中国科学院高能物理研究所

Large Array of imaging atmospheric Cherenkov Telescope

Performance and Characteristics of the First LACT Telescope

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2025.8.15 西昌(Xi Chang)

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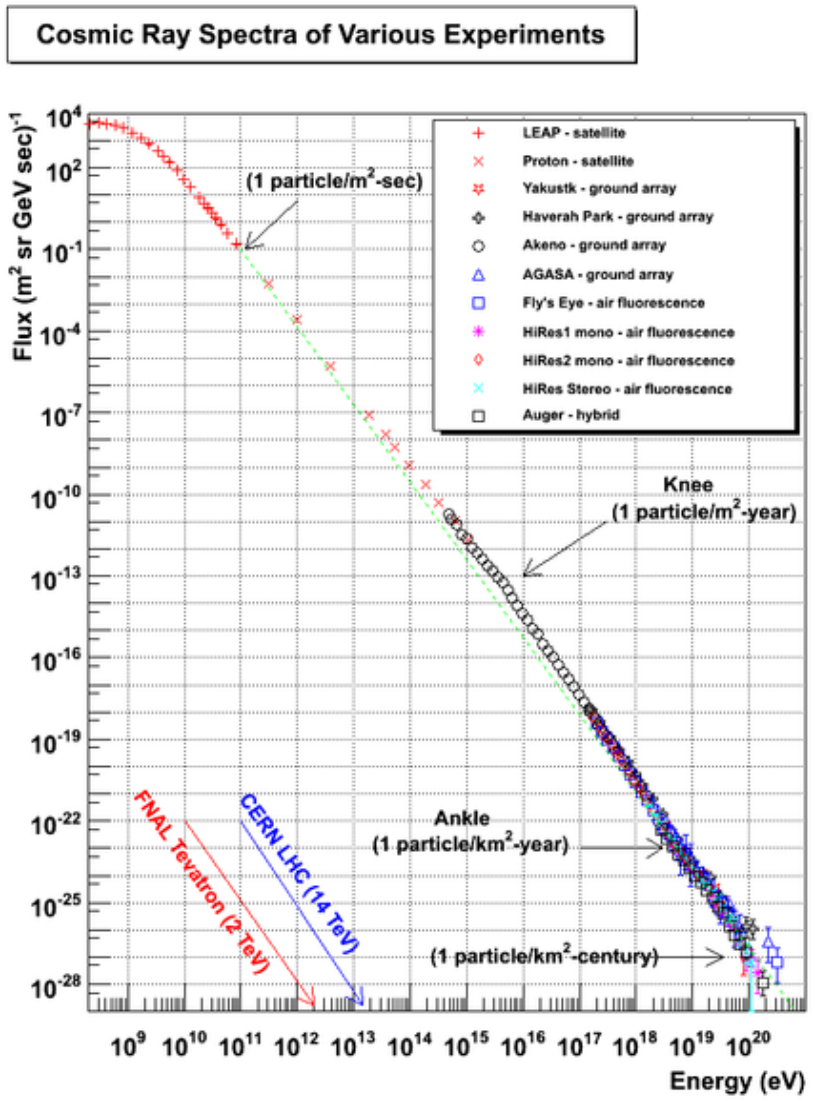
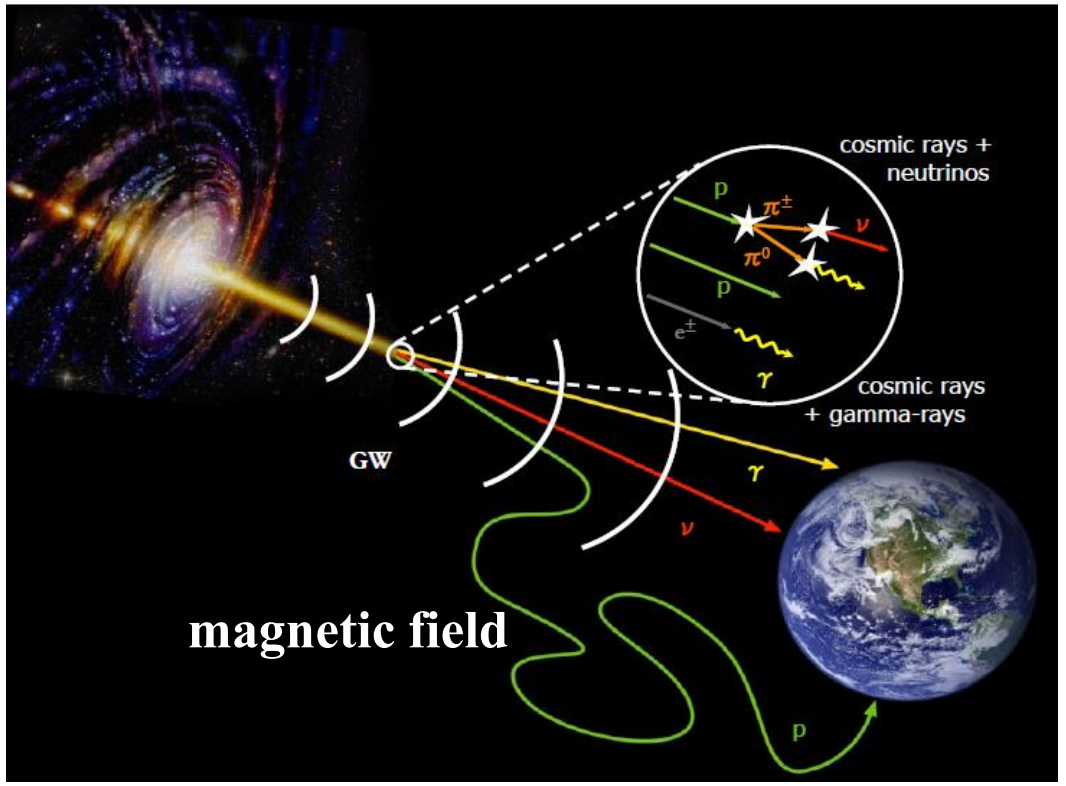
Motivation

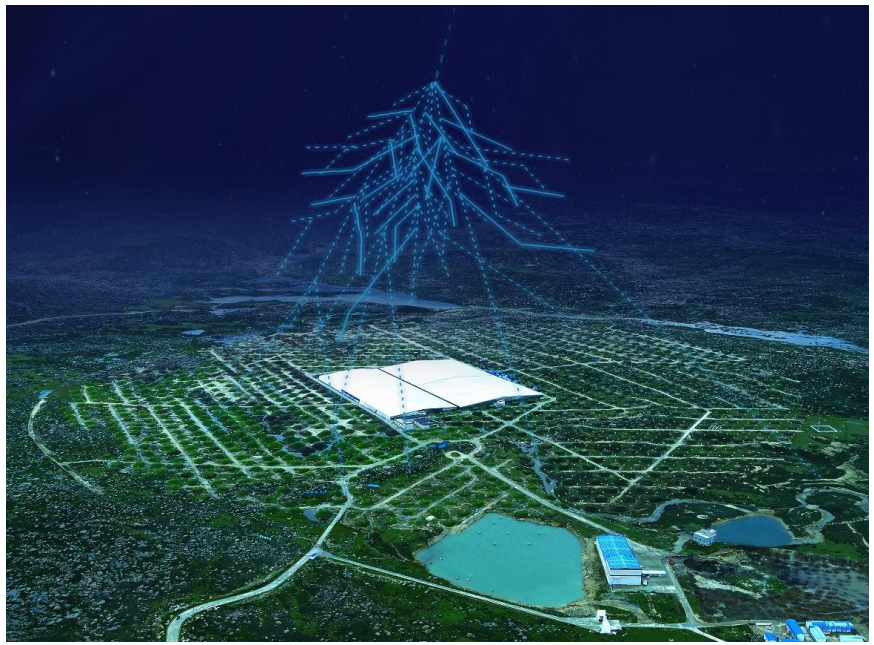


Where are (ultra) high energy cosmic rays from?



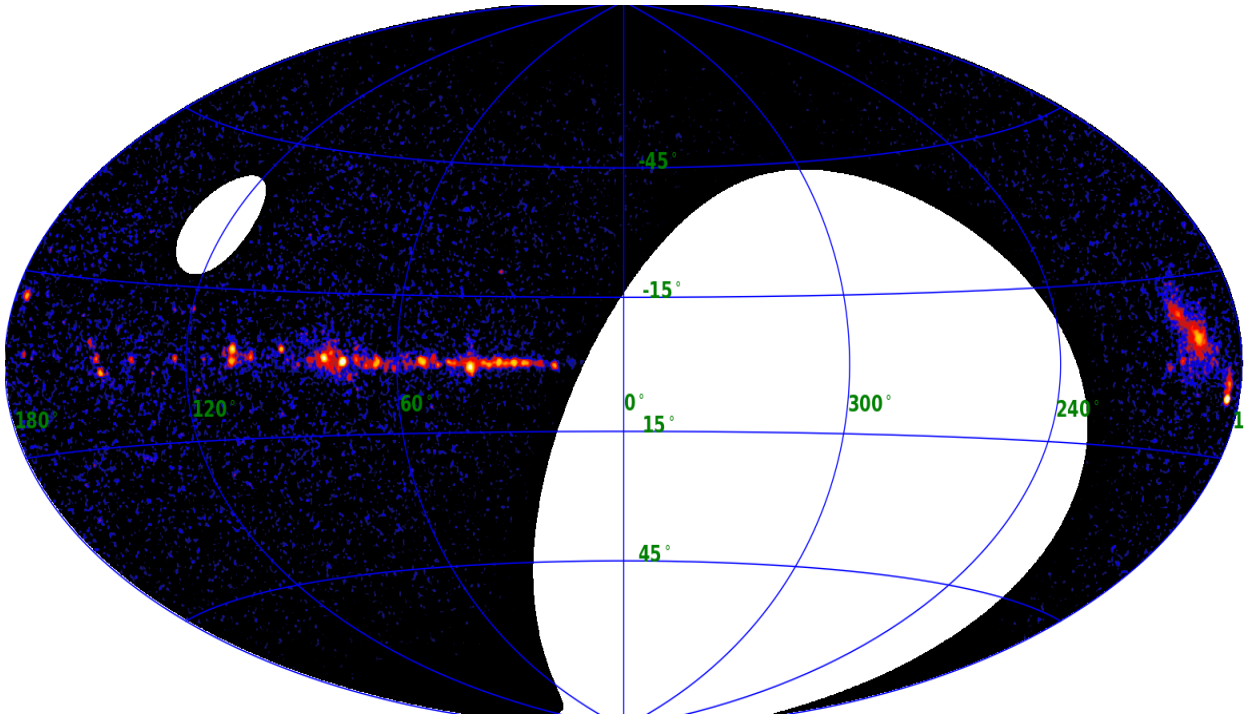
Gamma rays travel in straight lines.

Motivation



LHAASO, 4410 m, Full array: 2021 July

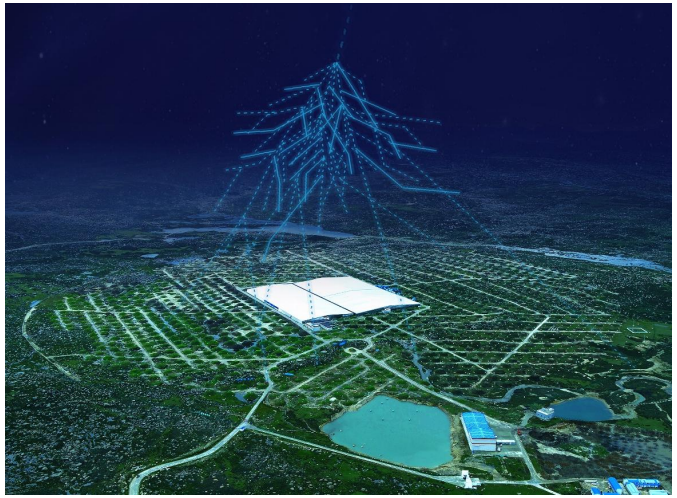
The most powerful operating gamma-ray all-sky survey observatory in the world.

