Detection of ultra-high energy cosmic ray air showers by Cosmic Ray Air Fluorescence Fresnel-lens Telescope for next generation

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UHECR 2018 Ultra High Energy Cosmic Rays

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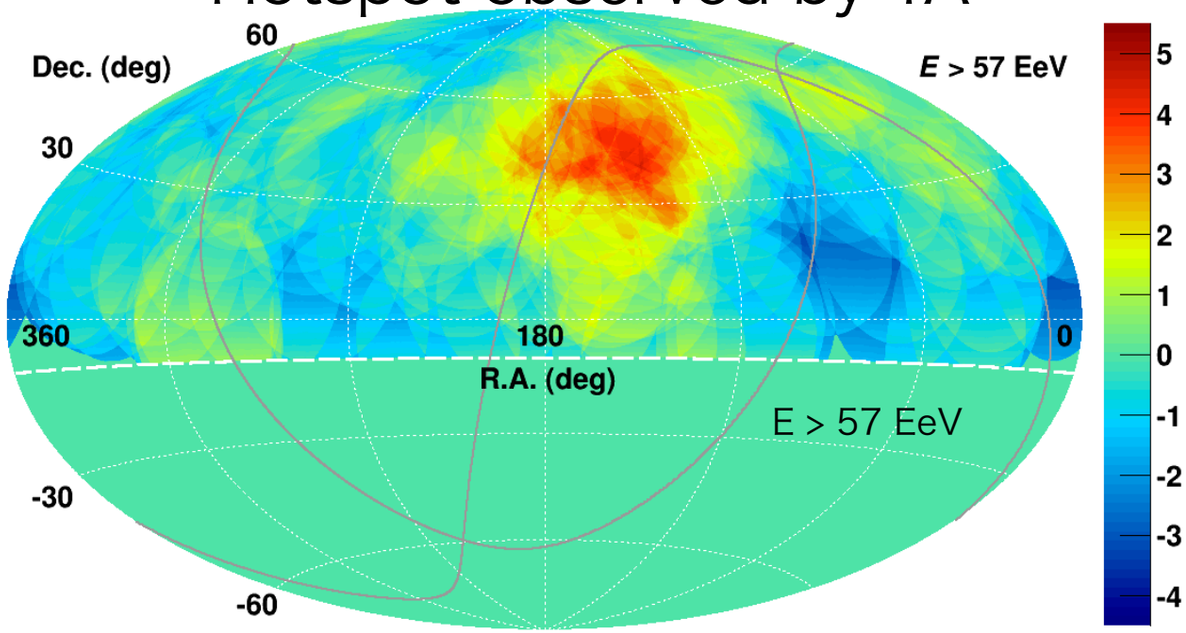
The present situation of UHECR observation

TA reported hotspot (5σ)

Intermediate scale anisotropy of the arrival direction of UHECRs (E>57EeV)

What should we do to clarify UHECR sources ?

Hotspot observed by TA



Is hotspot related to the population of UHECR sources ?

- Extension of detection area for larger statistics.

Can UHECRs propagate straight ?

- Observation of X_{max}

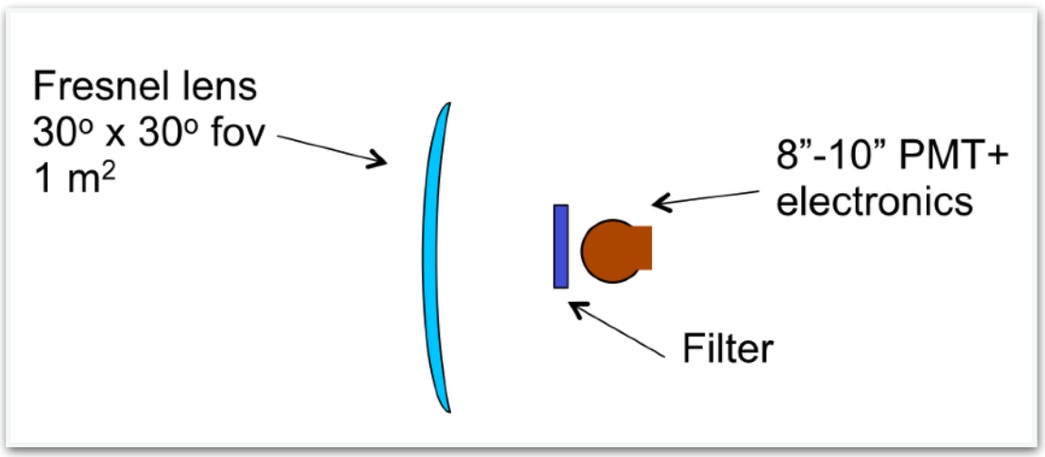
Solution :

Huge observatory using fluorescence detector(FD).

However, Cost of FDs in use are high :(

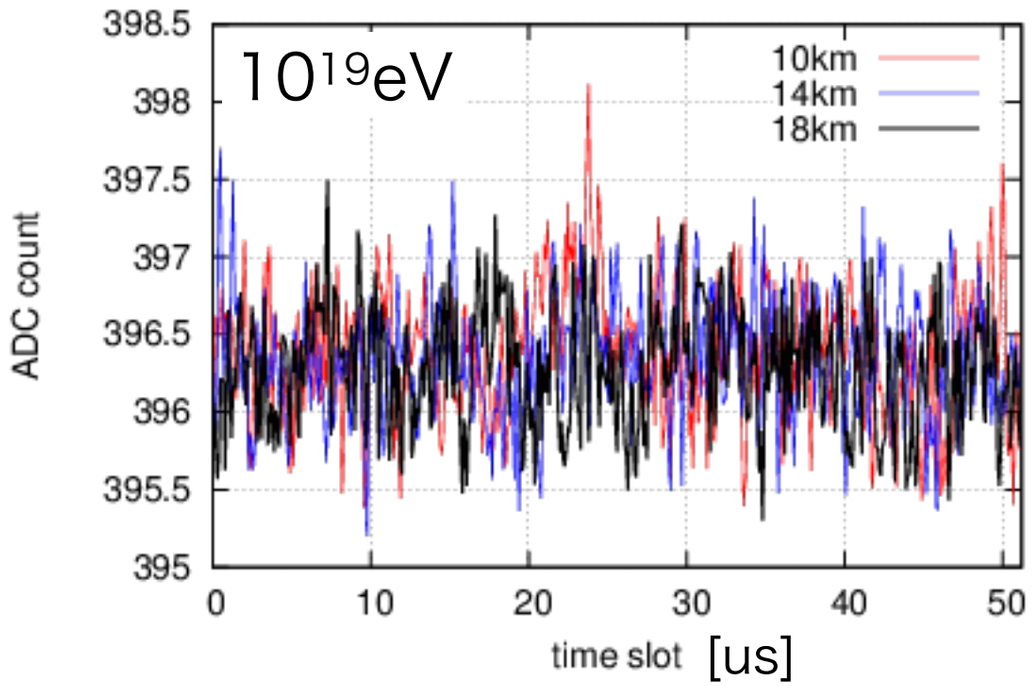
K. Kawata et al. ICRC2017

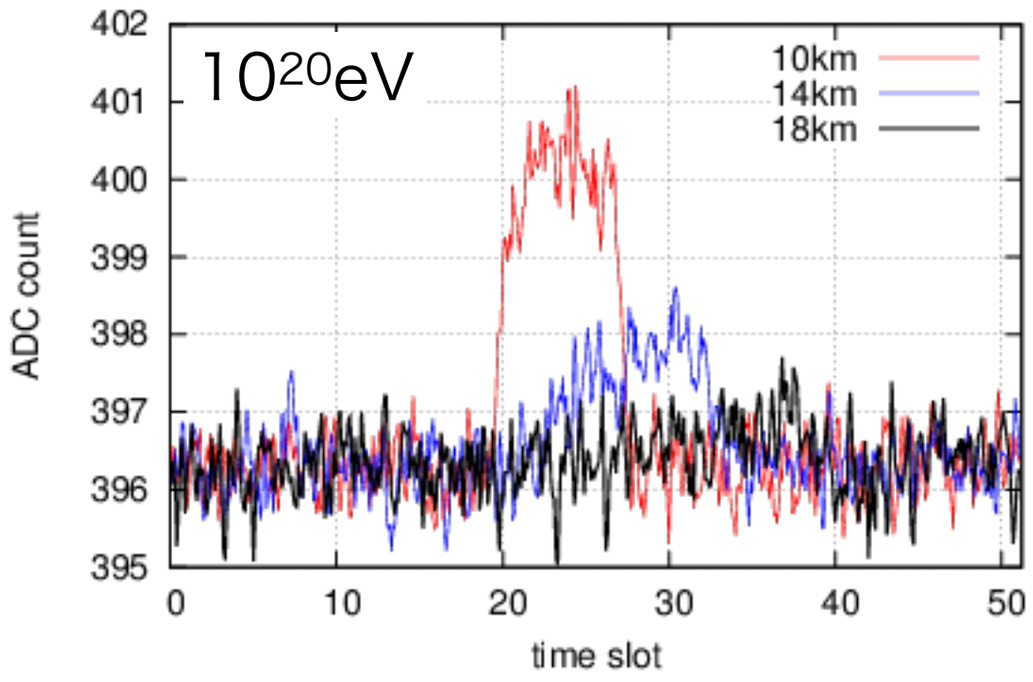
Proposed concept of simple structured FD.

