Scanning status in Japan

2019.02.1

Atsuhiro UMEMOTO

Contents

- Improvement of scanning speed
- Evaluation of elliptical fitting analysis
- Detector study for calculating DM cross-section
- Surface run at Nagoya with Equatorial telescope

Improvement of Scanning speed

- Kobayashi developed a new algorithm for improving the PTS3 scanning speed.

(the detailed was shown in previous kobayashi's slide)

- And the algorithm was installed in PTS2.

① Optimization of surface recognition

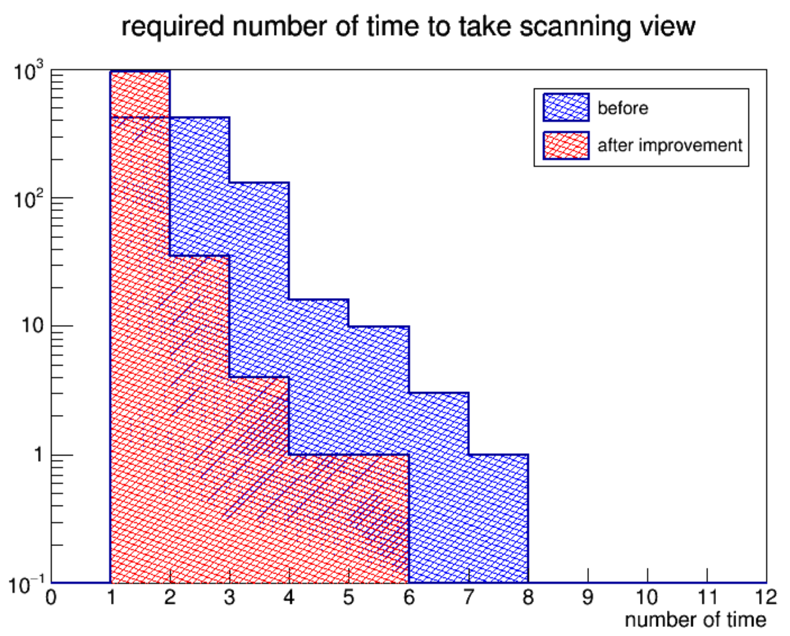
Our scanning uses surface recognition using Au40nm. If the surface is recognized, the scanning goes next Step(elliptical fitting and image saving). If not, scanning repeats surface recognition at same position.

In new algorithm, the surface position of next view is predicted by using the current surface position. The starting Z position can be tuned and the slope of sample surface is corrected.

992 view scanning by PTS2

	N of all trial	1	2
before	1778	415	417
after	1042	951	35

Total scanning time 992view	before	76min 10sec
	after	58min 30sec



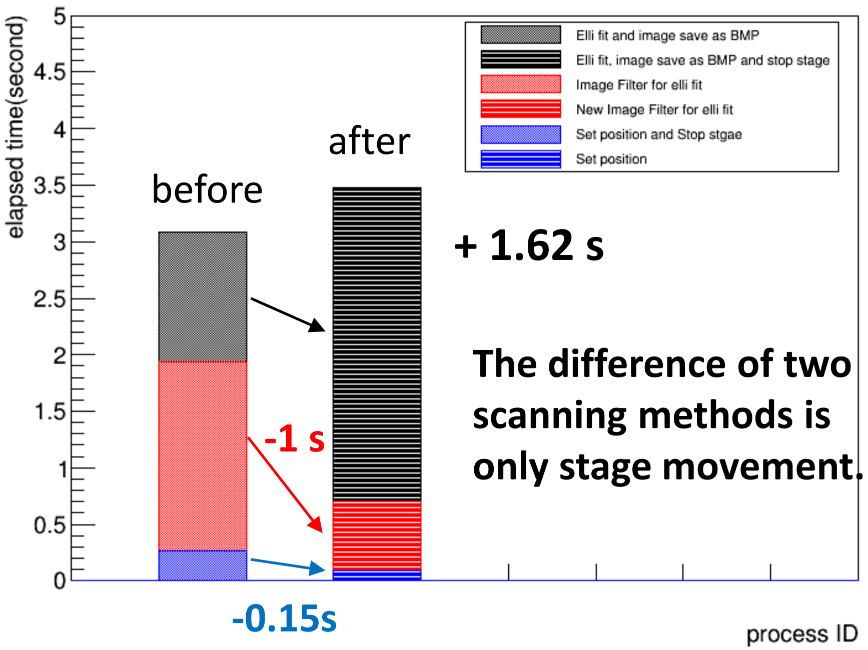
Improvement of Scanning speed

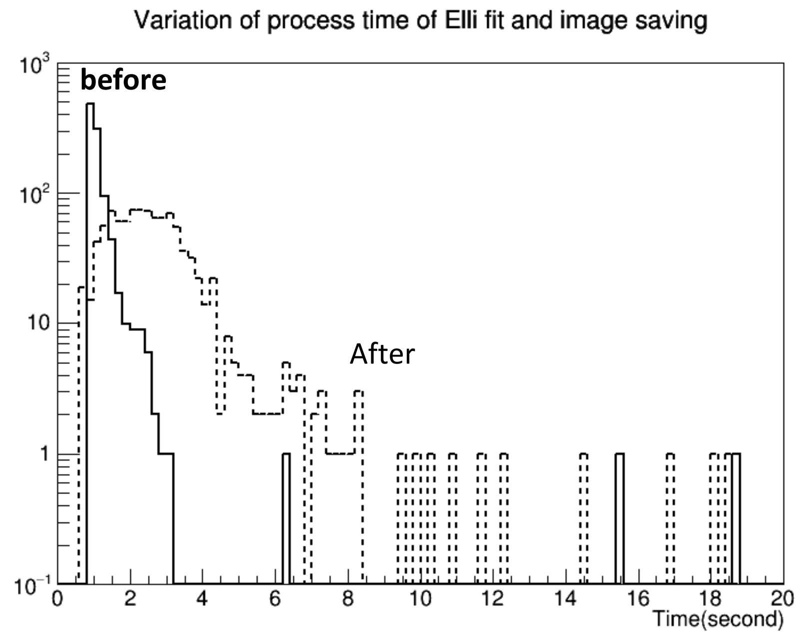
② Each image filter processing before elliptical fit was speed up with GPU stream.

③ Stage control and elliptical fitting (w/ image saving) were parallelized.

Scan condition: 4MB image × 96 layer. Sample: FAN113gf 0day after MAA (F.D. = 0.12/(10um)^3 w shrink)
Same area was selected for scanning speed check.

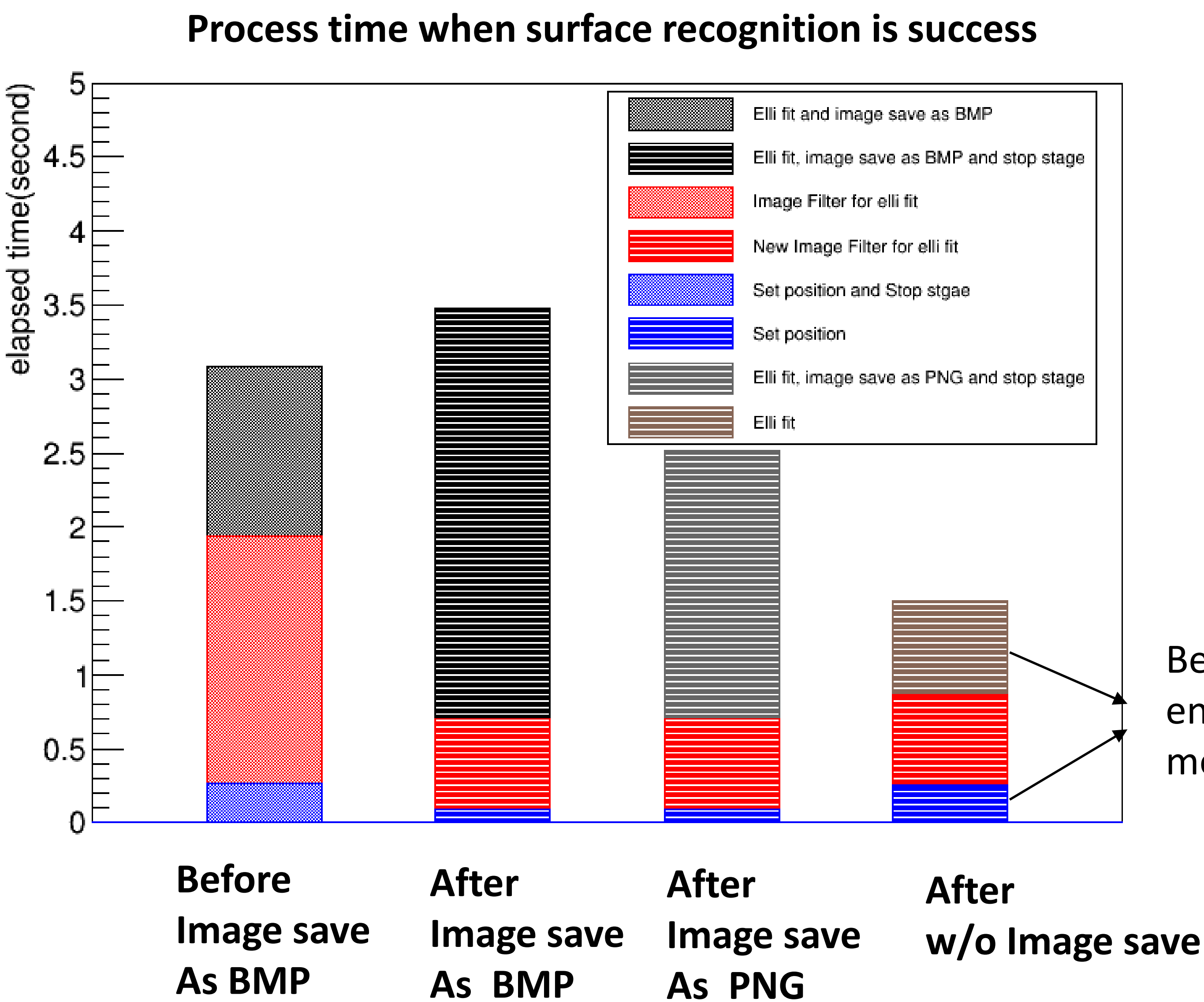
Process time when surface recognition is success





Estimation: the number of retake (surface recognition) is reduced In the new method.
The size of scanning data access to HDD per unit time is increased.
⇒ HDD always needs to work, the treatment efficiency will be worse.

Improvement of Scanning speed



*PNG image = 1.4 MB/layer

Because it has enough time to move and wait stage

	Ready to scan	Image filter	Elliptical fit and image save	Total/view
Before	0.26 ±0.01 (s)	1.67 ±0.09 (s)	1.15±0.79 (s)	3.08 ± 0.79(s)
After BMP	0.09 ±0.14 (s)	0.61 ±0.01 (s)	2.78±1.64 (s)	3.48 ± 1.65(s)
After PNG	0.09 ±0.15 (s)	0.61 ±0.01 (s)	1.81±0.23(s)	2.51 ± 0.28(s)
After wo image	0.26 ±0.11 (s)	0.62 ±0.03 (s)	0.63±0.03 (s)	1.50 ± 0.12(s)

	Effective scan speed include surface recognition
Before	76min 10sec / 992views
After BMP	58min 30sec / 992views
After PNG	42min 30 sec / 992views
After wo image	26min 10sec / 992views

Current scanning, the image is required for eye-check, additional image solution etc..
We decide to save scanning image as PNG.
⇒ SSD is better for speed up of image saving than HDD.

