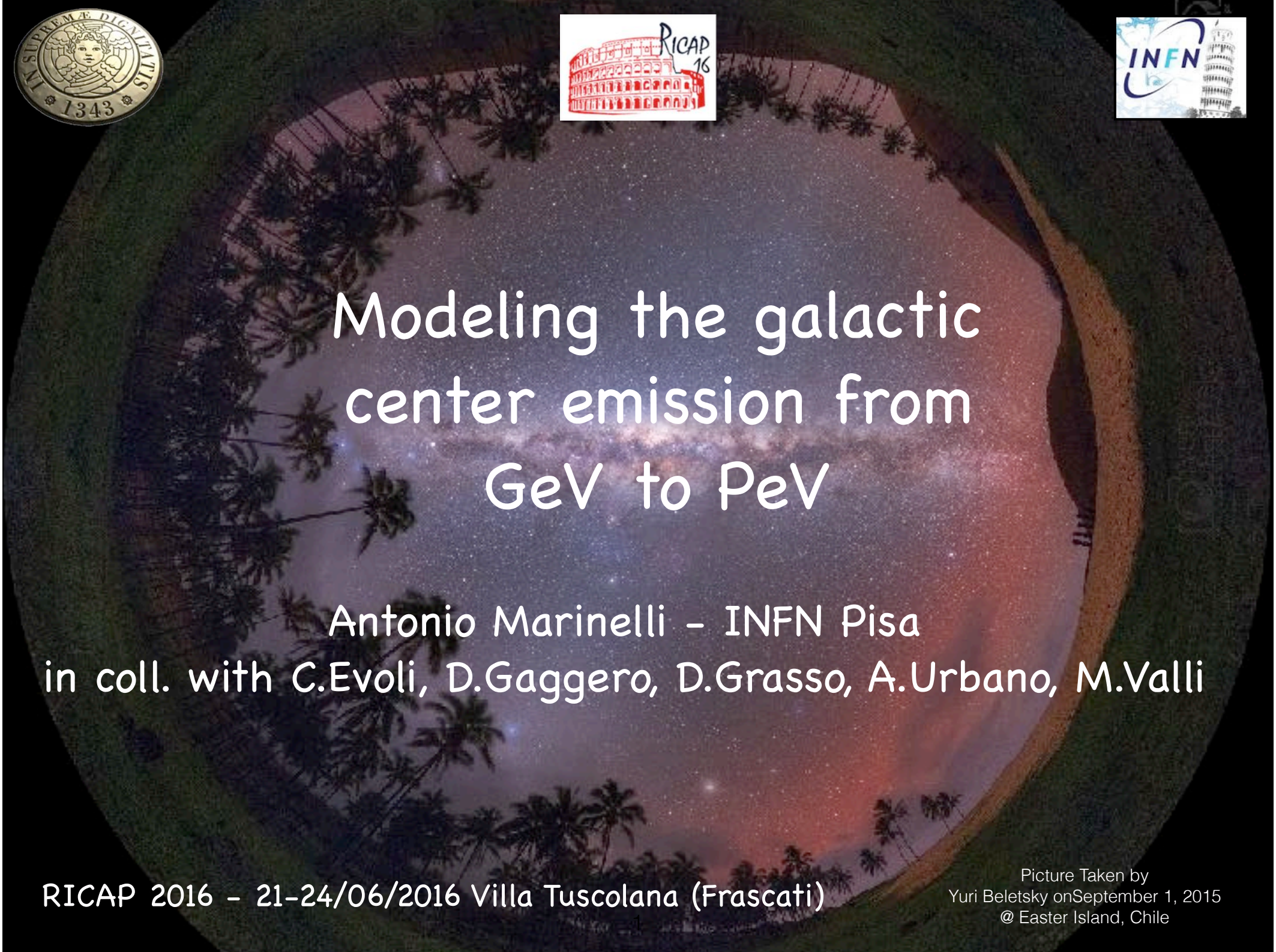


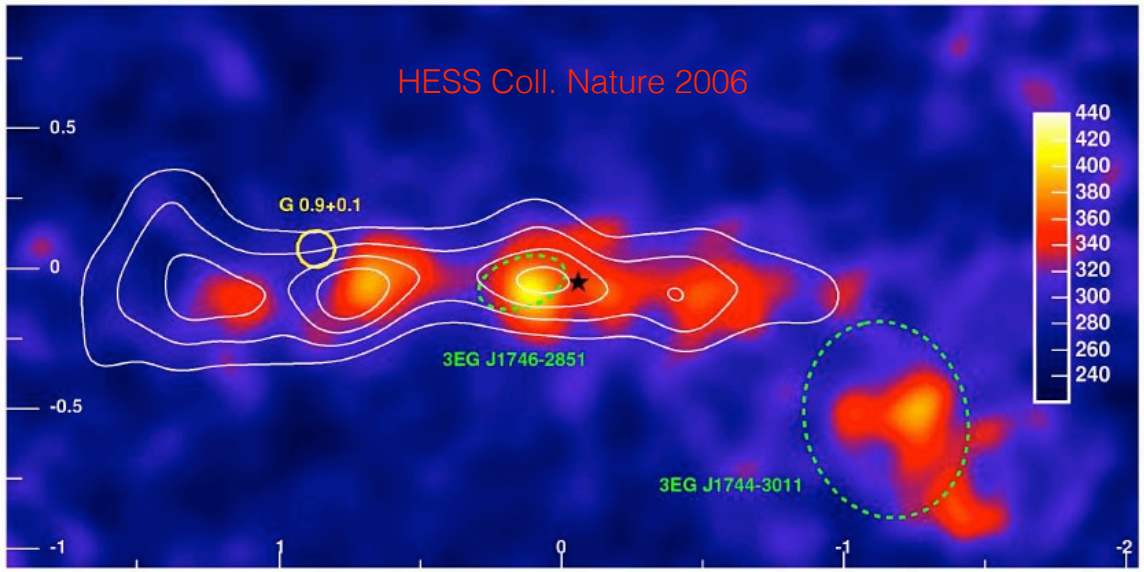
Modeling the galactic center emission from GeV to PeV

Antonio Marinelli - INFN Pisa
in coll. with C.Evoli, D.Gaggero, D.Grasso, A.Urbano, M.Valli

RICAP 2016 - 21-24/06/2016 Villa Tuscolana (Frascati)

Picture Taken by
Yuri Beletsky onSeptember 1, 2015
@ Easter Island, Chile

Galactic ridge from HESS 2006

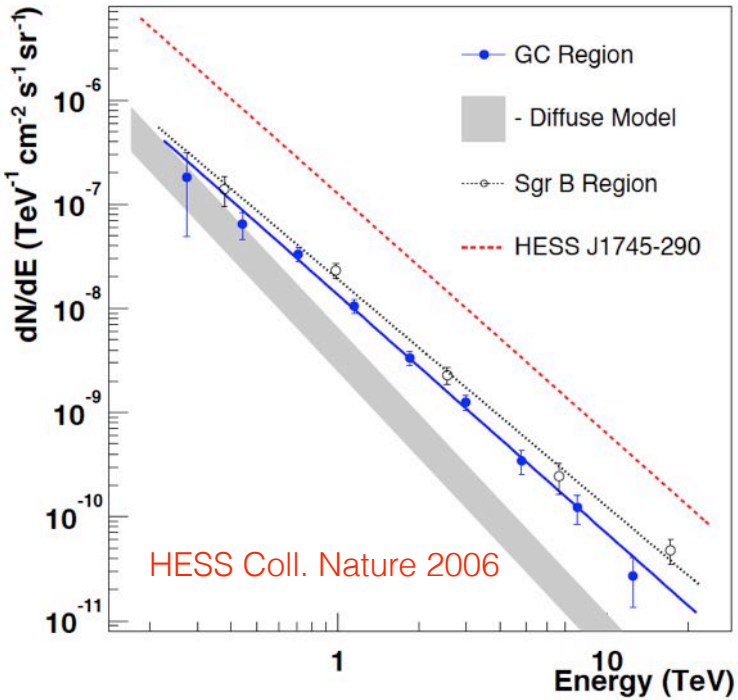


Diffuse gamma-ray emission measured by HESS collaboration after the subtraction of point-like components:

$-0.8° < |l| < 0.8°$ & $|b| < 0.3°$

$\Gamma = 2.29 \pm 0.07$ stat ± 0.20 sys

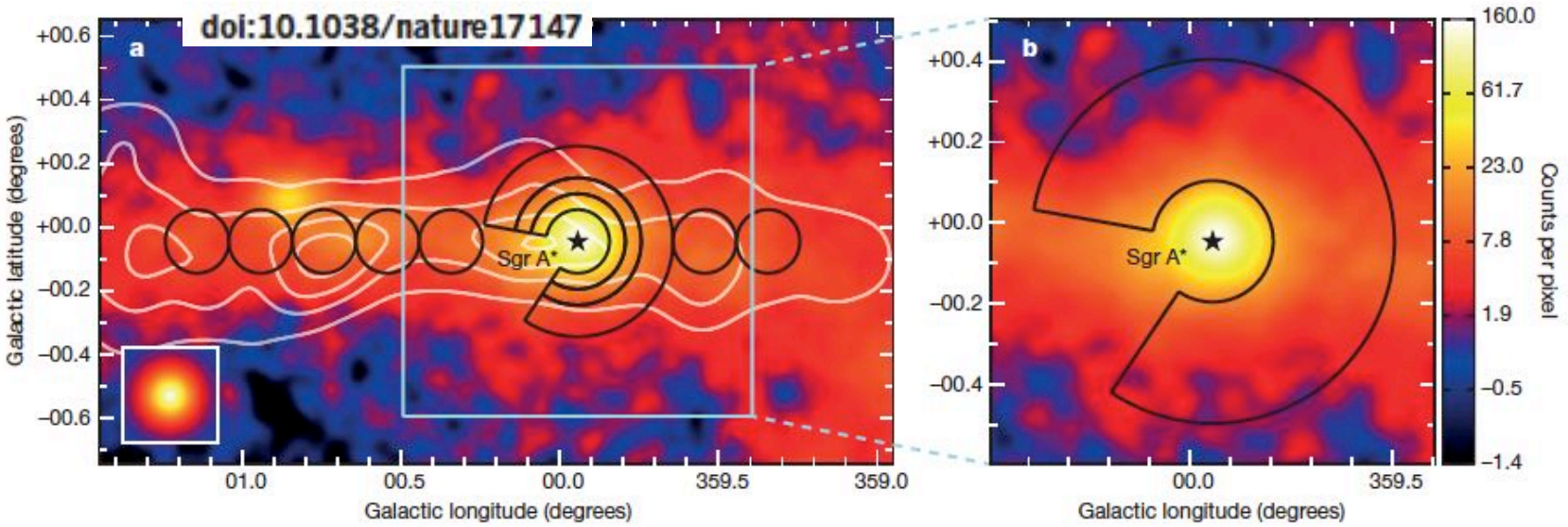
with a significance of 14.6 σ



The diffuse component expectation considering a CR spectral behavior similar to that one measured on earth seems far to the diffuse measured spectrum.

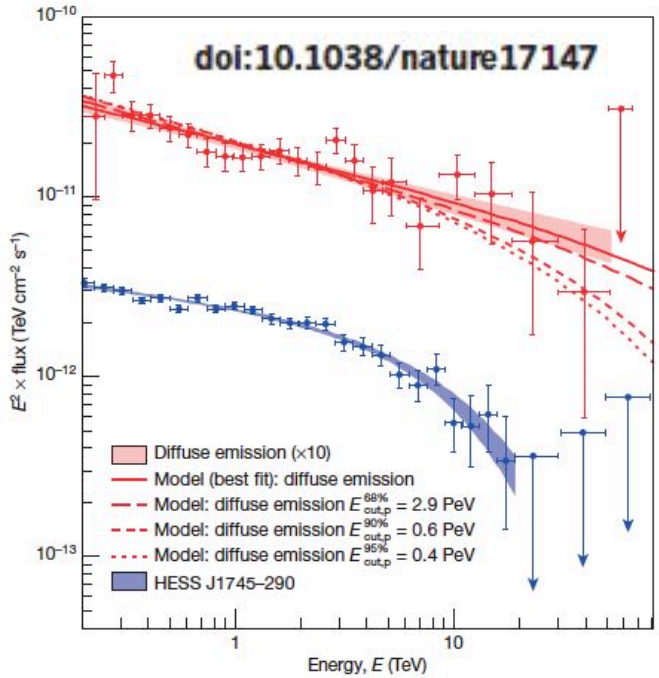
With this standard scenario a subdominant diffuse sea component is expected respect to the diffuse emission linked to the point-source present there.

Central "Pac-man" measured from HESS 2016



New observations of a diffuse gamma-ray spectrum possibly produced by a Pevatron source

1.4 x 10^-4 sr



Best Fit spectrum for the "pac-man" region:

Φ_0 =1.92 ± 0.08 stat ± 0.28 sys 10^-12 TeV^-1 cm^-2 s^-1

Γ = 2.32 ± 0.05 stat ± 0.11 sys

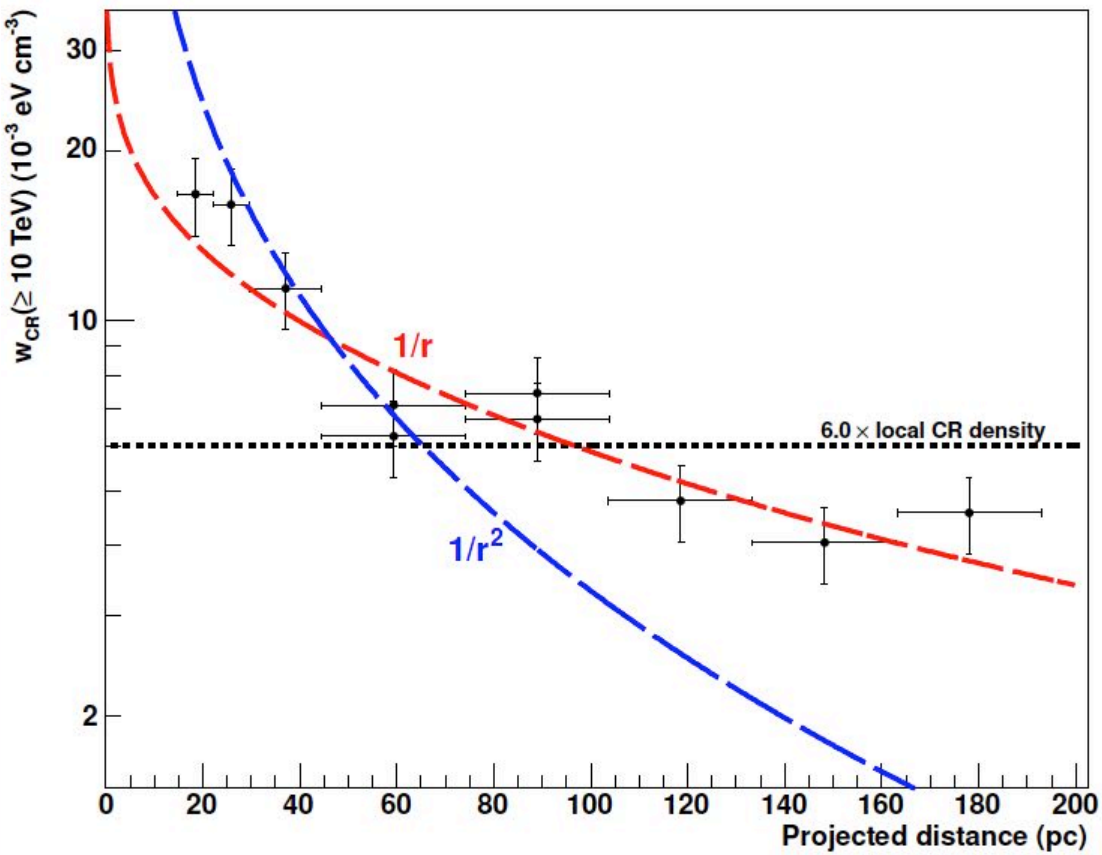
Best Fit spectrum for Sagittarius A*:

Φ_0 =2.55 ± 0.04 stat ± 0.37 sys 10^-12 TeV^-1 cm^-2 s^-1

Γ = 2.14 ± 0.02 stat ± 0.10 sys

Ecut= 10.7 ± 2.0 stat ± 2.1 sys TeV

Cosmic-ray profile obtained for the pac-man region



Cosmic-ray density profile measured for the first 200 pc from Sagittarius A*
The profile seems to be more consistent with a 1/r profile

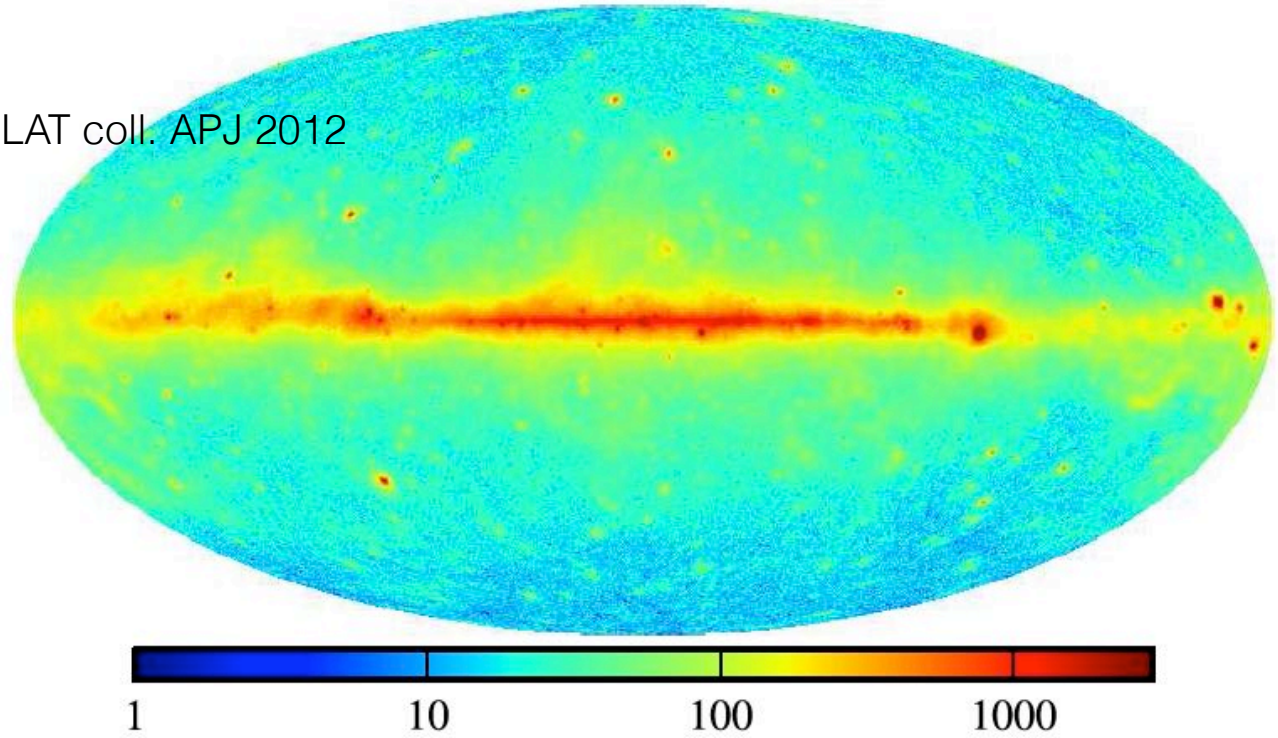
$$w_{\rm CR}(E,r,t) = \frac{\dot{Q}_p(E)}{4\pi D(E) r}\ {\rm erfc}(r/r_{\rm diff})$$

To estimate the level of cosmic-ray density for the galactic "sea" and see where this intercept the data help to understand also the injector characteristics and the size of the interaction size to produce this gamma-ray spectrum

The 1/r profile of the cosmic-ray density up to 200 pc indicates a quasi-continuous injection of protons into the central molecular zone from a centrally located accelerator on a timescale exceeding the characteristic time of diffusive escape of particles from the central molecular zone. This should be verified with other models for the diffuse sea present there.

