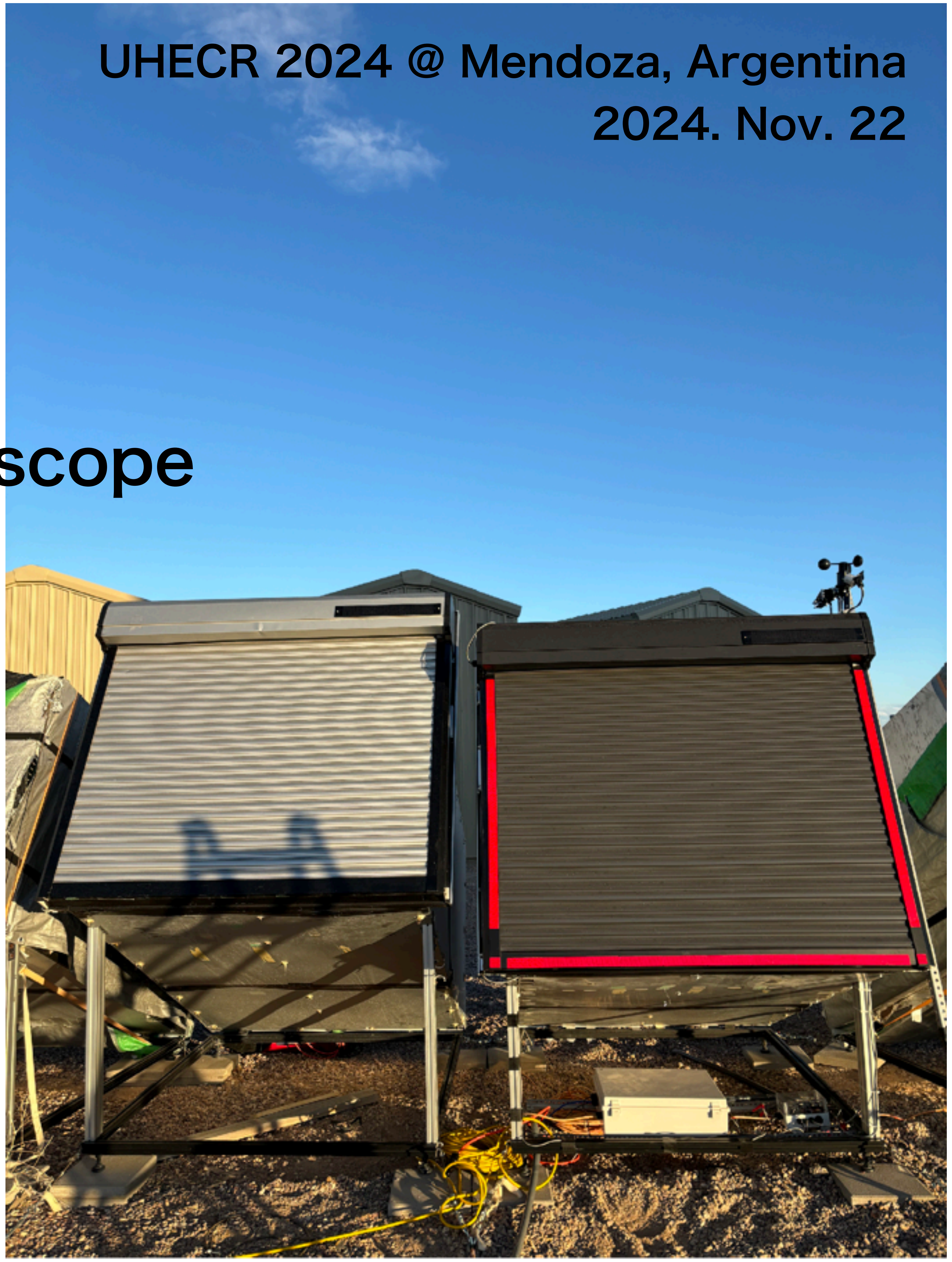
Progress in the development of the observation system for the CRAFFT project

Cosmic Ray Air Fluorescence Fresnel lens Telescope

Simple FD for UHECR future project



Y. Tameda[a],

T. Tomida[b], D. Ikeda[c], K. Yamazaki[d], J.H. Kim[e], K. Fujita[f], N. Okazaki[f], M. Mori[a], H. Iwagami[a], M. Murakami[a], E. Nishio[a], N. Shimamoto[a], A. Nagata[a], M. Nonoyama[a], M. Fujii[a], T. Katayama[a], Y. Kobayashi[a], R. Sakamoto[a], S. Inoue[a], Y. Kuzutani[a], H. Sasaki[a], T. Hanaoka[a], K. Komatsu[b], M. Kuroiwa[b], H. Hattori[b] For the CRAFFT collaboration

(a) Osaka Electro-Communication University
(b) Shinshu University
(c) Kanagawa University,
(d) Chubu university
(e) University of Utah
(f) University of Tokyo, ICRR

Motivation of CRAFFT

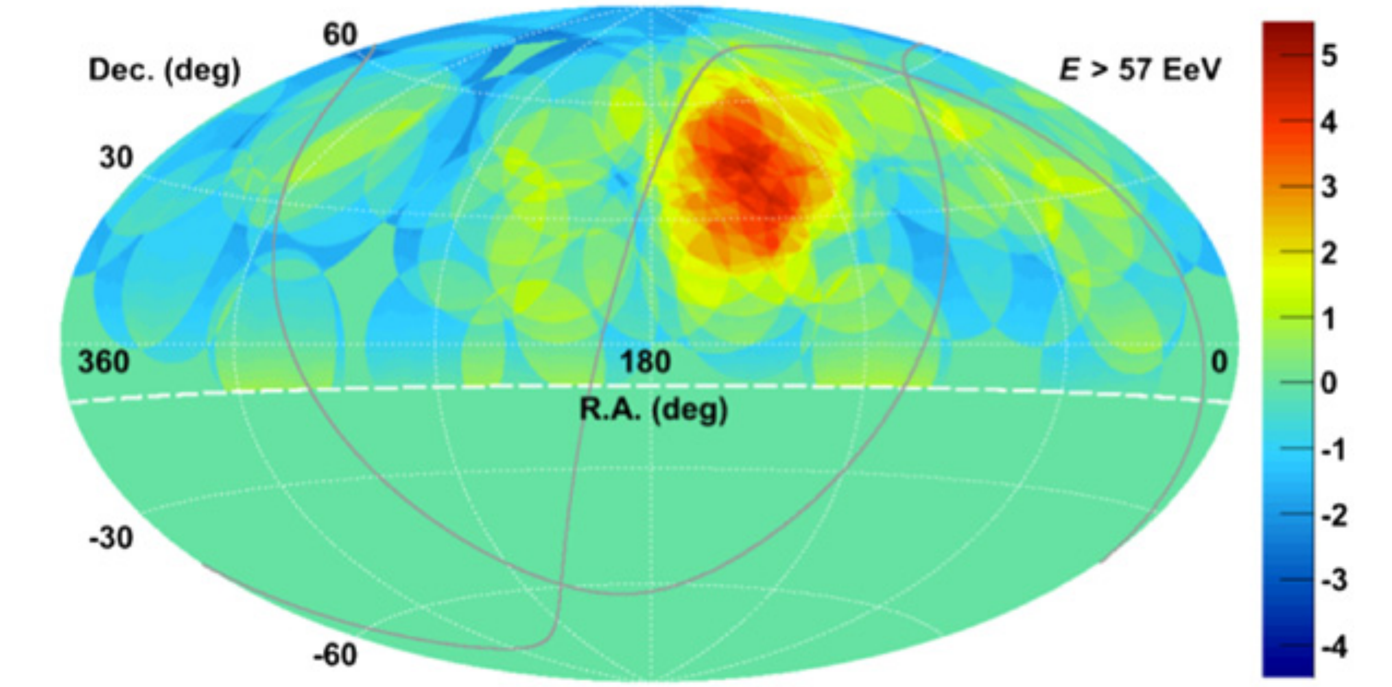
Indication of UHECR Anisotropy

- TA : Hotspot (> 57 EeV)
- Auger : Dipole structure (> 8 EeV)

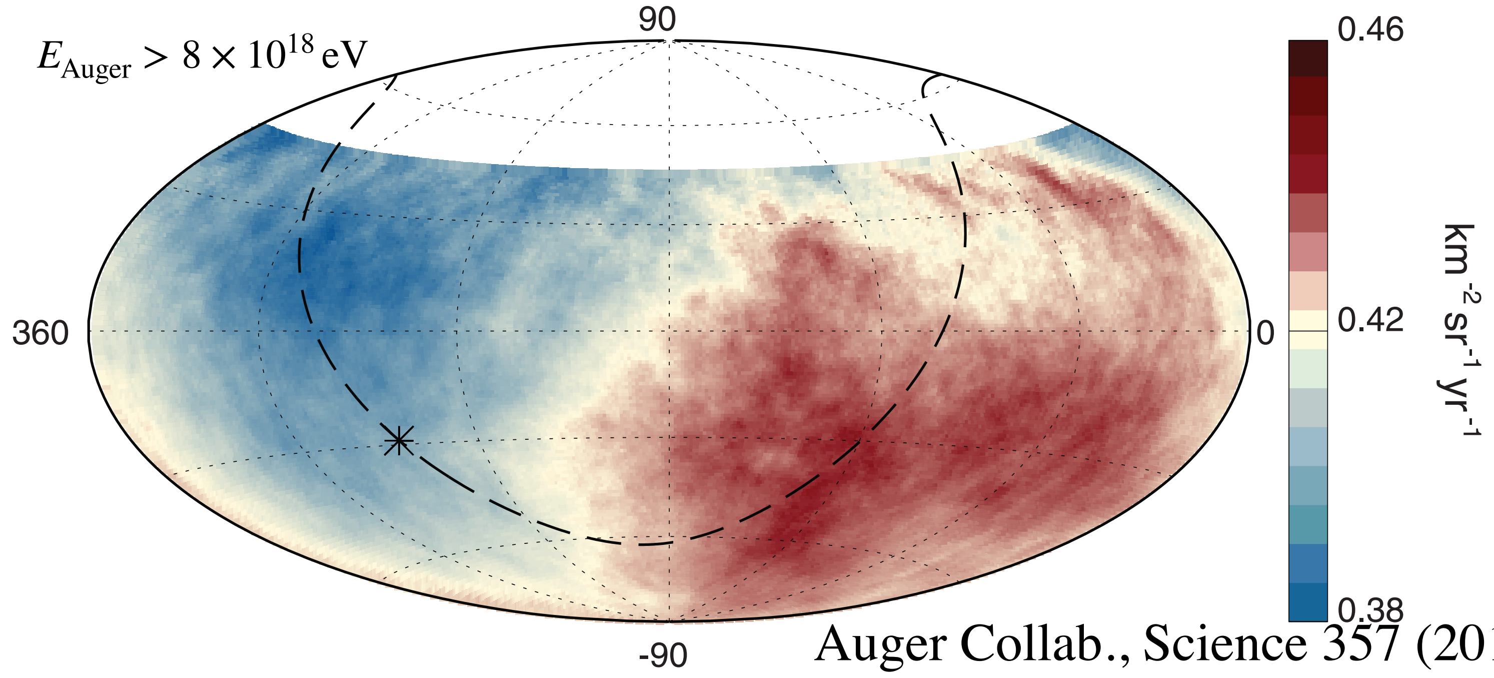
Where does the "Amaterasu" particle come from?

How do we identify UHECR sources?

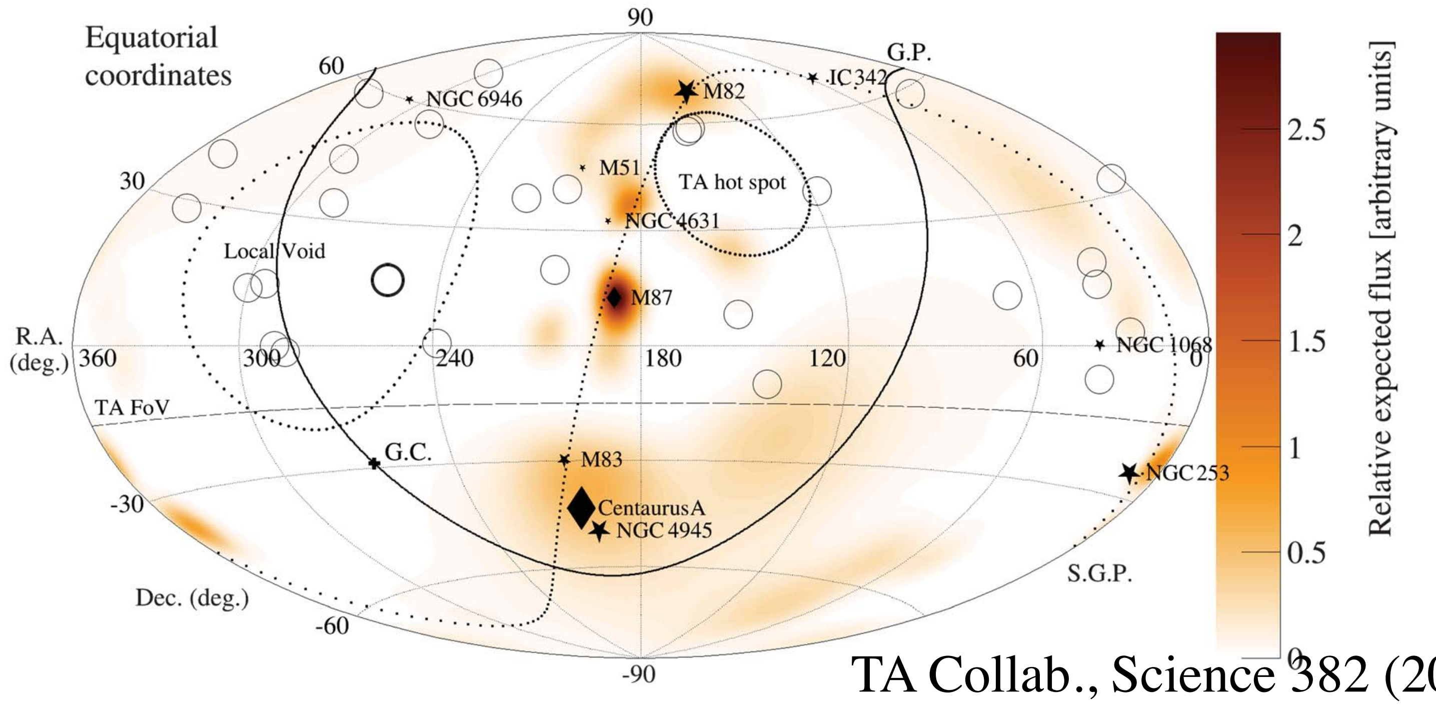
1. Expanding Detection Area
   - Enhance statistics with larger coverage
2. Rigidity Measurements
   - Propagation of UHECRs in magnetic field
   - Mass composition
3. All-Sky Surveys
   - Comprehensive analysis of arrival directions



