

Experimental study of double hypernuclei at J-PARC

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Inha Univ

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Double hypernuclei

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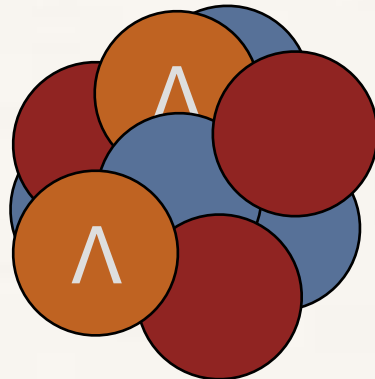
Baryon-Baryon interaction
described by $SU(3)_f$ symmetry

$S = 0, -1$

- nucleon scattering
- hypernuclei experiment

$S = -2$

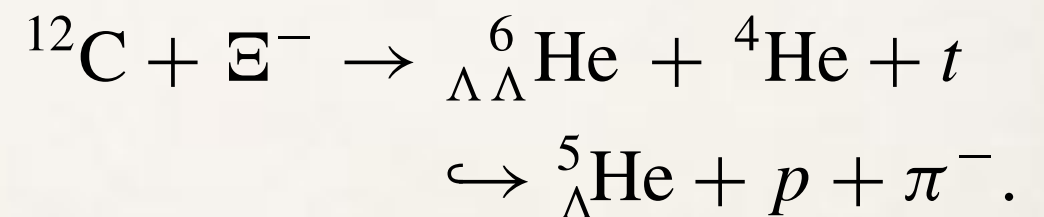
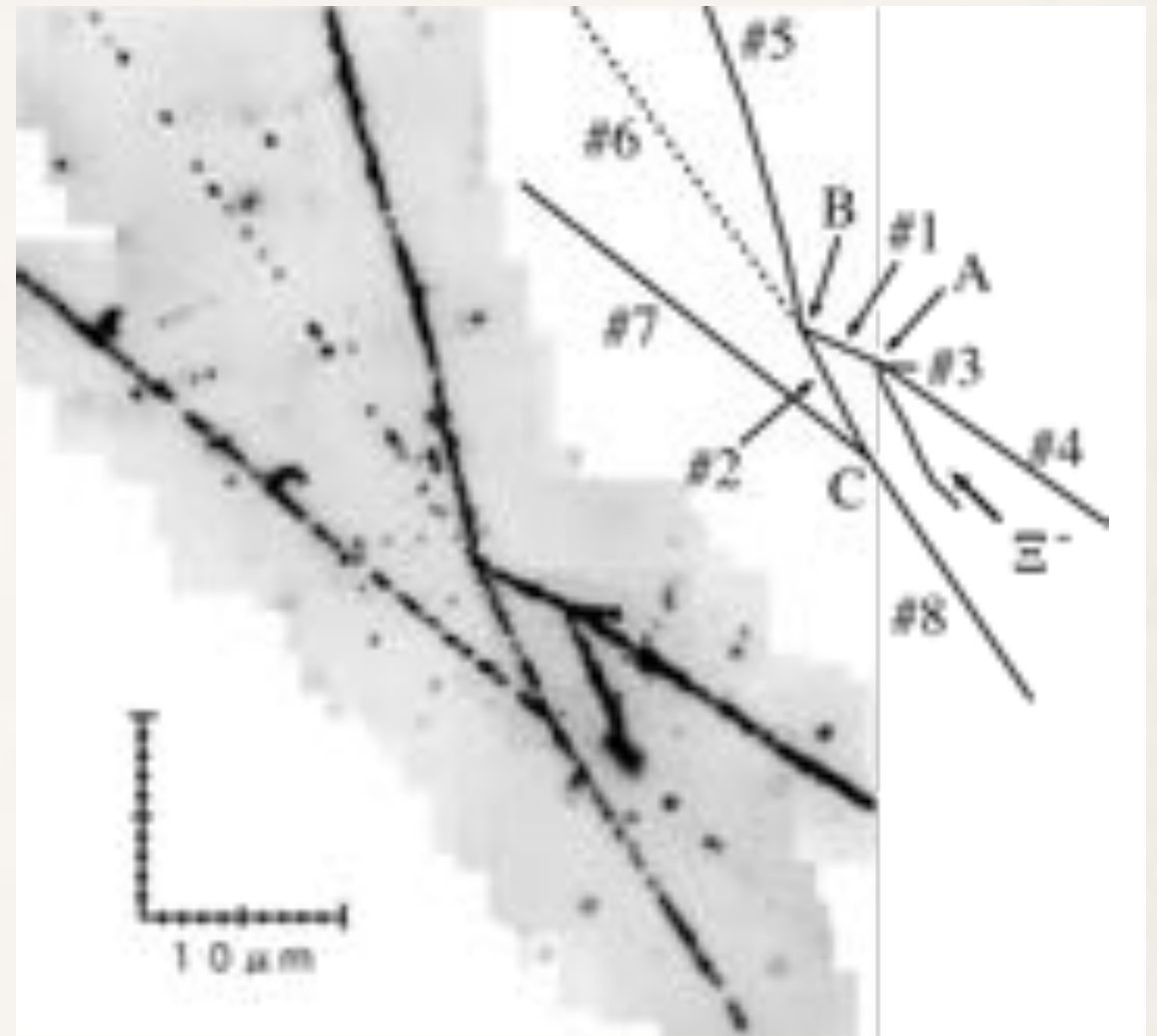
- valid data is limited
- hyperon scattering experiment is difficult
 - $\tau : \sim 10^{-10} \text{s}$



Double hypernuclei are important probes to study $S=-2$ physics

- two Λ s are in a nucleus
- $\Lambda\Lambda$ interaction can be extracted
- Emulsion experiment is effective
 - detect sequential weak decays
 - $<1 \mu\text{m}$ position resolution

NAGARA event (KEK E373)



$$B_{\Lambda\Lambda} = 6.91 \pm 0.16 \text{ MeV}$$

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

weakly attractive

J-PARC E07 Experiment

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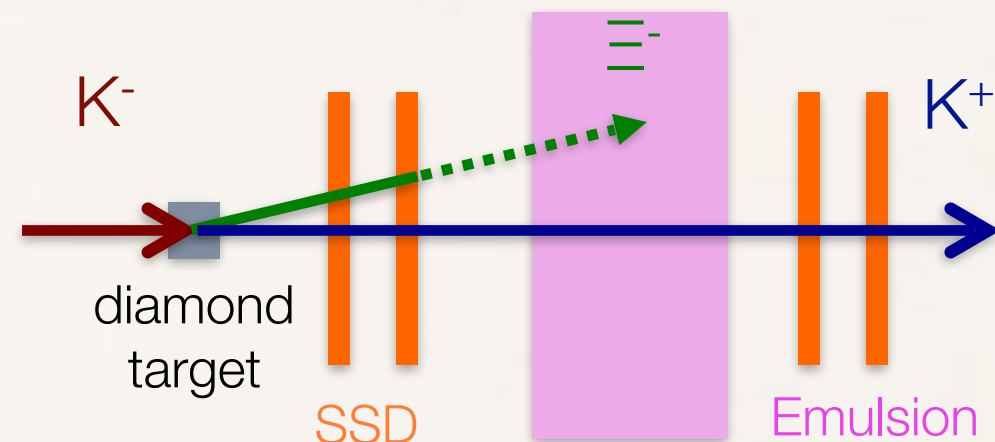
- **Double hypernuclei search experiment**
 - hybrid emulsion method

- **10 times larger statistics of E373 (10^4 Ξ^- stop)**
 - Emulsion amount (x2), K^- purity (x4), detector acceptance (x1.4)
 - 100 double hyper nuclei candidates
 - 10 species are expected to be identified
 - study A dependence of $\Delta B_{\Lambda\Lambda}$

