Balloon-borne Emulsion Gamma-ray Telescope

GRAINE project

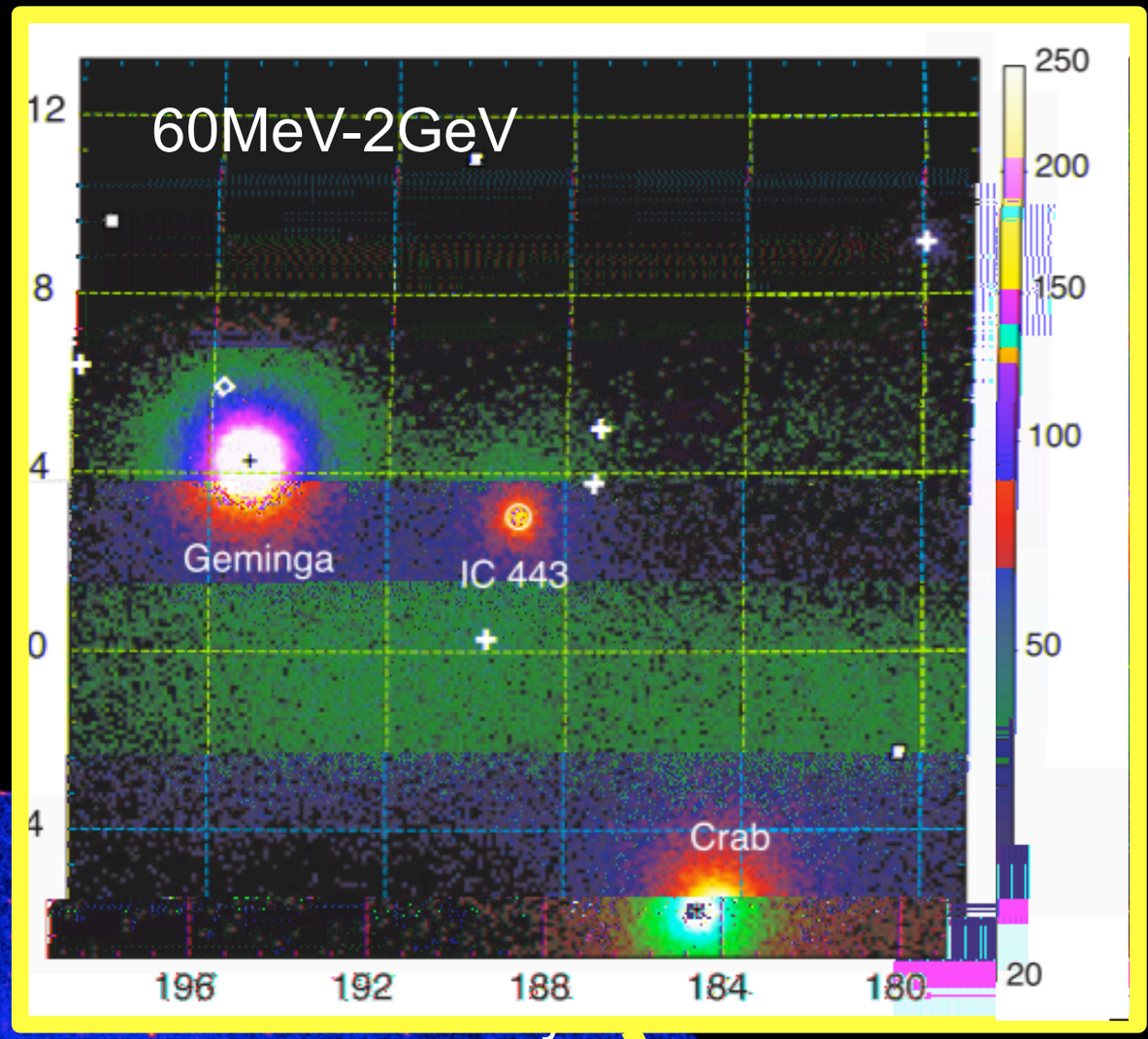
Gamma-Ray Astro-Imager with Nuclear Emulsion

Hiroki ROKUJO (Nagoya Univ.)
for GRAINE collaboration

Gamma-ray Observation (GeV/sub-GeV region)

	Telescope	Detected sources
1990-2001	EGRET spark chamber	271
2008-	Fermi-LAT SSD tracker	>3000

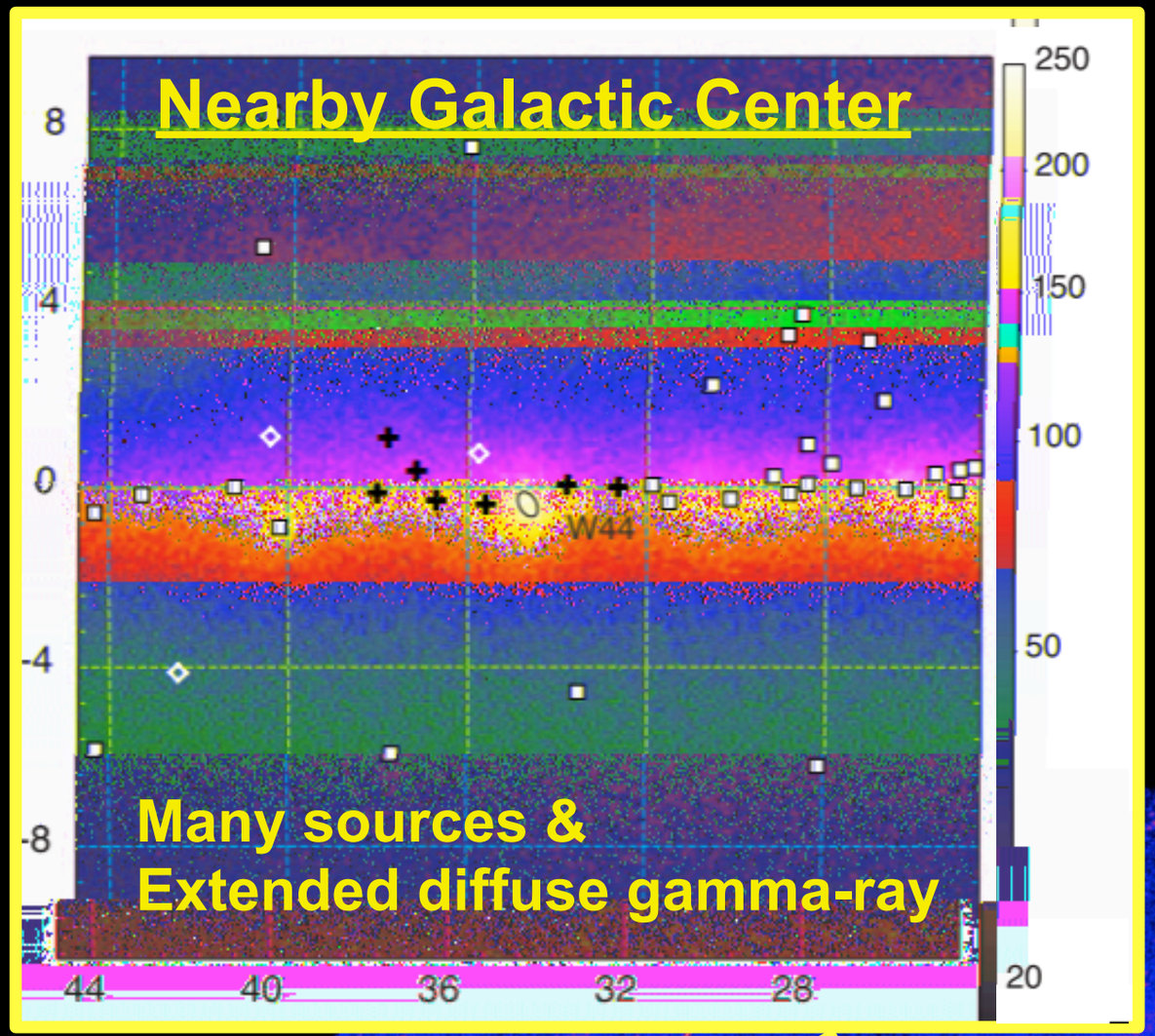
All-Sky Map
via gamma-ray
above 1 GeV

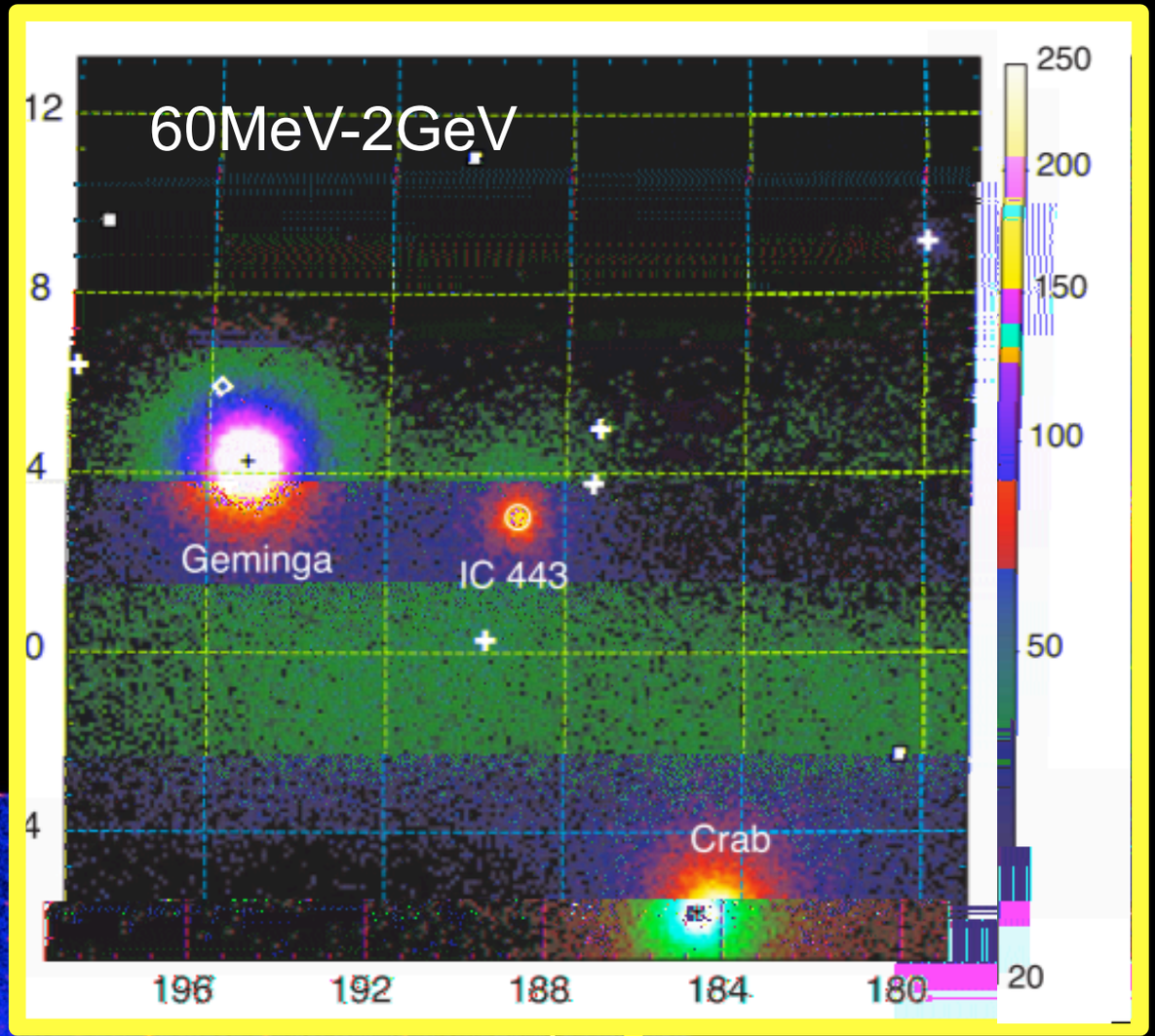


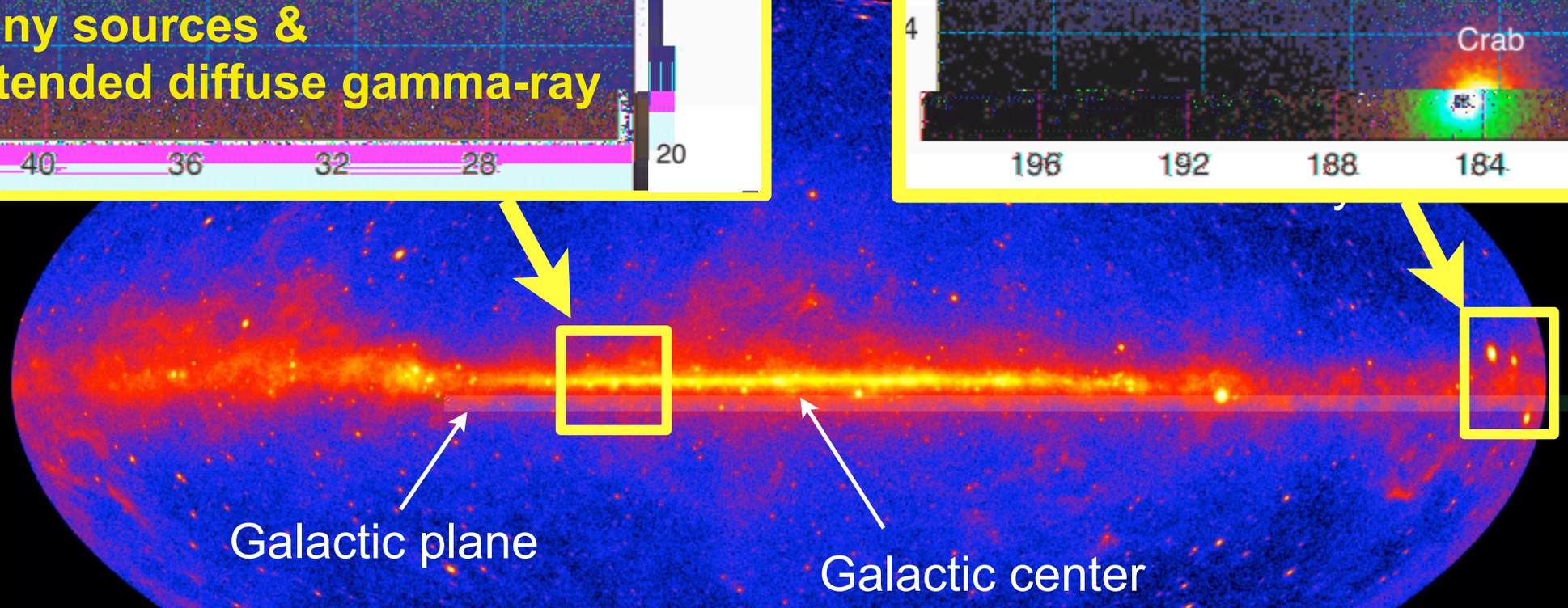
Galactic plane

Galactic center

Gamma-ray Observation (GeV/sub-GeV region)