TA Collab., ApJ Lett., 790 (2014) L21



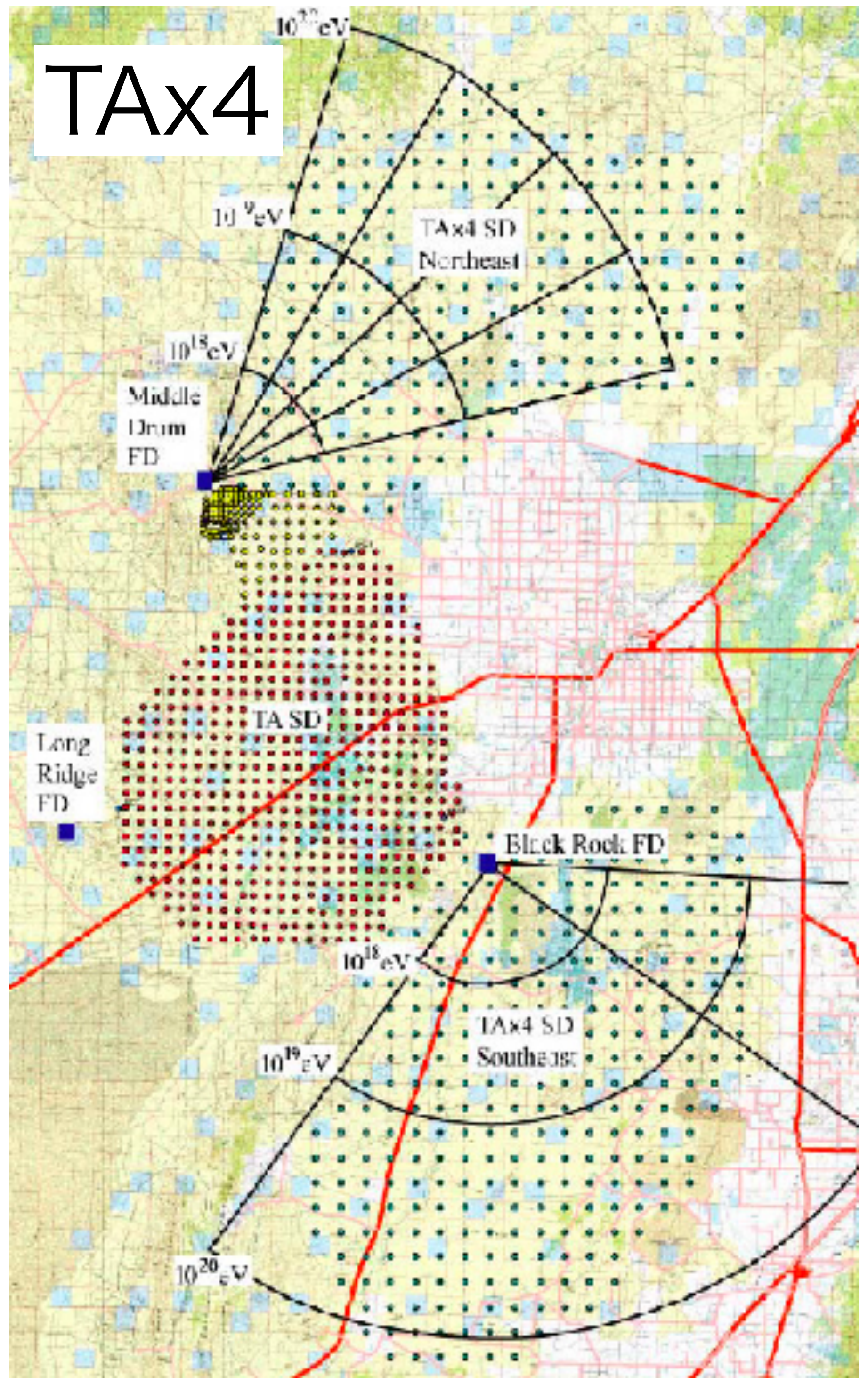
Auger Collab., Science 357 (2017) 1266

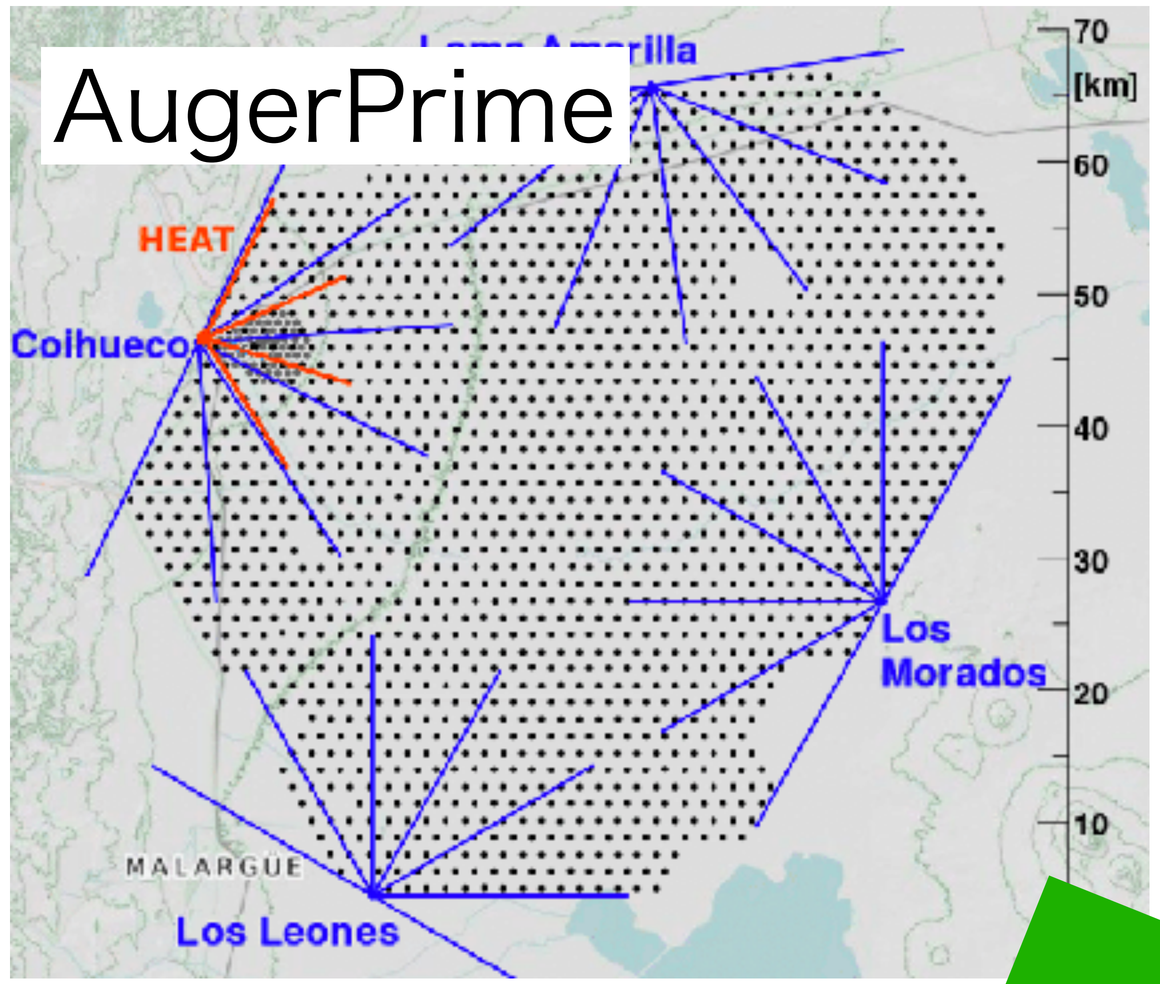


TA Collab., Science 382 (2023) 903

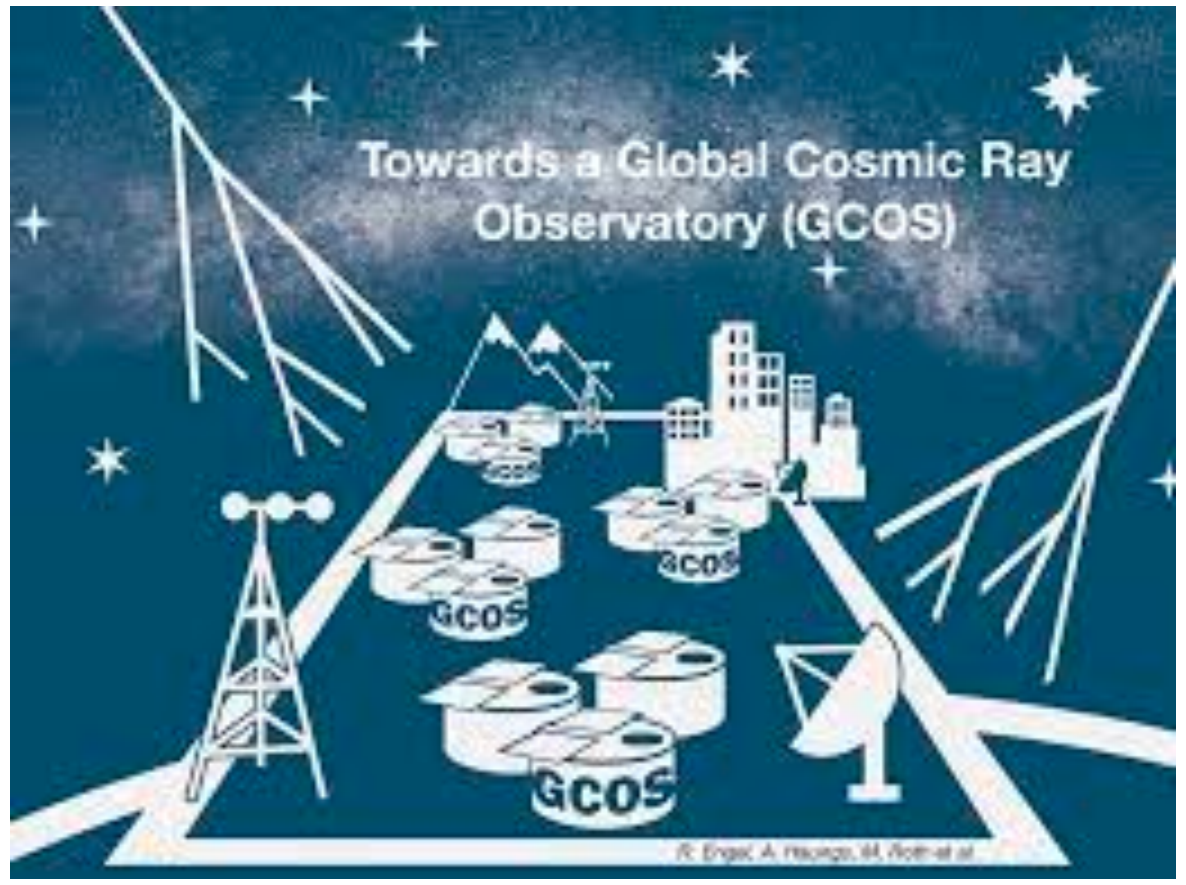
Future projects of UHECR

Ongoing project

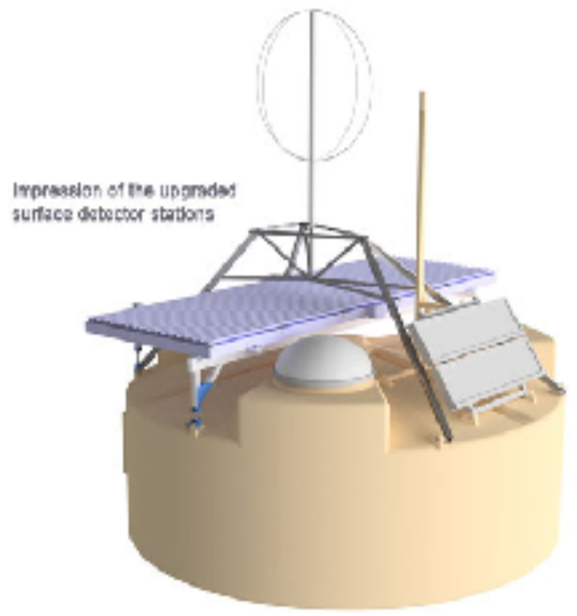




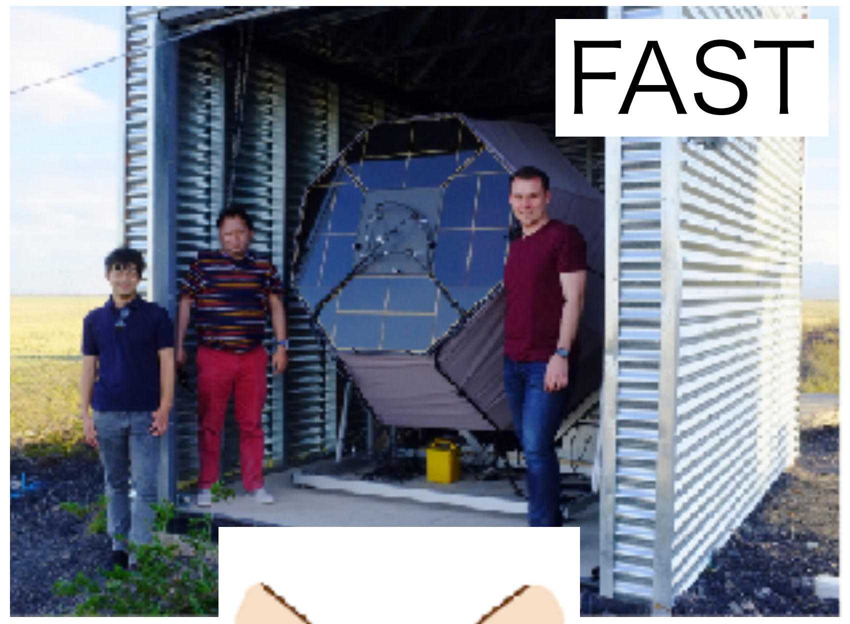
GCOS

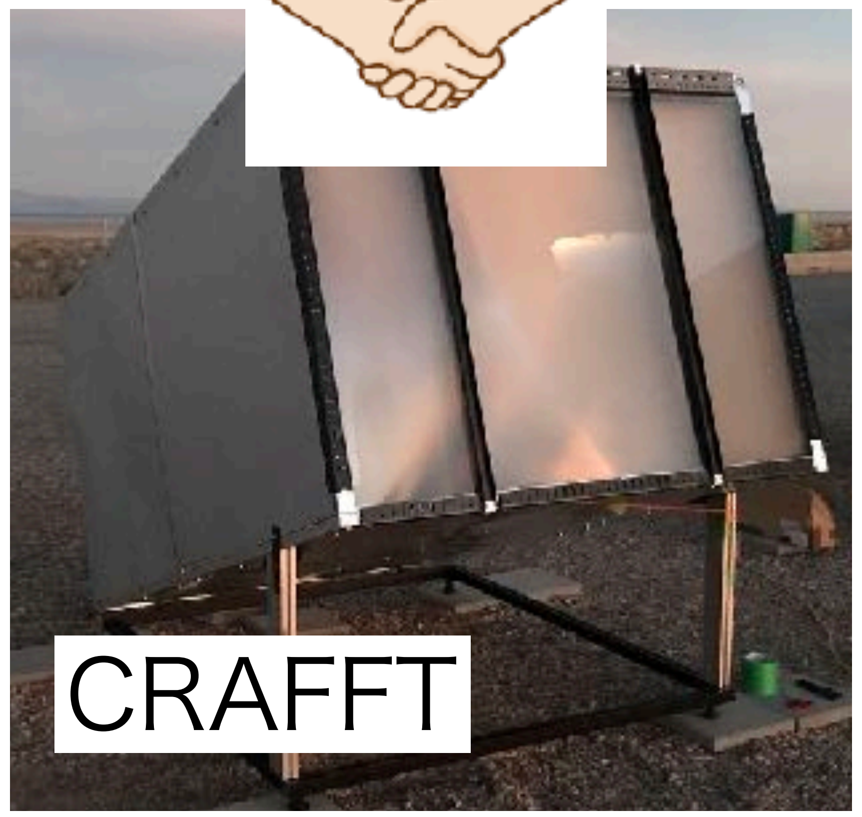


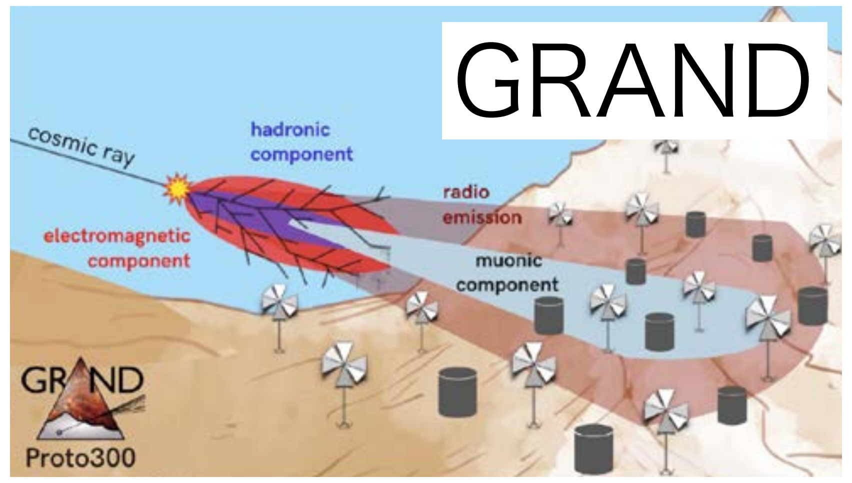
SD



Simple FD







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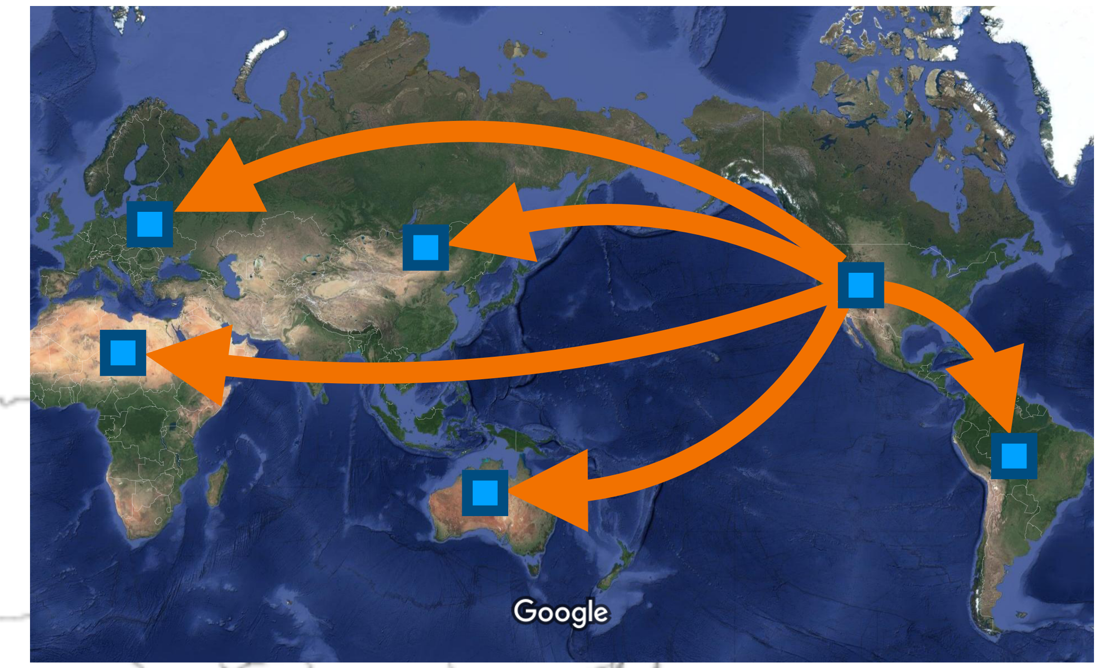
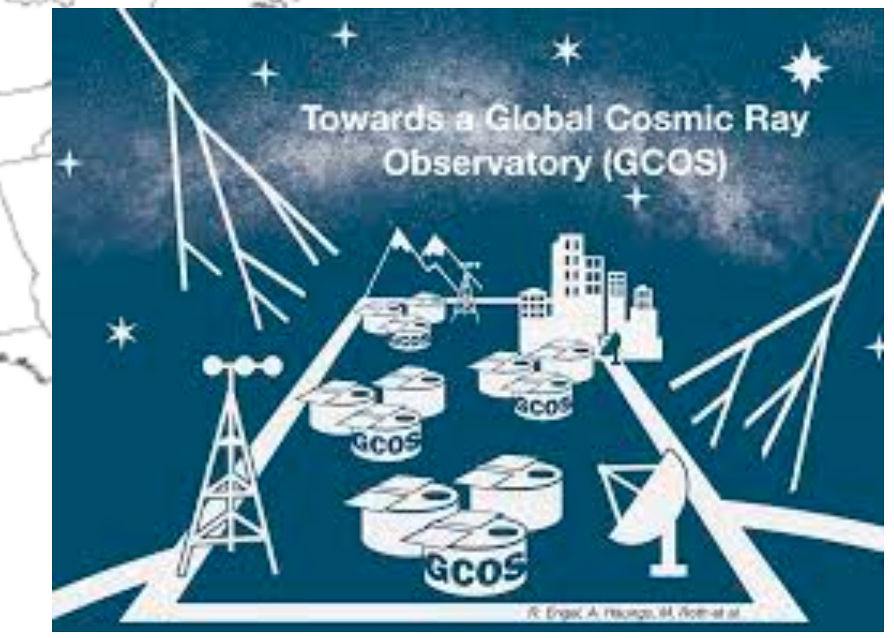
Concept of CRAFFT project

- Extension of detection area for much more statistics
  - Development of cost effective detectors
  - Operation with less man power
    - automation system and maintenance free
  - Low environment impact
    - Less detector density (wide spacing)
