Gamma Ray Astro Imager with Nuclear Emulsion project: Results in Operation for Time Stamper Emulsion Film and Status of Analysis on Balloon Experiment in 2023, Australia

○Shogo Nagahara, GRAINE collaboration[A, B, C, D, E, F]

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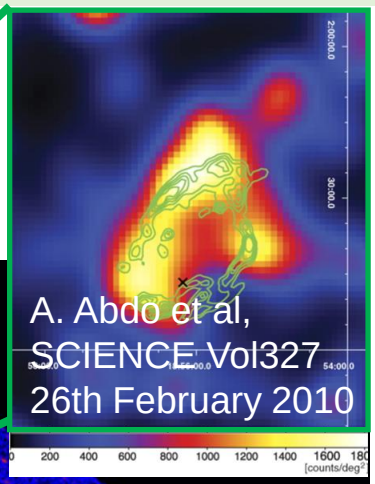
[D]Gifu University, [E]Aichi University of Education and [F]ISAS/JAXA

γ-ray Astronomy

Green：Infrared Observation （Spitzer）



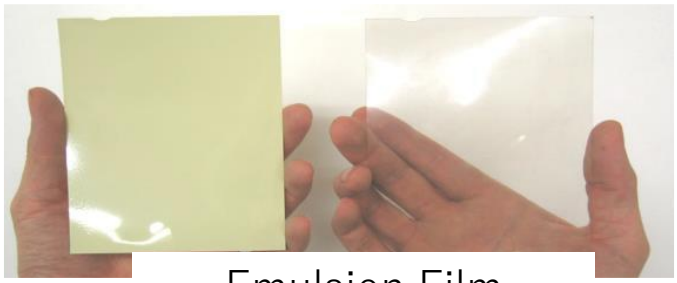
W44

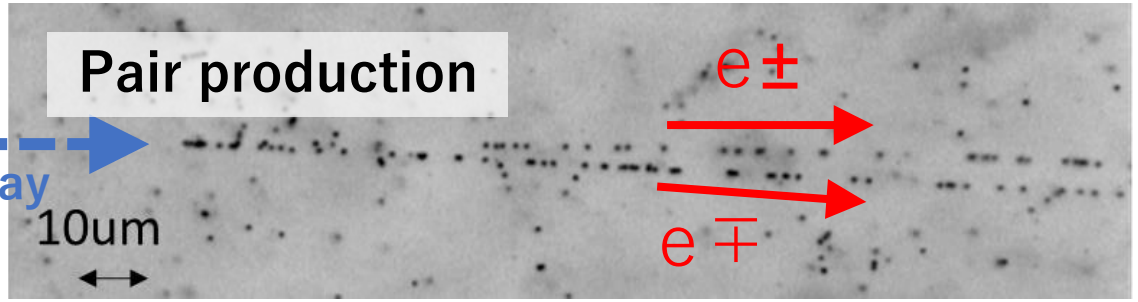
Image Credit:
NASA/DOE/Fermi LAT Collaboration

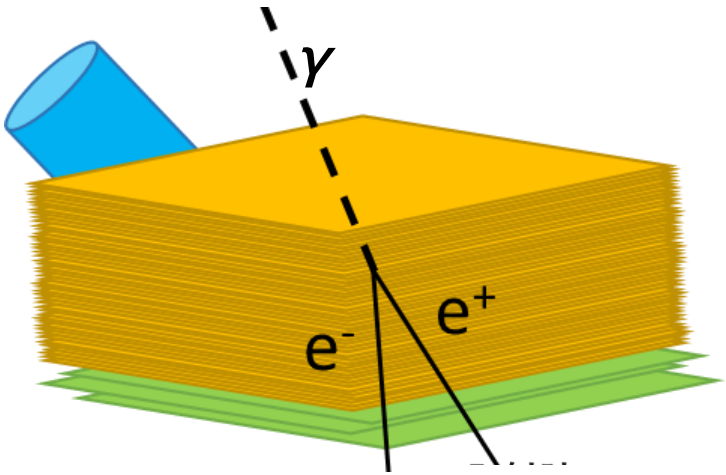
Fermi-LAT> 1GeV

GRAINE project

Gamma-Ray Astro Imager with Nuclear Emulsion





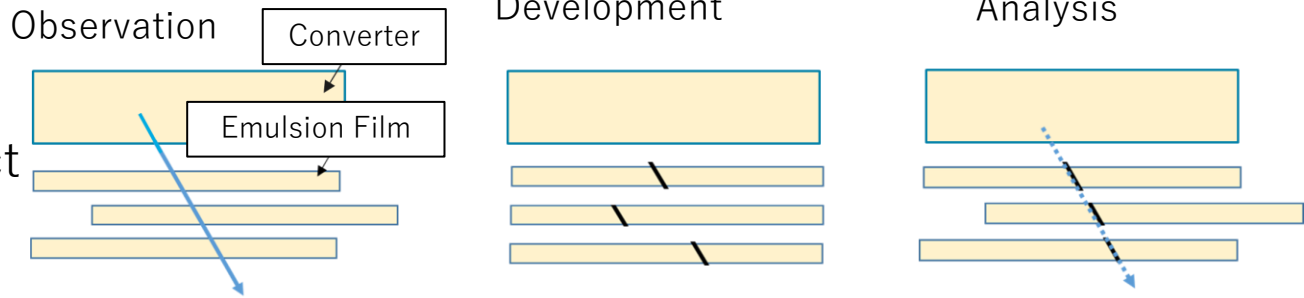


Converter
Emulsion film stack : The part that reconstructs the angle of gamma rays.

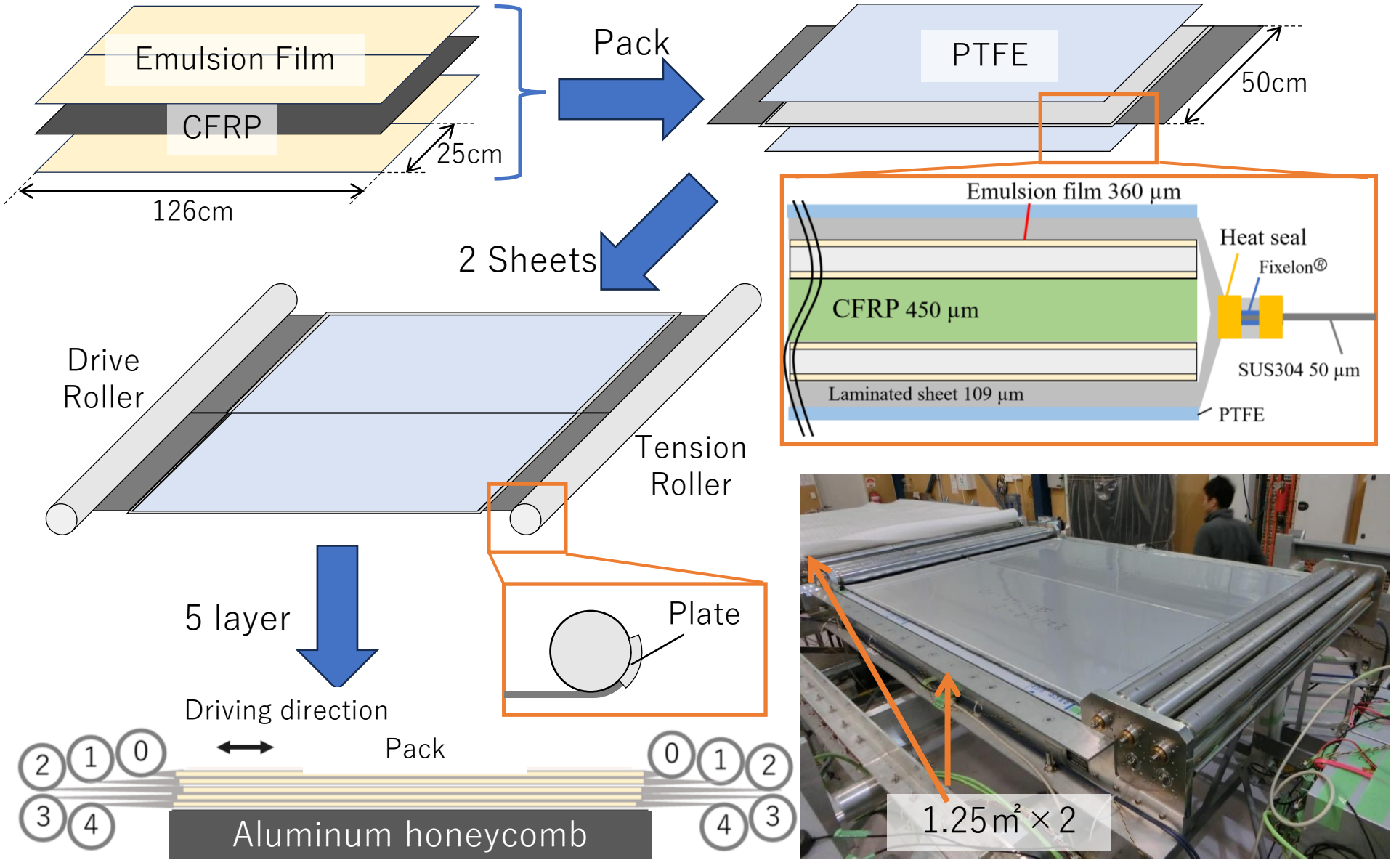
Attitude monitor
Star camera :

Time Stamper
Multi-stage shifter.

