Multi-messenger signal in neutrinos and gamma-rays

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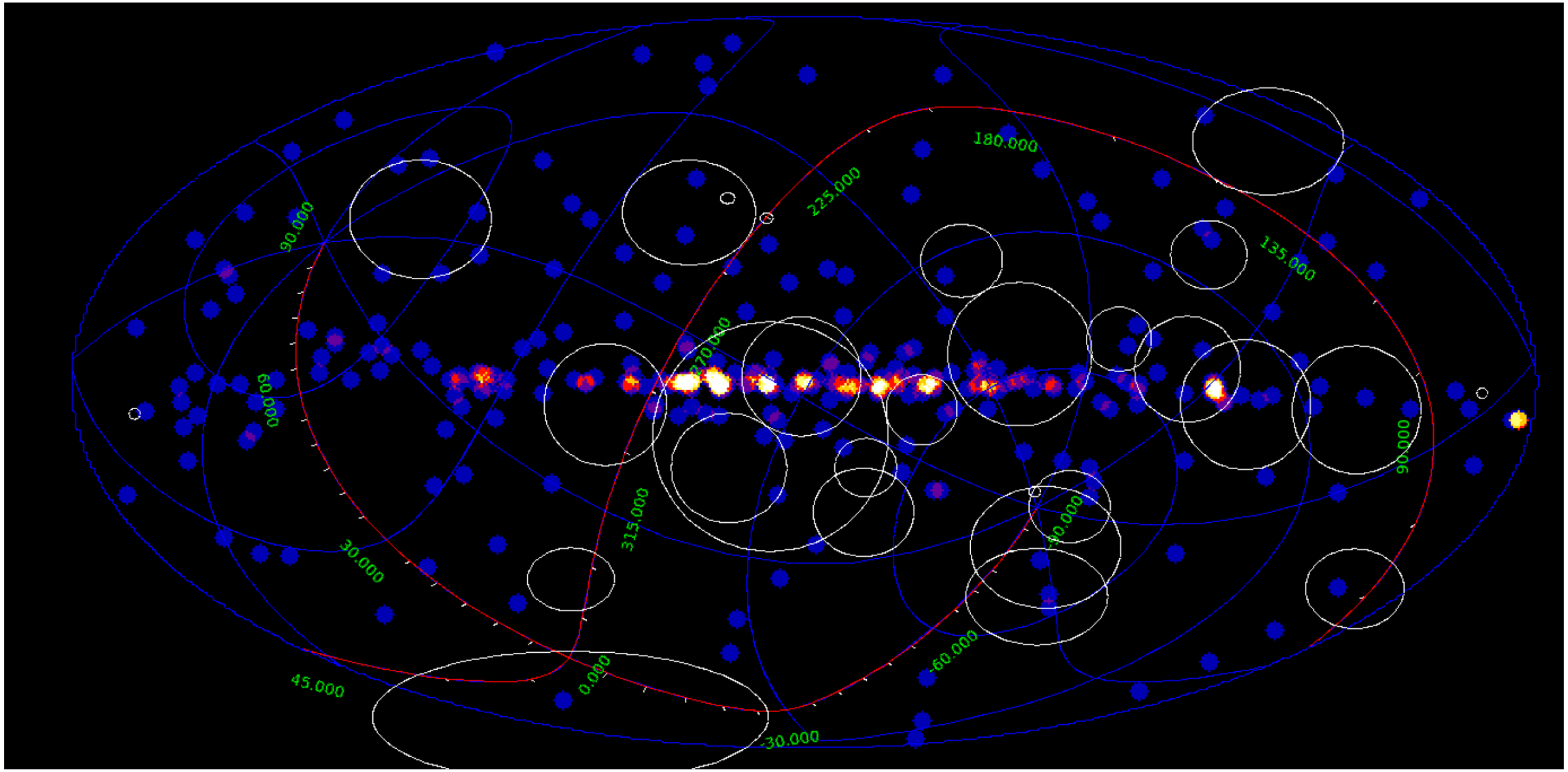
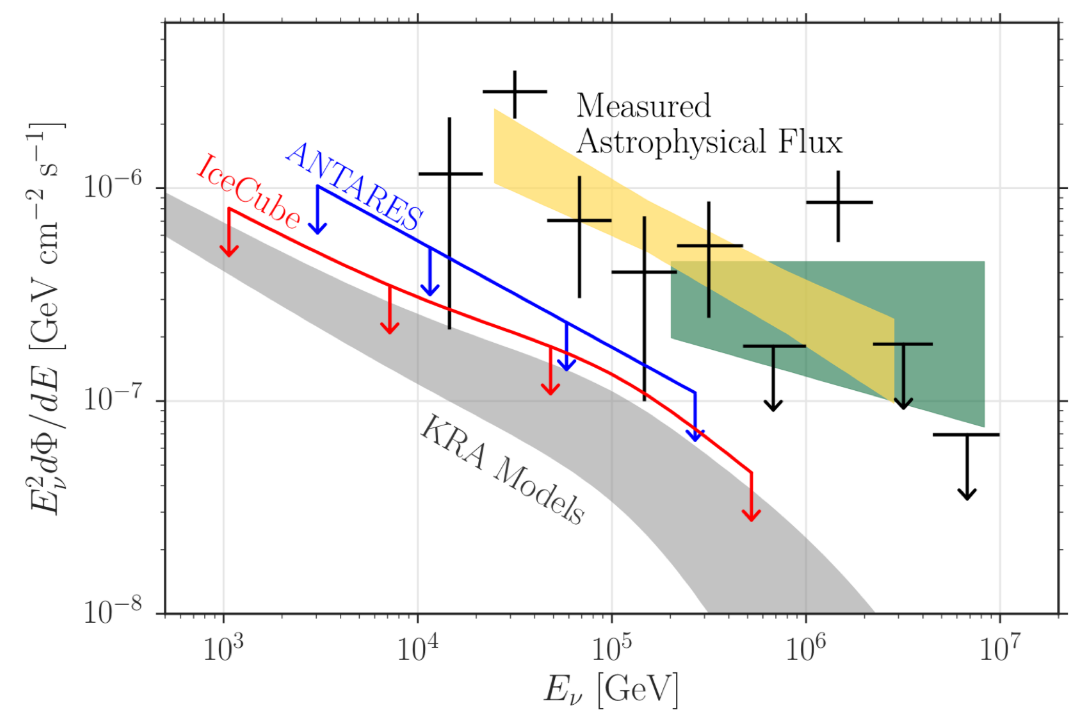
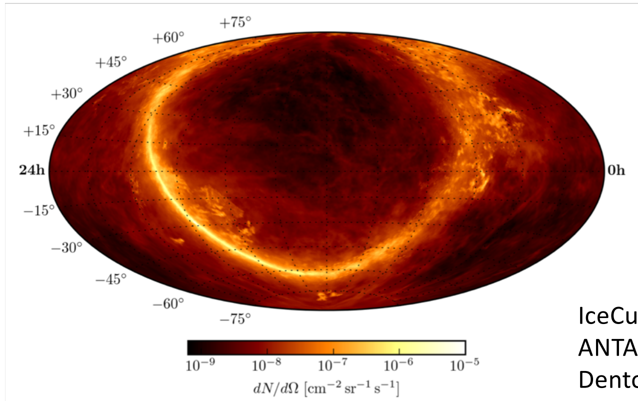


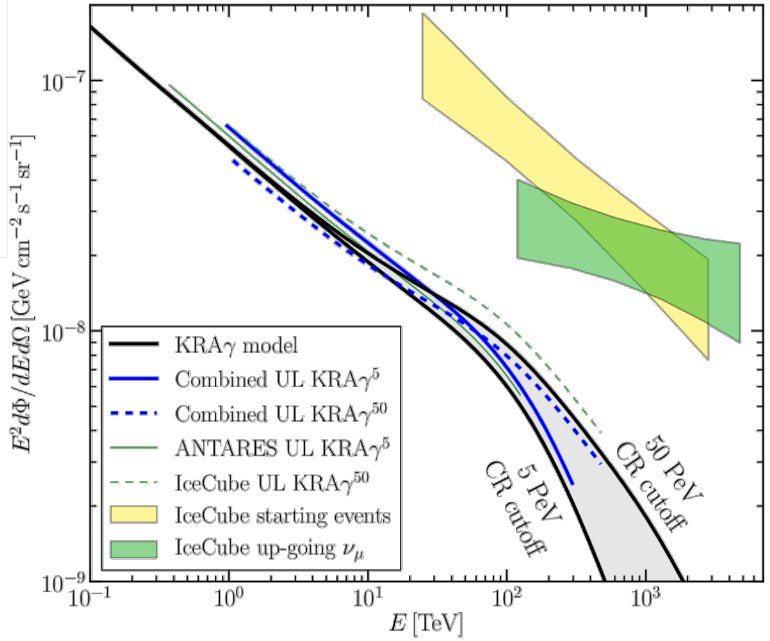
with D.Semikoz, M.Kachelriess

Bulk neutrino flux does not seem to come from the Galaxy……





IceCube Collab. ’17, ‘18
ANTARES Collab. 17, ’18
Denton, Marfatia, Weiler ’17
…………

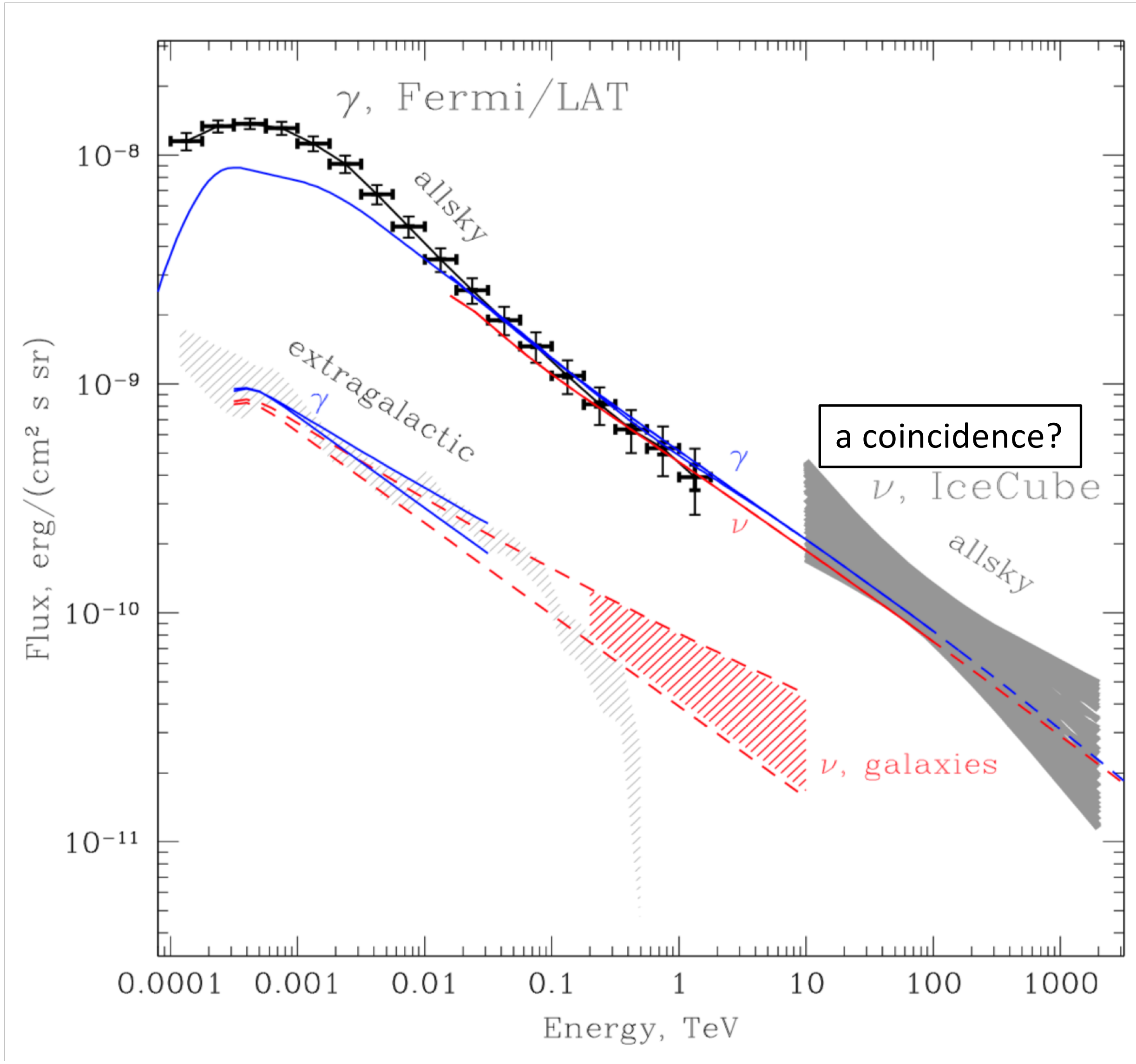


IceCube and ANTARES telescopes have reported tight limits on Galactic contribution to the astrophysical neutrino flux.

