WP3: SOURCES AND FLUXES OF NEUTRINOS AND OTHER MESSENGERS

Ofelia Pisanti and Giulia Pagliaroli

Nat-Net meeting L'Aquila 18 july 2023

WP3: Topics

- From low to high energy: relic neutrino detection prospects
- Axions and axion-like particles in astrophysical contexts
- Issues in big-bang nucleosynthesis neutrinos
- Improvements of solar neutrino models and low-energy flux detection
- Set-up of a reference geo-neutrino model
- Tests of core-collapse supernova physics
- High-energy neutrinos: study of astrophysical sources (within a multimessenger approach) and of propagation in the Earth

Plan of the session

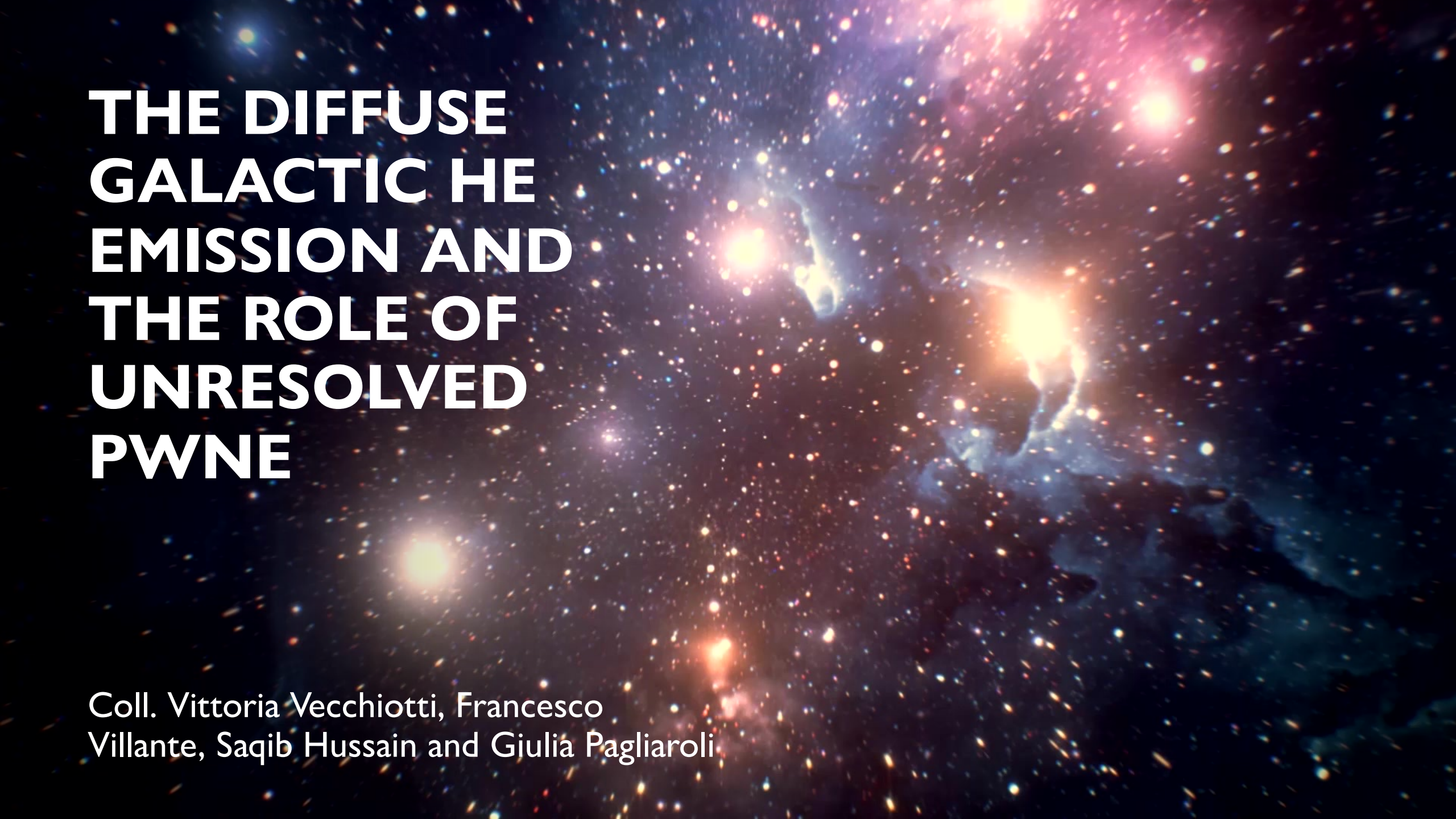
- Summary of the WP3 activity (Ofelia Pisanti & Giulia Pagliaroli)
- Contribution: *The diffuse galactic HE emission and the role of unresolved PWNe*, GP
- Contribution: *The invisible Axions in Astrophysics*, Mirizzi
- Contribution: *High-energy neutrinos From Starburst Galaxies,* Ambrosone
- Highlight talk: *Diffuse gamma-rays and neutrinos from Clusters of Galaxies,* Hussain
- Highlight talk: *Primordial Black Holes, Calabrese*

Papers in the WP3 (2021 – today)

44 papers with PRIN acknowledgments in peer review journals (PRD, JHEP, JCAP, …)

- 37 published
- 7 submitted

https://docs.google.com/document/d/1sXgpTEBwav5JI2MRiOMR_NmgRAP1bT82nrGo6Hcf8k/edit?pli=1#heading=h.a9ggzyr1sa7x



THE DIFFUSE GALACTIC HE EMISSION AND THE ROLE OF UNRESOLVED PWNE

Coll. Vittoria Vecchiotti, Francesco Villante, Saqib Hussain and Giulia Pagliaroli

