Study of UHE gamma emission from Star Forming Regions with LHAASO

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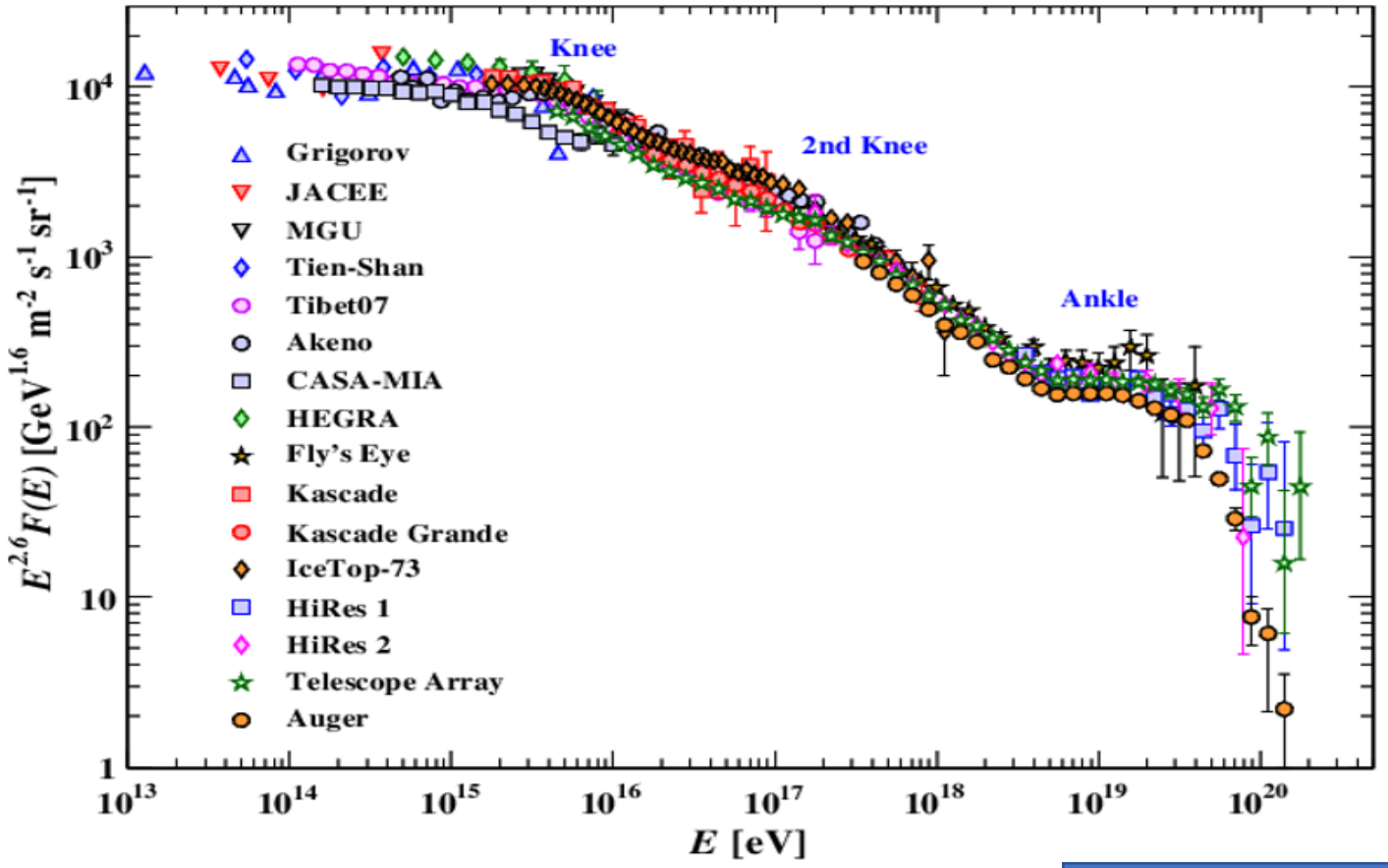
Outline

- Introduction
- Cygnus region analysis
- Other cluster
- Conclusion

Where dose the highest energy particles come from ?



