Progresses in γ–ray Astronomy and Cosmic-ray Research

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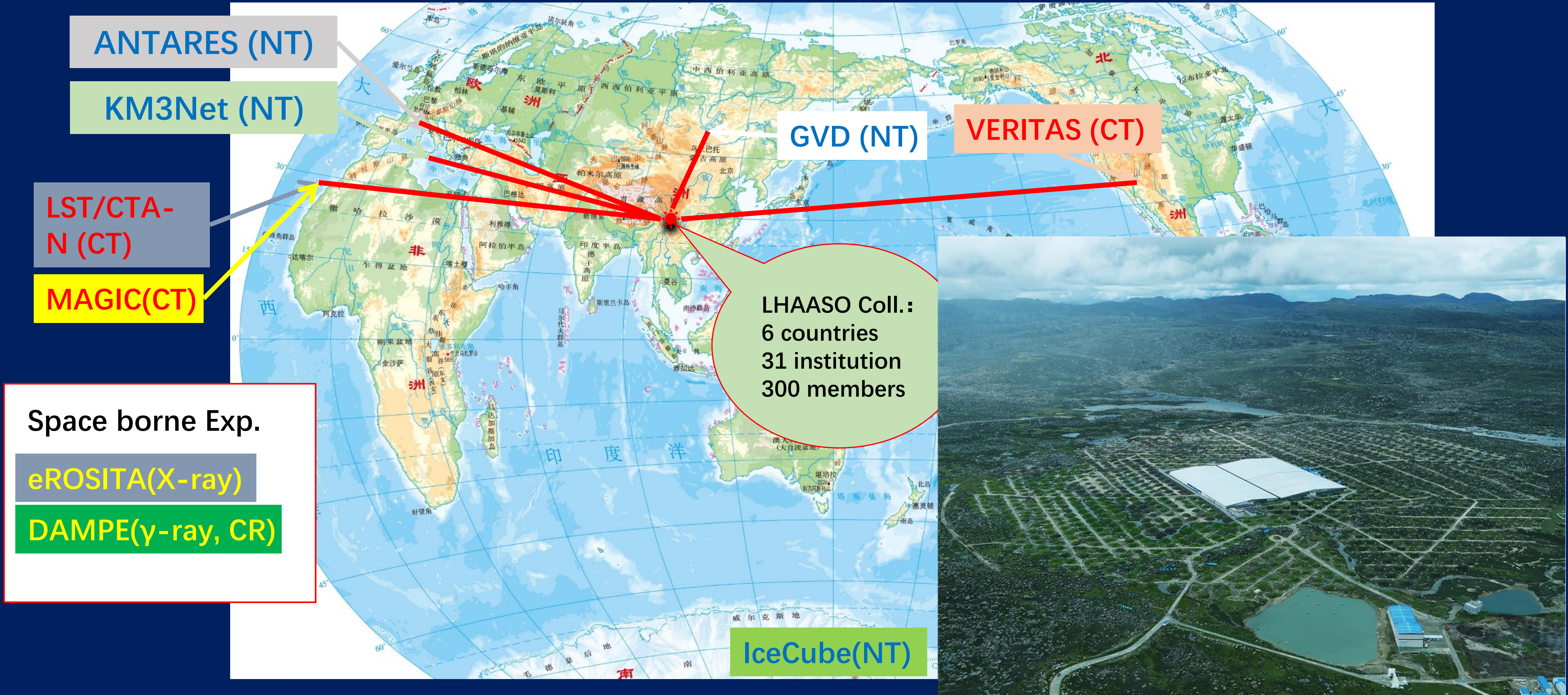
On behalf of LHAASO Collaboration
Institute of High Energy Physics(IHEP),CAS

γ-2024, Milan, 2024.9.

Multi-Messenger Collaboration Network



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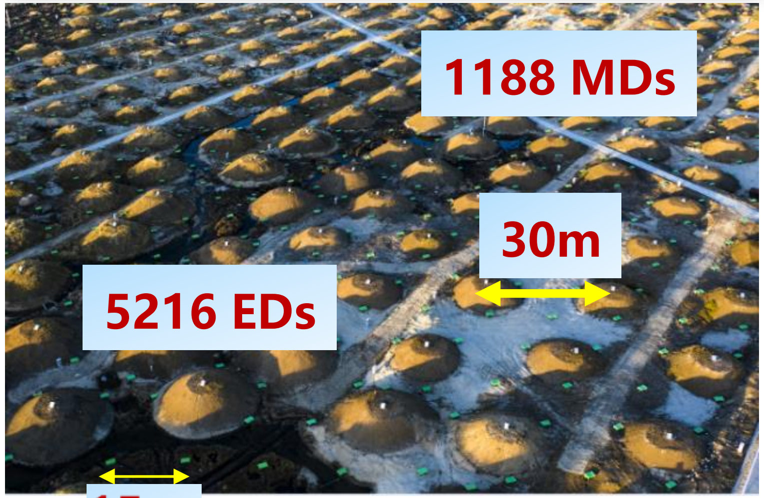
1. Introduction
2. LHAASO Experiment and Data
3. Astronomic Studies
4. Cosmic Ray Sources in the Milky Way
5. Cosmic Ray Diffusion in the Milky Way
6. CR Spectra around the Knees
7. New Physics Searches
8. Future Prospects

LHAASO a complex for both γ-astronomy and Cosmic Ray research

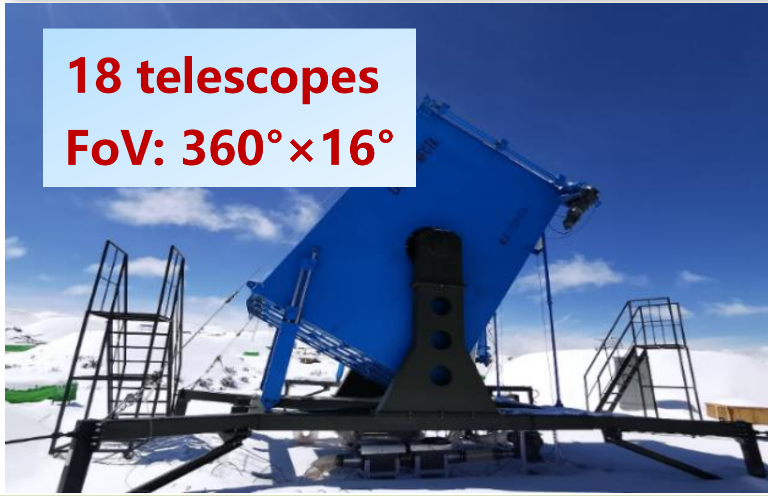
The ½ array started operation in 2019 and the full array in 2021

KM2A: Scintillator counters (ED) and muon counters (MD)	Water Cherenkov Detector Array (78,000 m²)	Wide FoV Cherenkov Telescope Array



Very sensitive γ-ray telescope above 10 TeV (~15 mCU)

Very sensitive γ-ray survey telescope above 1 TeV (15 mCU)



Very unique spectrometer of CR H, He and Fe above 30 TeV

Large High Altitude Air Shower Observatory

LHAASO

The ultimate goal is to identify origins of CRs

Scientific Goals

γ-ray astronomy:

Survey for sources (above 500 GeV)

PeVatrons (above 100 TeV)

All kind of sources: SNR, PWN, MYC, binary, pulsar, AGN, GRB etc.

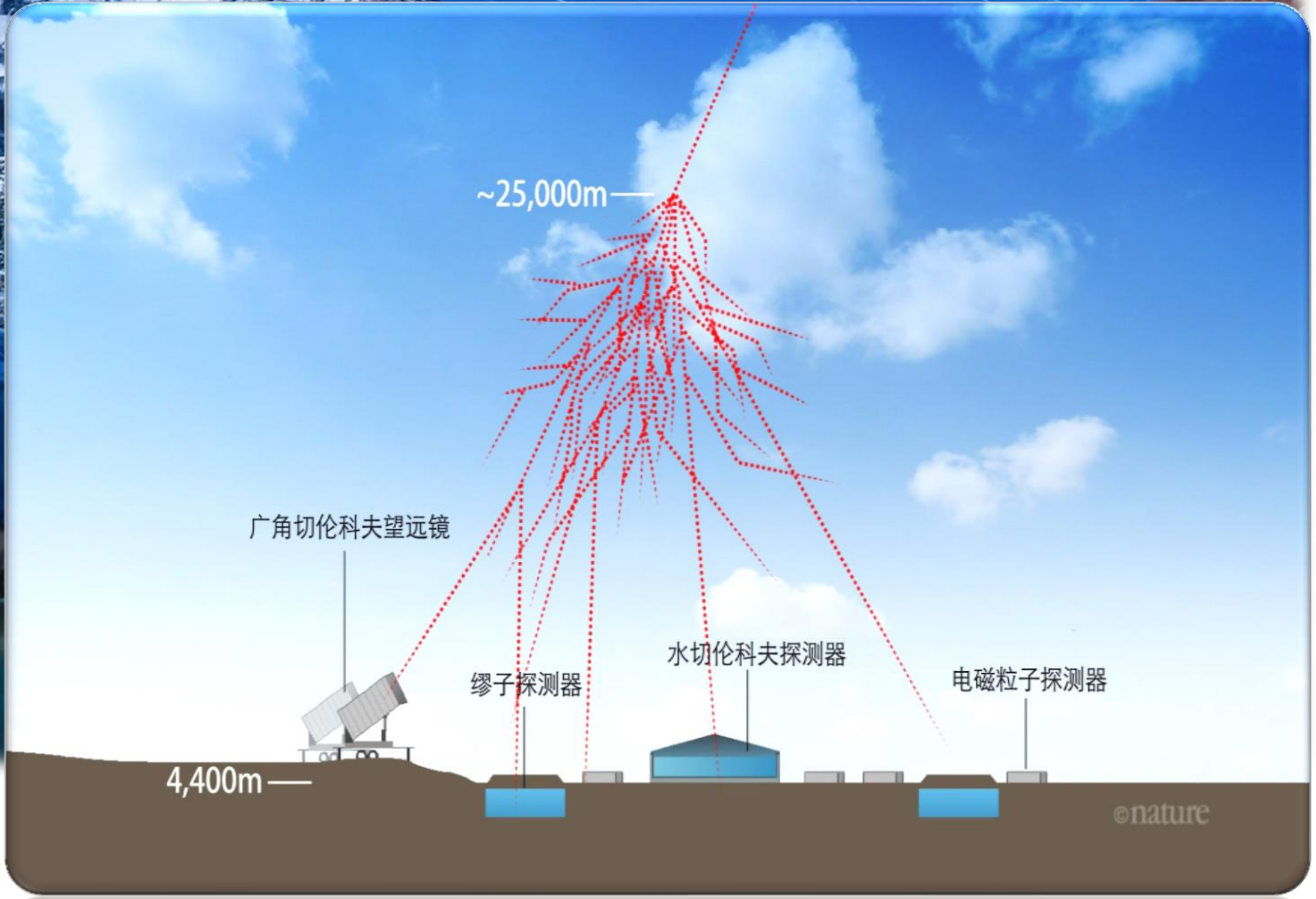
Cosmic Ray Physics:

The knees

Compositions : individual species H, He and Fe

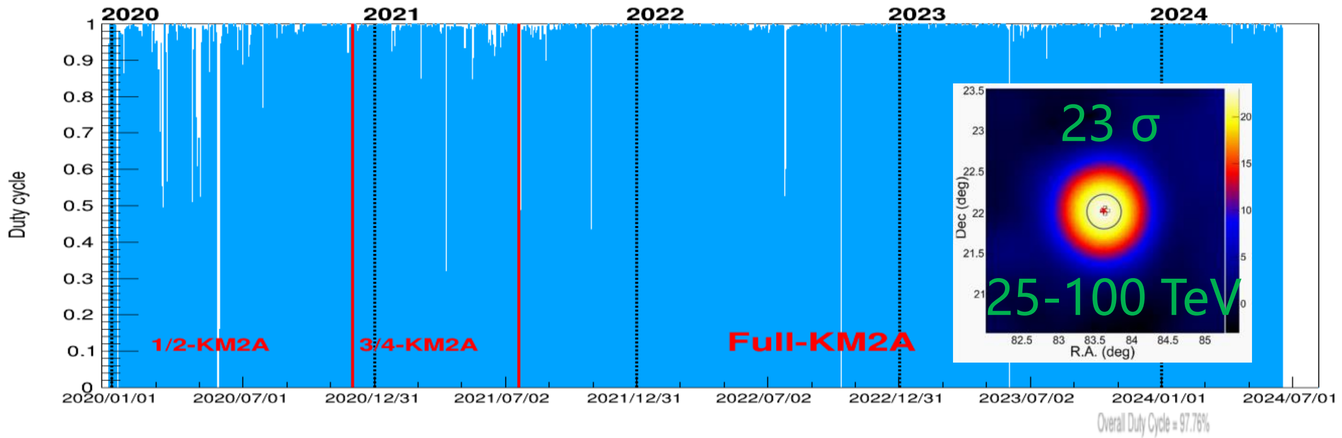
Anisotropy: (1 TeV to 10 PeV)

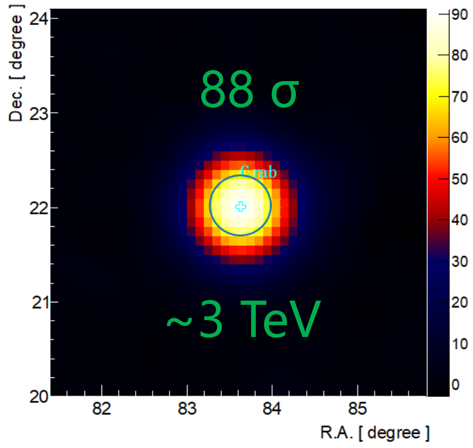
New Physics Front: DM, LIV, etc.

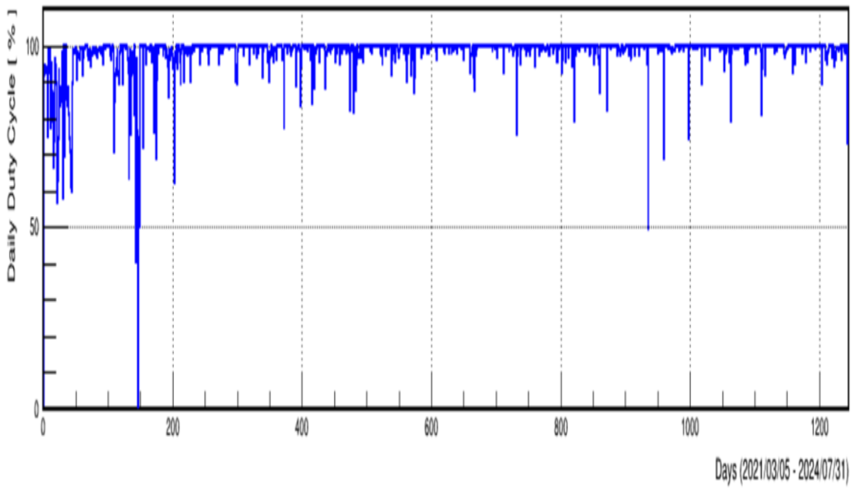


LHAASO Operation: Stable and High Quality

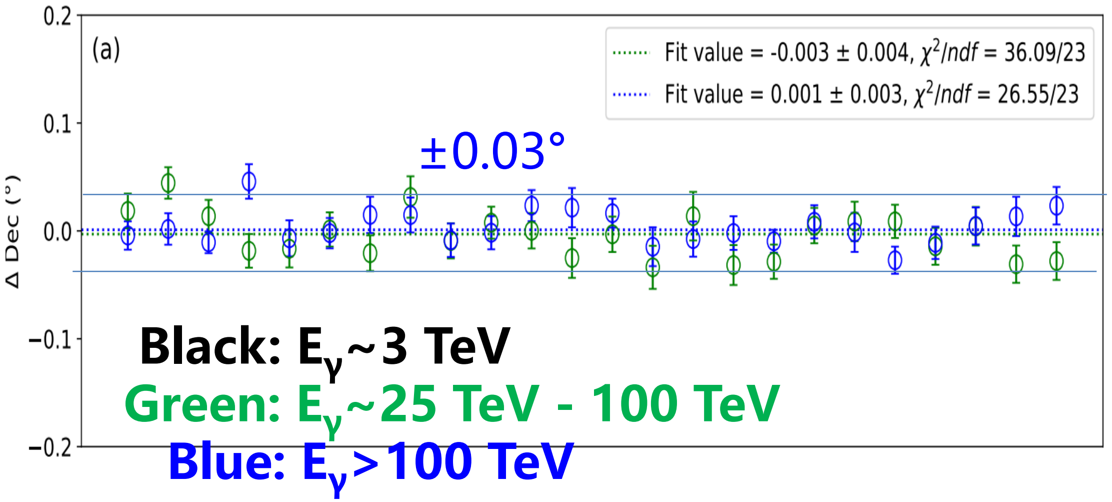
Duty Cycle>98% with failure rate<2%

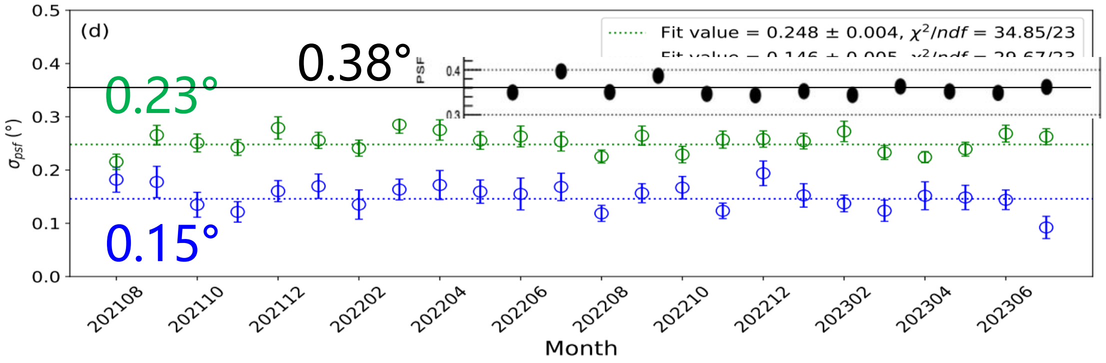






Pointing acurracy and resolution

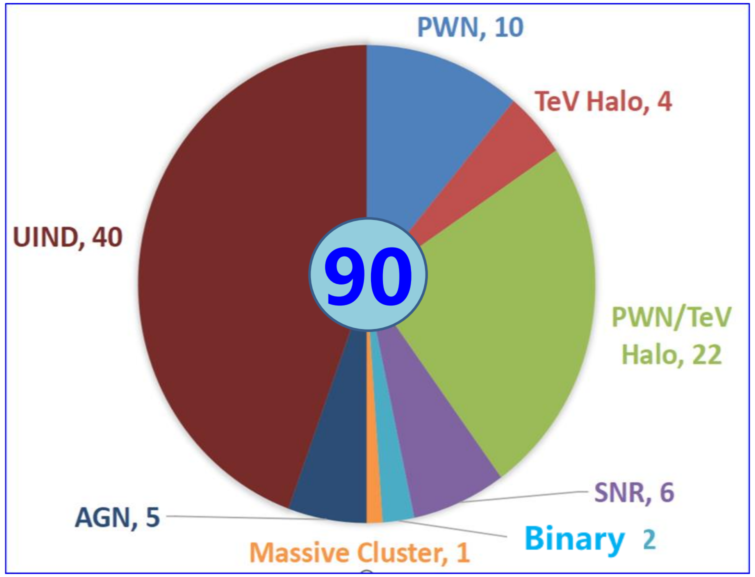




γ-ray Astronomy

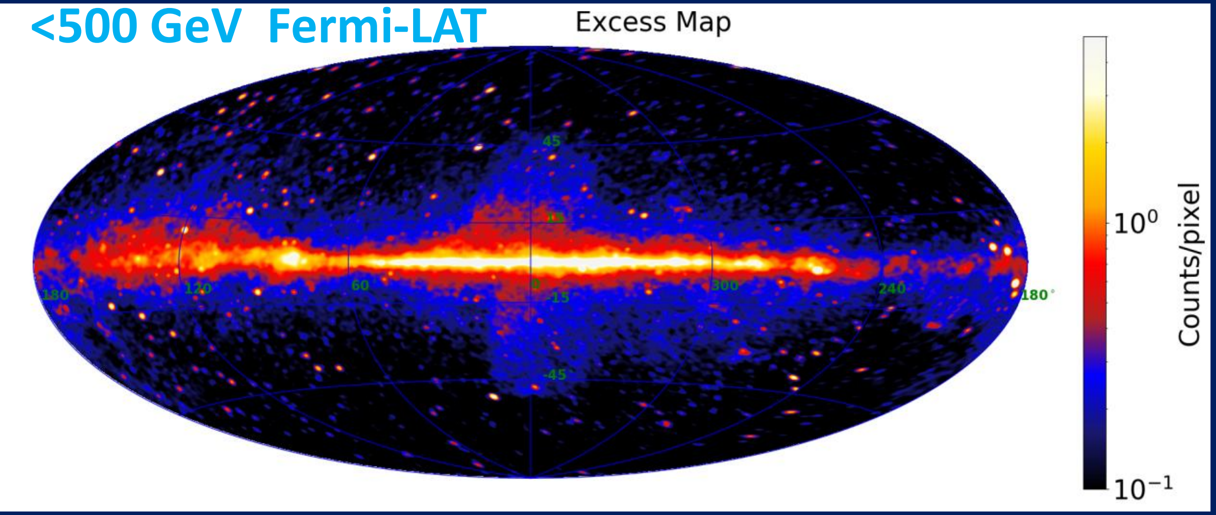
1. AGN, GRB and EBL
2. Microquasars
3. SNRs and Pulsar Halos
4. PWN and YMSC

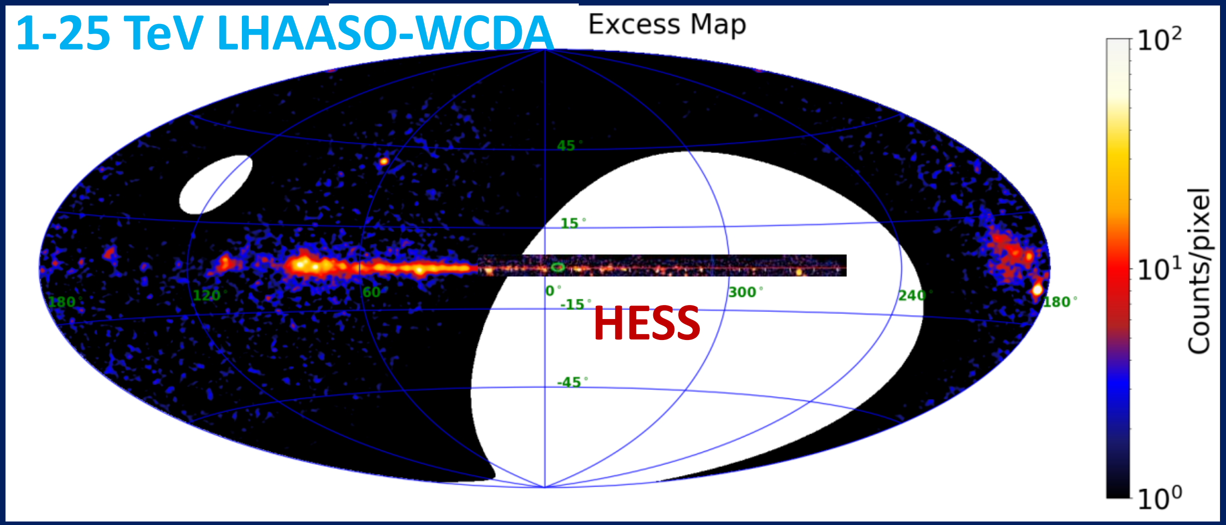
LHAASO Sources

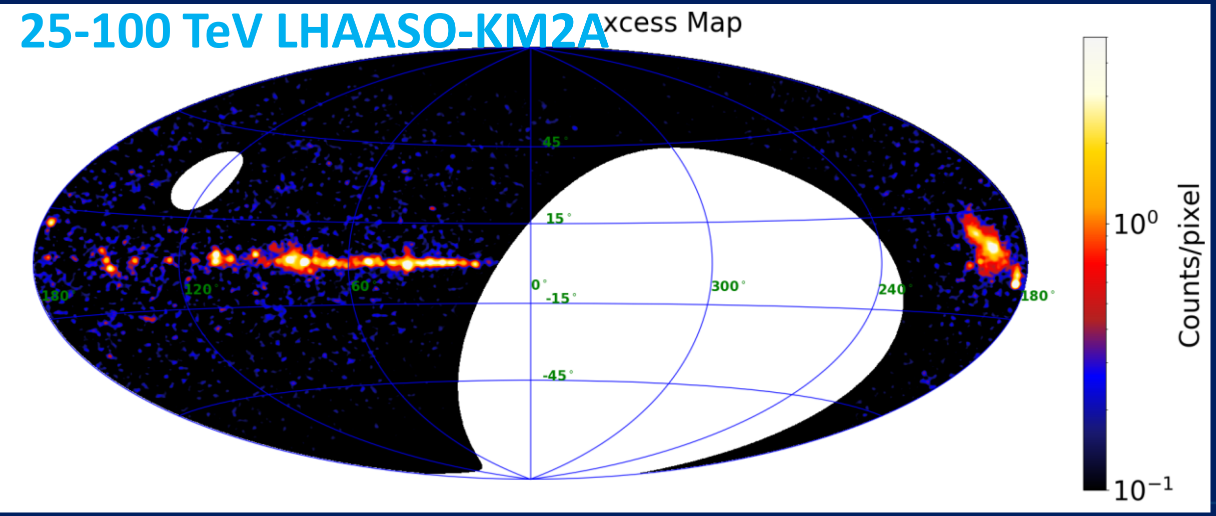


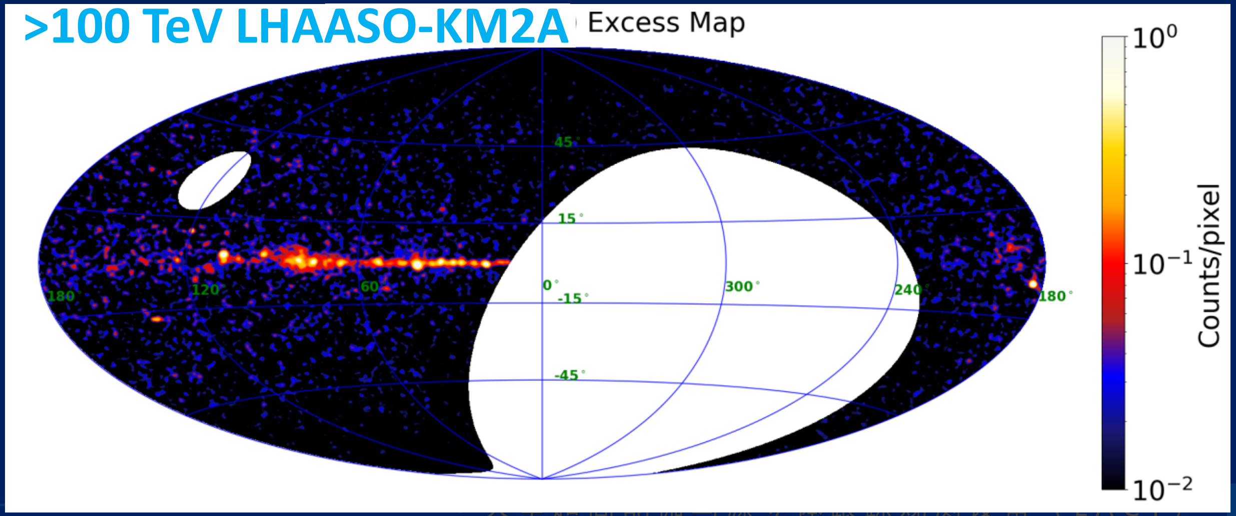
UHE γ-ray Astronomy: sources and diffuse emission

- **Survey discovered 30+ new sources, 40+ PeVatrons and diffuse γ-ray emission**



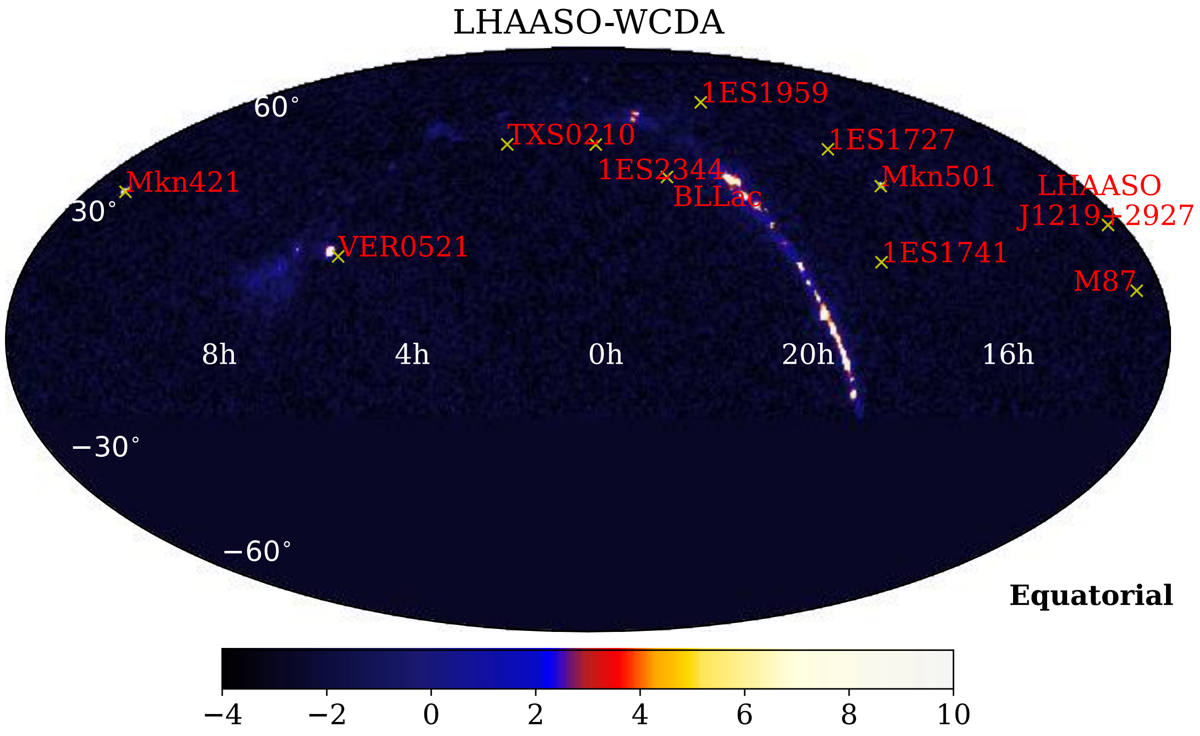






LHAASO AGNs

1. A Survey of extra-galactic sources with full-WCDA data (508 days)



Credit: Min Zha

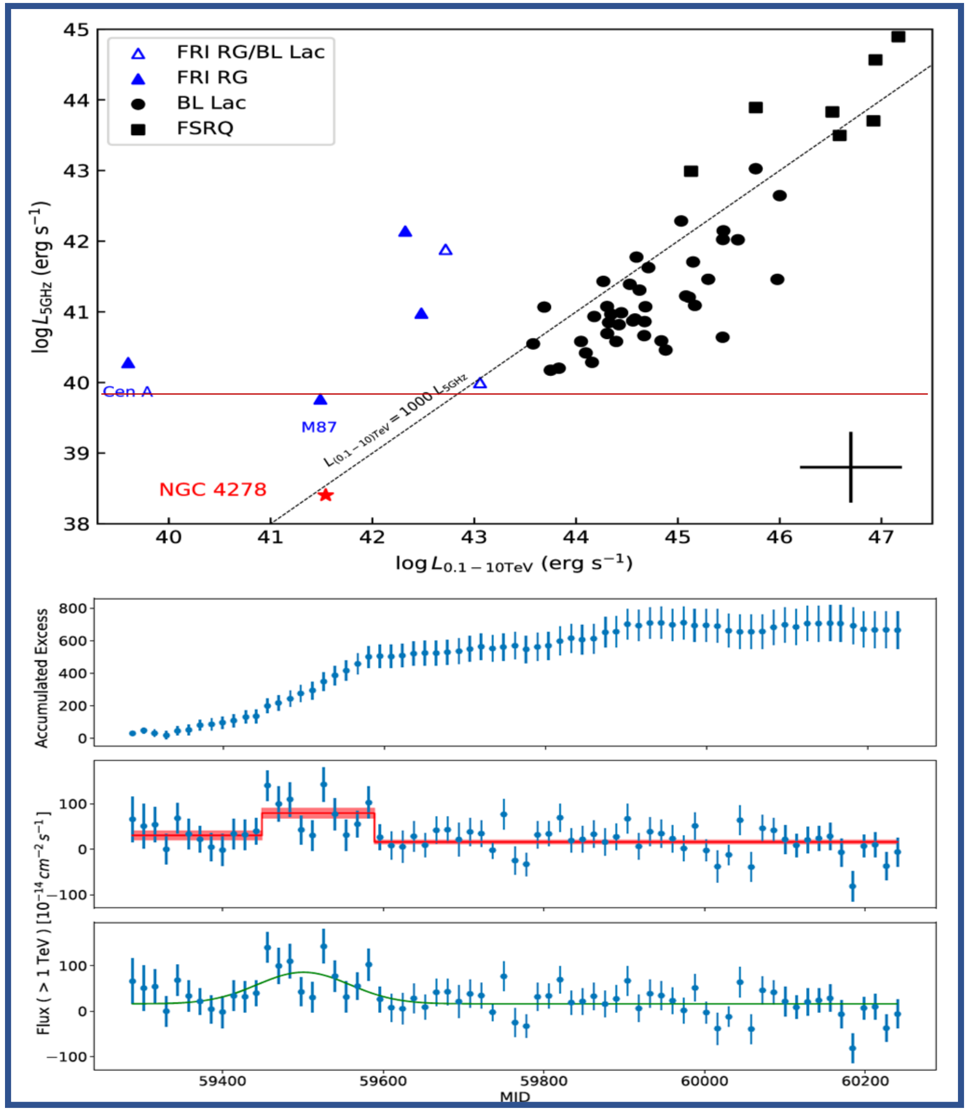
5 sources above 6σ are detected.