- **detect X-ray from Ξ^- atom with Ge detector array**
 - background suppression by Ξ^- stop tagging in emulsion
 - first measurement in the world

hybrid emulsion method

trace Ξ^- track into emulsion

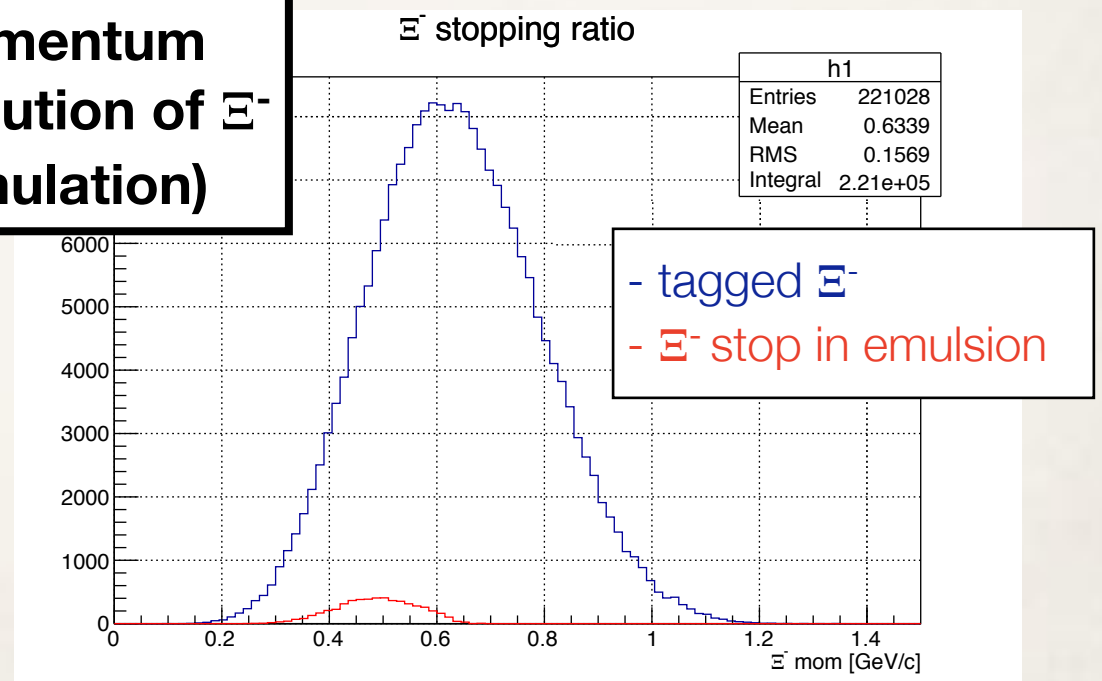


layers : 4 (XYX'Y')

position resolution : $15\mu\text{m}$

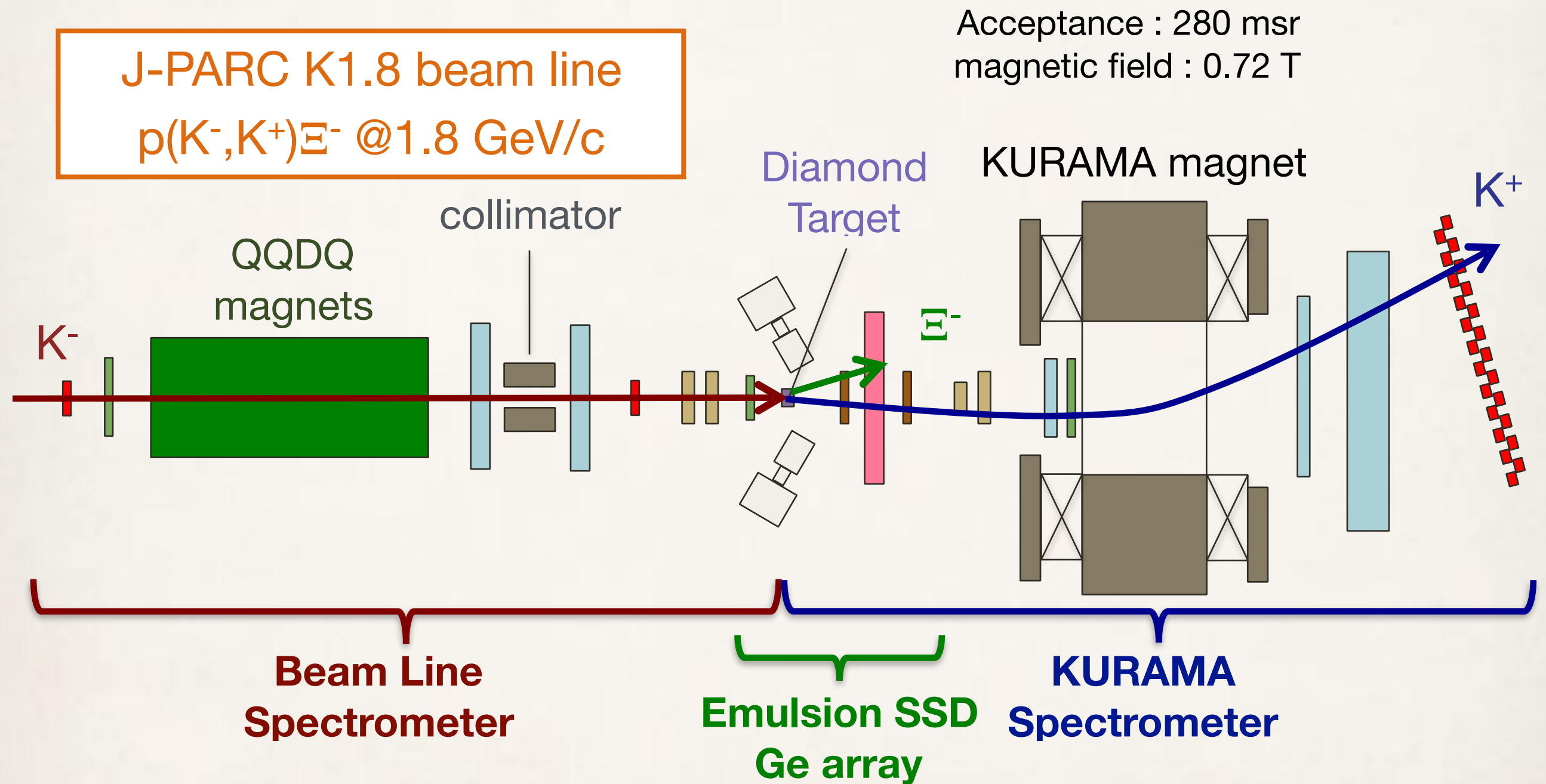
angular resolution : 20mrad

momentum distribution of Ξ^- (simulation)



2% of tagged Ξ^- will stop in emulsion

Setup



KURAMA spectrometer is newly constructed at J-PARC K1.8 beam line.

KURAMA detectors

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all detector were developed

BAC



PVAC



FAC



BH2



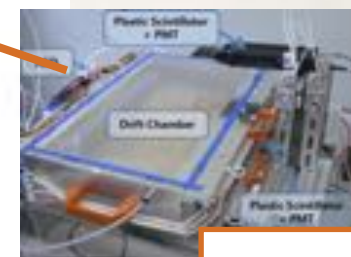
SDC3



SDC2



SDC1



TOF



CH



FBH



SSD



Hyperball-X



Emulsion

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size : 350mm x 345mm

density : 3.4g/cm³

amount : 118 stacks (2.1t emulsion gel)

acceptable track density : 10⁶/mm²

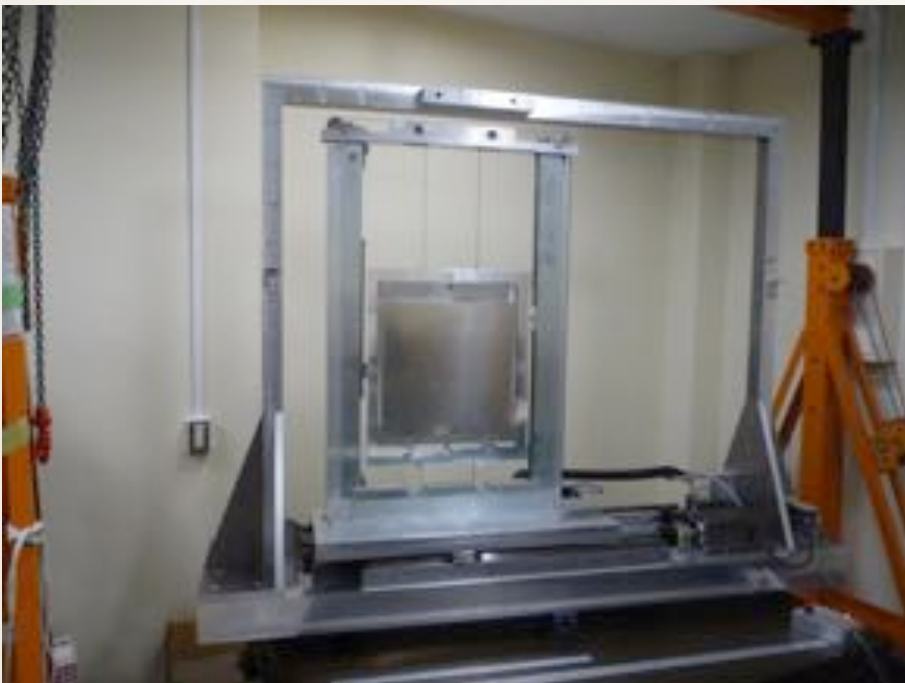
layer : 13

1 thin plate(0.38mm) + 11 thick plates(1mm) + 1 thin plate
components : C, O, N, H, Ag, Br ...

