LHAASO
高海拔宇宙线观测站

The LHAASO Experiment

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on behalf of the LHAASO collaboration

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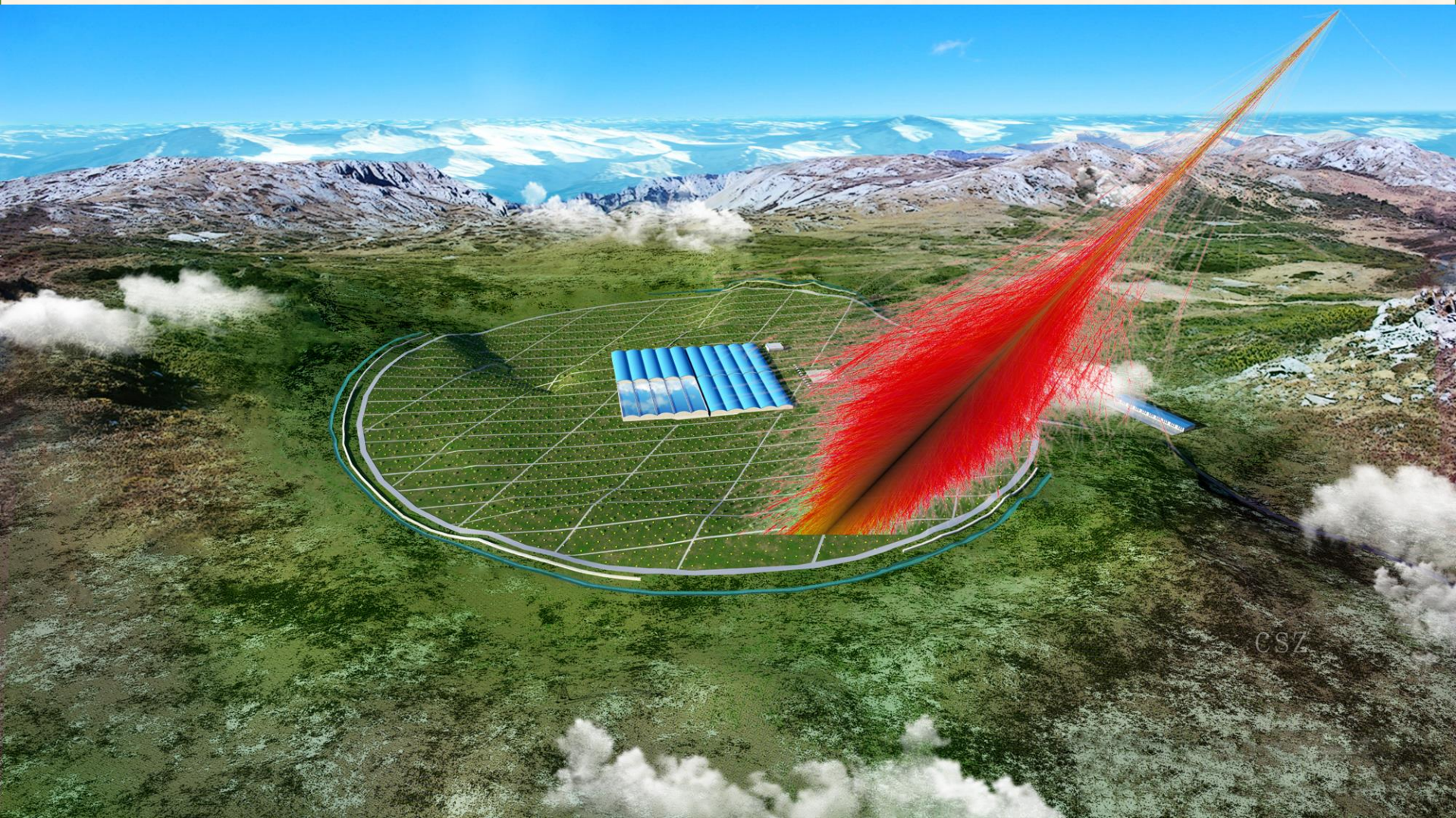
Outline

- 1. Introduction
- 2. LHAASO detector design
- 3. LHAASO science prospects
- 4. Prototyping at YBJ Tibet
- 5. Site preparation & detector deployment

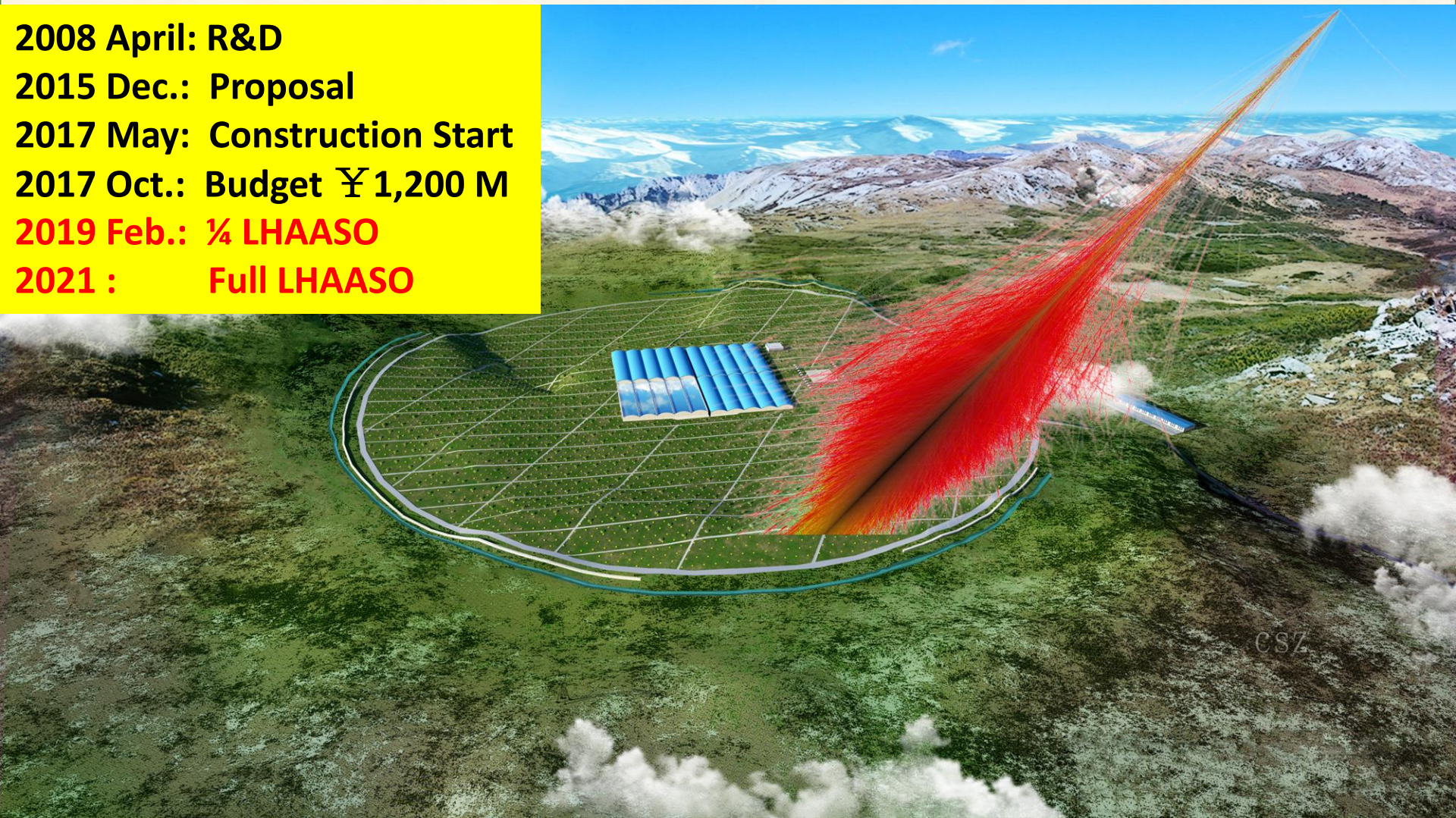
1. Introduction

LHAASO: Large High Altitude Air Shower Observatory



LHAASO: Large High Altitude Air Shower Observatory

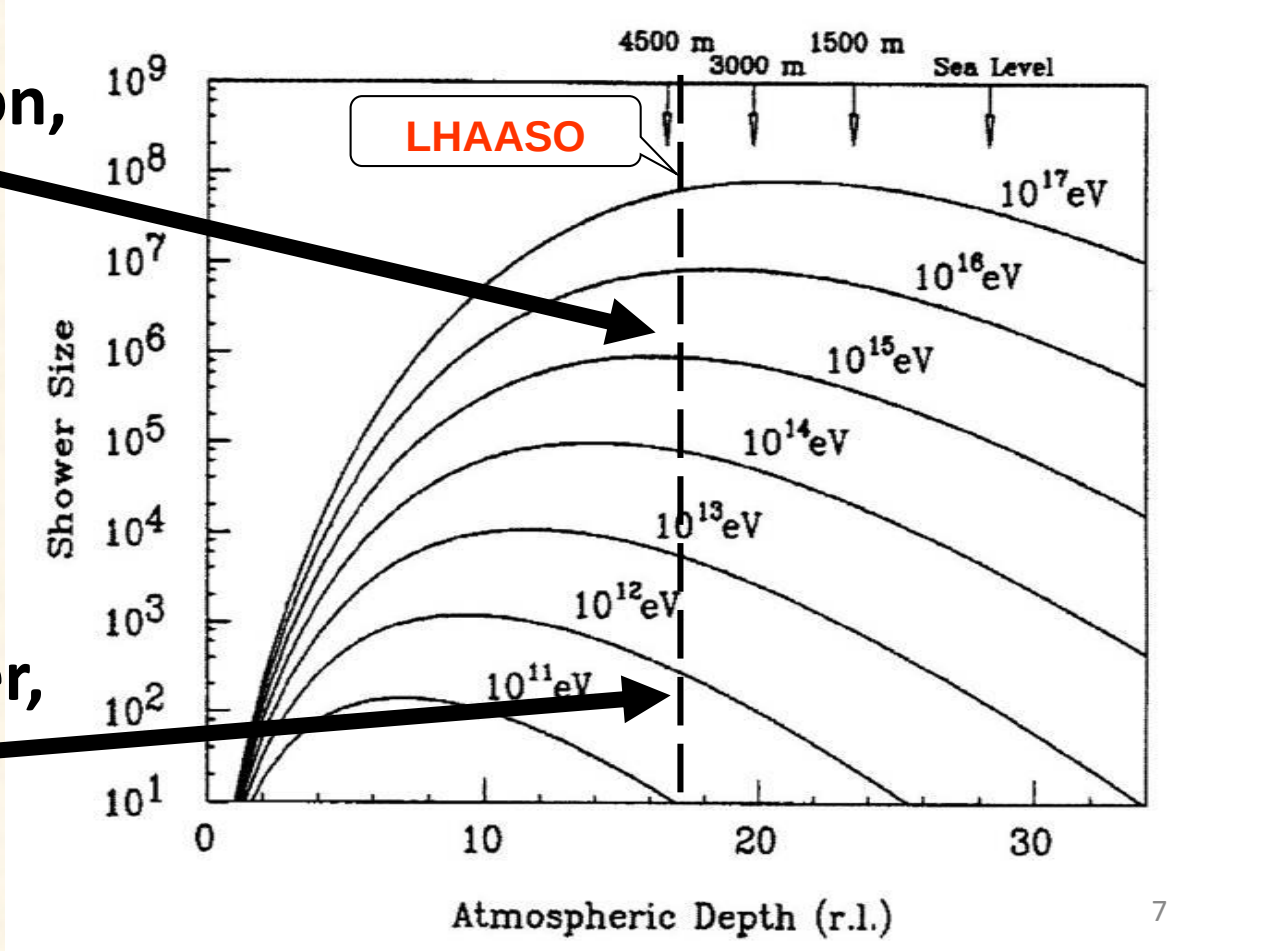
2008 April: R&D
2015 Dec.: Proposal
2017 May: Construction Start
2017 Oct.: Budget ￥1,200 M
2019 Feb.: ¼ LHAASO
2021 : Full LHAASO



- **Mt. Haizi (4410 m a.s.l., 29°21’ 27.6” N, 100°08’19.6” E), Sichuan, China**

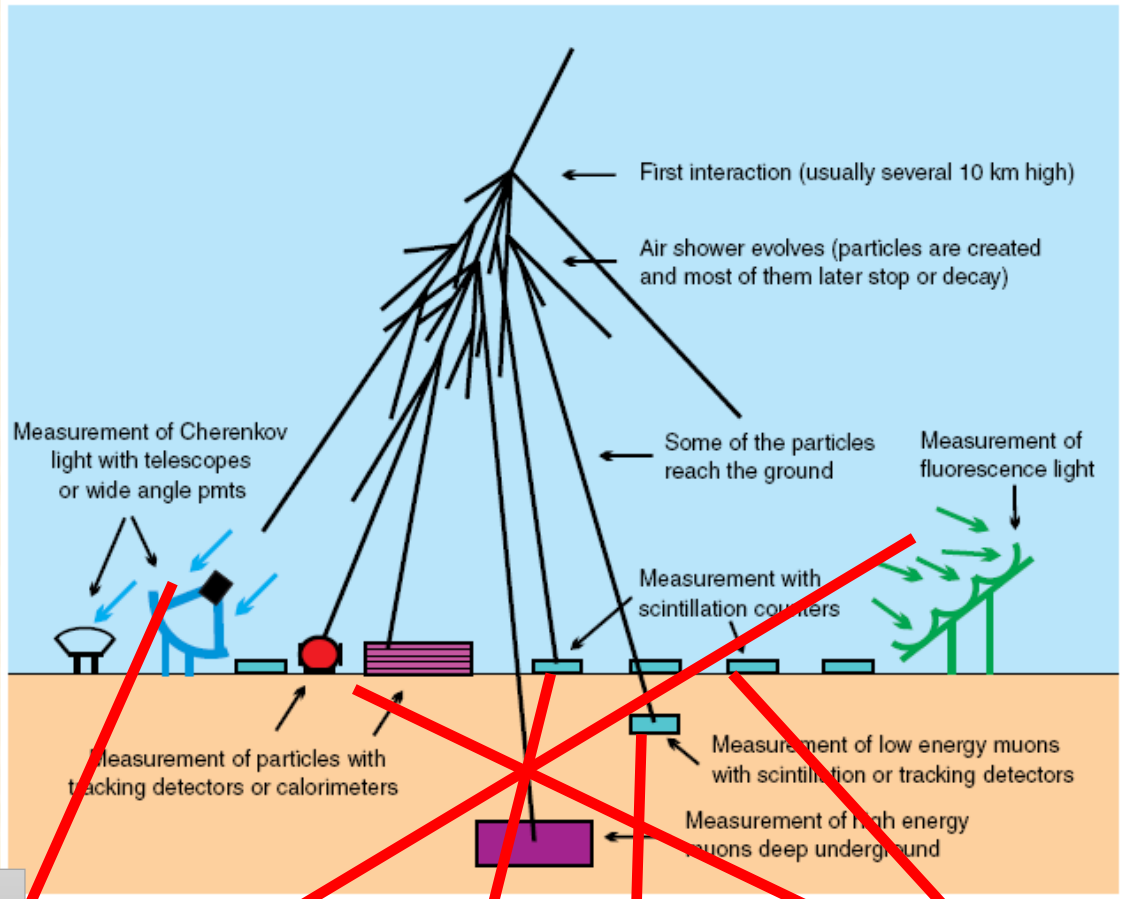
Measurement of air showers at high altitude