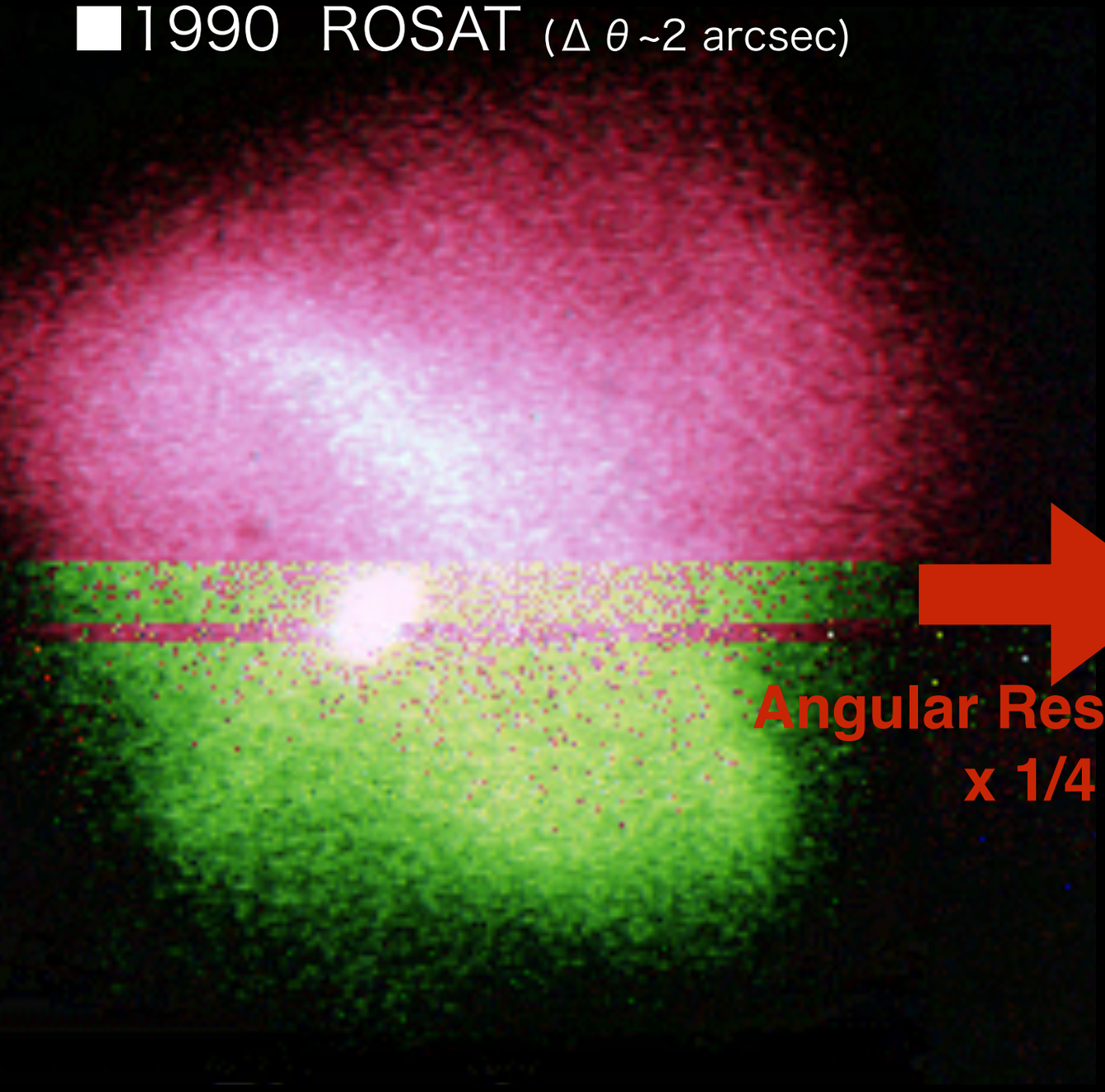




High-statistic → NEXT: Precise Observation

Impact of High-Resolution Observation (An Example in X-ray Astronomy)

■1990 ROSAT (Δ θ ~2 arcsec)



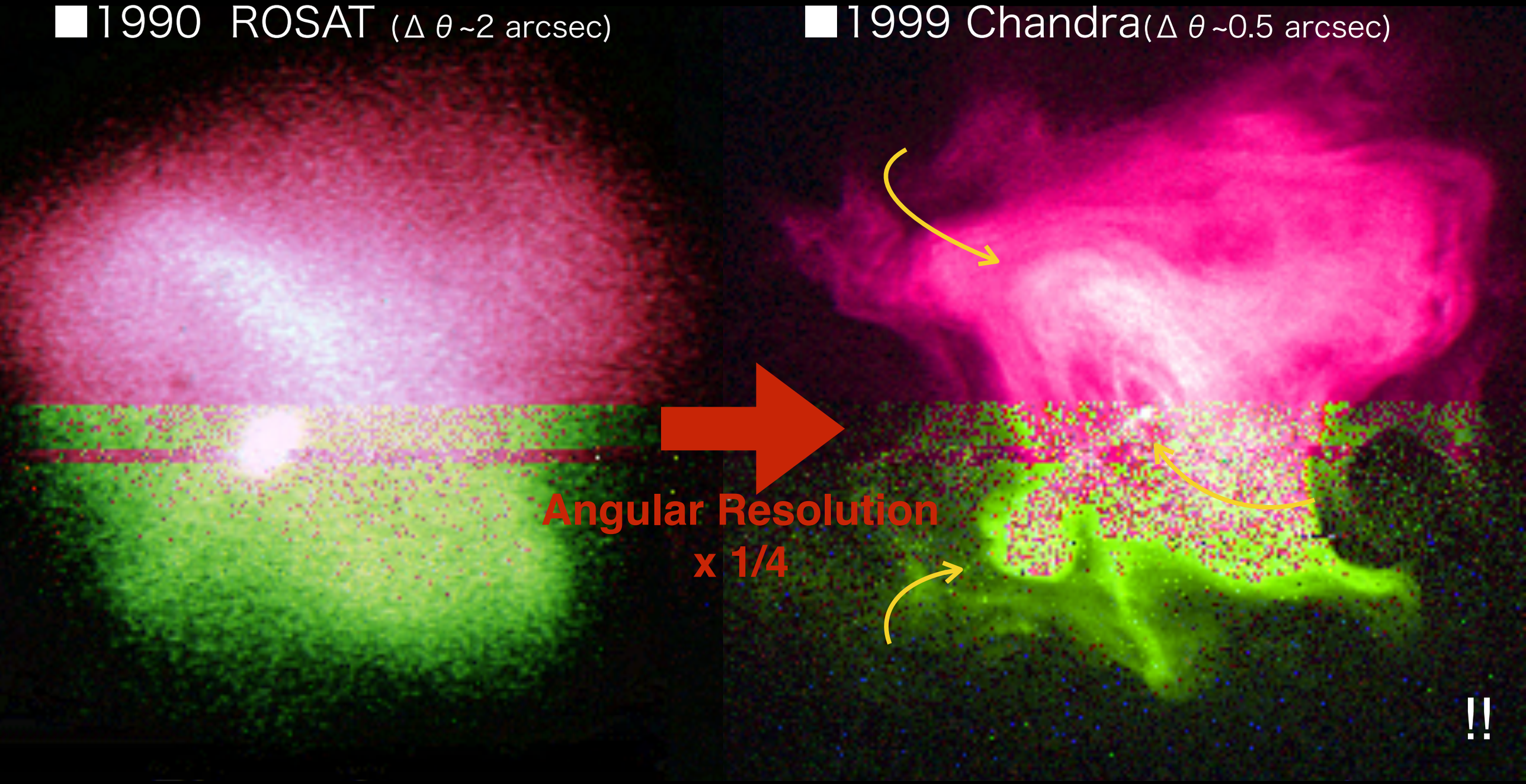
Angular Resolution
x 1/4

■1999 Chandra(Δ θ ~0.5 arcsec)

Impact of High-Resolution Observation (An Example in X-ray Astronomy)

■1990 ROSAT (Δ θ ~2 arcsec)

■1999 Chandra(Δ θ ~0.5 arcsec)



Improvement of Imaging Performance
→New discoveries are expected!!

