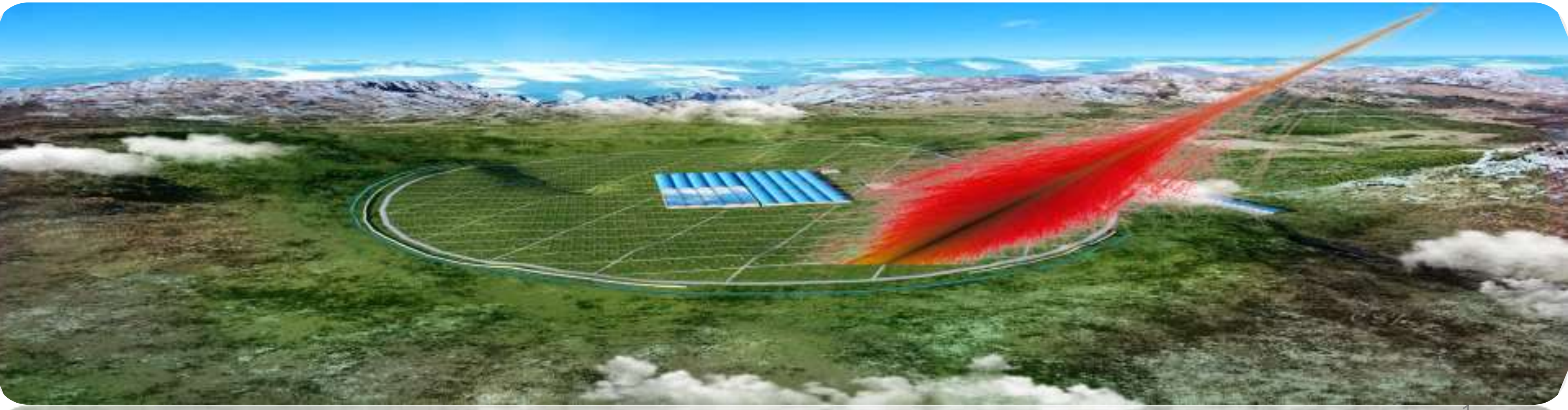
LHAASO Status and First Results

Yi Zhang
For the LHAASO collaboration
Purple Mountain Observatory, CAS



OutLine

- **Brief Introduction of LHAASO**
- **Construction Status**
  - **Scintillator-Muon Detector Array (KM2A)**
  - **Water Cherenkov Detector Array (WCDA)**
  - **Wide FoV Cherenkov Telescope Array (WFCTA)**
- **Preliminary Observational Results**
- **Summary**

LHAASO Collaboration

Member: 260

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Institutions: 33

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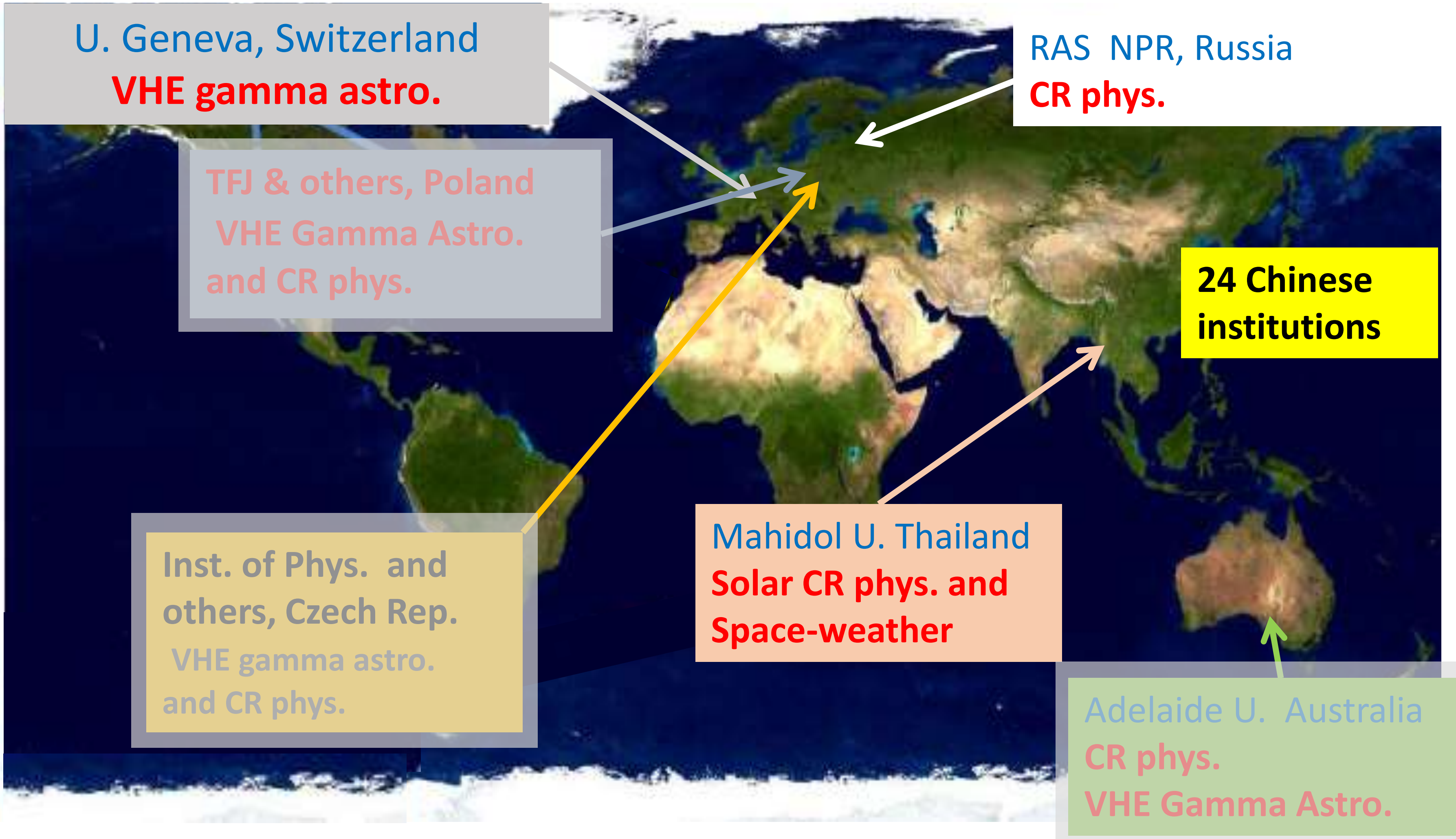
Waiting list by institutions:

- Adelaide U./Australia
- Polish group led by IFJ,PAN
- Czech group led by Inst. Phys. CAS
- Nankai U./China
- Xinjiang Observatory/China

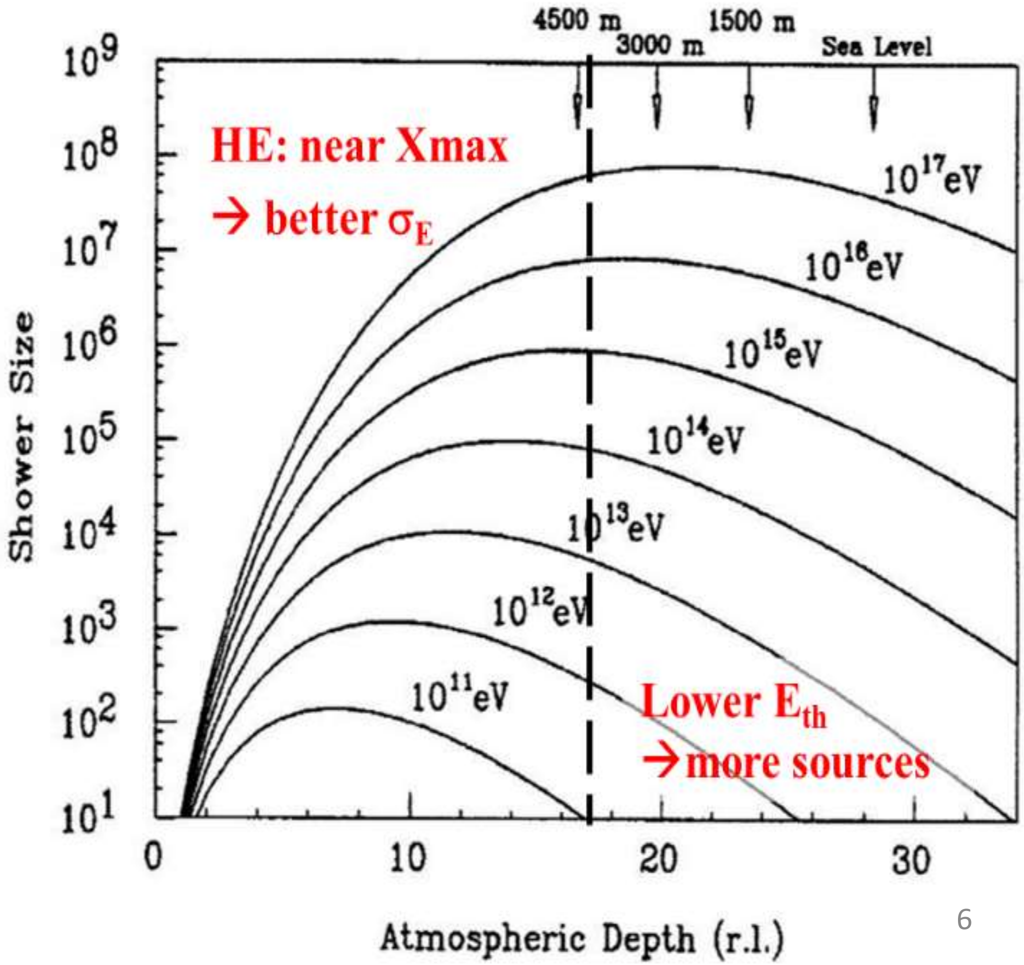
LHAASO Collaboration (by country)



