CRAFFT
Concept and Design

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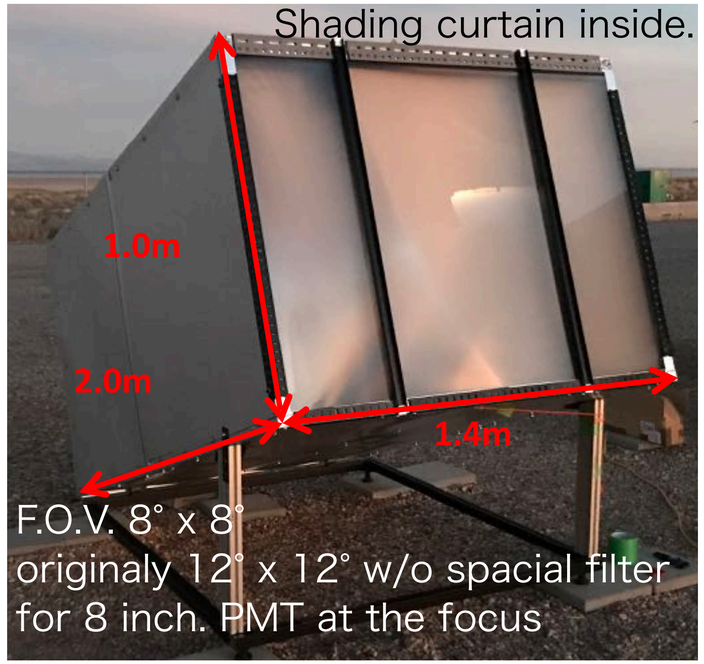
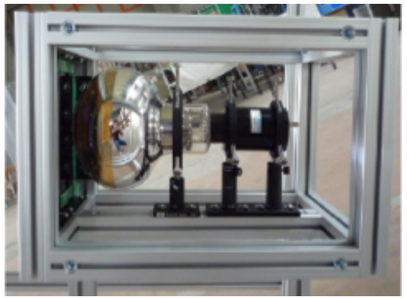
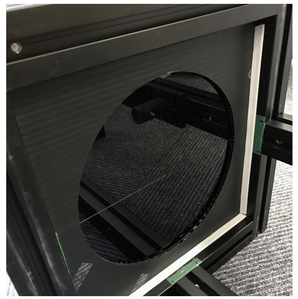
CRAFFT (Cosmic Ray Air Fluorescence Fresnel lens Telescope)



Appearance of CRAFFT prototype.



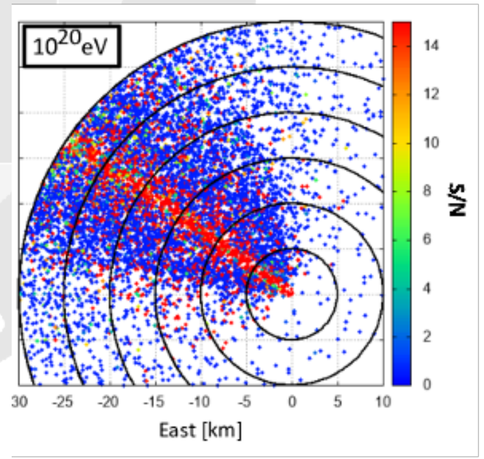


8 in. PMT with UV transmitting filter.
8° spacial filter for test observation.

For UHECR observation, we need a huge observatory with detectors which can measure Xmax such as FD.
We need reduce the cost.

- 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.

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

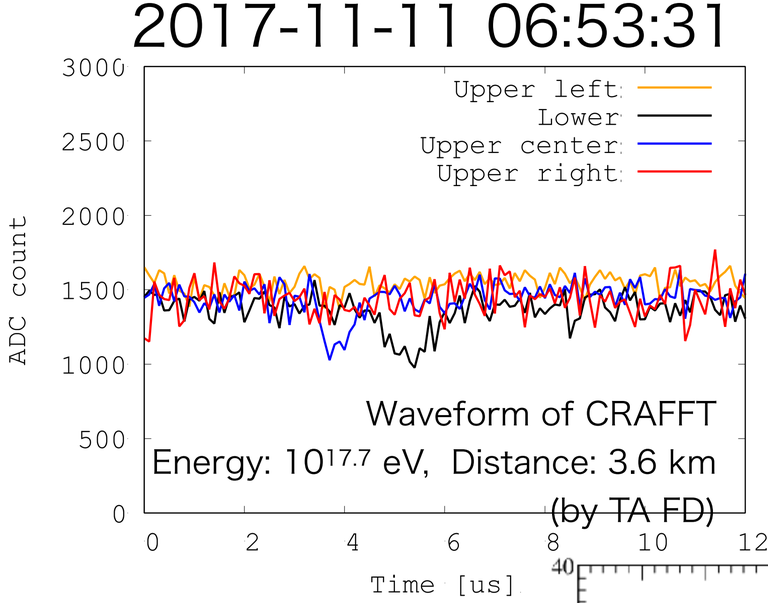


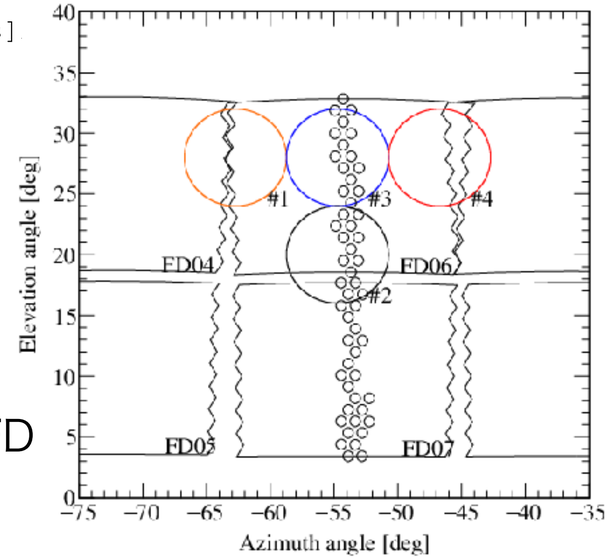
Detection efficiency.