Nuclear Emulsion

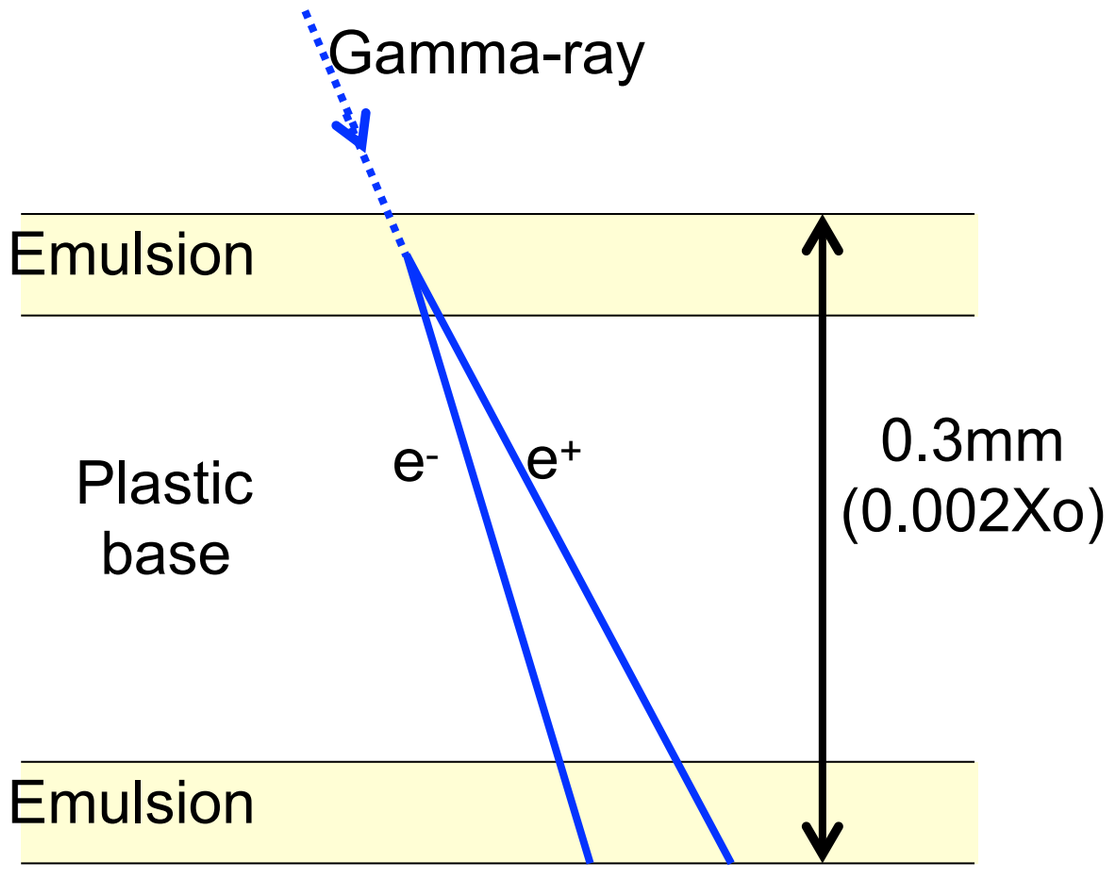
Microscopic view
10micron

Gamma-ray

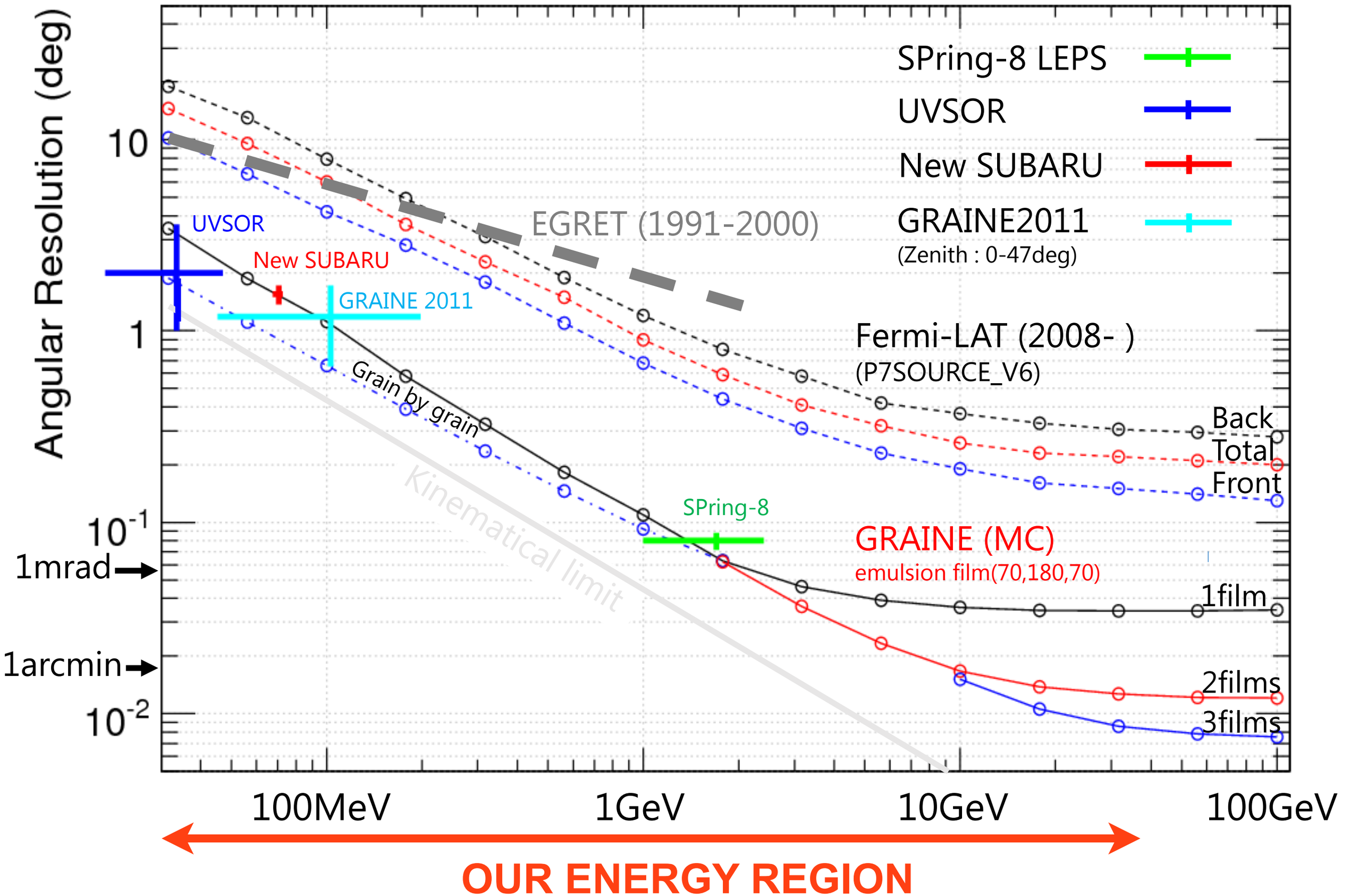
$e^{+/-}$

$e^{-/+}$

Cross sectional view of a plate



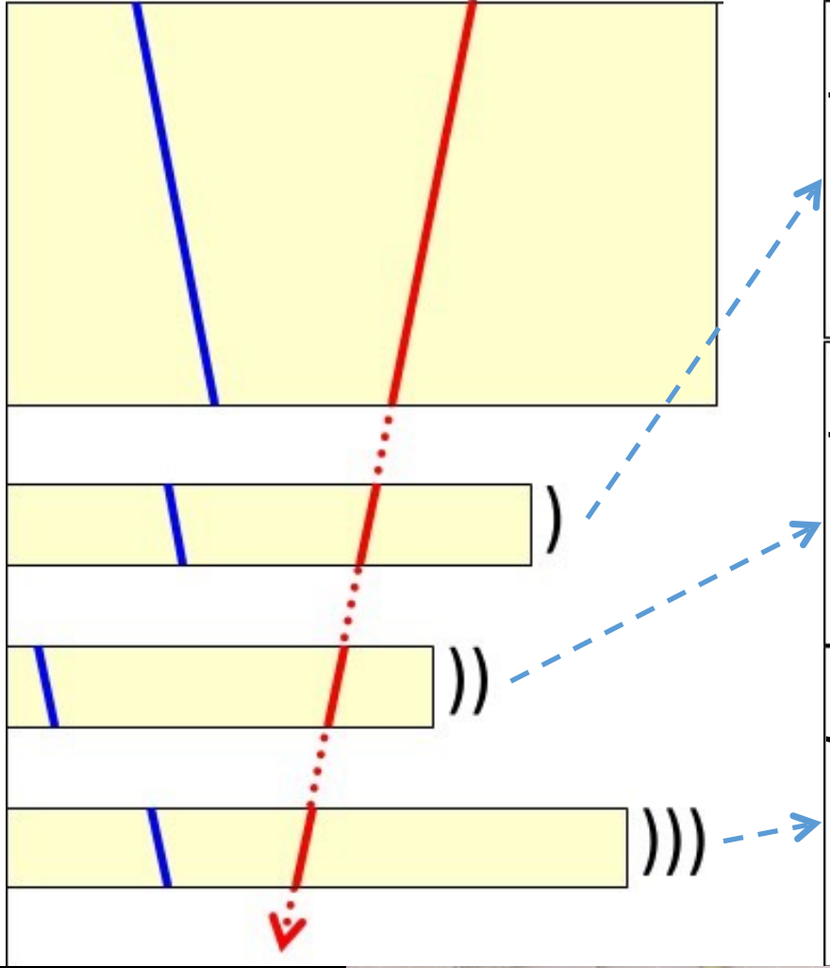
Angular Resolution for Gamma Ray

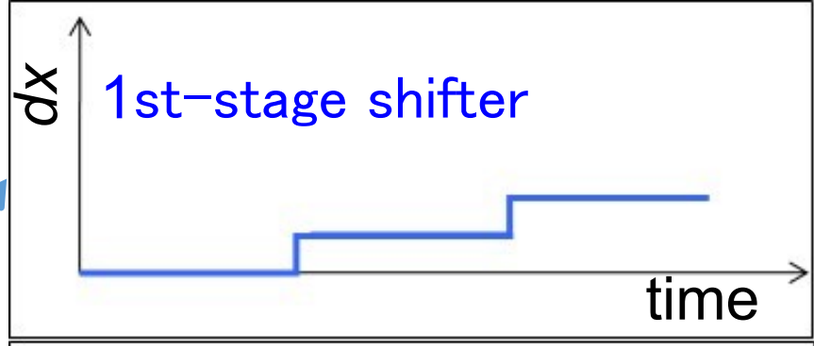


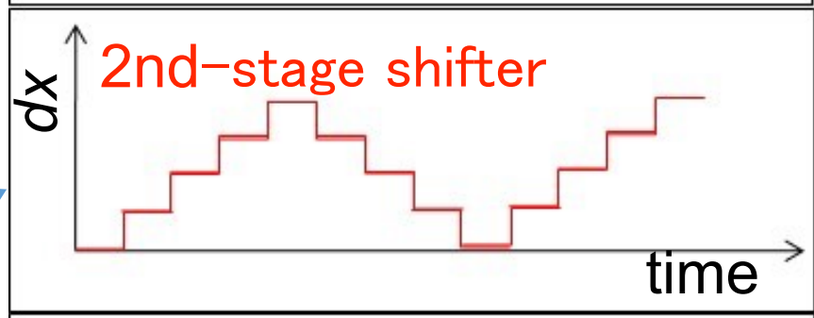
New technique for GRAINE

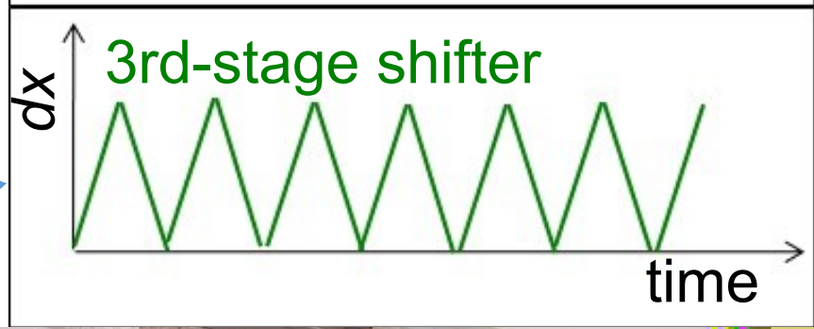
Multi-stage Shifter (Time stamper)

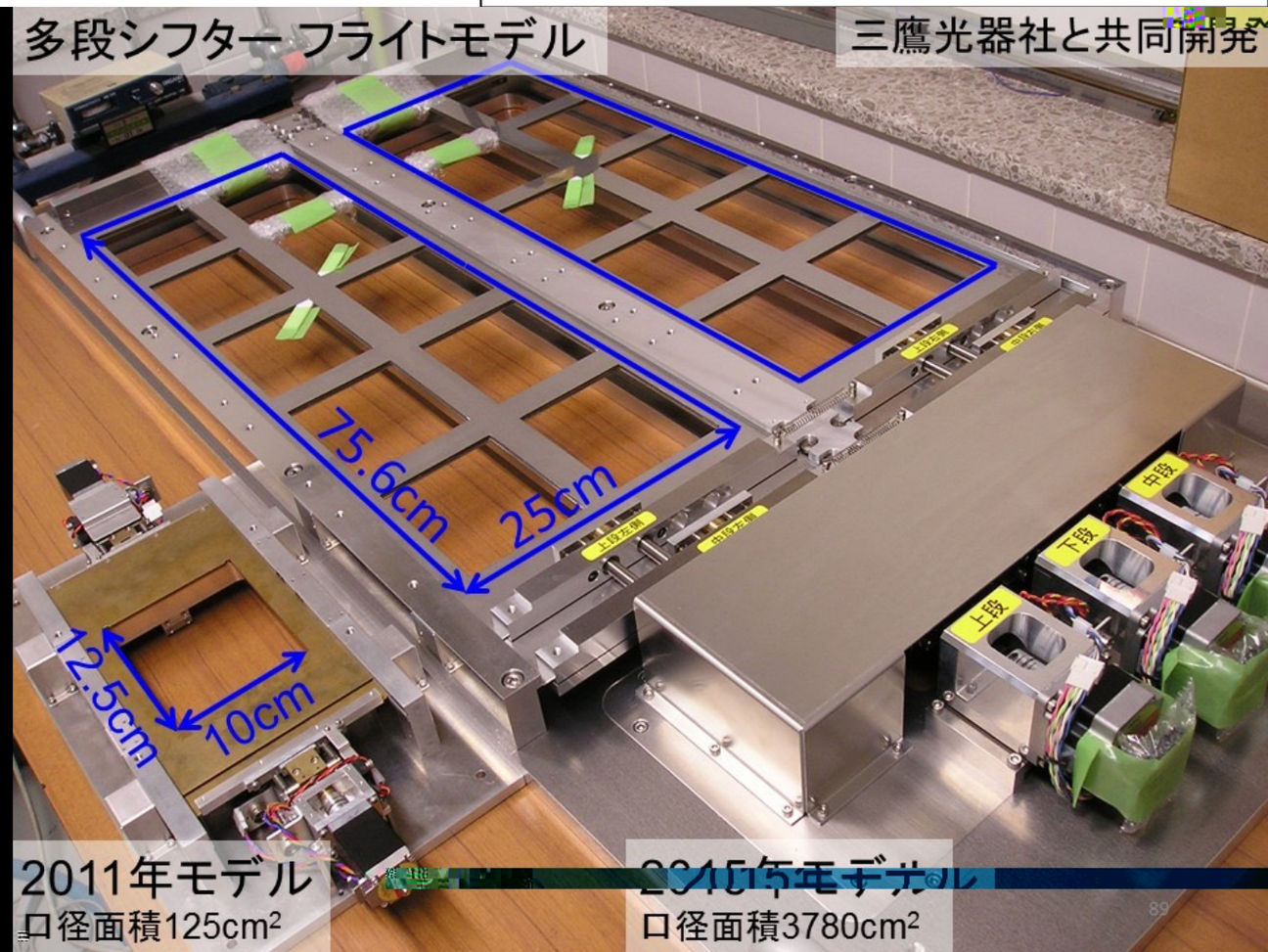
S. Takahashi et al.
NIM A620(2010) pp.192-195











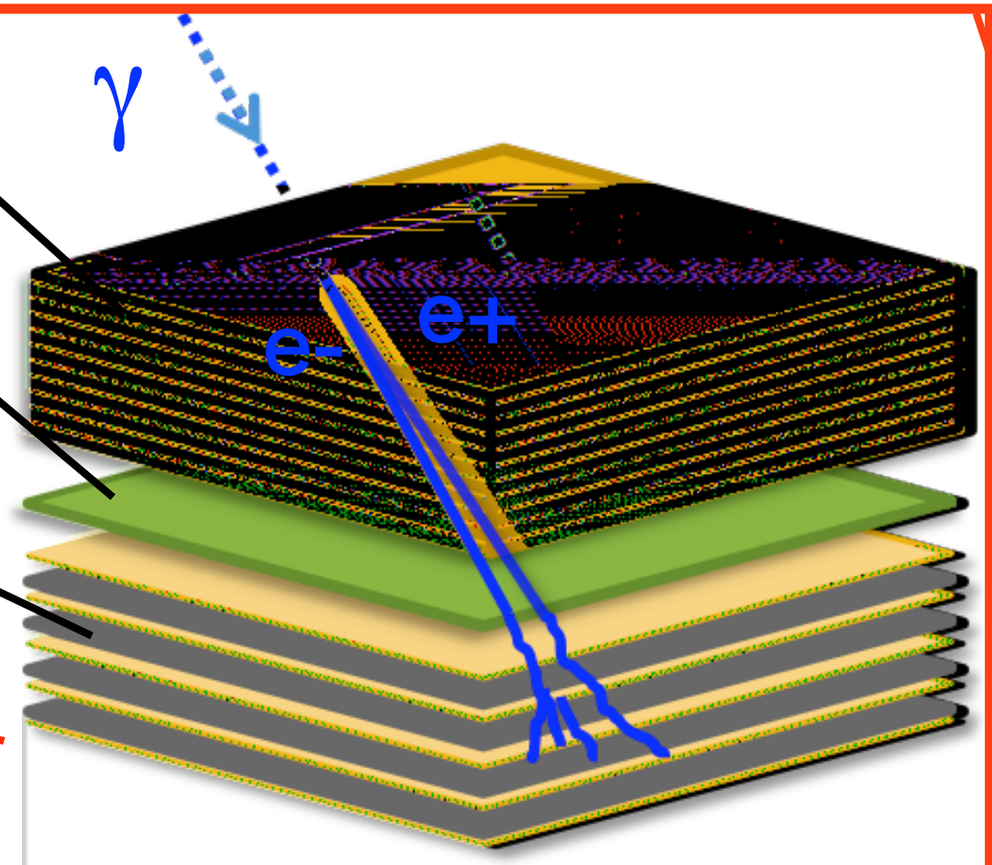
Emulsion Gamma-ray Telescope

Converter
Emulsion stack

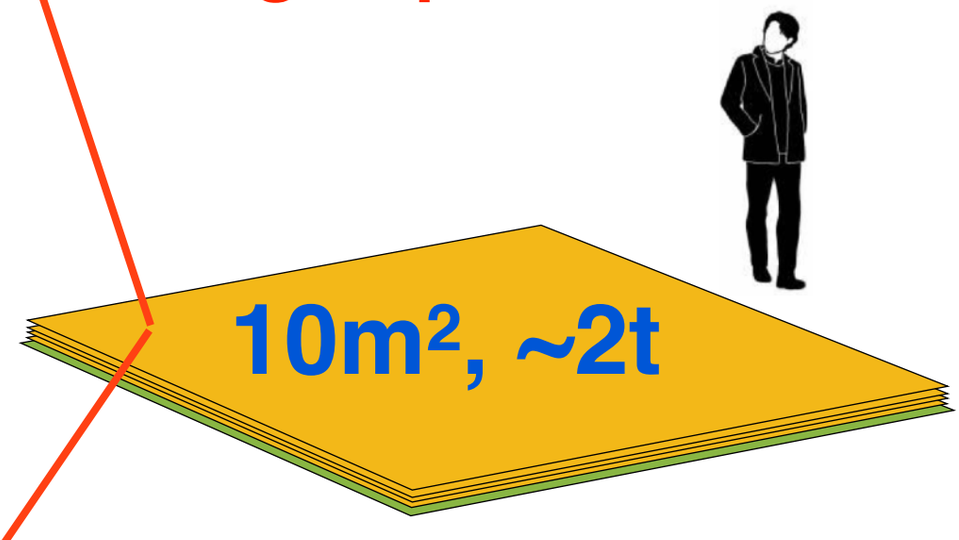
Timestamper
Multi-stage shifter

Calorimeter
Emulsion + metal plate

Attitude monitor
Star camera



- **Higher Angular Resol.**
- **Polarization Sensitive**
- **Large Aperture Area**



＊ $10m^{2}*\varepsilon_{trans}*\varepsilon_{conv}*\varepsilon_{det}$

Flow of experiment

Detector development /preparation

↓

Observation(balloon flight)
several days - 1 week

→ **Recovery of detector**

↑

Scanning (2nd data taking)

↖

Analysis

← **Detector development /preparation**

GRAINE project

2004– Development on ground

S.Takahashi et al. NIMA 620, 192 (2010)
K.Ozaki et al. NIMA 833, 165 (2016)

2011(Jun.) 1st Balloon-Exp.

