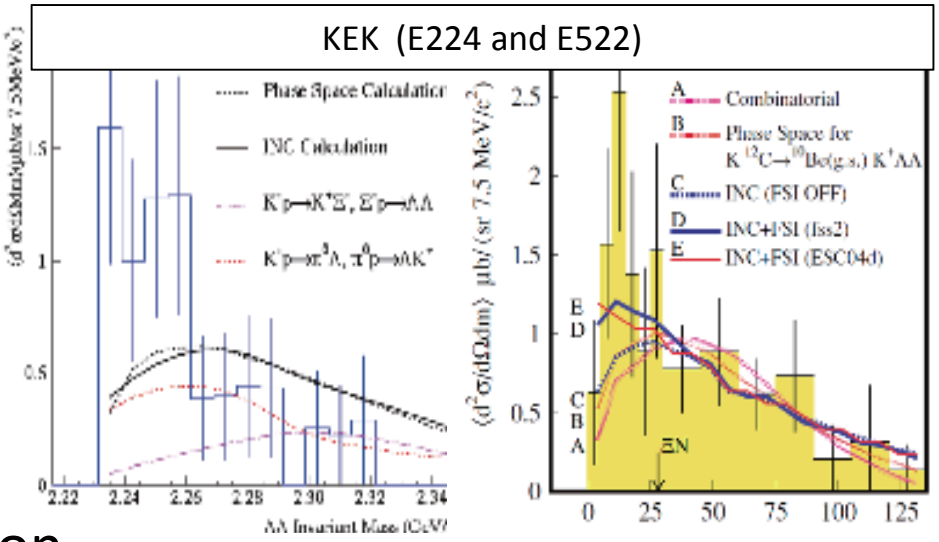
- Search for *H*-dibaryon via the A(K^-,K^+)*H*X

