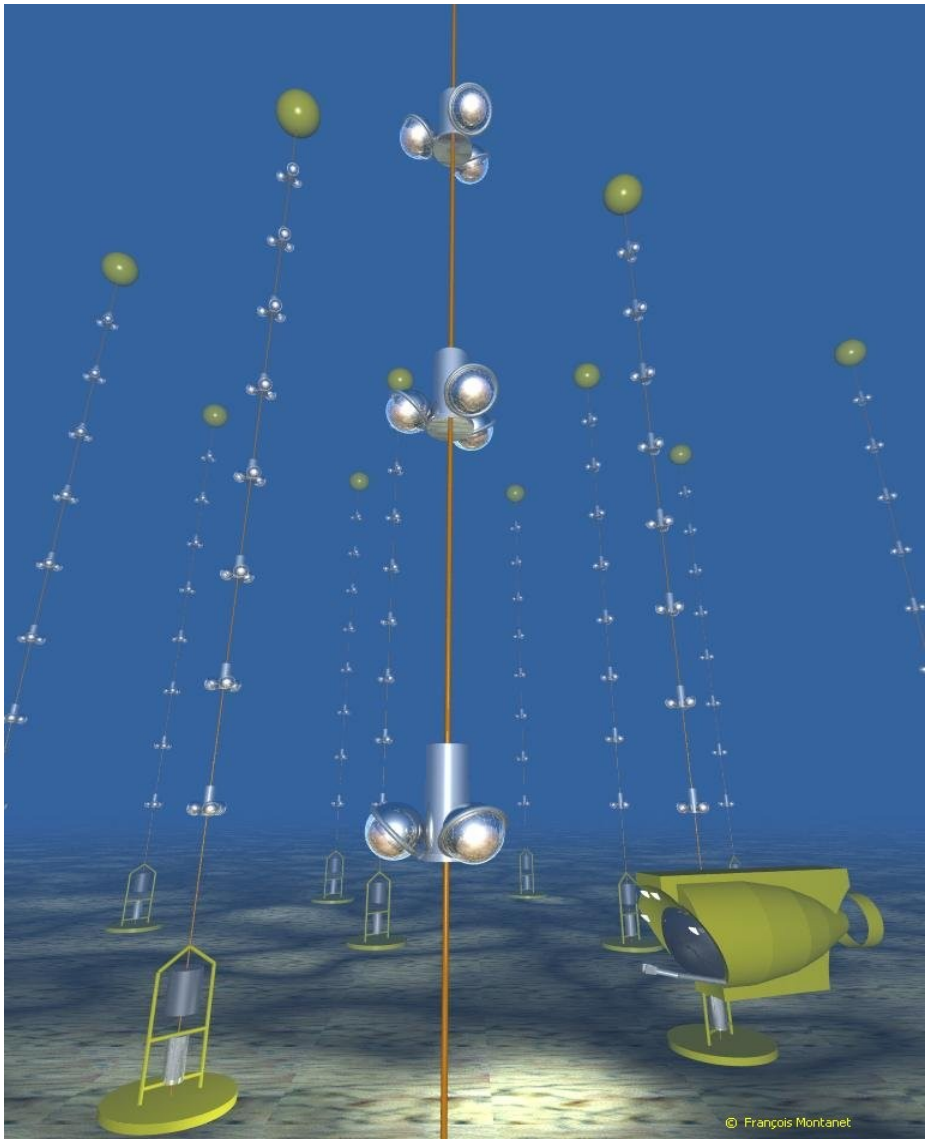
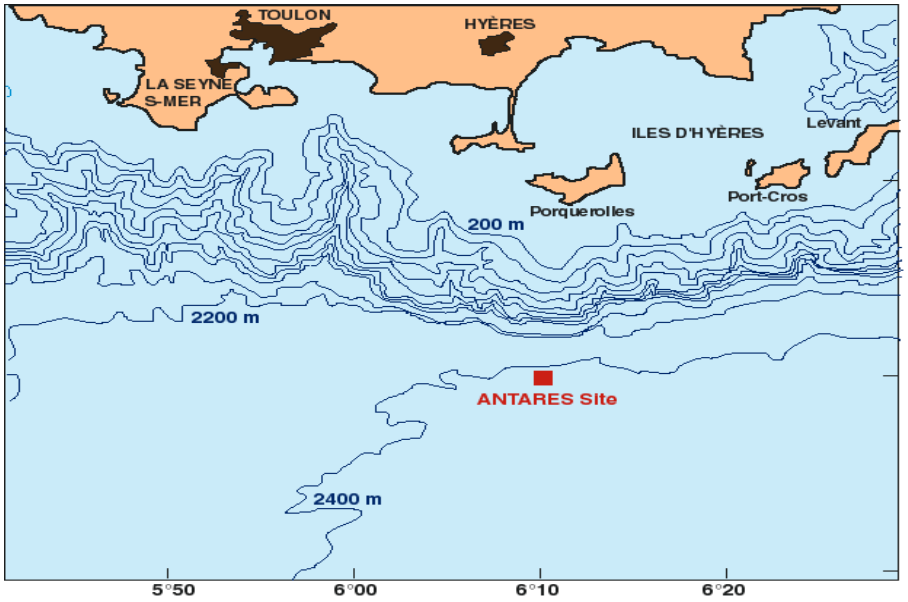
Latest results from the ANTARES neutrino telescope

The ANTARES collaboration

Presented by Rodrigo G. Ruiz

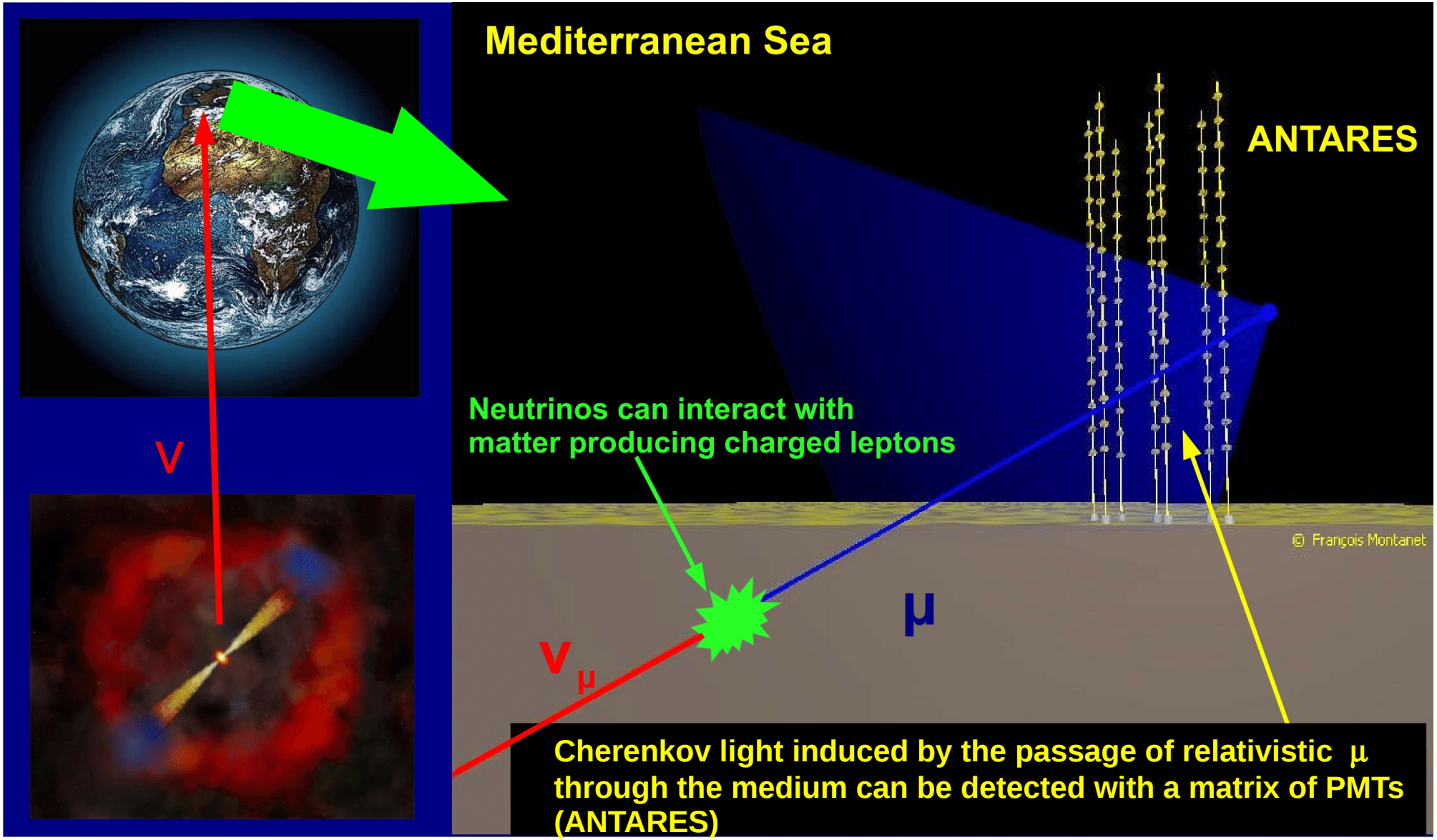
The ANTARES neutrino telescope



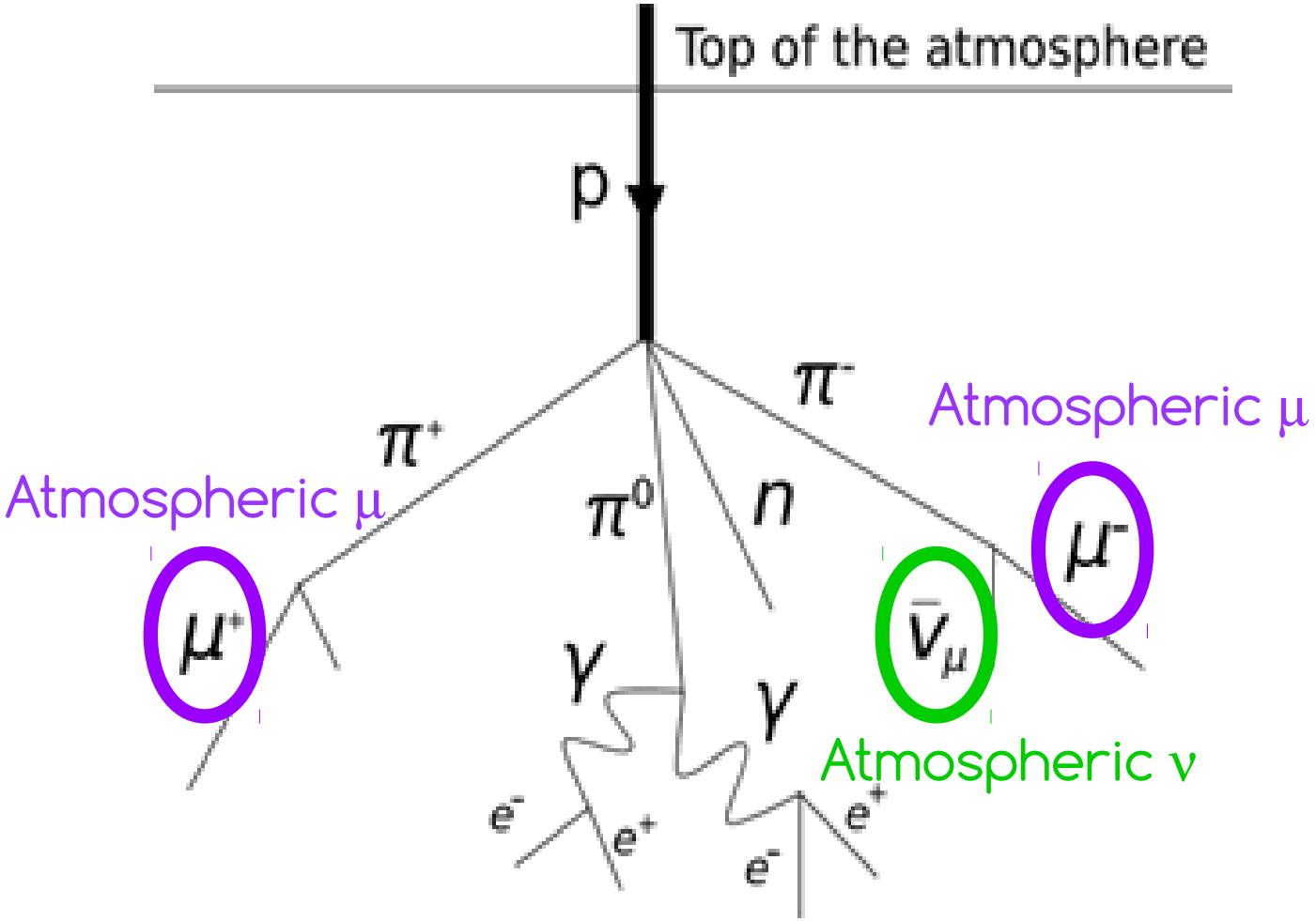


- Situated 25 km off-shore the South coast of France
- 12 lines with 70 m spacing
- 25 storeys per line
- 3 10-inch PMTs per storey
- Completed in 2008

