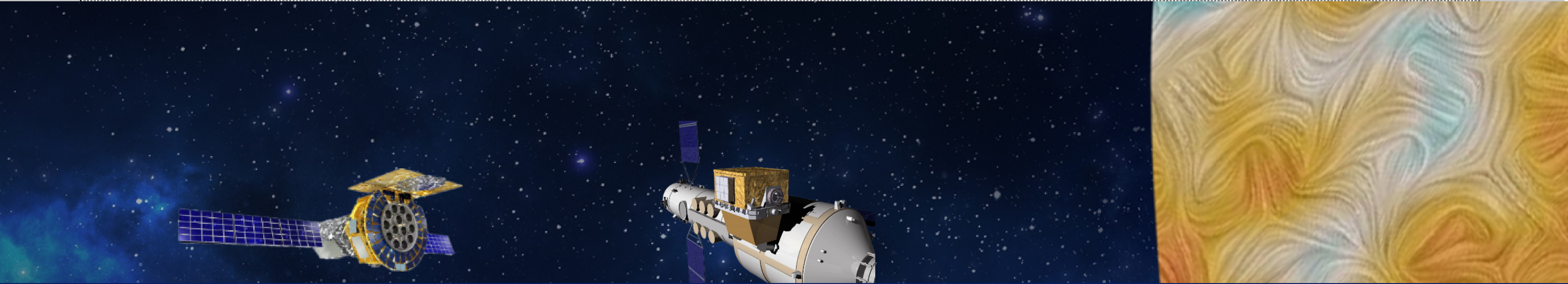


Recruitment needs for Particle Astrophysics Division (PAD)

Shoushan Zhang (zhangss@ihep.ac.cn)

Institute of High Energy Physics

Jan. 29, 2024

About PAD: mission

- **Particle Astrophysics**
  - formed by the close integration of **particle physics, astrophysics, and cosmology**
  - use high-energy particles and radiation as probes to study the **fundamental astronomical and physical problems** related to
    - **extreme energy, extreme gravity, extreme magnetic field, and large scale**

Extreme energy

Ultra-high-energy (UHE) cosmic rays

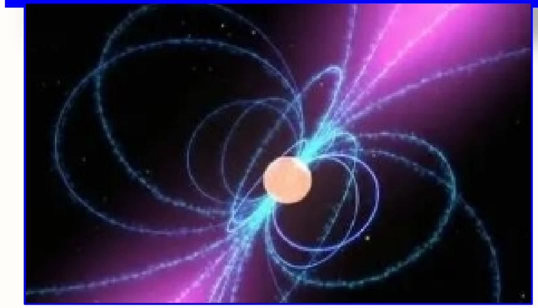
10^{16} times higher in energy than visible light photons

Extreme gravity

Near the event horizon of a black hole

10^{9} times stronger than the gravitational force on the surface of the Earth

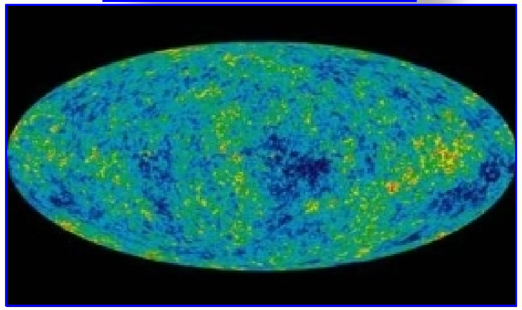
Extreme magnetic field



On the surface of a neutron star

10^{13-15} times stronger than the magnetic field on the surface of the Earth

Large scale



Primordial gravitational waves

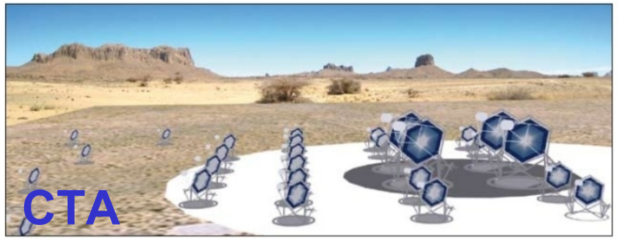
its wavelength reaches the cosmic scale of about 10^{10-11} light-years

About PAD: scientific questions

- **PAD focuses on three major scientific questions:**
  - the origin of cosmic rays, extreme gravity and magnetic fields of black holes and neutron stars, and primordial gravitational waves and cosmic expansion

Subjects	Goals
The origin of cosmic rays	The century-old mystery of the origin and acceleration mechanism of high-energy cosmic rays
Extreme gravity and magnetic fields of black holes and neutron stars	What happens around black holes, the mystery of the magnetic field structure and composition of neutron stars
Primordial gravitational waves and cosmic expansion	The mystery of the origin and accelerated expansion of the universe, the Hubble tension

