J-PARC E07

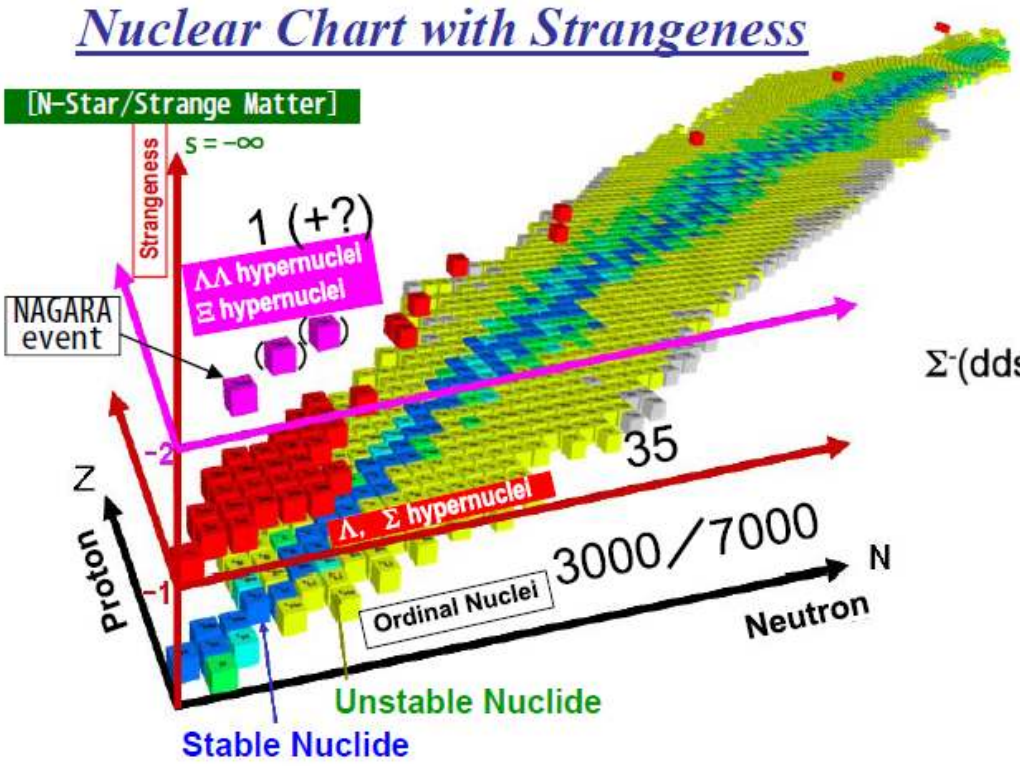
Systematic study of double-strangeness nuclei with hybrid-emulsion method

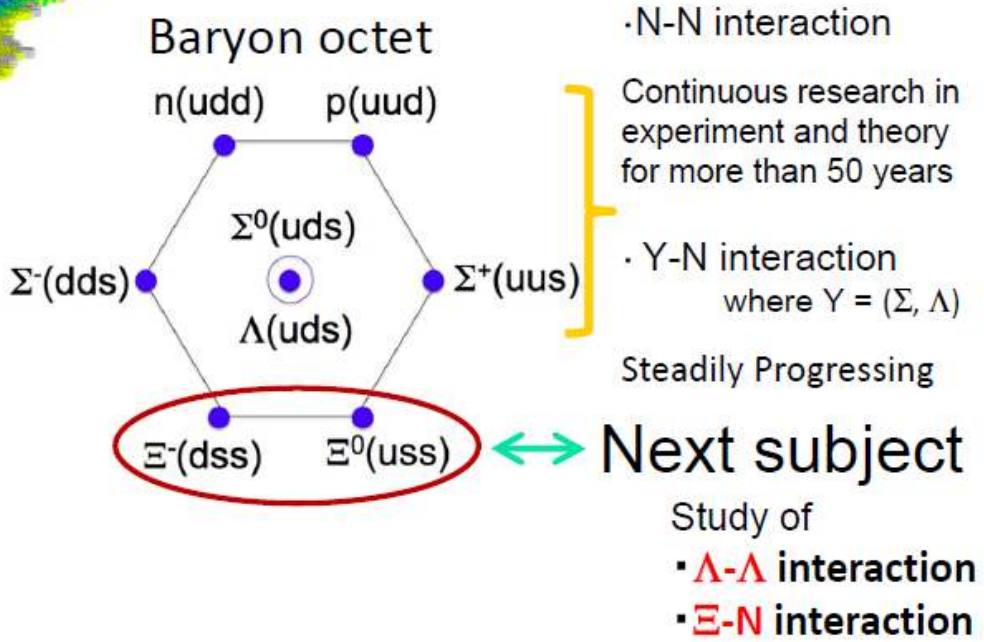
K.Imai[a], K.Nakazawa[b], H.Tamura[c], S.Ahmad[d], J.K.Ahn[e], B.Bassalleck[f], R.E.Chrien[g], D.H.Davis[h], H.Ekawa[i], Y.Y.Fu[j], S.Fukunaga[k], Y.Han[f], R.Hasan[d], S.Hasegawa[a], E.Hayata[i], M.Hirose[i], K.Hoshino[b], K.Hosomi[a], S.Hwang[a], M.Ieiri[l], K.Ito[m], K.Itonaga[b], T.Kawai[m], J.H.Kim[n], S.Kinbara[b], R.Kiuchi[o], T.Koike[c], H.S.Lee[e], J.Y.Lee[o], C.Li[j], Z.M.Li[j], A.Mishina[b], 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], K.T.Tint[r], A.Tokiyasu[p], D.Tovee[h], M.Ukai[c], K.Umehara[b], 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]

[a]*Japan Atomic Energy Agency (JAEA), Japan,*
[b]*Physics Department, Gifu University, Japan,*
[c]*Department of Physics, Tohoku University, Japan,*
[d]*Aligarh Muslim University, India,*
[e]*Pusan National University, Korea,*
[f]*Department of Physics and Astronomy, University of NewMexico, USA,*
[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]*Adanabon University, Myanmar,*
[s]*University of Fukui, Japan,*
[t]*Shanxi Normal University, China.*

YOSHIDA Junya
on behalf of E07 collaboration.

to understand Baryon-Baryon interaction





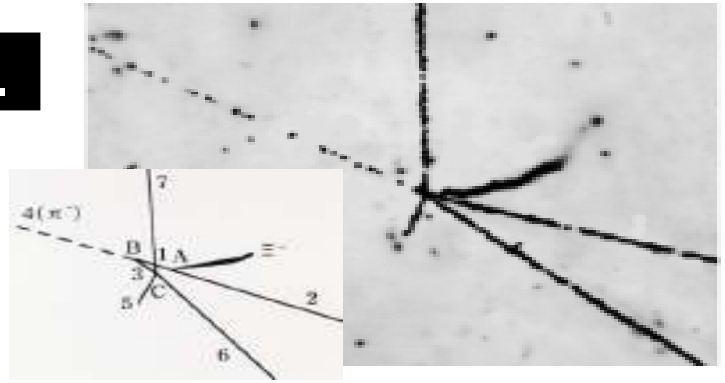
S=-2; double strangeness system
by introducing 2 strangeness into nucleus via Ξ-

S=-2 System, so far; Λ–Λ interaction

Only 3 candidate events in the 20th century.

M.Danysz et al., PRL.11(1963)29;
R.H.Dalitz et al., Proc. R.S.Lond.A436(1989)1
D.J.Prowse, PRL.17(1966)782
S.Aoki et al., NP. A828 (2009) 191-232

E176



2 lambdas as ground state in nucleus

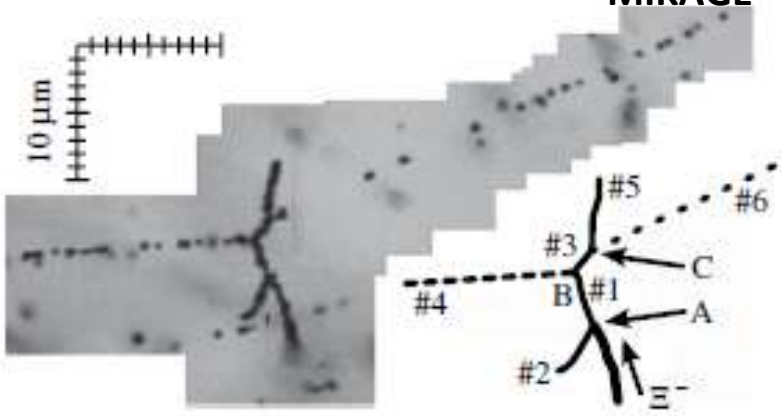
-> 7 more events in KEK E373.

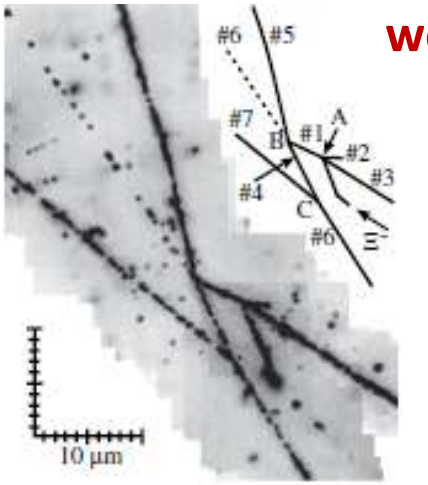
J.K. Ahn et al. PRC 88 (2013) 014003

$B_{\Lambda\Lambda}$ = 6.91 +- 0.16 MeV
$\Delta B_{\Lambda\Lambda}$ = 0.67 +- 0.17 MeV
(where B_{Ξ^-} = 0.13MeV)

