Measurement of Diffuse Galactic gamma-ray Emission based on source-deduction method at Galactic plane by LHAASO

Rui Zhang

Shiping Zhao, Xinyu He, Qiang Yuan, Yi Zhang, Xiaoyuan Huang

(Purple Mountain Observatory, CAS, China)

on behalf of the LHAASO Collaboration

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Outline

Cosmic-Ray Origin and Propagation

LHAASO data use

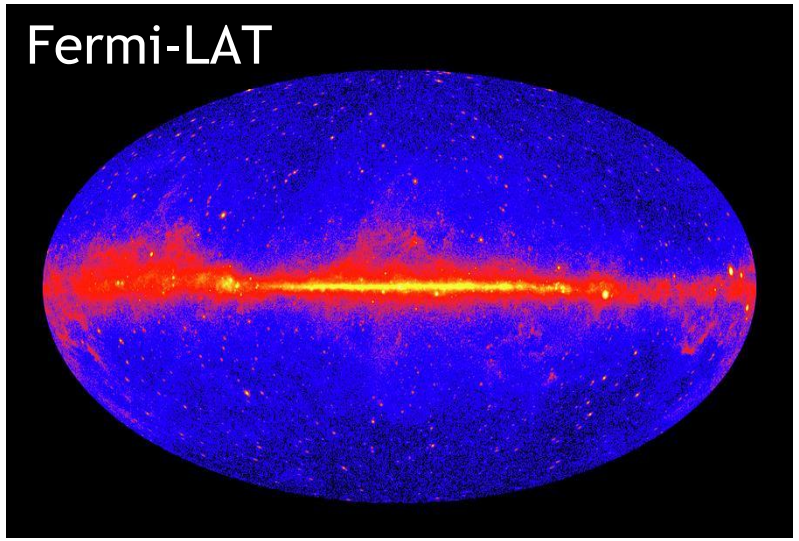
LHAASO DGE previous results

Resolved Sources and DGE at Galactic plane

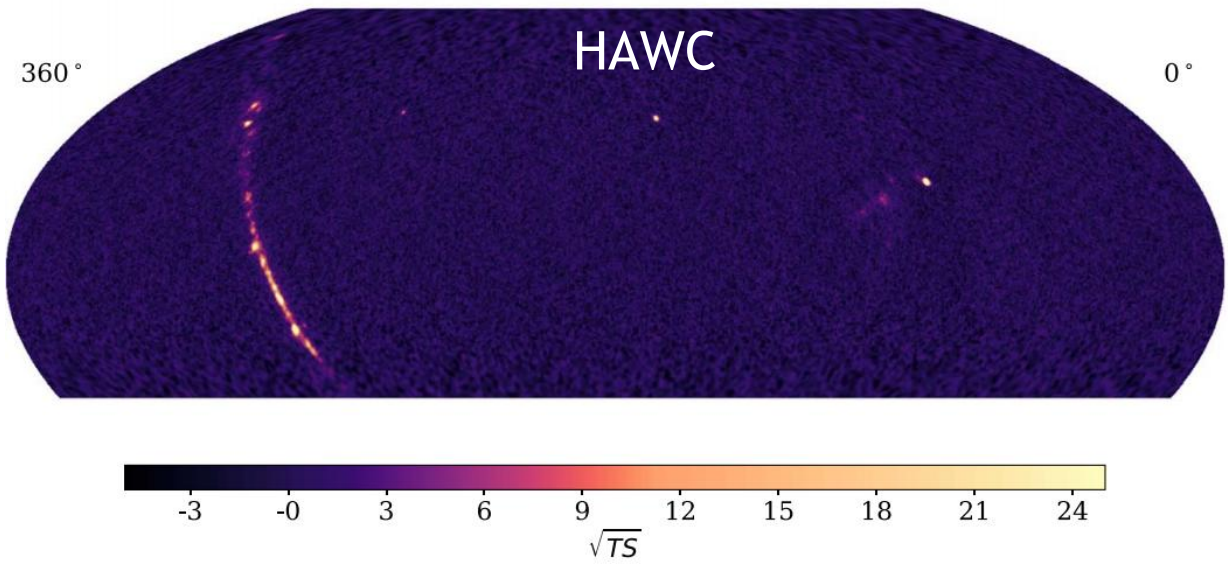
Analysis & Results

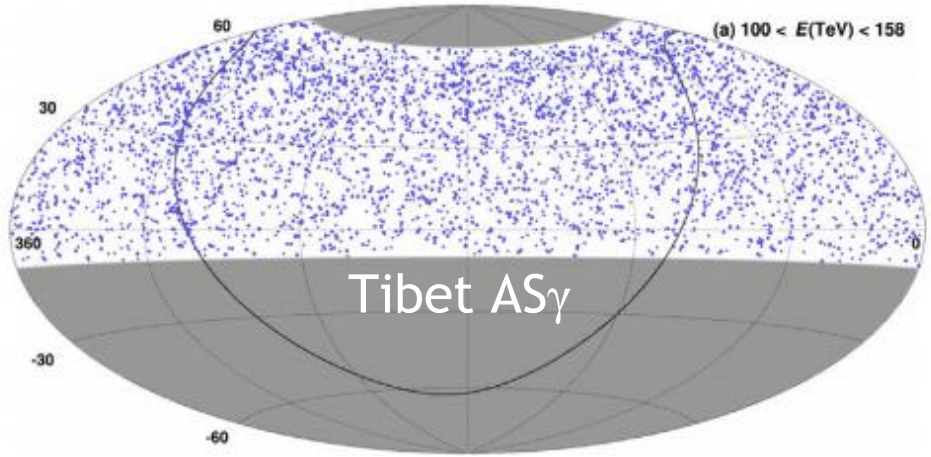
Conclusion

Probing CR acceleration and propagation with Diffuse Galactic gamma-ray Emission (DGE)



