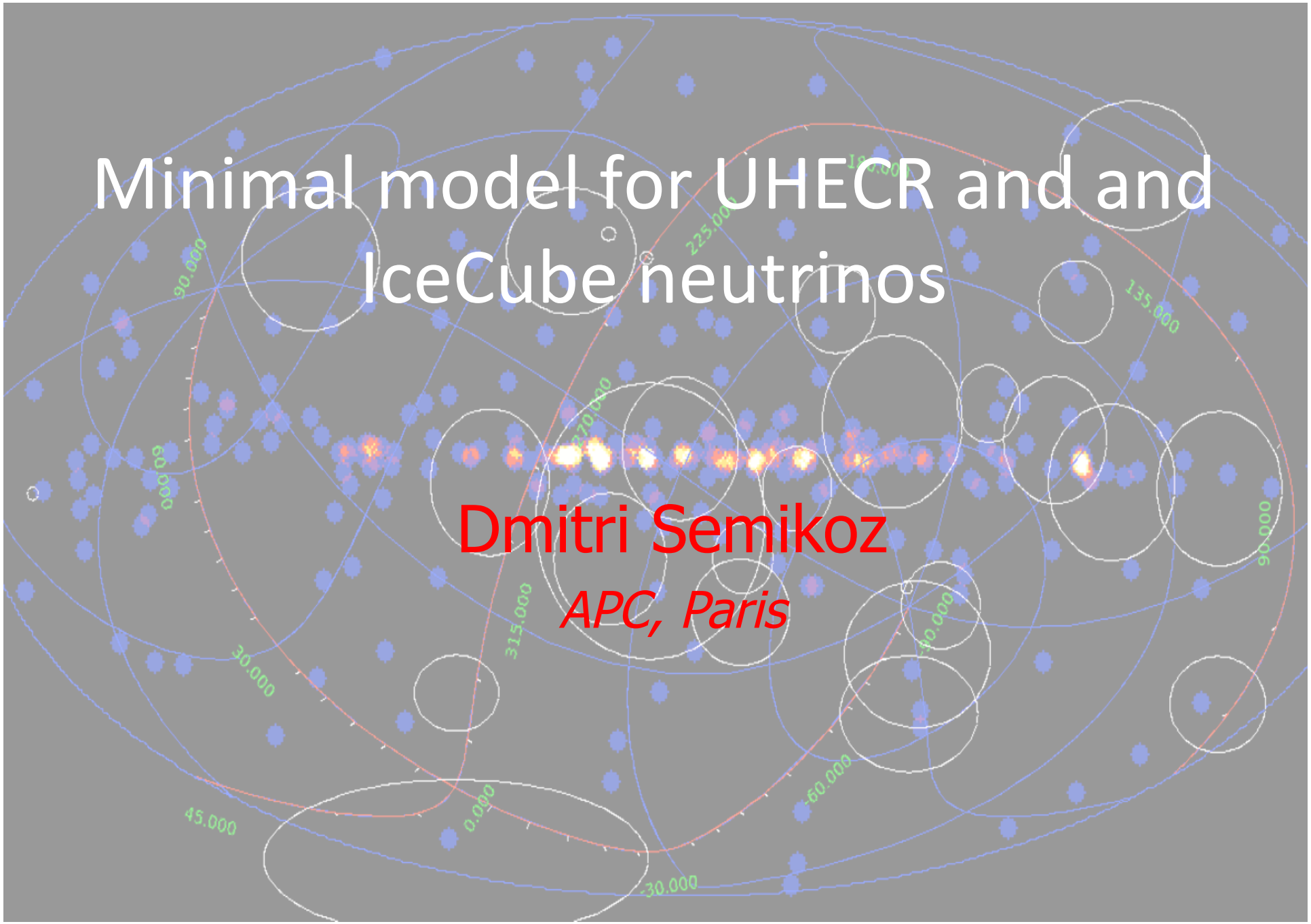
Minimal model for UHECR and and IceCube neutrinos



Dmitri Semikoz

APC, Paris

Plan:

- *UHECR and production of gamma-rays and neutrinos*
- *Icecube muon data self-consistency and blazar sources*
- *Extragalactic sources of UHECR, gamma-rays and neutrinos: minimal model*
- *TXS 0506 BL Lac and minimal model*
- *Conclusions*

Production of gamma-rays and neutrinos from UHECR sources

Pion production

$$N + \gamma_b \Rightarrow N' + \sum \pi^i$$

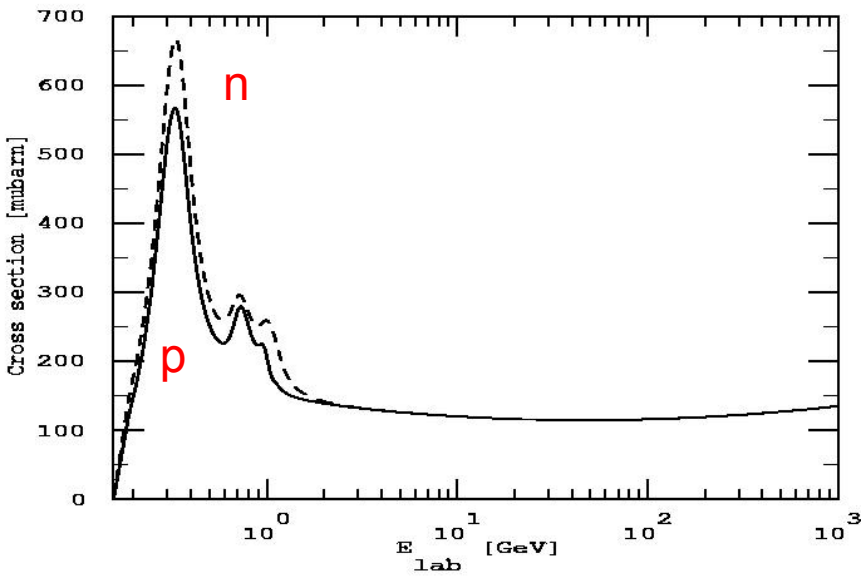
$$N + A_b \Rightarrow N' + \sum \pi^i$$

$$\pi^0 \Rightarrow 2\gamma$$

$$\pi^{\pm} \Rightarrow \mu^{\pm} + \nu_{\mu}$$

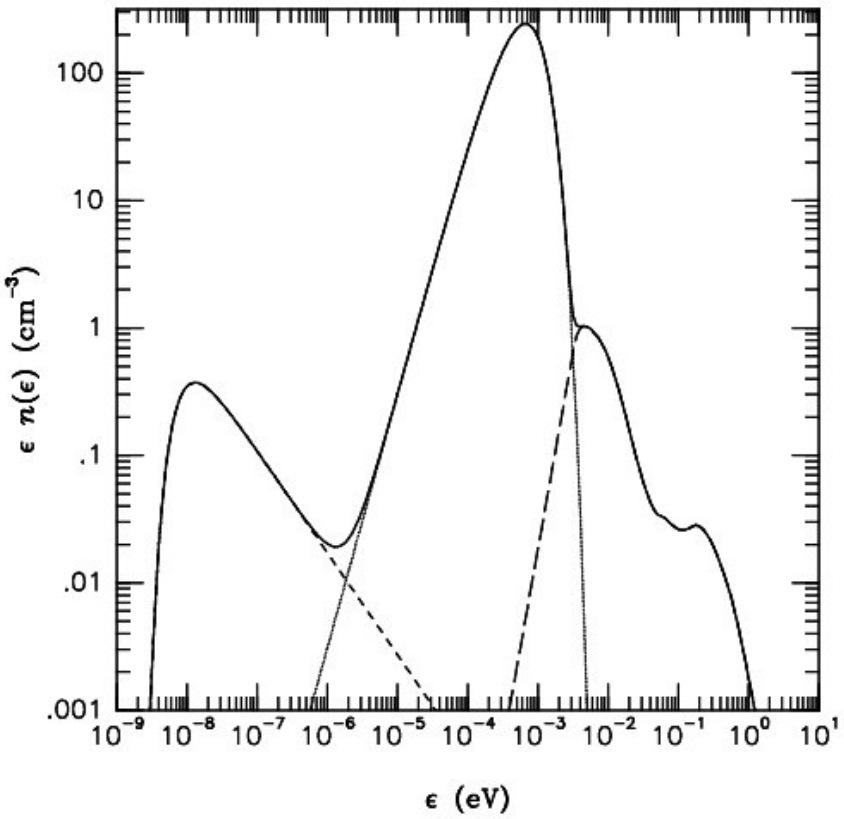
$$\mu^{\pm} \Rightarrow e^{\pm} + \bar{\nu}_e + \nu_{\mu}$$

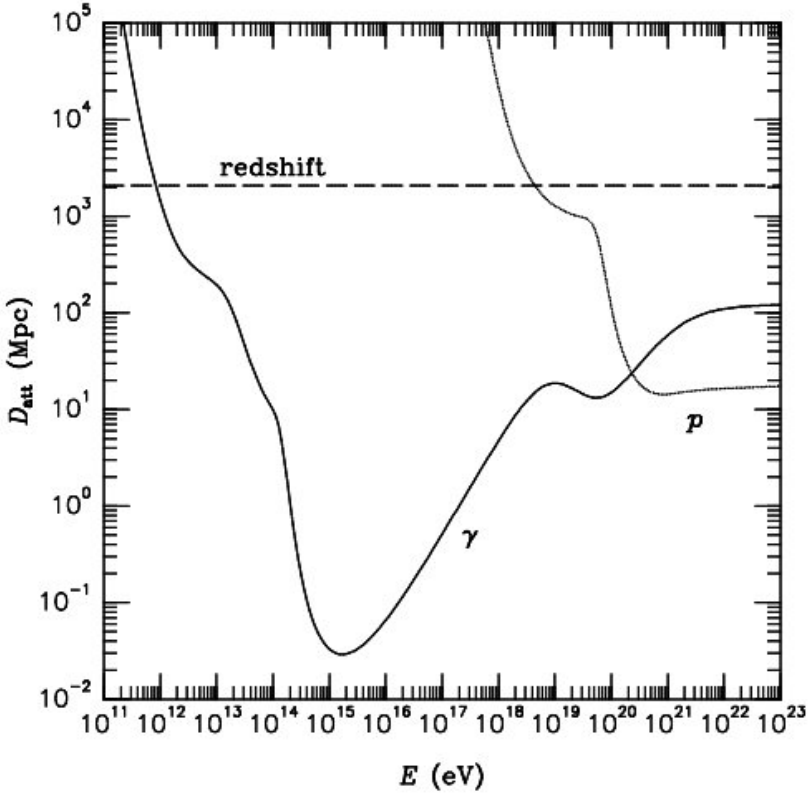
$$n \Rightarrow p + e^{-} + \bar{\nu}_e$$