Correct estimation of Diffuse sea is important

Fermi-LAT coll. APJ 2012



Observed Fermi-LAT counts in the energy range 200 MeV to 100 GeV after point-sources subtraction (log scale = counts/pixel)

The gamma-ray diffuse emission is mainly related:

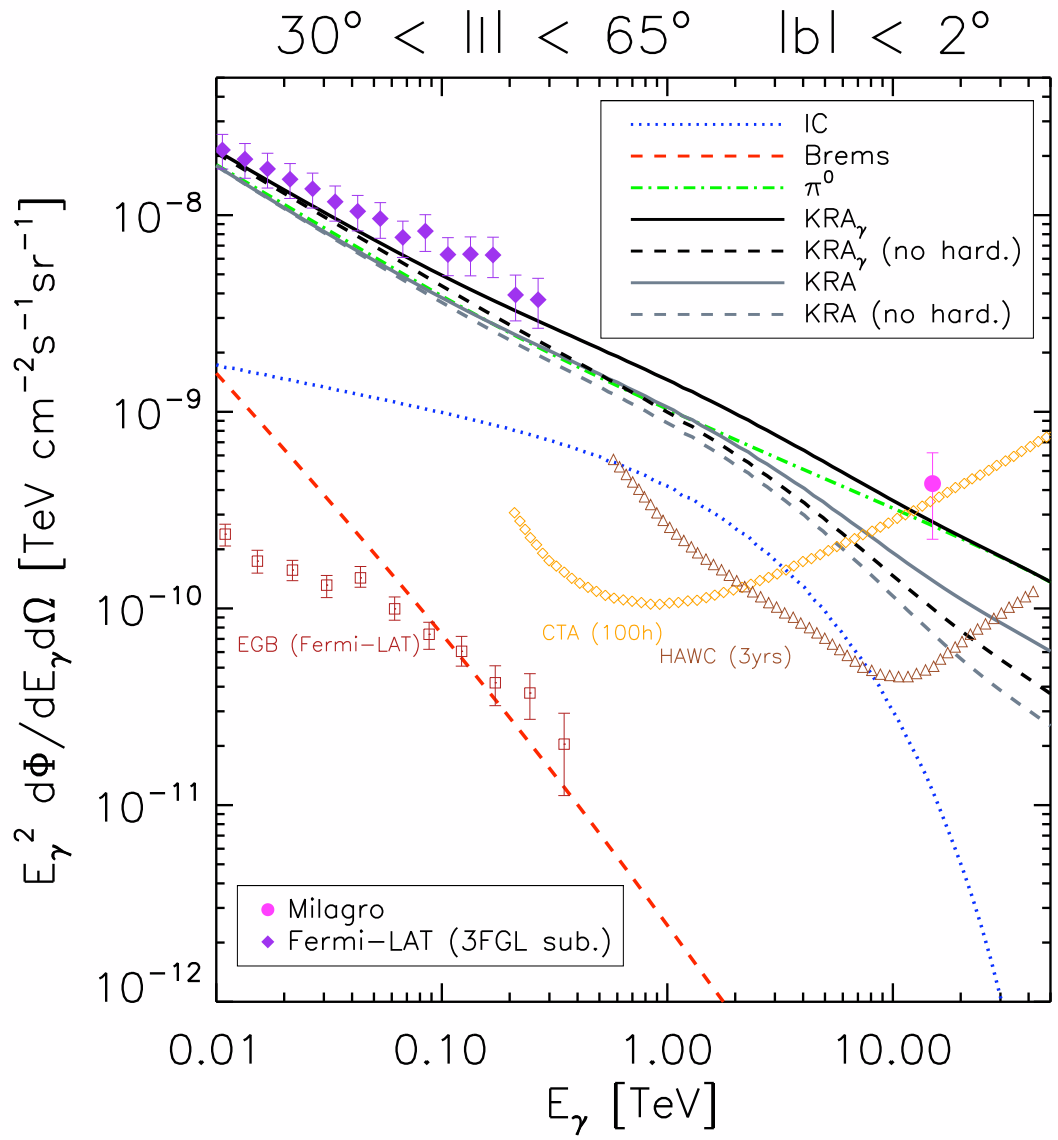
- Photopion production due to the CR/gas collision - Dominant for the inner GP, produce also ν
- Bremsstrahlung of relativistic electrons in gas
- Inverse-Compton of relativistic electrons with ISRF

Introducing the diffuse sea through the KRA$_\gamma$ model

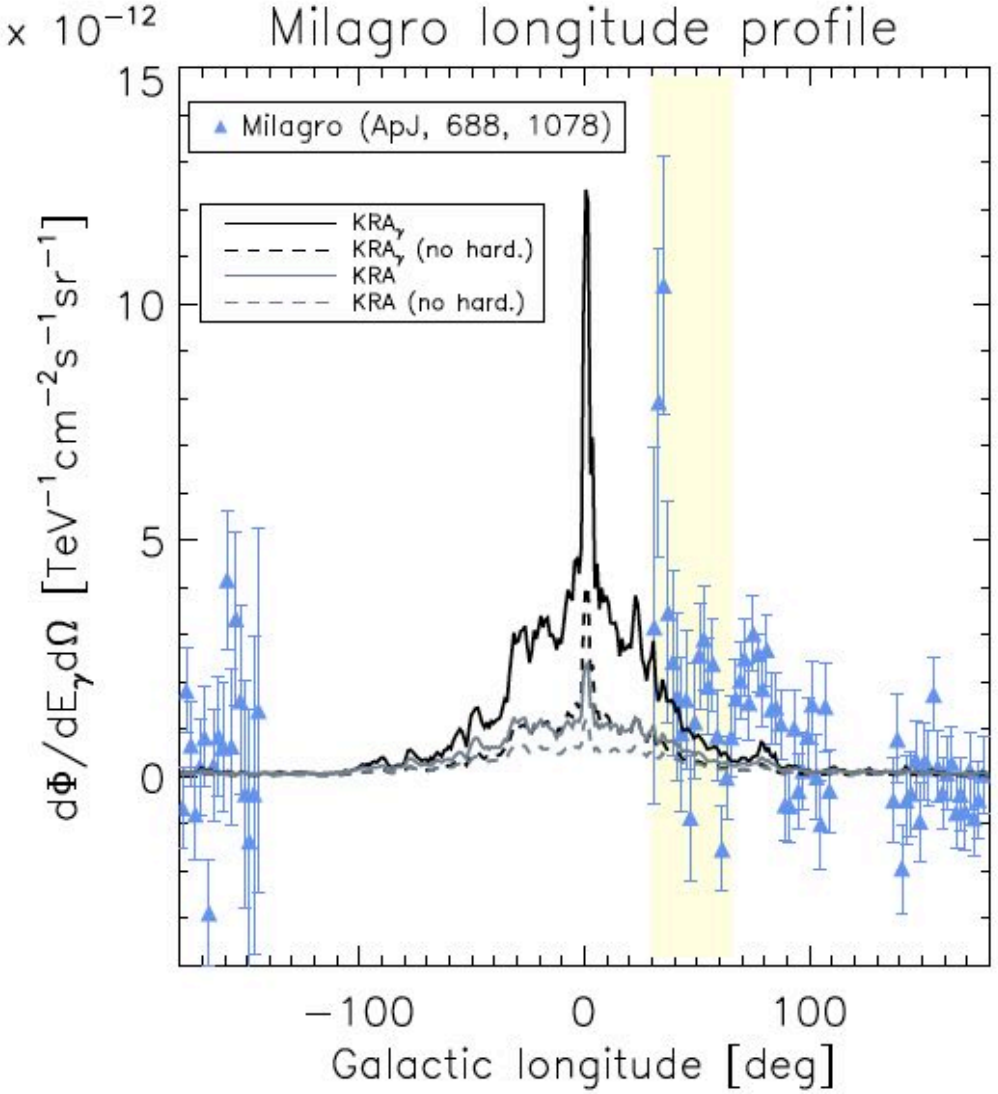
Introduced in Dario Grasso talk

Gaggero, Grasso, Marinelli, Urbano, Valli, arXiv:1504.00227

- Milagro measured the diffuse γ-ray flux from the inner Galactic plane @ 15 TeV
- Milagro flux exceeds the predictions of conventional models based on GALPROP. This a longstanding problem in CR physics
- The KRA$_\gamma$ model consistently reproduces Fermi-LAT data (point sources properly subtracted) and Milagro. No extra-tuning required !
- CR hardening @ 250 GeV/n is crucial though not sufficient.



