The very high energy γ-ray (and neutrino) diffuse emission from the Galactic Center

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in coll. with:

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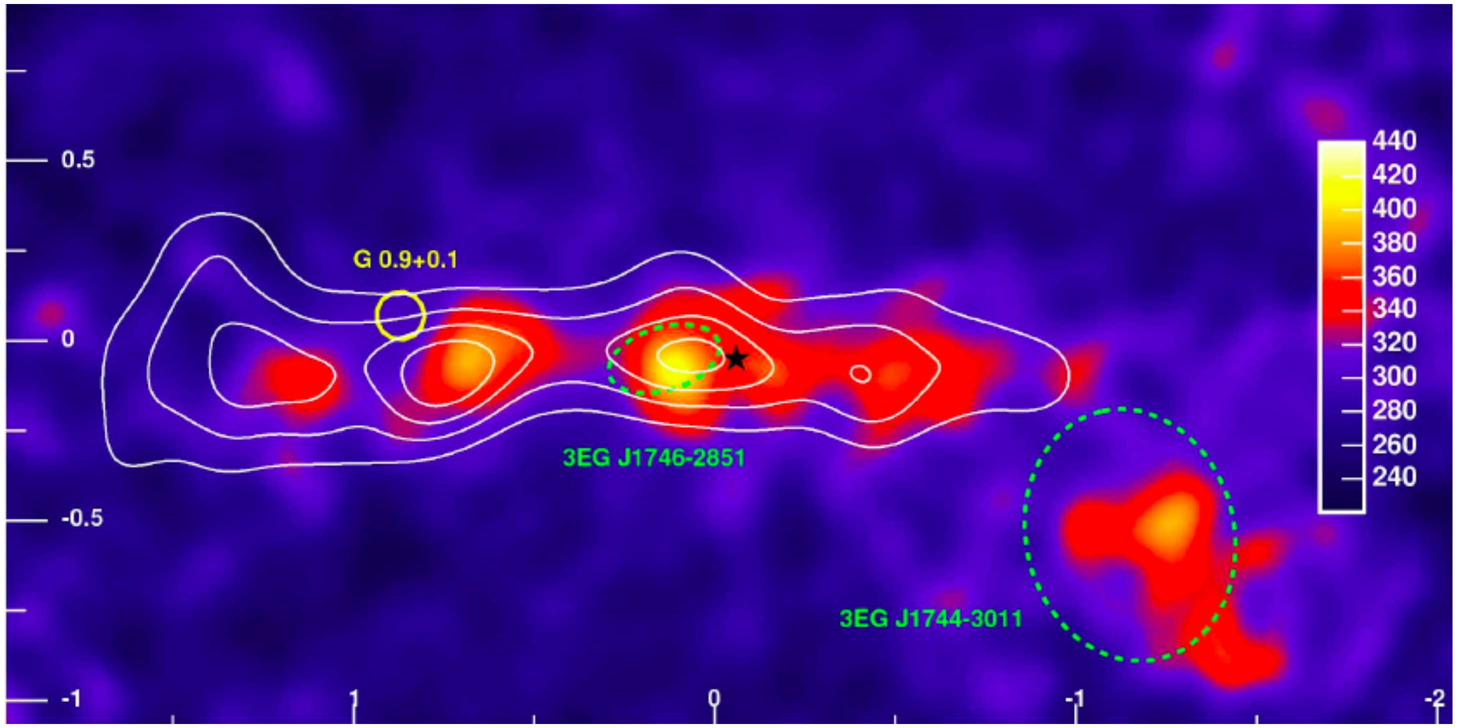
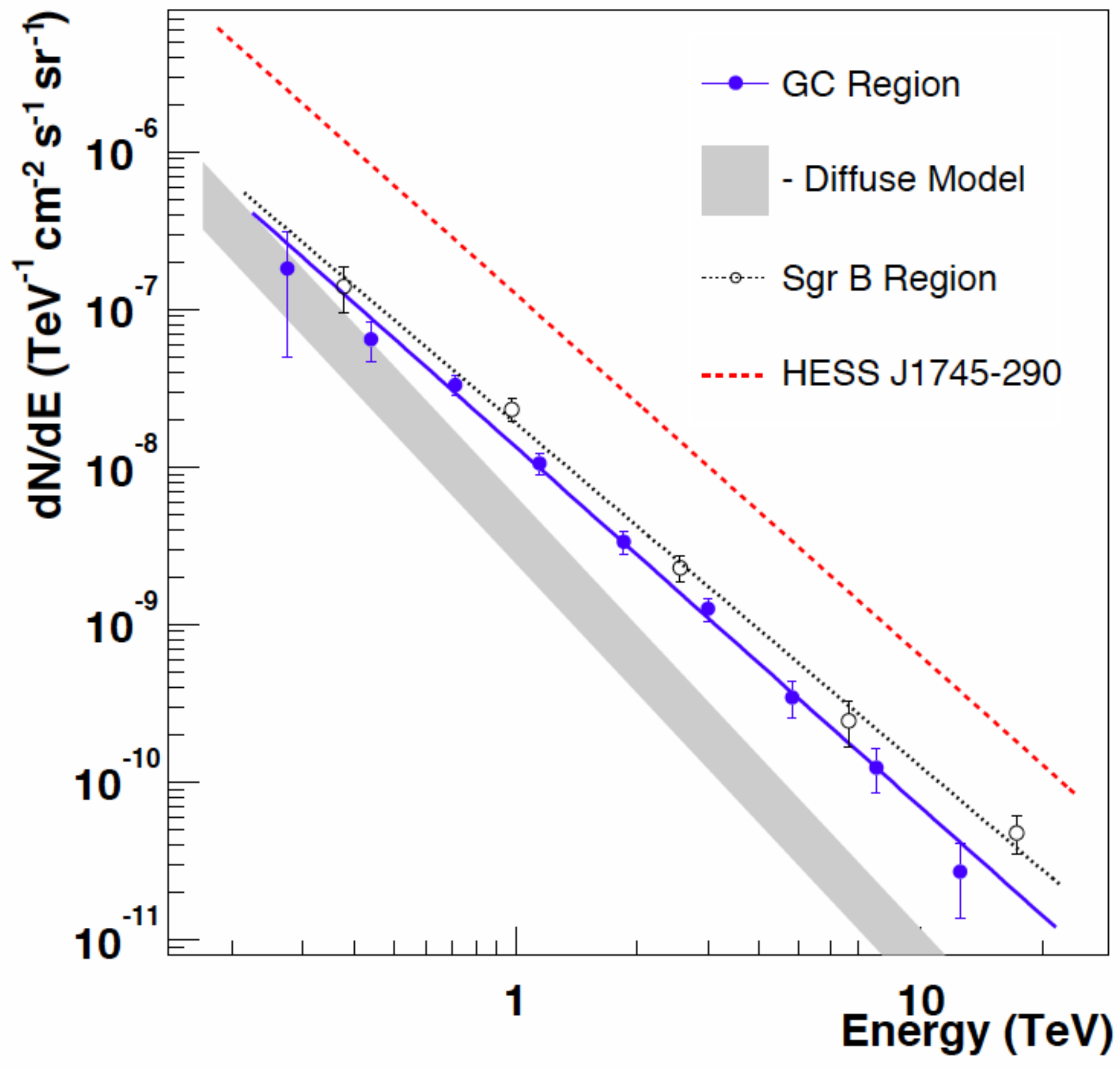
H.E.S.S. Nature 2006



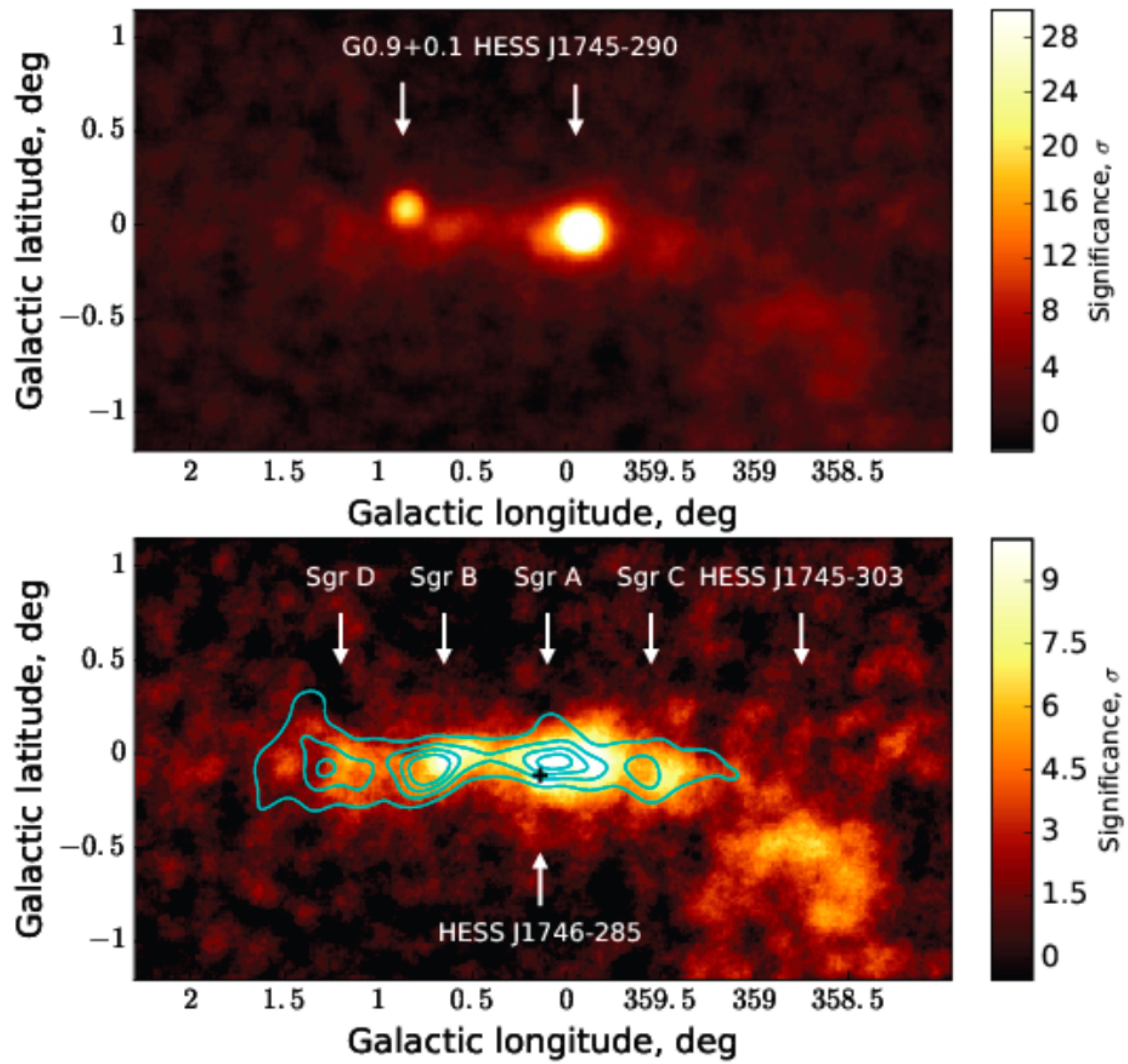
- The diffuse emission from the CMZ is harder ($\Gamma \simeq 2.3$) than expected from Galactic cosmic rays (CR) if their spectrum is the same of that at the Earth ($\Gamma \simeq 2.8$)