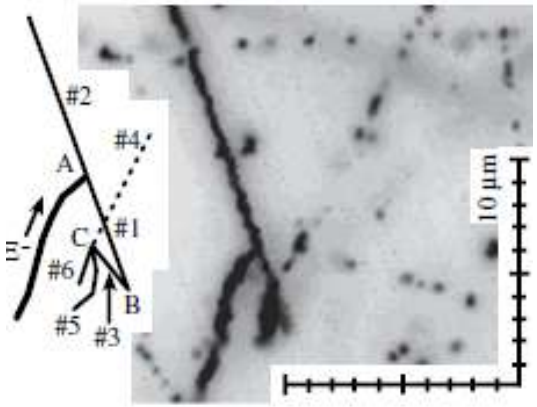
weakly attractive

MIKAGE





NAGARA event



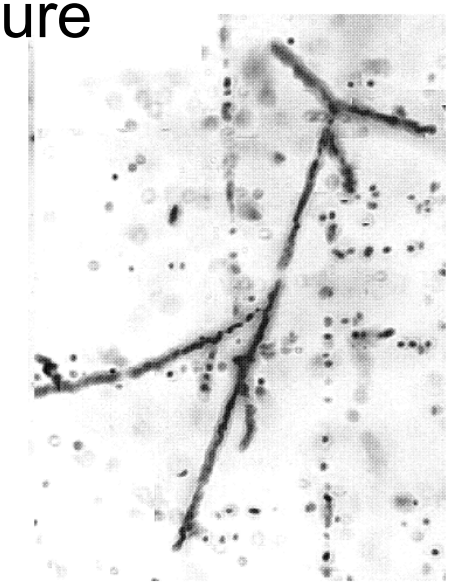
DEMACHIYANAGI

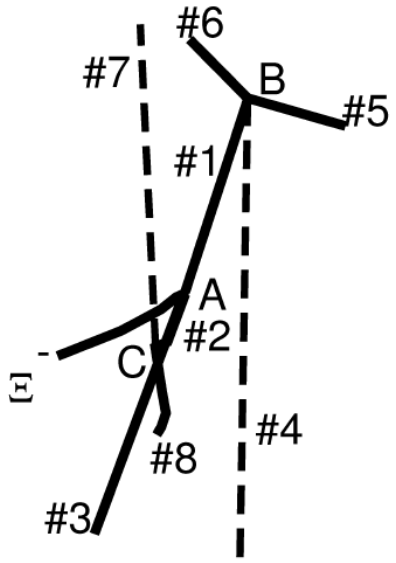
Twin Λ hypernuclei from Ξ^- capture

KEK E373
A.Ichikawa et. al, Phys.Lett.B500(2001)37

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

$B_{\Xi} = -2.6 \pm 1.2$ MeV



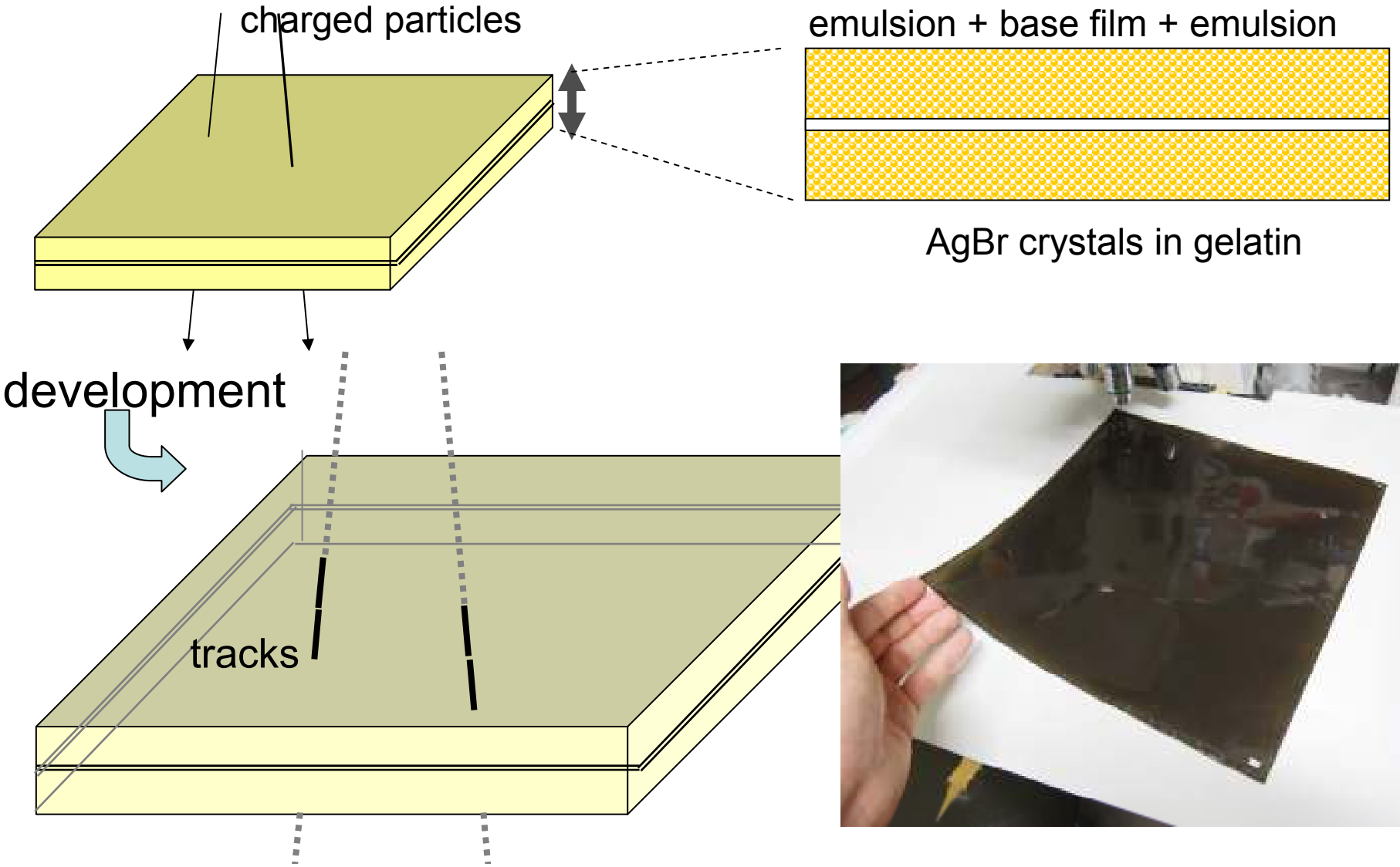


Missing mass spectroscopy of $^{12}C(K^-,K^+)^{12}_{\Xi}Be$

Spectrum shape suggests attractive potential (-14MeV)for Ξ.

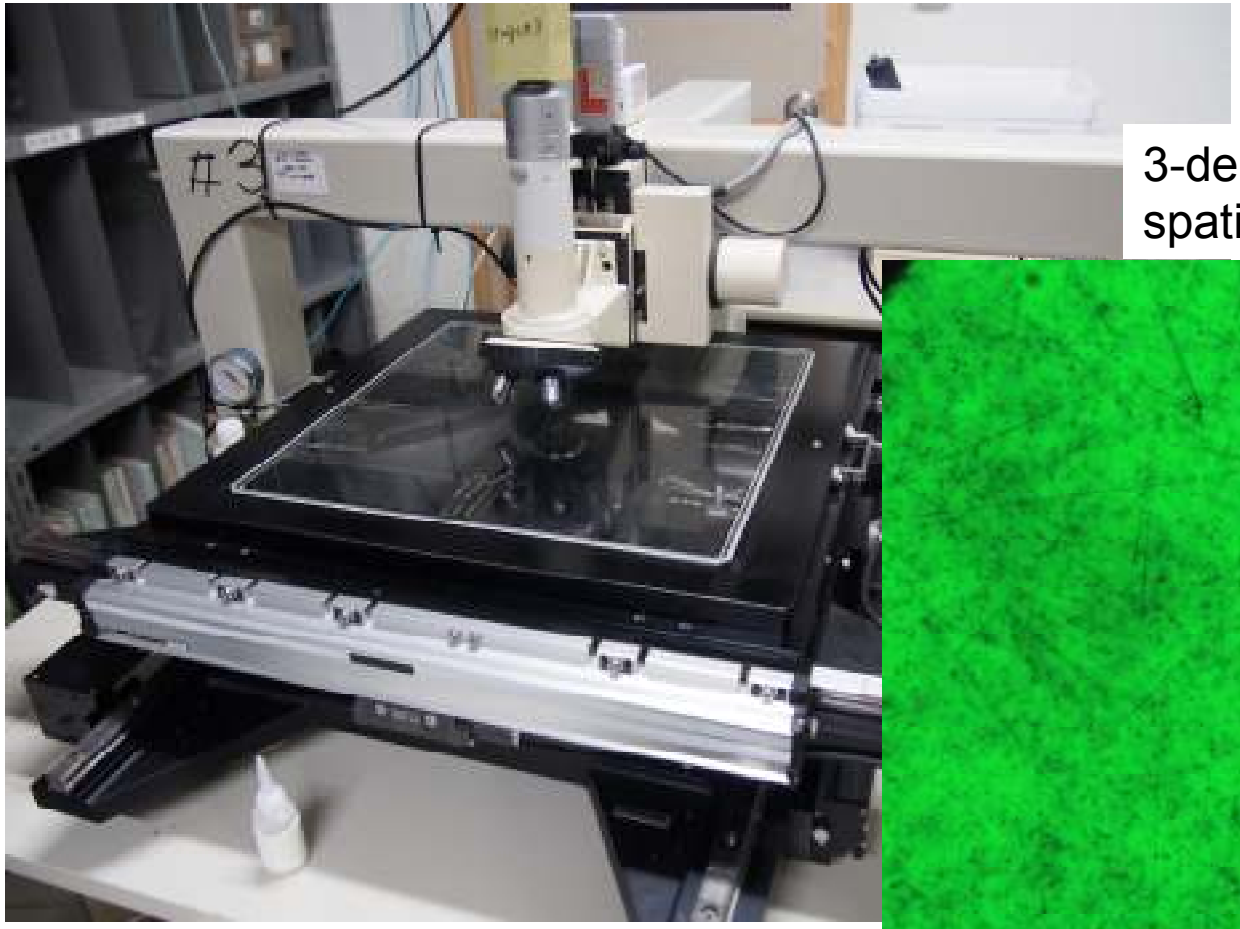
KEK E224 T.Fukuda et. al, PRC58(1998)1306
BNL AGS E885 P.Khaustov et. al, PRC61(2000)054603

