

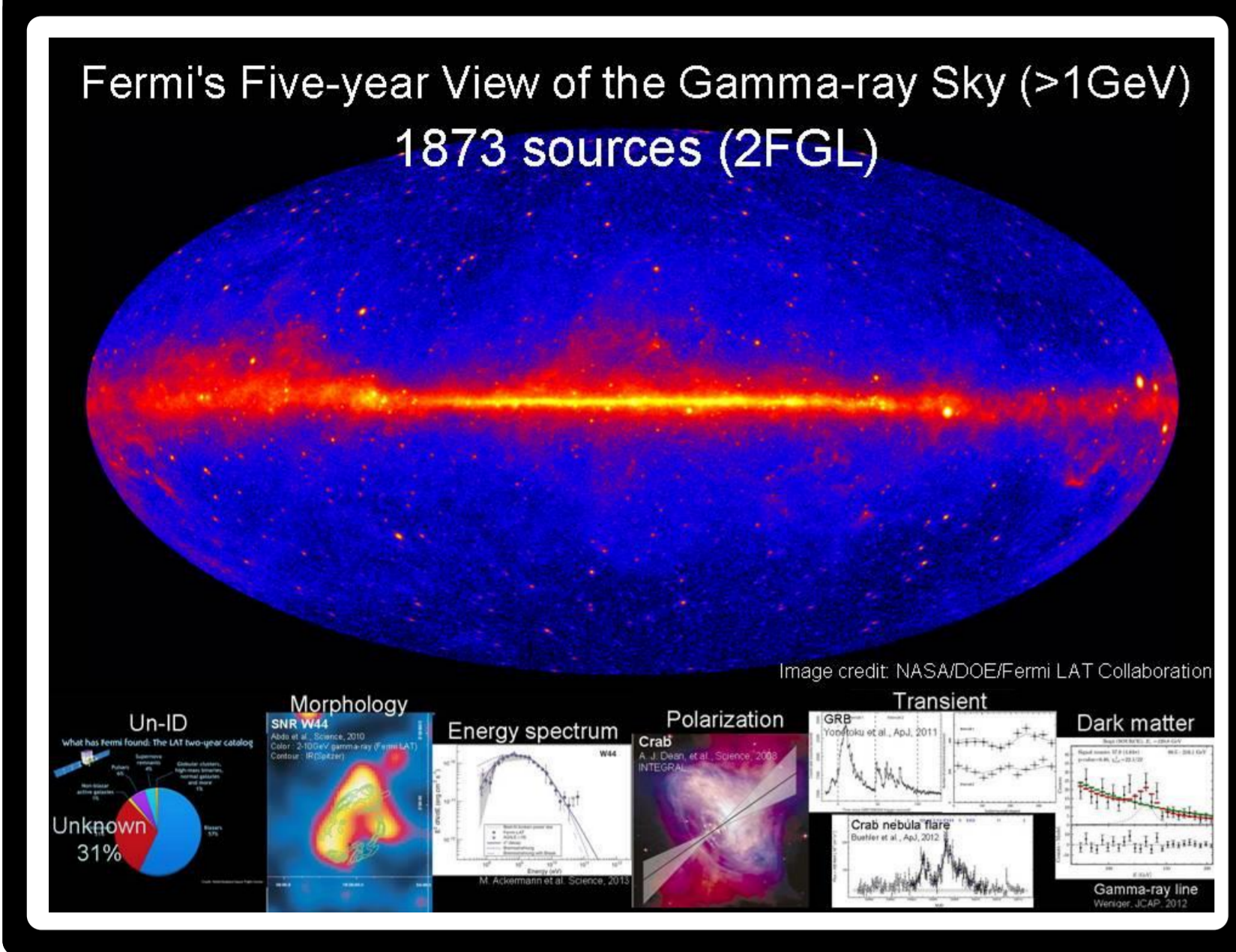
# GRAINE project, high resolution imaging and polarization sensitive gamma-ray observation with balloon-borne large aperture emulsion telescope

