Астрофизика частиц и космические лучи

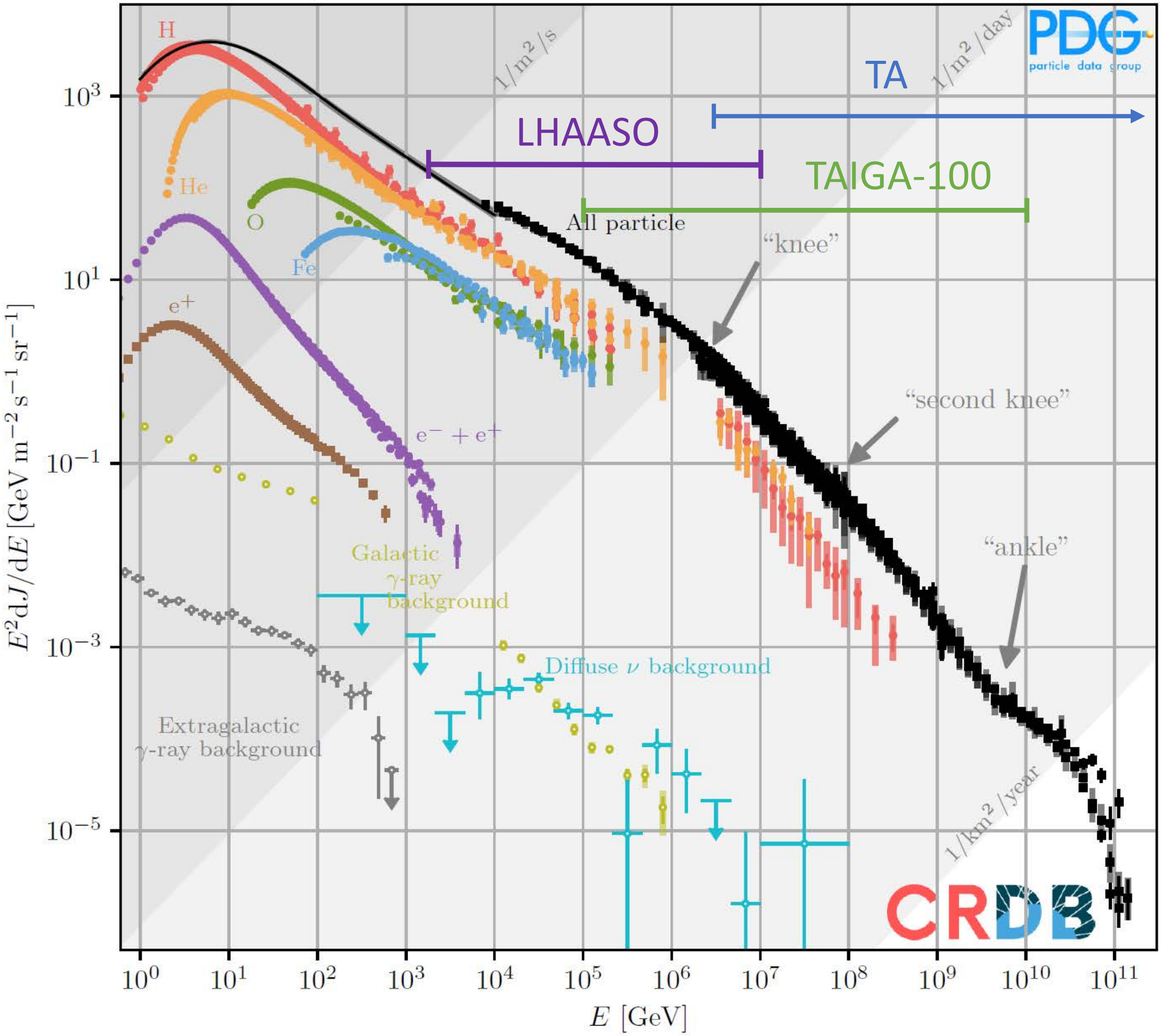
Кравченко Е.А.
ИЯФ СО РАН/НГУ

Разлив. 28.08.2026

План доклада

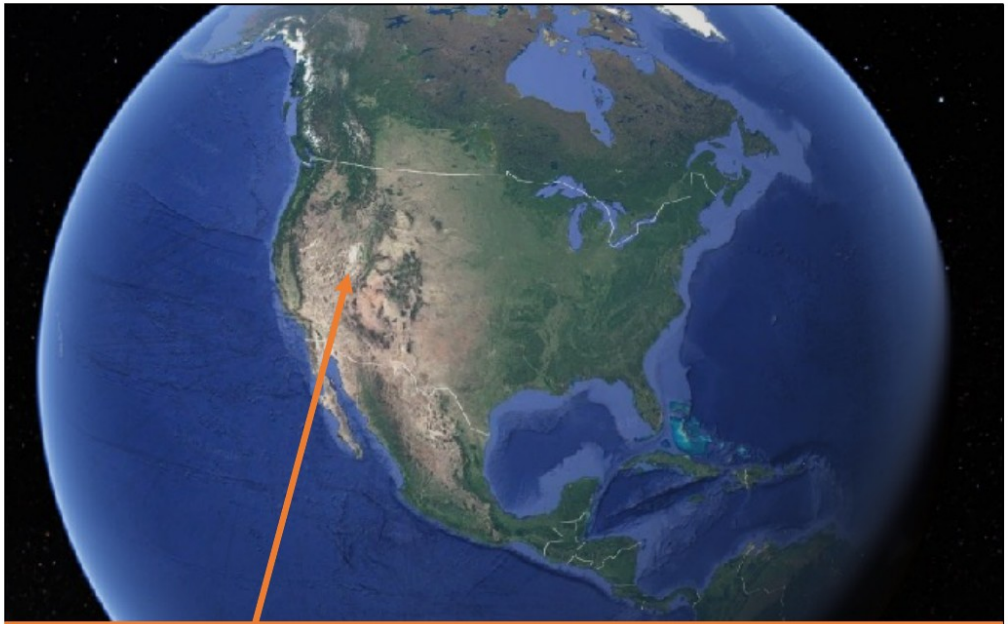
- Обзор результатов эксперимента Telescope Array (TA) [по докладу Г.И. Рубцова на ВККЛ2026]
- Обзор результатов эксперимента LHAASO [по докладу Zhiyong You на ВККЛ2026]
- Обзор проекта TAIGA-100 [по докладу Р.Д. Монхоева на ВККЛ2026]

Энергетический спектр космический лучей



Telescope Array observatory

- The largest cosmic ray observatory in the northern hemisphere



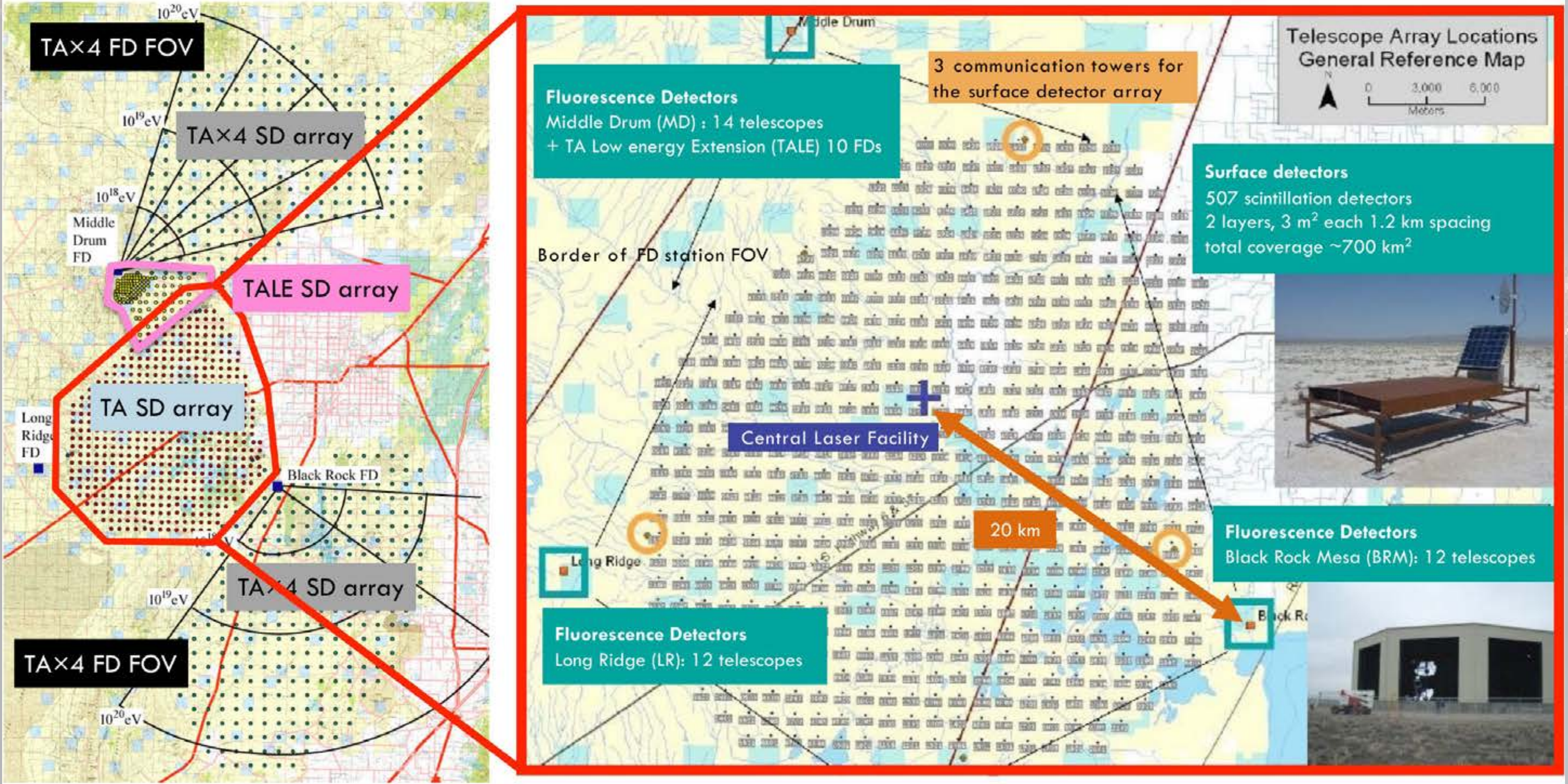
Telescope Array

- Delta, Utah, USA. ~1400 m above sea level
- Collaborators from HiRes, AGASA and other institutes

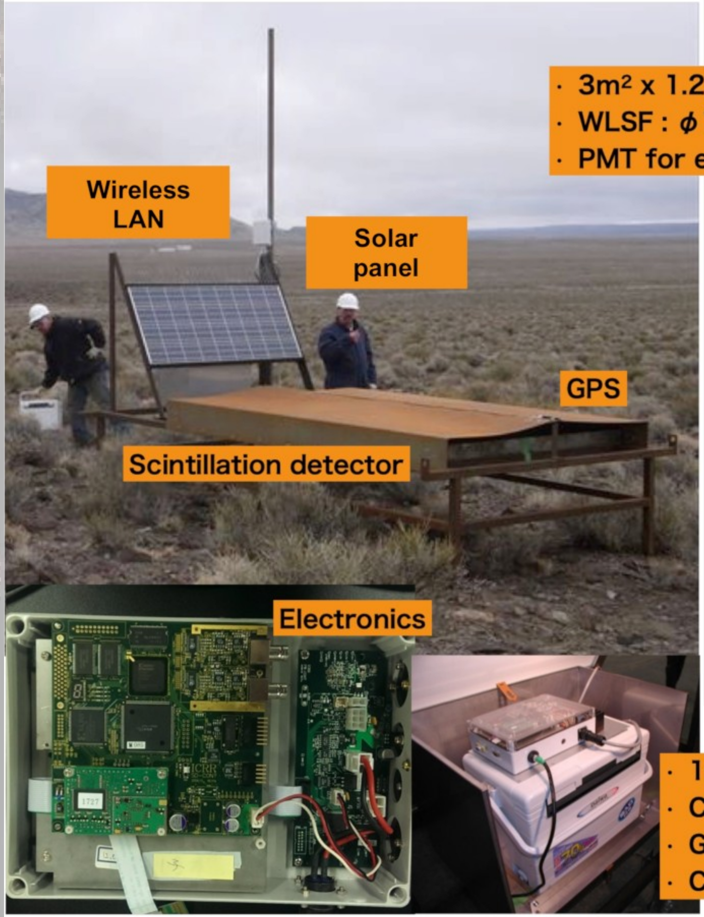
Scientific Goals

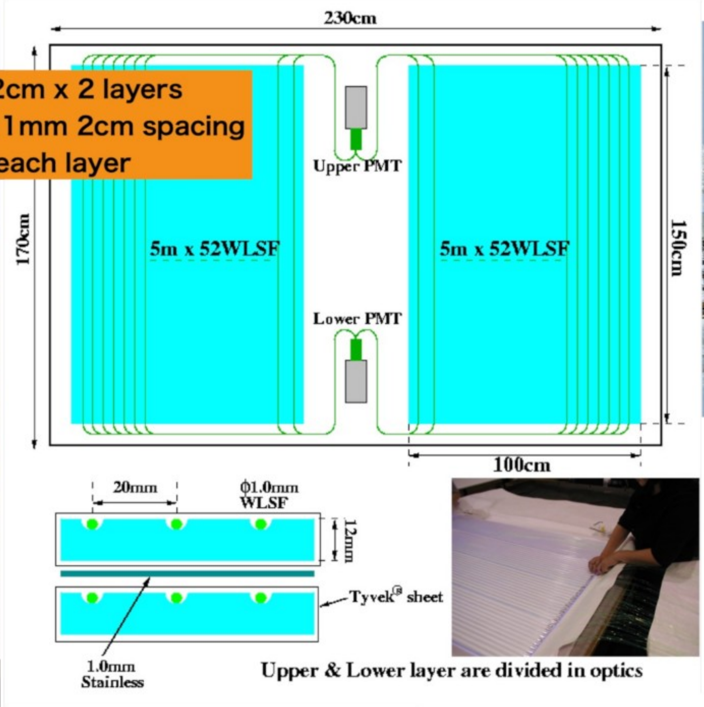
- Origin and nature of the ultra-high energy cosmic rays:
  - spectrum, composition, anisotropy
- Physics of high energy hadronic interactions
- Multi-messenger and interdisciplinary studies
  - photons, neutrinos, dark matters
  - thunderstorms, terrestrial gamma-ray flash
  - meteoroids
- Development of the next-generation experiments

Telescope Array observatory



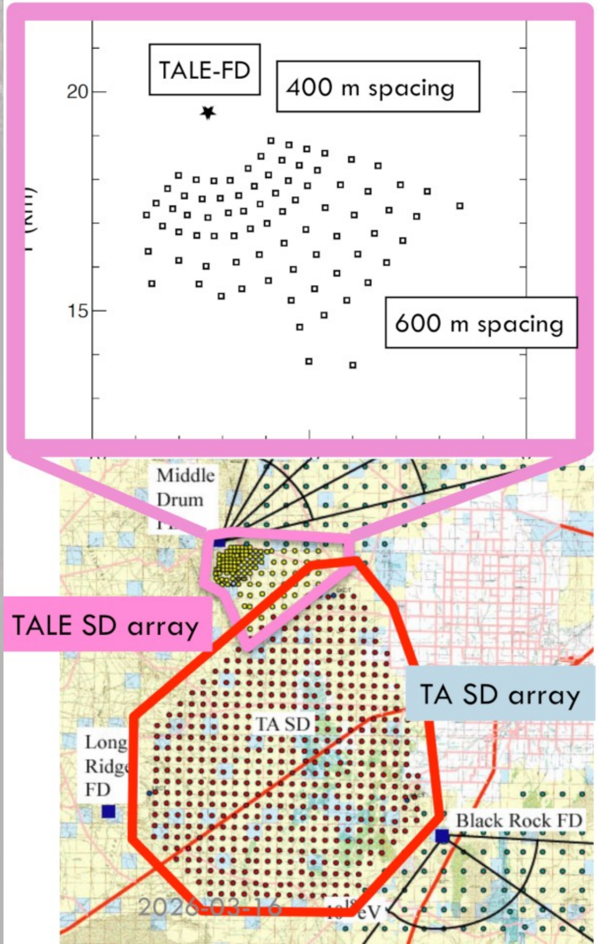
Surface Detector (SD)

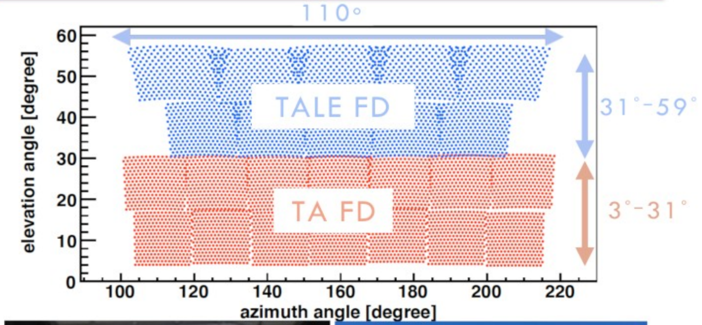




- 507 plastic scintillation stations
- 2 layers, 1.2 cm thick, 3 m^2 area
- 1.2 km square grid spacing covering **~700 km^2**

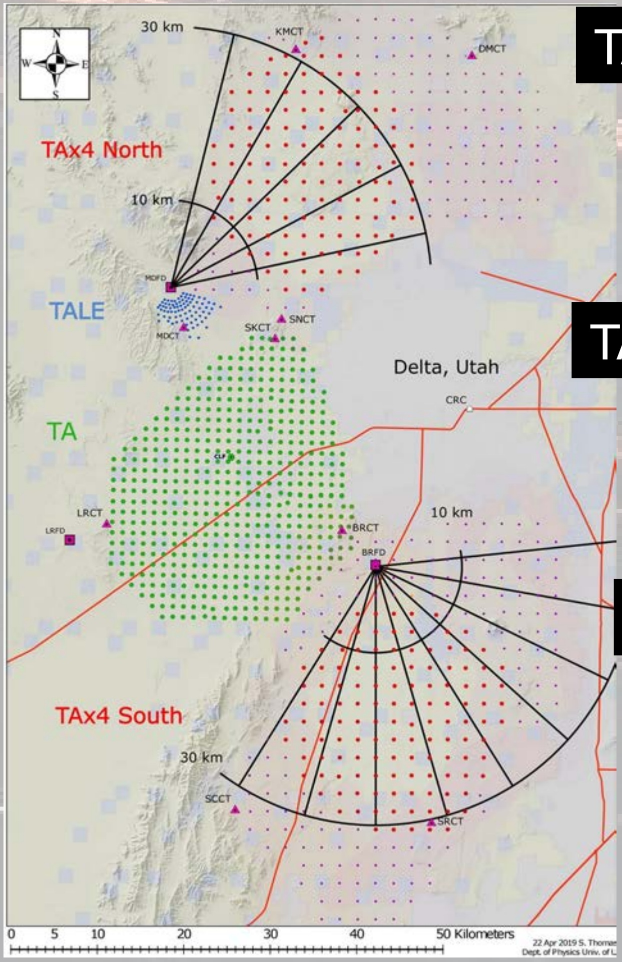
TA Low Energy extension (TALE)

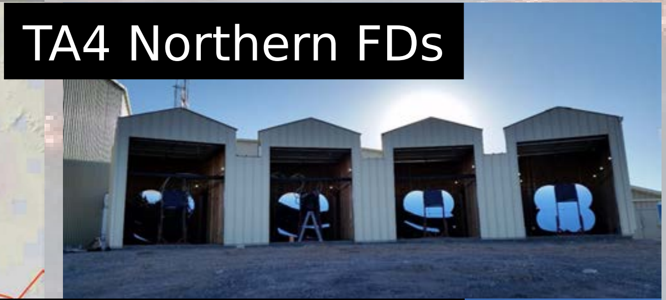




- Low energy extension of TA sensitivity down to ~10^{15} eV
- Hybrid measurement
  - 10 FDs observing higher elevation of 31°–59°
  - 80 SDs with 400–600 m spacing
  - 50 SDs with nearly 100 m spacing
- Precise measurement of the composition
  - FDs since Sep. 2013
  - SDs since Nov. 2017
  - 100 m SDs since Nov. 2023

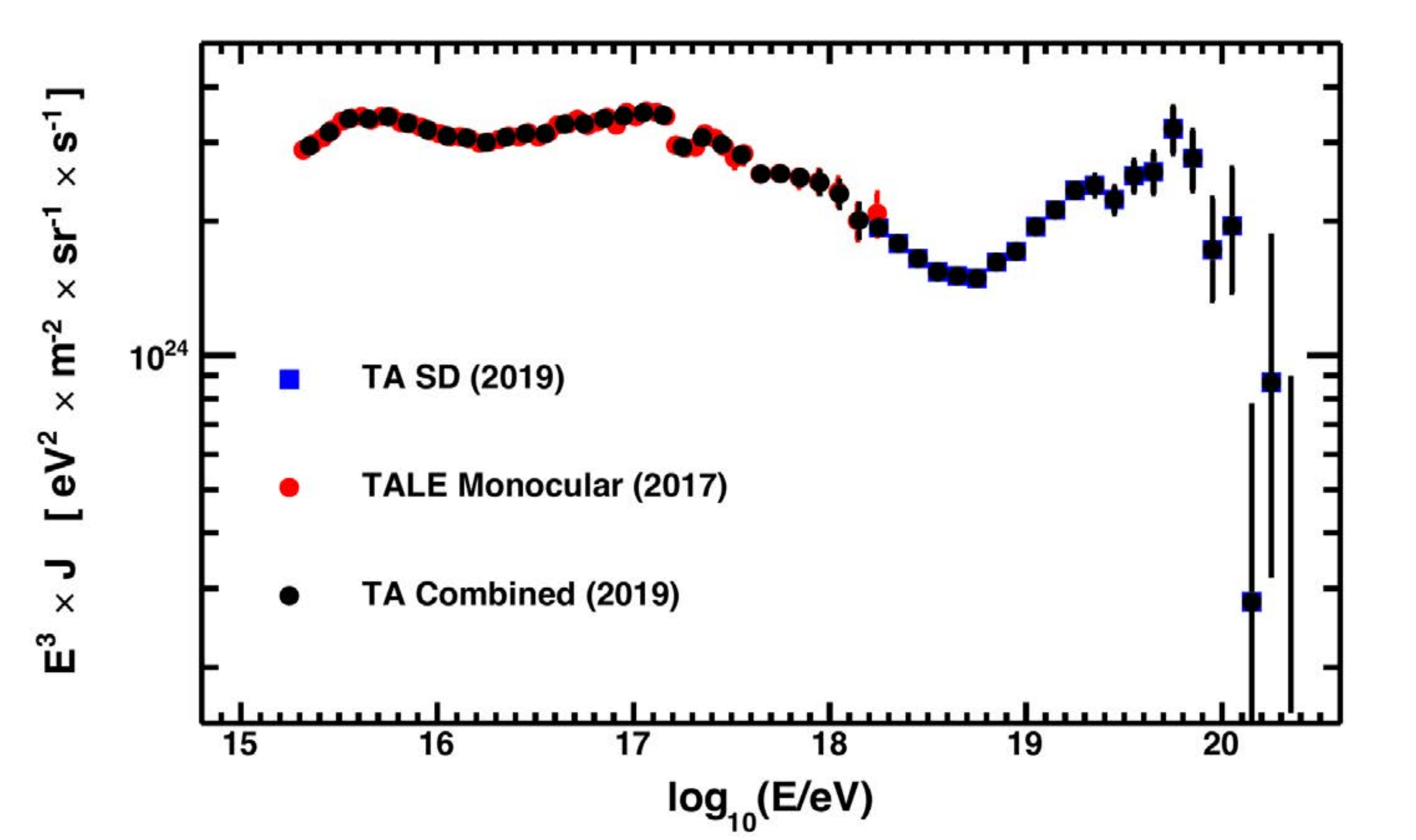
TAx4 project, ~3000 km²



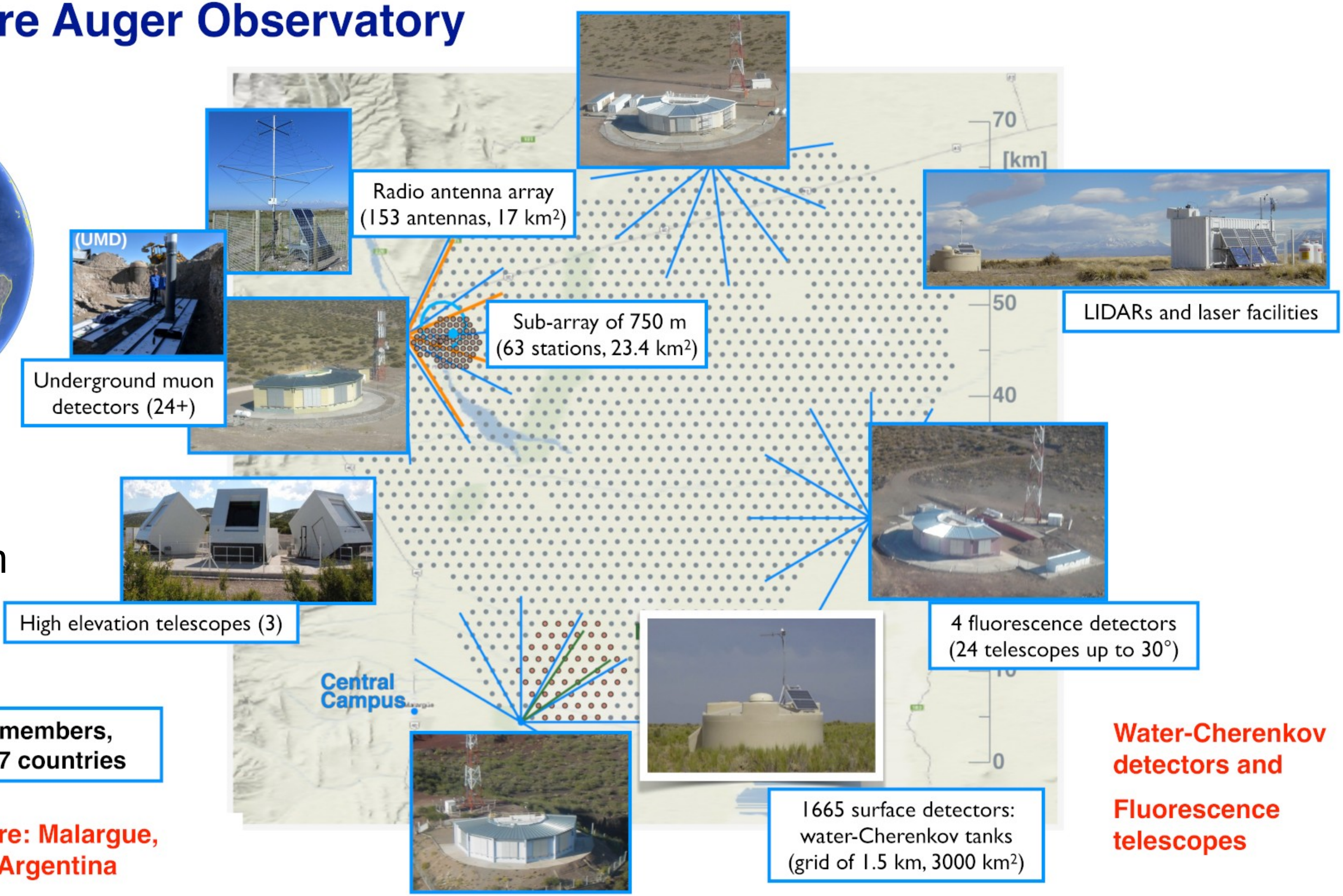


- TA4 motivation
  - greatly increase the data sample at the highest energies in order to identify UHECR sources
- SDs
  - 500 new SDs at 2.08 km spacing
  - 257 deployed thus far and operational since 2019
- FDs
  - 12 telescopes deployed and operational
  - 4 North and 8 South

