Measuring VHE diffuse gamma-ray emission from Galactic plane with LHAASO-KM2A

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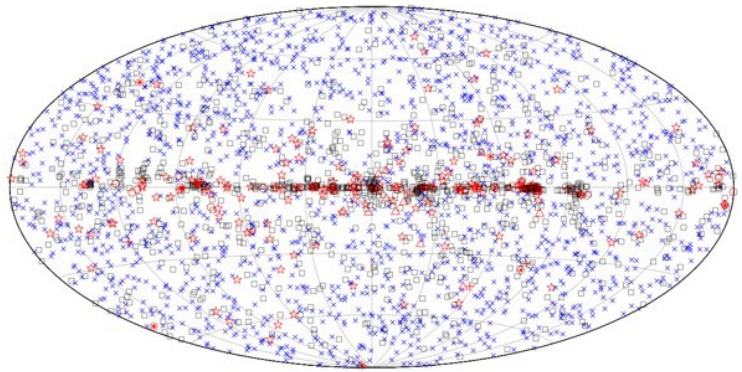
Outline

- Galactic CRs and Diffuse γ-Rays
- LHAASO-KM2A Observation
- Analysis Methods
  - Background Estimation*
  - Extraction of resolved γ-ray sources

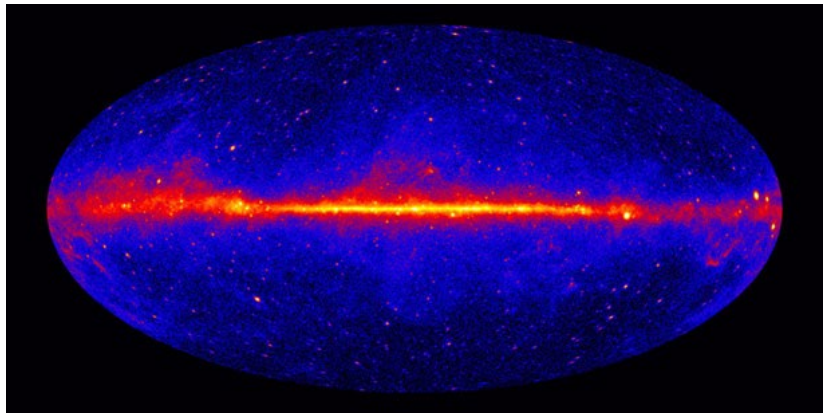
Sky maps of Gamma-Rays

Different Origins of Gamma-Rays…



Resolved Sources

Fermi

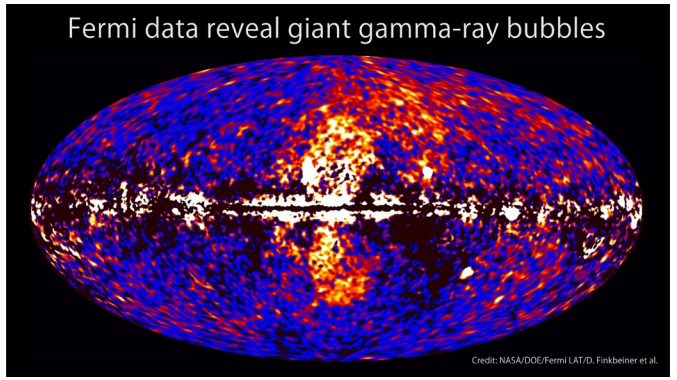


Fermi 3-year skymap

Galactic Diffuse Gamma-ray Emission(DGE)

Extra-galactic Diffuse Gamma-ray Emission

Large-scale extensive sources



Fermi

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Images from Fermi: https://fermi.gsfc.nasa.gov

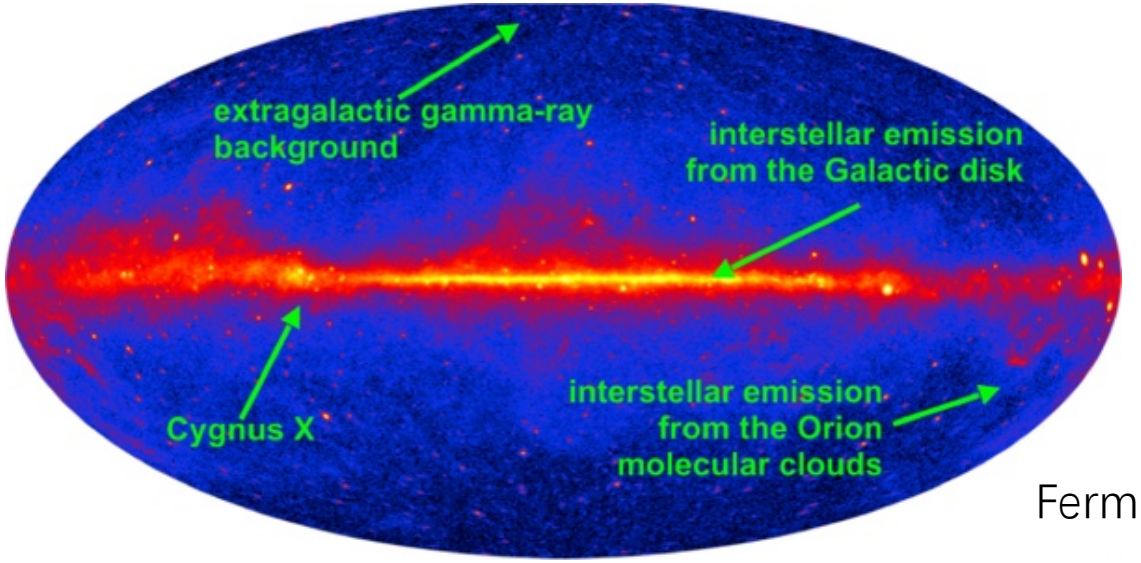
Galactic Diffuse Gamma-ray Emission(GDE)