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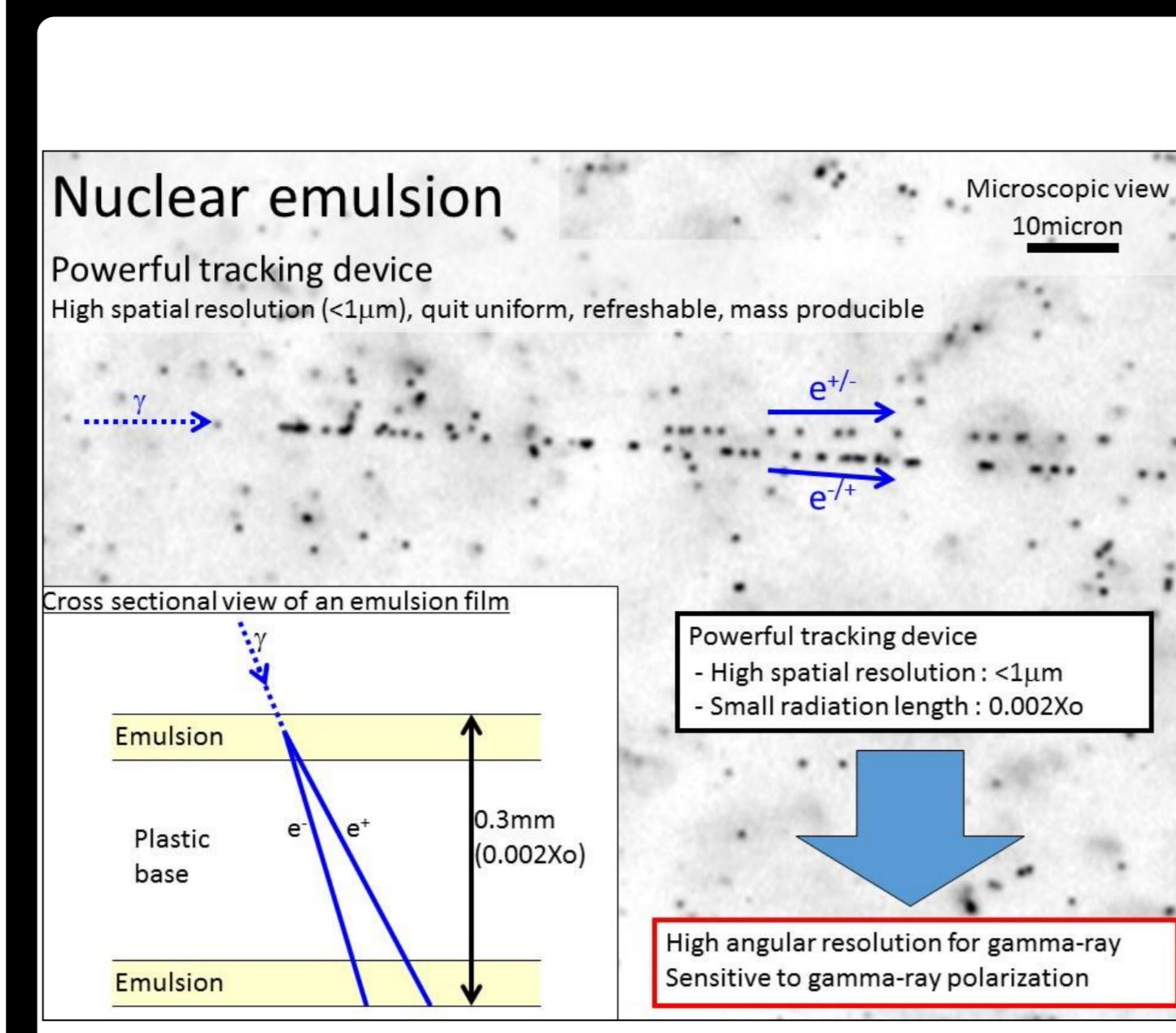
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Abstract : We are furthering GRAINE project of 10MeV-100GeV cosmic gamma-ray observation with precise (0.08deg@1-2GeV) and polarization sensitive large aperture area (~10m<sup>2</sup>) emulsion telescope by repeating long duration balloon flights. An overview and a status of GRAINE project are presented.