From 10^{15} eV to more than 10^{20} eV within one observatory



The Pierre Auger Observatory



Configuration until 31.12.2022

More than 400 members,
98 institutes, 17 countries

Southern hemisphere: Malargue, Province Mendoza, Argentina

Water-Cherenkov detectors and

Fluorescence telescopes

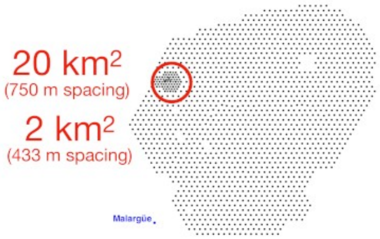
AugerPrime | Motivation & instrument

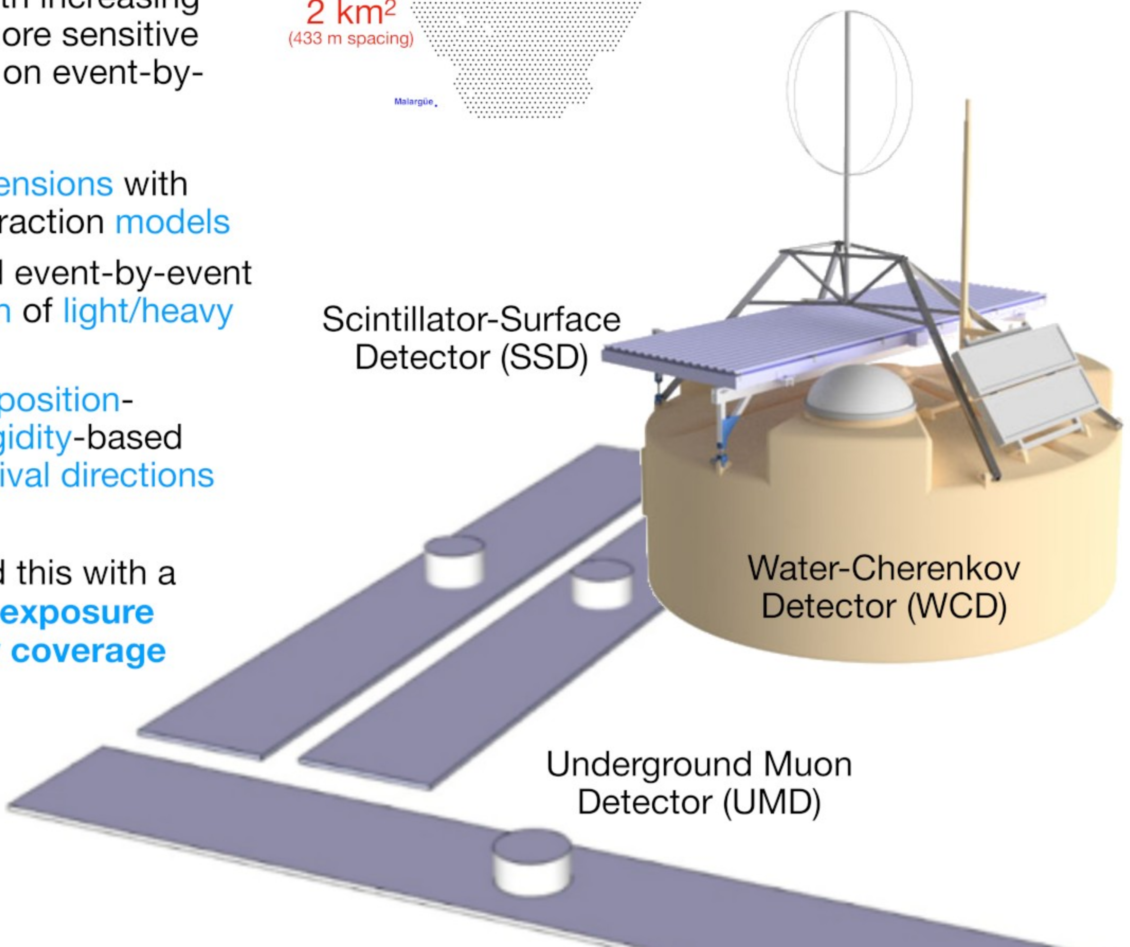
Motivation

Given new paradigm of heavier composition with increasing energy, need more sensitive measurements on event-by-event basis to:

- understand tensions with hadronic interaction models
- achieve good event-by-event discrimination of light/heavy particles
- perform composition-enhanced, rigidity-based studies of arrival directions

and we need this with a **very large exposure** and **full sky coverage**





D. Schmidt, ICRC 2025

Энергетический спектр

Greisen-Zatsepin-Kuzmin cutoff

1966

END TO THE COSMIC-RAY SPECTRUM?

Kenneth Greisen

Cornell University, Ithaca, New York

(Received 1 April 1966)

The primary cosmic-ray spectrum has been measured up to an energy of 10^{20} eV,[1] and several groups have described projects under development or in mind[2] to investigate the spectrum further, into the energy range 10^{21}-10^{22} eV. This note predicts that above 10^{20} eV the primary spectrum will steepen abruptly, and the experiments in preparation will at last observe it to have a cosmologically meaningful termination.

О ВЕРХНЕЙ ГРАНИЦЕ СПЕКТРА КОСМИЧЕСКИХ ЛУЧЕЙ

Г.Т.Зацепин, В.А.Кузьмин

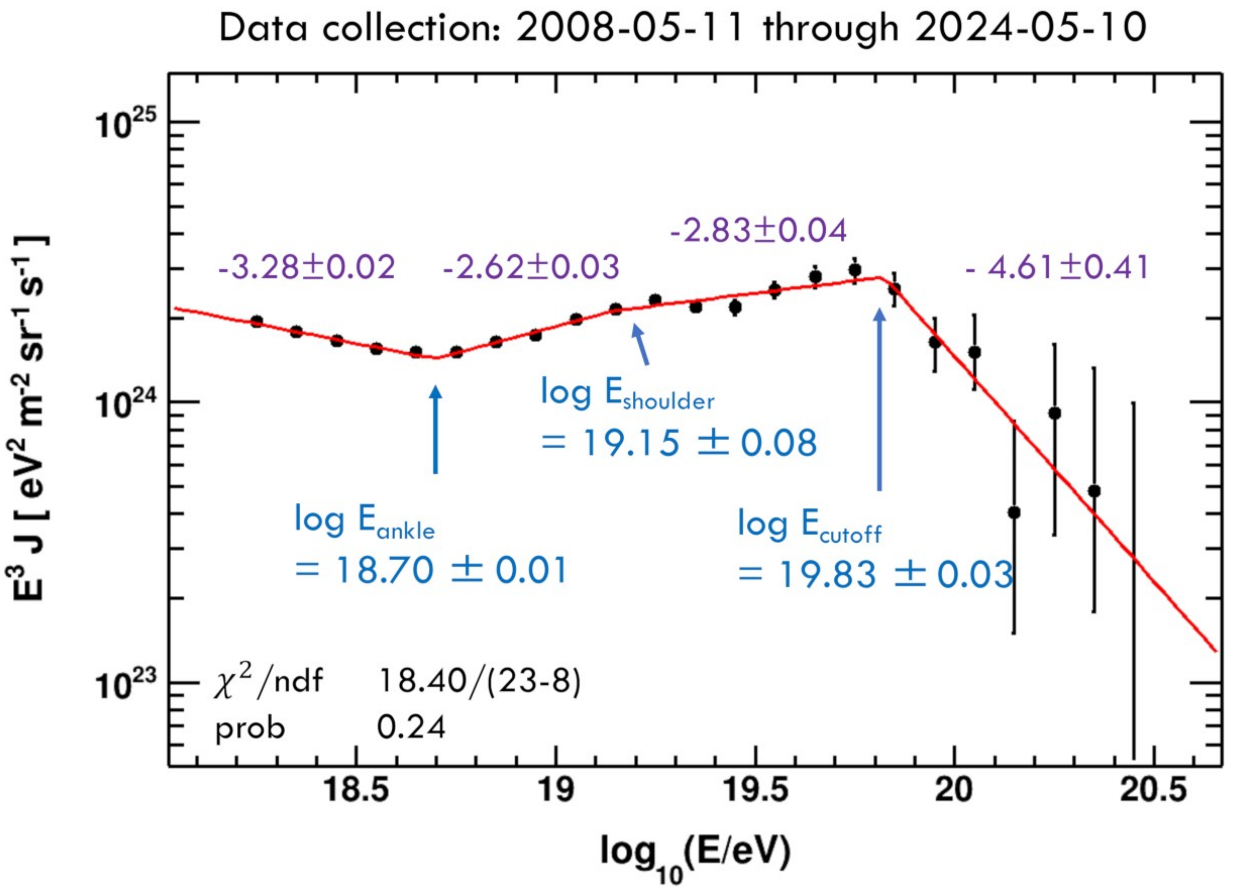
В недавних измерениях [I,2] обнаружено мощное изотропное тепловое излучение Вселенной, обладающее, по-видимому, распределением Планка с температурой $T \approx 3^{0}$К. Интенсивность этого излучения такова ($N \approx 550$ фотонов/см^3, $kT \approx 2{,}5 \cdot 10^{-4}$ эв), что возникают специфические эффекты при прохождении через него космических лучей сверхвысоких энергий, в частности обрезание спектра космических лучей в области 10^{20} эв.

$$p + \gamma_{2.7K} \rightarrow \Delta^{+} \rightarrow n + \pi^{+}$$
$$\rightarrow p + \pi^{0}$$

$E \gtrsim 10^{19.7}$ eV

Heavy nuclei photodisintegrate at the same energies

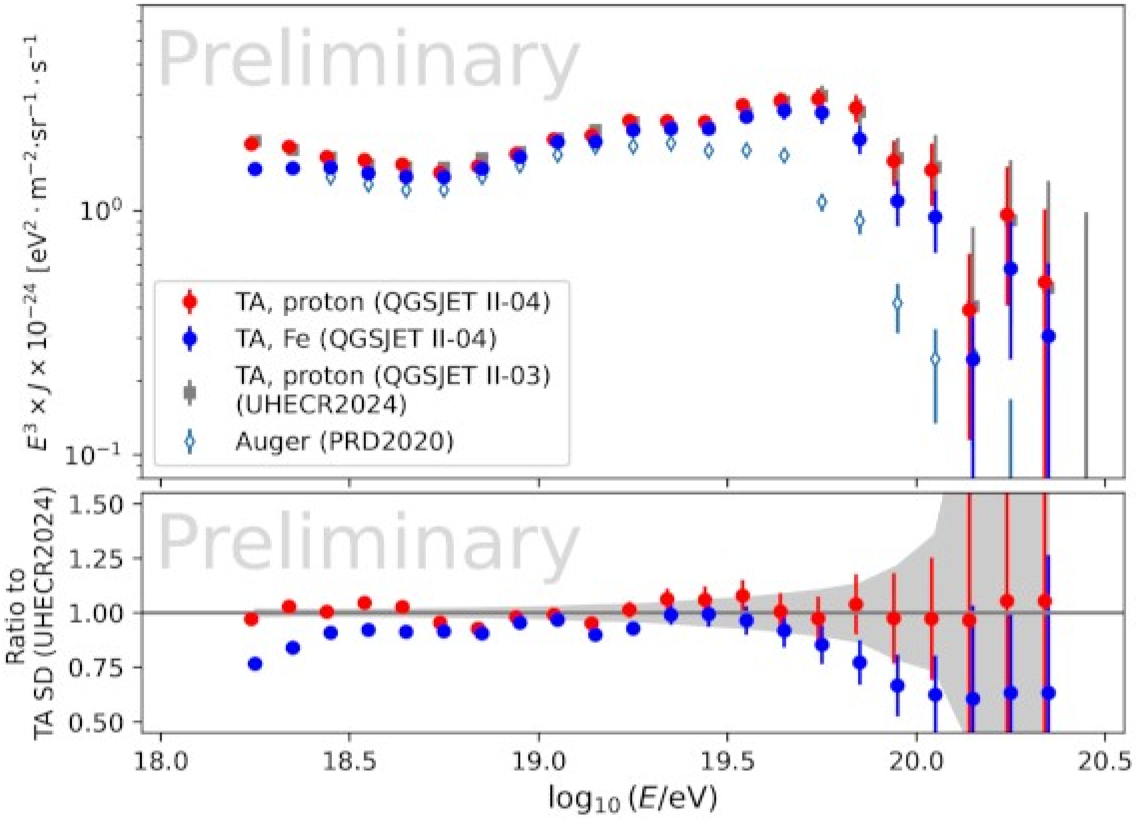
16-year TA SD Spectrum



- **Cutoff** feature at $10^{19.83}$ eV
  N_{exp}: 173.7
  N_{obs}: 97
  Chance probability: 1.6×10^{-10}, $\sim6.3\sigma$
- **Shoulder** feature at $10^{19.15}$ eV
  N_{exp}: 2156.4
  N_{obs}: 1921
  Chance probability: 1.3×10^{-7}, $\sim5.2\sigma$
- We observe the softening feature in the northern hemisphere at $10^{19.15\pm0.08}$ eV with a 5.2σ significance, while Auger sees it at $10^{19.15\pm0.03}$ eV (with +9% energy rescaling).
- TA and Auger agree well.

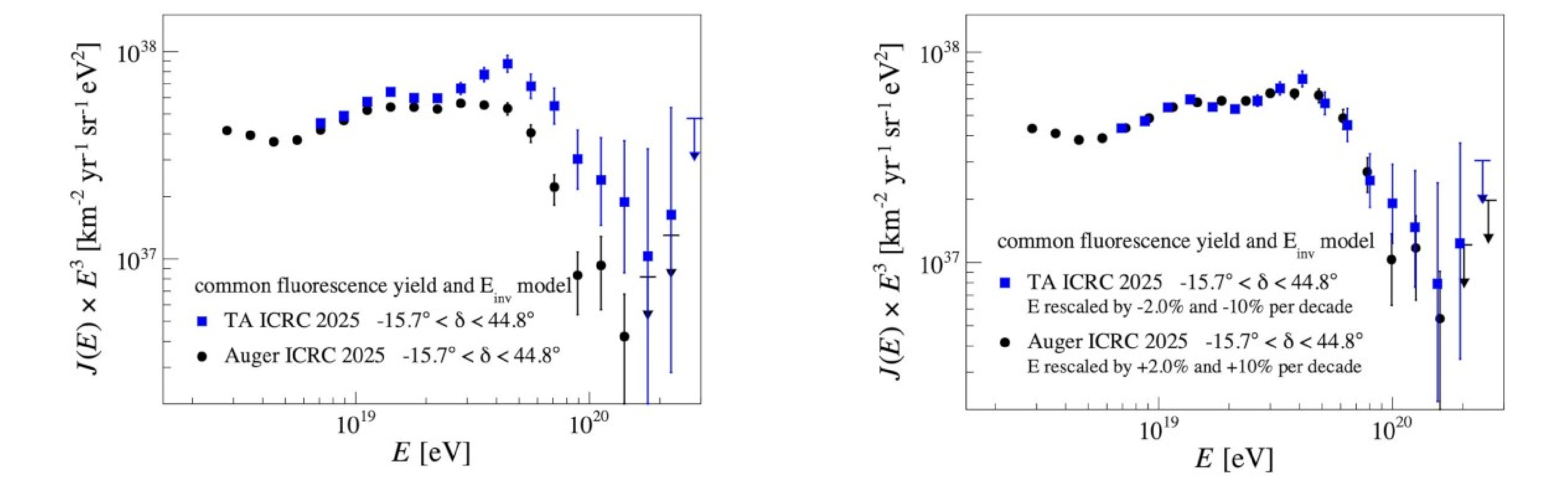
TA SD spectrum: Composition dependence

K. Fujisue, PoS(ICRC2025)259



- Demonstrated the systematic impacts from the primary mass assumption and the hadronic interaction model on the measured cosmic-ray energy spectrum.
- Energy-dependent bias was studied with extreme case of pure-iron MC simulations at entire energies.
- The discrepancy of the energy spectrum at higher energies was not explained in this study.

Auger and TA spectrum results

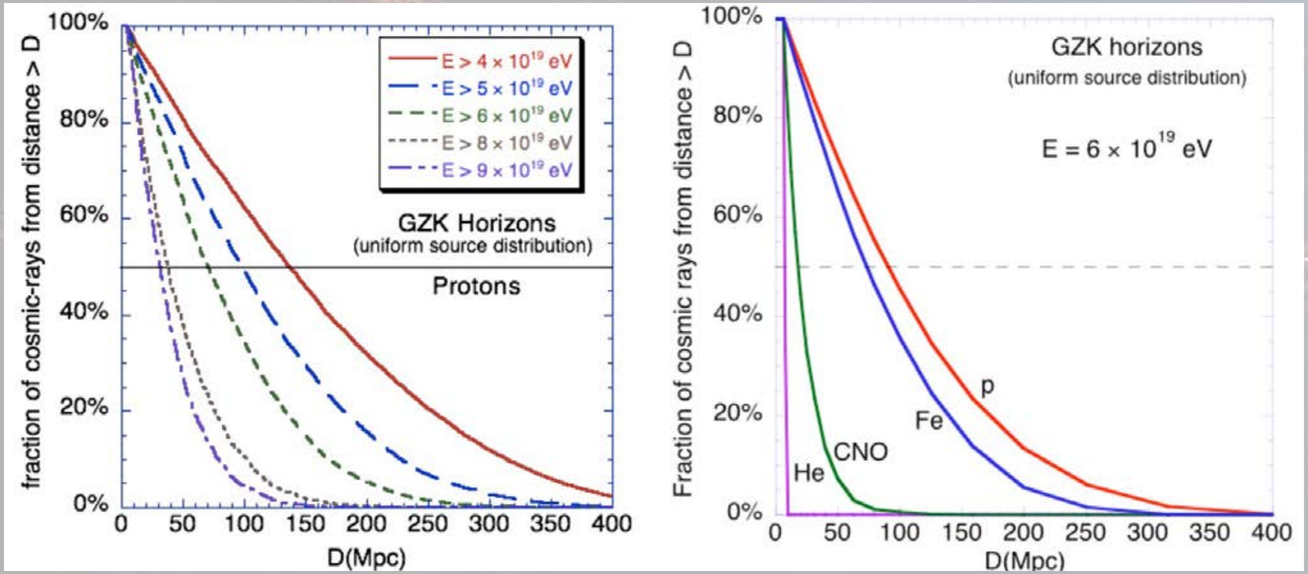


Auger and TA spectrum Working group
F. Salamida, ICRC'2025

Источники космических лучей

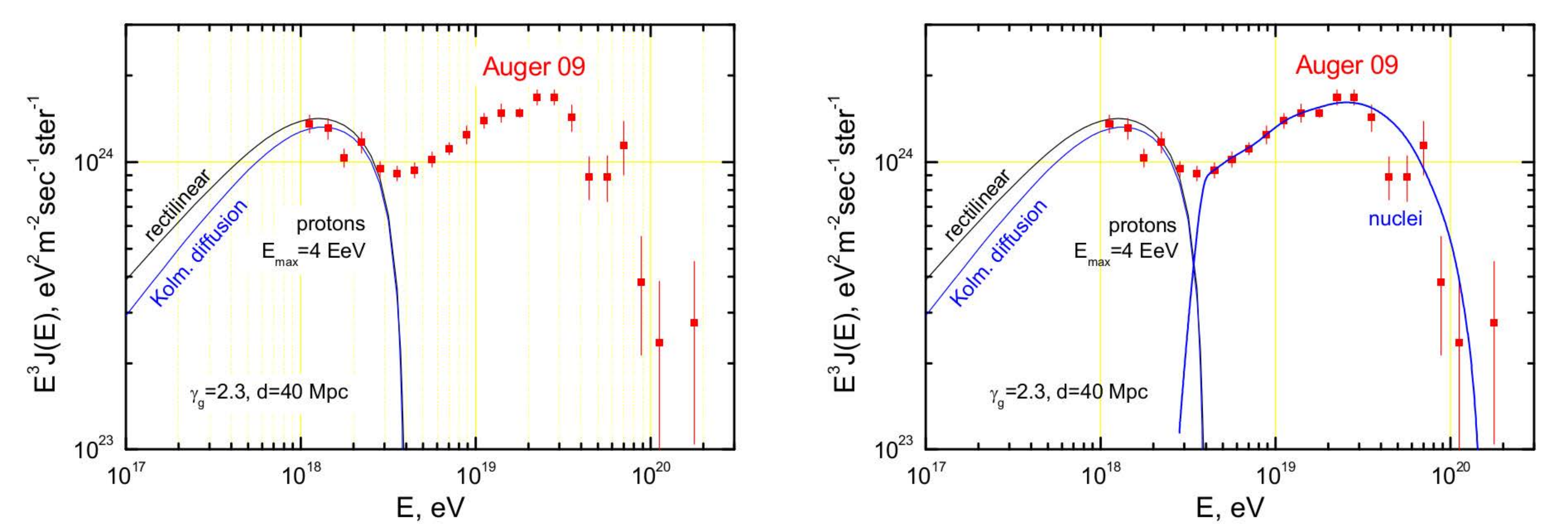
Is charged particle astronomy possible?

- Deflection of 60 EeV protons in the GMF is about 2°-6°
- Can we see the nearest source?
- Can we see GZK reaction? cosmogenic photons and neutrinos
  Berezinsky, Zatsepin, Phys. Lett B 28, 423 (1969)



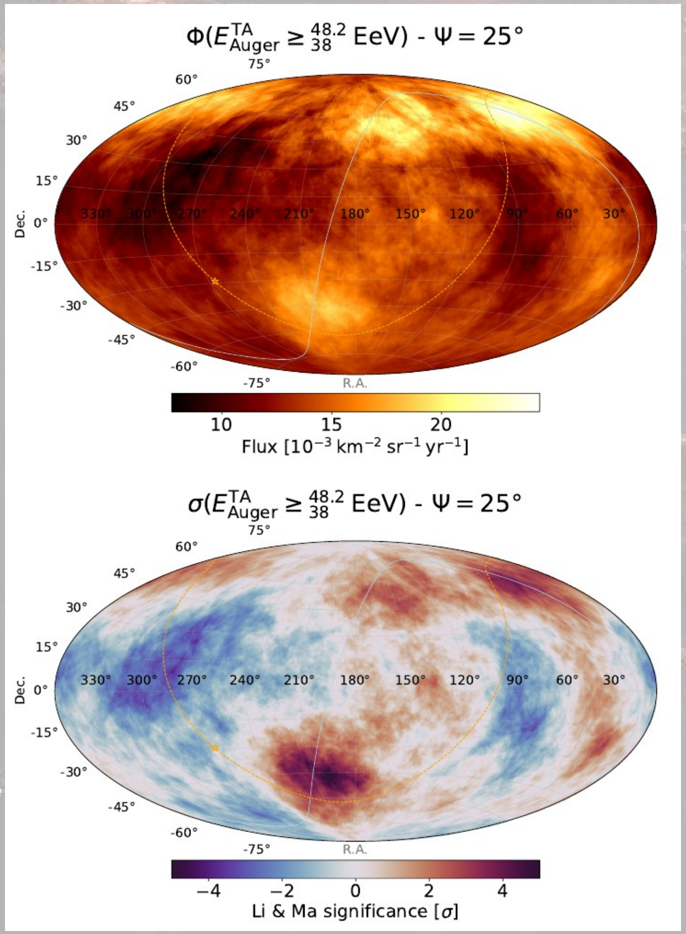
A. Olinto et. al., White paper on UHECR (2009)

Disappointing model?



- No cosmogenic photons, no cosmogenic neutrinos
- What we expect:
  - Dipolar and quadrupolar anisotropy
  - Astronomy with the highest energy particles

Observed UHECR sky

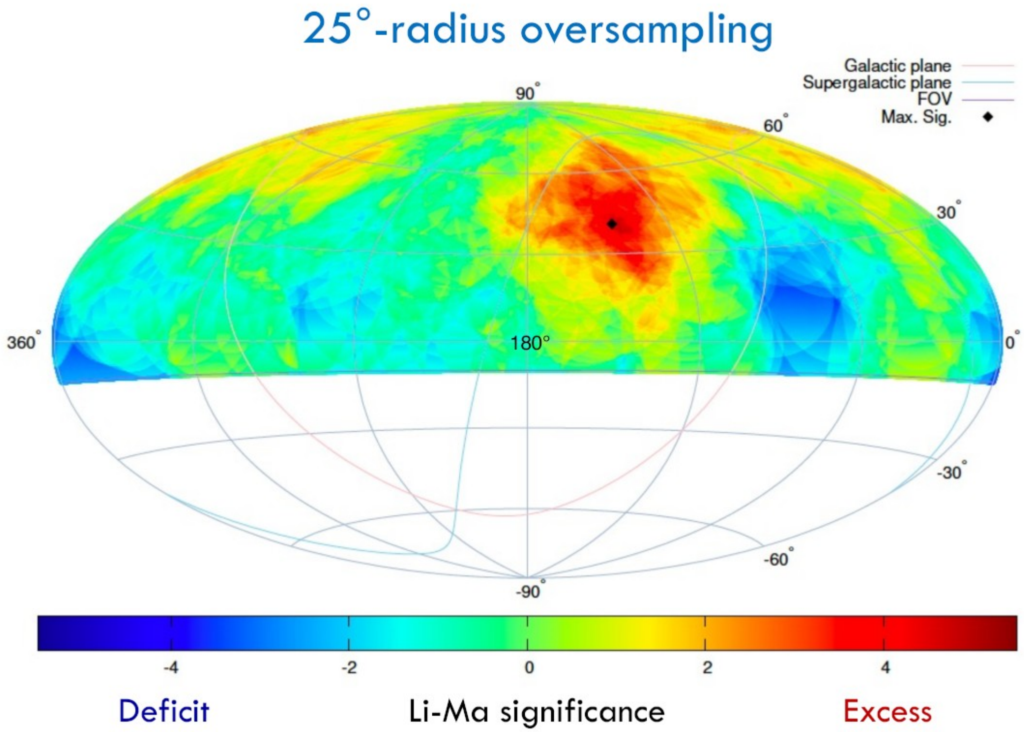


- Joint Auger + TA data
- Flux excess is observed in Centaurus A are at South and Ursa Major constellation and Perseus-Pisces Supercluster regions at North
- No individual sources are observed

L. Caccianiga, ICRC'2023

Telescope Array hot spot (5 yrs)

Li-Ma Significance Map with E ≥ 57 EeV



- 205 events (14-year TA SD data)
- Max local sig.: **5.1σ** at (144.0°, 40.5°)

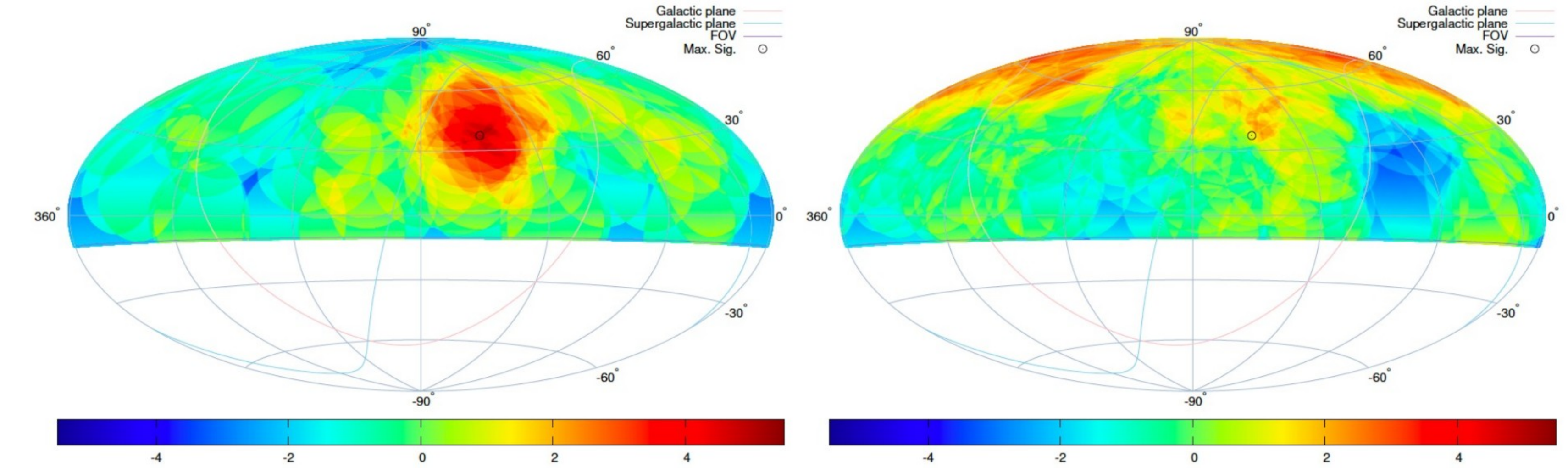
  Obs. : 44 events
  N_{bg} : 16.9 events
  ~160% excess