The analysis is based on “non-observation of the excess” along the Galactic Plane.

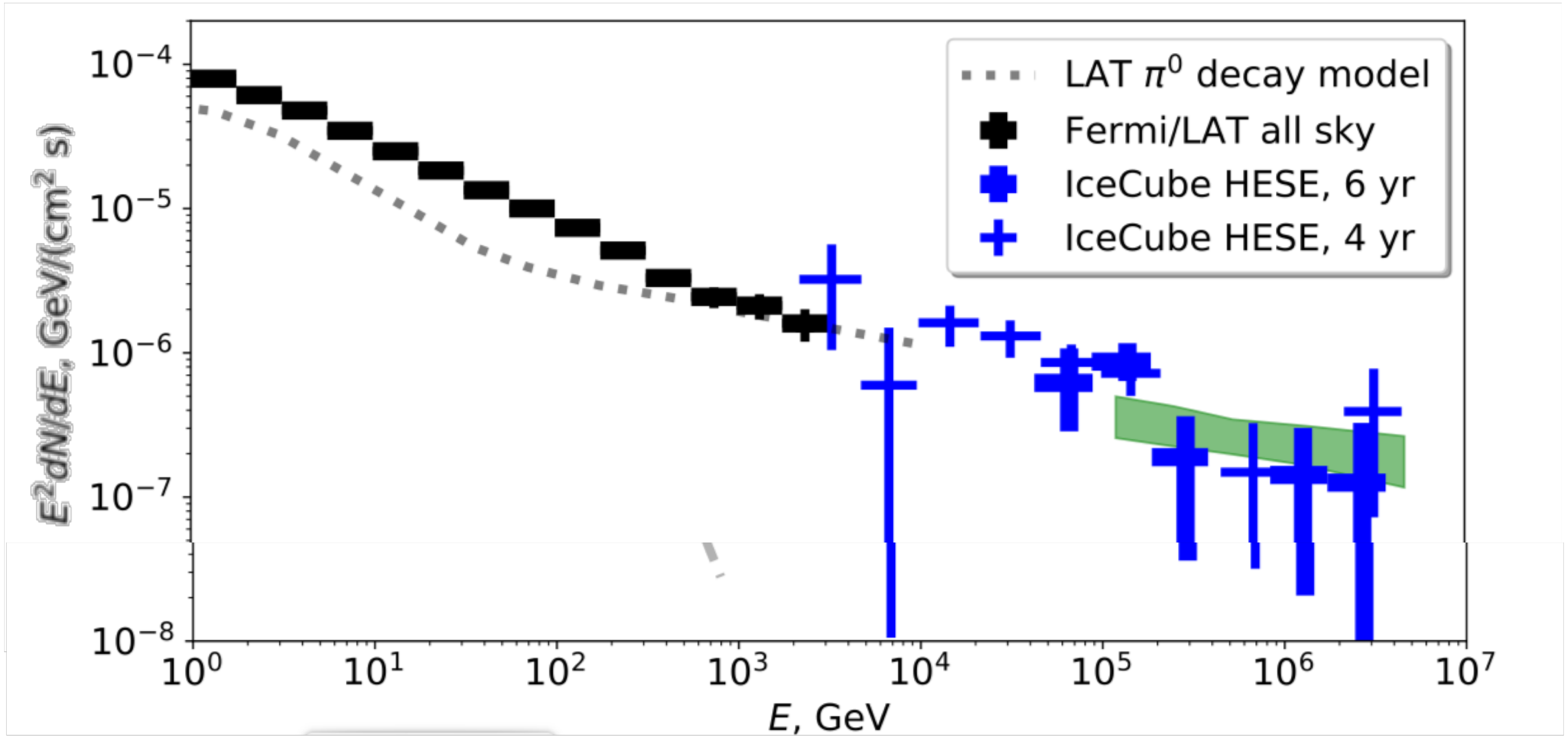
The analysis method uses a template of Galactic neutrino flux derived from modelling of cosmic ray propagation in the Galaxy.

… but the bulk of gamma-ray flux does come from the Galaxy



AN, Semikoz, 1412.1690

Neutrino flux and gamma-ray sky fluxes are compatible in TeV band

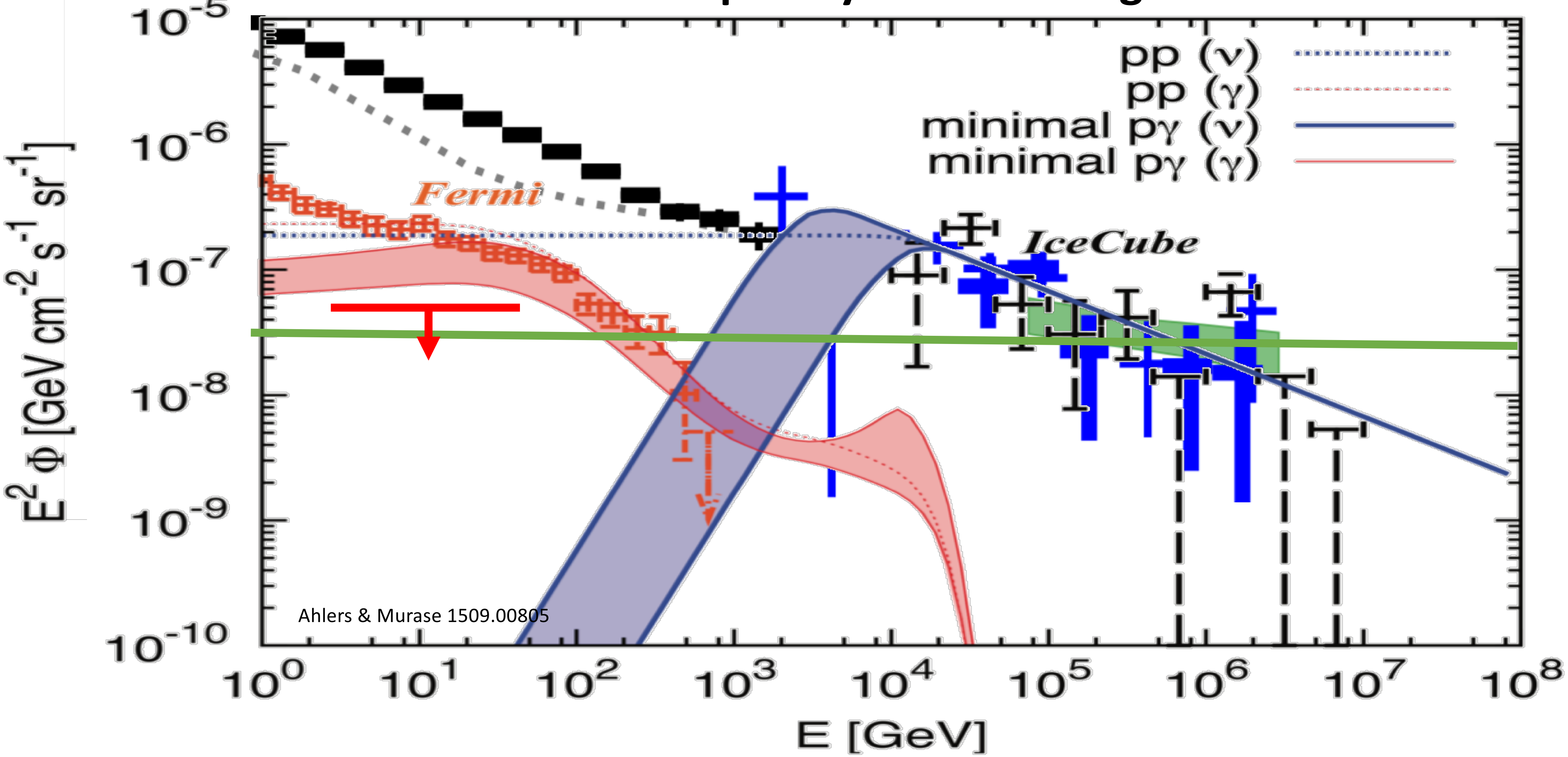


Fermi / LAT and IceCube start to see sky in overlapping energy range (multi-TeV).

Multi-TeV emission in gamma-ray band is of Galactic origin.

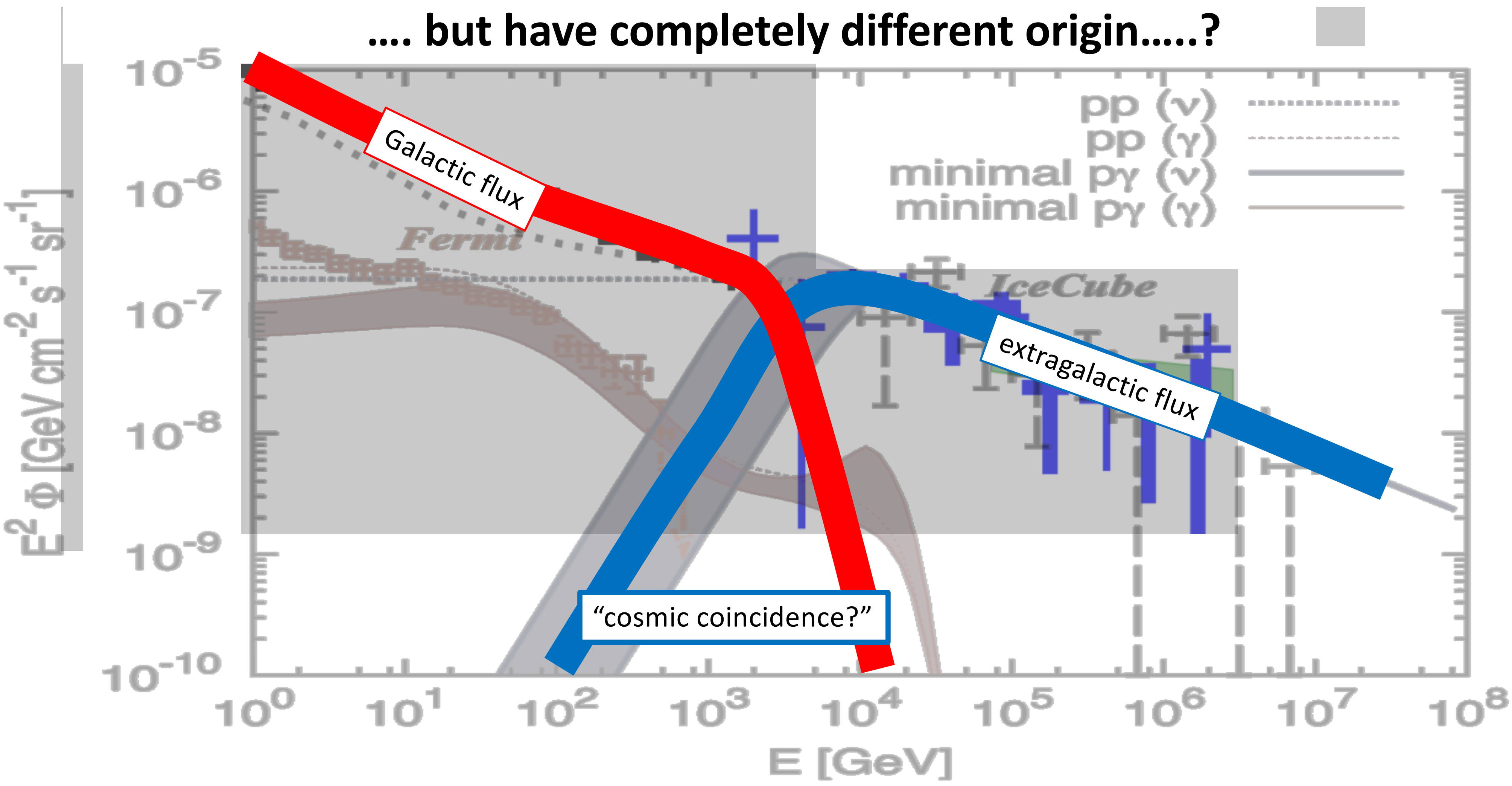
AN, Kachelriess, Semikoz, PRD98, 023004 (2018)
Acero et al. (Fermi/LAT collab.) 1602.07246

