

# Transition from galactic to extragalactic cosmic rays: cosmic rays, secondary neutrinos and gamma rays

**Dmitri Semikoz**

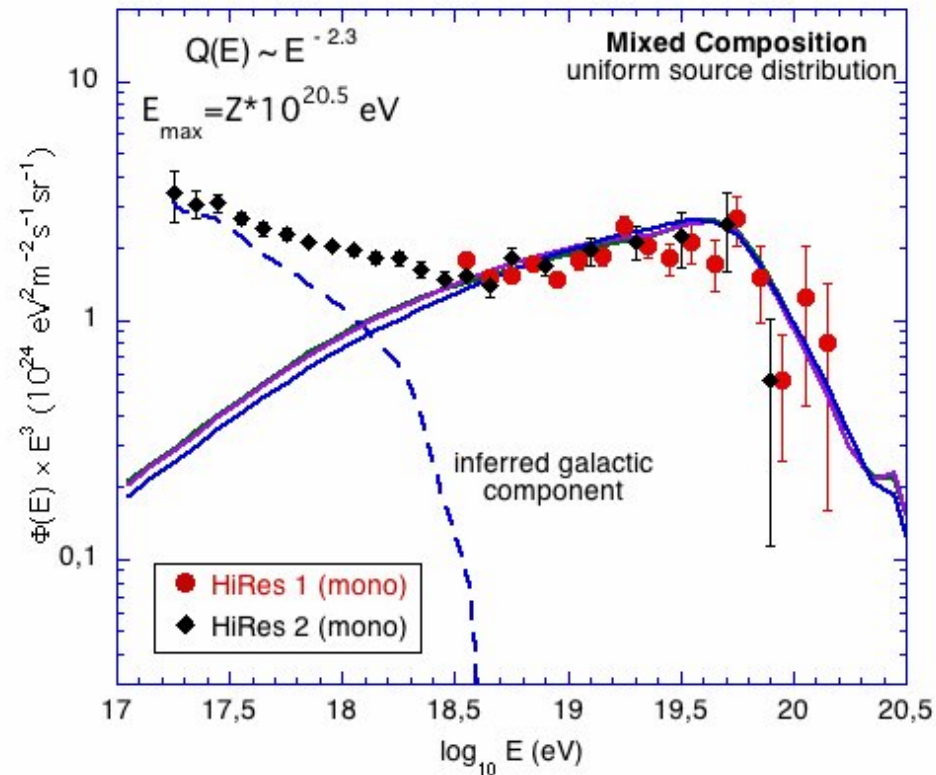
*APC, Paris*

*With G.Giacinti and M.Kachelriess,*

*O.Kalashhev and A.Neronov*

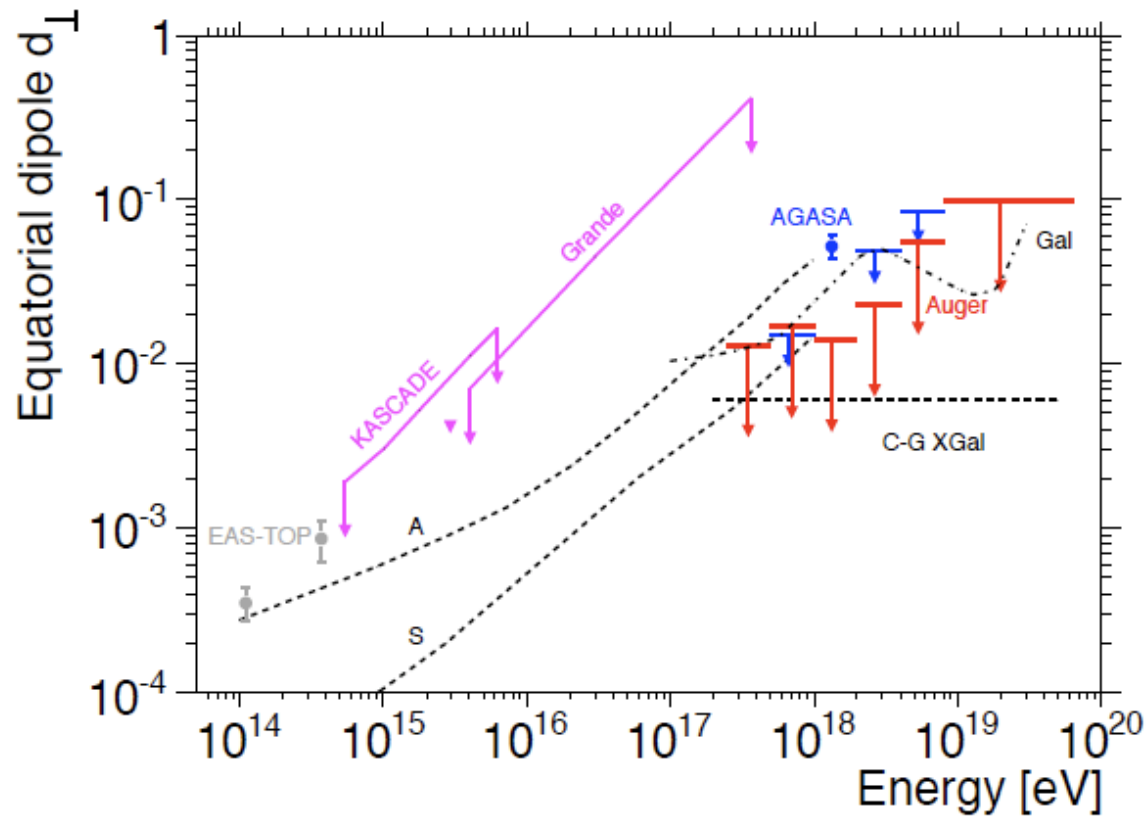
***arXiv: 1507.07534***

# Mixed composition model



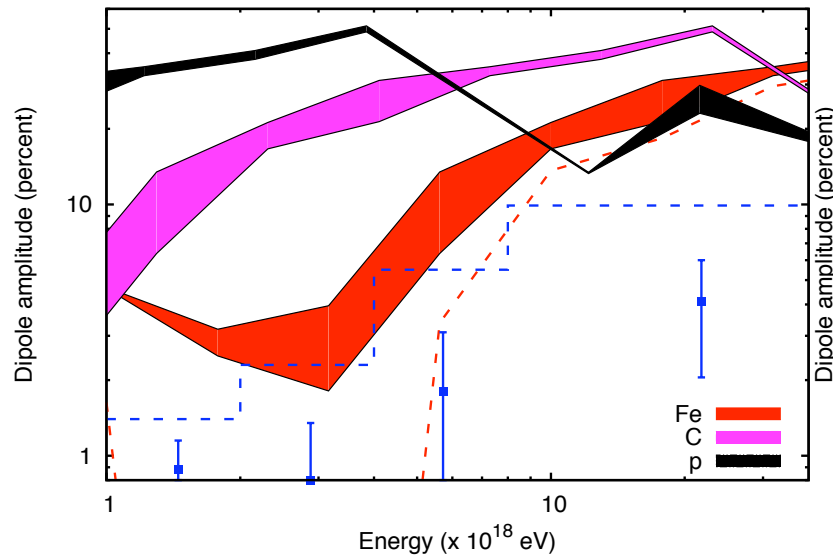
D.Allard, E.Parizot and A.Olinto, astro-ph/0512345

# Anisotropy dipole

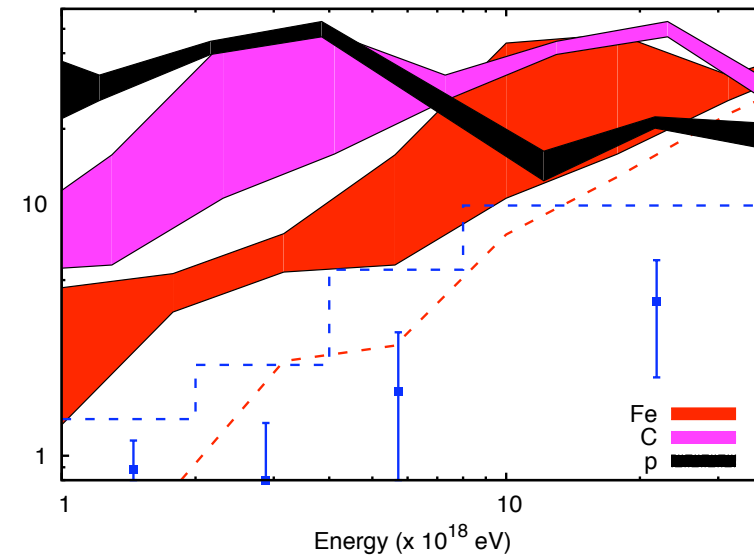


**Pierre Auger Collaboration, arXiv:1103.2721**

# Galactic sources: dipole calculation



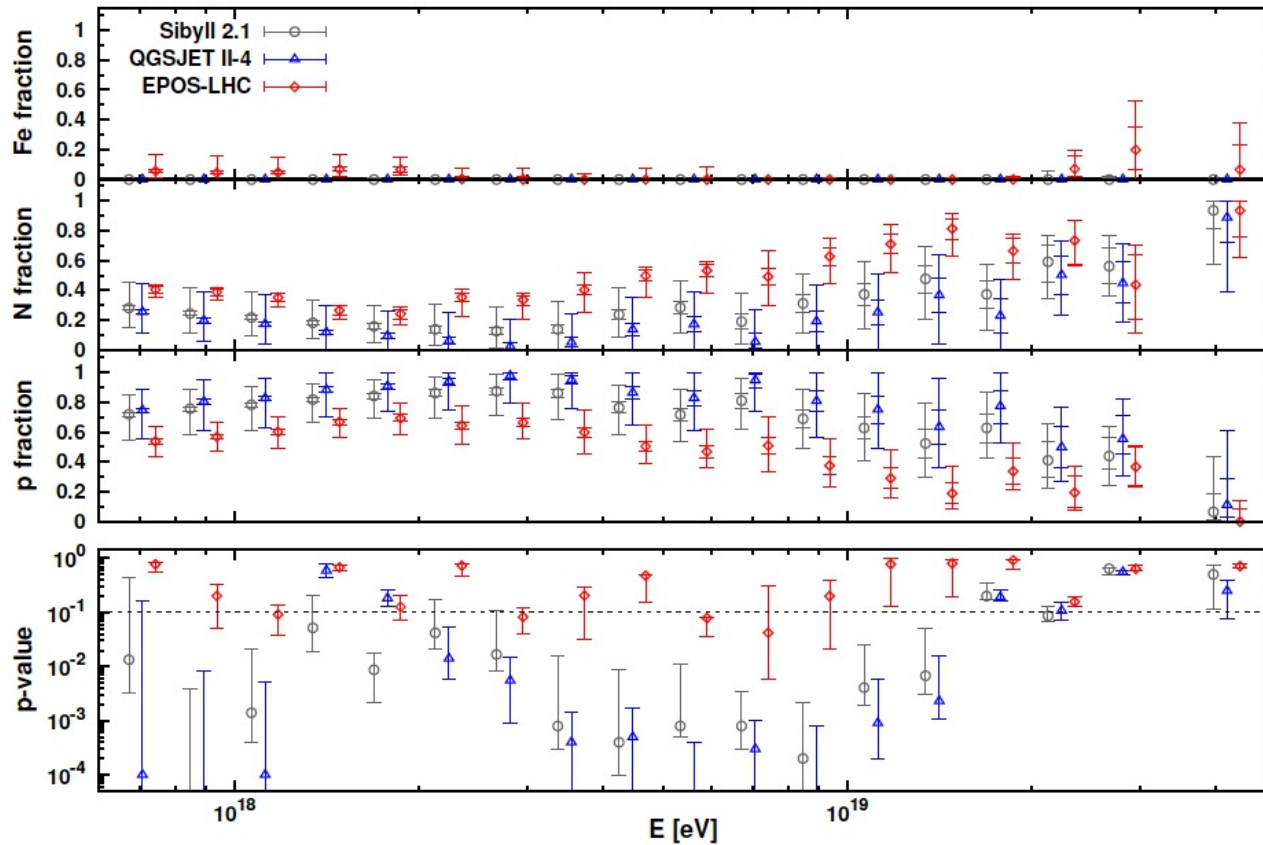
Turb. Magn. Field spectrum  
Kolmogorov/Kraichnan



