Searching for Galactic neutrino emissions with ANTARES and KM3NeT

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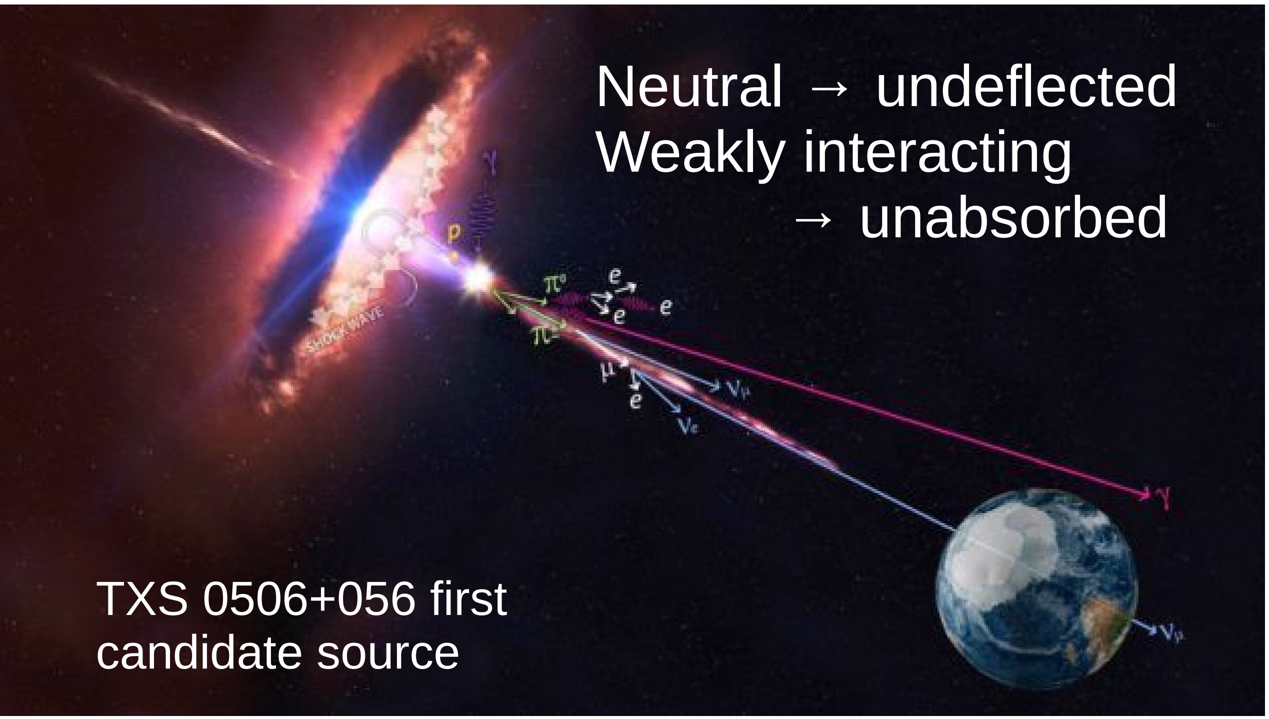
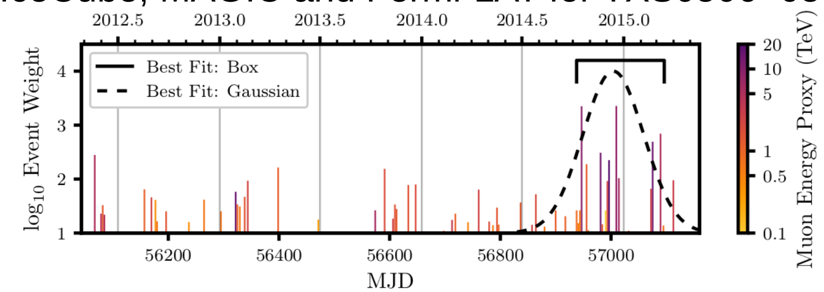
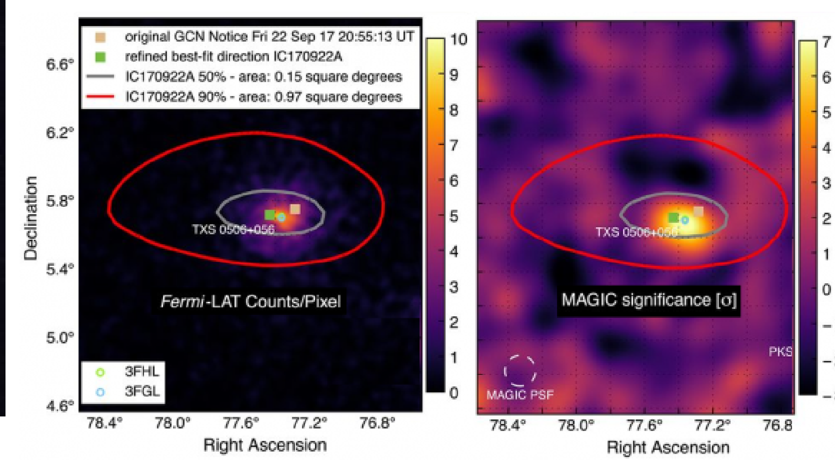
on behalf of the ANTARES and KM3NeT Collaborations

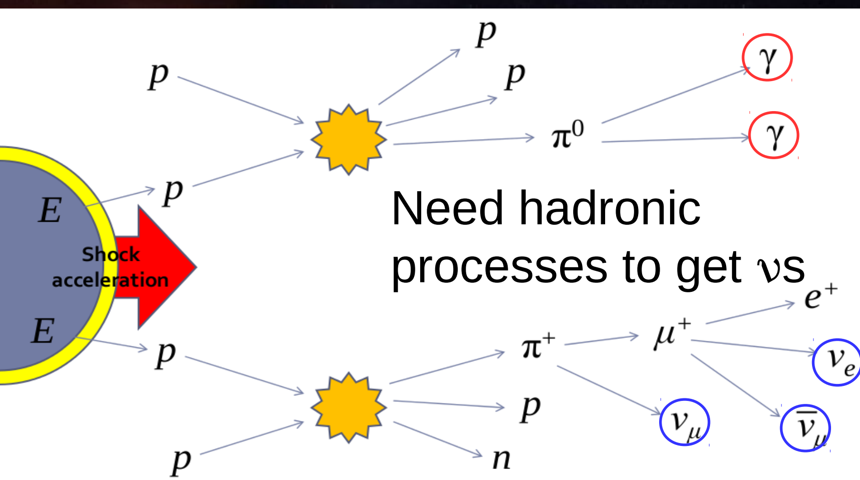
Neutrino astronomy in a nutshell



IceCube, MAGIC and Fermi-LAT for TXS0506+056







γ-ν connection in a multi-messenger/wavelength context

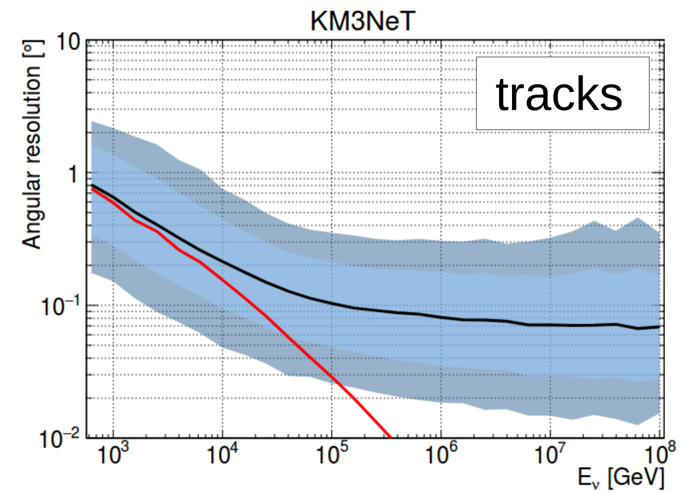
ANTARES & KM3NeT

Neutrino telescopes (under the sea*): *how-to*

- Large interaction volume
- Transparent medium
- Large number of optical sensors
- Precision measurement of the detected photons
- Large overburden (+ the Earth, just in case)
- Collect the data

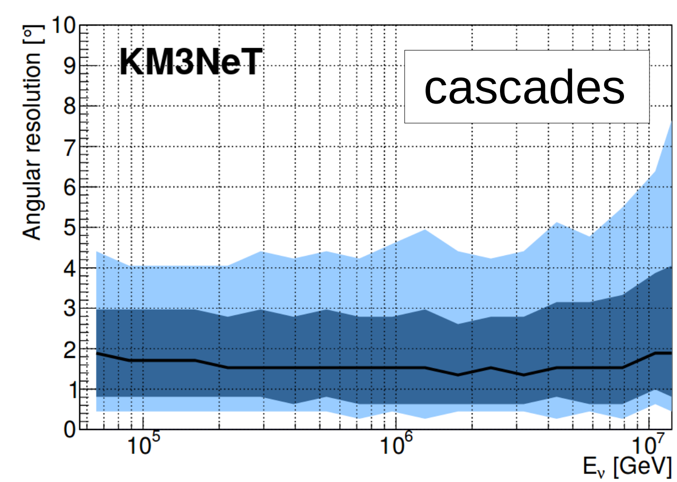
*Well, that's the same as in ice

Why a km³ neutrino telescope in the sea/underwater?



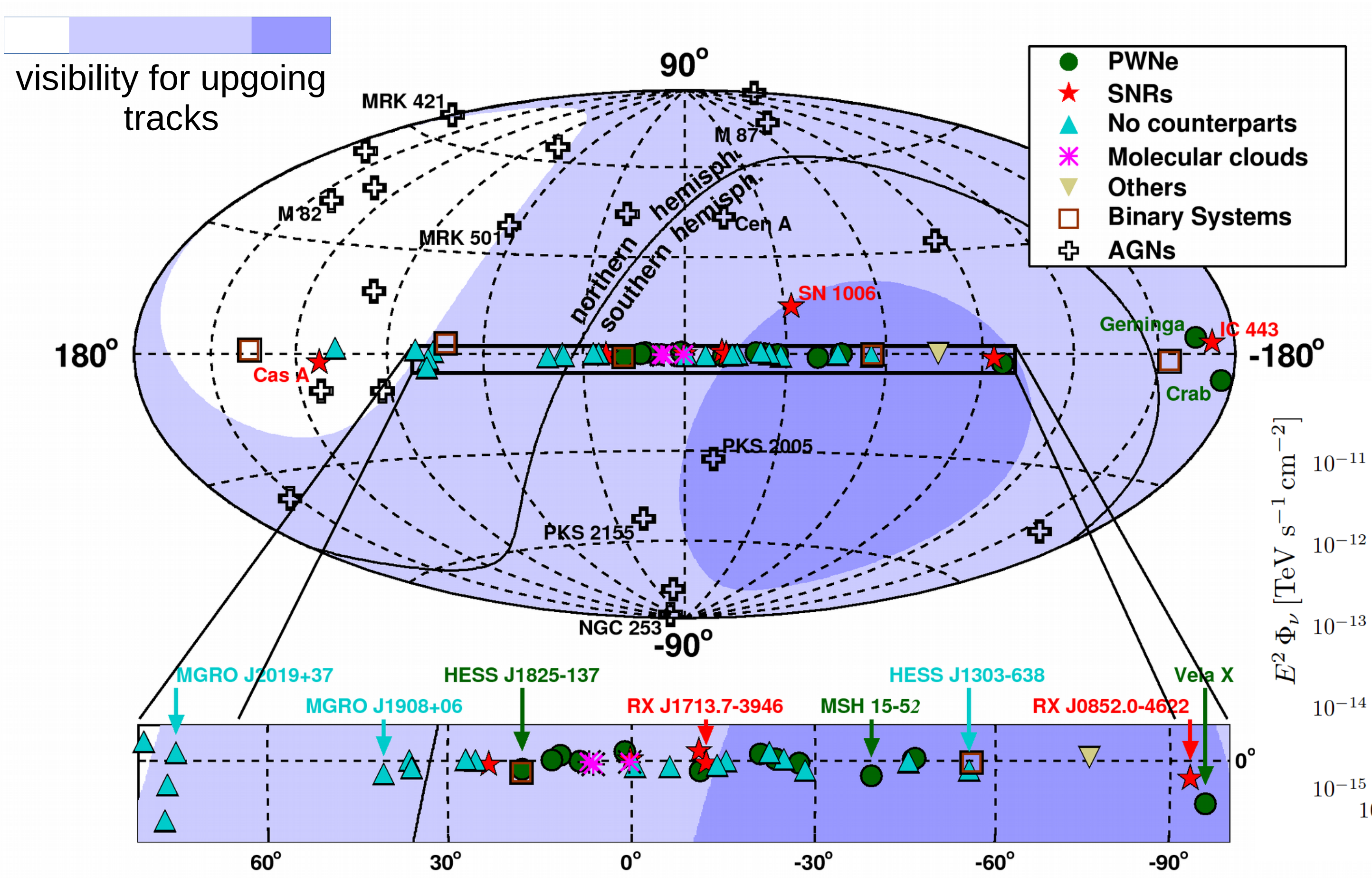
- Water is optimal for light
  - Limited scattering → direct photons
  - Homogeneous medium → easy sim

  → angular reconstruction accuracy
- Large depth accessible
  - Limit the CR-induced backgrounds

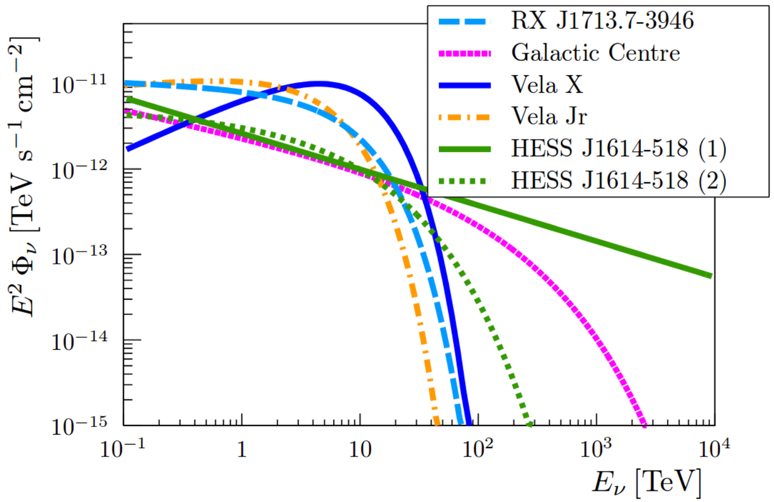


- Drawbacks: optical backgrounds
  - K40 (if salty) and biological → all-data to shore and filtering

Why a km³ neutrino telescope in the Mediterranean Sea/North?