Dominant Processes to Produce GDE:

$$e^{\pm} + \mathrm{ISM} \rightarrow \gamma$$
$$e^{\pm} + \mathrm{ISRF} \rightarrow \gamma\ (\mathrm{IC})$$

CRs(~PeV, 'Knee') **~100TeV**

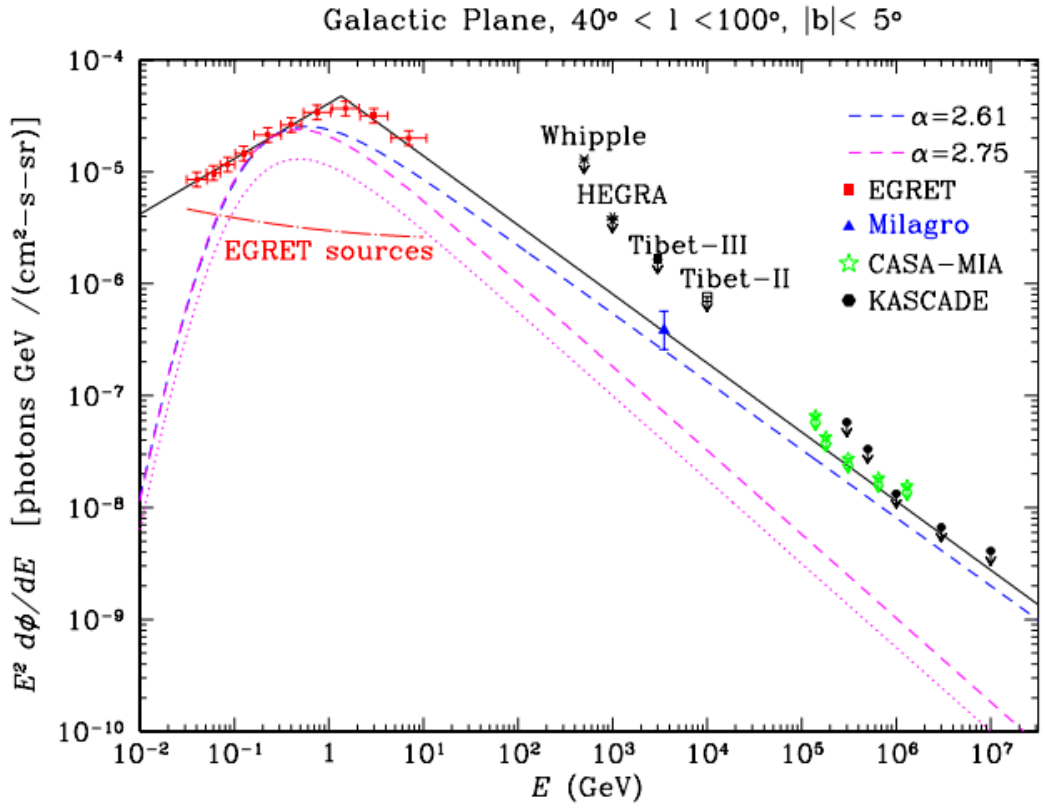
$$\mathrm{p}, \alpha + \mathrm{ISM} \rightarrow \pi^0 \rightarrow \gamma$$



Fermi-LAT

An indirect way to study CRs & DM
1) Propagating & Acceleration
2) Origin of "Knee" in SED of CRs
3) Dark Matter(DM) annihilation signal
4) ……

