# Experimental study of double hypernuclei with a hybrid emulsion method at J-PARC

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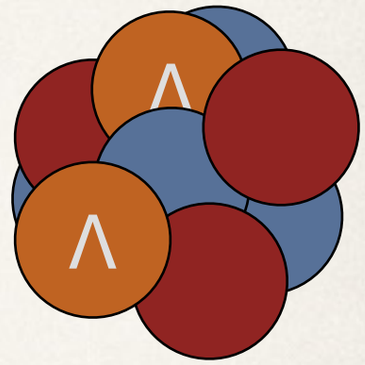
*Osaka Electro-Communication University.*

# Contents

# Double hypernuclei

## Baryon-Baryon interaction

- (u, d, s) system is described in $SU(3)_f$ symmetry.
- S=-2 data is very limited.
- Hyperon-Hyperon interaction is difficult to study experimentally.
  - life time : ~$10^{-10}$s



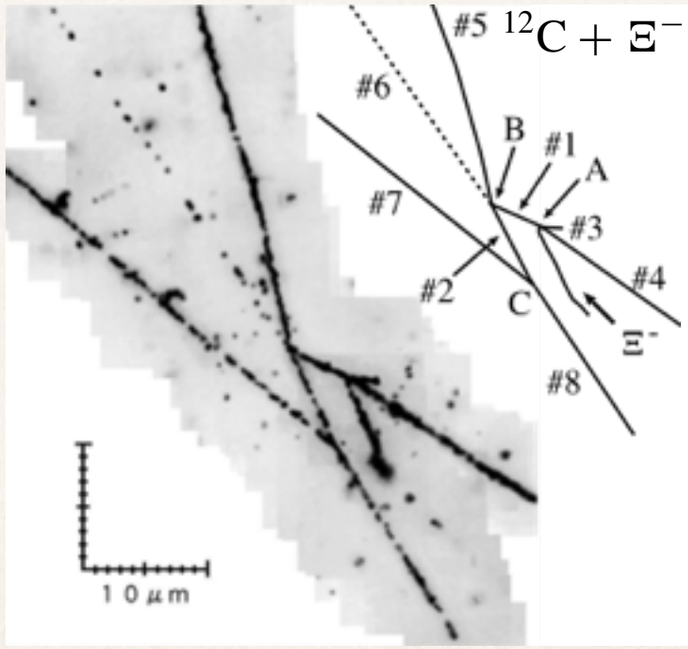

## Double hypernuclei

- Two Λ are bound in a nucleus.
- ΛΛ interaction can be extracted.
- sequential weak decay

## Emulsion experiment

- effective to detect double hypernuclei
- record decay topology
- < μm resolution

## NAGARA event (KEK E373)




$$^{12}\mathrm{C} + \Xi^- \rightarrow {}^{6}_{\Lambda\Lambda}\mathrm{He} + {}^{4}\mathrm{He} + t$$
$$\hookrightarrow {}^{5}_{\Lambda}\mathrm{He} + p + \pi^-$$

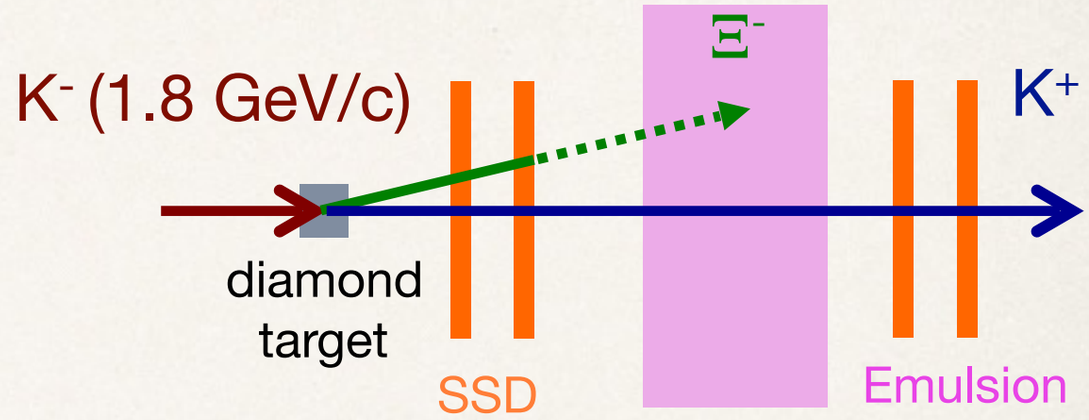
$B_{\Lambda\Lambda}$ = 6.91 ± 0.16 MeV
$\Delta B_{\Lambda\Lambda}$ = 0.67 ± 0.17 MeV ←weakly attractive

# J-PARC E07 experiment

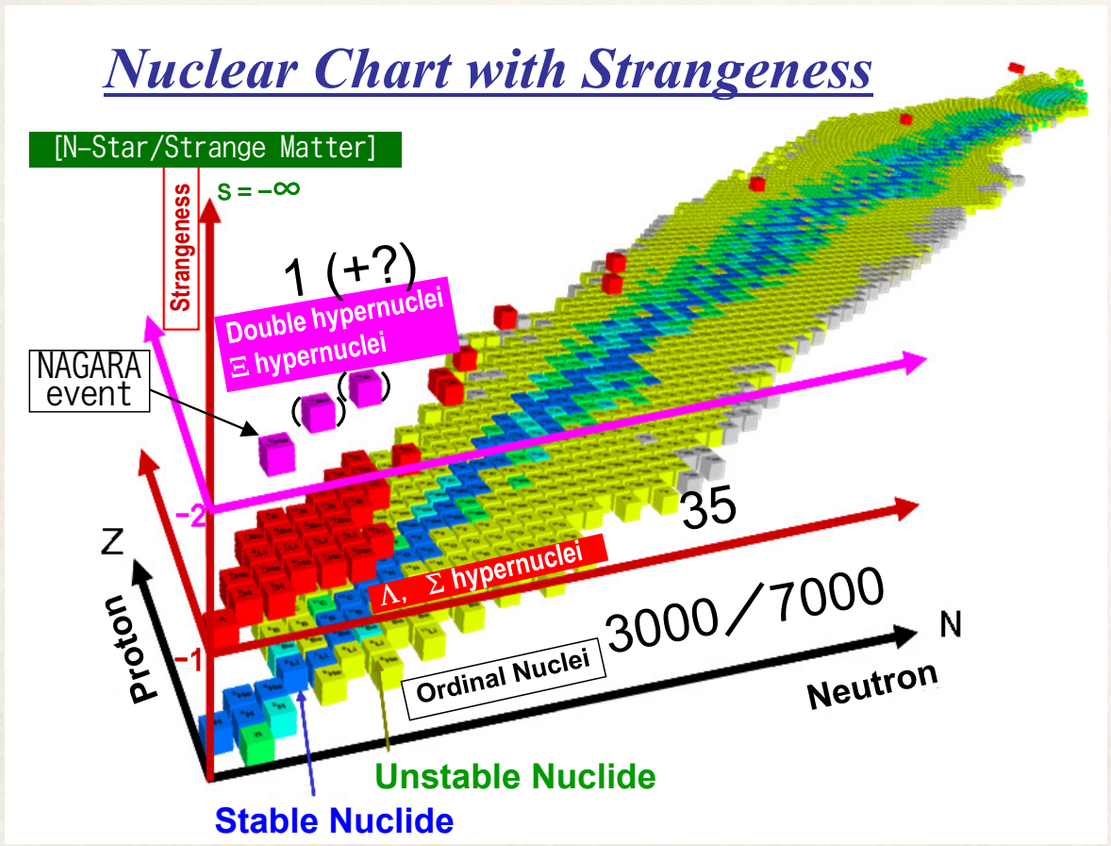
**J-PARC E07 experiment**

- double hypernuclei search experiment
- hybrid emulsion method
- statistics : KEK E373 x 10
  - $10^4$ $\Xi^-$ stop
  - 100 double hypernuclei candidates
  - 10 identified species
- detect $\Xi^-$ atom X ray with Ge detectors