Emulsion thin plate (after development)



Emulsion mover



move emulsion synchronized with spill
record position (resolution : a few μm)

Cassette



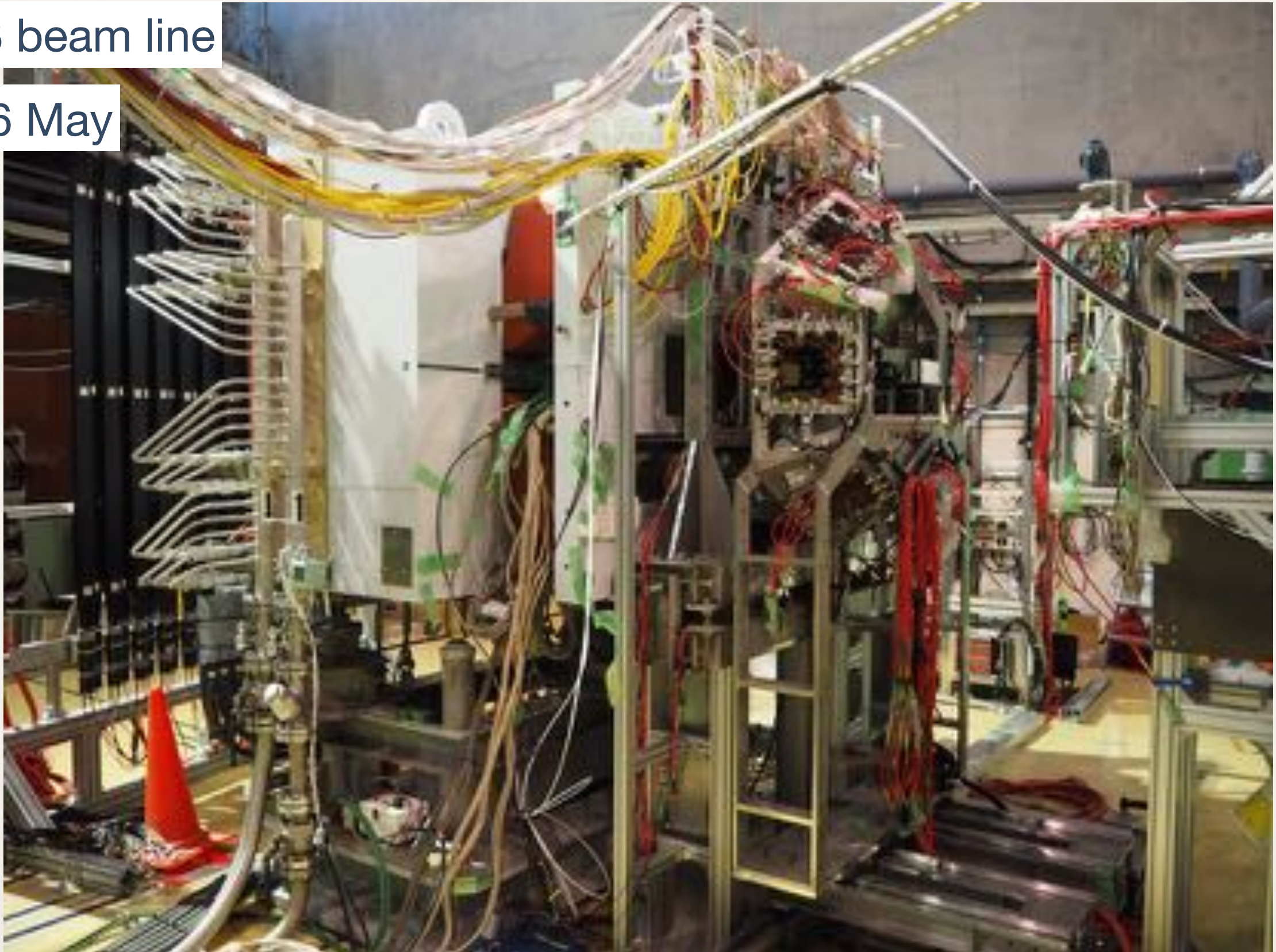
Emulsion stacks are packed in cassette.
Cassette are evacuated to fix emulsion plates.

KURAMA spectrometer

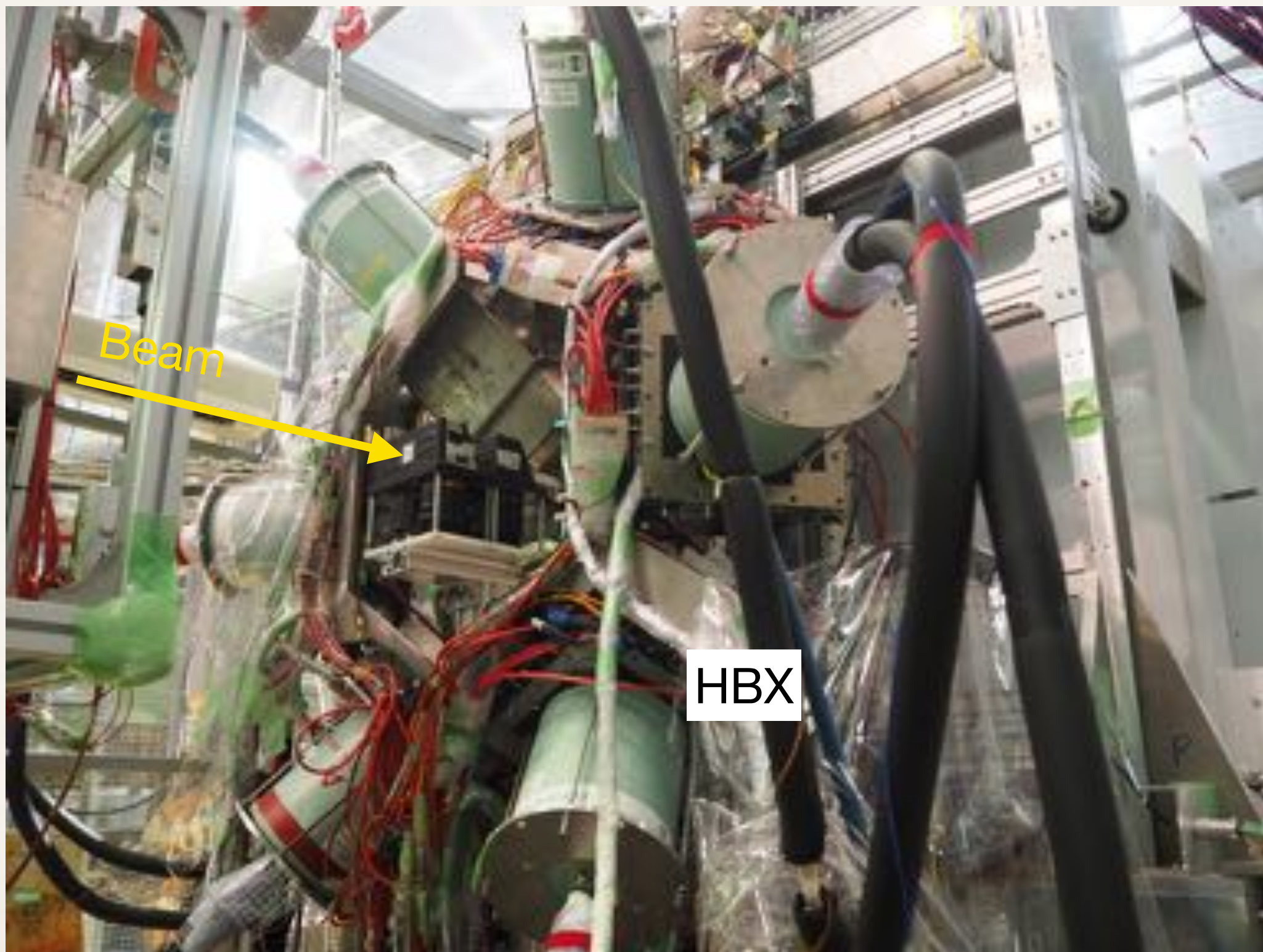
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K1.8 beam line

