Latest results in data from the ANTARES experiment

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on behalf of the

ANTARES Collaboration

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The physics of the ANTARES detector

- Neutrino astrophysics
- Multi-messenger studies
- Dark matter searches → see Javier's talk
- Atmospheric neutrinos
- Acoustic neutrino detection
- Earth and Sea sciences
- Exotic particles search: nuclearites, monopoles

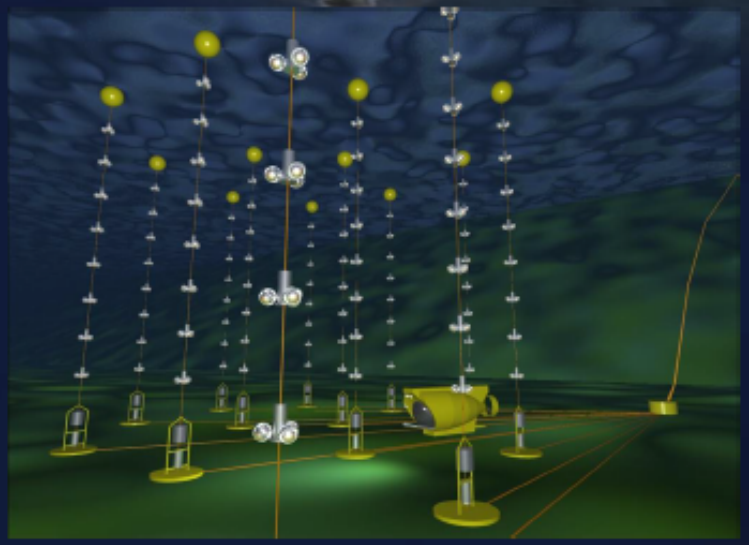
The ANTARES site

Toulon

Institut M. Pacha
control room

La Seyne-sur-Mer

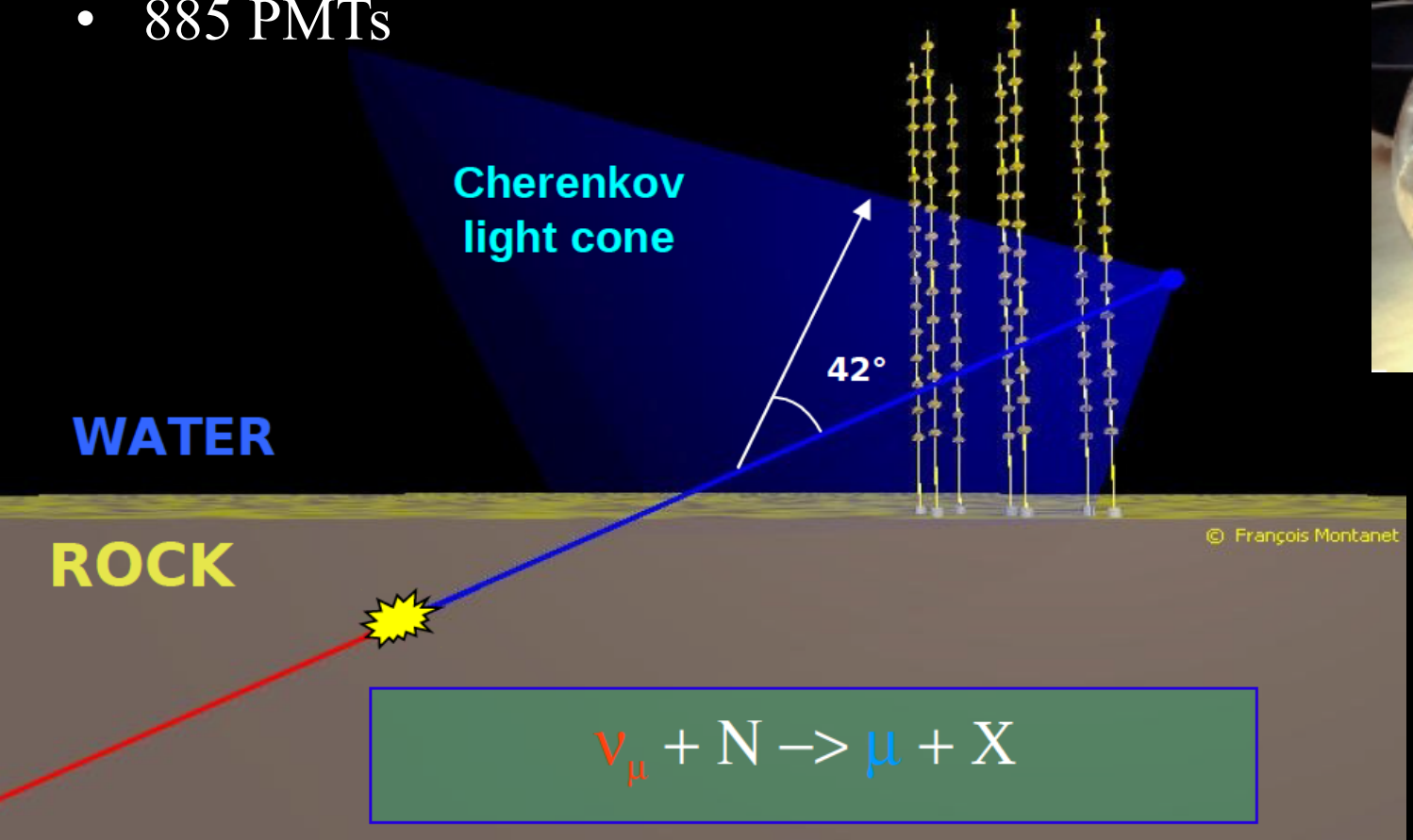
Electro-optical
Cable of
40 km



Site ANTARES
42° 50' N, 6° 10' E
2500 m under s.l.

