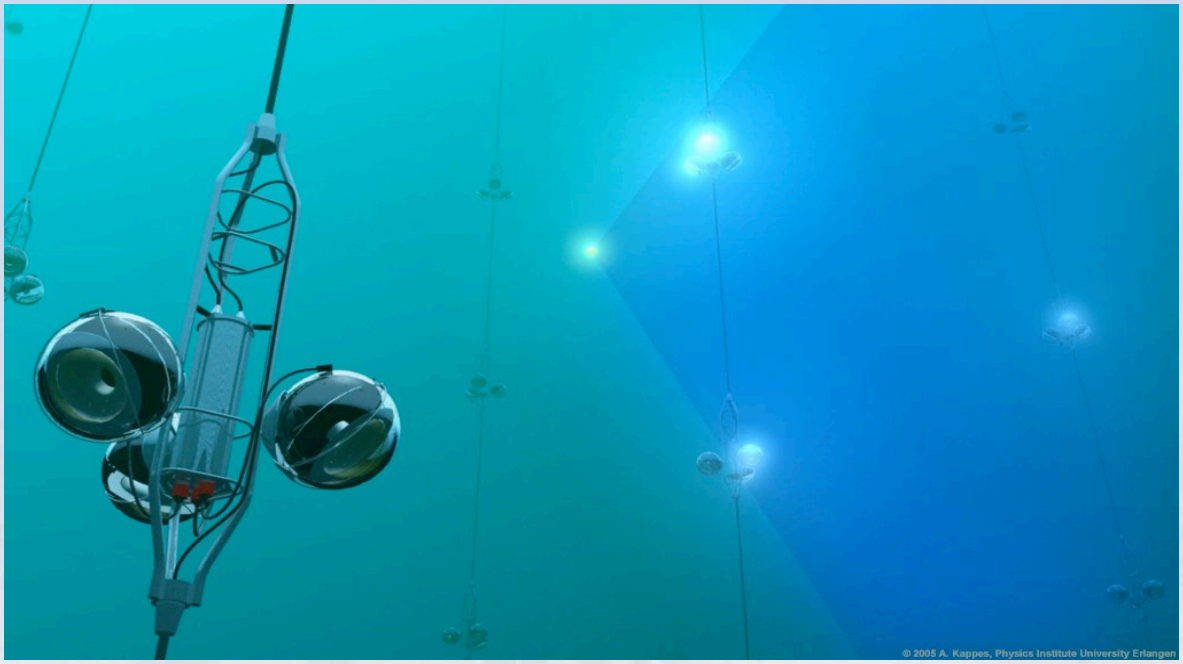
Latest results from ANTARES

Blois2014, May 18th



Hugon Christophe
INFN sezione di Genova

On behalf of the ANTARES Collaboration

Overview

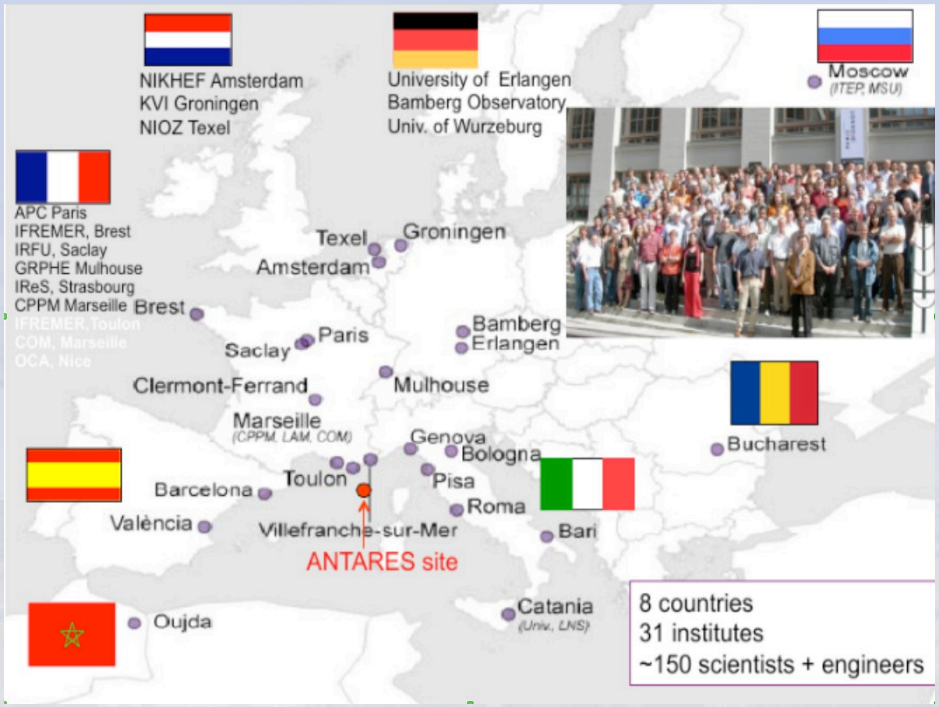
Introduction & description

- Overview
- The ANTARES detector
  - The collaboration
  - The site
  - The apparatus
- Track reconstruction

Physics results

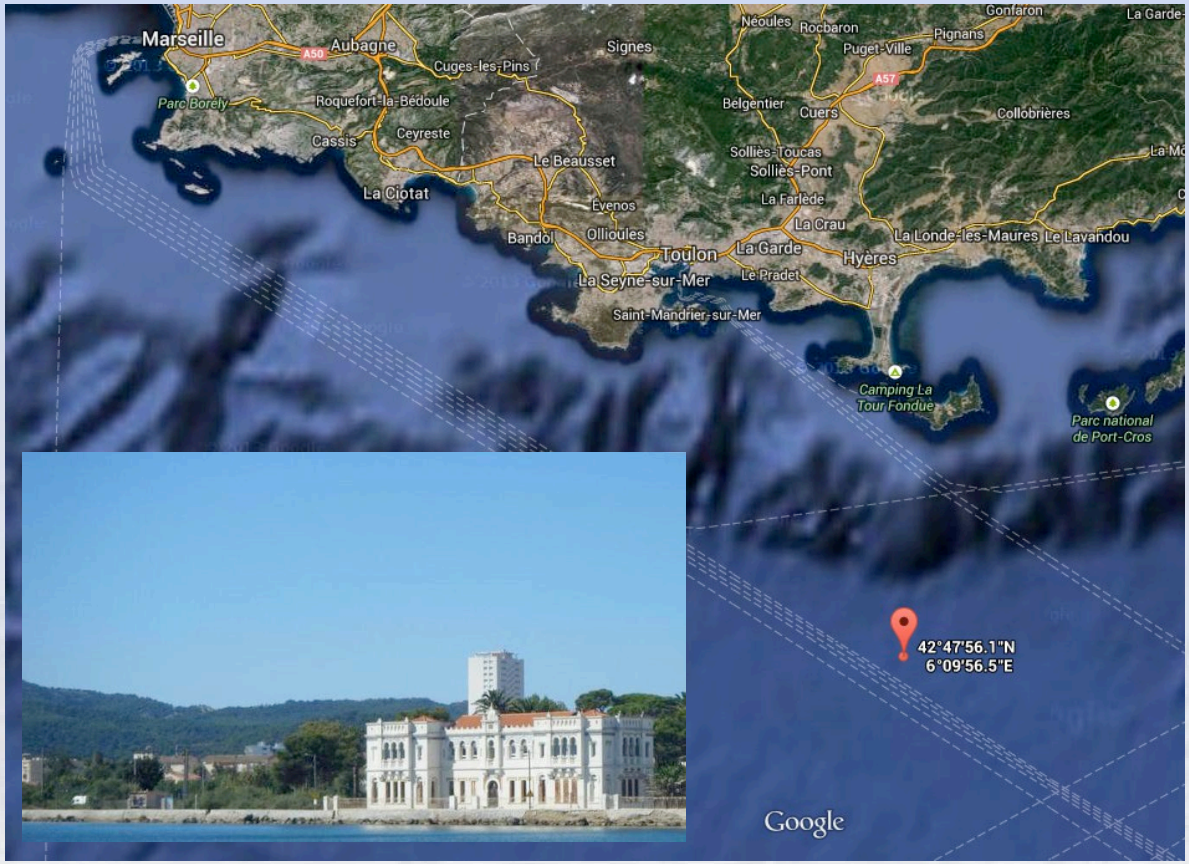
- Diffuse flux
- Neutrino point source search
- Fermi bubbles research
- Multi-messenger search
  - GRB results
  - Flaring sources
  - Gravitational waves
- Conclusion and perspectives