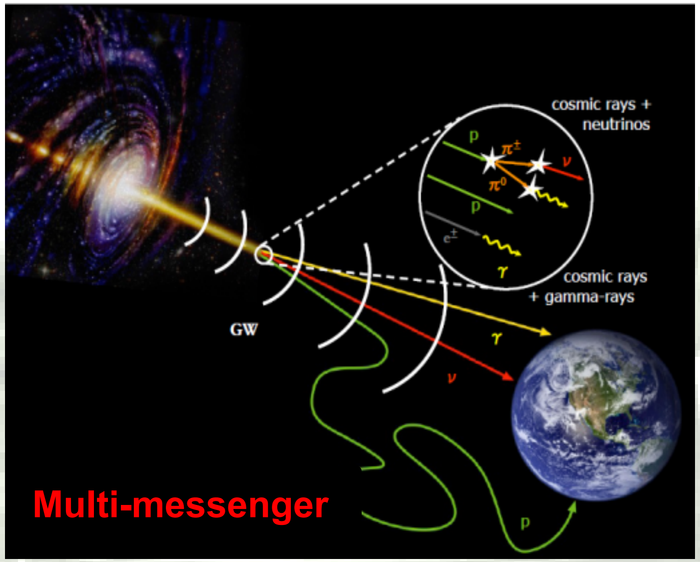
High Energy Cosmic Rays



VHEγ Astronomy

LHAASO

HESS， MAGIC, CTA

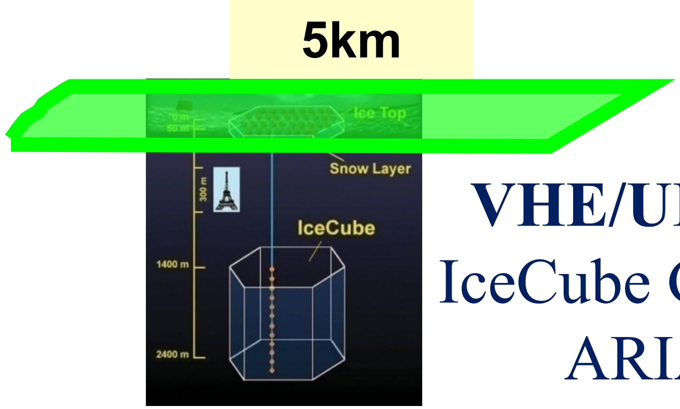


Origin of CRs
A century-old mystery

EHE CR Astronomy

TA, AUGER

JEM-EUSO



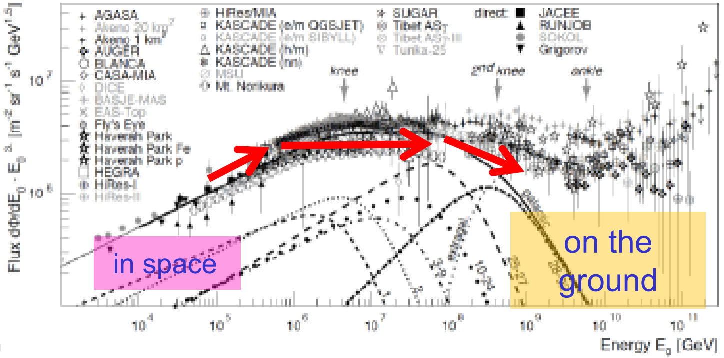
VHE/UHE Neutrinos

IceCube Gen2， KM3net

ARIANA ……

CR Features: knees

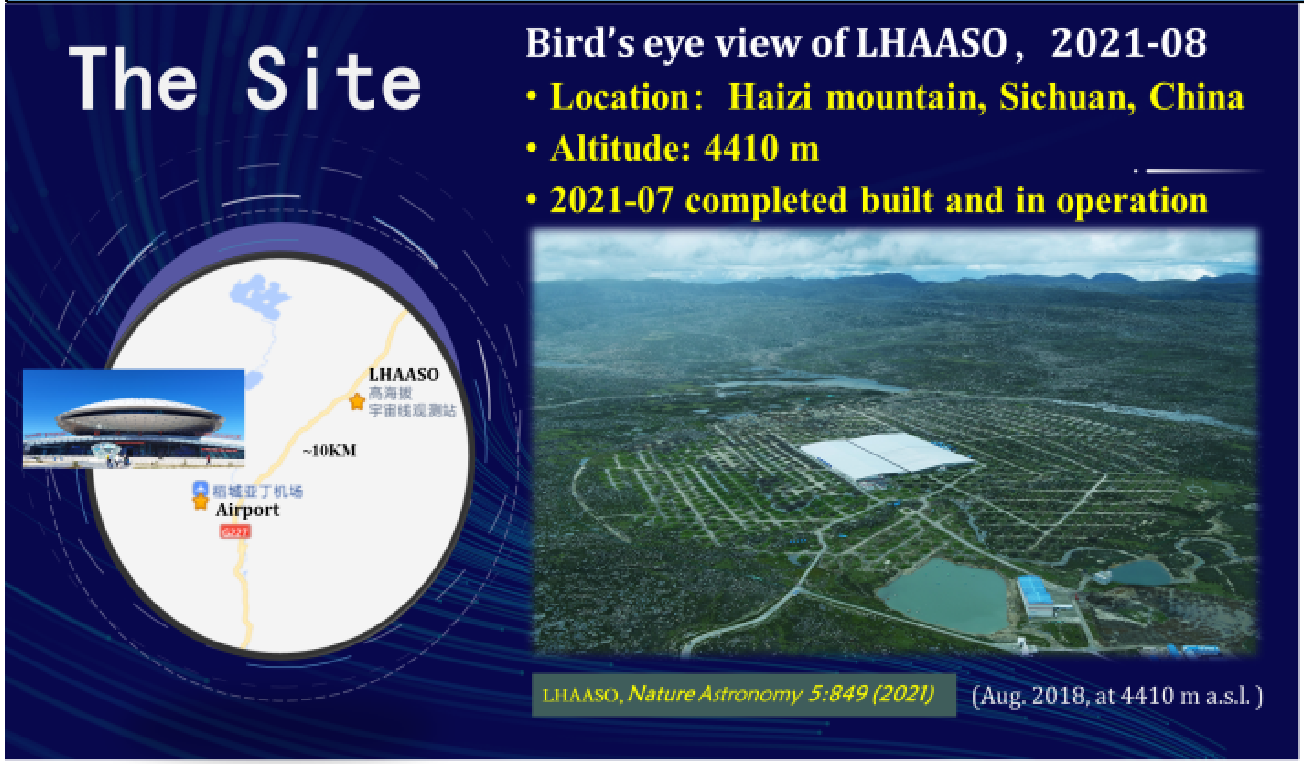
AMS02,Iss-CREAM,DAMPE,LHAASO……

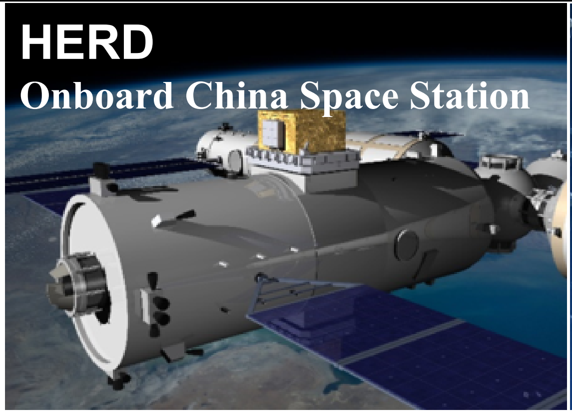


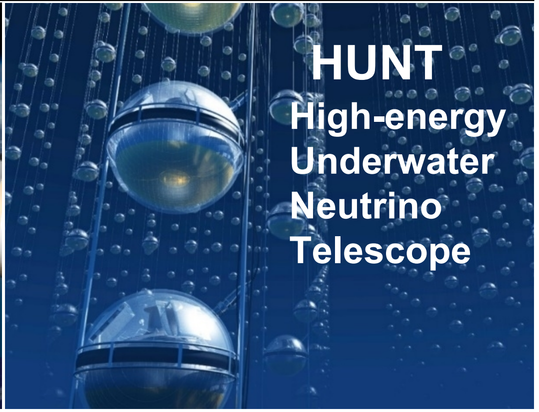
PAD roadmap of CR experiments

- **Cosmic Ray Experiment Development Roadmap of PAD**

Subjects	Projects in operation	Projects in construction	In R&D and for mission adoption
Origin of cosmic rays	LHAASO	HERD/LACT	HUNT

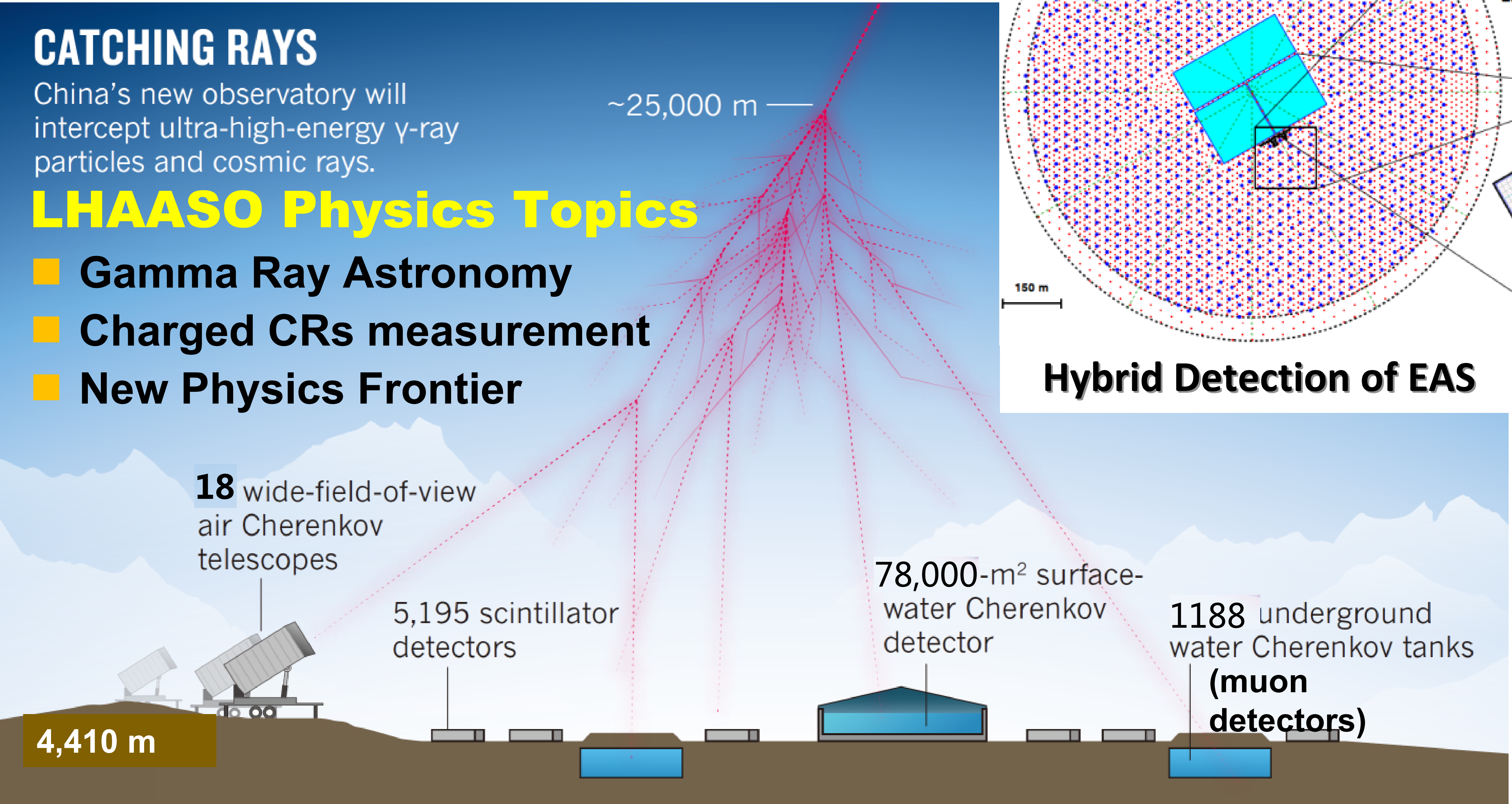






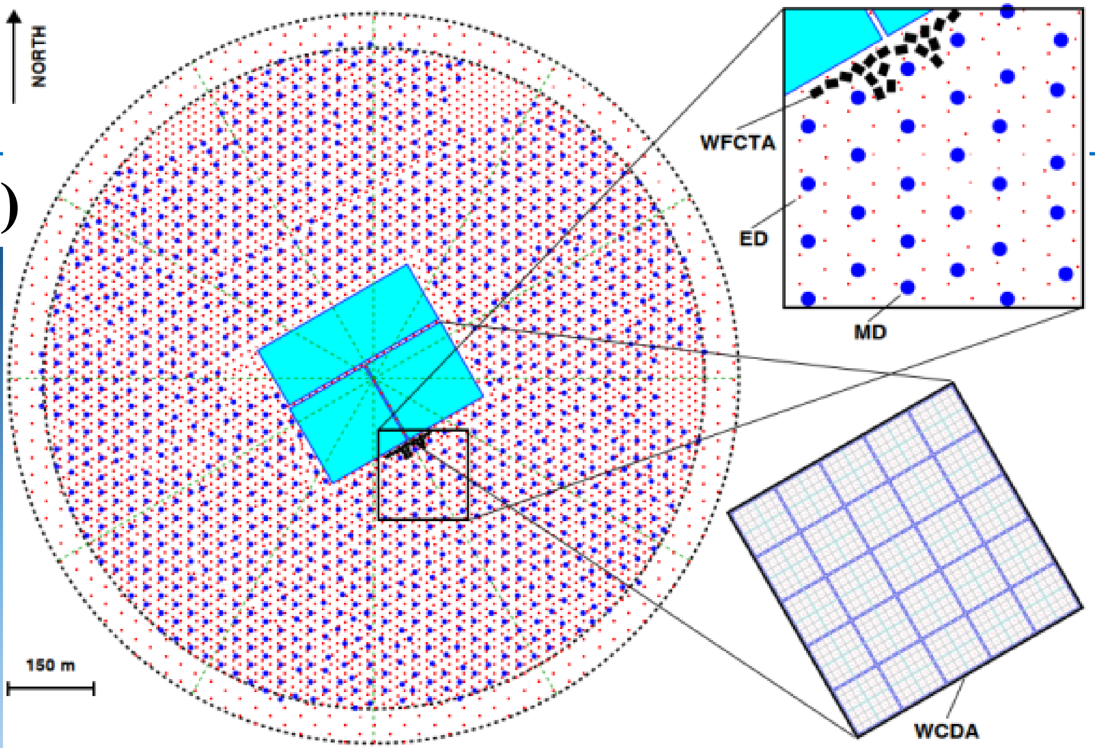
High Energy Cosmic Rays

Large High Altitude Air Shower Observatory (LHAASO)