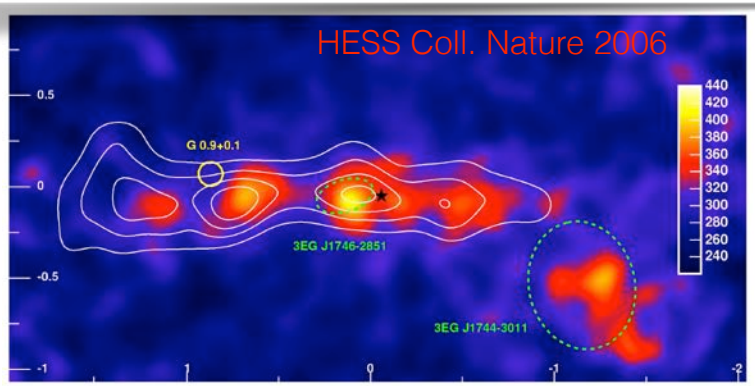
Galactic gamma-ray profile with KRA$_\gamma$ model



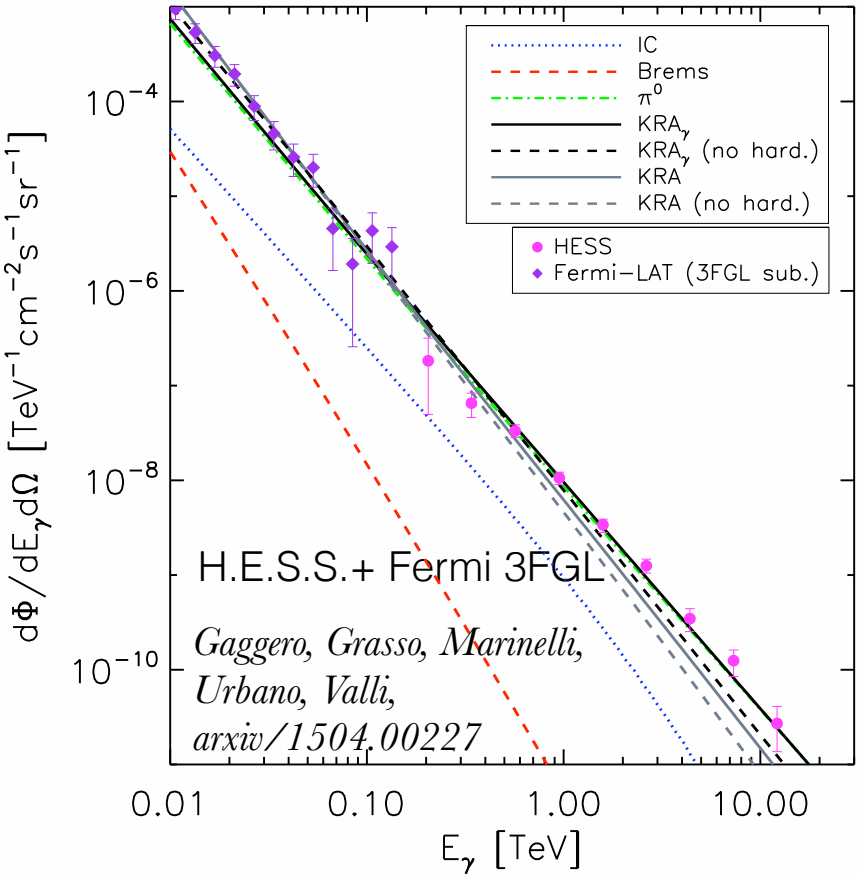
Gaggero, Grasso, Marinelli, Urbano, Valli, arXiv:1507.07796

We can see from this plot how the diffuse gamma-ray profile from the galactic plane obtained with KRA$_\gamma$ (scenario with a variable diffusion coefficient) better reproduce the measured Milagro profile respect to the KRA (standard scenario).

Reproducing the ridge emission from GeV to TeV with KRA$_\gamma$

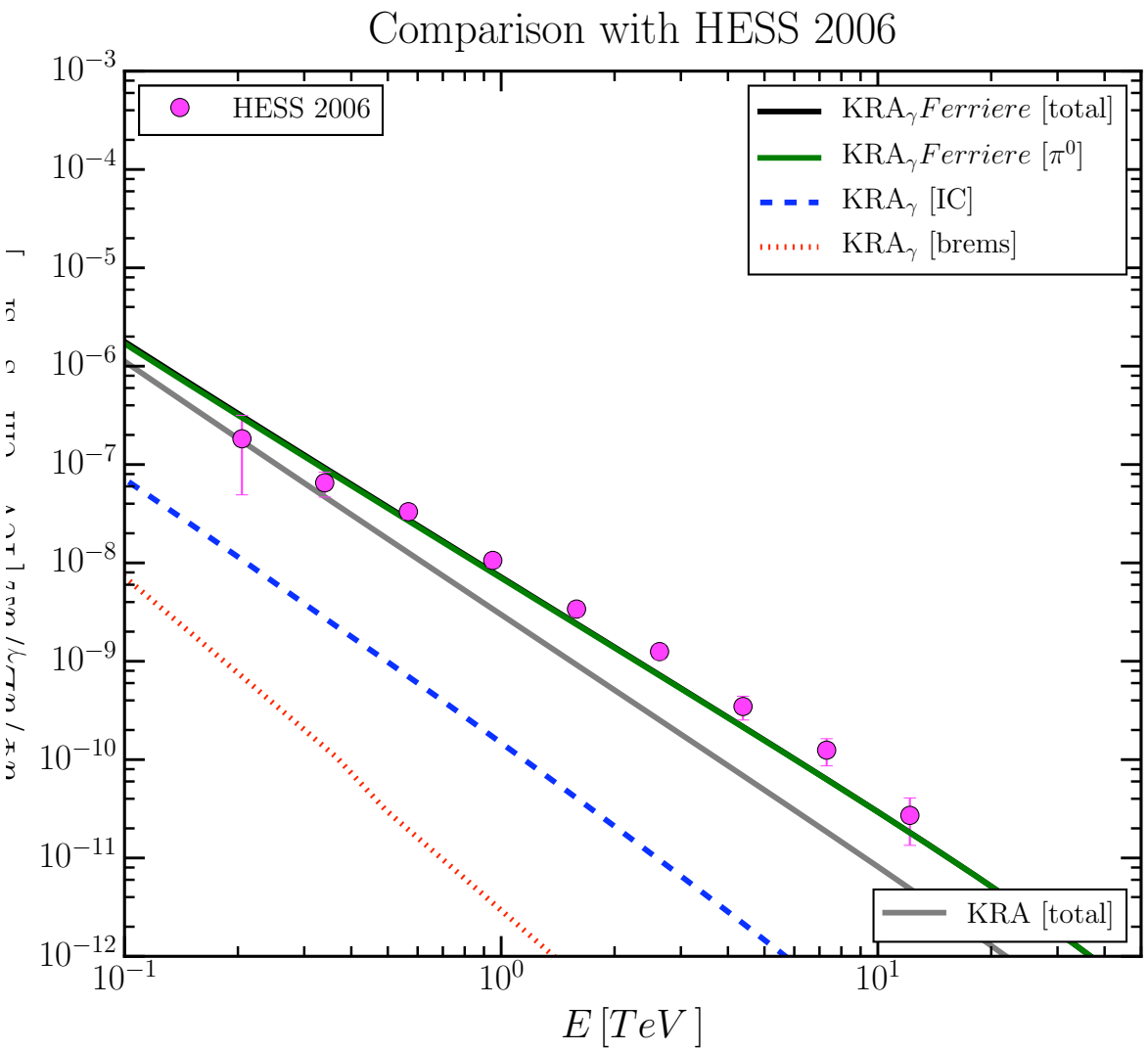


$|l| < 0.8°$ $|b| < 0.3°$



- KRA$_\gamma$ scenario is consistent with the hard spectrum Γ=2.3 of Galactic Ridge published by HESS coll. in 2006
- The KRA$_\gamma$ model well fits the gamma-ray emission (HESS+Fermi-LAT) from the central 200 pc of our galaxy
- A detailed gas model was used for the central molecular zone (Ferriere et al. 2007)
- FERMI + HESS
  KRAγ: $\chi 2$ = 1.79 /2.27 with/w.o. hard.
  KRA: $\chi 2$ = 2.92 /3.99 with/w.o. hard.