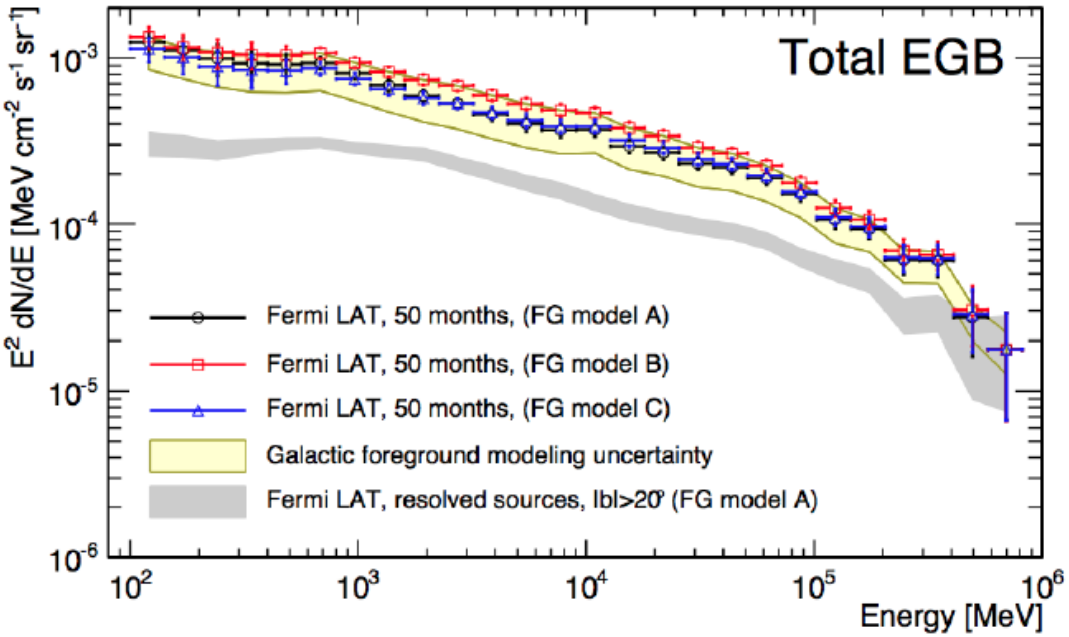


Conclusion: proton, photon and neutrino fluxes are connected in well-defined way. If we know one of them we can predict other ones: $E_{\gamma}^{tot} \sim E_{\nu}^{tot}$

Diffuse backgrounds

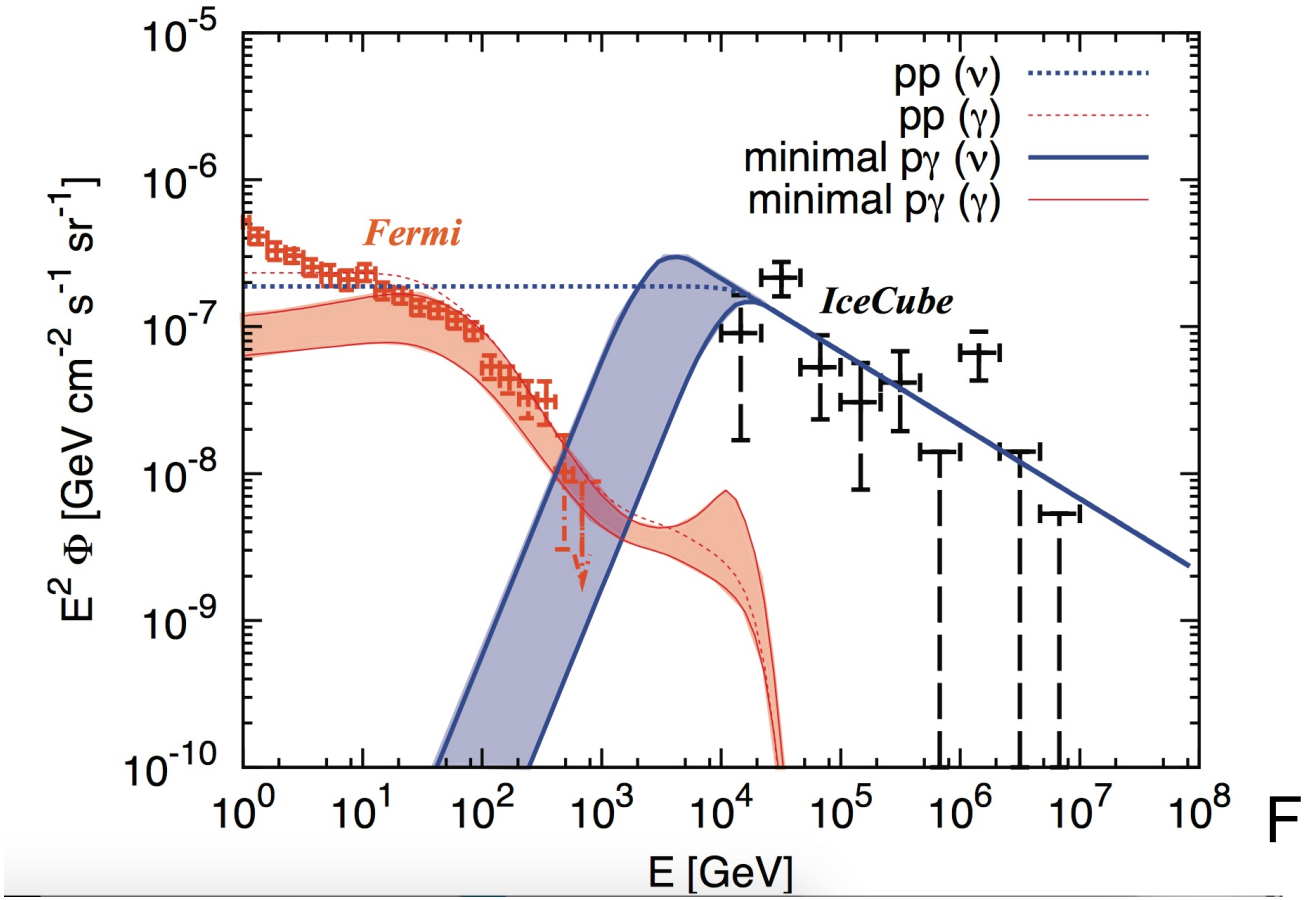






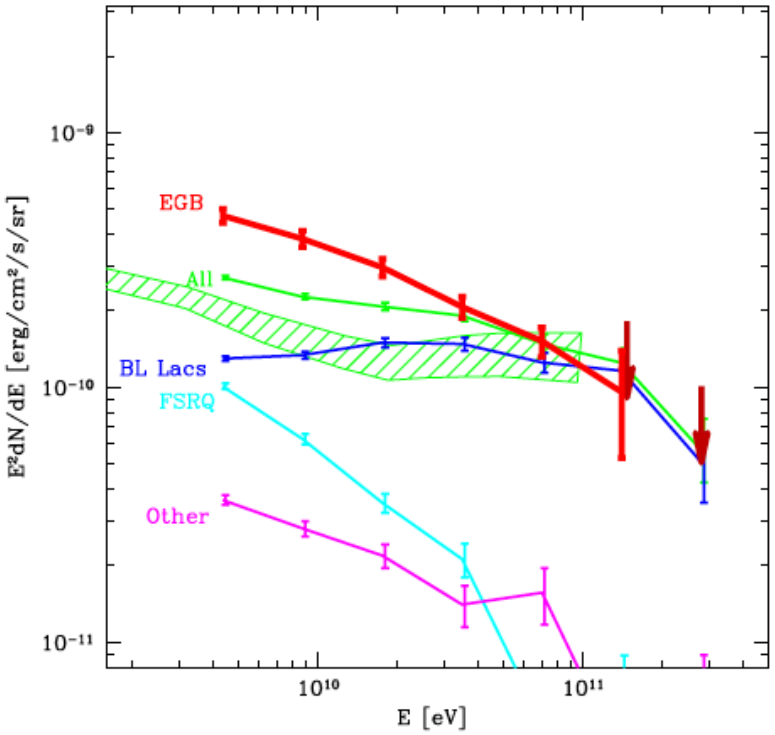
- **Sum of the intensities** of IGRB and the resolved high-latitude sources.
- Contribution of high-latitude Galactic sources **<< 5%.**
- Spectrum can be parametrized by **power-law with exponential cutoff**.
- Spectral index **~ 2.3**, cutoff energy **~ 350 GeV.**