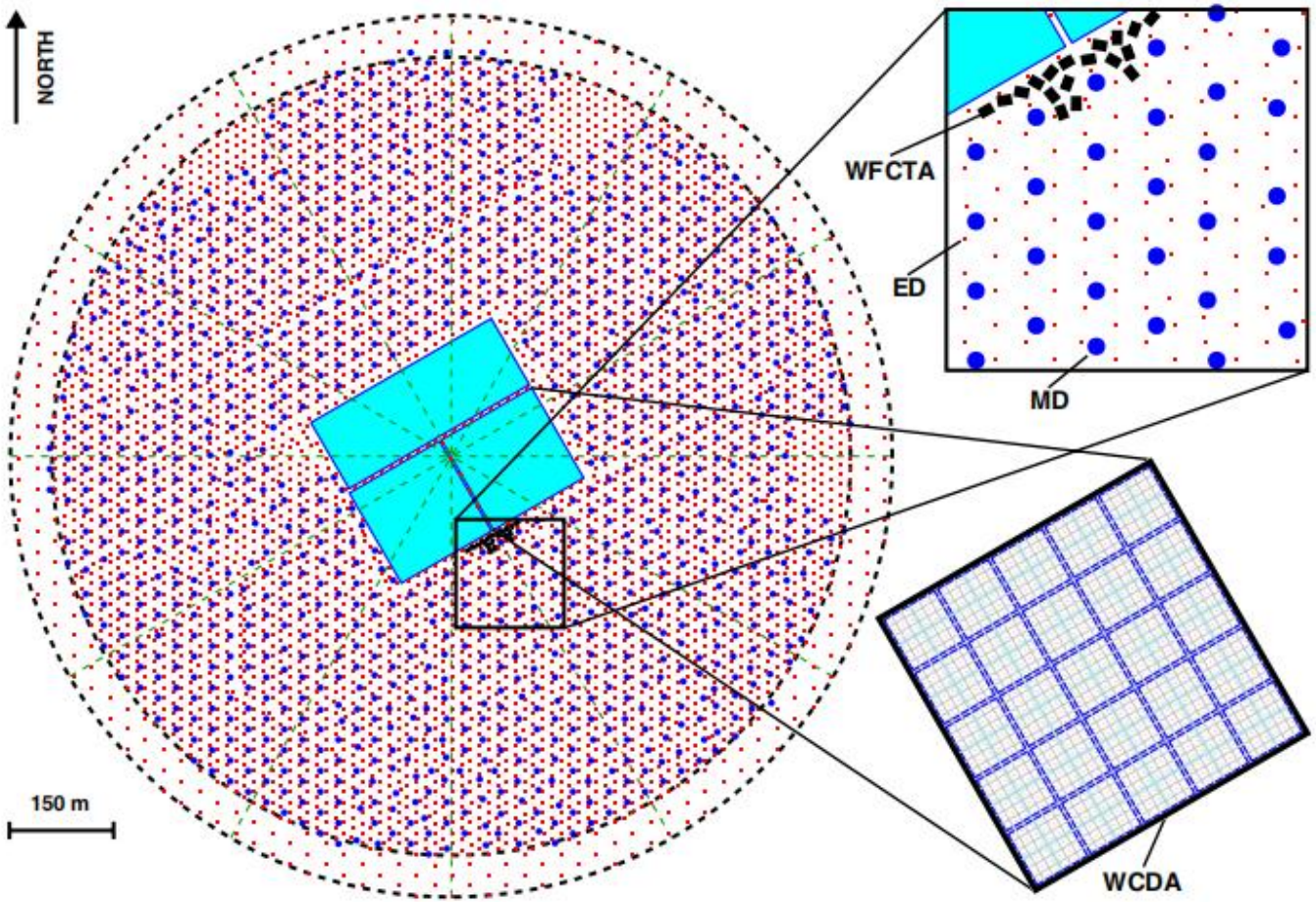
- $p,\alpha + \text{gas} \rightarrow \pi^0 \rightarrow 2\gamma$
- $e^{+/-} + \text{gas} \rightarrow \gamma$ (bremsstrahlung)
- $e^{+/-} + \text{ISRF} \rightarrow \gamma$ (inverse Compton scattering)





LHAASO data use

Detecting air showers produced by cosmic rays (and gamma rays)



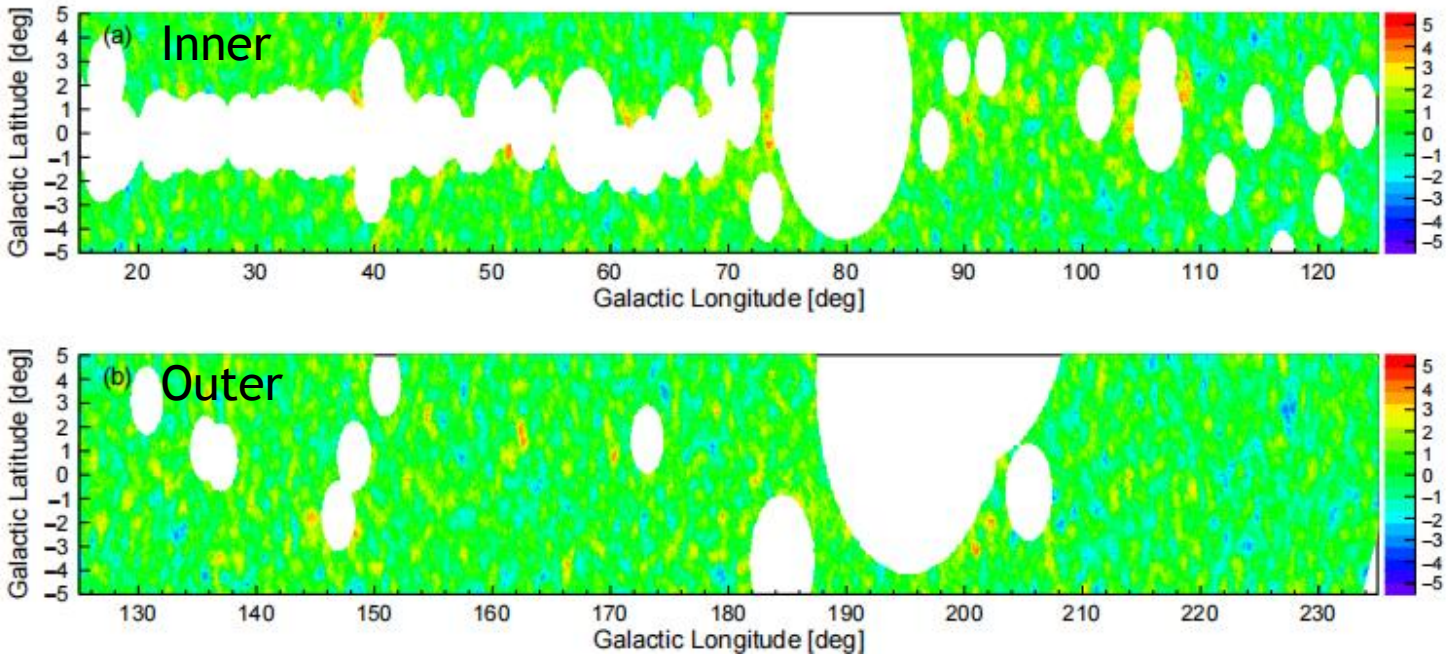
LHAASO:

- composition:
  KM2A、**WCDA**、WFCTA
- scientific targets: exploration of the origin of high-energy cosmic rays, scanning search for gamma sources, new physical phenomena, etc

- WCDA (1-25 TeV): 210305-240731
- KM2A (>25 TeV): 1/2+3/4+full (191226-241231)