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

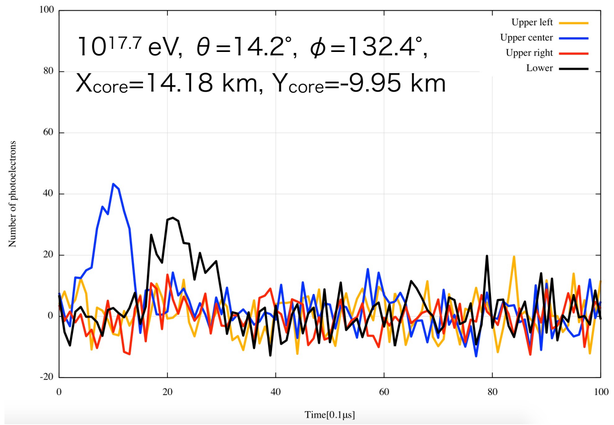

Deployed detectors next to to the TA FD building @ RBM



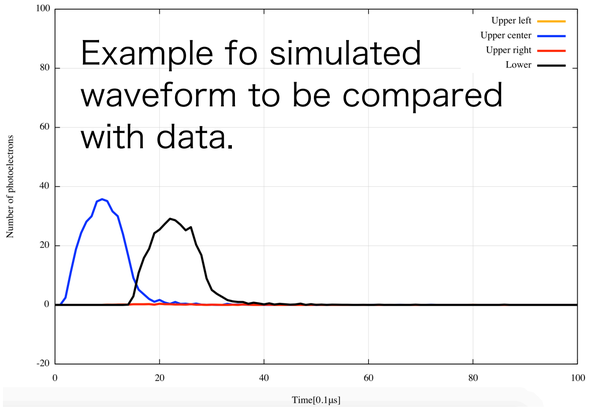


Event display of TA FD with CRAFFT F.O.V.

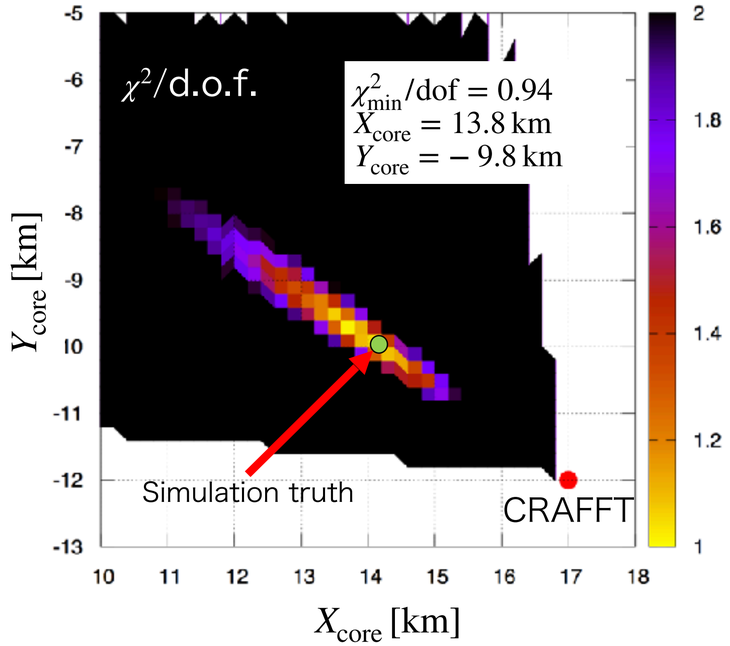
Reconstruction by waveform fitting

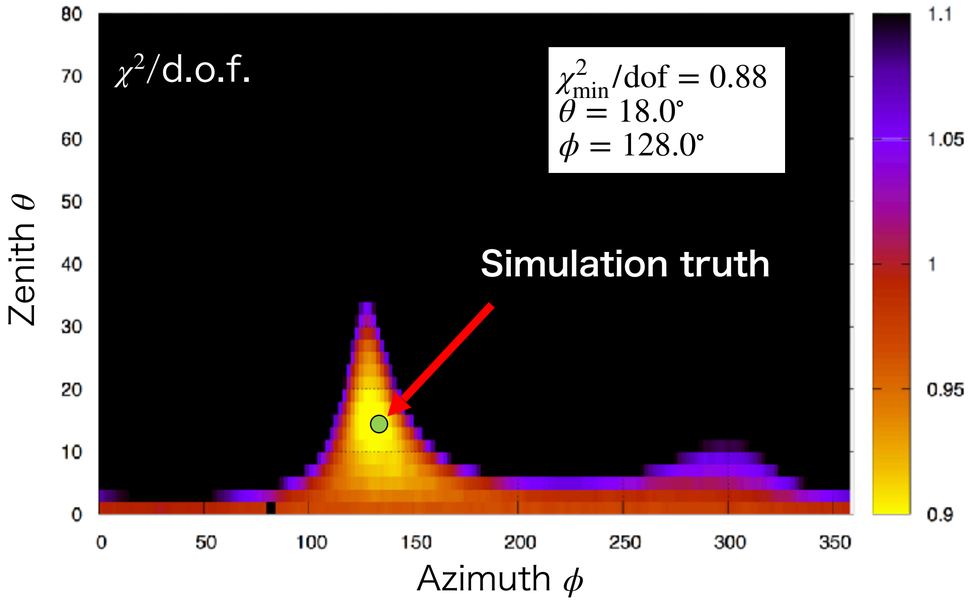


Simulated waveform based on the shower parameters reconstructed by TA FD with night sky background noise.



