Anagraphical picture of high energy Galactic neutrinos

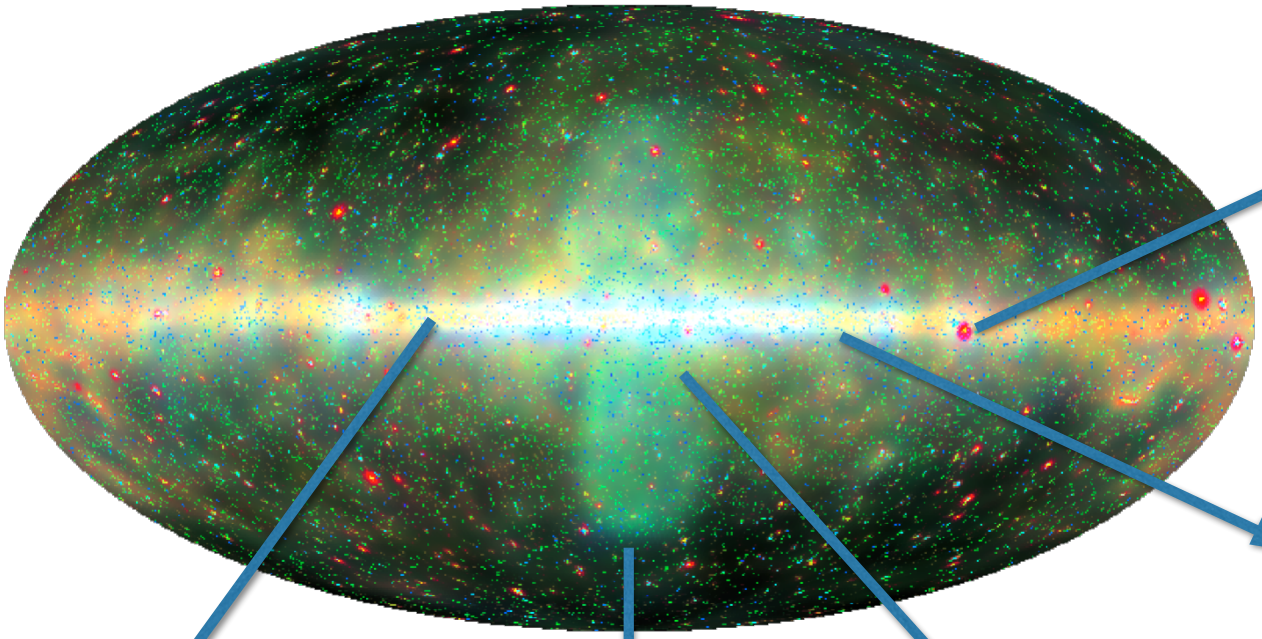
RICAP 2018

Antonio Marinelli

INFN and Pisa University

In coll. with Gaggero, Grasso, Ventura

Where we should expect Galactic ν



Point-like protons accelerators

More massive molecular clouds

Entire Galactic plane

Entire Fermi Bubbles Surface

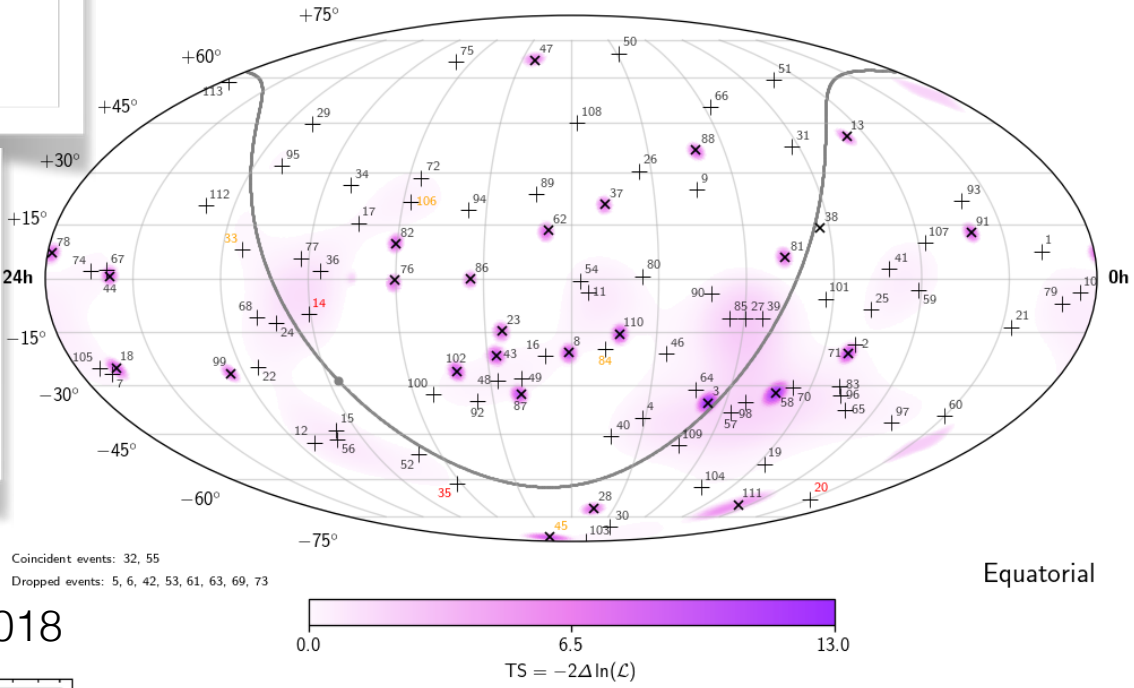
Low Latitude Fermi Bubbles

Last ν HESE results from IceCube

More than 100 HESE on 7.5 years of IceCube

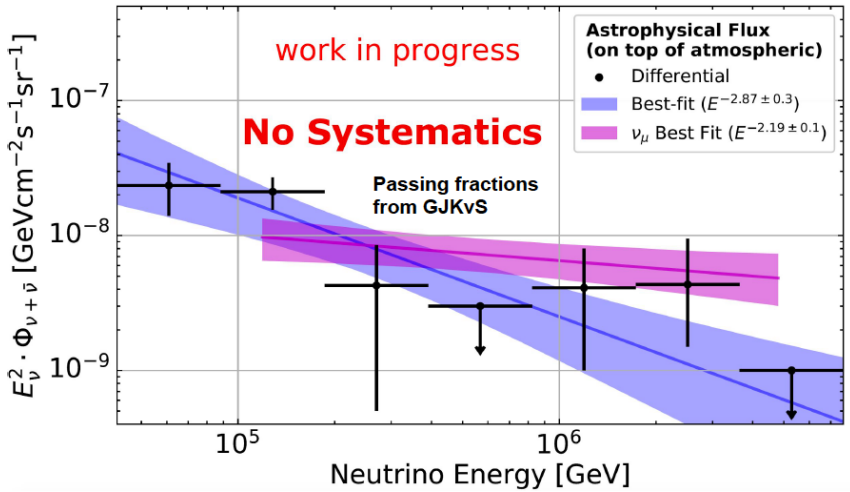
No spatial correlation with know Galactic emitters

Austin Schneider TeVPA2018



Differential Flux

Austin Schneider TeVPA2018

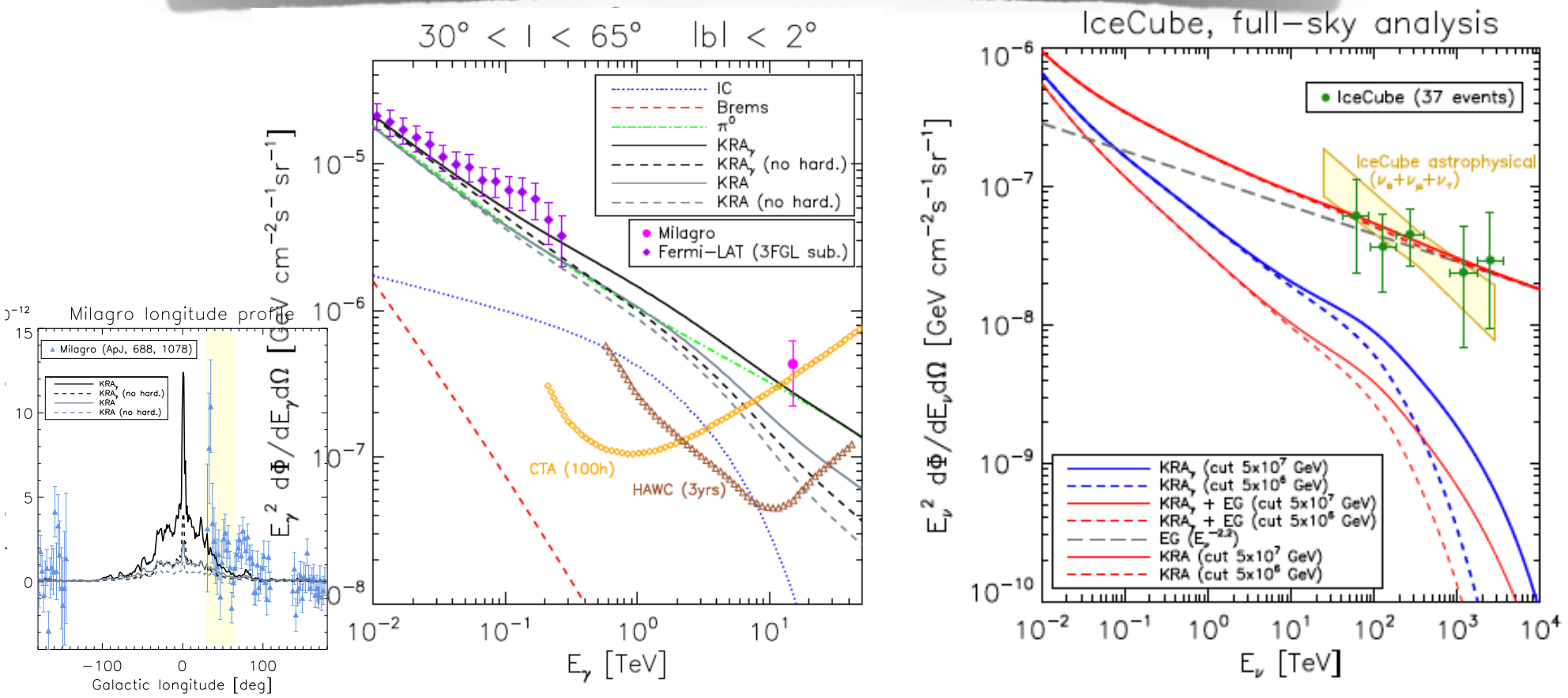


$E < 300$ TeV 300 TeV $< E <$ 1 PeV 1 PeV $< E$

Tension on the SEDs if we consider also the two lower energy bins

Contribution of diffuse Galactic ν to the full sky measured astrophysical spectrum

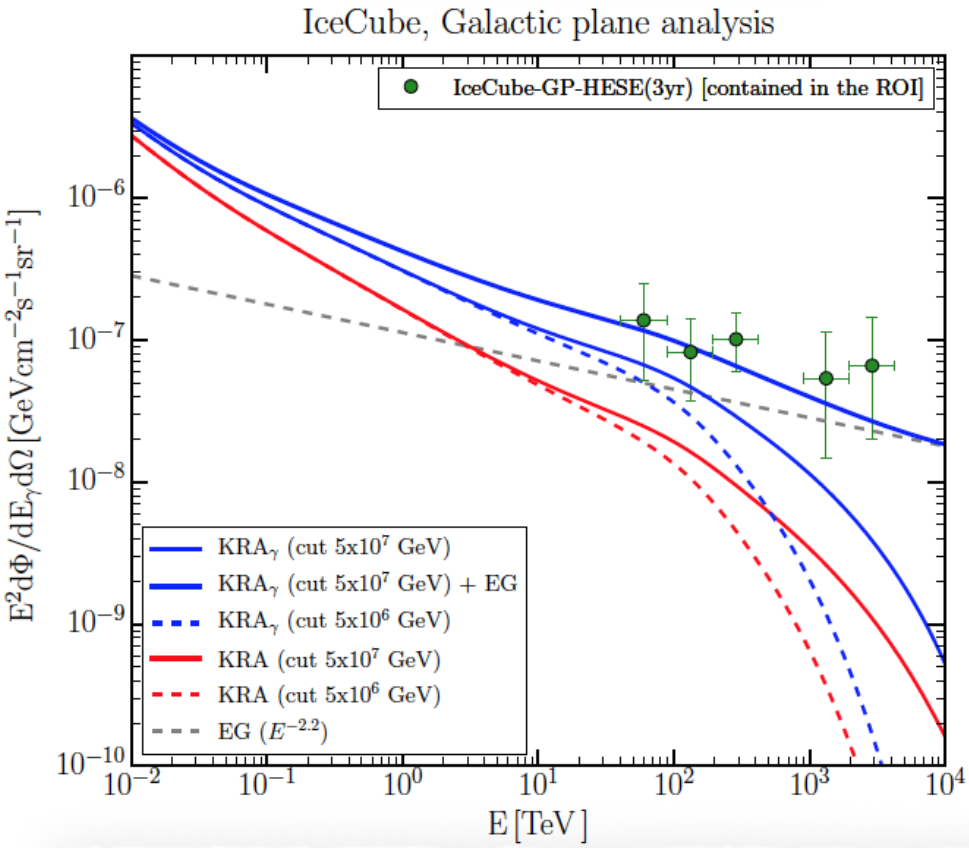
Gaggero, Grasso, A.M., Urbano, Valli, APJ Letter arXiv:1504.00227