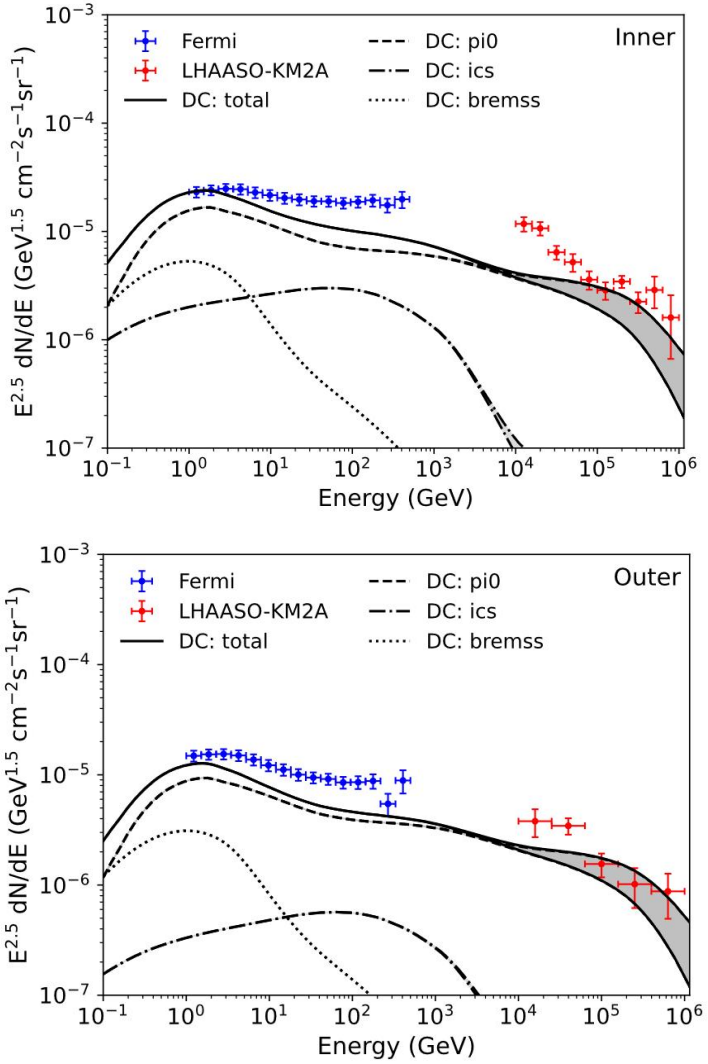
LHAASO DGE previous results

LHAASO-KM2A, mask1



- Inner: l [15 ° ,125 °], b [-5 ° ,+5 °]
- Outer: l [125 ° ,235 °], b [-5 ° ,+5 °]
- Mask: 2.5σ (KM2ACat + TeV Cat)

➢ few GeV ~ 60 TeV: obvious excess over model expectations

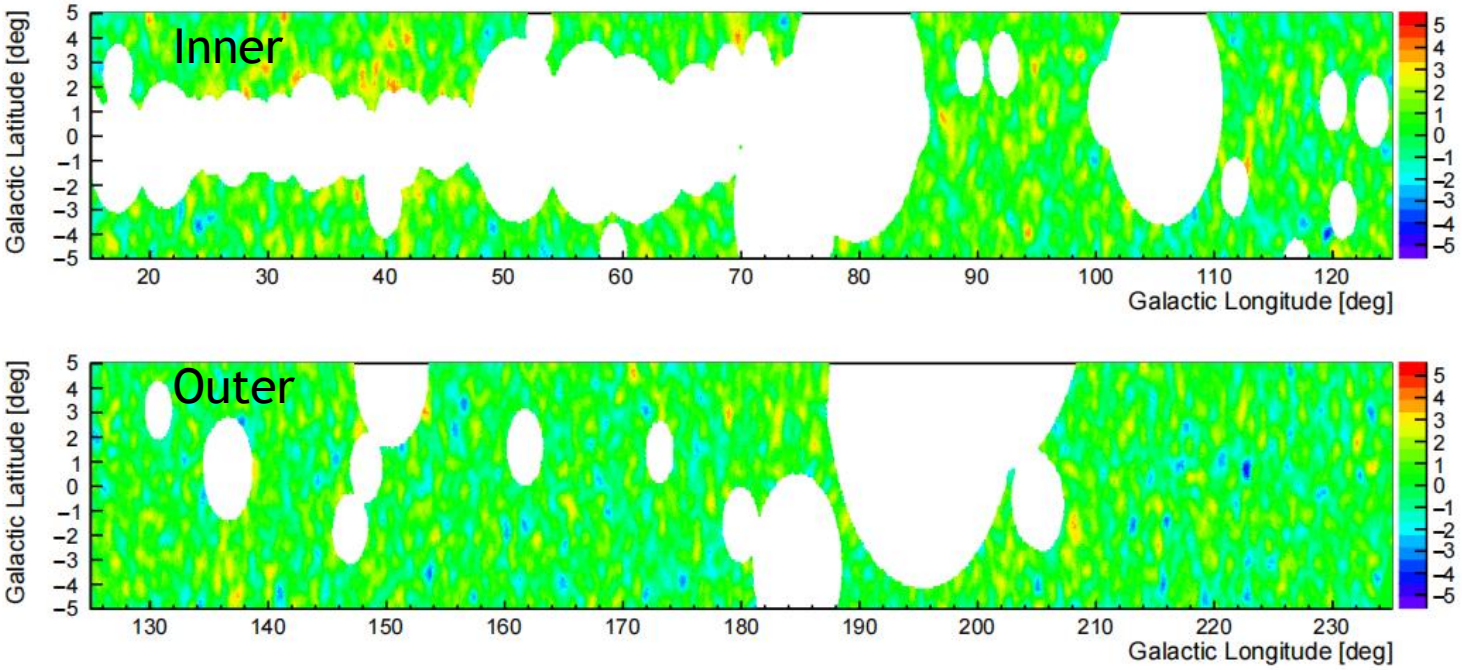


PRL, 131, 151001 (2023)

R. Zhang et al. (ApJ, 2023)

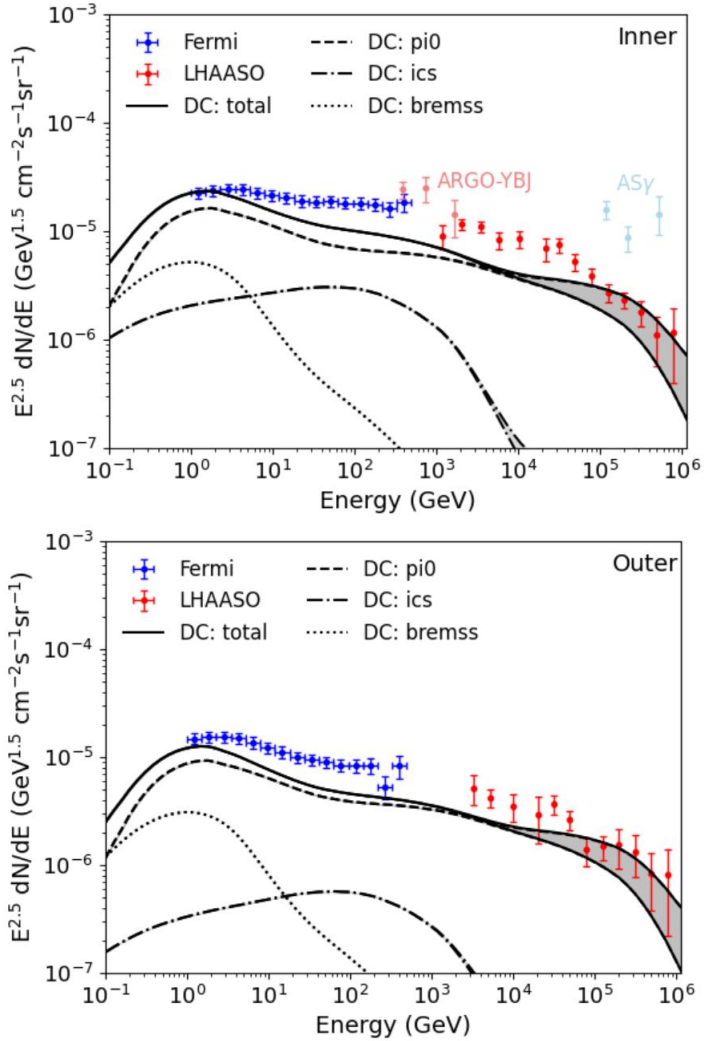
LHAASO DGE previous results

LHAASO-WCDA, mask2



- Inner: l [15 ° ,125 °], b [-5 ° ,+5 °]
- Outer: l [125 ° ,235 °], b [-5 ° ,+5 °]
- Mask: 2.5σ (LHAASOCat + TeV Cat)