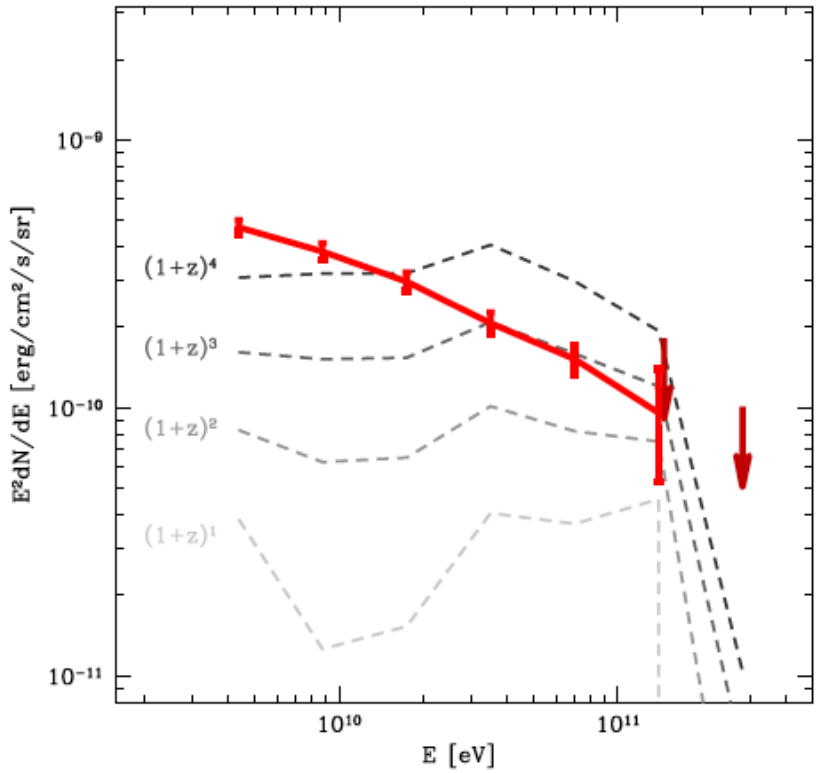
Self-consistent extragalactic sources



From M.Ahlers

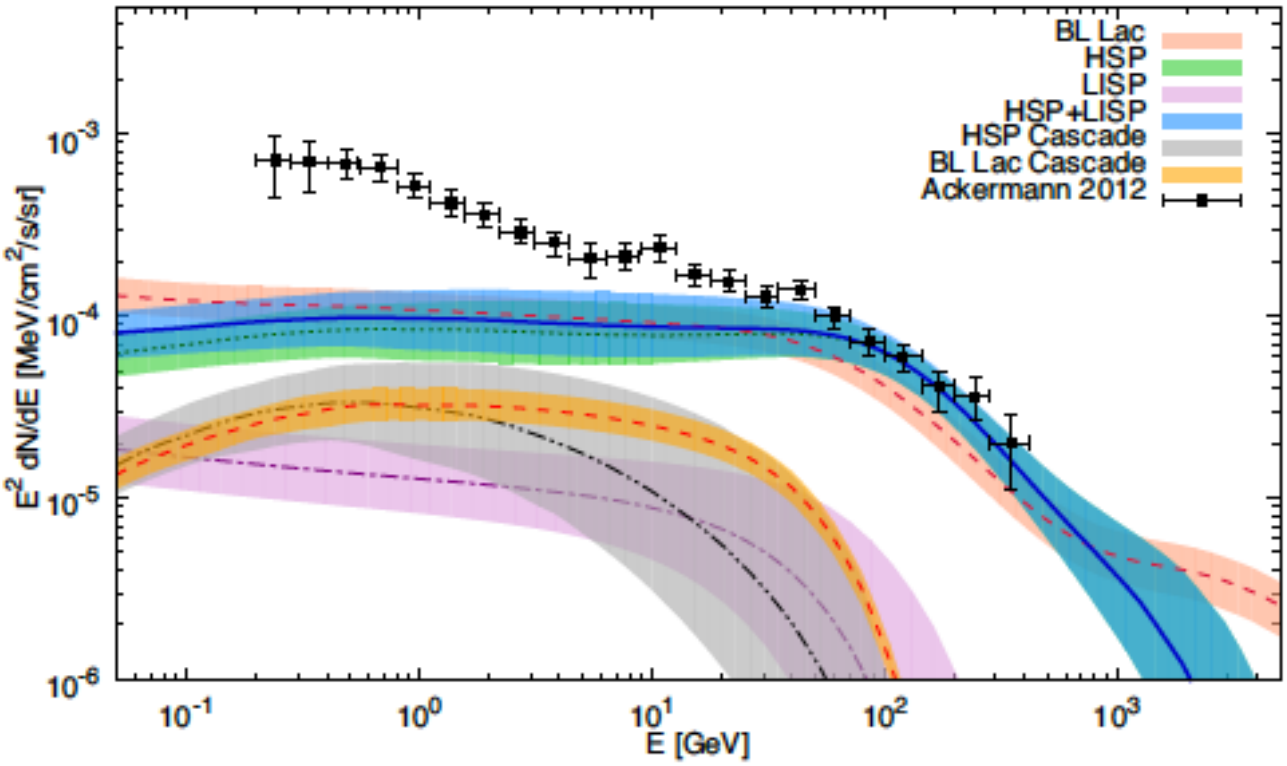
Unresolved BL Lacs give main contribution to diffuse gamma-ray flux





A.Neronov, D.S. Astrophys.J. 757 (2012) 61

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



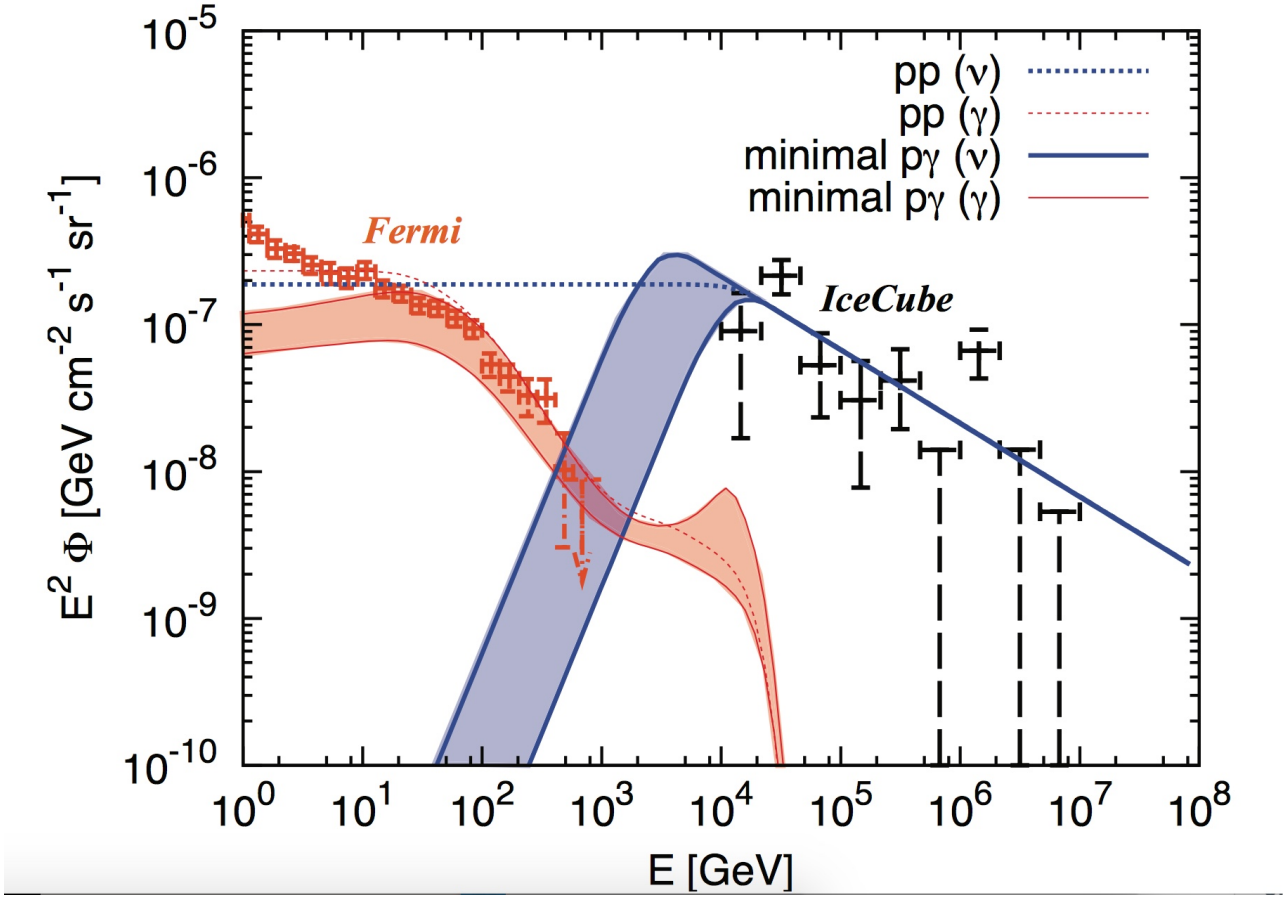
M. Di Mauro et al, arXiv:1311.5708

Fermi confirmed resolution of diffuse background with BL Lac sources above 50 GeV

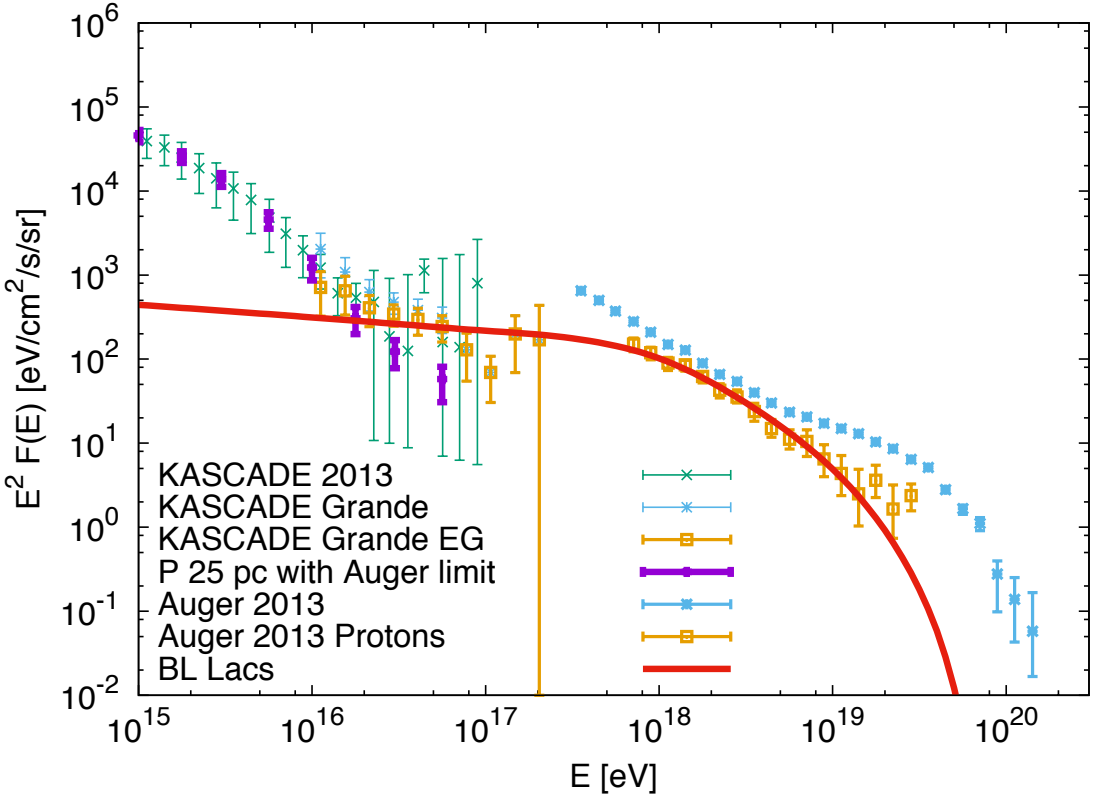
cm $^{-}$ s $^{\cdot}$). We employ a one-point photon fluctuation analysis to constrain the behavior of dN/dS below the source detection threshold. Overall the source count distribution is constrained over three decades in flux and found compatible with a broken power law with a break flux, S_b, in the range $[8 \times 10^{-12}, 1.5 \times 10^{-11}]$ ph cm^{-2} s^{-1} and power-law indices below and above the break of $\alpha_2 \in [1.60, 1.75]$ and $\alpha_1 = 2.49 \pm 0.12$ respectively. Integration of dN/dS shows that point sources account for at least $86^{+16}_{-14}\%$ of the total extragalactic γ-ray background. The simple form of the derived source count distribution is consistent with a single population (i.e. blazars) dominating the source counts to the minimum flux explored by this analysis. We estimate the density of sources

Fermi collaboration, arXiv:1511.00693

Are neutrino sources BL Lacs?