The ANTARES Collaboration



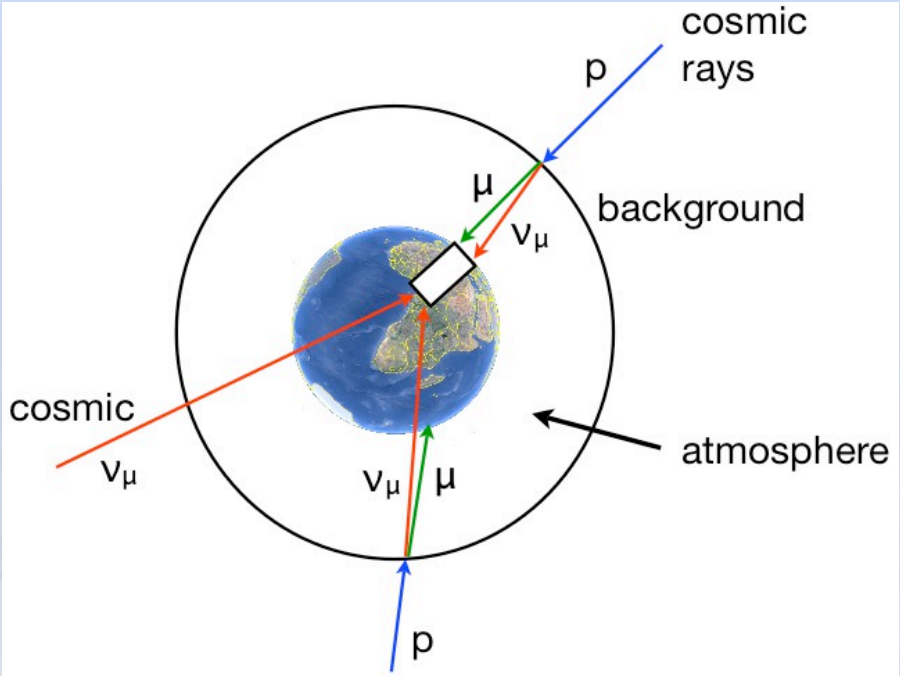
About 150 people Working in about 31 institutes in 8 countries