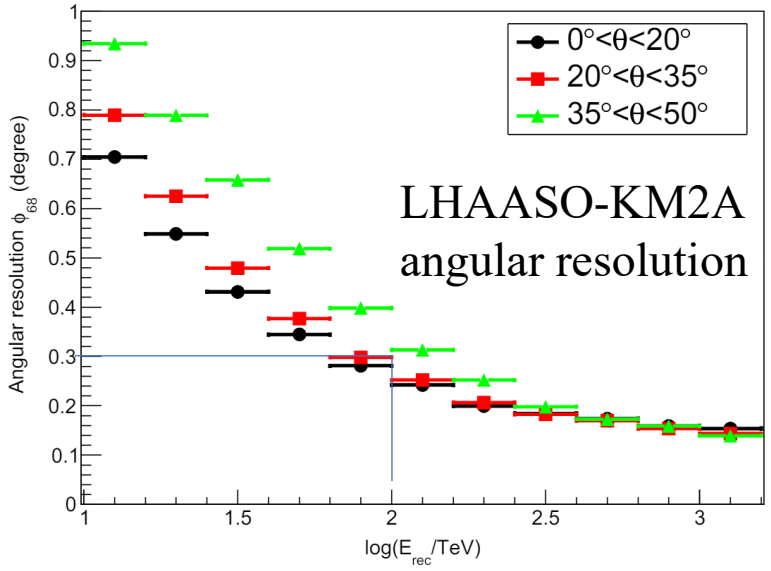


Discovered 43 ultra-high-energy gamma-ray sources

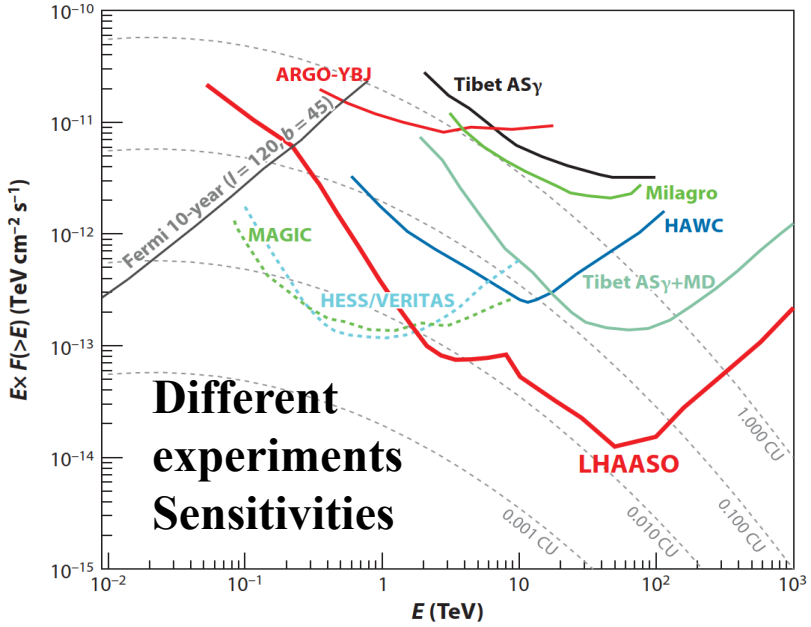
Opened a new window on ultra-high-energy gamma-ray astronomy

Motivation





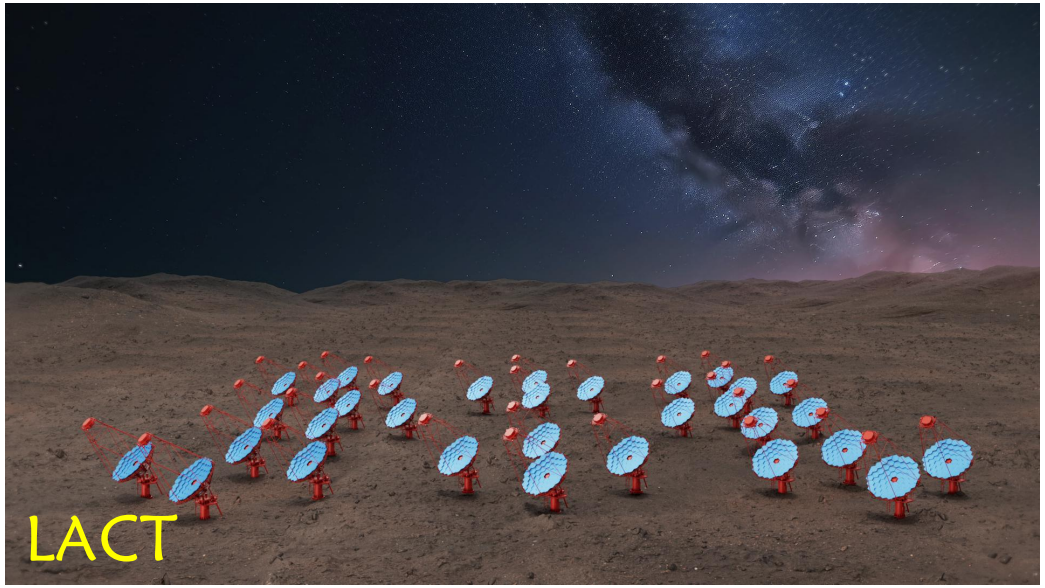
LHAASO all-sky survey
large field of view and high sensitivity
the angular resolution is about 0.3° at 100 TeV
insufficient to resolve nearby sources or the fine internal structure

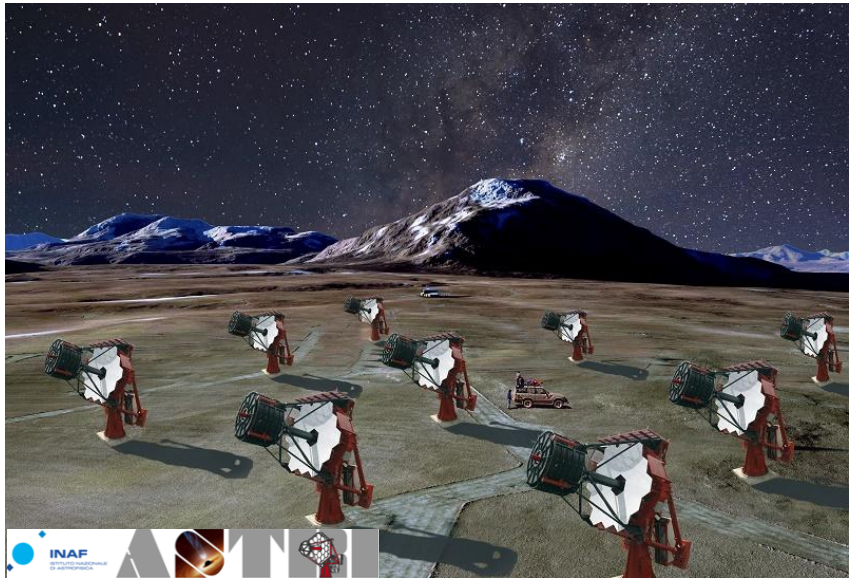


MAGIC VERITAS HESS

Angular resolution is about 0.05°, good enough, however, **the sensitivities of existing Cherenkov telescope arrays is critically low.**

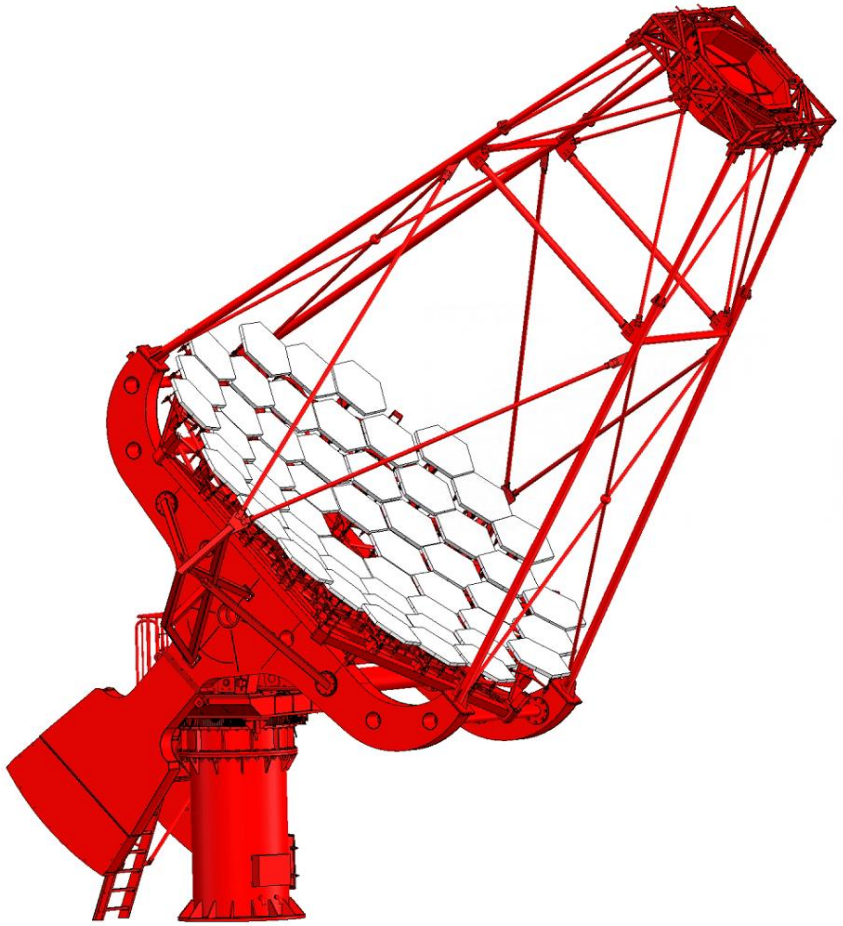
Motivation





2 Characteristics

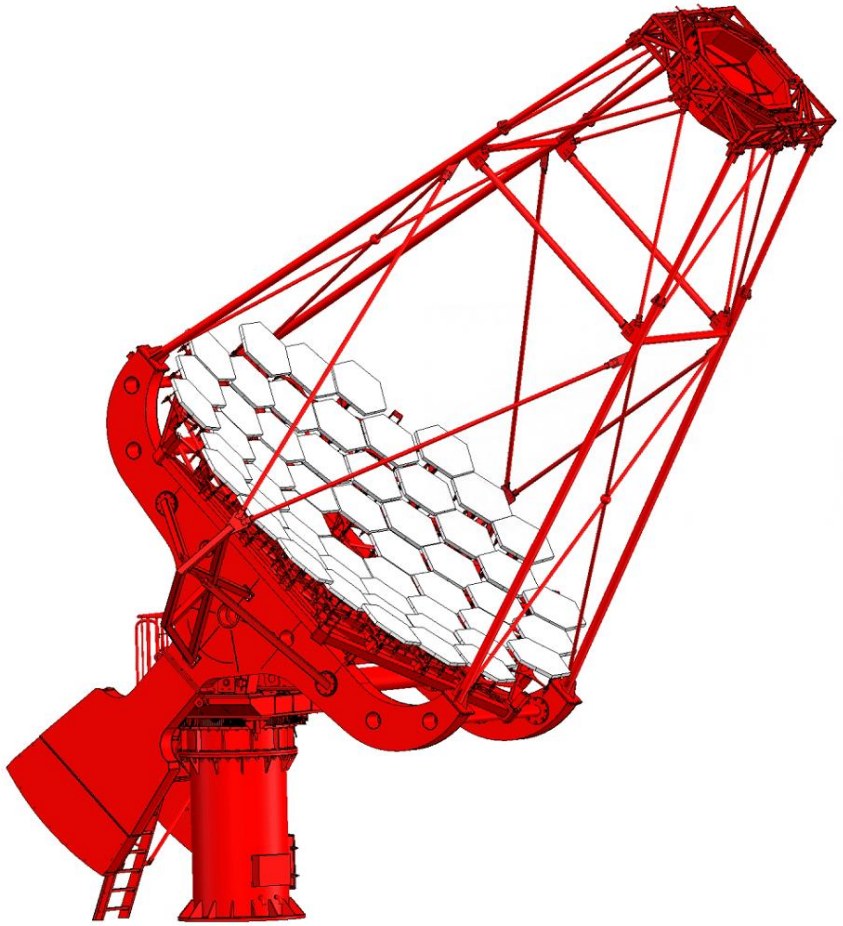
LACT



Main parts of LACT telescope

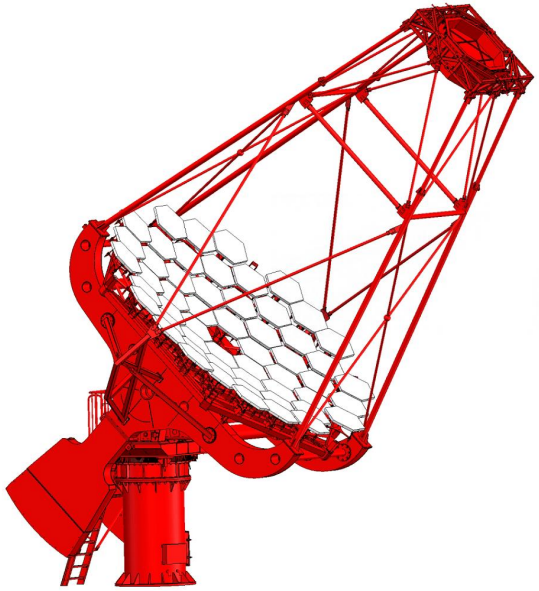
- ☐ Support and drive mechanism system
- ☐ Davies-Cotton reflector system
- ☐ SiPM camera
- ☐ Data acquisition system
- ☐ Slow Control system
- ☐ Calibration system

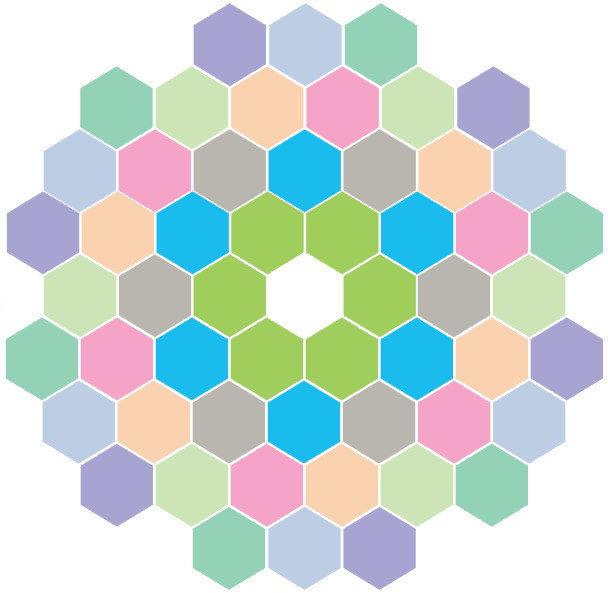
LACT Support and drive mechanism system

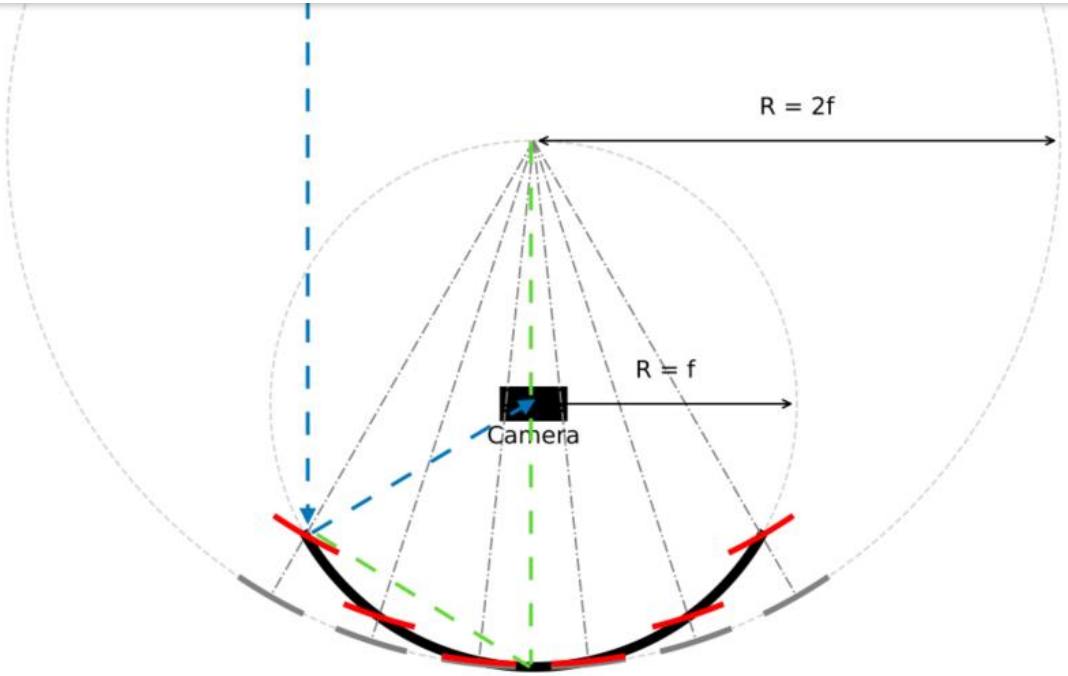


Parameter	values
Telescope Tracking System Rotation Performance	a) Azimuth Angle: ±270° b) Elevation Angle: -3~90° c) Maximum Azimuth Speed: 1°/s Maximum Elevation Speed: 1°/s
Pointing Accuracy	≤0.01°
Repeatability	≤0.01°
Camera Support Deformation	< 4 mm
Wind Resistance Performance	a) Normal operation at wind speeds up to 10 m/s b) Can be driven to stowed position at wind speeds up to 15 m/s c) No damage in stowed position at wind speeds up to 30 m/s