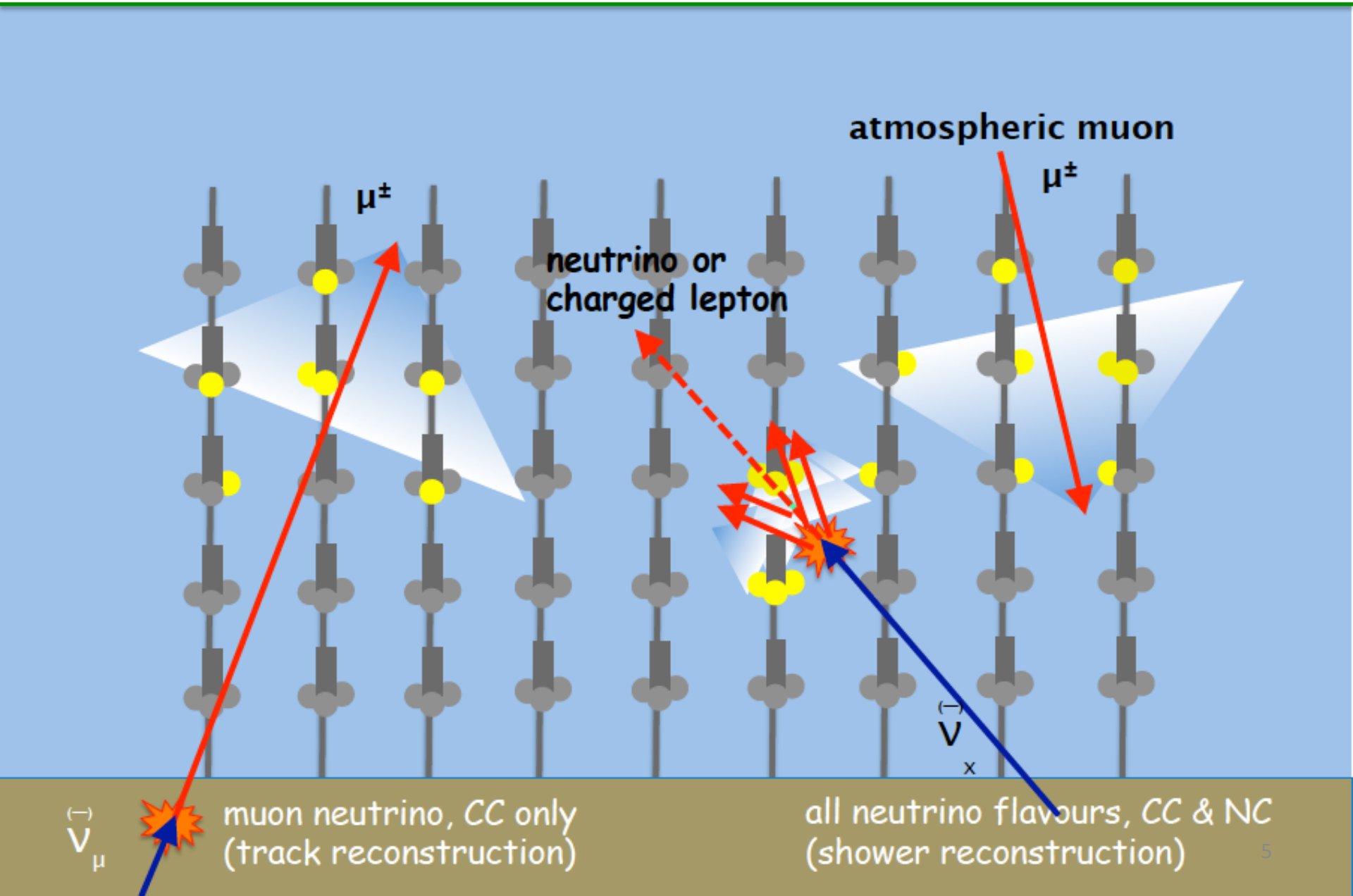
The ANTARES detector

- 12 lines of 75 PMTs
- 1 line for Earth and Marine sciences
- 25 storeys/line – 3 PMTs/storey
- 885 PMTs

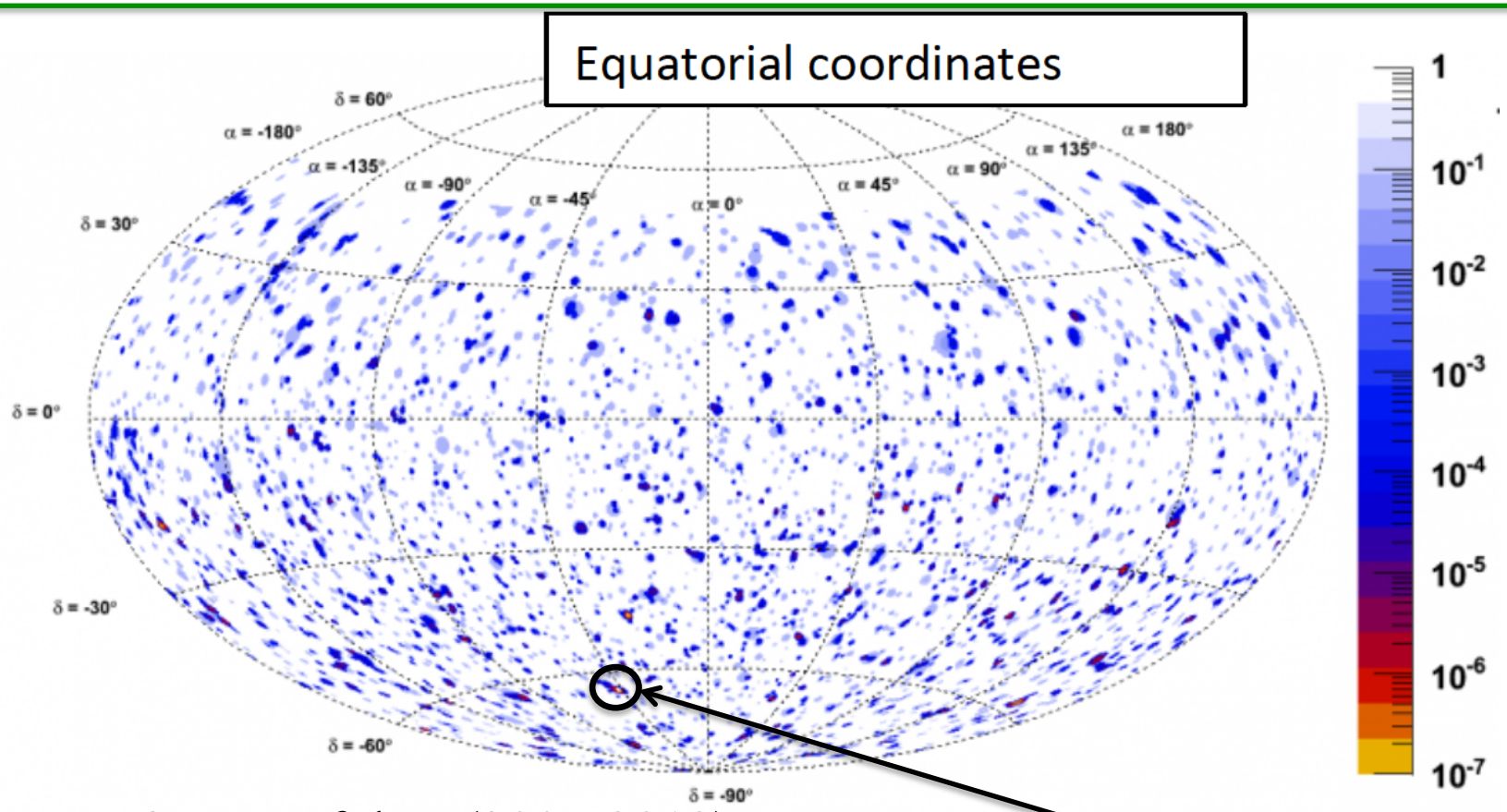


$$\nu_\mu + N \rightarrow \mu + X$$

How does the detector work?