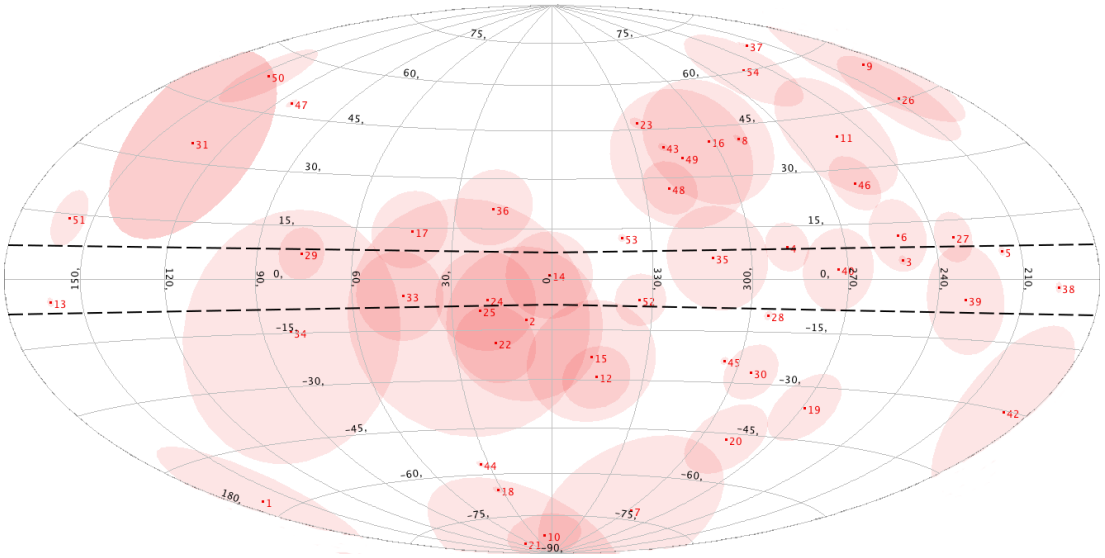
The contribution of diffuse Galactic neutrino flux resulted to be less than 20% of the measured Icecube full sky flux

Whole Galactic plane diffuse emission

AM et al. VLVNT2015



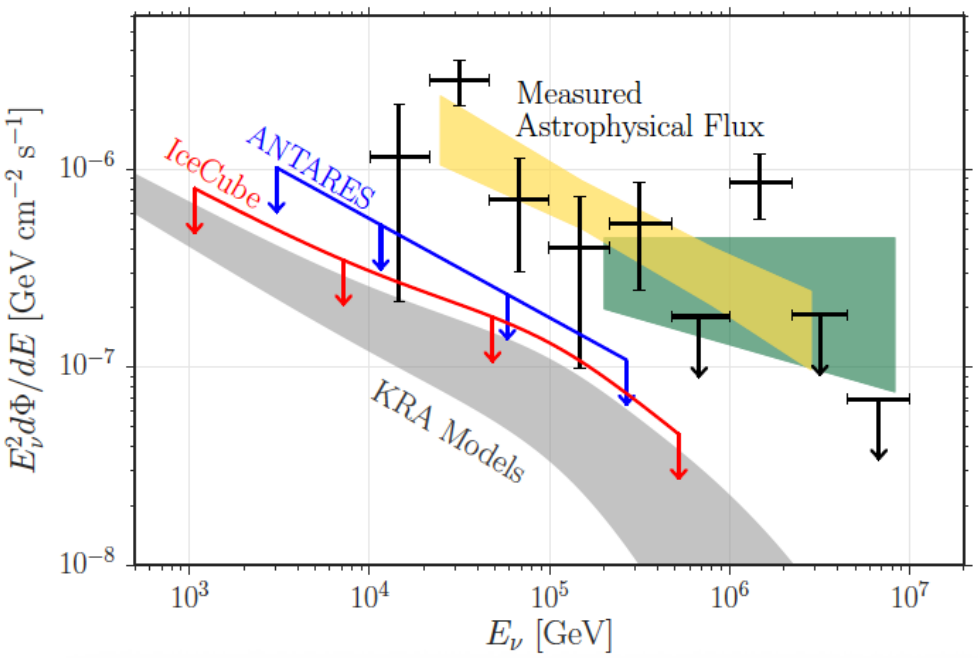
HESE 4 years Skymap



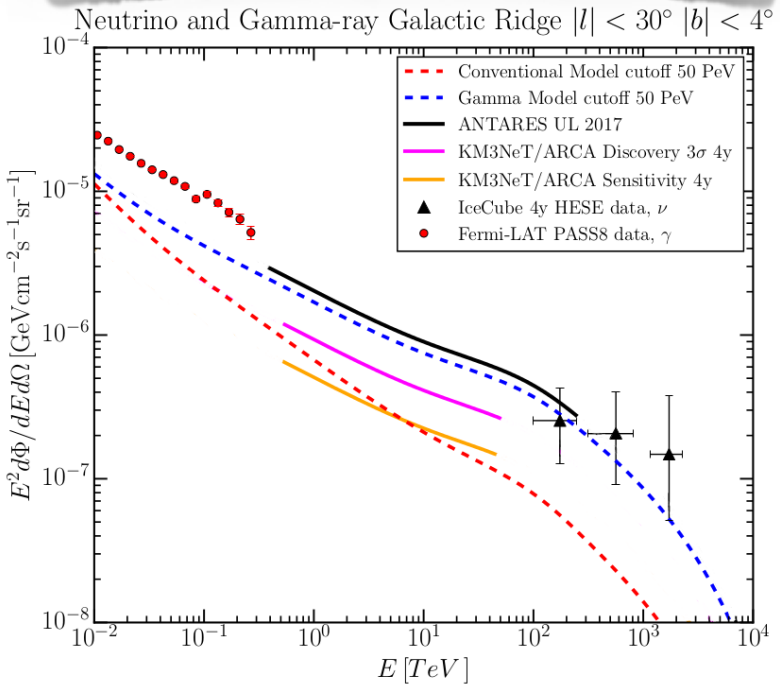
When considering the θ<7.5° region the diffuse Galactic contribution represent the 50% of the observed HESE neutrino flux leaving a large room for possible Galactic point-like contribution and EG in this region

Upper limits on Galactic diffuse emission

IceCube collaboration arXiv1707034161



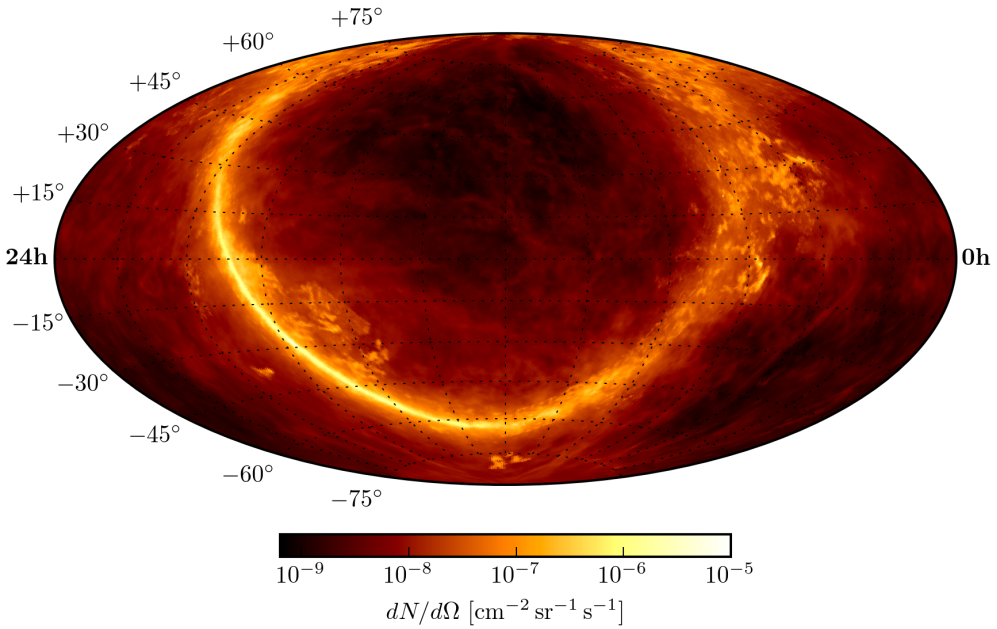
Coniglione, Fusco, AM . ICRC2017



ANTARES and IceCube constrained the maximum diffuse neutrino flux at a maximum value of ~16% of the total IceCube astrophysical measured flux.

With the incoming KM3NeT/ARCA experiment maybe possible the study of different regions of the Galactic plane

New Upper limits from IceCube + ANTARES

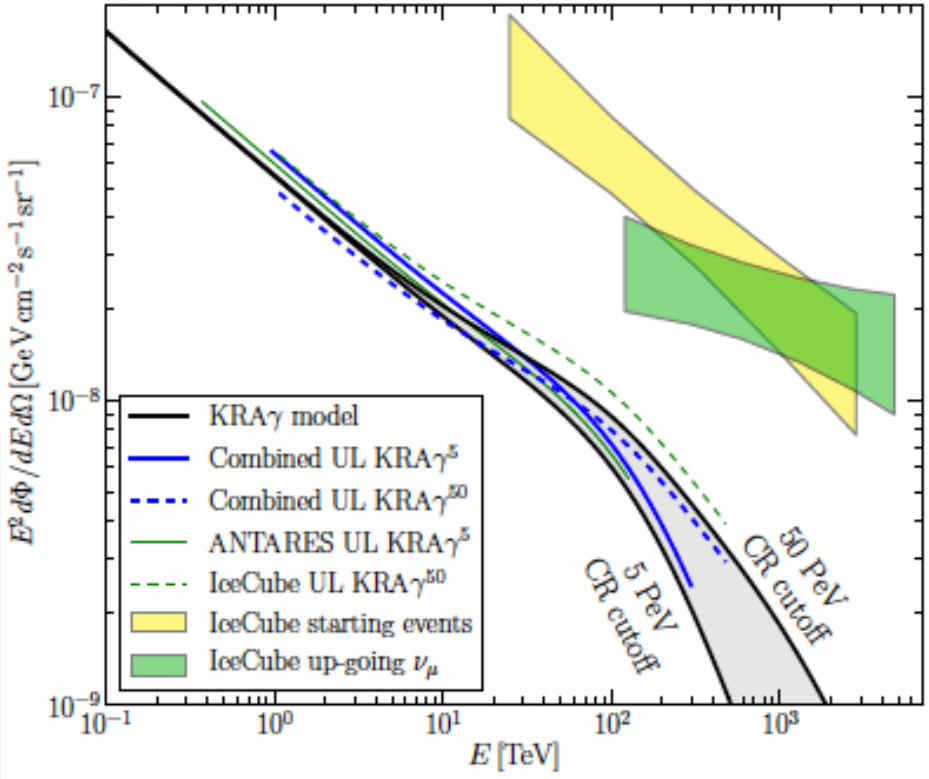


IceCube+Antares-arXiv180803531A

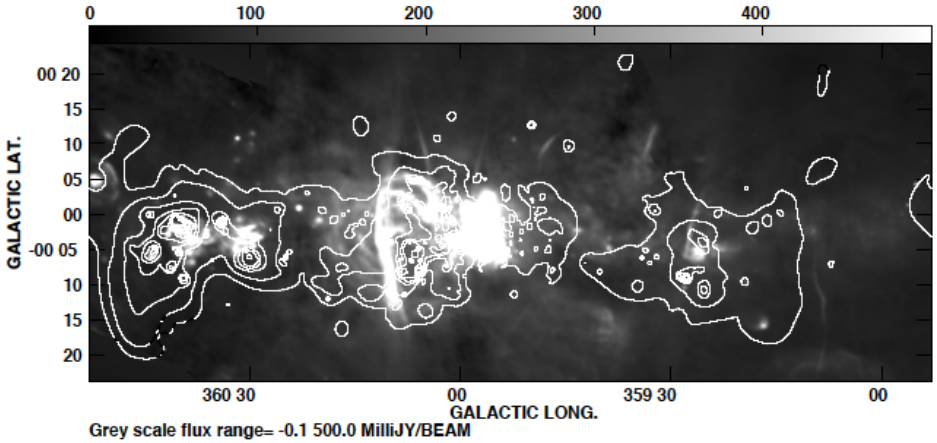
The same template of previous analyses is used with the two cut-offs 5 and 50 PeV for protons