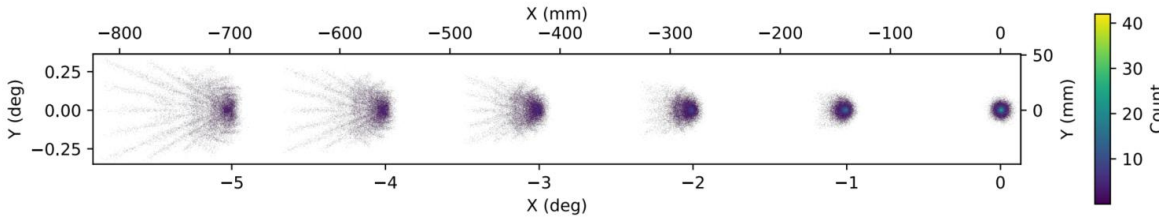
LACT optical system Davies-Cotton structure



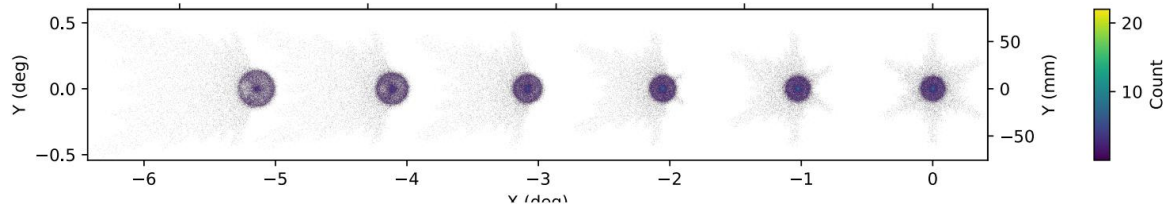




Parameter	Value
Primary mirror diameter	~ 6 meters
Focal Length	8000 mm
Effective Area	~24 m²
Spot Size (80% intensity)	< 14 mm (0.01°)
Sub-mirror Curvature Radius	16 m
hexagonal spherical mirror segments	54

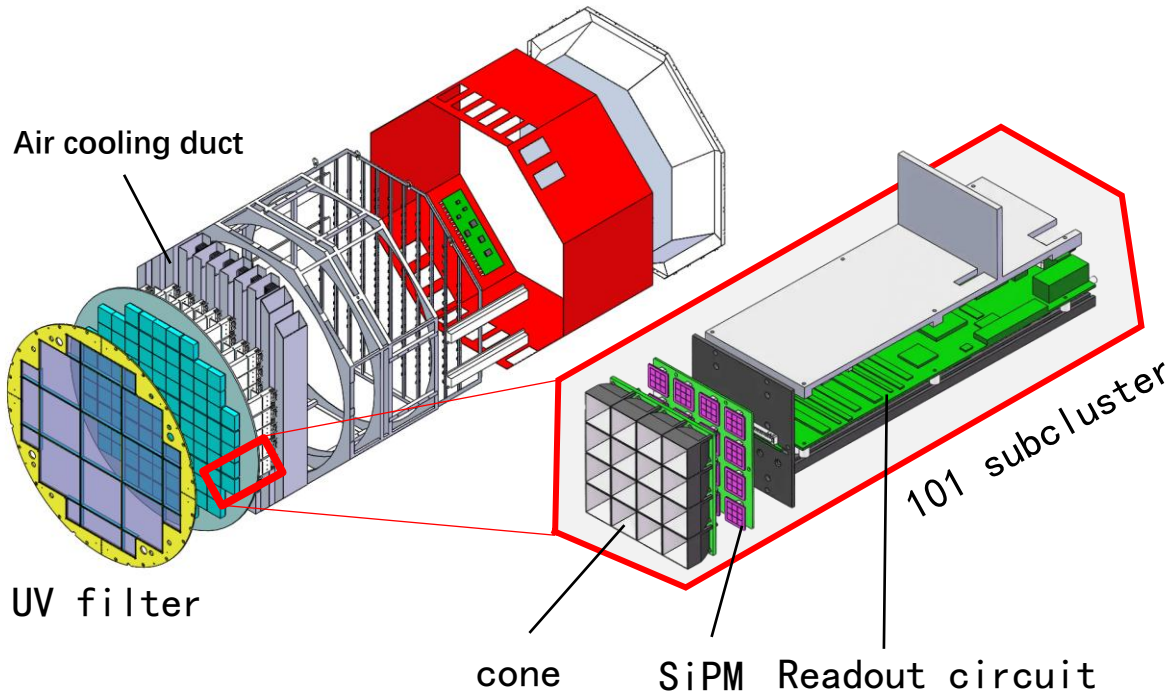


DC

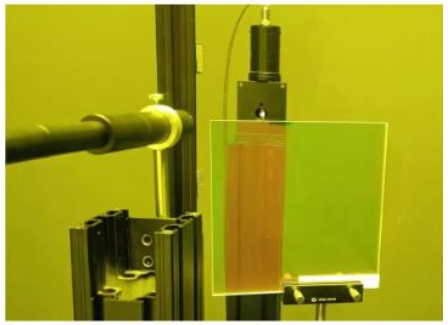


Sphere

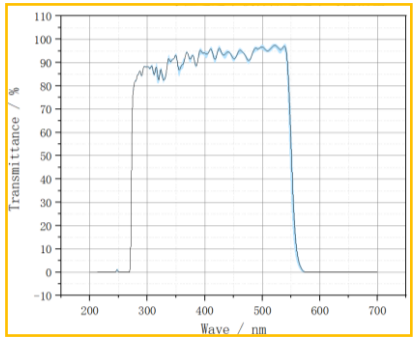
LACT SiPM camera



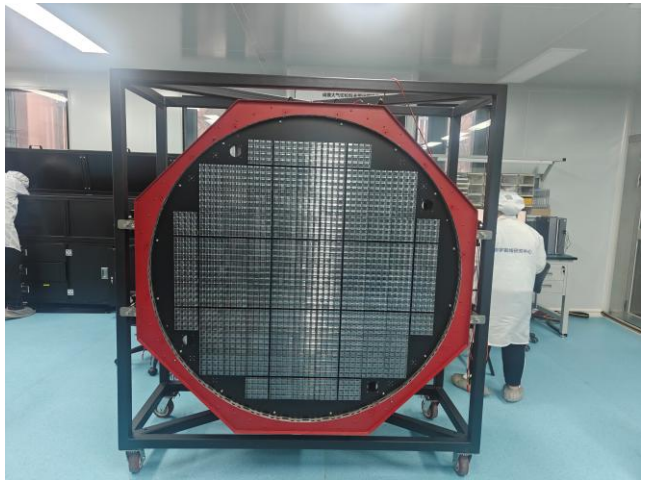
parameter	value
The number of pixels	1616
Pixel size	~ 0.2°
Field of view	~ 8°
Output pulse width	FWHM < 30 ns
Dynamic range	3.2 orders of magnitude
Charge resolution	< 5% @ > 1000 P.E.



UV filter



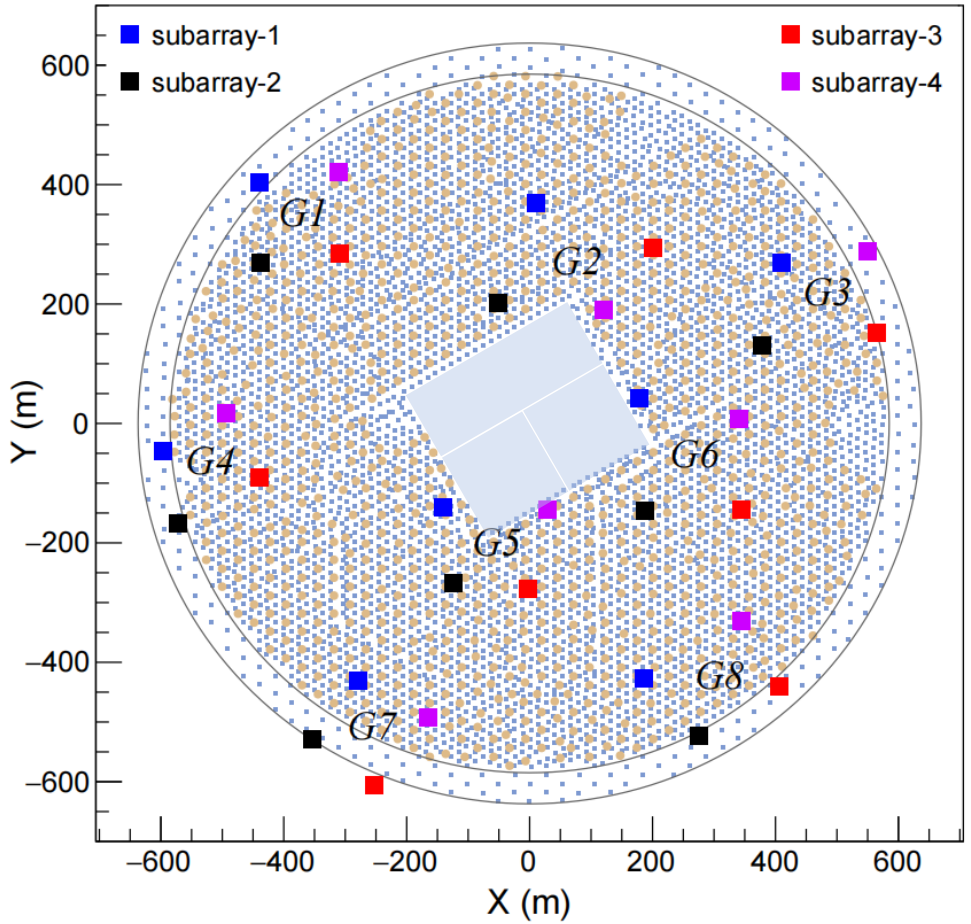
Transmittance spectrum curve

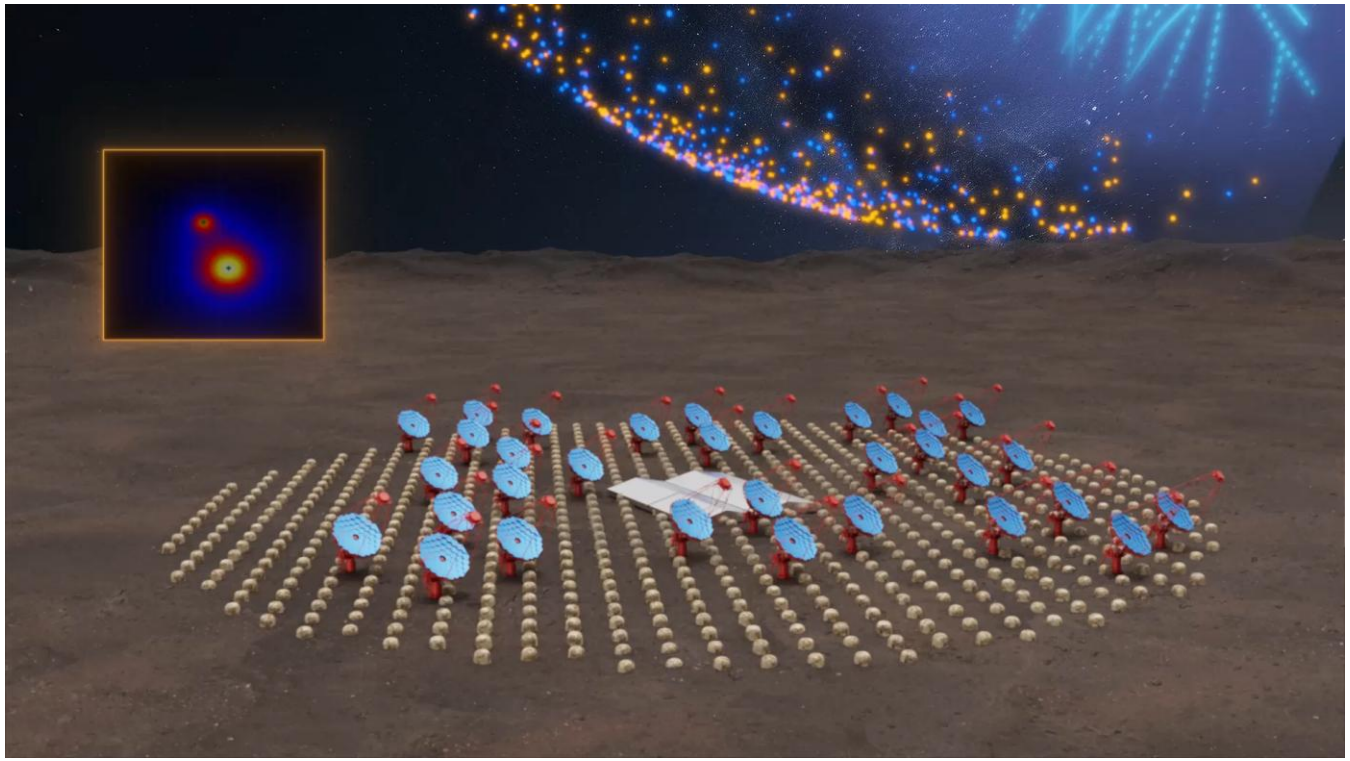


More details shown in Yang Mingji's report:

Design plan and development progress of the LACT SiPM camera

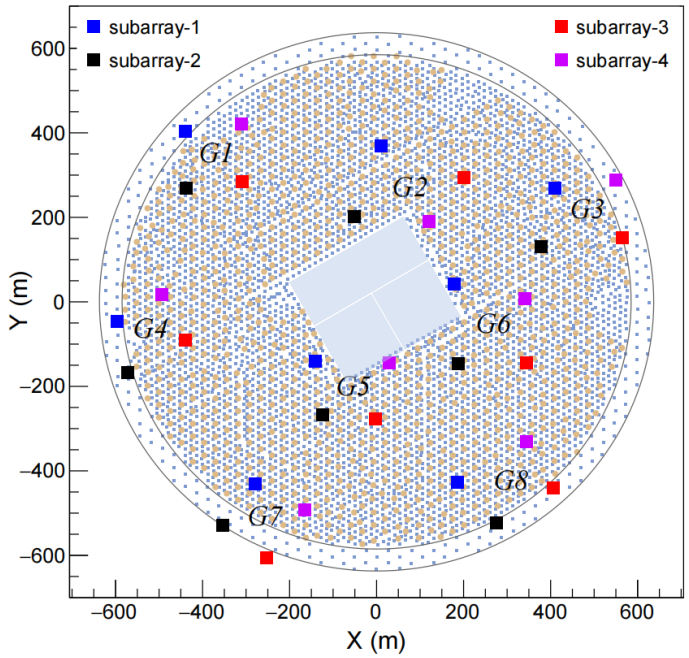
LACT Work with muon detectors



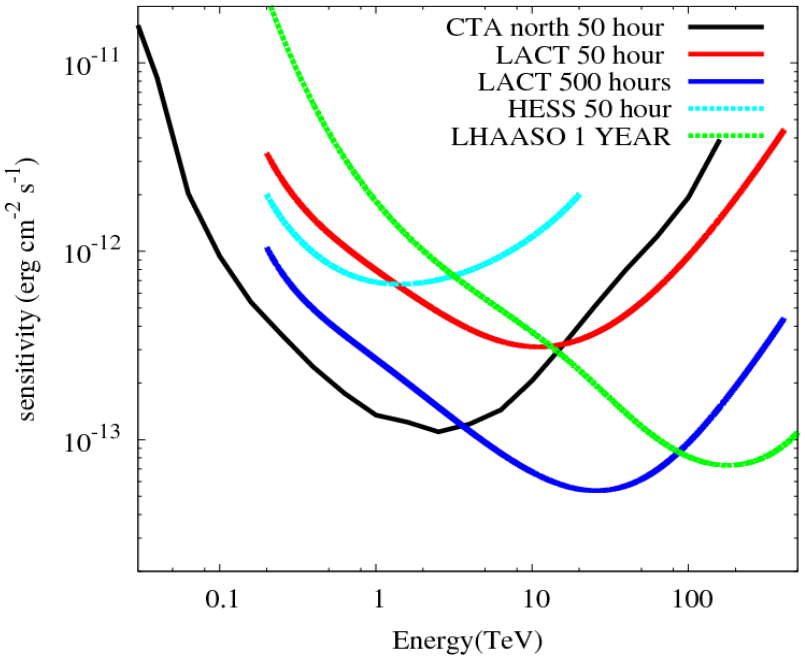


LACT

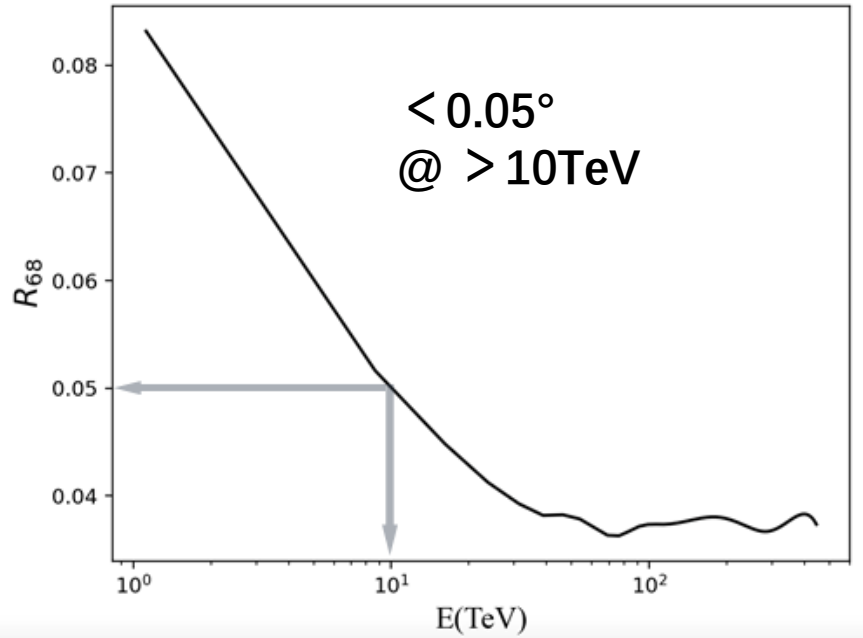
LACT layout in LHAASO site



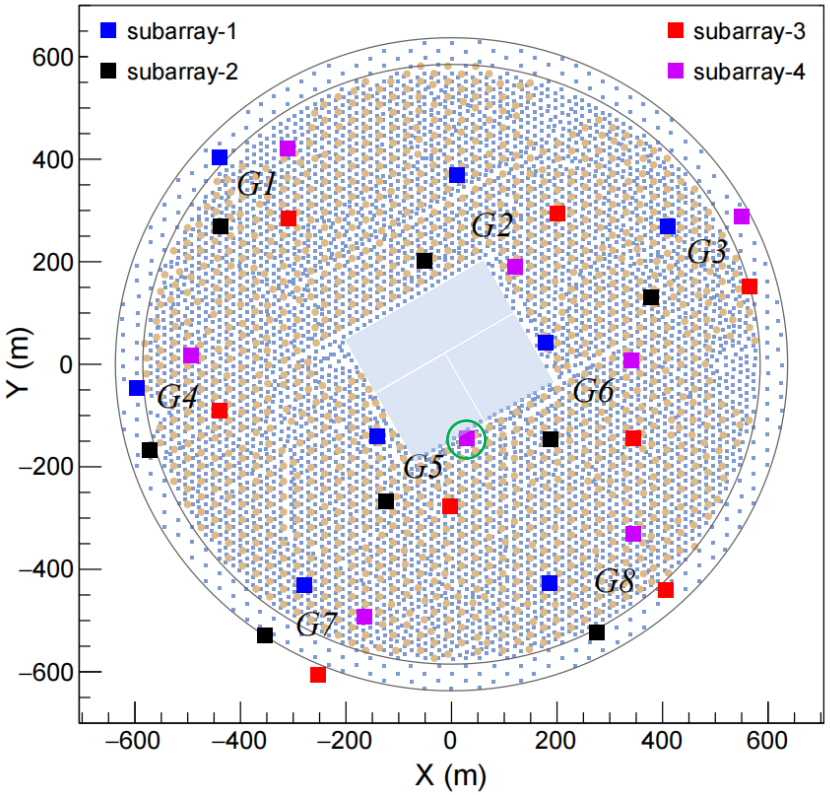
LACT sensitivity



LACT angular resolution

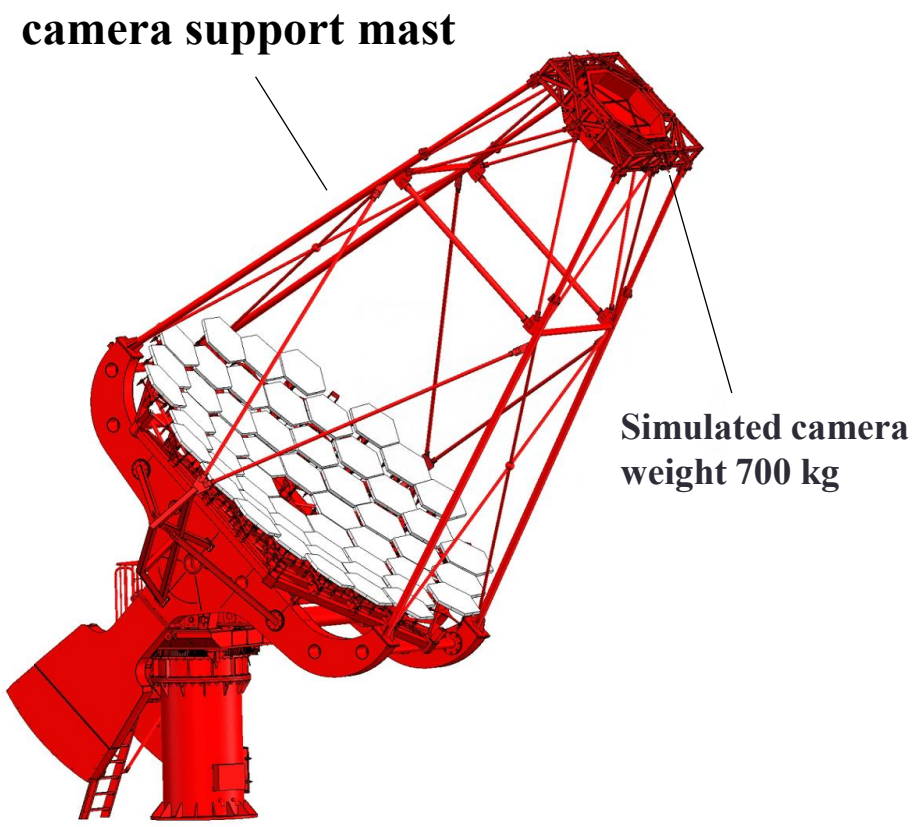


LACT first telescope

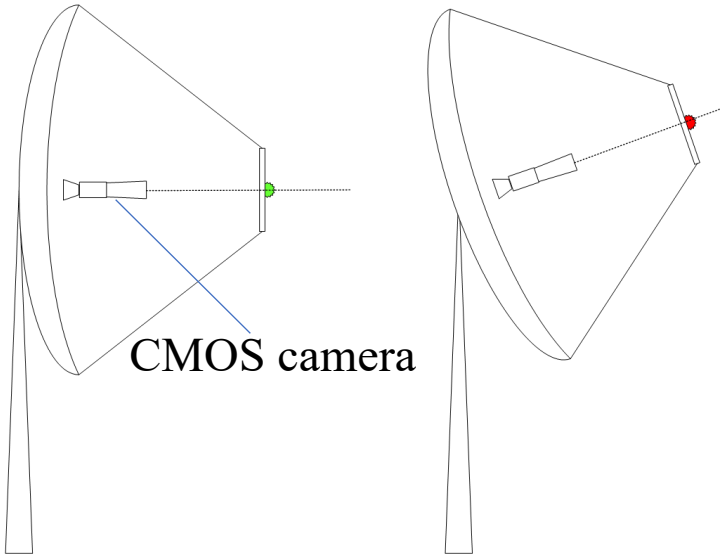


Performance tests

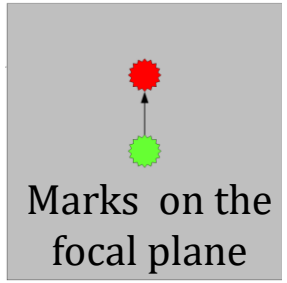
LACT camera support mast deformation

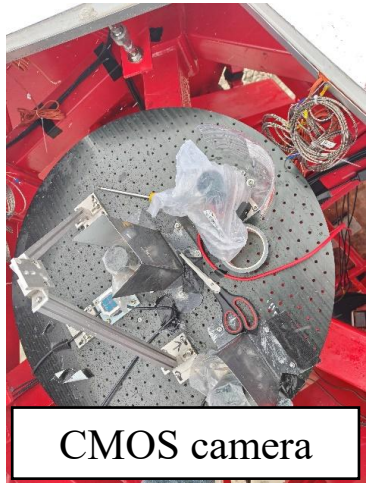


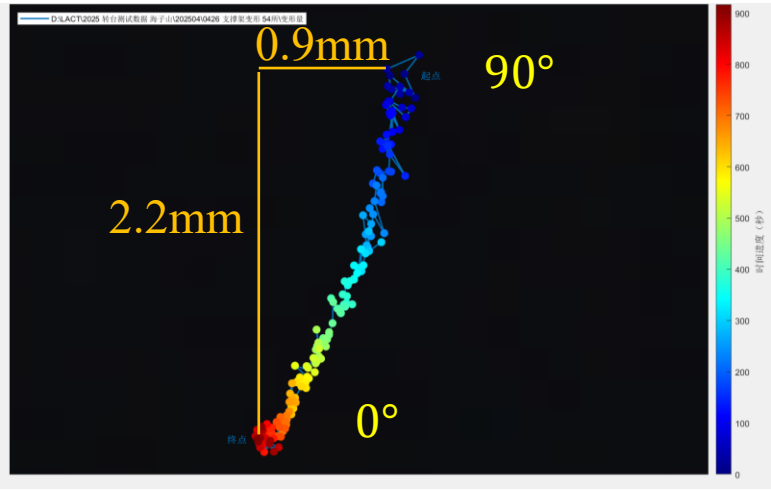
Requirement < 4 mm



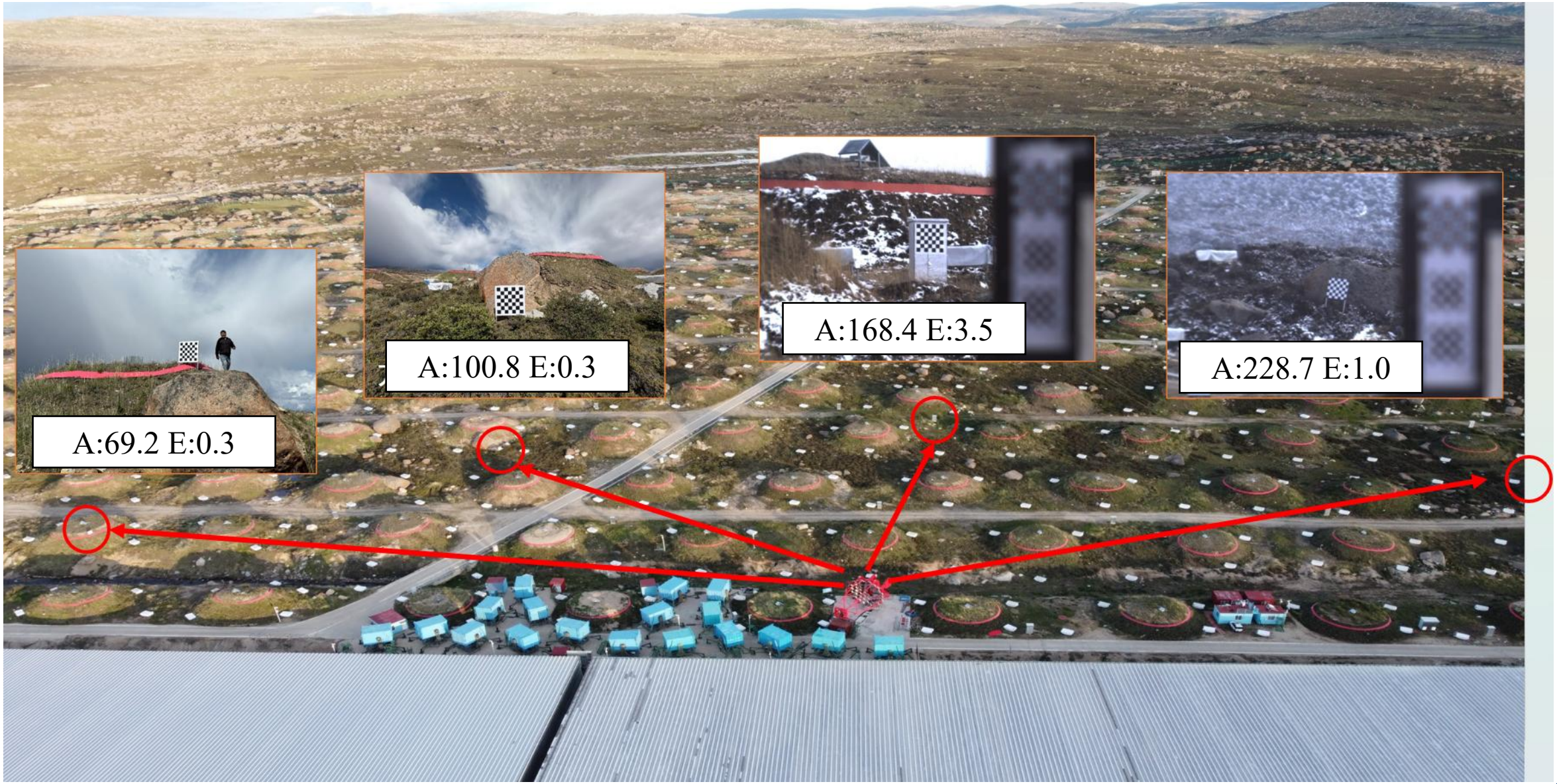
Different elevation angles







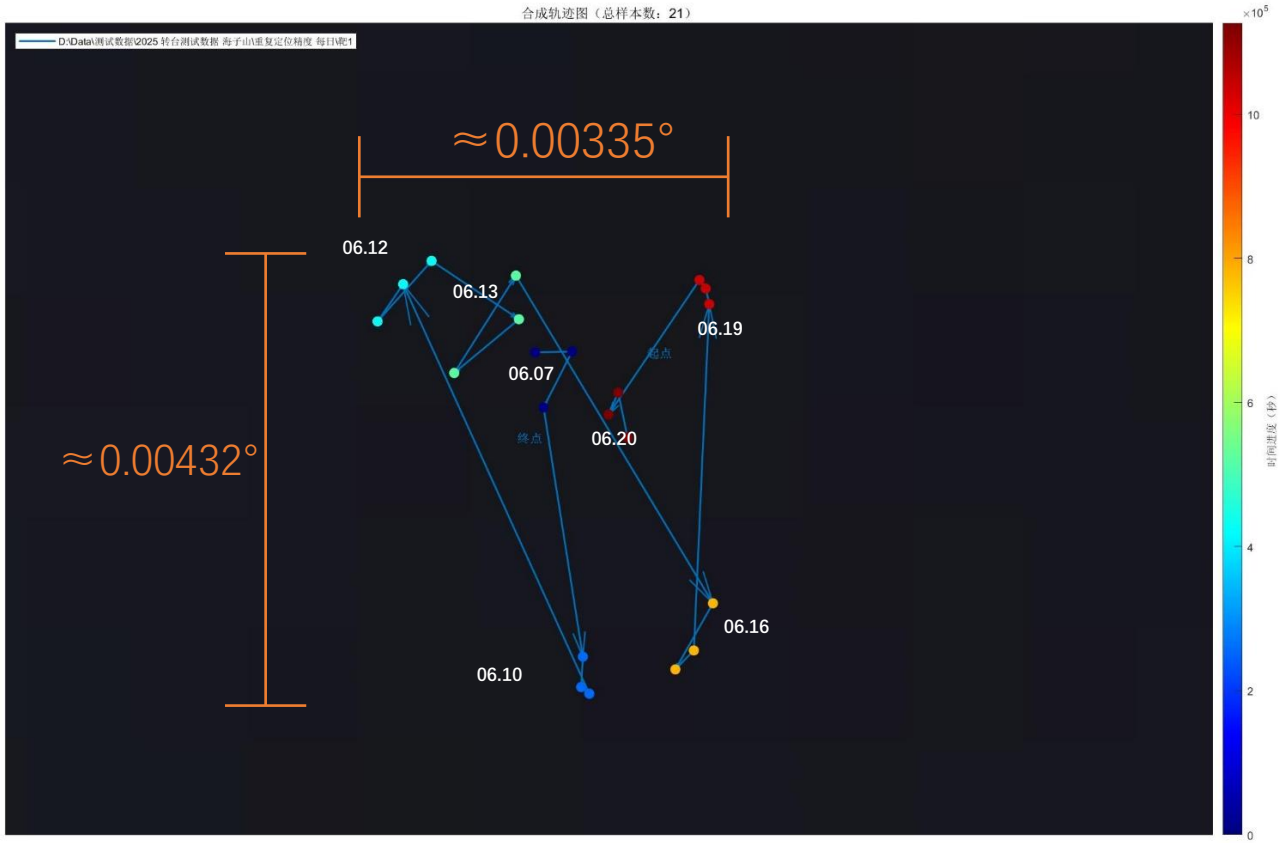
LACT Repeatability Positioning Accuracy Test



LACT Repeatability Positioning Accuracy Test

