



**HADRON NUCLEAR
PHYSICS 2015**

July 7- 11, 2015 @Krabi, Thailand

Automated scanning systems to search for double strangeness nuclei in nuclear emulsion

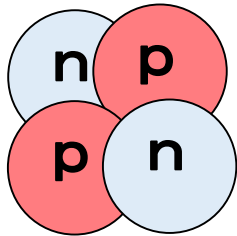
Junya Yoshida

Hiroki Ito, Shinji Kinbara, Hidetaka Kobayashi, Daisuke Nakashima, Kazuma Nakazawa, Akihiro Mishina, Myint Kyaw Soe, Aye Moh Moh Theint, Khin Than Tint and J-PARC E07 Collaboration

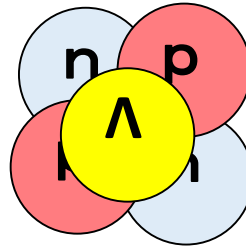
Physics department, Gifu University, Japan

Double Lambda hypernucleus,

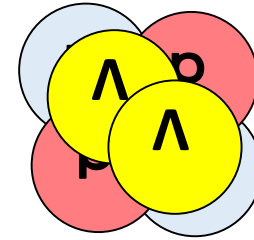
Exotic nucleus made up of two Lambda hyperons in addition to nucleons
They are important subject to understand baryon-baryon interaction.



${}^4\text{He}$

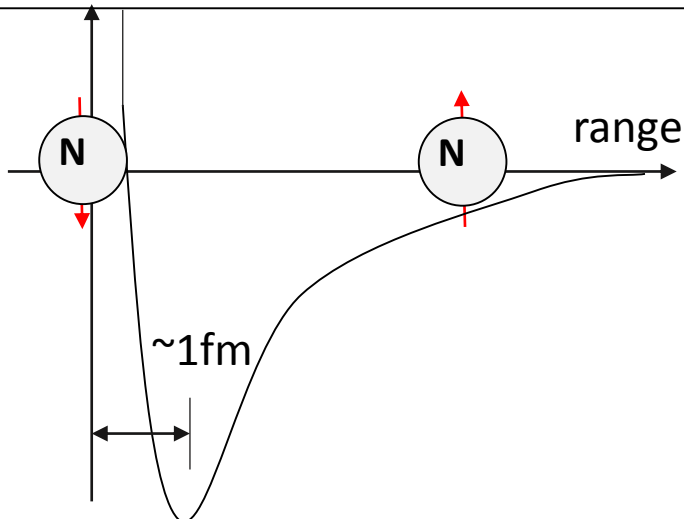


${}^5_{\Lambda}\text{He}$

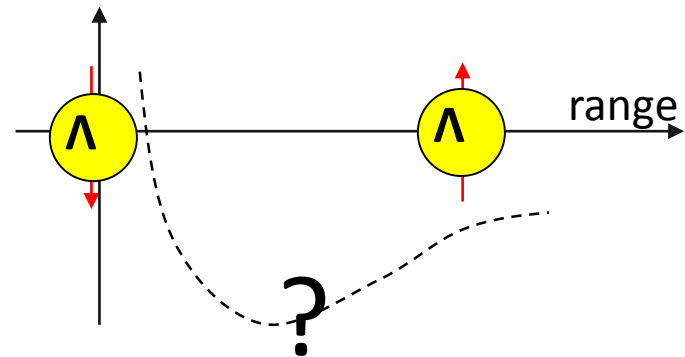


${}^6_{\Lambda\Lambda}\text{He}$ (lambpha)

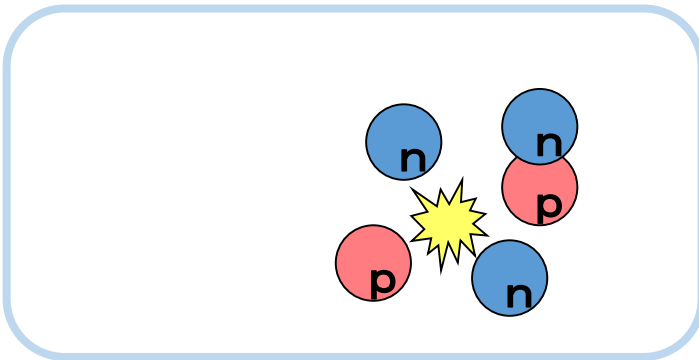
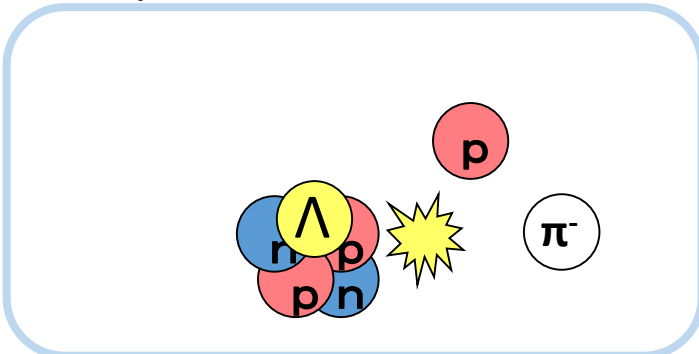
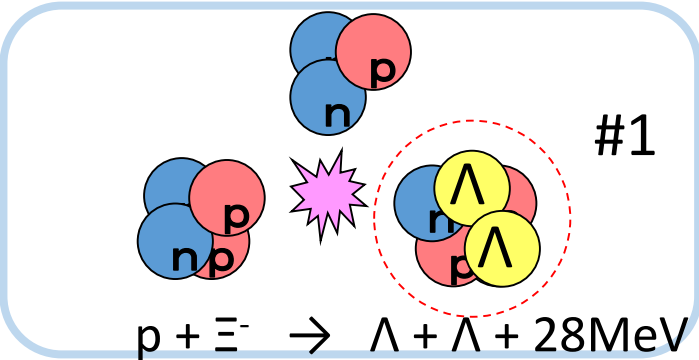
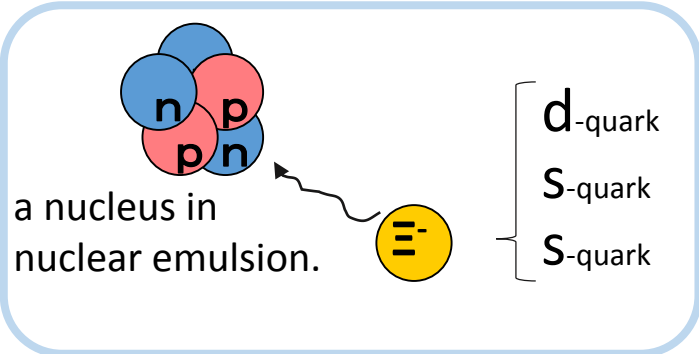
Potential energy of “nuclear force”



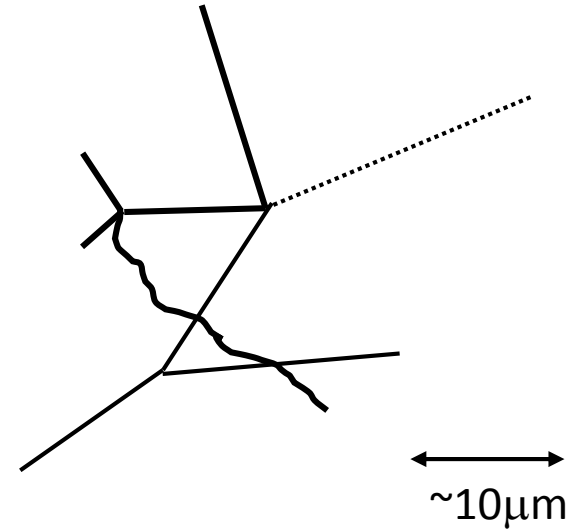
Potential energy between “two Lambdas”



Lambda-Lambda interaction is a key to understand baryon-baryon interaction.
Mass measurement of double Lambda hypernuclei is a unique way.



How to product and detect Double lambda hypernuclei?



- a tiny characteristic shape having 3 vertexes
- Range of the track of Double lambda hypernuclei is about 10 microns in solid
- -> Nuclear emulsion

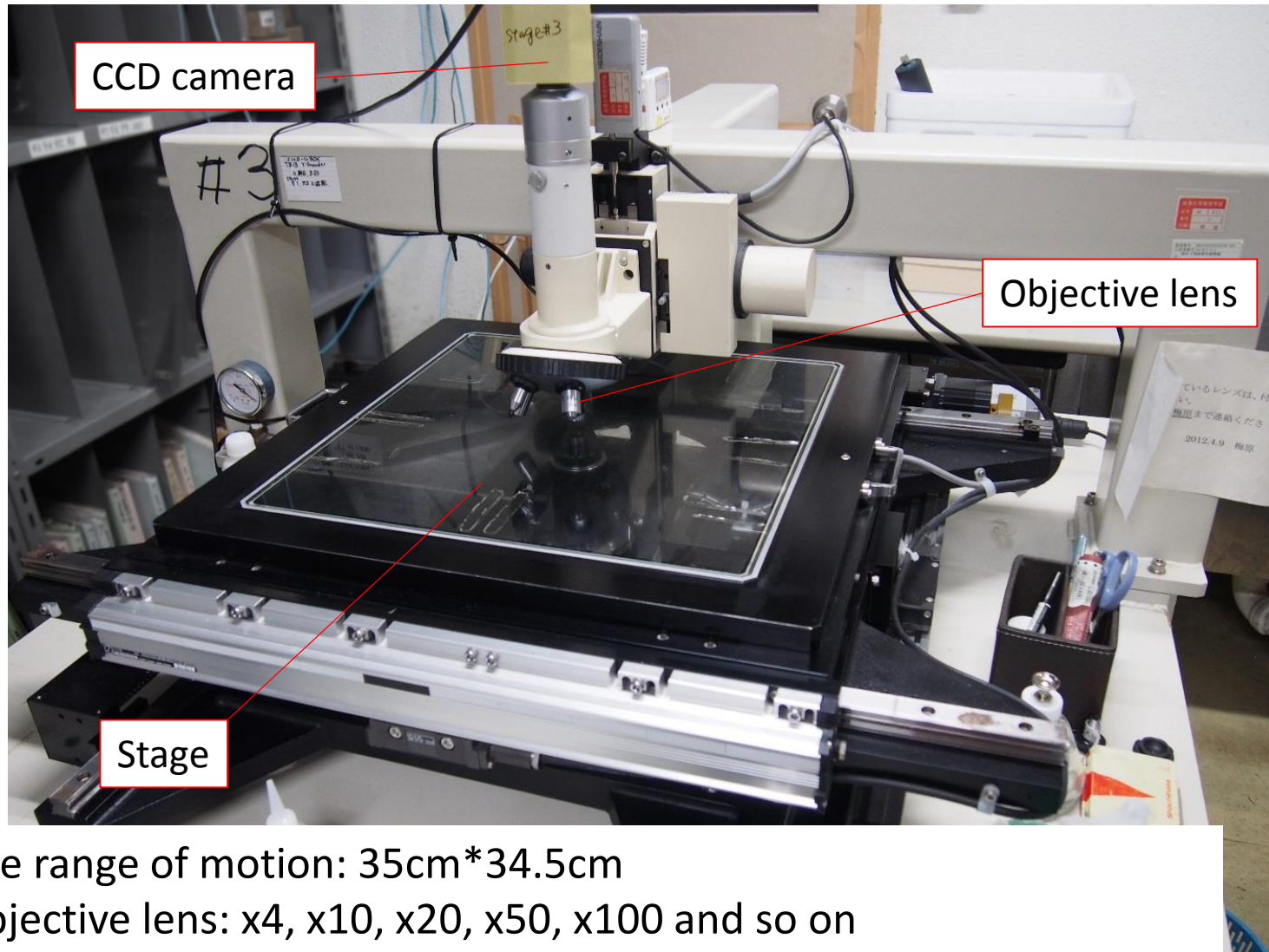
Nuclear emulsion plate for double strangeness nuclei (after photographic development)



