Fully Automatic Ξ^- Hyperons Tracking in Dense Exposed Nuclear Emulsion

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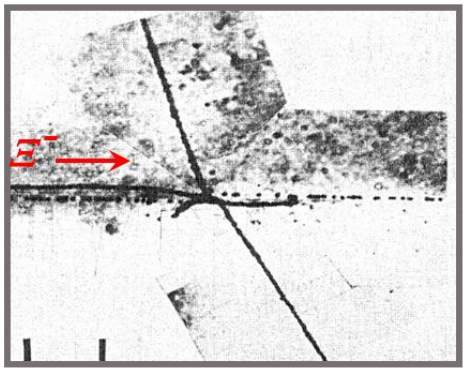
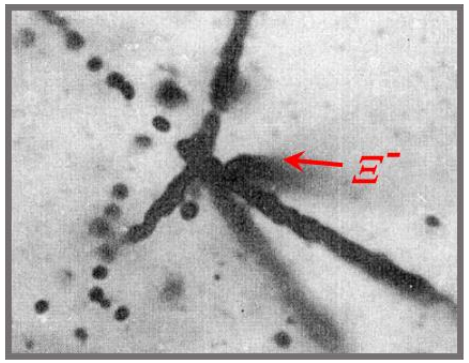
Introduction

For information of Λ-Λ & Ξ-N in S= -2 system;
Double-Λ hypernuclei and Ξ- hypernuclei are uniquely available sources

Revisit to double- Λ hypernclear events

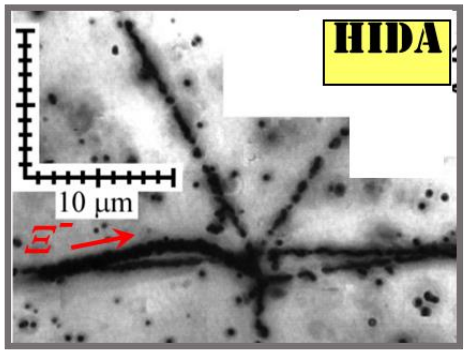


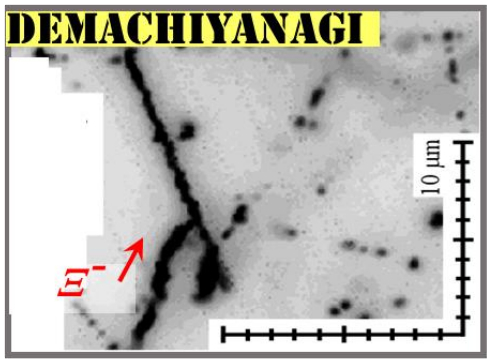
M.Danysz et al., PRL.11(1963)29;
First observation



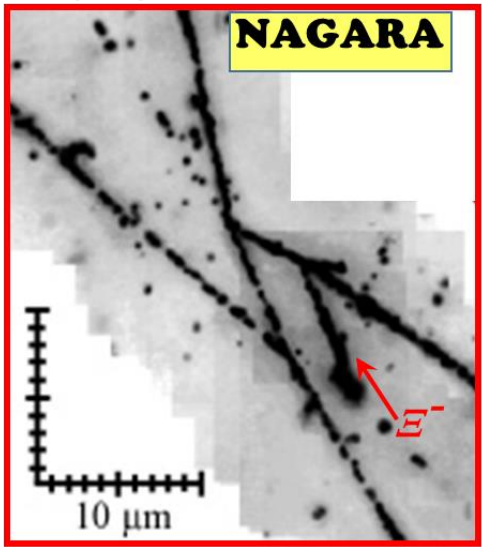
KEK-PS (E176); 1988 ~

S.Aoki et al., NP. A828 (2009) 191-232
Confirm existence of double Λ hypernucleus

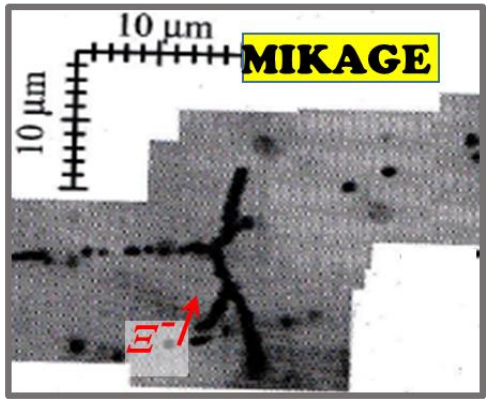




Uniquely identified



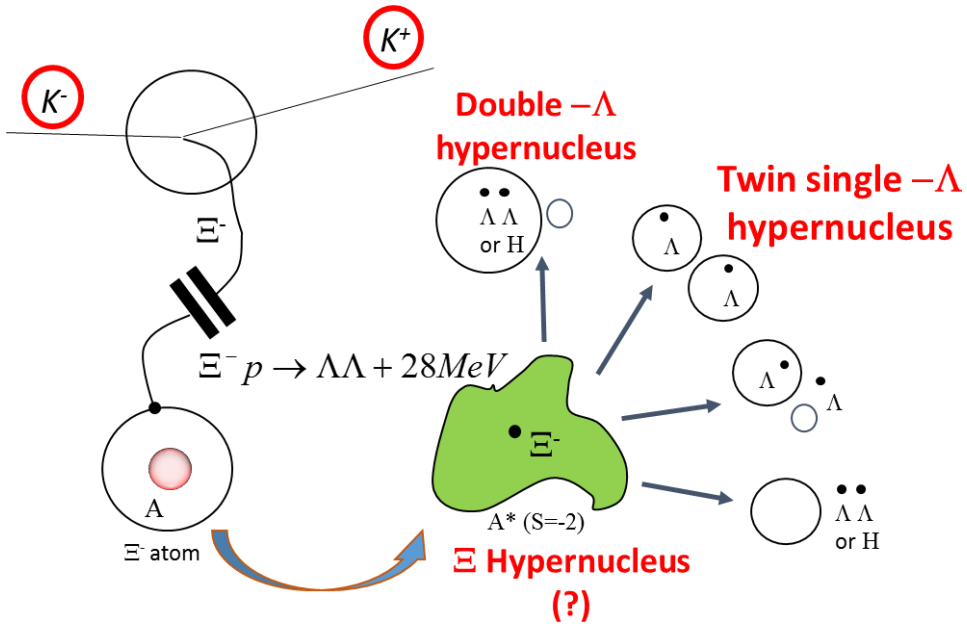
KEK-PS(E373)
1995~



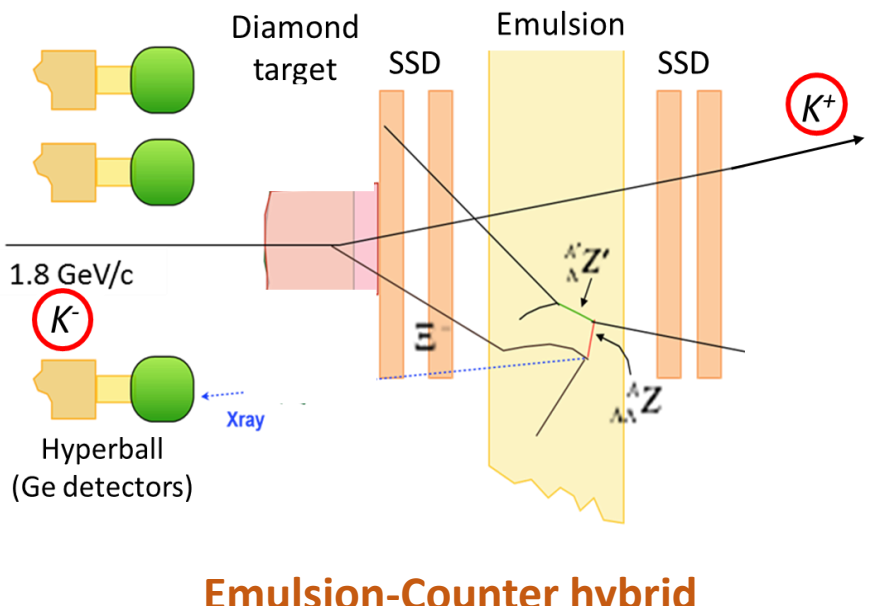
J. K. AHN et al., PRC 88 (2013) 014003

- Among double-Λ hypernuclear events, **NAGARA** event is uniquely identified to be 0.67±0.17 MeV for Λ-Λ interaction [Ref: *J. K. AHN et al., PRC 88 (2013) 014003*]
- In order to understand Λ-Λ interaction without nuclear core effect >> Λ-Λ interaction in different nuclear species
- To do so, E07 experiment will be carried out at J-PARC

Production of S = -2 in nucleus



E07 set up



Emulsion-Counter hybrid

By following Ξ- in emulsion with assist of SSD data, double -Λ hypernucleus will be detected

E373 & E07

Ref: Propsal for K1.8 beam line at J-PARC, http ; / / j-parc.jp / researcher / Hadron / en / pac_0606 / pdf / p07-Nakazawa.pdf (2006)

	E373	E07
Double-Λ hypernuclear event	7	~ 100
Twin single-Λ hypernuclear event	2	~ 30
Ξ^- stopping events in emulsion	~ 10^3	10^4