The ANTARES Site

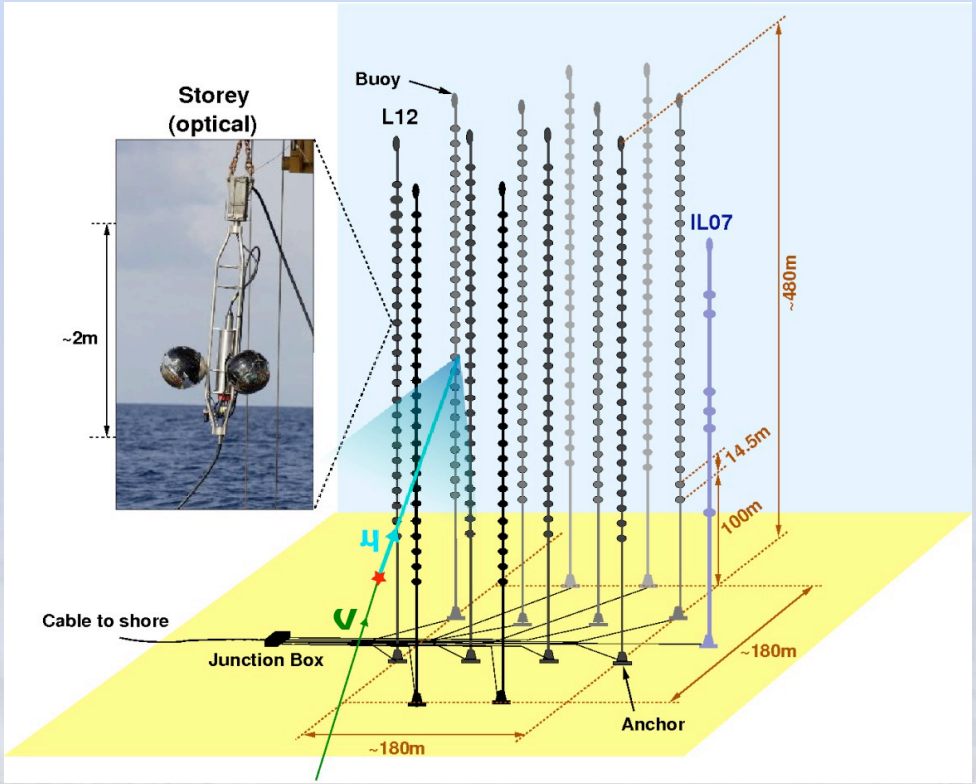


- On the Mediterranean sea bed
- 40 km off the Toulon coast
- 2475 m depth

The ANTARES apparatus

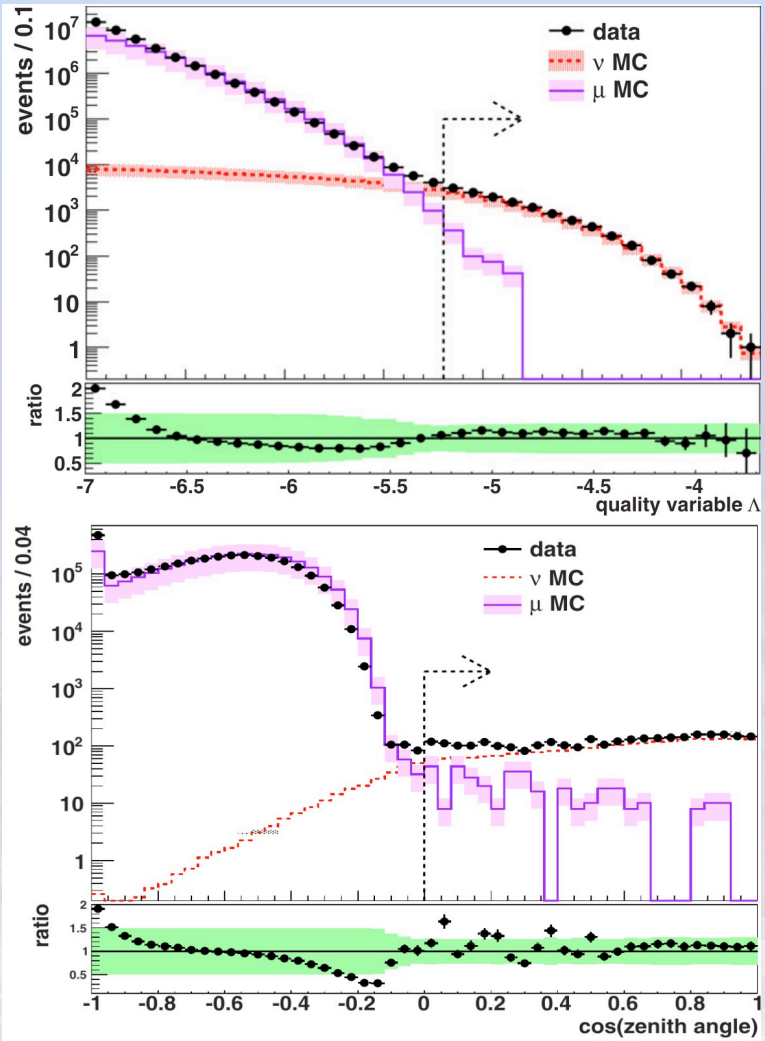


- Main target: cosmic neutrinos going through the Earth
- Main background
  - Atmospheric muons
  - Atmospheric neutrinos



- 12 lines compounded of 885 photo multiplier tubes
- Detect the Čerenkov effect
- Taking data since 2007

Track reconstruction



- Time and position
- Likelihood maximization method
- Cut on measured angle θ (atm. muons)
- Cut on the likelihood Λ (misrec. of track)

- Resolution ~ 0.3°
- ~ 3 – 10 muons/s
- ~ 4 ν/day
- Visibility: ¾ of the sky is covered, including the Galactic Center

Diffuse flux

Theory
- ν_μ from unresolved sources
- Flux from UHECRs and γ-rays

Search with the 2008-2011 data (855 days)
- dE/dx (hits repetitions) as energy estimator
- Negligible muon contamination
- Sensitivity:

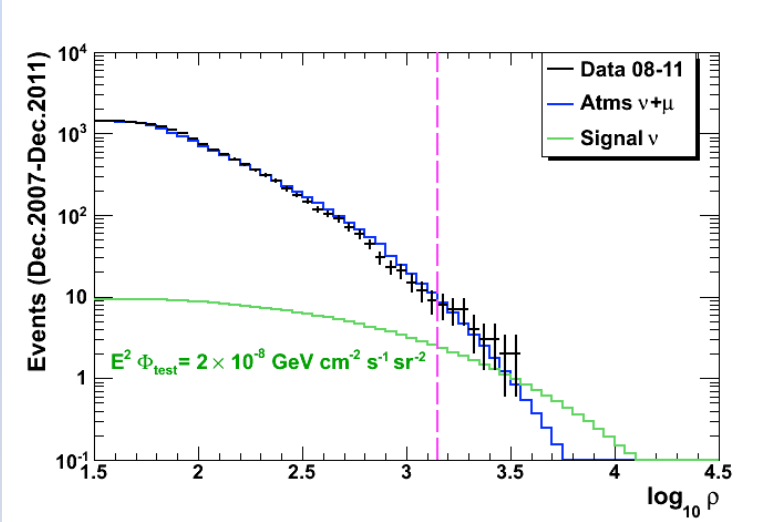
$$E^2\Phi = 4.7 \times 10^{-8}\ \mathrm{GeV cm^{-2} s^{-1} sr^{-1}}$$

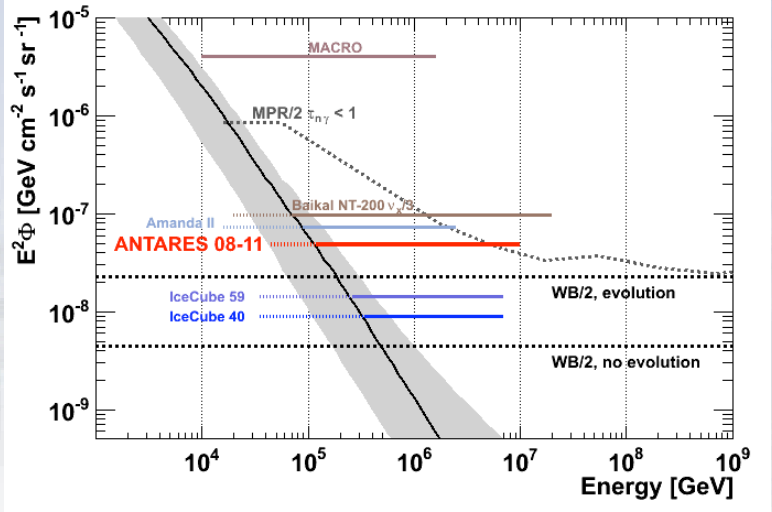
- Unblinded results (45 TeV to 10 PeV):

$$E^2\Phi_{90\%} = 4.8 \times 10^{-8}\ \mathrm{GeV cm^{-2} s^{-1} sr^{-1}}$$

$$N_{obs} = 8, N_{bkg} = 8.4, N_{sig} = 2.3$$

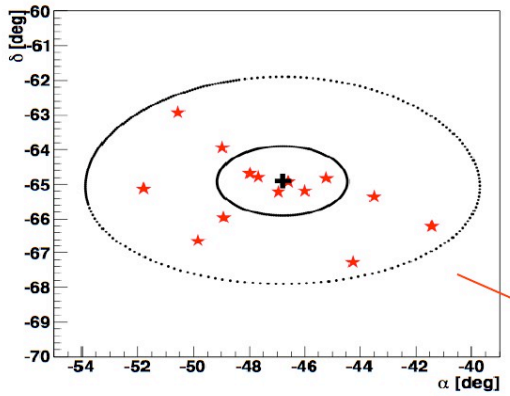
Phys. Lett. B 696 (2011) 16-22, arXiv:1011.3772
Waxman & Bahcall, Phys.Rev.D59(1998)023002
Feldman & Cousins, hys.Rev.D57(1998)3873





