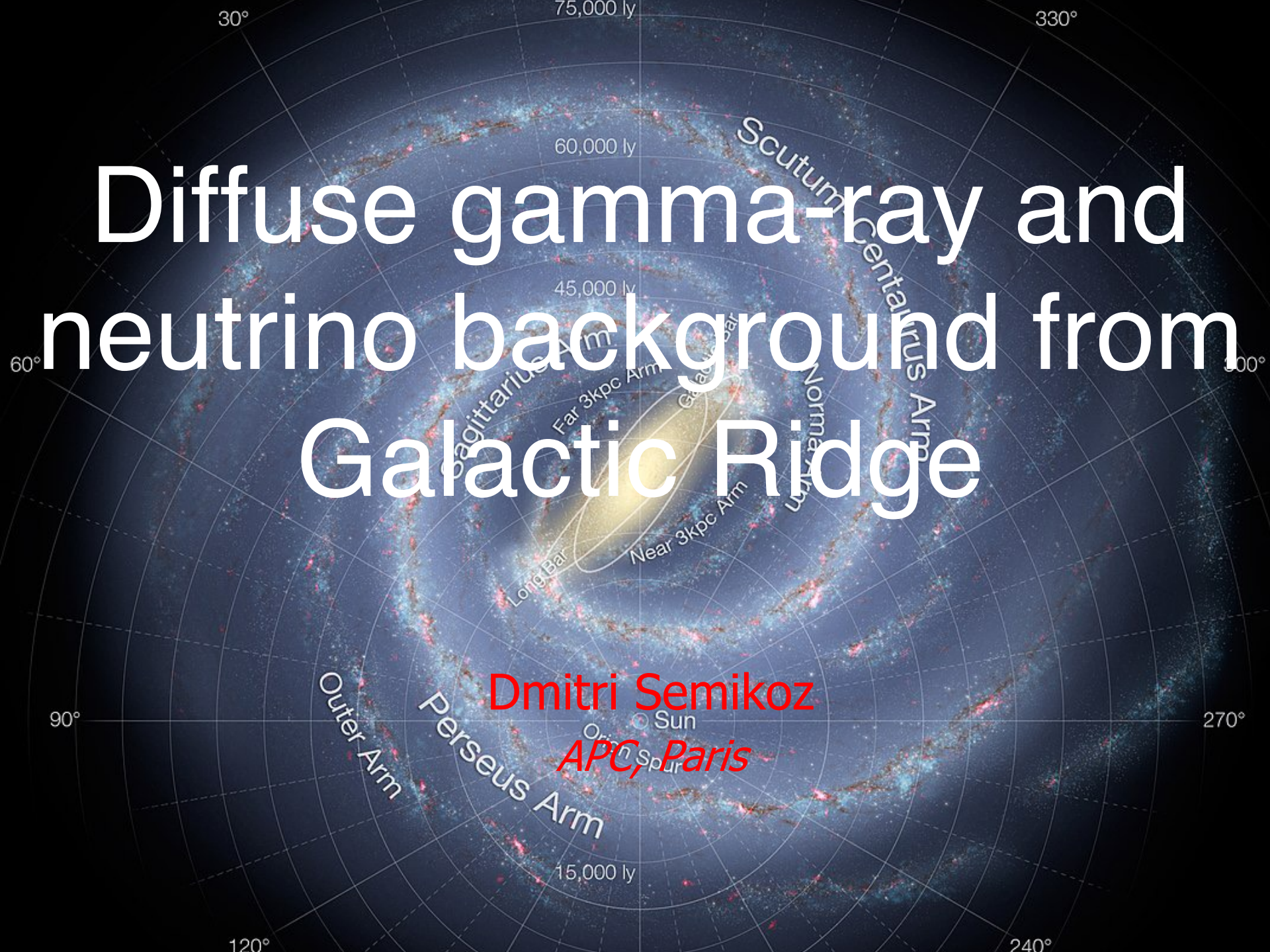


Diffuse gamma-ray and neutrino background from Galactic Ridge

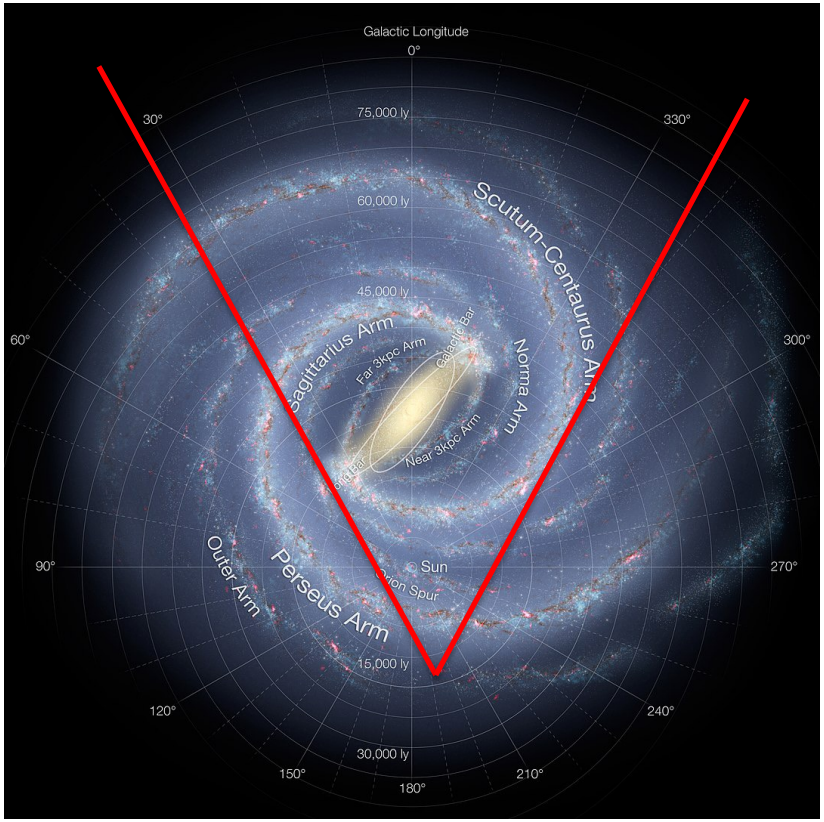
Dmitri Semikoz
APC, Paris

Plan

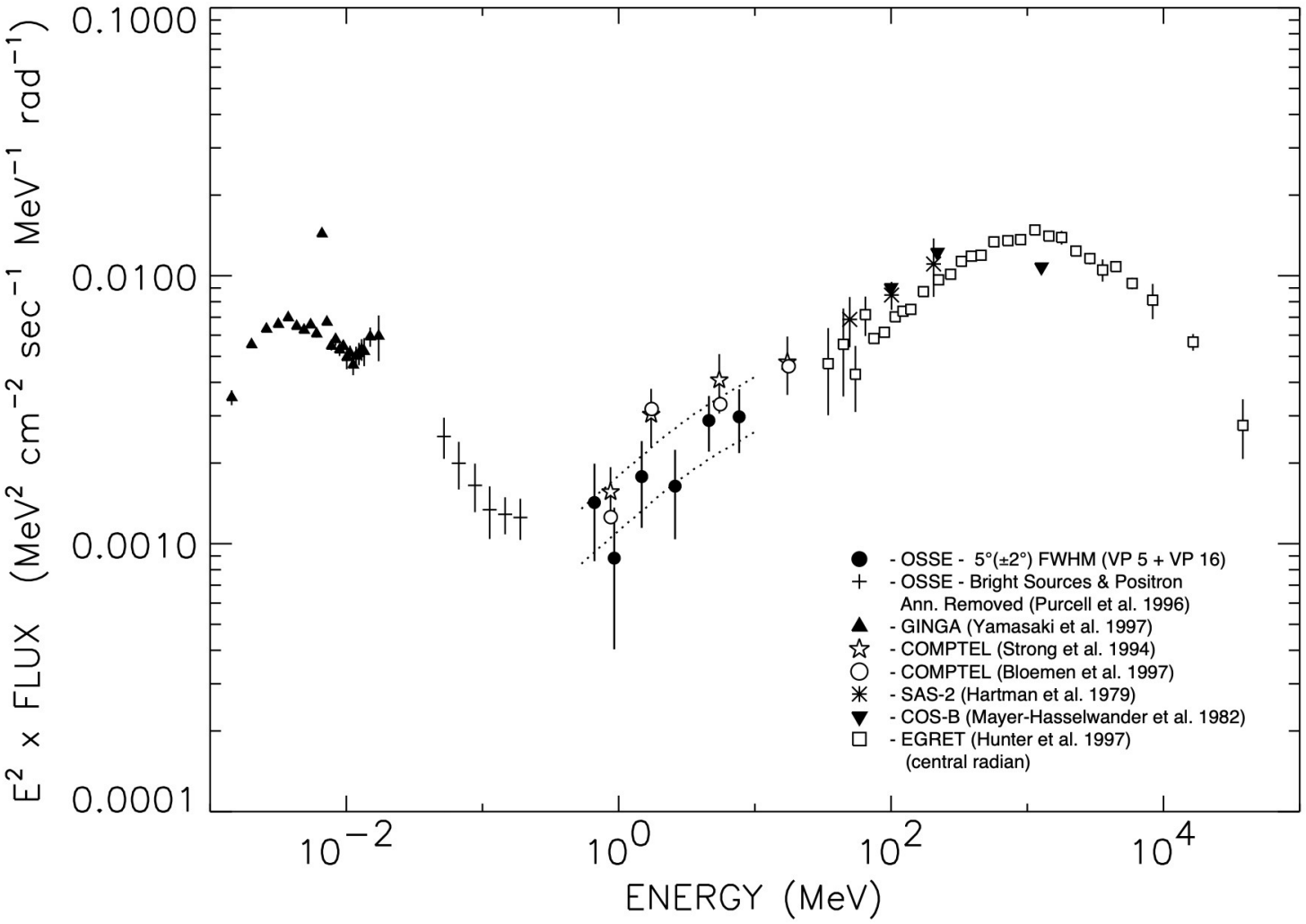
- Galactic Ridge: expectations for multi-messenger signal
- HESS and Fermi LAT spectrum of Ridge
- Neutrinos from Galactic Ridge in ANTARES and IceCube
- Perspectives: LHAASO, CTA and future neutrino observatories
- Conclusions

