Development of High speed readout machine for directional dark matter search experiment NEWSdm

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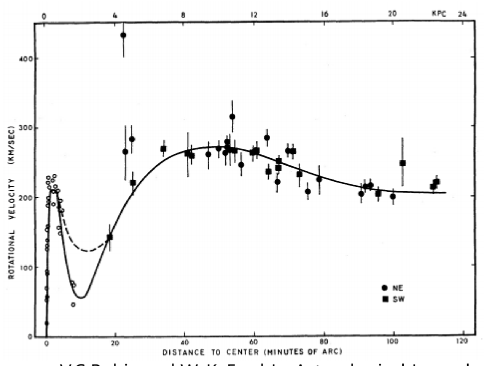
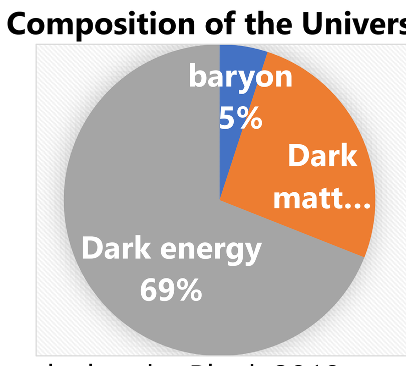
Introduction : Directional dark matter search experiment by solid tracking detector

Dark Matter & dark matter search

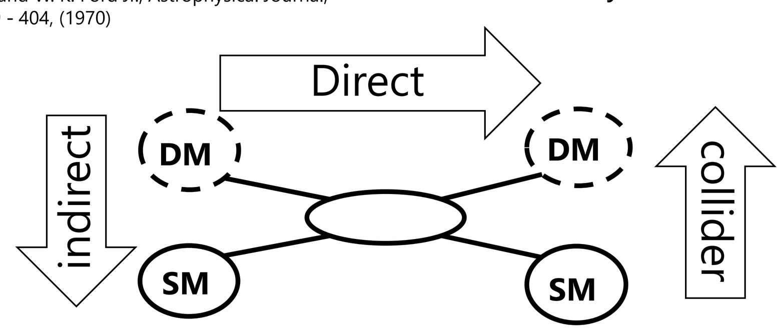


V.C Rubin and W. K. Ford Jr., Astrophysical Journal, 159, p.379 - 404, (1970)