LHAASO Coll. Chinese institutions

Where is LHAASO

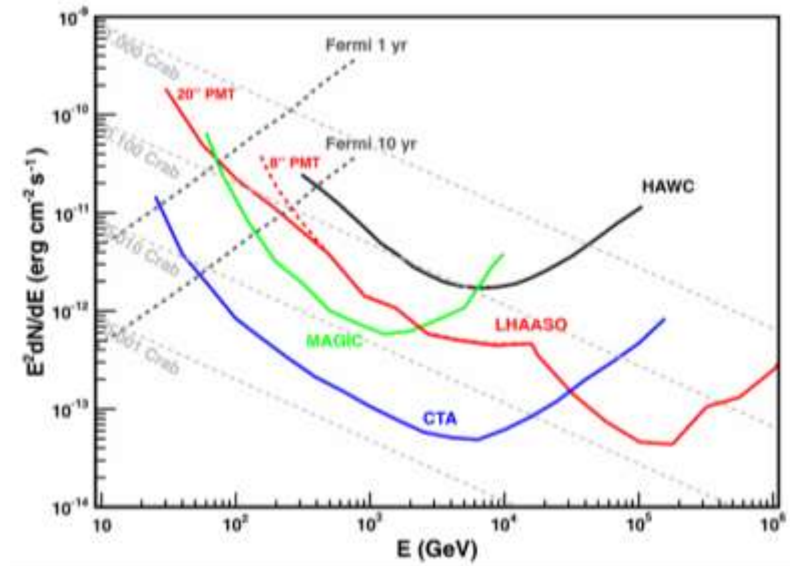
Mt. Haizi (4410 m a.s.l., 29º21’ 27.6” N, 100º08’19.6” E), Sichuan, China

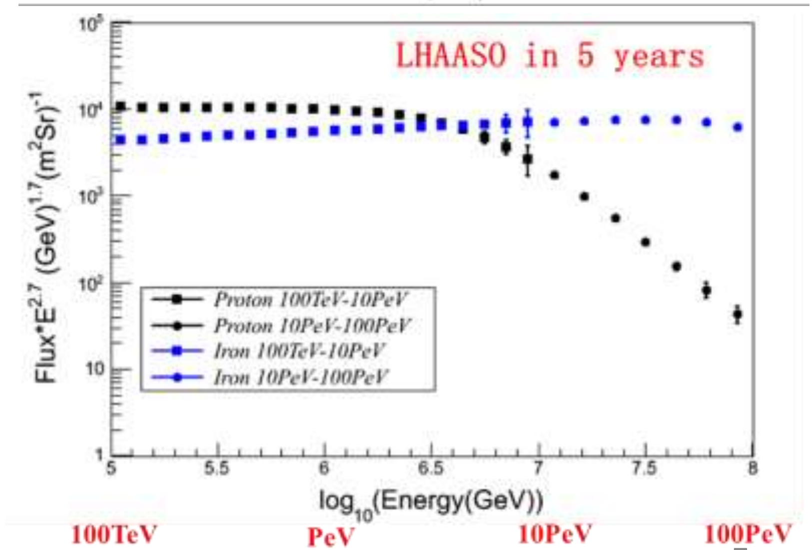


*LHAASO：**L**arge **H**igh **A**ltitude **A**ir **S**hower **O**bservatory*

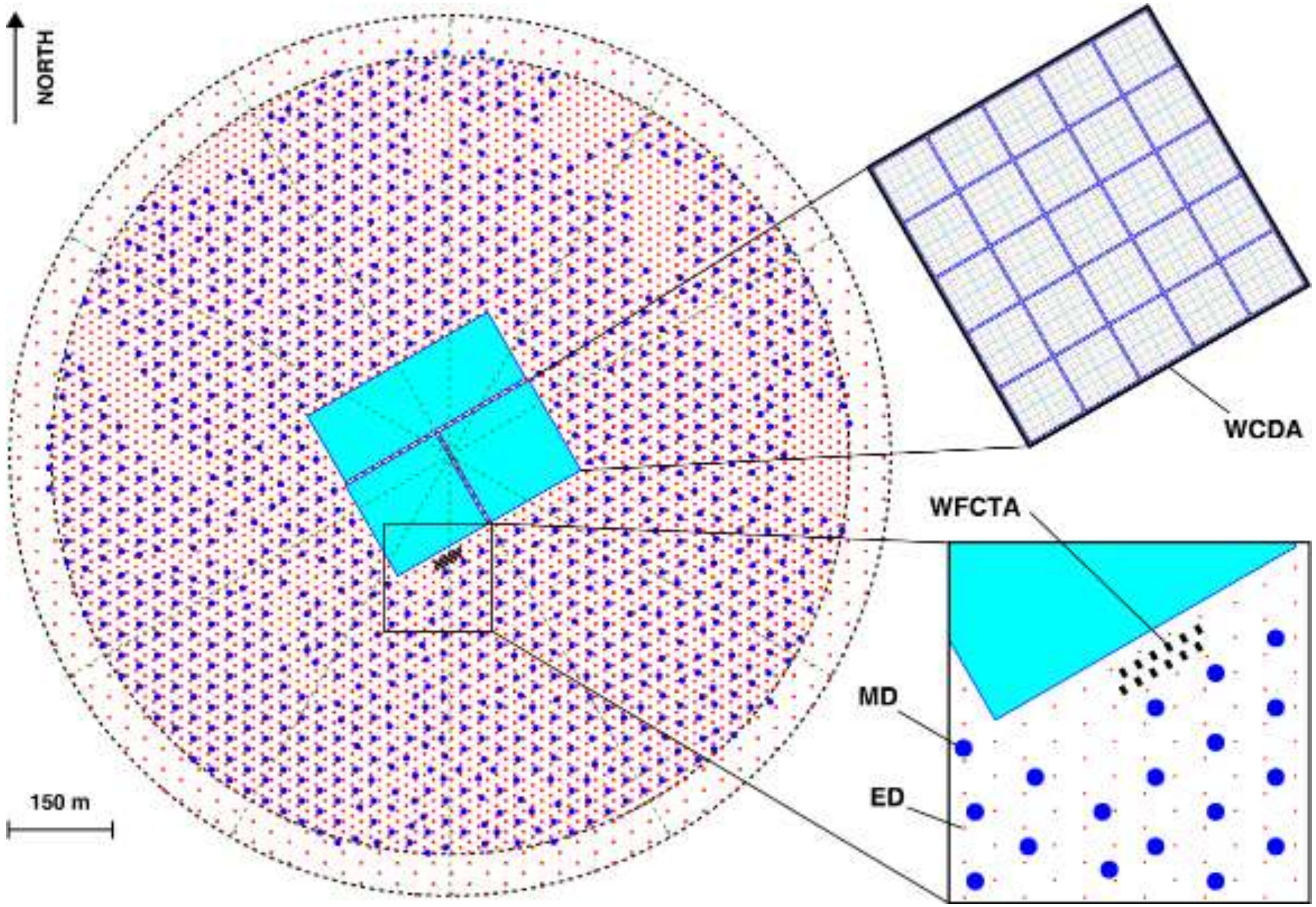
Major Scientific Goals

- **Origin of GCRs**
  - Searching for GCR sources by measuring gamma-ray SED with an unprecedented sensitivity of 1% I_{Crab} at 50 TeV
  - Energy spectra for individual compositions with energy from 10 TeV to 1 EeV, where the spectrum knees are located
- **Gamma ray astronomy**
  - Searching for TeV γ sources, especially extended and transient ones, with an unprecedented survey sensitivity of 1% I_{Crab} at 3TeV.
- **New physics frontier**
  - dark matter, Lorentz invariance, new physics beyond LHC energy, etc