Neutrino flux and gamma-ray sky fluxes are compatible in TeV band
…. but have completely different origin…..?

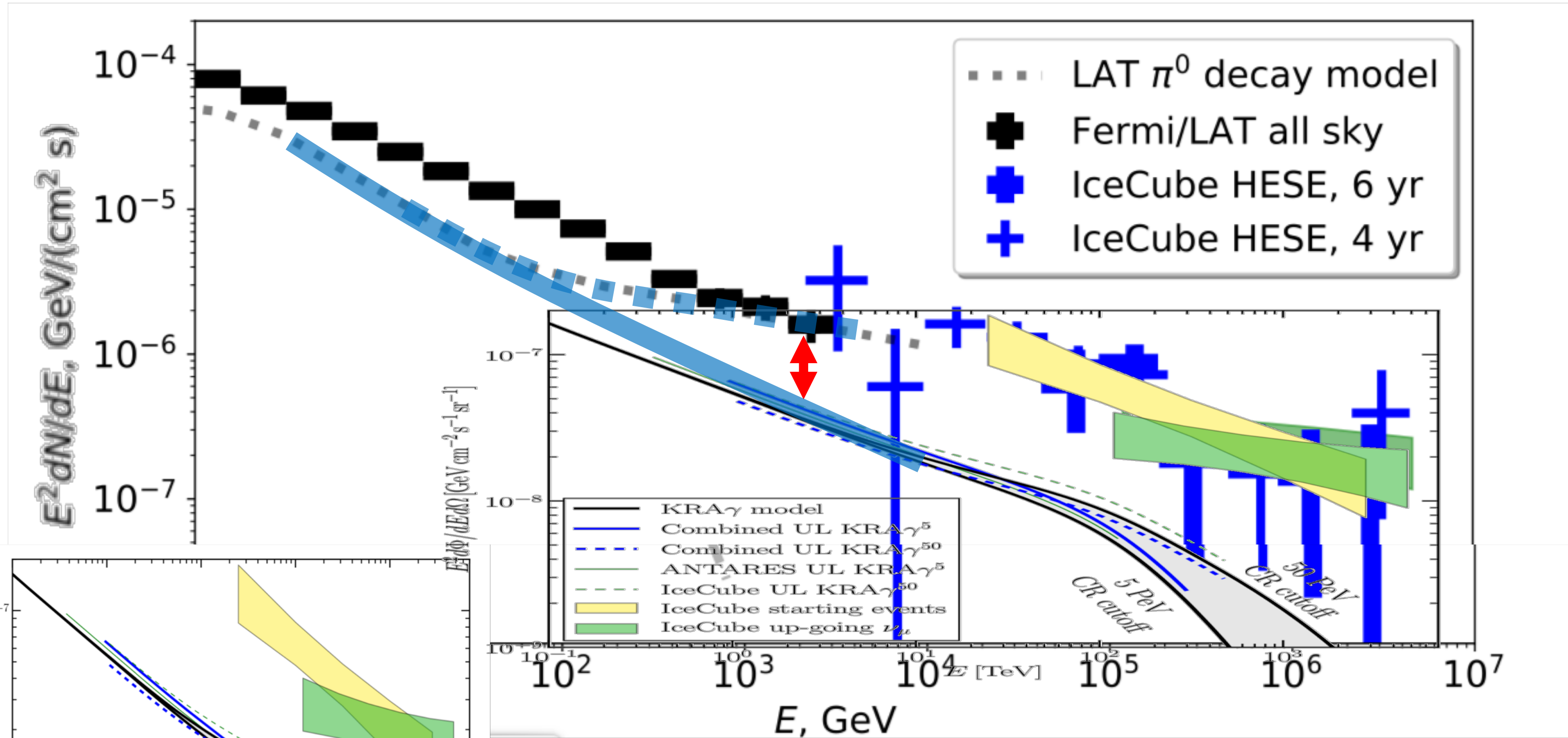


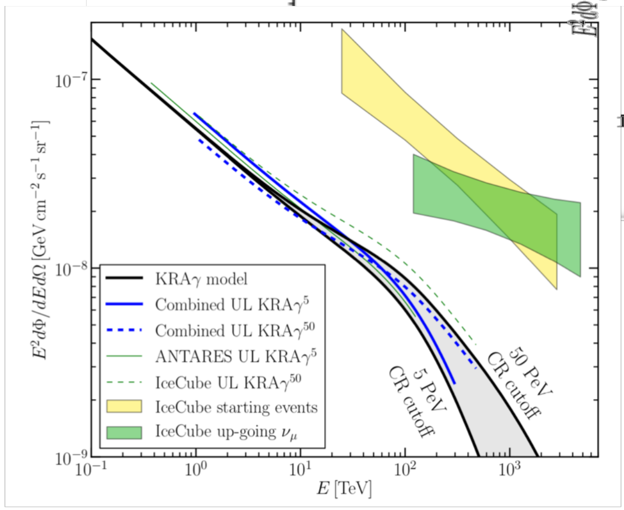
Neutrino spectrum measured in through going muon channel is consistent with extragalactic origin hypothesis.

Neutrino flux and gamma-ray sky fluxes are compatible in TeV band
…. but have completely different origin…..?



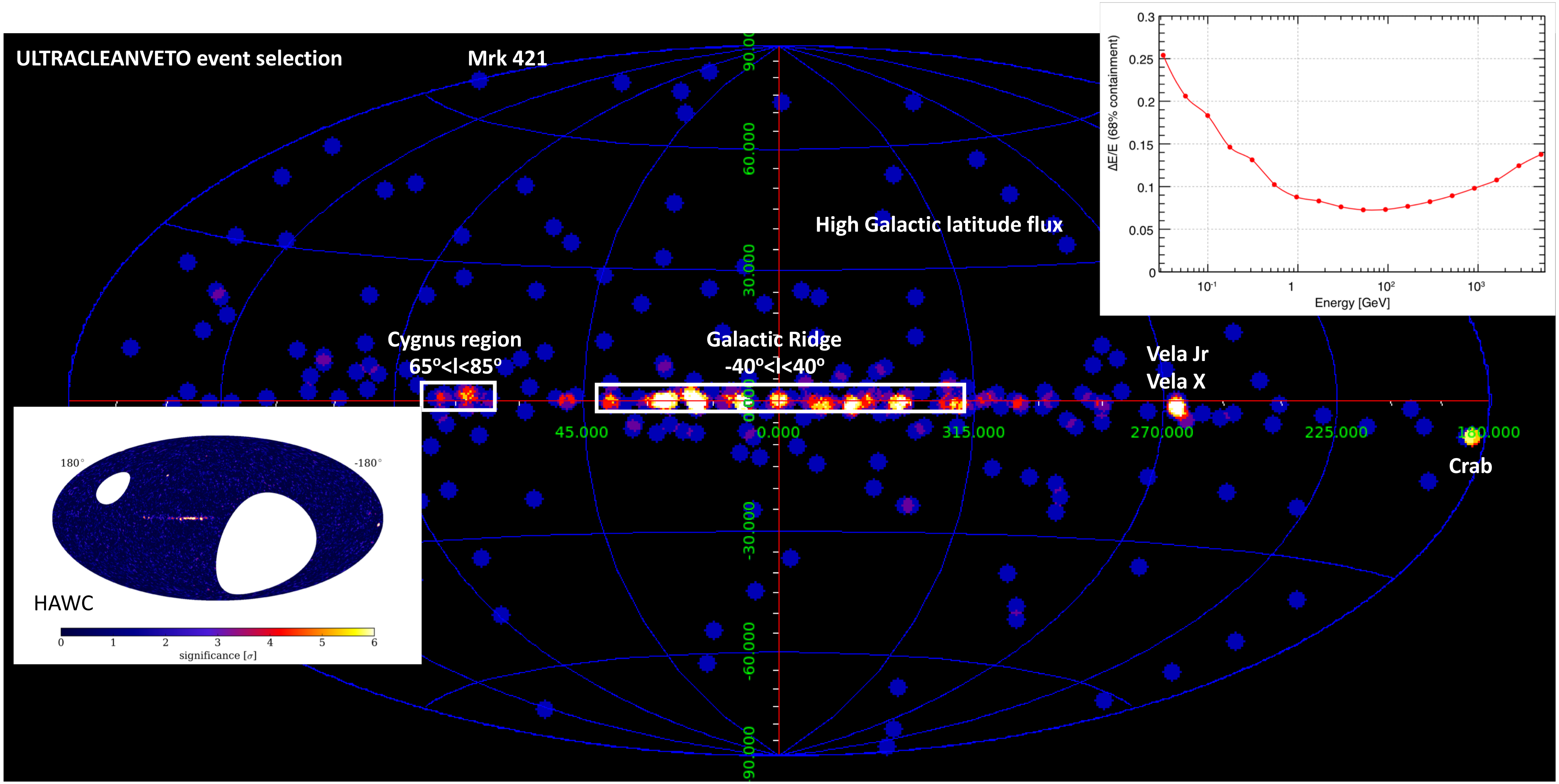
Astrophysical neutrino flux does not come from the Galaxy…….



