

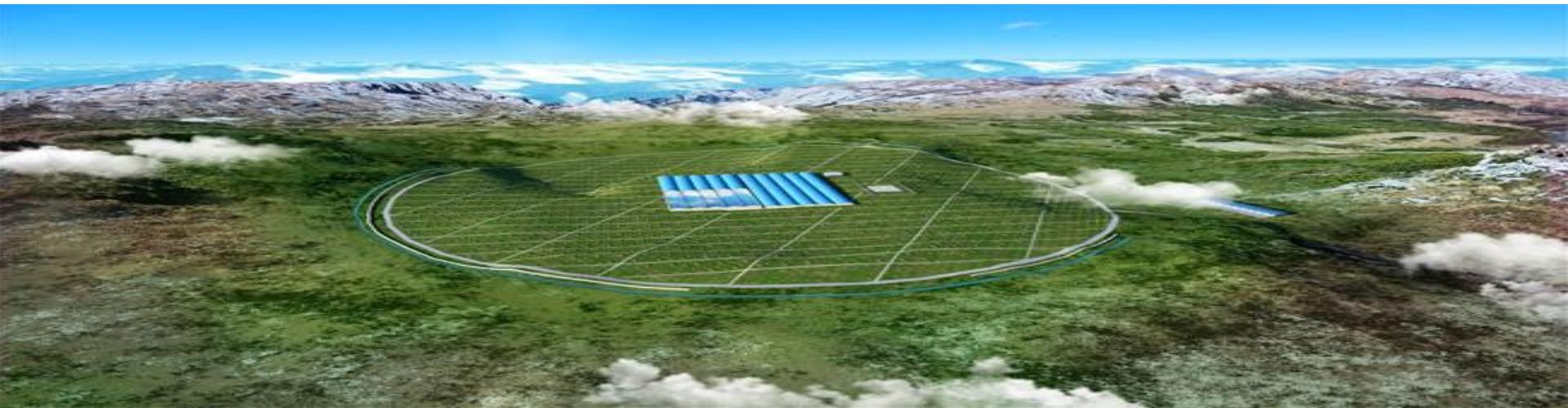
High Precision Measurement of Energy Spectra of CR Species with LHAASO

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For LHAASO collaboration

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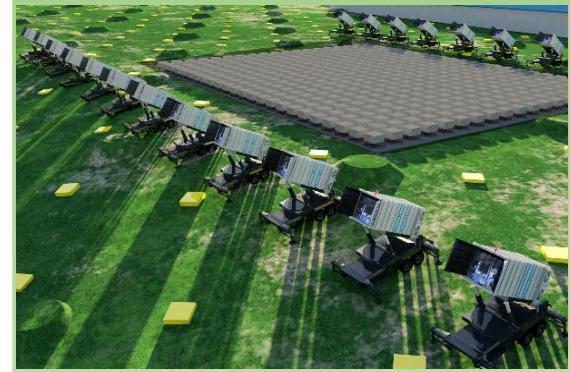
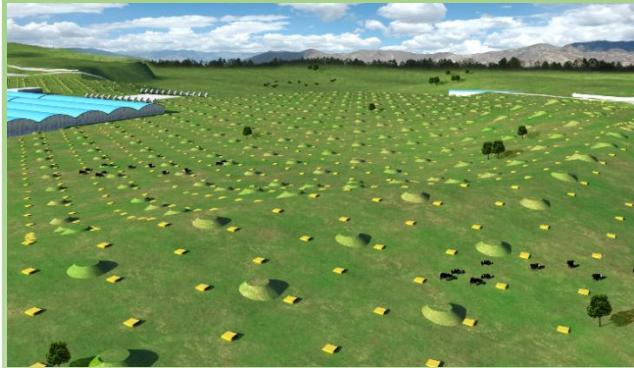
Email: llmallma@ihep.ac.cn



Outline

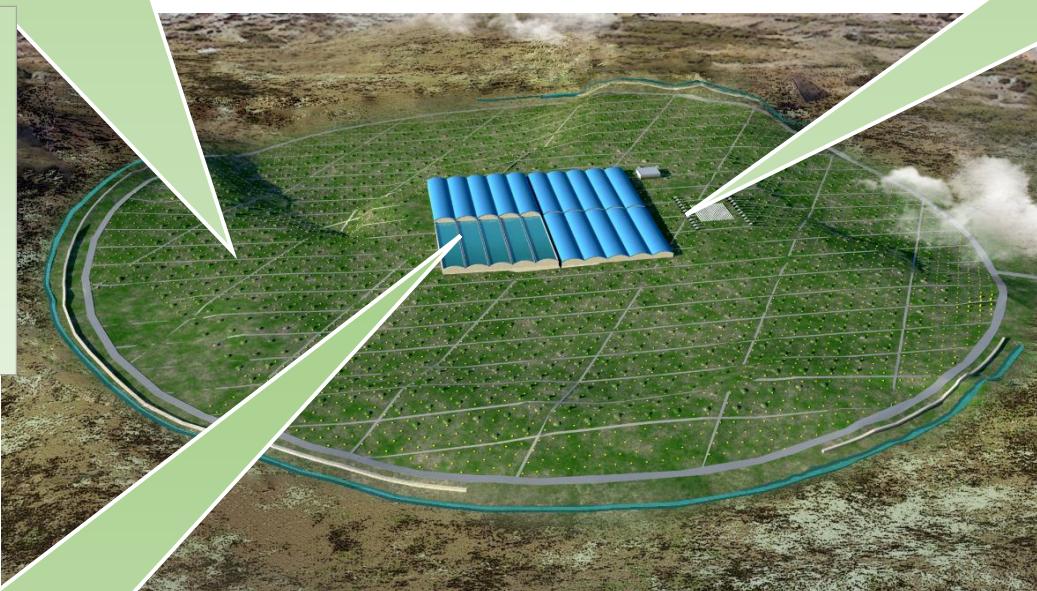
- LHAASO introduction
- LHAASO science in cosmic ray measurement
- The measurements of knees of cosmic rays for individual species.
- Summary

Large High Altitude Air Shower Observatory



KM2A:

- 5195 EDs: 1 m² each, 15m spacing
- 1171 MDs: 1146 MDs, 36 m² each, 30m spacing



WFCTA:

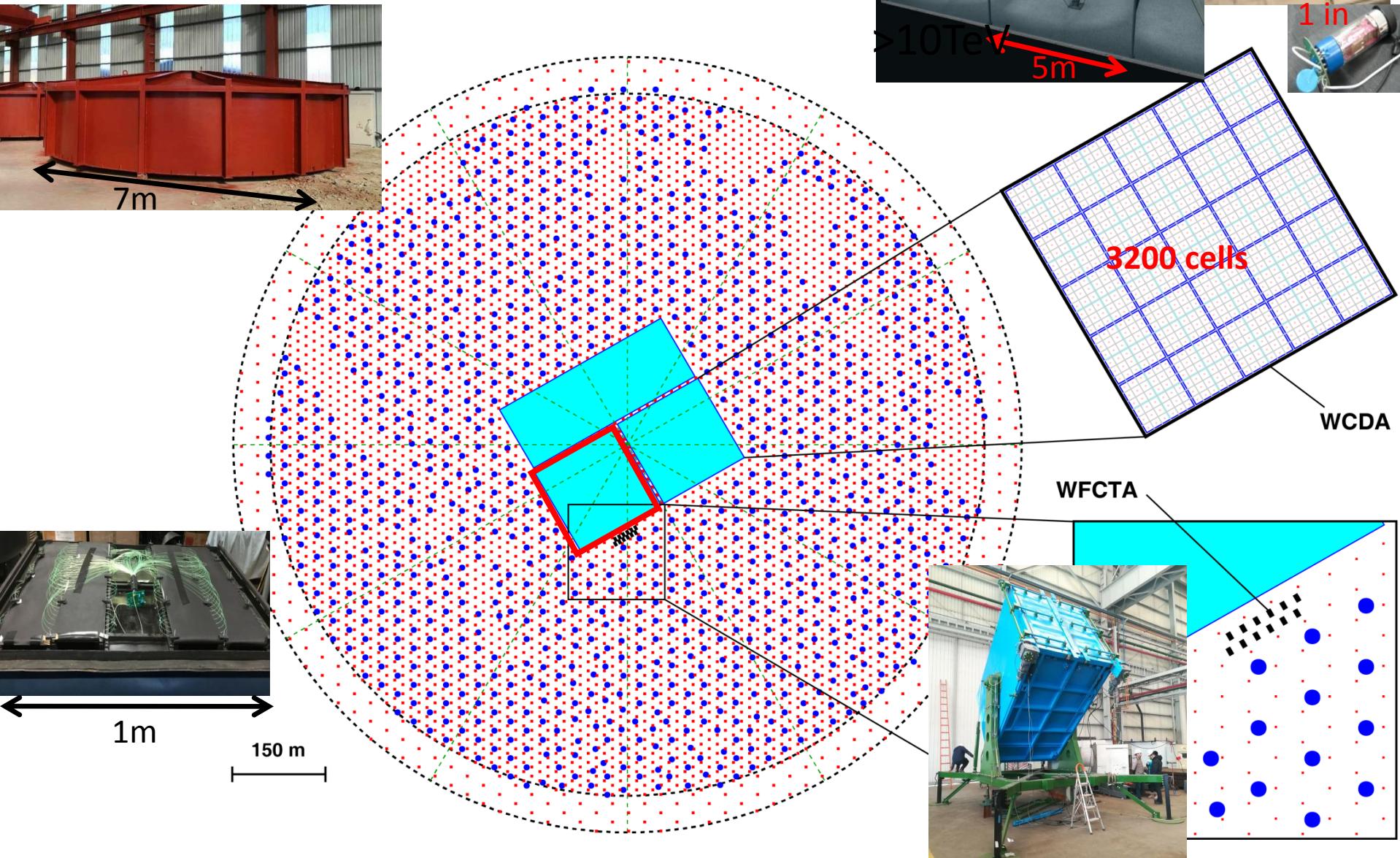
18 Cherenkov telescopes (1024 pixels/telescope)

WCDA:

three pools



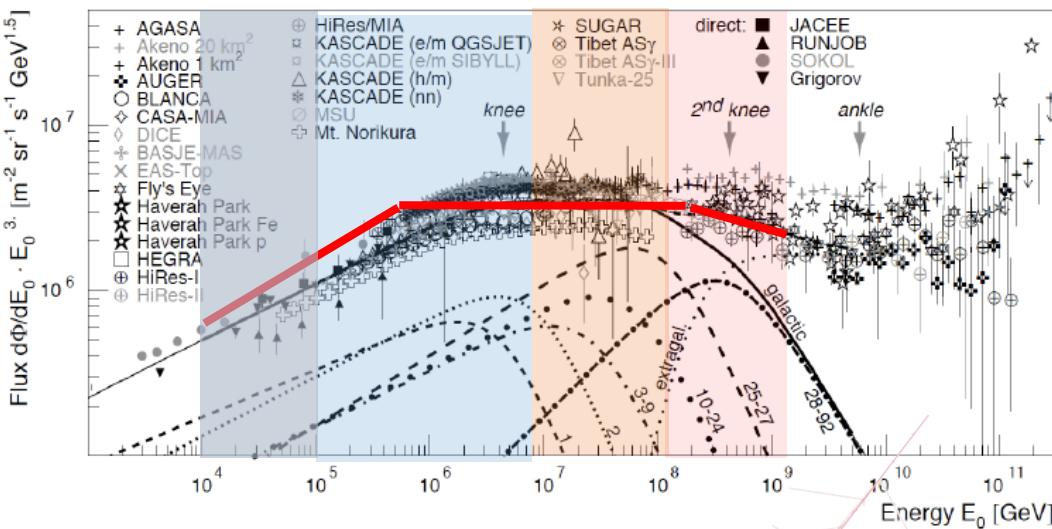
Hybrid Measurements of Showers



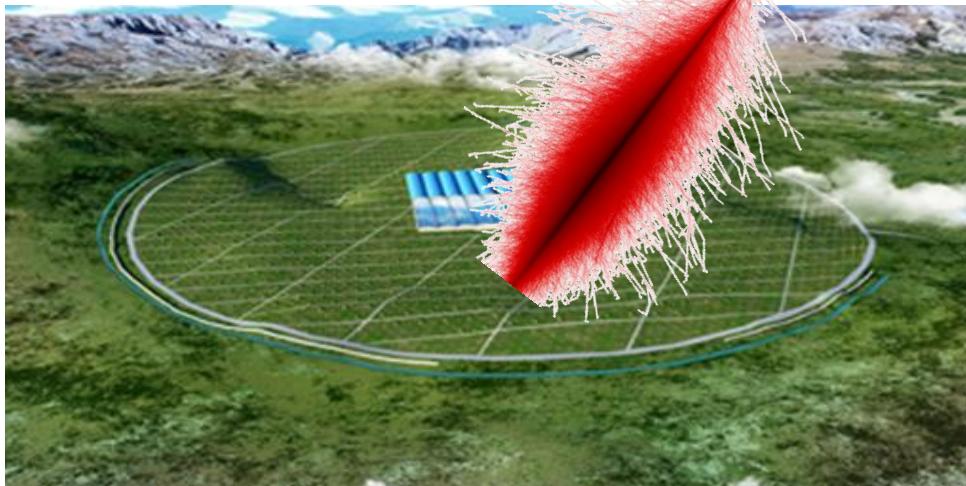
LHAASO science in cosmic ray spectra measurement