- Shower detector plane cannot be determined by single pixel detectors.
- Waveform recored by FADC (80 MHz) is only available.
- Least square fit using waveform data and simulated waveform.
- Parameters are Energy, $X_{\max}$, zenith, azimuth, X_{core}, and Y_{core}
- At least, 4 parameter fitting works to reconstruct shower geometry even with monocular measurement. (Energy and $X_{\max}$ are fixed here)

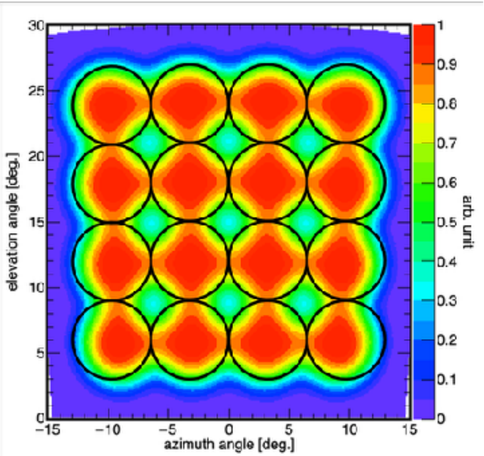




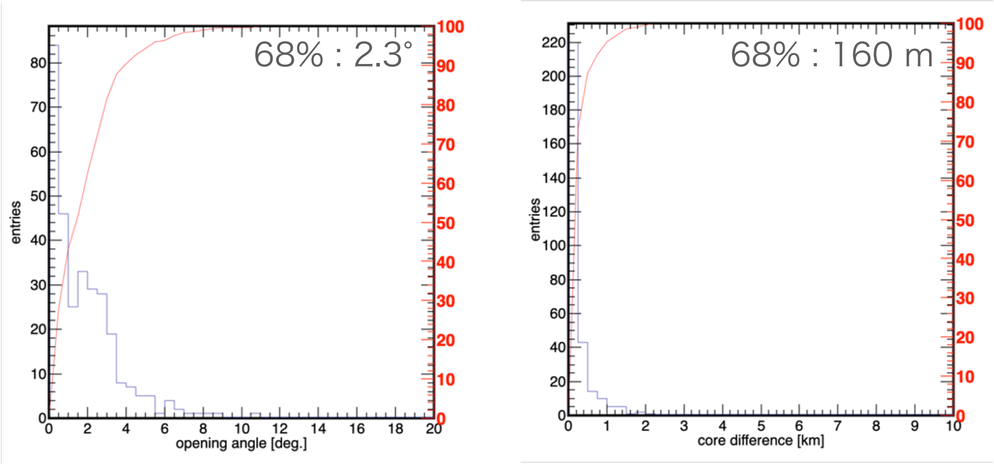
Optimization of detector configuration

- Number of pixels of the 1st prototype is one.
  - Only the waveform is available.
  - Worse S/N than conventional FD.
  - No spatial resolution in F.O.V.
- Optimizing detector configuration
  - To Improve reconstruction accuracy.
  - To extend F.O.V. per detector.
  - Considering 5 inc. PMT.
  - Number of pixels.
  - Arrangement of pixels.

5 inc. PMT
(Hamamatsu, R877)