Neutrino point source search

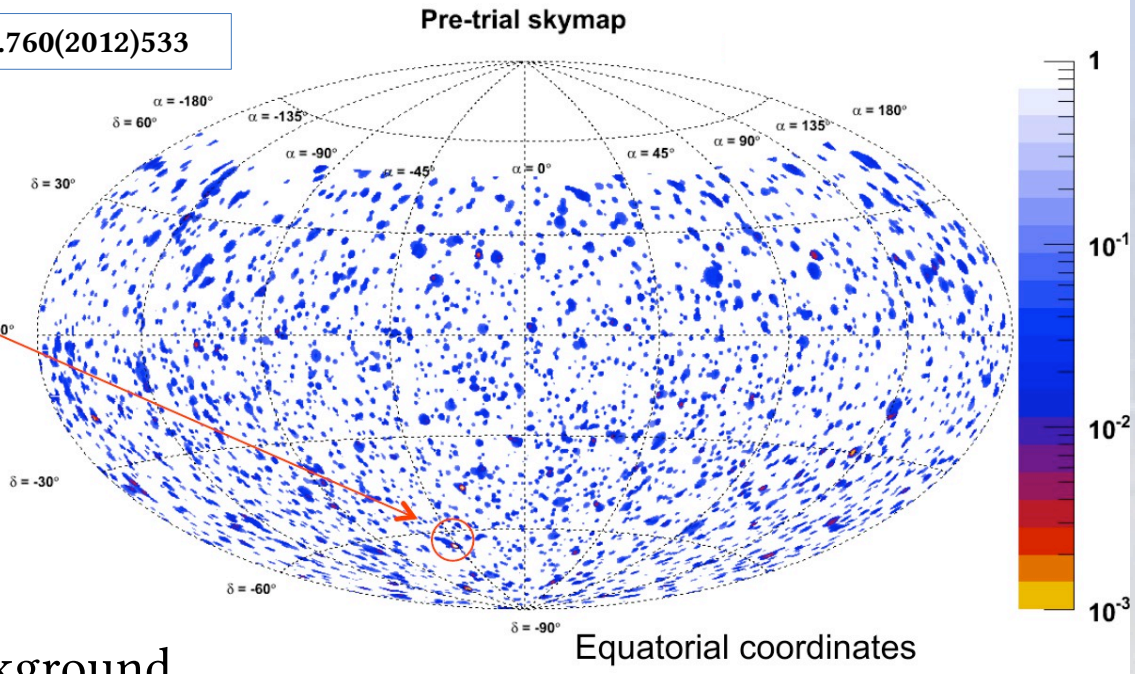
- 1340 days of data (2007-2012)
- 5516 neutrino candidates and no significant excess



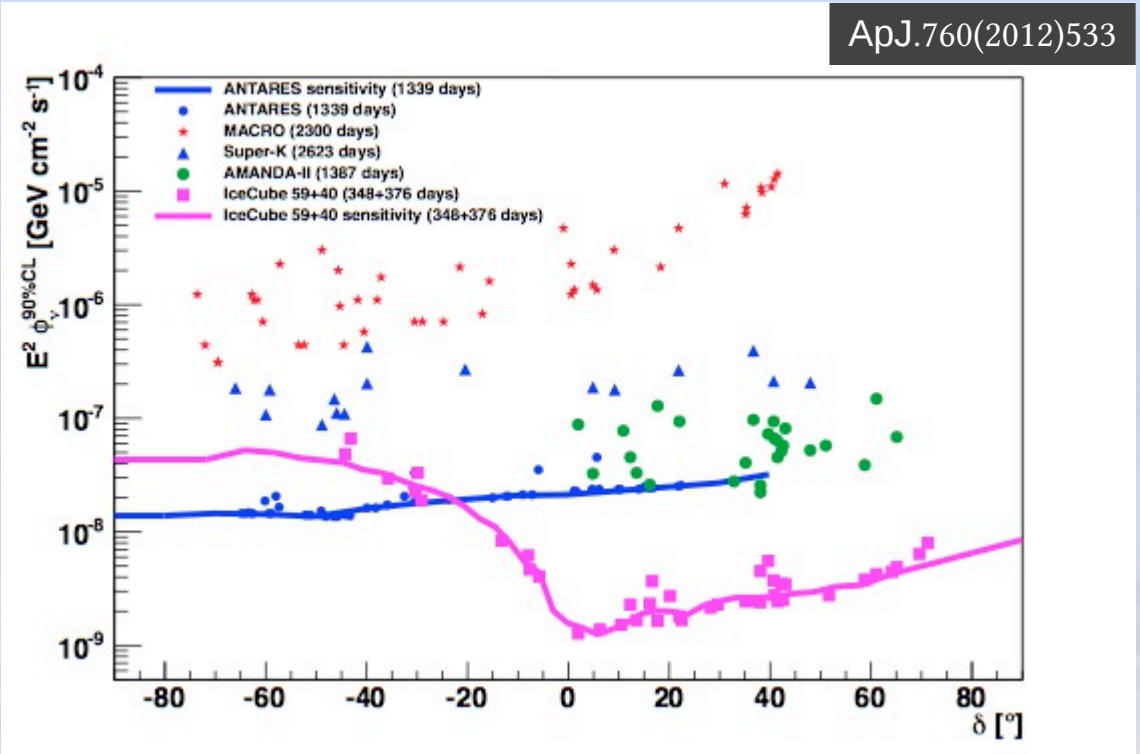
Most significant cluster, 14 events

P-value of 2.1% (~2 σ)
→ compatible with the background

ApJ.760(2012)533



Neutrino point source search

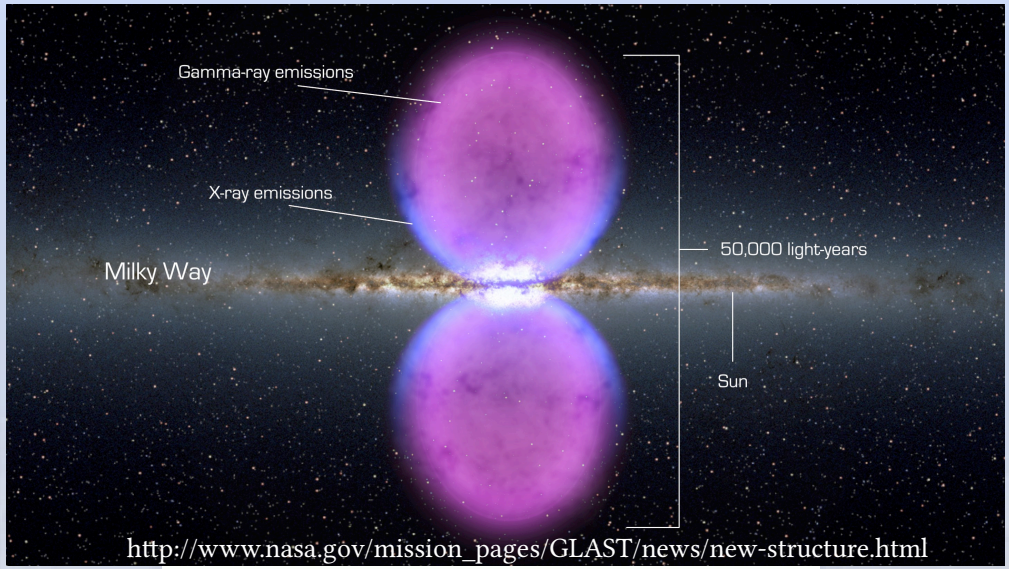


- 51 candidates
- The best sensitivity in southern sky (TeV)
- Improvement expected by including showers
  → arXiv:1312.4308