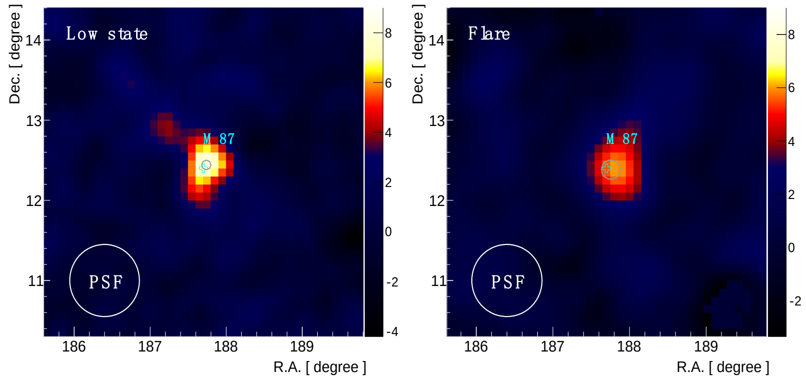
Name	RA[°]	Dec[°]	Significance[s.d]	Separation[°]
Mkn421	166.05	38.15	70.84	0.05
Mkn501	253.45	39.75	63.97	0.02
1ES2344+514	356.75	51.65	6.76	0.06
LHAASO J1219+2916	**184.95**	**29.25**	**6.71**	**x**
1ES1727+502	261.95	50.25	6.52	0.09
RXJ0648.7+1516	102.15	15.35	5.10	0.09
M87	**187.75**	**12.45**	**5.07**	**0.07**
TXS0210+515	33.65	51.75	4.95	0.05
1ES1741+196	265.85	19.55	4.41	0.15
BLLacertae	330.67	42.27	4.38	0.18
VER0521+211	80.55	21.05	4.23	0.19
1ES1959+650	299.65	65.05	4.18	0.18
W Comae	185.35	28.45	4.10	0.22

Active Galactic Nuclei

ApJL, Vol,971, No.2, L45, 2024

- The 1st Low luminosity AGN @ TeV NGC 4279
- First time measured the **duty cycle** for M87 and Mrk 421 etc.
- The size of the TeV emission is ~ few Schwarzchild radii of SMBHs



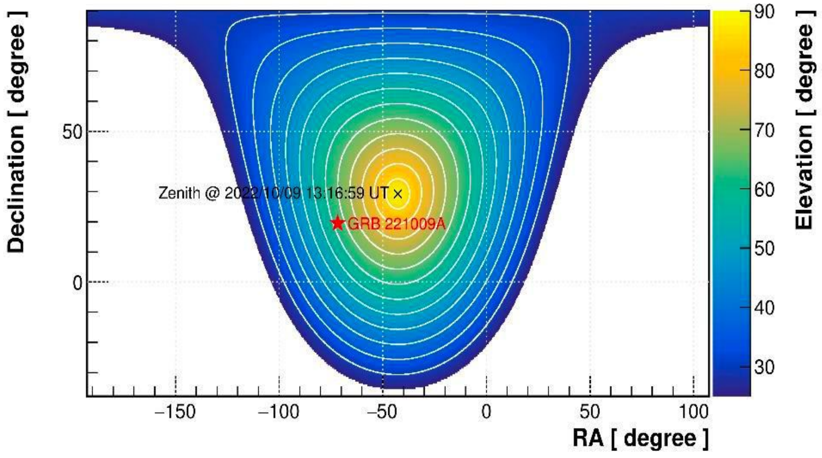


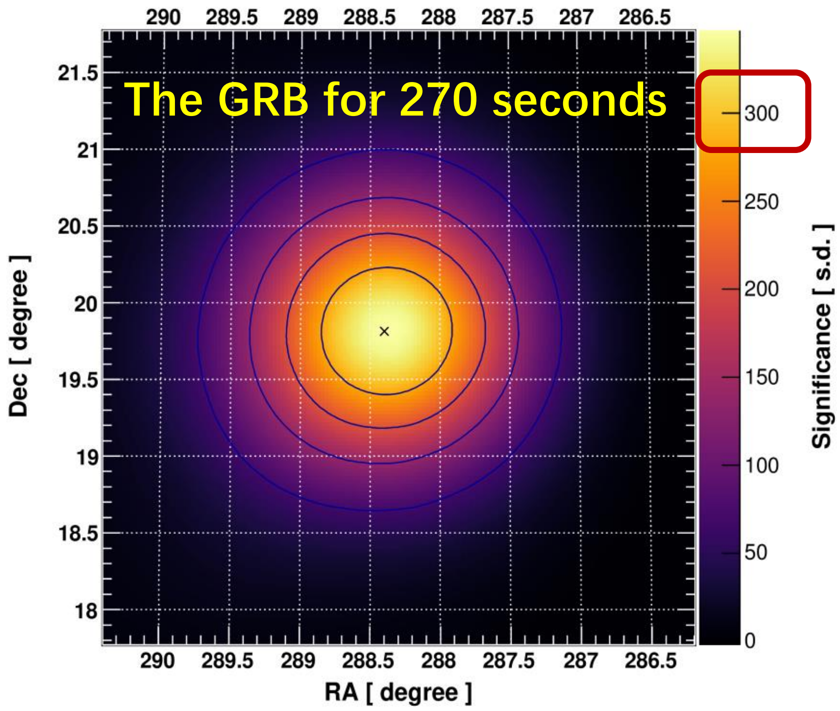
GRB: Even much less chance for it in the middle of FoV of LHAASO

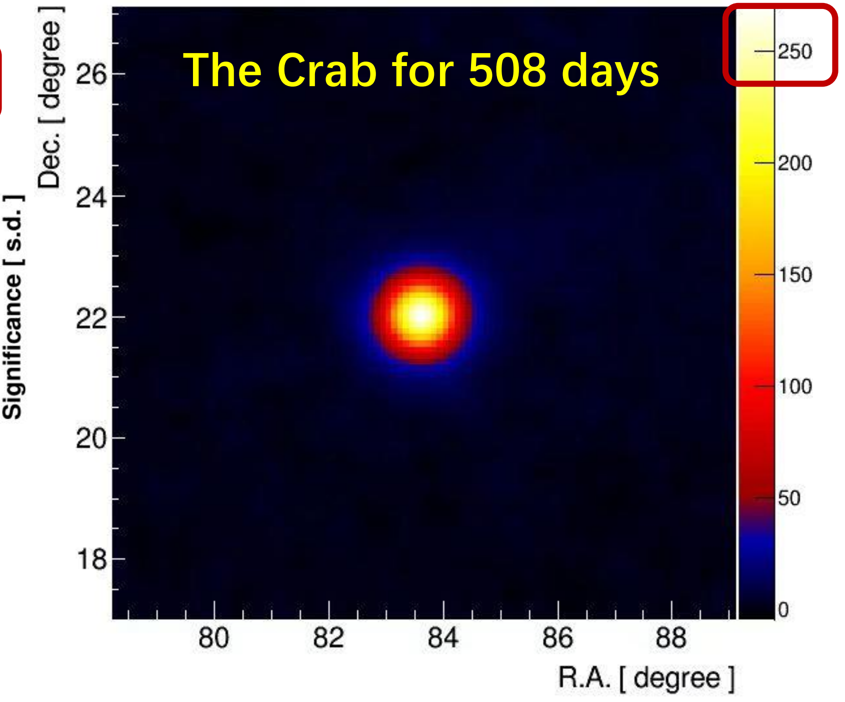
LHAASO
高海拔宇宙线观测站

- The burst of 64k photons in **270 seconds**
versus the exposure of the Crab for 508 days

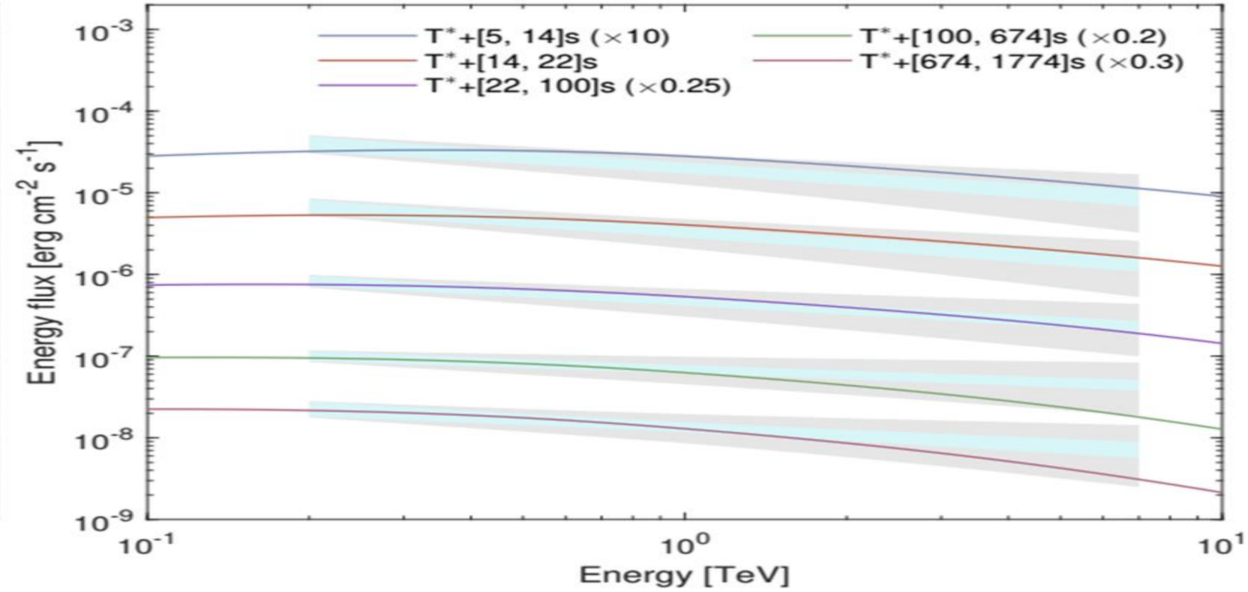
- LHAASO FoV at the GRB started



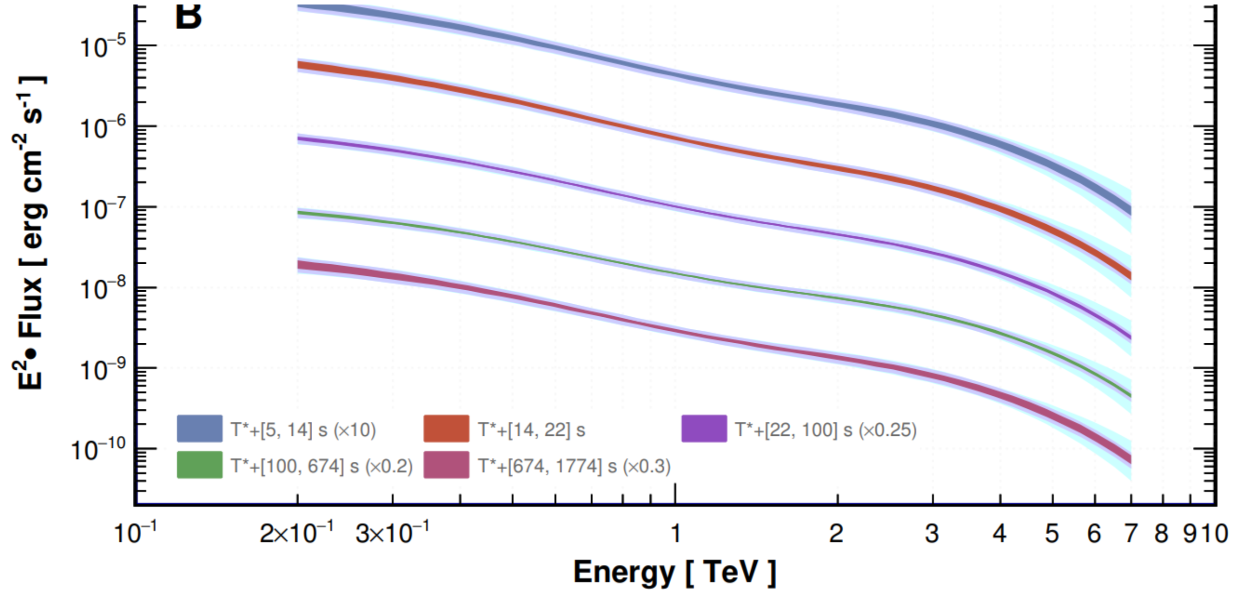


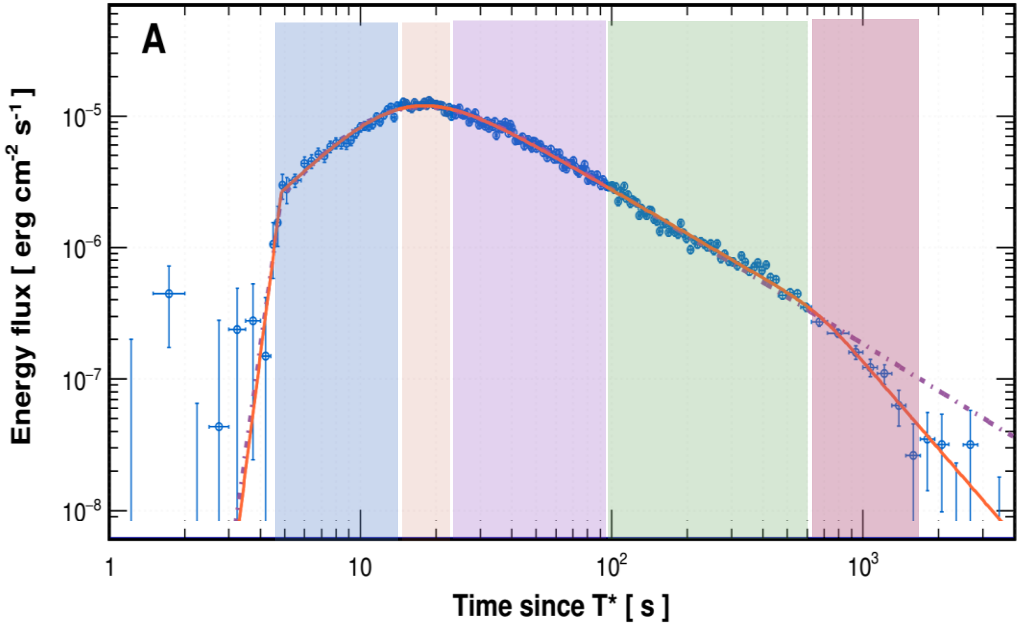


Light-curve and Time-sliding SEDs：



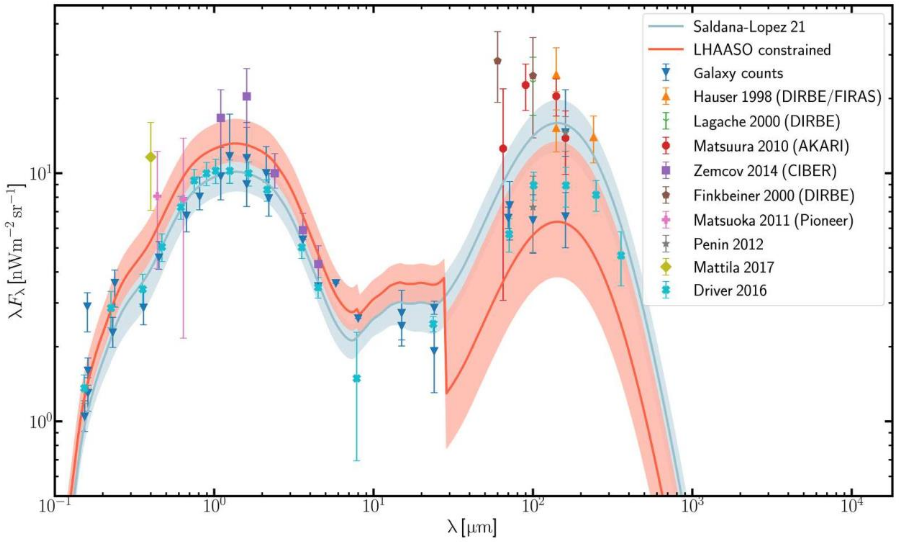
- z ~ 0.152, EBL absorption above 3 TeV
- EBL model: A. Saldana-Lopez et al., Mon. Not. R. Astron. Soc. 507, 5144-5160 (2021)
- Intrinsic SED:
  - Power law: $\sim E^{-2.3}$
  - No hint about cut-off below 10 TeV
  - Moderate spectral evolution is observed



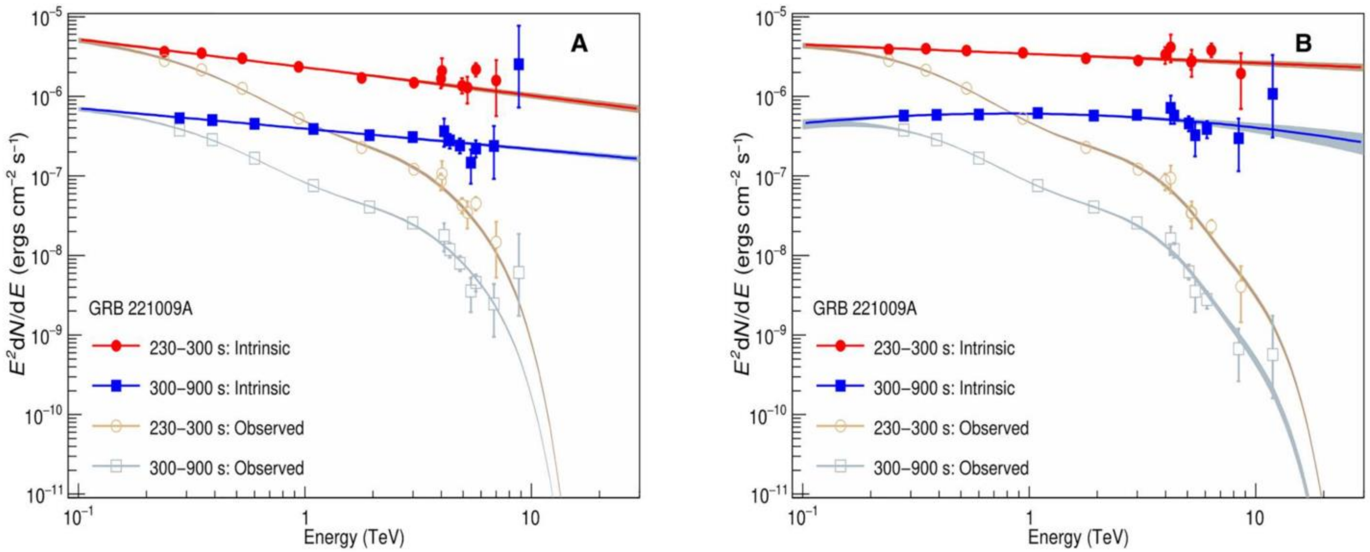


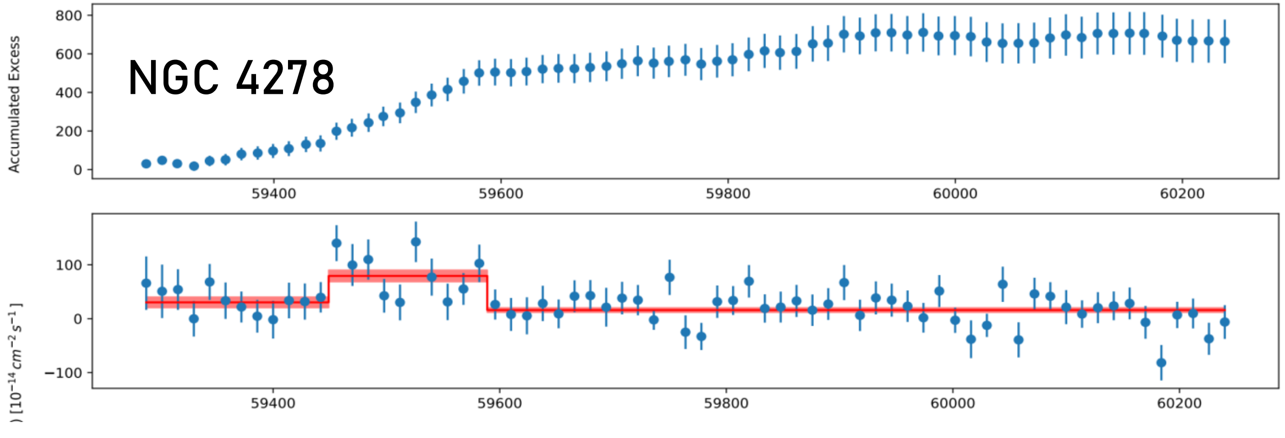
EBL: GRB 221009A (z~0.152)
Blazars (130 Mpc)、M87/NGC 4278 (~16 Mpc)

Extra Background Light



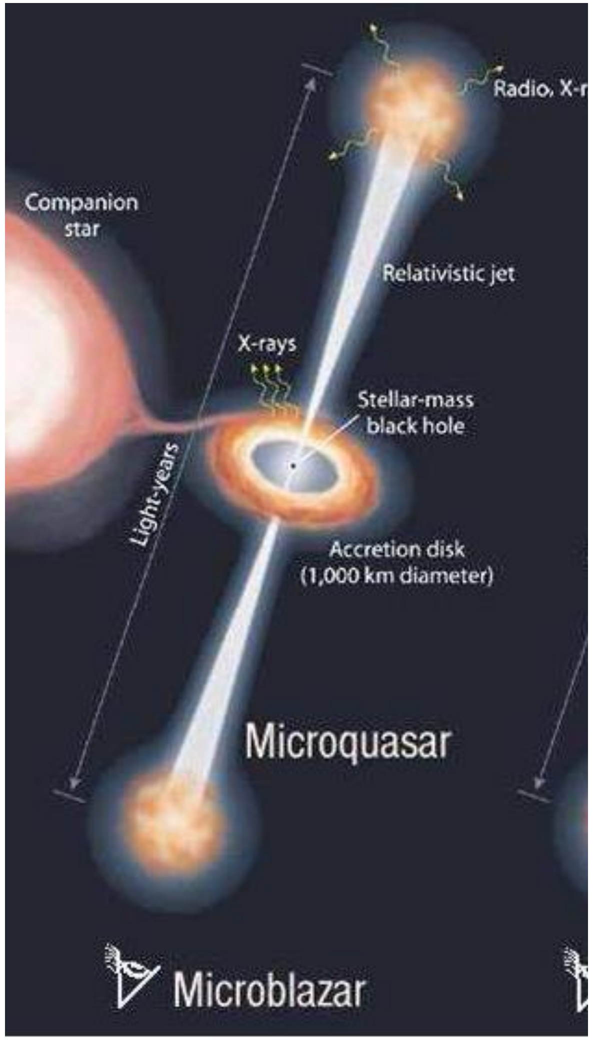
GRB 221009A





Micro-Quasars: UHE γ-emitters?

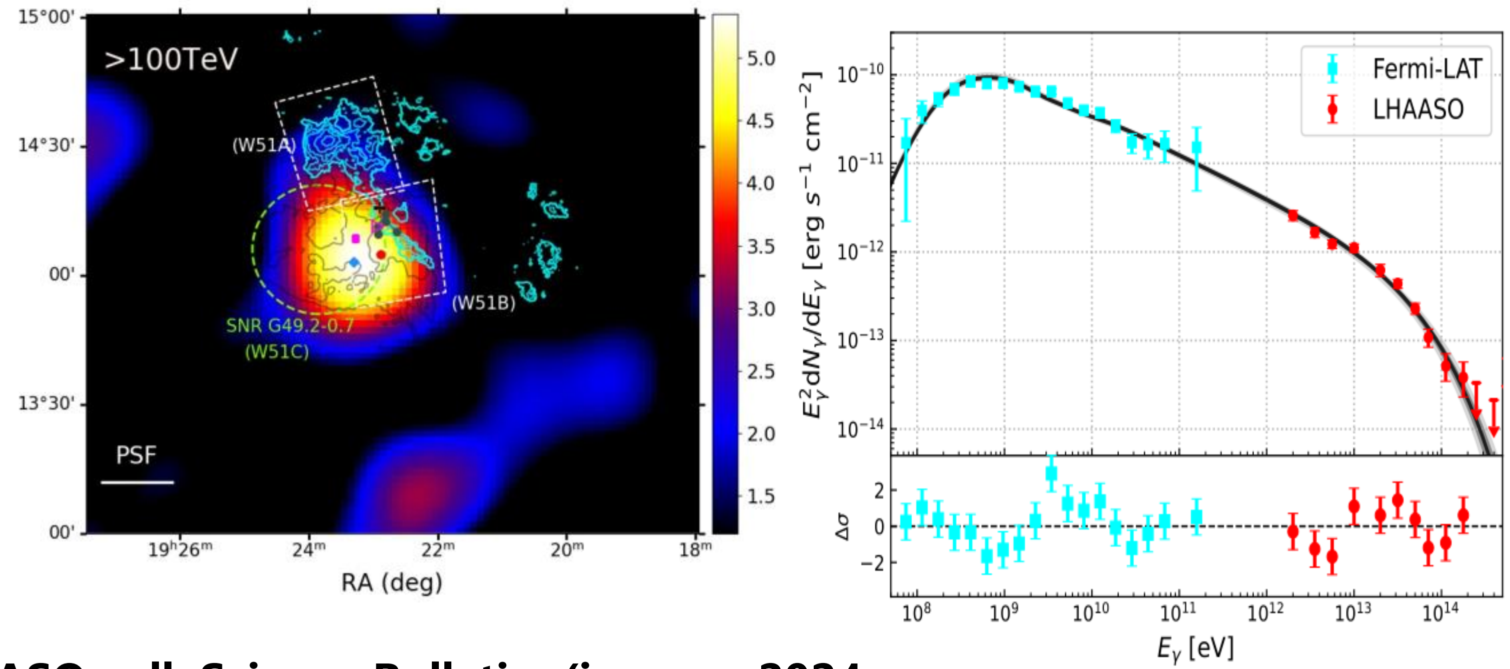
- About 20 μ-Quasars has been found in the MW
- 9 or 8 μ-Quasars in the FoV of LHAASO
- A systematic survey for the UHE radiation from them is on going



Microquasar	Distance (kpc)
SS 433 E.	4.6 ± 1.3 [46]
SS 433 W.	
V4641 Sgr	6.2 ± 0.7 [34]
GRS 1915+105	9.4 ± 0.6 [35]
Cygnus X-3	8.95 ± 0.96 [35]
Cygnus X-1	2.2 ± 0.2 [47]
XTE J1859+226	4.2 ± 0.5 [27]
XTE J1118+480	1.7 ± 0.1 [48]
CI Cam	$4.1^{+0.3}_{-0.2}$ [49]
V404 Cygni	2.39 ± 0.14 [50]

SNRs: W51 and others

- SNR W51 VHE radiation is found coincidence with the interacting region between SNR and Molecule Clouds
- LHAASO measures the cut-off clearly $E_{p,\mathrm{cut}} = 385^{+65}_{-55}\ \mathrm{TeV}$
- SNRs likely not to contribute the CRs above the knee



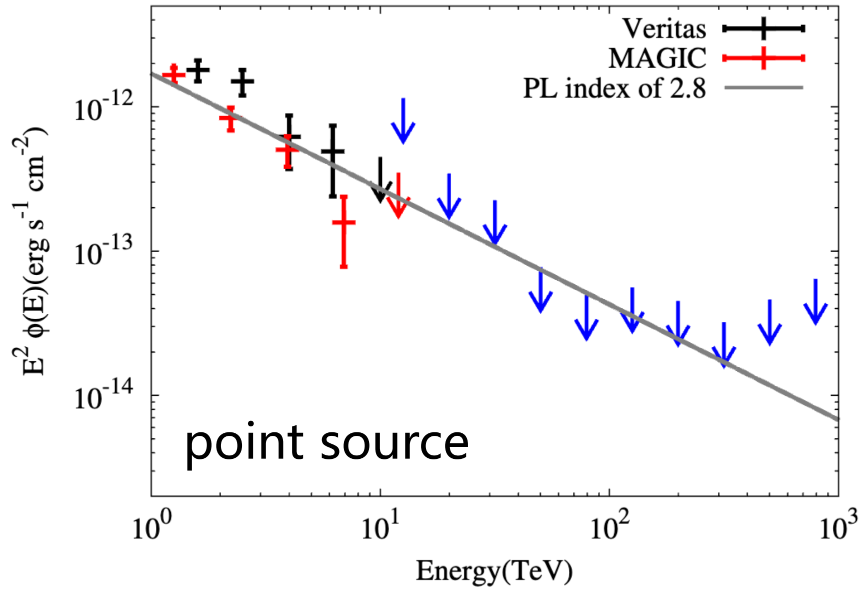
LHAASO coll. Science Bulletin, (in press 2024, https://doi.org/10.1016/j.scib.2024.07.017)

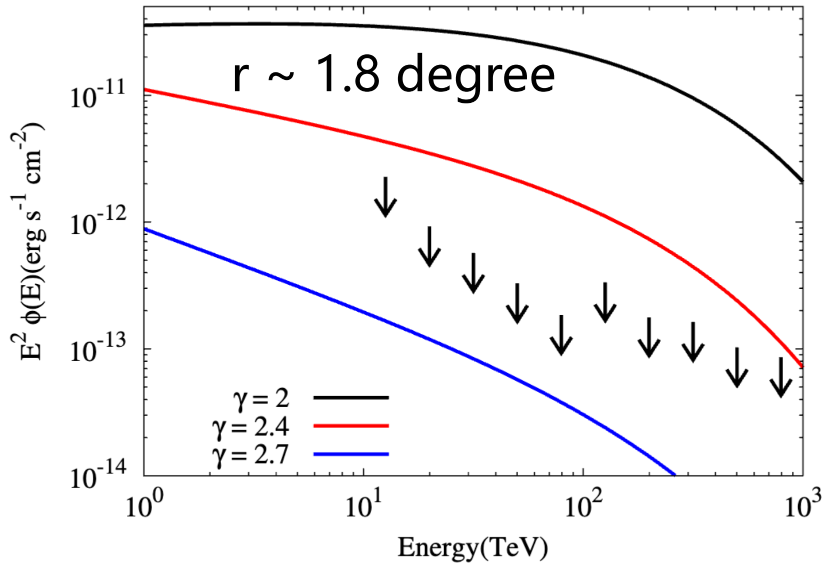
- γ-Cygni
- G-106
- G-150.3+4.5
- ……
- Young SNRs?
- Cas A

Upper limit on SNR Cas A

Using KM2A upper limit to constrain the total CR injected by Cas A

LHAASO collaboration, ApJL, 961, 43





- Stringent upper limit was set for the total VHE CRs injected by Cas A since explosion
- hints for other candidates of PeVatrons

TeV Halo: Pulsars have halos of electrons

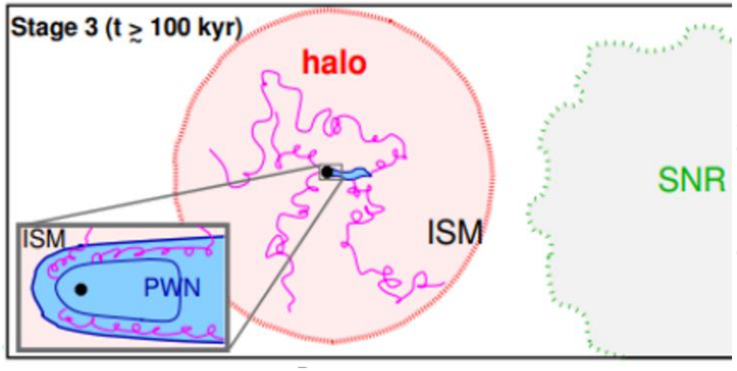
- **Diffuse coefficient of the electrons is 100 times smaller than that in ISM**
- **Cut-off structure <100 TeV**

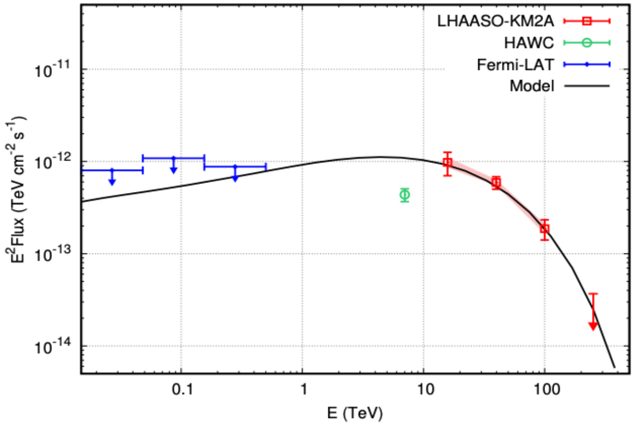
PSR J0622+3749: age~21万年
Distance ~1.6 kpc

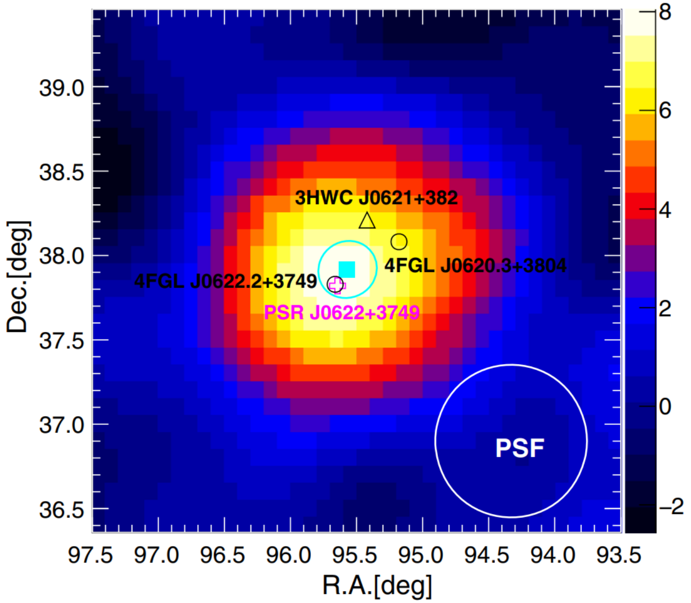
$$f(\theta) \propto \frac{1}{\theta_d(\theta + 0.085\theta_d)} \exp[-1.54(\theta/\theta_d)^{1.52}]$$

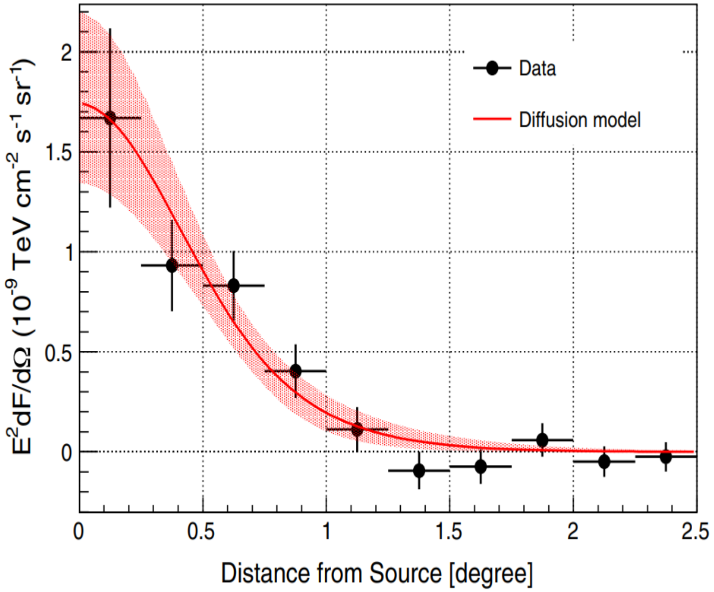
$$D \approx (8.9^{+4.5}_{-3.9}) \times 10^{27} (d/1.6\ \mathrm{kpc})^2\ \mathrm{cm^2\ s^{-1}}$$

$$E_e \sim 160\ \mathrm{TeV}$$







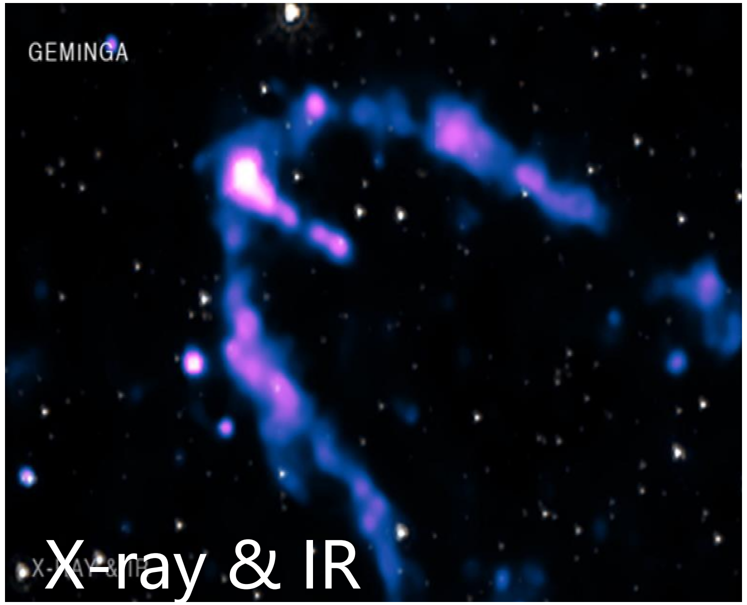


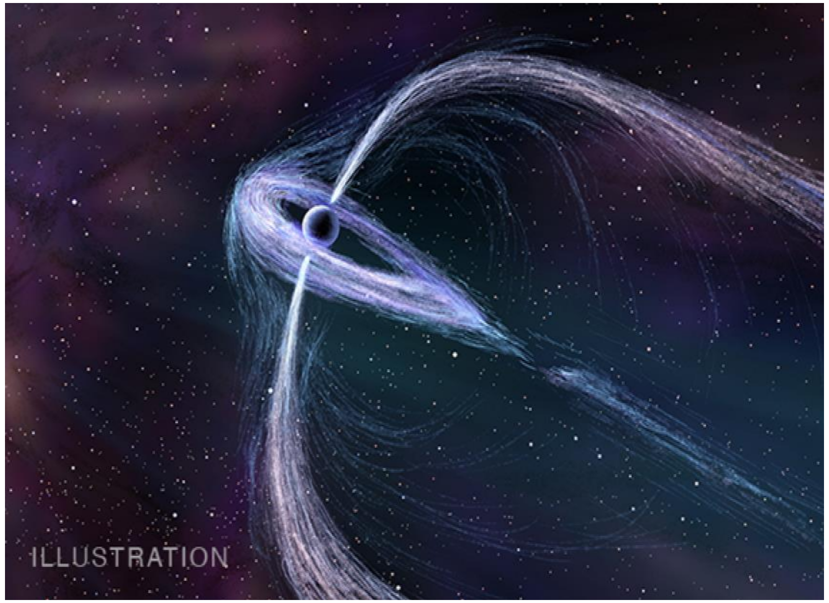
PRL 126, 241103 (2021)