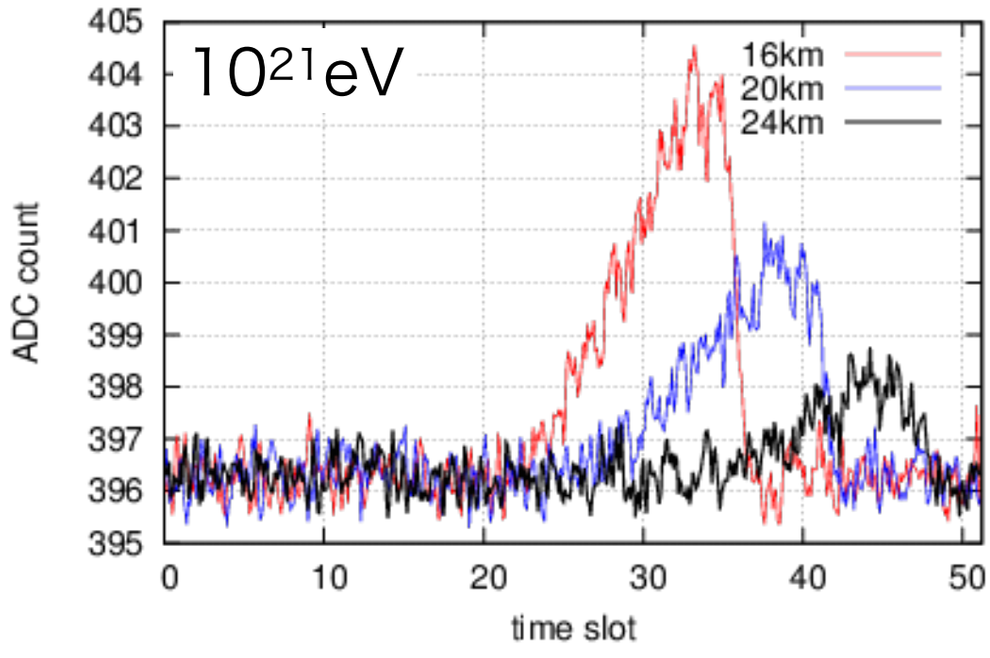


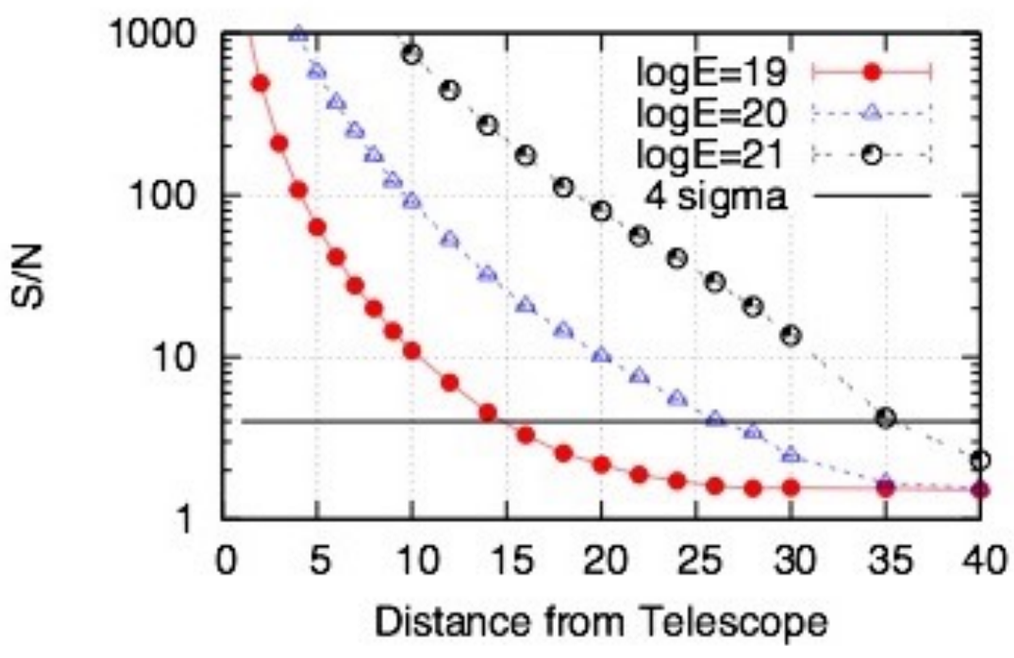
P. Privitera, et.al.UHECR(2012)

Expected signal of Single pixel FD



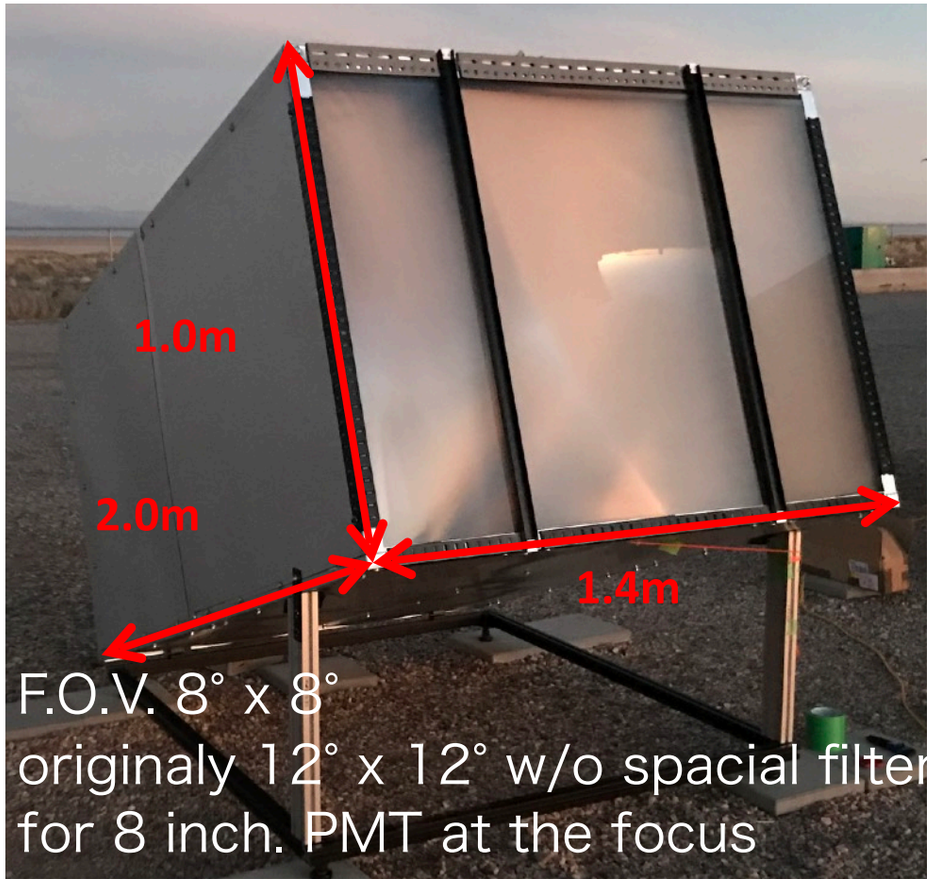




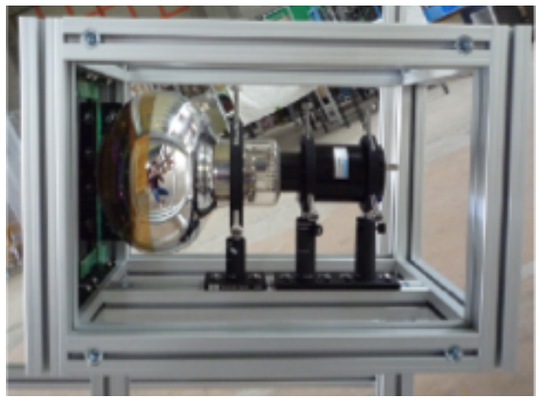


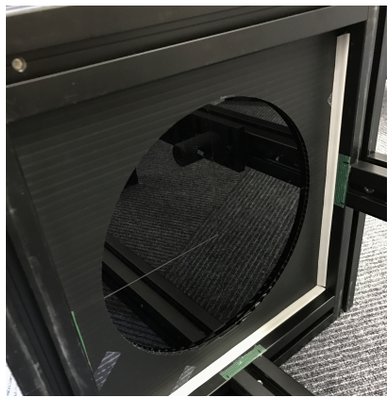
Simulation condition : 1 m^2 lens (90% trans.), 8 inc. PMT, UV filter (BG3), FOV 16°x16°

Cosmic Ray Air Fluorescence Fresnel lens Telescope



Appearance of CRAFFT detector.
Shading curtain inside.





8 in. PMT with UV transmitting filter.
8° spacial filter for test observation.

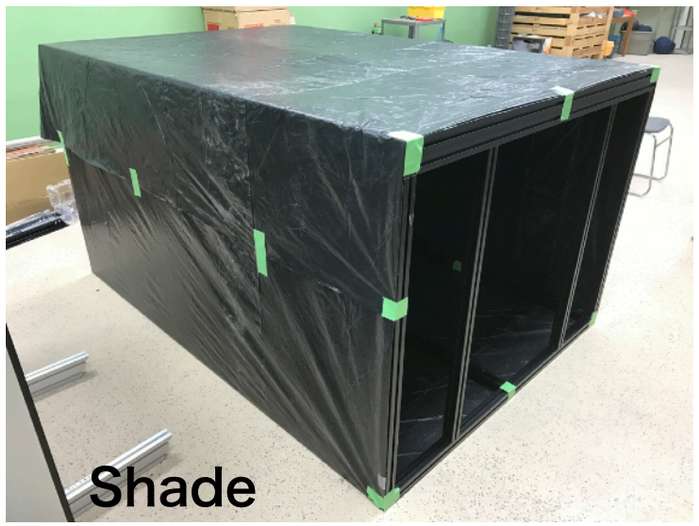
Single pixel Fresnel lens telescope

- Simple structure, without container
- Easy to deploy
- No obstacle between lens and focus
- Necessity of multiple observation for geometrical determination
- Worse S/N compared to multi pixels.

