

Locating a Super PeVatron at Cygnus Region

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On behalf of LHAASO Collaboration

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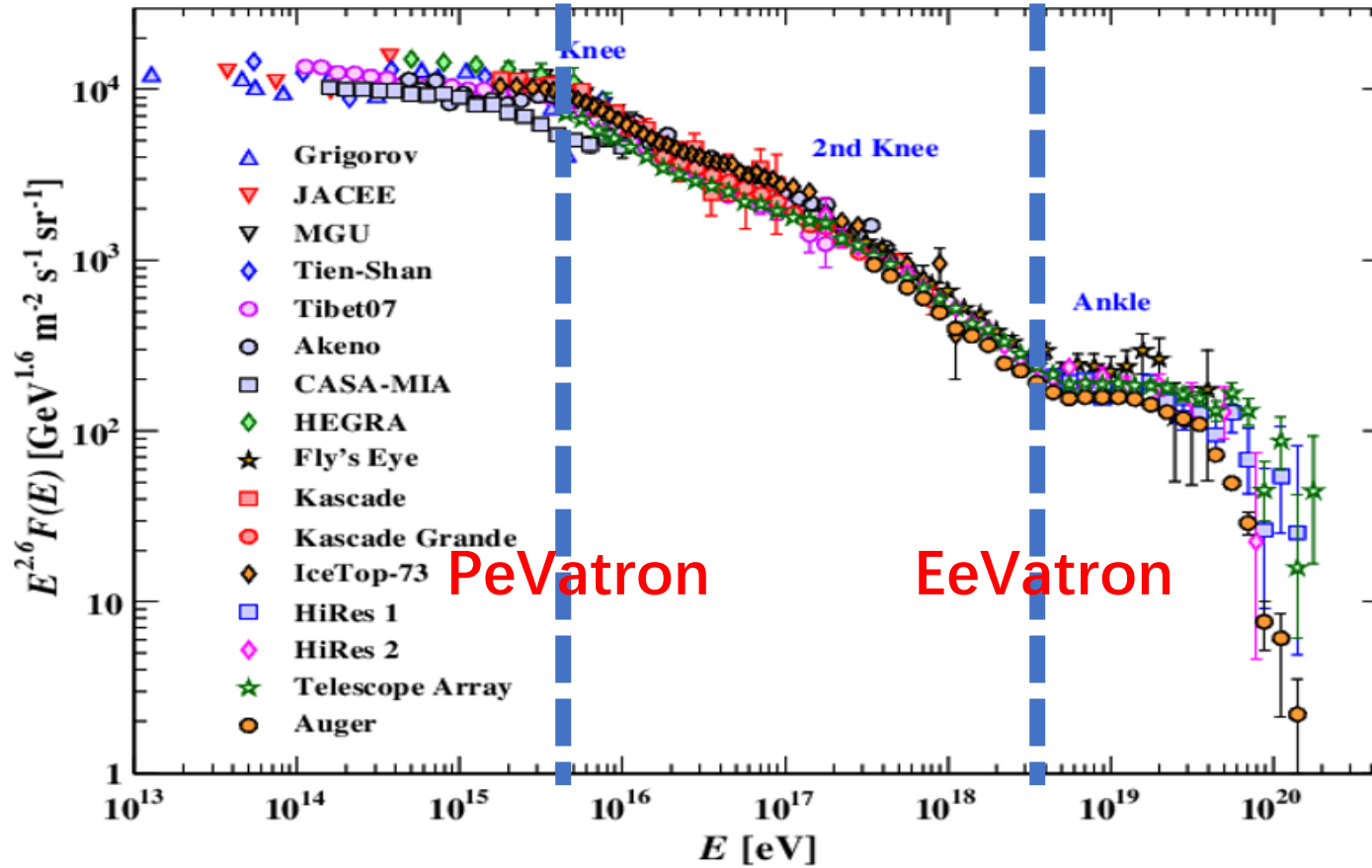
Institute of High Energy Physics(IHEP),CAS

Outline



- Origin of cosmic rays
- LHAASO detector
- Results from Cygnus region
- Prospects

Where do the highest energy particles come from ?



Galactic sources

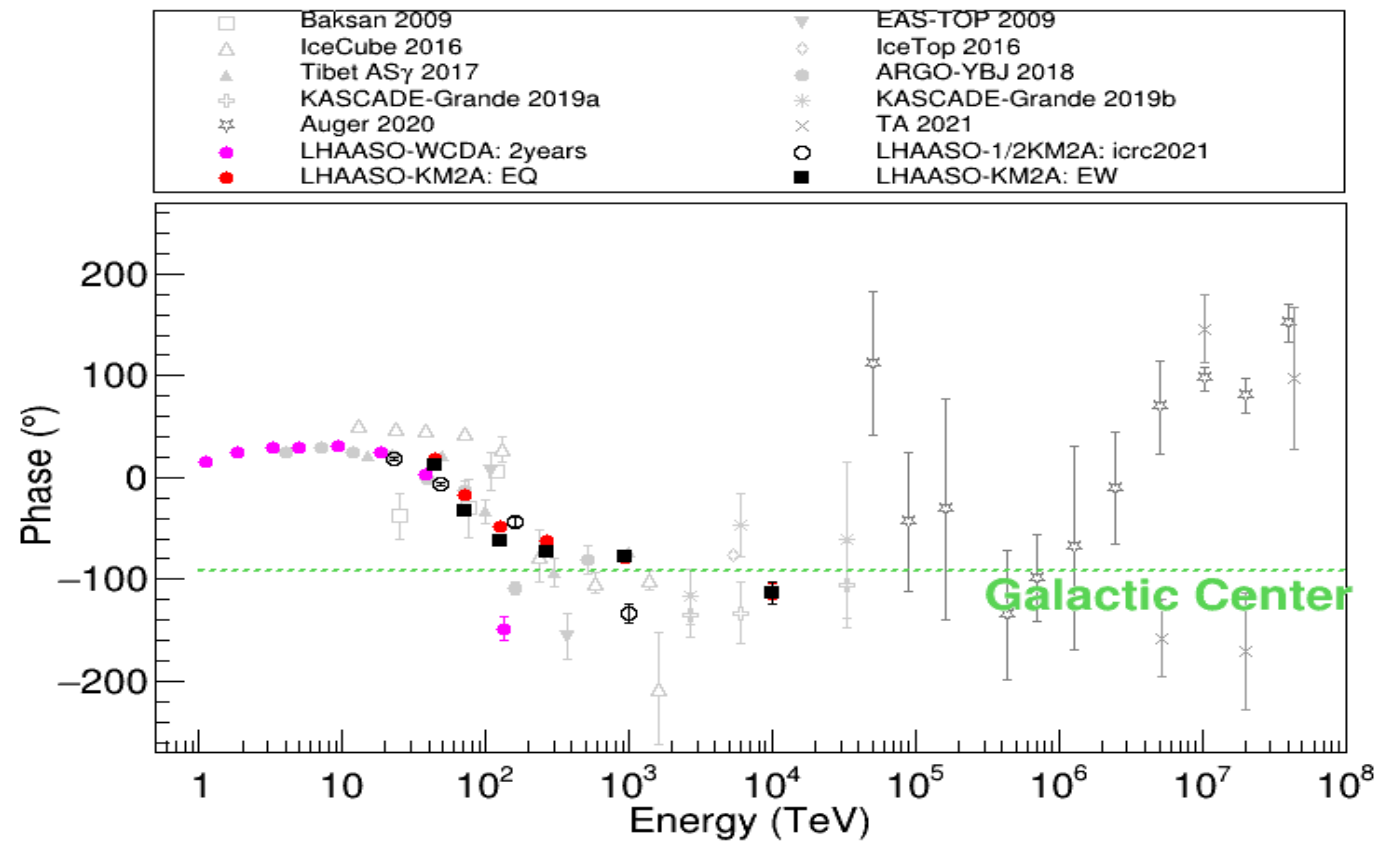
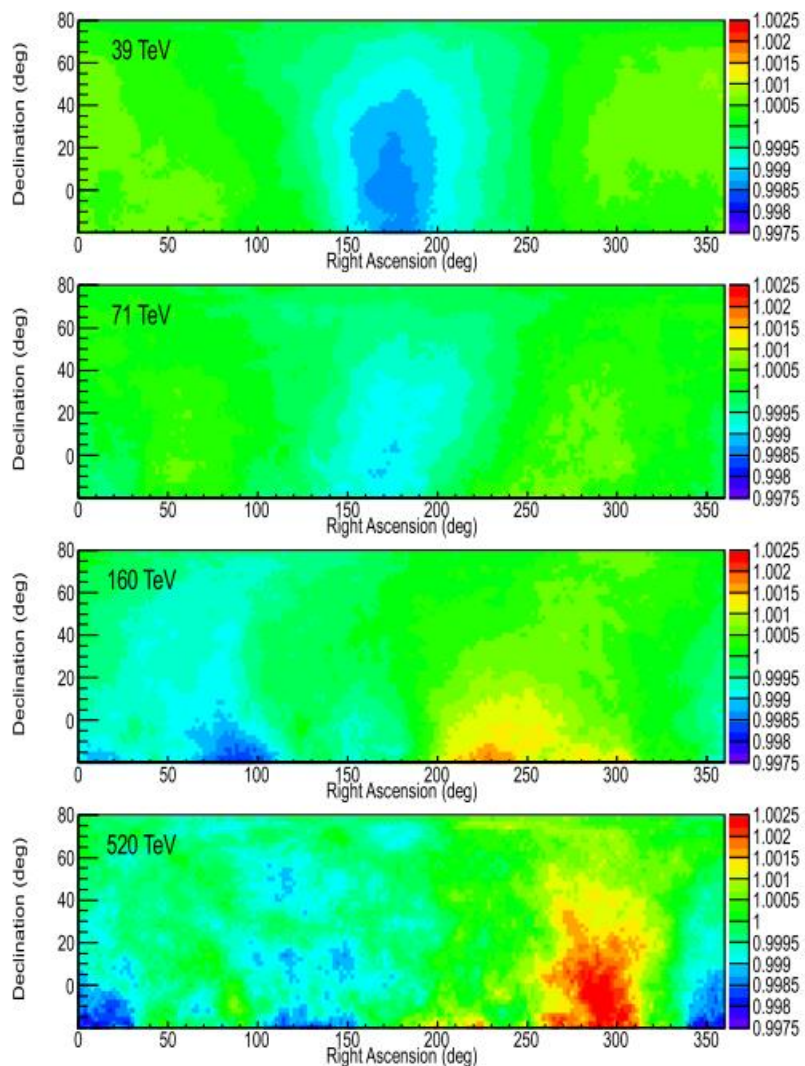


