ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Search for Neutrino Emission from the Fermi Bubbles with the ANTARES Telescope

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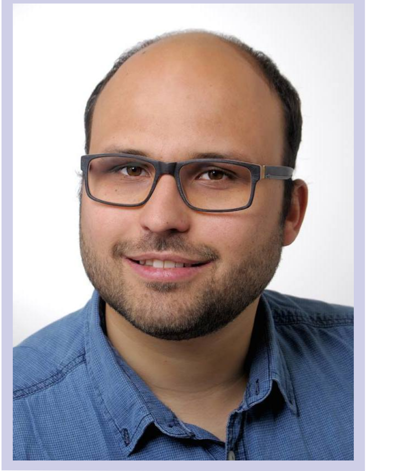
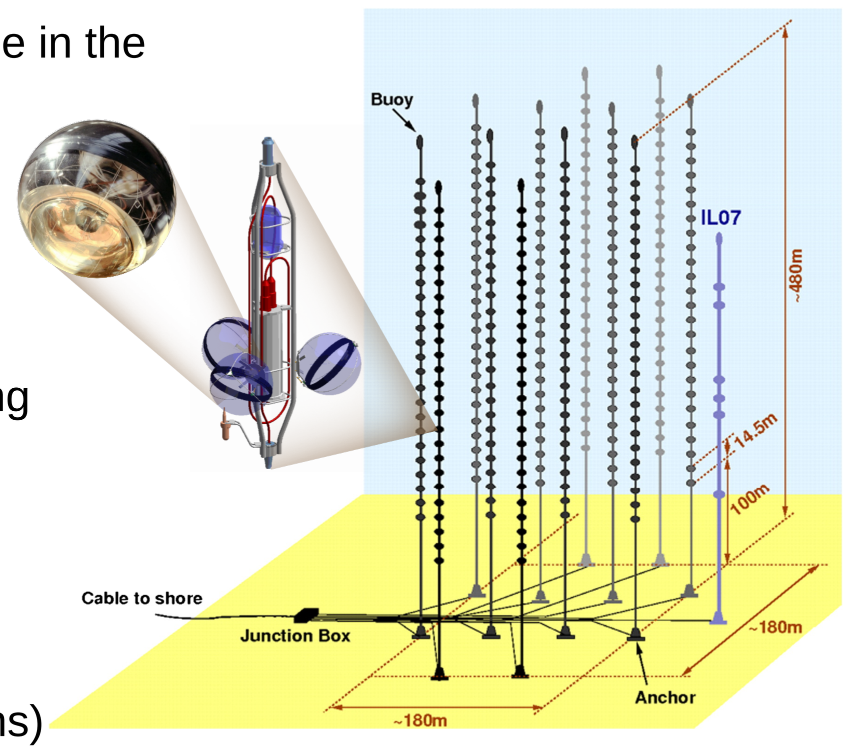


The Fermi Bubbles have been identified in Fermi-LAT data in 2010 [1]. They are two giant lobes of γ-ray emission extending 50° above and below the Galactic Center. To date, the origin of these structures is still unknown. Measuring a neutrino flux – present only in hadronic emission scenarios – could therefore discriminate between hadronic and leptonic emission.
Here, we present the analysis of shower-like event signatures recorded by the ANTARES neutrino telescope between 2008 and 2015. In combination with a previous analysis in the track-channel [2,3] all-flavour upper limits are derived.