Galactic Ridge

Milky Way Galaxy: Ridge



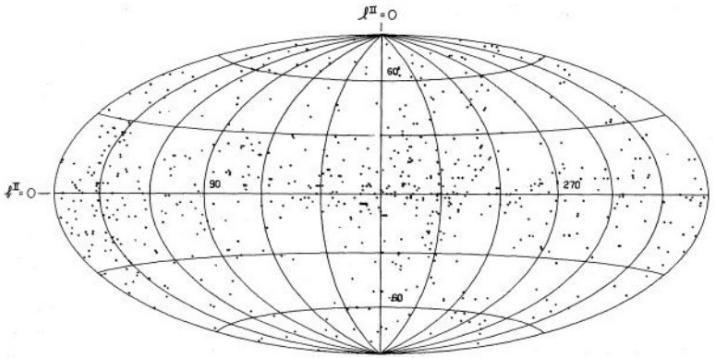
MW ridge: EGRET+X-rays



R.Kinzer et al, THE ASTROPHYSICAL JOURNAL, vol 515, 215, 1999

Diffuse γ-ray observations from space

OSO-3: 621 gamma-rays



COS-B

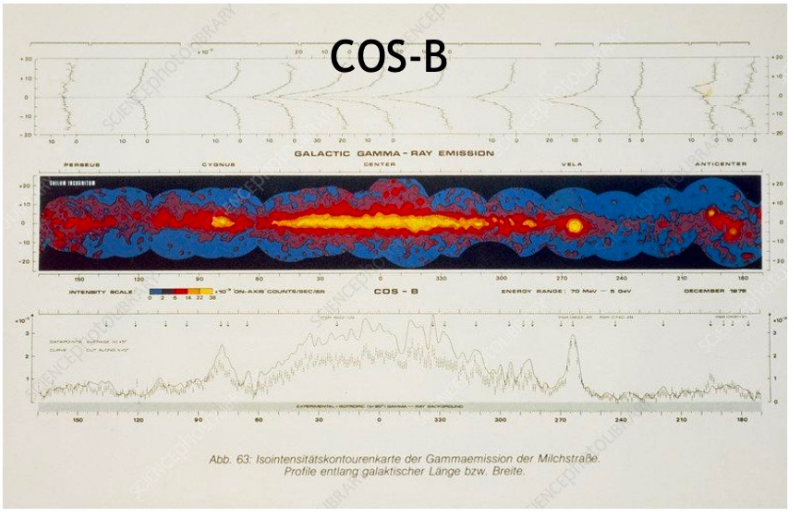
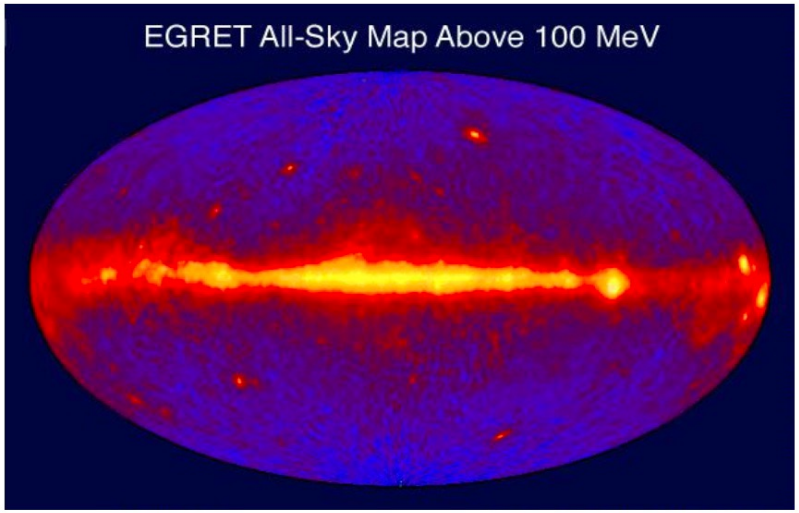
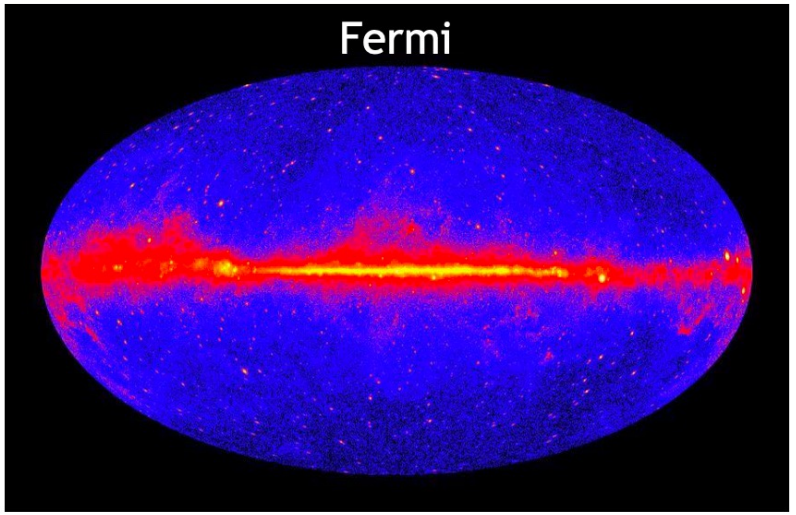


Abb. 63: Isointensitätskontourenkarte der Gammaemission der Milchstraße. Profile entlang galaktischer Länge bzw. Breite.



Fermi



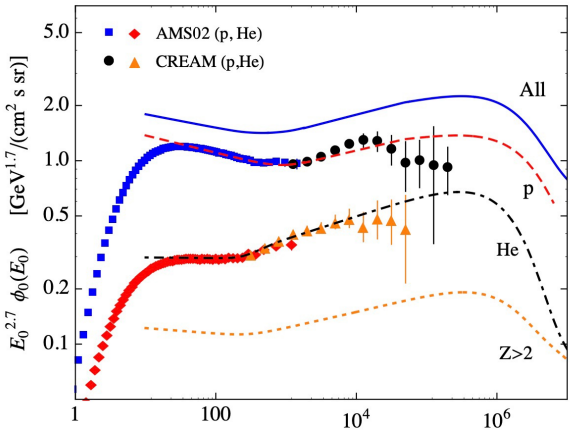
Diffuse gamma-ray and neutrino fluxes

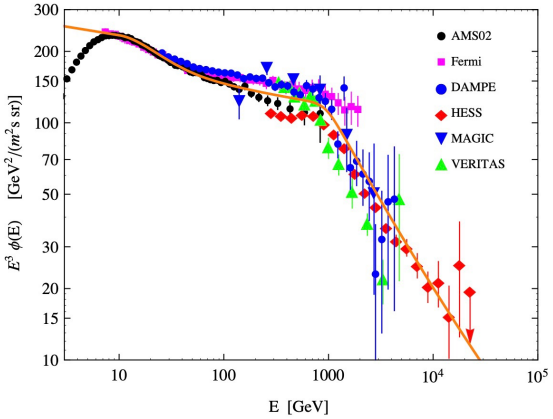
$$\Xi^{A,A'}(E,l,b) = \int_0^\infty \mathrm{d}s\, n^{A'}_{\mathrm{gas}}(\boldsymbol{x}) I^{A}_{\mathrm{CR}}(E,\boldsymbol{x})$$

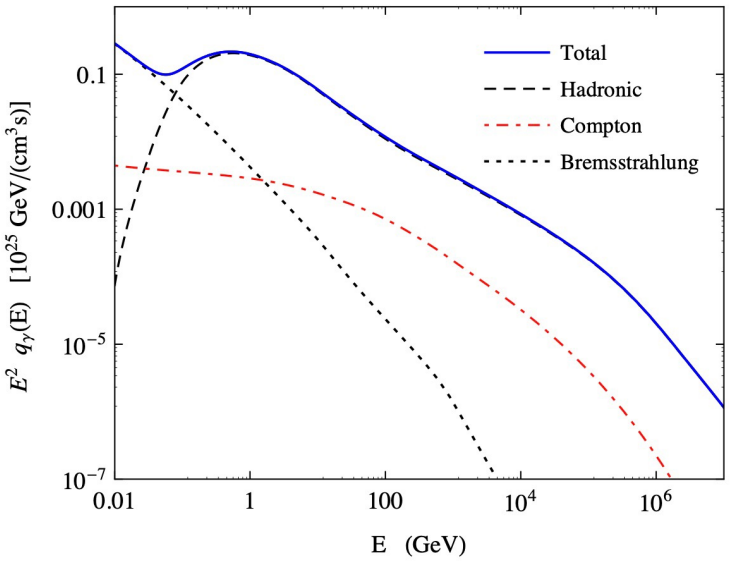
$$I_\nu(E,l,b) = \sum_{A,A'} \int_E^\infty \mathrm{d}E'\, \Xi^{A,A'}(E',l,b) \frac{\mathrm{d}\sigma^{AA'\to\nu}(E',E)}{\mathrm{d}E}$$

In case of multi-TeV energy and Milky Way galaxy
both gas and CR as space-dependent

Cosmic ray interaction

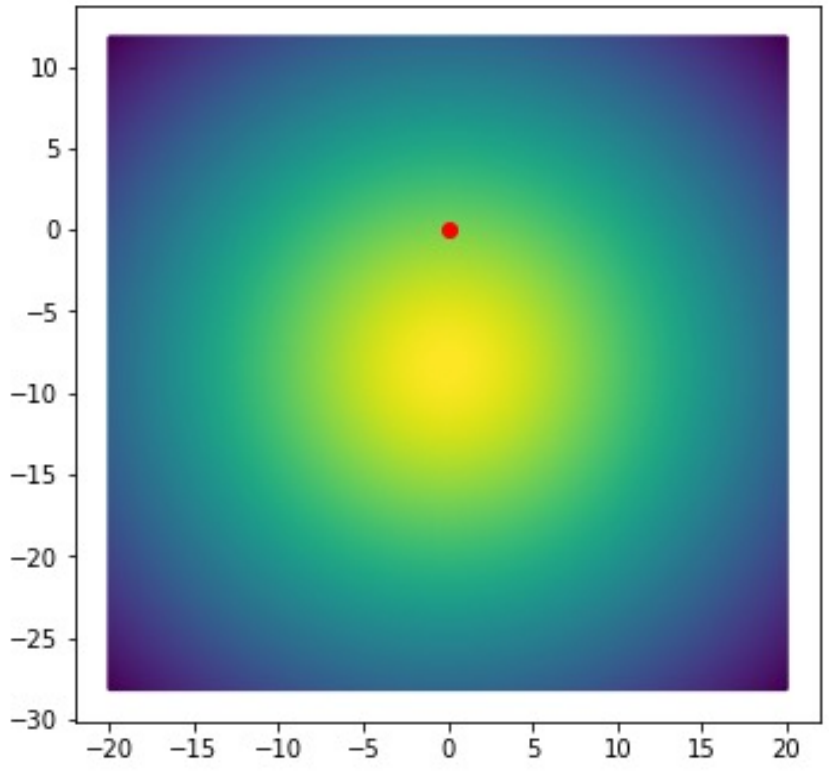






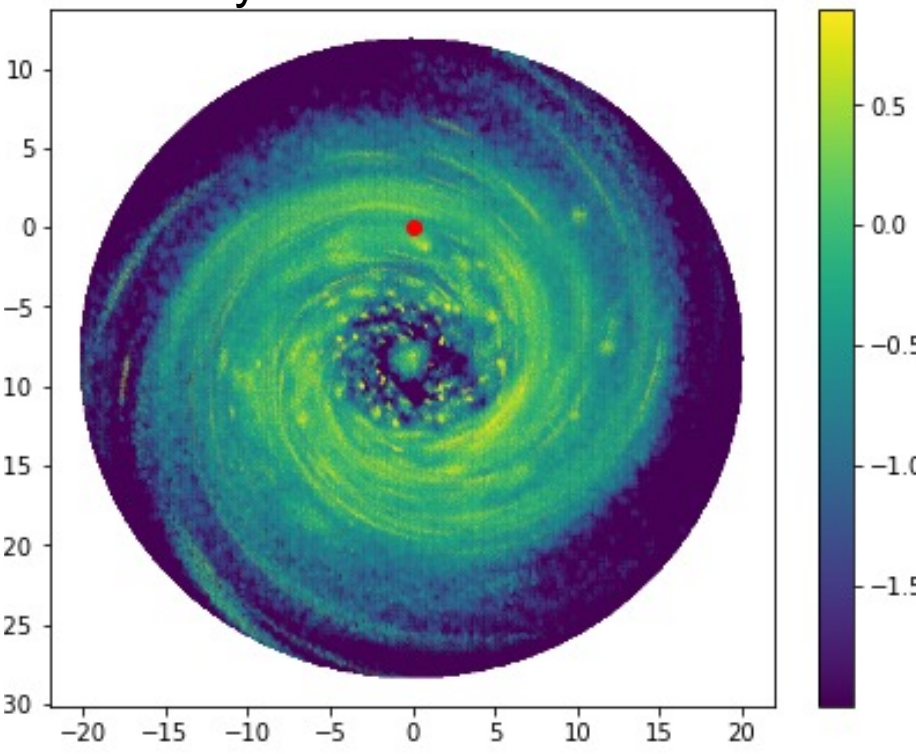
Lipari & Vernetto (2018)

1 PeV CR density in the Gal. plane



Lipari & Vernetto (2018)