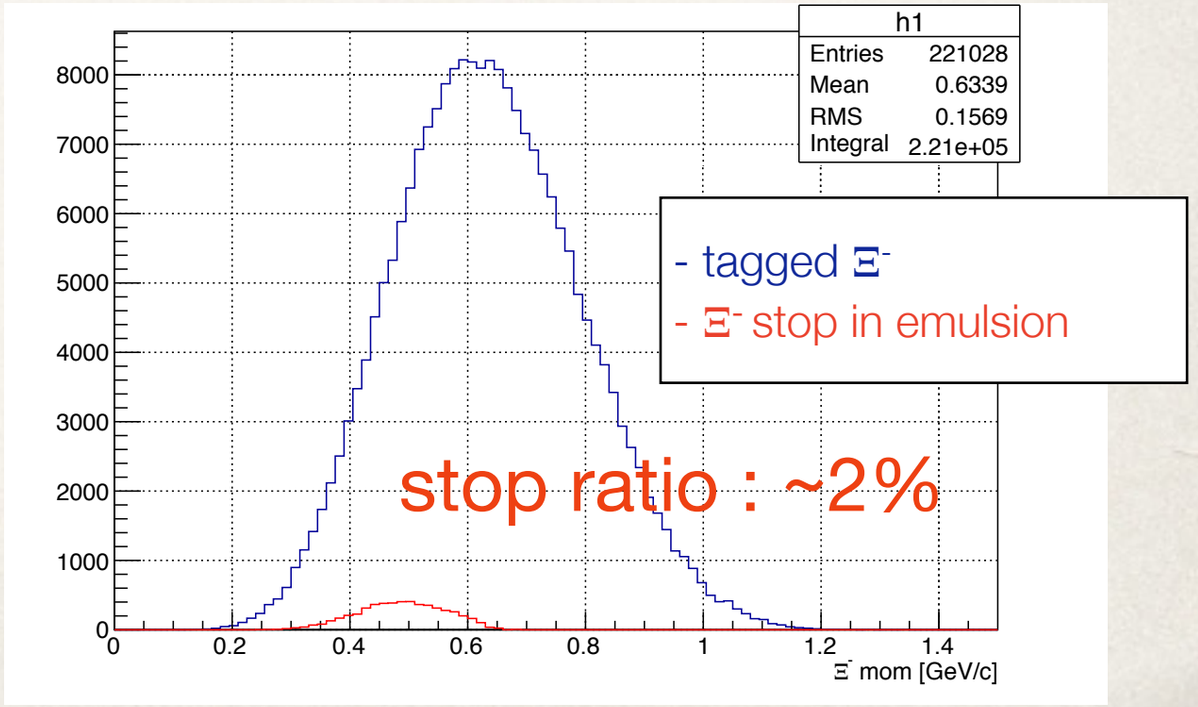
**Hybrid emulsion method**




predict $\Xi^-$ position and angle with SSD




**$\Xi^-$ momentum (simulation)**

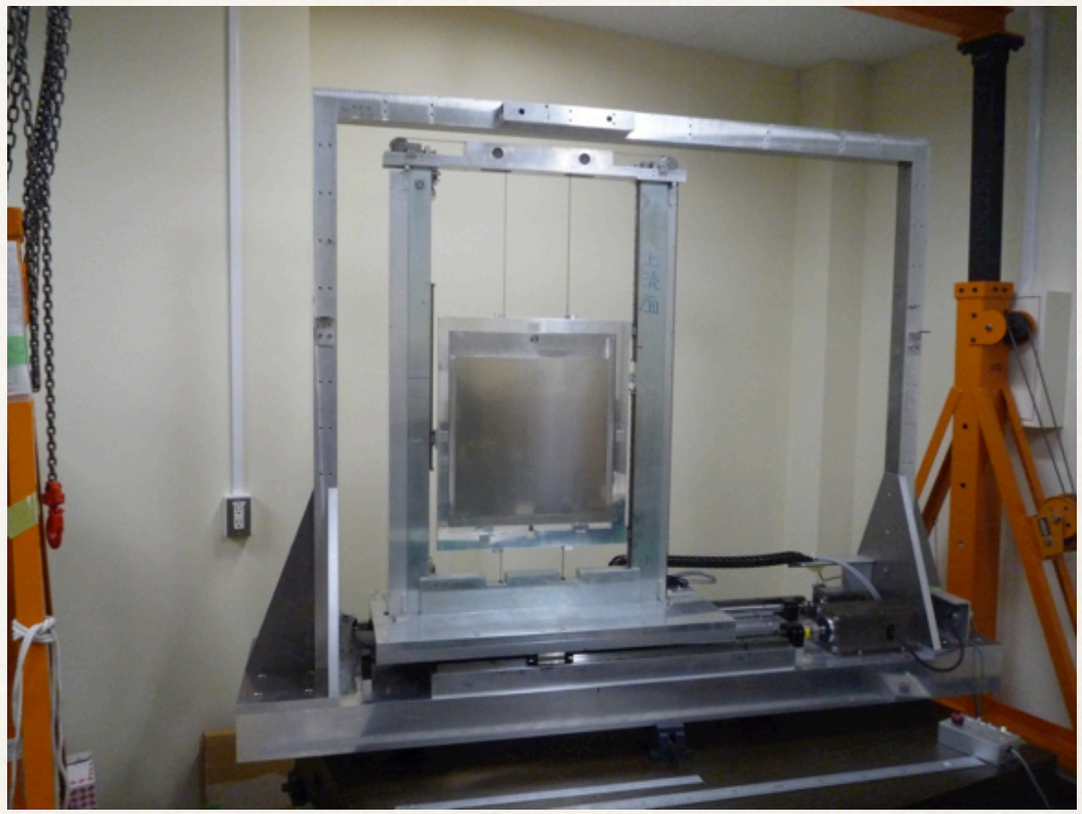


# Emulsion

- size (1stack): 350mm[H] x  345mm[W] x 12mm[T] (13 plates)
- density : ~3.4g/cm$^3$
- 118 stacks
- acceptable particle density : 10$^6$/cm$^2$
- elements : C, N, O, H, Ag, Br, ..
- Emulsion stack is packed in cassette.
- refreshed before beam exposure

## Emulsion plate (developed)

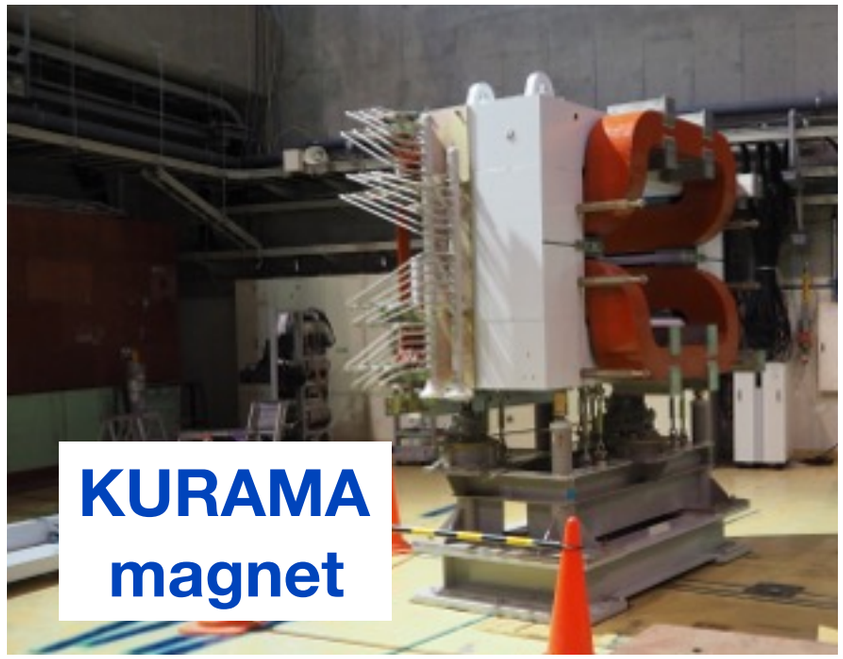
## Emulsion Mover



- Emulsion cassette is moved synchronizing with beam spill.
- Emulsion cassette position is recorded with a few μm resolution.