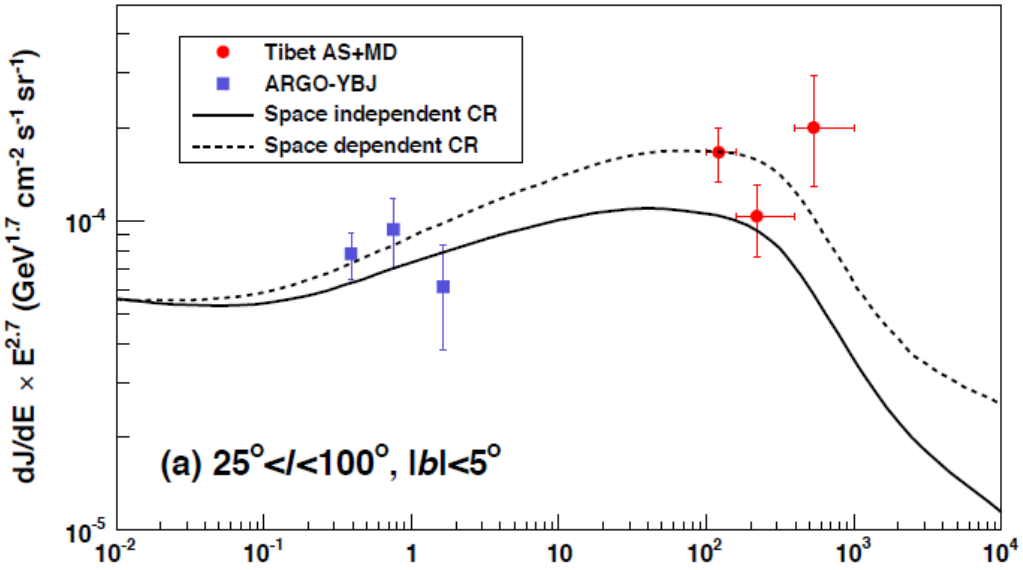
Observations of GDE



Tijana Prodanović, et al, 2007

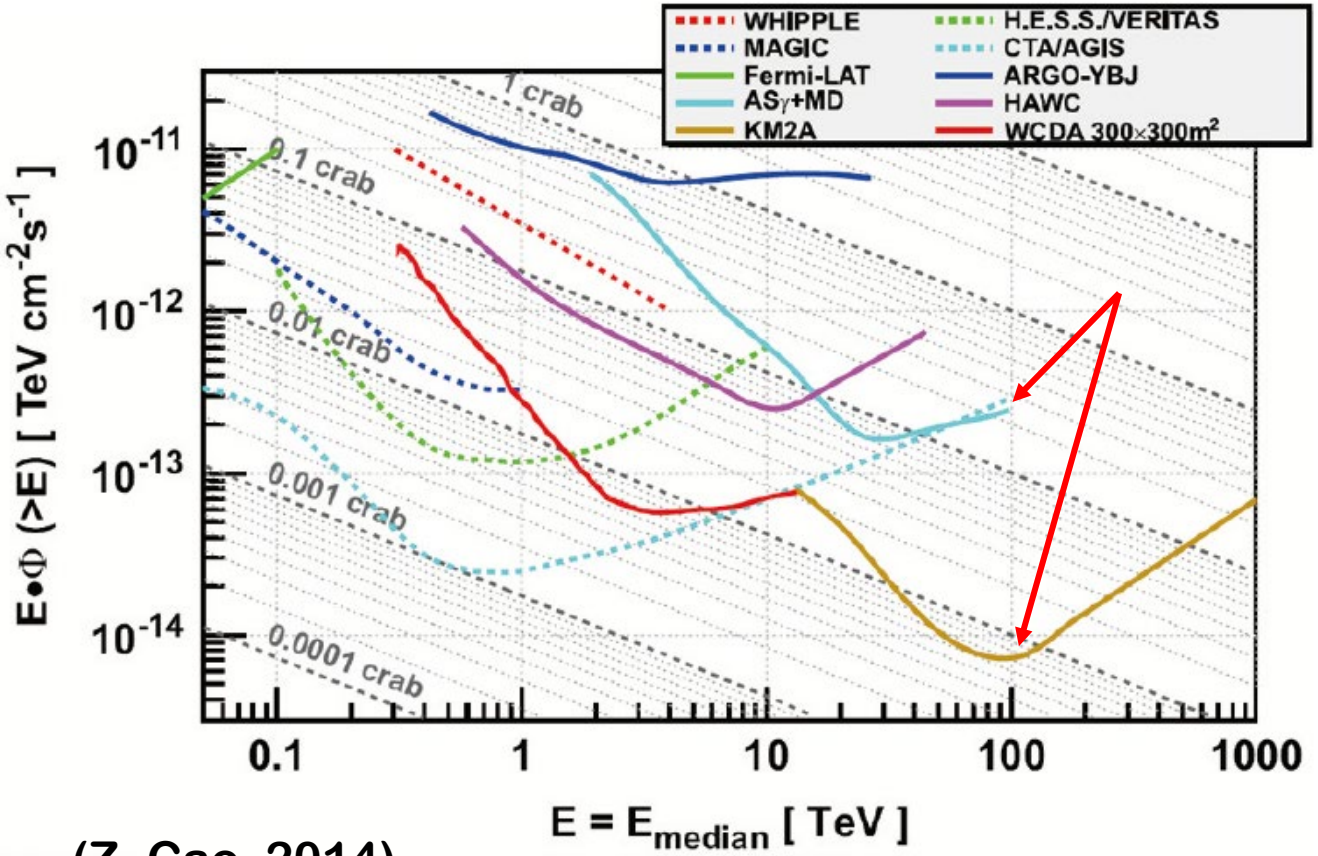
No significant excess over Energy ~100TeV