The new ULs comprises 2780 days of ANTARES (shower + tracks) and 2431 days of IceCube (tracks)

The new ULs for the case of 5 PeV cut-off for protons we set the maximal Galactic diffuse neutrino flux at the level of 8.5% of the total measured astrophysical flux measured by IceCube



CMZ: special Laboratory for Astrophysical Mechanisms

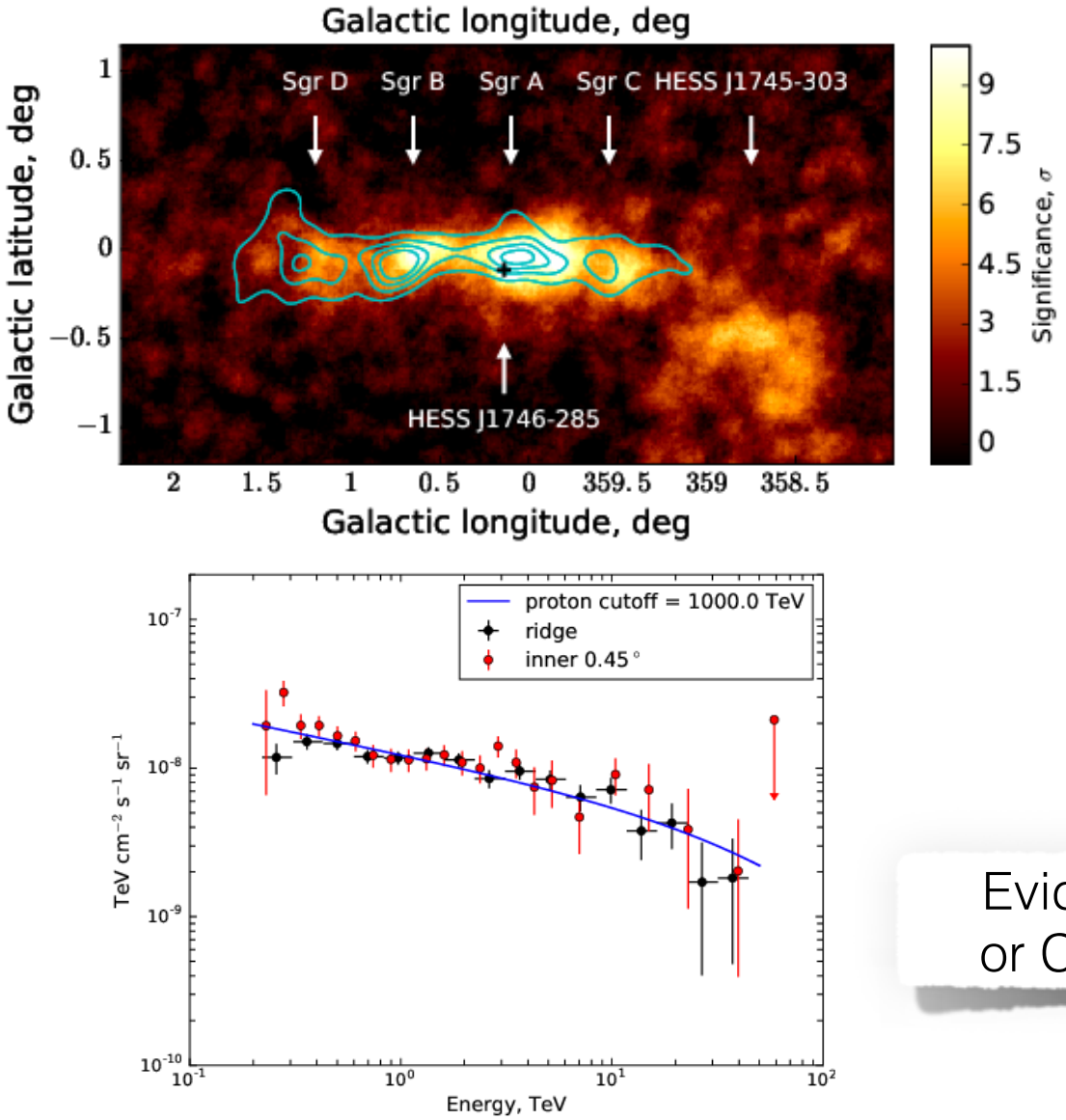


Hewitt et al. arXiv:1206.6882

Several hundreds of Parsecs surrounding the central SMBH

- Density of Gas 10^4 cm^-3 (2 orders of magnitude the average Galactic density at high scales)
- Total Molecular gas reservoir ~ 4 x 10^4 M⊙ (~5% of the total gas in the Milky Way)
- Star formation rate less than expected (higher activity in the past), high temperature, turbulent region, emitting radio, optical, UV, X and gamma, ν -> the most promising region for ESTER sample

New analysis of HESS for the central 200 parsecs



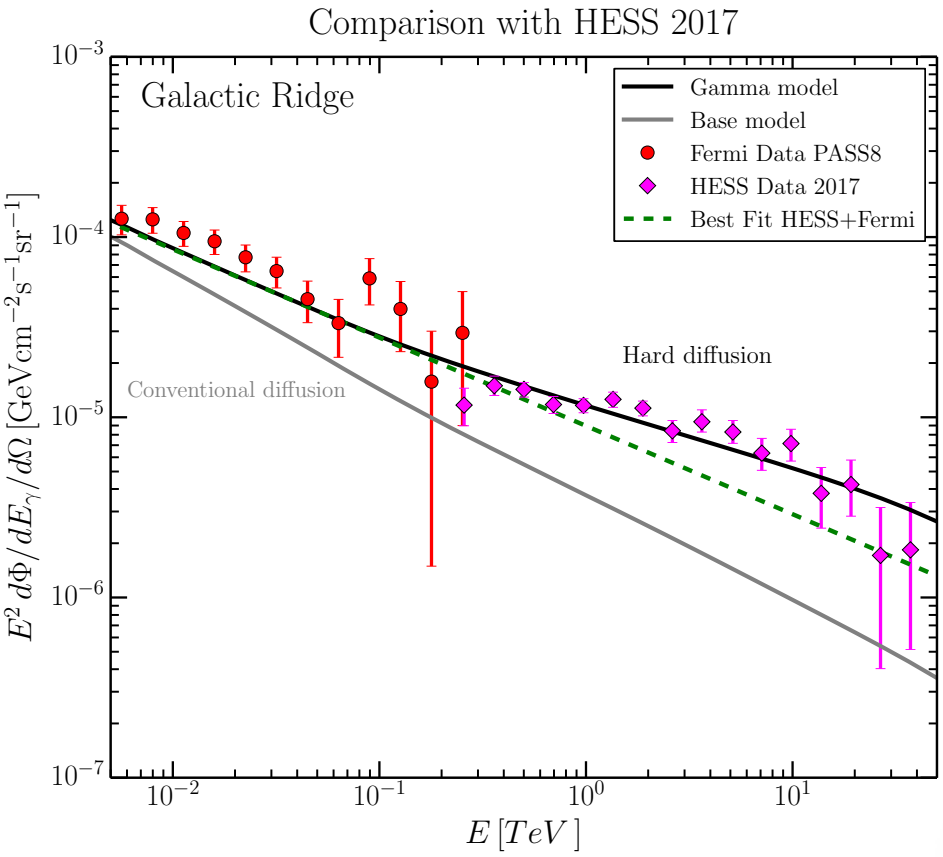
arXiv:1706.04535 HESS coll.

New morphological and spectral analysis of the gamma-ray emitting region with 250 hours of data

Spectral features of new GR 2017 similar to the ones of "Pacman" region

Evidence of fresh CRs from Pevatron or CR sea hardening close to the GC

Explaining the the GeV-TeV diffuse emission on the central 200 parsecs.



$$\Phi_{GR} = 1.181 \times 10^{-5} \left(\frac{E_\gamma}{1TeV}\right)^{-2.42} GeV^{-1} cm^{-2} s^{-1} sr^{-1}$$

Gamma & Base models with Ferriere source distribution ('01)

PhRvL.119c1101G

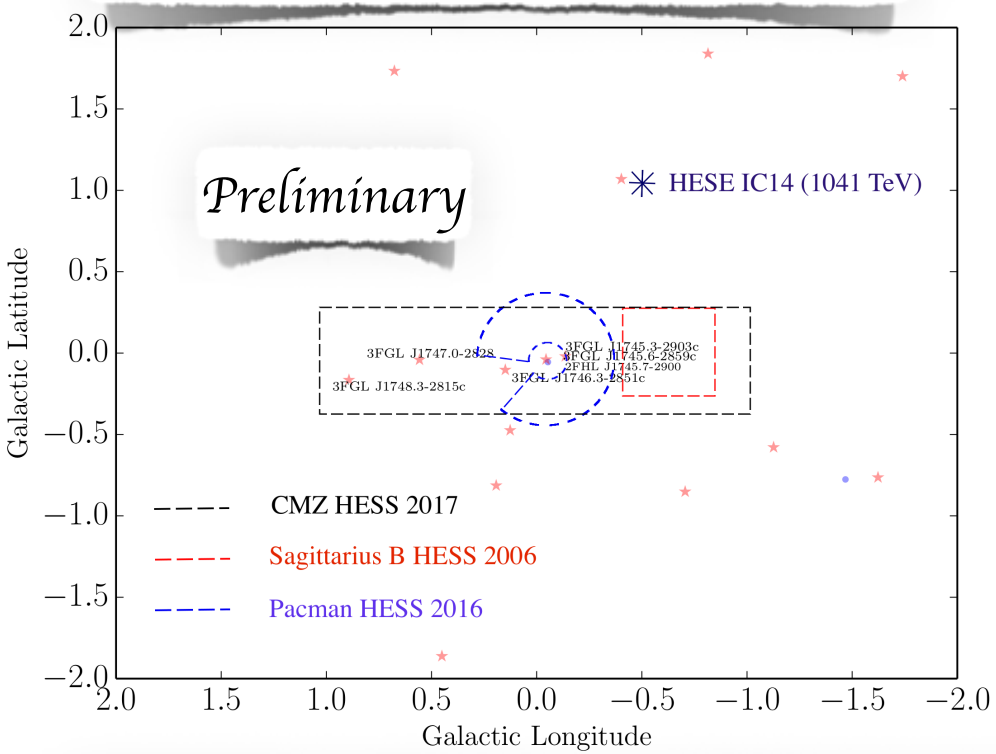
Gaggero, Grasso,A.M., Taoso, Urbano

The presence of all the Sagittarius clouds represent a preferential target region for CRs