➢ few GeV ~ 60 TeV: obvious excess over model expectations



PRL, 134, 081002 (2025)

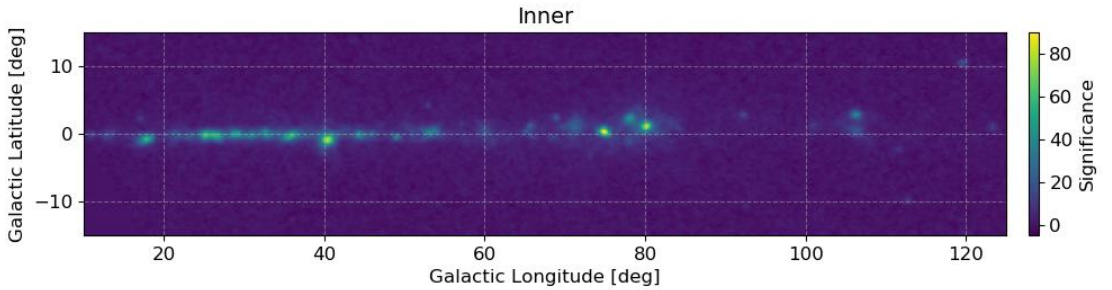
Gamma-Ray Emission at Galactic plane

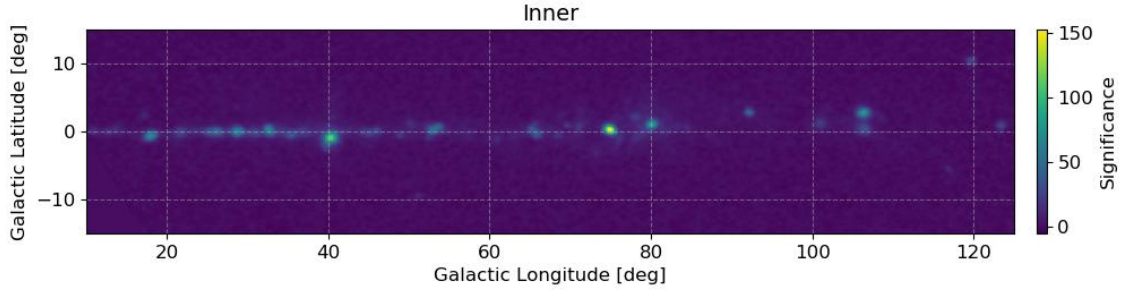
WCDA

KM2A

INNER

OUTER

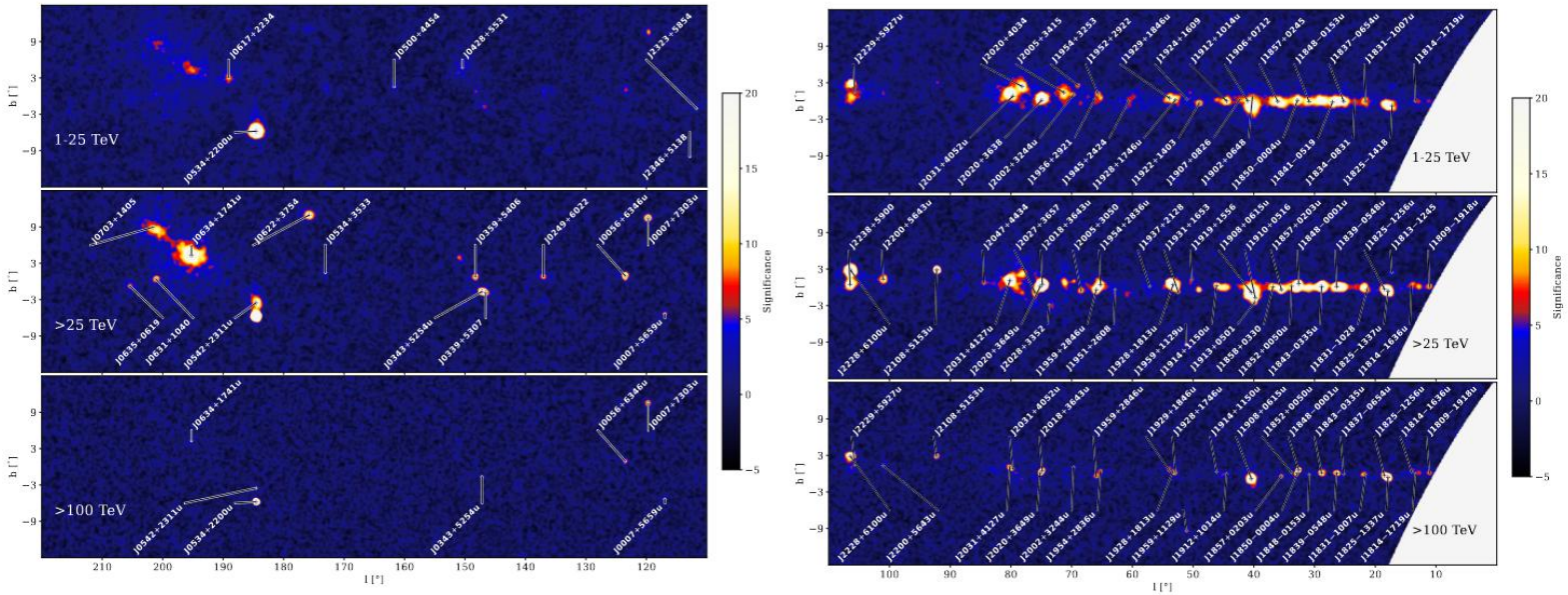




Motivation：

- Preserve ROI of DGE in the Galactic plane.
- Detailed investigation into the spatial/spectral characteristics of DGE.
- Enhance the understanding of resolved sources in the Galactic plane.

Resolved Source (RS) Measurement at Galactic plane



1st LHAASO Cat:

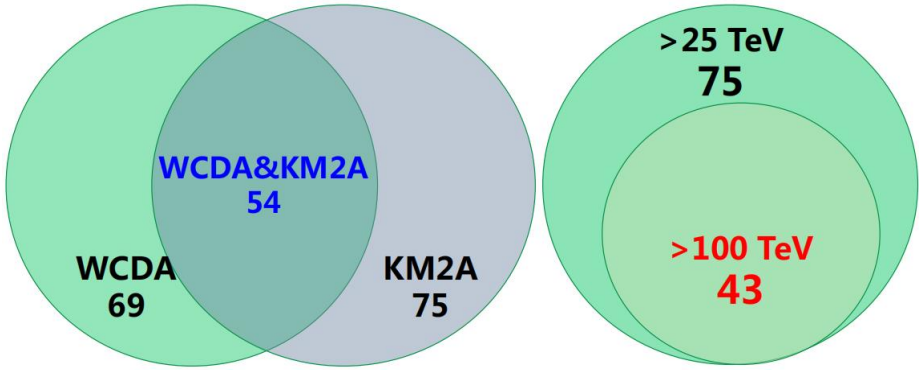
90 ALL

69 1-25 TeV（> 5σ）

75 > 25 TeV （> 5σ）

43 > 100 TeV（> 4σ）

1. 1st LHAASO Catalog source: initial values for Fitting
2. Sliding windows across the Galactic plane for 3D-Fitting
3. Source adding tests (more data, more sources...)
4. Spatial variations of DGE along longitude
5. Repeat to achieve stable results...