Timestamper :
create a unique positional displacements with respect to the time track recorded.



TimeStamper

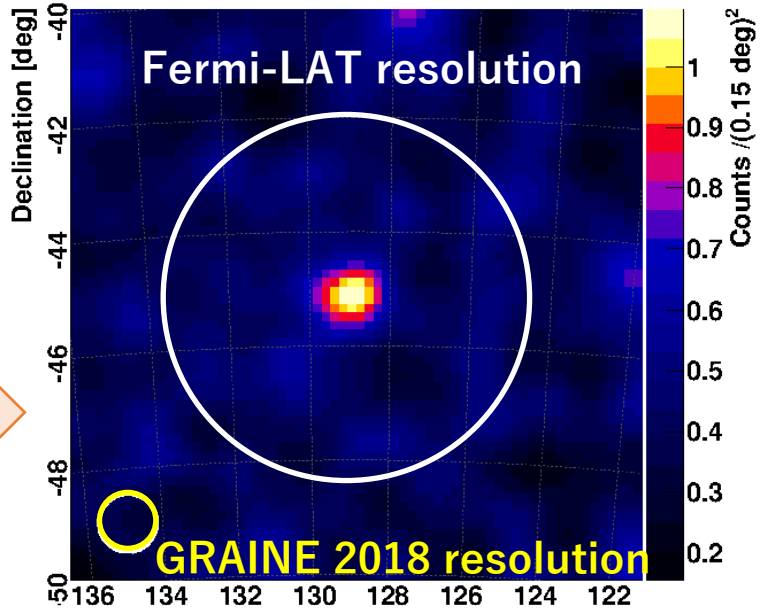


GRAINE roadmap

2011 1st Balloon exp.@Hokkaido
1.6hour, 0.0125㎡ aperture

2015 Demonstration @Australia
11.5hour, 0.378㎡ aperture

2018 Demonstration @Australia
14.7hour, 0.378㎡ aperture
Highest imaging of Vela pulser

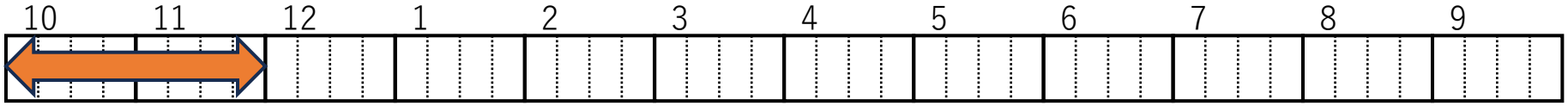


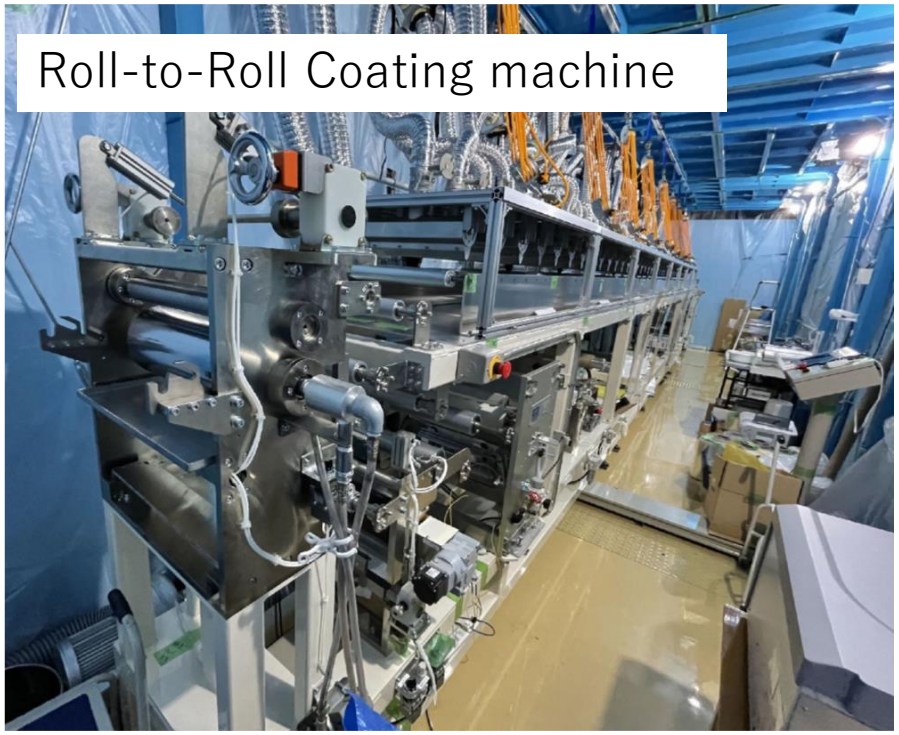
GRAINE 2018, Vela pulser
Takahashi et al., (2023)

NEXT
2023 Scientific flight@Australia
2023, 24.3hour, 2.5㎡ apereture

	Fermi-LAT		GRAINE
Angular resolution@100MeV	6.0° (105mrad)	x1/6 →	**1.0° (17mrad)**
@1GeV	0.9° (16mrad)	x1/9 →	**0.1° (1.7mrad)**
Energy range	20MeV-300GeV		10MeV-100GeV
Effective area @100MeV	0.25㎡	X8 →	**2.1㎡**
@1GeV	0.88㎡	X3 →	**1.4㎡**