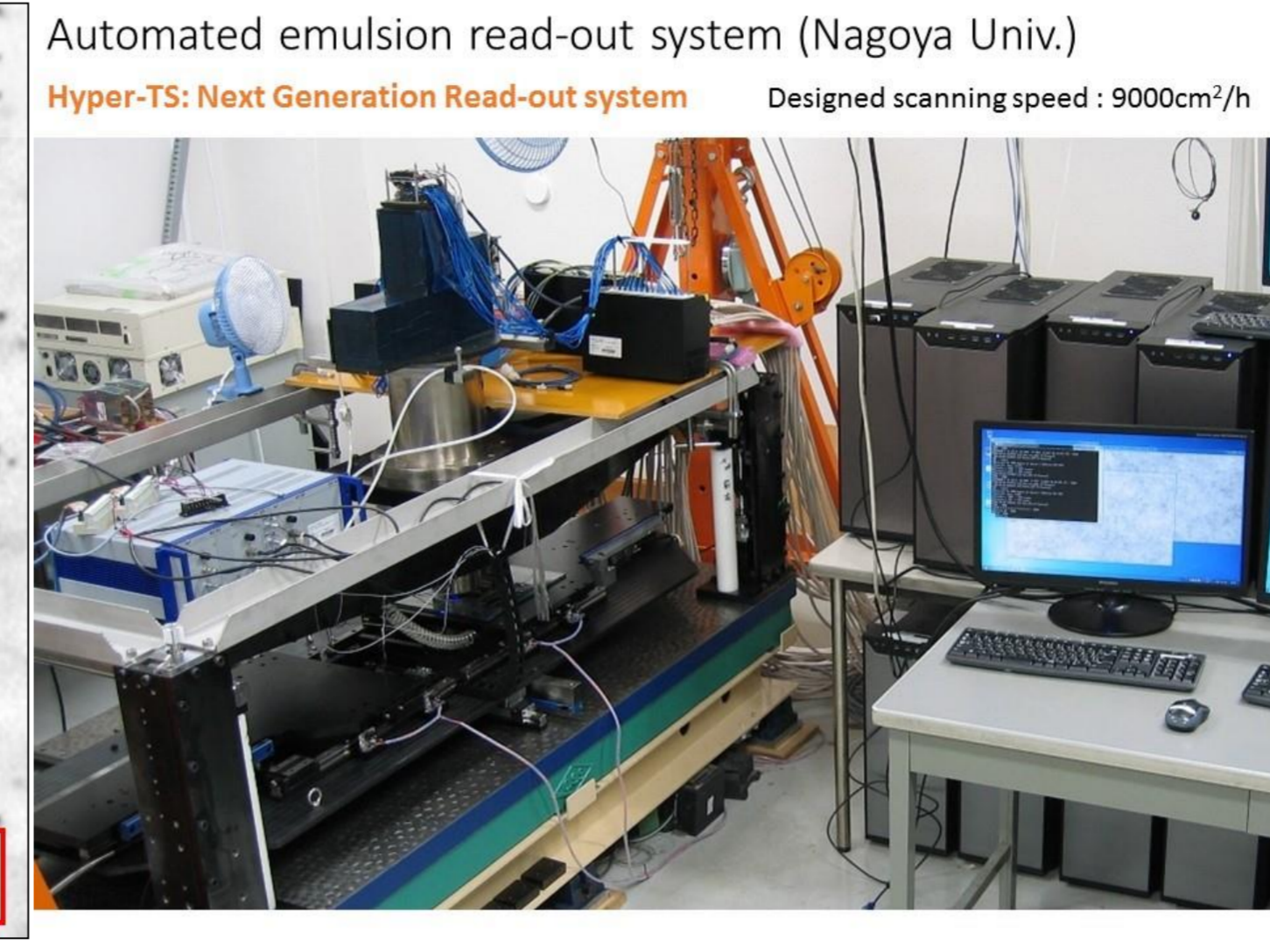
## Current situation