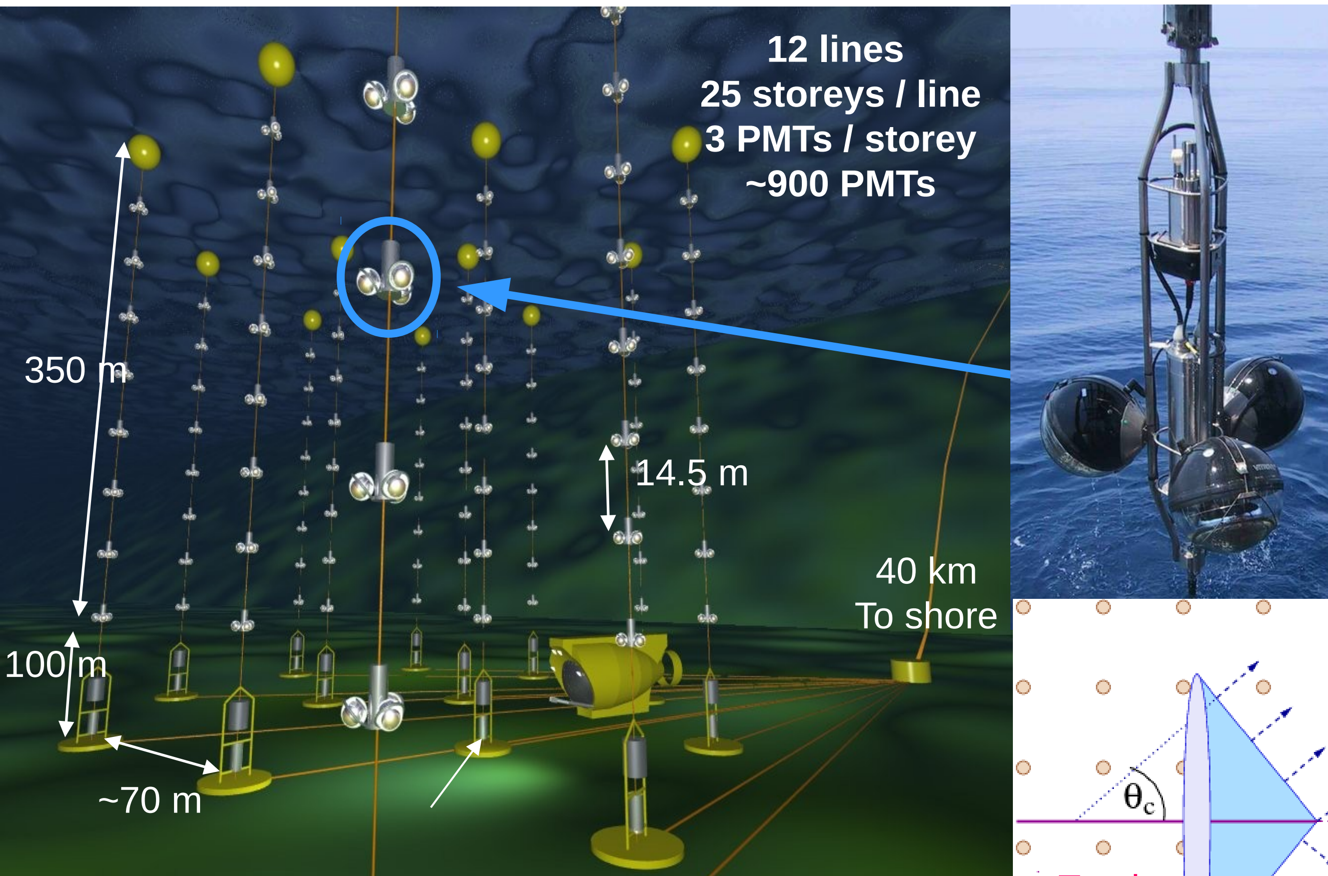
High visibility with 0.1-0.4° angular resolution



Soft spectra from γ obs.
→ lowE threshold analysis

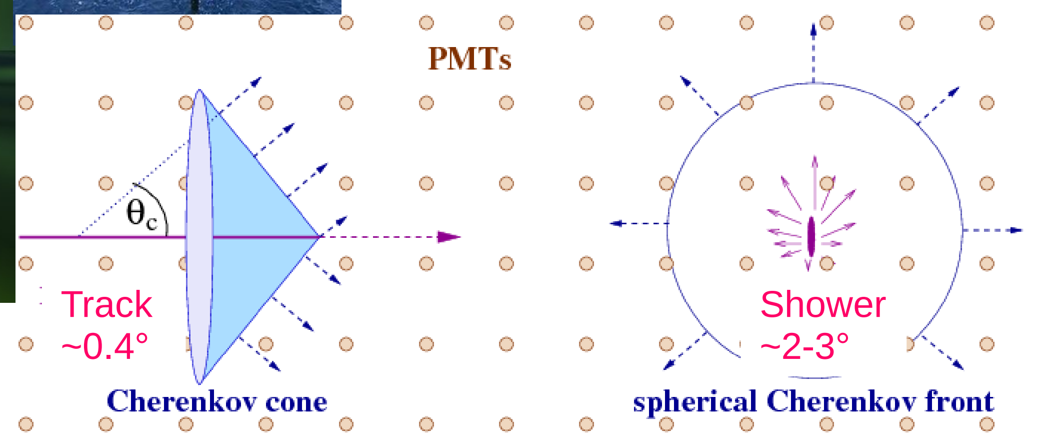
NIMA **656,1**: 11-38, 2011

The ANTARES detector



Cherenkov photons produced by the ν interaction products

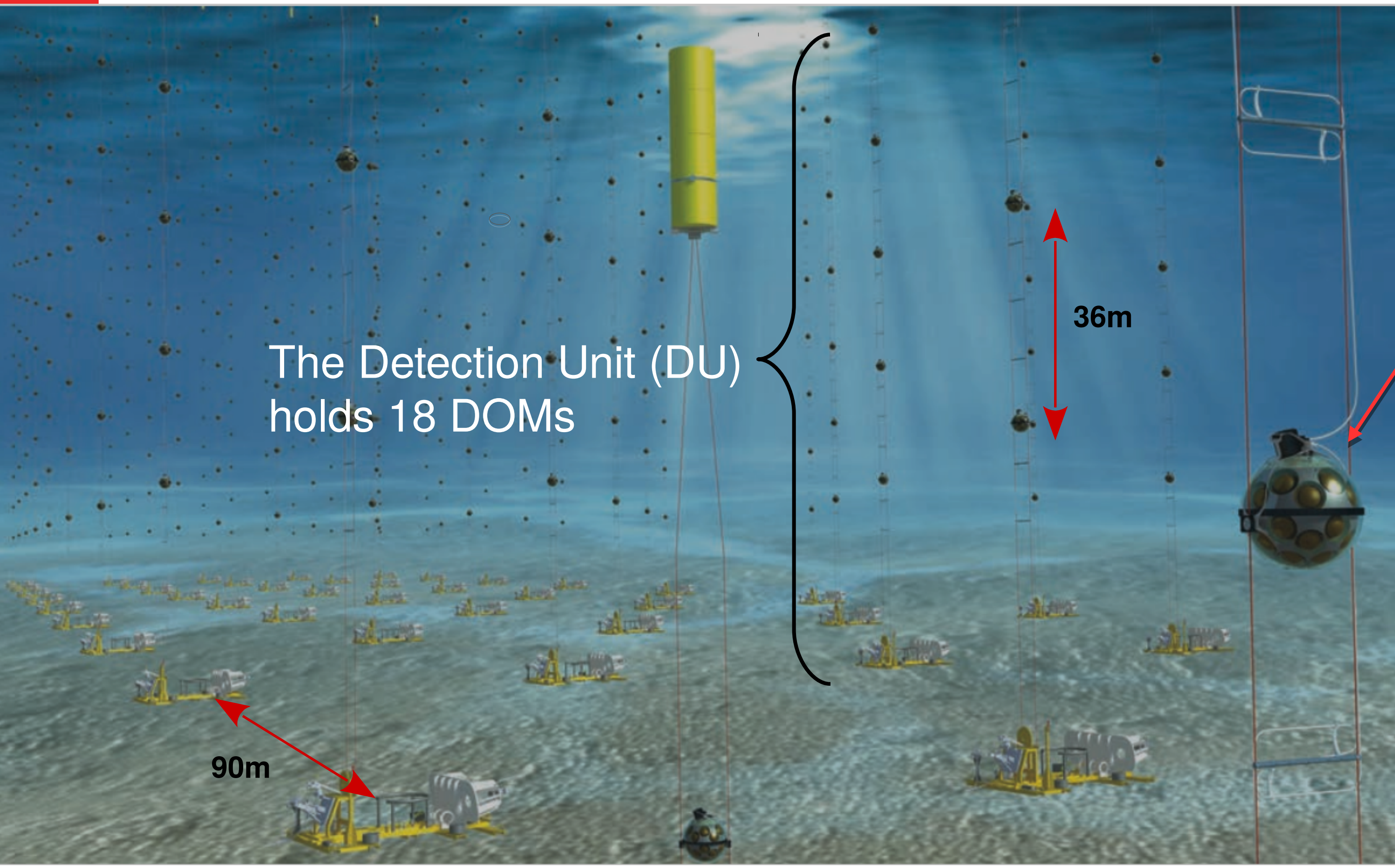
3D array of PMTs in a large volume of water to detect them and reconstruct the event