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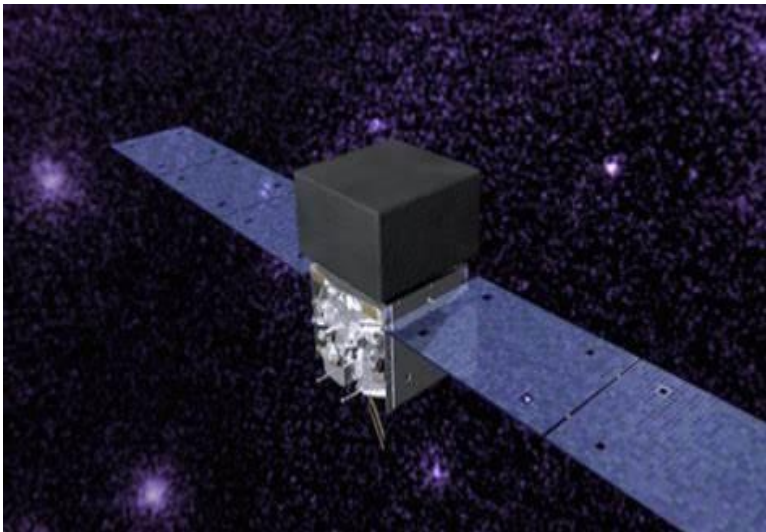
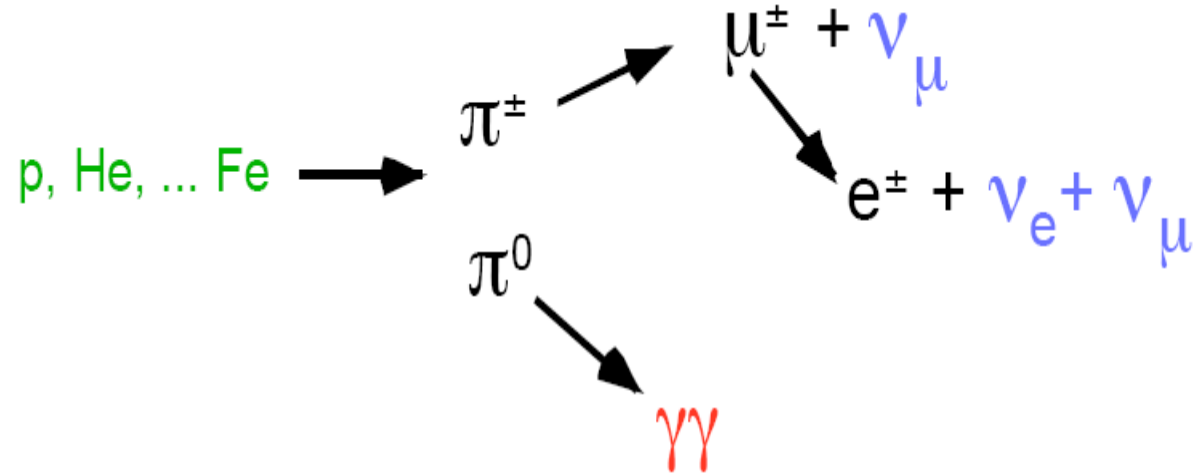
Extragalactic sources

Where dose the highest energy particles come from ?



Where is the upper limit for galactic accelerator ?

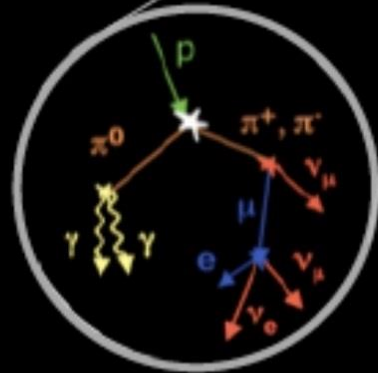
How to trace the cosmic ray accelerator?



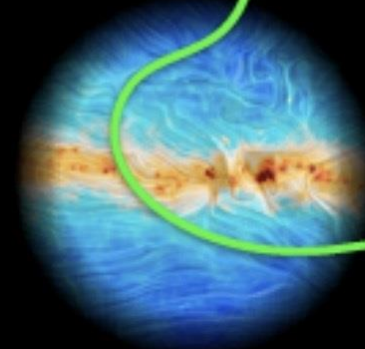
Gamma-rays Probe Cosmic Rays

- Gamma-rays point approximately to the position of accelerators.

Astrophysical beam dump



Galactic B-field
(Planck)