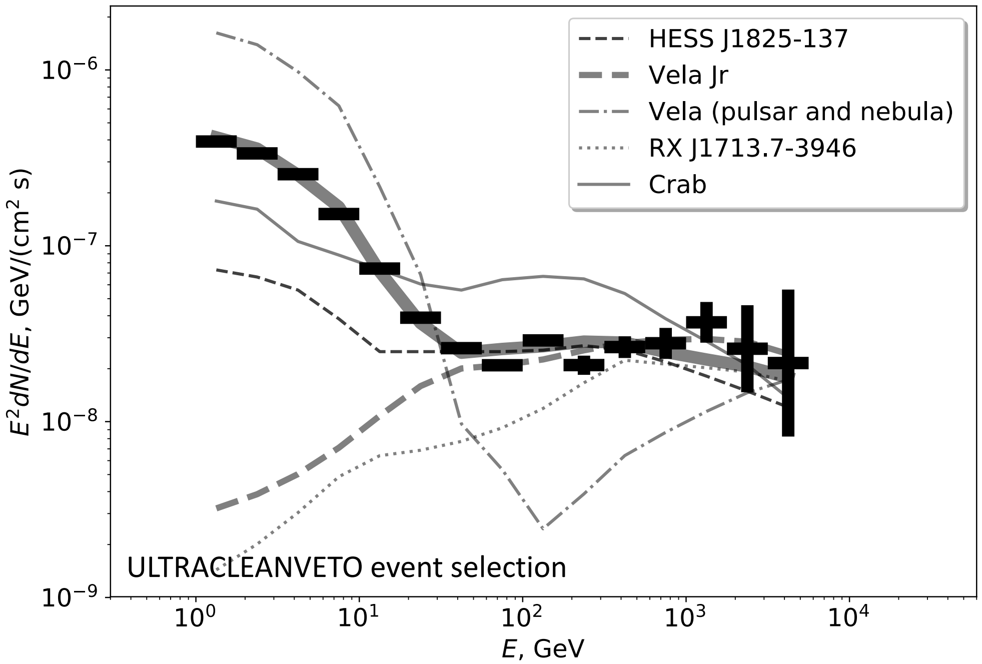


Model prediction relies on assumption that source distribution and mechanism of cosmic ray diffusion is well controlled and remains the same in GeV-10 PeV energy range. However, mechanism of injection and propagation of multi-PeV cosmic rays is not well known.

Fermi/LAT multi-TeV sky



Fermi/LAT multi-TeV sky

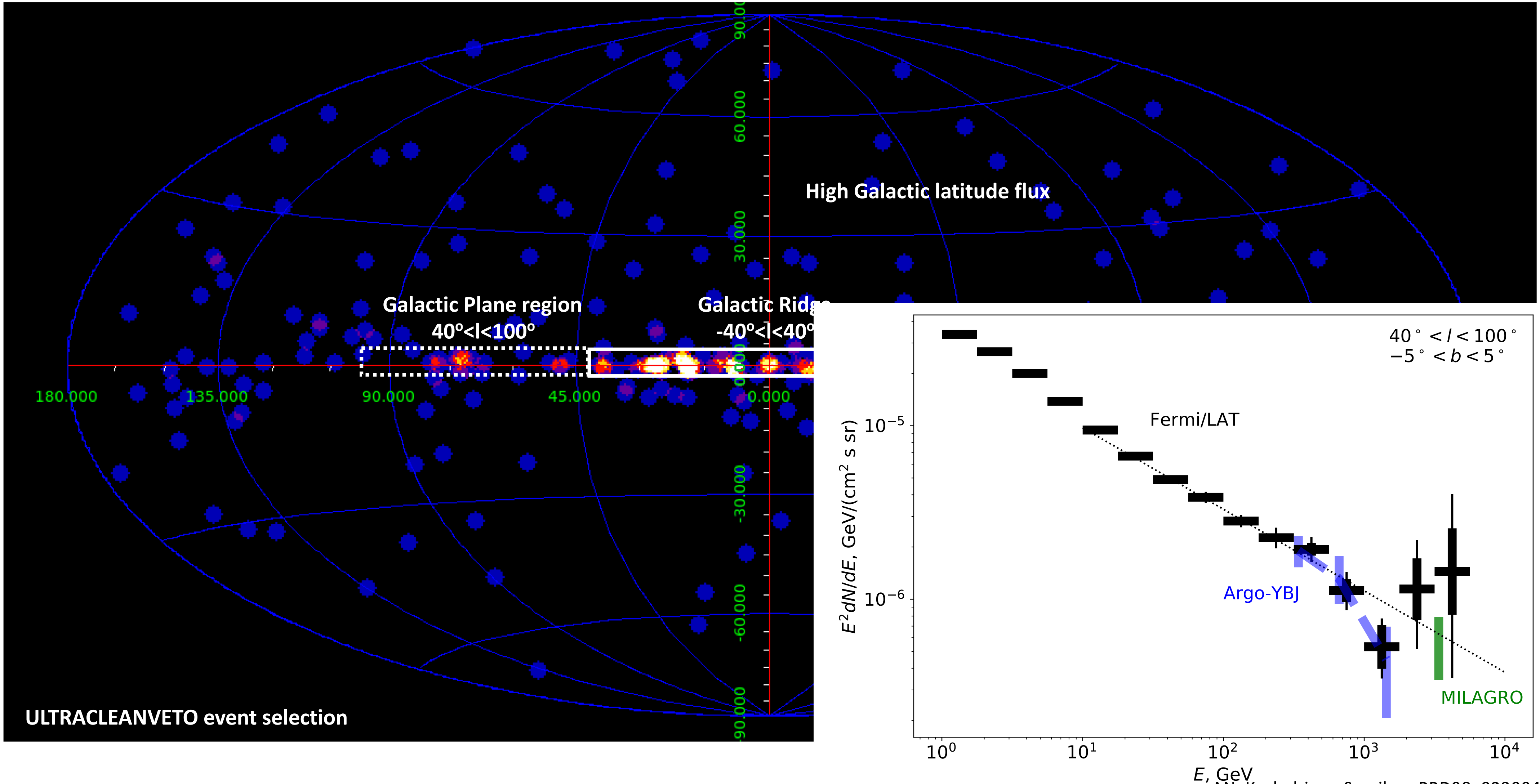


Fermi /LAT calibration is not assured above 1 TeV (https://fermi.gsfc.nasa.gov/ssc/data/analysis/LAT_caveats.html). Those need to be derived / verified.

This could be done via cross-calibration with the ground-based gamma-ray telescopes (HESS, MAGIC, VERITAS) and air shower arrays (MILAGRO, HAWC, ARGO-YBJ)