- Rigidity or mass composition measurements
  - Xmax measurements (ex. FD)
- All sky survey
  - Observation at multi location for covering huge detection area totally
  - Easy to construct or transport
- Fluorescence detector (FD) is one of the successful detector for UHECR observation.
- Cost-effective FD can be a solution to realize the next generation huge observatory for UHECRs.
- CRAFFT project has developed a simple FD to realize huge array of 360° view FD station



Can be distributed to the world



Roadmap of CRAFFT project

Phase 1

Confirmation of the concept of detectors

Succeeded to observe UHECR air showers with prototype detector with a 8 inc. PMT

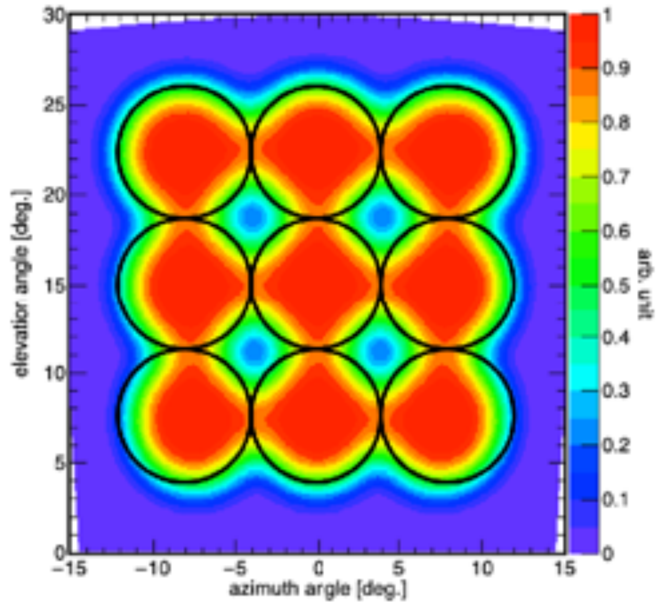
Phase 1.5

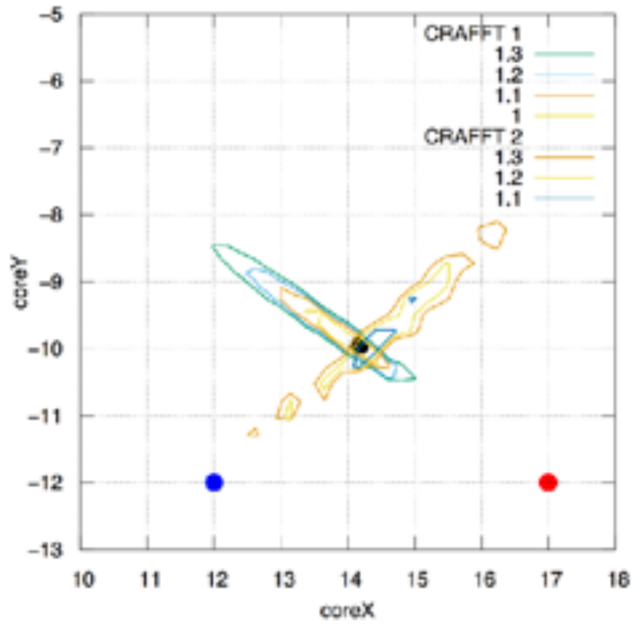
Optimization of detector design

Planning to use 5 in. PMT to improve reconstruction accuracy, and extend F.O.V. per detector