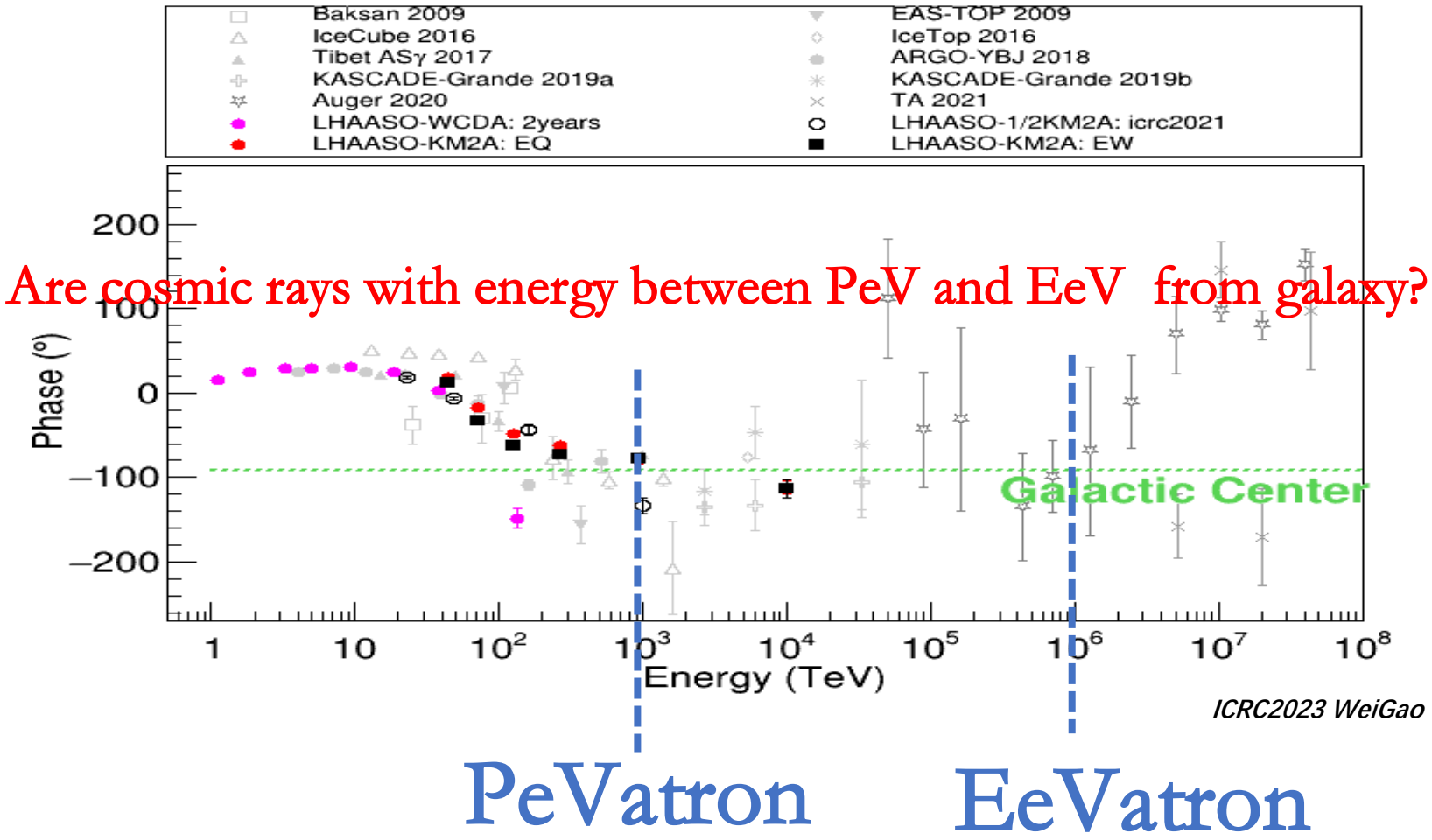
Galactic sources

???

Extragalactic sources

Physics Procedia 61 (2015) 425-434.arXiv:1910.03721v1

Where dose the highest energy particles come from ?

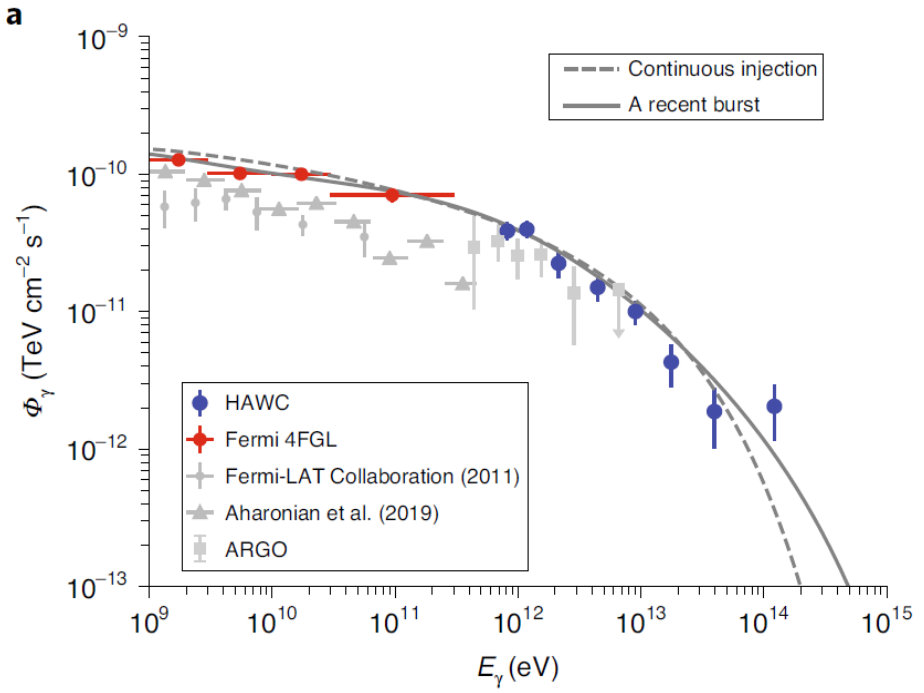


- There should be sources in our galaxy can accelerate particles to PeV or even up to EeV from the measurement of CRs at earth.

Cygnus region

Source name
LHAASO J0534+2202
LHAASO J1825-1326
LHAASO J1839-0545
LHAASO J1843-0338
LHAASO J1849-0003
LHAASO J1908+0621
LHAASO J1929+1745
LHAASO J1956+2845
LHAASO J2018+3651
LHAASO J2032+4102
LHAASO J2108+5157
LHAASO J2226+6057

- The first **PeV** photo was detected from this source, which makes it a promising PeVatron candidate