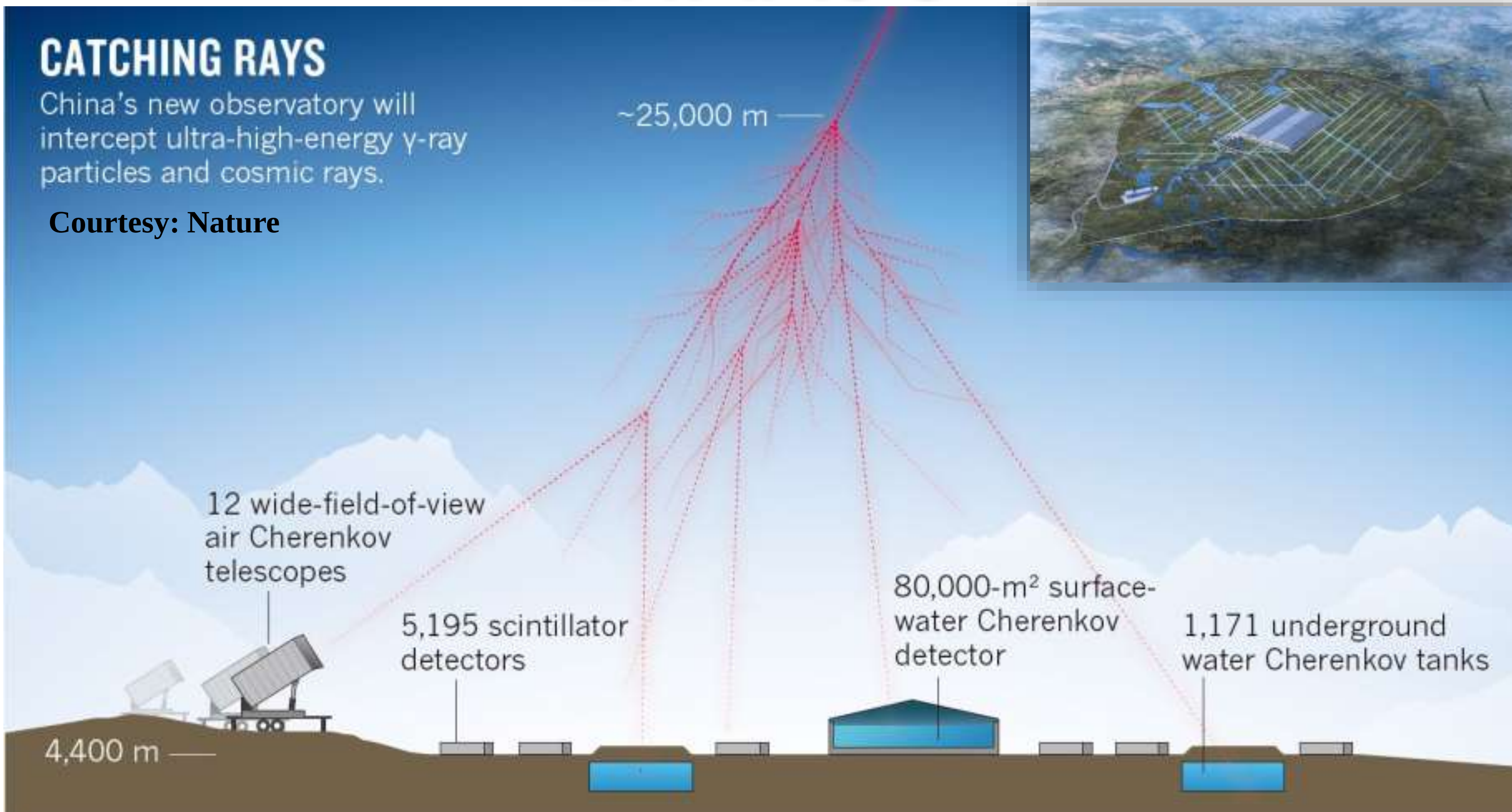


A Large area EAS array
covering 1.3 km^2



- **5242 EDs**
  - 1 m^2 each
  - 15 m spacing
- **1188 MDs**
  - 36 m^2 each
  - 30 m spacing
- **3120 WCDs**
  - 25 m^2 each
- **18 WFCTs**

Hybrid Detection of EASs by LHAASO



Courtesy: Nature

LHAASO bird-eye View from a drone

— *May. 2021*

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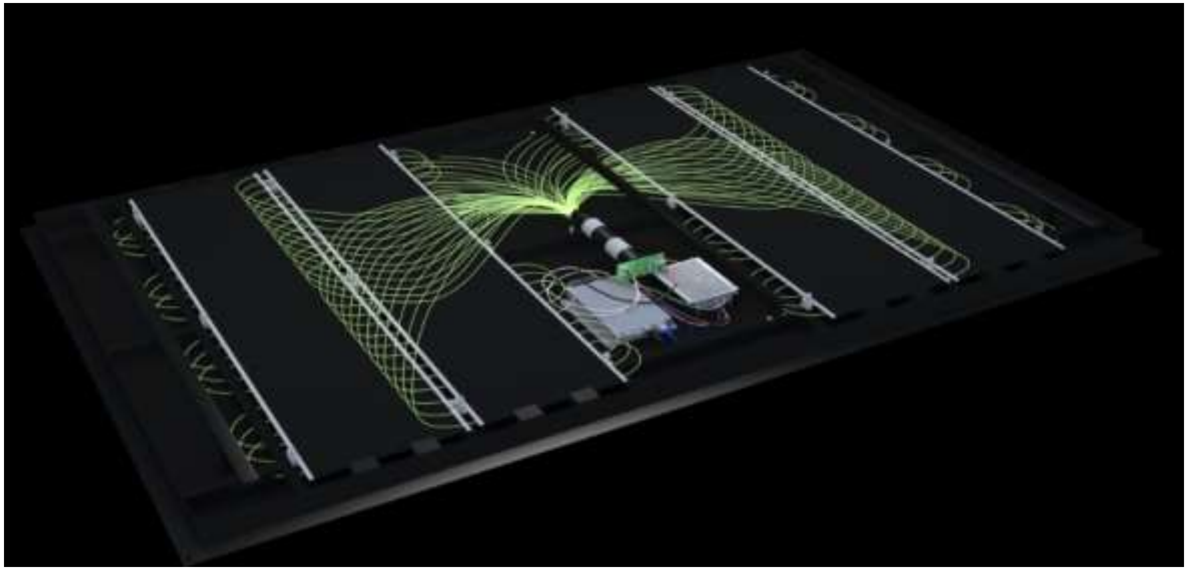
KM2A Electromagnetic particle Detectors



Scintillator Detector Unit

1/2 ED array, 2365 EDs started 2019-12

3/4 ED array, 3978 EDs (total 5242),

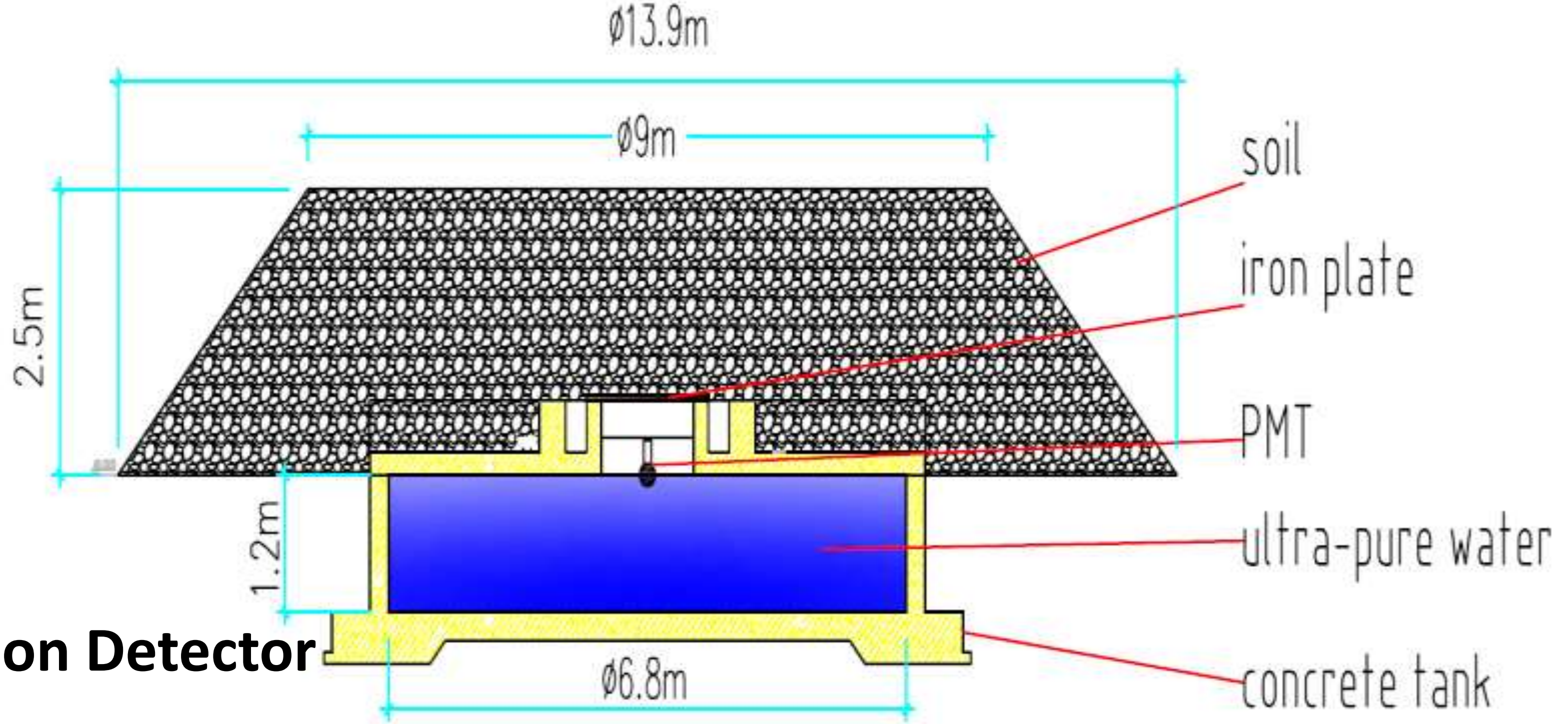
started operation 6/12/2020

Trigger rate ～ 1900Hz,

1.45TB one day

ED Specifications	
Detection area	1m×1m; 5mm Lead covered
Detection efficiency	＞95%
Time resolution	＜2ns
Dynamic range	1~10000 particles/m^2; 25%@1 particle, 5%@10000 particles
single channel rate	<2kHz@working Gain
Stable operation	＞20yrs (4410m, 0.6atm., ±25°C)