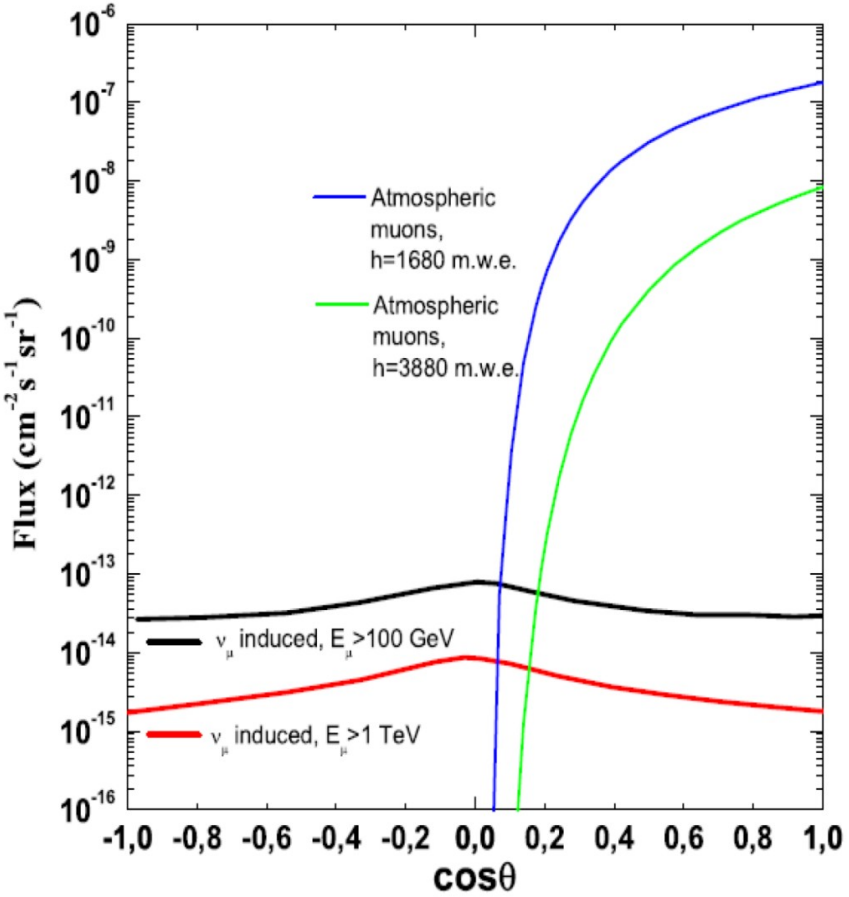
The detection principle

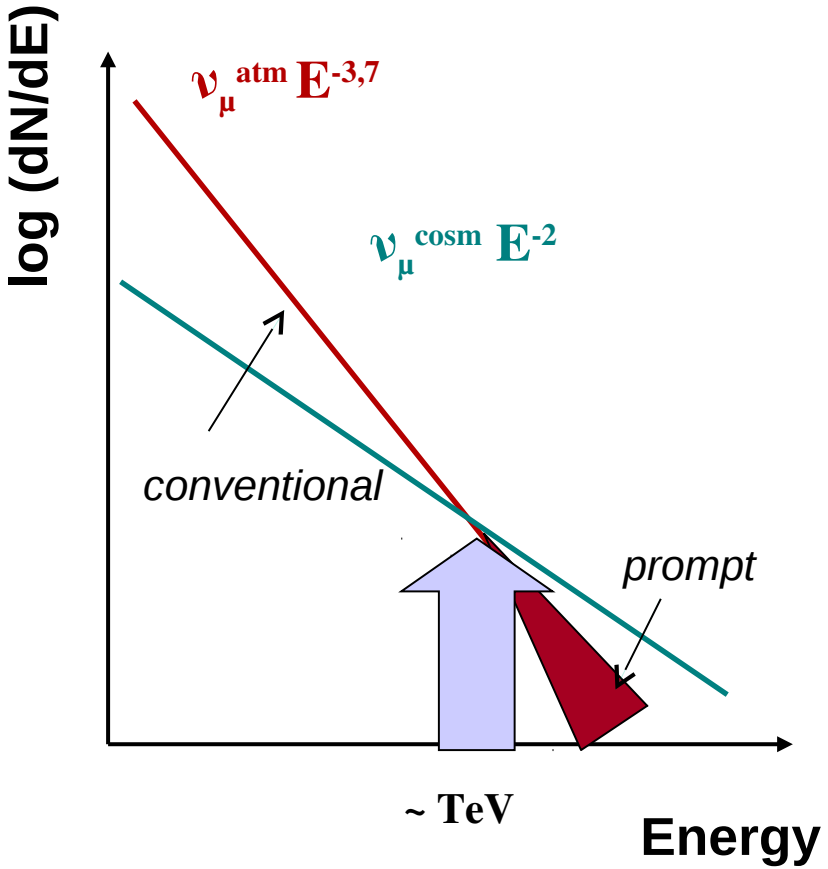


ANTARES sources of Background



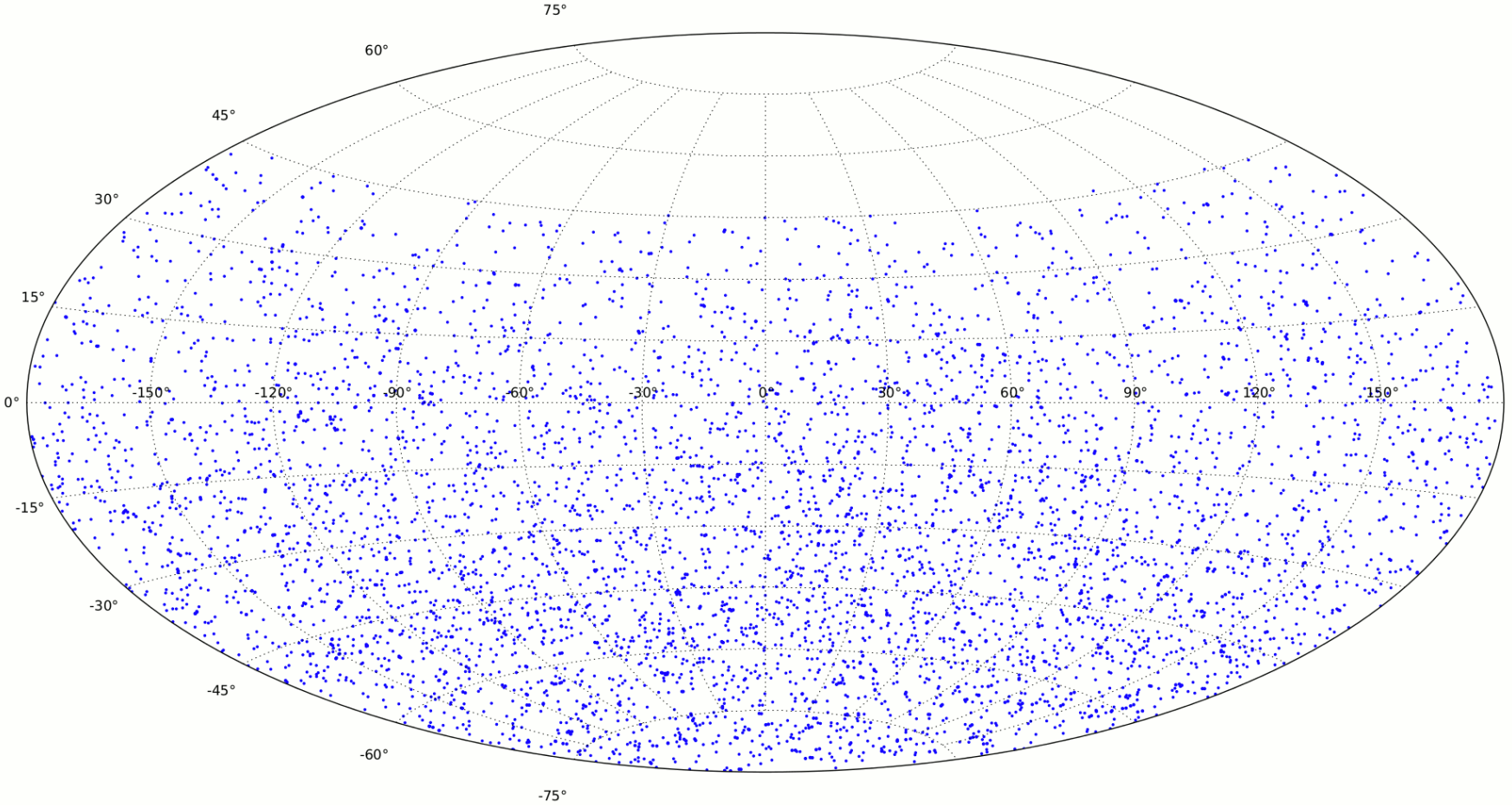
Cosmic ν vs atmospheric background





- Atmospheric μ:
  - Look down + selection of well reconstructed events
- Atmospheric ν:
  - Excess at high energy
  - Anisotropies, spatial clustering
  - Coincidences with other cosmic probes

The ANTARES time integrated sky map 2007-2012

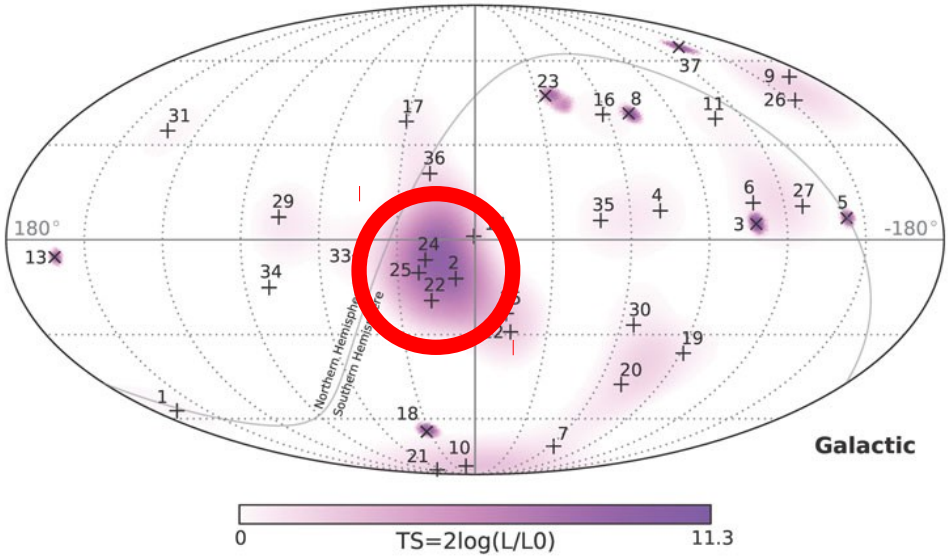


- 5516 up-going tracks
- 0.38° median angular resolution
- ~ 10% misreconstructed atmospheric muons