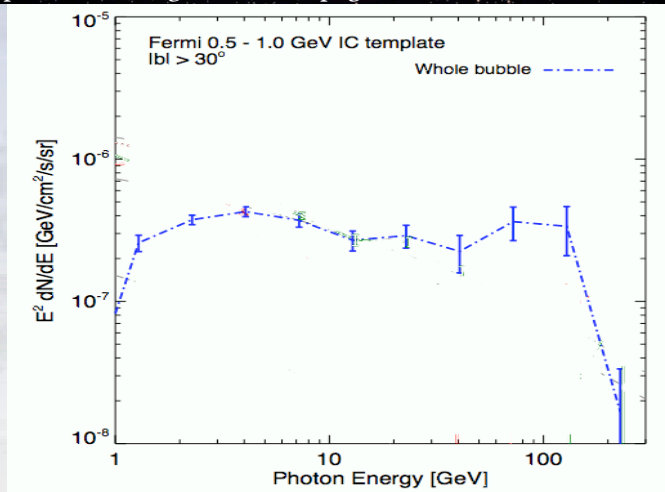
Fermi bubbles research

- Excess of γ and X rays above and below the Galactic Center
- Homogeneous flux in E^{-2}
- The Galactic wind is a possible origin
- An energy cut-off is probable
- The hadronic scenario is privileged
- $\Phi_\nu = 0.4 \times \Phi_\gamma$

M.Su et al., ApJ.724(2010)



http://www.nasa.gov/mission_pages/GLAST/news/new-structure.html

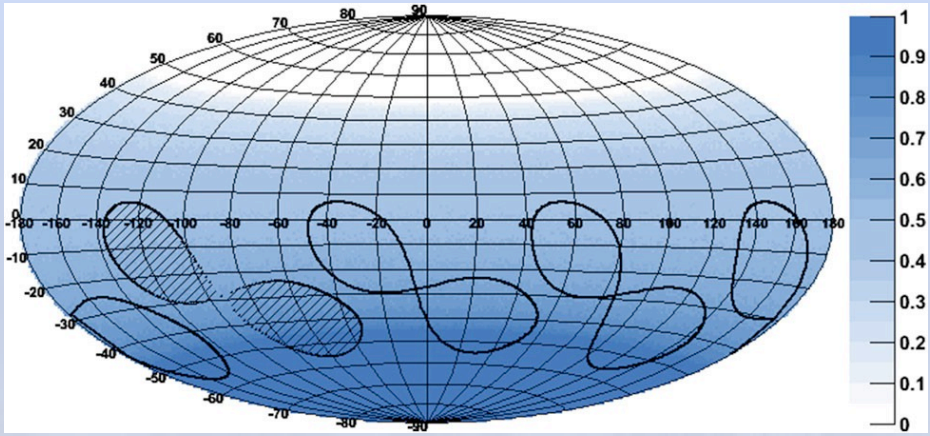


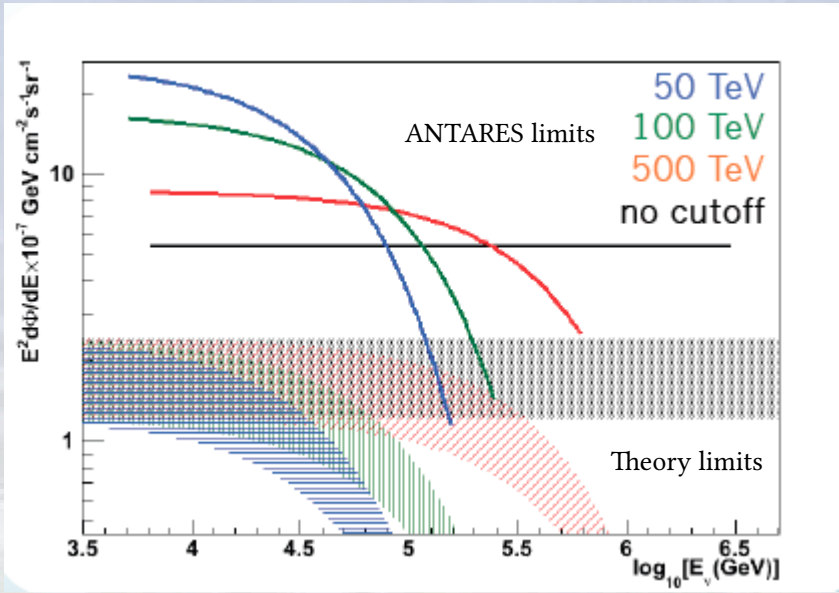
Fermi bubbles research

- 3 off zone to evaluate the background
- 806 days of data (2008 to 2011)
- Neural network for the energy estimation
- $N_{obs} = 16$, $N_{bg} = 11$

$\longrightarrow$ 1.2 σ, no significant excess

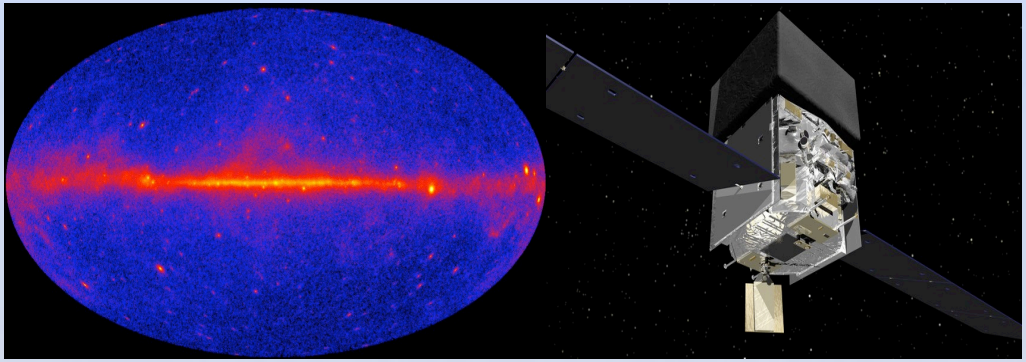
EPJ C 1434-6044(2014)





Multi-messenger search

GRB sources from GCN

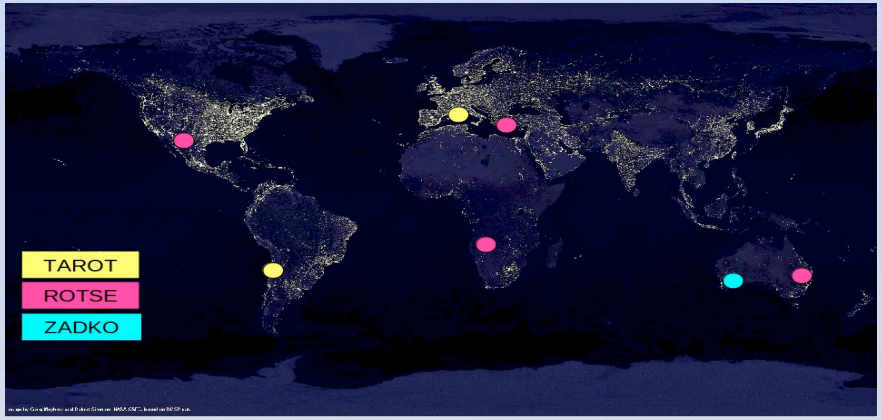


GCN provides time a coordinates of the GRBs from the Swift and Fermi satellites

- Neutrino in coincidence with GRB
- Better background rejection
- Better sensitivity

A&A 559, A9 (2013)