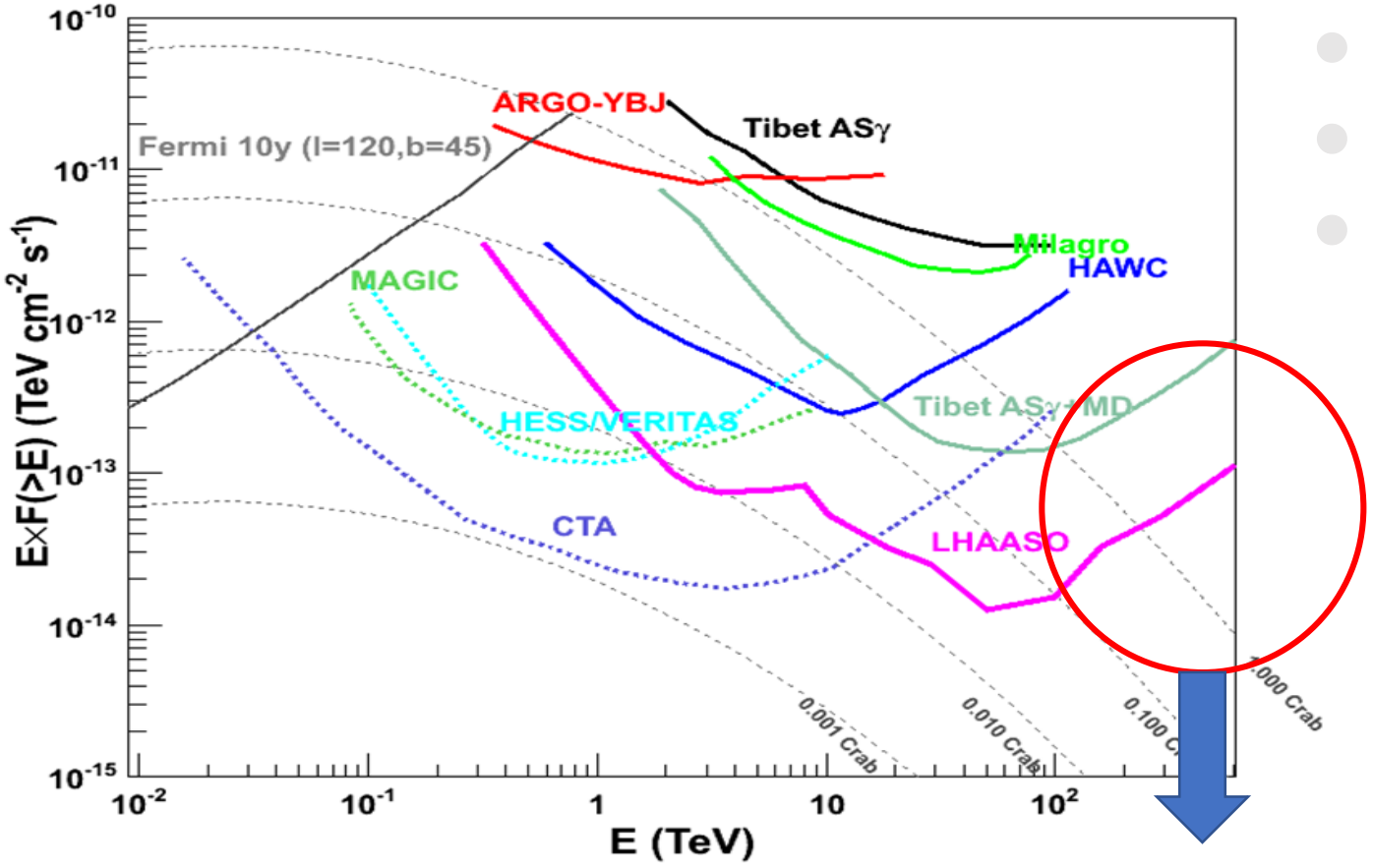
Is it correlated with Cygnus Cocoon?

Nature 594, 33–36 (2021)
Nat Astron 5, 465–471 (2021)

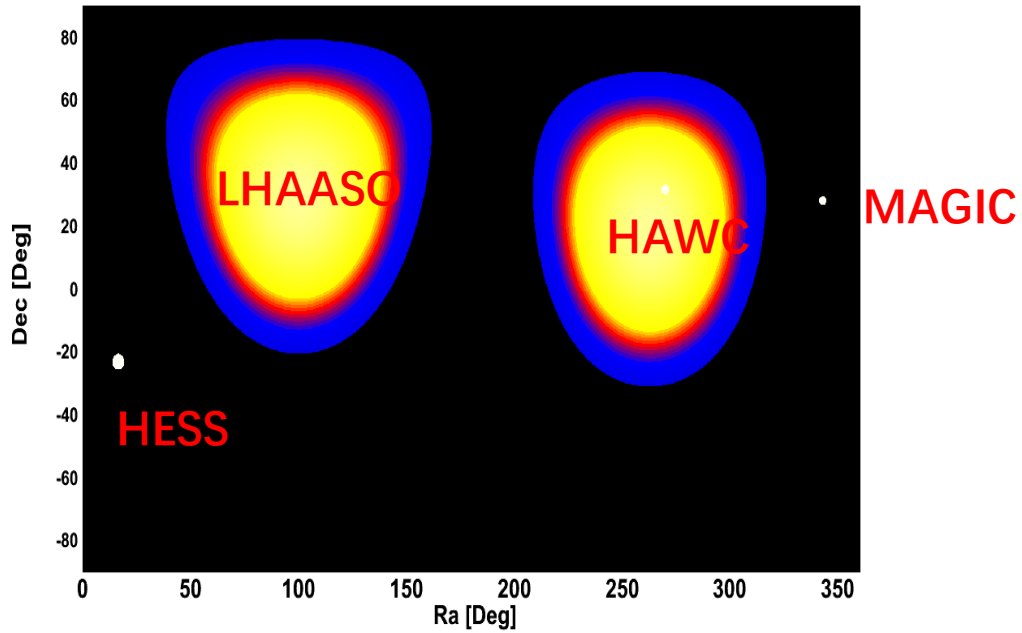
First UHE catlog


Location: 29°21′ 27.6"N 100°08′ 19.6"E
Altitude: 4410m a.s.l

LHAASO sensitivity



- **High sensitivity:** ~1% Crab @3TeV@100TeV
- **Wide energy range:** sub-TeV to 10 PeV



The most sensitive gamma ray detector to explore this highest energy range

LHAASO data analysis

◆Data:

- KM2A: Half array(299days)+quarter array(218days)+full array(658days);
- WCDA: Full array(735days);