# Setup

K1.8 beam line
@ J-PARC Hadron Experimental Facility

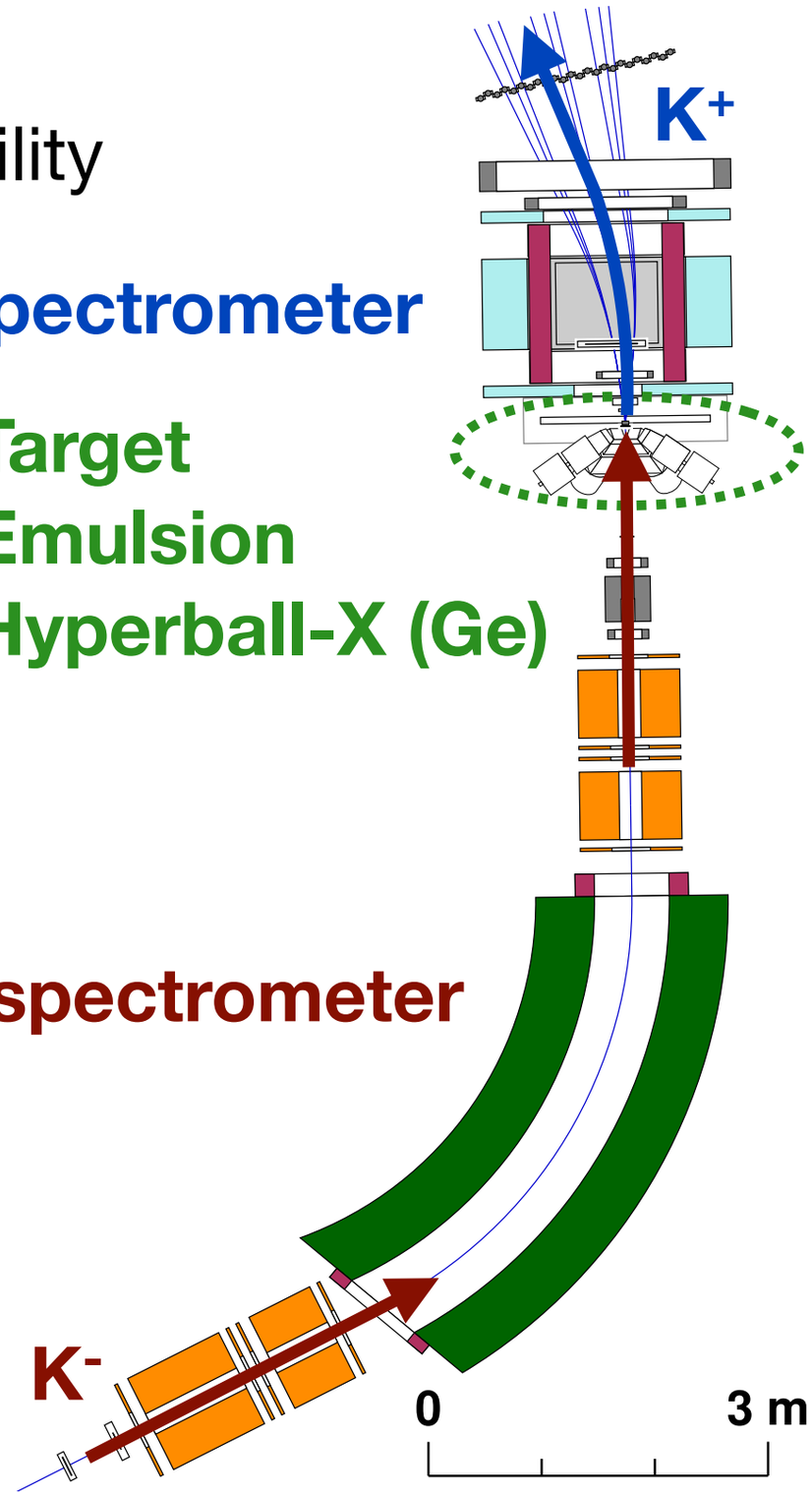



**KURAMA spectrometer**

**Target**
**Emulsion**
**Hyperball-X (Ge)**

**Beam line spectrometer**

**1.8 GeV/c $K^-$**

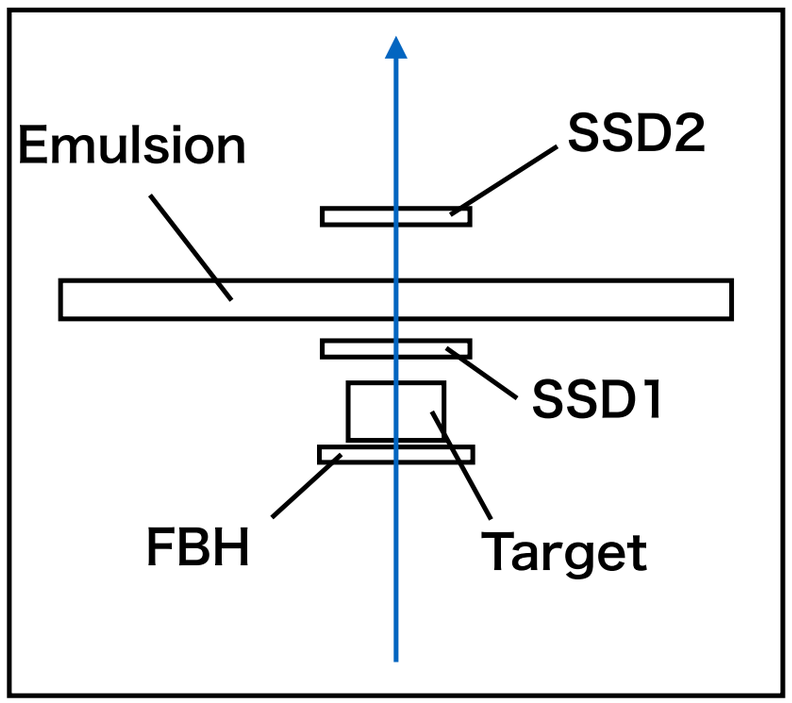


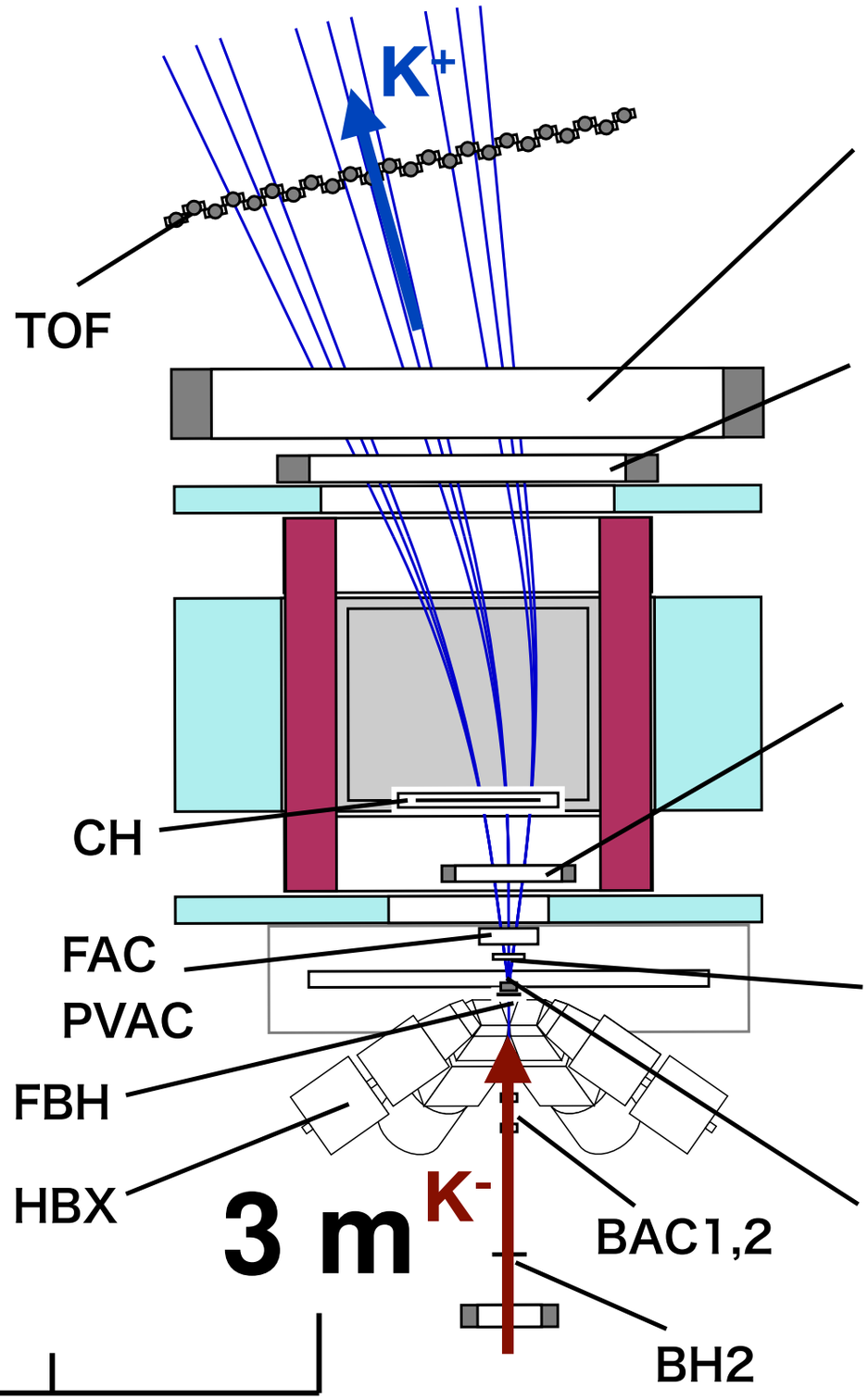
# KURAMA spectrometer

**magnetic field : 0.72T**

**acceptance : 280msr**

Target region




**SDC3**
wire pitch : 20mm
XX'YY' (honeycomb)

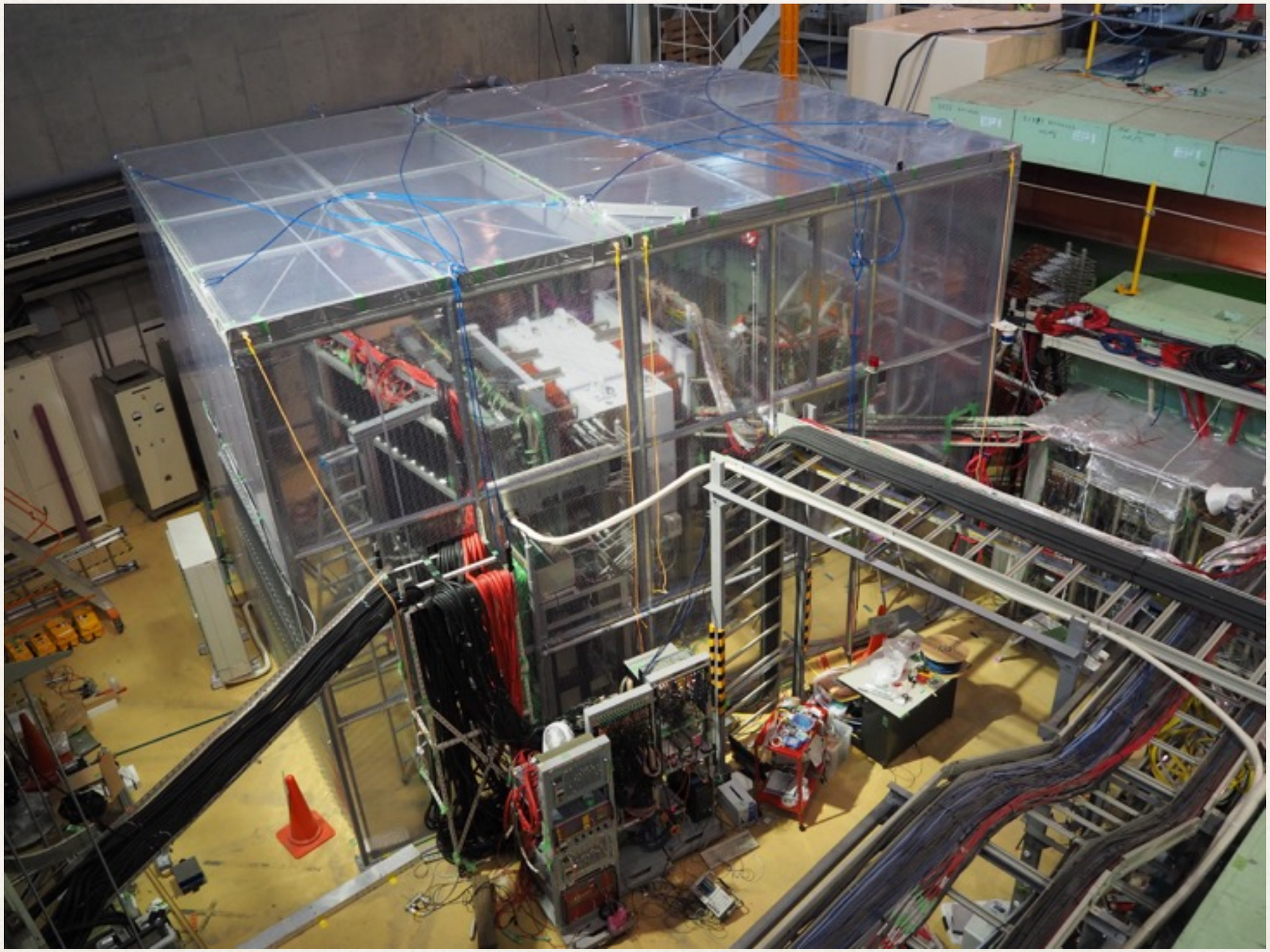
**SDC2**
wire pitch : 9mm
YY'XX' (honeycomb)

