



Interpreting the Galactic Diffuse emission from GeV to PeV

Giada Peron

In collaboration with V. Vecchiotti, S. Menchiari, E. Amato, G. Morlino, G. Pagliaroli & F. Villante

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The Galactic diffuse emission

$$\varphi_{GDE} = \varphi_{diff} + \varphi_{unres}$$

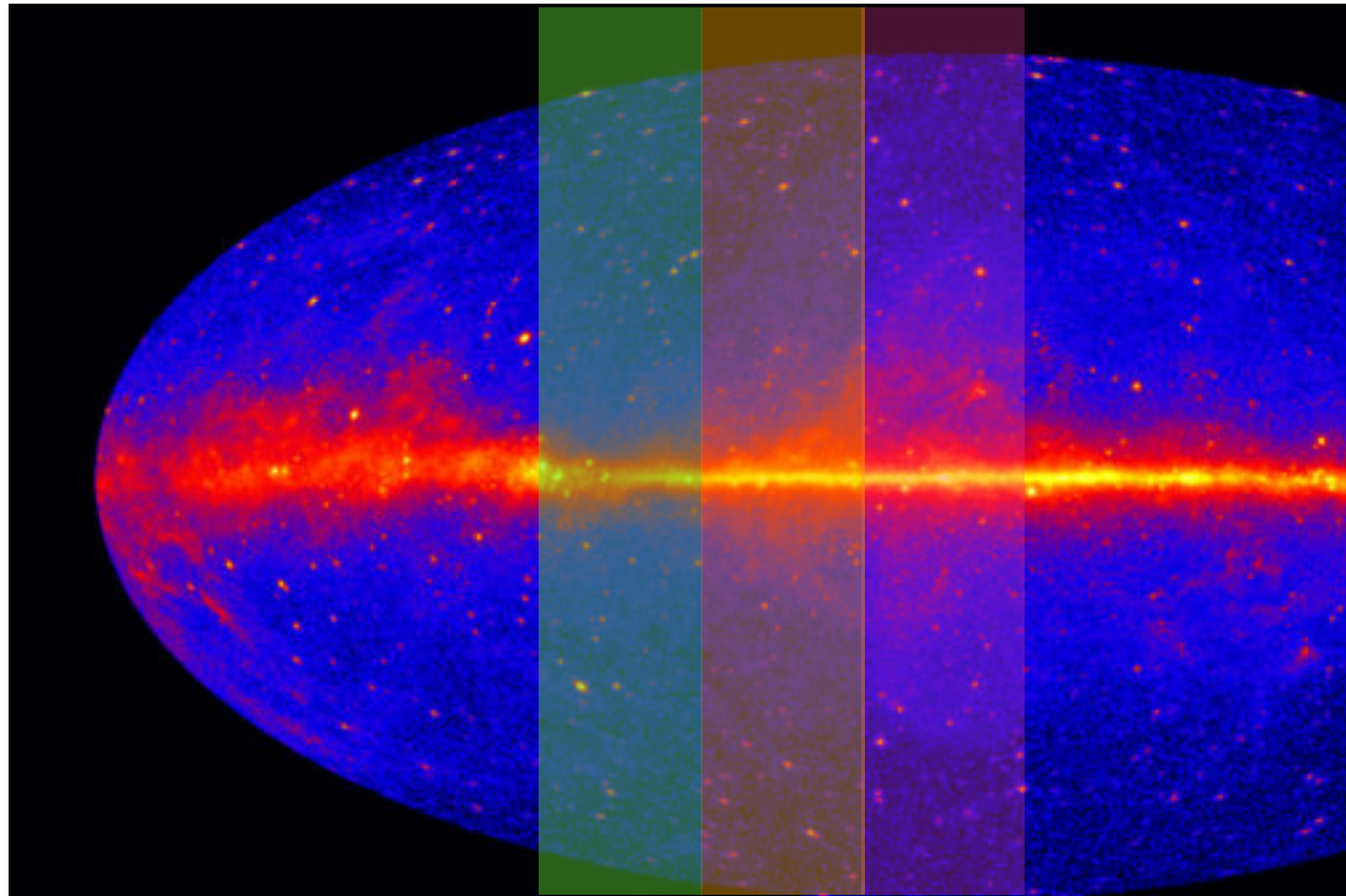
pp

IC

Bremm.

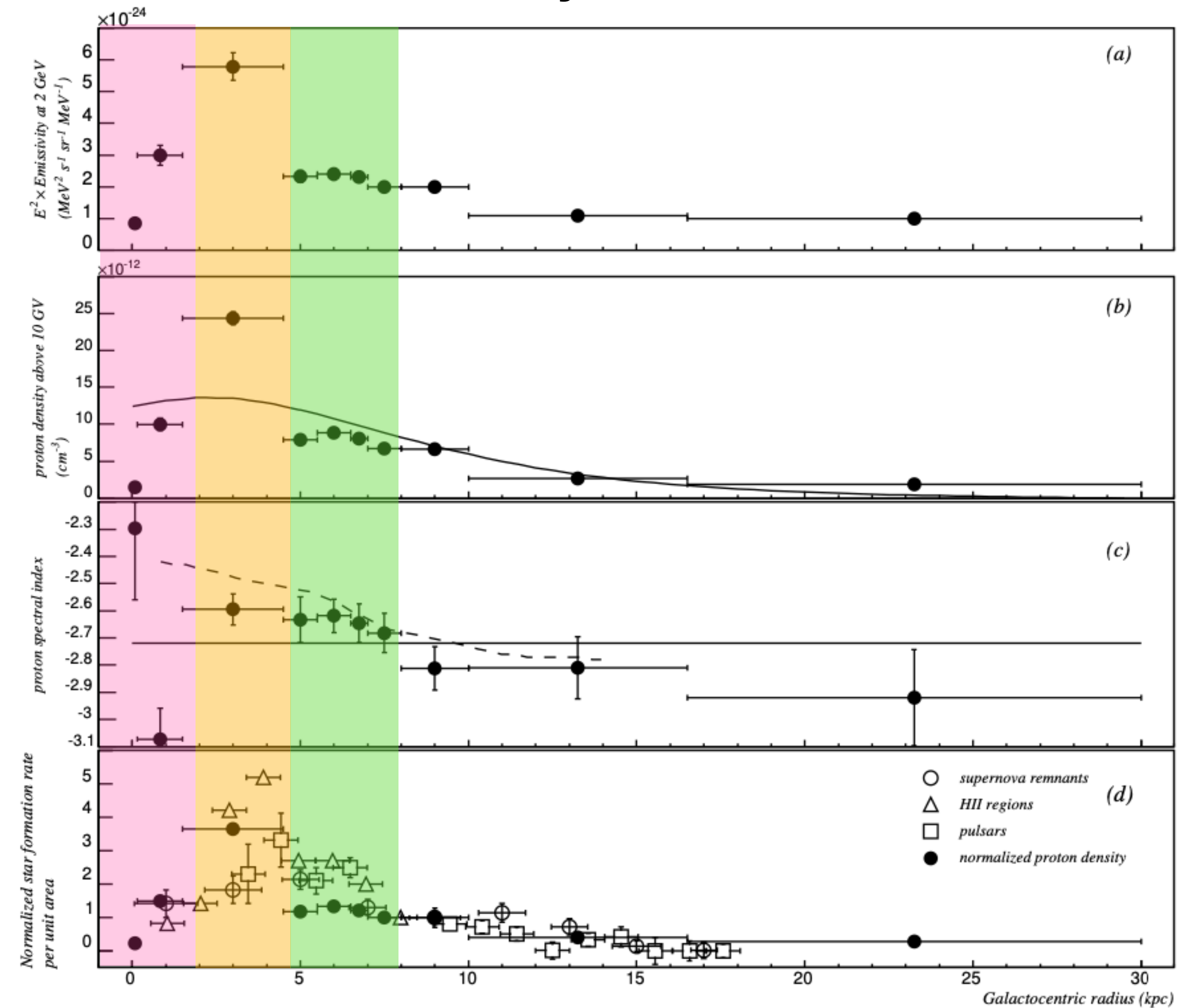
The Galactic diffuse emission

at GeV energies



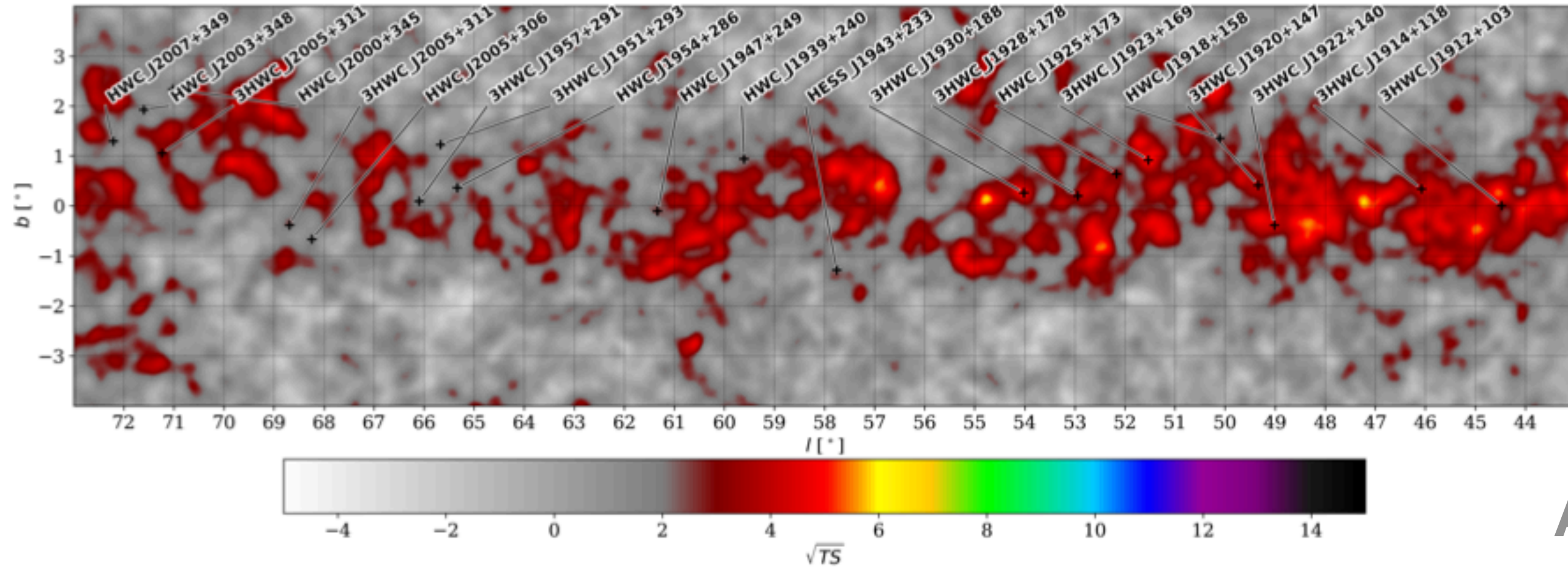
Enhancement of a factor ~5 compared to local CR in the inner Galaxy

Emissivity/H atom @ 2 GeV

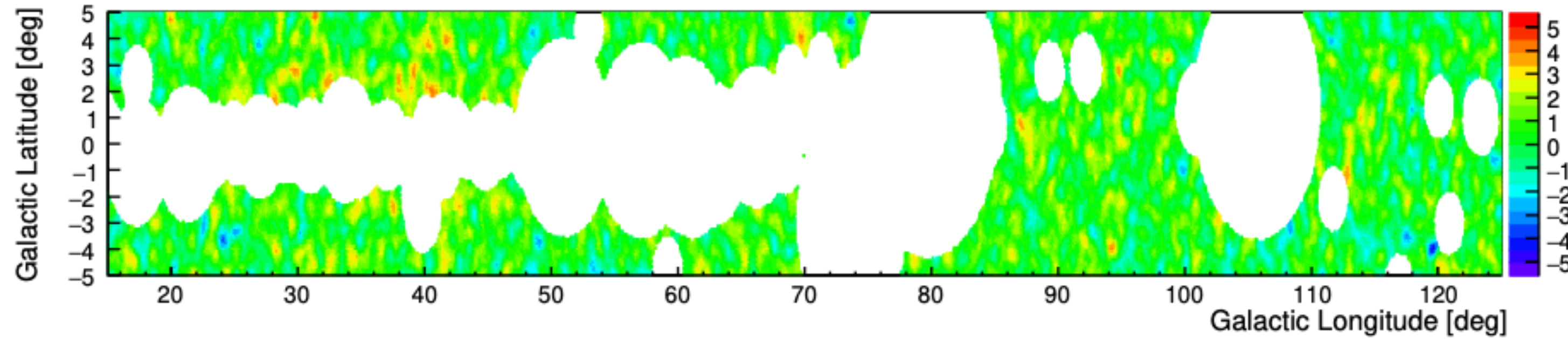


Acero+2016

The Galactic diffuse emission at TeV energies

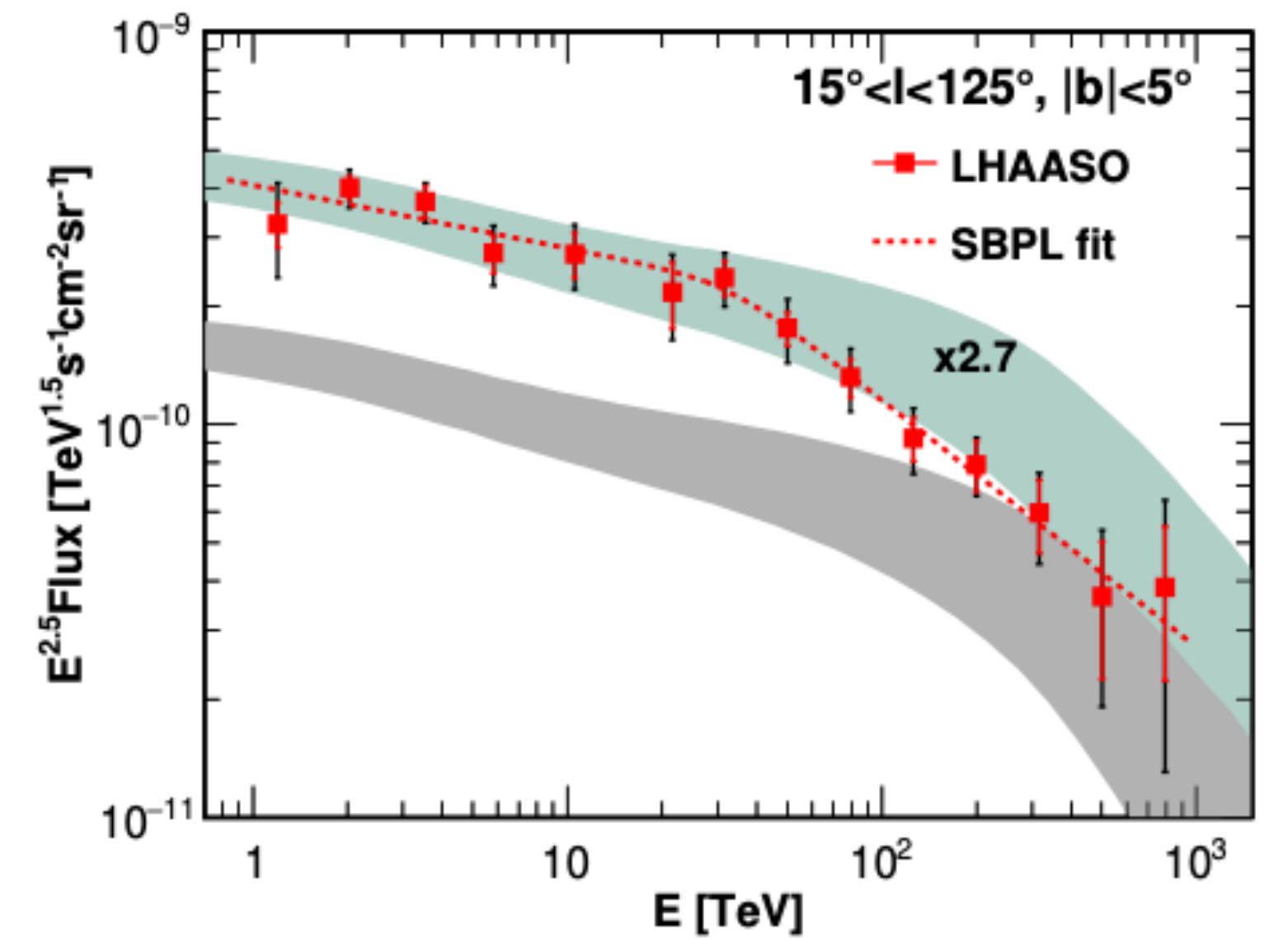
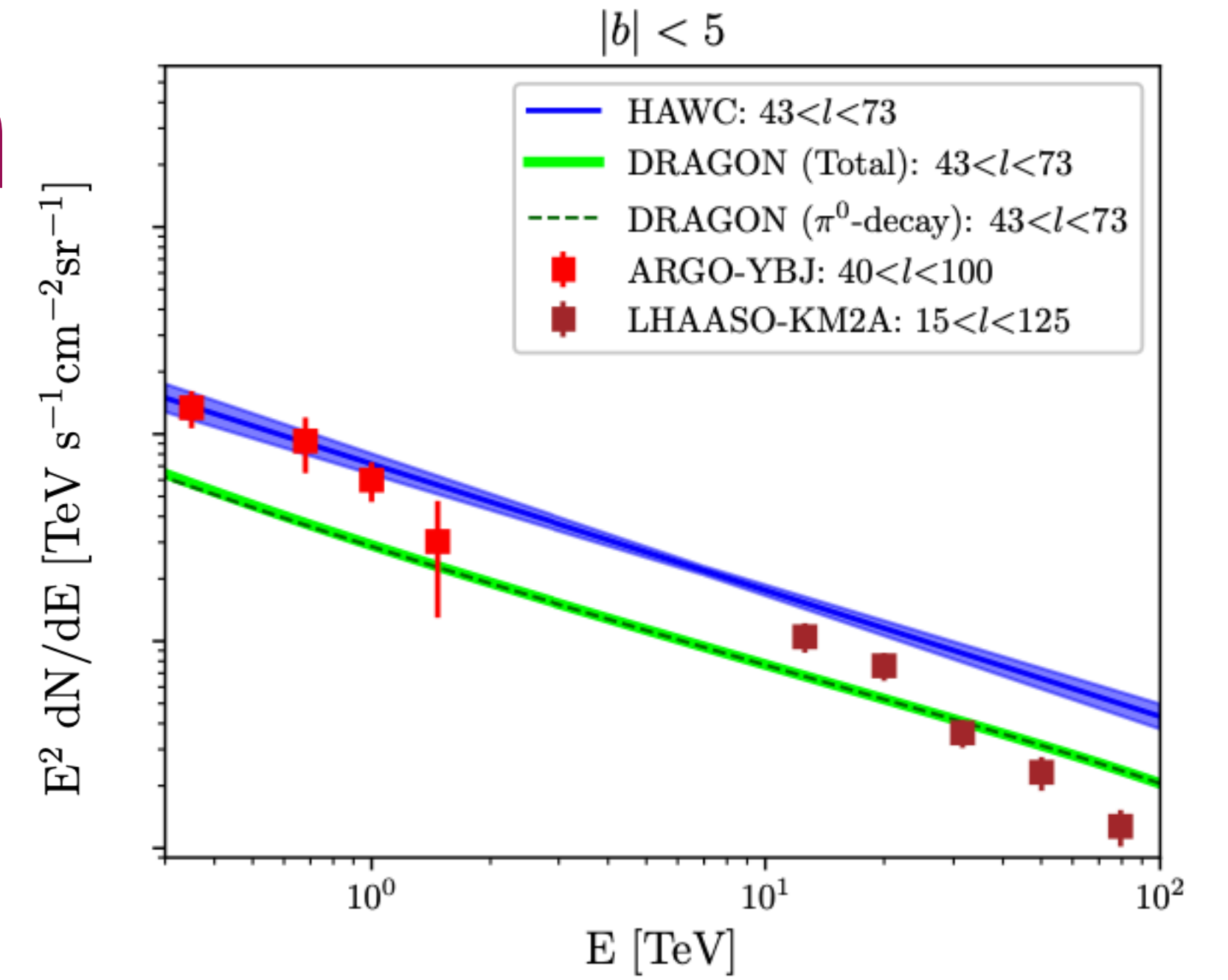