- A freshly accelerated (harder) component was invoked



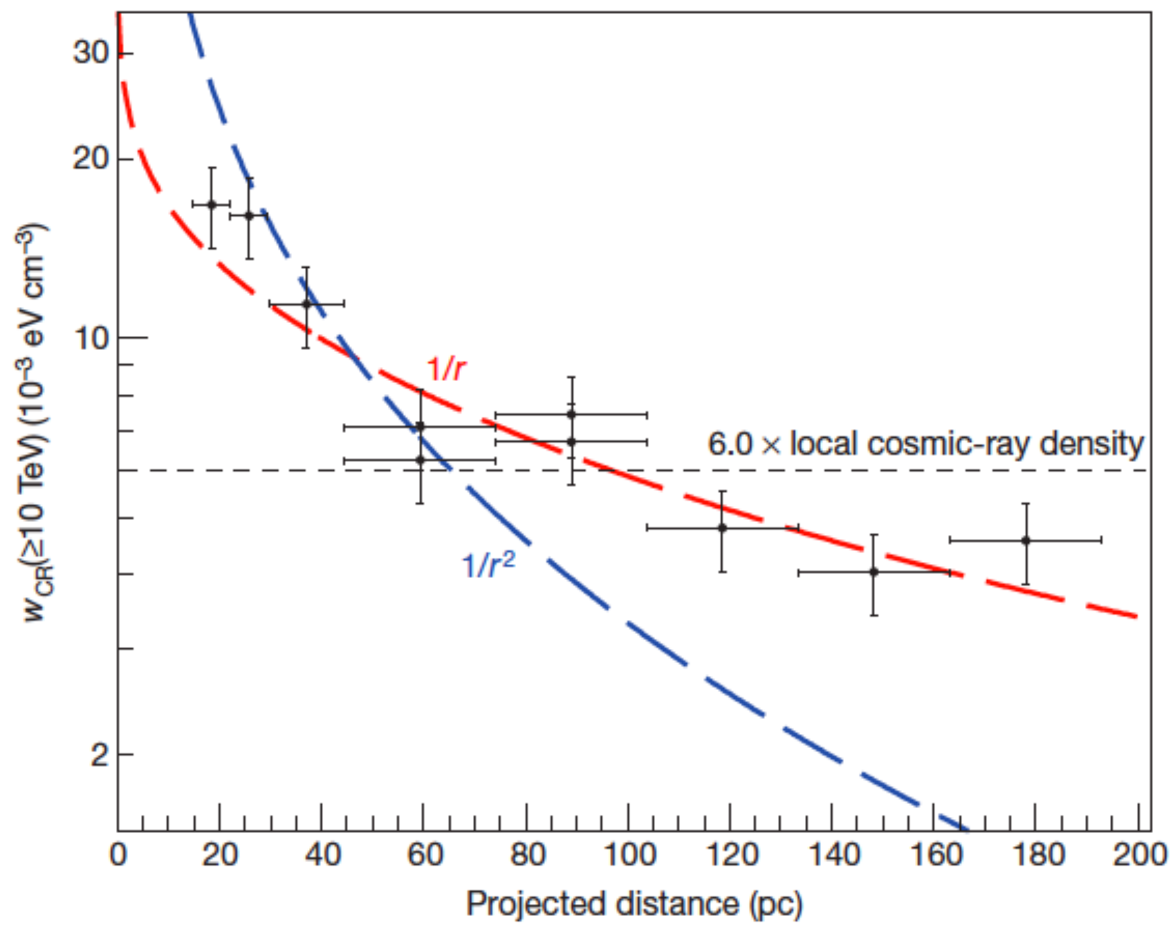
H.E.S.S. Nature 2016
+ arXiv 1706.04535

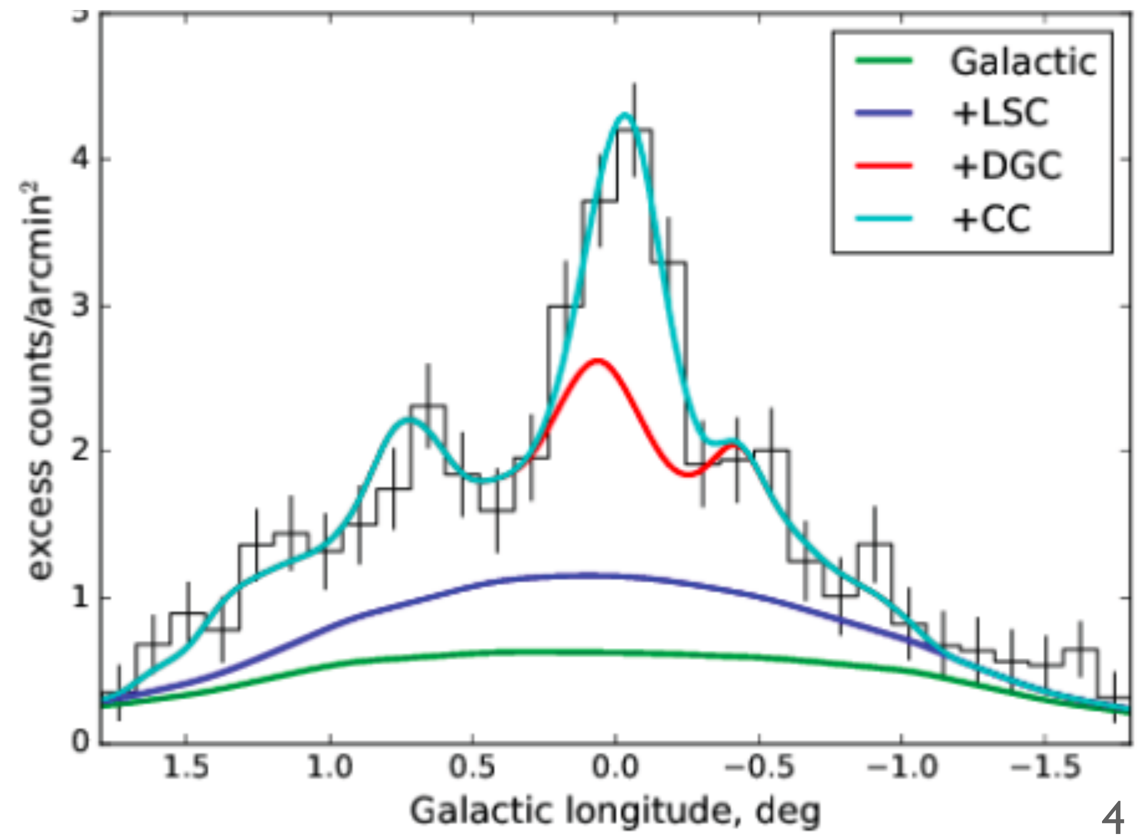
250 hours of observation of the γ-ray diffuse emission from 200 GeV to 50 TeV of the central molecular zone (CMZ) region



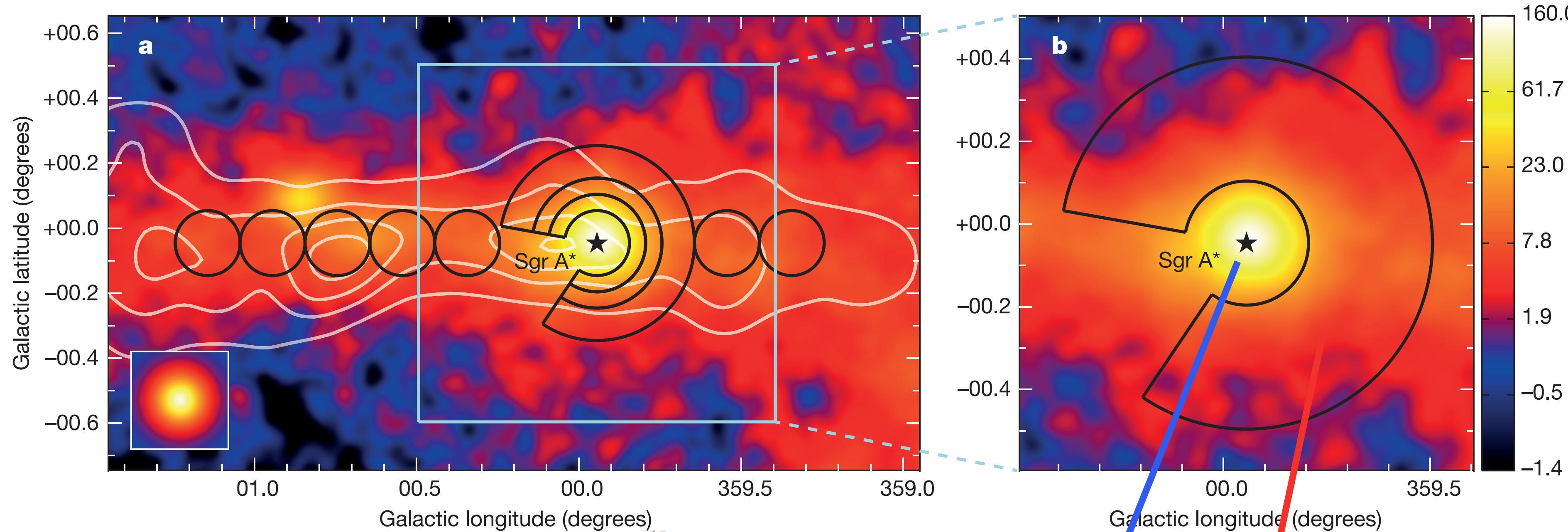
H.E.S.S. Nature 2016

- Emission correlated with the gas distribution (inferred from CO and CS emission maps)
- At the GC the emission profile seems more peaked than the estimated gas distribution. The same effect however may be due to a larger gas density in the inner 50 pc (*1° ≃ 150 pc* at the GC)
- The inferred CR density profile is consistent with that expected from CR diffusing out a stationary source. This conclusion, however, relies on an estimate of the Galactic large scale background based on local CR measurements





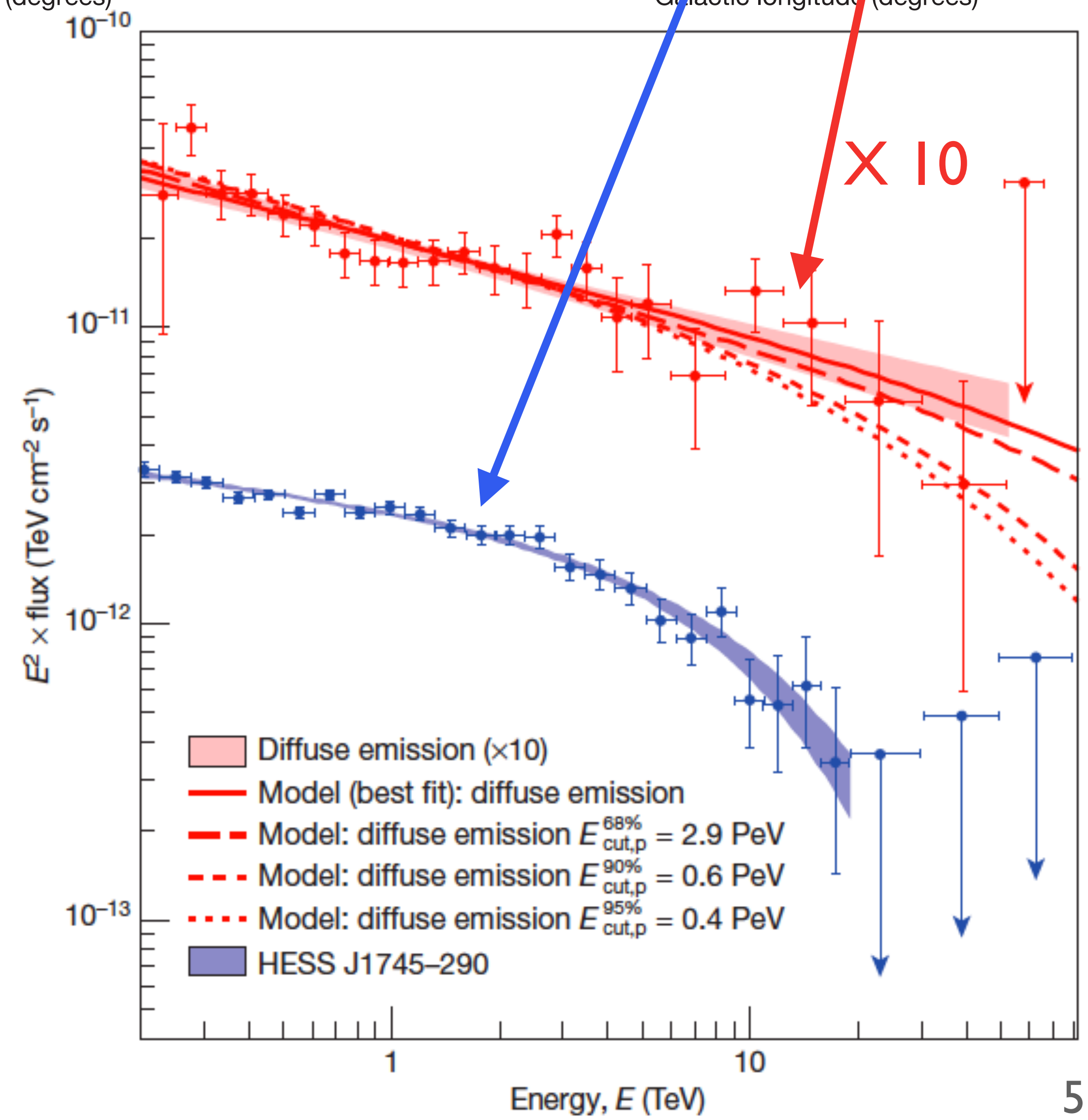
H.E.S.S. Nature 2016



- Diffuse emission traces gas, strong losses ➡ hadronic emission

- the diffuse emission around J1745-290 (positionally compatible with SgrA*) extends up to ~ 50 TeV ➡ CR protons up to ~ PeV