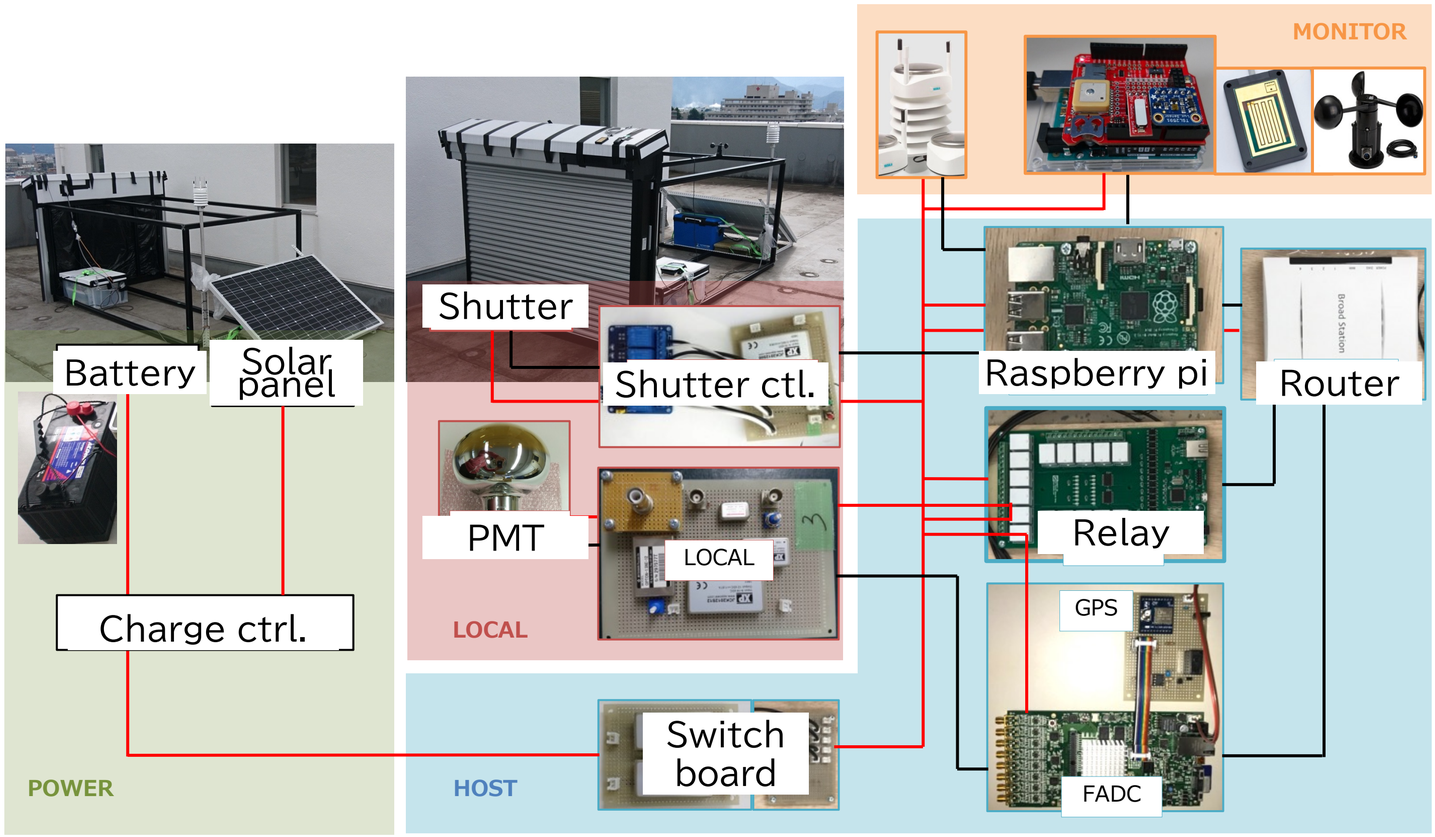
Light intensity map as a function of incident angle for optimized PMT arrangement.



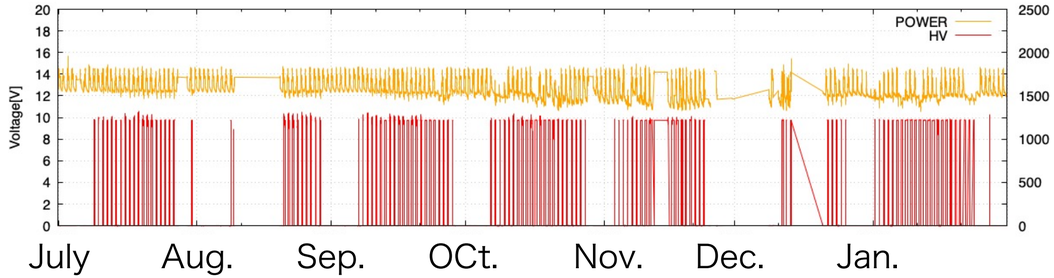
Determination accuracy of arrival direction and core position.

Automation of operation system

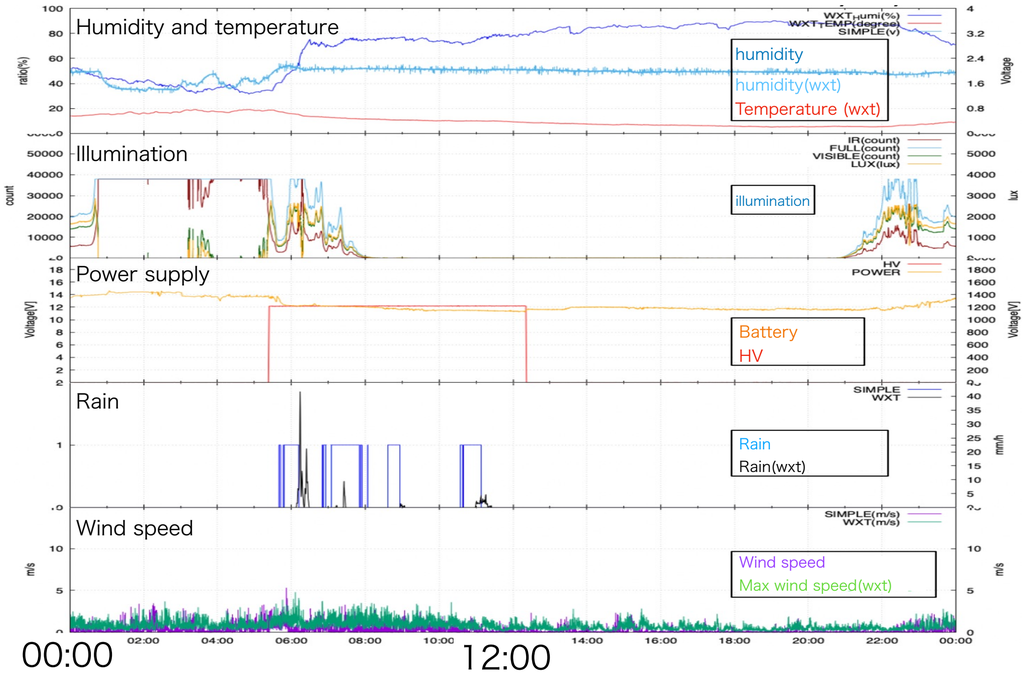
- Endurance test from Mar. 2020.