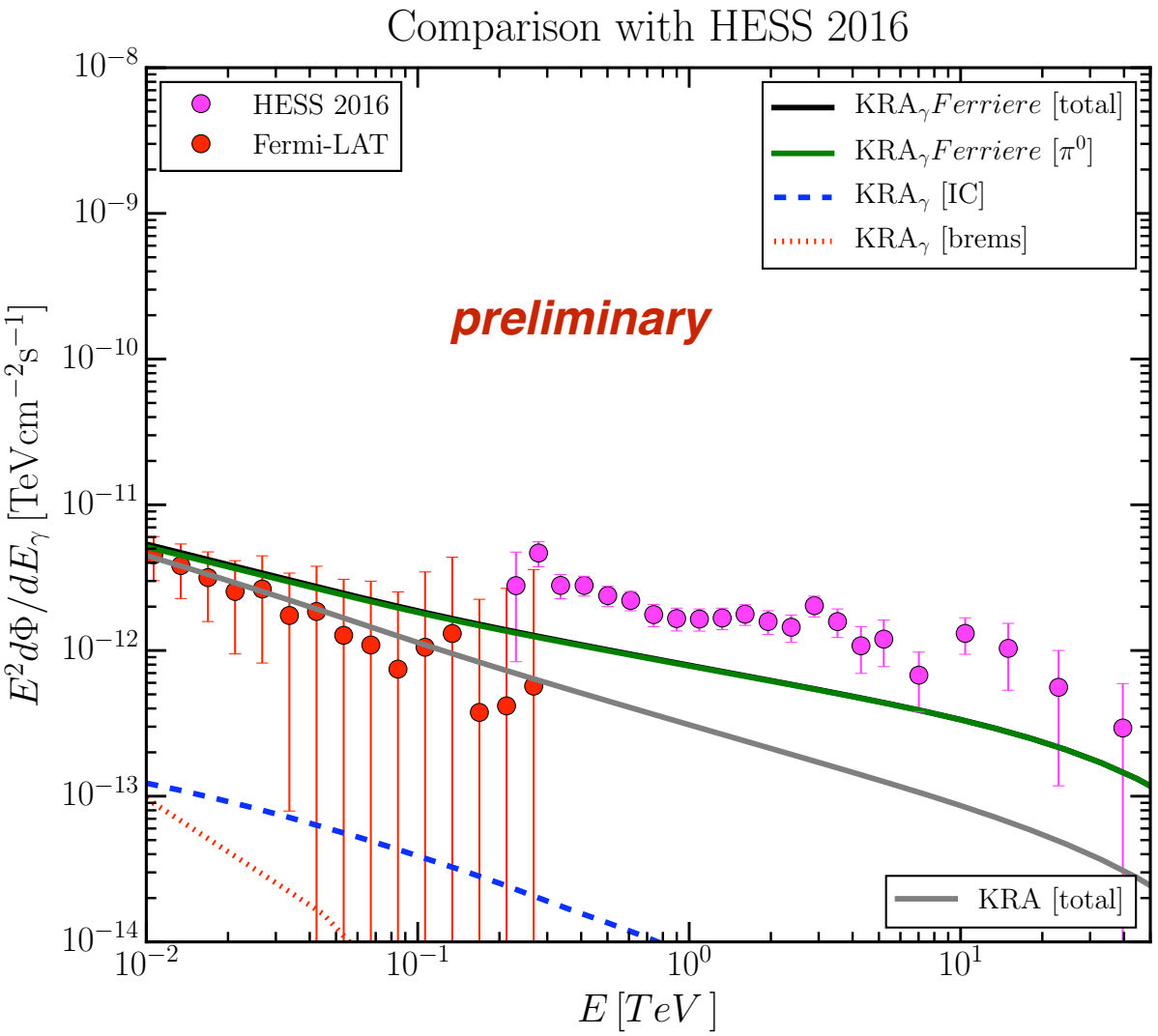
A detailed gamma-ray production through KRA$_\gamma$ for the ridge



A detailed run for the gamma-ray emission from the ridge region using Ferriere gas distribution (Ferriere et al. 2007) in the CMZ.

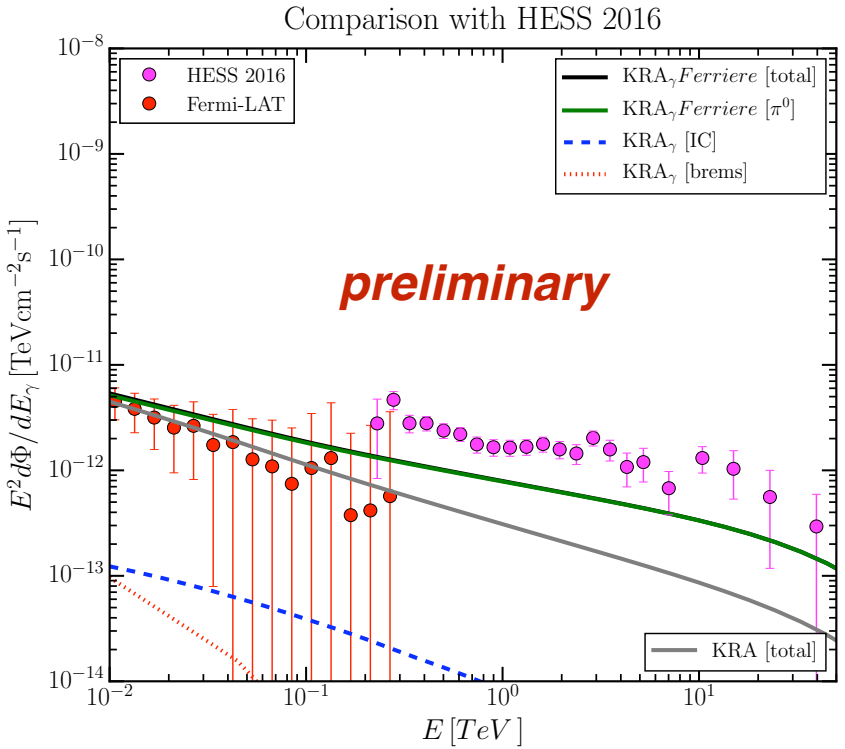
No room left for a remnant diffuse emission linked to a specific point-like source inside the ridge region if the KRA$_\gamma$ model is considered.

Galactic gamma-ray profile with KRA$_\gamma$ model



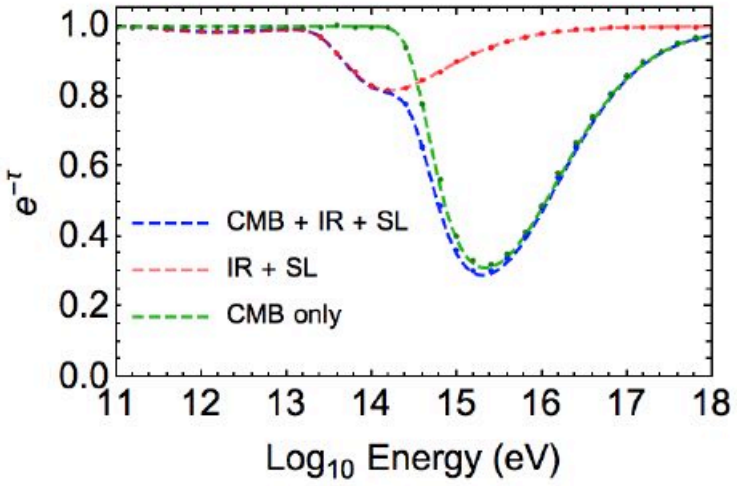
From this plot we can see that the diffuse galactic sea gamma-ray is a dominant component inside the Pevatron region if we consider the KRA$_\gamma$ model for the description, a small slot is left for the diffuse component linked to the injector if a standard KRA model is considered.

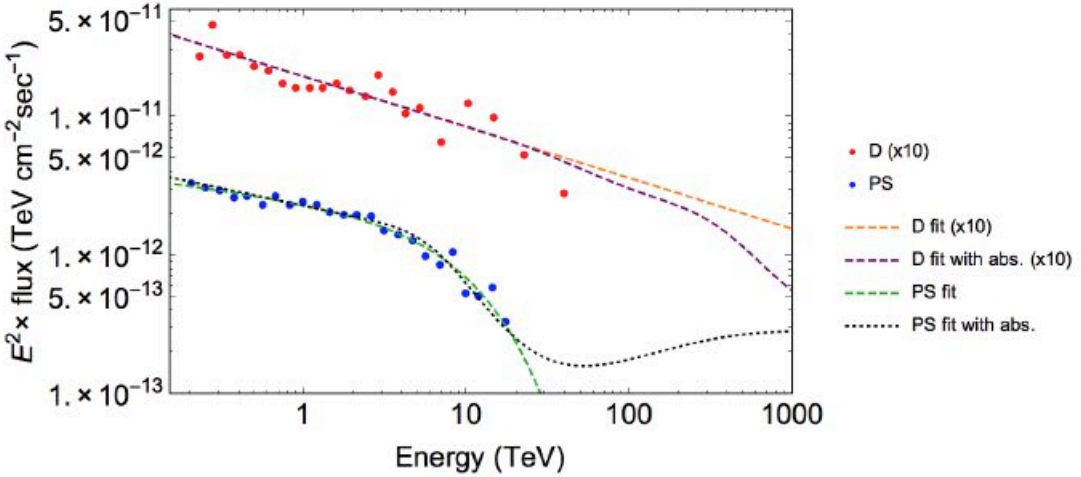
Link between galactic sea model and source absorption model