- the spectrum of the point source J1745-290 might be attenuated



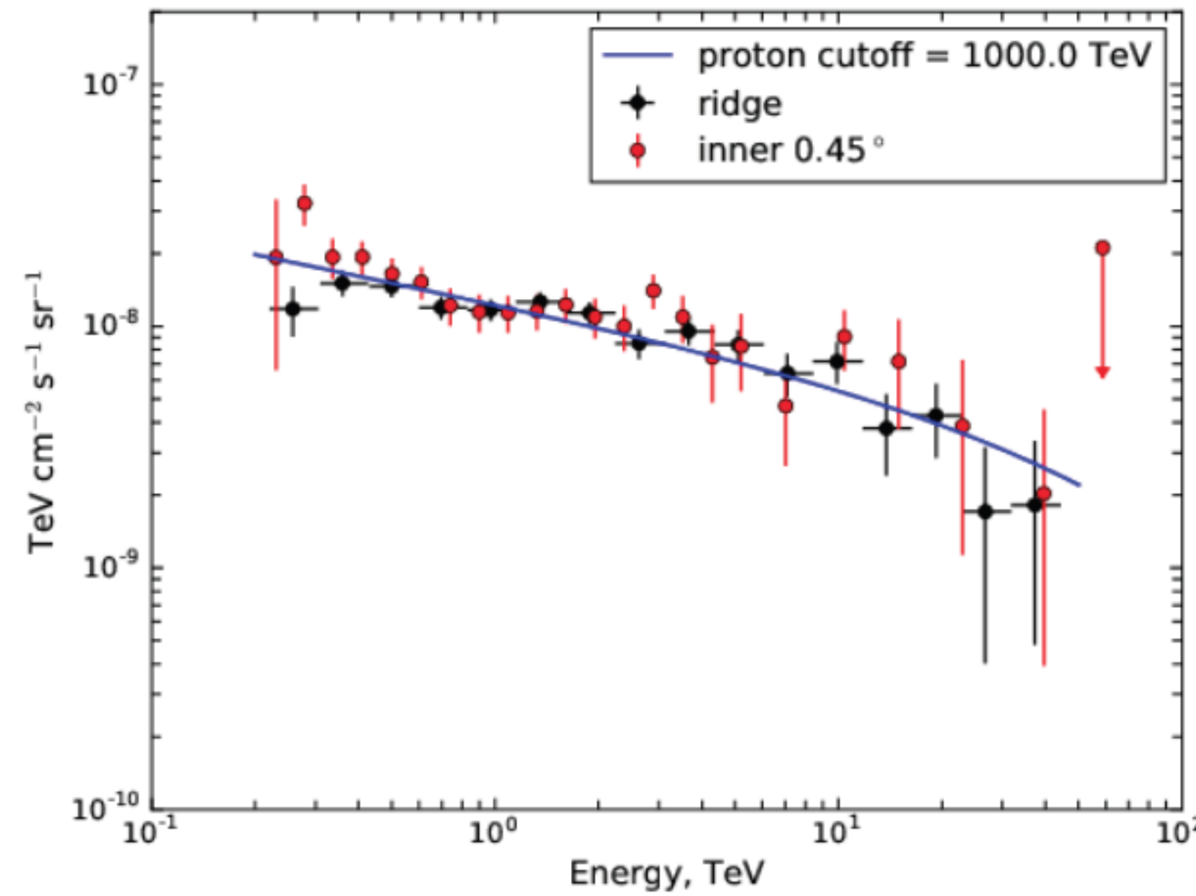
H.E.S.S. **Nature 2016**
+ arXiv 1706.04535

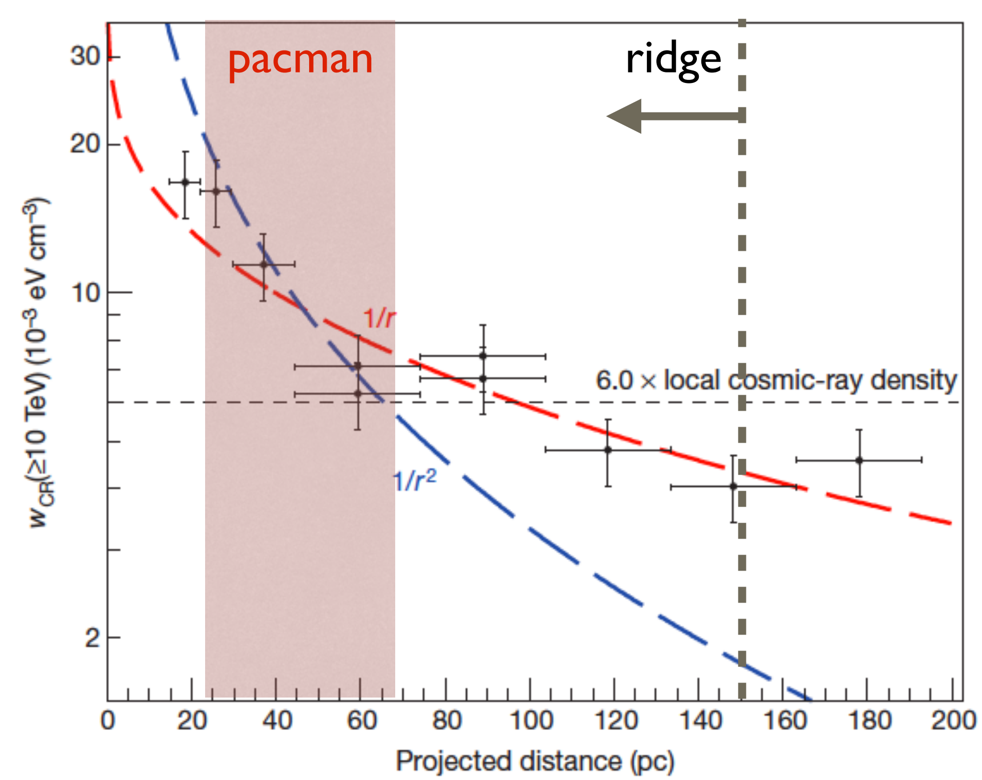
Same spectra in the ridge
(| l | < 1° , | b | < 0.3°), d < 150 pc

$\Gamma_{HESS17} = 2.28 \pm 0.03_{stat} \pm 0.2_{sys}$

and in the "*pacman*"
0.15° < θ < 0.45° , 22 < d < 67 pc

$\Gamma_{HESS16} = 2.32 \pm 0.05_{stat} \pm 0.11_{sys}$



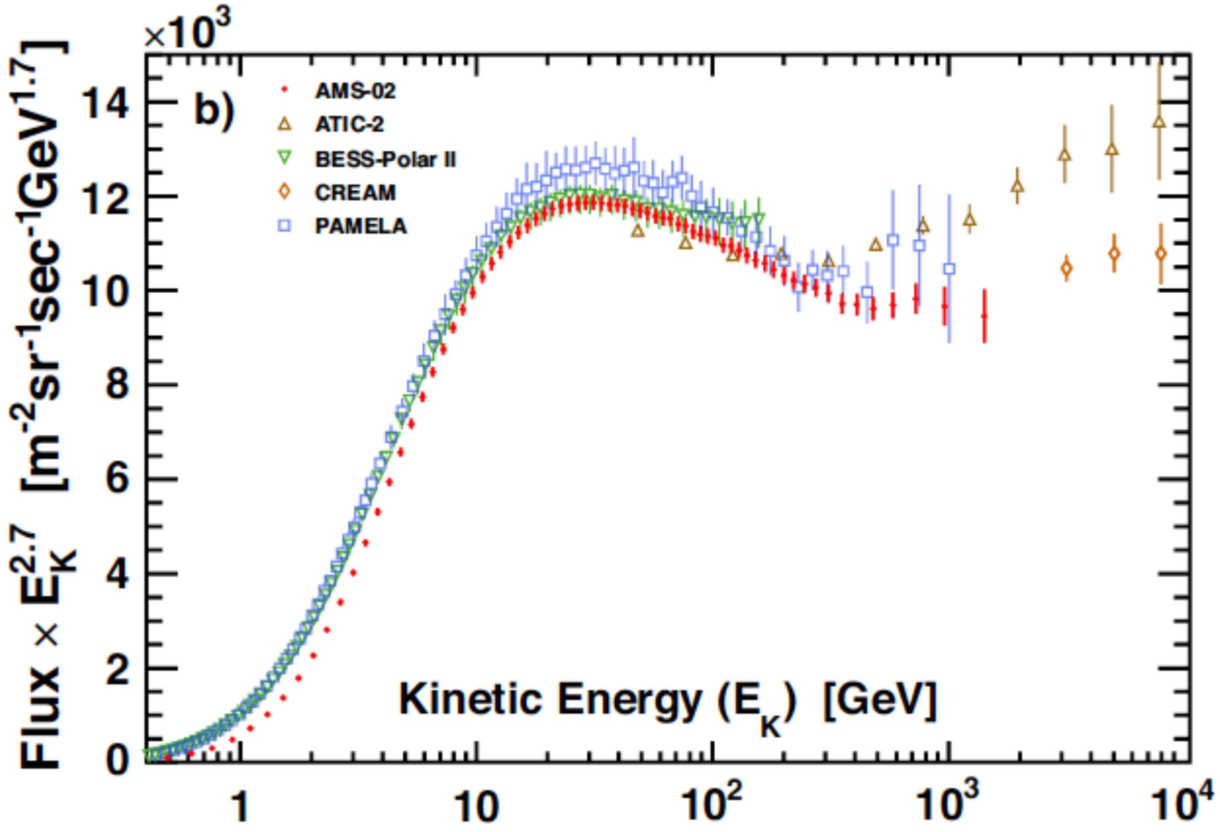


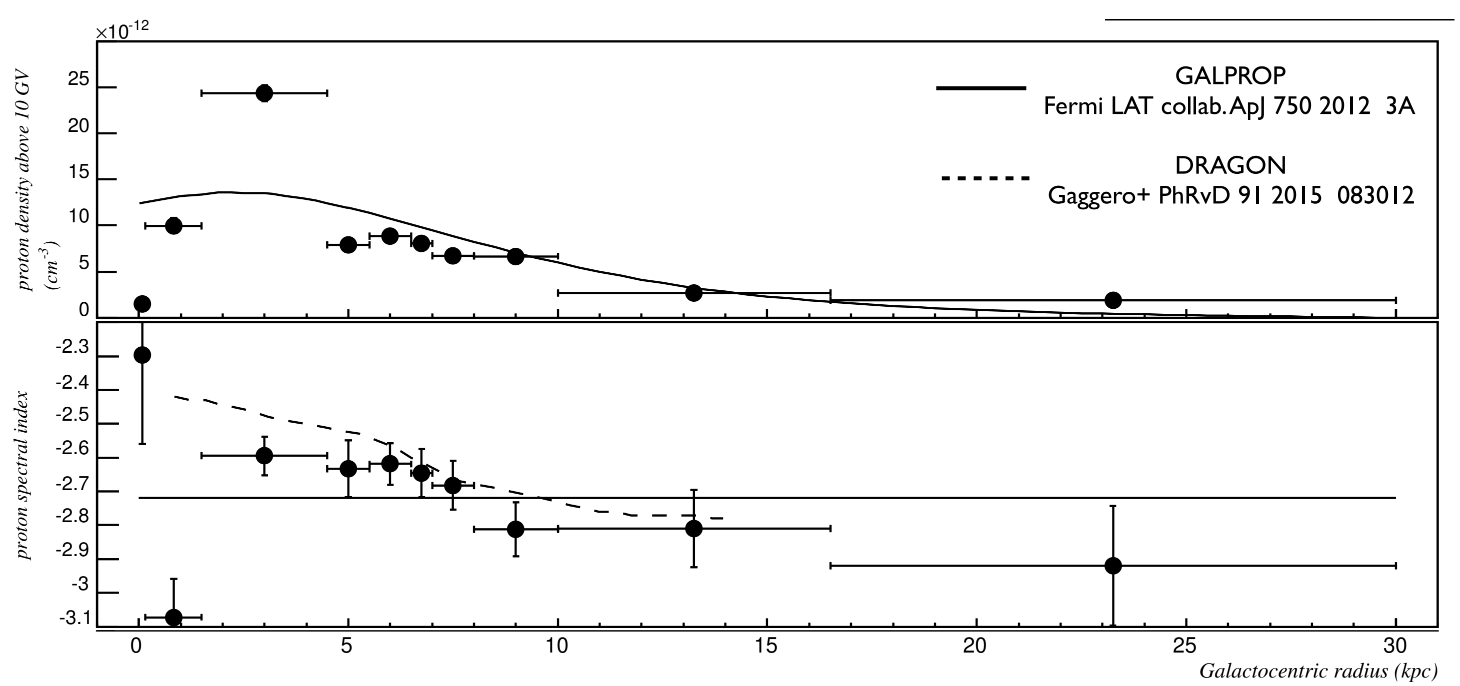
ADDING NEW PIECES TO THE PUZZLE

The GC PeVatron interpretation does not account for two new features which do not fit the conventional scenario