Component	Product	Specification	Cost/FD
Structure	MIWA	Aluminum frame	950
Fresnel lens	NTKJ, CF1200-B	1m², f=1.2m	370
UV trans. filter	Hoya, UL330	~90%,300-360nm	3,000
PMT	Hamamatsu, R5921	8 inch	2,000
FADC	TokushuDenshiKairo, Cosmo-Z	80MHz, 12bit	290
Amplifier	Lecroy, 612AM		1,000
HV	CAEN, N1470AR	8kV, 3mA	1,600
		Total ($) :	9210

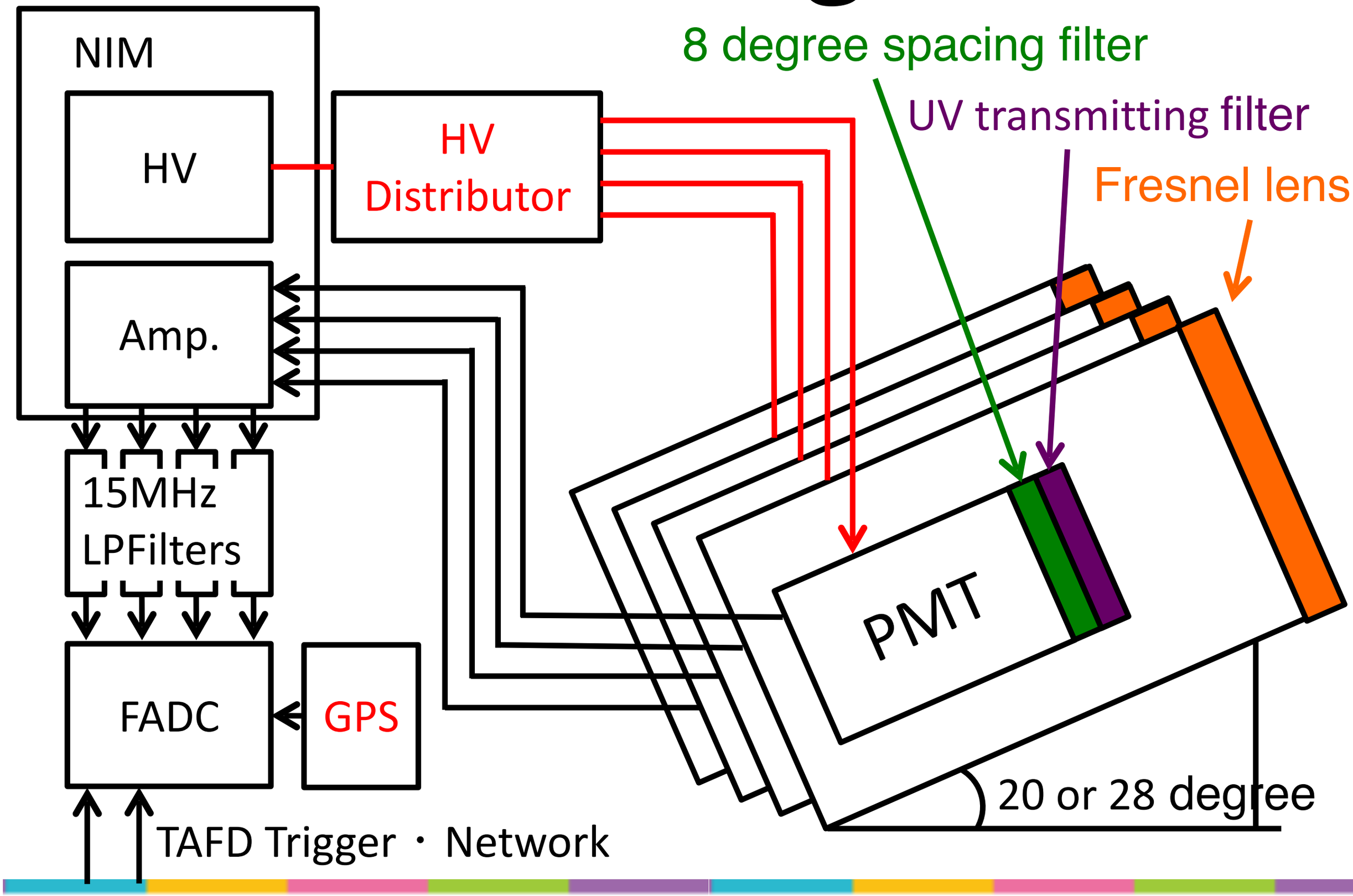
The status of CRAFFT

2017 Sep. Built four CRAFFT detectors.
2017 Oct. Deployed detectors at TA FD site.



Deployed CRAFFT detector
@ TA FD site

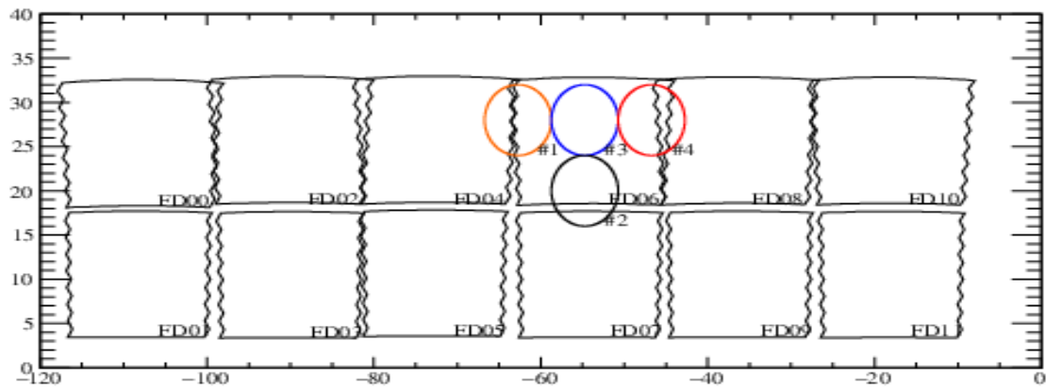
Detector configuration



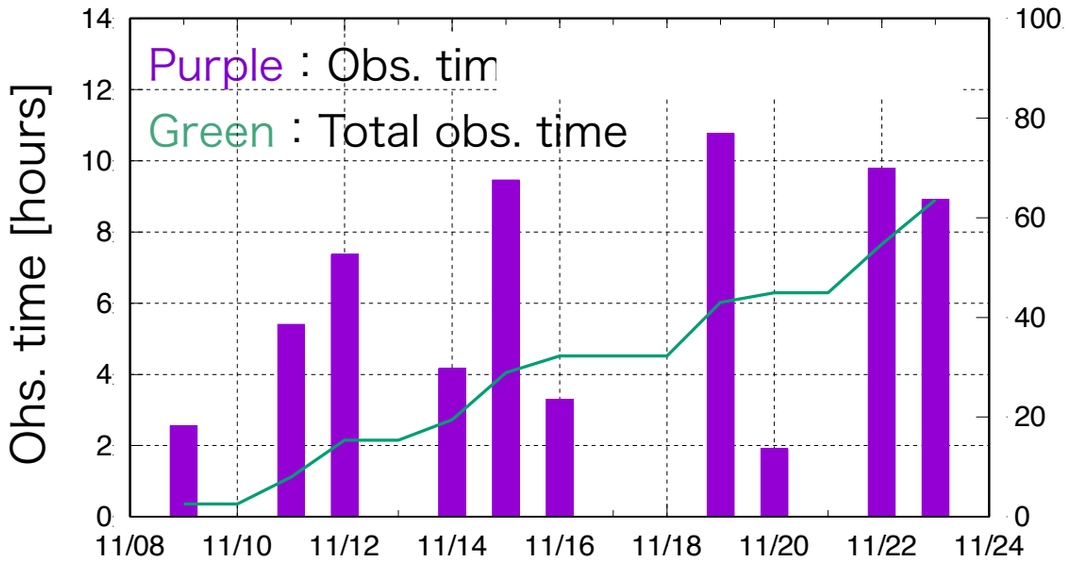
Test Observation at TA FD site

- Test observation at TA FD site
- 2017 Nov. 9 ~ Nov. 23
- Obs. time : 63.5 h (10 nights)
- Expected events / month :

  ~8 events (above 10^{17} eV)
- Triggered by TA FD triggering timing
- # of recorded events : 556,255



The F.O.V. CRAFFT detectors compared to TA FD F.O.V.



Performance test with TA CLF

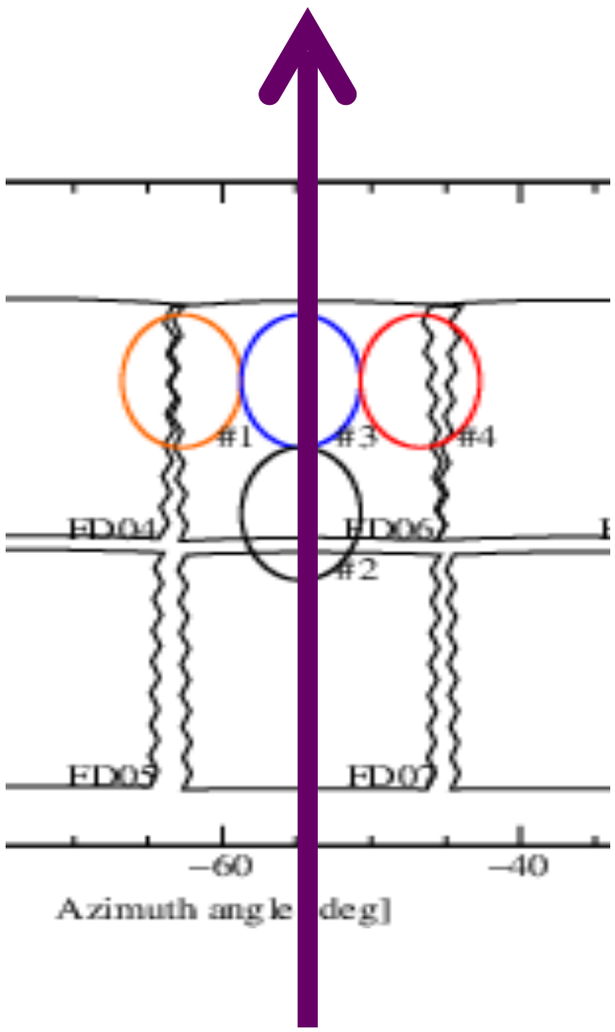
CRAFFT detected CLF laser event.