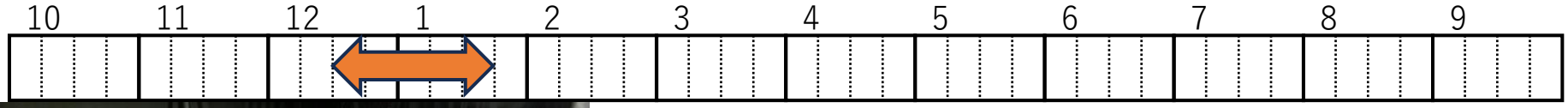
Emulsion Film production

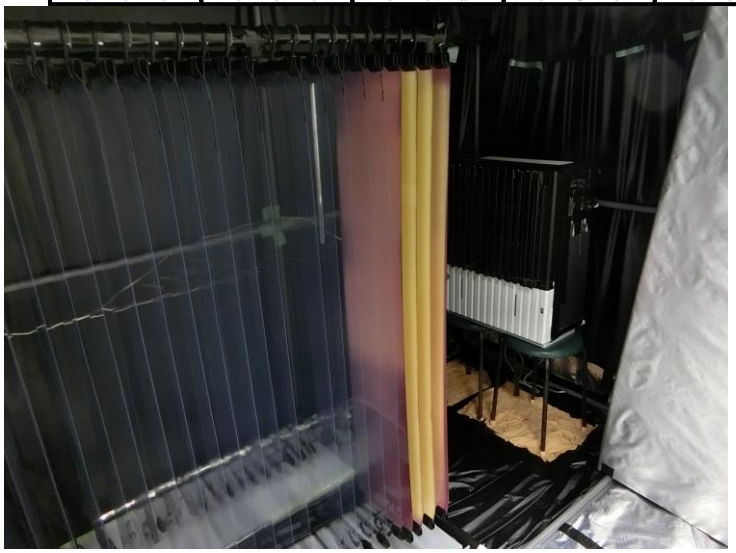


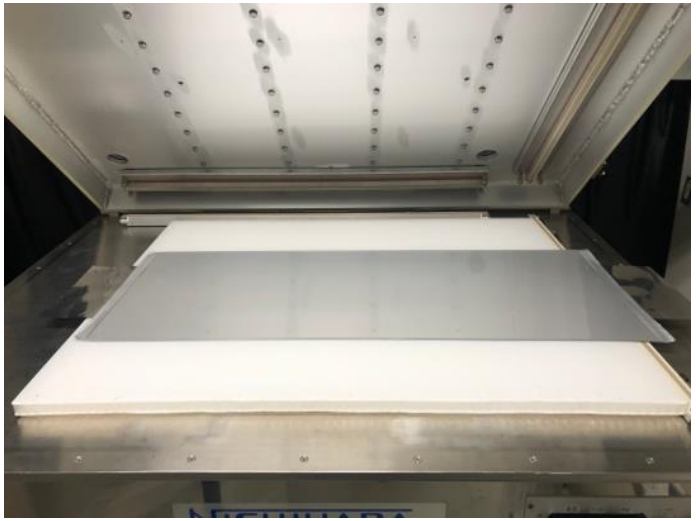


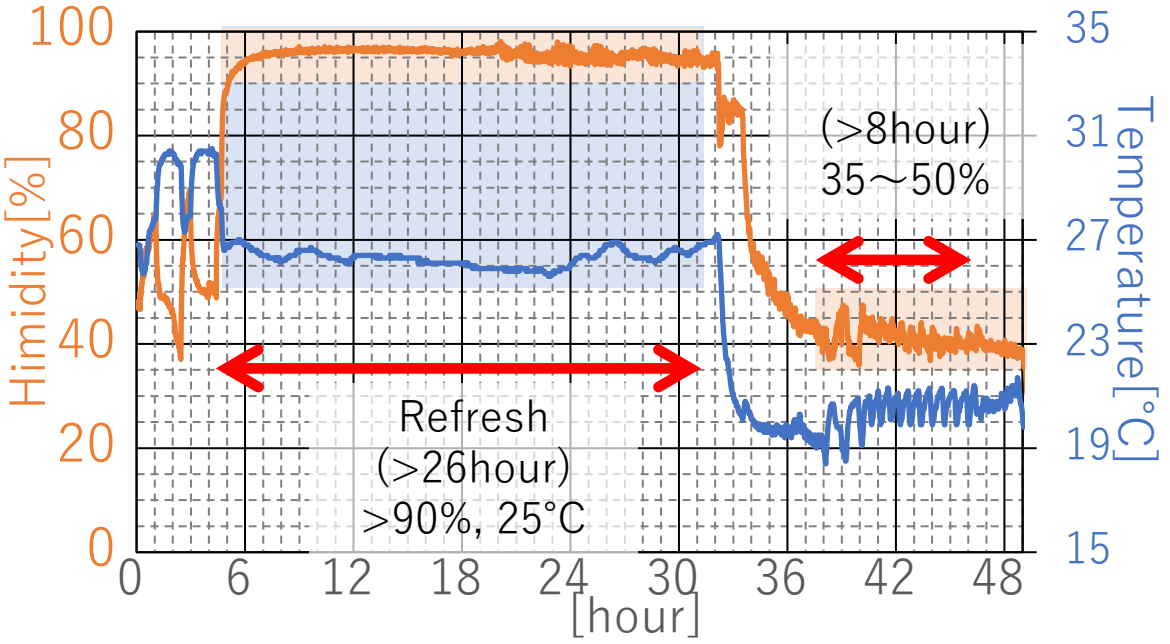
2000㎡/year

Packing



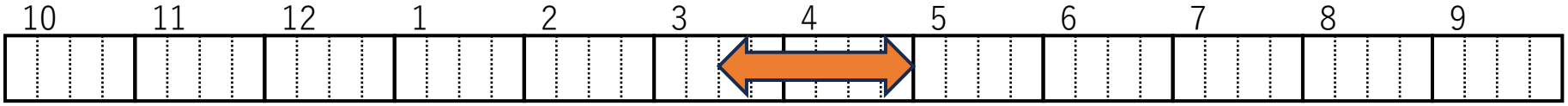


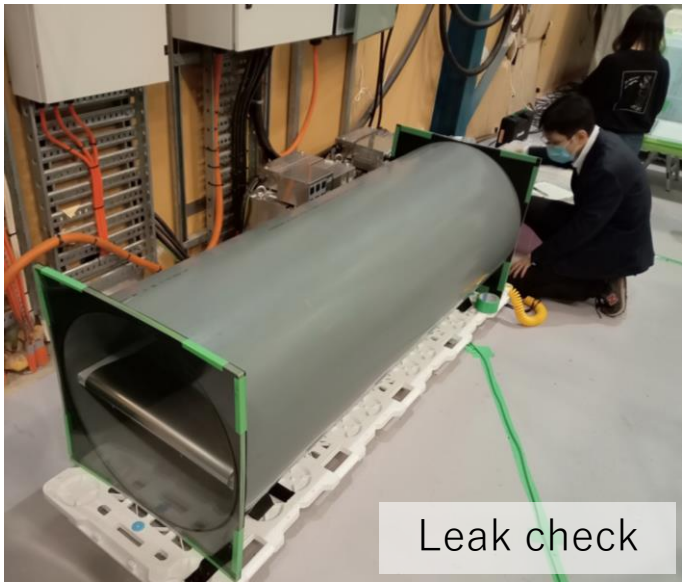


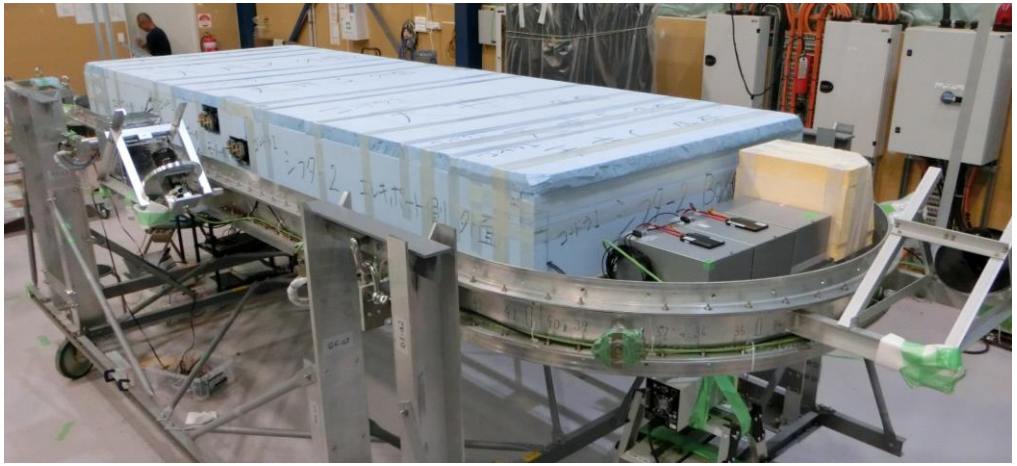


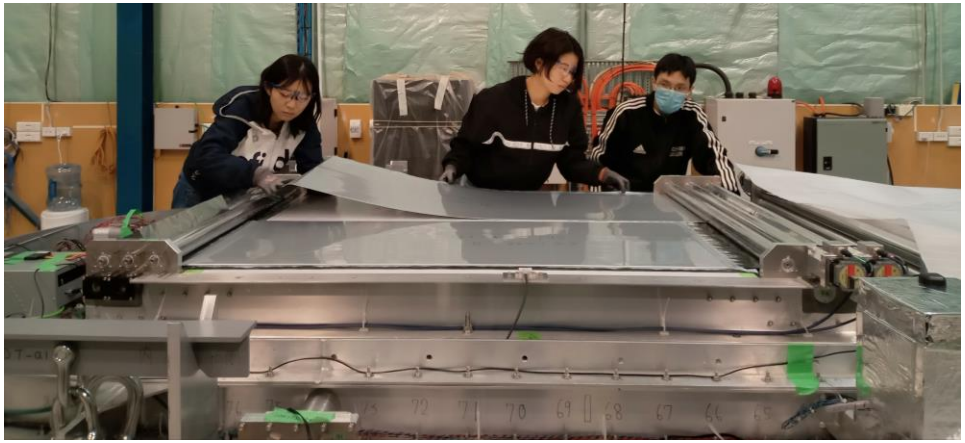
Refresh（25℃、95%RH）
Humidity control（30～50%RH）

