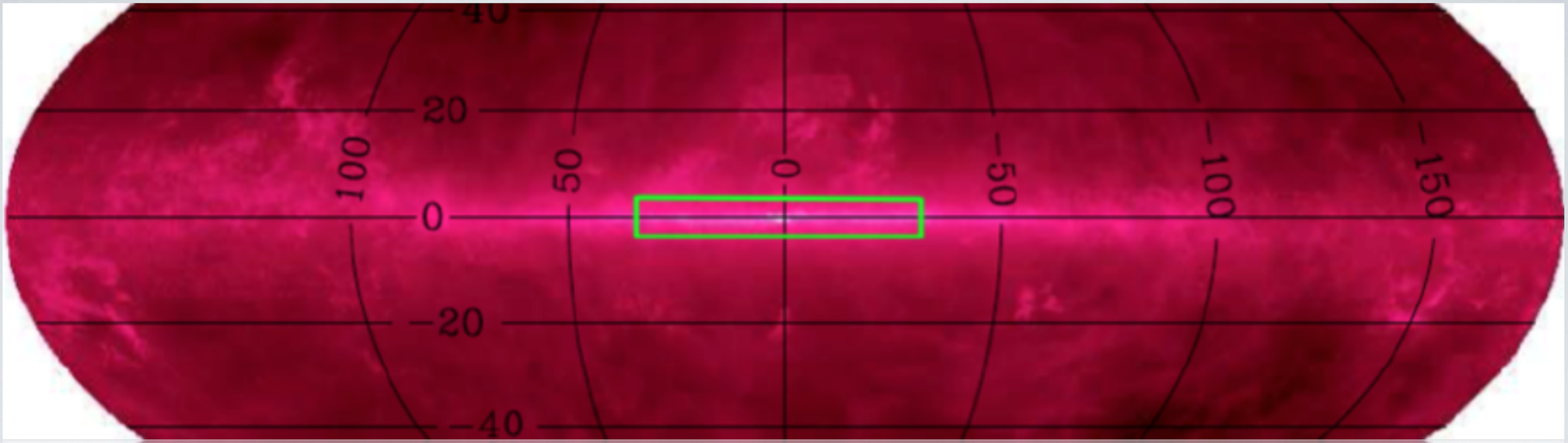


Gamma-ray and neutrino diffuse emissions of the Galaxy above the TeV with spatial dependent CR transport

D. Grasso (INFN, Pisa)
with D. Gaggero, A. Marinelli, A. Urbano, M. Valli

ICRC-2015 Id. 345

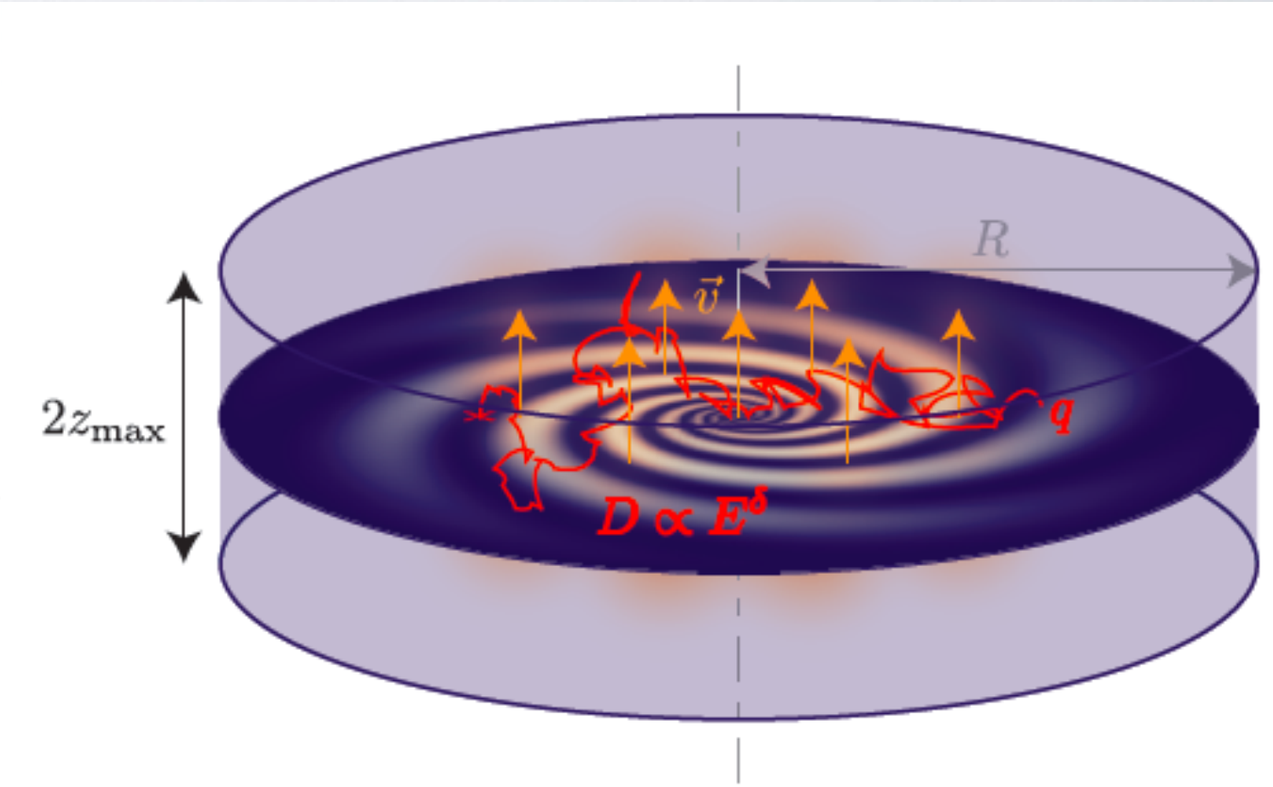
The conventional CR propagation scenario

- The diffusion coefficient $D \propto \rho^{\delta}$ and the convection velocity V_C are treated as independent on the Galactocentric distance R

ρ: particle rigidity , δ: constant

- The relevant parameters are tuned against local CR spectra and the secondary/primary ratios. These quantities however probe only few kpc's about our position.
  Propagation may behave quite differently in the inner few kpc of the Galaxy !
  This is also expected for theoretical reasons.

- Indeed while this scenario is very successful reproducing local quantities it faces some problems with γ-ray data from the inner Galactic Plane (GP) region



The Inner GP Milagro anomaly

a long standing (almost) forgotten problem

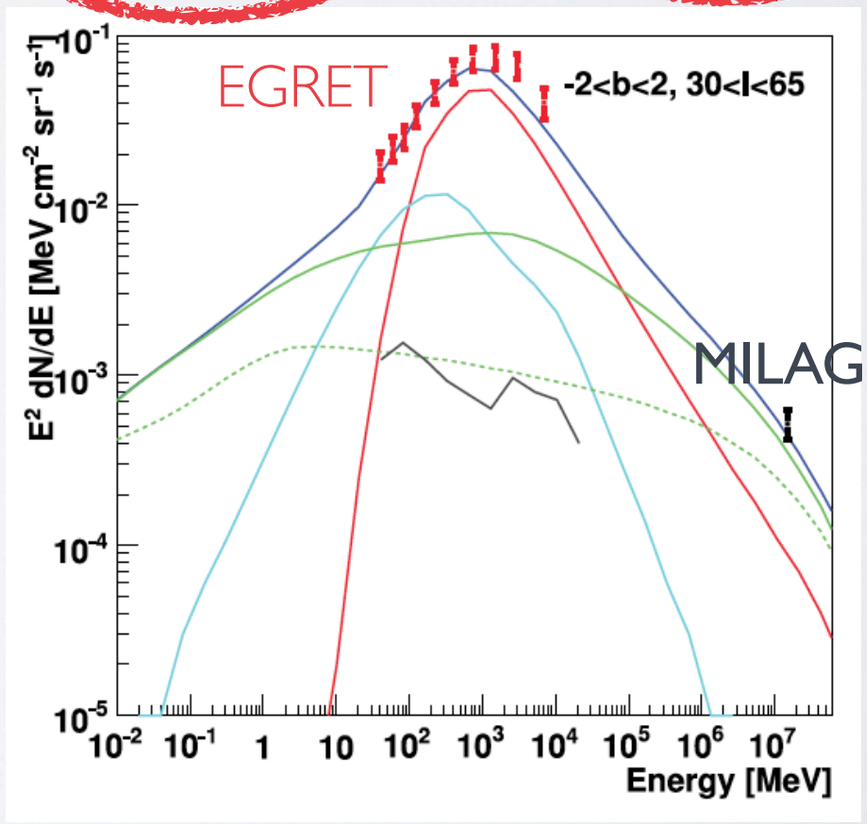
ABDO ET AL. *ApJ 2008*

TABLE 1

GAMMA-RAY EMISSION FROM THE GALACTIC PLANE AROUND 15 TeV

REGION FOR $\lvert b\rvert < 2^\circ$ (l, deg)	STATISTICAL SIGNIFICANCE σ	DIFFUSE FLUX ($\times 10^{-13}$ TeV^{-1} cm^{-2} s^{-1} sr^{-1})		
			GALPROP	
		Milagro[a]	Optimized	Conventional
30–65	5.1	$23.1 \pm 4.5^{+7.0}_{-8.0}$	20.0	4.9

- the measured flux is 5 times (4 σ) larger than computed with the conventional model
- an optimized model (augmented IC contribution) - proposed to account for the EGRET GeV excess - was found to match Milagro