Long term operation test



Environmental monitor



T. Tomida, ICRC2021

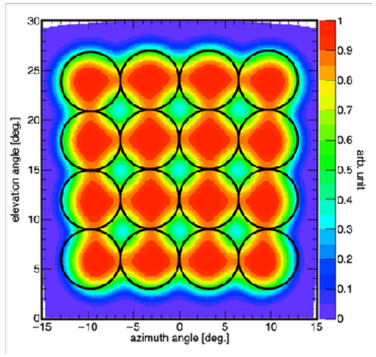
Osaka Electro-Communication University

Future prospect

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

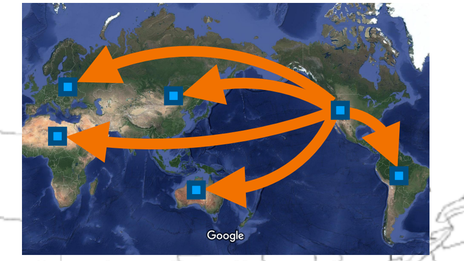
Optimization of detector design

Planning to use 5 inc. 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

Stereo observation
Deploy 6 + 6 CRAFFT at TA site
Wide area network



Can be distributed to the world

Phase 3

Large scale deployment

Array of 360° FD Station
20km spacing
500 station ~ 10 TA×4
400,000 km²
$150M

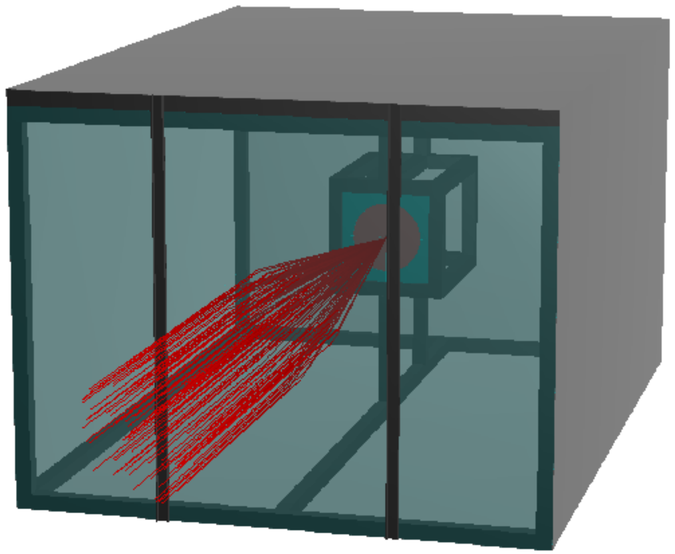
400,000 km²
FD Array

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 !!**
- Air shower reconstruction by waveform fitting seems to work even in monocular mode.
- Optimization of detector configuration for better accuracy of reconstruction and extension of the F.O.V. per detector.
- Automation DAQ system is under endurance test.
- Future prospect
  - We are planning stereo observation at TA site.
  - Our goal is to realize **a next generation huge observatory for UHECR observation**.

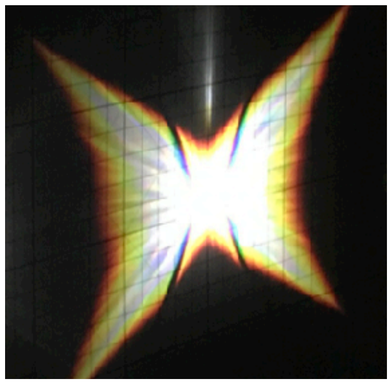
Detector simulation

- Detector simulation
  to understand our detector
- Spot shape is reproduced well.
- Waveform is well reproduced.

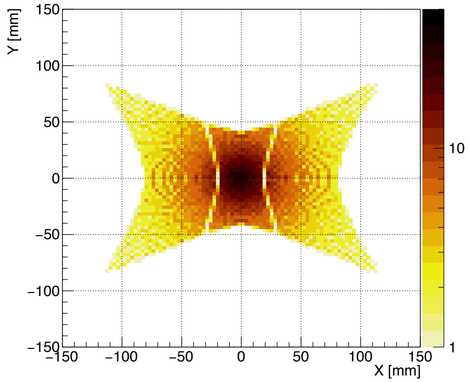


Ray trace simulation

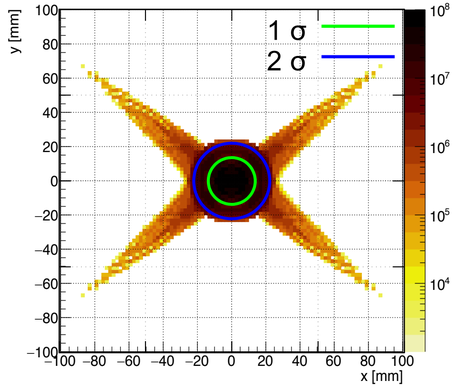
(ROBSAT : A. Okumura 2016)



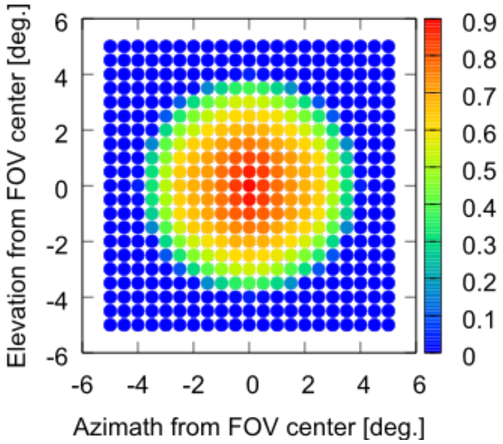
Unique spot shape of
fresnel lens at focal plane



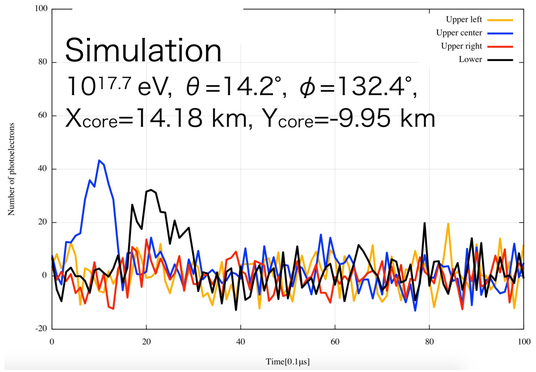
Shape of simulated spot
shows good agreement.



