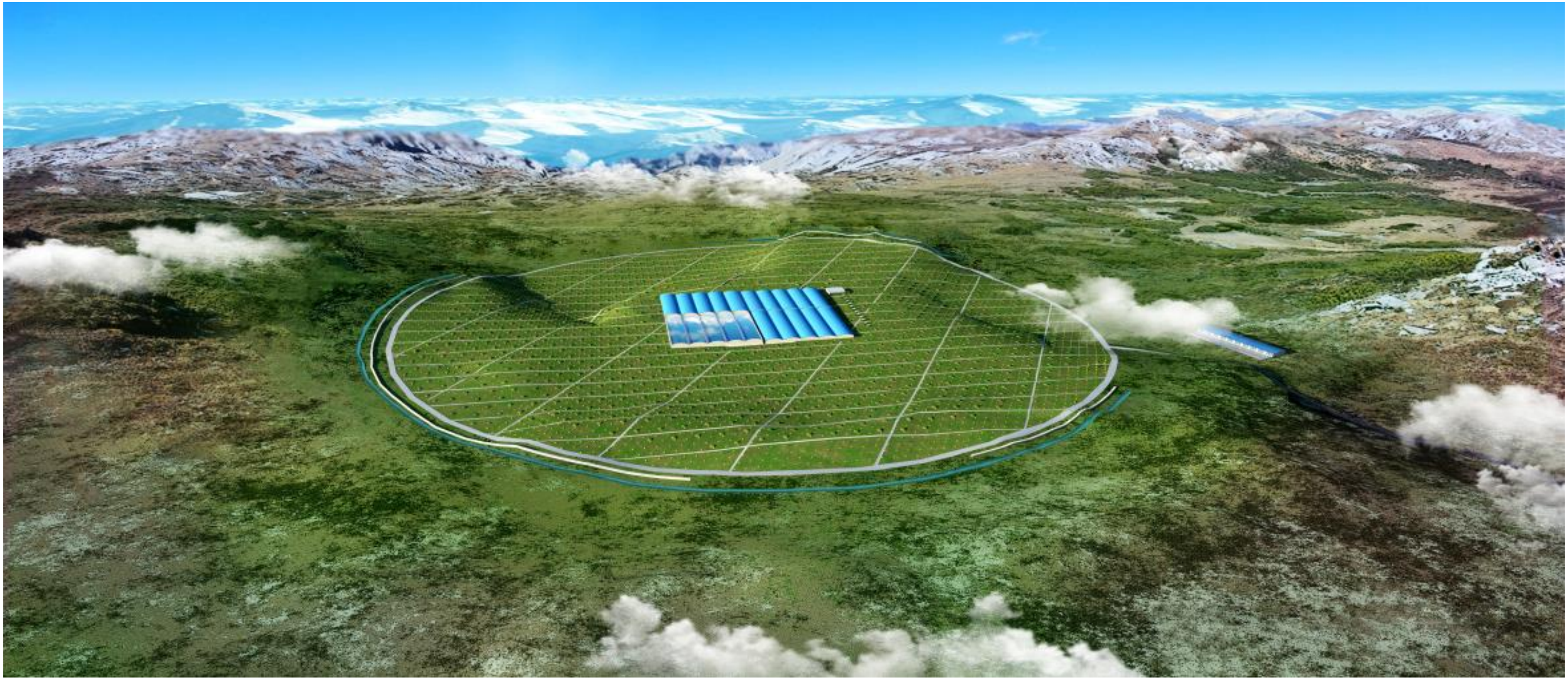


LHAASO

高海拔宇宙线观测站
LHAASO Large High Altitude Air Shower Observatory

中國科學院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

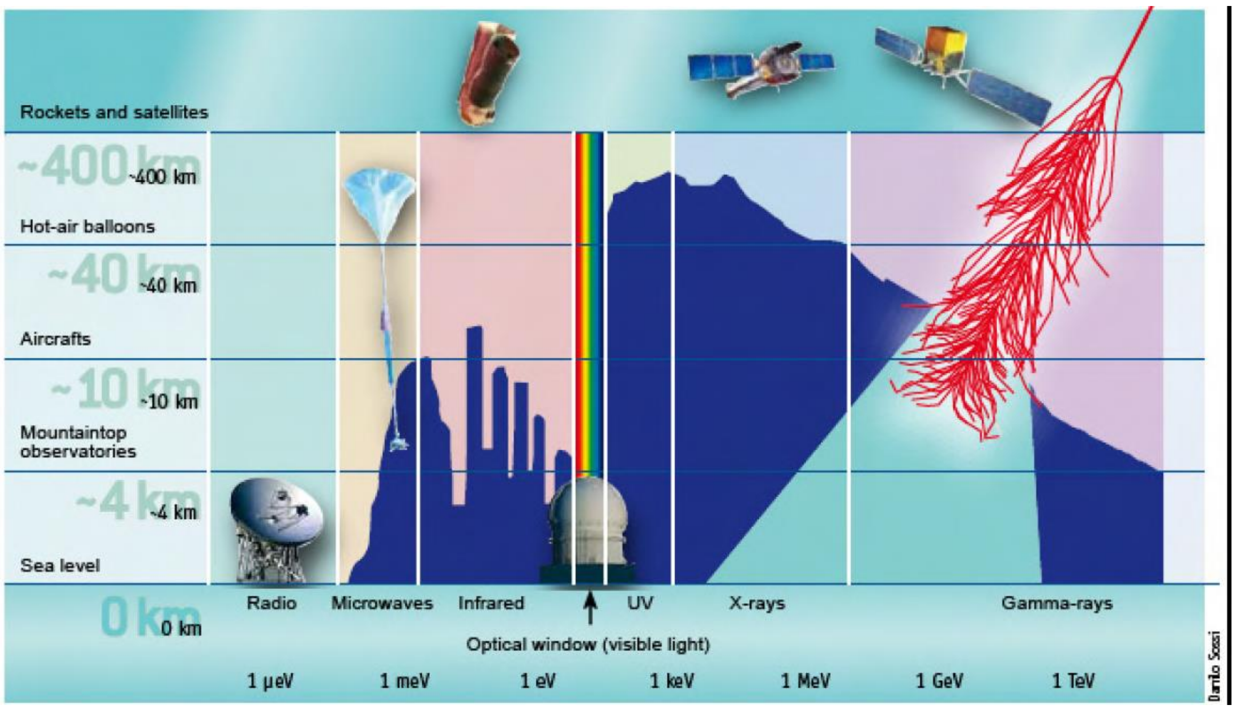
Sifan Wang (王思凡) Supervised by Prof. Wei Cui

THCA Student Seminar 2018/12/07

Outline

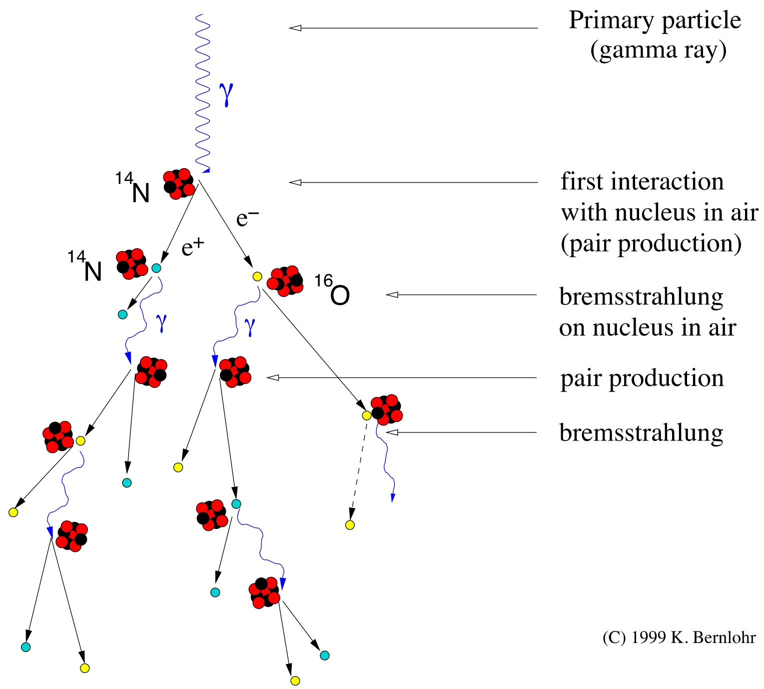
- Brief review on ground-based γ-ray astronomy
- Basic facts of LHAASO
- Main Scientific goals of LHAASO

Why ground-based?