Reconstruction by waveform fitting

Automatic DAQ system





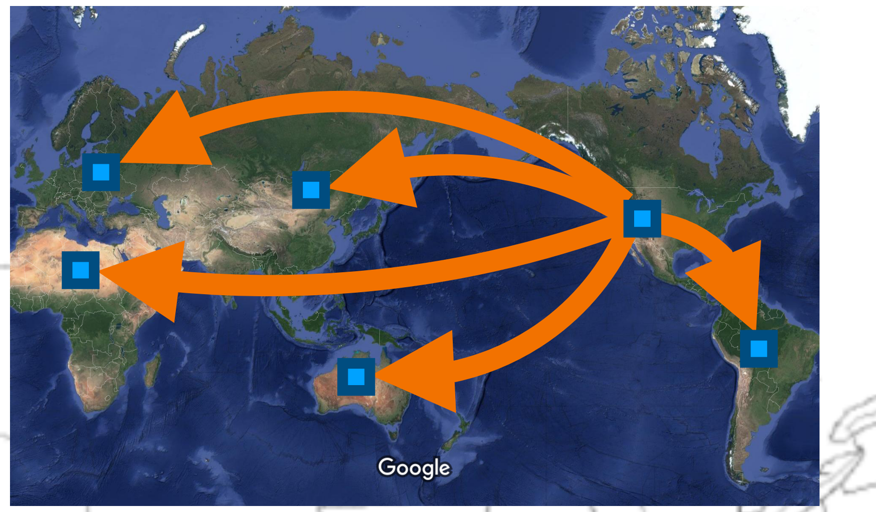
Phase 2

Confirmation of the concept of observation

Stable observation

Deploy optimized CRAFFT at TA site

Stereo obs. With wide area network



Can be distributed to the world

Phase 3

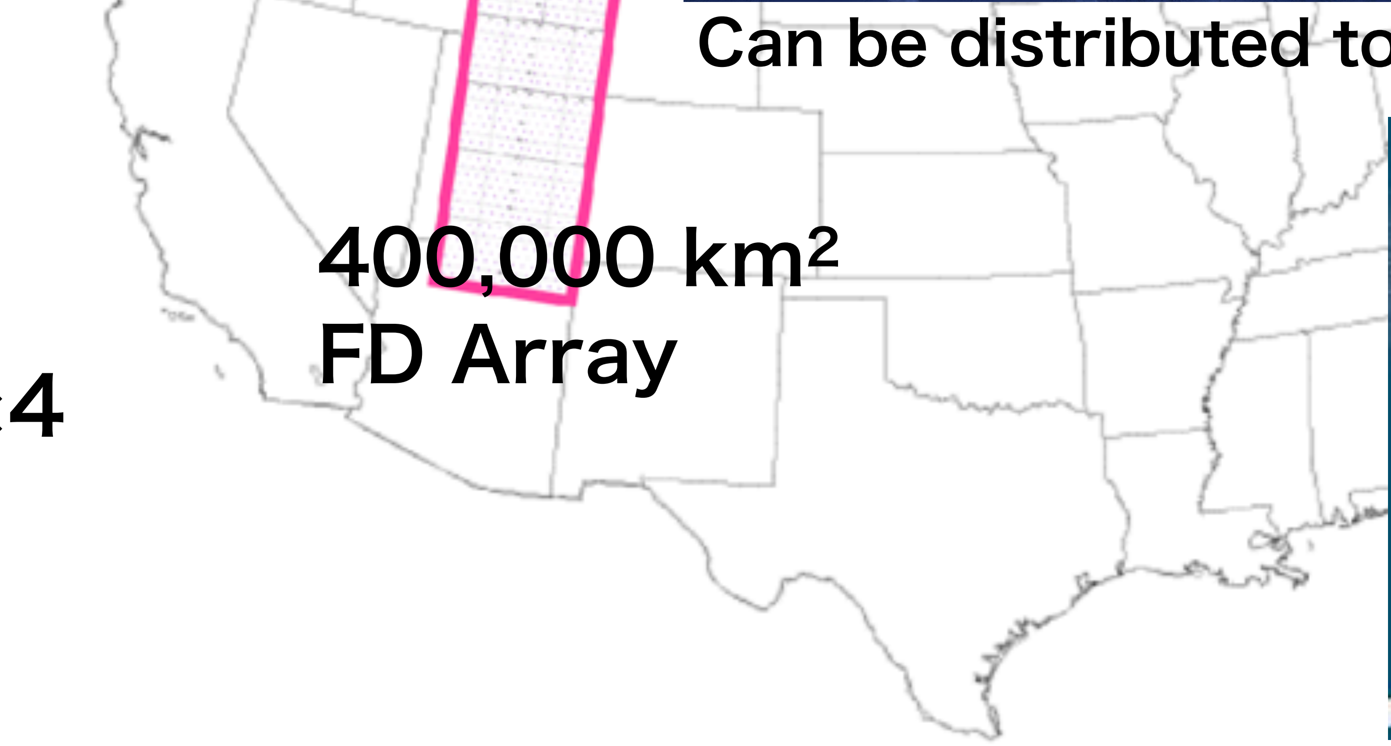
Large scale deployment

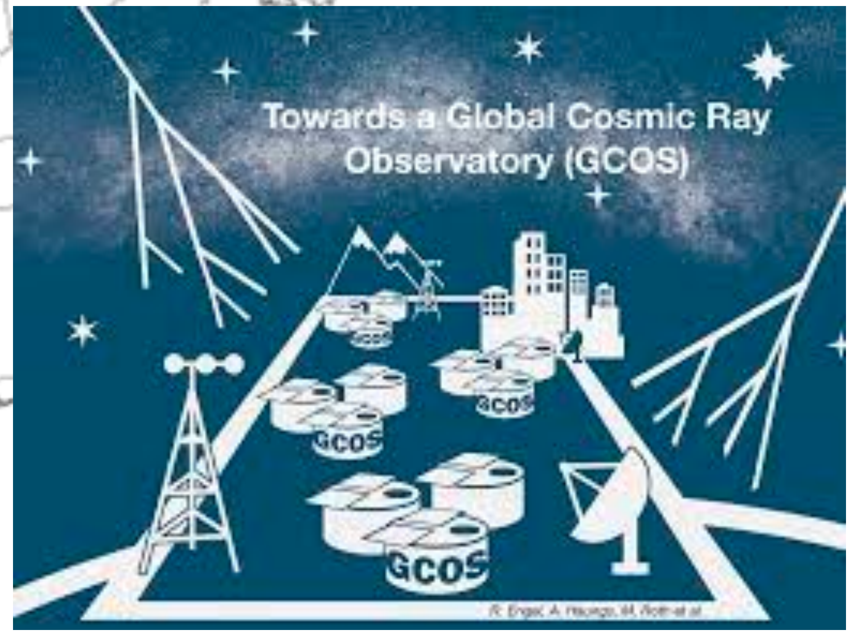
Array of 360° FD Station

20km spacing

500 stations ~ 10 TA×4

400,000 km^2





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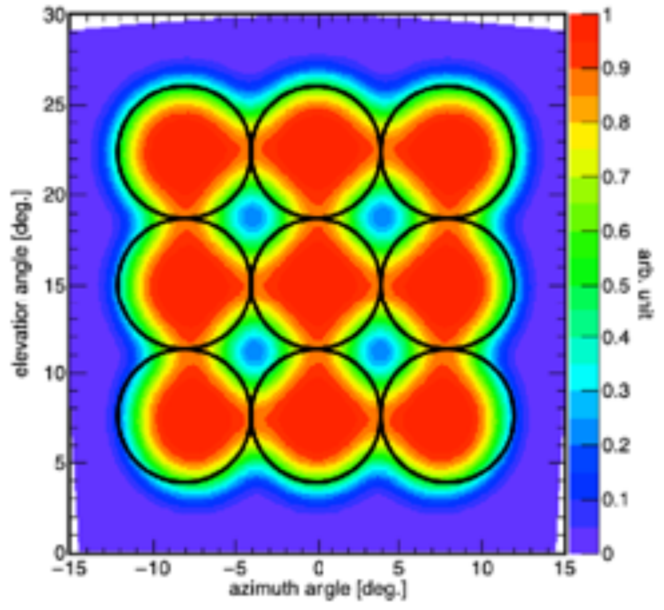
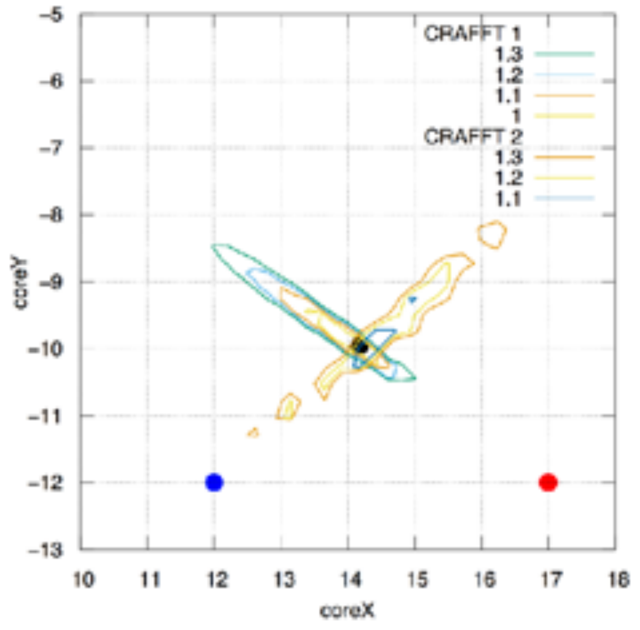
Reconstruction by waveform fitting.
Automatic DAQ system.





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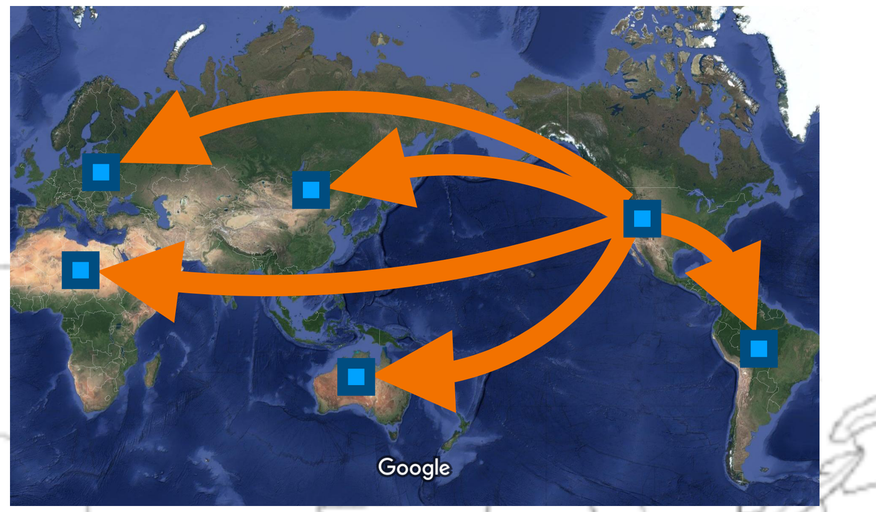
Confirmation of the concept of observation

Stable observation
Deploy optimized CRAFFT at TA site
Steteo obs. Wide area network



Can be distributed to the world

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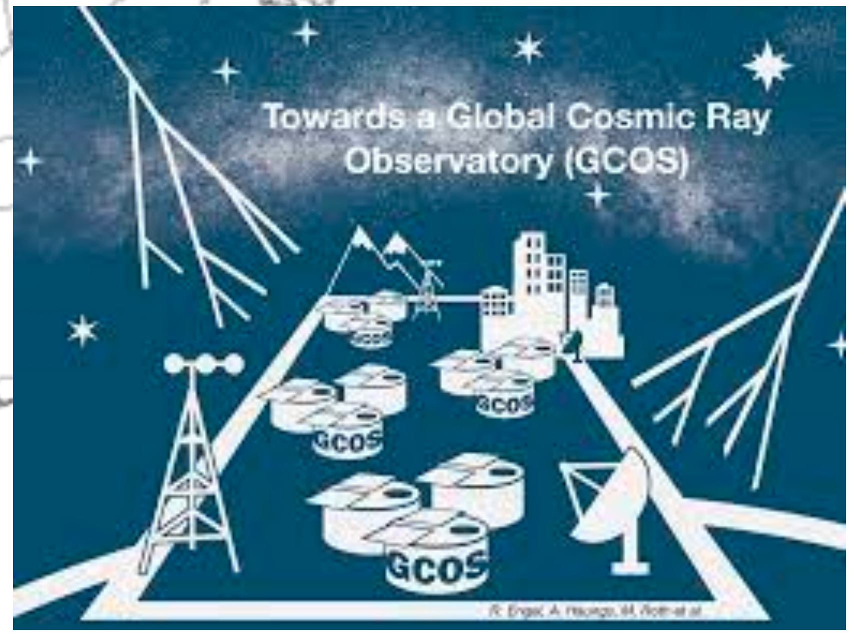