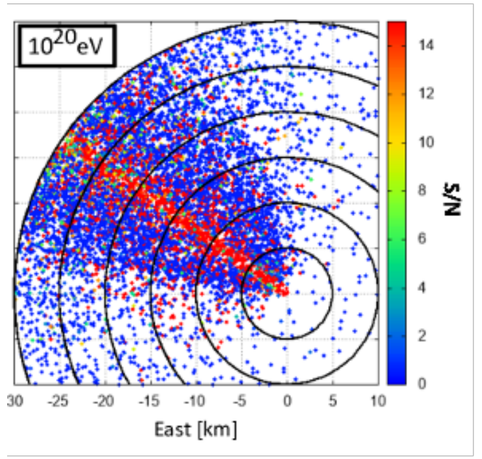
Spot size (95%) : 44 mm
λ = 280 ~ 400 nm, F = 1100 mm



Angular dependence of
light collective efficiency.



Simulated waveform with
parameters reconstructed by TA FD.

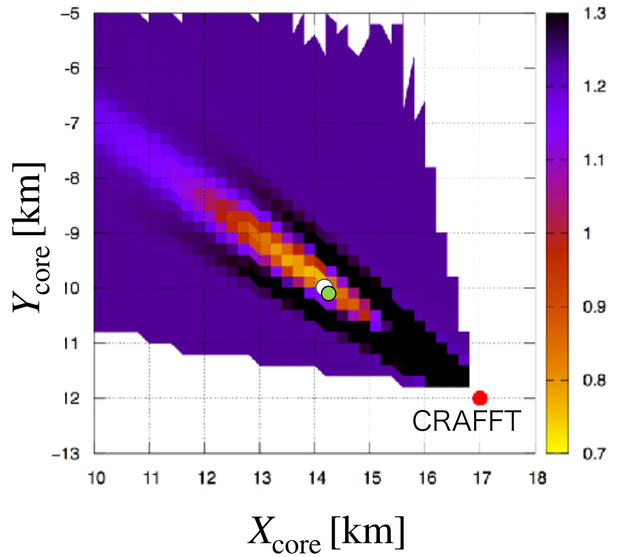


Detection efficiency.

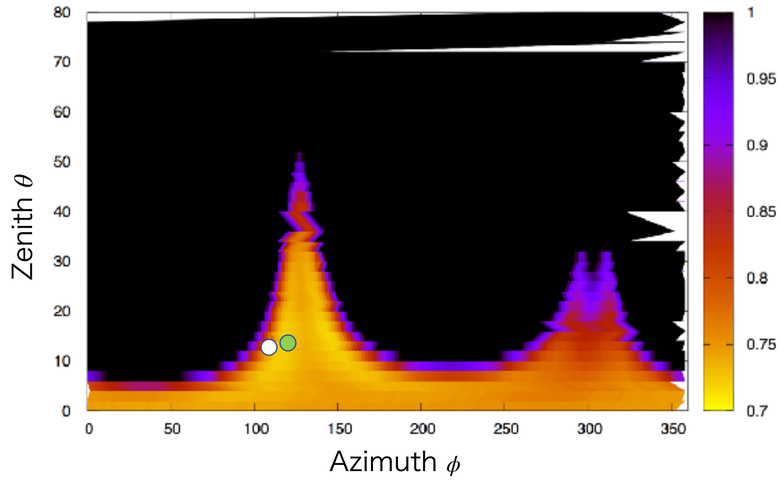
Reconstruction by waveform fitting

- Example of geometry reconstruction

	TA FD	Waveform fitting
Zenith	14.2°	14°
Azimuth	132.4°	146°
Xcore	14.18 km	14.25 km
Ycore	-9.95 km	-10.15 km
χ^2min / d.o.f.		0.71

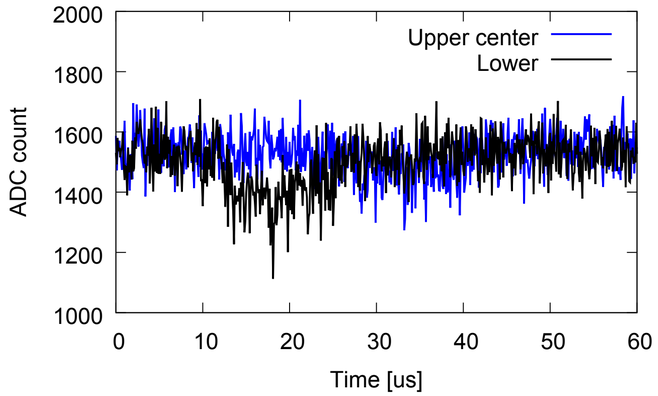


- Energy and Xmax are fixed.
- Core diff. = 210 m, opening angle = 3.3°
- PMT gain and uniformity are not been calibrated.
- For more precise reconstruction
  - Detector calibration.
  - Stereo reconstruction.
  - Optimization of detector configuration.