- Checking Feasibility

H.Rokujo et al. NIMA 701, 127 (2013).
S.Takahashi et al. PTEP 2015 043H01

2015(May.) 2nd Balloon-Exp.

- establishment of experimental flow
- demonstration of detector

K.Ozaki et al., JINST 10, P12018 (2015)
S.Takahashi et al. PTEP 2016, 073F01
+ in prep. (technical paper)

Prepare

2018(Apr.) 3rd Balloon-Exp.

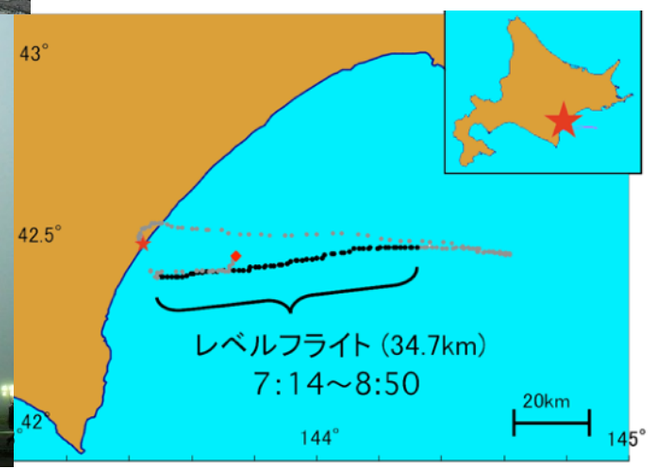
- Celestial source detection

2021- Start scientific observation w/10m²

GRAINE 2011

Aperture：0.013m²

1.6 h@35km

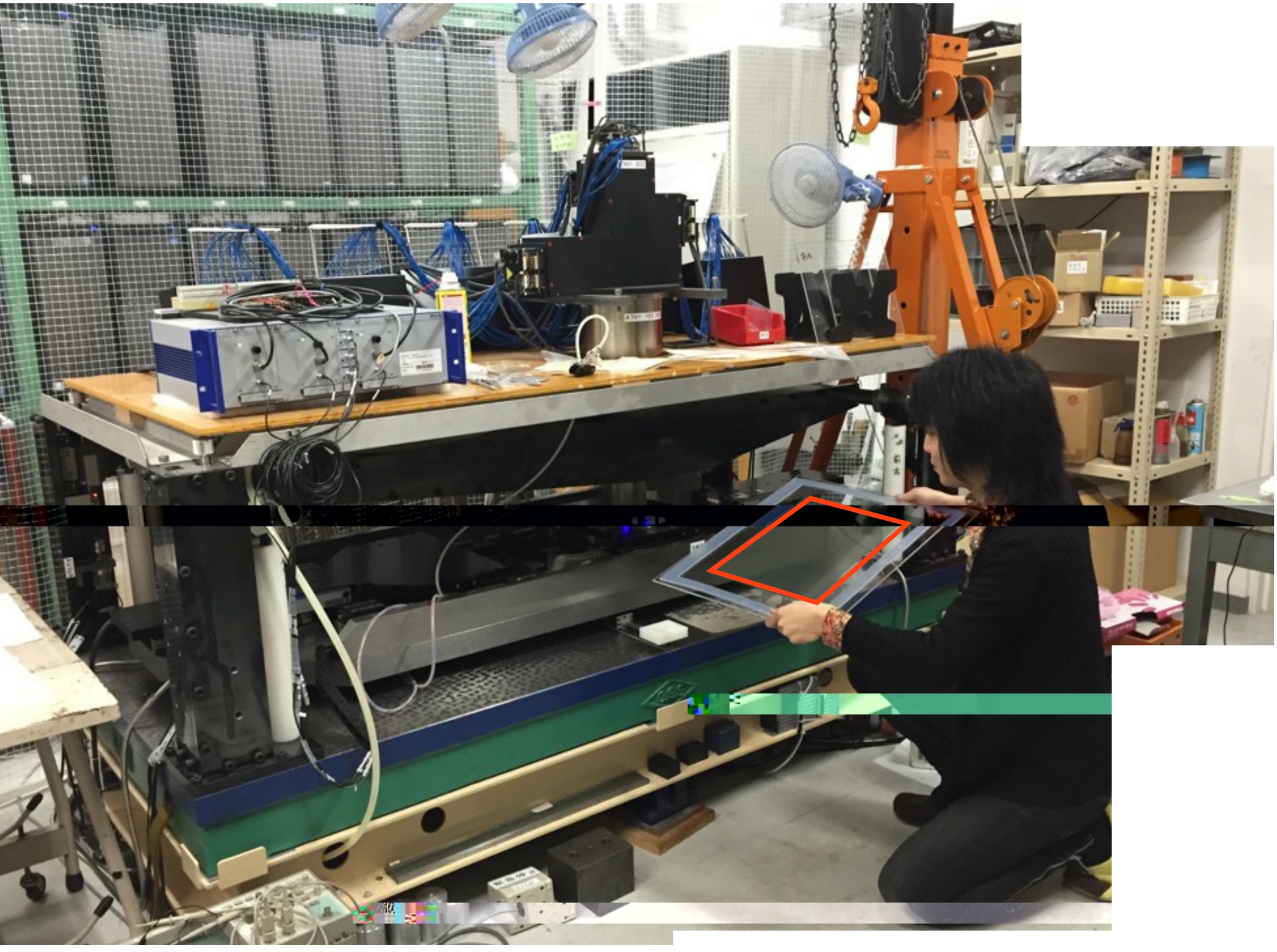


GRAINE 2015

Aperture：0.38m²

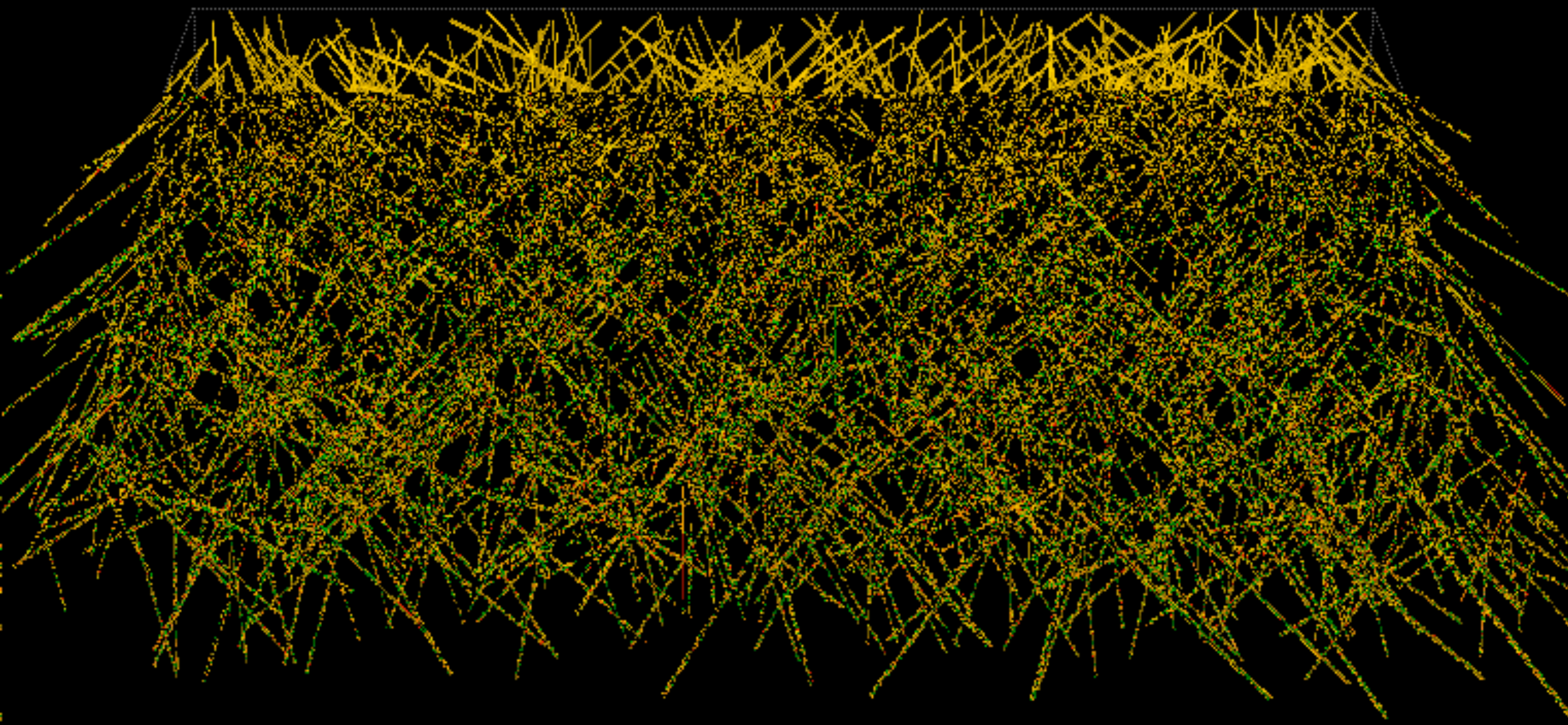
11.5 h@36-37km