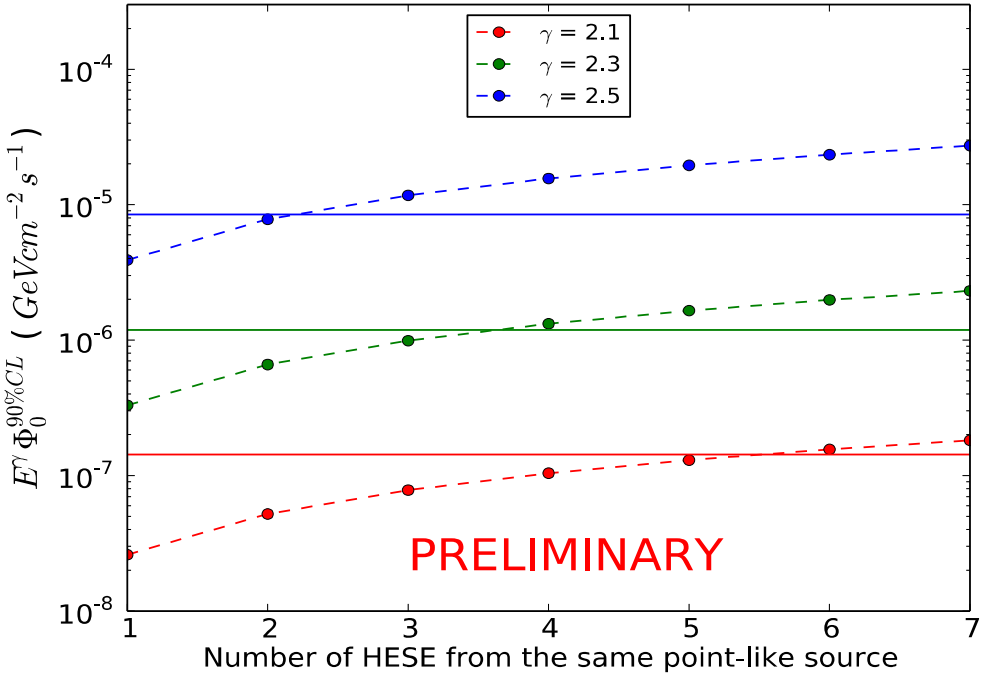
Point source search

Point Source search (I) Galactic center

- Motivation: IceCube hot spot near the GC
- PS search in 20^0 around $(\alpha,\delta)=(-79^0,-23^0)$
- No significant cluster found

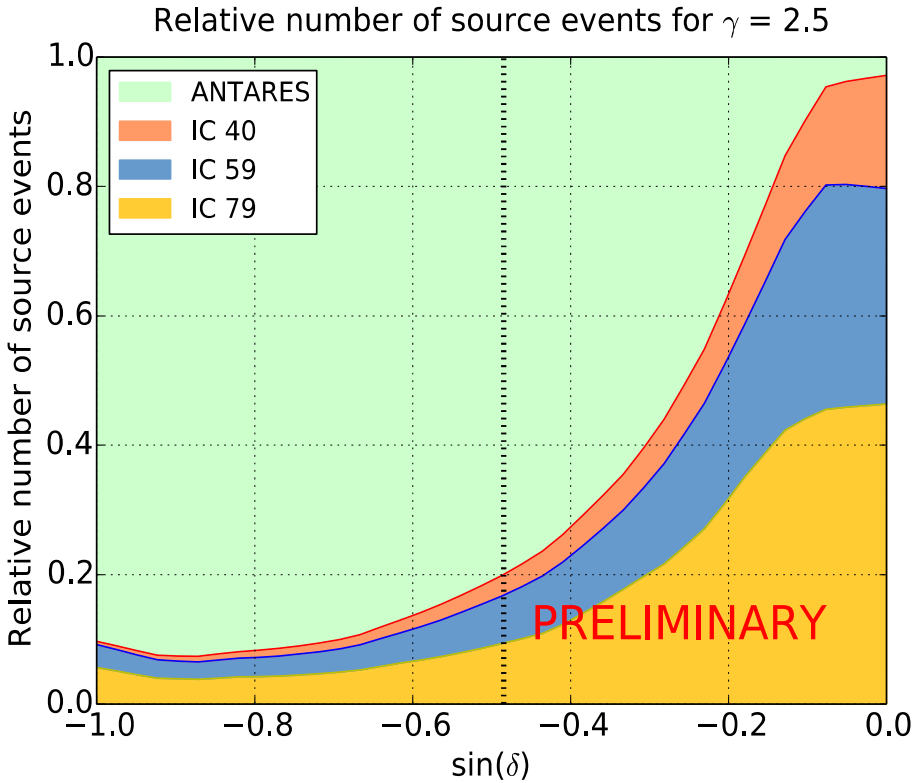


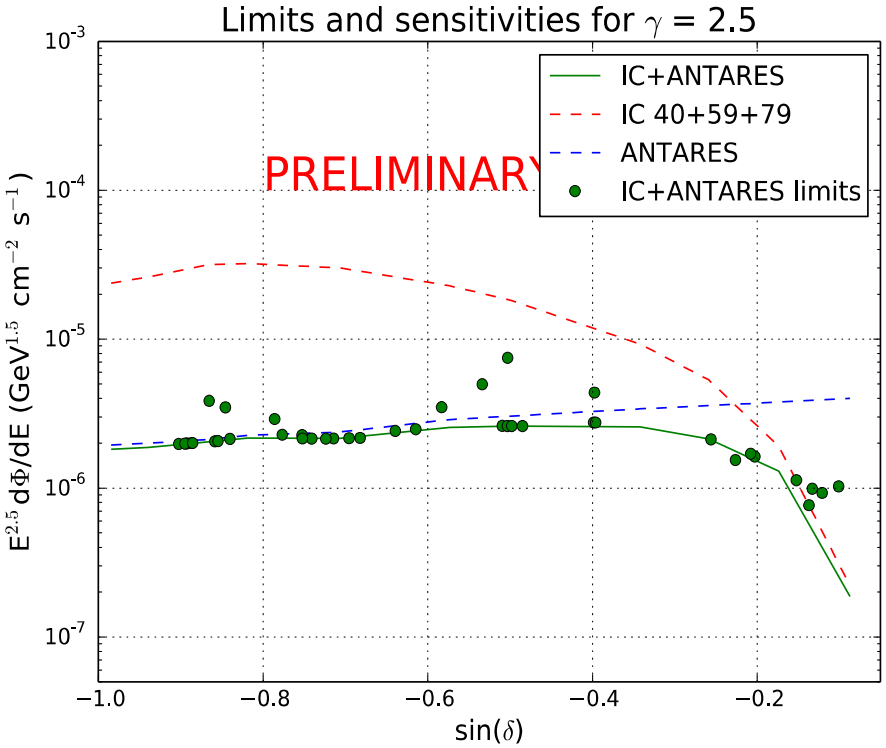
- Limits to the flux coming from PS for different spectral indices
- Exclude more than 2 IC events for $\Gamma = 2.5$



Point Source search (II)
ANTARES+IC joint search

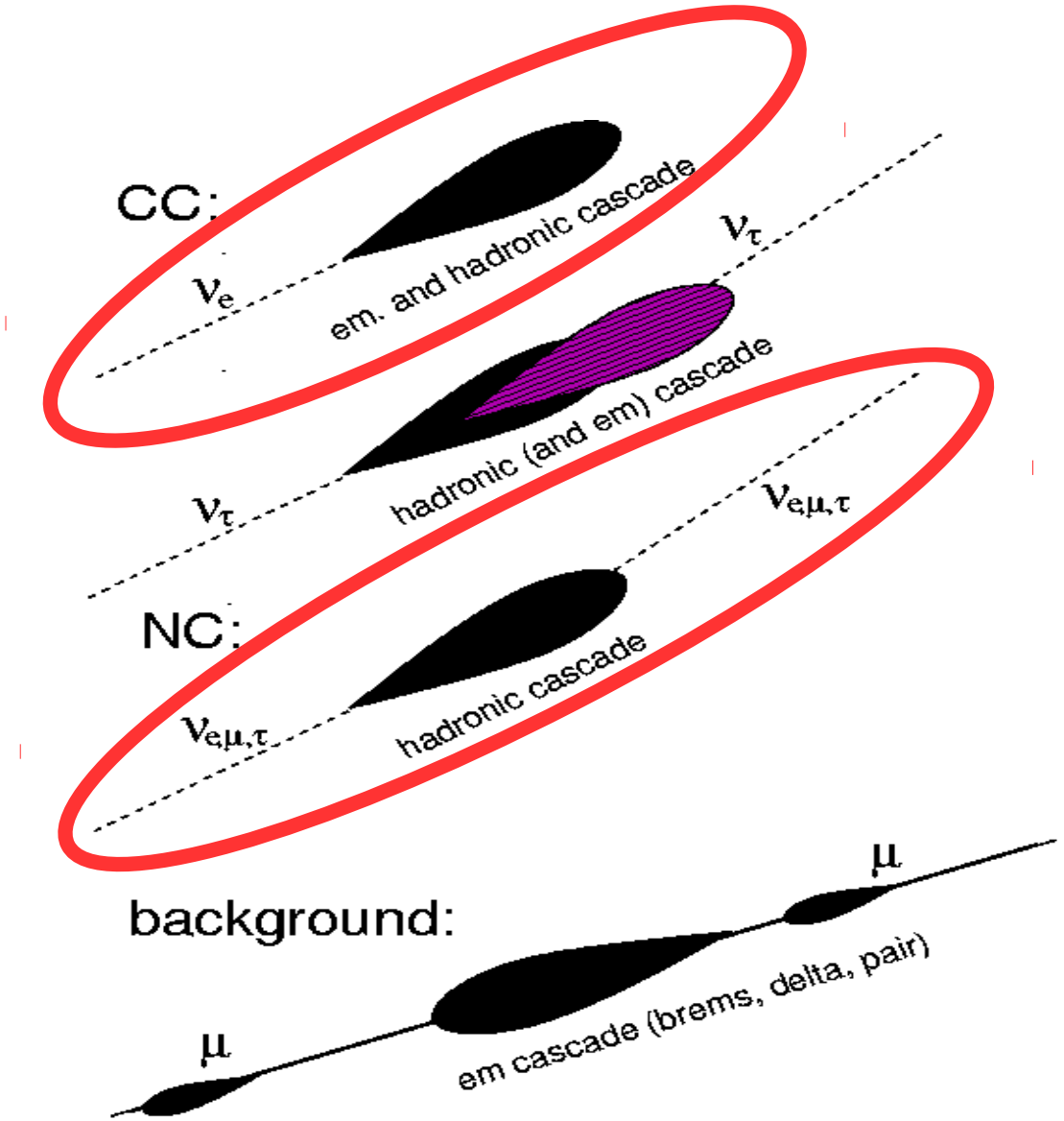
- ANTARES has better angular resolution (less scattering in water)
- IceCube has more events with better energy resolution (it's bigger)
- Different declination dependencies – complementary regions





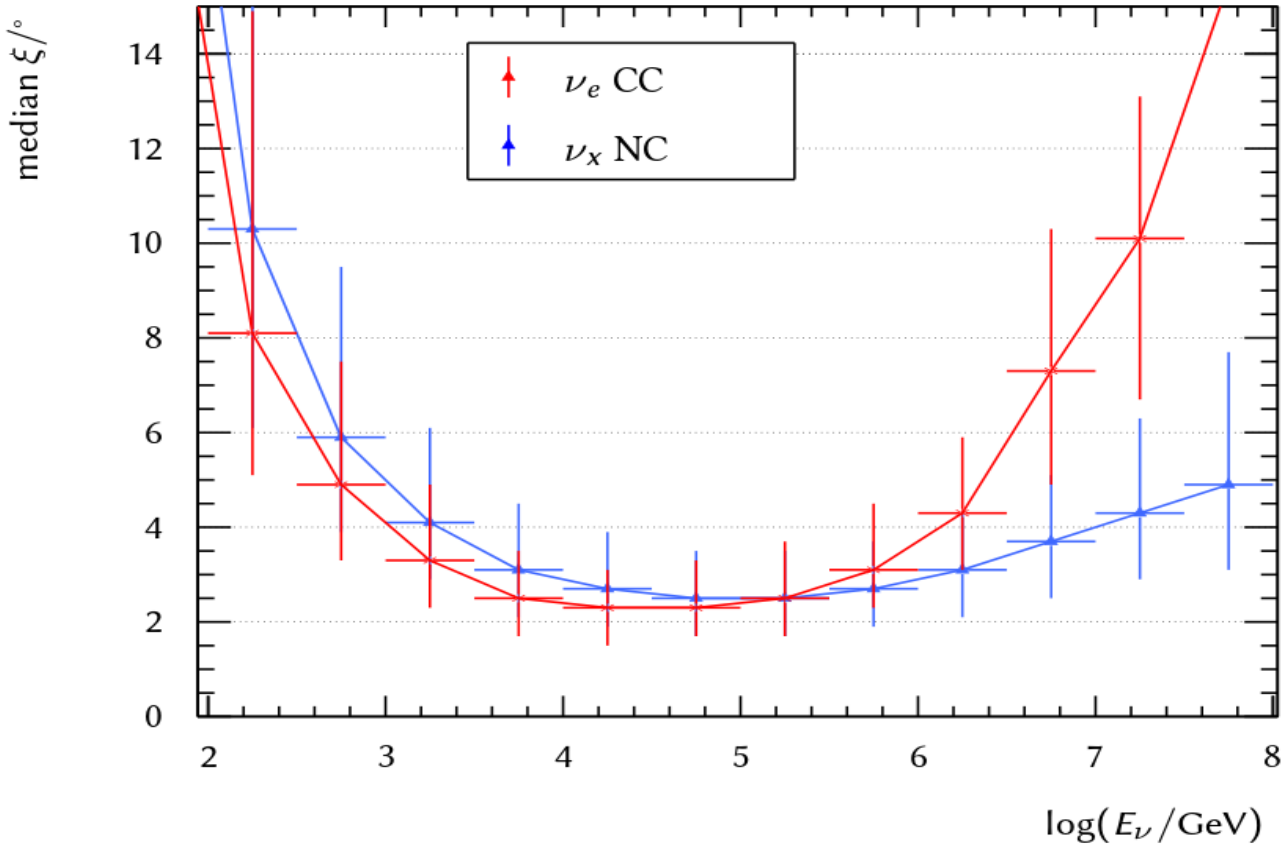
Enhanced sensitivity!