1. the CR hardening found by PAMELA, AMS and CREAM @ 300 GeV/nucleon

2. the CR proton spectral index radial gradient found in the Fermi-LAT data





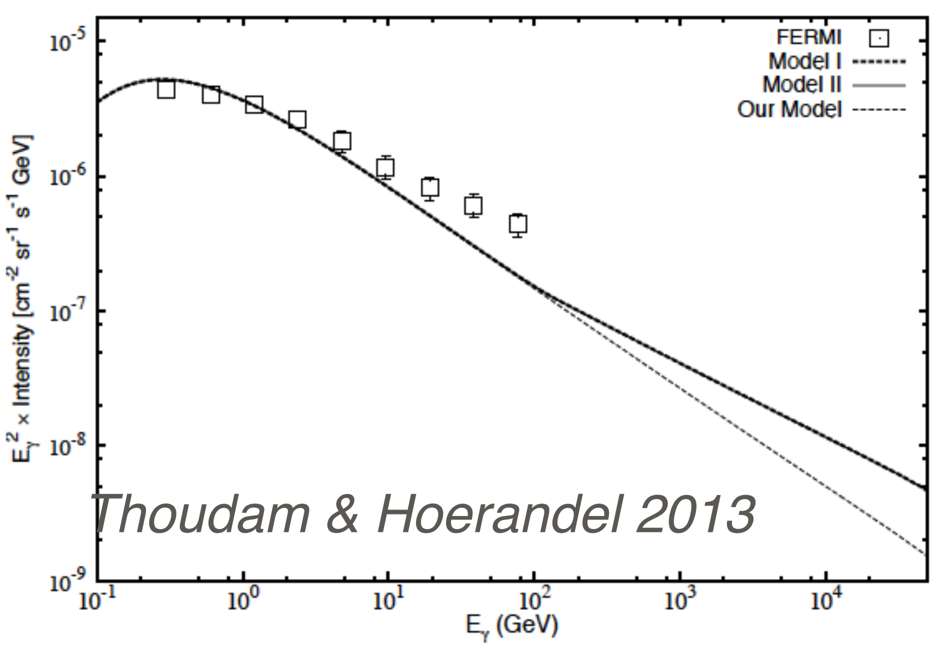
CR hardening @ 300 GeV/n

CREAM coll. ApJ Lett. 2010

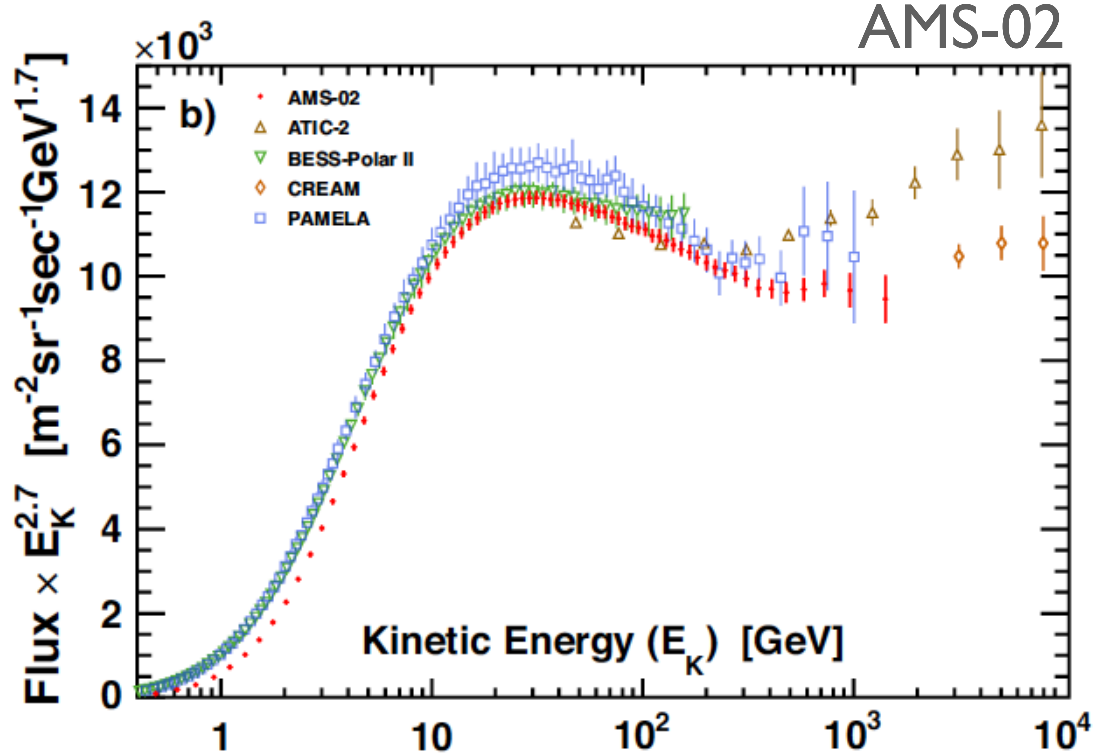
PAMELA coll. SCIENCE 2011

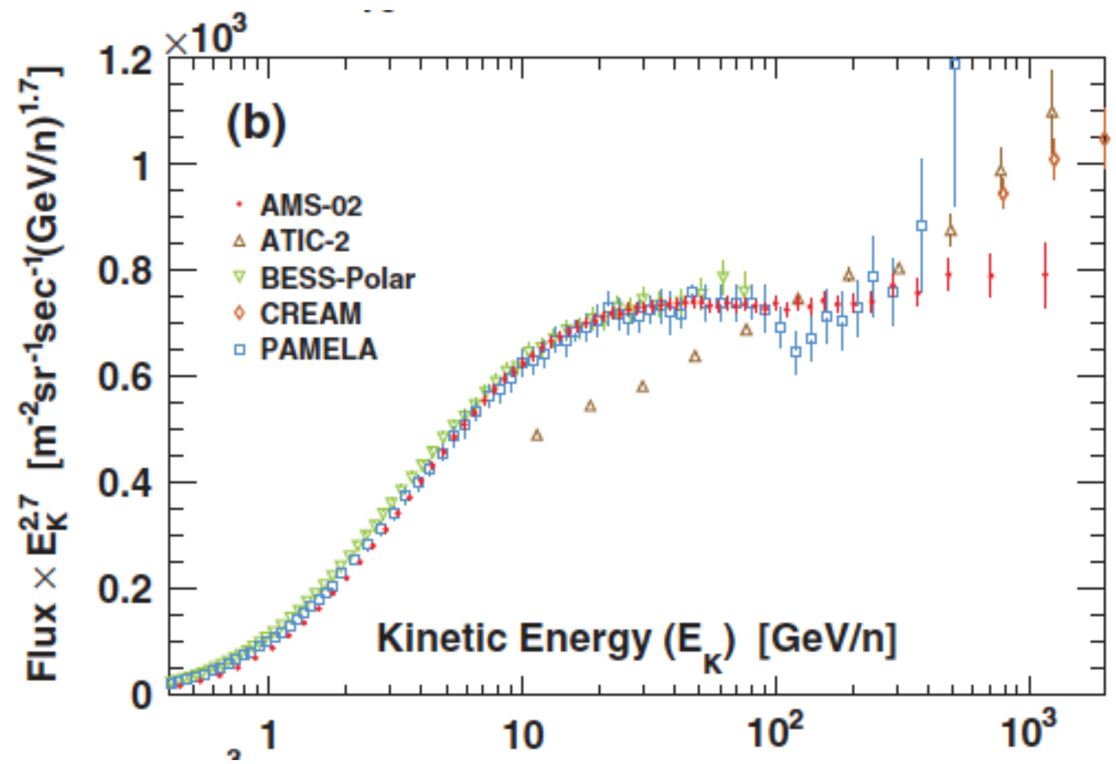
AMS-02 coll. PLR 2015

If the effect is present in the whole Galaxy - as expected if due to CR propagation (see e.g. *Blasi et al. 2012, 2015*) - *it should affect the diffuse γ-ray emission spectrum:*

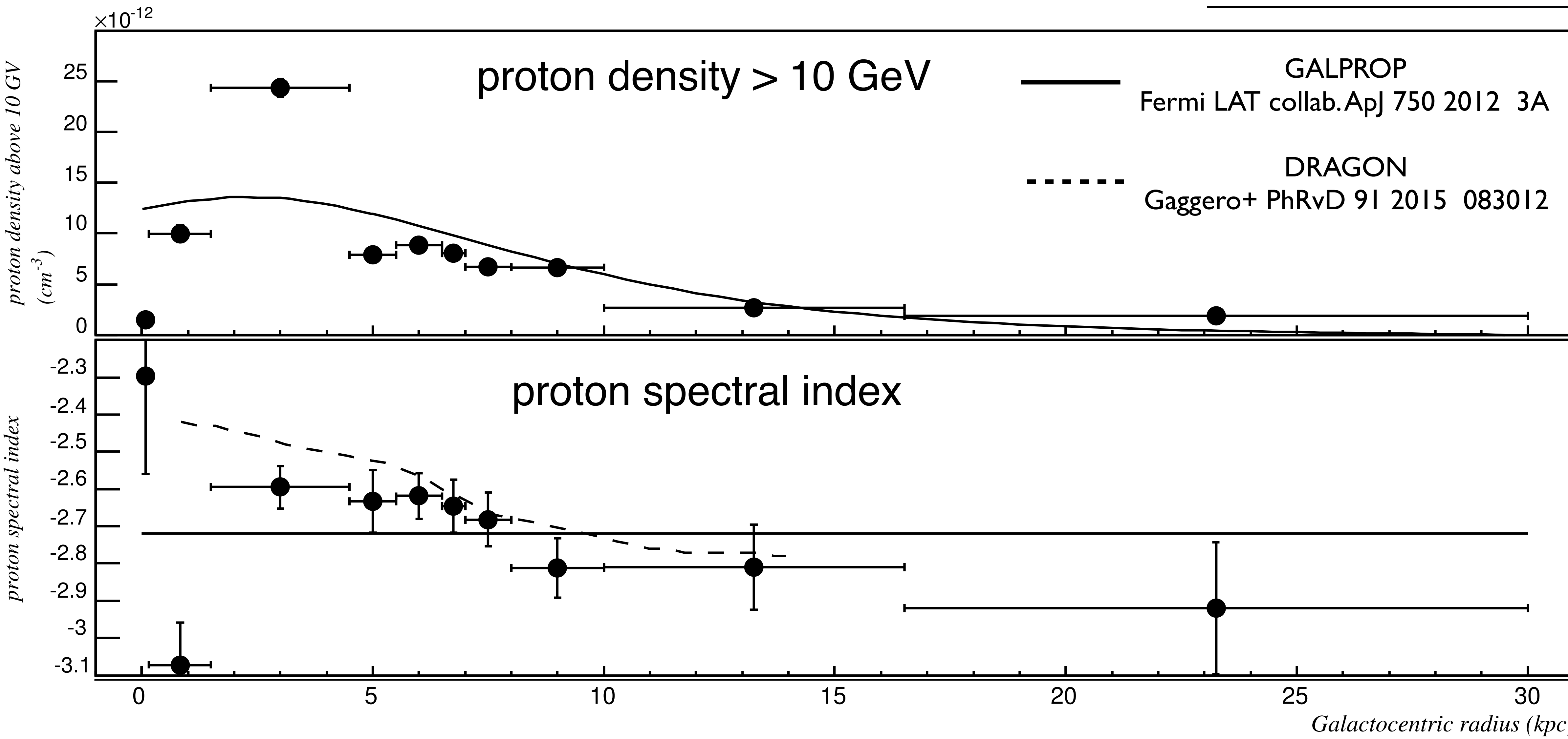


AMS-02





CR spectral index radial gradient



The model assumes a radial dependent diffusion coefficient $D(E) = D_0 \, (E/E_0)^{-\delta(R)}$