Point-like sources

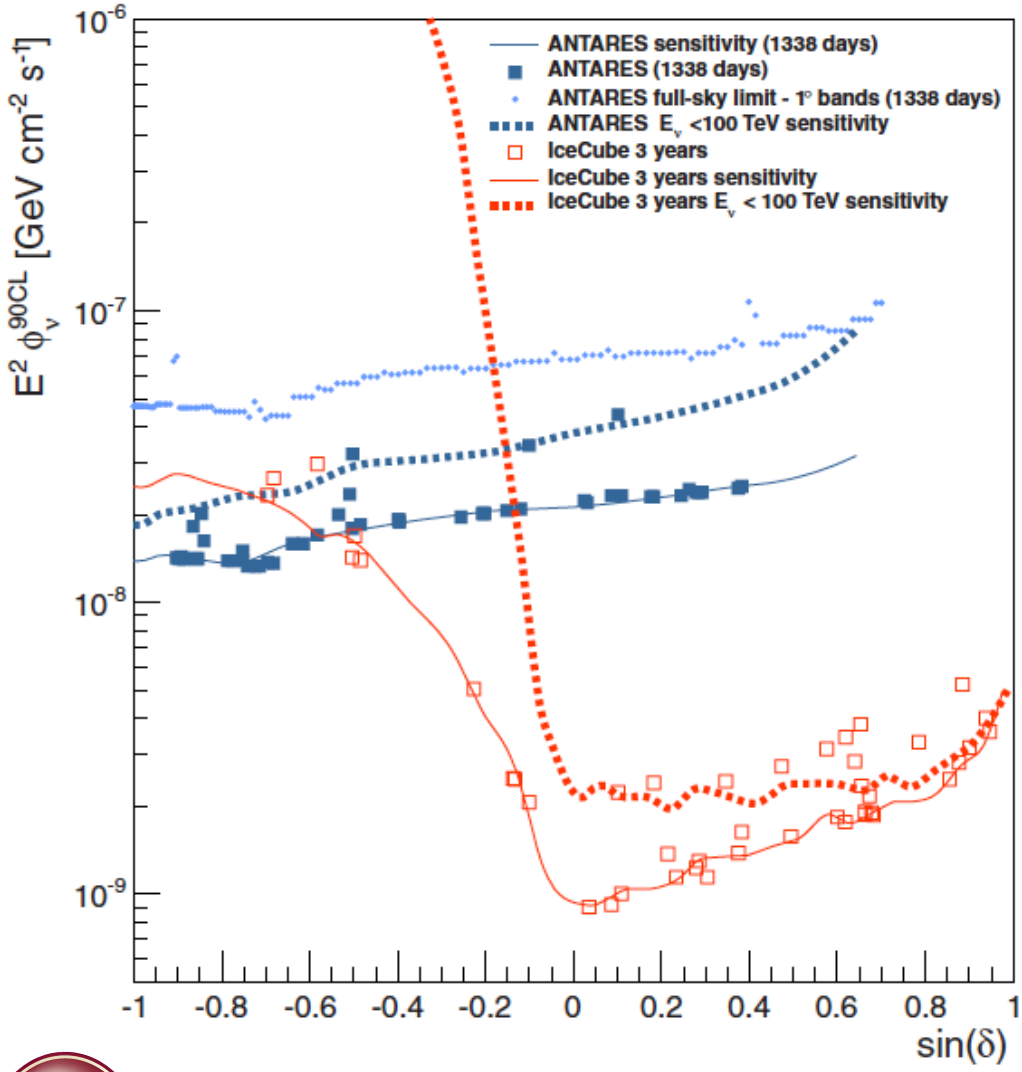


- 6 years of data (2007-2012)
- 50 pre-selected astrophysical sources
- Clusters of muon neutrinos over the expected atmospheric background have been looked for.
- No signal found.

$\alpha = -46°.8$, $\delta = -64°.9$
->2.2σ background fluctuation.

[S. Adrián-Martínez et al., The Astrophysical Journal Letters, 786:L5, 2014]

Point-like sources



90% CL flux upper limits and sensitivities on the muon neutrino flux for six years of ANTARES data. IceCube results are also shown for comparison.

- The light-blue markers show the upper limit for any point source located in the ANTARES visible sky in declination bands of 1°.
- The solid blue (red) line indicates the ANTARES (IceCube) sensitivity for a point-source with an E^{-2} spectrum as a function of the declination.
- The blue (red) squares represent the upper limits for the ANTARES (IceCube) candidate sources.
- The dashed dark blue (red) line indicates the ANTARES (IceCube) sensitivity for a point-source and for neutrino energies lower than 100 TeV, which shows that the IceCube sensitivity for sources in the Southern hemisphere is mostly due to events of higher energy.

[S. Adrián-Martínez et al., The Astrophysical Journal Letters, 786:L5, 2014]

Joint analysis ANTARES-IceCube

ANTARES data sample + IceCube (IC-40, IC-59, IC-79) data samples

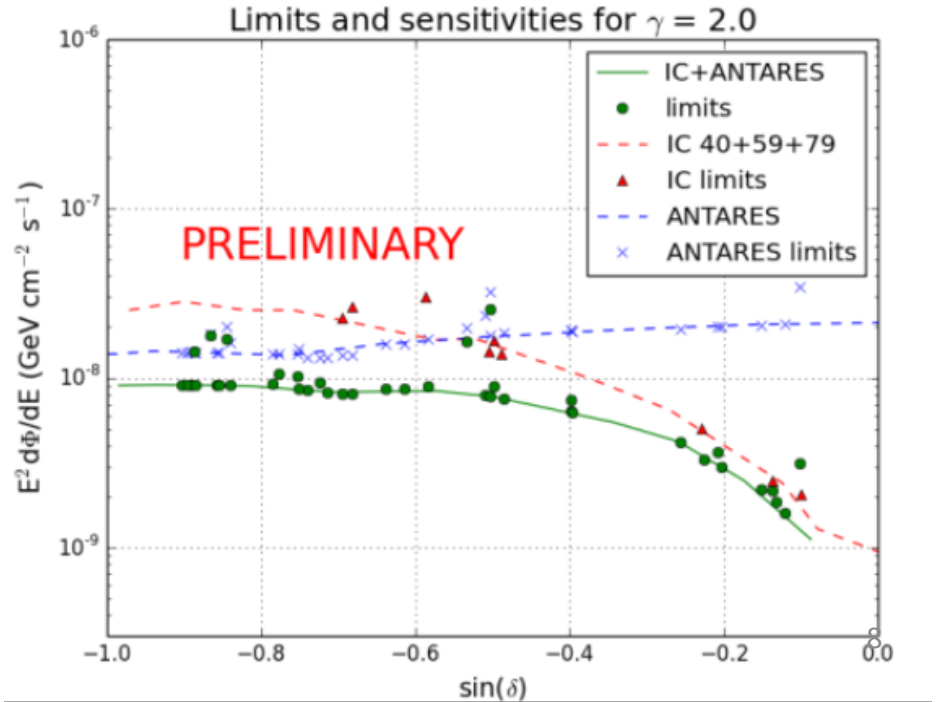
✓ Search for an excess over BG in the Southern Sky, for E^{-2} spectrum.

✓ Search over a pre-selected list of candidate sources with spectral index γ=2, 2.5; energy cutoffs at 1PeV, 300 TeV, 100 TeV.

ANTARES has better angular resolution (less scattering in seawater).

IceCube has more events with better energy resolution.

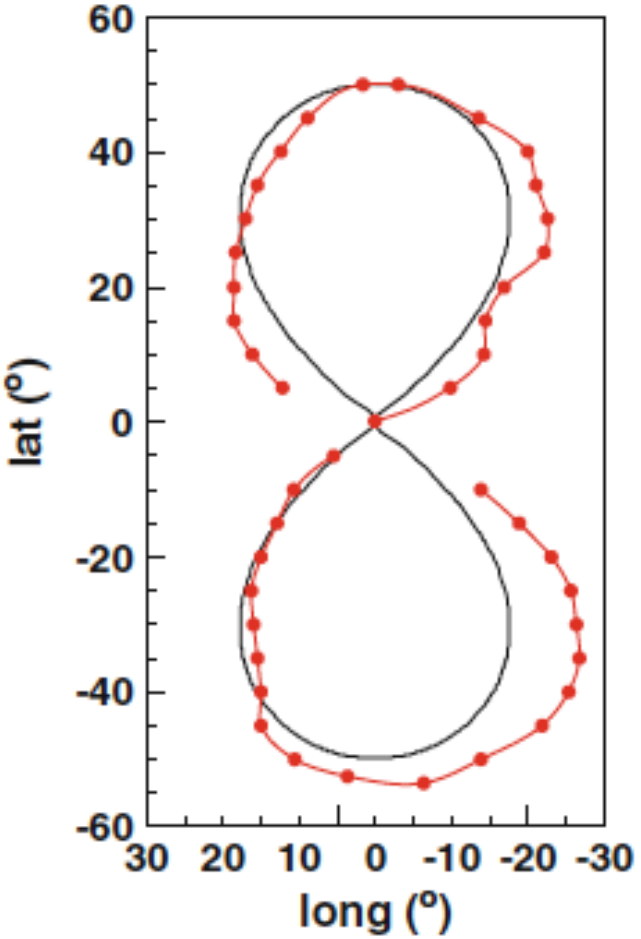
The point source sensitivity in a substantial region of the sky, centered approximately at the declination of the Galactic Center ($\delta = -30^\circ$), can be seen to have improved by up to a factor of two.