Alfaro+2024



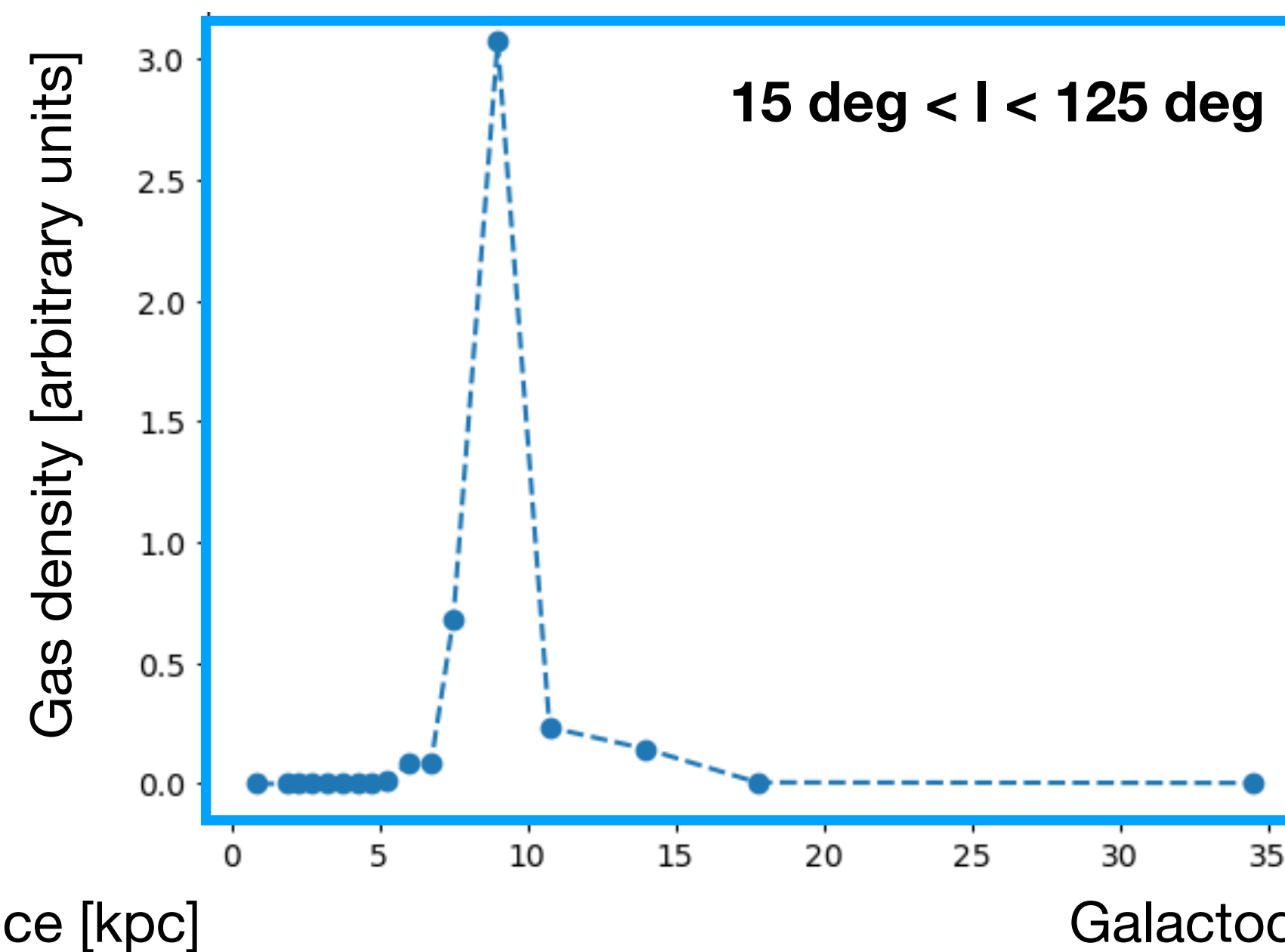
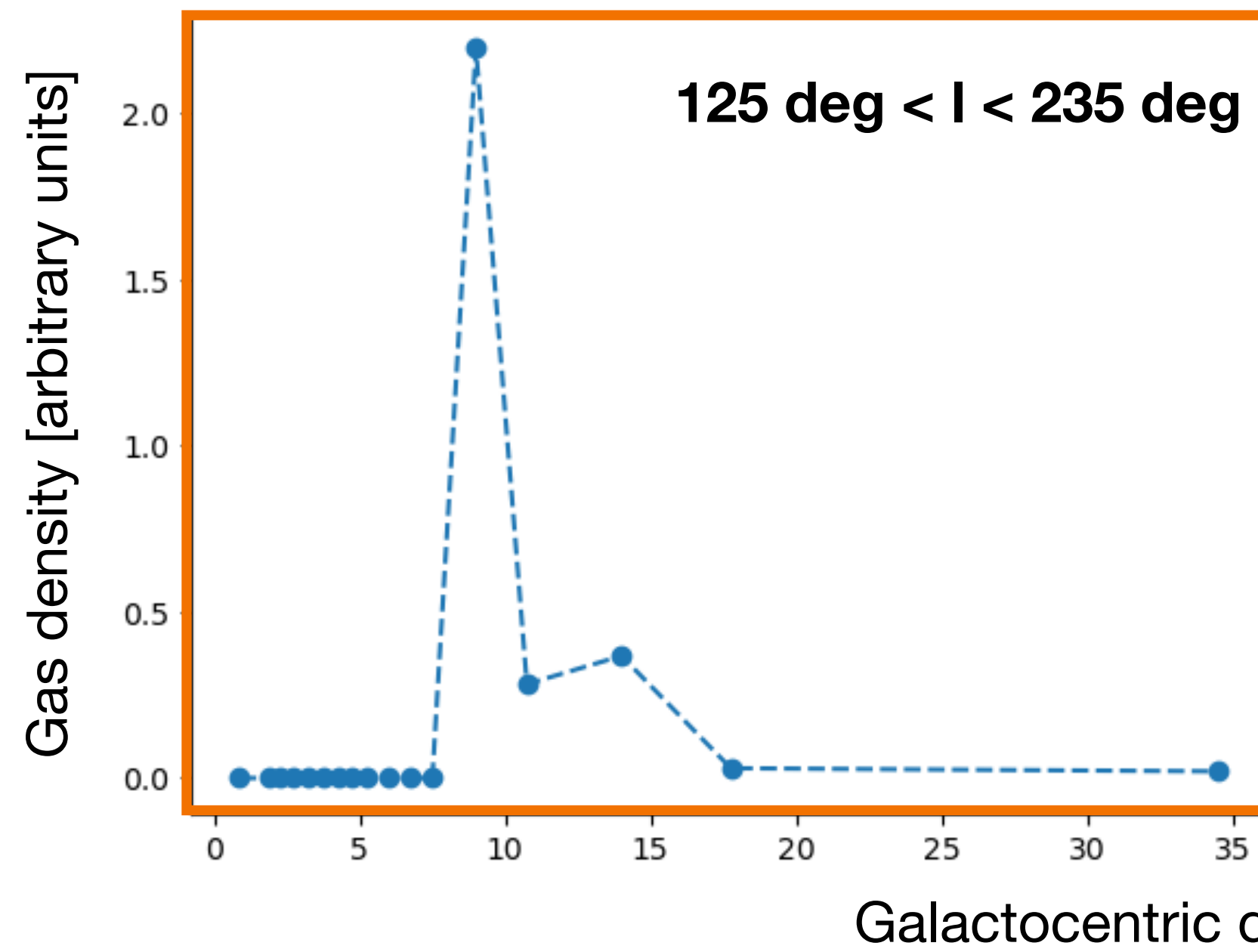
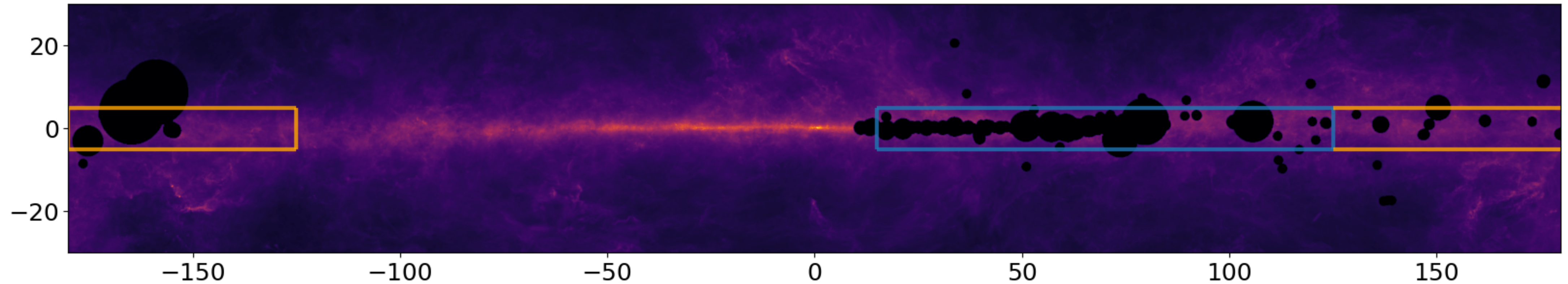
Cao+2025

Enhancement of a factor ~ 3 compared to local CR



The Galactic diffuse emission

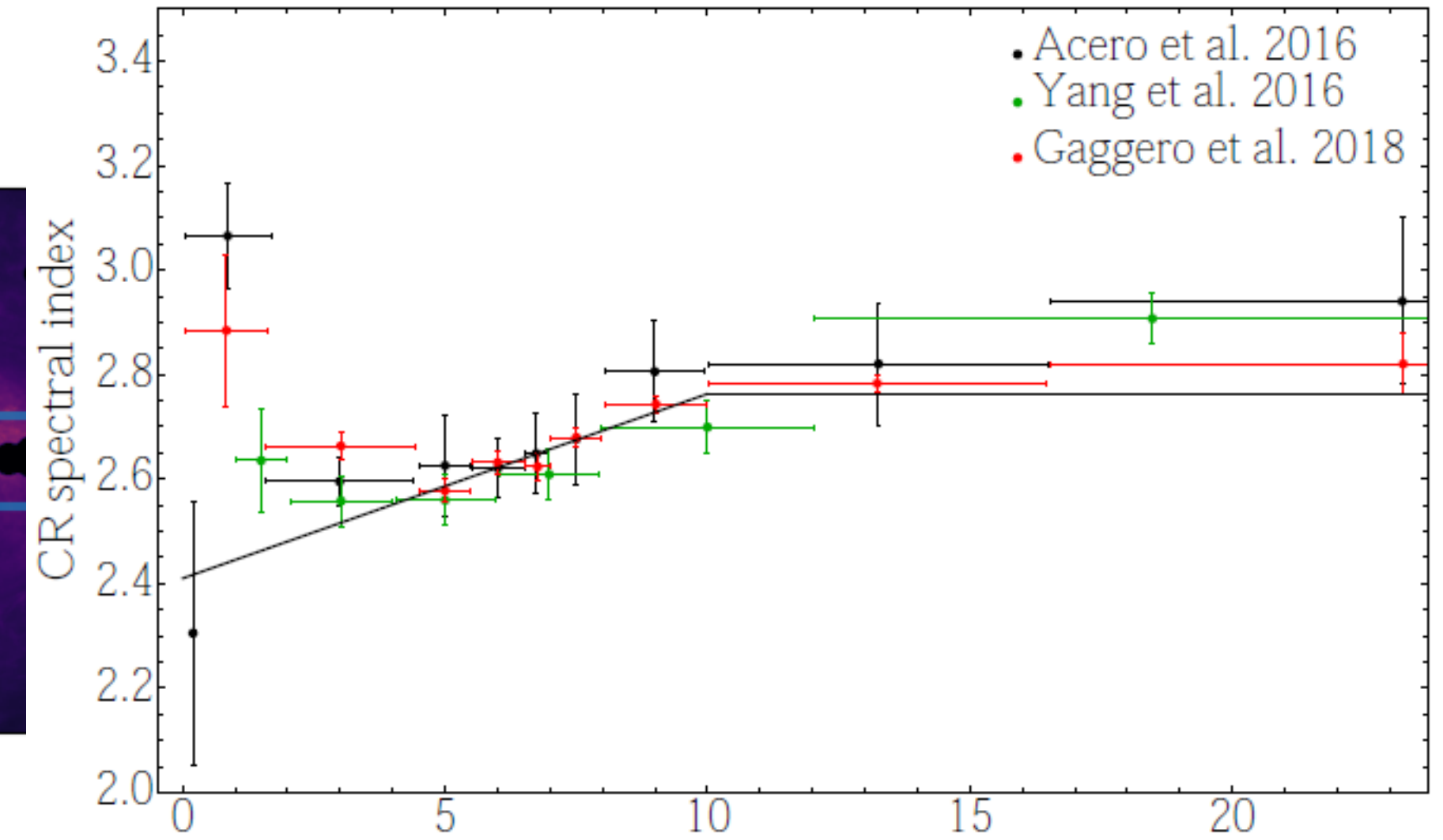
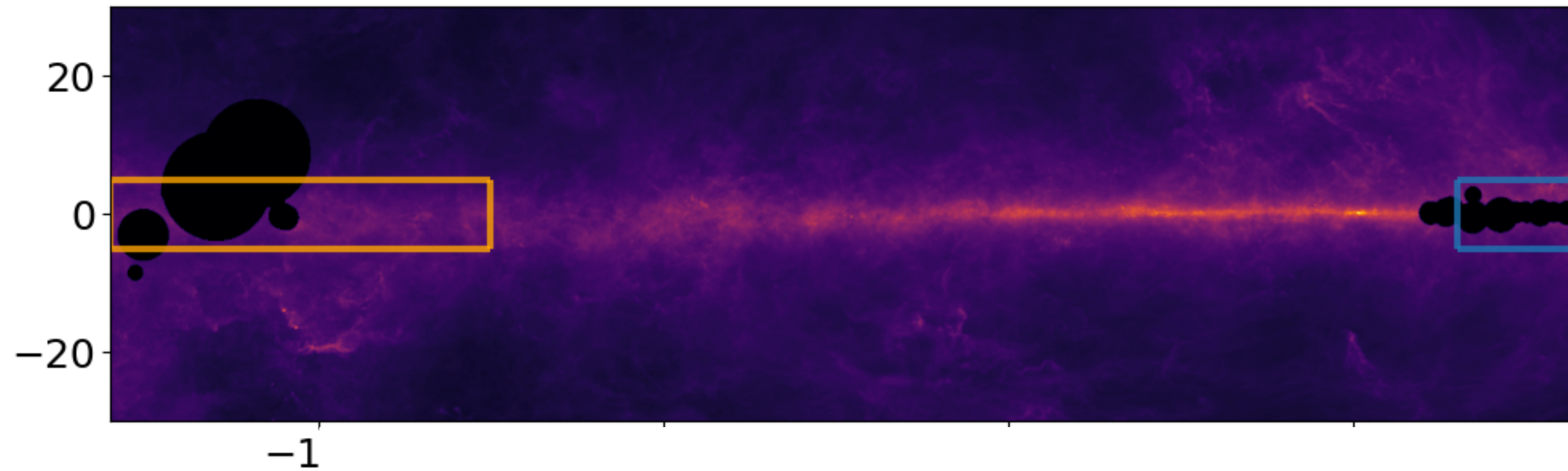
The role of the masks