TAToO: Alert and follow-up

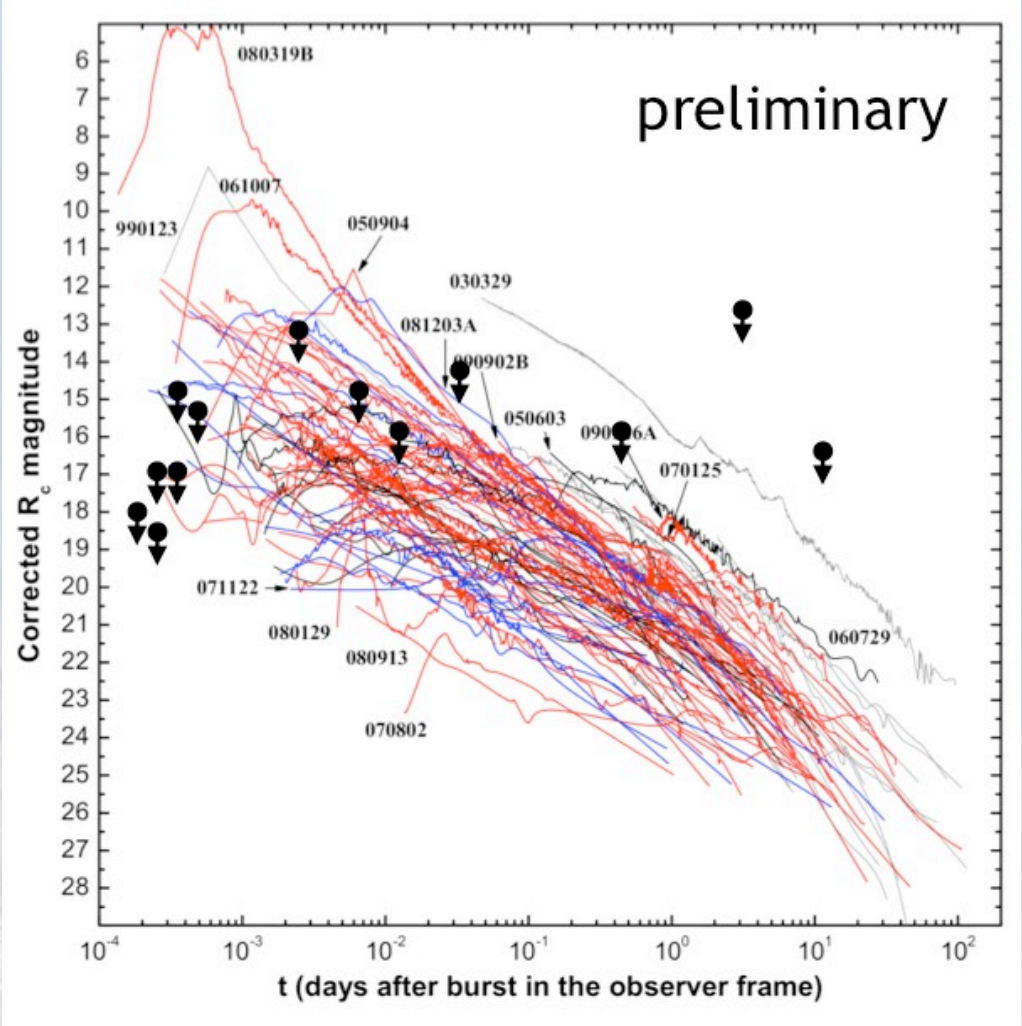


- Precision of 0.5° (E > 1 TeV)
- Reconstruction latency < 5 s
- Alert latency < 10 s
- Slewing latency < 5 s
- Large sky coverage
- Data from 02/09 to 12/12
- About 2 per month (115 alerts in total)
- 90 alerts well followed up
- 13 had prompt observation

Astropart. Phys. 35 (2012) 530-536

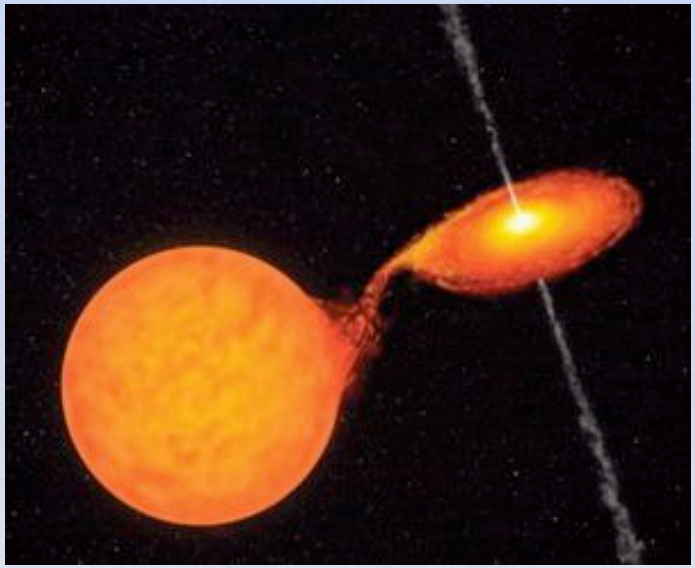
TAToO results

No neutrino detection associated yet



Multi-messenger search

Flaring sources ANTARES

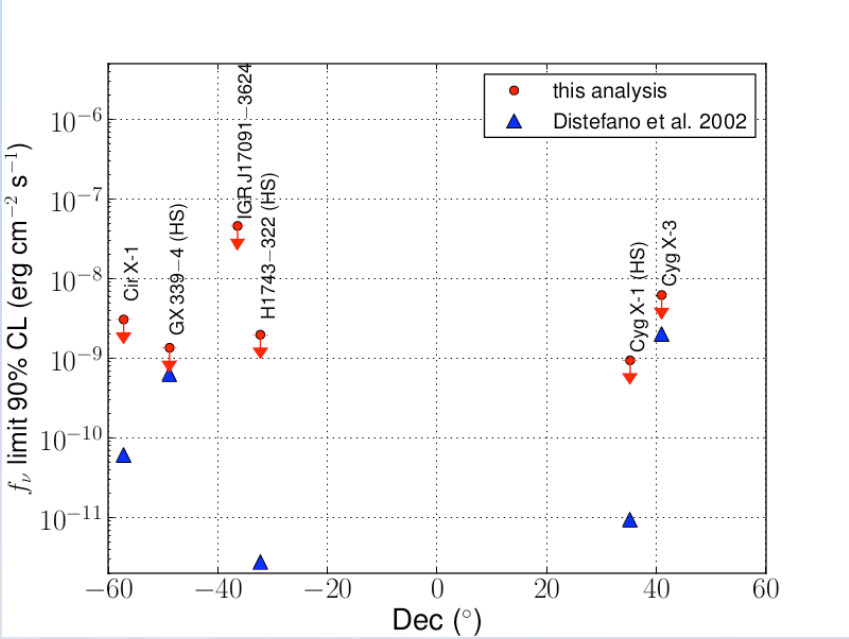


AP 36(2012)204-210

- 10 Blazars (2008)
  - 1 event in coincidence
- 41 Blazars (2008 ⟶ 2011)
  - 2 events in coincidence
- 6 Microquasars