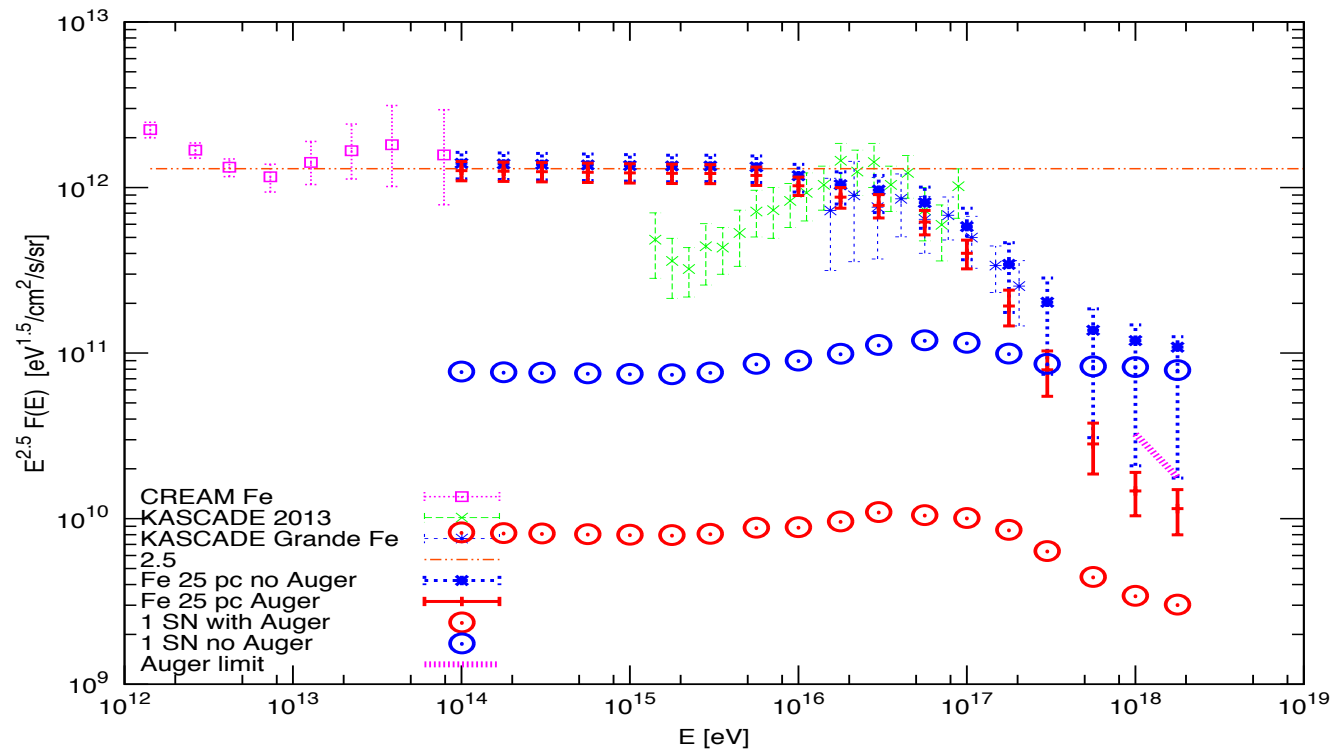
$L_{\max} = 100\text{-}300$  pc

G.Giacinti, M.Kachelriess, D.S. and G.Gigl, [arXiv:1112.5599](https://arxiv.org/abs/1112.5599)

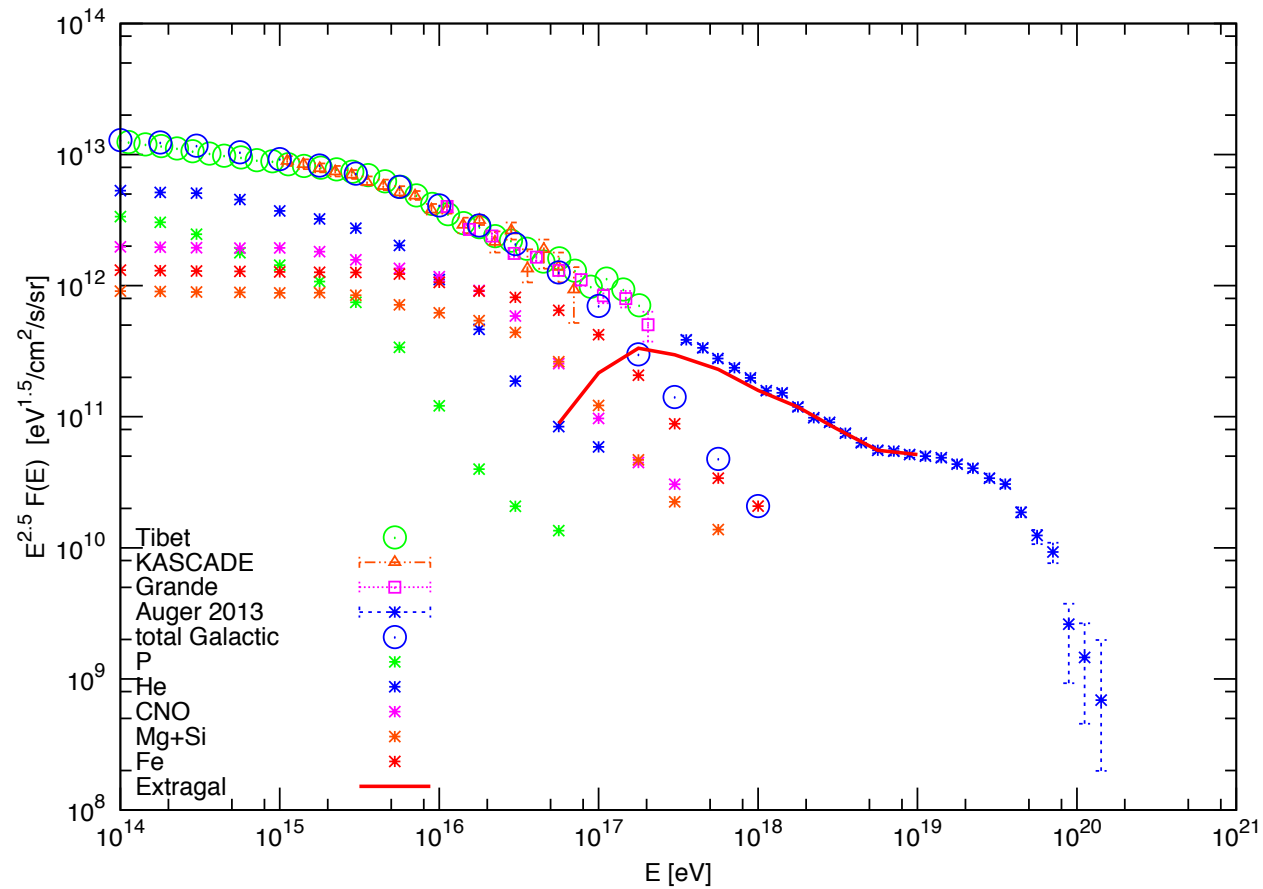
# Auger composition measurements



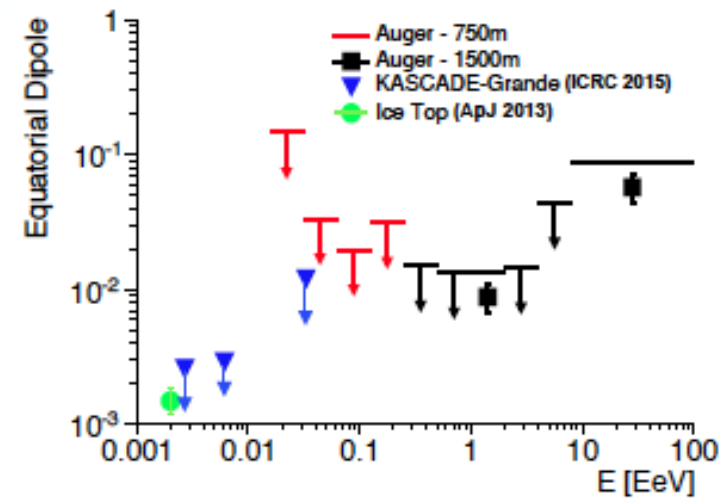
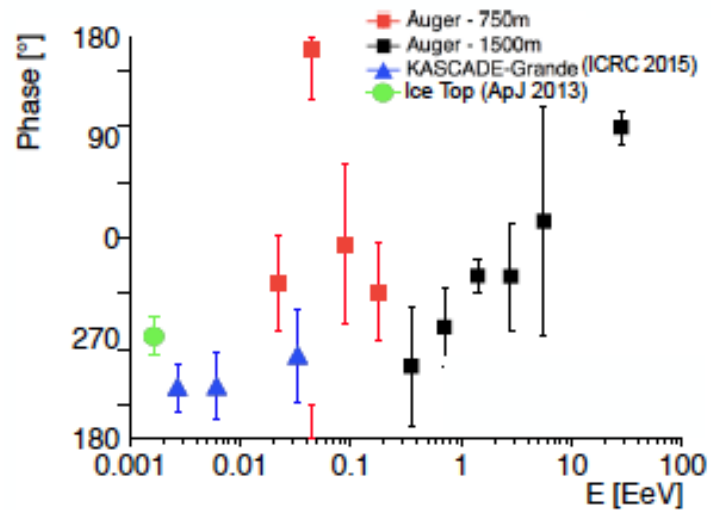
# Auger limit on Fe fraction