◆ Measure individual cosmic ray spectra from 10TeV to EeV

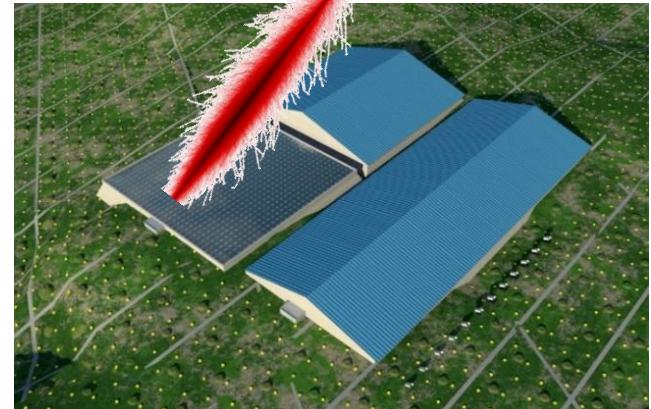
- Multi-stages, Multi-parameters



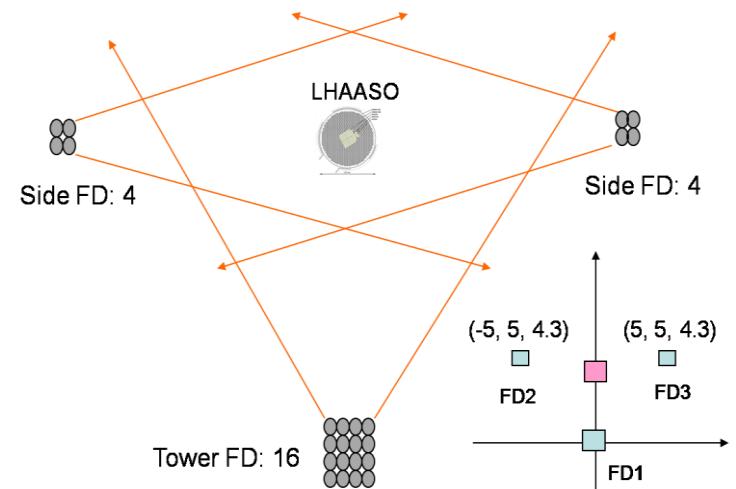
3. 10PeV-100PeV: knee for iron



1. 10TeV-100TeV : energy scale;
2. 100TeV-10PeV : H, He knees

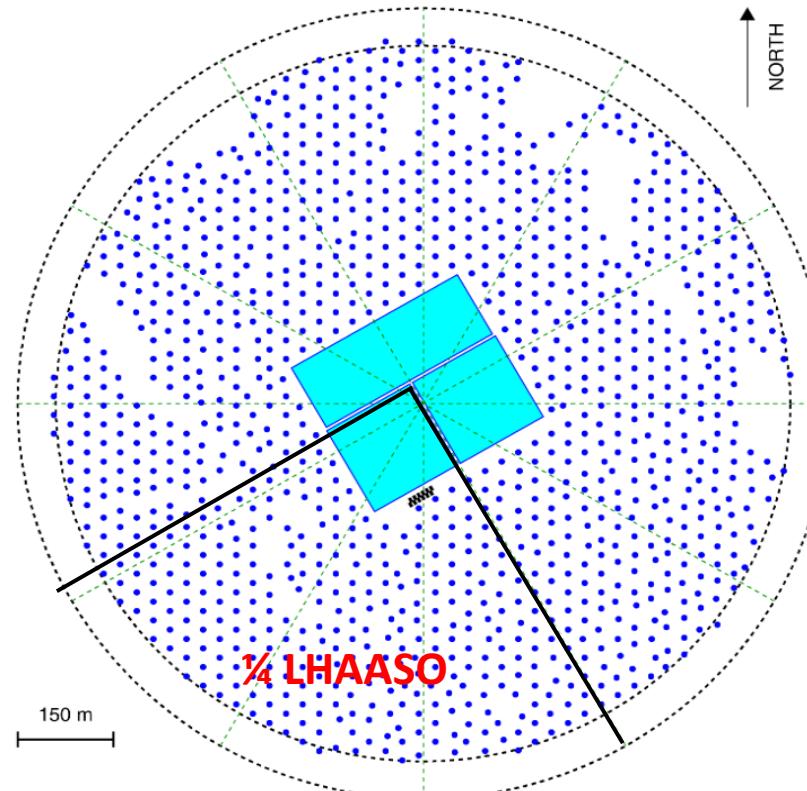


4. >100PeV: second knee



Prospects of P, He knees from 100TeV to 10PeV

- ◆ $\frac{1}{4}$ LHAASO array is expected to be operated by the end of this year
 - 6 WFCT telescopes
 - WCDA++, namely the pool with higher dynamic range.
 - 300 muon detectors



◆ Measurement and Reconstruction

■ WCDA

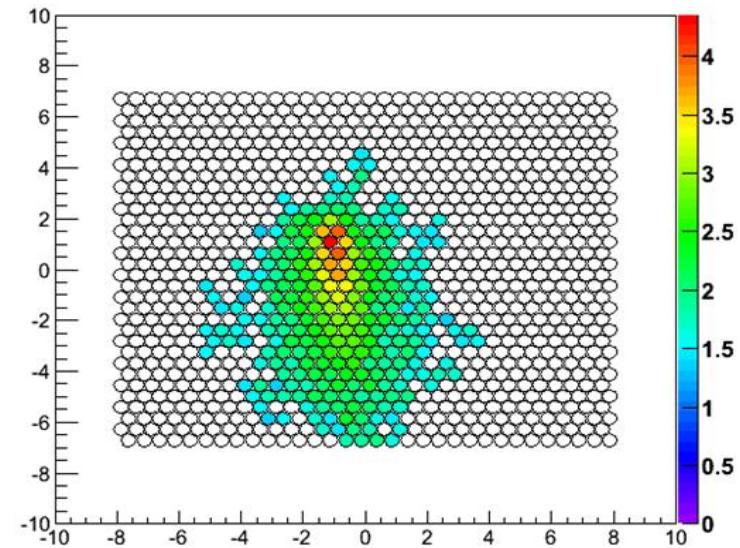
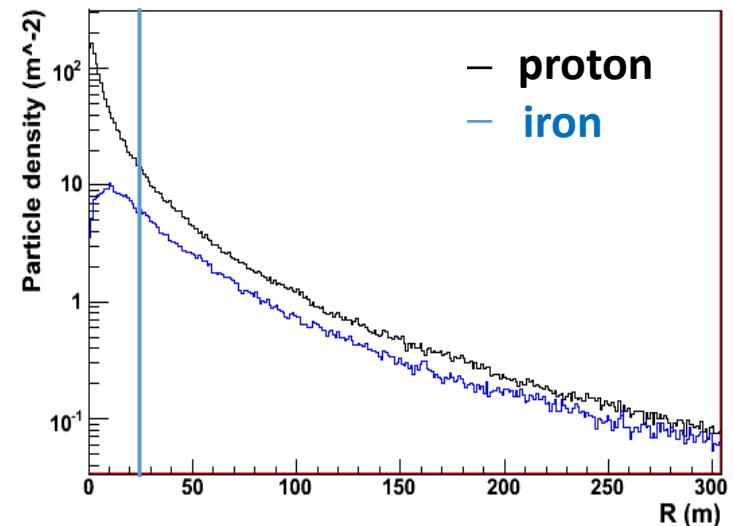
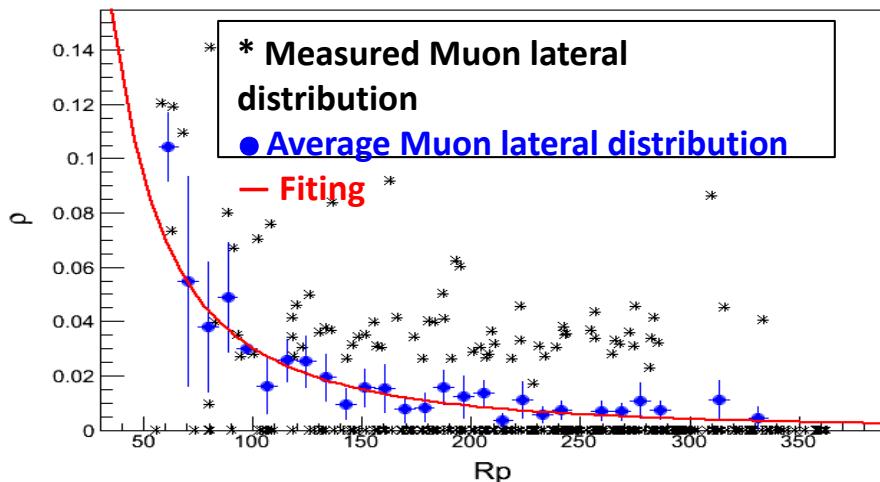
- Energy flux near the core
- Core reconstruction: 3m
- Arrival direction reconstruction: 0.3°