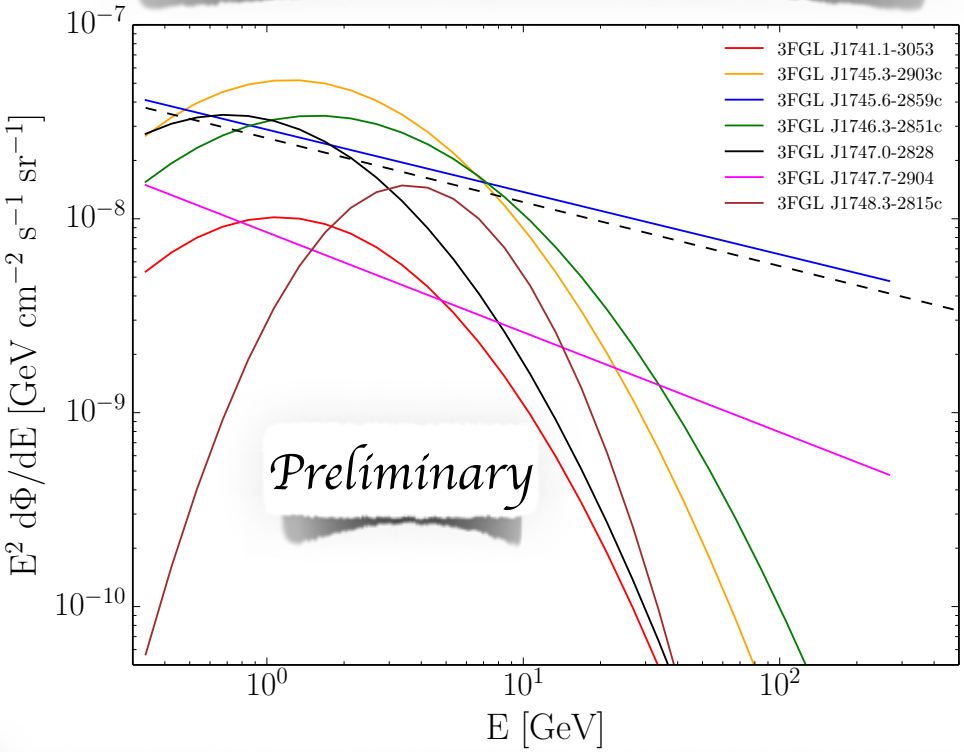
Gamma model fit with the hard spectrum

Regions of CMZ where we compute ν expectation

Regions of gamma diffuse



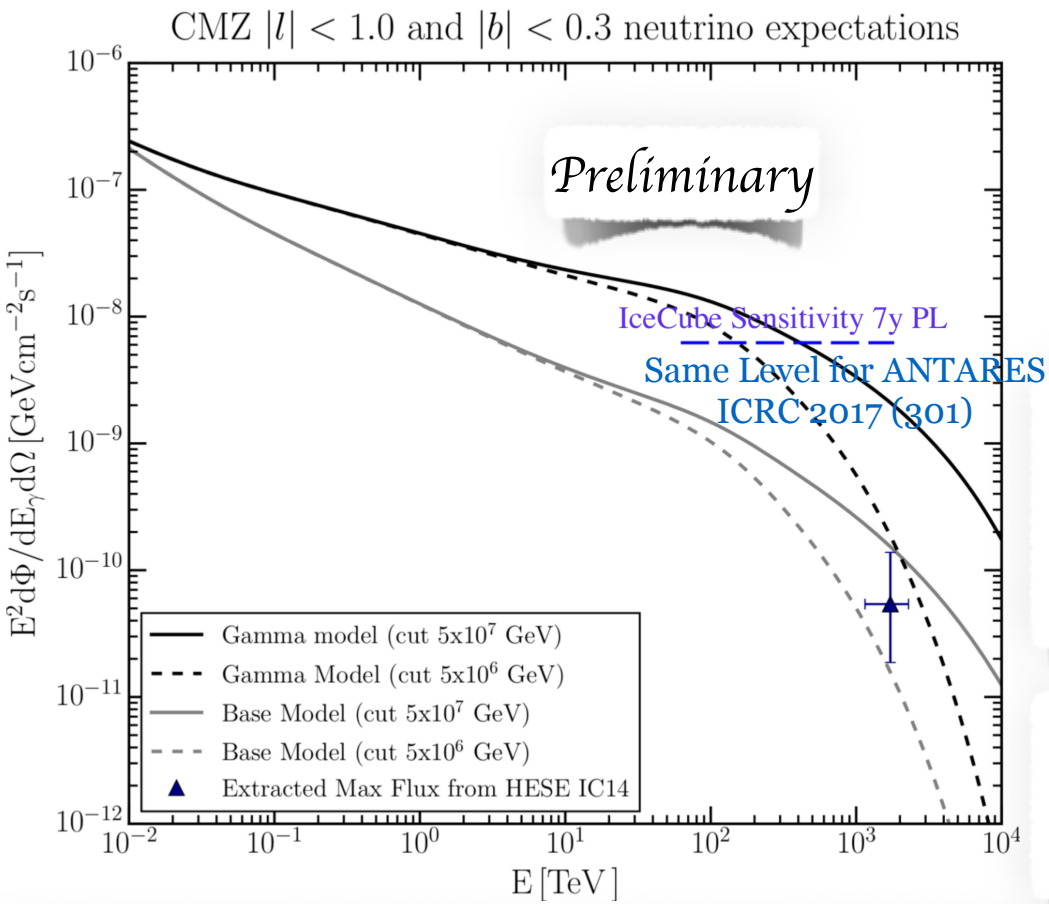
Fermi-LAT point like sources

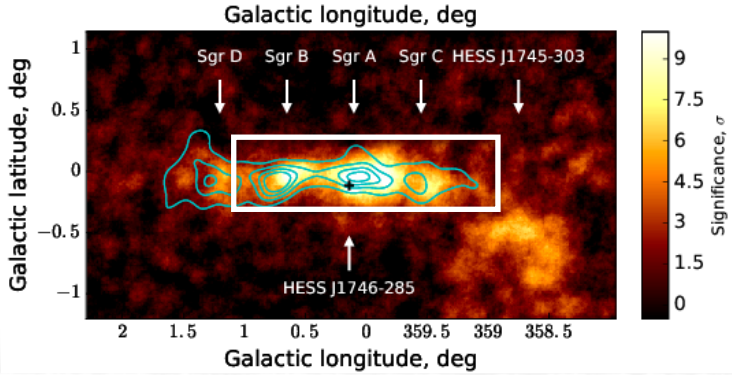


CMZ HESS 2017 |l|< 1°, |b|<0.3°
Sagittarius B 0.4°<l<0.9°, -0.2°<b<0.3°
Pacman, annulus 0.15<θ<0.4

SEDs of possible PLS (also 2FHL1745-290) from Fermi in the CMZ region of 200 pc

Neutrino from the 200 pc of the CMZ (HESS 2017)



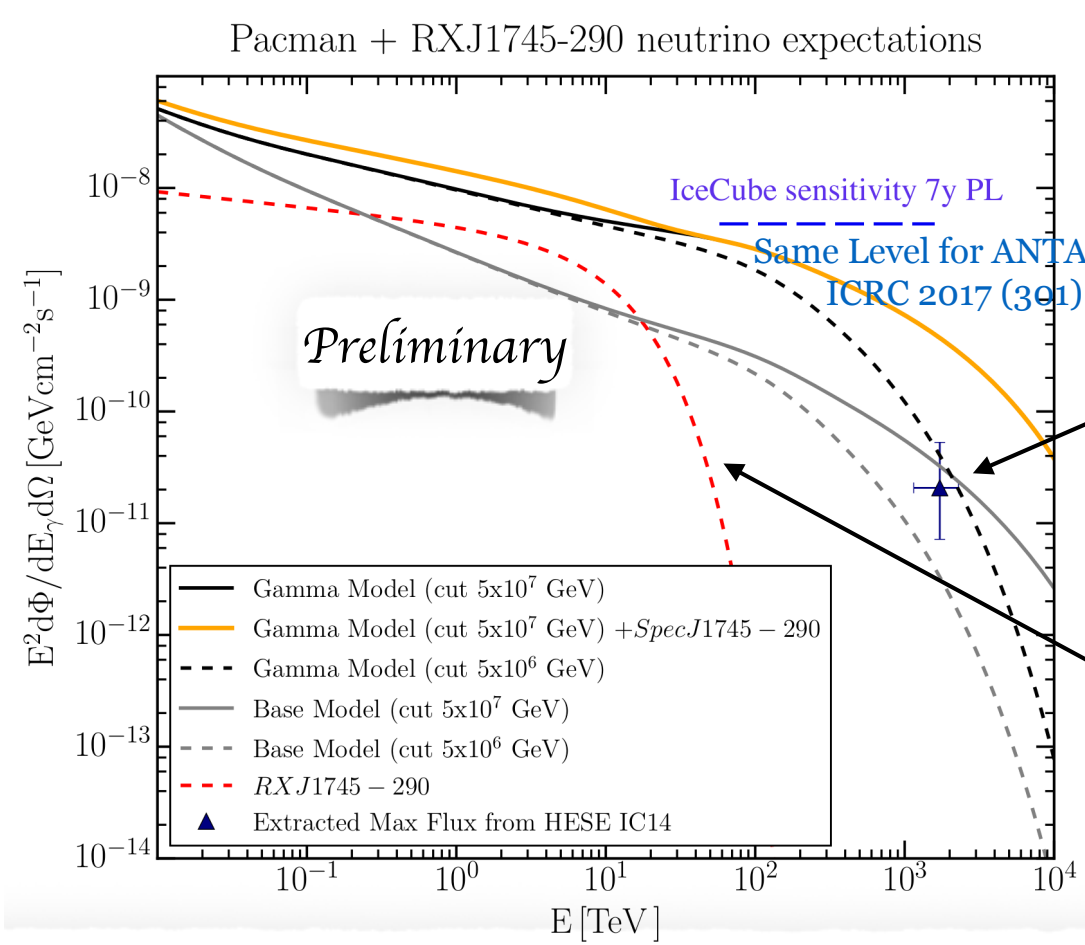


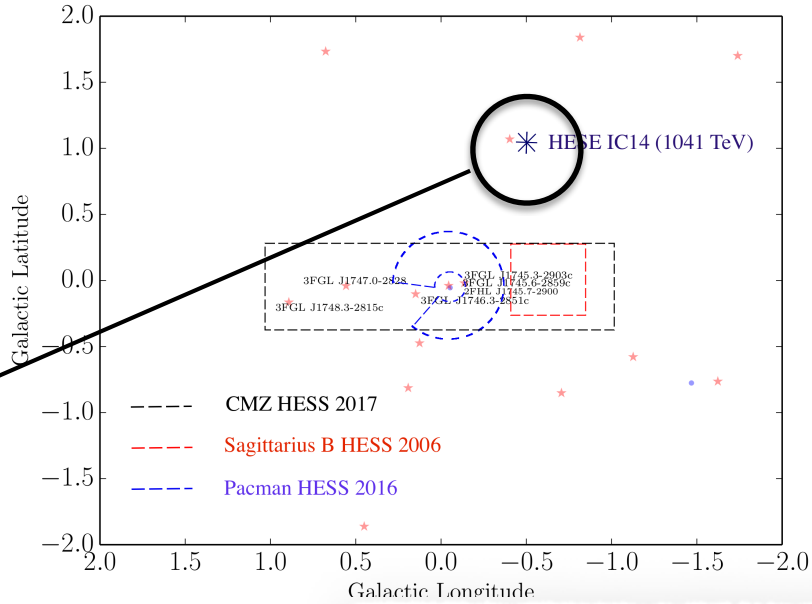
Integrating the flux of the full 200 parsecs better chances to see the signal for IceCube and ANTARES

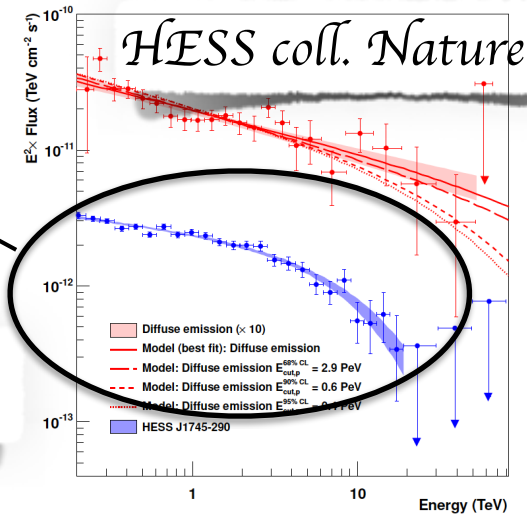
Good visibility should be expected for KM3NeT/ARCA

The extrapolated max flux from IC14 (1041 TeV) still more compatible with 5 PeV cutoff, we expect more HESEs in this region of the sky!

Neutrino from the Pacman region (HESS 2016)

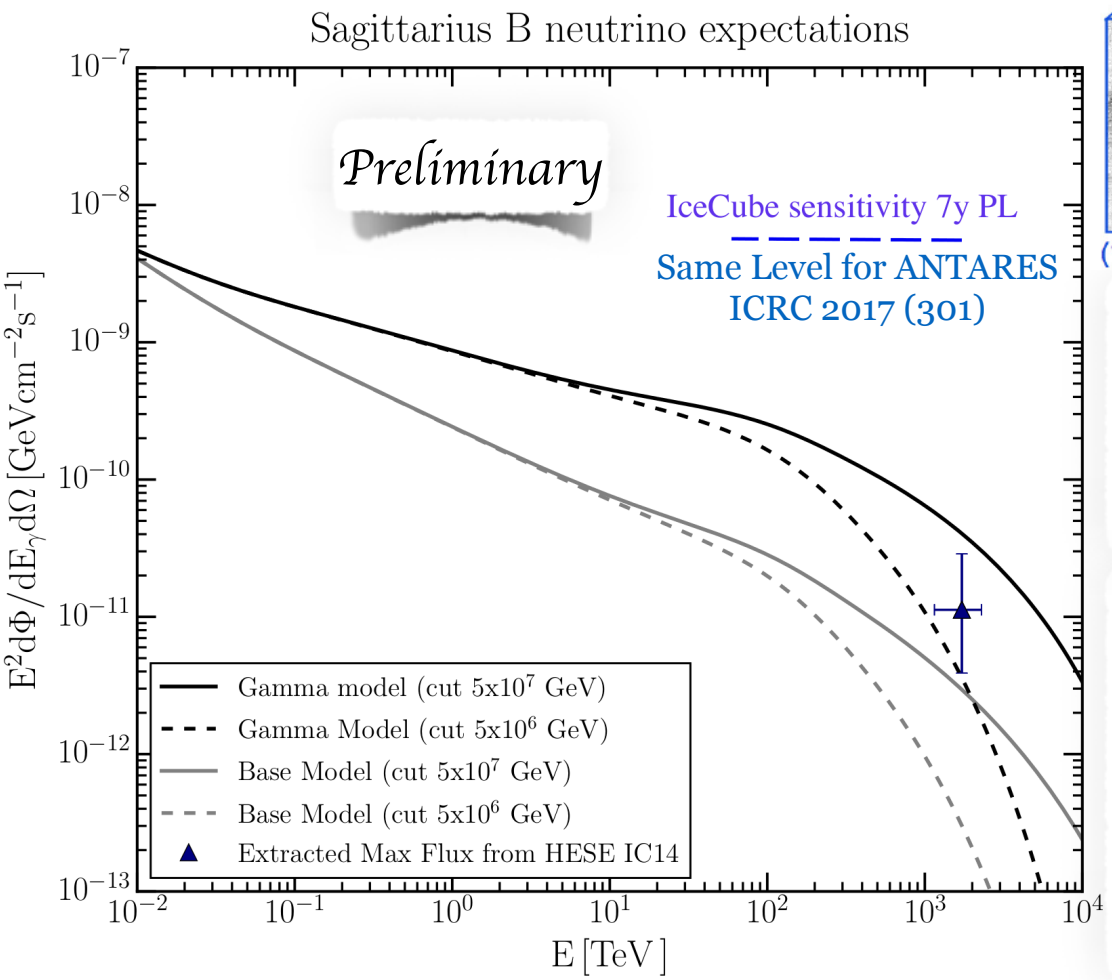




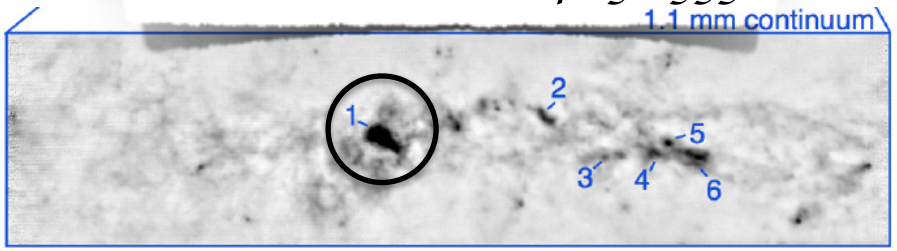


Better PLS sensitivity needed:

Neutrino from the Sagittarius B molecular complex



E.A.C Mills arXiv:1705.05332



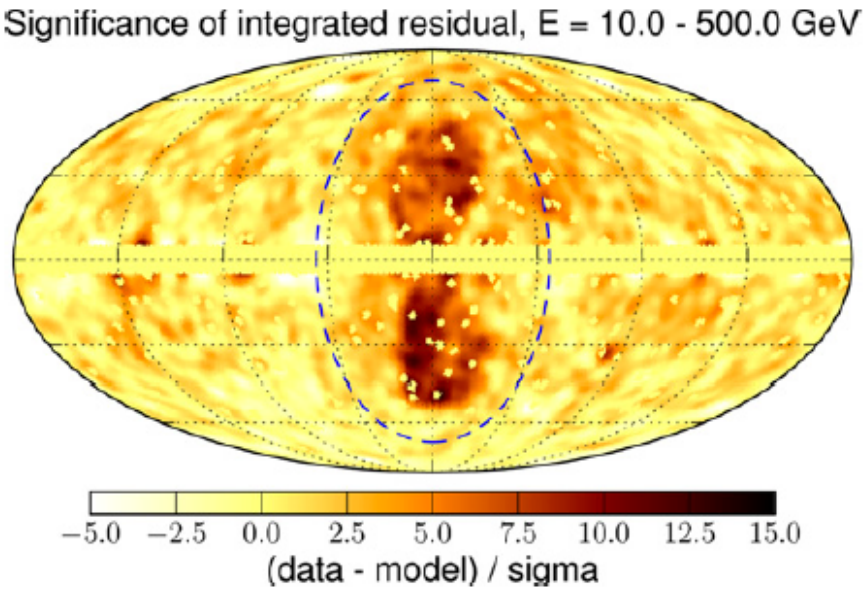
(1) Sgr B2, (2) M0.25+0.01, (3) M0.11-0.08, (4) M-0.02-0.07, (5) CND, (6) M-0.13-0.08

Sagittarius B far to be detected as a single PL source if the emitting region is only the one of HESS

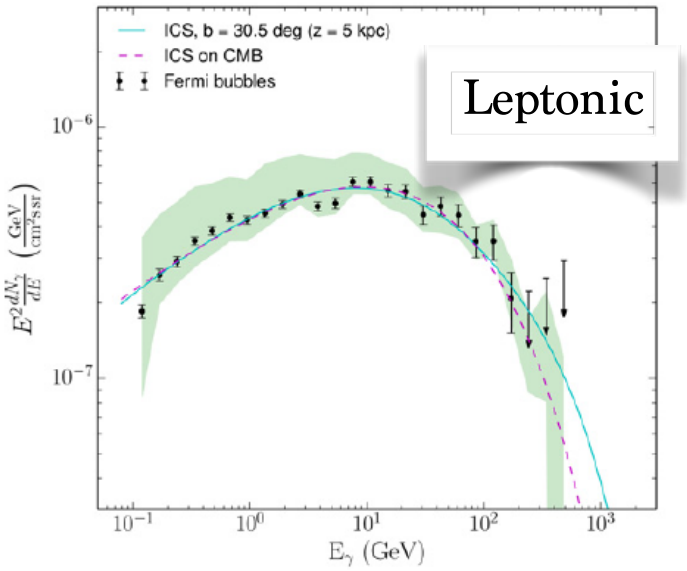
Only one PeV HESE event gives not a strong limit however the extrapolated flux seems more compatible with a 5 PeV cutoff instead of 50 PeV.

Fermi Bubbles observation with VHE gamma rays

Spectrum and morfology of the Bubbles Ackermann et al. 2014 Between 100 MeV and 500 GeV



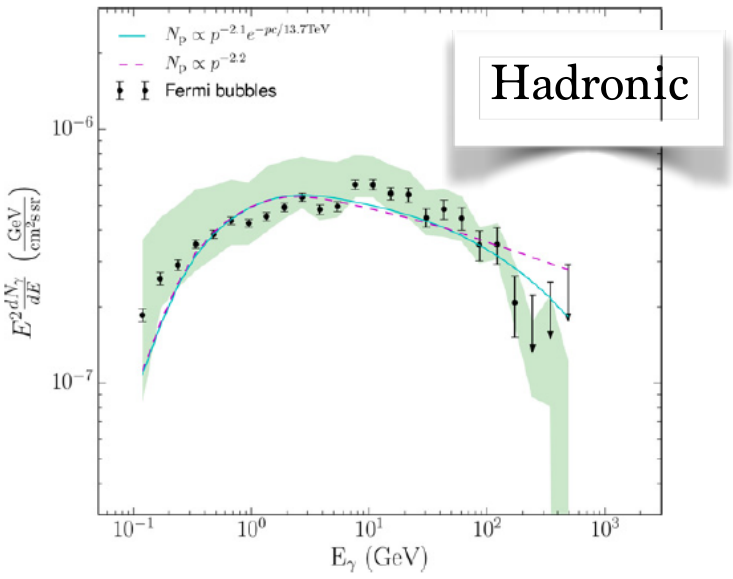
Residual map obtained excluding the Galactic and subtracting all known Fermi sources



Leptonic

Fermi-LAT coll APJ 2014

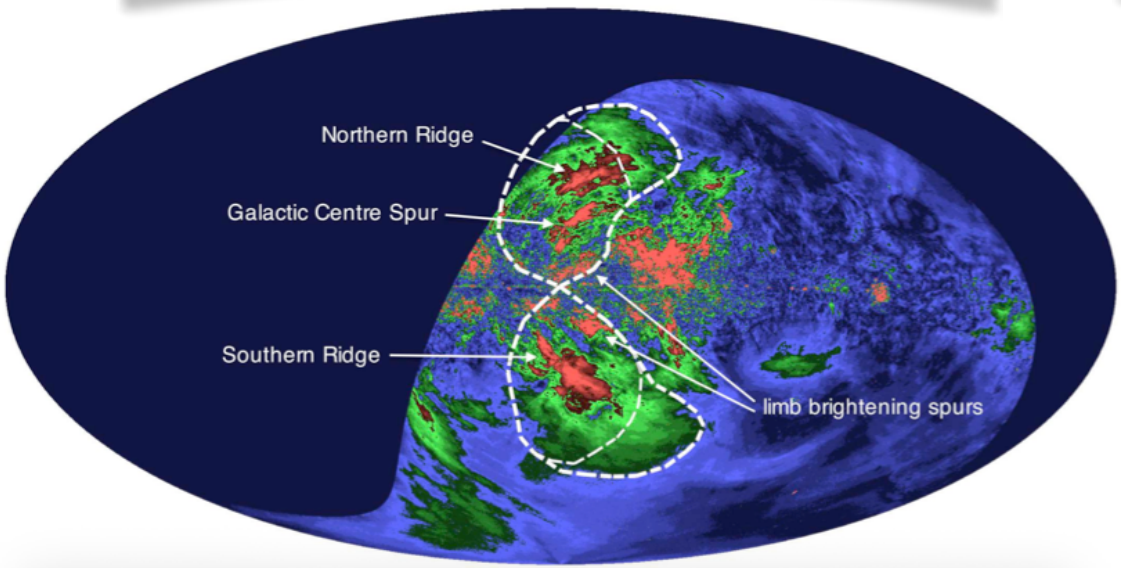
In the last 4 years different scenario have been analyzed. Stil open the possibility of a hadronic component



Hadronic

Modeling Fermi Bubbles emission from radio to gamma

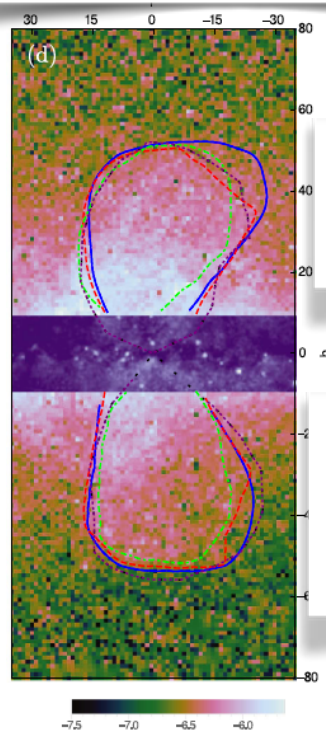
Carretti, et al. Nature 493 (2013) 66



Radio emission intensity of Bubbles

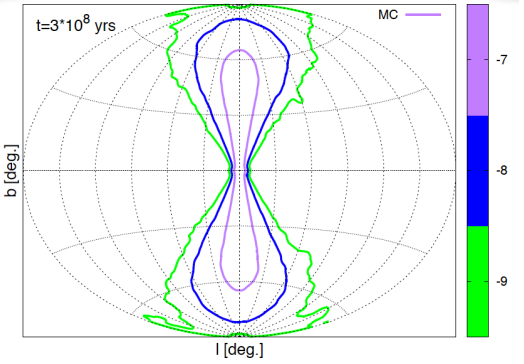
Giacinti & Taylor ICRC2017

CKeshet et al. APJ 2017 840 n7



Fermi Bubbles with PASS8 data

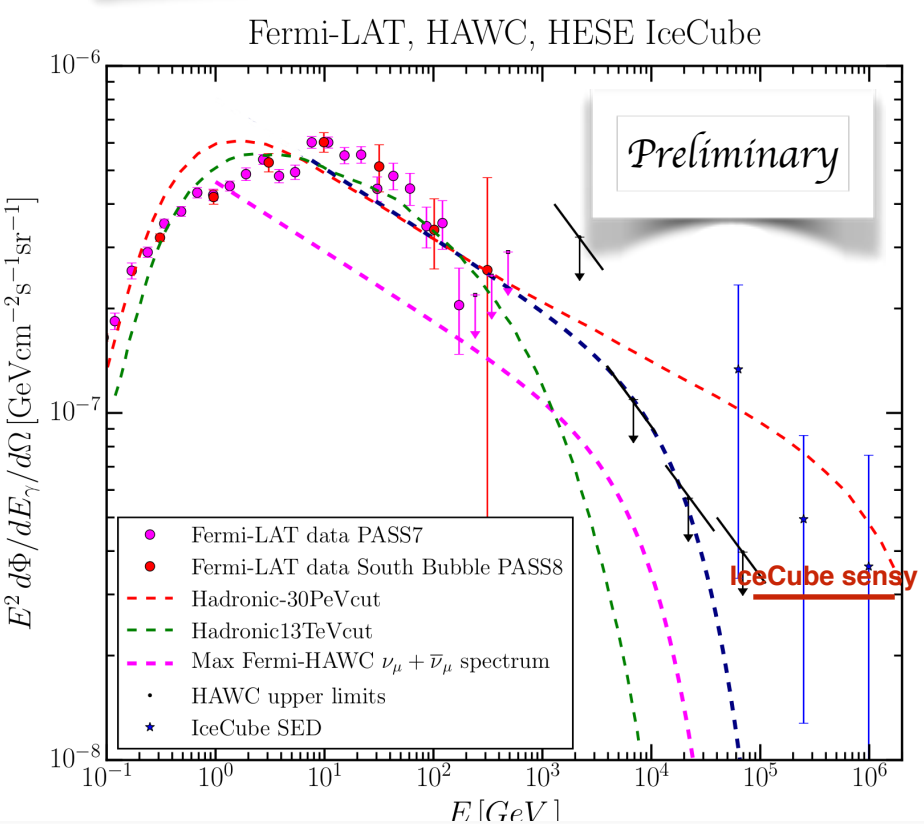
MC of hadronic emission at different energies