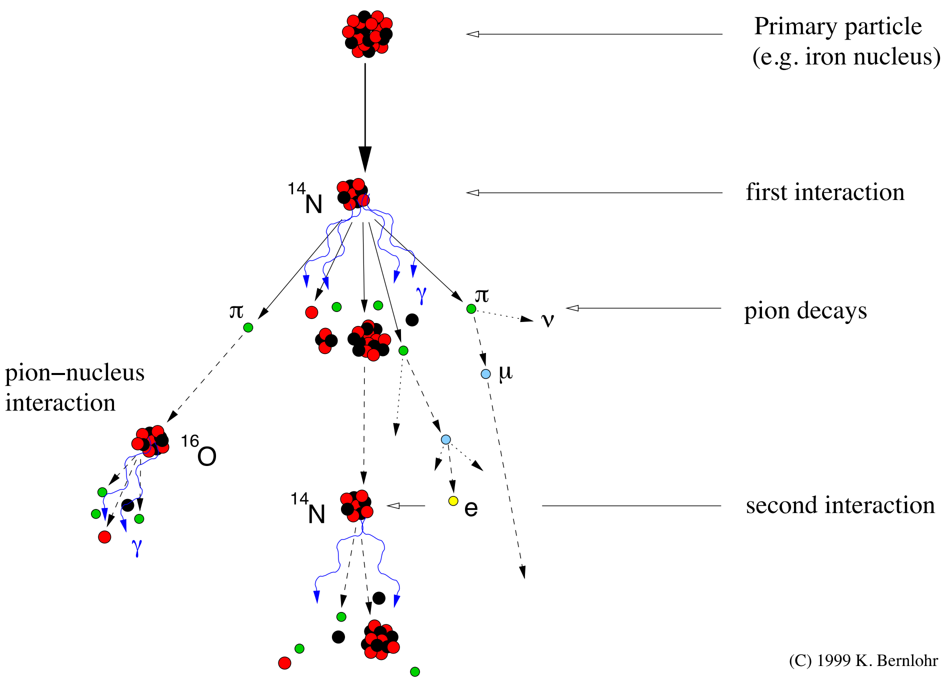


Extensive Air Shower (EAS)

Development of gamma–ray air showers



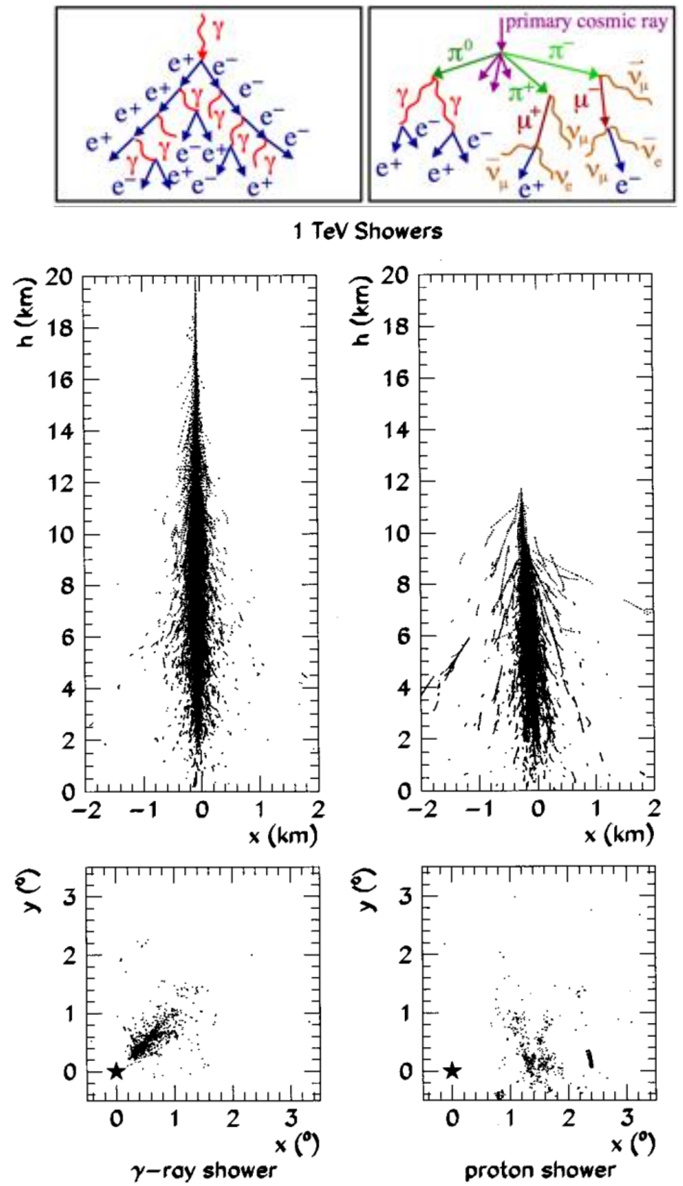
Development of cosmic–ray air showers



γ/Nuclei Discrimination

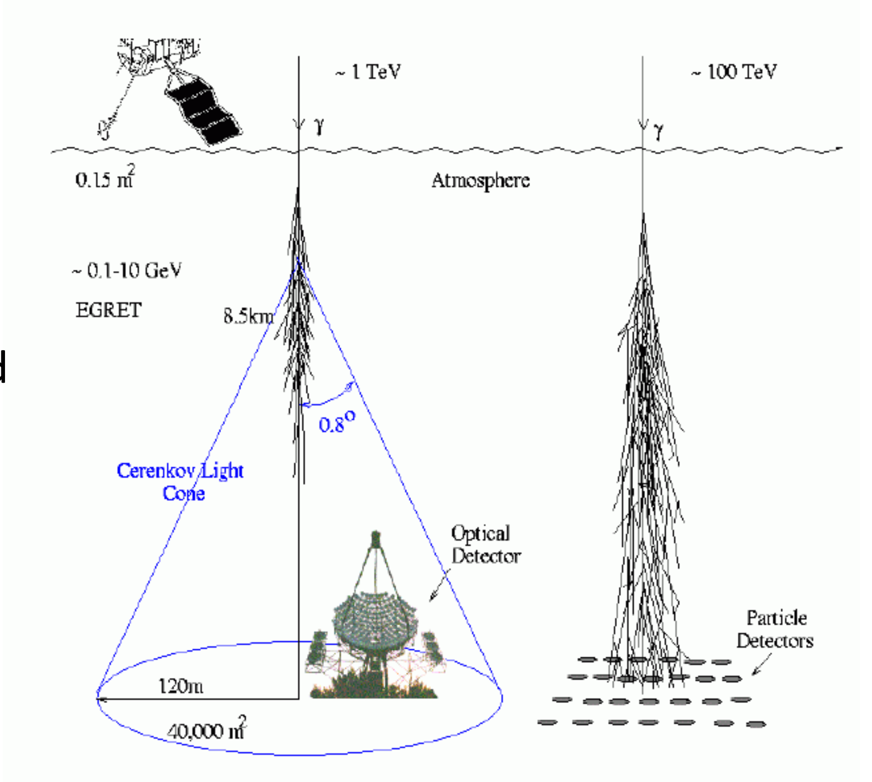
- γ-ray showers
  - Less muons
  - Compact, elliptical images
- CR showers
  - More muons
  - More interactions, less compact, irregular images

The capability to identify the CR background is one of the main factors that determines the sensitivity of an instrument.



Detecting Methods

- Shower particles reaching the ground ($\mu^{\pm}$, $e^{\pm}$, γ, ν)
  - HAWC, LHAASO …
  - Discoveries: transient sources, extended sources, sky survey…
- Cherenkov radiation induced by EAS
  - VERITAS, CTA …
  - Detailed studies: source identification, spectral energy distribution …



Complementary in practice!