**SDC1**
wire pitch : 6mm
UU'XX'VV' (honeycomb)
15° tilt

**SSD2**
sensor pitch : 50$\mu$m
XYX'Y'

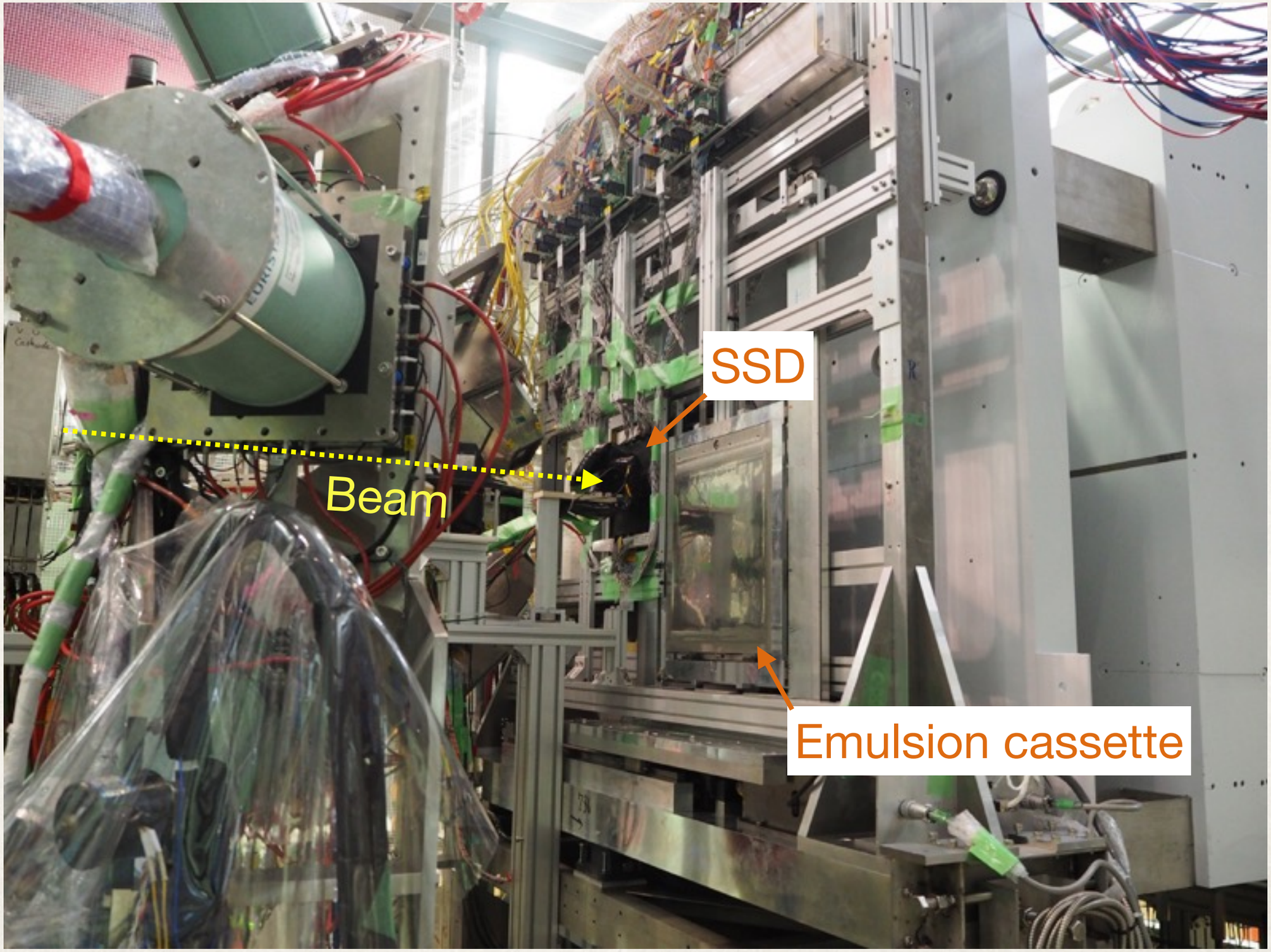
**SSD1**
sensor pitch : 50$\mu$m
YXY'X'

# KURAMA spectrometer



KURAMA spectrometer construction has been done in May 2016.
All detectors are contained in a tent to keep temperature.

# KURAMA spectrometer



# E07 2016 Run

- We carried out commissioning of KURAMA spectrometer and a part of emulsion exposure in Jun. 2016.


Run end photo @K1.8 counting room

**KURAMA Commissioning**

**5.0 days**

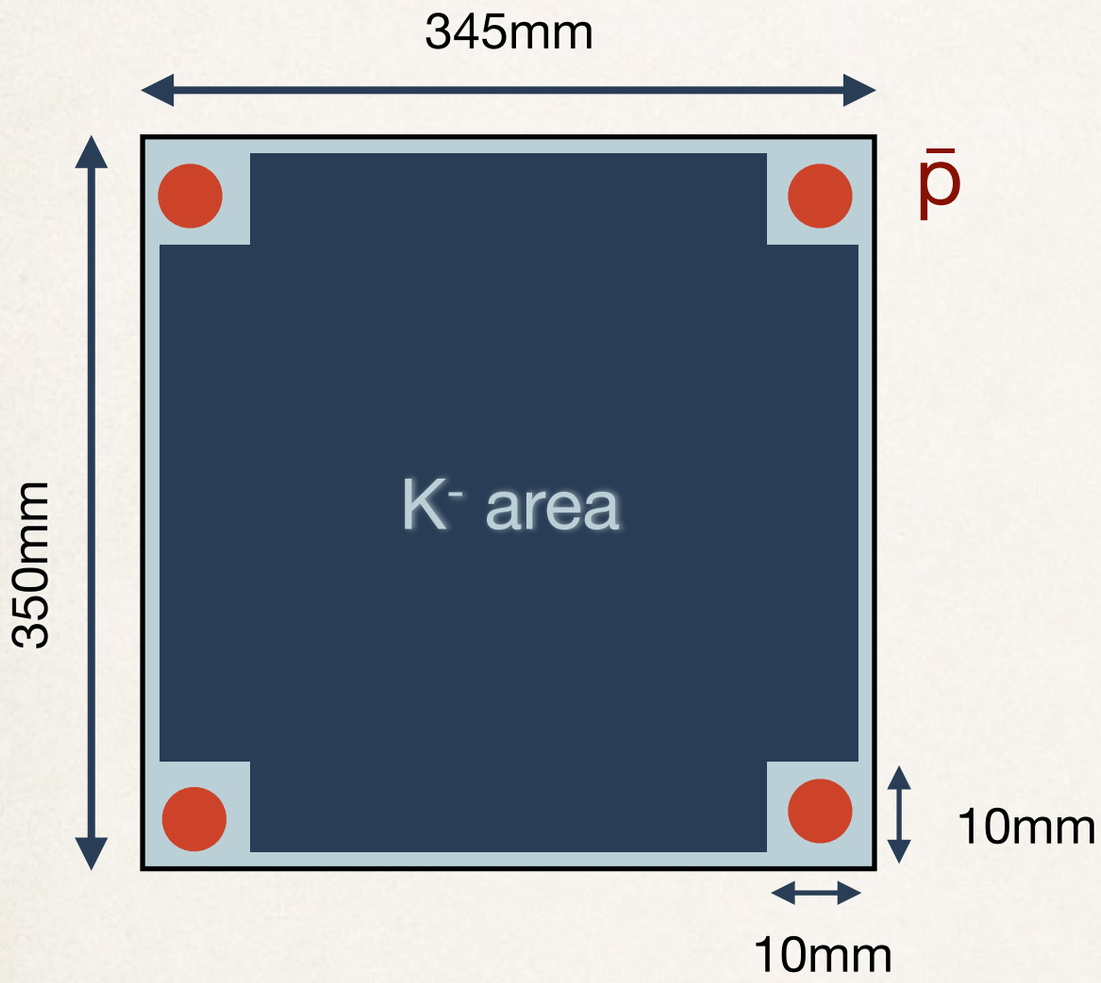
- detector check
- Beam through run
- $CH_2$ target run