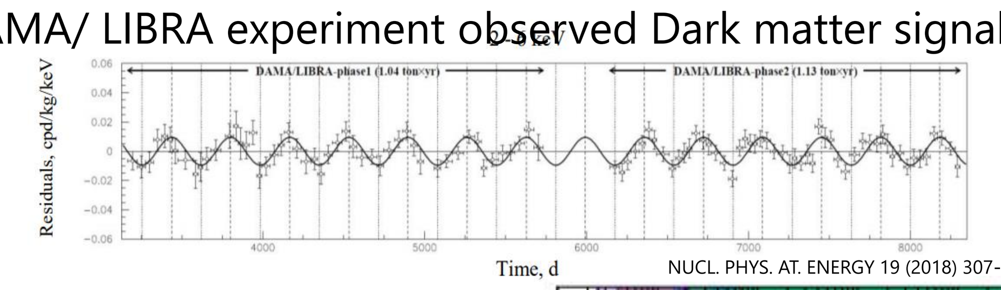
Composition of the Universe



calculate by Plank 2018 result

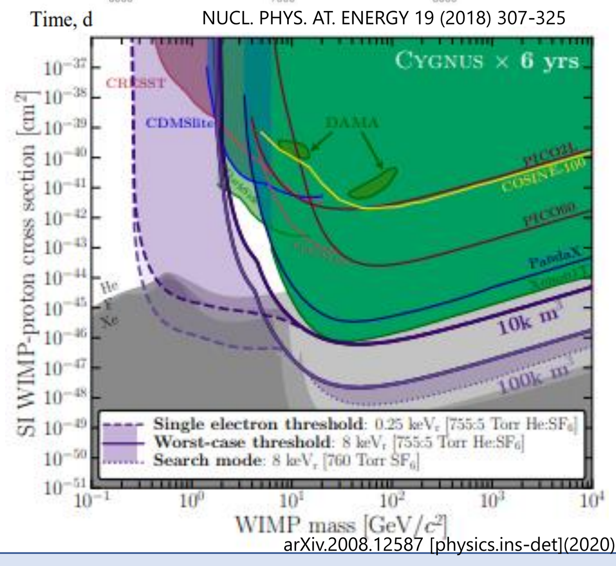


DAMA/ LIBRA experiment observed Dark matter signal !?



NUCL. PHYS. AT. ENERGY 19 (2018) 307-325

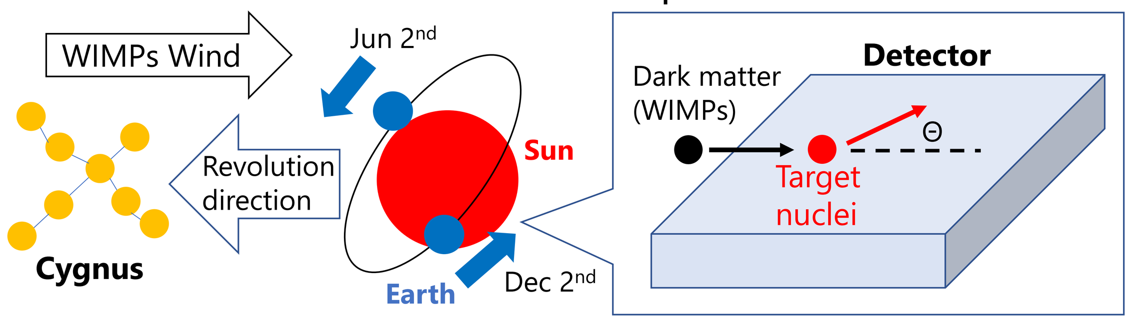
However, no experiment have observed same signal.



arXiv.2008.12587 [physics.ins-det](2020)

NEWSdm experiment

Directional Dark matter search experiment



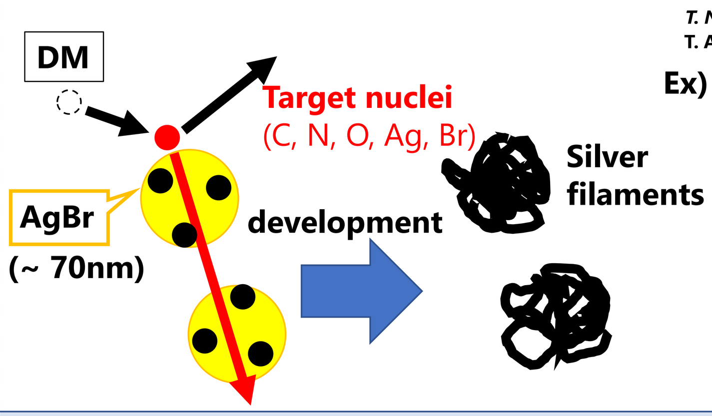
- **Verification with besides seasonal variation**
- **statistical advantage toward seasonal variation** ~O(100)
- **BG rejection by directional information** ex) Solar neutrino

Detector Nano Imaging Tracker : NIT

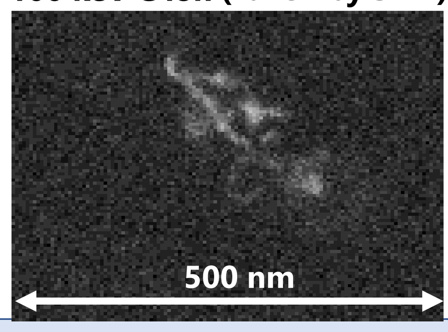
super fine grained nuclear emulsion

NIT is possible to record O(100 nm) tracks.