Point Source search (III)
Including cascades



Point Source search (III) Cascade reconstruction

- Angular resolutions: better than 4° from 10 TeV to 1 PeV
- This allows to include cascades in PS searches

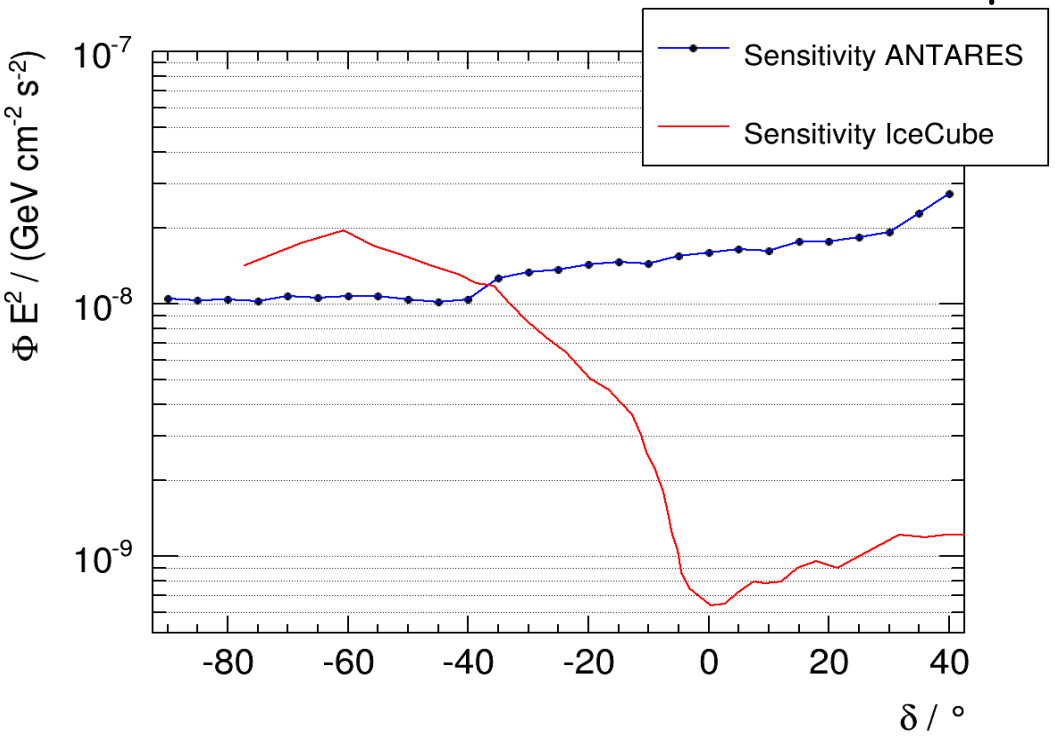


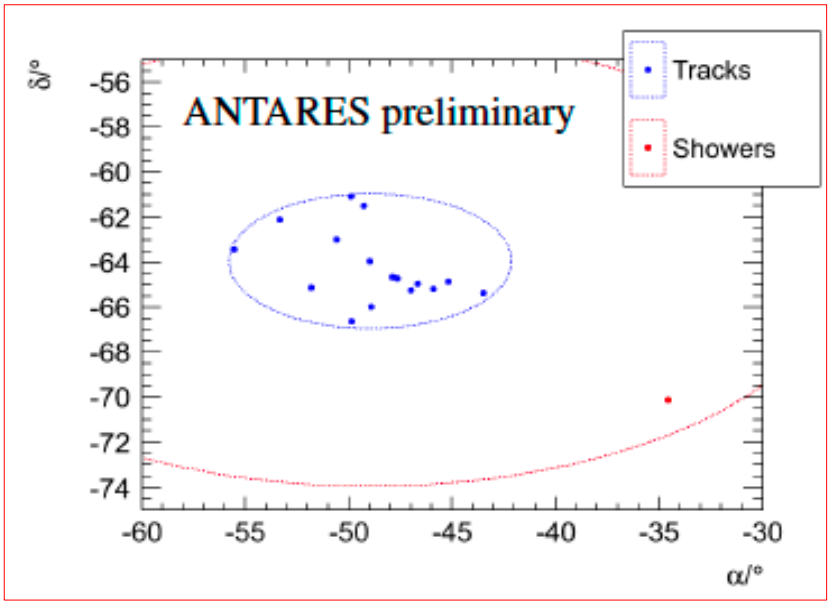
Point Source search (III) Analysis including cascades

- A point source search including tracks and cascades

  -The sensitivity is improved by 30% with respect to just tracks

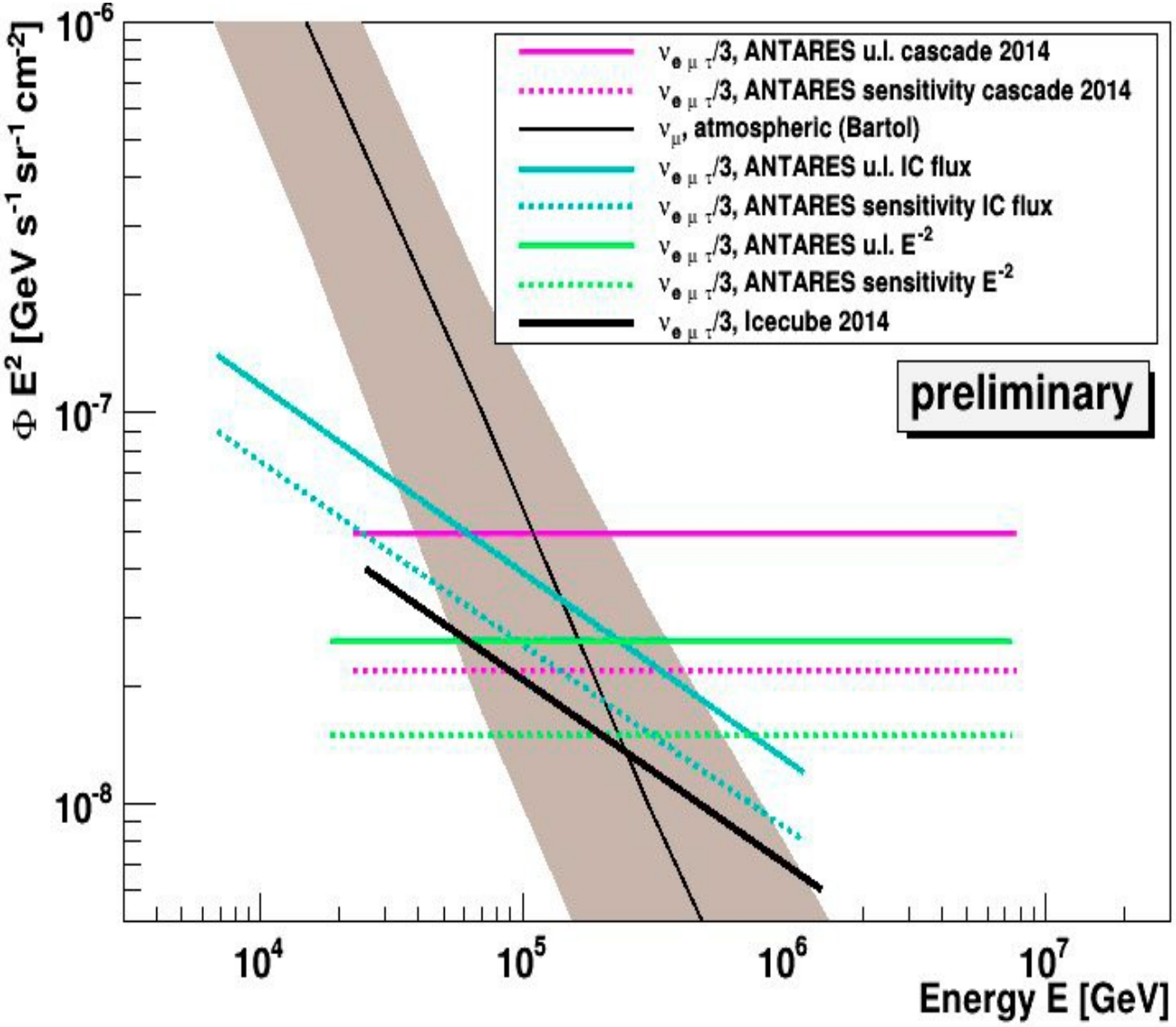
  -The best cluster shows a p-value of the 18.5 %





Diffuse flux studies

All sky



Expected:

- 9.5 ± 2.5 bkgd
- 5.0 ± 1.1 IC flux

Observed:

- 12 events
- 1.75σ excess

Results:

- Consistent with bkgd
- Consistent with IC

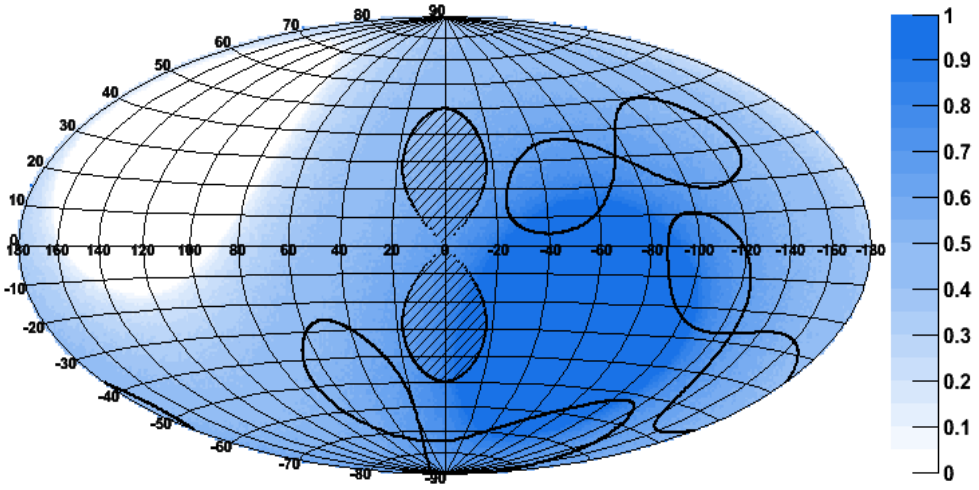
Fermi Bubbles

Analysis

$$E^{2.18}\frac{d\Phi_\gamma(E_\gamma)}{dE_\gamma} = 0.5-1.0 \times 10^{-6}\,\mathrm{GeV}^{1.18}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}$$

