LACT: Progress and Future Plans

Shoushan Zhang

for LACT working group

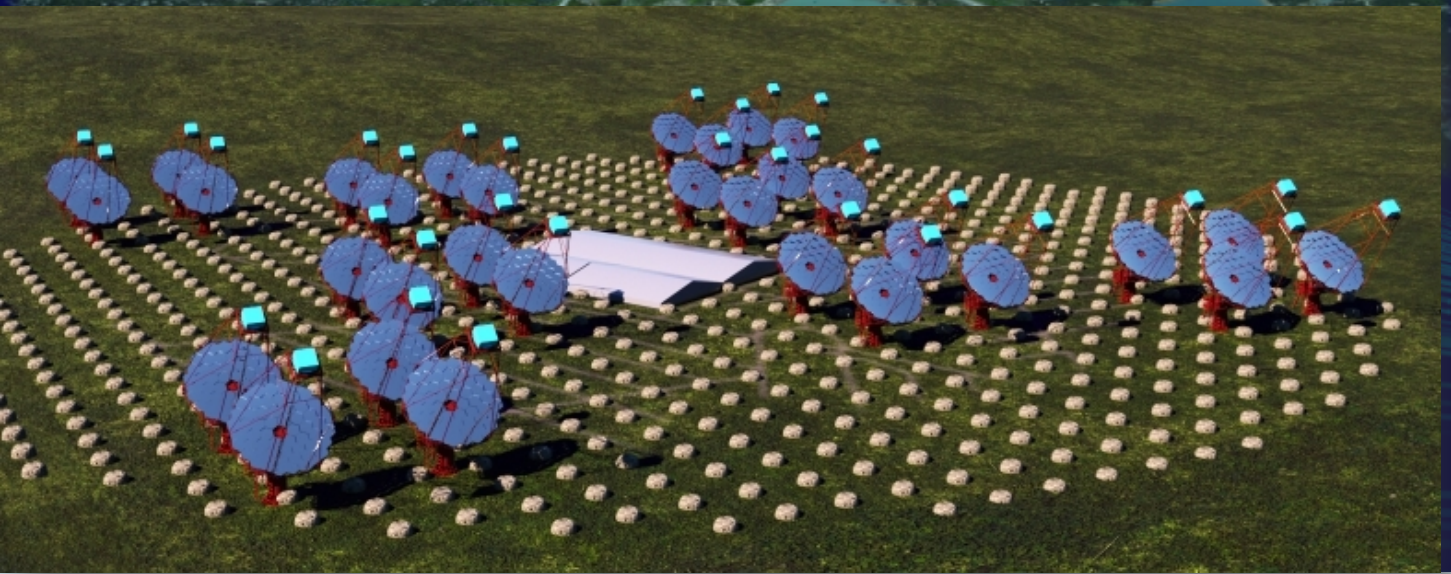
Institute of High Energy Physics，CAS，China

The 8th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy

2024/09/02-06, Milano, Italy

Large Array of Cherenkov Telescopes（LACT）

- Location： 29°21` 27.6`` N , 100°08`19.6`` E
- Altitude: 4410 m

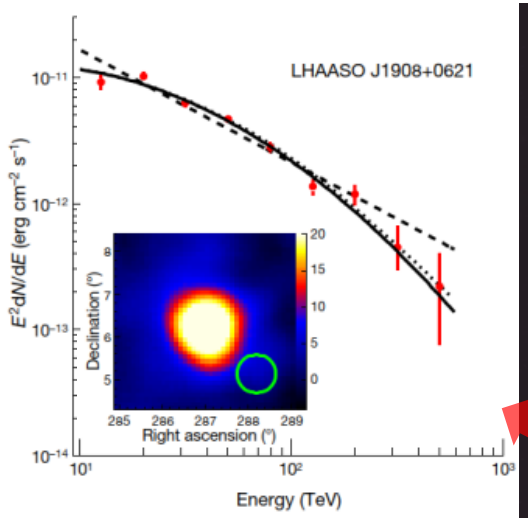


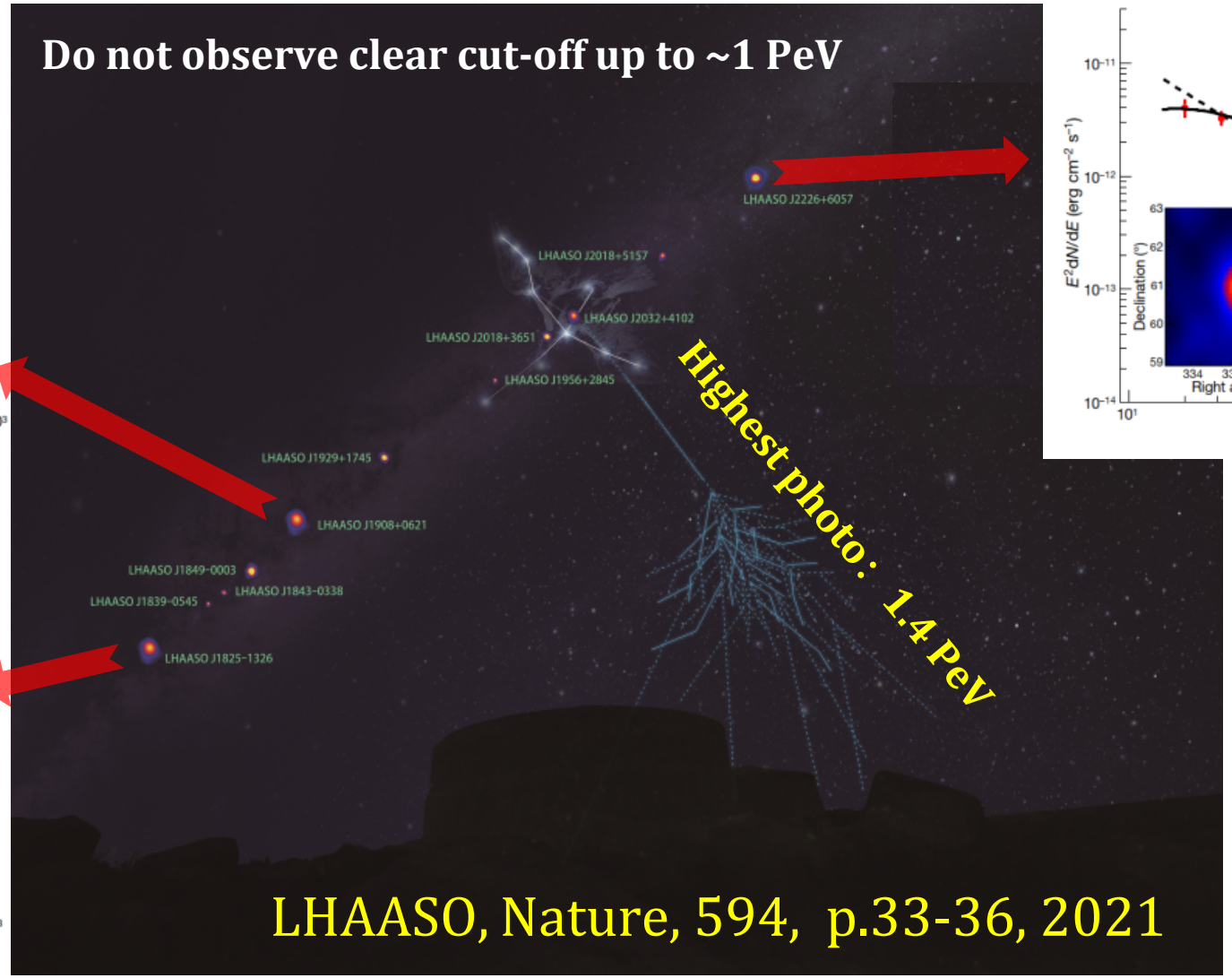
- Next generation of Image Atmosphere Cherenkov Telescope experiment
- 32 telescopes built on LHAASO site

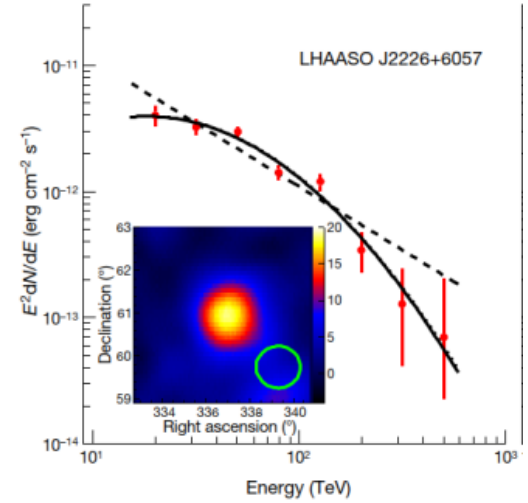
Required energy range	1 TeV - 1PeV
Total number of telescopes of LACT	32
Optical design	Davies-Cotton
Reflector diameter	~ 6 m
Focal length	~ 8 m
Field of view	~ 8°
Number of pixels in each camera	1616
Pixel size	~ 0.19°
Photodetector type	SiPM
Pointing accuracy	≤ 18 arcseconds

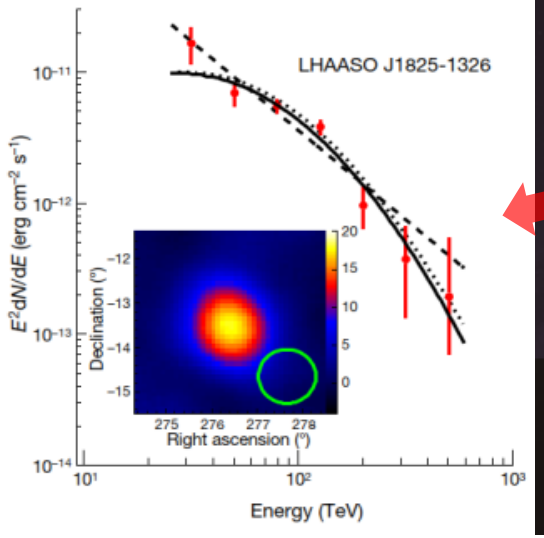
LHAASO started a new era of UHE γ-ray astronomy