- Post-trial probability:

$$P(S_{MC} > 5.1\sigma) = 7.4\times10^{-4} \rightarrow \mathbf{3.2\sigma}$$

Telescope Array hot spot (14 yr)

Independent Dataset Analysis



- 72 events (First 5-year)
- **5.0σ** at (144.0°, 40.5°)

  Obs. : 22 events

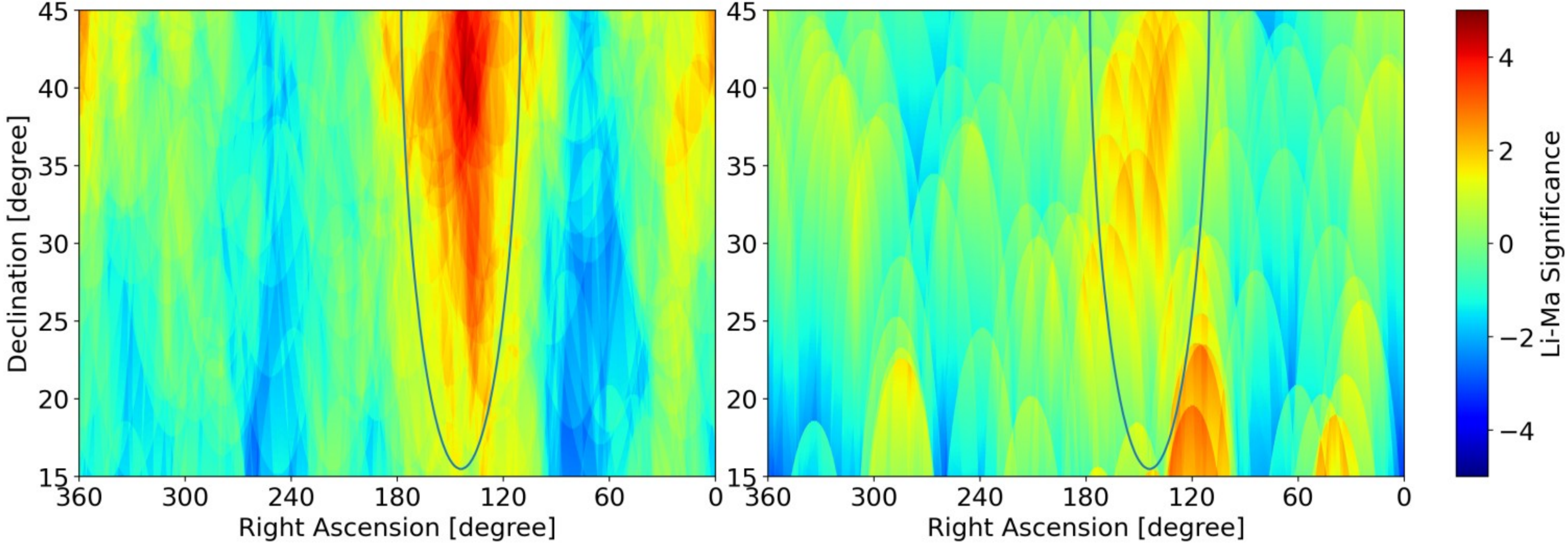
  N_{bg} : 5.2 events

- 133 events (Last 9-year)
- **2.5σ** at (144.0°, 40.5°)

  Obs. : 22 events

  N_{bg} : 11.6 events

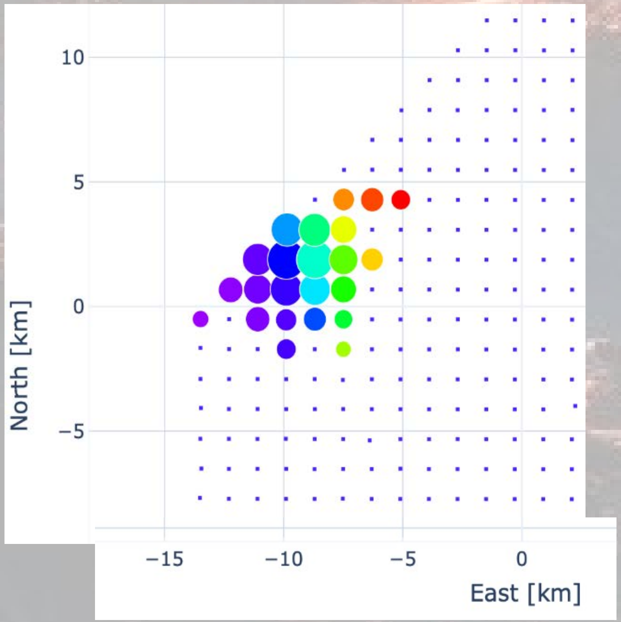
Can Auger see TA hotspot?

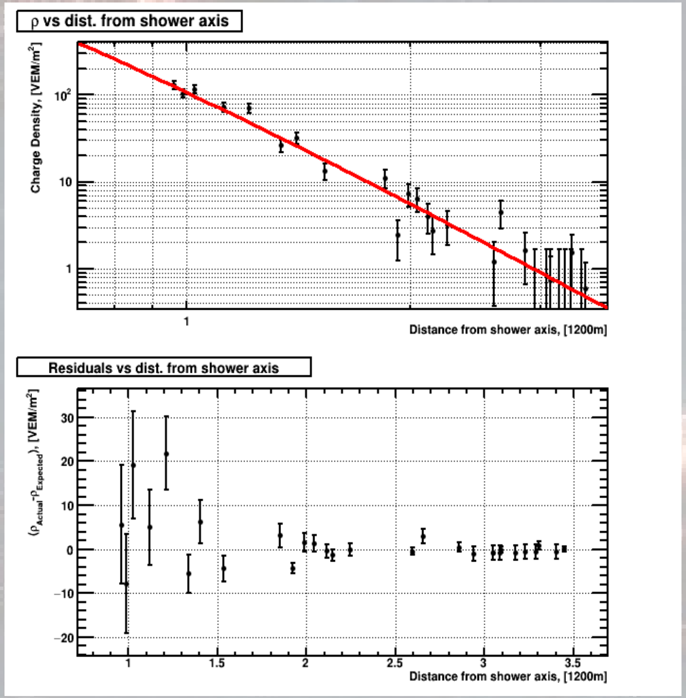


TA hotspot observed by TA

TA hotspot as expected to appear at Auger (highly inclined analysis)

An extreme Energy Event registered by TA SD



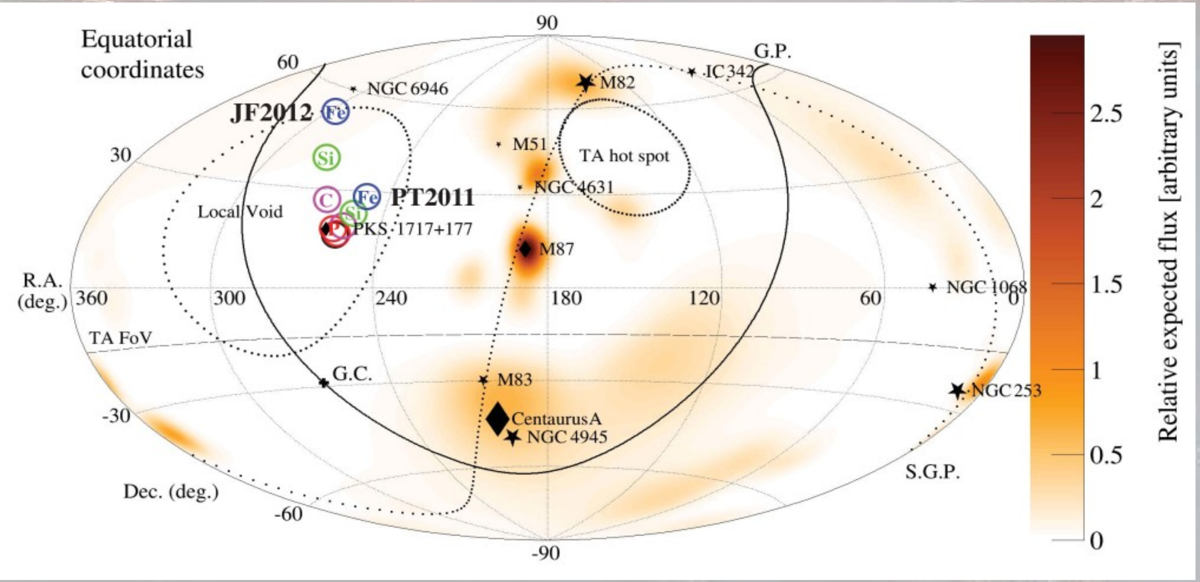


- Observed with TA SD at 10:35:56 on 27 May 2021 (UTC). No FD observation

Science 382, 903–907 (2023).

- E = **244 ± 29(stat.) ± 51(syst.) EeV**, zenith angle $\theta = 38.6°$

Observation of the event with extremely high energy

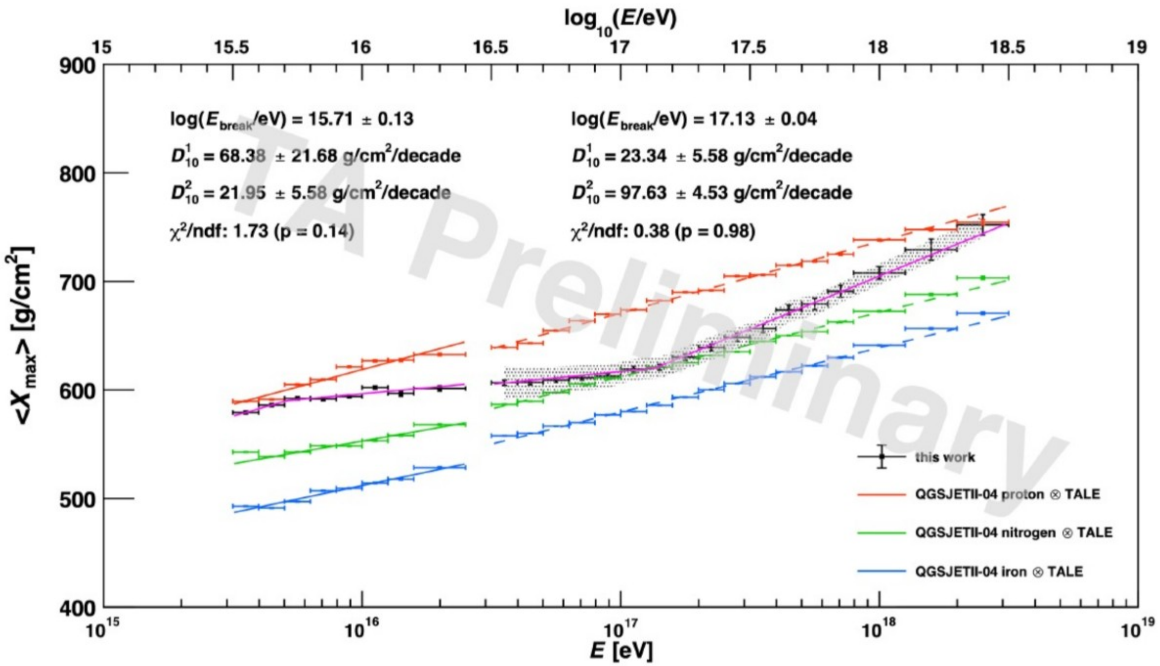


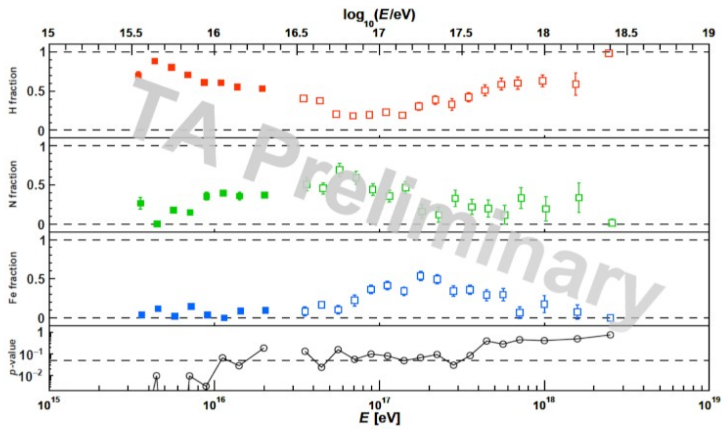
- E = 2.44x10^{20} эВ
- Event is coming from cosmic void
- Not a gamma-ray
- Primary particle should be a **heavy nuclei**
- The source is closer than 5 Mpc

Telescope Array Collaboration, Science 382, 903–907 (2023).
M. Kuznetsov, JCAP 04 (2024) 042

Состав космических лучей

TALE and TALE infill hybrid composition

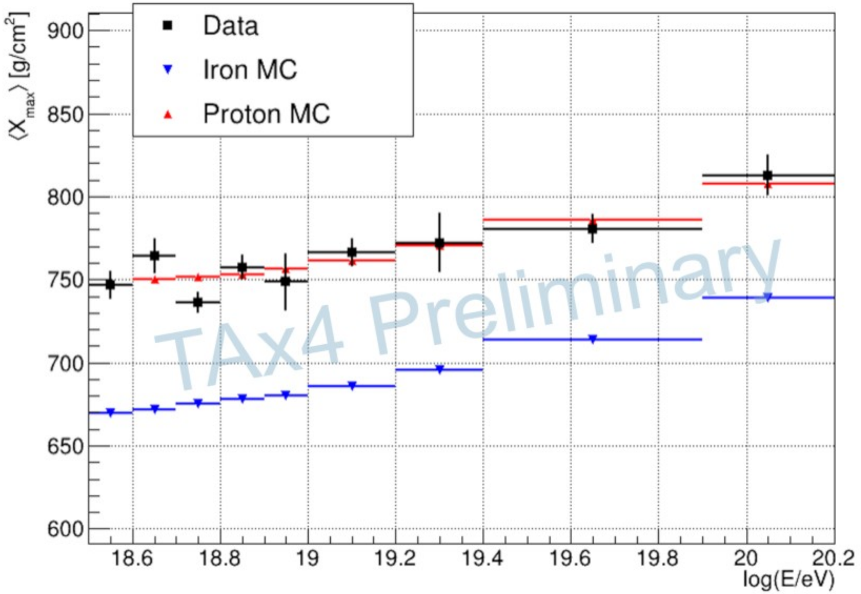


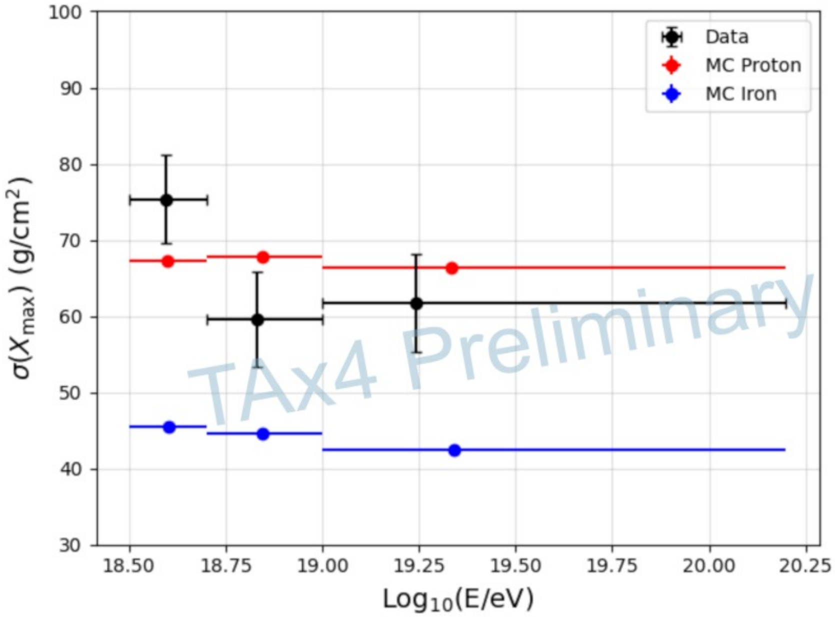


Telescope Array Collaboration, Phys.Rev.D 113 (2026) 6, 062003

- Breaks in the ⟨X_{max}⟩ coincide with the knee and second knee.
- X_{max} distribution fits show a transition from light to heavy composition, peaking near $10^{17.13}$ eV.
- Further studies with He nuclei, and interaction models EPOS-LHC-R and QGSJET-III are ongoing.

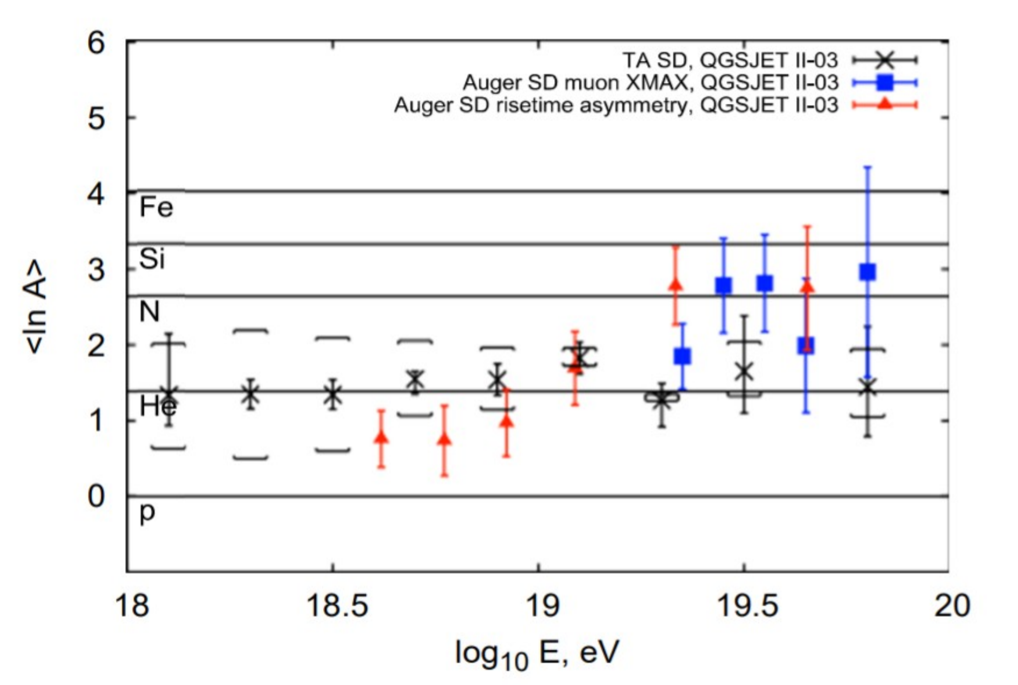
TAx4 hybrid XMAX

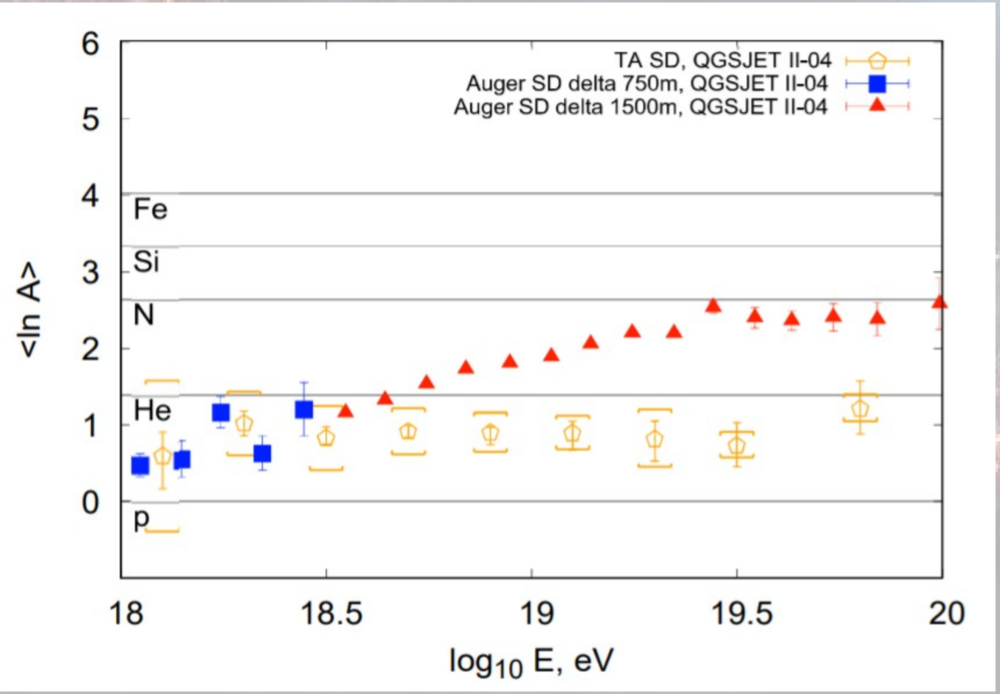




- Four years of TA×4 Hybrid data were compared to MC simulations of single-element primary distributions using the QGSIIJet-03 hadronic interaction model.
- The data are consistent with MC protons in both absolute scale and elongation rate.
- $\sigma(X_{max})$ is less model-dependent, but requires large statistics to measure reliably.

Primary composition

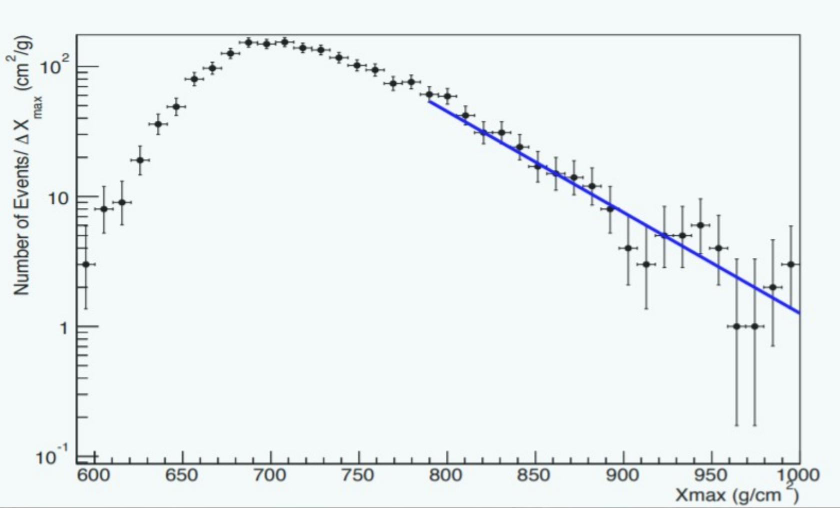




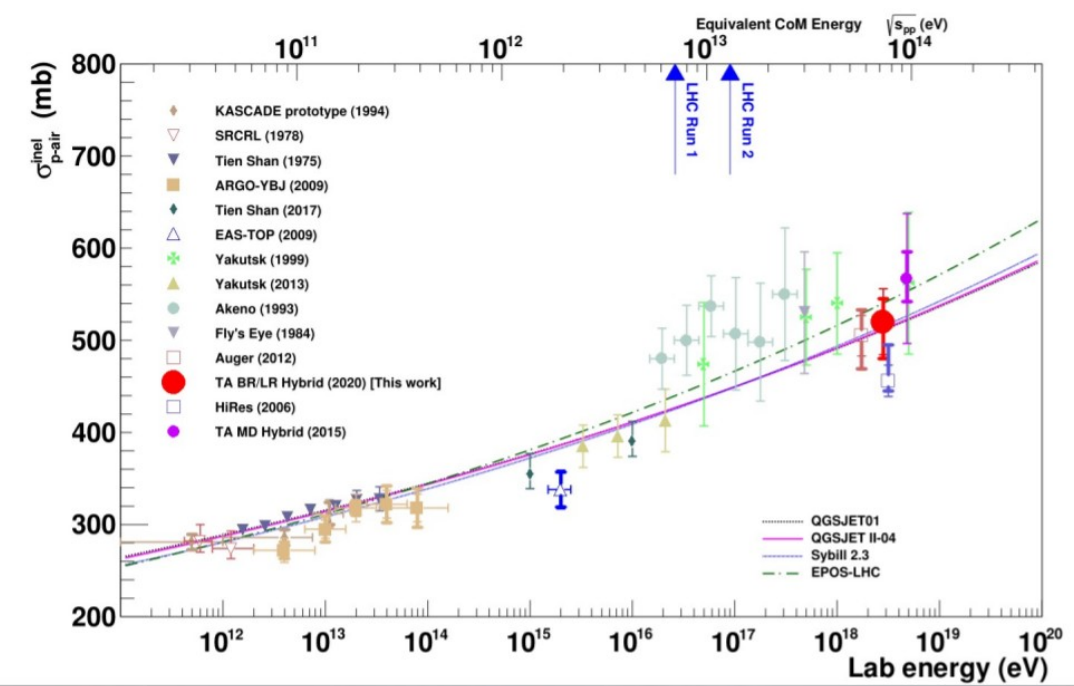
Machine learning technique based on Boosted decision trees

Phys.Rev.D 99 (2019) 2

TA proton-air cross-section



Measuring XMAX attenuation length in hybrid mode.