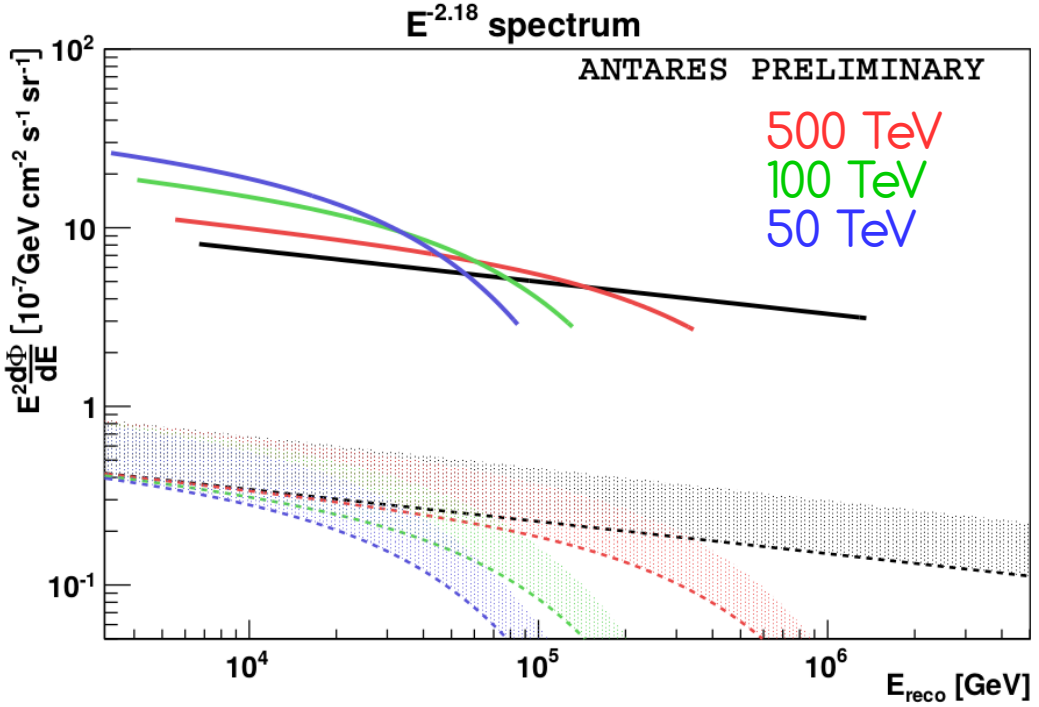
C. Lunardini, S. Razzaque, and L. Yang, arXiv1504.07033

- Assuming a hadronic scenario,
  $\Phi_\nu(E) = 0.36 \cdot \Phi_\gamma(E)$
- Off-zone analysis: search for an excess in the on-zone with respect to the off-zones

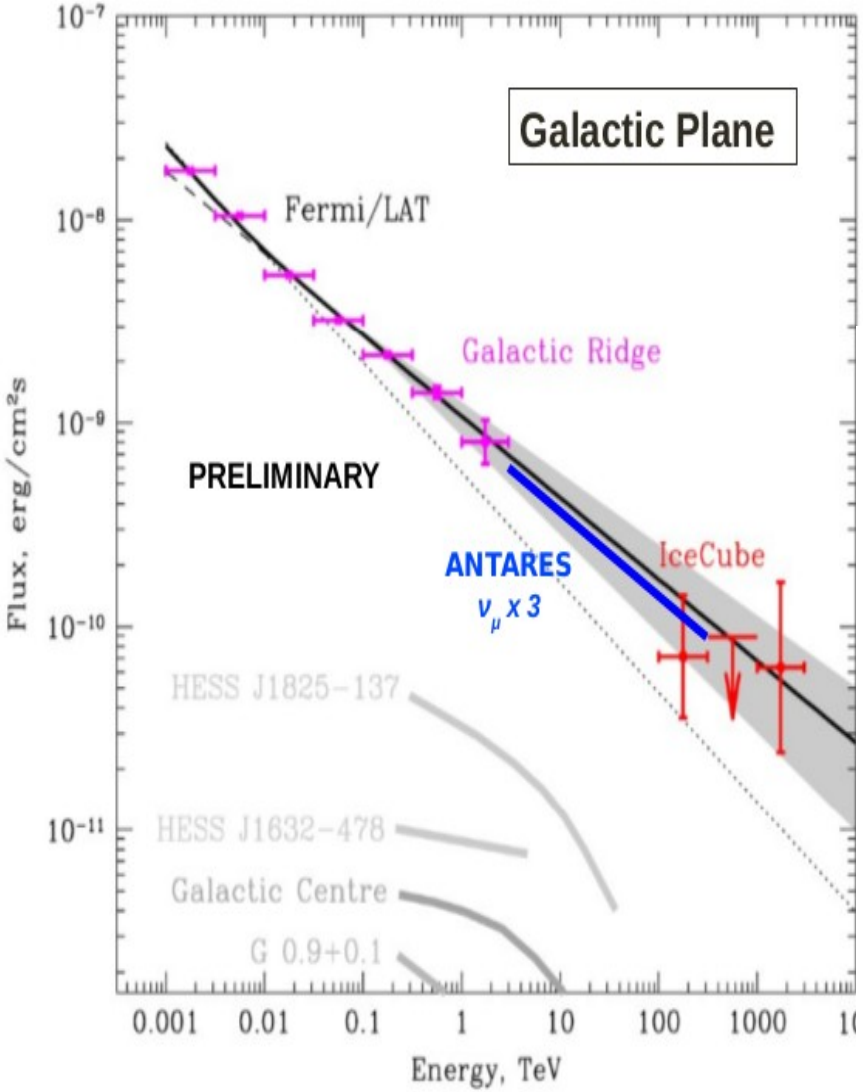


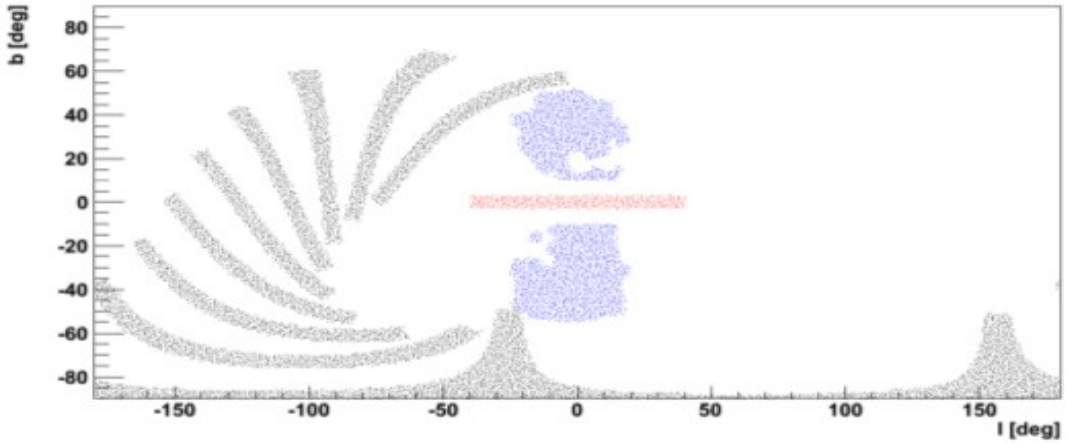
Results

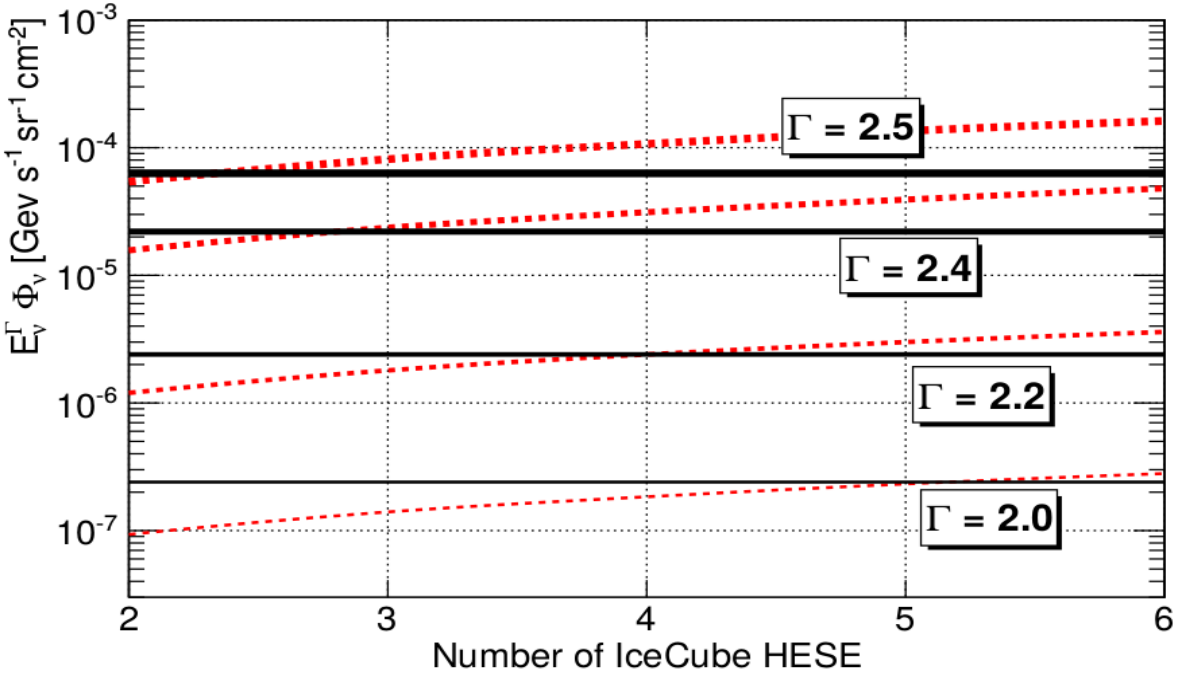
- Previous analysis (806 days):
  -1.2σ excess
- New analysis (806+366 days):
  -1.9σ excess
  -Upper limits for different cutoffs