CLF(Central Laser Facility)

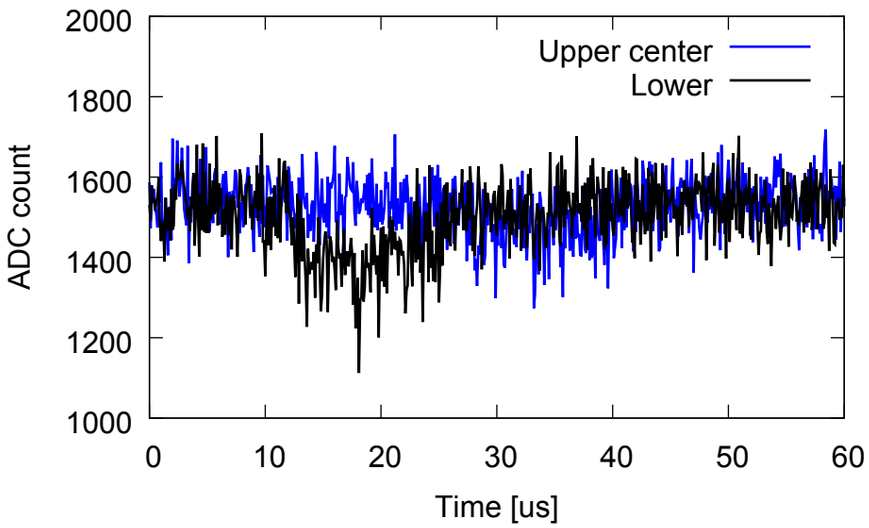
Nd:YAG pulse laser, λ =355 nm, 5mJ,

20 km apart from CRAFFT detectors.

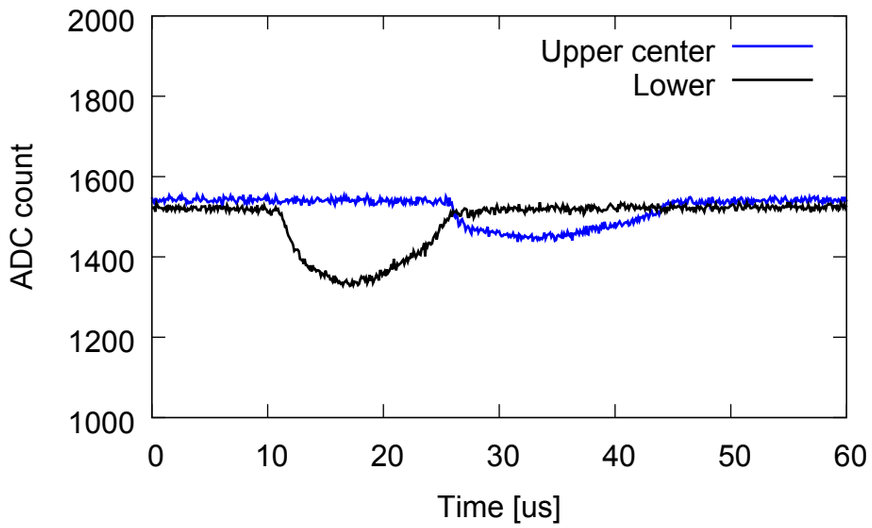
Corresponding to 10^{20} eV air shower



CLF laser is crossing the F.O.V. of CRAFFT detector and TA FD.



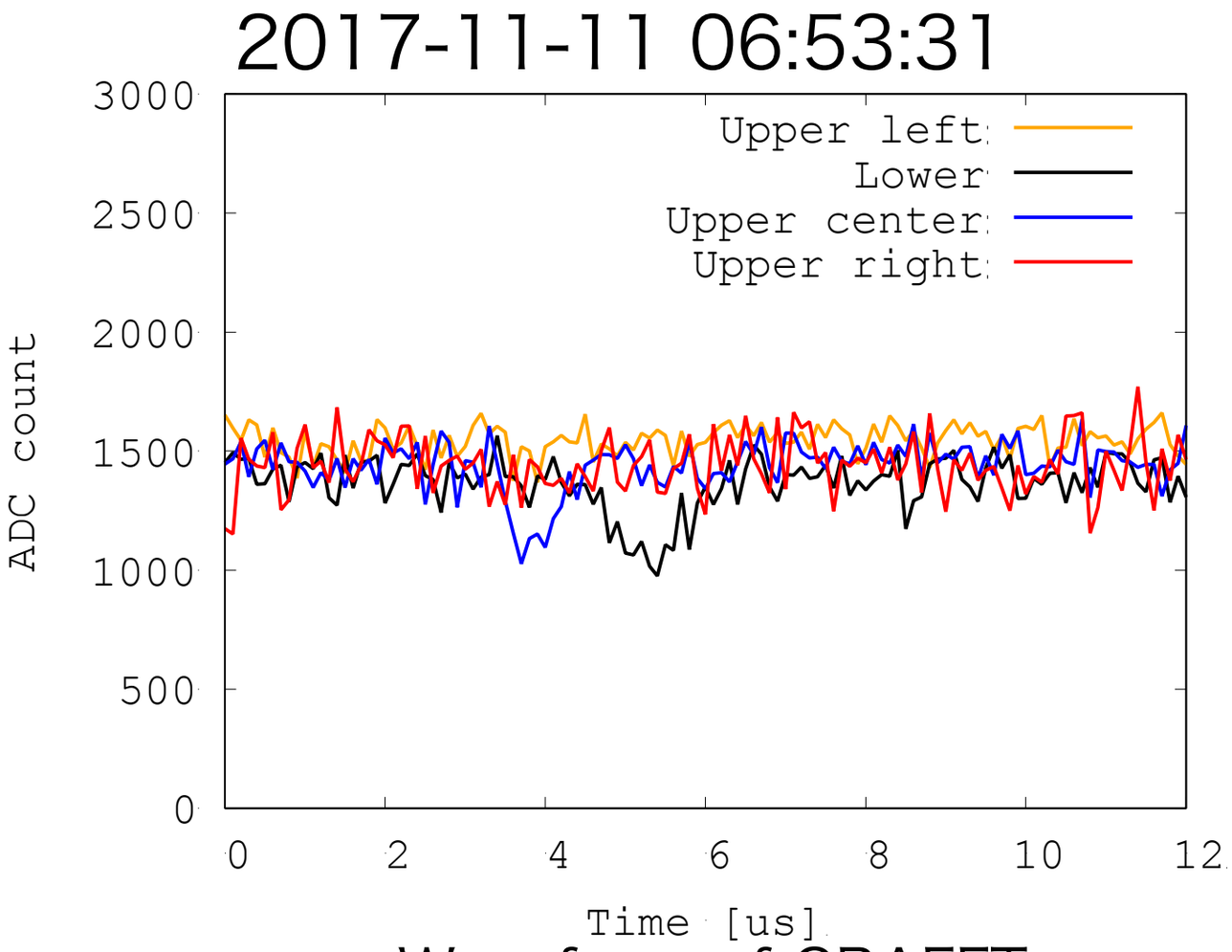
single event



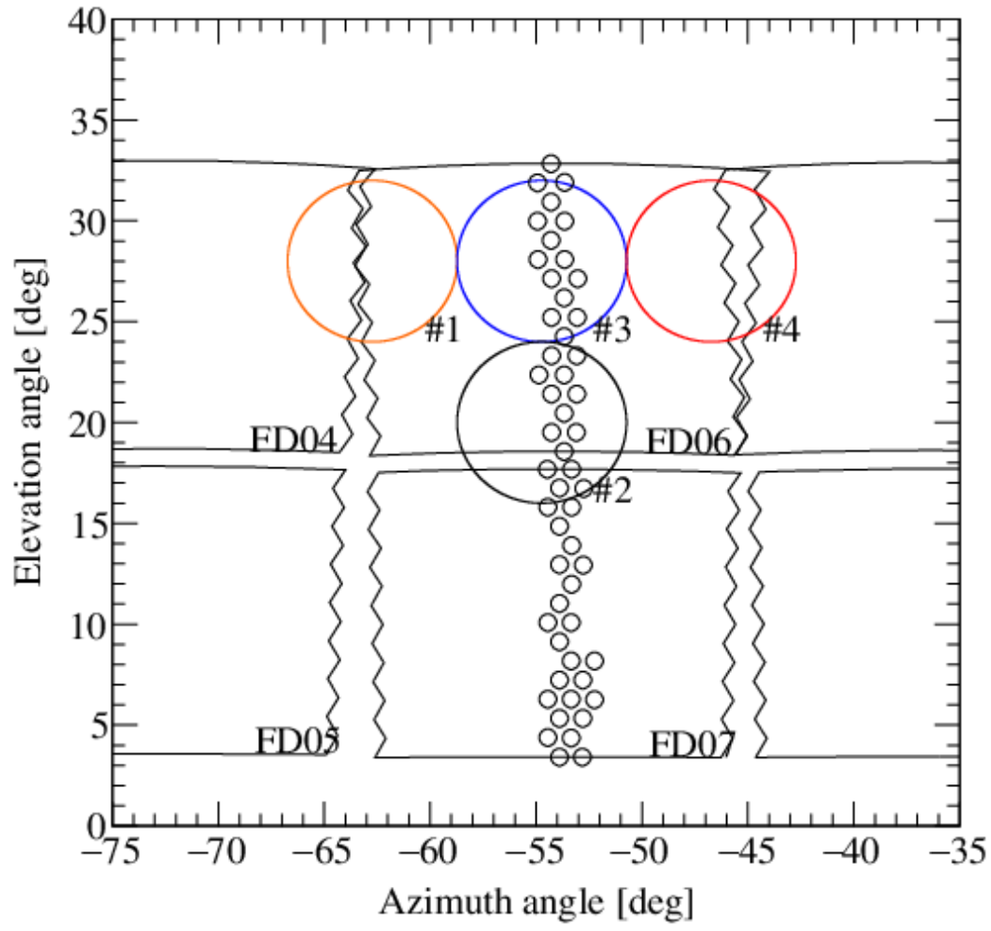
133 events average

Air shower event observed by CRAFFT

We succeeded to detect air shower events !!