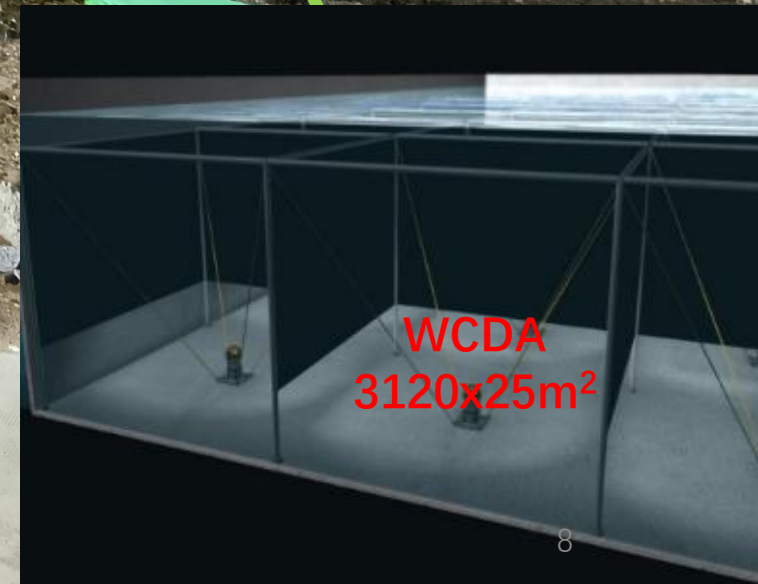
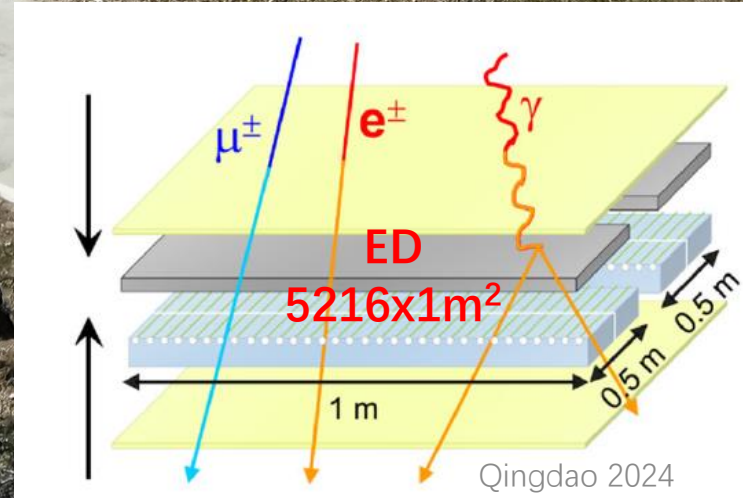
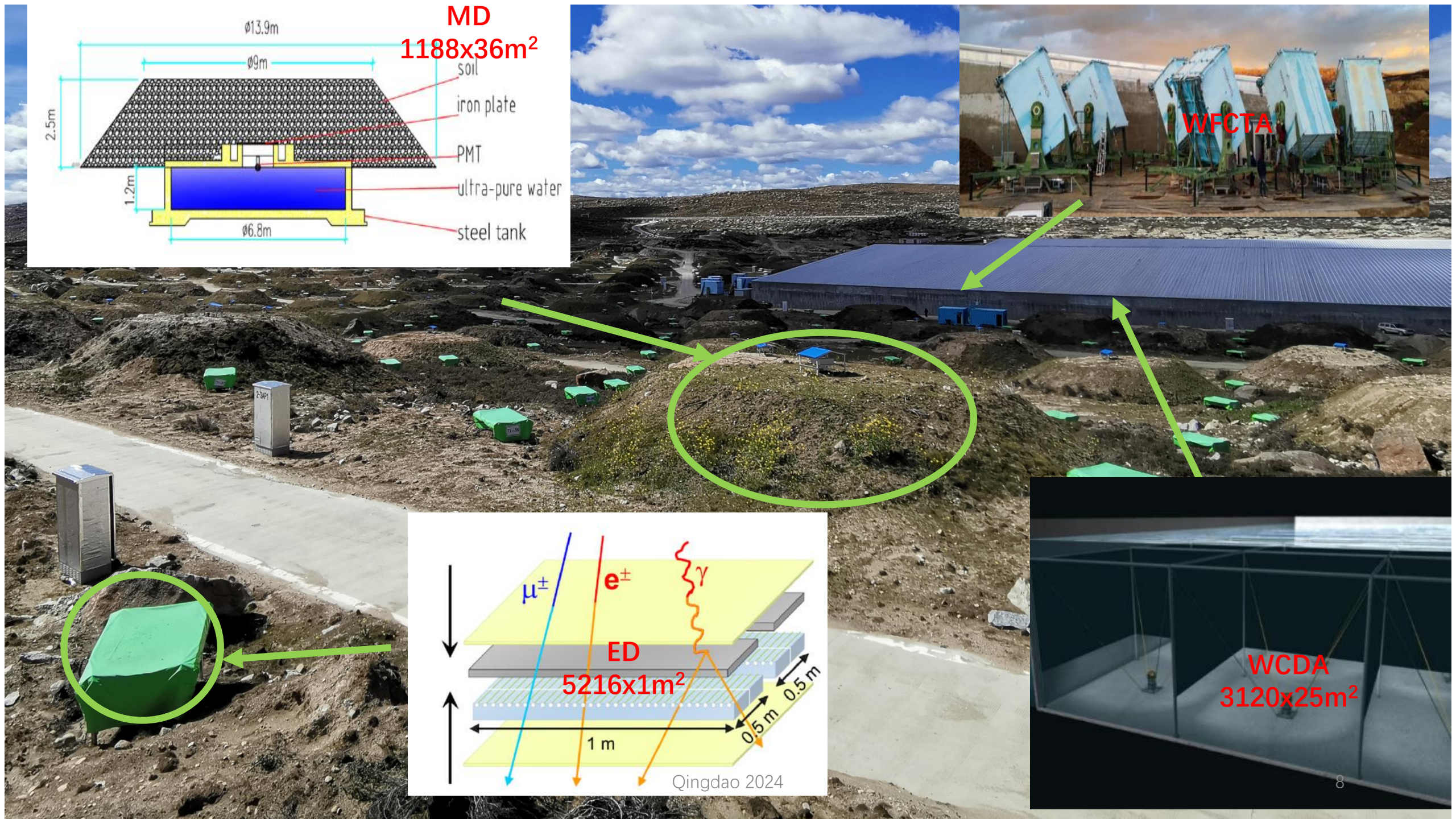
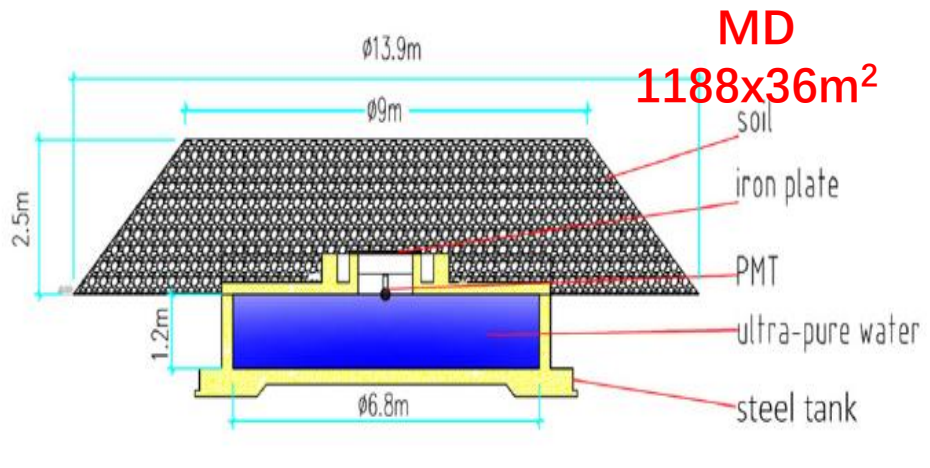


- Cosmic rays directions are randomized by Magnetic Fields in the Universe.