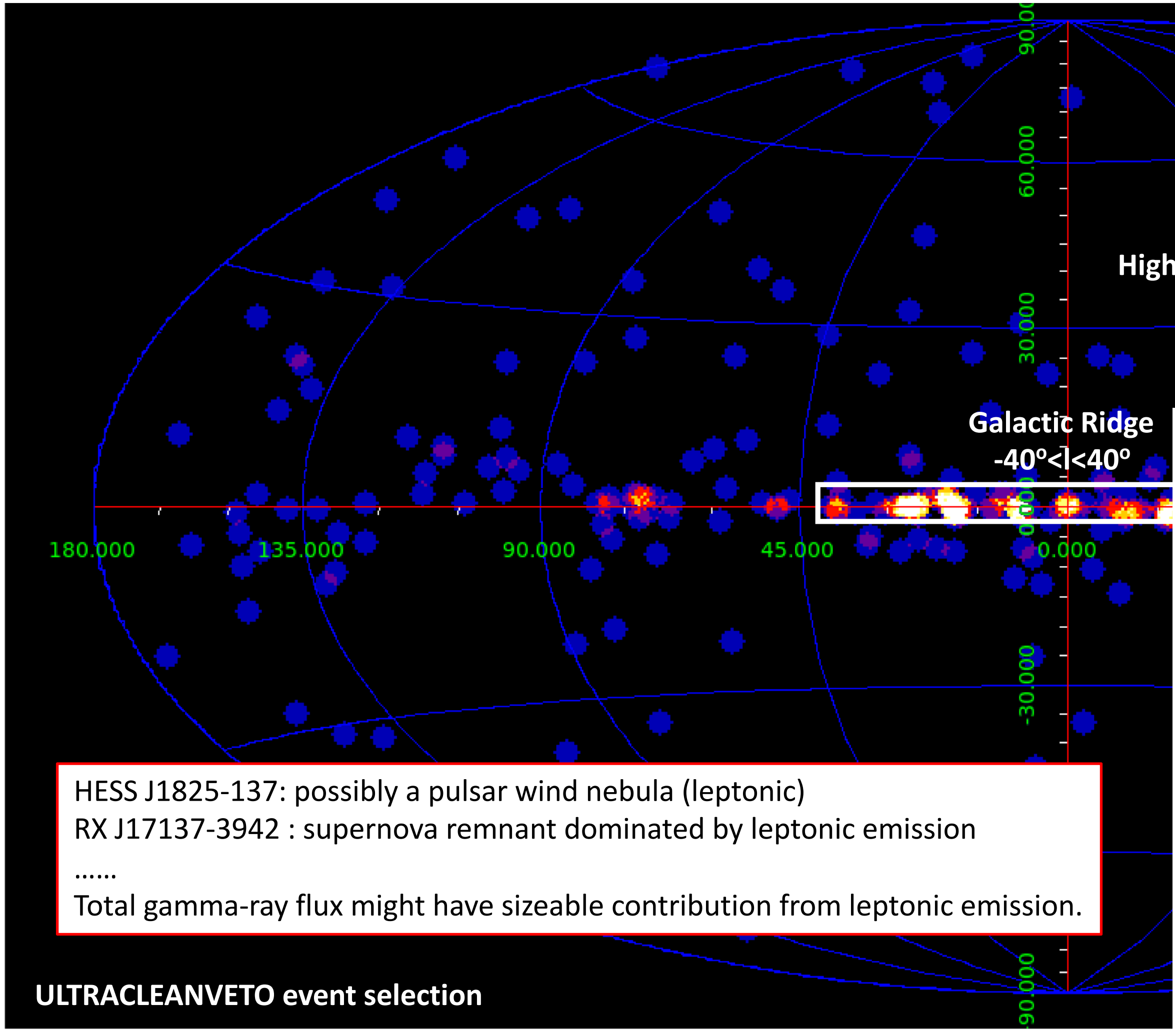
AN, Kachelriess, Semikoz, PRD98, 023004

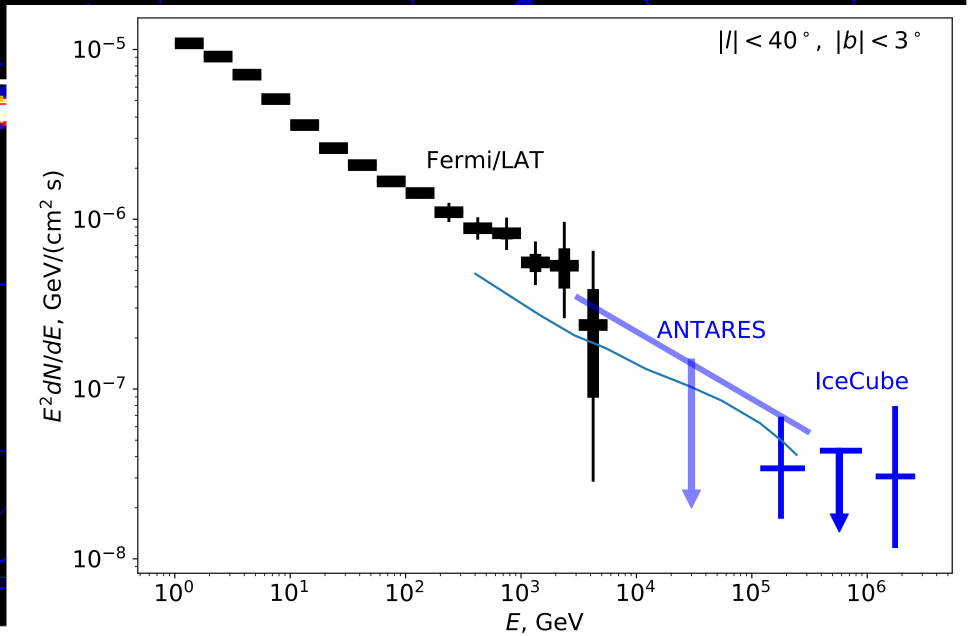
Fermi/LAT multi-TeV sky



AN, Kachelriess, Semikoz, PRD98, 023004

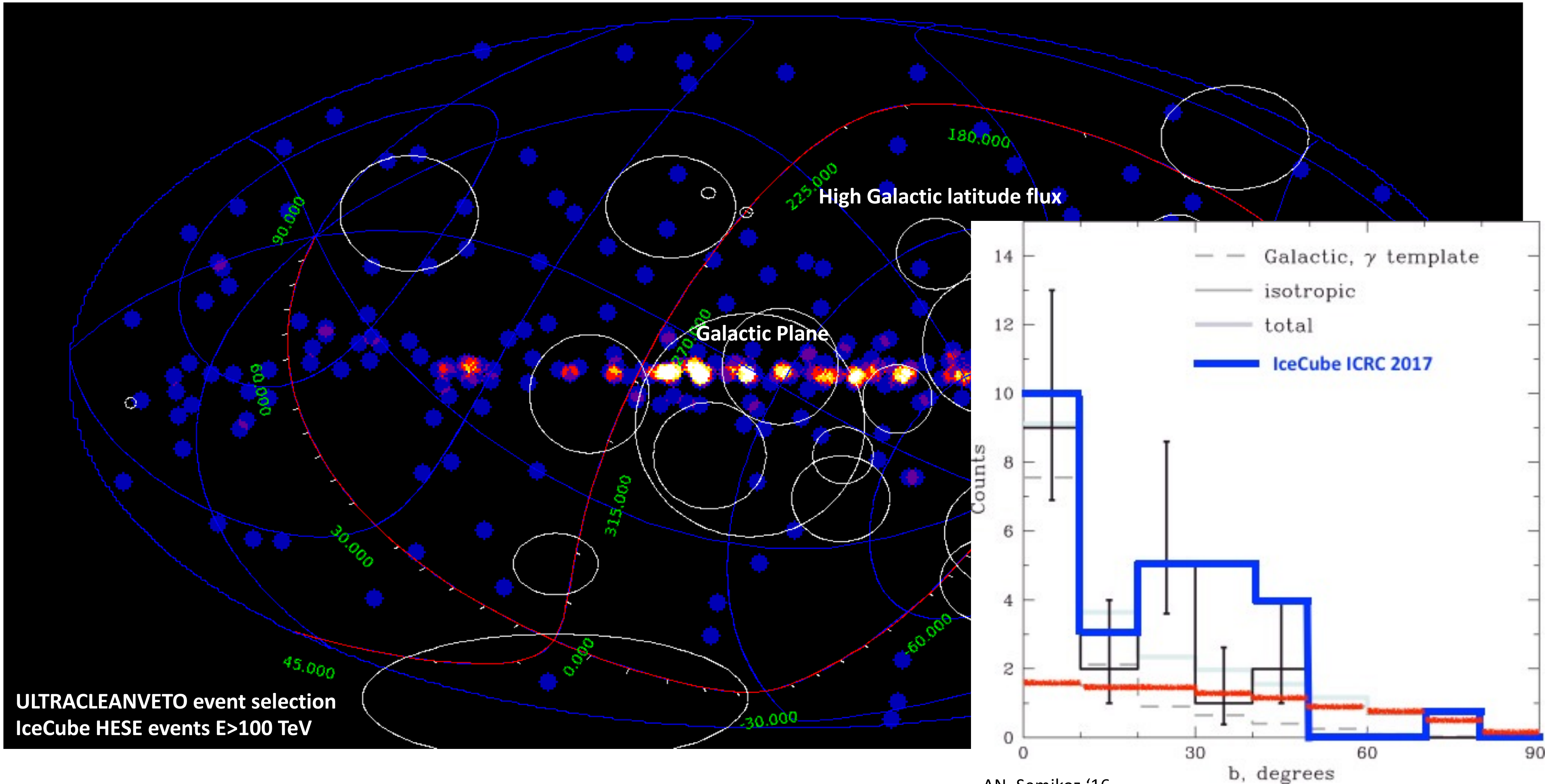
Fermi/LAT multi-TeV sky





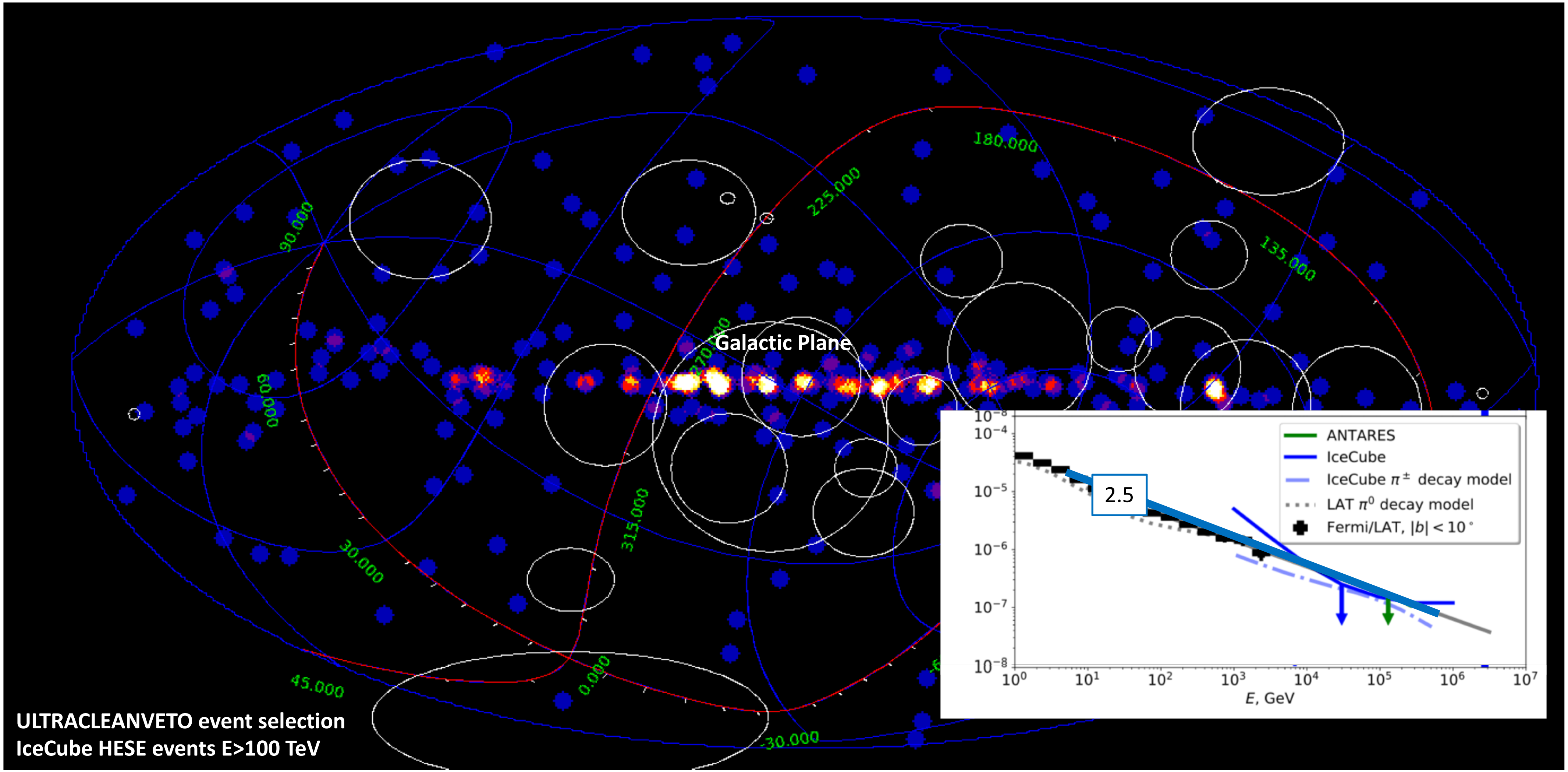
AN, Semikoz, Tchernin ‘14, Adrian-Martinez et al. ’16