2019/12-2020/12, 308 days, 1/2 array







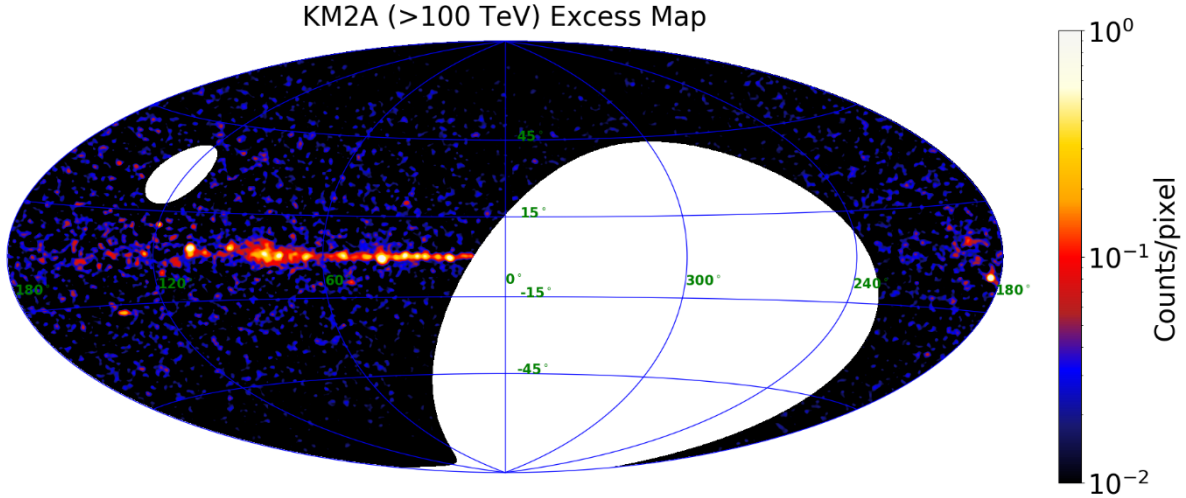


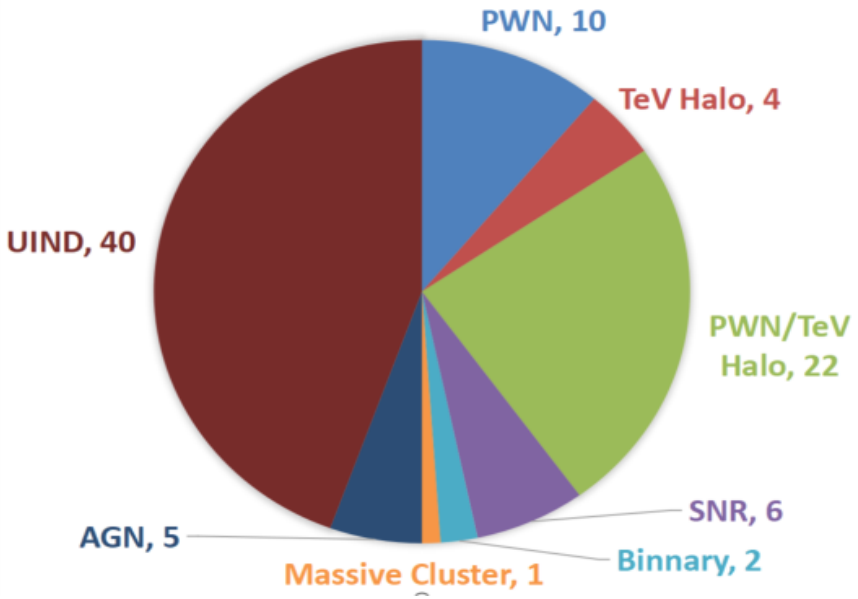
For the first time, twelve ultra-high energy gamma-ray sources have been discovered in the Milky Way, revealing the widespread existence of "petaelectron particle accelerators" in the galaxy, whose acceleration capabilities

Journey of Ultra High Energy Gamma Ray Detection
The First Catalogue of Very/Ultra High Energy Gamma Sources Released

- **In 2024**: release the first catalog of very-high-energy and ultra-high-energy gamma-ray sources detected by LHAASO
  - 90 VHE/UHE gamma-ray sources
  - The number of UHE gamma-ray sources increased to 43
  - Associate with supernova remnants, pulsar wind nebulae, pulsar clouds, and massive star clusters and so on
  - This provide a crucial set of best candidate celestial bodies for uncovering the origin of high-energy cosmic rays

- KM2A: 2019-12 to 2022-09
- 933 days (~730 days full array)





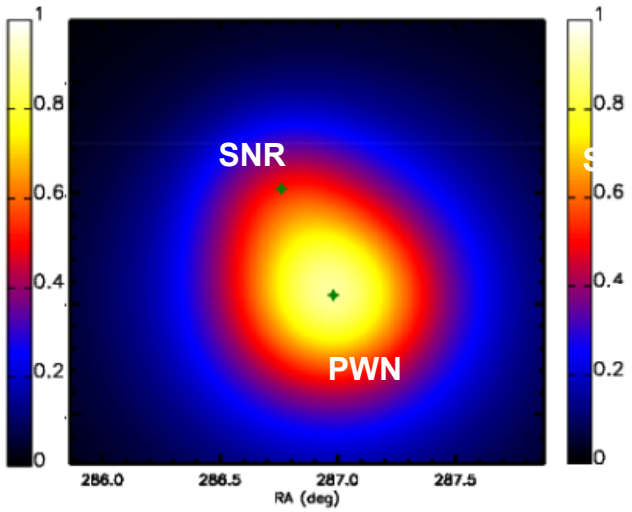
LHAASO Col., ApJS, 271:25 (2024)

Large Array of Cherenkov Telescopes（LACT）

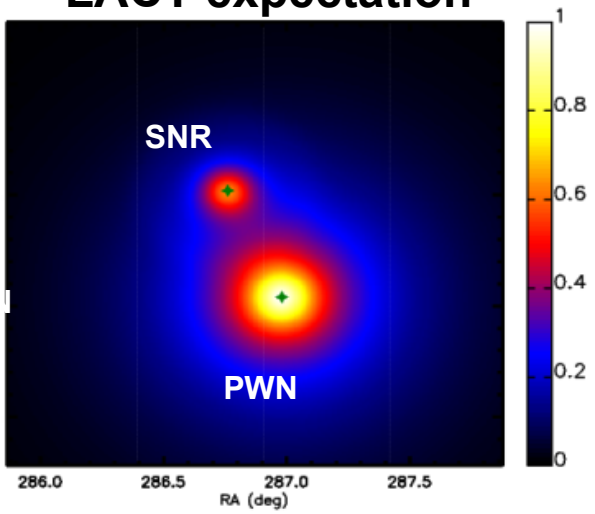
- Most of UHE gamma ray source are extended source
- Next generation IACT: LACT
  - High angular resolution：~0.05°
  - High sensitivity (very big array)：to detect enough number of UHE gamma rays
  - To measure its morphology and identify which celestial body the UHE gamma rays come from
  - To study the UHE photon emission mechanism and explore the origin of cosmic rays

LHAASO J1908+0621

LHAASO measurement

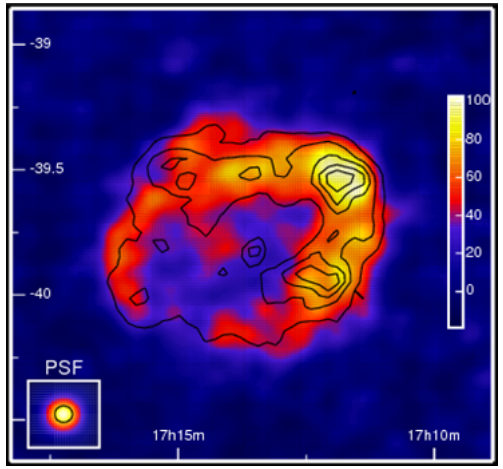


LACT expectation

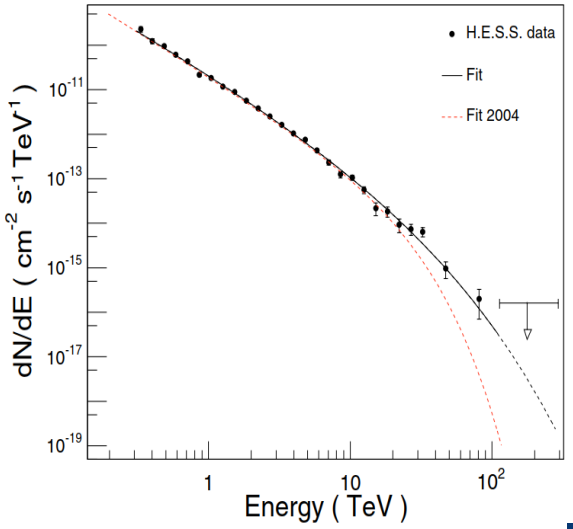


HESS，Aharonian et al., 2006 (astro-ph/0611813)