LHAASO Physics Topics

- Gamma Ray Astronomy
- Charged CRs measurement
- New Physics Frontier

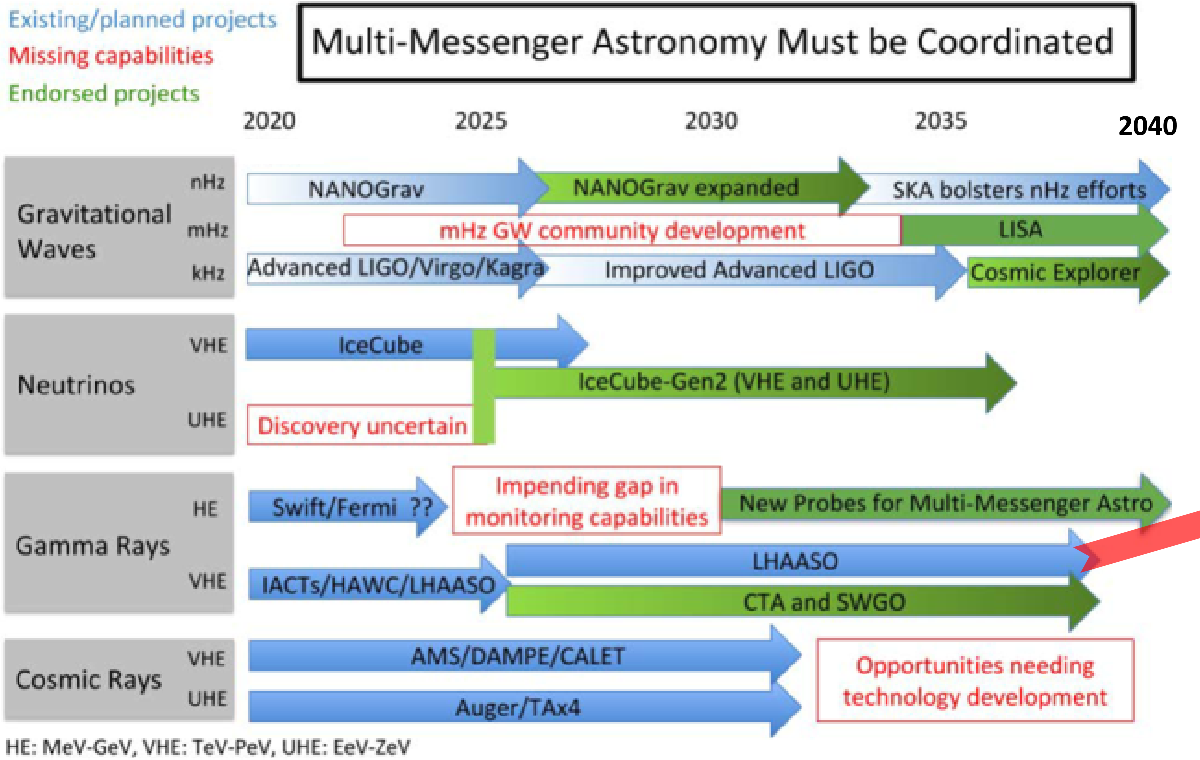


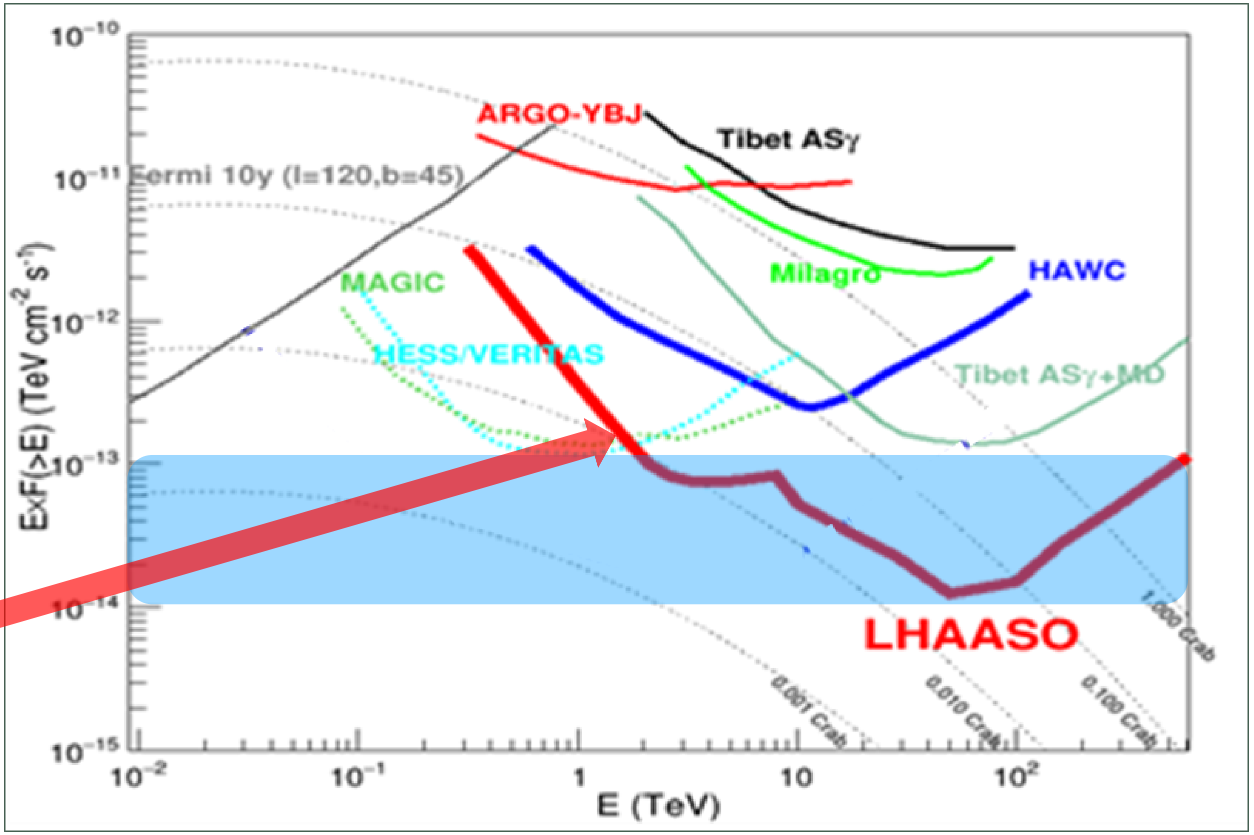
Hybrid Detection of EAS

LHAASO: A dual-purpose observational facility CR/γ-ray

- **Astro2020 put LHAASO such a leading position in γ-ray experiments in the world**
  - **The highest sensitivity in ultra-high energy γ-ray detection ~10^{-14} erg/cm^2/s**
  - **The highest all-sky survey sensitivity in very high energy γ-rays**