PAPERS

- Vecchiotti *et al. The contribution of Galactic TeV pulsar wind nebulae to Fermi-LAT diffuse emission.* Published in: Communications Physics 5, Article number: 161 (2022) DOI: 10.1038/s42005-022-00939-7
- Vecchiotti *et al. Unresolved Sources Naturally Contribute to PeV Gamma-Ray Diffuse Emission Observed by Tibet ASγ.* Published in: *Astrophys.J.* 928 (2022) 1, 19. DOI: 10.3847/1538-4357/ac4df4
- "The Galactic population of Pulsar Wind Nebulae and the contribution of its unresolved component to the diffuse high energy gamma-ray emission", Giulia Pagliaroli, Saqib Hussain, Vittoria Vecchiotti, Francesco Lorenzo Villante, submitted to MDPI, Universe, Special Issue "Pulsar Wind Nebulae", editors: E. Amato and F. Aharonian
- Vecchiotti *et al. Setting an upper limit for the total TeV neutrino flux from the disk of our Galaxy.* e-Print: 2306.16305 [astro-ph.HE]
- Vecchiotti *et al*. *Unveiling the nature of galactic TeV sources with IceCube results*, e-Print: 2307.07451 [astro-ph.HE]

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HIGH ENERGY GAMMA-RAYS

- Vecchiotti *et al. Setting an upper limit for the total TeV neutrino flux from the disk of our Galaxy.* e-Print: 2306.16305 [astro-ph.HE]
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HIGH ENERGY NEUTRINOS

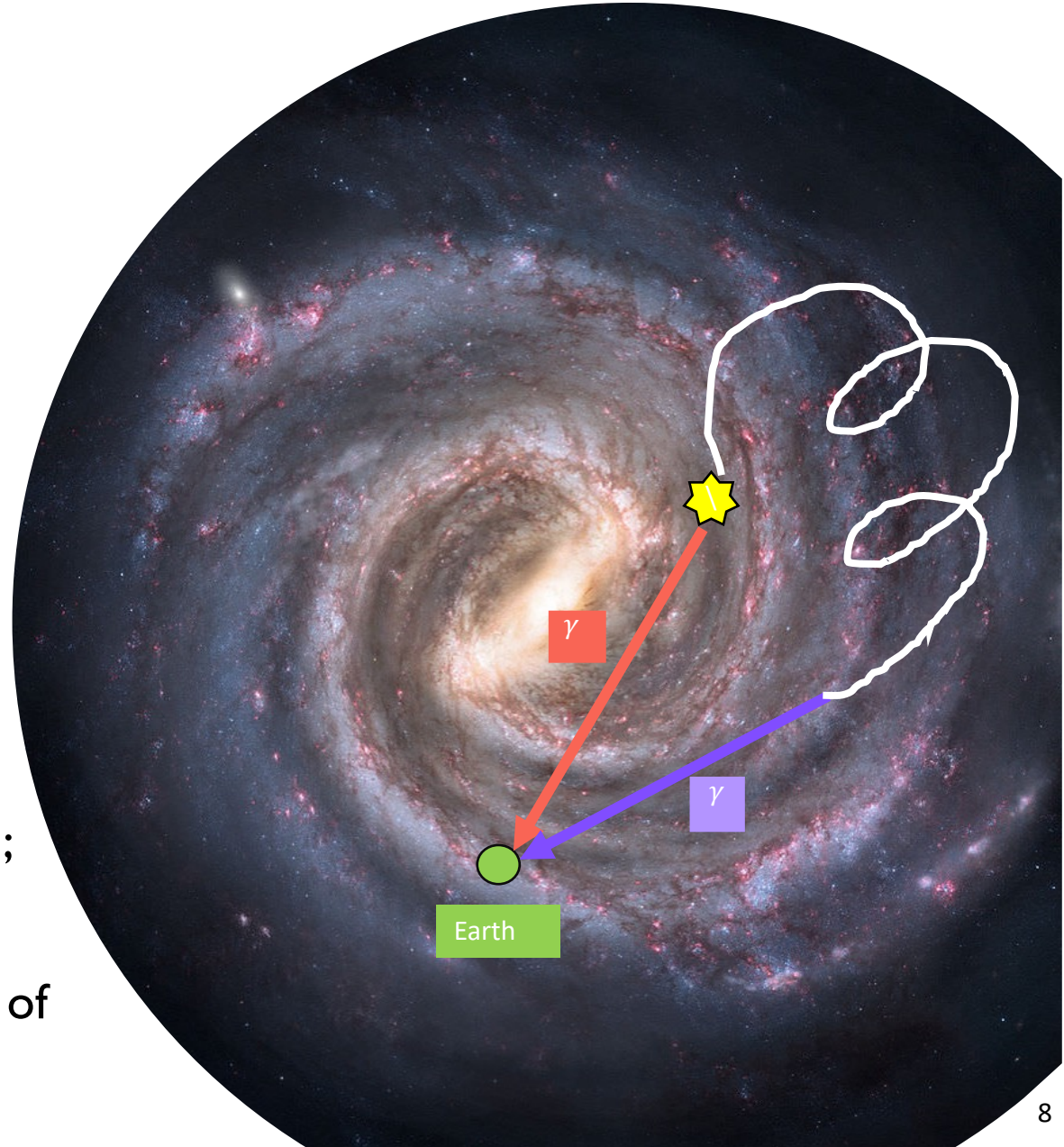
Total Galactic emission at TeV-PeV:

$$\phi_{\gamma,tot} = \phi_{\gamma,S} + \phi_{\gamma,\mathrm{diff}} + \cancel{\phi_{\gamma,IC}}$$

Source component is due to the interaction of accelerated particles (hadrons or leptons) with the ambient medium (ISM or CMB) within or close to an acceleration site (such as PWNe, SNRs).