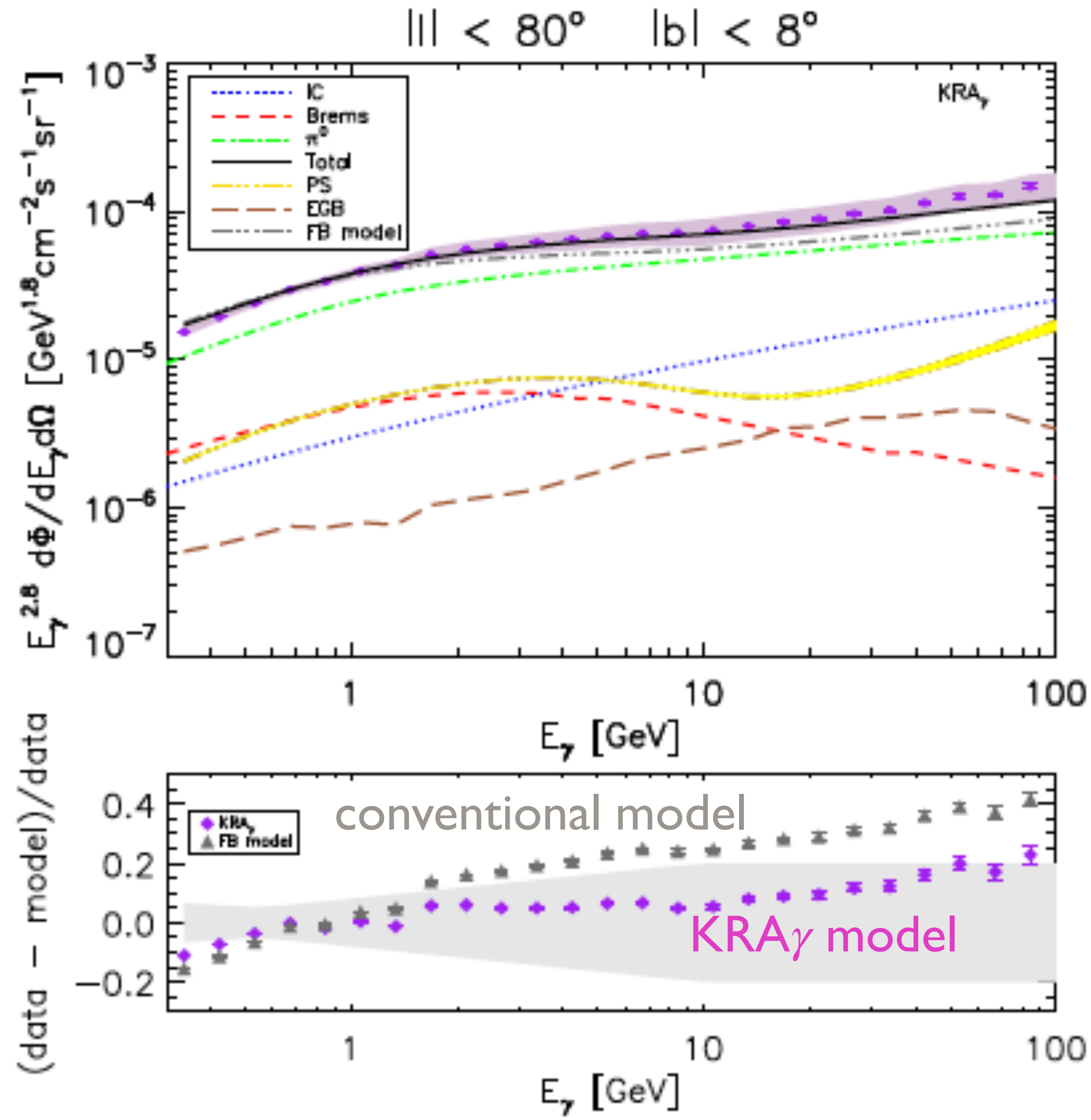
with $\delta(R) = A\,R + B$

so that $\Gamma(R) = \Gamma_{int} + \delta(R)$

CR spectral index radial gradient

Gaggero, Urbano, Valli & Ullio PRD 2015

The model reproduces CR spectra and the diffuse γ-ray spectrum on the whole sky including the inner Galactic plane where conventional models underestimate the flux



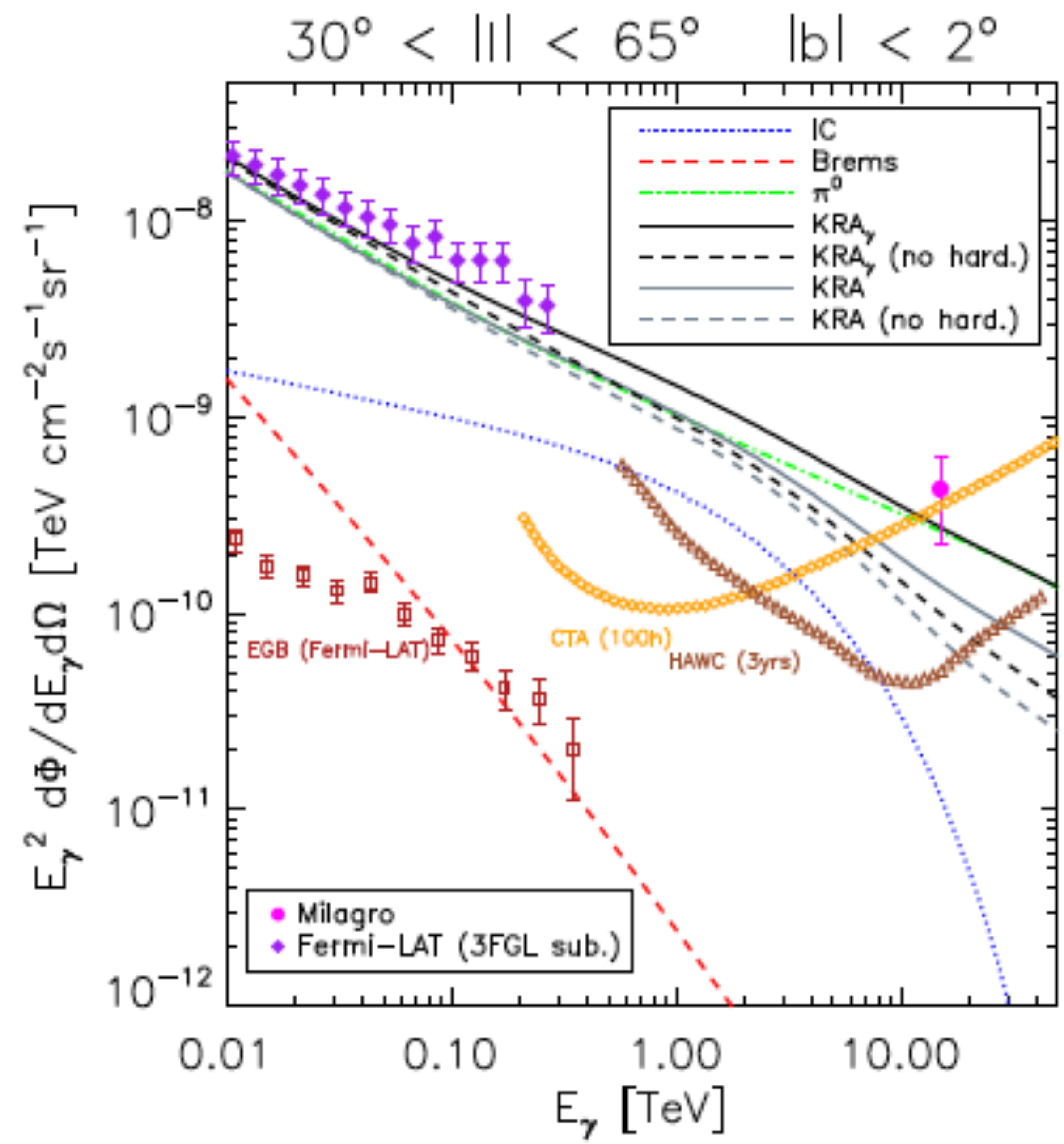
The first step above the TeV: solution of the Milagro anomaly

Gaggero, D.G., A. Marinelli, Urbano, Valli ApJ L 2015

Incorporate the CR spectral hardening in the KRAγ model (assuming it is present in the whole Galaxy).

This automatically reproduces the Milagro flux @ 15 TeV which was 4σ larger than the GALPROP prediction

testable by HAWC (work in progress) and CTA !