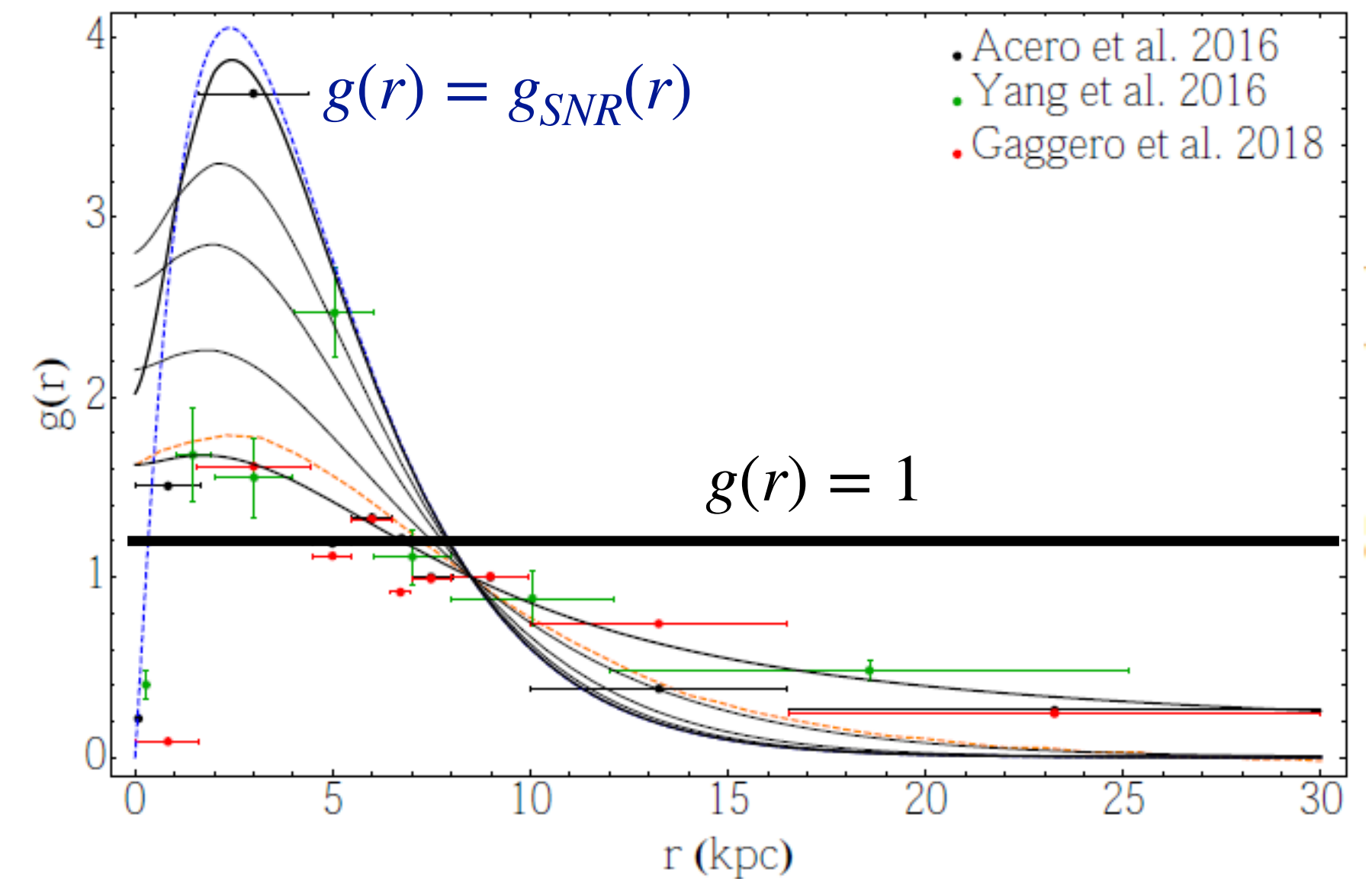
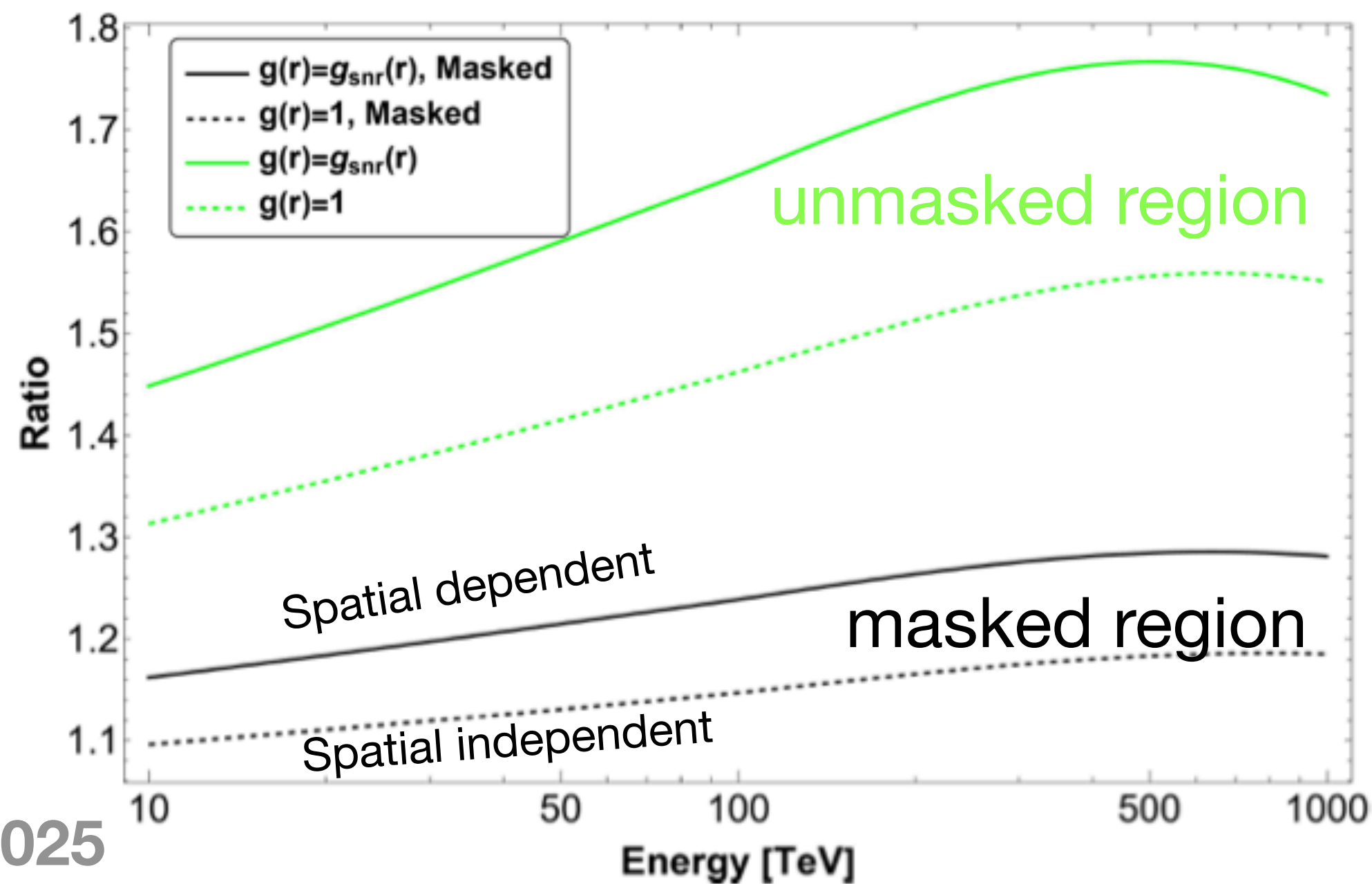
The target gas
outside the masks
is ~**Local** in the
analyzed regions

The Galactic diffuse emission

The role of the masks



The target gas outside the masks is **~Local** in the analyzed regions



The Galactic diffuse emission

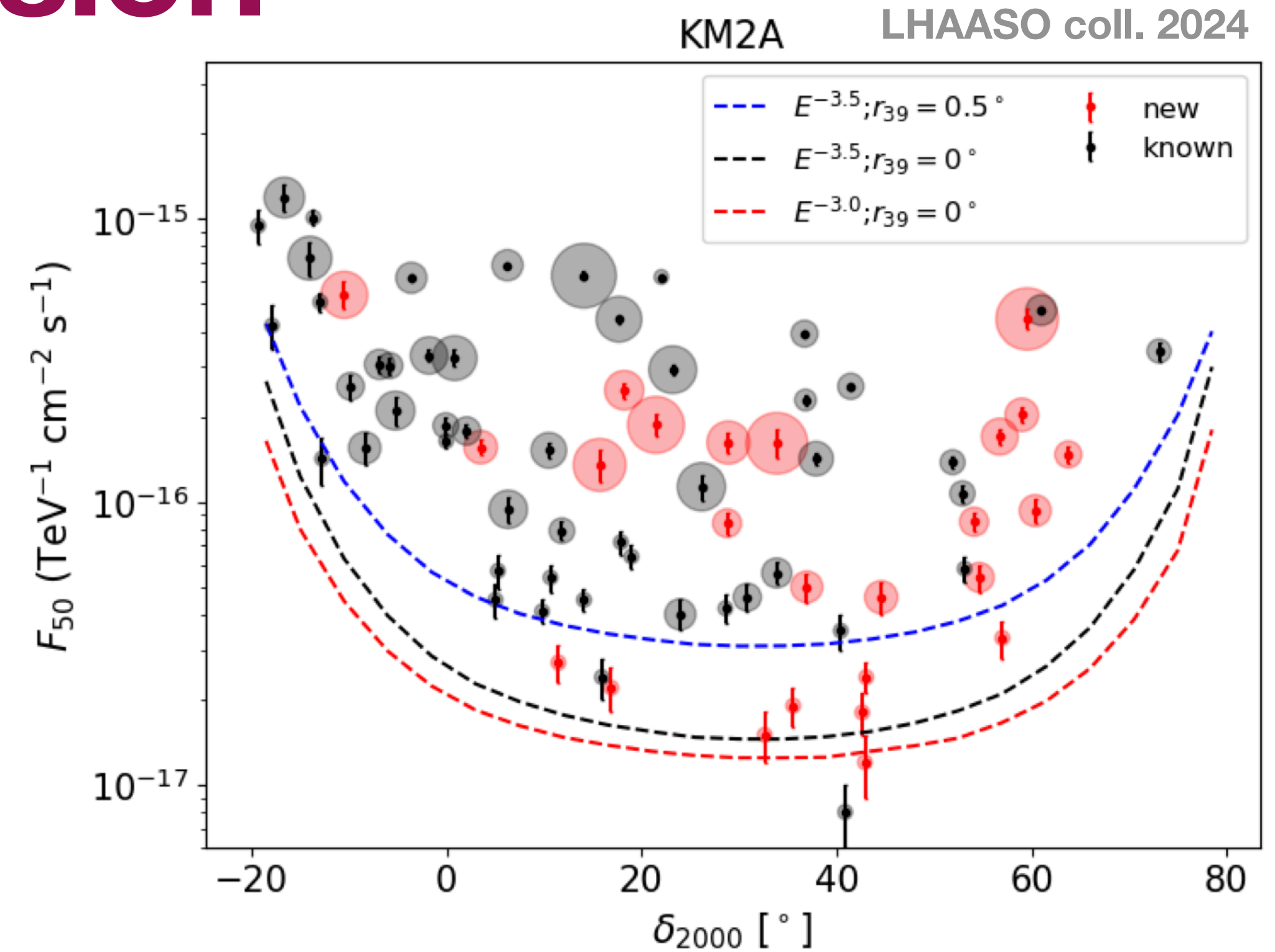
The role of unresolved sources

- **Synthetic source population**
 - Distributed as PSRs (Lorimer+2006)
 - Luminosity age dependent
 - Luminosity function tuned on H.E.S.S. catalog
 - Number $\sim 2/\text{century}$

The Galactic diffuse emission

The role of unresolved sources

- **Synthetic source population**
 - Distributed as PSRs (Lorimer+2006)
 - Luminosity age dependent
 - Luminosity function tuned on H.E.S.S. catalog
 - Number $\sim 2/\text{century}$
- Sources are considered unresolved for KM2A if $F_\gamma(50 \text{ TeV}) < F_{sens}(50 \text{ TeV})$