nuclear emulsion; photographic emulsion visualizing tracks of particles

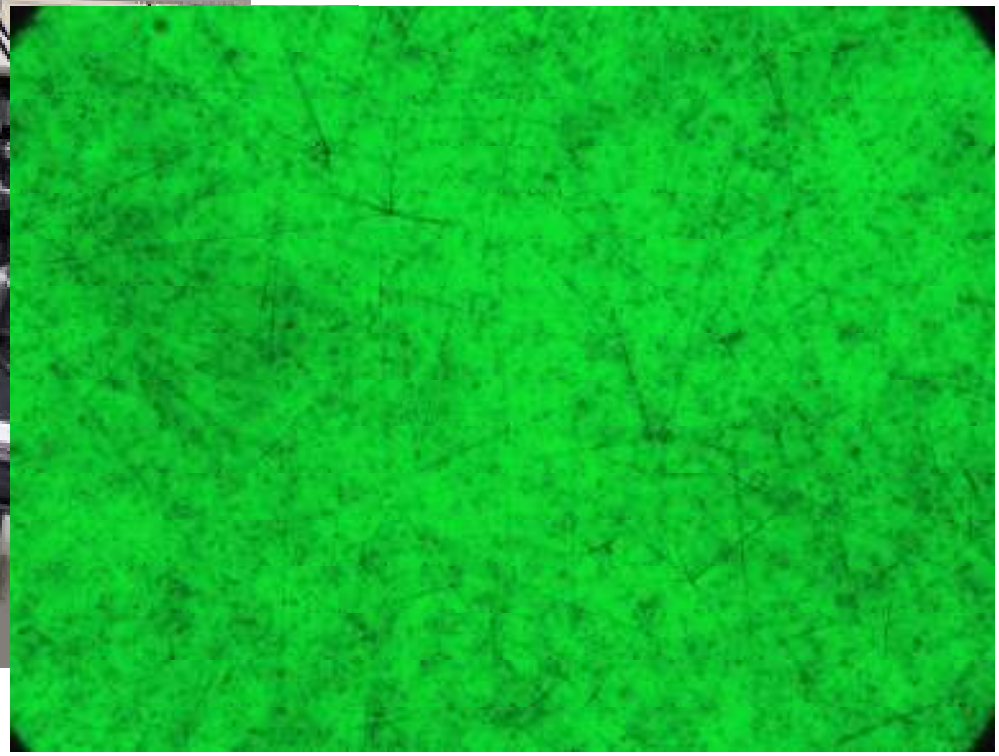


One of the most powerful method for the detection of Double Lambda Hypernuclei

Readout under optical microscope



3-demensional solid state tracker
spatial resolution:~0.2 microns



Microscopic view x20 objective
Field of view: 650*850 microns

Motivation of J-PARC E07

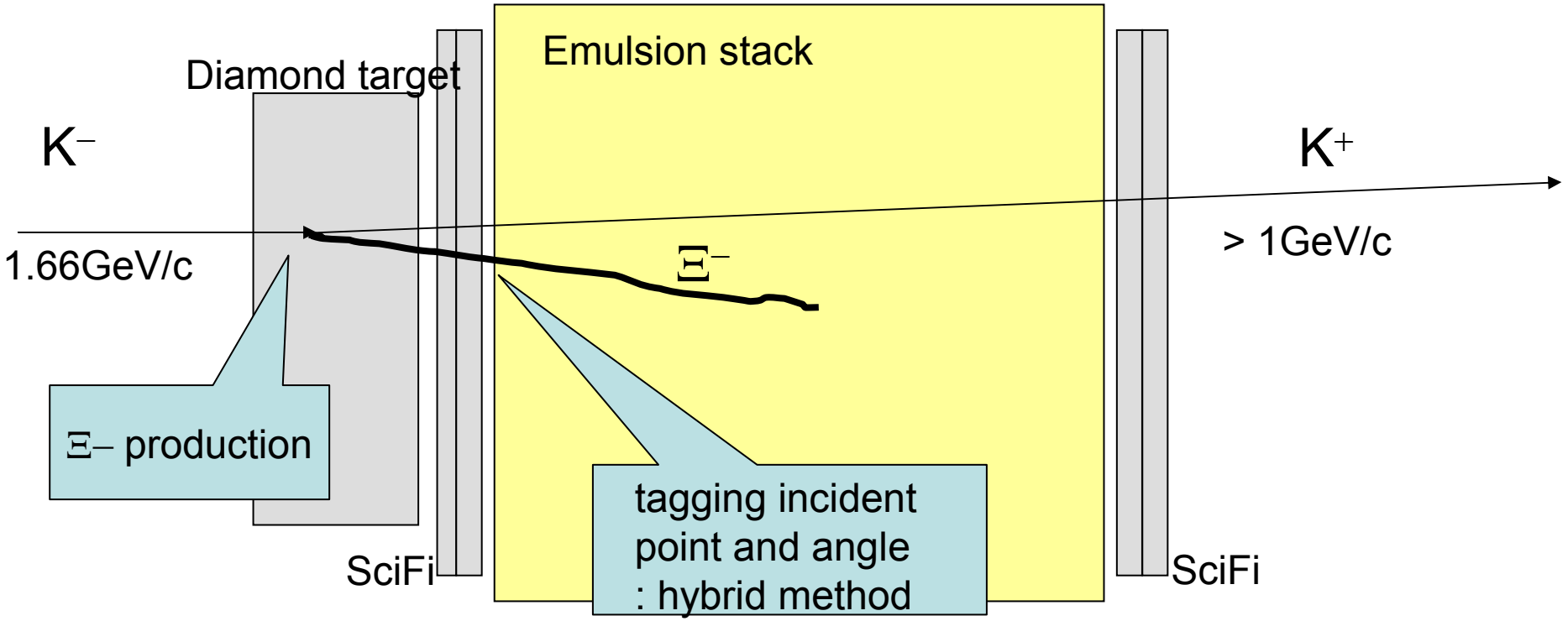
Emulsion volume: 70L -> 153L
K- purity: ~20% -> ~85%(designed value)

- Detection of double hypernuclei by new hybrid method
  - 10 times' statistics of E373 ⇔ 10^4 Ξ^- stop
    10^2 double hypernuclei
    ~10 identified nuclides
  - Nuclear (A) dependence of $\Lambda\Lambda$ binding energy
  - Ξ-N interaction via twin Λ hypernclei
  - H-dibaryon ?

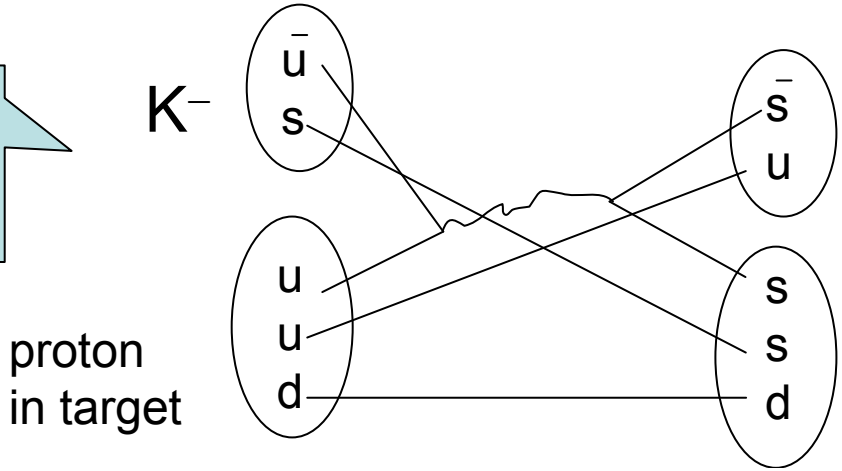
- X-rays from Ξ-atom (Ag/Br)
  - Ξ-Nucleus potential in the surface region
    ⇔ Spectroscopy of Ξ-hypernuclei

*Experimental concept of E07 (based on KEK E373)
*Current status of detectors

Detection and mass measurement of Double Lambda Hypernuclei (KEK-PS-E373)



quasifree '*p*'(*K*–,*K*+)Ξ- reaction



proton in target

strangeness x2

SSD

Sensor (Hamamatsu)

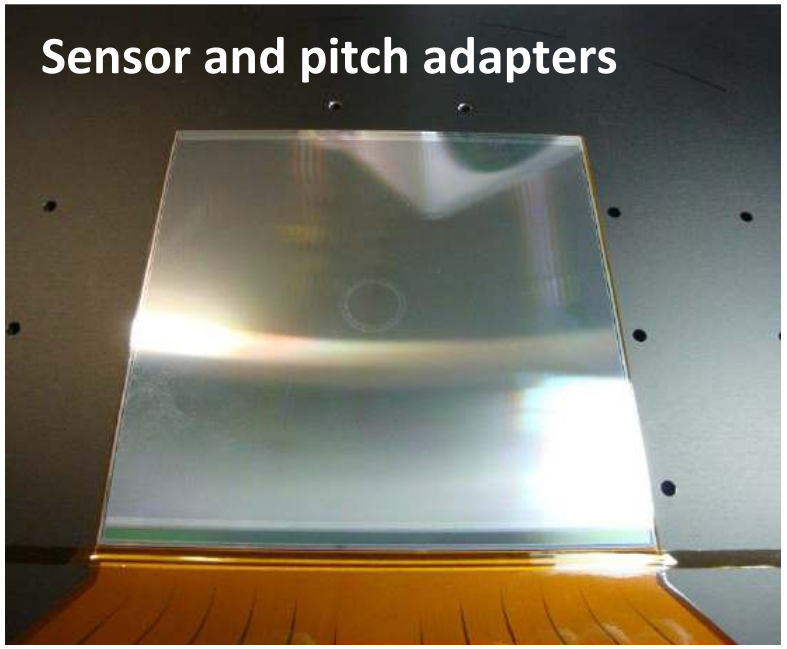
- single-side 50μm pitch
- N-bulk with 320μm thickness
- 90 x 90 mm^2

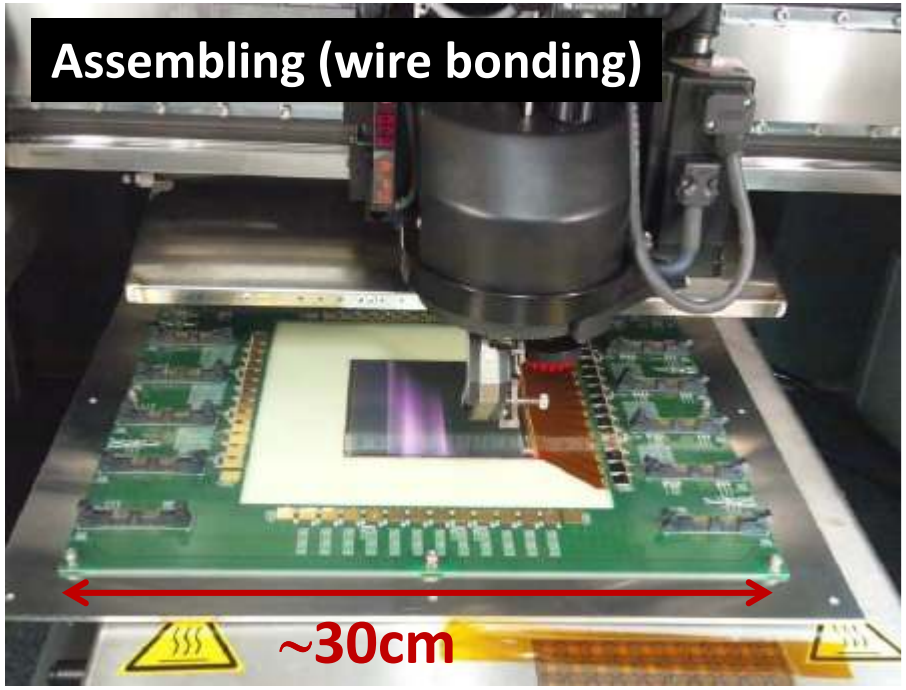
Configuration

- XYXY stacks at up- and down-stream of the emulsion
- 77x77 mm^2 eff. area
- 1536/1792 ch./layer R.O.
- APV front-end for DAQ