The scanning will be changed that does not save images
after understanding the both signal and noise characteristics. (April or May)

Current scanning

PTS2 scanning. Data is being analyzed now.
FAN113gf (DM search at surface lab -20℃ for 1month)

Optical mark by 400 nm Au

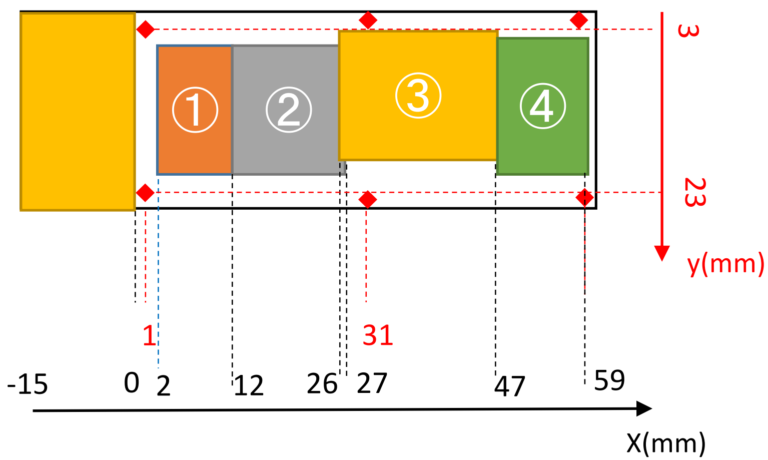
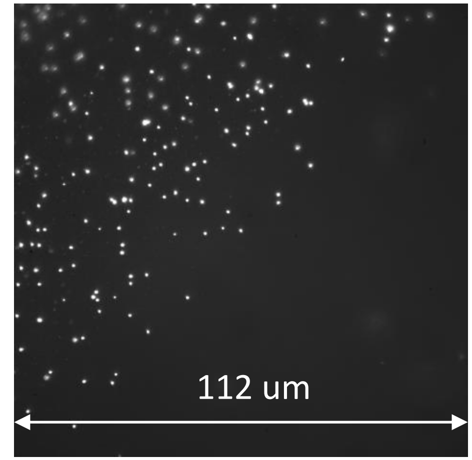


Image of Optical mark

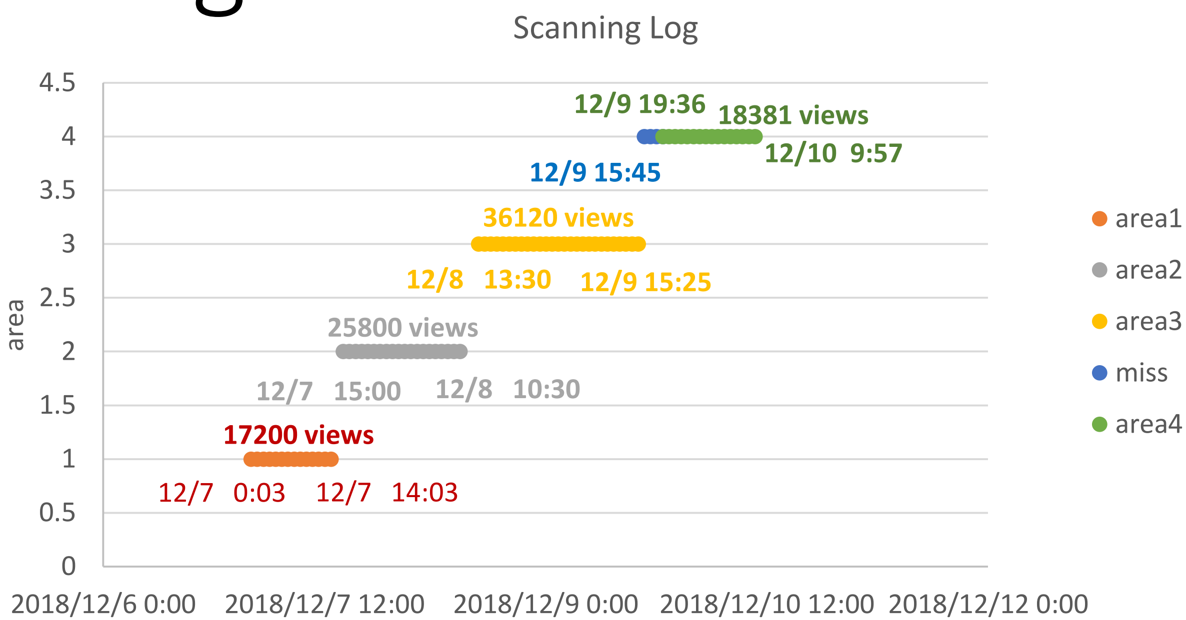


- The position of optical mark was recorded.
- The scanning area was separated into four
(to save each scanning image to different HDDs)

area1	9.9 × 17 mm2 =17200 views	*2.3 TB PNG Image and txt file
area2	14.9 × 17 mm2 =25800 views	
area3	20.9 × 17 mm2 =36120 views	
area4	12 × 18 mm2 =18381 views	

Total=97501 views

Time log



area1	14 hours / 17200 views	2.93 sec/view
area2	19.5 hours / 25800 views	2.72 sec/view
area3	25.92 hours /36120 views	2.59 sec/view
area4	14.5 hours /18381 views	2.84 sec/view

Total = 81hours and 54 minutes（loss time 8hours and 7minutes）
Effective Scanning time= 73 hours 47min /97501 views.
If all area of views (except surface) are available for data analysis
(112um)^2 ×（64 layer × 0.3125um/0.6）× 10^-12 × 97501 × 3.44 = 0.14 g / 3.07 days ⇒ 1 g /22days

PTS2 and PTS3

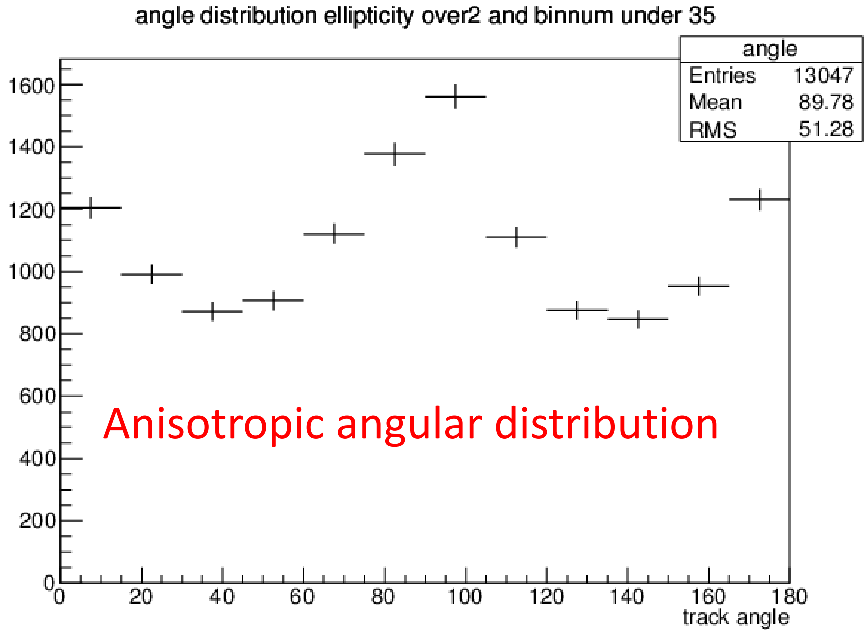
	Maximum Speed (w image saving)	**Maximum Speed (w/o image saving)**
PTS2	<16.6 g/year	<27.0g/year
PTS3	<22.0 g/year	<32.0g /year
PTS2+3	<38.6 g/year	<59.0 g/year

We need more study to use scanning data of both PTS2 and PTS3.
The difference of detection efficiency, angular resolution and fog density should be understood.

We are going to operate PTS2 and PTS3 scanning in this May.

Elliptical fitting

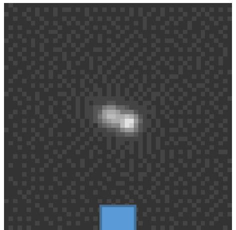
We used a Image filtering and “rectangle recognition method” to get minor, major, ellipticity and track angle in previous, but this was much affected by the digitized pixel.



2017/02~04 BG run in LNGS
0.035 g Scanning data of FAN085gf4
- Ellipticity cut >=2.0

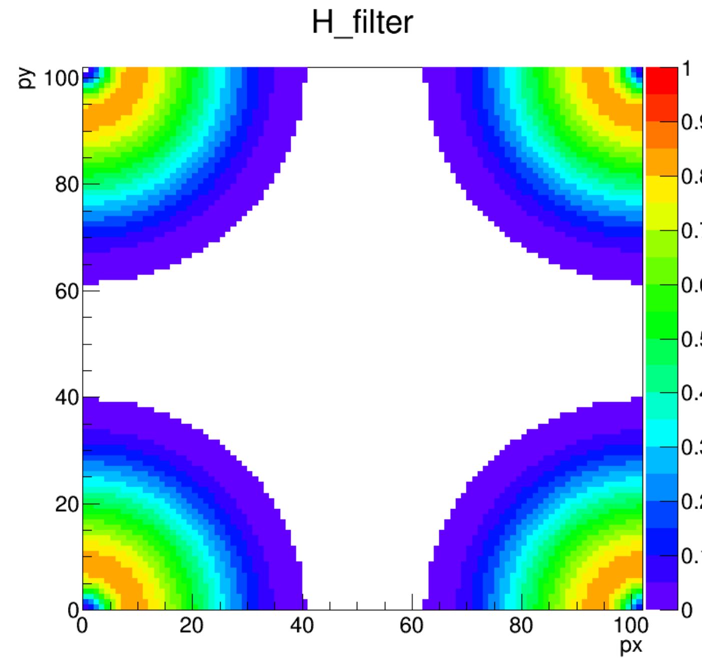
We developed a new elliptical fitting method using image frequency .

Elliptical Fitting by FFT

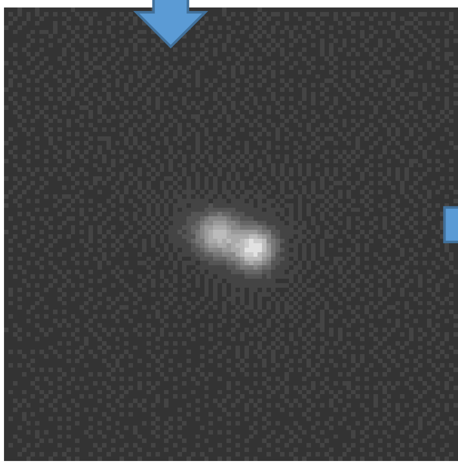


51 pixel (2.8 um)

Not online

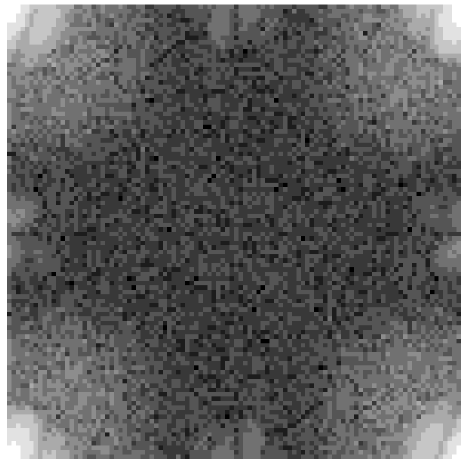


Bicubic



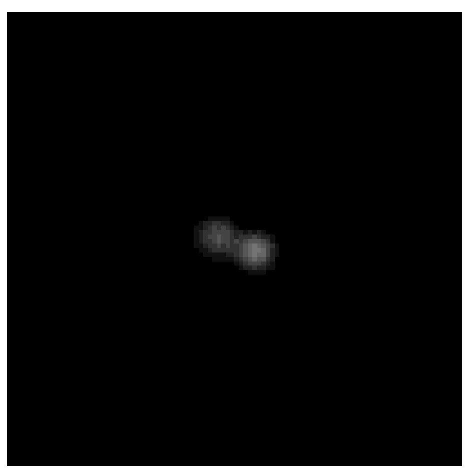
102 pixel (2.8 um)

DFT



Filtering

IDFT

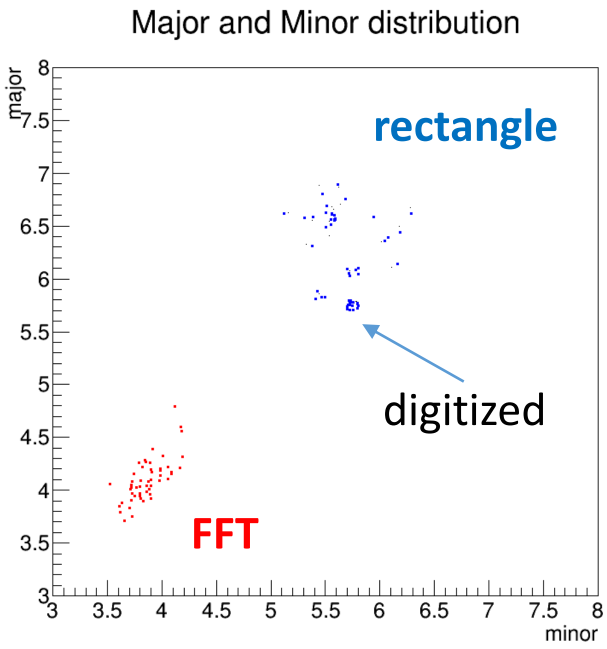


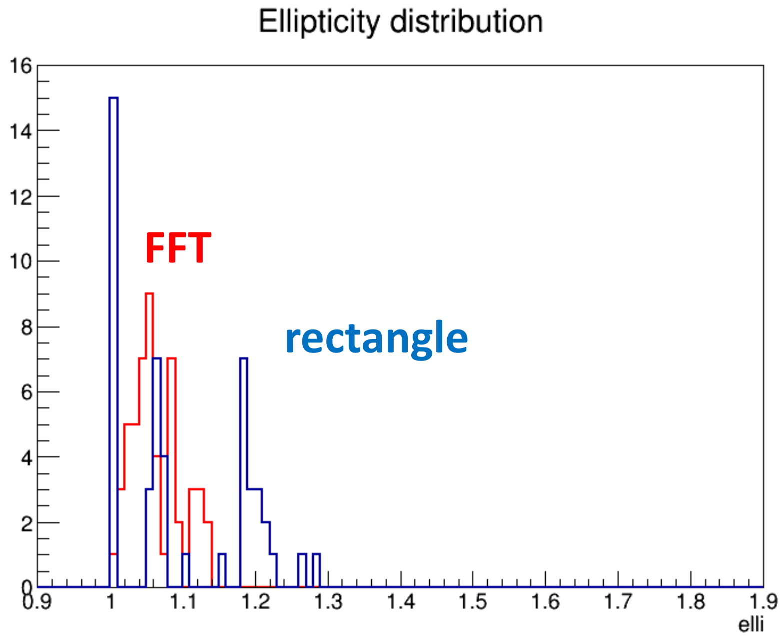
Elliptical Fitting by using brightness distribution