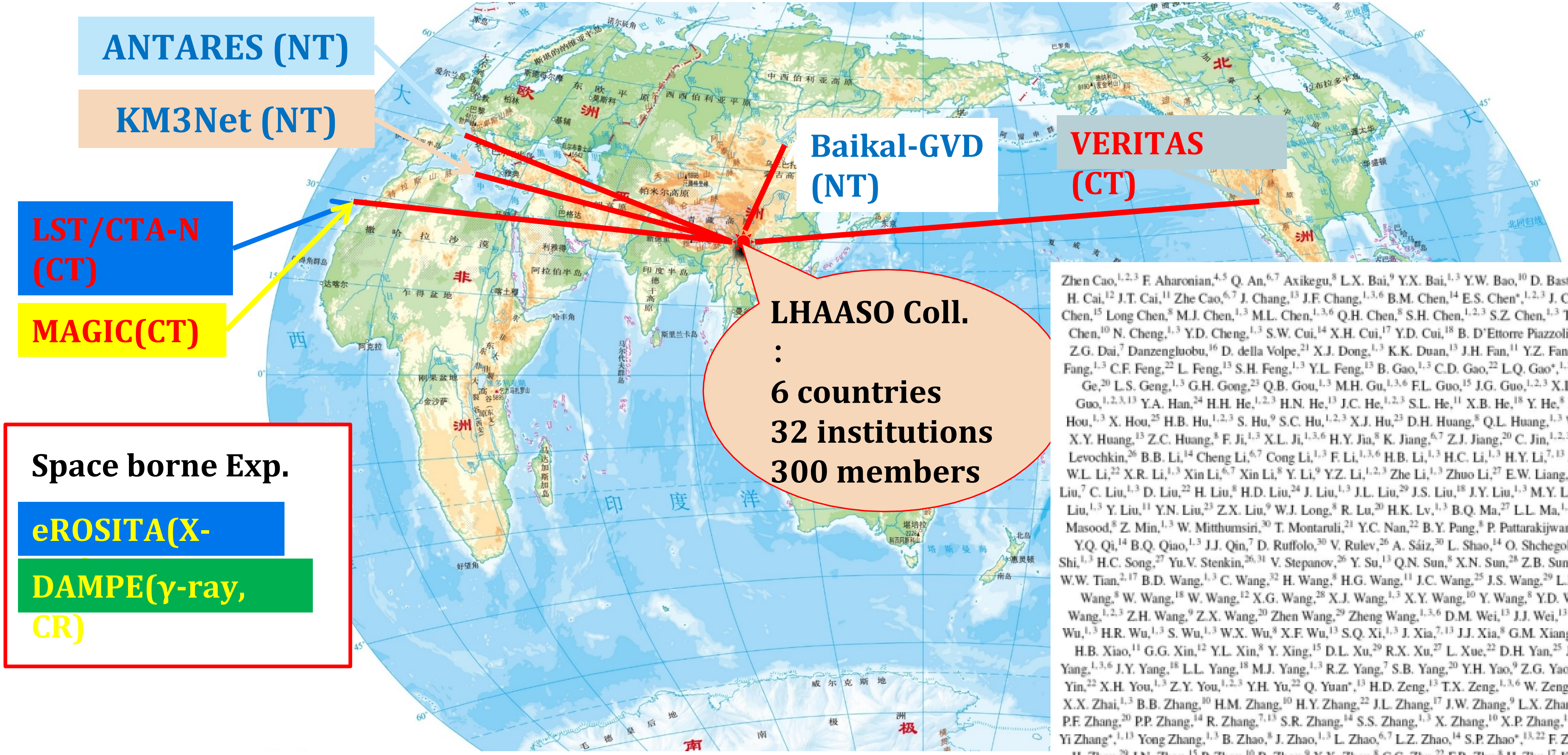
USA released the Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020) in 2021





LHAASO: Multi-Messenger Collaboration Network

The LHAASO collaboration has signed MOUs with 8 international detector collaboration.



Zhen Cao,[1,2,3] F. Aharonian,[4,5] Q. An,[6,7] Axikegu,[8] L.X. Bai,[9] Y.X. Bai,[1,3] Y.W. Bao,[10] D. Bastieri,[11] X.J. Bi*,[1,2,3] Y.J. Bi,[1,3] H. Cai,[12] J.T. Cai,[11] Zhe Cao,[6,7] J. Chang,[13] J.F. Chang,[1,3,6] B.M. Chen,[14] E.S. Chen*,[1,2,3] J. Chen,[9] Liang Chen,[1,2,3] Liang Chen,[15] Long Chen,[8] M.J. Chen,[1,3] M.L. Chen,[1,3,6] Q.H. Chen,[8] S.H. Chen,[1,2,3] S.Z. Chen,[1,3] T.L. Chen,[16] X.L. Chen,[1,2,3] Y. Chen,[10] N. Cheng,[1,3] Y.D. Cheng,[1,3] S.W. Cui,[14] X.H. Cui,[17] Y.D. Cui,[18] B. D'Ettorre Piazzoli,[19] B.Z. Dai,[20] H.L. Dai,[1,3,6] Z.G. Dai,[7] Danzengluobu,[16] D. della Volpe,[21] X.J. Dong,[1,3] K.K. Duan,[13] J.H. Fan,[11] Y.Z. Fan,[13] Z.X. Fan,[1,3] J. Fang,[20] K. Fang,[1,3] C.F. Feng,[22] L. Feng,[13] S.H. Feng,[1,3] Y.L. Feng,[13] B. Gao,[1,3] C.D. Gao,[22] L.Q. Gao*,[1,2,3] Q. Gao,[16] W. Gao,[22] M.M. Ge,[20] L.S. Geng,[1,3] G.H. Gong,[23] Q.B. Gou,[1,3] M.H. Gu,[1,3,6] F.L. Guo,[15] J.G. Guo,[1,2,3] X.L. Guo,[8] Y.Q. Guo,[1,3] Y.Y. Guo,[1,2,3,13] Y.A. Han,[24] H.H. He,[1,2,3] H.N. He,[13] J.C. He,[1,2,3] S.L. He,[11] X.B. He,[18] Y. He,[8] M. Heller,[21] Y.K. Hor,[18] C. Hou,[1,3] X. Hou,[25] H.B. Hu,[1,2,3] S. Hu,[9] S.C. Hu,[1,2,3] X.J. Hu,[23] D.H. Huang,[8] Q.L. Huang,[1,3] W.H. Huang,[22] X.T. Huang,[22] X.Y. Huang,[13] Z.C. Huang,[8] F. Ji,[1,3] X.L. Ji,[1,3,6] H.Y. Jia,[8] K. Jiang,[6,7] Z.J. Jiang,[20] C. Jin,[1,2,3] T. Ke,[1,3] D. Kuleshov,[26] K. Levochkin,[26] B.B. Li,[14] Cheng Li,[6,7] Cong Li,[1,3] F. Li,[1,3,6] H.B. Li,[1,3] H.C. Li,[1,3] H.Y. Li,[7,13] Jian Li,[7] Jie Li,[1,3,6] K. Li,[1,3] W.L. Li,[22] X.R. Li,[1,3] Xin Li,[6,7] Xin Li,[8] Y. Li,[9] Y.Z. Li,[1,2,3] Zhe Li,[1,3] Zhuo Li,[27] E.W. Liang,[28] Y.F. Liang,[28] S.J. Lin,[18] B. Liu,[7] C. Liu,[1,3] D. Liu,[22] H. Liu,[8] H.D. Liu,[24] J. Liu,[1,3] J.L. Liu,[29] J.S. Liu,[18] J.Y. Liu,[1,3] M.Y. Liu,[16] R.Y. Liu,[10] S.M. Liu,[8] W. Liu,[1,3] Y. Liu,[11] Y.N. Liu,[23] Z.X. Liu,[9] W.J. Long,[8] R. Lu,[20] H.K. Lv,[1,3] B.Q. Ma,[27] L.L. Ma,[1,3] X.H. Ma,[1,3] J.R. Mao,[25] A. Masood,[8] Z. Min,[1,3] W. Mitthumsiri,[30] T. Montaruli,[21] Y.C. Nan,[22] B.Y. Pang,[8] P. Pattarakijwanich,[30] Z.Y. Pei,[11] M.Y. Qi,[1,3] Y.Q. Qi,[14] B.Q. Qiao,[1,3] J.J. Qin,[7] D. Ruffolo,[30] V. Rulev,[26] A. Sáiz,[30] L. Shao,[14] O. Shchegolev,[26,31] X.D. Sheng,[1,3] J.R. Shi,[1,3] H.C. Song,[27] Yu.V. Stenkin,[26,31] V. Stepanov,[26] Y. Su,[13] Q.N. Sun,[8] X.N. Sun,[28] Z.B. Sun,[32] P.H.T. Tam,[18] Z.B. Tang,[6,7] W.W. Tian,[2,17] B.D. Wang,[1,3] C. Wang,[32] H. Wang,[8] H.G. Wang,[11] J.C. Wang,[25] J.S. Wang,[29] L.P. Wang,[22] L.Y. Wang,[1,3] R.N. Wang,[8] W. Wang,[18] W. Wang,[12] X.G. Wang,[28] X.J. Wang,[1,3] X.Y. Wang,[10] Y. Wang,[8] Y.D. Wang,[1,3] Y.J. Wang,[1,3] Y.P. Wang,[1,2,3] Z.H. Wang,[9] Z.X. Wang,[20] Zhen Wang,[29] Zheng Wang,[1,3,6] D.M. Wei,[13] J.J. Wei,[13] Y.J. Wei,[1,2,3] T. Wen,[20] C.Y. Wu,[1,3] H.R. Wu,[1,3] S. Wu,[1,3] W.X. Wu,[8] X.F. Wu,[13] S.Q. Xi,[1,3] J. Xia,[7,13] J.J. Xia,[8] G.M. Xiang,[2,15] D.X. Xiao,[16] G. Xiao,[1,3] H.B. Xiao,[11] G.G. Xin,[12] Y.L. Xin,[8] Y. Xing,[15] D.L. Xu,[29] R.X. Xu,[27] L. Xue,[22] D.H. Yan,[25] J.Z. Yan,[13] C.W. Yang,[9] F.F. Yang,[1,3,6] J.Y. Yang,[18] L.L. Yang,[18] M.J. Yang,[1,3] R.Z. Yang,[7] S.B. Yang,[20] Y.H. Yao,[9] Z.G. Yao,[1,3] Y.M. Ye,[23] L.Q. Yin,[1,3] N. Yin,[22] X.H. You,[1,3] Z.Y. You,[1,2,3] Y.H. Yu,[22] Q. Yuan*,[13] H.D. Zeng,[13] T.X. Zeng,[1,3,6] W. Zeng,[20] Z.K. Zeng,[1,2,3] M. Zha,[1,3] X.X. Zhai,[1,3] B.B. Zhang,[10] H.M. Zhang,[10] H.Y. Zhang,[22] J.L. Zhang,[17] J.W. Zhang,[9] L.X. Zhang,[11] Li Zhang,[20] Lu Zhang,[14] P.F. Zhang,[20] P.P. Zhang,[14] R. Zhang,[7,13] S.R. Zhang,[14] S.S. Zhang,[1,3] X. Zhang,[10] X.P. Zhang,[1,3] Y.F. Zhang,[8] Y.L. Zhang,[1,3] Yi Zhang*,[1,13] Yong Zhang,[1,3] B. Zhao,[8] J. Zhao,[1,3] L. Zhao,[6,7] L.Z. Zhao,[14] S.P. Zhao*,[13,22] F. Zheng,[32] Y. Zheng,[8] B. Zhou,[1,3] H. Zhou,[29] J.N. Zhou,[15] P. Zhou,[10] R. Zhou,[9] X.X. Zhou,[8] C.G. Zhu,[22] F.R. Zhu,[8] H. Zhu,[17] K.J. Zhu,[1,2,3,6] and X. Zuo[1,3]