[EPJ Web Conf. 116 (2016) 04005]

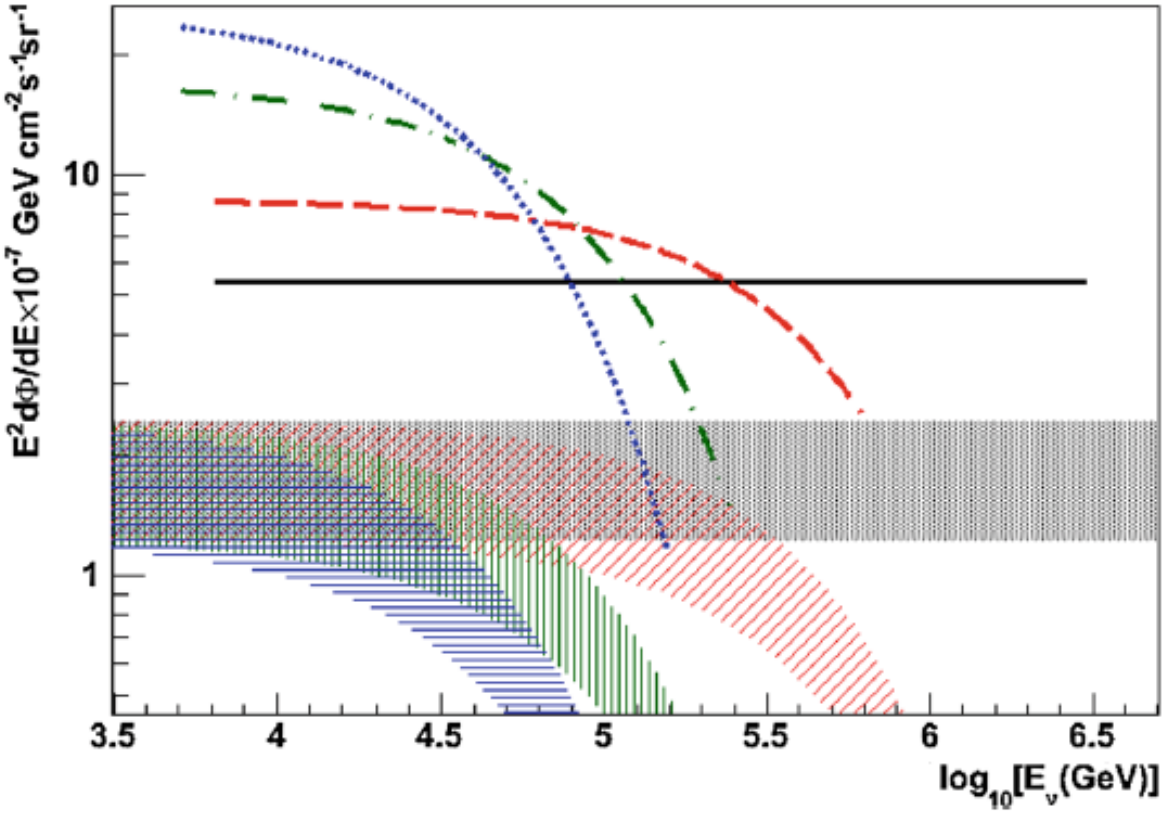
Fermi Bubbles

- Analysis of the Fermi-LAT data has revealed two extended structures above and below the Galactic Center emitting gamma rays with a hard spectrum, the so-called Fermi bubbles.
- Hadronic models attempting to explain the origin of the Fermi bubbles predict the emission of high-energy neutrinos and gamma rays with similar fluxes.
- The ANTARES detector has a good visibility to the Fermi bubble regions.
- Using data collected from 2008 to 2011 no statistically significant excess of events is observed and therefore upper limits on the neutrino flux in TeV range from the Fermi bubbles are derived for various assumed energy cutoffs of the source.



[S. Adrián-Martínez et al., Eur. Phys. J. C (2014) 74:2701]

Fermi Bubbles



Upper limits on the neutrino flux from the Fermi bubbles for different cutoffs:

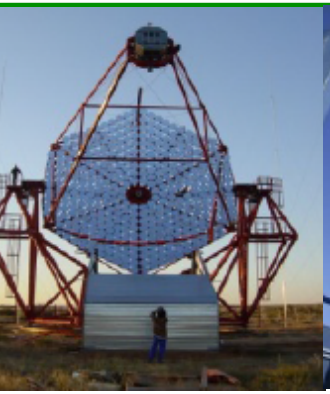
- no cutoff (black solid),
- 500 TeV(red dashed),
- 100 TeV (green dot-dashed),
- 50 TeV (blue dotted)

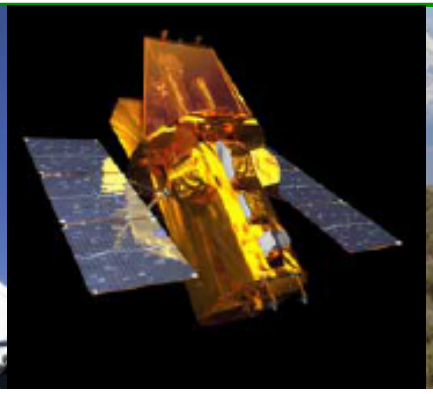
together with the theoretical predictions for the case of a purely hadronic model (the same colours, filled areas).

- 1.2 σ excess of events in the Fermi bubble regions, compatible with the no-signal hypothesis.
- The sensitivity will improve as more data is accumulated (more than 65% gain in the sensitivity is expected once 2012–2016 data is added to the analysis).

[S. Adrián-Martínez et al., Eur. Phys. J. C (2014) 74:2701]

Multi-messenger analyses





GeV-TeV γ-rays
Fermi/H.E.S.S.

[JCAP 03 (2013) 006]
[A&A 559 (2013) A9]
[JCAP 05 (2014) 001]
[JCAP 12 (2015) 014]

Ultra-high energy cosmic rays
Auger

[APJ 774 (2013) 19]

High energy neutrinos

- Different messengers from common sources.
- Decrease in the parameter space to look for.
- Uncorrelated backgrounds and systematics.