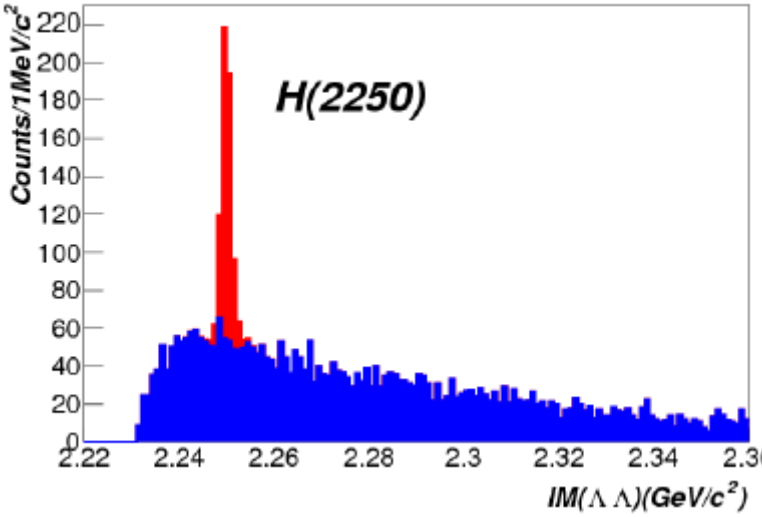
  H → ΛΛ , Λπ^-p, Σ^-p

  Λ → π^- p

  Σ^- → π^- n

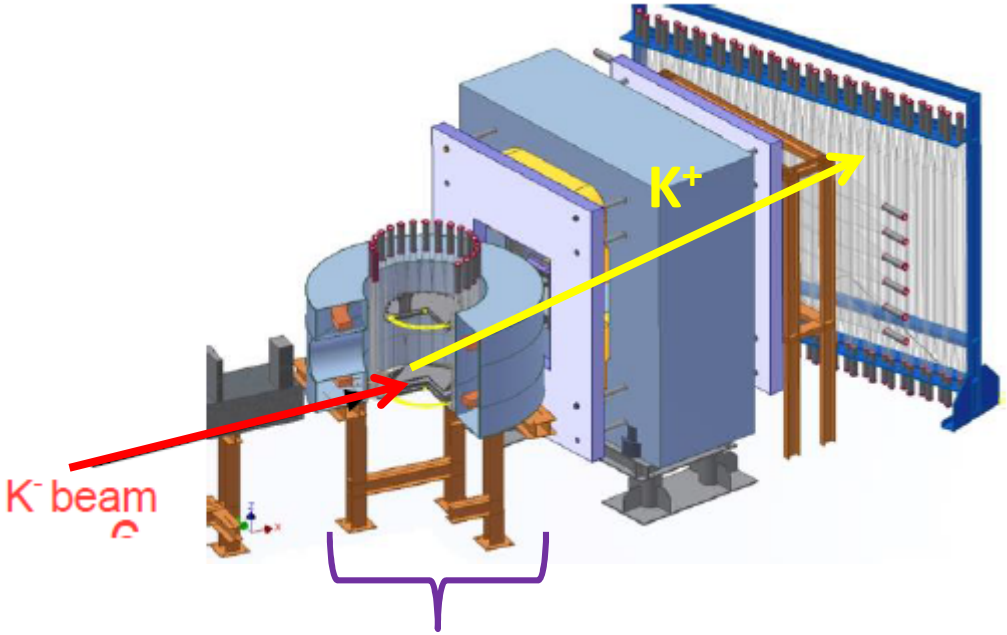
- High statistics of >10k events (x 100)
- Good invariant mass resolution of ~1MeV/c^2 (x 1/10)

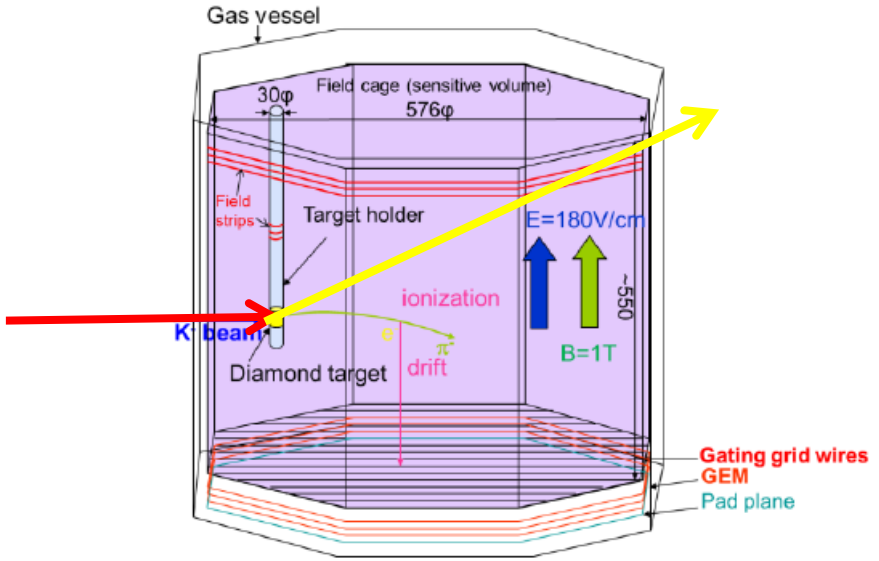




J-PARC E42 setup

KURAMA (existing)





Large acceptance **Hyperon Spectormeter** (HS)
(to be constructed)

S.C. Helmholtz mag. ~1T

TPC (Hyp-TPC) ϕ50cm × 55cm

3-layers of GEM ~10^4

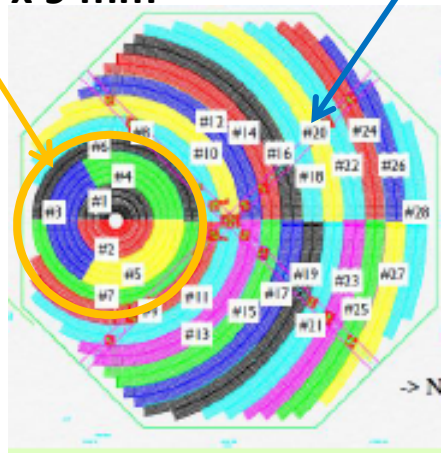
amplifier/shaper (AGET)+ flash ADC (AsAd)