2.5 km depth, 40km off-shore Toulon
10 Mton instrumented volume

Journal of Physics G
43 (8): 084001, 2016

The KM3NeT/ARCA detector

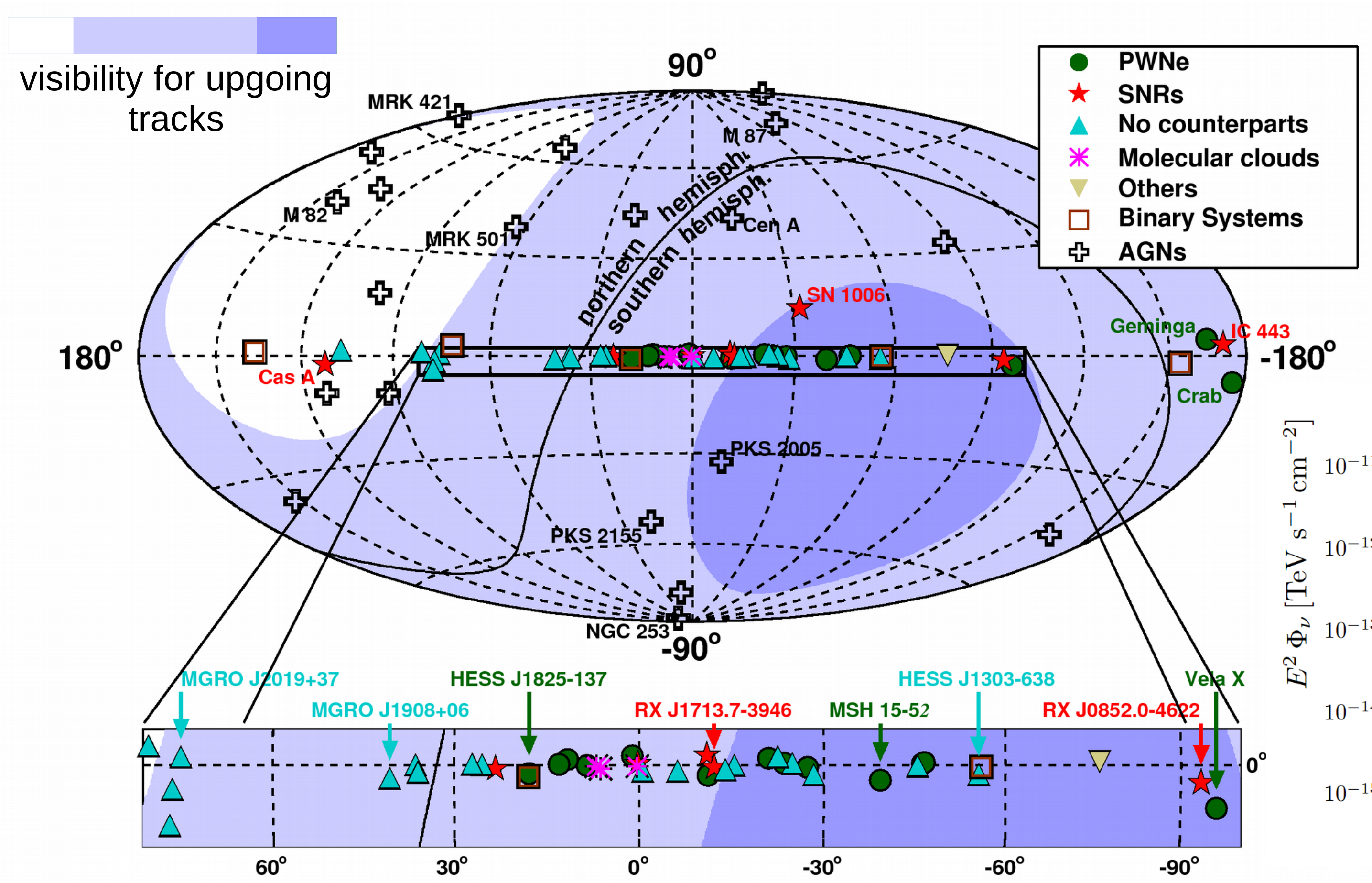


The optical sensor: Digital Optical Module (DOM). Each DOM comprises 31 3'' PMTs

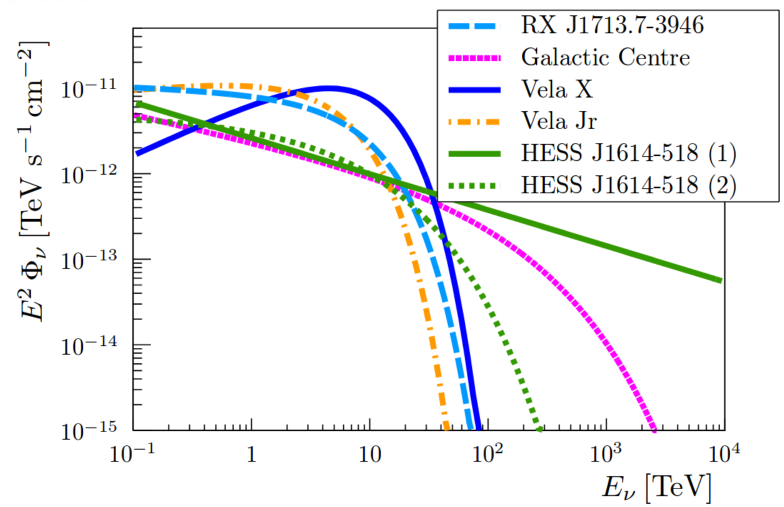
2 Building blocks, 115 DU each, will constitute ARCA → ~km³ instrumented volume

Unprecedented reconstruction performances
~0.1° for tracks, ~2° for showers

Then, what to search for?



High visibility with 0.1-0.4° angular resolution



Soft spectra from γ obs.
→ lowE threshold analysis

Phys.Rev. D **96** no.8: 082001 (2017)

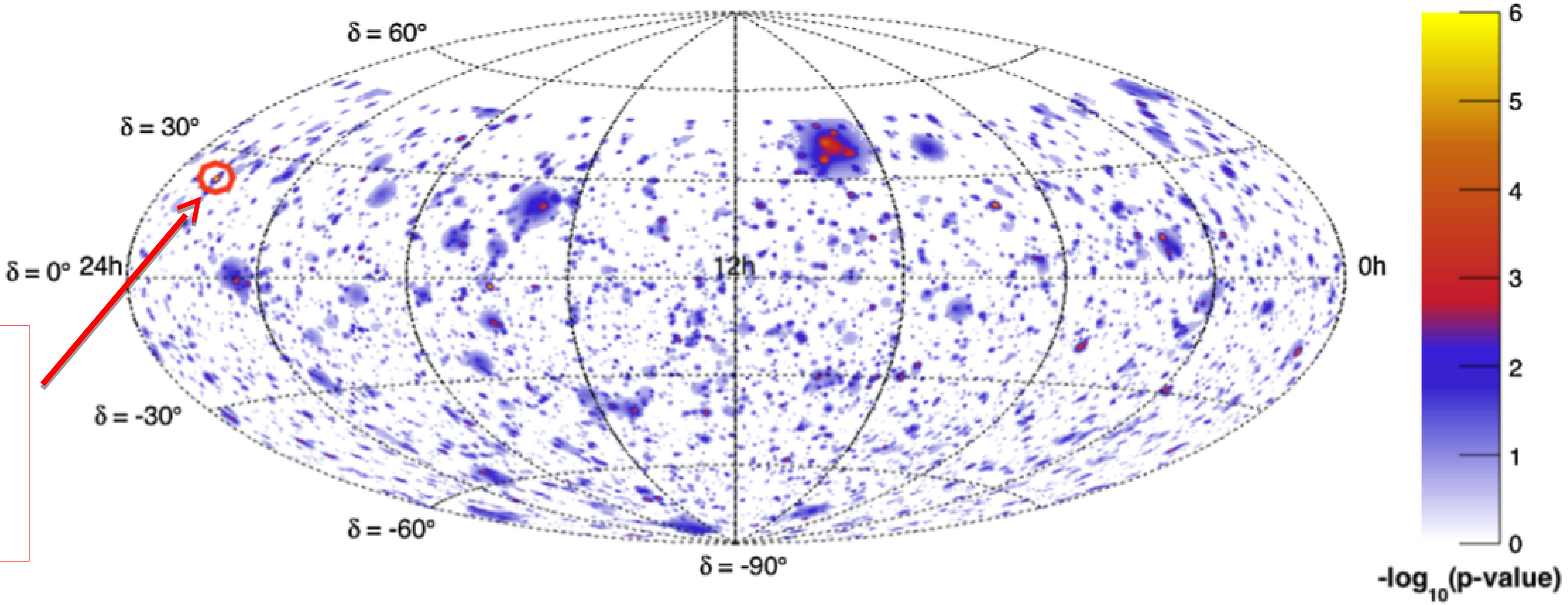
ANTARES point source searches

2007-2015 ANTARES dataset, all neutrino flavours

9yr data set, 7622 tracks + 180 showers

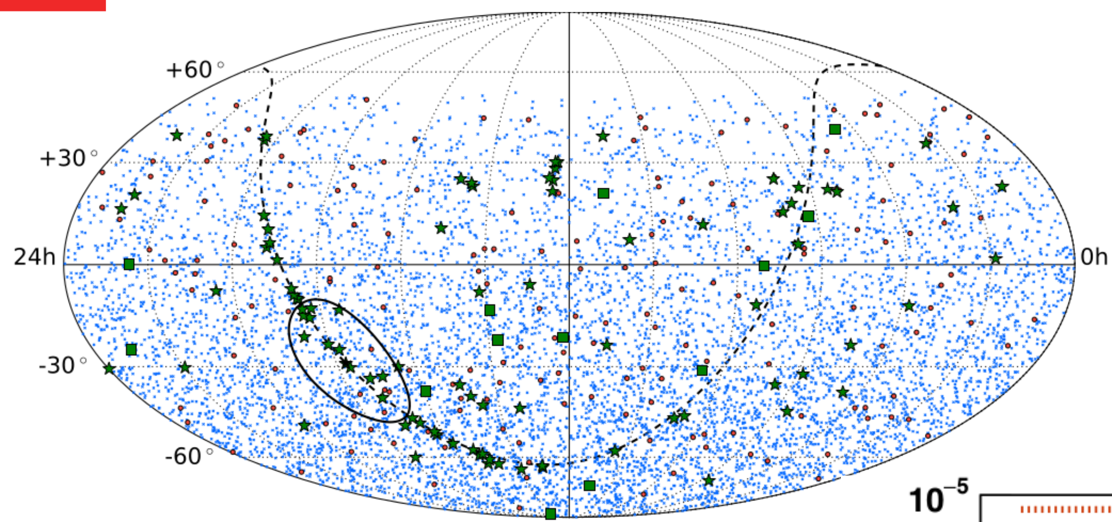
1°x 1° grid search over the full sky, no source assumption

Search for time-integrated clustering of neutrino events



δ = 23.50°
α = 343.80°
most significant cluster (1.9 σ)

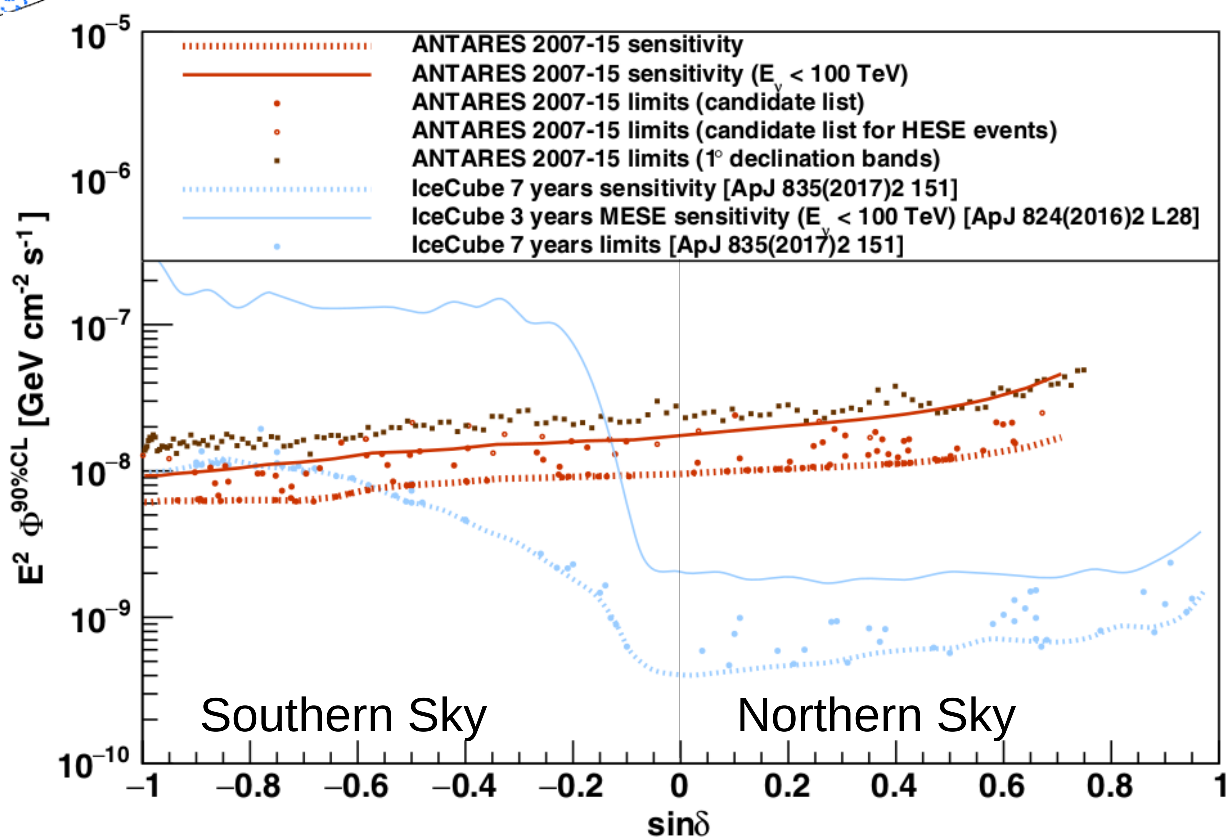
ANTARES point source searches



- Tracks (7622)
- Showers (180)
- Candidate source
- IC tracks

Max. likelihood search for clustering of neutrinos around:

TeV gamma-sources (106)
IceCube tracks (13)
GC region

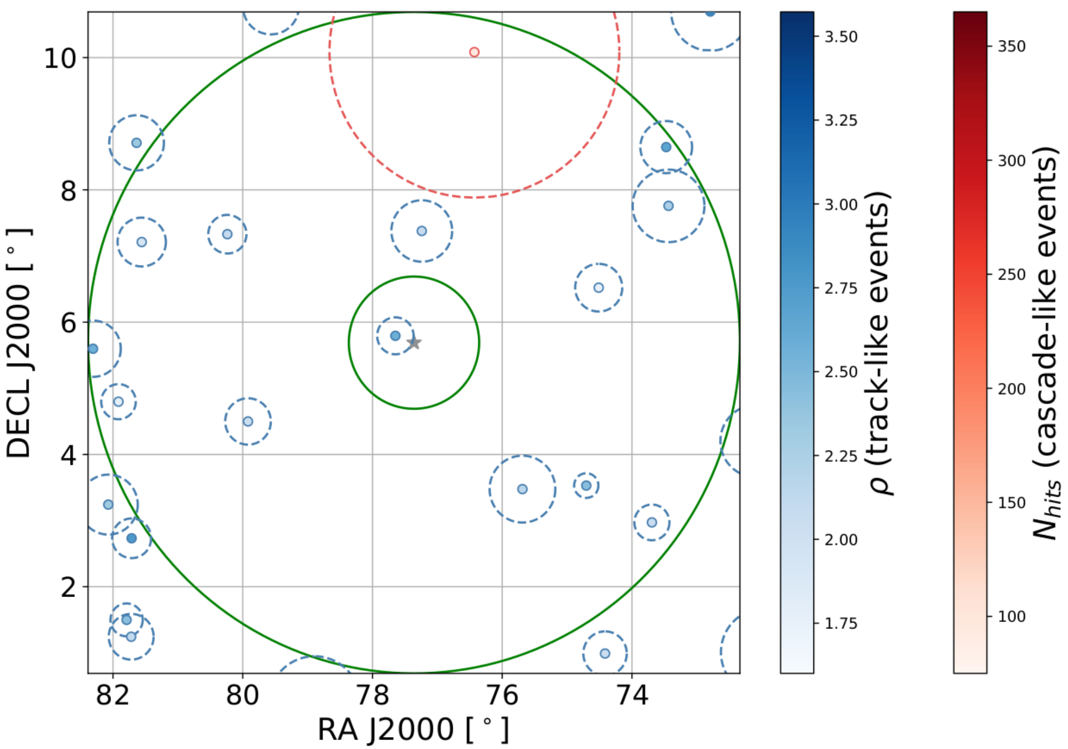


No excess observed
ANTARES best for low declination
or soft spectra South
or 100 TeV-ish cutoff South

APJ. Lett. **863** no.2: L30, 2018

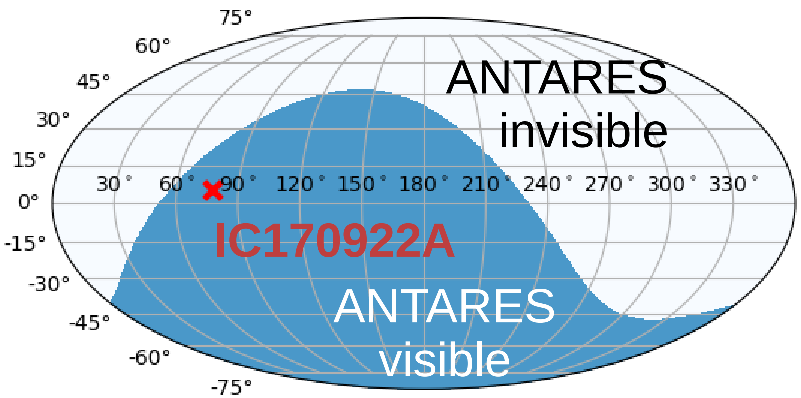
Intermezzo: TXS0506+056

Offline analysis (2007-2017)



1.03 signal-like events fitted → p-value = 3.4% (pre-trial)

3[rd] most significant candidate out of 107*

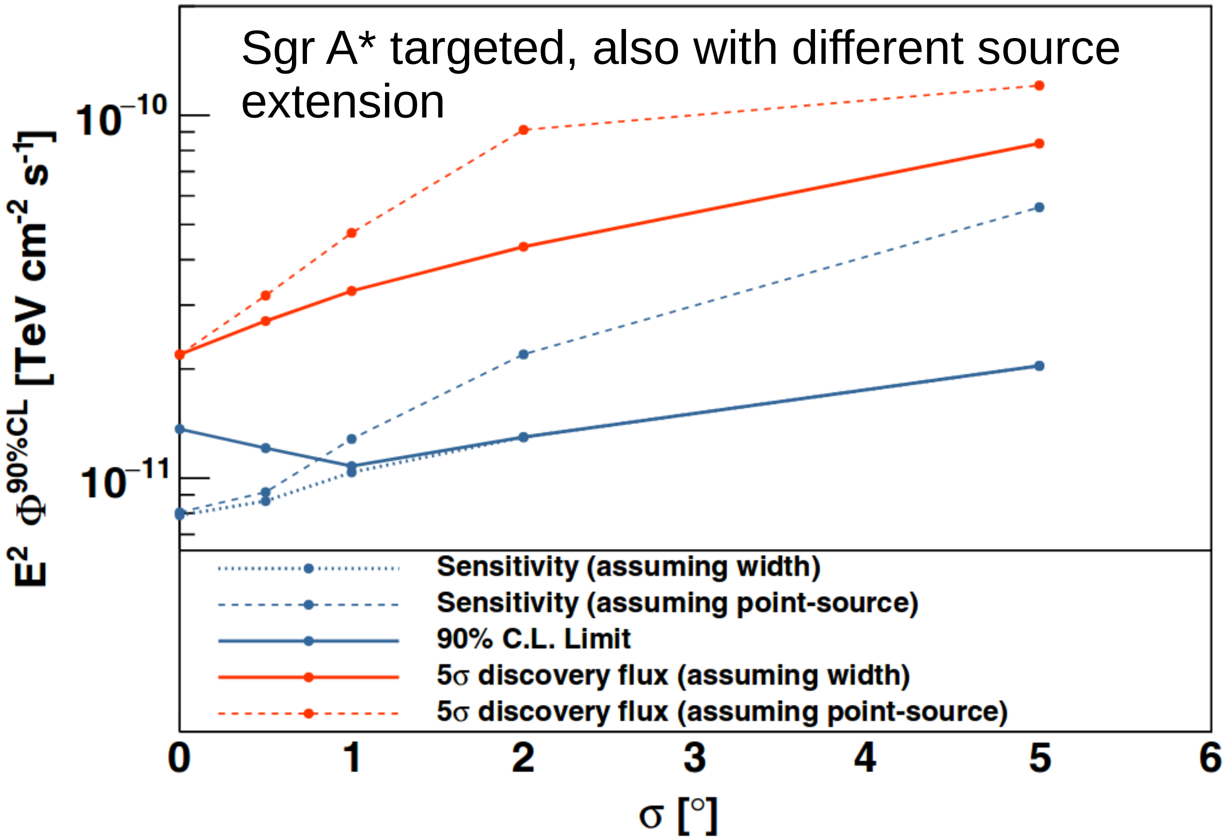


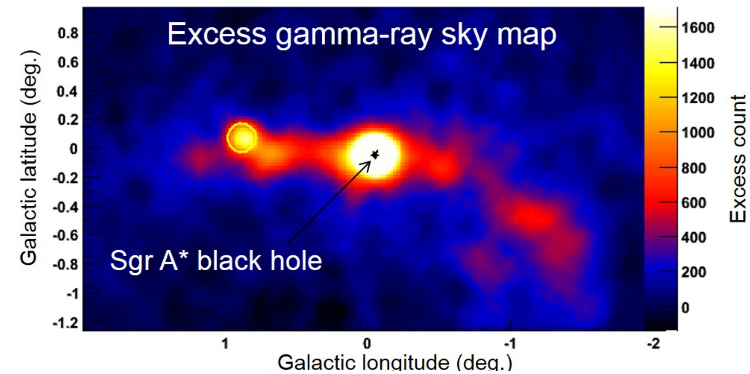
Online data-stream analysis
→ no coincident event
ATEL #10773 released by ANTARES the following day

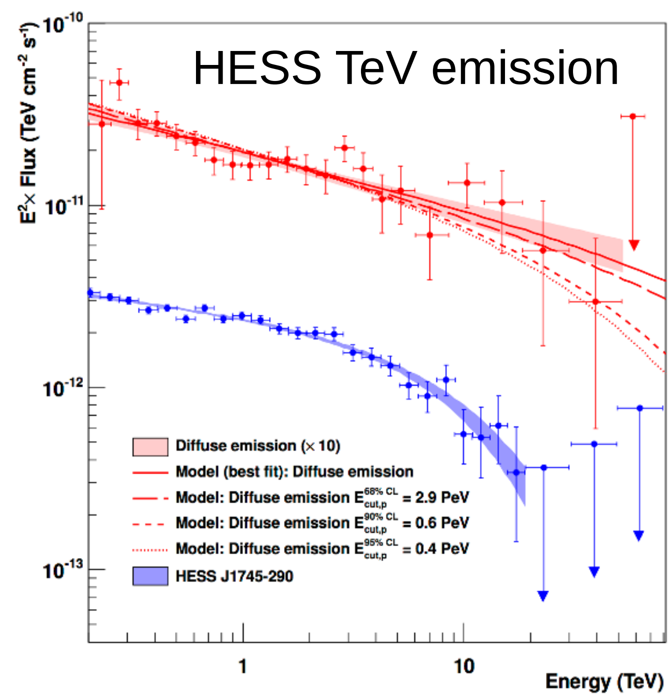
+ time dependent search for space-time clustering with the IC neutrino flare – no excess observed