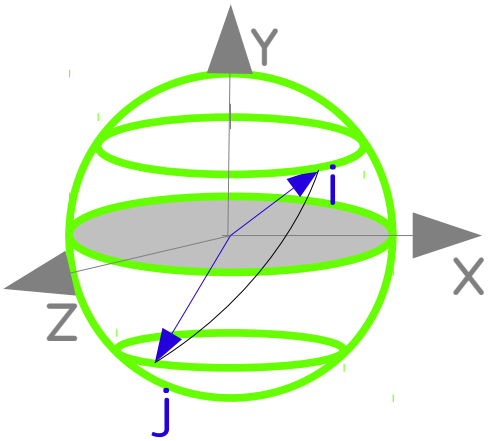
Galactic plane

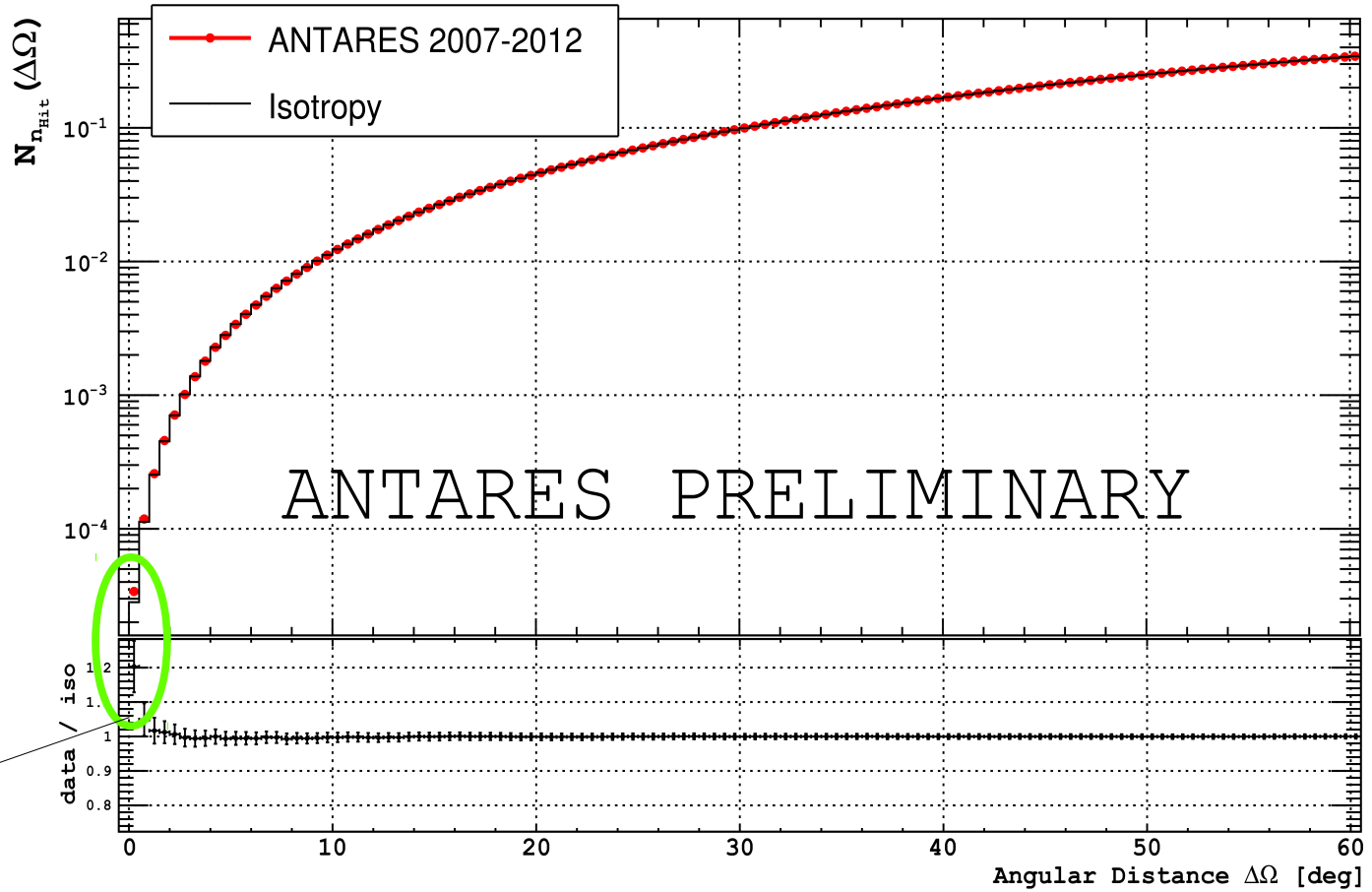






Correlation Analysis





2.3 σ excess at
0.5° scales

Multi-messenger astronomy

TAToO

An X-ray and optical follow up of ANTARES neutrino alerts

Collaborators

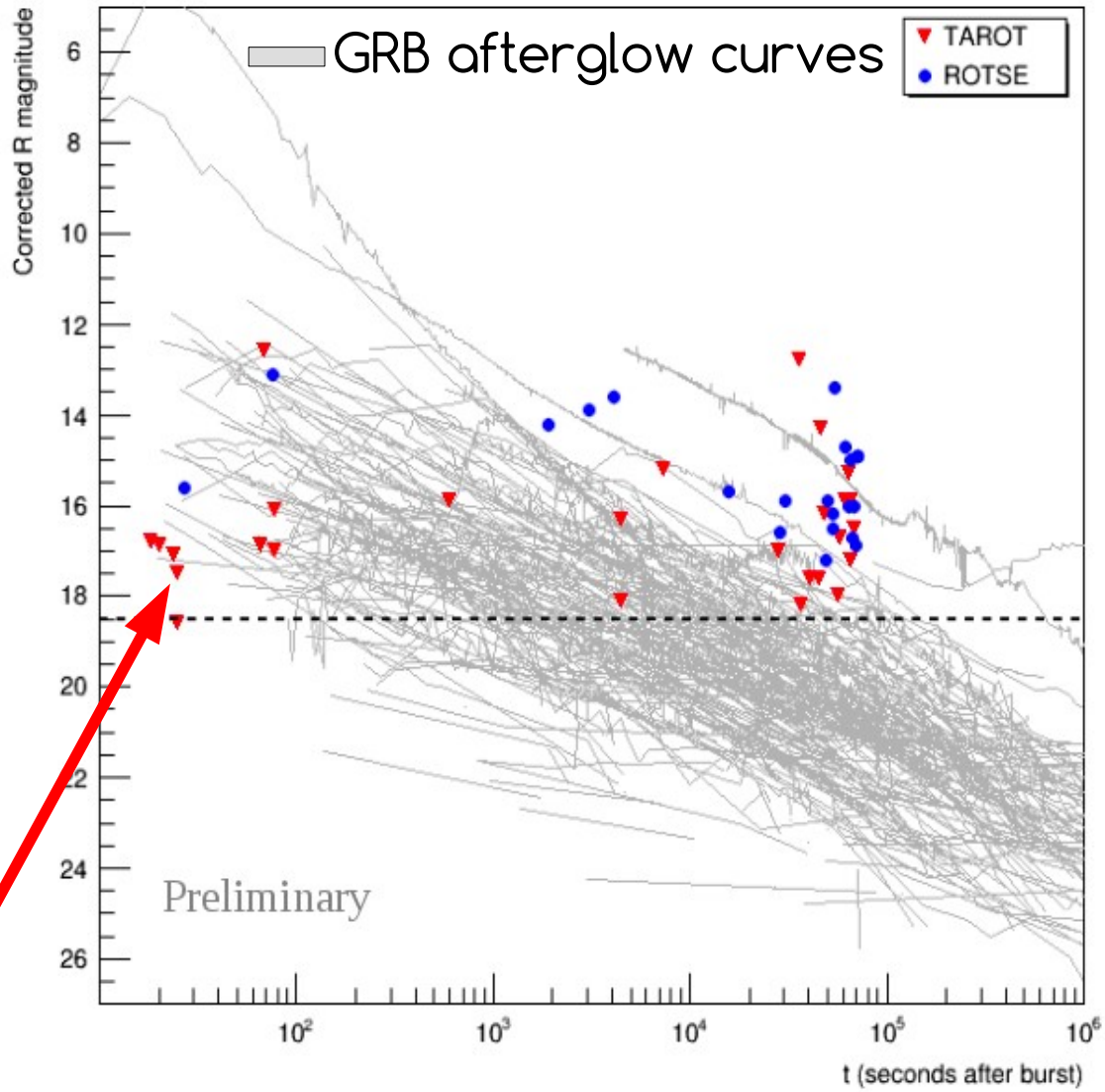
- TAROT
- Zadko
- MASTER → Optical
- Swift-XRT → X - ray

Trigger criteria

- Single **high energy** neutrino
- **Pointing** towards local galaxy (<0.5°)
- **Doublet trigger** (2 neutrinos within 3° in less than 15 min)

Results

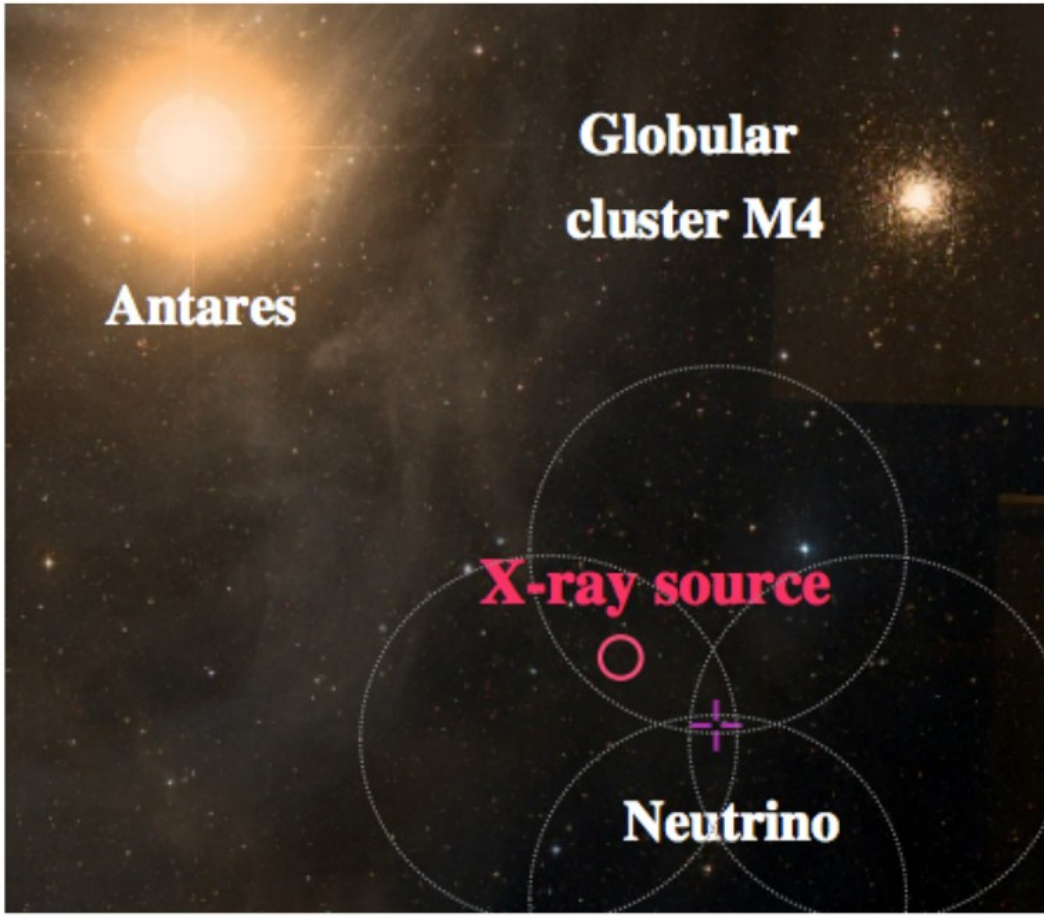
- **Upper limits** in GRB magnitudes

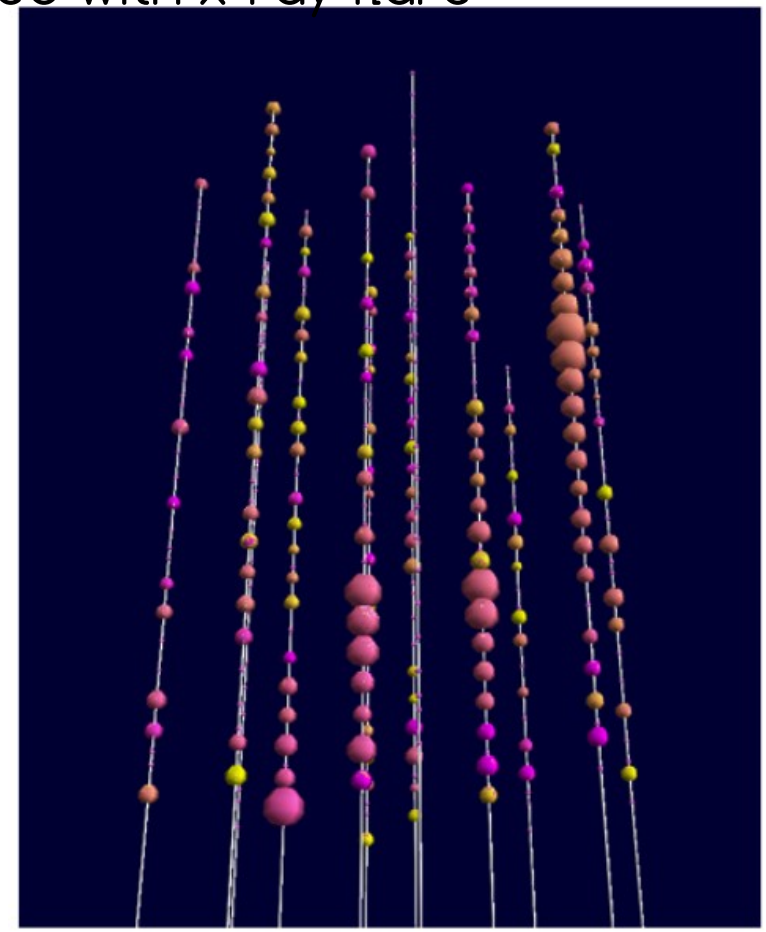


TAToO: Recent alert

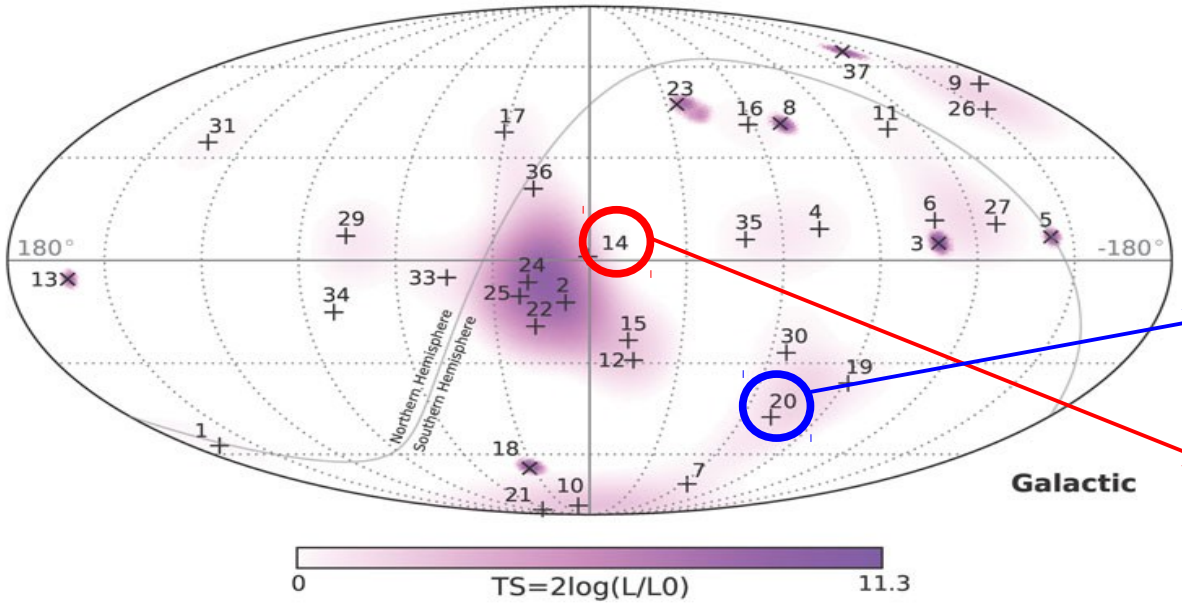
- Very high energy alert (~60 TeV)
- **Time:** 2015/09/01 07h38m25s UT
- **RA (J2000):** 16h 25m 42s (246.3064d)
- **DEC (J2000):** -27d 23m 24s (-27.4684d)