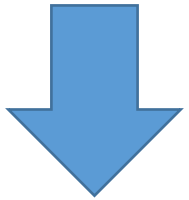
Diffuse component is due to the interaction of accelerated hadrons with the interstellar medium;

Inverse Compton: is due to the interaction of accelerated leptons with the CMB ;



Diffuse Galactic gamma-ray emission measured by Fermi-LAT or Tibet-AS or .. Is the sum of two components:

$$\phi_{\gamma,S}^{UnRes} + \phi_{\gamma,\mathrm{diff}}$$



$$\varphi_\gamma^{diff}(E_\gamma,\hat{n}_\gamma) = \int_{E_\gamma}^{\infty} dE \frac{d\sigma(E,E_\gamma)}{dE_\gamma} \int_0^{\infty} dl\, \varphi_{CR}(E,\bar{r}_{Sun}+l\hat{n}_\gamma)\, n_H(\bar{r}_{Sun}+l\hat{n}_\gamma)$$

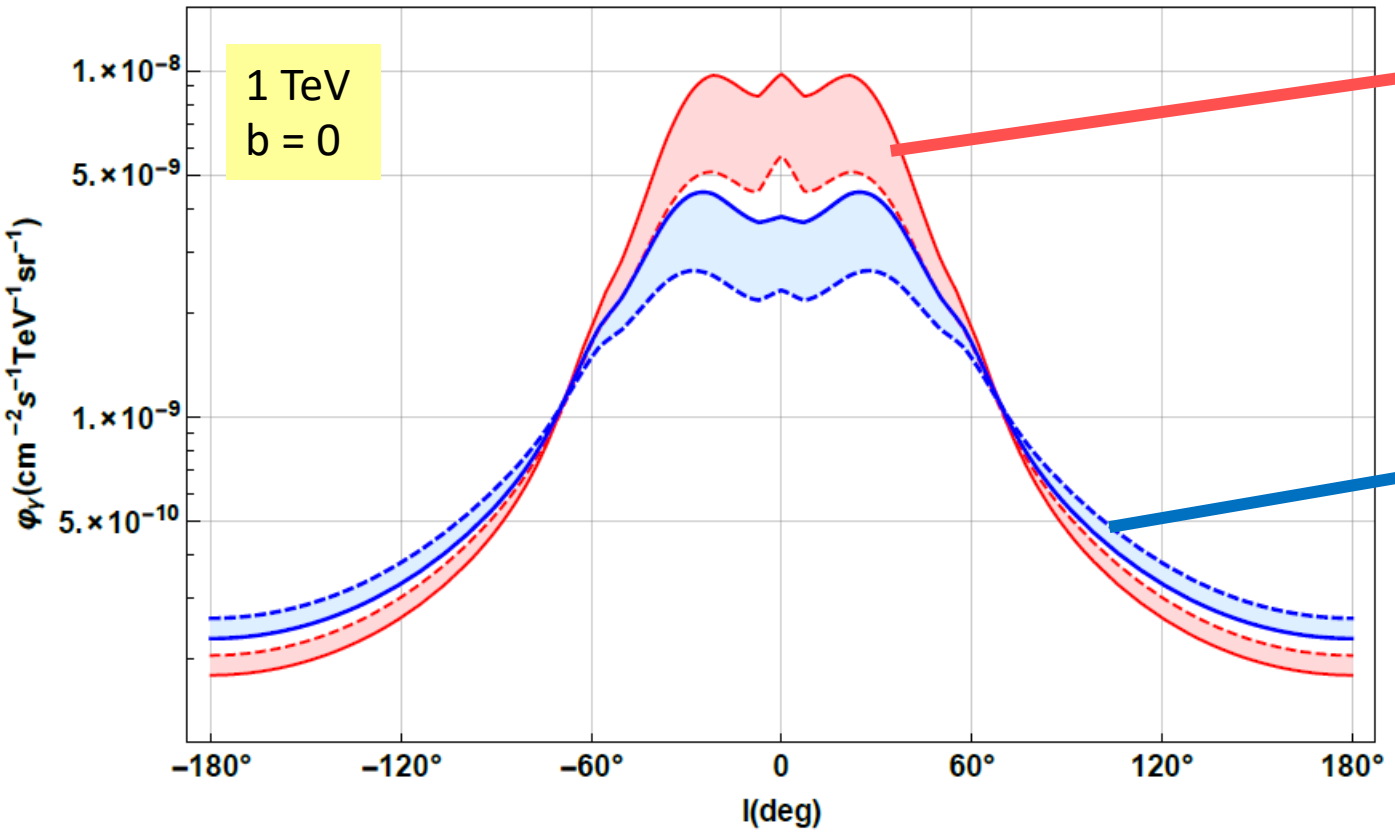
Interstellar gas distribution in the Galaxy *[Galprop]*

Differential inelastic cross section of pp interaction from the SYBILL code *[Kelner,Aharonian,Bugayov (2006)]*

Cosmic-ray energy and spatial distribution

2 models for the diffuse fluxes **for 2 assumptions of the CR distribution** in the Galaxy.