	Cherenkov Telescope	EAS arrays
Energy Threshold	Low (<200 GeV)	High (>1 TeV)
Background Rejection	Excellent (>99.7%)	Moderate (>50%)
Field of View	Small (<5°)	Large (>45°)
Duty Cycle	Short (5%-10%)	Long (>90%)

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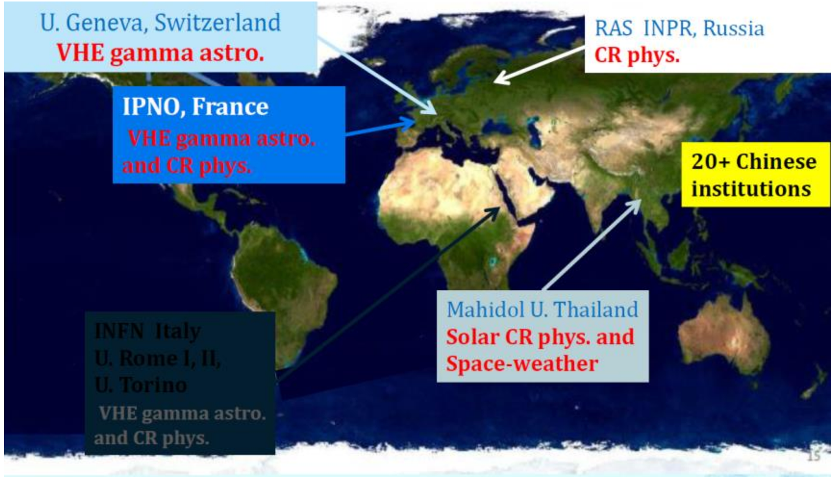
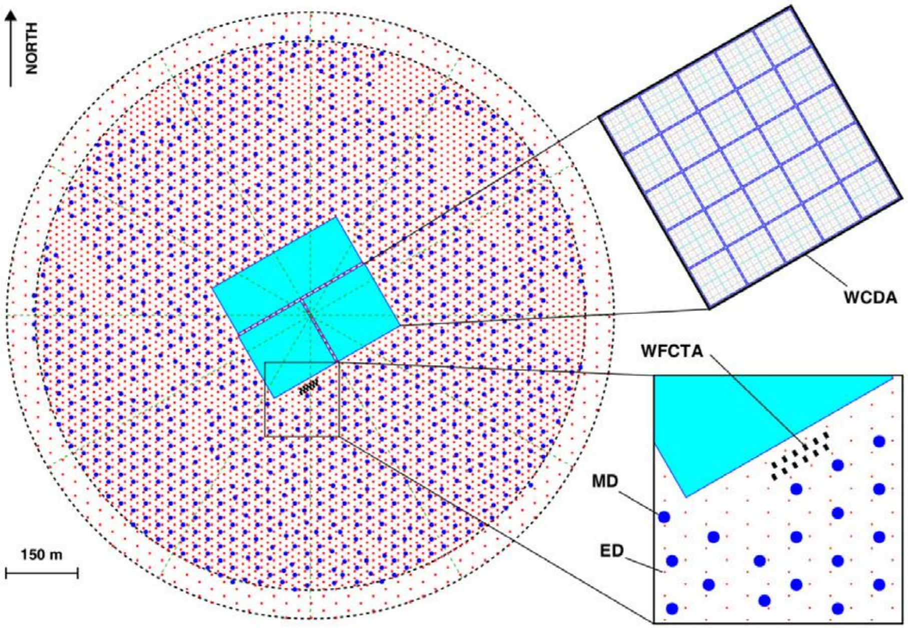
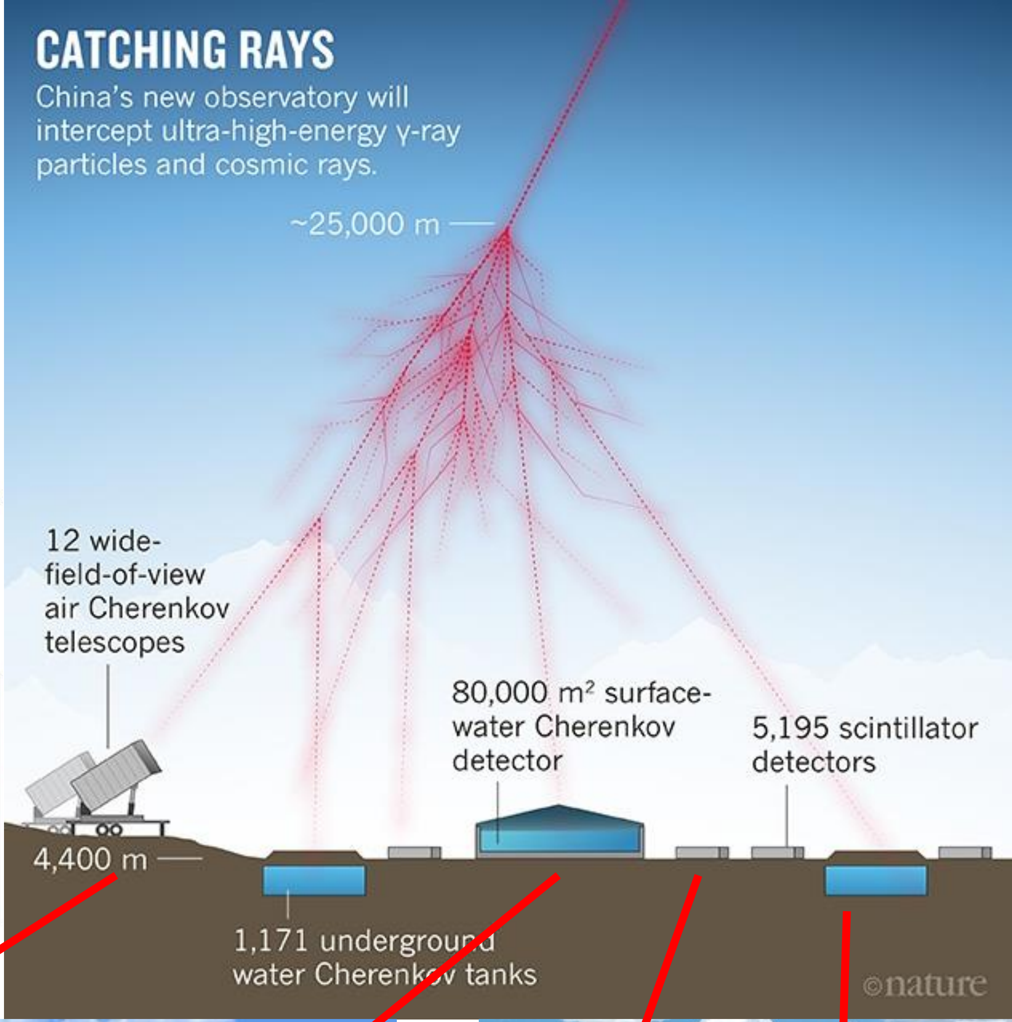
Basic Facts

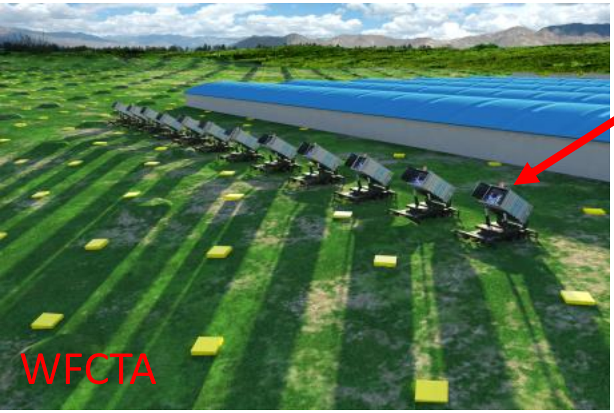
- Hybrid EAS array
  - Water Cherenkov Detector Array (WCDA)
  - 1 km² Array (KM2A, ~1.3km²)
    - Electromagnetic particle detectors (ED)
    - Muon detectors (MD)
  - Wide Field Cherenkov Telescope Array (WFCTA)
- Daocheng, Sichuan, 4410m a.s.l. (四川省稻城县海子山)
- Funded mainly by China, 20+ institutions joining the collaboration
- 1.2 billion RMB (174 million USD)
- Energy band covered
  - gamma ray: $2 \times 10^{11} - 10^{15}$ eV
  - cosmic ray: $10^{12} - 10^{18}$ eV