LHAASO started a new era of UHE γ-ray astronomy

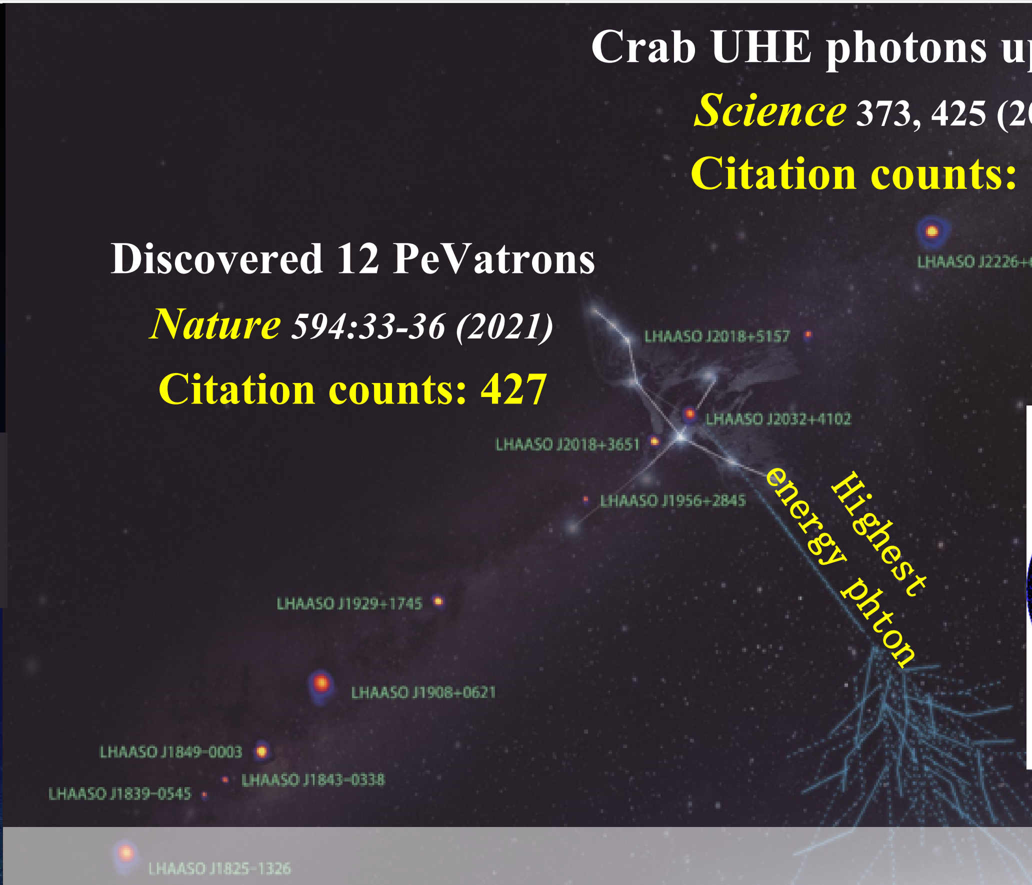
BOAT and highest energy GRB

Science 380, 1390 (2023), *Citation counts: 53*

Science Advance eadj2778 (2023)

LHAASO performance

Nature Astron. 5, 8, 849 (2021)



Discovered 12 PeVatrons

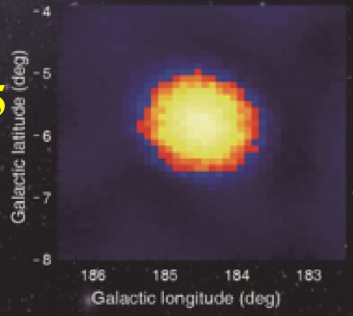
Nature 594:33-36 (2021)

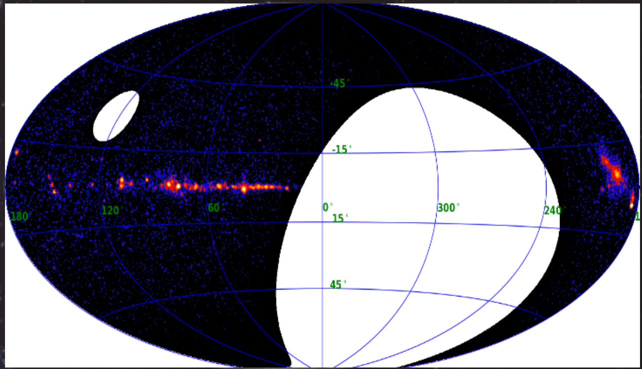
Citation counts: 427

Crab UHE photons up to PeV

Science 373, 425 (2021)

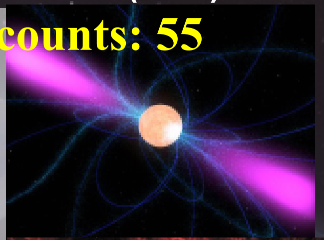
Citation counts: 125





arXiv:2305.17030 (APJ)

Citation counts: 55

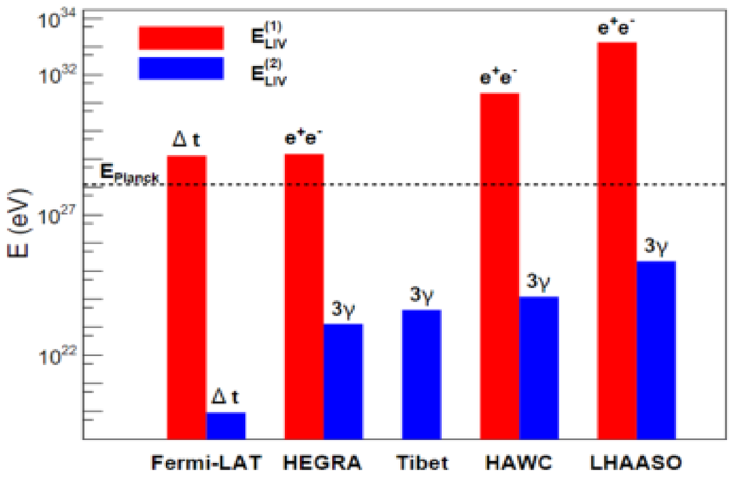


- 1st LHAASO source catalogue: 90 VHE/UHE γ-ray sources
  - Discovered 43 UHE γ-ray source, Revealed a large number of PeVatron candidates in the Milky Way
- The highest energy photon ever observed up to 2 PeV
- Almost all types of HE celestial objects are associated

LHAASO: New Physics Frontier

☐ Testing Lorentz Invariance for any violation

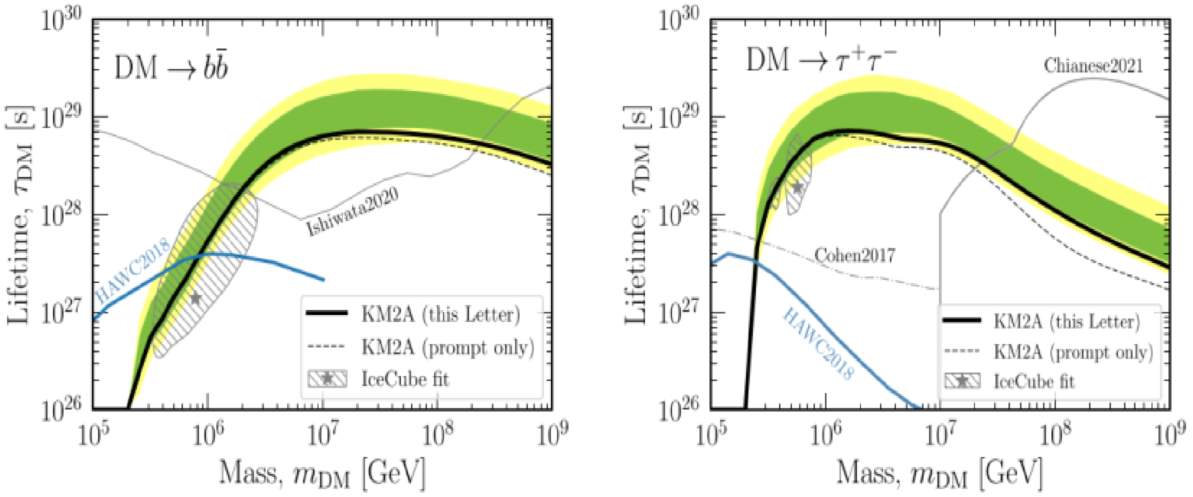
- Using the most energetic γ-rays observed by LHAASO
- The Lorentz symmetry was tested for the 1st order effect with the breaking energy 10^5 higher than the Planck scale, a dozen of times higher than the previous result
- The 2nd order effect is still possible, with the breaking energy 10^3 below the Planck scale



LHAASO Coll., PRL 128, 051102 (2022) ,
Citation counts: 31

☐ Constraints on Heavy Decaying Dark Matter

- 570 Days of LHAASO Observation on the Galactic halo
- The strongest constraints on heavy DM (1 PeV to 10PeV) lifetime is ~10 times higher than existing limits
- Highlighted by PRL in 2022.