**Emulsion exposure**

**4.9 days**

- 18 stacks of emulsion (15%)
- 1.5 times larger statistics than KEK E373

# Emulsion exposure



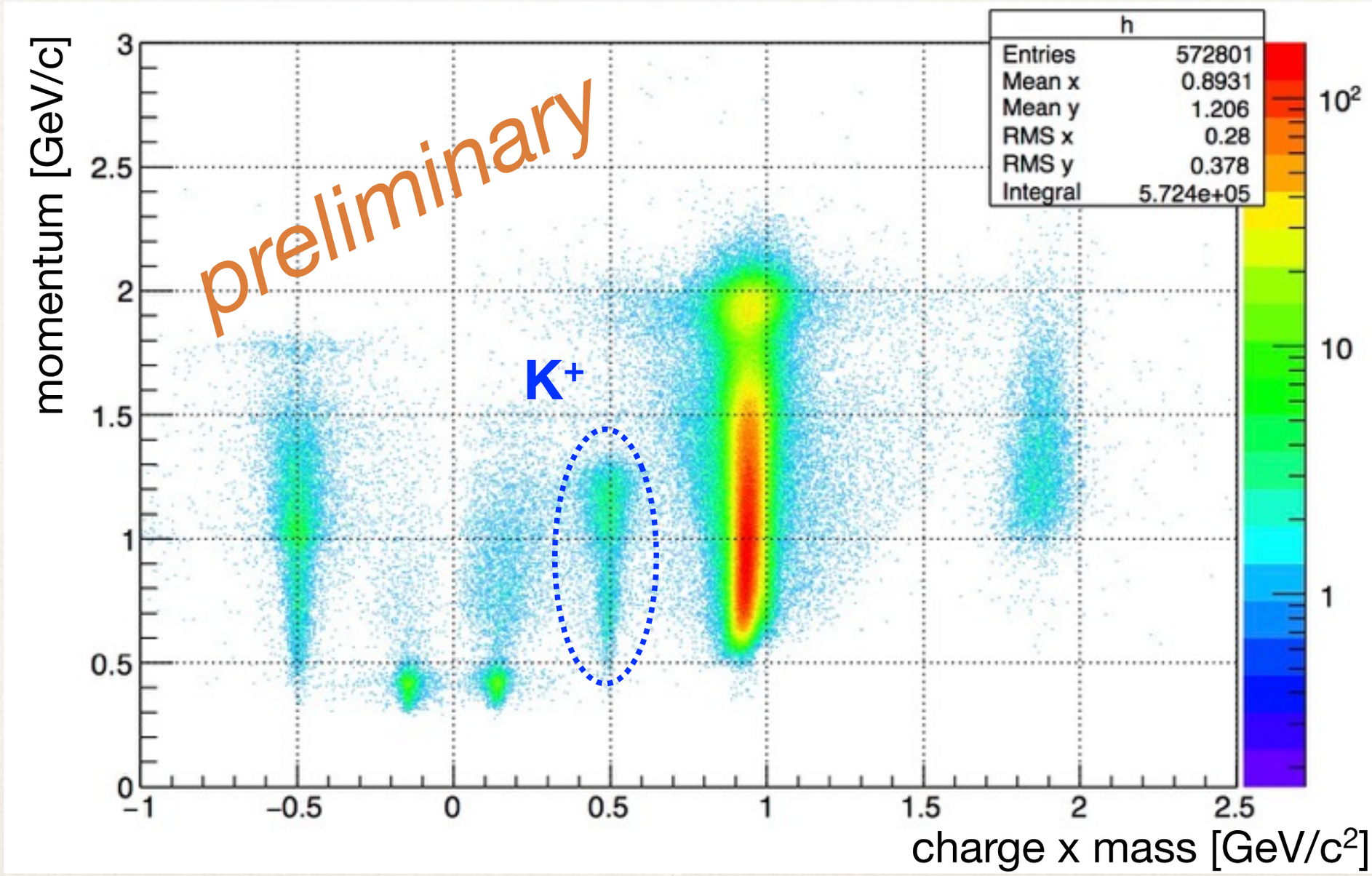

- time : ~7h / stack
  - exchange cassette
  - p̄,K⁻ beam exposure
- Beam condition
  - K⁻ intensity : 260k/spill
  - K⁻ purity : 82%
- Trigger rate
  - 1380/spill (5.5s cycle)
  - DAQ Eff : 83%

- p̄ beam was irradiated at 4 corners for SSD-Emulsion alignment (pattern matching).
- K⁻ beam was irradiated all effective area except corners.
  - density : ~$10^6/cm^2$

# KURAMA spectrometer analysis

- Momentum of scattered particles are analyzed by Runge-Kutta method.
- $K^+$ are clearly identified.

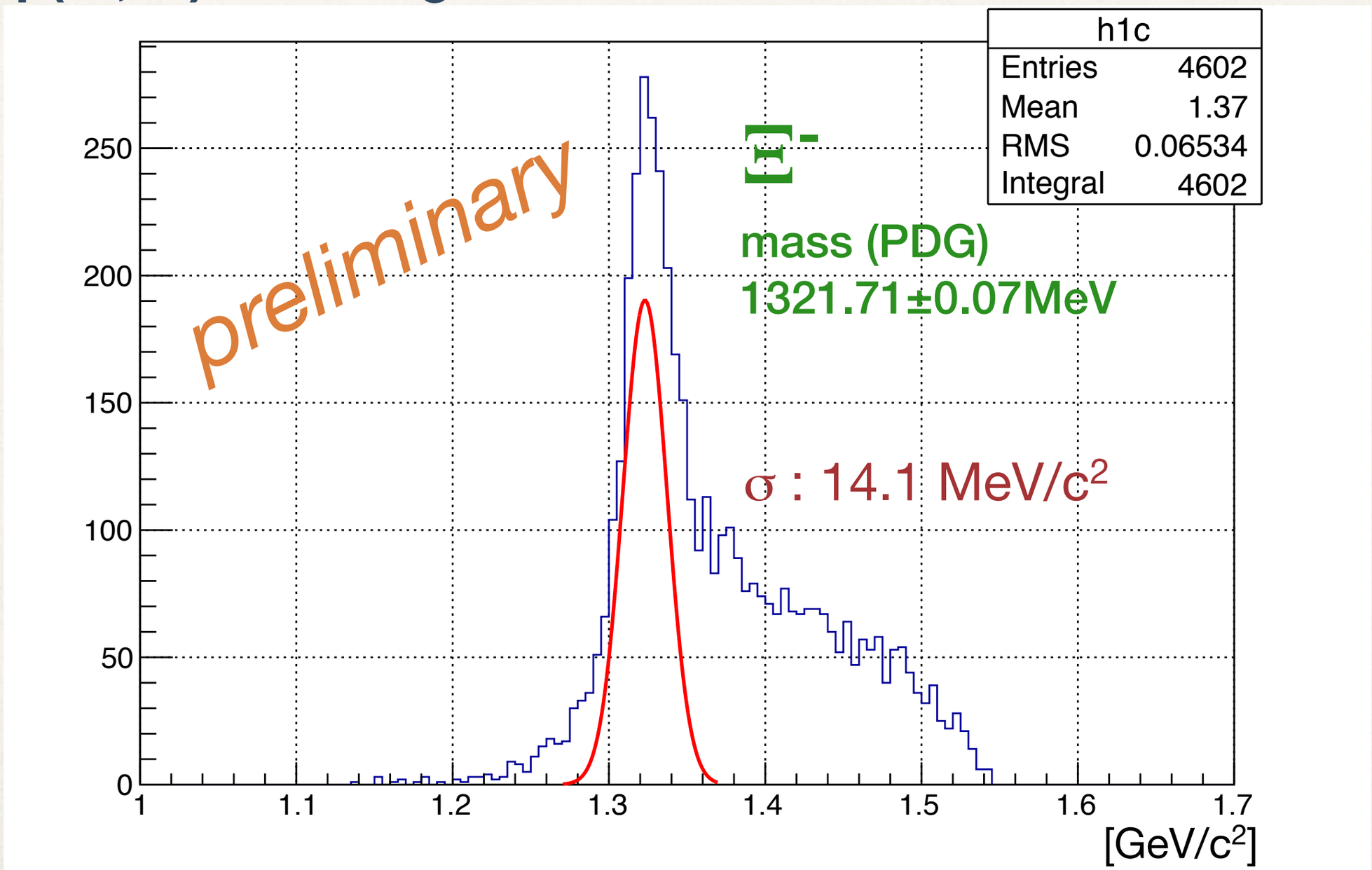
**correlation between mass and momentum (scattered particles)**



# Missing Mass spectrum ($CH_2$ target)

- $p(K^-,K^+)\Xi^-$ peak is observed on quasi-free component.

**$p(K^-,K^+)X$ Missing Mass**



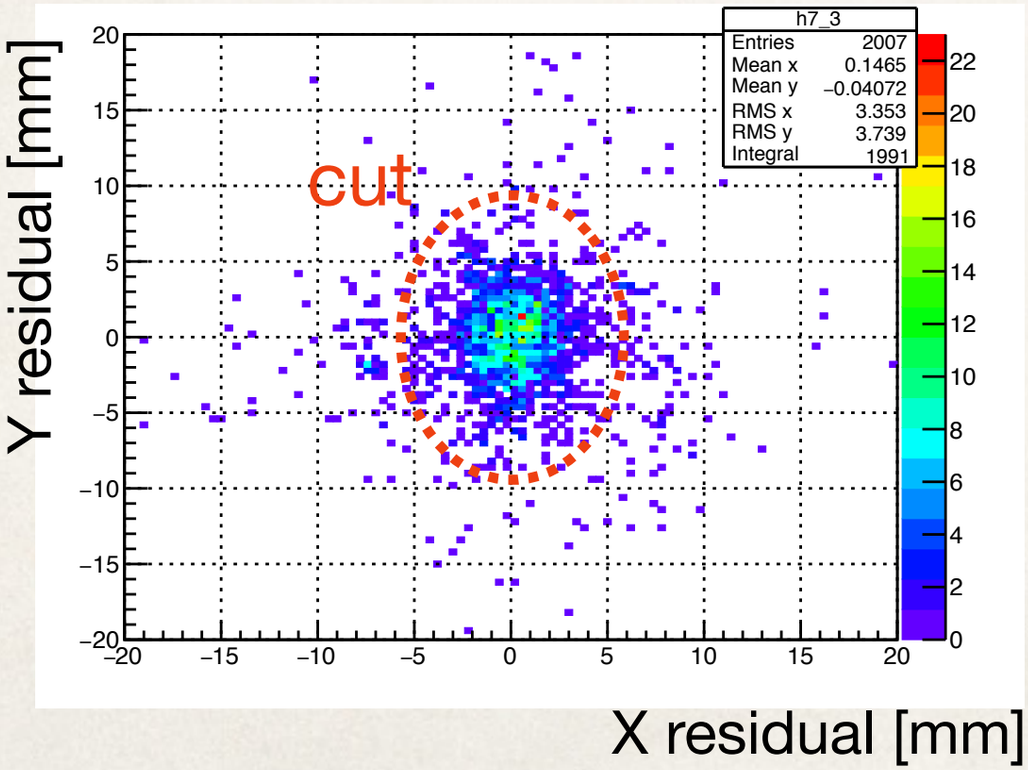
# $\Xi^-$ detection

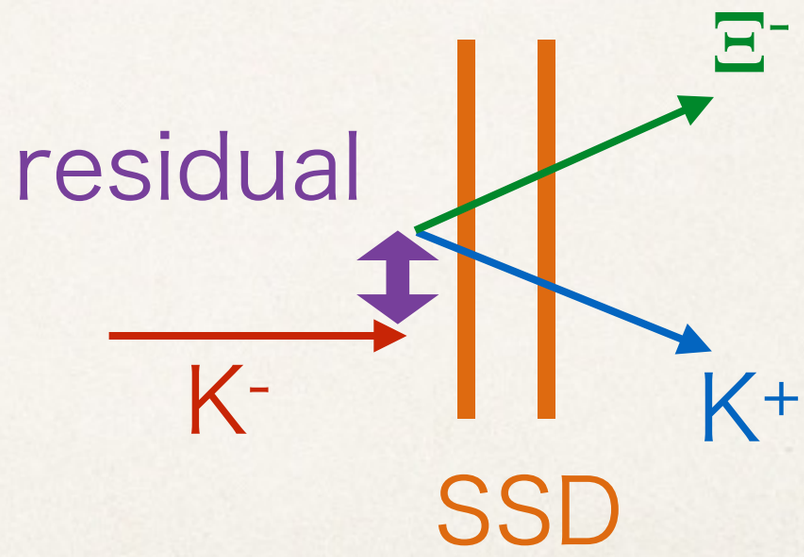
- $\Xi^-$ detection in SSD is important for hybrid emulsion method.
  - dE・position・angle information