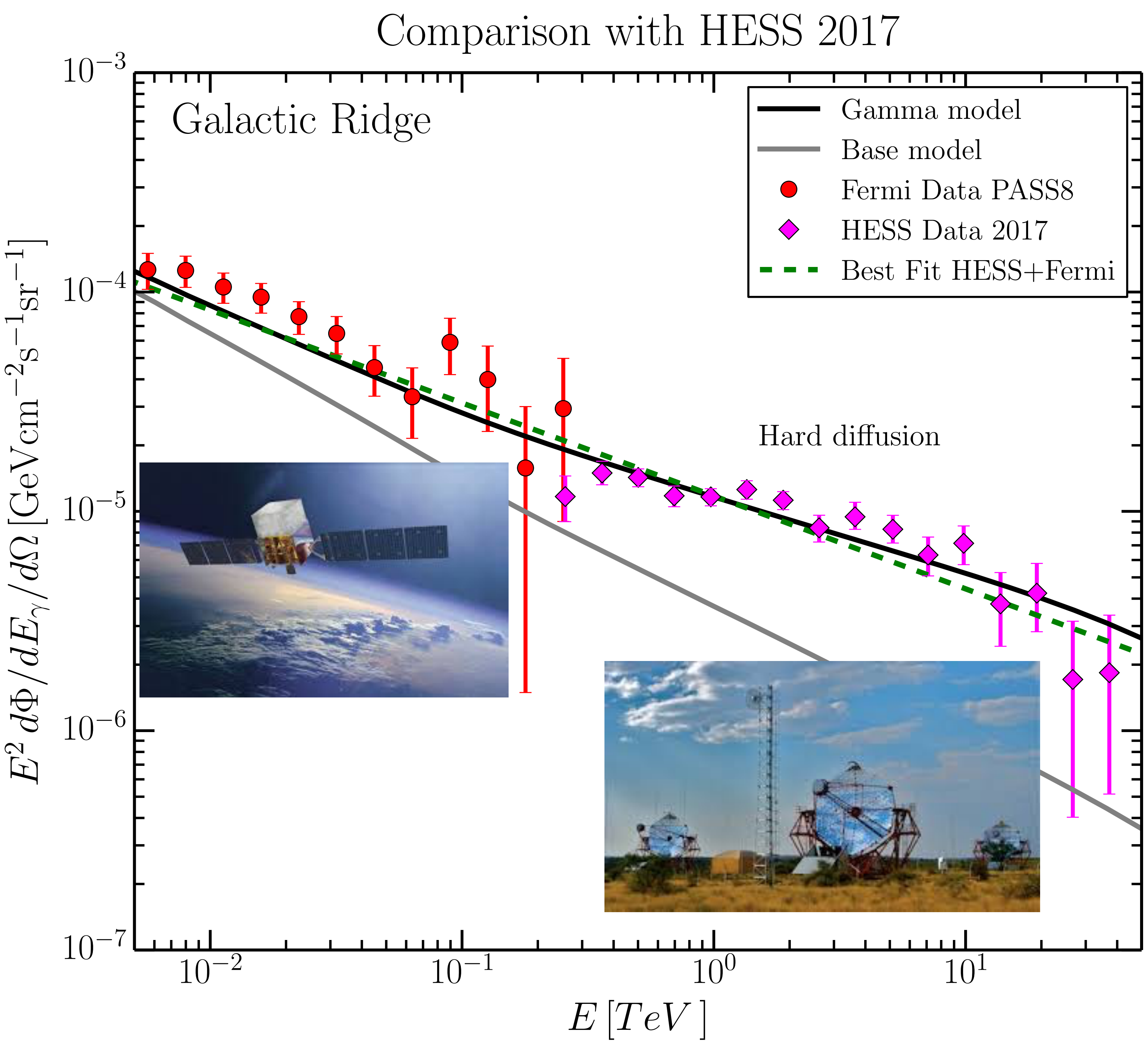


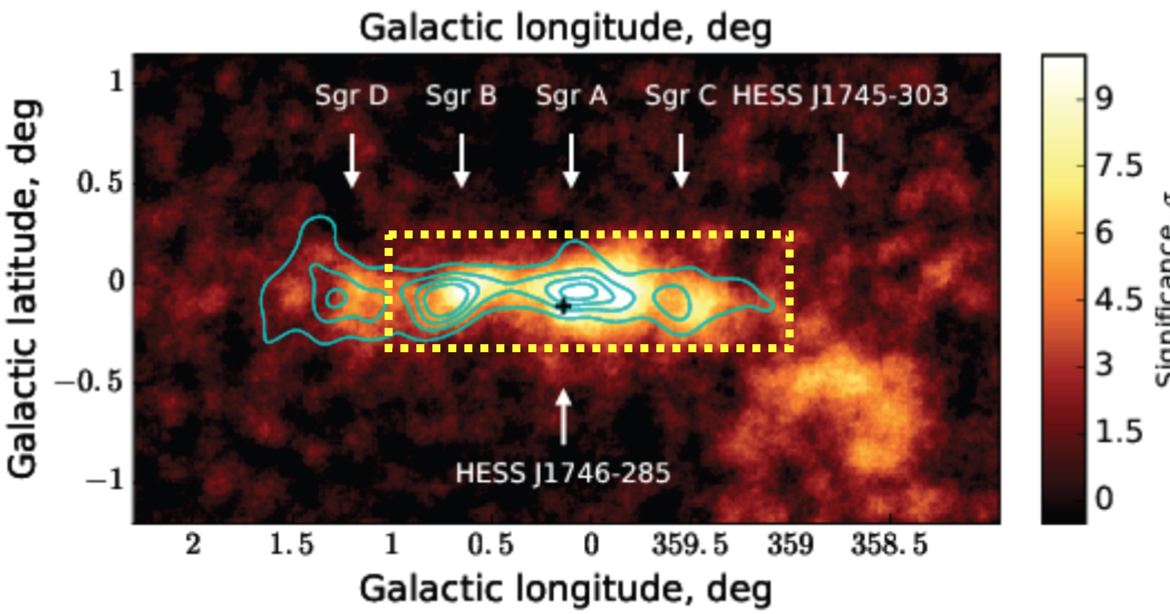
H.E.S.S. + Fermi-LAT

Gaggero, D.G., A. Marinelli, Taoso & Urbano, PRL 2017

+ S. Ventura

| l | < 1° , | b | < 0.3°



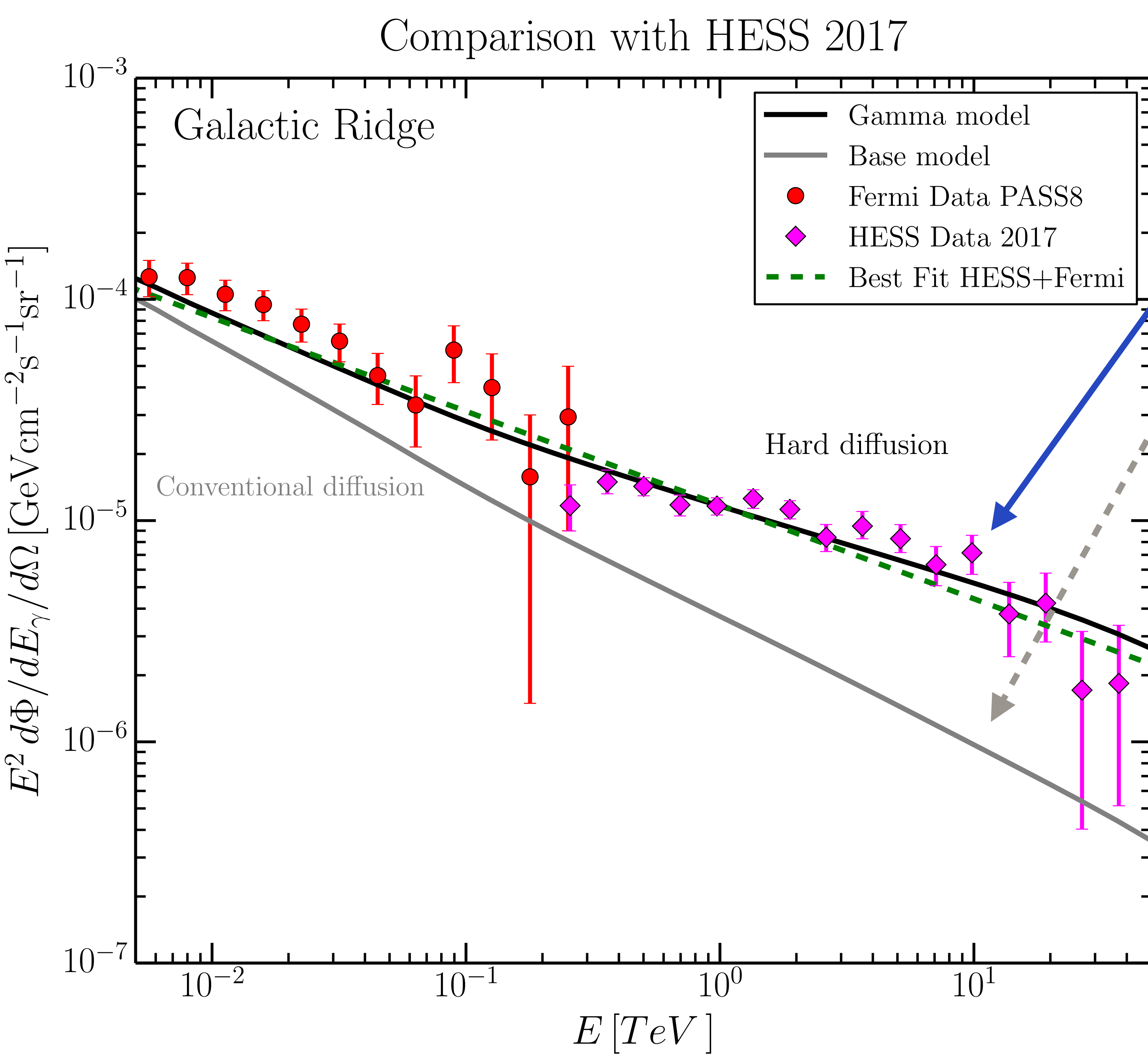


PASS8 Fermi-LAT 470 weeks of data extracted with the v10r0p5 Fermi tool. Point sources from the 3FGL catalogue subtracted.