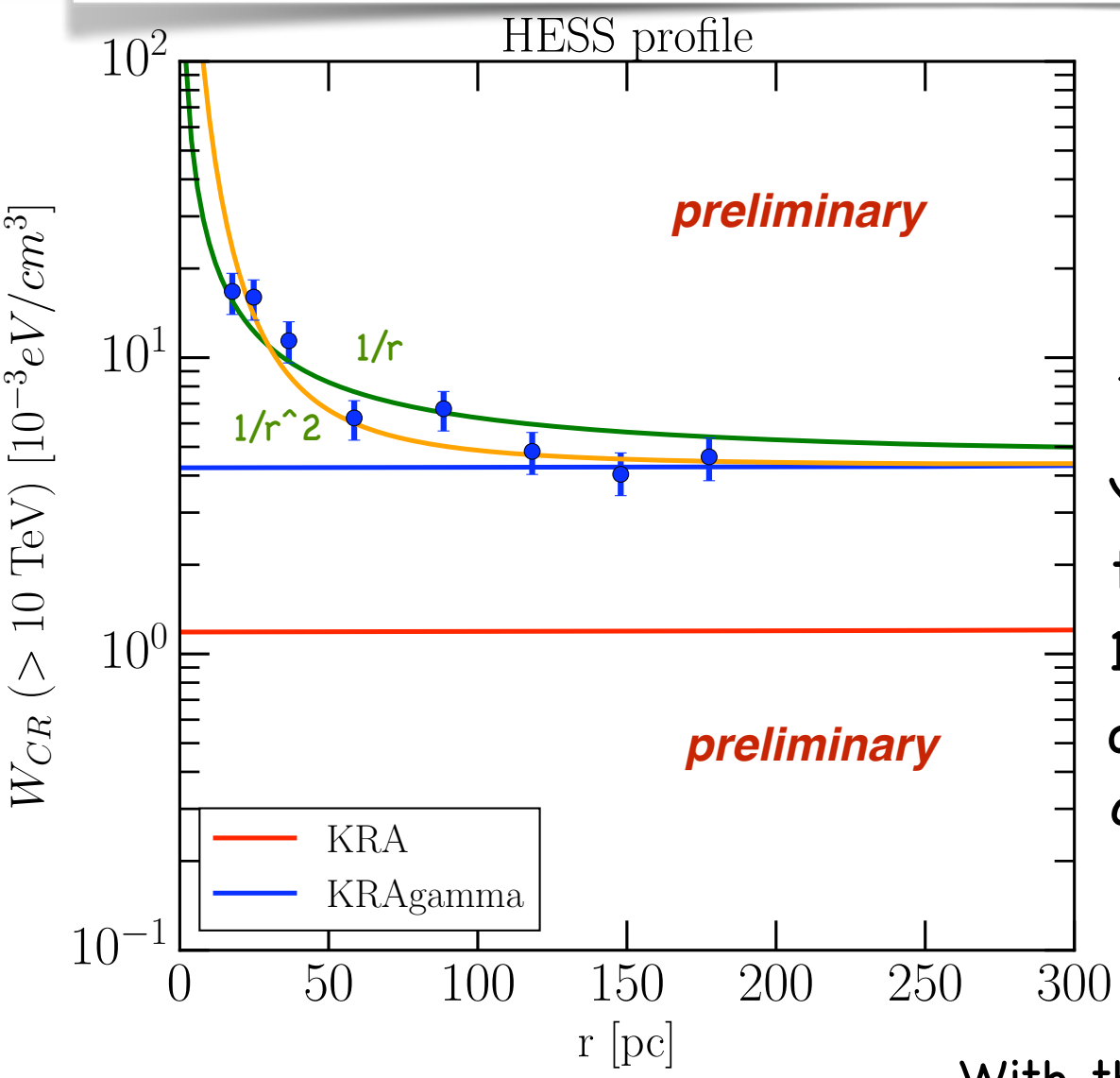
If we assume the KRA$_\gamma$ model, the diffuse sea intercept the measured gamma-ray spectrum after 10 TeV, leaving open the possibility of a intrinsic cut-off for this particular point-source instead of a strong absorption needed.

from: Celli S., Palladino A., Vissani F. arXiv:1504.00227





Cosmic-ray density profile compared to KRA$_\gamma$ model



Rate of injection

$$w_{\rm CR}(E,r,t) = \frac{\dot{Q}_p(E)}{4\pi D(E) r}\,{\rm erfc}(r/r_{\rm diff})$$

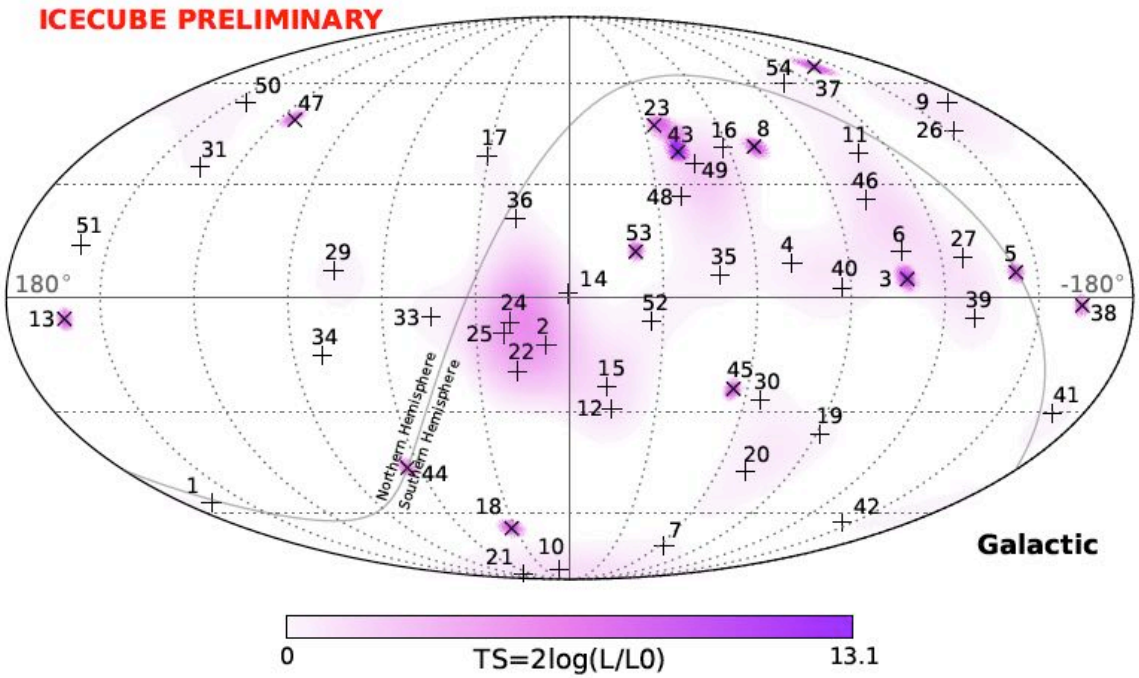
Diffusion Coefficient

Radius

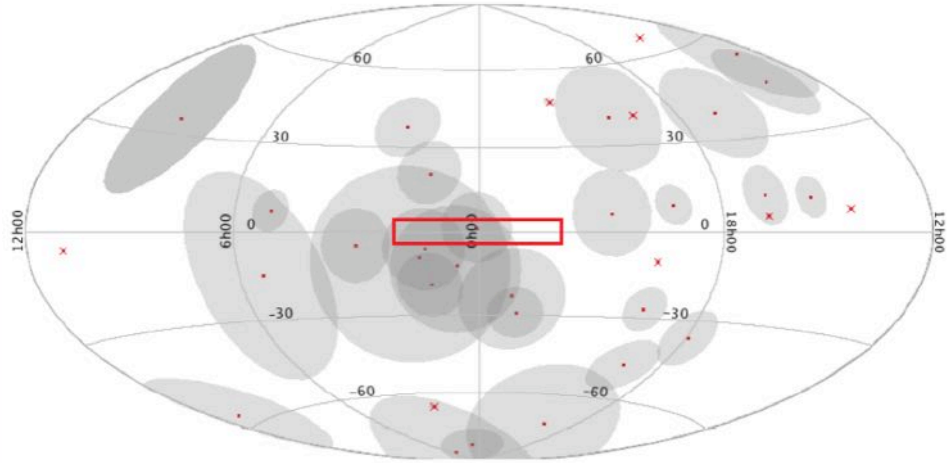
You can see from this plot that the plateaux is reached after 100 pc where the KRA$_\gamma$ CR density profile intercept the asymptotic behavior of 1/r^2

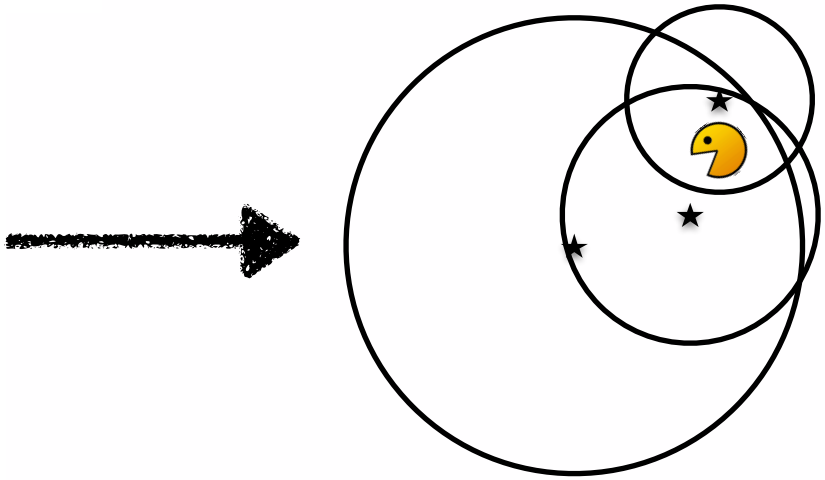
With this assumption the conclusion about the Pevatron should be revised!!

looking at possible nu signature from the "pac-man"