Location: $29^{\circ}21'27.6''N$ $100^{\circ}08'19.6''E$

Altitude: $4410m$ *a.s.l*

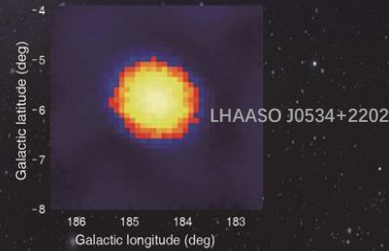




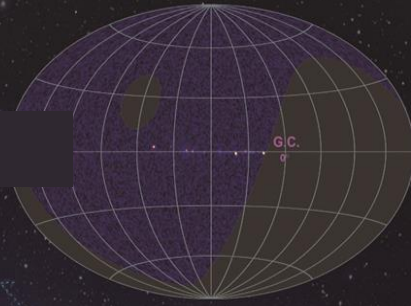
The 1st CR-Source Candidate by LHAASO



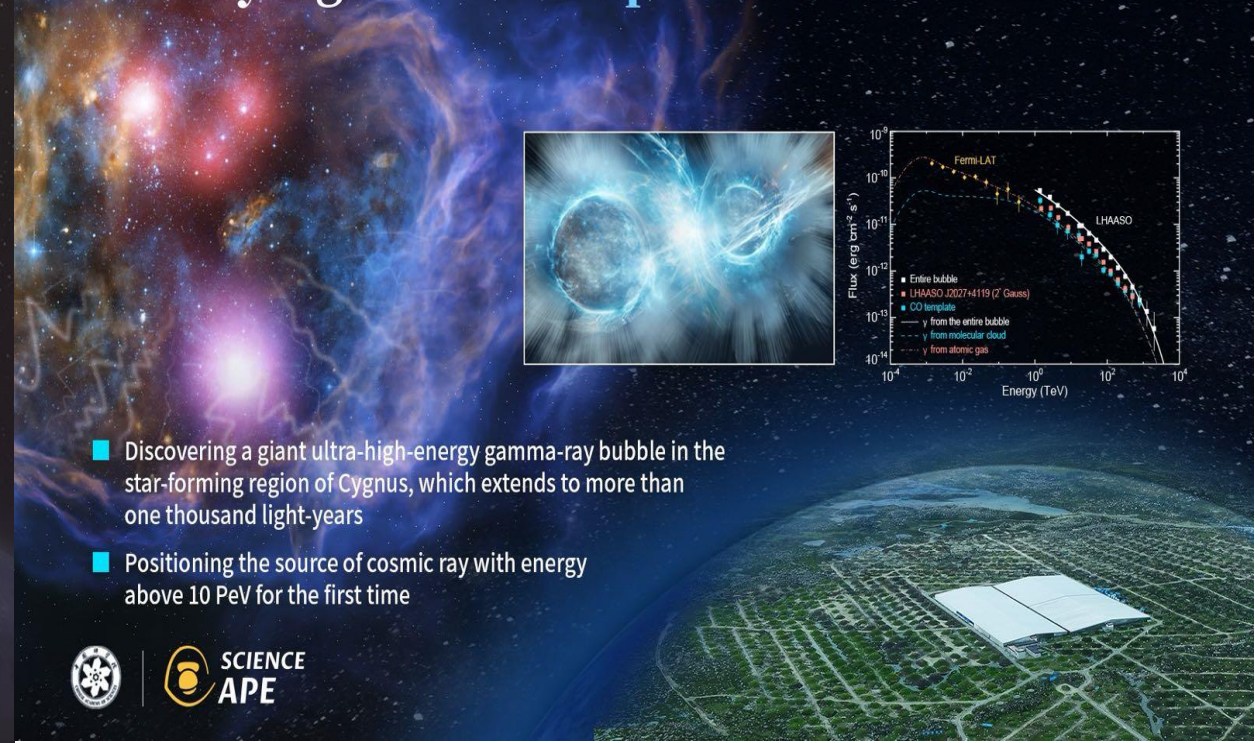
Cygnus Bubble,
Science Bulletin,
arXiv:2310.10100



PeVatrons, *Nature* 594:33-36 (2021)



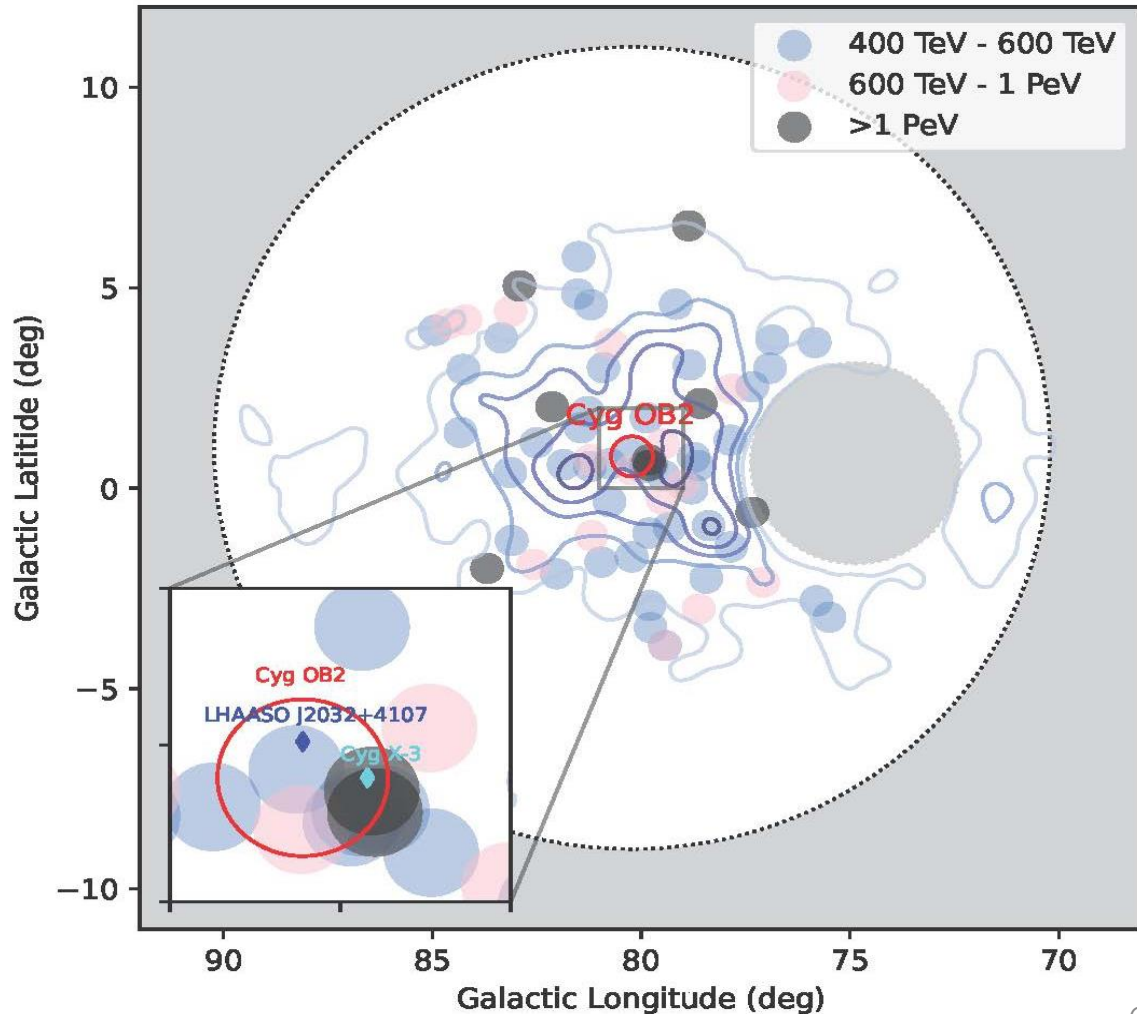
LHAASO discovers giant ultra-high-energy gamma-ray bubble, identifying the first Super PeVatron



- Discovering a giant ultra-high-energy gamma-ray bubble in the star-forming region of Cygnus, which extends to more than one thousand light-years
- Positioning the source of cosmic ray with energy above 10 PeV for the first time



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



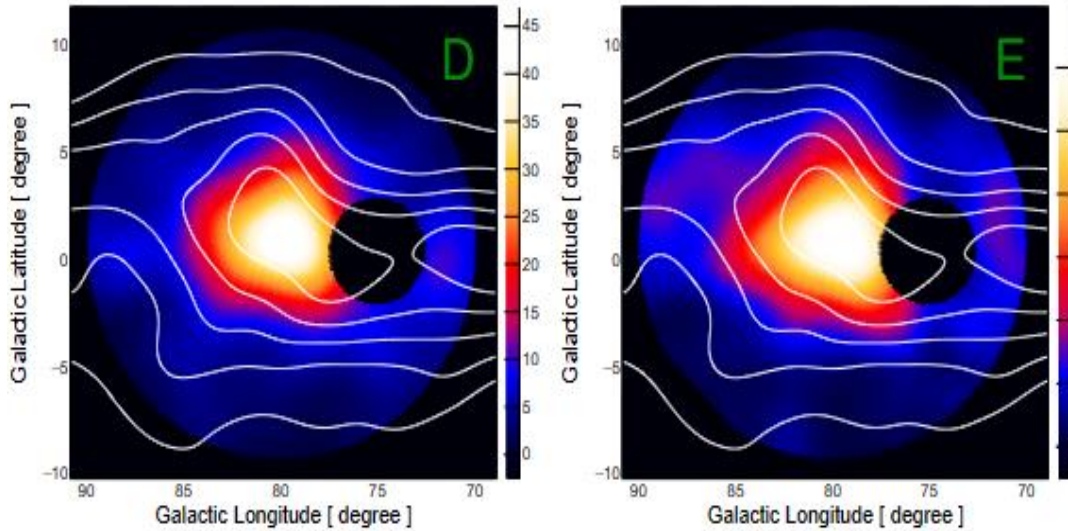
Energy (TeV)	Ne	Nu	Theta (deg)	Dr (m)
1087	5904	13	19.4	143
1188	5480	14	34.4	73
1208	6939	13	14.2	131
1350	6938	8	27.1	43
1379	6469	9	17.4	52
1421	6258	7	12.7	57
1784	6665	13	18.0	41
2481	13815	29	33.0	99