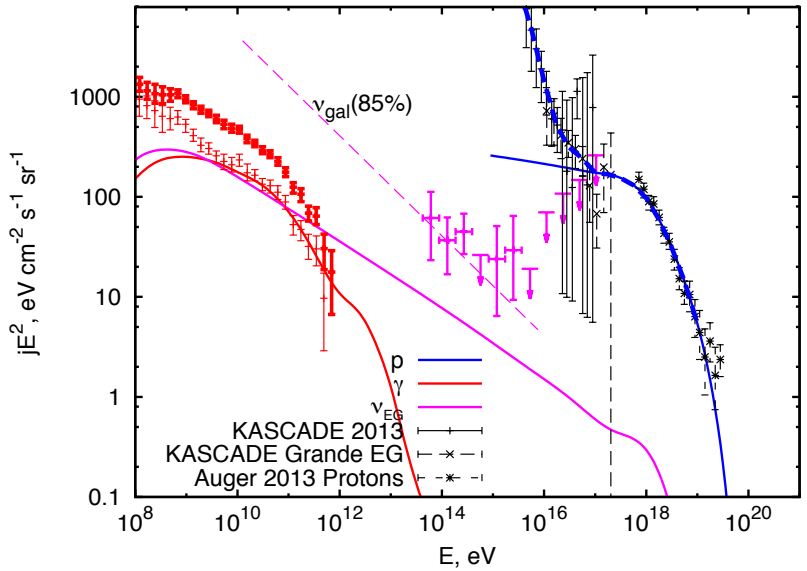
UHECR proton flux from BL Lacs



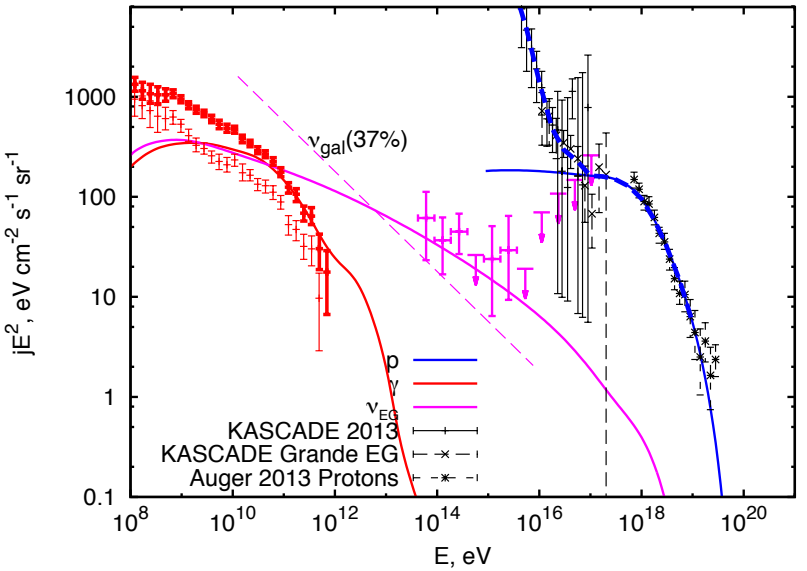
G.Giacinti et al, , **arXiv: 1507.07534**

Miltimessenger signal from BL Lacs: dependence on escape energy

0.3 TeV



100 TeV



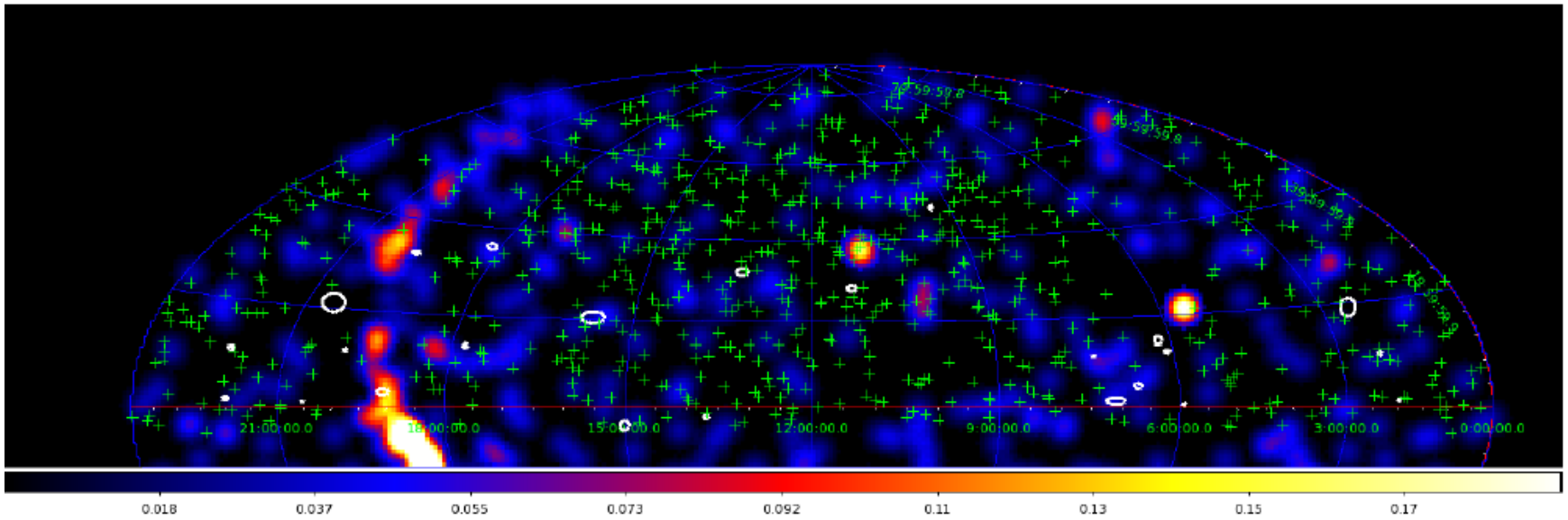
G.Giacinti et al, **arXiv: 1507.07534**

Icecube muon data self-consistency and blazar sources

Constraints on BL Lac neutrino sources

- 1) correlation with Fermi BL Lacs

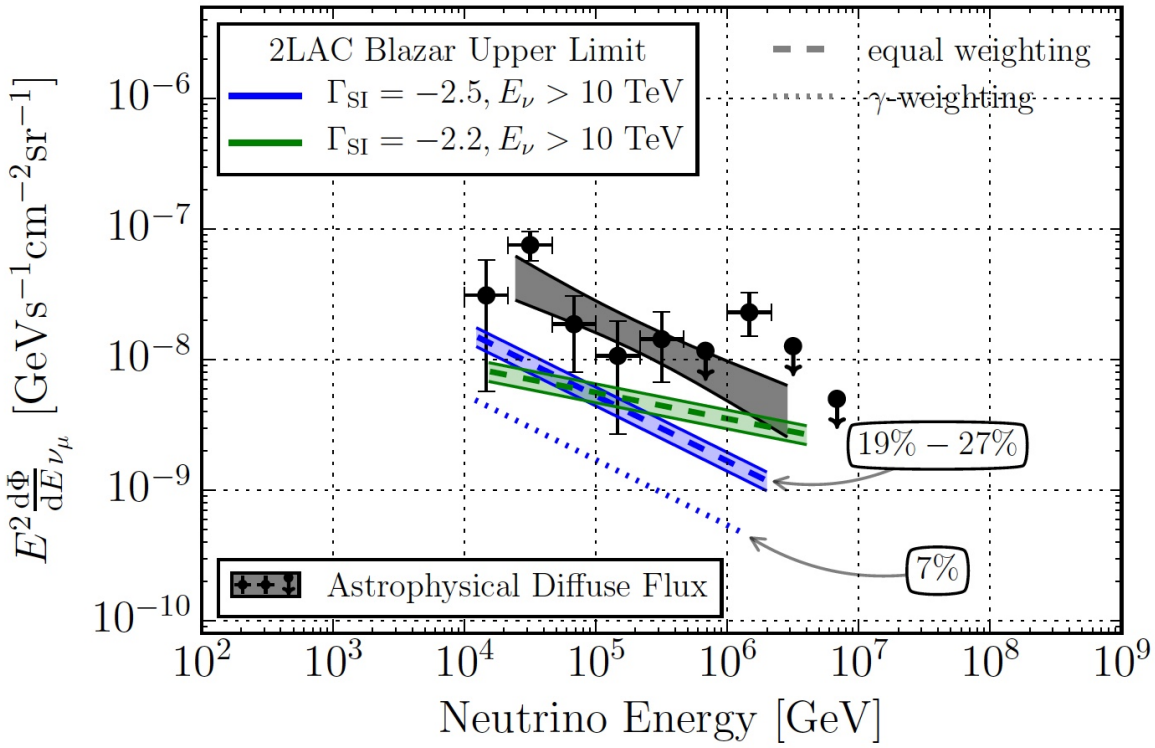
Fermi blazars and IceCube neutrinos



A.Neronov, K.Ptitsyna and D.S, arXiv:1611.06338

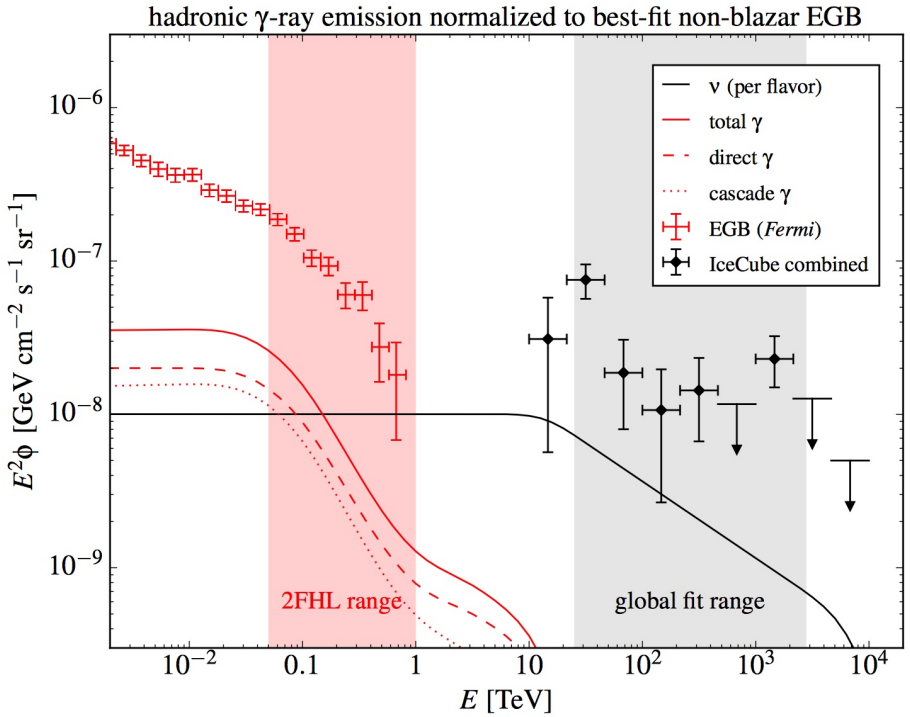
Blazars are subdominant sources

TeV Blazars?