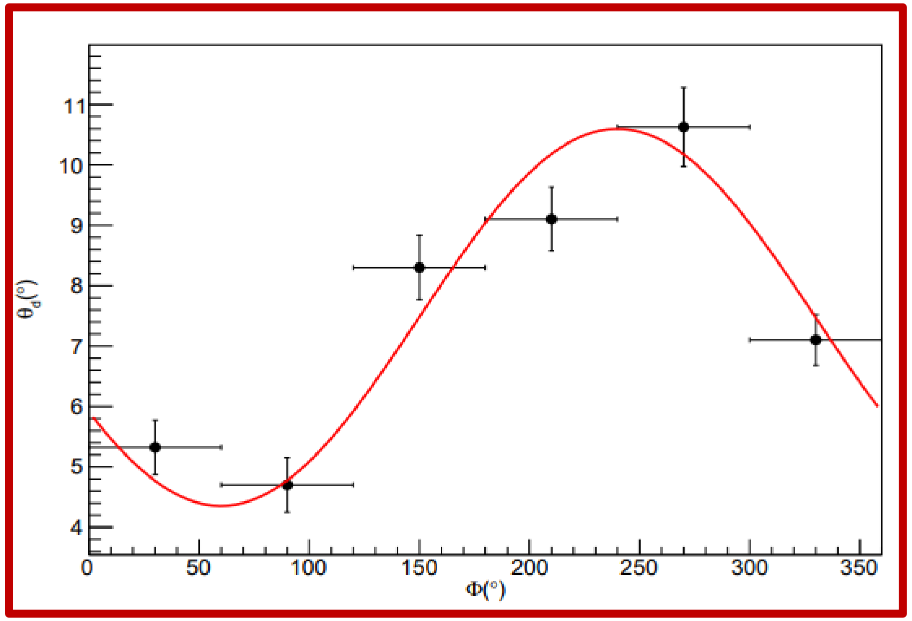
Asymmetric slow diffusion in TeV Halos

- **Geminga，age~340 kyr, distance~250 pc**
- **Slow diffusion**

Preliminary



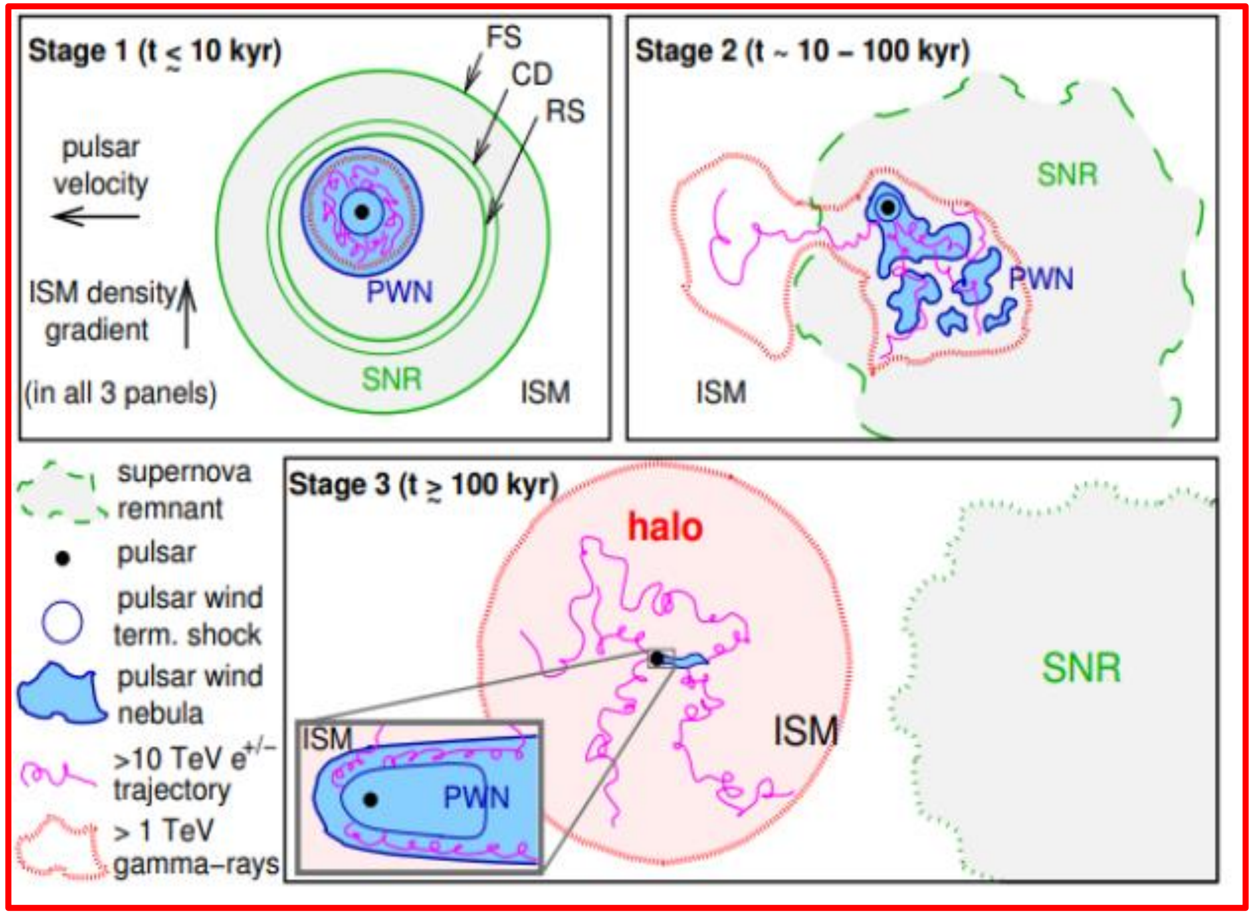




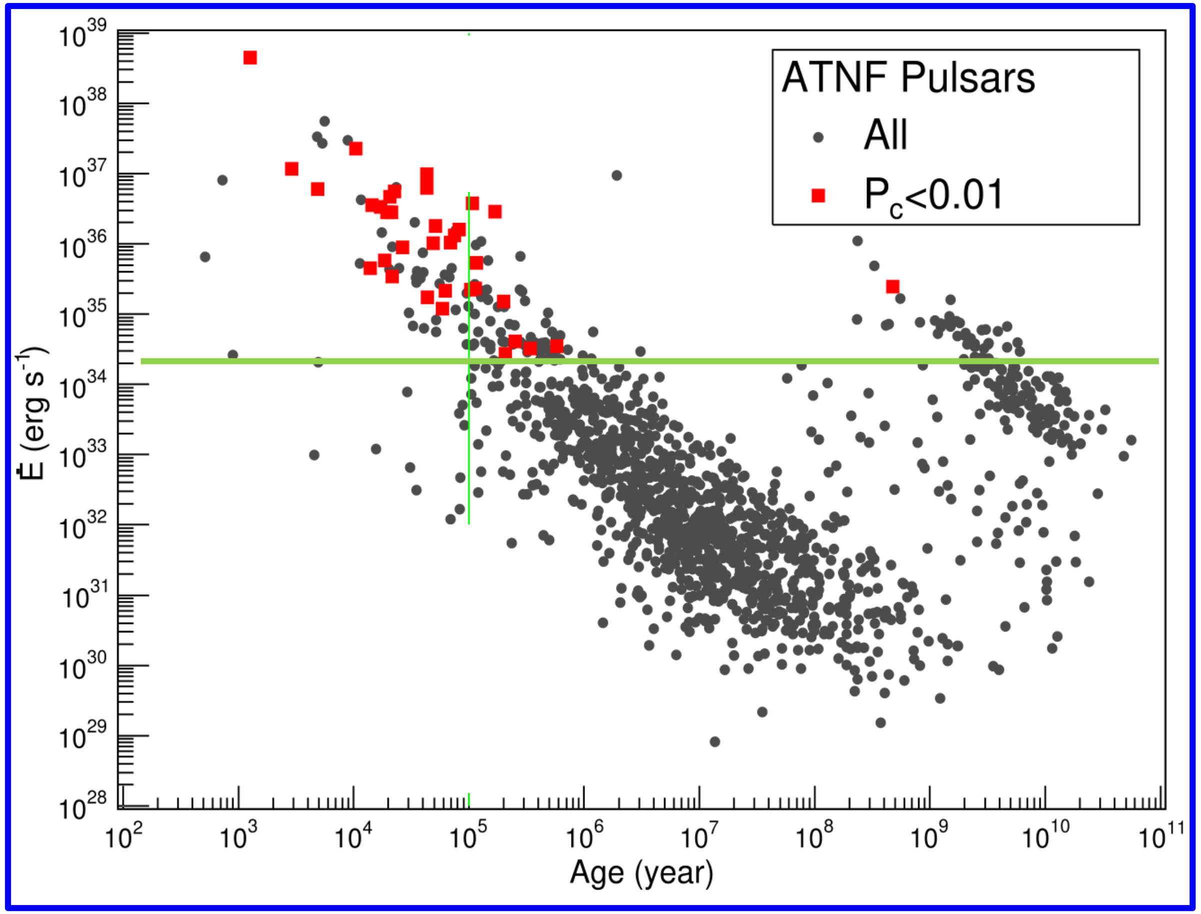
See X.J. Bi's talk on 28th

PWNe: the largest population in LHAASO catalog

Evolution of PWNe

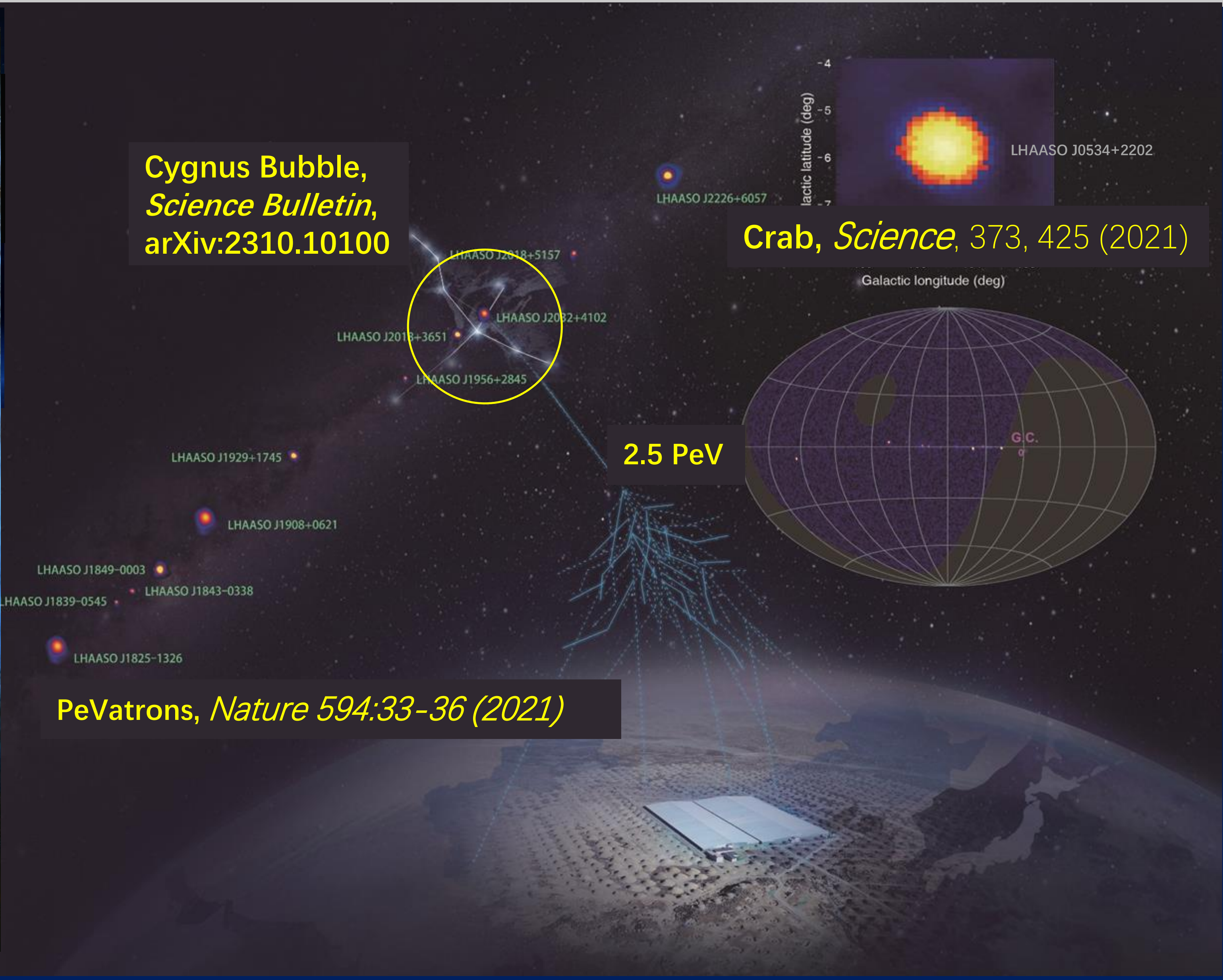


LHAASO PWNe



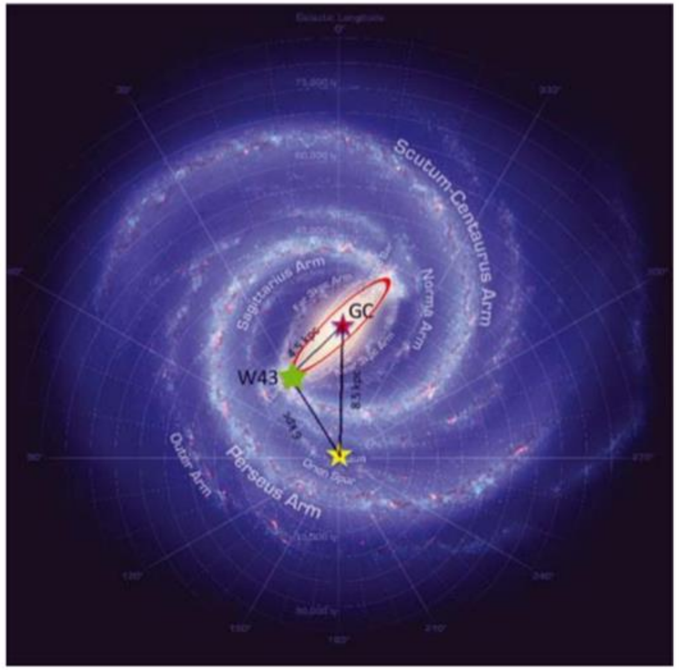
LHAASO coll., ApJS 271:25(2024)

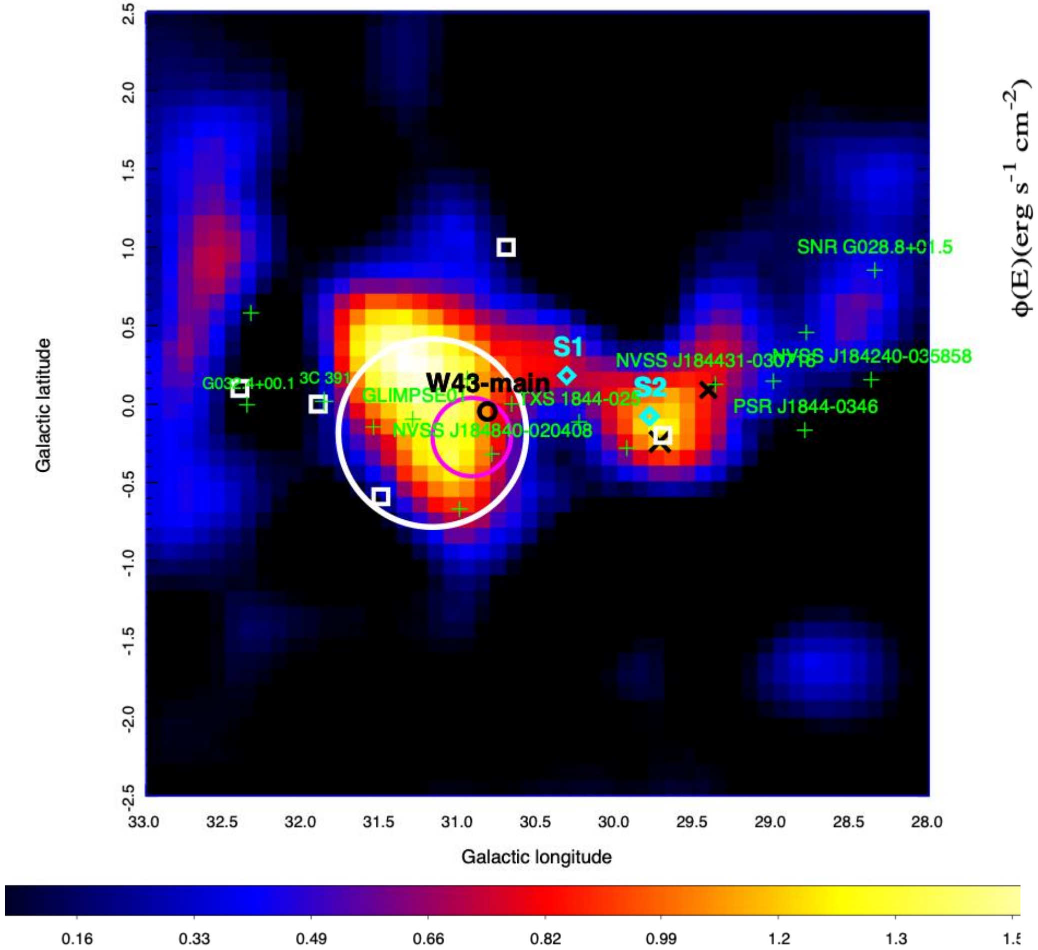
Star Cluster: the 1st CR-Source by

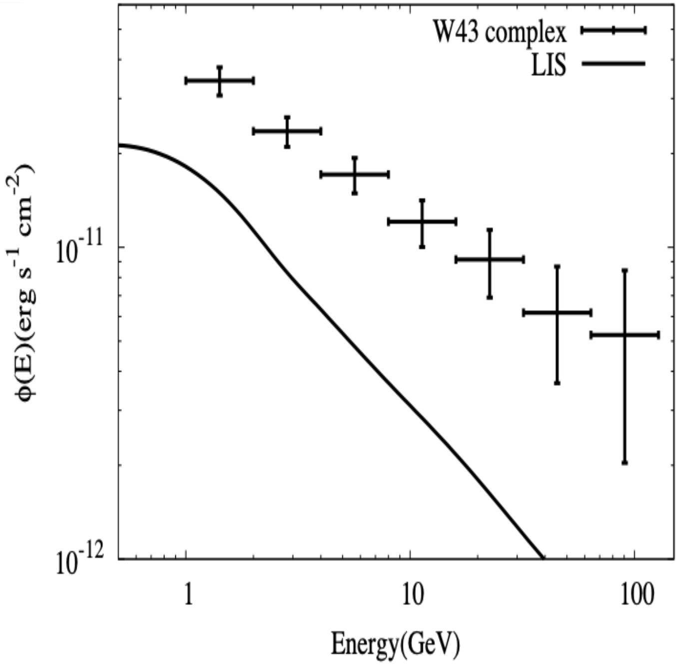


Galactic mini starburst W43

- Galactic mini star burst
- Contribute 10% of the Galactic star formation rate
- Huge HII region excited by central WR/OB cluster
- GeV detection



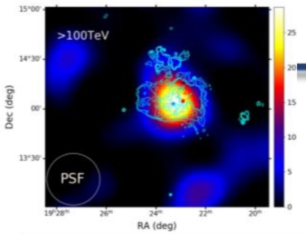




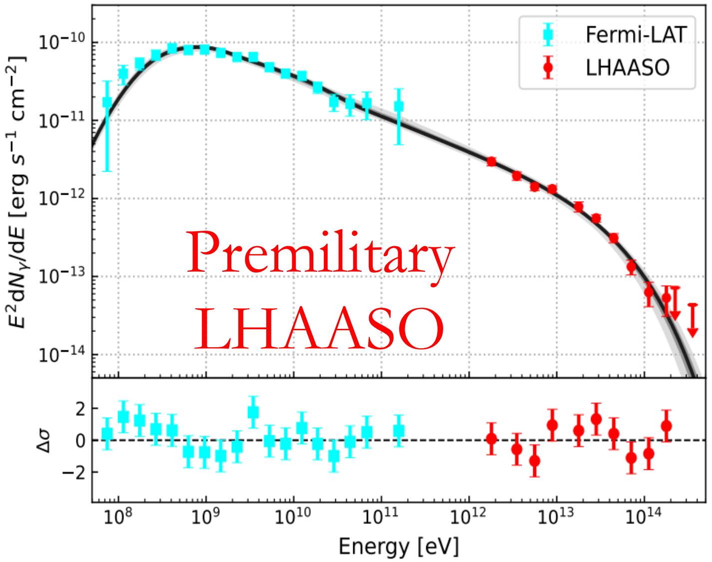
Cosmic ray Sources

1. W51
2. The Cygnus Bubble
3. SS 433
4. Extreme accelerators： Crab and others

Cosmic Ray Source Candidates

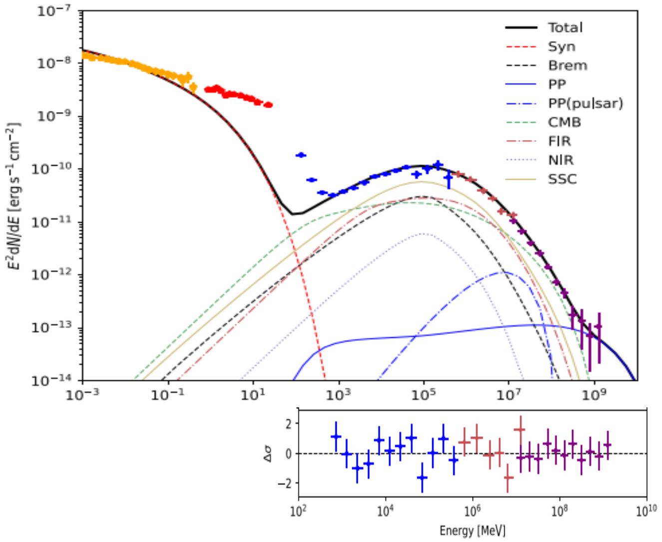


W51C



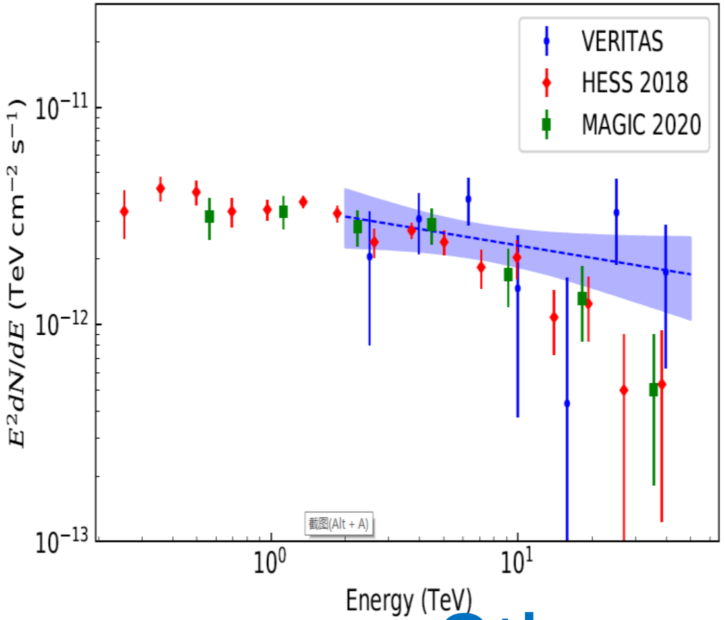
SNR

Crab



PWN

G.C. by IACTs



Other sources

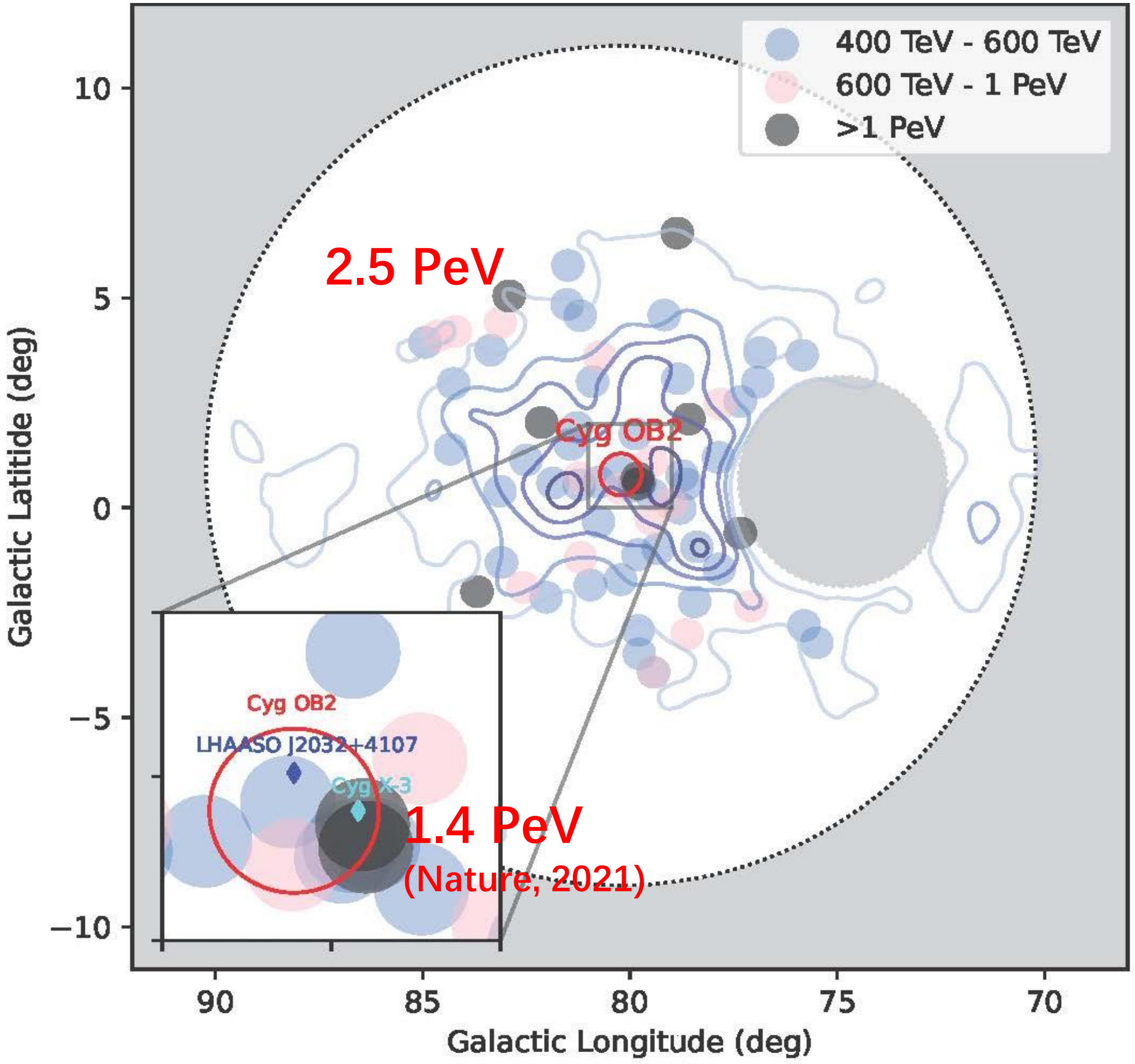
...

Many types of sources have the potential to accelerate particles to 1 PeV and above

A&A 671, A12 (2023)
Science 10.1126/science.abg5137 (2021).
The Astrophysical Journal, 913:115 (11pp), 2021 June 1

A Bubble of UHE γ's centered at a complex core

Cygnus OB2, binary J2032+4107, Binary X-3



8 γ's above 1 PeV!

Energy (TeV)	Ne	Nu	Theta (deg)	Dr (m)
1087	5904	13	19.4	143
1188	5480	14	34.4	73
1208	6939	13	14.2	131
1350	6938	8	27.1	43
1379	6469	9	17.4	52
1421	6258	7	12.7	57
1784	6665	13	18.0	41
2481	13815	29	33.0	99

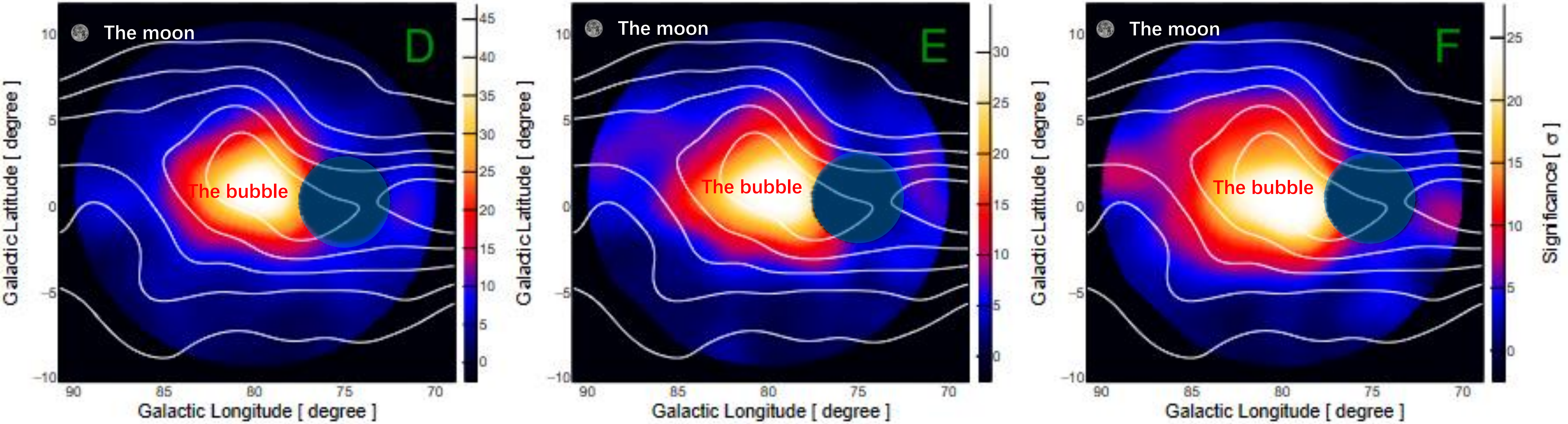
- PeV Photons are scattered in the Bubble, and seem not to associate with any small scale sources

Association with HI gas distribution over ~200 pc

- The significance map is smoothed with a Gaussian kernel=1.0°
- The contour is from HI4PI 21-cm line survey

◆ Clear correlation with gas distribution indicating a hadronic origin of photons in the Bubble

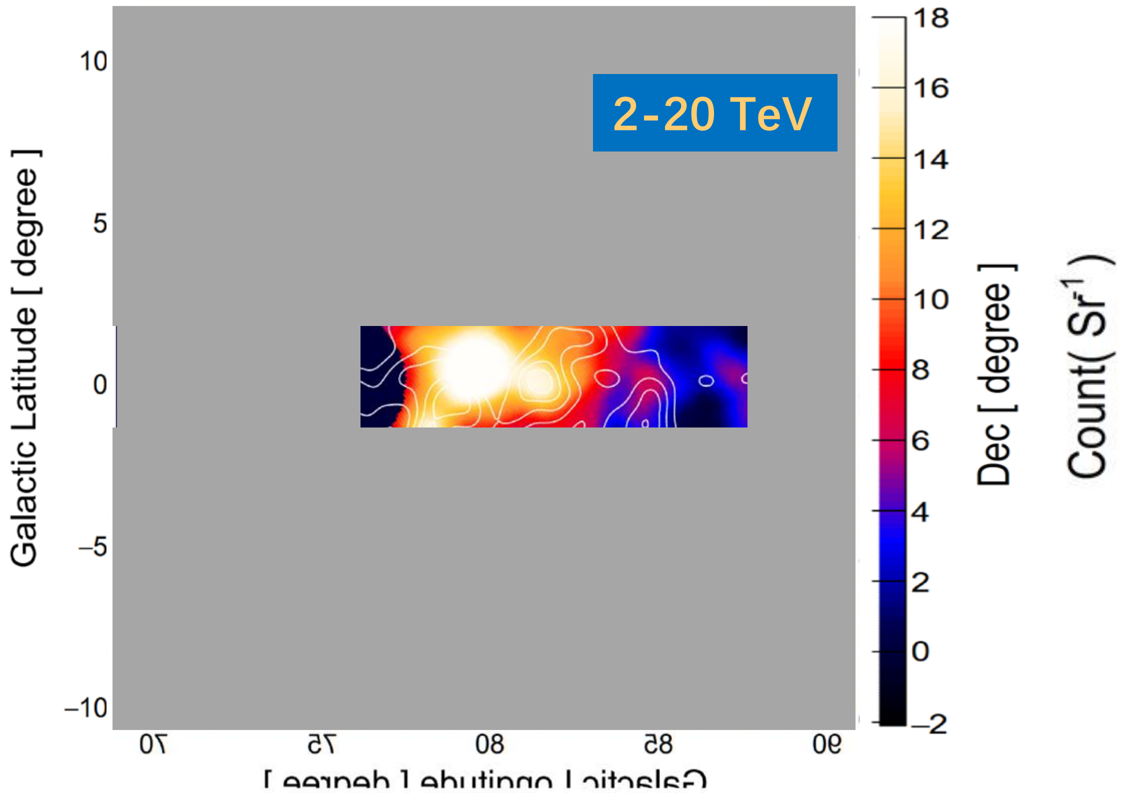
◆ The signal is elongated along the disck and extends to 10°