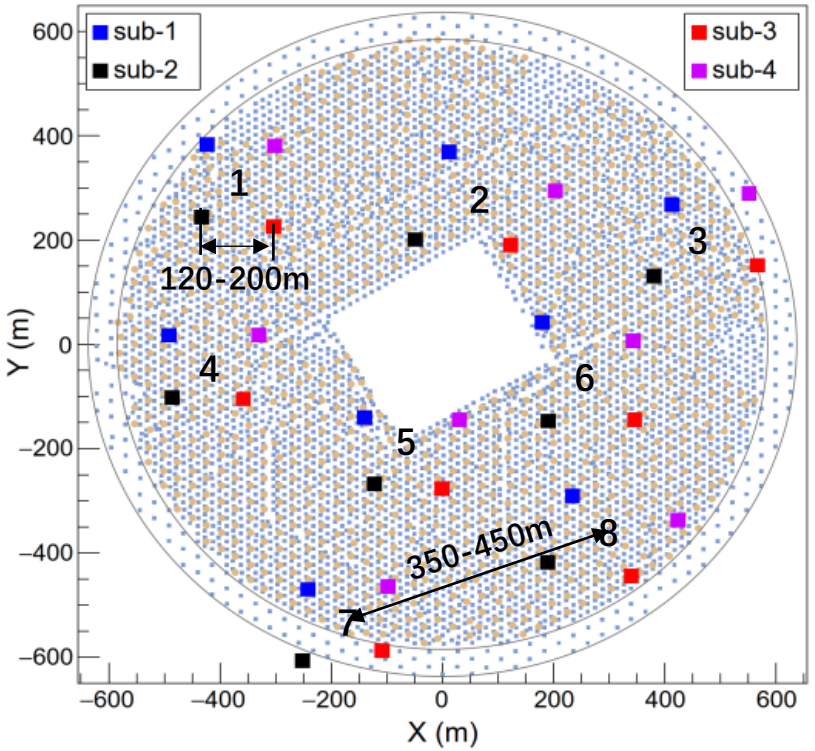
Morphology

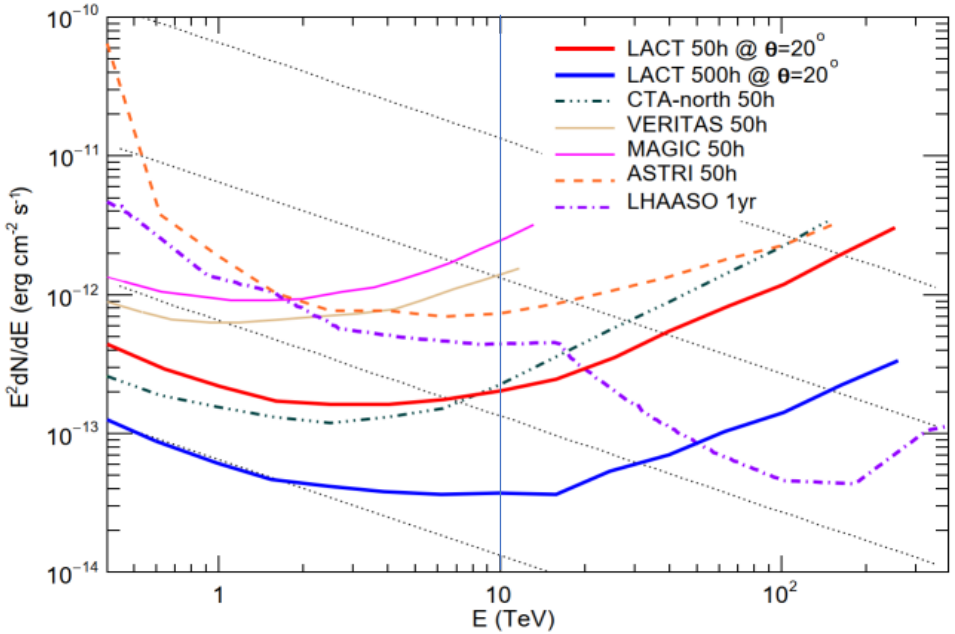


SED

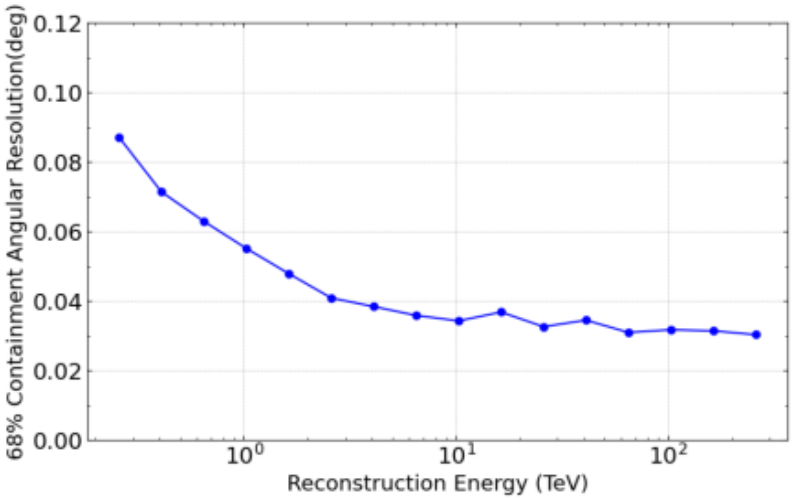


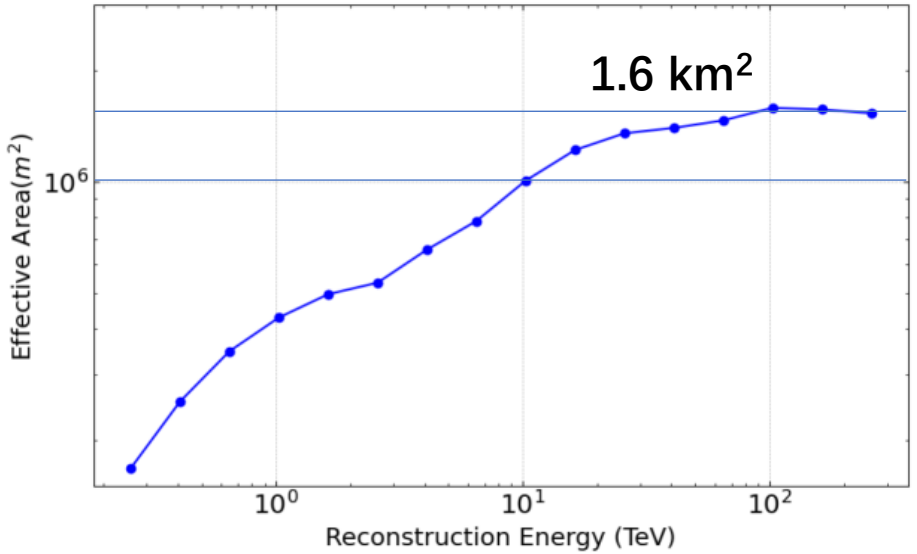
- **32 telescopes on site**
  - **Placed in the gap between muon detectors**
  - **Close to the road for easy construction**
- **Small zenith angle (zenith<50°) observations for lower energy thresholds**
- **Collection area: 1 km² @ 10TeV**
- **Angular resolution: <0.06° @ >1TeV**
- **Threshold Energy: ~200GeV**



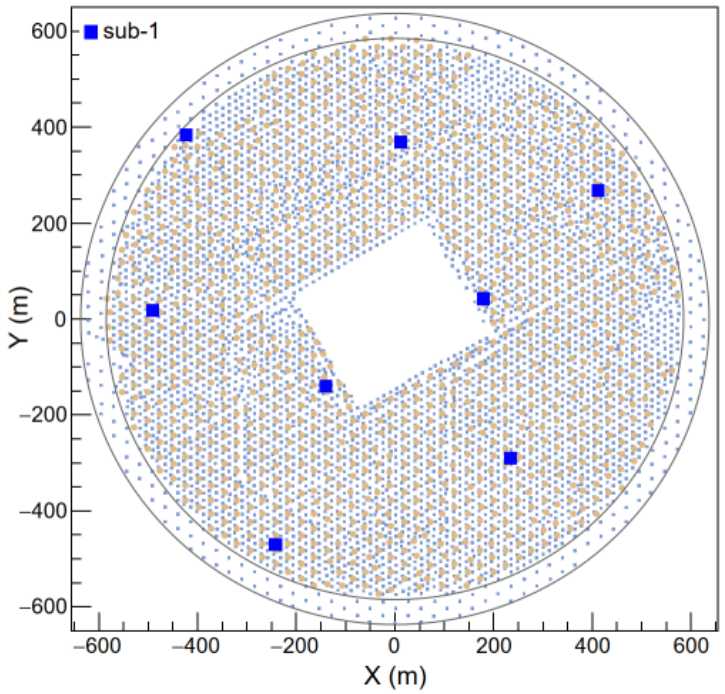


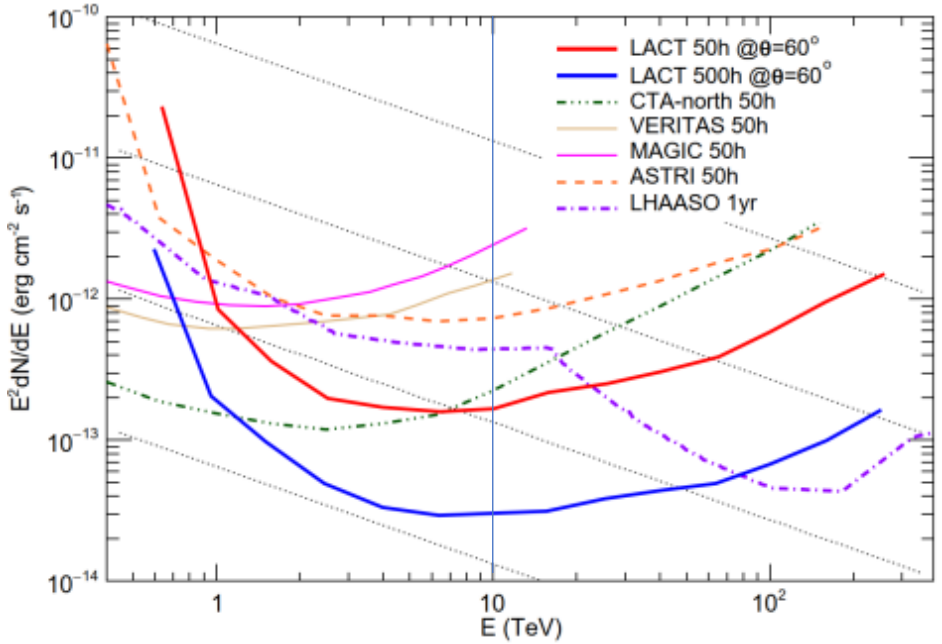
Sensitivity of point source



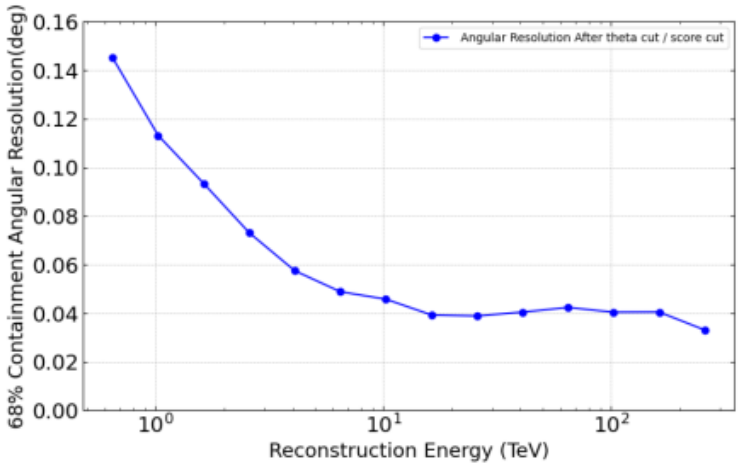


- **Large zenith angle (zenith: 50°-70°) observations for ultra-high energy events**
- **8 telescopes: LACT has four sets of eight telescopes that can simultaneously observe four UHE sources**
- **Getting larger collection area: 3 km²@ 100TeV**
- **Higher Threshold Energy : ~1TeV**
- **Angular resolution: <0.06° @ >4TeV**





Sensitivity of point source



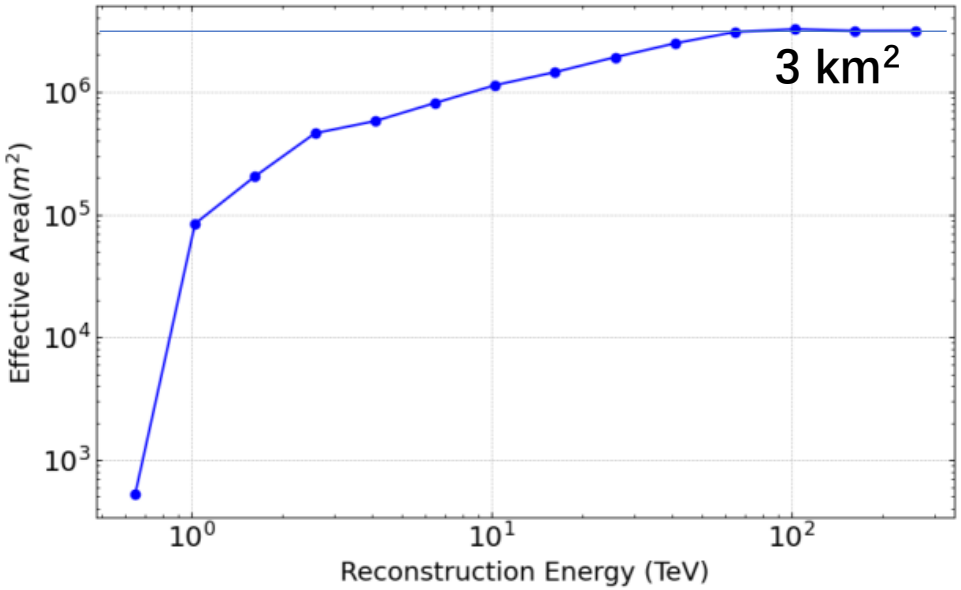
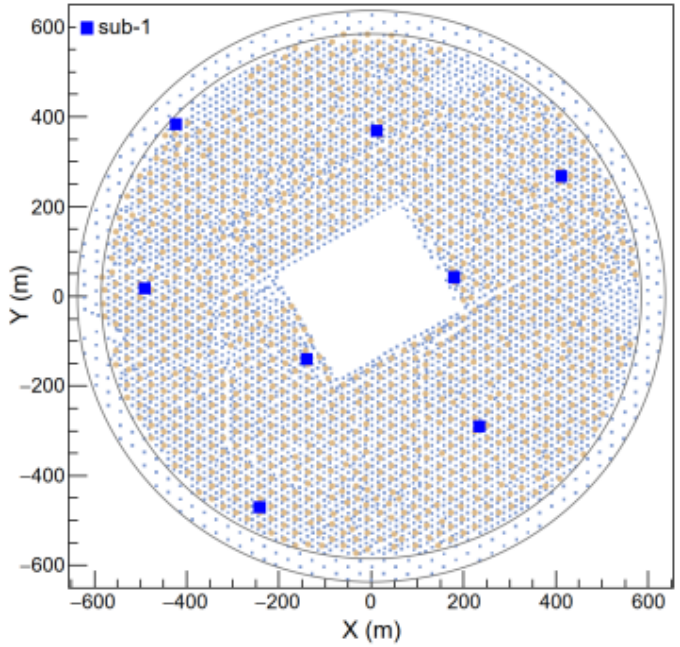
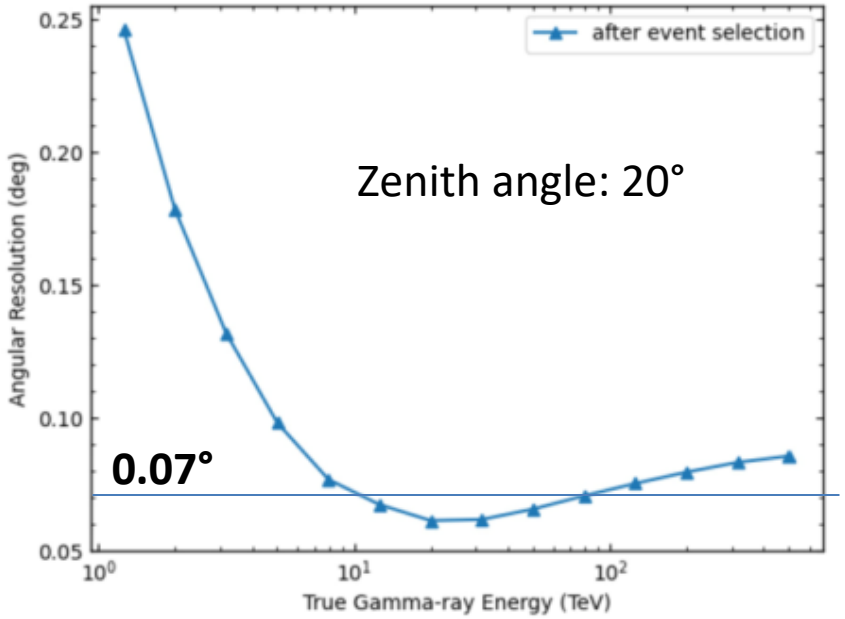