# Contribution of extra-Galactic sources

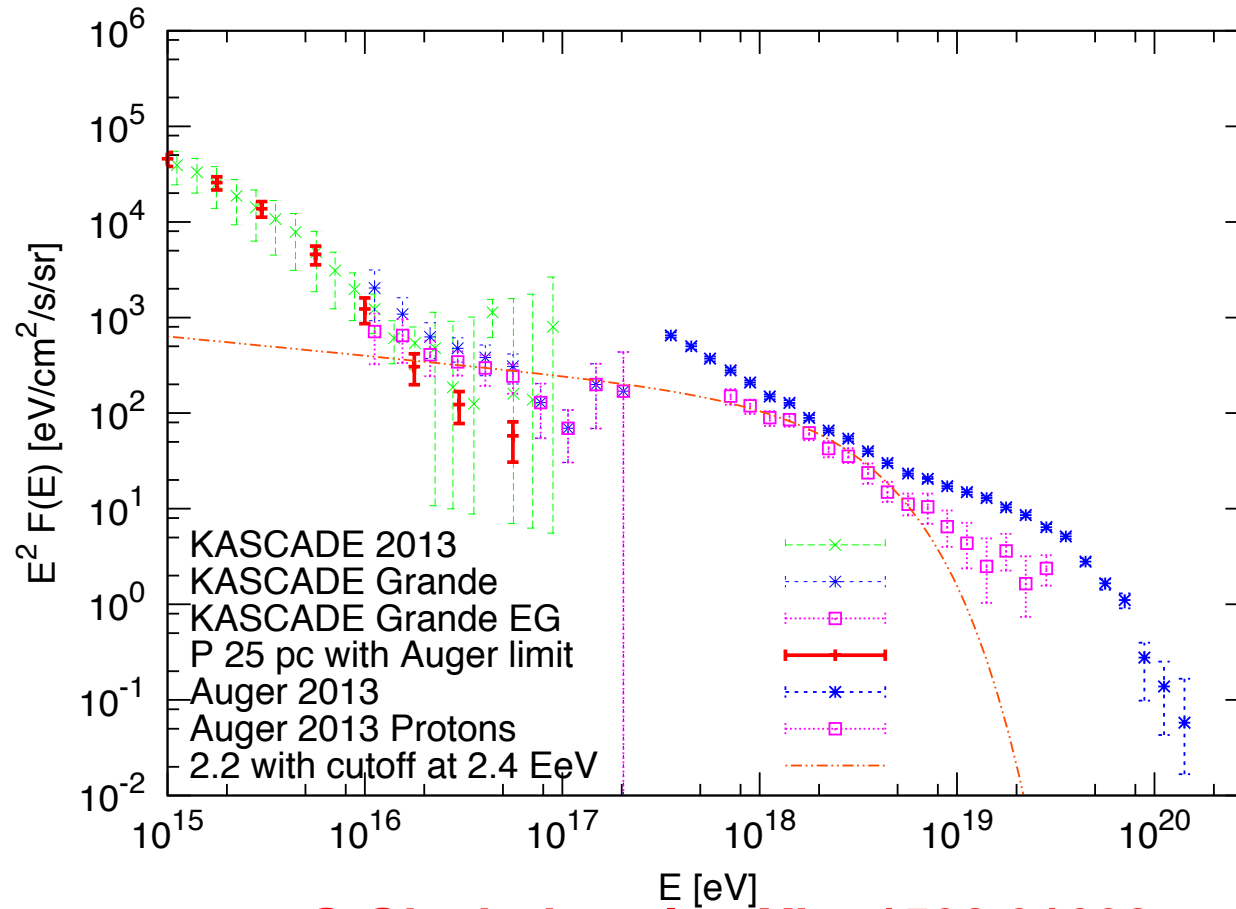


# Auger dipole measurements



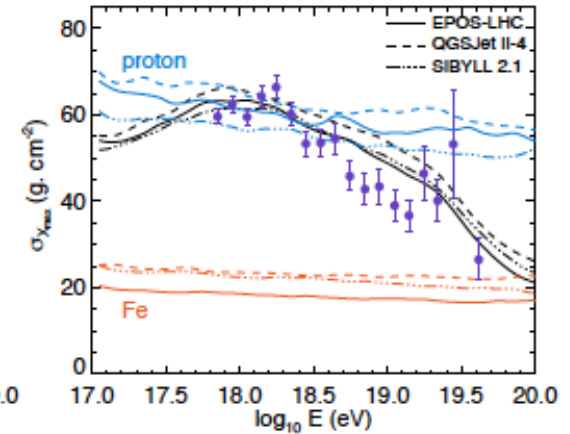
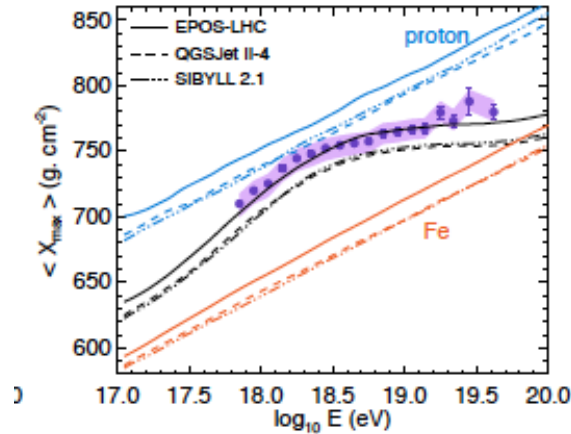
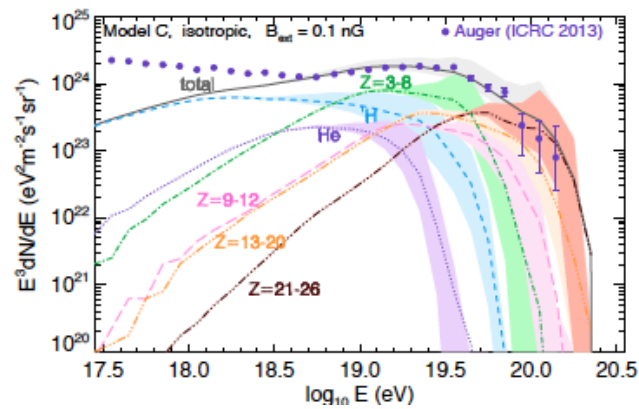


# Contribution of extra-Galactic protons to cosmic ray proton flux



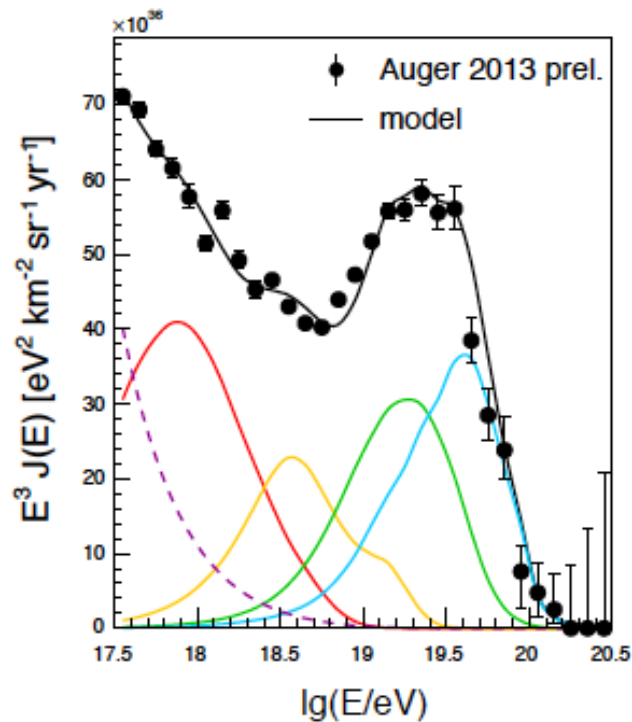
**G.Giacinti et al, arXiv: 1502.01608**

# GRB as UHECR source

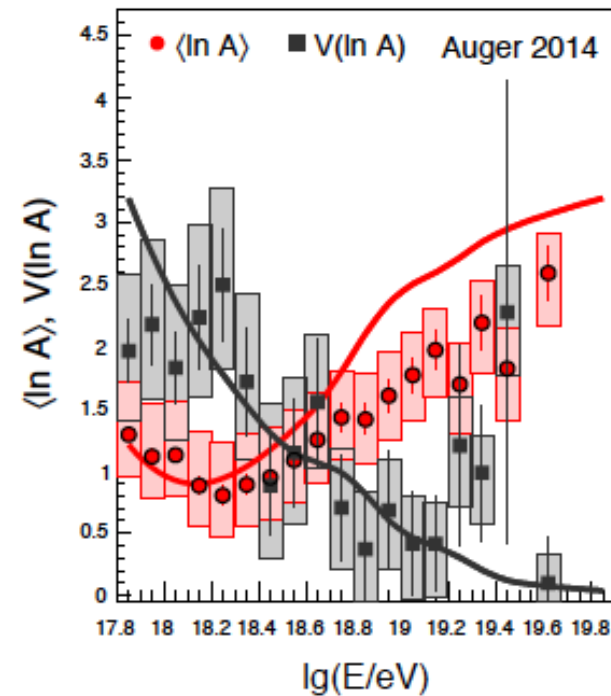


**N.Globus, D.Allard and E.Rarizot, arXiv: 1505.01377**

# Generic UHECR source



(a) Flux at Earth

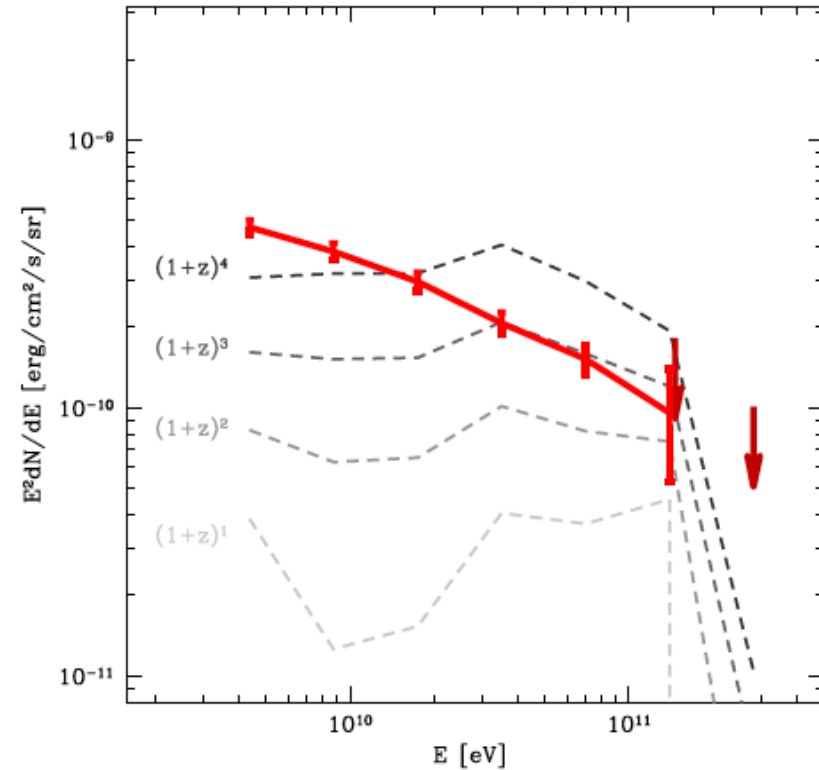
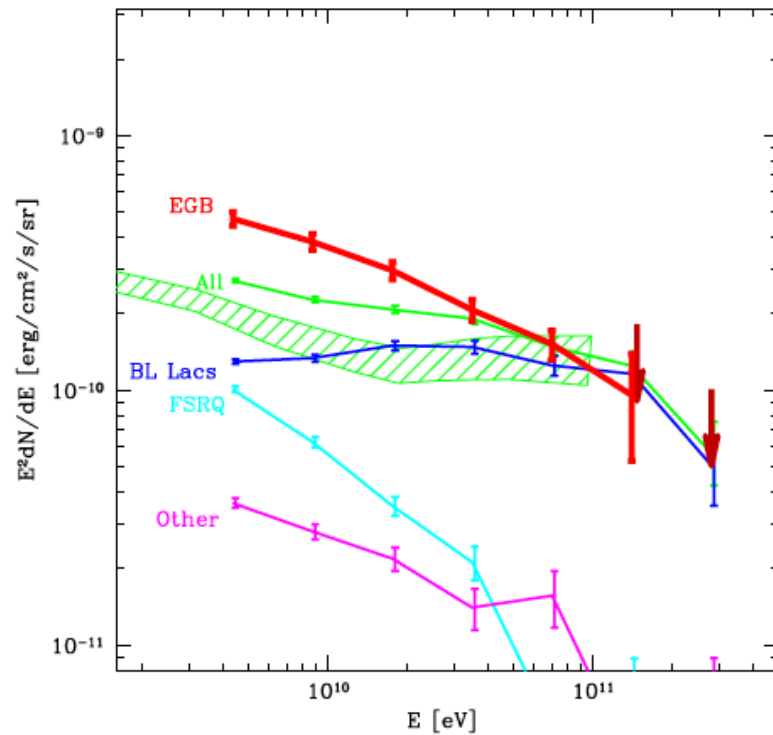