Install

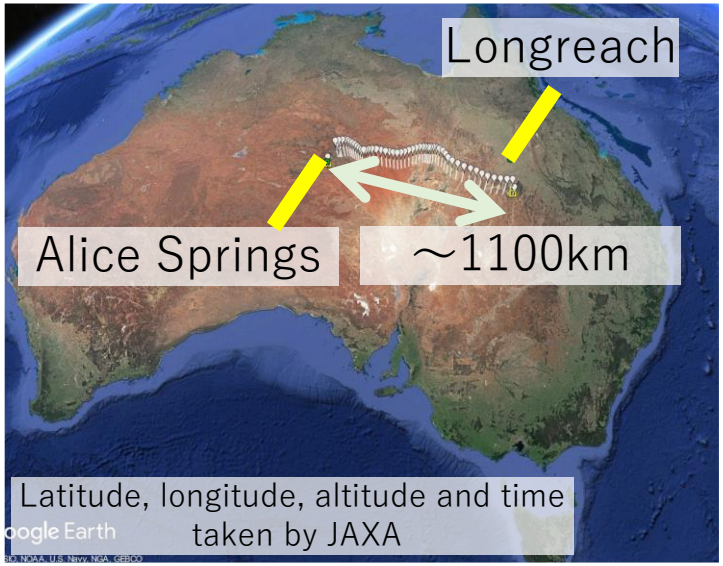


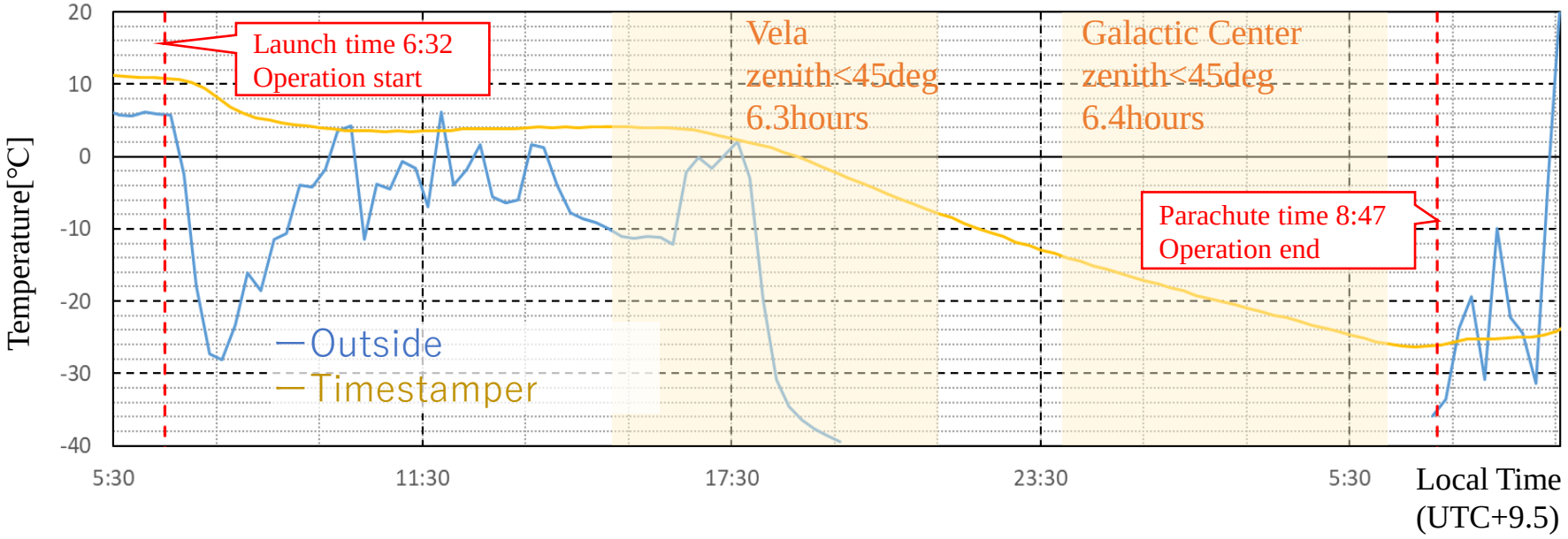




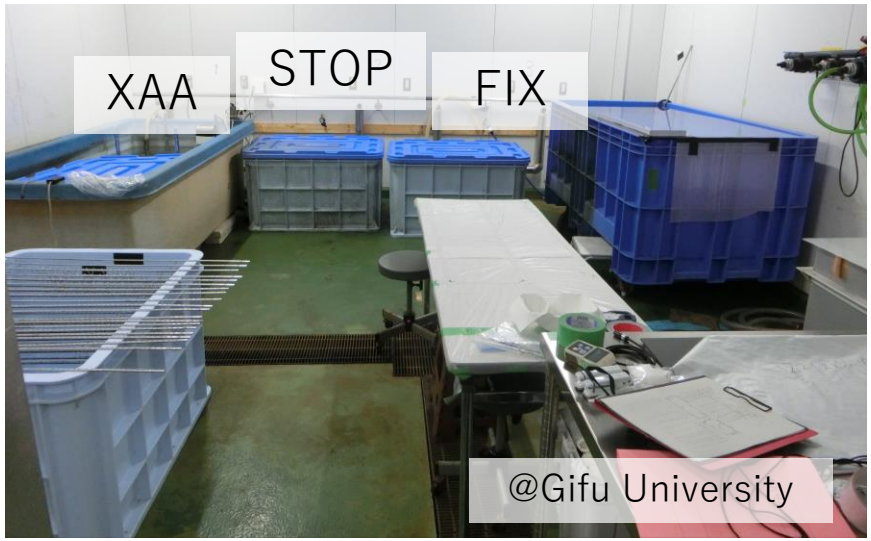


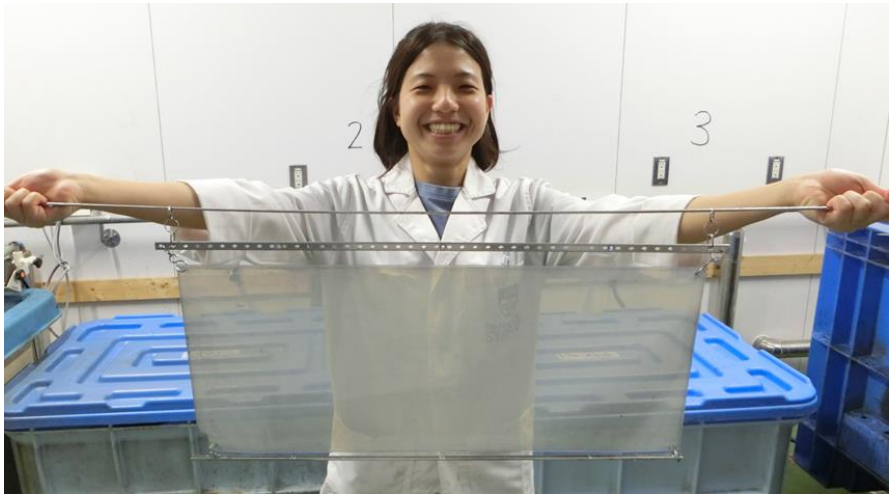
Flight （4/30 6:32）

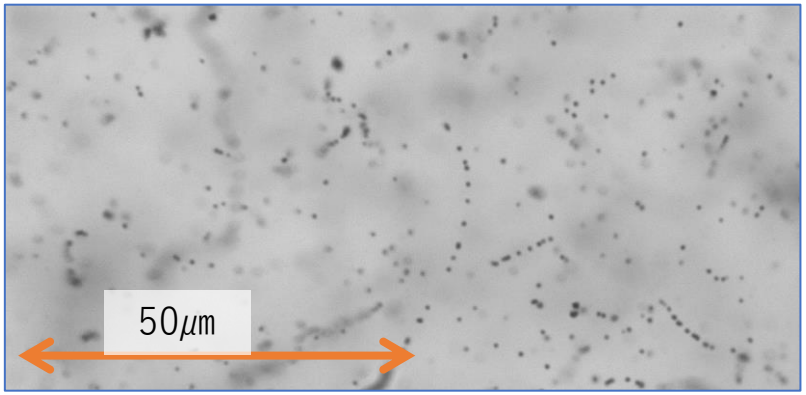




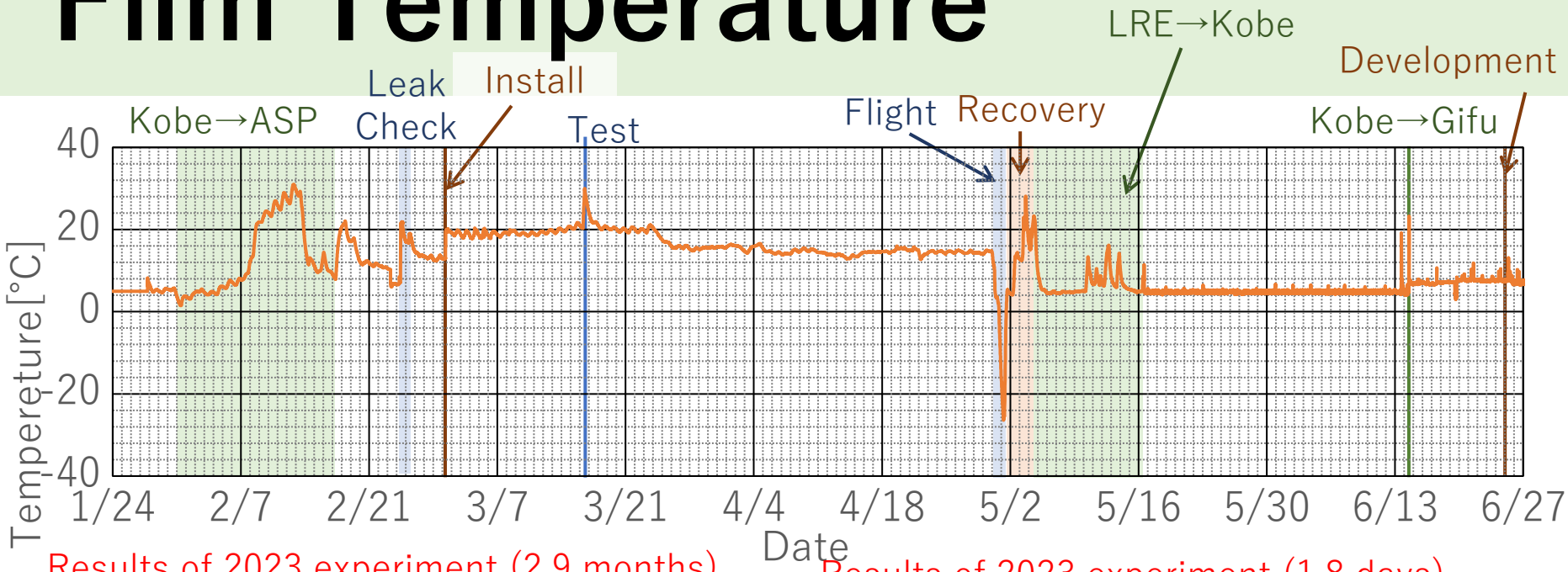