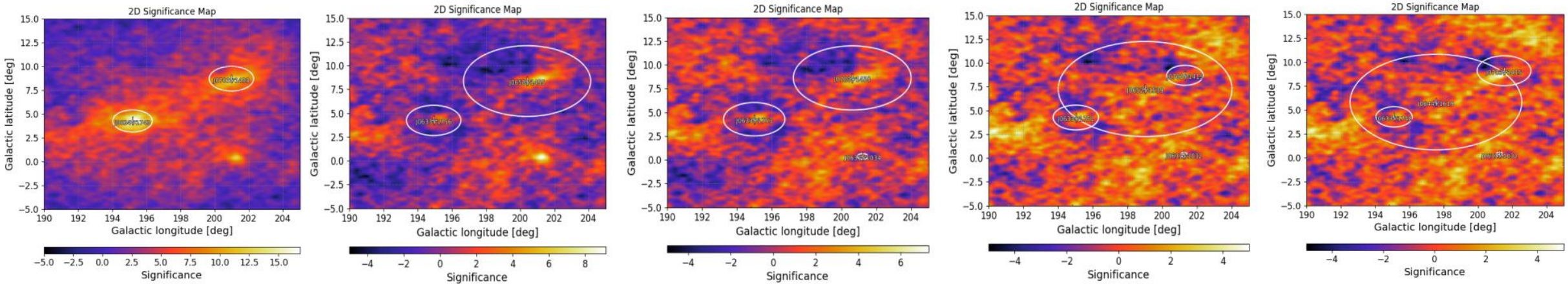


ApJS, 271, 25 (2024)

Extract RS from DGE

1. **RS:** Morphology - Gaussian & Spectrum - Power-Law / Log-Parabola
2. **DGE:** Morphology - Planck Dust Map & Spectrum - Power-Law / Log-Parabola
3. **Extension:** RS with extension exceeding a threshold value -> DGE (excluding Geminga, Monogem, and Cygnus)

WCDA: Geminga



1st LHAASO Cat | refit | +1 source | +2 sources | +3 sources

Extract RS from DGE

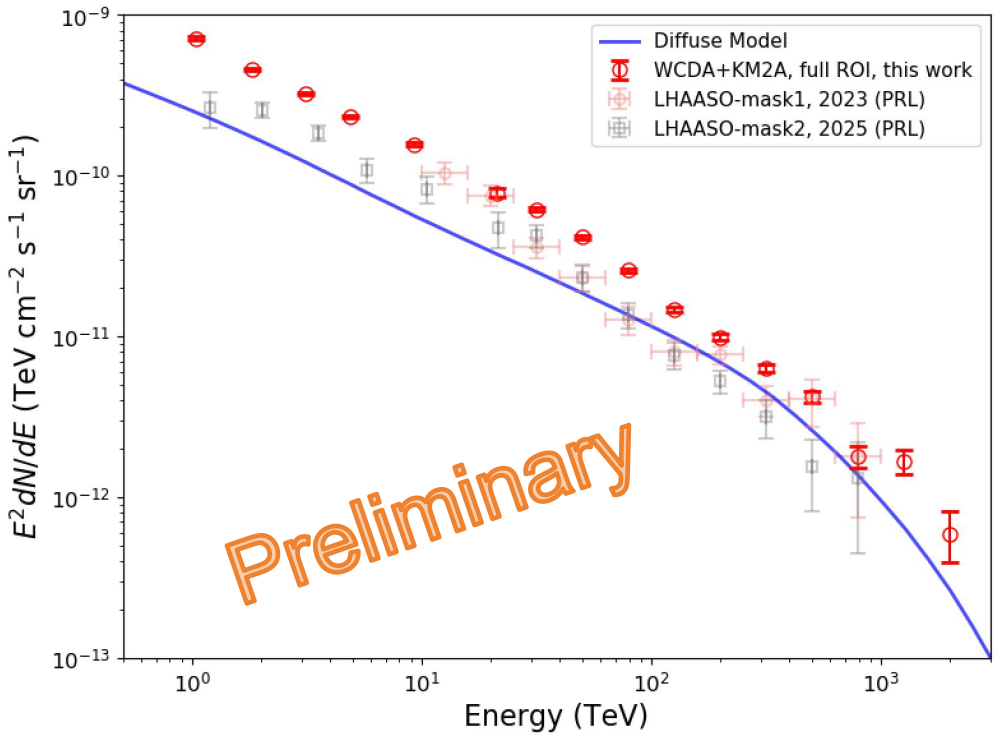
1. **RS:** Morphology - Gaussian & Spectrum - Power-Law / Log-Parabola
2. **DGE:** Morphology - Planck Dust Map & Spectrum - Power-Law / Log-Parabola
3. **Extension:** RS with extension exceeding a threshold value -> DGE (excluding Geminga, Monogem, and Cygnus)

Galactic Plane (|b|<15 degree):
90 resolved sources, WCDA
90 resolved sources, KM2A
114 resolved sources, JOINT-fit

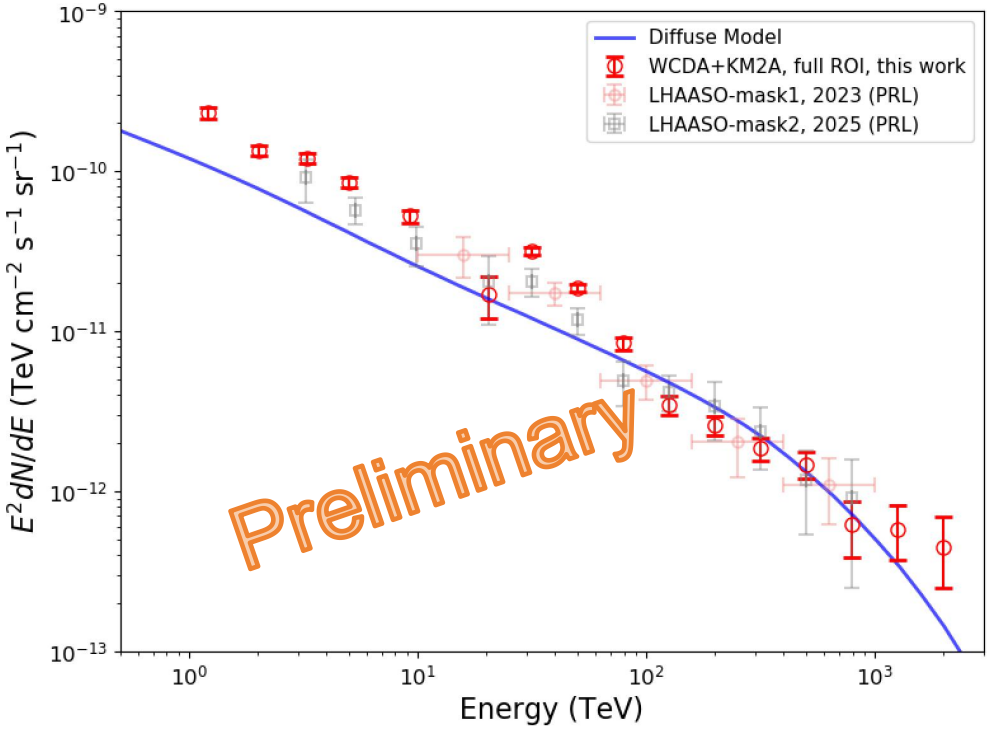
- Subtract RS emission from whole gamma-ray skymap
  -> Expect a Pure DGE Galactic Plane!