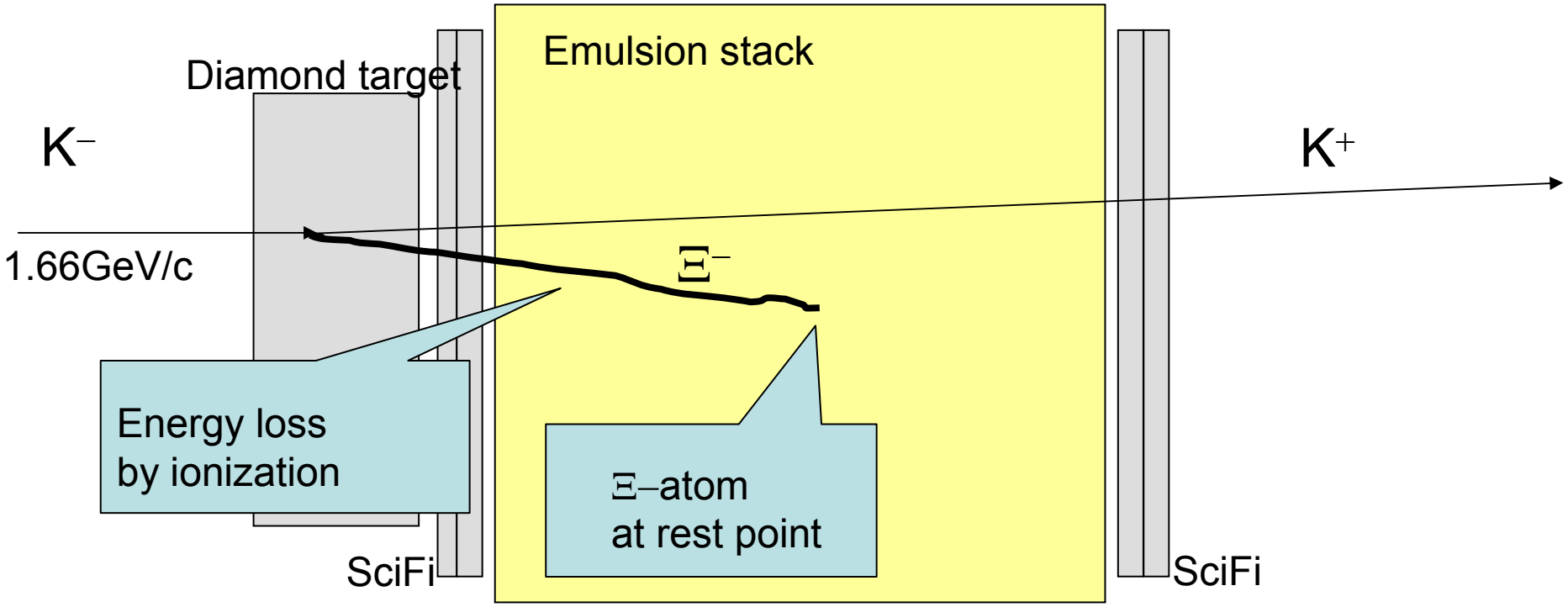
ΔX ~30μm $\Delta X'$ ~10mrad

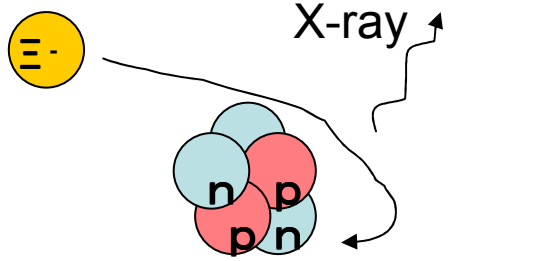
Current status: Waiting for wire bonding with SSD sensor and pitch-adopter.
Full system will be ready in June, 2014.

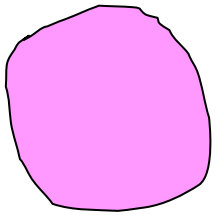




Detection and mass measurement of Double Lambda Hypernuclei (KEK-PS-E373)







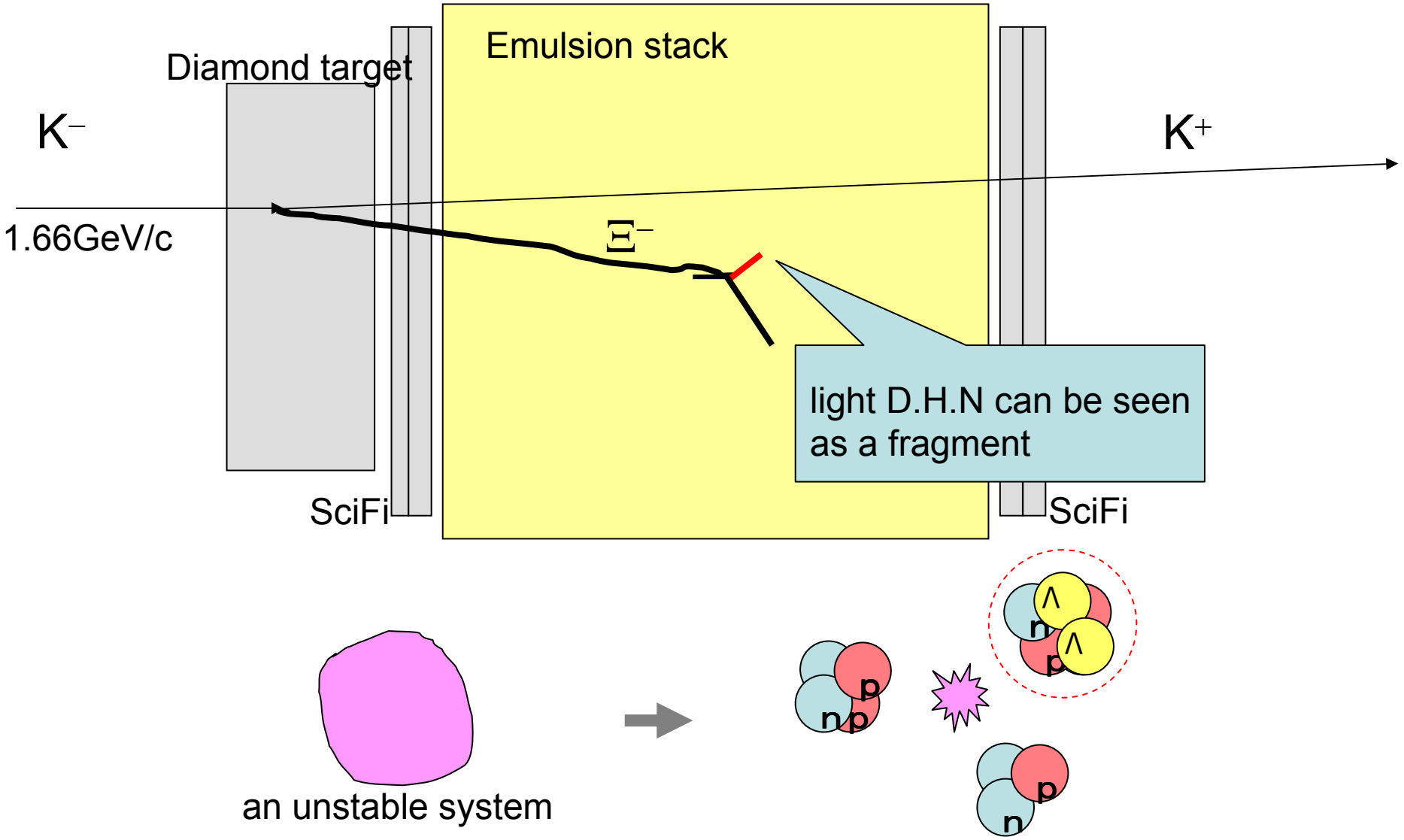
$p + \Xi^- \rightarrow \Lambda + \Lambda + 28\text{MeV}$

5 protons + 6 neutrons + 2 lambdas
+ excess energy

i.e. $^{12}C + \Xi^-$ system (Ξ-atom)

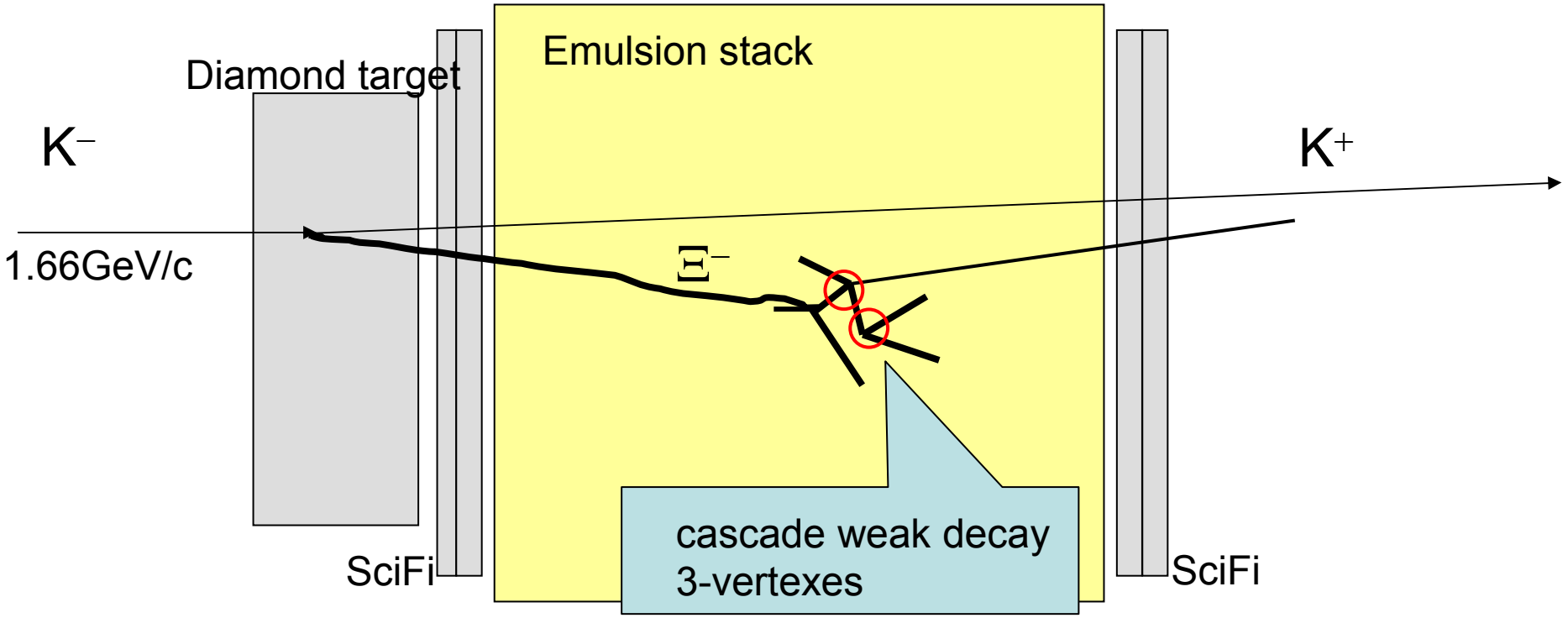
$E = M(^{12}C) + M_{\Xi^-} - B_{\Xi^-}$

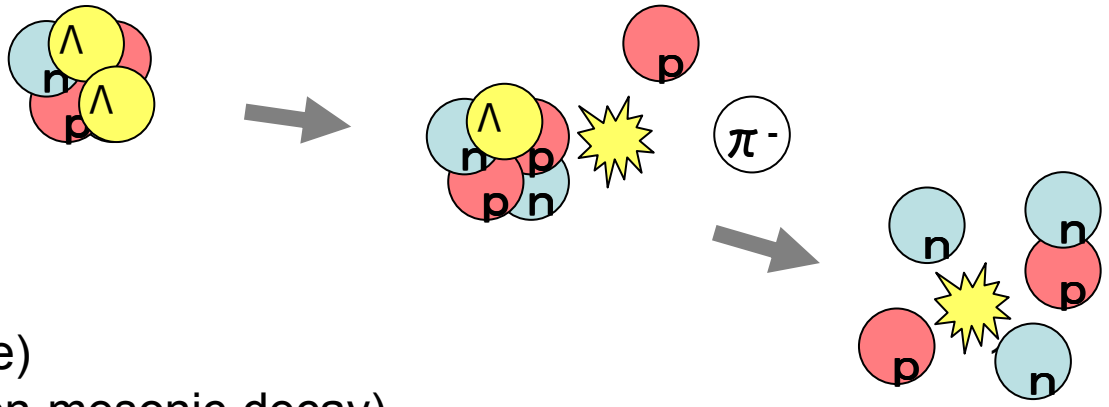
Detection and mass measurement of Double Lambda Hypernuclei (KEK-PS-E373)



Double Lambda Hypernuclei is formed if Lambdas are bound in a nuclei fortunately

Detection and mass measurement of Double Lambda Hypernuclei (KEK-PS-E373)