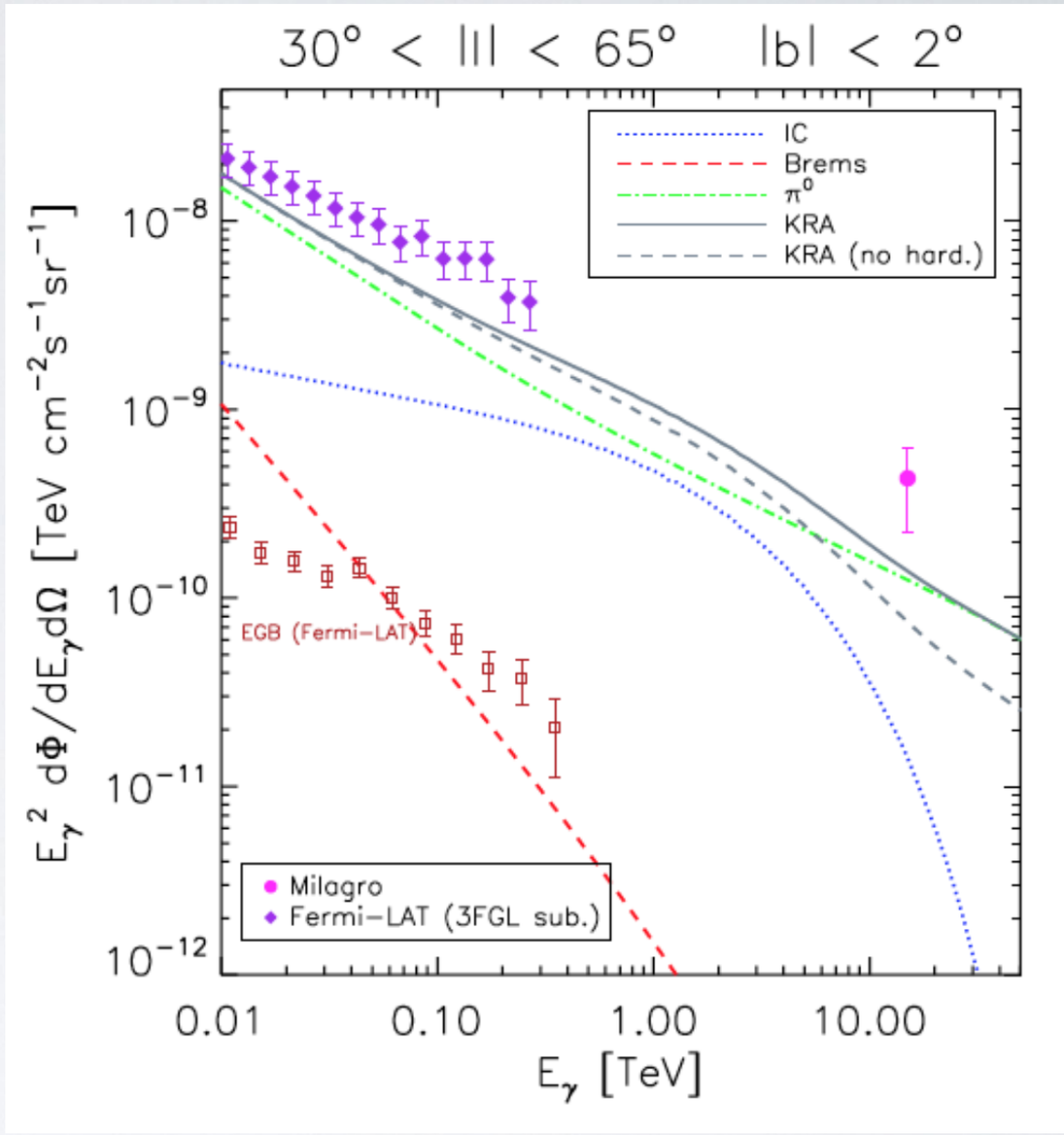
The Inner GP: Milagro anomaly

the current situation

- Fermi-LAT excluded the GeV excess and the optimized model
  Fermi-LAT coll. PRL 2009

- conventional models tuned against local CR observables and matching the "full-sky" Fermi-LAT diffuse emission do not match Milagro !

- the problem holds even assuming that the p and He spectral hardening at ~ 250 GeV (required to match PAMELA and AMS-02 and CREAM data)

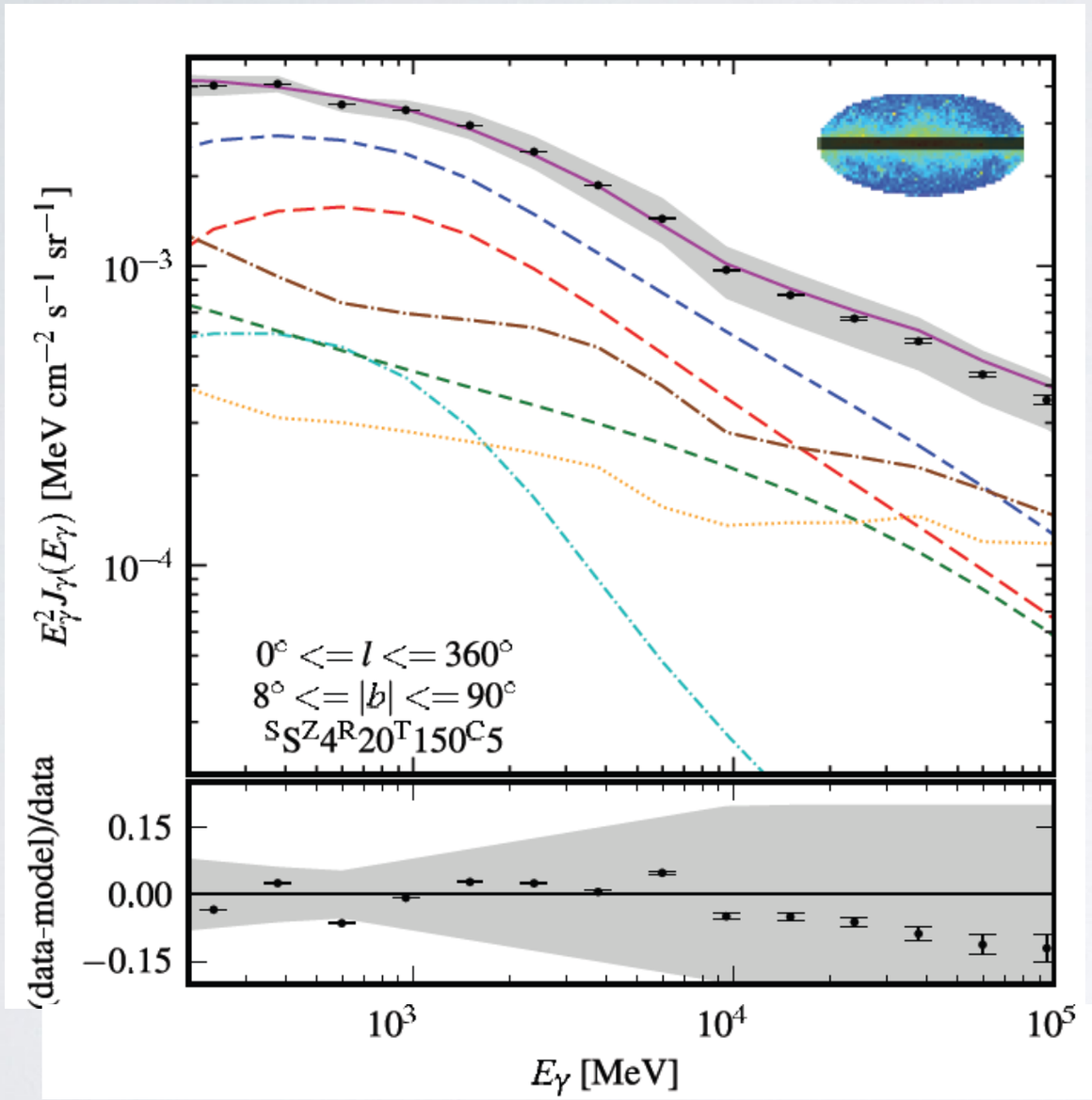


KRA: representative conv. model tuned against CR spectra (see below)

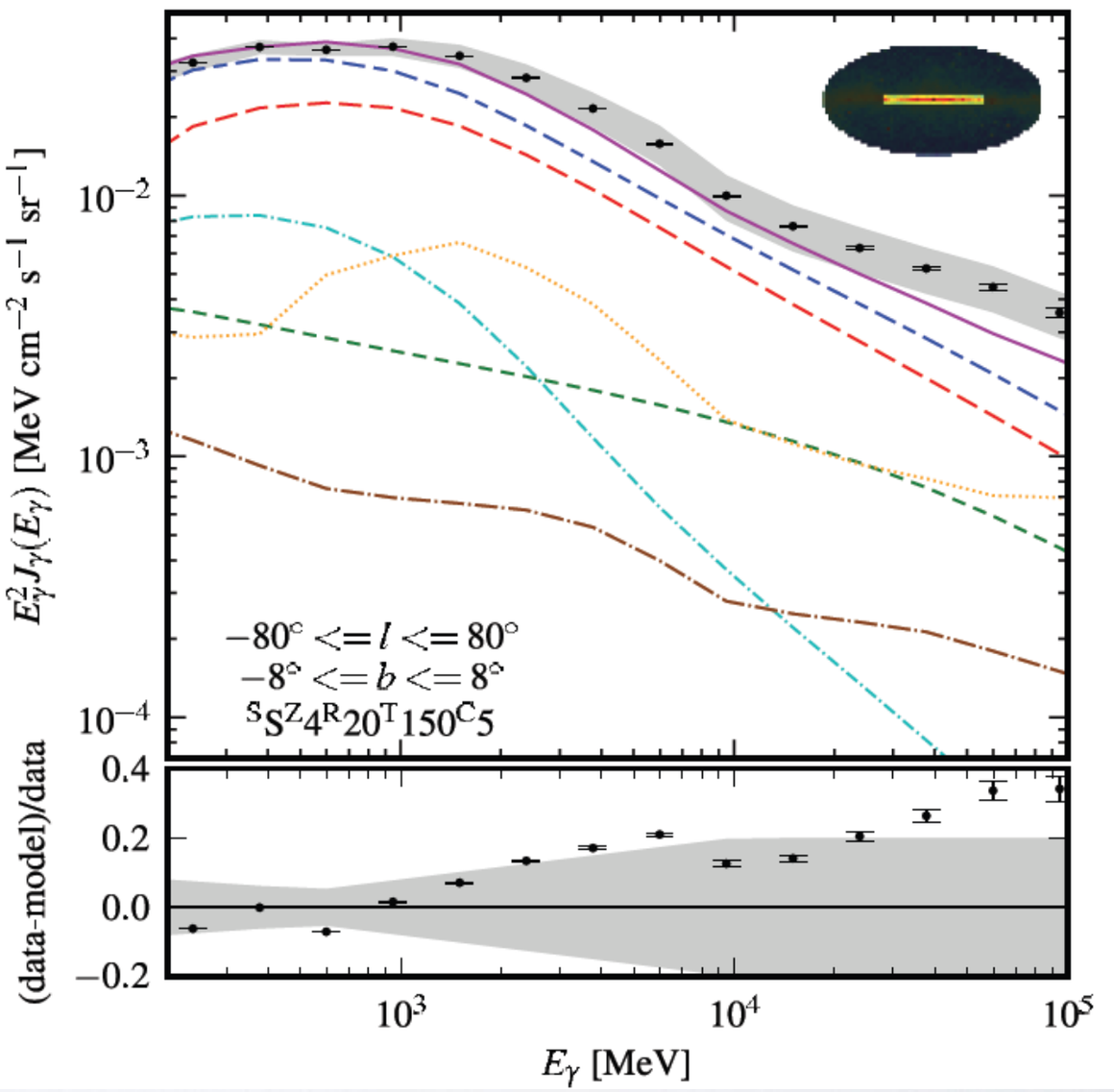
Conventional models against Fermi data

Fermi coll. ApJ 2012

full-sky but the GP



inner GP



Fermi Benchmark (FB) conventional model:

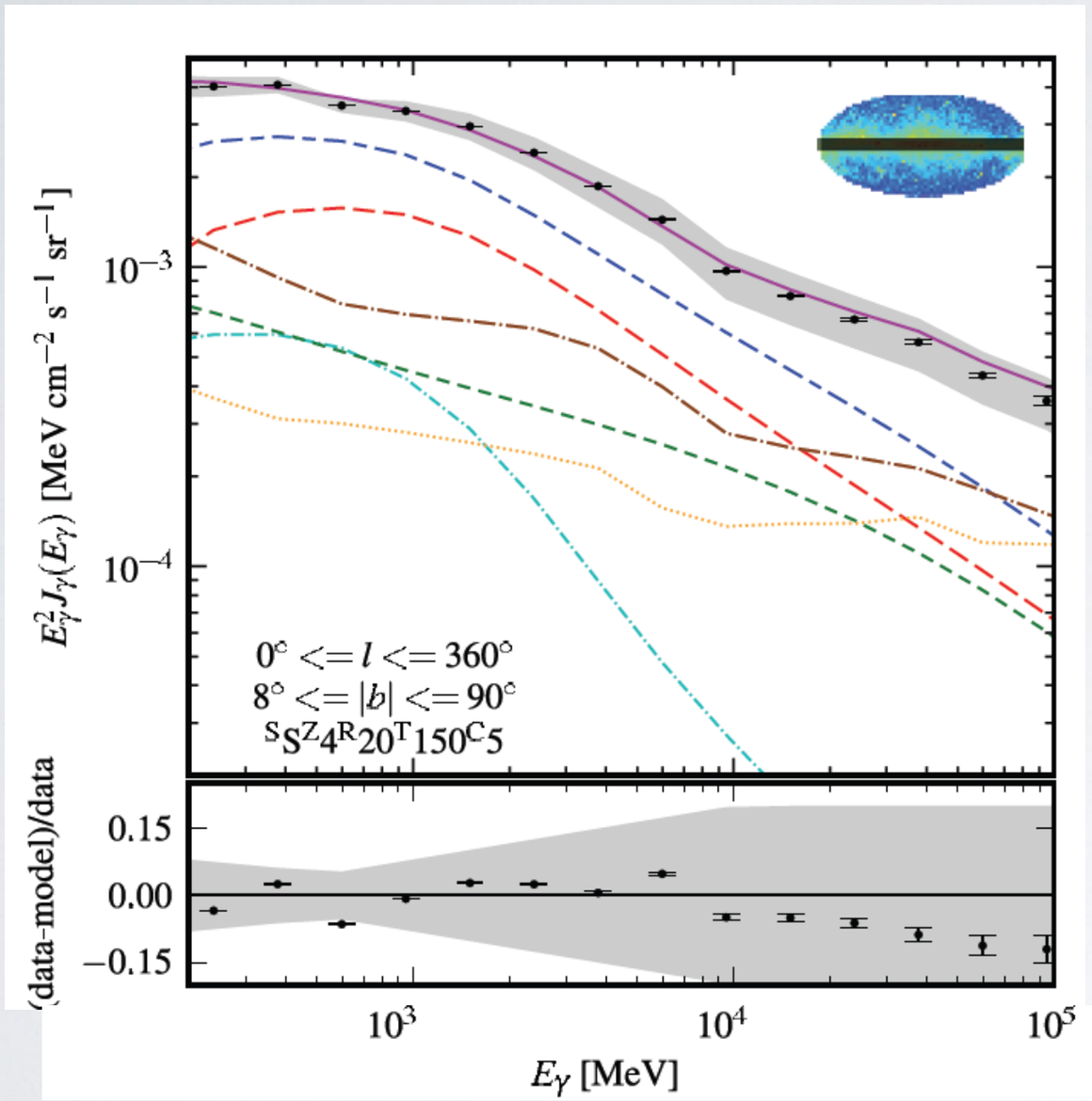
$\delta = 0.3$, $\gamma_P = 2.72$ (in the whole Galaxy), $z_h = 4$ kpc

Conventional models against Fermi data

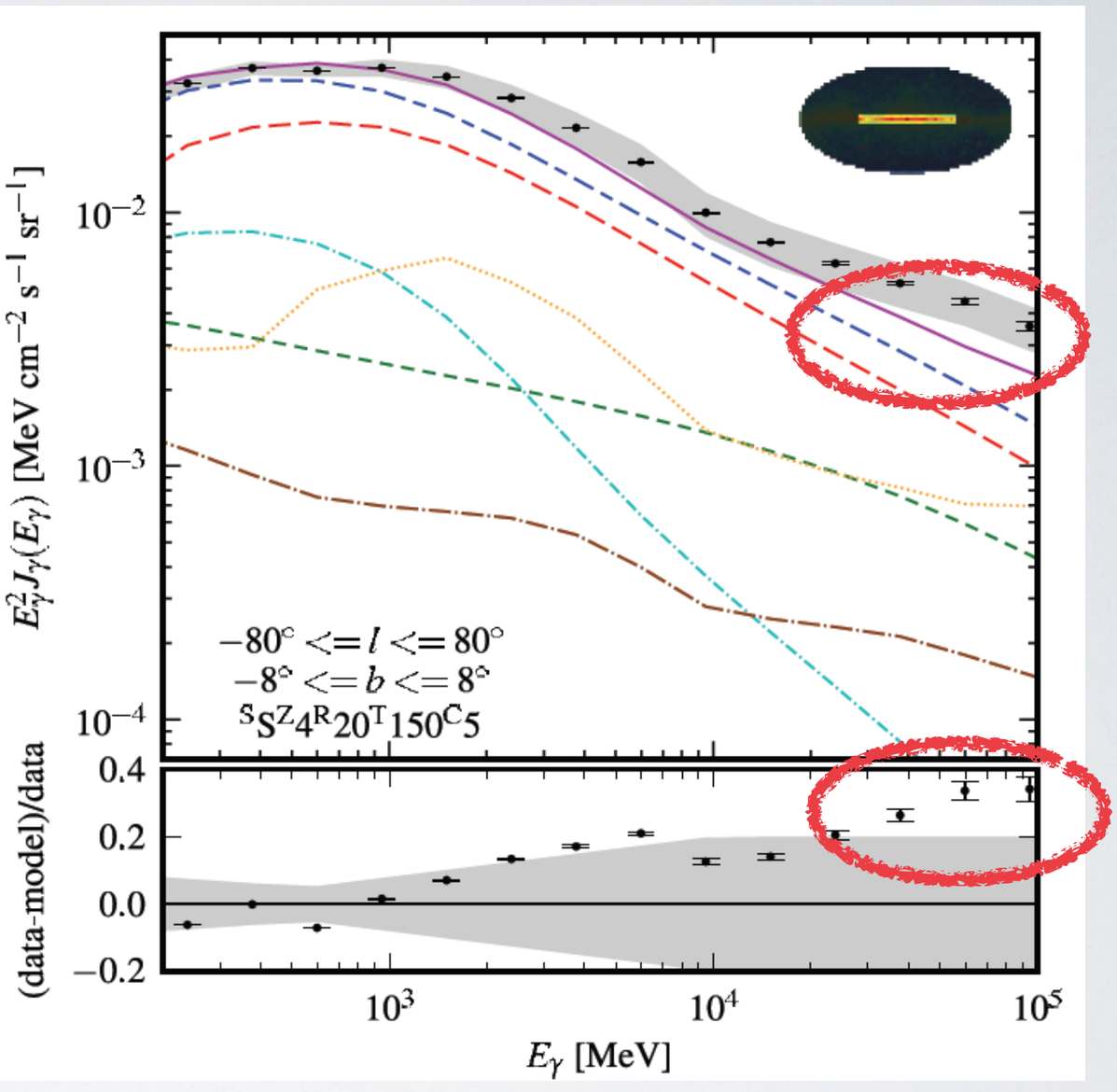
in the inner Galaxy

Fermi coll. *ApJ 2012*

full-sky but the GP



inner GP



Fermi Benchmark (FB) conventional model:

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An unconventional approach

Gaggero, Urbano, Valli & Ullio
arXiV: 1411.7623 PRD 2015

The KRA$_\gamma$ model - implemented with the DRAGON code
adopts a radial dependent diffusion coefficient

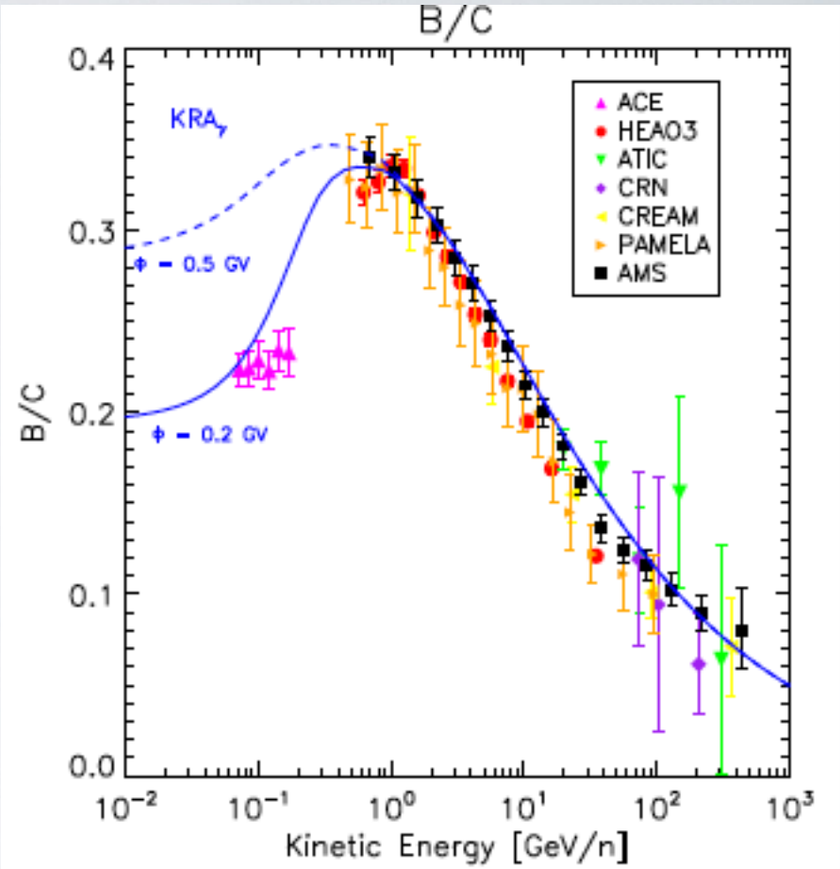
$\delta(R) = A\,R + B$ such that $\delta(R_{\rm sun}) = 0.5$