SED of DGE

INNER



OUTER

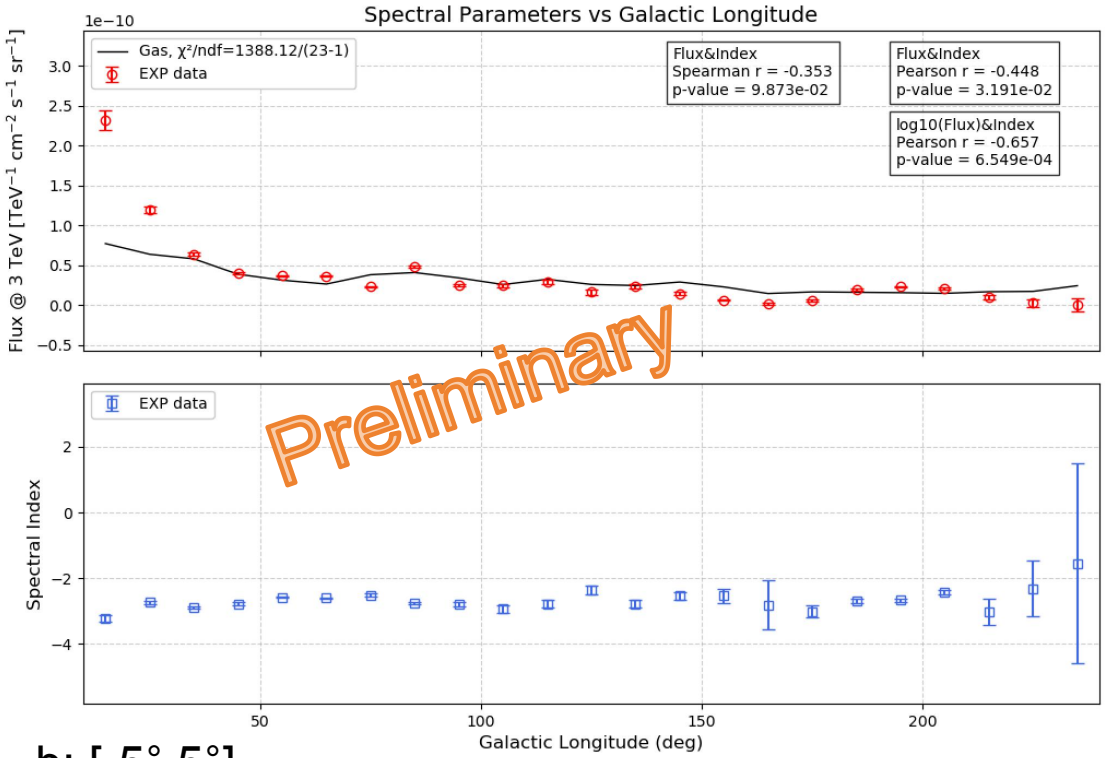


- Diffuse Model: base on LHAASO CR (proton) spectrum (w/o considering Distribution of CRs)
- E < 100 TeV: extra component with Ecut around 100 TeV
- E > 100 TeV: similar spectral shape (index) as that of measurements

LHAASO p: arXiv:2505.14447v1

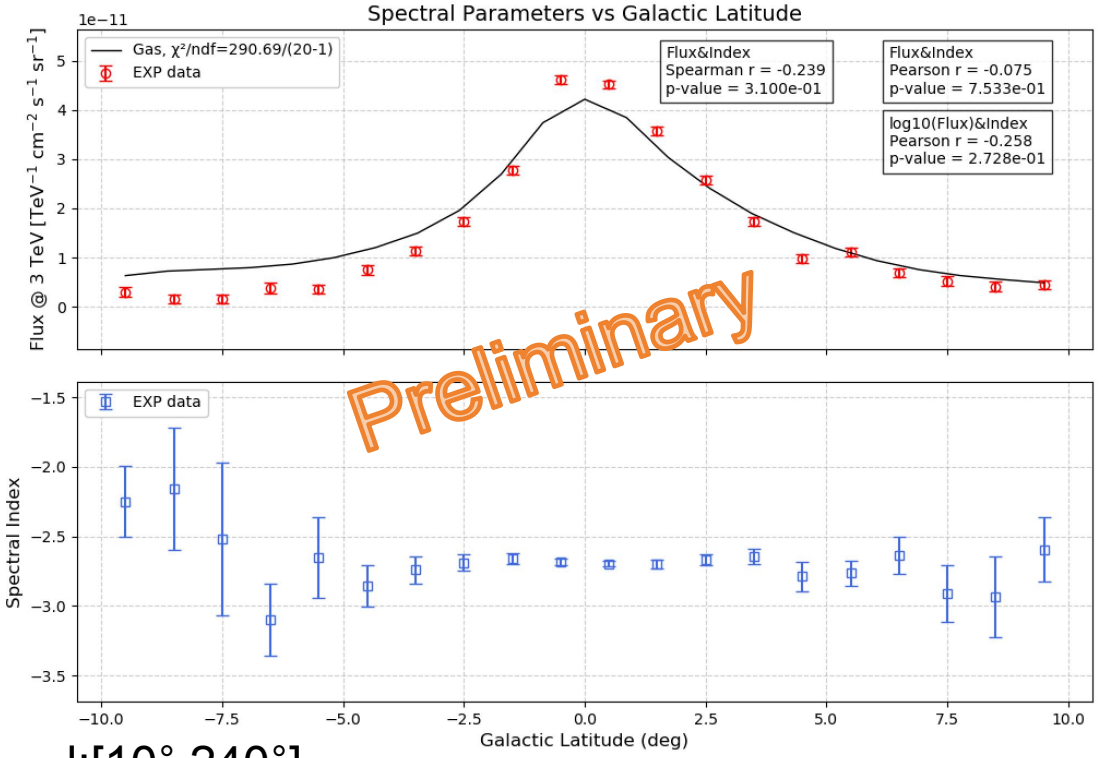
Profile of Galactic Longitude & Latitude (1 - 25 TeV)

Longitude



b: [-5°,5°]