- **HE: near Xmax →lower fluctuation, better σ_E**
- **Lower E_{th} →deeper, more sources**

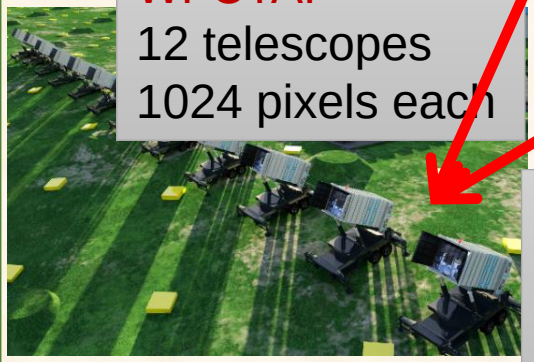


2. LHAASO detector design

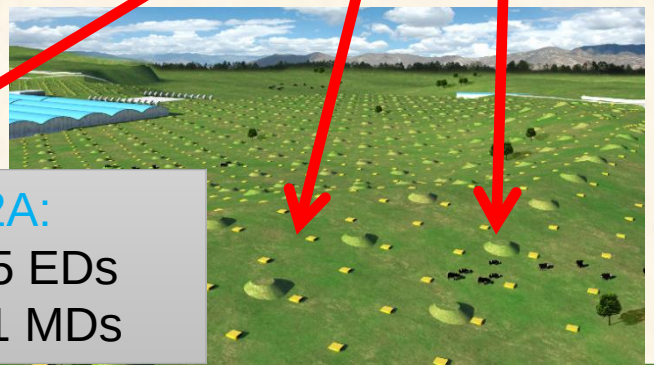
Hybrid Detection of Extensive Air Showers by LHAASO



WFCTA:
12 telescopes
1024 pixels each

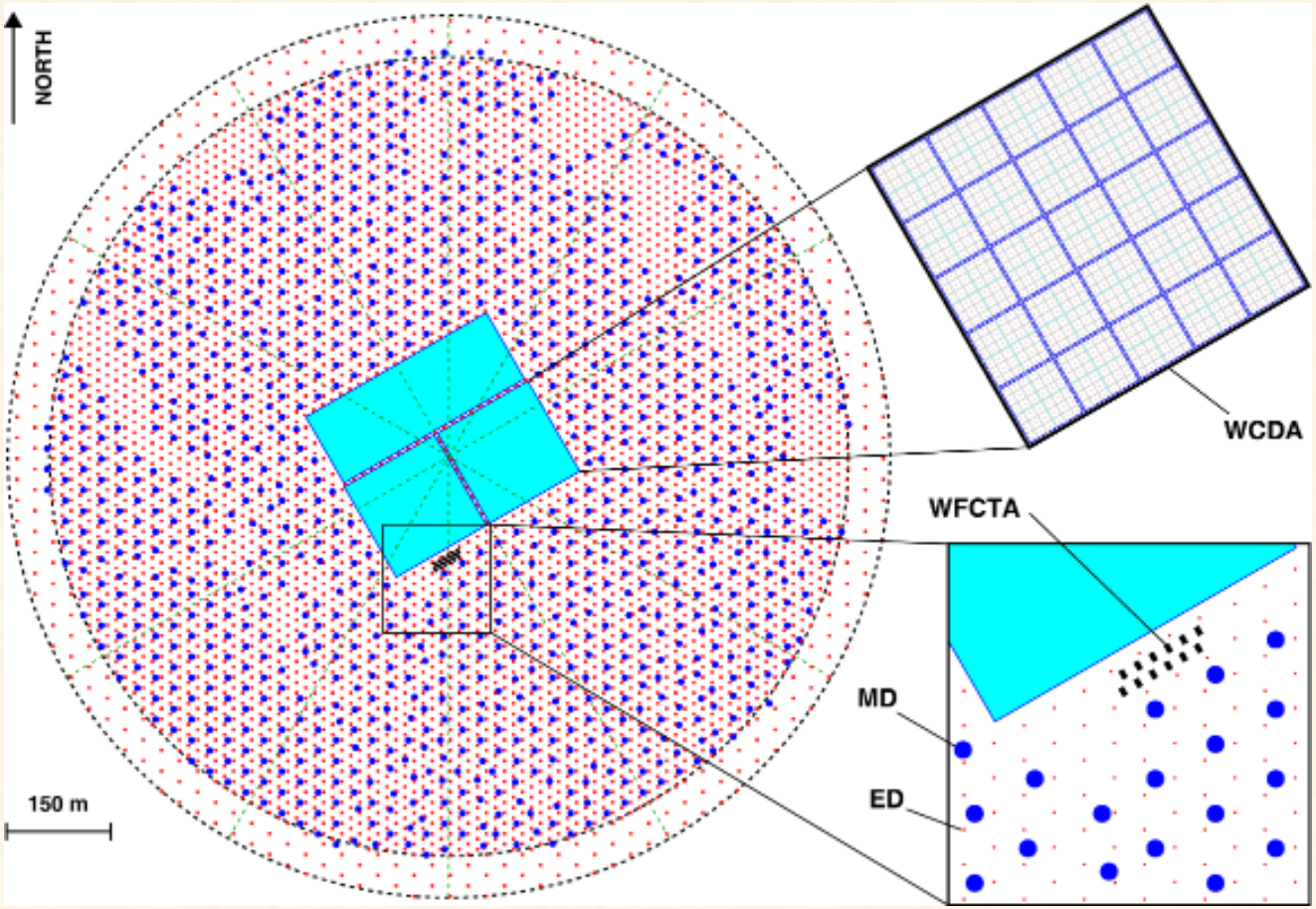


KM2A:
5195 EDs
1171 MDs



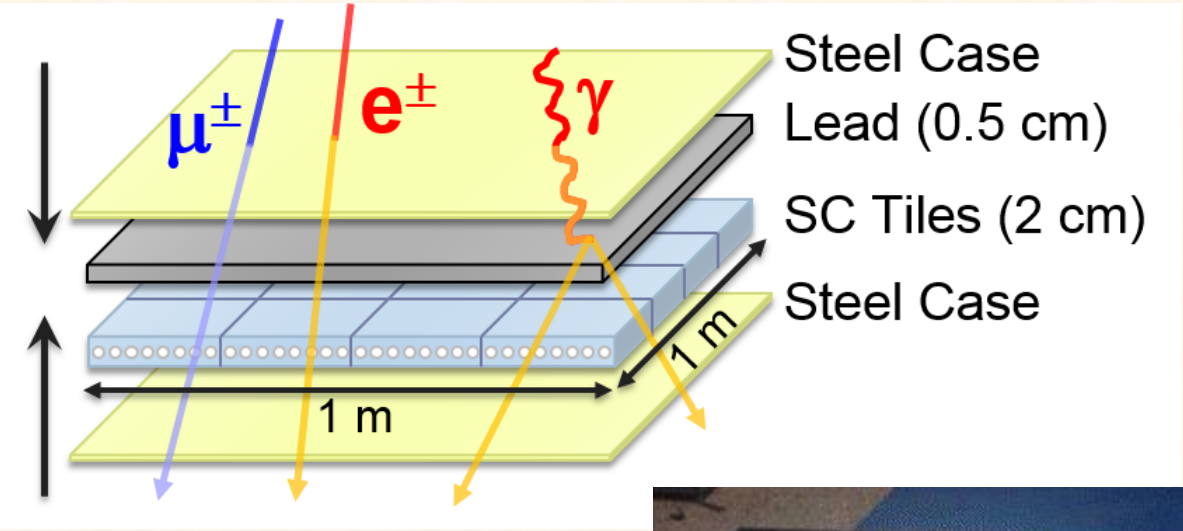
WCDA:
3120 cells

LHAASO layout

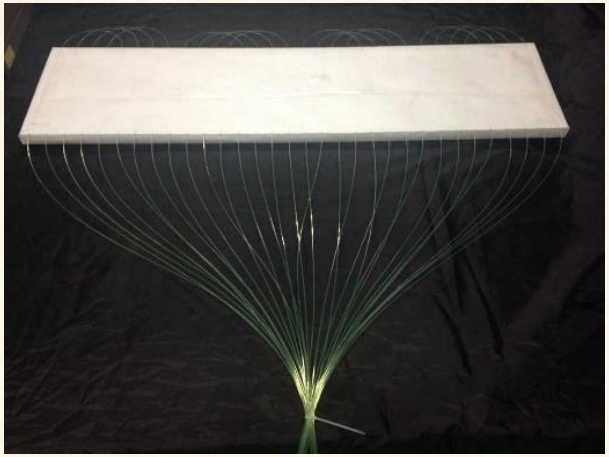


- 5195 EDs
  - 1 m^2 each
  - 15 m spacing
- 1171 MDs
  - 36 m^2 each
  - 30 m spacing
- 3120 WCDs
  - 25 m^2 each
- 12 WFCTs

ED: Electromagnetic particle Detector

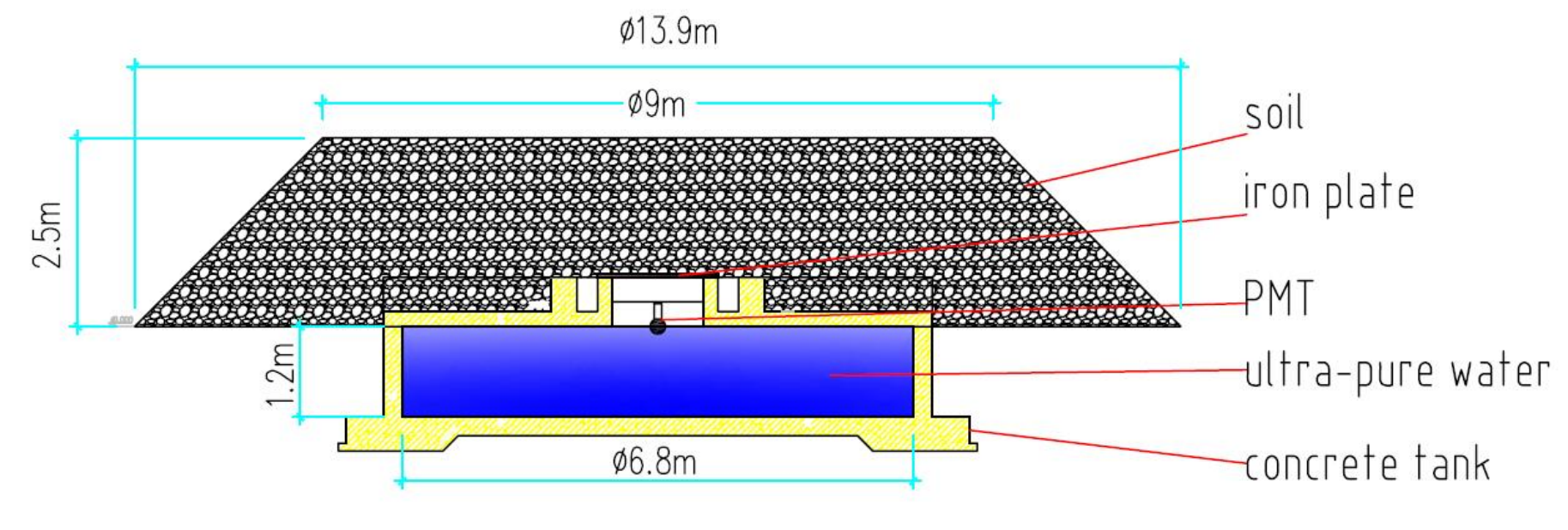


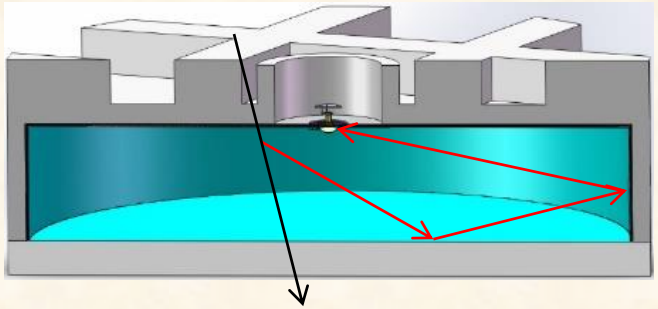
- **Uniformity for 5195 units: < 10%**
- **Stability within ±25°C: ±5%**