Blazar stacking limits derived from Fermi-LAT AGN catalogue (2LAC) [IceCube'16]

Blazars are subdominant in neutrinos. Major neutrino sources are subdominant in gamma-rays

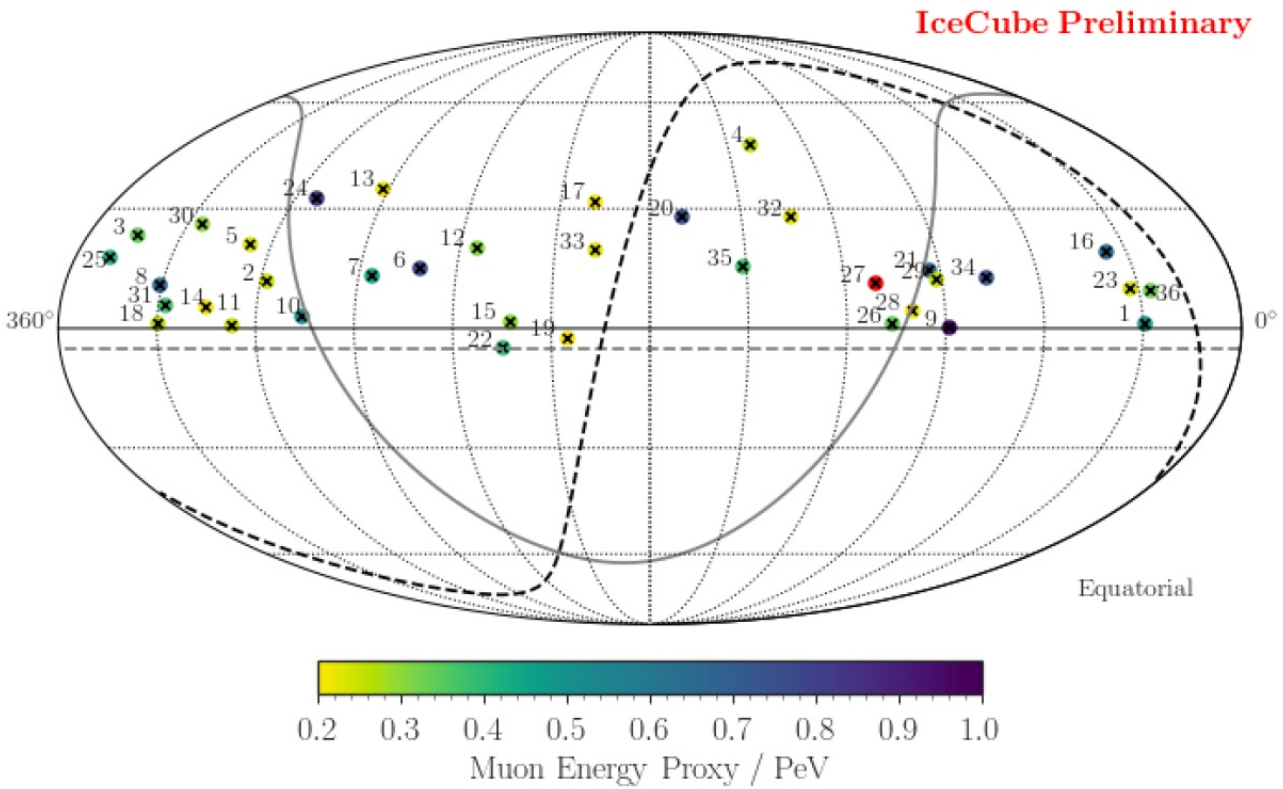


[Bechtol, MA, Ajello, Di Mauro & Vandenbroucke'15]

Constraints on BL Lac neutrino sources

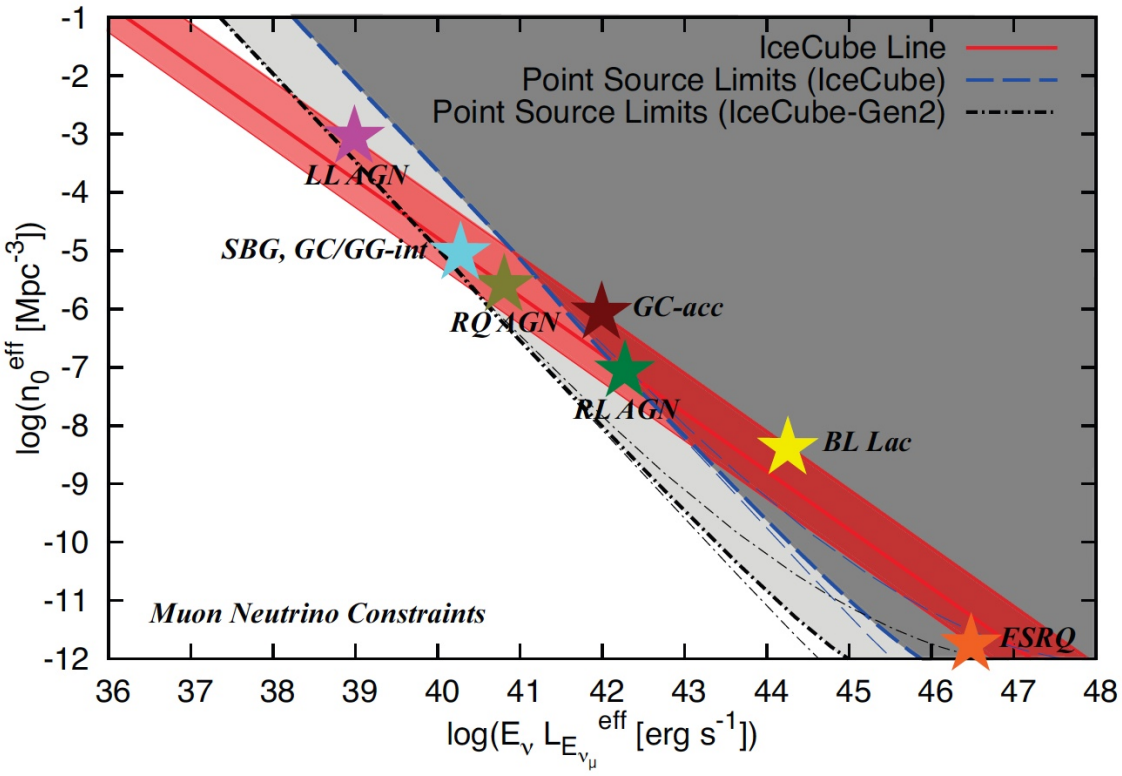
- 1) correlation with Fermi BL Lacs: no correlation
- 2) neutrino dominant sources: high density on sky: no doublets

Icecube 8 years muon neutrinos



IceCube ICRC 2017

No doublets put limit on density of sources



K.Murase, E.Waxman, 1607.01601

Constraints on BL Lac neutrino sources

- 1) correlation with Fermi BL Lacs: no correlation
- 2) neutrino dominant sources: high density on sky: no doublets

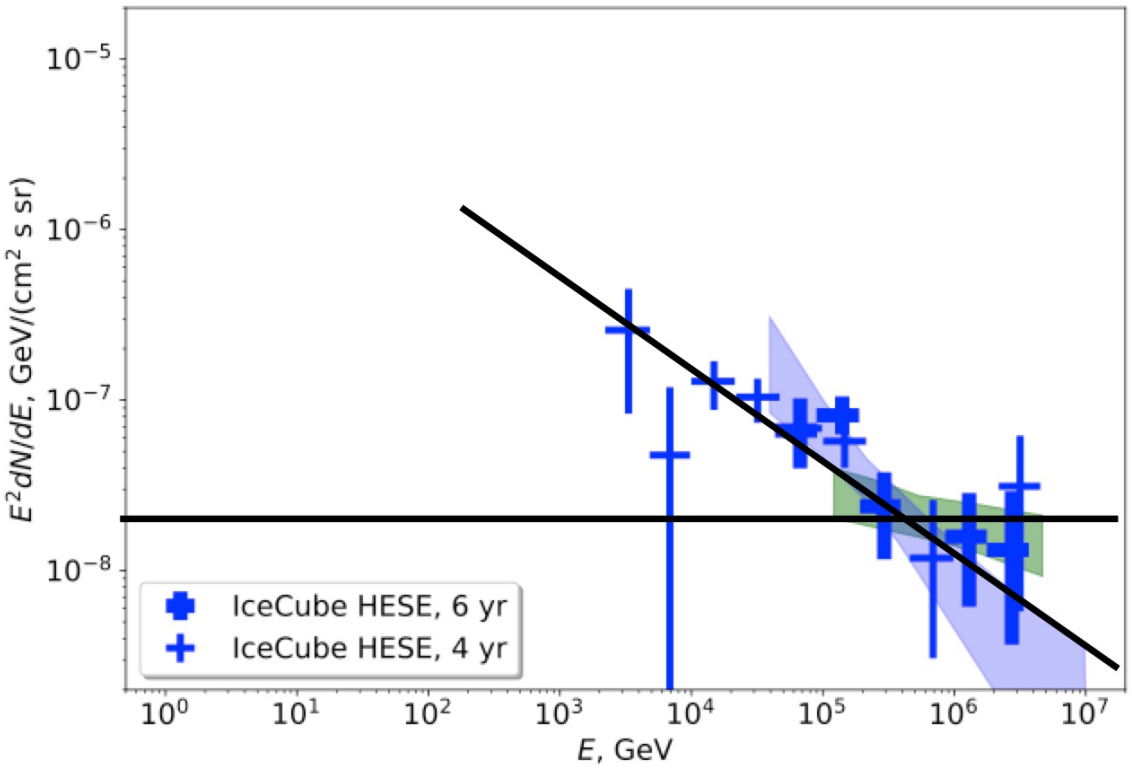
- What we can do with minimal model?

Constraints on BL Lac neutrino sources

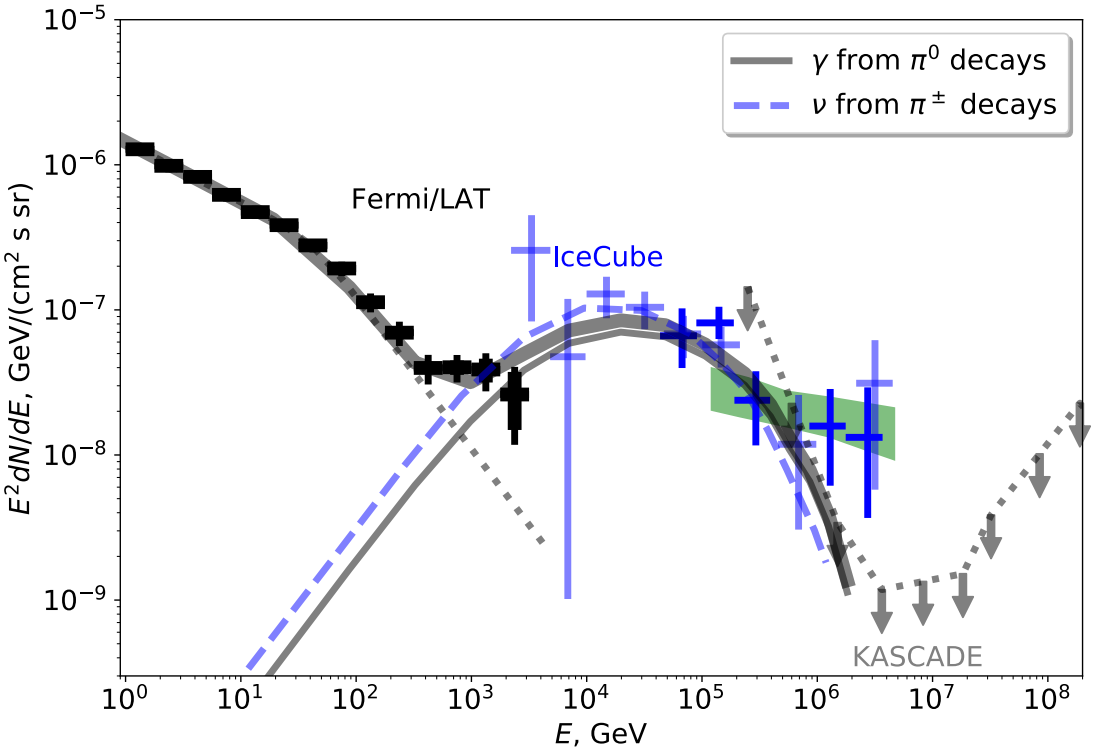
- 1) correlation with Fermi BL Lacs: no correlation
- 2) neutrino dominant sources: high density on sky: no doublets