- **Swift:** uncatalogued x- ray source witihin 8 arcmin from the neutrino direction
- **Optical:** Bright star in Swift source location
- **Multiwavelength observations:** Star correlated with x-ray flare





ANTARES + TANAMI



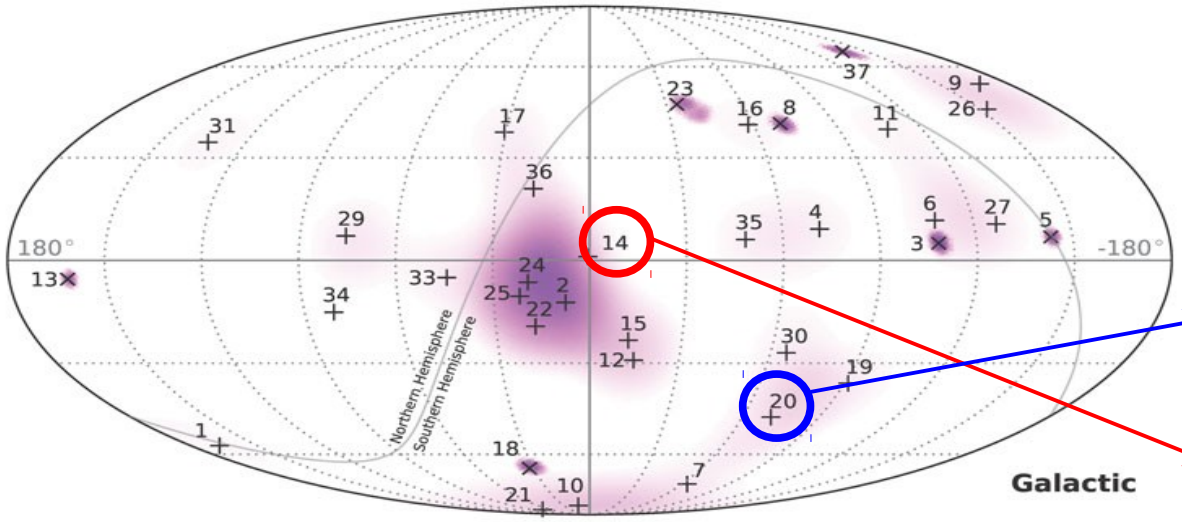
Krauß, F. et al., 2014, A&A 566, L7

Source	F_γ [GeV cm^{-2} s^{-1}]	N_{ν_e}	IC
0235−618	$\left(6.2^{+3.1}_{-3.1}\right) \times 10^{-8}$	$0.19^{+0.04}_{-0.04}$	20, 7
0302−623	$\left(2.1^{+0.4}_{-0.4}\right) \times 10^{-8}$	$0.06^{+0.01}_{-0.01}$	20
0308−611	$\left(4.7^{+1.8}_{-1.8}\right) \times 10^{-8}$	$0.14^{+0.05}_{-0.05}$	20
1653−329	$\left(2.8^{+0.3}_{-0.3}\right) \times 10^{-7}$	$0.86^{+0.10}_{-0.10}$	14, 2, 25
1714−336	$\left(1.5^{+0.3}_{-0.4}\right) \times 10^{-7}$	$0.46^{+0.10}_{-0.12}$	14,2,25
1759−396	$\left(7.5^{+1.9}_{-1.9}\right) \times 10^{-8}$	$0.23^{+0.50}_{-0.40}$	14, 2, 15, 25

- The **TANAMI** collaboration **identifies 6 bright blazars** within the IC14 and IC20 IceCube events PSF

- **Can** their neutrino spectra **be constrained**?
  - **ANTARES** performed a "candidate list" point source search

ANTARES + TANAMI



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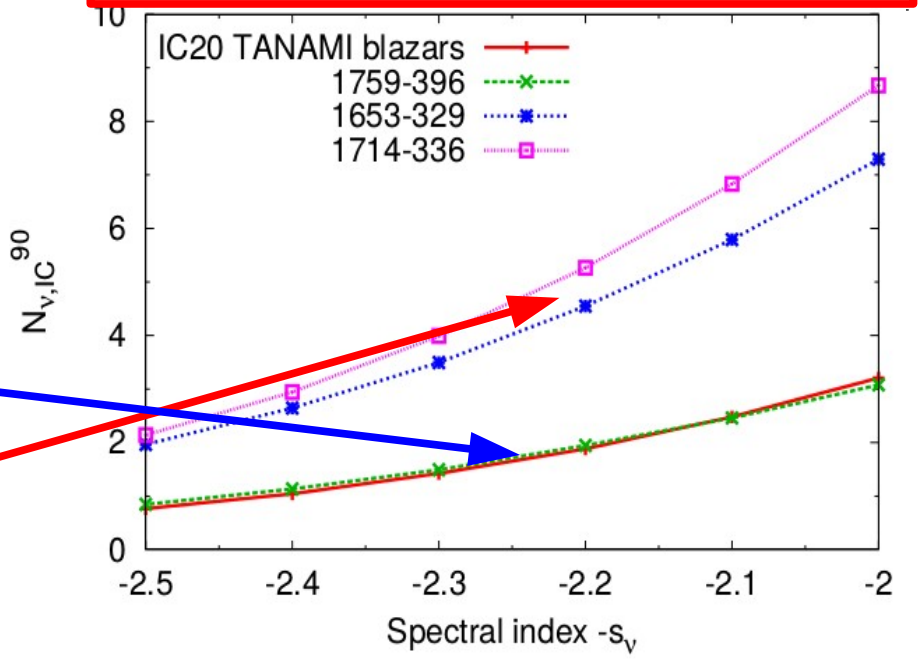
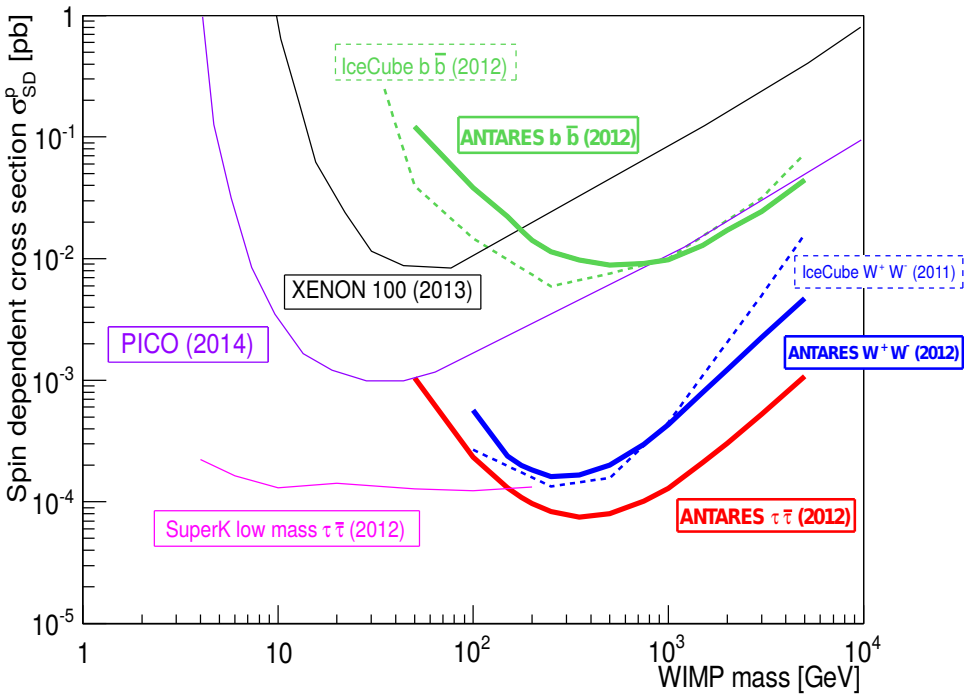
- No neutrino associated. Limit on the blazars spectral indices
- 1 neutrino associated with each blazar, compatible with IC14-Source association but also with BG.



Indirect search for dark matter

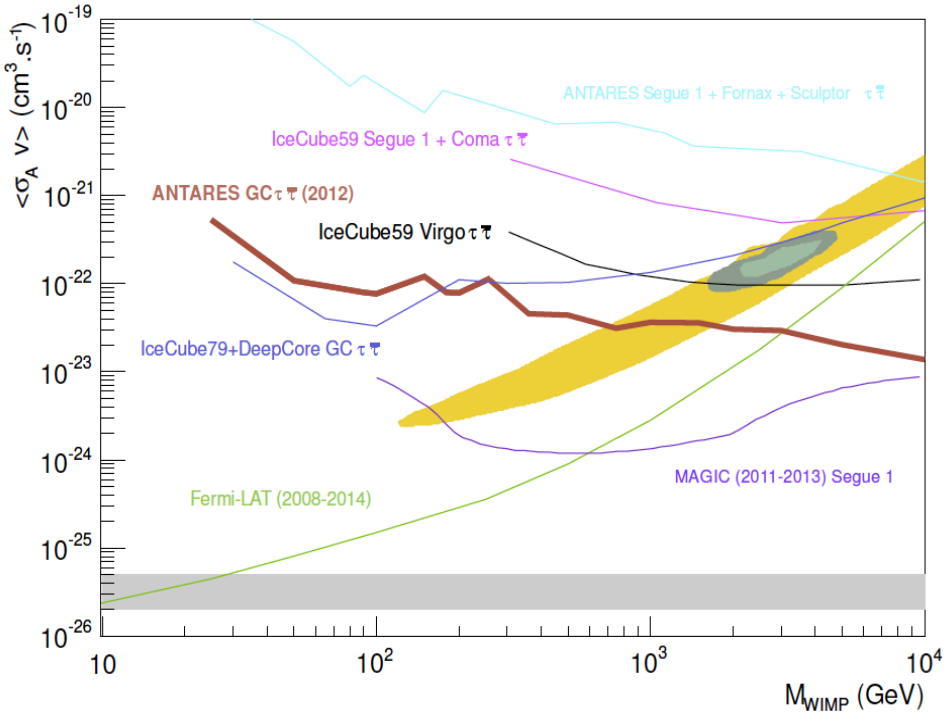
Dark Matter

Sun



- Limits in the spin-dependent Wimp-nucleon cross section

Galaxy



- Limits on the Wimp self annihilation cross section

Competitive limits!