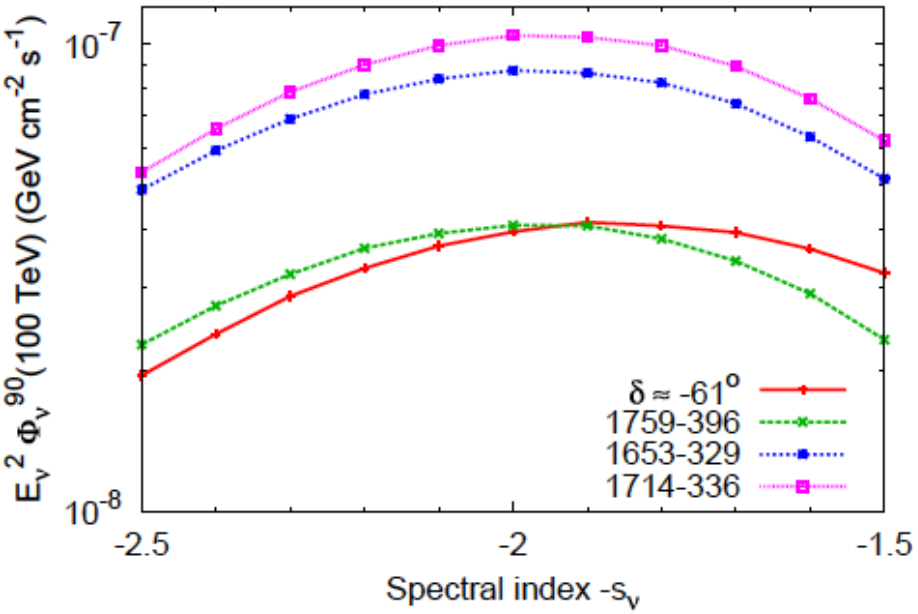
Gravitational Waves
LIGO/Virgo

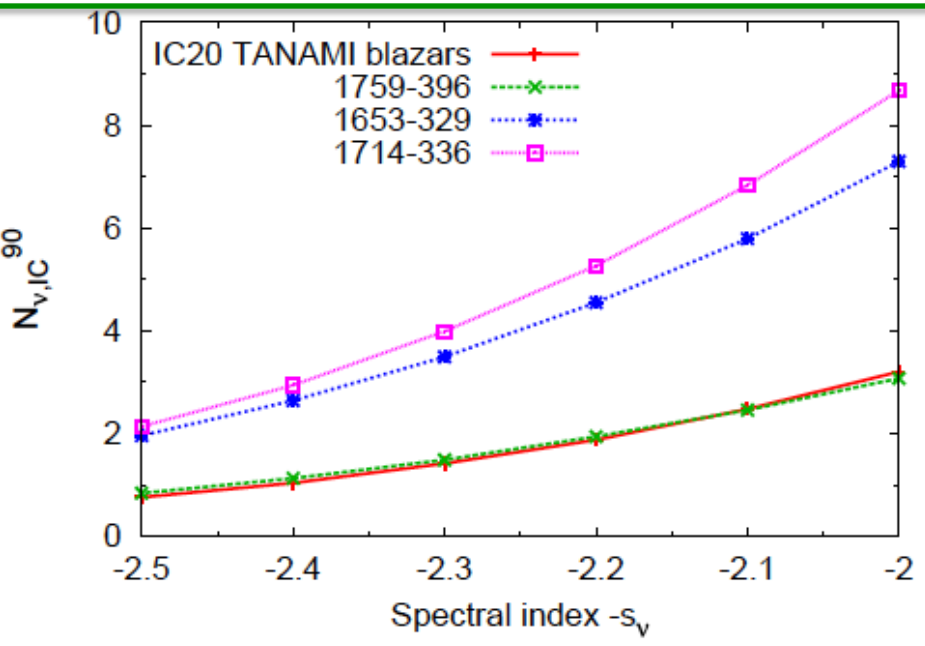
[JCAP 06 (2013) 006]
[arXiv:1602.05411]

Optic/X-ray TAROT, ROTSE/ Swift, ZADKO

[APP 36 (2012) 204]
[A&A 559 (2013) A9]

ANTARES constrains a blazar origin of two IceCube PeV neutrino events





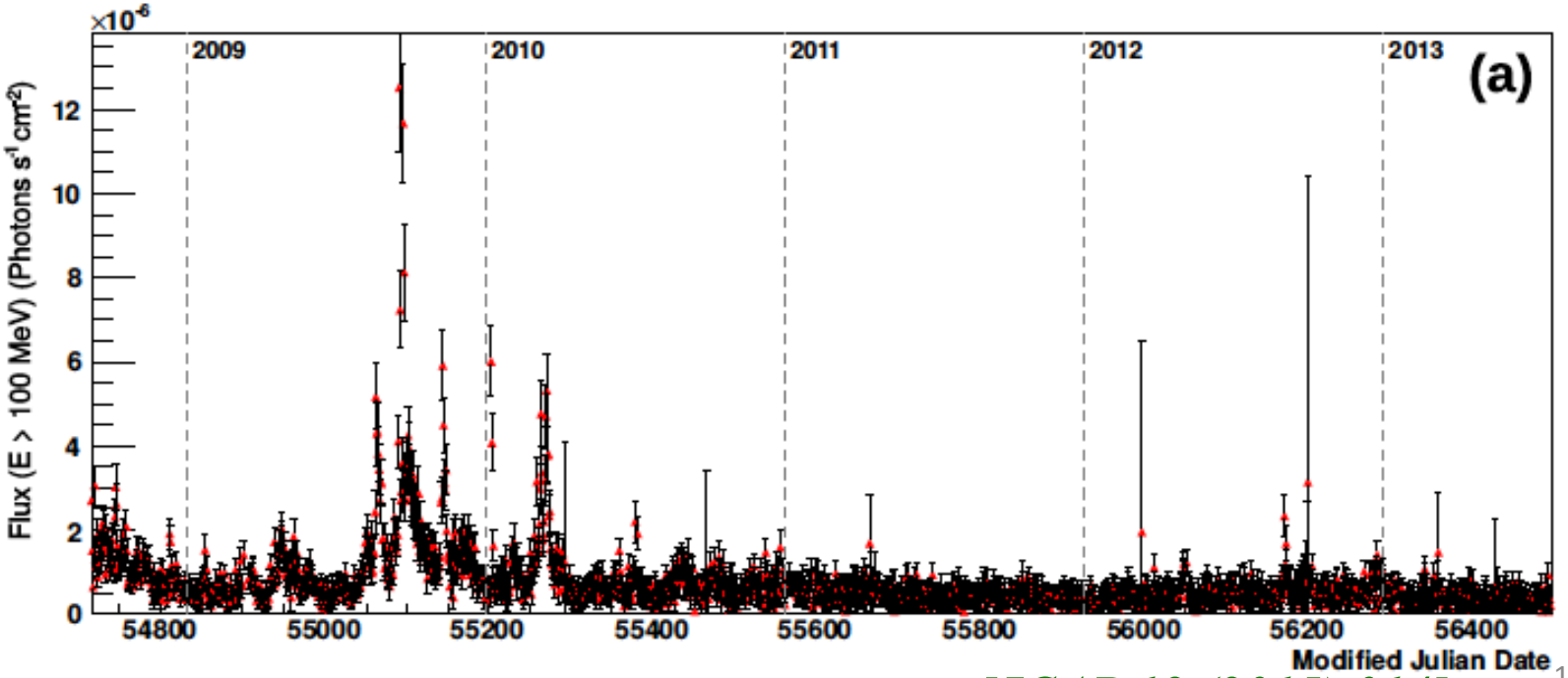
- The TANAMI Collaboration recently reported on the multiwavelength emission of six bright, variable blazars which are coincident in position with two of the most energetic IceCube events.
- 6 year sample consists of 5516 events, with an estimated atmospheric muon contamination of 10%, and a median angular resolution of 0°.38.
- After analysis, one event in the direction of two of the blazars (IC14).
- Consistent with the blazar-origin hypothesis of the IceCube event IC14 for a broad range of blazar spectra, but atmospheric origin cannot be excluded.
- Left: ANTARES 90% confident limits on a flavor-uniform neutrino flux from the six blazars as a function of the spectral index. Right: Corresponding limits on the expected number of IceCube events of blazar origin.

[A&A 576, L8 (2015)]

GeV and TeV γ-ray flaring blazars

- Blazars, being radio-loud active galactic nuclei with their jets pointing almost directly towards the observer, are particularly attractive potential neutrino point sources, since they are among the most likely sources of the very high-energy cosmic rays.
- Neutrinos and gamma rays may be produced in hadronic interactions with the surrounding medium.
- Time-dependent analysis applied to a selection of flaring gamma-ray blazars observed by the FERMI/LAT experiment and by TeV Cherenkov telescopes using five years of ANTARES data taken from 2008 to 2012.