- What we can do with minimal model?
- Add one more parameter ☺

IceCube data: 2 contributions



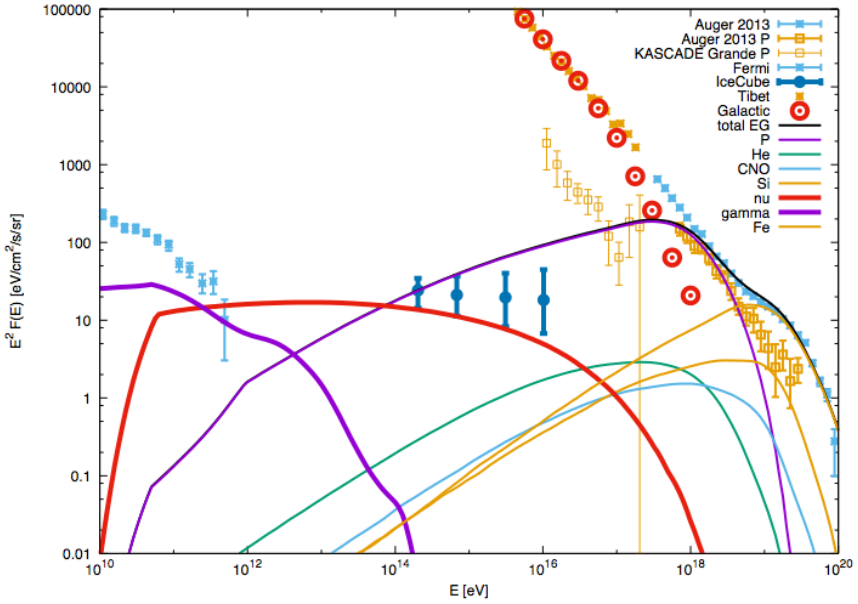
IceCube + Fermi LAT : local source or DM

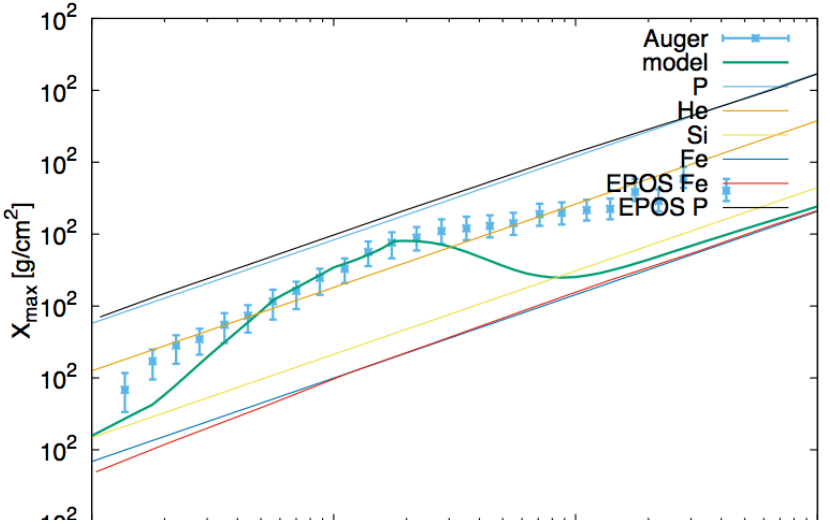


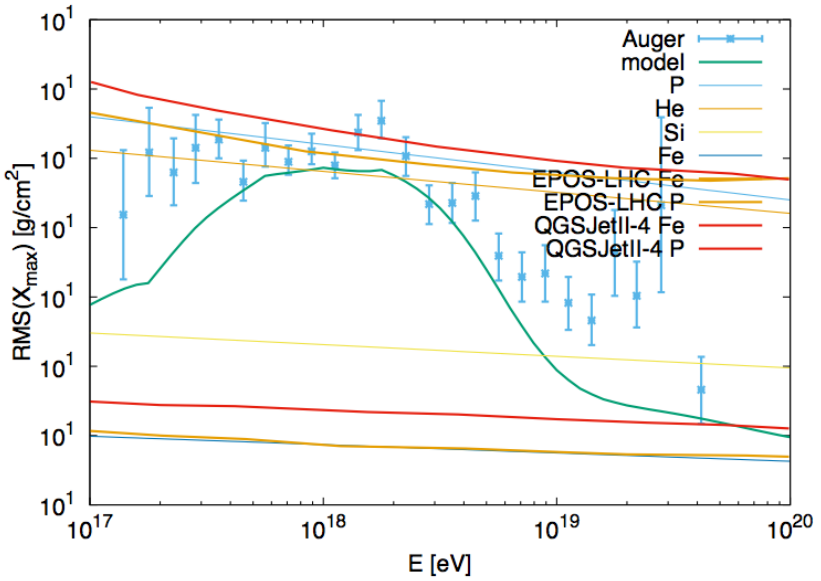
A.Neronov, M.Kachelriess and D.S. , arXiv:1802.09983