**Analysis scheme**

1. tag ($K^-$,$K^+$) events by spectrometers
2. make tracks from high dE hit combinations
3. check vertex points
4. check angle residual from missing momentum

**vertex residual distribution**

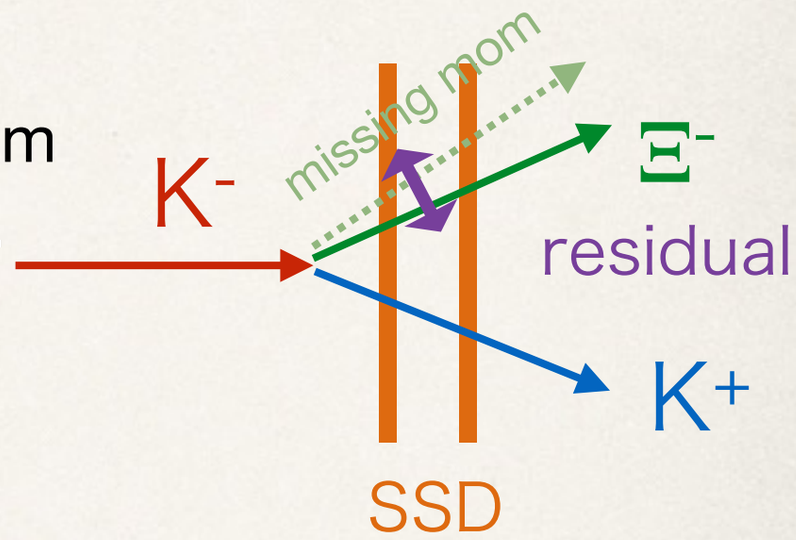


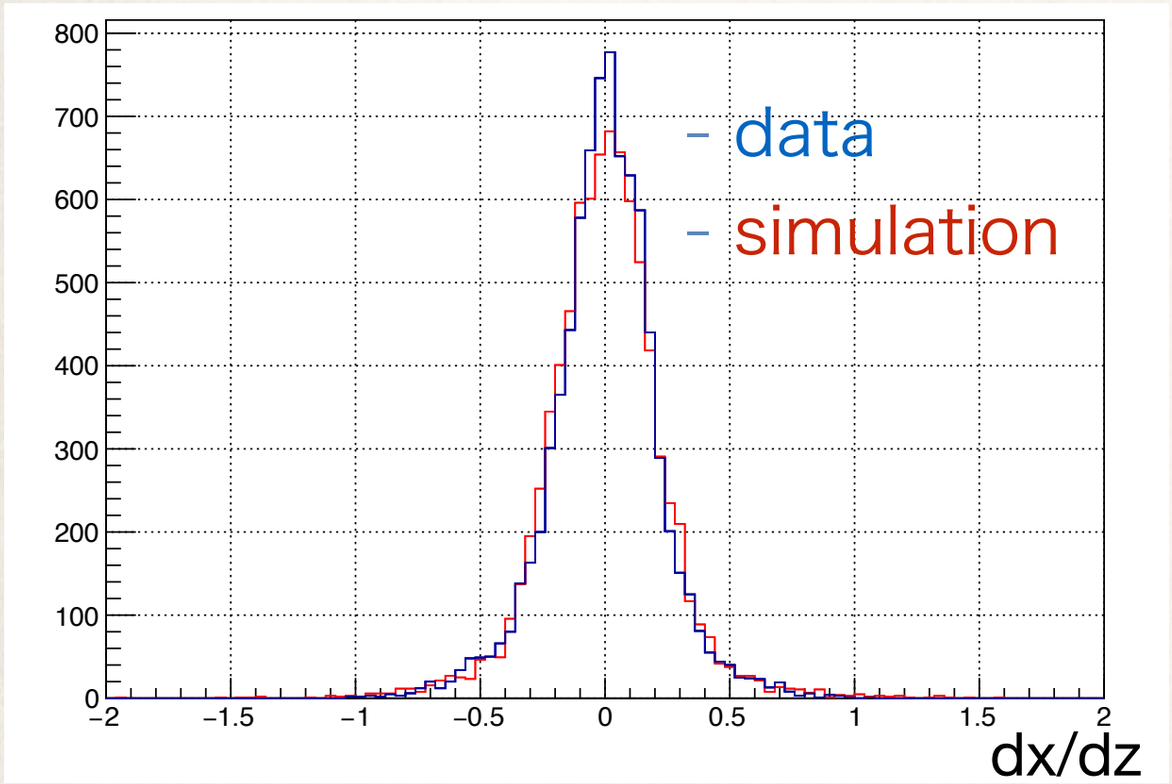

($K^-$,$K^+$,$\Xi^-$) have same vertex point

# $\Xi^-$ angle residual

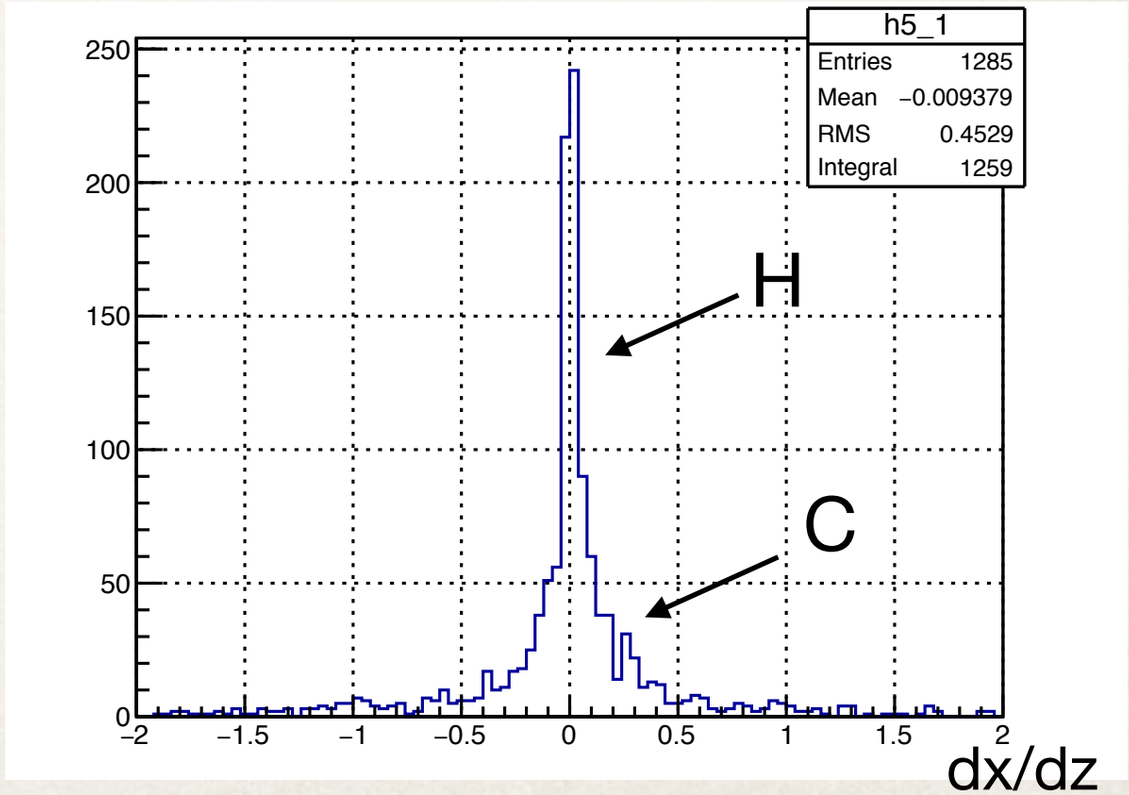
- check $\Xi^-$ angle residual from that of missing momentum
- Angle distribution can be understood by fermi motion.
- Sharp peak (H target) is observed in $CH_2$ target data.
- $\Xi^-$ is kinematically identified in SSD.