Found by X- candidates tracking for **several years**

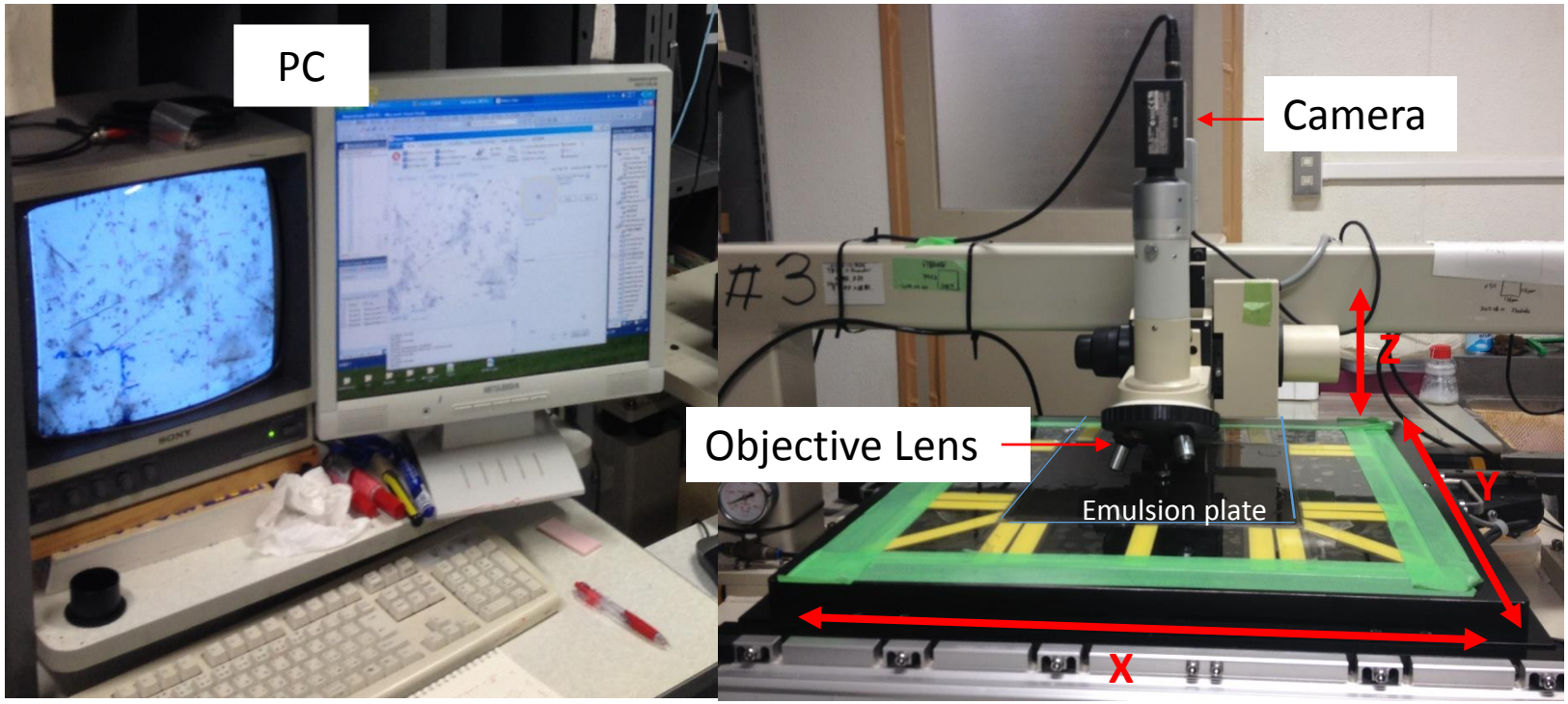
How long???

In order to finish all Ξ^- candidates following in a few years and to reduce human-power, automatic Ξ^- tracking in nuclear emulsion plate is developed

Motivation of this work

“Automatic Ξ^- tracking in dense exposed nuclear emulsion”

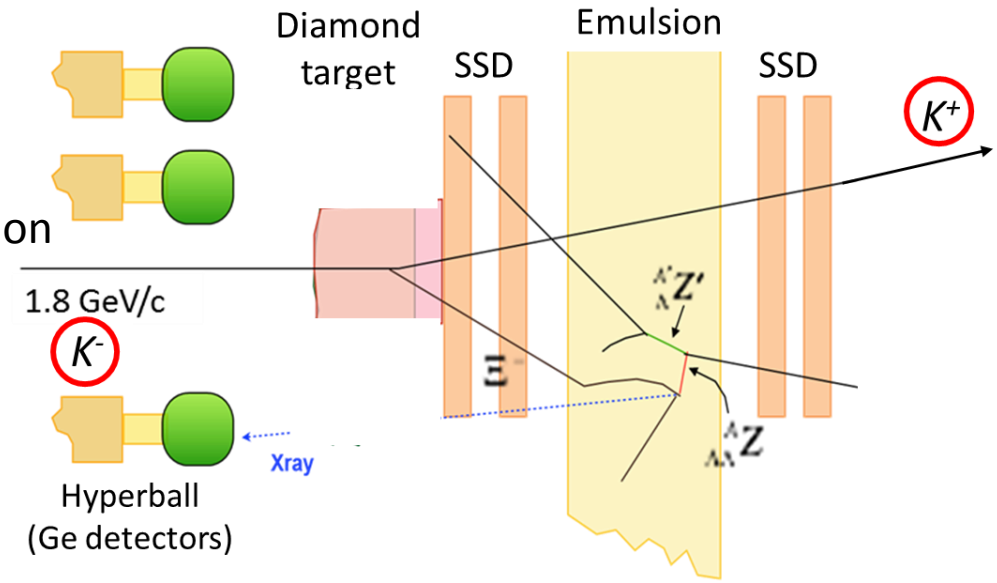
Computer-aided Microscope System

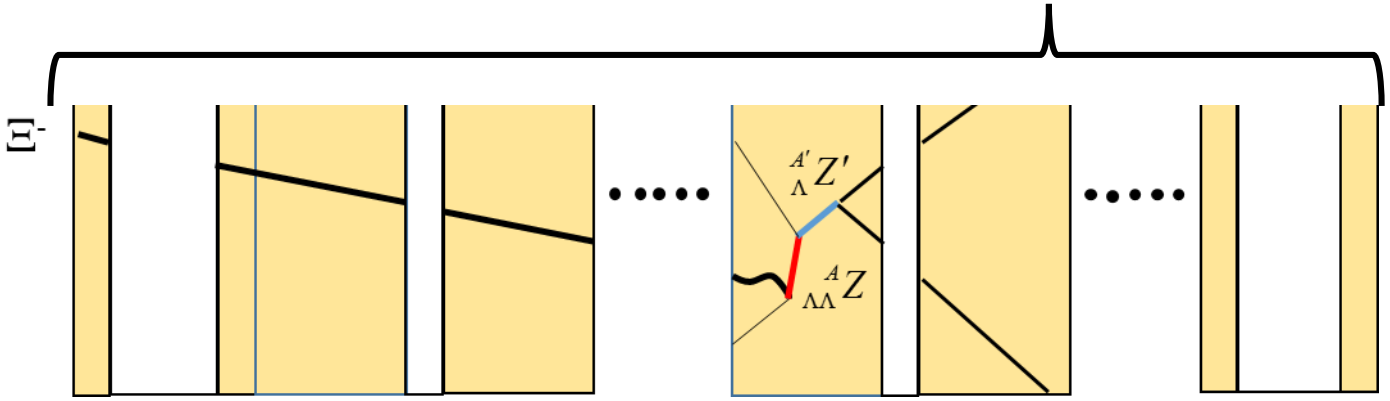


Flow of Method

- Track data (angle dx/dz, dy/dz, (x_0,y_0) from SSD or previous plate)

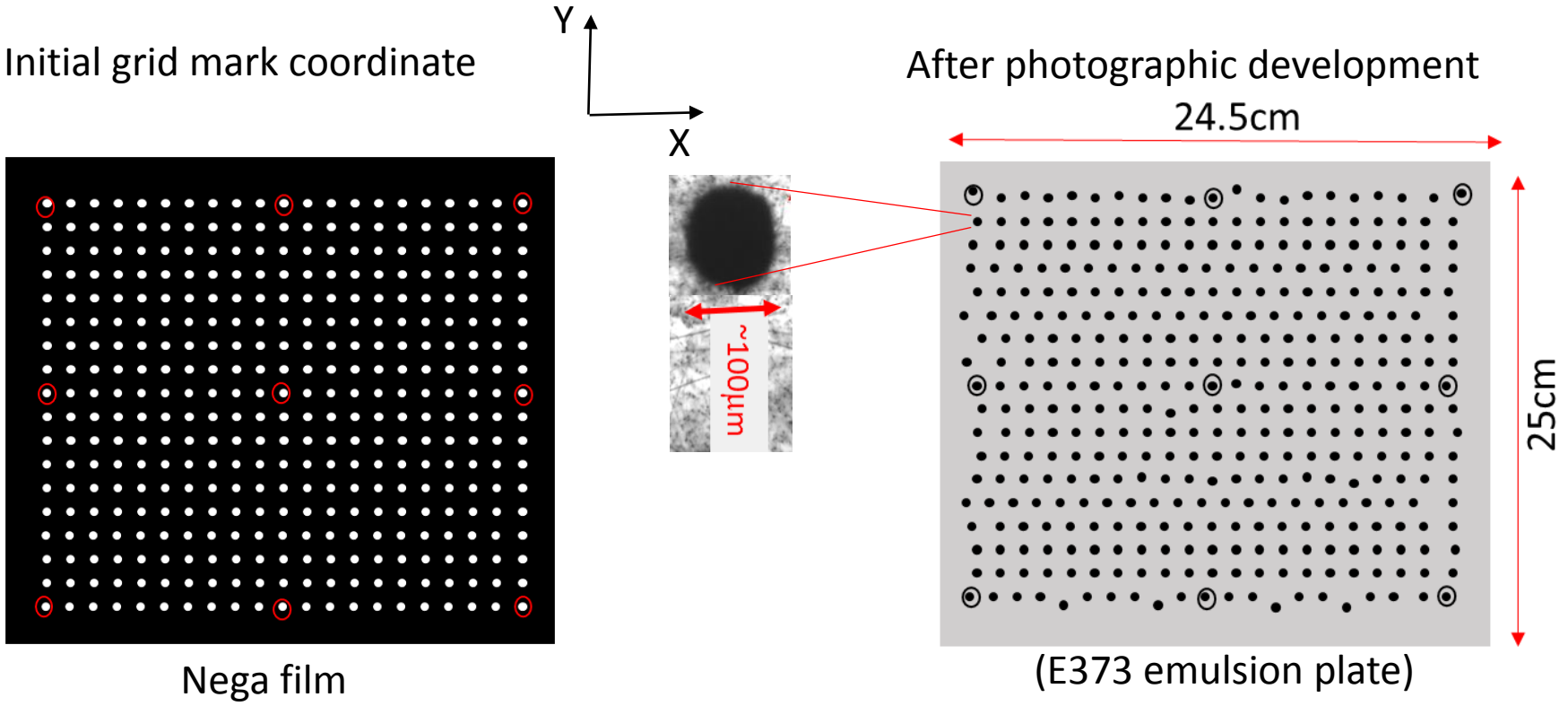
1. Track position estimation in emulsion
2. Correction of the track position
3. Plate to plate alignment
4. Emulsion surface detection
5. Track following