(Minor, Major, Ellipticity) =
(4.1506 9.59089 2.31072)

Ag40 nm spherical

Brighter event was selected by brightness parameters and image eye-check was done.
52 events selected by Max brightness 160<=Max<=200, Mean brightness 65<=mean<=105



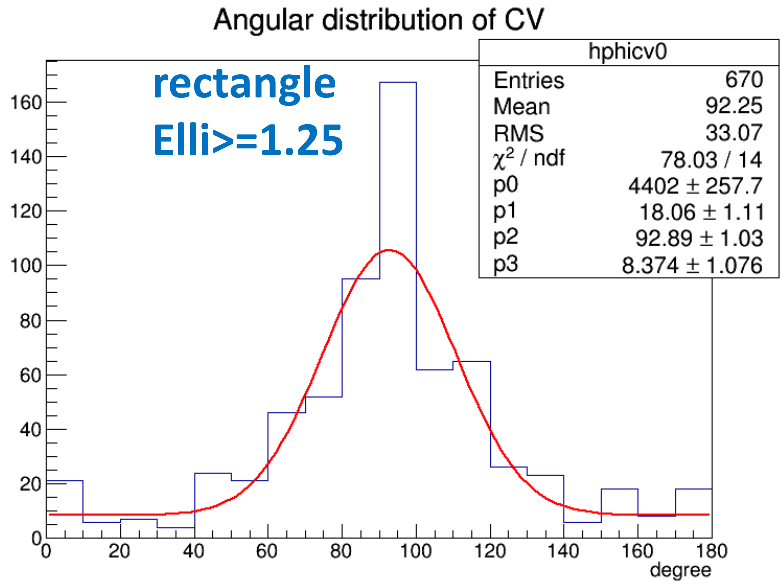


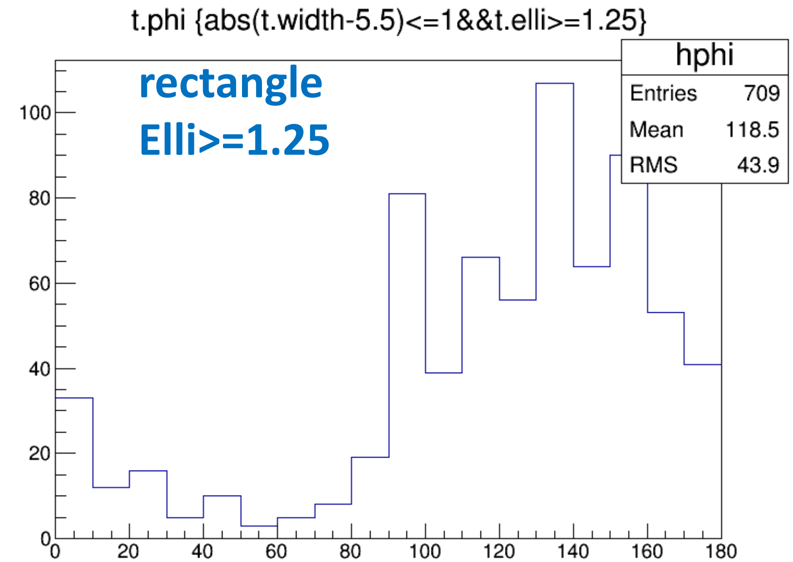
Carbon 100 keV ion w 10 degree implant

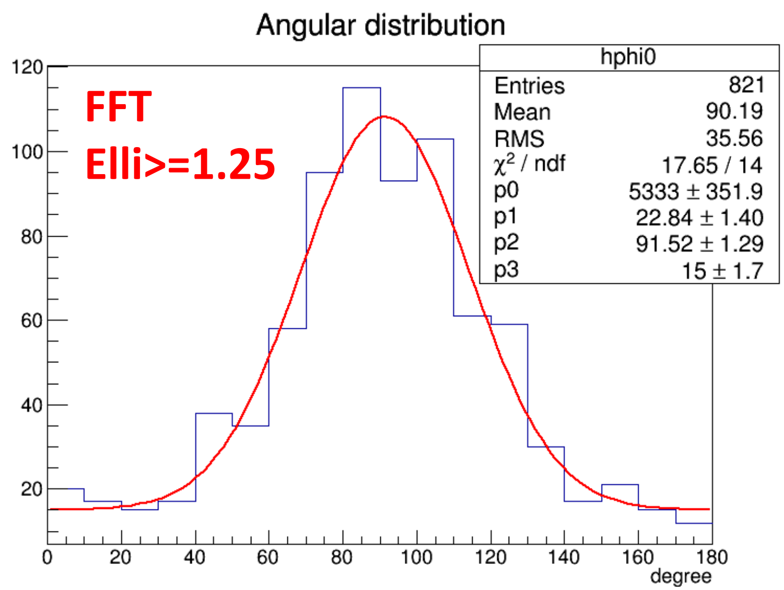
FAN113gf NIT-70nm

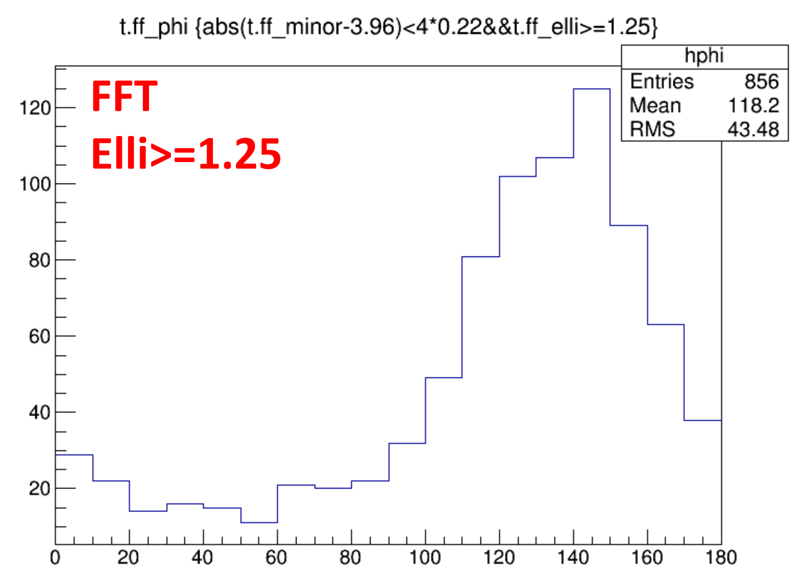
Camera X-axis pixel arrangement was beam direction(90d)

Camera was rotated about 45d by manually.
⇒beam direction became 135d



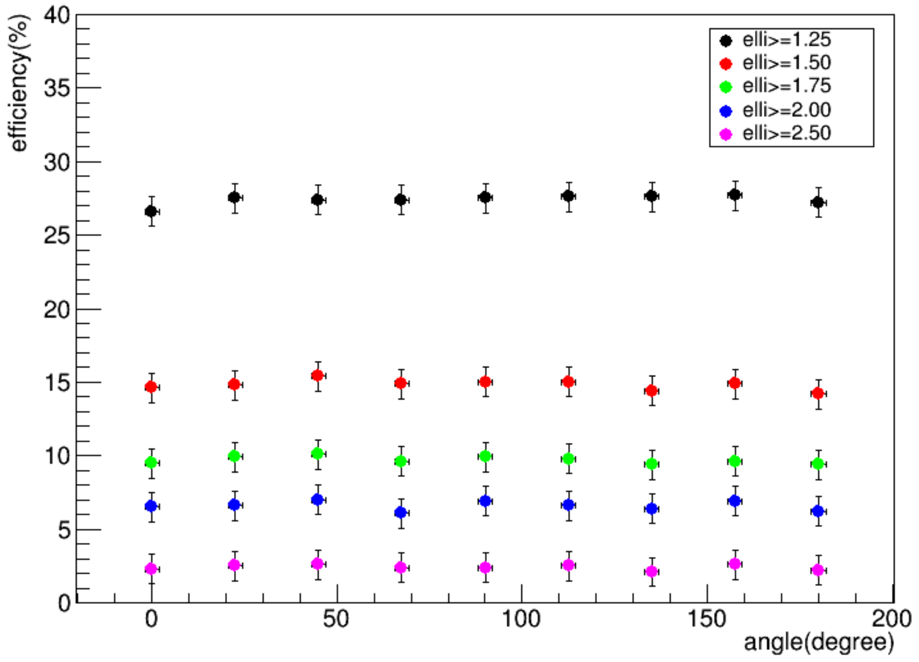






Detection efficiency and angle by FFT

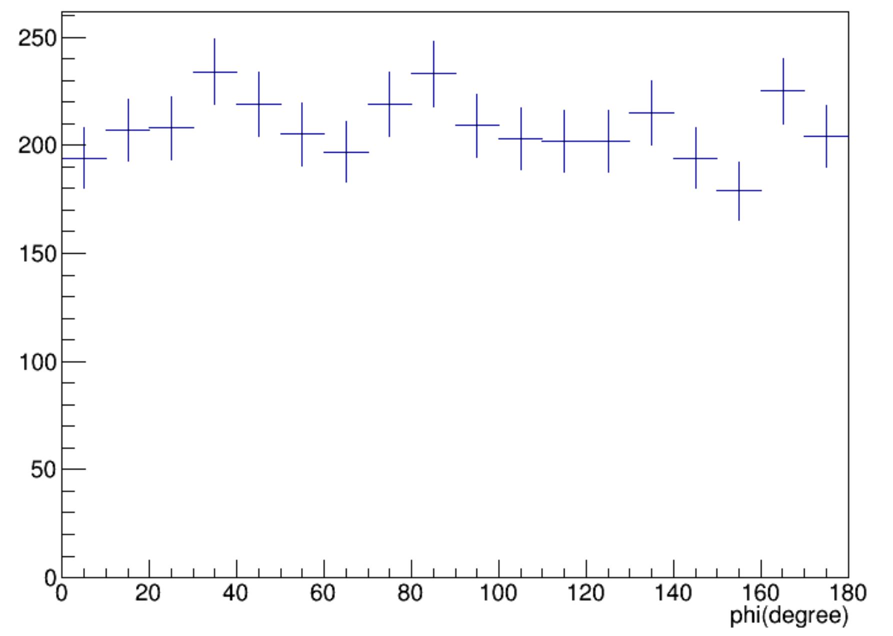
FAN113gf NIT-70nm



Selection parameter

- Absolute (minor - 3.89) < 4 × 0.24

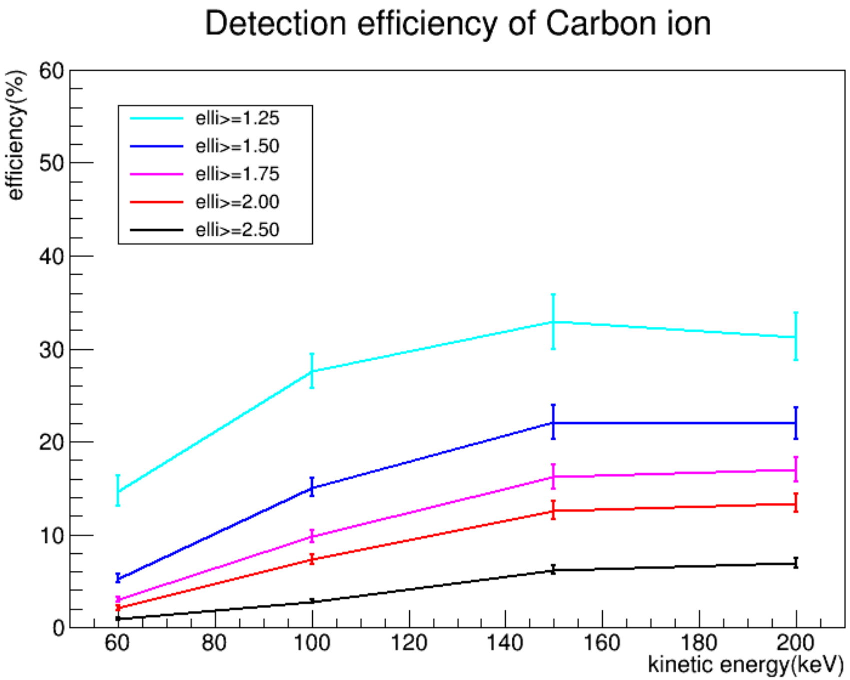
FAN113gf DM search area1



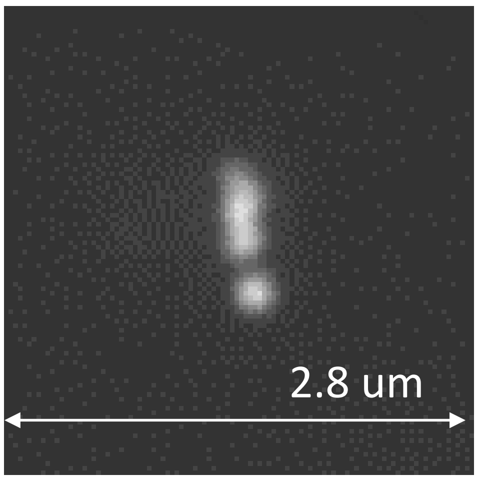
Selection parameter

- Absolute (minor - 3.89) < 4 × 0.24
- elli>= 1.75
- 100<=Max –BG brightness <= 150
- 30<=Mean –BG brightness <= 75
- 35<=number of Pixel<=75