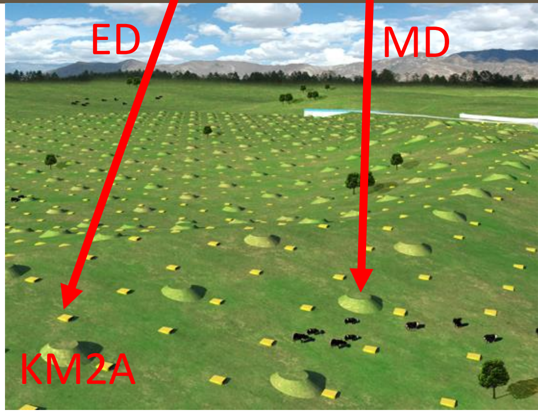


Detectors & Layout



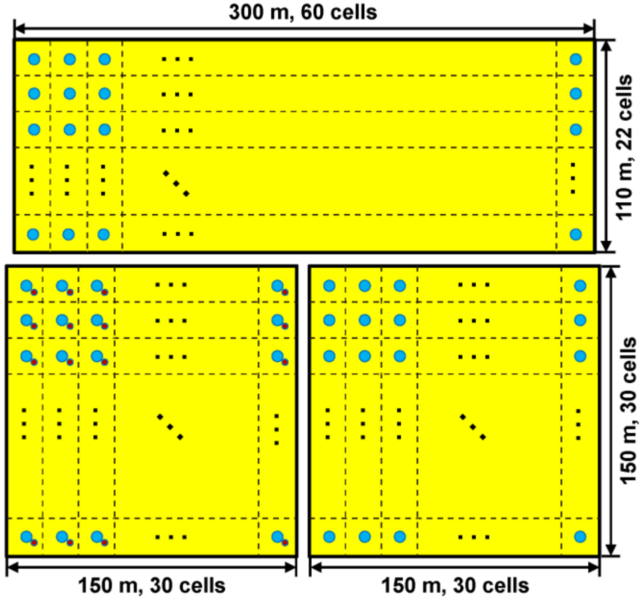


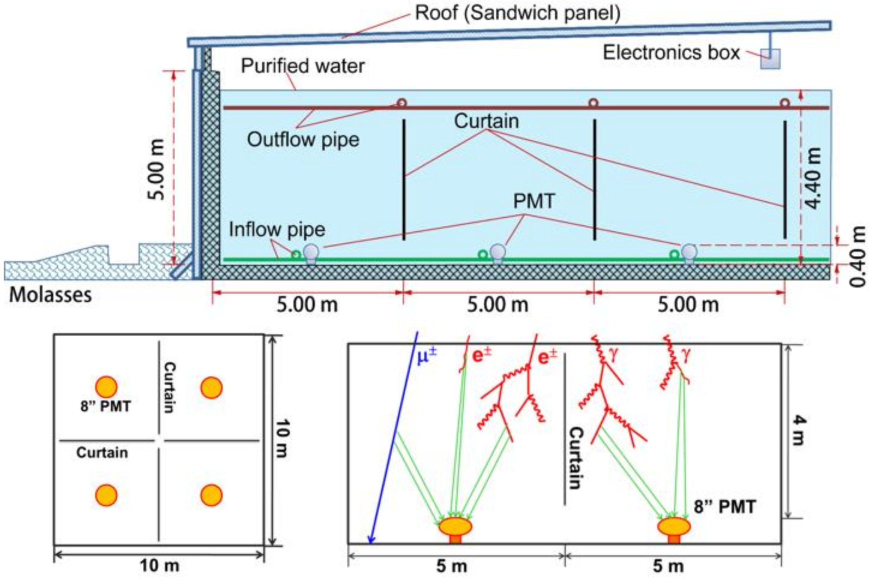




WCDA

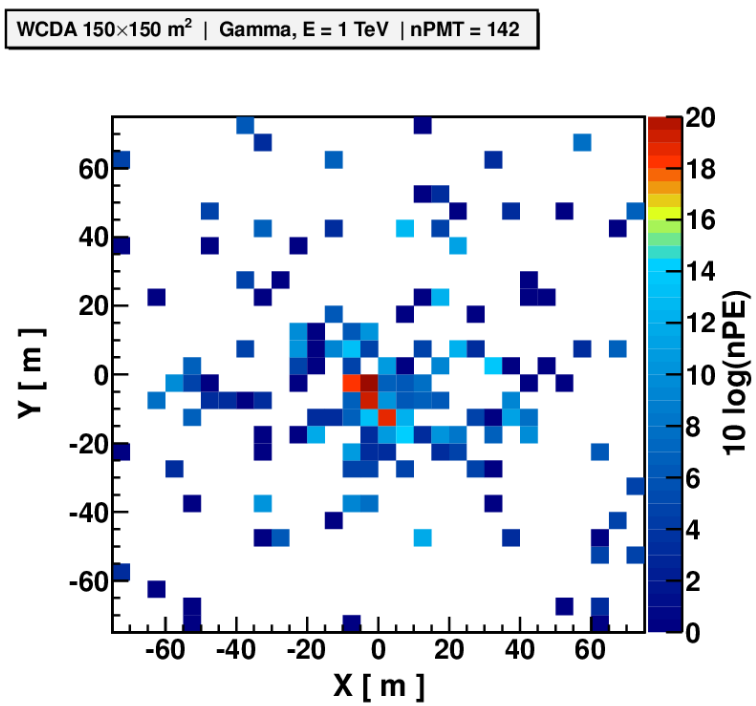
- 3 ponds, 78000 m², 4.4 m water depth
- 3120 cells (5 m * 5 m each)