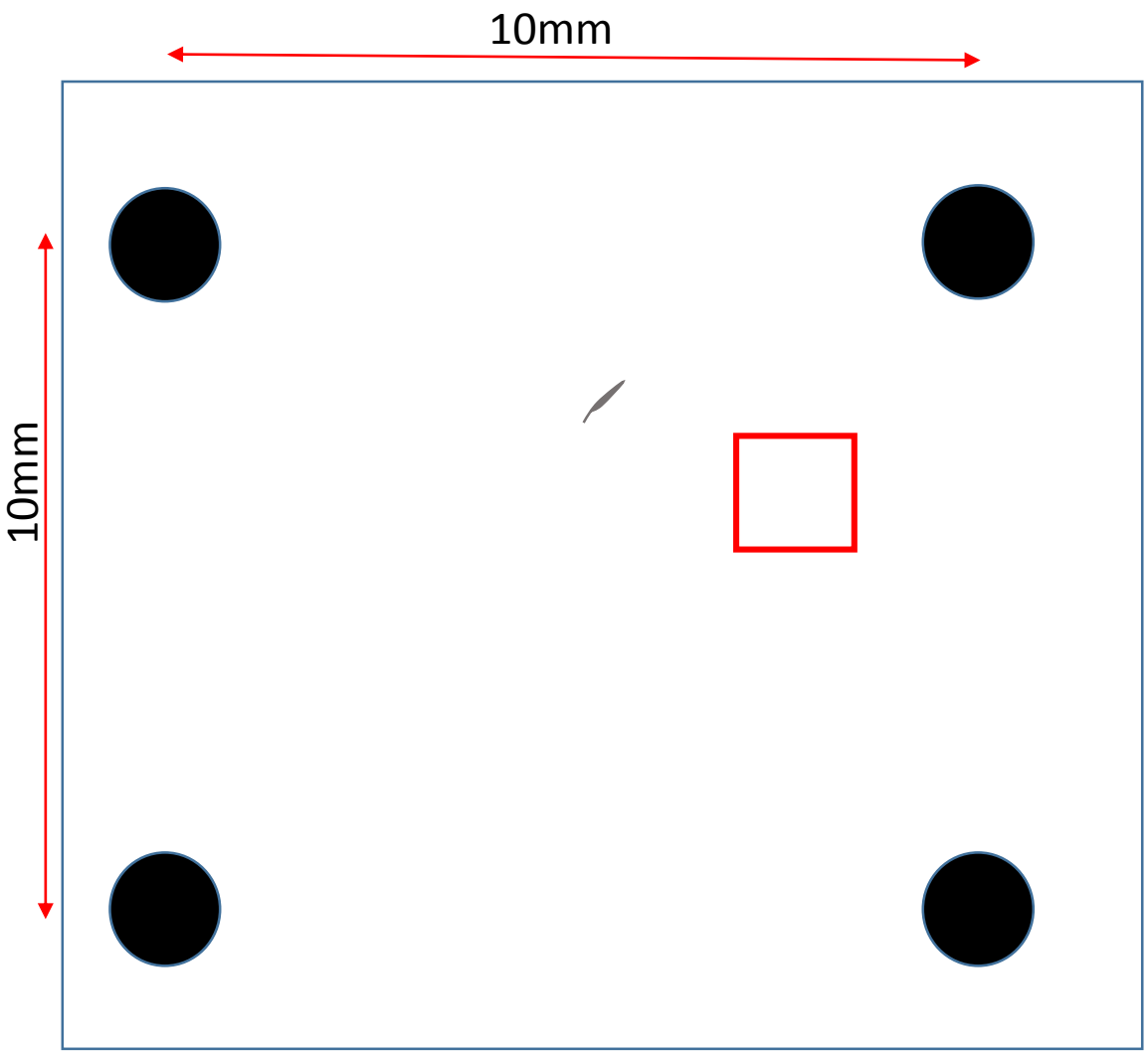
#E373 emulsion plates are used to develop tracking system#

Track position estimation in emulsion



- Grid marks are printed at 1 cm intervals on emulsion plates (same in E07)
- By measuring coordinates of 9 grid marks of current emulsion plates after photographic development and they are mapped with initial grid coordinates
- Affine parameters are given and all tracks` positions are estimated by use of this parameters.

Correction of estimated track position



One view of 50× microscope lens (125 μm × 130 μm)

Followed track

Grid mark

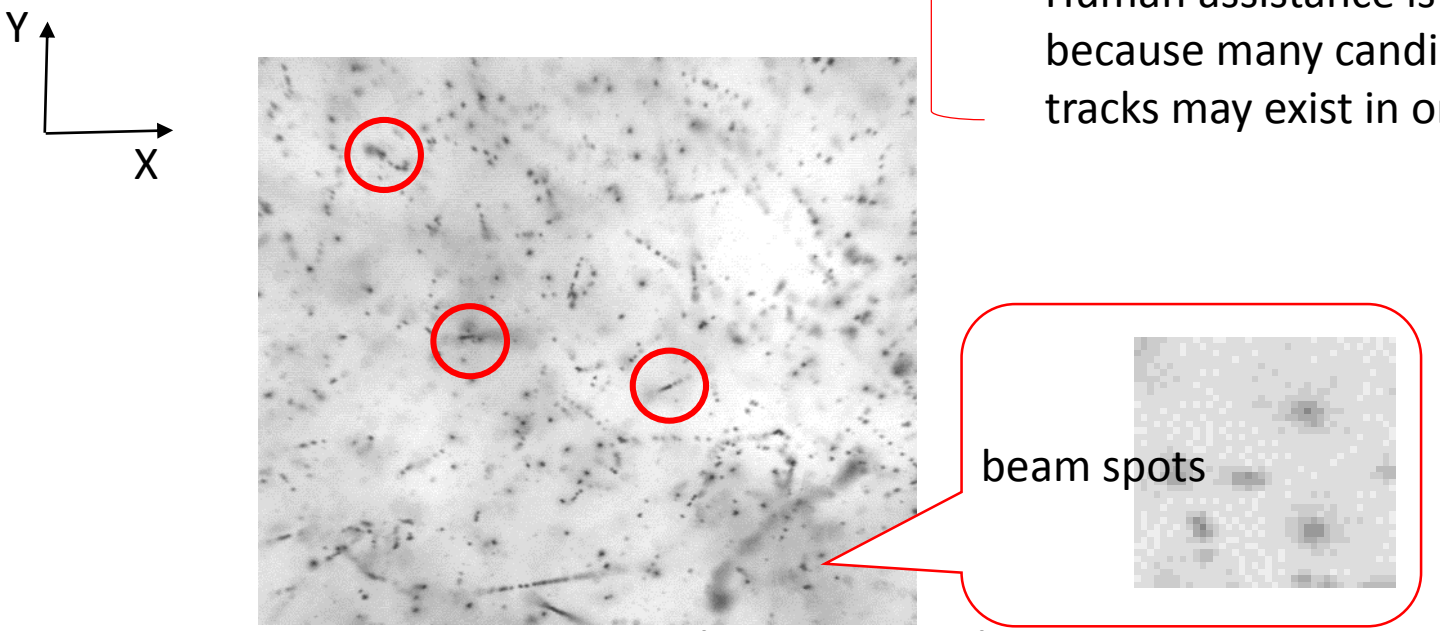
- Go and search near grid mark
- Take coordinate of this grid mark and get affine parameter
- Correct estimated track position

Accuracy is 17.4 ± 9.2 μm

- Track exist within one view

Alignment of plate by plate connection with K^- beam matching

- Alignment with grid marks :: 17.4 ± 9.2 μm
  - Not enough for automated system
  - Human assistance is required because many candidate tracks may exist in one view