T. Naka et al., Nucl. Inst. Meth. A 718 (2013) 519-521
T. Asada, T. Naka et. al., PTEP (2017) 2017 (6) : 063H01



Ex) 100 keV C ion (Taken by SEM)

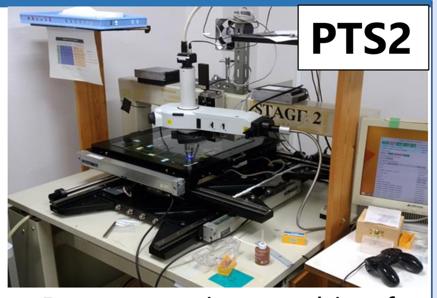


Post Track Selector : PTS

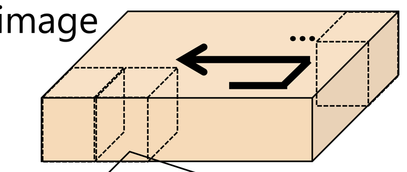
Automatic readout system for sub-μm track in NIT

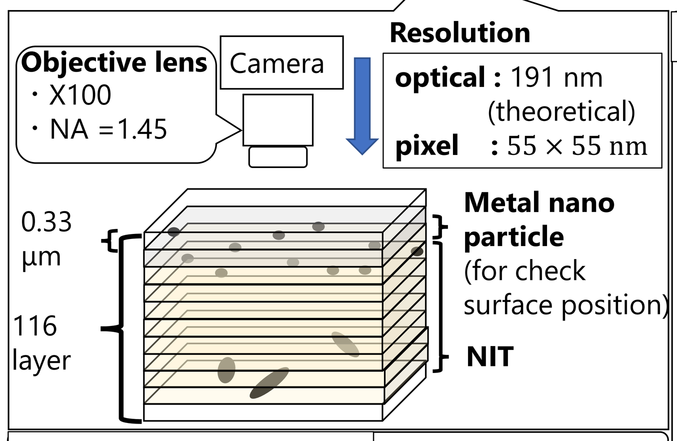
How to readout ?

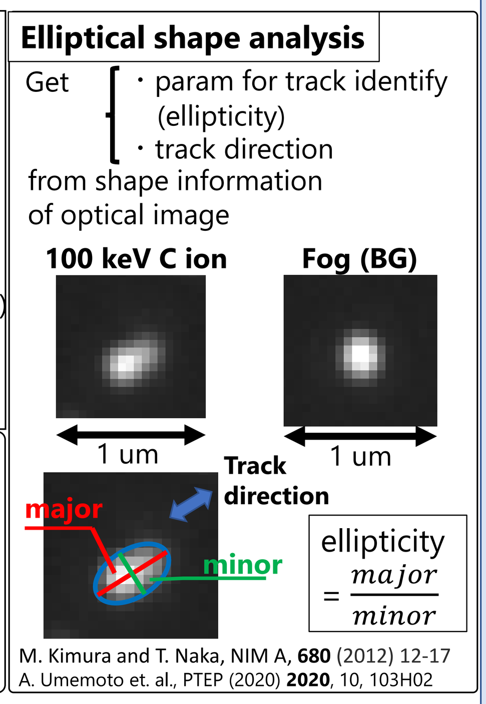
To get 3D information of inside NIT, Get tomographic image



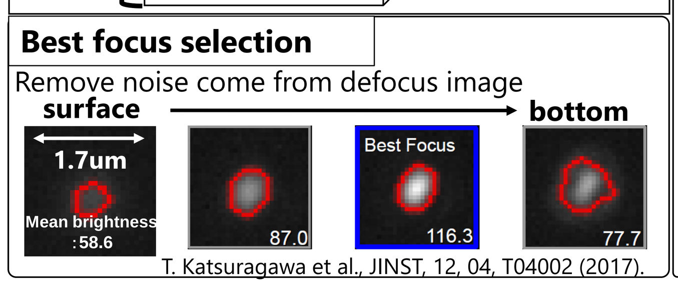
Demonstration machine for readout sub-μm tracks