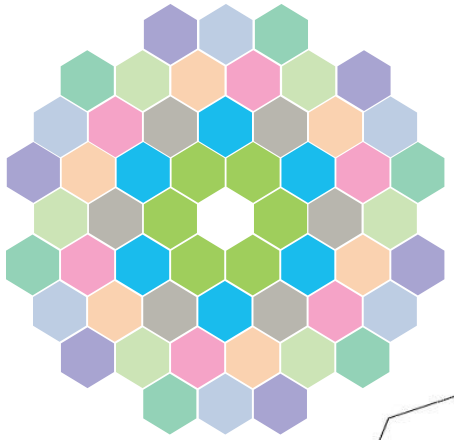
Maximum Daily Horizontal Displacement **0.00282°**
Maximum Daily Vertical Displacement **0.00144°**

Maximum Horizontal Displacement in Two Weeks **0.00353°**
Maximum Vertical Displacement in Two Weeks **0.00432°**



All measurements are within the specification, being less than **0.01°**.

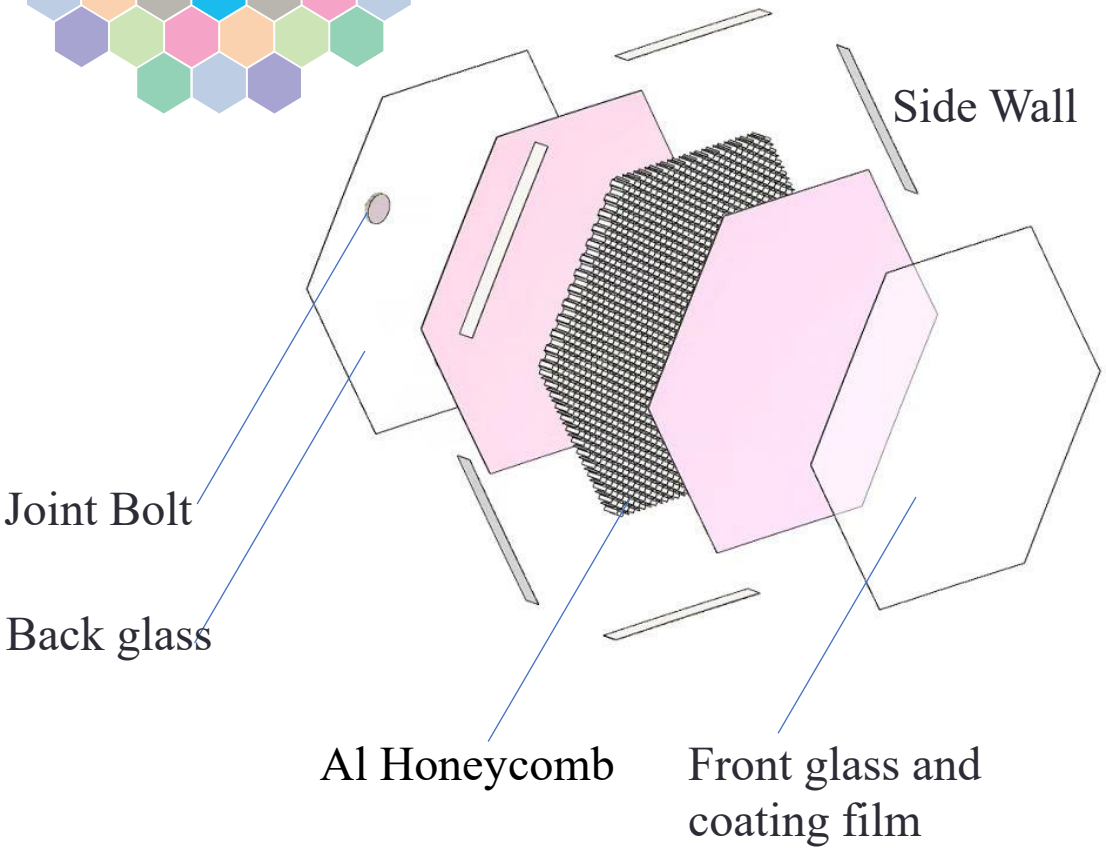
LACT mirror development



Cold pressing

One mold，One piece one day

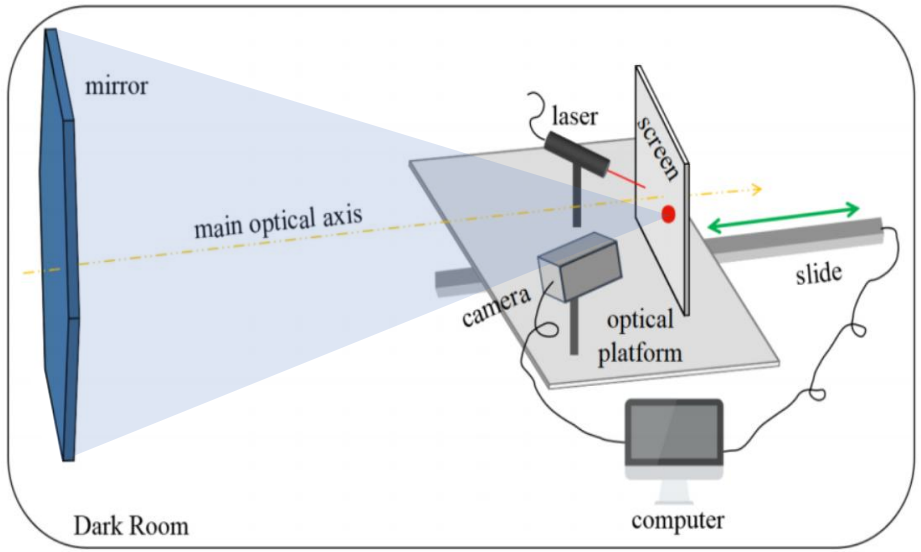
Cheap

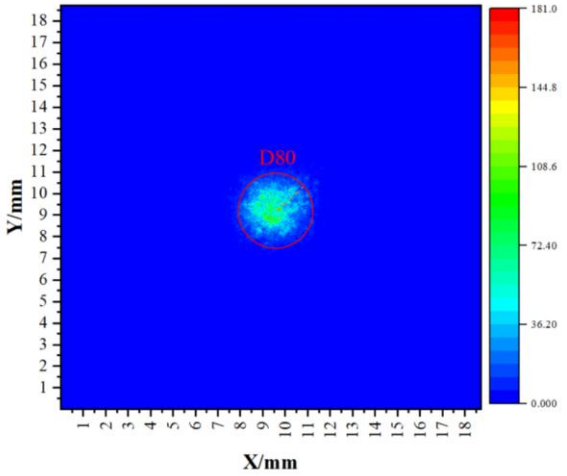


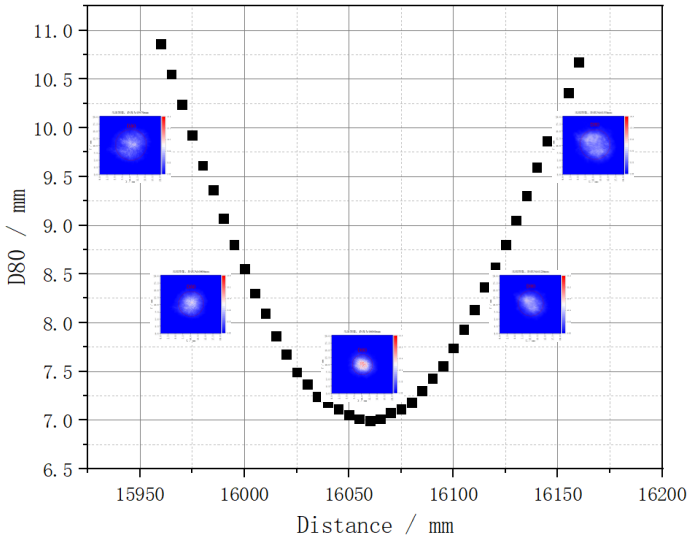
Main specifications of the spherical mirror	
Mirror segment shape	hexagon
Mirror size (edge to edge)	800 mm
Radius of curvature	16 m±50 mm
Mirror surface figure (D80@2f)	<8 mm @20°C
Reflectivity (300–550 nm)	>85%
Mirror thickness	<50 mm
Mirror weight	<12 kg