Ground-Based Experiments

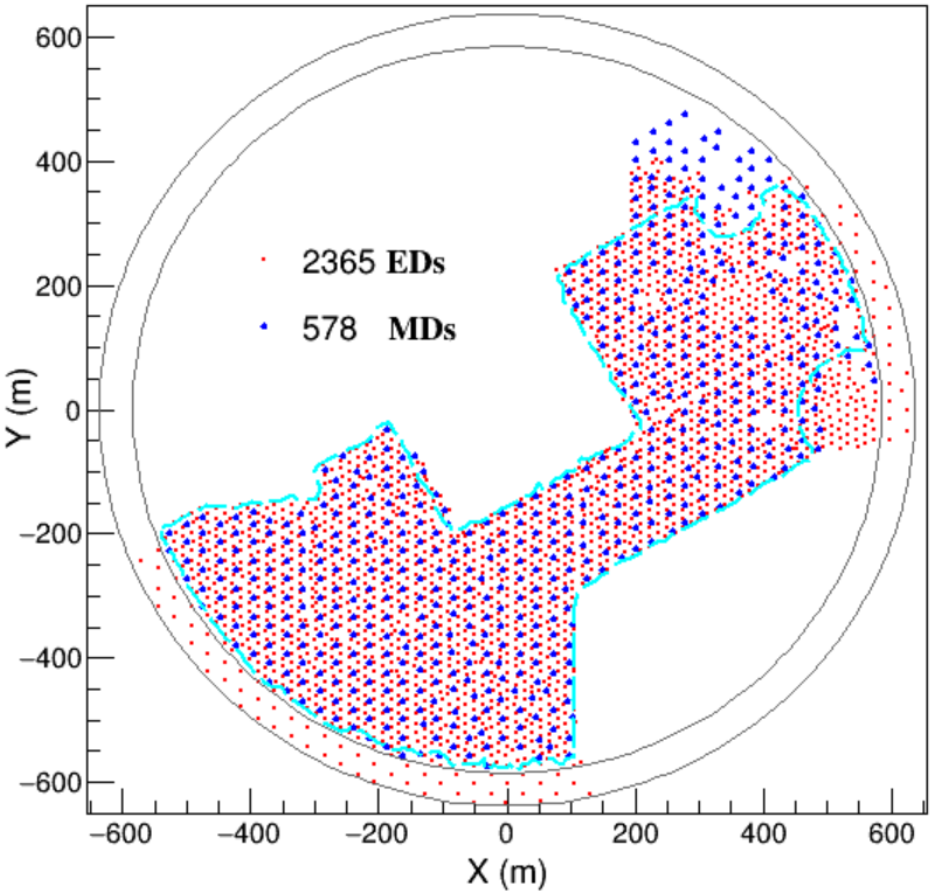


ASγ，2020

LHAASO-KM2A Observation



(Z. Cao, 2014)



KM2A(1/2 Array) Detectors Distribution

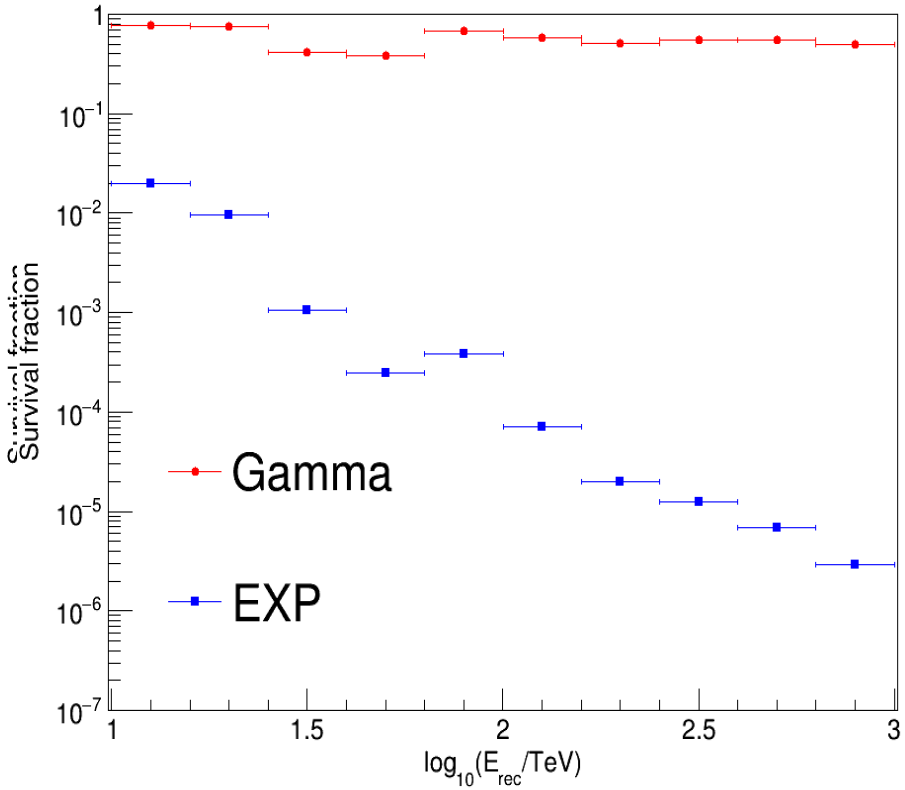
KM2A(Half-Array) Data: 2019/12/27 ~ 2020/11/30

γ-Proton Discrimination

$$est := log_{10} \frac{N_\mu + 0.0001}{N_e}$$

log10(E/TeV)	CUT
1.0-1.2	-5.00
1.2-1.4	-3.20
1.4-1.6	-5.96
1.6-1.8	-6.17
1.8-2.0	-2.50
2.0-2.2	-2.69
2.2-2.4	-2.79
2.4-2.6	-2.74
2.6-2.8	-2.75
2.8-3.0	-2.79