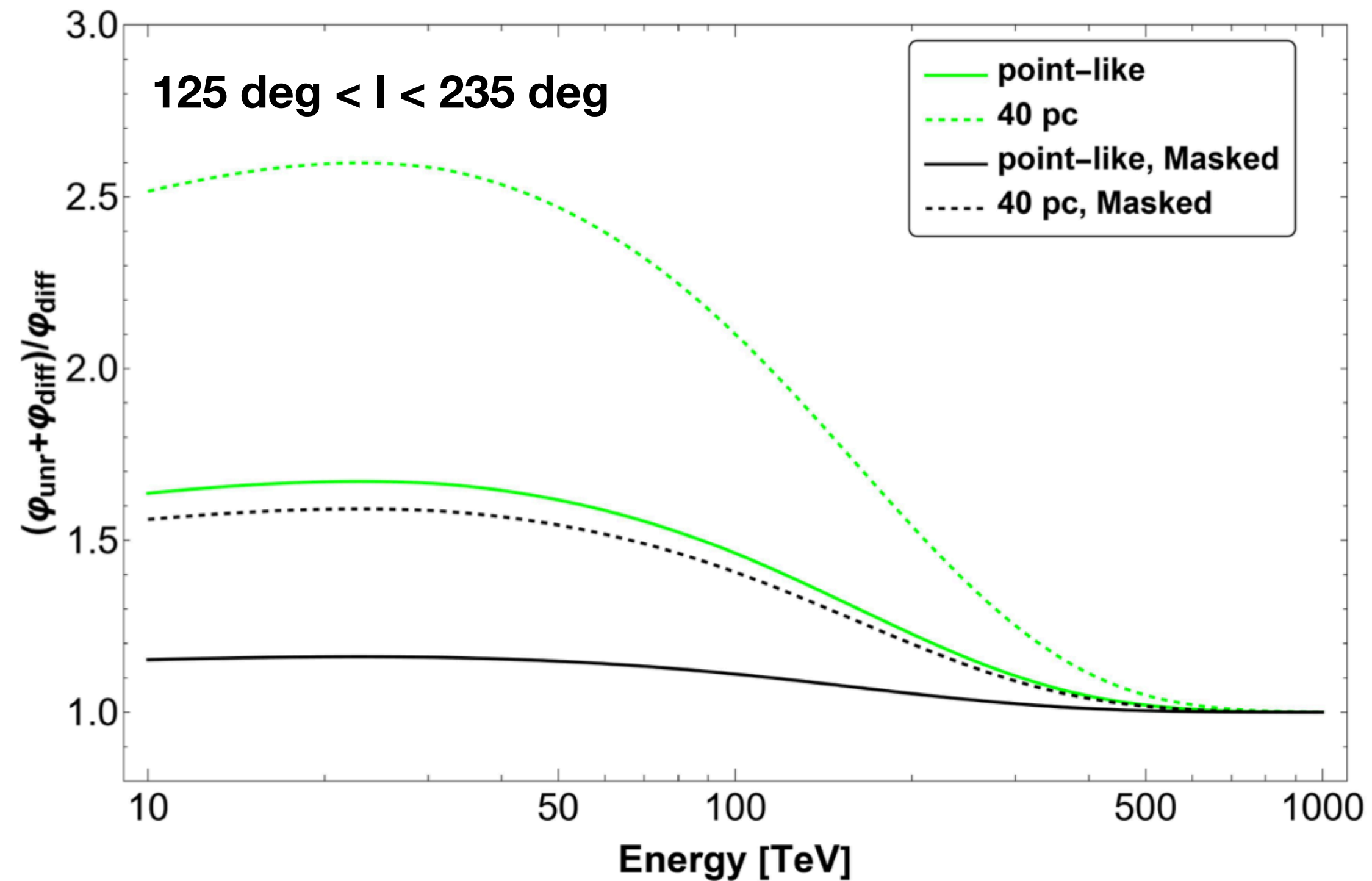
		N_R	φ_R	φ_{UNR}	$\varphi_{UNR,H}$
$15^\circ < l < 235^\circ, b < 5^\circ$	MC	84^{+9}_{-9}	$1.69^{+0.62}_{-0.43} \times 10^{-14}$	$2.82^{+0.15}_{-0.14} \times 10^{-15}$	—
	KM2A	65	1.51×10^{-14}	—	—
$15^\circ < l < 125^\circ, b < 5^\circ$	MC	72^{+8}_{-8}	$1.32^{+0.37}_{-0.33} \times 10^{-14}$	$2.56^{+0.14}_{-0.16} \times 10^{-15}$	$2.23^{+0.34}_{-0.36} \times 10^{-16}$
	KM2A	55	1.38×10^{-14}	—	—
$125^\circ < l < 235^\circ, b < 5^\circ$	MC	12^{+4}_{-4}	$2.82^{+1.8}_{-1.1} \times 10^{-15}$	$2.53^{+0.46}_{-0.35} \times 10^{-16}$	$2.08^{+0.49}_{-0.34} \times 10^{-16}$
	KM2A	10	1.30×10^{-15}	—	—

$< 2\sigma$

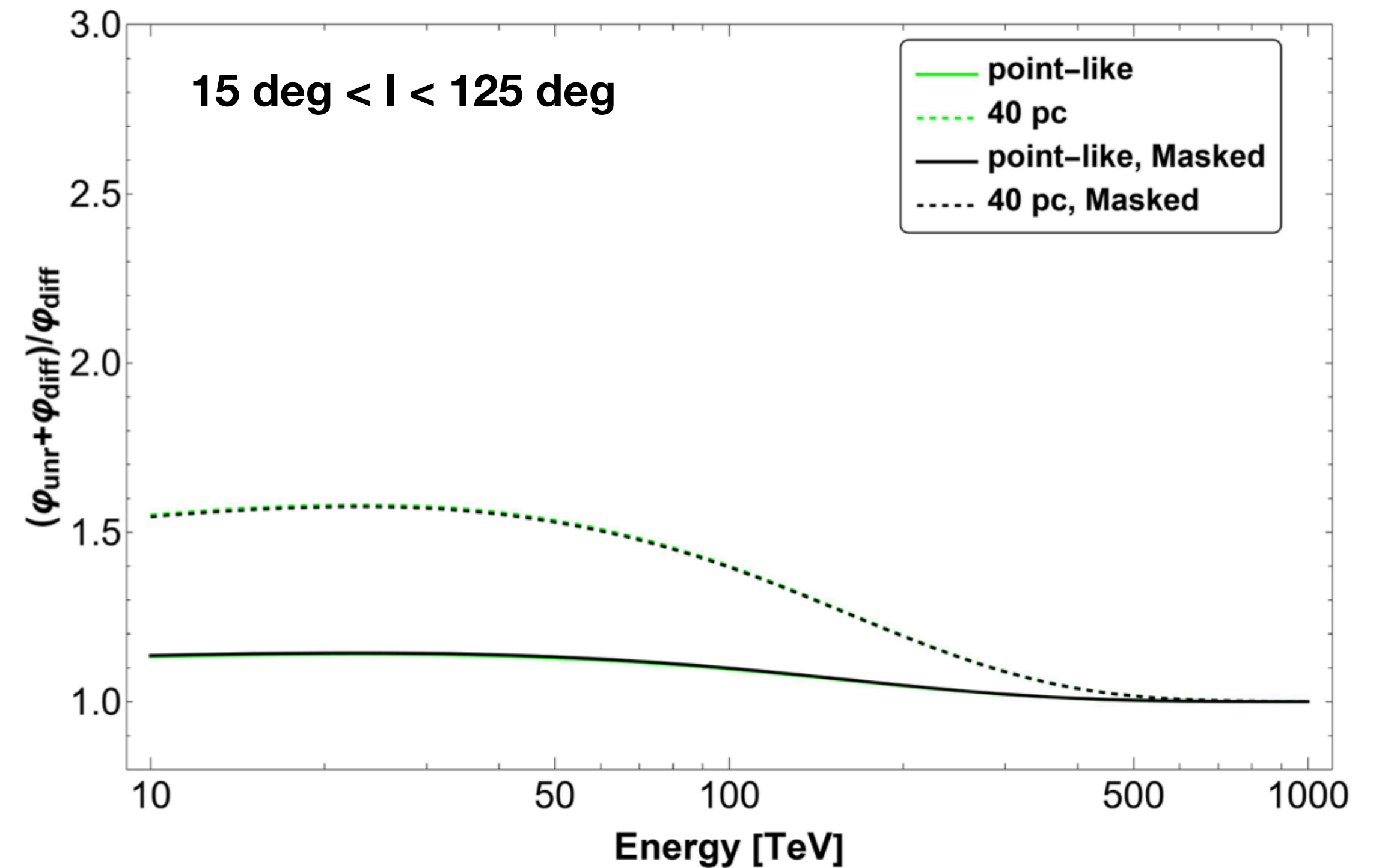
The Galactic diffuse emission

The role of unresolved sources

Vecchiotti, GP,+2025



(a)

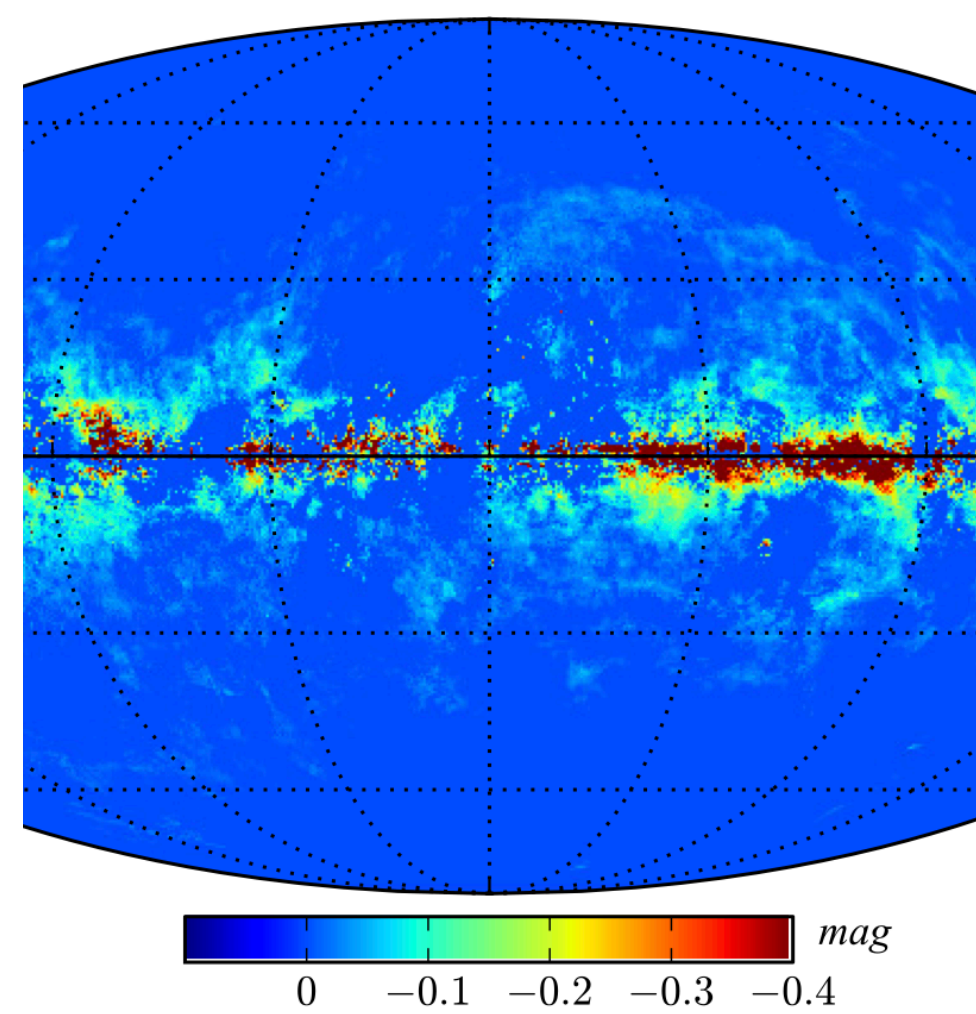


(b)

The Galactic diffuse emission

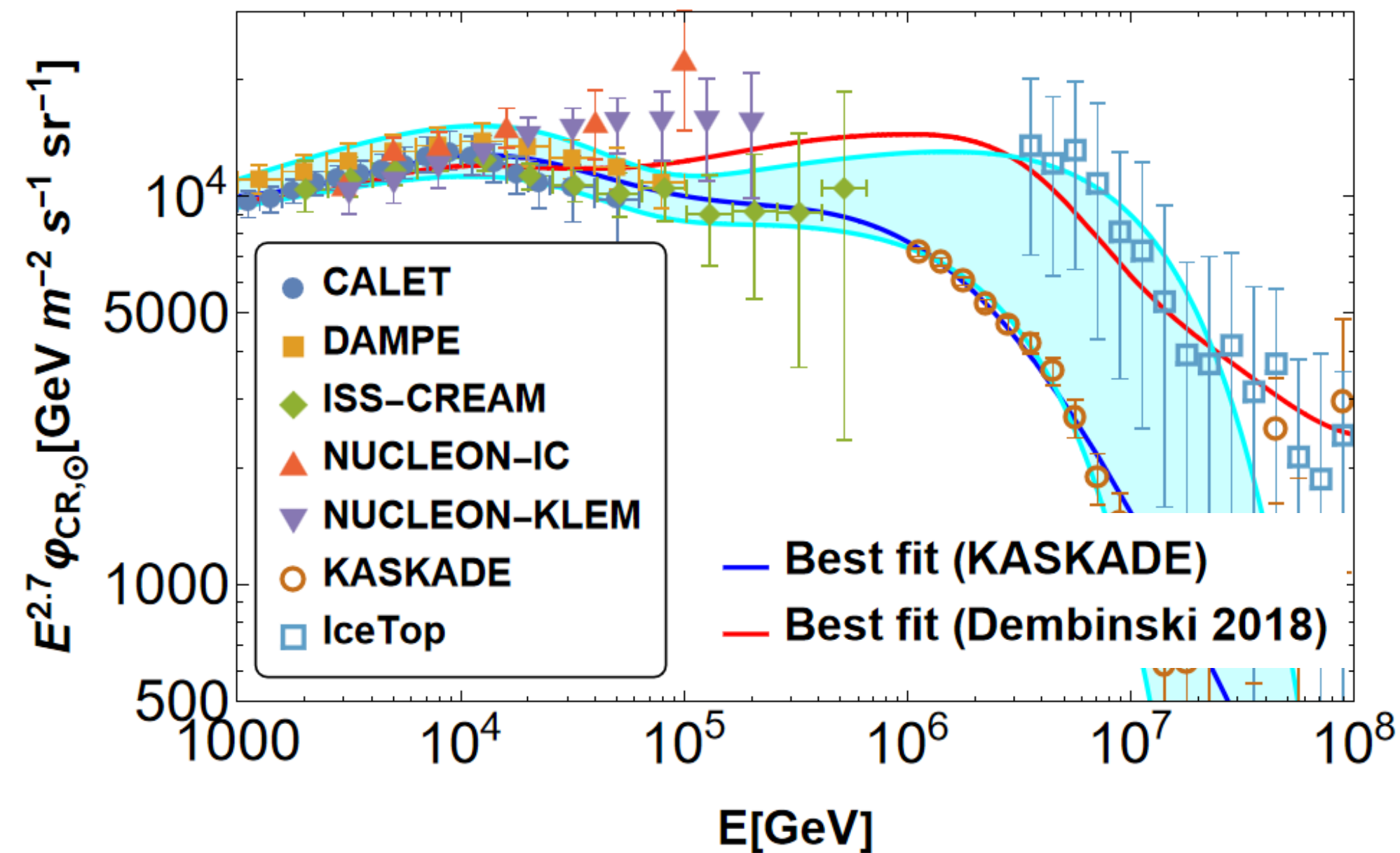
Intrinsic uncertainties

Gas uncertainties



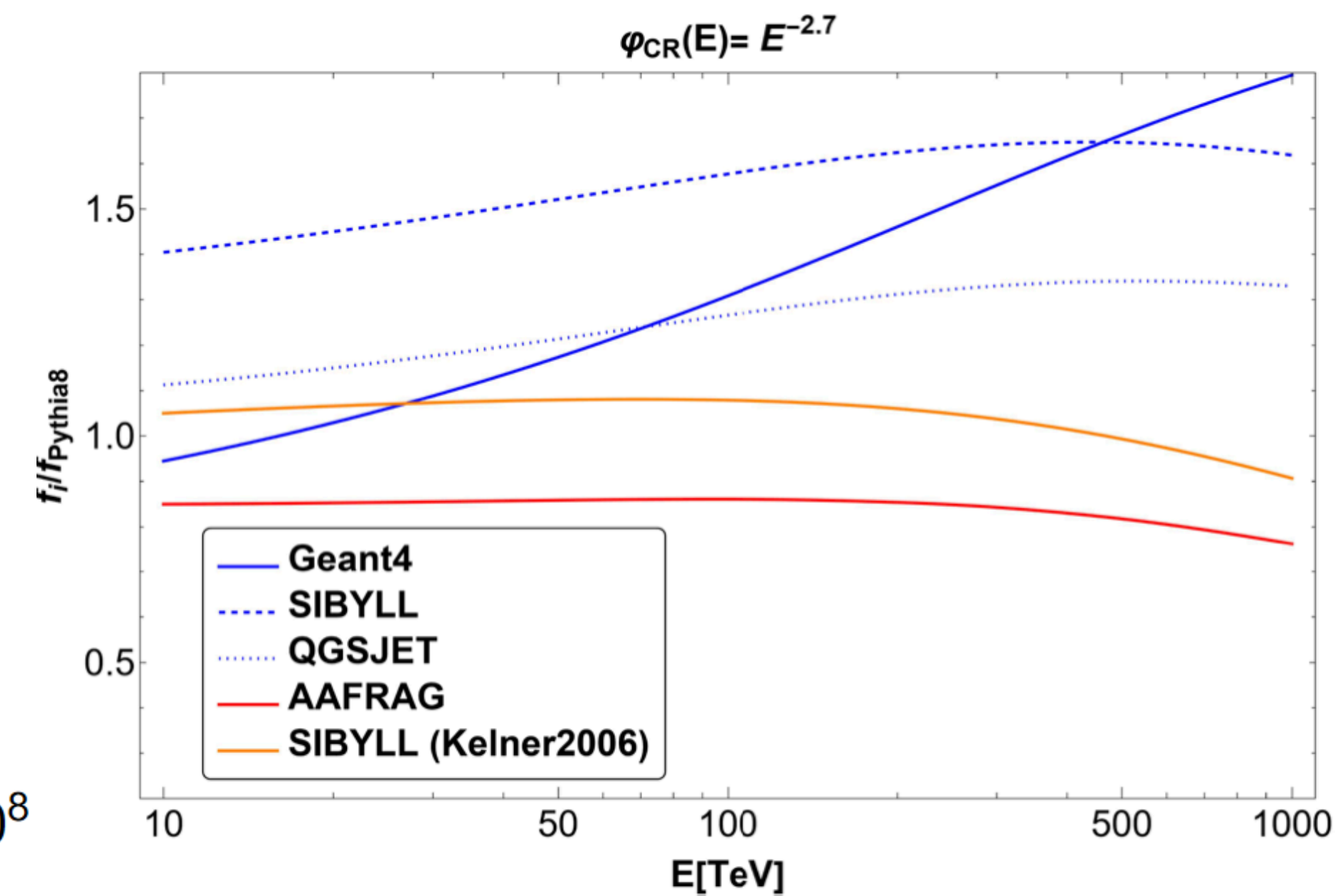
~ 20/50% difference with different gas tracers