Diffuse Galactic gamma-ray emission:



Model with hardening

$R = 1\ kpc$

$R = \infty$

Model without hardening

$R = 1\ kpc$

$R = \infty$

Unresolved Source component:

Study of the Pulsar wind nebulae population in the TeV range:

Cataldo et al. *Astrophys.J.* 904 (2020)

We fit the H.G.P.S. catalogue with an unbinned likelihood

$$L_{max} = L^{BF}$$
$$\tau = \tau^{BF}$$

$$\Phi^{\mathrm{tot}}_{1-100\ TeV}$$

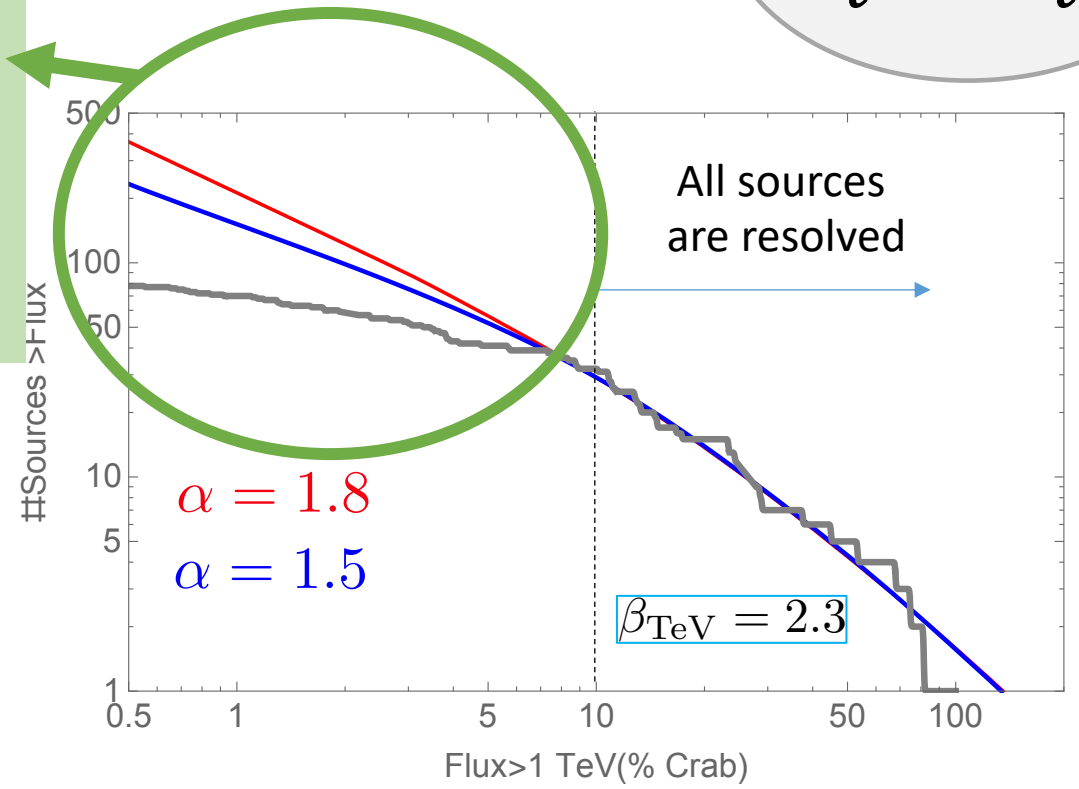
Unresolved Sources:

$$\Phi^{\mathrm{unr}}_{1-100\ TeV}$$

$\alpha = 1.5$

$L_{max} = 5.0{\times}10^{35}\ erg\ s^{-1}$

$\tau = 1.7\ kyr$



IMPLICATIONS FOR THE FERMI DIFFUSE GAMMA-RAY EMISSION

Total diffuse emission=Truly diffuse emission due to CR interactions + cumulative flux due to Unresolved sources (**PWNe** +…)

TAKE HOME MESSAGE #2

Unresolved TeV PWNe and the truly diffuse emission, due to CRs interactions add up and shape the radial and spectral behaviours of the total diffuse γ-ray emission observed by Fermi-LAT