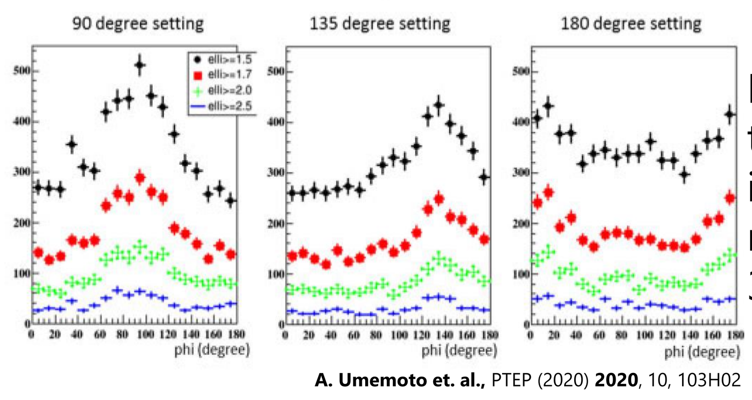


M. Kimura and T. Naka, NIM A, 680 (2012) 12-17
A. Umemoto et. al., PTEP (2020) 2020, 10, 103H02



T. Katsuragawa et al., JINST, 12, 04, T04002 (2017).

Reconstructed angle distribution of 30 keV C ion



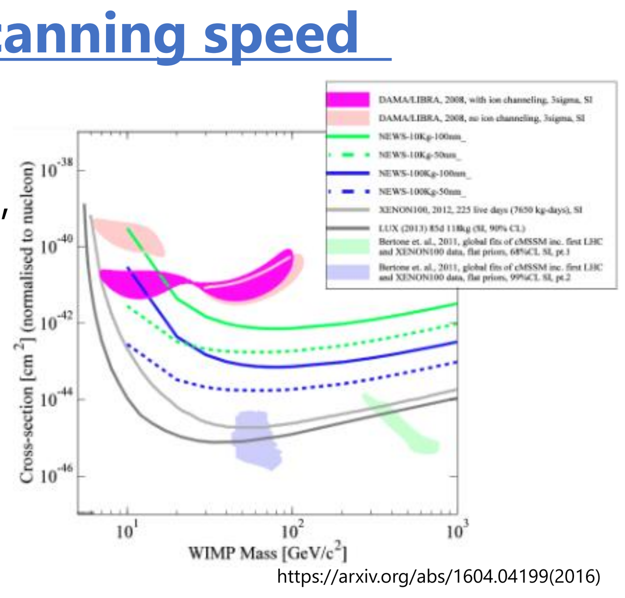
A. Umemoto et. al., PTEP (2020) 2020, 10, 103H02

Demonstrated to readout directional information on more than 30keV C ion tracks

problem : slow scanning speed

Requirements for scanning speed

If using NIT to verify the DAMA-observed signal, at least 10 kg・year scale experiment is requested



https://arxiv.org/abs/1604.04199(2016)