TA Collaboration, Phys. Rev. D 102 (2020) 062004

Recent Results from LHAASO on Cosmic Rays

Zhiyong You（游智勇） IHEP
On behalf of the LHAASO collaboration

39th All-Russian conference on cosmic rays, Dubna, Russia, June 2026

Large High Altitude Air Shower Observatory (LHAASO)

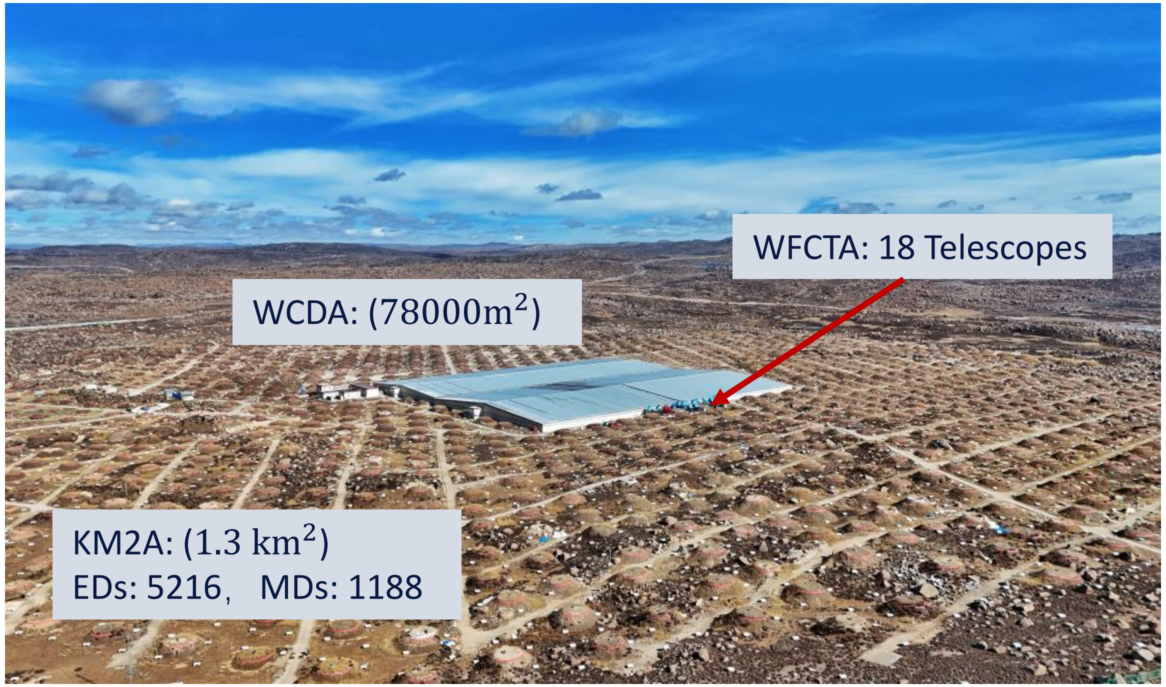
- **Location:** Mt. Haizi, Sichuan, China (N 29°21, E 100° 8’)
- **Altitude:** 4410 m a.s.l. ($600\ \mathrm{g/cm^2}$)
- **Construction period:** 2017-2021 (four years)
- **318 researchers from >30 institutes of 5 countries**

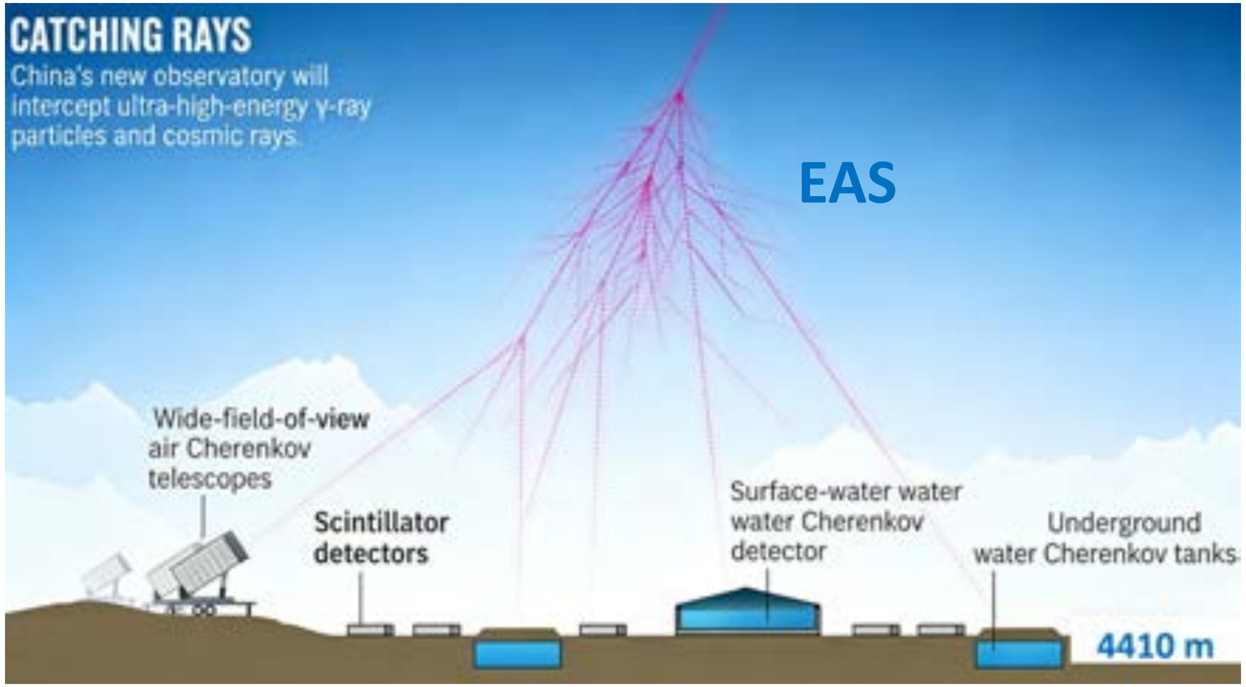
Before construction (2016-11)

Under construction (2018-10)

After construction (2025-8)

Large High Altitude Air Shower Observatory (LHAASO)

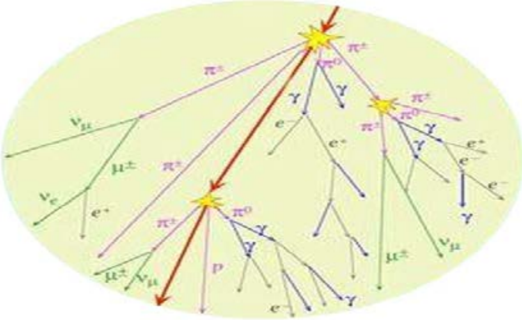




Hybrid Detection of EAS

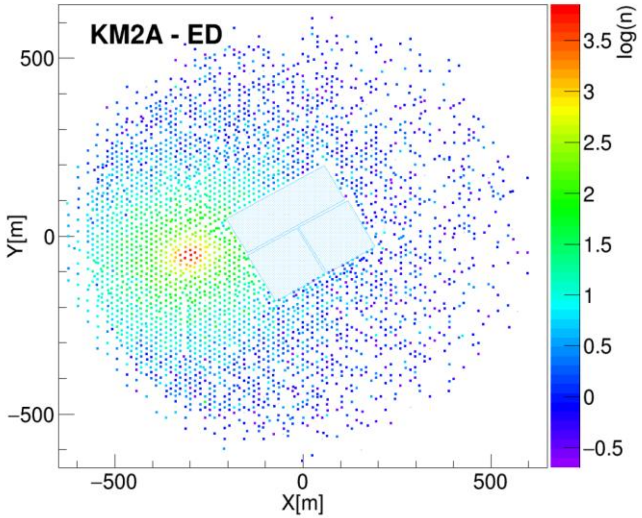
WFCTA
- **Cherenkov photons**

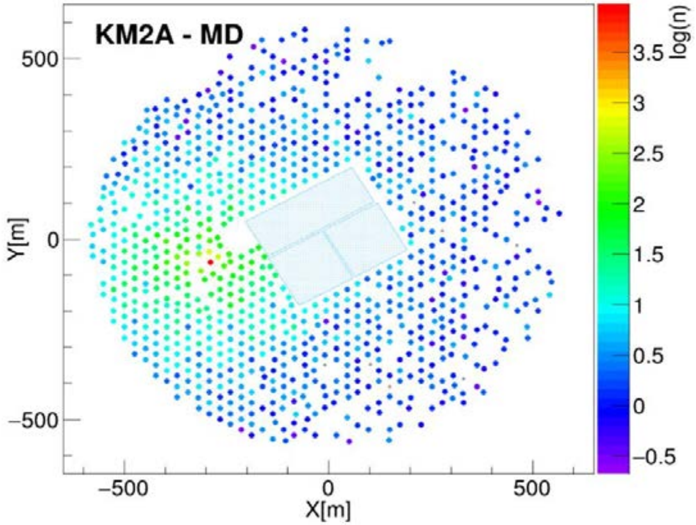
WCDA KM2A
- **Gamma rays, e^+, e^-**
- **Hadrons, muons**

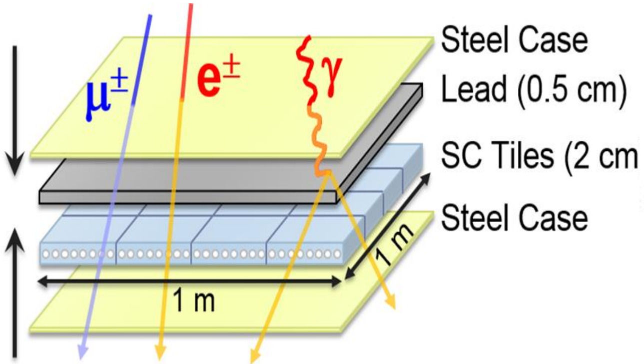


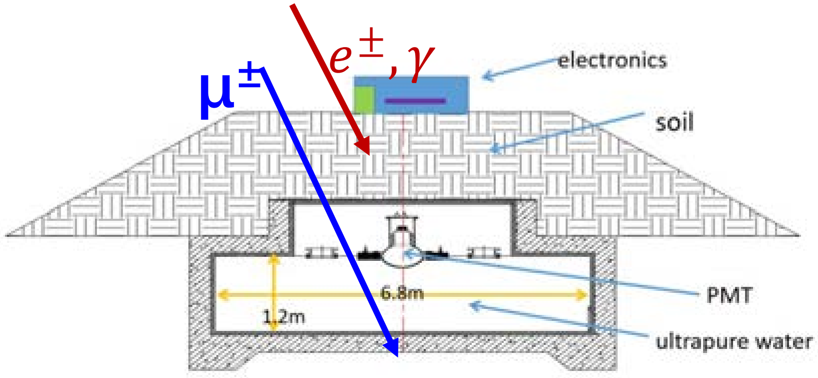
- **Longitudinal development** — **WFCTA**
- **Lateral distribution** — **WCDA**, **KM2A**

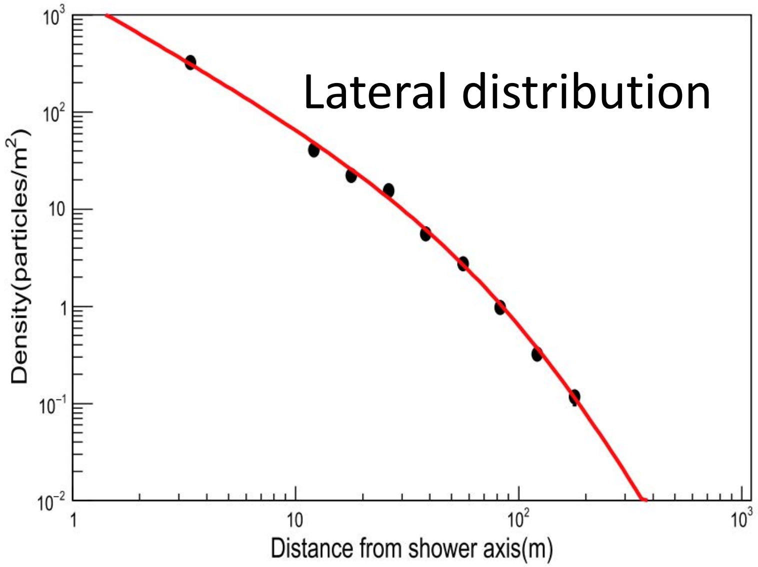
KM2A







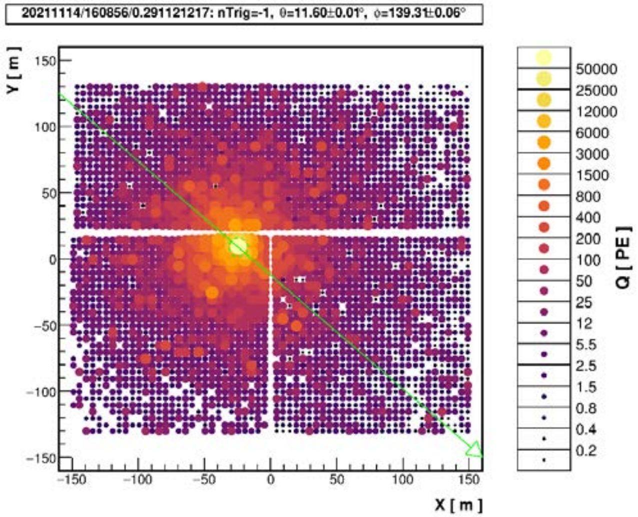


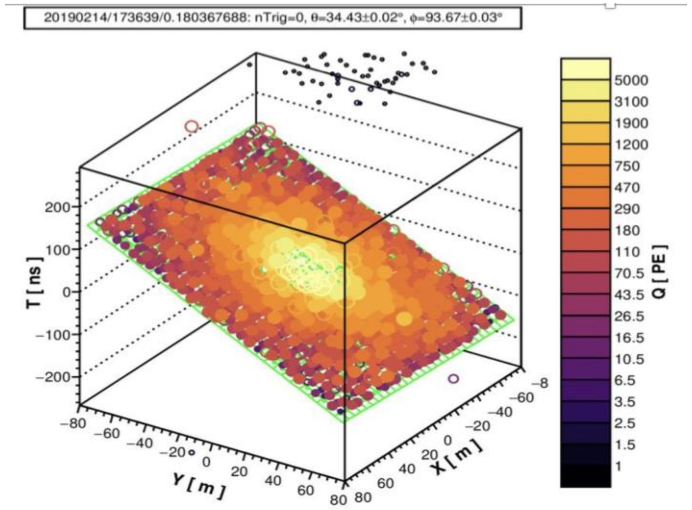


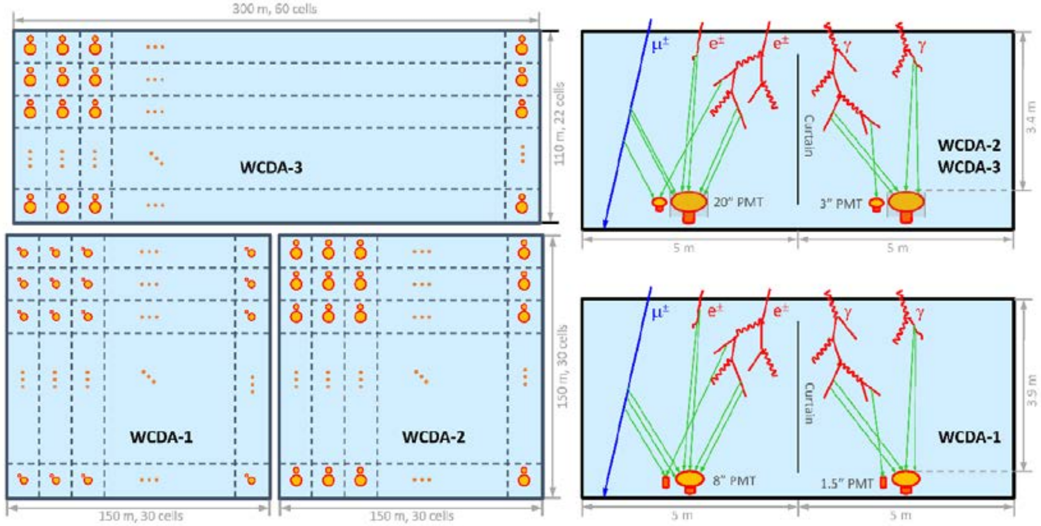
Electromagnetic Detector (5216 EDs):
Spacing: 15m; Area: 1 m^2 each

Muon Detector (1188 MDs):
Spacing: 30m; Area: 36 m^2 each

WCDA





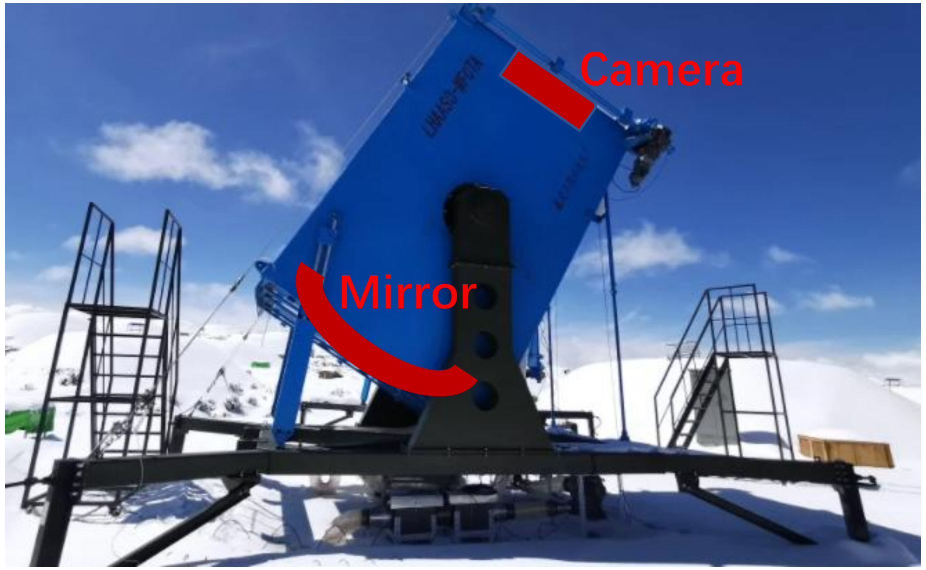


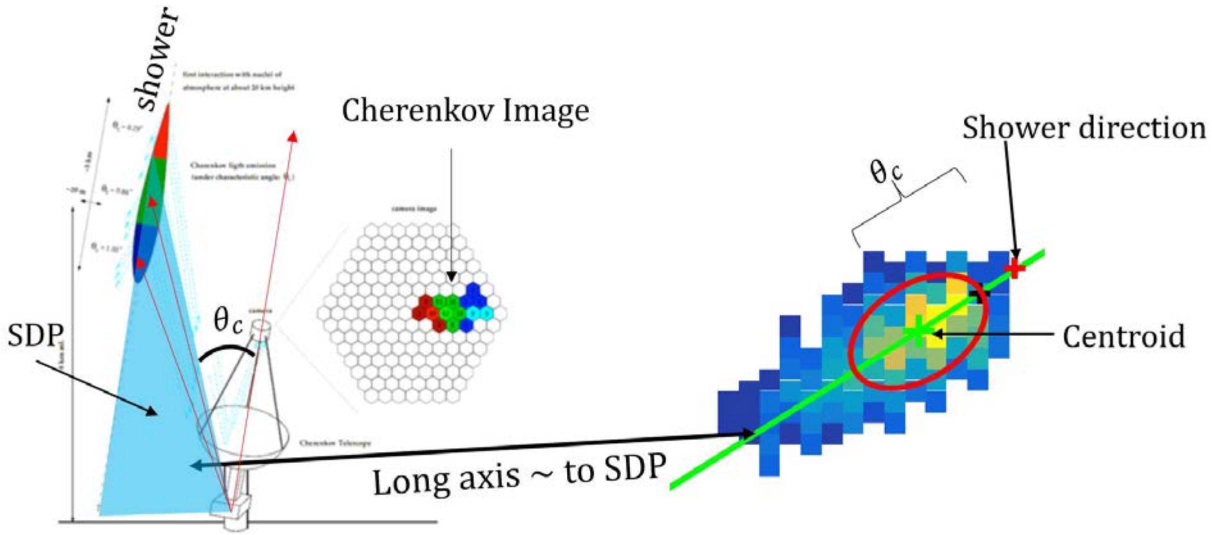
For cosmic rays at lower energy

- Total area: 78,000 m^2
- Detection unit: $5 \times 5\ \mathrm{m}$
- Threshold: hundreds GeV

Measure the arrival time, signal intensity, and spatial distribution of secondary particles

WFCTA



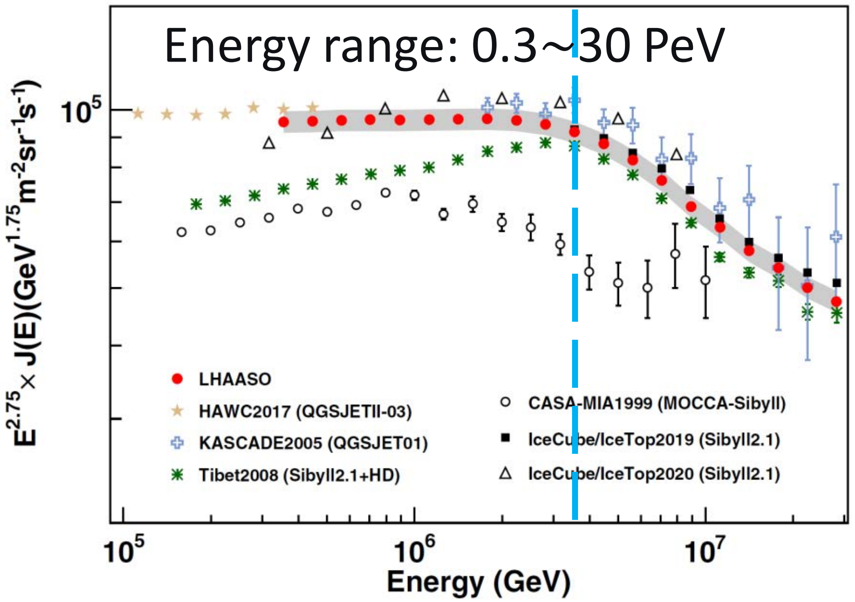


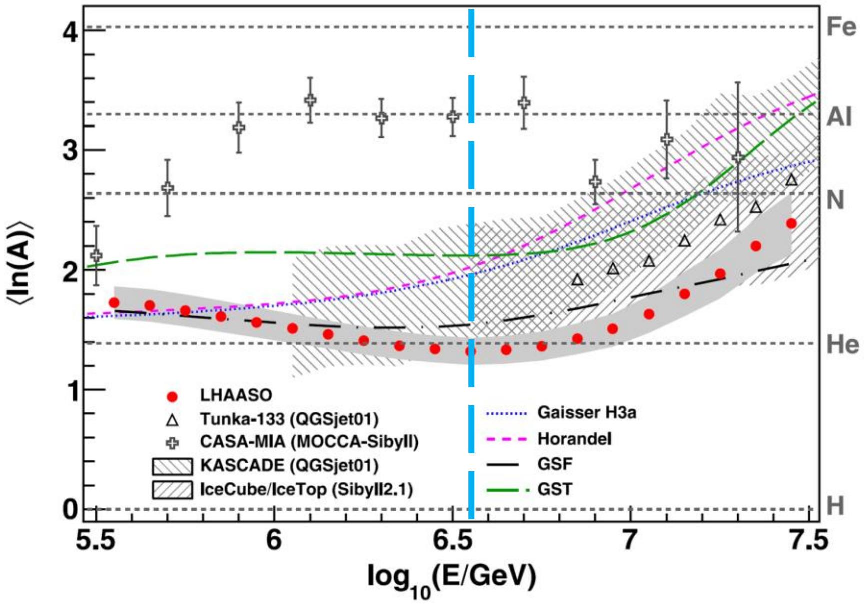
LHAASO-WFCTA measures the longitudinal development of the EAS

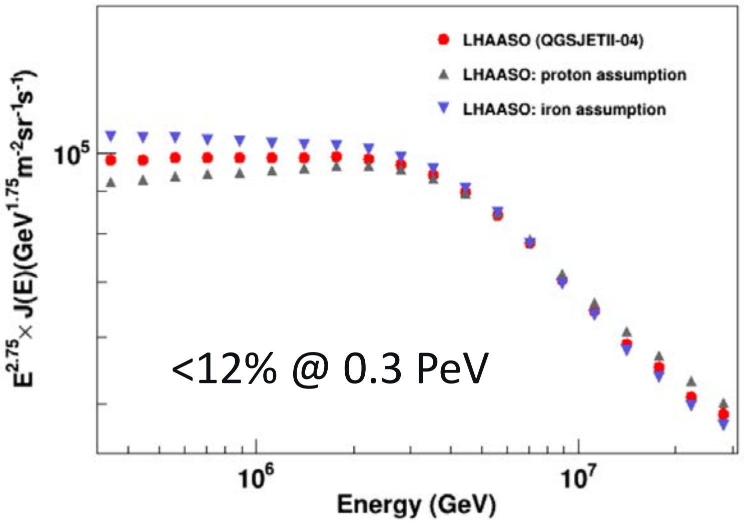
- **Cherenkov photons** are **collected by mirrors** onto the camera
- The **long axis of Cherenkov image** corresponds to **a plane** containing the shower axis and the telescope
- Along the long axis, **different SiPMs measure** Cherenkov photons originating from **different air depths**

Cosmic ray energy spectra measured by LHAASO

LHAASO results: all-particle spectrum







- **Small uncertainties:**
  - **Composition assumption**: **<12%** for pure proton/iron assumptions
  - **Interaction model**: **2.5%** (QGSJETII-04, EPOS-LHC and SIBYLL-2.3d)

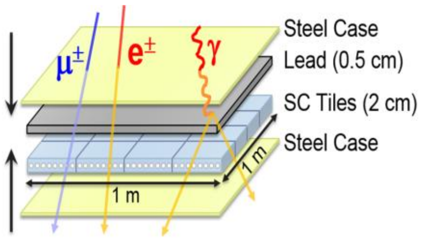
- **Precise results:**
  - **Knee position**: $\mathbf{3.67 \pm 0.05 \pm 0.15}$ **PeV**
  - **Composition:** shows a clear correlation between the flux and the composition in the knee region

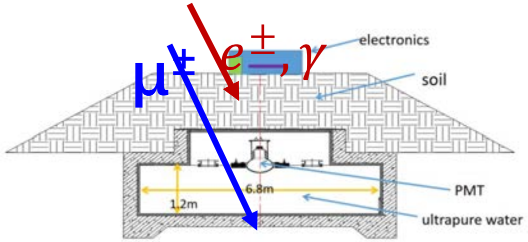
Composition-sensitive parameter

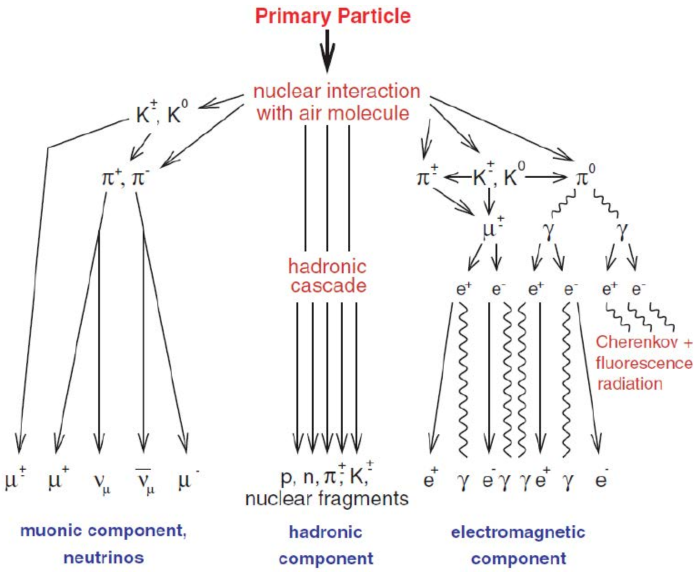
$$N_\mu \propto A^{1-\beta}\left(\frac{E_0}{1\ \mathrm{PeV}}\right)^{\beta}$$

$$N_e \propto A^{1-\alpha}\left(\frac{E_0}{1\ \mathrm{PeV}}\right)^{\alpha}$$

$$\log A = \frac{\alpha}{\alpha-\beta}\log\left(\frac{N_\mu}{N_e^{\beta/\alpha}}\right) - \frac{\alpha}{\alpha-\beta}\log\left(\frac{K_\mu}{K_e^{\beta/\alpha}}\right) = \frac{\alpha}{\alpha-\beta}\log\left(\frac{N_\mu}{N_e^{\beta/\alpha}}\right) + \mathrm{const}$$