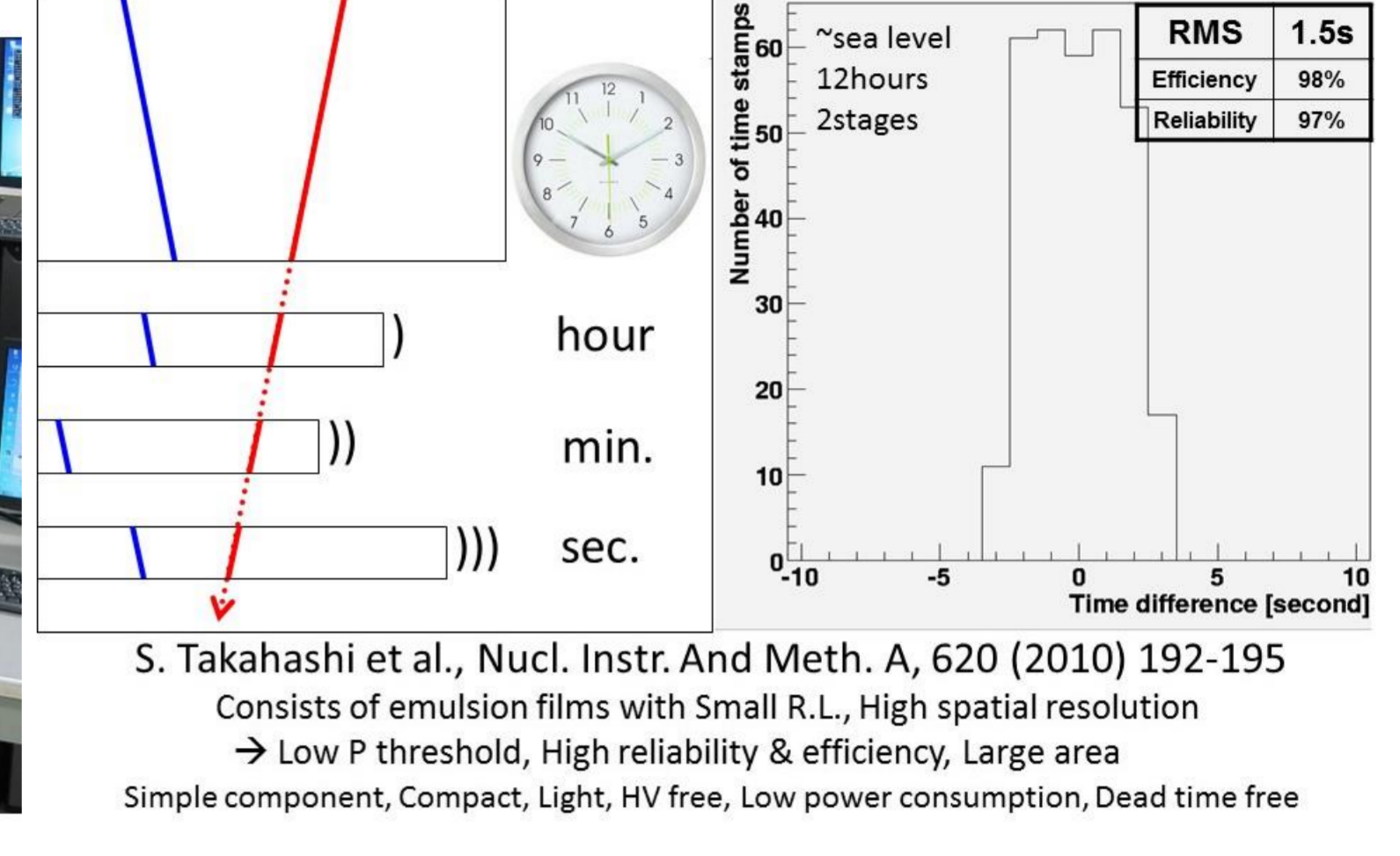
## GRAINE project



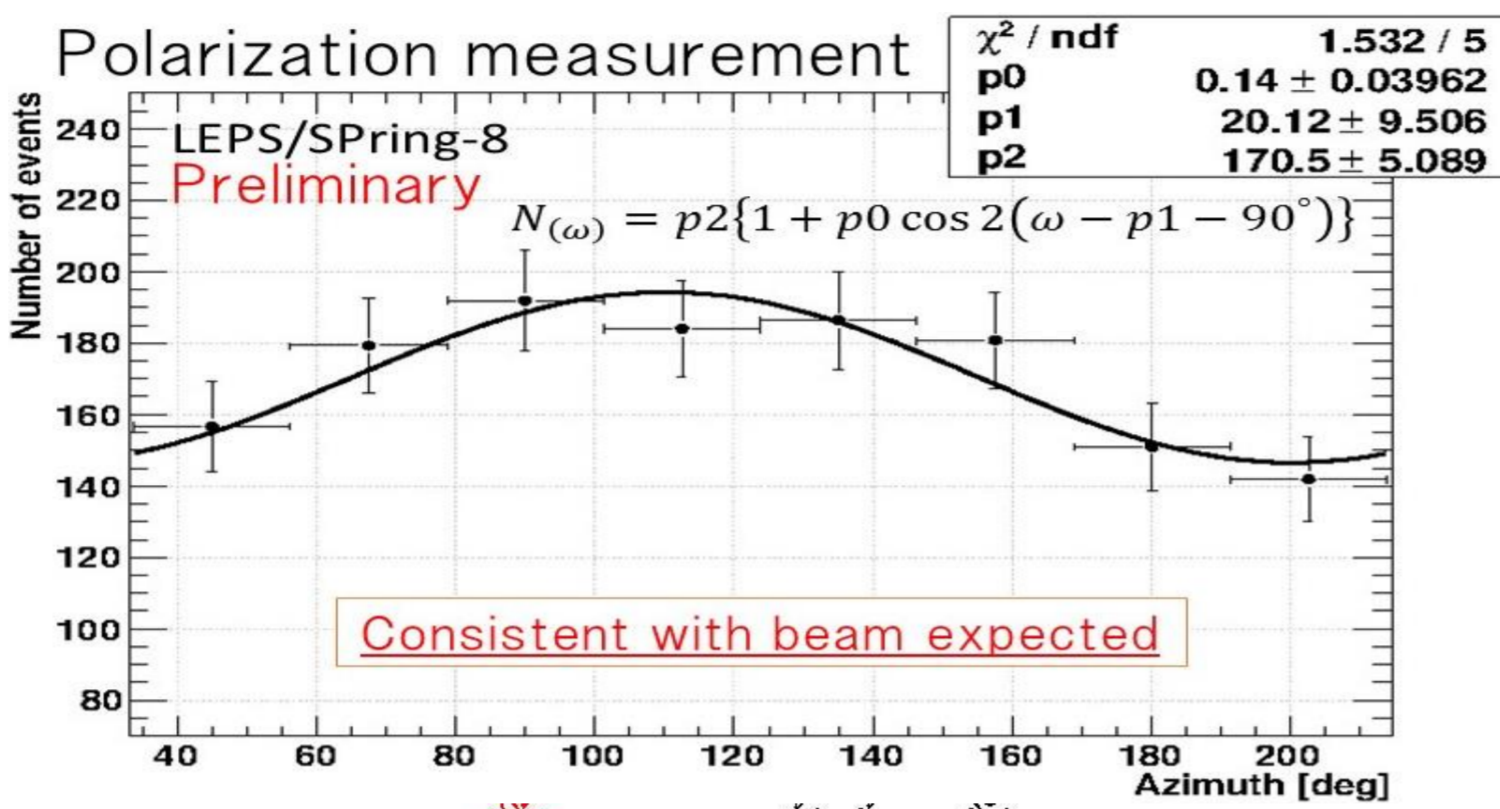