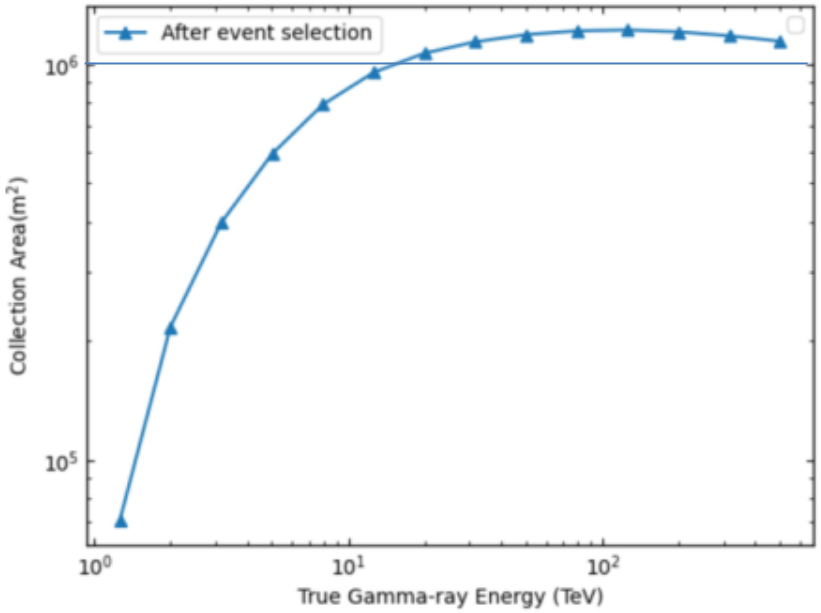
Table 2: **Observation times for specific sources by LACT between October 1, 2024, and April 1, 2025, categorized by zenith angles below 50° and between 50-70°. This calculation does not take weather conditions into account and represents an ideal scenario.**

Source	RA	DEC	0–50°	50–70°
SS433	19h10m37s	+05d02m13s	75h	152h
J1908+0621	19h08m12s	+06d21m0s	76.25h	154.75h
Galactic center	17h45m39.6s	-29d0m22s	0h	37h
J1825-134	18h25m49s	-13d46m35s	2.5h	99h
J2226+6057	22h27m0s	+60d57m	386h	371h
cygnus	20h31m33s	+41d34m38s	217h	233h

No.	UHE γ-ray Source	Type	Exposure (hours)
1	J0008+7303u	PWN /SNR /PSR	789.3
2	J0056+6346u		889.5
3	J0534+2200u	SNR/PSR	933.6
4	J0542+2311u	TeV Halo /PSR	947.2
5	J0634+1741u	TeVHalo Geminga	954.6
6	J0703+1405	TeV Halo /SNR /PSR	953.0
7	J2228+6100u	SNR /PSR	551.7
8	J2229+5927u	New source	550.6
9	J1837-0654u	PWN /SNR /PSR	119.7
10	J1843-0336u	SNR /PSR	142.6
11	J1908+0615u	SNR /PSR	208.2
12	J2018+3643u	PWN /PSR	350.1
13	J2031+4126u	SNR /PSR	373.4

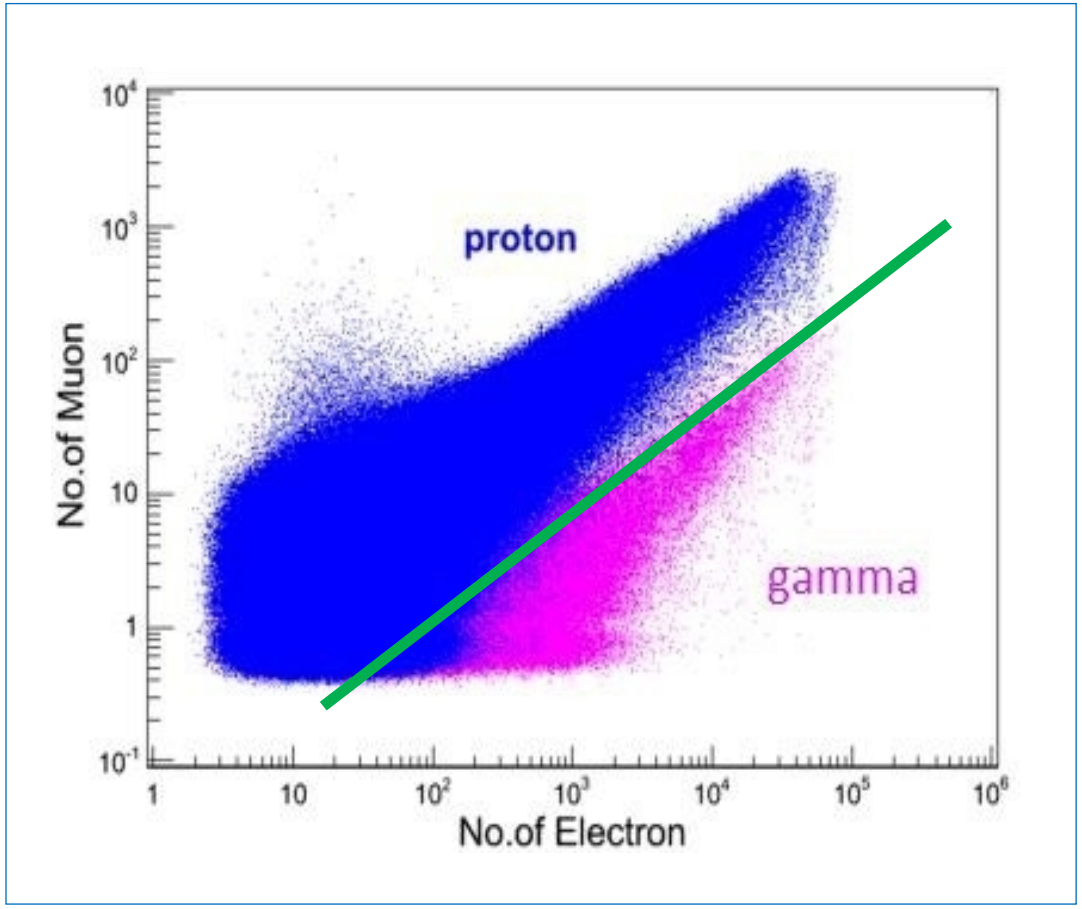


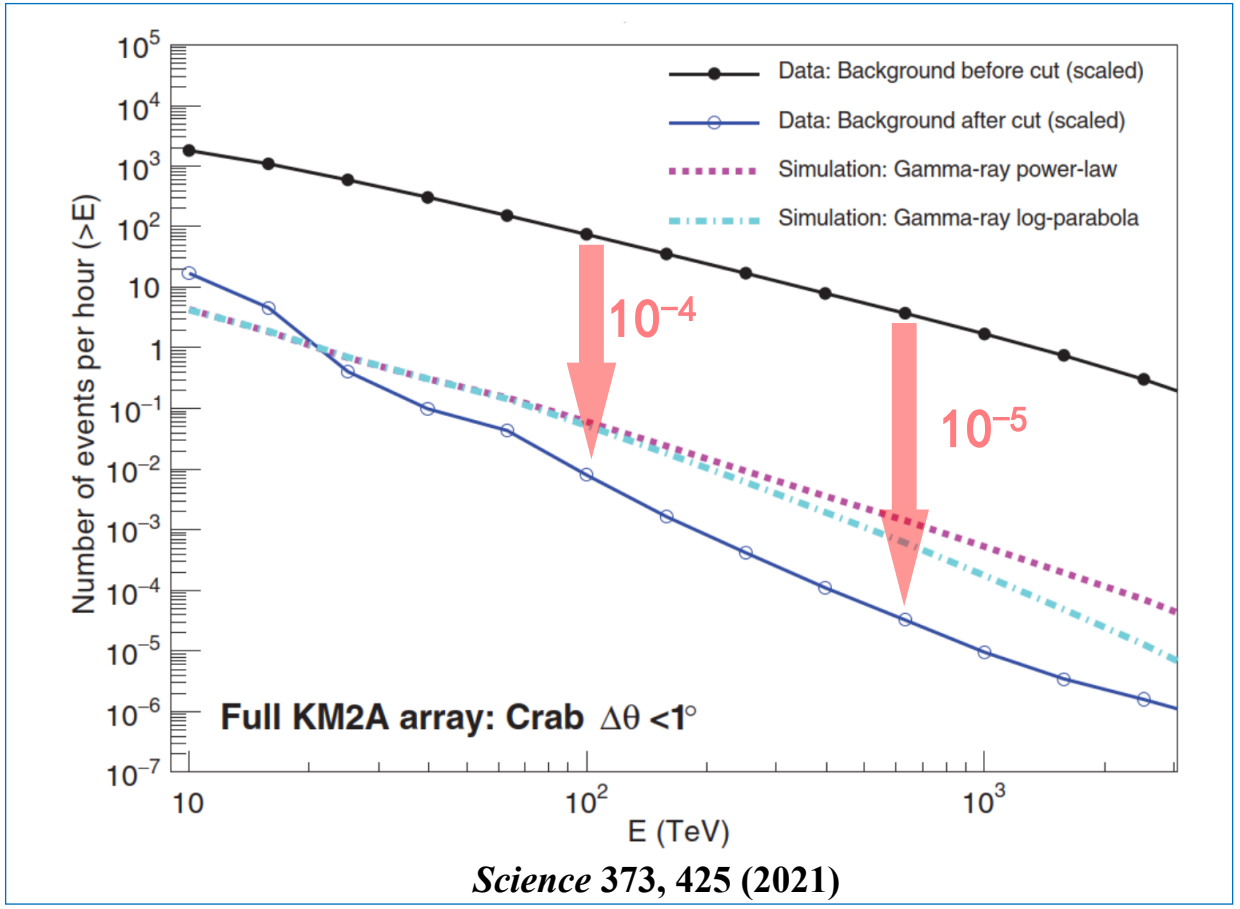




- **8 telescopes for small zenith angle observations for ultra-high energy events**
- **Getting higher Threshold Energy**
- **Collection area: 1.3 km²**
- **Angular resolution: ~0.07° @ 10 TeV**