Waveform of CRAFFT

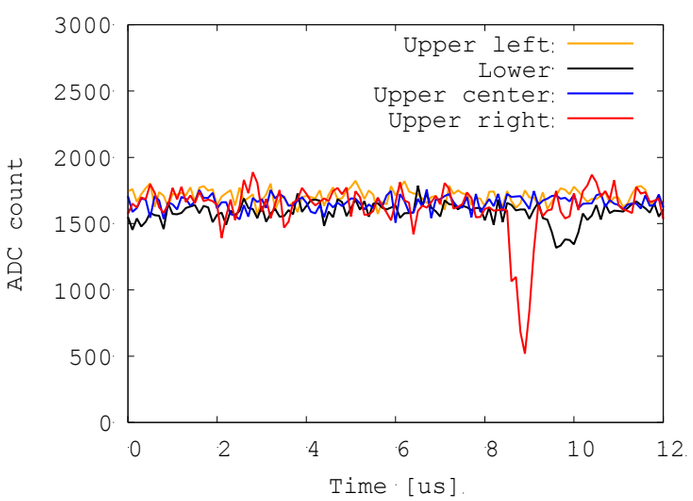


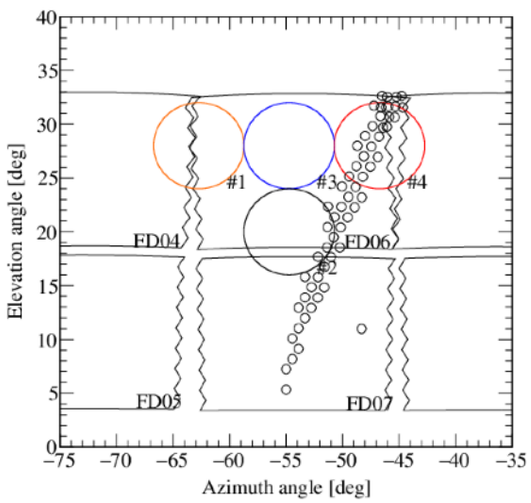
Event display of TA FD
with CRAFFT F.O.V.

Energy: $10^{17.7}$ eV, Distance: 3.6 km (by TA FD)

Air shower events observed by CRAFFT

2017-11-15 05:47:08





$10^{17.9}$eV, 3.9 km

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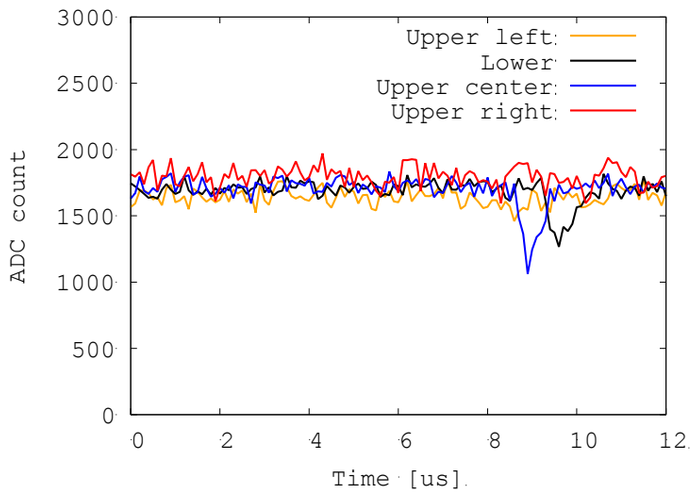

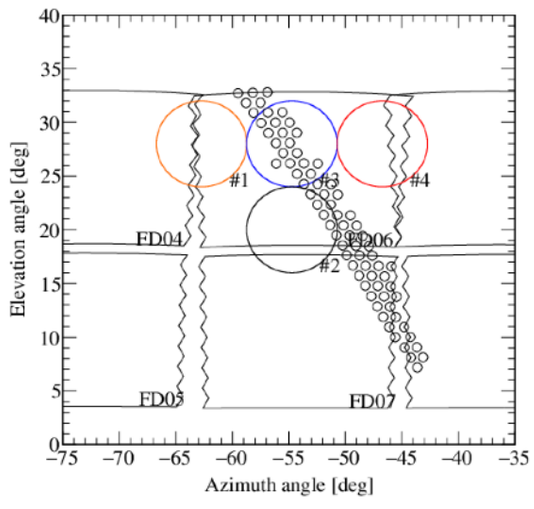

$10^{18.0}$eV, 2.3 km

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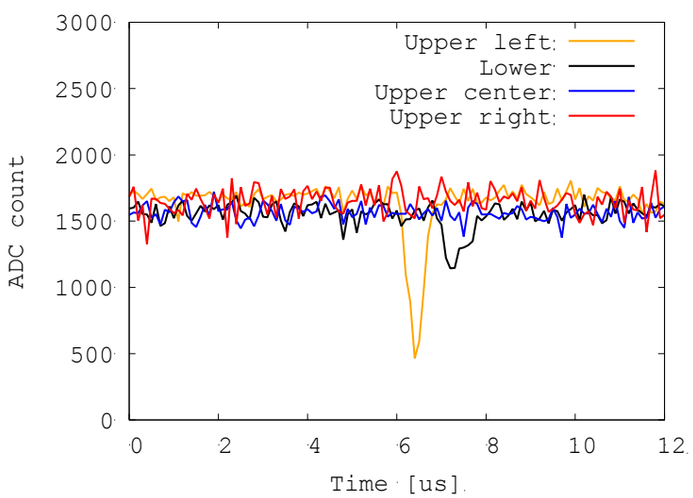

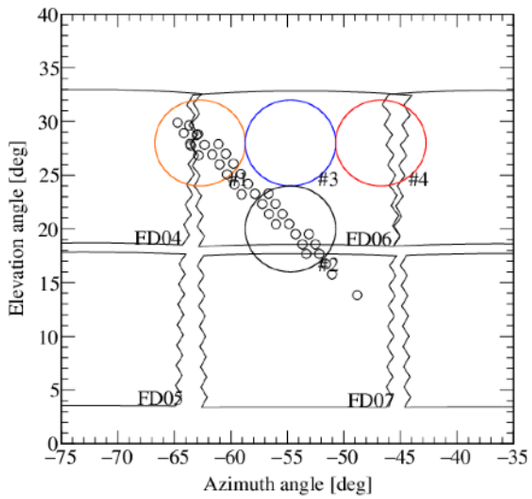

$10^{18.0}$eV, 3.5 km

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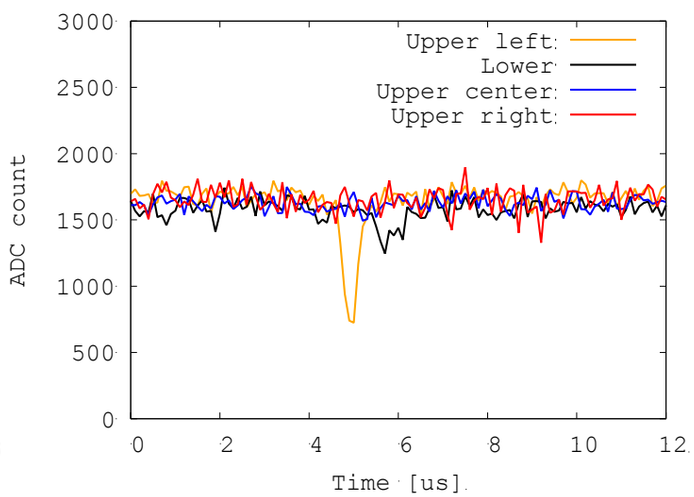

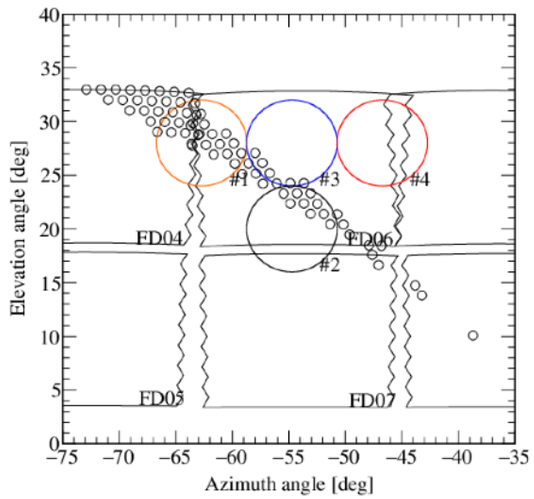

$10^{17.9}$eV, 2.4 km

Air shower event observed by CRAFFT

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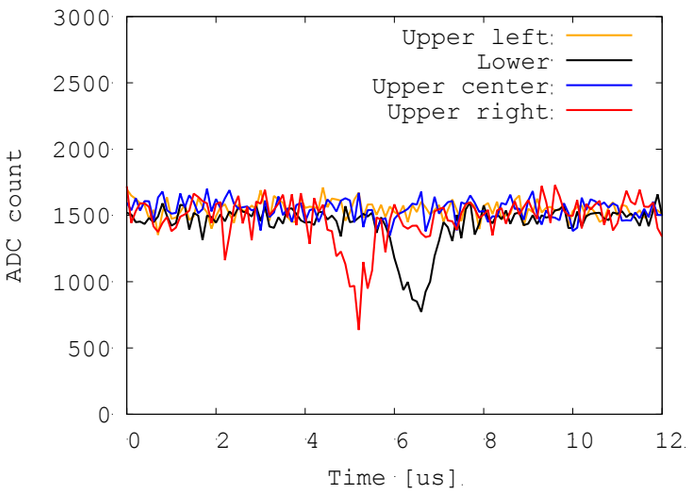

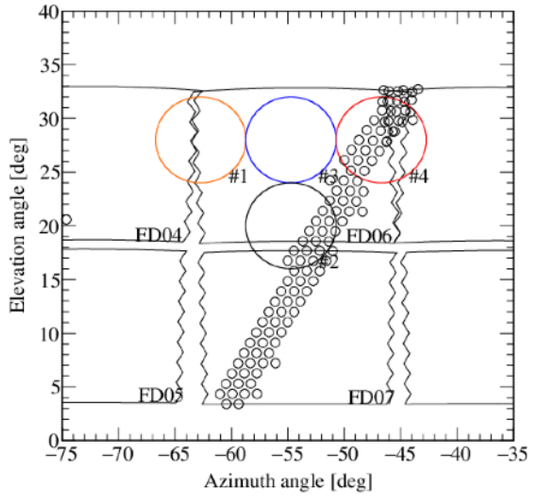

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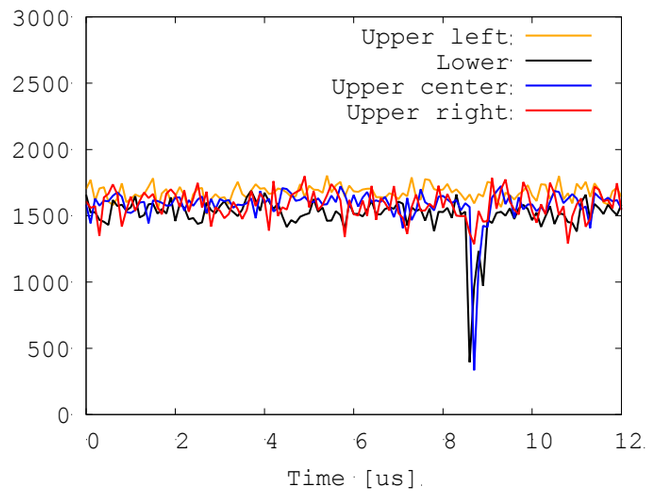