Development & Scan



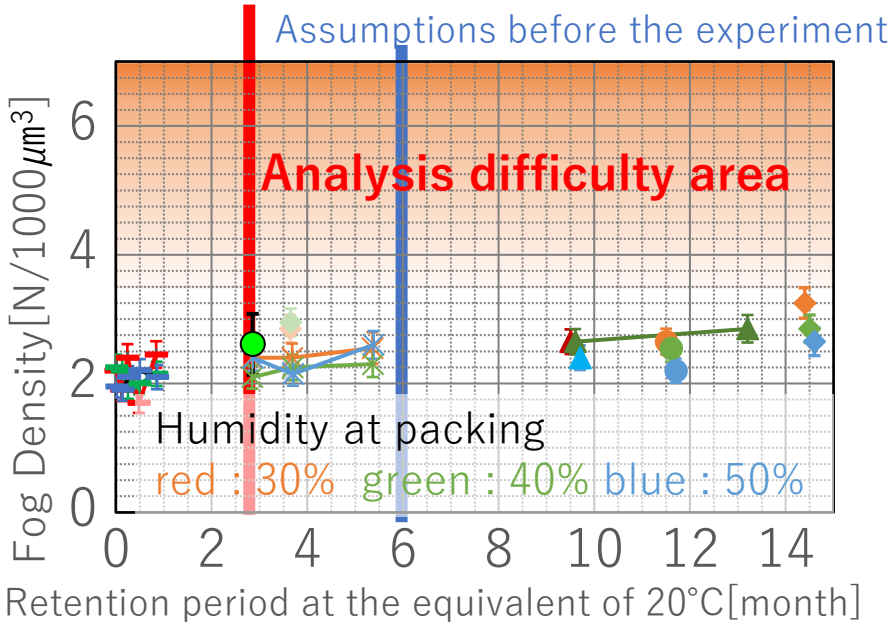




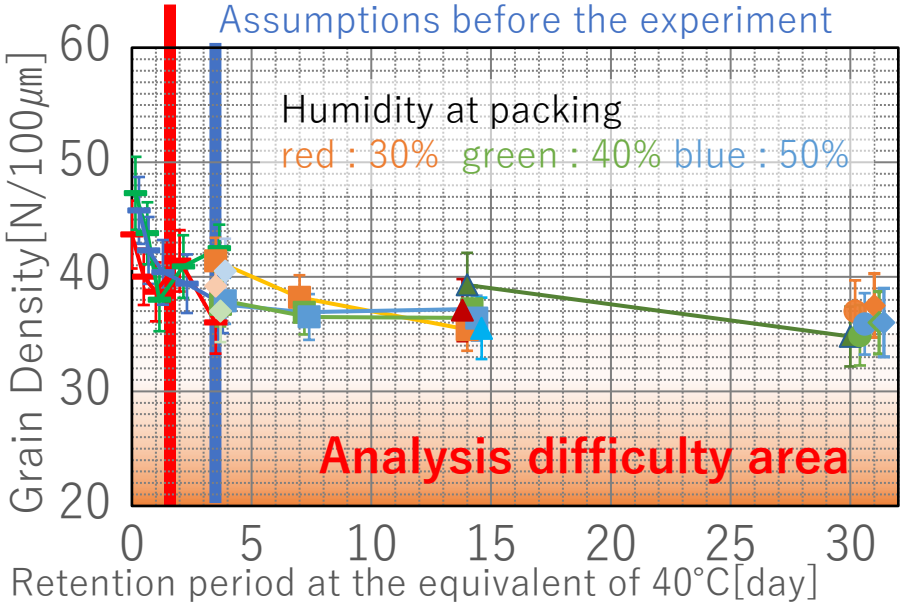
Film Temperature



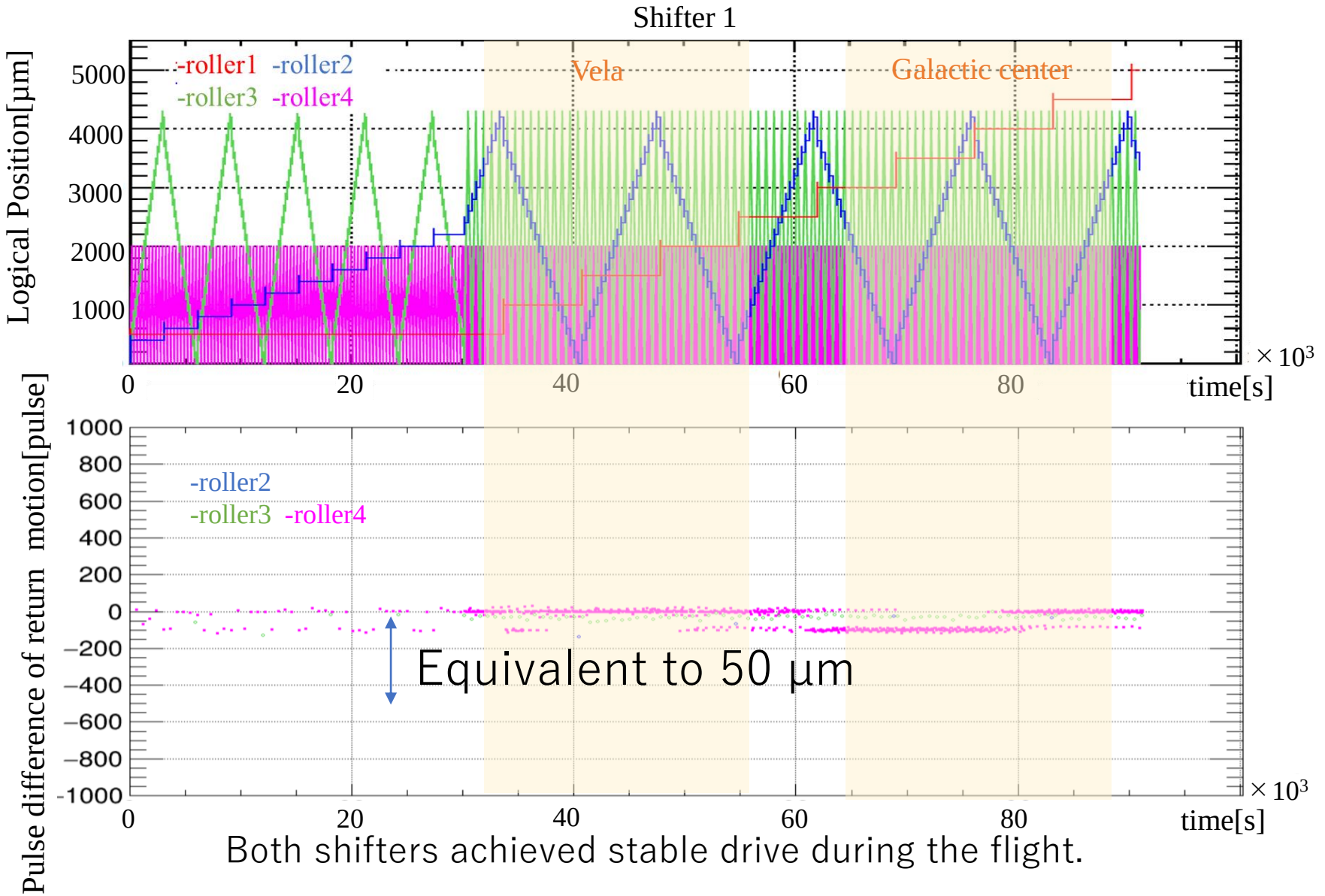
Results of 2023 experiment (2.9 months)



Results of 2023 experiment (1.8 days)