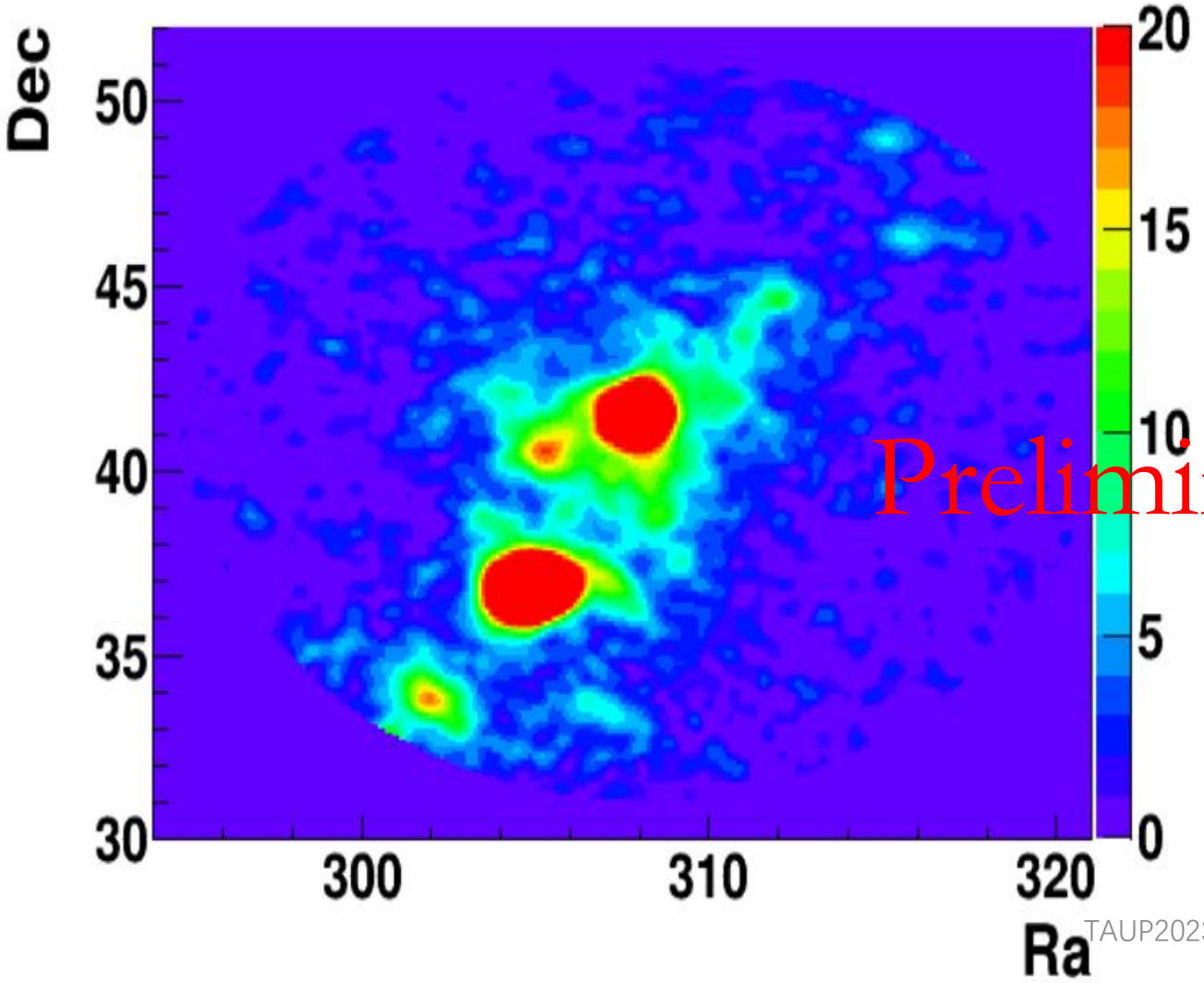
◆CR background estimation：

- Direct integration method
- Region with distance less than 10deg from Galactic plane are masked

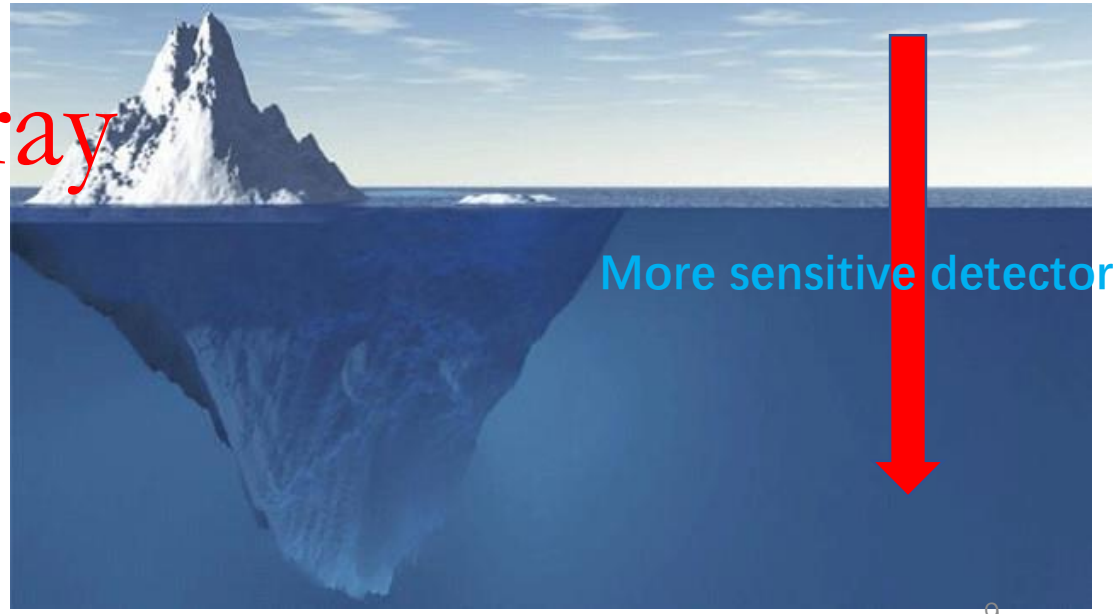
◆Analysis method:

- A 3D likelihood fitting framework is developed

An overview for this region

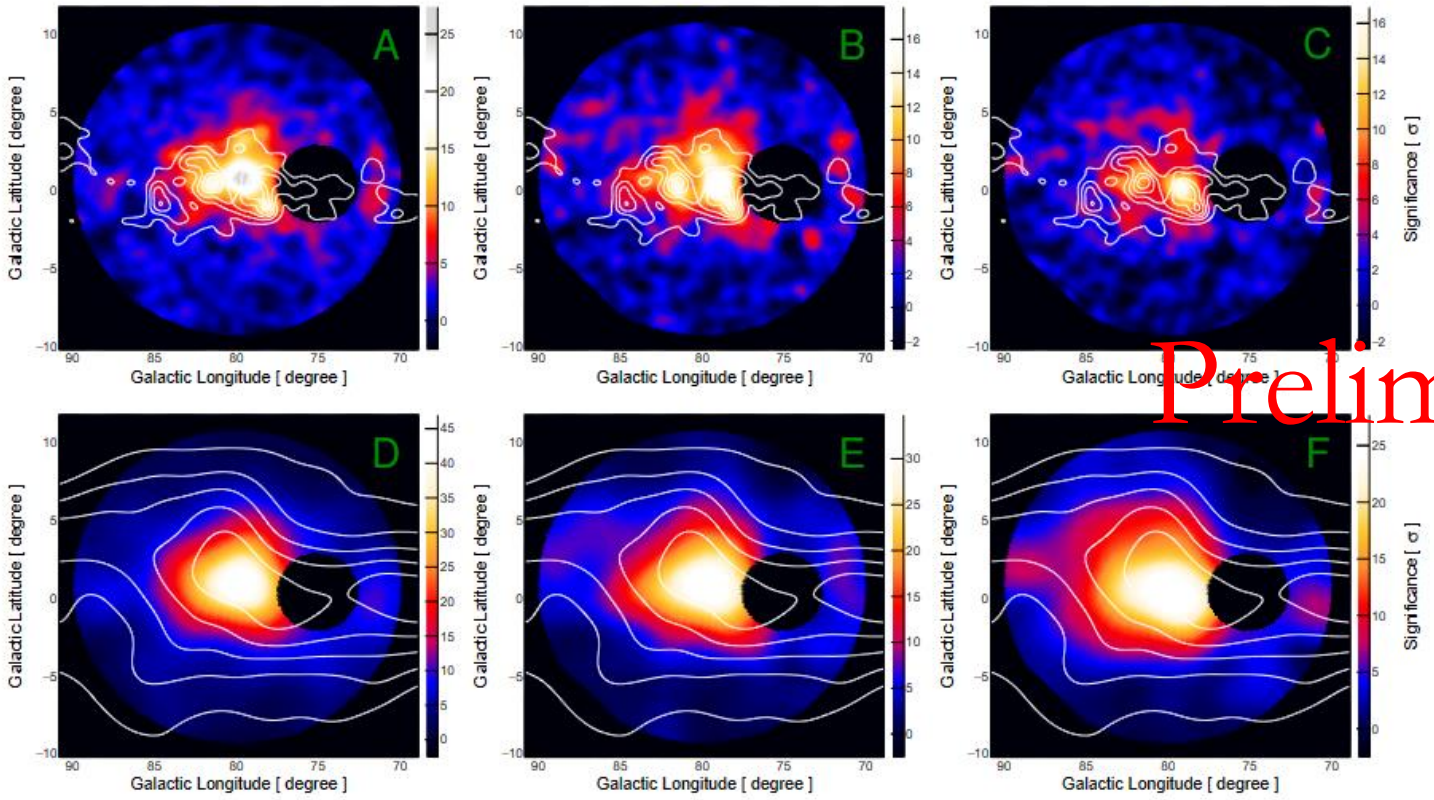


◆Except for the previous detected TeV sources, several new sources and a large scale diffuse emission are clear.



Correlation with Clouds

- The significance map is smoothed with a Gauss kernel=0.3^0(upper) and 1.0^0(lower);
- The contour is from CfA galactic CO survery (upper) and HI4PI 21-cm line survey(lower) ;

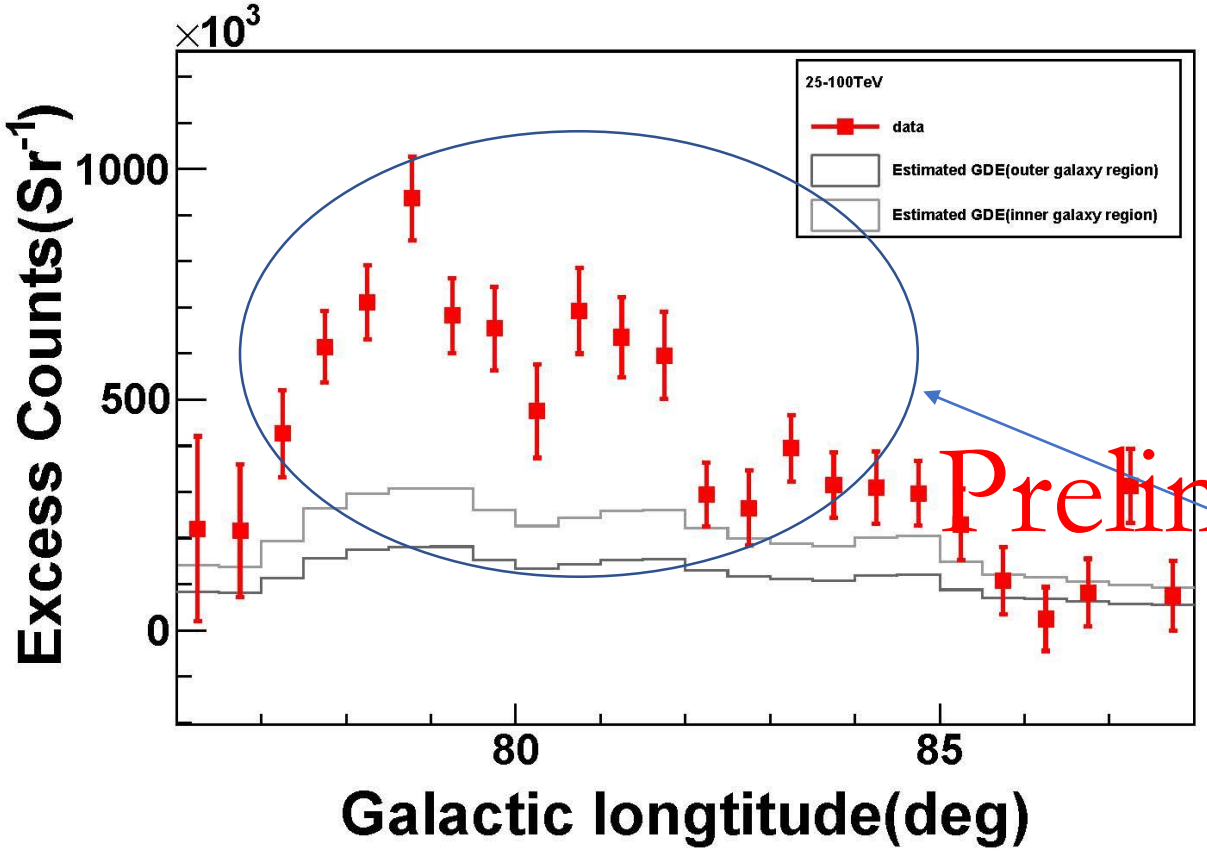


1~25TeV 25~100TeV >100TeV

Preliminary

- Clear correlation with gas distribution, which indicates a hadronic origin.
- The signal is asymmetrical and can extend at least to 10deg.