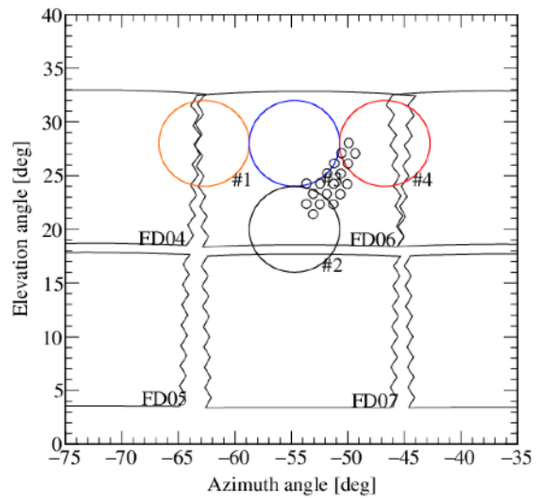

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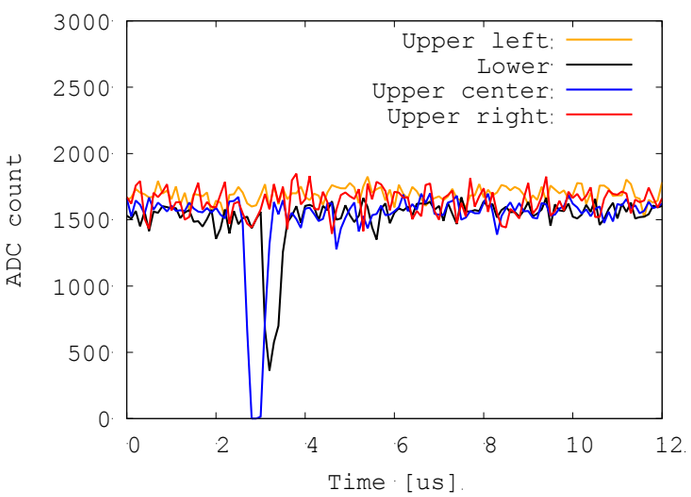

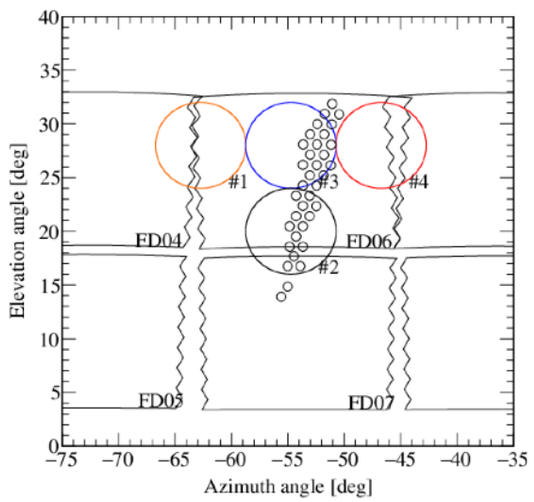

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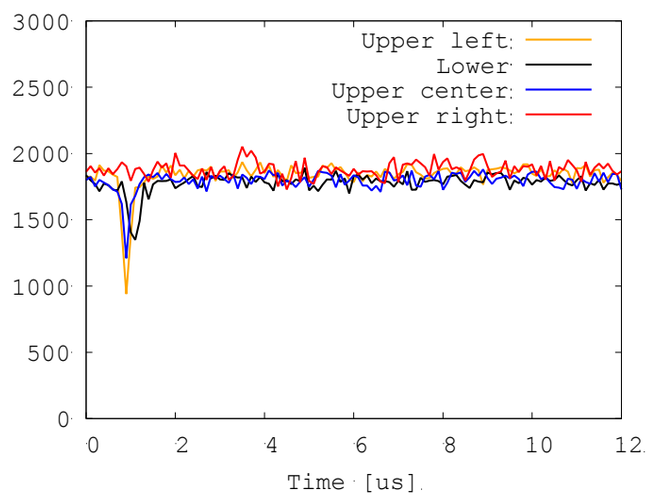
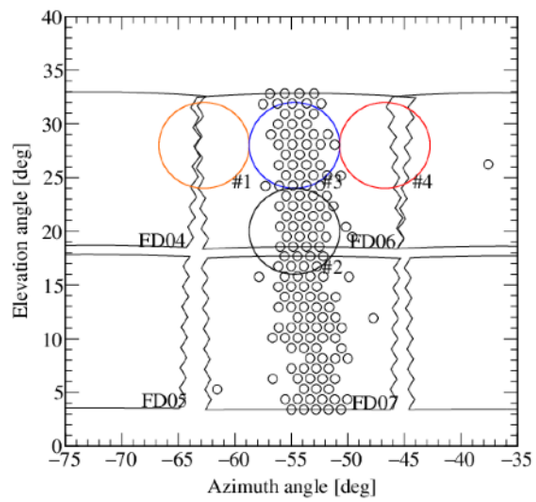
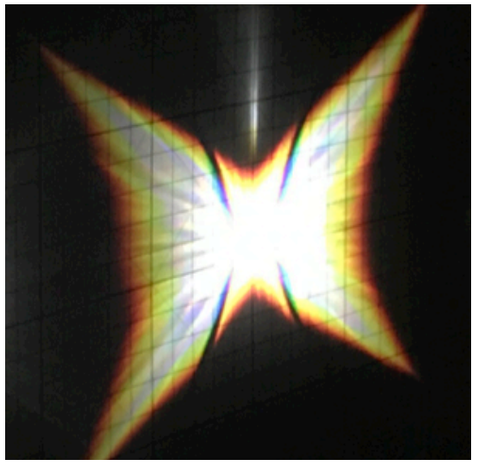


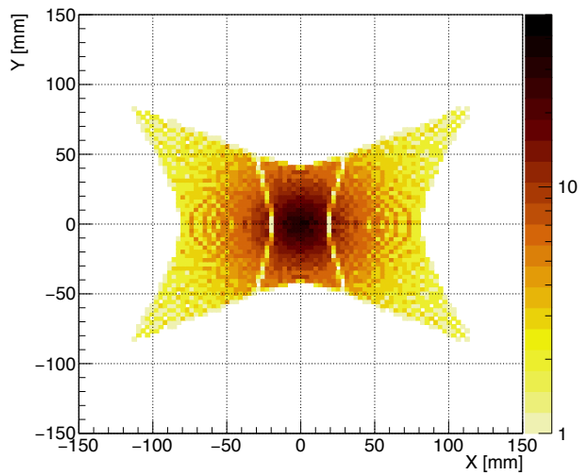


Ray tracing simulation

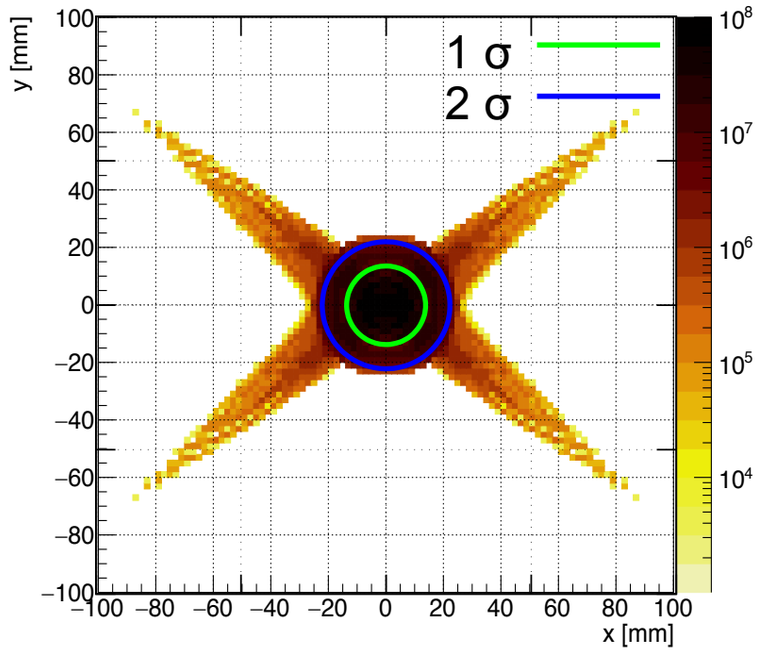
to understand the optics and optimize the detector configuration.



Spot of white light at focal plane.