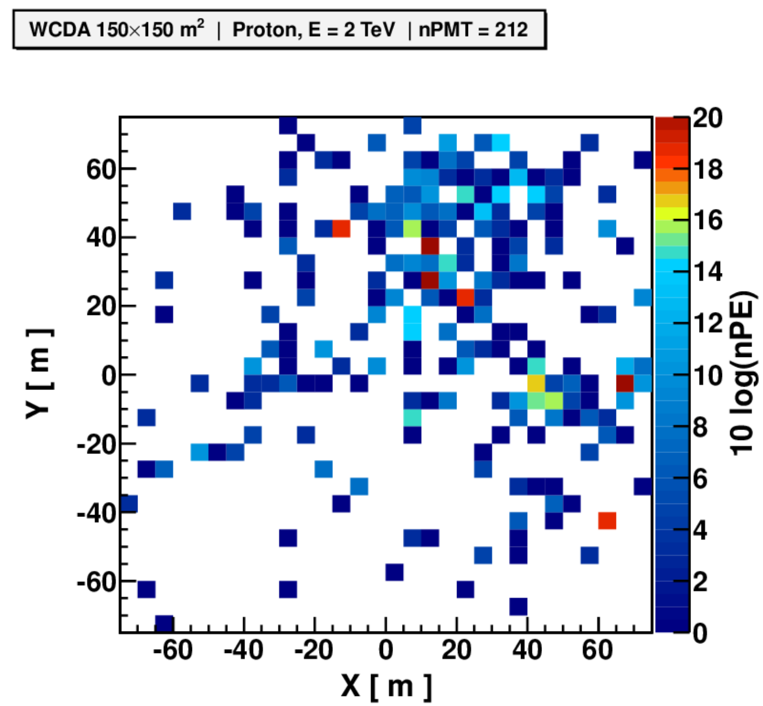




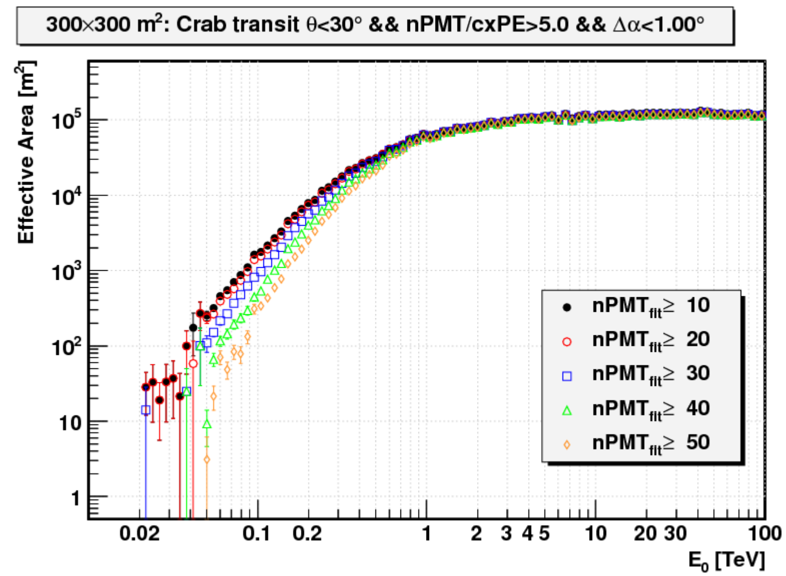
γ/Nuclei Discrimination - WCDA

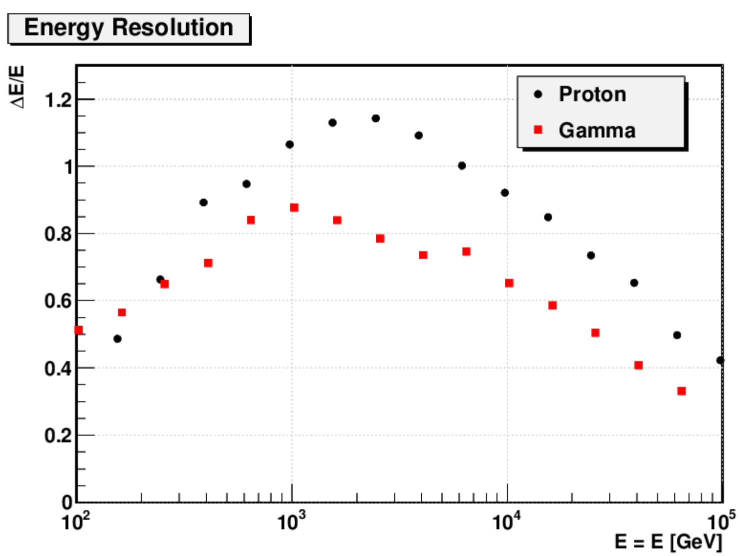
- “Compactness” can be employed to reject CR background efficiently.

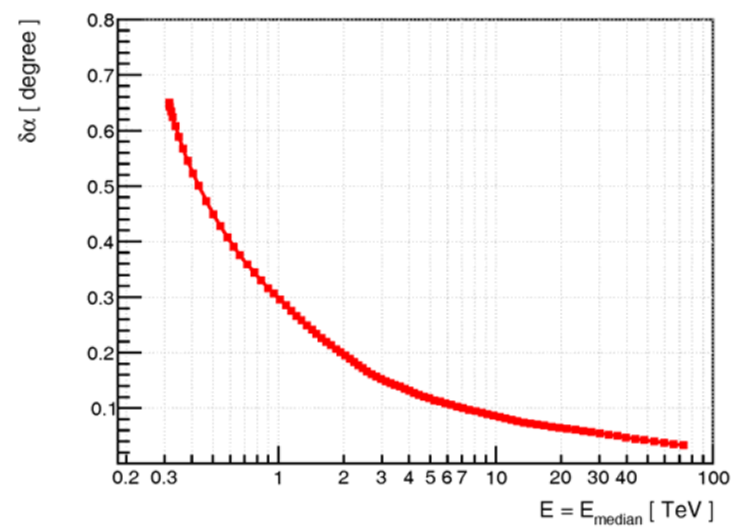




WCDA Specifications	Value
Duty Cycle	~100%
Energy Threshold	100 GeV to 20 TeV
Field of View	> 2π/3 sr
Angular Resolution	~0.3 deg @ 1 TeV ~0.12 deg @ 5 TeV
Sensitivity	~0.013 Crab @ 2 TeV
Effective area	~1,000 m² @ 100 GeV >80,000 m² @ 5 TeV



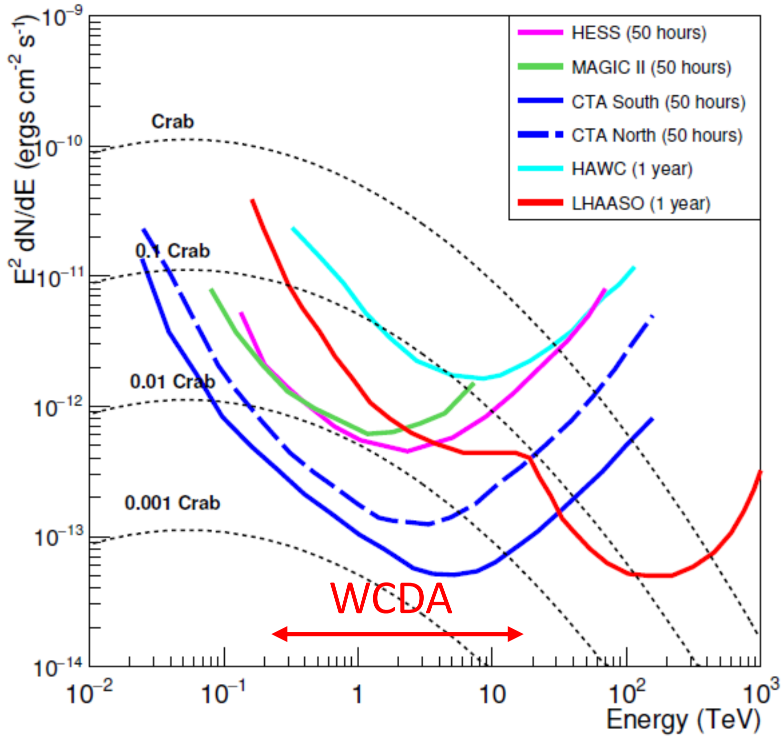




WCDA vs HAWC

- Both High altitude
- Both Large FOV
- Larger area (3.5 times)
- More sensitive

Sensitivity of ground-based γ-ray detectors to Crab-like point sources

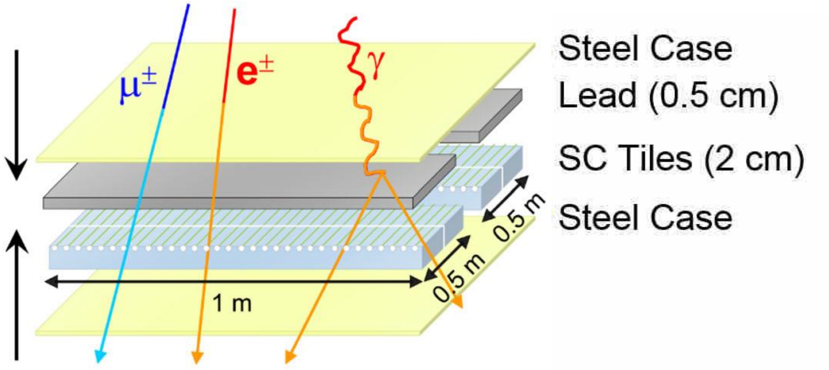


Specifications	HWAC	LHAASO-WCDA
Energy Threshold	100 GeV - 100 TeV	100 GeV - 20 TeV
Sensitivity	~0.1 Crab @ 2 TeV	~0.013 Crab @ 2 TeV
Field of View	2 sr	> 2π/3 sr
Area	22000 m²	78000 m²
Altitude	4100 m a.s.l.	4410 m a.s.l.

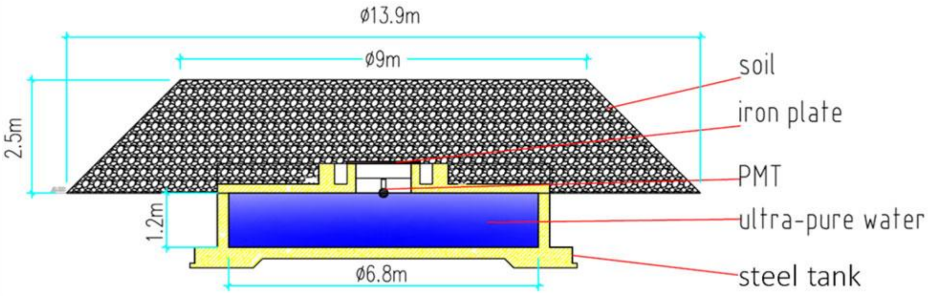
KM2A

- 5195 EDs: $1m^2$ each, 15m spacing
  - Measure energy and direction of primary rays
- 1171 MDs: $36m^2$ each, 30m spacing
  - γ/nuclei discrimination