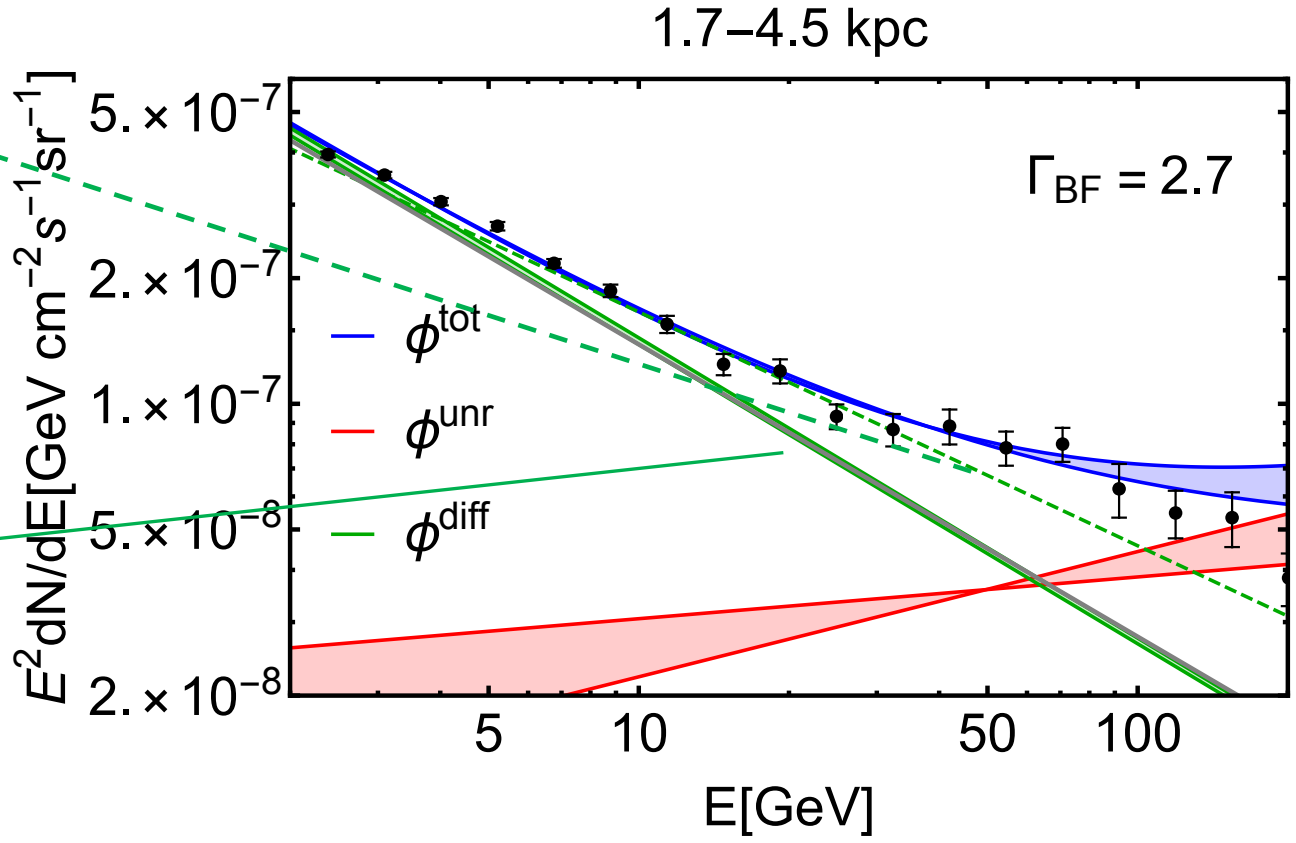
REINTERPRETING the diffuse emission observed by Fermi-LAT

Dashed-green line: best-fit power-law of FERMI data without the PWNe contribution

$$\Gamma_1 = 2.56$$

Thick green line: best-fit power-law of the truly diffuse emission due to CRs

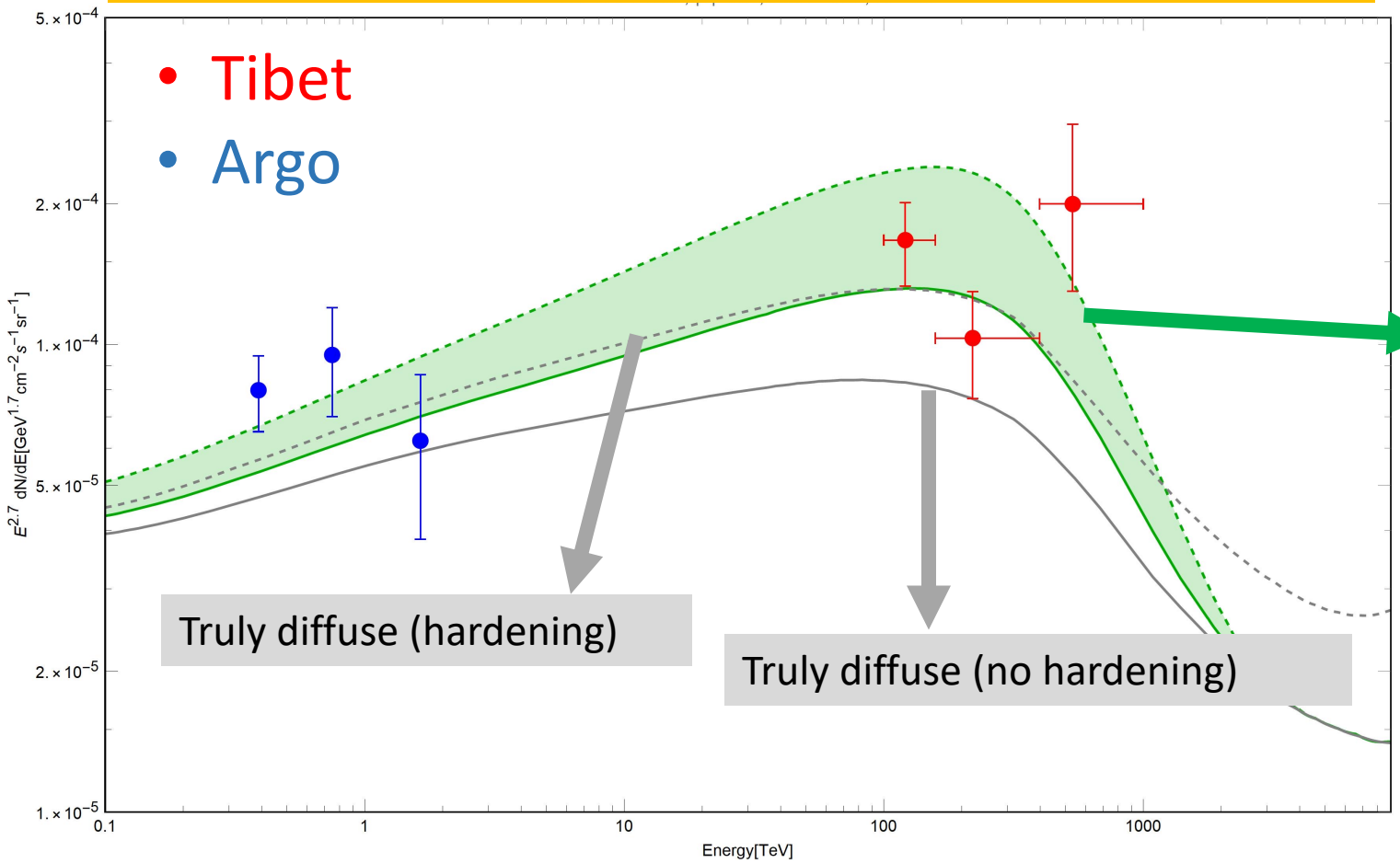
$$\Gamma_{\rm BF} = 2.72$$



Tibet ASγ : We add the contribution of unresolved sources to the truly diffuse emission without the hypothesis of CR spectral hardening.