KM2A Muon Detector array



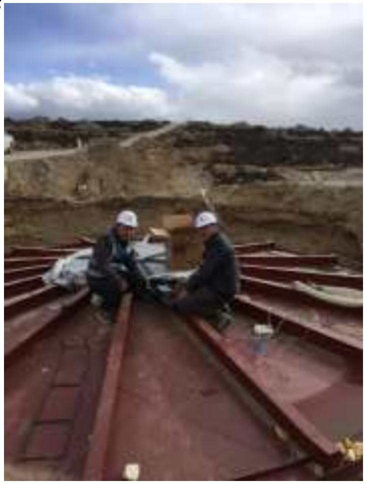
Muon Detector

1/2 MD array, 592 MDs (total 1188) started operation from 12/2019

3/4 MD array, 914 MDs (total 1188) started operation from 12/2020

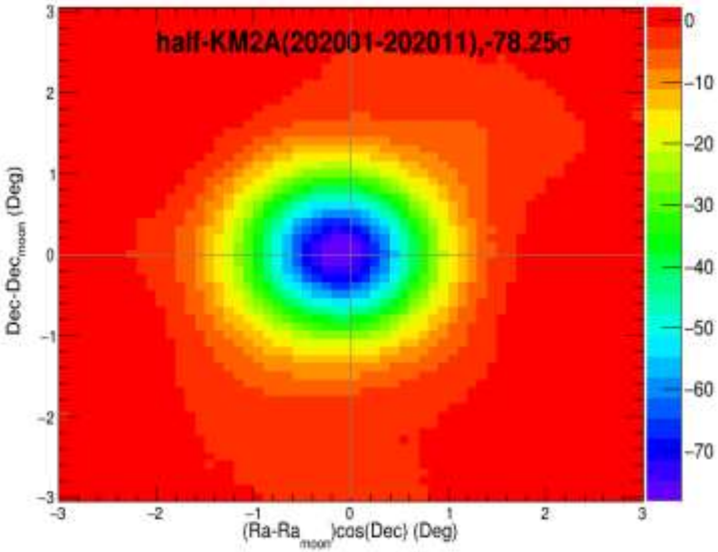
Installation of a Muon Detector

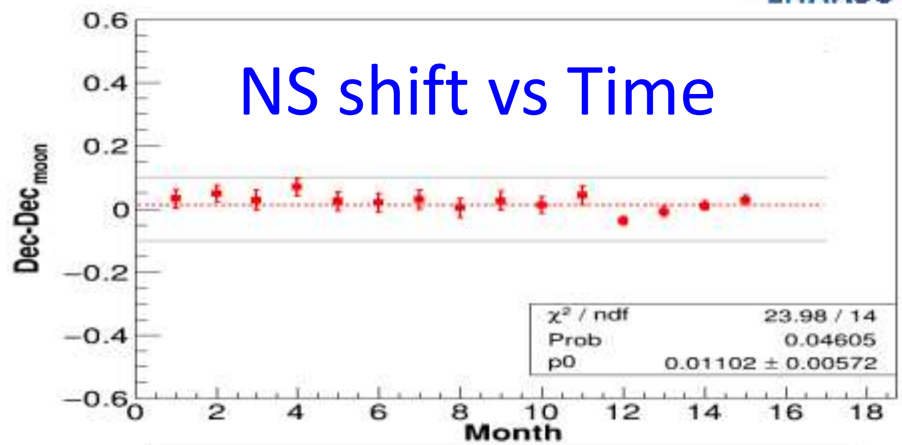
Foundation pit treatment → Fabrication of side wall and bottom plate → Head cover mounting → Install insulation →

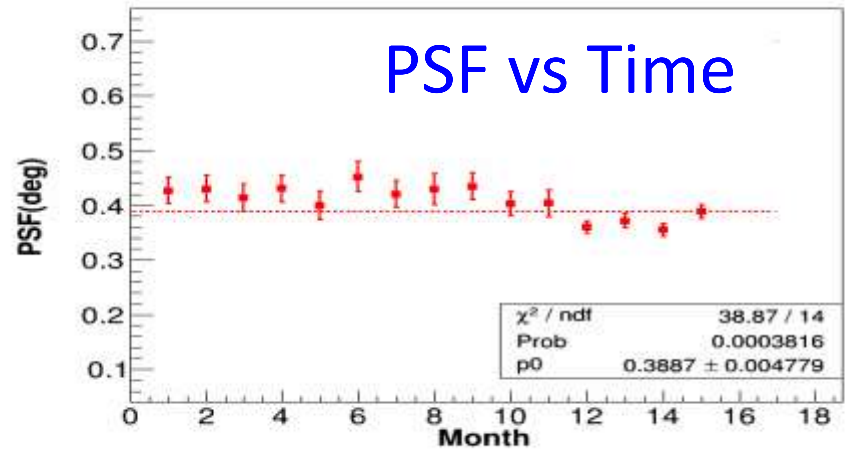


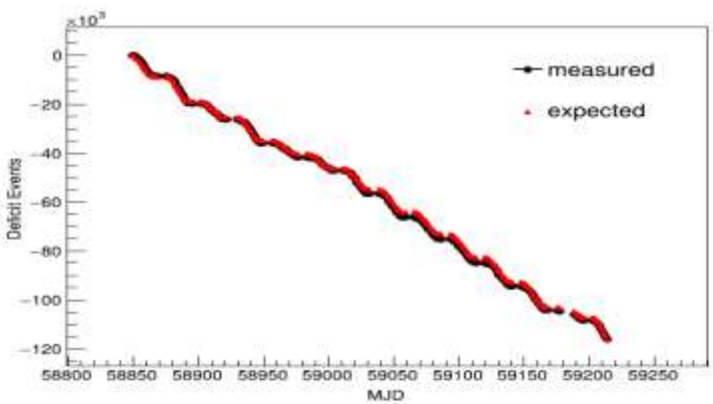
Install liner and PMT → ultrapure water infusion → debug → Covering soil → intergrated test