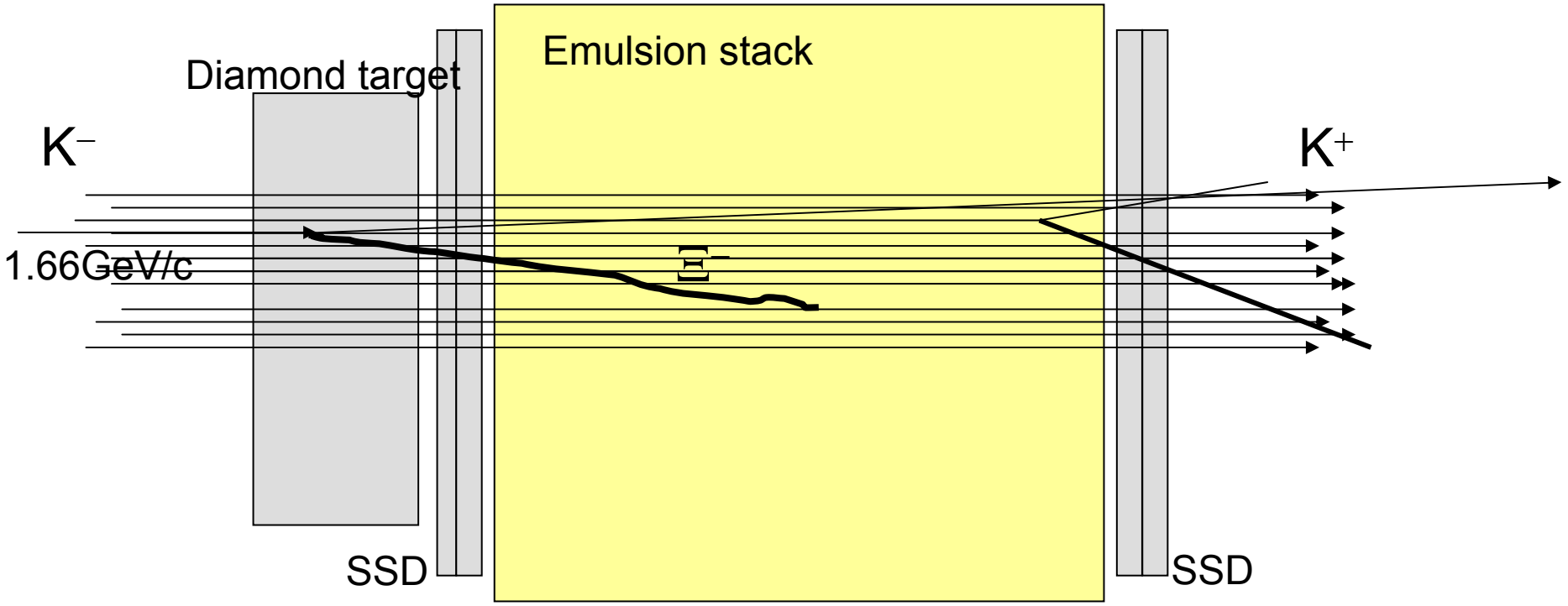
Decay modes of Λ

Λ -> p + π^- + 37.8 MeV

-> n + π^0 + 41.1 MeV (rare)

Λ + N -> n + N + 176.1MeV (non-mesonic-decay)

Emulsion mover



Emulsion stack records all beam track

* Incident K- 8* 10^8
* Ξ- production ~3500
* Ξ- stop event ~70

*emulsion is moved spill by spill

-> emulsion mover

Emulsion mover, in readiness

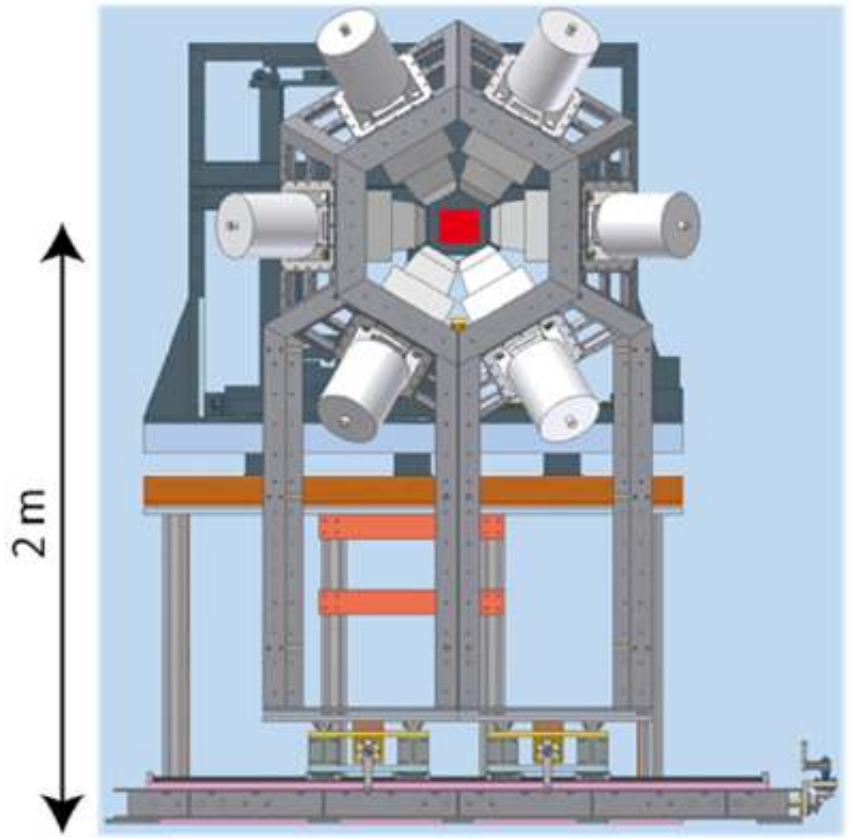
Hirose, Hayata (Kyoto)

Ge detector; Hyperball-X

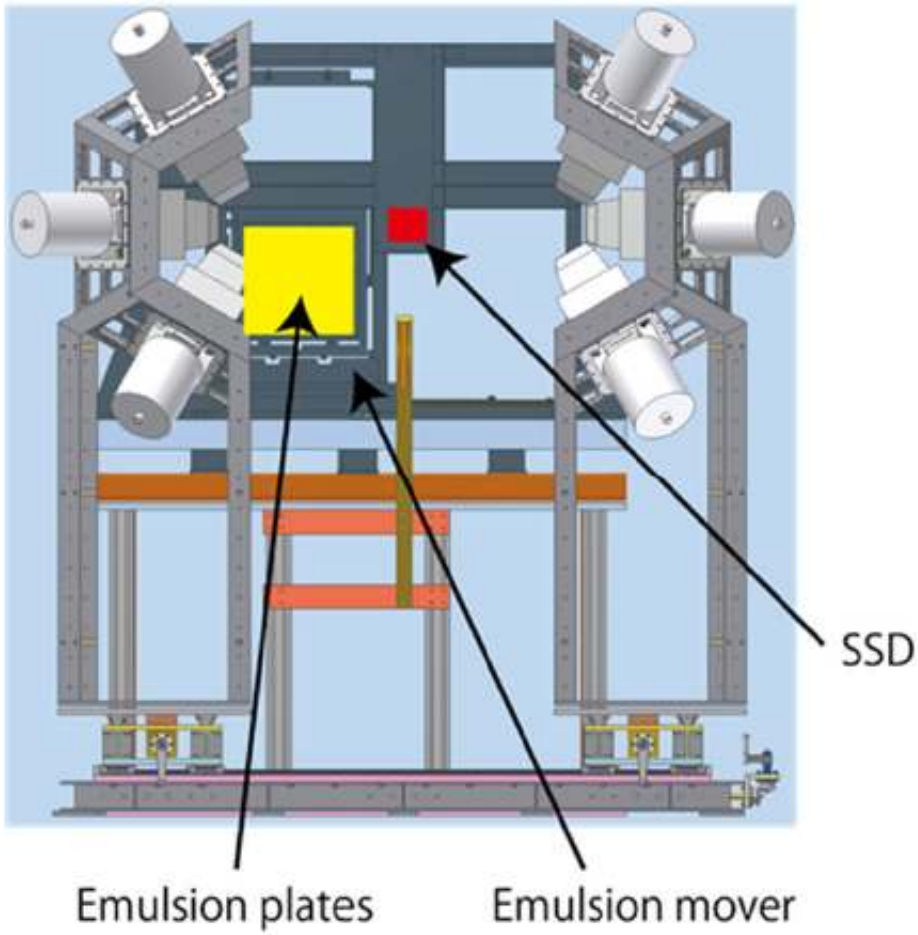
X-rays from Ξ-atom (Ag/Br)
Ξ-Nucleus potential in the surface region

- 6 units of clover-type Ge detectors
- 4 Ge crystals per unit
- BGO for B.G. (π^0 & Compton) suppressor
- ~3% photo-peak efficiency at 350keV

Closed position (for beam exposure)



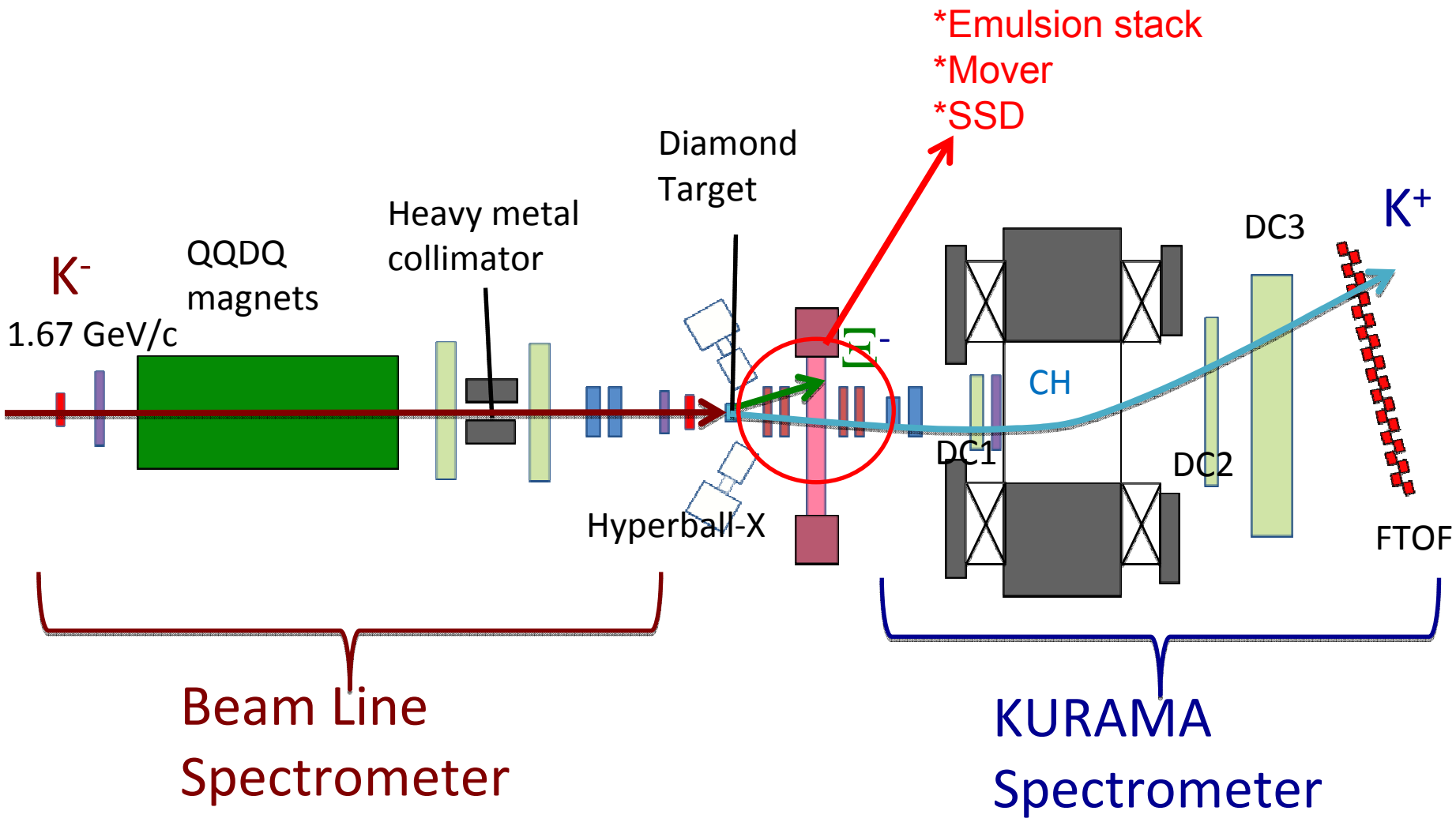
Opened position (for emulsion exchange)



Support frame: coming soon
Assembling: ~April.