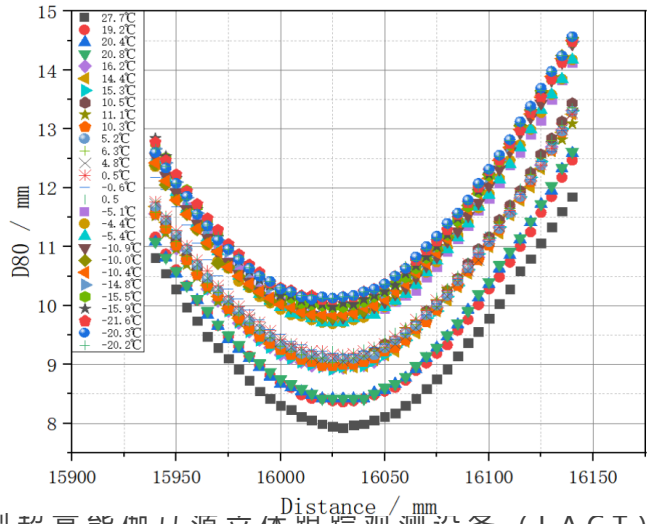
LACT mirror test

2f method

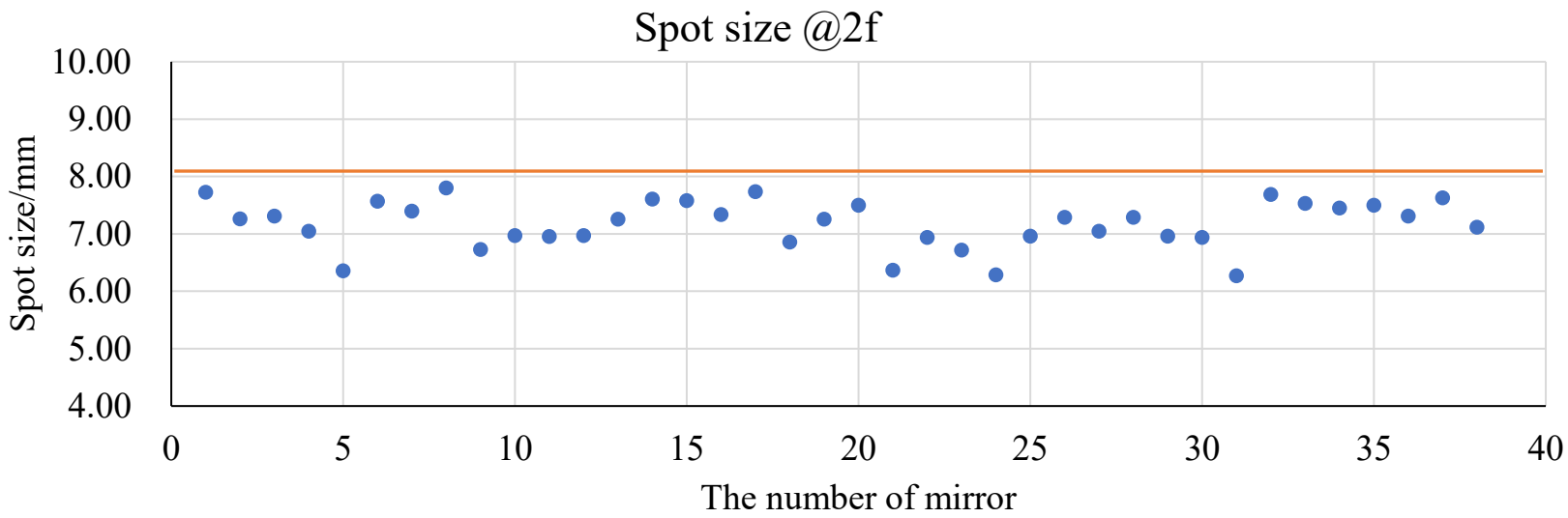






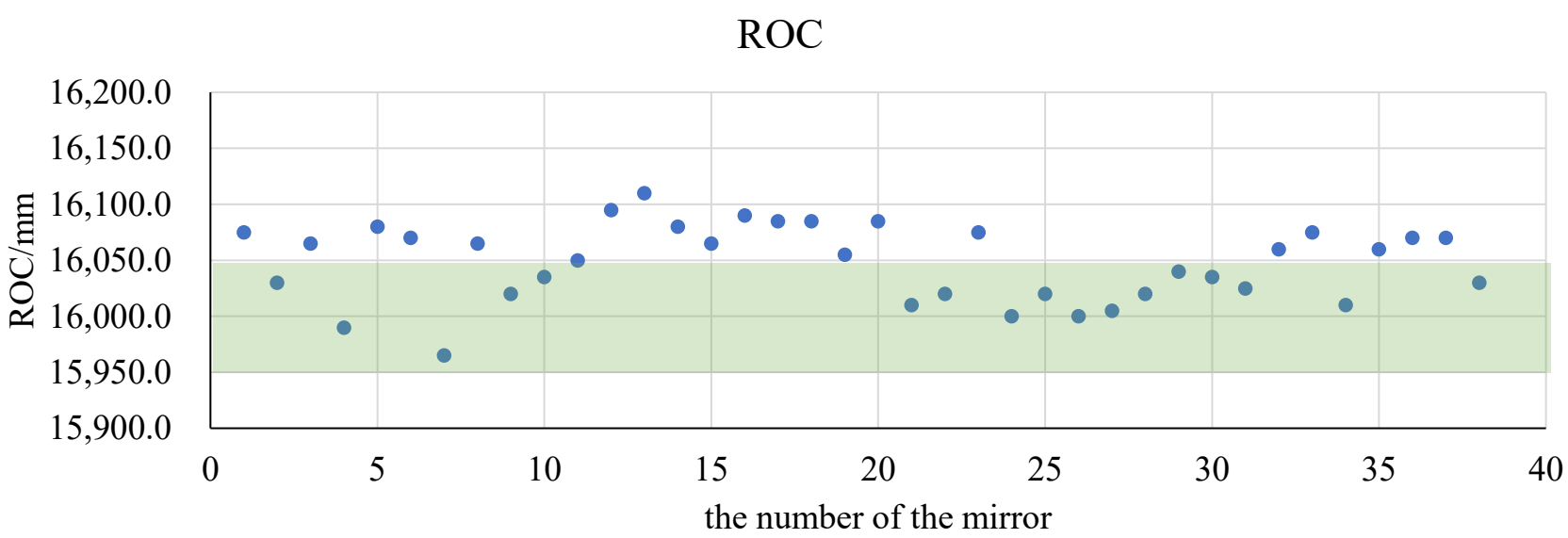


LACT mirror test



Radius of curvature	16 m±50 mm
Mirror surface figure (D80@2f)	<8 mm @20℃

The spot sizes at 2f meet the requirement.



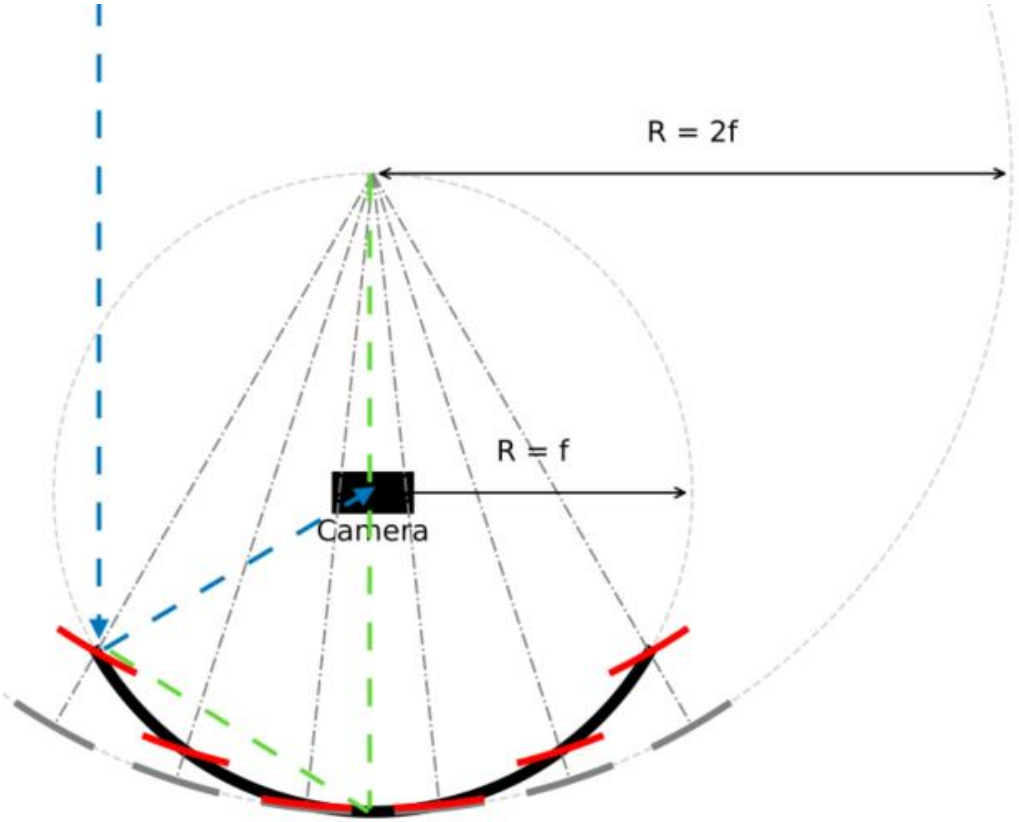
The average radius of curvature is **16048 mm**.

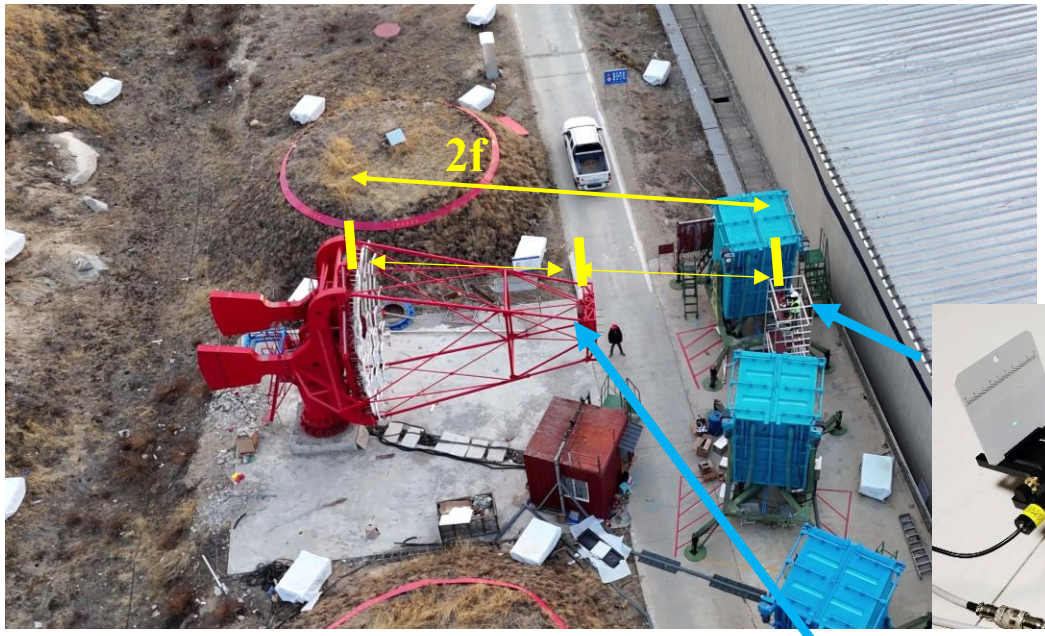
The mold requires compensation and correction of the radius of curvature.