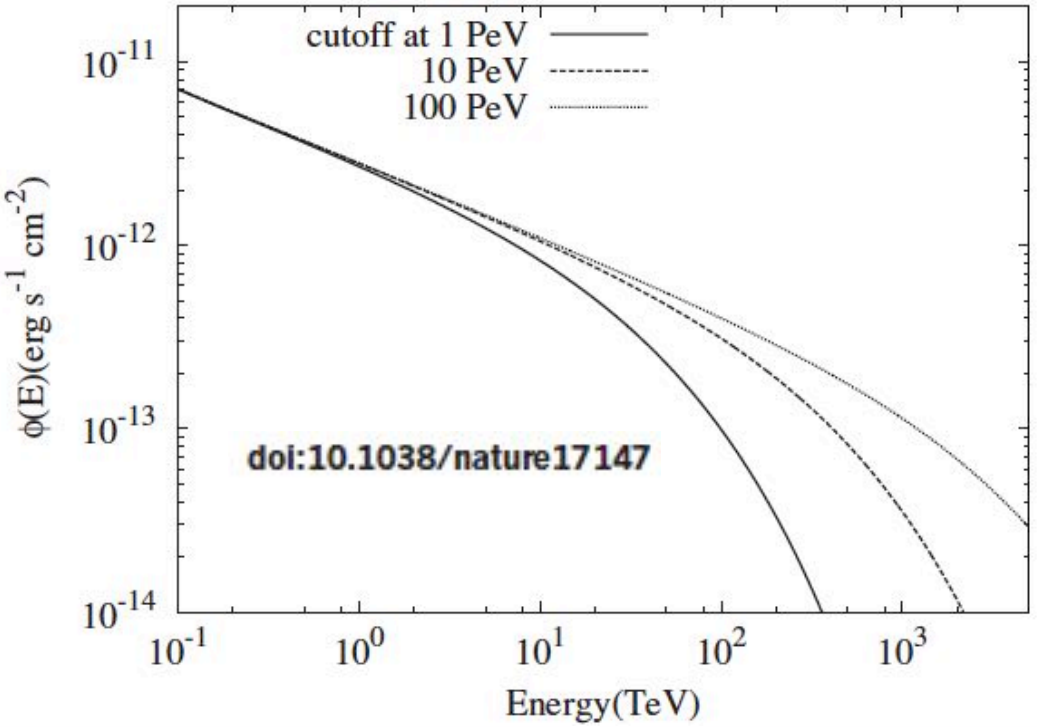


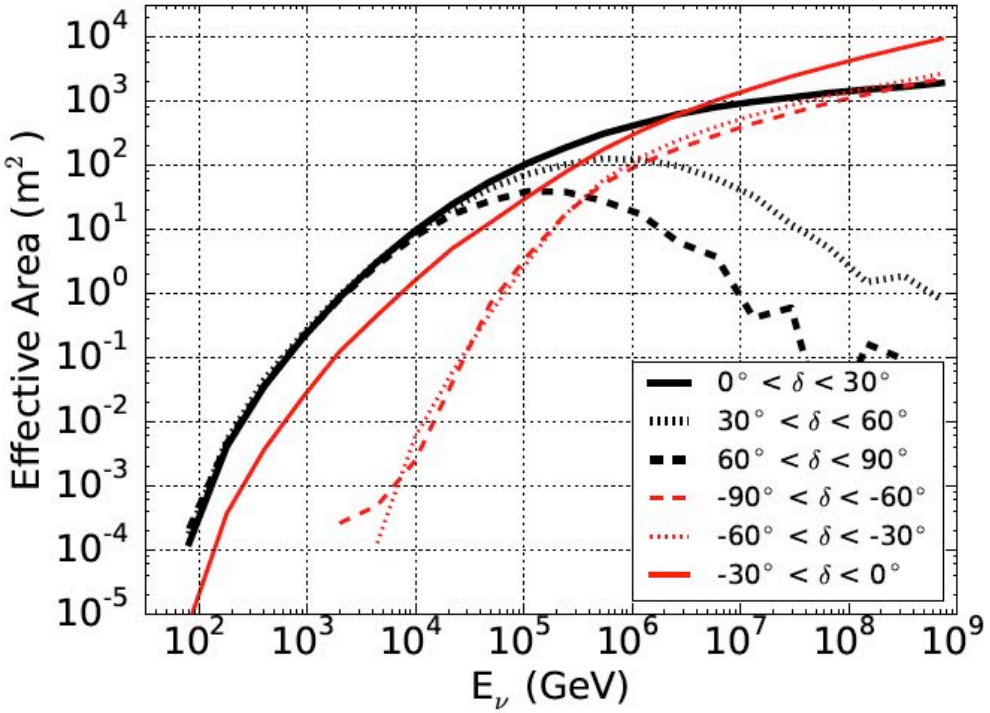
HESE IceCube events collected in 4 years: comprises
13 track-like events and
41 shower events
no one contained contained inside the pac-man however tre shower compatible, one of the is a PeV neutrino.





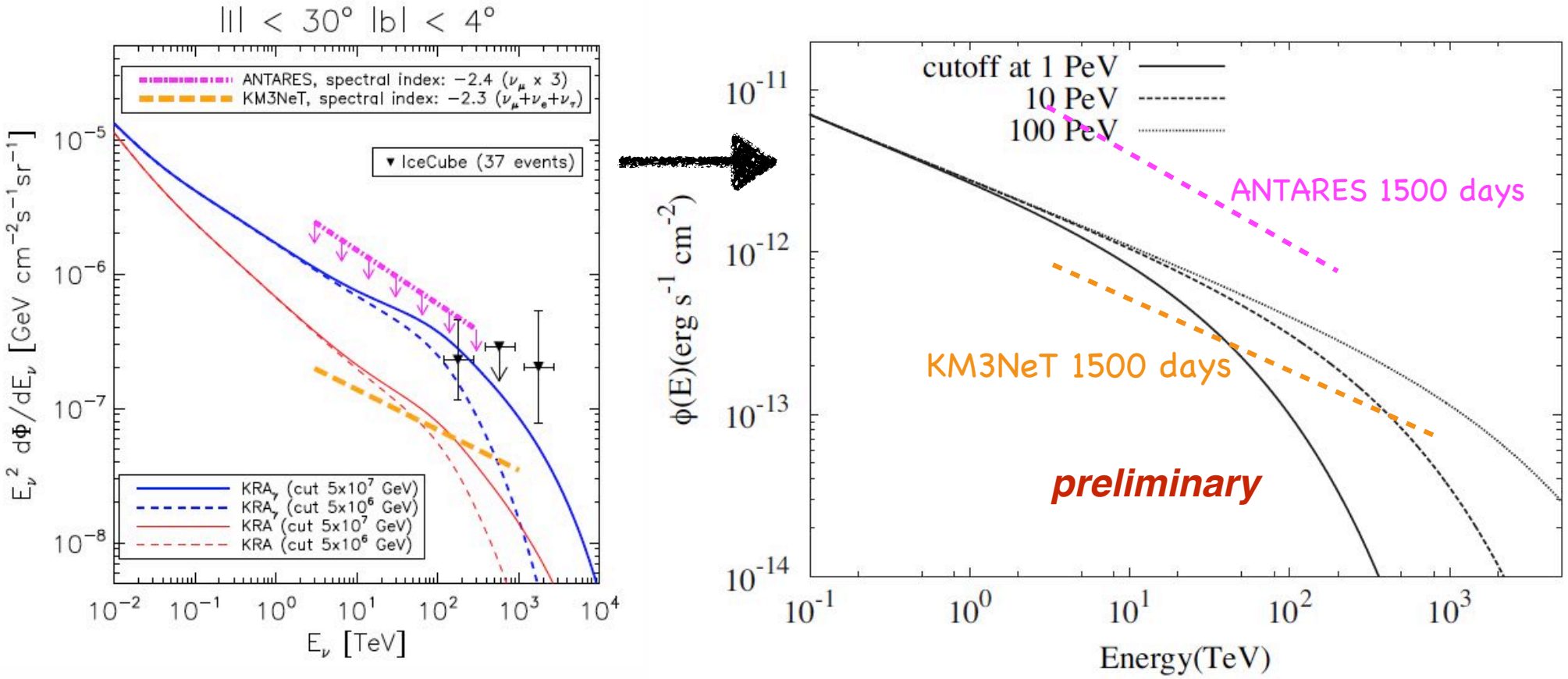
Neutrino events from the pac-man expected in IceCube





nu evt HESE 4	Cut-off 1 PeV	Cut-off 10 PeV	Cut-off 100 PeV
E > 25 TeV	4 x 10^-2 evt	0,127 evt	0,189 evt
E >10 TeV	9 x 10^-2 evt	0,2 evt	0,27 evt
E > 1 TeV	0,26 evt	0,40 evt	0,47 evt

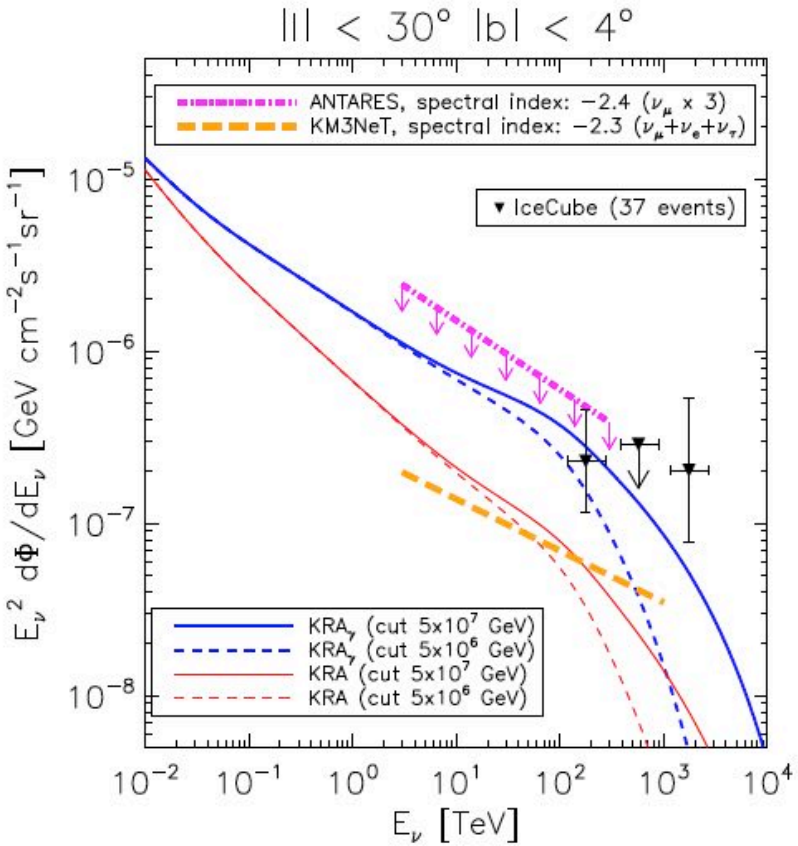
Observing the pac-man nu emission from Mediterranean sea