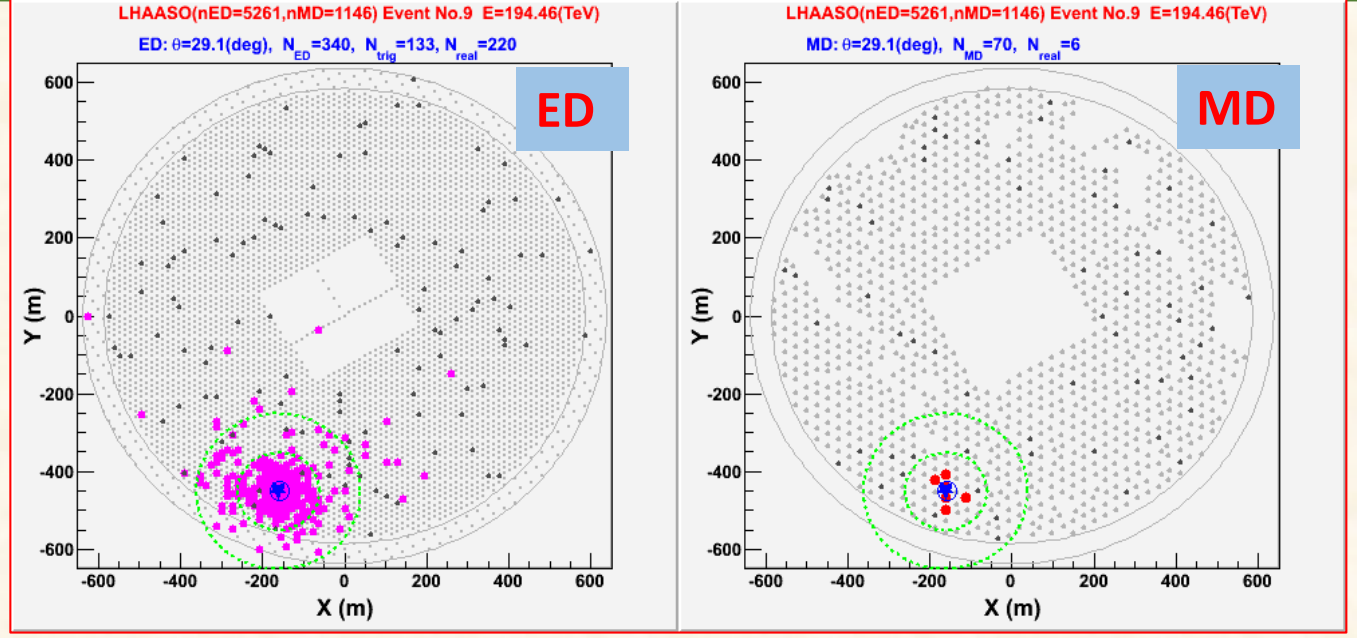
MD: Muon Detector

- **Water Cherenkov detector underneath soil**





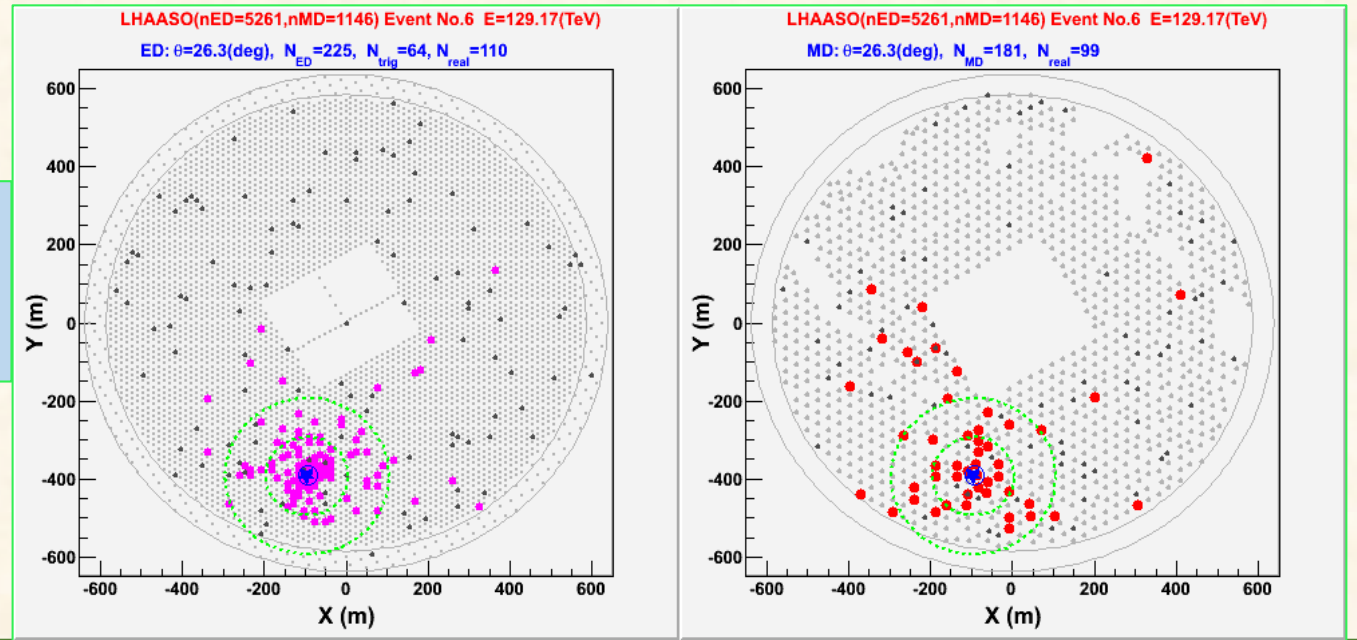
Gamma-ray
E=194 TeV



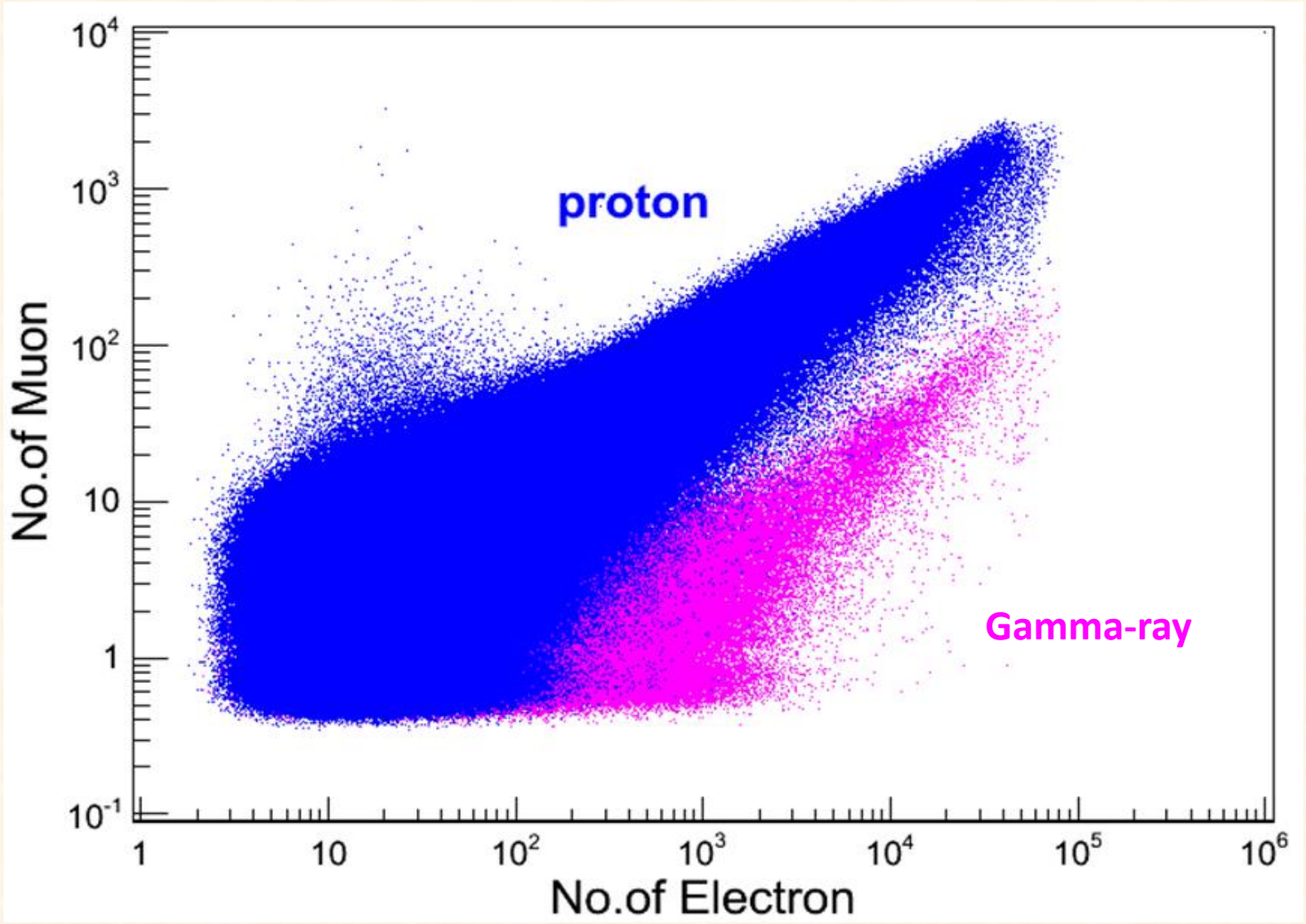
Geant4 based

γ/P discrimination

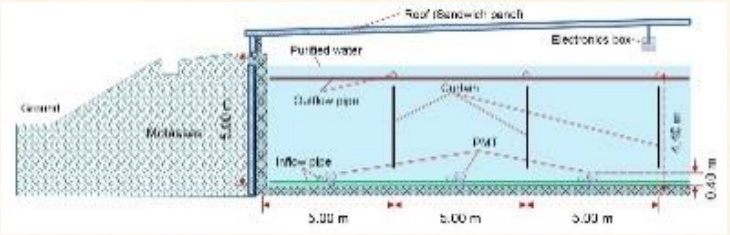
Proton
E=129 TeV

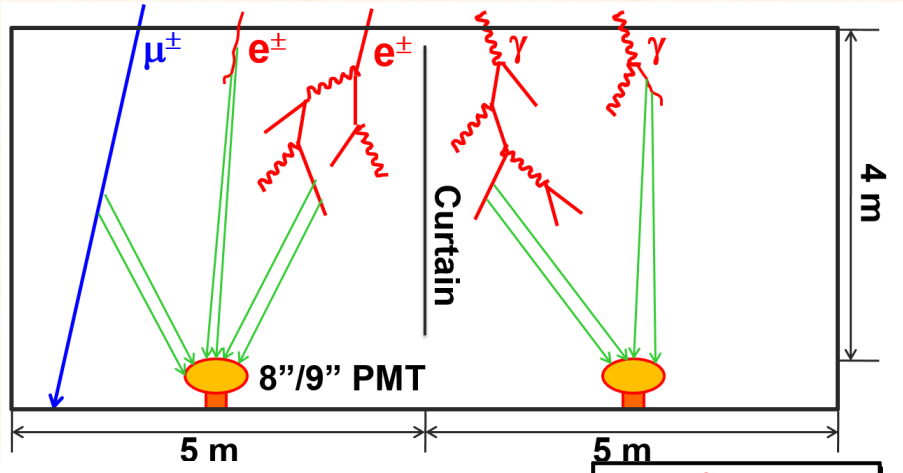


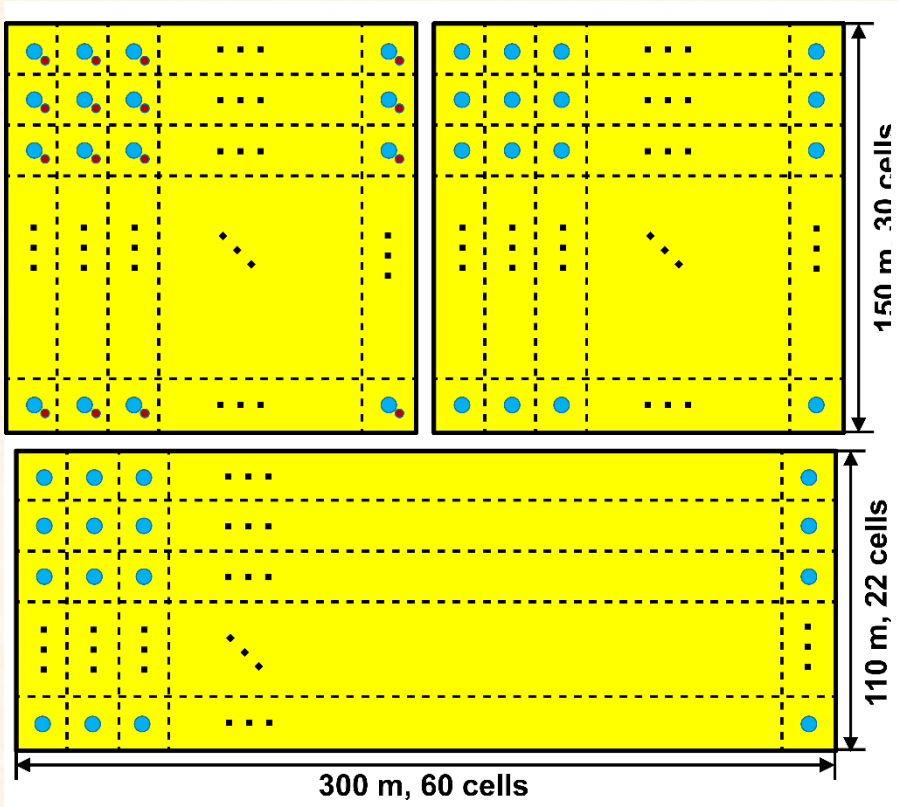
γ/P discrimination

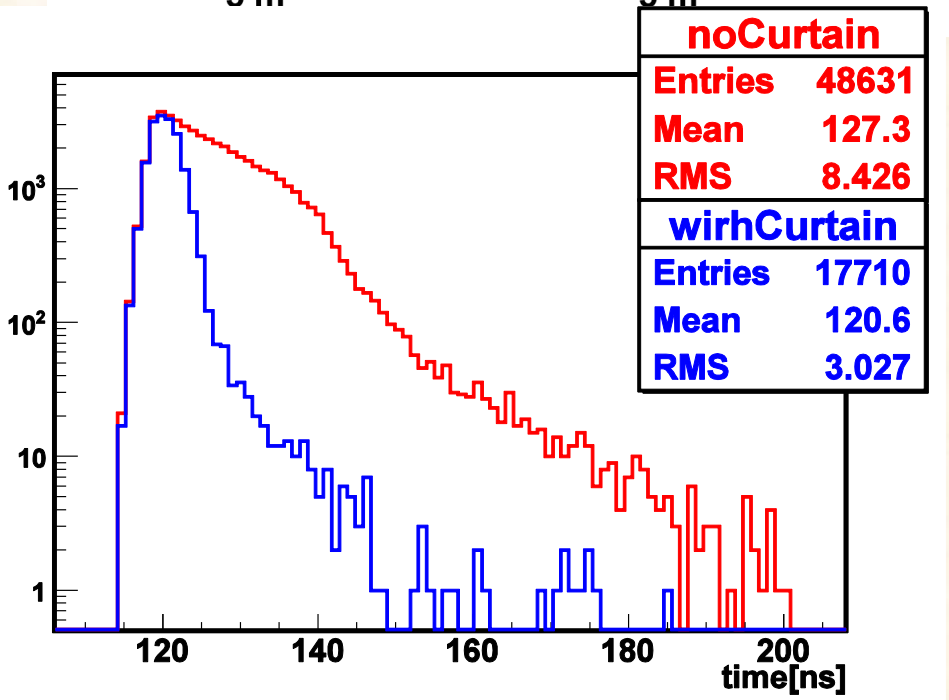


WCDA:Water Cherenkov Detector Array

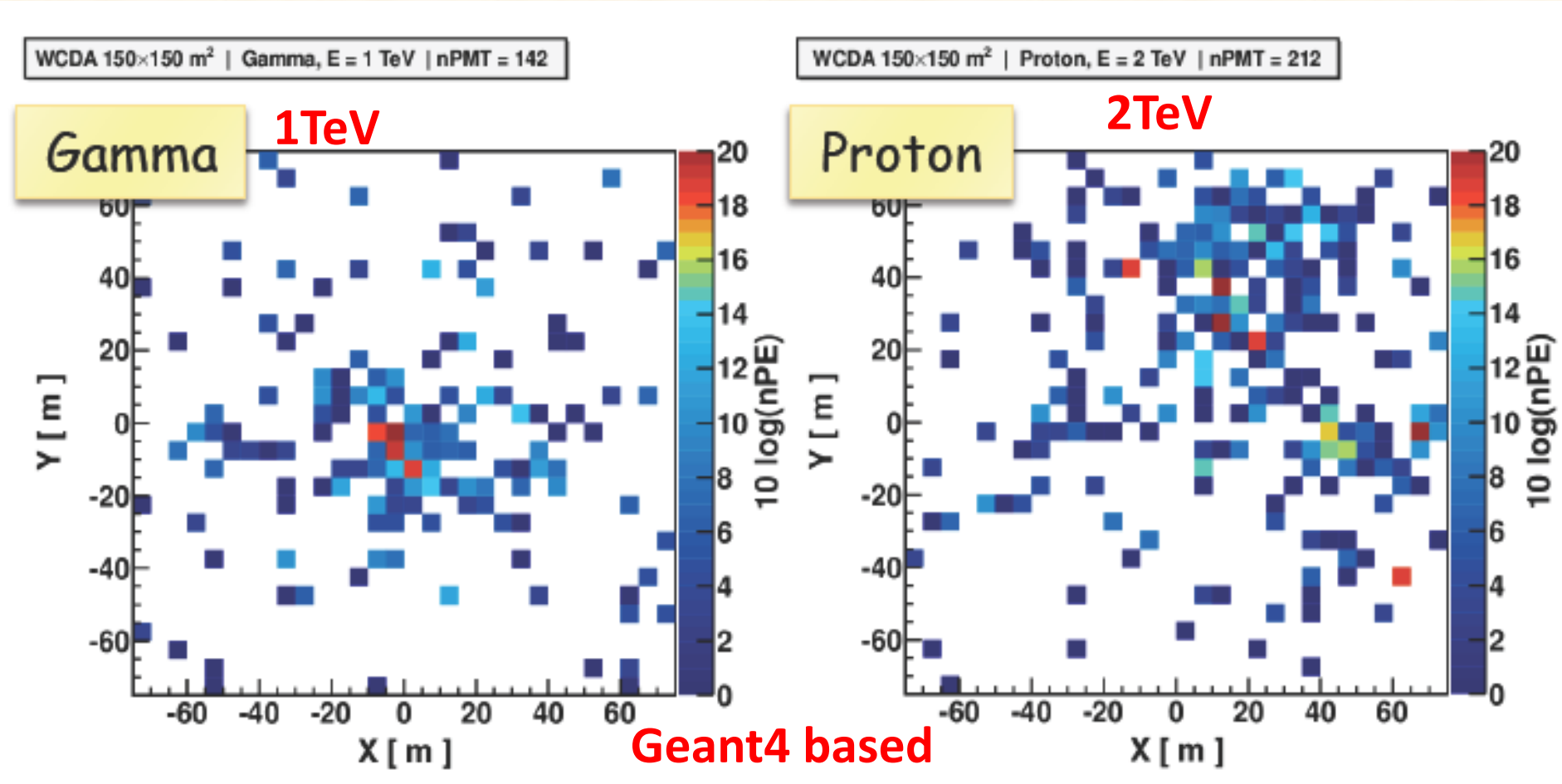




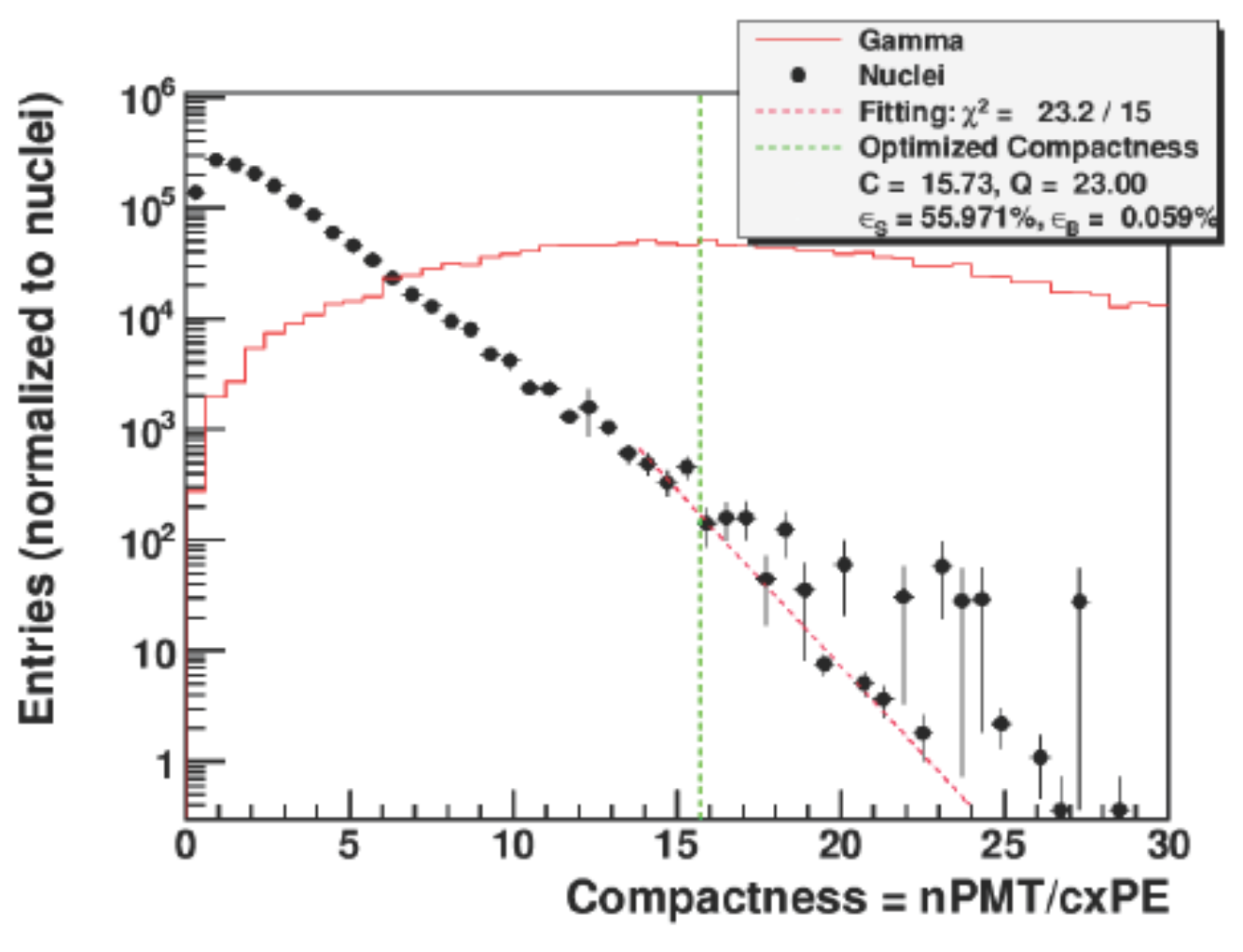




γ/P discrimination

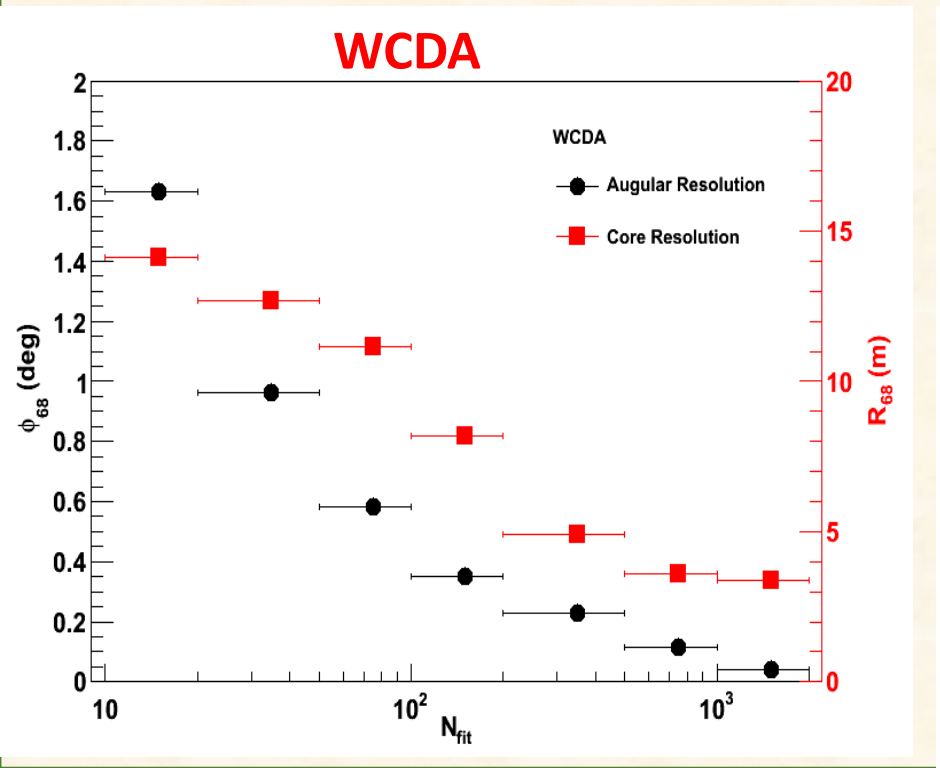


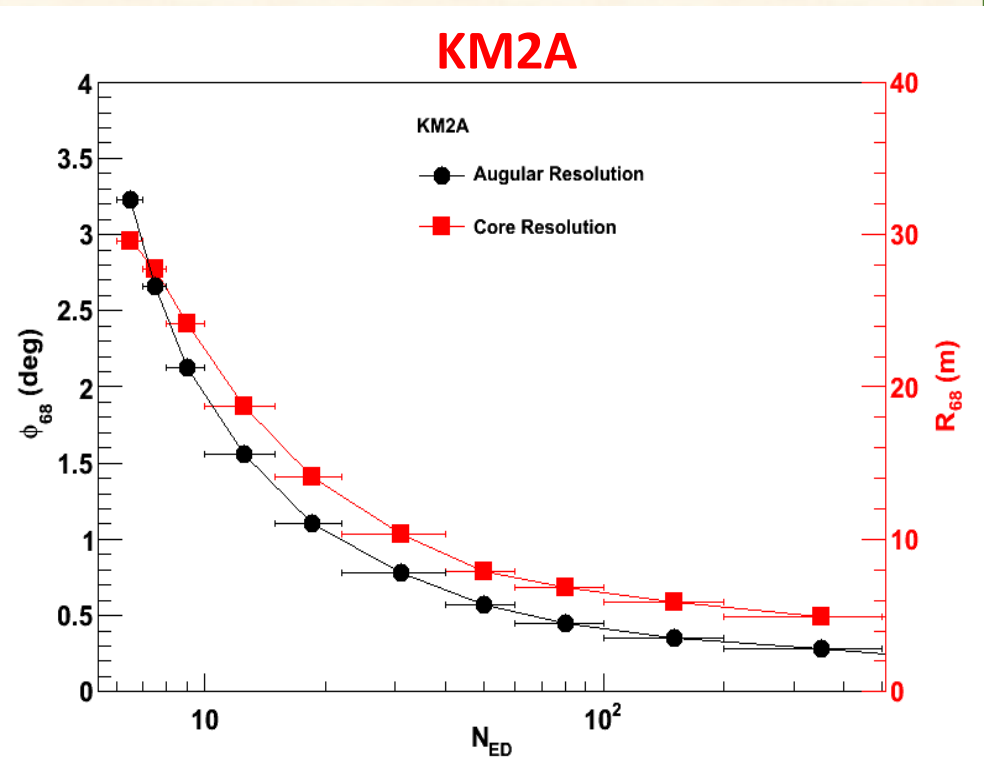