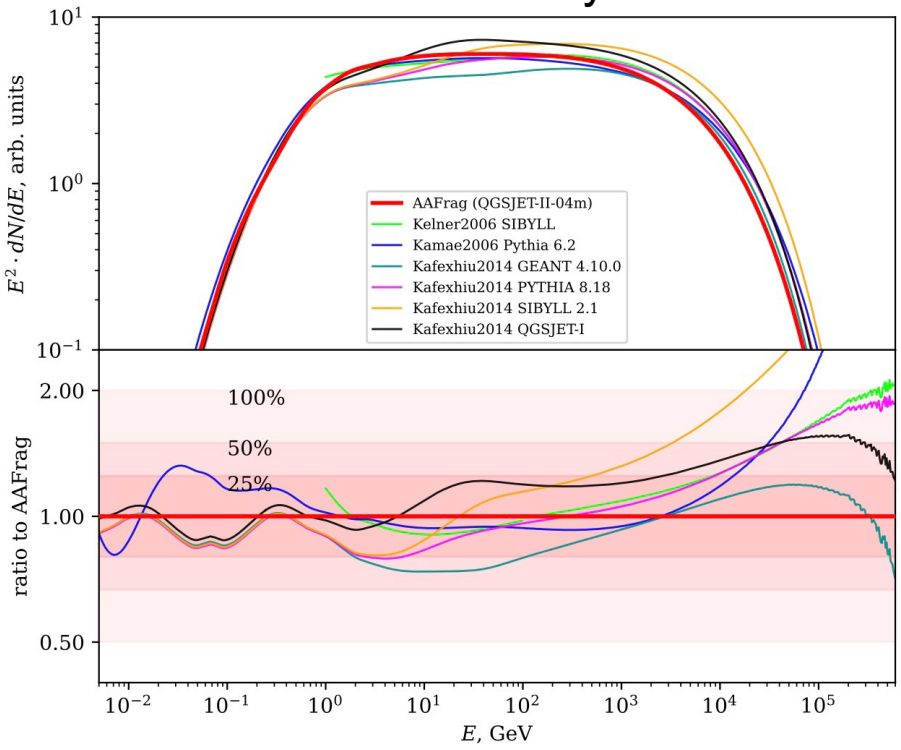
Poster by G.Giacinti PCRI1-28



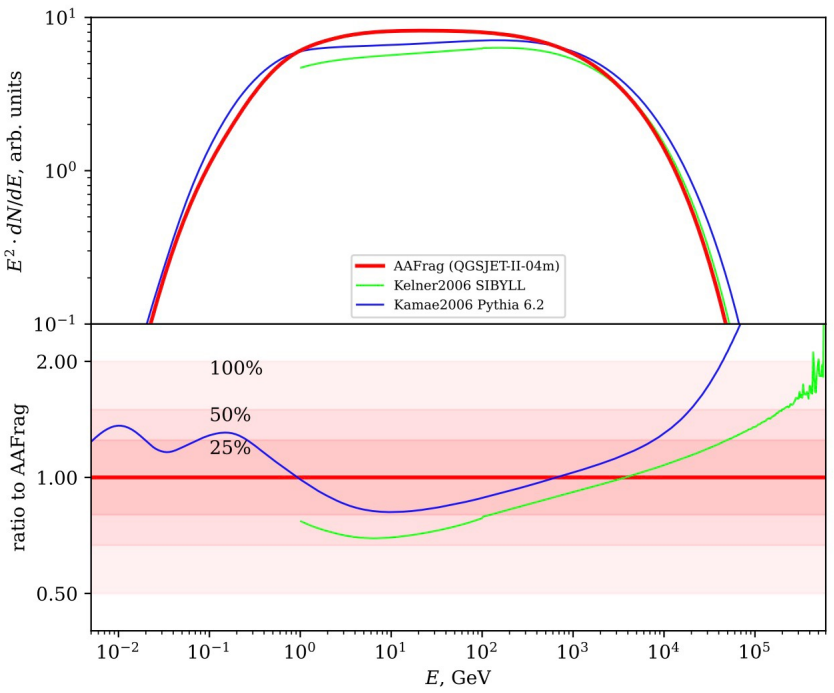
G.Giacinti & D.S., 2305.10251

Secondary gamma-rays and neutrinos from AAfrag QGSJetII-4m

Gamma-rays

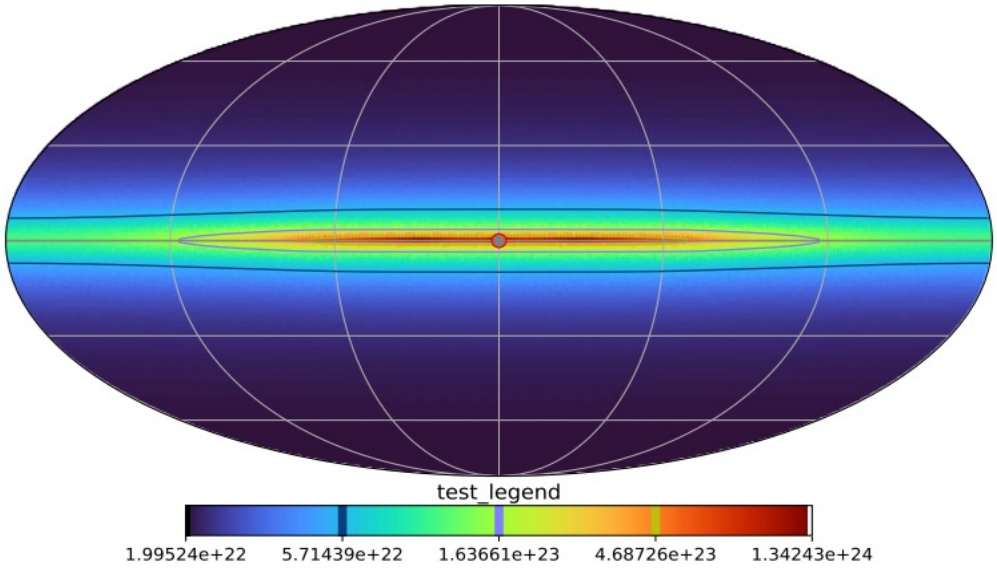


neutrinos



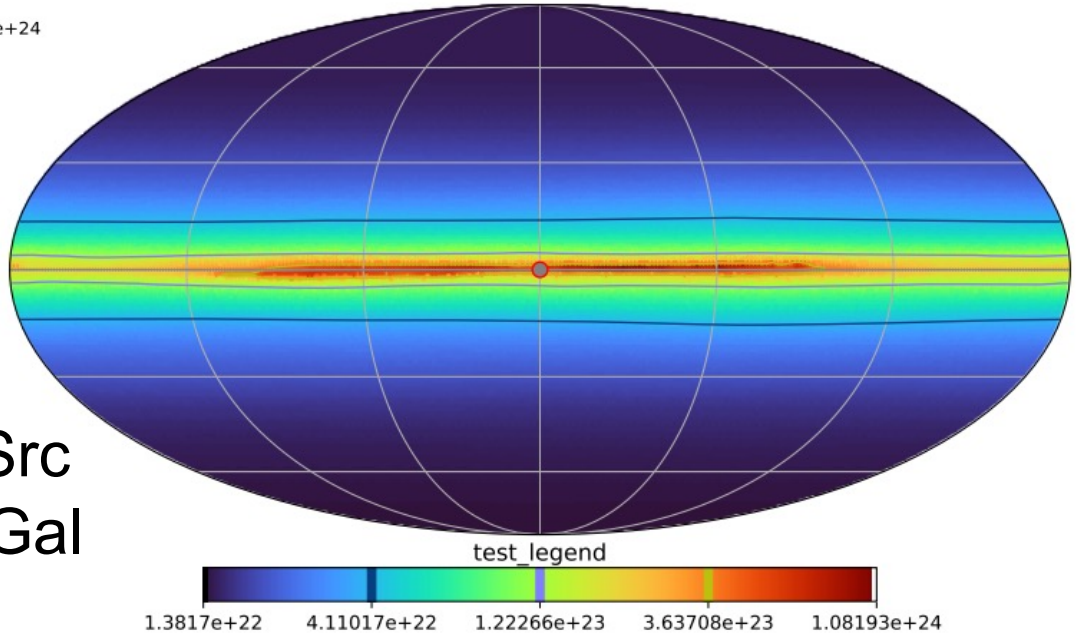
S.Koldobskiy et al, *Phys.Rev.D* 104 (2021) 12, 123027, arXiv 2110.00496

Diffuse 100 TeV γ-ray emission



Lipari & Vernetto (2018)

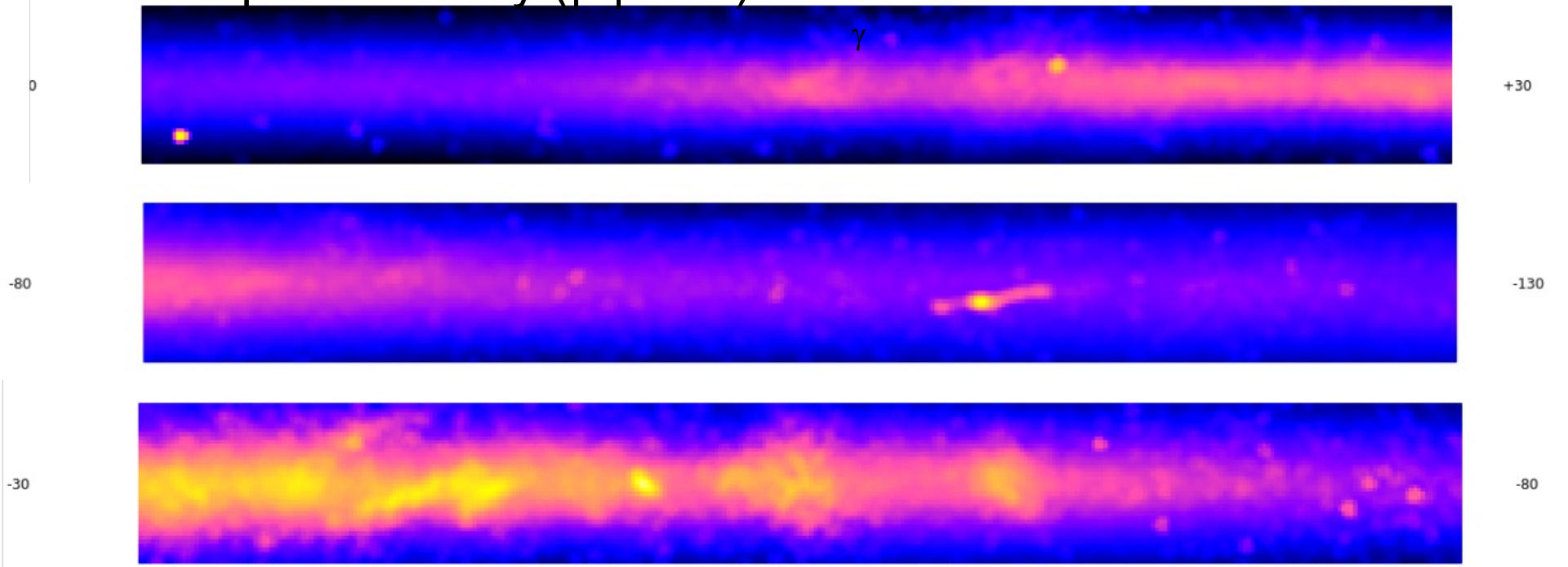
Giacinti,Kachelriess, Koldobskiy, Neronov D.S., In prep. (2023)



→ More patchy + Extended Src
→ Less contrast inner/outer Gal
→ Broader in some places.

Zoom on our simulated Gal. plane

Galactic plane survey ($|b| < 3^{o}$) at E_{γ} = 100 TeV in the simulation:

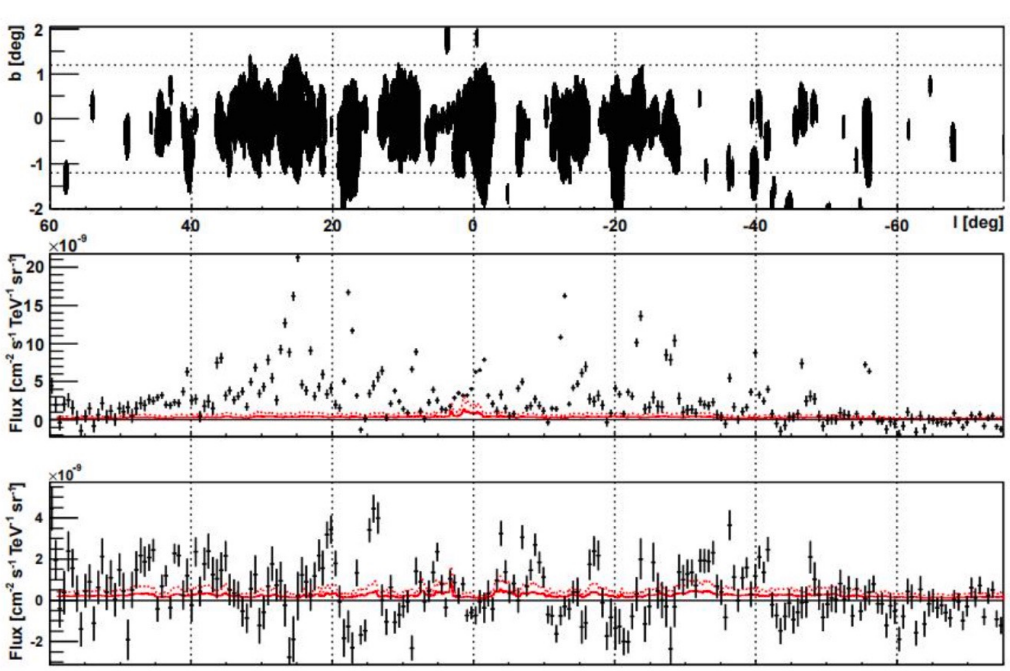


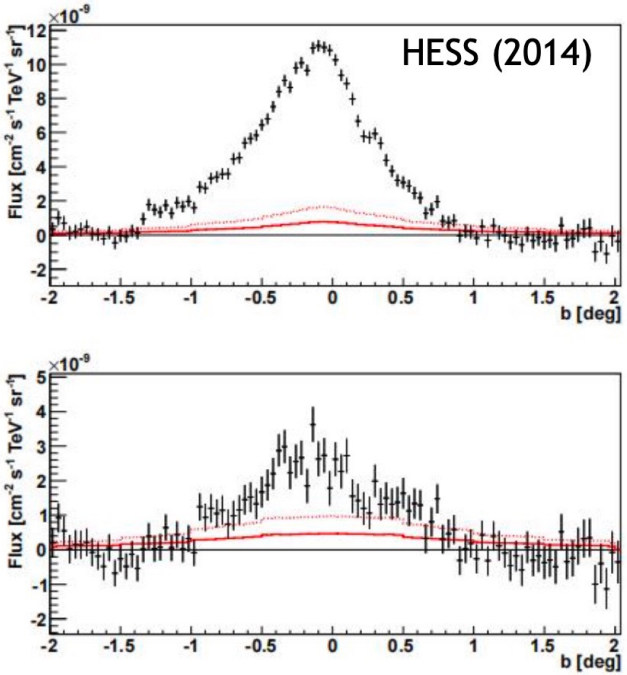
G.Giacinti, M.Kachelriess, S.Koldobskiy, A.Neronov, D. Semikoz, In prep.