Extragalactic sources of UHECR, gamma-rays and neutrinos: minimal model

AGNs: Proton-proton interactions in the source region

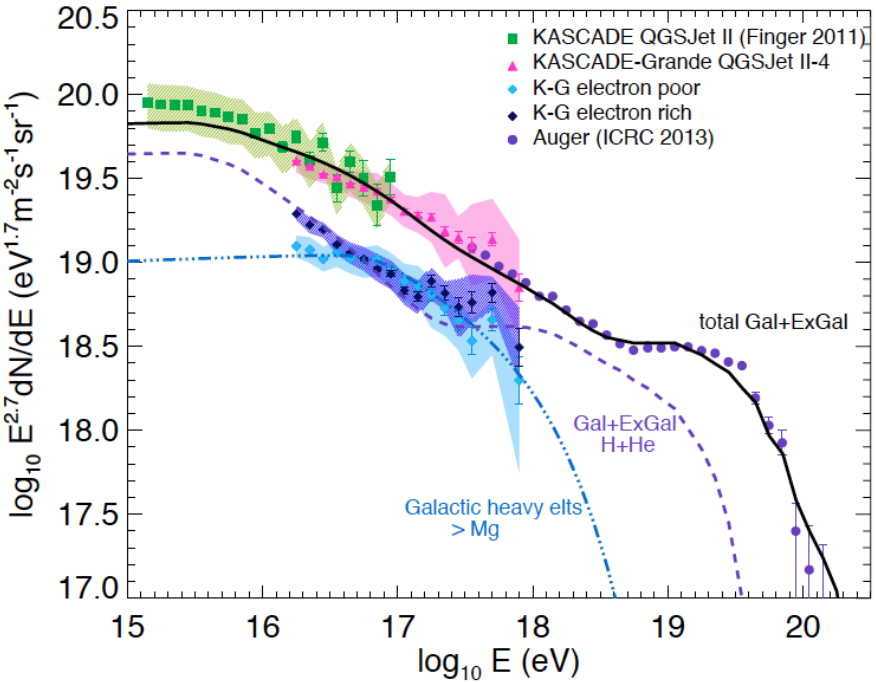




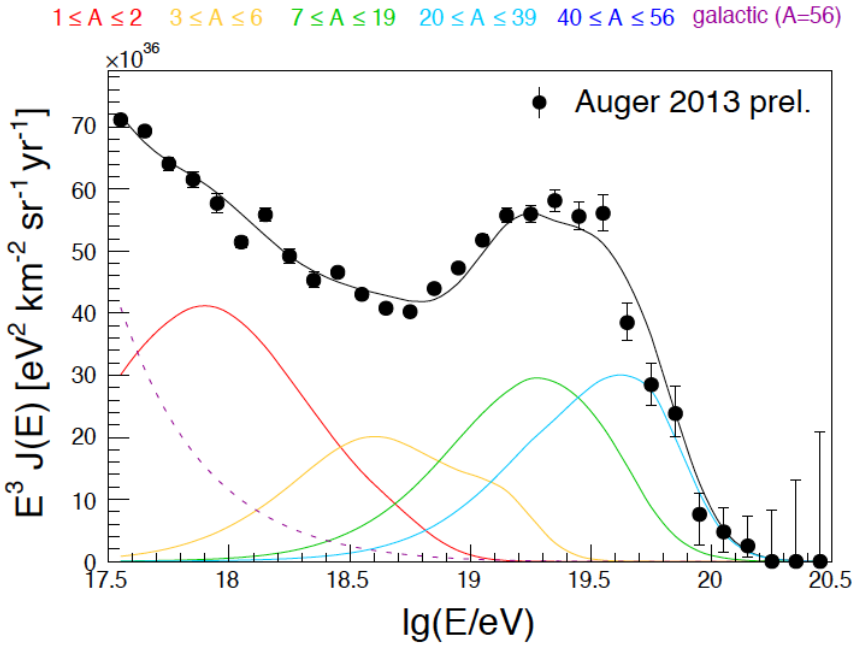


Kachelriess et al, 1704.06893

UHECR sources p-gamma interaction with tau>1 for nuclei

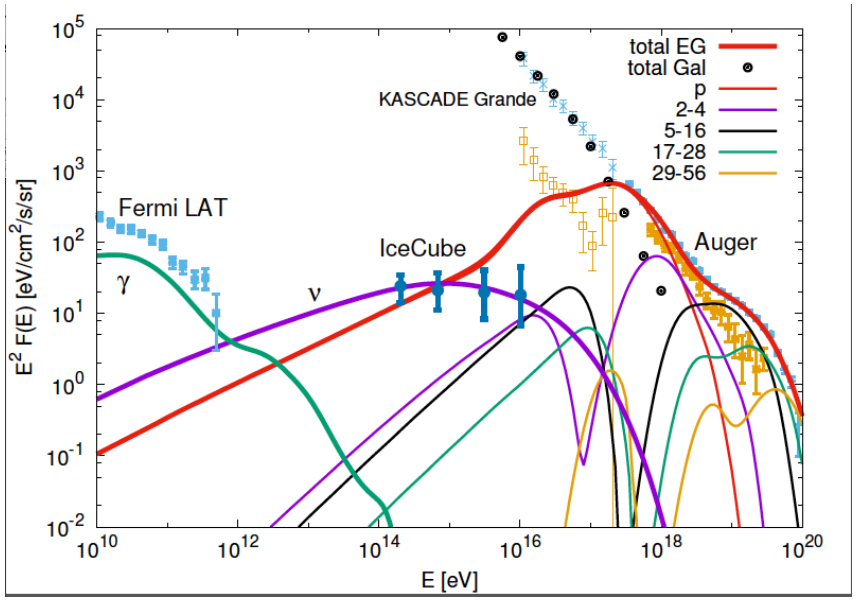


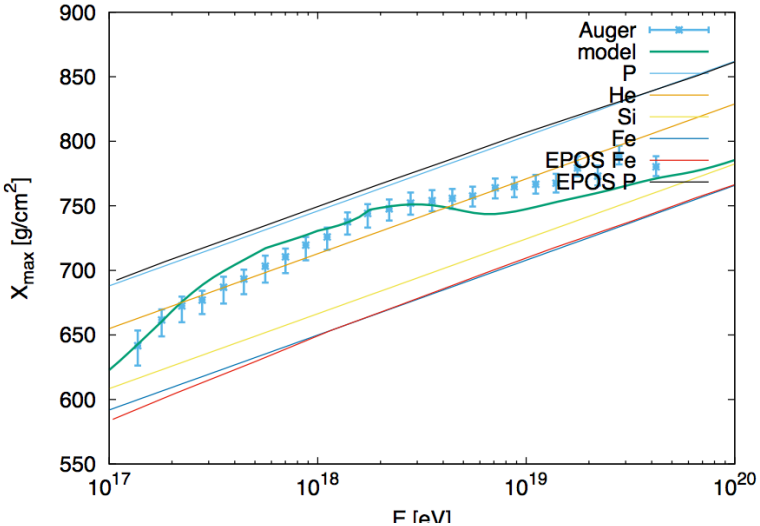
D.Allard et al, 1505.1377

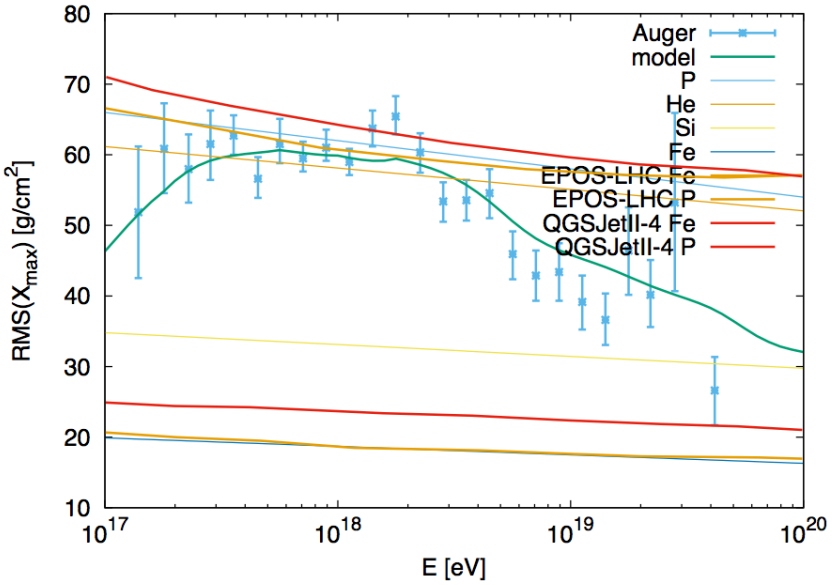


M.Unger et al, 1505.02153

AGN's: P-gamma + Proton-proton interactions in the source region







Kachelriess et al, 1704.06893

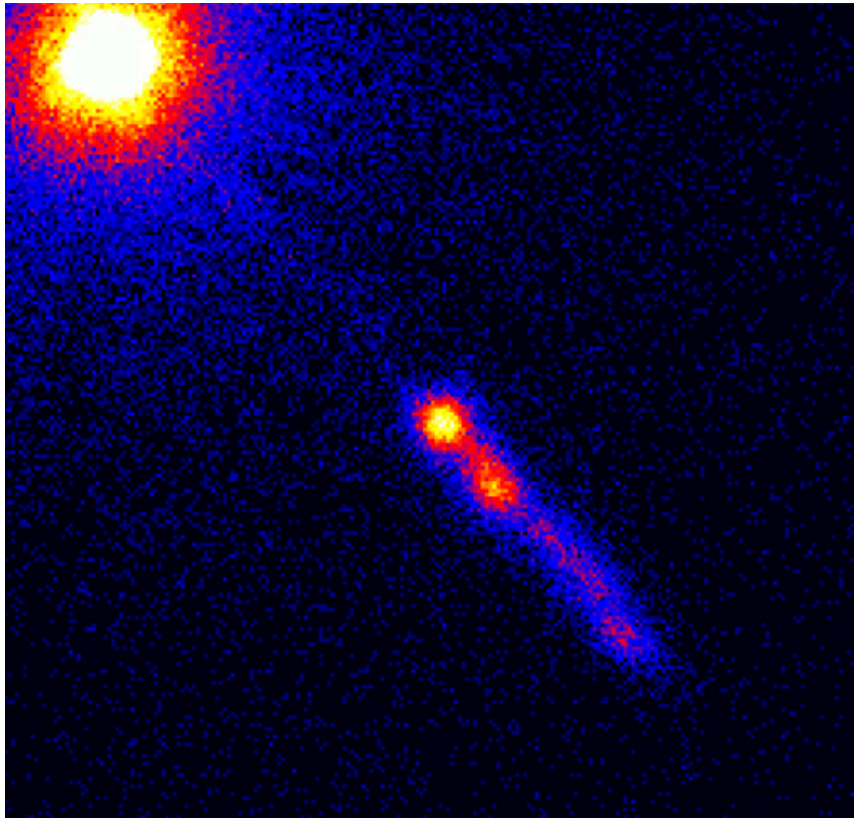
Evidence for the first source

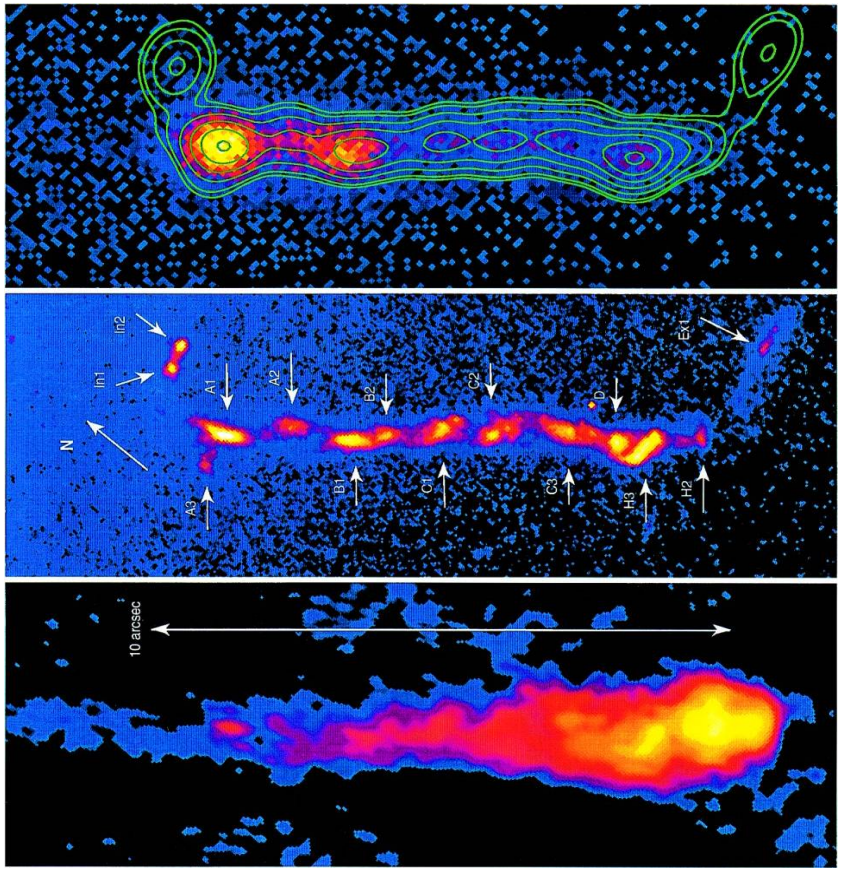
First neutrino source candidate TXS 0506+056

- Blazar TXS 0506+056 is Fermi source, one of 50 bright sources , but not in first 20.
- Icecube event: IceCube-170922A Sept 22 2017
- TXS 0506+056 has redshift z=0.3365
- HESS/VERITAS observed Sept 23-24: no detection
- MAGIC detected flair Sept 28 2017
- Fermi detected activity of source in the same period.

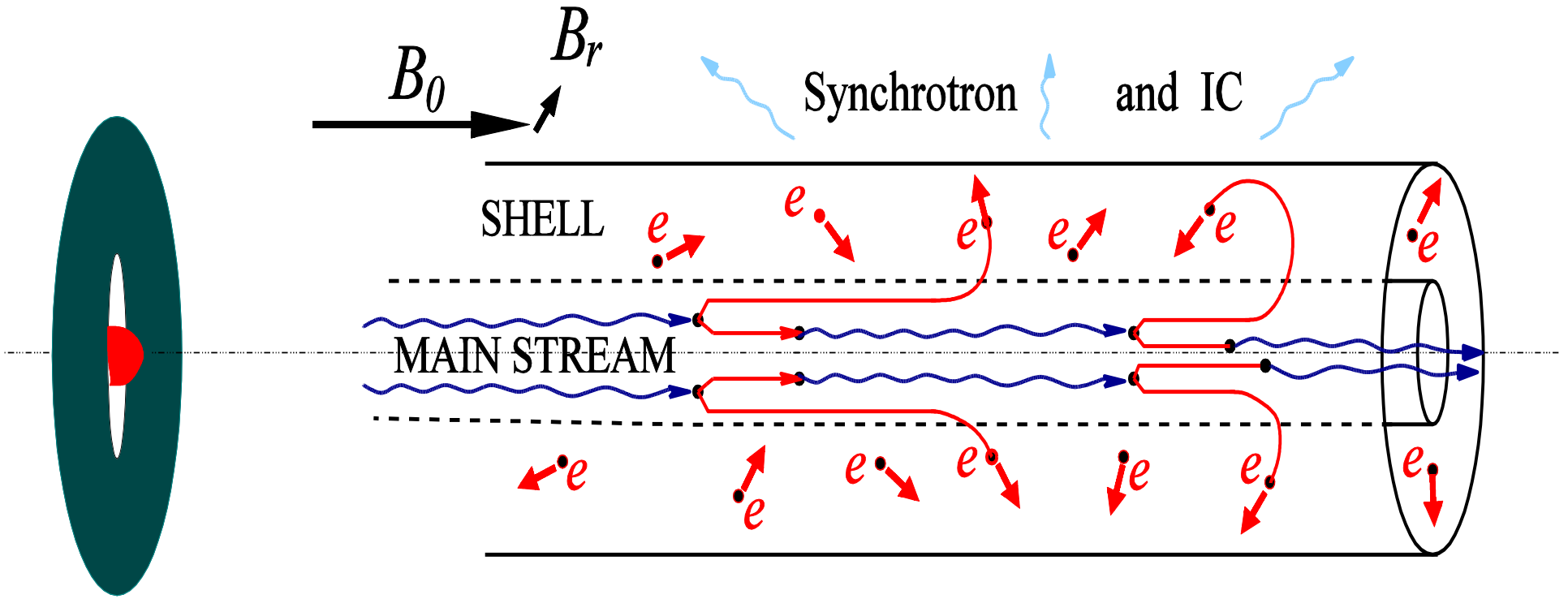
Model: jet with small openning angle for neutrinos