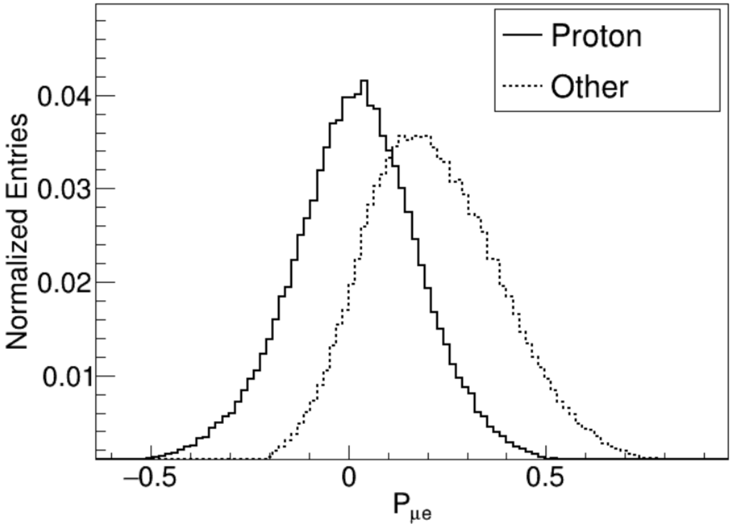






$$P_{\mu e} = \log_{10}\frac{N_\mu}{N_e^{0.82}}$$

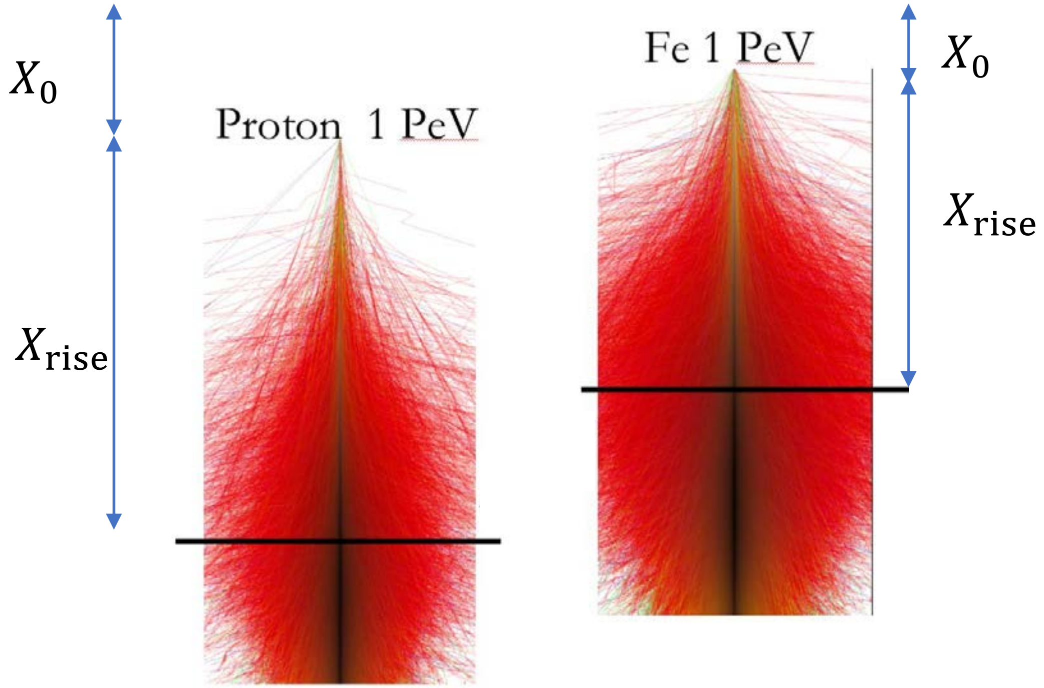
- N_μ: number of muons measured by MDs
- N_e: number of EM particles measured by EDs

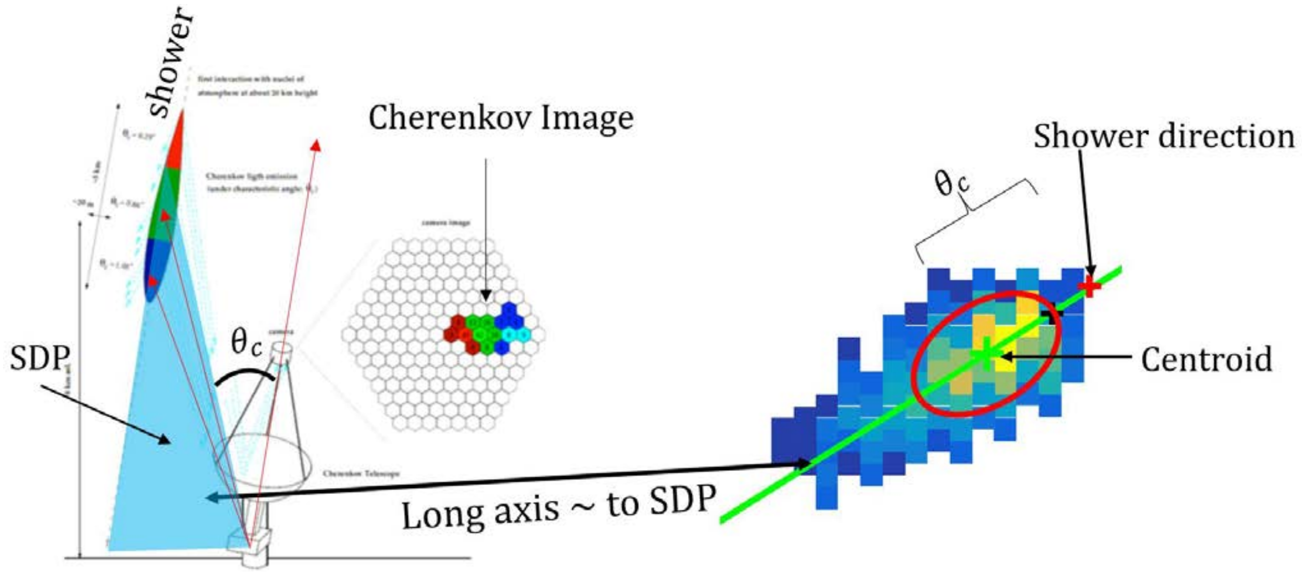


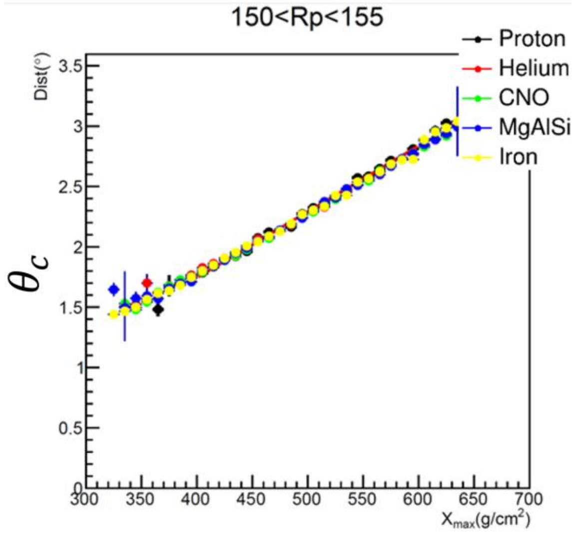
Composition-sensitive parameter

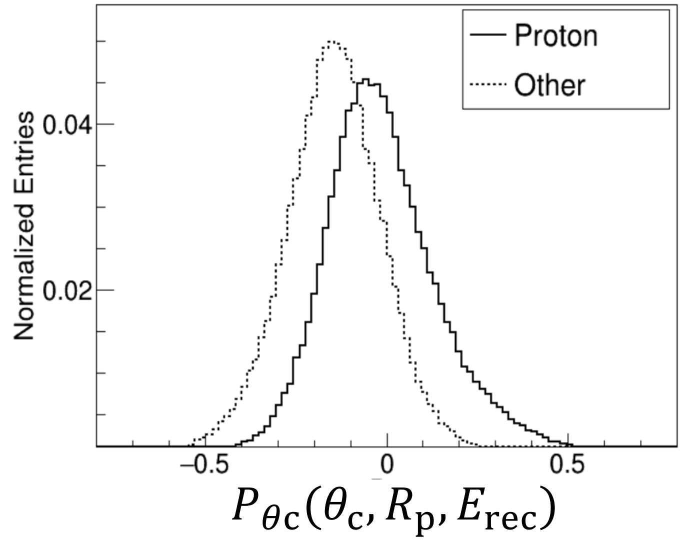
Longitudinal development: At the same energy, proton showers develop deeper

$$X_{\text{max}} = X_0 + X_{\text{rise}}$$

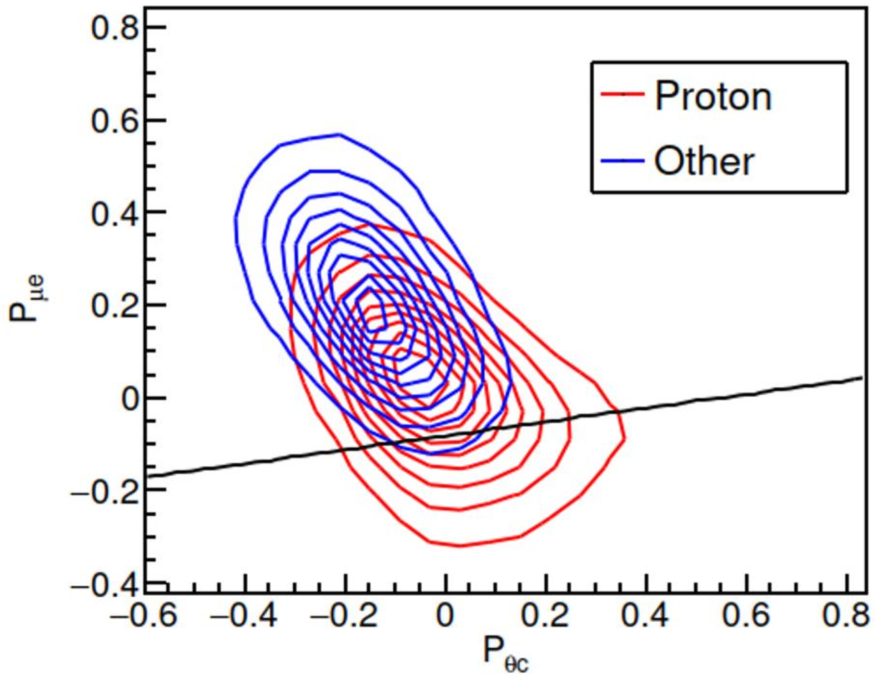


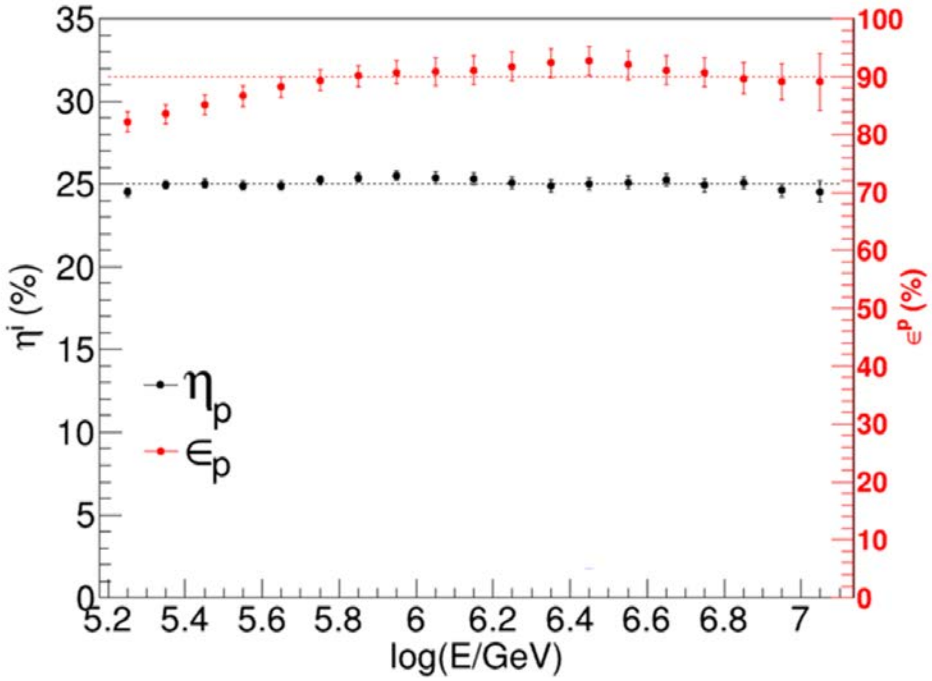






Proton selection



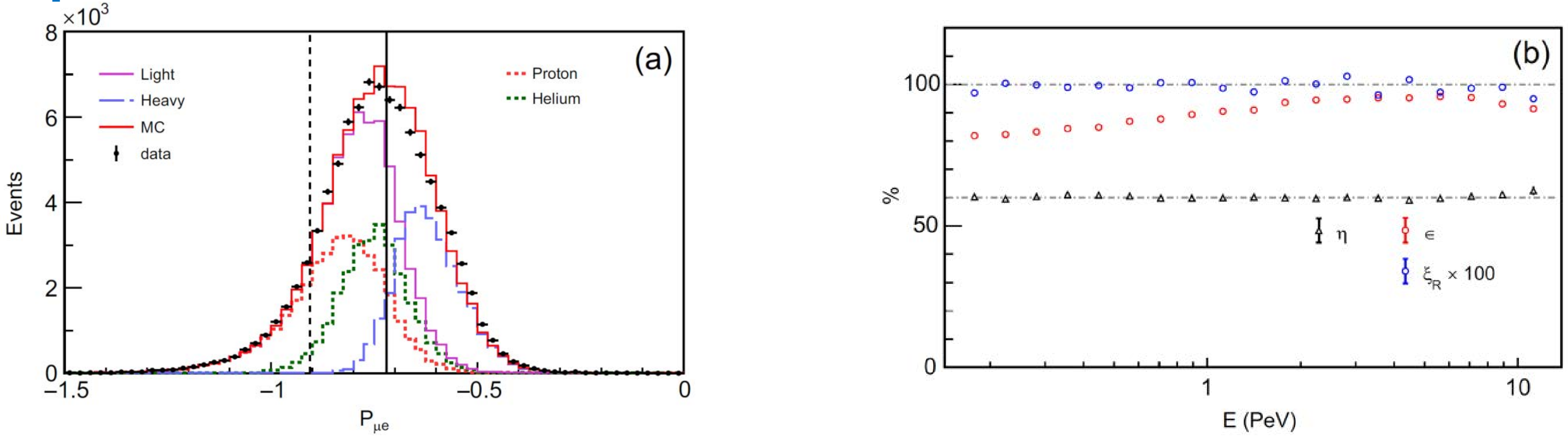


Combine $P_{\mu e}$ and $P_{\theta c}$ to select proton events:

- Selection efficiency: $\eta_P = \frac{N_S^P}{N_0^P} \sim$ **25%**
- Proton purity: $\epsilon_P = \frac{N_S^P}{N_S^{All}} \approx \frac{N_S^P}{N_S^P + N_S^{He}} \sim$ **90%**(>500TeV)

Main pollution: Helium events

Light component selection



Helium lies between protons and heavy events, difficult to select high-purity helium sample

Calculation of the helium spectrum:

$$F_{He} = F_L - F_P$$

F_L: spectrum of light component

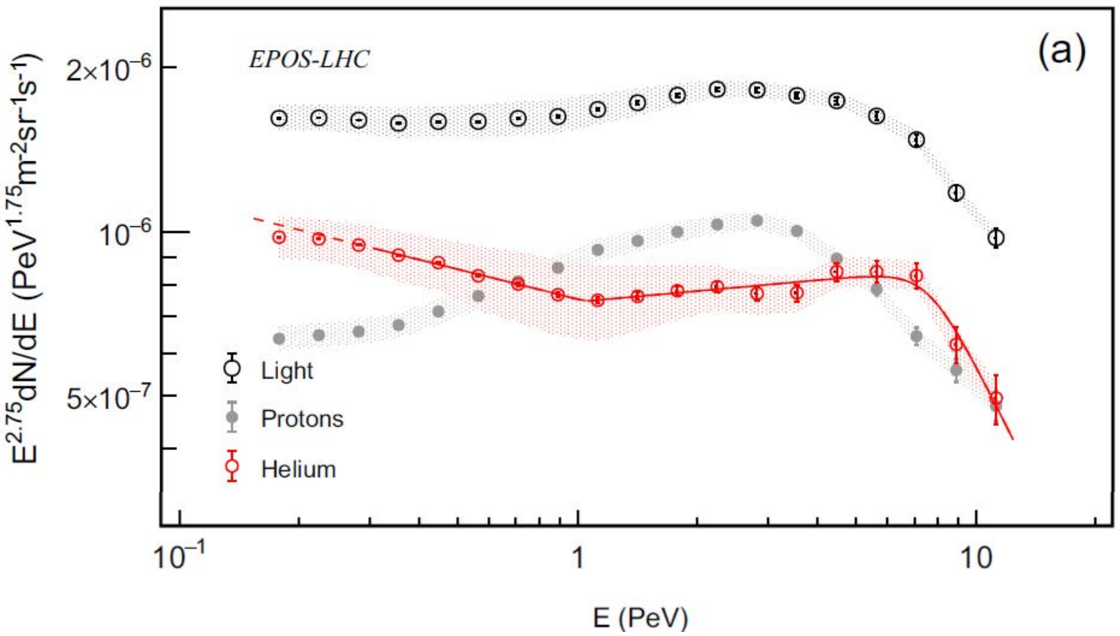
F_P: proton spectrum

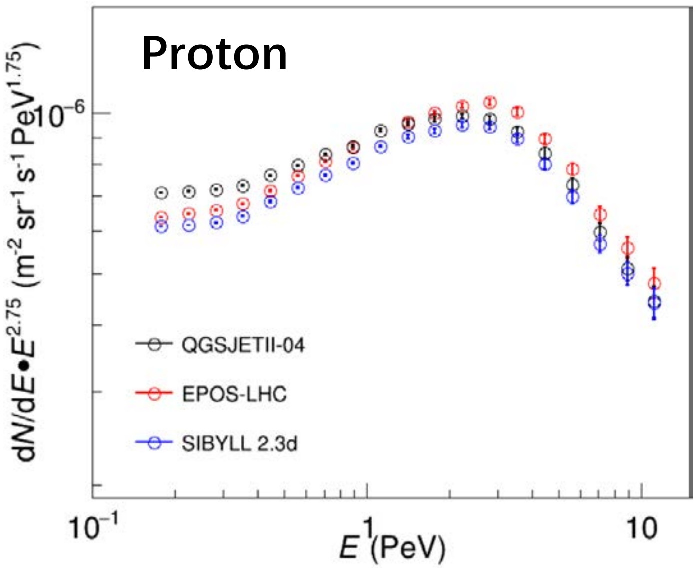
Based on the fact that the proton-to-helium ratio does not change before and after selection

High-purity light component sample:

- Selection efficiency： $\eta_L \sim$ **60%**
- Light component purity： $\epsilon_L >$**80%**
- After selection, the proton-to-helium ratio remains unchanged: $\xi_R \sim 1$

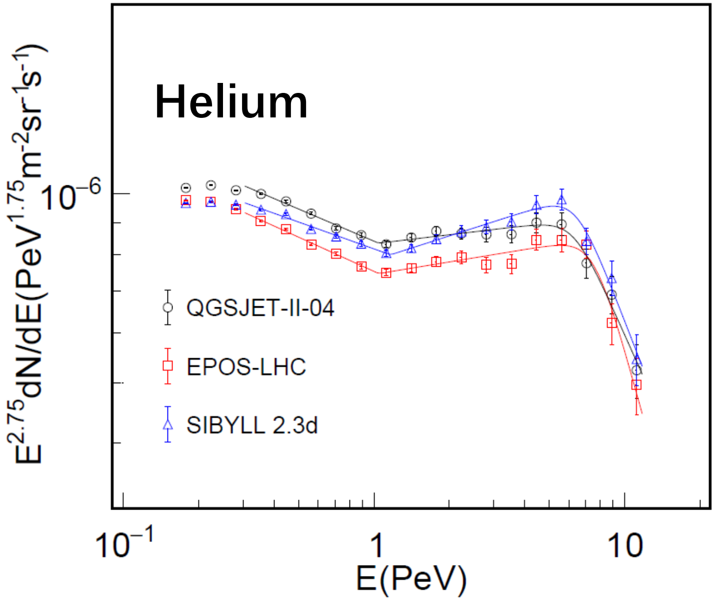
LHAASO results: Proton, Helium spectrum



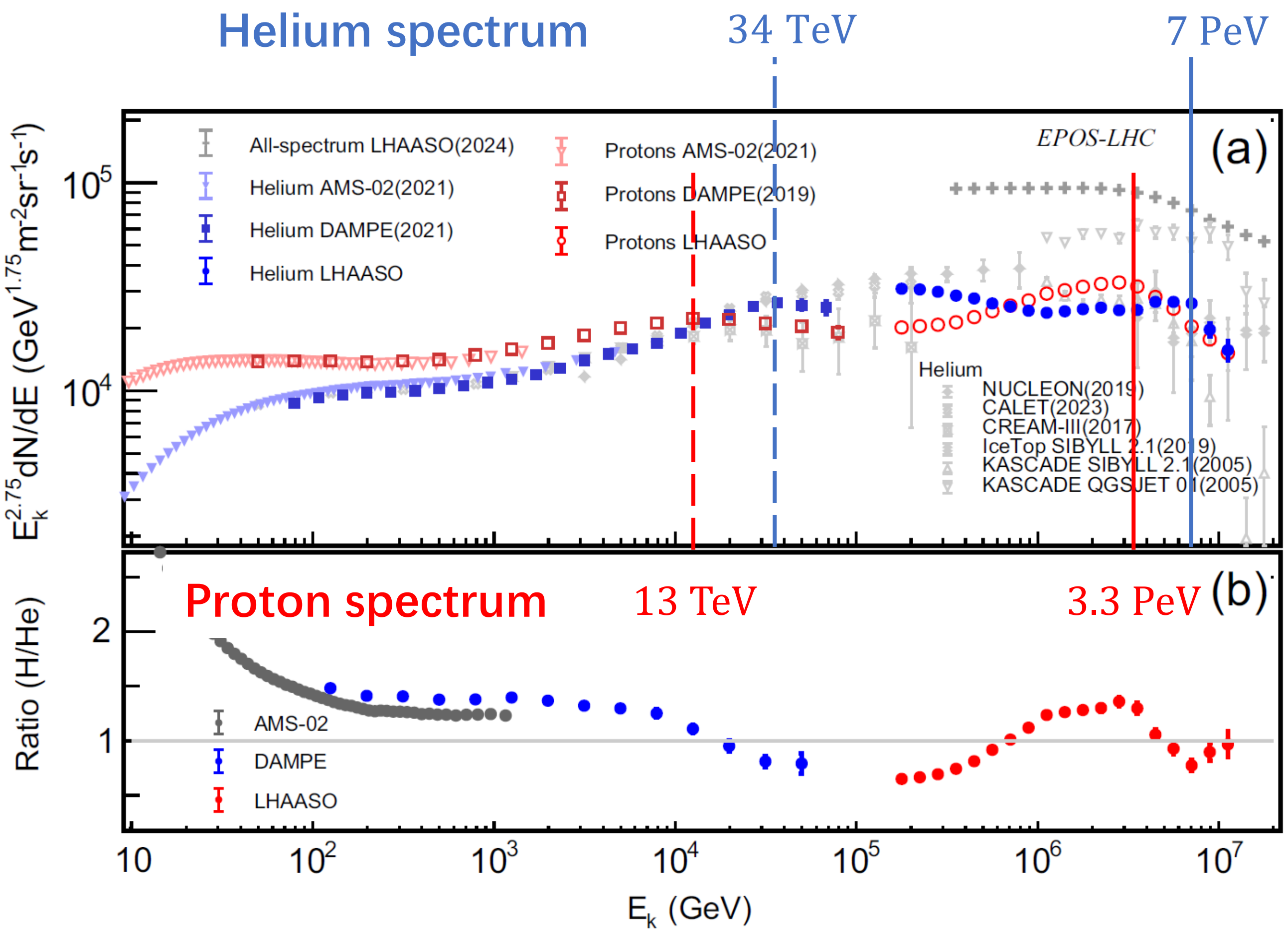


Systematic uncertainties

	Proton	Helium	Light
Calibration (pressure, humidity, bkg light)	2.5%	4.7%	3%
Composition models	2%@3PeV	5%@6PeV	2%@6PeV
Selection efficiency	2.5%	2%	1%
Hadronic interaction	12%@3PeV	15%@6PeV	3%@6PeV



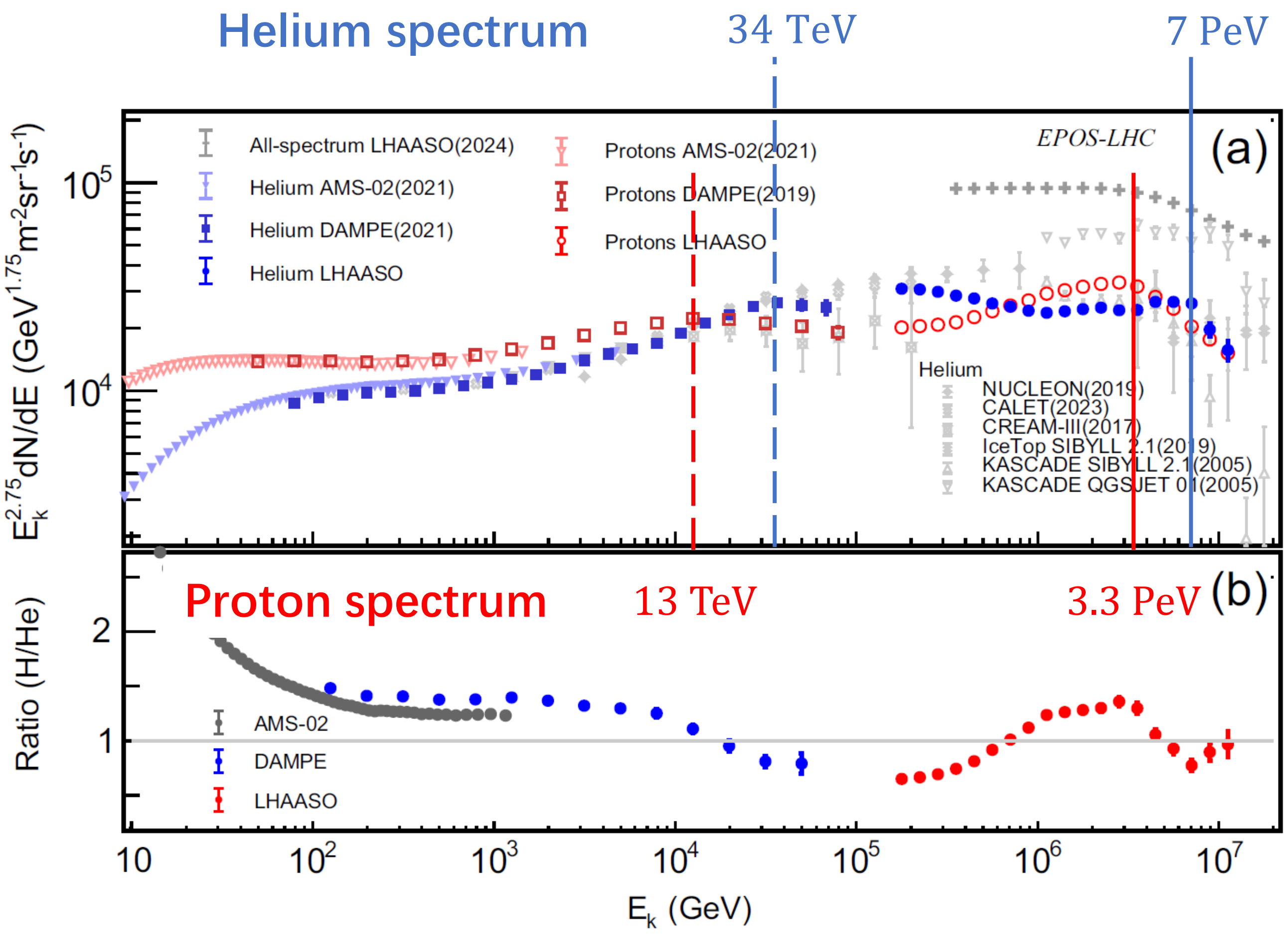
LHAASO results: Proton, Helium spectrum



Multiple components in energy spectra

- Spectral structure: **hardening-then-softening** structure both below and near the knee region (two bump structure)