Galactic diffuse emission?



- Large uncertainty from galactic diffuse emission measurement. LHAASO's result implies there are unresolved sources or strong positional correlated diffuse emission.
- Even though we can not rule out the contribution from GDE , the **main part** should from local accelerator.

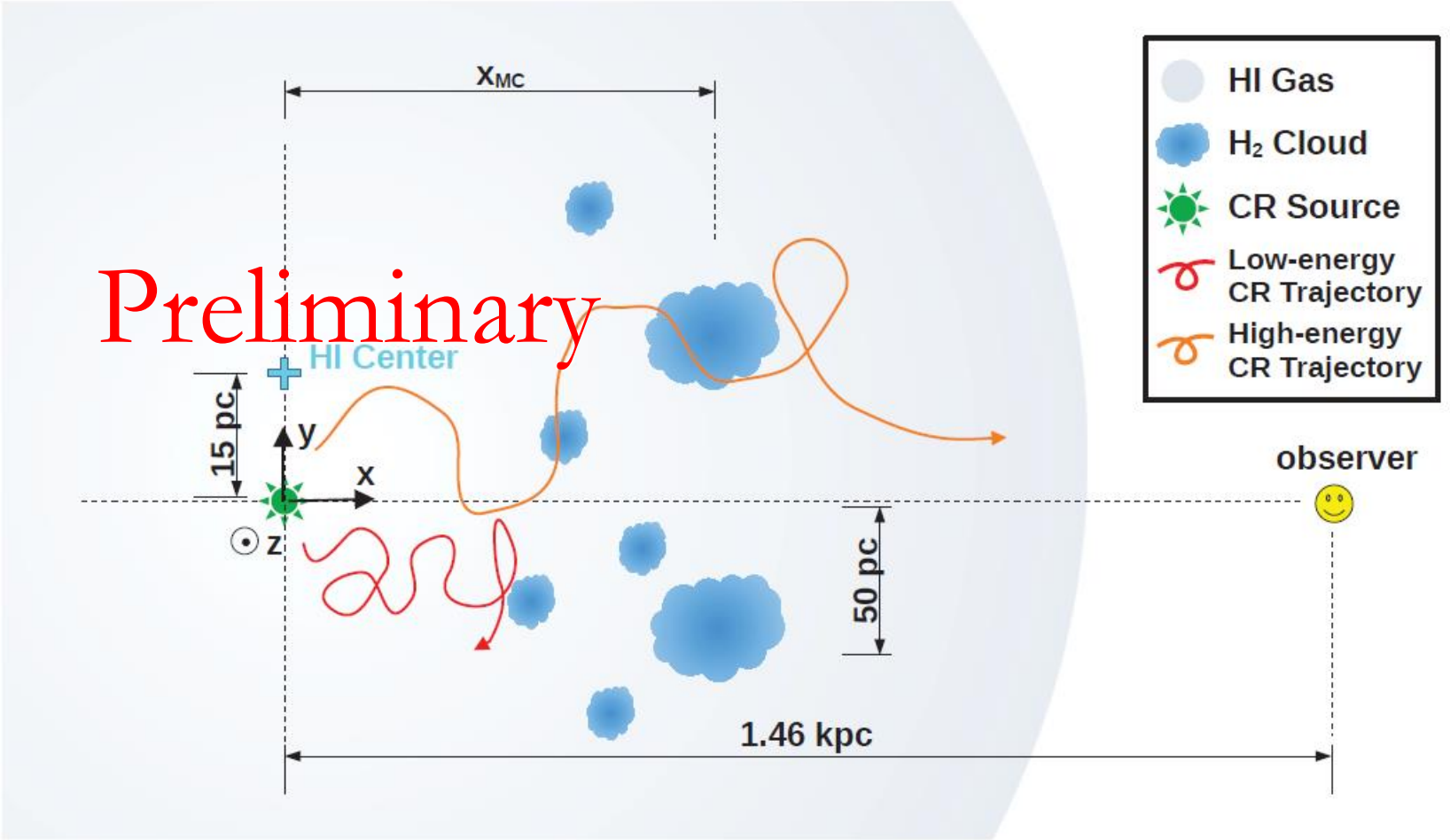
The distribution of counts with longitude within a latitude range of :$-2^0 \sim 2^0$.