Fermi/LAT and IceCube multi-TeV sky



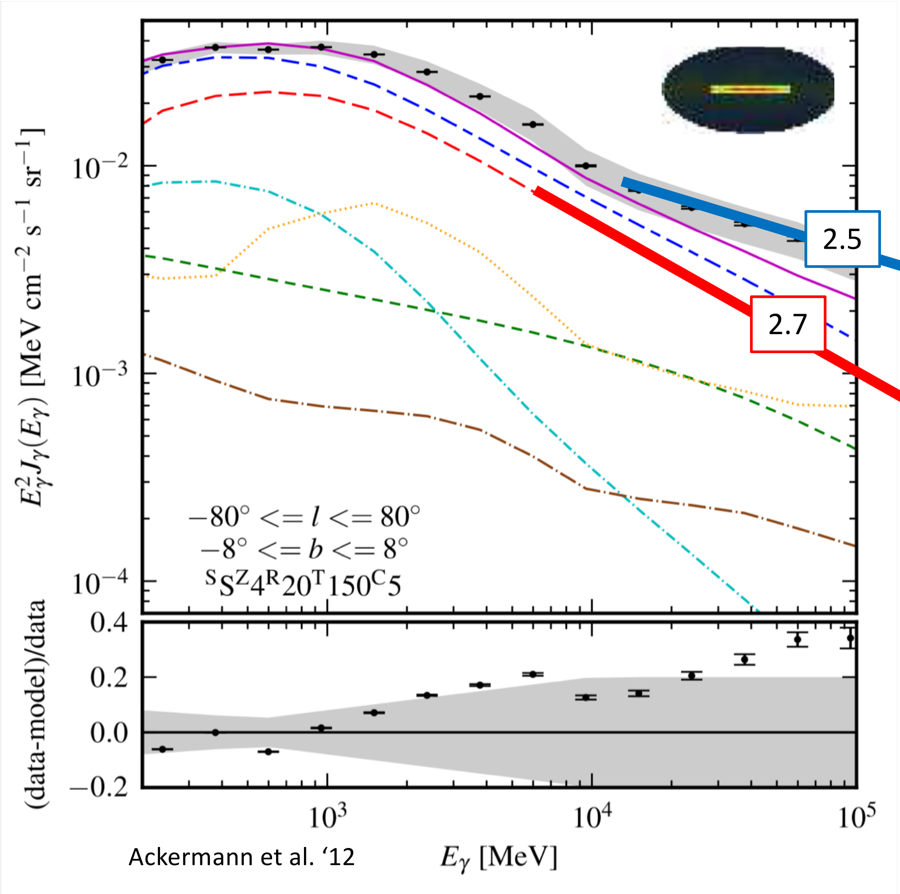
AN, Semikoz '16

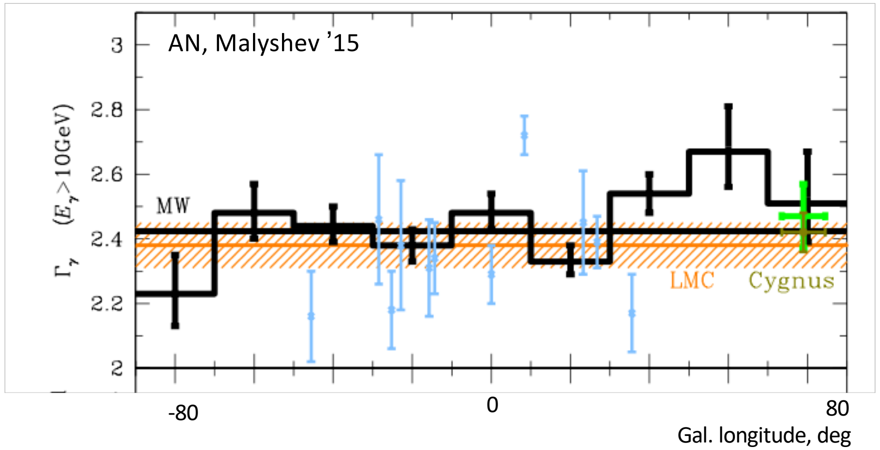
Fermi/LAT and IceCube multi-TeV sky



AN, Kachelriess, Semikoz, PRD98, 023004

Fermi/LAT and IceCube Galactic Plane

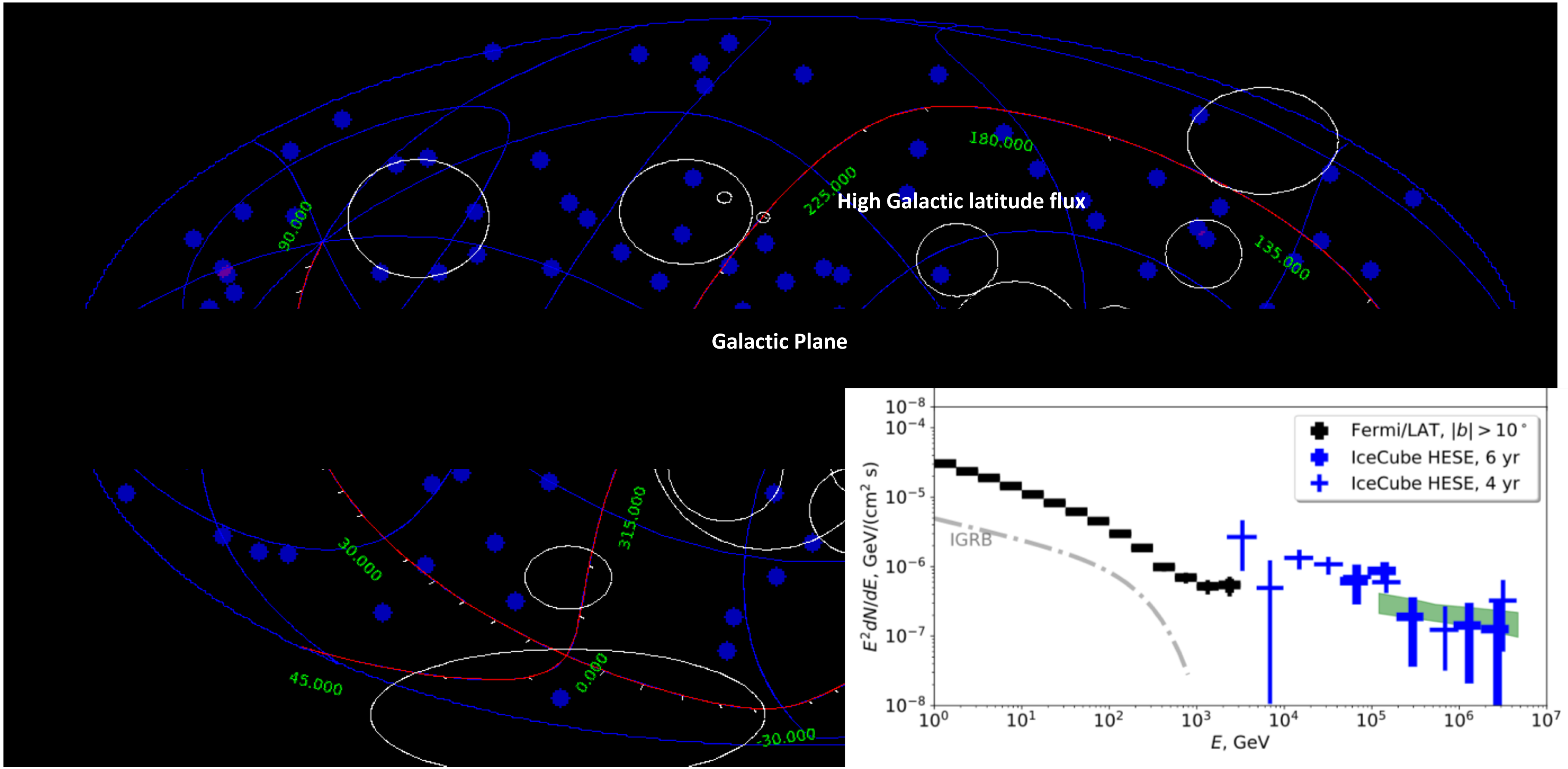




AN, Malyshev '15
Gaggero et al. '15
Fermi LAT Collab. '16
Yang, Aharonian '16

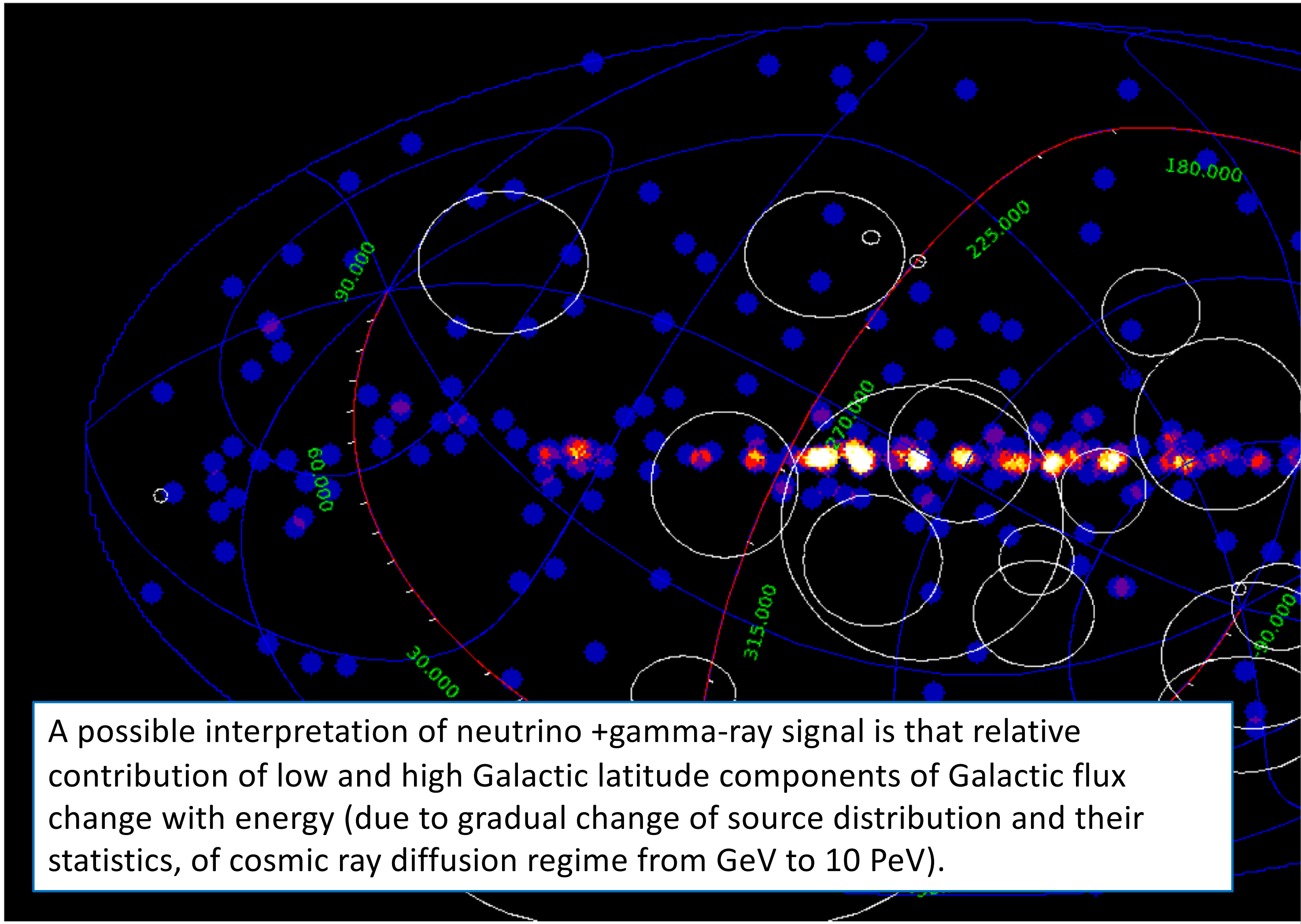
Slope of the gamma-ray spectrum of Galactic Ridge / inner Galactic Plane is harder than the slope of the local cosmic ray spectrum.

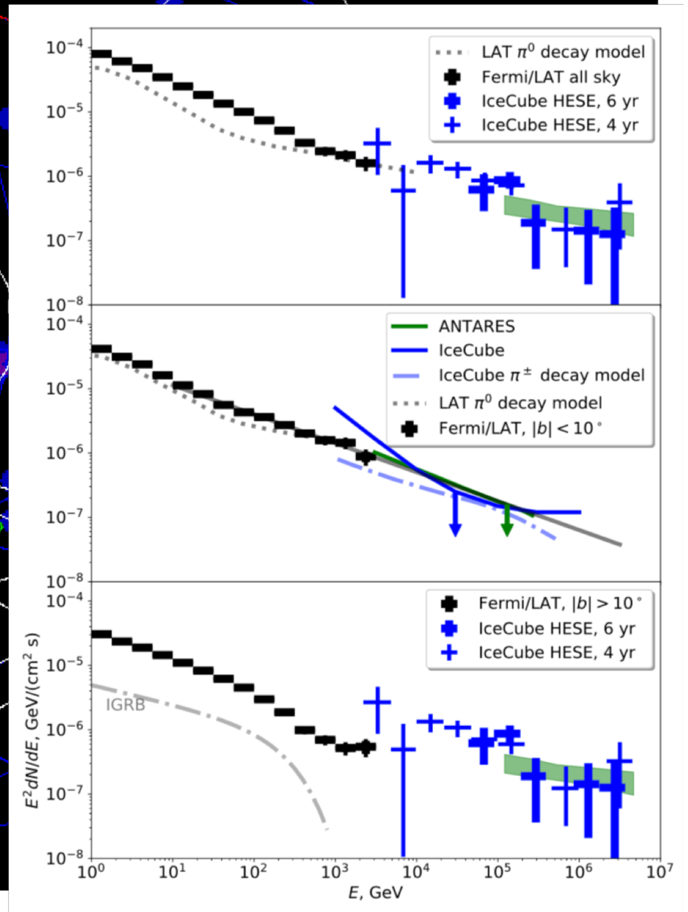
Fermi/LAT and IceCube high Galactic latitude regions