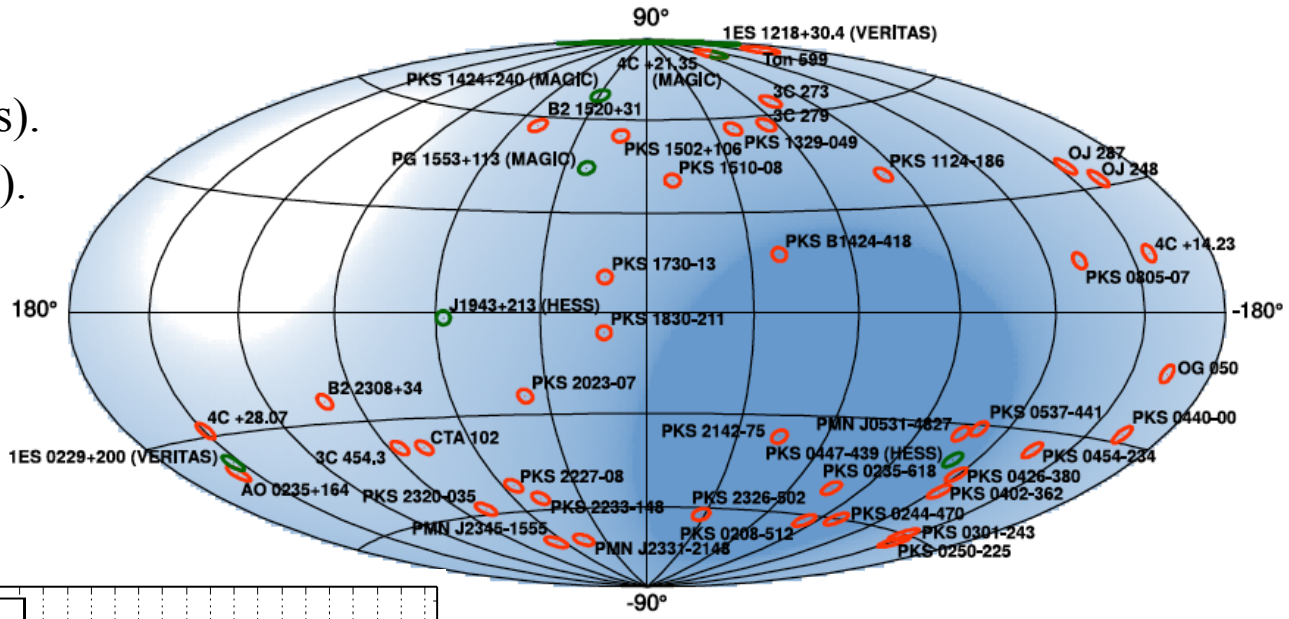
Source 3C273: γ-ray light curve using the Fermi data with threshold of 100 MeV

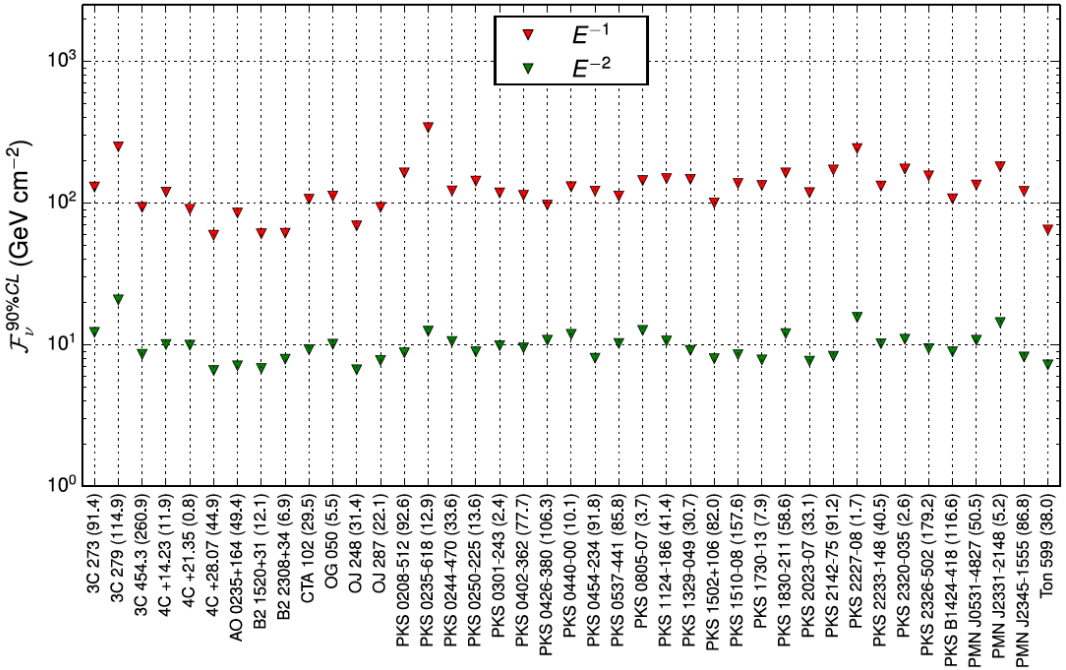


[JCAP 12 (2015) 014]

GeV and TeV γ-ray flaring blazars

- 41 Fermi blazars (red circles).
- 7 TeV blazars (green circles).
- ANTARES visibility (dark blue is maximal).

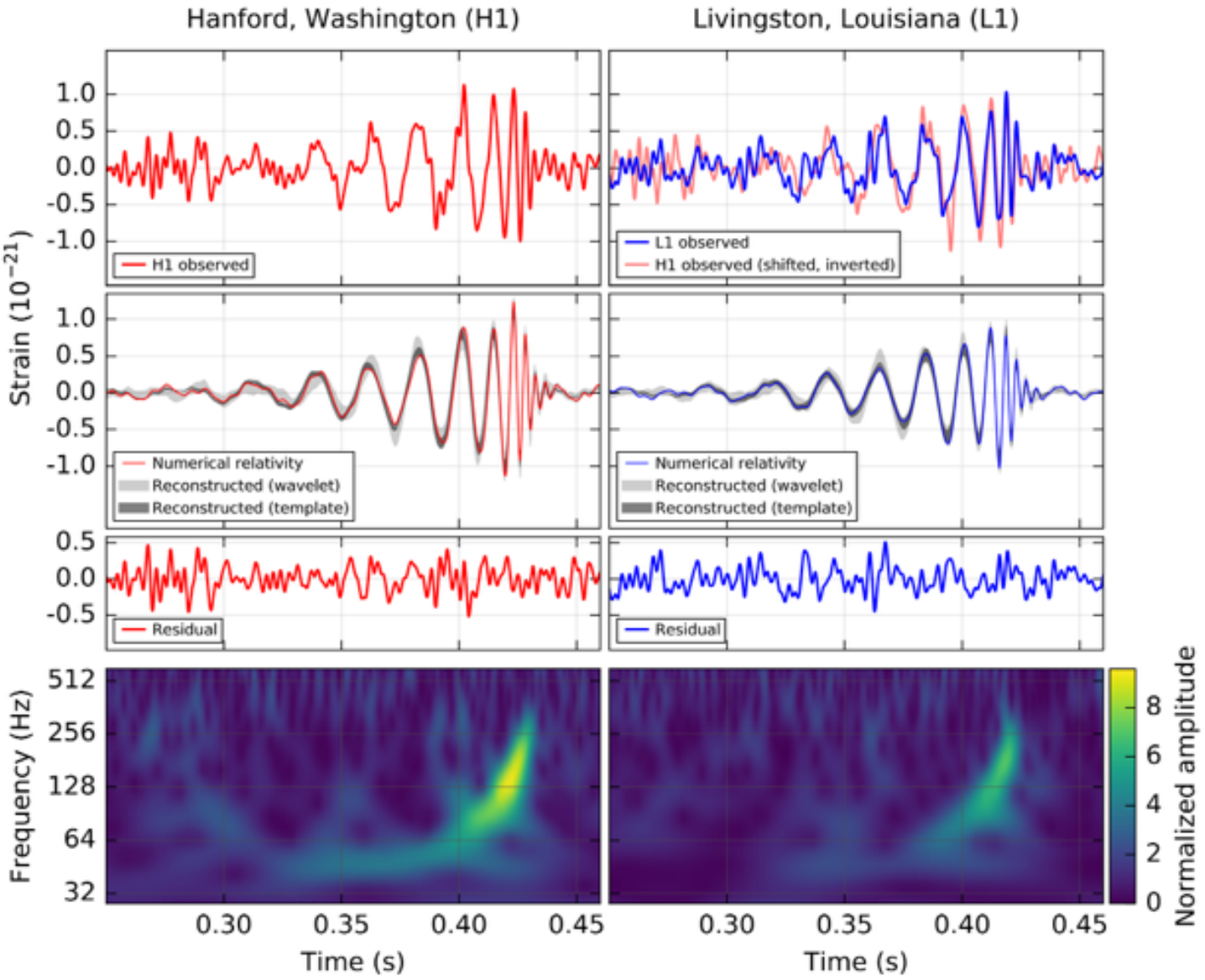




Upper limits on the neutrino fluence (F) for the 41 studied Fermi blazars in the case of E^{-2} (green) and E^{-1}(red) neutrino energy spectra. The number in parenthesis after the name of the source in the x-axis indicates the total effective flare duration Δt in the studied period.