2nd-Data taking by Scanning System



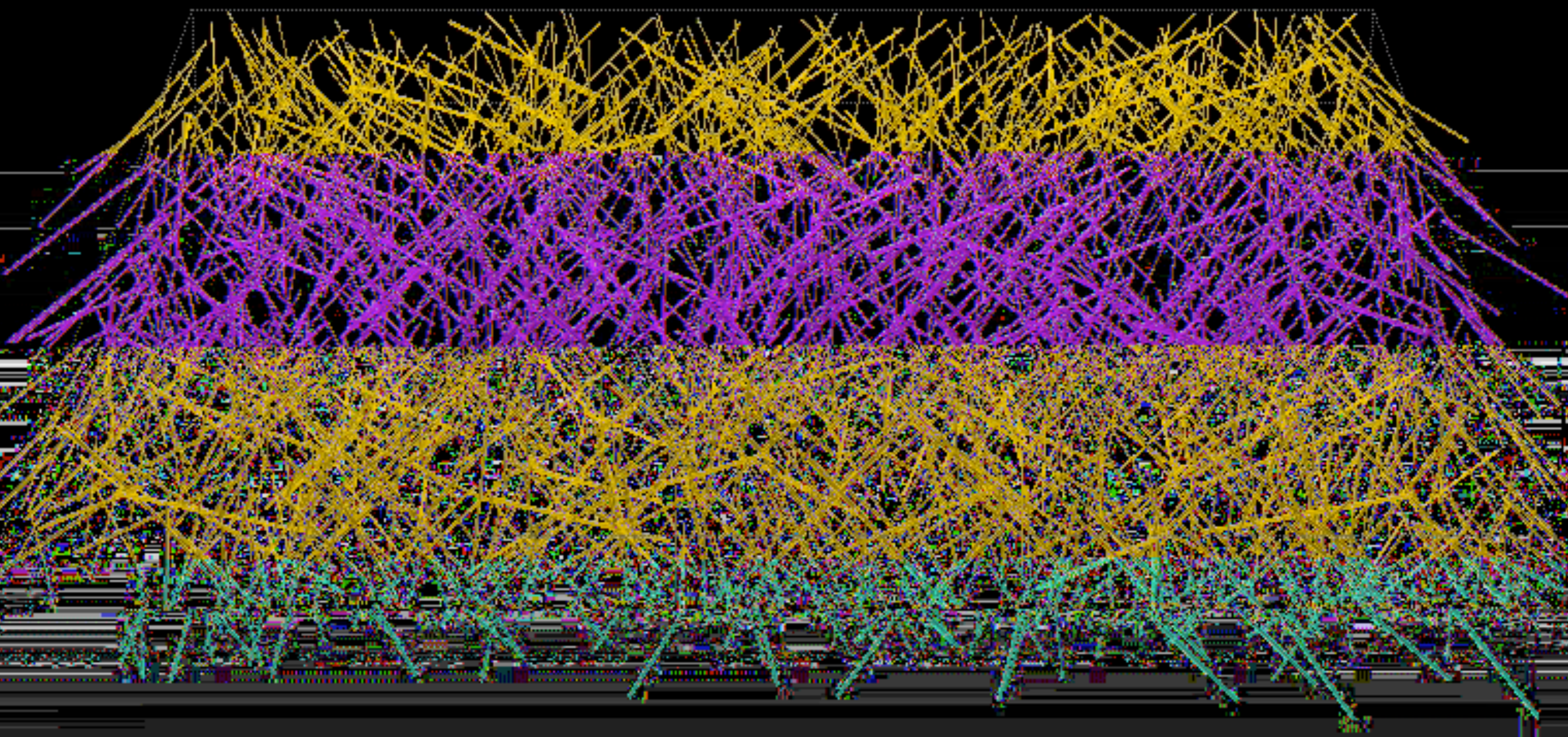
→

Flight data



2 mm x 2 mm of single film

Flight data



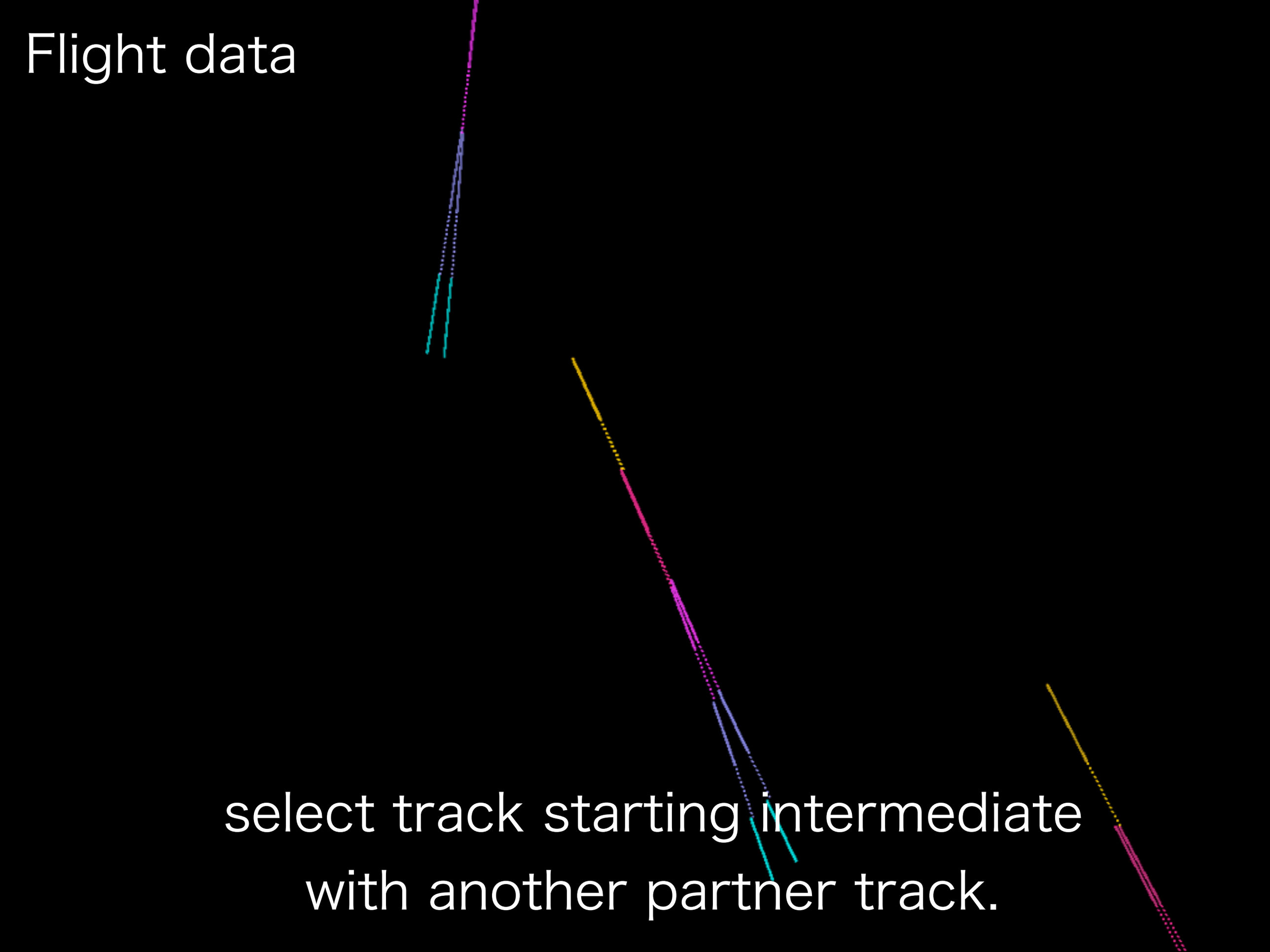
emulsion film records all charged particles.

density ~400 tracks/mm^2

Flight data

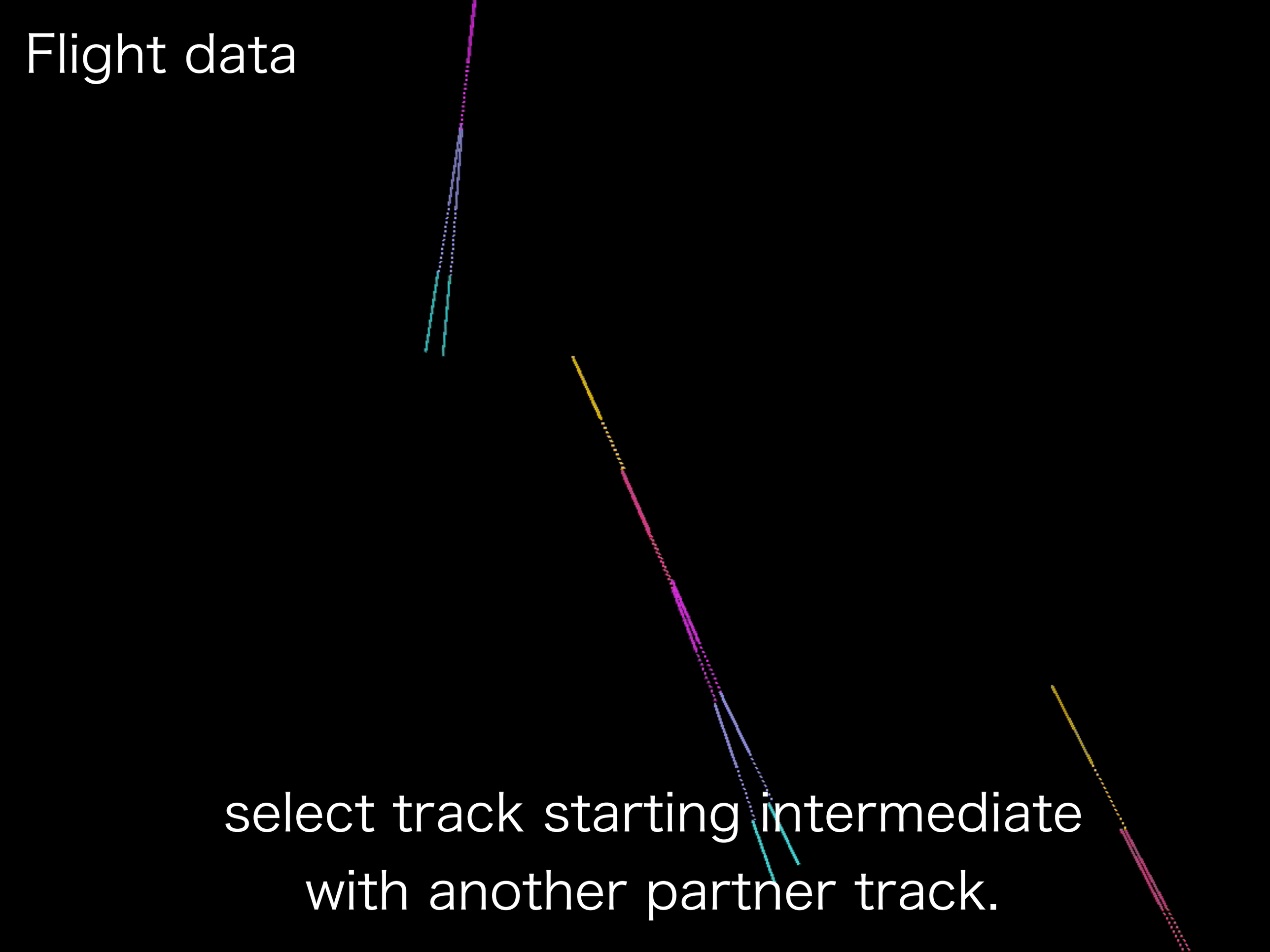
track connection plate by plate
(colors indicate different plates)

Flight data



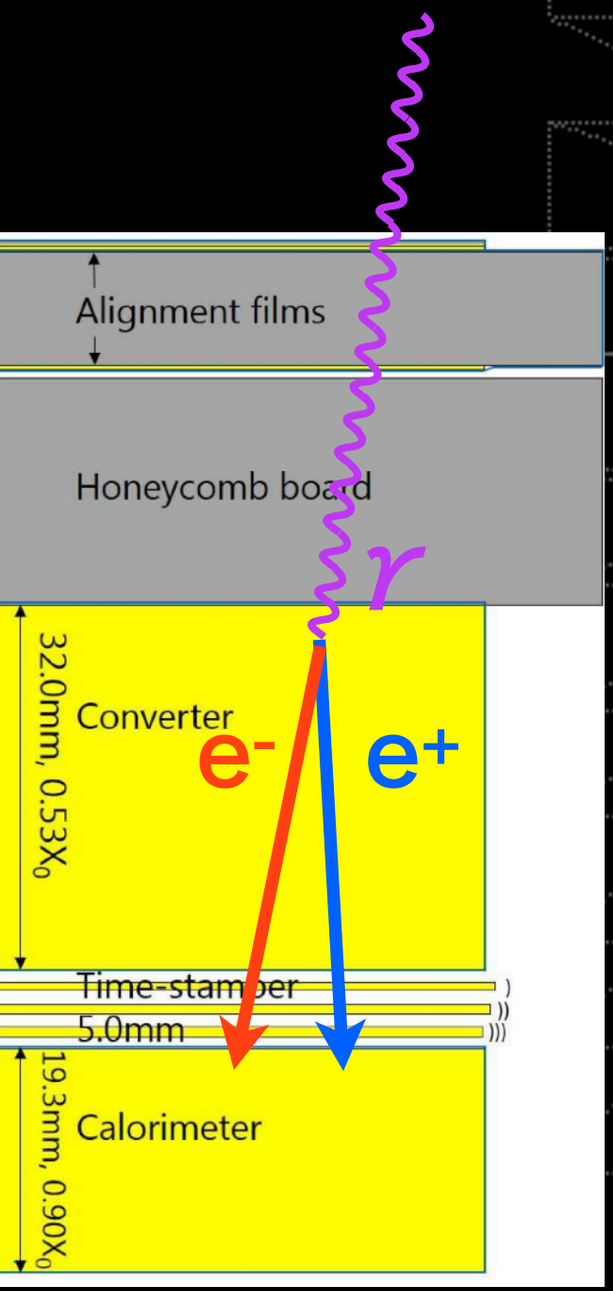
select track starting intermediate
with another partner track.

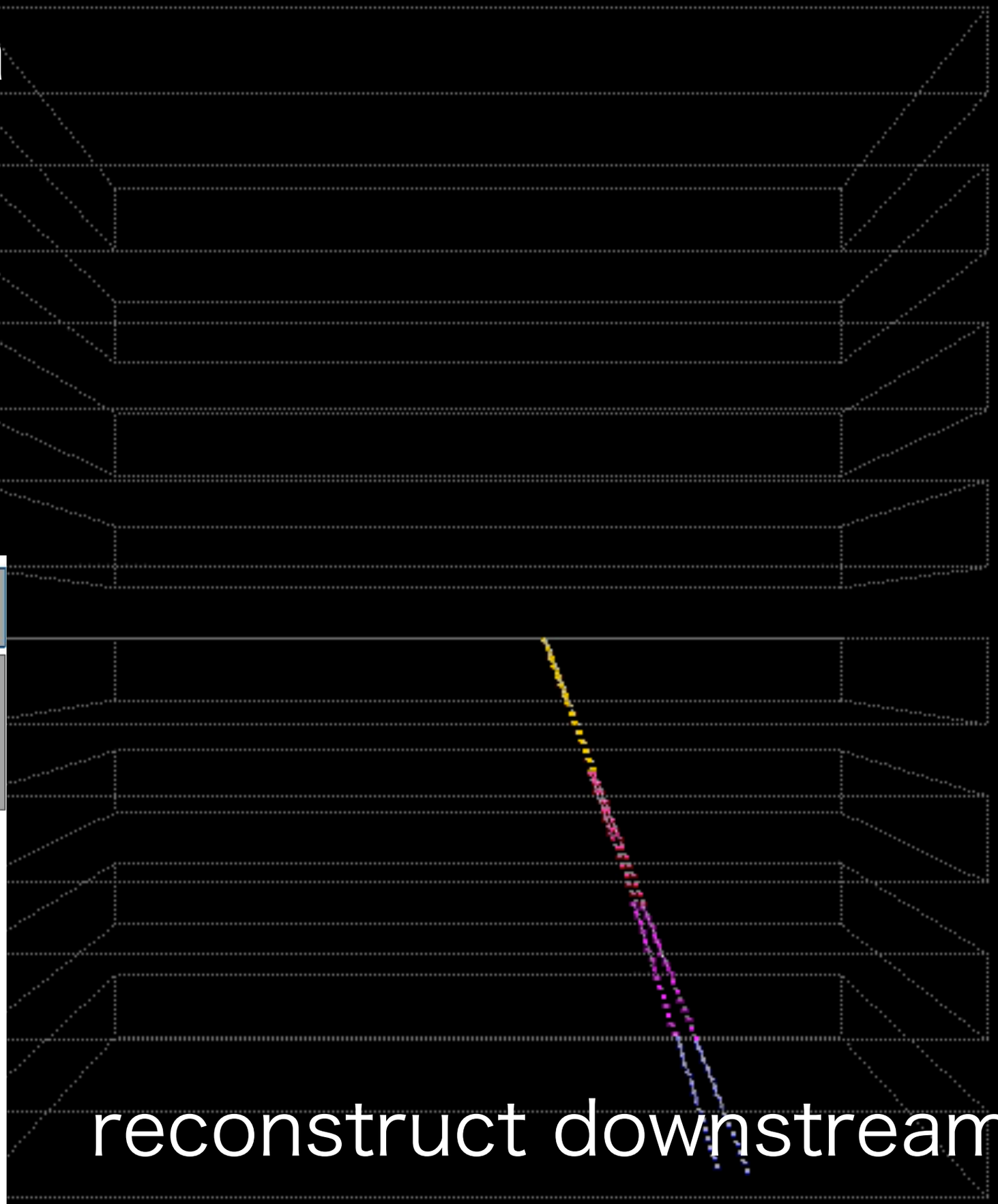
Flight data



select track starting intermediate
with another partner track.