Definition: Hardening ≡ spatially dependent CR spectral index

$$25° < l < 100°, |b| < 5°, E_{cut} = 500\ TeV$$

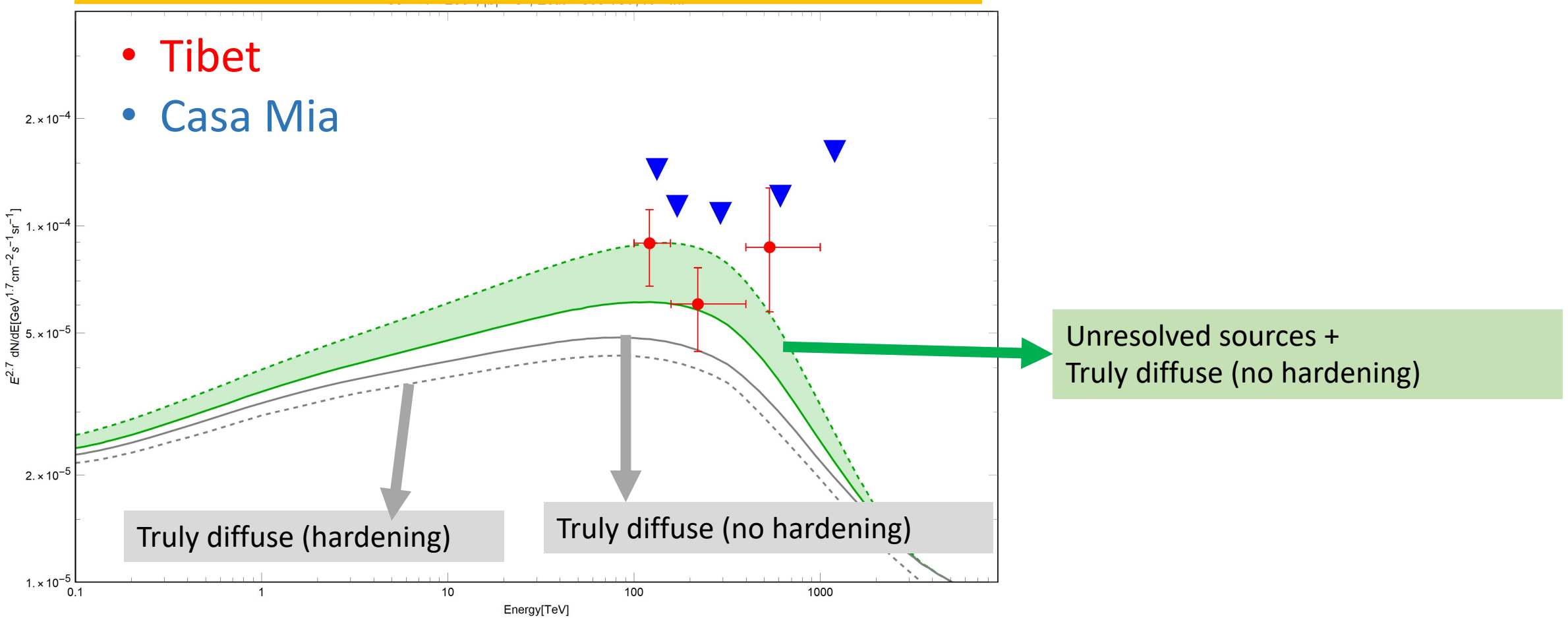


Unresolved sources +
Truly diffuse (no hardening)

Tibet ASγ : We add the contribution of unresolved sources to the truly diffuse emission without the hypothesis of CR spectral hardening.