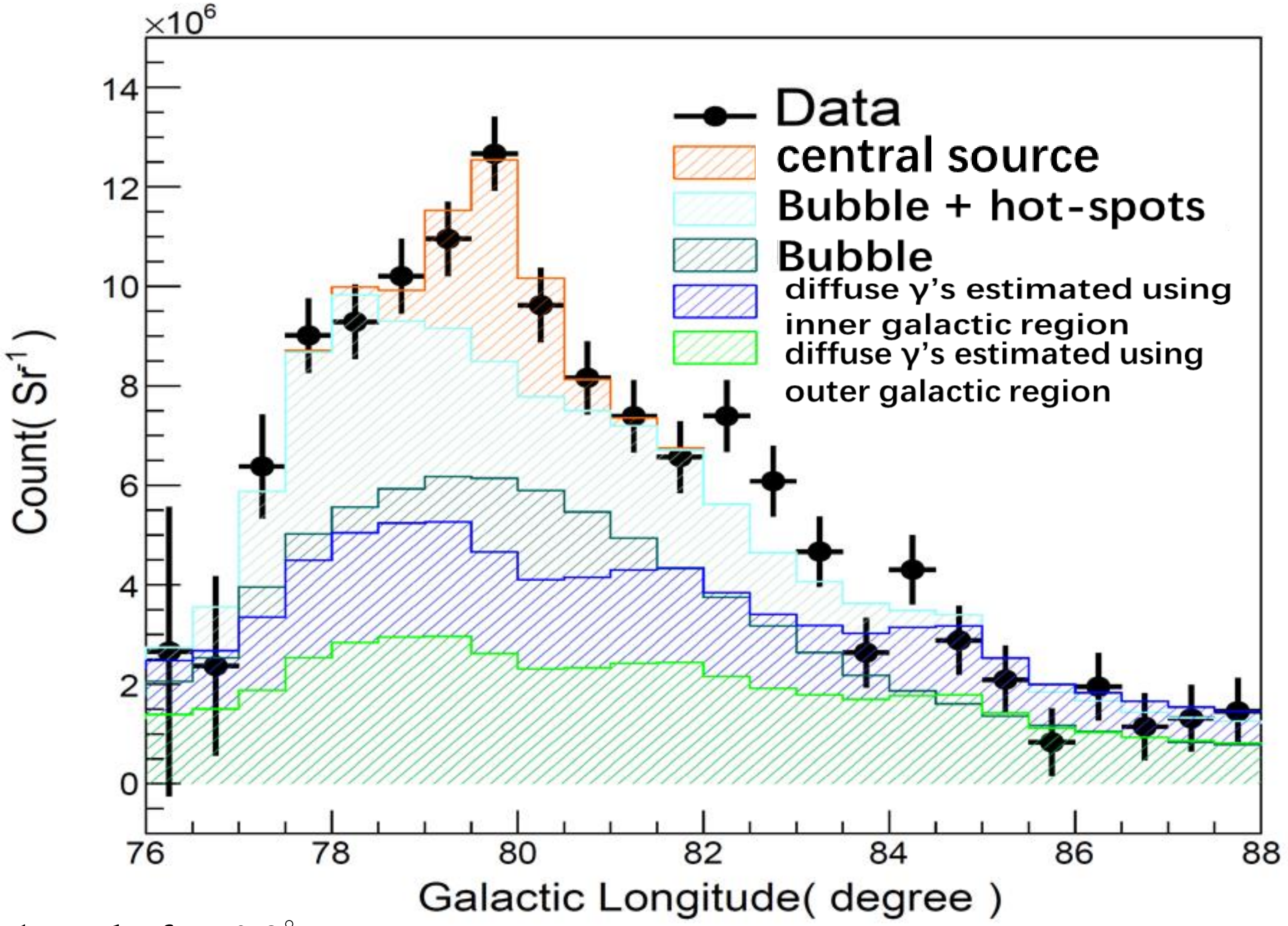


The Bubble at 2-20 TeV by WCDA

1-D Flux in ±2°

Clampy structure of the Bubble: hot spots

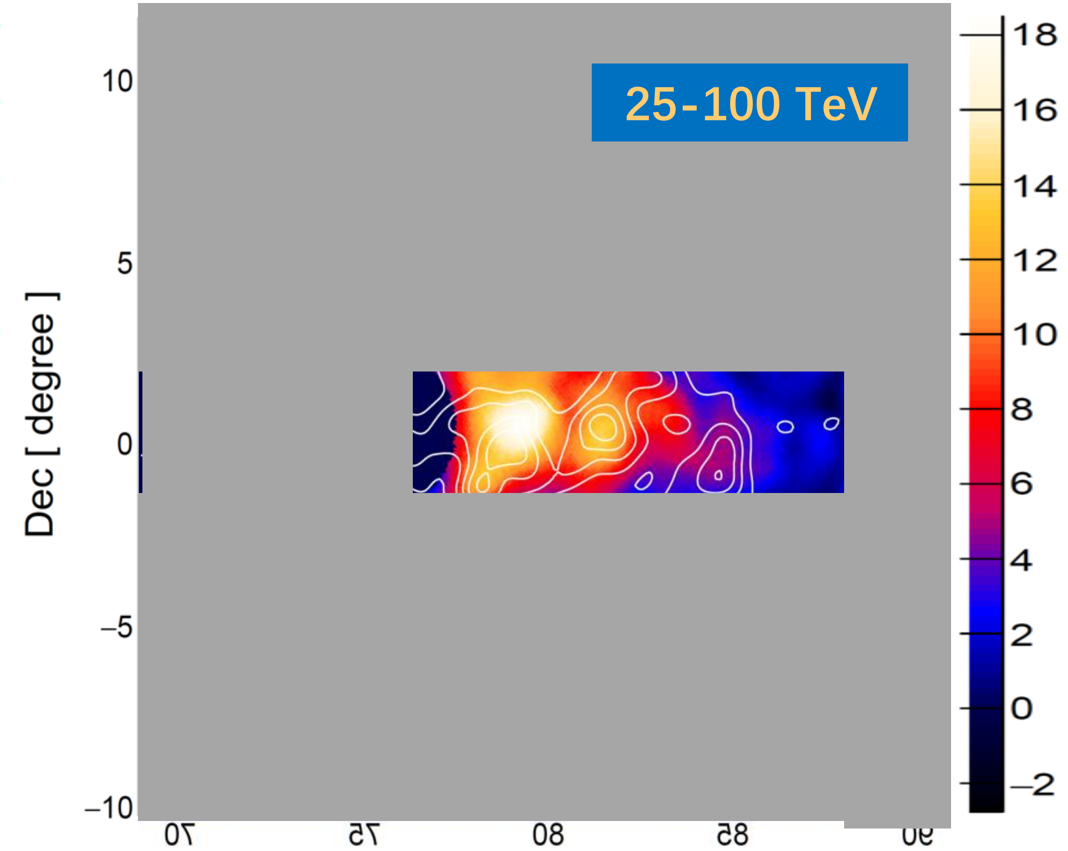


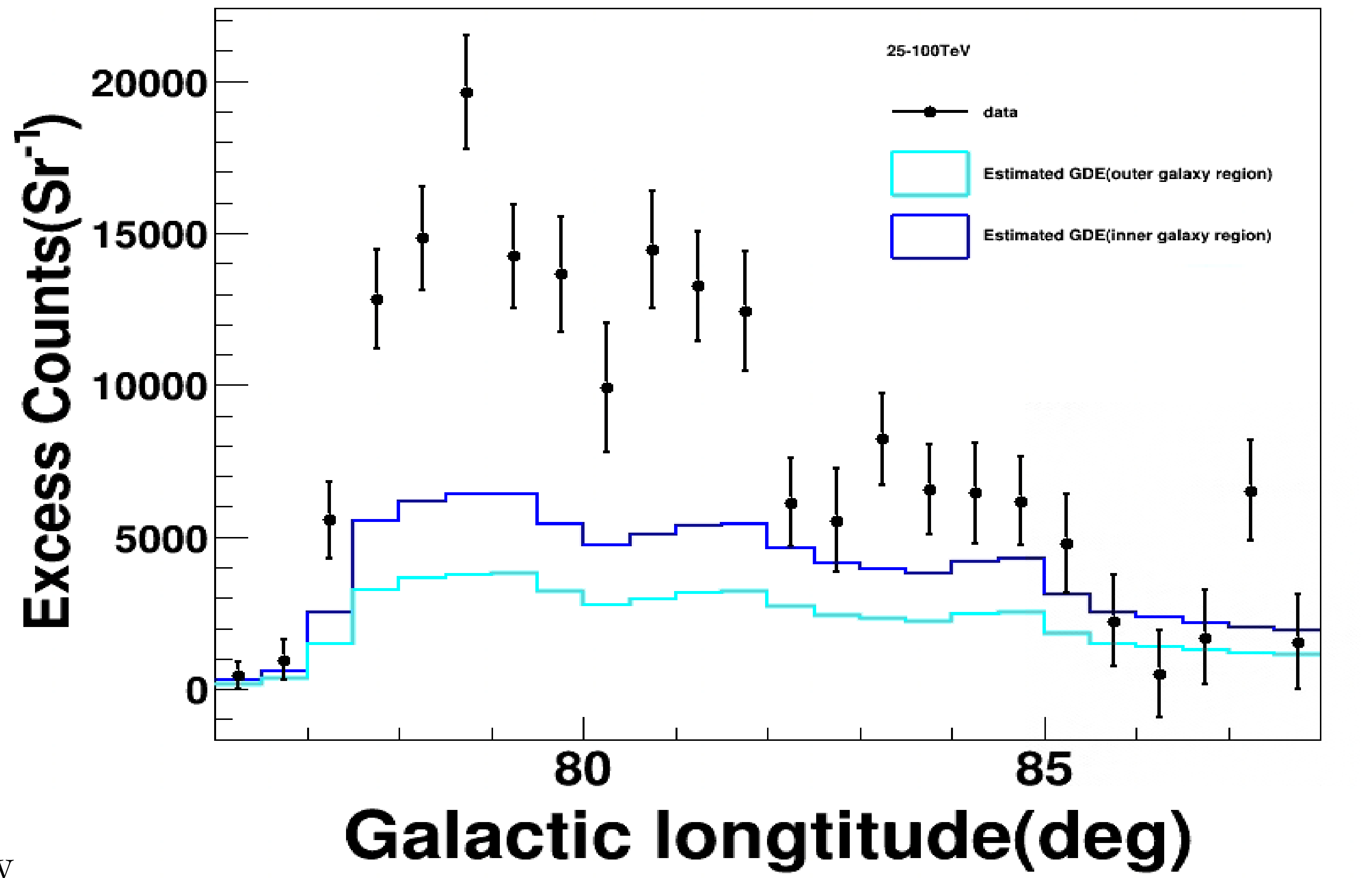


- The contour is from CfA galactic CO survey
- The significance map is smoothed with a Gaussian kernel of σ=0.3°

The Bubble at 25-100 TeV by KM2A

1-D Flux in ±2°

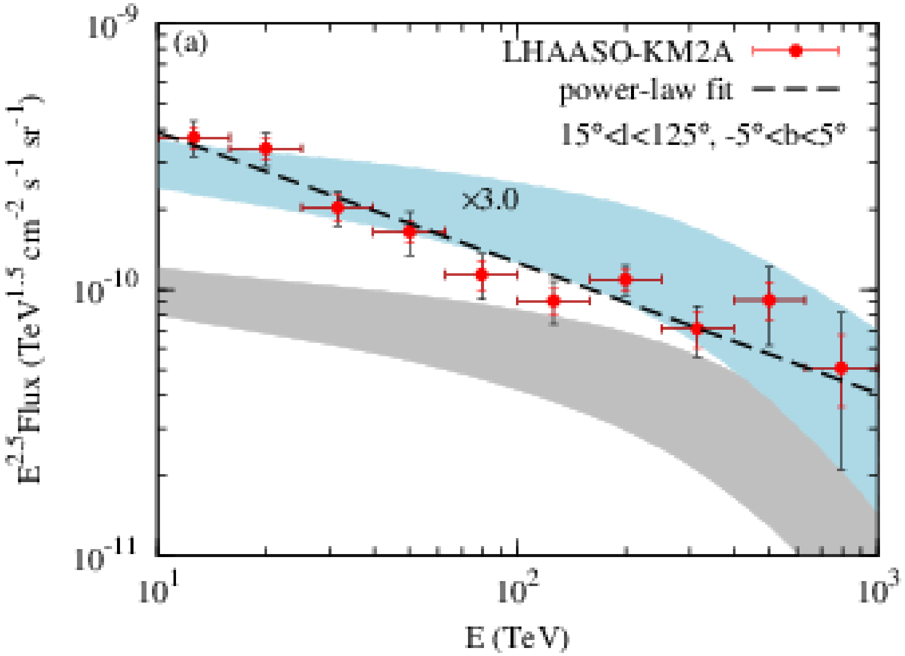




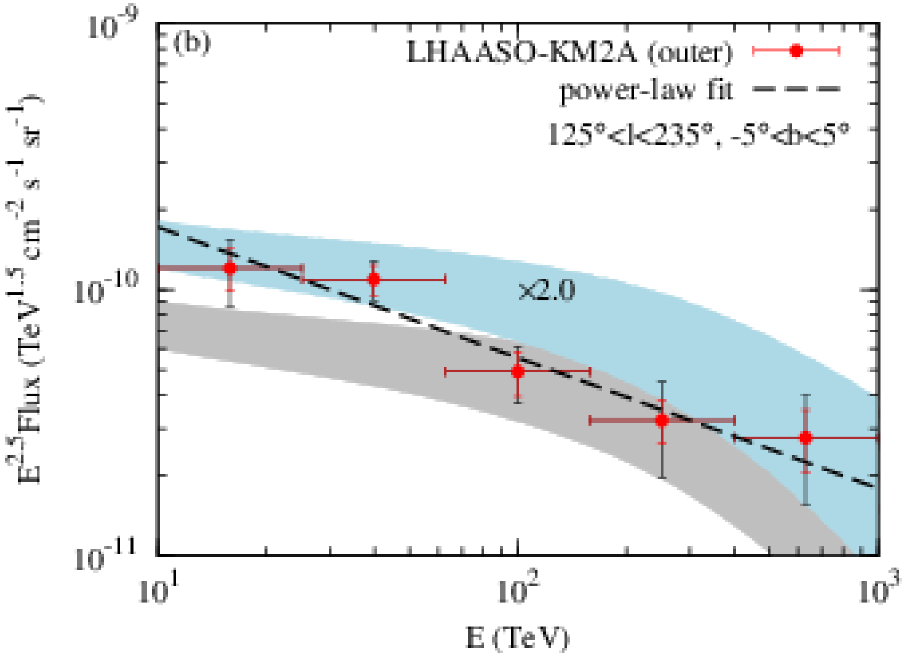
- The contour is from CfA galactic CO survey
- The significance map is smoothed with a Gaussian kernel of σ=0.3°

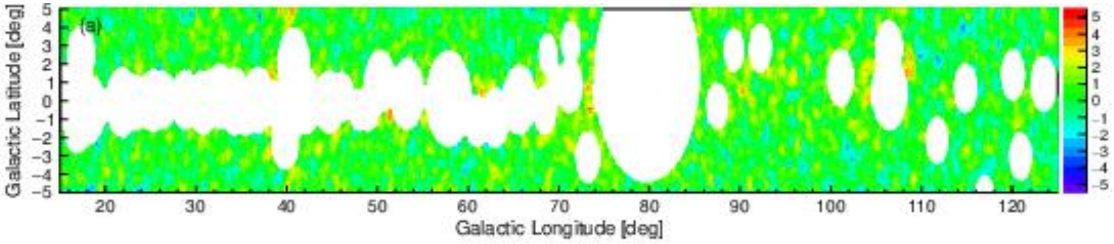
LHAASO measured the Galactic Diffuse Emission

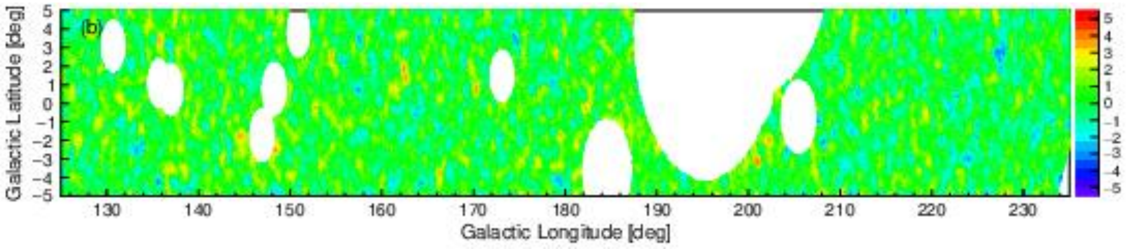
Inner Galactic Region



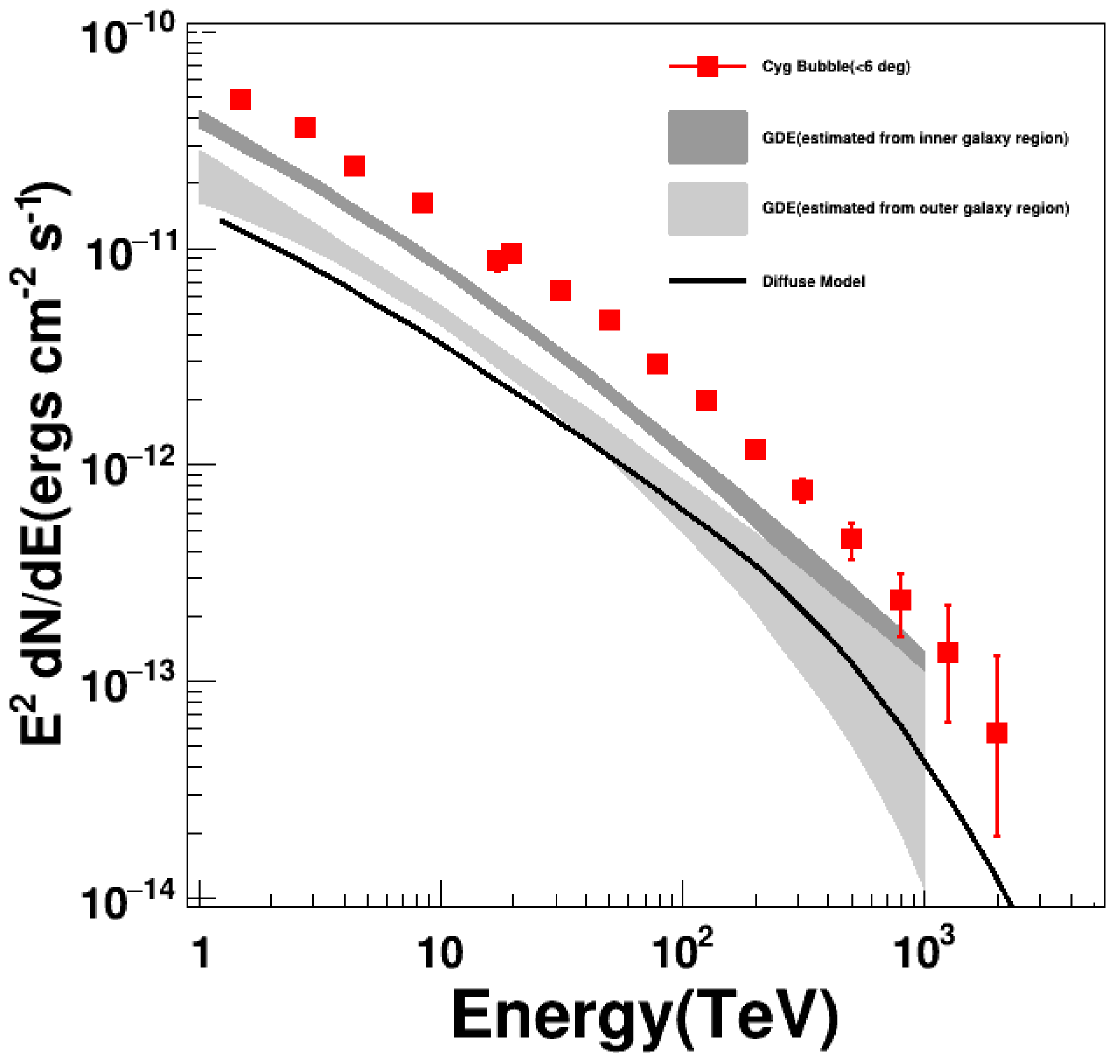
Outer Galactic Region







Spectral Energy Distribution of the Bubble

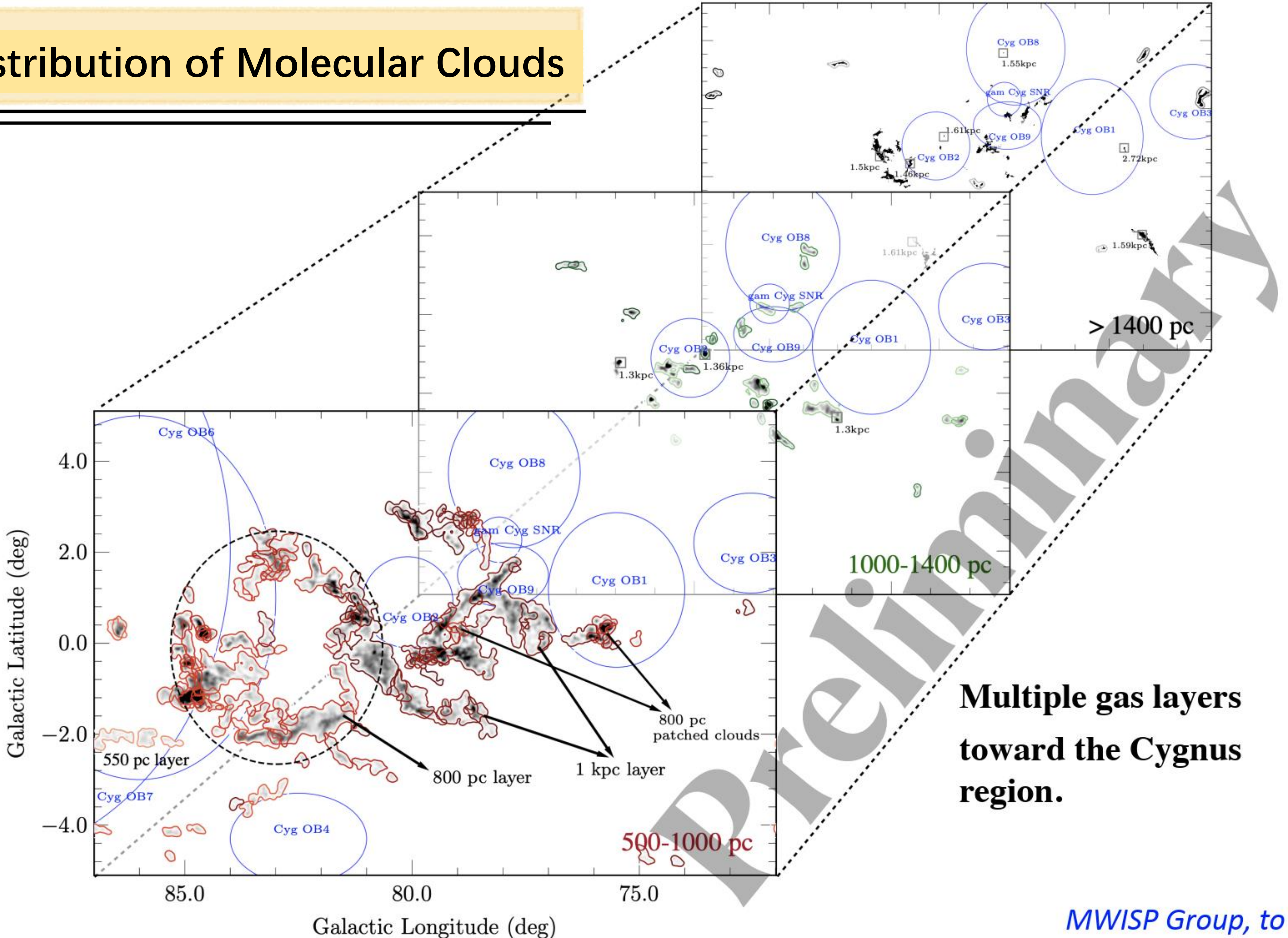


Energy Bin	Non	Nb
400TeV-630TeV	42	6.8
630TeV-1PeV	14	1.9
1PeV-1.6PeV	6	0.6
1.6PeV-2.5PeV	2	0.2

Almost background free

- ◆The spectrum spans 3 decades up to 2 PeV
- ◆Spectral index ~ 2.7
- ◆No indication of cut-off in the spectrum

3-D distribution of Molecular Clouds

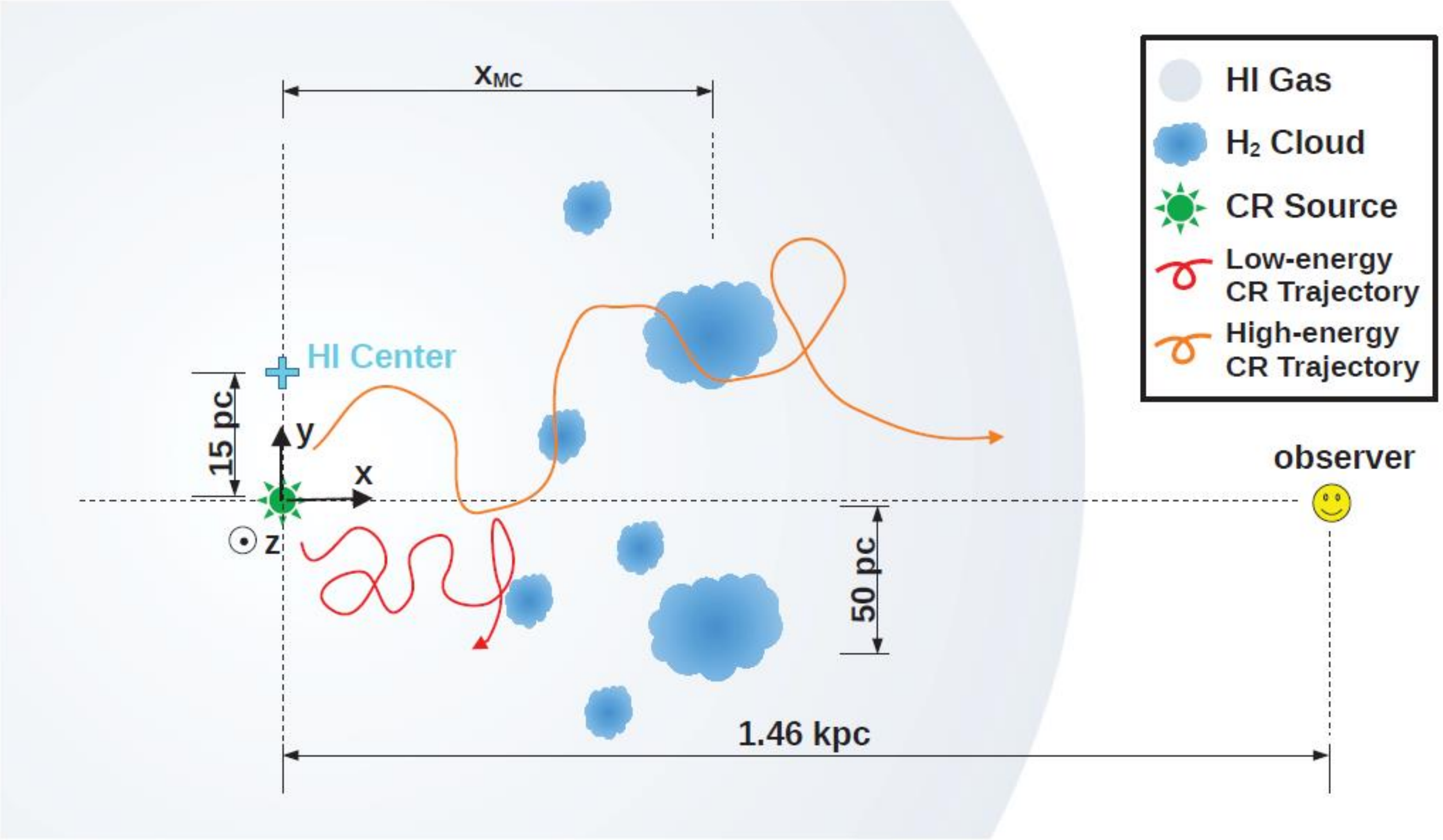


Multiple gas layers toward the Cygnus region.

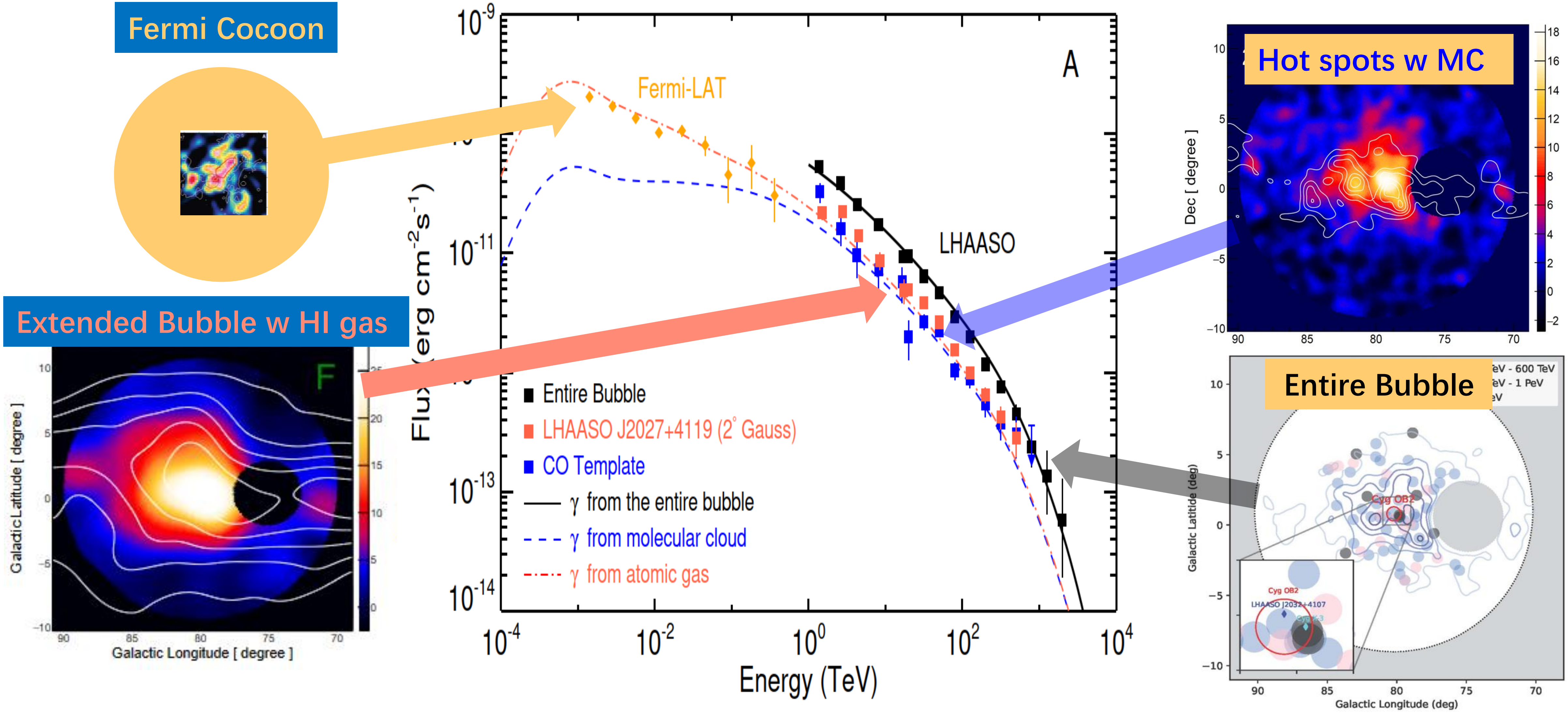
MWISP Group, to be submitted

HE Protons injection from the core region

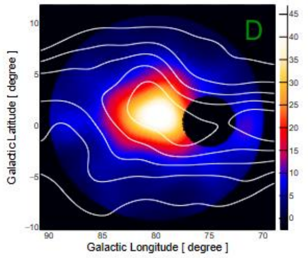
- High energy cosmic rays escape from the accelerator in the core
- Diffusing through the H1 gas and producing γ's in p-p collisions
- Hitting on clampy molecular clouds making hot-spots
- Slow diffusion ~1%DC in ISM

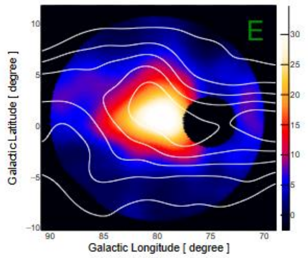


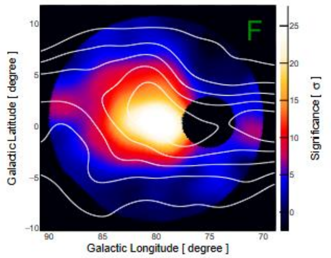
Model w 3 components : SED over 8 decades



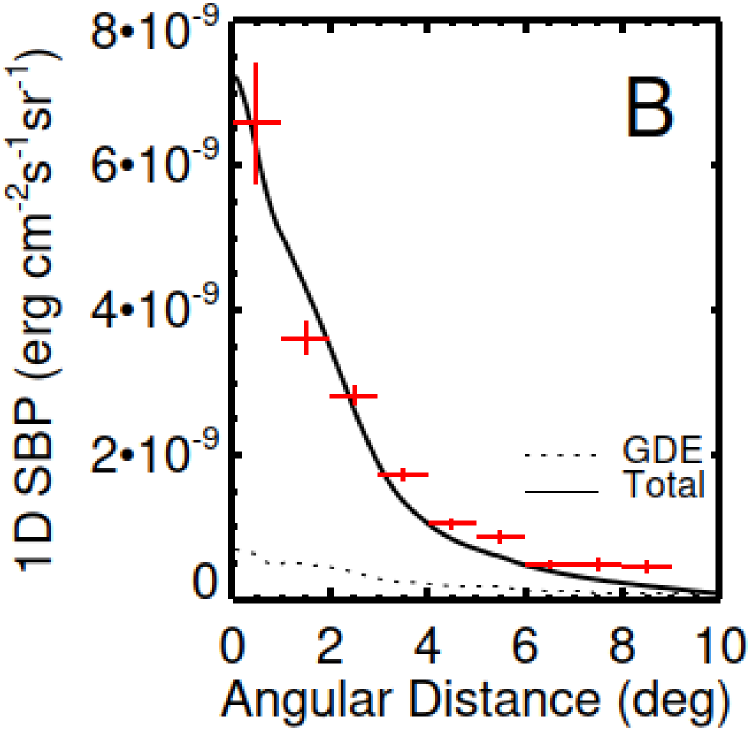
Model: Diffuse CR's generate γ's Spatial Profile over 10° from the core