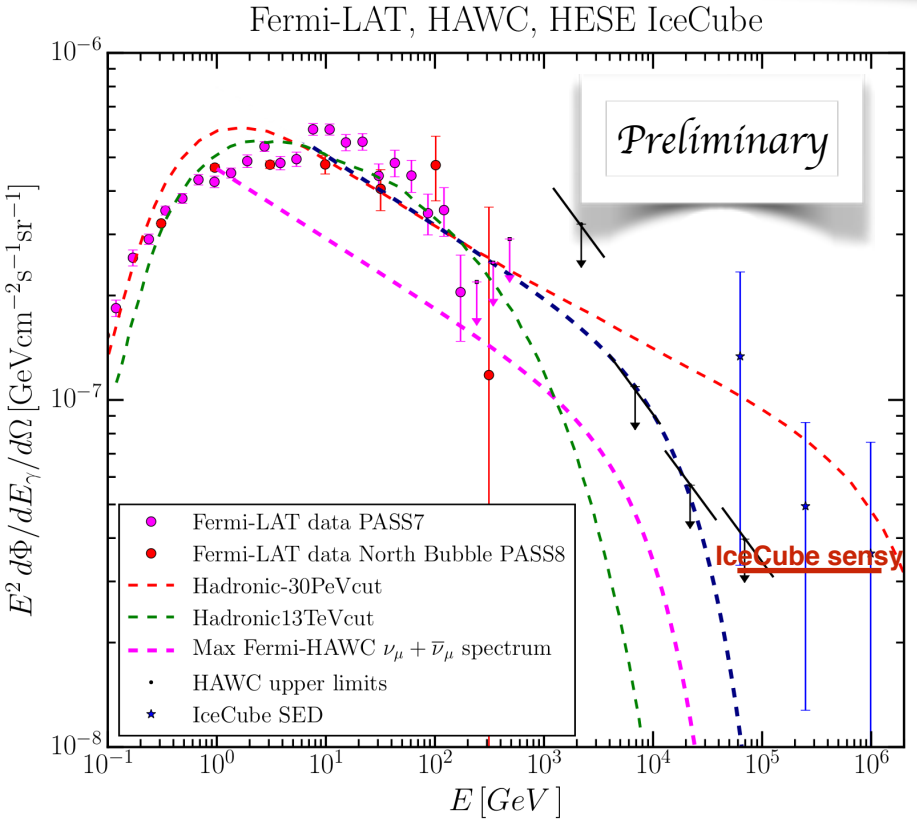


Extension of non thermal radio emission region outside the gamma-ray bubbles favors the connection with CR production

Introduction of PASS8 data for the Fermi Bubbles

PASS8 data allow for the same SED modeling of PASS7



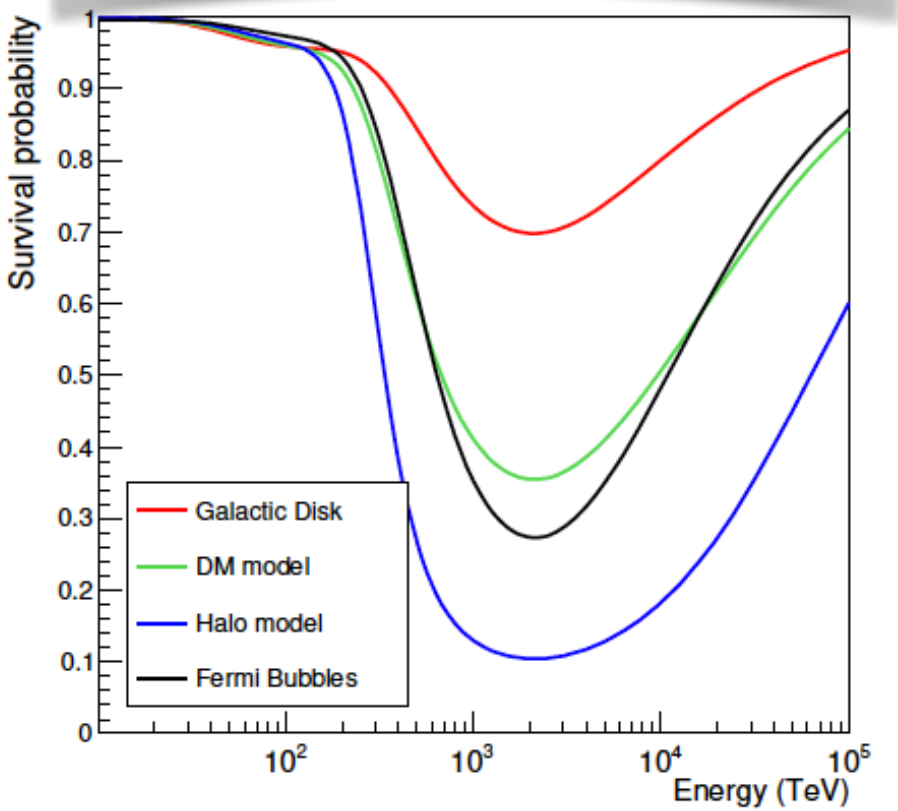


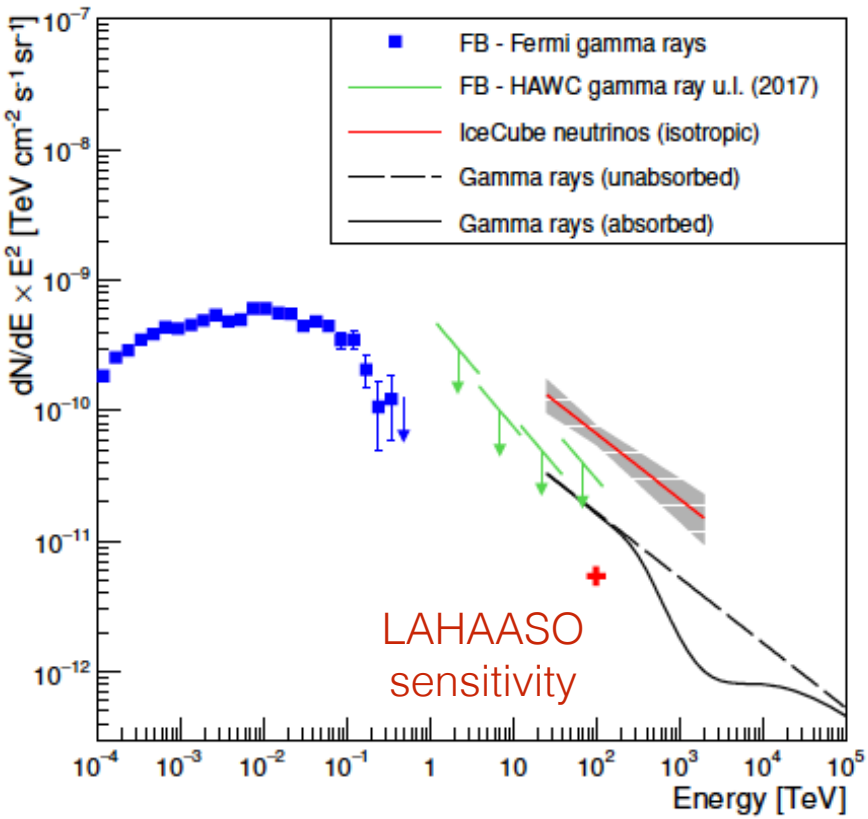
Introduction of PASS8 data for Bubble South

Introduction of PASS8 data for Bubble North

Possible absorption of VHE gamma ray from the Bubbles

ICRC 2017 Vernetto e Lipari

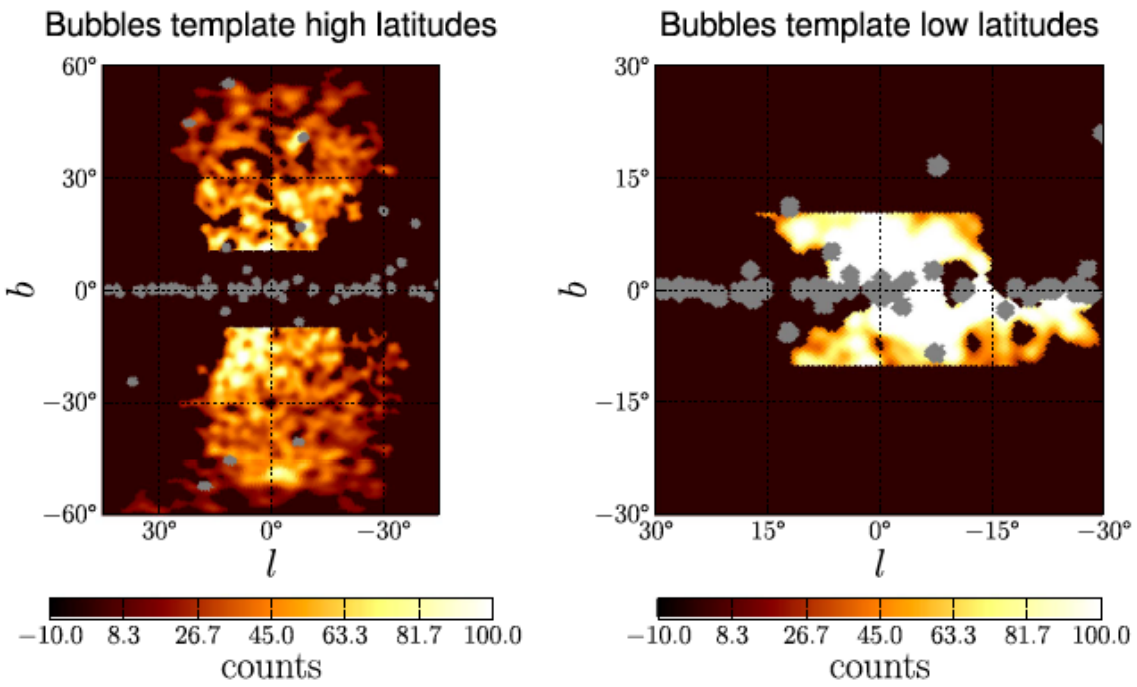




Absorption model built through the measured infrared emission from our Galaxy

No Major absorption effects seem important for the Bubbles below 100 TeV

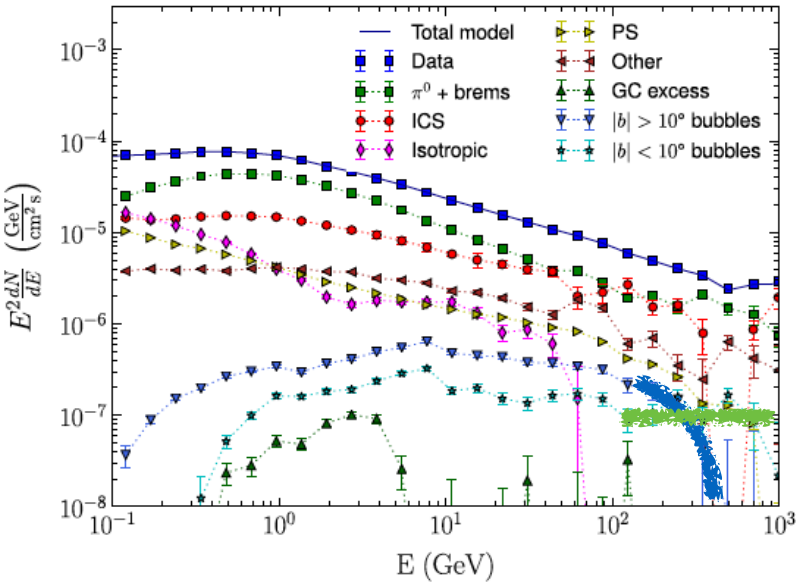
New Fermi-LAT analysis for low latitude Bubbles



New Fermi-LAT paper

APJ 2017

The Fermi-LAT coll. look now to the Bubbles template at lbl<10°

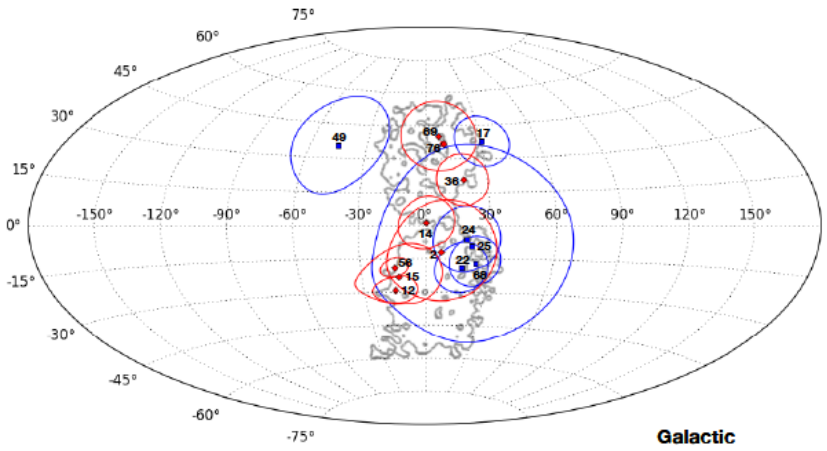


Possibility that the low latitude Fermi Bubbles have a different behavior with a harder SED for E>100 GeV