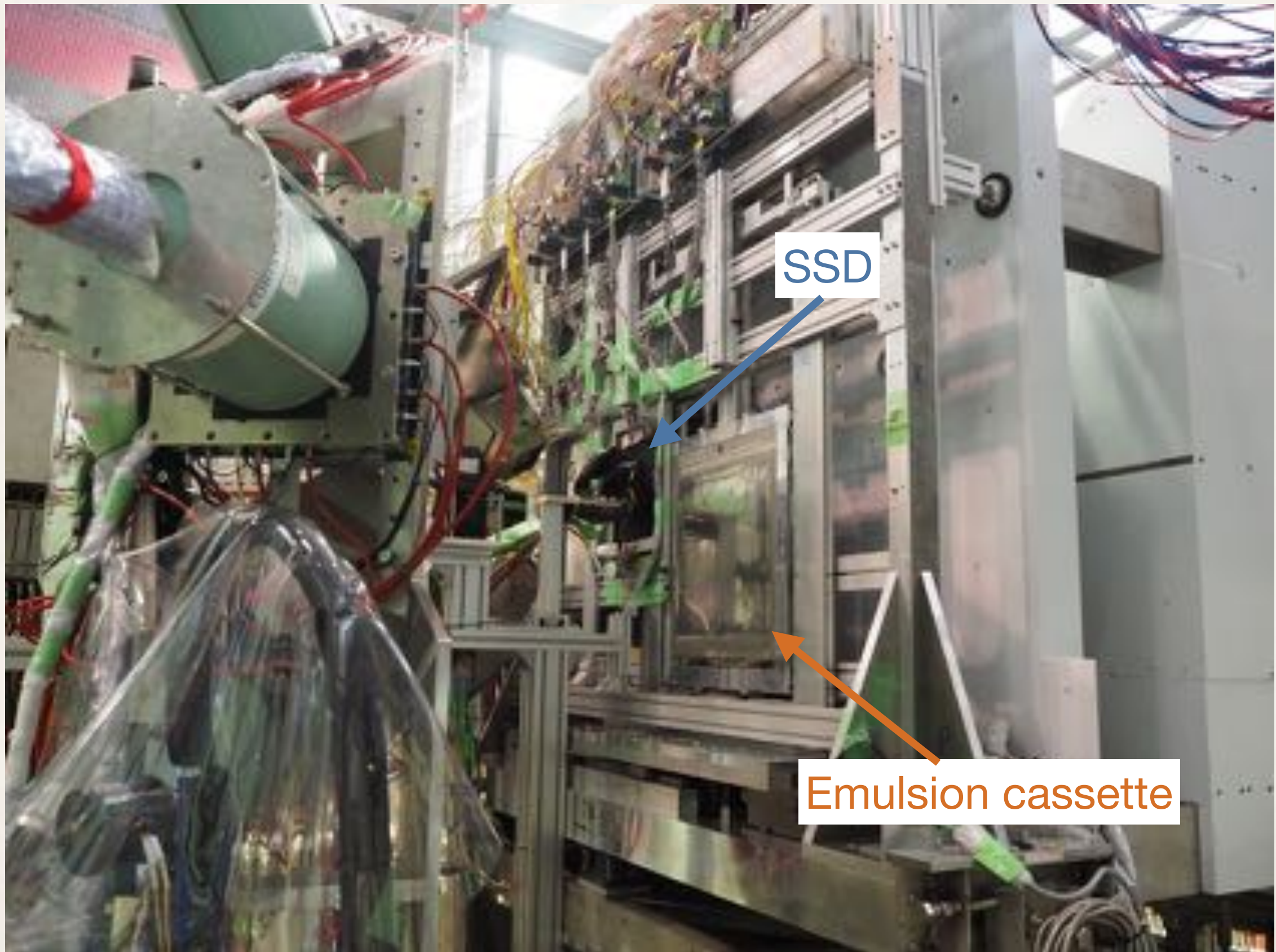
2016 May



Target region

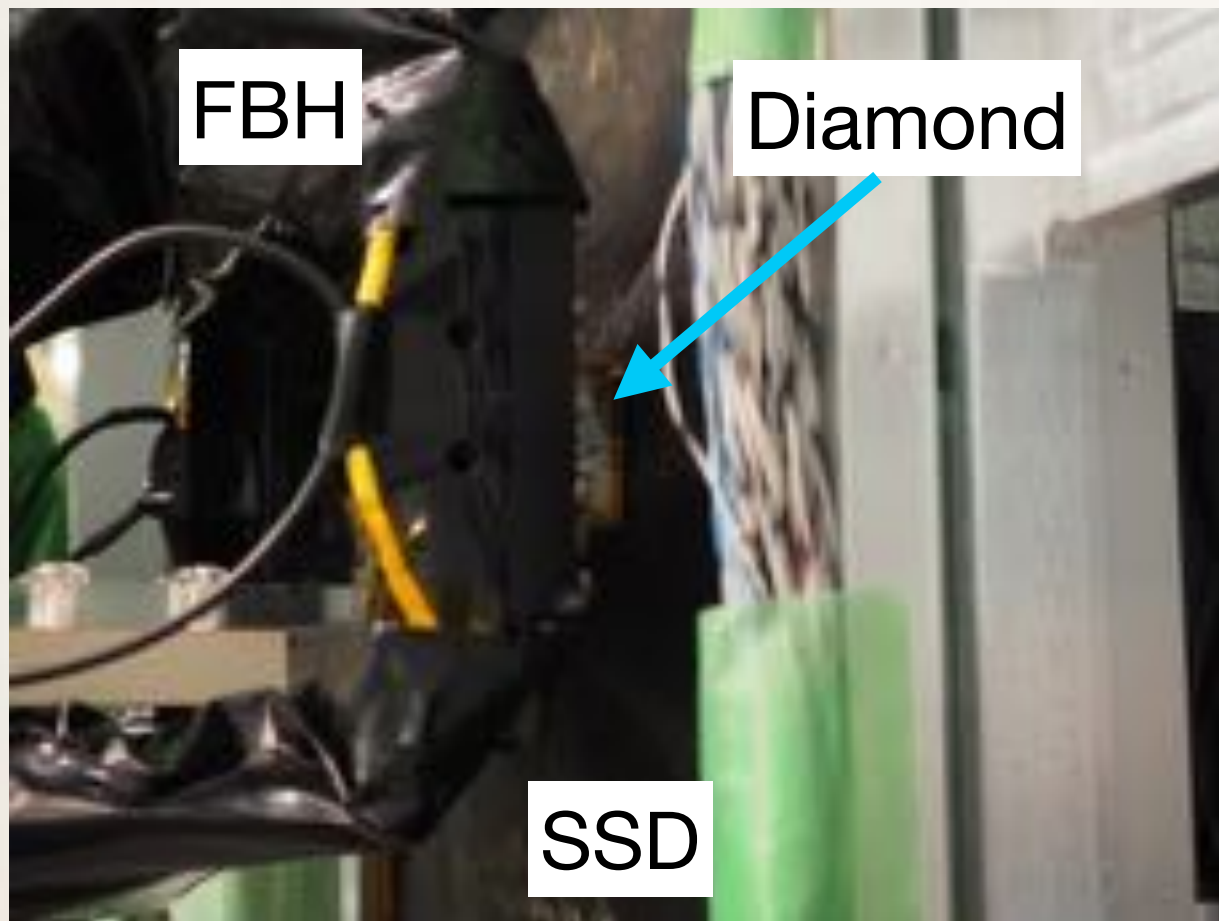


Target region



Diamond target

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Diamond target is attached on the surface of FBH

size : 5 cm(W) x 3 cm(H) x 3 cm(T)
density : 3.24 g/cm³

E07 2016 Run

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KURAMA spectrometer commissioning and emulsion exposure were carried out at Jun. 2016.

18 stacks of emulsion were exposed.



User time : 9.9 days
(request : 12 days)

Commissioning
5.0 days

Emulsion exposure
4.9 days (18stacks)
statistics : E373 x 1.5
(15% of all emulsions)