Flight data

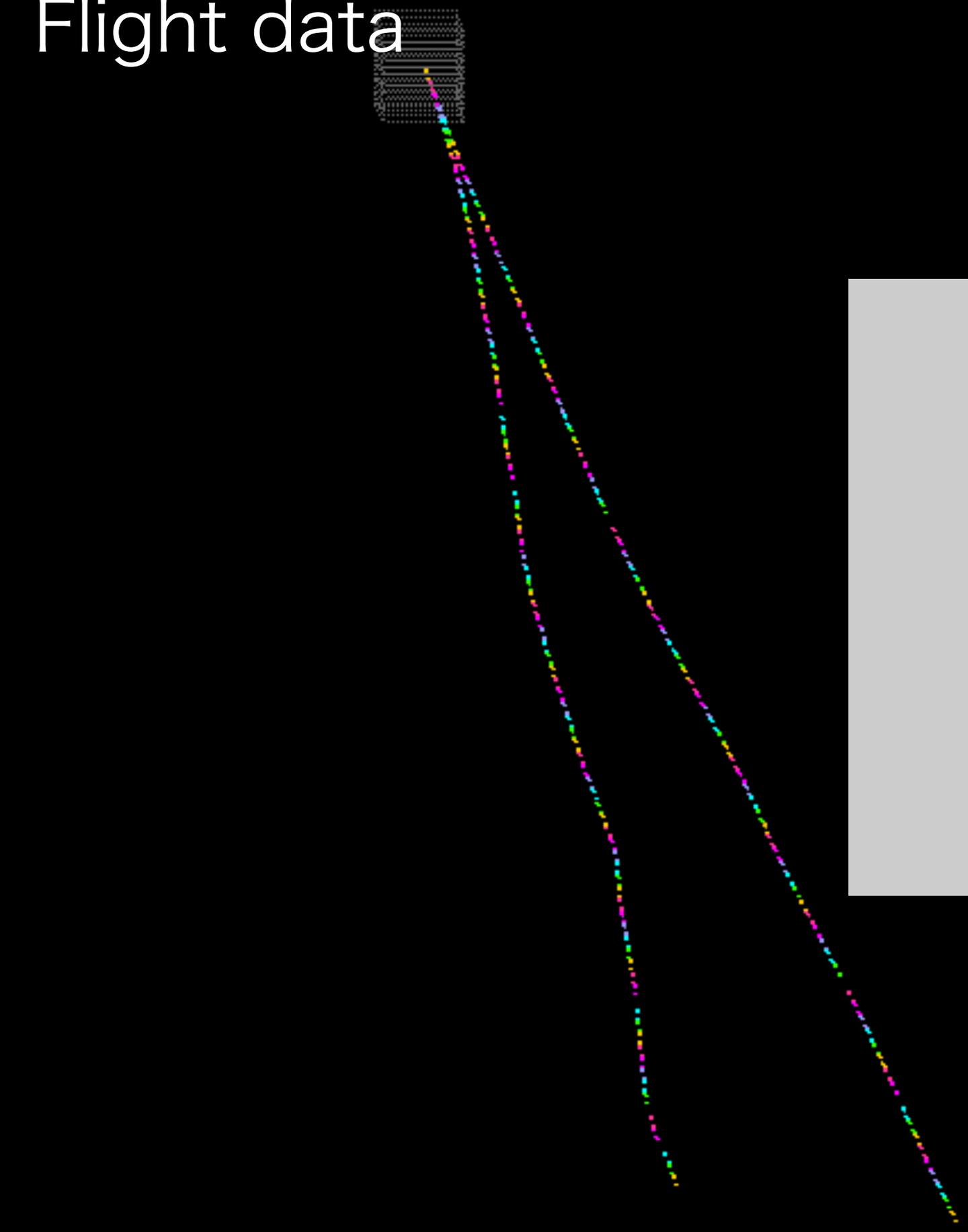




reconstruct downstream tracks

(Follow down for 95 plates in this event)

Flight data

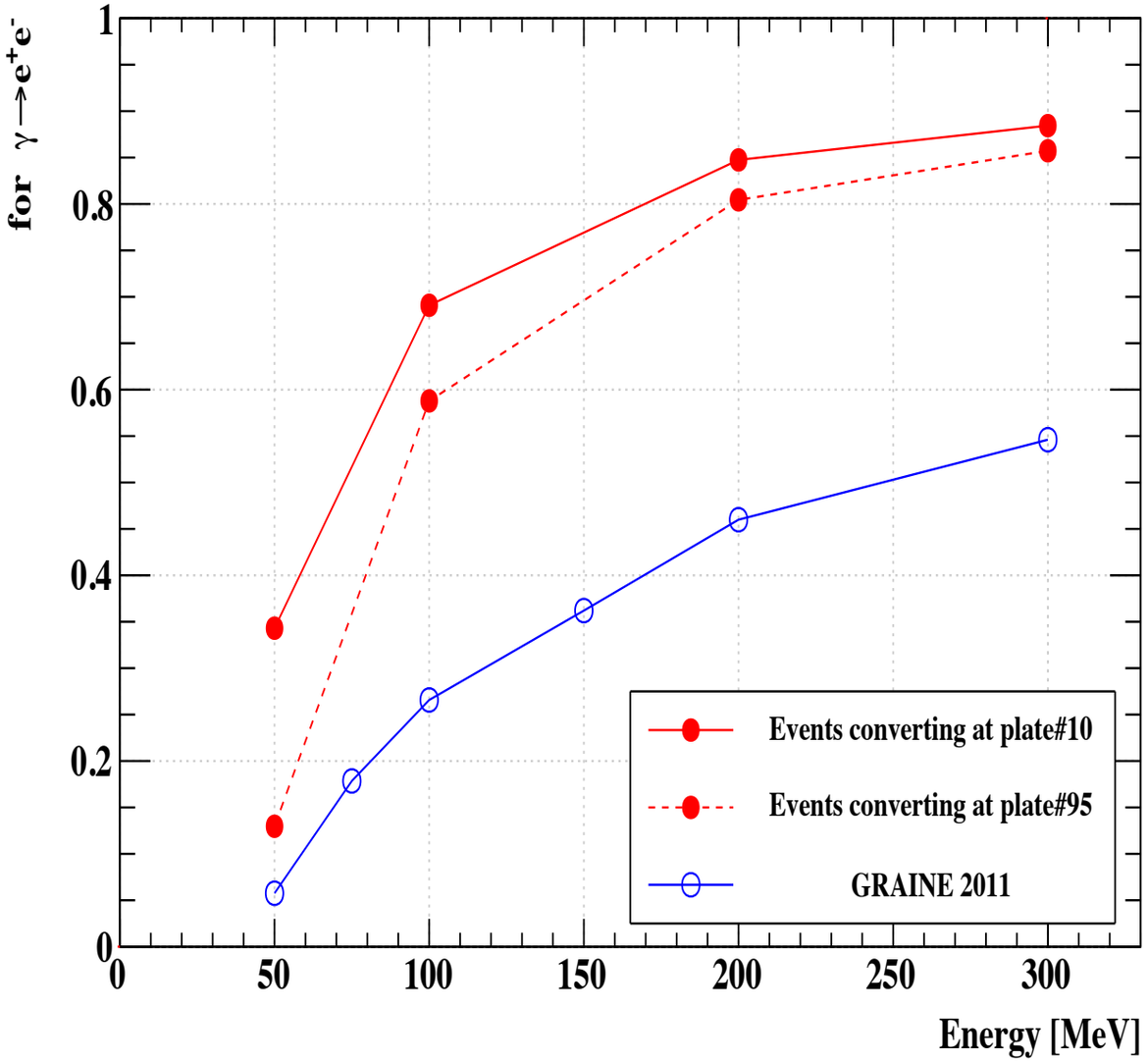


H.Rokujo, et al. in prep.

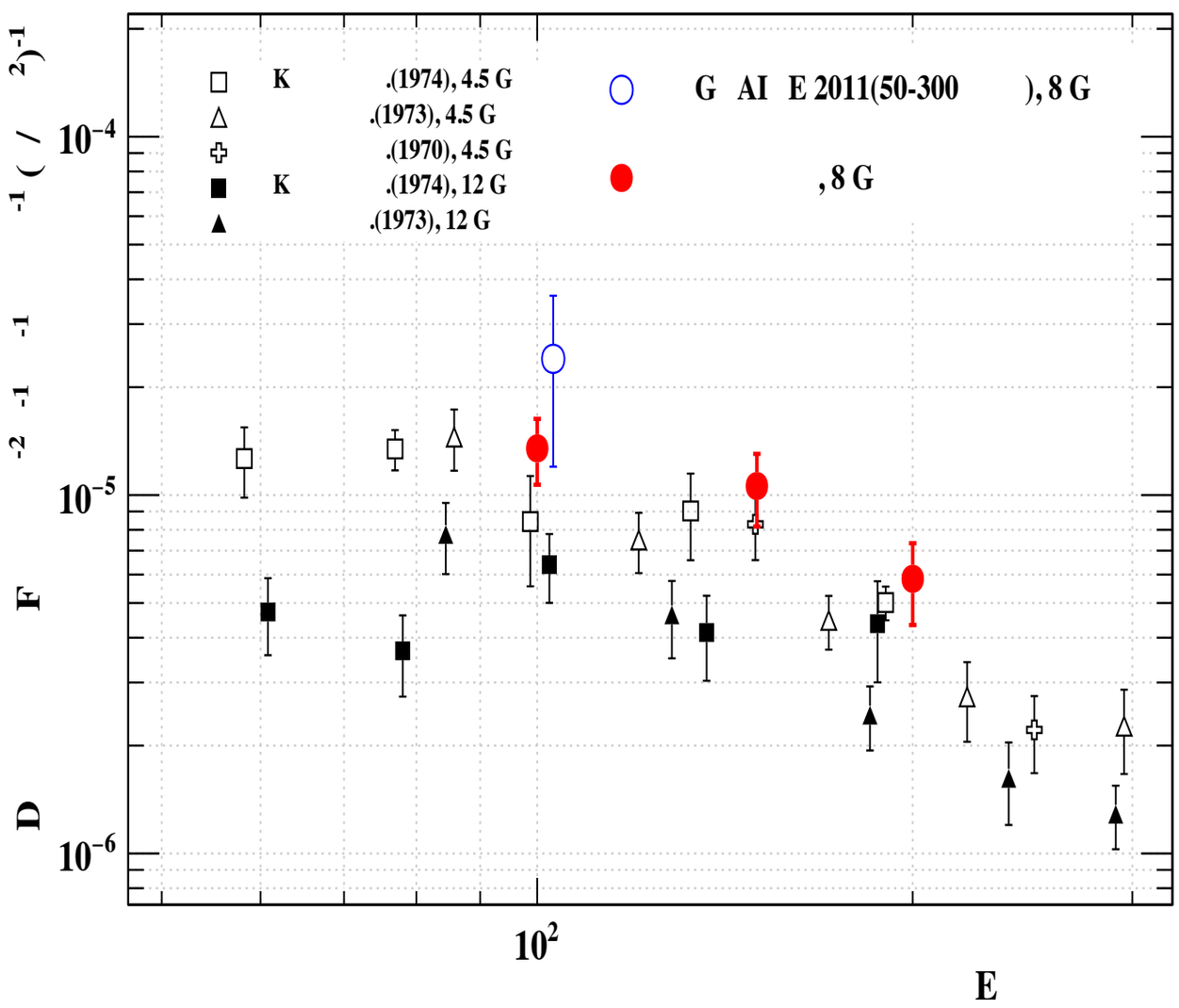
H.Rokujo, et al. in prep.

Recent Progress of GRAINE

▪Selection Performance(MC)