LACT mirror segments installation

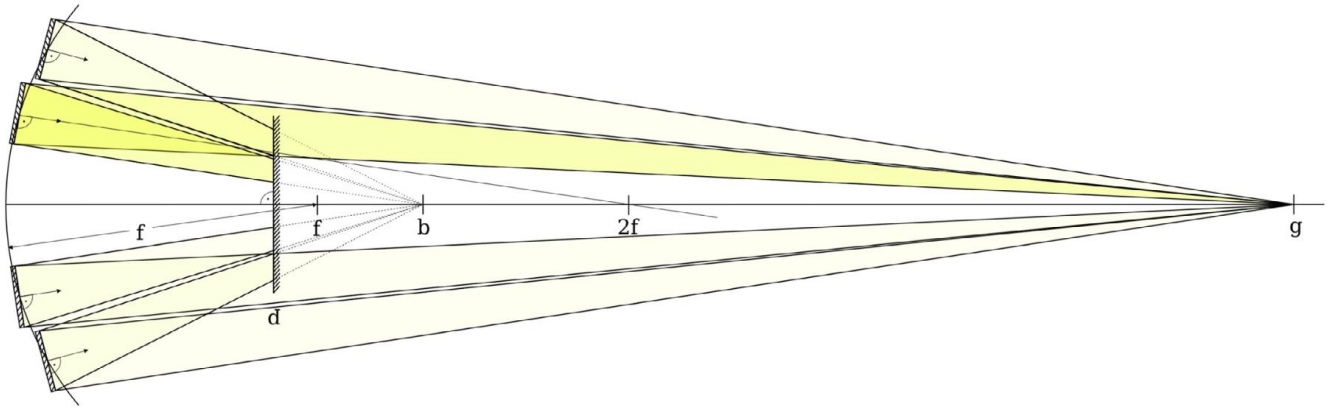
LACT alignment——2f method

2f method

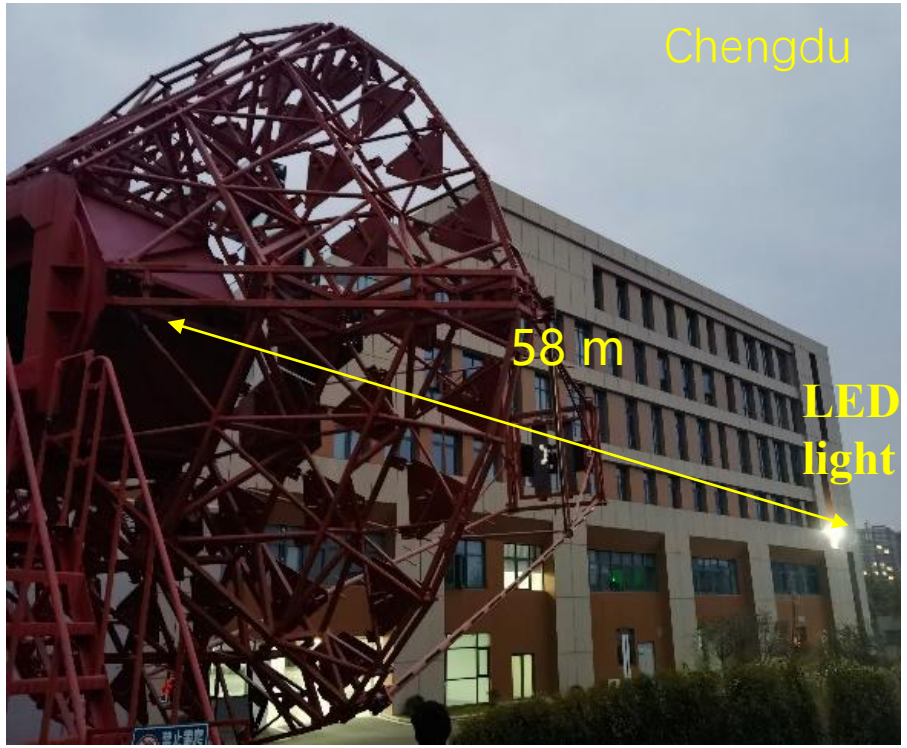




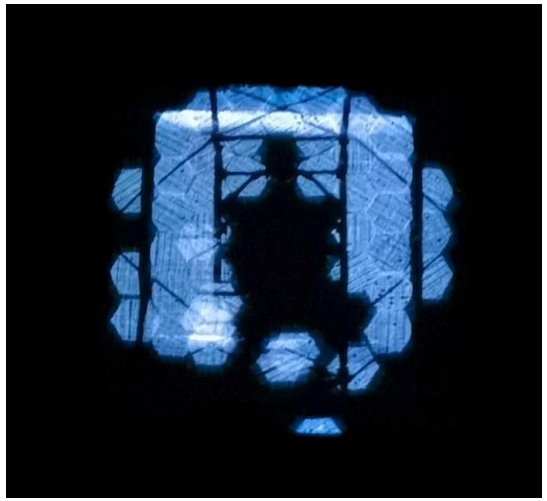
LACT Bokeh method

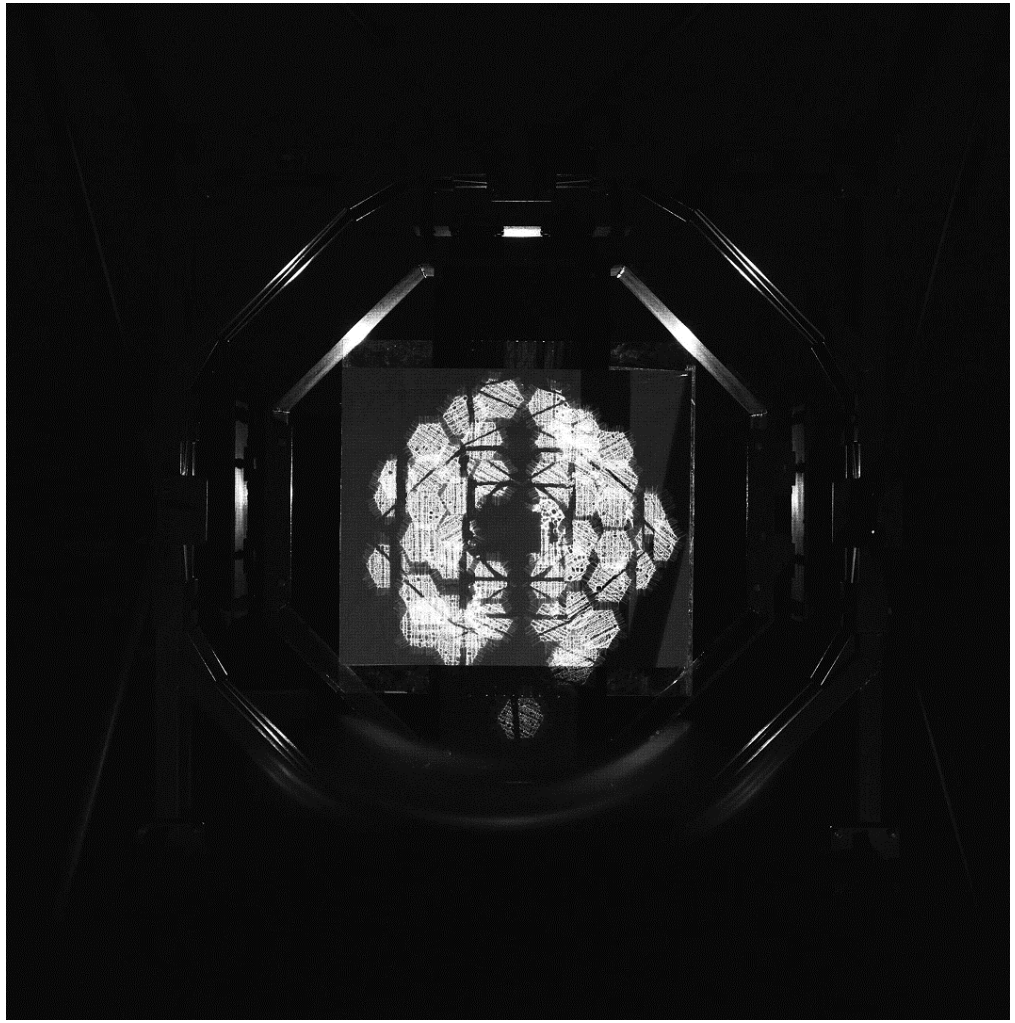


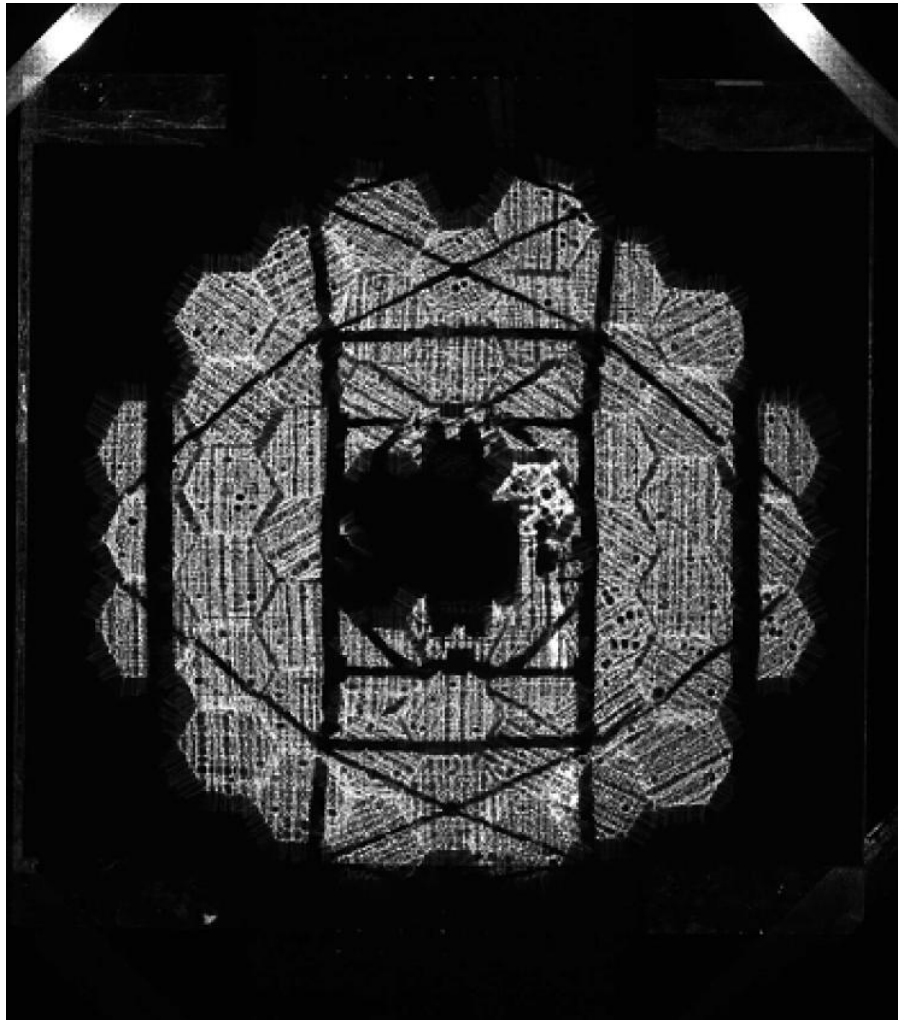
The light source is placed at more than twice the focal length (2f), allowing us to observe the image near the focal plane.



LACT Bokeh method

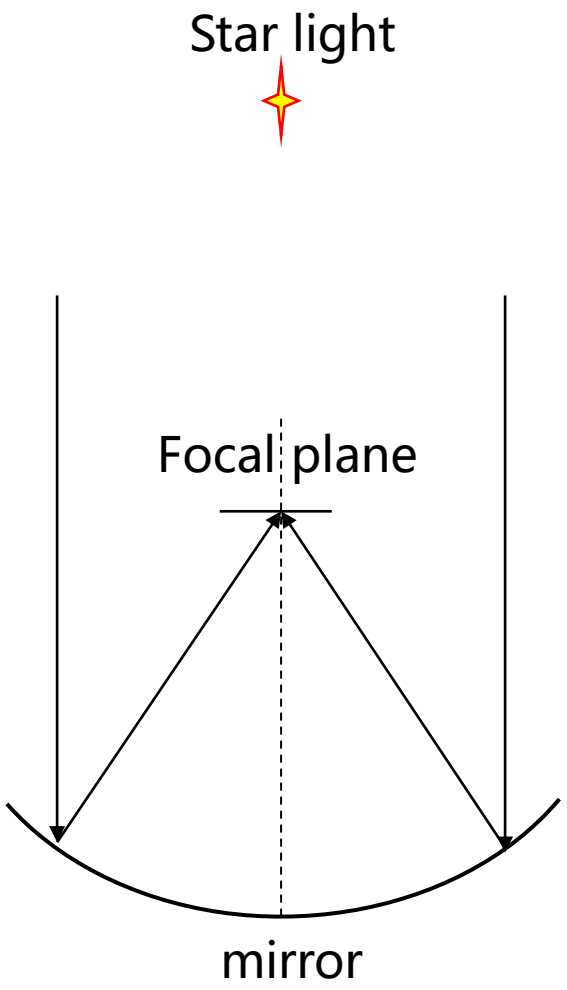


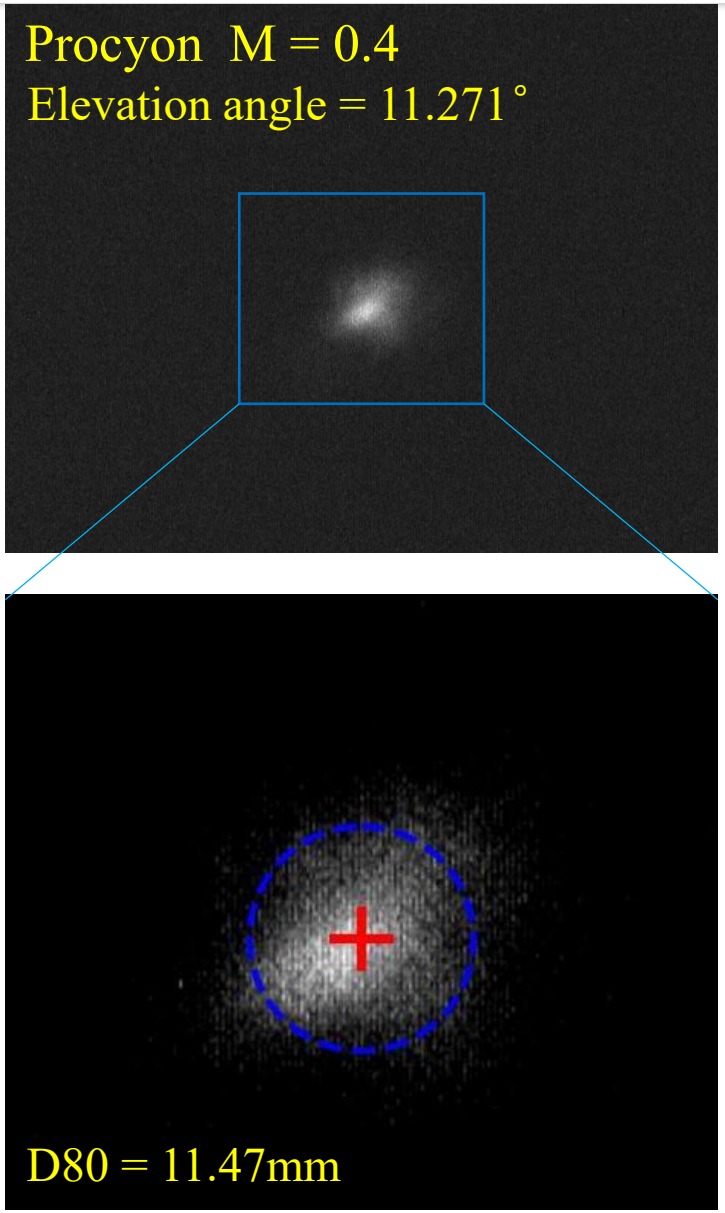




The alignment process of the bokeh method.