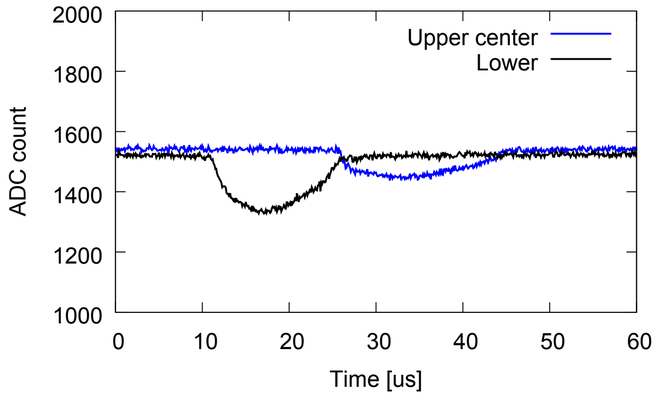


Performance test with TA CLF

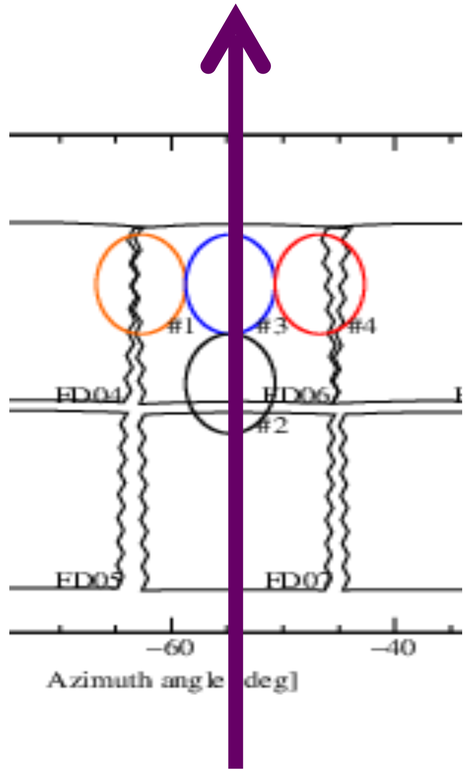
- CRAFFT detected CLF laser event.
- CLF(Central Laser Facility)
  - Nd:YAG pulse laser, λ =355 nm, 5mJ,
  - 20 km apart from CRAFFT detectors.
  - Corresponding to 10^{20} eV air shower



single event



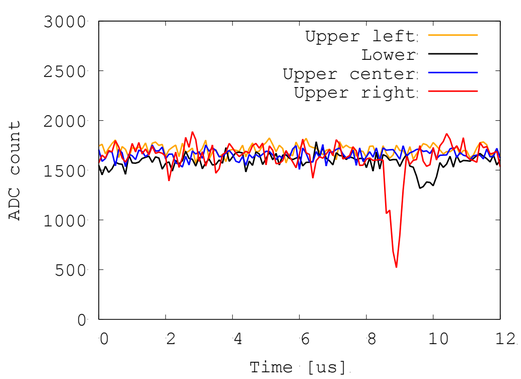
133 events average

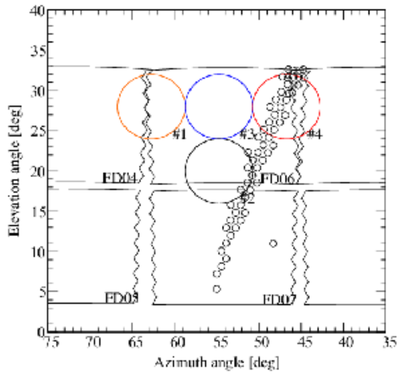


CLF laser is crossing the F.O.V. of CRAFFT detector and TA FD.

Air shower events observed by CRAFFT

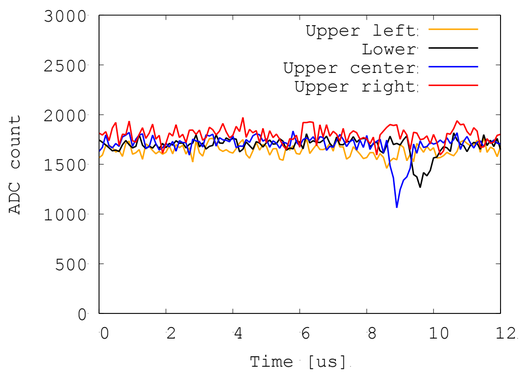
2017-11-15 05:47:08

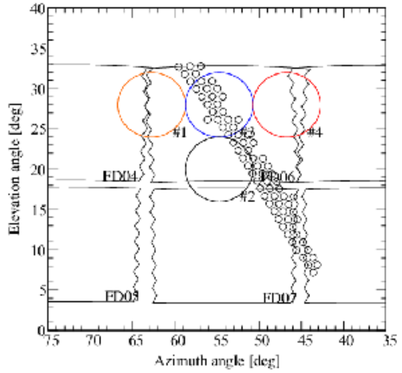




$10^{17.9}$eV, 3.9 km

2017-11-19 03:33:46





$10^{18.0}$eV, 2.3 km

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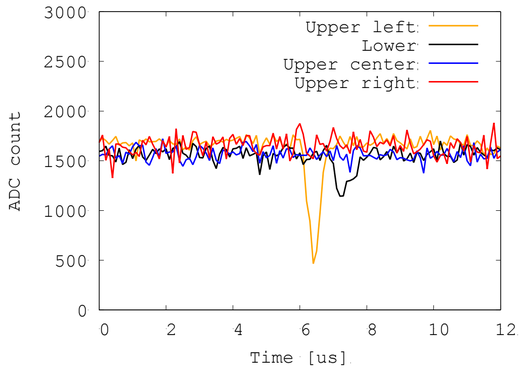