KEK-PS E373's emulsion plate

- *Photographic film having sub-micron of special resolution
- *They record the tracks of charged particles passing through an emulsion film.
- *The size of a plate: 25cm*24.5cm
- *Thickness : ~1mm (before development) -> ~0.5mm (after development)

An optical microscope for emulsion scanning



The range of motion: 35cm*34.5cm

Objective lens: x4, x10, x20, x50, x100 and so on

CCD camera: 512pix*440pix*50Hz

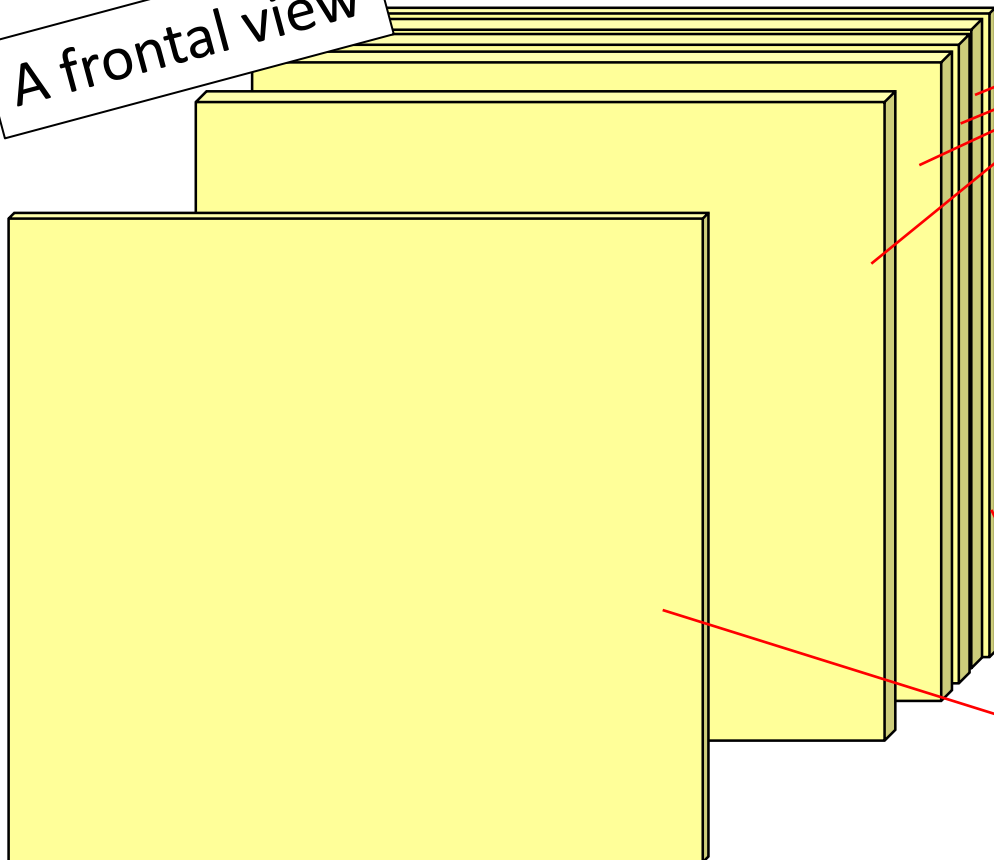
The stage is driven by computer-controlled motors(X,Y and Z-axis)

7stages in Gifu-University

Microscopic view

An emulsion stack

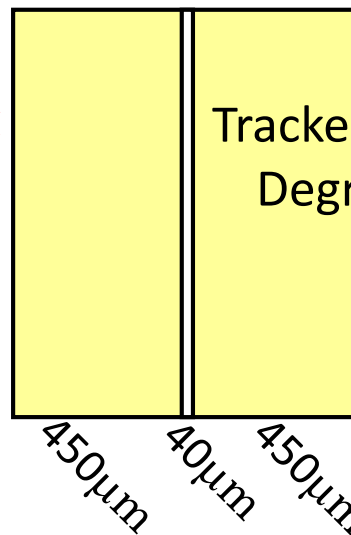
A frontal view



350mm*345mm*10mm thickness
[Thin-type + 12Thick-type + Thin-type]

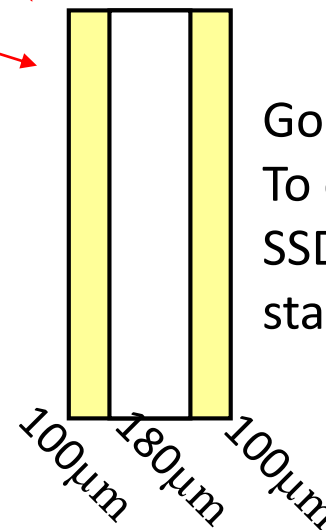
An emulsion stack is packed in an envelope for light shielding and moisture-proof