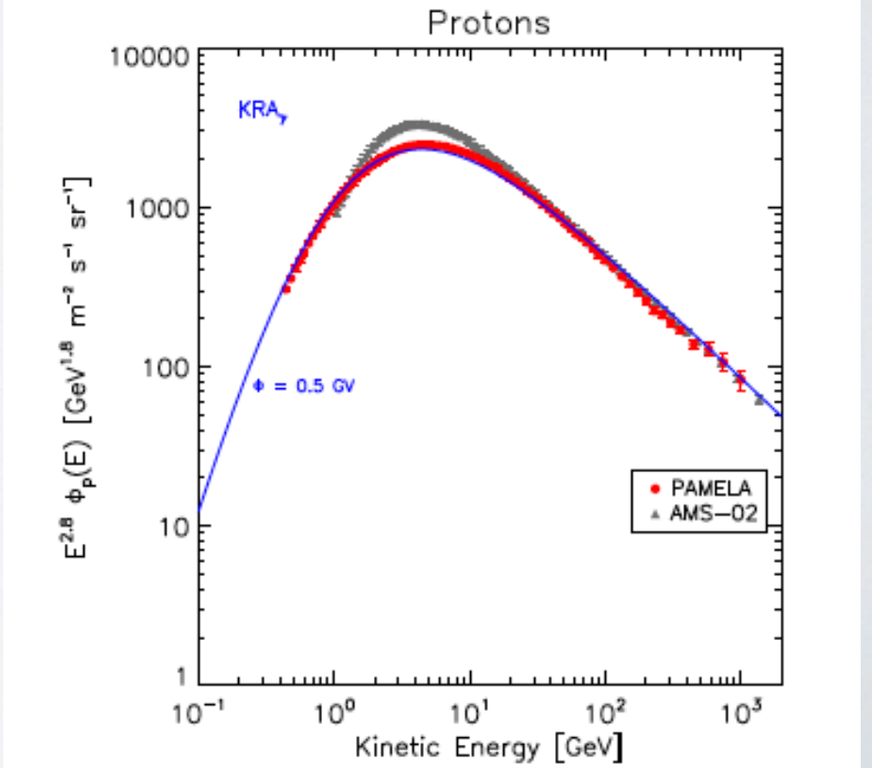
and convective velocity

$$\frac{dV_C}{dz} = 100\ \mathrm{km\ s^{-1}\ kpc^{-1}}$$ for R < 6.5 kpc

vanishing a larger radii.

The model is tuned to reproduce the proton and He spectra measured by PAMELA including the spectral hardening at 250 GeV/n and B/C updated data

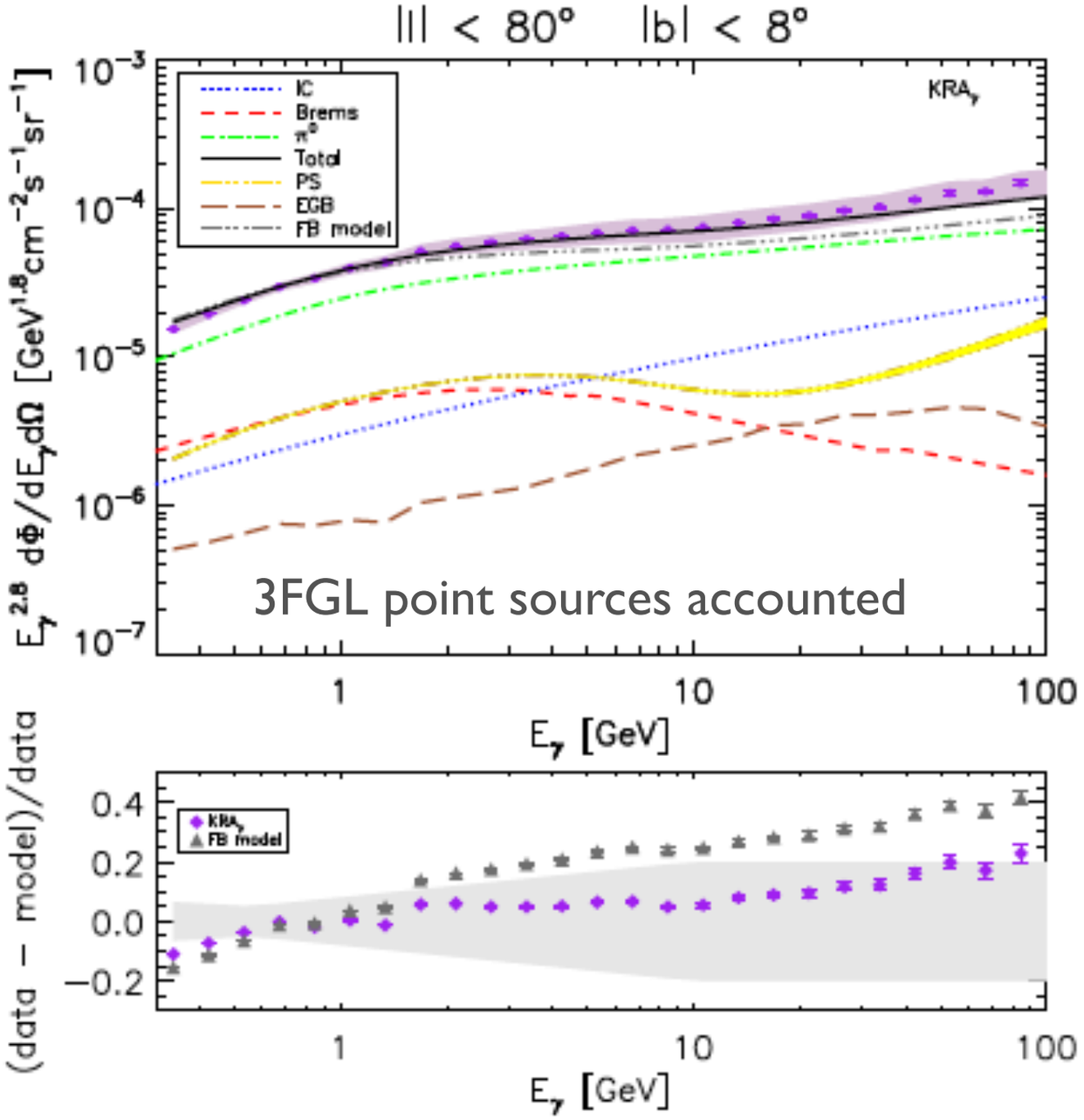


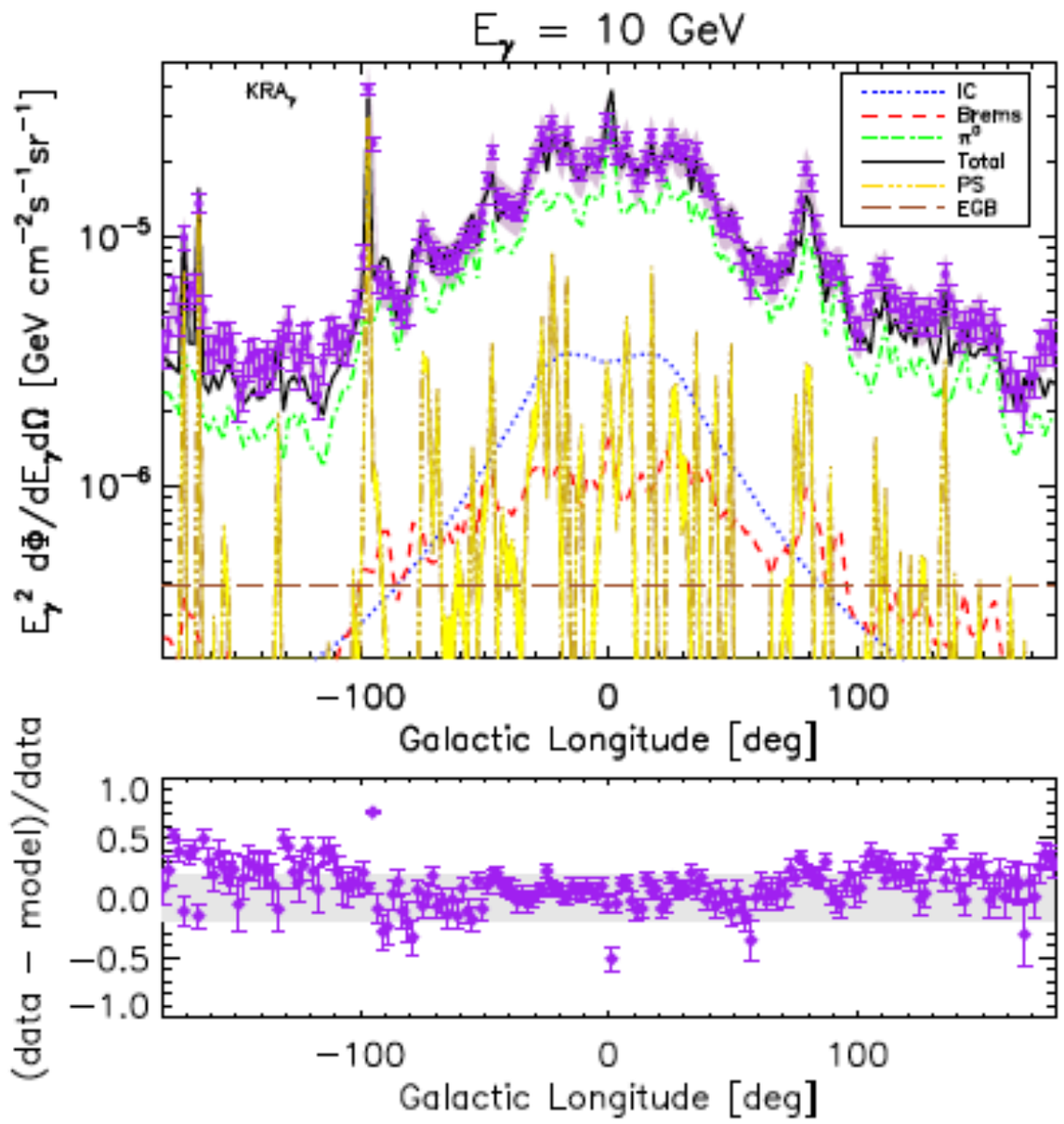


An unconventional approach

The KRA$_\gamma$ model reproduces the full-sky Fermi spectrum and angular distribution. It also provides a better fit in the inner GP region