(b) Composition at Earth

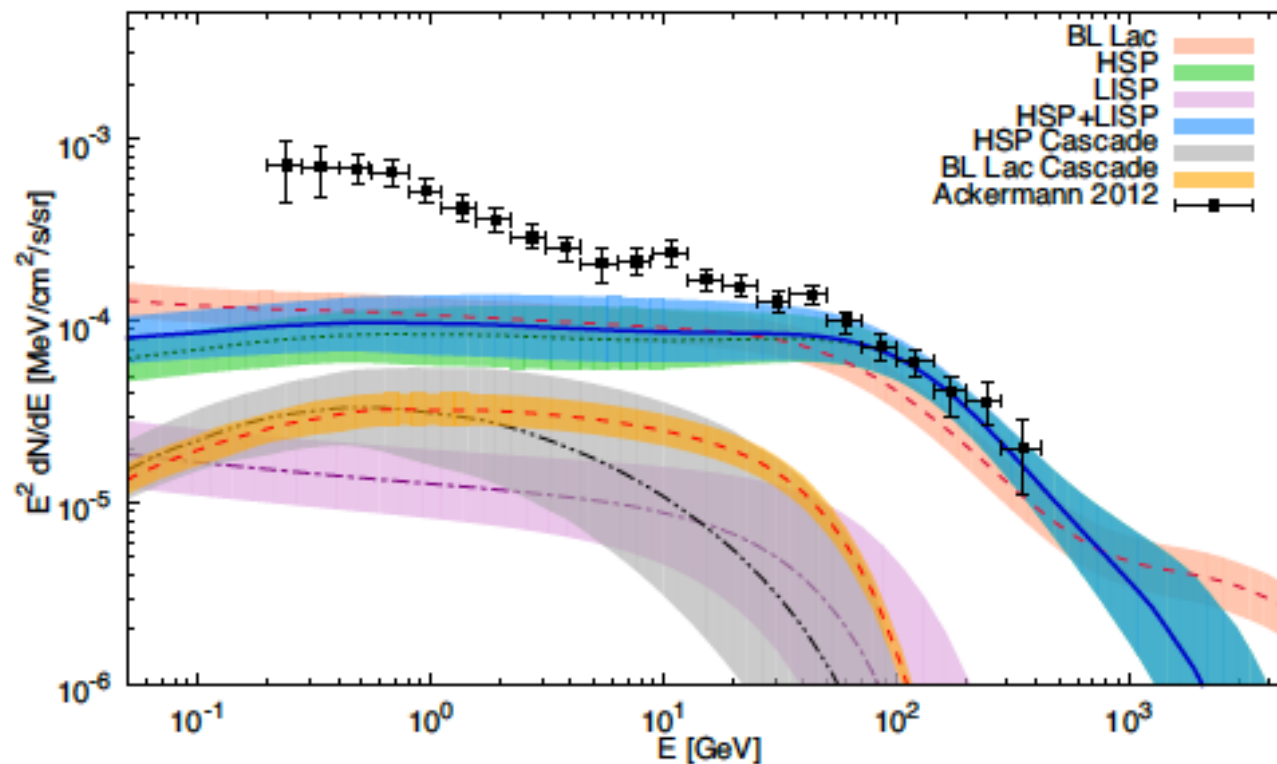
**M.Unger, G.Farrar and L.Anchordoqui, arXiv: 1505.02153**

# Diffuse gamma-ray background

# BL Lacs give main contribution to high energy part of diffuse gamma-ray flux



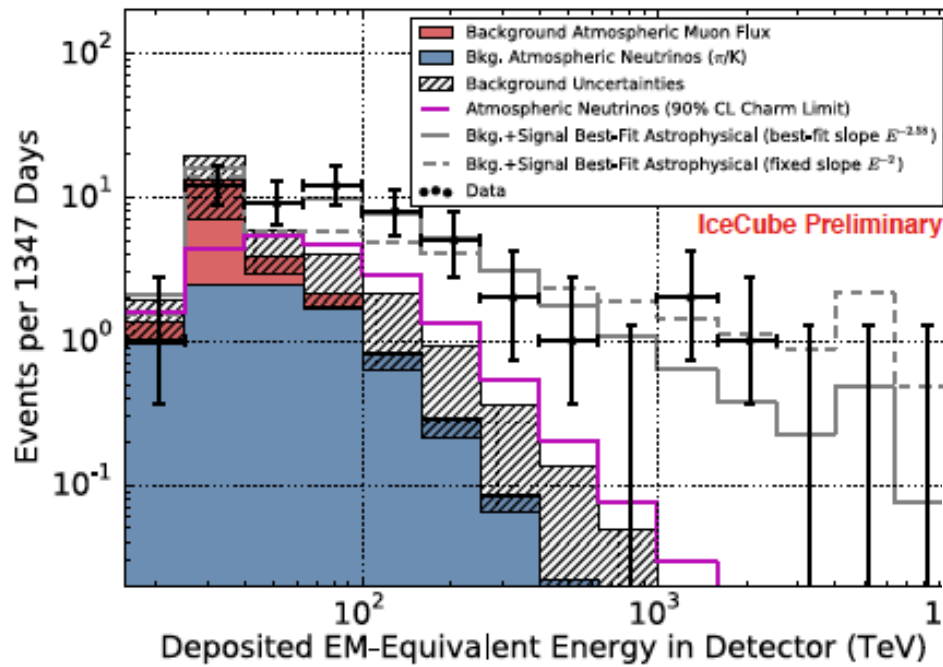
# BL Lacs give main contribution to high energy part of diffuse gamma-ray flux



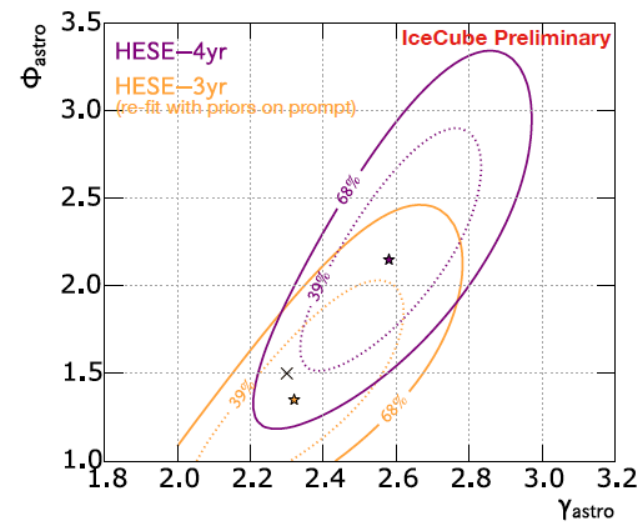
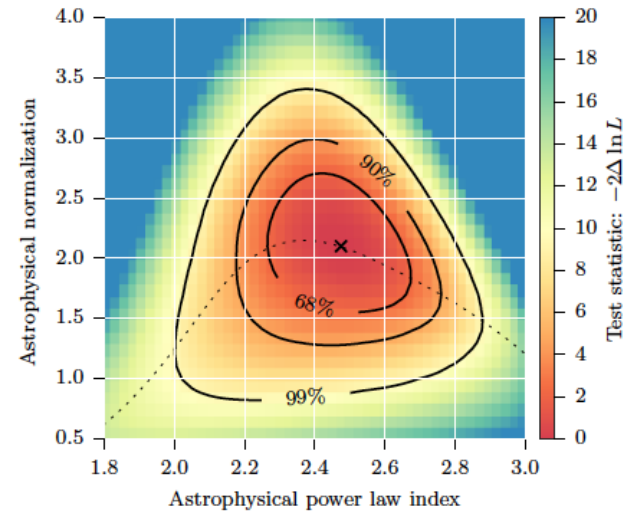
**M. Di Mauro et al, arXiv:1311.5708**

# CR spectrum from astrophysical neutrinos

# IceCube data 4 yrs



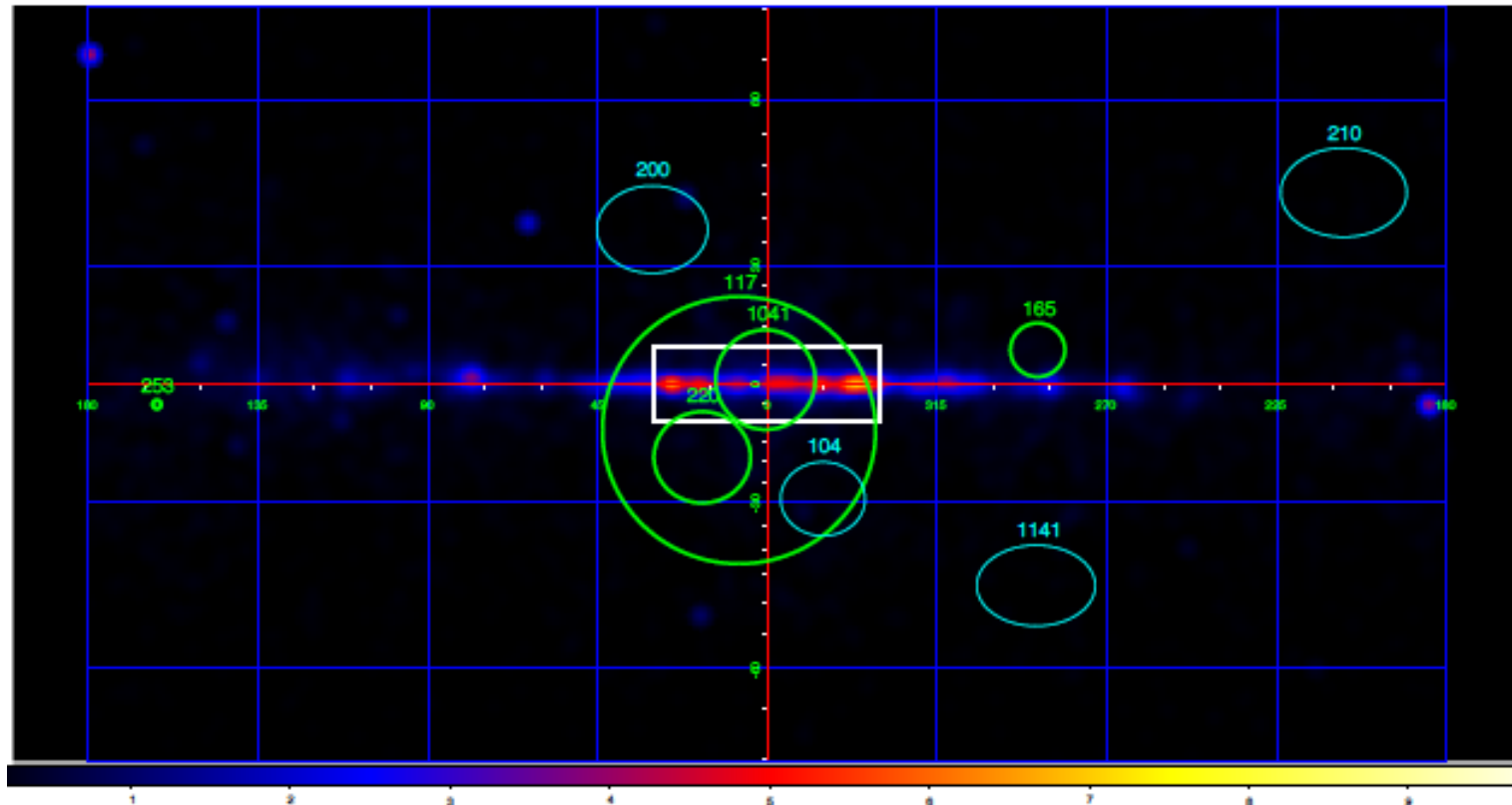
IceCube





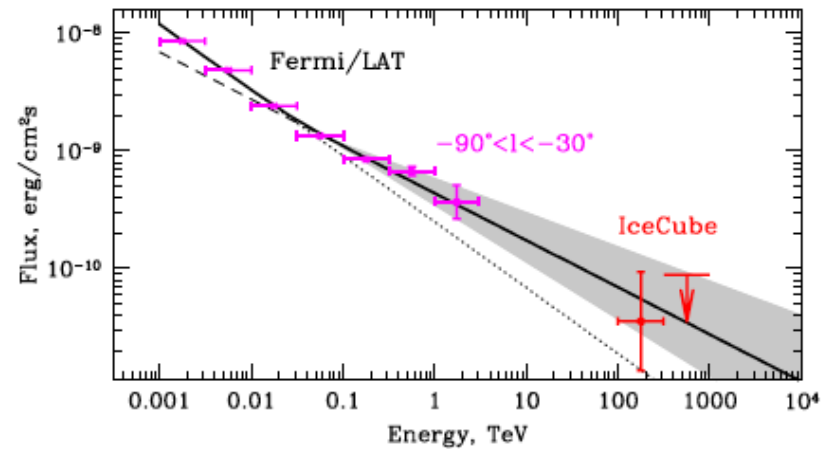
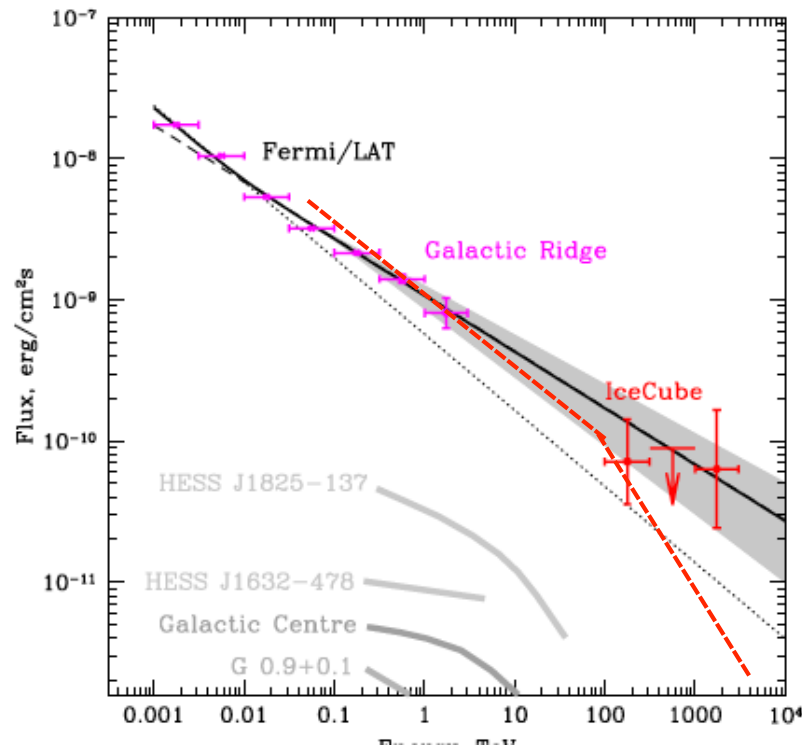
Karlsruhe, Sept 22, 2015