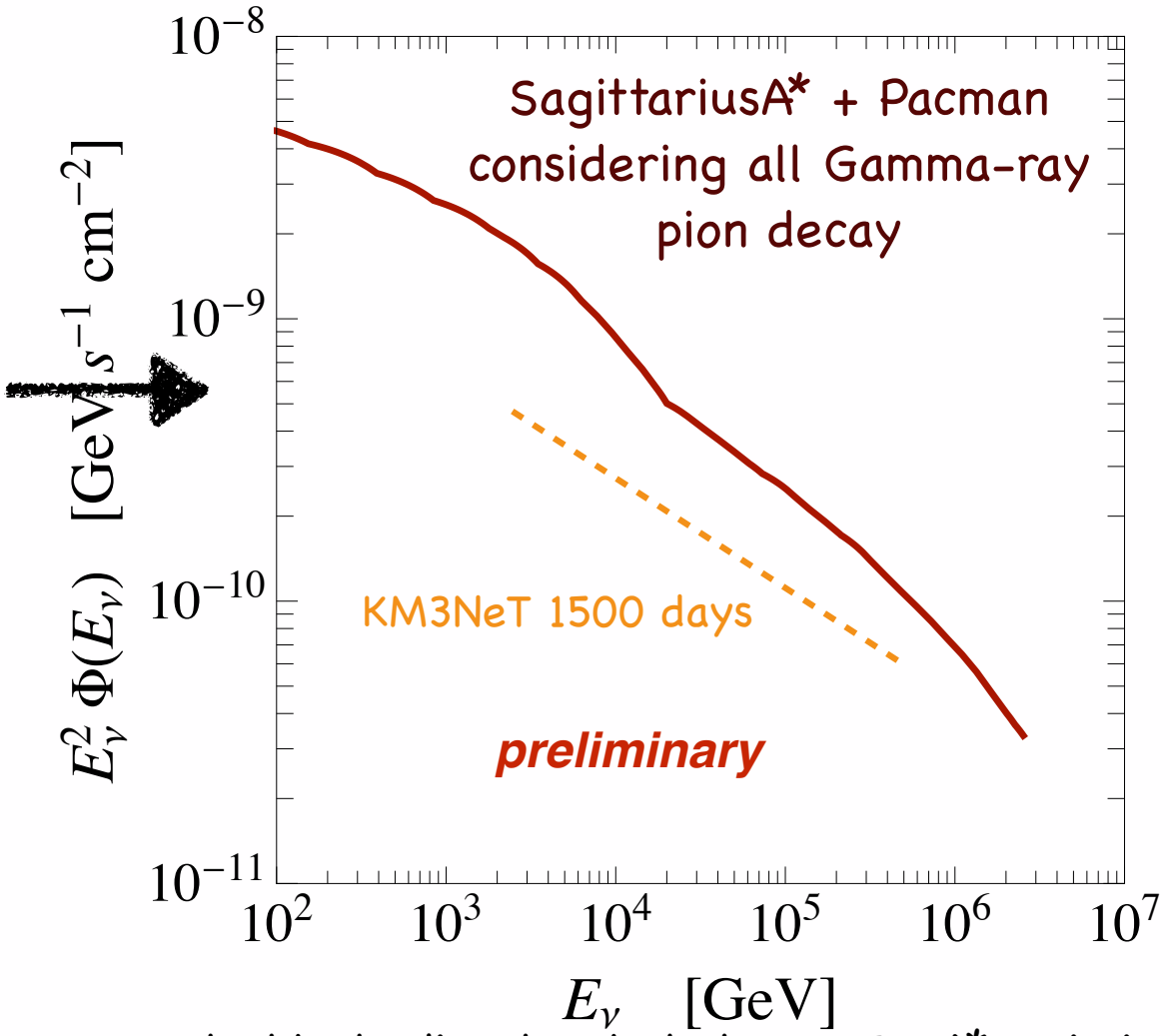


If we take as a reference the neutrino spectra published by HESS coll. seems that in a few years we can have a good estimation of neutrino flux coming from the "pac-man" with a KM3NeT observatory

Observing the pac-man + Sag A* nu emission

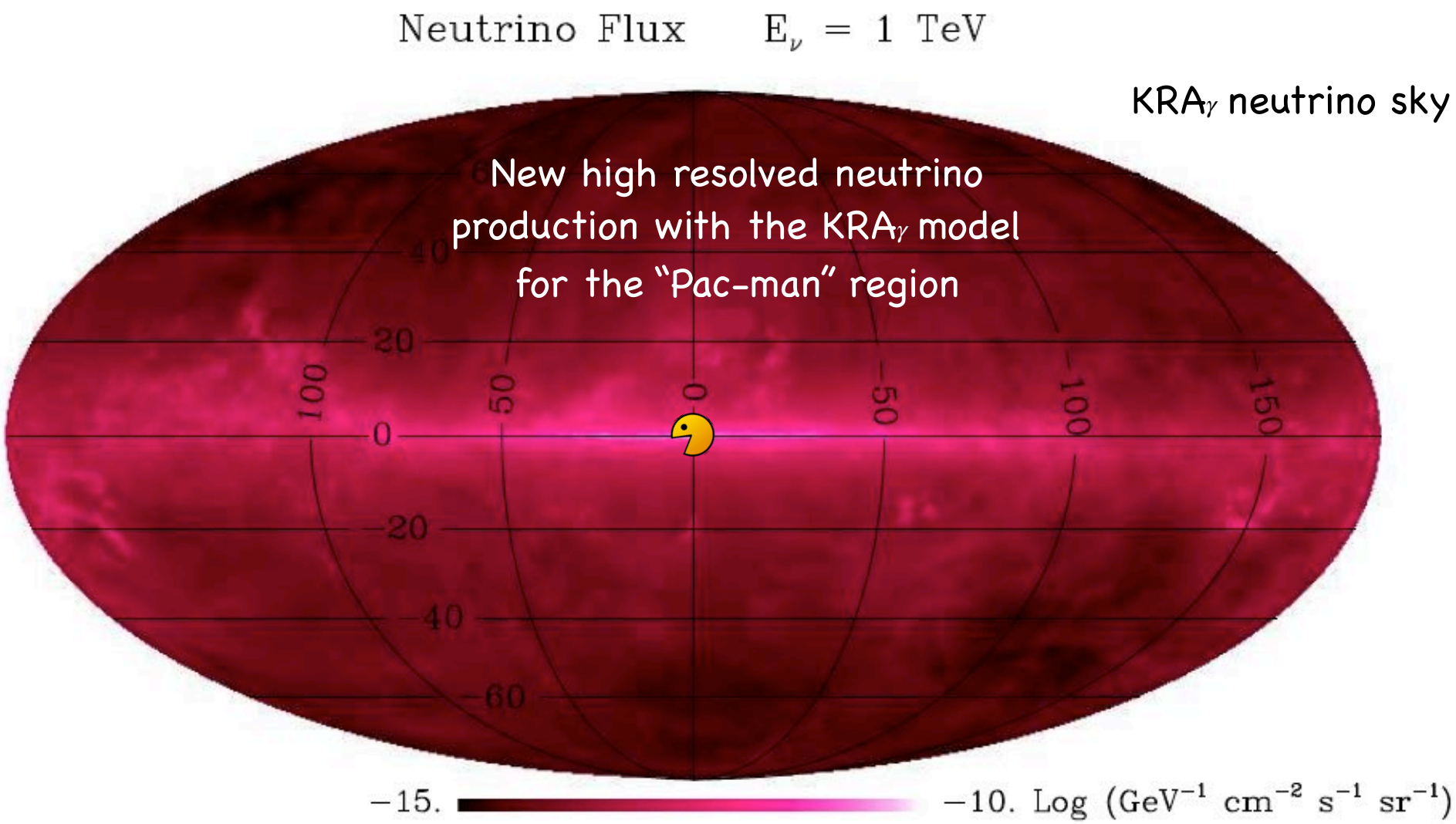
Gaggero, Grasso, Marinelli, Urbano, Valli, 2015ApJ...815L..25G





Considering that the neutrino telescope are not able to disentangle between SagA* emission and the "pacman" we still need few years to see the resultant neutrino emission from both components

Next step analyzing the "pacman" neutrino emission



SUMMARY

- A new diffuse region of gamma-ray emission has been observed around Sag A* with a spectrum possibly extending to PeV energies.

- We addressed the galactic diffuse sea component in the selected region, obtaining a dominant component when the KRA$_\gamma$ model is applied to the CR transport description.

- While for the ridge region observed in 2005 the sea component can explain the entire spectrum measured, for the new "pacman" Pevatron region we have a room for the diffuse component linked to a specific source.

- New Campaigns of Imaging Cherenkov (HESS, VERITAS, MAGIC, CTA) and future ground Cherenkov Array (HAWC south) are needed to have a clear picture of this region of the sky.

- Neutrino emission from the Pevatron region can be clear observed only with the future KM3NeT observatory with a few years of observation