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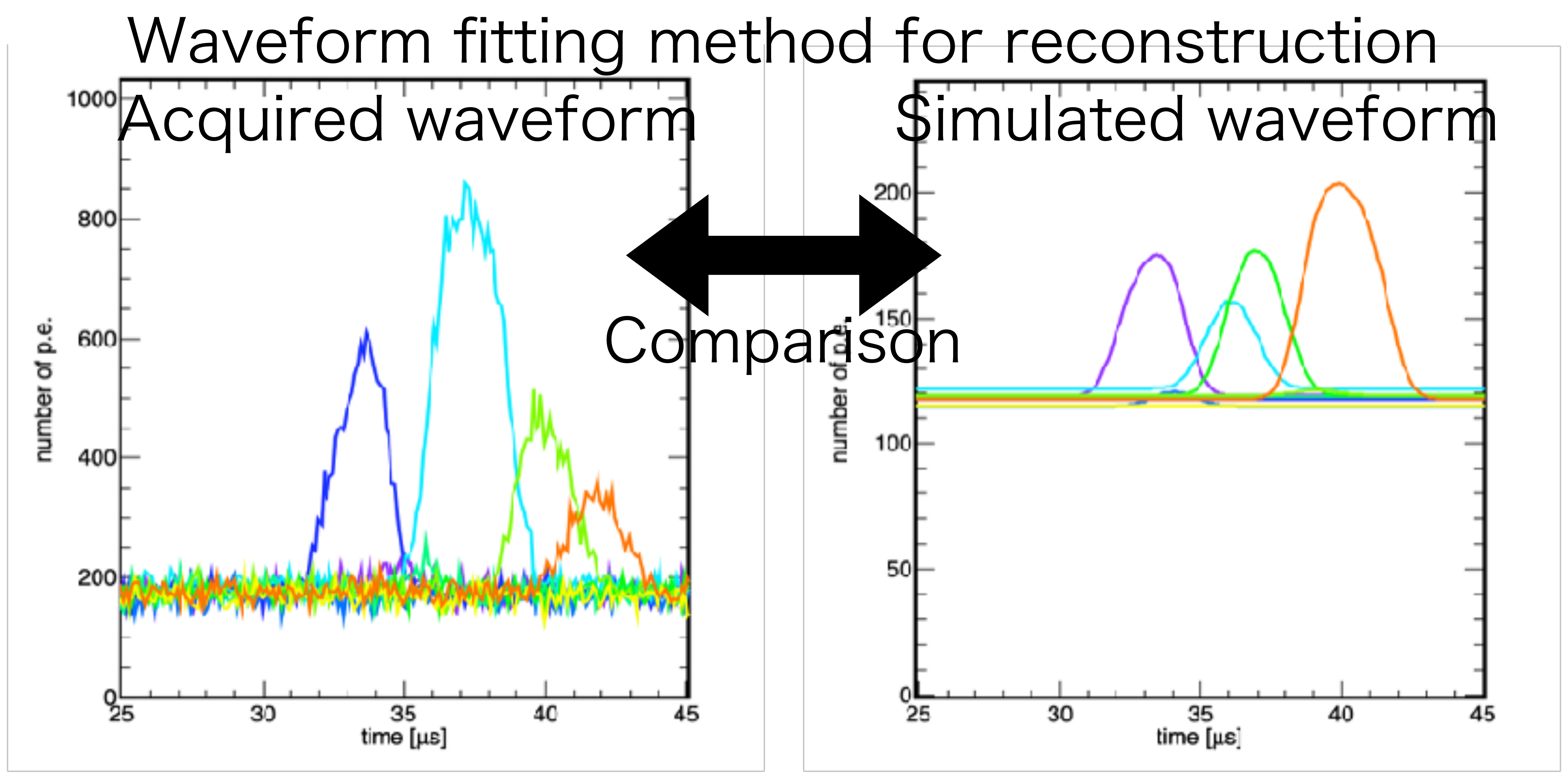
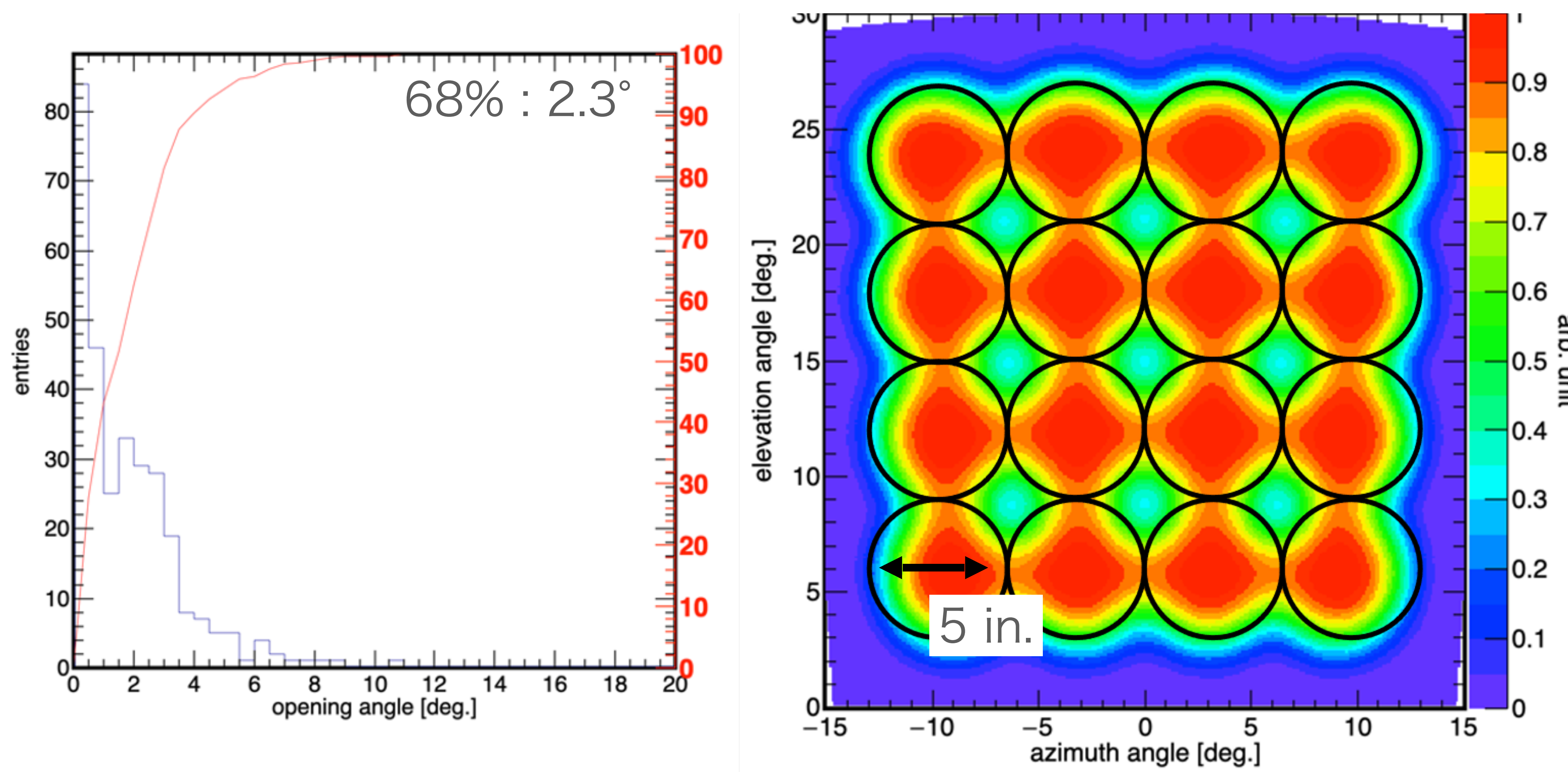
Detector optimization

- To Improve reconstruction accuracy, field of view (F.O.V.) per detector, and S/N ratio.
- Explore cost-effective multipixelization of PMT clusters.
- Reconstruction with waveform fitting method
  - Simulate and match observed waveforms to identify shower geometry and profile.
  - Parameters fitted: core (X, Y), zenith, azimuth, energy, and Xmax.
  - Geometrical reconstruction accuracy matches TA FD mono level using 4-parameter fitting.
- Deploy four optimized telescopes to cover the equivalent of one TA FD station.





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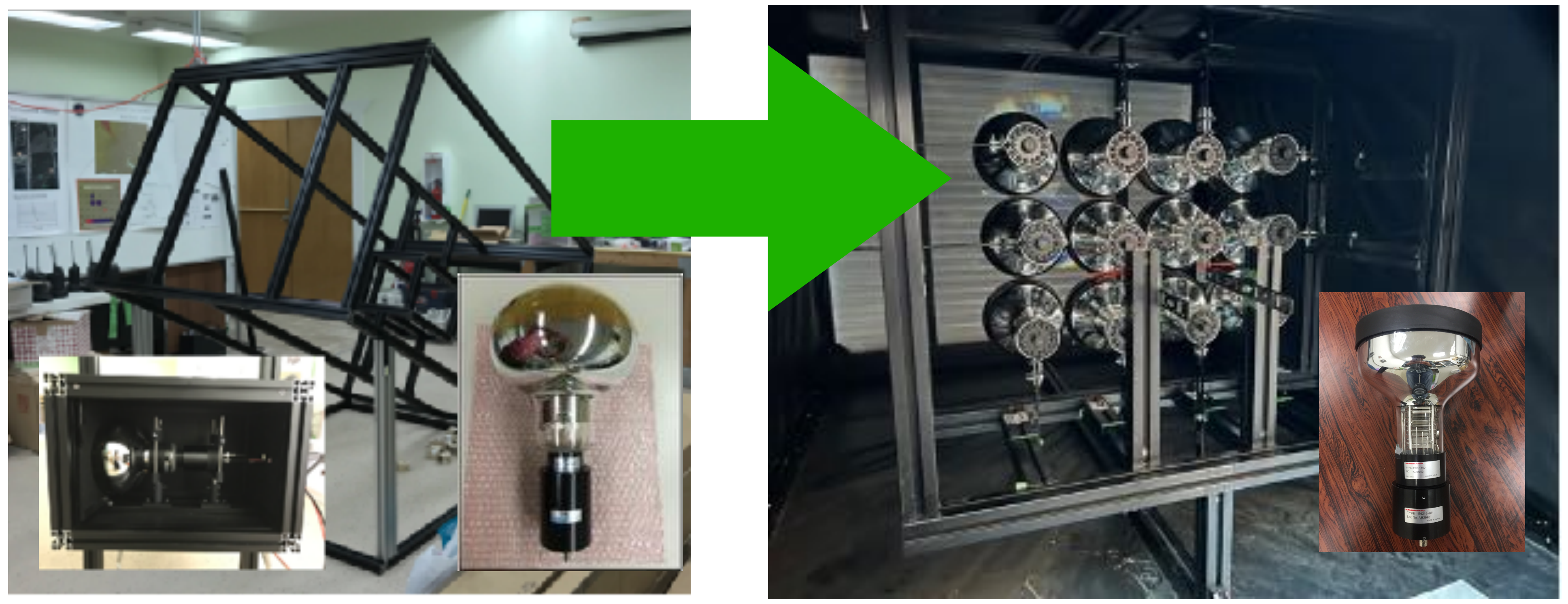
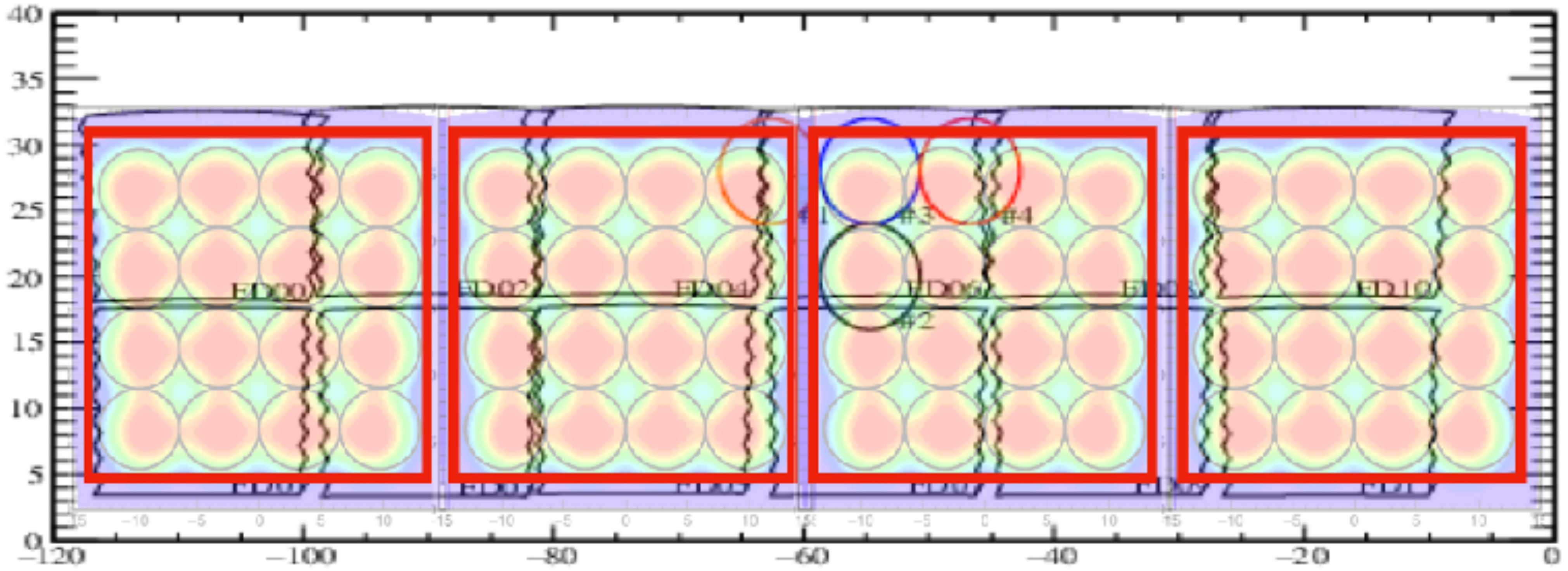


Prototype CRAFFT
Single pixel(8in. PMT)

Optimized CRAFFT
12 pixels(5in. PMT)