■ WFCTA

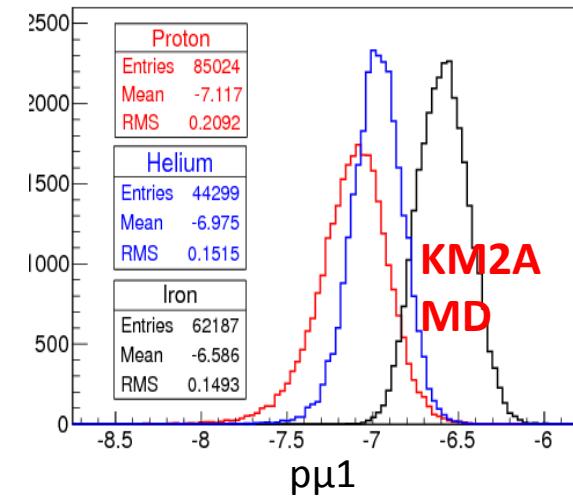
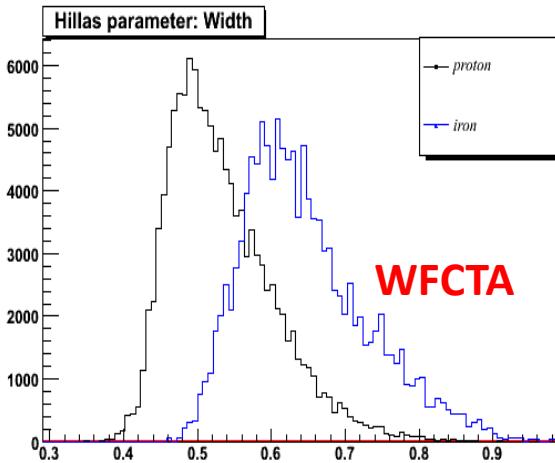
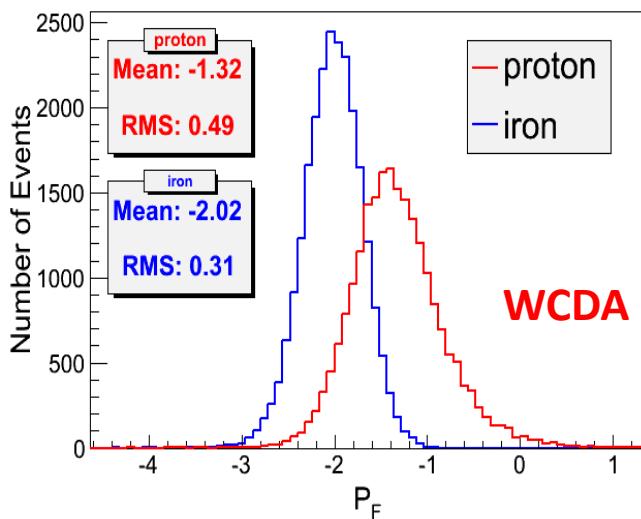
- SIZE (total PE in image)
- Width, Length
- Angular offset between arrival directions to the image center

■ KM2A - MD

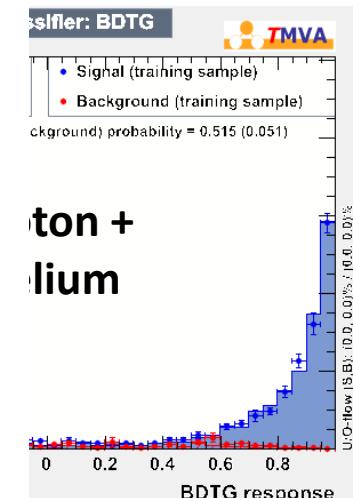
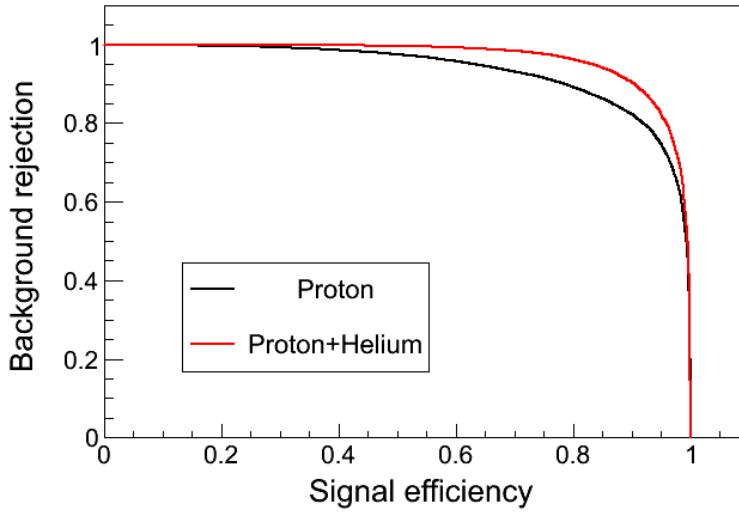
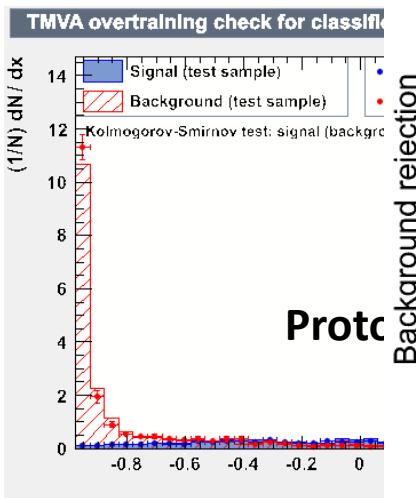
- Lateral distribution of Muon