Half of ICECUBE events  $E > 100$  TeV are in Galactic plane. Are they correlate with gamma-rays?



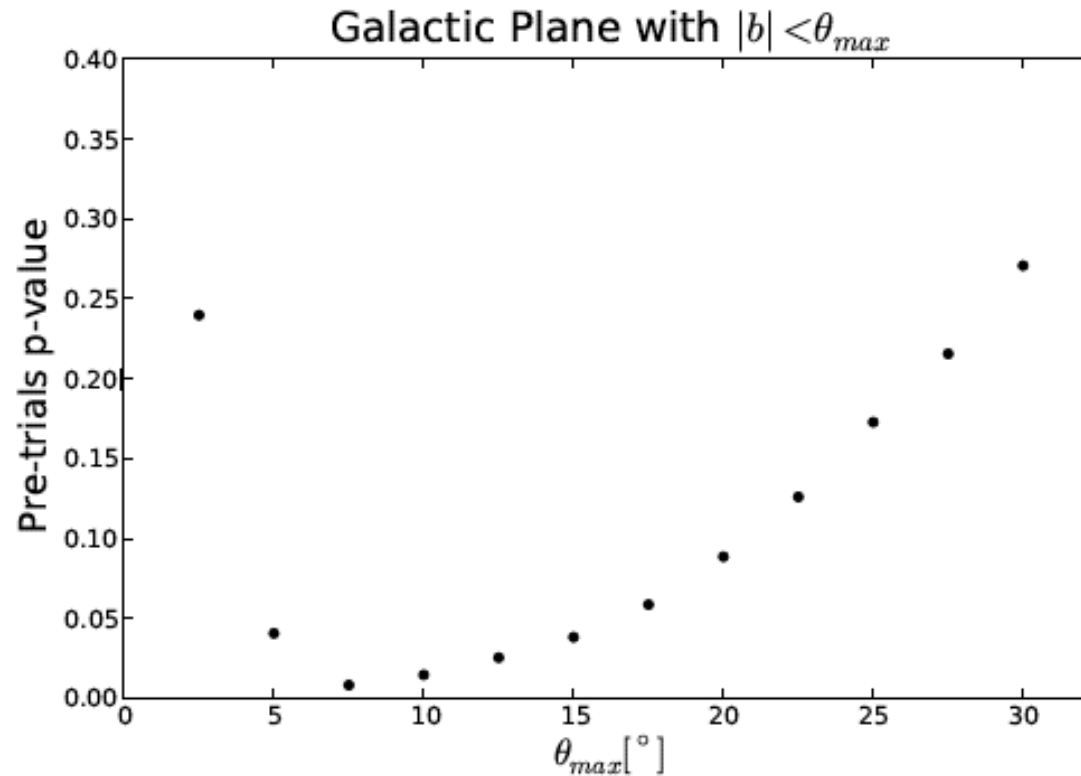
A.Neronov, D.S. and Tchernin, arXiv:[1307.2158](https://arxiv.org/abs/1307.2158)