Carbon ion efficiency by FFT



200 keV carbon track

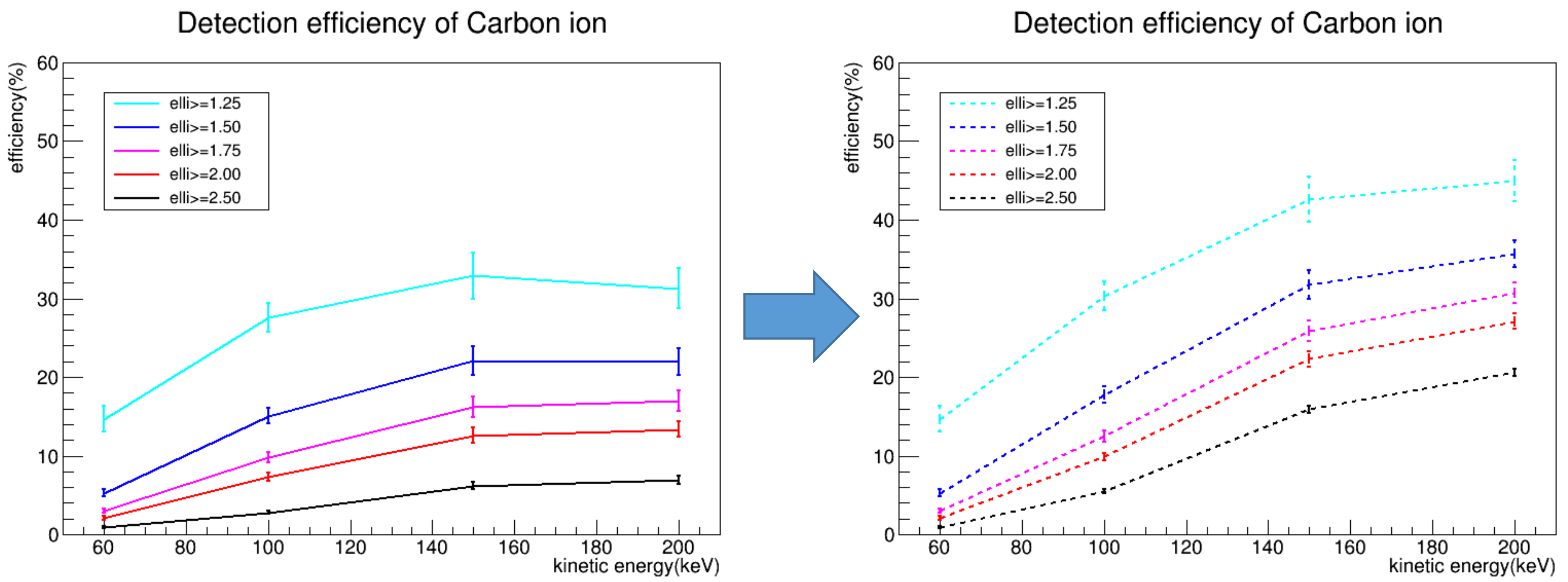


The event was recognized as two separated grain, then in current system
it was judged as noise (like a dust).

$$\text{Effi}= \frac{\text{Signal}_{\text{ellicut}} - \text{Mask}_{\text{ellicut}}}{\text{Signal}_{\text{all}} - \text{Mask}_{\text{all}}}$$

The higher kinetic energy, those events got increased ⇒ need a tracking method.

Carbon ion efficiency by FFT



I estimated the efficiency
if tracking methods was available

It is not easy to develop a tracking program soon.
After finishing the current data analysis, I will try developing .

Detection efficiency of Nuclear recoil

- It is important to understand the relation between Ellipticity and track length.

- We evaluated the detection efficiency of only Carbon ion with Elliptical fitting.

- Our DM target nuclei are {C,N,O,Ag,Br}.

⇒ we will estimate the detection efficiency of all target nuclei from the result of carbon efficiency using the relation between track length and ellipticity.

- The systems between DM search and ion implantation are different.

⇒ Ion data has the tracks which are scattered out from NIT. Those events are negligible in the case of DM search (interaction is occurred inside of NIT)

Detection efficiency should be converted to DM search system.

Cross-section Limit

- To calculate the DM cross-section, we have to understand the “Recoil Energy”, “Emulsion track length”, and “Ellipticity”.

Recoil Energy E_{Recoil}
calculation can be done
when DM mass and velocity
are assumed.

$E_{Recoil} \Leftrightarrow R_{emulsion}$

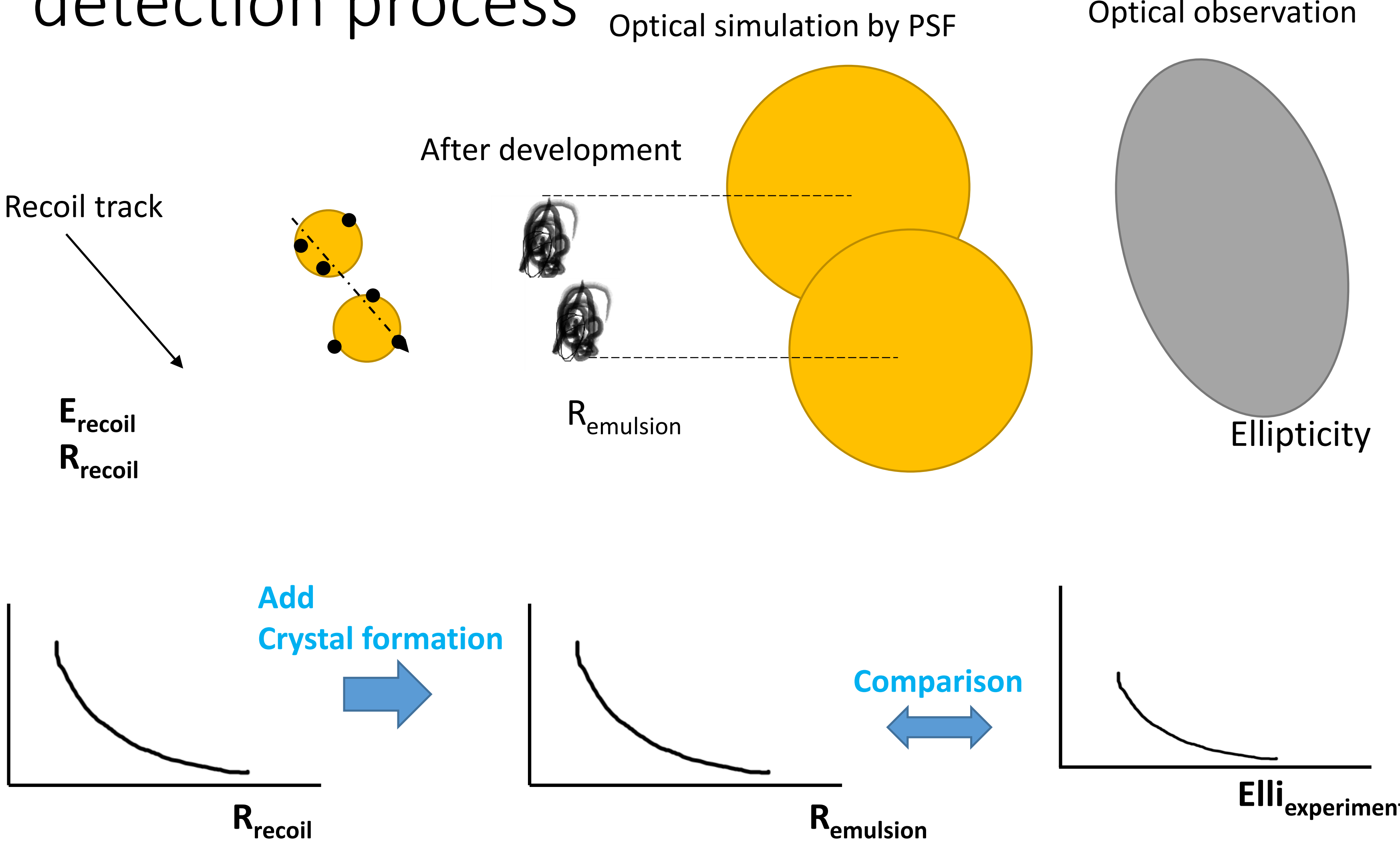
Recoil track length
Converted from the relation
track length and recoil energy
by SRIM.
↓
<u>Emulsion track length</u> is decided by
the crystal formation and crystal
sensitivity of NIT.

NIT Param..
Crystal size = 44 nm
Crystal density = 10000 /um3
Crystal sensitivity ~ 100% (30keV Carbon)

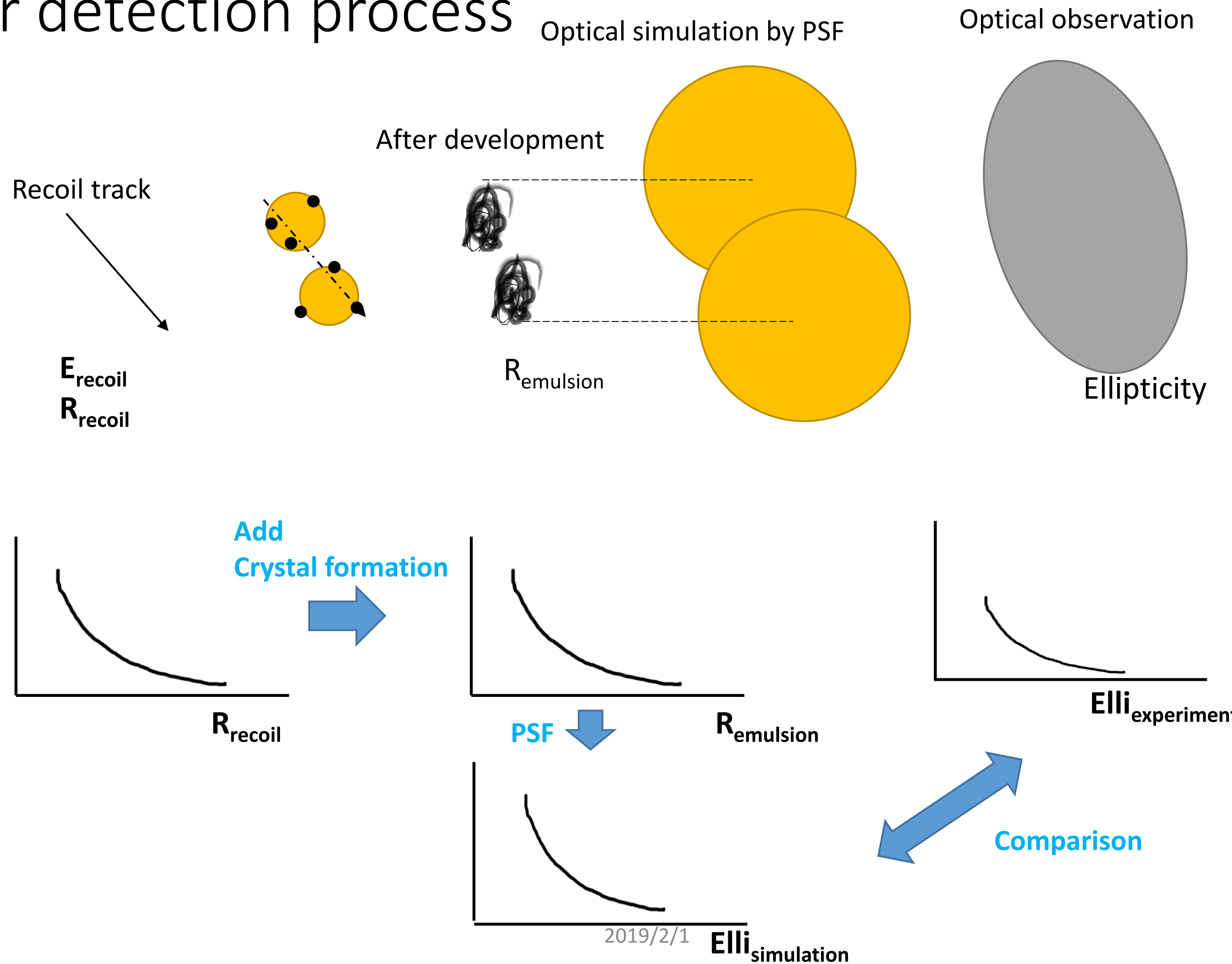
Detectable in experiment
Ellipticity , event rate

$R_{emulsion} \Leftrightarrow$ Ellipticity

Our detection process



Our detection process



SRIM+NIT+Optical Simulation

- The relation between track length and ellipticity is studied using SRIM simulation with a virtual emulsion detector and optical simulation.
- The virtual emulsion and SRIM calculation were done by Asada.