ED

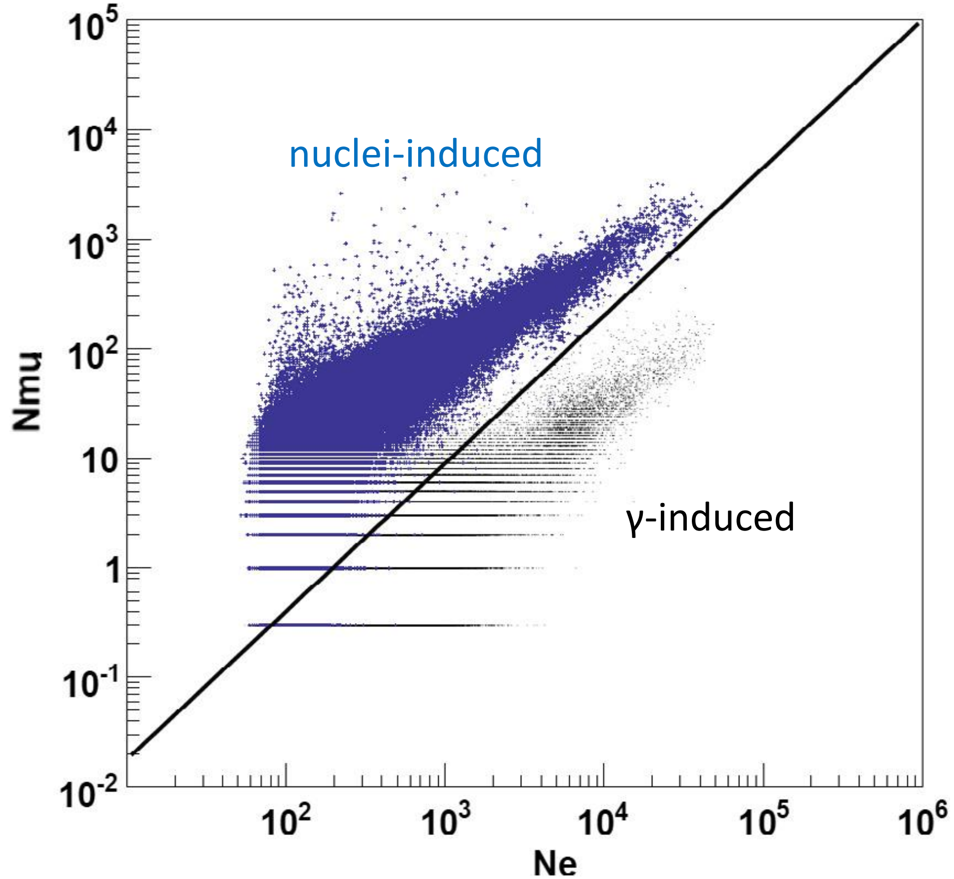


MD



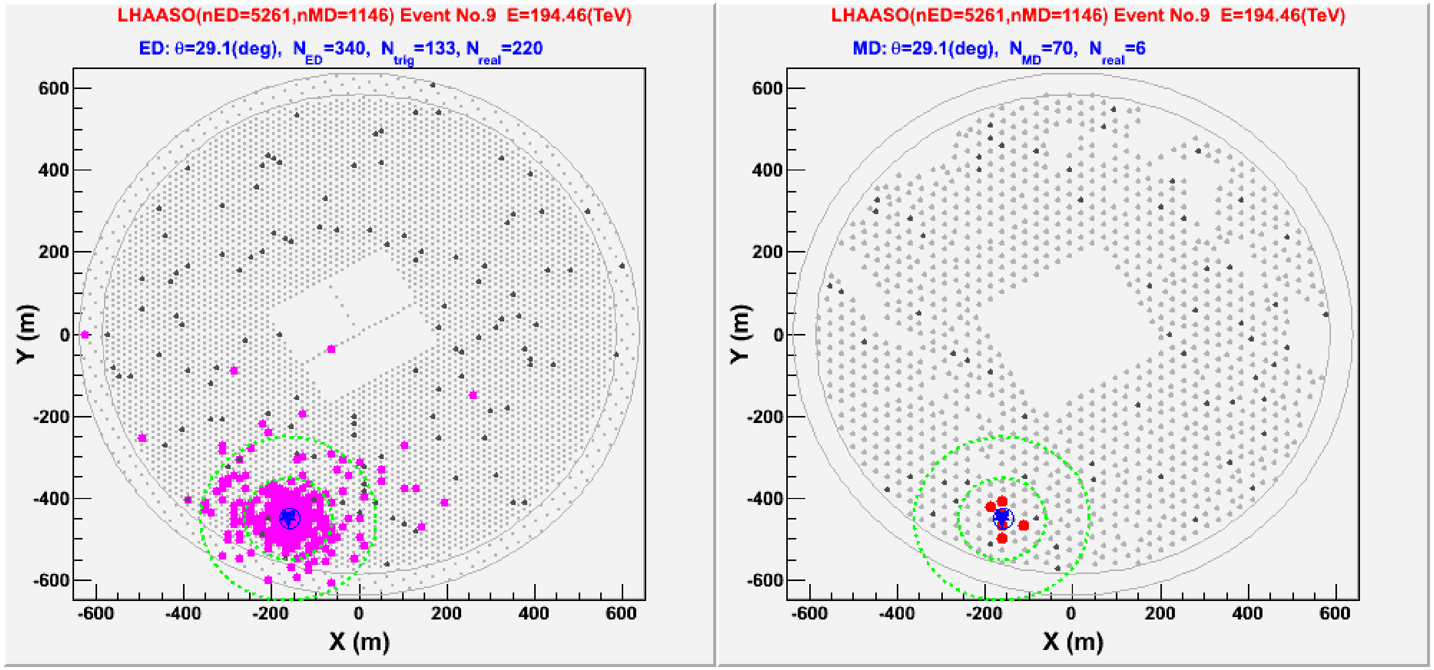
γ/Nuclei Discrimination - KM2A

- KM2A-MD background rejection level: 10^{-4} @ 50 TeV



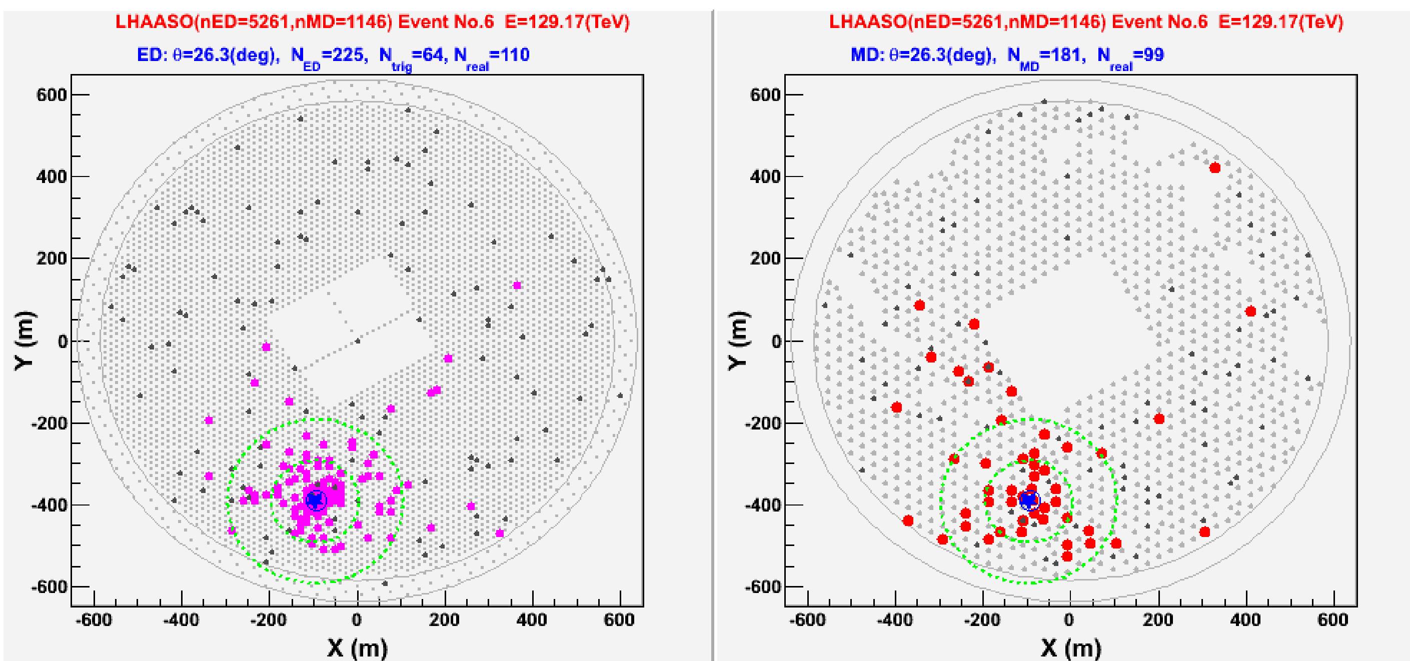
Event A

γ-induced

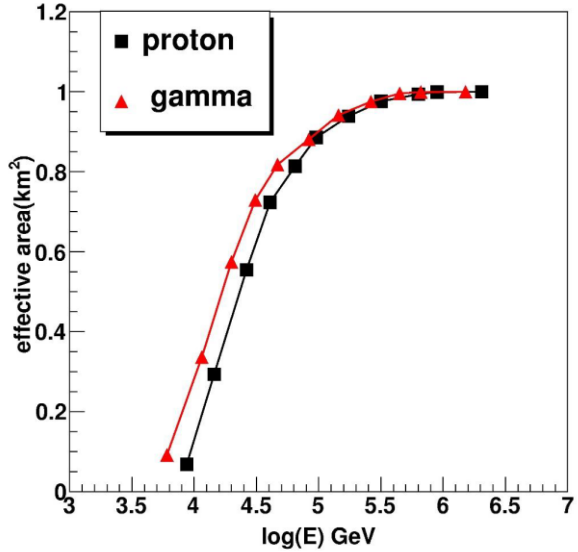


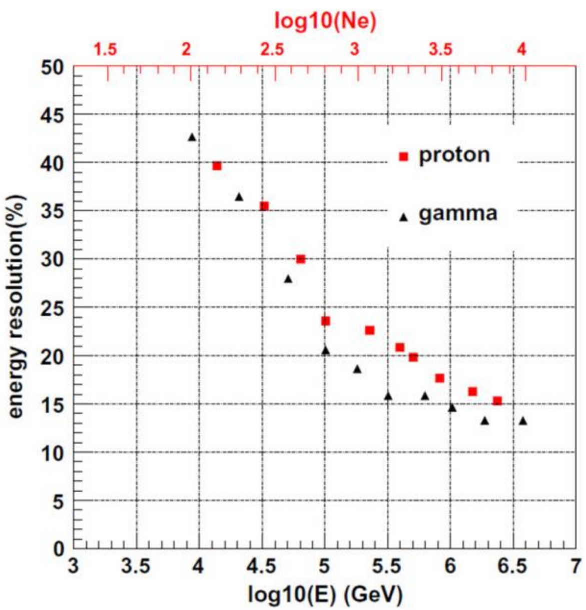
Event B

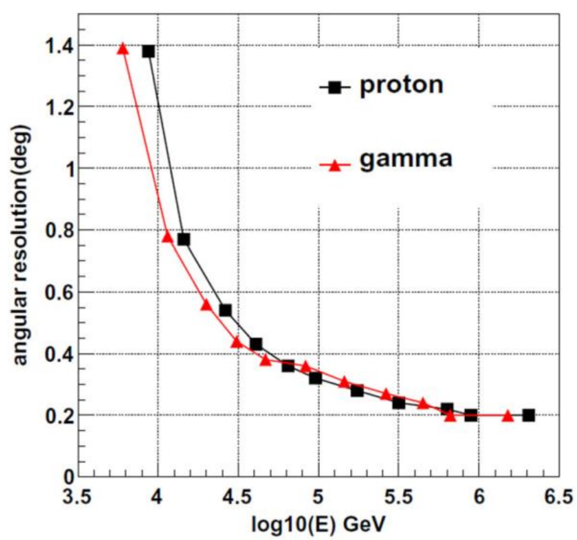
nuclei-induced



KM2A Specifications	Value
Energy Threshold	10 TeV~1 PeV
Background Rejection	~10E-4 @ 50 TeV
Angular Resolution	~0.3 deg @ 100 TeV ~0.5 deg @ 30 TeV
Sensitivity	~1% Crab @ 100 TeV
Energy resolution	~20% @ 100TeV

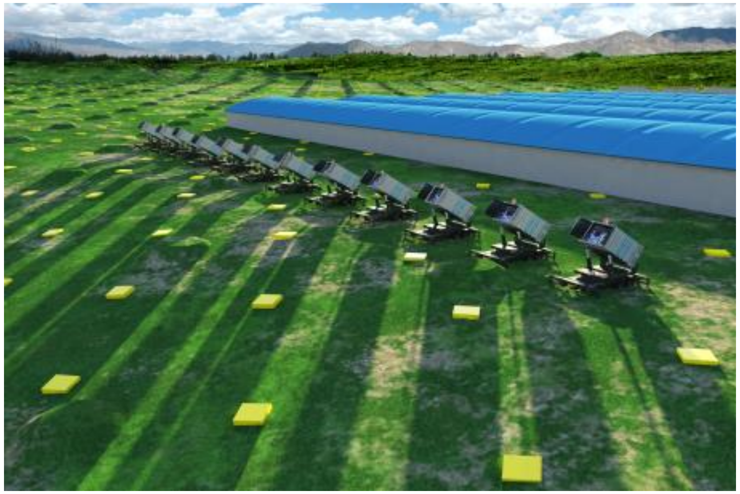






WFCTA

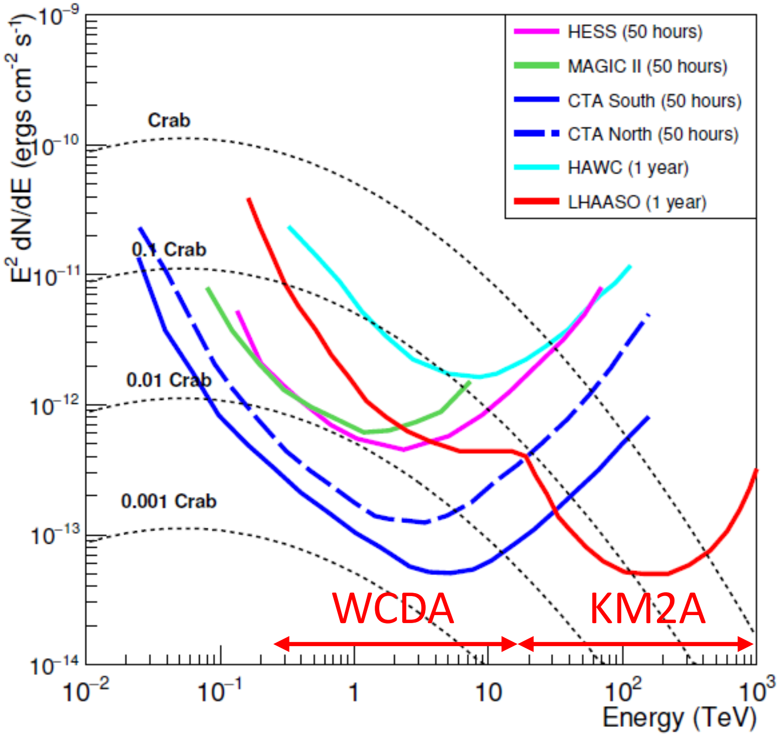