Particle Identification

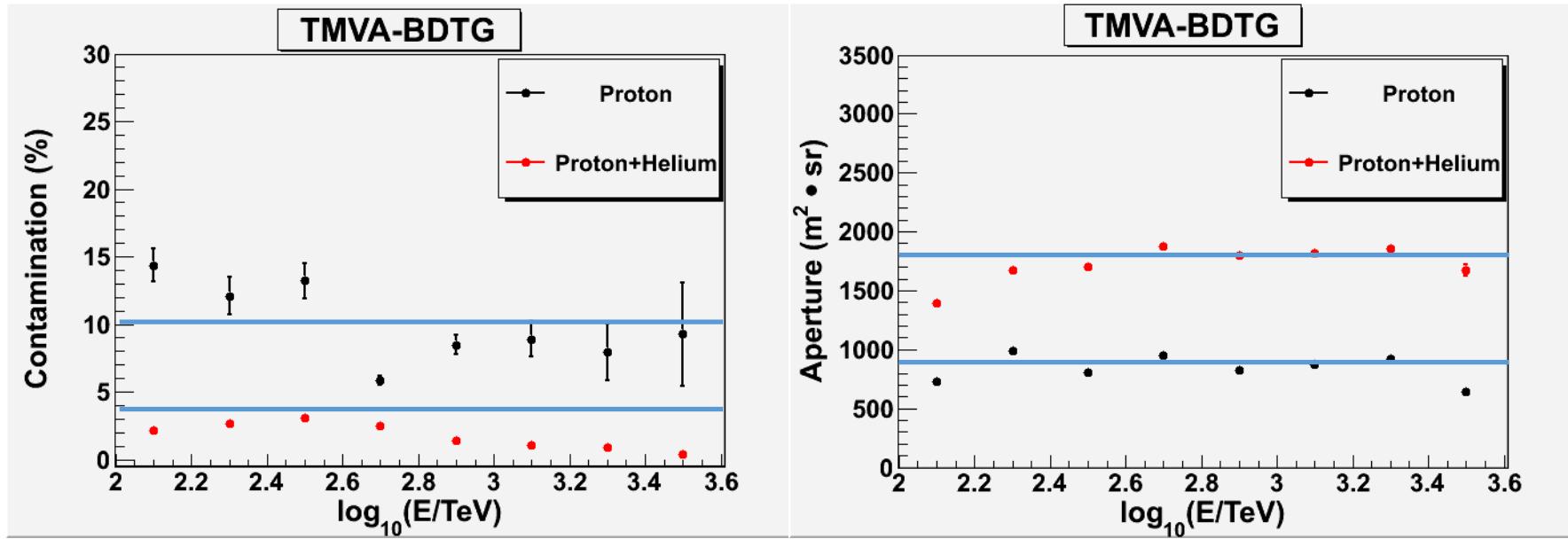


TMVA-BDTG



Particle identification Results

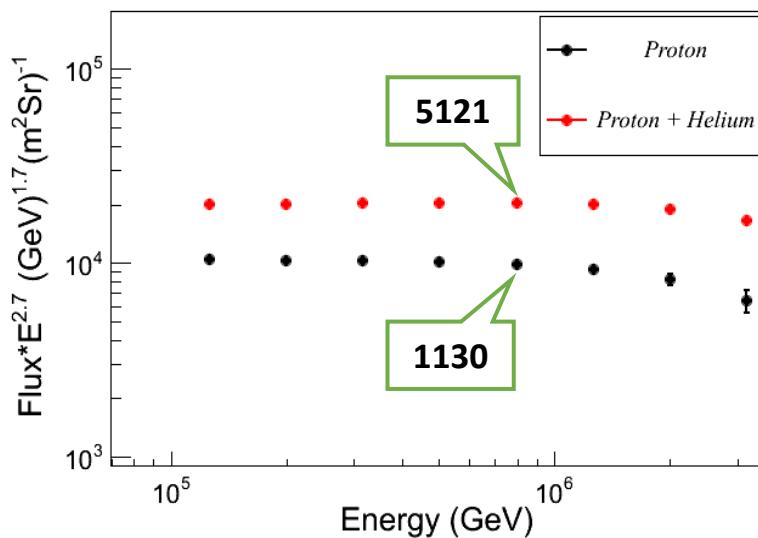
1/4 LHAASO



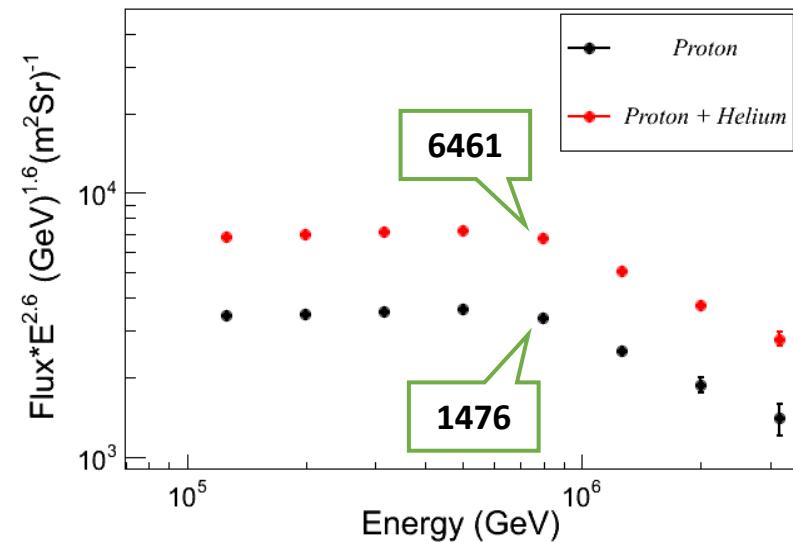
	Proton	Proton+Helium
Aperture	~900	~1800
Contamination	~10%	<4%

Prospects for cosmic ray spectra

- ◆ One year statistics, 10% duty cycle
- ◆ 6 Cherenkov Telescopes



Horandel model



ARGO-YBJ & WFCT Model

Prospects of iron knee from 10PeV to 100PeV

- **KM2A:**

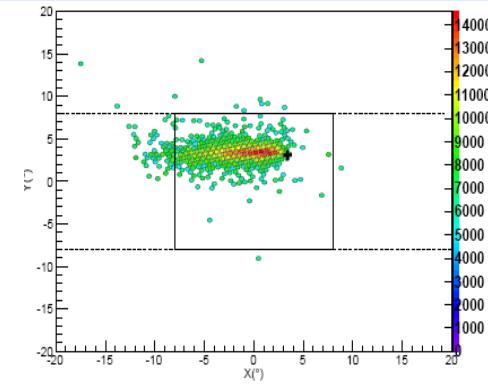
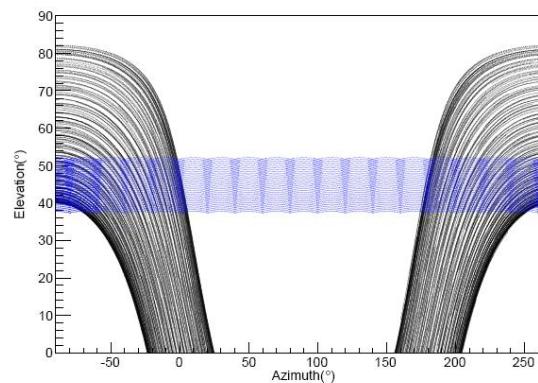
- Geometry reconstruction
 - 3m, 0.3°
- No. of Muons
- No. of electromagnetic particles

- **WFCTA:**

- Px: angular offset between shower arrival direction and the image center X_{max}
- Size: Number of pe. in the Cherenkov image

Selection criteria:

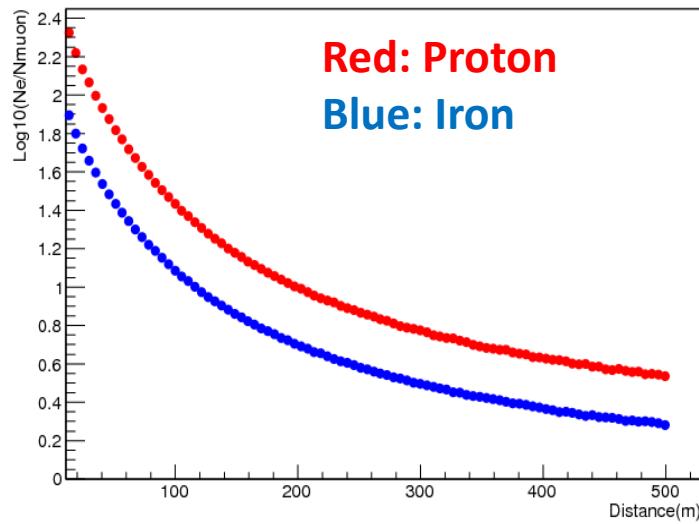
- 1: The cores should be in the array of KM2A
- 2: The arrival directions should be in the FOV of WFCTA ($|Y| < 7^\circ$)
- 3: image completeness $N_{\text{trigger}} > 100$



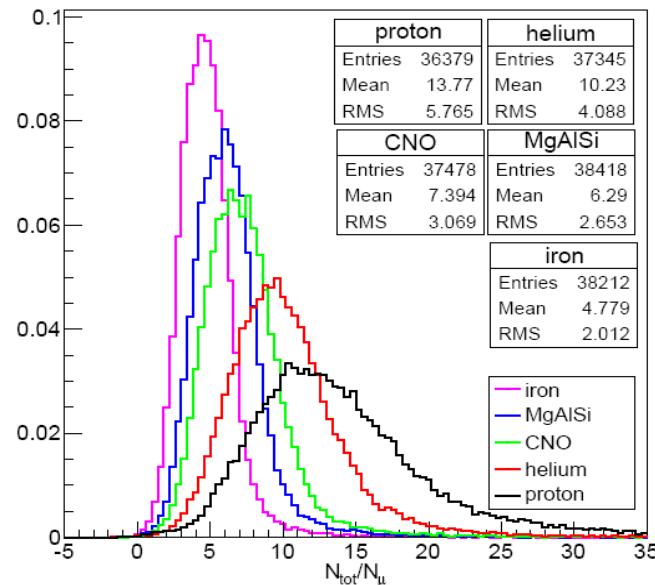
Elevation of 45° toward North
with full-moon duty cycle $> 30\%$