- The UHE photos are dispersed distributed, and are not correlated with any small scale sources. 10

Association with HI gas distribution over ~ 200 pc

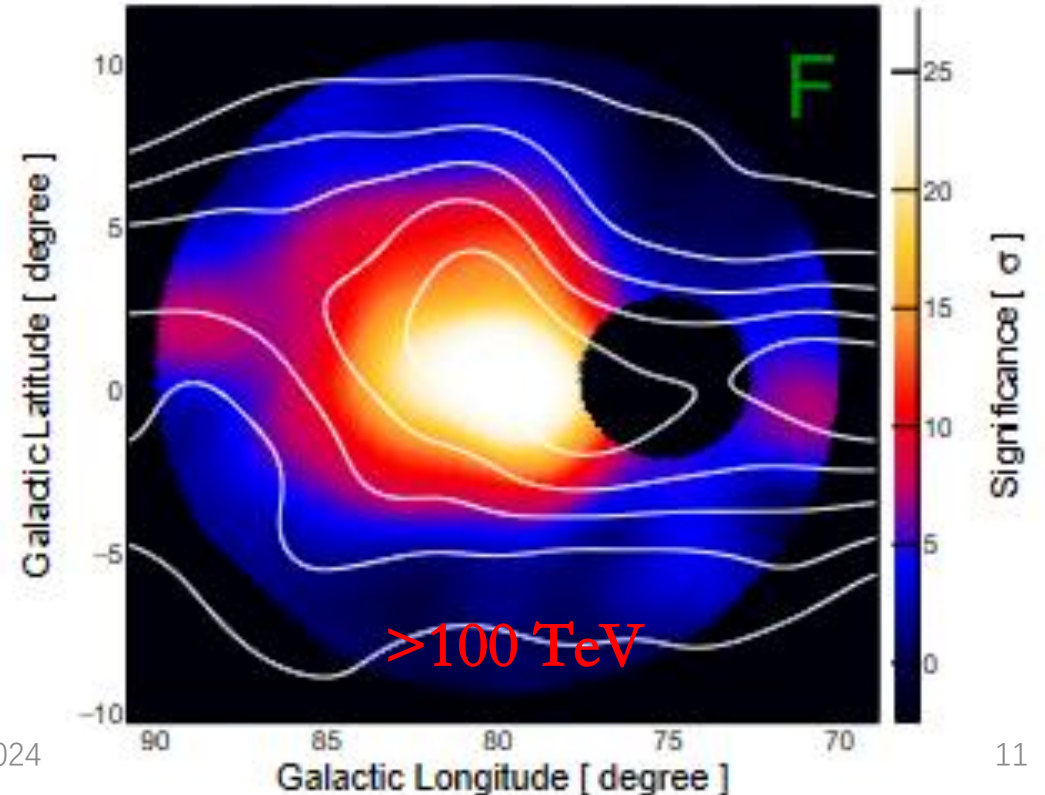
- The significance map is smoothed with a Gaussian kernel= 1.0°
- The contour is from HI4PI 21-cm line survey

- ◆ Clear correlation with gas distribution indicating a hadronic origin of photons in the Bubble
- ◆ The signal is elongated along the disk and extends to 10°



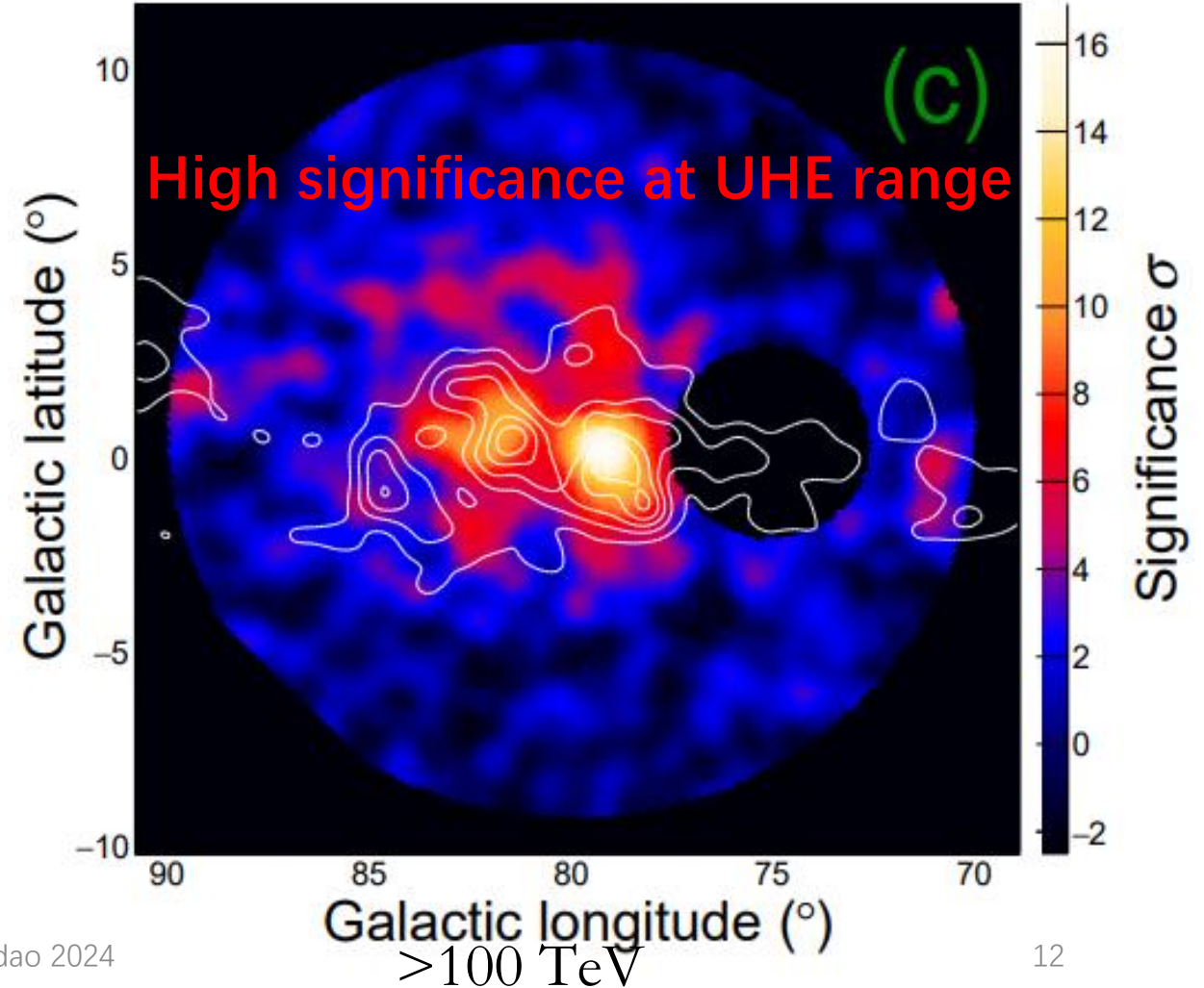
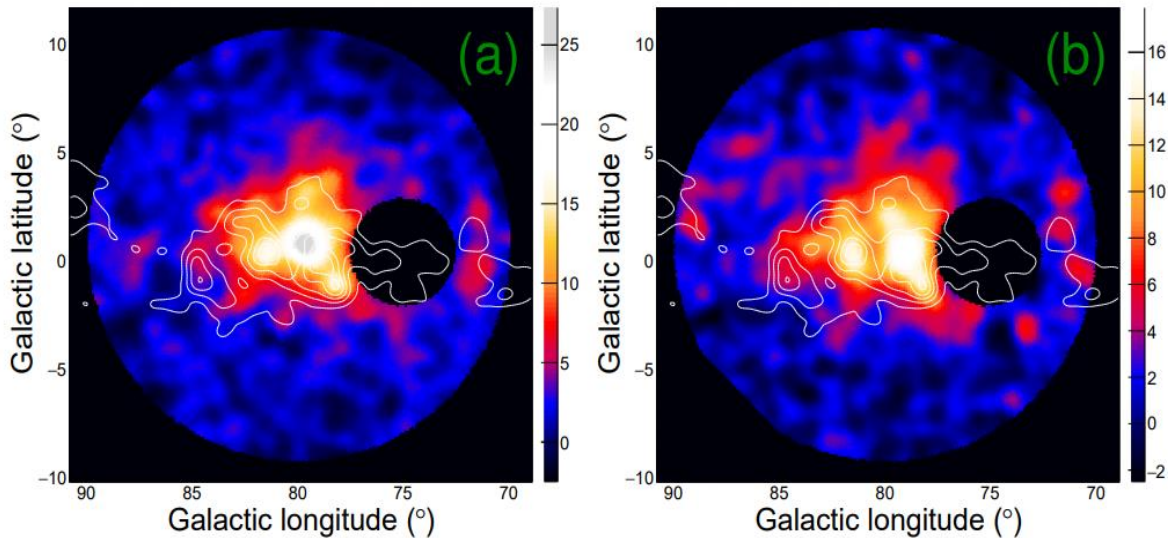
1-20TeV