Latitude

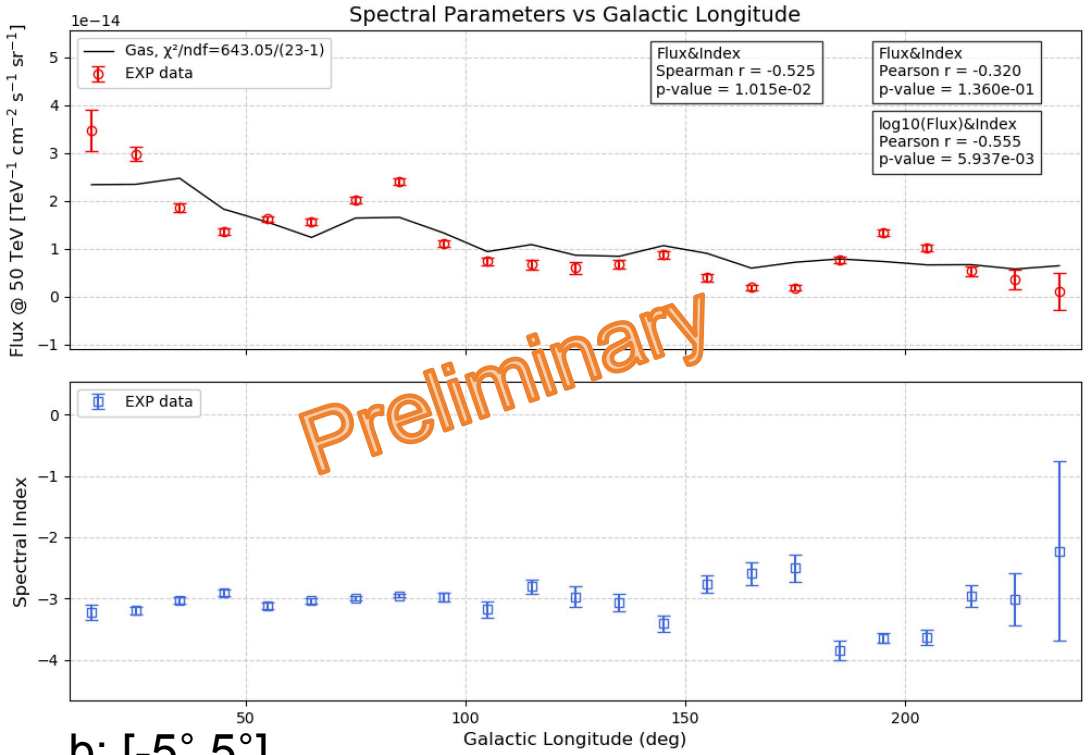


l:[10°,240°]

- Discrepency between measurements and Gas distribution (PLANCK Dust Map), low longitude.
- Spectral Index varies along Galactic longitude and Latitude.

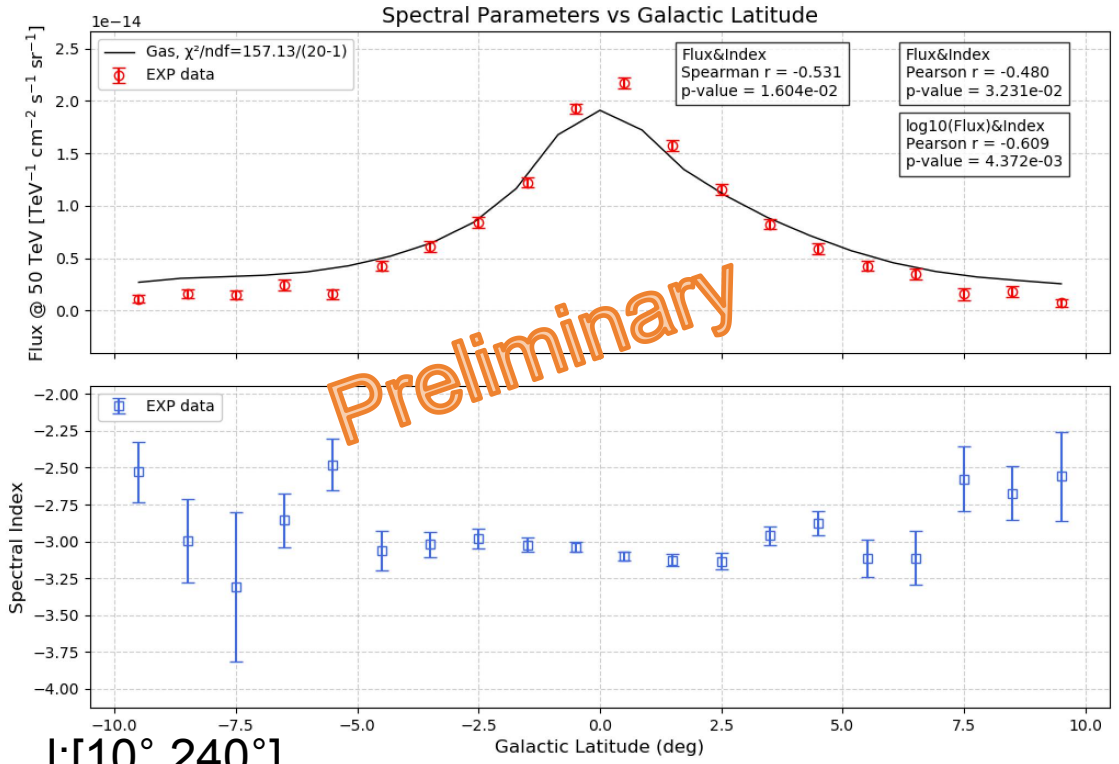
Profile of Galactic Longitude & Latitude (> 25 TeV)

Longitude



b: [-5°,5°]

Latitude



l:[10°,240°]

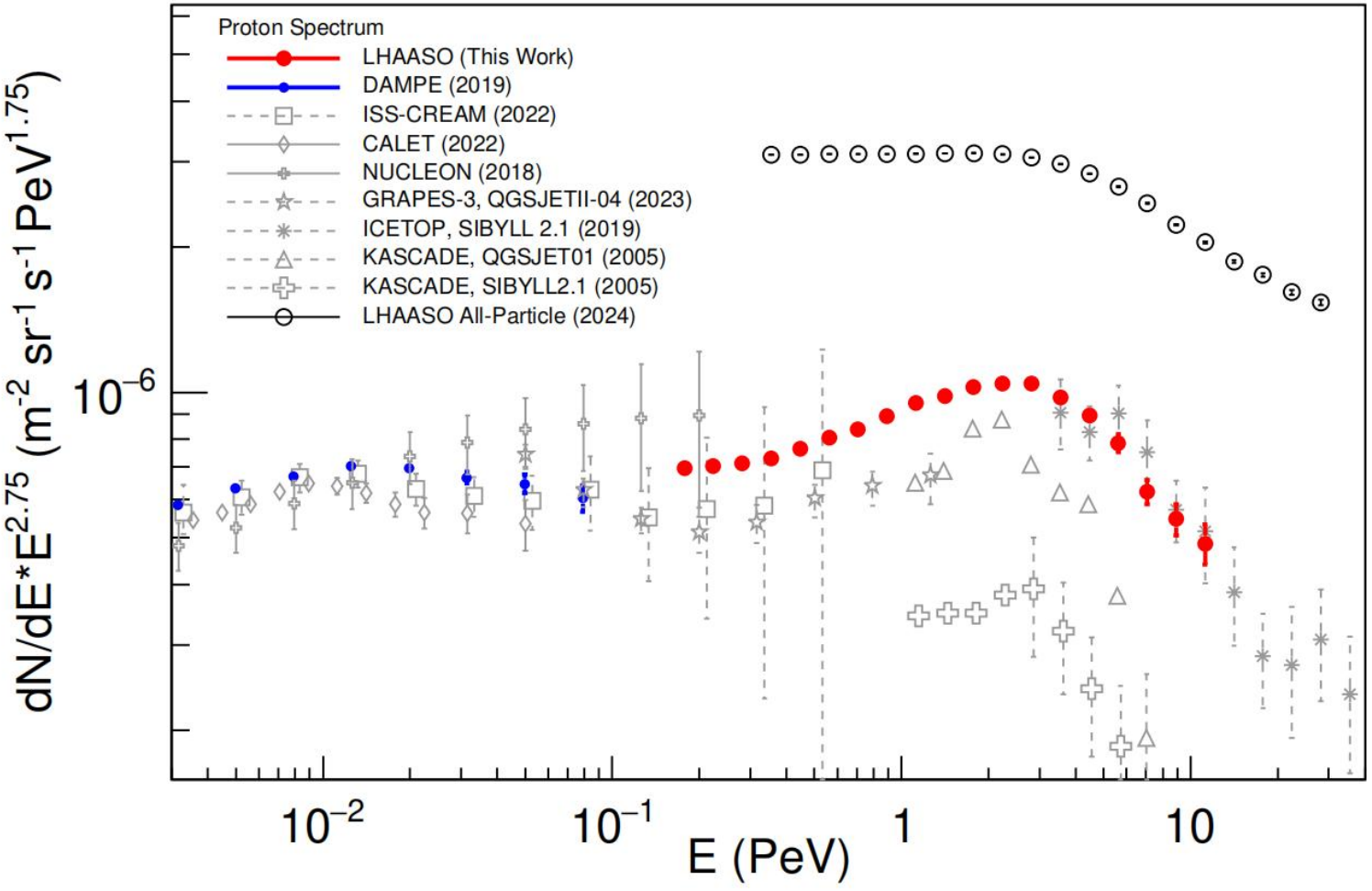
- Discrepency between measurements and Gas distribution (PLANCK Dust Map), Cygnus, Geminga.
- Spectral Index varies along Galactic longitude and Latitude.