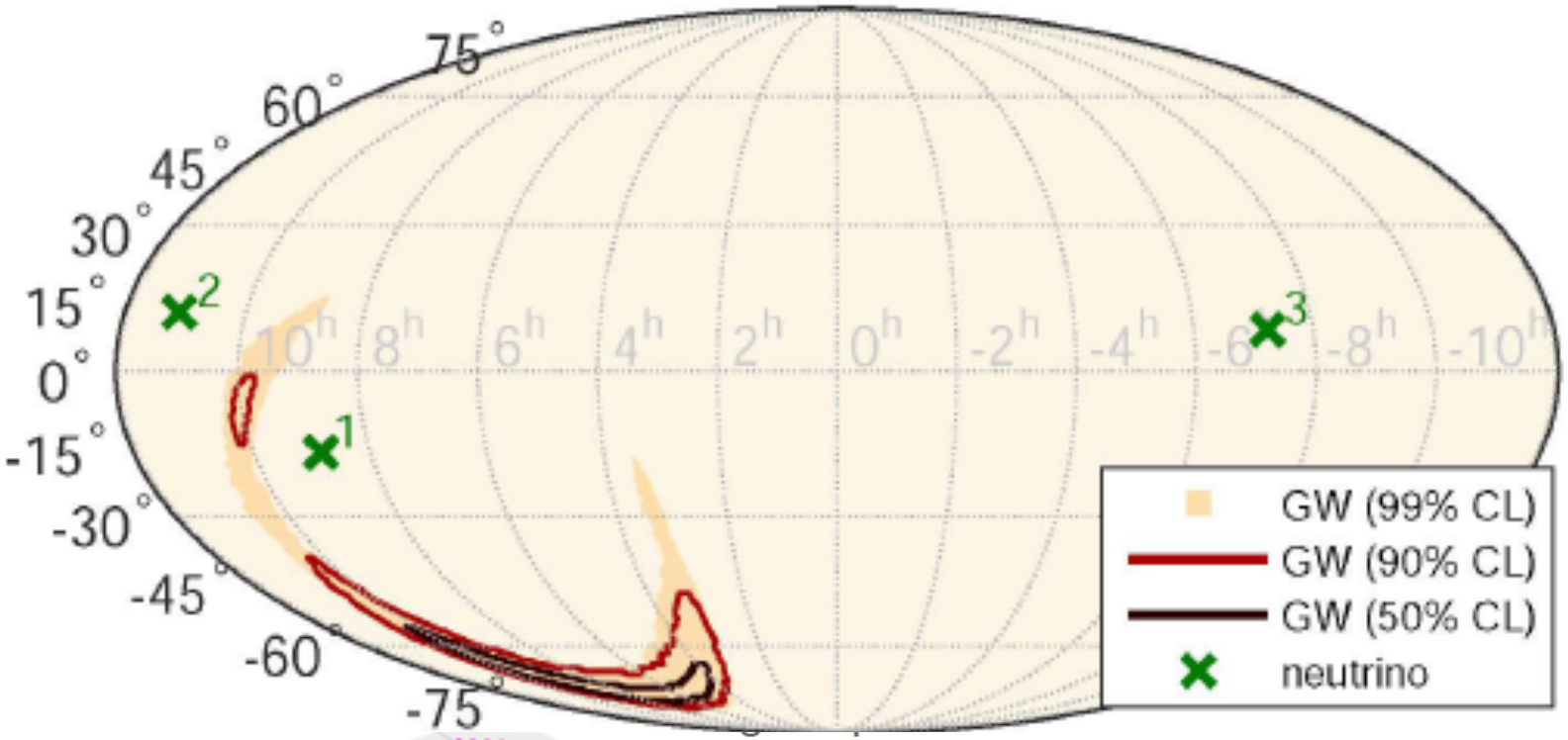
[JCAP 12 (2015) 014]

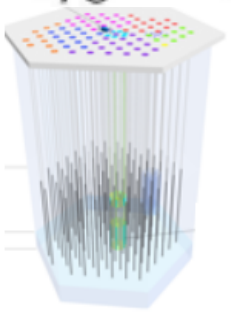
Joint search with LIGO-Virgo on GW150914



[arXiv:1602.05411]

Joint search with LIGO-Virgo on GW150914

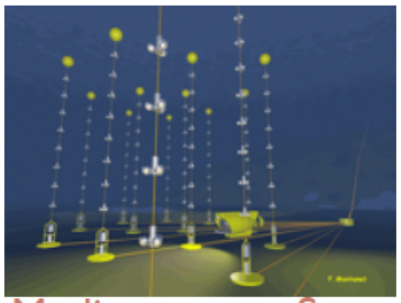




IceCube

South Pole

ANTARES



Mediterranean Sea

[arXiv:1602.05411]

Summary

- ANTARES: the largest underwater neutrino telescope; good angular resolution + Southern Sky direct observation.
- Constraints on the possible origin of the IceCube signal.
- Several analyses exploiting mainly the track-channel.
- Data taking until 2016.

Experiments in extreme environment!