Event: est < CUT  **More likely a gamma event**



Survival fraction of Gamma & CRs, respectively

Background-Estimation: Method I,II

We've tried different methods…

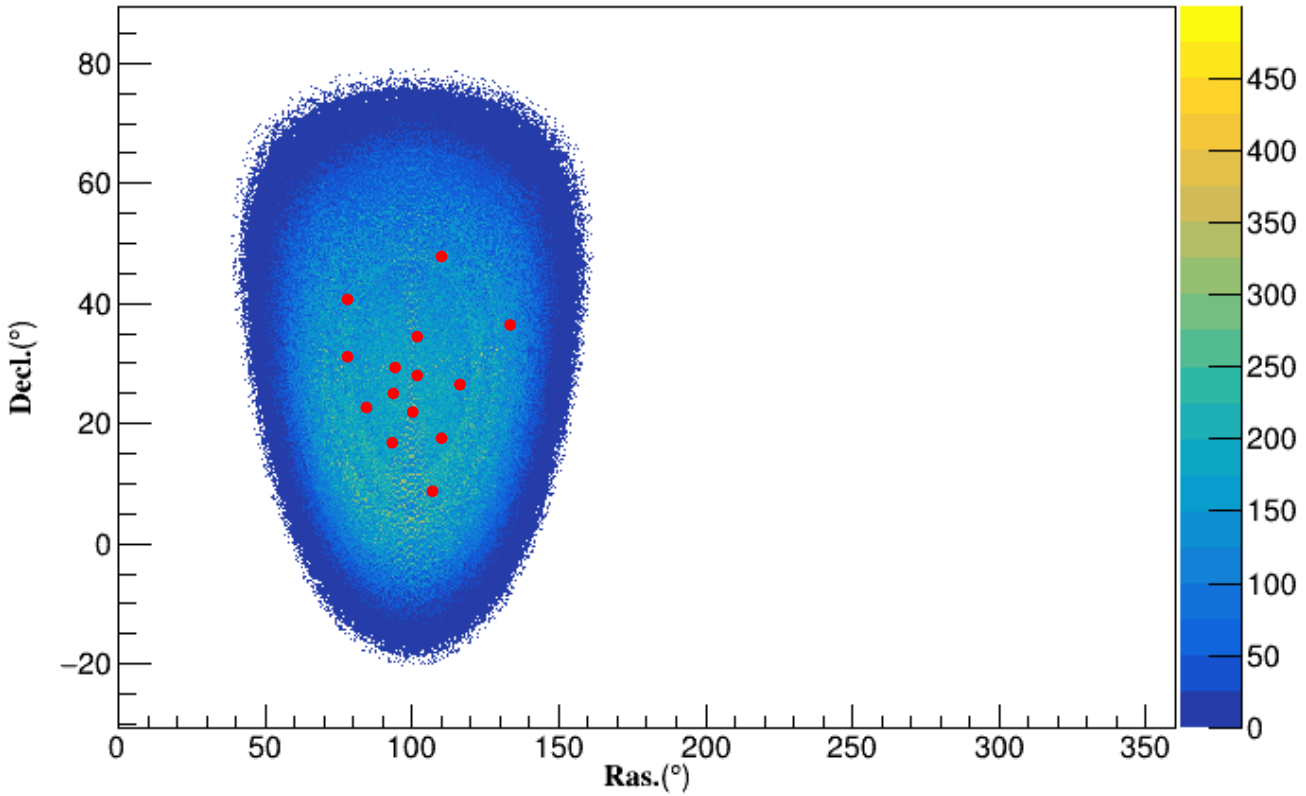
Local sidereal time(LST): Method I

MJD: Method II

1) Get distribution of CRs $f(t,\theta,\varphi)$

2) Random sampling the backgrounds
—following $f(t,\theta,\varphi)$

How many backgrounds should be sampled?
—— as many as observed in the experiment



CRs (background) distribution
$t(LST) = 100$

Sampling the Backgrounds

$$\text{Total } Events = \underbrace{\quad}_{Backgrounds} + \underbrace{\quad}_{Gamma\ photons\ from\ Sources}$$

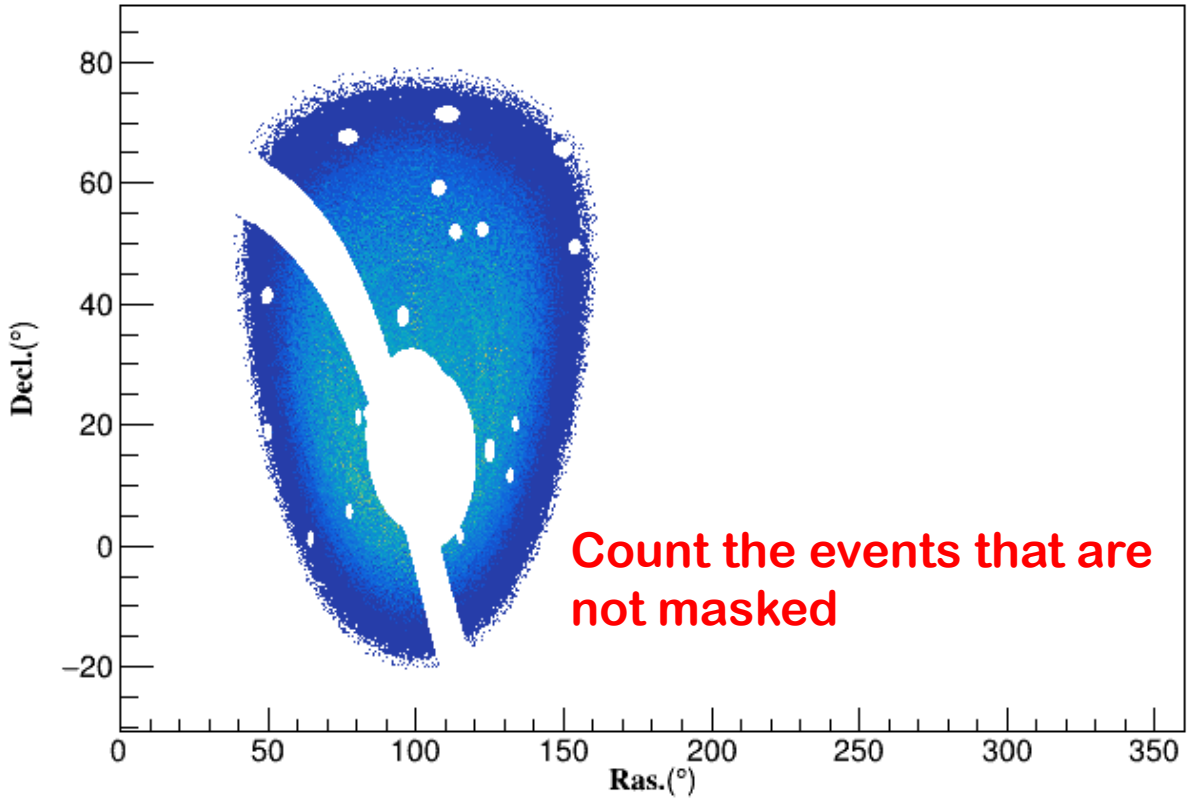
Regions "Masked":
1) **-5°<b<5°**
2) **TeV catlog sources** $(r < R)$

$$R = 3\sqrt{\sigma_{ext}^2 + \sigma_{p.s.f.}^2}$$

p.s.f.: Gaussian variance, 10TeV~15TeV

Events in Regions not masked = Backgrounds

Observed number of backgrounds (count of events not masked): $N_{observed}(\text{LST} = 100°)$