* off the published 2007-2015 analysis; 87% post-trial

ANTARES Galactic Centre region



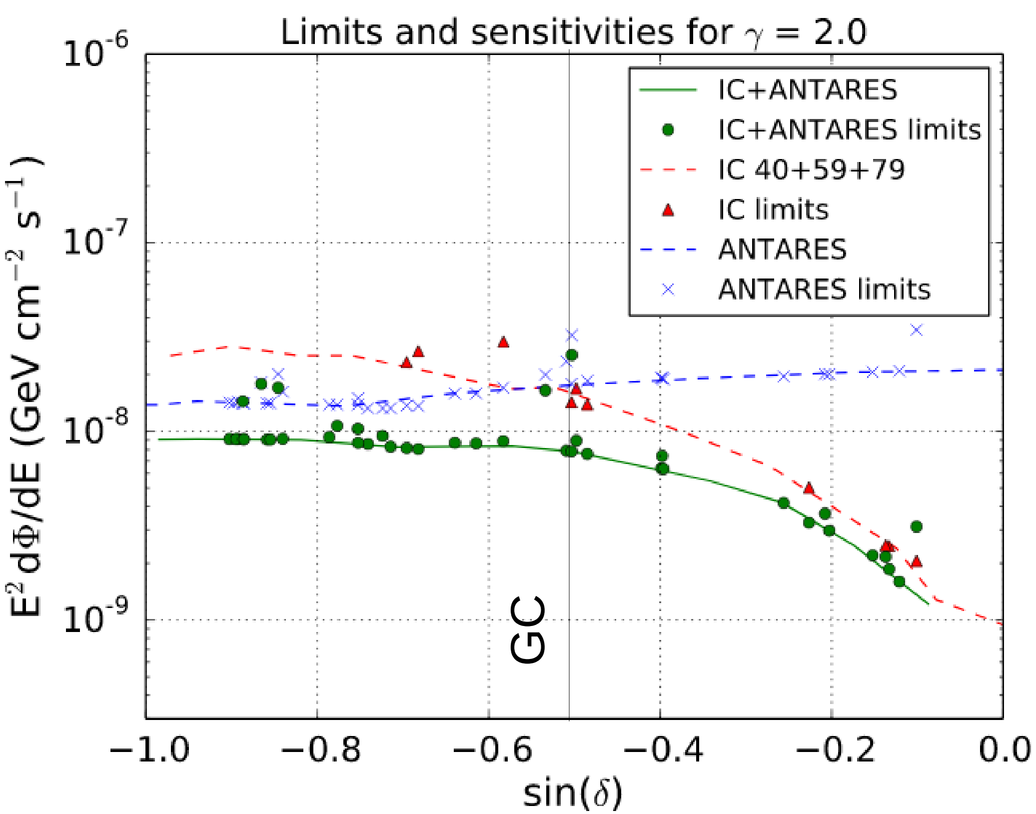


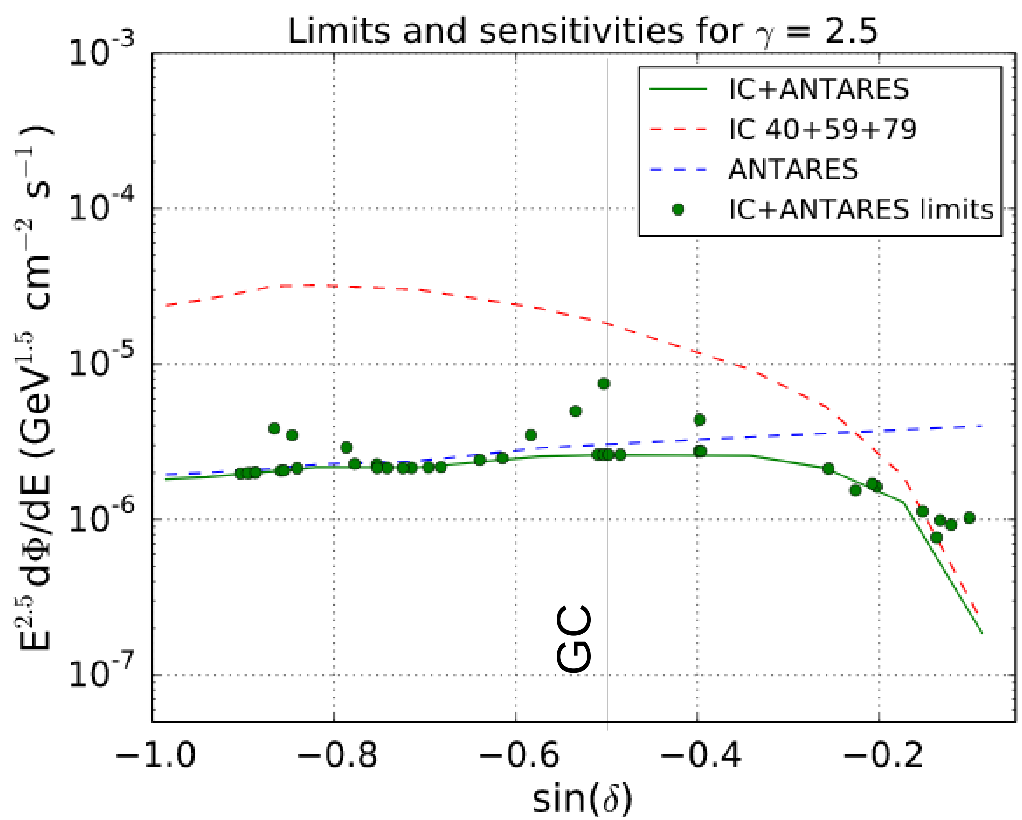


Still way above the HE gamma observations

ANTARES + IceCube (Ep.1 point-like sources)

No excess observed in the Southern Sky



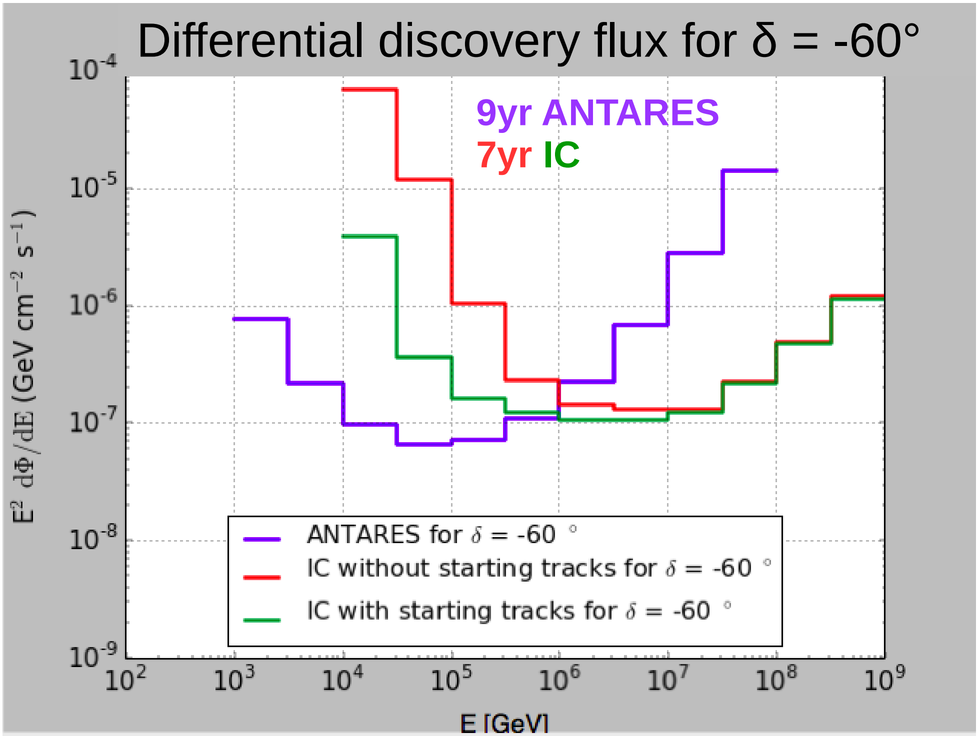


Limits and sensitivity for individual analyses (**ANTARES** and **IceCube**) and **combination**

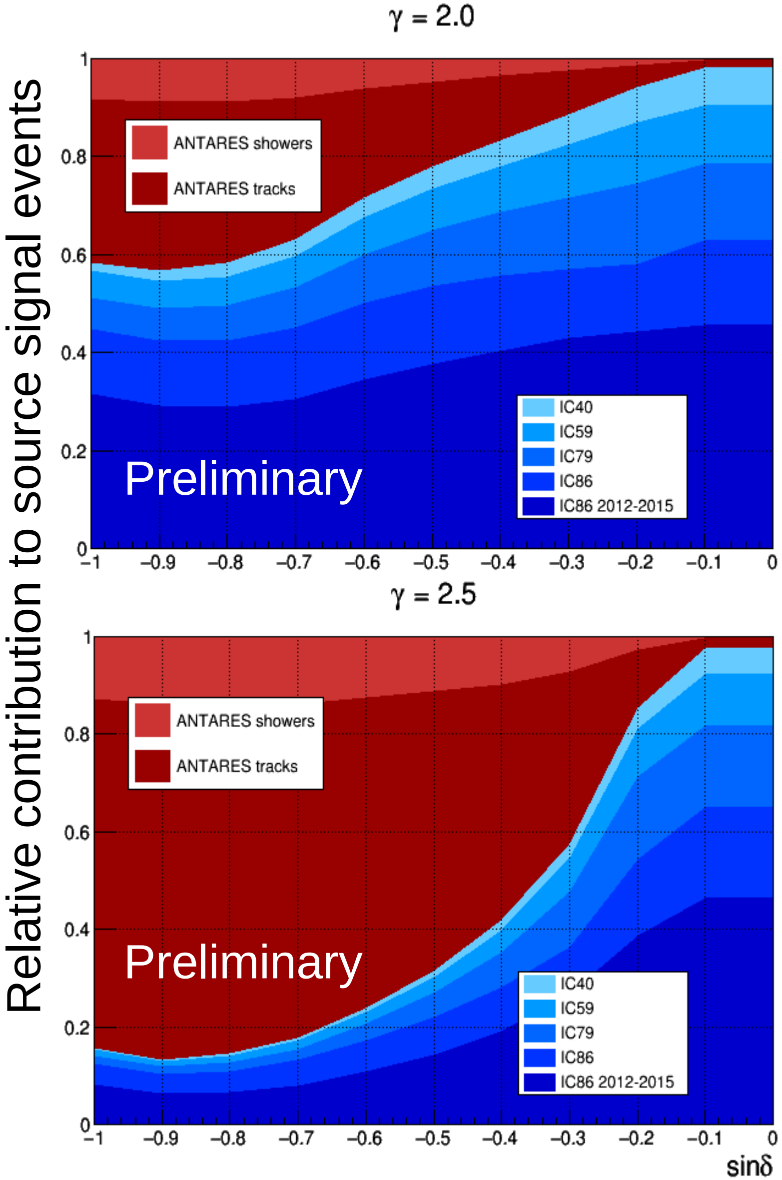
Analysis being updated now for new data samples

Astrophys. J. **823**: 65, 2016

ANTARES + IceCube (Ep.1 point-like sources)