γ/P discrimination



Angular and core resolution

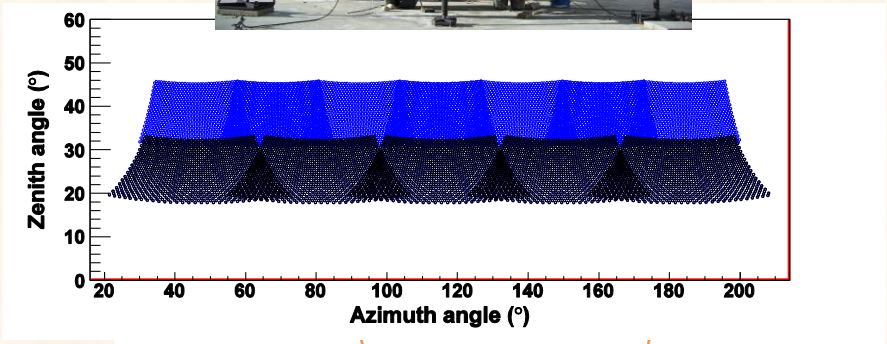
- WCDA: 0.6 deg, 11m (68% containing) @1 TeV
- KM2A: 0.5 deg, 6m @100 TeV

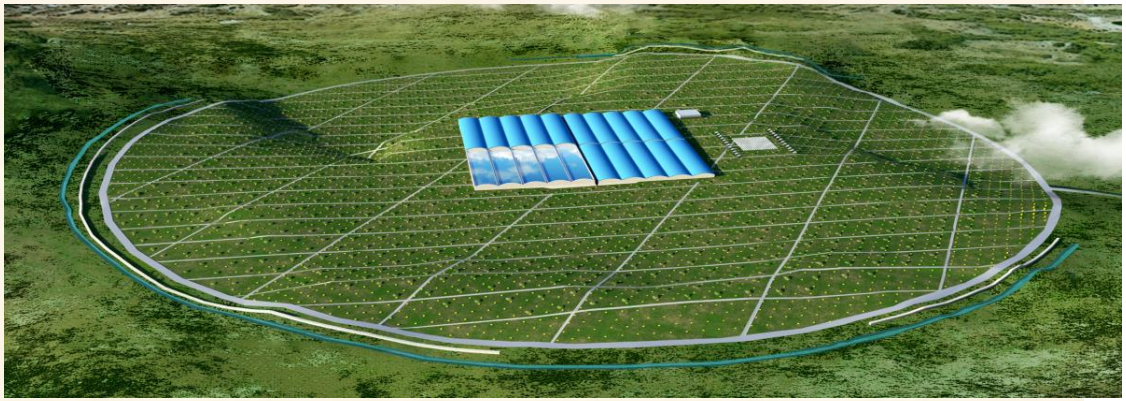


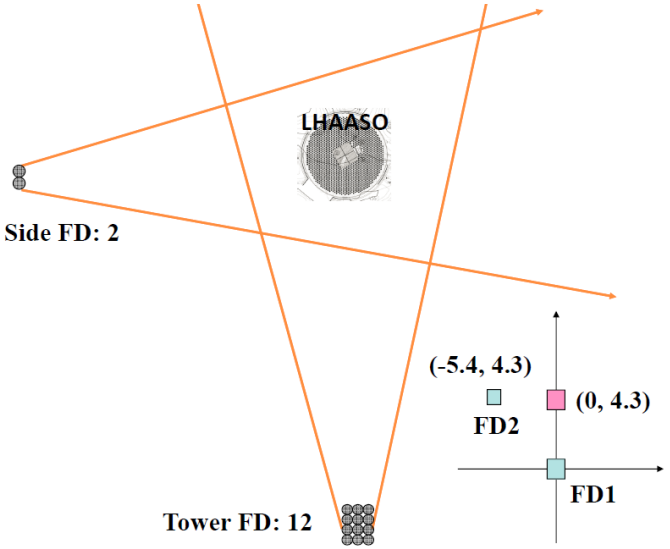


WFCTA: Wide FOV Cherenkov Telescope Array

- 32×32 pixels, 0.5° each
- 4.7 m^2 collection area
- Energy coverage by different configurations
  - <10^{16} eV
  - 10^{16}-10^{17} eV
  - 10^{17}-10^{18} eV







LHAASO detector timing

Over 7,000 detector units
Spread around 1km^2 area

0.5° Angular resolution for shower reconstruct from *timing* of hits TOF

Synchronous timing among detectors

1000m coax cable in 30°C change, Δ delay = 15ns!