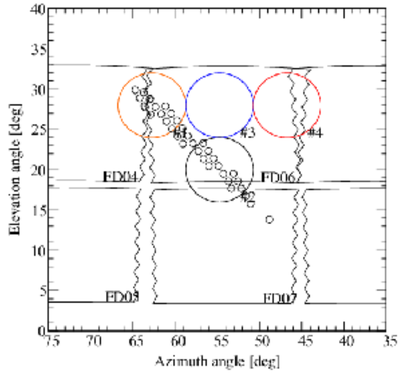

$10^{18.0}$eV, 3.5 km

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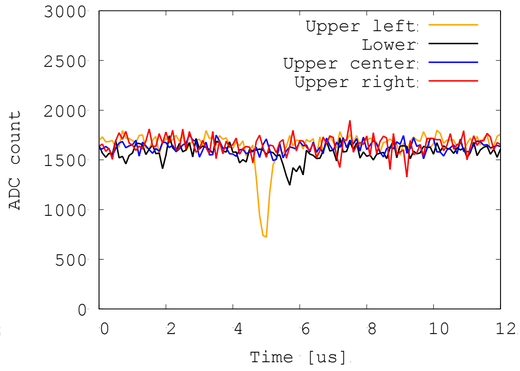
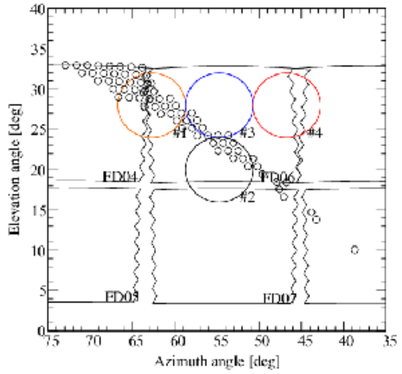
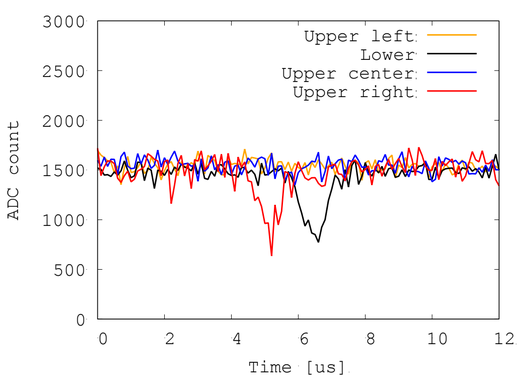


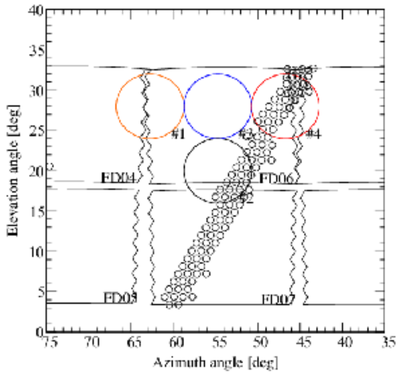


$10^{17.9}$eV, 2.4 km

Air shower event observed by CRAFFT

2017-11-11 05:59:54





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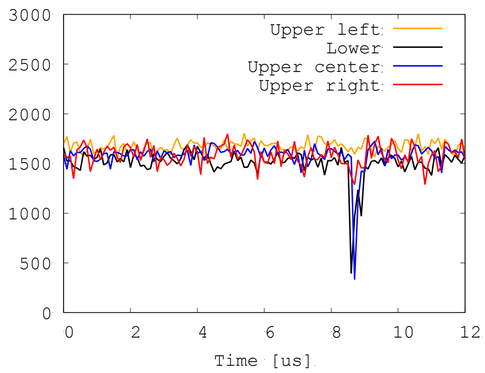

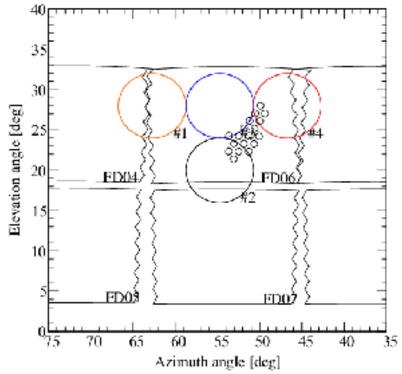

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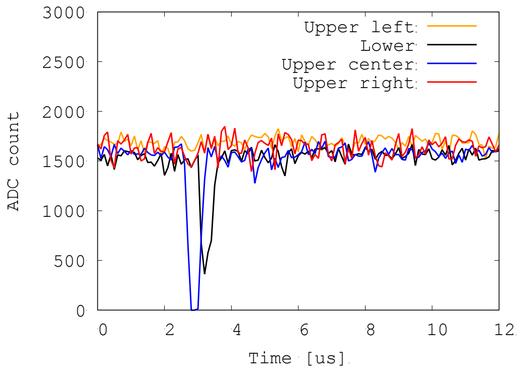

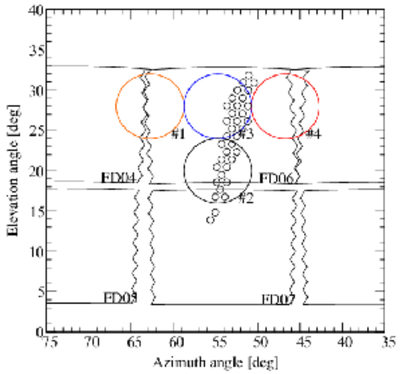

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