Muon information from LHAASO

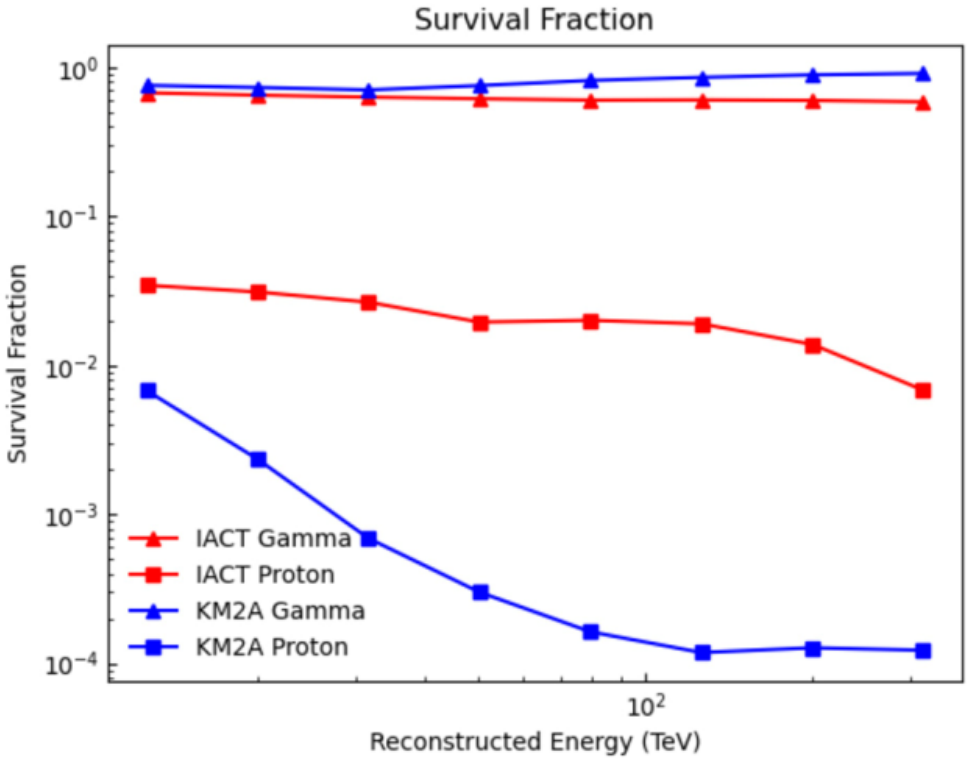




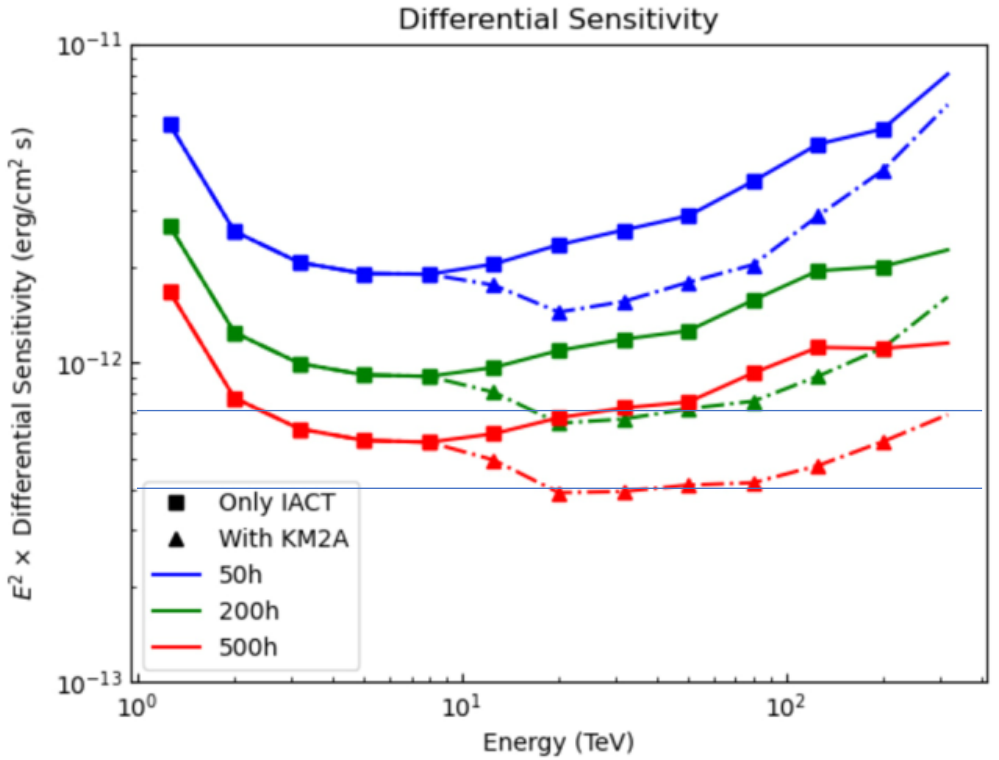
Science 373, 425 (2021)

Muon information from LHAASO

- The joint reconstruction of LACT and LHAASO muon detector array can increase the sensitivity of LACT by 1.6 times, especially for extended sources and long exposure time.



8 telescopes, zenith angle=20°

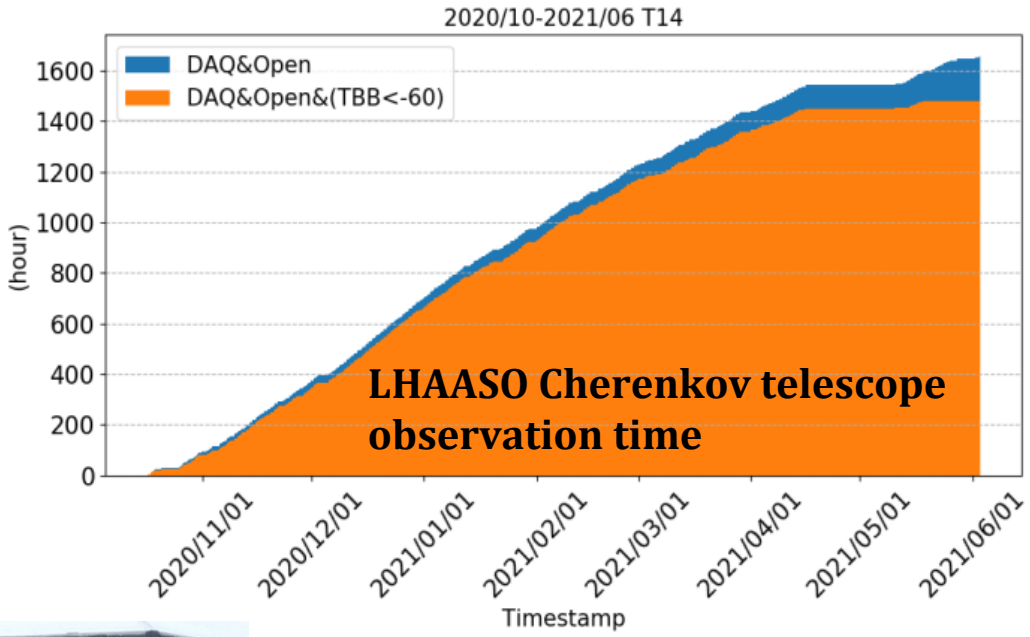


Sensitivity of extended source

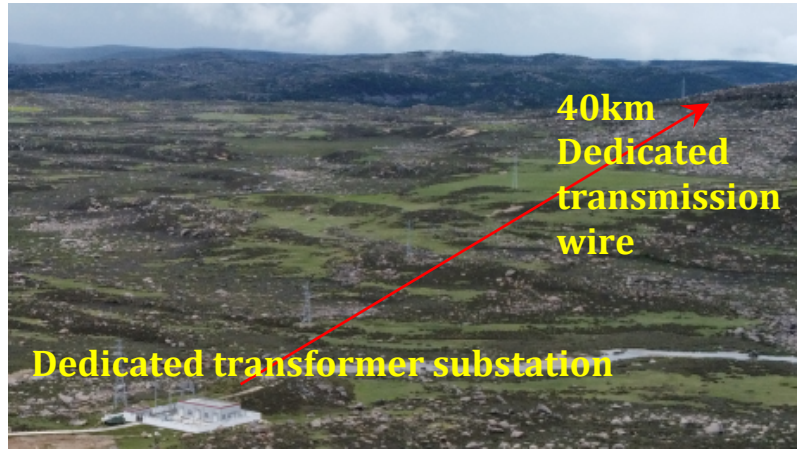
Zhipeng Zhang, Ruizhi Yang, Shoushan Zhang et al., Journal of High Energy Astrophysics 43 (2024) 280–285

LACT on LHAASO site

- Altitude: 4410 m
- >50 km from Daocheng County: very low city background light
- Annual cumulative observation time: > 1400 h/year
- The site already has: power supply, network, computing, data center etc.
- Daocheng Base provides excellent logistical support
- Convenient transportation: 15 km away from Daocheng Airport

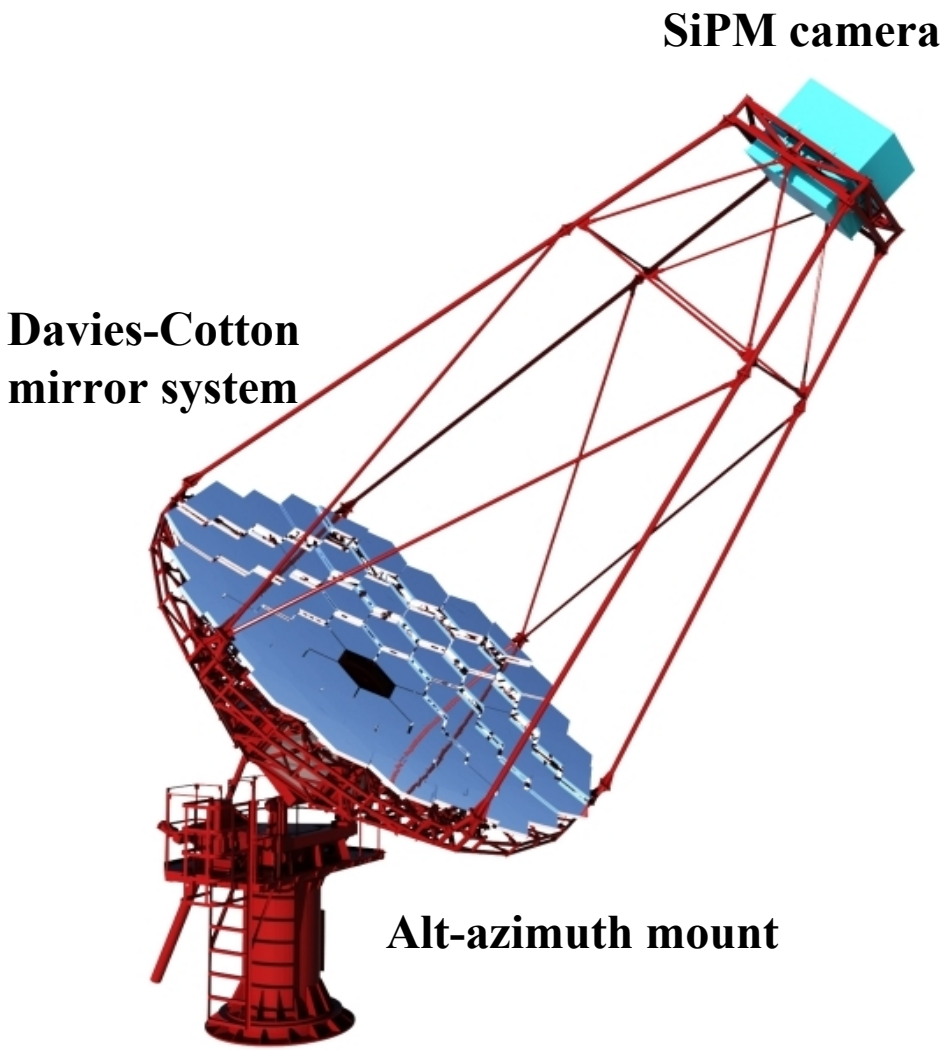


Full power backup power supply



LACT - telescope

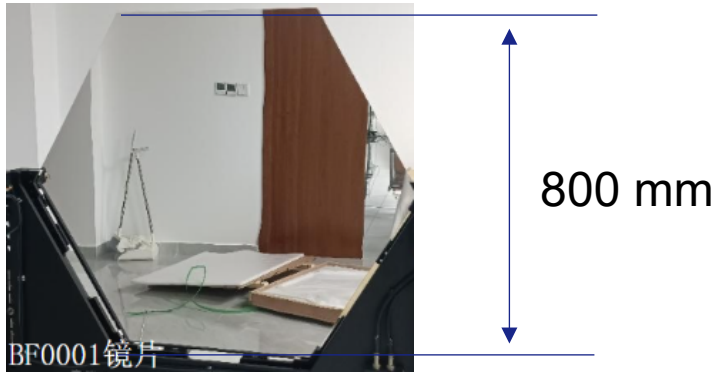
- Davies-Cotton mirror
- Alt-azimuth mount
- SiPM camera
- Readout electronics system
- Slow control system
- Data acquisition system
- Calibration system