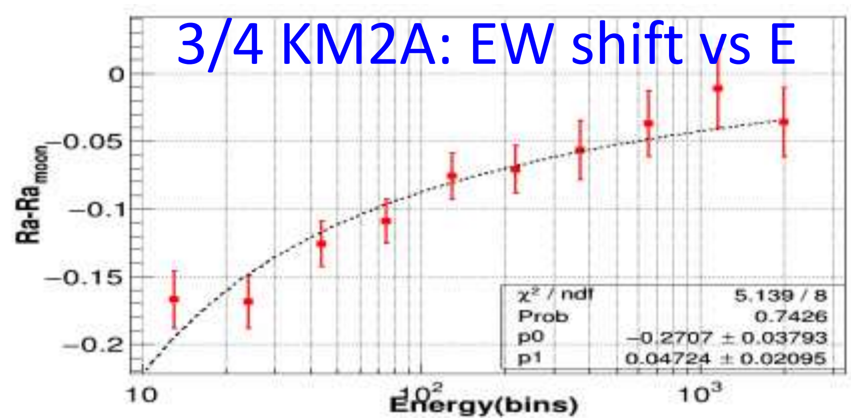
Moon shadow monitor



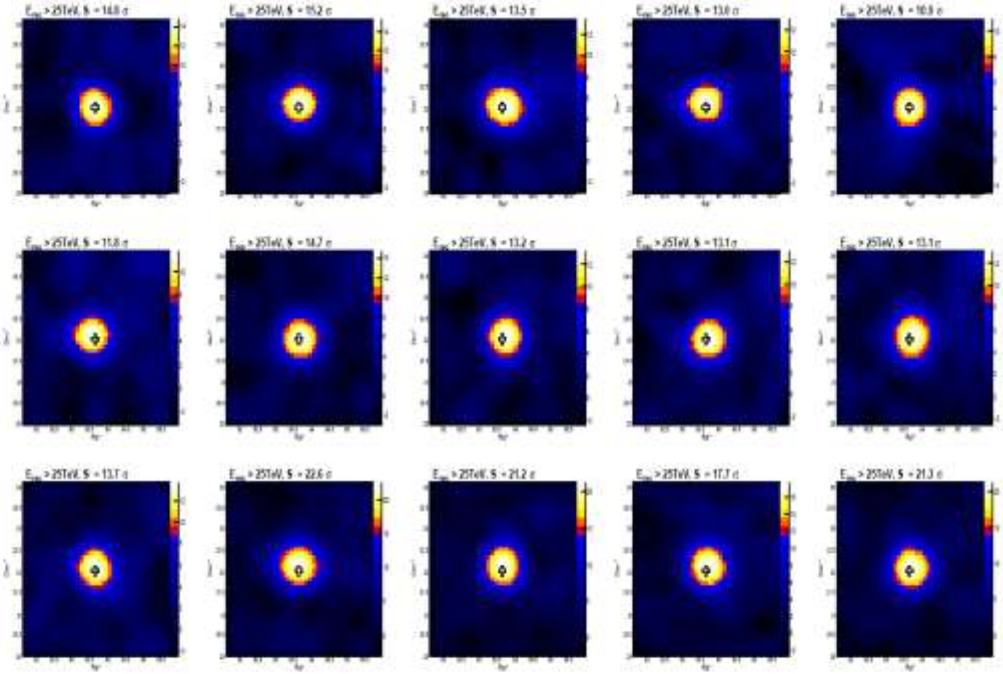


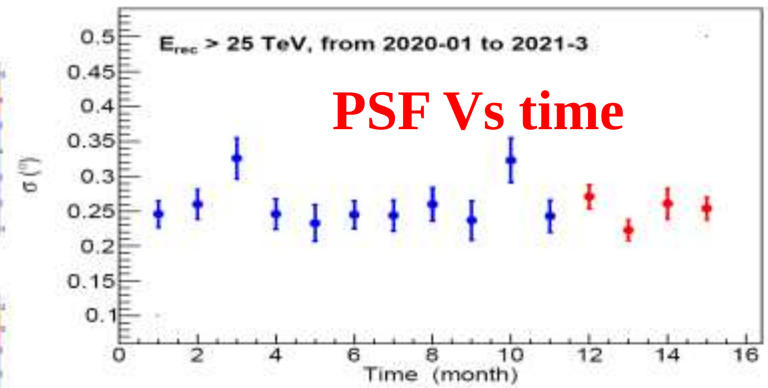


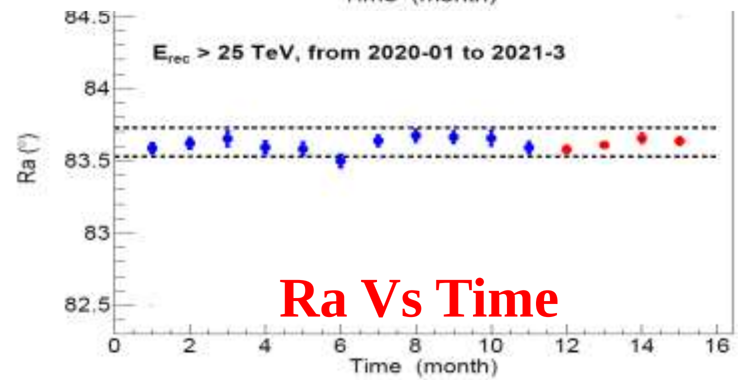


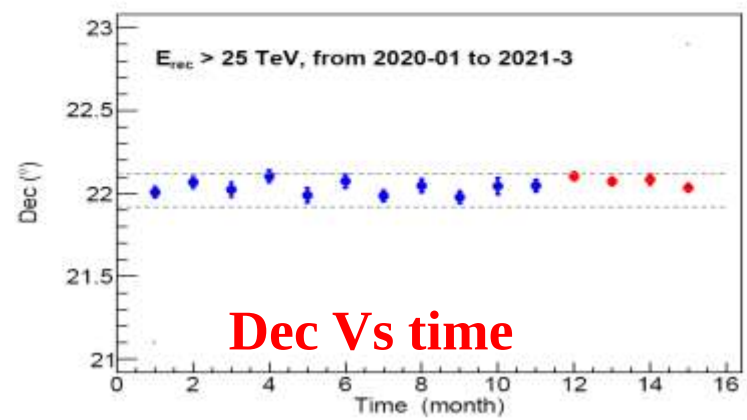


Crab Nebula monitor



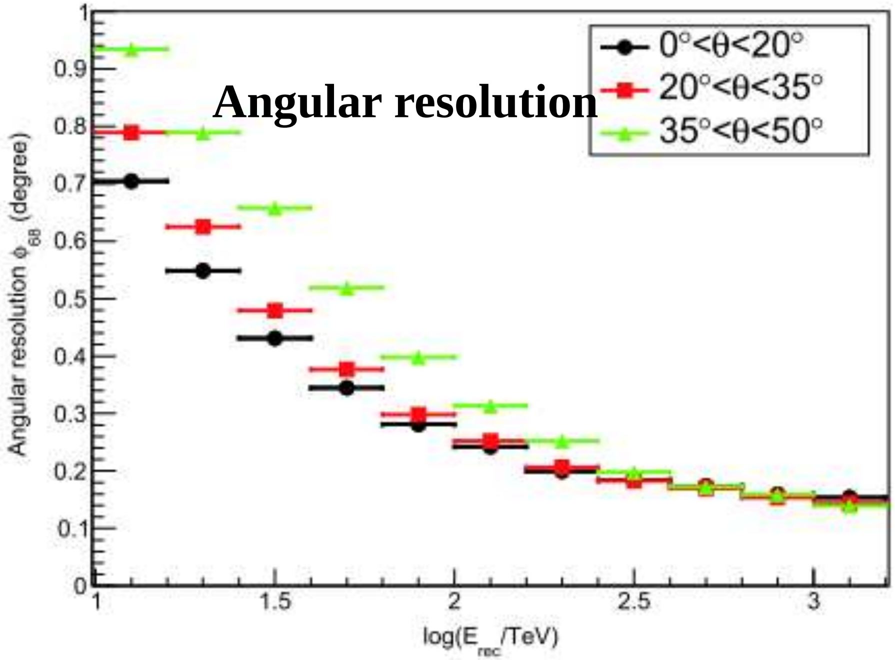


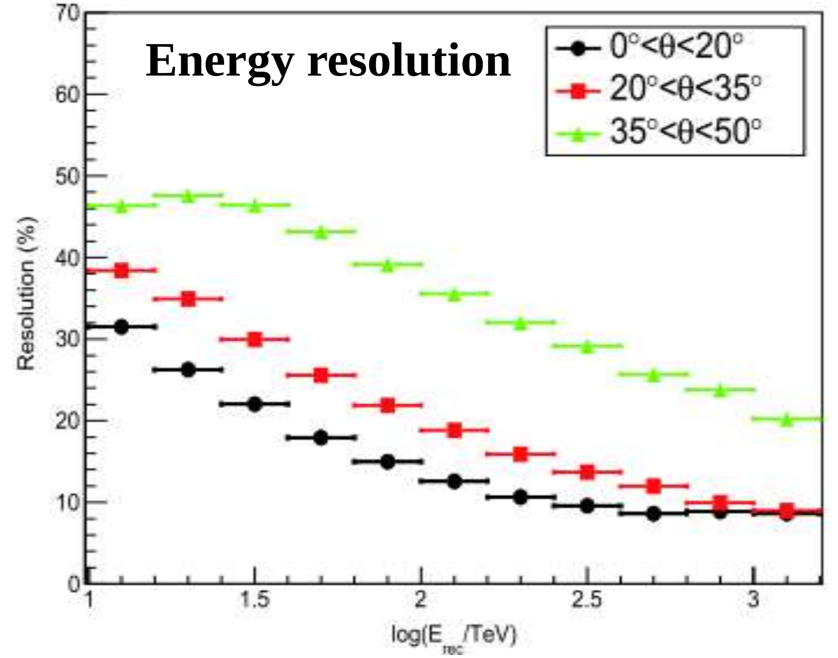