Time-stamp Synchronization

Time stamps of >7,000 nodes to be aligned <500ps (rms).

Frequency distribution & phase locking

Distribute synchronous ADC clock with **<100ps** skew.

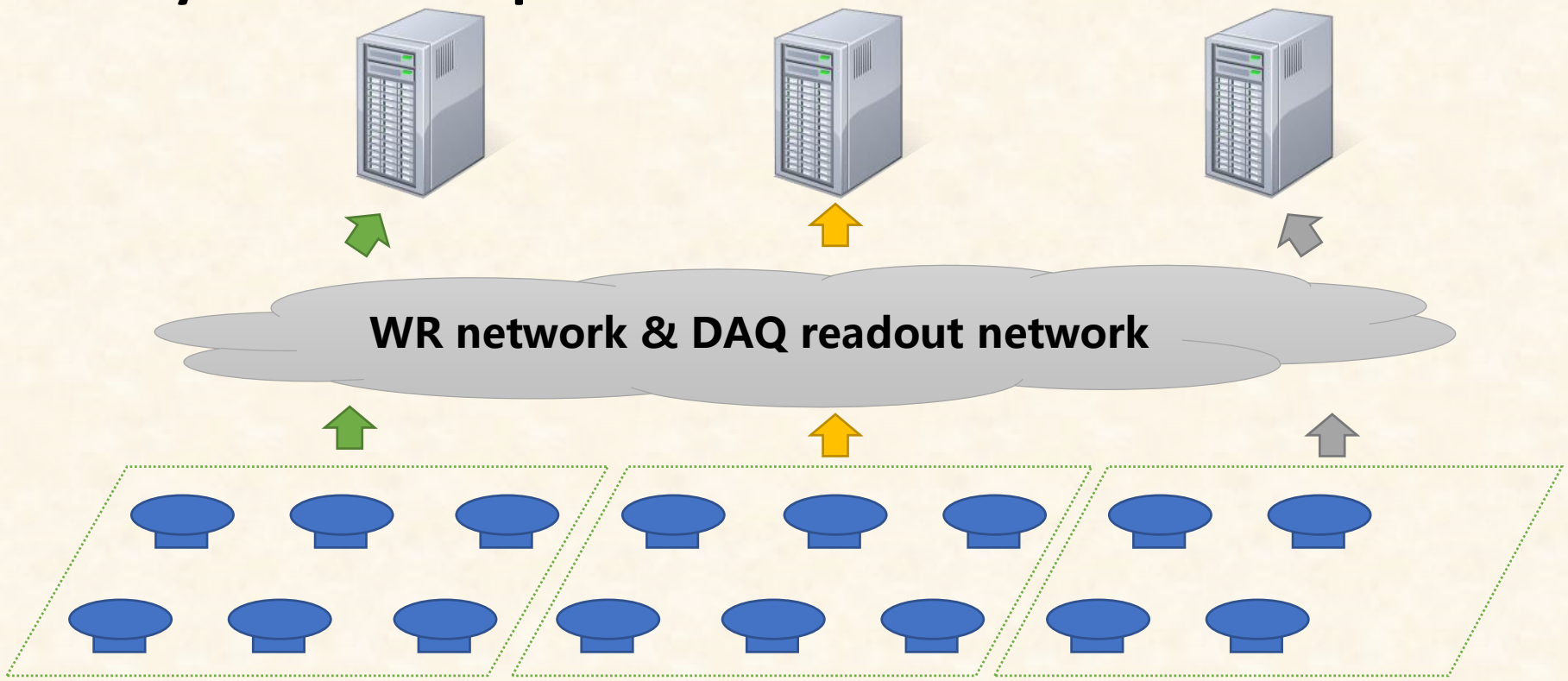
Traceability & Real-time calibration

Timing delay compensation due to environmental perturbation in hardware in real time.

“Triggerless” DAQ

---hybrid measurement of showers

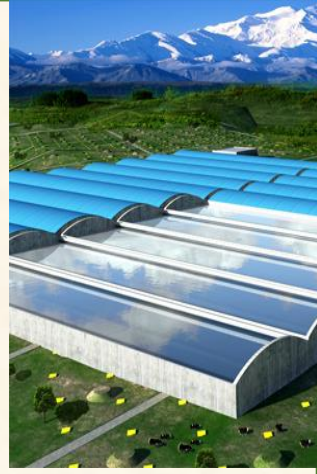
- **Triggering, building, (re-construction) and storage by online computers**

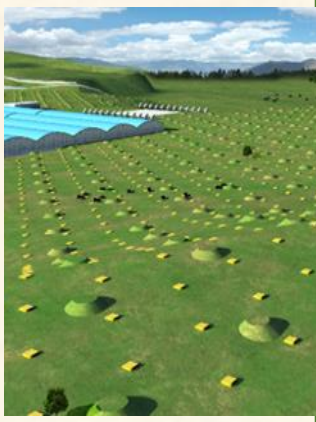


3. LHAASO science prospects

Main goals of LHAASO

- TeV gamma-ray survey → WCDA (100 GeV-30 TeV)
  - AGN, GRB, survey new source, …
- >20 TeV gamma-ray survey →KM2A (10TeV-1PeV)
  - SNR, PWN, Superbubble, diffuse around 100TeV, …
- Individual nuclei spectra →WFCTA (10TeV to EeV)
  - Different configures
  - Combined with WCDA, WCDA++, KM2A
- Benefit regions:
  - Anisotropy, Solar physics, dark matter, EBL, IGMF, Lorentz invariance, hadronic interaction, …



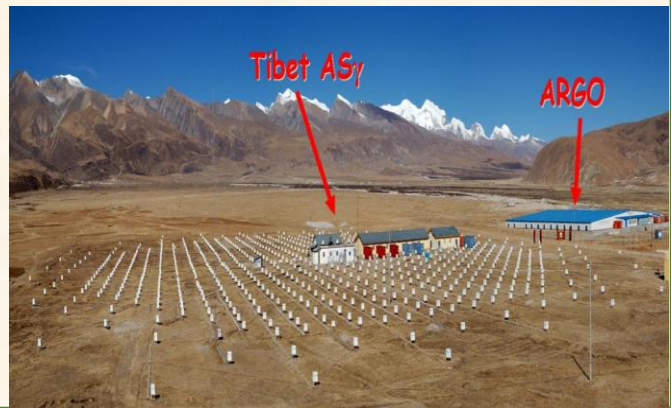


Gamma ray astronomy

- **IACTs detect most of the VHE sources with:**
  - Angular resolution: ~ 0.1 degree.
  - Sensitivity: ~1% crab unit
  - FOV: 3~5 degree
- Wide FOV EAS **array is essential for:**
  - **Transient source: AGN flare, GRB**
  - **Extended source: GP diffuse, Fermi bubble, superbubble, PWN, SNR …**
  - **Sky survey**
  - **High energy: up to ~100 TeV**

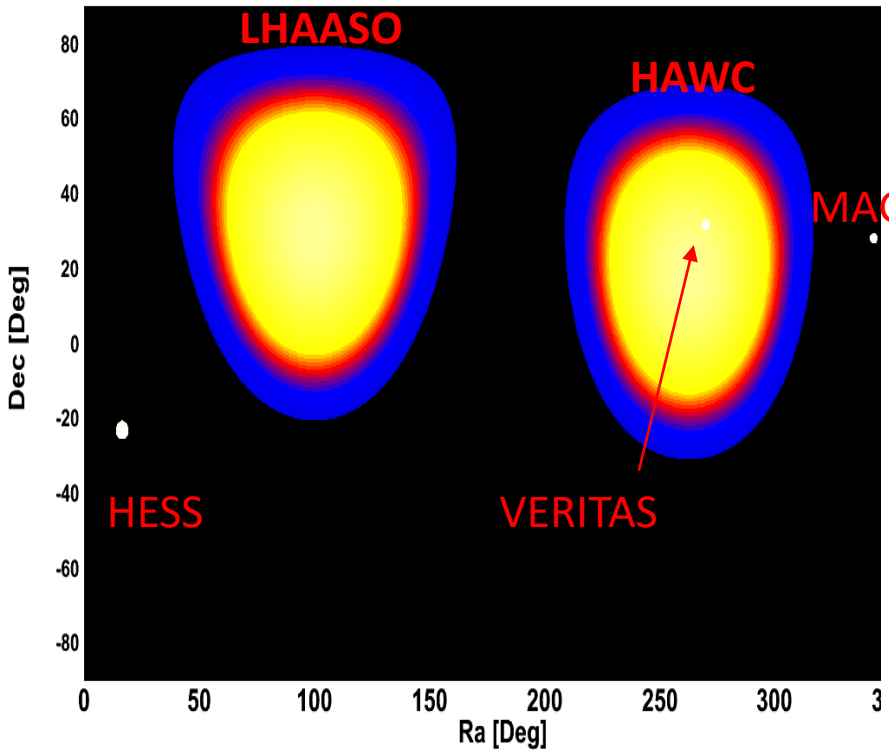
IACTs: HESS,VERITAS, MAGIC→ CTA

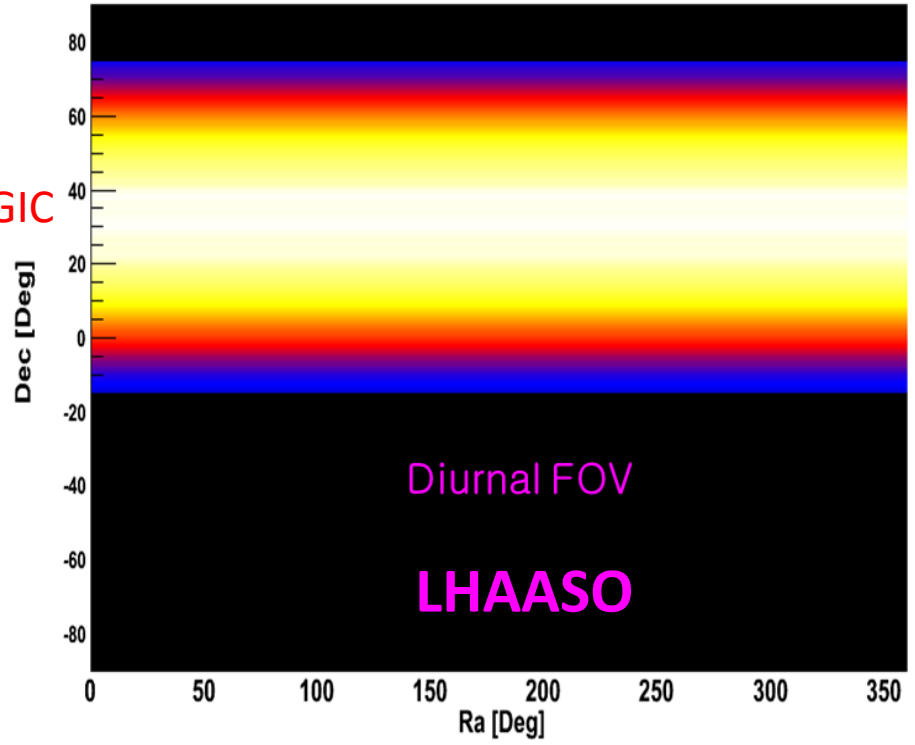
EAS arrays: ASr, Milago, ARGO-YBJ, HAWC → LHAASO



LHAASO:FOV

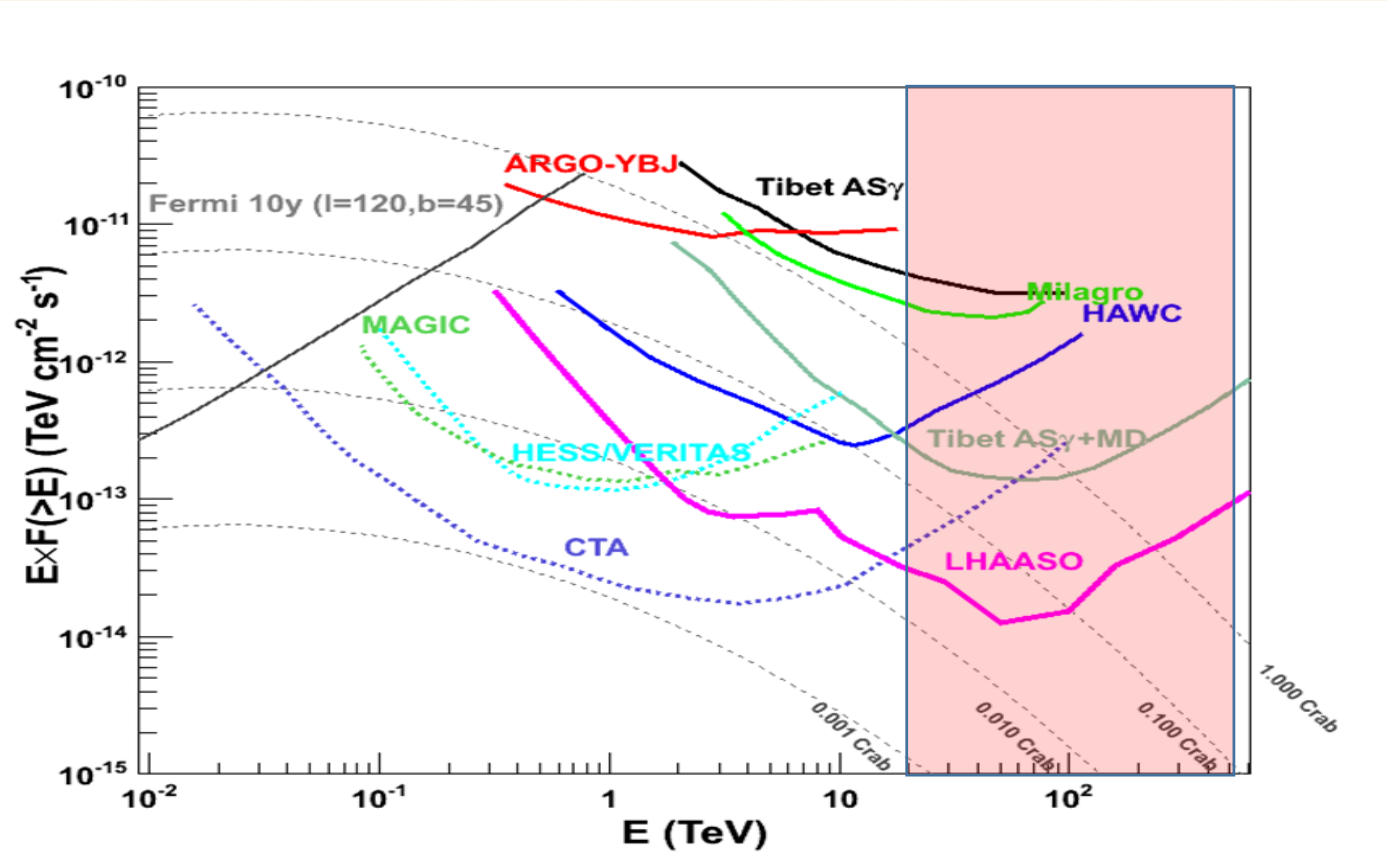
- **1/7 of the sky at each moment**
- **60% of the sky every day**