Gaggero, Urbano, Valli & Ullio
arXiV: 1411.7623 PRD 2015

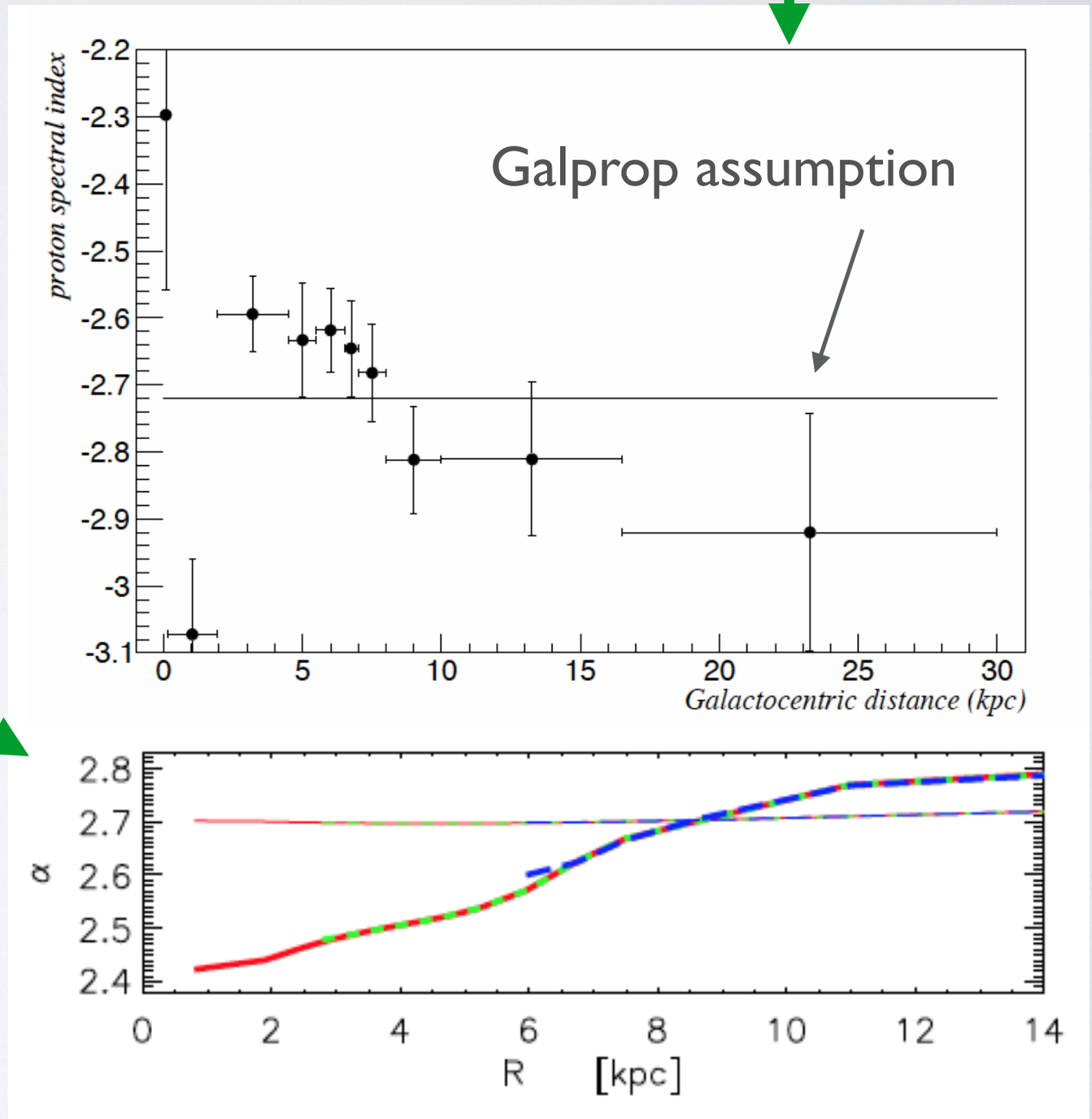




Evidence of radial dependent CR spectral index in the Fermi data

Casandajian [Fermi coll.] Oct.2014, 5th Fermi symp. submitted to ApJ

a template-fitting analysis of the diffuse γ-ray emission measured by Fermi found such evidence



it is consistent with *Gaggero et al. 2015* KRAγ model predictions

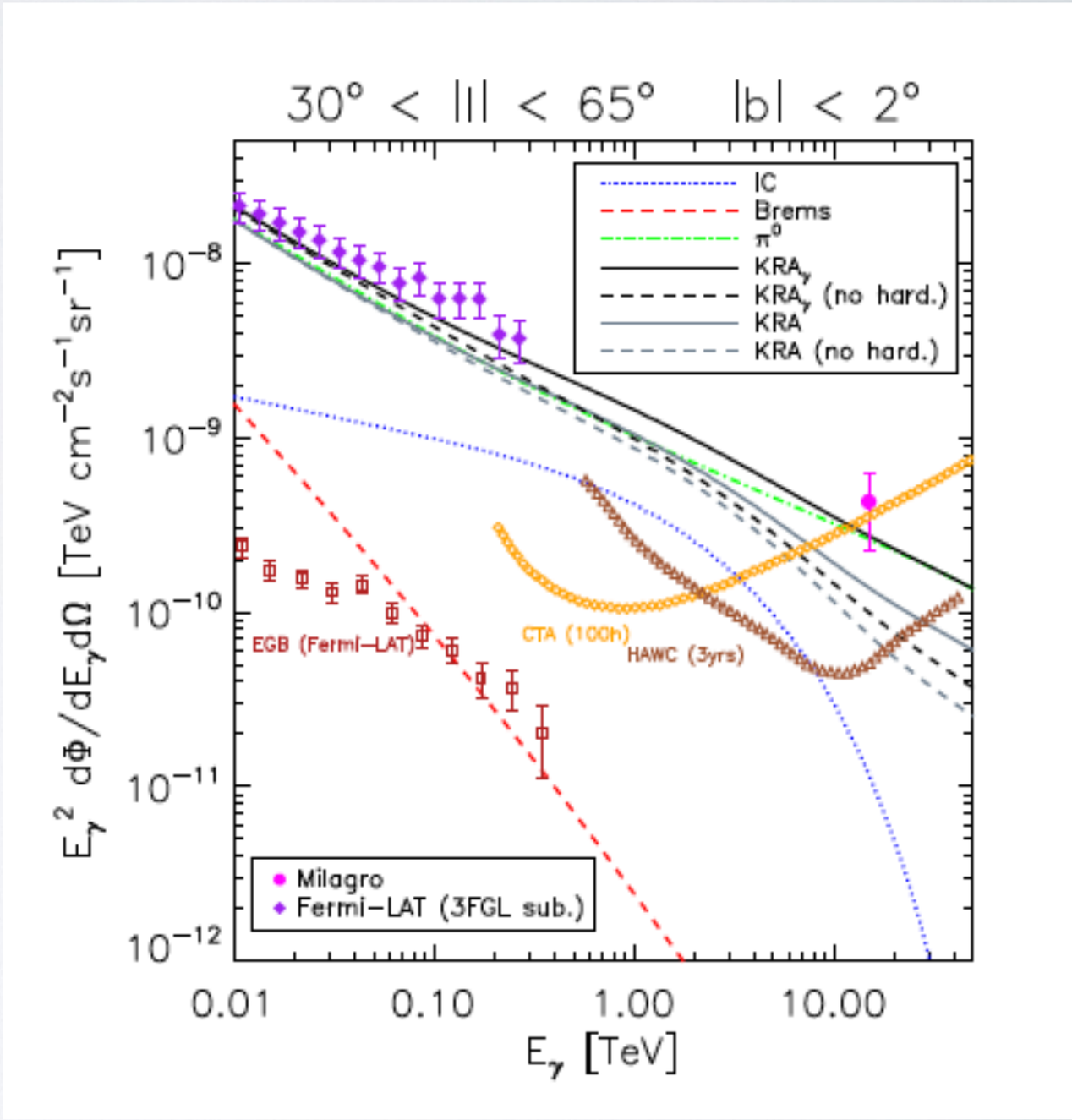
Solution of the Milagro anomaly

Gaggero, D.G., Marinelli Urbano &Valli
arXiV: 1504.00227

The KRAγ model nicely matches MILAGRO consistently with Fermi data (point sources cleaned) without further tuning !

Since the model assumes a CR spectral hardening at 250 GeV/n to match PAMELA and AMS-02
the hardening cannot be a local effect
instead it must be present at least in a large fraction of the inner GP volume !