- 4.7m² spherical mirror
- 32 × 32 SiPM array, pixel size of 0.5 deg
- FOV: 16 deg × 16 deg
- Study CR energy spectrum and composition: 10 TeV-EeV



The WFCTA prototype at ARGO-YBJ site

LHAASO vs CTA

- LHAASO
  - Large FOV
  - Long duty cycle
  - Unprecedented sensitivity at energy above 20 TeV
- CTA
  - Small FOV
  - Low duty cycle
  - Very high sensitivity under 20 TeV



The double structure of LHAASO:
WCDA 0.2 – 20 TeV, KM2A 20 TeV – 1 PeV

Status

- ¼ of the array will be turned on for scientific operation next spring
- set for completion in the beginning of 2021
- photos from Xinhua 2018/6/19

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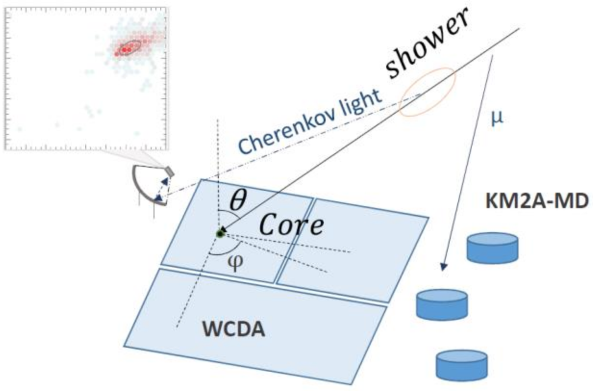
Discovery Potential