LHAASO: Sensitivity

- **1% Crab unit at 2 TeV**
- **Unprecedented sensitivity at energy above 20TeV.**

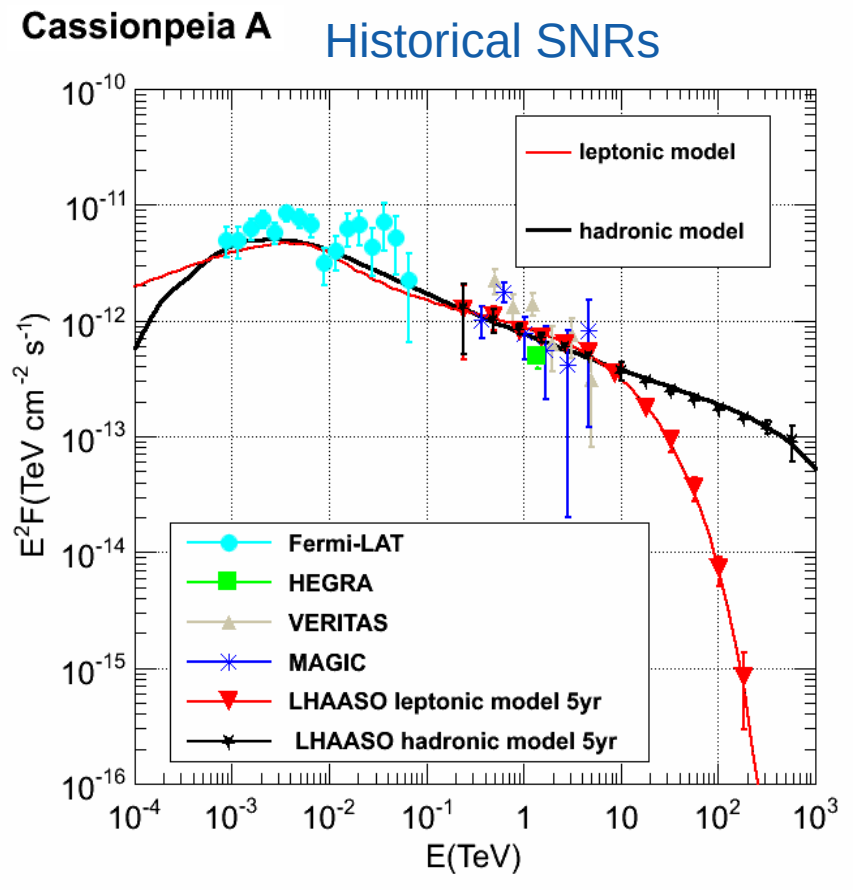


LHAASO: 100TeV

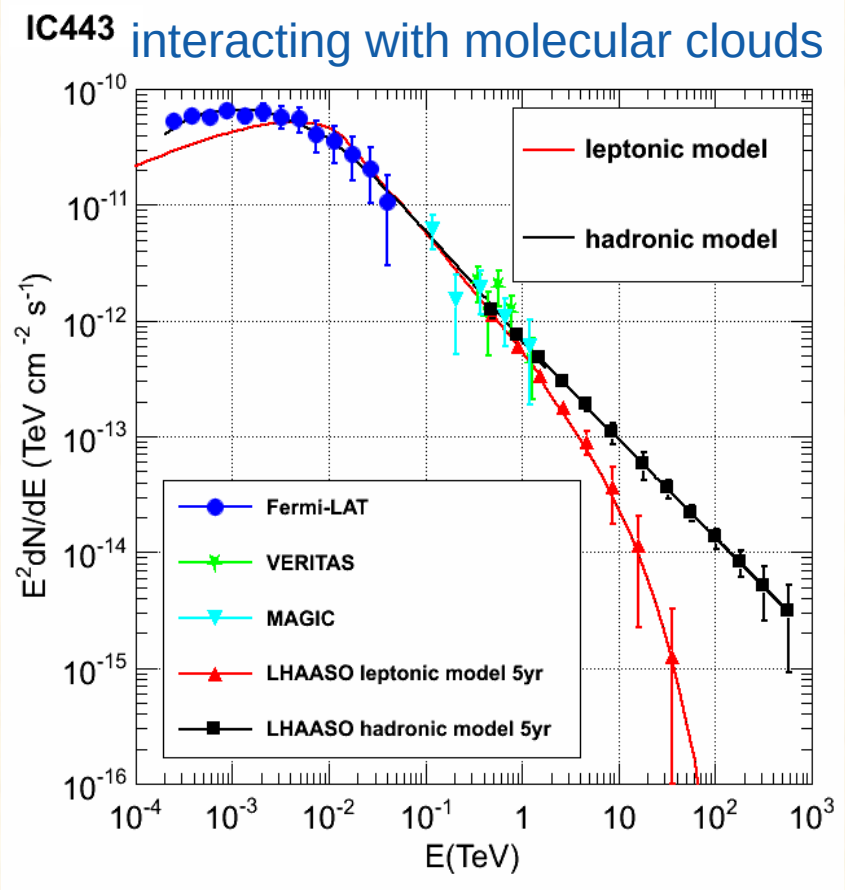
100 TeV gamma-ray is crucial to identify Cosmic ray source

PeVatron

Historical SNRs



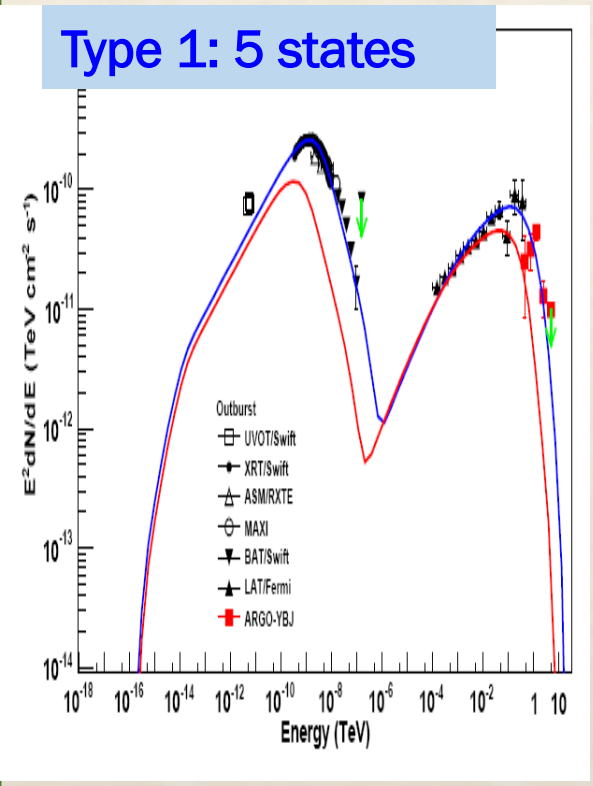
interacting with molecular clouds

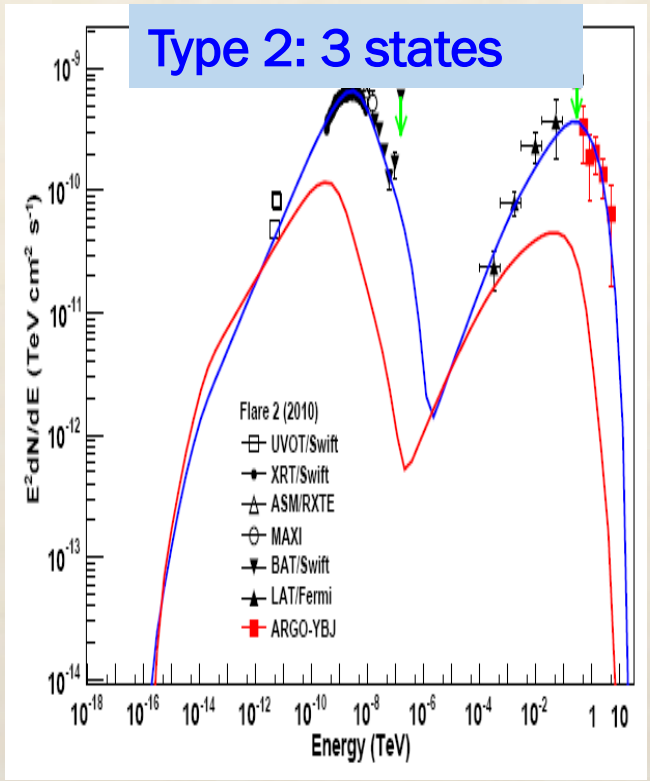


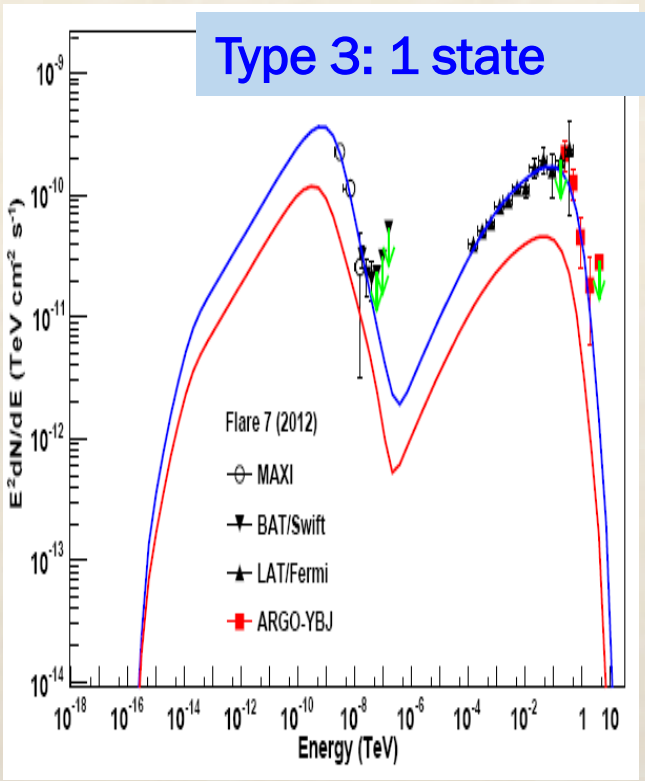
Liu, et. al. ApJ, 826:63, (2016)

LHAASO: long-term continue observation

Long-term MWL monitor is essential to systematic study the flares of AGNs







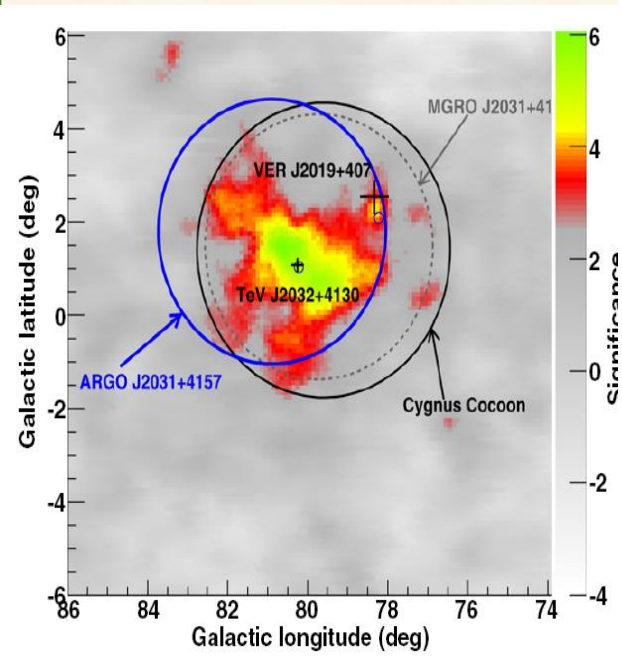
ARGO-YBJ coll., ApJS, 222:6, (2016)

LHAASO: wide FOV

Wide FOV is essential for Extended source & Sky survey

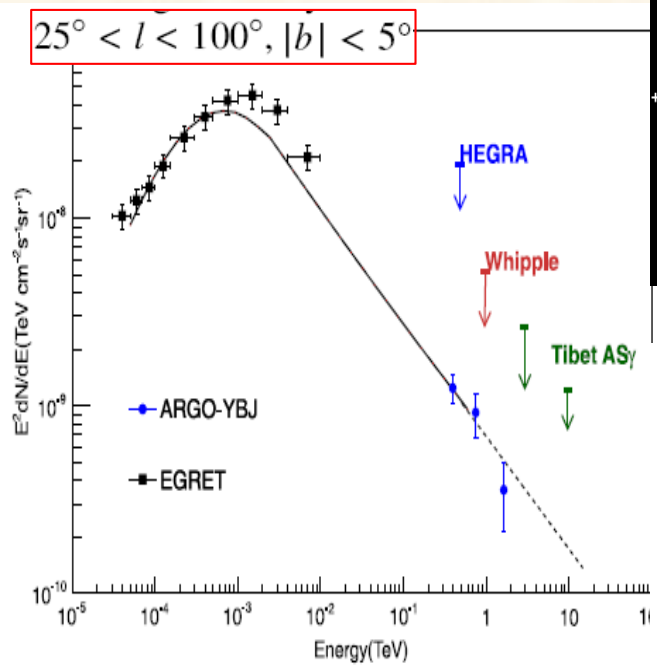
Sky survey

Superbubble, Geminga, Monogem



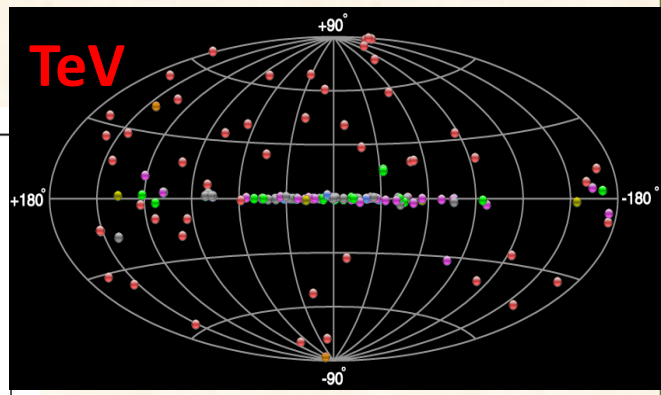
ARGO-YBJ coll., ApJ, 790:152, (2014)