Thick-type



A cross-sectional view

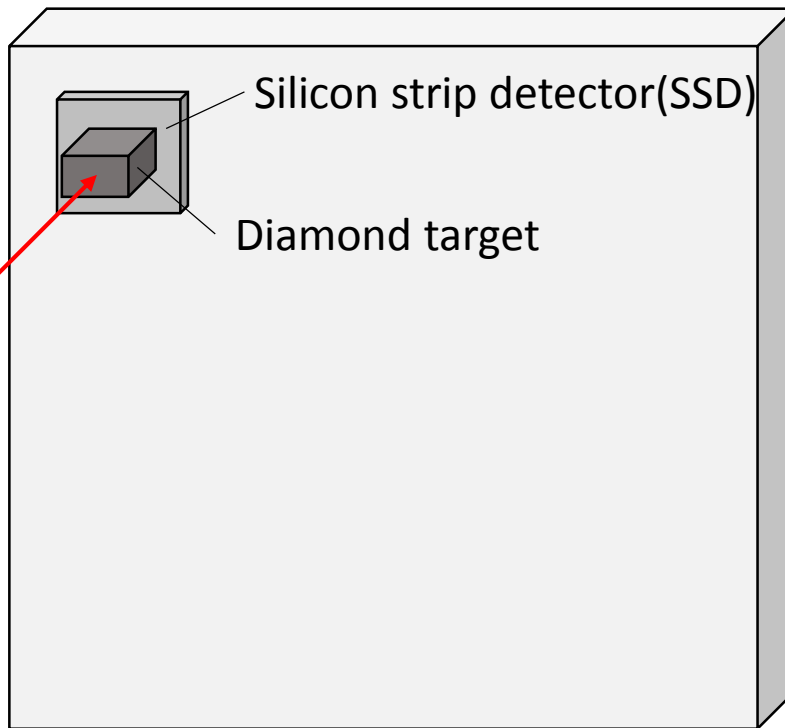
Thin-type



Good angular resolution.
To connect tracks from
SSDs to the emulsion
stack

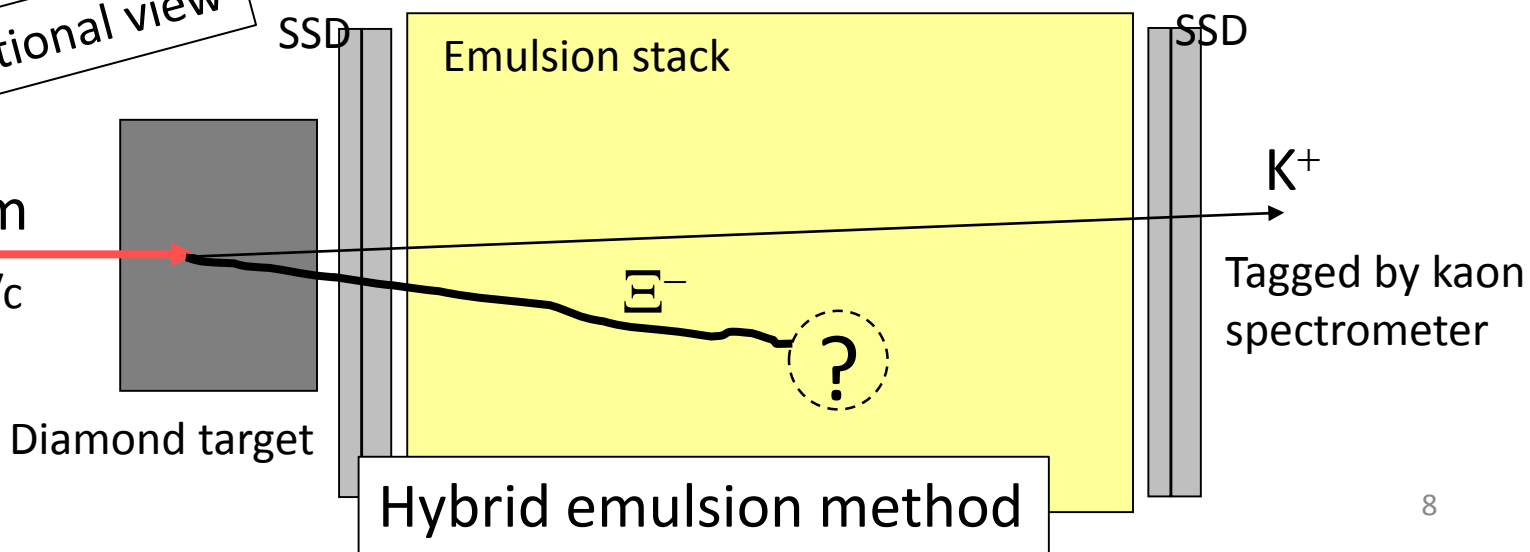
A frontal view

K^- beam
1.66 GeV/c

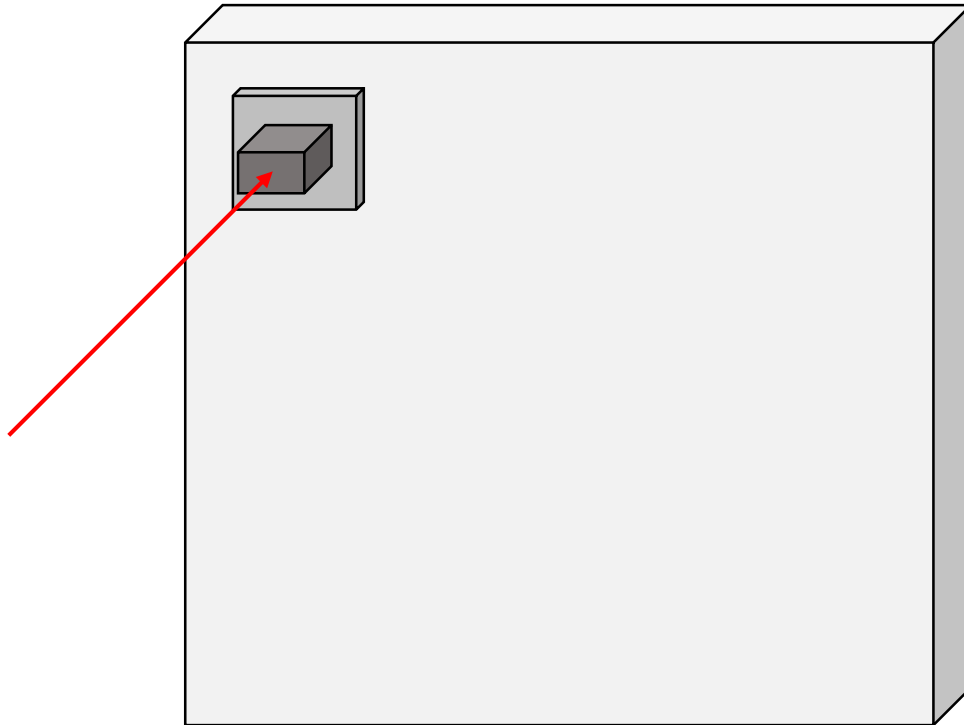


A cross-sectional view

K^- beam
1.66 GeV/c

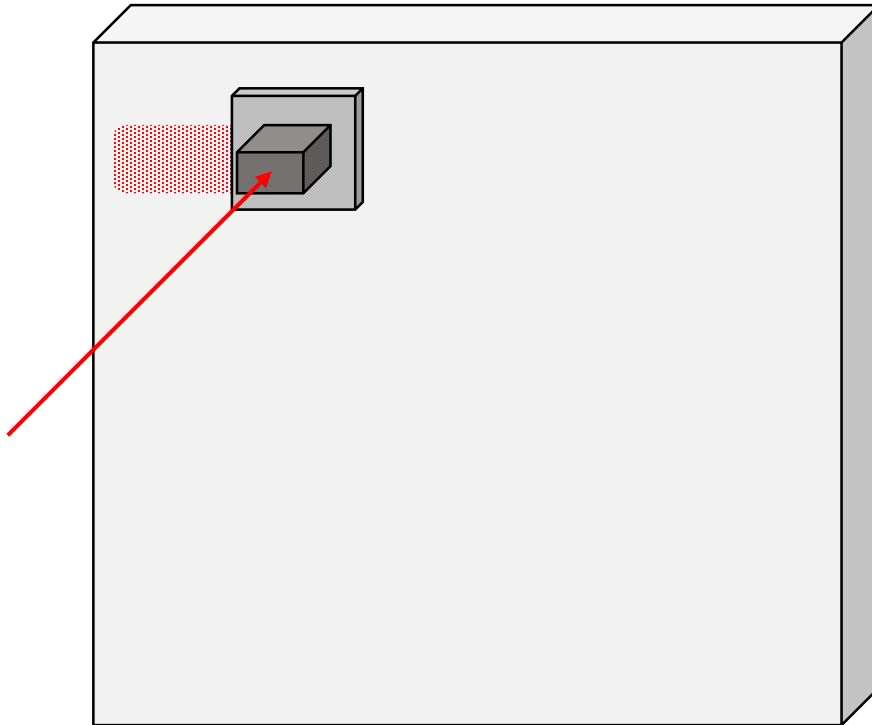


Ξ^- hyperon production and “stop-event” is very rare.
Track density must be limited less than 10^6 / cm^2 .
We move an emulsion stack spill by spill

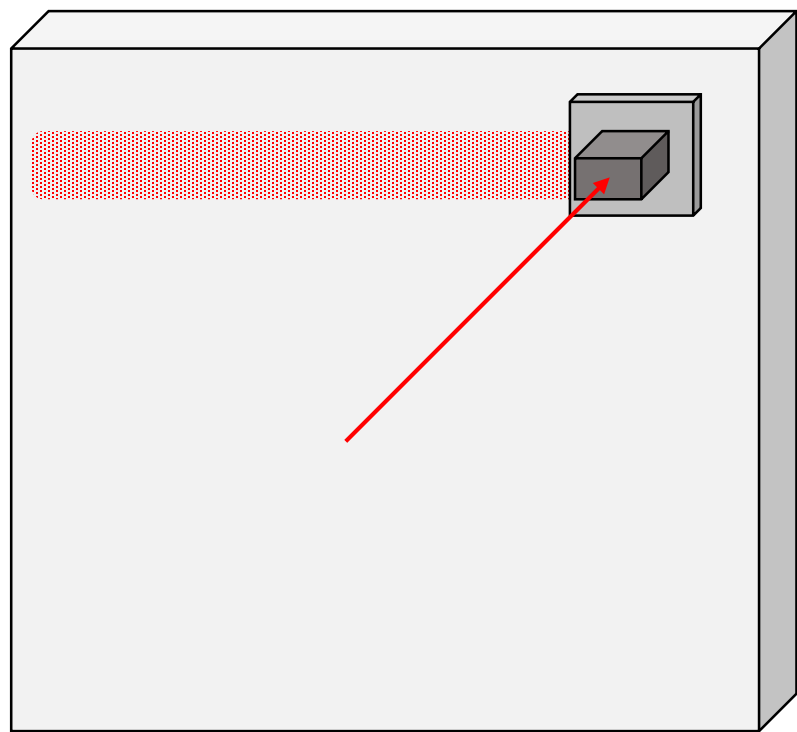


Production cross section of Ξ^- hyperon : $\sim 200 \mu\text{b}$ @ $\sim 1.7\text{GeV}/c$ Kaon-Carbon
Trigger condition: $K^+ > 1.0 \text{ GeV}/c$
Stop-event: $\sim 2\%$
Production of Double Lambda hypernucleus $\sim 1\%$ of Ξ^- stop event

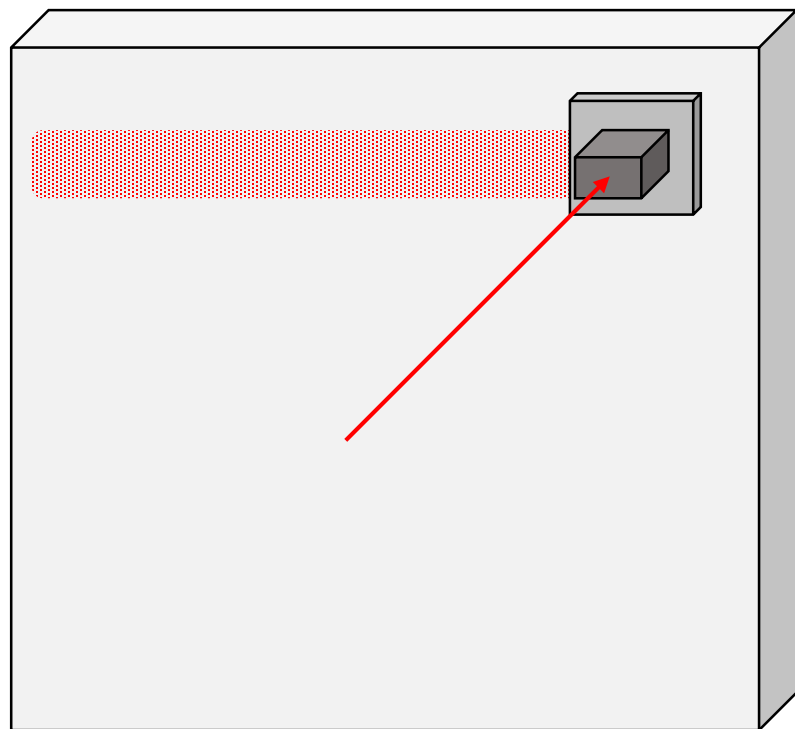
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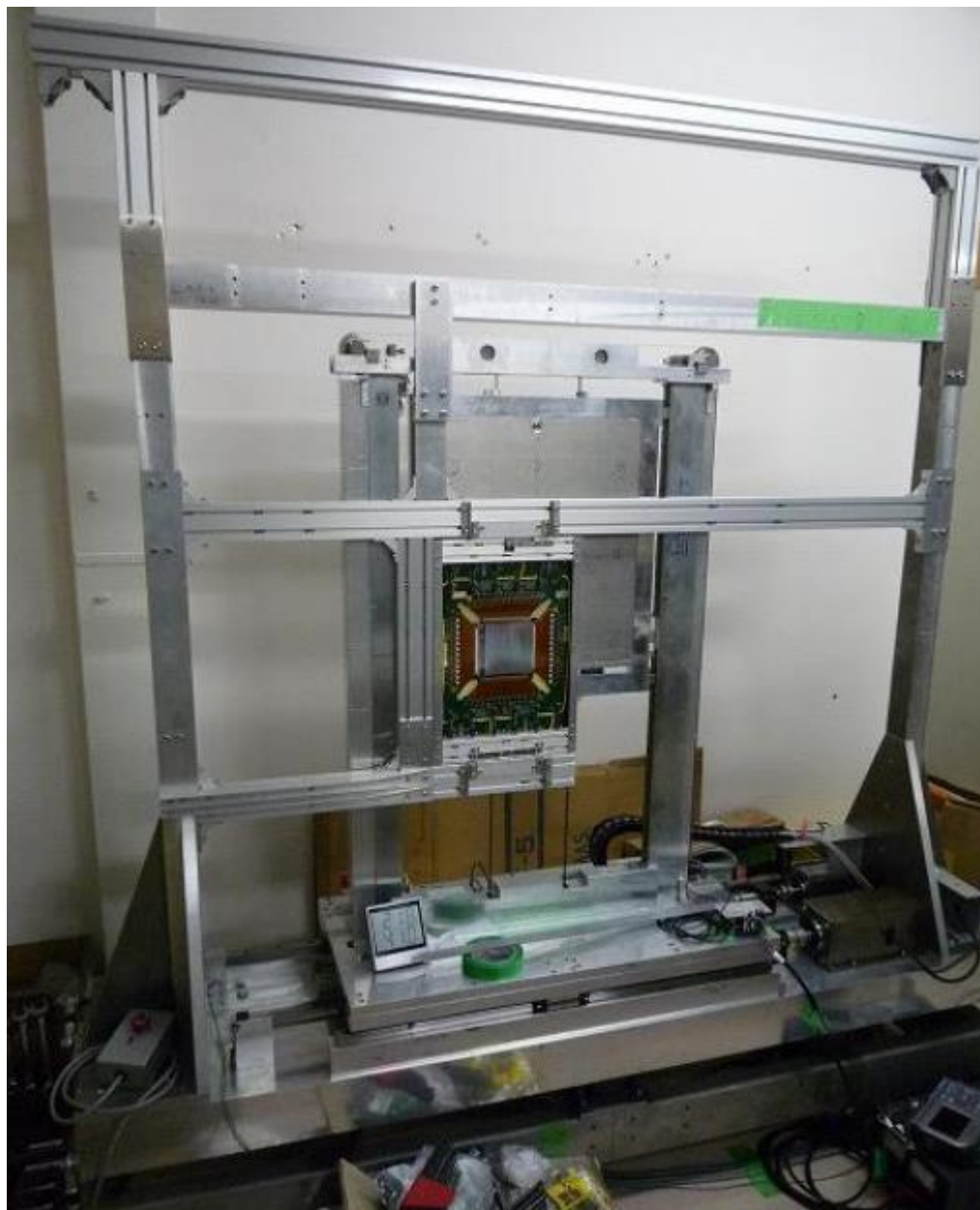
Ξ^- hyperon production and “stop-event” is very rare.
Track density must be limited less than 10^6 / cm^2 .
We move an emulsion stack spill by spill