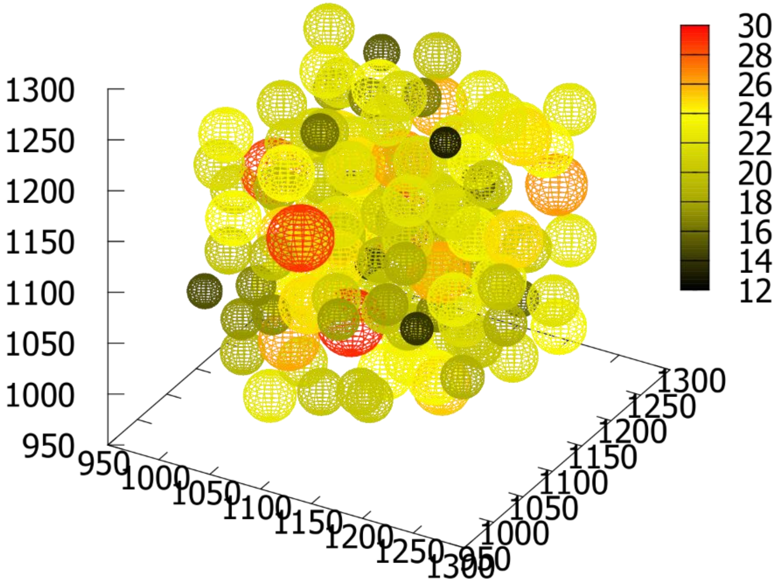
 - the size of crystal has a distribution like actual AgBr crystal.

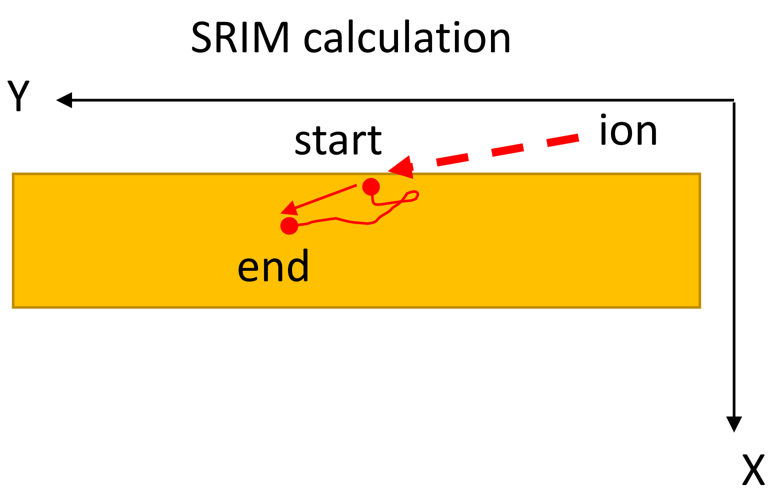
 - track range by SRIM is determined as the length from start point to end point.

- Optical image was calculated by Fresnel equation by Shiraishi.

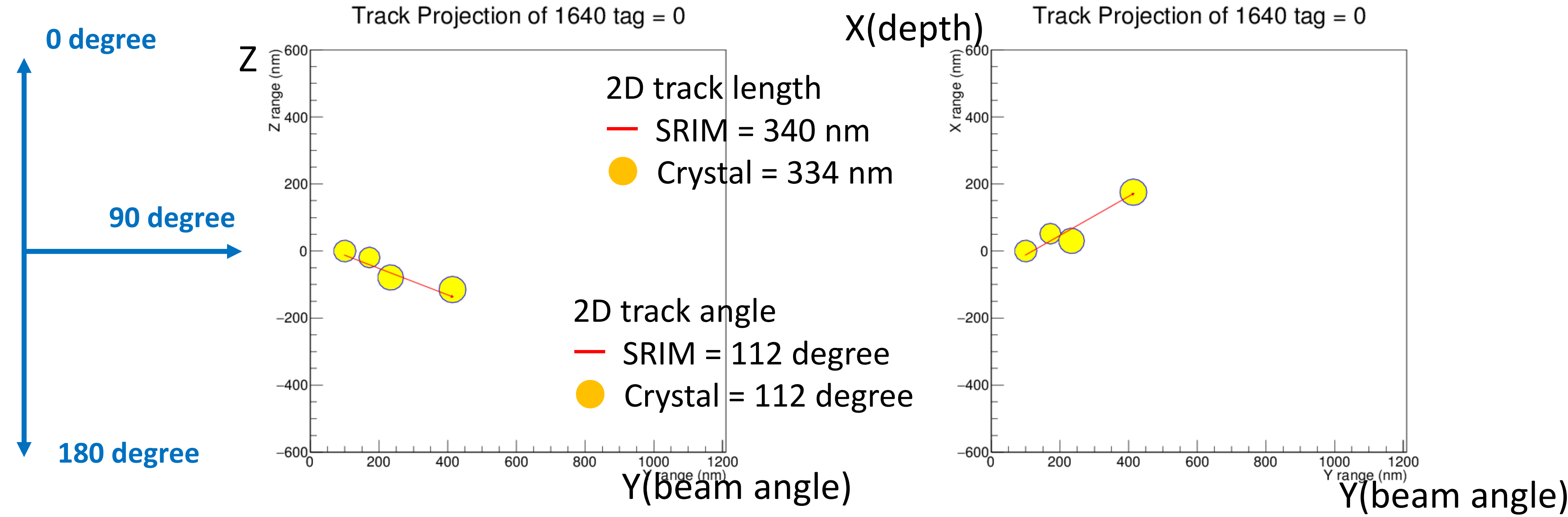
 ⇒elliptical fit and get parameters.

NIT. face-centered cubic lattice and random walk

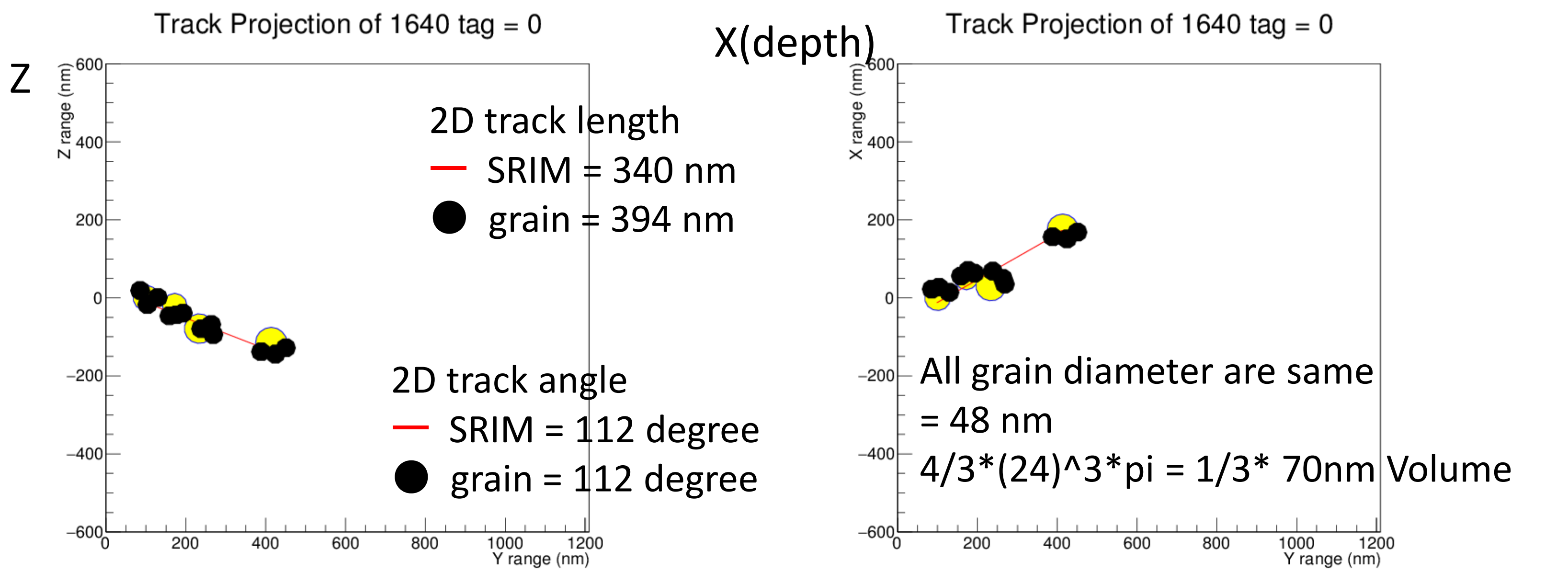




NIT70 nm   C100 keV 10degree implantation

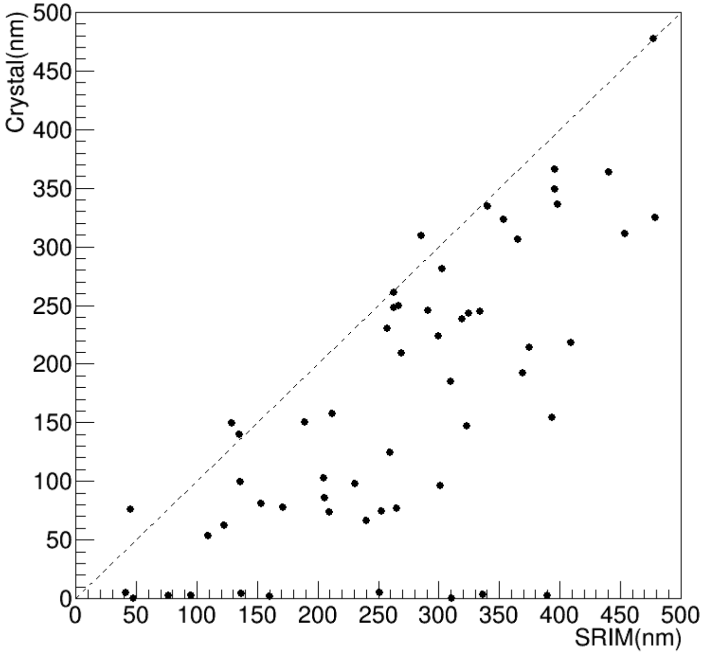


As a first test, 3 latent image specs were generated at random point in each AgBr crystal