LHAASO results: Proton, Helium spectrum



Multiple components in energy spectra

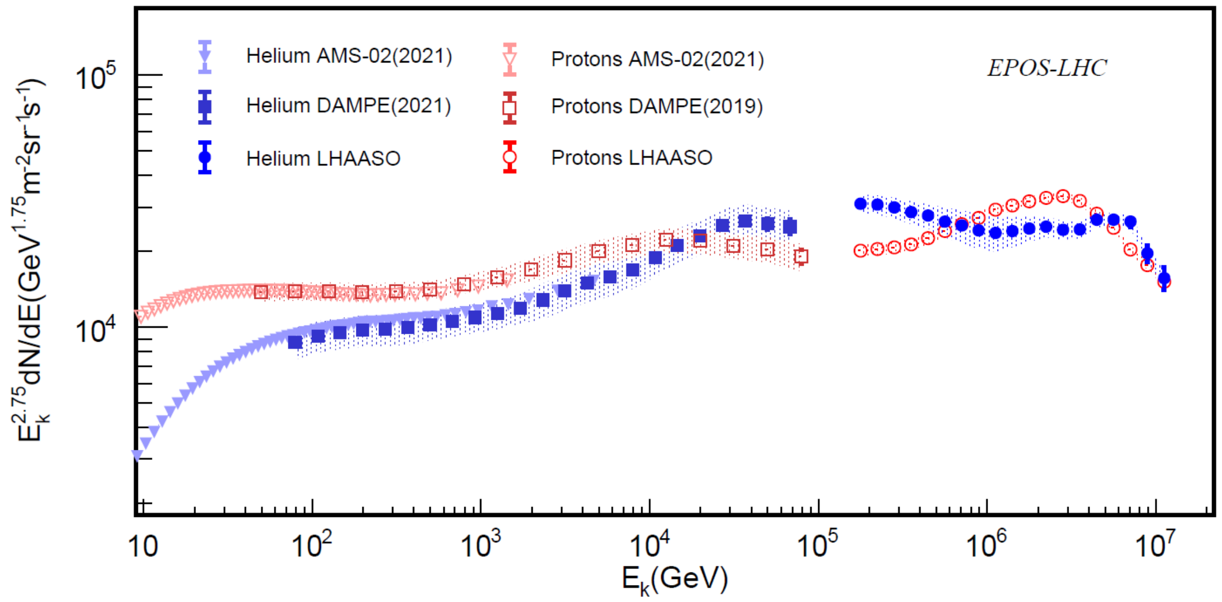
- Spectral structure: **hardening-then-softening** structure both below and near the knee region (two bump structure)

Complex source characteristics and propagation features

- He-rich ~0.1PeV
- Proton-rich ~3PeV
- The all-particle knee (3.67 PeV) is very close to the proton knee

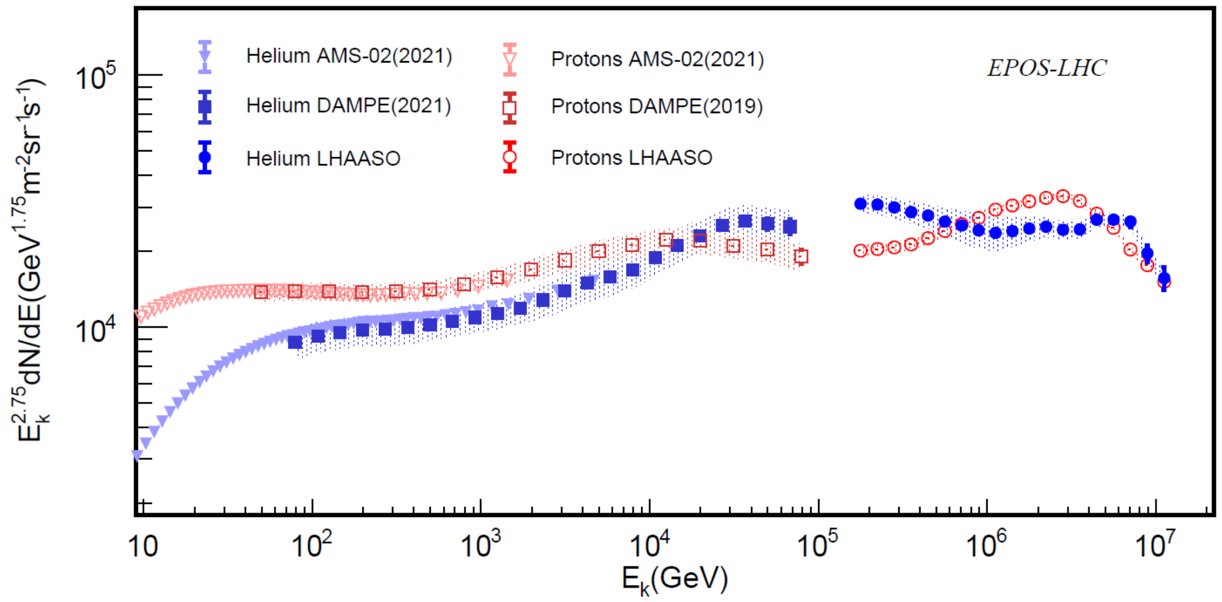
LHAASO results: Energy calibration using Moon shadow

Spectral Results from Space Experiments and LHAASO



- **Discrepancy:** Possible flux difference between different experiments
- **Main factor:** Difference in absolute energy scale
- **Unify the energy scales of different experiments:**
  - Measure spectra over the same energy range
  - Perform absolute energy calibration independently

Spectral Results from Space Experiments and LHAASO



- **Discrepancy:** Possible flux difference between different experiments
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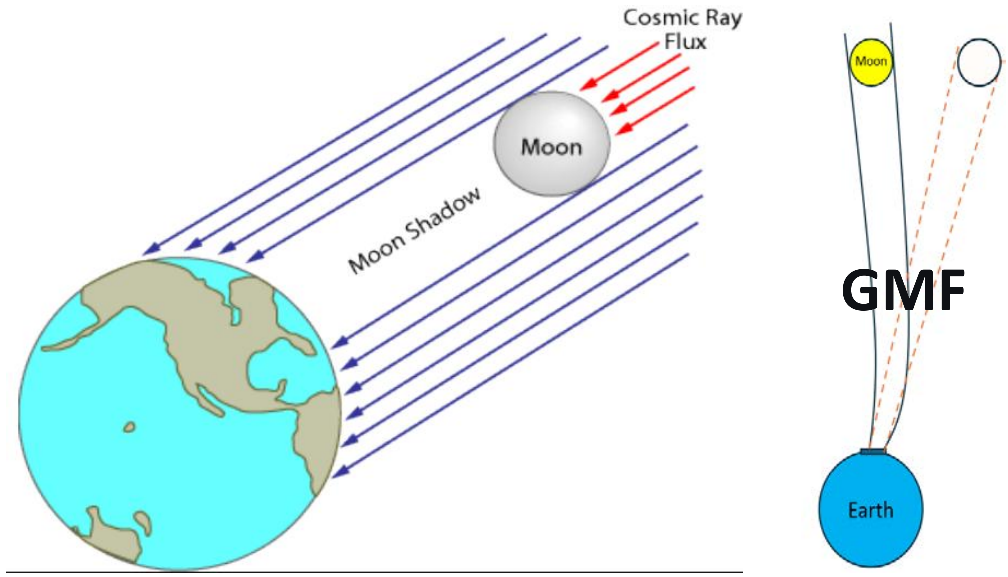
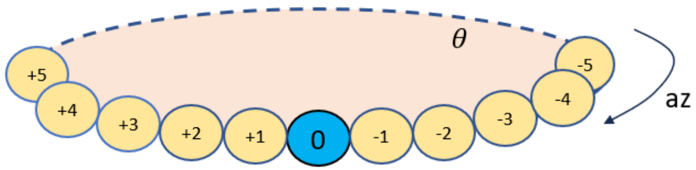
Energy calibration using Moon shadow



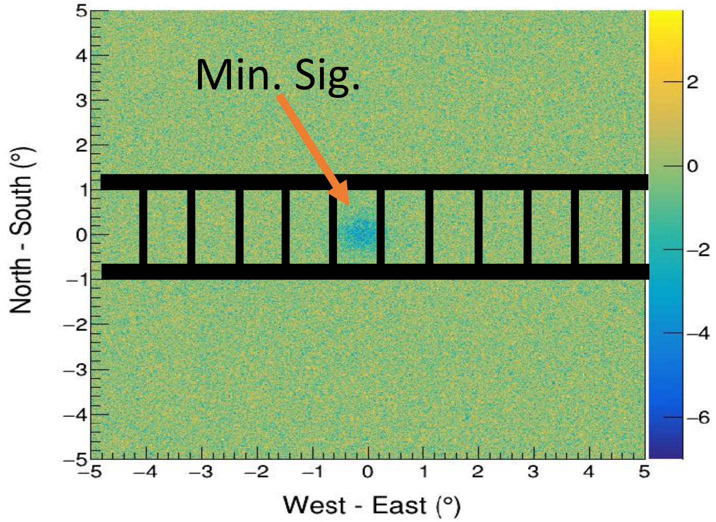
- **Moon shadow:** Cosmic ray blocked by the Moon
- **Shift of the Moon shadow:** Deflect of the cosmic rays by the Geomagnetic Field (GMF)
- **Absolute energy calibration:** Lower energy → larger shift $\boldsymbol{\Delta = -1.59° \times Z/E(TeV)}$

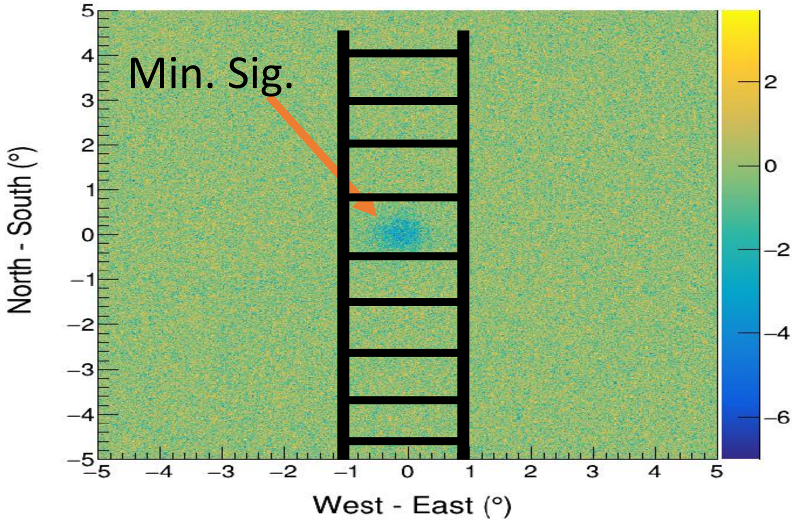
LHAASO results: Energy calibration using Moon shadow

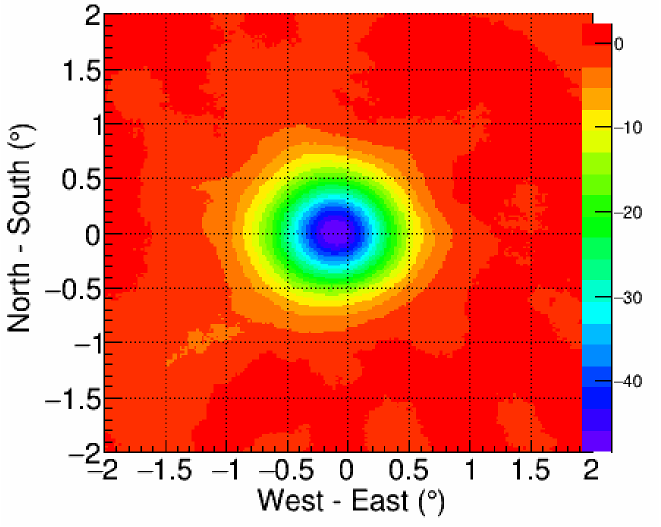
- From 2021/07 to 2025/01, 3.5 years
- Background Estimation: Equi-Zenith method

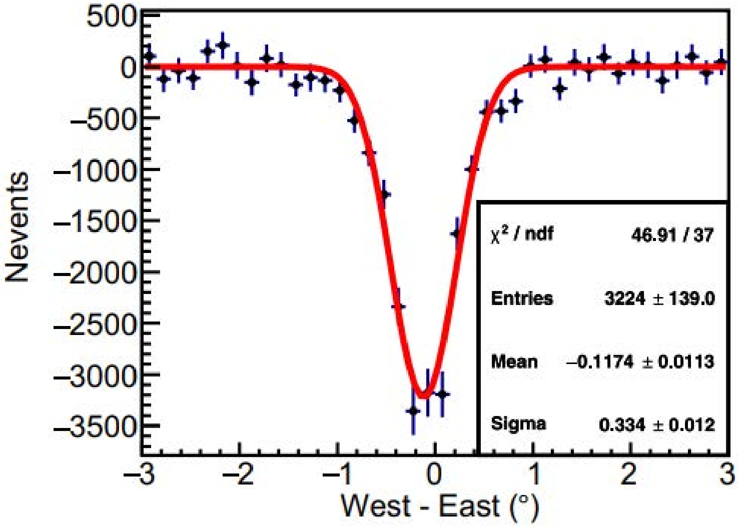


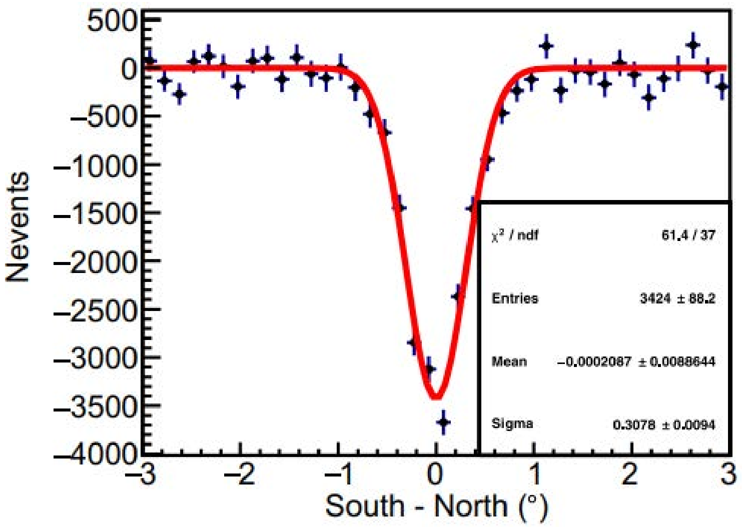
1-on, 10-off (10° × 10°)





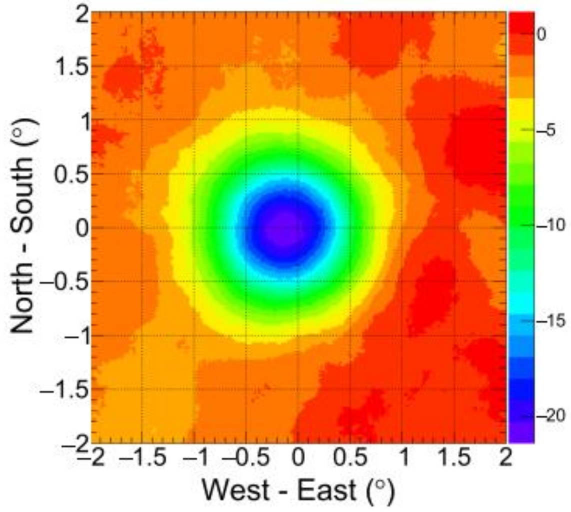




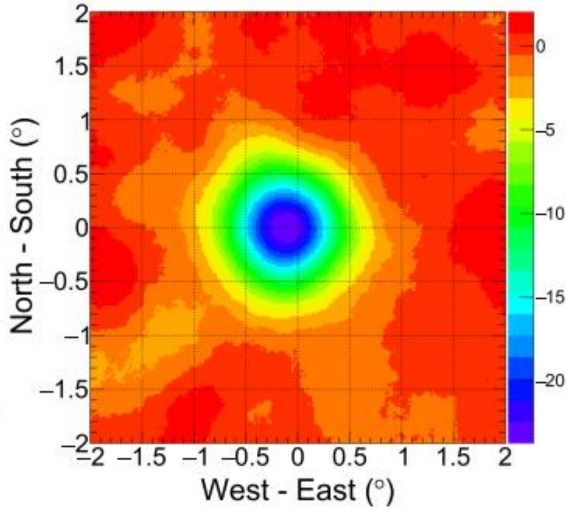


LHAASO results: Energy calibration using Moon shadow

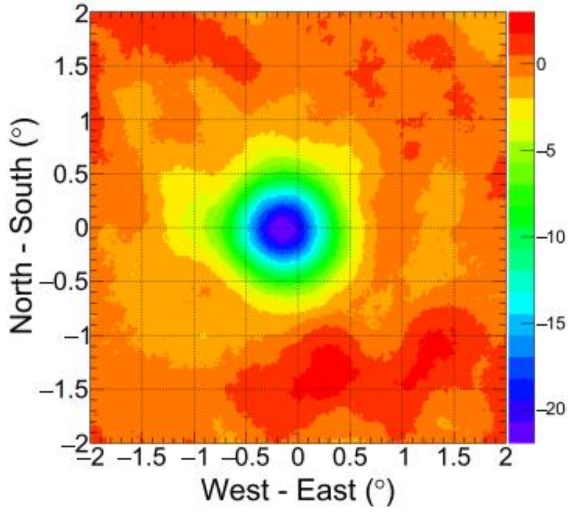
$\log_{10}N_{e\mu}$: 1.2~1.64

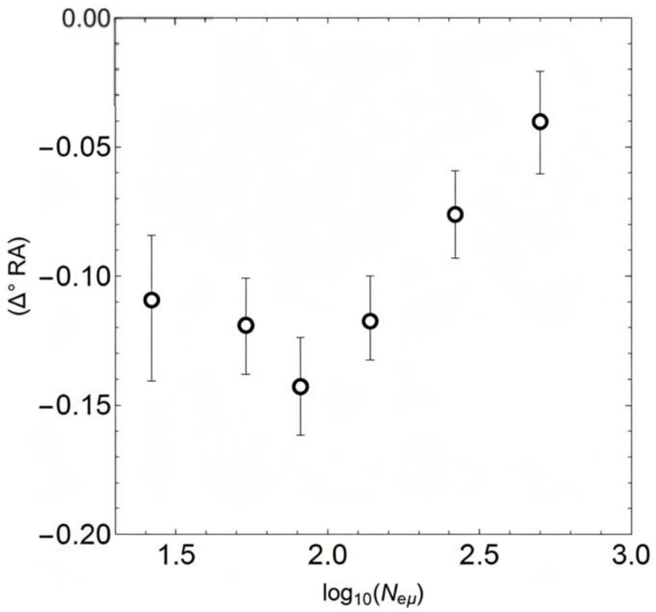


$\log_{10}N_{e\mu}$: 1.64~1.82

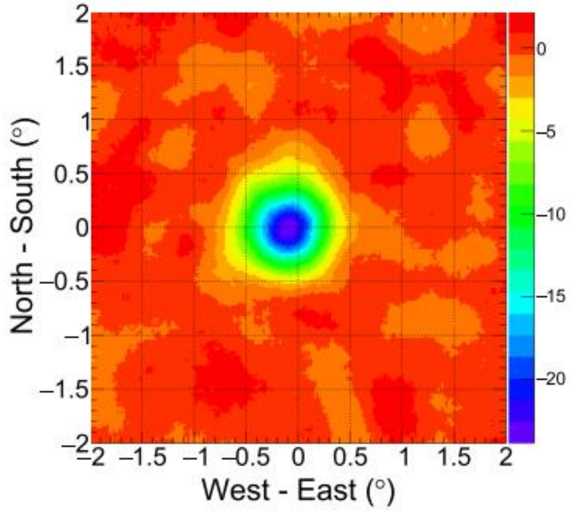


$\log_{10}N_{e\mu}$: 1.82~2.0

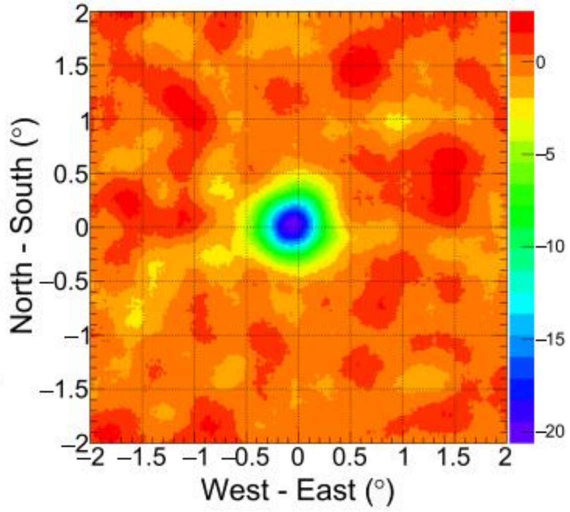




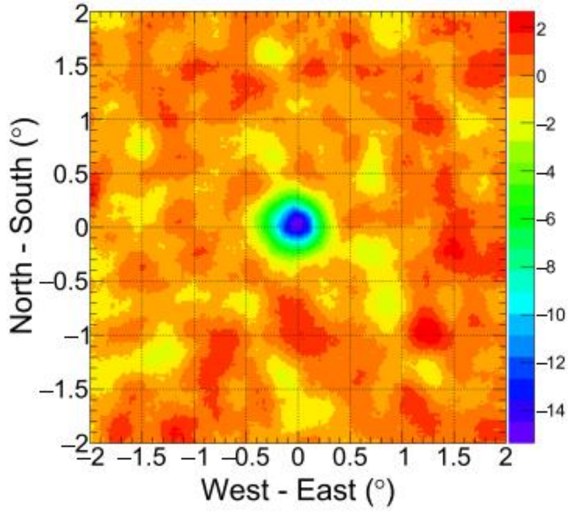
$\log_{10}N_{e\mu}$: 2.0~2.28

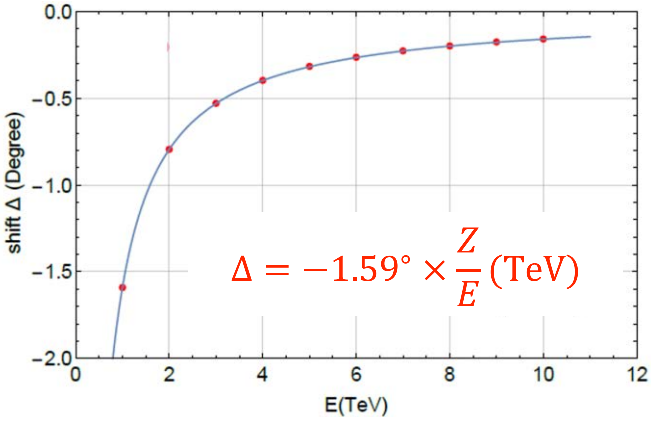


$\log_{10}N_{e\mu}$: 2.28~2.56



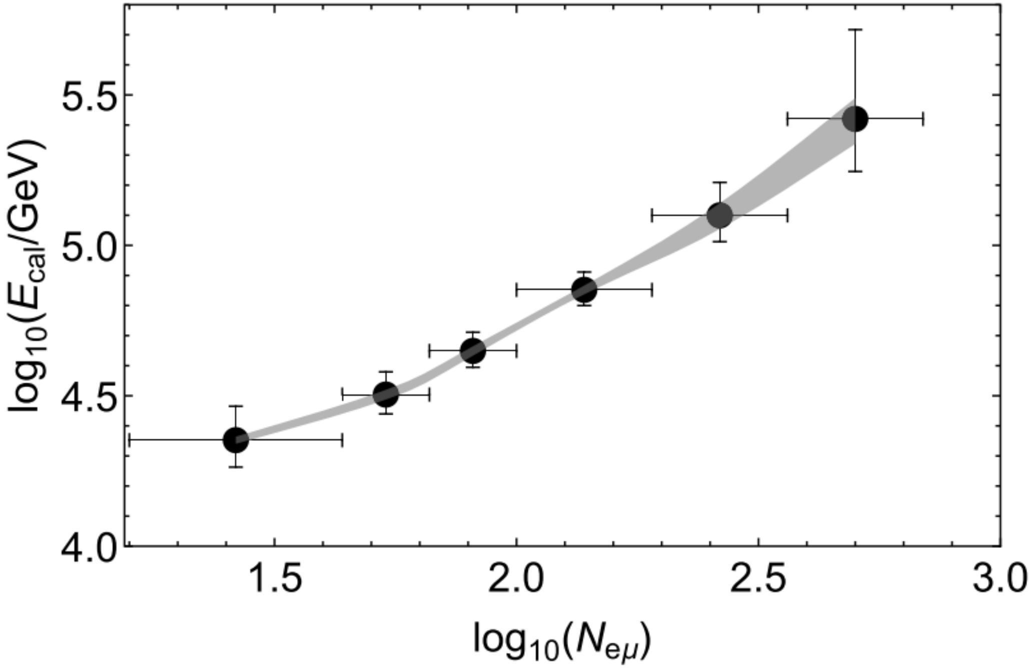
$\log_{10}N_{e\mu}$: 2.56~2.84

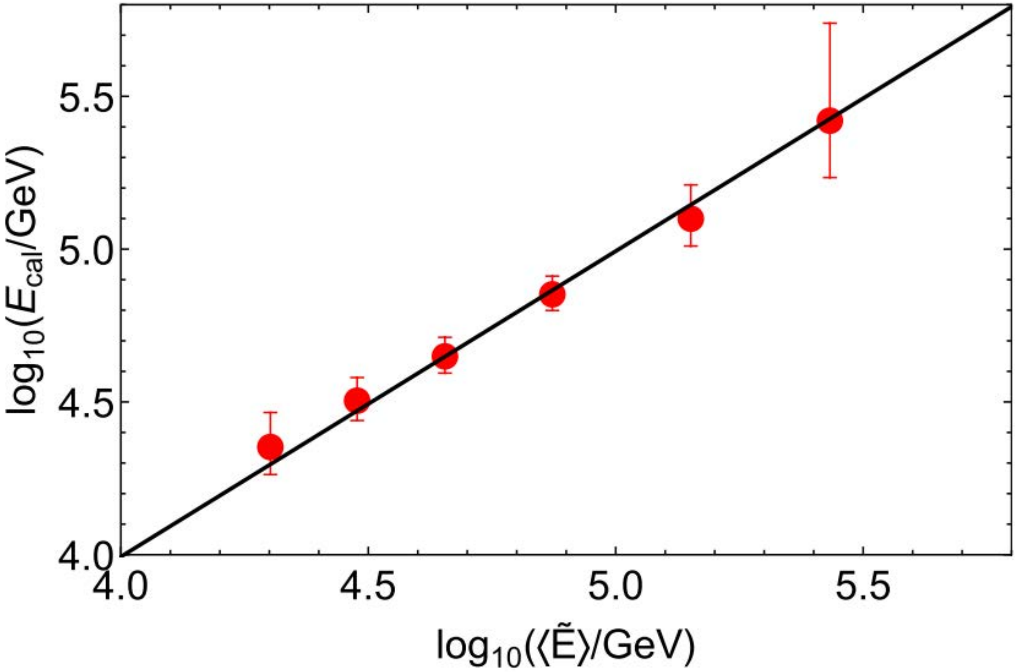




$$E_{\mathrm{cal}} = -1.59\frac{\langle Z\rangle}{\Delta}$$

LHAASO results: Energy calibration using Moon shadow





- **Systematic uncertainties:**
  - Geomagnetic field model: $<1\%$
  - Estimation of $\langle Z\rangle$: $2\%\sim17\%$
    - Composition models (Gaisser, Horandol, GSF, GST)
    - Interaction models (QGSJETII-04, EPOS-LHC)
    - Ray tracing