25-100TeV



Association with molecular cloud

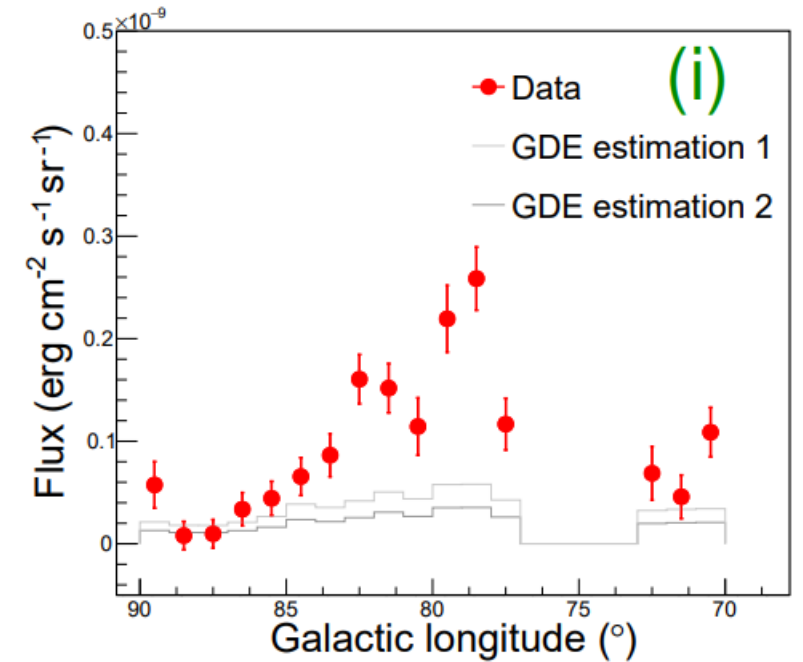
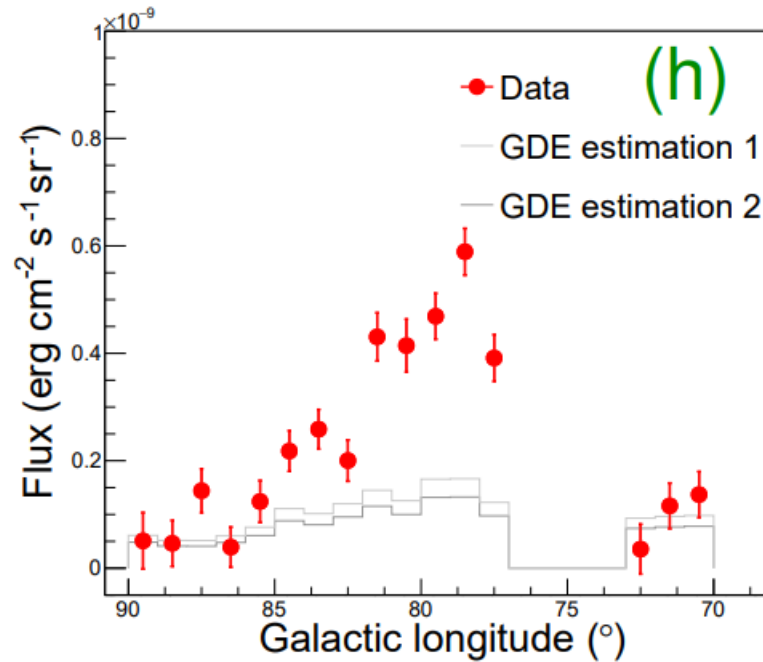
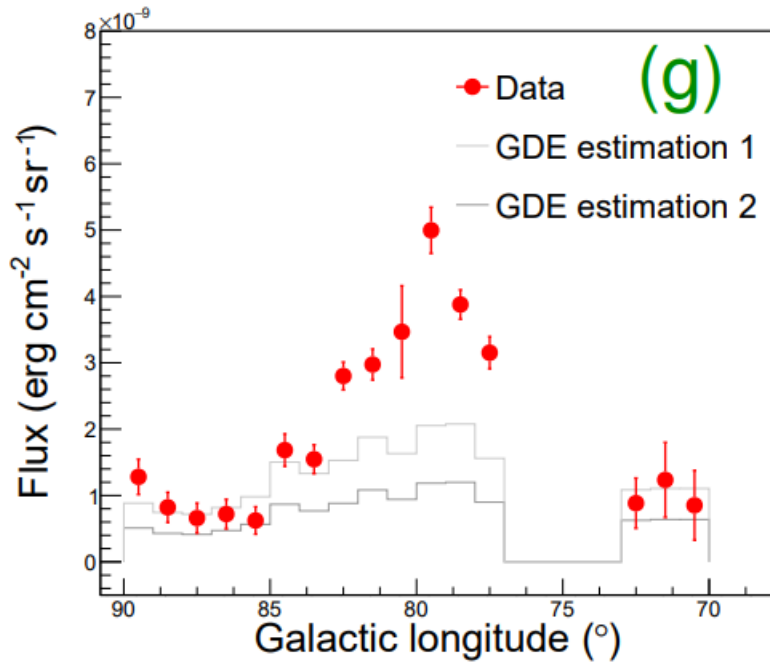
- The contour is from CfA galactic CO survey
- The significance map is smoothed with a Gaussian kernel of $\sigma=0.3^\circ$



Radial profile of the extended emission

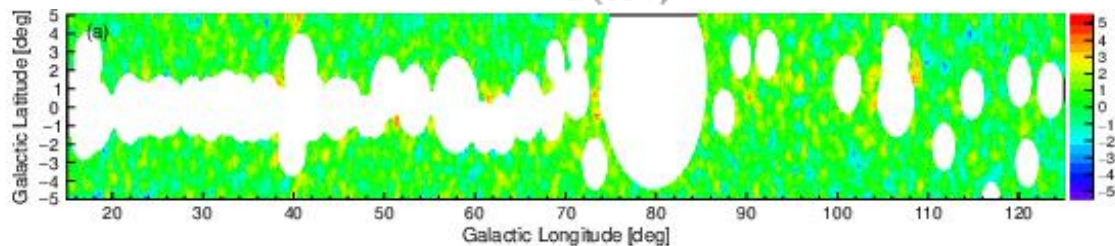
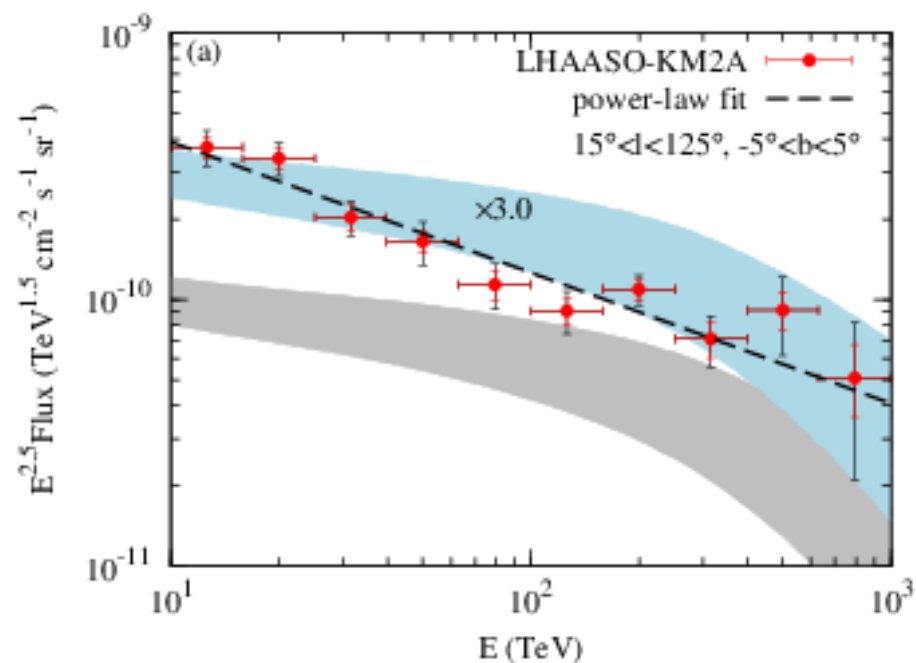
$$F_{\gamma} = W_{CR} \times N_{HI+H2}$$

- A very sharp distribution of gamma ray emission towards the center agree with CR propagation scenario and rule out a significant contribution from GDE.