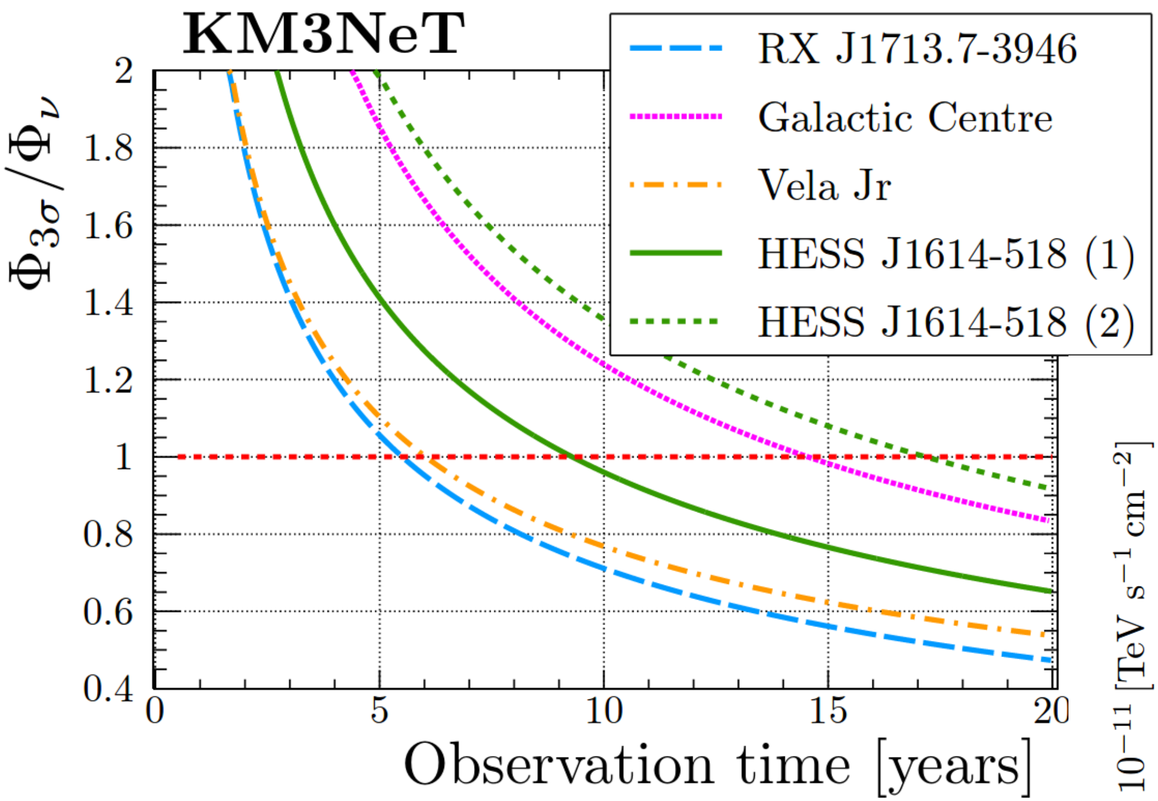


ANTARES relevant for negative declinations and low-energy emissions



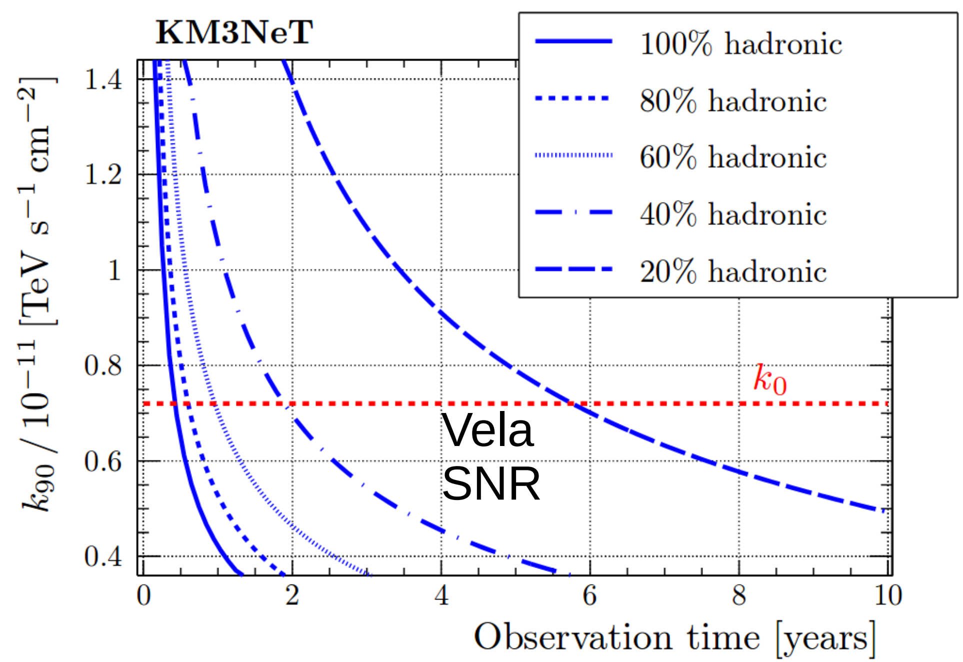
arXiv:1810.08499

KM3NeT/ARCA perspectives

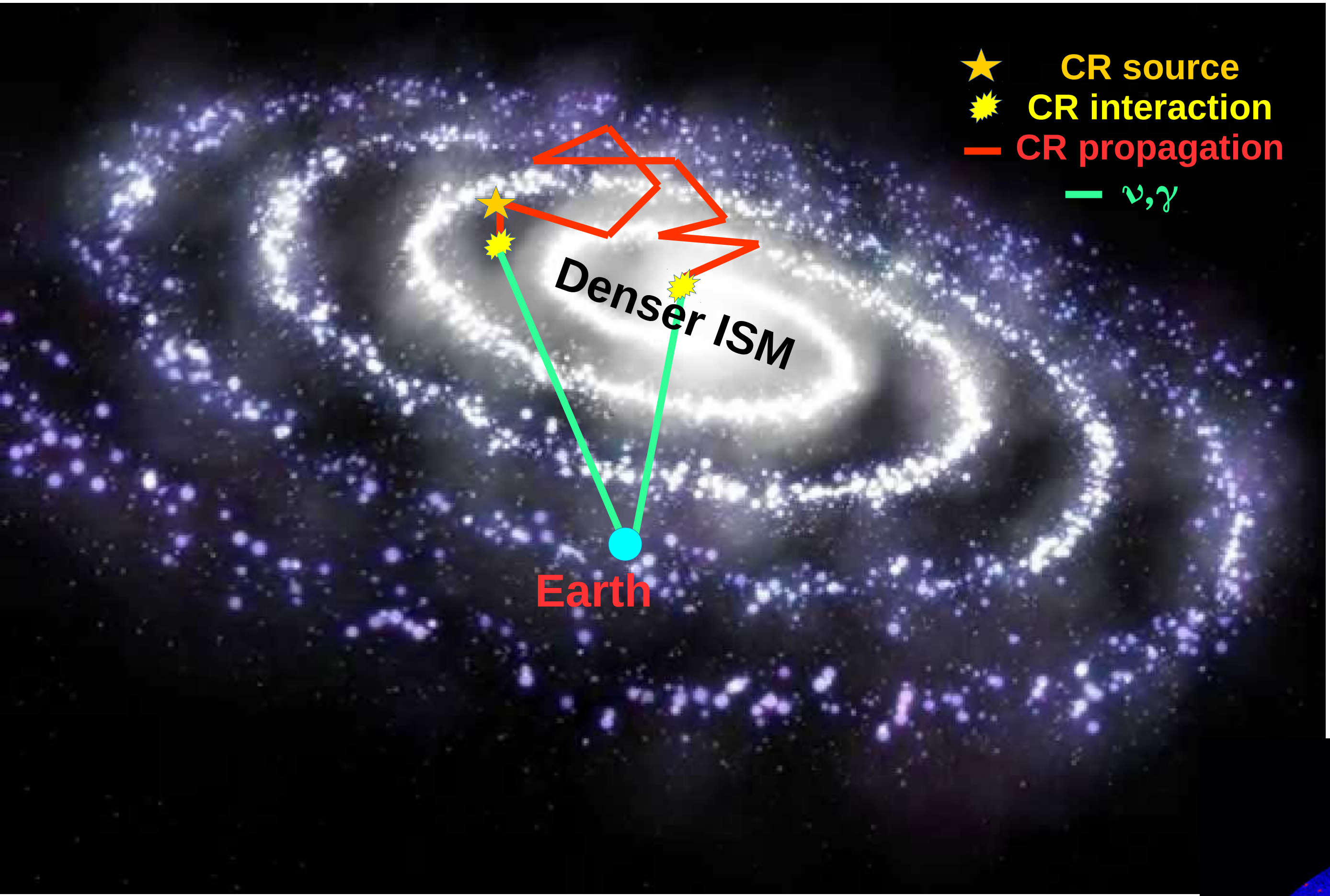


Discovery potential for potential Galactic targets

If no neutrino observation → constrain the hadronic component



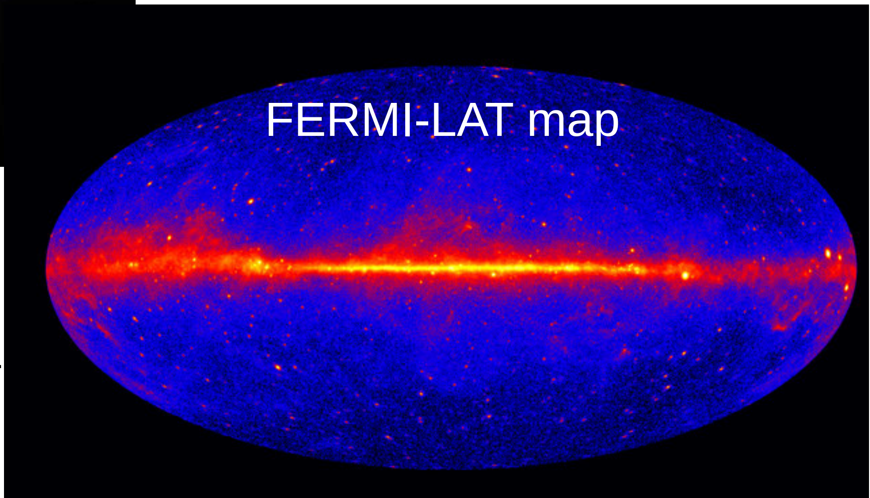
γ and ν: CR propagation in the Milky Way



Neutrinos carry direct information on CR propagation. e.g.:

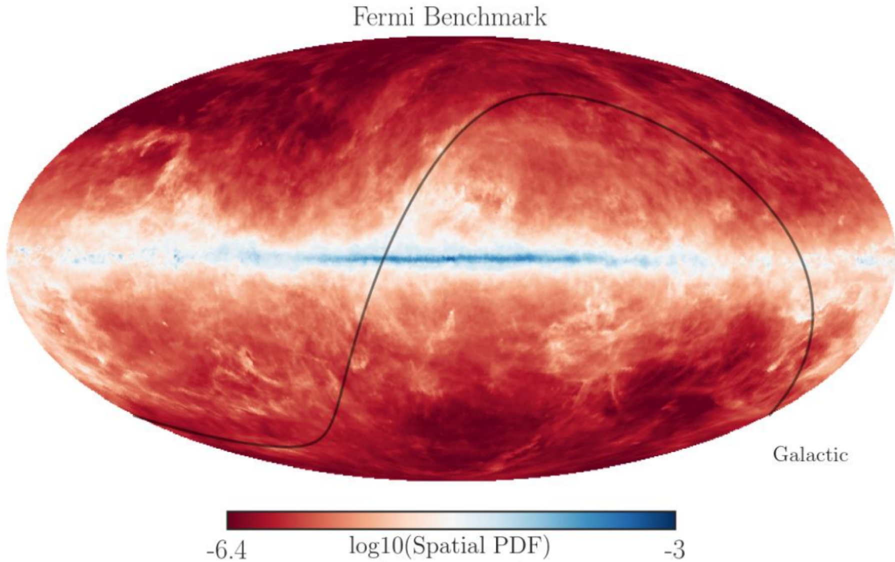
- Non-homogeneous diffusion can enhance γ and ν emission

- Molecular clouds/dense environments boost γ and ν fluxes



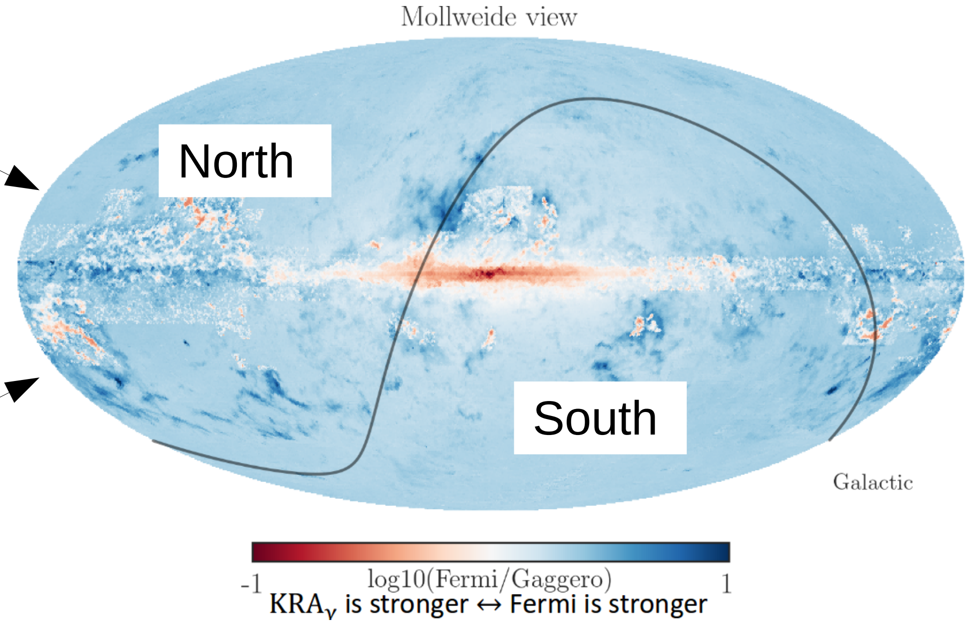
*Astrophys.J., **750:** 3, 2012
APJLett. **815: L25, 2015

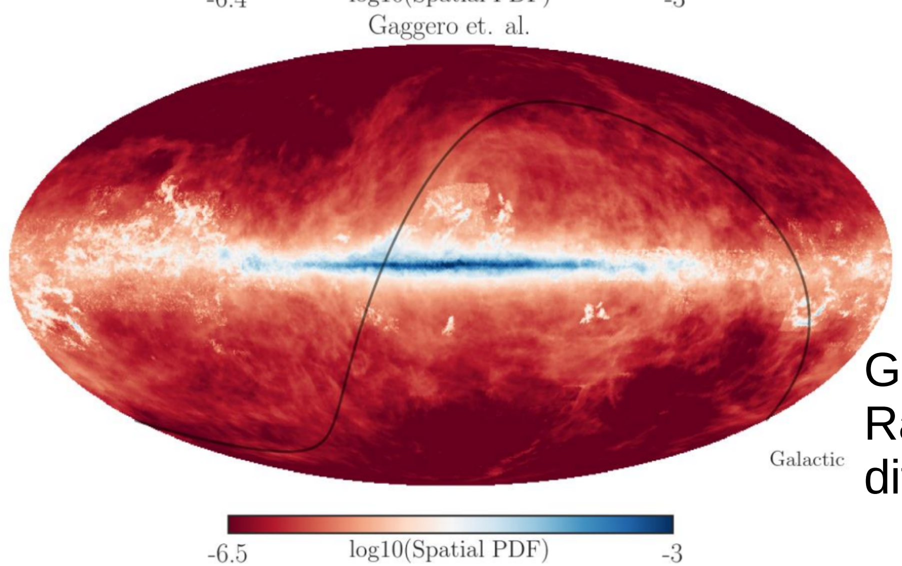
ν models from GCR and γ



Standard model*

Ratio of the two





Gaggero et al.**
Radially dependent diffusion – data tuned

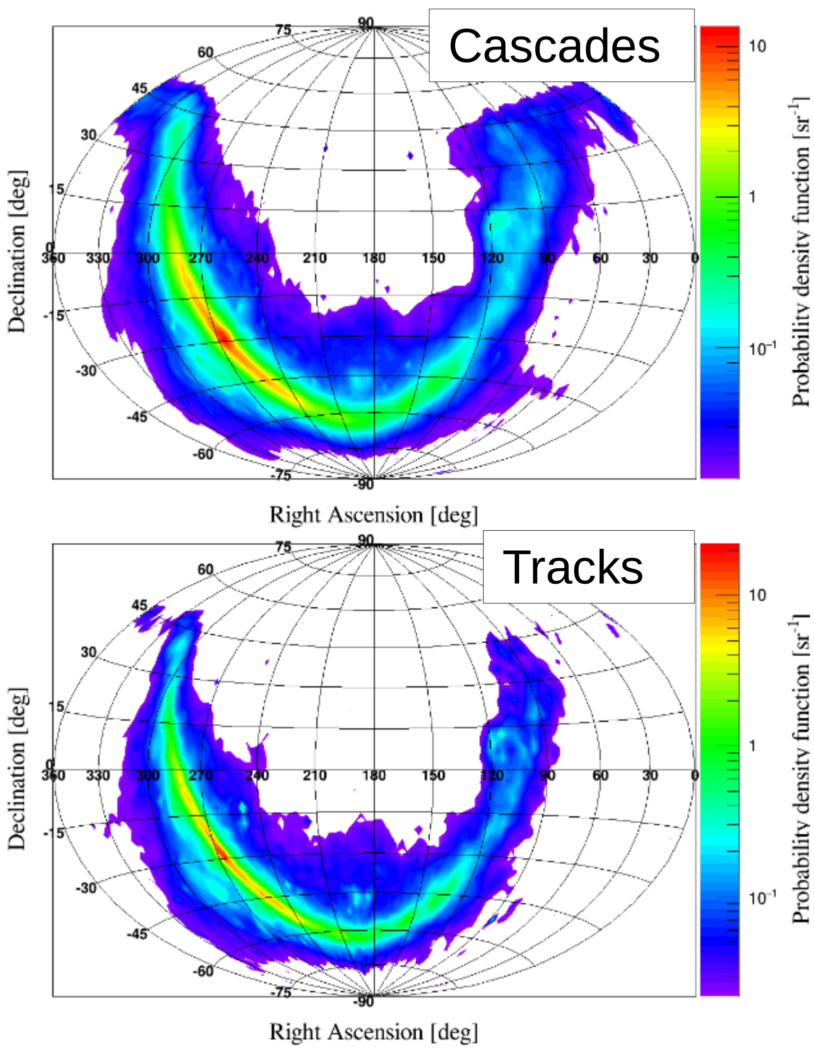
Harder/stronger in the centre
Softer/lower in the periphery
→ **different fields of view can test differently the model**