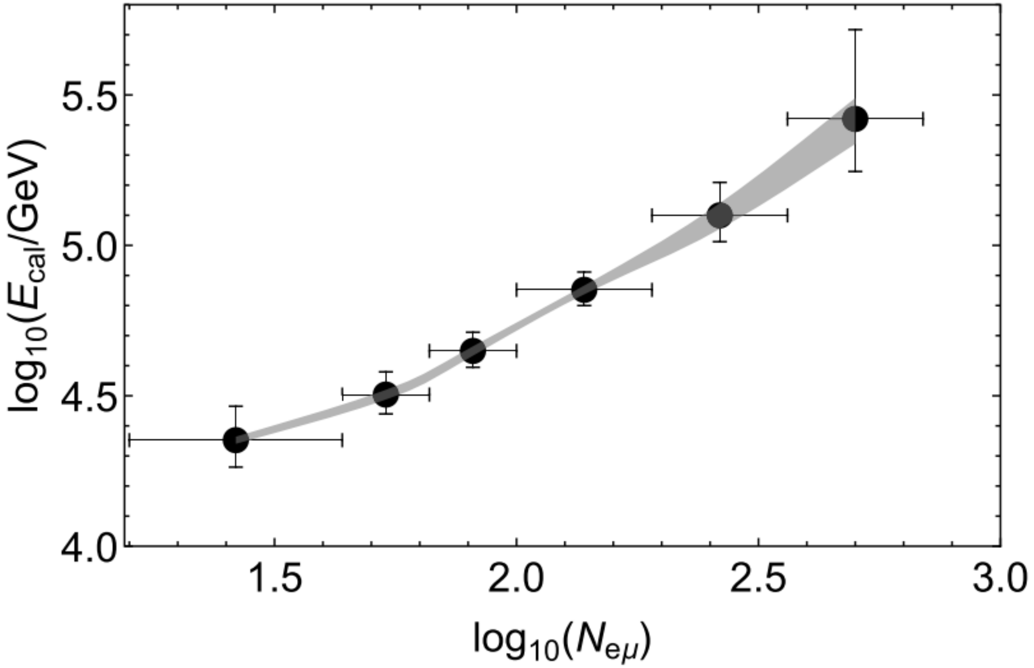
- **Energy Calibration**

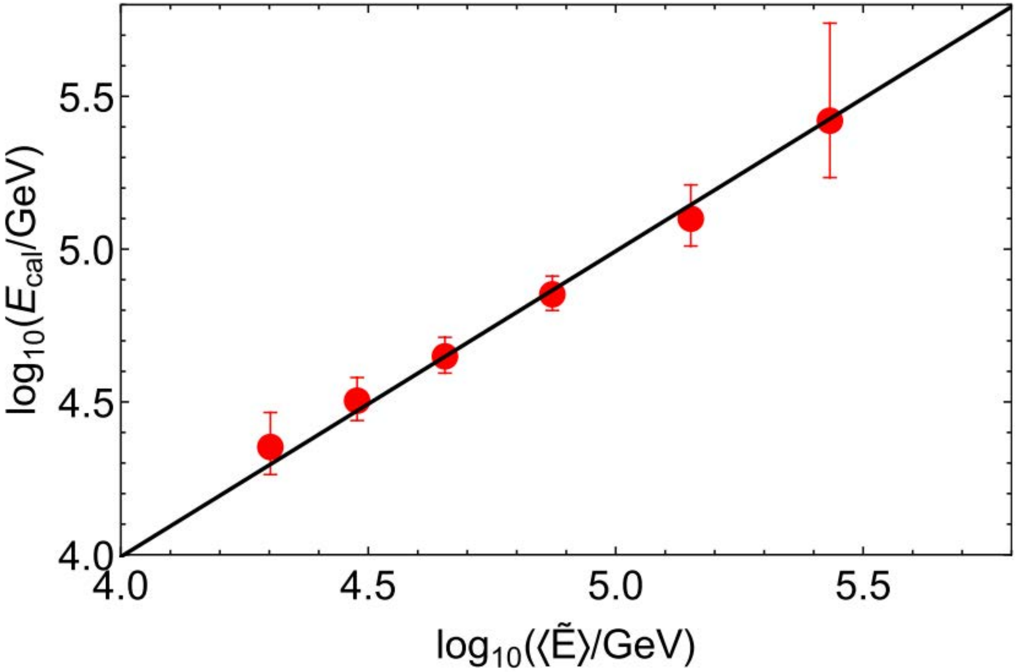
$$E_{\mathrm{cal}} = (1-\varepsilon)\langle\tilde{E}\rangle$$

$$\varepsilon = 0.015 \pm 0.08$$

Calibrated energy is in good agreement with the simulation

LHAASO results: Energy calibration using Moon shadow





➢ **Systematic uncertainties:**

- Geomagnetic field model: $<1\%$
- Estimation of ⟨Z⟩: $2\% \sim 17\%$
  - Composition models (Gaisser, Horandol, GSF, GST)
  - Interaction models (QGSJETII-04, EPOS-LHC)
  - Ray tracing

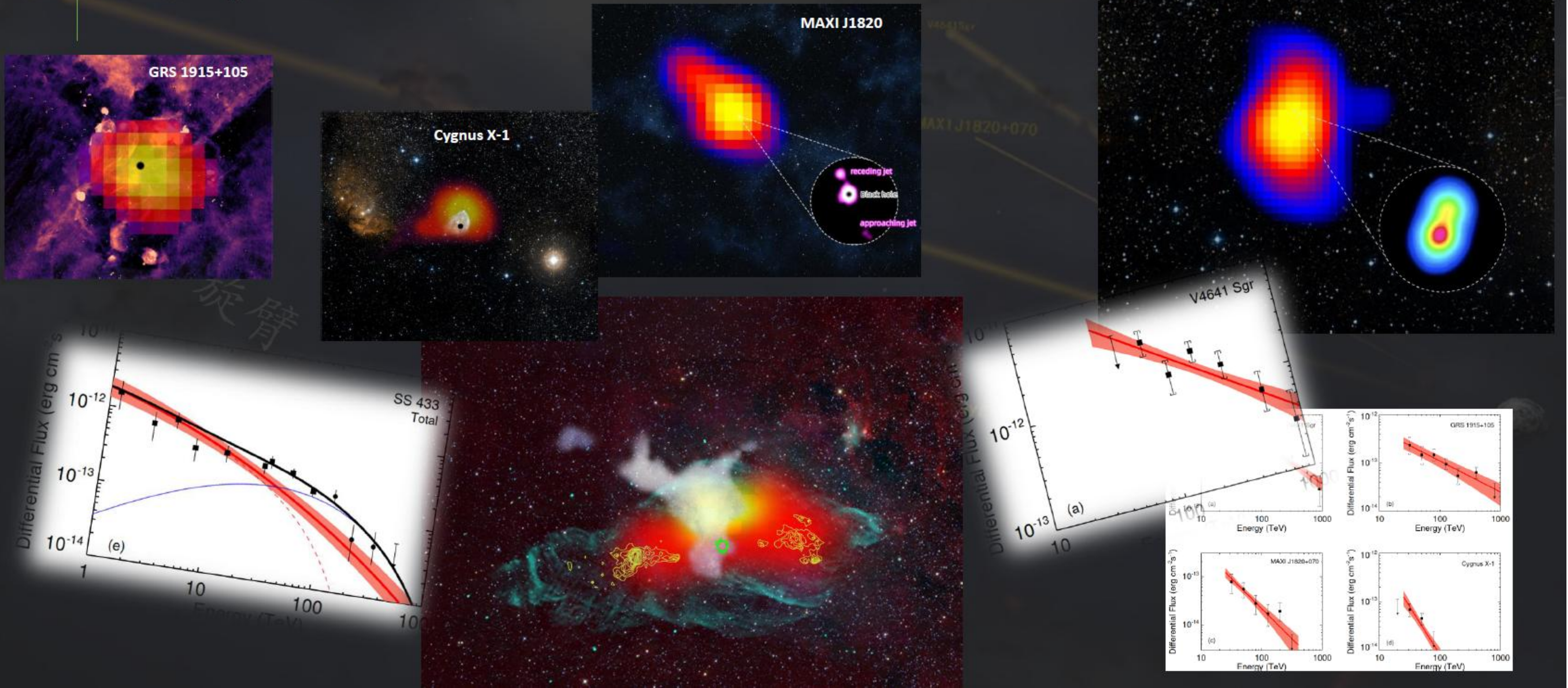
➢ **Energy Calibration**

$$E_{\text{cal}} = (1-\varepsilon)\langle \tilde{E} \rangle$$

$$\varepsilon = 0.015 \pm 0.08$$

Higher statistics → Better calibration

Six μ-Quasars are identified to be PeVatrons



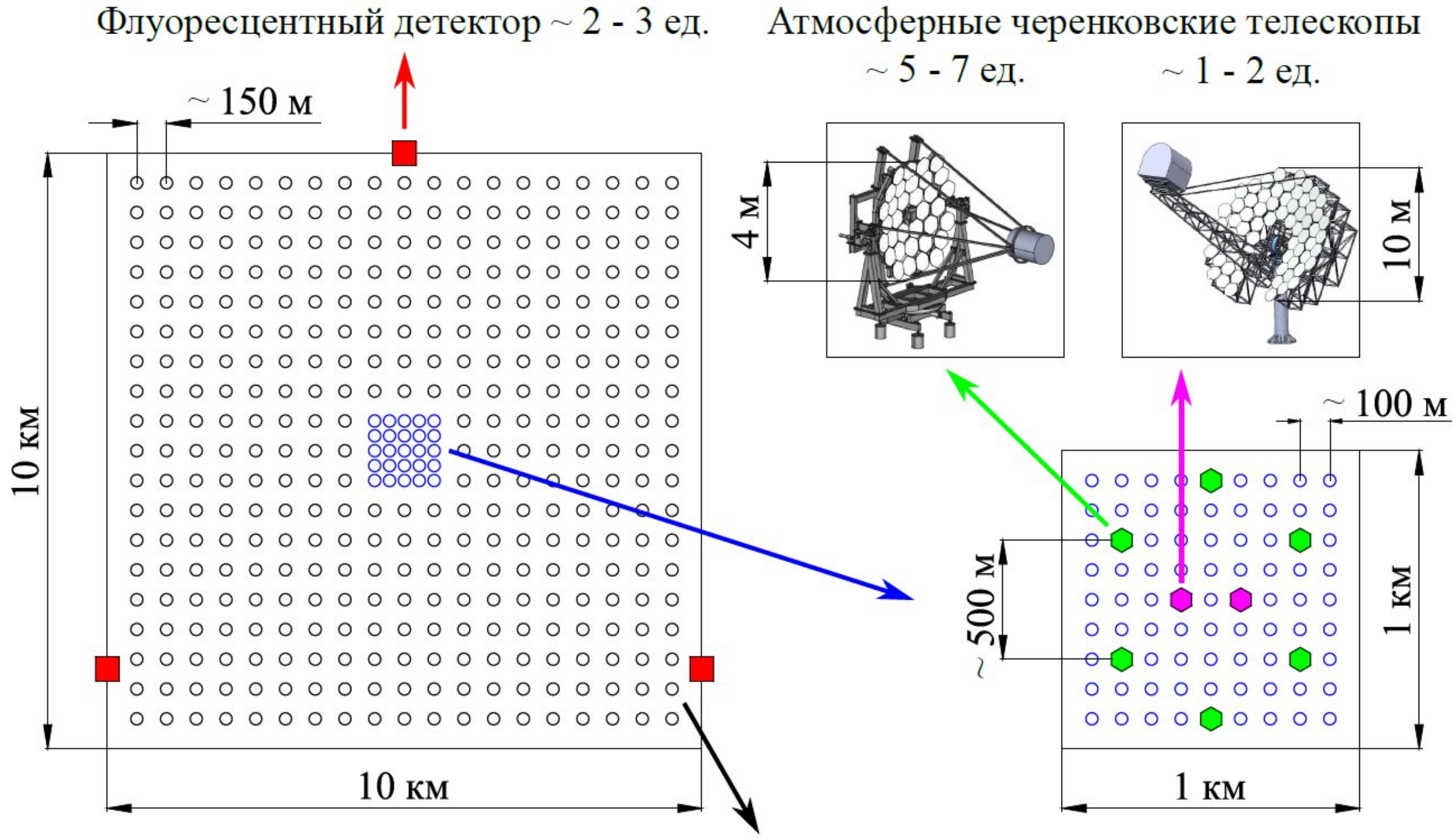
Астрофизический комплекс TAIGA-100

TAIGA-100 – проект крупномасштабного экспериментального комплекса следующего поколения с гибридной системой детекторов на площади порядка 100 км^2.

Научная программа

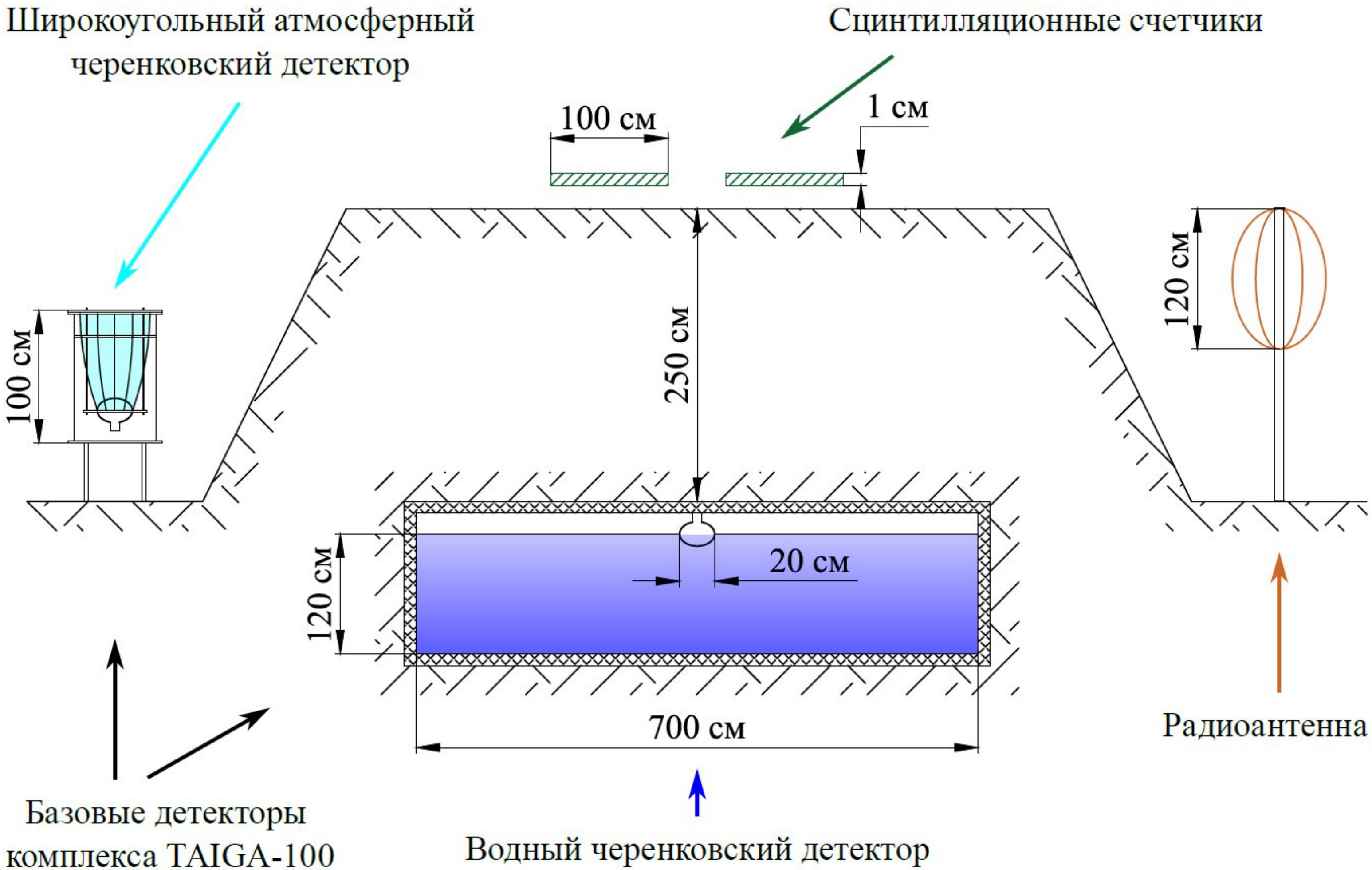
1. Исследования в области гамма-астрономии при энергиях $\geq 10^{14}$ эВ
2. Исследования в области физики космических лучей (КЛ) в диапазоне 10^{14} - 10^{19} эВ
3. Поиск диффузного гамма-излучения в интервале энергий 10^{14} - 10^{19} эВ
4. Поиск гамма-квантов от гамма-всплесков с энергией $\geq 5 \cdot 10^{12}$ эВ
5. Поиск горизонтальных нейтринных событий с энергией $\geq 10^{17}$ эВ
6. Исследования в области геофизики
7. Поиск «новой физики»

Состав комплекса и схематичное расположение детекторов



Станция ~ 3000 ед.:
Широкоугольный атмосферный черенковский детектор, водный черенковский детектор, сцинтилляционные счетчики, радиоантенна

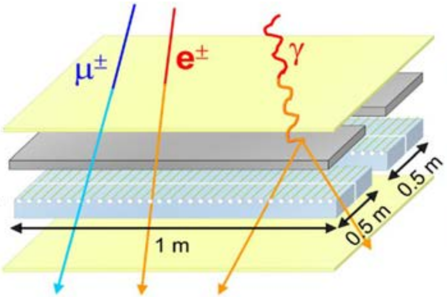
Станция

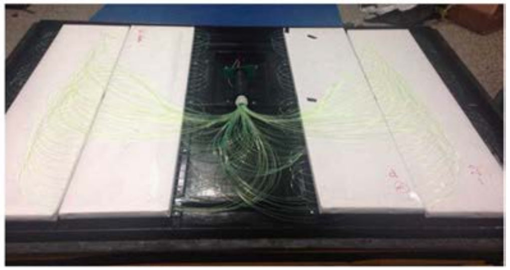


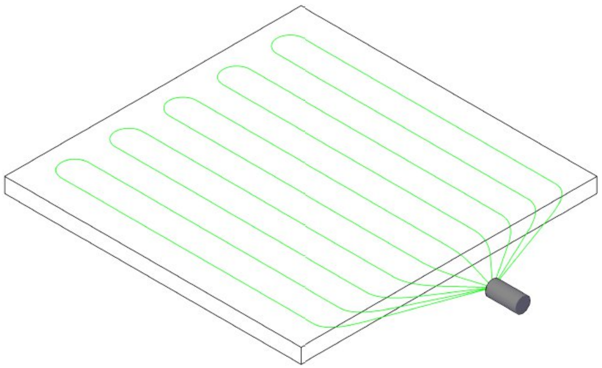
Широкоугольный атмосферный
черенковский детектор
Сцинтилляционные счетчики
100 см
1 см
250 см
120 см
100 см
20 см
120 см
700 см
Радиоантенна
Базовые детекторы
комплекса TAIGA-100
Водный черенковский детектор

Сцинтилляционные счетчики

Детектор установки KM2A обсерватории LHAASO

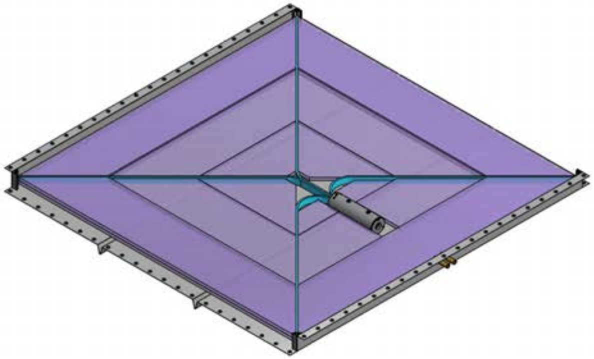






Варианты

Детектор установки TAIGA-Muon



- Эффективная площадь ~ 1 м^2
- Толщина сцинтиллятора ~ 1 см
- Неоднородность светосбора ≤ 20%
- Динамический диапазон ~ 10^4 частица/м^2
- Поглотитель для конвертации гамма-квантов
- Порог регистрации ШАЛ ~ 10^{14} эВ (~ 2000 м н.у.м) или ~ 10^{15} эВ (700 м н.у.м).

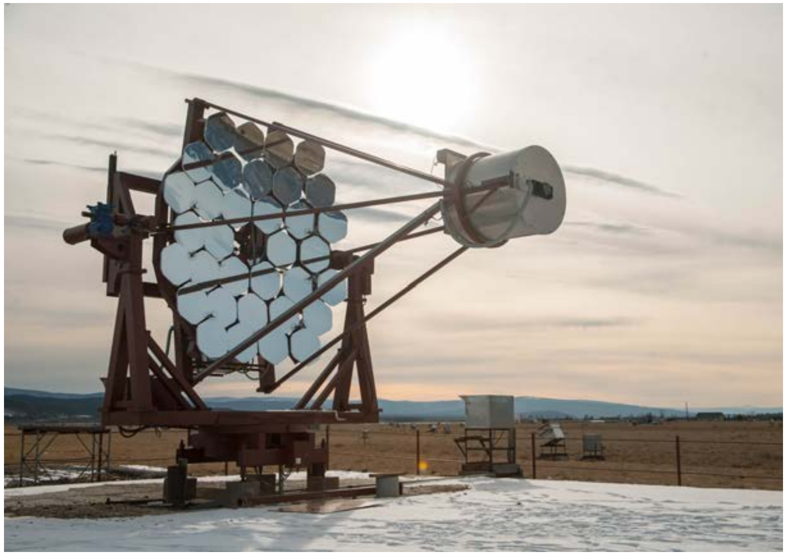
Радиоантенна

- Установка Tunka-Rex
- Диапазон частот ~ 30 - 80 МГц

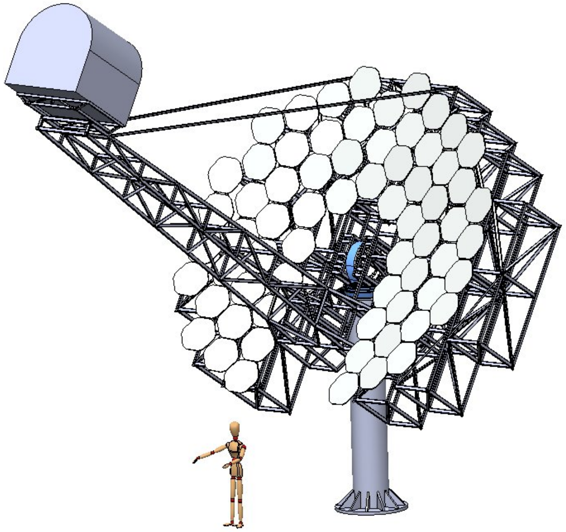
- Установка GrandProto300
- Диапазон частот ~ 50 - 200 МГц

- Энергетический порог регистрации КЛ ~ 10^{17} эВ
- Регистрация горизонтальных ШАЛ
- Автономная работа антенн

Атмосферные черенковские телескопы

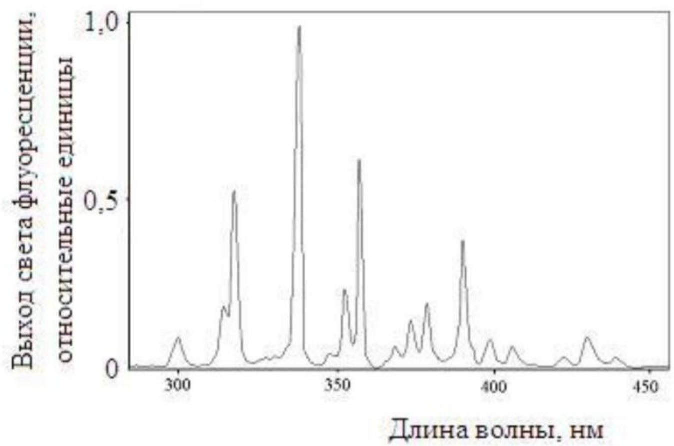


• 5 телескопов в составе комплекса TAIGA-1
• Порог регистрации гамма-квантов ~ $3 \cdot 10^{12}$ эВ
• Замена ФЭУ на SiPM - ?

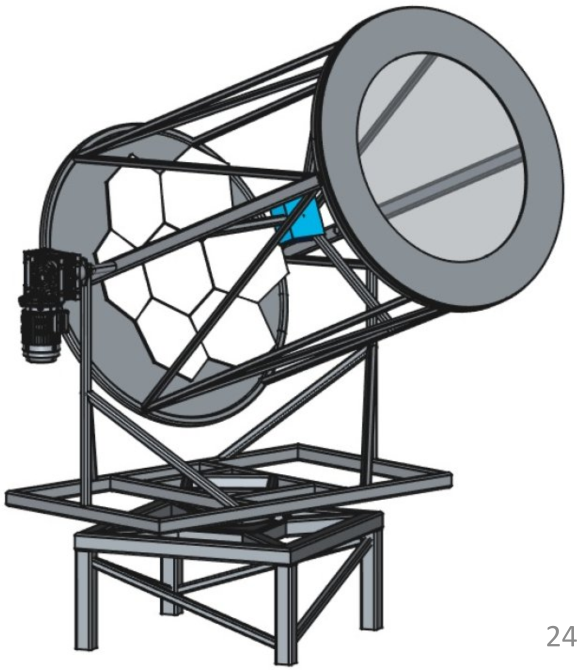


• Дизайн Дэвиса-Коттона
• Полная площадь отражателя ~ 80 $м^2$
• Камера из ~ 2000 пикселей (SiPM)
• Угол обзора пикселя и камеры – 0.24° и ~ 5°
• Порог регистрации гамма-квантов ~ $3 \cdot 10^{11}$ эВ
• Прототип телескопа проекта ALEGRO

Флуоресцентный детектор



Конструкция:
- Телескоп Шмидта
- Диапазон длин волн 300 - 400 нм
- 7 сегментированных зеркал диаметром ~ 60 см
- Фокусное расстояние ~ 1 м
- Угол обзора телескопа ~ 60°

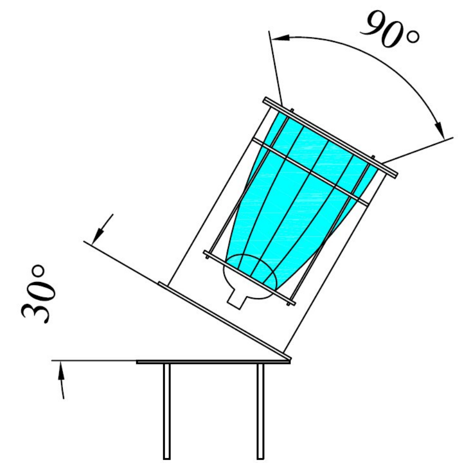


Задачи:
- Исследования КЛ при энергиях ≥ 10^{18} эВ
- Энергетическая калибровка сцинтилляционной установки

Широкоугольный атмосферный черенковский детектор

Оптическая станция TAIGA-HiSCORE

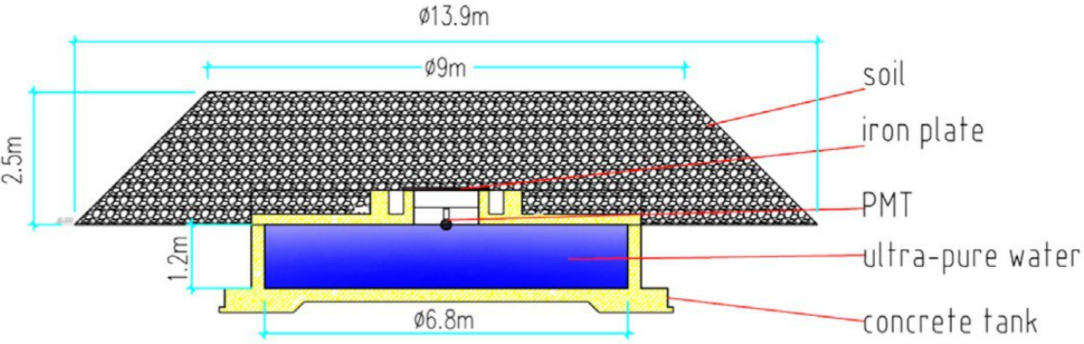
Детектор TAIGA-100



- Конструкция: конус Винстона и ФЭУ диаметром ~ 20 см
- Угол обзора конуса Винстона ± 45°, угол наклона детектора ~ 10 - 30°
- Порог регистрации гамма-квантов ~ $2 \cdot 10^{14}$ - $4 \cdot 10^{14}$ эВ
- Угловое и энергетическое разрешение установки ~ 0.15° и 15%
- В 2025 г на одной станции TAIGA-HiSCORE установлены экспериментальные конуса