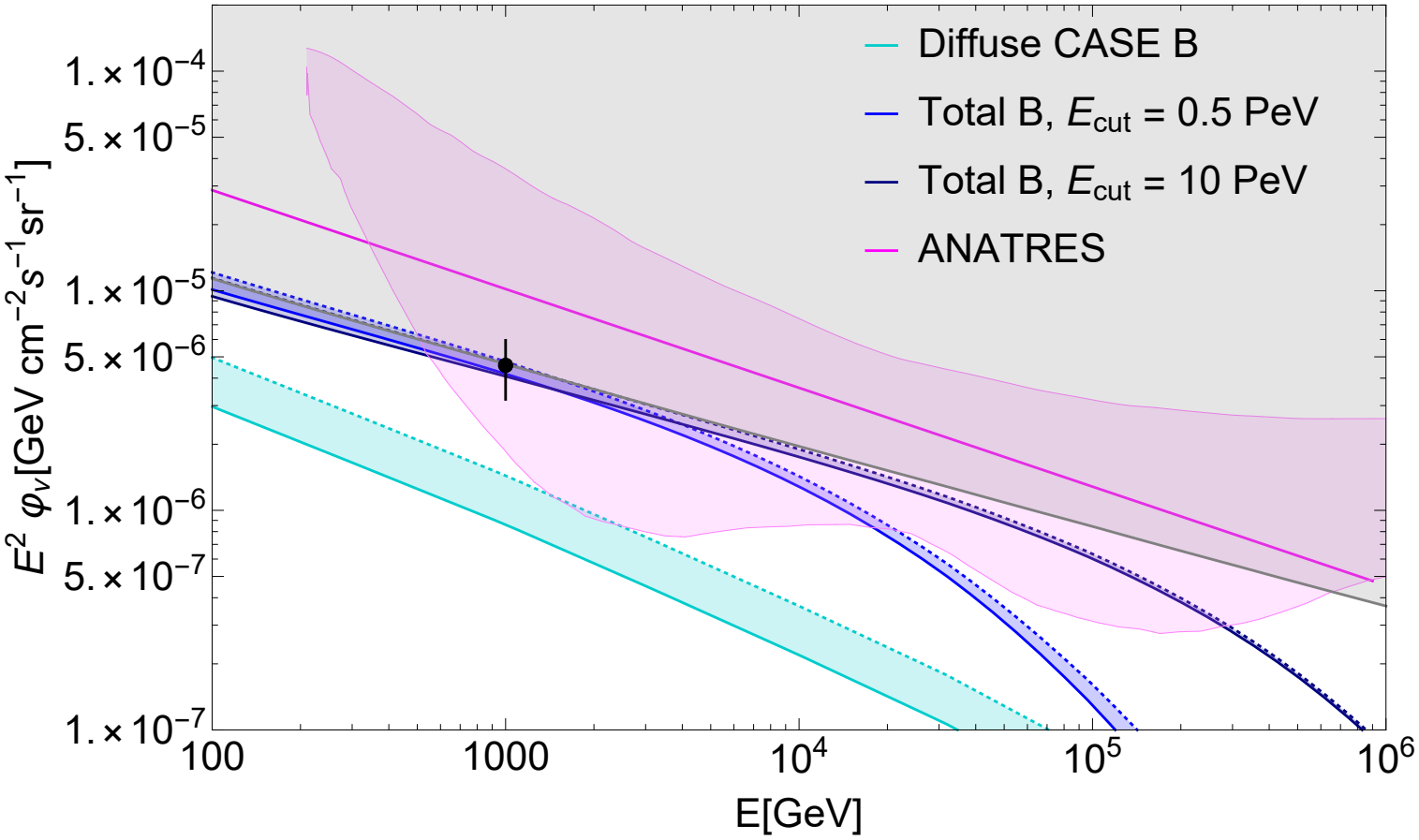
Definition: Hardening ≡ spatially dependent CR spectral index

$$50° < l < 200°, |b| < 5°, E_{cut} = 500\ TeV$$



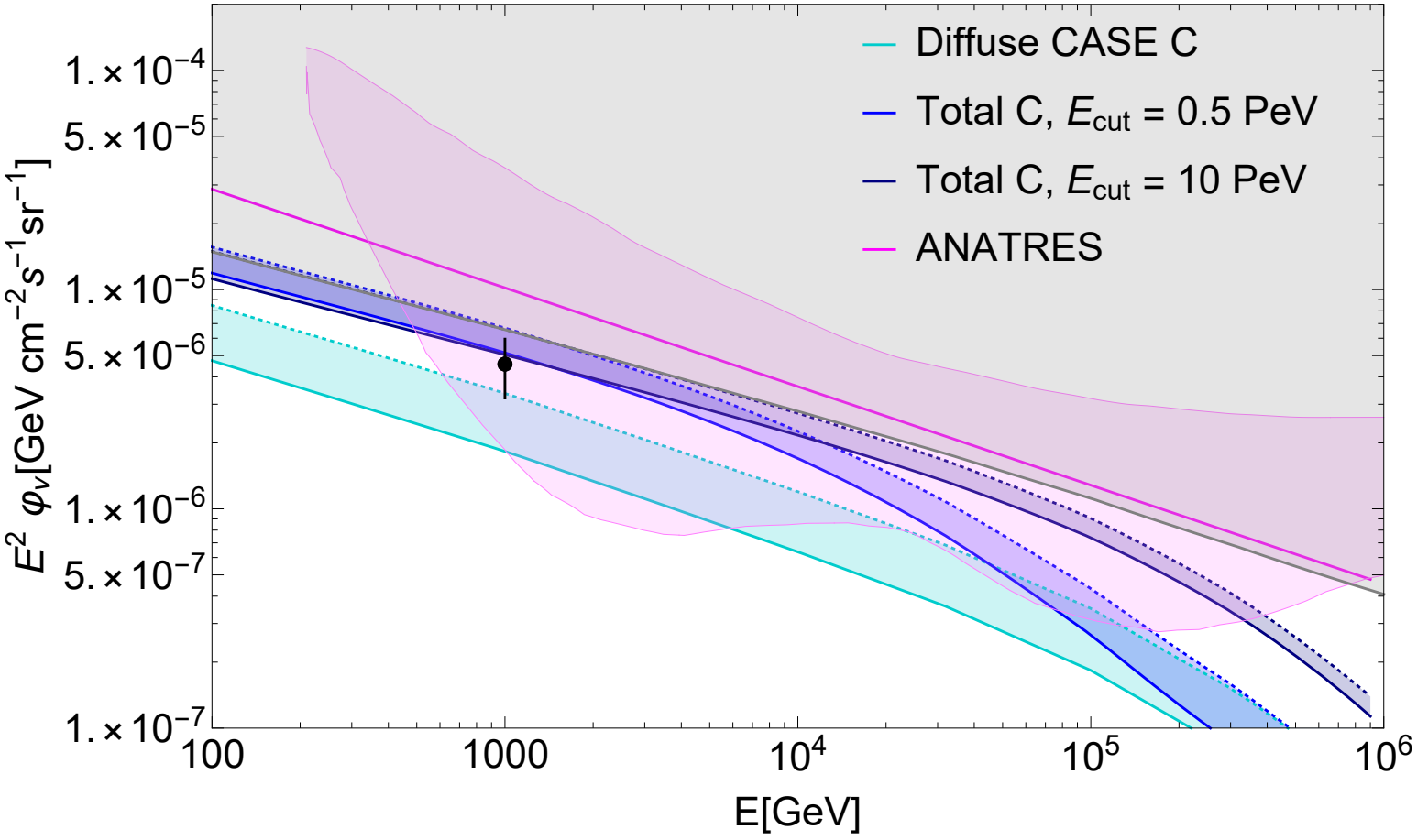
Setting an upper limit for the total TeV neutrino flux from the disk of our Galaxy