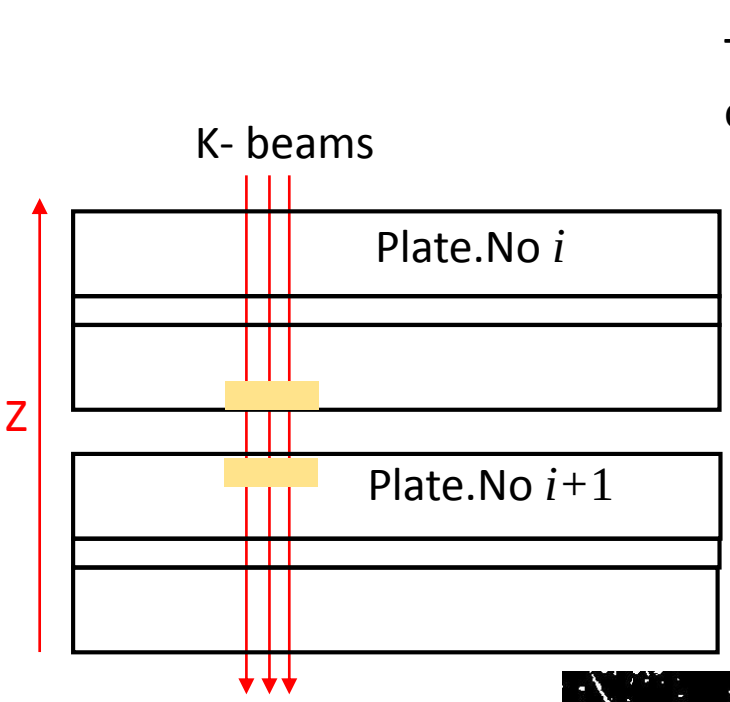


One view of 50× objective lens (125 μm × 130 μm)

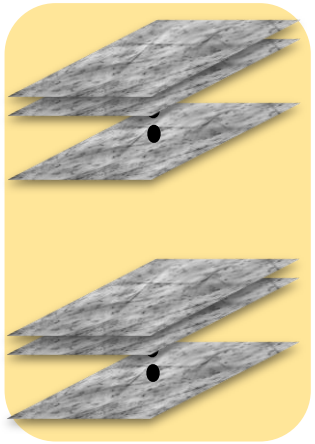
- For automated system, it is necessary about 1 μm alignment accuracy

K^- beam pattern matching method is performed

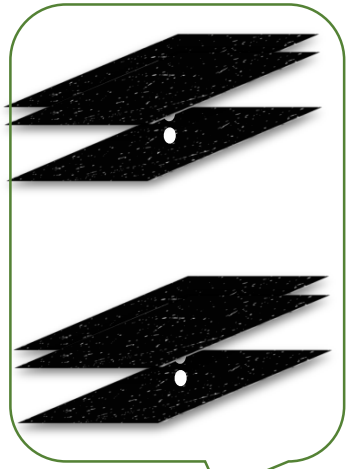
Gathering beam pattern from microscope image