Scintillator hodoscopes

R.O. pads

2.3-2.4 x 12.5 mm²

2.1-2.7 x 9 mm²

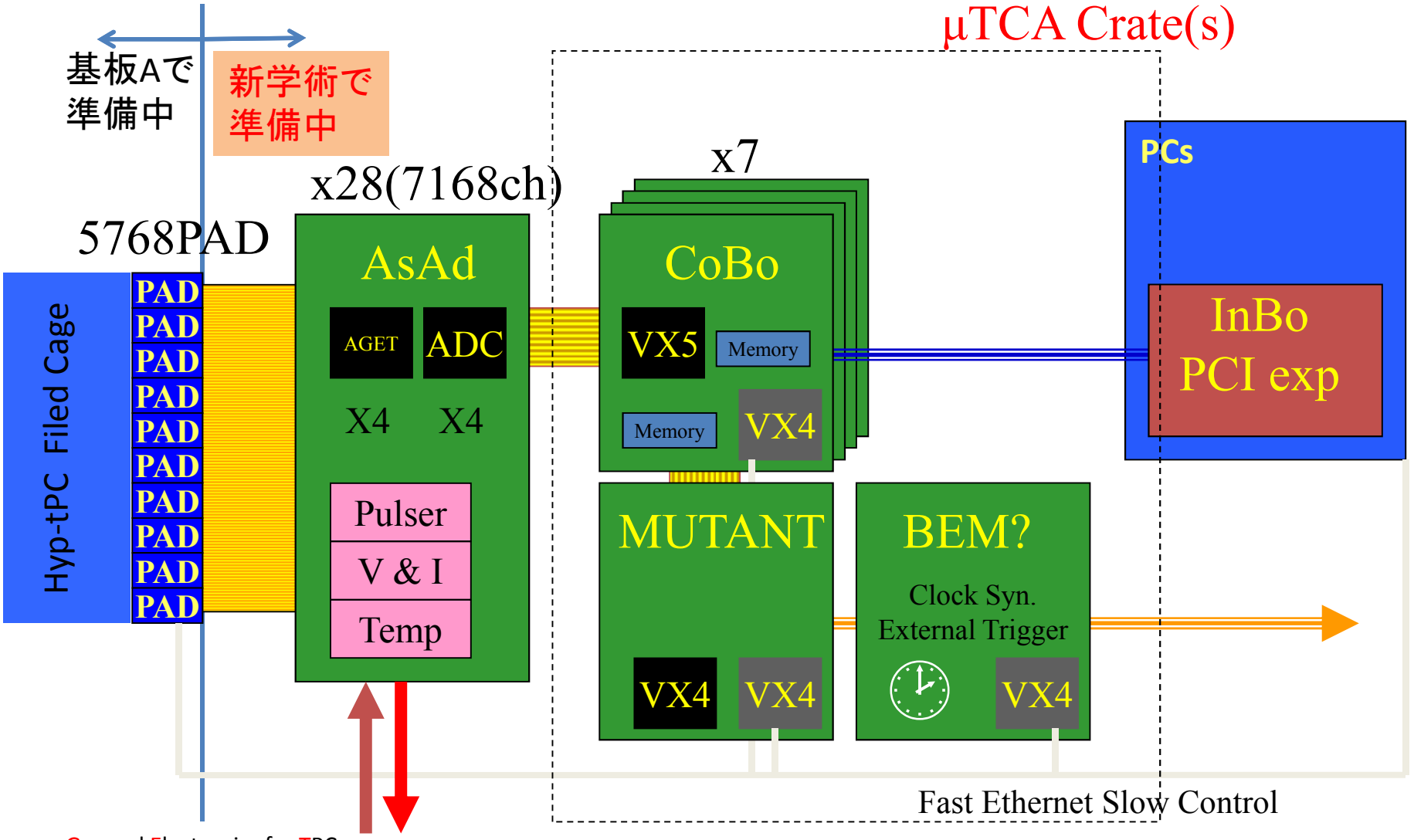


Status of TPC R&D

JAEA group (H.Sako et al.)