Conclusion & Outlook

ANTARES is providing important results in a wide range of physical analyses

- Accurate angular resolution in tracks + cascades & excellent visibility of the southern sky:

  -First PS search including cascades: Increased sensitivity

  - Point source search: Limit physical scenarios to explain the origin of the IC hot spot

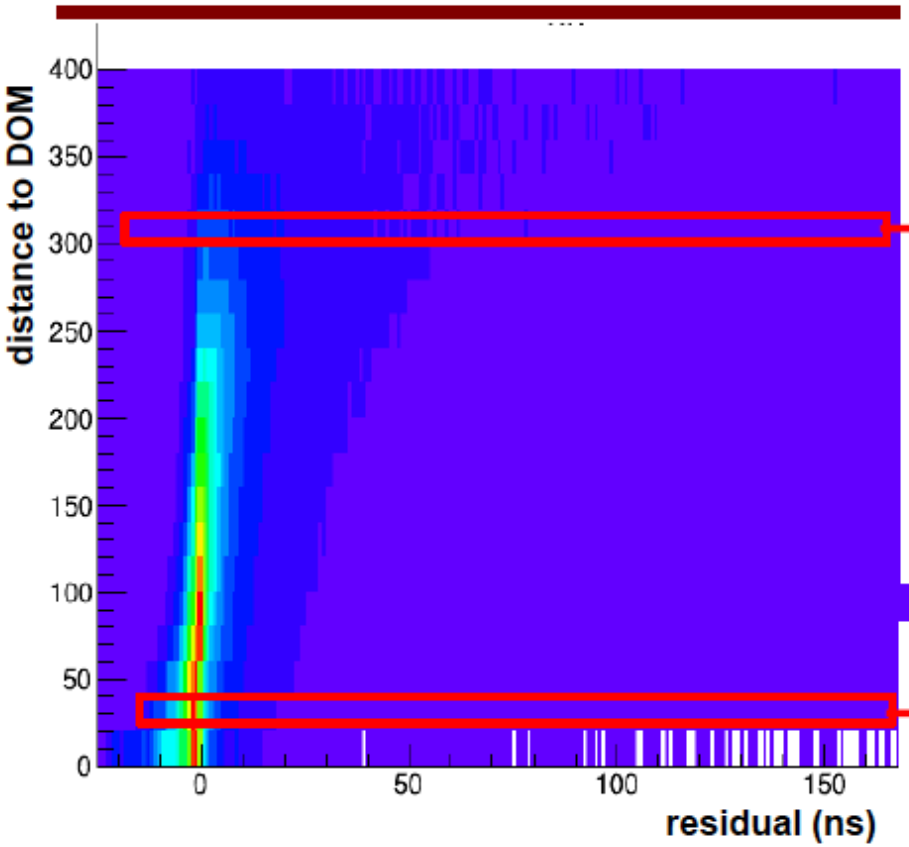
    - Galactic plane
    - Galactic Center
    - Blazars

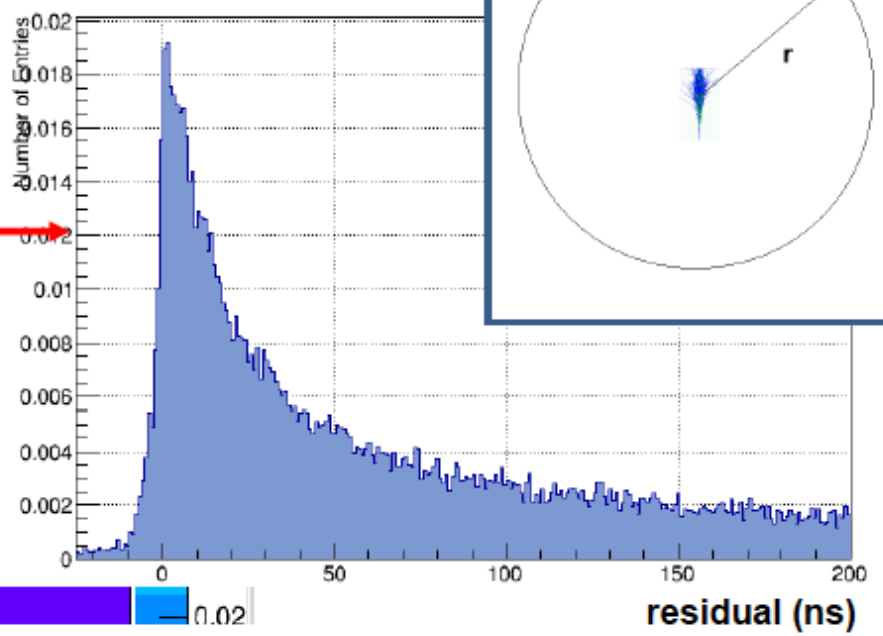
- Multi-messenger astronomy: Limits on GRB magnitudes (TAToO)
- Diffuse flux: Improved results in FB analysis. Still more data to be analyzed
- Dark Matter: competitive limits for the spin dependent WIMP-proton cross section from the Sun observations

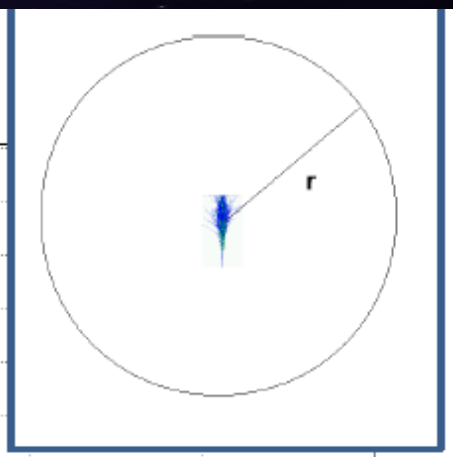
Backup

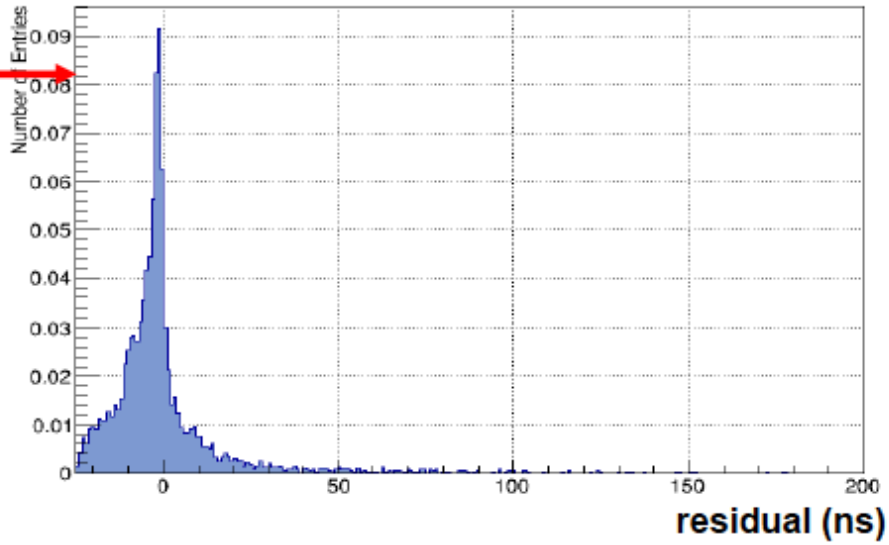
Cascade reconstruction

Cascade signature in water: time







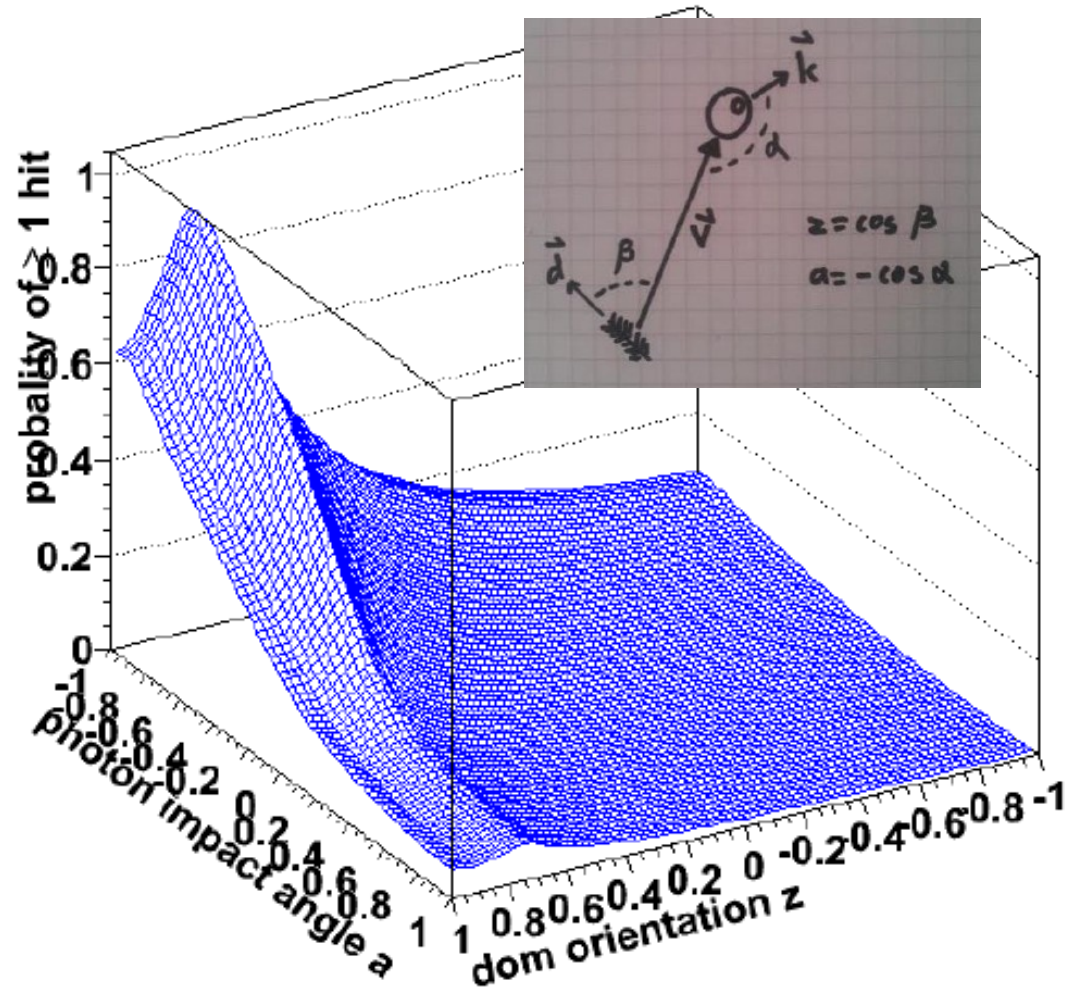


Concerning arrival times:

- spherically expanding shell of light around shower maximum
- allows accurate vertex resolution
- To first order *no direction* information in timing.

Cascade reconstruction

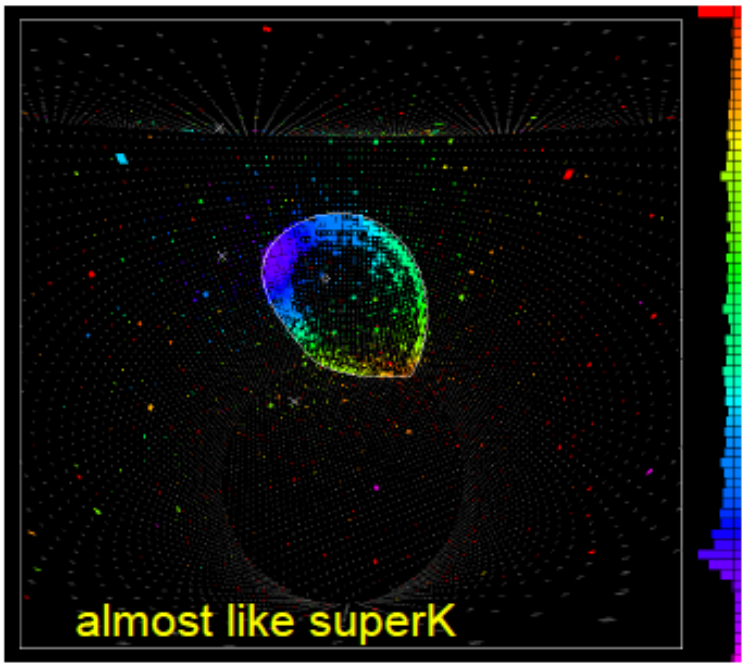
PDF for E = 1 PeV at r = 250 m



– Light is beamed in the Cherenkov direction.

– Pattern remains at large distances from the shower.

– energy independent!



need to measure the light amplitude (ToT)