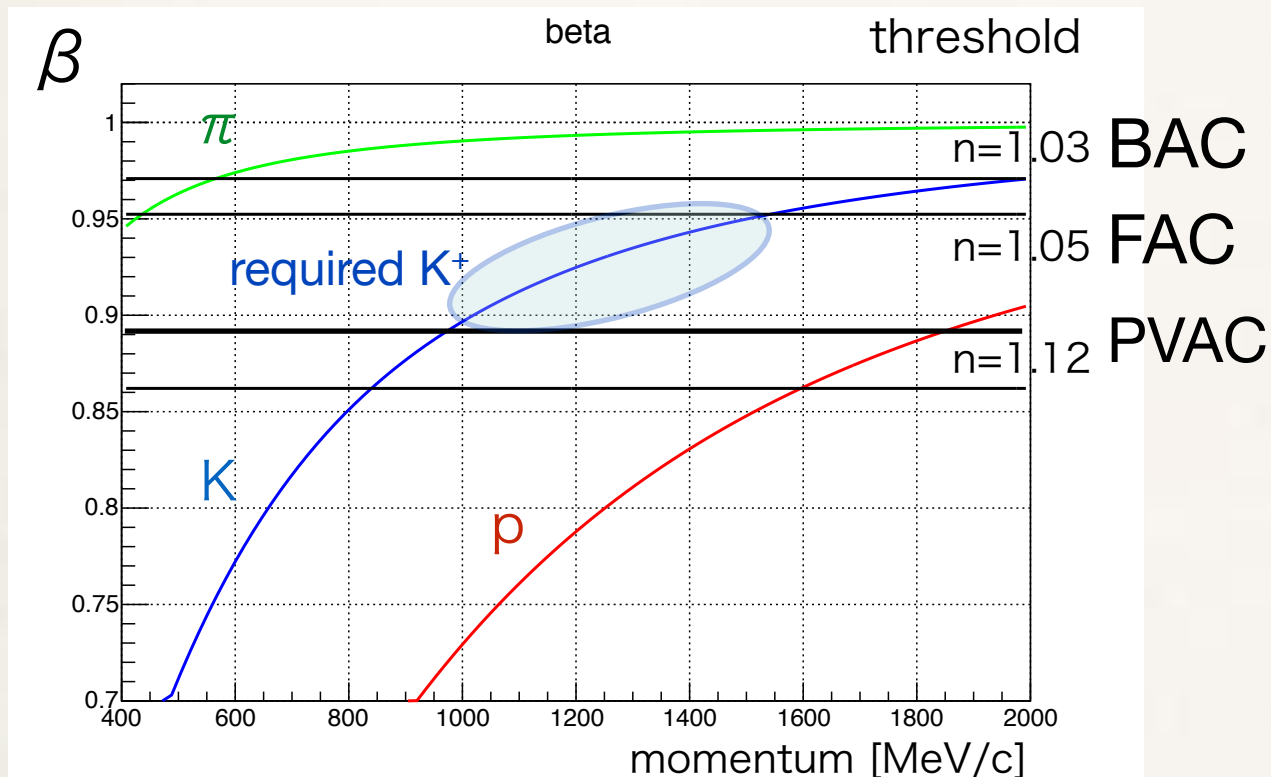
Run-end photo @ K1.8 counting room

Trigger

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(K⁻,K⁺) trig : BH1 x BH2 x $\overline{\text{BAC}}$ x PVAC x $\overline{\text{FAC}}$ x TOF x Mtx

incoming K⁻ outgoing K⁺



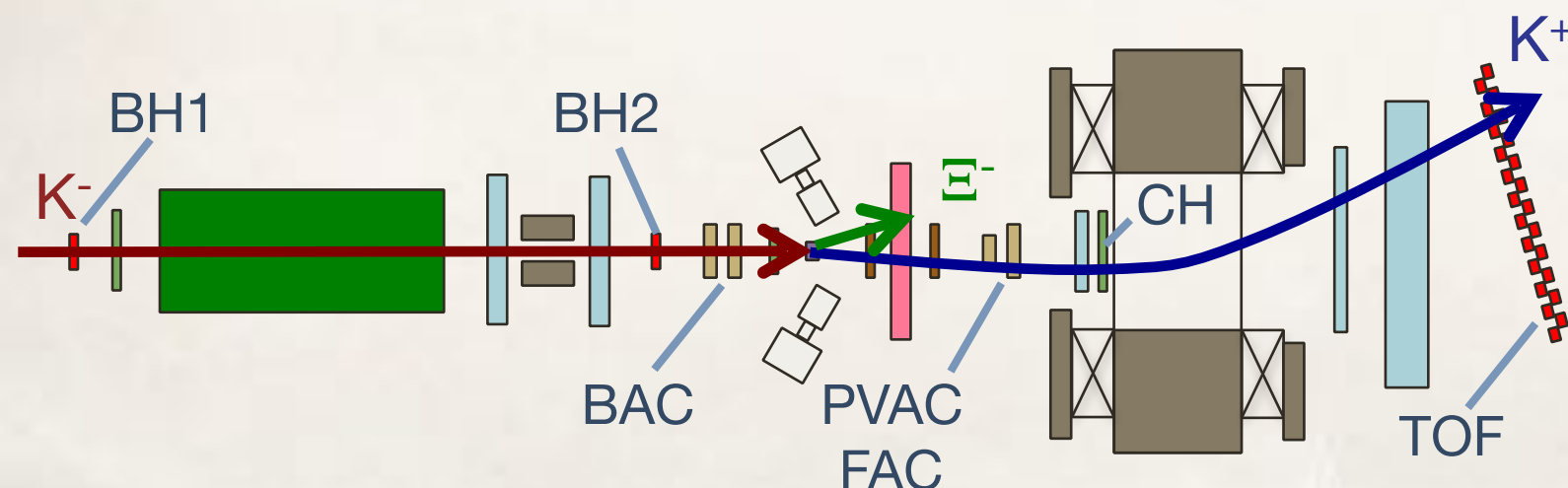
Matrix Trigger (Mtx)

select particle track in magnetic field
by hit pattern combination (CH & TOF)
→ select momentum & charge

Trigger rate : 1380/spill (5.5s cycle)

- (K⁻,K⁺) : 1250/spill
- (beam, TOF) : 80
- (π , TOF) : 50

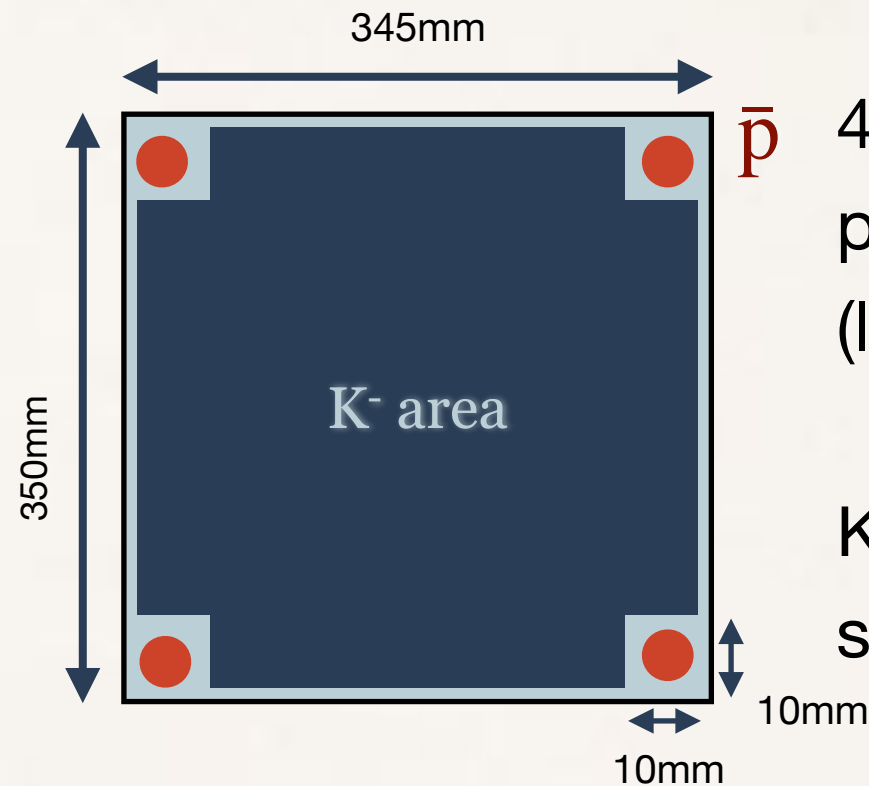
DAQ eff. : ~85%



Emulsion exposure

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- Beam condition
 - ❖ K^- intensity : 260k/spill
 - ❖ K^- purity : 82%
 - ❖ beam size : $\sigma(X)$: 15.5mm
 $\sigma(Y)$: 4.9mm



4 corners are used for pattern match (low intensity \bar{p})