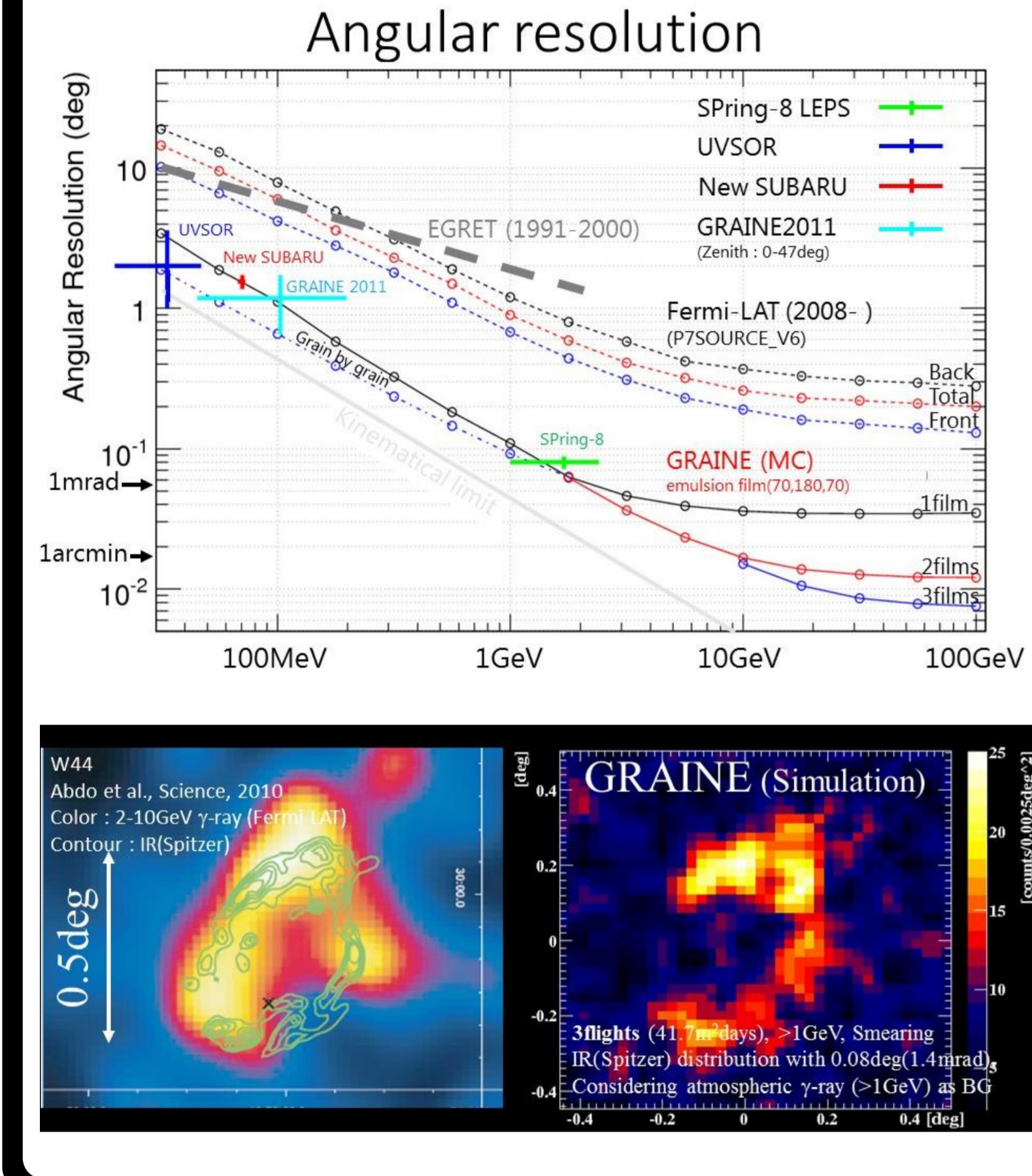
## The latest emulsionics