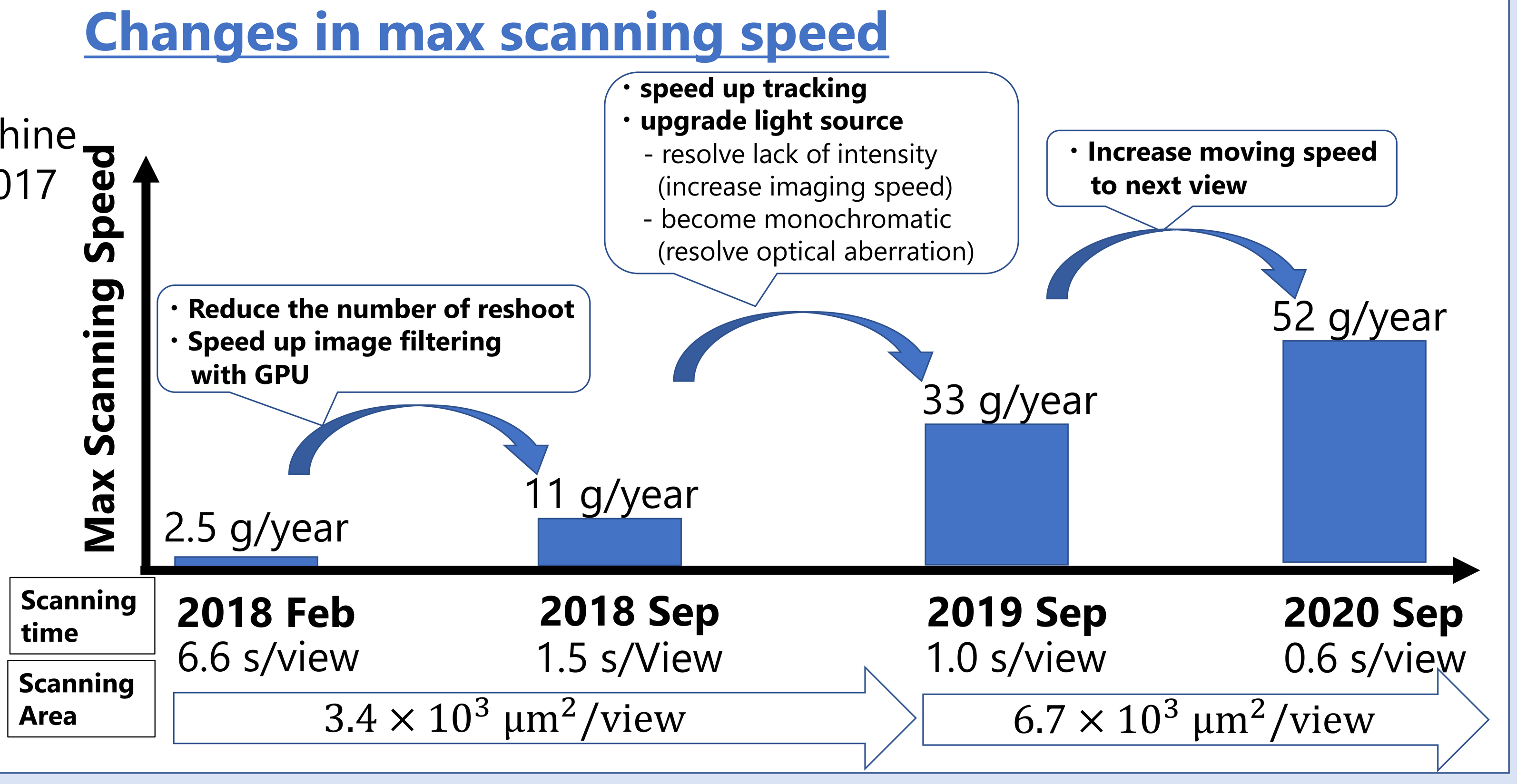
In order to execute above experiments, Ability of scanning at least 10kg of NIT par year is required