Fermi LAT and HESS flux from MW Ridge at 1TeV

Galactic Plane Survey

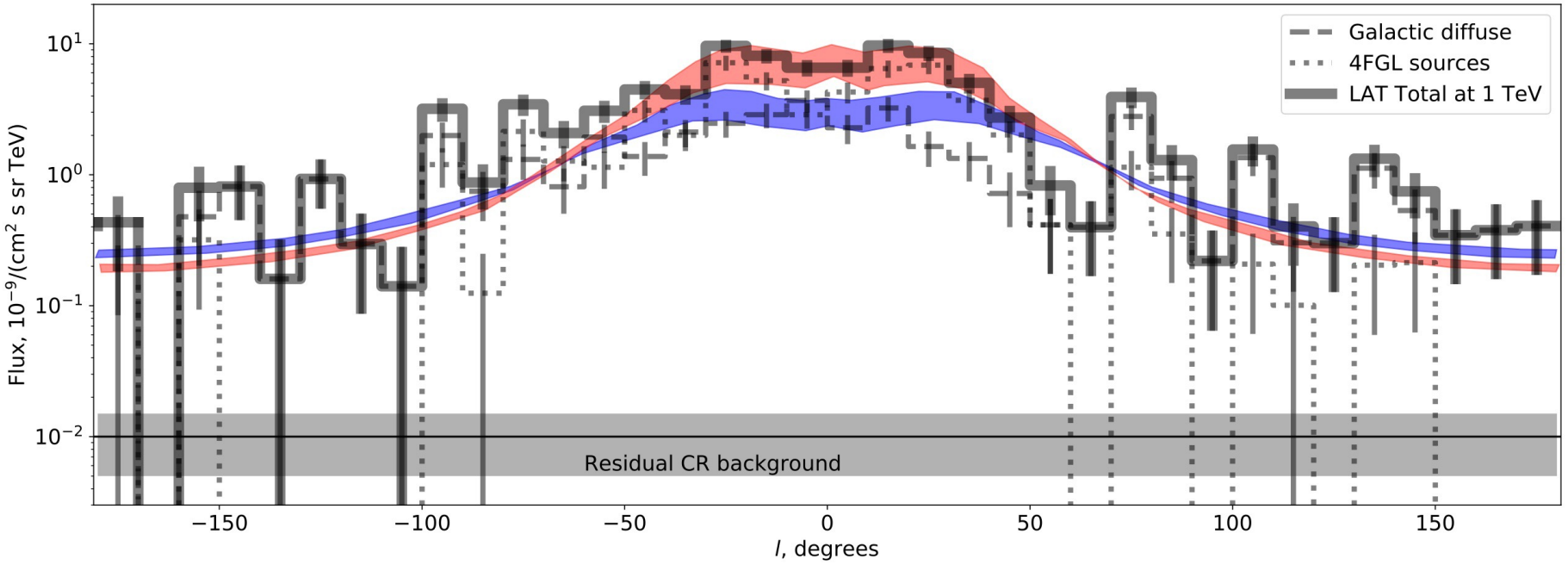
VHE diffuse emission by HESS





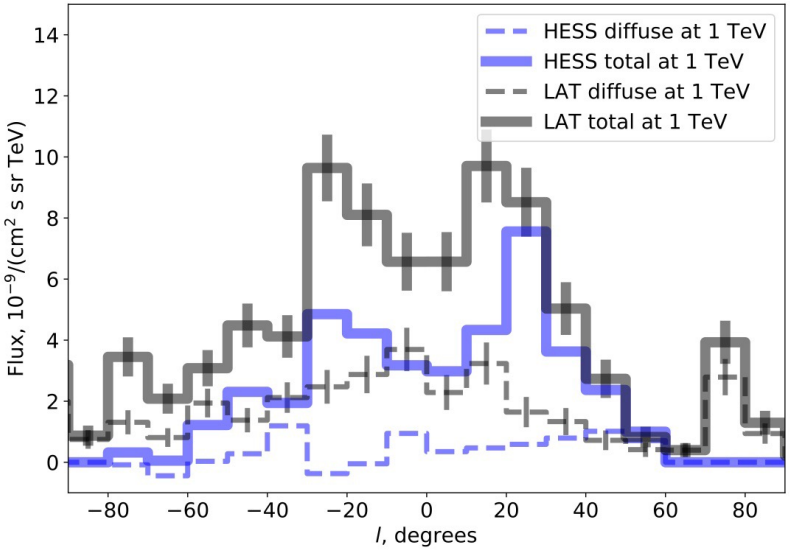
ray flux measurements were made over an extensive grid of celestial locations. Longitudinal and latitudinal profiles of the observed γ-ray fluxes show characteristic excess emission not attributable to known γ-ray sources. For the first time large-scale γ-ray emission along the

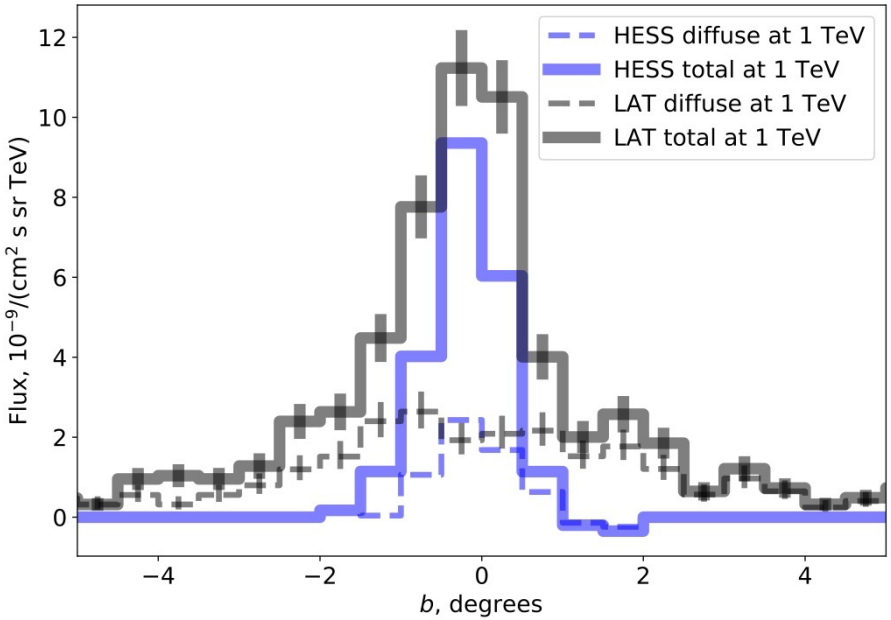
Fermi LAT galactic plane 1TeV



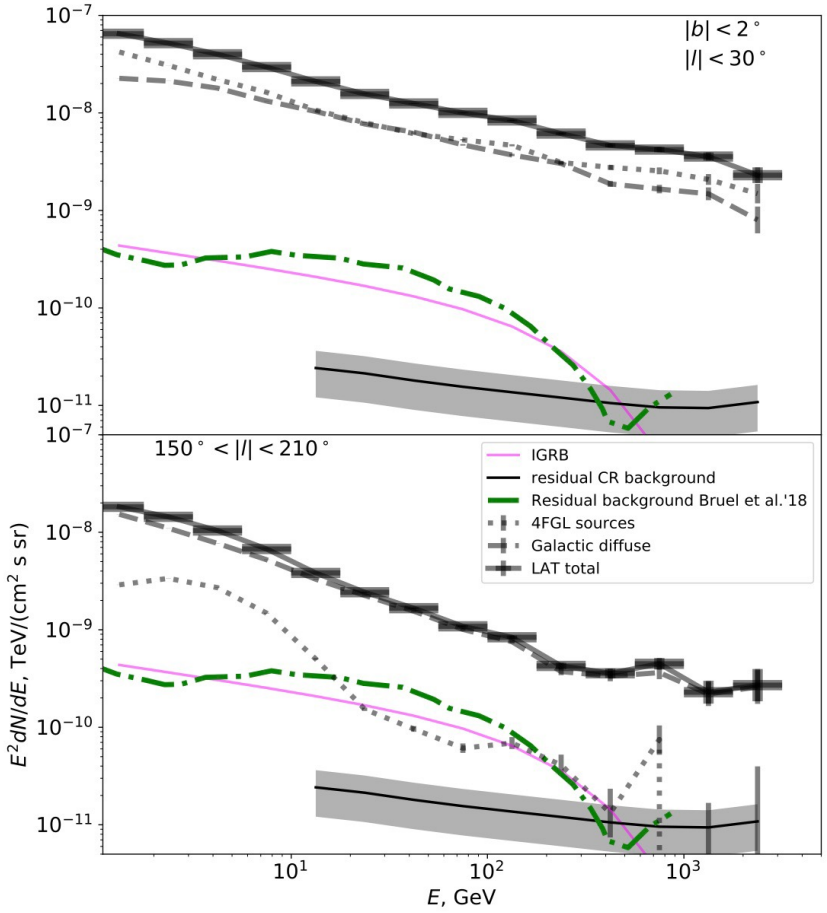
A,.Neronov and D.Semikoz, Astron.Astrophys. 633 (2020) A94, arXiv:1907.06061