3C 273 in X-ray, optics and radio



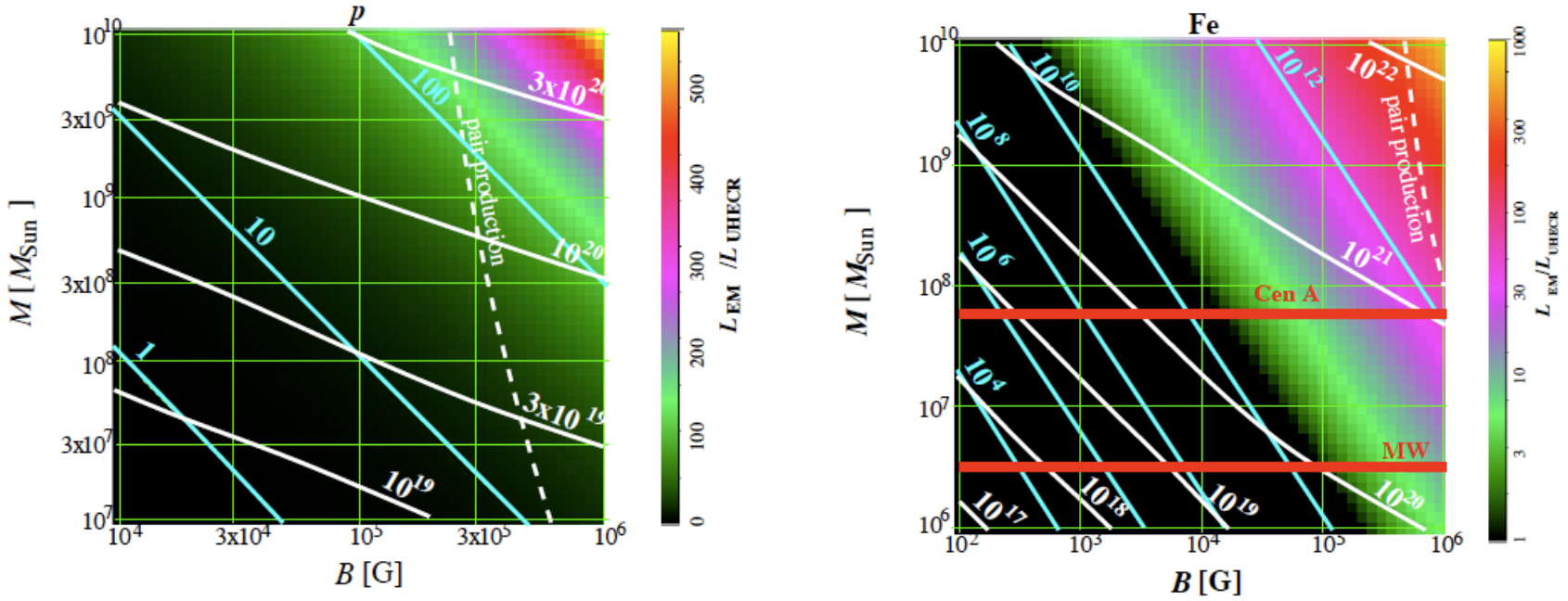


Model of the jet.



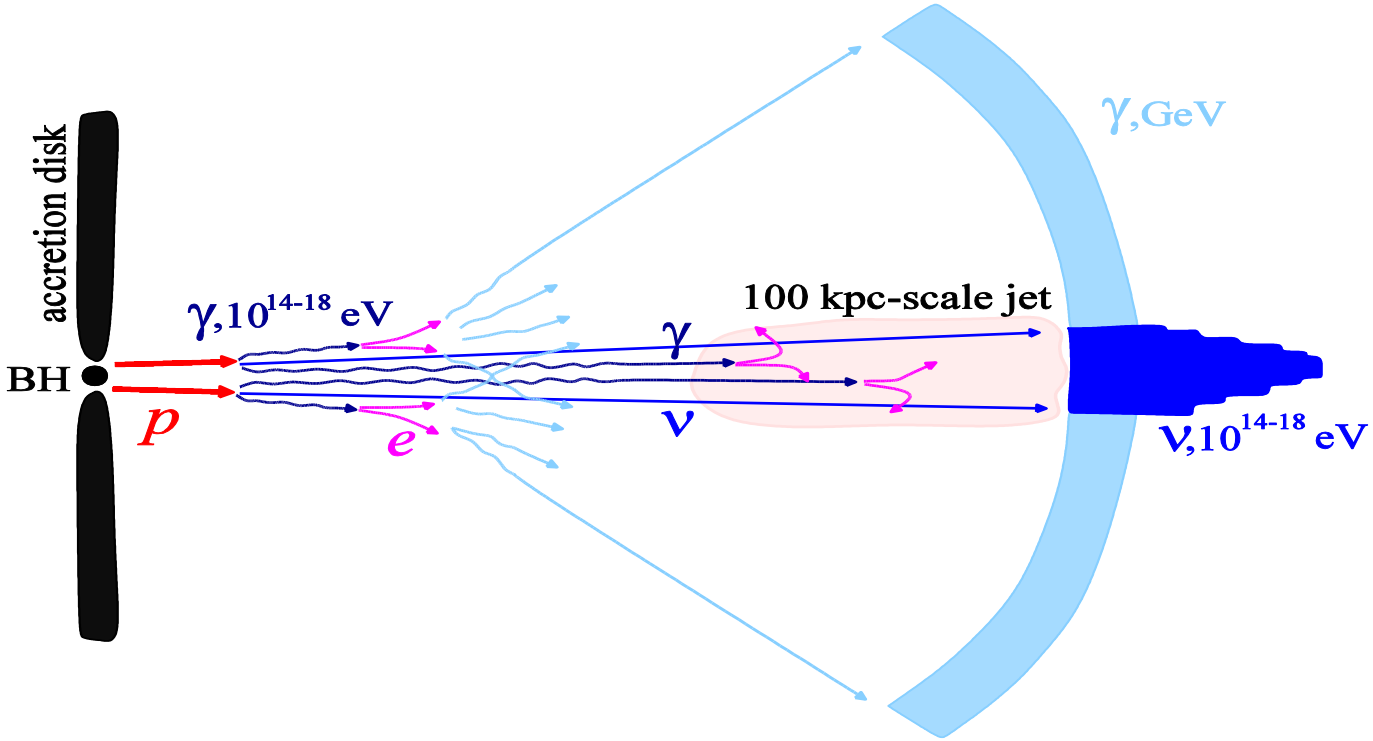
A.Neronov, D.S, F.Aharonian and O.Kalashev hep-ph/0201410
PRL 89 051101 2002

Acceleration near Black Hole in the electric field



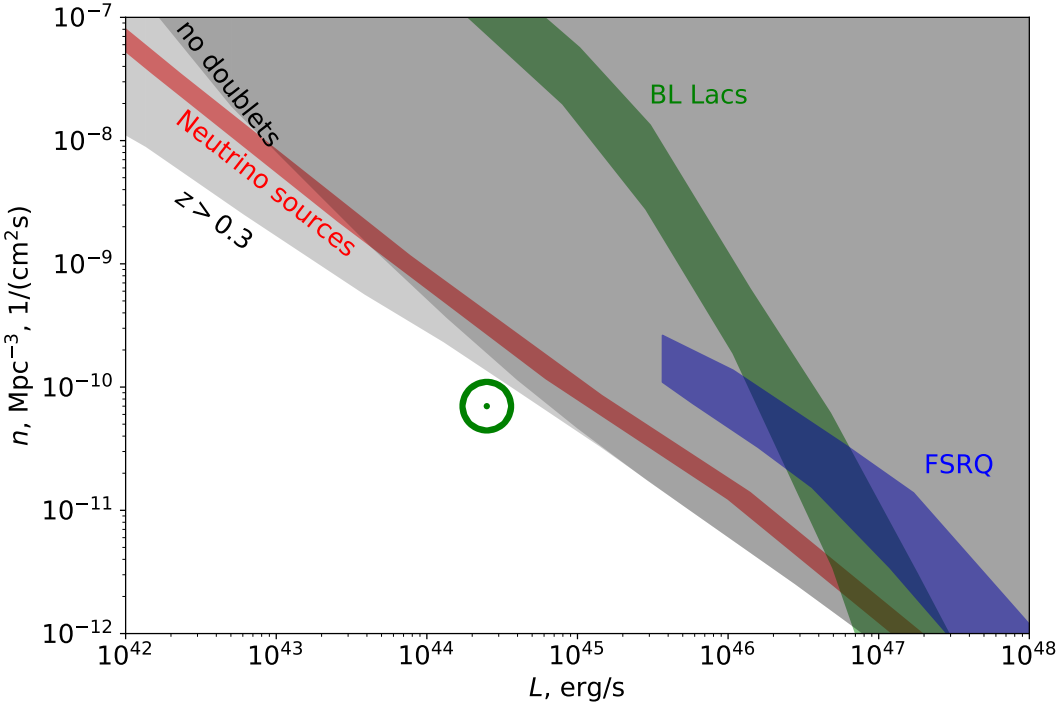
A.Neronov, D.Semikoz and I.Tkachev astro-ph/0712.1737

Neutrino production in AGN



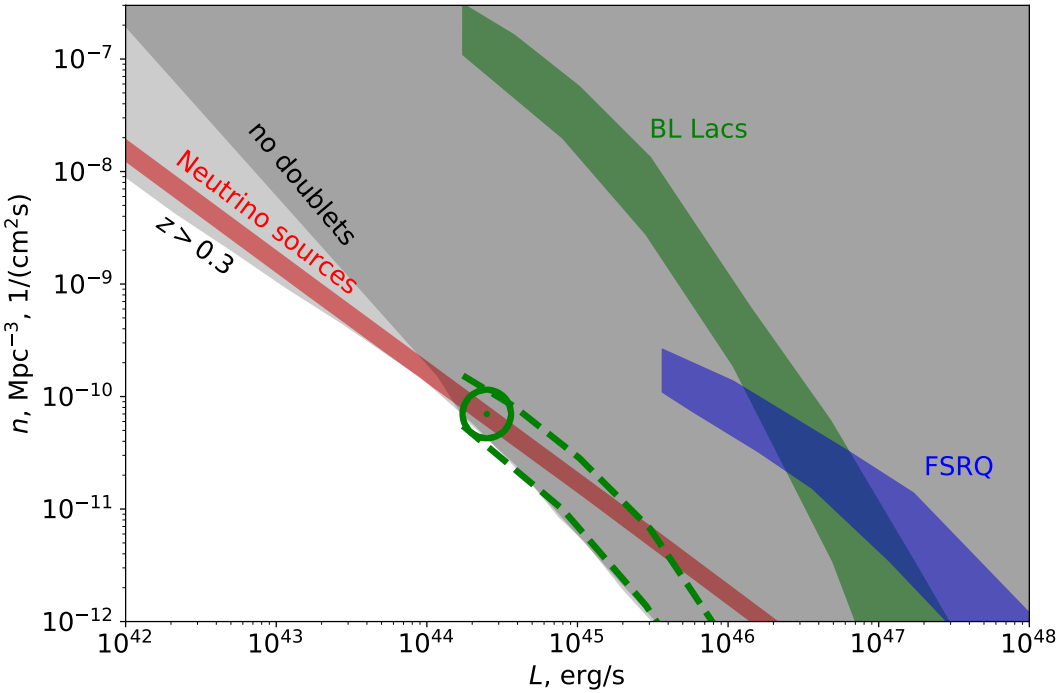
A.Neronov, D.S PRD 66 123003 2002
hep-ph/0208248

Standdard L0 neutrino sources



A.Neronov, D.S. arXiv:1810xxxx, in preparation

Strongly evolving sources



A.Neronov, D.S. arXiv:1810xxxx, in preparation

Summary

- *Minimal model explains extragalactic part of IceCube signal with hard $1/E^{2-2.2}$ spectrum as secondary from UHE proton-proton interaction in sources. One can combine it with proton production from nuclei in sources to explain UHECR composition data*
- *Negative result for blazar correlation search and absence of doublets constrain contribution of blazars to neutrino flux*
- *First neutrino source is blazar? One can overcome constraints with small jet opening angle of neutrinos, but one should see doublets SOON!*