HAWC can soon test this prediction

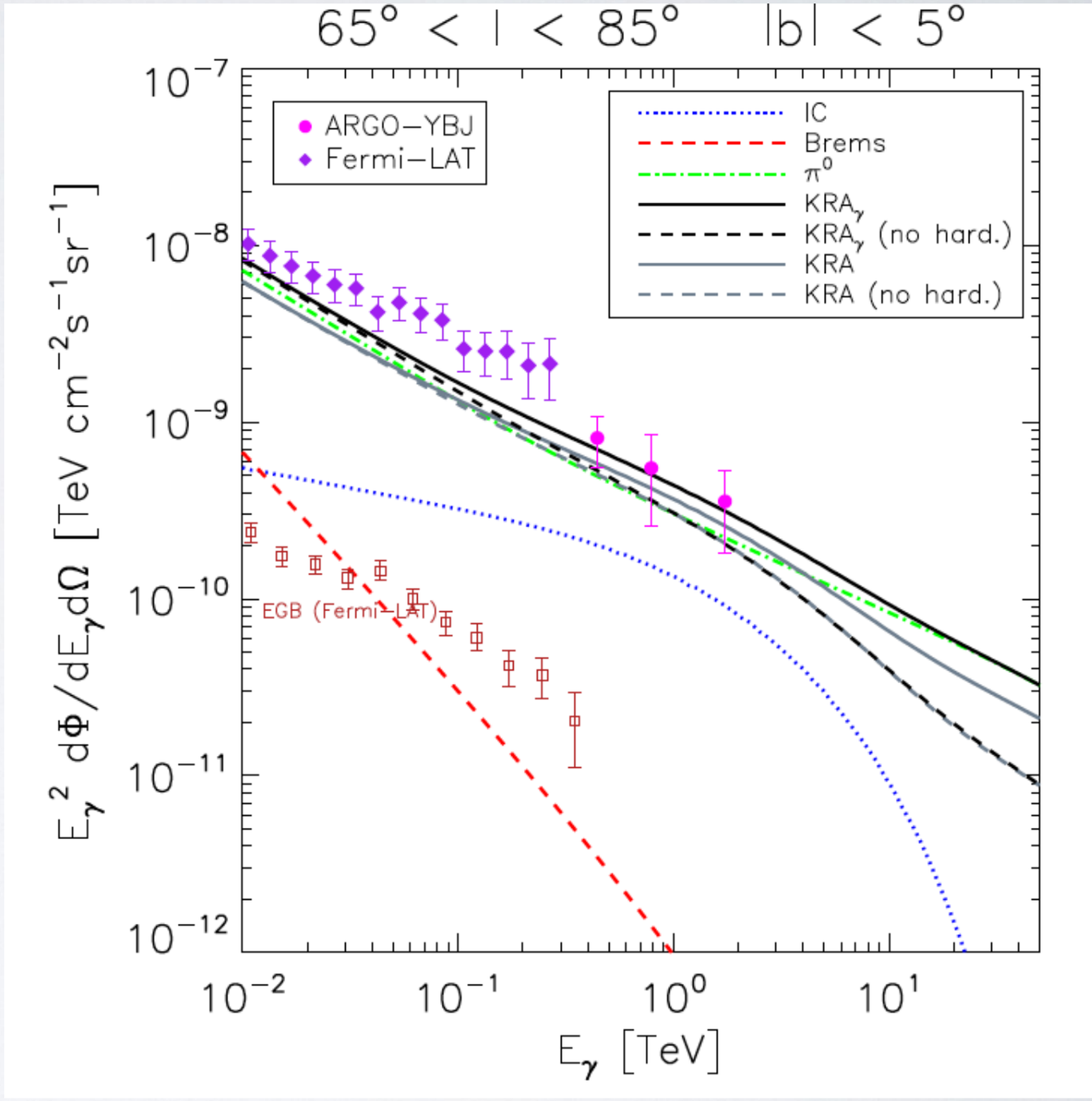


Our model against ARGO-YBJ results

ARGO-YBJ coll., ApJ 2015

the innermost region for which they released data is 65 < l < 85 deg. including Cygnus region

although those data do not allow to discriminate among the scenario we considered, the KRAγ model agrees with those data (if not preferred).



Solution of the HESS Galactic ridge anomaly ?

HESS (*Nature 2006*) measured a spectrum harder ($\Gamma \sim -2.3$) than expected on the basis of conventional CR models, associated with the molecular complex in the inner 200 pc of Galaxy

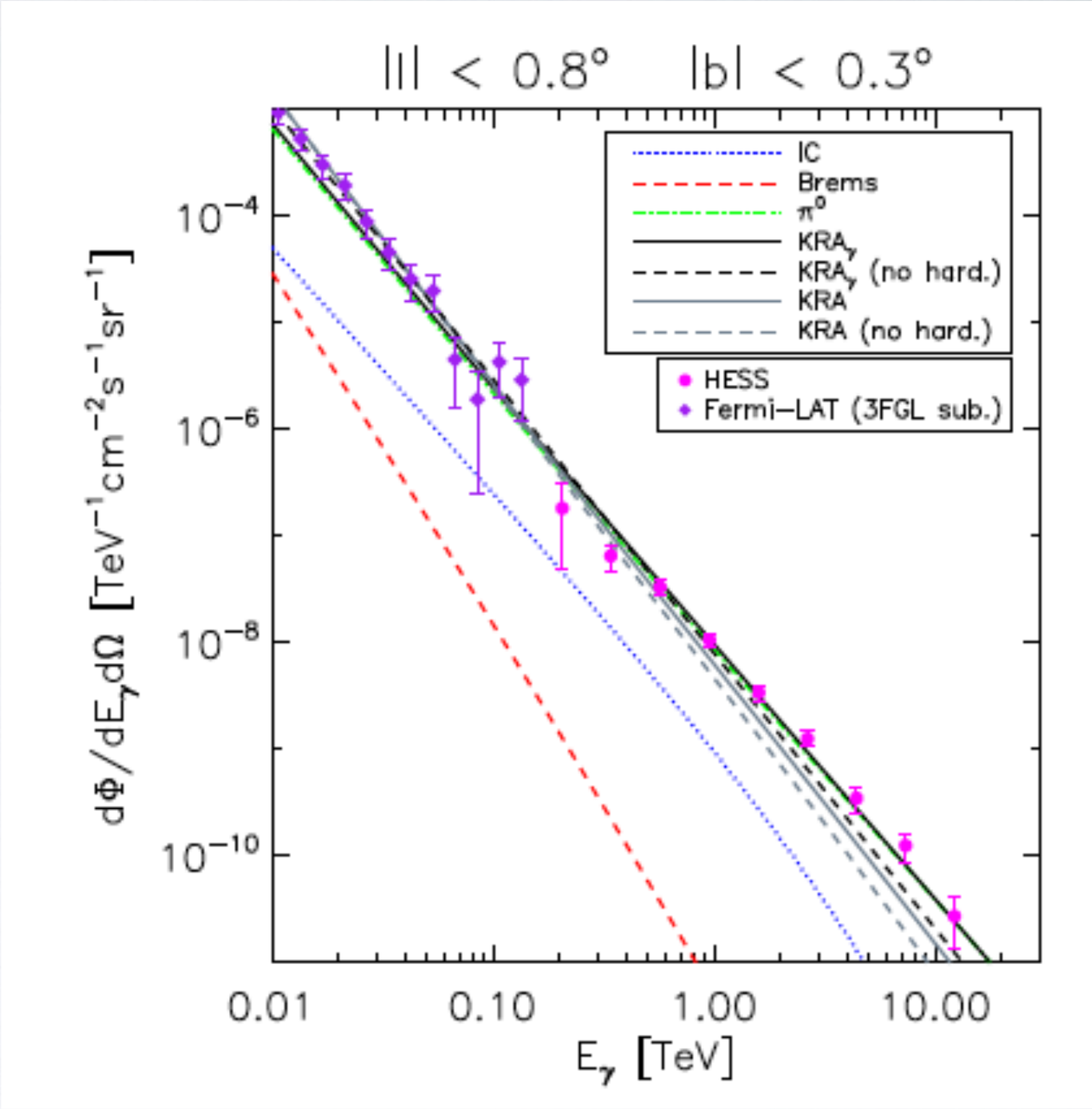
this is also the case for the updated Fermi benchmark conventional model

FERMI + HESS

KRAγ: $\chi 2$ = 1.79 /2.27 with/w.o. hard.

KRA: $\chi 2$ = 2.92 /3.99 with/w.o. hard.

the spectrum normalization is correctly reproduced using an improved gas model in the G.C. region (*Ferriere et al. 2007*)

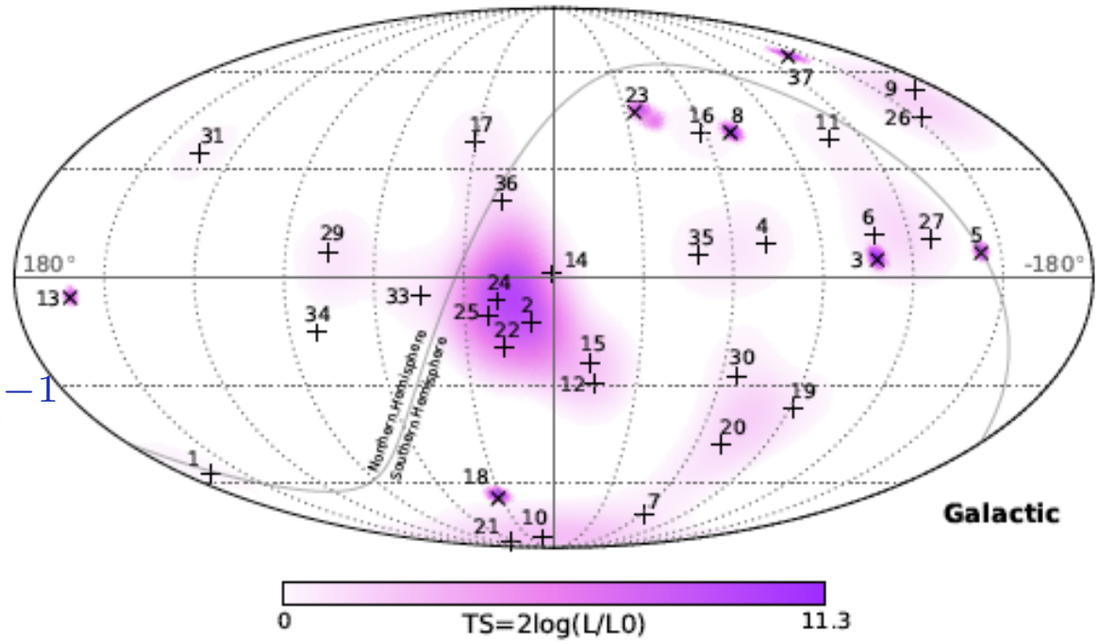


Growing evidences of Galactic neutrinos

IceCube 2013, 14 detected 37 events with E > 30 TeV : 5.7σ excess respect to the atm. bkg.

In 2015 the astrophysical **ν** flux above 25 TeV was measured full sky. Single power-law fit:

$$\Phi_\nu = 6.7^{+1.1}_{-1.2} \times 10^{-18} \left(\frac{E_\nu}{10^5\ \mathrm{GeV}}\right)^{-2.5} \mathrm{GeV}^{-1}\mathrm{cm}^{-2}\mathrm{sr}^{-1}\mathrm{s}^{-1}$$

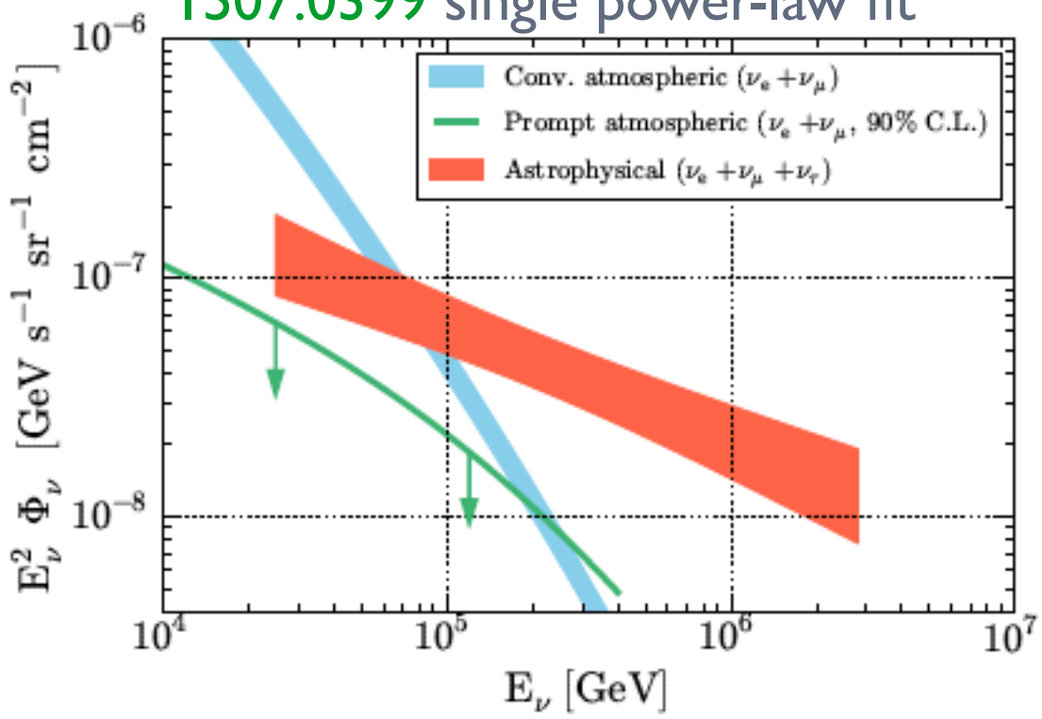


1507.0399 A North-South analysis favors a larger and flatter spectrum from the South hemisphere

Parameter	Best fit	68% C.L.	90% C.L.
ϕ_N	2.1	$0.5 - 5.0$	$0.1 - 7.3$
γ_N	2.0	$1.6 - 2.3$	$1.2 - 2.5$
ϕ_S	6.8	$5.3 - 8.4$	$4.4 - 9.5$
γ_S	2.56	$2.44 - 2.67$	$2.36 - 2.75$

Note. — ϕ_N and ϕ_S are the all-flavor neutrino fluxes at 100 TeV in the northern and southern sky, respectively; γ_N and γ_S are the corresponding spectral indices. The fluxes are given in units of $10^{-18}\,\mathrm{GeV}^{-1}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{cm}^{-2}$.