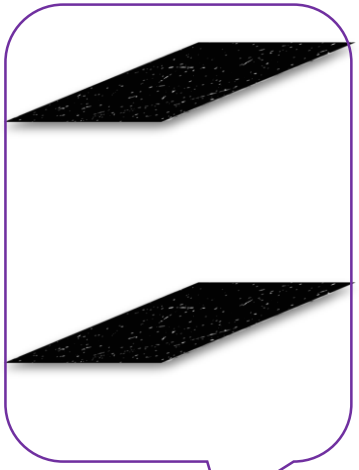
Take 7 micrographs on both sides

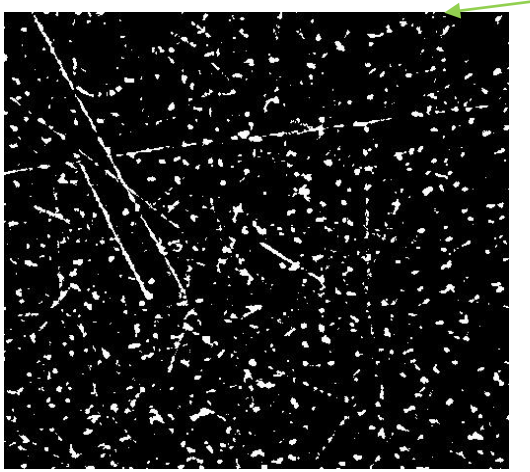


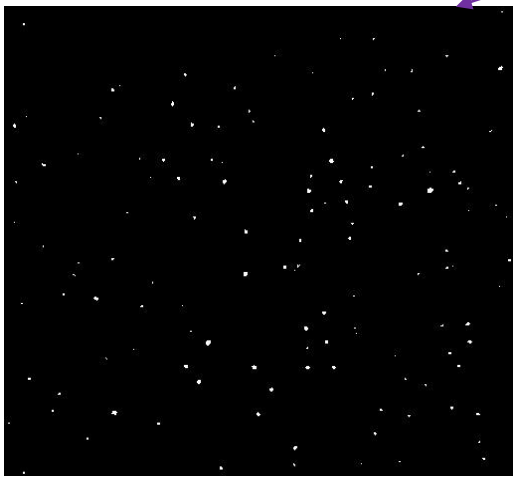
Processed images



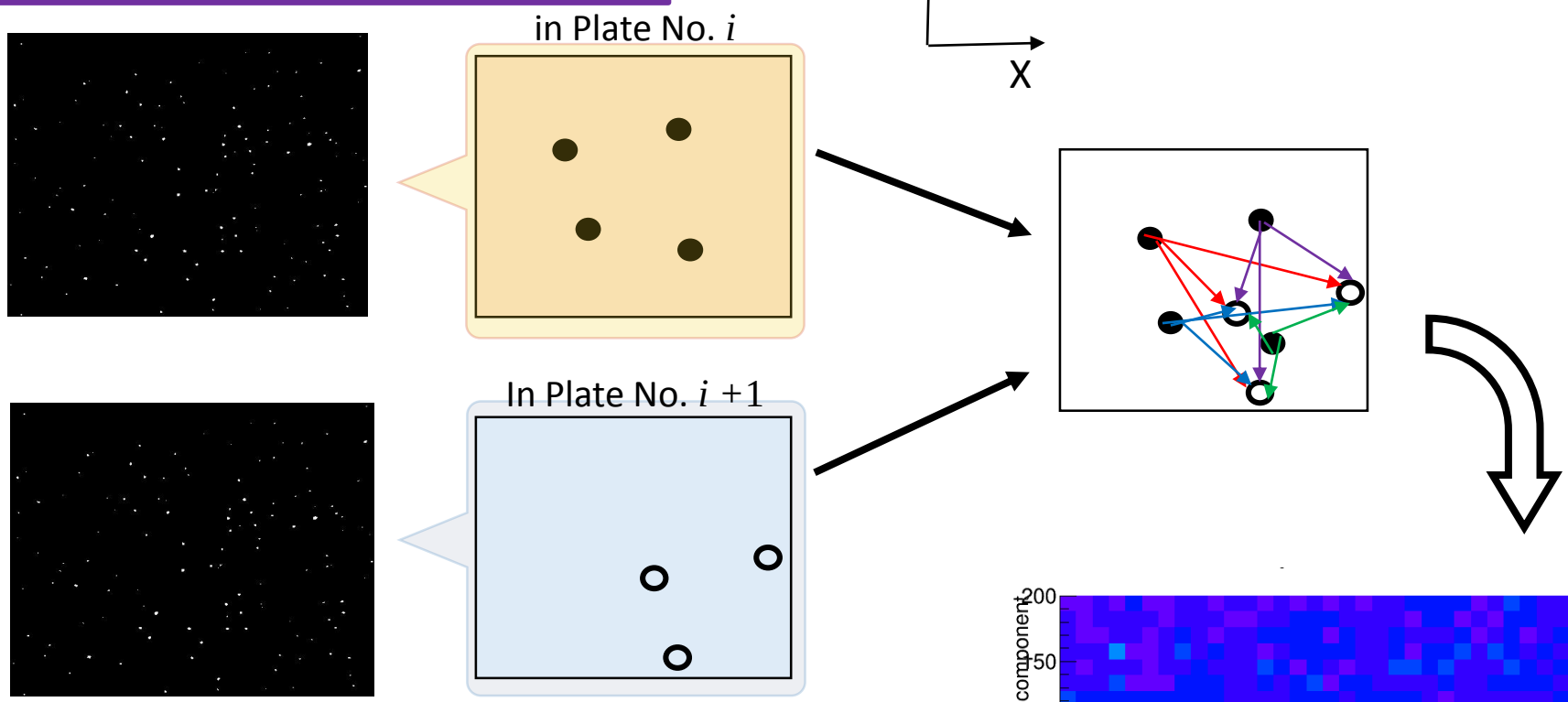
Superimposed and Binarized image



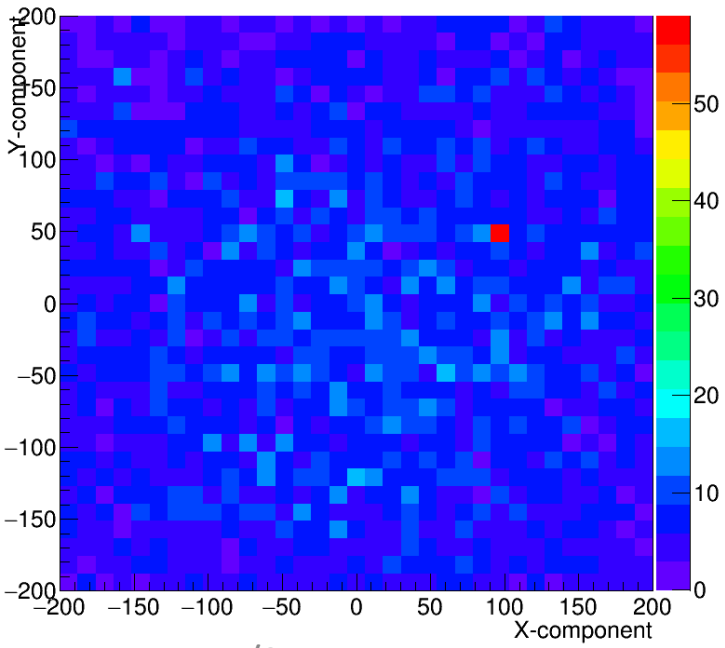




Beam pattern matching



Demonstration of beam pattern matching

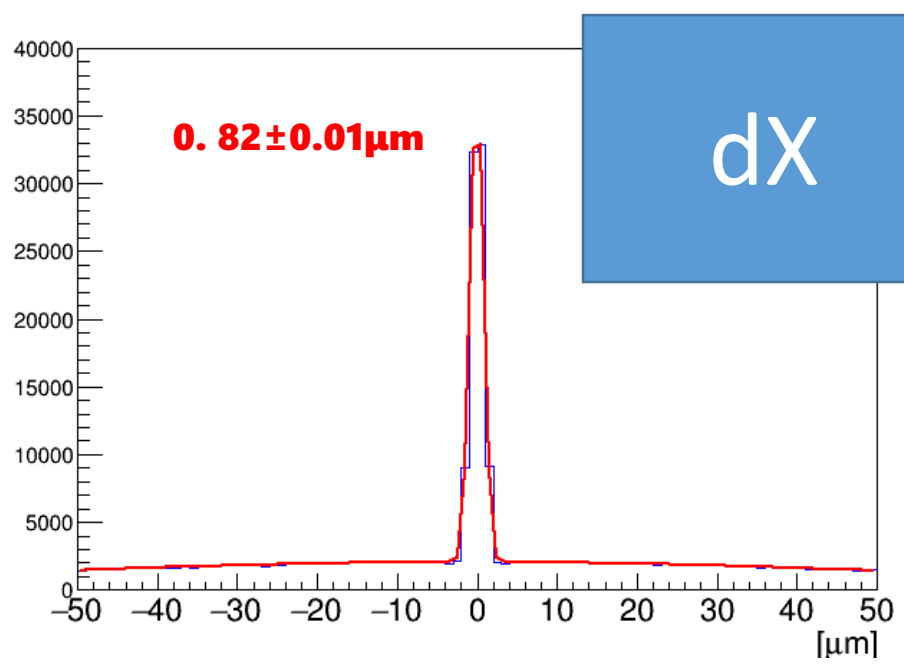


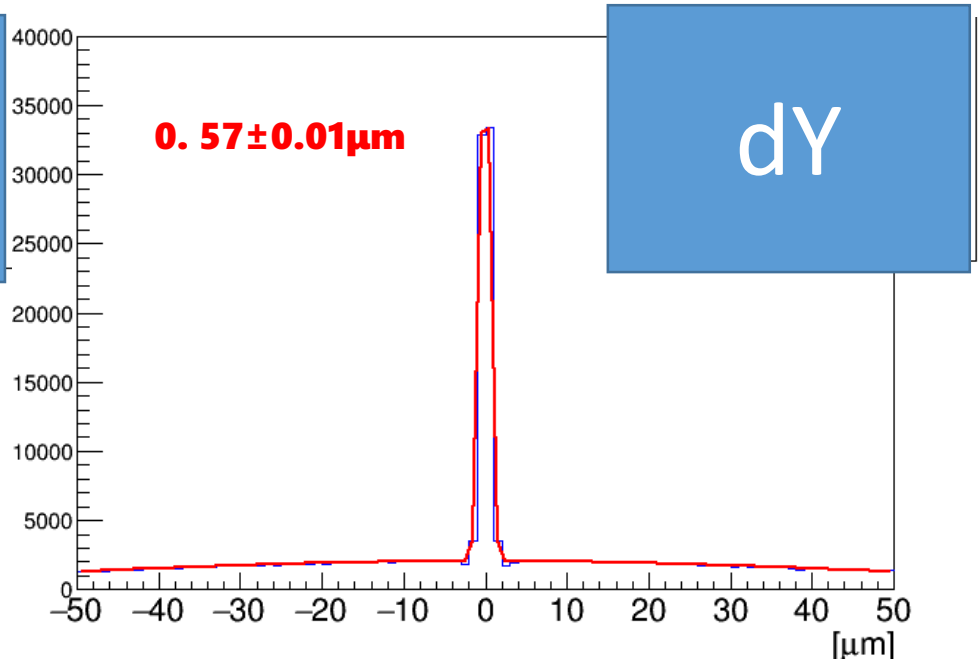
- Peak of 2D histogram becomes the offset (Δx, Δy)

Automatic alignment was successful

- accuracy is less than 1μm

Position accuracy of alignment from 740 image samples

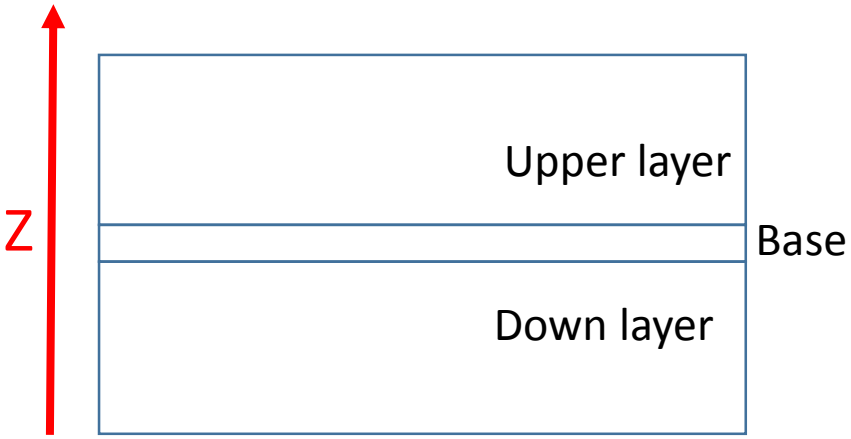




This method is very important for automatic tracking system

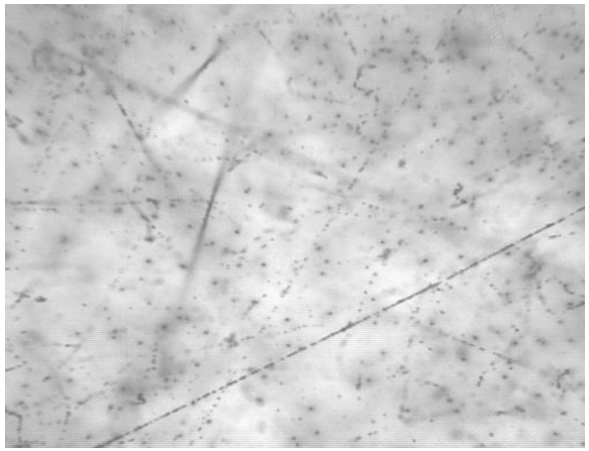
Emulsion surface detection

- Charged particle tracks are visible only in emulsion layers



- It is important to distinguish between inside and outside of emulsion layers
- It can be detected automatically by checking contrast of images along the optic Z- axis with the performance of **image processing**

Micrograph inside of emulsion



Micrograph outside of emulsion

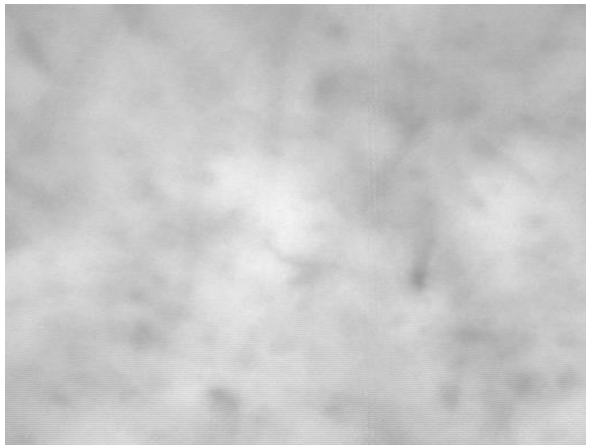
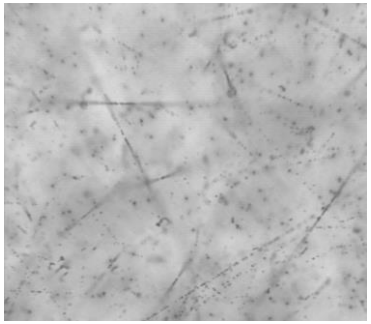
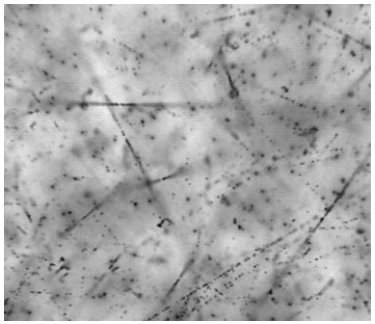


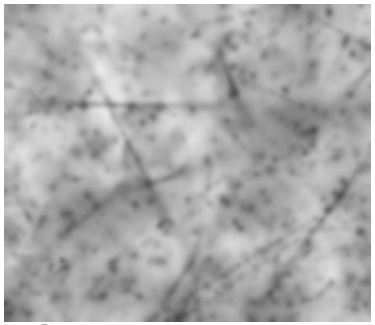
Image processing



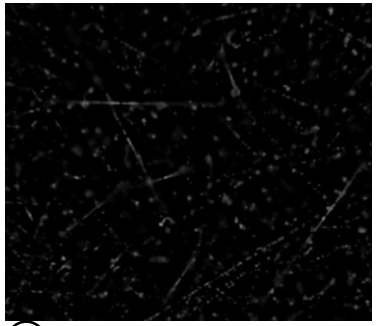
① Original image (micrograph)