Discussion & Conclusion

1. We have preliminarily achieved the measurement of the DGE using the source-subtraction method.
2. Spatial distribution of DGE deviates from the distribution of the Planck Dust map; Spectral index of DGE exhibit significant variations with longitude and latitude.
3. SED of Inner and Outer Galaxy, >100 TeV similar spectral shape as diffuse model, <100 TeV extra component with Ecut: a soft component (unresolved sources) with Ecut over a hard component (CR-ISM) ?
4. For some complex regions like Geminga region, we need a more detailed separation of RS from DGE.

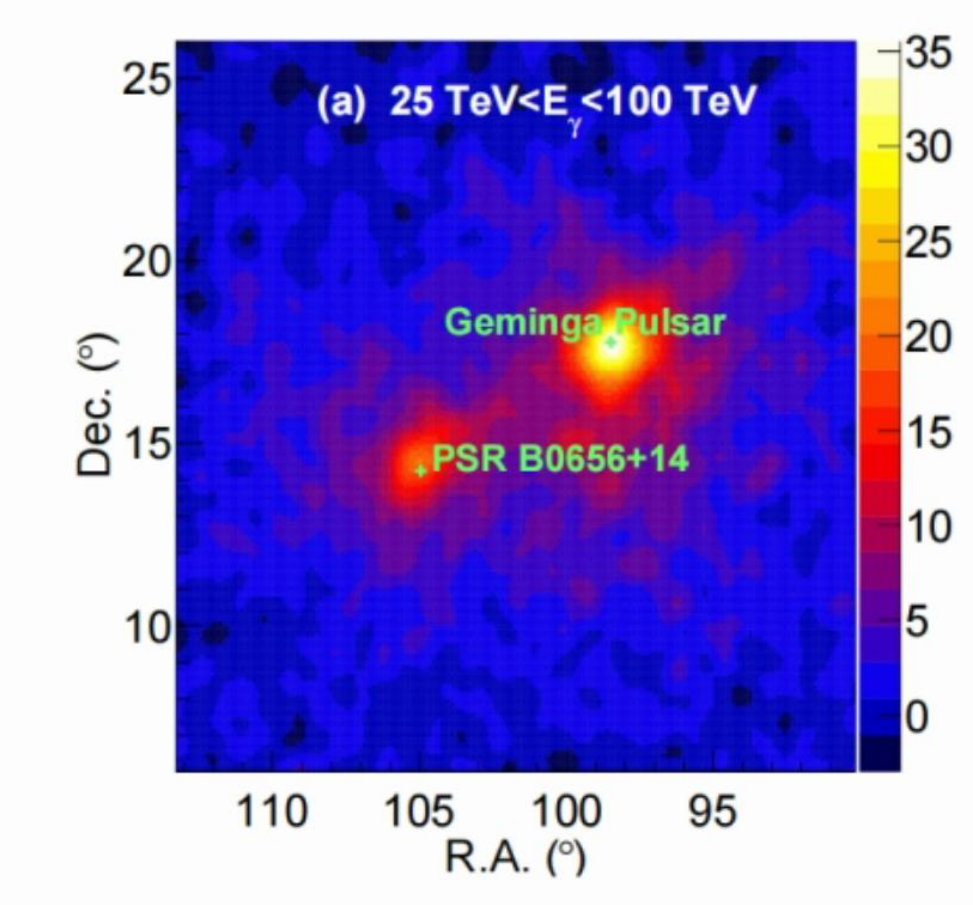
Backup

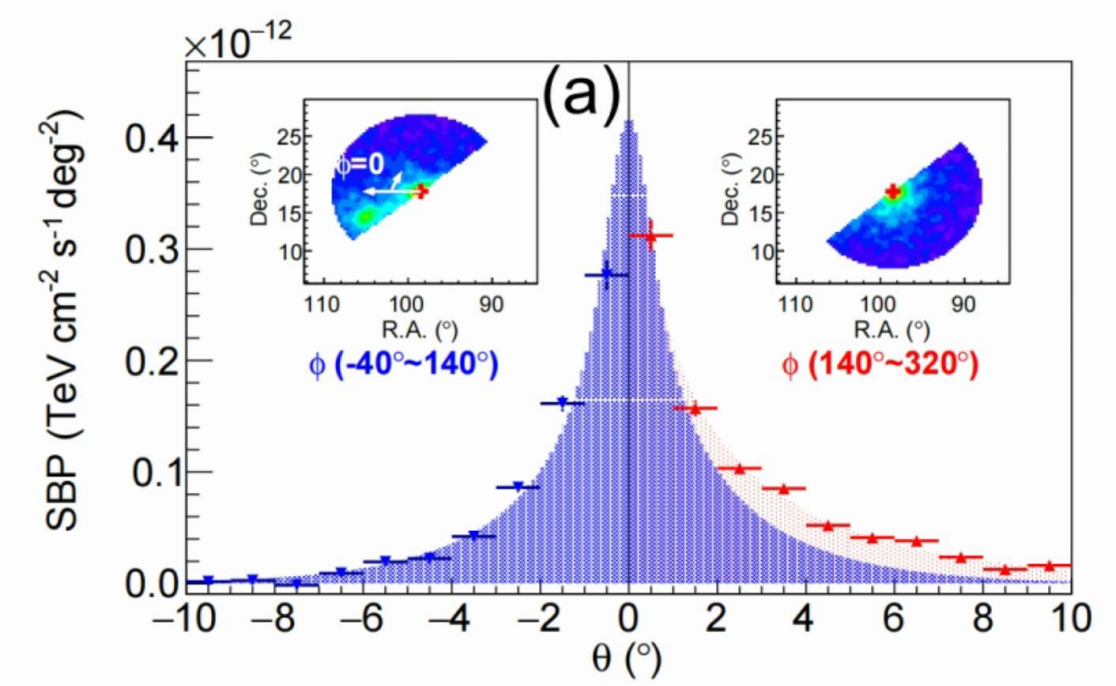
First Identification and Precise Spectral Measurement of the Proton Component in the Cosmic-Ray 'Knee'



arXiv:2505.14447v1

Geminga Region





- Asymmetric halo morphologies are observed for Geminga and Monogem, which suggest that the diffusion of electrons and positrons is non-uniform or anisotropic.