The ANTARES detector

ANTARES [4] is a deep-sea neutrino telescope in the Mediterranean Sea near Toulon (France).
The detector is taking data in its complete configuration since 2008



ANTARES consists of

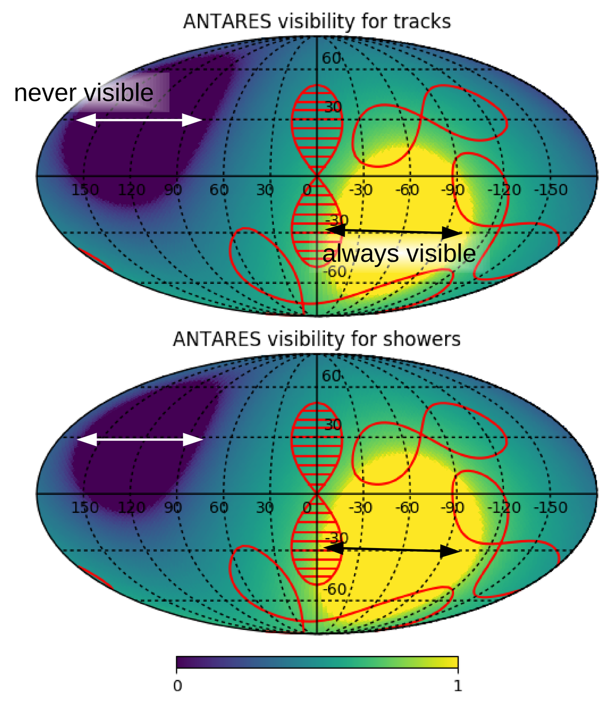
- **12 detection strings** separated by ~70m
- **25 storeys / string** with 14.5m vertical spacing
- **3 optical modules (10" PMTs) / storey**
- Total: 885 PMTs to register Cherenkov light from neutrino interactions

Good angular resolution:

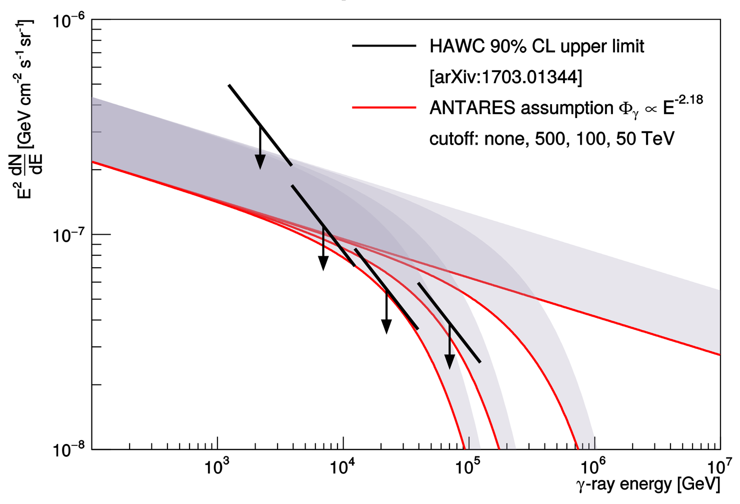
- **<0.4°** for muon **tracks** (from ν_μ-CC interactions)
- **~2°** for TeV – PeV neutrino-induced particle **showers** [5]

On- and off-zone analysis

Up-going events or events close to horizon:
cos(zenith, track)<0 , cos(zenith, shower)<0.1
→ required to suppress atmospheric muon background
→ High visibility for Fermi Bubbles' region



Background is determined from data **using three off-zones** shifted in time by ¼, ½ and ¾ of a sidereal day.
→ equal visibility of the on- and all off-zones.
→ differences in expected number of events in on-/off-zones compatible with statistical fluctuations



$$E^{2.18}\frac{\mathrm{d}\Phi_\gamma}{\mathrm{d}E} = (0.5-1.0)\times10^{-6}\,\mathrm{GeV}^{1.18}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}$$

Starting from a fit to the high energy part of the Fermi-LAT spectrum [6], the neutrino flux is obtained assuming...

→ Neutrino flux per flavour is proportional (36% for $E^{-2.18}$) to the γ-ray flux [7].
→ Harder spectral indices and high cutoffs are constrained by the recent HAWC measurement [8].

→ Efficient proton acceleration within our galaxy only up to 1–10 PeV [9].
→ Average 5% of energy conversion into neutrinos.
→ 50–500 TeV neutrino cutoff.