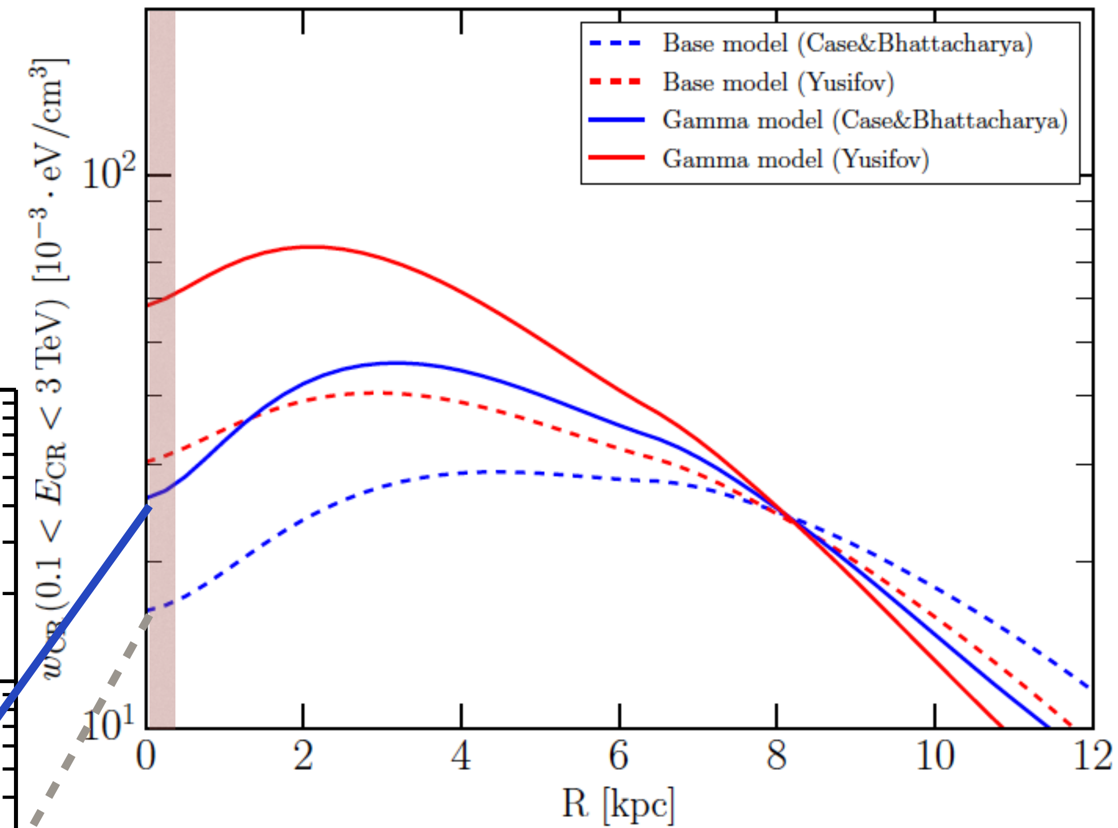
The effect of the new CR sea at the GC

Gaggero, D.G., A. Marinelli, Taoso & Urbano, PRL 2017

+ S. Ventura



| l | < 1° , | b | < 0.3°

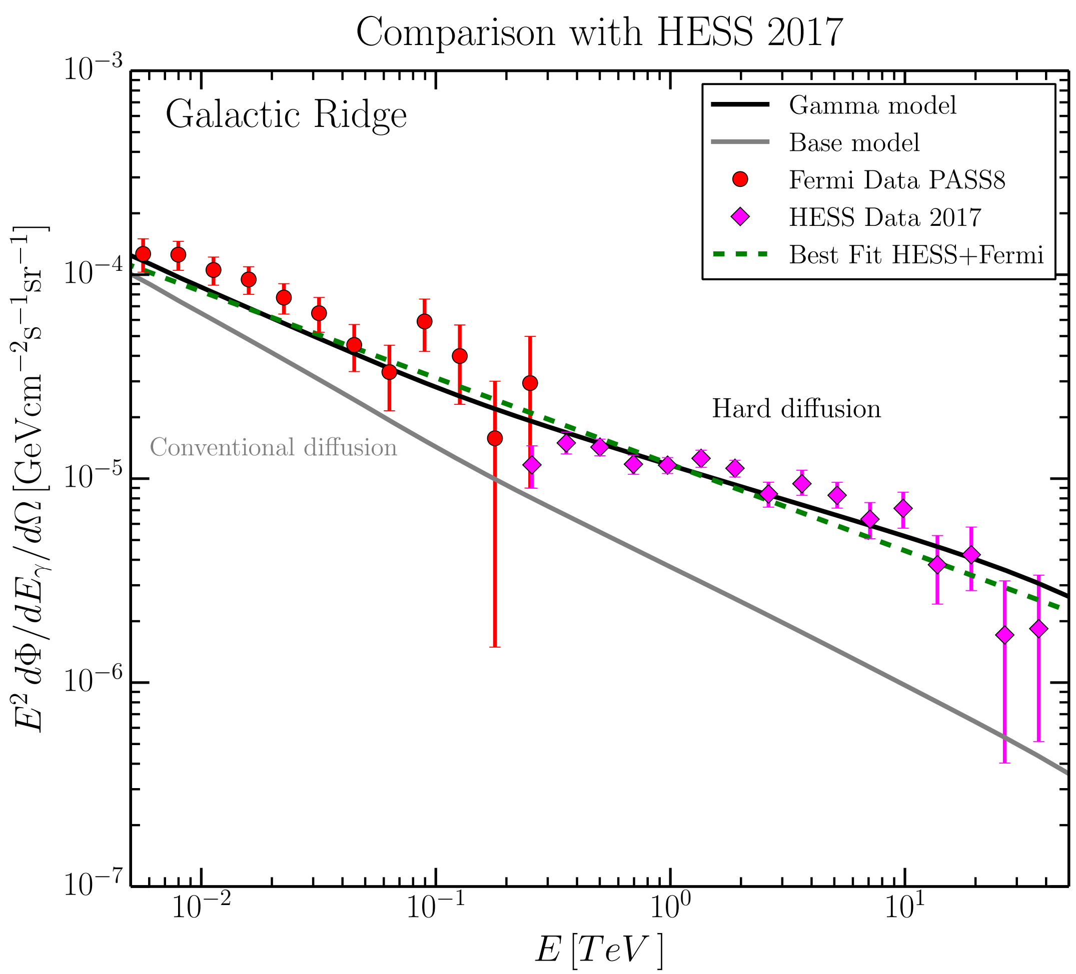


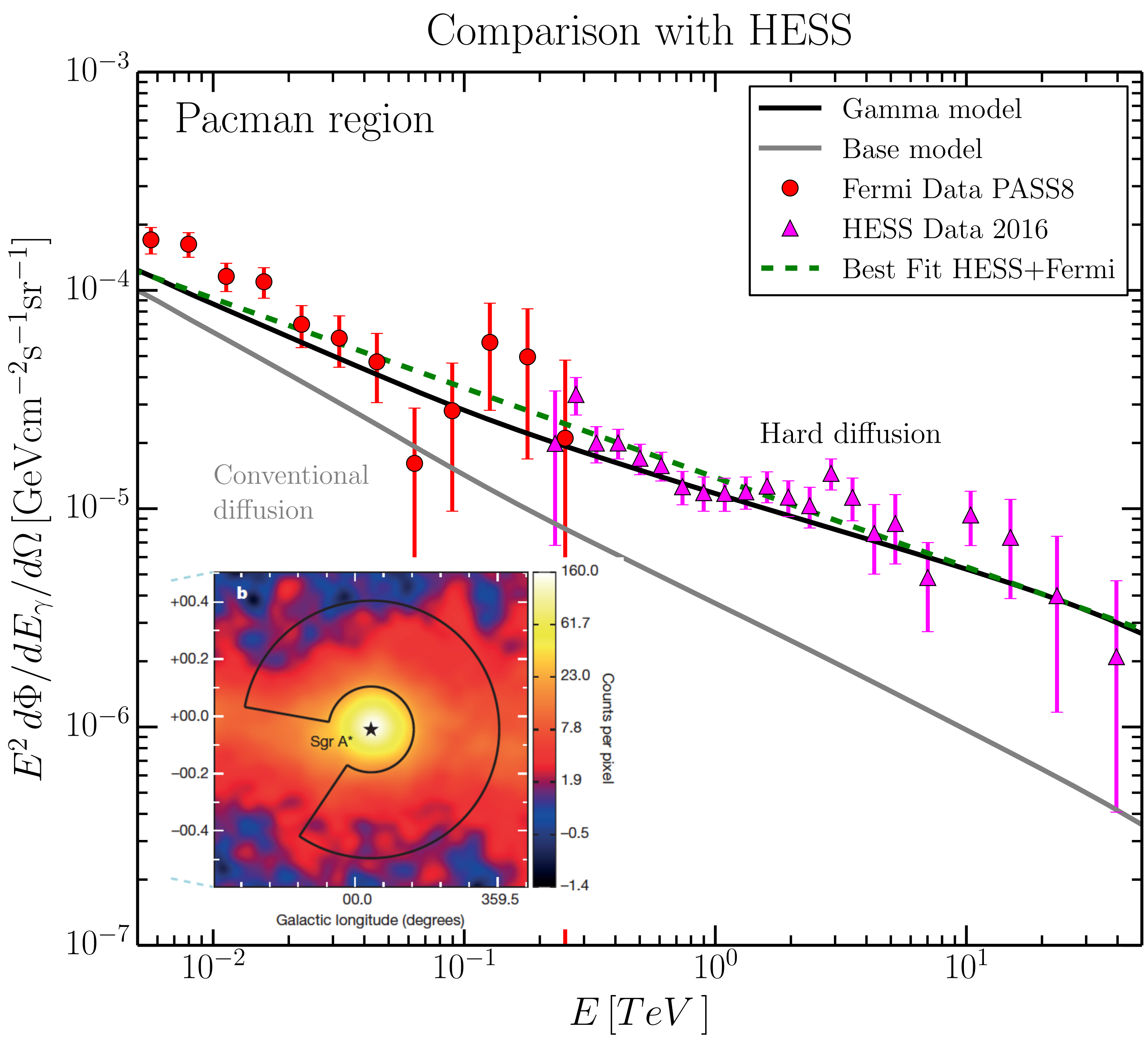
Degeneracy between poorly known gas and CR source densities at the GC

We use the [*Ferriere 2007*] 3-D gas model choosing a normalisation (X_{CO}) such to match the gas column density maps adopted by HESS

The effect of the new CR sea at the GC

Gaggero, D.G., A. Marinelli, Taoso & Urbano, PRL 2017
+ S. Ventura



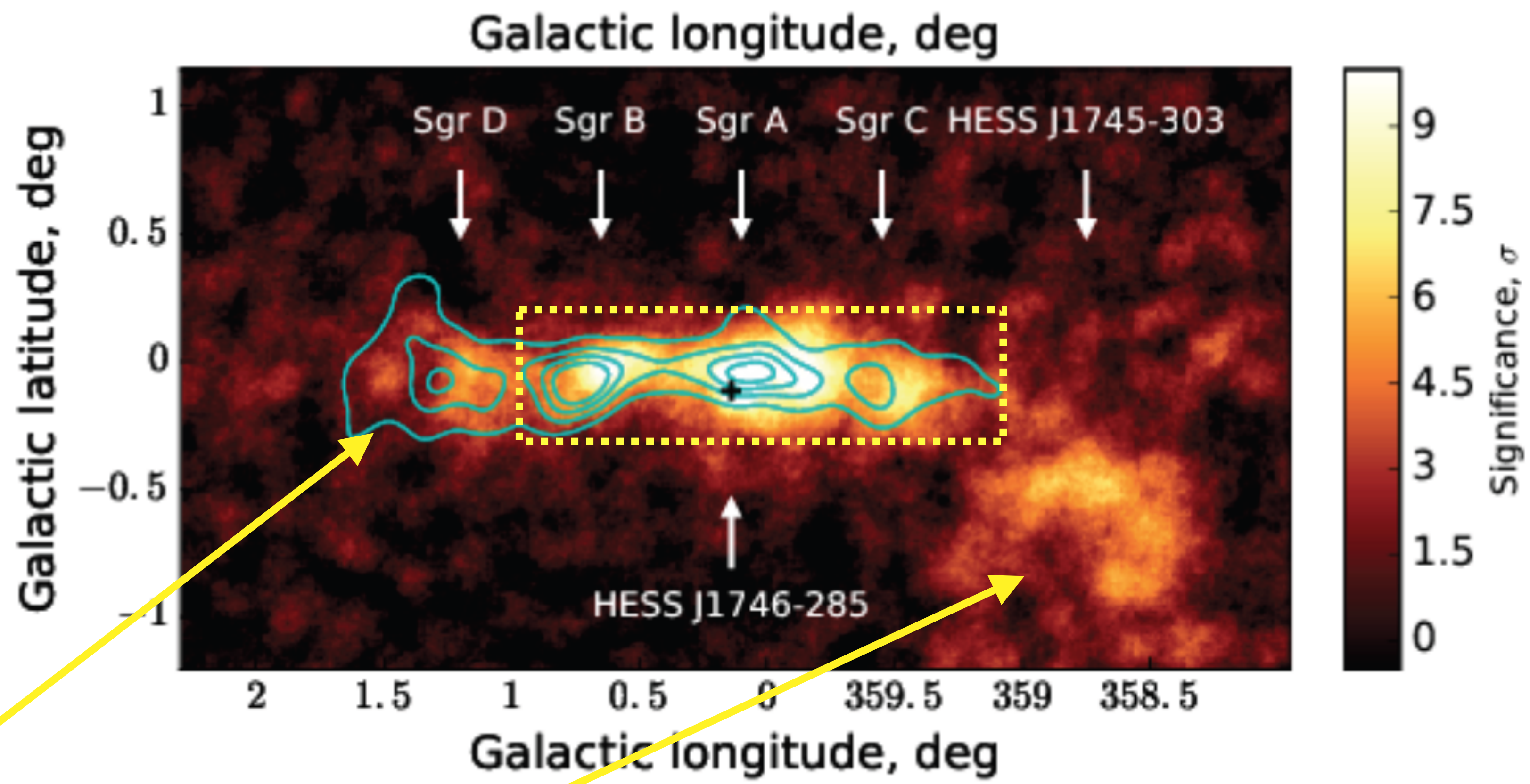


No evidence a local component taking over a high energy and dominating at the Galactic center

Very good agreement with large scale model of the diffuse emission based on Fermi data

Future perspectives

CTA may observe more external clouds where the PeVatron scenario predicts a lower CR density than that expected in our scenario