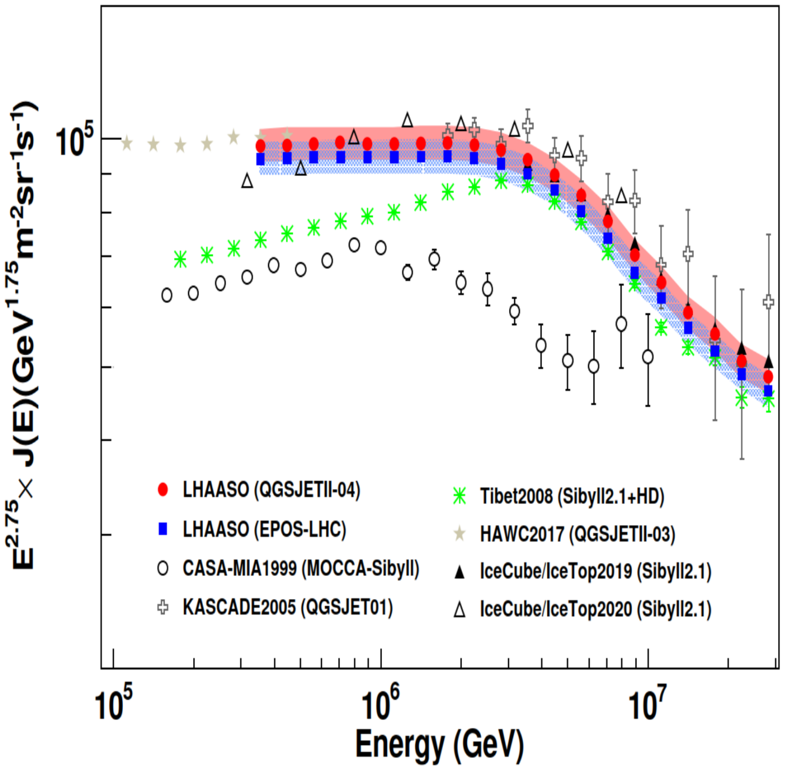


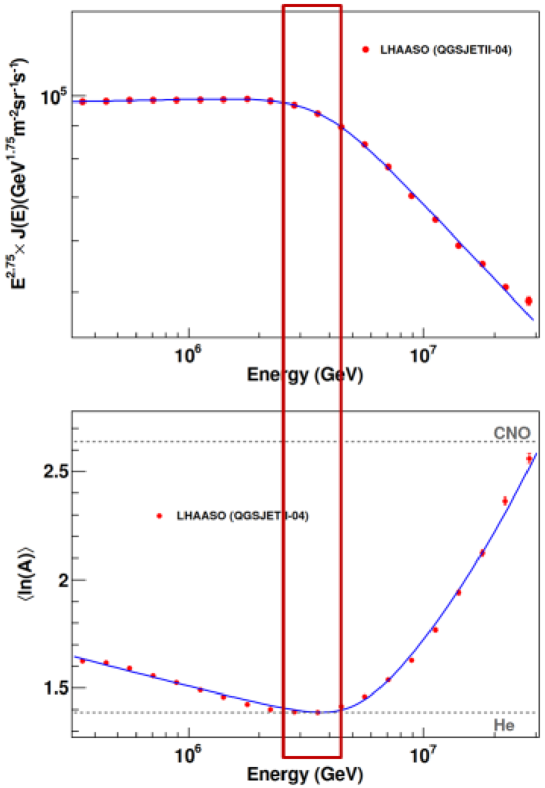
LHAASO collaboration, PRL 129, 261103 (2022)
Citation counts: 22

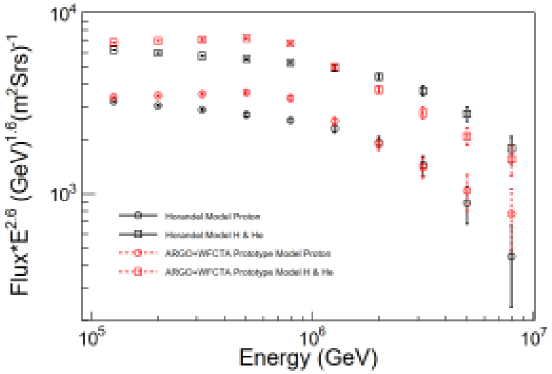
CRs Energy Spectra and Composition

- LHAASO has accurately measured the knee of all particle energy spectrum and composition, and for the first time discovered their correlation
  (PRL, undergoing a second review)

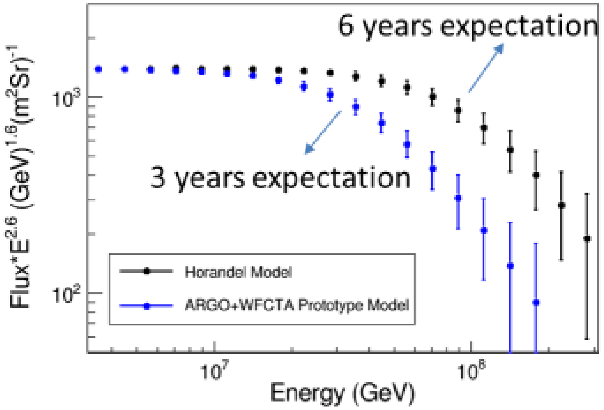
- LHAASO can achieve the knee of proton spectrum and proton + helium spectrum measurements within this year.
- The iron knee energy spectra can be achieved in three years.





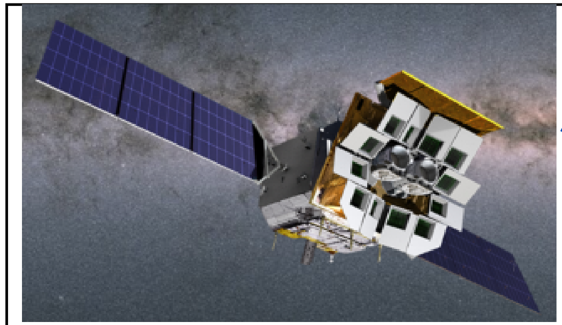


Proton knee expectation by LHAASO

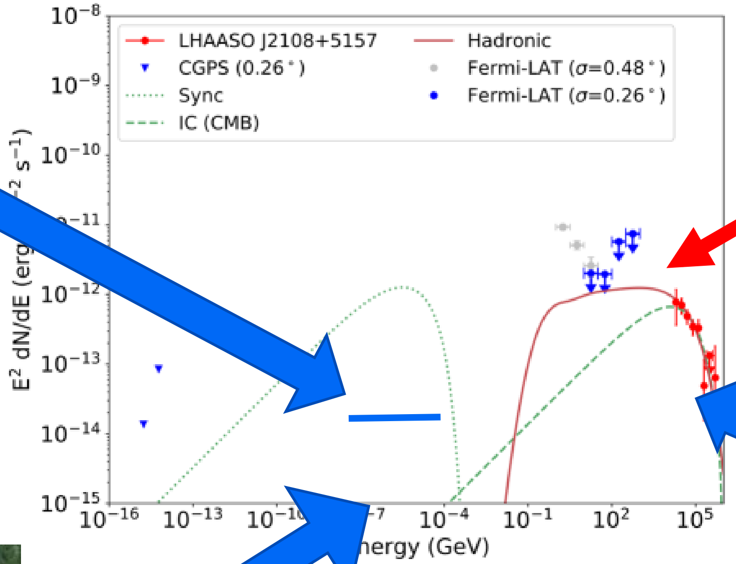


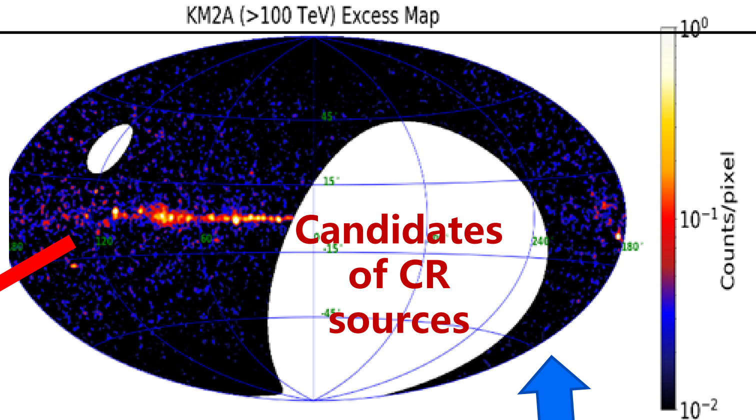
Iron knee expectation by LHAASO

Joint observation of LHAASO, X-ray telescope and Radio telescope



Einstein Probe (EP) was launched a few days ago detects time variation of X-ray spectrum