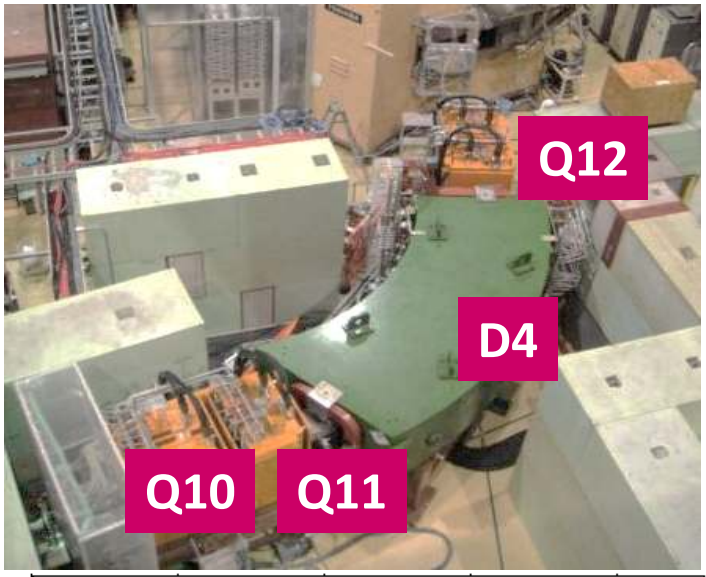
E07 Setup

K1.8 Beam Line @J-PARC

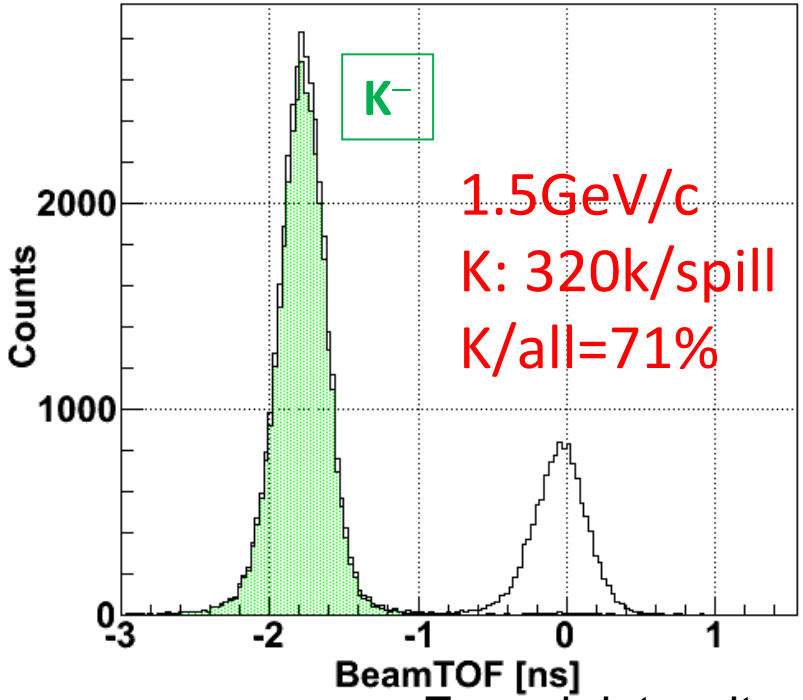


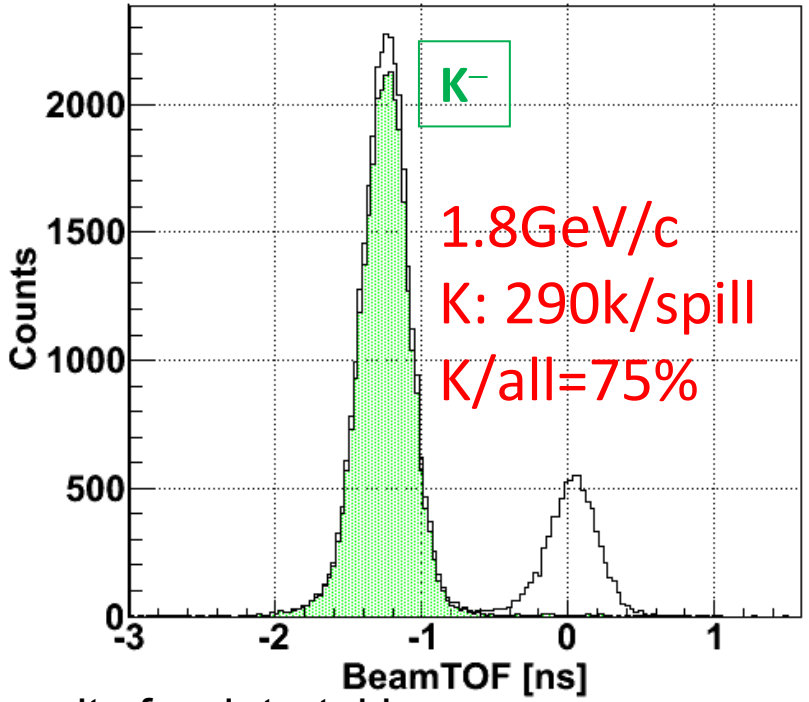
K^- beam & Beam Spectrometer.

*QQDQ + collimator
*profile: X~40mm, Y~15mm
*K^- purity: ~75%



E13 commissioning at 20kW
ESS1/ESS2 = +- 250kV (max +- 375kV)

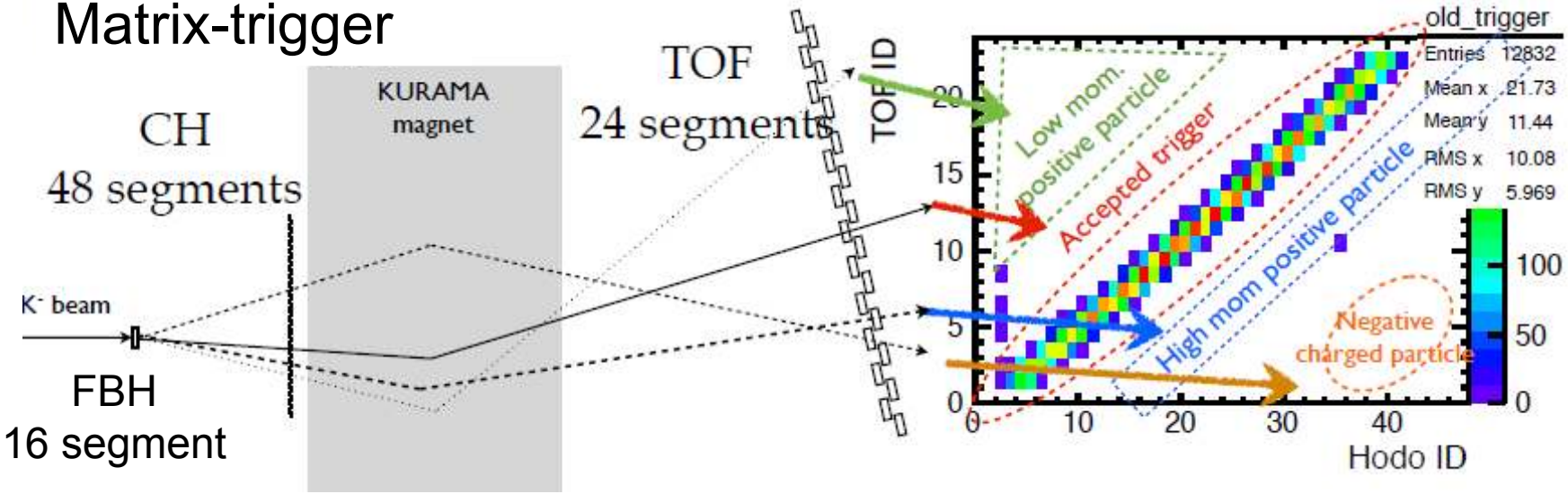




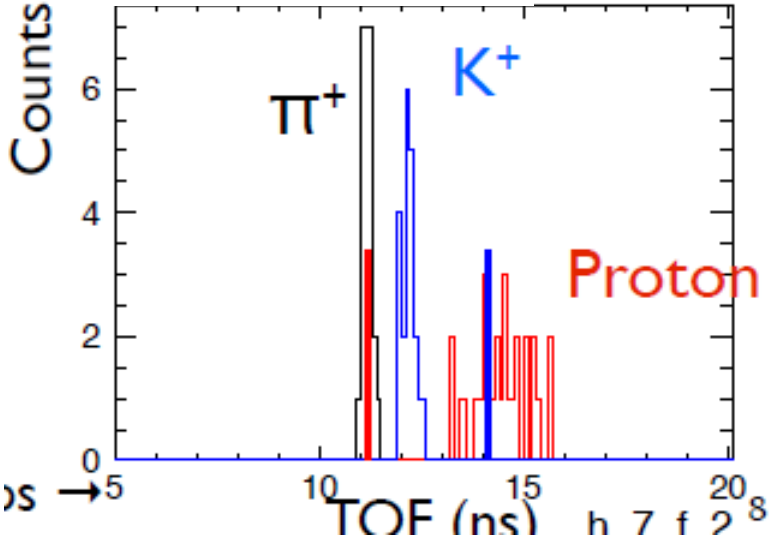
Enough intensity and purity for data-taking,
Further optimization gives better performance.