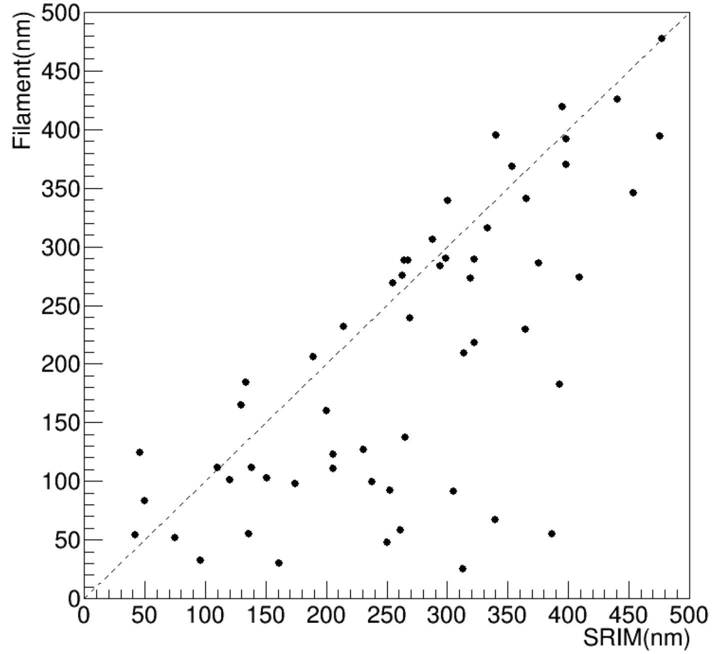


Track length

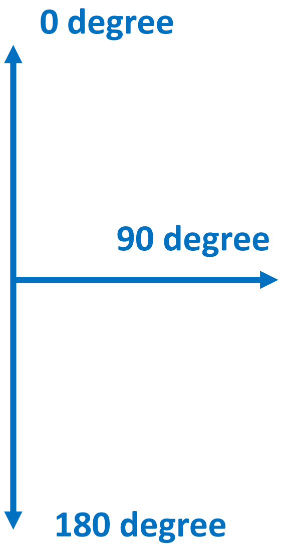
SRIM and the end of crystal

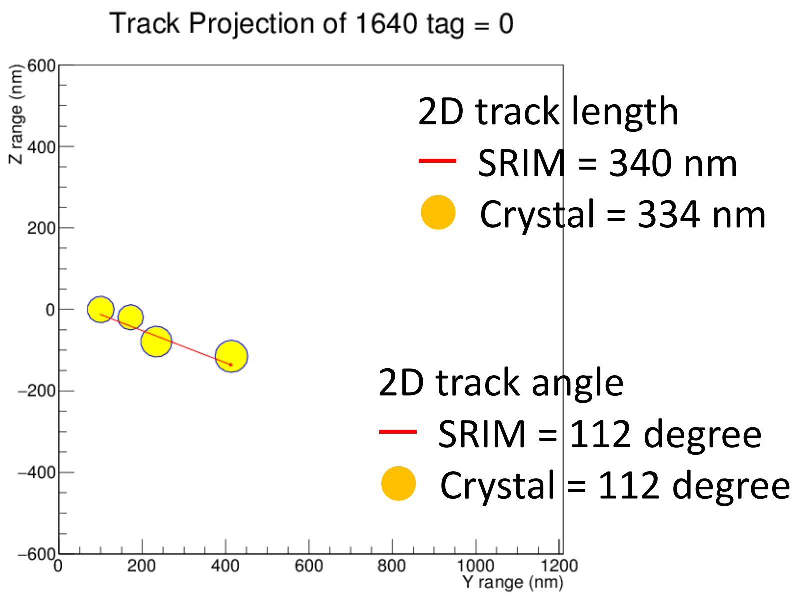


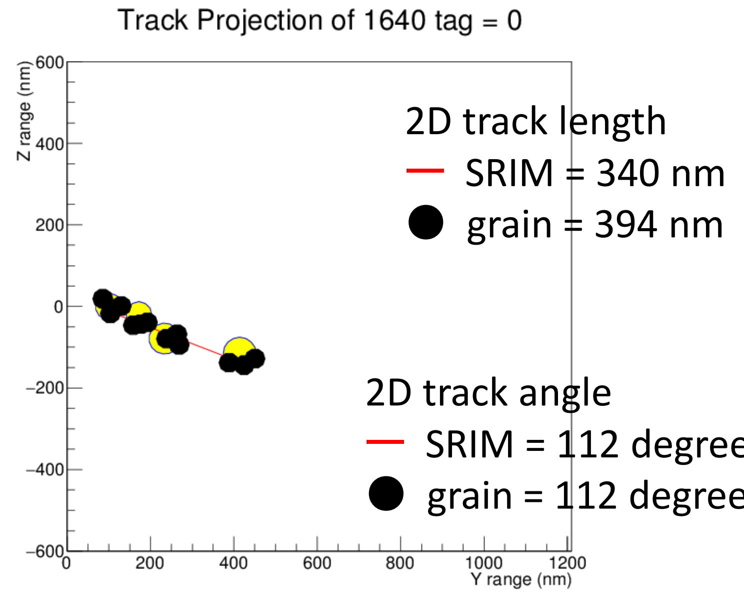
SRIM and the end of grain



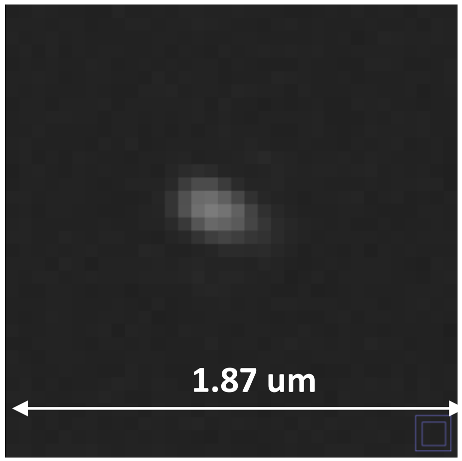
NIT70 nm





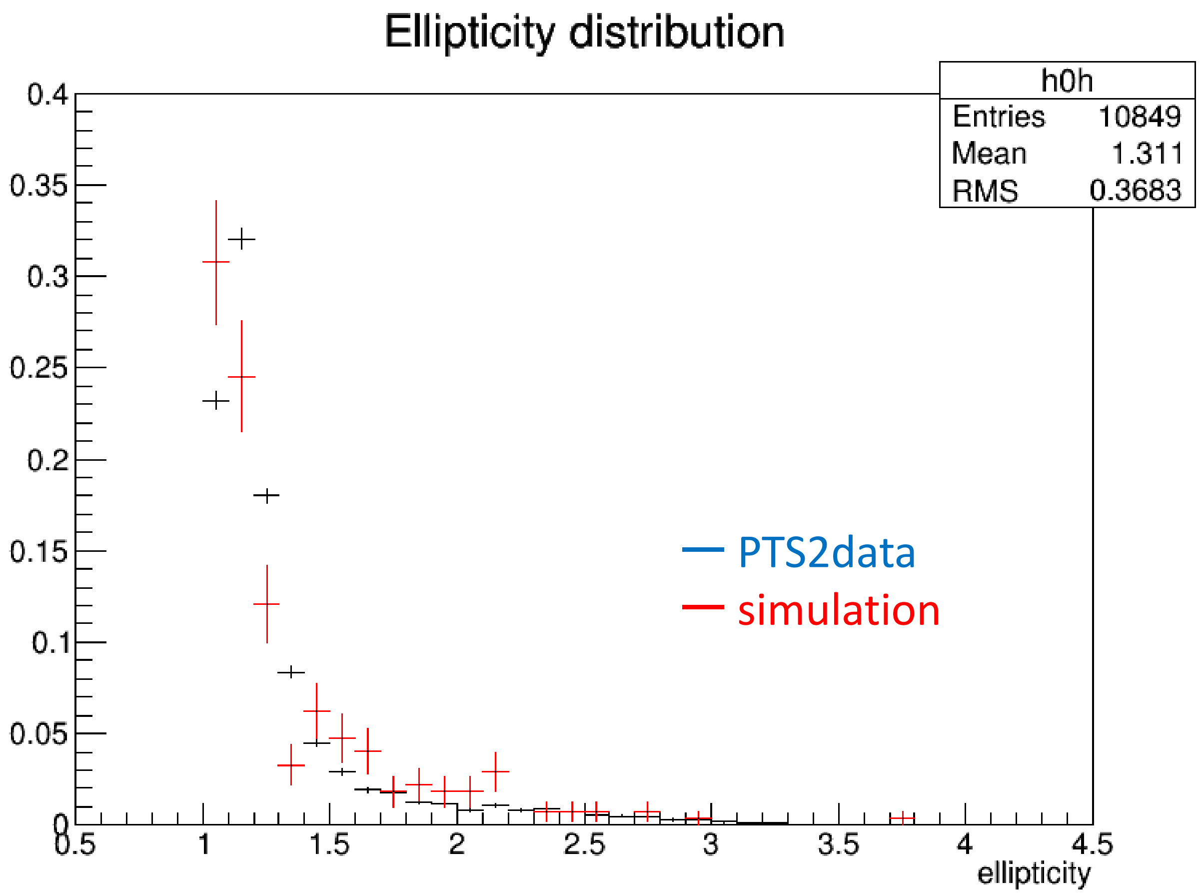


Each grain was set as apertures with R=48 nm.
The optical image was generated (NA1.4 and λ=510 nm)



FFT elliptical fitting
Minor : 3.50747
Major : 5.70059
Elli : 1.62527
Track angle : 112.721

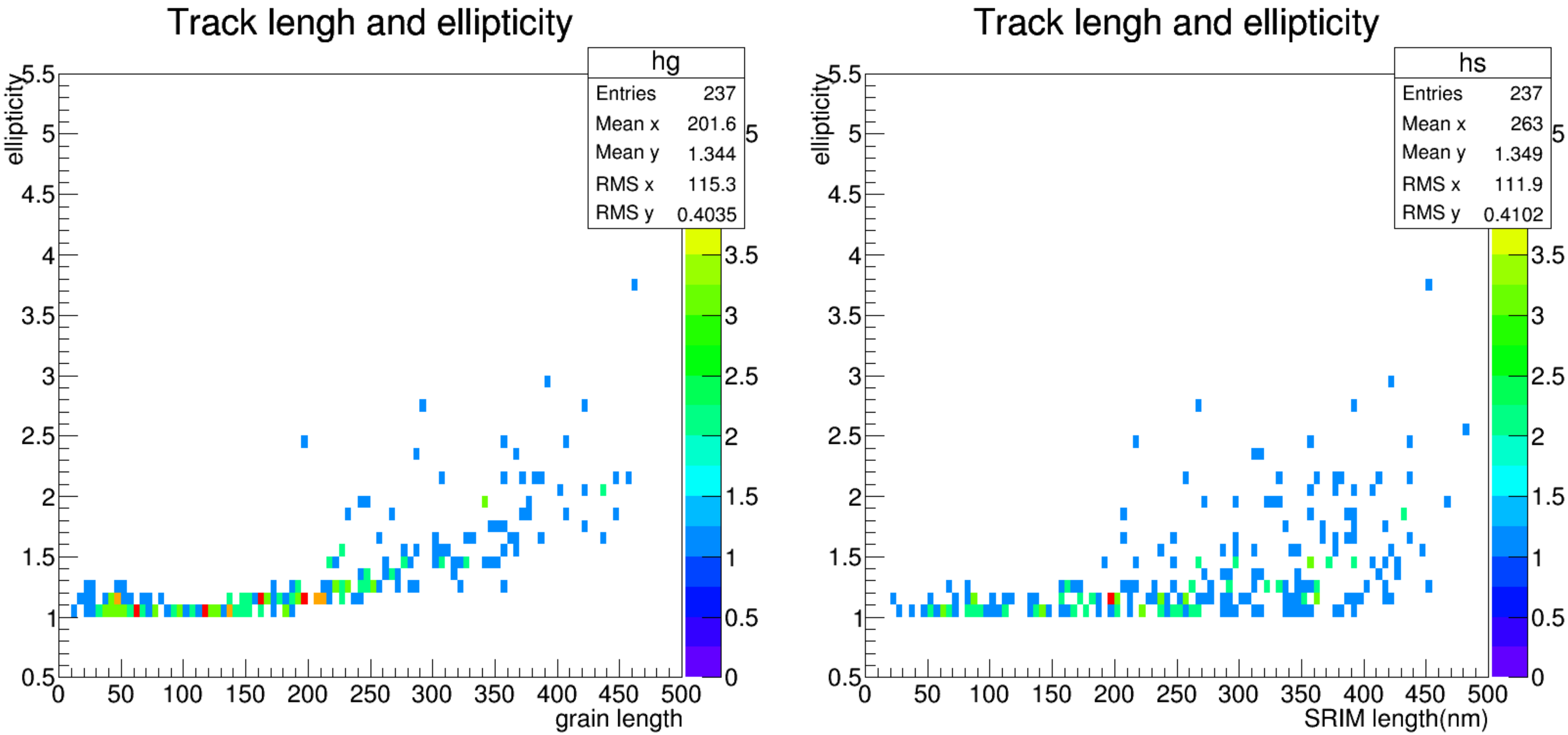
C100 keV ion comparison



- The fog event was subtracted using mask in PTS2 data.

The relation between track range(kinetic energy) and ellipticity seems to be found.