FAST (radio detector): gas distribution and magnetic field intensity

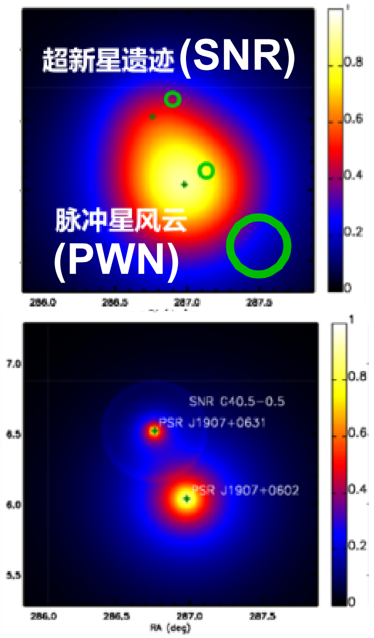
LHAASO discovers new UHE γ-ray sources w/ their SEDs

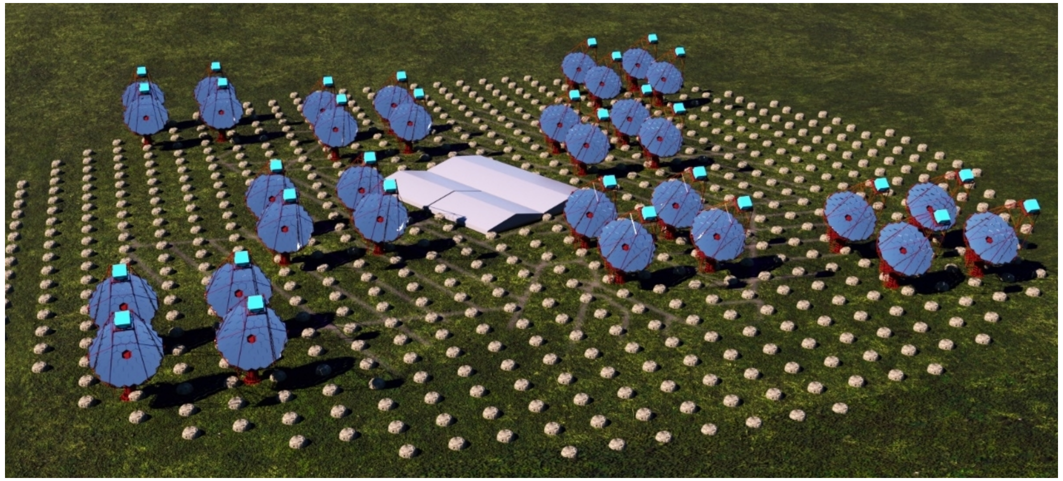
Multiple devices jointly observe and confirm PeV cosmic ray accelerating celestial bodies with unprecedented capabilities

Future Missions：UHE IACT array with LHAASO

➢ Large Array of Cherenkov Telescopes（LACT）

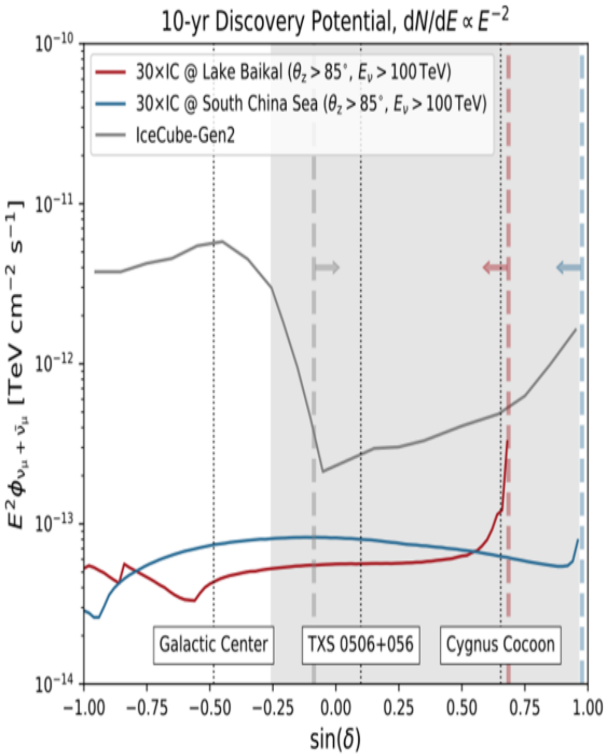
- Next generation of Image Atmosphere Cherenkov Telescope experiment
- 32 telescopes built on LHAASO site
- Angular resolution: < 0.05° @ > 10 TeV
- LHAASO MD array provides γ/p discrimination
- Matching the LHAASO sensitivity with 500 hr/yr
- To identify the gamma ray sources in PeVatrons and measure their morphology in detail, which can help us to reveal the mechanism of the gamma ray emission and then deeply explore the origin of the high energy cosmic rays.

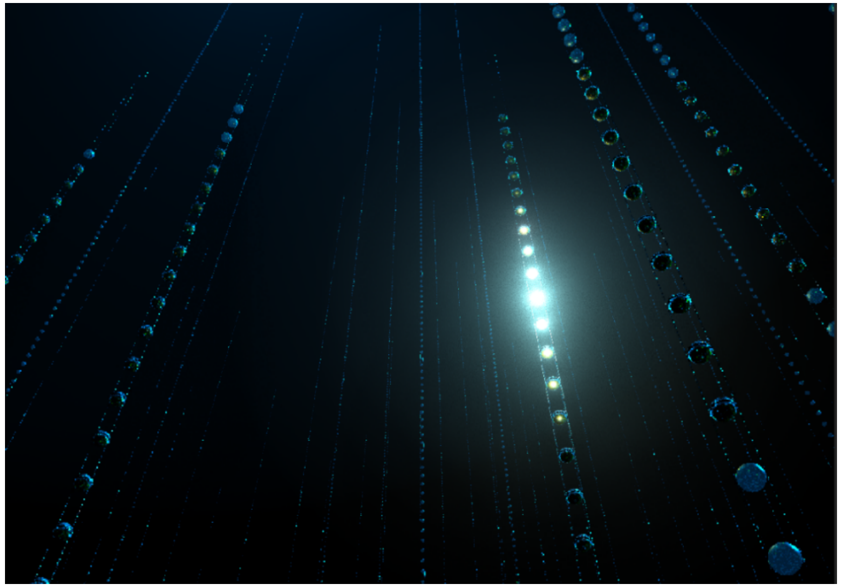


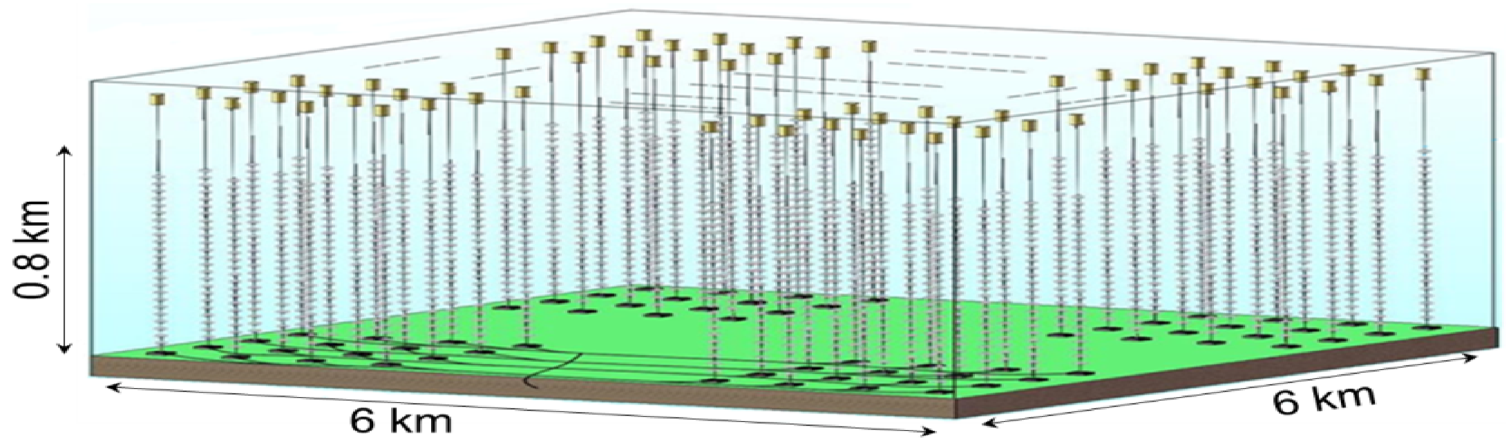


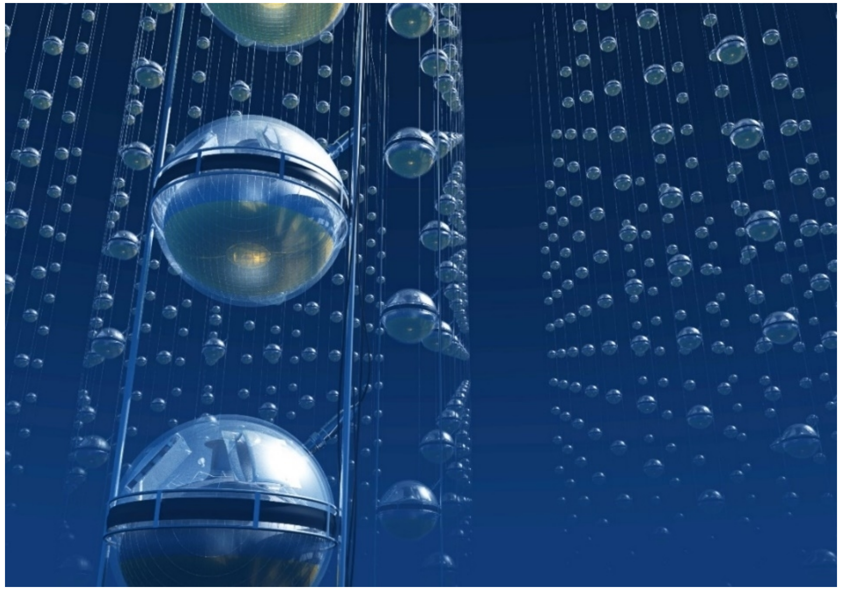
Future Missions : HE neutrino telescope

- **High-energy Underwater Neutrino Telescope (HUNT)**
  - Next generation of neutrino telescope
  - 30 km^3 (sensitivity：100 × IceCube)
  - Candidate site： Lake Baikal or South China Sea
- **Detecting high-energy neutrinos from PeVatrons with 5σ in 3 yrs,** as a final confirmation of the cosmic ray origin