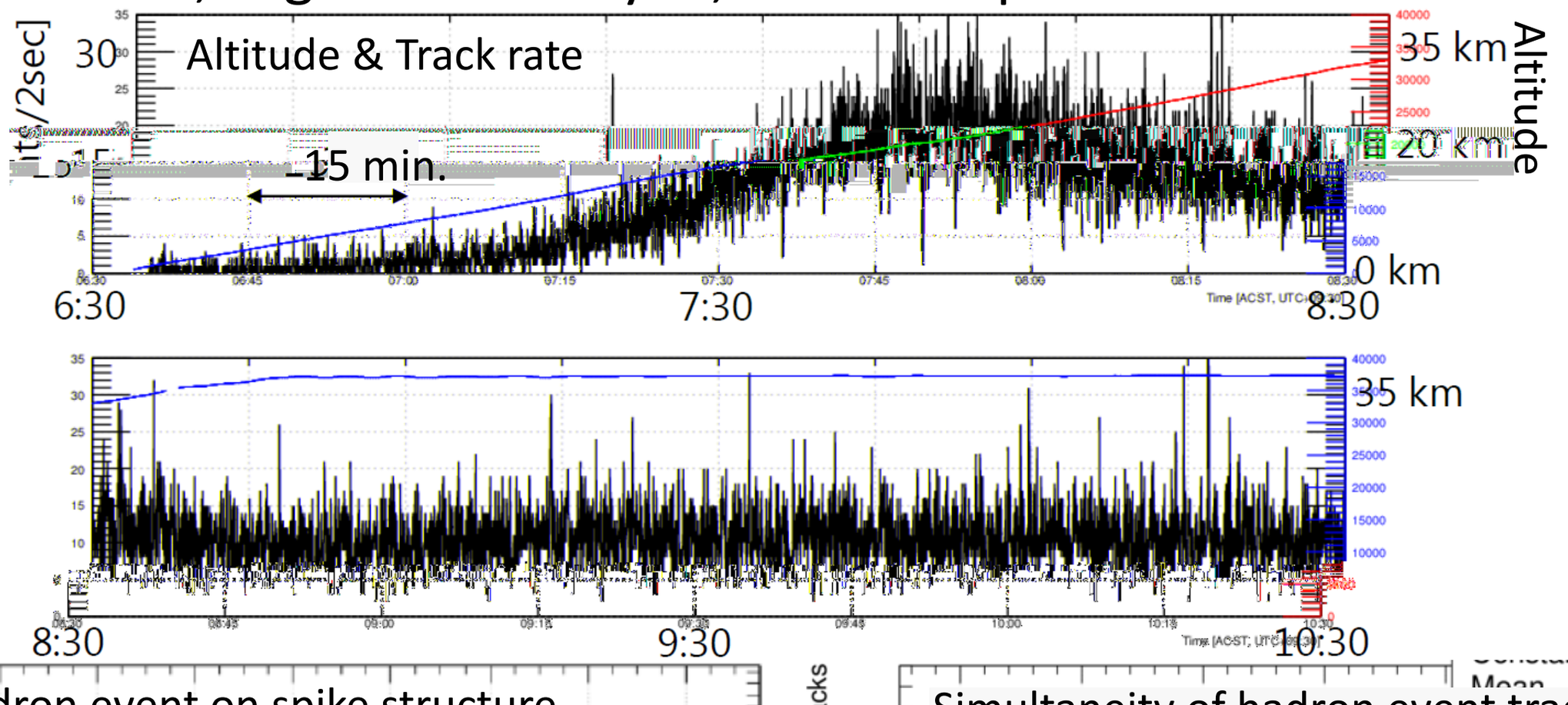


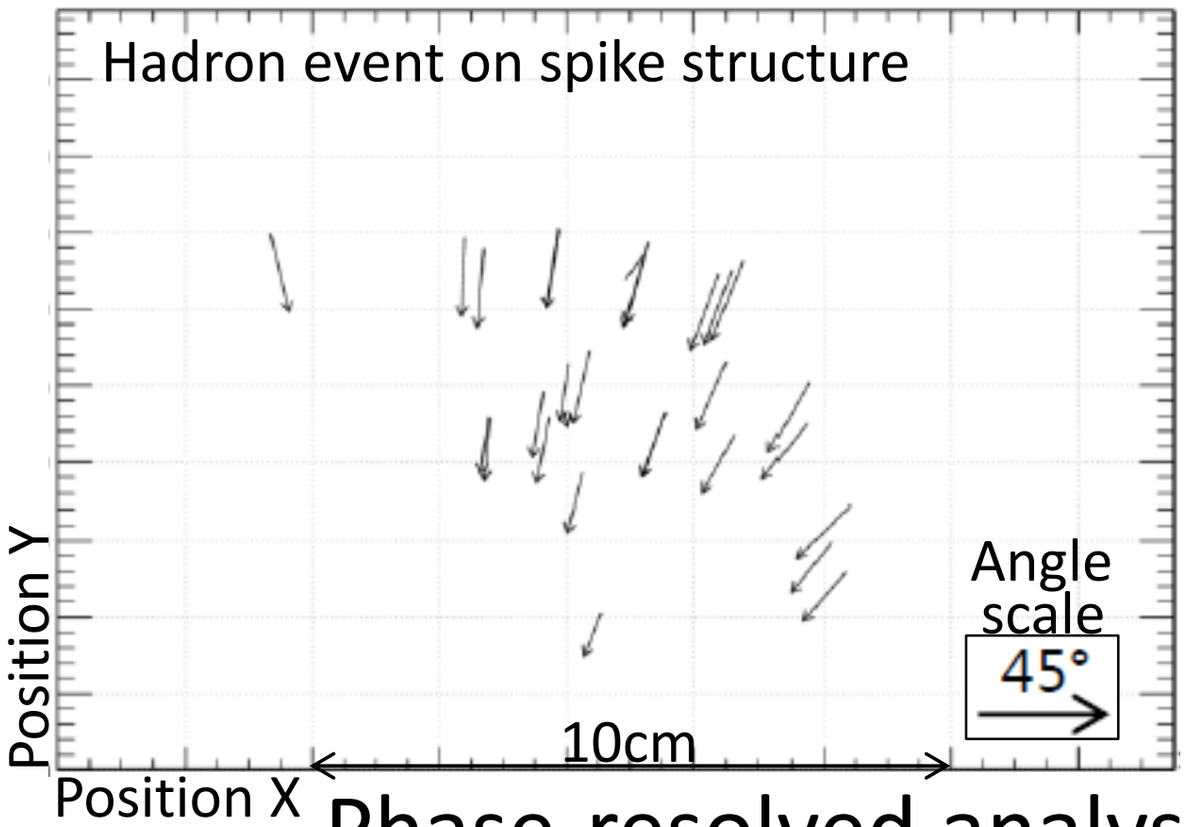
▪BG measurement

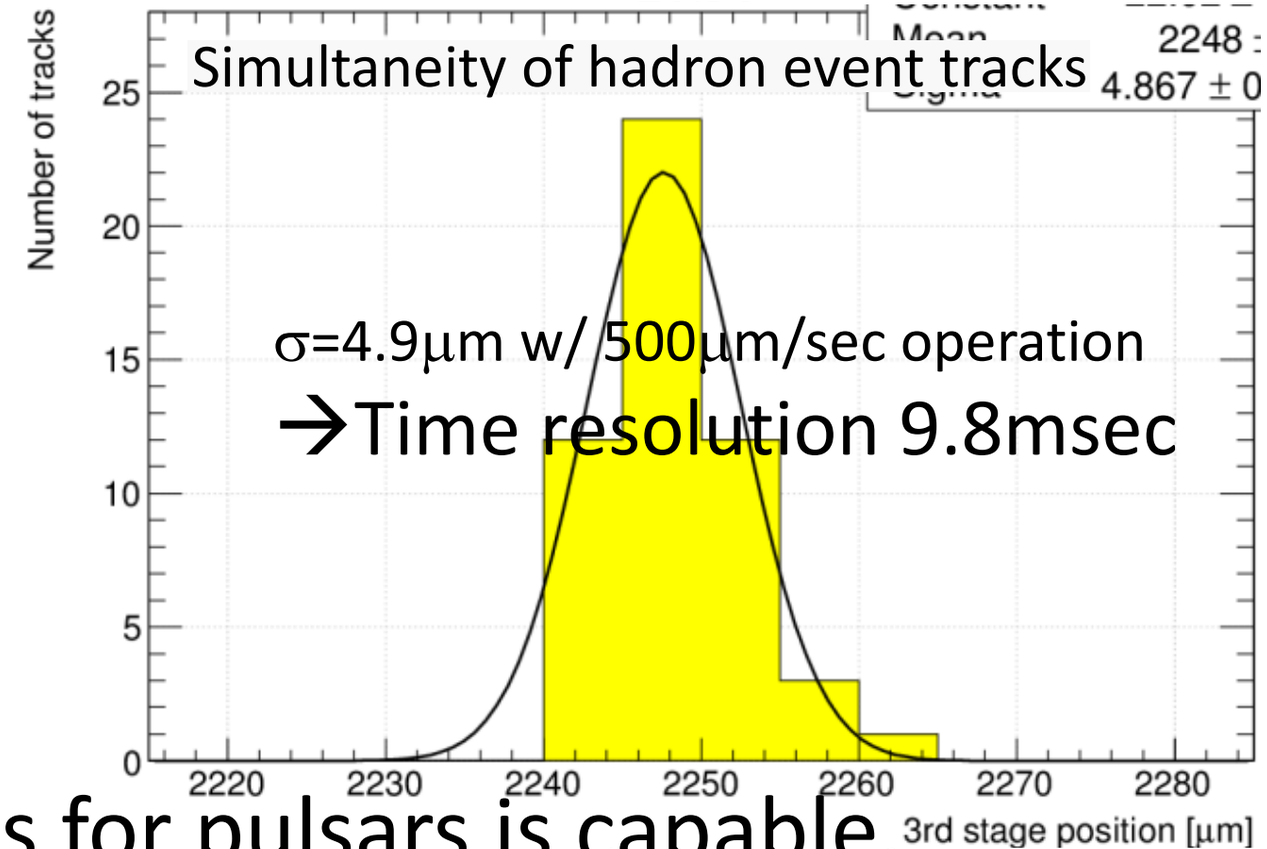


GRAINE 2015, Flight data analysis, Timestamper

Analyzed by F.Mizutani



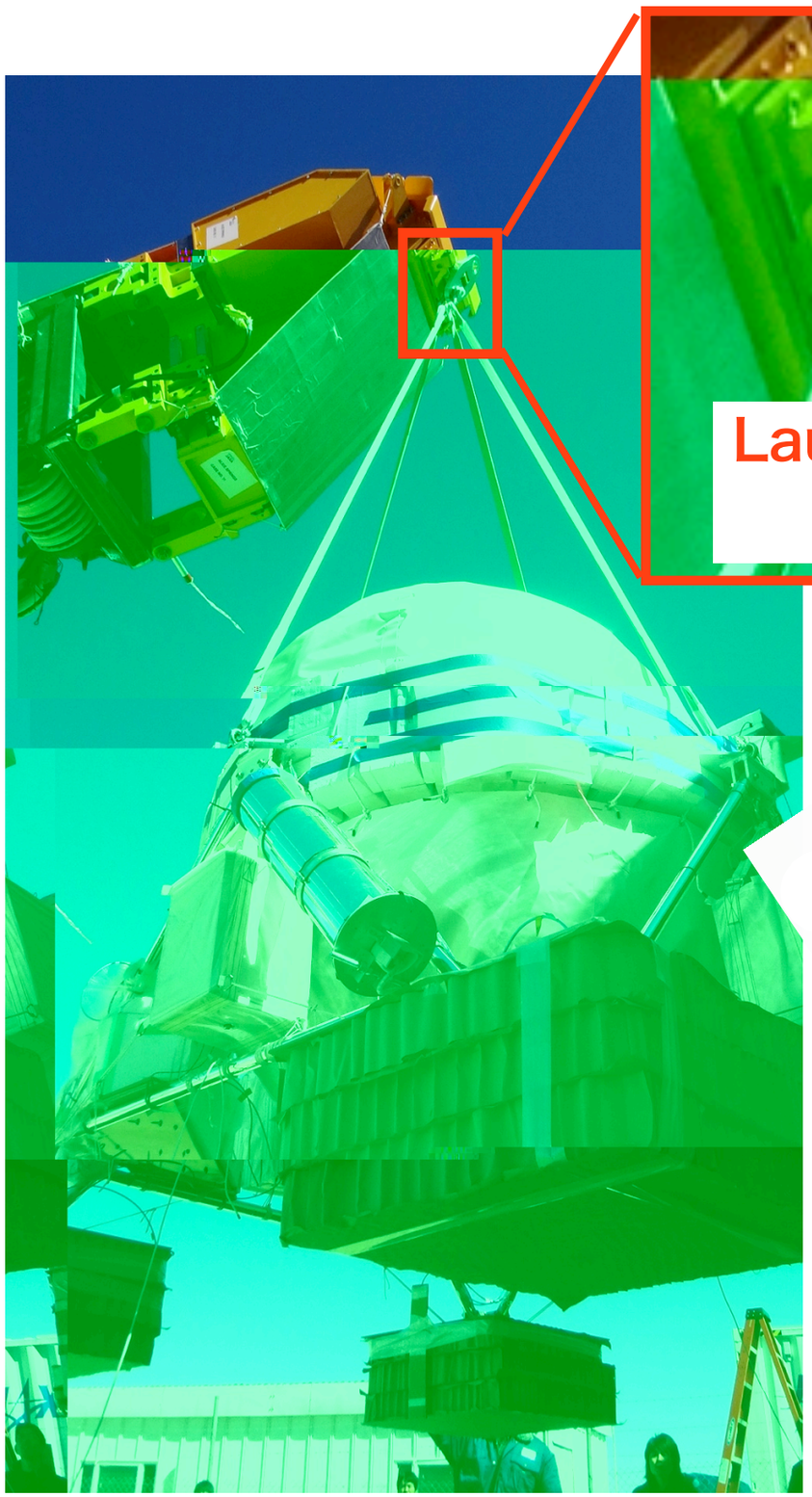


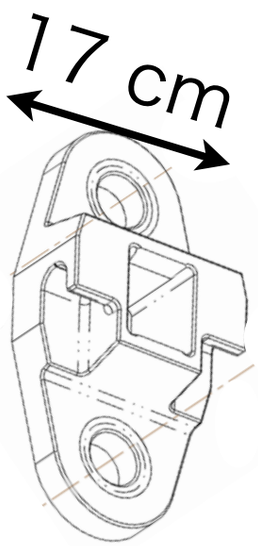


Phase-resolved analysis for pulsars is capable.

e.g. 89msec period of Vela pulsar

Demonstration of Gamma-ray Imaging during Balloon Observation





Aluminum
4.6 kg

Extrapolated positions
at the height of
the launching plate

CR (protons, etc.)