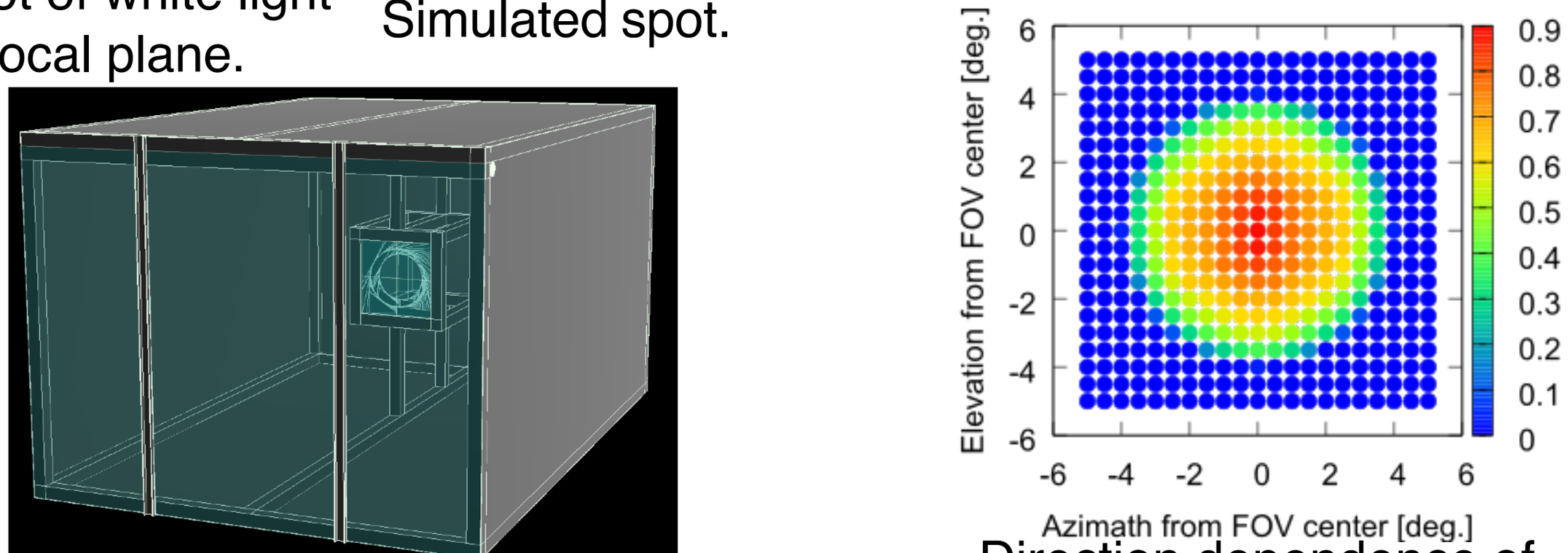


Simulated spot.



95 % spot size : 44 mm

λ = 280 ~ 400 nm, Focus = 1100 mm



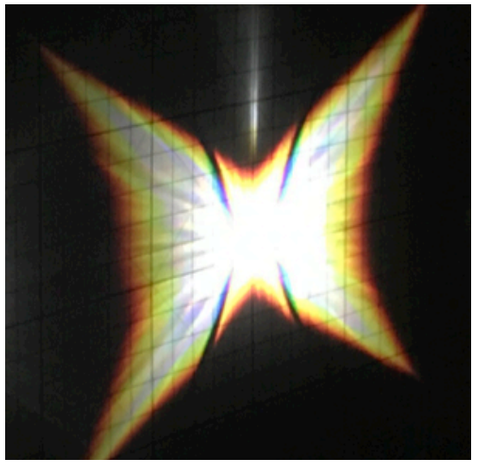
Direction dependence of light collection efficiency

Ray tracing simulation by ROBAST

(ROBSAT : A. Okumura 2016)

Ray tracing simulation

to understand the optics and optimize the detector configuration.



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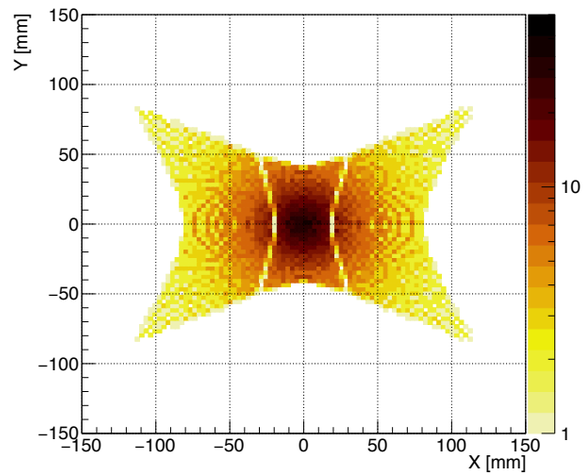

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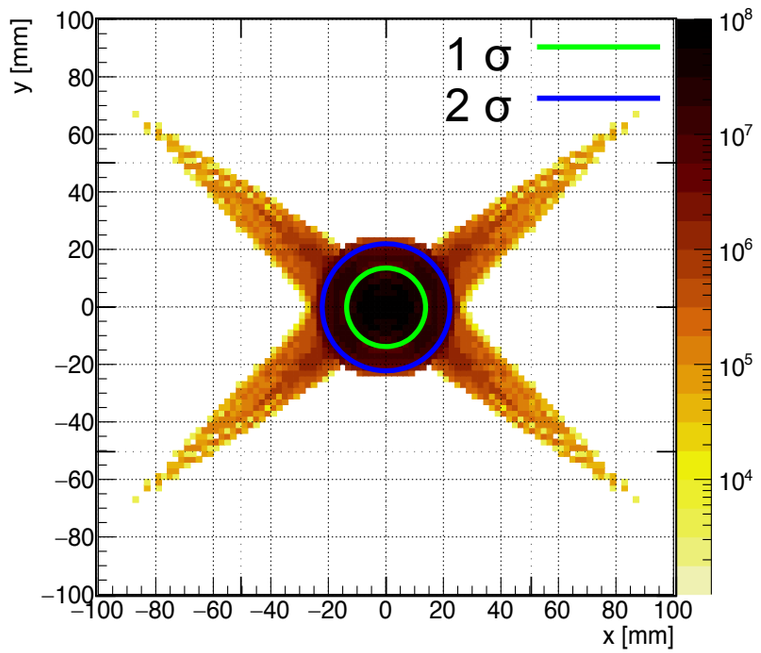

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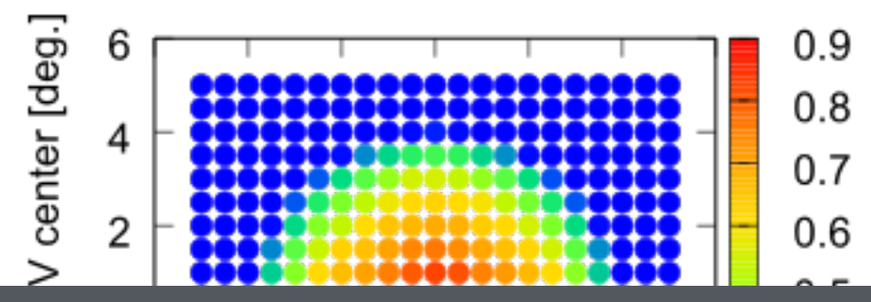
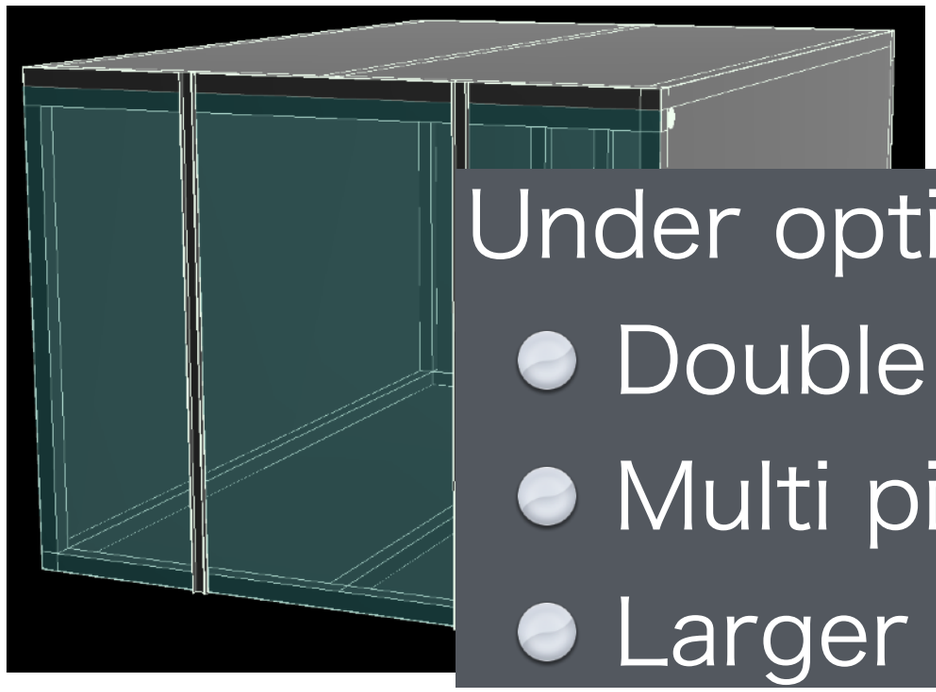


light collection efficiency



Ray tracing simulation by ROBAST

(ROBSAT : A. Okumura 2016)

Under optimization of the detector

- Double lenses to extend the F.O.V.
- Multi pixels to improve S/N ratio
- Larger size of lens to extend aperture

Automation system

Automation system test

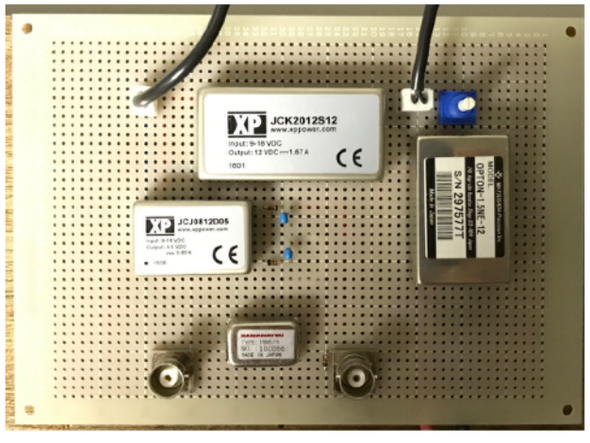
Planed data : 2018 Oct, Nov @TA FD site

- Solar power system
- Automation DAQ system
- Update electronics except FADC board.

Detector protecting system will be tested in Japan.

Now, we mounted roll curtain inside the Fresnel lens.