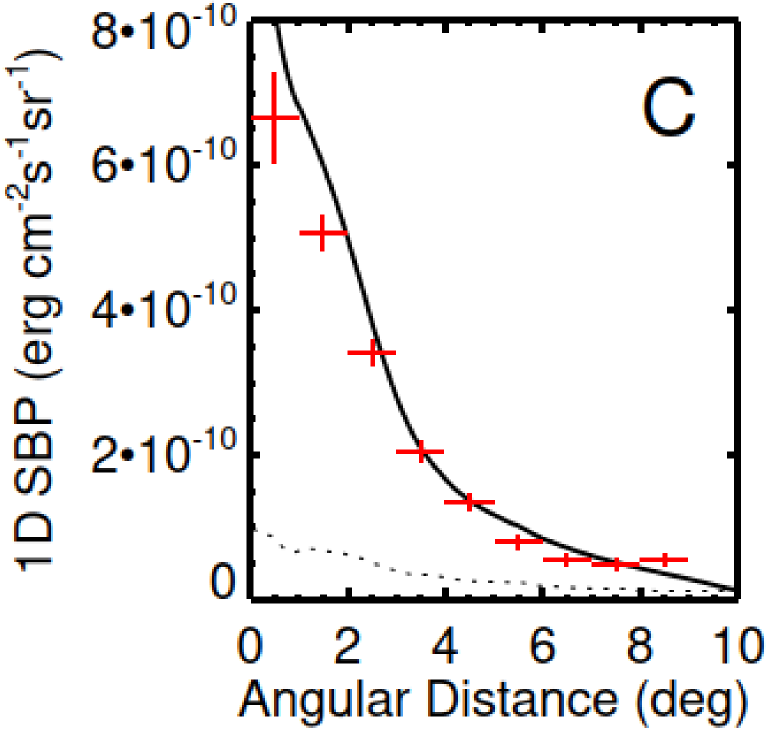




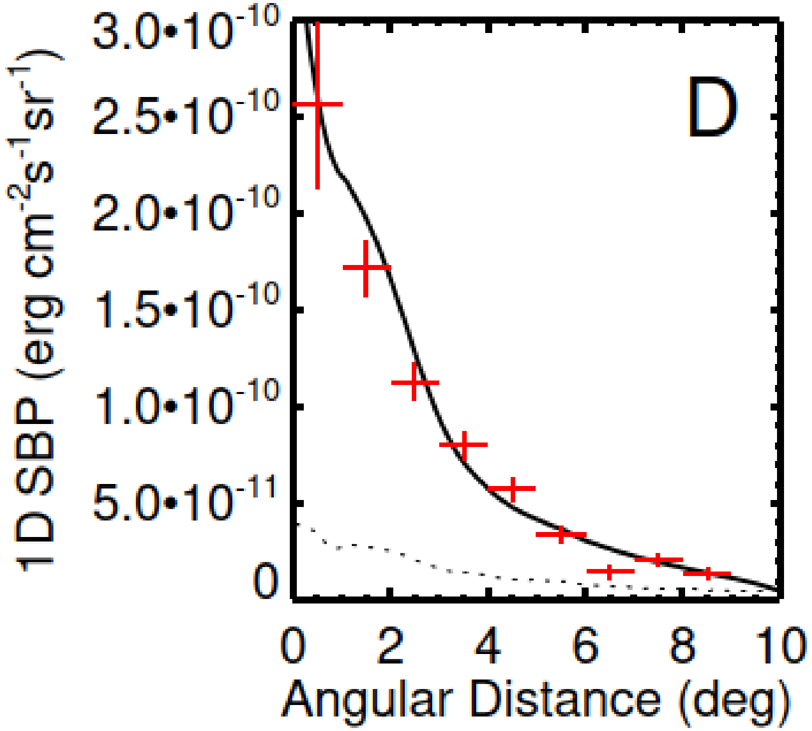
2-20 TeV



25-100 TeV

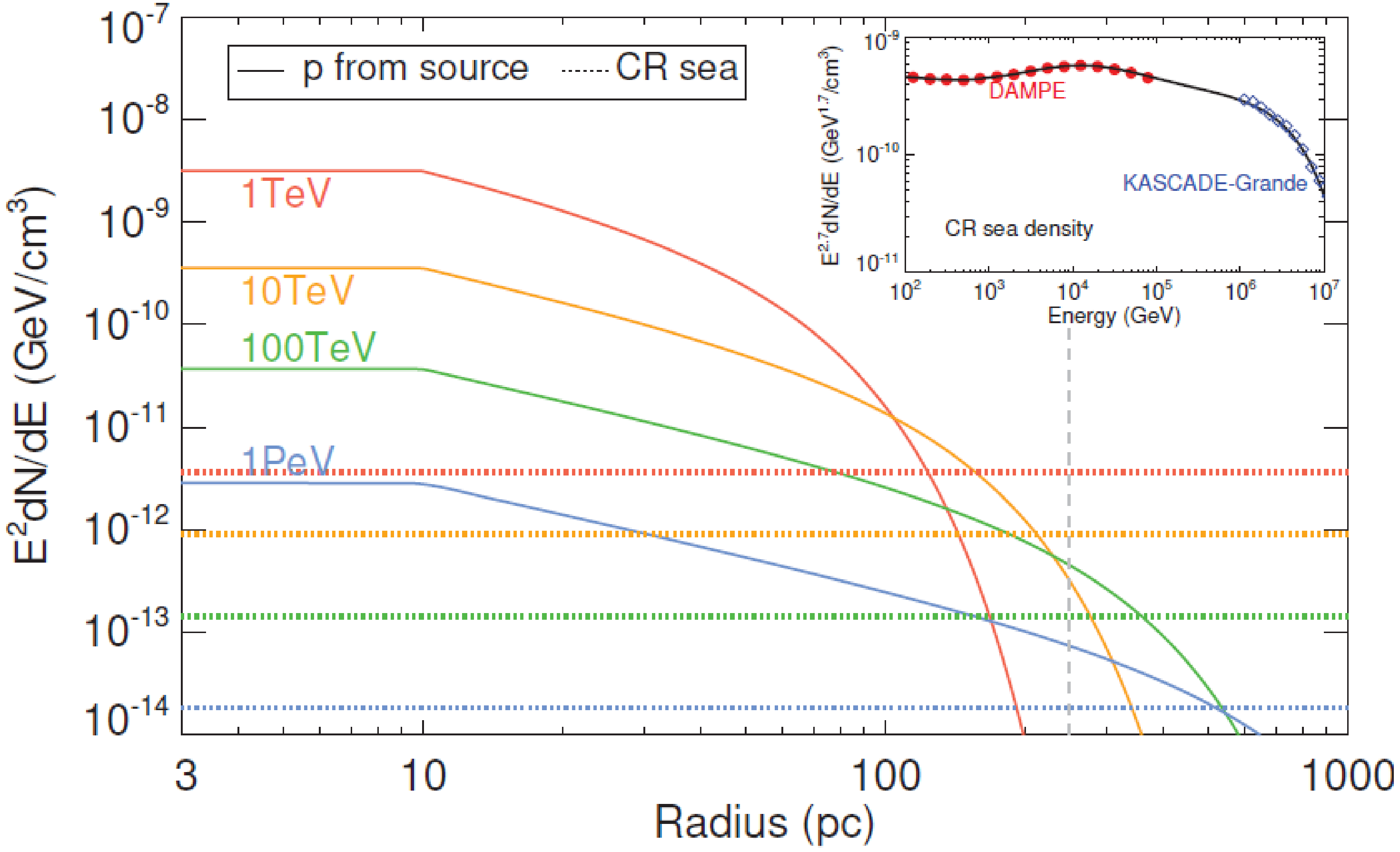


>100 TeV



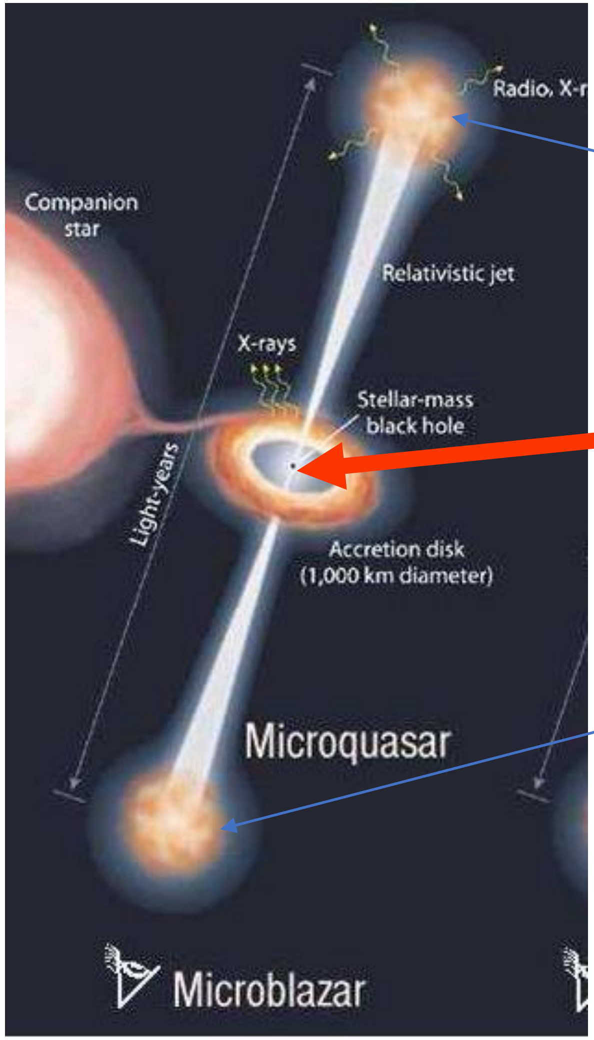
Derived Cosmic Ray bubble over ~200 pc

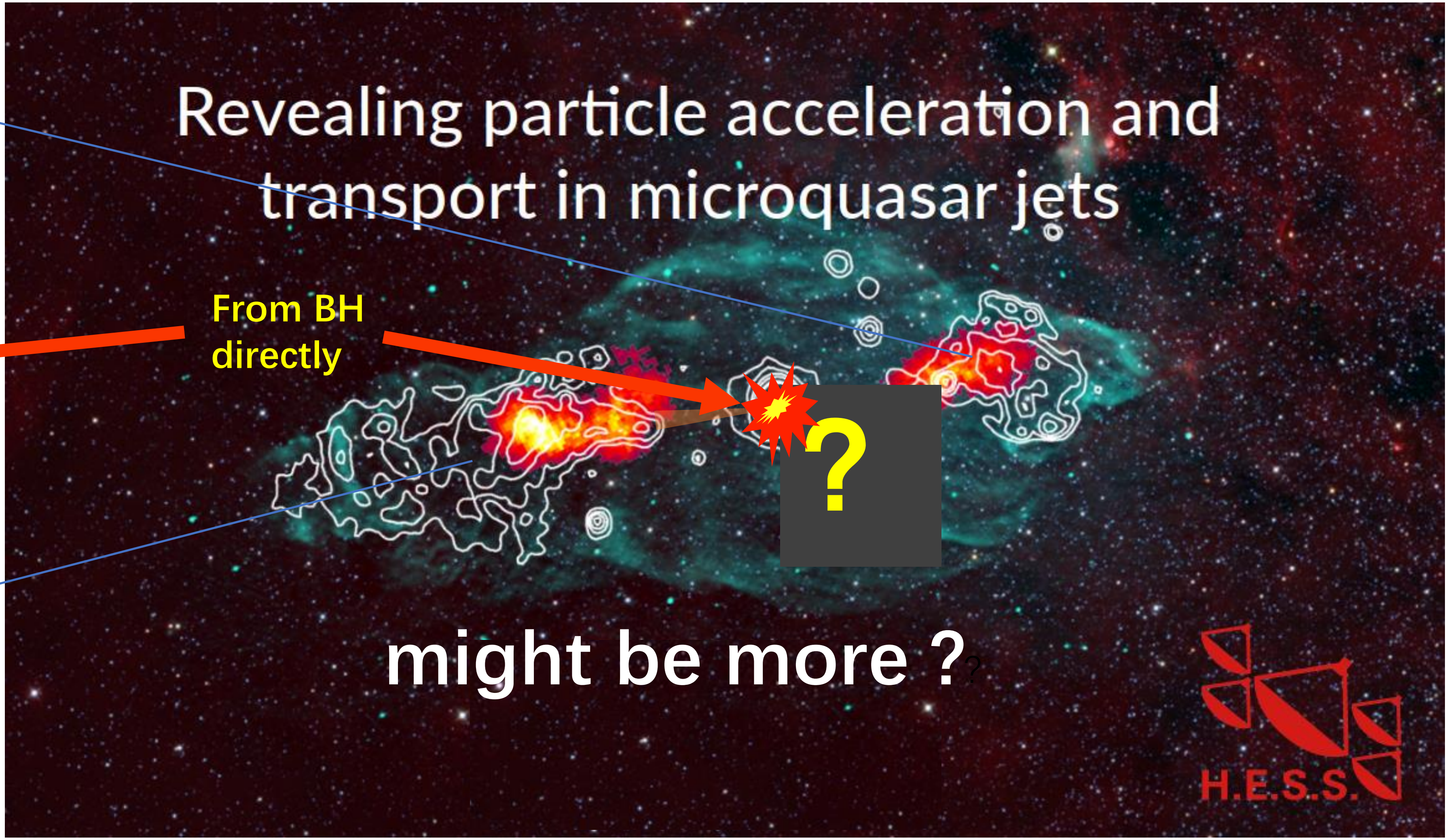
LHAASO
高海拔宇宙线观测站



- ◆There is a large cosmic ray bubble
- ◆A rather small propagation ecoefficiency around the source
- ◆The size of the visible bubble depends on the level of diffuse γ-rays

SS 433: UHE γ-emitters?

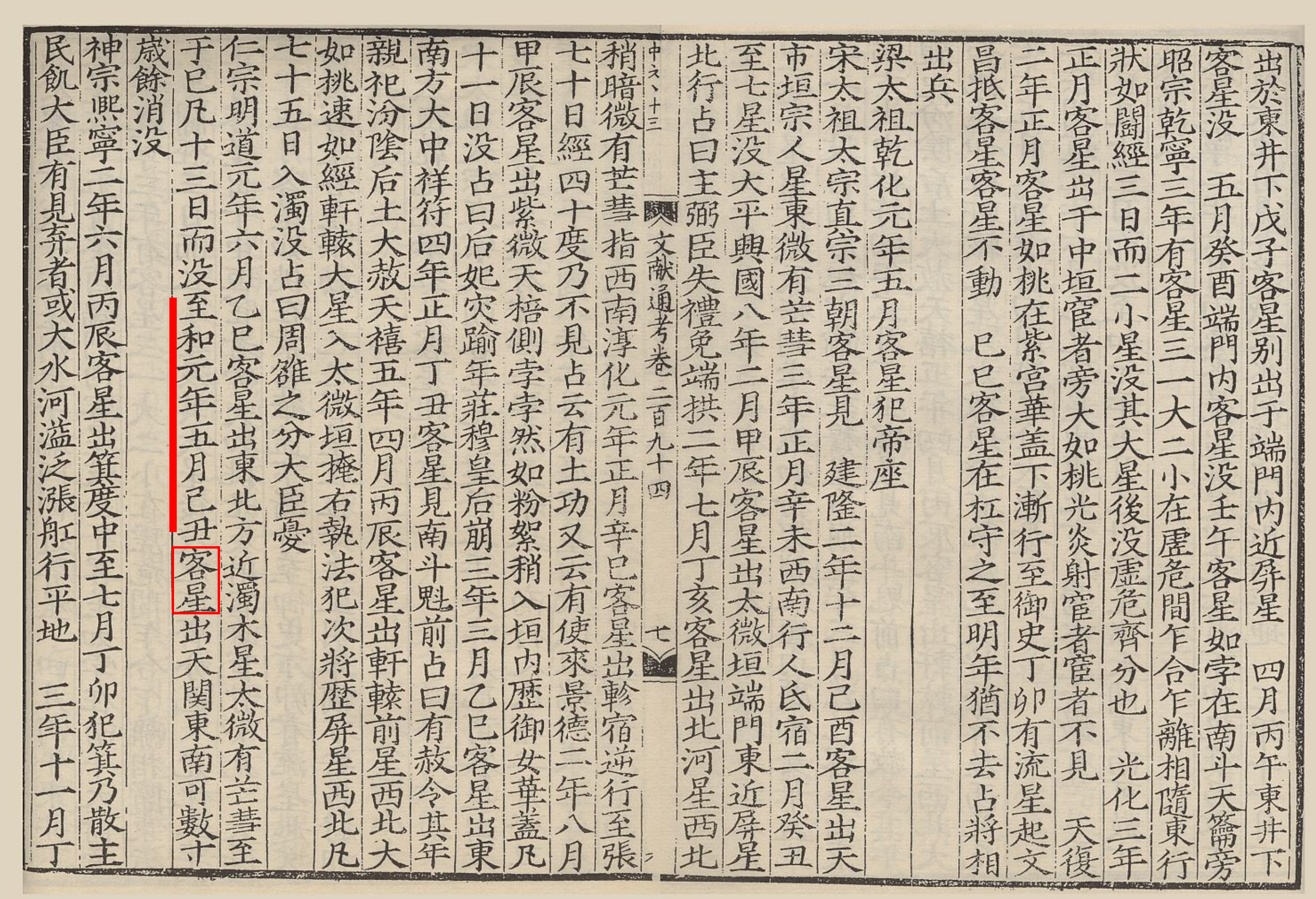




- **Extreme Accelerators**

The First Observation 967 years back

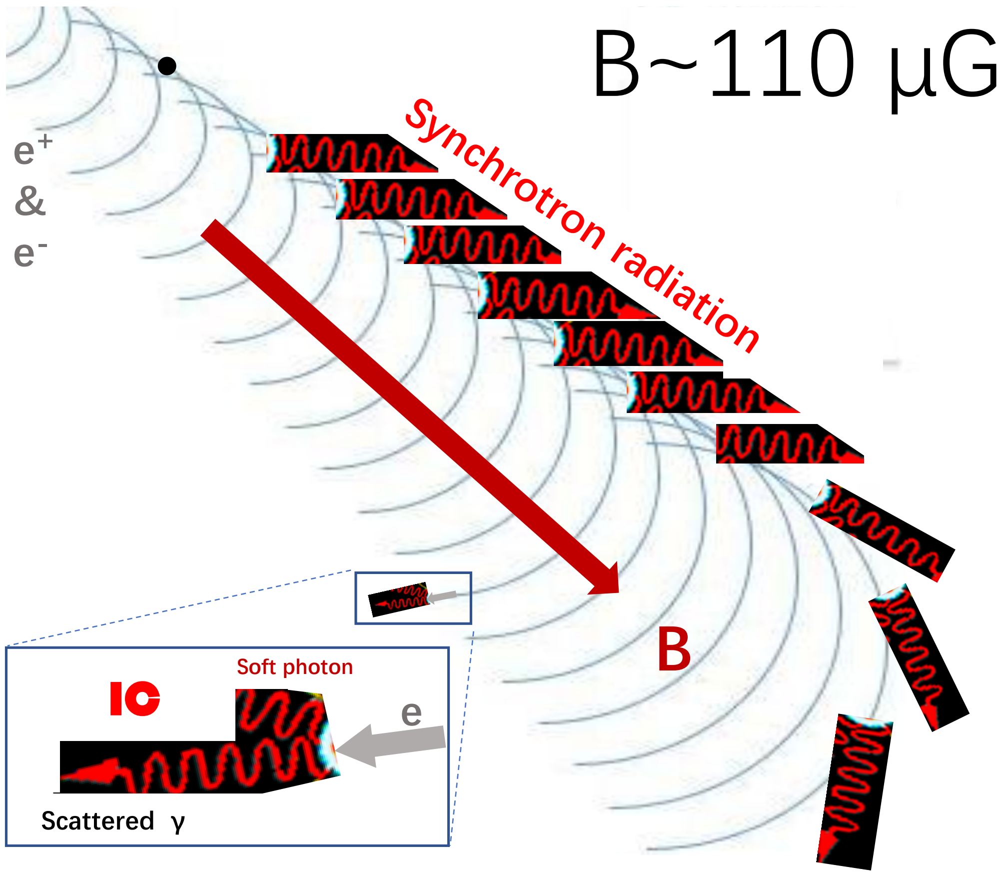
- **Song Dynasty Official (司天监) recorded the "guest star"**
- **The first identified Supernova**
- **The accurate occur time: the night of July, 4th,1054**

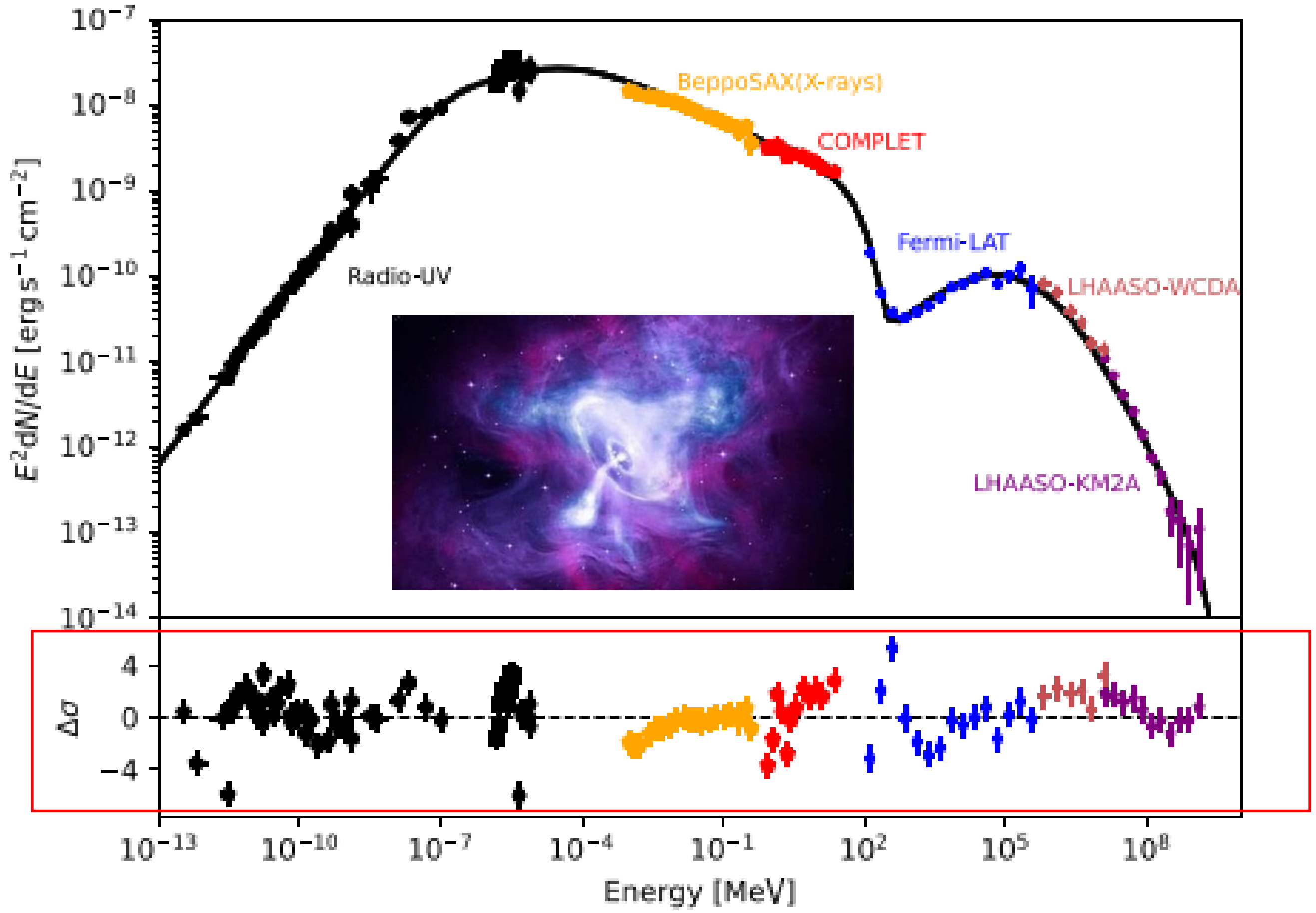

出於東井下戊子客星別出于端門內近屛星 四月丙午東井下
客星沒 五月癸酉端門內客星沒壬午客星如孛在南斗天籥旁
昭宗乾寧三年有客星三一大二小在虛危間乍合乍離相隨東行
狀如鬬經三日而二小星沒其大星後沒虛危齊分也 光化三年
正月客星出于中垣宦者旁大如桃光炎射宦者宦者不見 天復
二年正月客星如桃在紫宮華蓋下漸行至御史丁卯有流星起文
昌抵客星客星不動 己巳客星在杠守之至明年猶不去占將相
出兵
梁太祖乾化元年五月客星犯帝座
宋太祖太宗真宗三朝客星見 建隆二年十二月己酉客星出天
市垣宗人星東微有芒彗三年正月辛未西南行入氐宿二月癸丑
至七星沒大平興國八年二月甲辰客星出太微垣端門東近屛星
北行占曰主弼臣失禮免端拱二年七月丁亥客星出北河星西北
文獻通考卷二百九十四 七
稍暗微有芒彗指西南淳化元年正月辛巳客星出軫宿逆行至張
七十日經四十度乃不見占云有土功又云有使來景德二年八月
甲辰客星出紫微天棓側孛孛然如粉絮稍入垣內歷御女華蓋凡
十一日沒占曰后妃災踰年莊穆皇后崩三年三月乙巳客星出東
南方大中祥符四年正月丁丑客星見南斗魁前占曰有赦令其年
親祀汾陰后土大赦天禧五年四月丙辰客星出軒轅前星西北大
如桃速如經軒轅大星入太微垣掩右執法犯次將歷屛星西北凡
七十五日入濁沒占曰周雒之分大臣憂
仁宗明道元年六月乙巳客星出東北方近濁木星太微有芒彗至
于巳凡十三日而沒至和元年五月己丑客星出天關東南可數寸
歲餘消沒
神宗熙寧二年六月丙辰客星出箕度中至七月丁卯犯箕乃散主
民飢大臣有見斥者或大水河溢泛漲舡行平地 三年十一月丁

"Extreme Electron PeVatron"

- One-zone Leptonic Model： remarkable feature over 22 orders
- The photons above 1 PeV pose challenges to particle accel. Theory

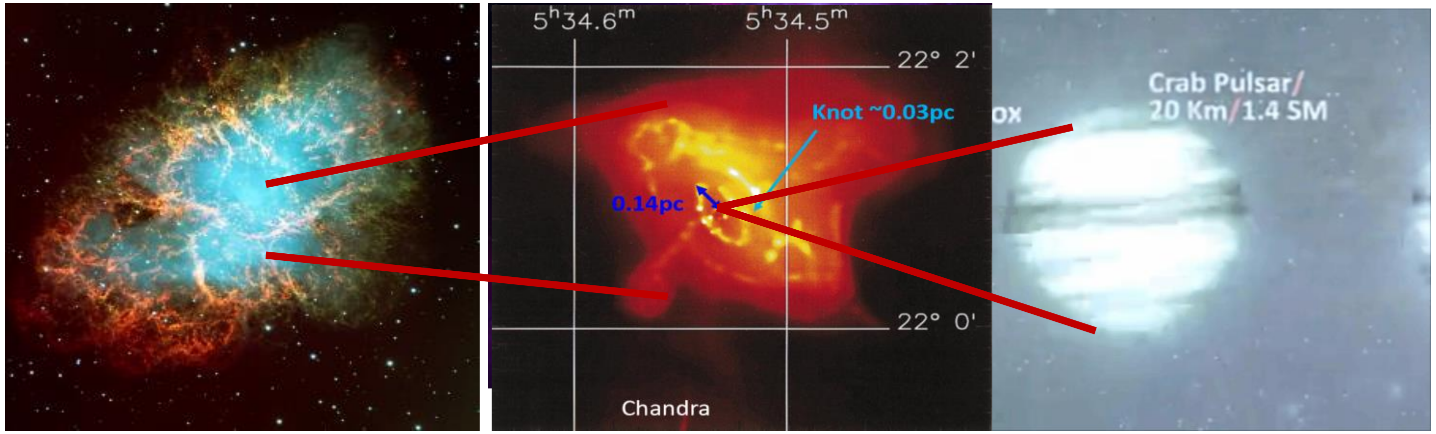
L. Nie et al., ApJ, **924** 42 (2022), arXiv:2201.03796



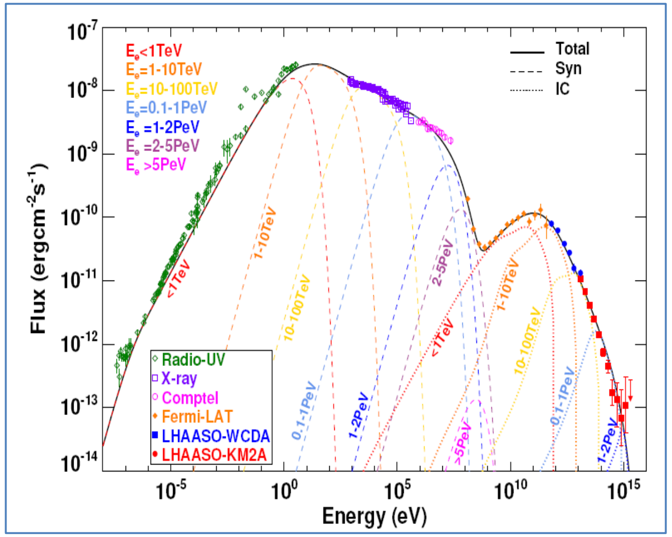


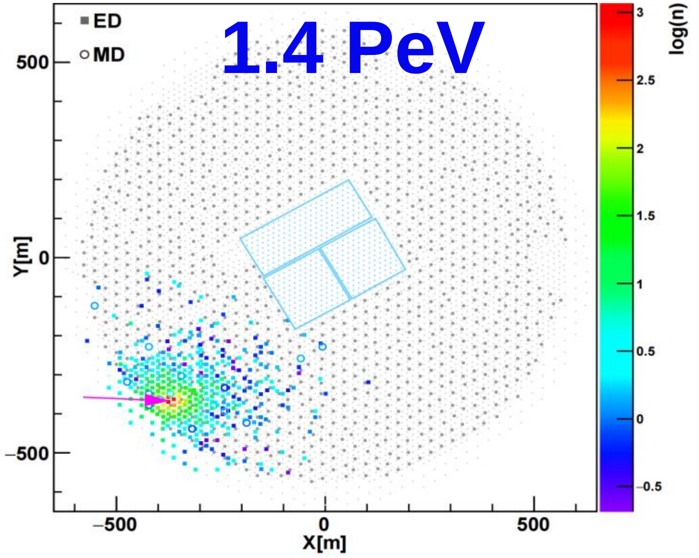
The Crab Nebula: emitting photons above 1 PeV

- Electron/positron accelerator in the heart of the nebula
- Acceleration rate approaching the theoretic limit



- Record HE photons 1.1PeV→1.4 PeV
- Electron energy must be higher than 2.3 PeV→2.8 PeV
- Acceleration rate η≈0.16→0.26
- size of accelerator R_g=0.025 pc→0.032 pc





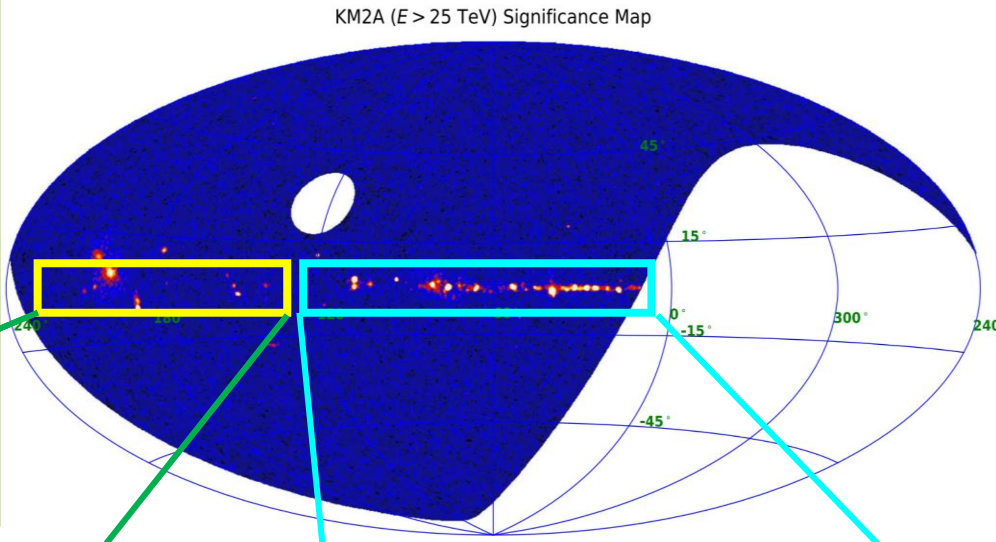
Science,373:425 (2021)

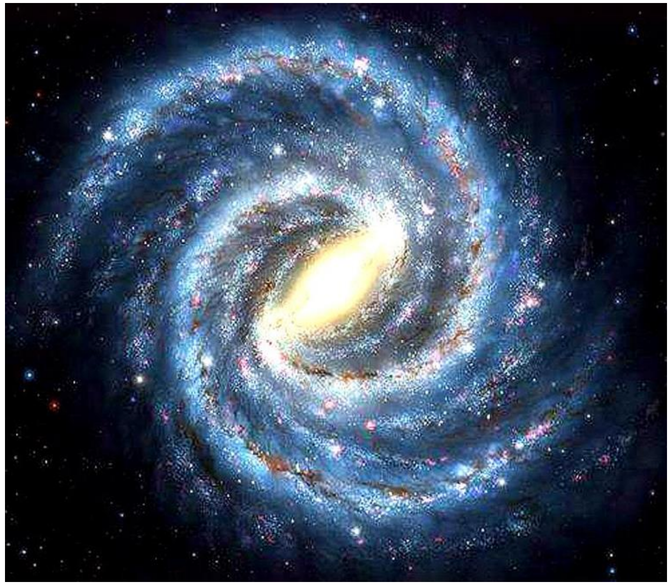
- **Diffuse γ-rays**

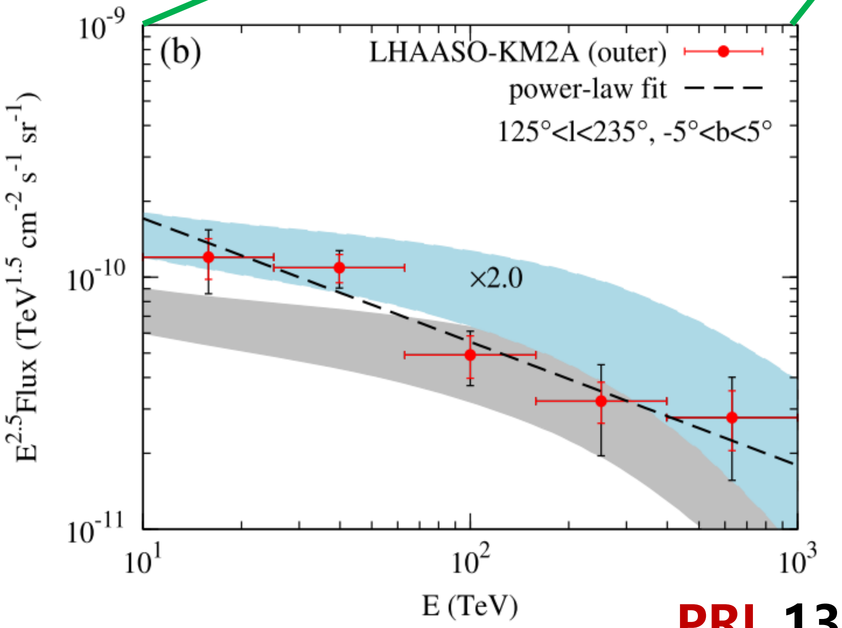
& Cosmic ray Anisotropy

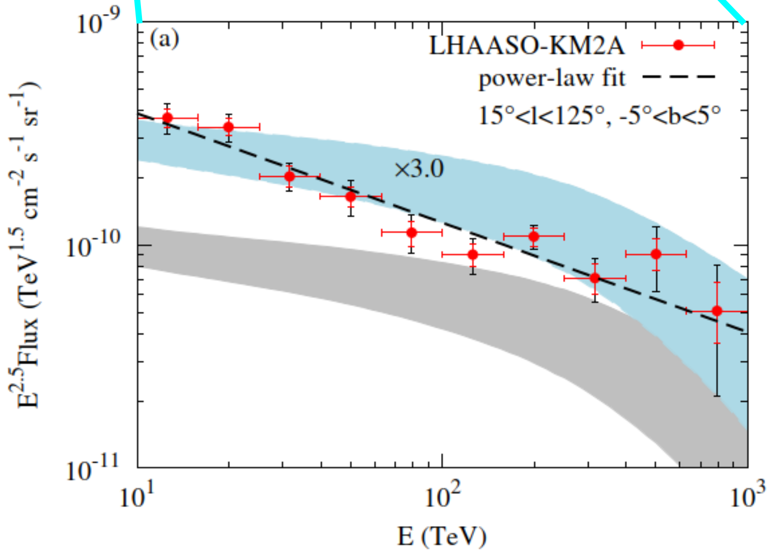
Diffuse γ-rays: trace the propagation of CRs in the MW