AN, Kachelriess, Semikoz, PRD98, 023004

Fermi/LAT and IceCube high Galactic latitude regions

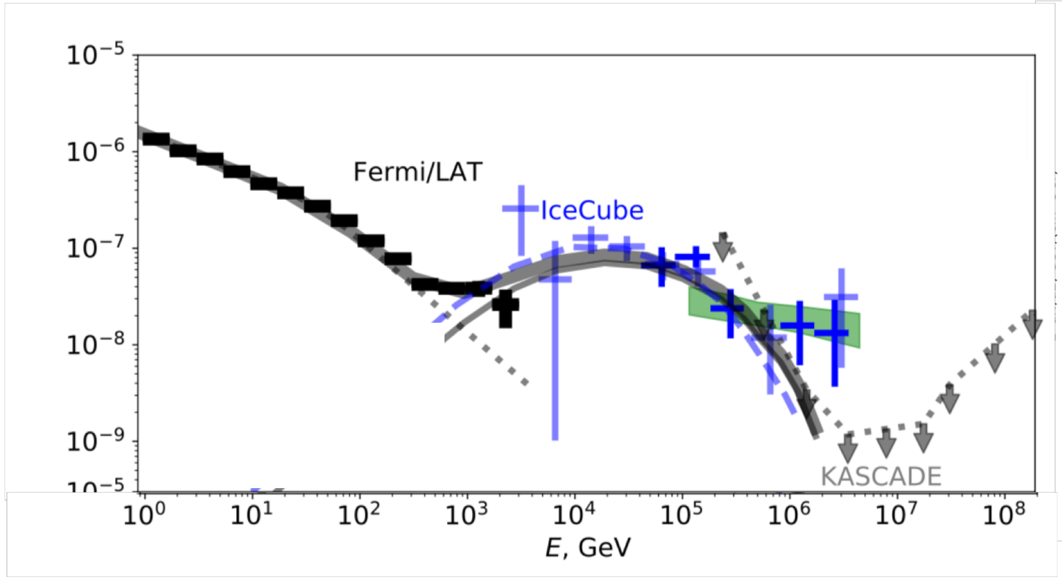


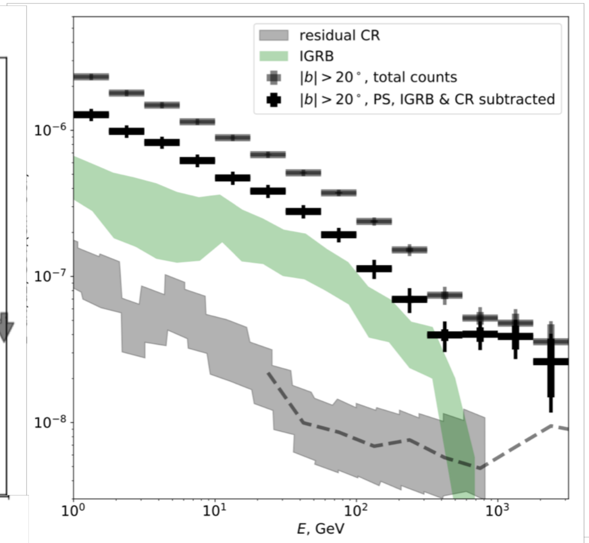


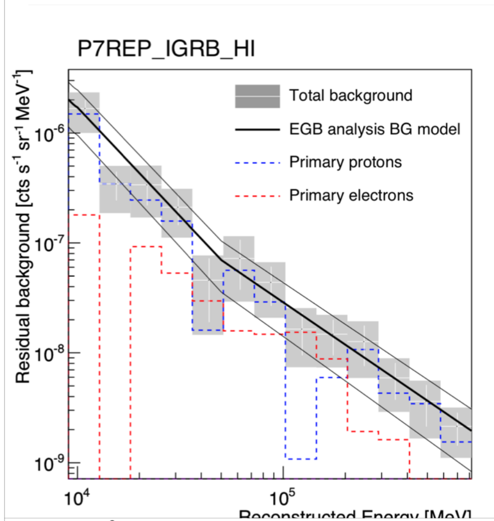
A possible interpretation of neutrino +gamma-ray signal is that relative contribution of low and high Galactic latitude components of Galactic flux change with energy (due to gradual change of source distribution and their statistics, of cosmic ray diffusion regime from GeV to 10 PeV).

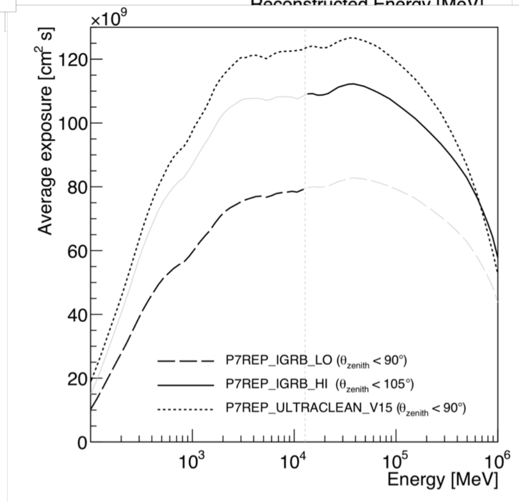
AN, Kachelriess, Semikoz, PRD98, 023004

Fermi/LAT and IceCube high Galactic latitude regions









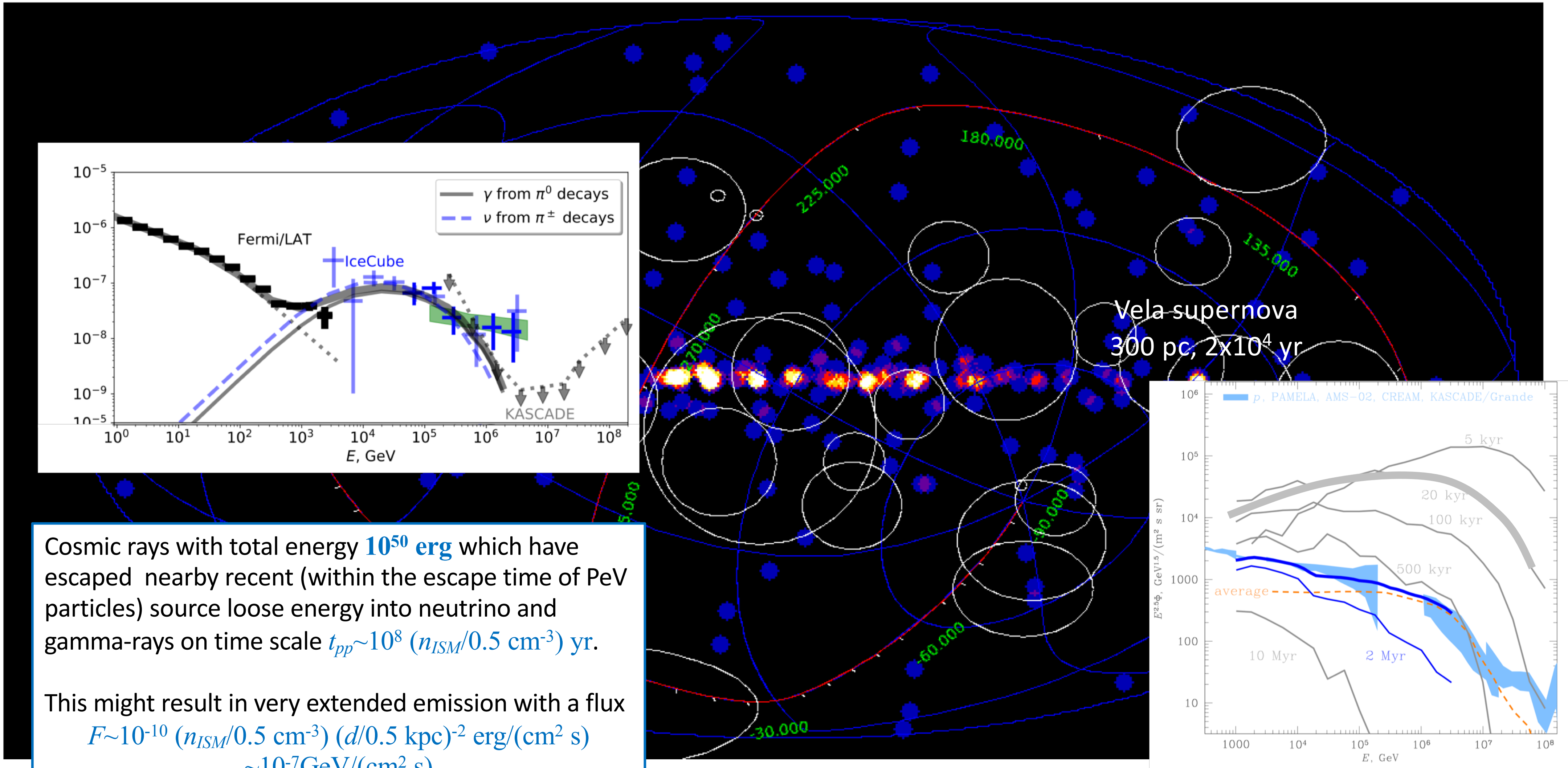
High Galactic latitude gamma-ray flux (|b|>20°) exhibits hardening above 300 GeV, which is pronounced if isotropic (extragalactic) flux component is subtracted.

Hard component of gamma-ray flux could be consistently interpreted as gamma-ray Multi-messenger counterpart of astrophysical neutrino flux in the overlapping energy range.

* Flux estimate suffers from uncertainty of residual cosmic ray background estimate. It is derived assuming that residual particle background countrate is powerlaw in energy (as in Pass7 IGRB data).

AN, Kachelriess, Semikoz, PRD98, 023004

High Galactic latitude emission from local source



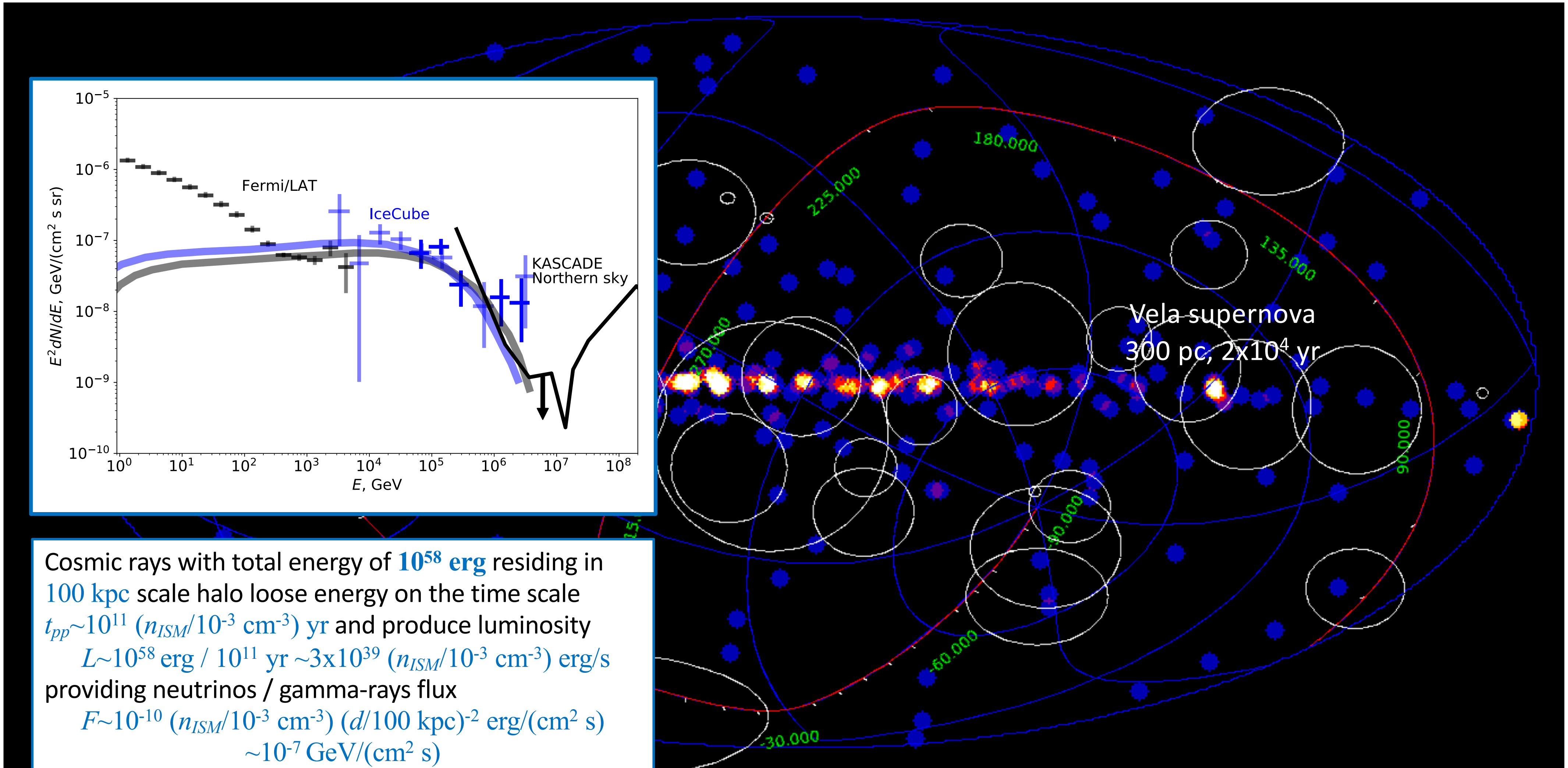
Cosmic rays with total energy **10^{50} erg** which have escaped nearby recent (within the escape time of PeV particles) source loose energy into neutrino and gamma-rays on time scale $t_{pp} \sim 10^8\ (n_{ISM}/0.5\ \mathrm{cm}^{-3})$ yr.