HESS vs Fermi LAT galactic plane 1TeV





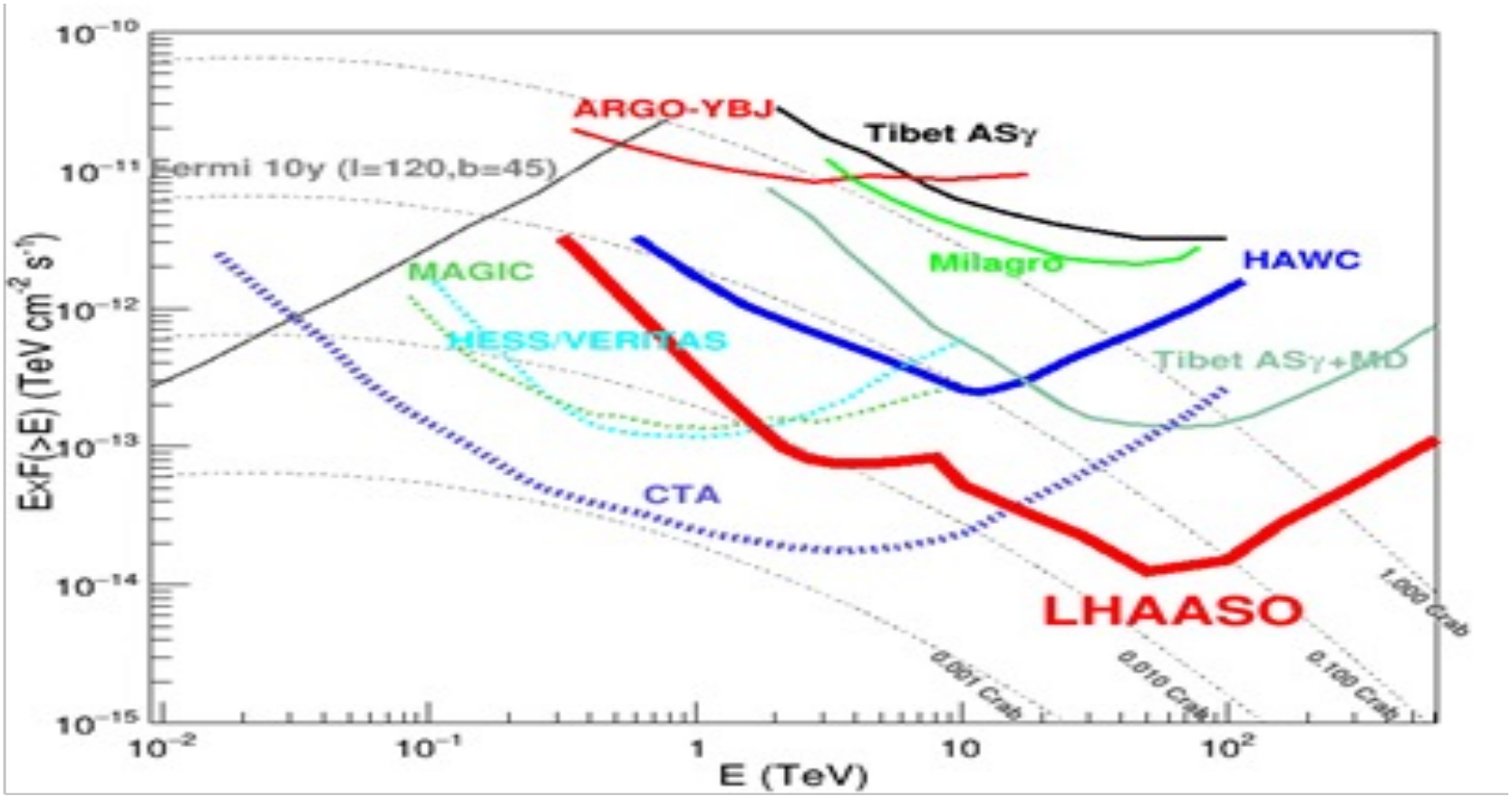
A,.Neronov and D.Semikoz, Astron.Astrophys. 633 (2020) A94, arXiv:1907.06061



A,.Neronov and D.Semikoz, Astron.Astrophys. 633 (2020) A94, arXiv:1907.06061

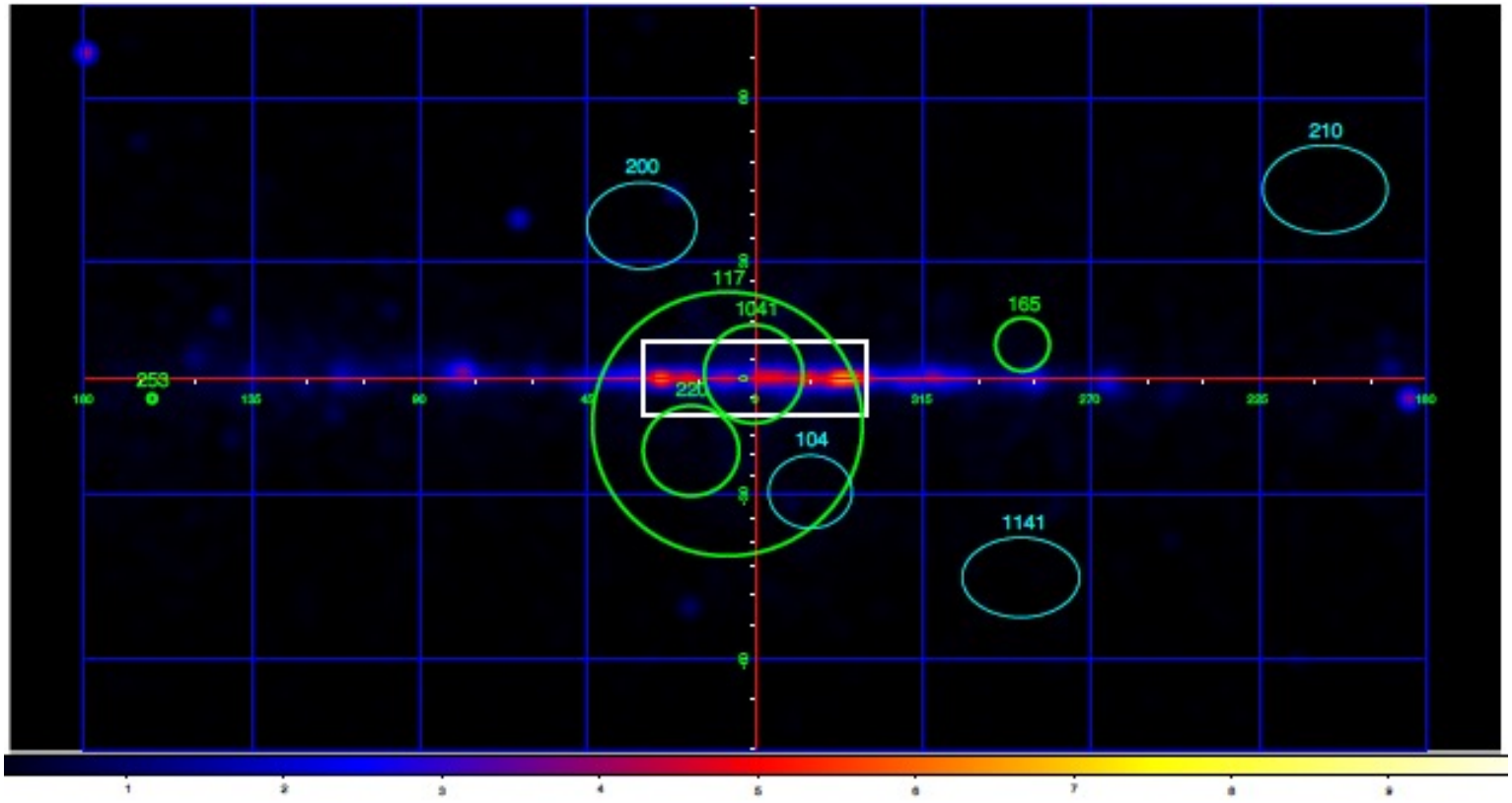
CTA and LHAASO sensitivity

E<10 TeV CTA , E>10 TeV LHAASO



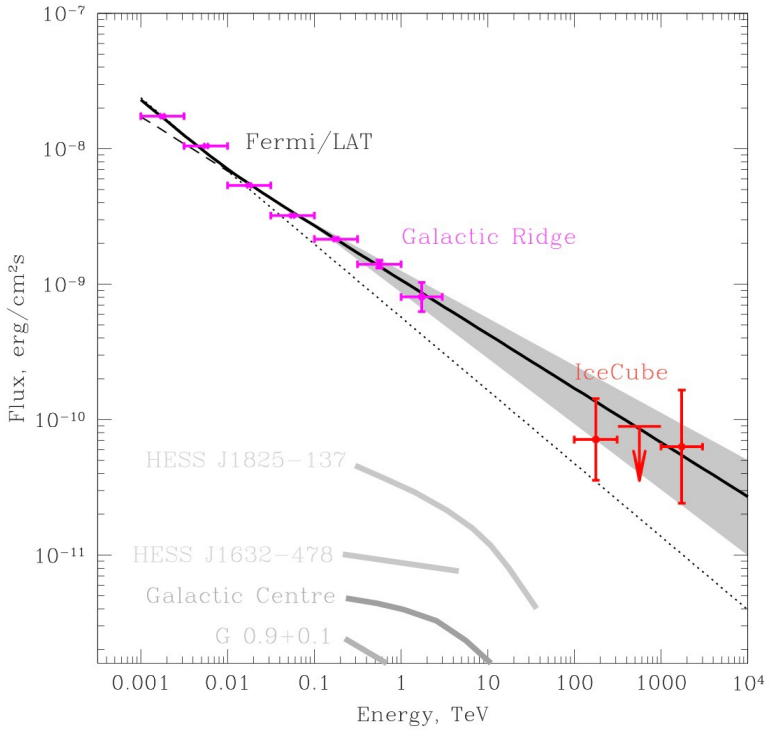
Neutrino flux from Ridge in ANTARES and IceCube

First 3 years: half of ICECUBE events E>100 TeV are in Galactic plane. Are they correlate with gamma-rays?



A.Neronov, D.S. and C.Tchernin, arXiv:1307.2158

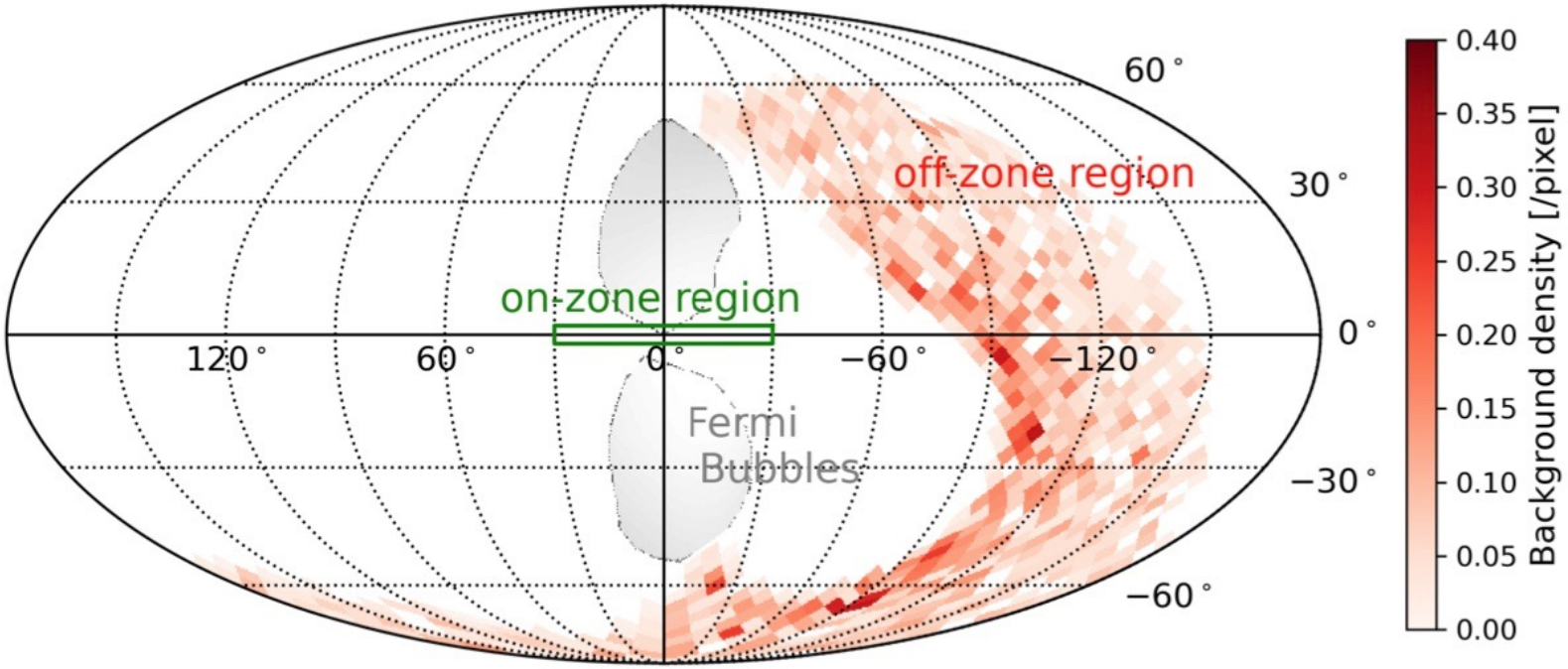
Fermi LAT and IceCube flux from galactic ridge