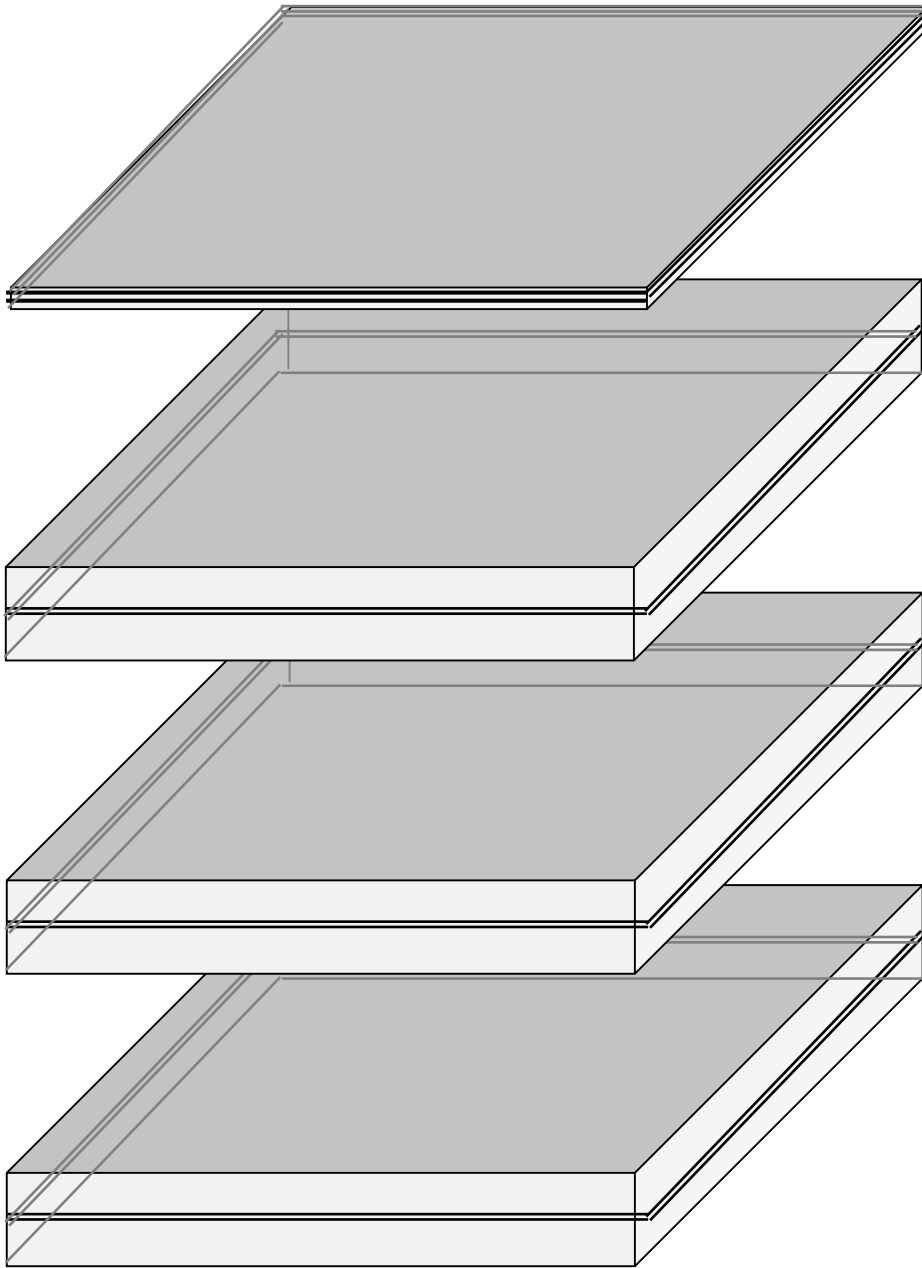


The emulsion mover for the coming experiment, J-PARC E07



We irradiate K-beam to About 100 emulsion stacks one after another

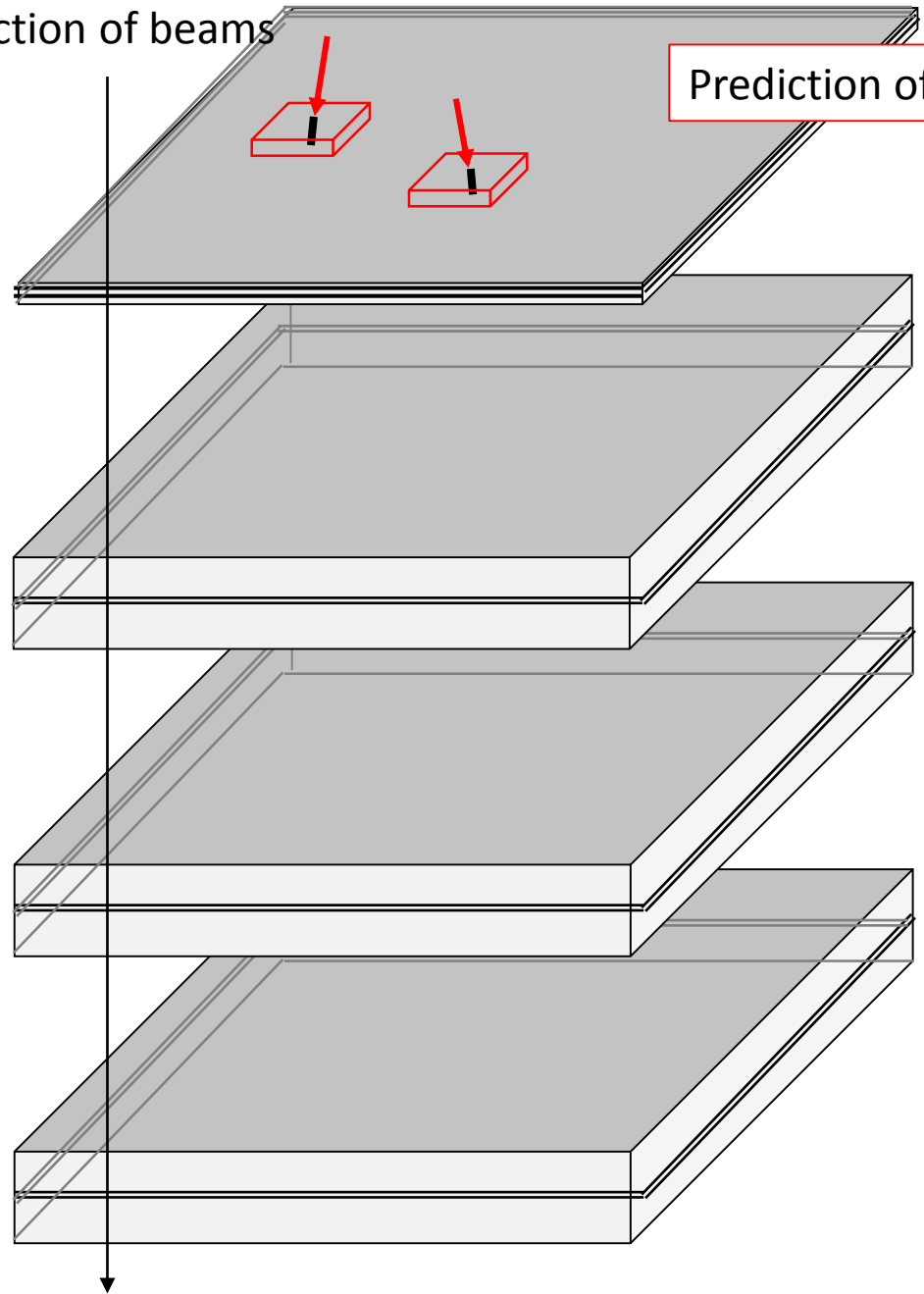




- *De-packing
- *Disassembling
- *Photographic development

*Track following

Direction of beams

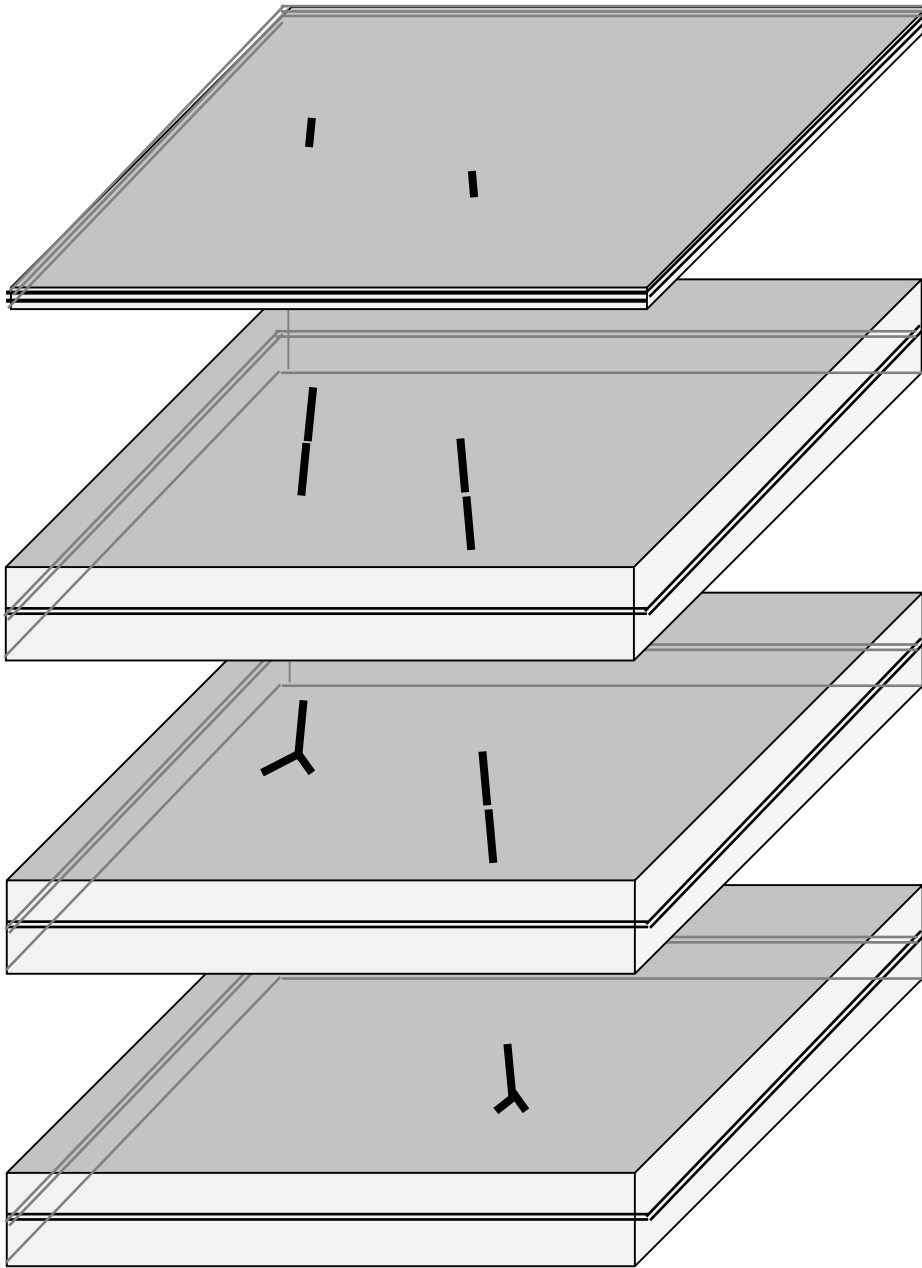


Prediction of incident points of the Ξ - hyperons

Searching area : 1view $\sim(120\mu\text{m})^2$

The number of searching point : ~ 400

Found tracks under a microscope



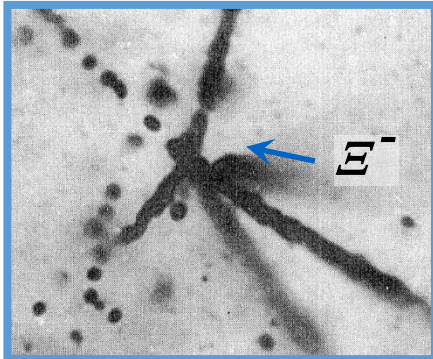
“Track following”