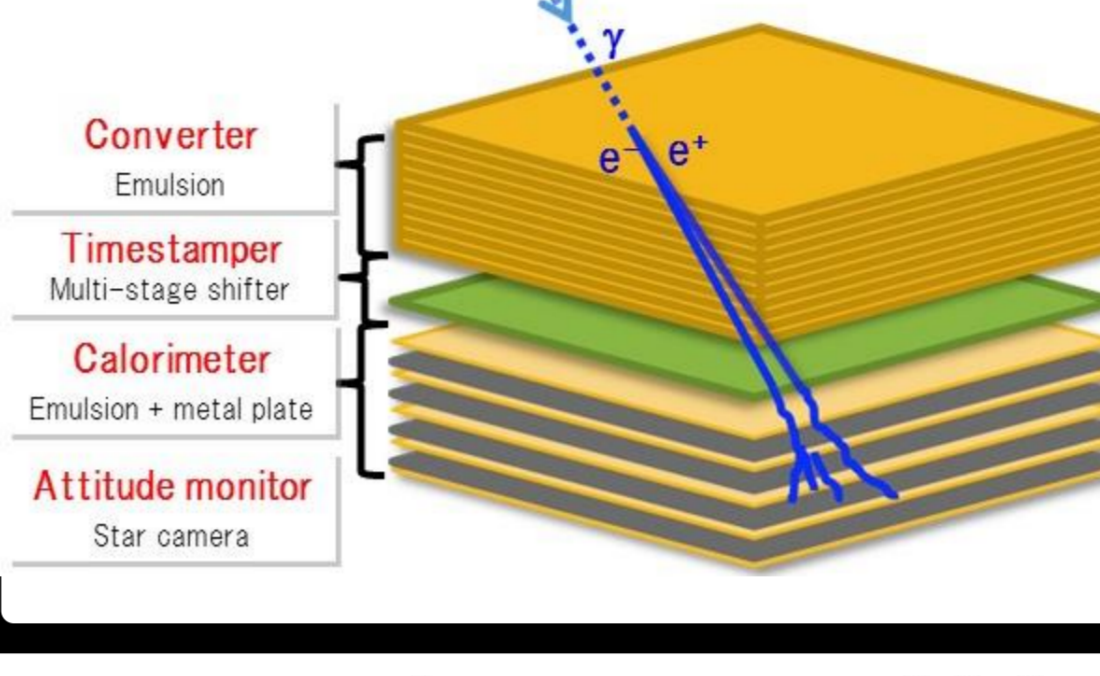
## Time-resolved emulsion multi-stage shifter