- prototype TPC
  - $10 \times 10 \times 20$ cm^3 with 10×10 cm^2 GEM(50+50+100μm)
  - gain of 10^4 at 325V (50μm) and 488V (100μm)
  - 1 month operation without breaking of GEM
- High rate beam test at RCNP (Nov. 2011)
  - σ~400μm(w/o B) with 4mm width pads
  - >95% efficiency up to 10^6/(s$\cdot$cm^2)
- Laser test under magnetic field (Apr. 2013)
  - Resolution improvement by 50-70% as B=0→0.7T

AGET(Asic for General Electronics for TPC) of Time Projection Chamber ("HypTPC")



General Electronics for TPC

French laboratories actively support the GET Project. IRFU, CENBG, Saclay and GANIL are partially, financed by a French ANR grant.

Develop read out ship, controller, software.

Other TPC applications: ACTAR TPC (France), AT TPC (USA), MINOS (France), SAMURAI-TPC (Japan), Pusan-TPC, etc

Hyp-TPC読出し関連 (GET, AdAd, ZAP, etc.) schedule

2012.08	AGET v1.0 production
2012.09	AsAd v1.0 production and test start
2013.11	R-cobo test
2013.01	AsAd v2.0 production
2013.03	AsAd v2.0 and r-cobo at J-PARC
2013.04-06	R-cobo Test at J-PARC
2013.05-09	ZAP for hypTPC production
2013.10	AGET v2.0 production complete
2013.12	AsAd v2.1 complete
2014.01-2014.06	TPC 2nd prototype test with full GET system (r-CoBo)
2014.01-2014.03?	COBO,MUTANT production
2015.03	TPC and electronics complete

Effects of the Accident

- Recovery of beam operation and experimental programs in Hadron are unknown at present.
- However, we plan to construct detectors etc as originally planed.
- Emulsion for E07 experiment
  - Contract of purchase was done in May 2013
  - delivered to Gifu Univ. from mid-Dec
  - Plate making will finish by April 2014
  - They will be kept in Kamioka-Mine

Summary

- S=-2 Baryon-baryon interactions are studied by three experiments at J-PARC
  - Hybrid emulsion exp. (E07)
    - ΛΛ-Nucleus — ΛΛ-Int.
    - X-ray from Ξ-atom (Ag, Br) — ΞN-Int.
  - Search for H with L.A. Hyperon Spectrometer (E42)
    - flavor-singlet states in B-B interaction
  - Spectroscopy of $^{12}_{\Xi}$Be (E05)
- Overall scanning method is developing.
  - application to E373 emulsion

    ⇒ candidates of double strangeness have been found

backups

JFY2012

- Detectors (K1.8BL & KURAMA spectrometer ...)
  - Beamline DC upgrade
  - FTOF, CH scintillators
  - R&D of new ADC/TDC module using DRS4 chip
- PC x 2 (Hybrid & overall scanning)
- Laser calibration system for (TPC)
- VME crates and modules for Decay Spectrometer

JFY2013 (plan)

- Emulsion (contract done)
  - delivered from mid-Dec.
  - Plate making from Dec. to Mar.
  - keep them in Kamioka Mine with Lead shielding
- AGET chips for TPC R.O. (done?): End of Nov.
- TPC R.O. boards (with R&D)
- KURAMA setup (detector frames etc.)
- Design of S.C. magnet for D.S.

Meetings in JFY2012

- Takayama W.S. [co-hosted] 11/25—27
- Collaboration Meeting
  - E03/E07 10/10(KEK), 3/23 (KEK)
  - E42 9/26(Pusan)
- Meetings
  - E03/E07 11/14, 11/28, 12/12, 12/22, 1/8, 1/23, 2/6, 2/28, 3/12
  - E42 10/22, 11/7, 11/21, 1/8

Meetings in JFY2013

- Collaboration Meeting
  - E03/E07 6/28(KEK), 8/31(KEK)
  - E42 6/24(Pusan)
- Meetings
  - E03/E07 5/8, 5/22, 6/5, 6/19, 7/9, 7/24, 8/7, 9/11,
  - E42 4/3, 4/17, 5/15, 5/29, 6/12, 7/31, 8/19, 9/4