K^- were irradiated all surface except corners

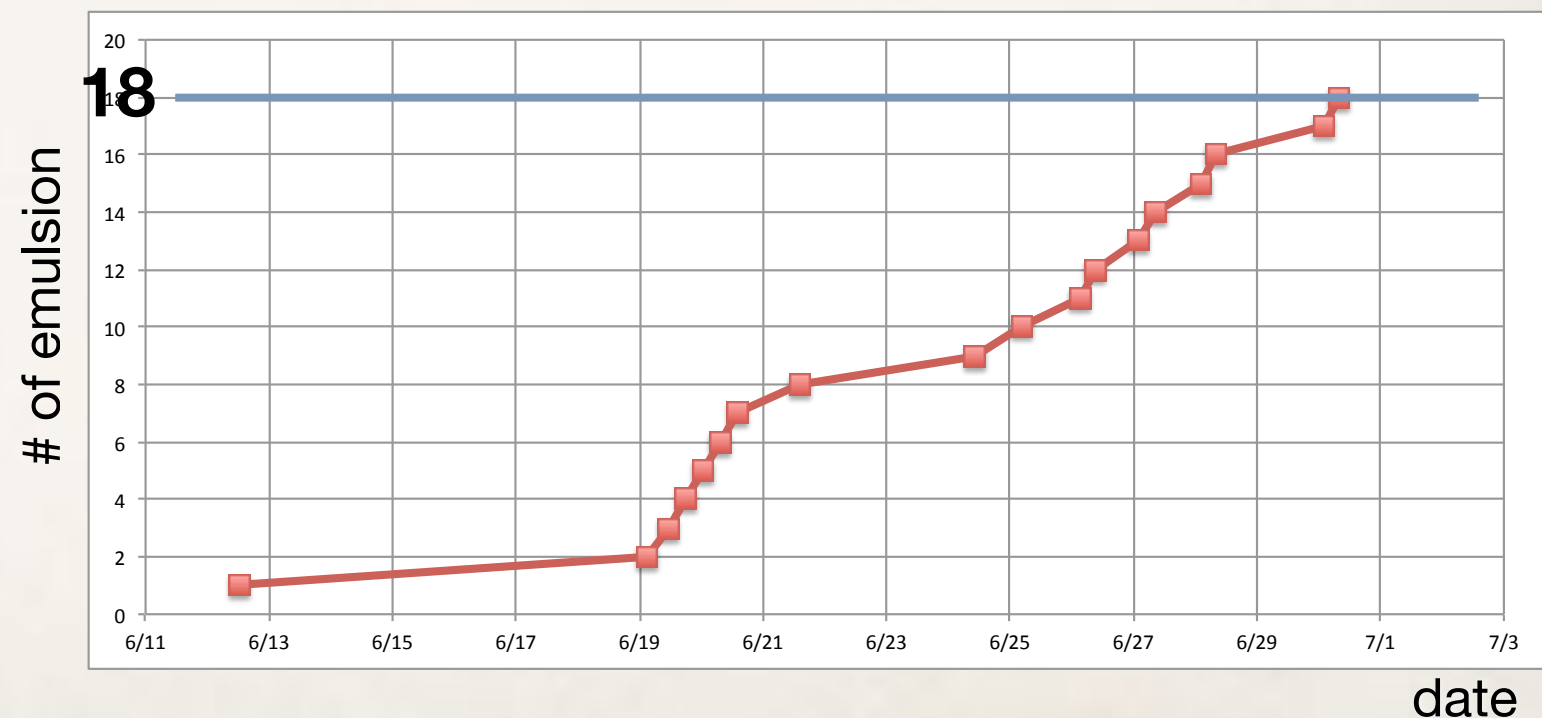
Procedure

1. Exchange emulsion (0.5h)
2. pattern match (0.5h)
3. K^- exposure (6h)

Emulsion plates were measured and packed in the dark room.

1 cycle (stack) need 7 hours.

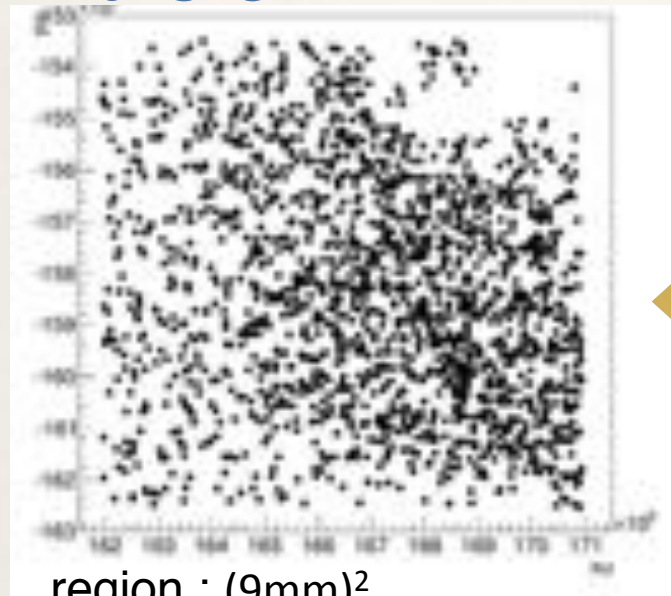
Progress of exposure



Pattern match

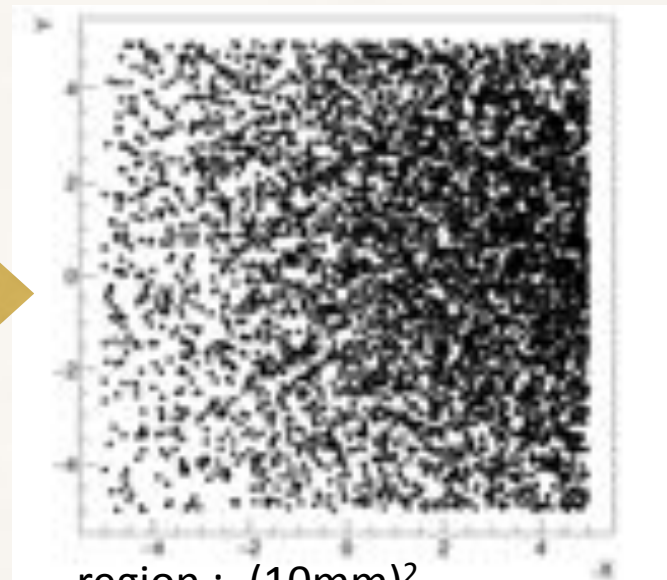
We use pattern match method to align SSD and Emulsion.