Matrix/Mass Triggers to reduce trigger rates

Matrix-trigger



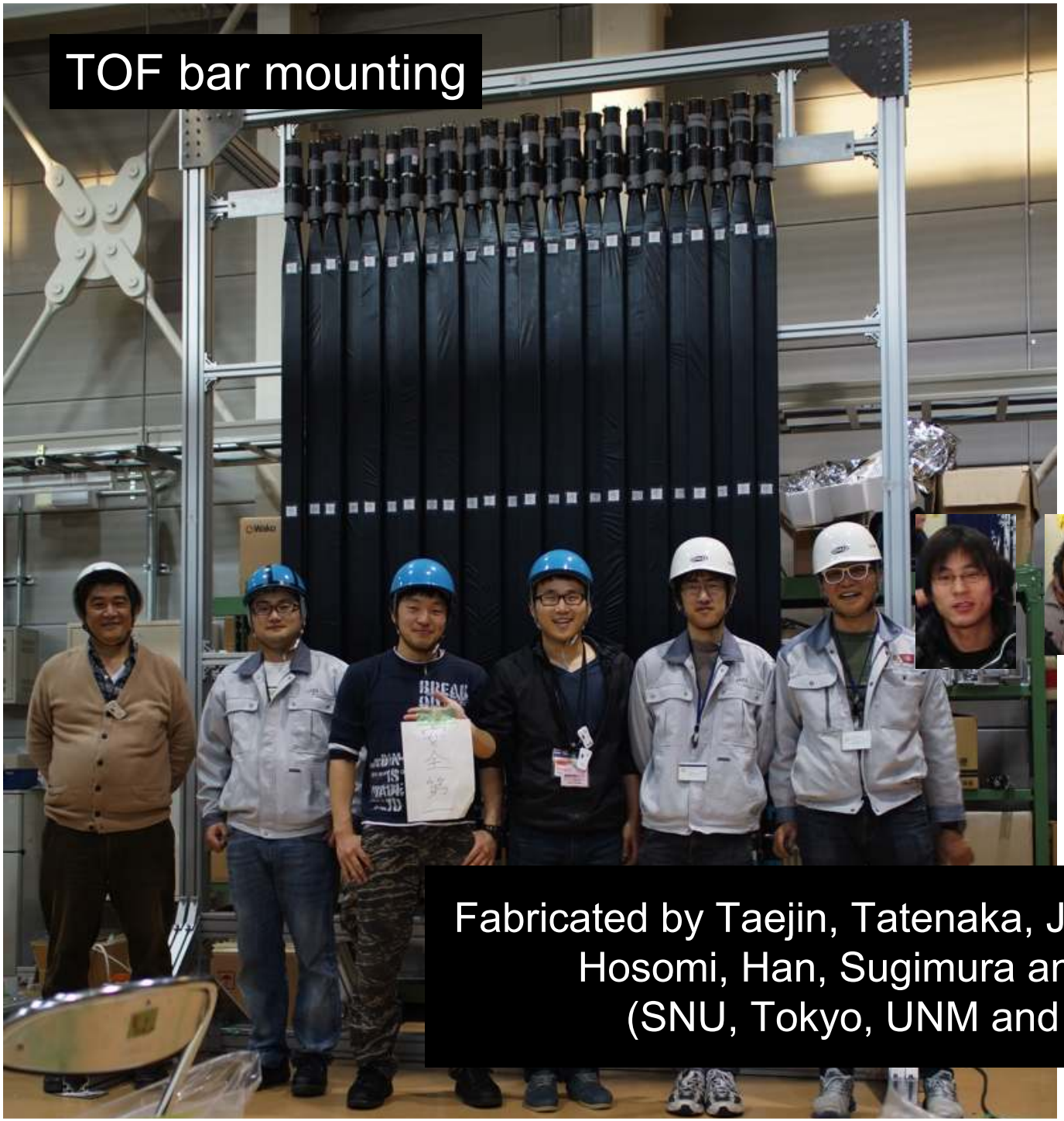
Mass-trigger



the charges and momentum are roughly selected in the online trigger by taking the matrix coincidence of the CH and the TOF,

TOF bar mounting

2014/02/28



Fabricated by Taejin, Tatenaka, Jaeyong, Ekawa, Hosomi, Han, Sugimura and Hwang (SNU, Tokyo, UNM and JAEA)

KURAMA magnet
(from downstream)

pole gap: 50cm → 80cm (x 1.25)
to compensate the reduction
of emulsion (2.6t → 2.1 t)

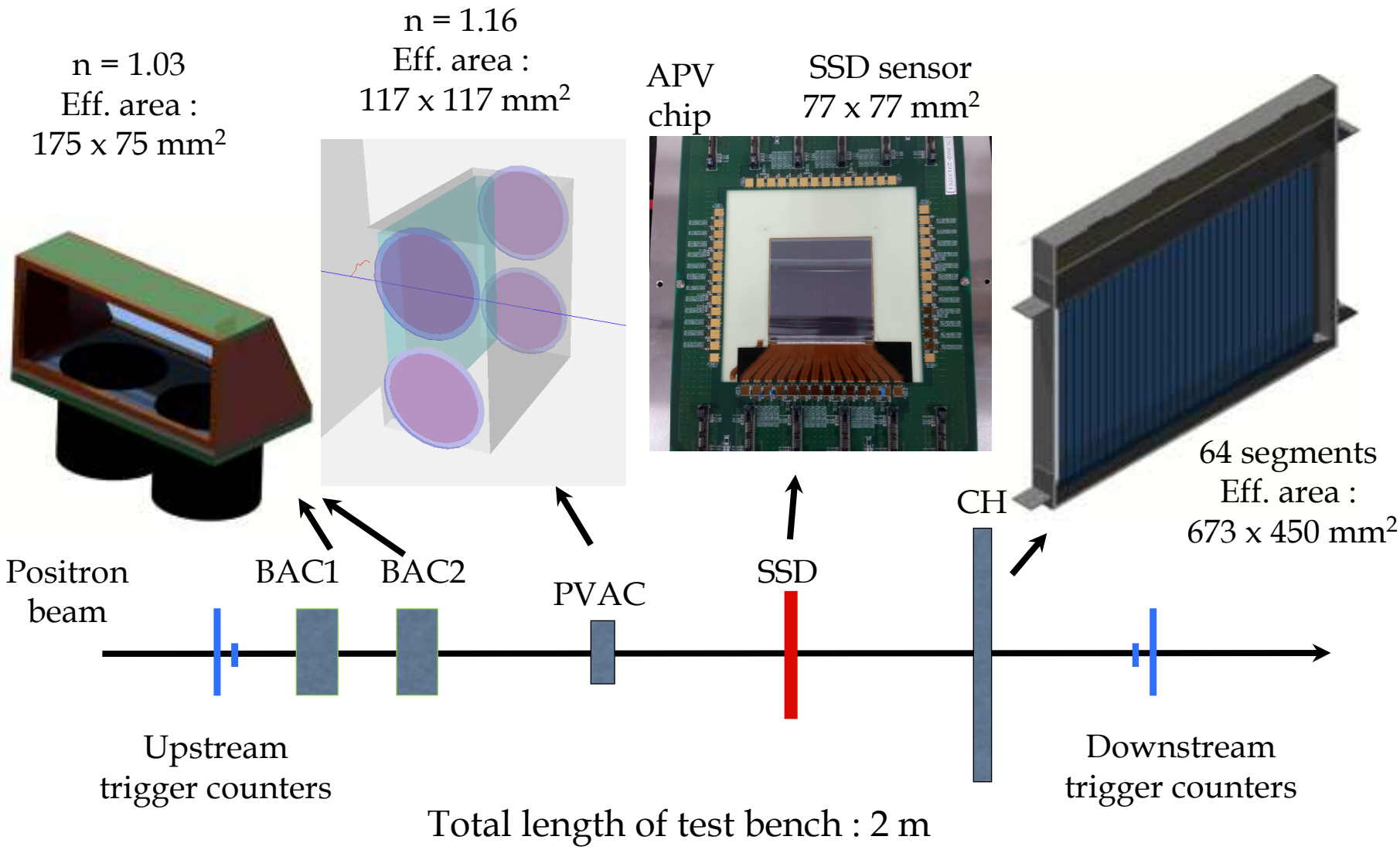
Downstream drift chambers

DC2 (KL chamber)
1185 x 1185
XX'YY'
9mm spacing

DC3 (AIDA chamber)
1900 x 1280
XX'YY'
20 mm spacing

readout test is on-going.

Test experiment in ELPH@Tohoku univ (June~July, 2014)