Gamma=2.4

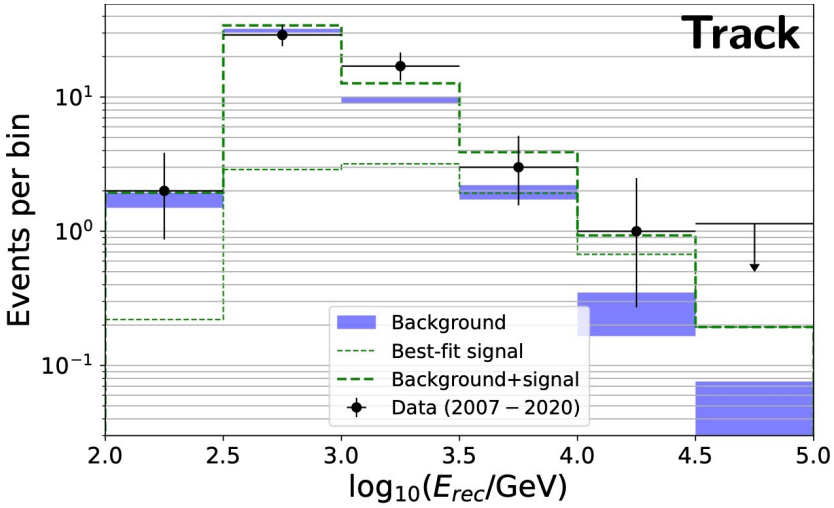
A.Neronov, D.S. and C.Tchernin, arXiv:1307.2158

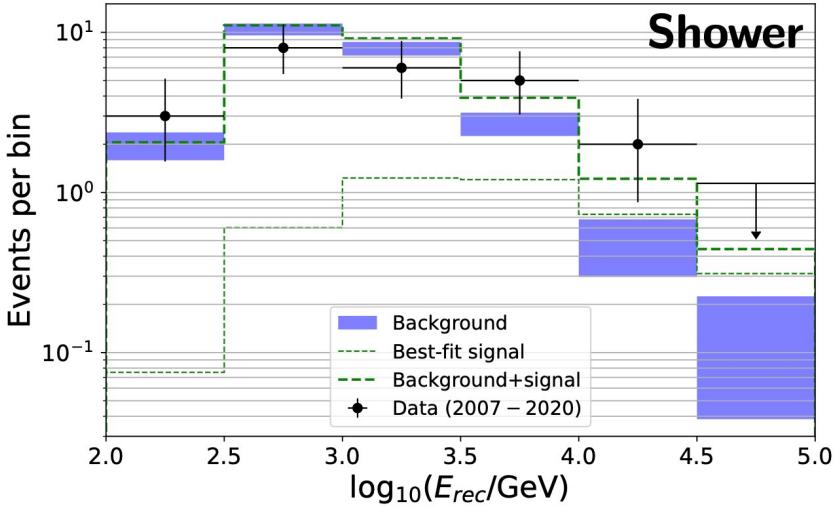
ANTARES 2022



A.Albert et al, arXiv:2212.11876

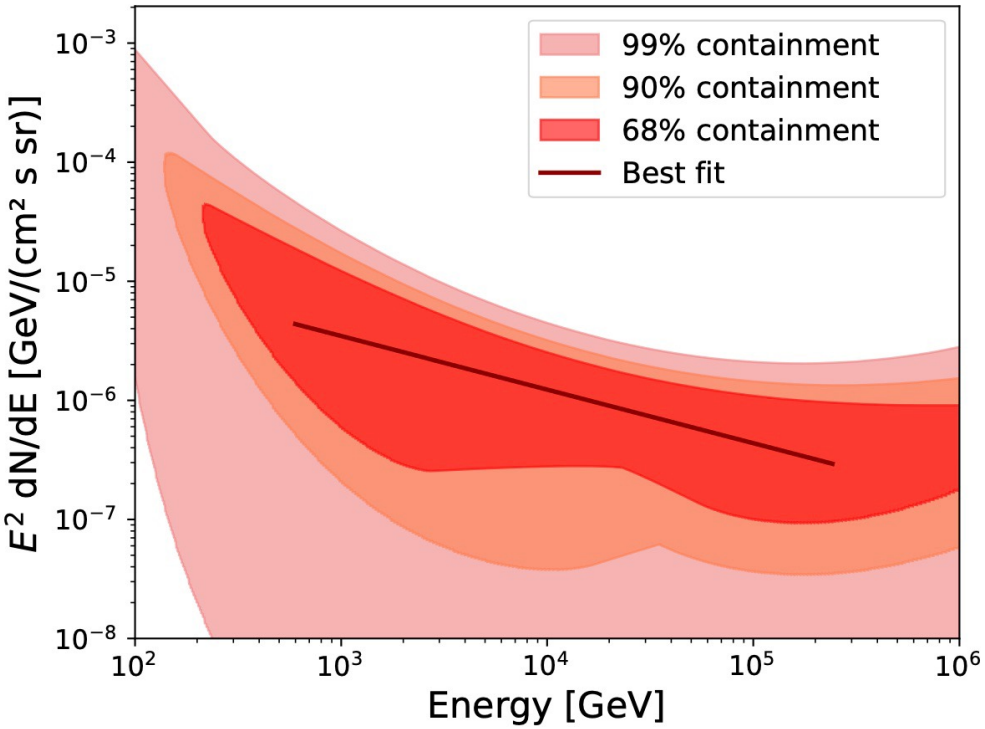
ANTARES 2022





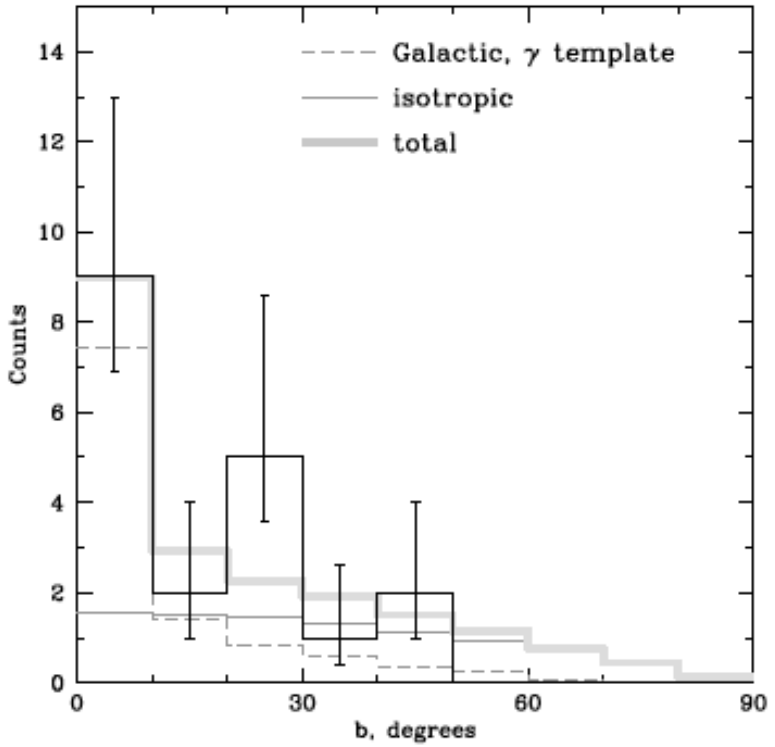
A.Albert et al, arXiv:2212.11876

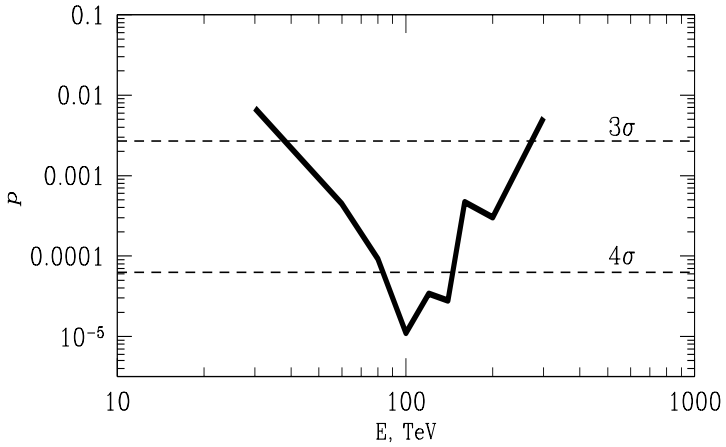
ANTARES 2022



A.Albert et al, arXiv:2212.11876

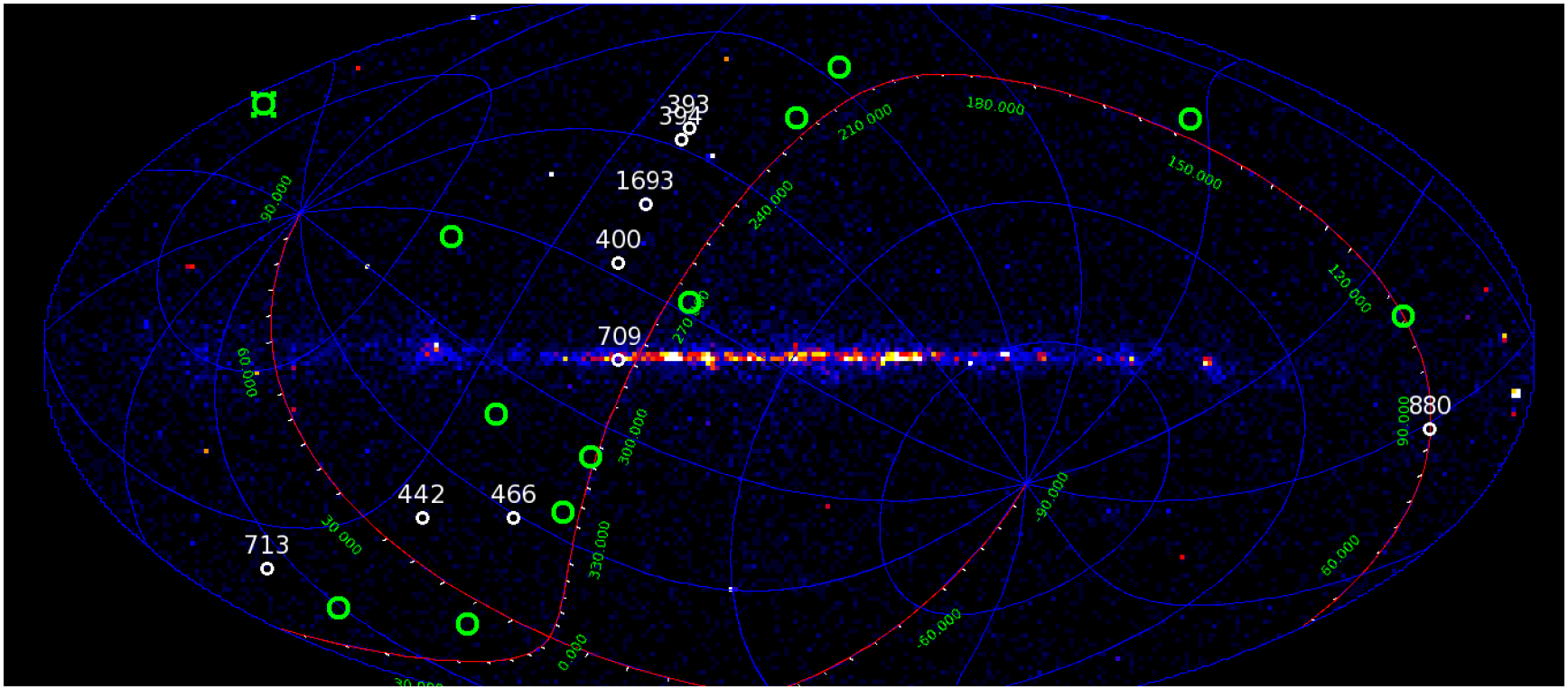
Evidence of Galactic component in 4 year IceCube data E>100 TeV