Nothing significant

Method and results



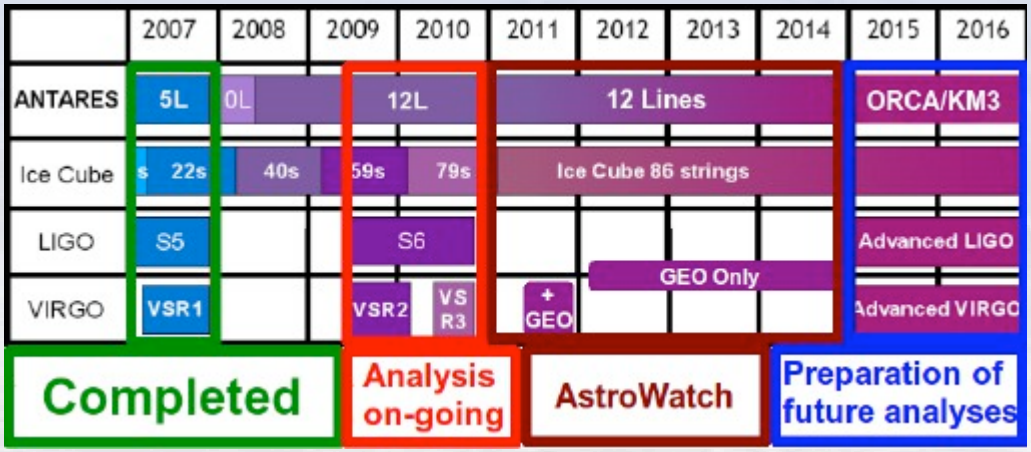
- Sources taken from Fermi, xray, radio… catalog
- γ-ray light curve
- Likelihood maximization
- No significant coincidence
- Flux model:

$$E_\nu^{-2} e^{-\frac{E_\nu}{100\ \mathrm{TeV}}}$$

Levinson, Waxman (2001)
DiStefano et al. (2002)
arxiv.org/abs/1402.1600

Multi-messenger search

Gravitational waves



Method and results

Sources

- Visible: GRBs (short, long low luminosity), SGRs
- Not visible: failed GRBs (choked)

Method

- HE neutrino as a trigger
- Gravitational waves in time/space coincidence
- Off zone background estimation

Results

- No coincidences found
- Exclusion distances on common GW/HEN emitters

JCAP06(2013)008

Conclusion and perspectives

- ANTARES is the current largest neutrino telescope in the Northern Hemisphere
- Technically, it is a great success
- It has competitive physics results
- The potential of the data analysis is still big (shower, catalogs, statistics, analysis method improvement..)

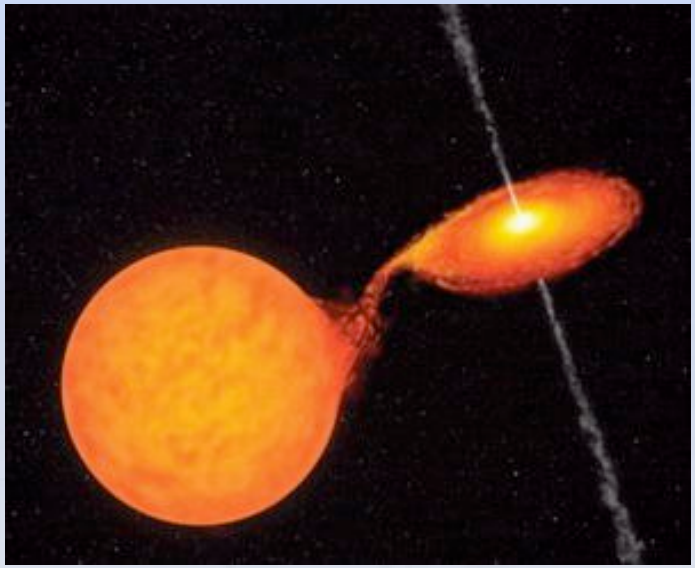
The future is in preparation with KM3NeT:

- Aim to be the largest neutrino telescope on Earth
- A sensitivity largely improved
- A wider field of physics studies will be open (eg neutrino oscillations with the ORCA project)

Backups

Multi-messenger search

Flaring sources ANTARES



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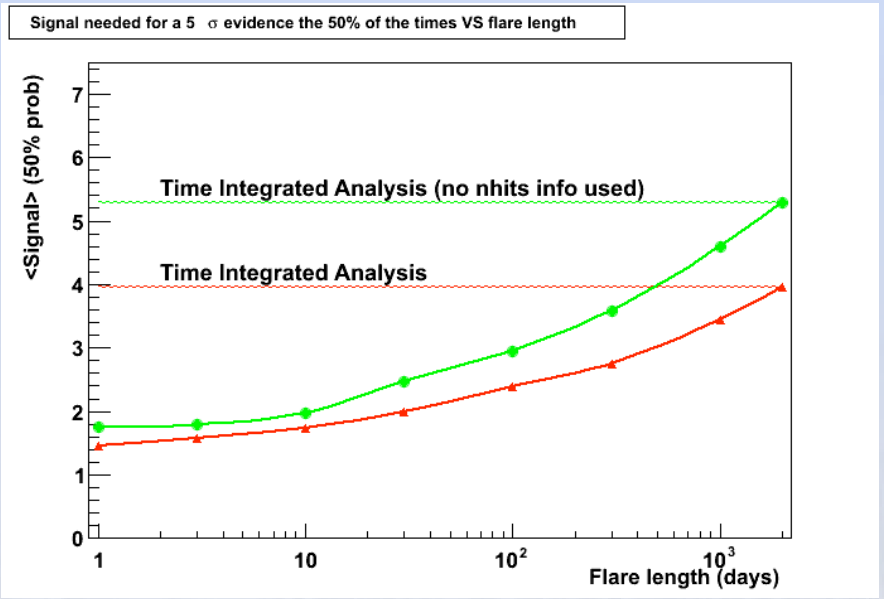
AP 10.1016/j.astropartphys.2012.06.001

Method and results



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- Likelihood maximization
- No significant coincidence
- Flux model:

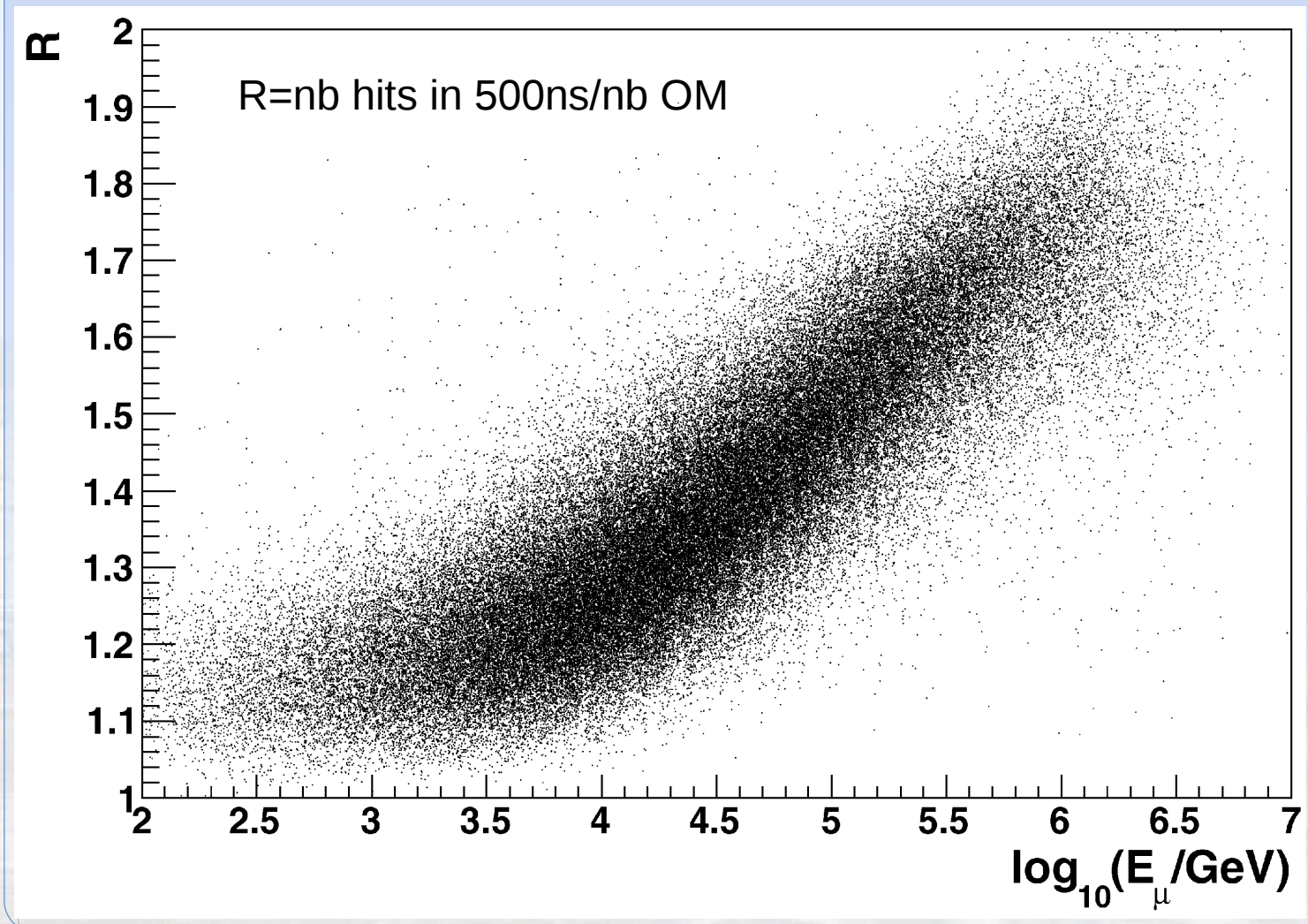
$$E_\nu^{-2} e^{-\frac{E_\nu}{100\ \mathrm{TeV}}}$$

TAToO results

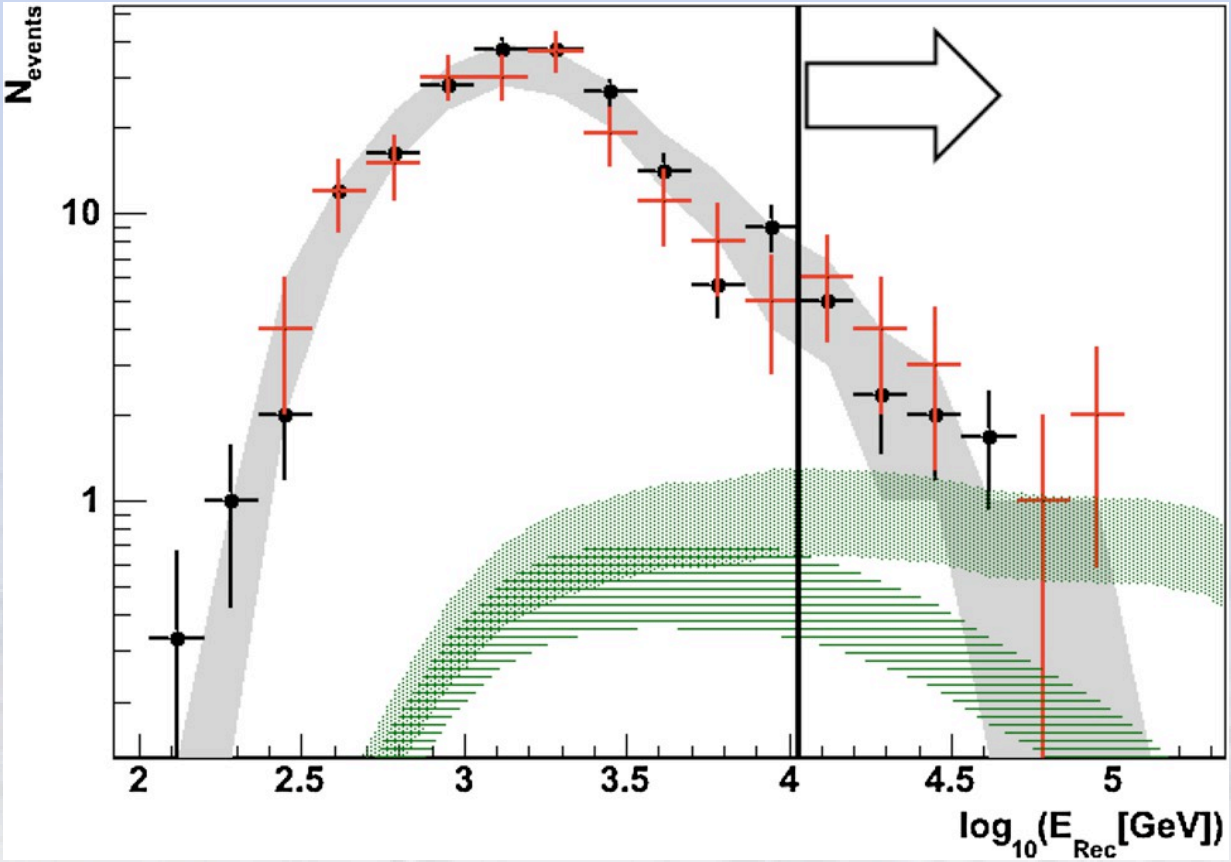
Ratio S/N > 5
No neutrino detection associated yet

neutrino ID	delay (day)	lim mag	Gal ext
ANT100123A	0.64	12	0.2
ANT100302A	1.01	15.7	0.2
ANT100725A	$8.7e^{-4}$	14.5	0.3
ANT100922A	$4.7e^{-2}$	14.0	0.5
ANT101211A	0.5	15.1	0.1
ANT110409A	$3.0e^{-3}$	18.1	6.7
ANT110529A	$5.2e^{-3}$	15.6	1.2
ANT110613A	$7.8e^{-4}$	17.0	2.3
ANT120730	$2.4e^{-4}$	17.6	0.2
ANT120907	$2.9e^{-4}$	16.9	0.2
ANT121010	$2.8e^{-4}$	18.6	0.1
ANT121206	$3.1e^{-4}$	16.9	0.2

Repetition


R
R=nb hits in 500ns/nb OM
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
log10(Eμ/GeV)

Fermi bubles results



Distribution of the reconstructed energy of the events after the final cut on : events in on-zone (red crosses), average over off-zones
(black circles), 68 % confidence area given by the total background
simulation (grey area), expected signal from the Fermi bubbles without
neutrino-energy cutoff (green dotted area) and 50 TeV cutoff (green
cut is represented by the black line with an
dashed area). The chosen E Rec is represented by the line with the arrow