② Contrast enhancement

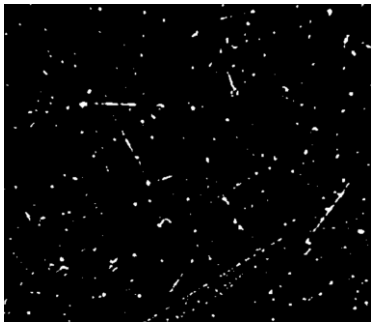


③ Gaussian filter



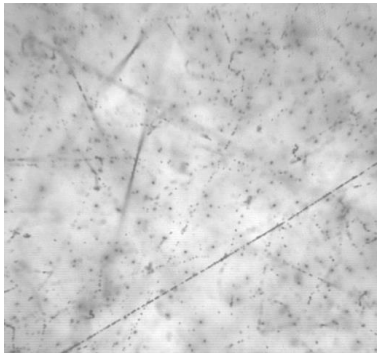
④ Background uniformity

(③ − ②)

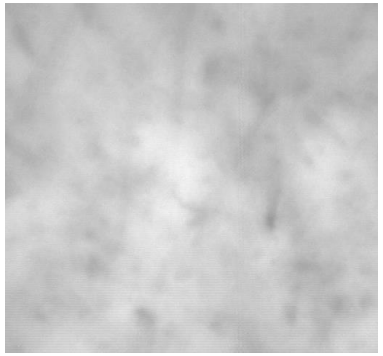


⑤ Binarization

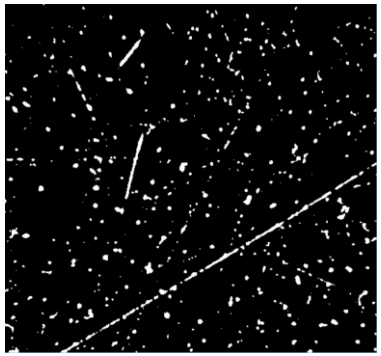
Inside of emulsion



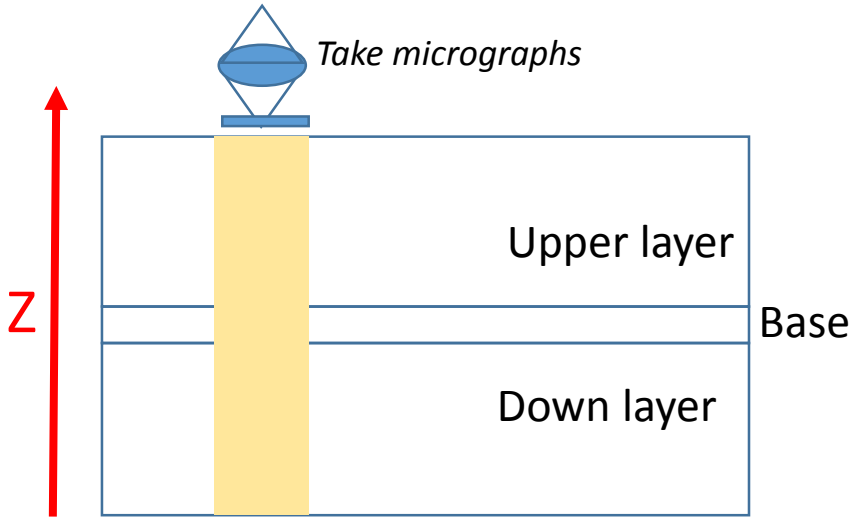
Outside of emulsion

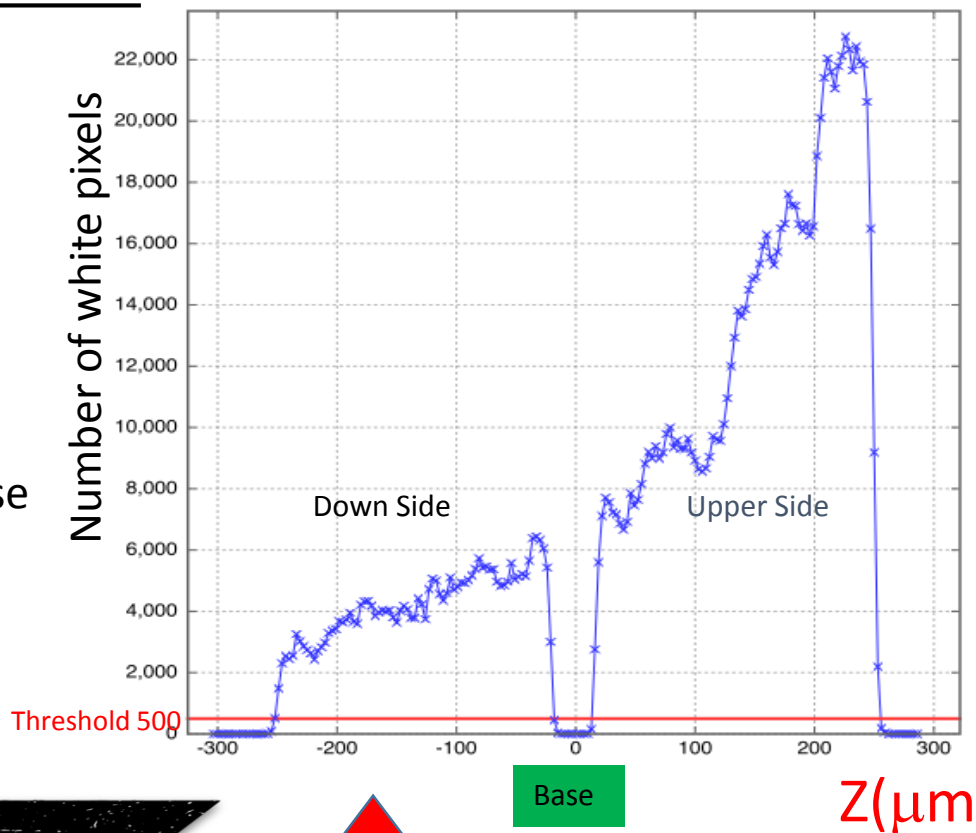


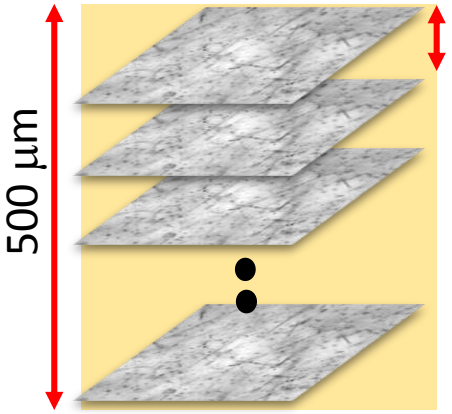
After image processing, the difference between inside and outside of emulsion



Number of white pixels are plotted along Z position







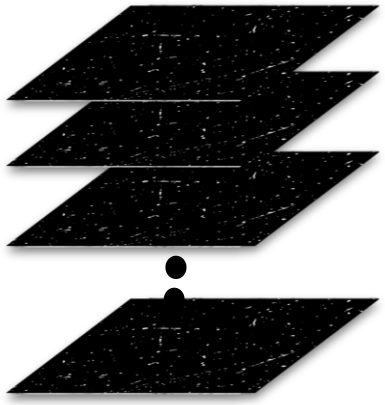


Image processing

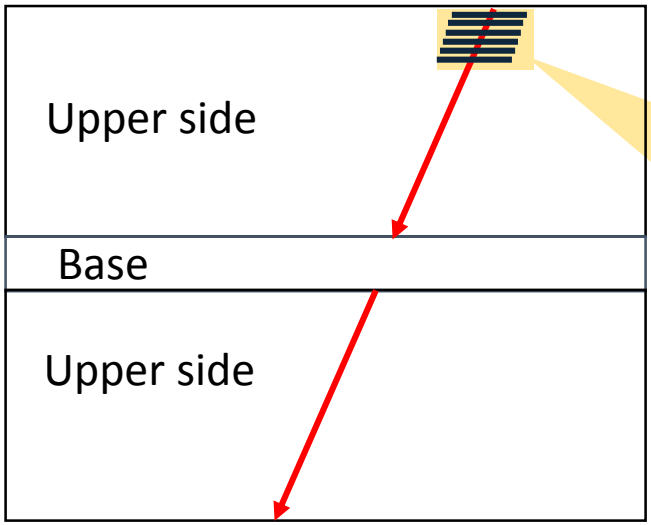
Accuracy of automatic surface detection is 2.6±2.0μm

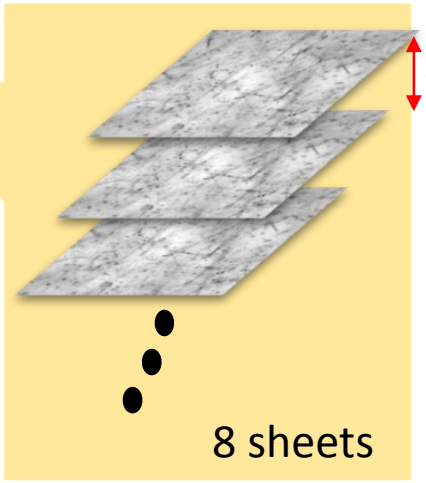
- Sufficient for a fully automatic tracking system