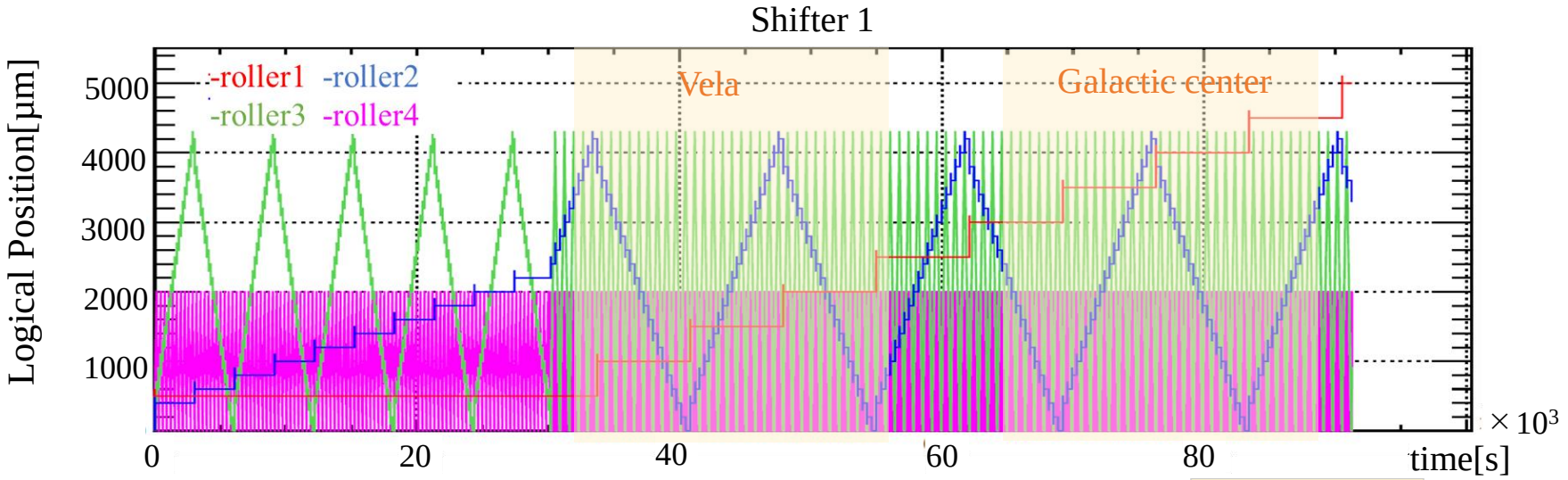


In-flight operations

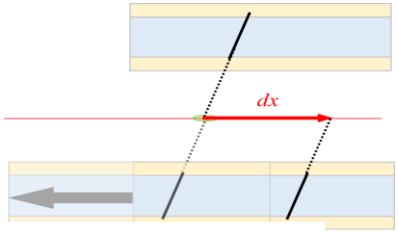


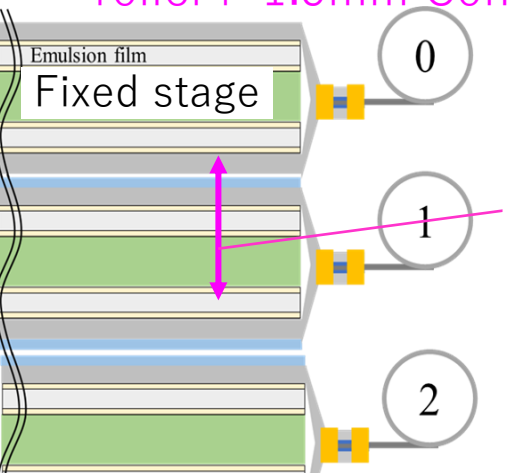
Both shifters achieved stable drive during the flight.

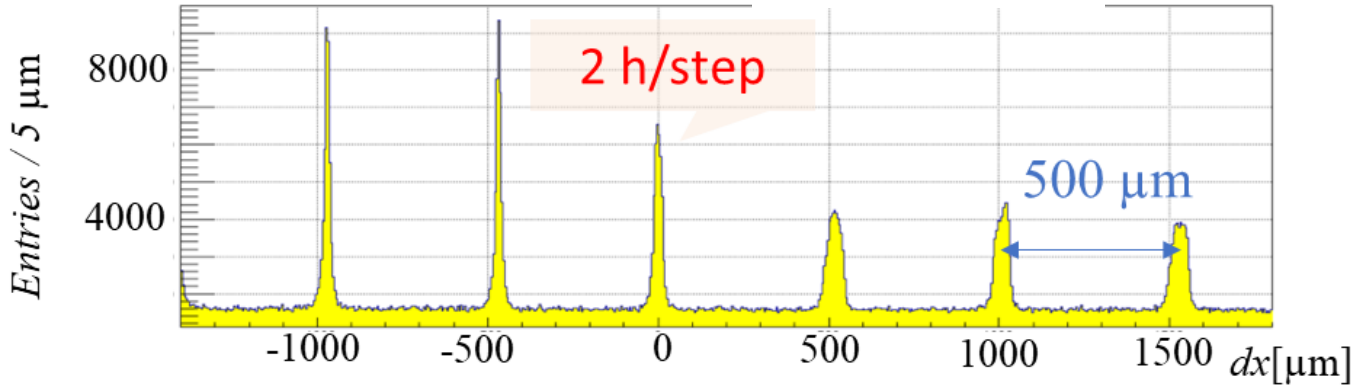
In-flight operations



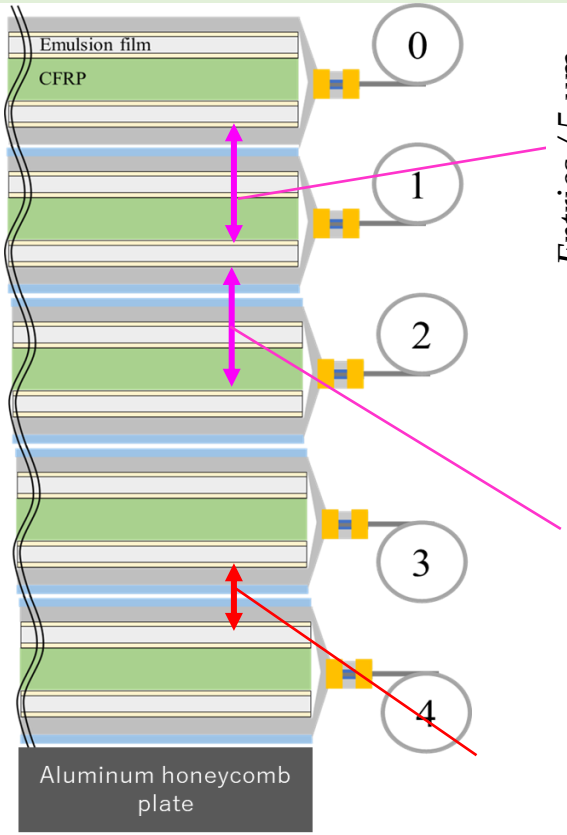
roller1 500 μm × 9 step(～2h/step)
roller2 200 μm × 20 step (～6min/step)
roller3 200 μm × 20 step (～15s/step)
roller4 1.5mm Continuous (100μm/s or 10μm/s)