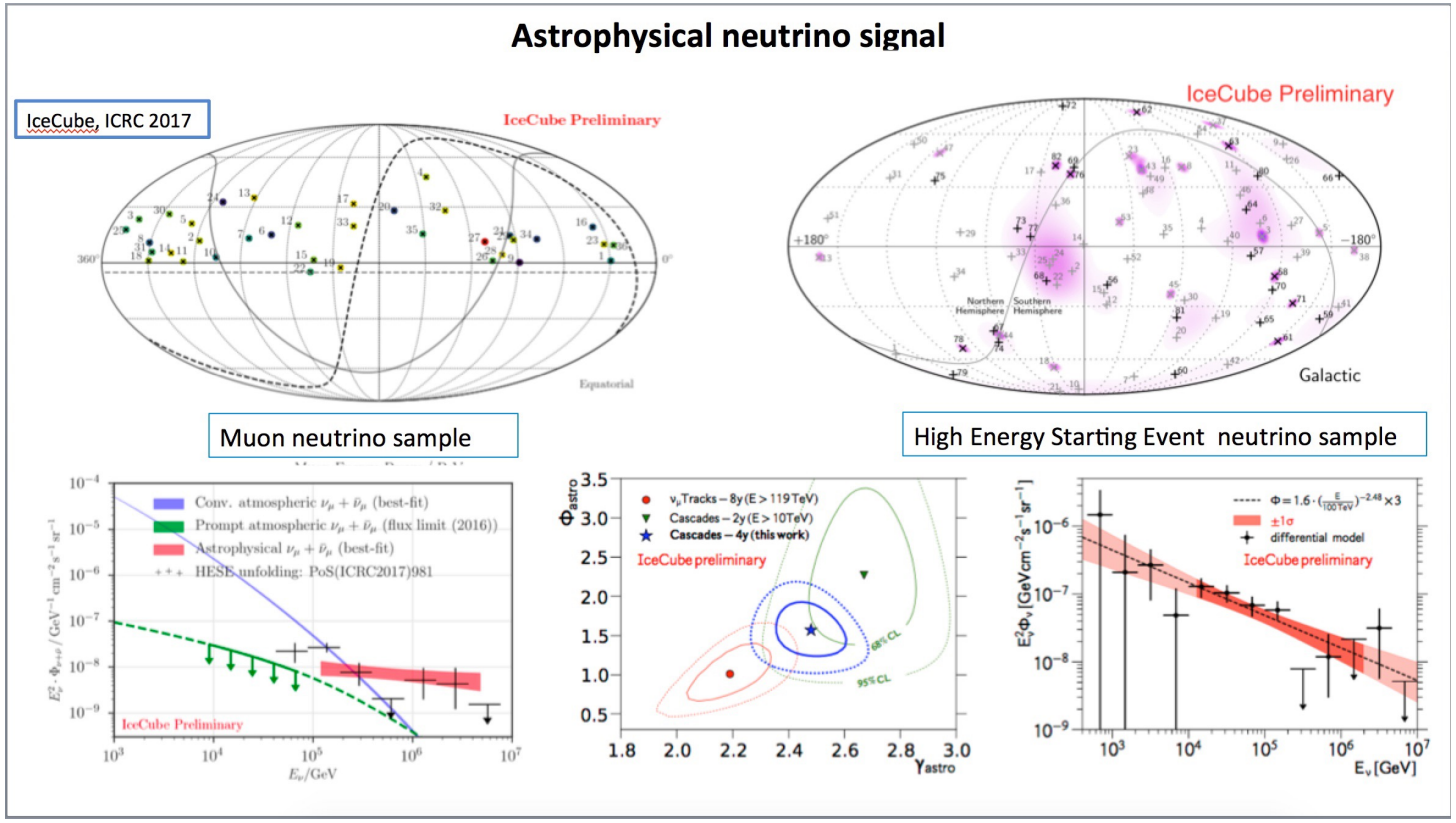
A. Neronov & D.S. arXiv: 1509.03522

Muon neutrinos

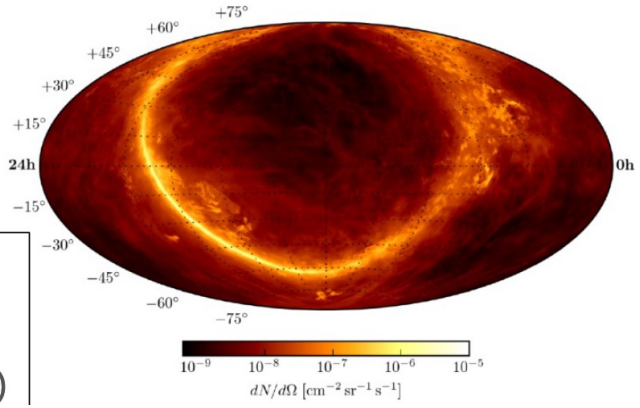


IceCube, ICRC 2015

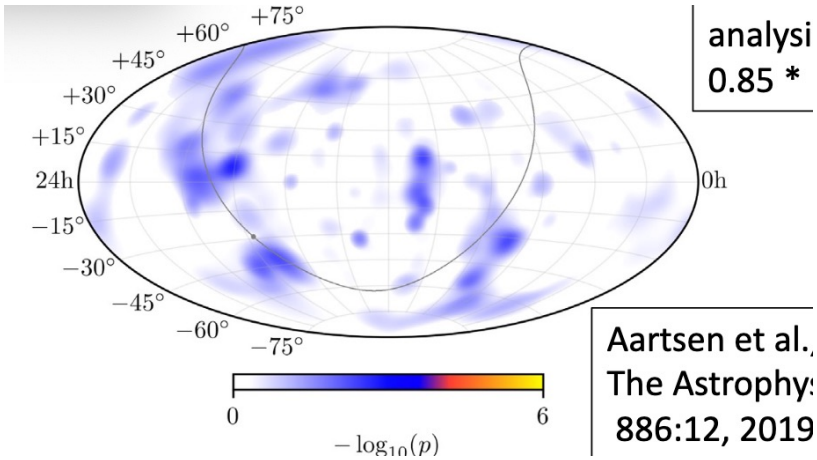
IceCube cascade and muon channel



IceCube galactic plane



Kheirandish
Astrophysics and Space Science 365(6)

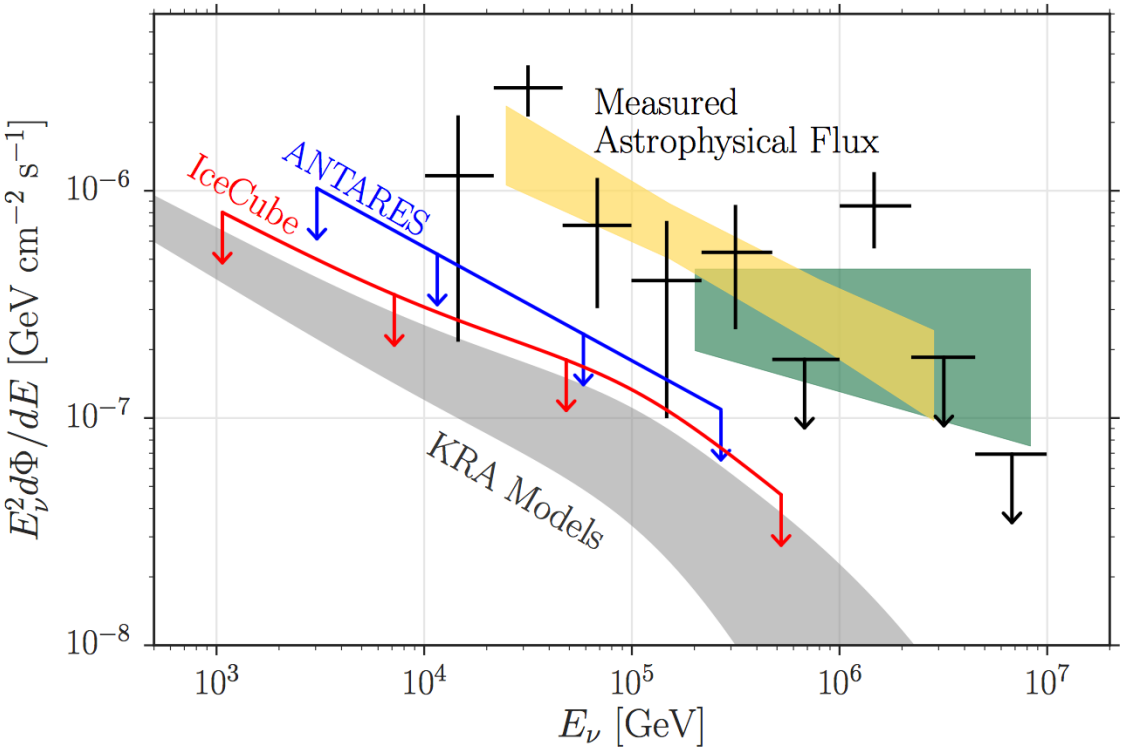


analysi
0.85 *

Aartsen et al.,
The Astrophys
886:12, 2019

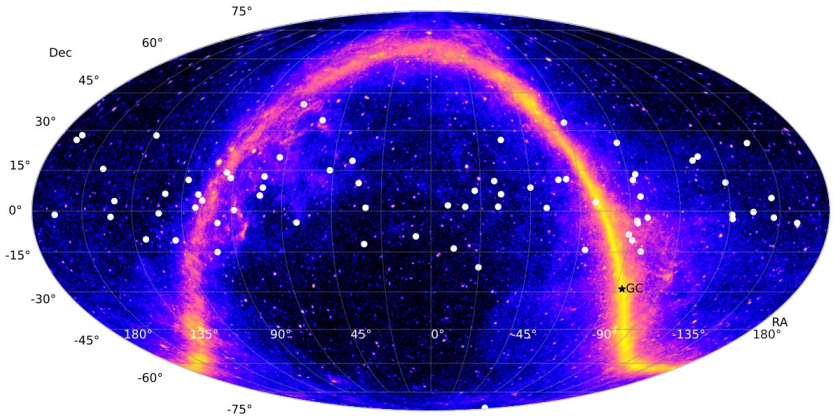
Fermi LAT and IceCube data

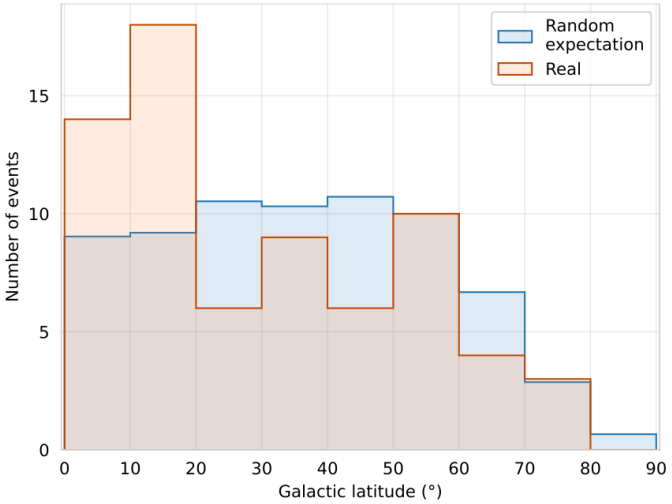
IceCube and ANTARES galalactic plane limits



ICRC 2017

IceCube muon neutrinos from Galaxy at 20 degree scale





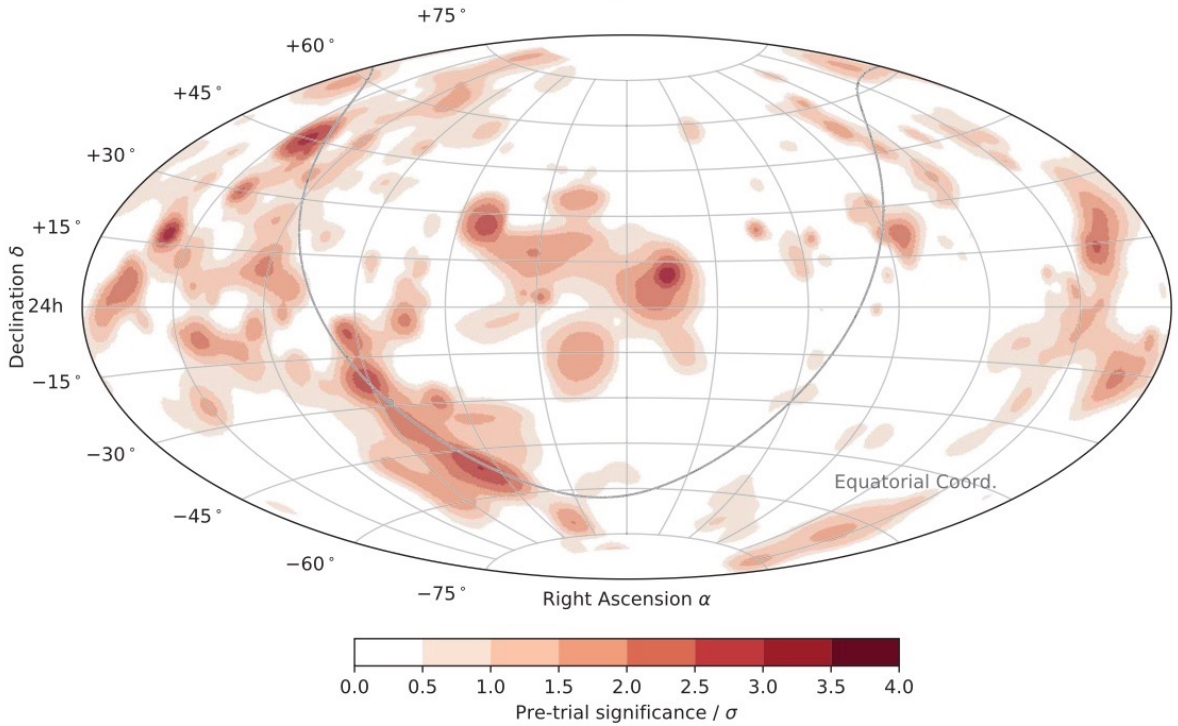
4.3 sigma excess in 20 degrees from galactic plane