LACT optical performance





4 Summary

Summary

1. The era of ultra-high-energy gamma-ray astronomy has arrived, calling for a Cherenkov telescope array with better sensitivity.
2. 32 telescopes will be built at LHAASO site. The angular resolution will be 0.05° @ > 10TeV
3. The support mechanism of the first telescope has been completed.
4. The camera support mast deformation is only 2.2 mm, meeting the requirement 4 mm.
5. Maximum error of the repeatability of the support mechanism is 0.00432°, meeting the requirement of 0.01°.
6. The spot sizes at 2f meet the requirement. The mold requires compensation and correction of the radius of curvature (50 mm).
7. The star light spot size is 11.47 mm at elevation angle 11.271°.
8. Two telescopes will be completed by the end of 2025, eight telescopes by 2026, and the full array will be operational by 2028.

Thank You!

backup

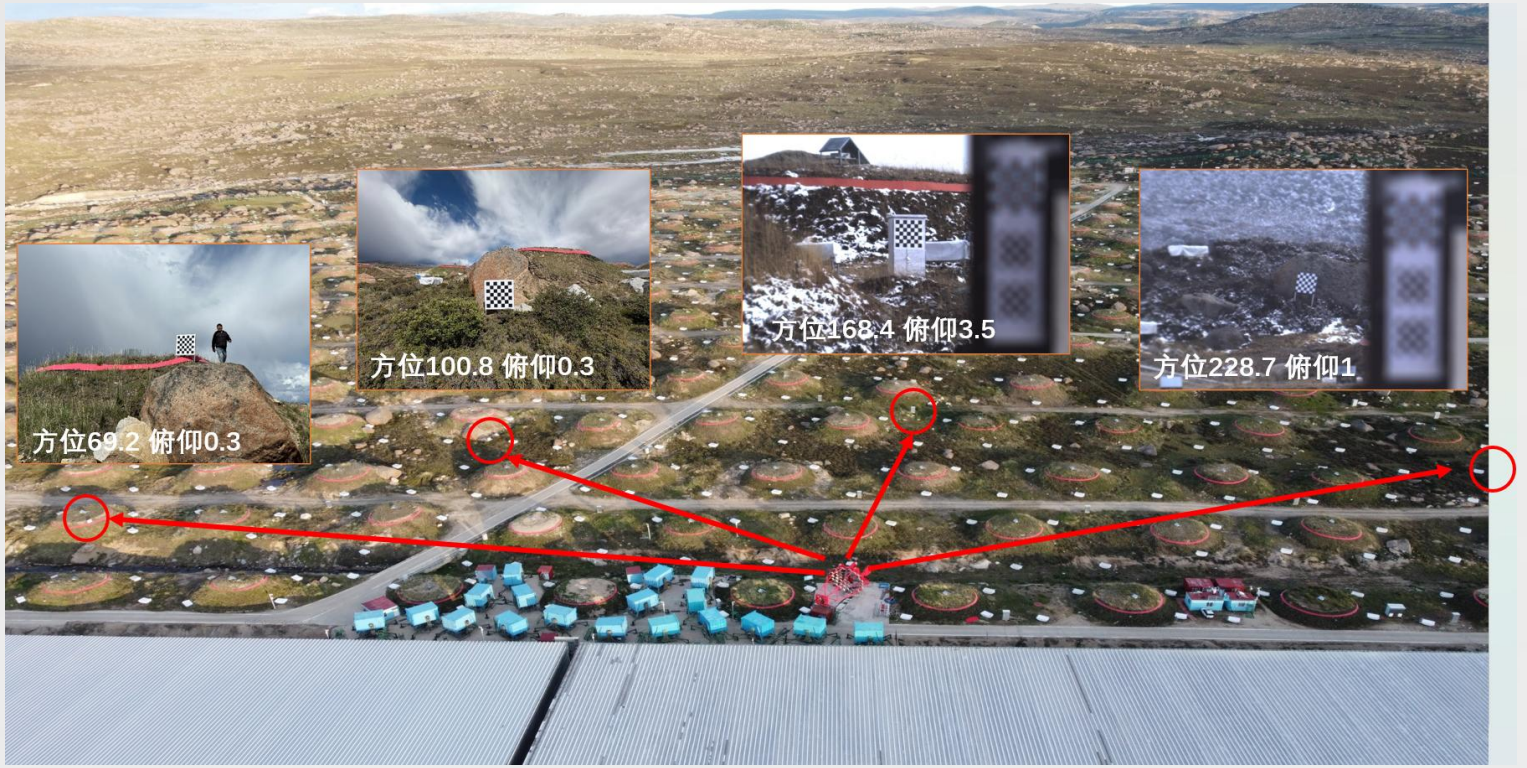
LACT mirror install and alignment

04.重复定位精度测试

A.技术指标：：每次重复定位某标准点角度误差＜0.01°

B.方法：望远镜中心圆盘安装相机，确定转台拍摄角度，运动后回到该角度，重复拍摄棋盘格，计算运动前后角点的像素位置偏差，计算得出重复定位精度；

$$偏移 = arctan\frac{偏移像素个数 * 像素尺寸}{焦距}$$



分辨率： 3096*2080像素

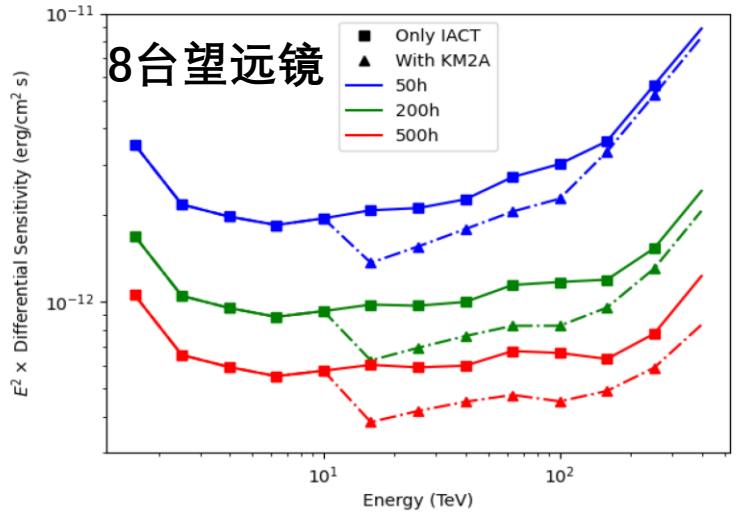
焦距：120mm

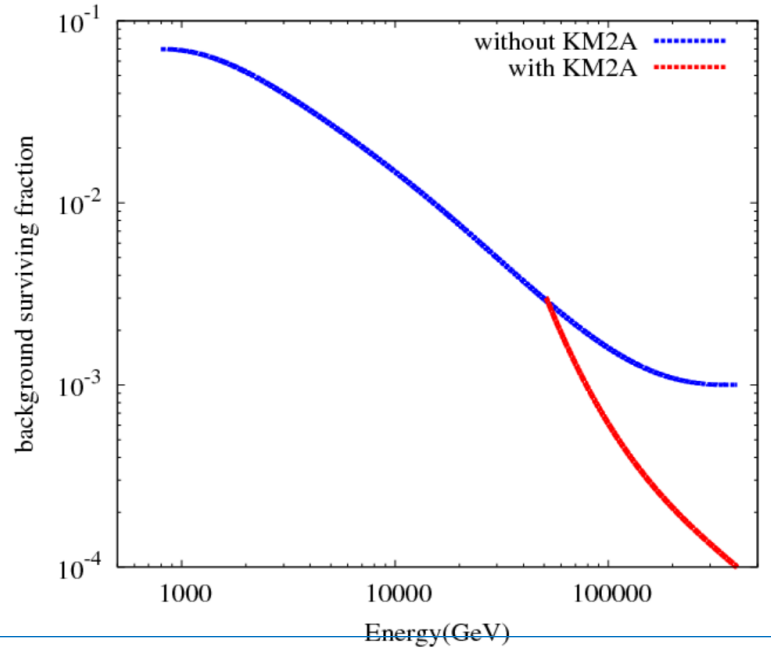
像素尺寸：横向 7.4/3096 = 0.0023901

纵向 5.0/2080 = 0.0024038

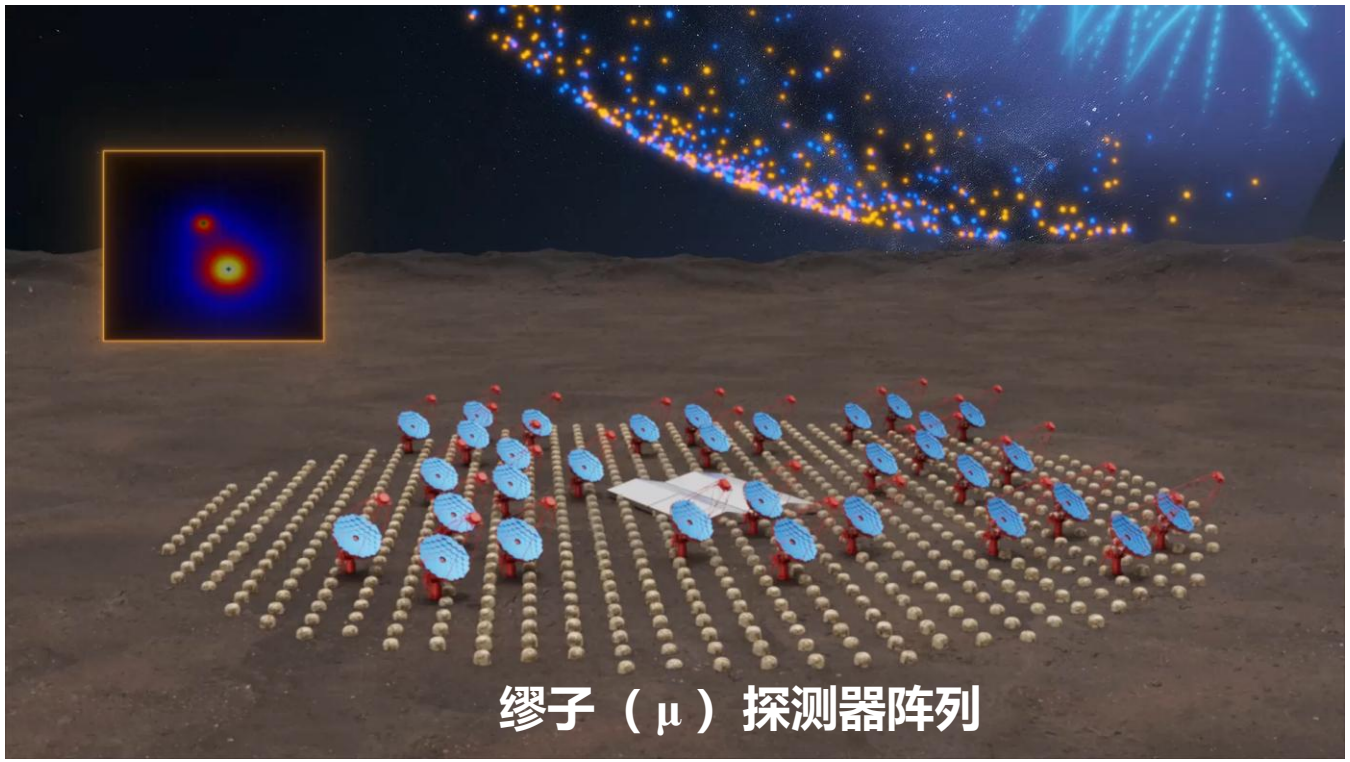
单个像素尺寸：**0.0024mm**

LACT站址：LHAASO站点，现成的缪子测量信息





- LHAASO缪子（μ）探测器阵列
- 世界上面积最大的缪子探测器阵列
- 具有**国际领先**的超强抗背景噪声能力



LACT反射镜检验

- 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, the sensitivity of the LACT can be significantly enhanced.
  - Main scientific goal: morphology of PeVatrons and locating UHE γ-emitters
- Construction Schedule
  - 2 telescopes will be constructed in the end of 2025
  - 8 telescopes will be completed by 2026
  - The full array will be completed by 2028
- LACT phase-1
  - The construction of 4 telescopes (Phase-1) will be completed in July 2026
  - Gamma-ray source observations will begin right after detector commissioning.