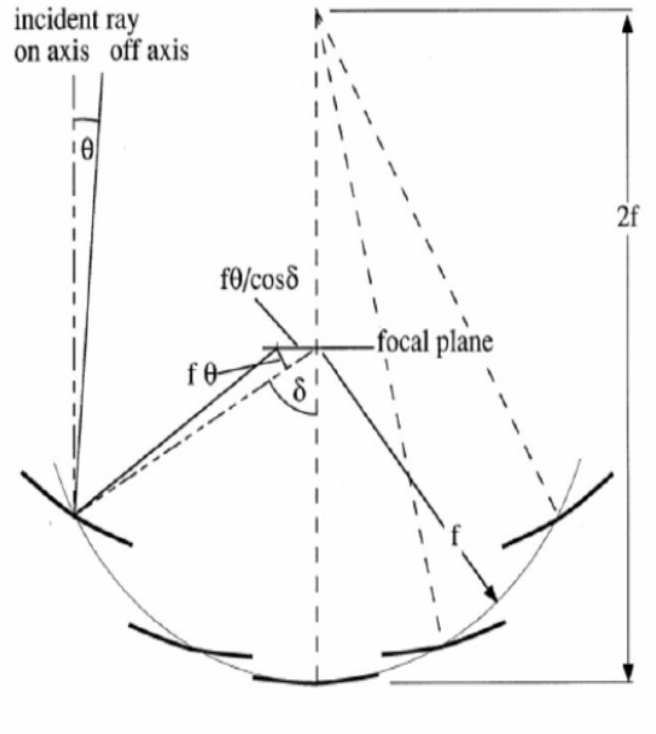
Mirror

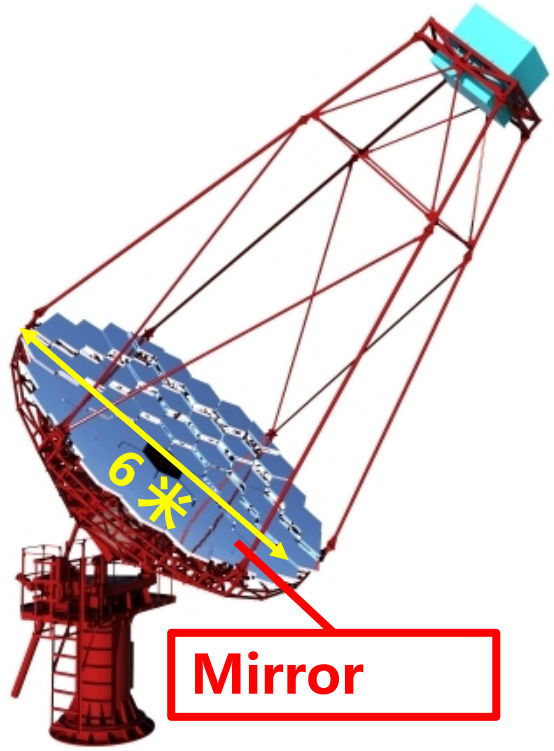
➢ Davies-Cotton design

- **Consist of 54 hexagonal spherical mirror facets**
- **Diameter：~6 m**
- **Effect area：~24 ㎡**
- **Spot （80% energy）： <25.8 mm**
- **Curvature radius of facet: 16 m**



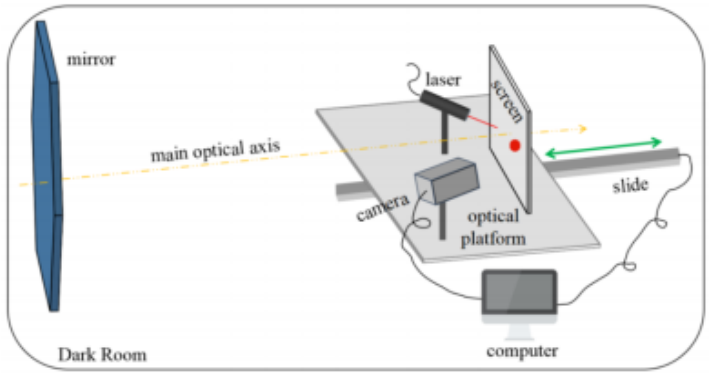
A mirror facet



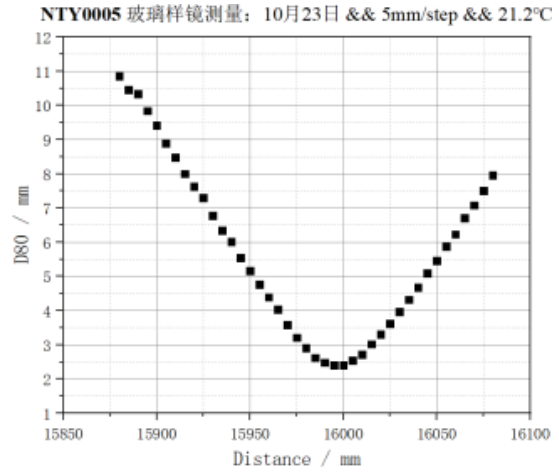


Mirror facet R & D and their performance testing

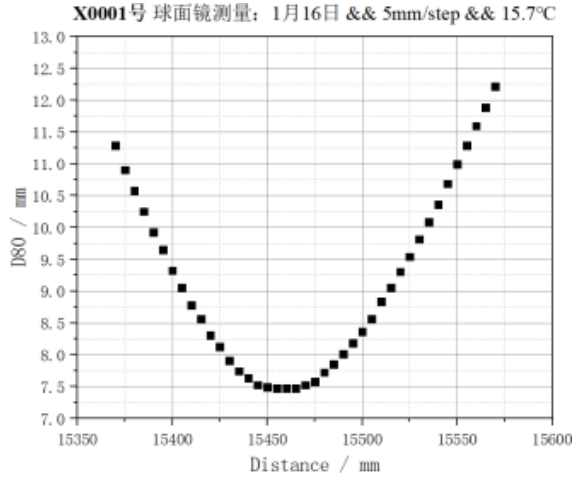
Mirror facet testing device



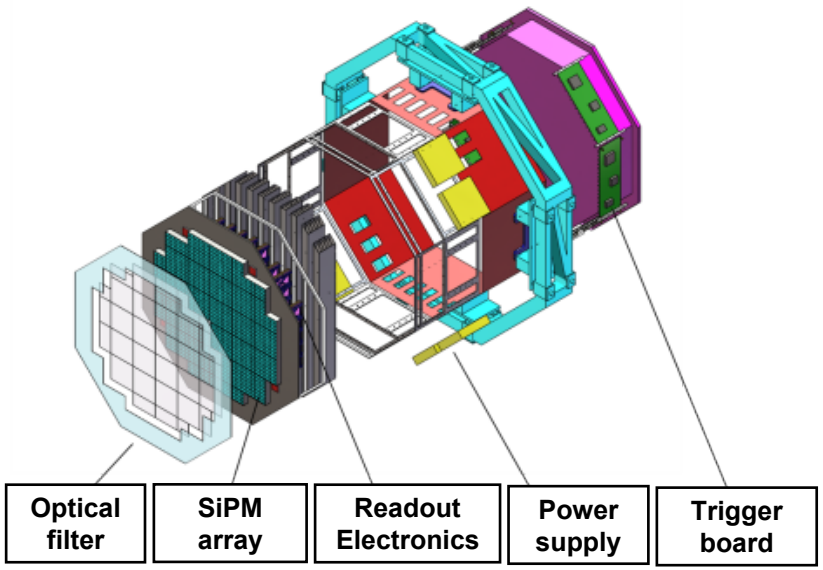
Full glass mirror facet



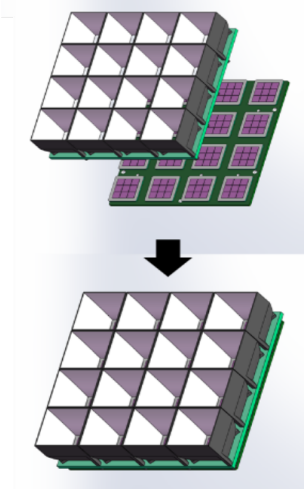
Honeycomb sandwich structure mirror facet



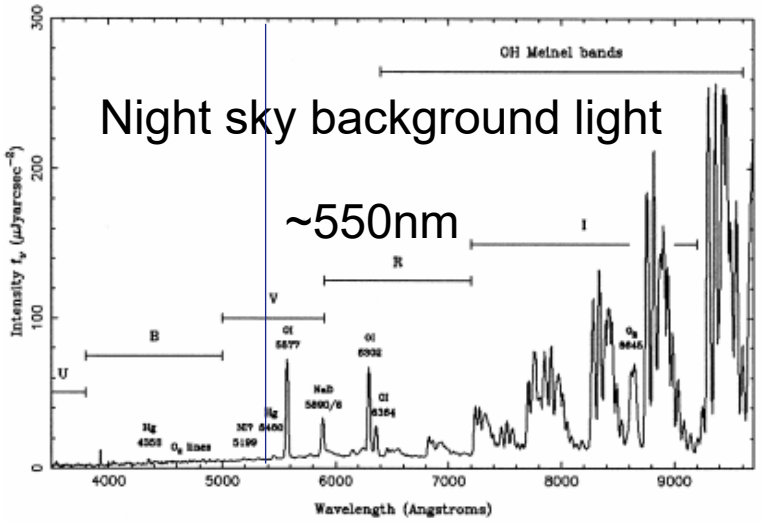
SiPM camera

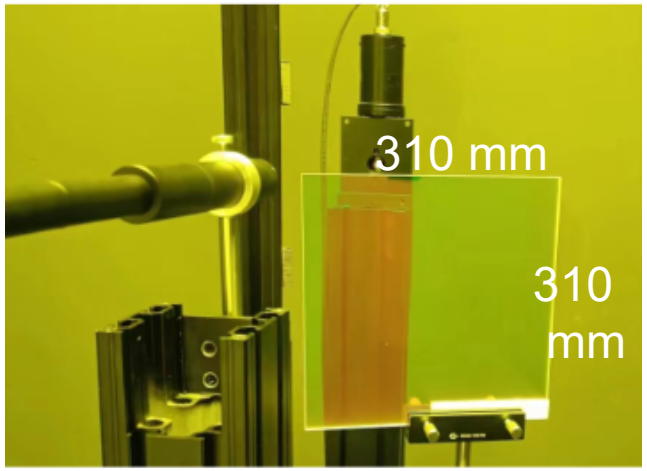


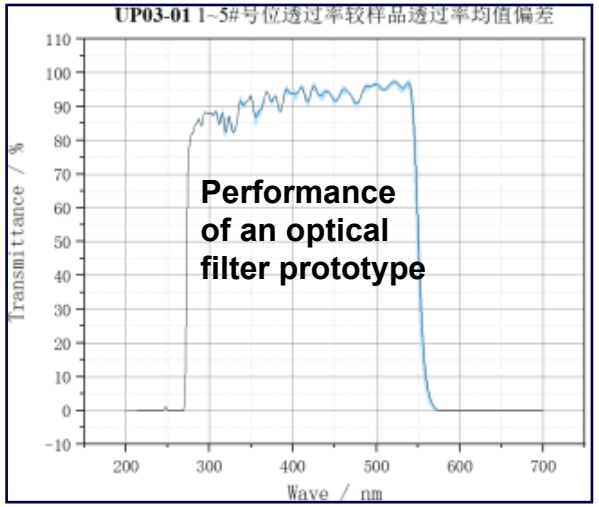
Number of pixels	1616
Pixels size	~ 0.2°
FoV	~ 8°
SiPM output pulse width	FWHM < 30 ns
Dynamic range of each pixel	3.2 orders of magnitude
Moon night observation capability	Yes



SiPM and Winstone cone sub-array





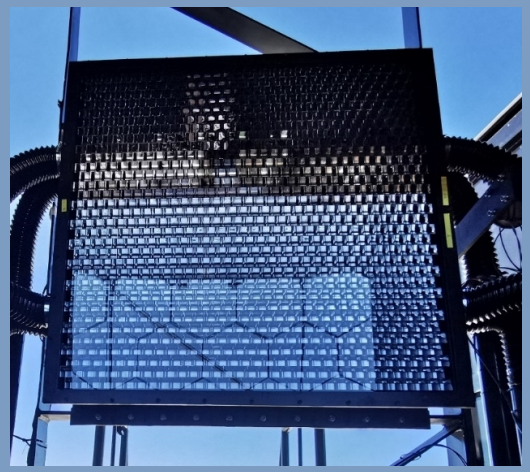


LHAASO small Cherenkov Telescopes for cosmic ray measurement

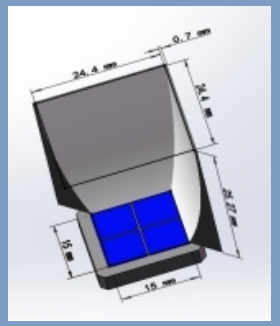
◆ Telescope parameters:

- ~5 m^2 spherical mirror
- Camera: 32×32 SiPMs array
- FOV: $16^\circ \times 16^\circ$
- Pixel size: 0.5°

Mirror

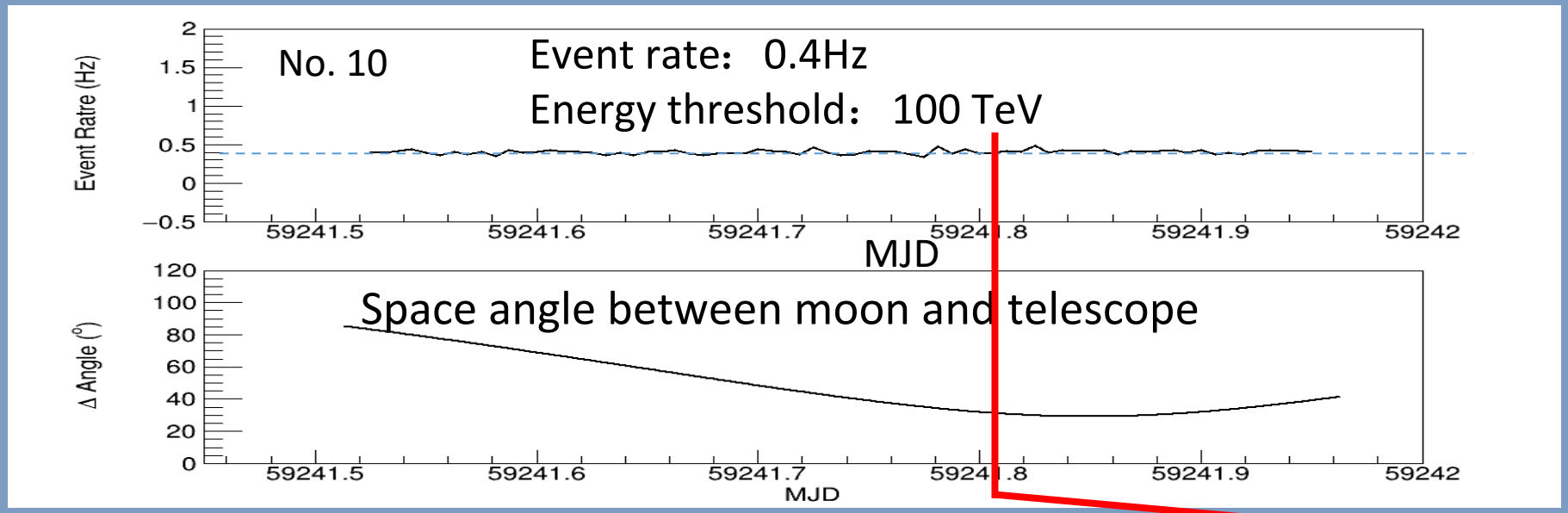


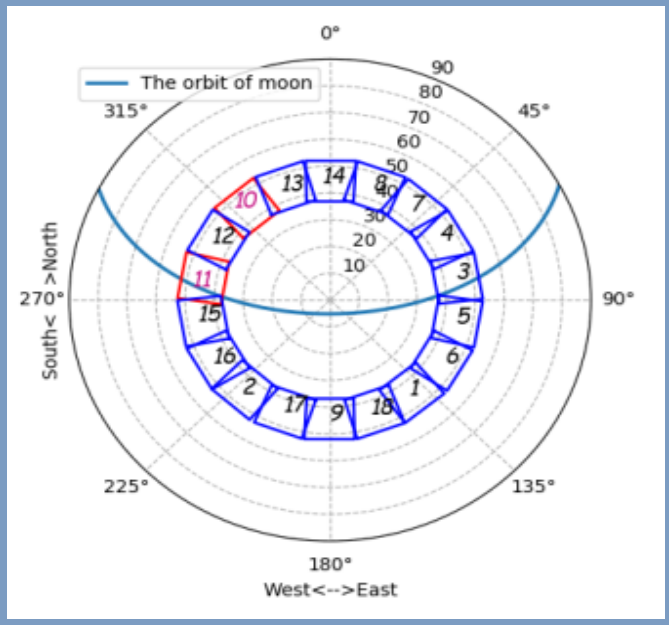
SiPM camera



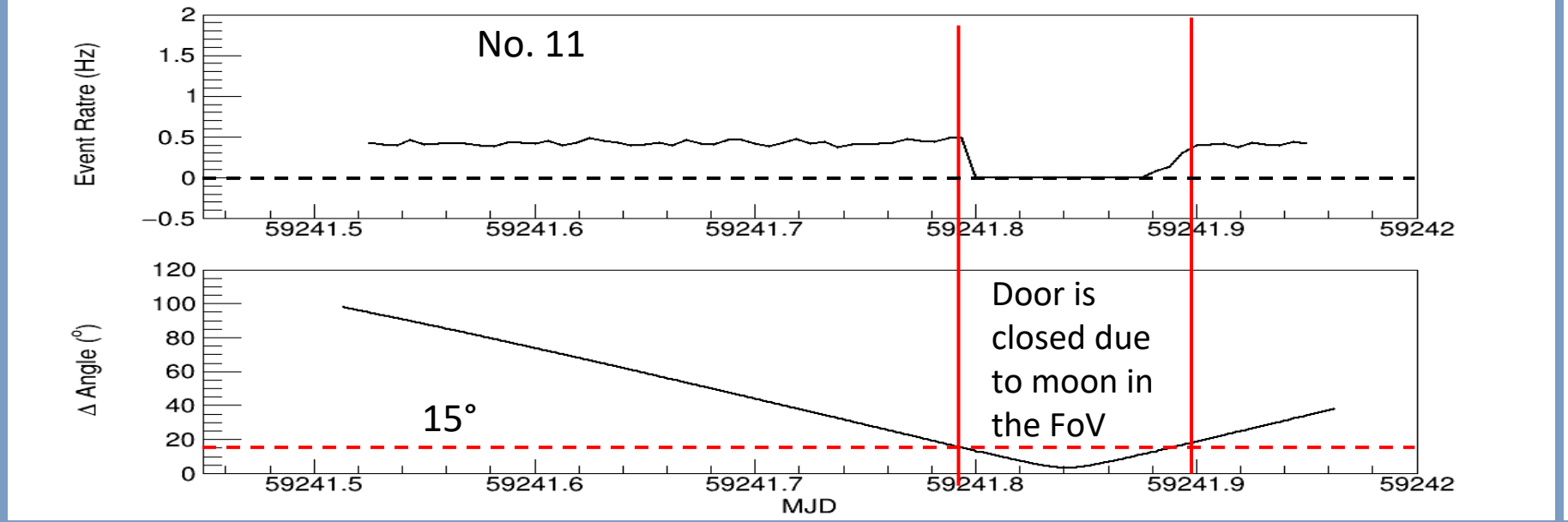
SiPM and Winstone cone

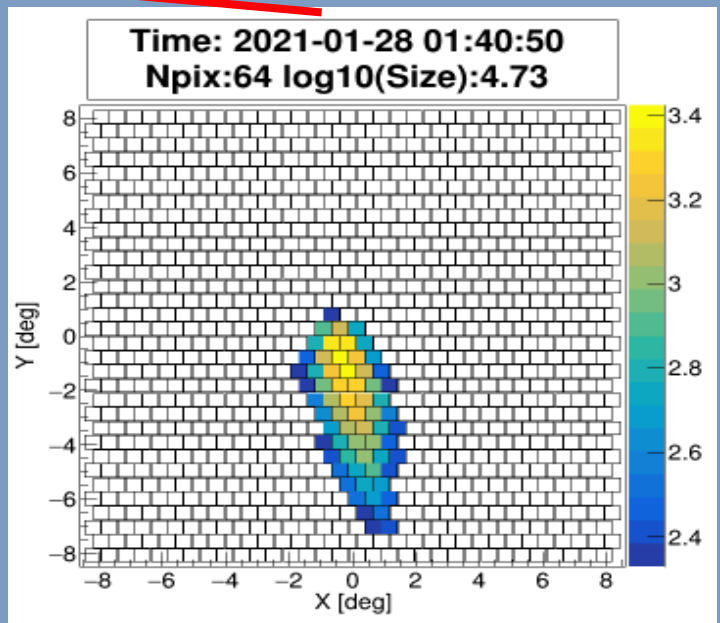
Telescope observation on the full moon night





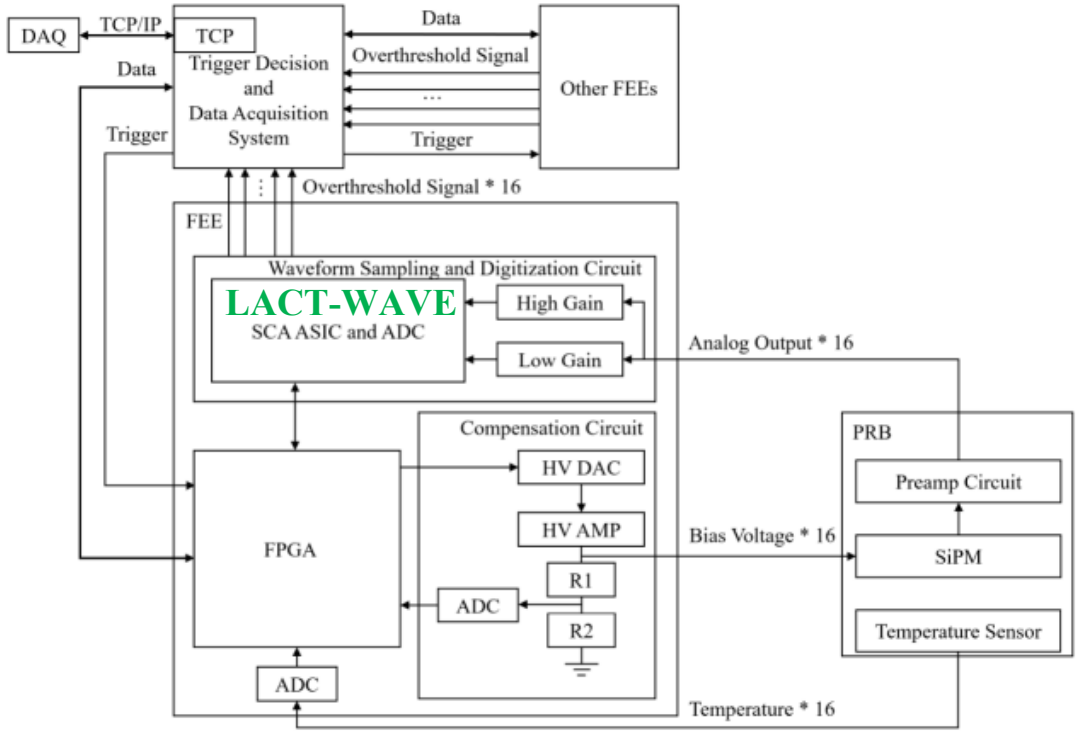
SiPM camera: LHAASO Coll., Eur. Phys. J. C (2021) 81:657