Bubbles |b|<10°

Bubbles |b|>10°

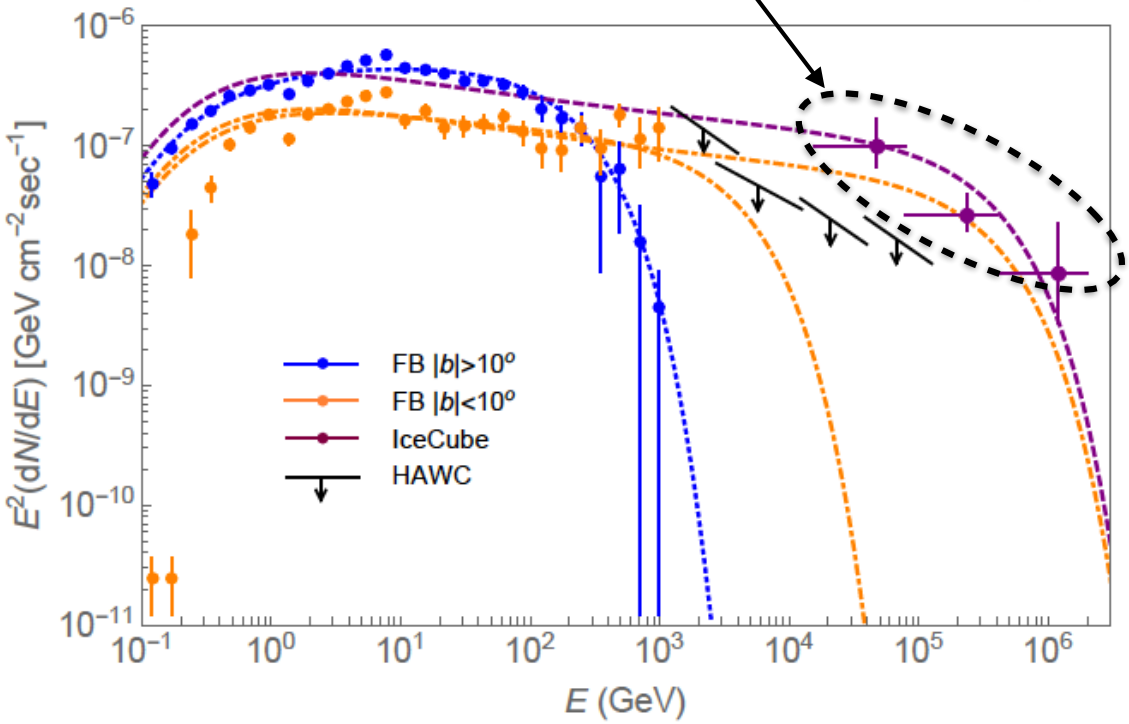
Coparison of new gamma-ray SED and ν SED



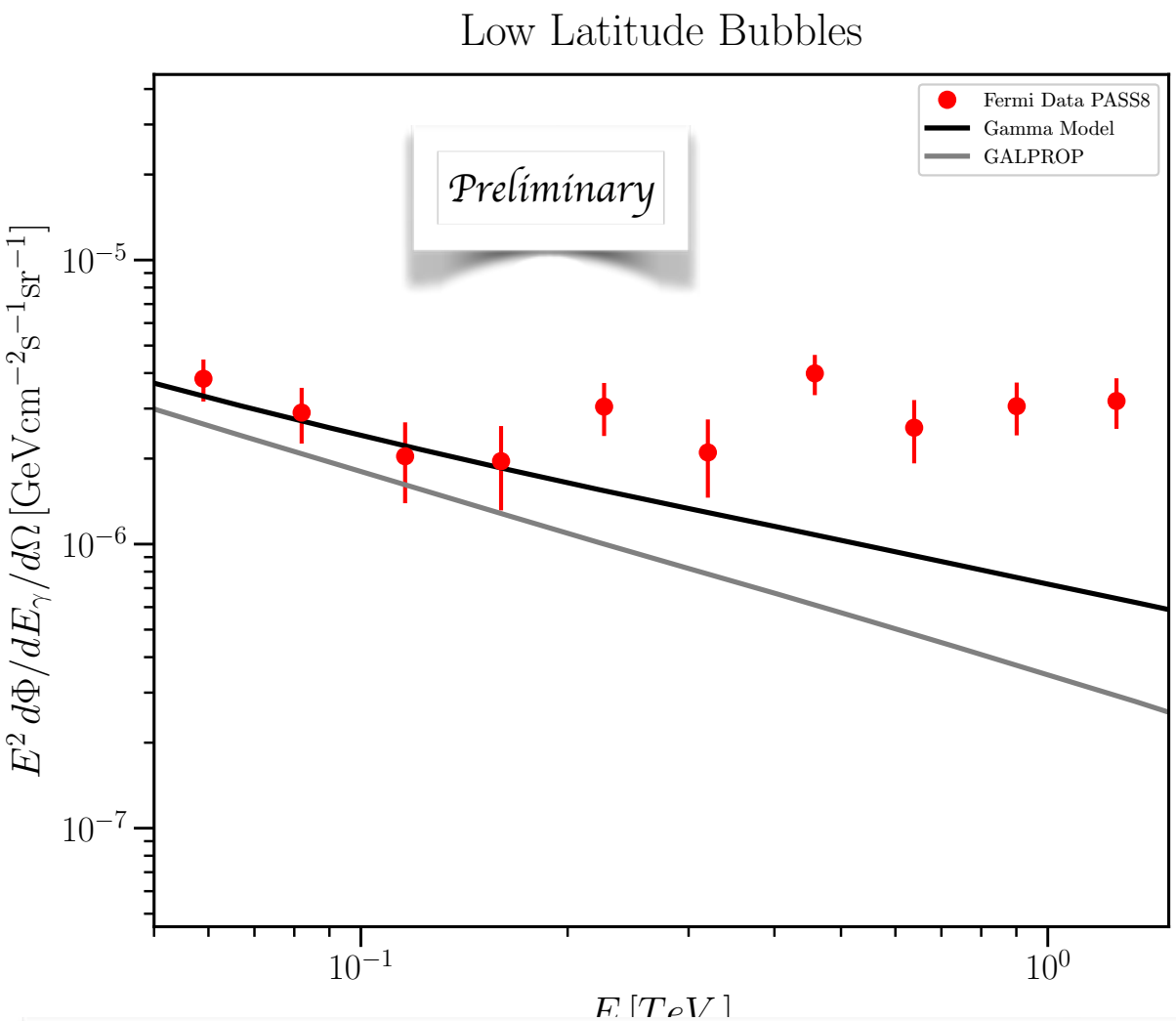
Razzaque & Yang Galaxies 2018

IC neutrino events: 8 strongly and 6 weakly-correlated HESE events with the surface of FB

The possibility to have a harder SED for the low latitude Bubbles can reconcile the Fermi-LAT and HAWC data with the inferred neutrino SED for the HESE catalog.



Low latitude Bubbles in comparison to diffuse Model



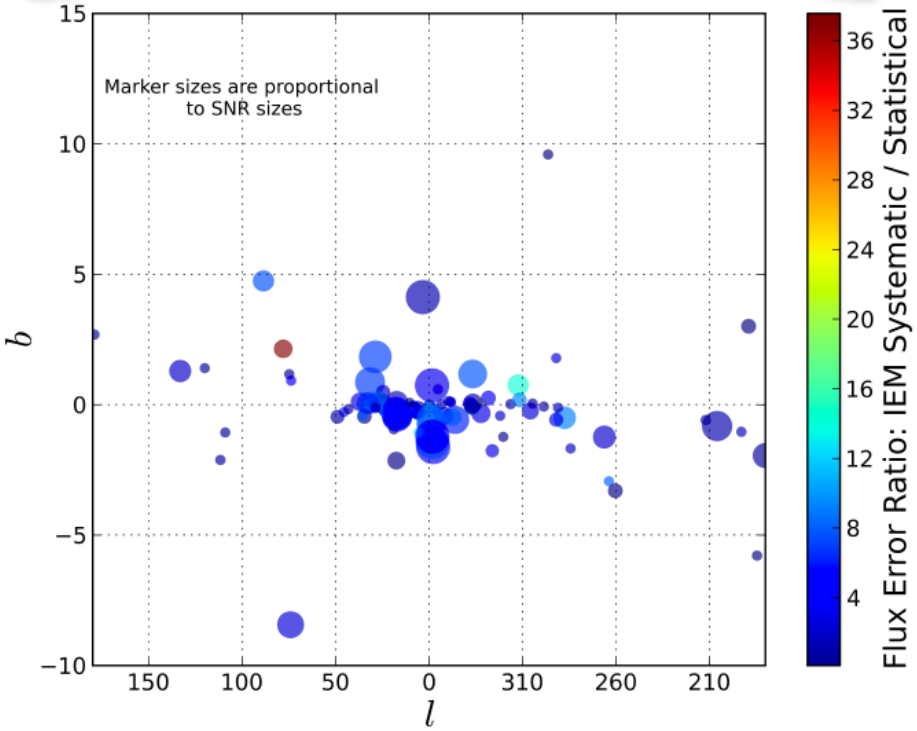
The Fermi-LAT data in the region of the low latitude Bubbles (|b|<10°) can be explained through diffuse Galactic component just up to hundred of GeVs

The gamma-ray hardening at low latitude Bubbles (|b|<10°) need to be understood

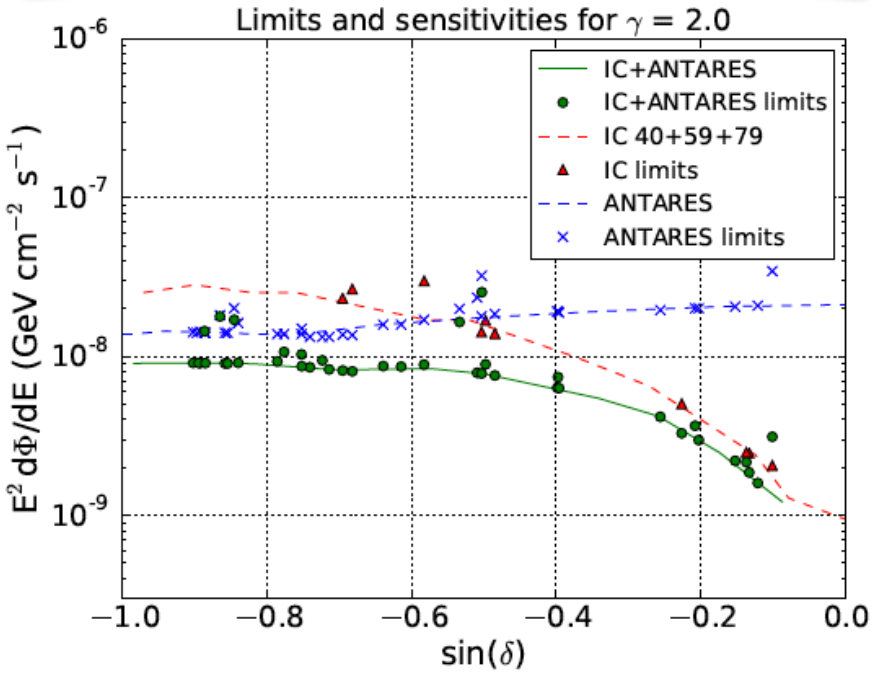
If this hardening in the gamma-ray SED is really due to the low latitude Bubbles and not just unresolved sources, give more chances to observe correlated ν events