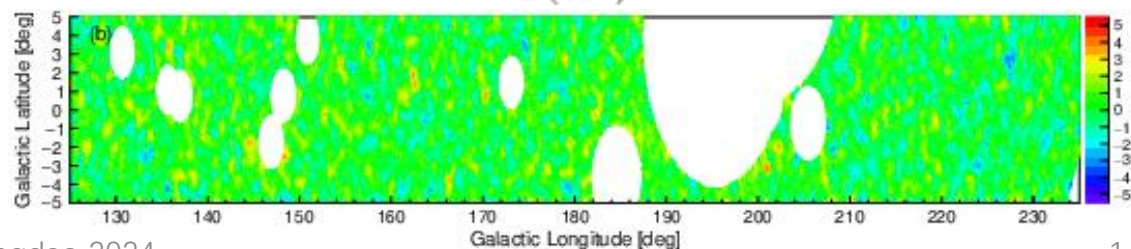
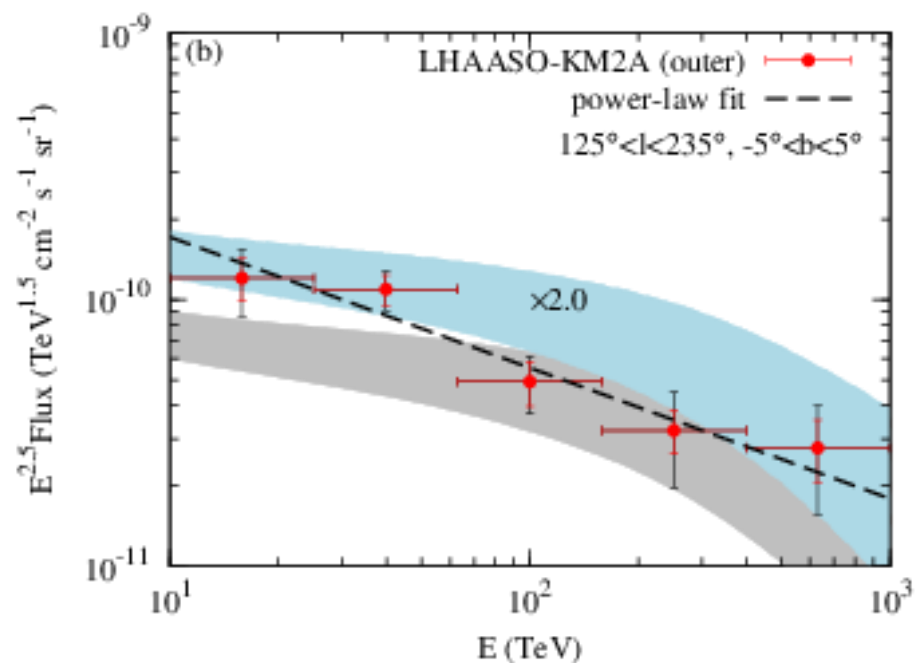