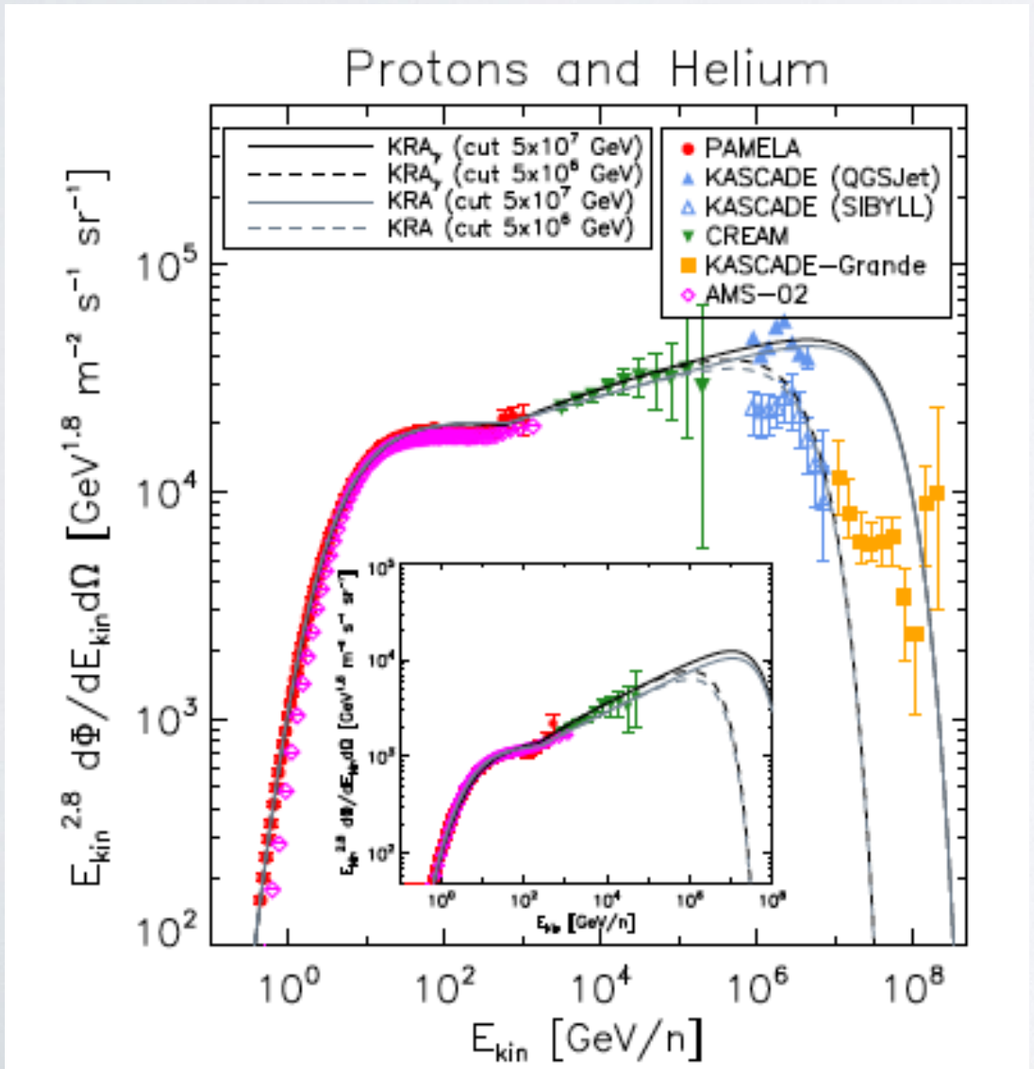
1507.0399 single power-law fit



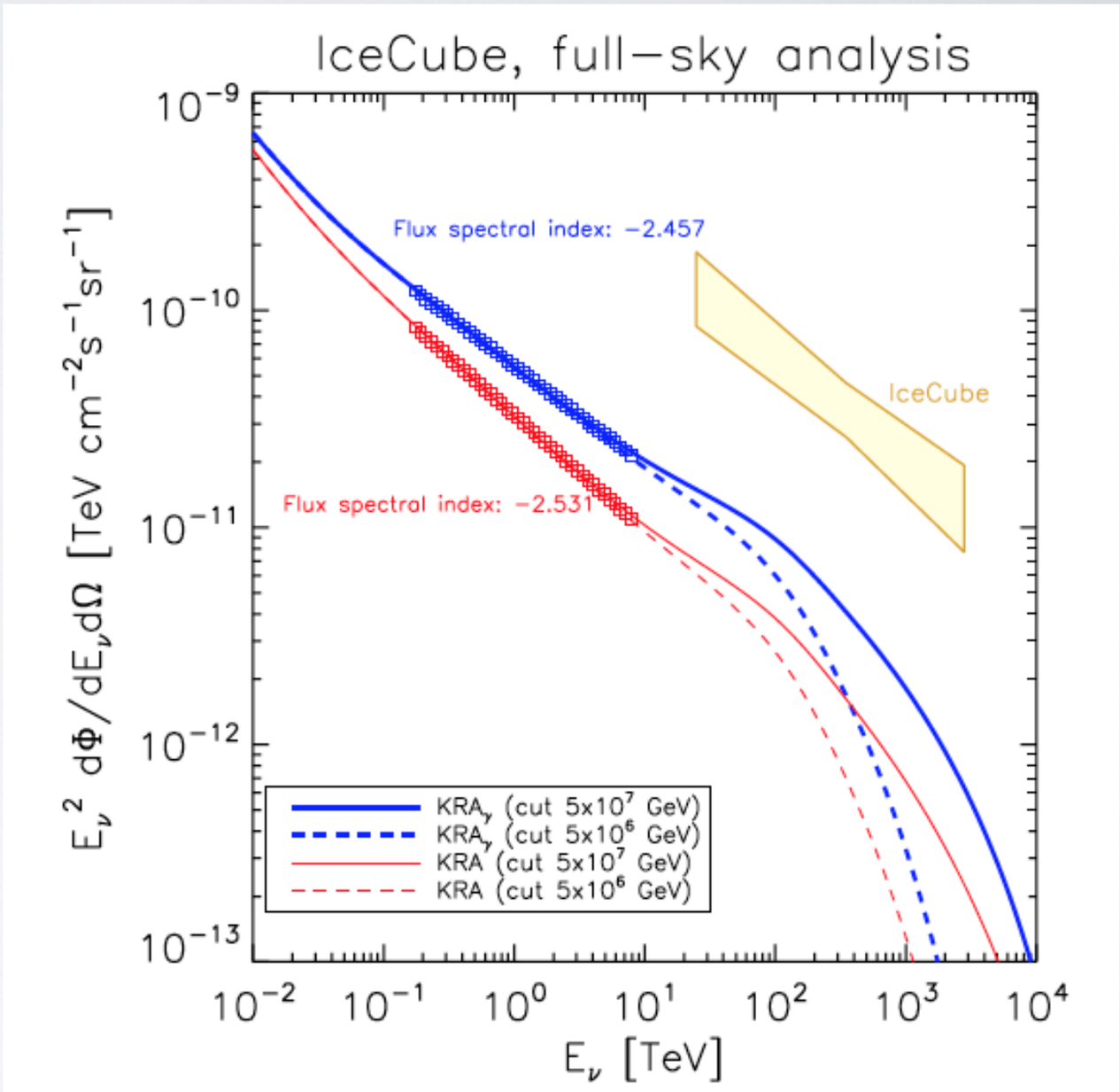
Enhanced ν emission of the Galaxy from the KRAγ model

Conventional CR models predict a rather low **ν** spectrum

the KRAγ setup predicts a higher and harder spectrum form the inner Galaxy.