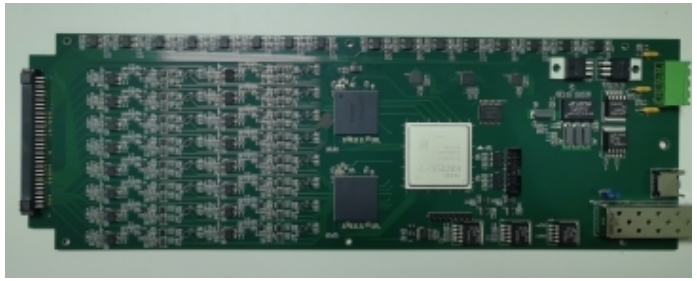


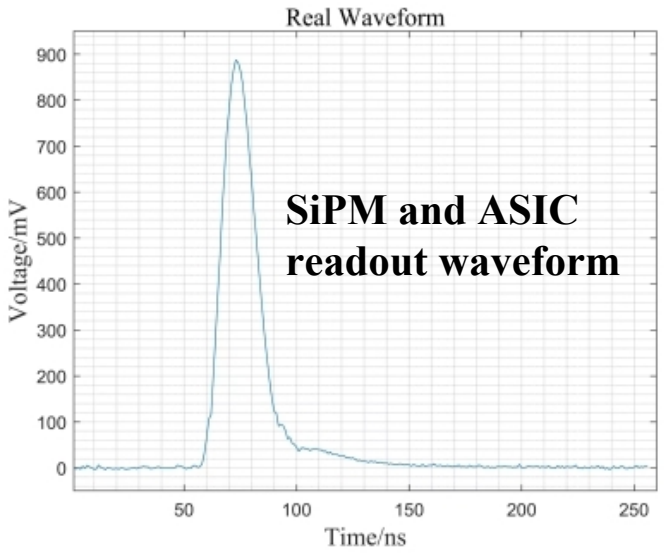


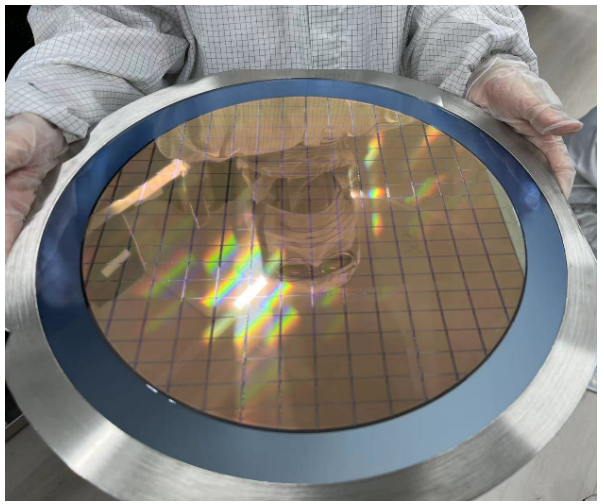
Readout electronics system

- LACT-WAVE
  - ASIC designed for LACT
  - 1 GHz sampling，10 bits ADC
- Dual gain design, meeting 3.2 orders of magnitude





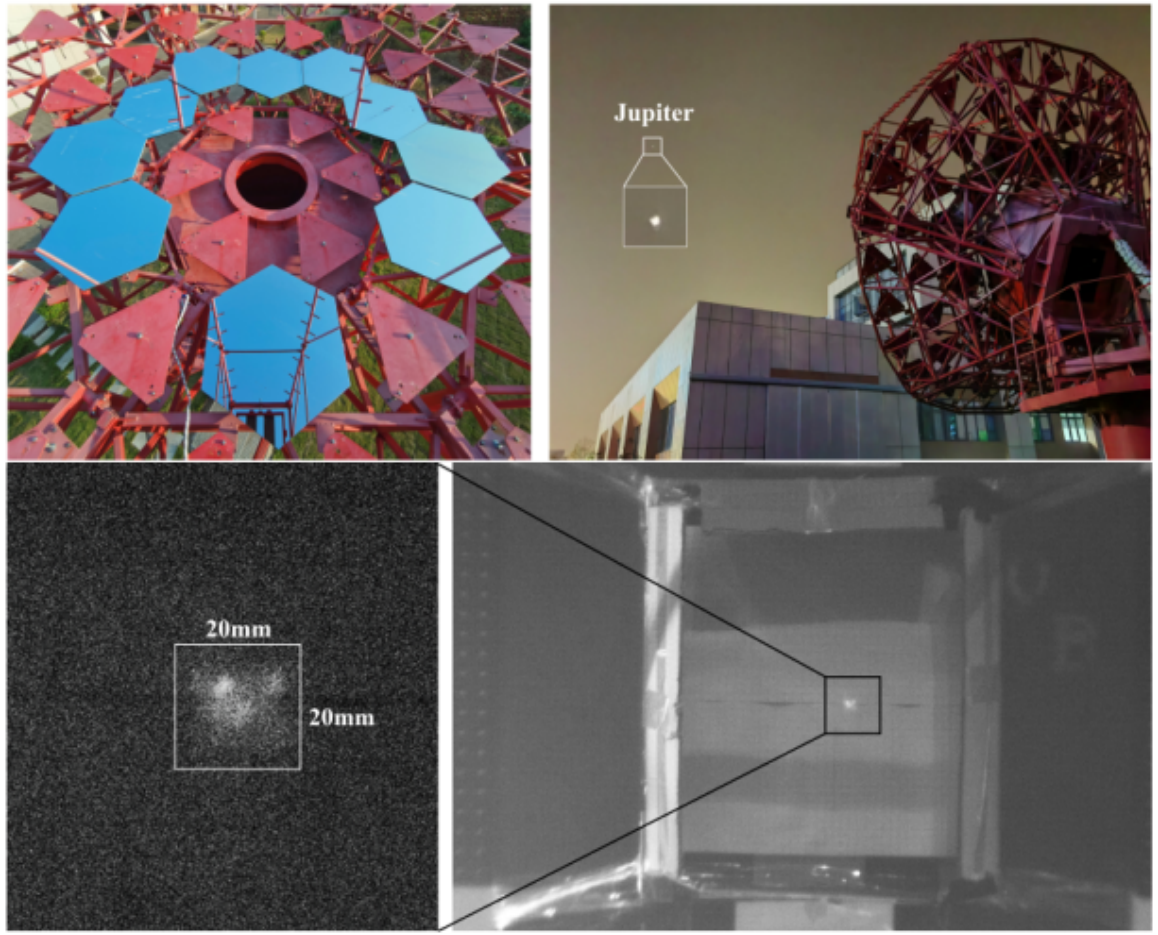




LACT-WAVE
designed by IHEP

A prototype in LHAASO

A prototype in Chengdu



- A prototype of LACT installed at the Tianfu Cosmic Ray Research Center, with 10 mirror facets installed on the telescope.
- It observed the spot imaging of Jupiter (with a visual magnitude of approximately -2.9) on the focal plane, with almost all photons focused within a square frame with a side length of 20mm, which is smaller than the pixel size (25.8m × 25.8mm) and better than our design requirements.

Shoushan Zhang, Yudong Wang et al., Large Array of imaging atmospheric Cherenkov Telescopes (LACT): status and future plans, PoS (ICRC2023) 808

LACT Construction Plan

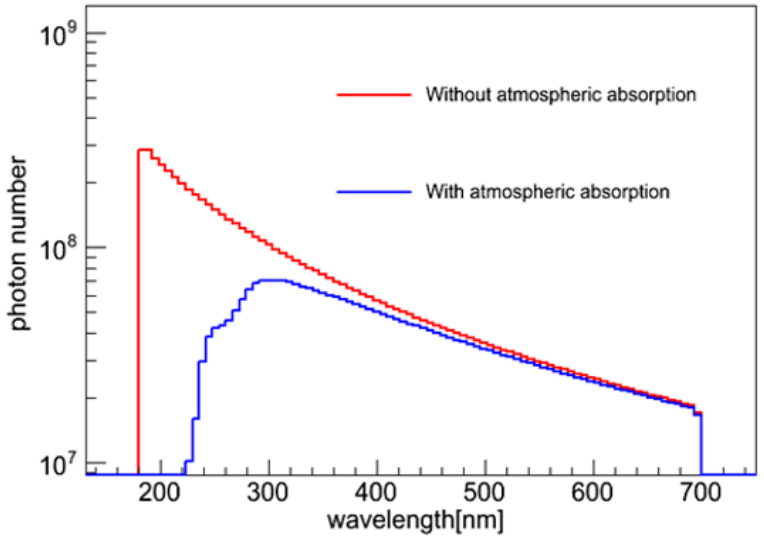
	Construction plan	2024	2025		2026	2027	2028
		1-12	1-7	8-12	1-12	1-12	1-12
1	First telescope optimization and commissioning						
2	Second telescope construction and commissioning						
3	The next six telescopes construction and commissioning (total 8 tels)						
4	The full array complete the construction and commissioning (total 32 tels)						

Summary

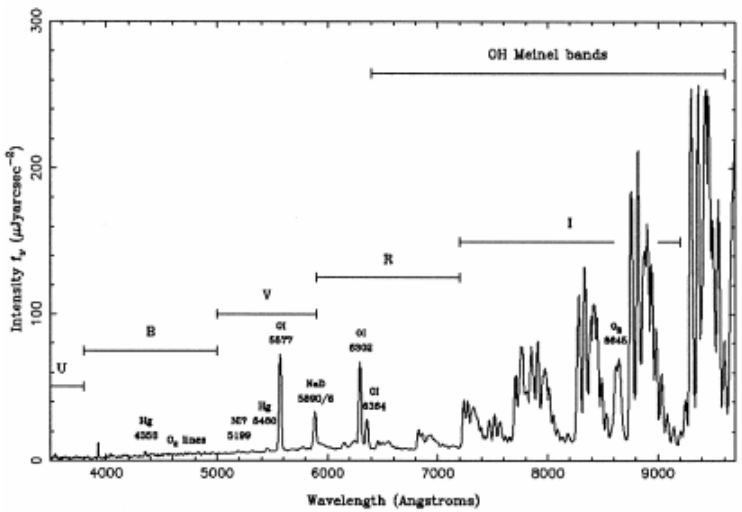
- **LHAASO has been stably operating since 2021**
  - **43 UHE γ-ray source are detected and started a new era of UHE γ-ray astronomy**
  - **LHAASO angular resolution: ~0.3° @ 30 TeV**
- **Next generation IACT: Large Array of Cherenkov Telescopes（LACT）**
  - **Plan to build 32 telescopes in the LHAASO detector array**
  - **LACT angular resolution: < 0.05° @ > 10 TeV**
  - **The LHAASO muon array can offer excellent gamma-hadron discrimination, thus，the sensitivity of the LACT can be significantly enhanced.**
  - **Main scientific goal: morphology of PeVatrons and locating UHE γ-emitters**
- **LACT project will soon receive support and have started construction this year**
- **One prototype will start operating next year and 8 telescopes will be completed by 2026, and the full array will be completed by 2028**

Thank you!

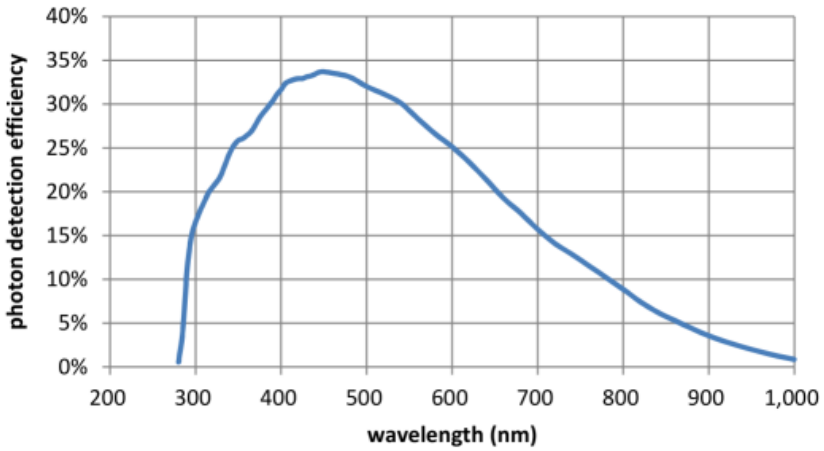
夜空背景光影响抑制方案



Cherenkov light spectrum



Night sky background light



SiPM PDE

（WFCTA HAMAMATSU-S14466）