4.4 m

25 cm

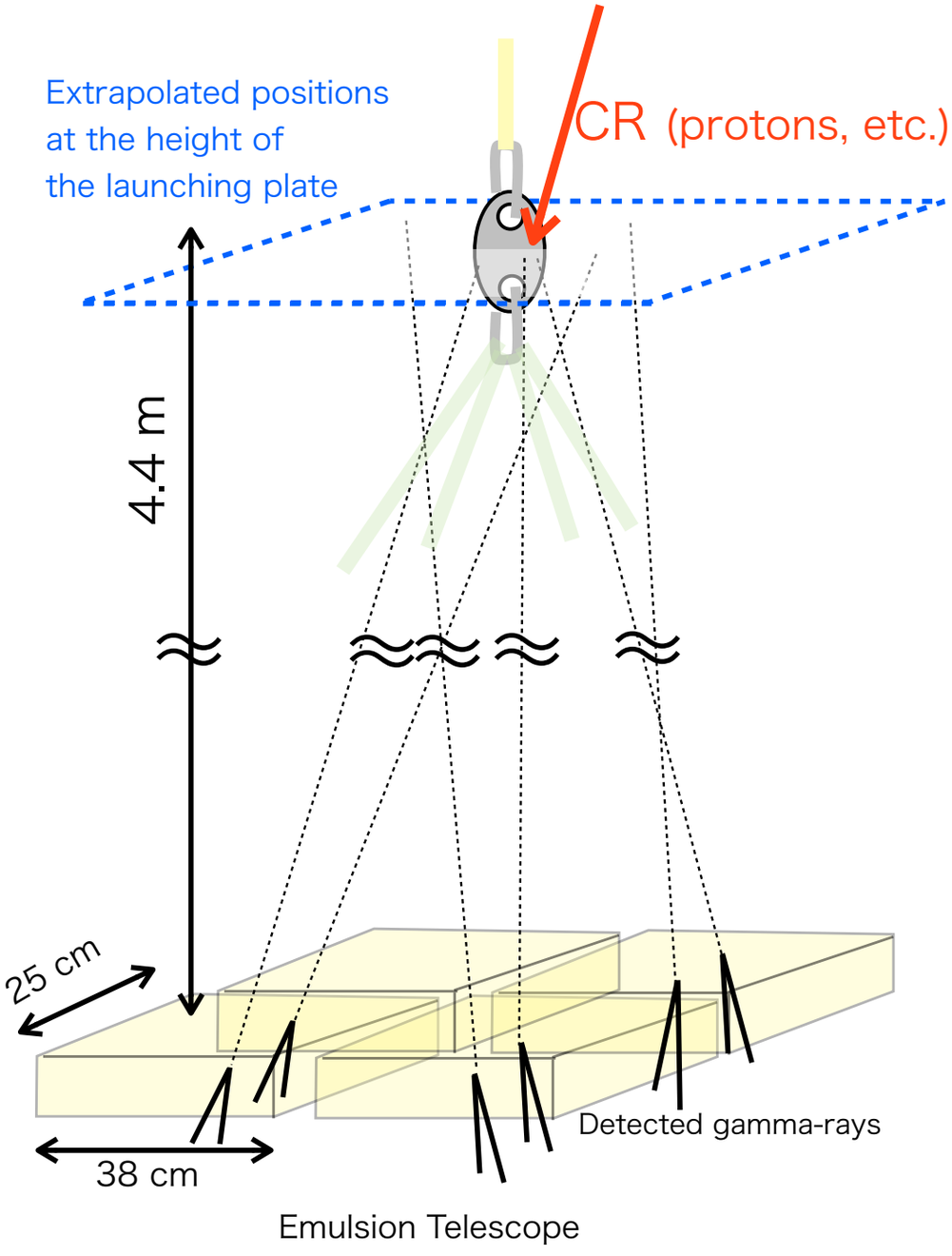
38 cm

emulsion
telescope

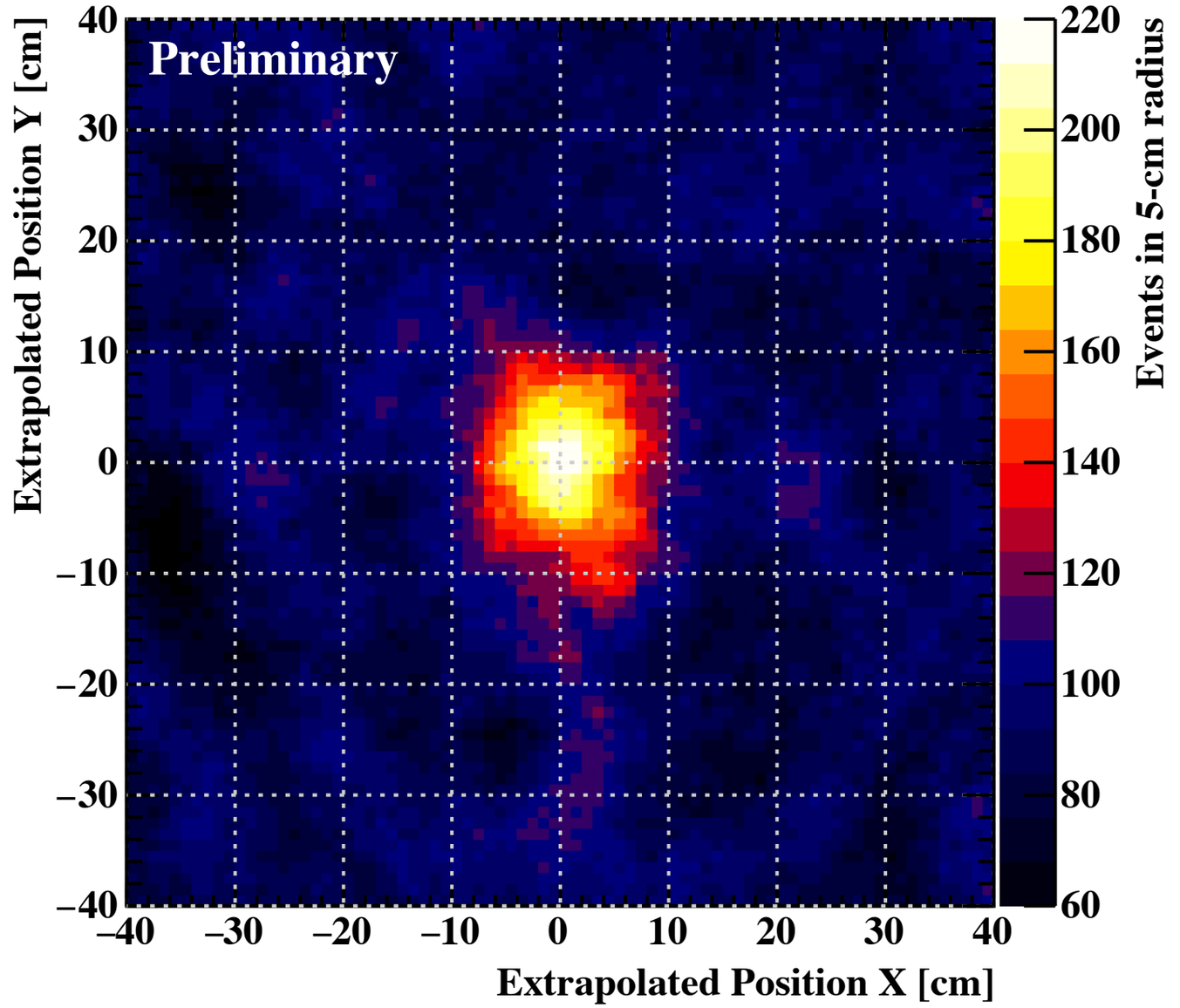
Detected gamma-rays

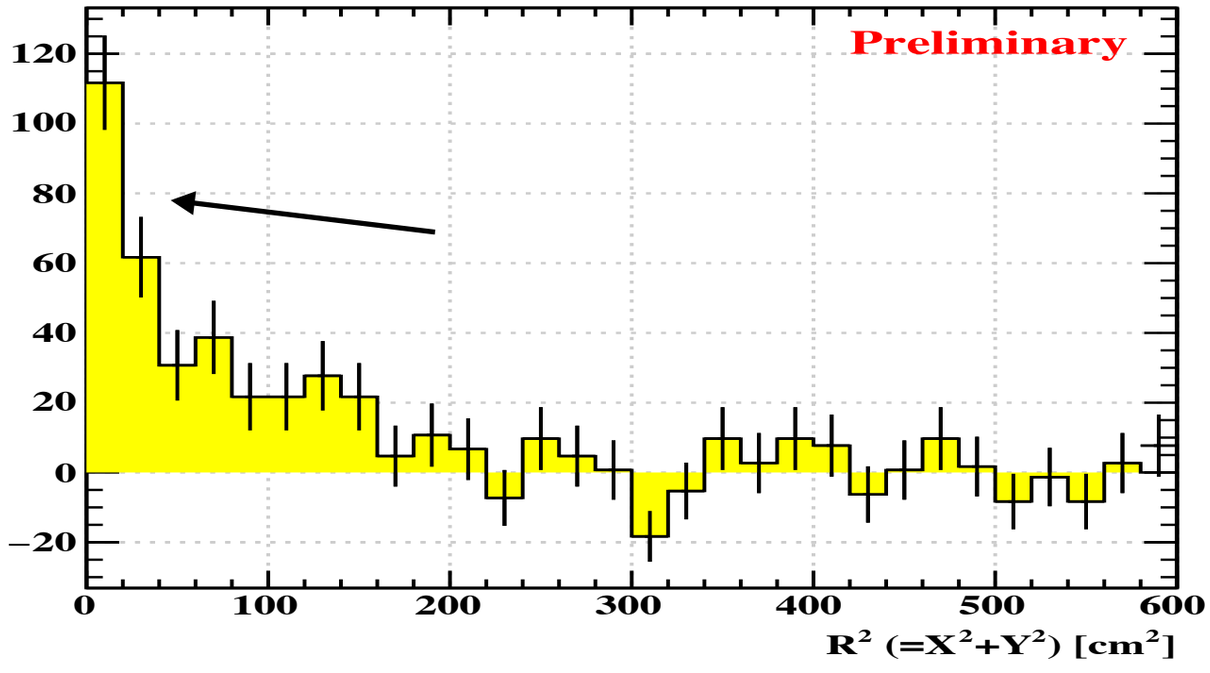
Gamma-ray Image of the launching plate

H.Rokujo, et al. in prep.

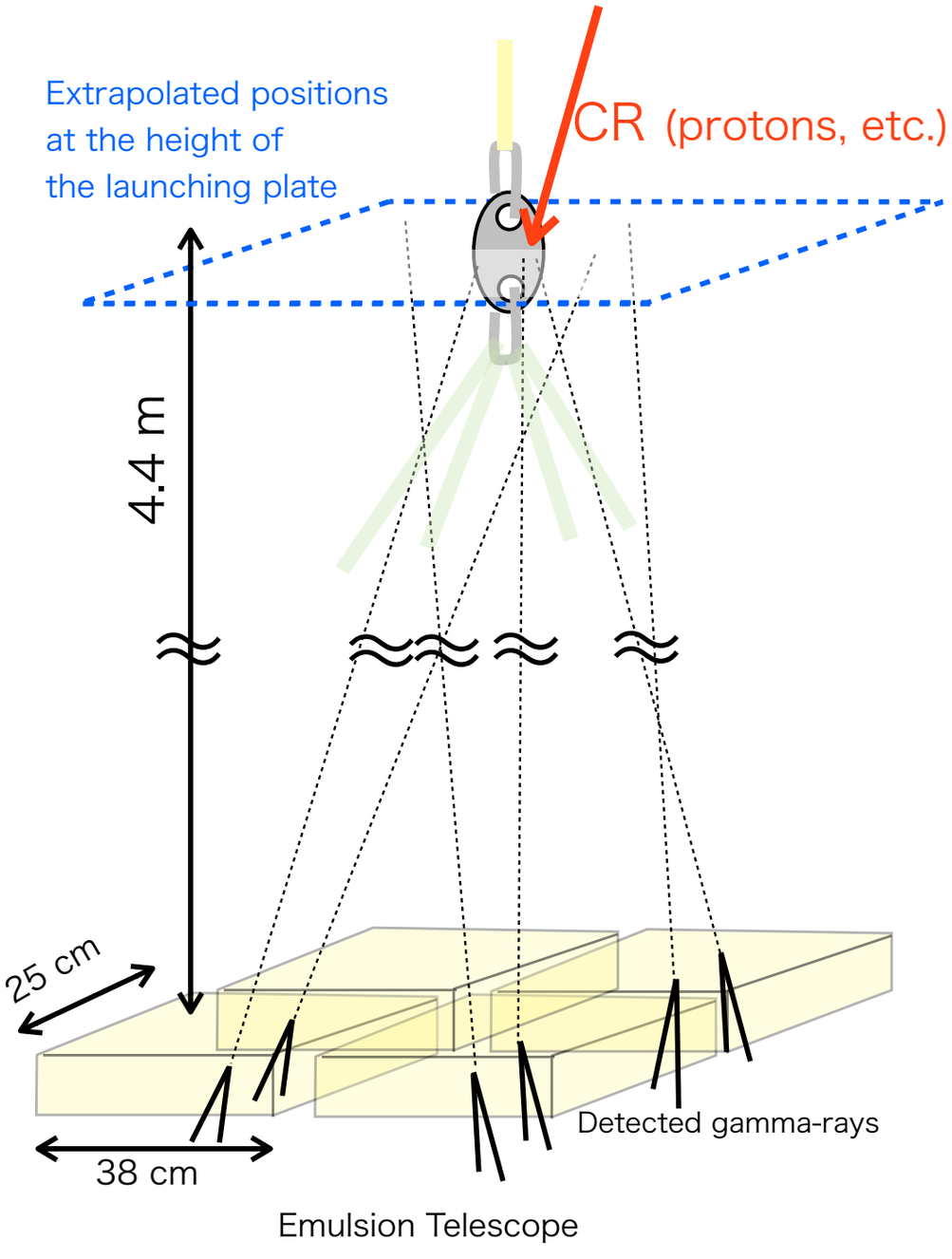


Emulsion Telescope

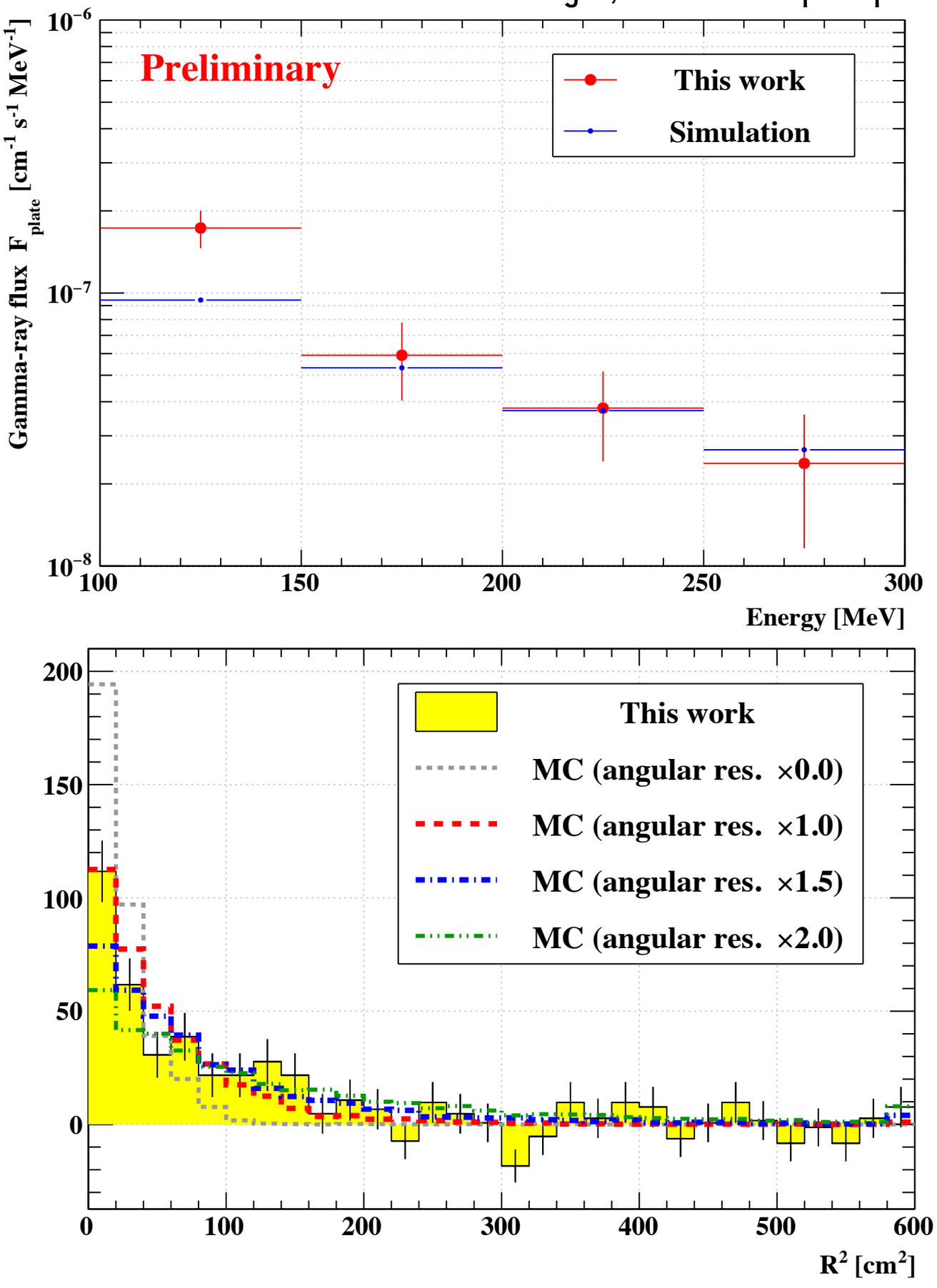




Gamma-ray Image of the launching plate



H.Rokujo, et al. in prep.



Summary & Prospects

- **GRAINE project**
  - Precise observation by balloon-borne emulsion gamma-ray telescope
  - High angular resolution, Polarization sensitive, Large effective area
  - SNR, Galactic center/plane, un-ID sources, Polarimetry, Burst events
- **2015-Balloon experiment in AUS**
  - Flight, Scanning, and Analysis were established.
  - Achieved 9.8 ms of time resolution by multi-stage shifter.
  - Demonstrated gamma-ray imaging performance @100-300 MeV as expected
- **Next balloon experiment**
  - The goal is confirming the overall performance by detecting a celestial gamma-ray source(Vela pulsar).
  - Please go to the following Poster Sessions!!
    - Y. Nakamura: Preparation of emulsion films
    - K. Kuretsubo: Preparation of Multi-stage shifter