# Real multimessenger fluxes, $\alpha=2.5$



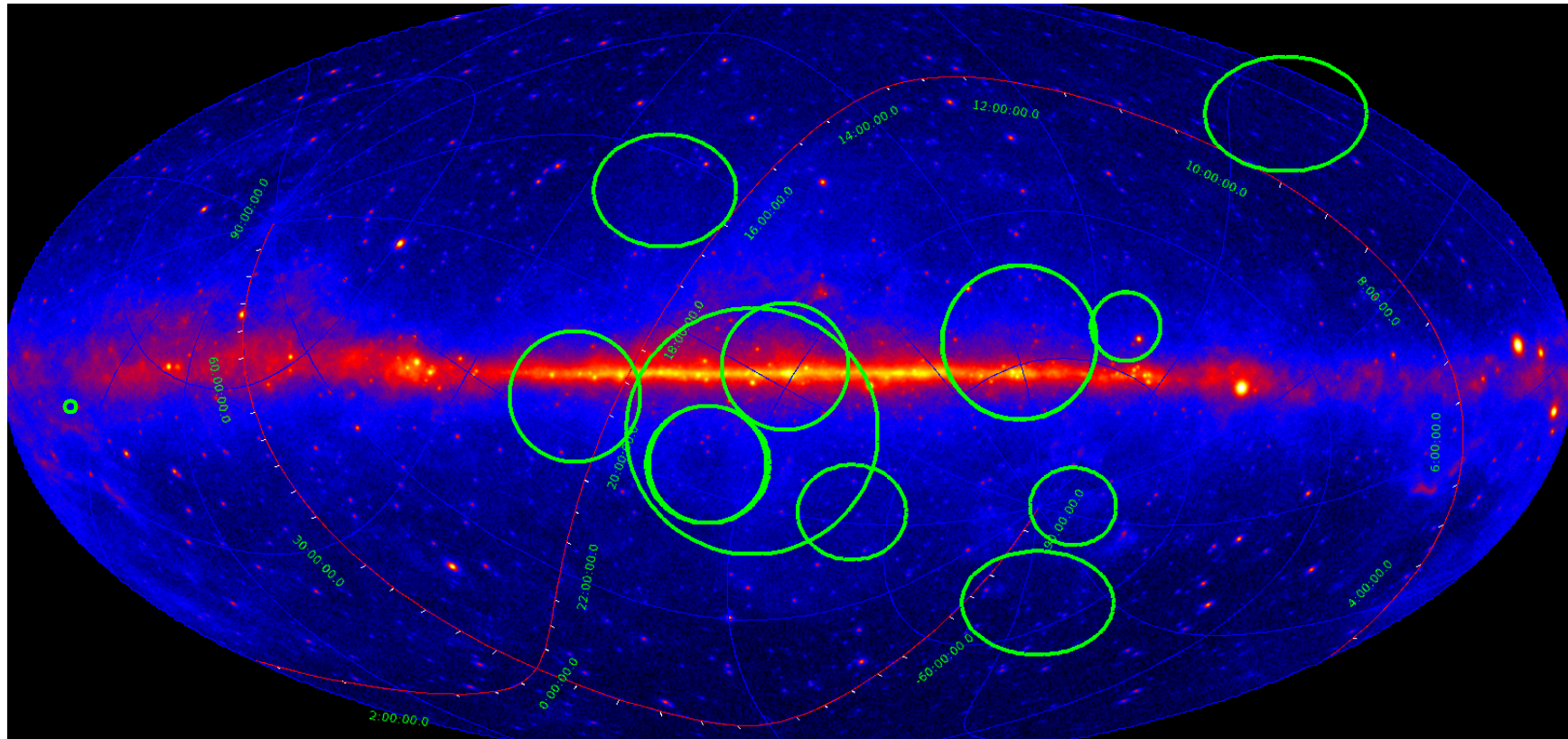
V.Berezinsky & A.Smirnov 1975

## IceCube galactic plane 3 years: 2% by chance – small statistics

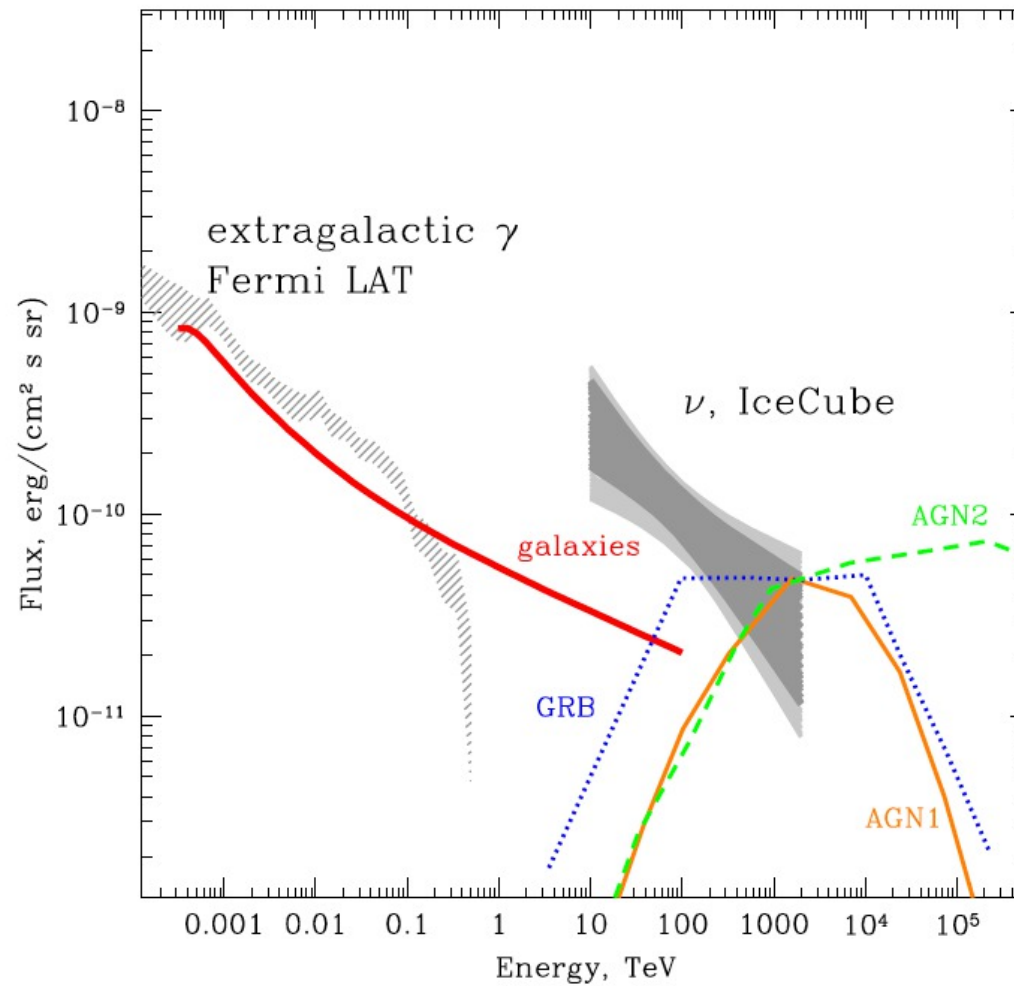


Karlsruhe, Sept 22, 2015

# IceCube neutrino sky map 3 years $E > 100$ TeV

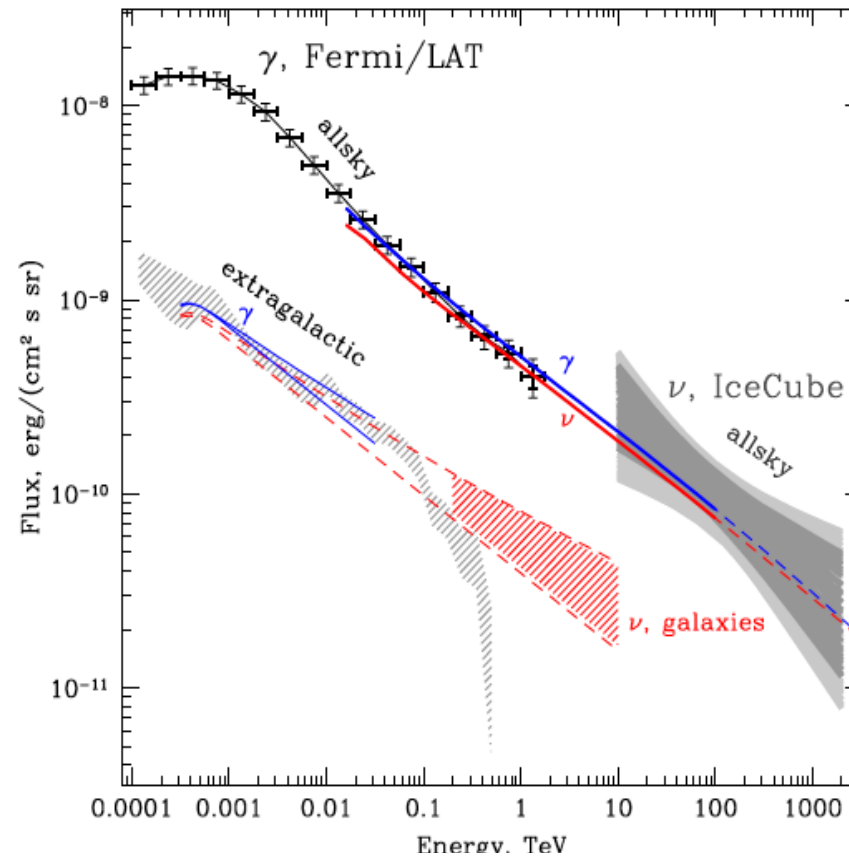


# IceCube + Fermi LAT



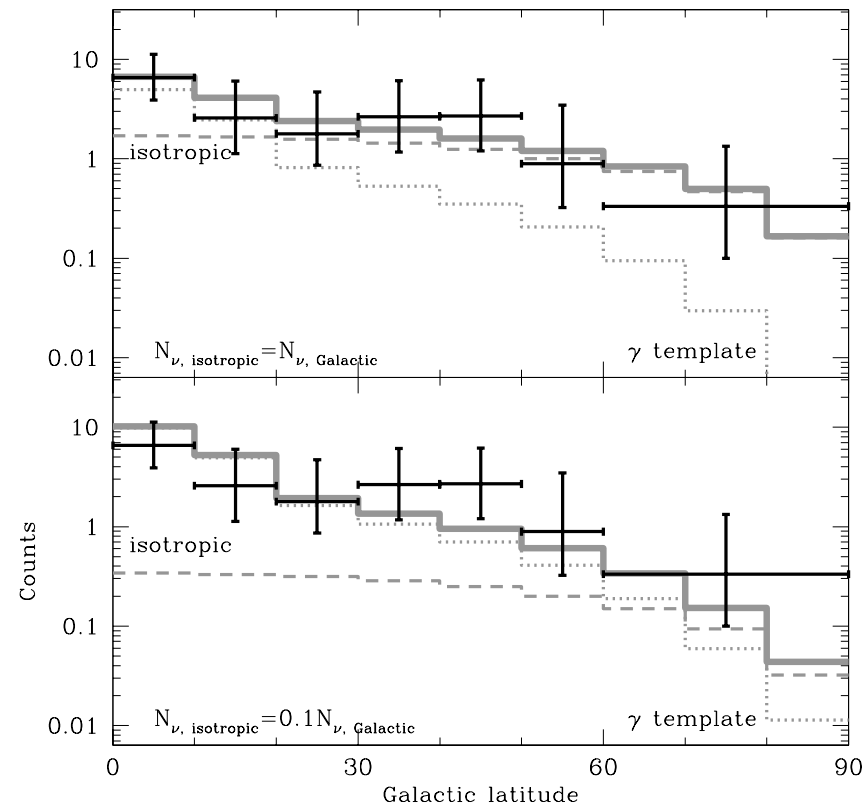
A.Neronov, D.S. arXiv:1412.1690

# IceCube + Fermi LAT all sky: protons $1/E^{2.5}$

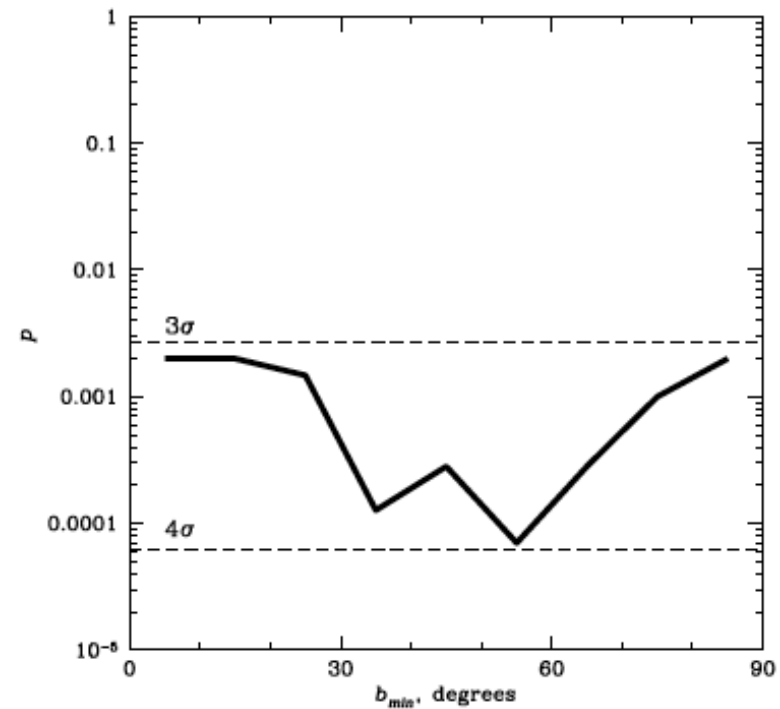
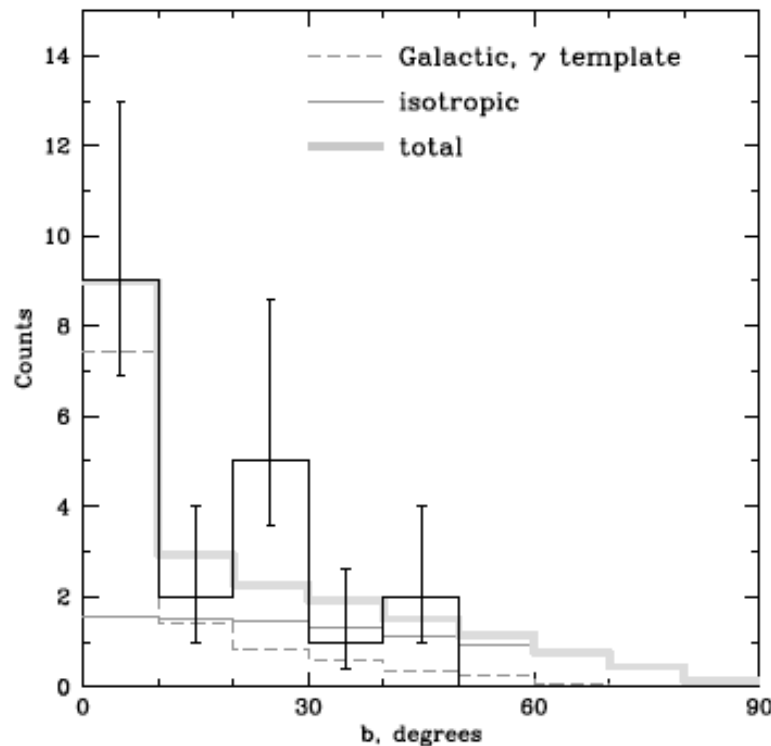


A.Neronov, D.S. arXiv:1412.1690

# Neutrino profile



# Evidence of Galactic component in 4 year IceCube data $E > 100$ TeV



**A. Neronov & D.S. arXiv: 1509.03522**



# BL Lacs as UHECR, neutrino and gamma-ray sources

## Protons in the source:

- Accelerated

$$\frac{dN_{CR}}{dE} \propto E^{-\alpha_p} \exp\left(-\frac{E}{E_{\text{cut}}}\right)$$

- Escape at UHECR energy:

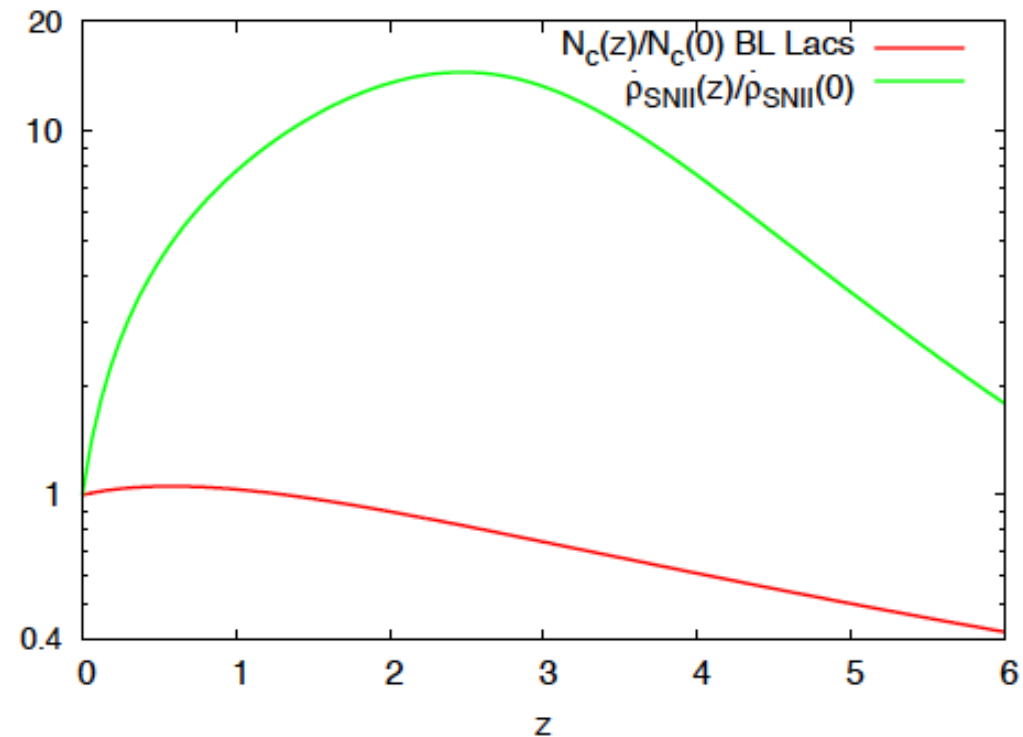
$$E_{\text{free}} \simeq eBR \simeq 3 \times 10^{20} \text{ eV} \frac{B}{10^4 \text{ G}} \frac{R}{10^{14} \text{ cm}},$$

- Trapped in the source at low energies:

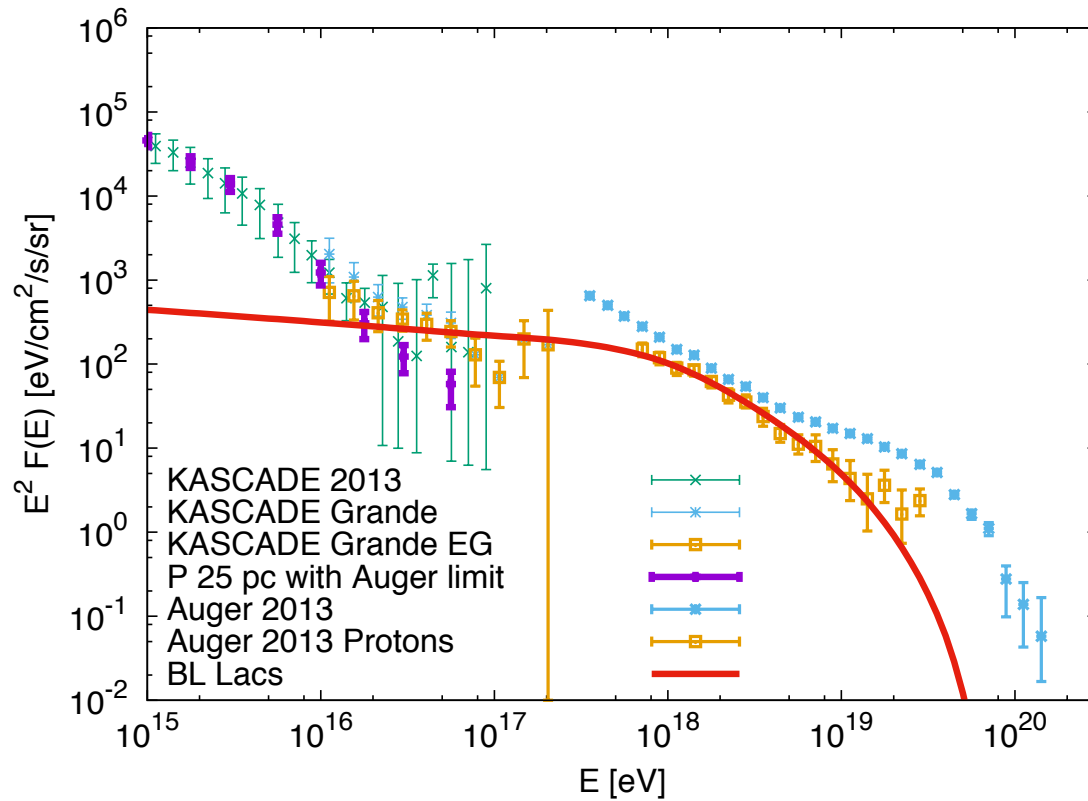
$$t_{\text{esc}} = \frac{R}{c} \left(\frac{E}{E_{\text{free}}}\right)^{-1/3} \simeq 5 \times 10^6 \text{ s} \left[\frac{E}{10^{11} \text{ eV}}\right]^{-1/3}$$

$$t_{pp} = \frac{1}{cK\sigma_{pp}n} \simeq 1 \times 10^6 \text{ s} \left(\frac{n}{10^9 \text{ cm}^{-3}}\right)^{-1}$$

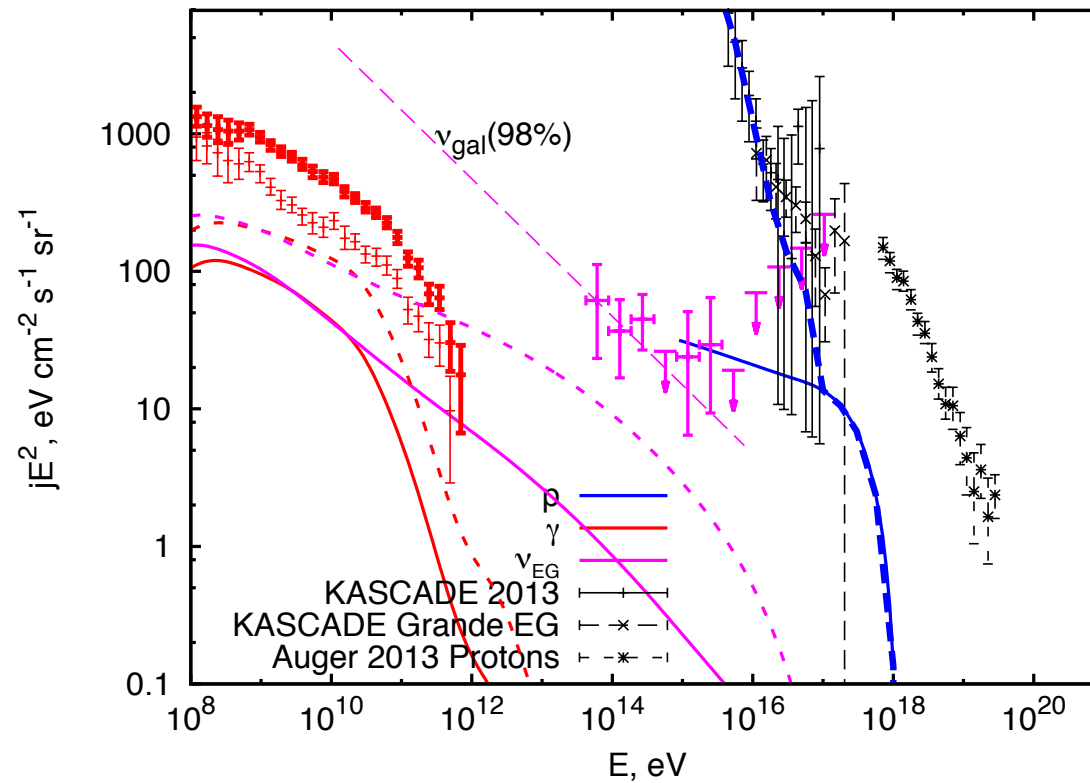
# Evolution of BL Lacs/SB galaxies



# UHECR proton flux from BL Lacs



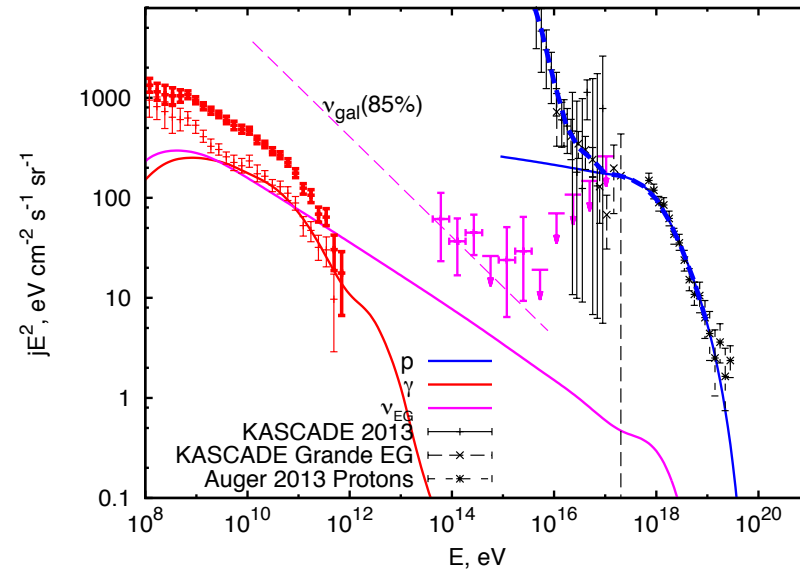
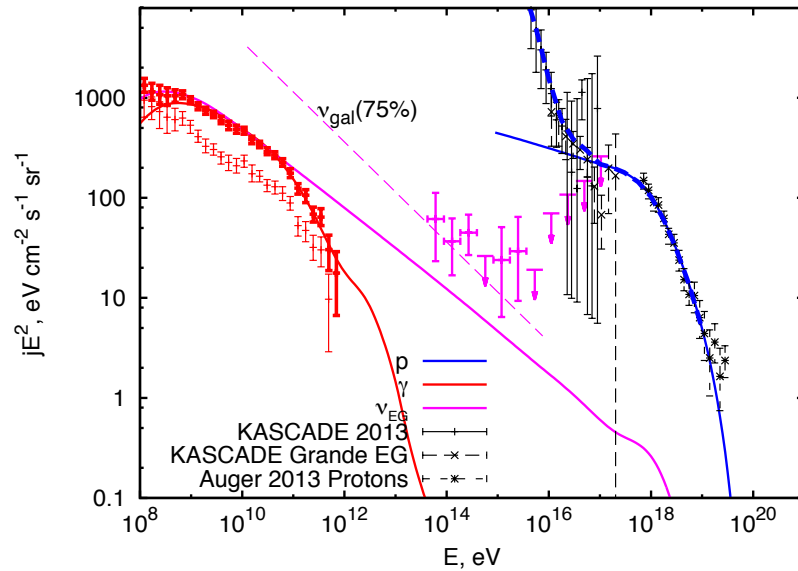
# UHECR proton flux from Star Burst galaxies



# Multimessenger signal from BL Lacs: dependence from accelerated spectrum

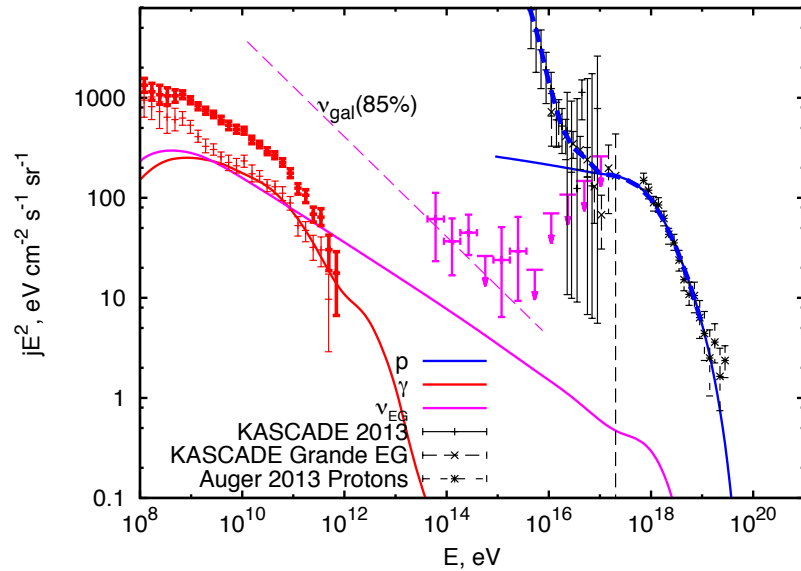
2.17

2.1

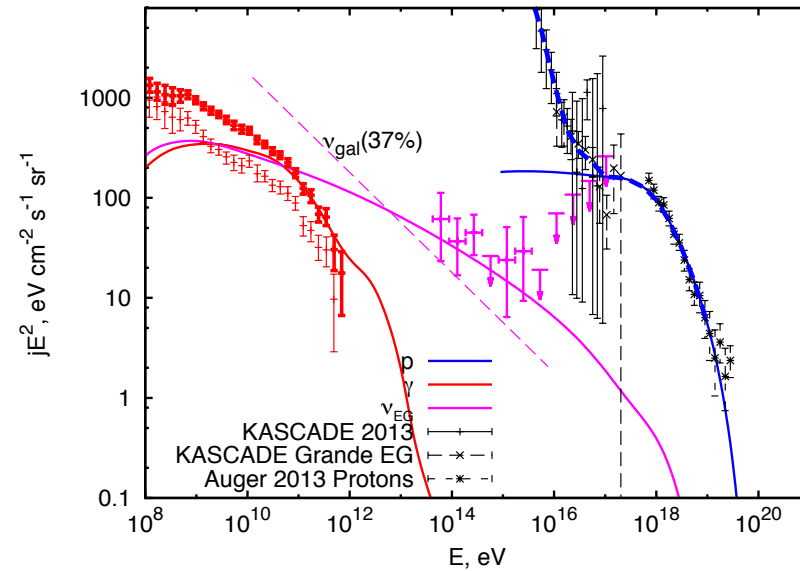


# Multimessenger signal from BL Lacs: dependence on escape energy

0.3 TeV



100 TeV



# Conclusions

- *First diffuse neutrino flux measurements contain galactic and extragalactic components.*
- *Galactic component consistent with diffuse galactic gamma-ray flux measured by Fermi and proton power law 2.5*
- *This is consistent with nuclei spectra.  
Exception: LOCAL protons and partly He.  
M.Kachelriess talk tomorrow: nearby 2 Myr old SN explain  $P$ , anti- $P$ , positrons and anisotropy*