Galactic Diffuse Emission

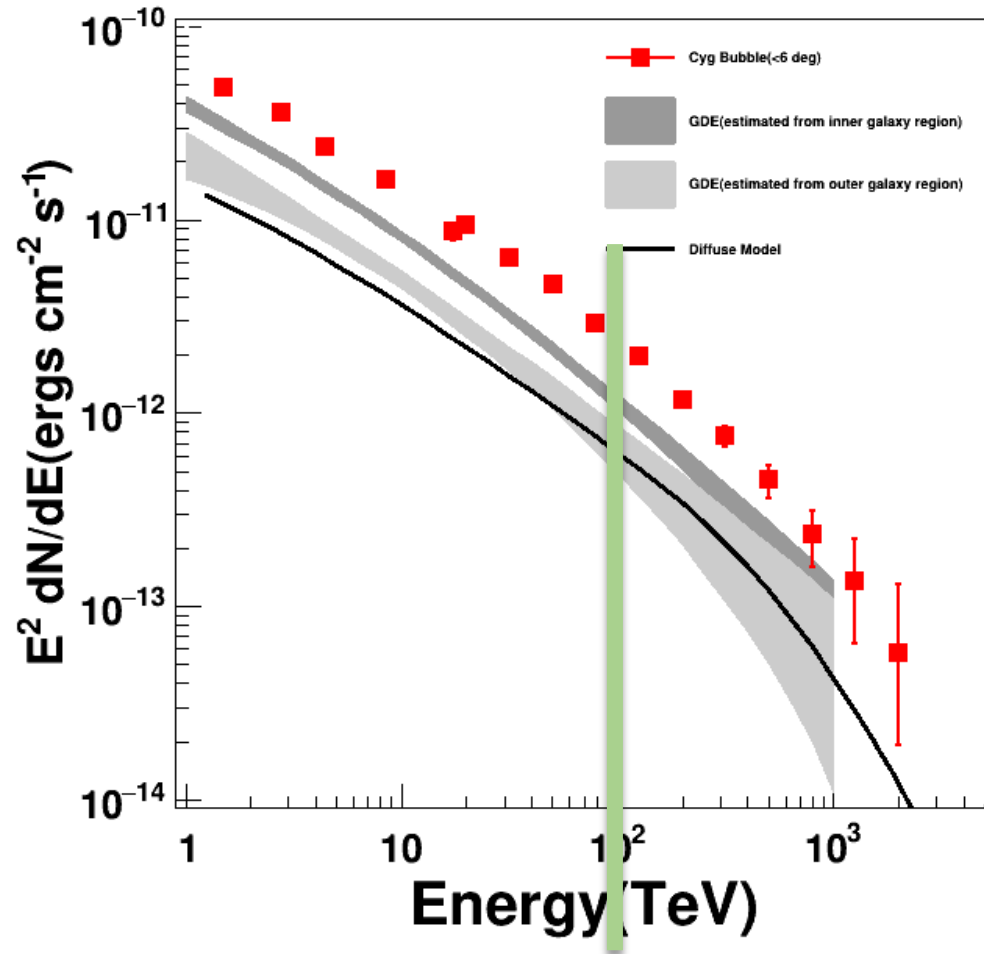
Inner Galactic Region



Outer Galactic Region



Energy spectrum



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



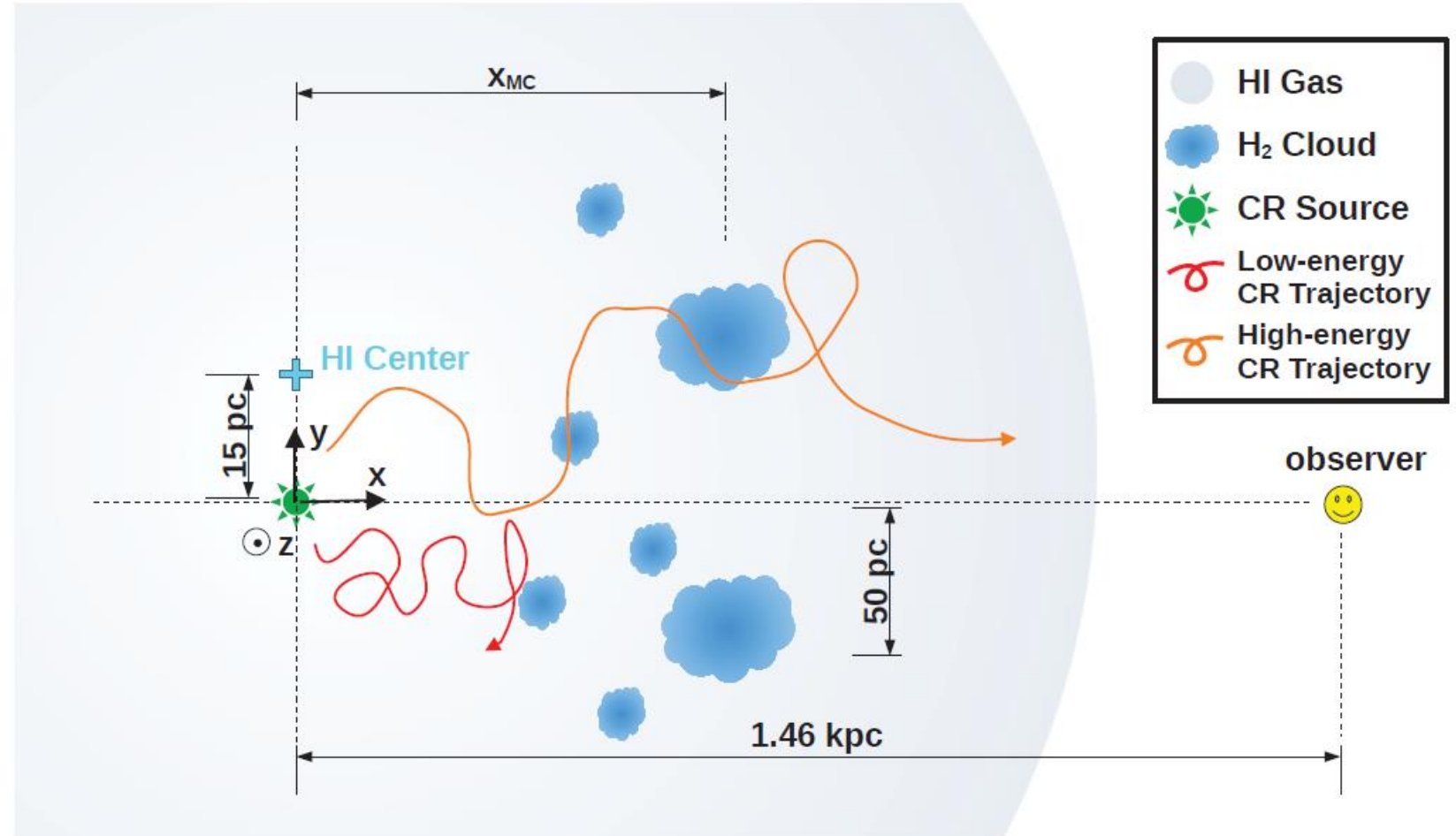
Almost background free

- ◆ The spectrum can extend beyond PeV without sharp cut-off, which shows a slightly softening feature.

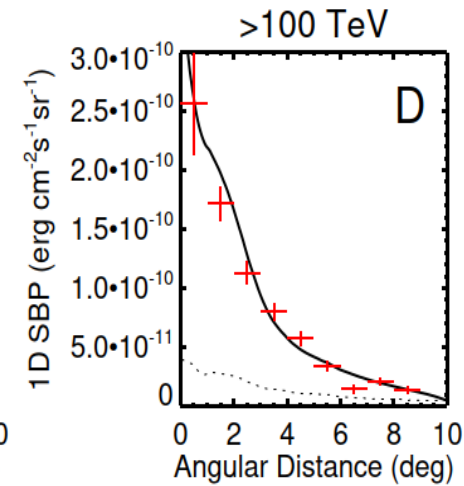
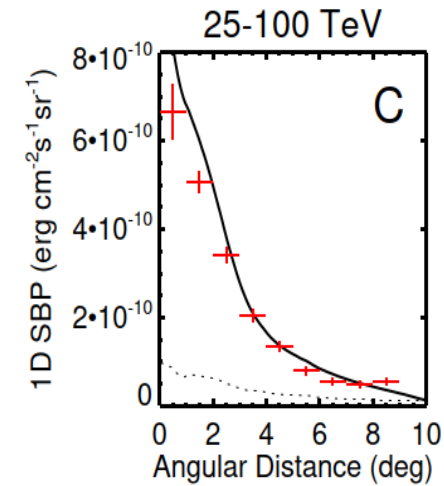
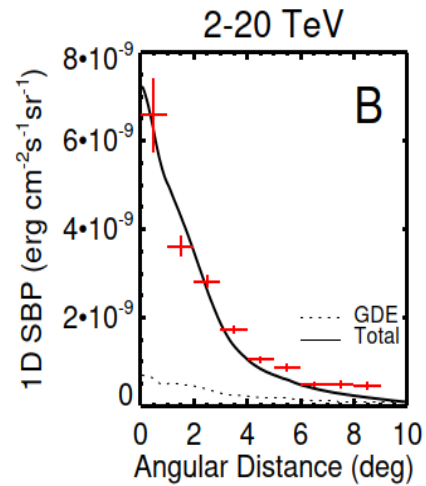
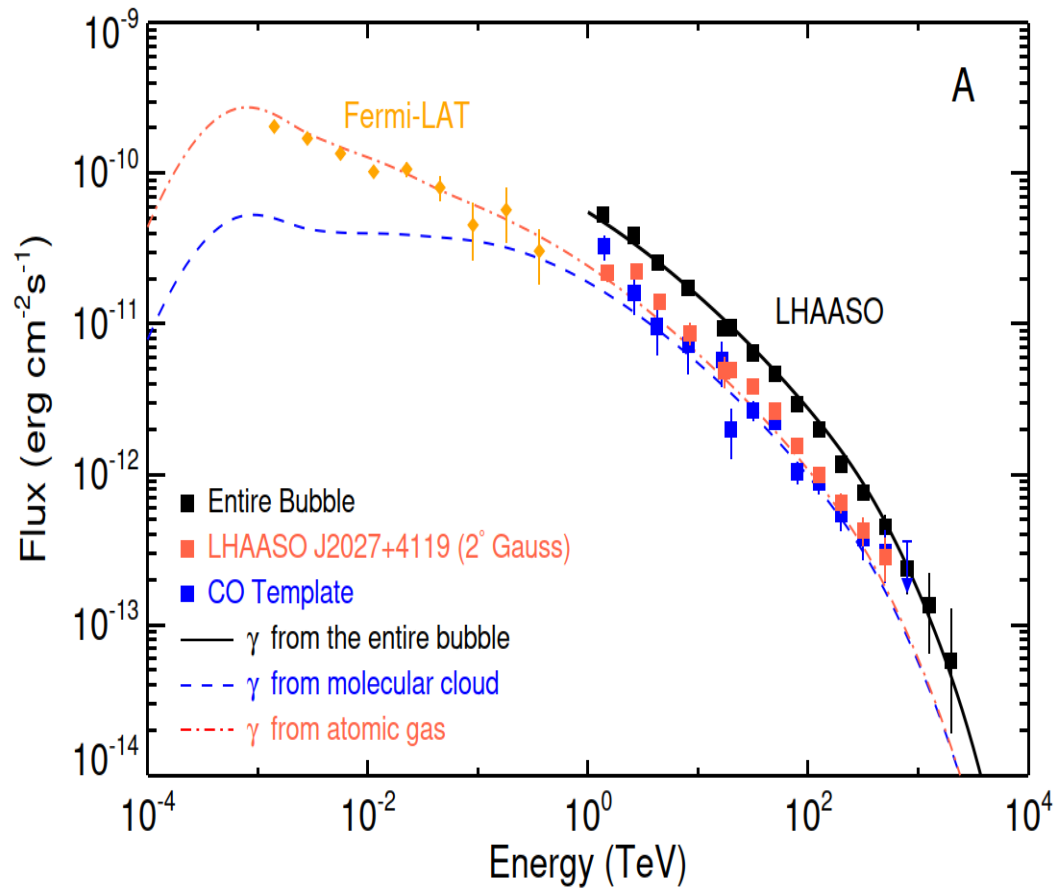
It is definitely a PeVatron, or even a Super-PeVatron

Interpretation

- Have the highest energy cosmic rays have escaped from the accelerator?
- What we observed is the projection of gamma rays produced is a 3D space.



Fitting results



- ◆ The energy spectrum and morphology can be fitted well if we assume a PeV cosmic ray accelerator at the center of Cygnus region.

Conclusion

- A giant ultra-high energy gamma-ray bubble is discovered at Cygnus Region.
- The morphology and spectrum indicates a cosmic ray accelerator located at the center accelerating cosmic rays at least to 10 PeV.
- This is the first time locating a Super PeVatron in galaxy.

Thanks very much !

Any question?

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