Past development

Start developing practical machine for Dark matter search since 2017

Practical machine for dark matter serch

Changes in max scanning speed



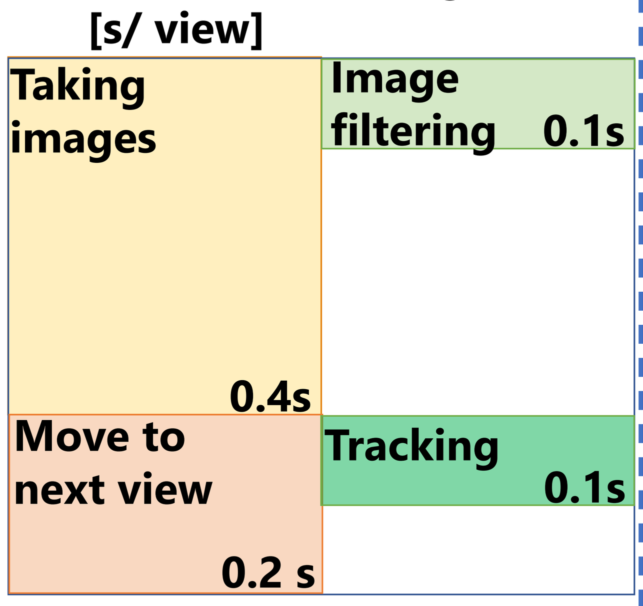
Recently development : install highspeed camera & speed up stage velocity

Bottleneck of scanning speed

Major part of scanning time

- **Taking images**
- **Move to next view** (return objective lens to surface position)

Detail of Scanning time [s/ view]



Total : 0.6 s/view

Speed up image taking

Install high speed camera

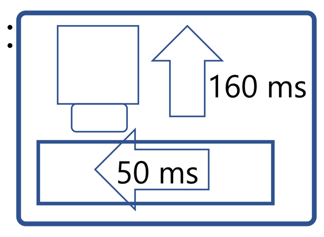
	Current camera	New camera
resolution	(W) 2048 pixel × (H)1088 pixel	(W) 1920 pixel × (H)1080 pixel
Pixel size	5.5 μm × 5.5μm	5.5 μm × 5.5μm
Shatter speed	300 fps	908 fps