The Neutrino Galactic Flux vs Antares data



Upper Flux : The total gamma-ray flux produced by all the sources, resolved and unresolved by H.E.S.S., is produced via hadronic interaction and, hence, is coupled with neutrino emission.

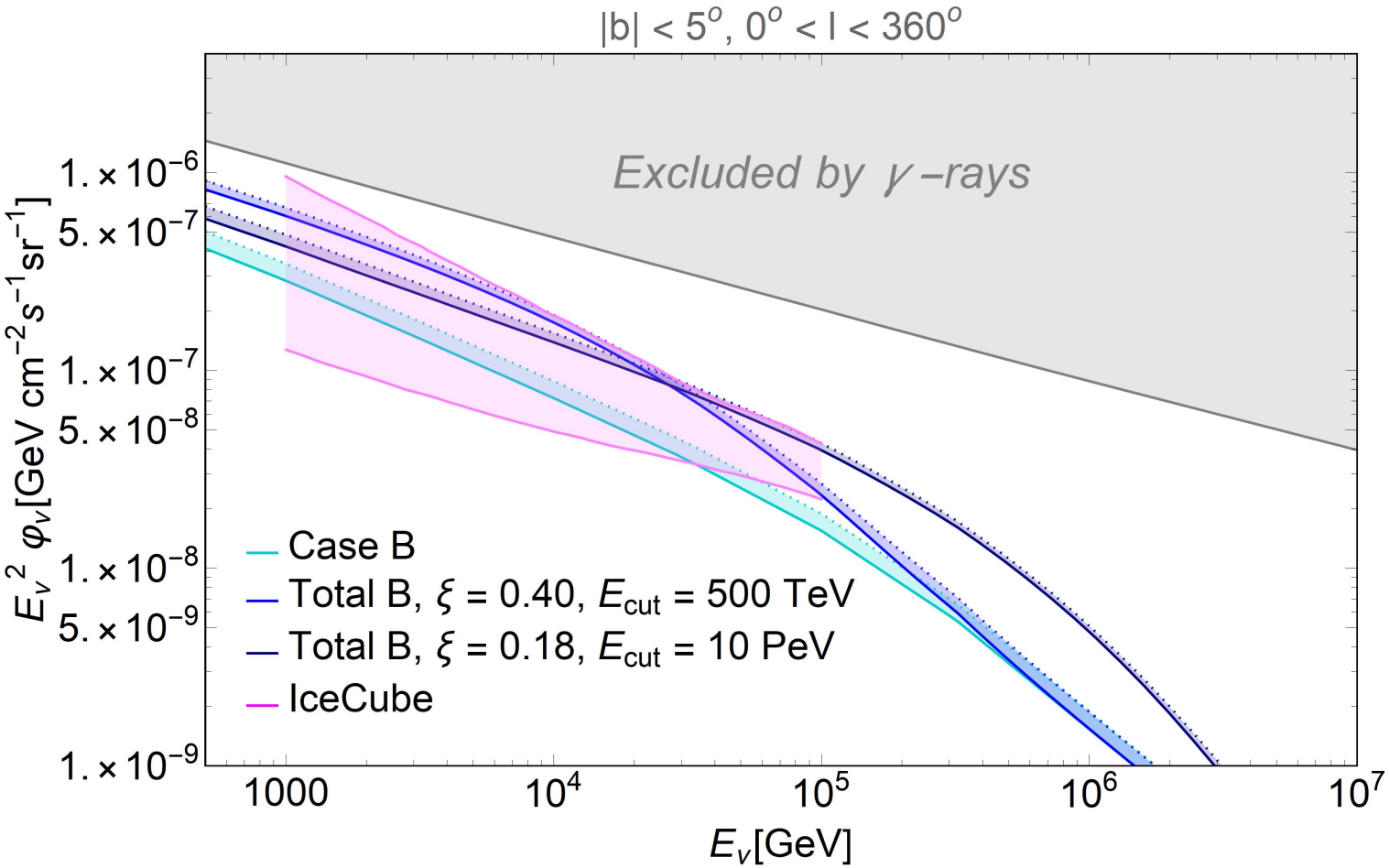
The Neutrino Galactic Flux vs Antares data



We show that the ANTARES best-fit flux requires the existence of a large source component, close to or even larger than the most optimistic predictions.

The fraction of Galactic TeV gamma-ray sources (resolved and unresolved) with hadronic nature

The neutrino galactic flux vs The IceCube data



To be compatible with the IceCube results, this fraction should be less than ~ 40% corresponding to a cumulative source flux Φv,s ≤ 2.6 × 10−10cm−2s−1 integrated in the 1-100 TeV energy range


Thank you!