Considering electric powered shutter or roll screen



Future prospect : CRAFFT Array

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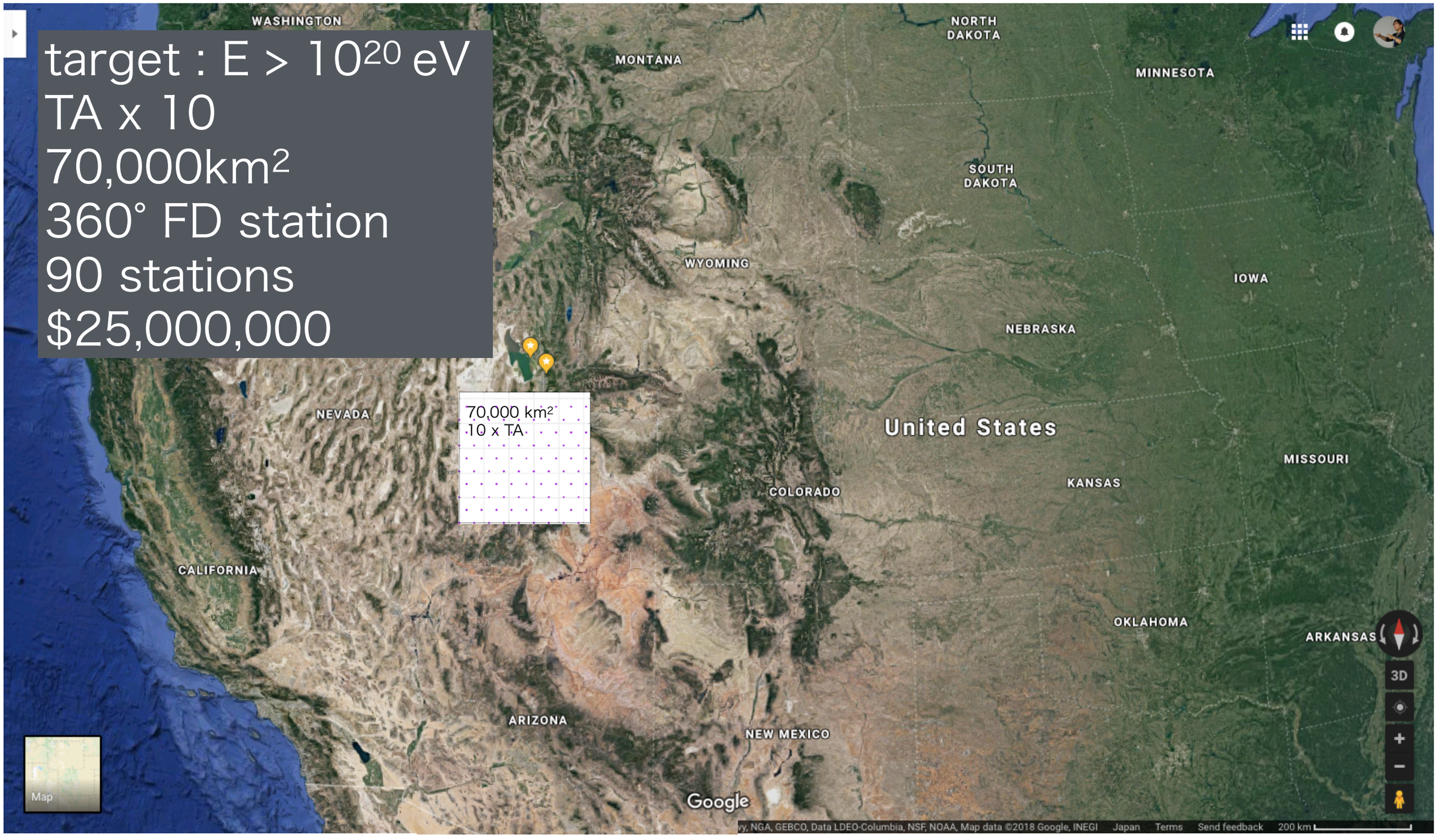
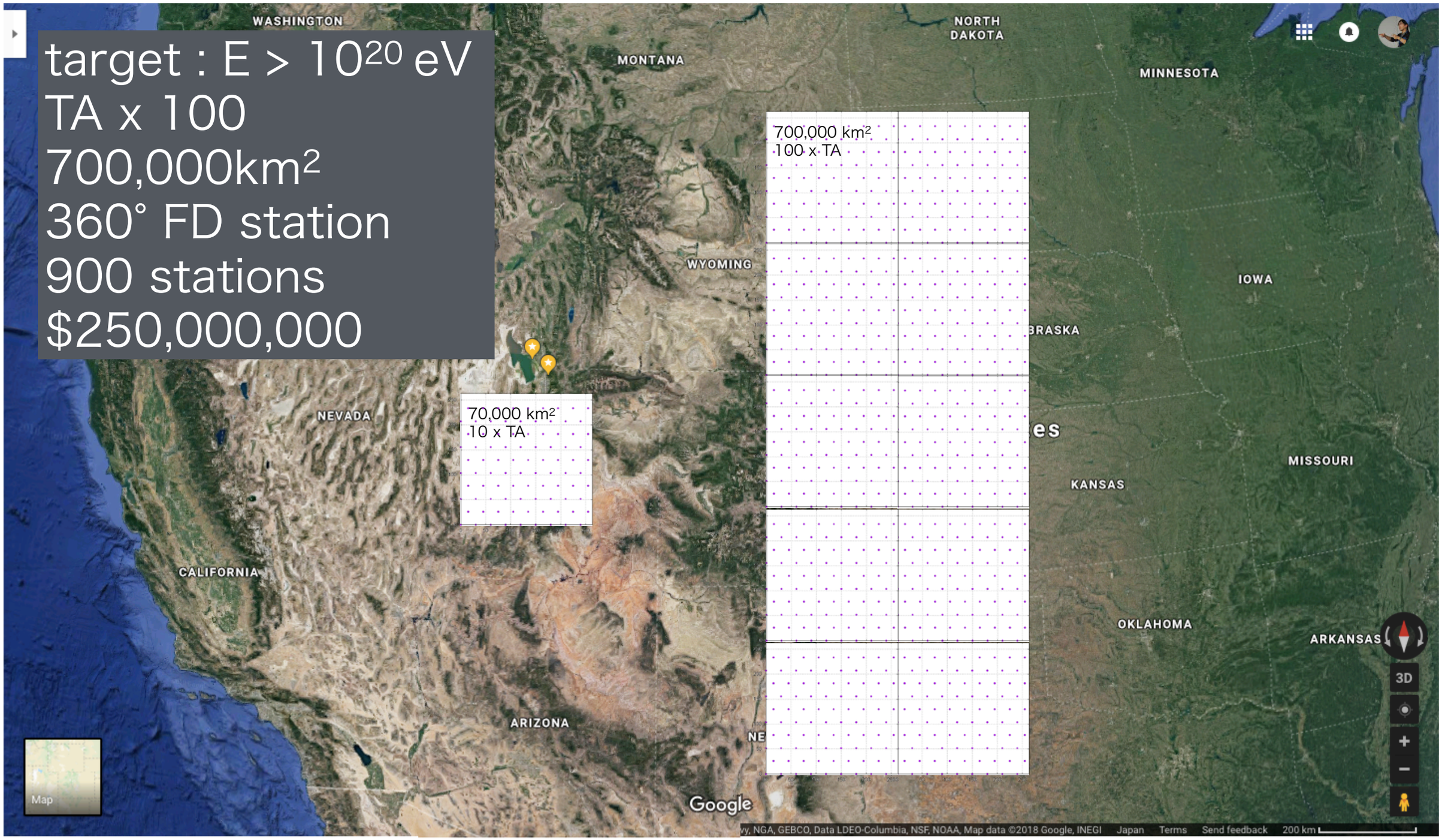


Future prospect : CRAFFT Array



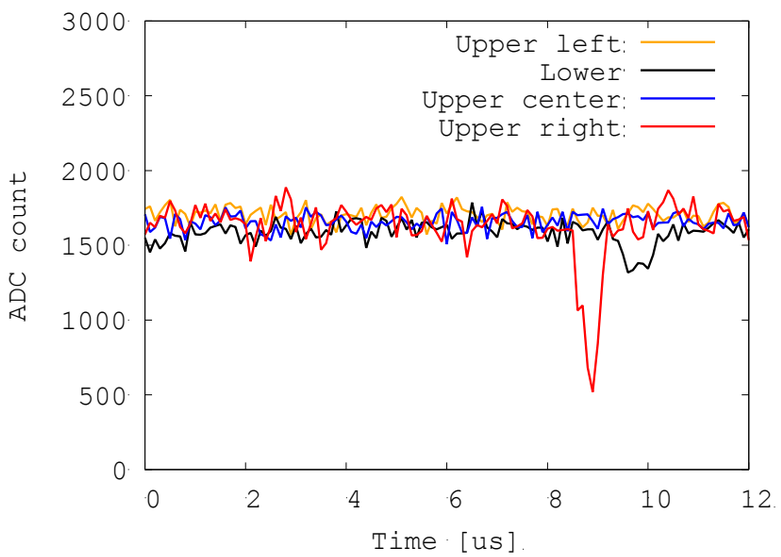
Summary

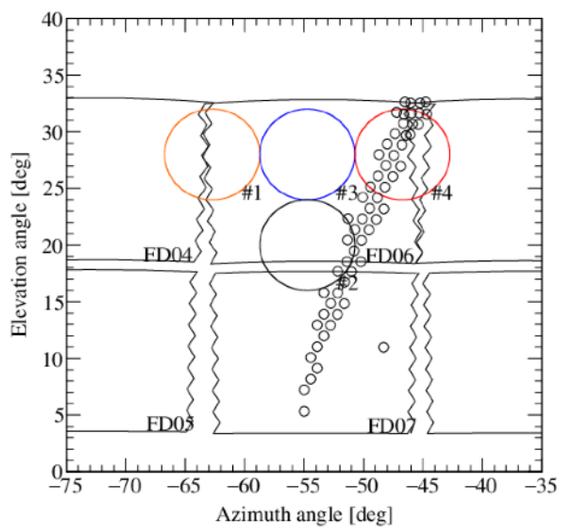
CRAFFT (**C**osmic **R**ay **A**ir **F**luorescence **F**resnel lens **T**elescope)

- Developing a low cost FD using Fresnel lens and single pixel
- Deployed four CRAFFT detectors at TA FD site.
- Test observation : 2017 Nov. 9 ~ Nov. 23 (10 nights, 63.5 h)
- **Succeed to detect 10 UHECR air shower events !!**

Future prospect

- Optimizing detector configuration
- Now is the time to discuss next generation UHECR observatory






CRAFFT