Our knowledge on Λ - Λ interaction

List of double hypernuclei

KEK-E176

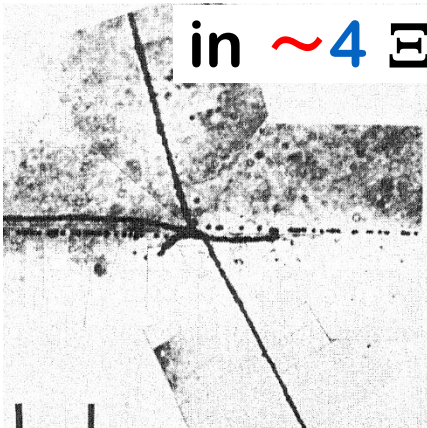
in ~ 80 Ξ^- stops



S.Aoki et al., NP. A828 (2009) 191-232

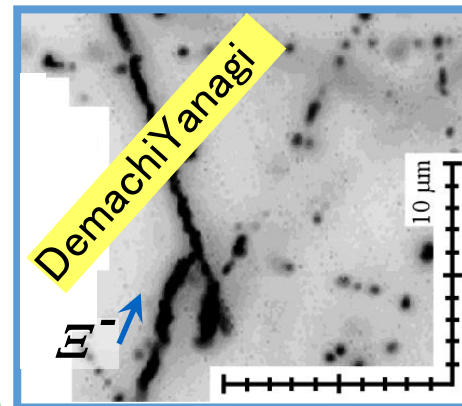
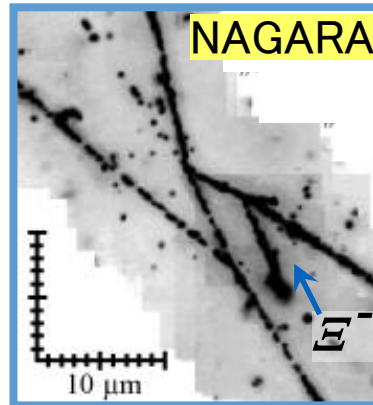
M.Danysz et al., PRL.11(1963)29;
R.H.Dalitz et al., Proc. R.S.Lond.A436(1989)1

in ~ 4 Ξ^- stops



KEK-E373

$\sim 10^3$ Ξ^- stops



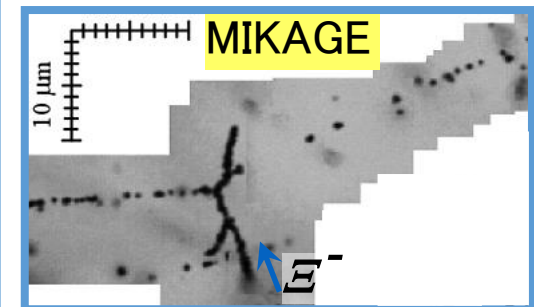
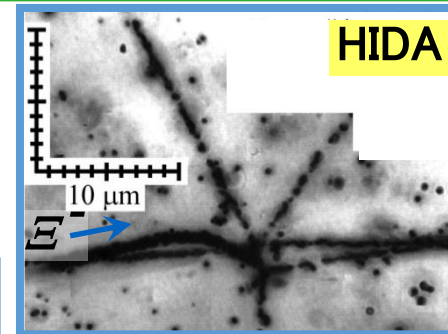
E07 @ J-PARC

(expected)

$\sim 10^4$ Ξ^- stops

$\rightarrow \sim 10^2$ Double

~ 50 Twin-hyper



4 D.H.N in 7 samples by E373

Only 9 events are observed in 2000s in the world.

Various double lambda hypernuclei must be detected to investigate $\Lambda\Lambda$ interaction.

How we obtain more double lambda hypernuclear events?

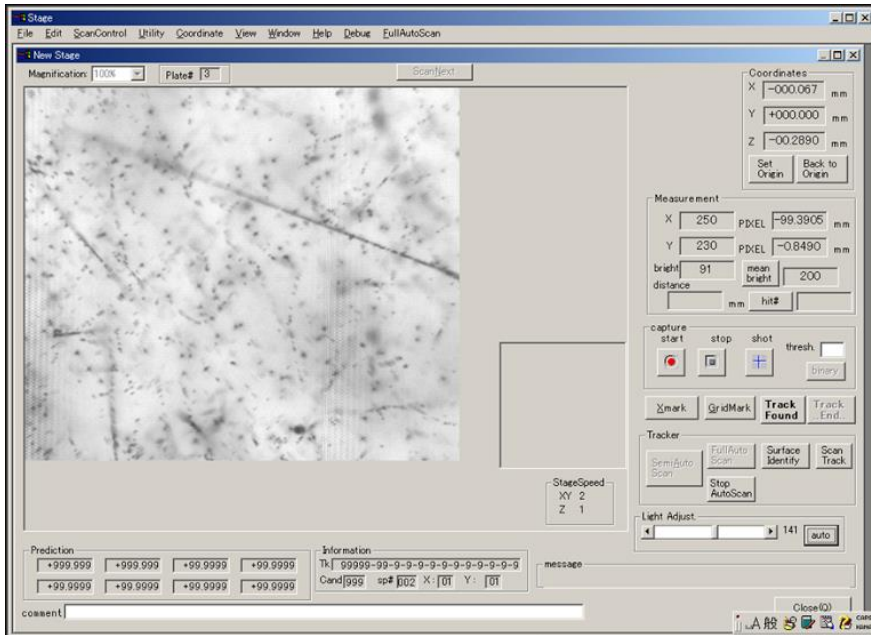
* The experiment ten times larger than the previous experiment. (J-PARC E07)

	KEK PS-E373	J-PARC E07
Emulsion gel	800kg	2.1tons
K/ π ratio	1/4	6/1
Ξ - stop	700	10^4
$\Lambda\Lambda$ event	7	10^2
Identified	1(${}^6_{\Lambda\Lambda}\text{He}$)	~ 10

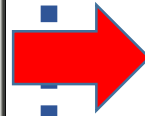
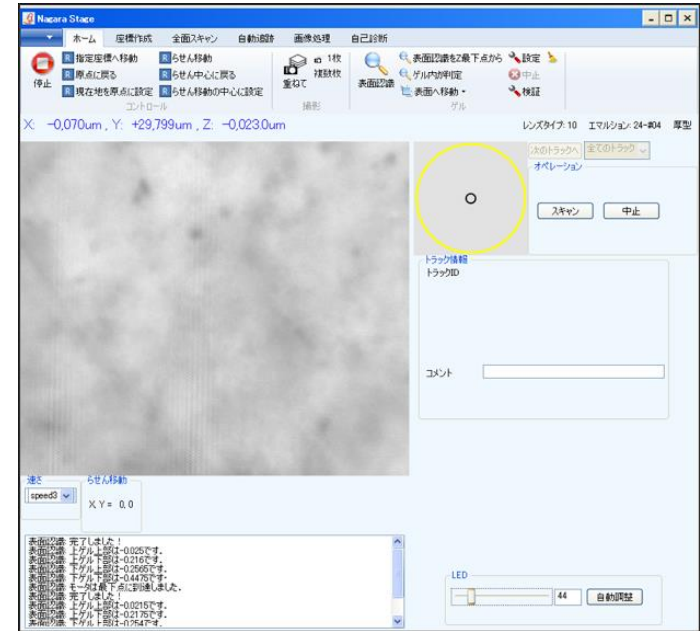
Moreover,

X-ray measurement from Ξ -atom with Ge detector

Previous software (1999~)



Current software



Auto Stage (Visual basic 6.0)

Driver

Driver, img proc.

Stage

Camera

Nagara Stage GUI (Visual C#)

Nagara Stage (C#)

Driver

Driver

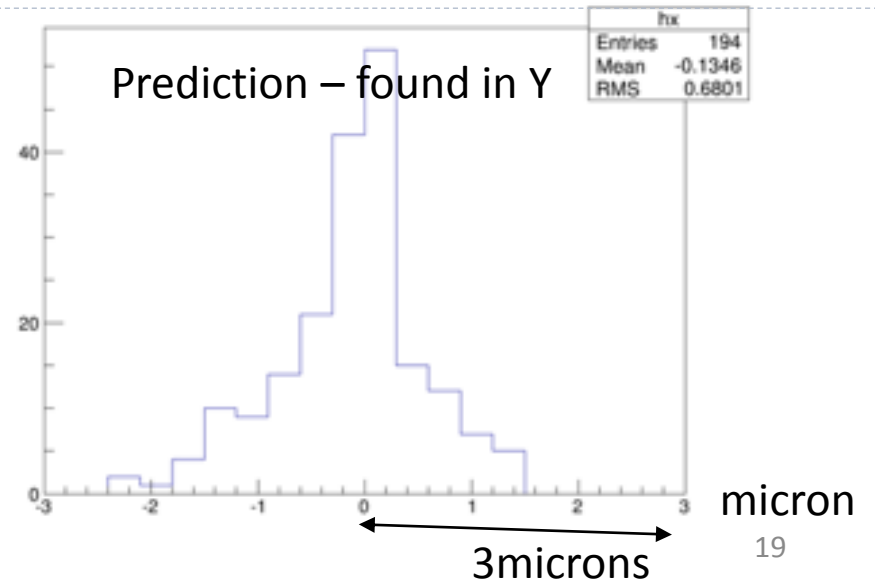
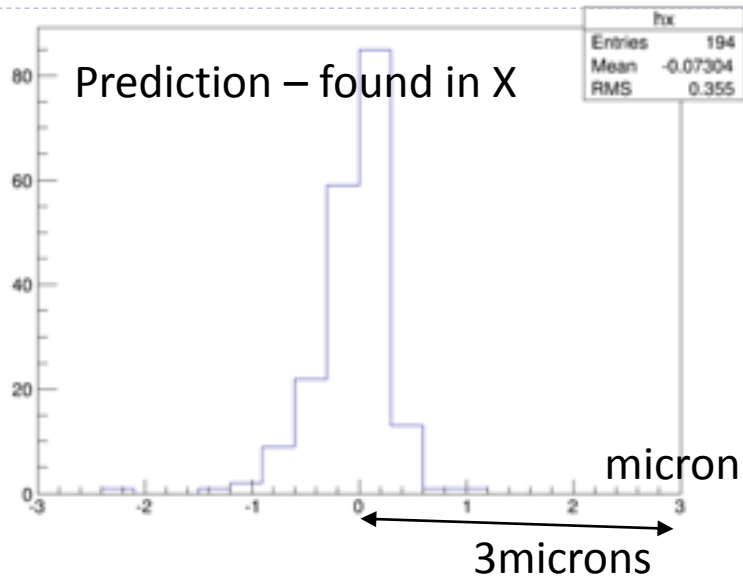
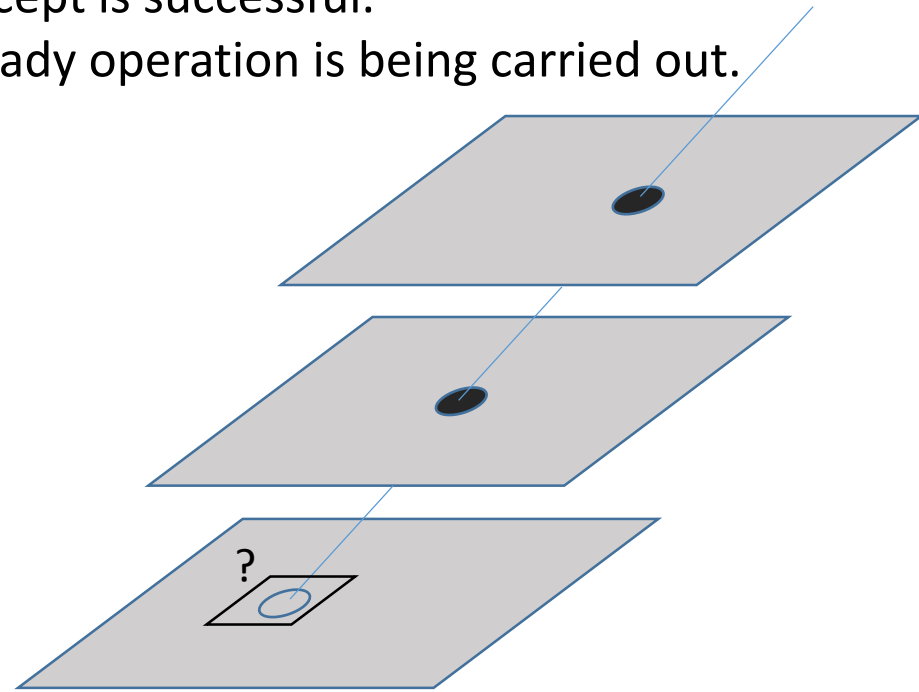
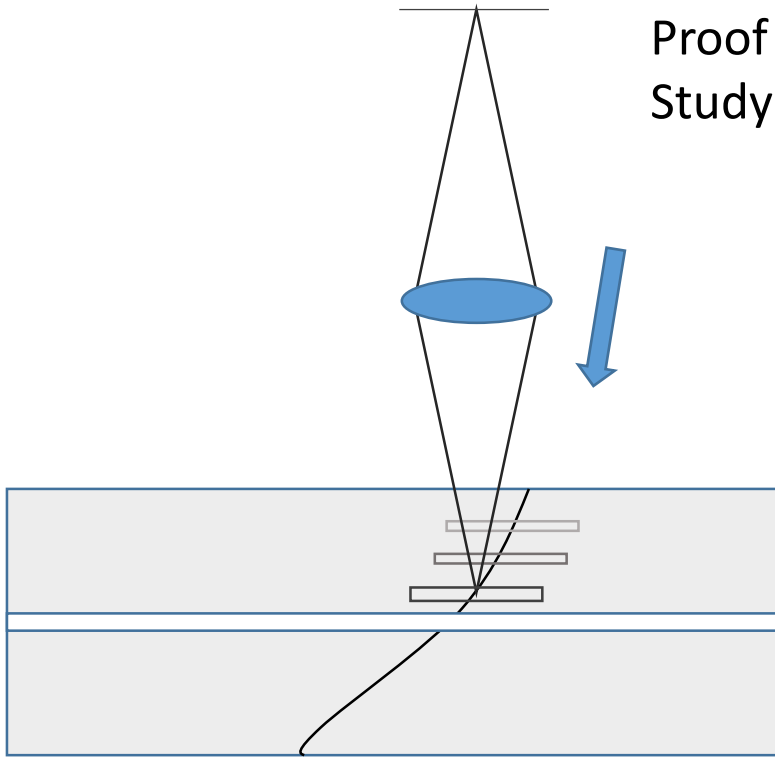
Img Proc.