Time of taking images
390 ms -> 130ms

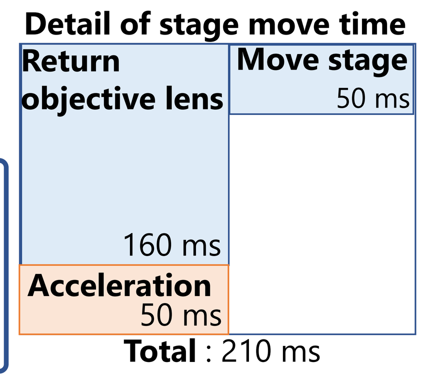
Speed up moving to next view

Main part of moving time : Return objective lens to surface

Shorten return time : 160 ms → 50 ms



Detail of stage move time



Total : 210 ms

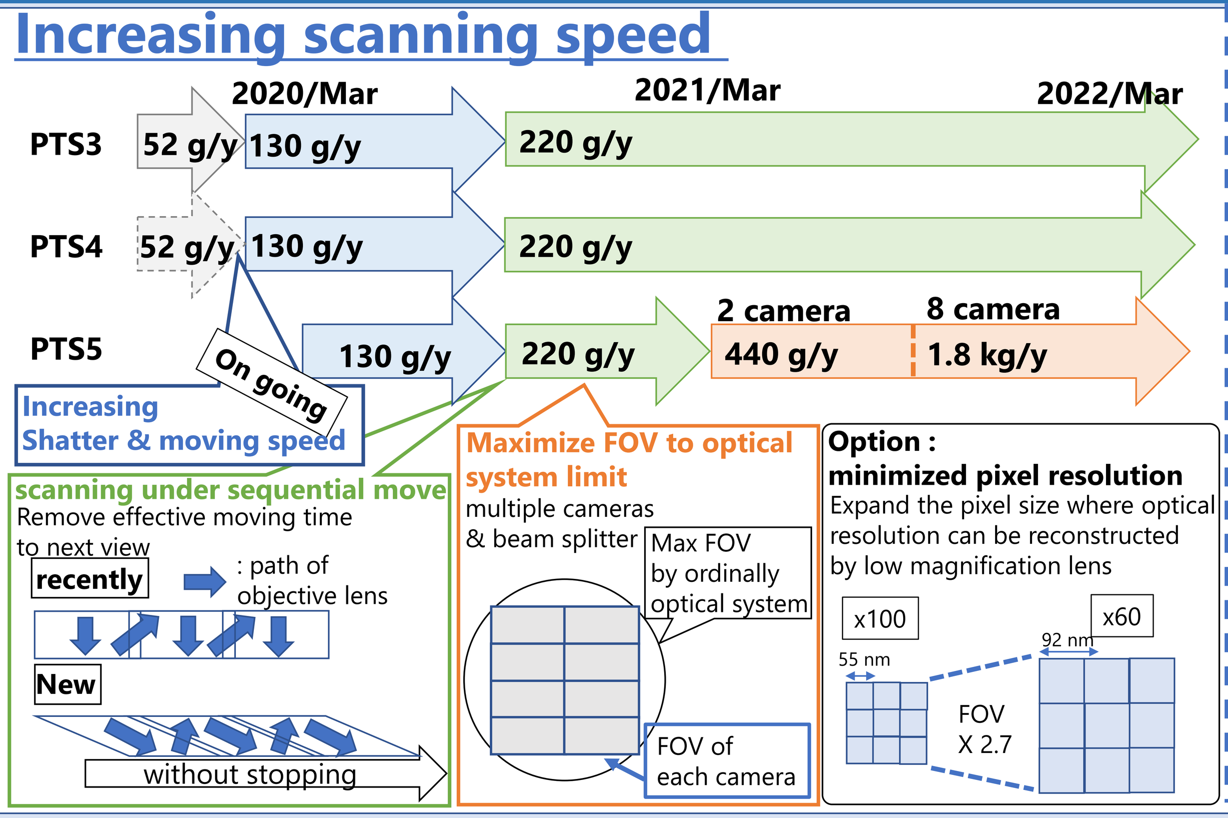
under evaluate { stage vibration effect to optical image / efficiency of new camera

By 900 fps camera + increasing stage speed

Scanning time : 0.6 s/view -> 0.25 s/view (Maximum)

Future plan : increasing scanning speed plan & event selection with machine learning

Increasing scanning speed



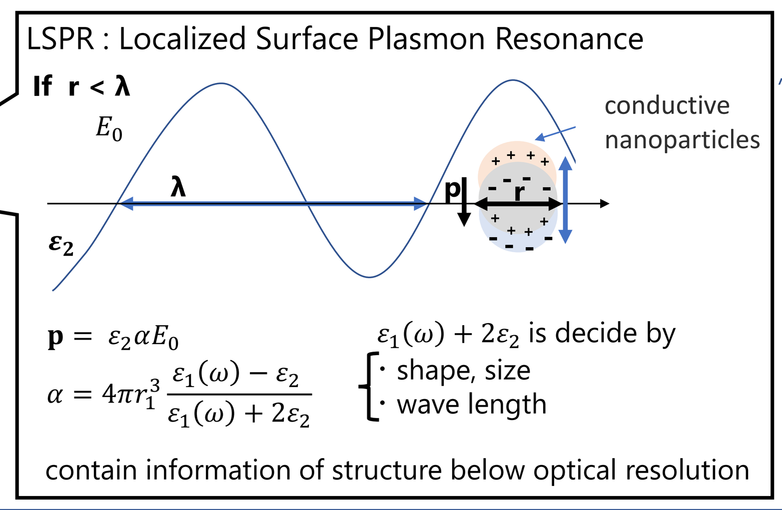
Event selection with machine learning

What information is contained in optical image?

- shape
  - size etc.)
- brightness
- color, polarization (comes from LSPR)

etc.

Optical image must contains vast amount of information



At conventional event selection, focus on a few of the feature for ease of use.

Ex)
- simple shape
  - ex) ellipse, # of pixel
- brightness

Problem

1. The vast amount of information contained in the optical image is not being utilized.
2. Event select by track like or not

Aiming for more sophisticated event selection With feature extraction and parameter optimization with machine learning