CR spectrum uncertainties



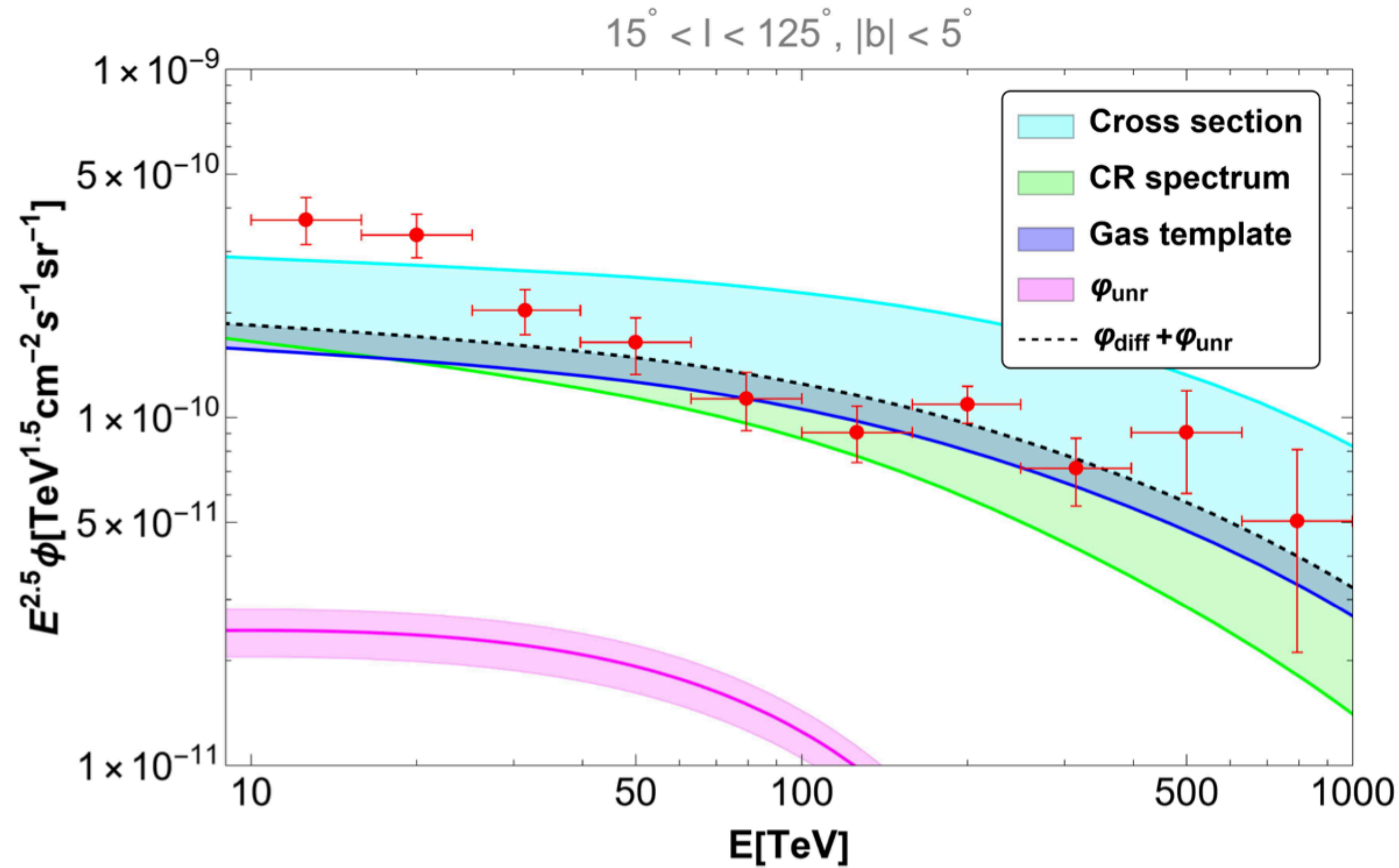
~ 10/20% effect on the DGE

Cross section



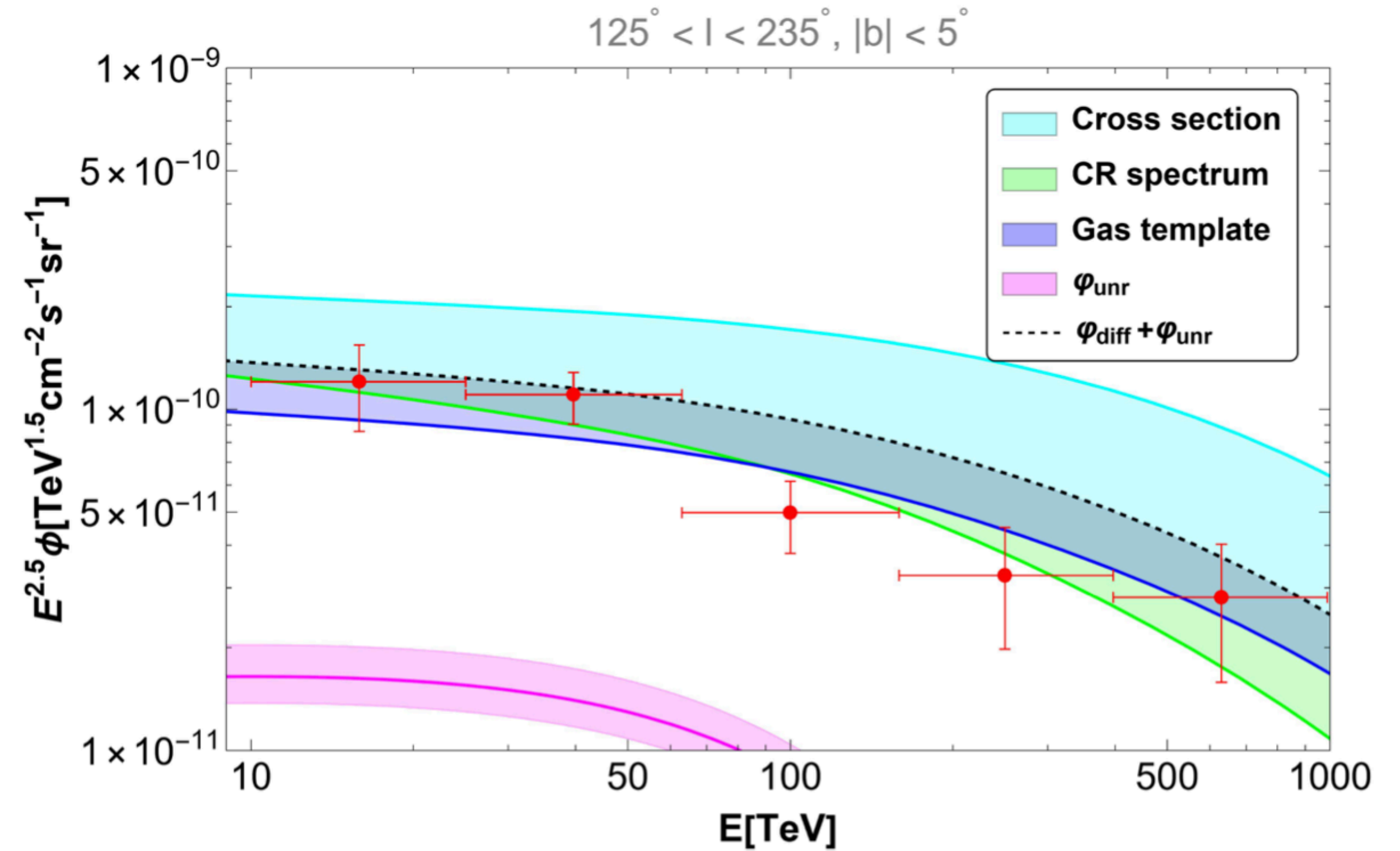
Up to 150% effect on the DGE depending on energy

The Galactic diffuse emission



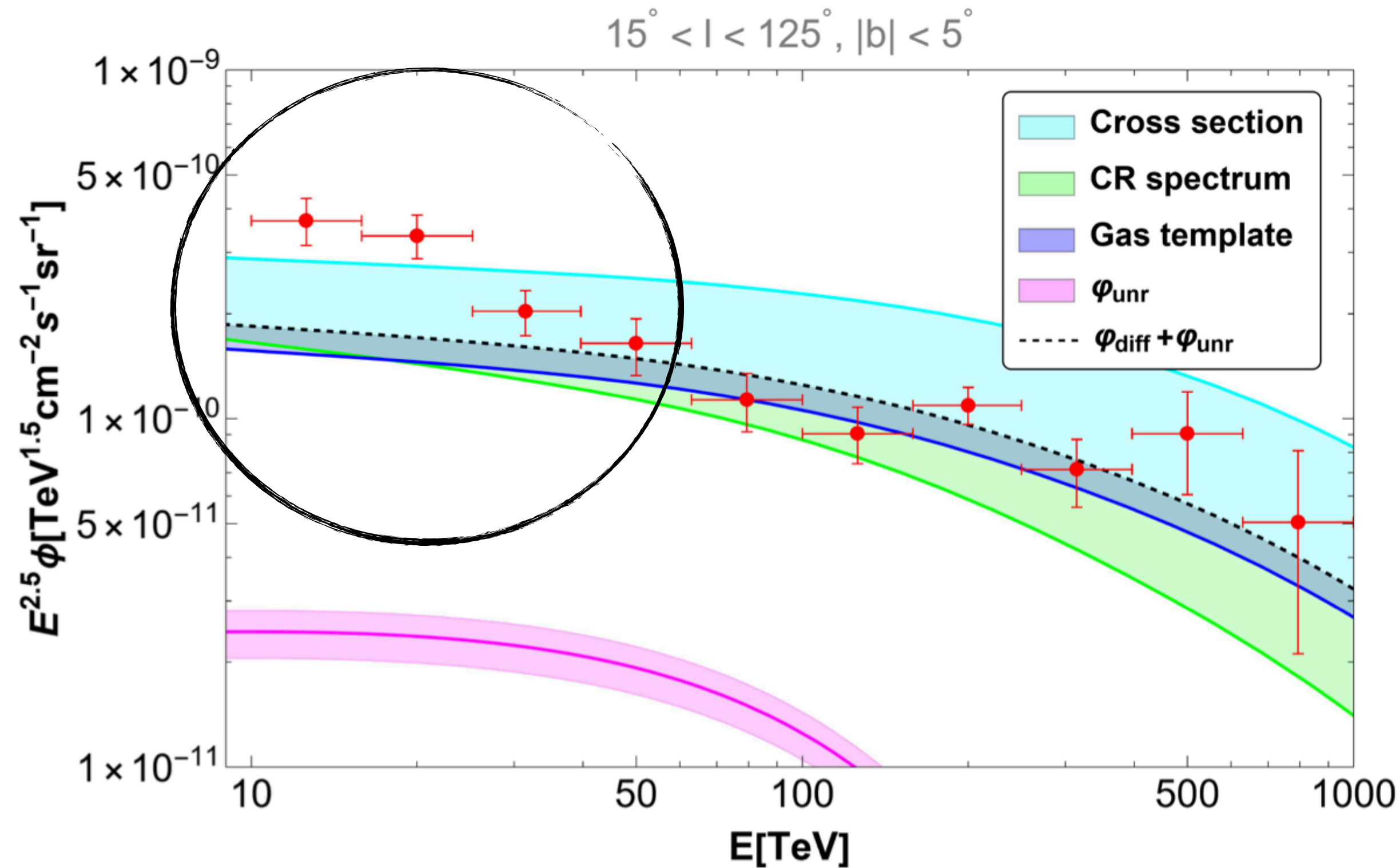
(a)

Vecchiotti, GP,+2025



(b)

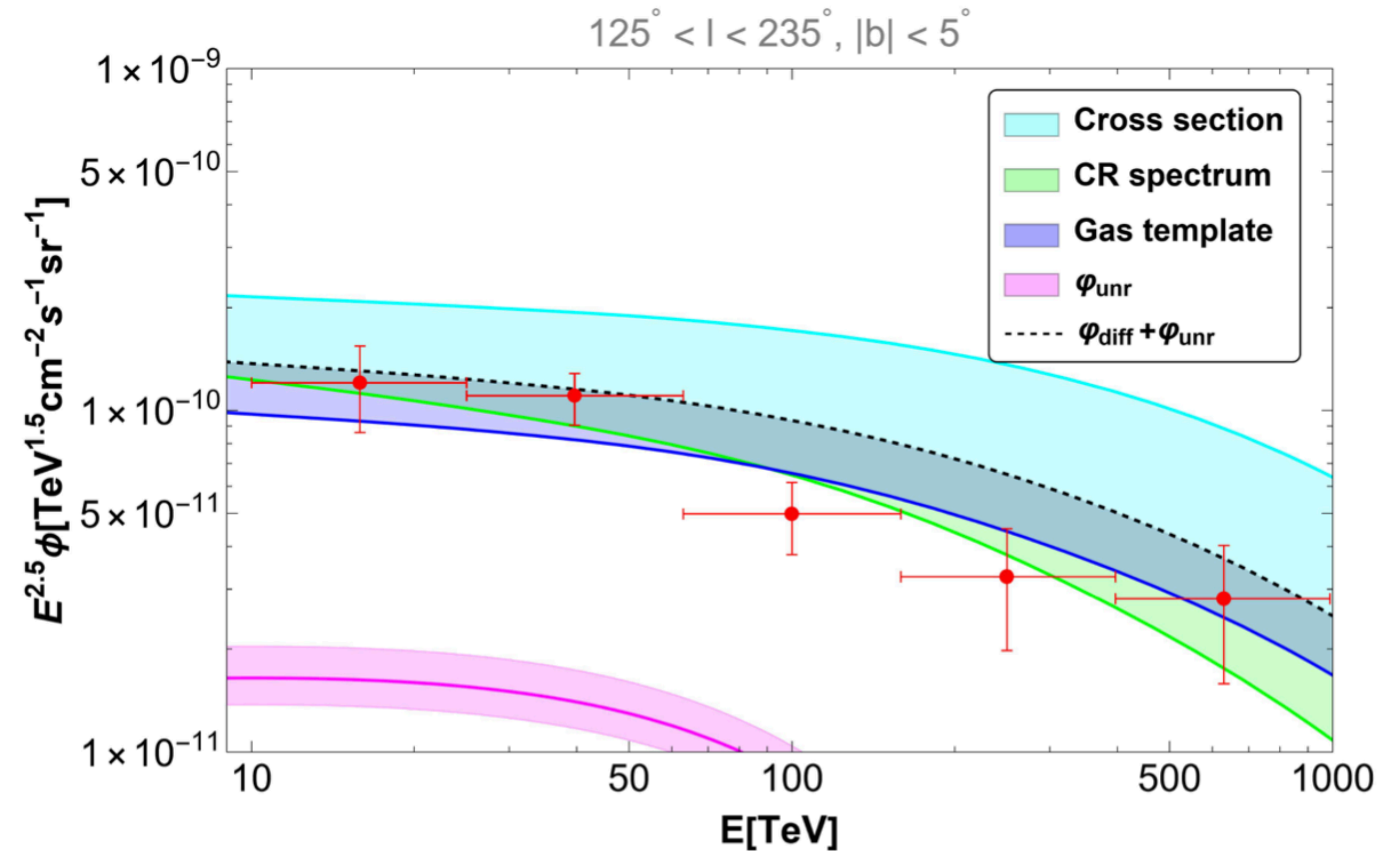
The Galactic diffuse emission



(a)