70 events: 23 33% atmospheric background
13 18.5% astro-anisotropic: galactic
34 48.5% astro-isotorpic: extragalactic

Yu.Kovalev, A.Plavin and S.Troitsky , 2208.08423

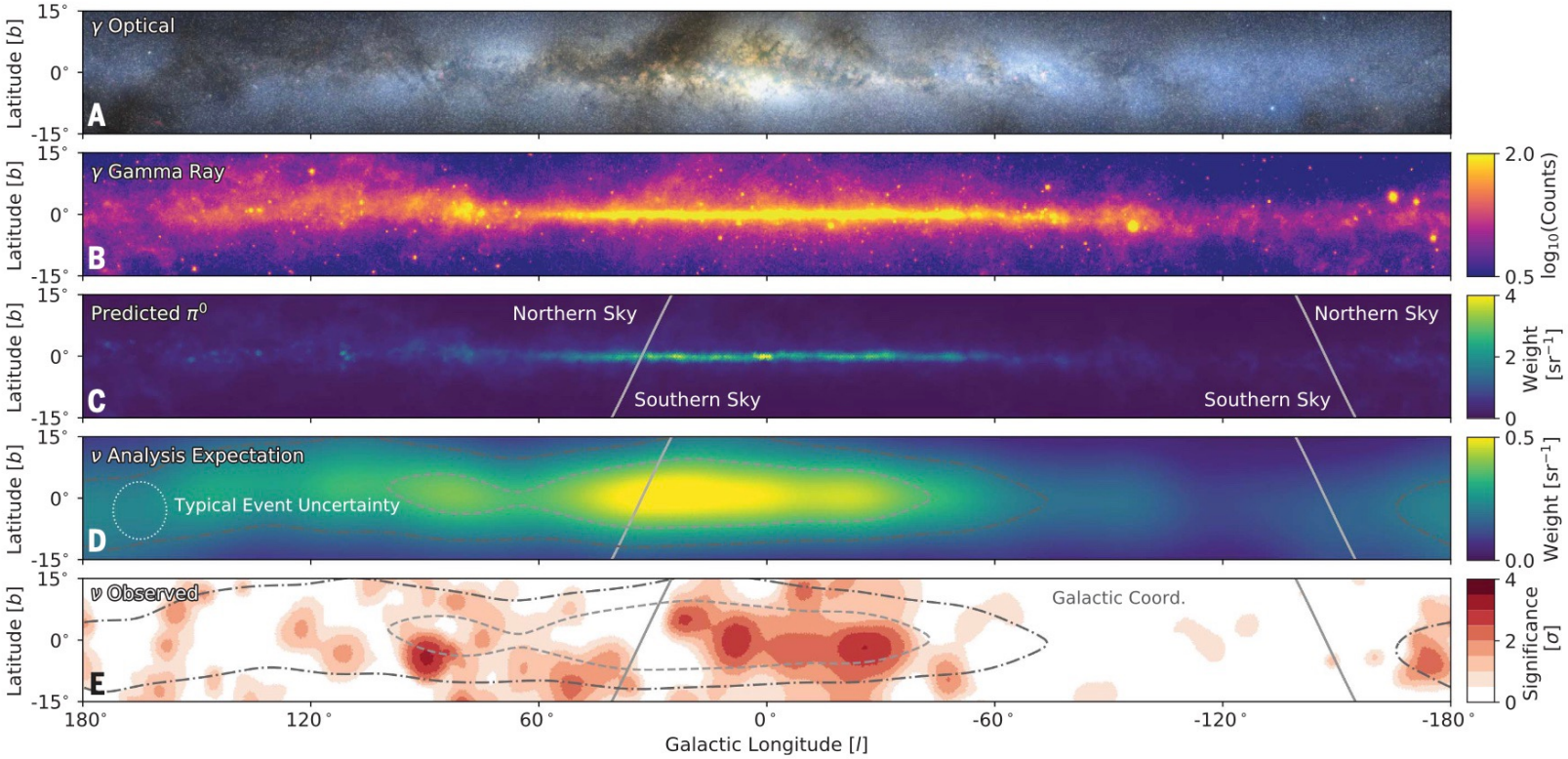
IceCube Galactic plane

IceCube cascades



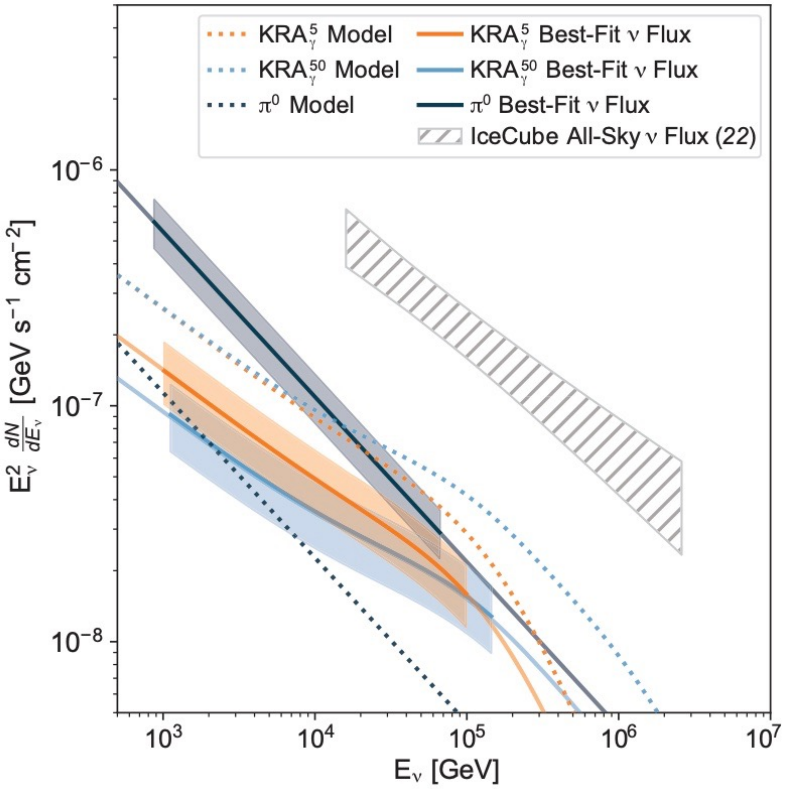
IceCube collaboration, Science **380**, 1338 (2023)

IceCube cascades galactic plane



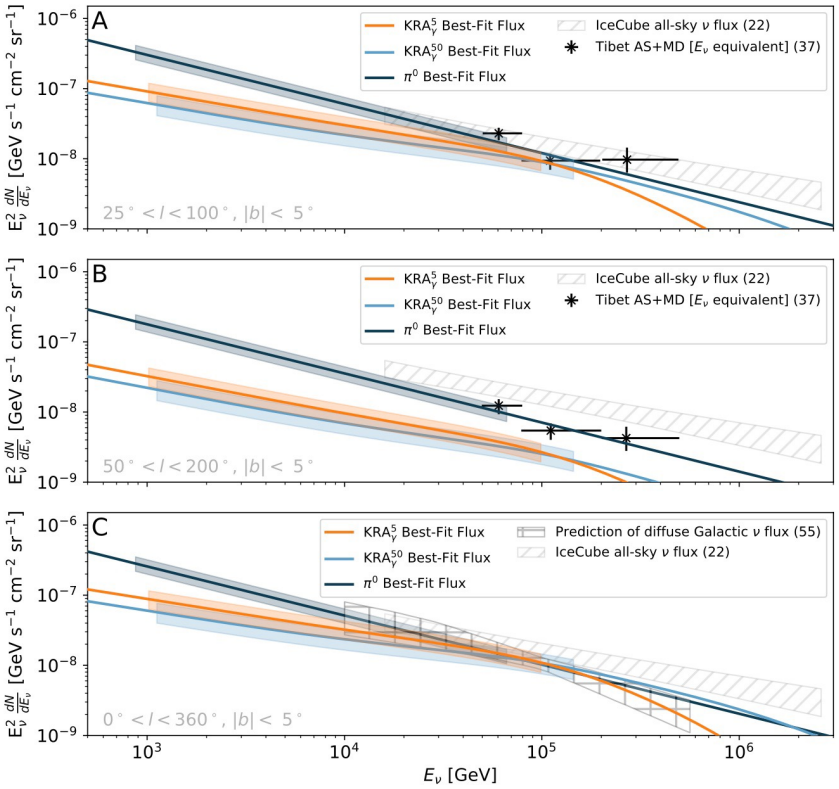
IceCube collaboration, Science **380**, 1338 (2023)

IceCube flux all sky



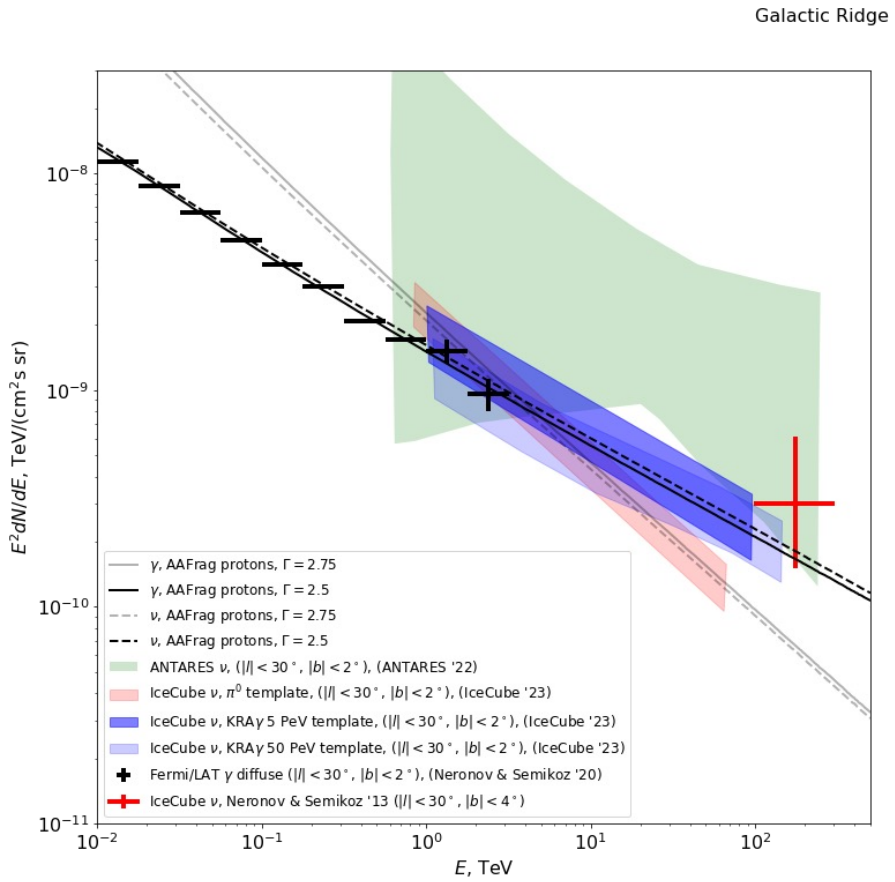
IceCube collaboration, Science **380**, 1338 (2023)

IceCube flux parts of sky



IceCube collaboration, Science **380**, 1338 (2023)

IceCube and ANTARES ridge



A.Neronov, D.Semikoz, J.Aublin, M.Lamoureux, A.Kouchner, 2307.07978, to appear in PRD

Summary

- Galactic ridge is brightest part of Galaxy in gamma-rays and neutrinos, dominated by pion decays
- ANTARES has 2 sigma excess.
- IceCube first data have excess
- IceCube new Science paper show non-zero flux from Galaxy with 4.5 sigma, again brightest region is Galactic ridge. IceCube is consistent with ANTARES
- Next step: LHAASO can measure part of this region 10-30 degrees, study flux in gamma-rays and compare with neutrinos;
- SWGO will measure all Ridge including Galactic center.
- CTA will measure detailed spectra of sources in Ridge region and help to distinguish between extended sources and true diffuse emission.
- Future neutrino observatories will help to sort out lepton and hadron sources.