Stage

Camera

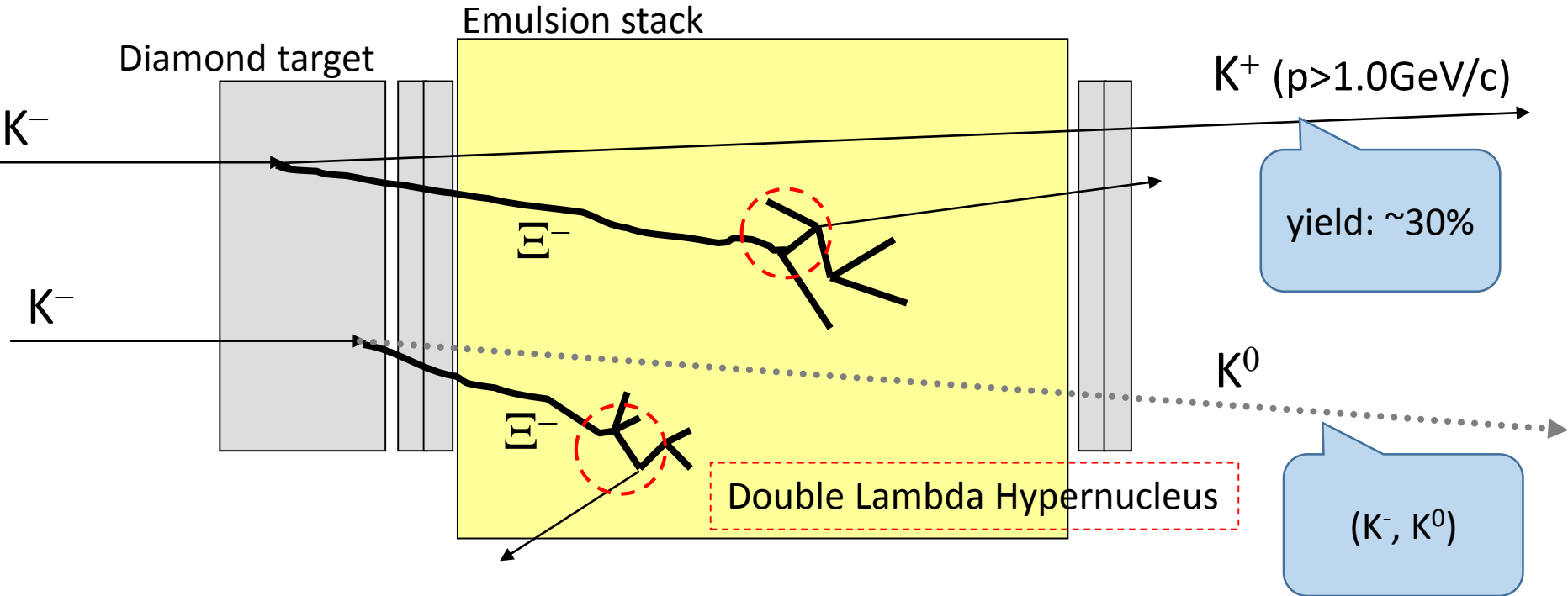
- * Hardware is the same
- * Easy to write, object oriented architecture, modern data I/O
- * CPU-Based Image processing

Proof of concept is successful.
Study for steady operation is being carried out.



How we obtain more double lambda hypernuclear events?

New searching method: Overall-scanning method

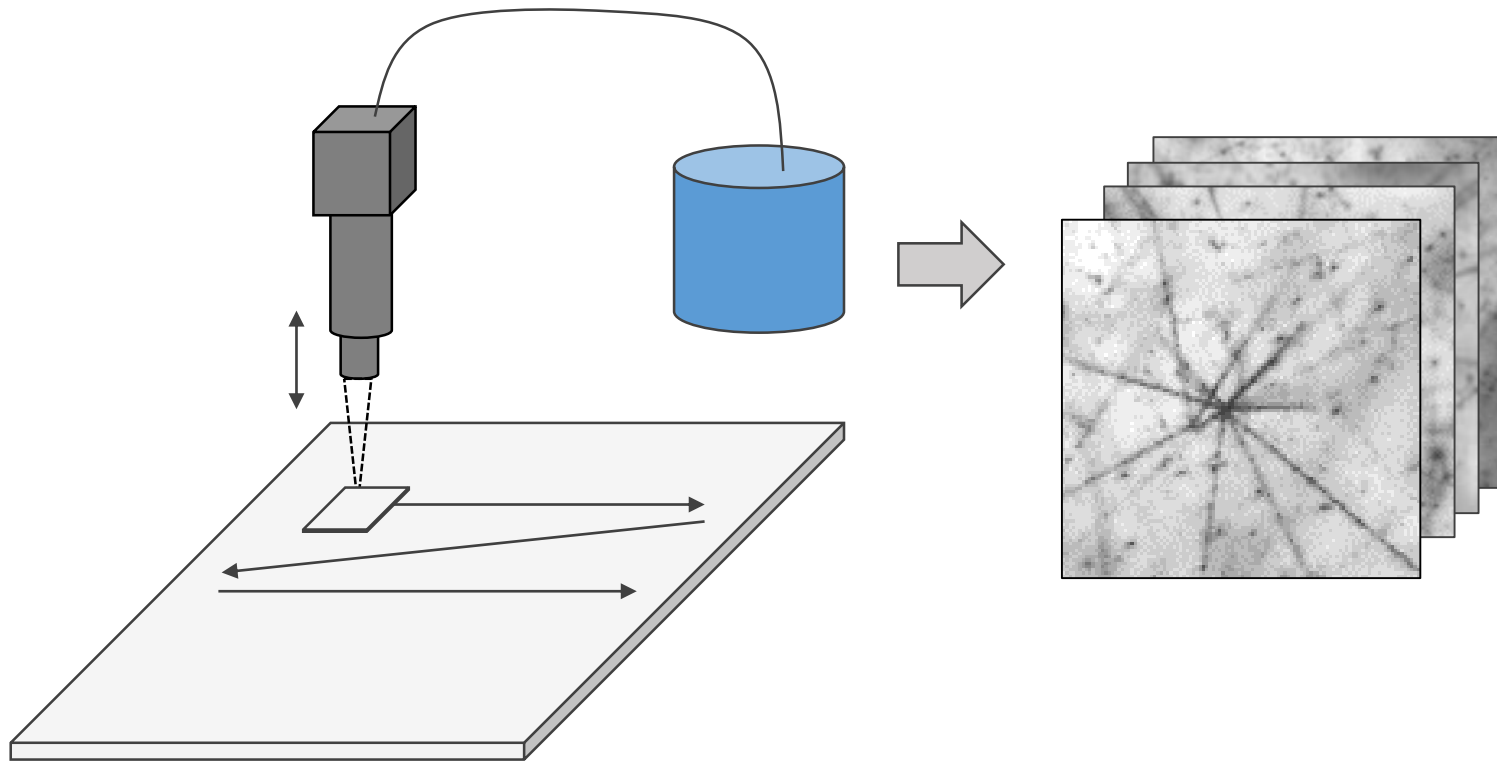


* Latent events (~10 times) may be recorded.

Concept and Key technologies;

(1). 3-dimensional scanning under optical microscopic view.

(2). Image process to find multi-vertex shape in emulsion.