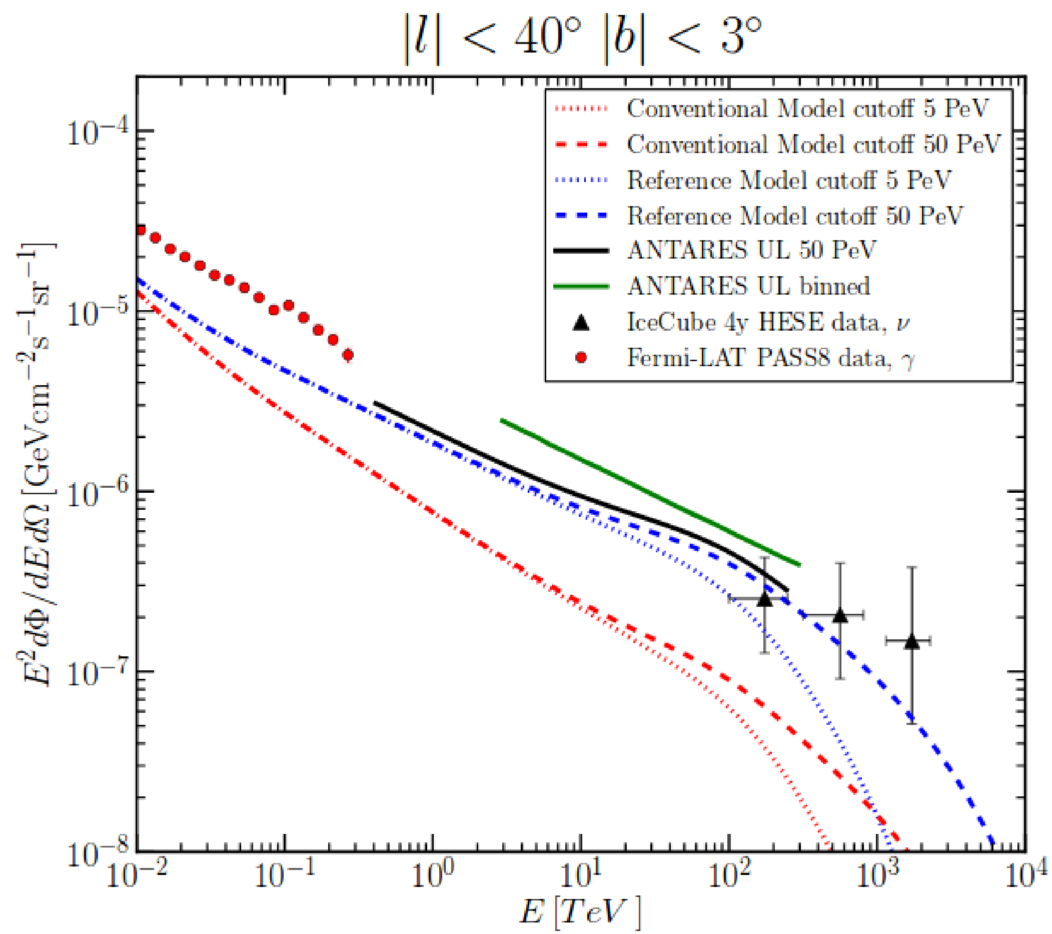
Phys. Rev. D **96**, 062001 (2017)

ANTARES Galactic Plane

Spatial and spectral information* used in a likelihood fit to the ANTARES data-set → Background-compatible observations and consequent UL~1.1-1.2 x Φ_{model}

Detector-smeared distributions

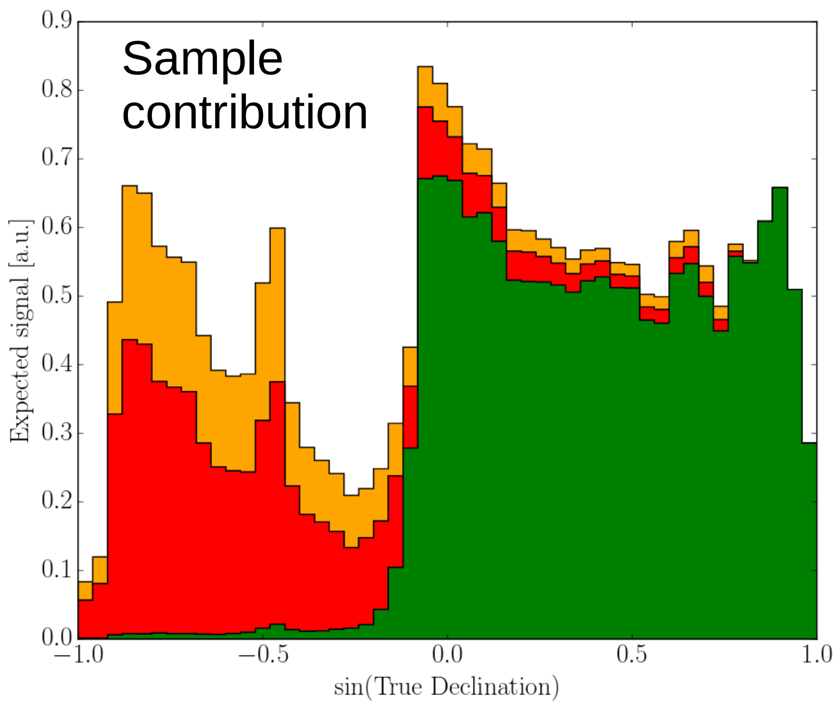




*from Gaggero et al.

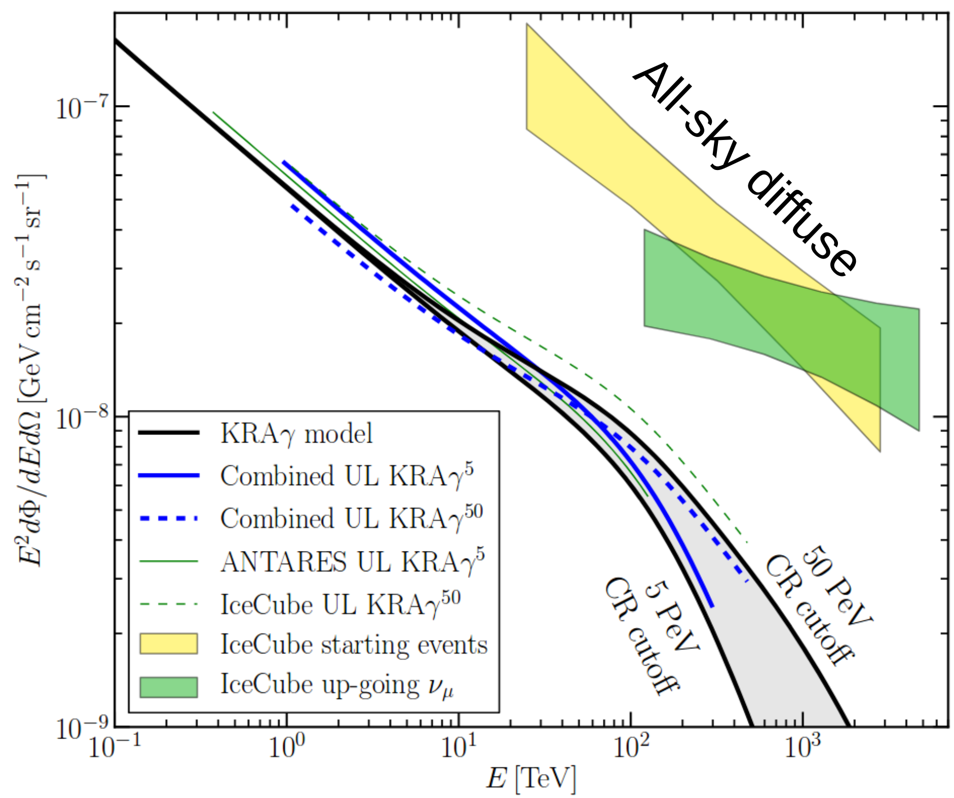
ANTARES + IceCube (Ep.2 – Galactic Plane)

Joint analysis ANTARES (**tracks** + **cascades**) and IceCube (**tracks**)