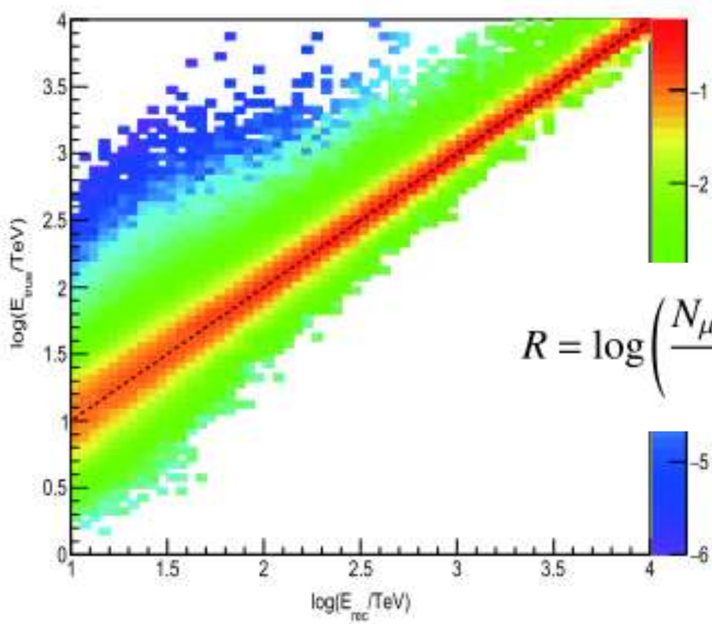


Pointing accuracy <0.1 º

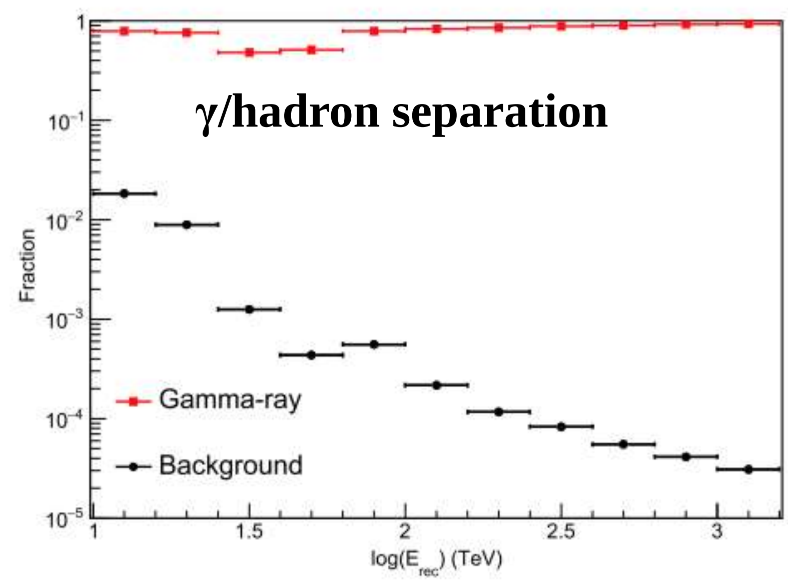
Performance of ½ KM2A



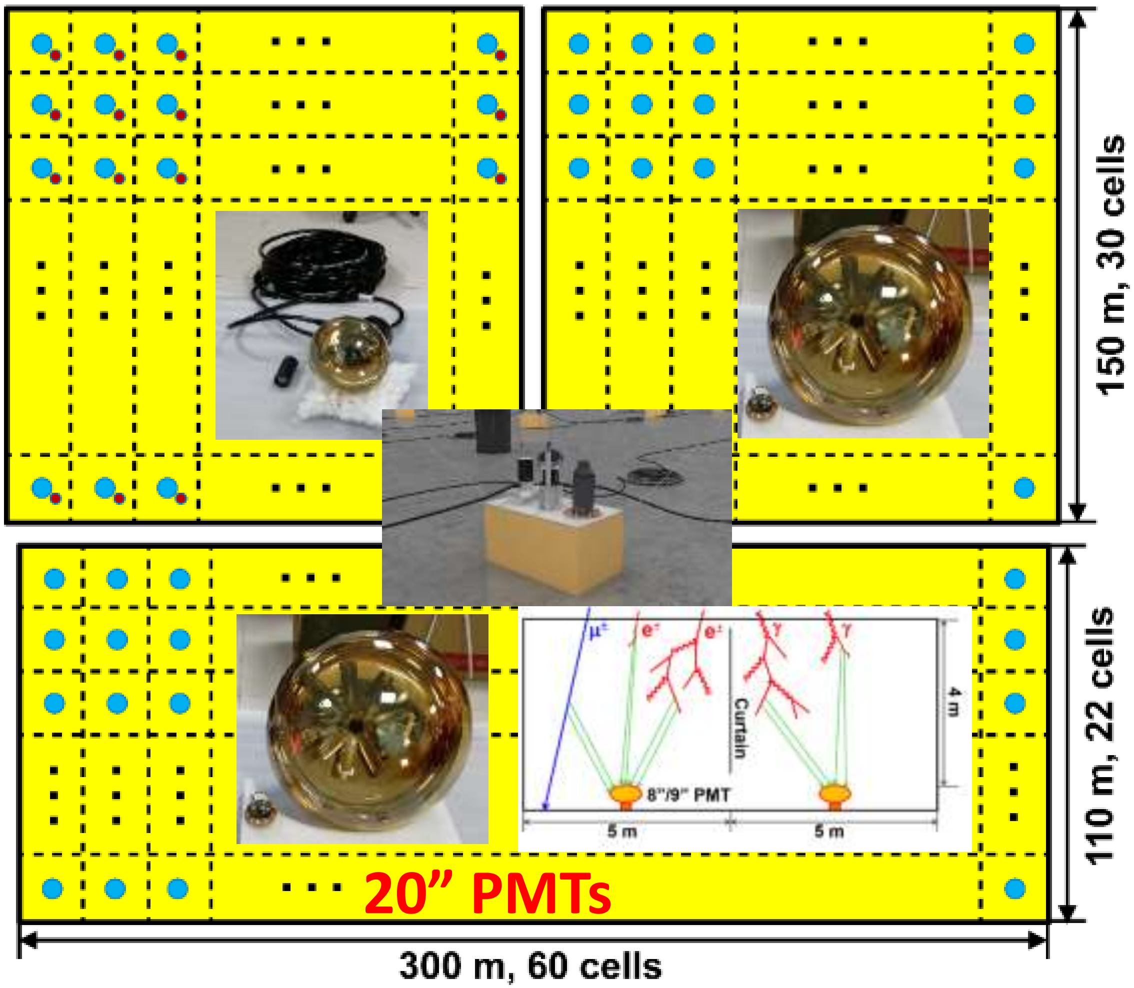


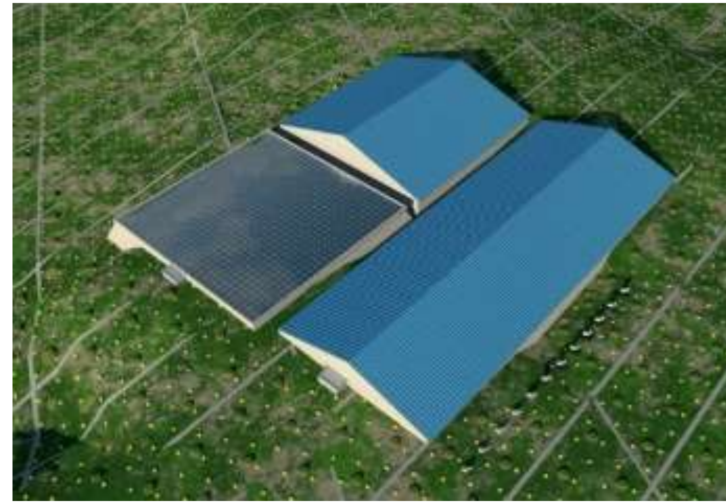


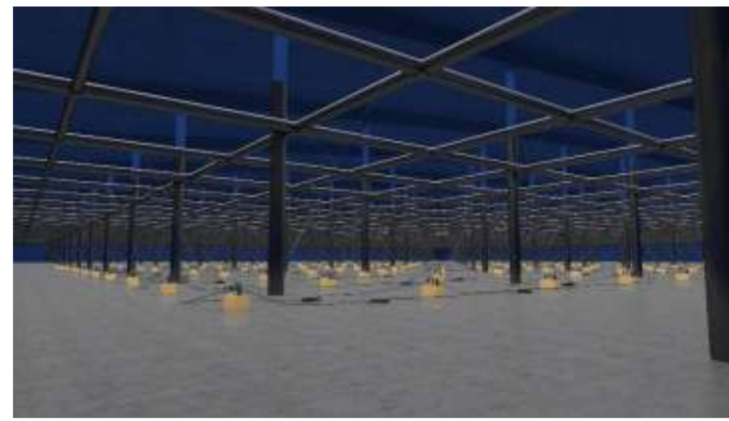
$$R = \log\left(\frac{N_\mu + 0.0001}{N_e}\right)$$