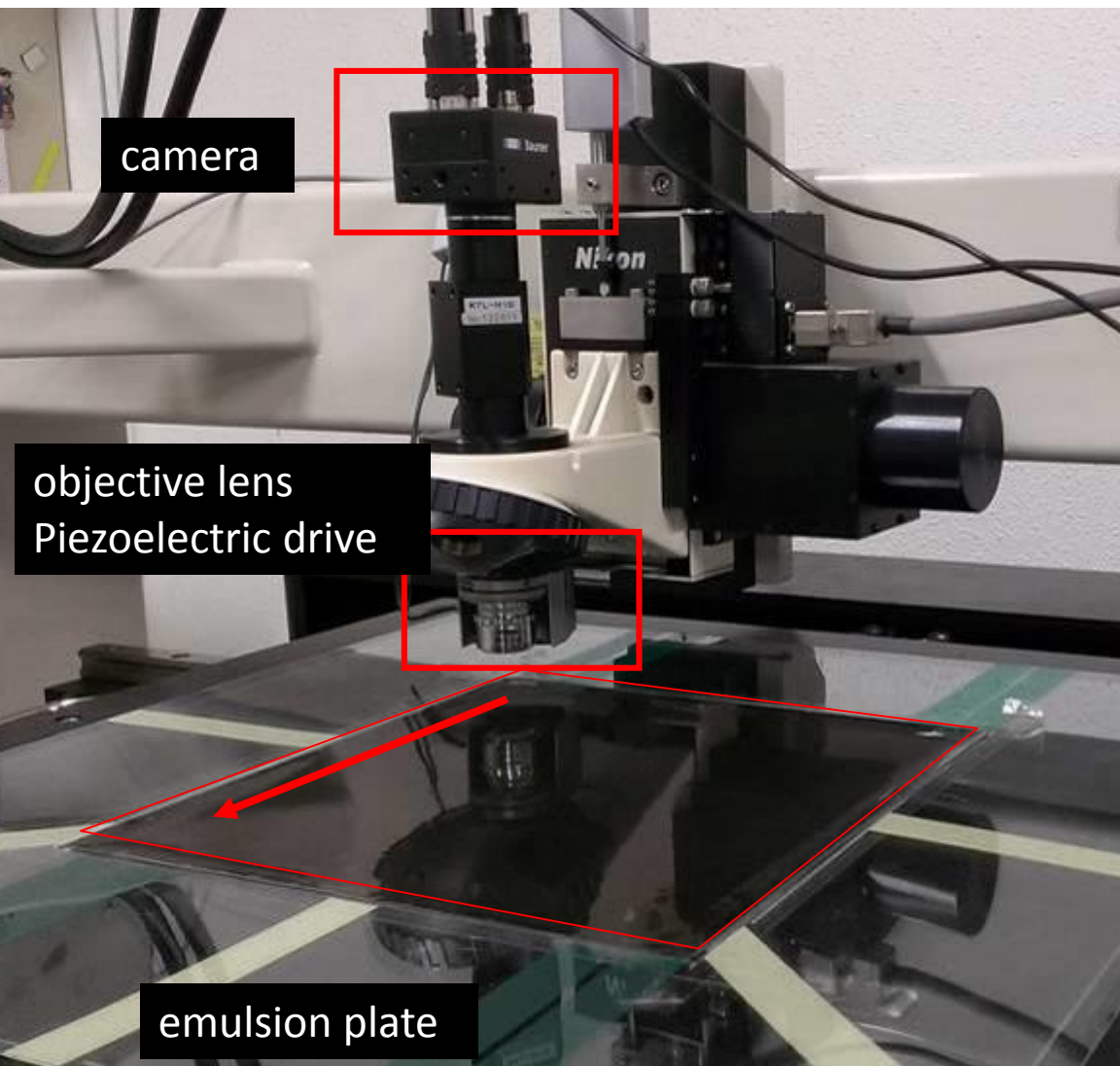


Exhaustively 3D scanning

vertex-like shapes which consist of several black tracks

Overall-scanning method

(1). A dedicated scanning system (Stage#7,8) collaborate with UNIOPT Co.



camera

objective lens
Piezoelectric drive

emulsion plate

high resolution CMOS
2048*358 pixel

high frame rate
800fps

wide F.O.V.
x20 dry lens (NA0.35)
1142*200 micron²

Piezoelectric drive
stroke 500 micron
period 5Hz
picture 40pics /cycle

Continuously stage moving

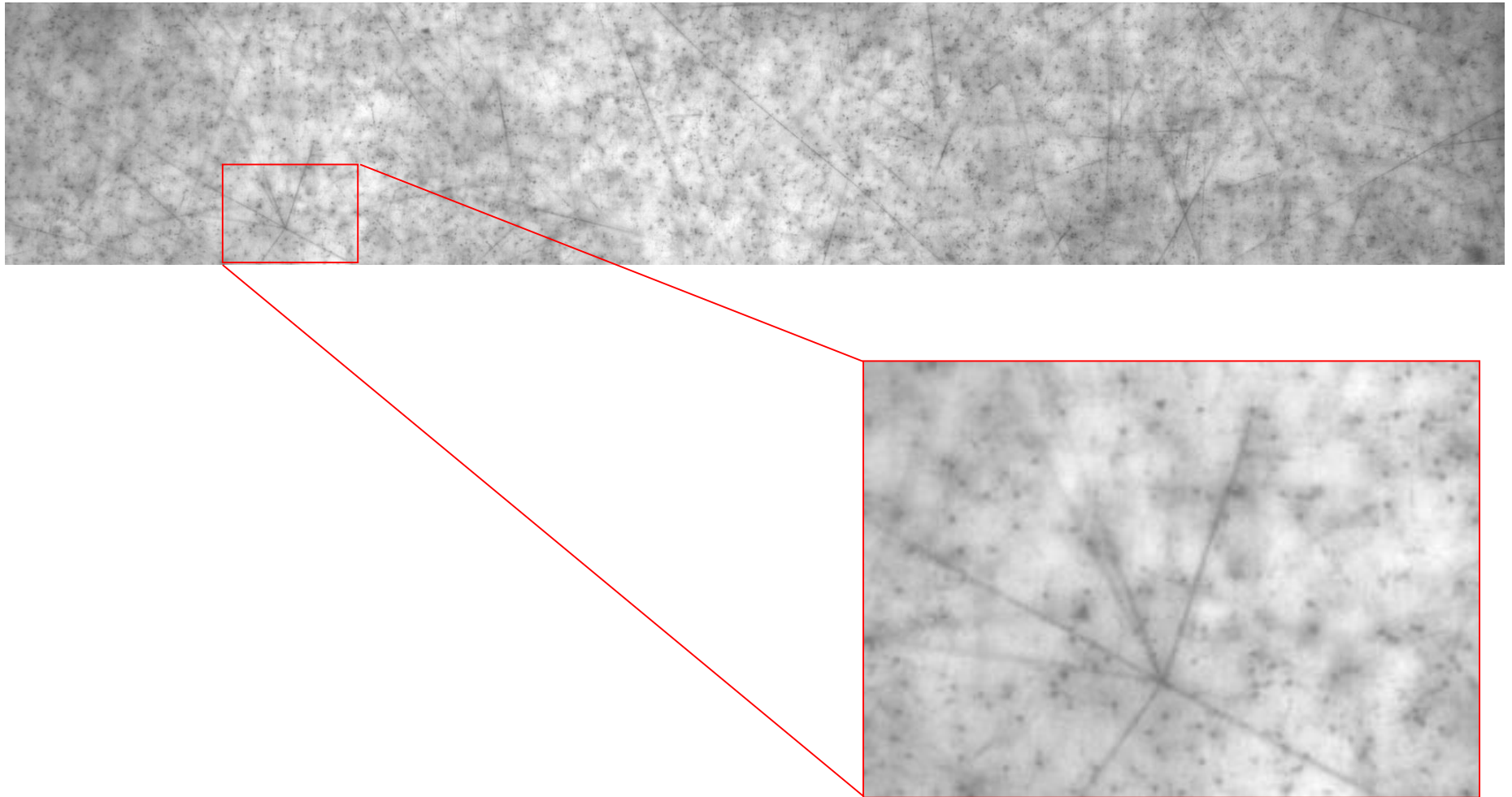
Designed speed:

10mm*10mm*0.9mm / 2min. = ~40 hours @plate (340*335*0.9[mm³])

To accomplish scanning of ~1000 films within a few year.

Pixel size: 2048*358

Field of view 1142 μm * 200 μm

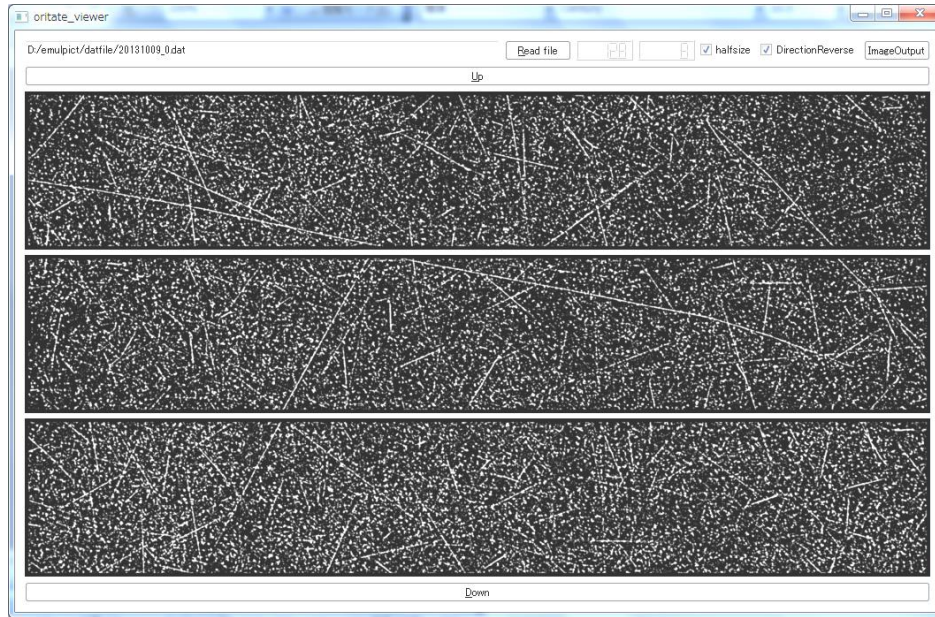


Fast-speeded and Exhaustively 3D scanning works successfully

* Stage drive, piezoelectric, camera are synchronized. Trigger timing is proper.

* Missed trigger and troubles in data transfer < 3%

Exhaustiveness of image taking

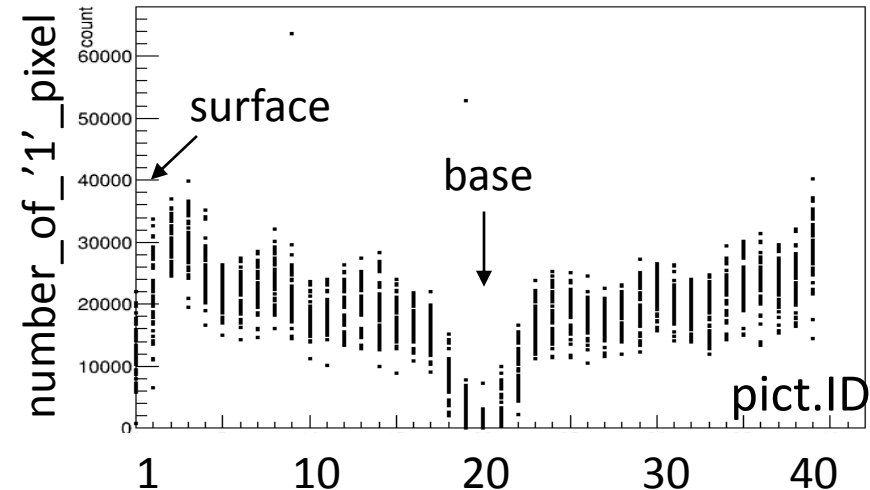
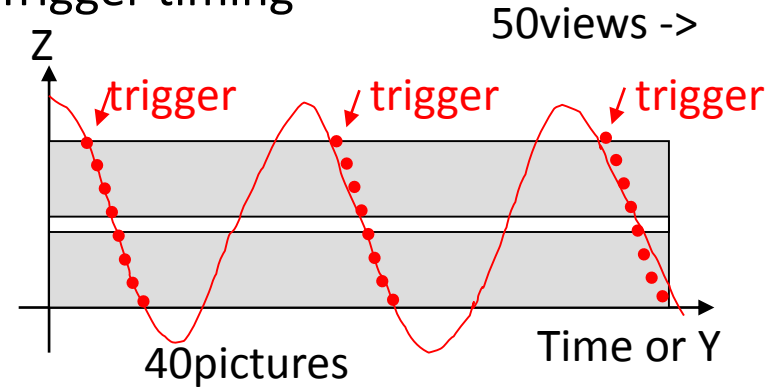


Tiled binalized images.