Interpretation

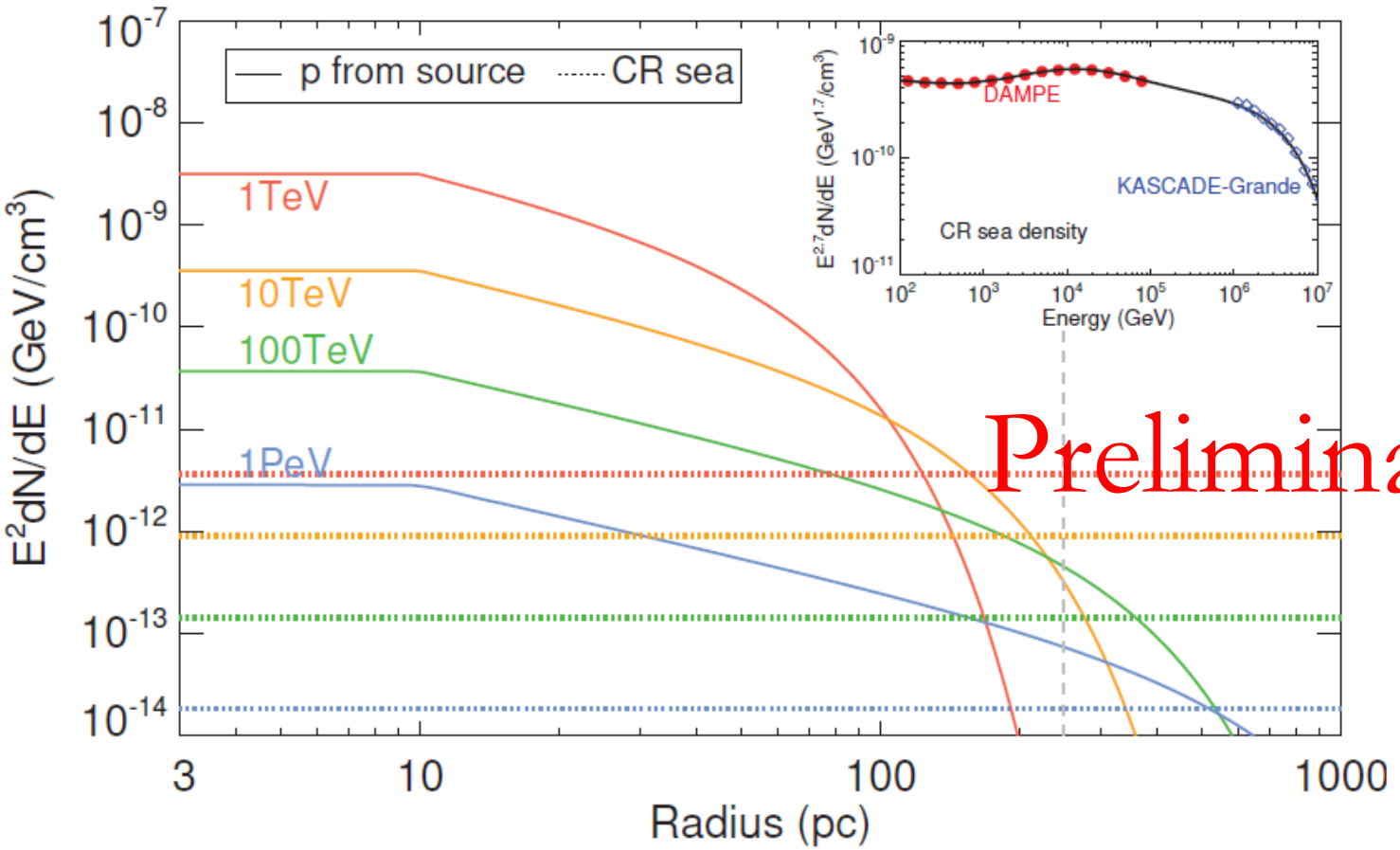
- Have the highest energy cosmic rays have escaped from the accelerator?

- What we observed is the projection of gamma rays produced is a 3D space.

  - Unfortunately we know little about the 3D distribution of gas, thus it is difficult for use to know the details of propagation of cosmic rays



Energy-dependent cosmic ray bubble?