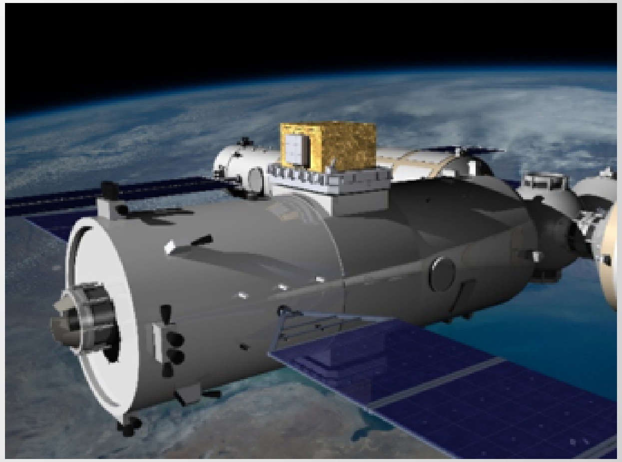






HERD: High Energy Cosmic Radiation Detection Facility

- HERD is a next generation space cosmic ray facility onboard China Space Station.
- HERD is composed of five scientific instruments, including Calorimeter with Intensified scientific CMOS, Tracker, Plastic Scintillation Detector **,** Silicon Charge Detector and Transition Radiation Detector.
- The primary instrument in the innermost is a deep 3D imaging calorimeter with an **innovative design** with accepting particles impinging on its top face but also on the four lateral faces.



Scientific Goals:

- **Precise measurement of the cosmic electron spectrum and search for dark matter signals with high sensitivity** , Take leading position in the search for dark matter in space and make a key contribution to solving a most important mystery: the dark matter problem.
- **Cosmic ray origin and cosmic ray physics**, Precise & direct cosmic ray spectrum and composition measurements up to PeV energy, explore the century-old mystery of cosmic ray origin
- **Gamma-ray monitoring with a wide FOV and full sky survey with high sensitivity**, search and identify gamma-ray corresponding celestial bodies of multi-messenger astronomical signals

Parameter	Value
Energy range (e/γ)	10 GeV - 100 TeV (e); 0.5 GeV - 100 TeV (γ)
Energy range (CR)	30 GeV – 5 PeV
Energy resolution (e)	1.5%@200 GeV
Energy resolution (p)	25%@100 GeV – PeV
e/p separation	~$3*10^5$
G.F. (e)	>3 m^2sr@200 GeV
G.F. (p)	>2 m^2sr@100 TeV
Payload mass	≯4300 kg

HERD is expected to be launched around 2027. Current status: Phase B. Ready for phase C.

The scientific requirements analysis, key technology study (crystal array, image intensifier, transition radiation detector, etc), and 2023 beam test have been successfully completed, and the payload system has been fully designed.

Summary

- **LHAASO is the world's leading cosmic ray observation facility**
  - **It has found 43 PeVatrons in our galaxy, thus started the era of UHE γ-ray astronomy**
  - **Discovered many new phenomena:**

    highest energy gamma photon, highest energy GRB …
  - **Its discoveries changed our view about the nonthermal universe**
- **HE CR origins will be identified, extreme accelerators will be revealed,**

  the 'knee' of the single element will be accurately measured,

  the exploration results of DM and LIV will be updated and so on in the near future
- **Propose the next generation of cosmic ray observation facilities**
  - **HERD: is expected to be launched around 2027**
  - **LACT: will receive funding support this year and complete the construction of 32 telescopes on LHAASO site within the next 5 years**
  - **HUNT: an underwater neutrino telescope with 100 times the sensitivity of IceCube is in R&D**

Recruitment needs information of PAD

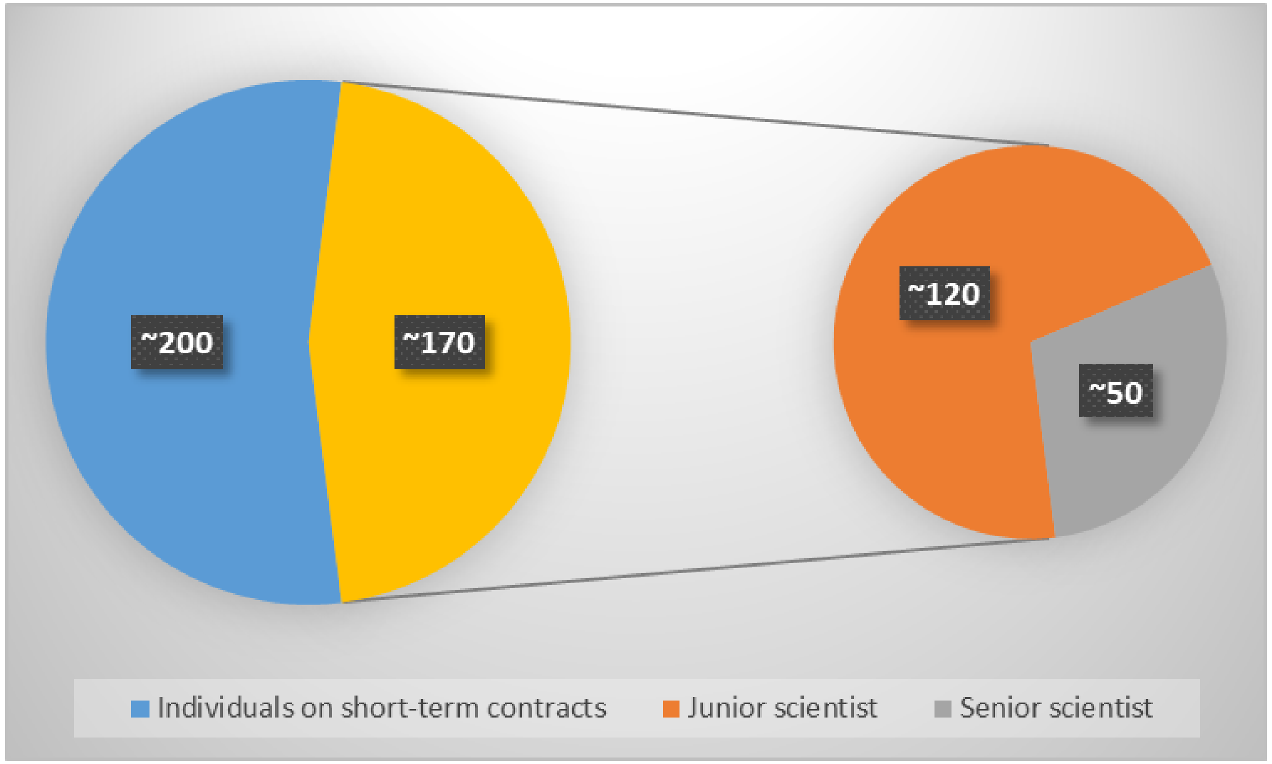
- **High-level Talents for LHAASO, HERD, LACT and HUNT**
- **Postdoctoral position for LHAASO, HERD, LACT and HUNT**
- **LHAASO Postdoctoral Fellowships in Astrophysics (two positions)**
  - **Salary and position will be higher than postdoctoral positions**
- **Visiting Fellowship**
- **For further details and information, please contact:**
  - **Ground based experiment (LHAASO, LACT, HUNT) :**

    Shoushan Zhang, zhangss@ihep.ac.cn
  - **Space based experiment (HERD):**

    Shaolin Xiong, xiongsl@ihep.ac.cn
  - **http://english.ihep.cas.cn/ju/jo/**

Welcome to Join us!

About PAD: general status



- A high-level research team consisting of
  - **~170 permanent employees**, including around **50 senior scientists**
  - **~200 individuals on short-term contracts**, which include **postdoctoral** researchers and graduate **students** from IHEP or adjunct researchers between IHEP and other institutions

The Site

Bird's eye view of LHAASO，2021-08

- **Location： Haizi mountain, Sichuan, China**
- **Altitude: 4410 m**
- **2021-07 completed built and in operation**

LHAASO, ***Nature*** *Astronomy* ***5:849 (2021)***

(Aug. 2018, at 4410 m a.s.l.)