200micron*1140micron*3views

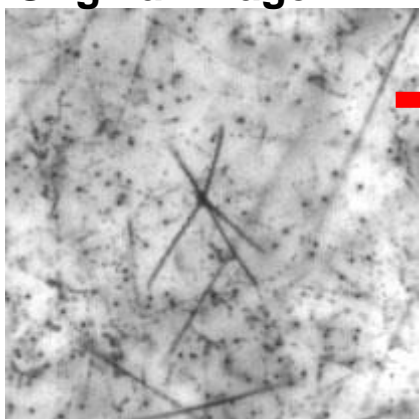
The same layer ID

Trigger timing



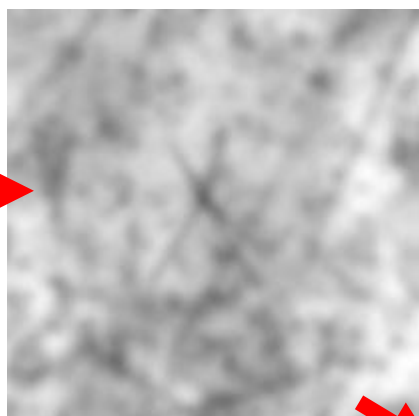
(2). Image process

Original image



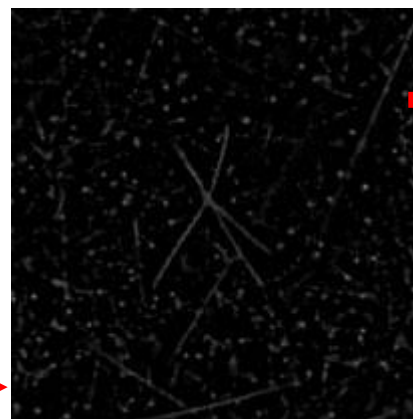
x20 Objective (NA0.35)
1 pix = ~0.6 micron

Gaussian filter



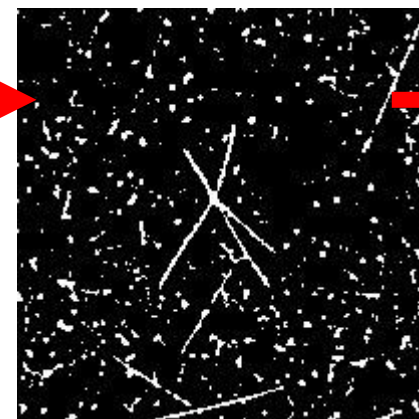
kernel size = 17pix

Difference of Gaussian



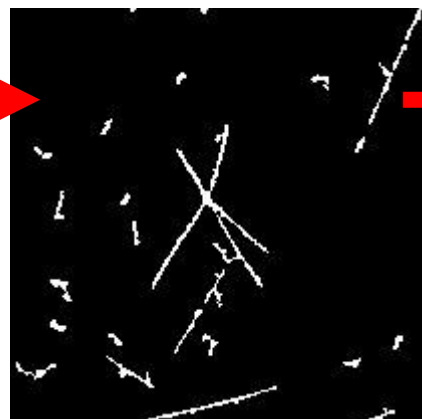
(smoothed - source)
if negative, brightness=0

Binalization



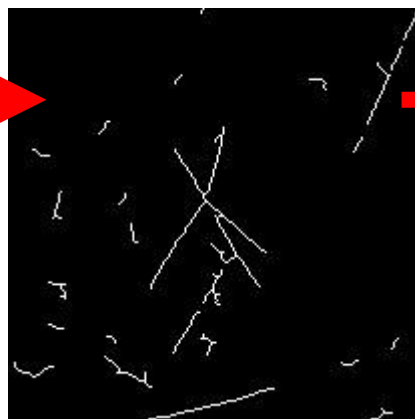
threshold \sim peak*0.2

Filter for bold tracks

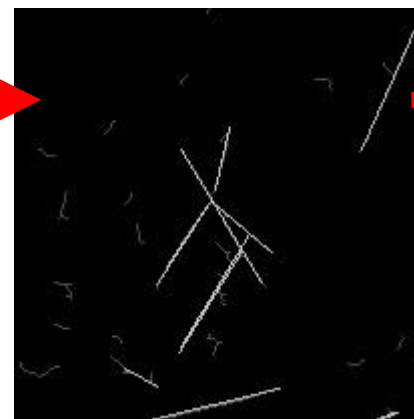


contour length > 5pix
area > 10pix

Thinning



Prob. Hough Trans.



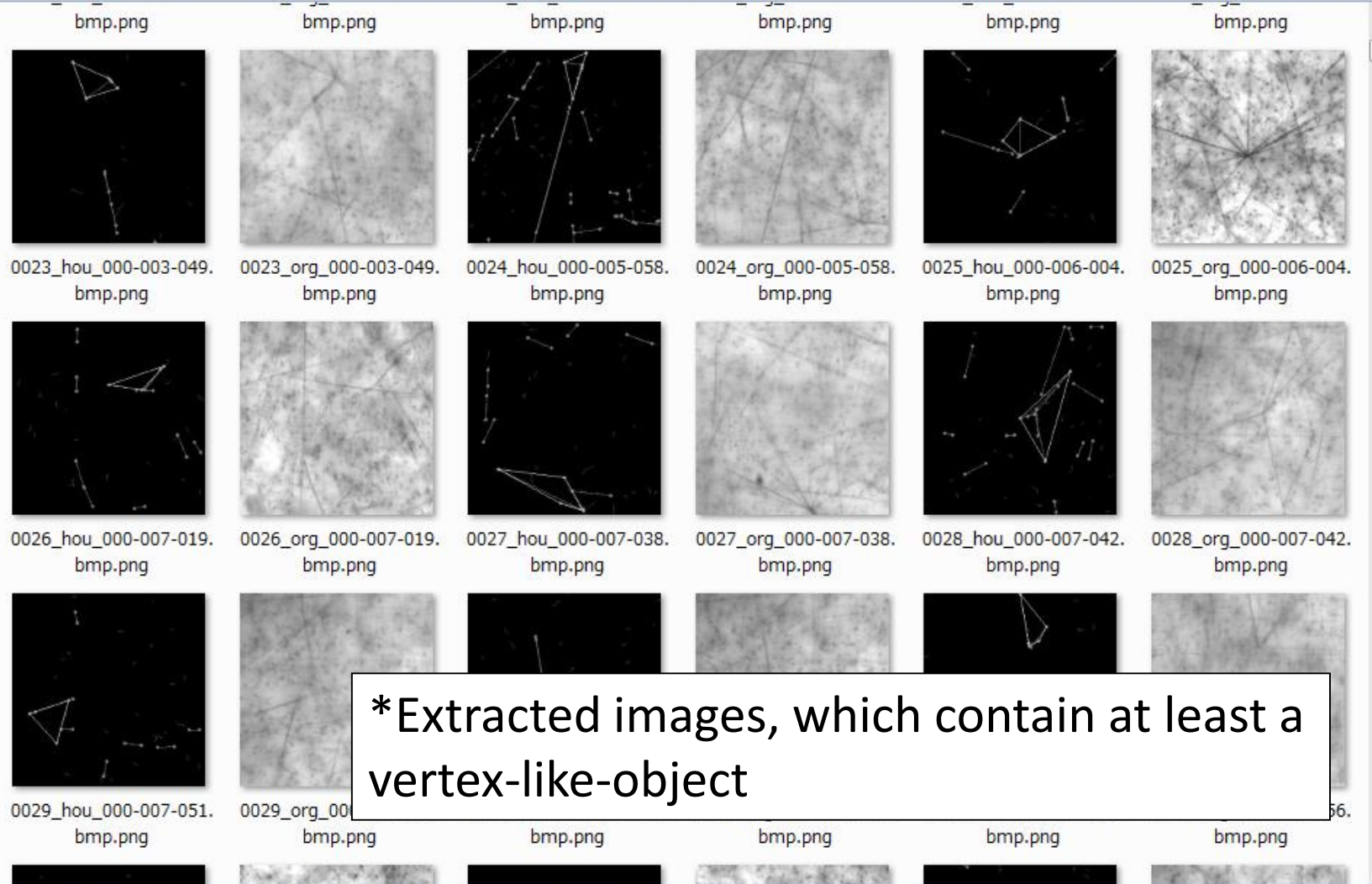
resolution = 1degree
threshold = 16 pix / line

Vertexing



dist-edge-to-edge = 15pix
N_Tracks > 3
polygon area > 1000pix

- お気に入り
- ダウンロード
- デスクトップ
- 最近表示し
- ライブラリ
- ドキュメン
- ピクチャ
- ビデオ
- ミュージック
- ホームグルー
- コンピュータ
- ローカル デ
- ローカル デ
- SD Card (G
- htdocs (¥¥:
- MSN の My
- ネットワーク



*Extracted images, which contain at least a vertex-like-object

Operation

Prototype → Upgraded

High-speed

Since Stage	~2011	2014	2013
Camera		100fps CCD	800fps CMOS
Z-drive		Stepping motor	Piezoelectric
Optics			
Field of View	0.11*0.13mm ²	0.18*0.21mm ²	0.20*1.14mm ²
Speed[mm ³ /h]	2.6	13.1	2700
Site	Gifu-univ. Toho-univ,Japan GNU,Korea	Gifu-univ. GNU,Korea	Gifu-univ.

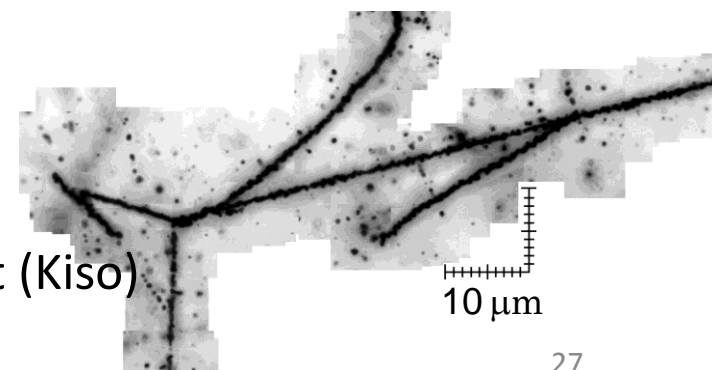
Found events;

~10⁴ alpha decays

~500 single hypernuclear event

7 three-vertexes candidates.

A typical twin-single-lambda- hypernuclear event (Kiso)



Summary

*J-PARC E07 has started to investigate the $\Lambda\Lambda$ interaction energy systematically with nuclear emulsion.

*Fully automated track following

Proof of concept is successful.

Study for steady operation is being carried out.

* Overall scanning

In operation in Gifu-univ., Toho-univ., Japan, GNU, Korea.

~700 candidates of single hypernuclear

~7 3-vertexes candidates.

A typical twin-single-lambda- hypernuclear event (Kiso)

Improvement of detection efficiency and S/N ratio is being carried out.

Second image-taking and image-process under x50 objective lens

Acknowledgements

*JSPS KAKENHI Grants Number 23224006

*MEXT Grants Numbers 15001001, 24105002

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