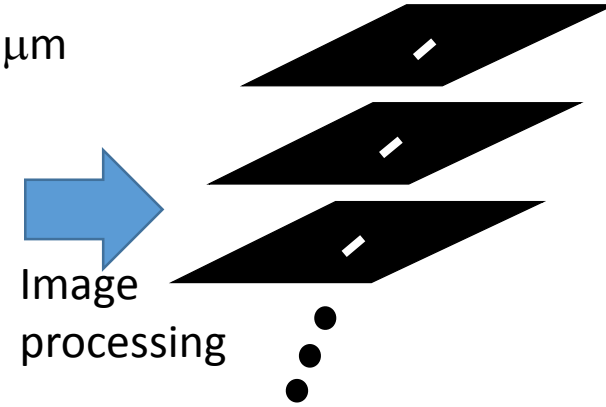
Track Following

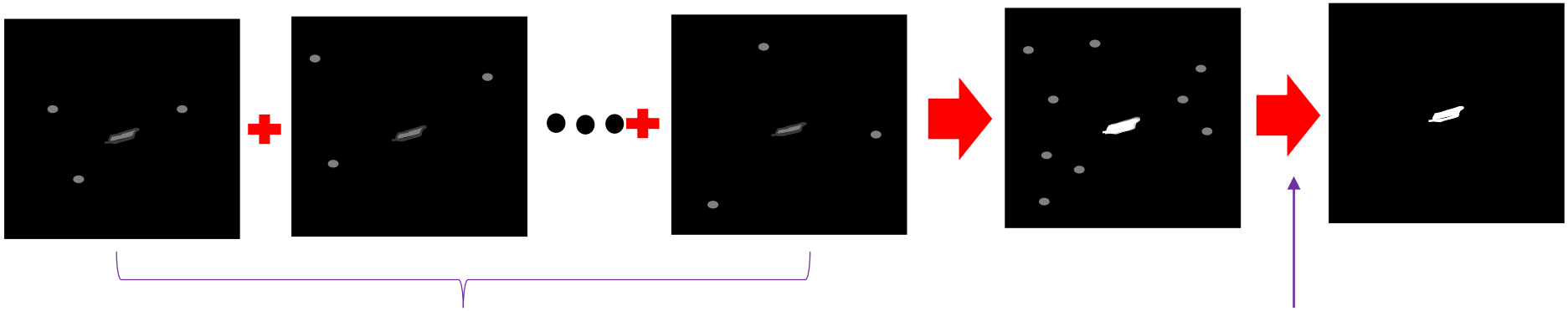
Step 1

- Take 8 micrographs with interval of 6 μm
- Take images slightly shift with estimated angle (tan θ)

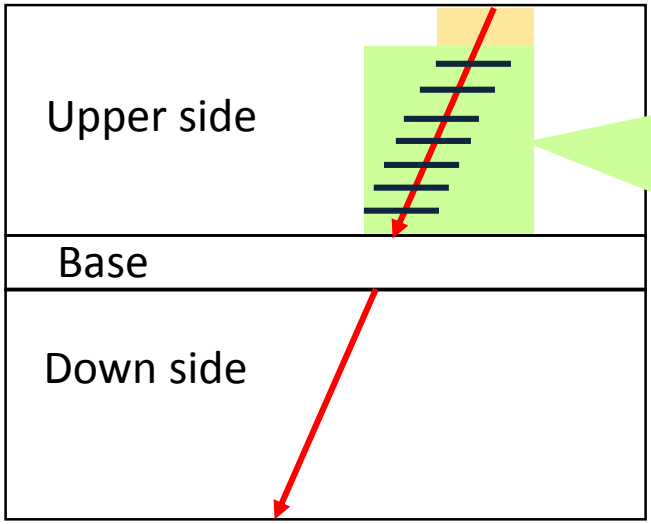


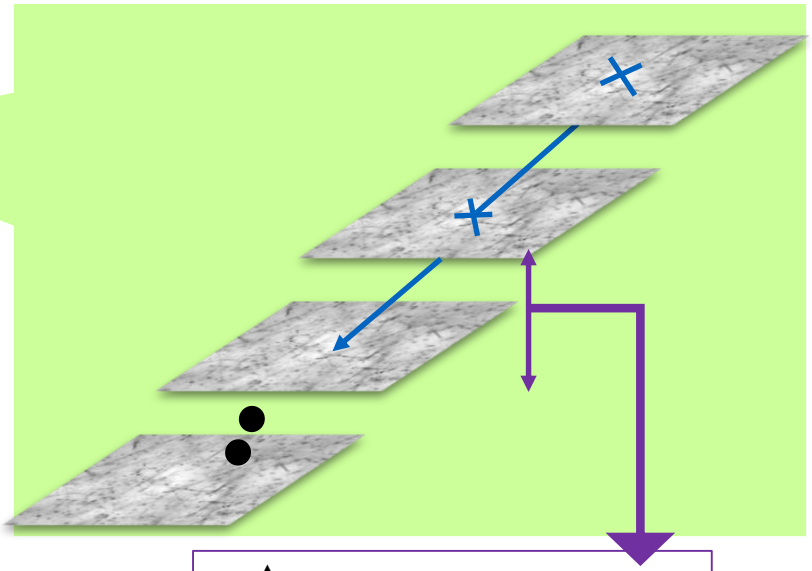




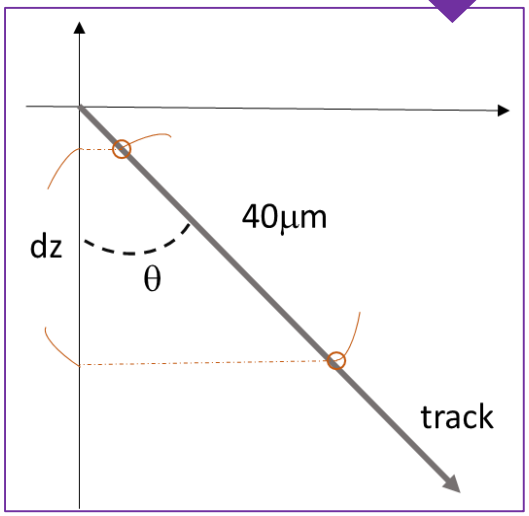


Step 2



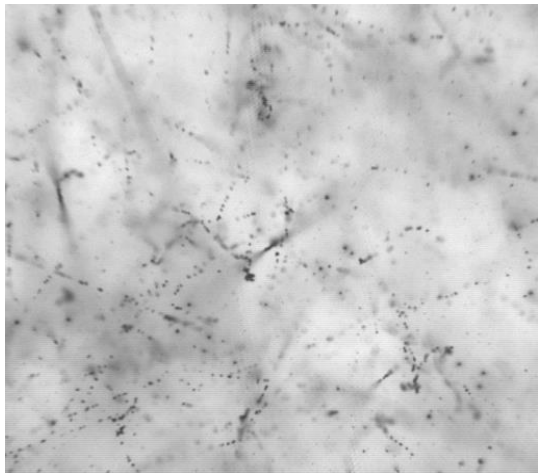


- Take just one image in each estimated positions
- Shift length of dx, dy, dz are calculated to be track range 40 μm
- Tracking in Down side is as same process as in Upper side