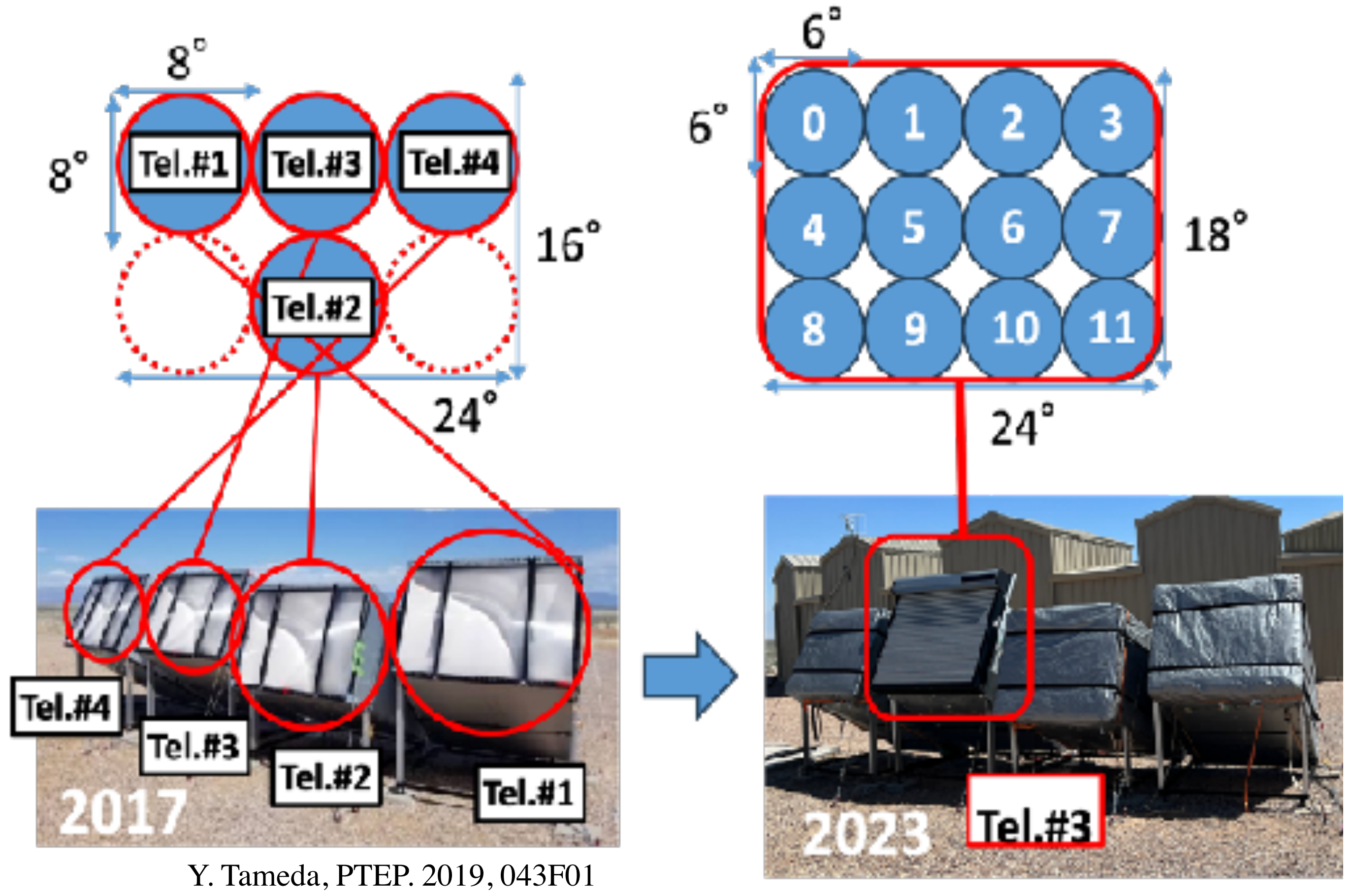


F.O.V. of TA FD station / optimized CRAFFT

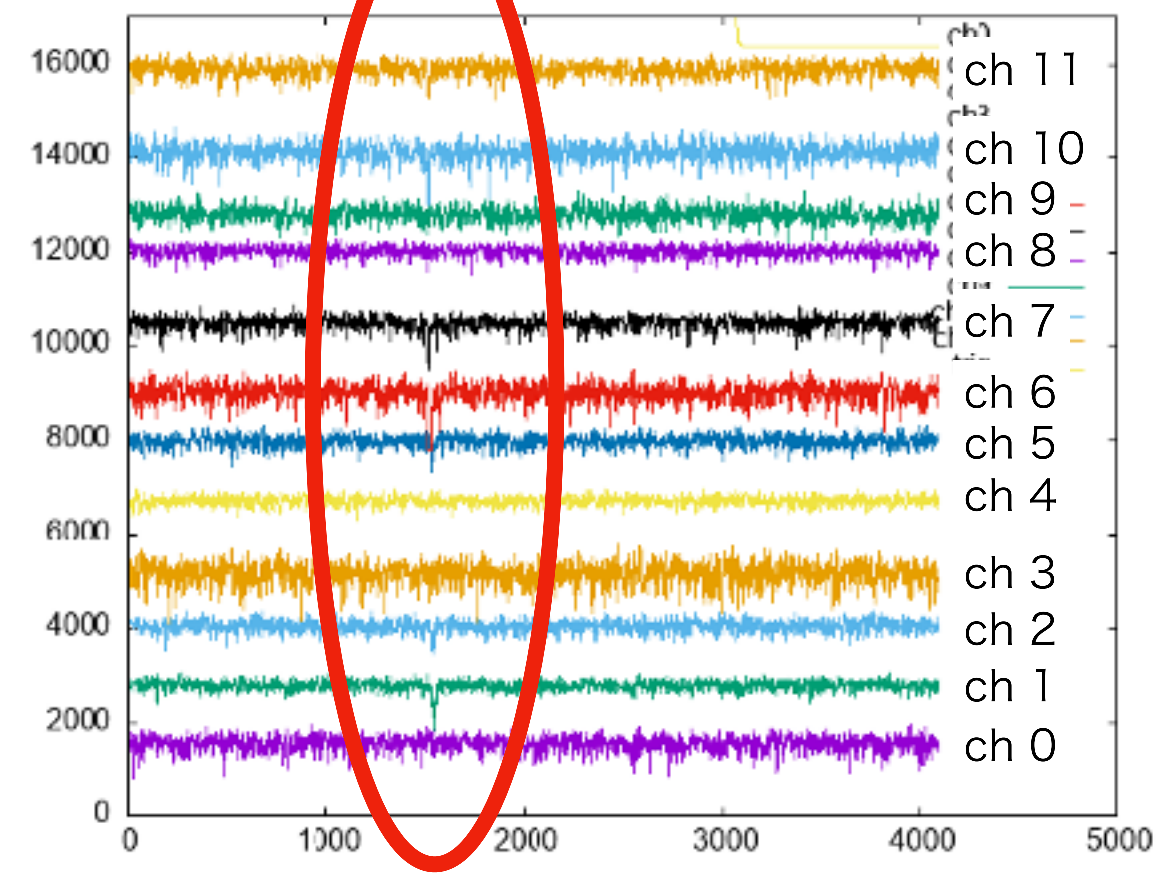
Test observation with new configuration CRAFFT

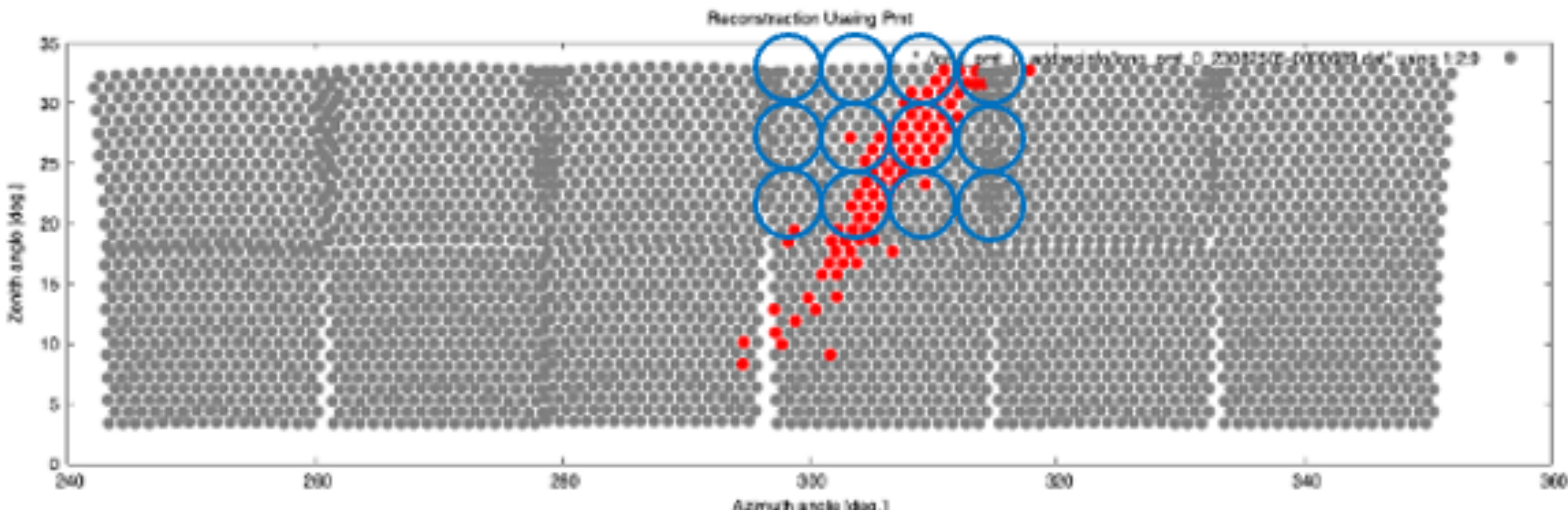
- Test observations at TA FD site (2023/08/25–08/28).
  - Deployed one optimized telescope with 12 PMTs (R877, 5 in. diameter) covering the F.O.V. of four prototype telescopes
  - Trigger timing from TA FD.
- Observed at least 10 air shower events,

  ex. Energy: $10^{18.5}$eV, Rp: 1.1 km, Zenith: 29.0°, Azimuth: 2.3° (reconstructed by TAFD)
- Surveyed optimal threshold with simple trigger algorithm not to miss above events
  - 7σ with any two condition



Y. Tameda, PTEP. 2019, 043F01

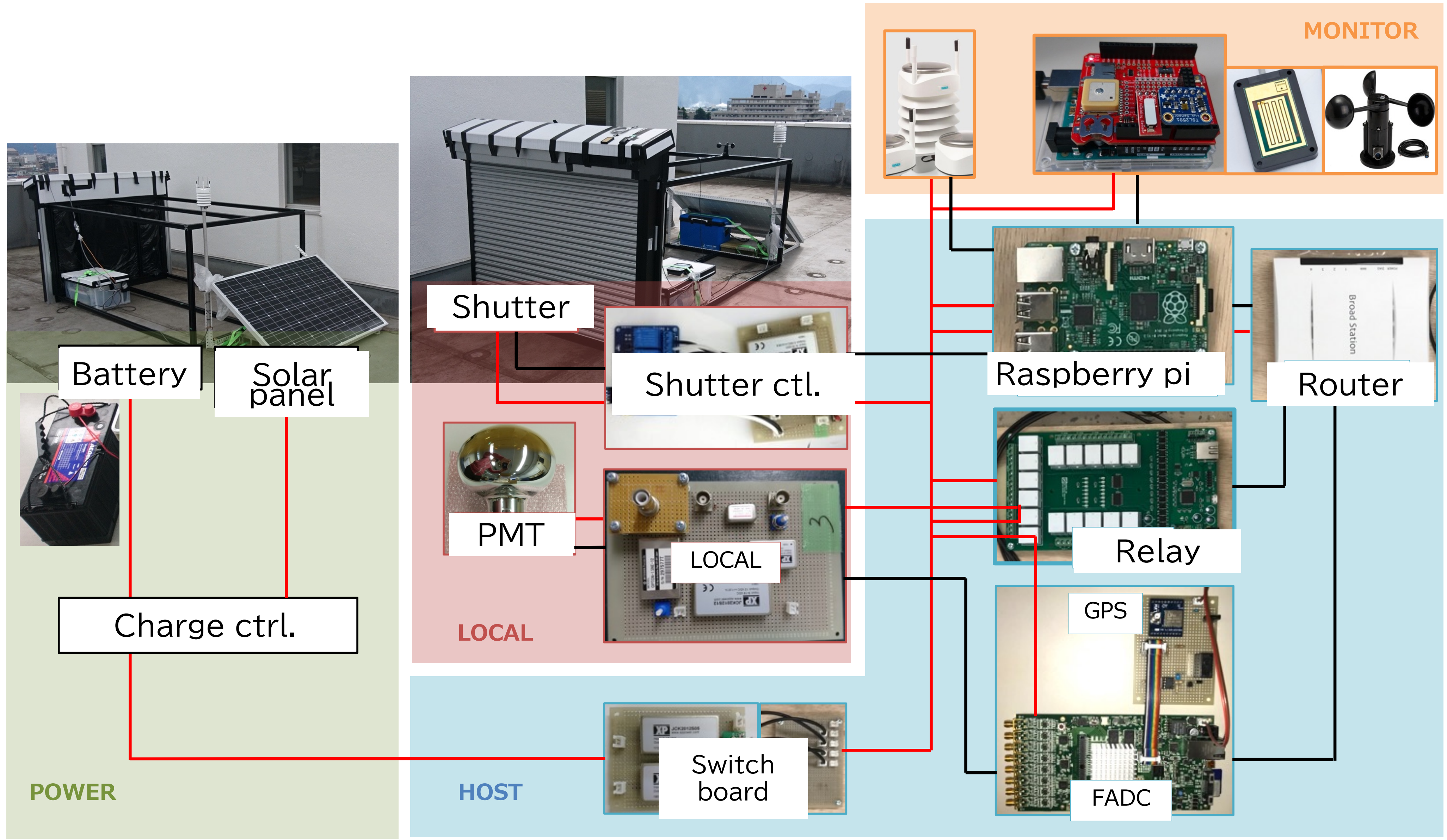




Phase 1.5

Development of automation system

- Essential for reducing operational costs and minimizing manpower needs.
- Shutter and DAQ control is fully automated.
- Environmental monitoring determines observation readiness.
- Component
  - Solar power system
  - Environmental monitor
  - Telescope protection
  - DAQ system
    (FADC board, HV, amplifiers).
  - Fisheye camera for cloud monitoring.



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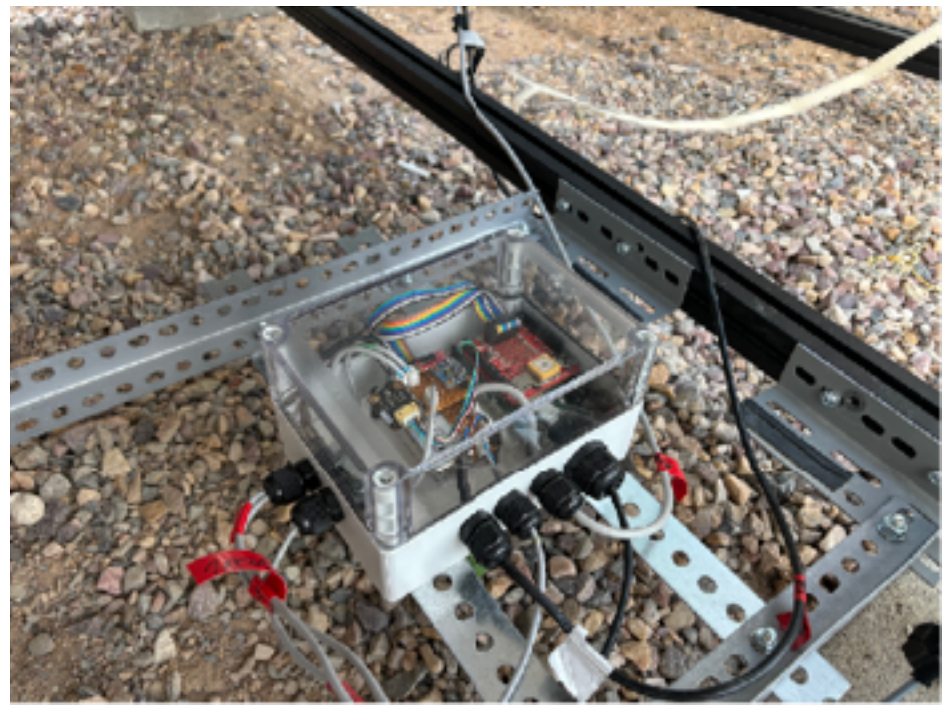
Environmental Monitoring System

- Installed on CRAFFT telescopes at TAFD site (Nov. 2024)
- Weather Monitoring:
  - Tracks temperature, pressure, humidity, wind speed, and brightness.
- Detector Condition Monitoring:
  - Shutter status (limit switch).
  - PMT voltage monitoring (in development).
- Power Supply by solar system:
  - Fully solar-powered for sustainable 24/7 operation.
- Observation conditions automatically evaluated based on real-time data.





Phase 1.5

Testing Automatic DAQ System

- Automated Shutter Control:
  - Opens at observation start and closes at the end.
- Remains closed under unfavorable environmental conditions detected by monitors.
- Ensures smooth, hands-free operation to maximize observation time and protect equipment.