An excess is still there

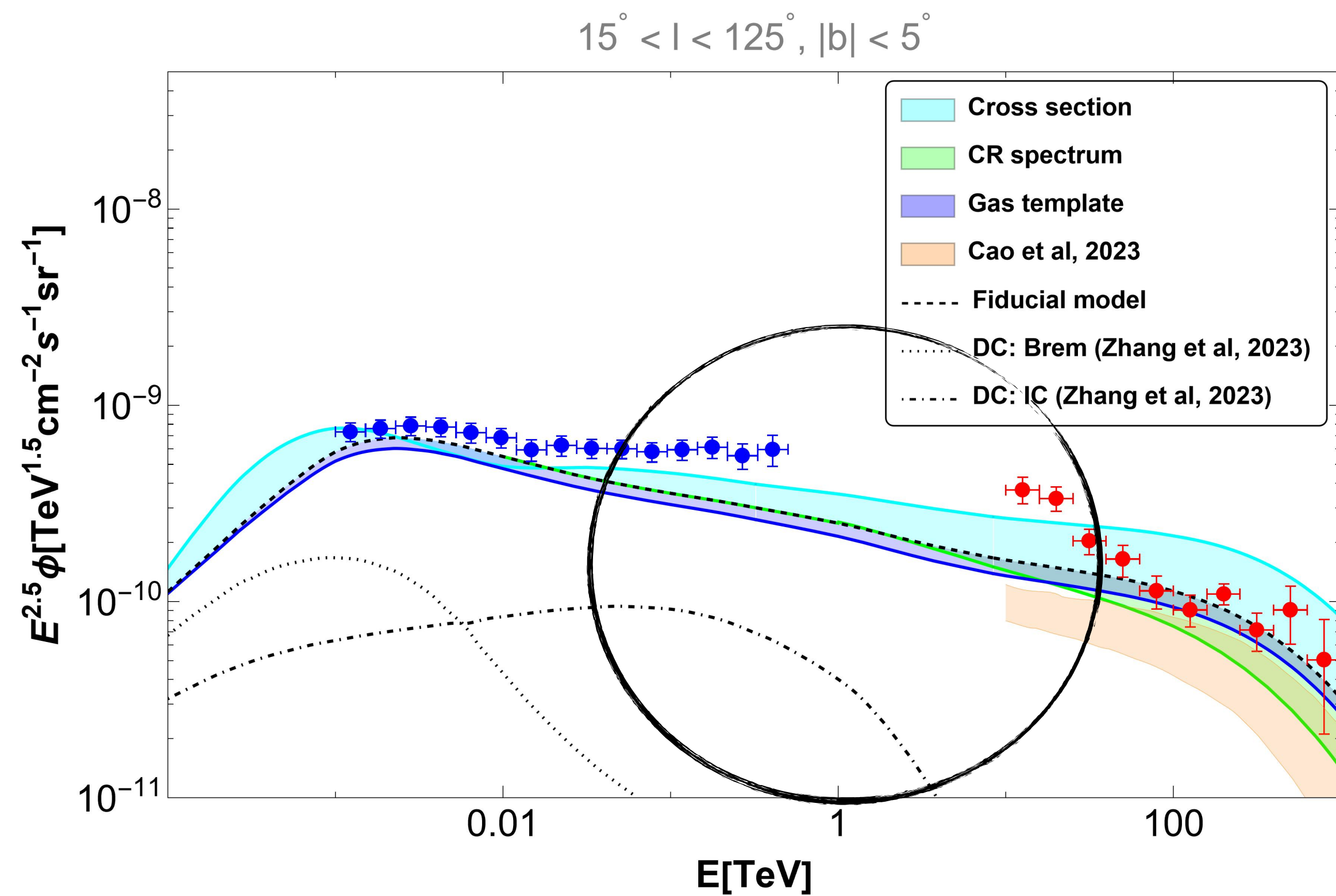
Cannot be accounted by all these effects incl. a PSRs unresolved population



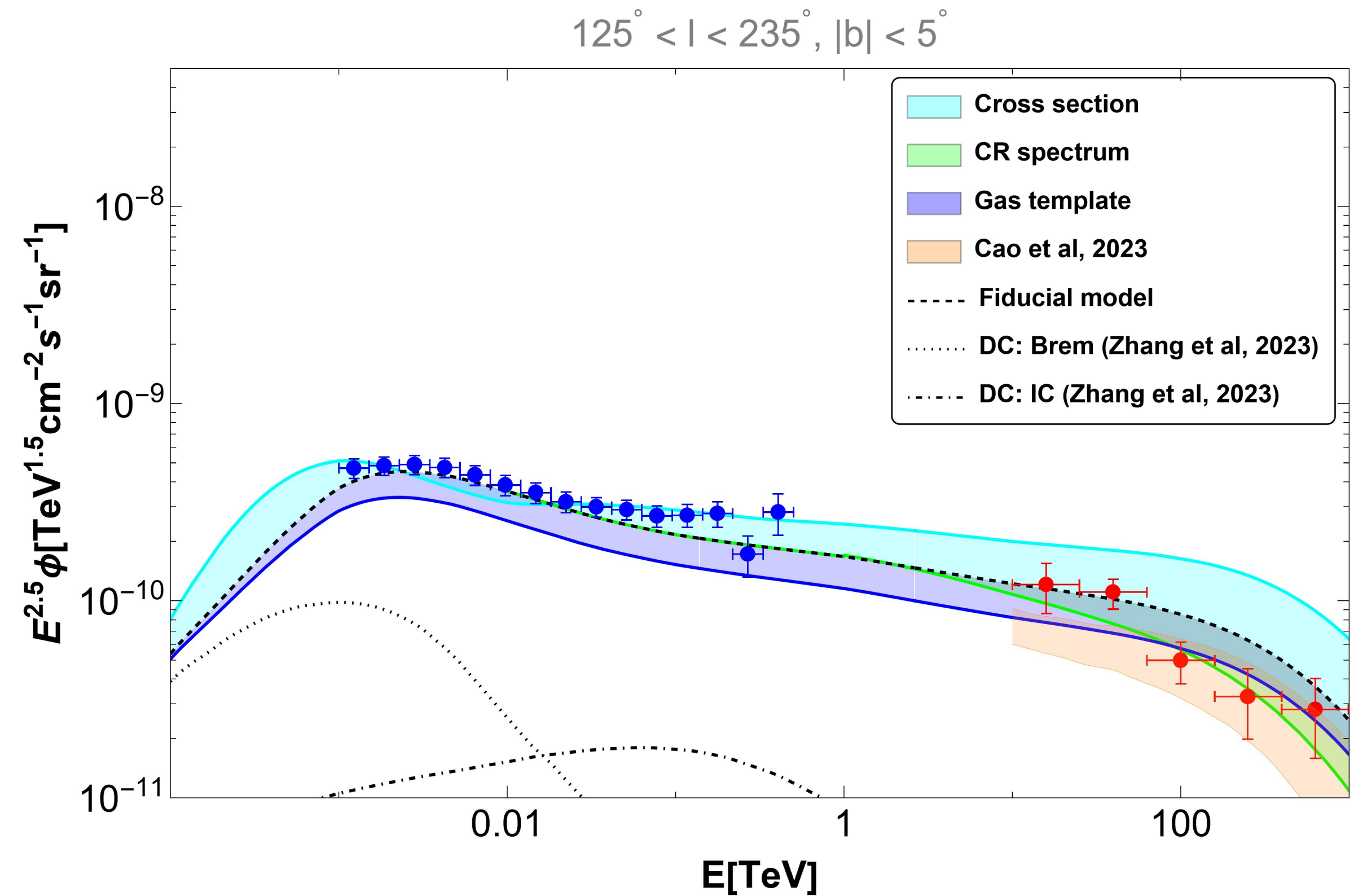
(b)

Vecchiotti, GP,+2025

What else?



Vecchiotti, GP,+2025 [Adapted]



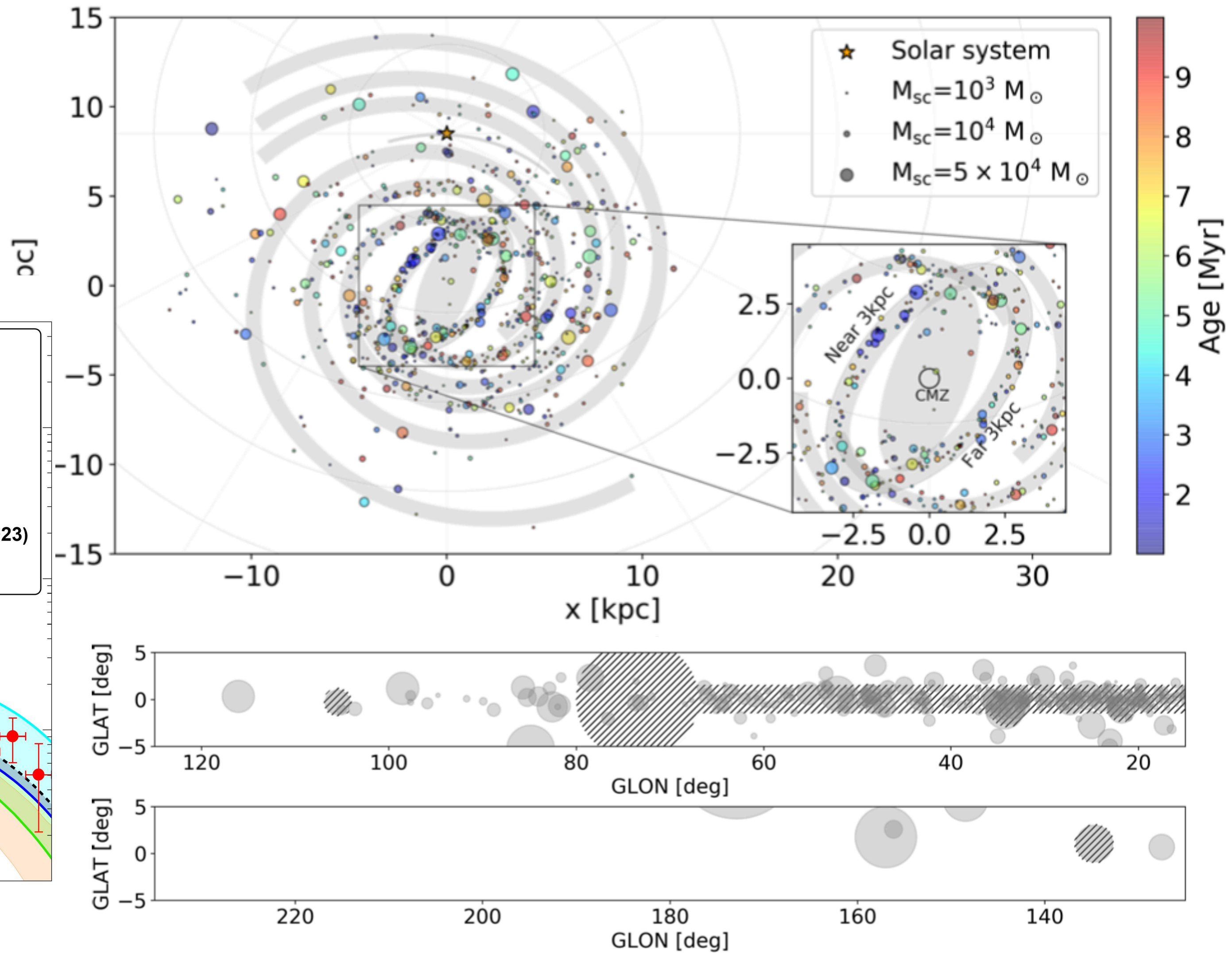
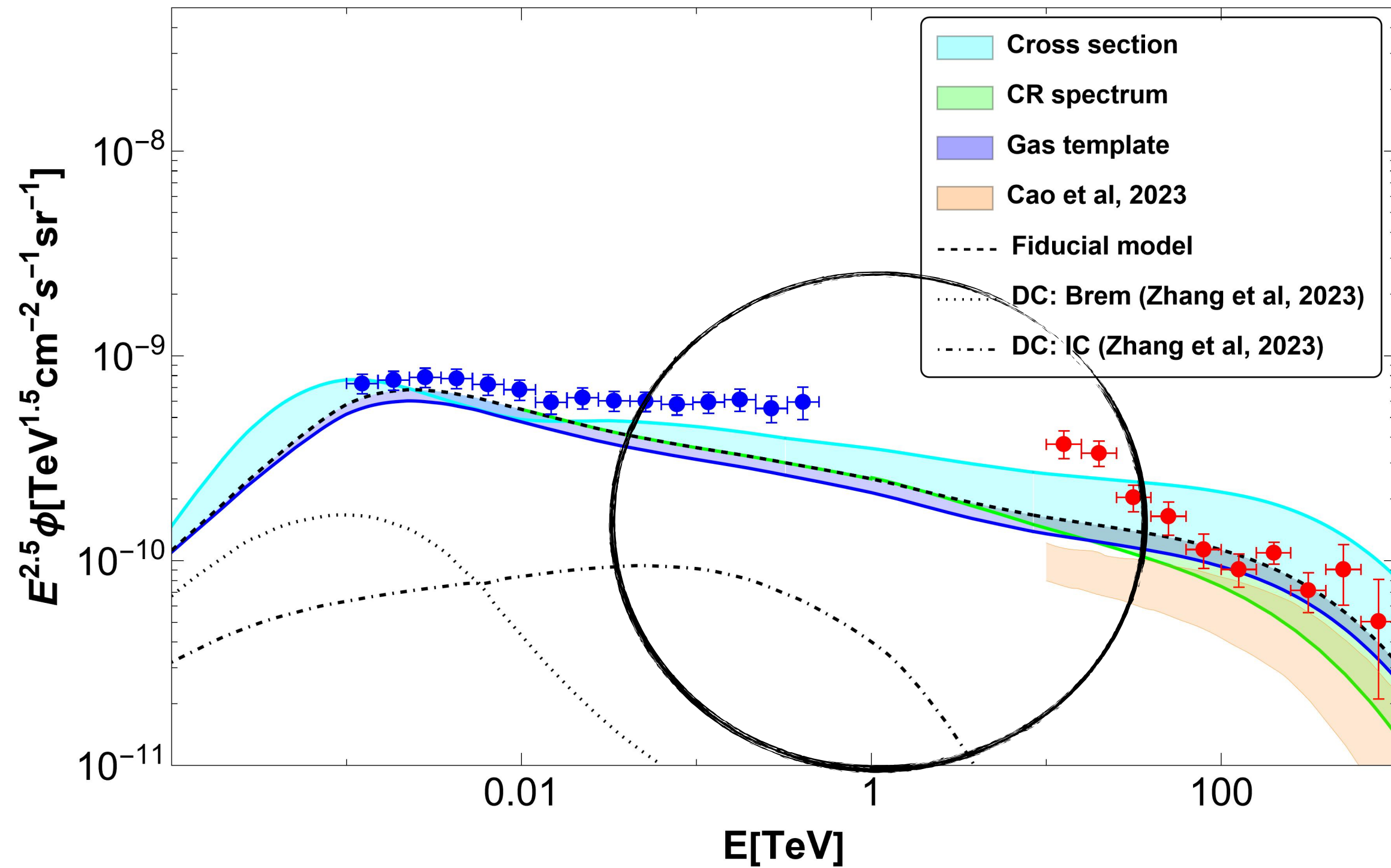
Vecchiotti, GP,+2025

An excess is still there
 Cannot be accounted by all these effects incl. a PSRs
 unresolved population

What else?

The role of star clusters

$15^\circ < l < 125^\circ, |b| < 5^\circ$



Menchiari, Morlino, ... GP, +2025

Vecchiotti, GP, +2025 [Adapted]

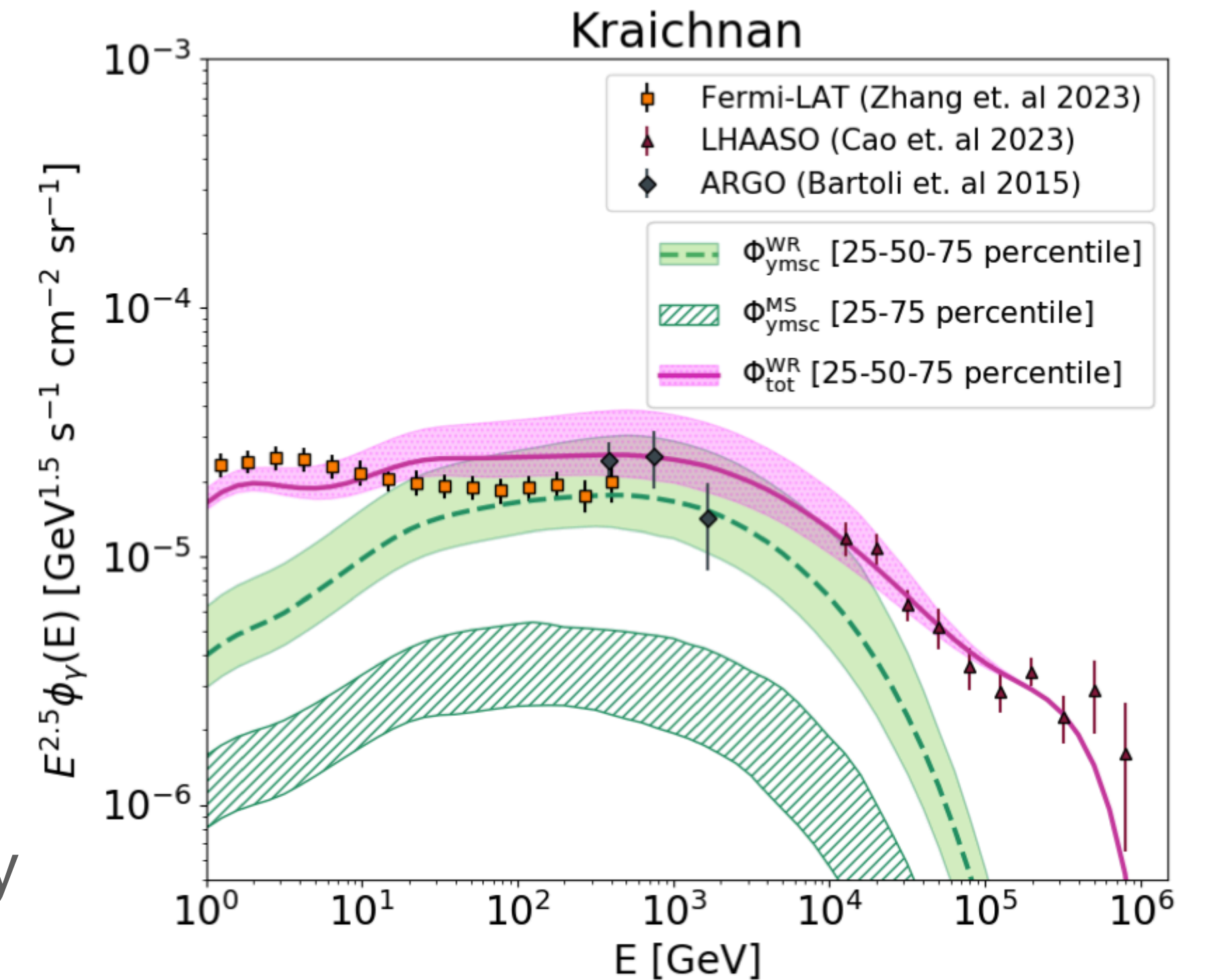
An excess is still there

Cannot be accounted by all these effects incl. a PSRs unresolved population -> **Star clusters are large and faint...**

What else?