+ spectral energy distributions are different in the model

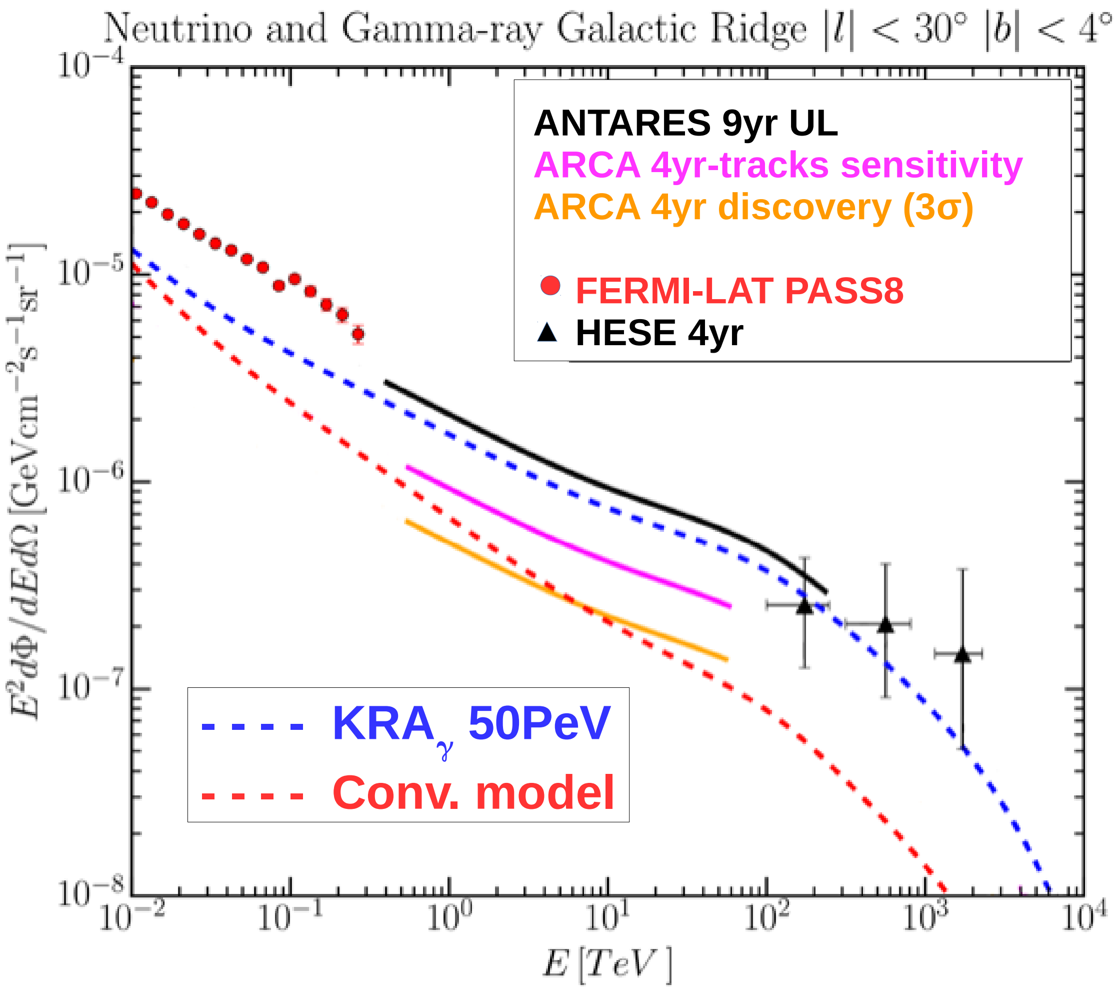
No significant excess observed

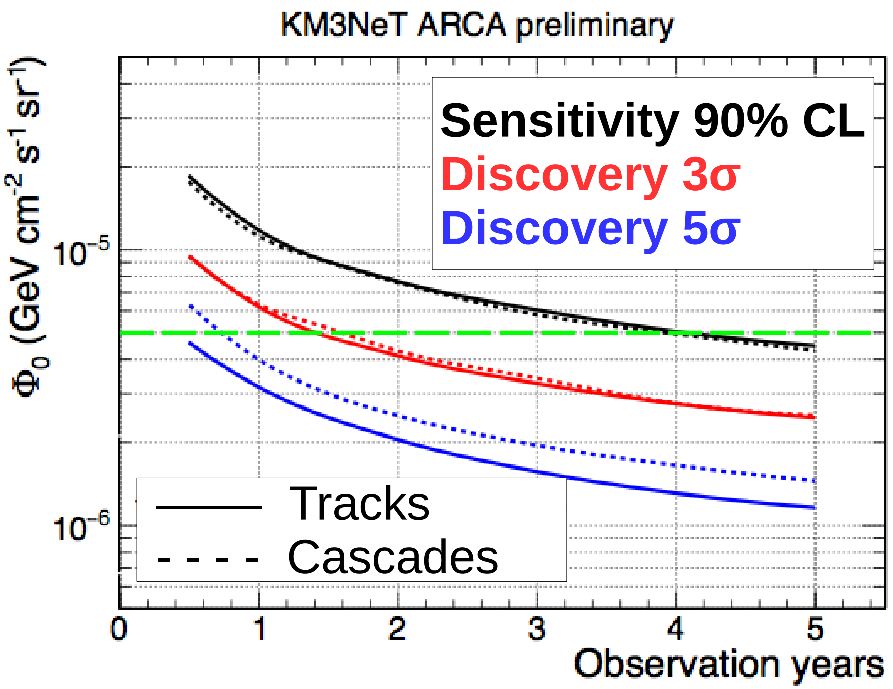


Low latitude Galactic contribution constrained to 8% of the all-sky flux

APJ Lett. **868**: L20, 2018

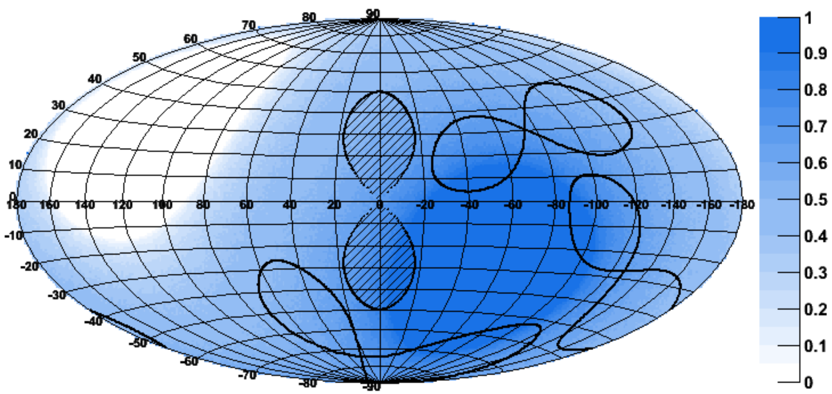
KM3NeT GP sensitivities





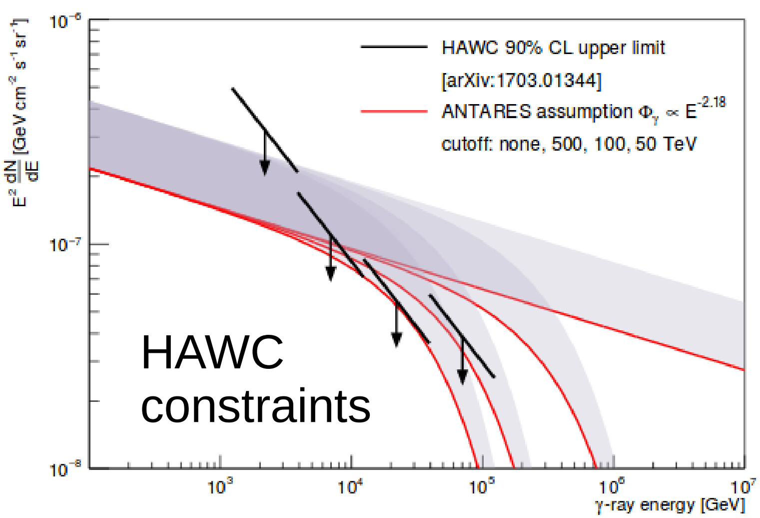
Convey information on a large range of possible fluxes

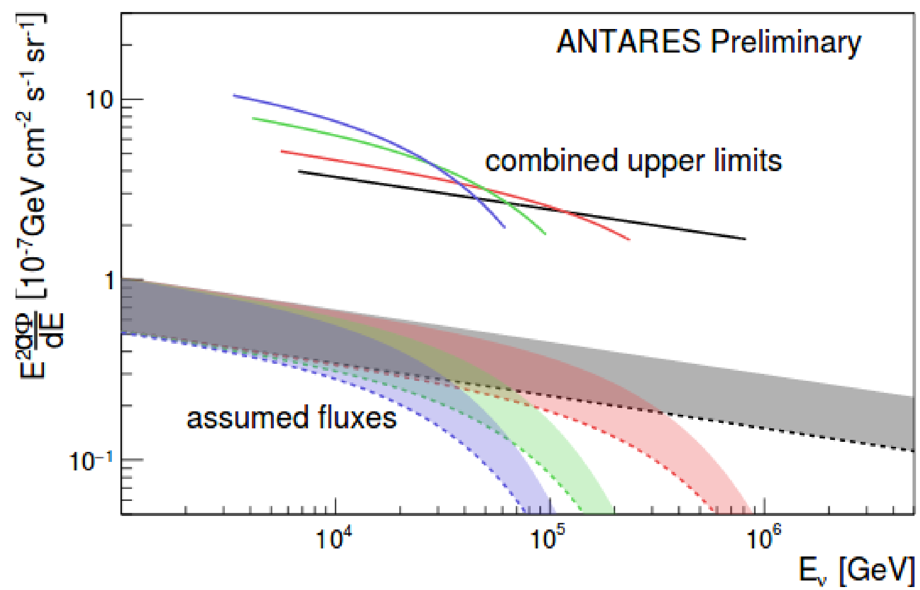
More, extended – Fermi Bubbles



Combined tracks + cascades
Search for HE events (signal ~ $E^{-2.2}$)

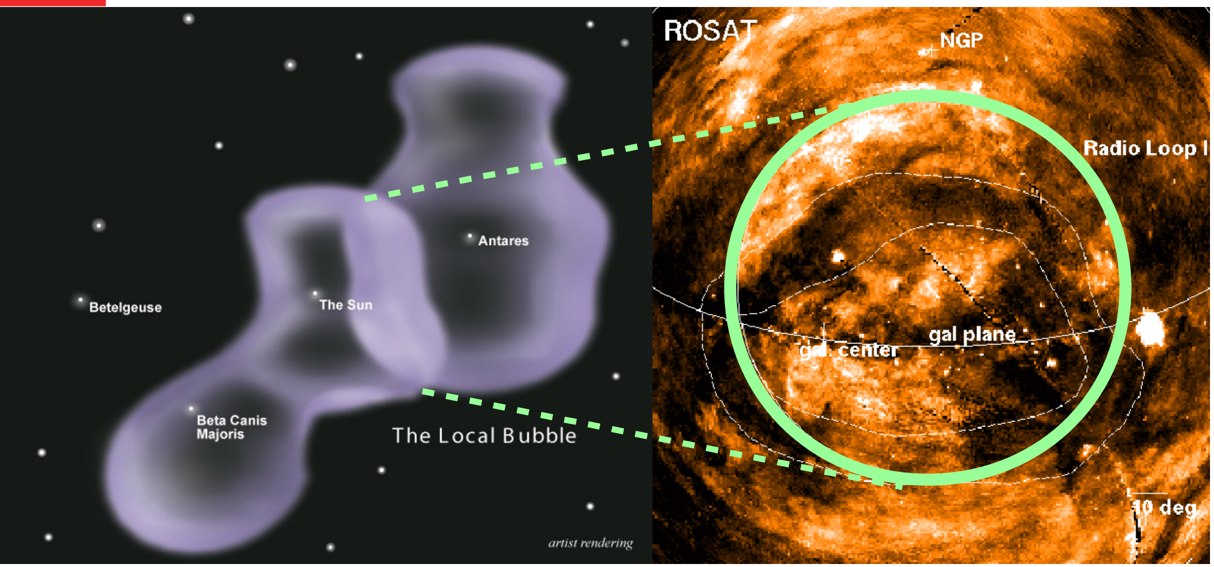
No significant excess observed (~1.5σ)
over 9 yrs o data taking





*as from Andersen, Kachelrieß, Semikoz APJLett **861**,2: L19 (2018)

More, extended – Local Bubble&Loop1



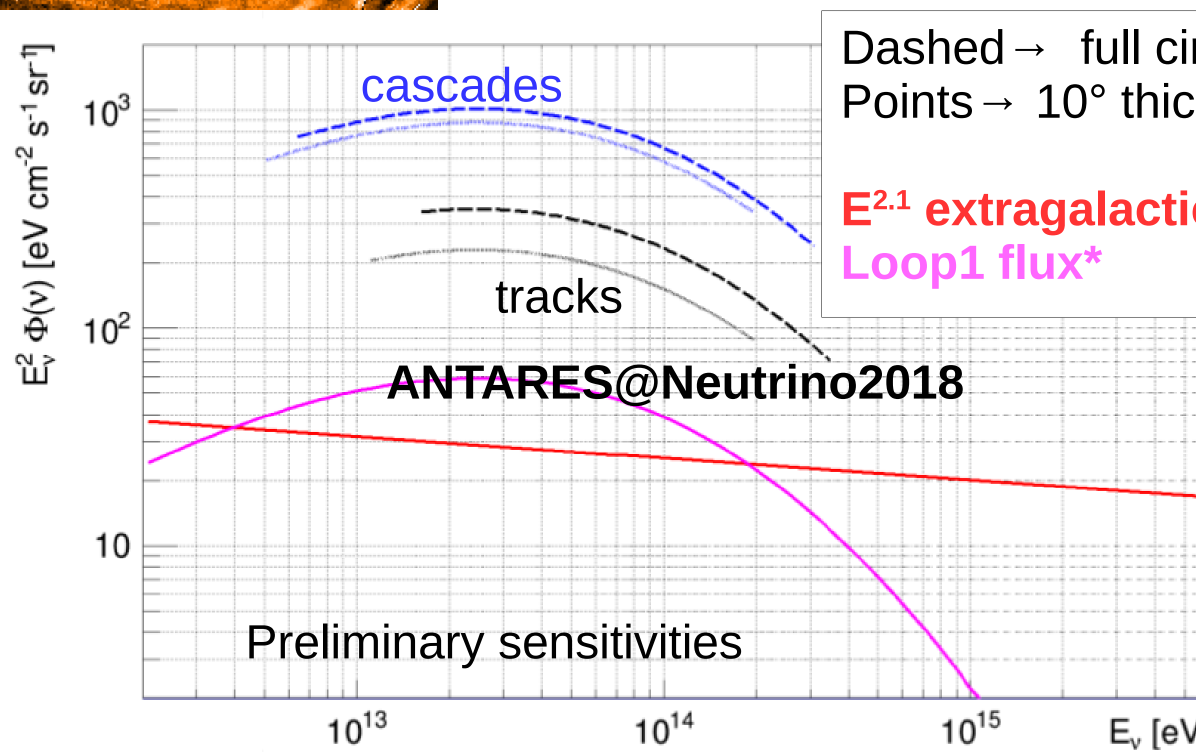
Matter density + magnetic field inhomogeneites
→ enchance neutrino production?

Large extension on our sky
→ contribute to the all-sky flux, though not easily detectable

60° radius, centered just above the GC/GP

ANTARES sensitivities based on 10yrs of data

~sensitivity 3-6 x Φ_{model}



Dashed → full circle
Points → 10° thick ring

$E^{2.1}$ extragalactic
Loop1 flux*

13/12/2018

Conclusions and outlook

- Large amount of searches for neutrinos in our Galaxy
- Northern Hemisphere telescopes do play their part
- Current generation is now starting to touch the sensitivity levels required to study GCR through ν
- KM3NeT/ARCA will aim at discoveries