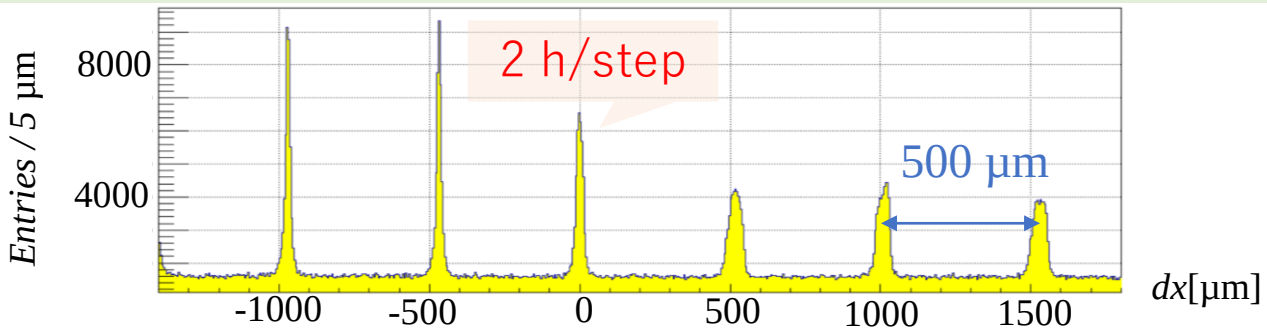




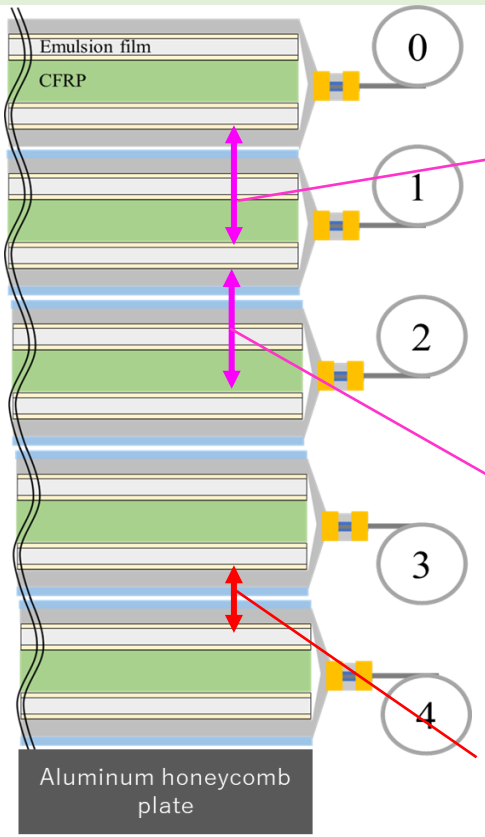


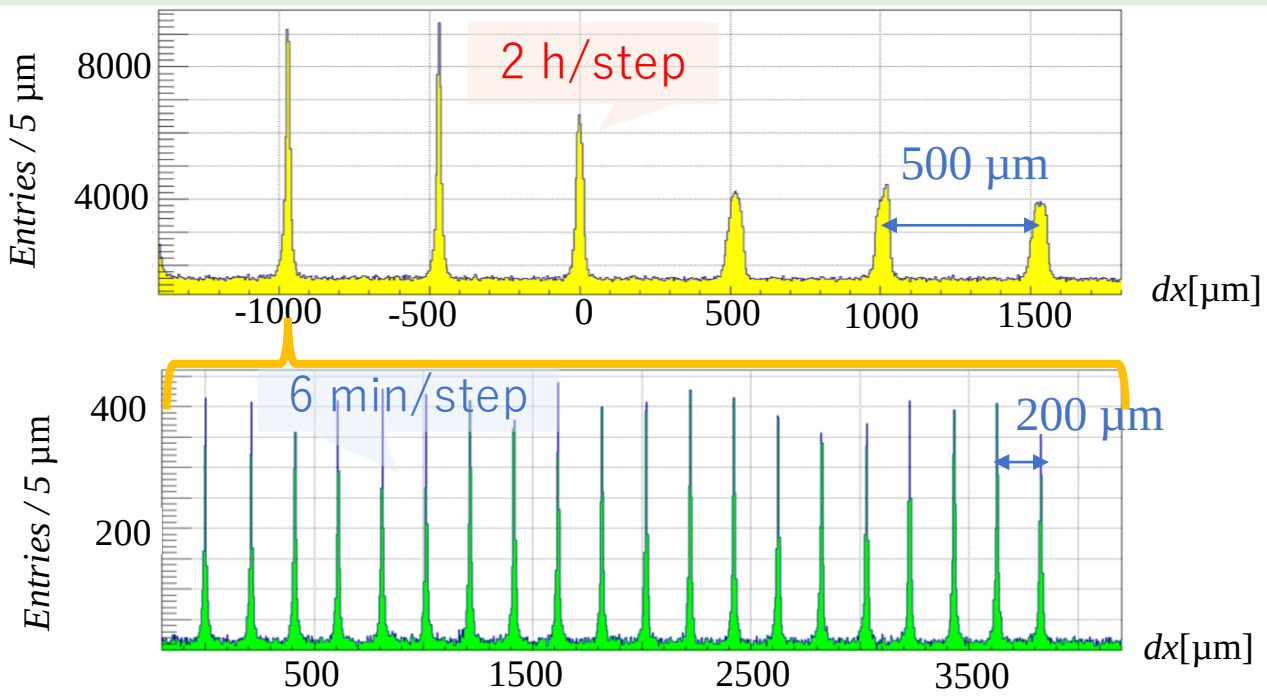
Time stamp


Emulsion film
CFRP
0
1
2
3
4
Aluminum honeycomb plate

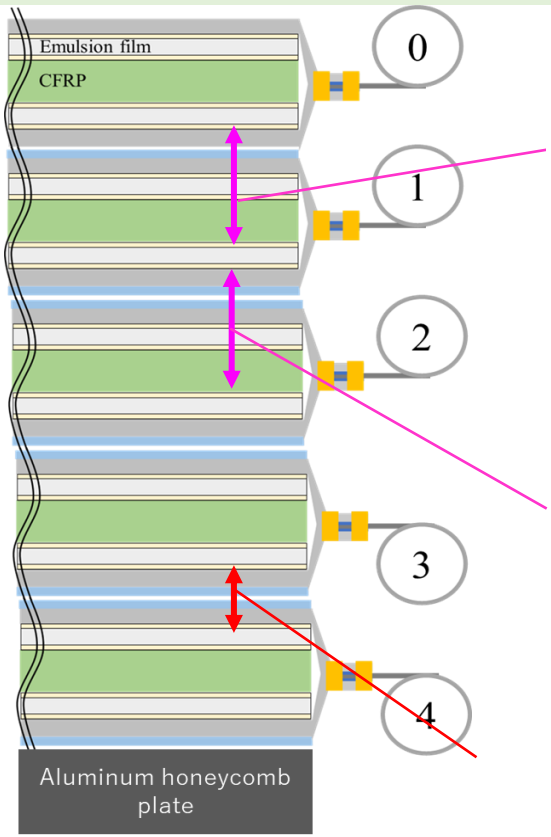

Entries / 5 µm
8000
4000
2 h/step
500 µm
-1000
-500
0
500
1000
1500
dx[µm]

Time stamp


Emulsion film
CFRP
0
1
2
3
4
Aluminum honeycomb plate


Entries / 5 µm
8000
4000
2 h/step
500 µm
-1000
-500
0
500
1000
1500
dx[µm]
Entries / 5 µm
400
200
6 min/step
200 µm
500
1500
2500
3500
dx[µm]