The role of star clusters

- **Synthetic source population of SCs**
 - Spatially distributed as giant molecular clouds;
 - Acceleration computed following Morlino+2021 assuming different diffusion regimes and 10% acceleration efficiency;
 - Hadronic emission considering target of 10 cm⁻³
 - Normalized to the cluster formation rate throughout the Galaxy
 - Stellar population modeled with Kroupa's IMF for each cluster
- SCs are considered unresolved for KM2A if they are 5-sigma above background : $\sim \frac{\phi_{\gamma}(100 \text{ TeV})}{\phi_{bkg}(100 \text{ TeV})} > 5\sigma$



...Several assumptions but
...We obtain reasonable level of emission (this is not a fit)

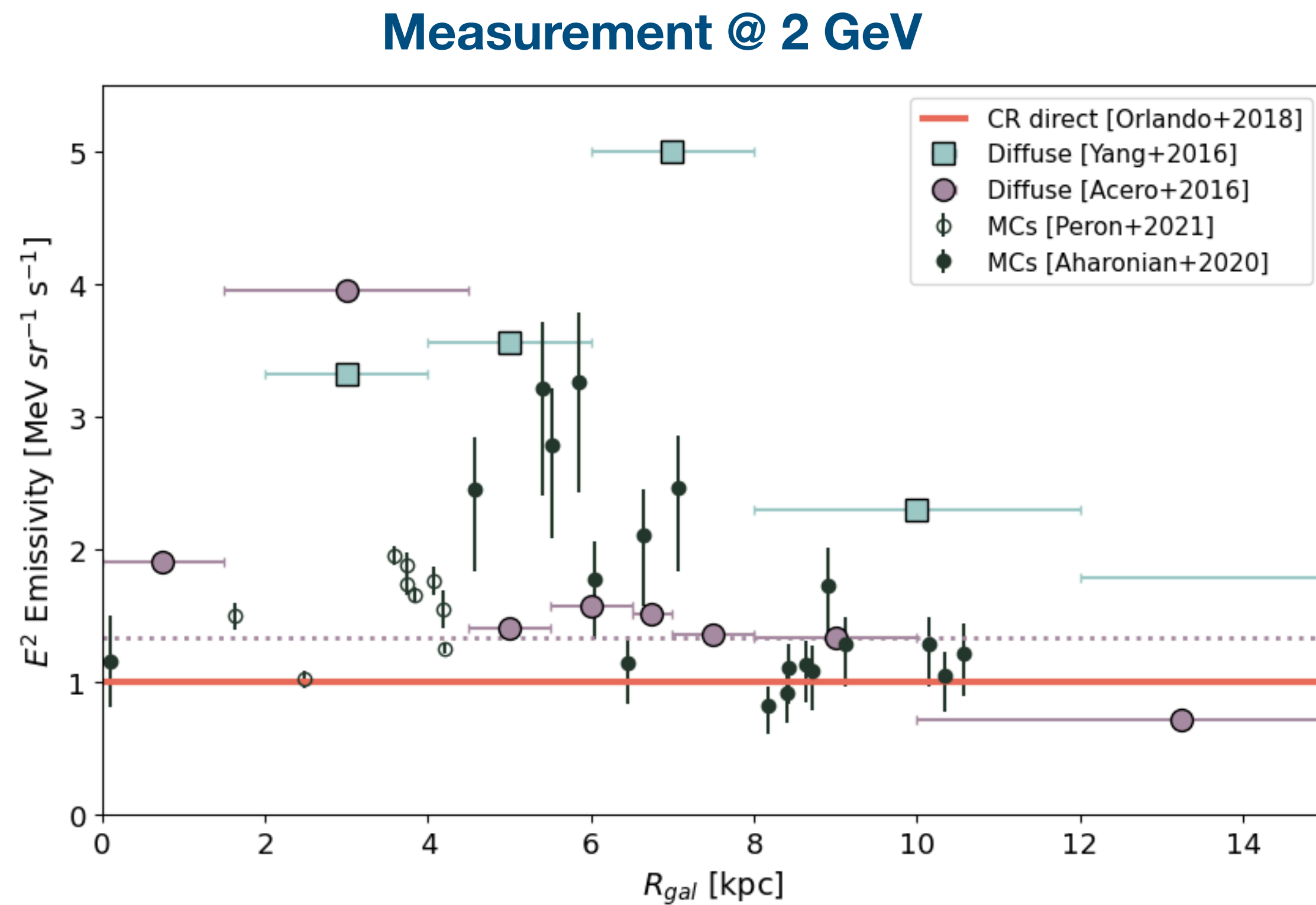
See details in Menchiari, Morlino, ..., GP, +2025