Водный черенковский детектор

1188 детекторов установки KM2A
обсерватория LHAASO

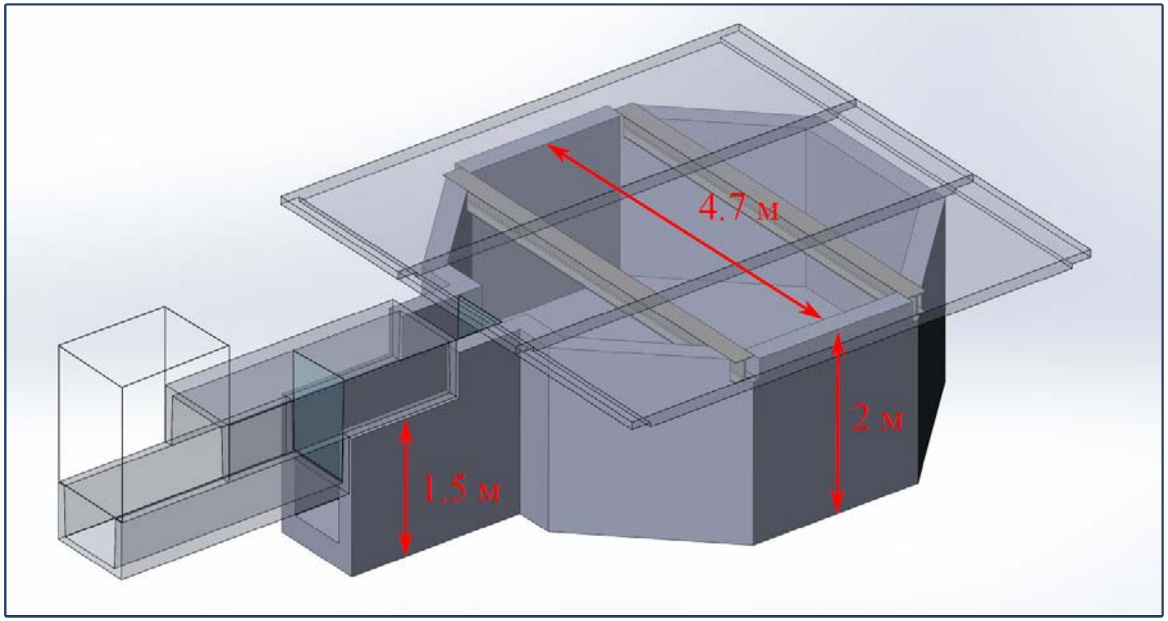


Параметры детектора TAIGA-100:

• ФЭУ диаметром ~ 20 см
• Площадь детектора ~ 40 м^2
• Динамический диапазон ~ 10^4 частиц
• Прозрачность воды (длина поглощения) ≥ 30 м
• Коэффициент диффузного отражения поверхности ≥ 95%
• Отсутствие подогрева и системы очистки воды

Прототип водного черенковского детектора

Лето-осень 2024 года



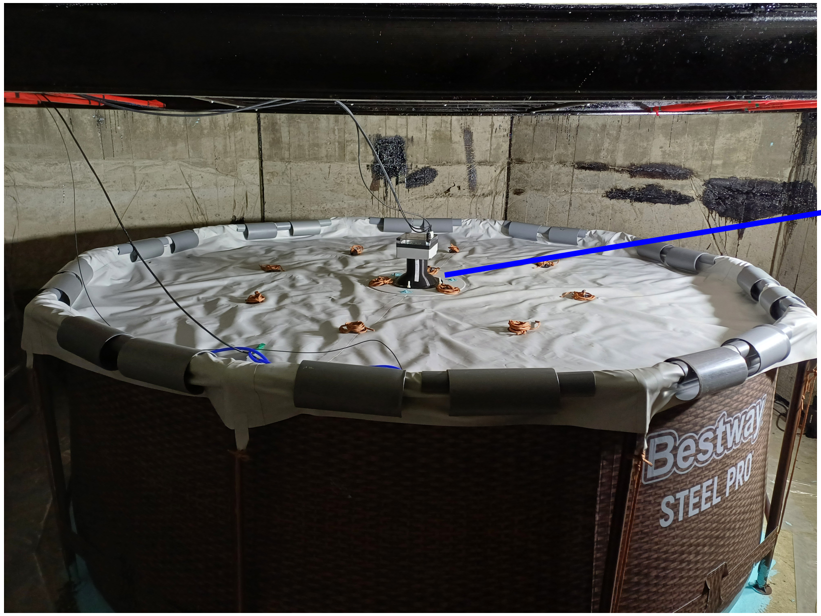
Мониторинг температуры воды:

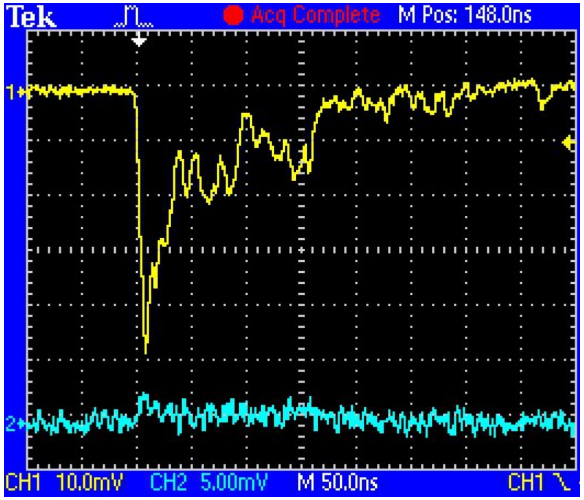
T_{min} в июне 2025 года + 1°C

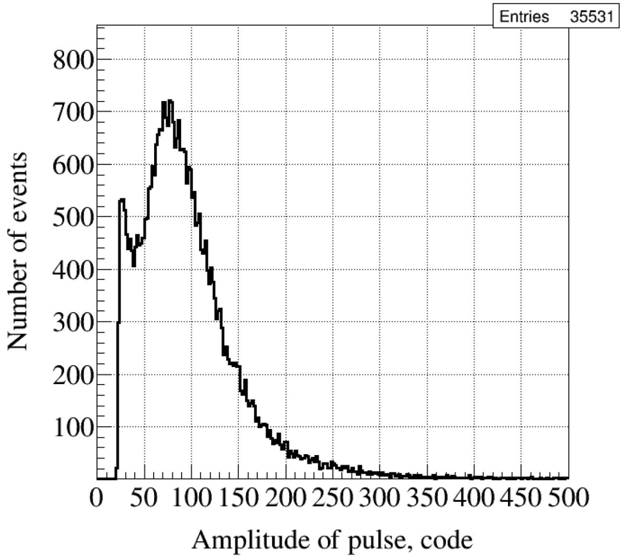
T_{max} в октябре 2025 года + 8 °C

Прототип водного черенковского детектора

Развертывание детектора осенью 2025 года

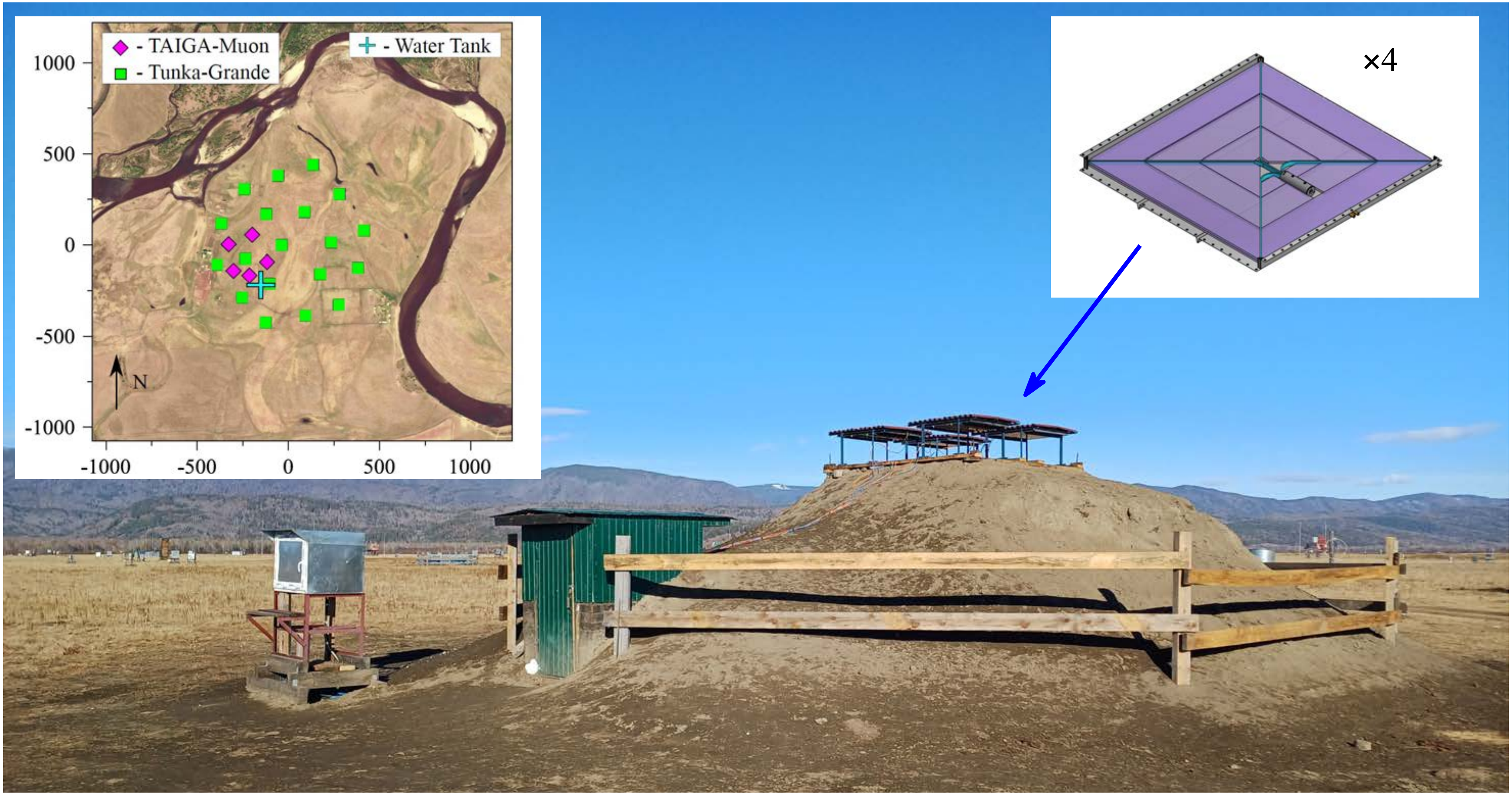






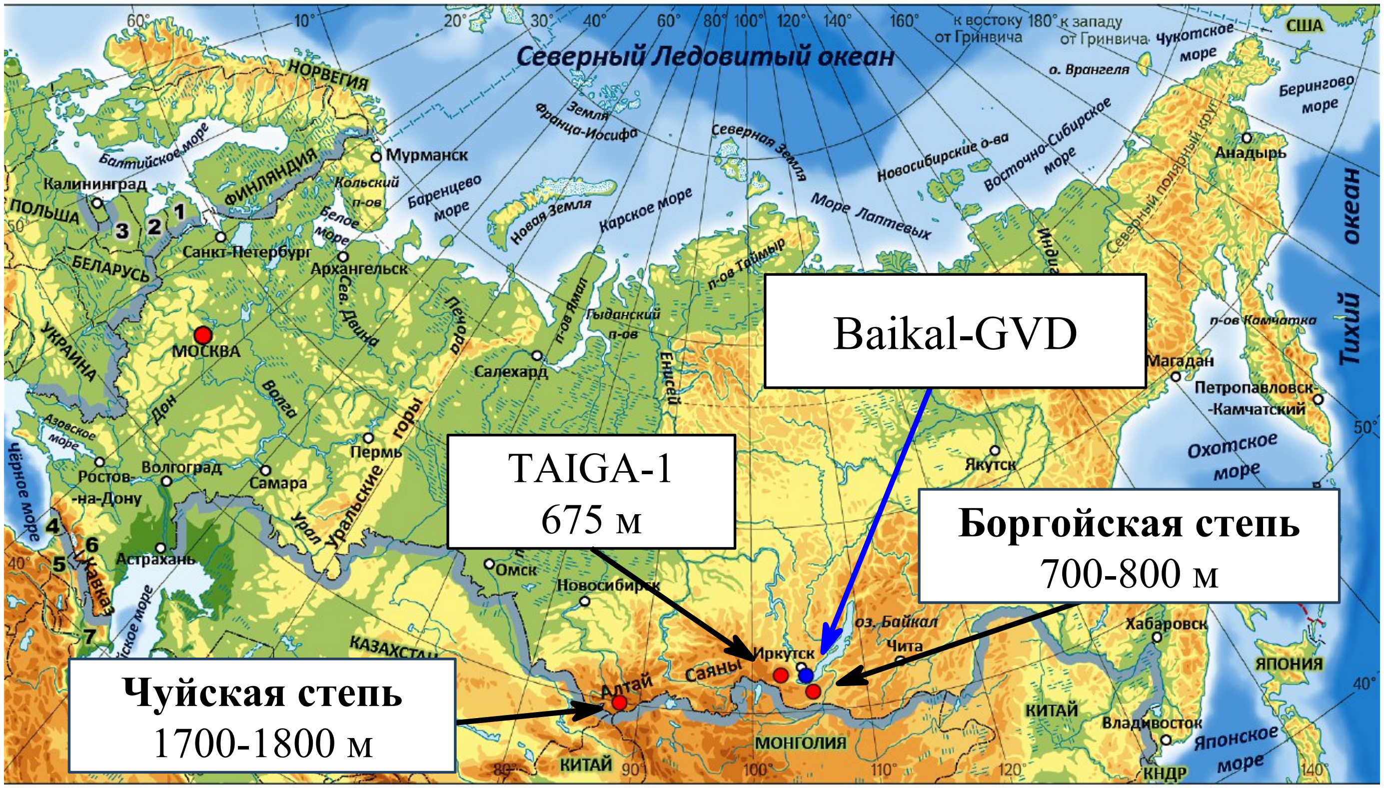
- ФЭУ Hamamtsu R5912
- Отражатель Tyvek 1082D
- Объем залитой воды ~ 6.5 м^3 (R = 1.5 м, H = 90 см)
- Электрическая проводимость воды ~ 5 мкСм/см

Прототип водного черенковского детектора



28 ноября 2025 года станция запущена в набор данных совместно с установками Tunka-Grande и TAIGA-Muon.

Поиск площадки



Астроклимат и особенности местности

Количество безоблачных ночей, прозрачность атмосферы, антропогенная засветка и т.д.

Инфраструктура

Транспортная доступность, энергетика, телекоммуникации и т.д.

<u>Доклад Иванова А.Л. «Поиск площадки для развертывания астрофизического комплекса TAIGA-100»</u>

Ожидаемые результаты TAIGA-100

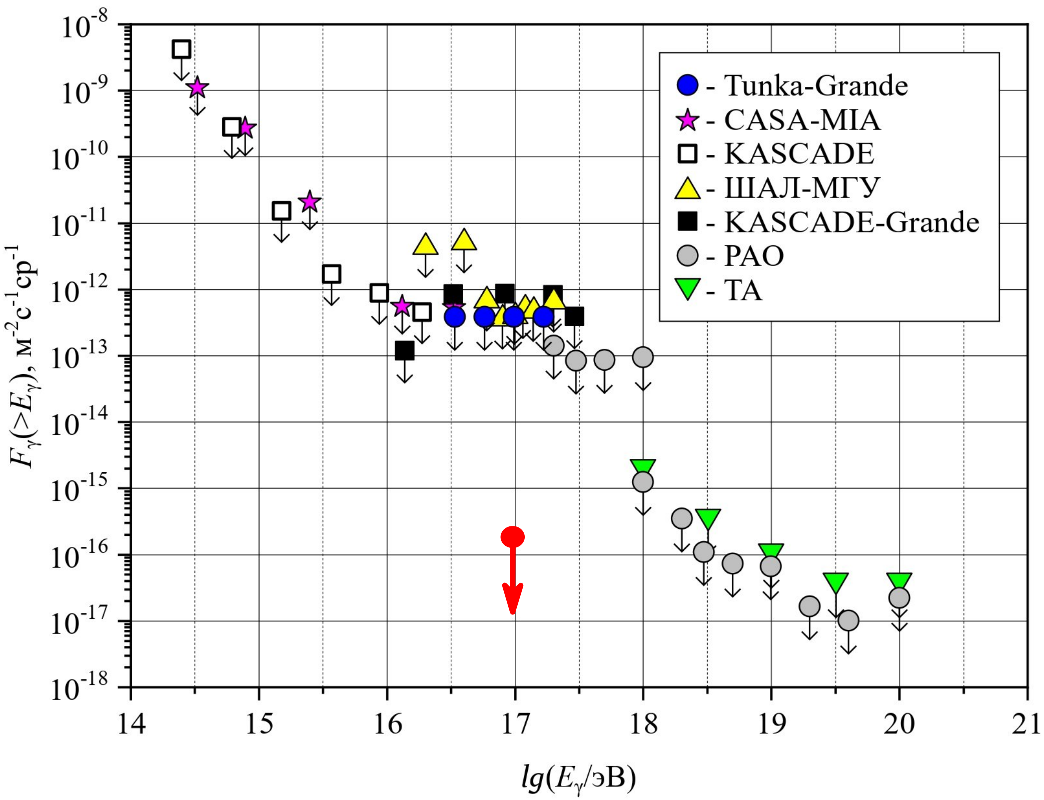
Космические лучи:

• Выше 100 ПэВ и 10 ЭэВ ожидается ~ 10^6 и 10^2 событий за календарный год

• Тунка-133 и Tunka-Grande по ~ 600 событий с энергией выше 100 ПэВ за календарный год

Диффузное гамма-излучение:

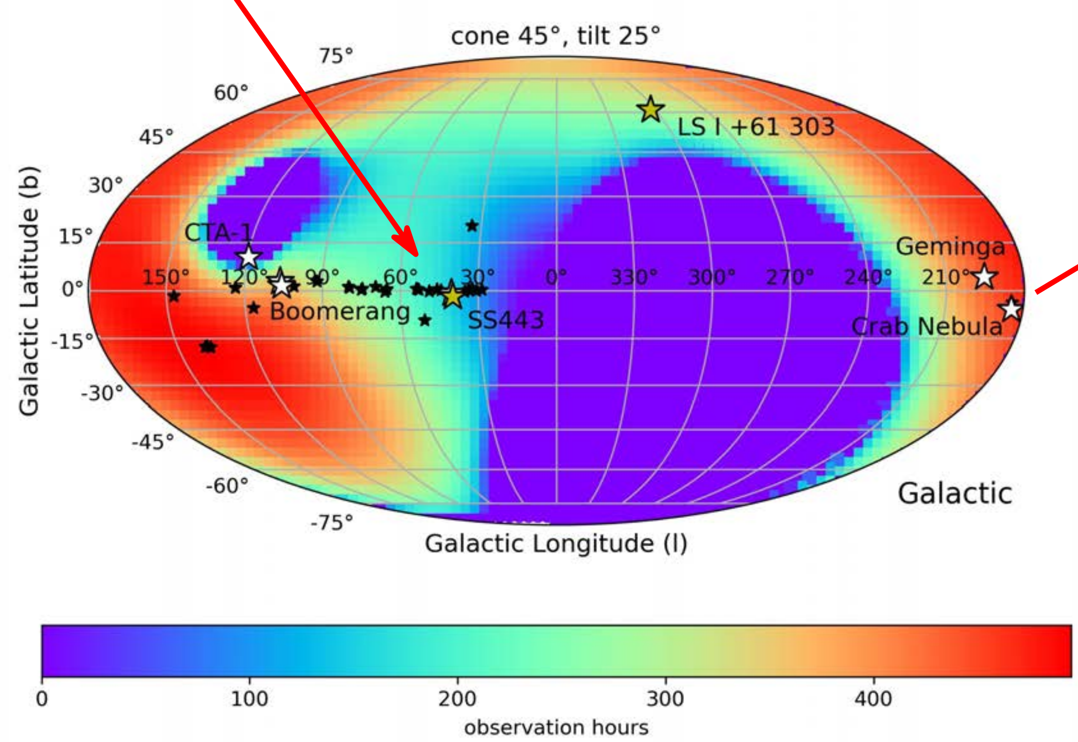
• Ограничение на уровне ~$5 \cdot 10^{-3}$ км$^{-2}$год$^{-1}$ср$^{-1}$ за 10 лет набора данных

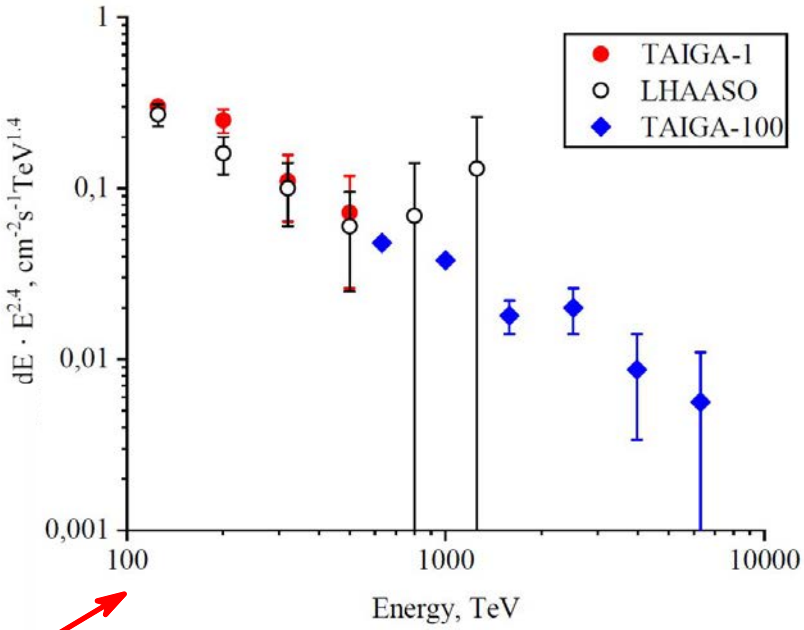


Ожидаемые результаты TAIGA-100

Гамма-астрономия

Источники LHAASO с энергией выше 40 ТэВ

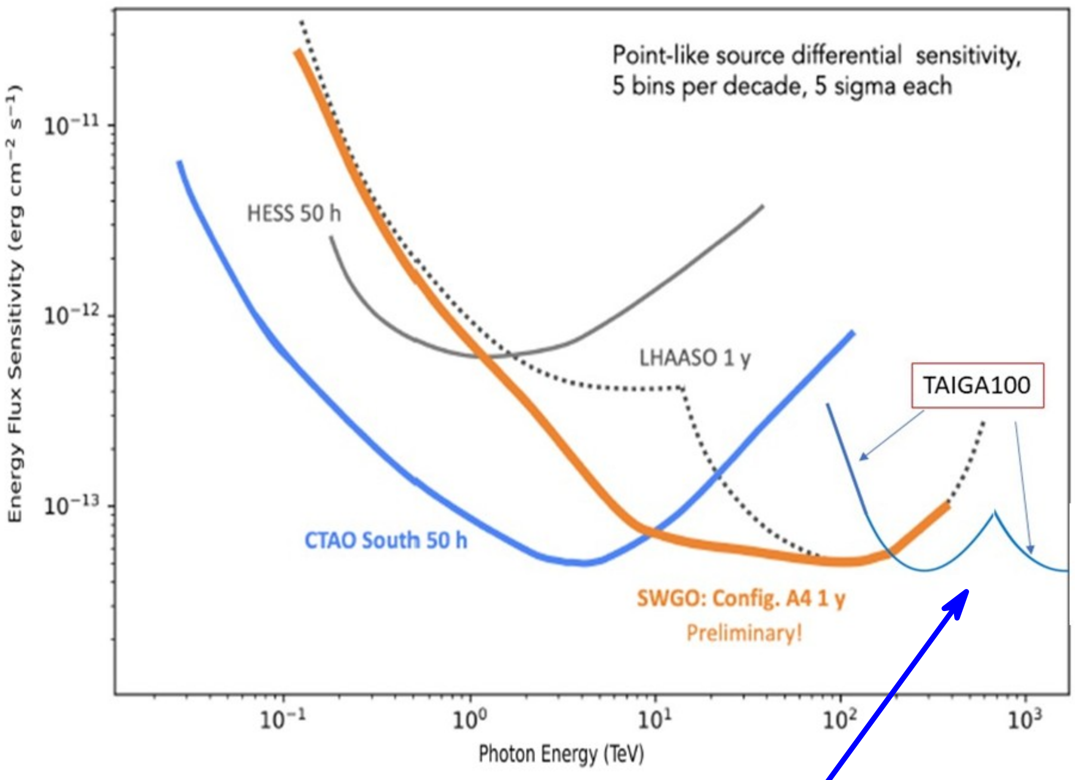




Ожидаемый спектр гамма-квантов от Крабовидной туманности за 1 календарный год (~ 500 часов)

Ожидаемые результаты TAIGA-100

Дифференциальная чувствительность



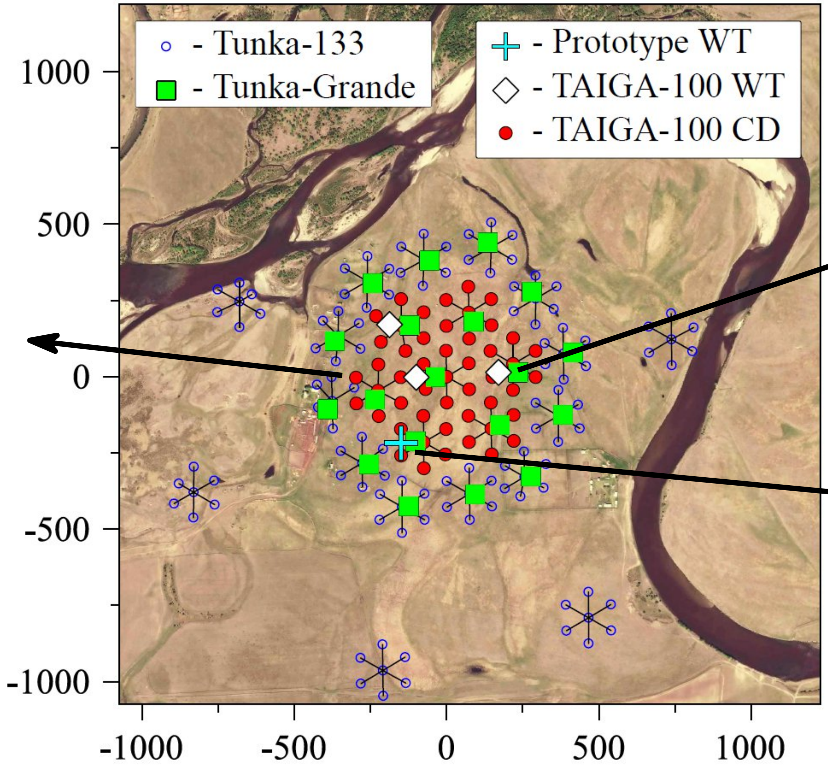
Чувствительность TAIGA-100 за один календарный год

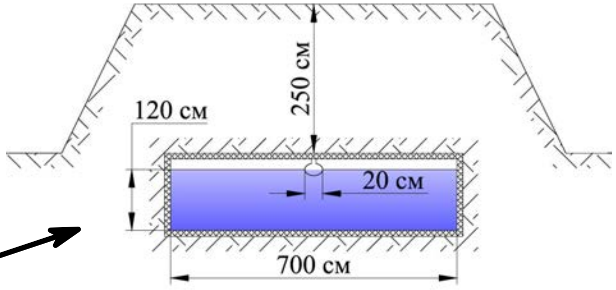
Планы

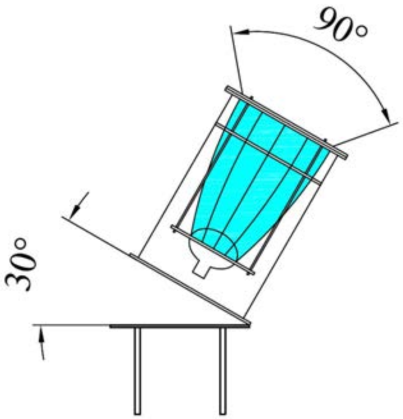
Лето - осень 2026 года:

• Развертывание 3 полноценных водных детектора площадью ~ 40 м^2

• Модернизация 49 оптических детекторов установки Тунка-133







2030 год:

• Развертывание ~ 20 станций на полигоне TAIGA-1

• Выбор площадки

• Подготовка проекта TAIGA-100