CRAFFT mnitor (2024/11/10 23:40:00)

Recorded date	Recorded Time	Timezone
2024/11/10	23:36:22	UTC

Observation start	Observation end	Status
07:45:41	12:38:11	NG

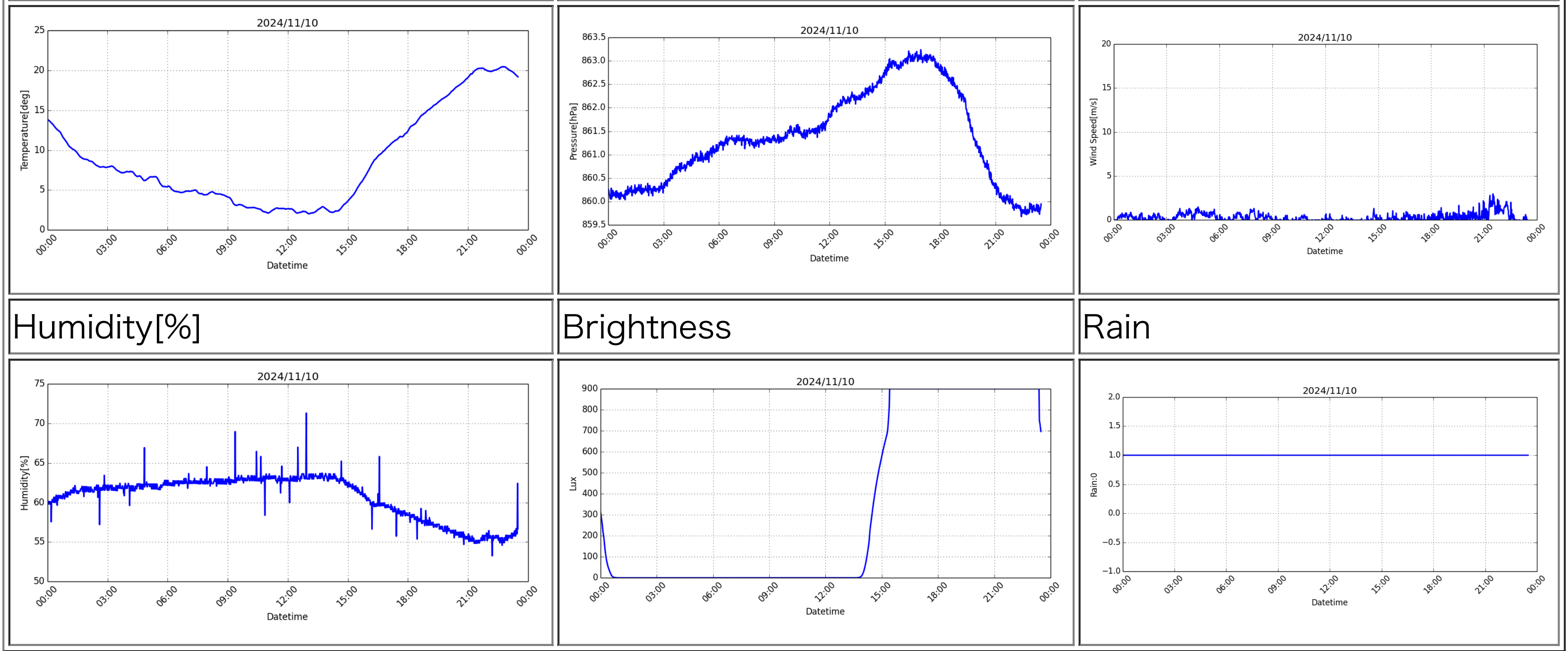
Temperature	Pressure	Wind speed	Brightness	Rain	Shutter
18.93 ℃	859.908 hPa	0.04 m/s	BRIGHT	OK	CLOSE

Status of solar power system

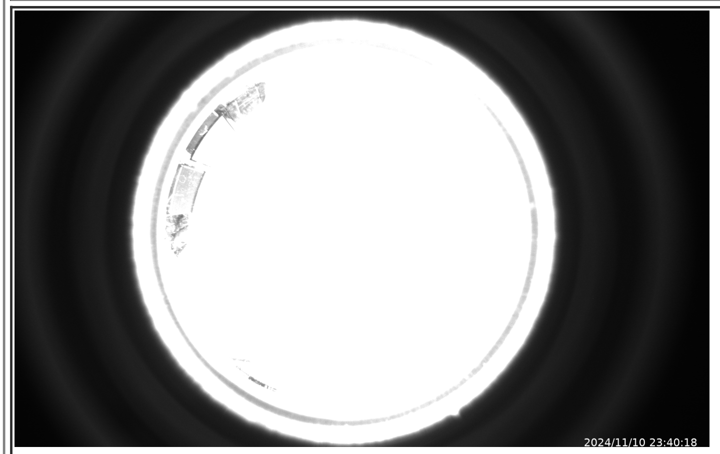
Solar		
Voltate	Current	Power
14.34V	0.09A	1.43W
Load		
Voltate	Current	Power
13.03V	0.59A	7.68W
Battery		
Voltate	Current	Power
13.03V	-0.44A	1.56W
State of charge		
71%		

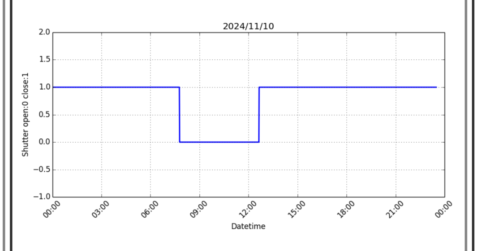
Environmental monitor

Temperature[℃]	Pressure[hPa]	Wind speed[m/s]
Humidity[%]	Brightness	Rain



Sky Monitor	Shutter status





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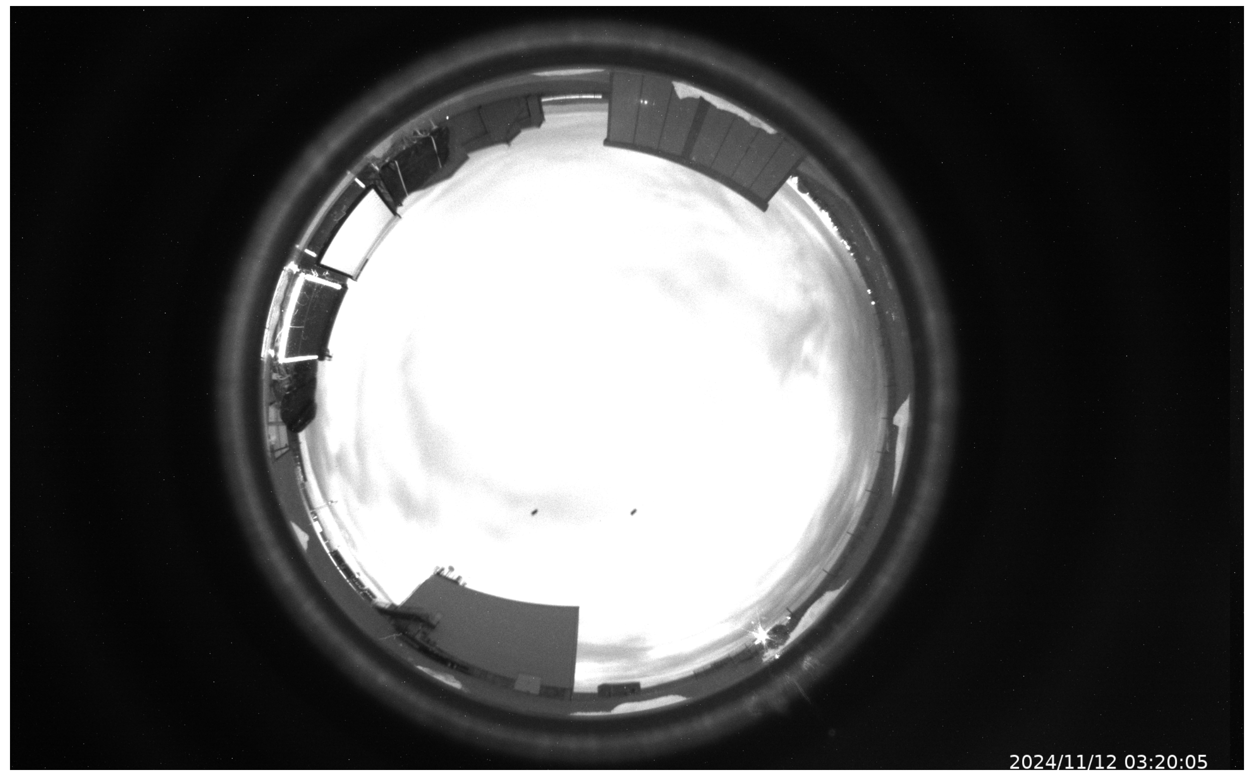
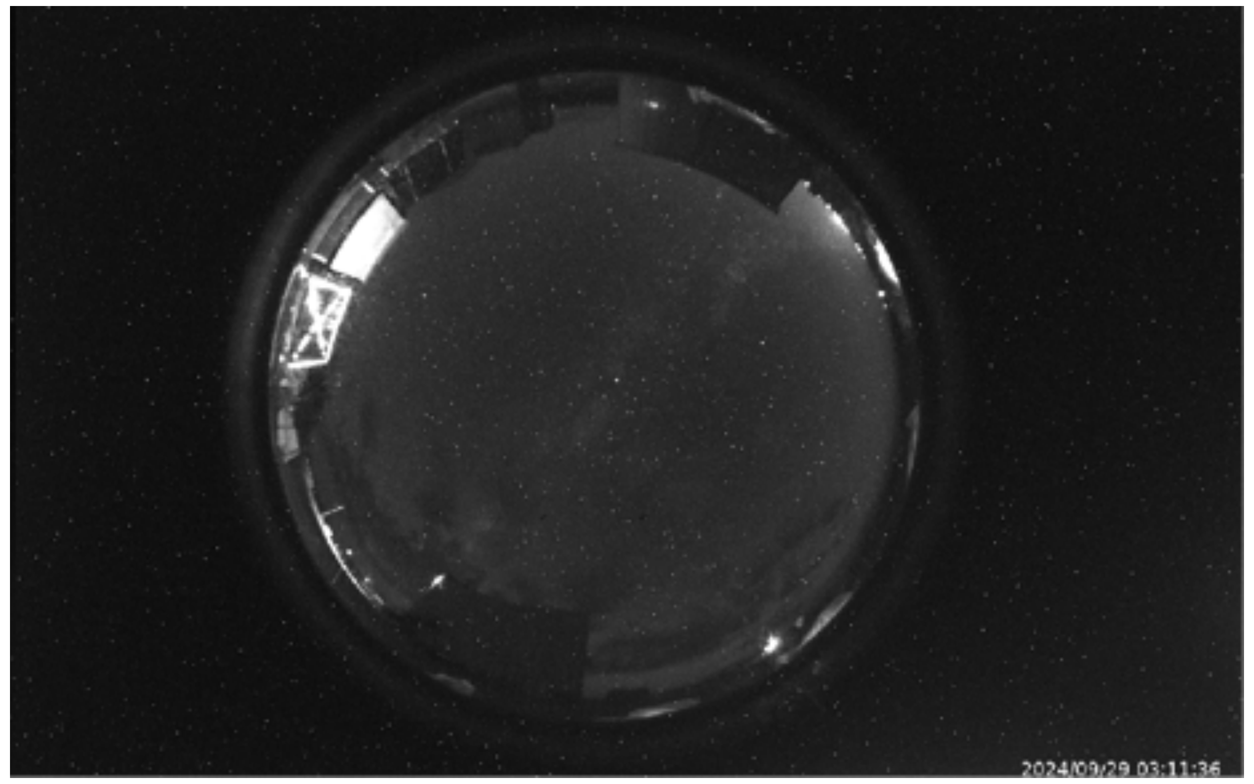
Phase 1.5

Sky Monitoring System

- Sky monitor consisting of CMOS sensor and fisheye lens
- Cross checking the shutter status
  - Red light reflected by reflectors
  - Gain and exposure time are being adjusted
- Sky monitor takes pictures every 10 min.

- Sky monitor also see the sky above the site.
  - We can see stars and clouds.
  - We are developing the algorithm to judge the cloudiness or transparency of atmosphere.
  - It will help to judge obs. condition.





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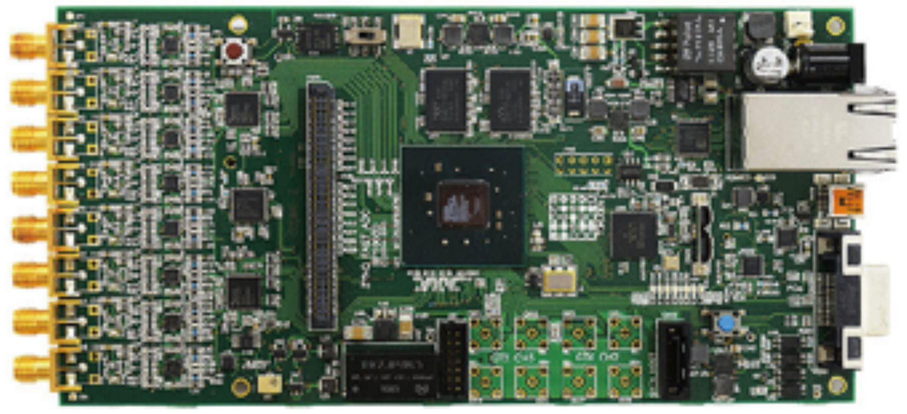
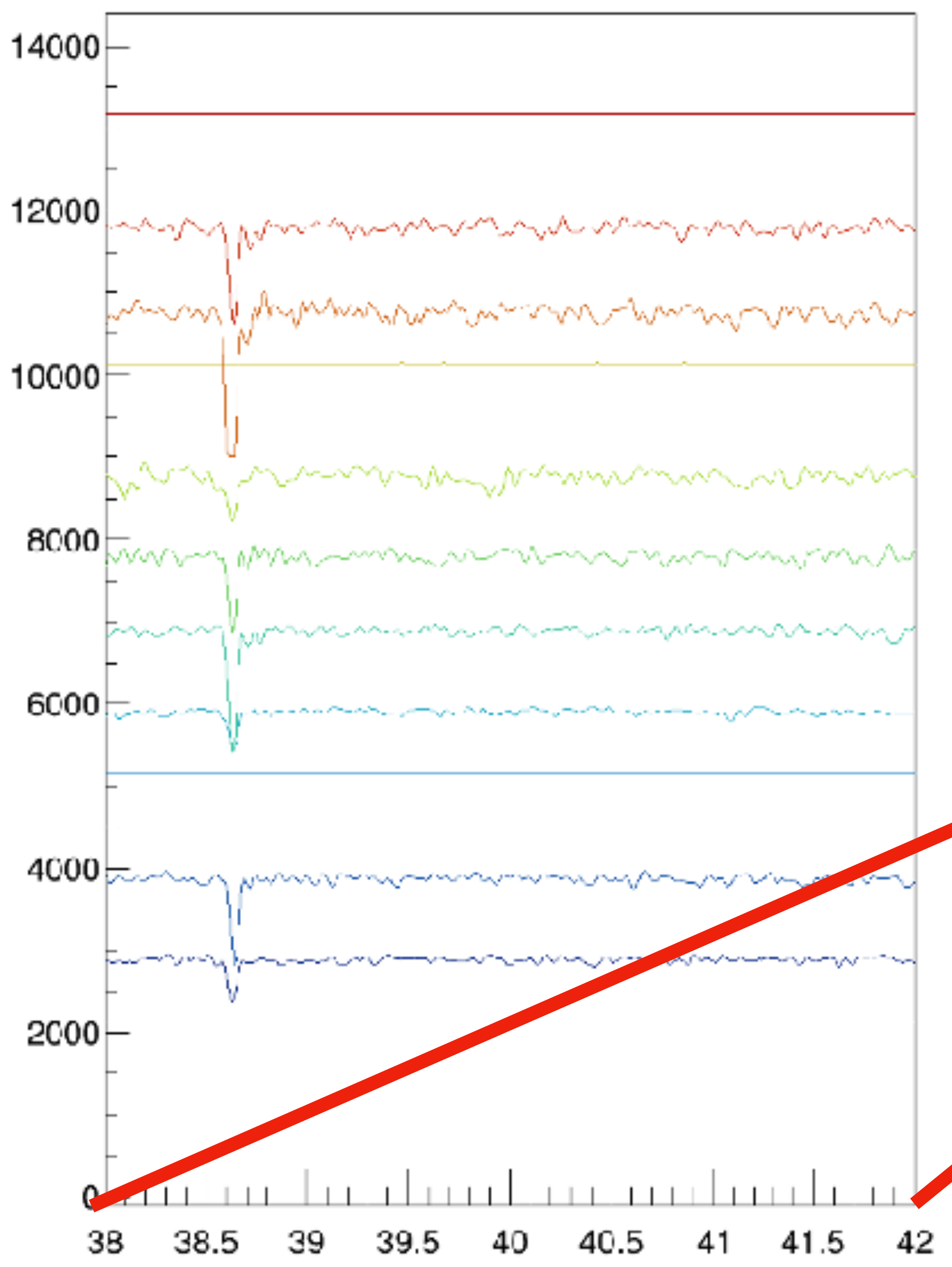
Phase 1.5