Emulsion

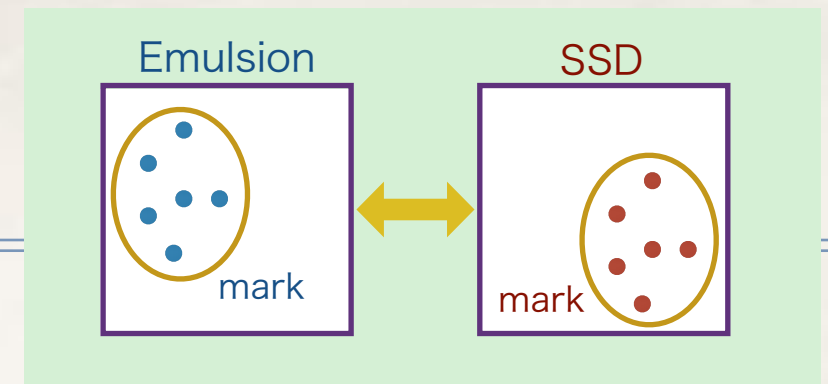


region : $(9\text{mm})^2$
< 25mrad, 1.7k tracks

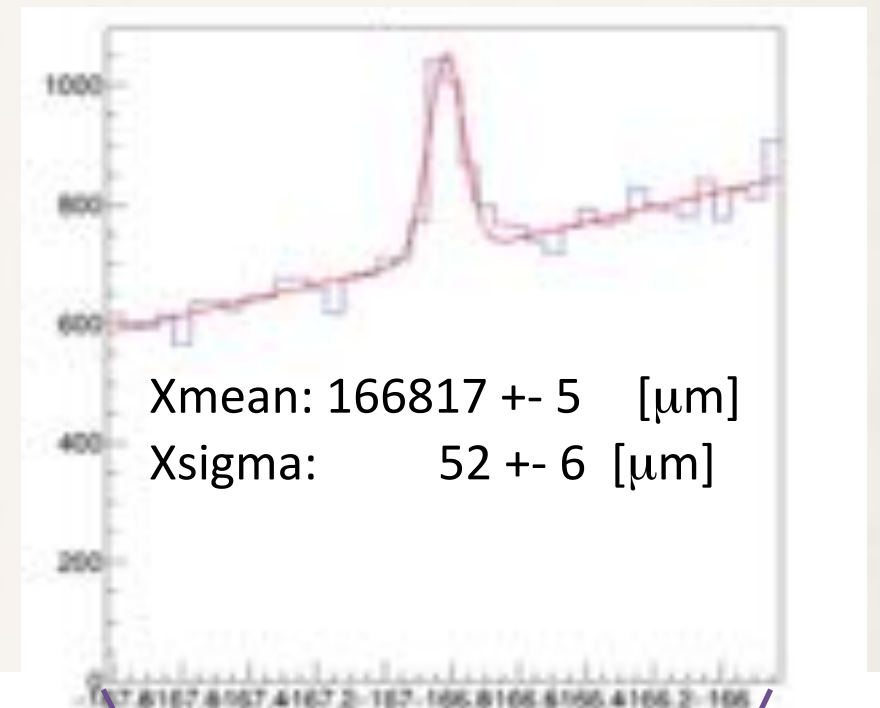
SSD



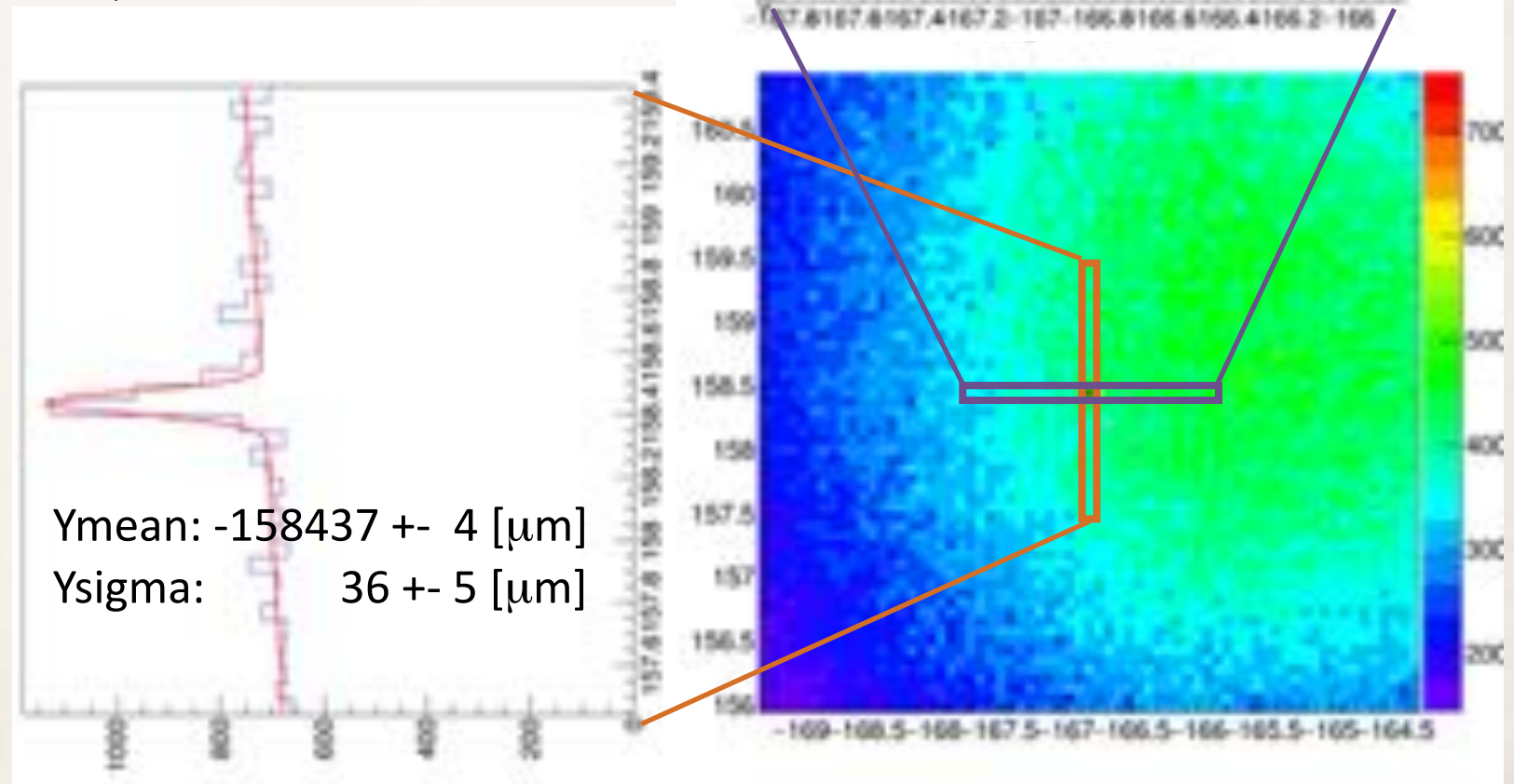
region : $(10\text{mm})^2$
< 50mrad, 3.1k tracks



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Xmean: 166817 +/- 5 [μm]
Xsigma: 52 +/- 6 [μm]



Ymean: -158437 +/- 4 [μm]
Ysigma: 36 +/- 5 [μm]

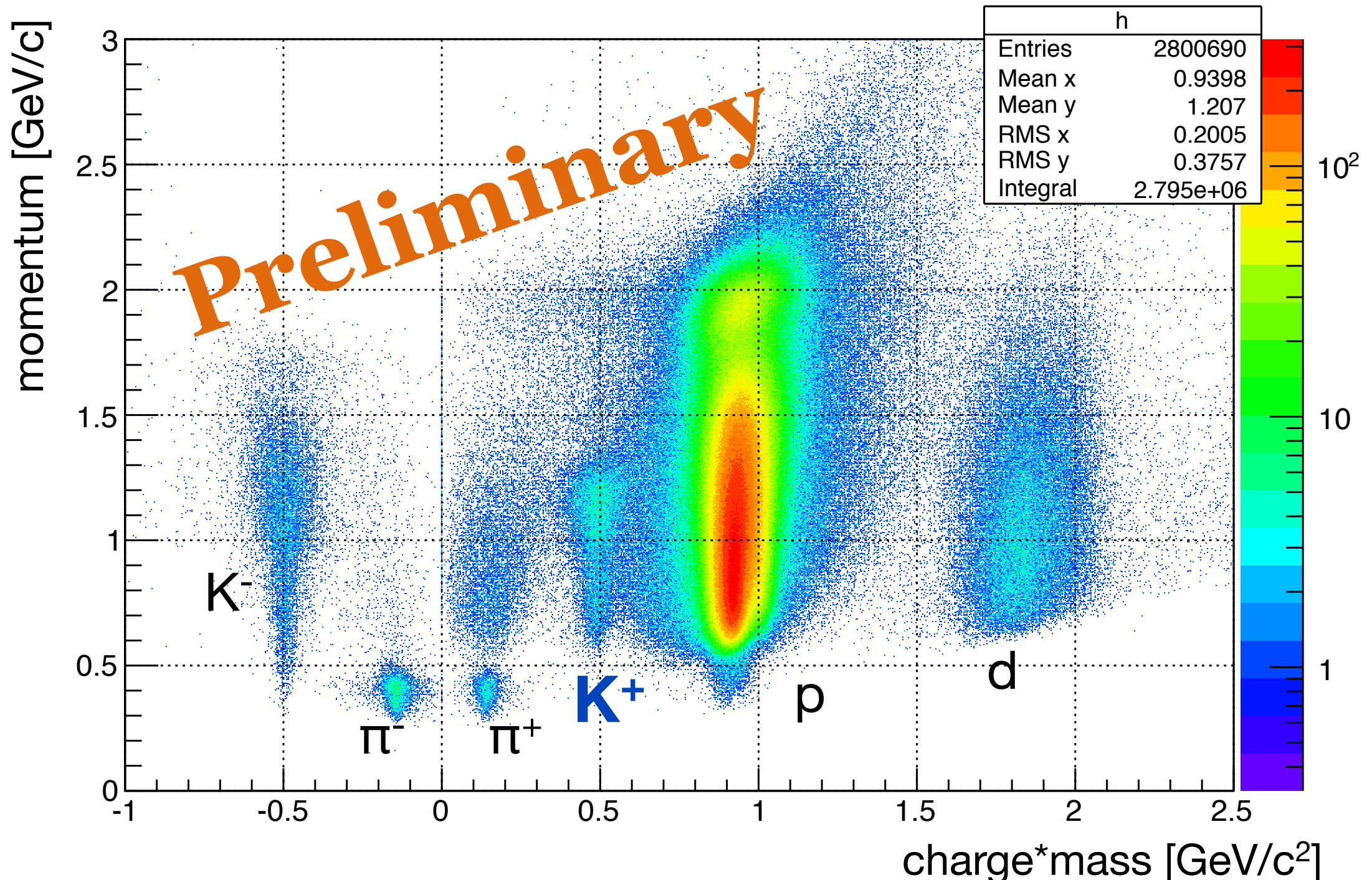
We analyzed Emulsion and SSD
to find \bar{p} tracks.

Pattern match signal was found.

Evaluation of accuracy and
efficiency is ongoing.