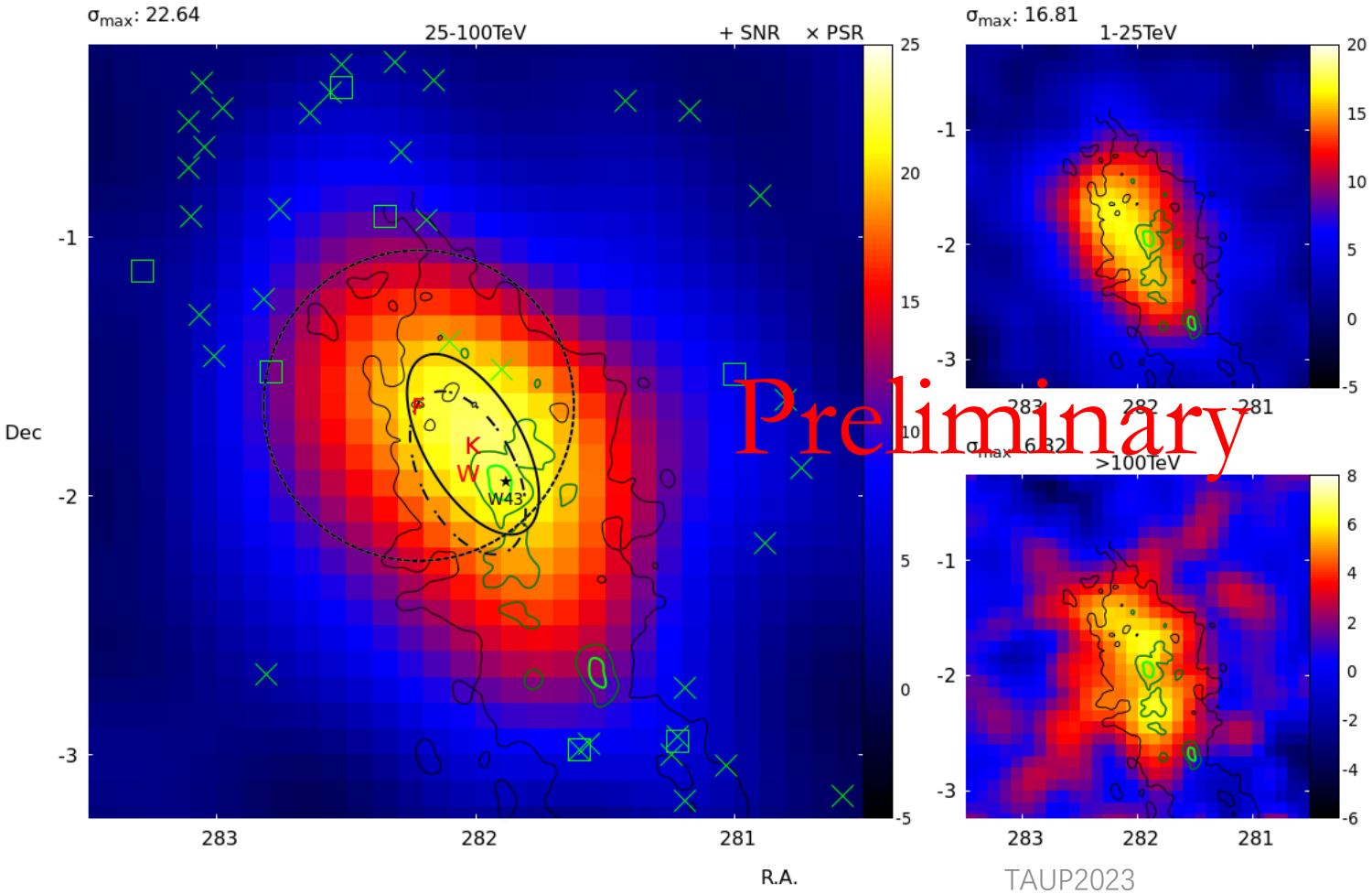


$$D = D_0(E/1\,\mathrm{TeV})^{\beta}.$$

$$D_0 \simeq 2 \times 10^{26}\,\mathrm{cm}^2/\mathrm{s}$$

- There is a large cosmic ray bubble , which implies a rather small diffusion coefficient around the source.
- The bubble extension evaluation is strongly depending on the diffuse gamma.

Other cluster-W43



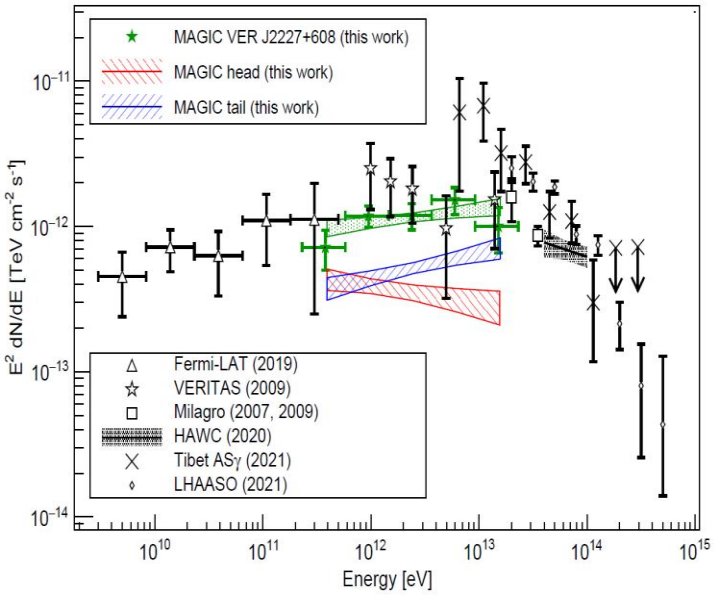
◆W43 is a galactic mini-starburst region.

● Signal with energy above 100TeV is detected from W43, which is positionally correlated with gas distribution.

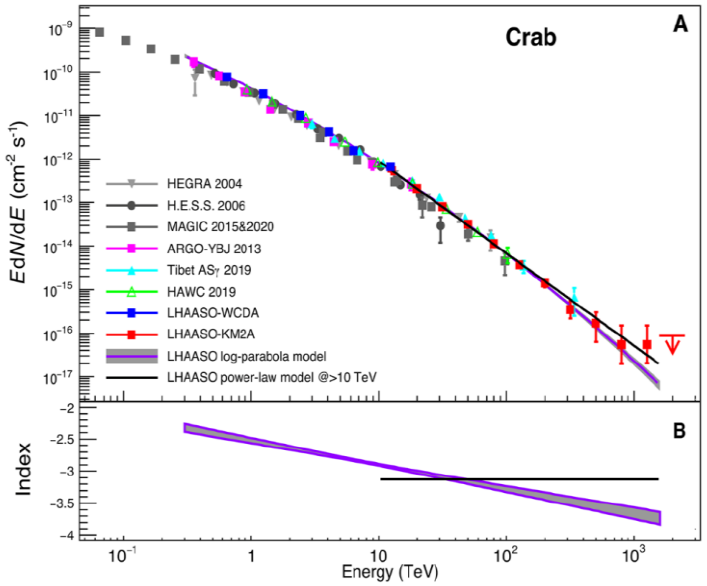
Conclusion

- A large scale extended emission from Cygnus direction is detected with spectrum beyond PeV, which implies a **Super-PeVatron**.
- The galactic diffuse emission can only contribute part of this emission. Further investigation is needed.
- It implies a large cosmic ray bubble but the size of bubble is strongly dependent on the level of galactic diffuse emission.
- Other interesting clusters, such as W43, are detected by LHAASO.

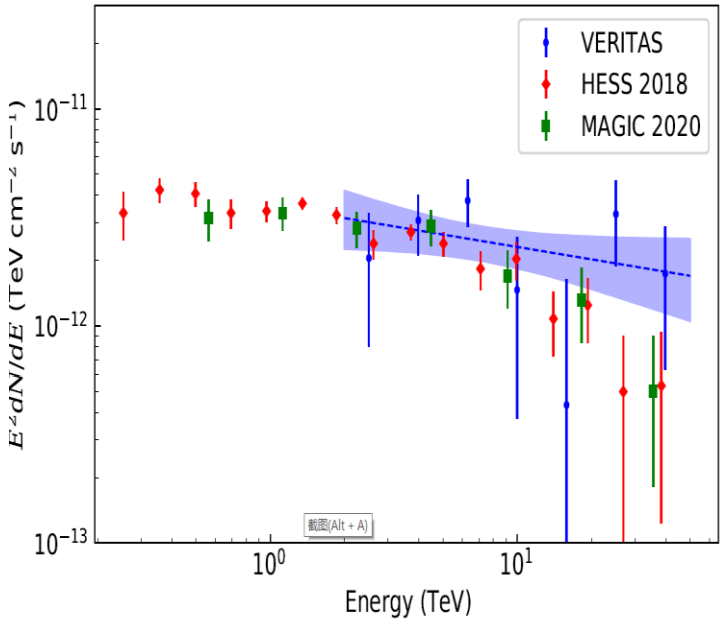
Galactic hadronic PeVatron candidates



SNR



PWN



Other sources

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Even though no source is definitely identified as a hadronic PeVatron, it seems several kinds of sources have the potential to accelerate particles to PeV.

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