$R_p < 400\text{m}$

Particle Identification N_{tot}/N_{μ}

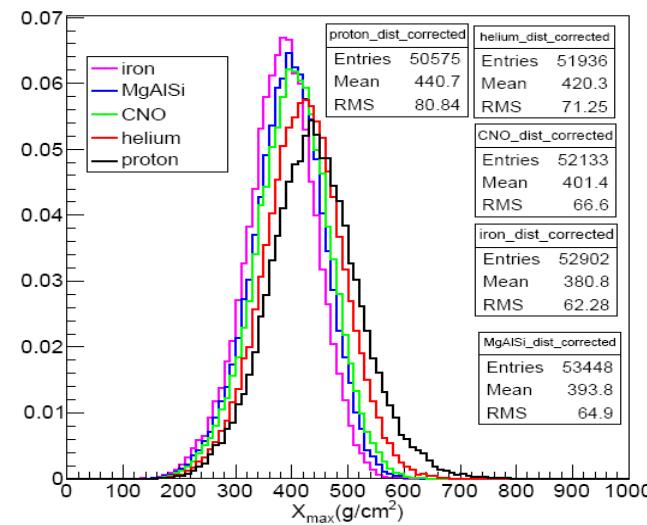
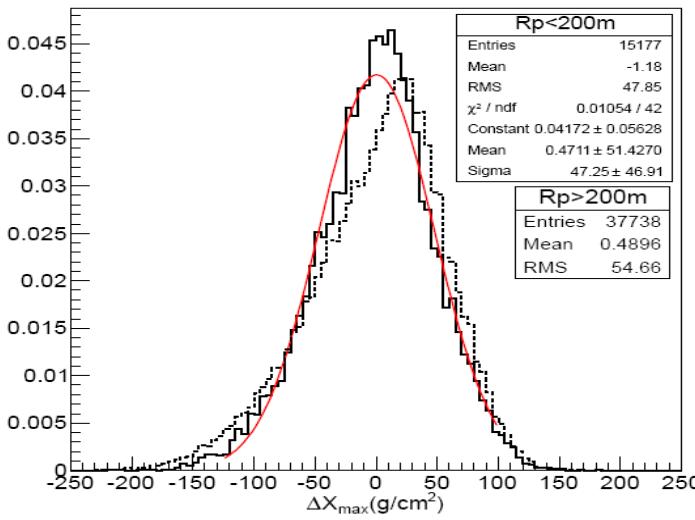
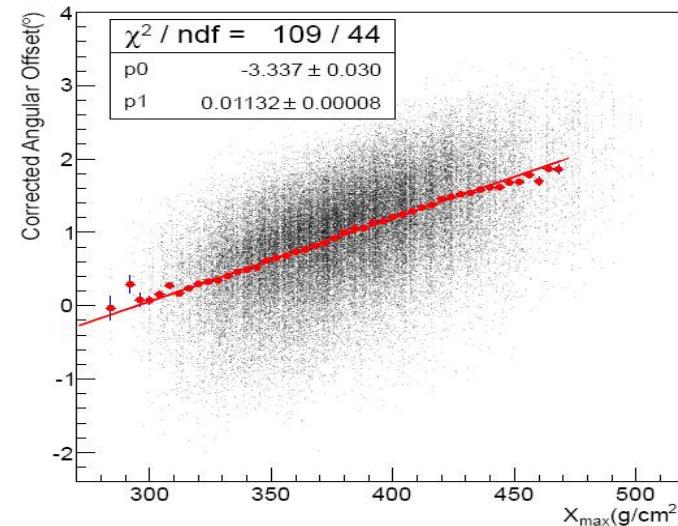
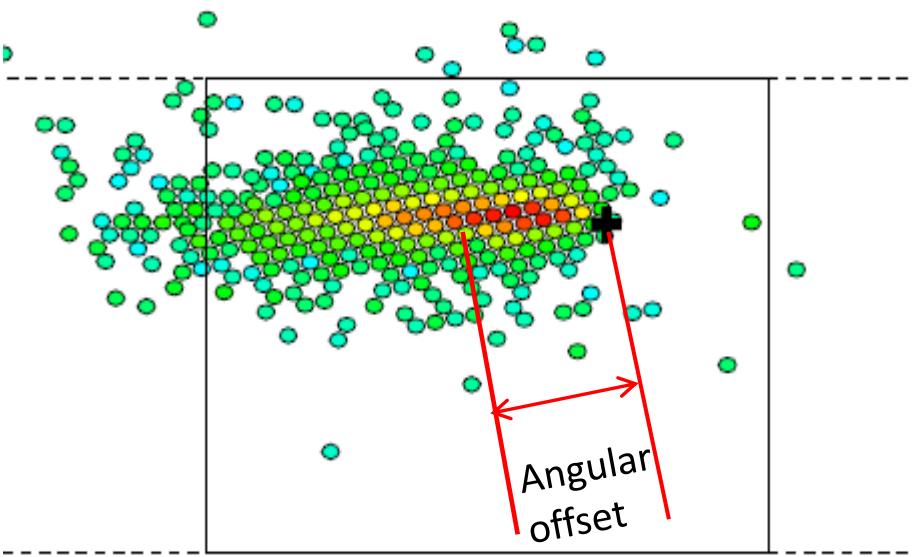


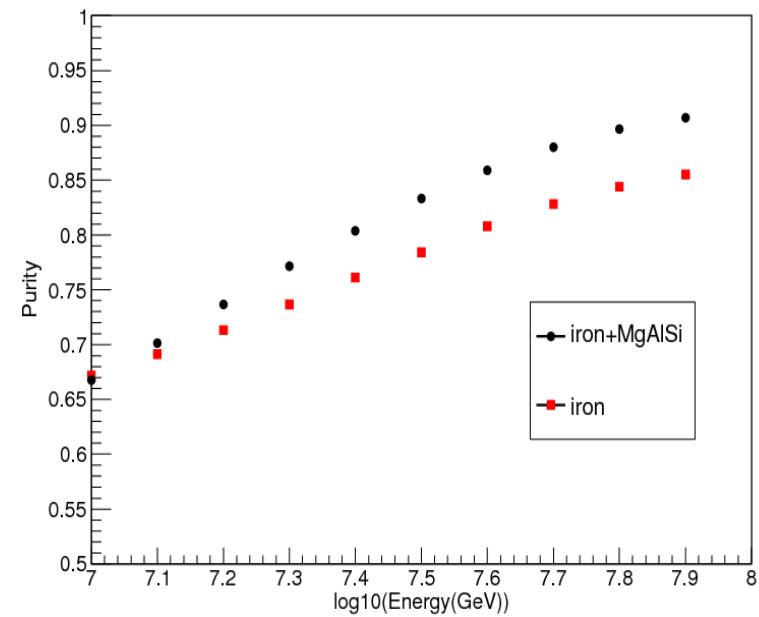
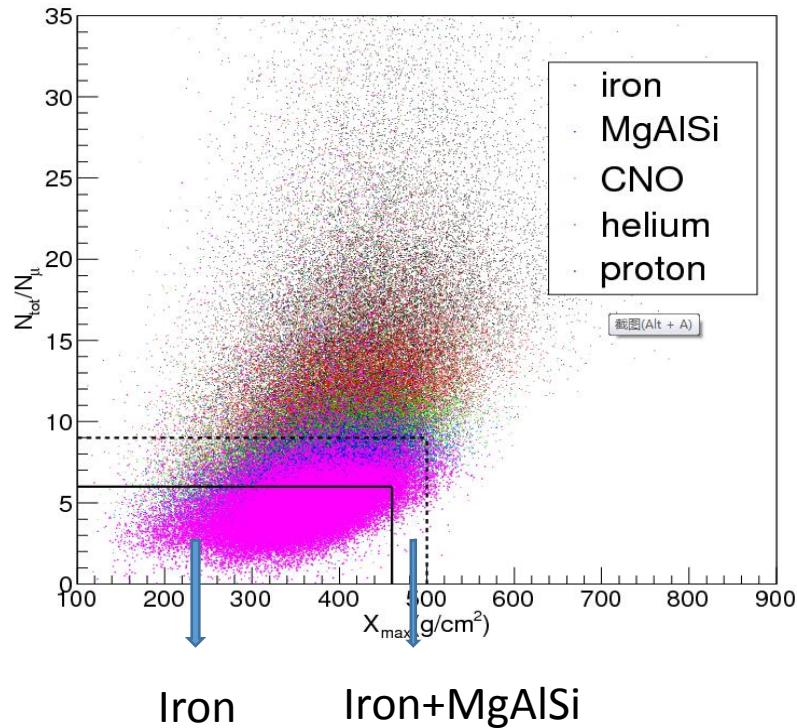
Lateral distributions of $\text{Log10}(N_{\text{tot}}/N_{\mu})$