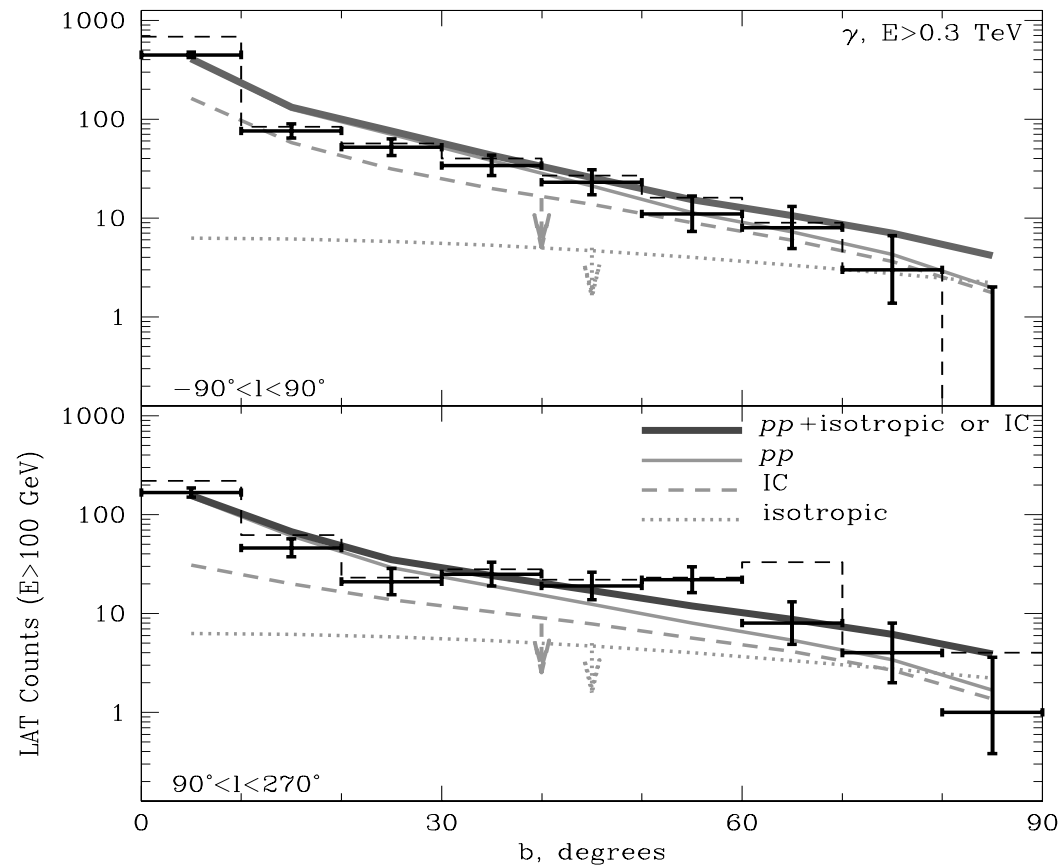


# Conclusions

- *BL Lacs are excellent candidates for sources of extragalactic CR, extragalactic part of astrophysical neutrinos and of diffuse gamma-rays*

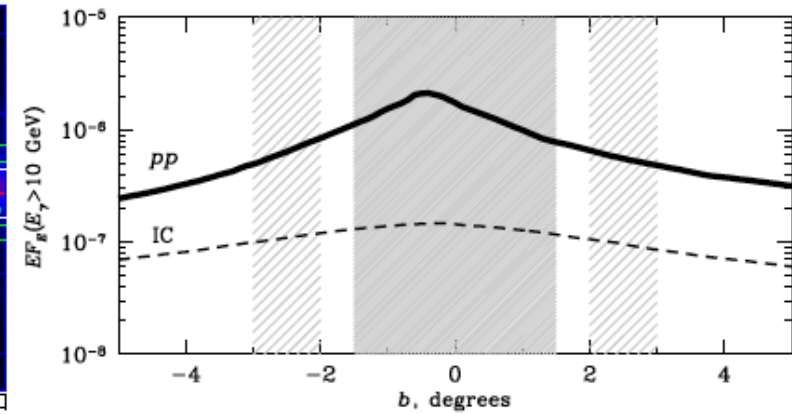
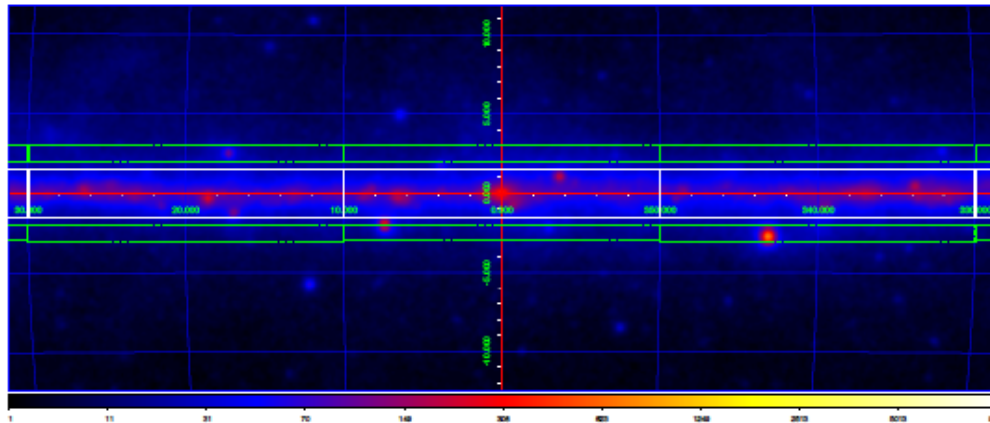
# Backup slides

# Profile gamma



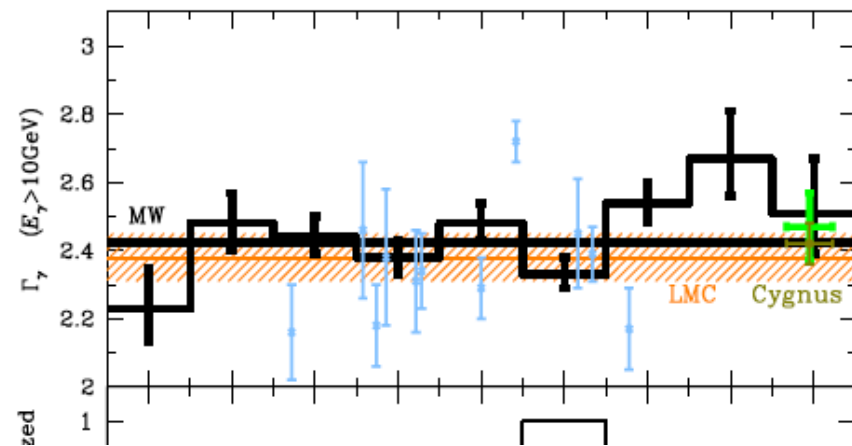
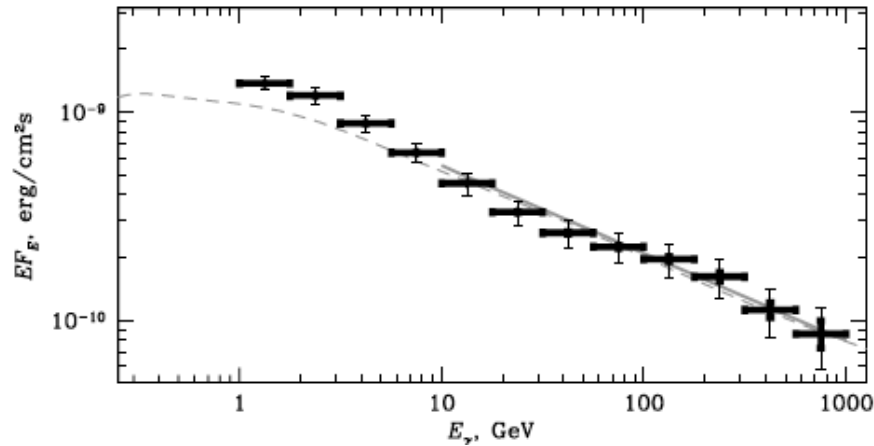
Karlsruhe, Sept 22, 2015

# Milky Way inner Galaxy Fermi $E > 10$ GeV

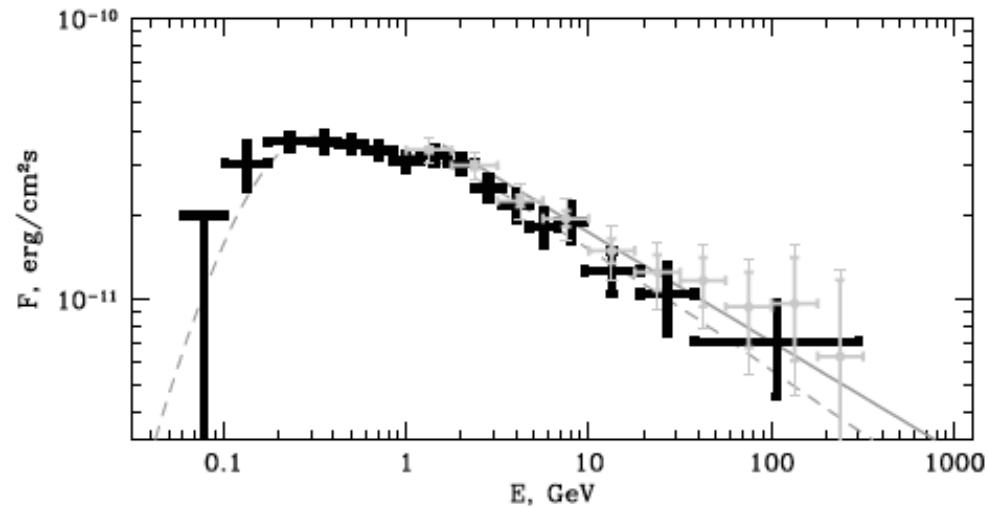
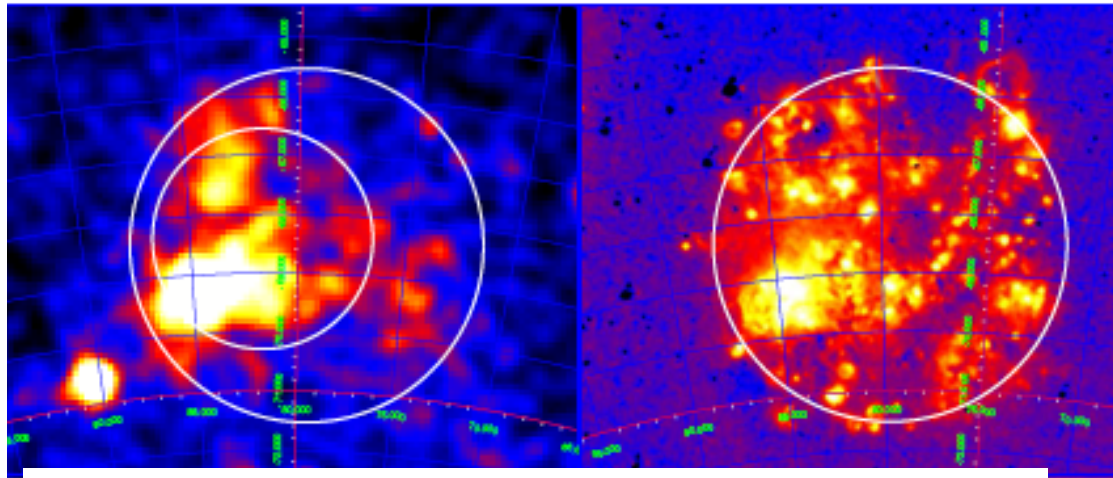


**A.Neronov and D.Malishev, arXiv: 1505.07601**

# Milky Way inner Galaxy Fermi $E > 10$ GeV: spectrum 2.45



# In LMC average proton spectrum 2.45



**A.Neronov and D.Malishev, arXiv: 1505.07601**