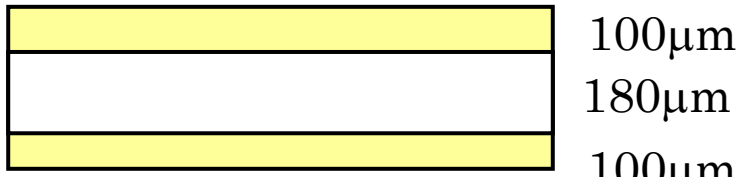


mass production of emulsion plates

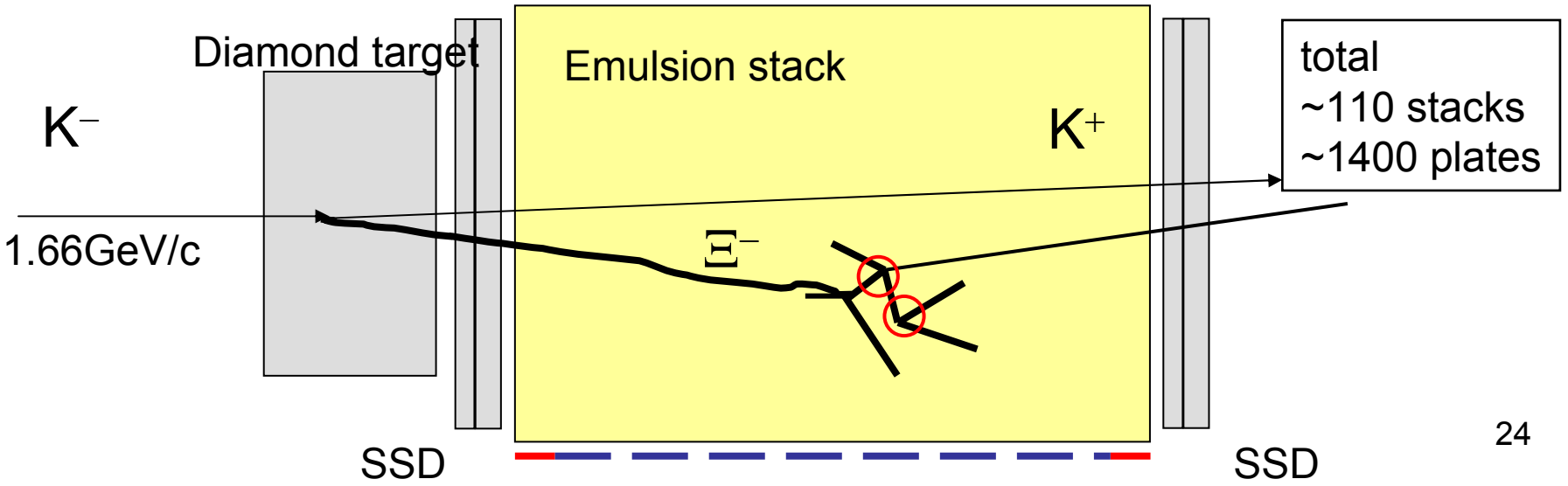
Thick type 12plates /stack

Less insensible volume
For detection of D.H.N

Thin type 2plates/stack

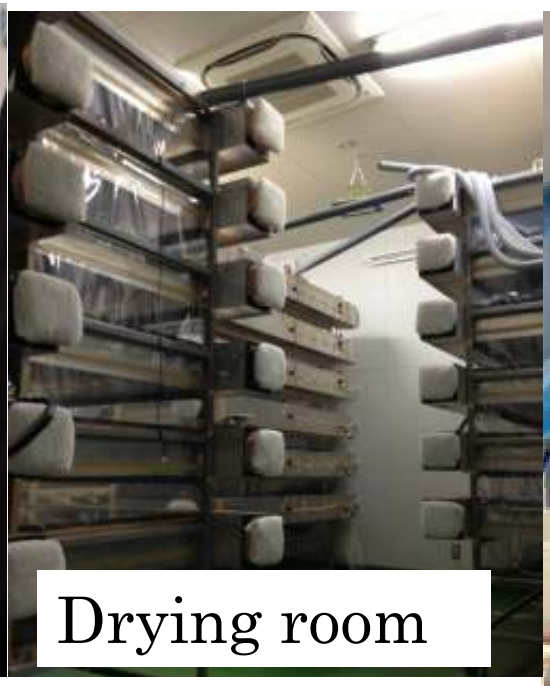


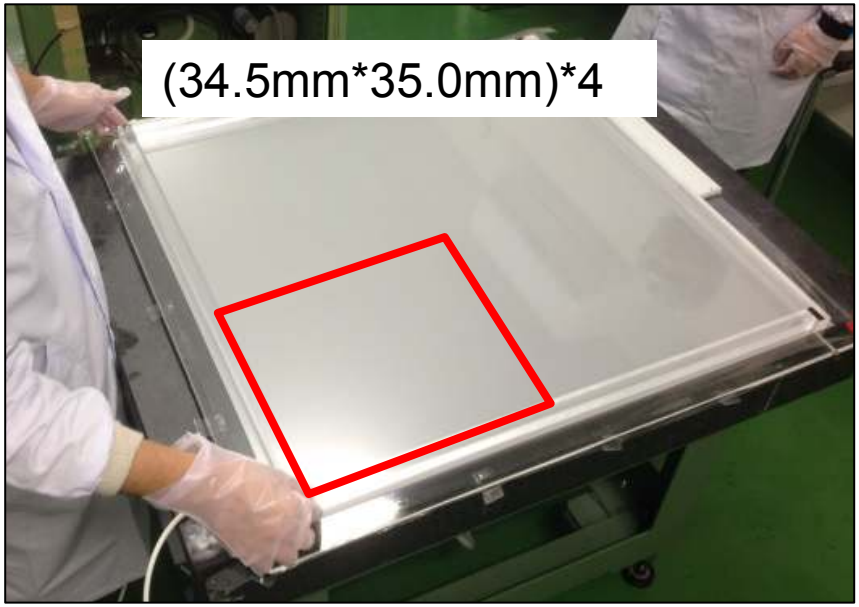
Good angler resolution
For SSD – emulsion connection



Emulsion facility in Gifu-univ. (~100m^2)

<Pouring room>
Three flat stone bases , Hot bath
Cutting machine
<Drying room>
Temp 30 ℃ and R.H. 75%.
<Development room>
1200 liters’ chemical solutions





Demonstration of gel pouring
by dummy-gel (gelatin solution)

Left: vacuum chuck on flat base

Left-down: gel pouring

Right-down: storing on drying cabinet

performance of the 8th cycle of emulsion plate making

8 Mar.	Preparation	
9	Pouring 1st surface (18sheets)	
10		Pouring 1st surface (18sheets)
11	Surface coat (18sheets)	
12		Surface coat (18sheets)
13	Pouring 2nd	
14		Pouring 2nd surface (18sheets)
15	Surface coat (18sheets)	
16		Surface coat (18sheets)
17	Final dry	
18	Cutting 36sheets(710mm × 700mm) → 144plates(350mm × 345mm)	

about 80% of emulsion plates have been made.
Mainly MC students and under graduate students
performed essential roles

K.Nakazawa, K.T.Tint, R.Xu, J.Yoshida, M.K.Soe
S.Kinbara, A.Mishina, H.Ito, Y.Endo and H.Kobayashi

Emulsion plates are stored in KAMIOKA mine until beam exposure
To avoid cosmic-ray and gamma-ray

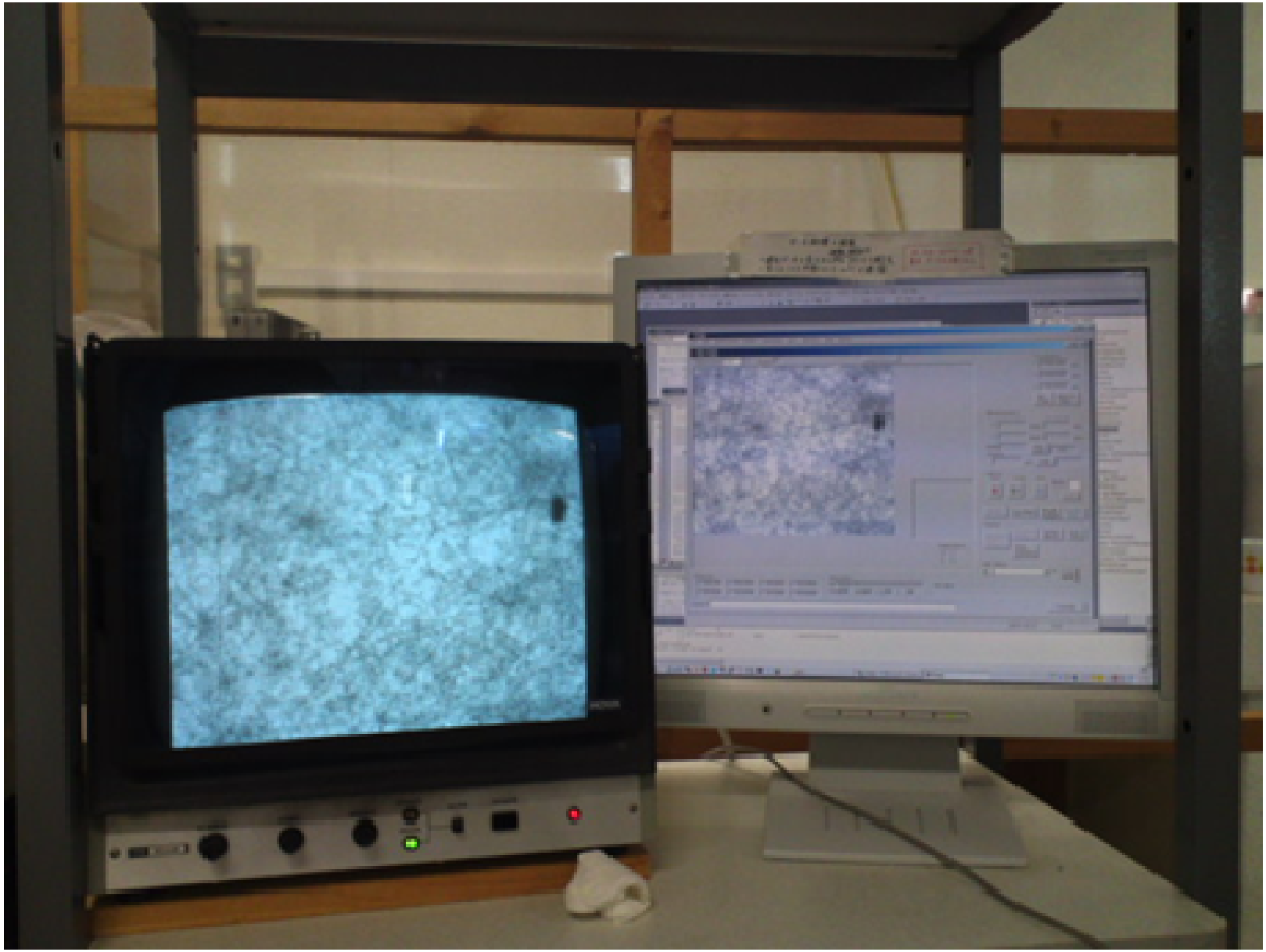
Emulsion analysis

Scanning room in Gifu

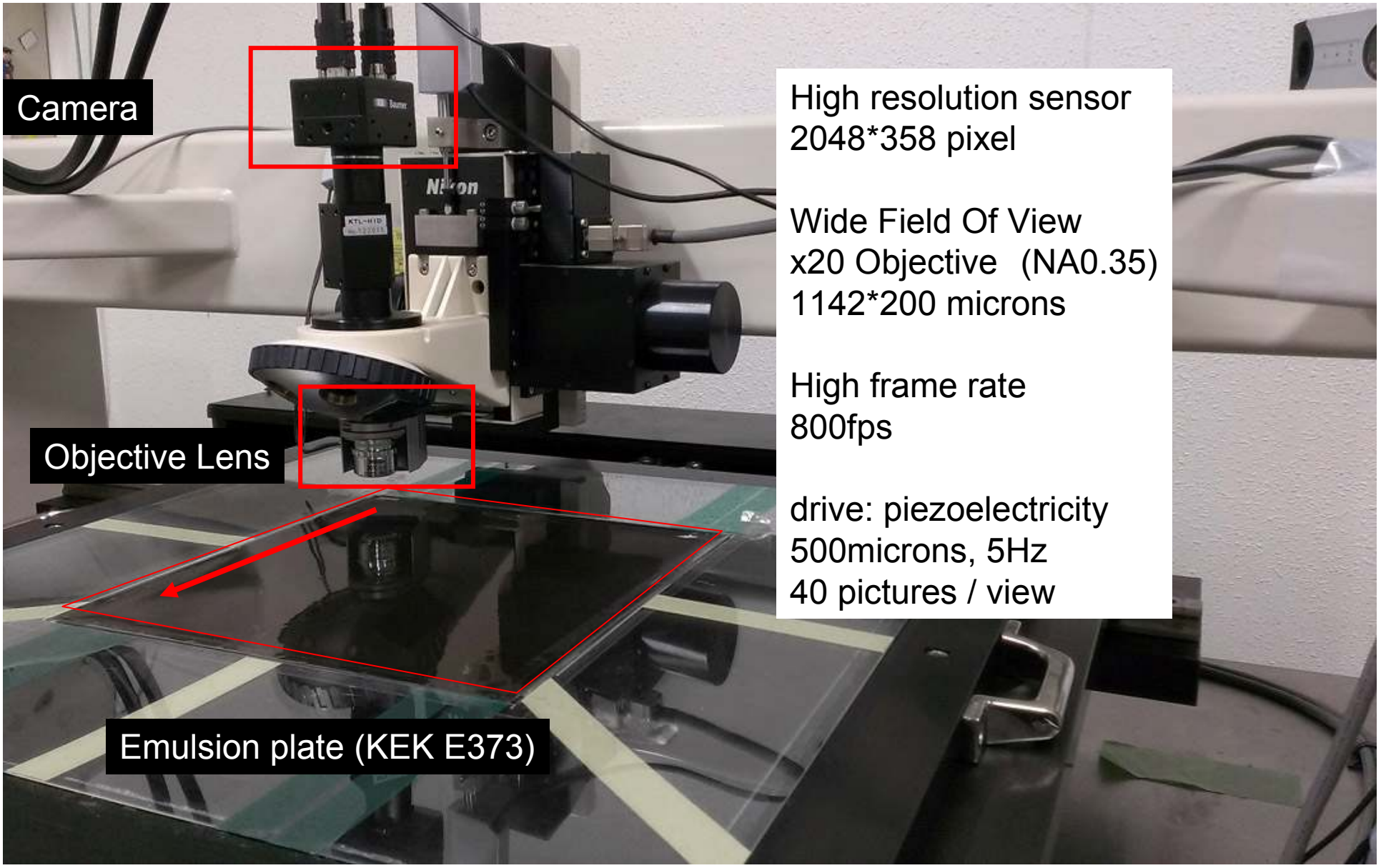
*7 computer-controlled + 2 manual microscopes are in readiness.

*Temperature(20 deg C) and humidity (65%) is stable

microscope-human interface software



Stage for Overall scanning with UNIOPT. CO.,Ltd



Some candidates of 3-vertexes were found

- E07 aims to collect 10 times' statistics of double hypernucleus of the previous experiment
  *A-dependence of $\Lambda\Lambda$ interaction
  *ΞN interaction
    from twin hypernuclei / X-ray measurement

- Beam exposure is planed on 2015.
- However, construction of the detectors and analysis framework is gradually underway.