- **High precision measurements covering (10 TeV, 1 PeV) with all sources removed**
- **GDE measured in outer-galaxy for first time**
- **×3 of the predicted assuming uniform distribution of CRs in the MW**



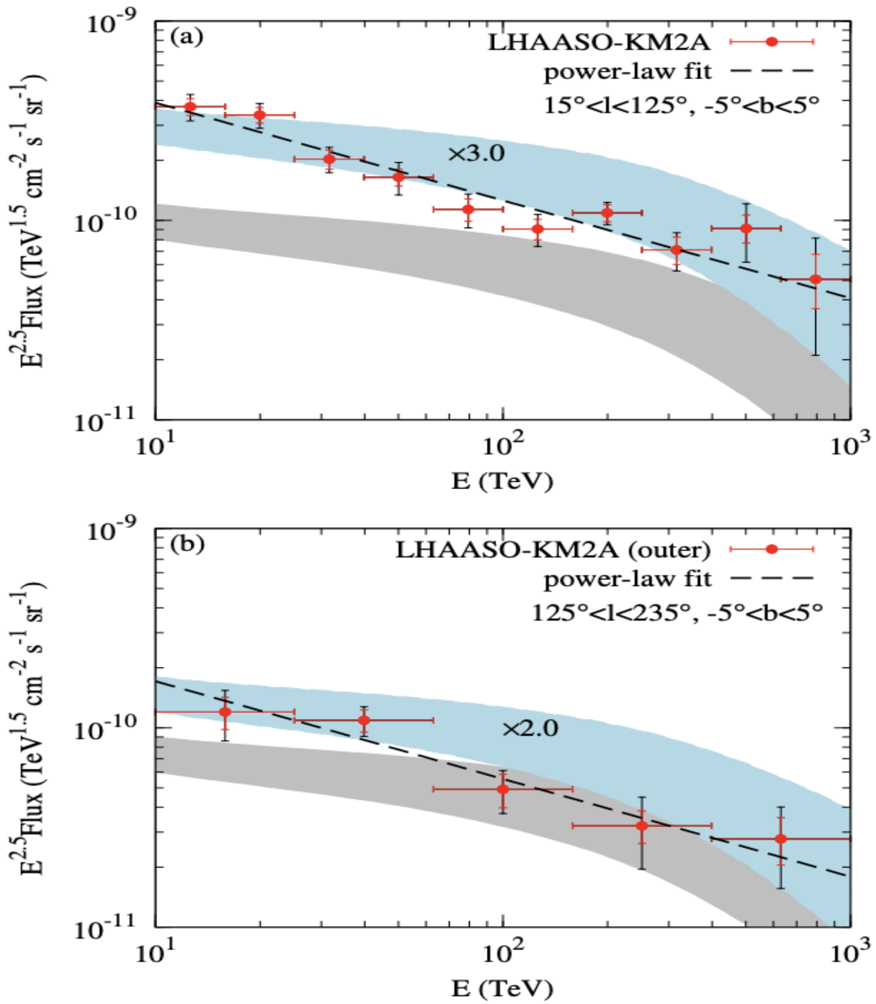


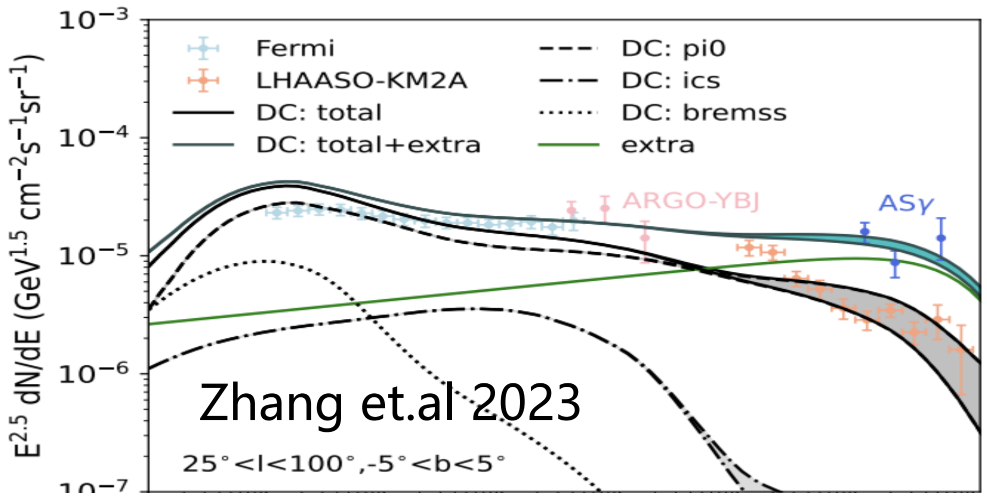


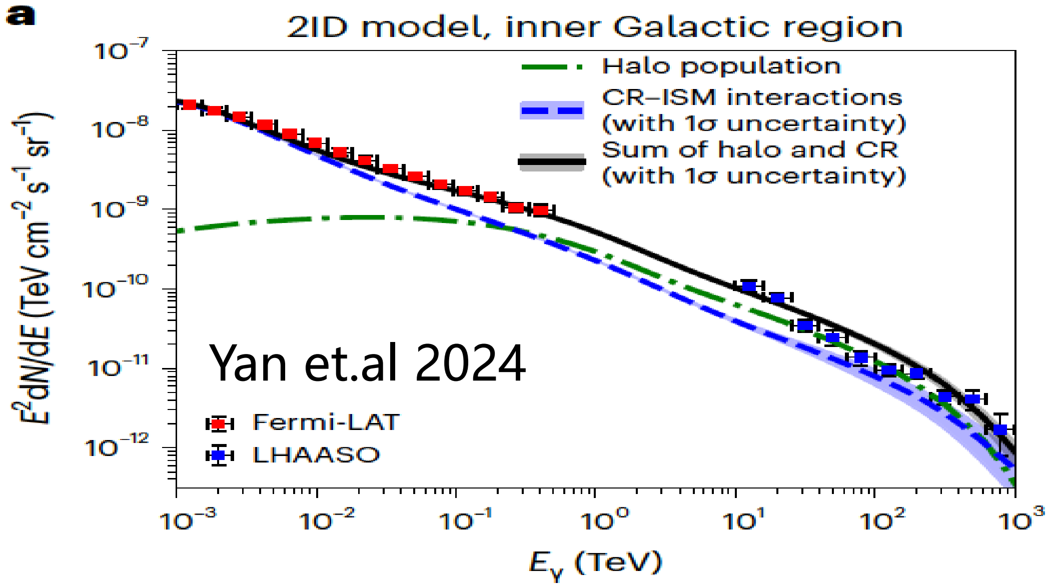


PRL 131:151001(2023)

Diffuse gamma-ray emission







Phys. Rev. Lett. 131, 151001 (2023)

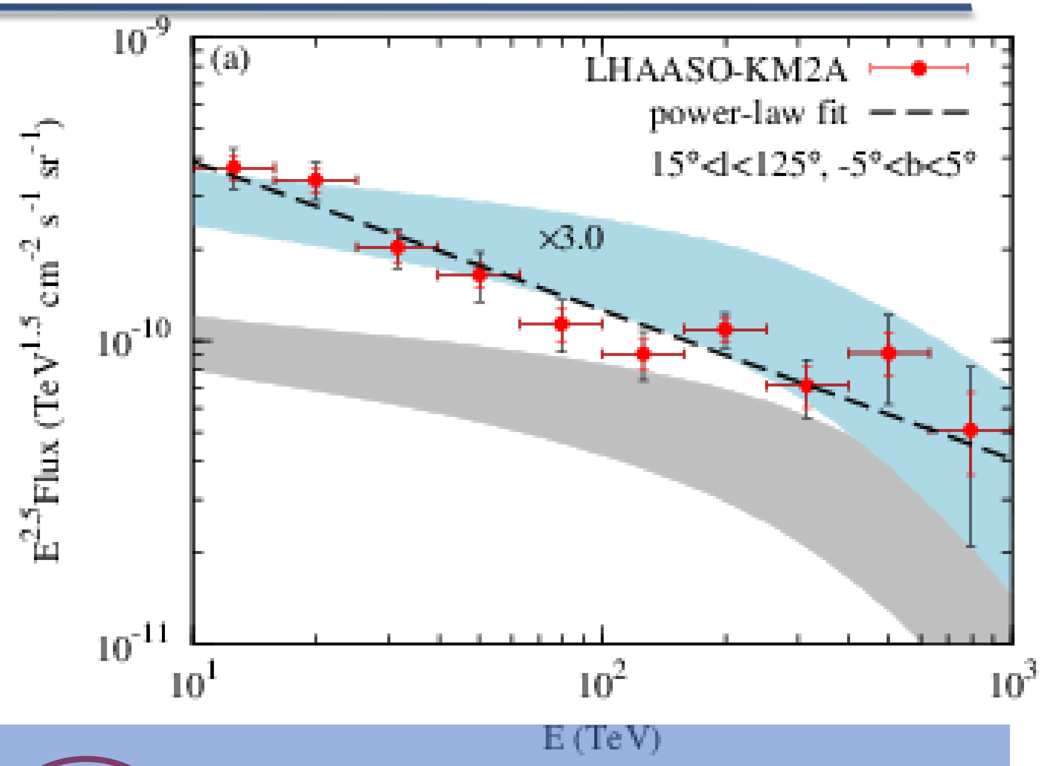
\`Excess' revealed in multi-TeV band

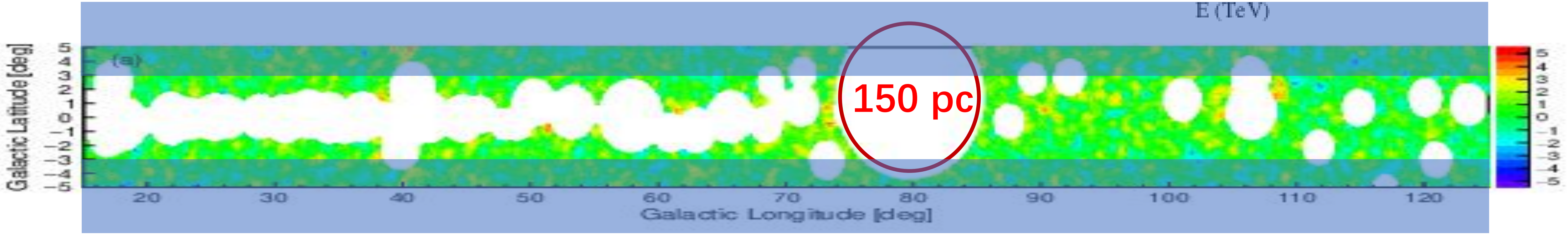
A new component in GDE? From Pulsar halos?

The Galactic Diffuse Emission is X3 higher than the expectation

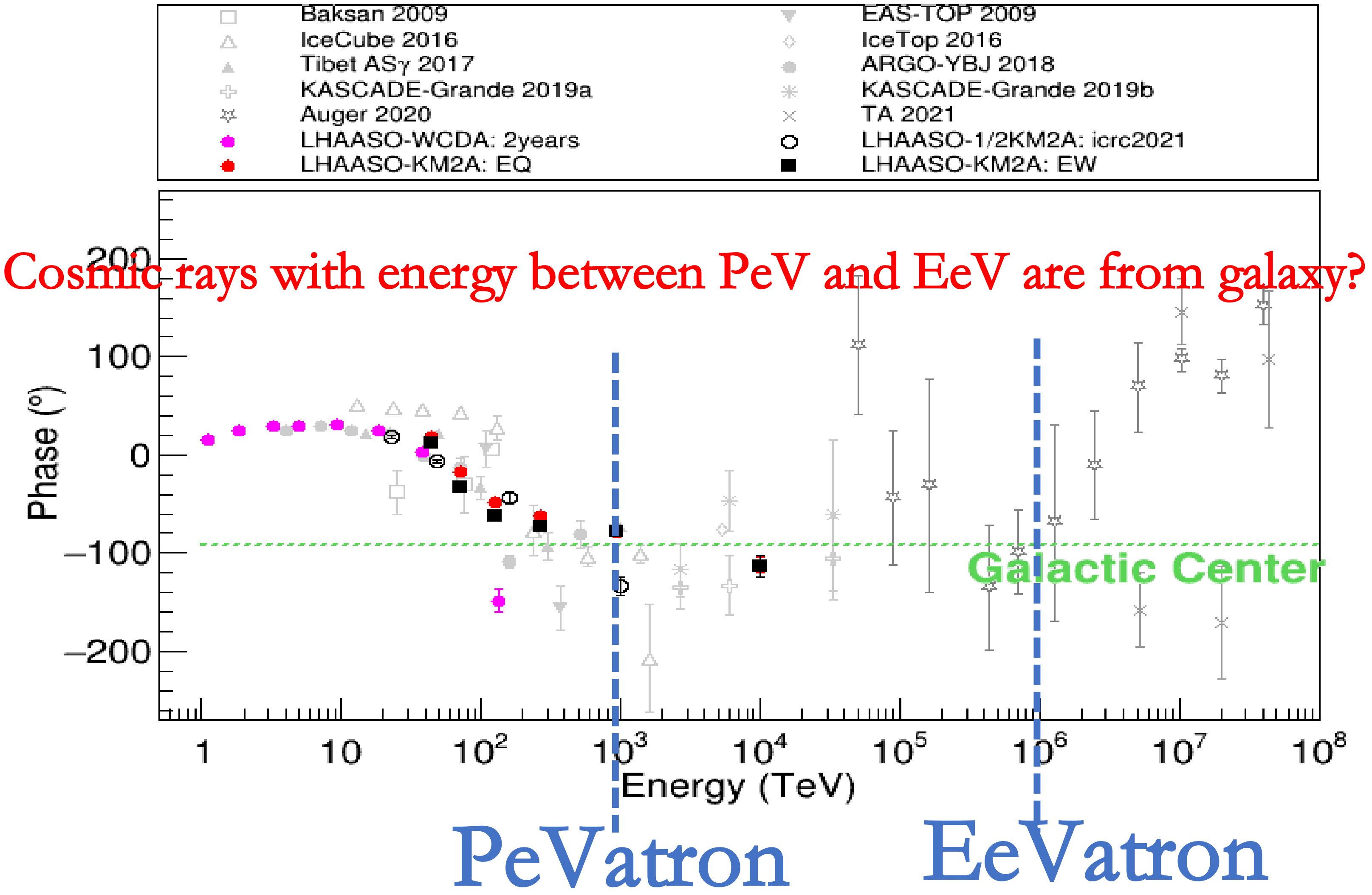
Inner Galactic Region

- Likely to be the extension of bubbles
- Cygnus bubble is a good example
- Measurements in belts |b|>5° or 3° may help to understand better





Cosmic ray anisotropy



- There should be sources in our galaxy can accelerate particles to PeV or even up to EeV from the measurement of CRs at earth.

ICRC2023 WeiGao

Cosmic-ray Spectra around Knees

- Pure Protons
- light comppnent
- All-particle Spectrum

Hybrid Measurement of CR Showers around the Knee

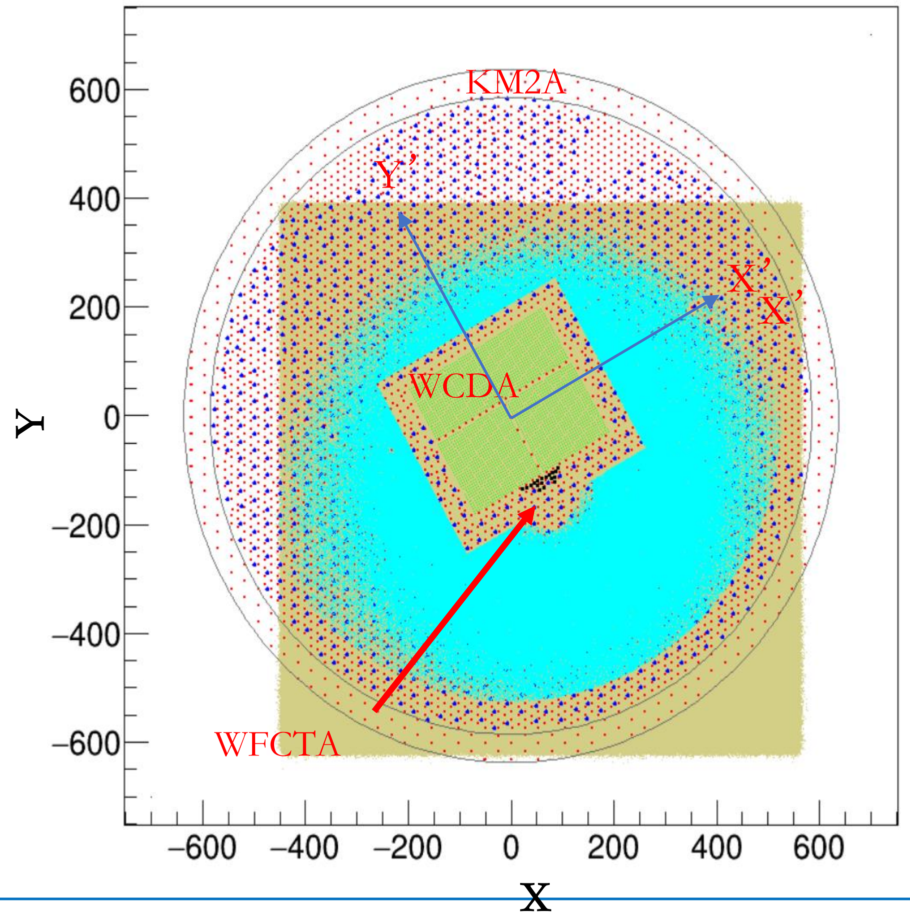
高海拔宇宙线观测站 Large High Altitude Air Shower Observatory

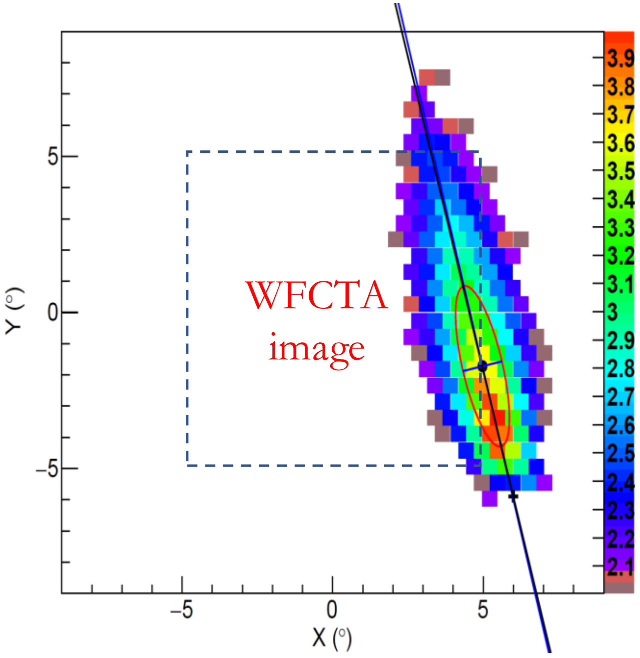
➢ WFCTA:

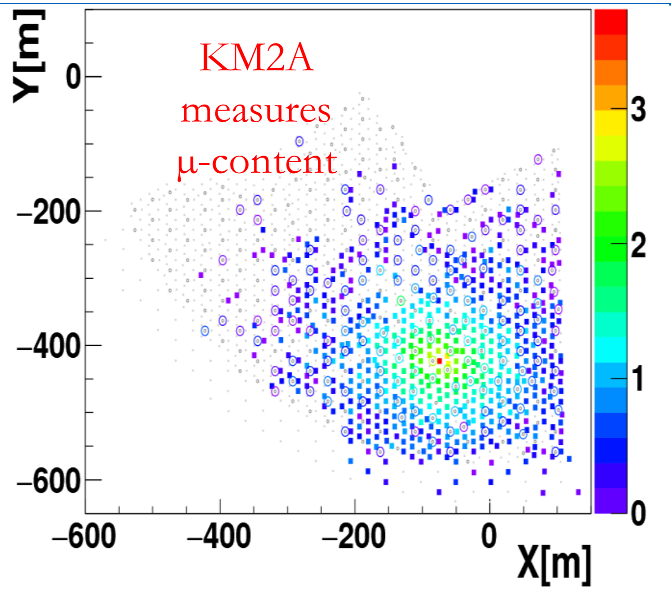
1. Number of pixels: Npix>6
2. FoV: 10° × 10° for the centroid of the image
3. R_p: 100 – 300 m

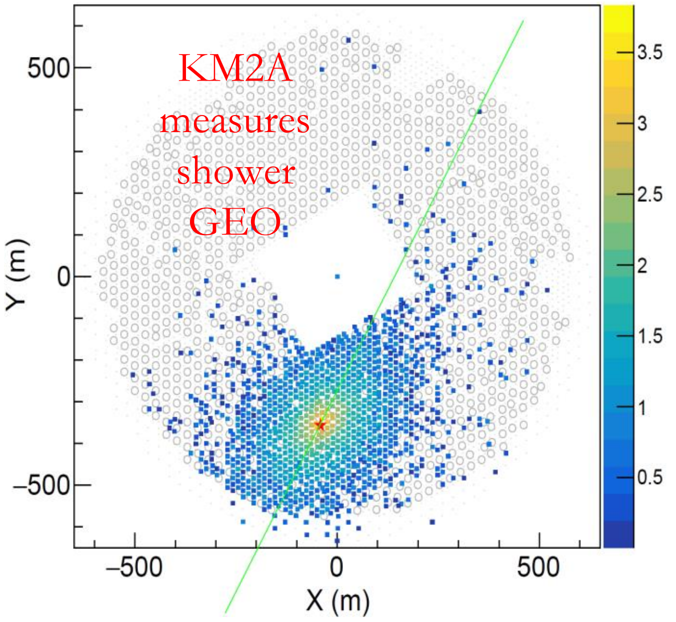
➢ KM2A:

1. Core (x, y)
   - $\sqrt{x^2 + y^2} < 500\ m$
   - !(|x'|<200 m & |y'| <150 m)
2. Number of hits in KM2A > 20







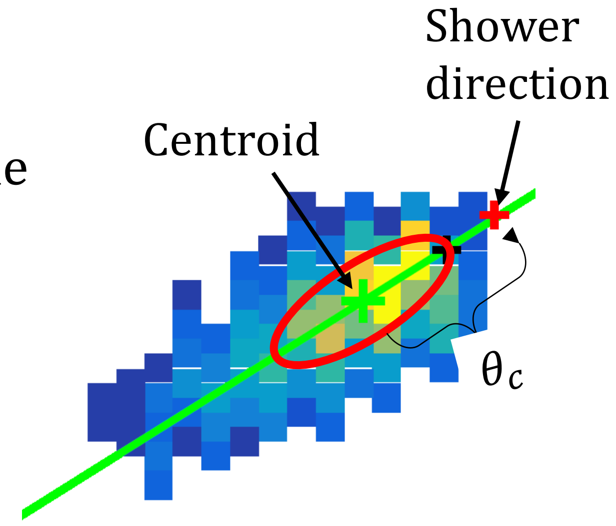


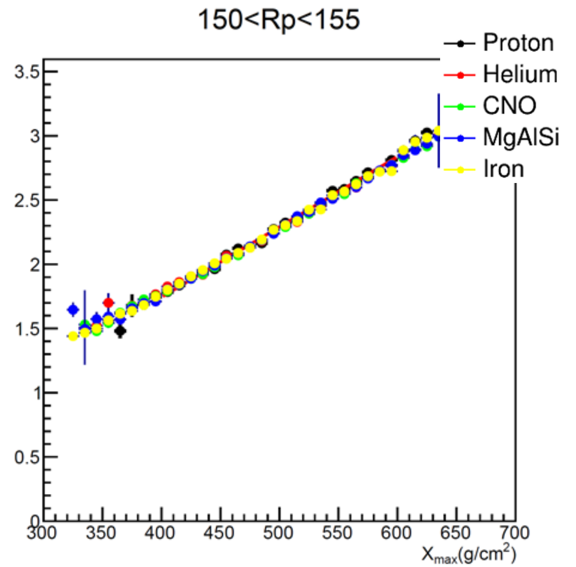
Proton Event Selection

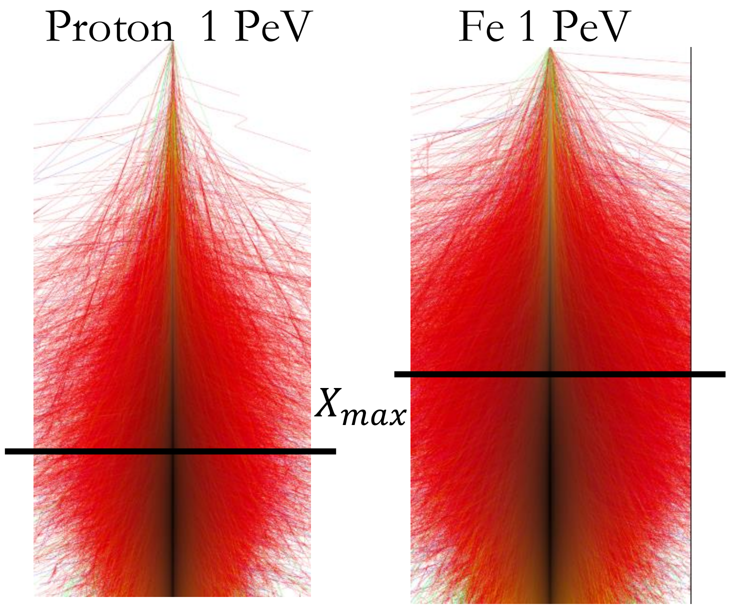
EAS maximum at X_{max} : $X_{max}^{A} = X_{max}^{P} - \lambda_r \ln A$

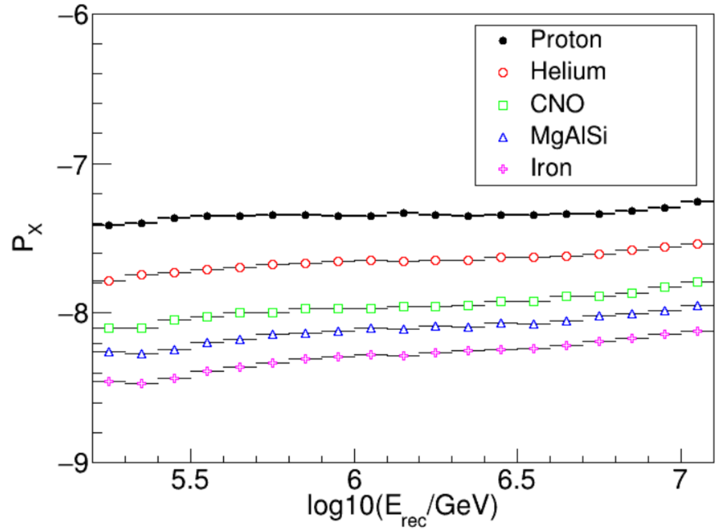
Elongation rate : $\Lambda \equiv \frac{dX_{max}}{d\log_{10}E} \approx 58\mathrm{g} \cdot \mathrm{cm}^{-2}/\mathrm{decade}$

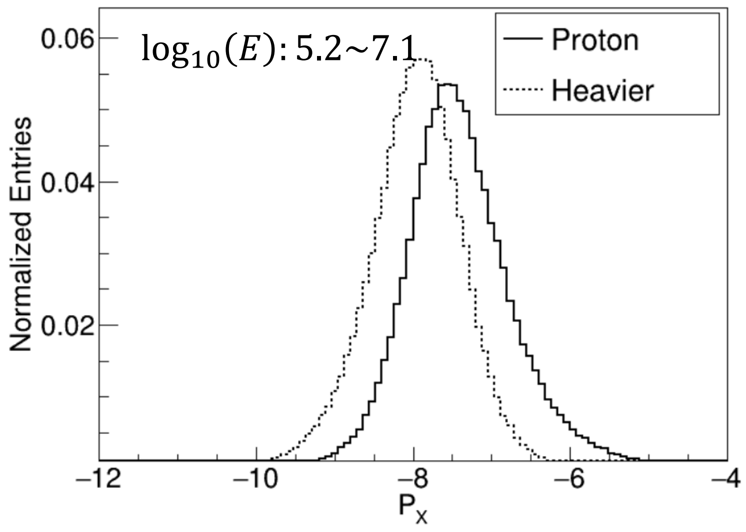
- $P_0 = \theta_c / \cos zenith - 1.32 \times 10^{-2} R_p$
- $P_X = P_0 + 0.13 \times \lg^2 E_{rec} - 2.16 \times \lg E_{rec}$









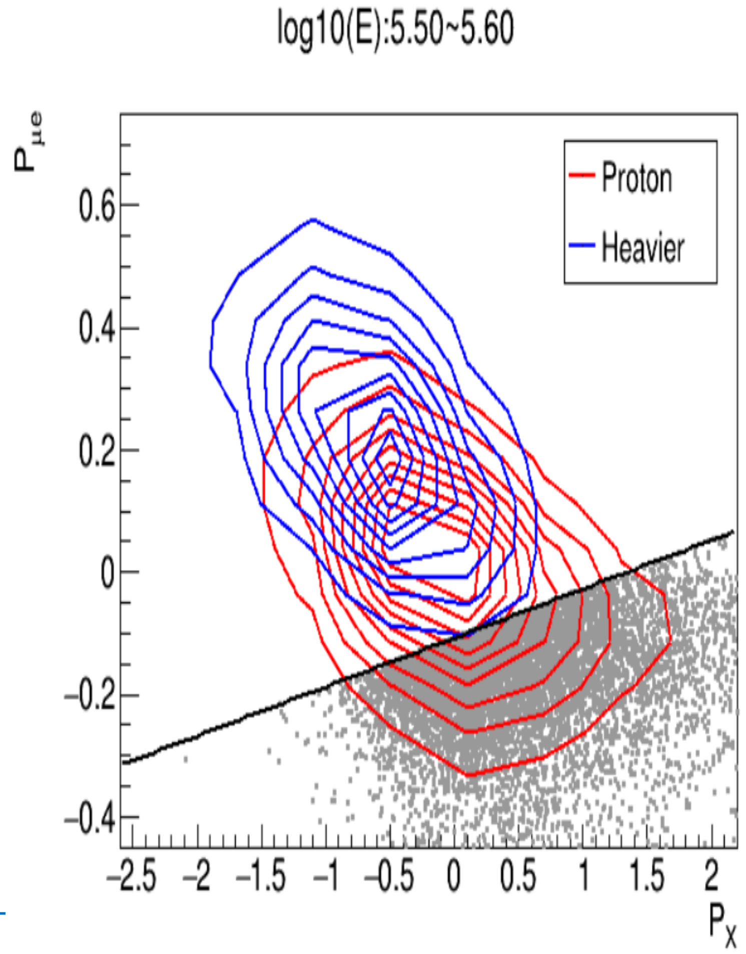


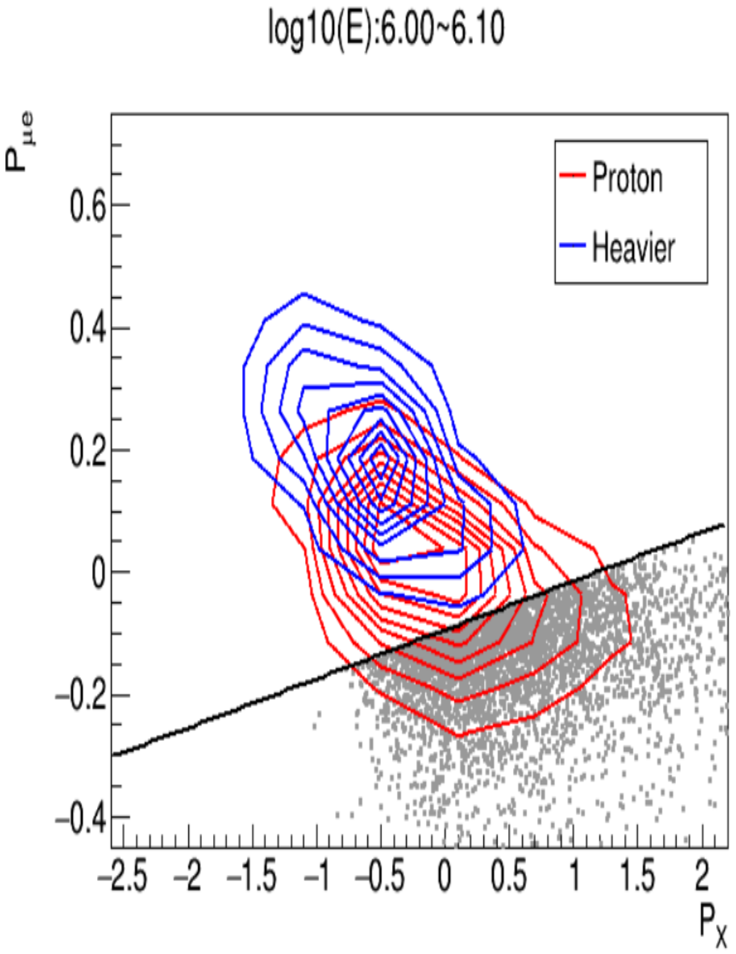
Proton Shower Selection: shower maximum depth & μ-content