## Performance

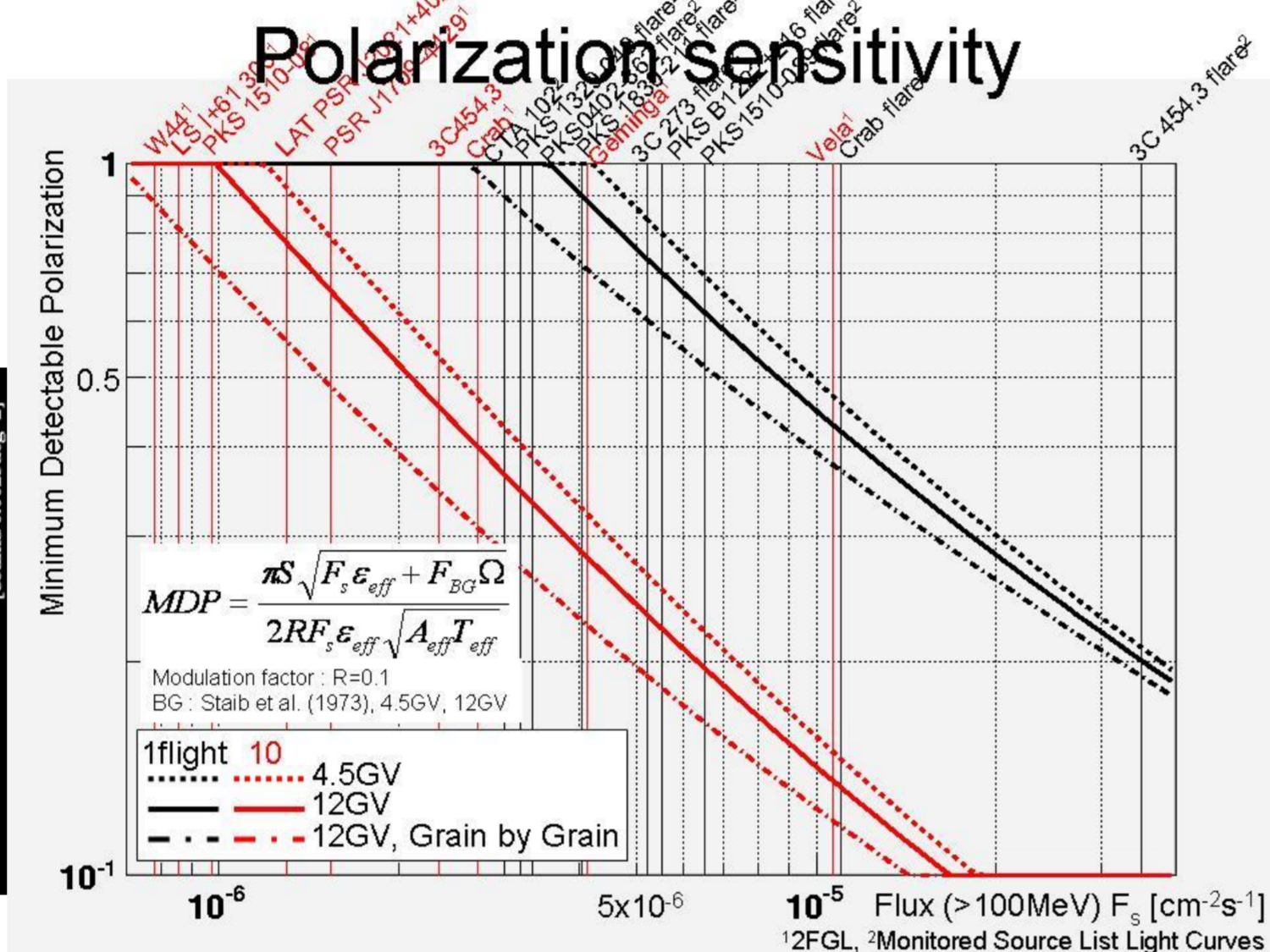


## Emulsion γ-ray telescope

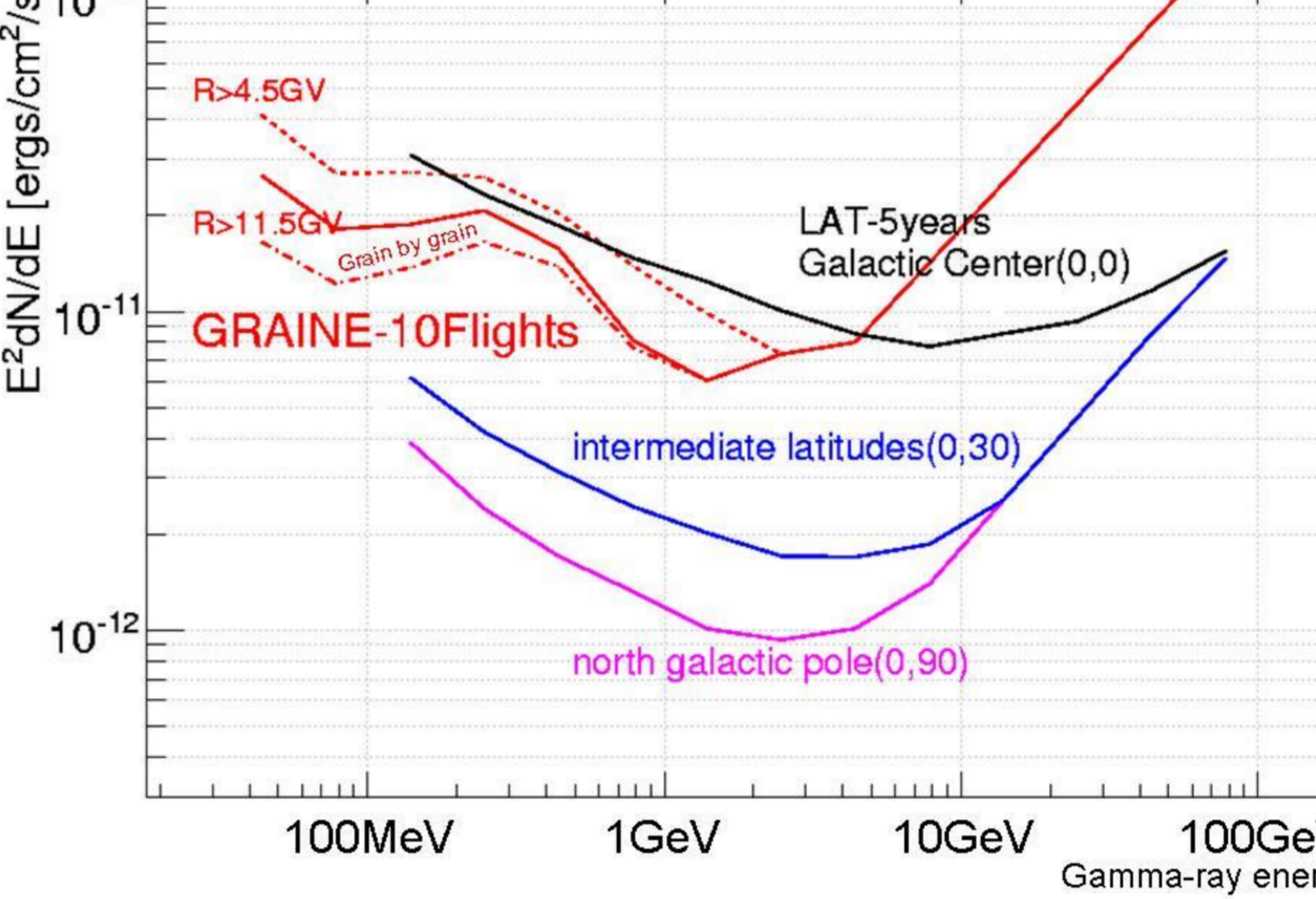


	Fermi LAT	GRAINE
Angular resolution @100MeV	6.0deg (105mrad)	1.0deg (17mrad) $\times 1/6$
@1GeV	0.90deg (16mrad)	0.1deg (1.7mrad) $\times 1/9$
Energy range	20MeV - 300GeV	10MeV - 100GeV
Polarization sensitivity	No	Yes
Effective area @ 100MeV	0.25m <sup>2</sup>	2.1m <sup>2</sup> * $\times 8$
@ 1GeV	0.88m <sup>2</sup>	2.8m <sup>2</sup> * $\times 3$
Dead time	26.5 μs (readout time)	Dead time free