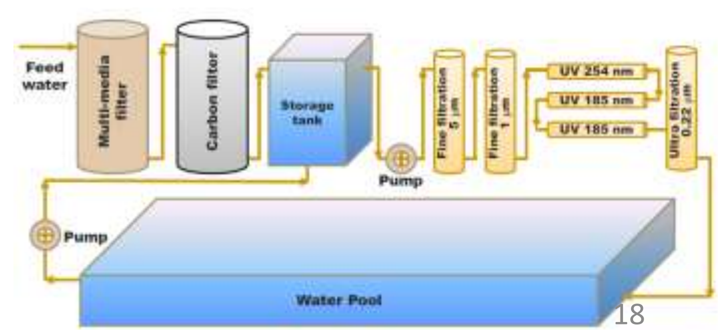


Water Cherenkov Detector Array



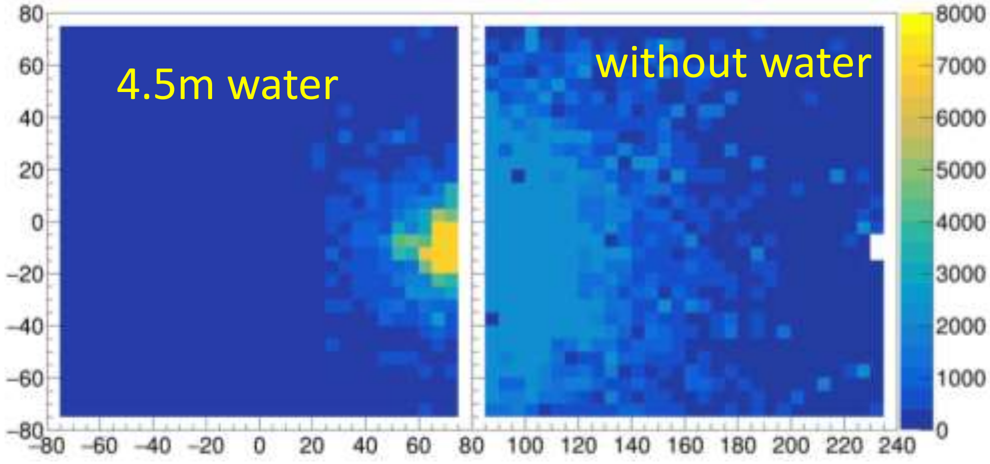




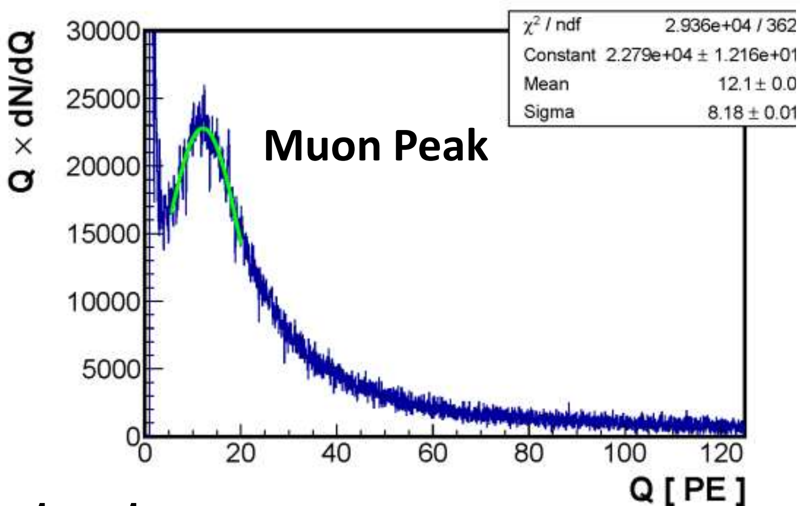


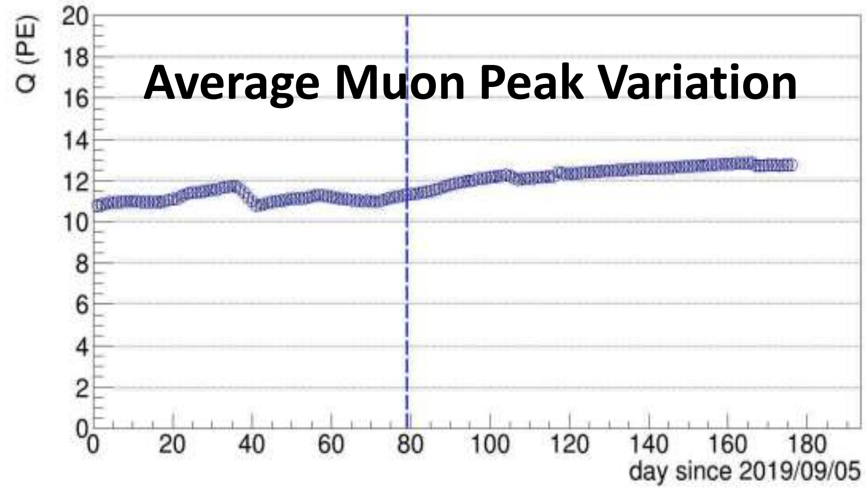
Inside WCDA-2

- Start the test operation



Performance of WCDA-1



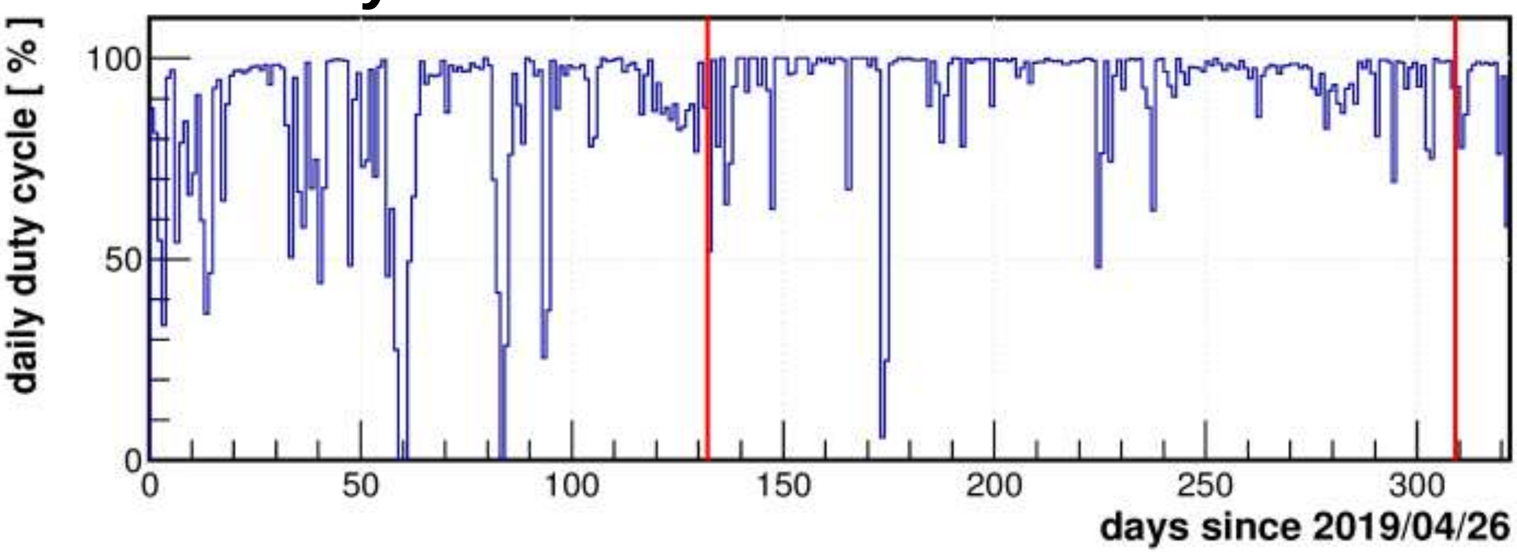


Event rate：

~20k Hz

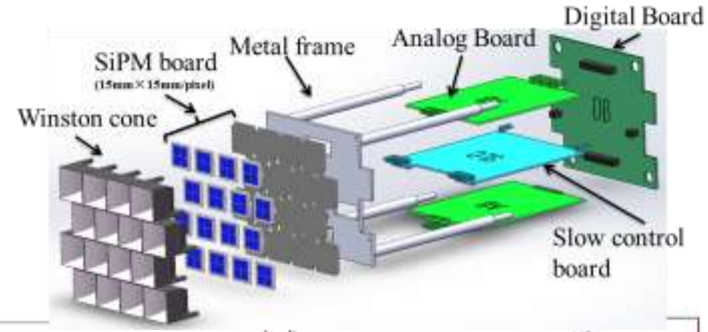
1.7B events/day

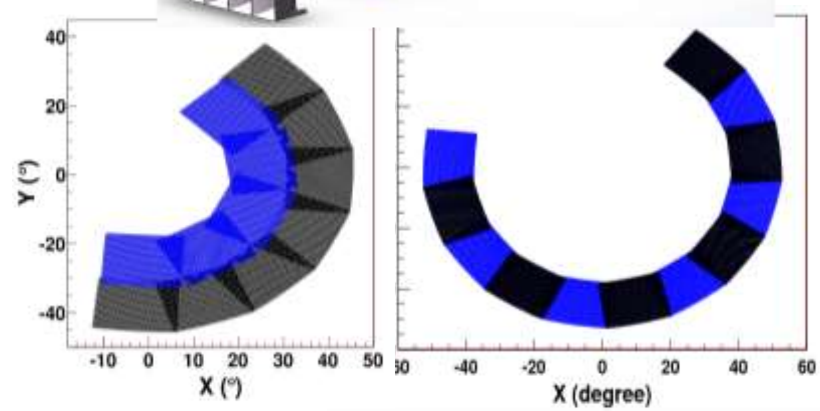
Daily Duty cycle



Wide FOV Cherenkov Telescope Array

- 5m^2 spherical mirror
- FOV: 16º×16º
  - ➢ 32×32 SiPMs array
  - ➢ Pixel size 0.5°
- Portable design





Phase II

Phase II: 18 telescopes

- 100 TeV - 100 PeV
  - 45° in zenith
  - **10 telescopes started operation in 2021/01**

More (the rest eight telescope) are coming on line.

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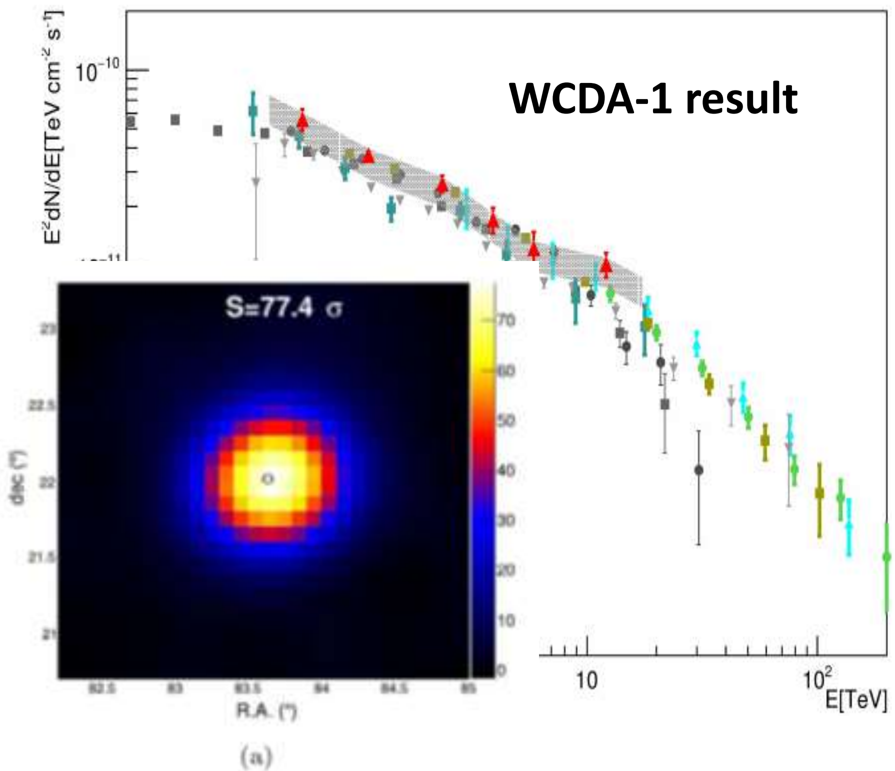
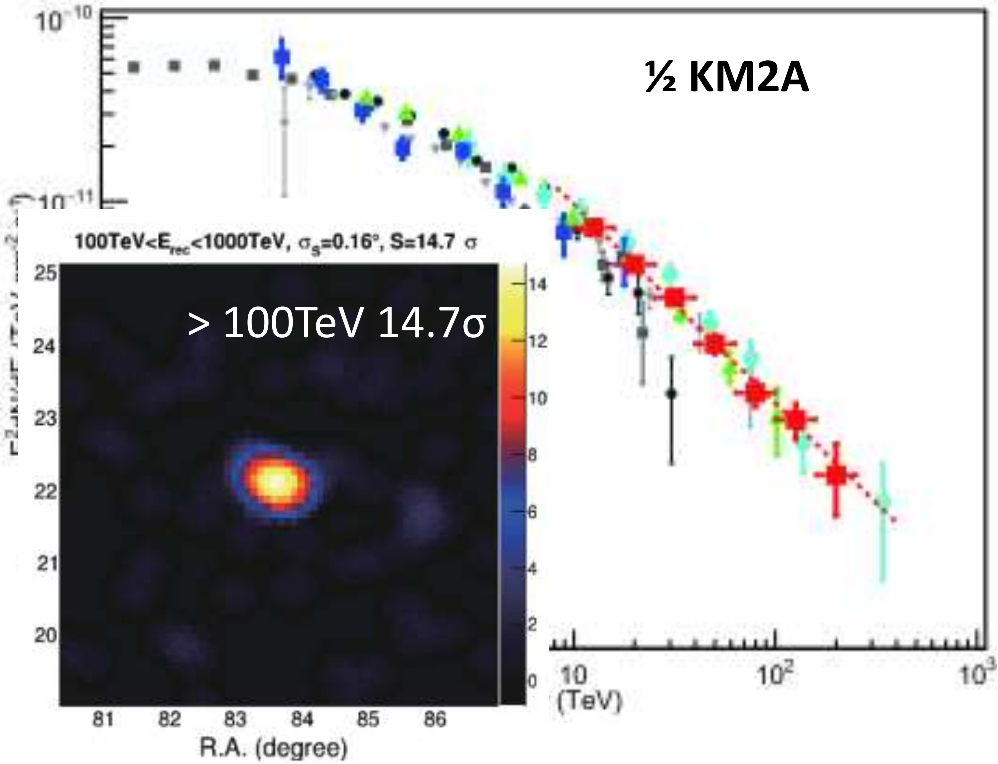
Crab analysis by WCDA-1 and ½ KM2A