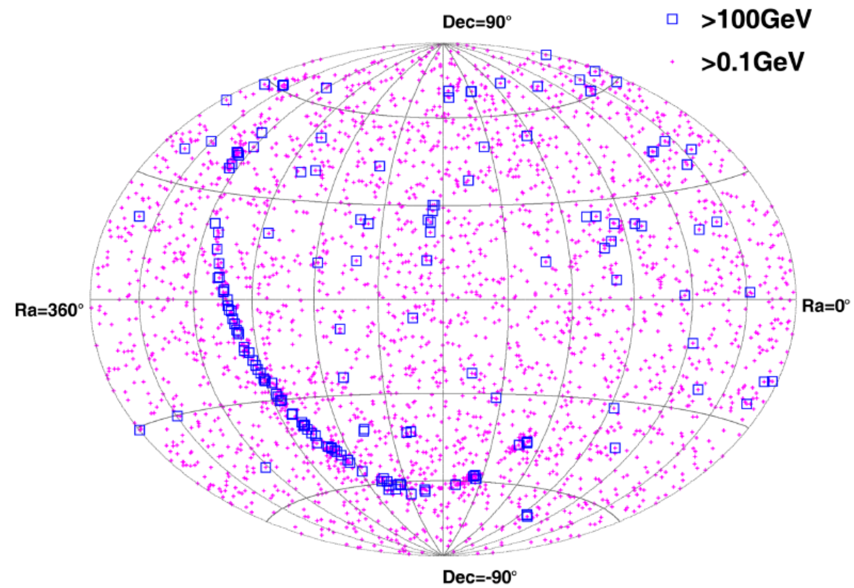
- VHE γ-sky survey (100 GeV-30 TeV) → WCDA(100 GeV-20 TeV)
  - Extragalactic sources & flares
  - VHE emission from GRB
  - Galactic sources
  - Diffused Gamma rays
- CR physics (1 TeV-10 PeV) → KM2A(10TeV-1PeV), WFCTA(10TeV-EeV)
  - Anisotropy of VHE cosmic rays
  - Cosmic ray spectrum
  - Cosmic electrons
  - Hadronic interaction models
- Other topics
  - Dark matter
  - Quantum gravity
  - Lorentz invariance violation



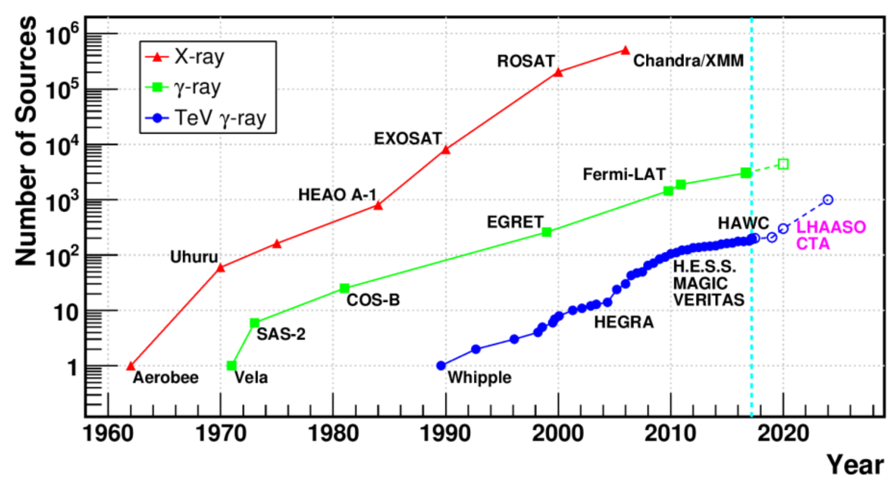
Hybrid detection of the EAS
at the LHAASO Observatory

Main goals of LHAASO
TeV γ-ray sky

- Galactic
  - Pulsar
  - SNR
  - Compact binary system …
- Extragalactic
  - AGN
  - GRB …
- 1/3 of galactic sources are still unidentified.
- No photons from >100 TeV
- LHAASO – WCDA & KM2A



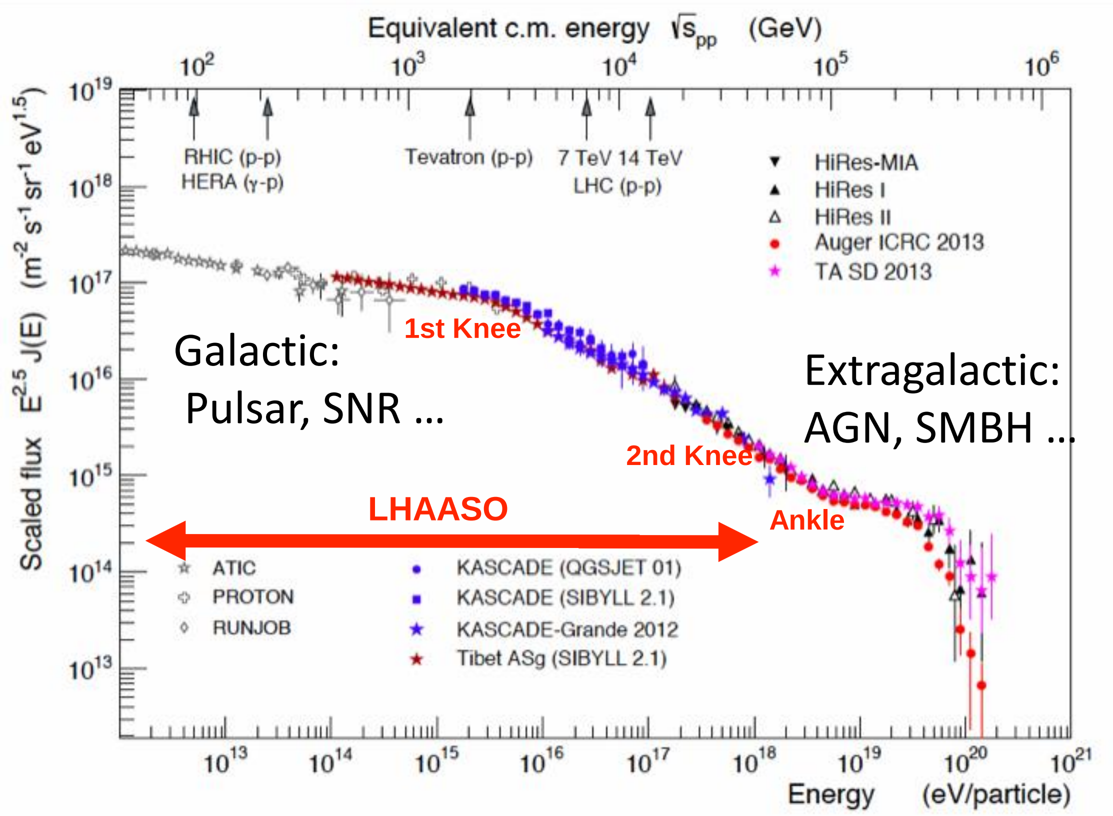
Known 3033 GeV γ-ray sources and 160 TeV γ-ray sources in the sky (2015, http: //tevcat.uchicago.edu/)



Main goals of LHAASO
Origins of CRs

$$\frac{dN}{dE} \propto E^{-\gamma}$$

- Above the knee, the power-law spectrum steepens to an index of ~3.
- Above the ankle, the power-law spectrum flattens to an index of 2-2.7.
- What's the origin of the knee?
- LHAASO - KM2A(20 TeV-1 PeV) & WFCTA(10 TeV-EeV)



Summary

LHAASO 高海拔宇宙线观测站 Large High Altitude Air Shower Observatory

- Ground-based observatory detects EAS particles/Cherenkov radiation to investigate cosmic γ-rays and CRs.
- Wide-filed survey and narrow-filed imaging are complementary in practice. LHAASO is more sensitive than HAWC, complementary with CTA in the future.
- LHAASO will be the leading ground-based project to clarify questions of γ-ray astronomy and CR physics.
- It is an great opportunity for China to become a major player in the young but exciting field of TeV γ-ray astronomy, as well as CR physics.

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