Gaggero, D.G., Marinelli Urbano &Valli
arXiV: 1504.00227



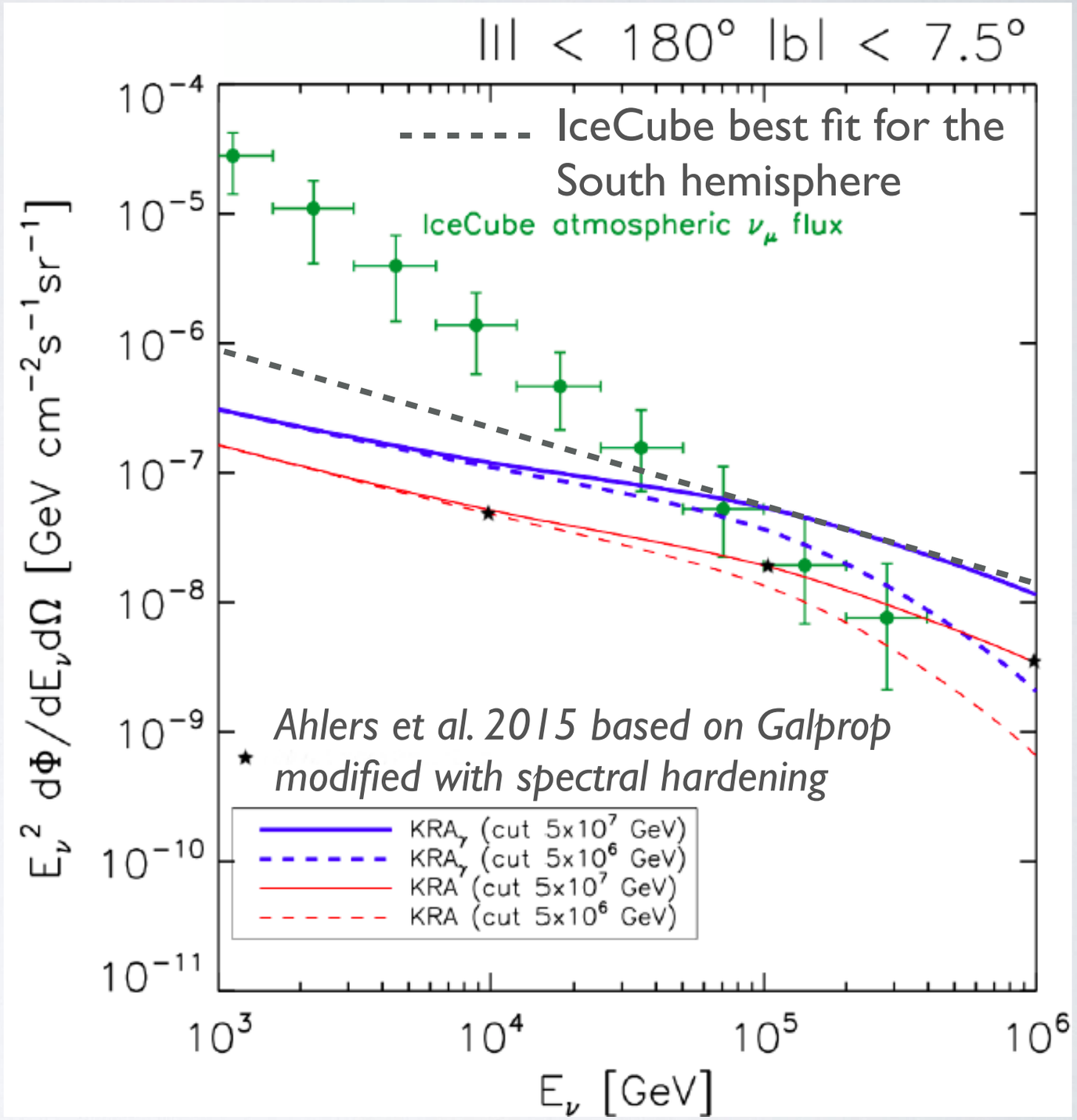
ν emissivities from Kamae et al. 2006
and accounted for **ν** oscillations

Enhanced ν emission of the Galaxy from the KRAγ model

The model can account between 10 and 40 % of the IceCube HESE event excess above 60 TeV (full-sky) compared to 5 -10 % computed with GALPROP (Ahlers et al. 2015)

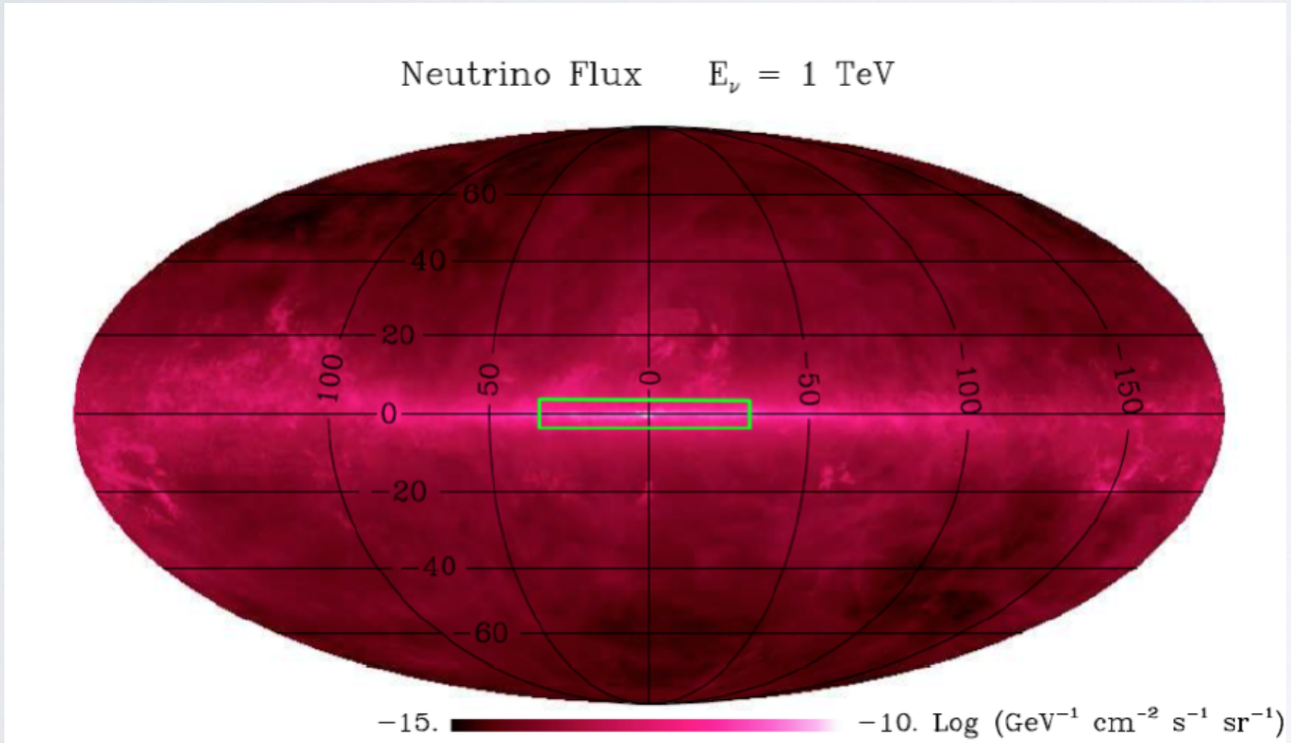
according to Ahlers et al. 2015 this is still compatible with the IC events angular distribution

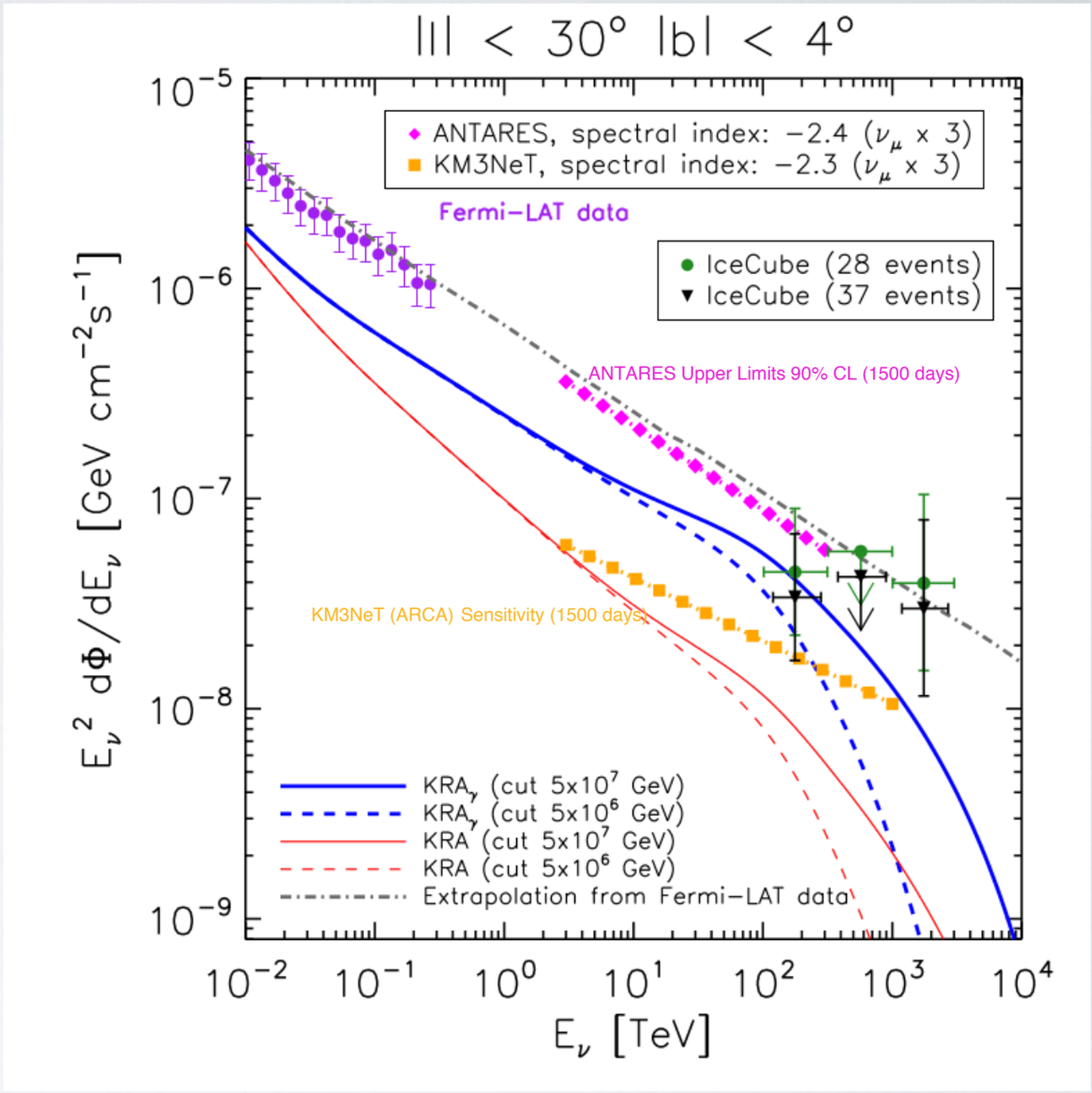
The excess may be better detected in the GP region where the flux should be dominated by the Galactic emission ➡



Enhanced ν emission of the Galaxy from the KRAγ model

The excess is expected to be higher in the GC region. This may be probed by ANTARES and Km3Net
(see A. Marinelli's talk)





CONCLUSIONS

- Fermi-LAT data favor a Galactic CR propagation model with δ decreasing with R (harder CR spectrum in the GC region)

- The same model, when accounting for CR the hardening at 250 GeV/n, allows to reproduce Milagro excess at 15 TeV (HESS Galactic ridge spectrum is also reproduce consistently with Fermi data). This provides the first consistent description of sub-TeV and TeV diffuse γ-ray diffuse emission data.
  HAWC may soon confirm this scenario

- Our model also predicts a significantly larger/harder Galactic neutrino flux which may help interpreting the increasing evidence of a Galactic component in the IceCube signal

- The Galactic neutrino emission should be dominant in the inner Galactic plane region. This may testable by ANTARES and, most likely, by Km3Net