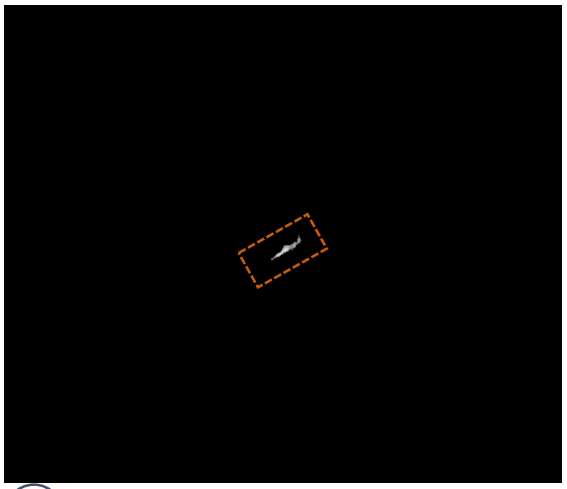


$$\tan\theta = \frac{\sqrt{dx^2 + dy^2}}{dz^2}$$

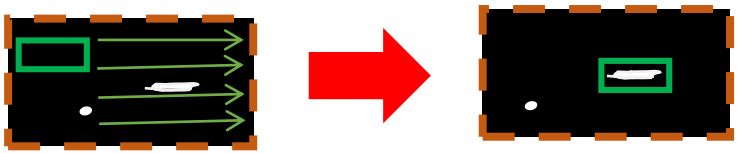
Track recognition in emulsion layer



1 Acquired image

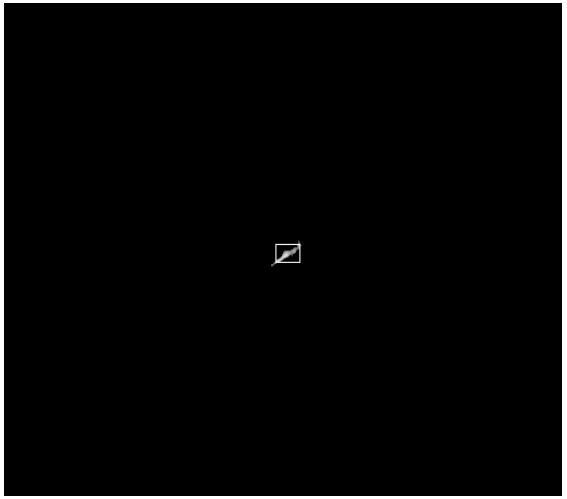


2 Cut track searching range

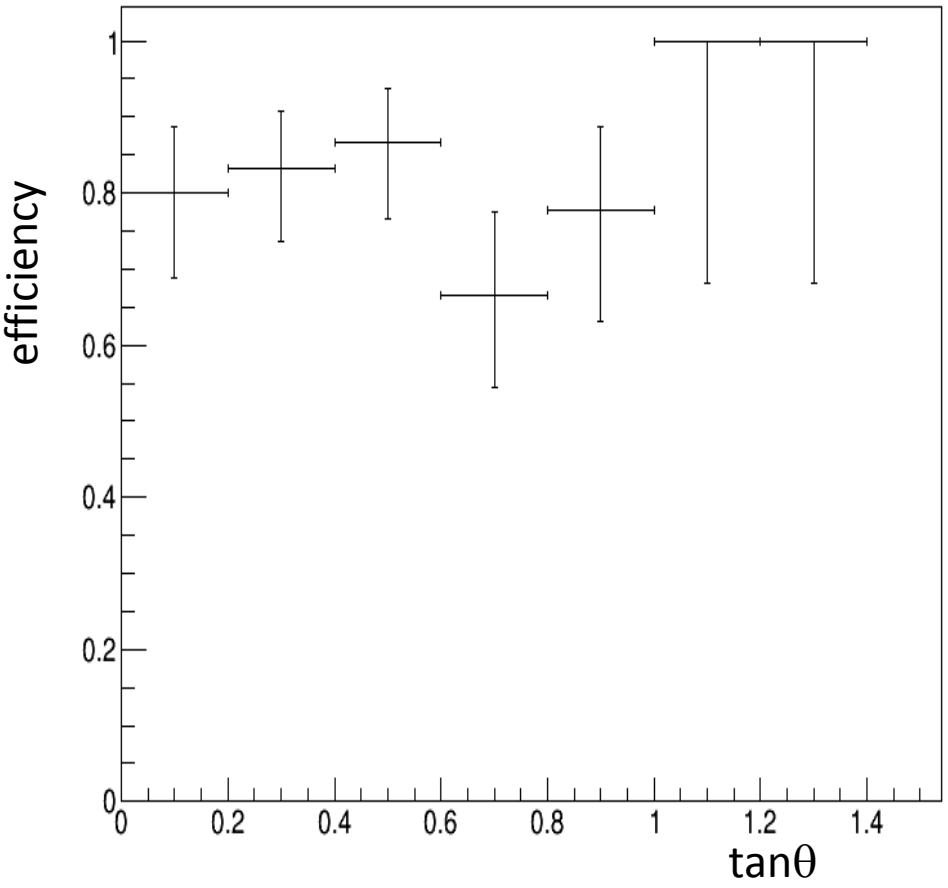


3 Track detection

- Make small mark
- Match small mark in cut range



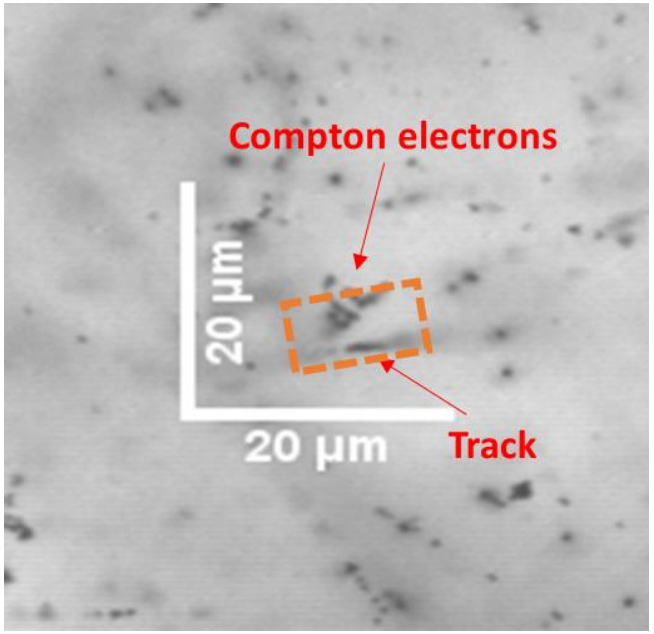
Efficiency of track recognition as track angles (tanθ)



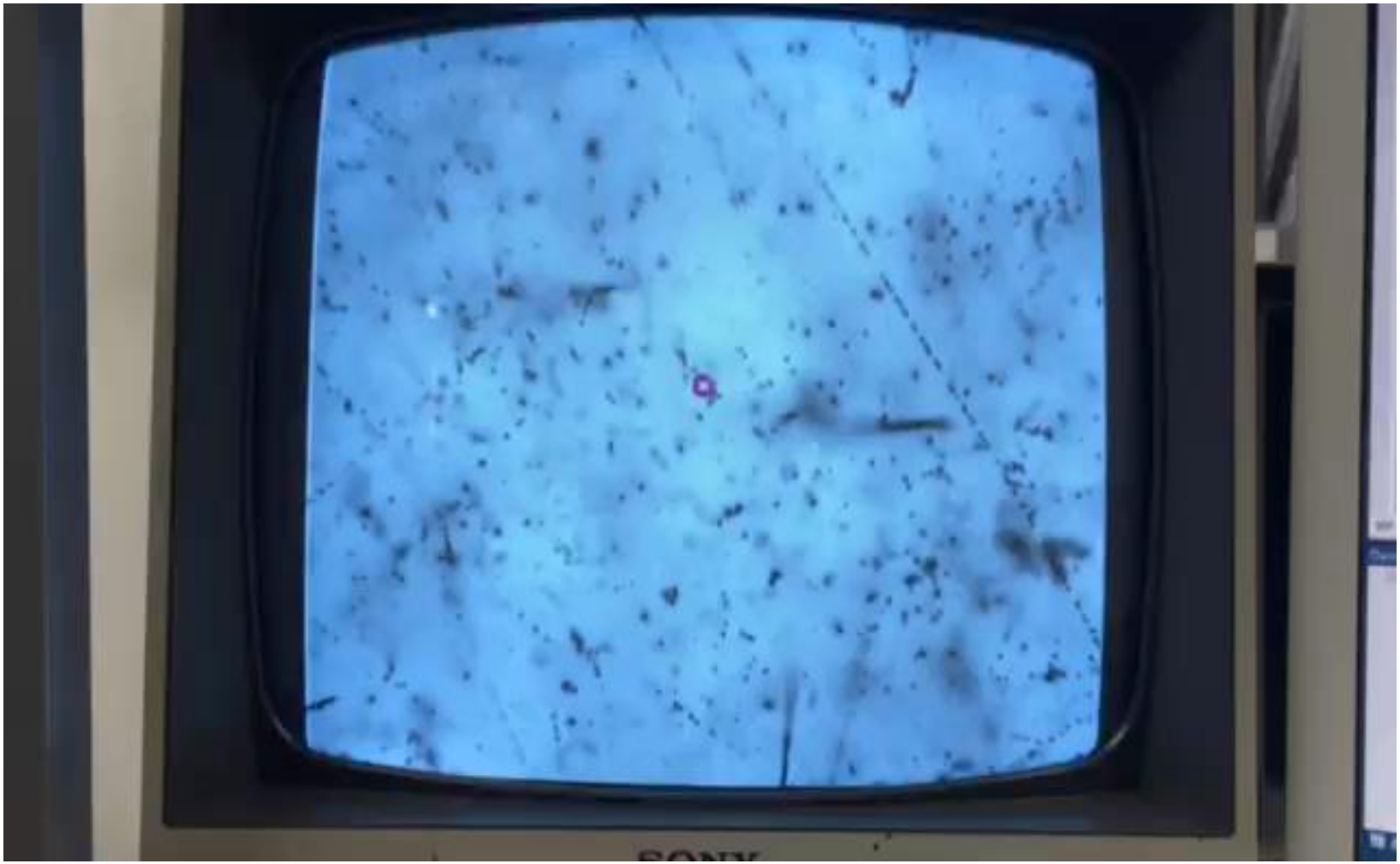
Development is ongoing

- Misrecognition

  >> Compton electron in emulsion



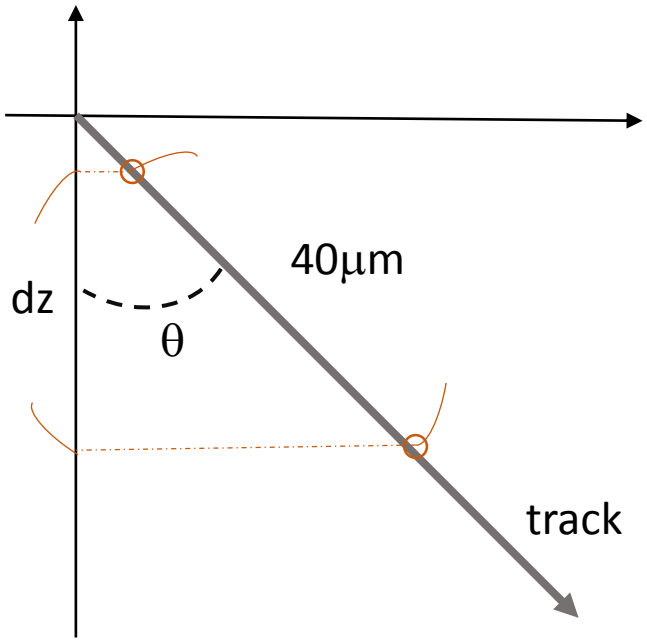
Video image for automatic Ξ^- tracking



Summary

- E07 experiment will be carried out at J-PARC to study S=-2 system with high statistics
- We expect Ξ- stopping events (about 10^4) in nuclear emulsion from J-PARC E07 experiment
- In order to finish Ξ- tracking work in a few year, automatic tracking system is developed
- All steps are almost finished with position accuracy in x and y axes: less than 1 μm and emulsion surface detection accuracy : about 2 μm.
- Development of track recognition is ongoing

Thank you


40μm
dz
θ
track

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