Galactic Plane diffuse

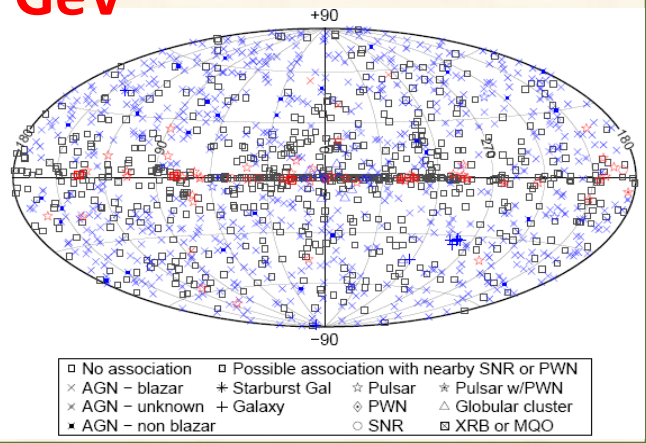


ARGO-YBJ coll., ApJ, 806:20, (2015)

TeV

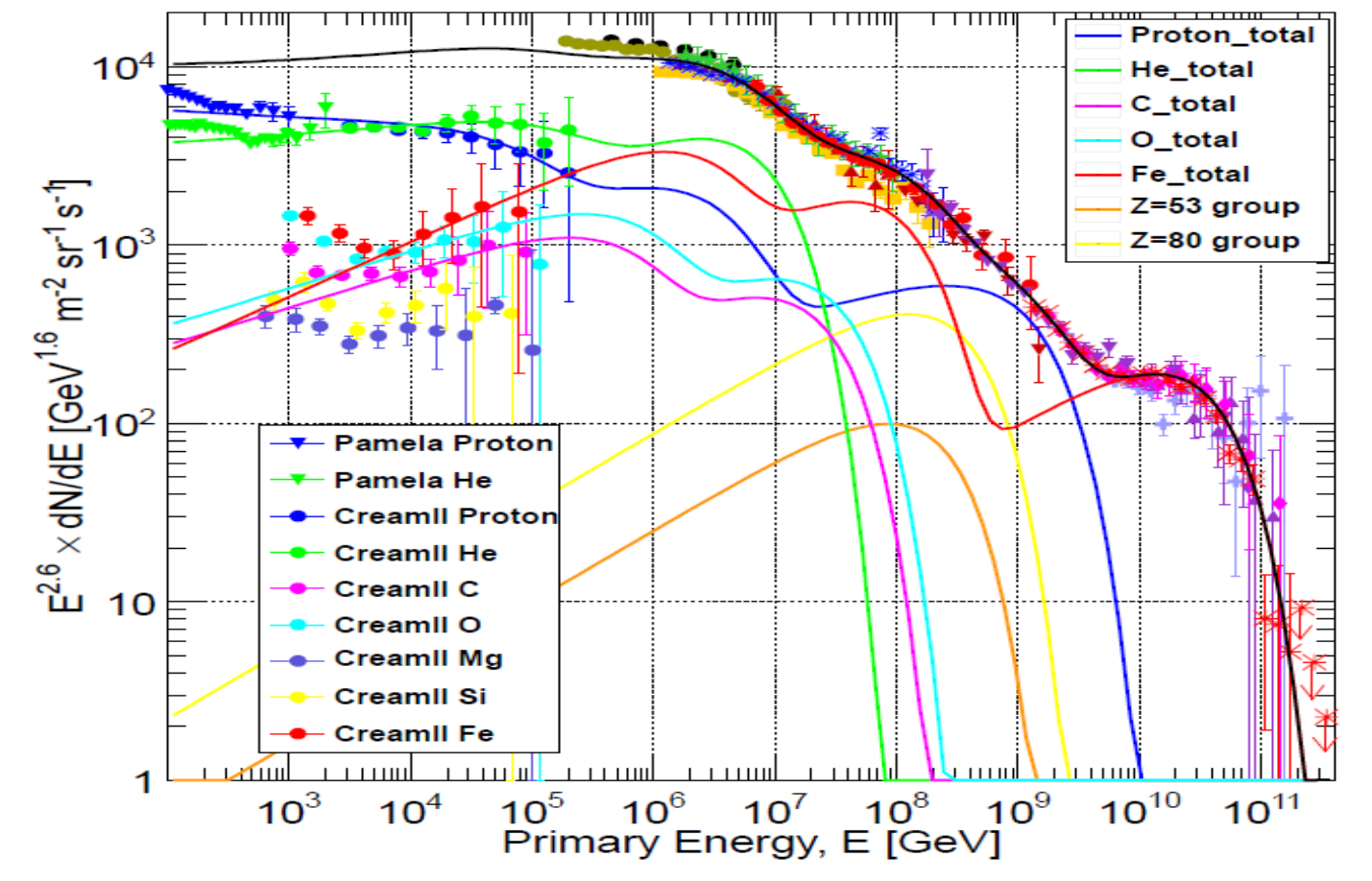


GeV



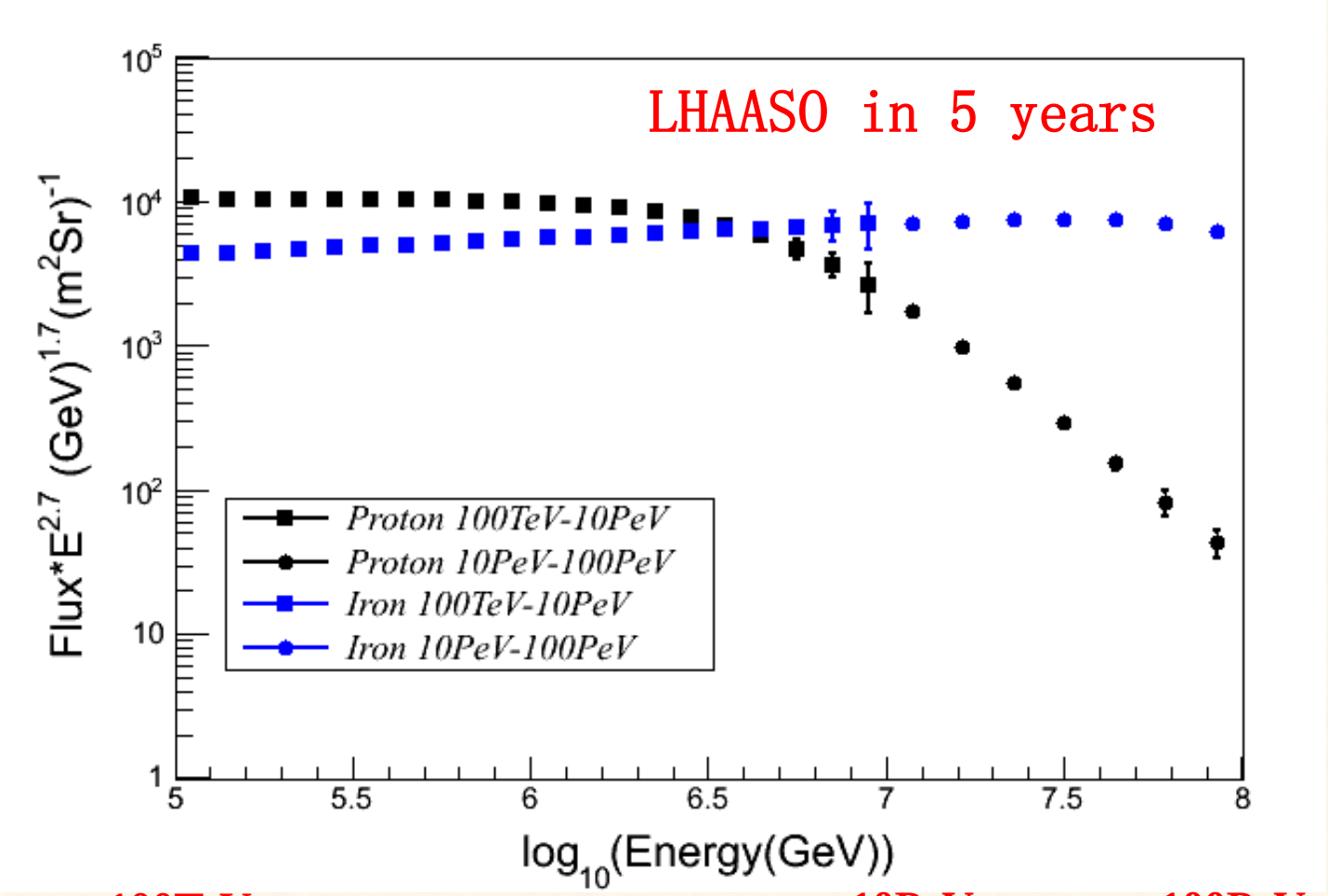
LHAASO: cosmic ray physics

- Knee physics: what? where? why?



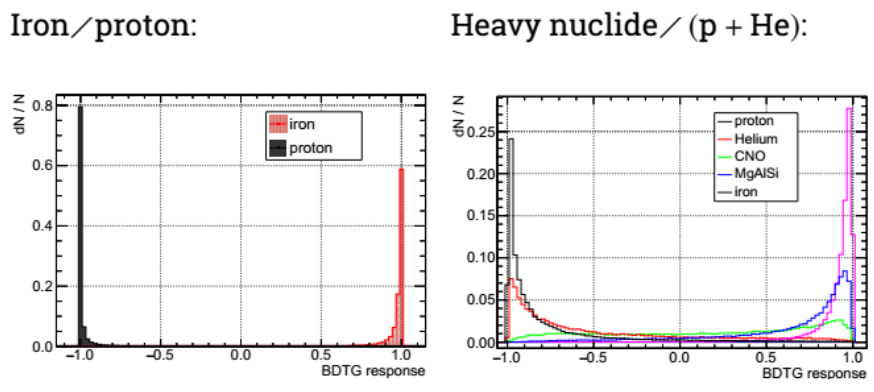
Gaisser et al. 2013

The Knees of GCR spectra:



IPN-Orsay in LHAASO collaboration

- One researcher: Pr. Tiina Suomijärvi
- A PhD. Student Z. Zong worked for LHAASO (2014 to 2017):
- Zong's doctoral thesis defended in Oct. 2017 at IPNO
  - **Simulations** of WFCTA
  - **Multivariate analysis** of the primary mass with LHAASO simulation

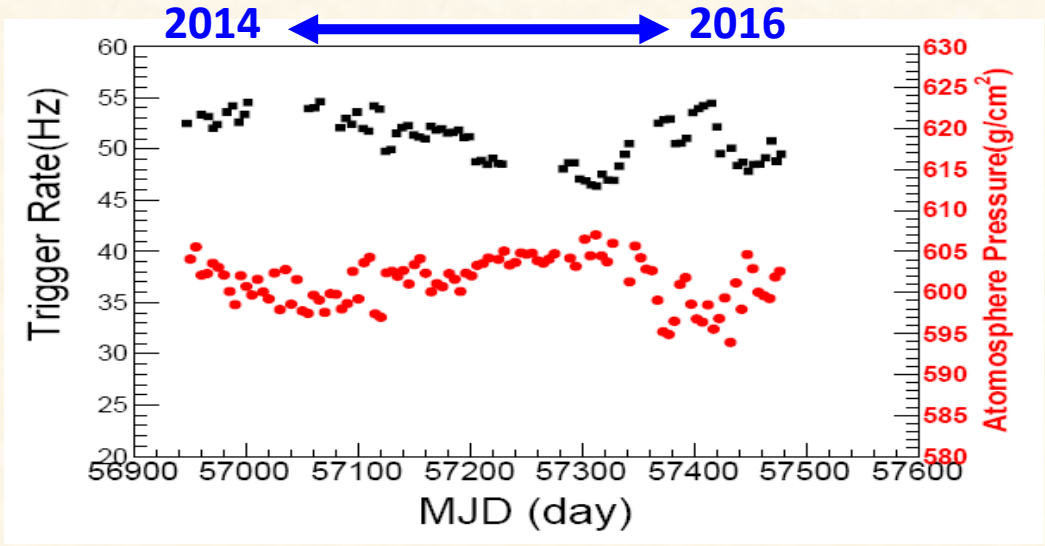


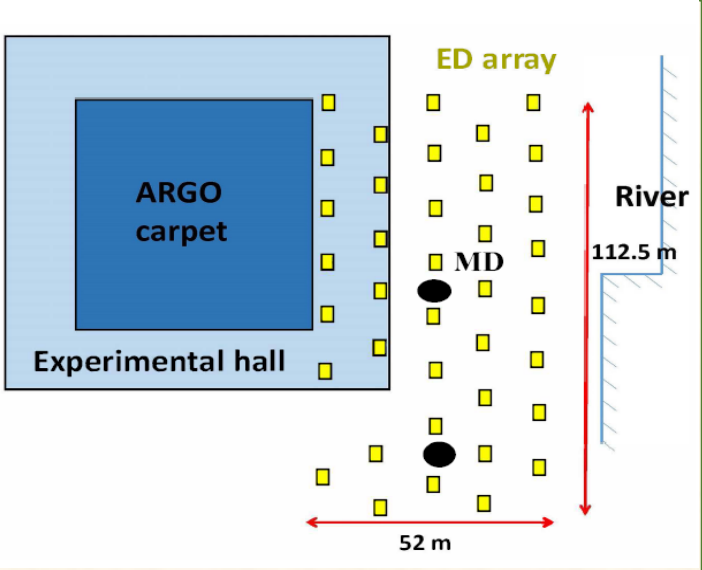
Good results for the Iron/Proton and Heavy nuclide/p + He separations.