Astroparticle physics

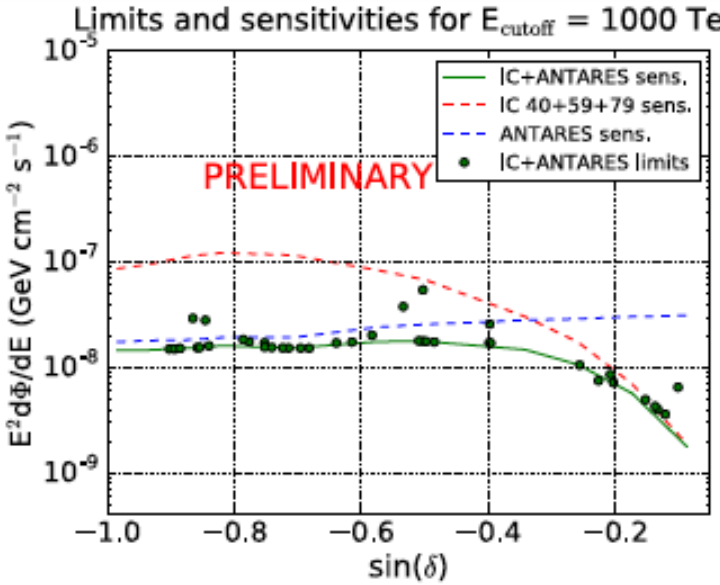
Hang on, that's not a neutrino

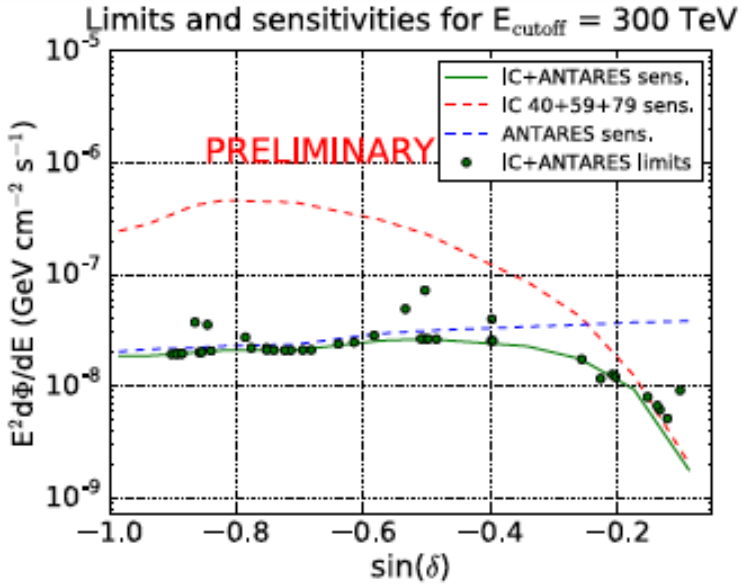
The Economist

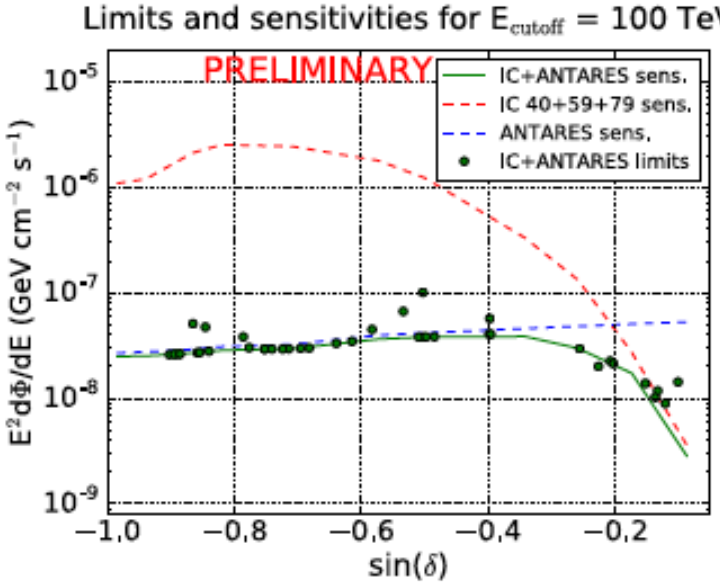
Dec 1st 2010, 16:10 by J.P.

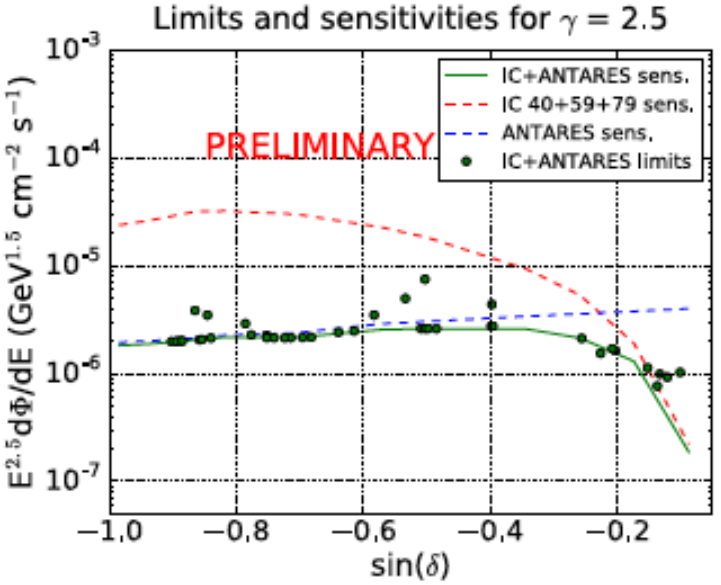
PHYSICISTS are often accused by the public and other scientists of spending inordinate sums on fancy kit that does little apart from merely satisfying human curiosity. Besides stressing that there is nothing mere about knowledge, the boffins will typically respond by trotting out a long list of blue-sky projects that yielded serendipitous results, from microwave ovens to the internet. They can also offer plenty of examples of how their own research has aided colleagues in other fields, from climate science to, somewhat more improbably, marine biology.

Joint analysis ANTARES-IceCube



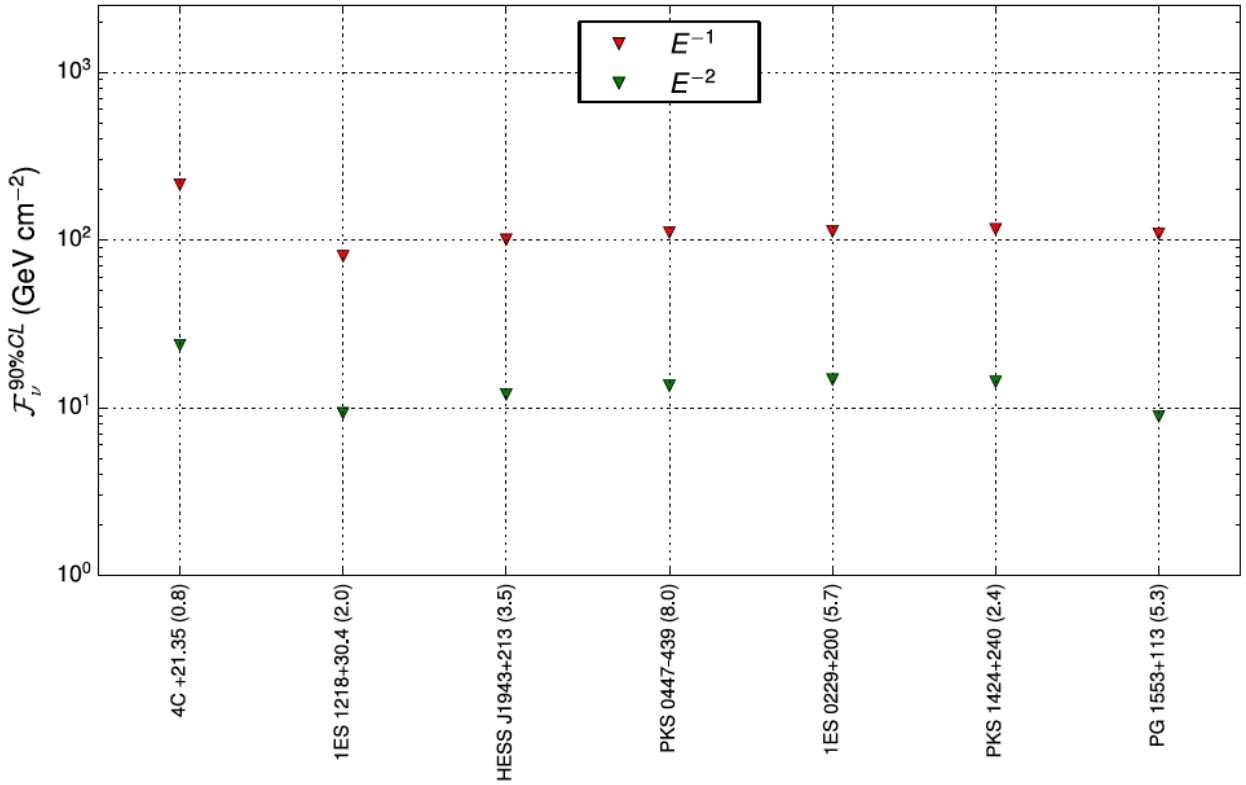






[EPJ Web Conf. 116 (2016) 04005]

GeV and TeV γ-ray flaring blazars



Upper limits on the neutrino fluence (F) for the 7 TeV blazars in the case of E^{-2} (green) and E^{-1}(red) neutrino energy spectra. The number in parenthesis after the name of the source in the x-axis indicates the total effective flare duration Δt in the studied period.