## $\Xi^-$ dx/dz residual

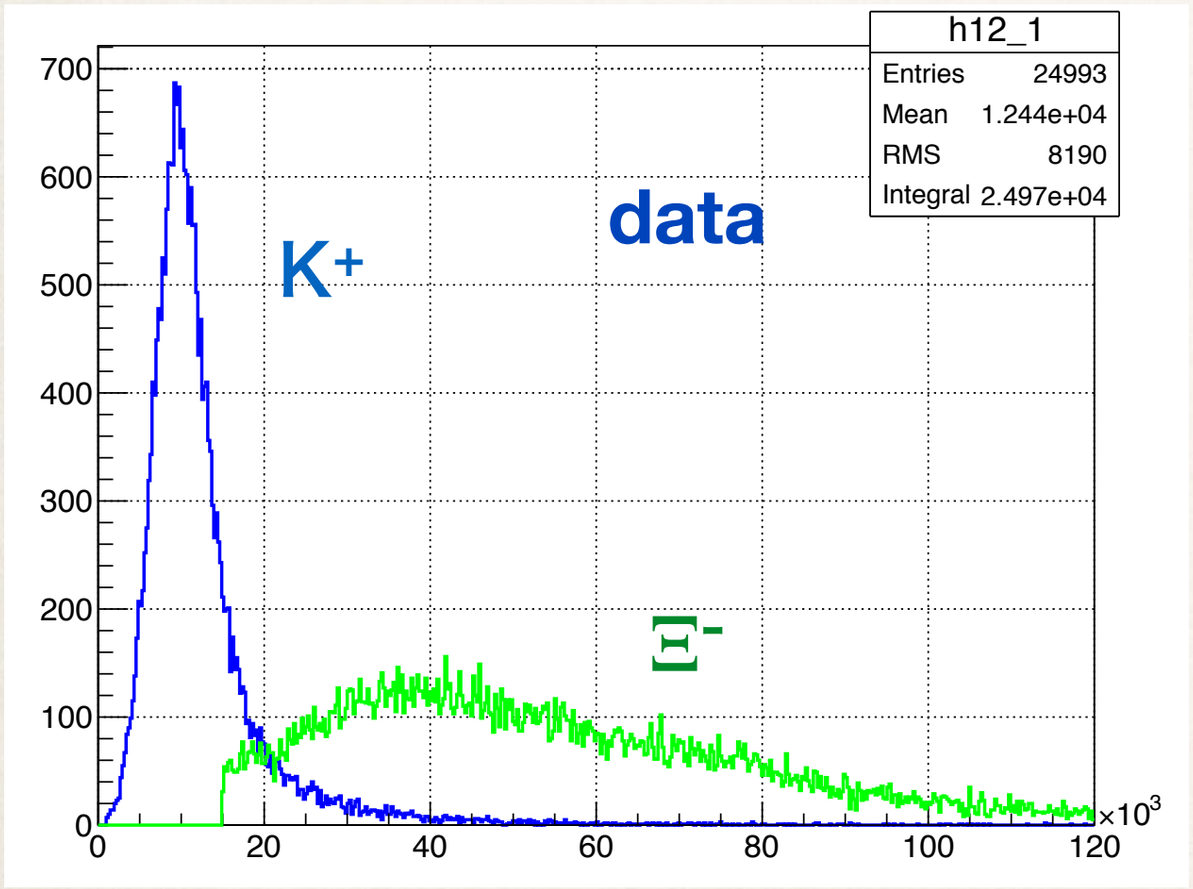


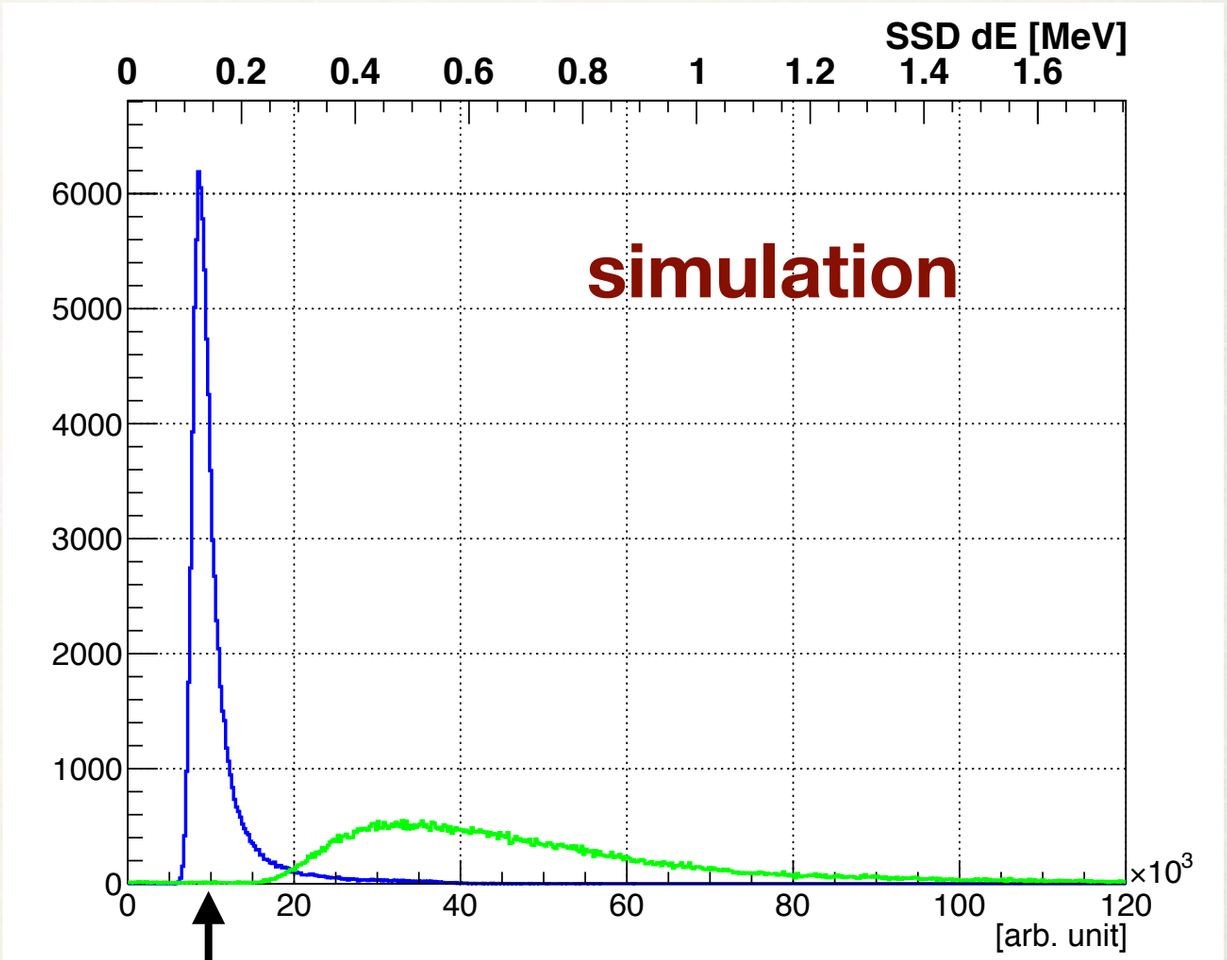

## $\Xi^-$ dx/dz residual ($CH_2$ target)



# Ξ⁻ dE

- check dE distribution of Ξ⁻ and K⁺ in SSD after Ξ⁻ identification
- Data distribution is consistent to simulation.
- Data is broader than simulation because of energy resolution and noise effect.