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

Proton Purity: $\epsilon^p = \frac{N_{sel}^P}{N_{sel}^{MC}} > 90\%$

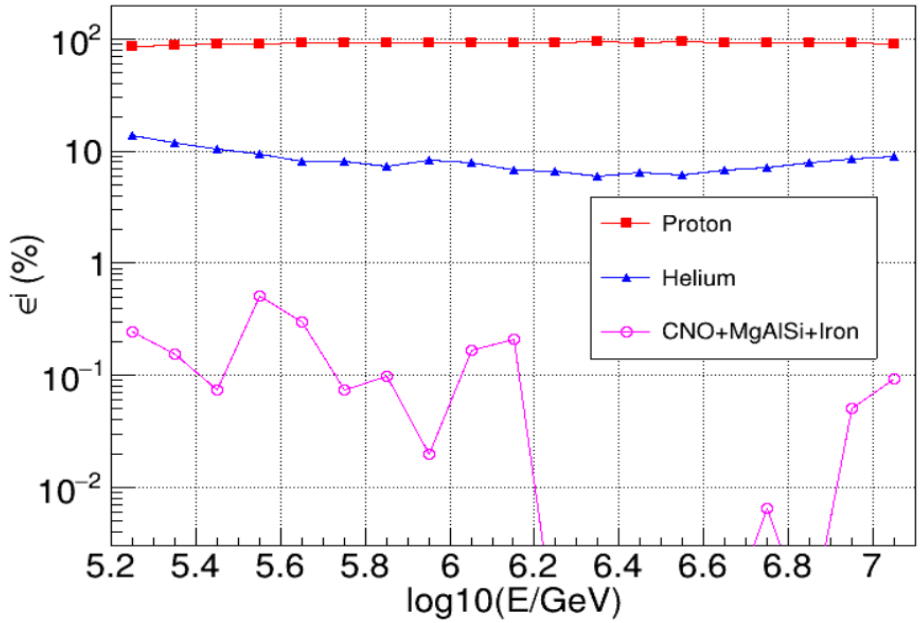
$(for\ Eproton > 300\text{TeV})$

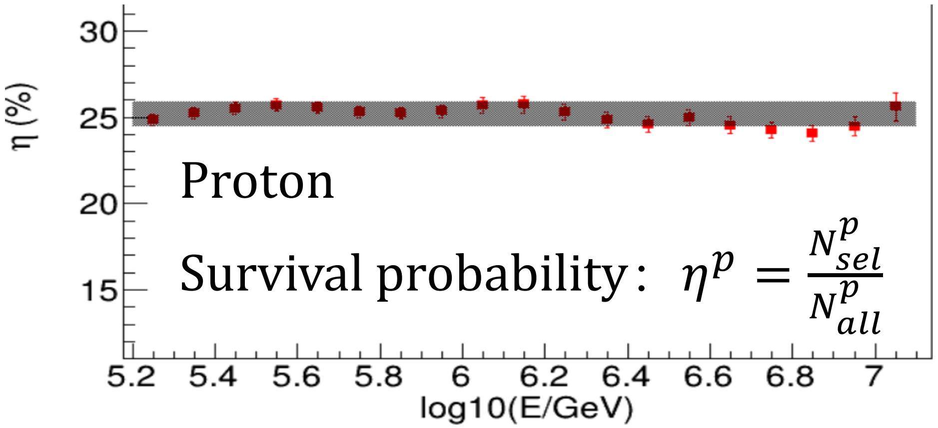




Composition: $\epsilon^i = \frac{N_{sel}^i}{\Sigma N_{sel}^i}$ i= H, He, Other

(After selection)





Proton

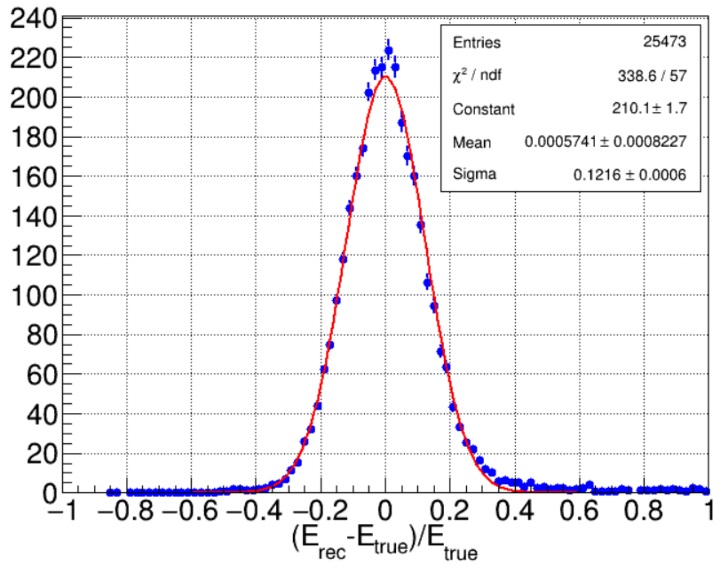
Survival probability: $\eta^p = \frac{N_{sel}^p}{N_{all}^p}$

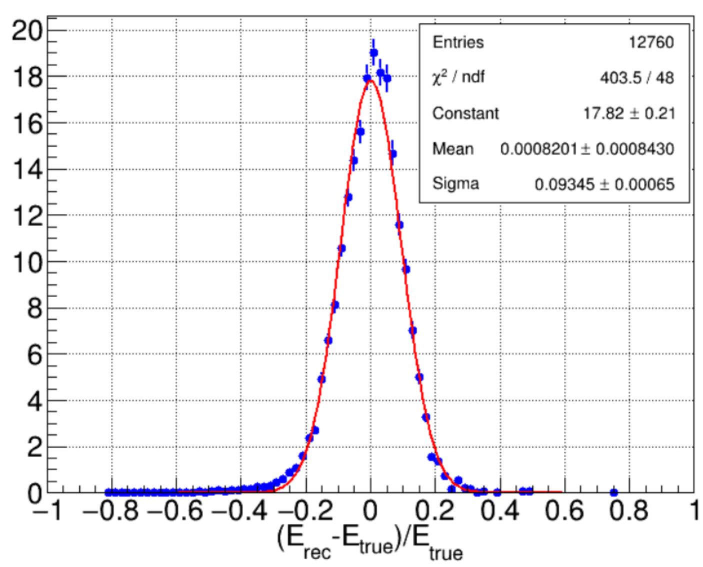
Proton Energy Reconstruction

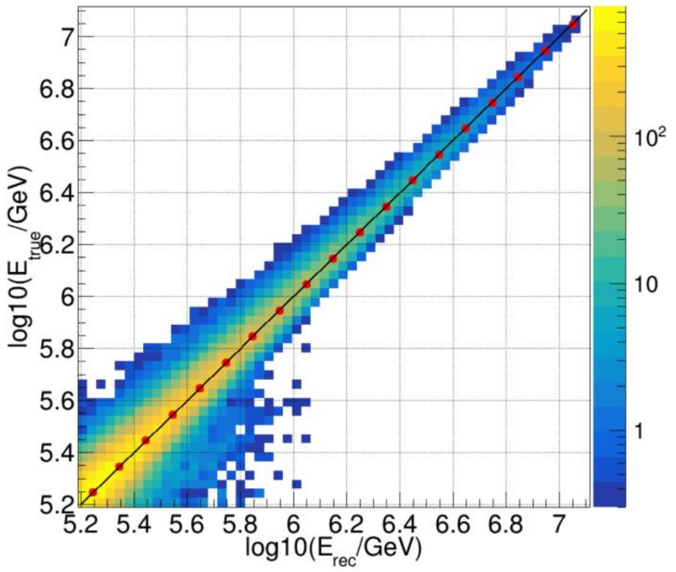
高海拔宇宙线观测站 LHAASO Large High Altitude Air Shower Observatory

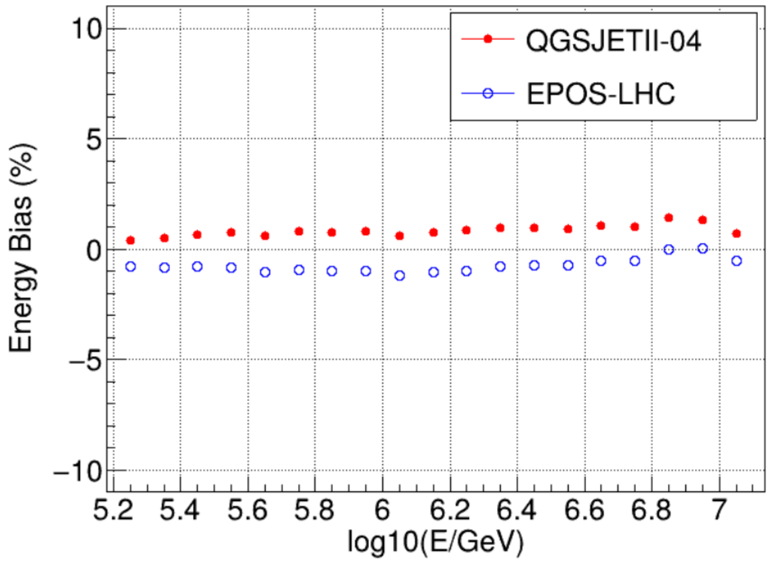
- Energy Resolution： <15%
- Systematic Bias： <2%
  (independent of shower energy)

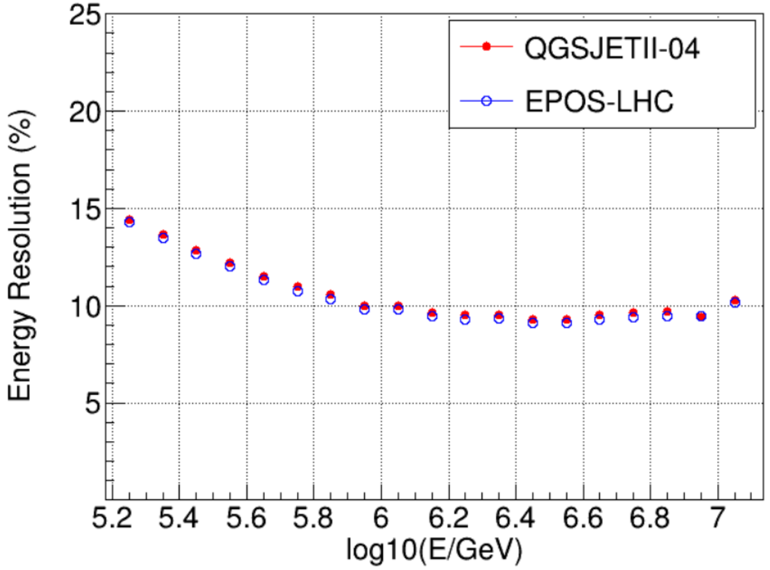
- Uncertainty mainly due to **hadronic interaction models**： ~1.4%





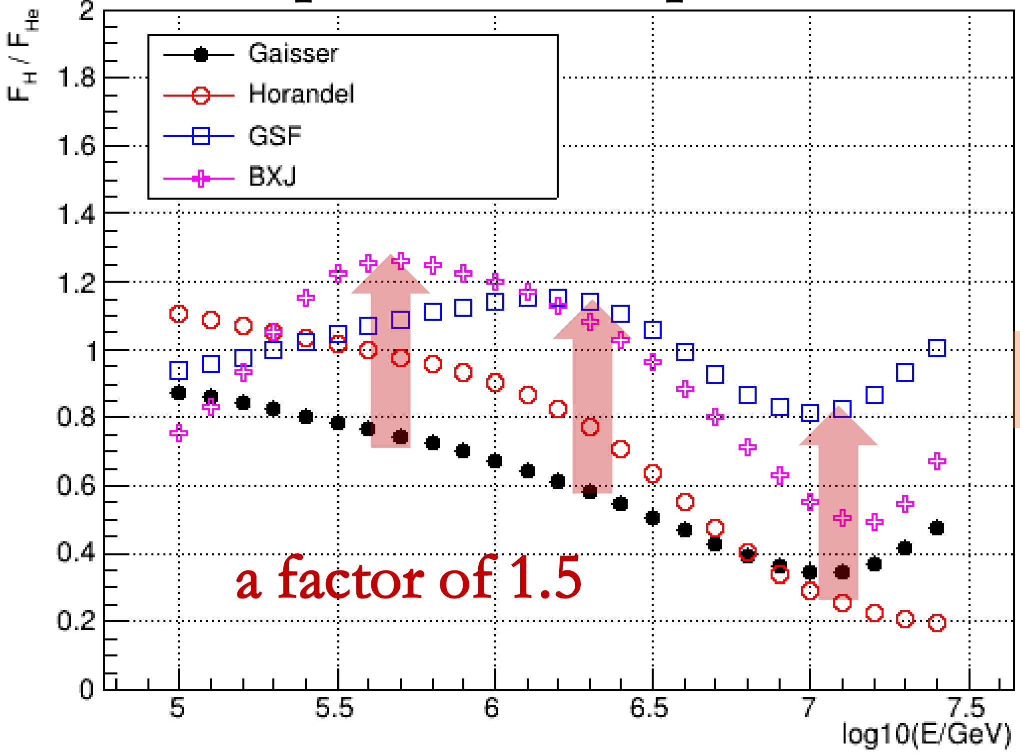




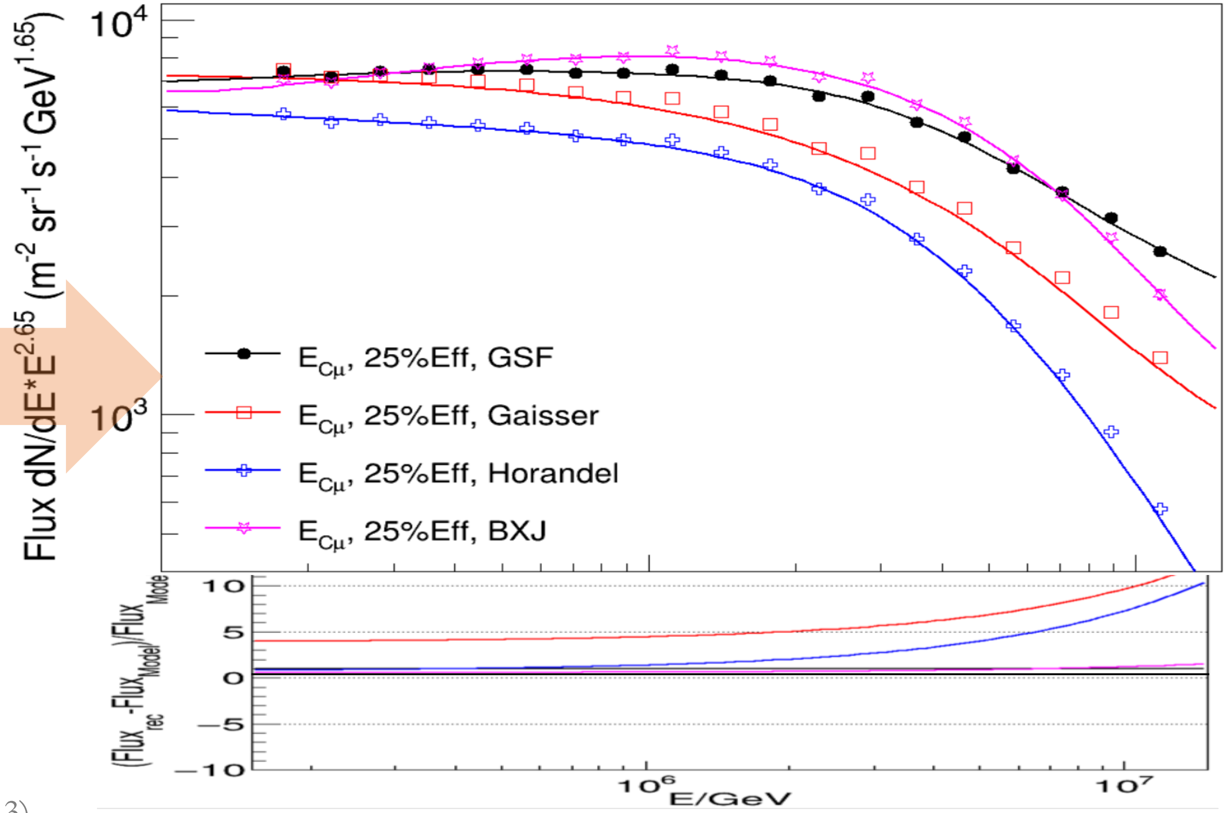


Tests using generated samples

Ratio of proton vs Helium nuclei in composition assumptions



re-produced pure-proton spectra under 4 assumption of composition mixtures



Gaisser Model: Gaisser, T.K., Stanev, T. & Tilav, S. Front. Phys. 8, 748 – 758 (2013)

Horandel Model: Horandel J R. Astroparticle Physics, 2003, 19(2):193 – 220

GSF Model: H. P. Dembinski, R. Engel, A. Fedynitch, T. Gaisser, F. Riehn, and T. Stanev, PoS ICRC2017, 533 (2018)

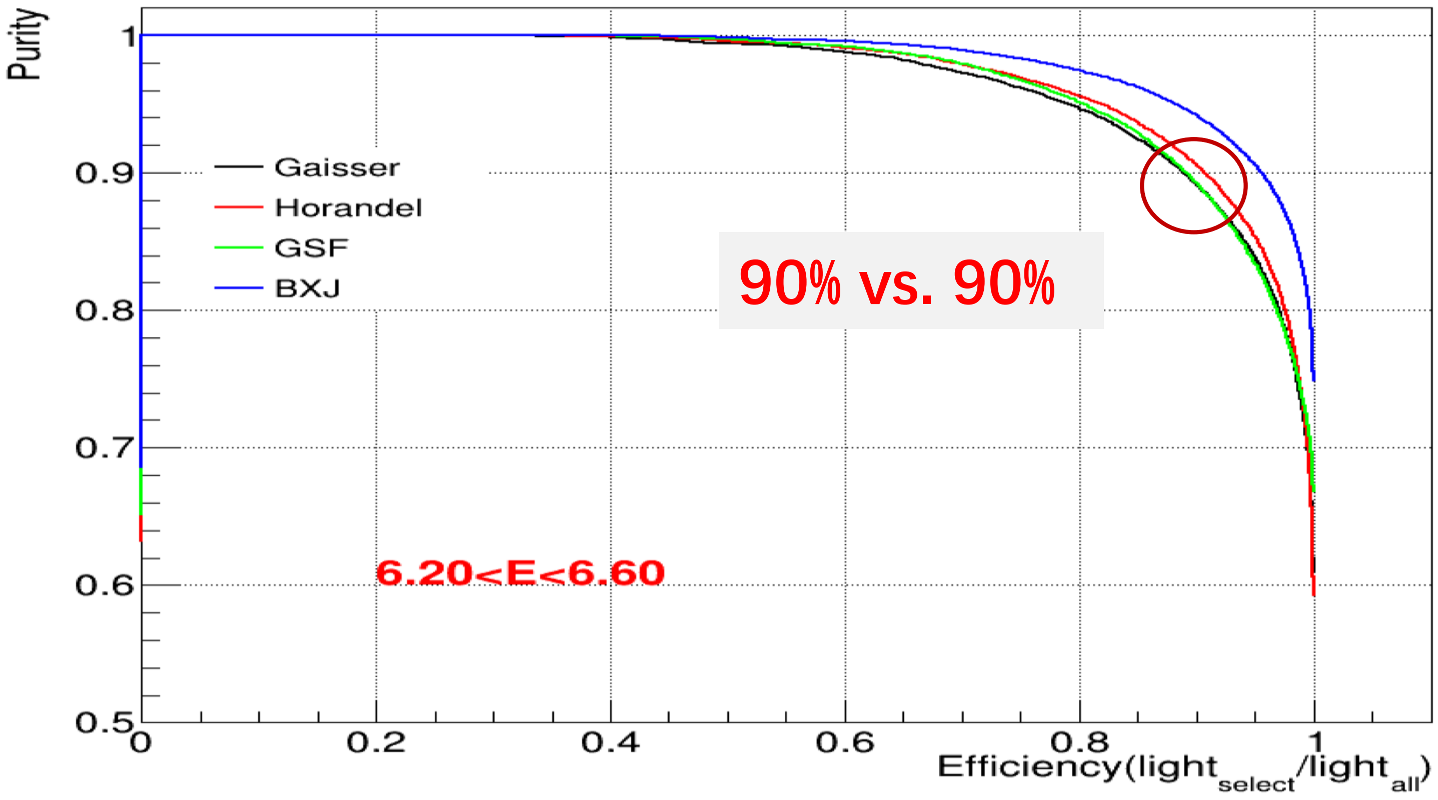
BXJ Model: Lv X.-J., Bi X.-J., Fang K., et al. , arXiv:2403.11832. (2024)

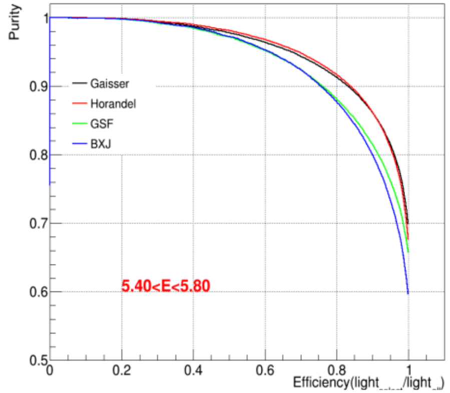
Light Component Spectrum → Helium Spectrum

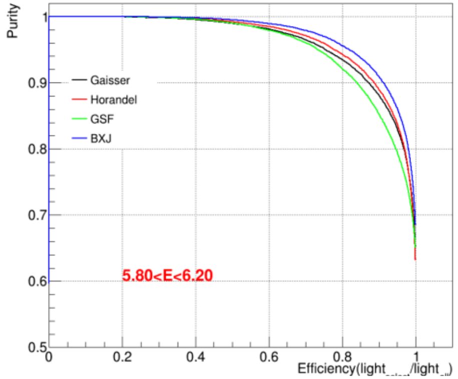
$$P_{\mu} = \log_{10}\frac{\rho_{\mu}}{\rho_e^{0.83}}$$

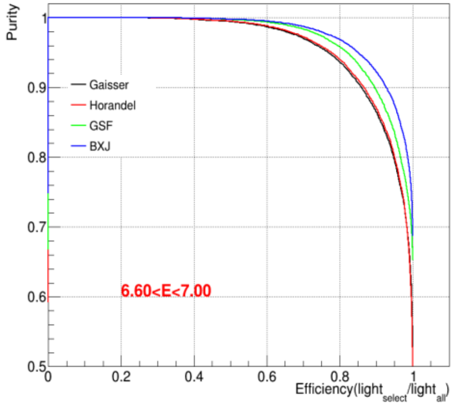
ρ_{μ}: *muon density in the ring between 40m and 200m* from the core

ρ_e: *EM − particle density in the ring between 40m and 200m*



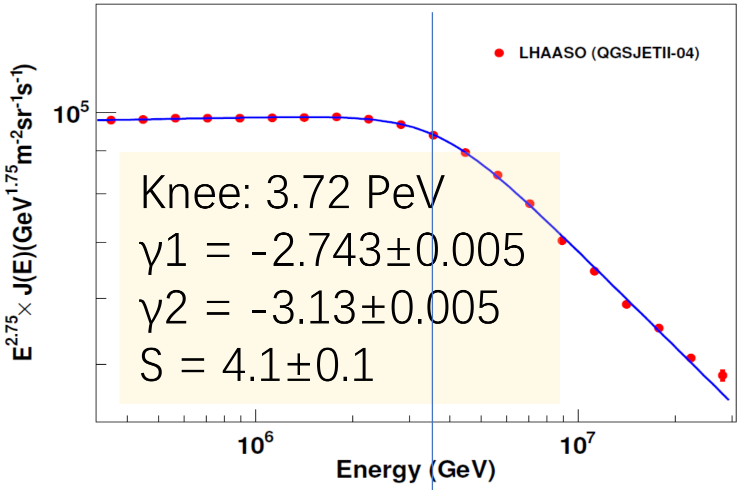


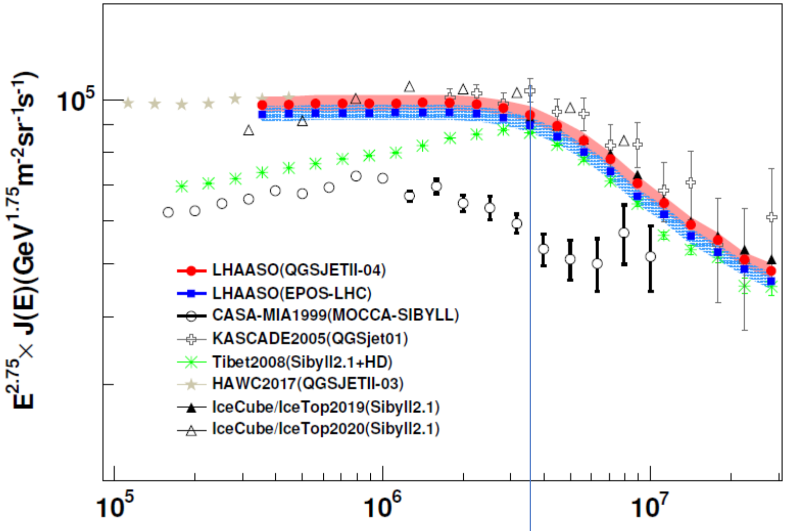


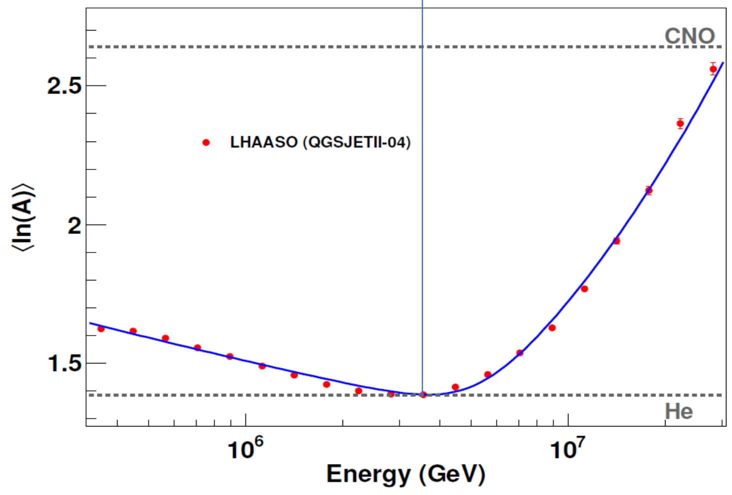


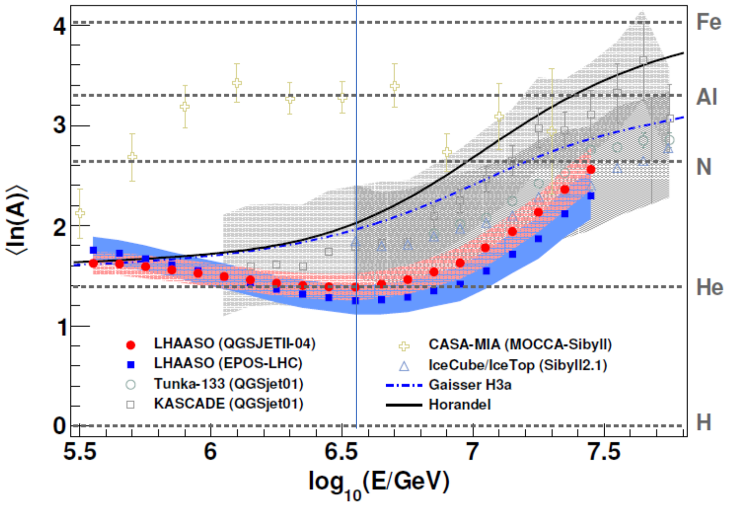
All-particle energy spectrum & composition by LHAASO

(from 0.3 to 30 PeV)







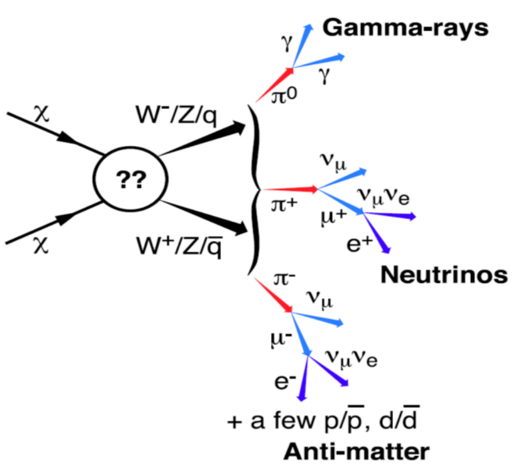


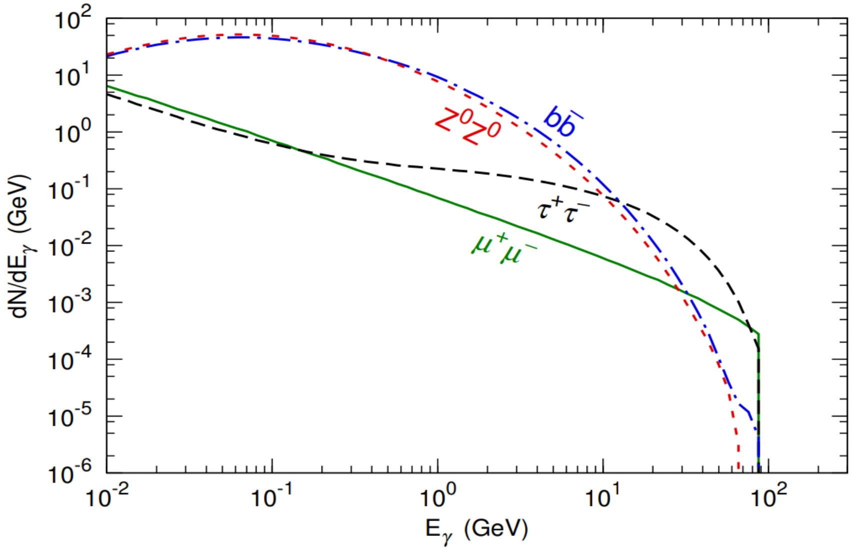
- Systematic uncertainties are sufficiently small
- This unveils a clear correlation between the flux and the composition at the knee

- **Search for new Physics**

Indirect search of the Dark Mater

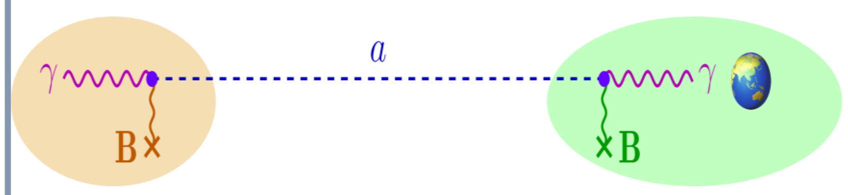
- Decay into γ's
- Annihilation: γ's in final states
- Oscillation between axions and photons

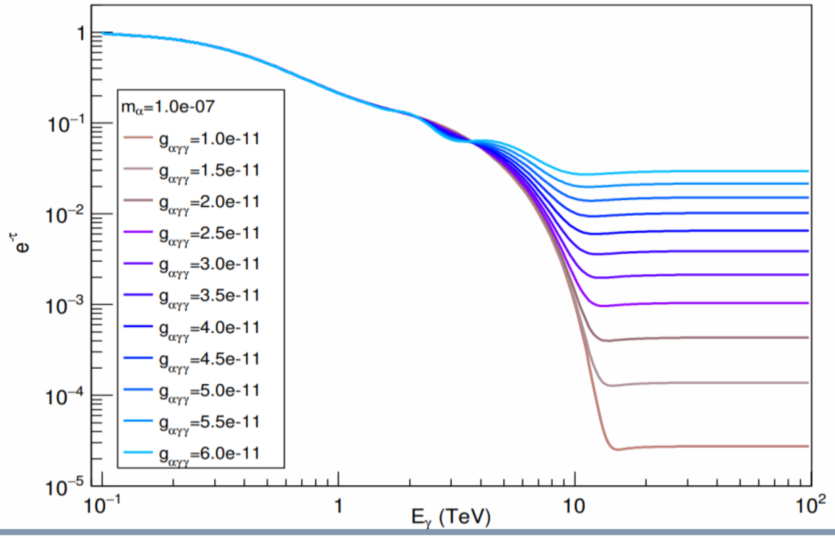




- Searching in
  - Dwarf Galaxies
  - Galactic Halo
  - G.C.

$$\mathcal{L}_{a\gamma\gamma} = -\frac{1}{4} g_{a\gamma\gamma} a F_{\mu\nu} \tilde{F}^{\mu\nu} = g_{a\gamma\gamma} a \boldsymbol{E} \cdot \boldsymbol{B}$$





Credit Z.H. Yu

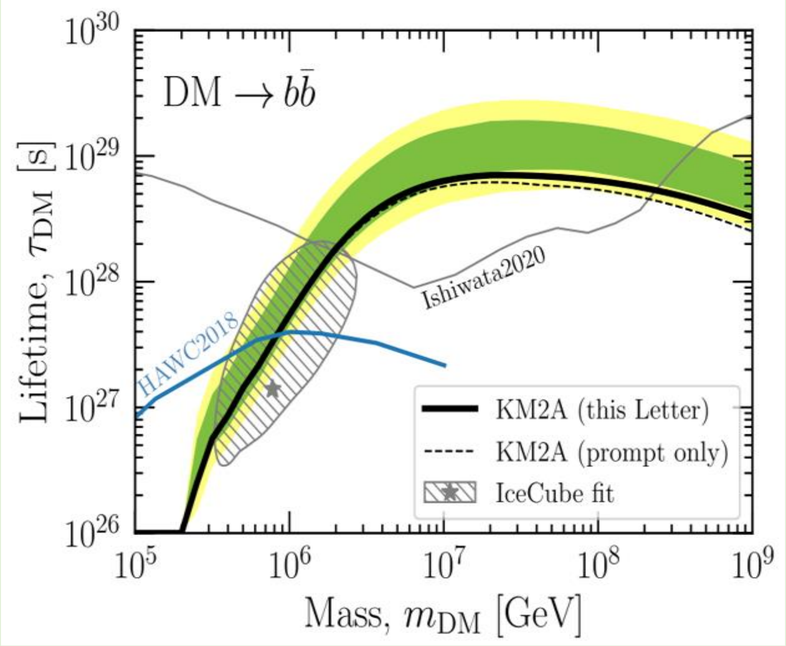
LHAASO searches for DM

LHAASO 高海拔宇宙线观测站

In the halo, for decay signals

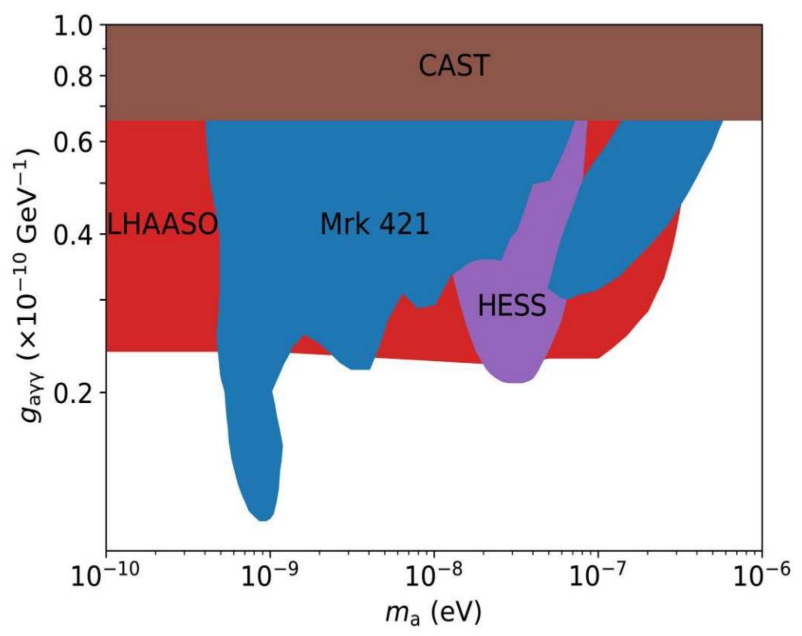
The most strict constraint in massive DM : life time