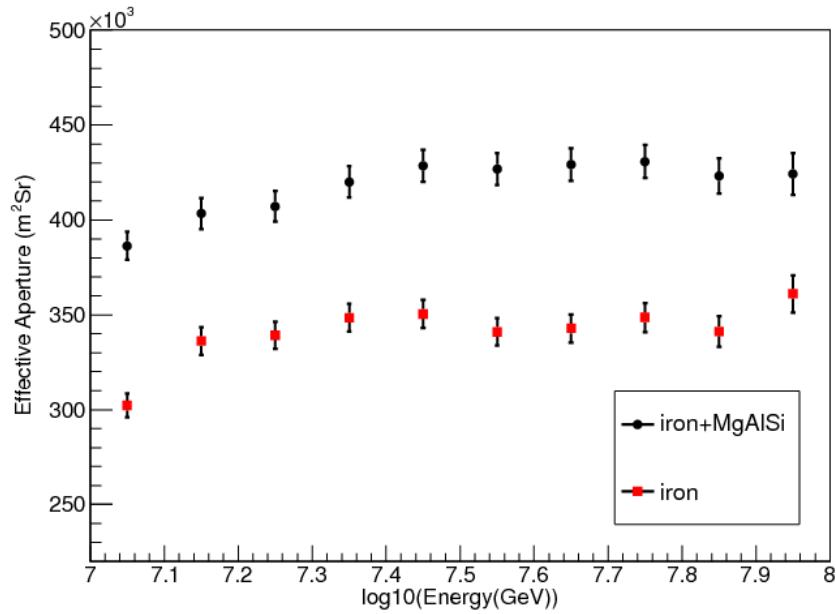
Normalized to 1

Particle Identification vertical X_{\max}

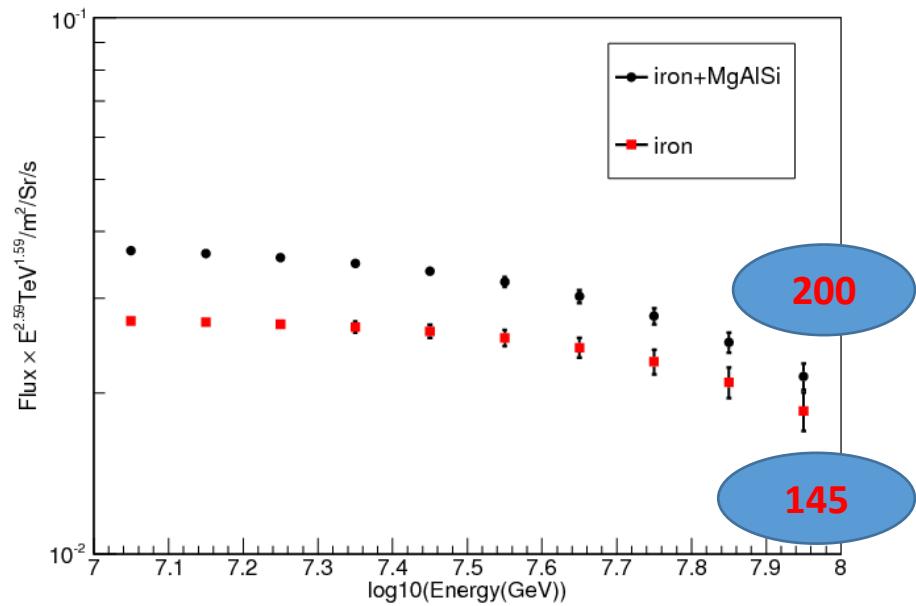




The correlation is less then 0.9

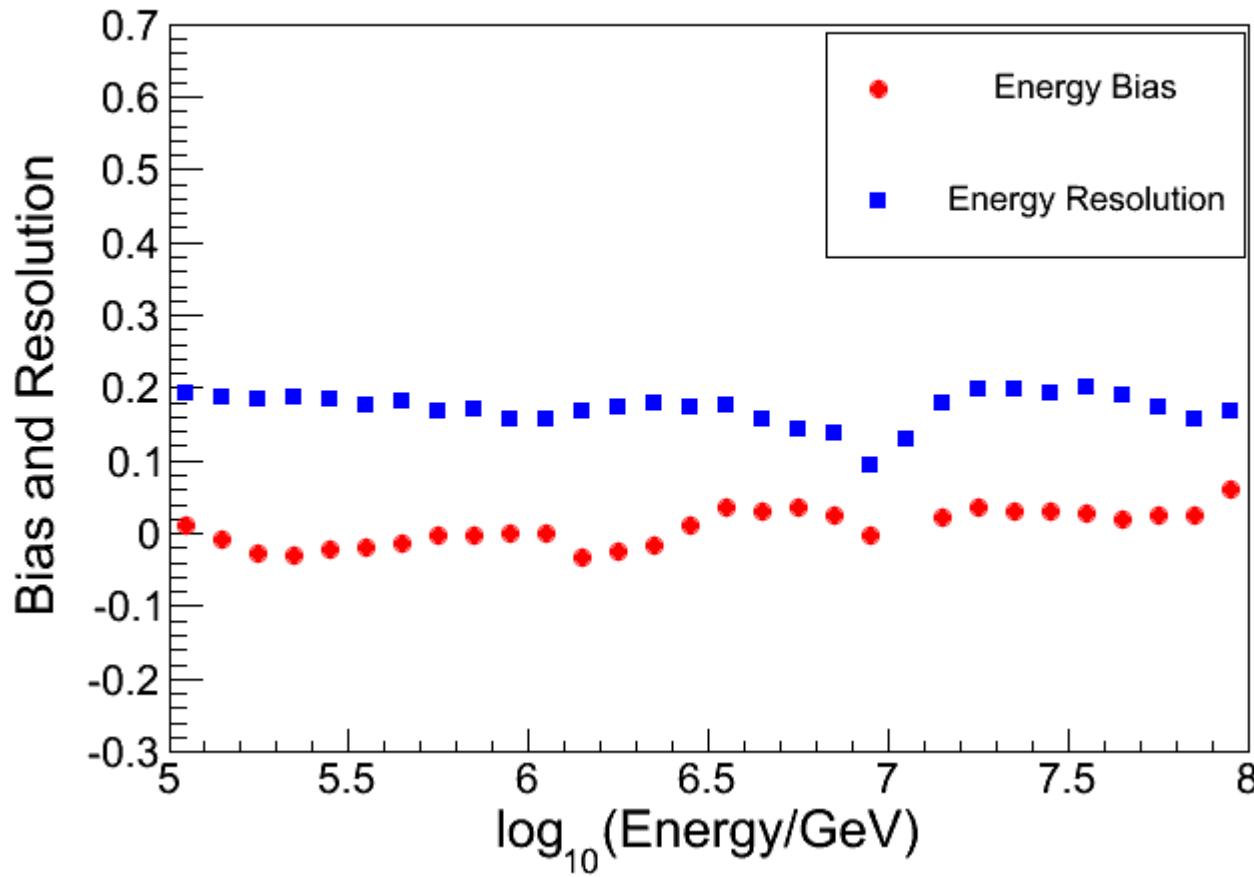


Aperture for iron : $3.5 \times 10^5 m^2 \text{Sr}$



Horandel model

Energy Resolution



Summary

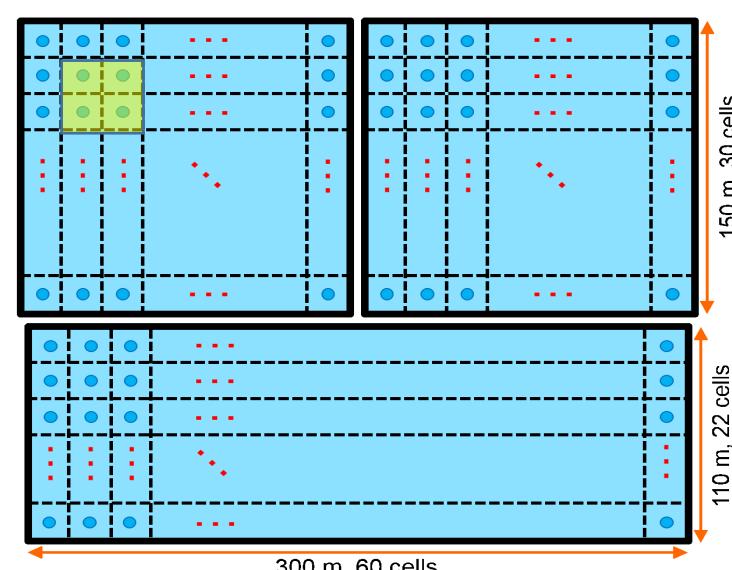
- ◆ The knees of proton and proton + helium spectra can be obtained by 6 CTs, MD, and the first pool of WCDA.
- ◆ The knees of iron or iron + MgAlSi spectra can be obtained by 18 CTs (45 in elevation)+ ED+ MD array
- ◆ With high statistics , high purity energy resolution is better than 20%.

Thank you !

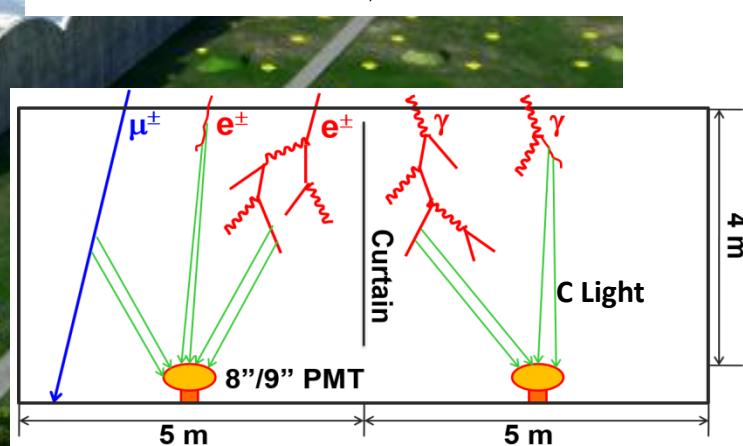
Water Cherenkov Detector Array