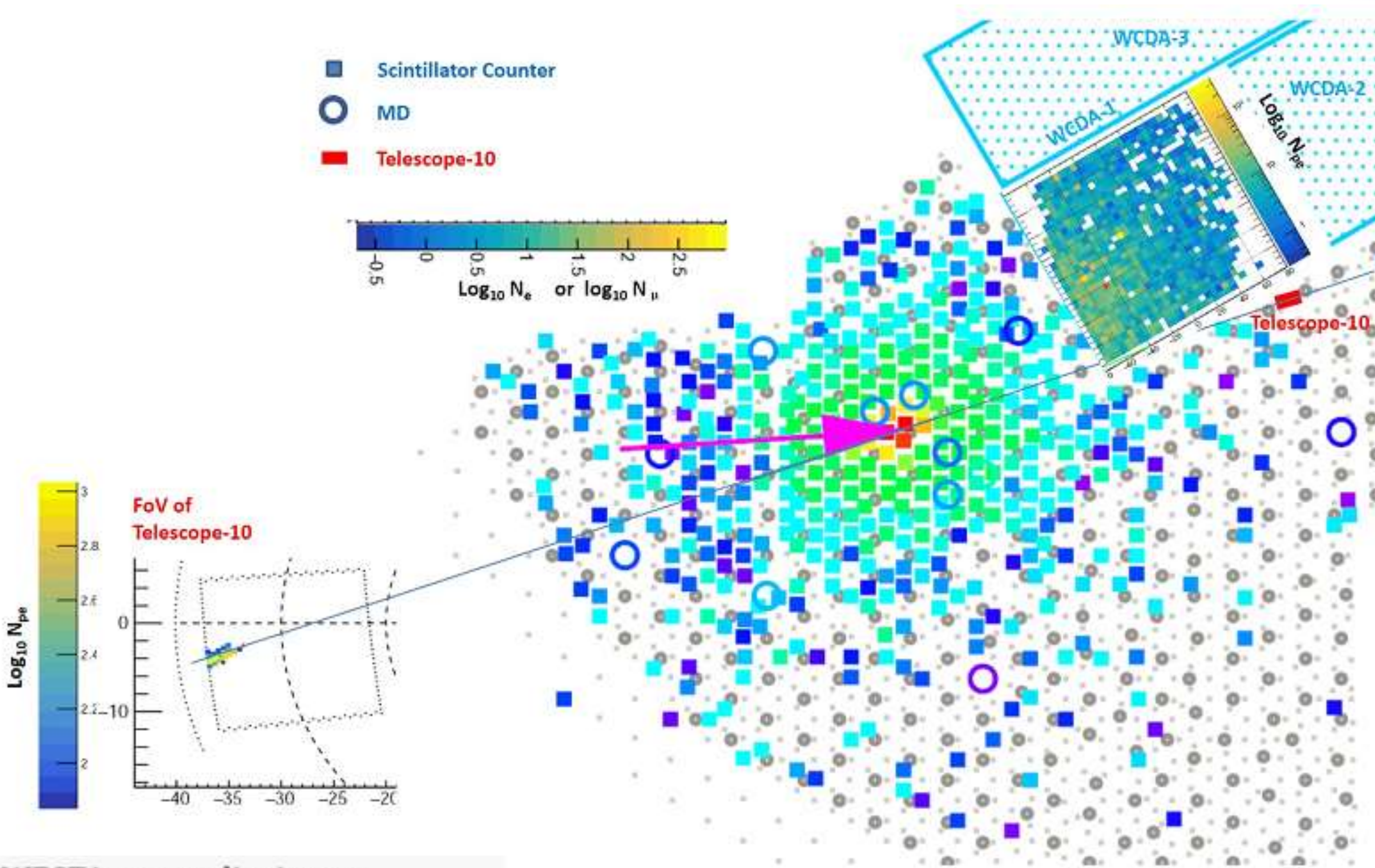


- **Nhit> 100,**
- **2019-09-05 to2020-02-29**
- **Pointing error <0.05°.**

- **Ne> 10,**
- **2019-12-27 to 2020-05-28**
- **Pointing error <0.1°.**

Aharonian, et al. *Chin. Phys. C*, 2021, 14.

~1 PeV Photon observed by LHAASO



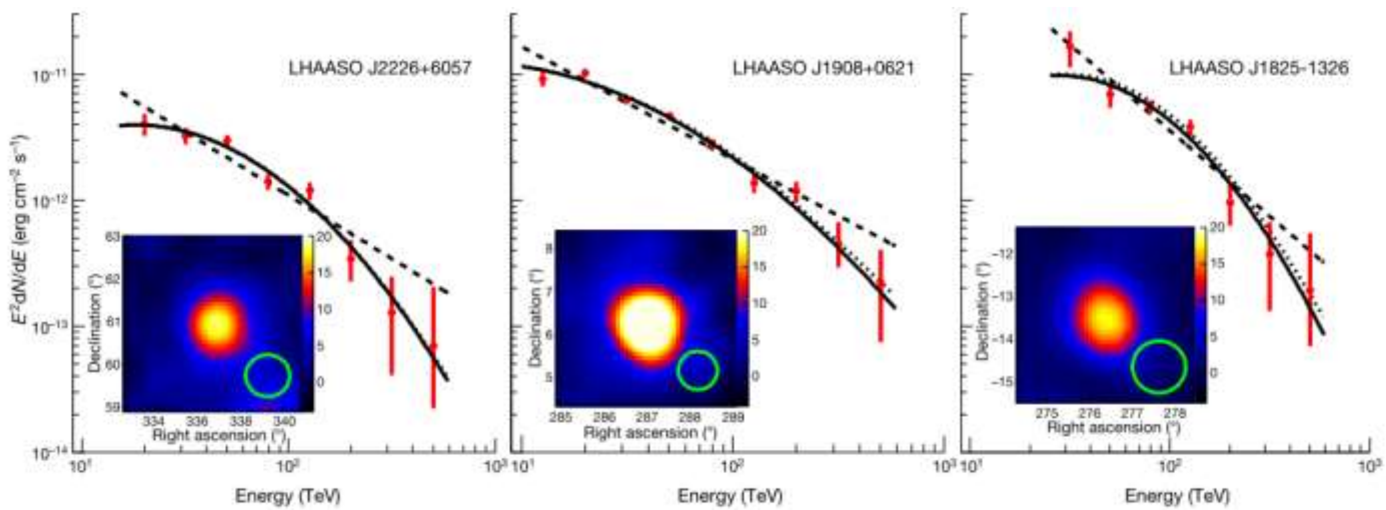
- WFCTA: very slim image, L/W~2.6, Npe~9100,
- 1.2 ± 0.3 PeV (assuming proton), 0.9 ± 0.2 PeV (assuming gamma)
- ED: Nd~395, Ne~4574, E~0.9 PeV
- Chance probability: <0.1% (15 μ's detected in 11 MDs)

Twelve γ-ray Galactic sources above 100TeV

Table 1 | UHE γ-ray sources

Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26\,_{-0.10}^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71\,_{-0.07}^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

Celestial coordinates (RA, dec.); statistical significance of detection above 100 TeV (calculated using a point-like template for the Crab Nebula and LHAASO J2108+5157 and 0.3° extension templates for the other sources); the corresponding differential photon fluxes at 100 TeV; and detected highest photon energies. Errors are estimated as the boundary values of the area that contains ±34.14% of events with respect to the most probable value of the event distribution. In most cases, the distribution is a Gaussian and the error is 1σ.



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Summary

- LHAASO observatory for gamma ray astronomy and CR phys.
  - Unique for UHE (>0.1PeV) γ–astronomy: full with PeVatrons in Milky Way which are generating super-PeV photons, Window for evidences of hadronic origin of cosmic rays
  - SED measurements covering a range of 0.1-1000 TeV by LHAASO
  - Wide FOV monitoring for transient phenomena
  - Precision measurements of E-spectra of CR species
- 1/2 of the array in scientific operation since Dec., 2019
- Full array will be completed by the end of 2021.