$\tau > 10^{21}$ yr



PRL 129:261103(2022)

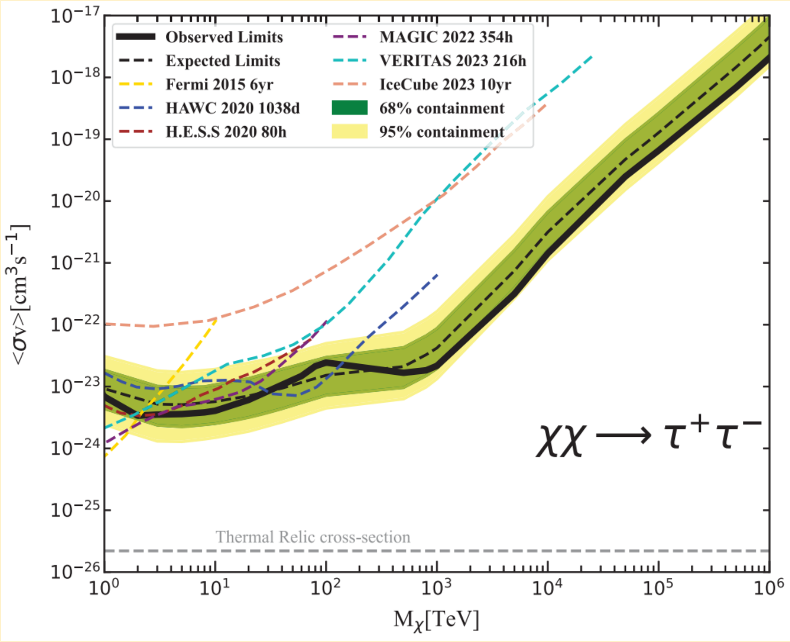
EBL absorption of 10 TeV photons from remote GRB (z=0.152) puts constraint in coupling between axion and photons



Science Advances 9:eadj2778 (2023)

In dwarf galaxies, for annihilation signals

The most strict constraint in massive DM



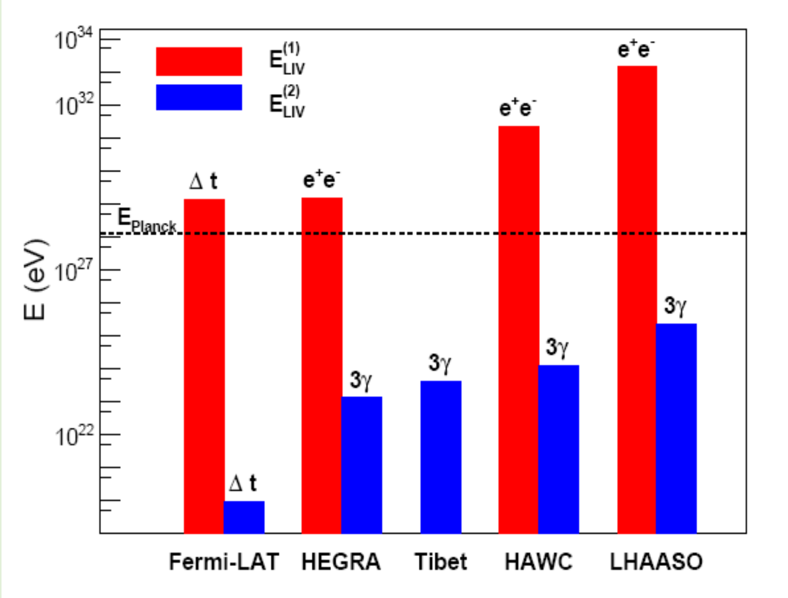
PRL 133:061001 (2024)

LHAASO on Lorentz Invariance Violation (LIV)

LHAASO 高海拔宇宙线观测站

Decay of PeV photons from remote sources

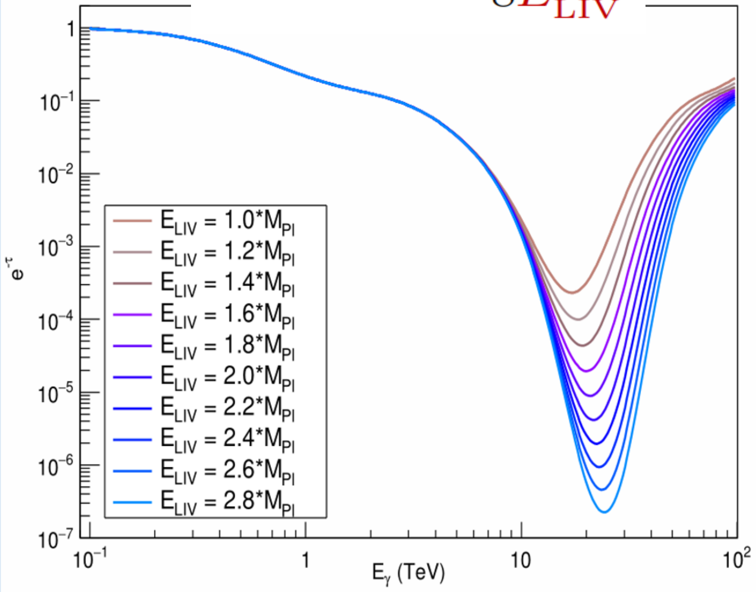
$$E_\gamma^2 - p_\gamma^2 = \pm|\alpha_n| p_\gamma^{n+2}$$



PRL 128:051102(2022)

EBL absorption of 10 TeV photons from remote GRB (z=0.152)

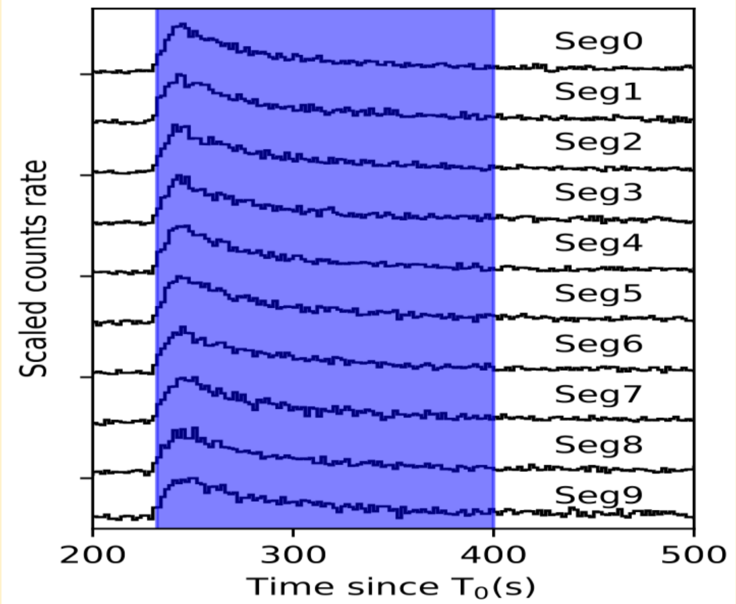
$$\epsilon_{\rm thr} = \frac{m_e^2}{E} + \frac{E^2}{8E_{\rm LIV}^{(1)}}$$



Science Advances 9:eadj2778 (2023)

Energy dependence of the Speed of light

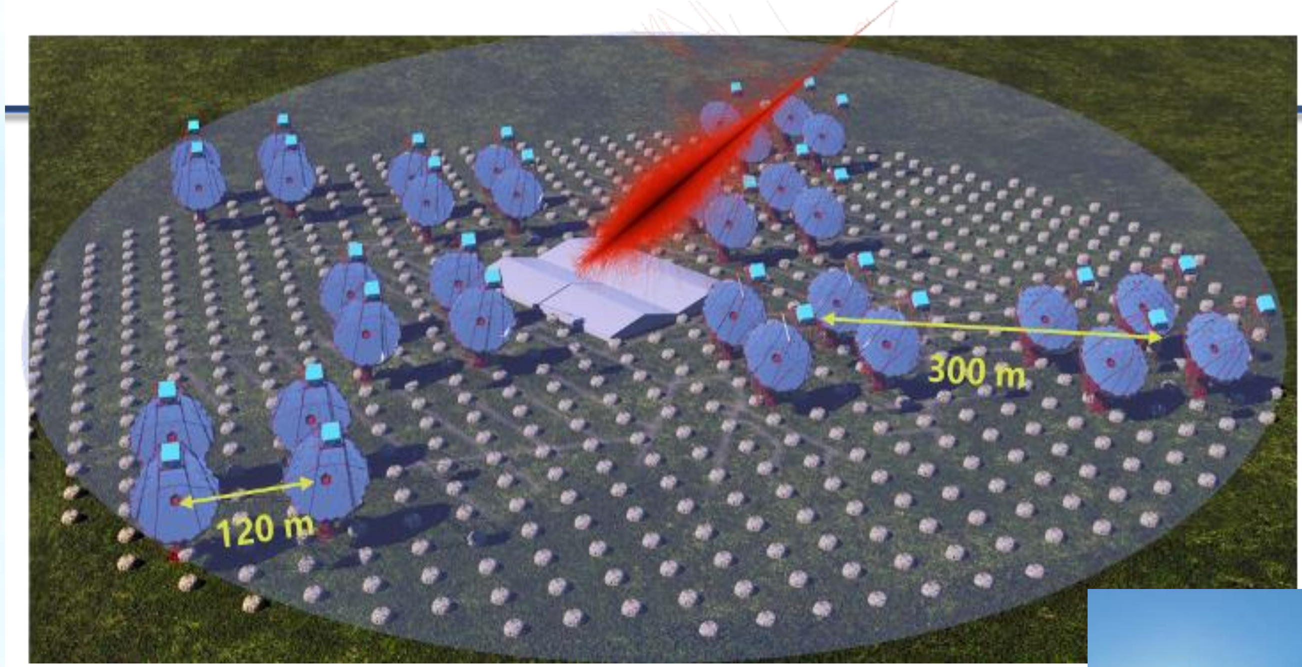
$$\Delta t_{\rm LIV} = s\frac{n+1}{2}\frac{E_h^n - E_l^n}{E_{{\rm QG},n}^n}\int_0^z \frac{(1+z')^n}{H(z')}dz'$$



PRL in press, arXiv:2402.06009

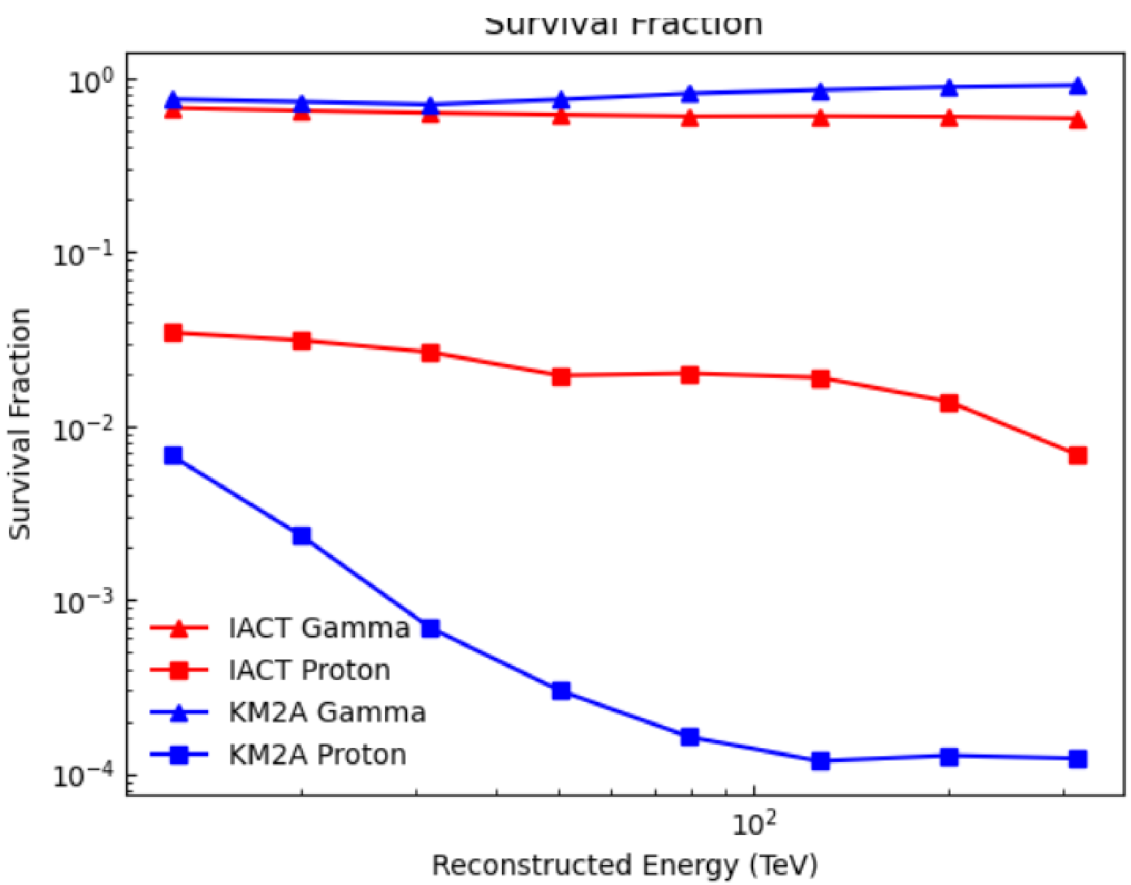
- **Prospects**

LACT : an IACT array in LHAASO

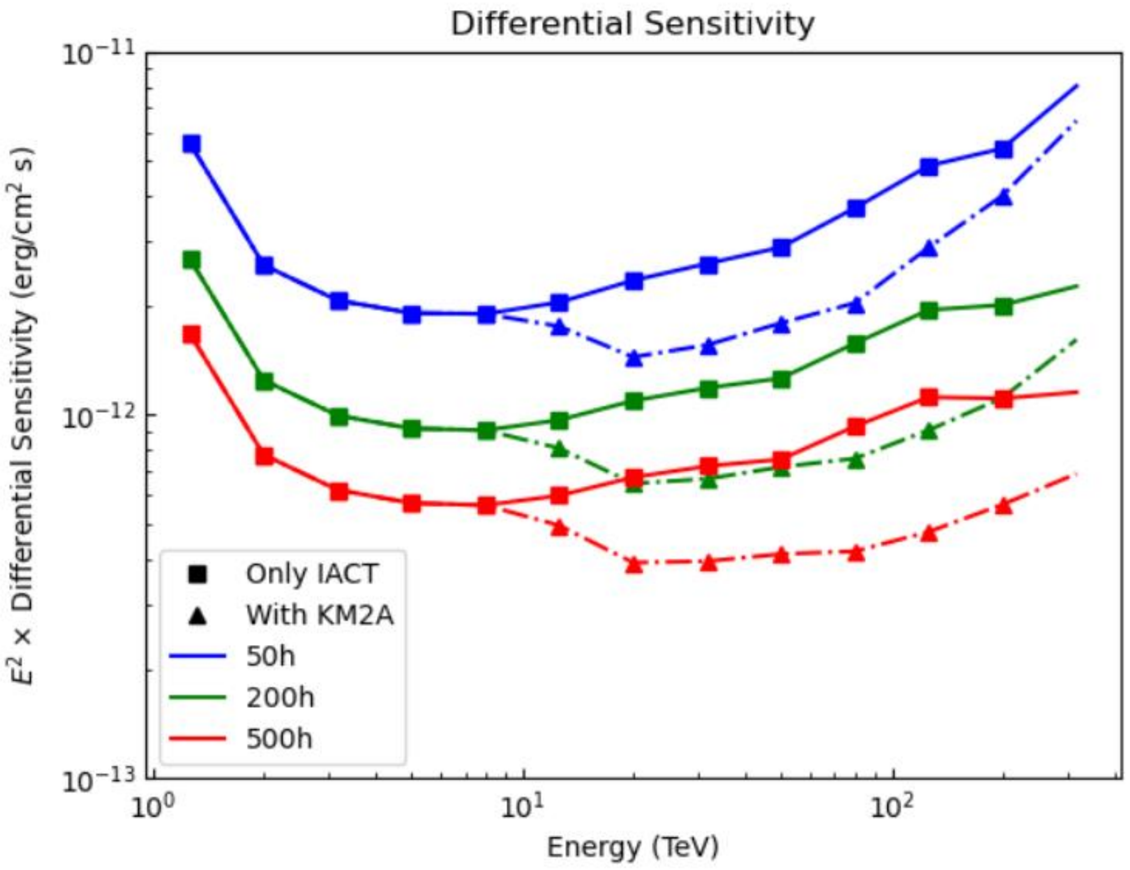


- Funded
- 8X4 array at LHAASO site
- 6-m telescopes
- two proto type telescopes
- First light soon in next year!

Synergy with LHAASO-KM2A

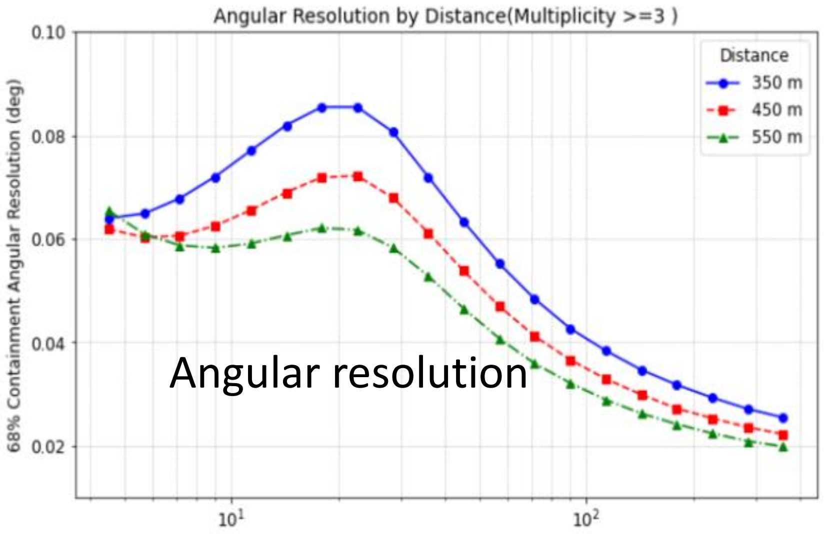


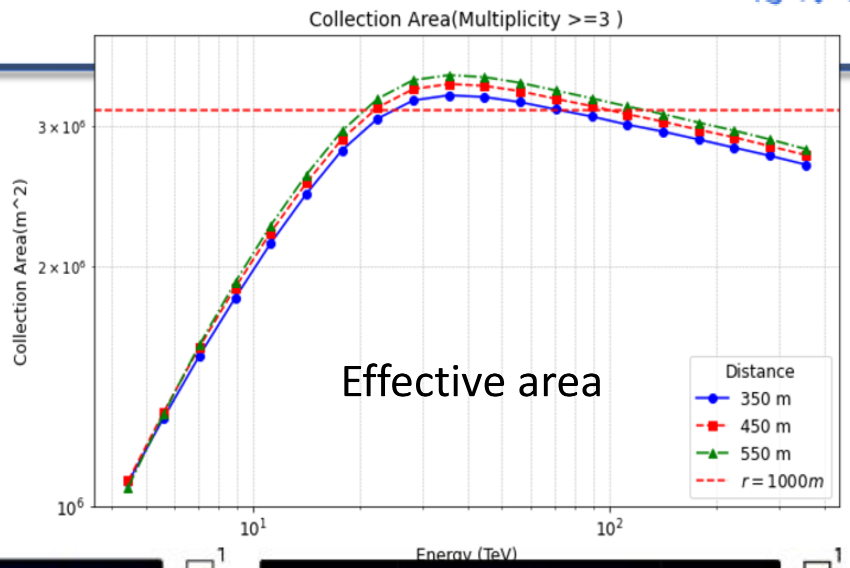
Using KM2A for γ/p separation

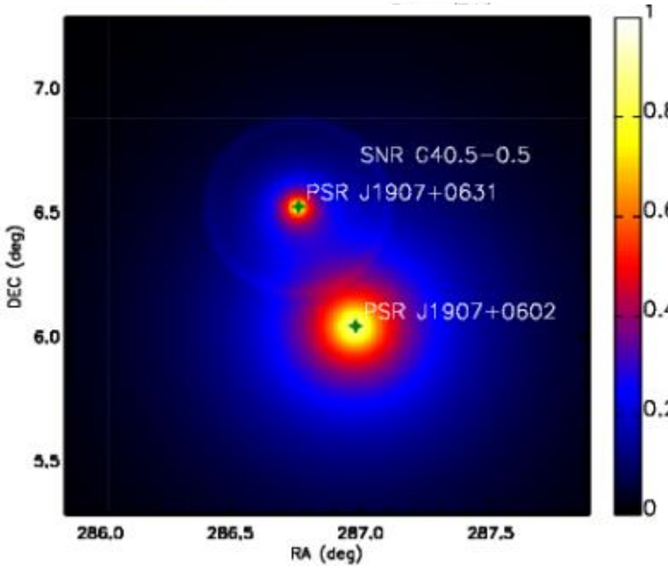


Sensitivity of LACT can be significantly improved above 10 TeV

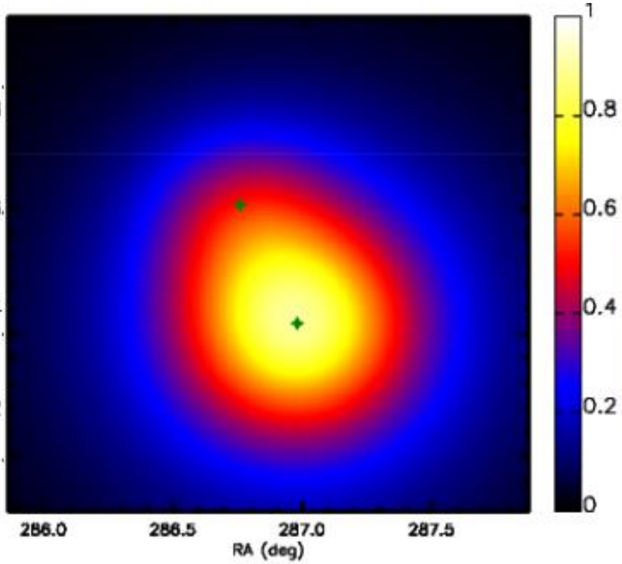
Expected performance



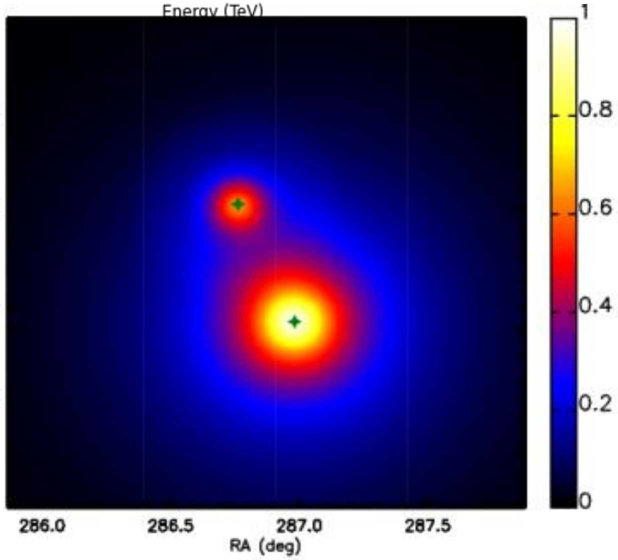




Intrinsic distributions

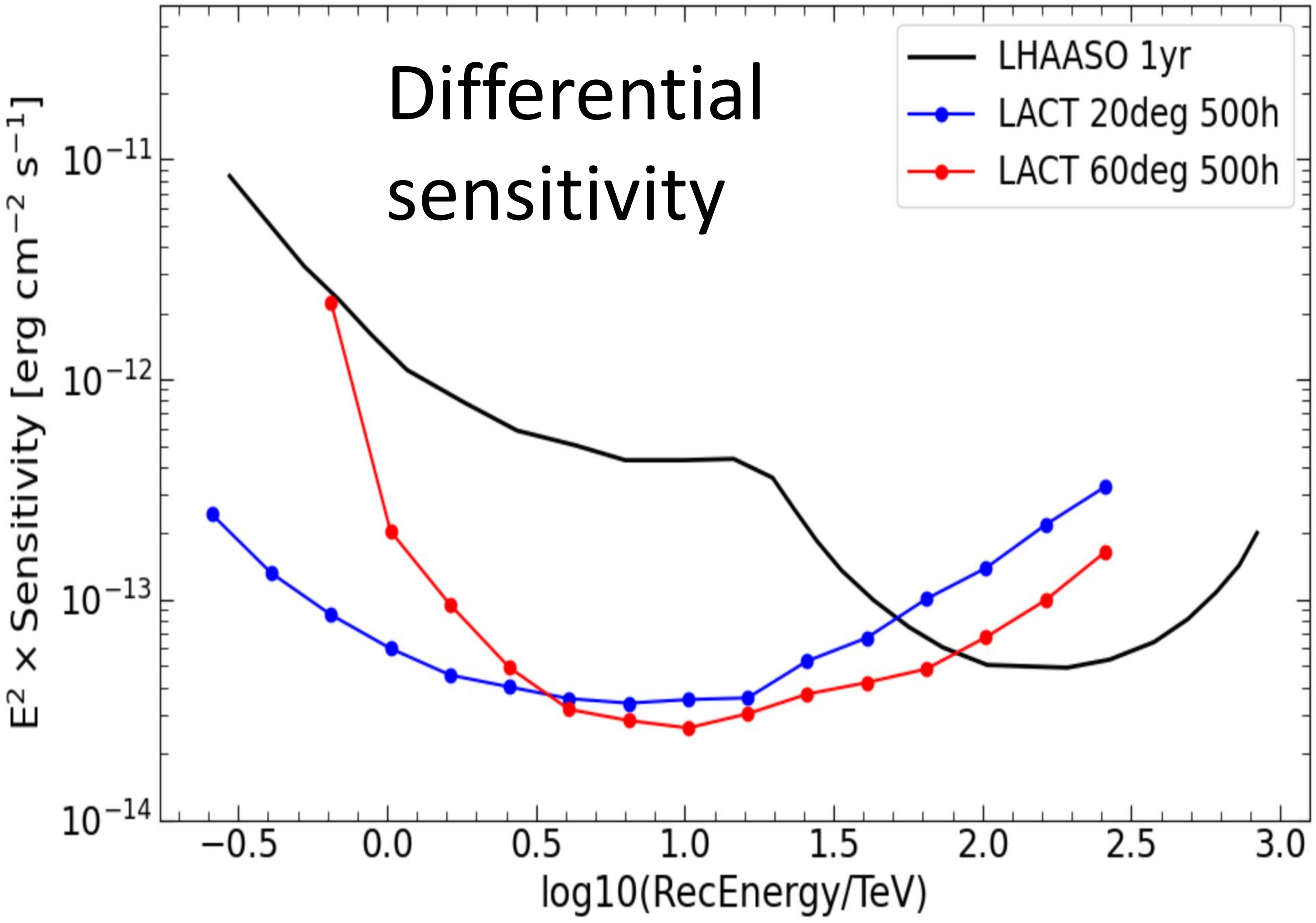


Observation by LHAASO



Observation of IACTs

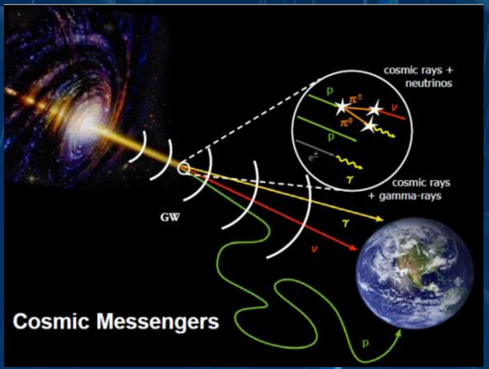
Expectations



Construct Schedule

	LACT progresses				
	2024	2025	2026	2027	2028
First telescope	11 months				
¼ array		10 months			
½ array			11 Moths		
32 telescopes				22 months	
Test running					6 months

High-energy Underwater Neutrino Telescope
H U N T



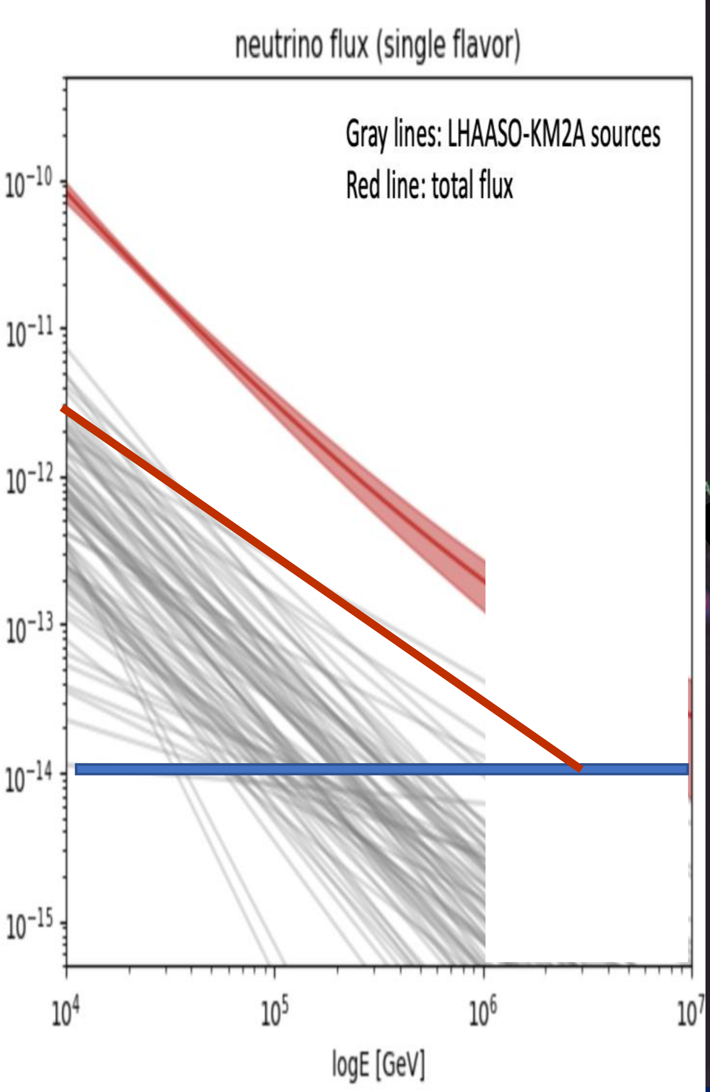
36 m

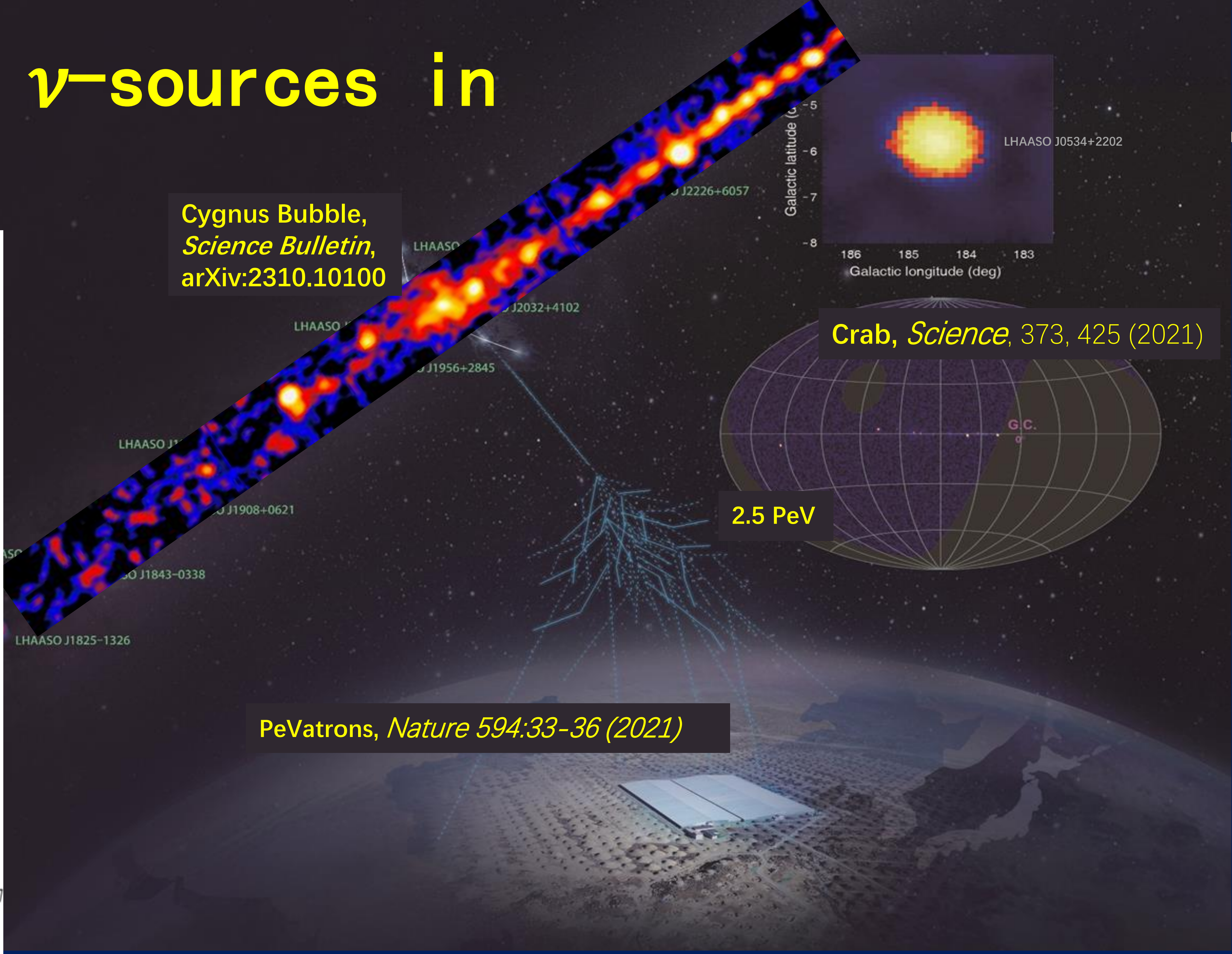
- Resulution ~0.1°(tracks), <3°(cascades)
- Energy resolution: ΔlogE~0.3(tracks)
  ΔE~10-30% (cascades).
- Discovering Neu sources (>100 TeV) at the level of 5σ within several years

- Volume： 6×6 = 36 km^2, **~30 km^3**
- Separations of strings： Dstring ~ 130 m
- Separation of optical modules： DOM ~36 m
- Length of each string： ~860 m
- ~2,300 strings, 24 OMs in each string， 55000 OMs in total

130 m

Guaranteed ν-sources in our galaxy





Summary

- LHAASO has been stably operating since 2021
- Progresses in both γ-ray astronomy and CR researches
  - RG, Blazars and GRB observations provide insight of AGN radiation mechanisms and useful way to constrain EBL
  - Many new discoveries in galactic sources for deep investigations of their features
  - Discovering galactic Sources of Cosmic Rays above the knee is particular exciting
  - Diffuse photon flux is found a factor 2 or 3 higher than expectation, a big issue!
  - Measuring CR Spectra of Individual Species around knees is a big step towards understanding the knee feature
- Progresses in New Physics Search: massive DM, axion DM and LIV
- Future
  - Better resolution (3') in UHE γ-observation in short term
  - Neutrinos from PeVatrons is the goal for a long run