◆ 3 water ponds:

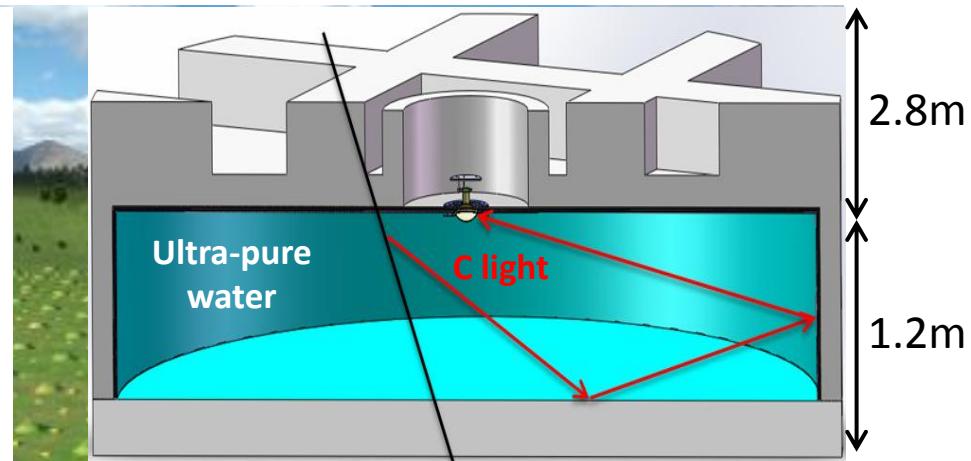
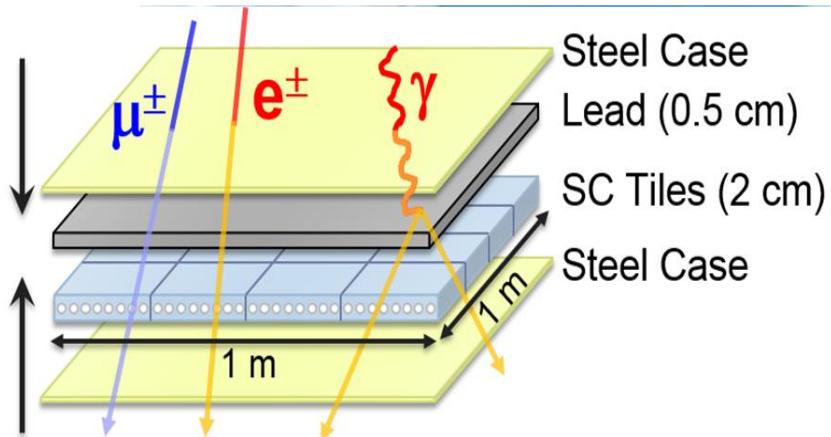
- 78,000 m² in total;
- 4 m effective depth;
- 3120 cells, with an 8"/9" PMT in each cell;
- Cells are partitioned with black curtains.
- Detect Cherenkov photons produced by secondary particles in the water.



◆ WCDA++: 1"PMTs enhance dynamic range



KiloMeters² Array



Electromagnetic Detector

Muon Detector

	ED	MD
Effective area	1m^2	36m^2
Spacing	15m	30m
Total NO. of detectors	5195	1171
Time resolution	2ns	10ns

Wide Field of View Cherenkov Telescope Array

- ◆ 5m² spherical mirror
- ◆ 32 × 32 SiPMs array
- ◆ Pixel size 0.5°
- ◆ FOV: 16° × 16°
- ◆ Detect the Cherenkov and fluorescent composition in EAS
- ◆ Duty cycle: 30%