Supernova Remnants as a Point-like ν neutrino emitters

Fermi-LAT Coll. APJ 2016

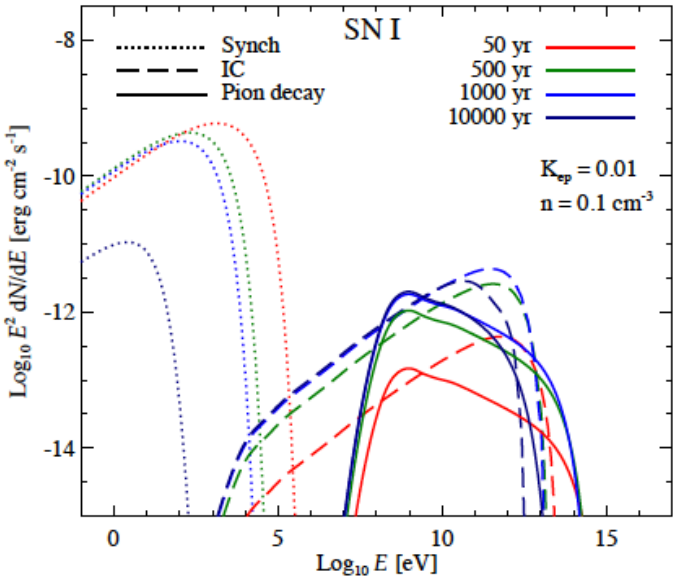


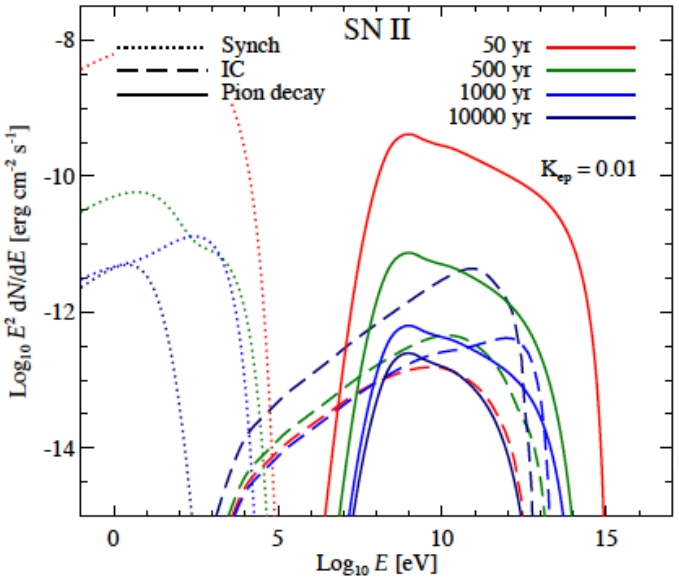
Icecube+ Antares Colls. APJ 2016



Considering the spatial extension of Fermi-LAT and Cherenkov telescopes observations of SNRs we introduce the ones with harder spectrum and Highest energy emission between the interesting point-like ν emitters

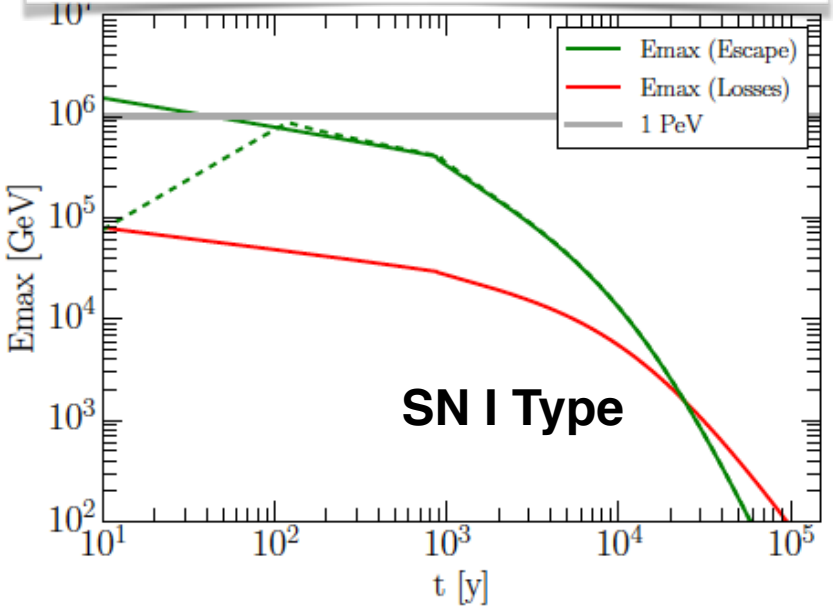
SNRs gamma-ray emission evolves with time



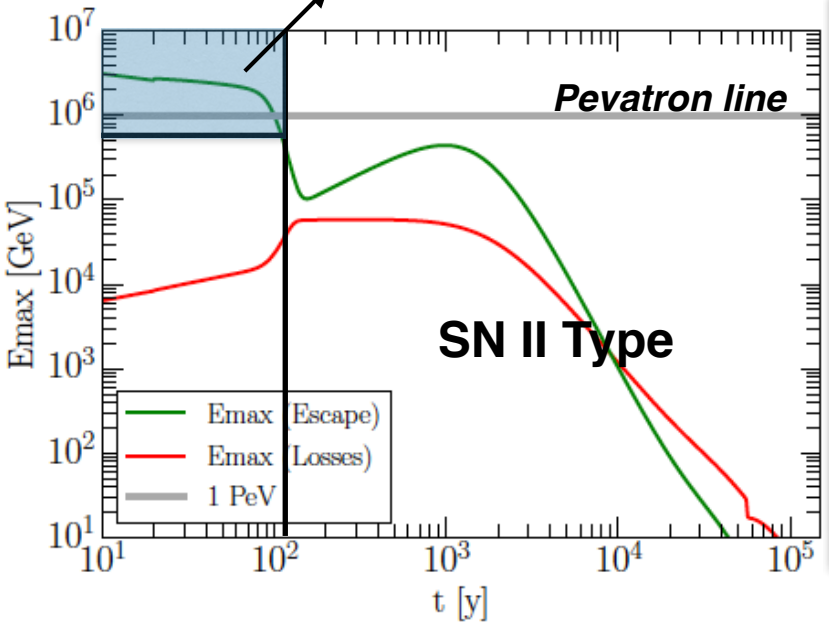


With more than 500 years inverse Compton component becomes dominant respect to the pion decay

Gaggero et al. MNRAS2017



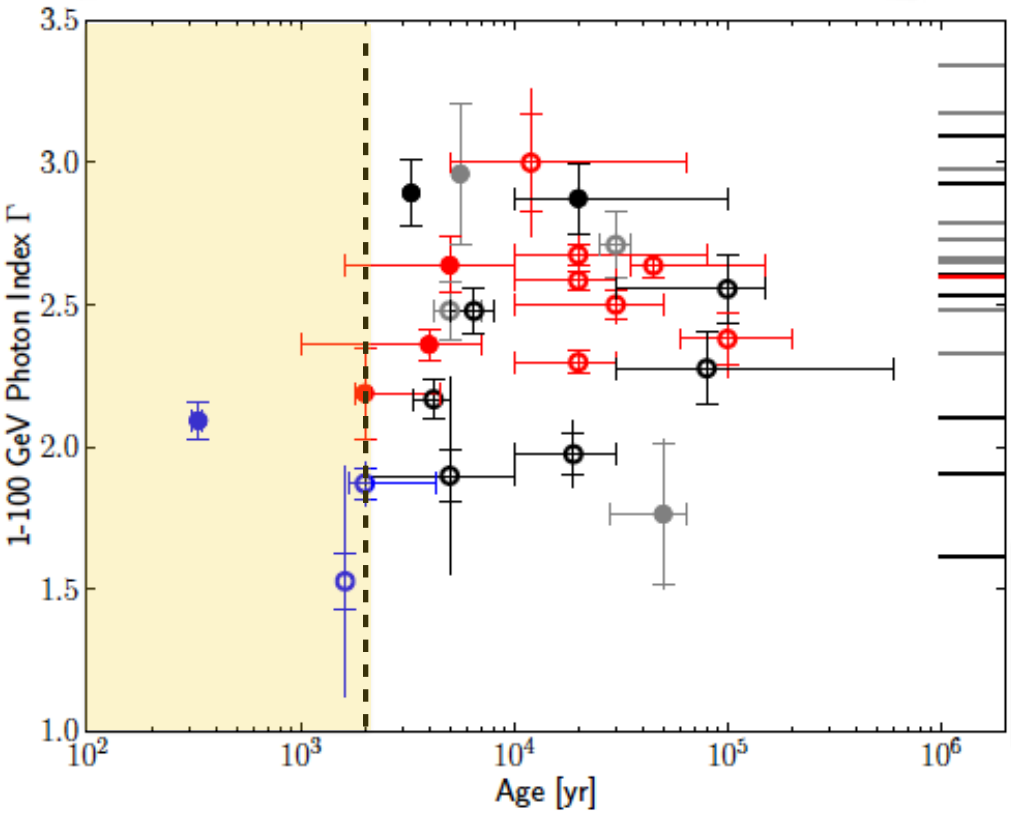
VHE neutrino production



Possibility to observe SNR as a point -like neutrino emitters only with a SNR life < hundreds of years

Restricting the sample of SNRs visible as a point-like ν

Fermi-LAT Coll. APJ 2016



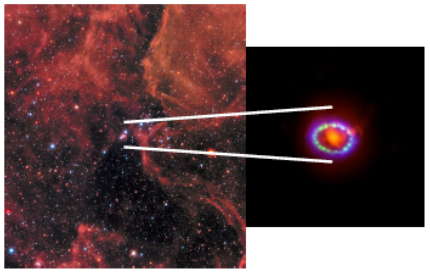
If we want the emission confined around 1° of the SNR (point-like searches) we can roughly consider the time of Pevatron phase (oreden~ hundred years) plus the the proton diffusion around (~100 pc) the source that correspond to:

t_diff (E) ~ 1.500 years
(L/ 100 pc)^2 (E / 1 PeV)^ (- 1/3)

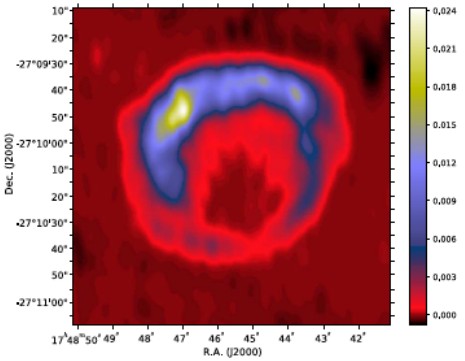
With these considerations the number of SNR good candidates for a point-like neutrino searches can be reduced

Looking to the age of SNRs to select point-like ν emitters

The young remnants



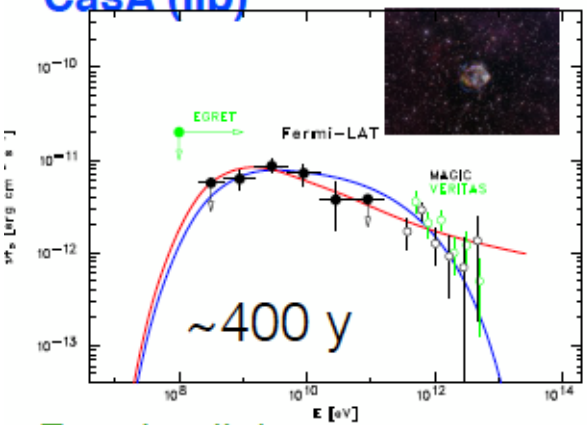
SN1987A:
the youngest remnant in the Local Group, 50 kpc, projenitor: blu spupergiant



G1.9+03
The youngest remnant in our Galaxy (~100) located in the GC region

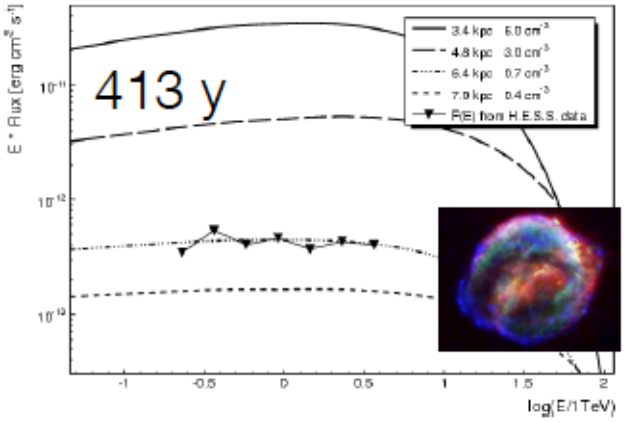
Middle-aged remnants:

CasA (IIb):

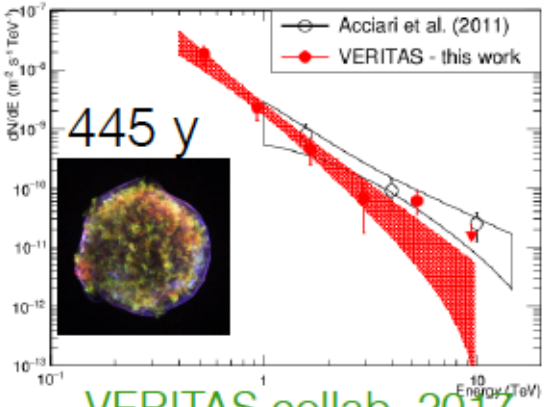


Fermi collab. 2010

Kepler SN 1604 (Ia):



Tycho SN 1572 (Ia):



VERITAS collab. 2017

Should we concentrate only on these kind of SNRs to see the point-like hadronic emission?

SUMMARY

- The total diffuse ν Galactic component seems to be limited (ANTARES + IceCube ULs) at the level of the 10% of the full sky astrophysical ν flux.

- The massive Galactic molecular clouds need more observational time to be observed by IceCube and the arrival of KM3NeT, however CMZ should be visible soon.

- Small chances to observe ν emission from the Fermi Bubbles after the ULs set by HAWC observatory, however if the low latitude Bubbles emission will be confirmed the optimism arise.

- The catalog of most promising SNRs to be observed as a point-like TeV ν emitters should be revised if we consider the duration of the Pevatron phase and the escaping time.