\* 10m<sup>2</sup> \* ε<sub>trans</sub> \* ε<sub>conv</sub> \* ε<sub>det</sub>



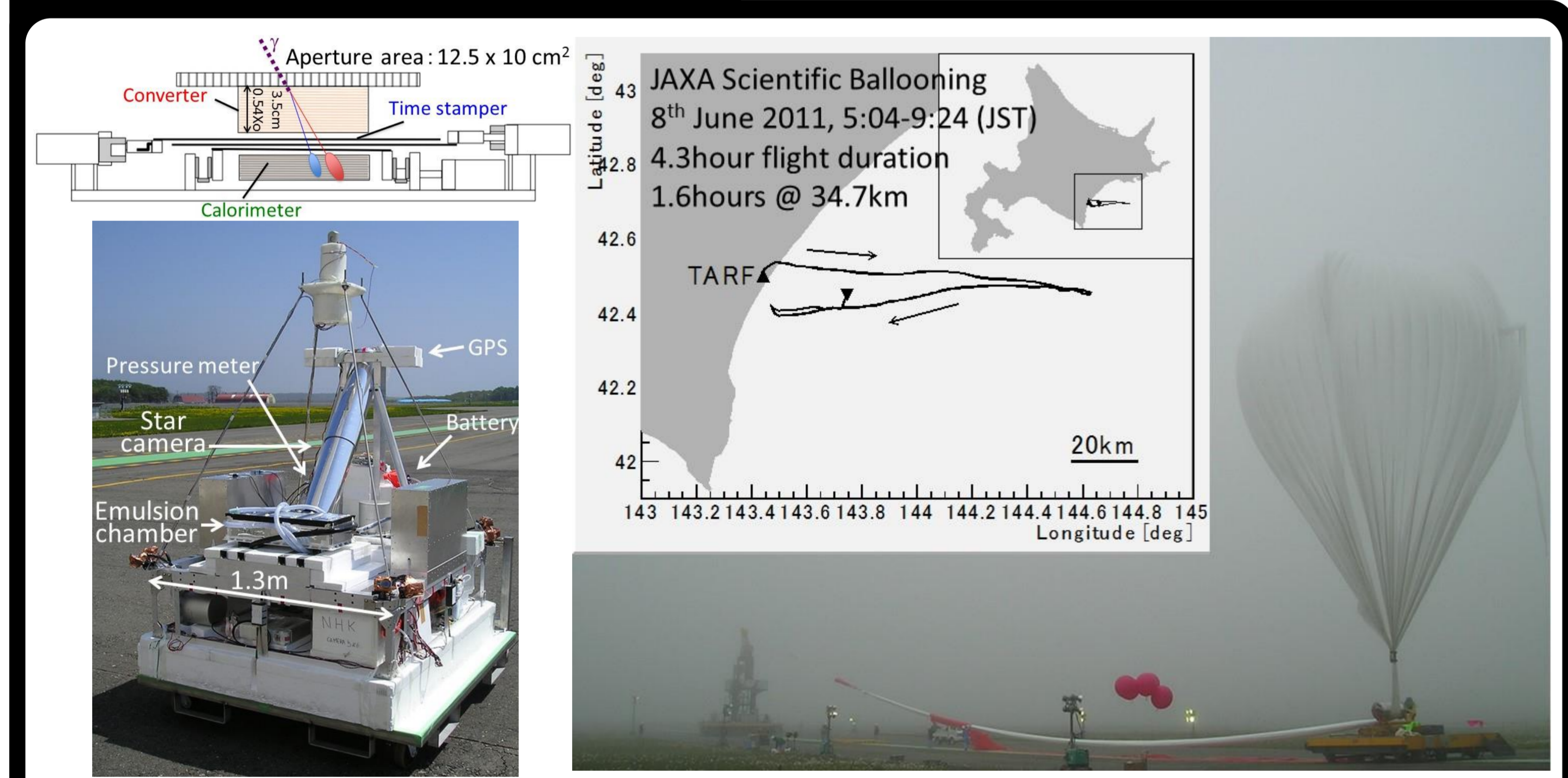
## Source sensitivity



## Roadmap

- Feasibility Phase  
2011(8th June), TARF, JAXA Scientific Ballooning  
12.5cm x 10cm aperture area, 4.3hour (1.6hours@35km) flight duration  
• Working and performance test  
• Background measurement
- Demonstration Phase  
2015(Planned), Alice Springs, JAXA International Scientific Ballooning  
3600cm<sup>2</sup> aperture area, 1 day flight duration  
• Overall test by detecting known gamma-ray source (Vela)  
• Observation with highest imaging resolution
- Observation Phase  
2016-  
10m<sup>2</sup> aperture area, 7day flight duration  
• Starting scientific observation

## 2011 balloon experiment



## Next balloon experiment

2015(Planned), Alice Springs, JAXA International Scientific Ballooning  
3600cm<sup>2</sup> aperture area (30 times), 1 day flight duration (6 times),  
Higher timing resolution (msec order)  
• Detection of Vela pulsar with >5σ level  
• ~100 times higher resolution imaging in solid angle  
• Data taking for the first polarization measurement  
• Time-resolving 89msec pulse emission

Vela pulsar  
Fermi-LAT, <300MeV  
Abdo et al. ApJ, 696, 2009

Emulsion production  
Nagoya Univ., Fuji Janet Co., Ltd.  
Gelatin 1/4, No type, Fe x 2, MIP (XAA, 20deg, 40min)  
New type GD=86.1±4.7 FD=2.9±0.9  
OPERA type GD=34.8±0.6 FD=3.7±0.4

Tracking efficiency 97.7±0.25 [%]

Production progress

Quality control

Fabric vessel Ref. ATIC

Star camera  
• Modified hood aperture/length  
• High QE camera  
• Multi-direction

	GRAINE2011	2014 model
Field of view	5.9° x 4.5°	5.9° x 4.5°
Limit magnitude	6.1	6.7
Attitude determination ratio	74% (1camera)	>99% (3cameras)
Monitoring accuracy	< 0.4 mrad	< 0.1 mrad

Flight model of multi-stage shifter  
Co-developed with Mitaka Kohki Co., Ltd.

Leak check

Schedule

Japan  
- Feb./2015 Film production  
On-board equipment  
Vessel and gondola

Sydney Univ.  
Mar. Development setup  
May, Jun. Film development

Alice Springs  
Mar., Apr. Assembling  
May Launching

Emulsion scanning

	S-UITS	HTS (Commissioning)	HTS
Scanning speed	0.0072 m <sup>2</sup> /h	0.07m <sup>2</sup> /h	0.9m <sup>2</sup> /h
GRAINE 2014 50m <sup>2</sup>	600days	60day	6days
GRIANE future 1000m <sup>2</sup>	12000days	1200days	100days

2011 model  $\times 29$  Aperture area : 3600cm<sup>2</sup>

GRAINE First Light

Atmospheric γ-ray flux [cm<sup>-2</sup>sr<sup>-1</sup>MeV<sup>-1</sup>]  
Energy [MeV]  
Exposure [cm<sup>2</sup>hour]