Molecular clouds

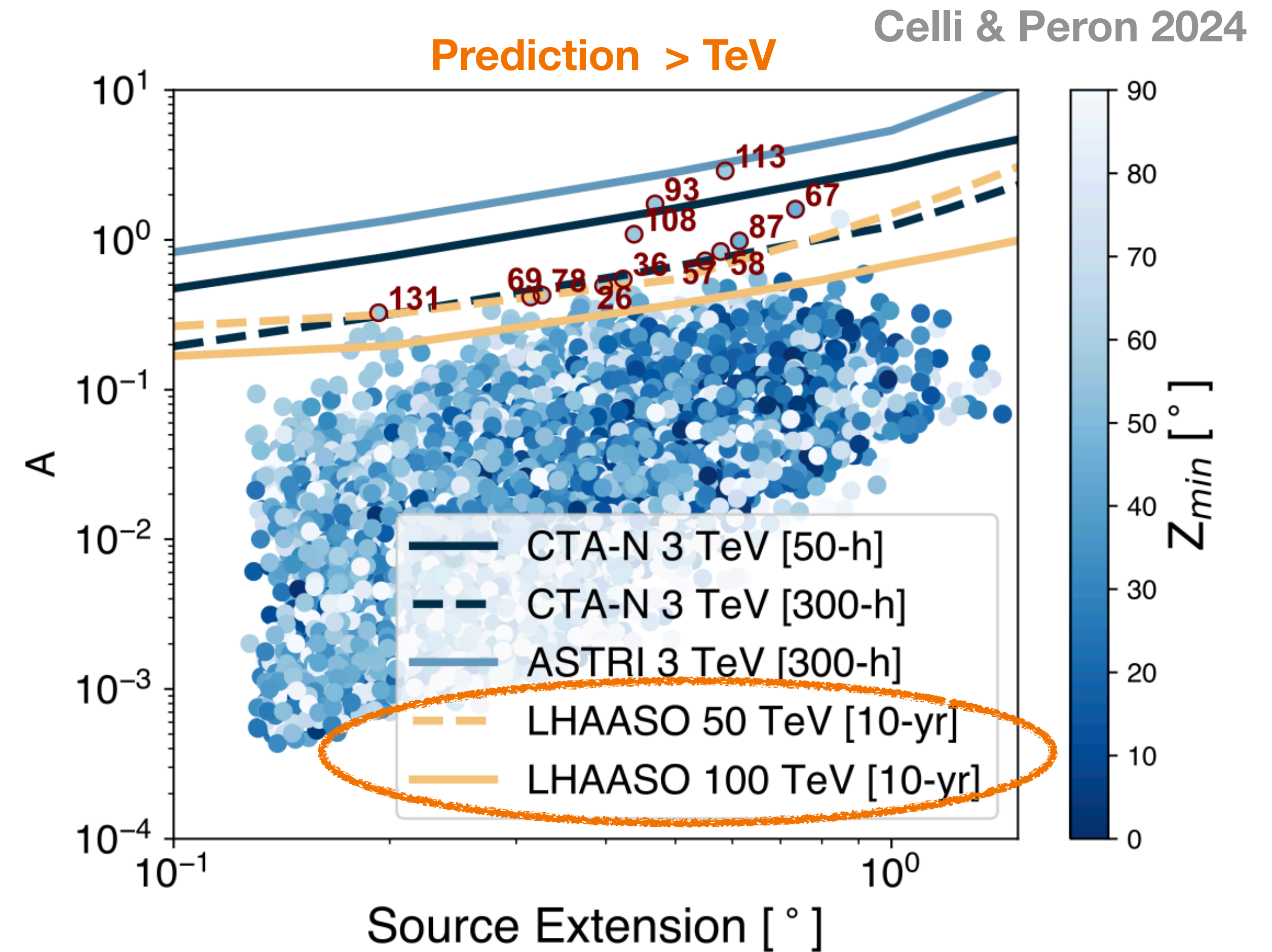
Probes for Galactic diffuse emission

Gamma rays from clouds

- Assuming local CR distribution
- $A = M_5 / d_{kpc}^2$

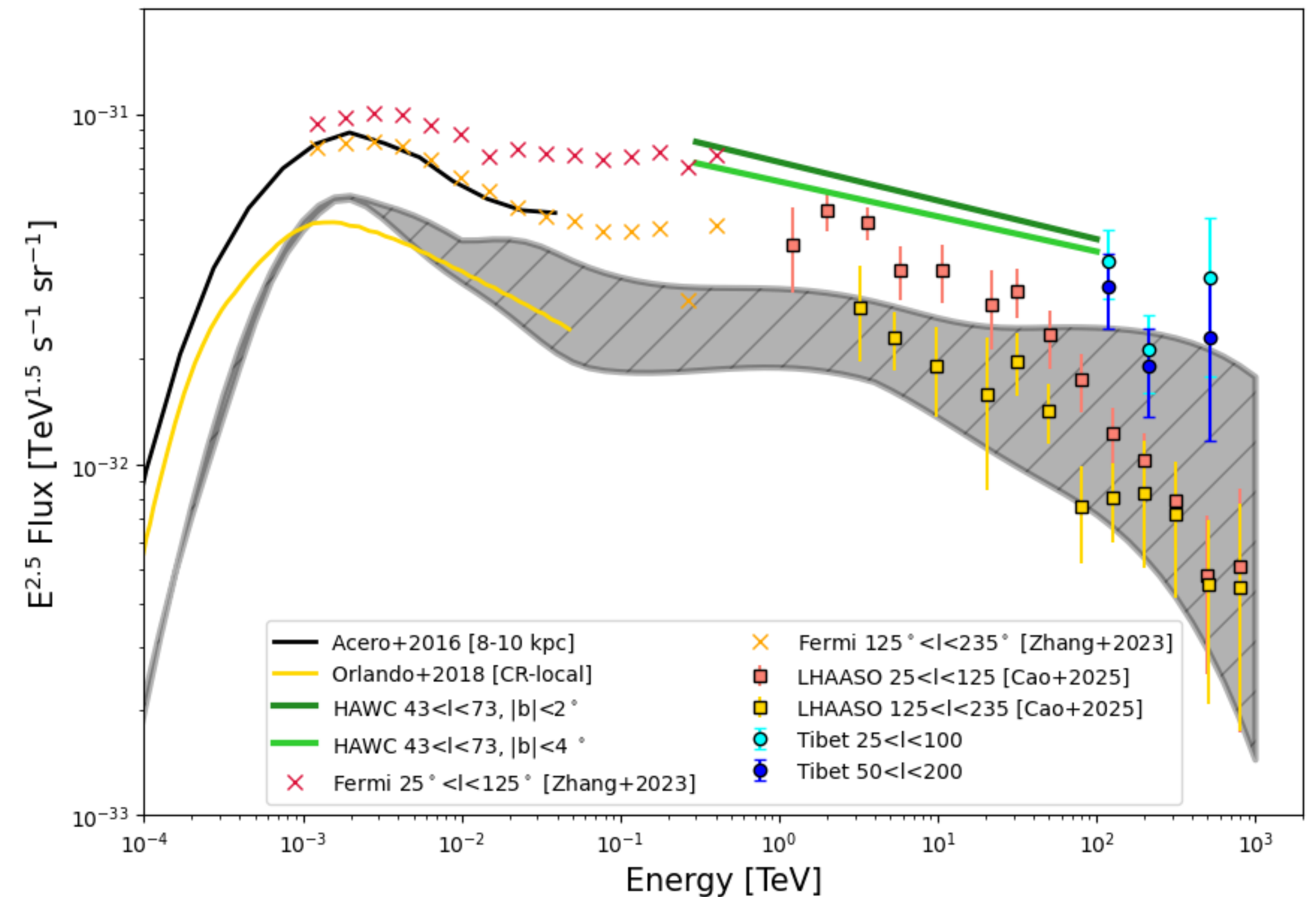


Peron++2020,2021



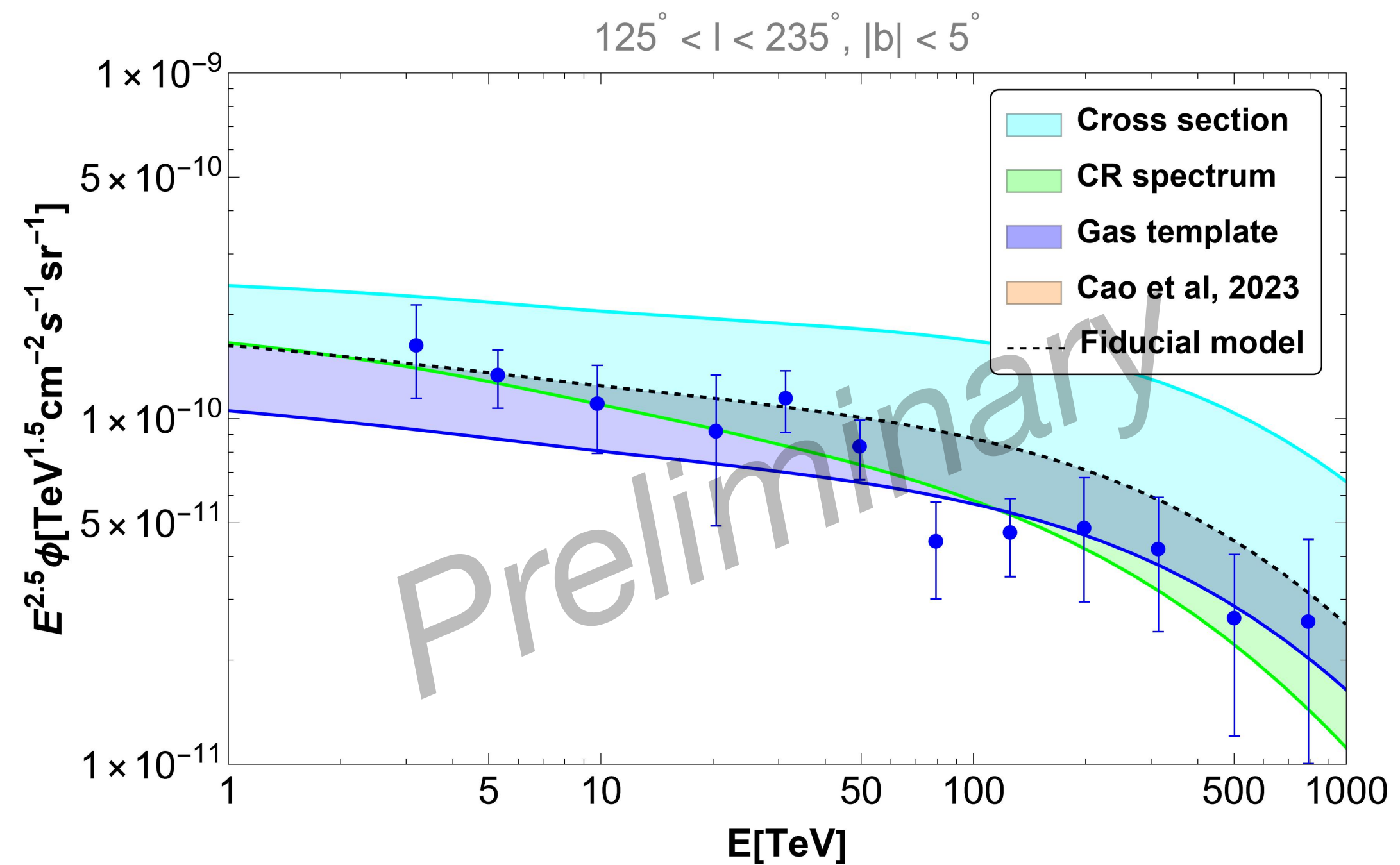
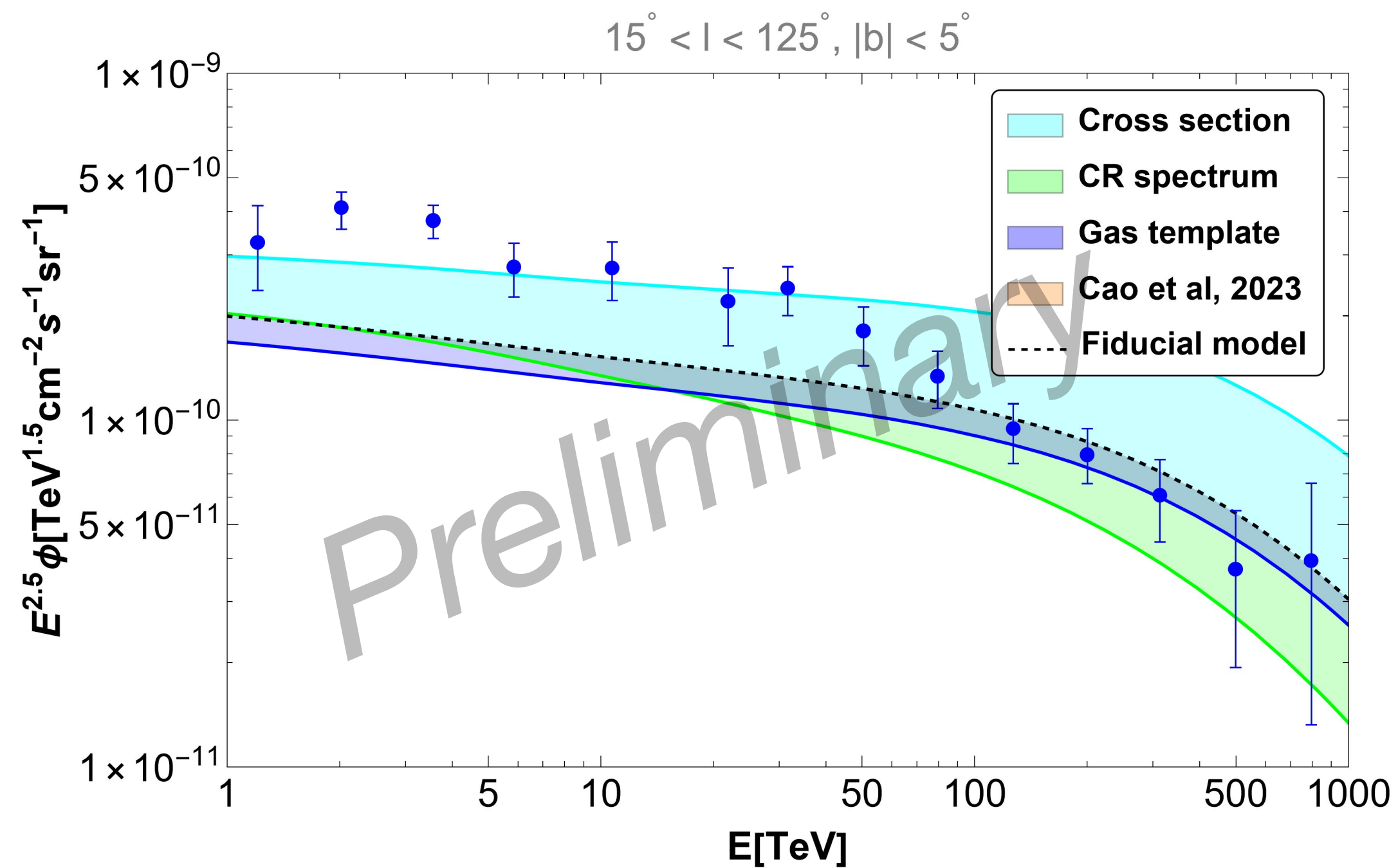
Outlook

- The galactic diffuse emission GDE encodes the information about CR distribution
- Current measurements are limited to regions where it is hard to unveil a hardening;
- The contribution of \sim point-like unresolved sources should be negligible in the area measured by LHAASO; but not in other regions of the Plane
- Star clusters could produce a substantial contribution to the GDE but the models should be tuned with more observations;
- The study of clouds can give insights into the GDE in smaller, less contaminated regions



Back-up

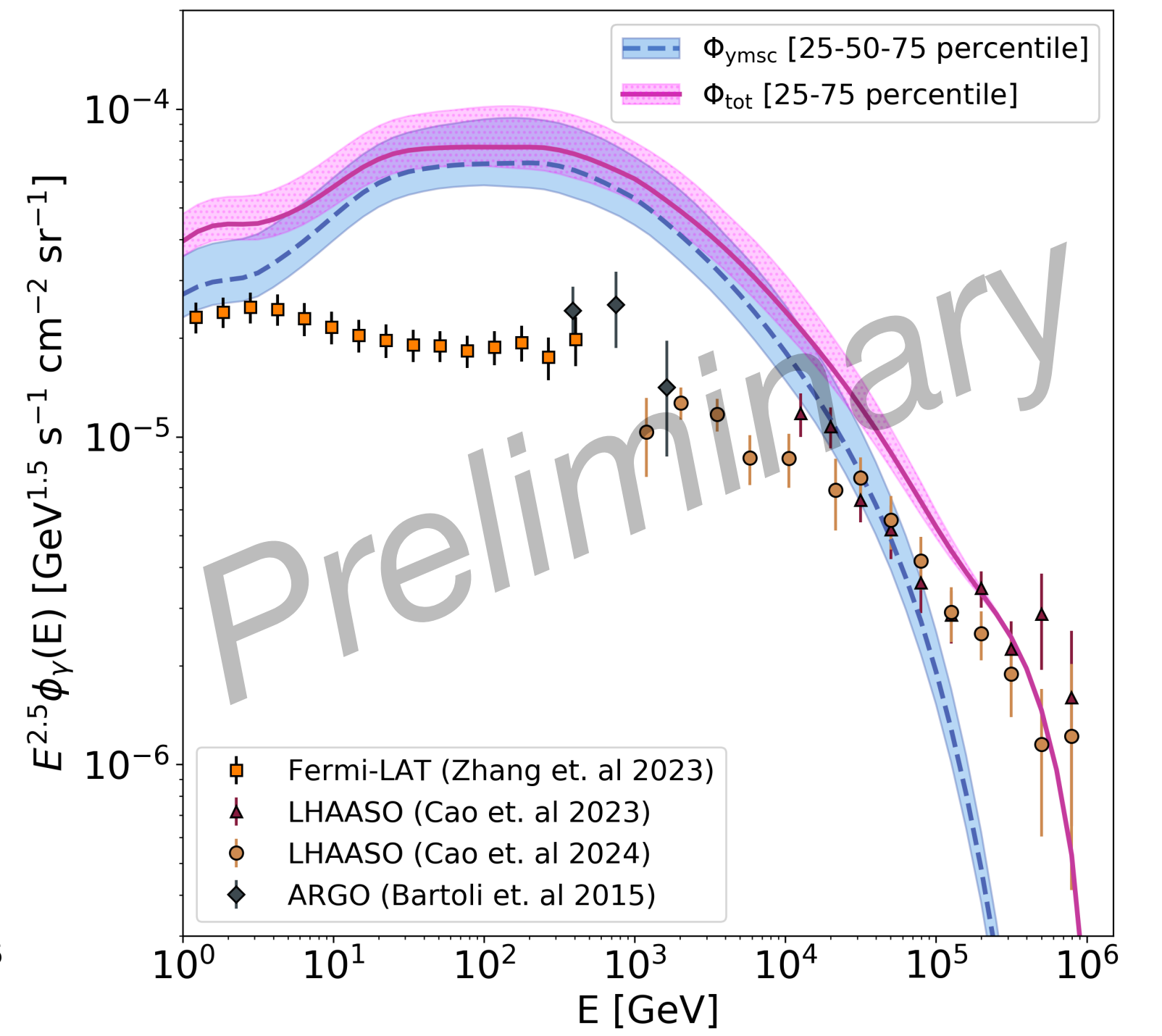
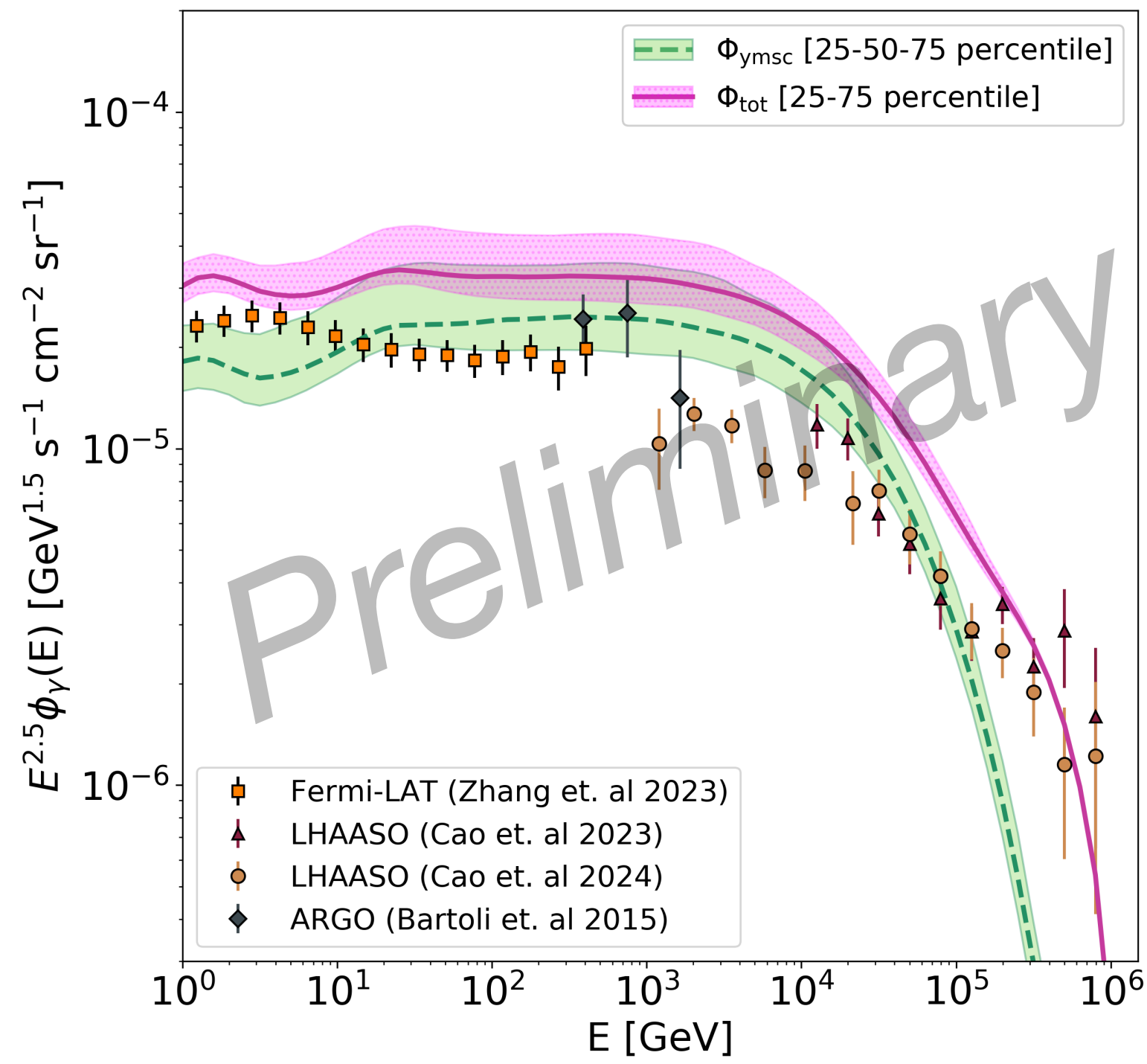
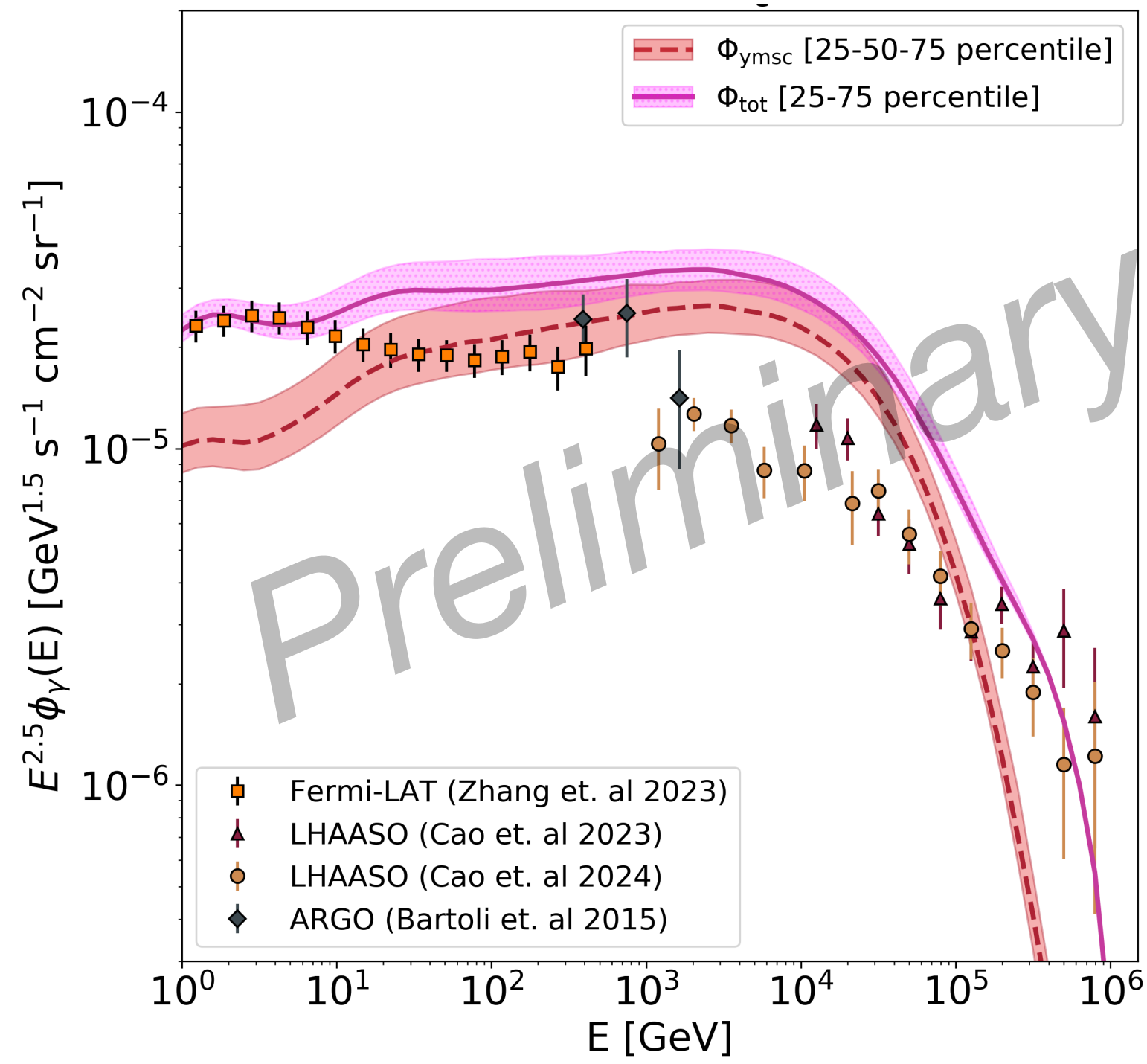
The model applied to the new dataset [WCDA+KM2A]



Vecchiotti++in prep.

Caveat: no evaluation of the unresolved sources possible yet:
need to be tuned to lower energy

SCs + SNRs in clusters



Menchiari++in prep.