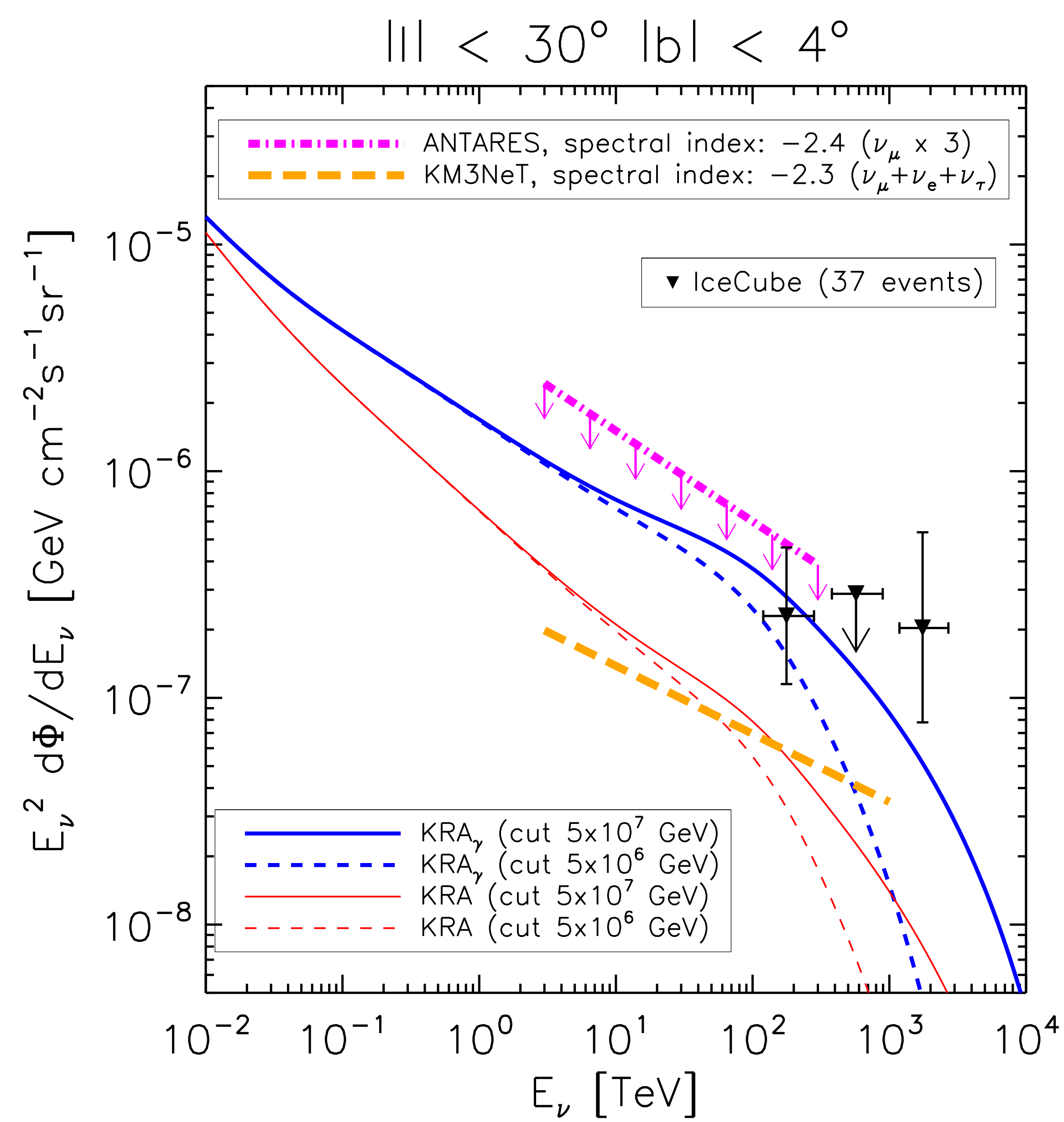
Implications for neutrino astronomy

Gaggero, D.G., A. Marinelli, Urbano, Valli ApJ L 2015

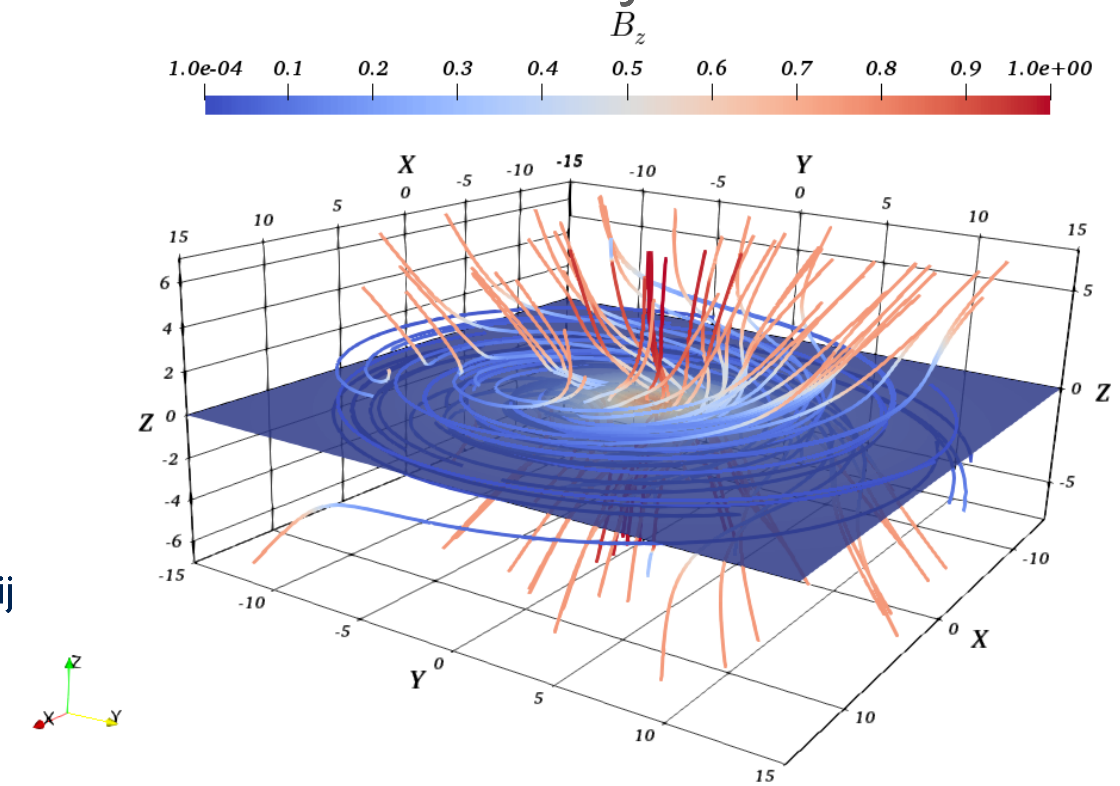
ANTARES coll. , Phys. Lett. B, 2016

ANTARES coll. + *D. Gaggero, D.G.* arXiV:1705.00497

- On the whole sky the diffuse flux due to the Galaxy is 8 % (4 % for conventional models) of that measure by IceCube
- In the inner Galactic plane however the gain is much more consistent ➡
- A neutrino telescope in the North hemisphere is more suited to detect the Galactic component. IceCube coll. is using our templates to look for this Galactic component. ANTARES present upper limit is at 1.25 times our most optimistic prediction. Observable by KM3NeT (work in progress) !



based on Jansson & Farrar 2012



A possible theoretical interpretation

Cerri, Gaggero, Vittino, Evoli & DG, to be submitted. 2017

Anisotropic CR diffusion in the presence of a poloidal magnetic field component

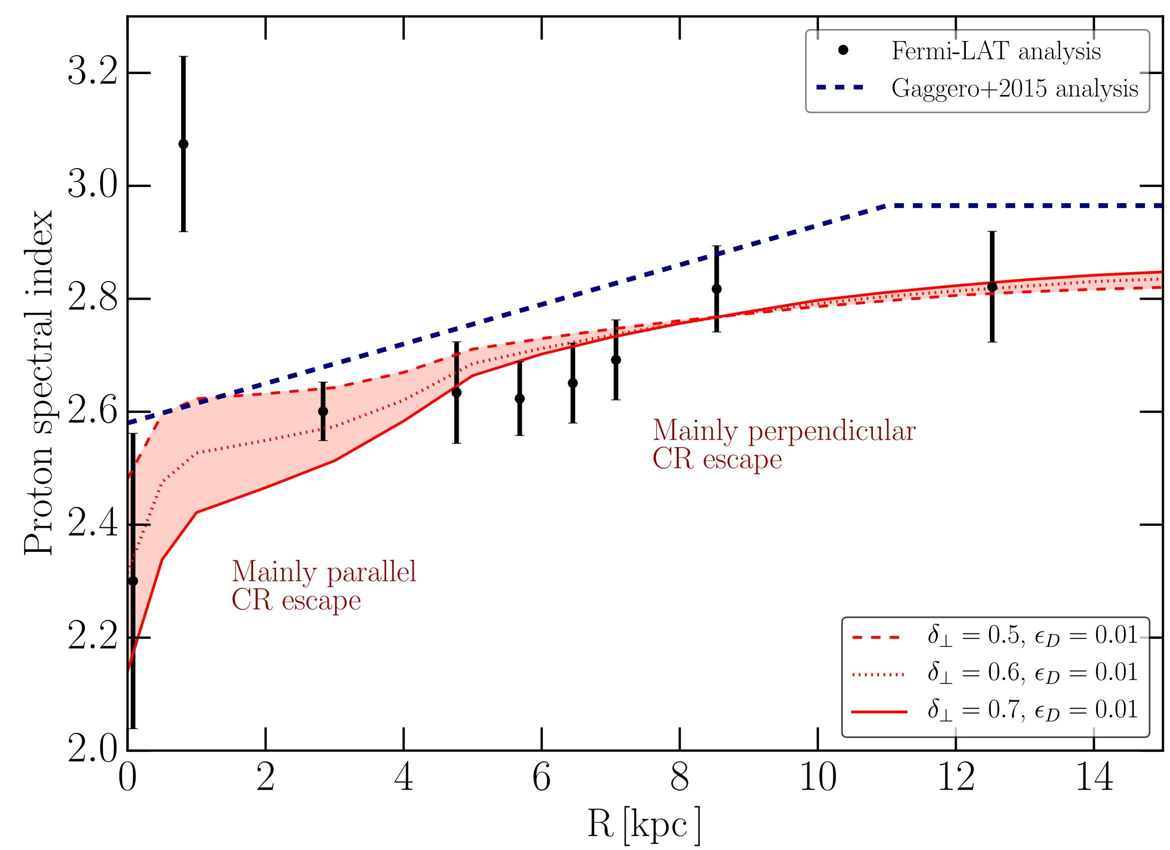
$$D_{ij}(\mathbf{x},\rho) = [\, D_{||}(\mathbf{x},\rho) - D_{\perp}(\mathbf{x},\rho) \,]\, b_i\, b_j + D_{\perp}(\mathbf{x},\rho)\, \delta_{ij}$$

$D_{||}$ and $D_{\perp}$ are expected to have different rigidity dependence (*Blasi, De Marco, Stanev 2007 and Snodin et al. 2012*) found

$$D_{||} \propto \rho^{1/3} \quad D_{||} \propto \rho^{1/2}$$

for Kolmogorov turbulence.

We incorporated this behaviour in the DRAGON 2 code (*Evoli, Gaggero, Vittino,, Di Bernardo, Ligorini, Di Mauro, Ullio, DG , JCAP 2017)* allowing for anisotropic diffusion



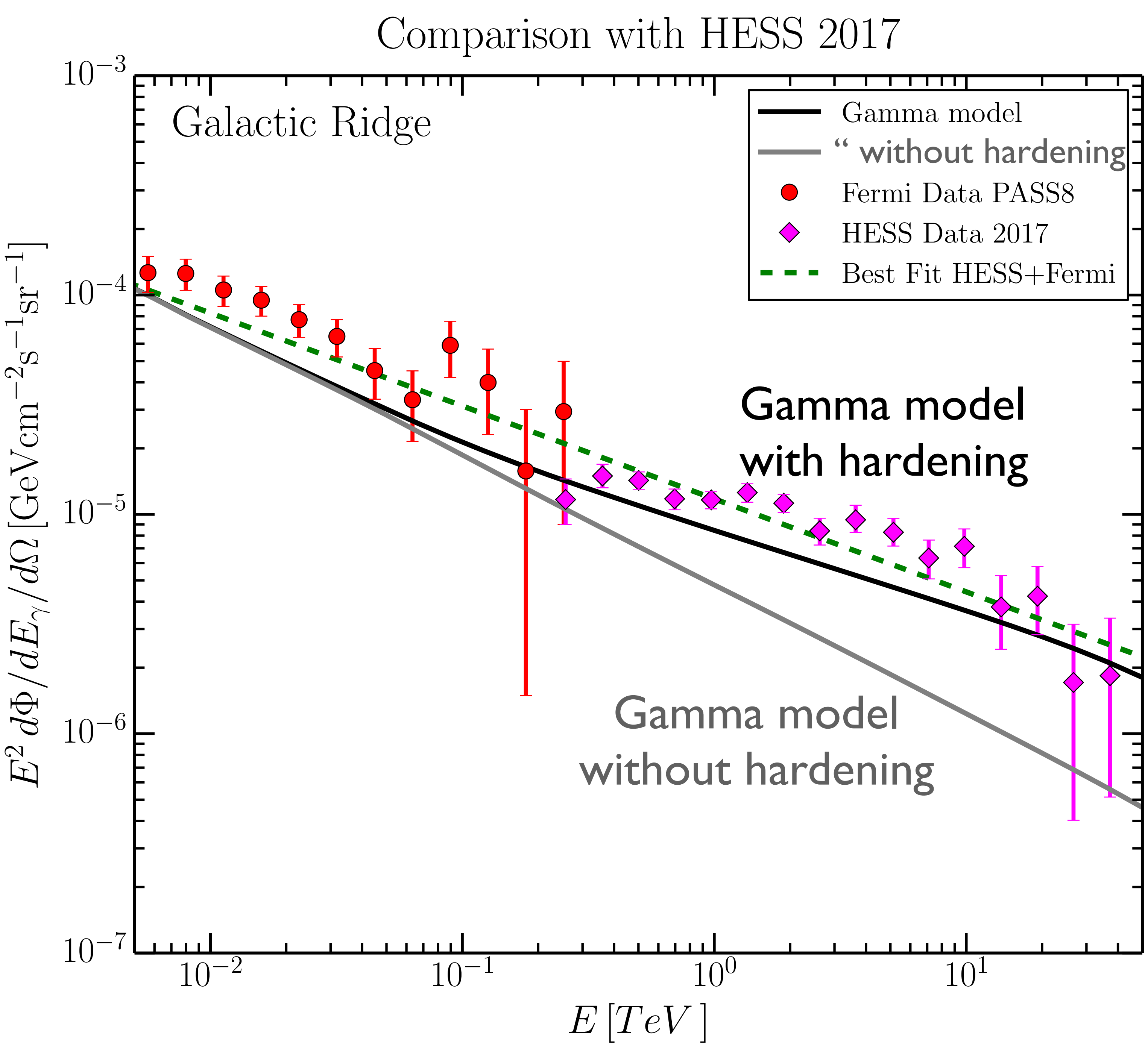
CONCLUSIONS

- H.E.S.S. and Fermi-LAT data are consistent showing the presence of a single CR component in the CMZ region with index $\sim$ 2.3
- The large scale, steady-state, CR Galactic population can nicely account for that emission if computed with a model accounting for the radial gradient of the CR spectral index found in the Fermi data and the CR spectral hardening found by Pamela & AMS
- CTA may confirm the scenario we proposed observing the emission from molecular clouds at distances > 200 pc from the GC
- The neutrino emission from the Galactic ridge is expected to be significantly enhanced under those conditions and be detectable by KM3NeT
- Those results strongly motivate to go beyond conventional modelling of CR propagation in the Galaxy

BACKUP SLIDES

The spectrum in the ridge without CR spectral gardening @ 300 GeV/n

| l | < 1° , | b | < 0.3°



This seems to require that the hardening found in the proton and He spectrum by Pamela and AMS is present in the whole Galactic disk !