Count the events that are not masked

Map of masked regions

Events not masked
$t(LST) = 100°$

Sampling the Backgrounds

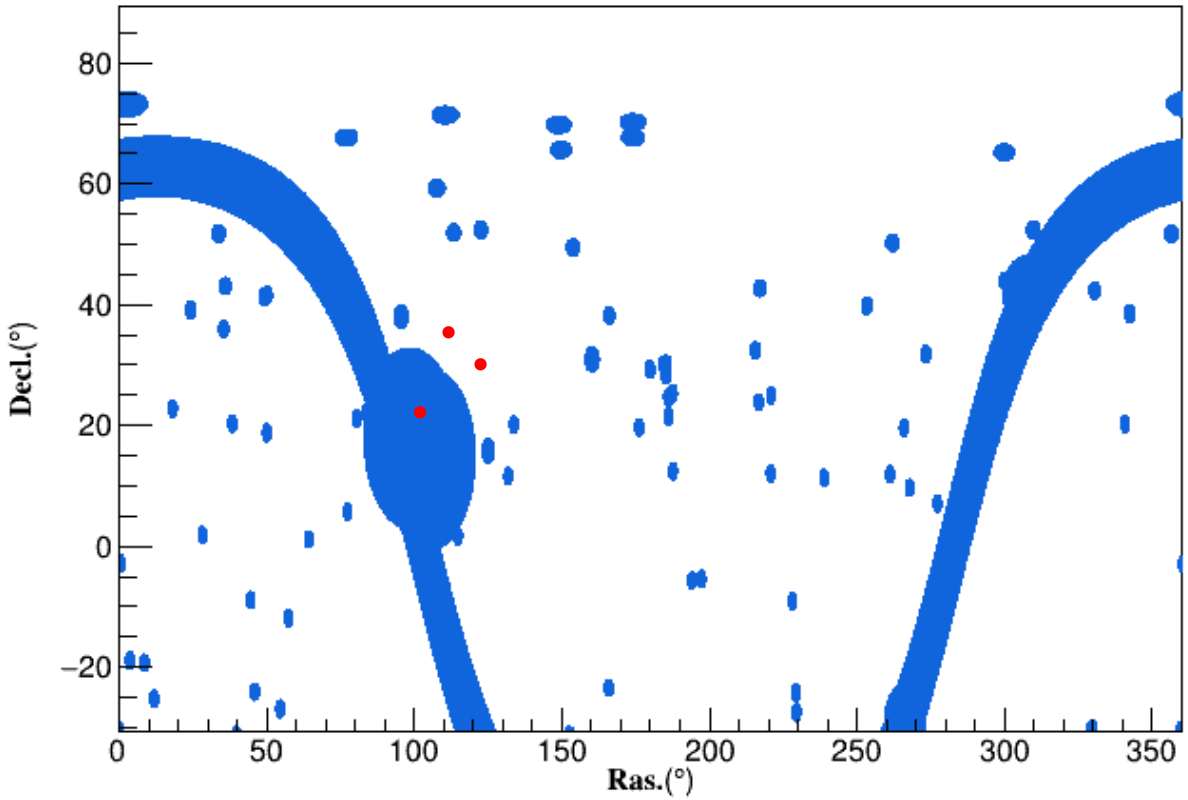
Looping when:

$$N_{sampled}(not\ masked) \neq k \cdot N_{observed}(not\ maske$$

$$k = 2;$$
$$N_{observed} = 1$$

N_{bkg}	N_{sample} $(not\ masked)$	$k \cdot N_{observed}$
3	2	2

Condition is met now

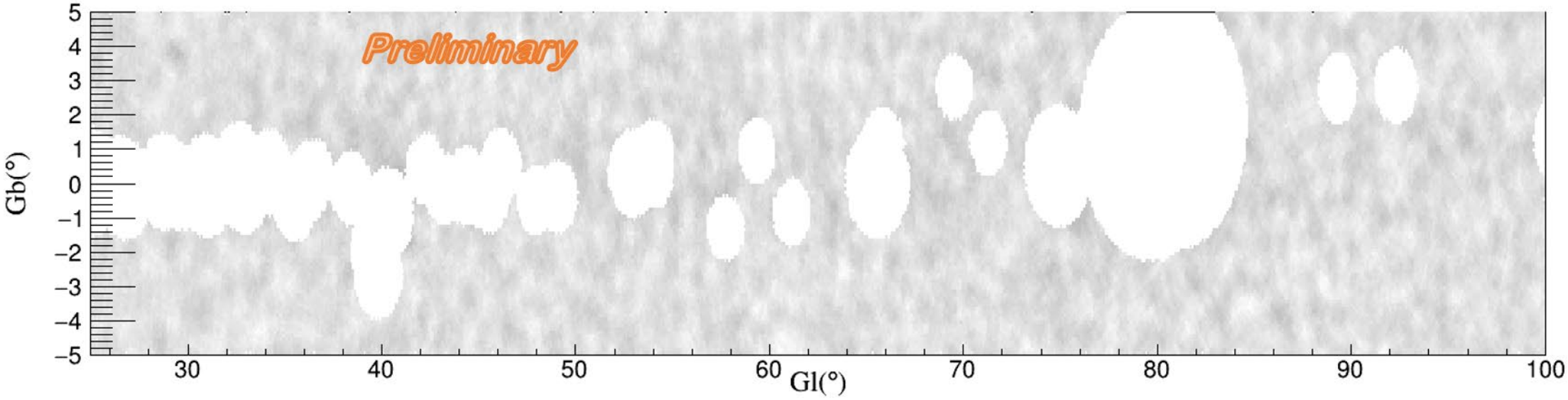


CRs (background) distribution
$t(LST) = 100$

Extraction of Resolved Sources

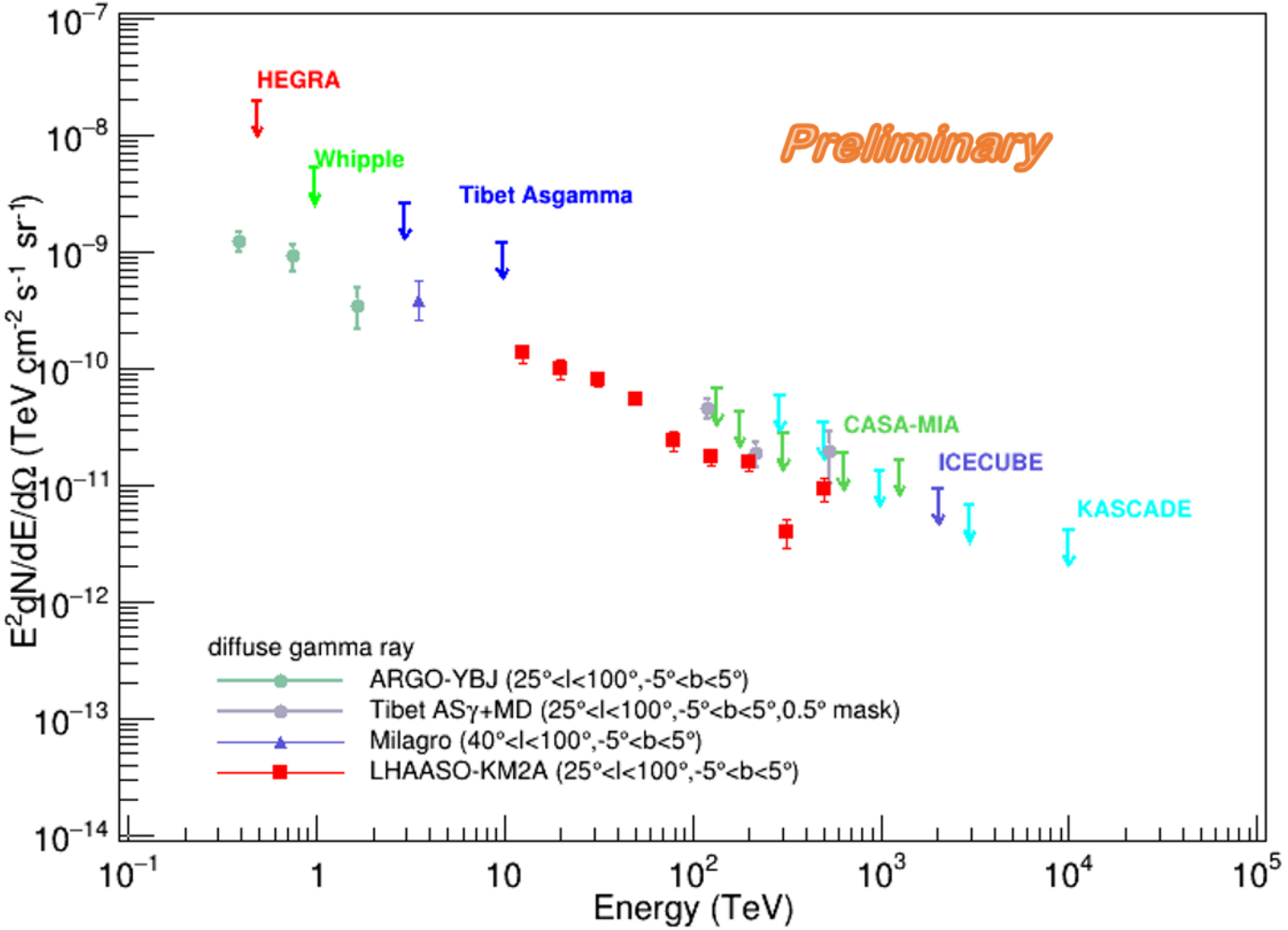
Region:
Inner Galactic Plane
(25°<l<100°)