Ellipticity and SRIM ,grain length



Equatorial telescope

- We tested a prototype of equatorial telescope for DM directional detection.
- New nano. tracker (SIGHTRON company) was used.

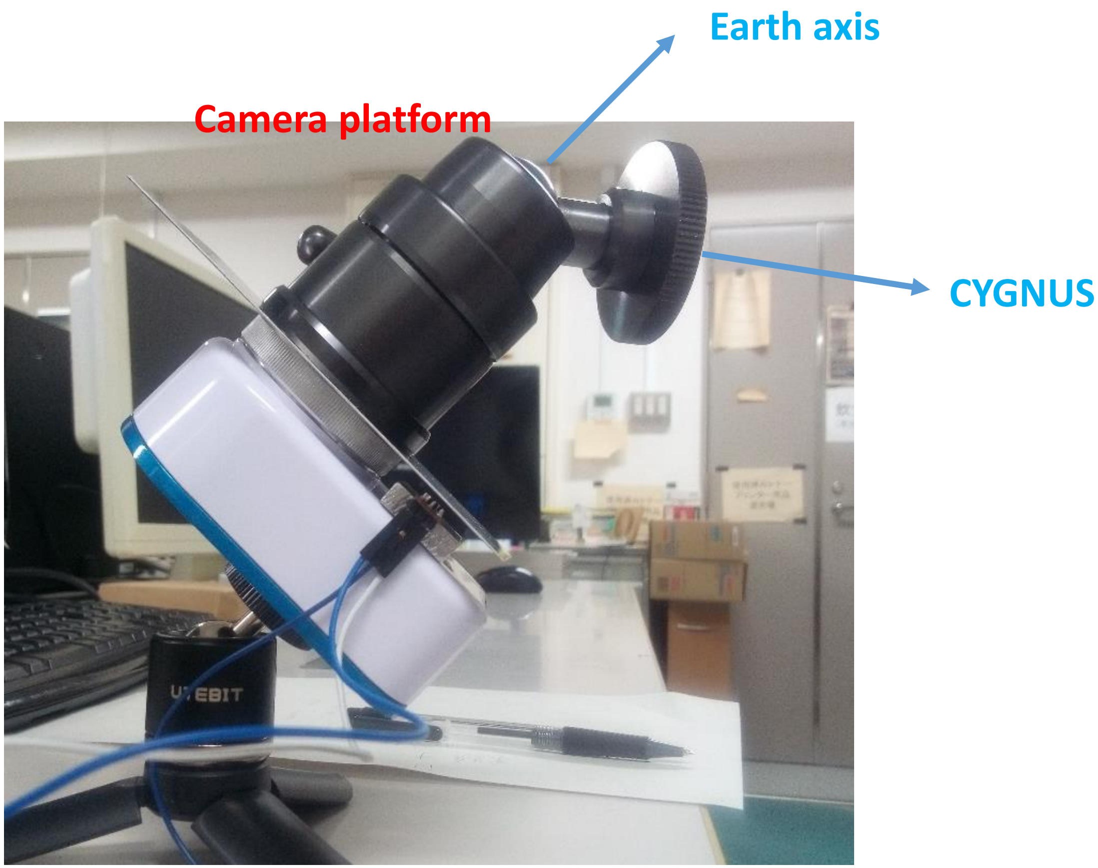
http://www.sightron.co.jp/sightron/sightron_products25/

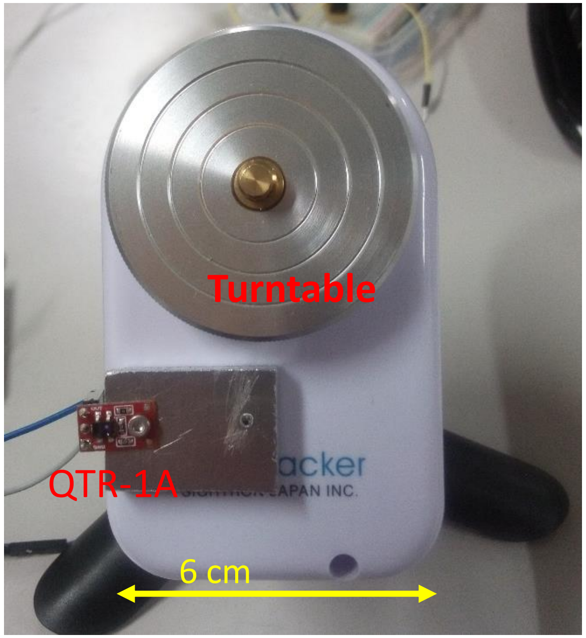
New nano. tracker

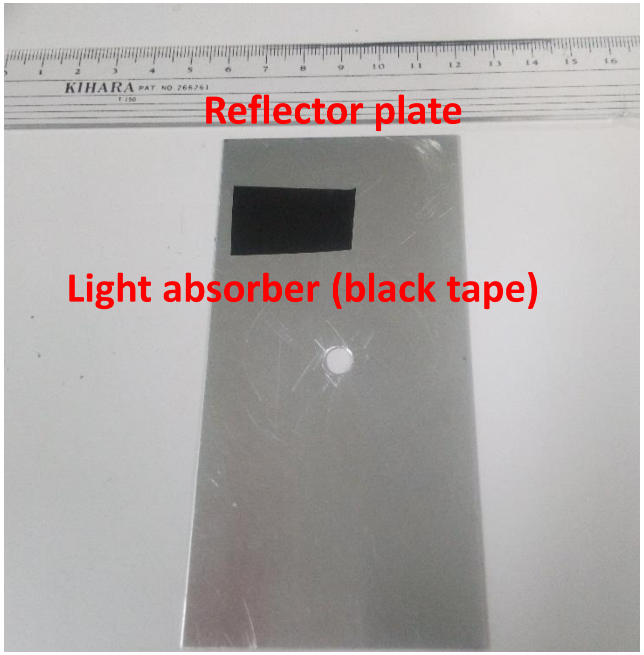
From WEB page

- Portable equatorial telescope
- 60×98×44 mm , 400g
- Power supplied from socket with USB
- Guaranteed temperature -10 ~ 40℃

Equatorial telescope setup

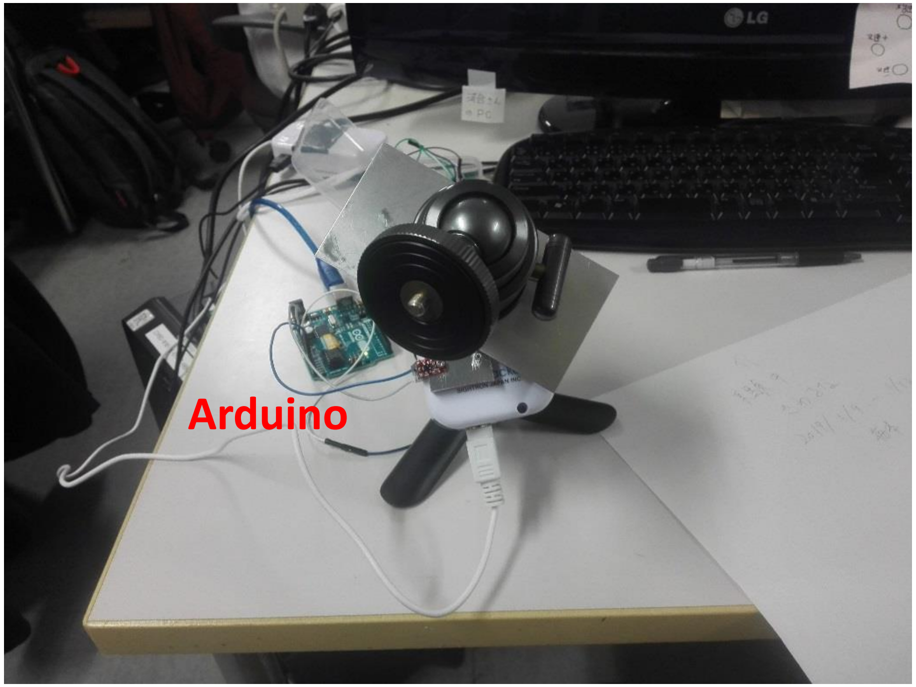


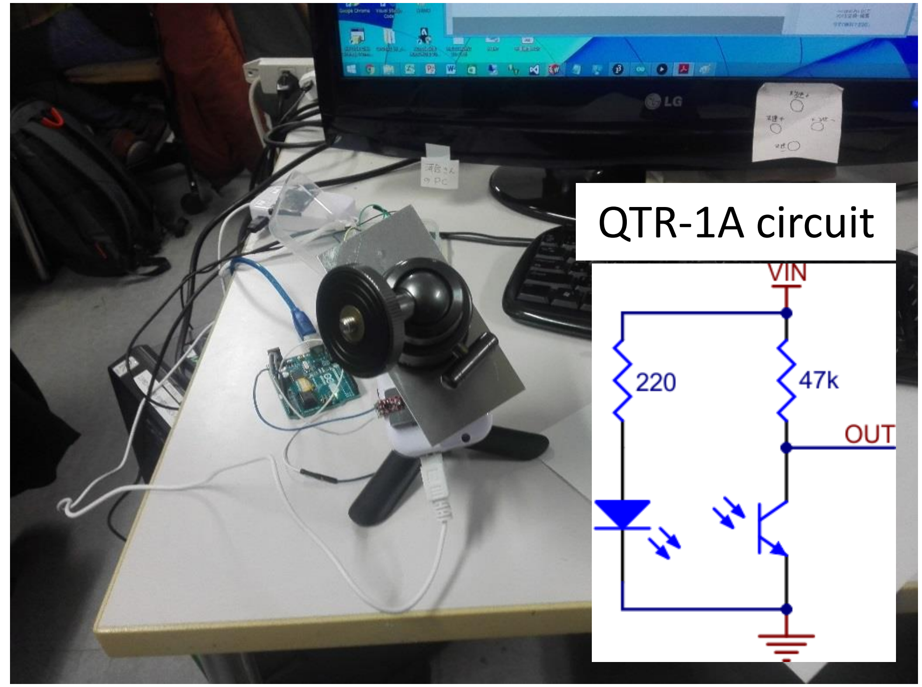




Our telescope consists of

- Camera platform for setting NIT toward CYGNUS
- Reflector plate and photoreflector (QTR-1A) to monitor telescope running
- Microcomputer for data taking of photo reflector





2019/01/11/15:03

2019/01/11/17:01

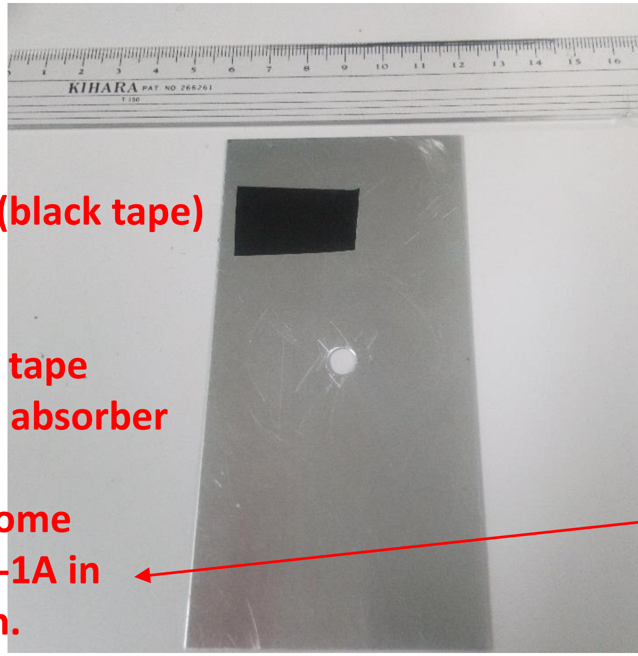
Equatorial telescope rotates the camera platform with reflector plate.
QTR-1A catches emitted light by itself when the reflector plate comes upward of QTR-1A.
Then the output voltage of QTR-1A becomes lower.
- Reflector plate is not square in this test, so we can get the time difference of output voltage and it has the relation with the telescope movement.

“arduino” (a kind of microcomputer) operates QTR-1A and also records output voltage in time as a text file.