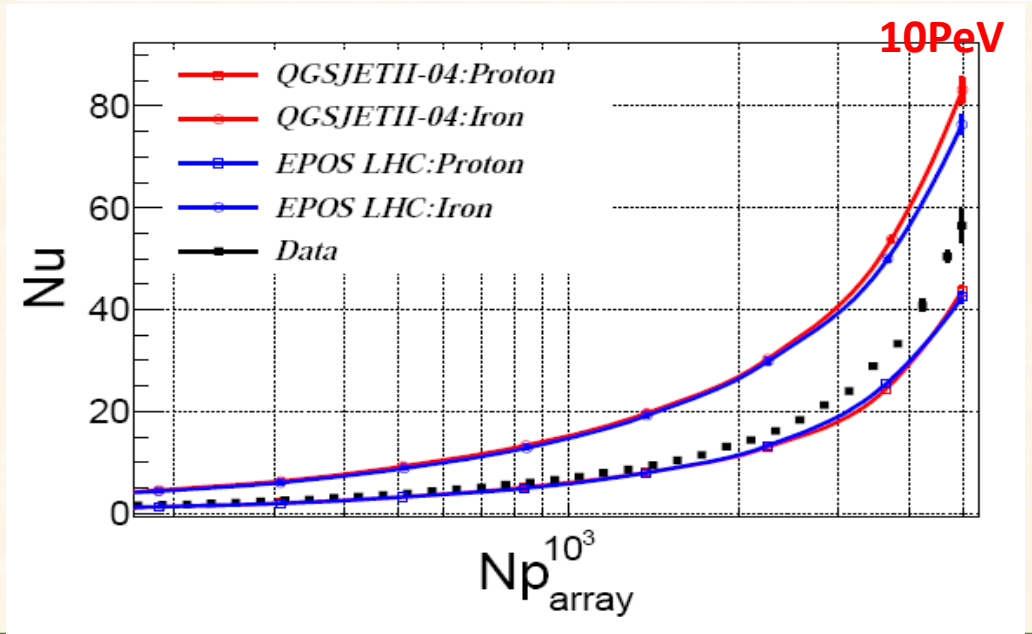
- A proceeding for ICRC 2017:
  - Primary particle identification with MVA method for the LHAASO project, PoS (ICRC2017) 547, Z. Zong et al for the LHAASO collaboration

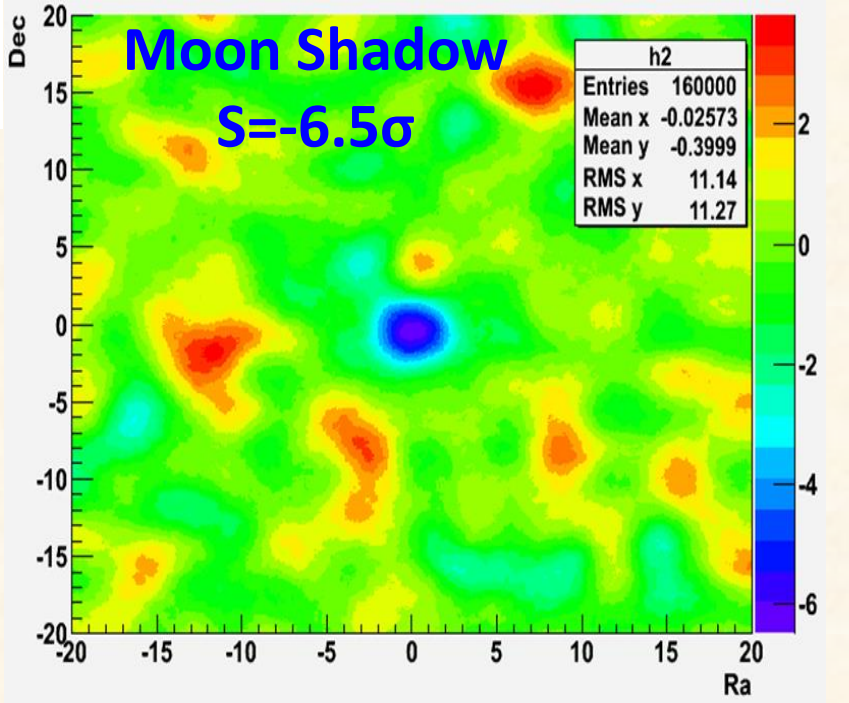
4. Prototyping

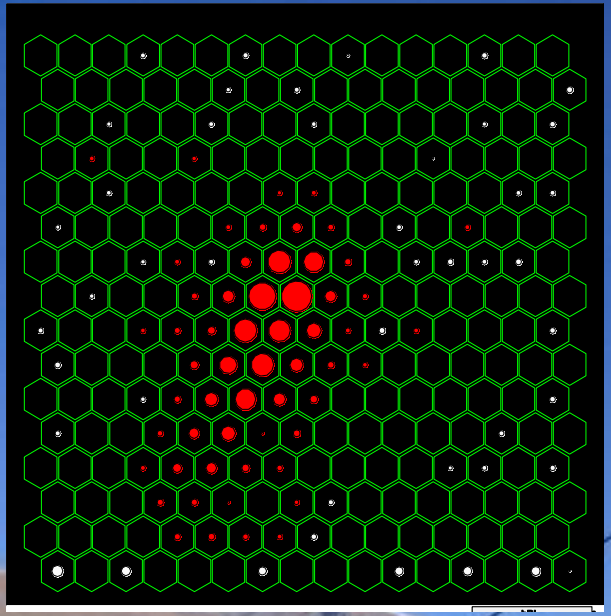
1% KM2A Porotype array





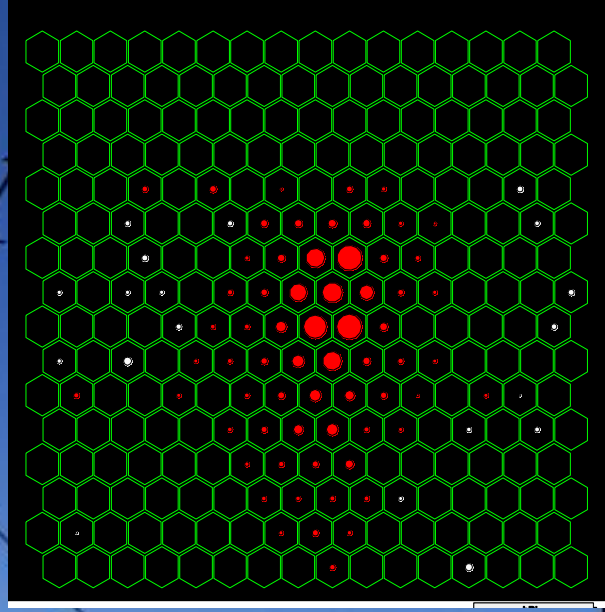




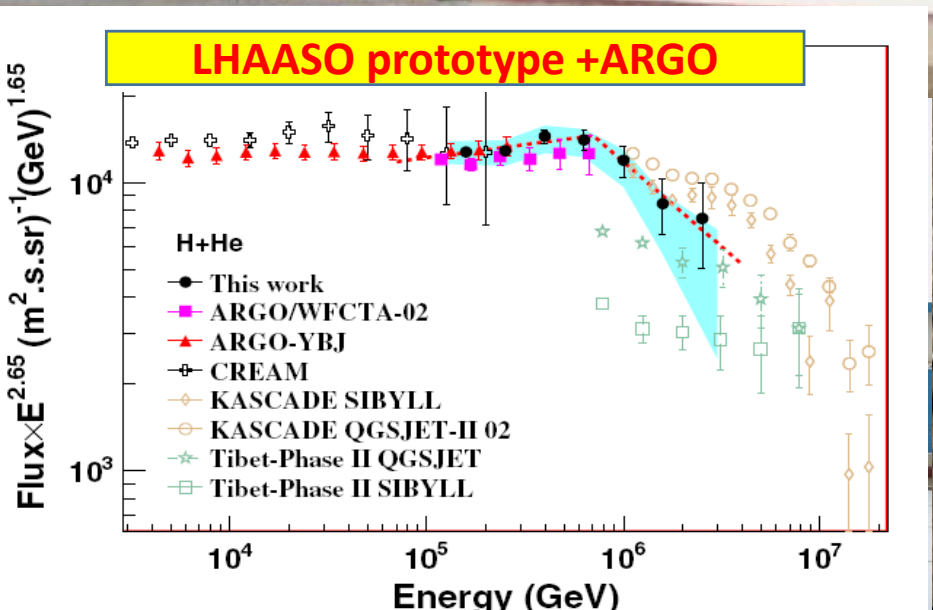


WFCTA porotype

CRTNT@Y



LHAASO prototype +ARGO



5. Site preparation & detector deployment

Living Base (3750 m a.s.l.)

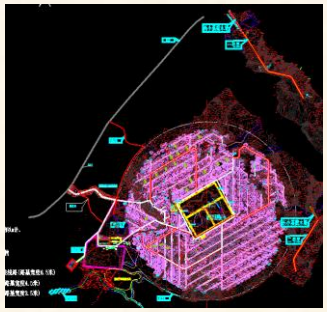
Started in Aug. ,2016, completed in Oct., 2017

35KV Transmission Line

- **29 km Sangdui village → LHAASO site, 92 towers**
- **3800 m → 4410 m a.s.l.**

Site Preparation

- **2 canals**
- **Backbone: 5.9 km**
- **Branch: 15 km**
- **……**



WCDA pool #1： 150m×150m

2017-11

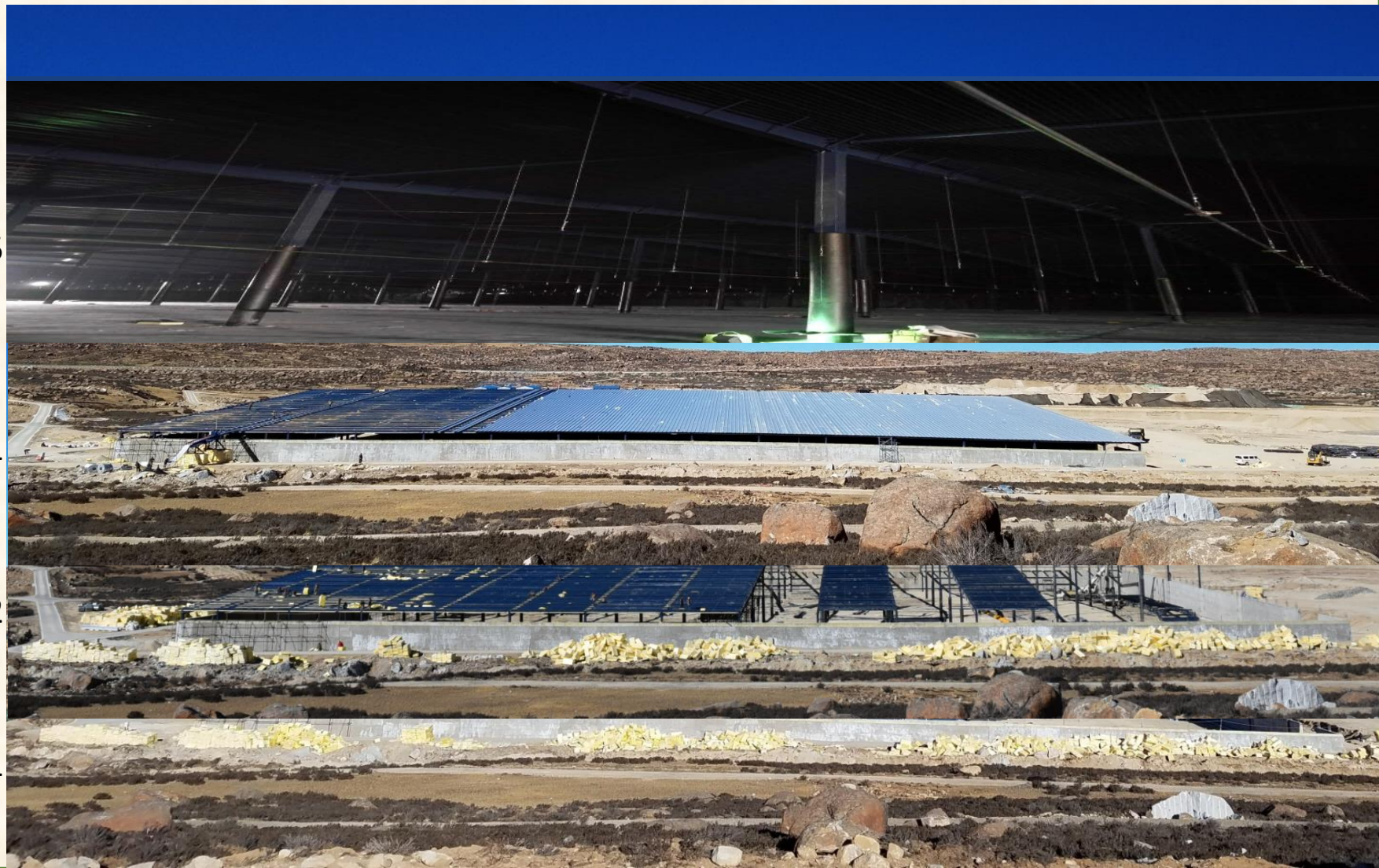
WCDA pool #1： 150m×150m

2017-12

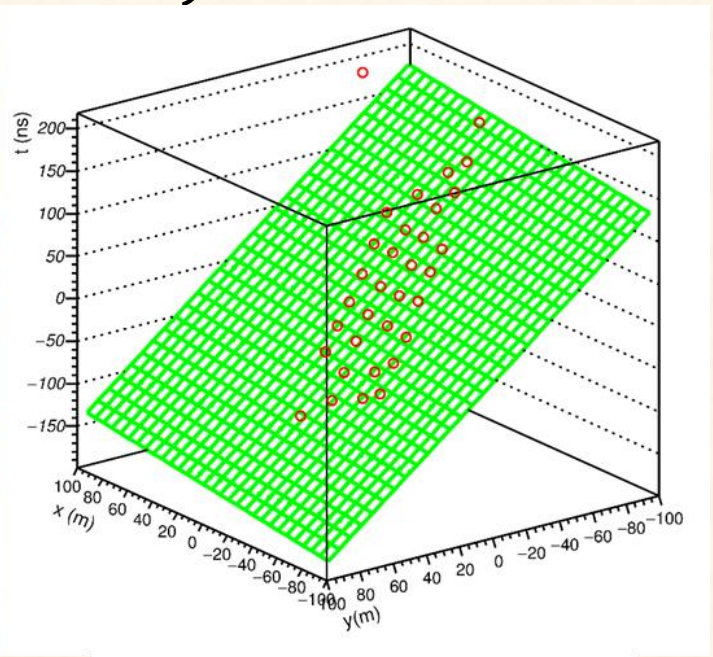
2017-11

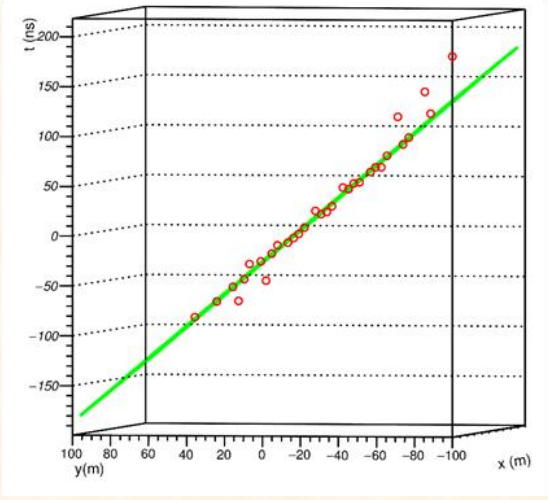
WCDA pool #1： 150m×150m

WCDA pool #1： 150m×150m



33 EDs deployed in Jan, 2018





Welcome to LHAASO!