Masked radius $\mathrm{R} < 2\sqrt{\mathrm{p.s.f}^2 + \sigma_{ext}^2}$



TeVCat: http://tevcat2.uchicago.edu/

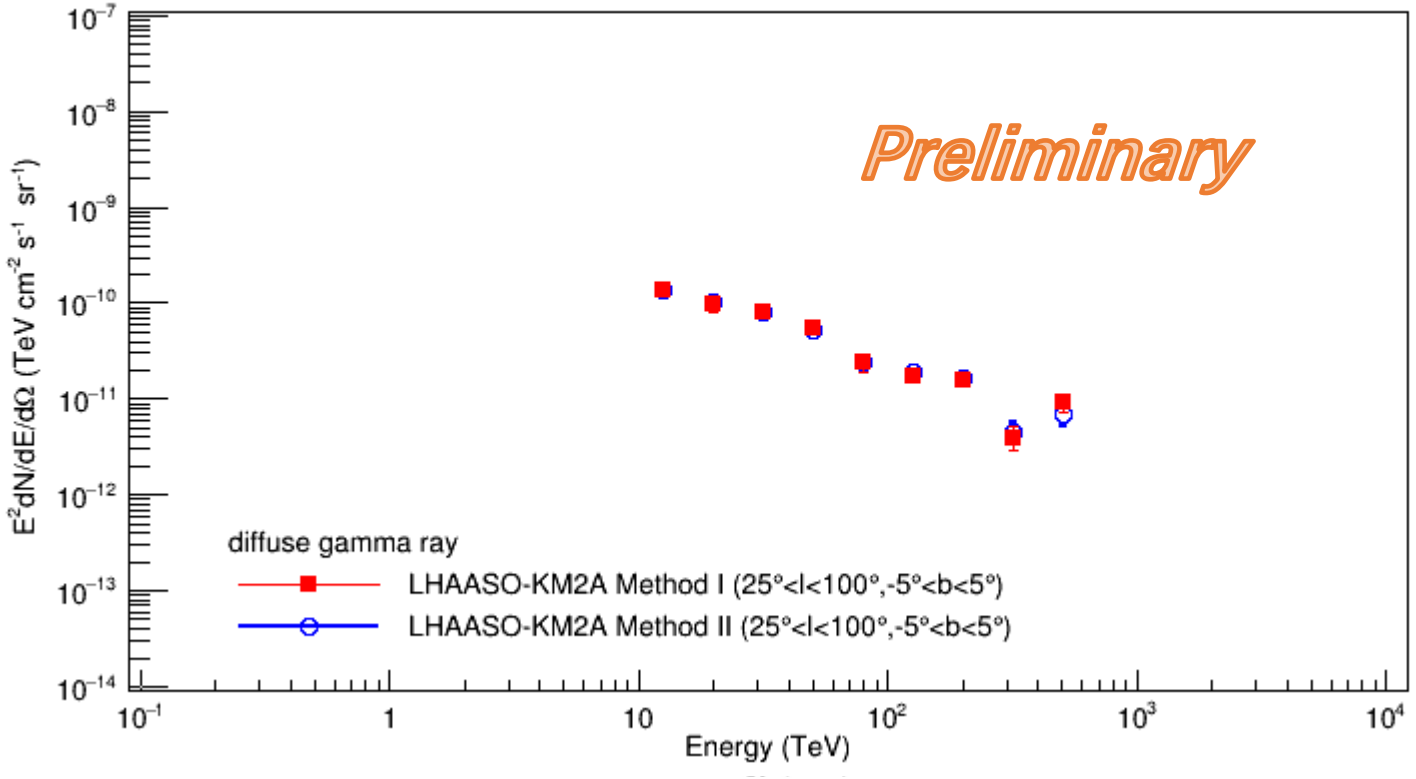
Spectra Energy Distribution
—— 25°<l<100°

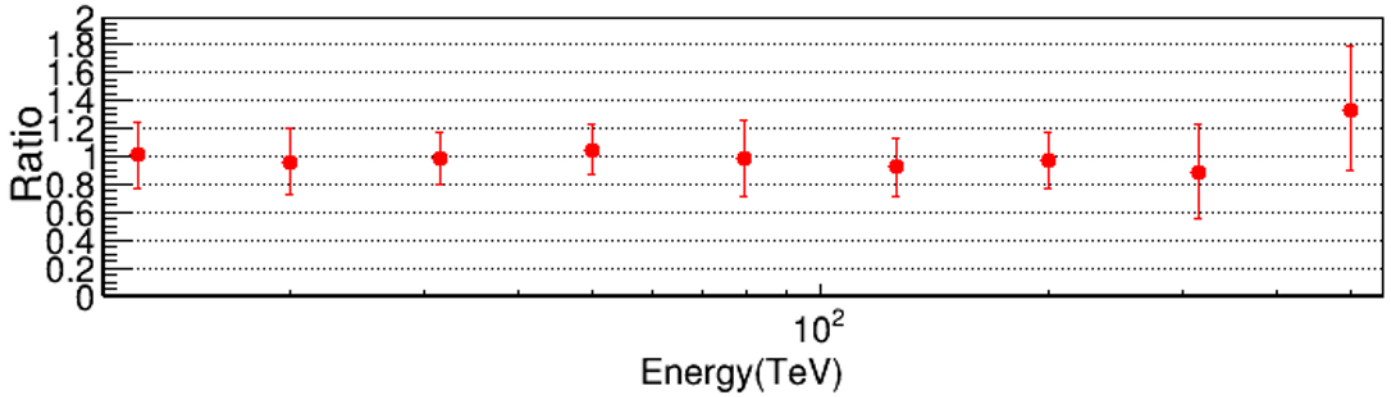


Method I v.s. II

Consistent with each other within error

$$Ratio = \frac{flux(Method\ I)}{flux(Method\ II)}$$





Conclusion

- Background estimation method has been presented
  - SEDs deduced from different methods are consistent with each other.
- The extraction of sources when estimating background and measuring the GDE
- The preliminary results of single power-law shaped SEDs are presented

Thanks...

References

- Fermi images: https://fermi.gsfc.nasa.gov (images on page 3 and page 4)

- Tijana Prodanović, Brian D. Fields, John F. Beacom, Diffuse gamma rays from the Galactic Plane: Probing the “GeV excess” and identifying the “TeV excess”, Astroparticle Physics, Volume 27, Issue 1, 2007, Pages 10-20 (image on page 5, left)

- M. Amenomori, Y. W. Bao, X. J. Bi et al, on behalf of Asγ Collaboration, First Detection of Sub-PeV Diffuse Gamma Rays from the Galactic Disk: Evidence for Ubiquitous Galactic Cosmic Rays beyond PeV Energies, 2020 (image on page 5, right)

- Z. Cao. “Status of LHAASO updates from ARGO-YBJ”. Nuclear Instruments and Methods in Physics Research A, vol. 742, (2014) pp. 95–98. (image on page 6, left)