Analysis (KURAMA spectrometer)¹⁵

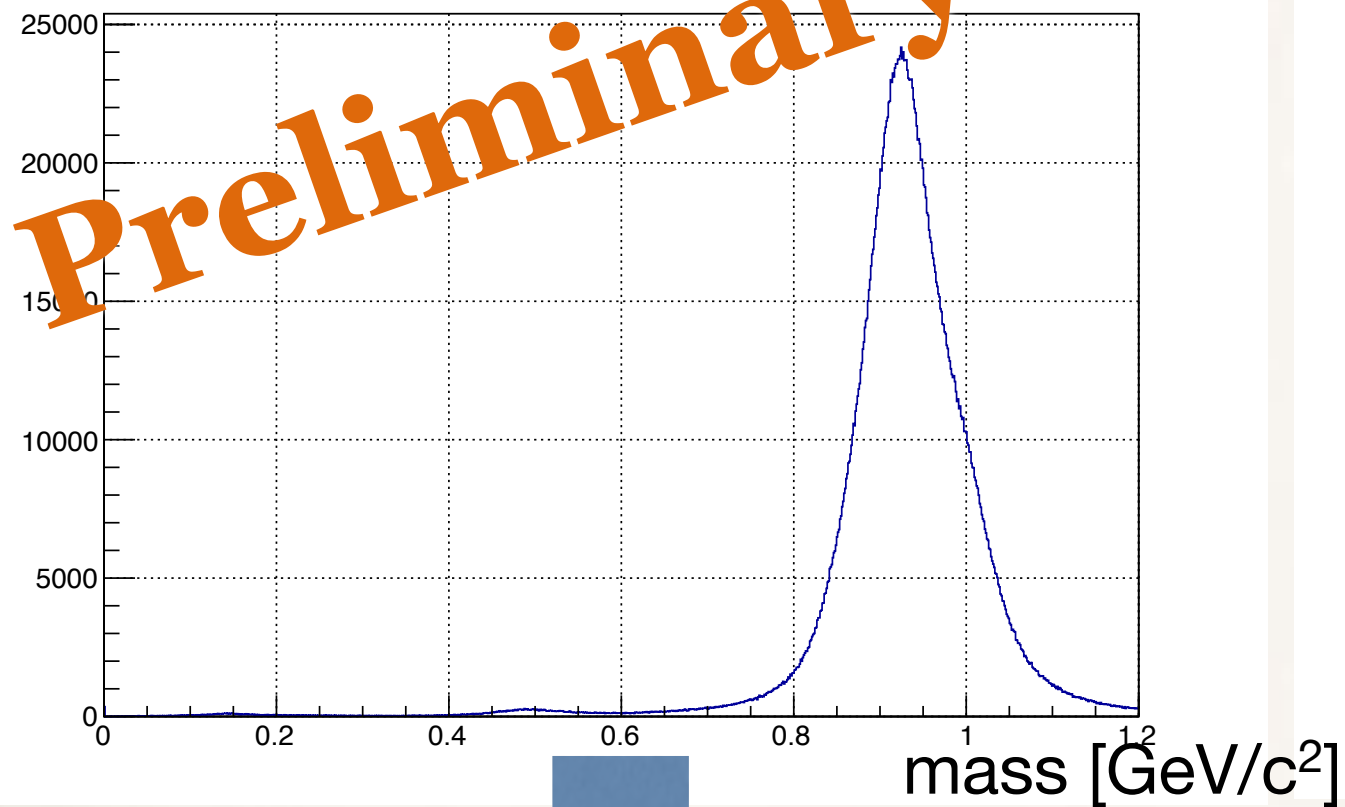
- ❖ particle momentum are analyzed by Runge Kutta
- ❖ K^+ can be identified.



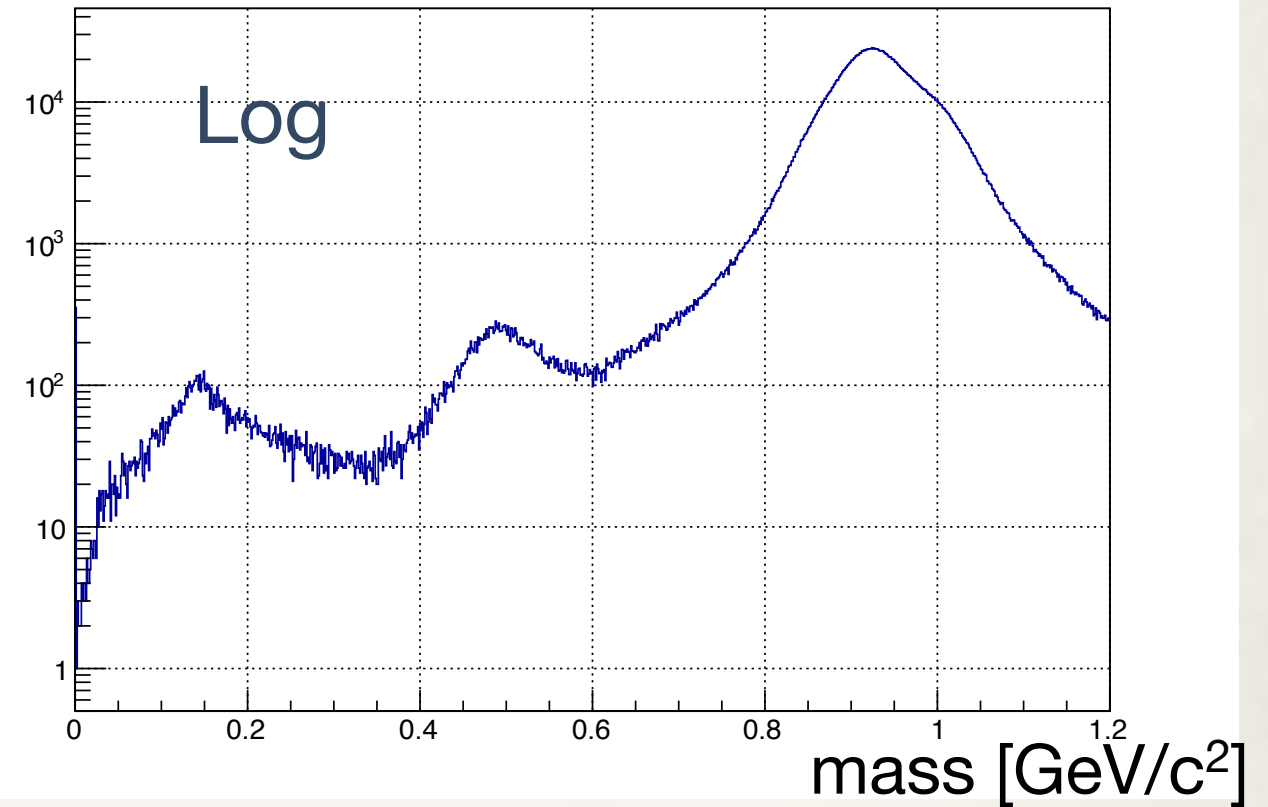
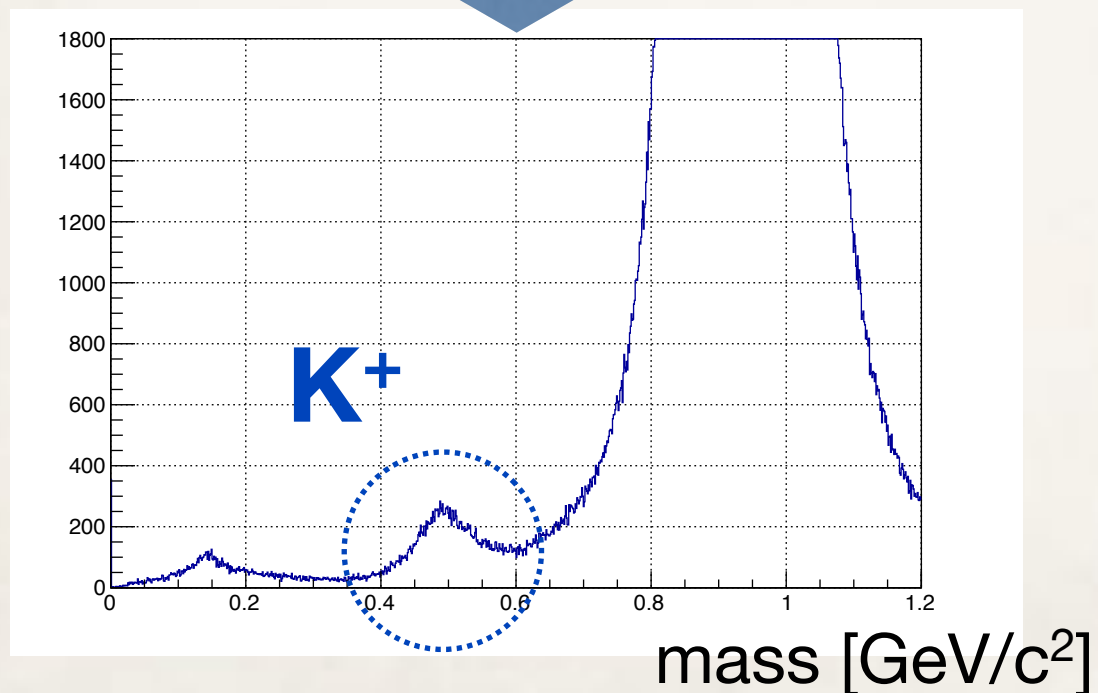
Mass distribution

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Preliminary



zoom



- proton background is large
- We will check SSD data with (K^-, K^+) reaction in order to search Ξ^- track into emulsion

- ❖ J-PARC E07 experiment is double hypernuclei search experiment with hybrid emulsion method
- ❖ 100 double hypernuclei will be detected including 10 identified species.
- ❖ Commissioning run for KURAMA spectrometer and emulsion exposure were performed in 2016 Jun.
- ❖ 18 stacks of emulsion were exposed. (15% of full statistics)
- ❖ Plan
 - Ξ^- track will be searched by SSD analysis
 - remaining 100 stacks of emulsion will be exposed in 2017.
 - improve DAQ efficiency (mass trigger, reduce SSD noise)