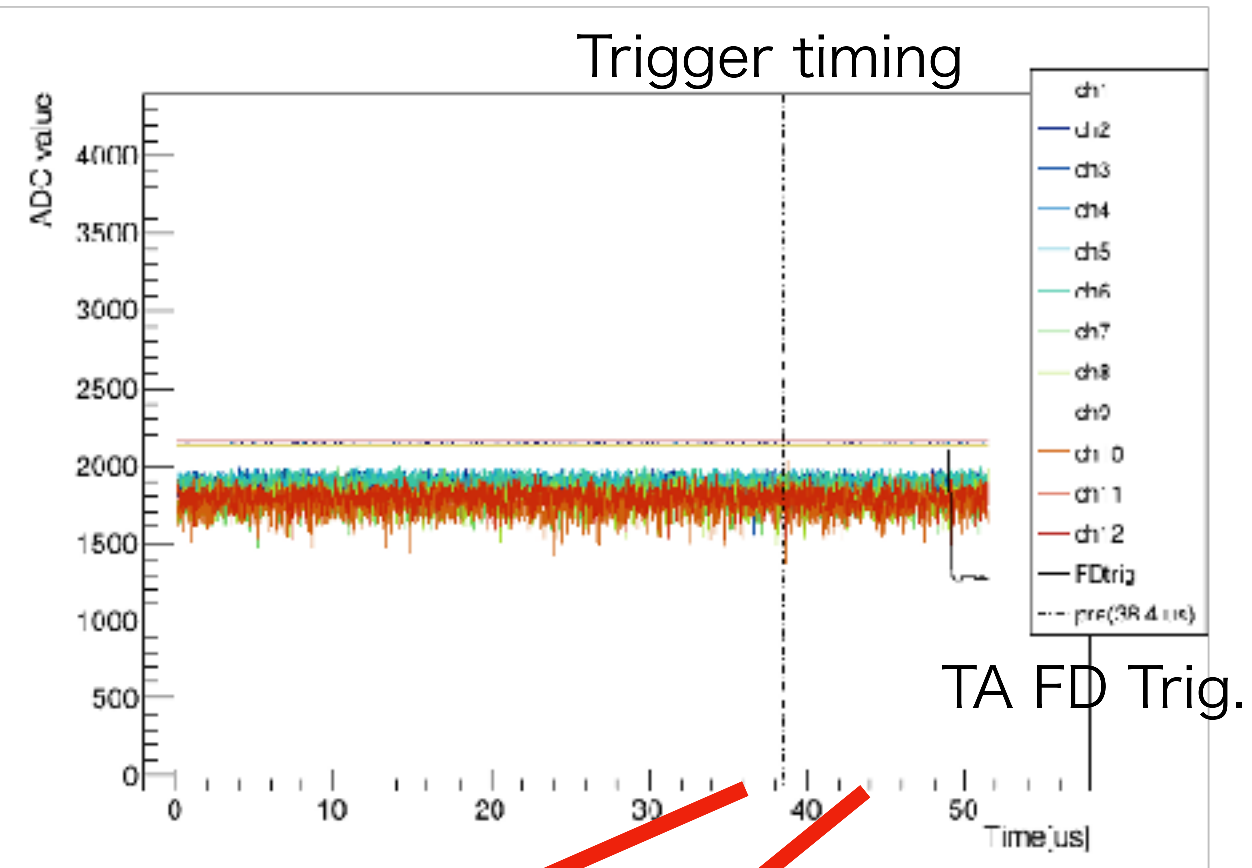
Test observation on 2024

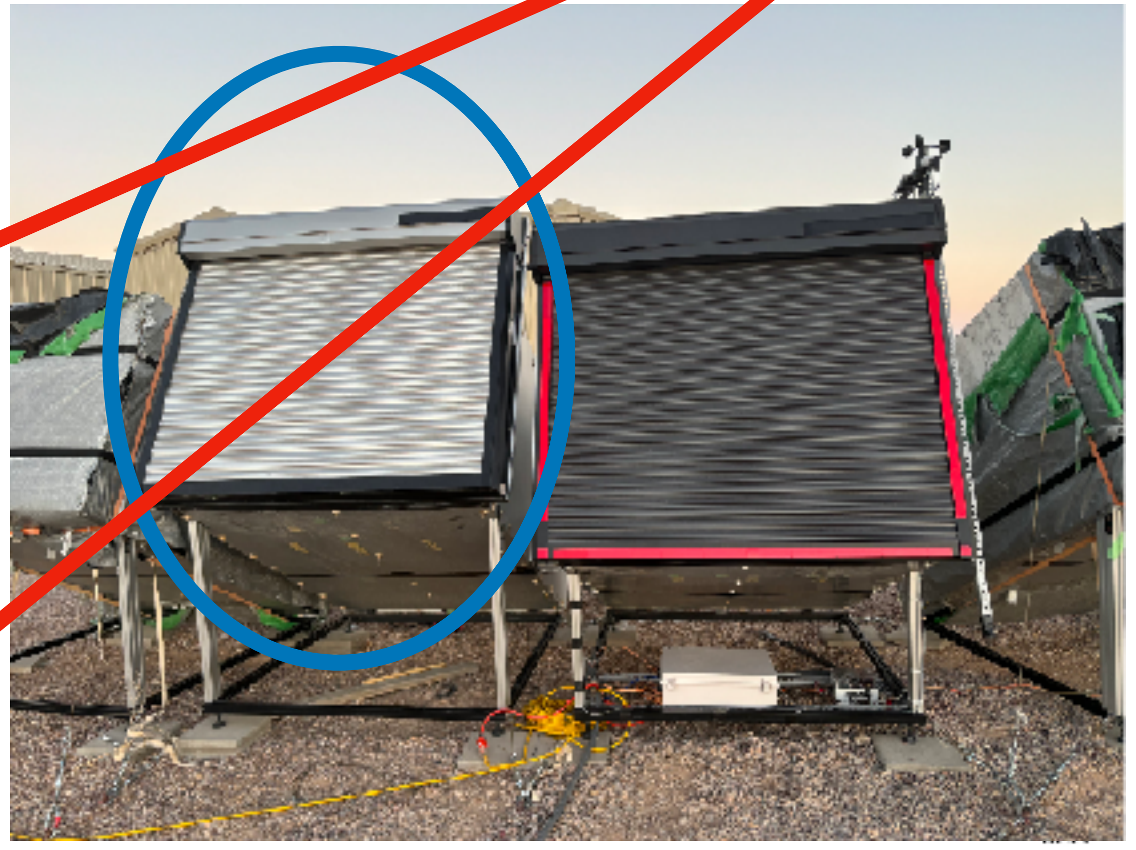
- Test observations at TA FD site (2024/09/26, 27).
- Implemented trigger algorithm on a programmable FADC board (Cosmo-Z: A flexible ADC board with FPGA for customization.).
  - Falling edge method with a 7 σ threshold against background noise to find signal.
  - Triggered with any two condition
- We succeeded to acquire waveforms by self triggering.
  - Data analysis is on going to check the simple trigger algorithm working.



Cosmo-Z FADC board w/ FPGA







Phase 1.5

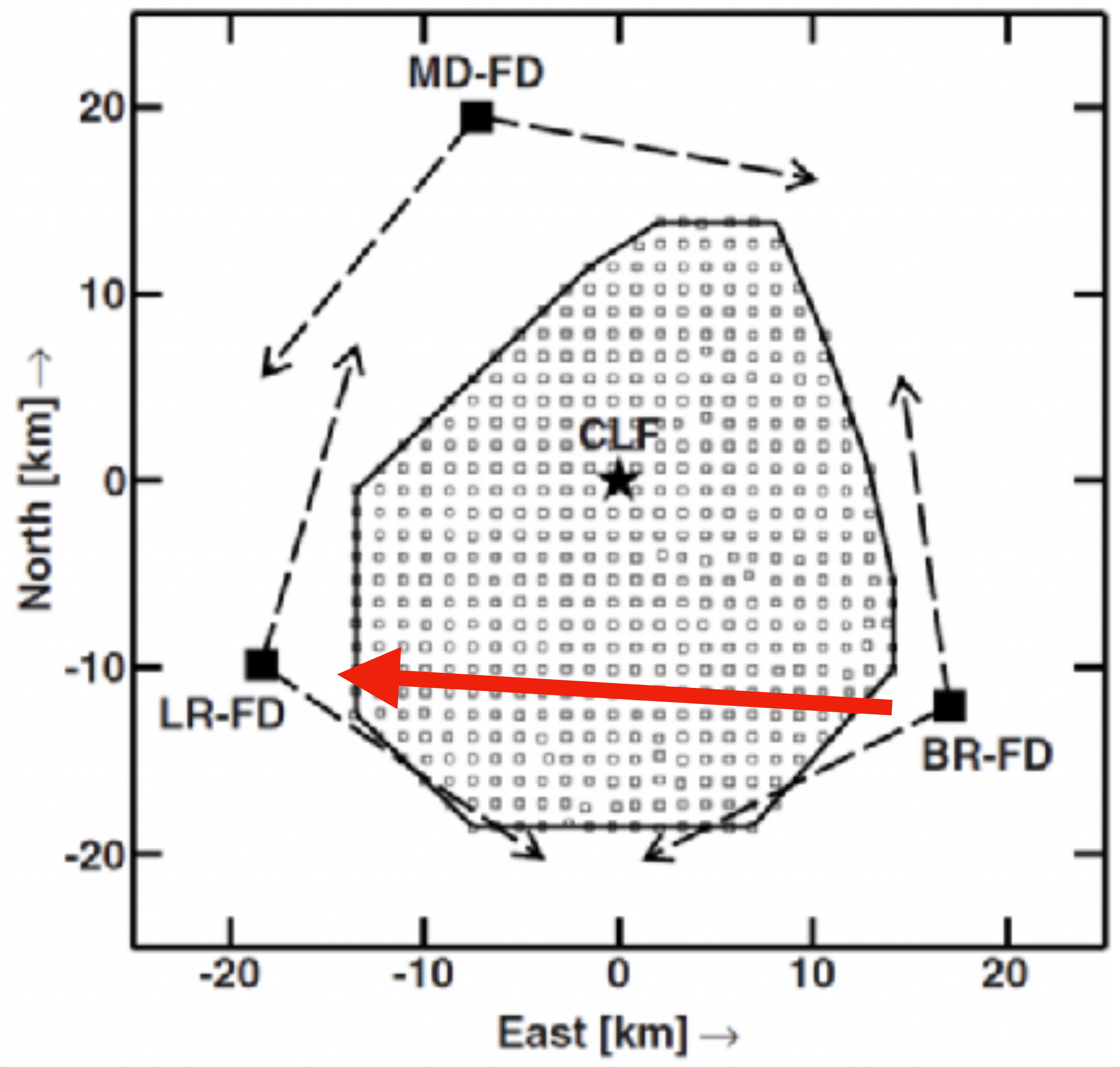
Future plan

Electronics Upgrades:

- Update DAQ system with advanced trigger algorithms
  - Adjacent conditions, GPS timestamp, …
- Improve hardware
  - high-voltage supply circuits and signal amplifiers.

Observation Plan:

- Continue testing environmental monitoring and shutter control until next summer.
- Relocate CRAFFT telescopes to LR station for operational deployment.
- Initiate observations with a fully automated DAQ system.



Summary

CRAFFT Overview:

- Cosmic Ray Air Fluorescence Fresnel Lens Telescope (CRAFFT).
- Simplified FD design for next-generation UHECR observatories like GCOS.

Achievements:

- Optimized detector configuration to improve reconstruction accuracy, extend the field of view, and improve S/N ratio.
- Environmental monitoring system deployed and under evaluation.
- Automated shutter control successfully implemented.
- DAQ with self triggering with simple trigger algorithm.

Future Vision:

- Deploy optimized telescopes with full automation at TA LR site.
- Establish a large-scale, next-generation observatory for UHECR research.