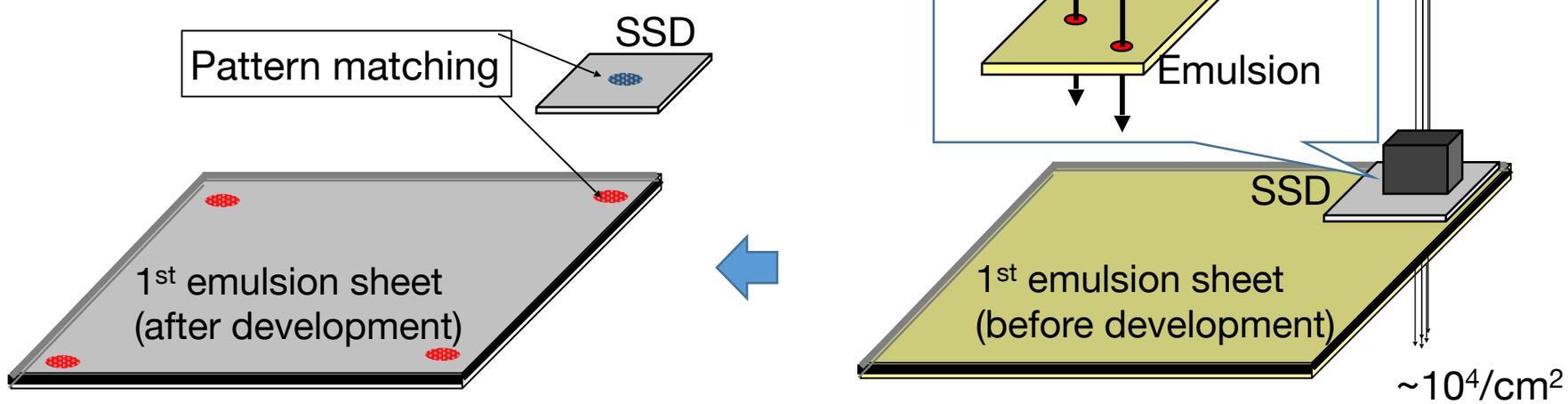


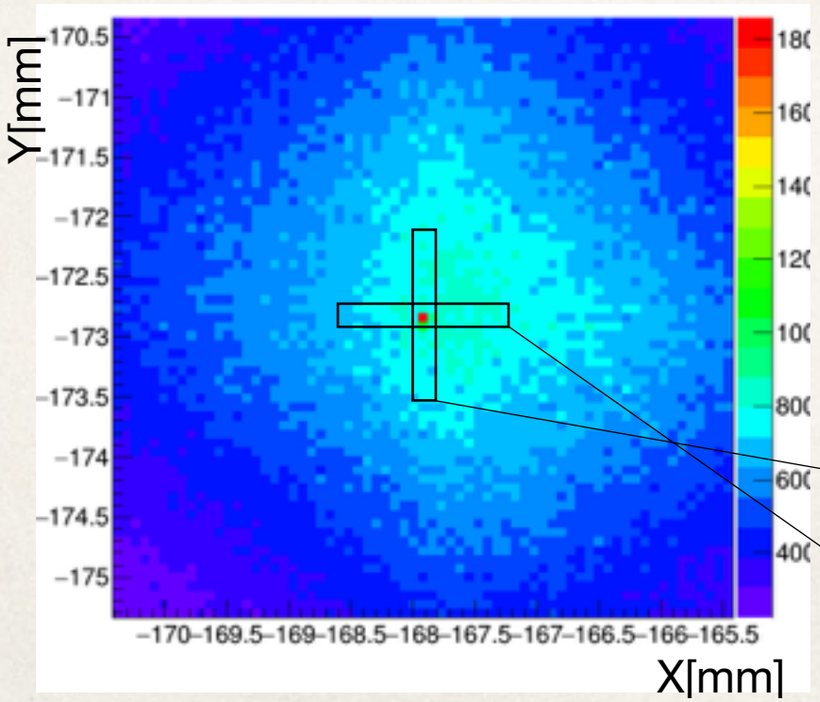

value is scaled to data by K⁺ peak

# SSD-Emulsion connection

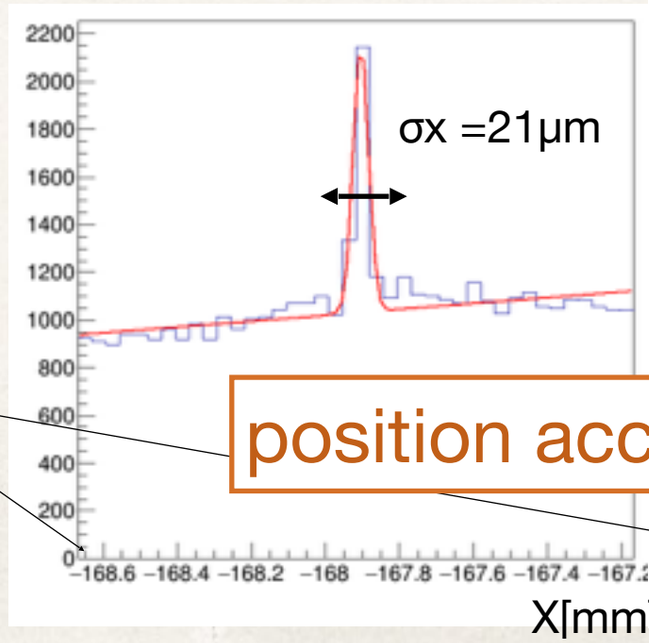
Detector alignment : SSD – Emulsion
With pattern matching of p̄ beam tracks



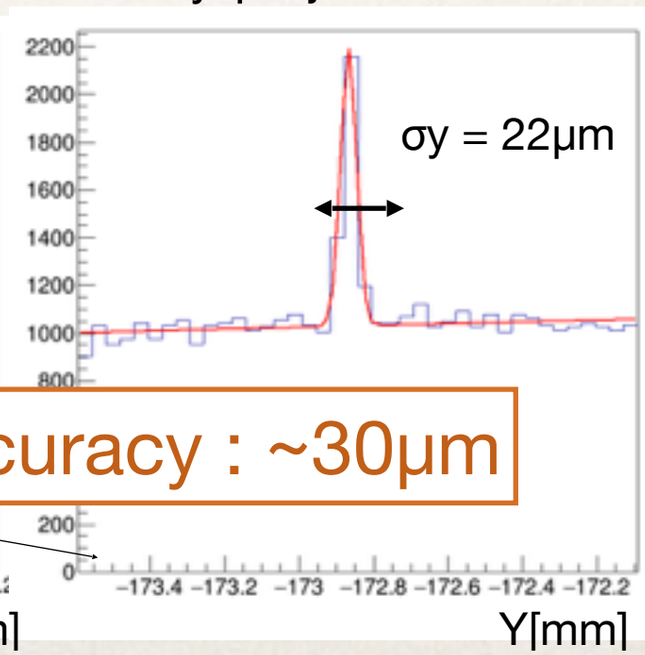

Pattern matching dy : dx




X-projection




y-projection

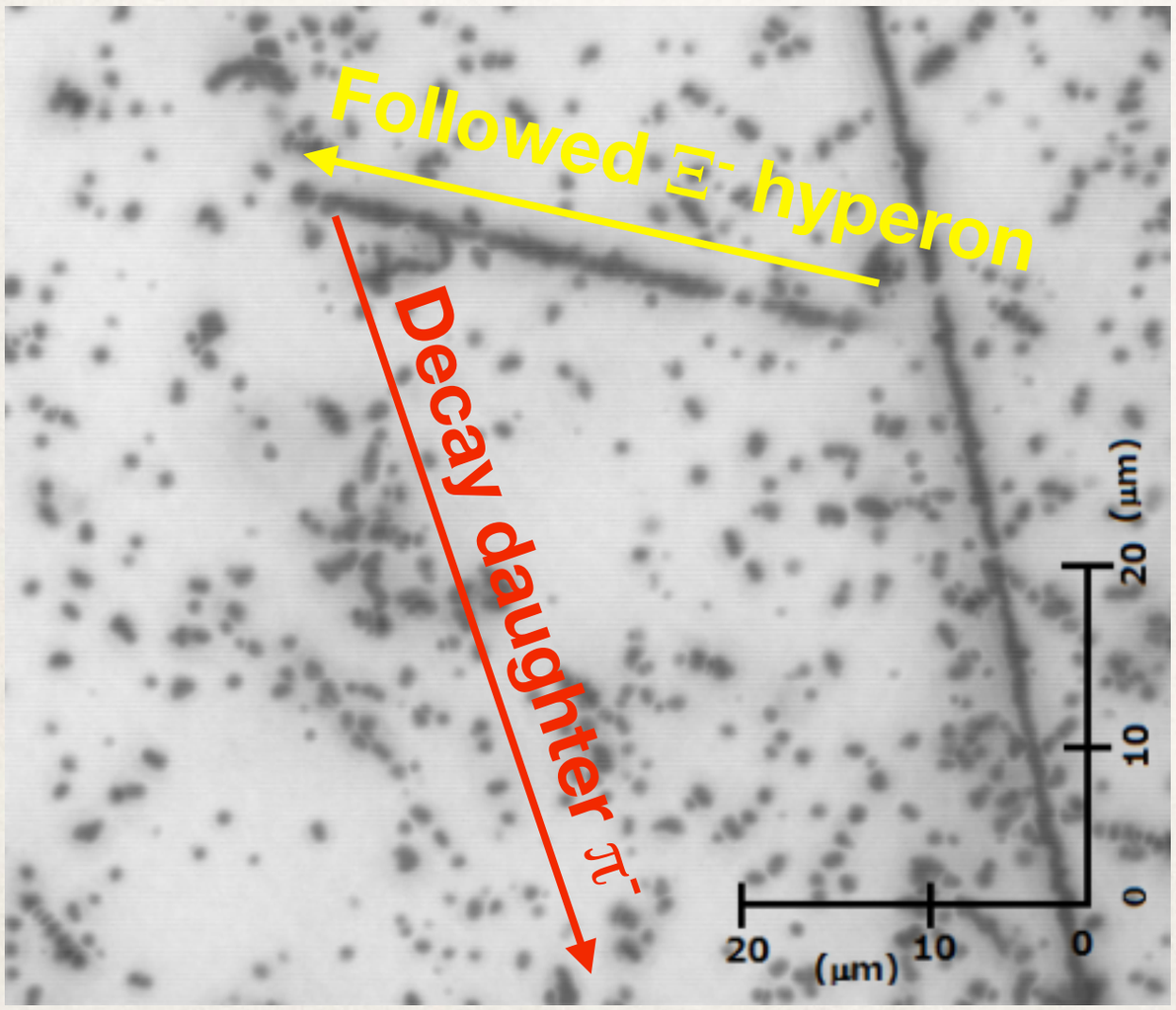



position accuracy : ~30μm

# $\Xi^-$ track in Emulsion

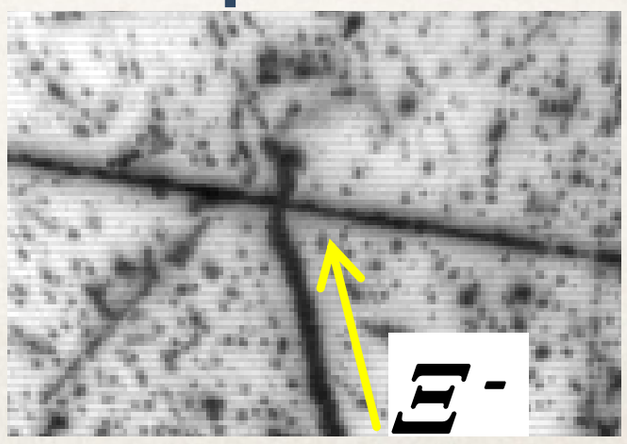
- Emulsion development (18 stacks) has been already done.
- $\Xi^-$ are found in Emulsion from SSD prediction.
- Hybrid emulsion method is working well !

## $\Xi^-$ decay event




- Some $\Xi^-$ tracks are traced and a decay event are found ($\Xi^- \rightarrow \Lambda + \pi^-$).
- Full automatic scanning will start soon.

## $\Xi^-$ stop event



# E07 2017 Run

- E07 2nd run is planned in Apr. - May 2017.
  - 100 stacks of emulsion
  - improve data quality
    - SSD noise reduction → DAQ Eff. will be improved
    - target position optimization → $\Xi^-$ stop ratio will be improved

## Yield estimation (preliminary)

| Run | Emulsion | $K^+$ | $\Xi^-$ | $\Xi^-$ stop (calc from simulation) |
|---|---|---|---|---|
| 2016 | 18 | $1.1 \times 10^5$ | $2.6 \times 10^4$ | 1600 |
| 2017 expected | 100 | $6.6 \times 10^5$ | $1.8 \times 10^5$ | 12000 |

We can achieve $>10^4$ $\Xi^-$ stop events with full statistics !

# Summary

- J-PARC E07 is a double hypernuclei search experiment with a hybrid emulsion method.
- E07 1st run was carried out in Jun. 2016 and 18 stacks of emulsion has been exposed (15% of all emulsion).
- $\Xi^-$ are identified in SSD and some of them are traced in emulsion.
- Remaining emulsion (100 stacks) will be exposed in Apr. - May 2017 and we will achieve 10 times larger statistics than KEK E373.