This might result in very extended emission with a flux

$$F \sim 10^{-10}\ (n_{ISM}/0.5\ \mathrm{cm}^{-3})\ (d/0.5\ \mathrm{kpc})^{-2}\ \mathrm{erg/(cm^2\ s)}$$
$$\sim 10^{-7}\ \mathrm{GeV/(cm^2\ s)}$$

AN, Kachelriess, Semikoz, PRD98, 023004
Kachelriess, AN, Semikoz, PRL115, 181103

High Galactic latitude emission from large scale halo



Cosmic rays with total energy of **10^{58} erg** residing in 100 kpc scale halo loose energy on the time scale $t_{pp}\sim 10^{11}$ $(n_{ISM}/10^{-3}\ \mathrm{cm}^{-3})$ yr and produce luminosity

$$L\sim 10^{58}\ \mathrm{erg}\ /\ 10^{11}\ \mathrm{yr} \sim 3\mathrm{x}10^{39}\ (n_{ISM}/10^{-3}\ \mathrm{cm}^{-3})\ \mathrm{erg/s}$$

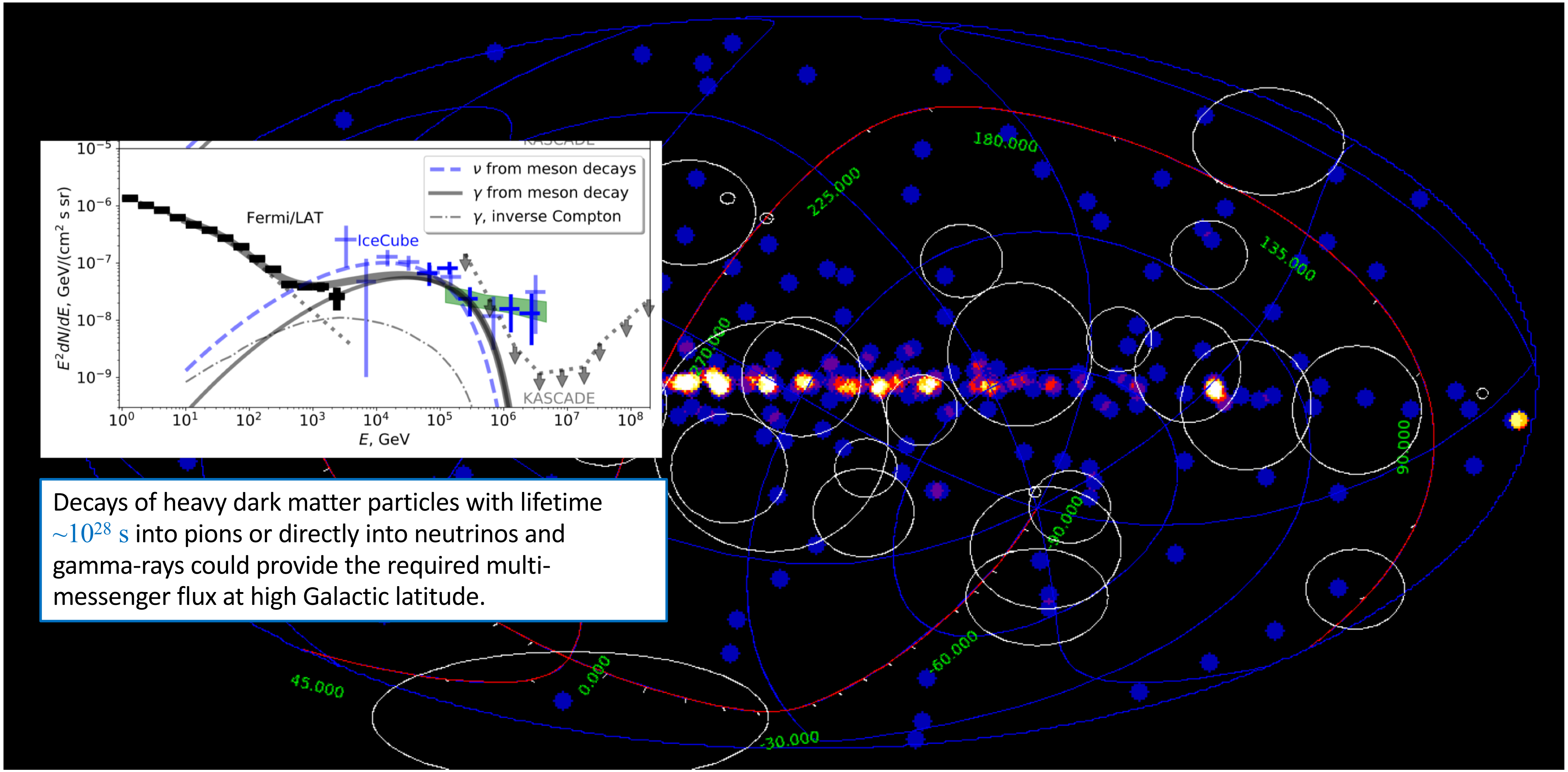
providing neutrinos / gamma-rays flux

$$F\sim 10^{-10}\ (n_{ISM}/10^{-3}\ \mathrm{cm}^{-3})\ (d/100\ \mathrm{kpc})^{-2}\ \mathrm{erg/(cm^2\ s)}$$
$$\sim 10^{-7}\ \mathrm{GeV/(cm^2\ s)}$$

Taylor, Gabici, Aharonian ‘14

AN, Kachelriess, Semikoz, PRD98, 023004

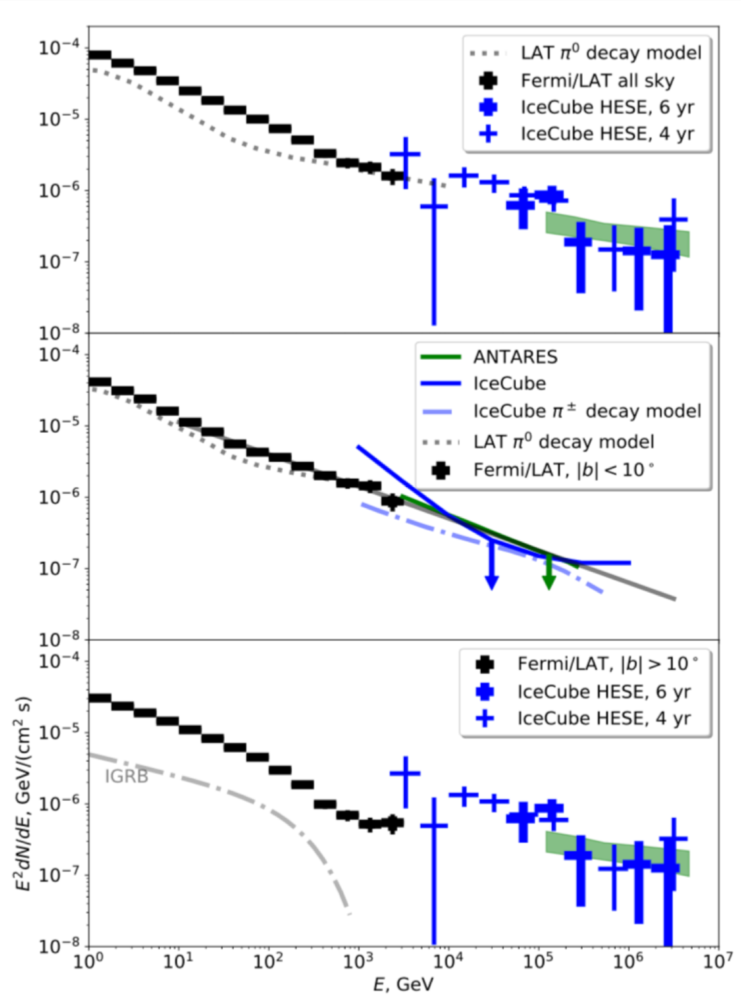
High Galactic latitude emission from dark matter decays

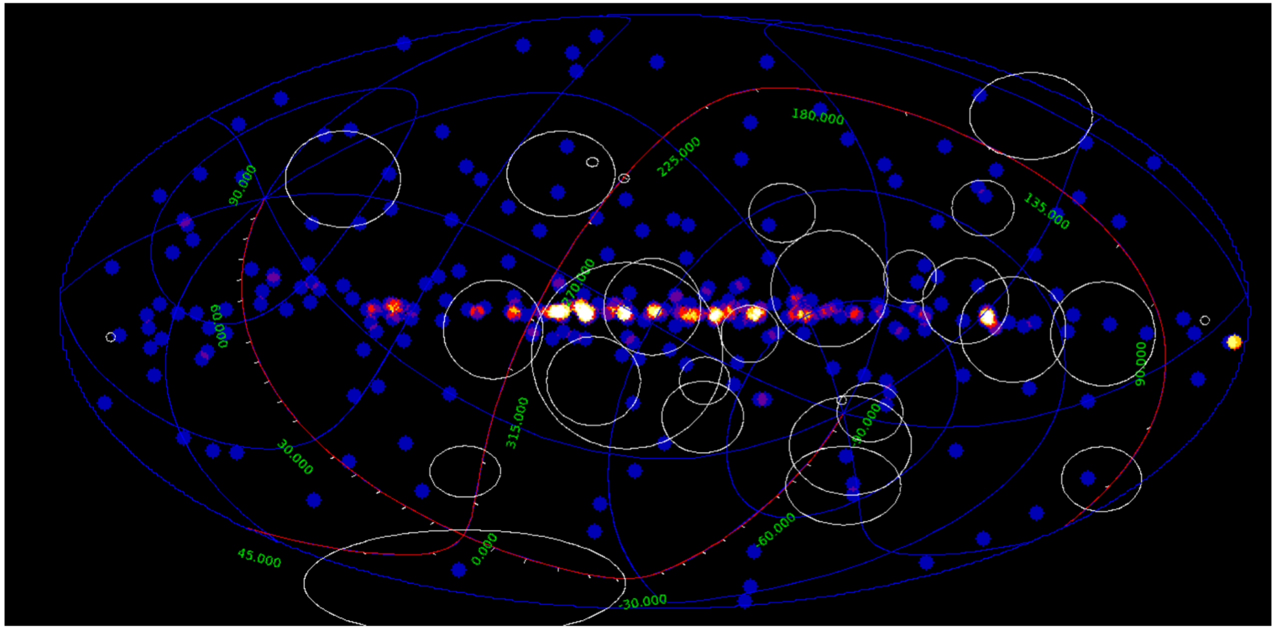


Decays of heavy dark matter particles with lifetime $\sim 10^{28}$ s into pions or directly into neutrinos and gamma-rays could provide the required multi-messenger flux at high Galactic latitude.

AN, Kachelriess, Semikoz, PRD98, 023004

Summary





Astrophyisical neutrino flux has gamma-ray ”multi-messenger” counterpart in the multi-TeV band.

High Galactic latitude gamma-ray flux exhibits hardening above 300 GeV. High Galactic latitude neutrino flux is consistent with gamma-ray flux in mutli-TeV band.

Combined gamma-ray and neutrino signal reveal new flux component which could be from local source (Vela?), large scale halo or dark matter decays.

Multi-messenger spectrum of the Galactic Plane

IceCube, ICRC2017