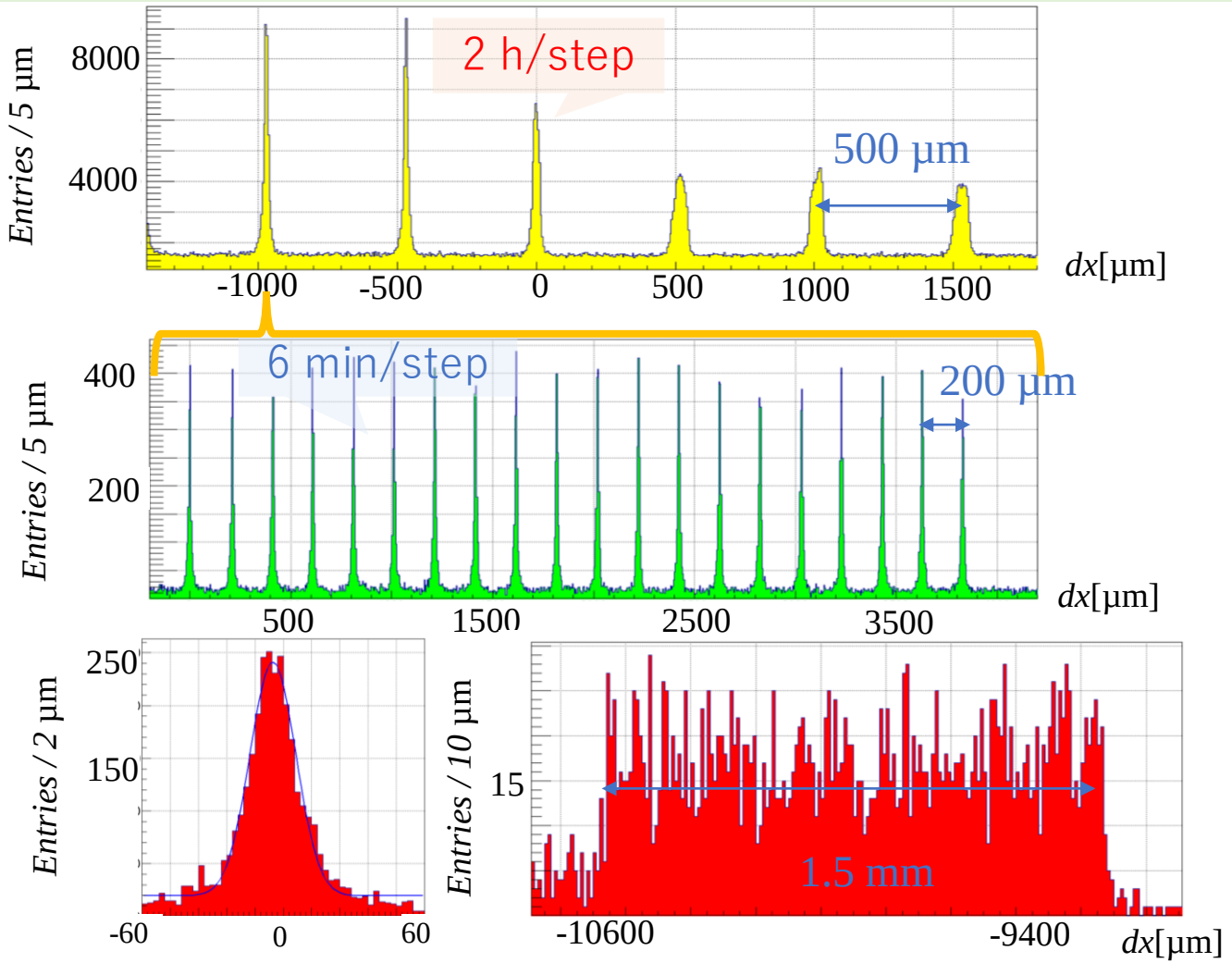
Time stamp



tanθ<1.0

Reconstruction accuracy

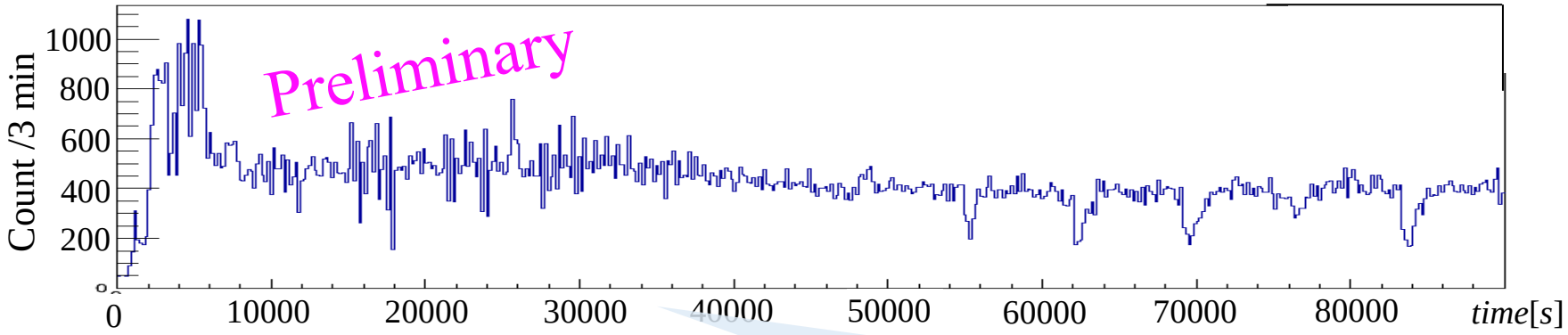
σ=9.1 ± 0.1 μm

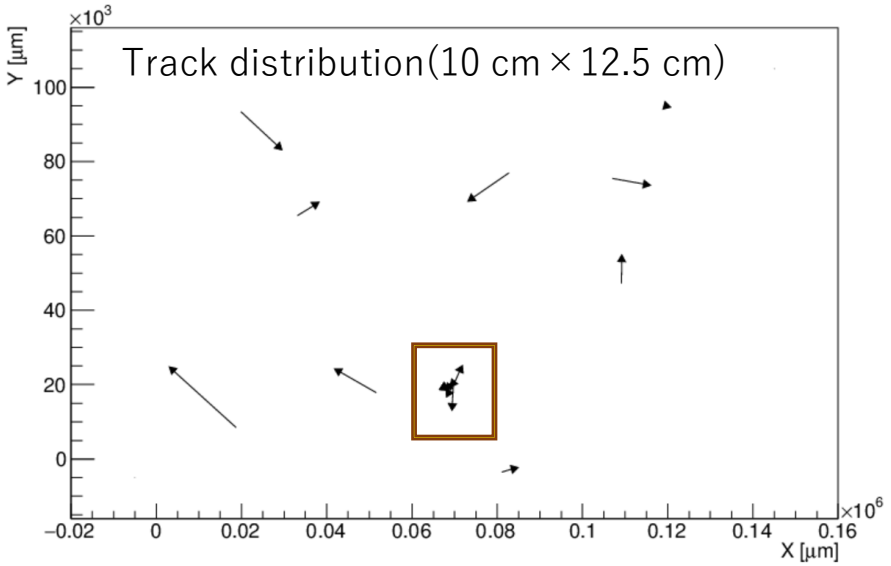


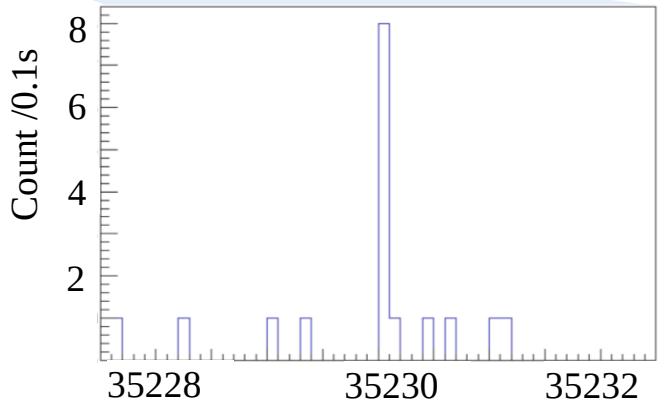
Time resolution = Reconstruction accuracy / Driving speed

σt = 9.1 [μm] /100 [μm/s] = ~0.1 [s]

Time stamp



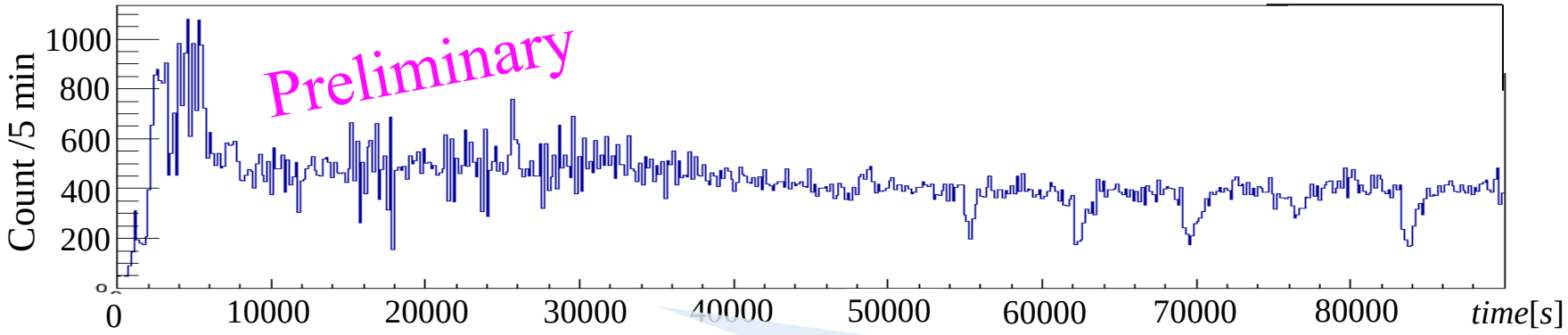


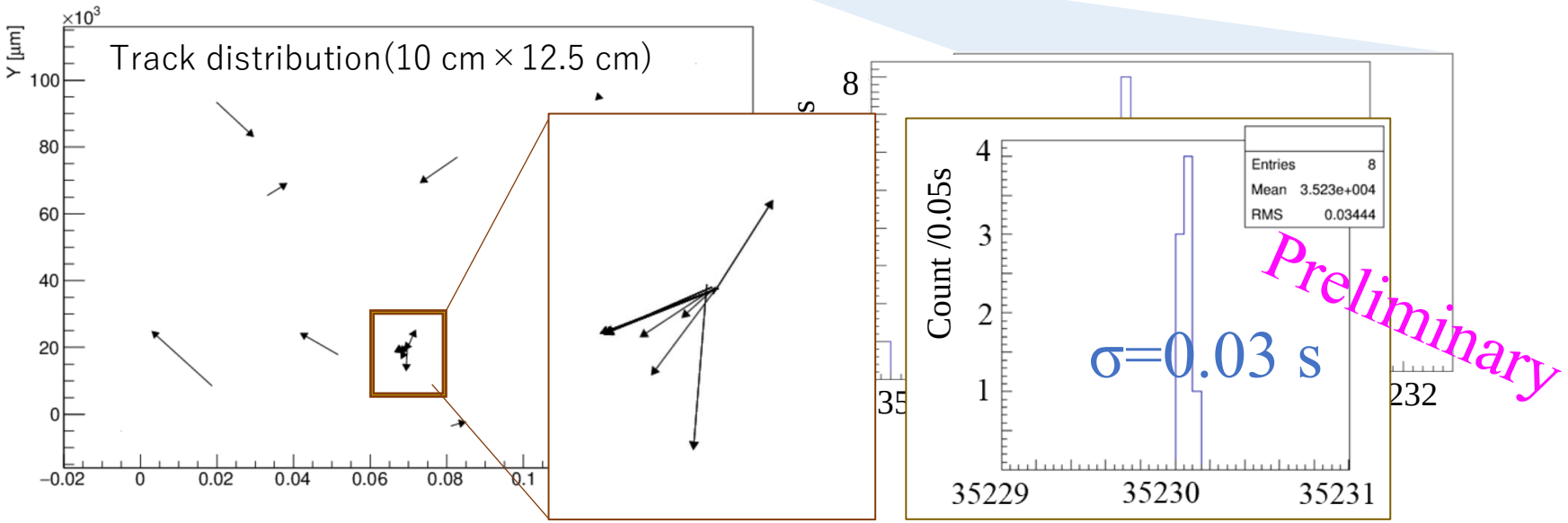


Search for events where multiple tracks converge upstream to a single point.
Evaluate time resolution by considering them as hadron jets.

Time stamp

(角度ずれ0.01° 以内、y方向位置ずれ50 μm以内)





Search for events where multiple tracks converge upstream to a single point.
Evaluate time resolution by considering them as hadron jets.

Conclusion

- **We performed our first scientific observation, the 2023 balloon experiment.**
- **The 2023 experiment succeeded in developing the film in about half the time previously assumed.**

- **We confirmed the operation of timestamper with tracks.**
  - High time resolution of **~0.1 s**.
  - Gondola rotation angle of the 2018 experiment 0.31 deg/s
    - **High angular resolution imaging of 0.1° is expected.**

- **Large-area scanning of film is in progress.**
  - we will try to observe Vela pulsar precisely (0.1° @1 GeV) and detect Galactic Center region.