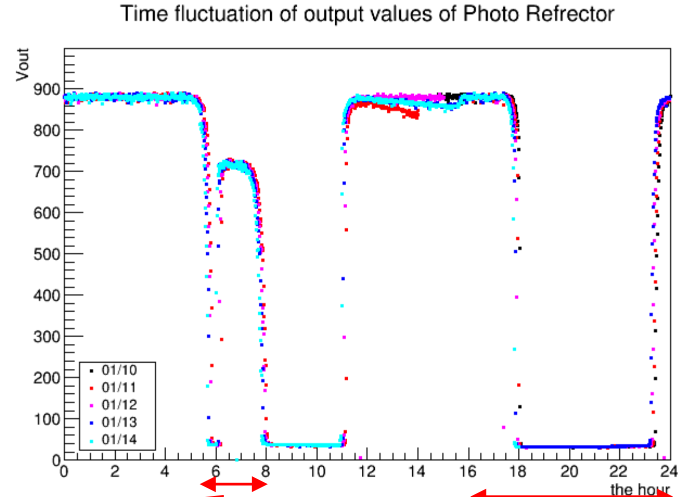
Test at room temperature

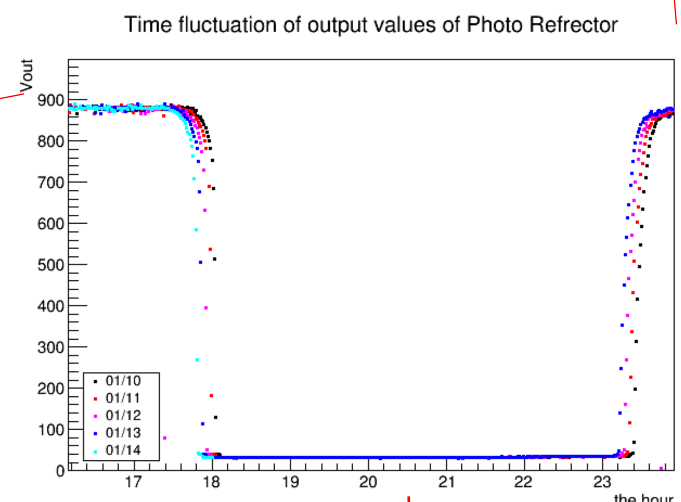
Data taking in a minute

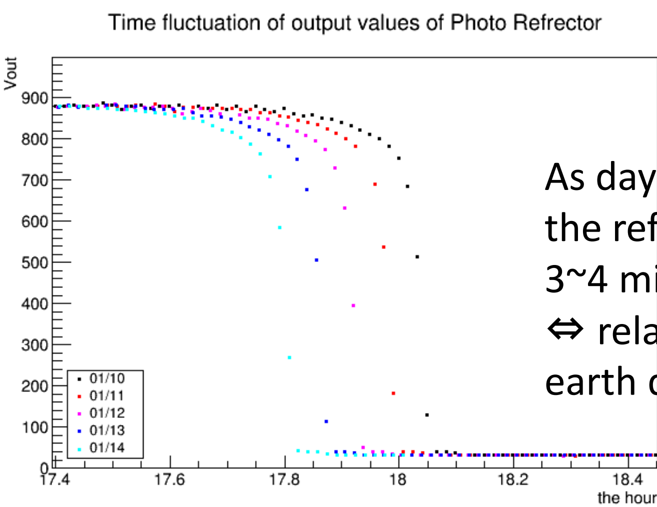
Light absorber (black tape)



I checked if the tape worked as light absorber in this test .
The tape was come upward of QTR-1A in this time region.



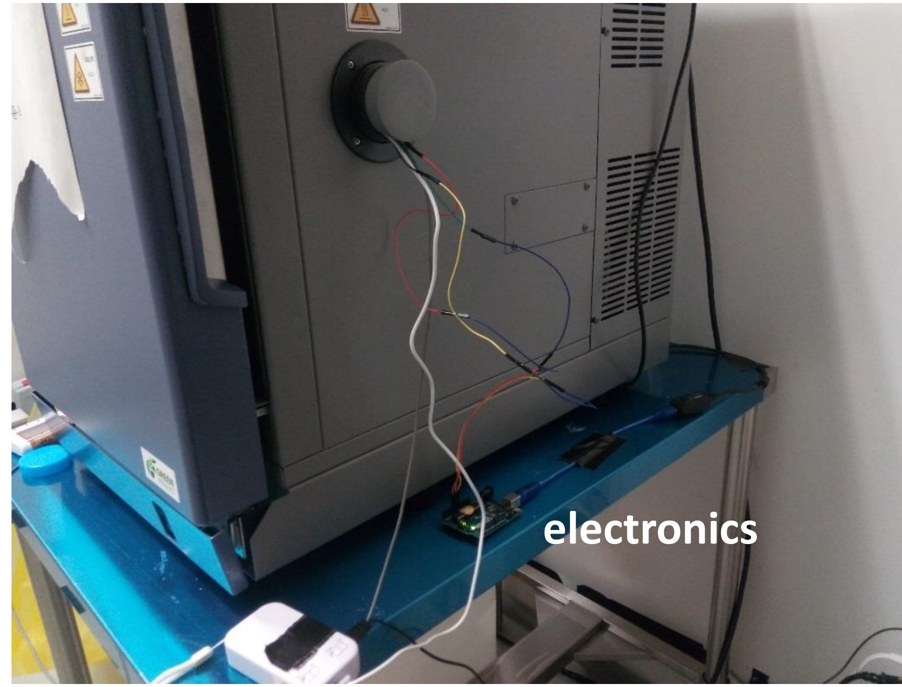




As day passes,
the reflector plate came 3~4 minutes earlier.
⇔ relation with the earth diurnal rotation

I checked the reflector plate came on the QTR-1A sensor by eyes.

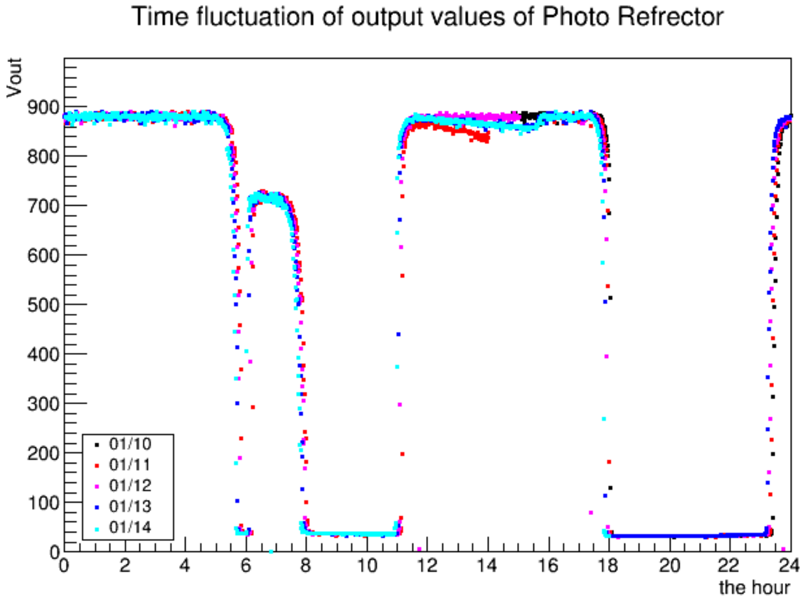
Test at -10 degree

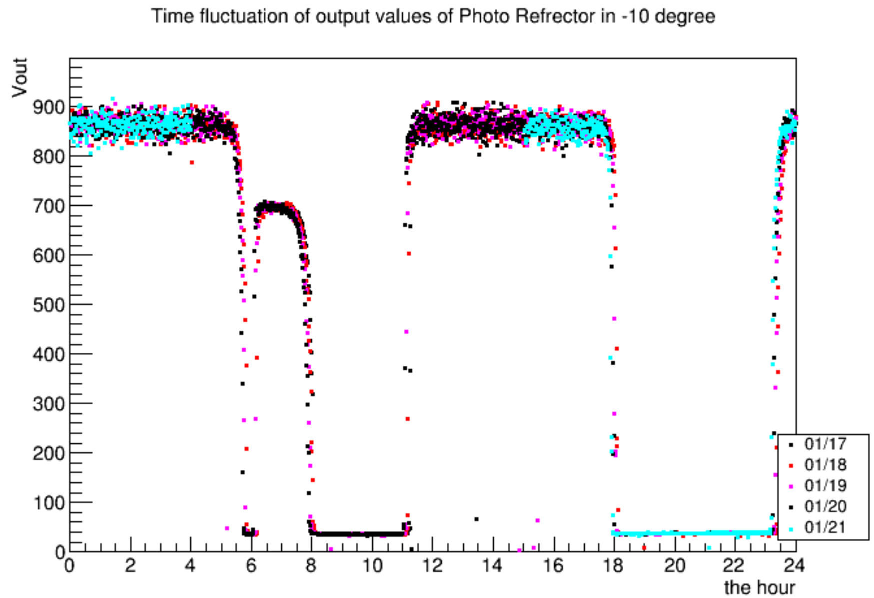


Temperature sensor

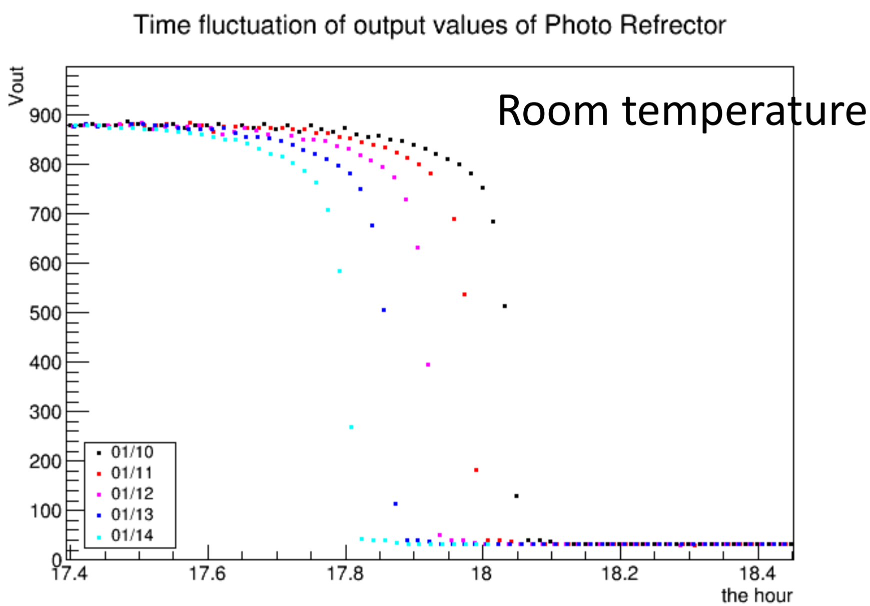
Room temperature

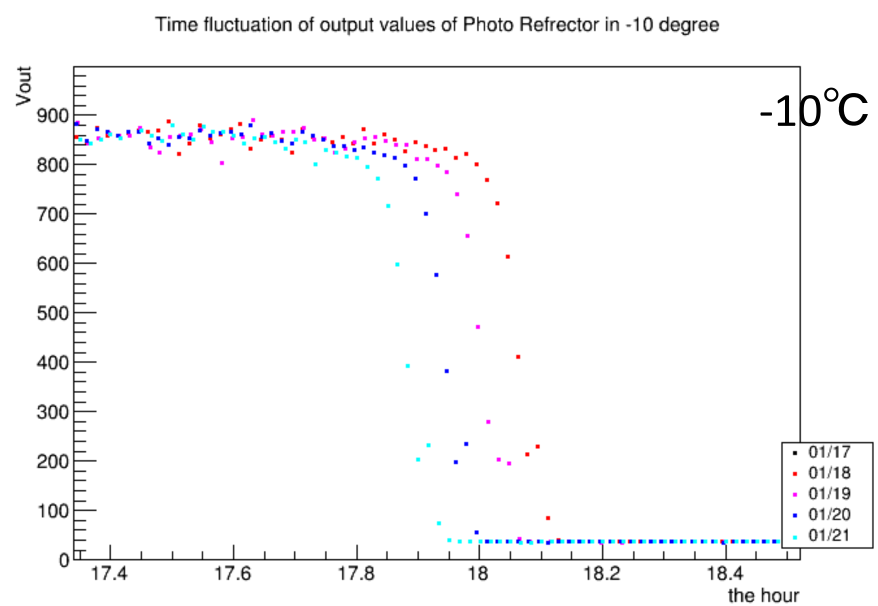
-10°C





The shape of Vout in -10 degree was almost same as that of room test.





Plan and summary

- Scanning speed is enough to do 1 gram DM search. (Only PTS2)
- The angular resolution was improved by FFT elliptical fitting and DM directional search can be done with equatorial telescope($\Rightarrow$ BG event has flat distribution).
- DM cross-section will be calculated using ellipticity and SRIM.

Our important task is rejecting dust events.

- The number of dust event generated by development process can be reduced by tuning the pAg in NIT gel production. I would like to produce this NIT and set it on the equatorial telescope at surface-lab.
- Brightness and Phase-contrast information
- NIT70 should be better than NIT40 for rejecting dust (it has to be evaluated)