Neutrino flux assumption:

$$E^{2.18}\frac{\mathrm{d}\Phi_{\mathrm{model}}}{\mathrm{d}E} = (1.8-3.6)\times10^{-7}\,\mathrm{GeV}^{1.18}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\times\exp\left(-\frac{E}{E_{\mathrm{cutoff},\nu}}\right)$$

Shower-like signatures

Dataset:

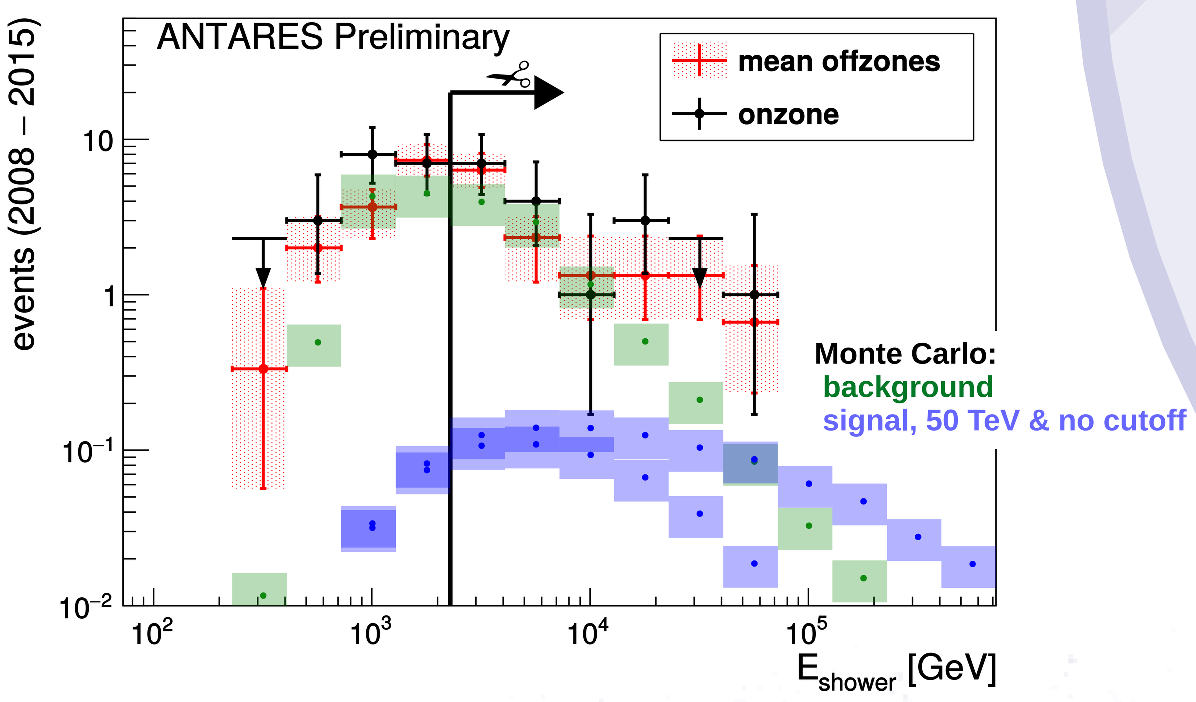
2096 days livetime recorded between Mar. 2008 – Dec. 2015

Event selection:

- Events reconstructed close to instrumented volume
- Not selected by track analysis (→ disjoint sample)
- Pre-selection of well-reconstructed events

- Analysis cuts optimised for 50 TeV cutoff to obtain most stringent average upper limit:
  → angular error of shower reconstruction
  → shower likelihood (suppresses track signatures)
  → shower RDF value [10]
  → estimated shower energy **> 2.3 TeV**

Measured background: 13.3 events per off-zone
On-zone measurement: 16 events
→ Non-significant excess (0.6σ) [11]

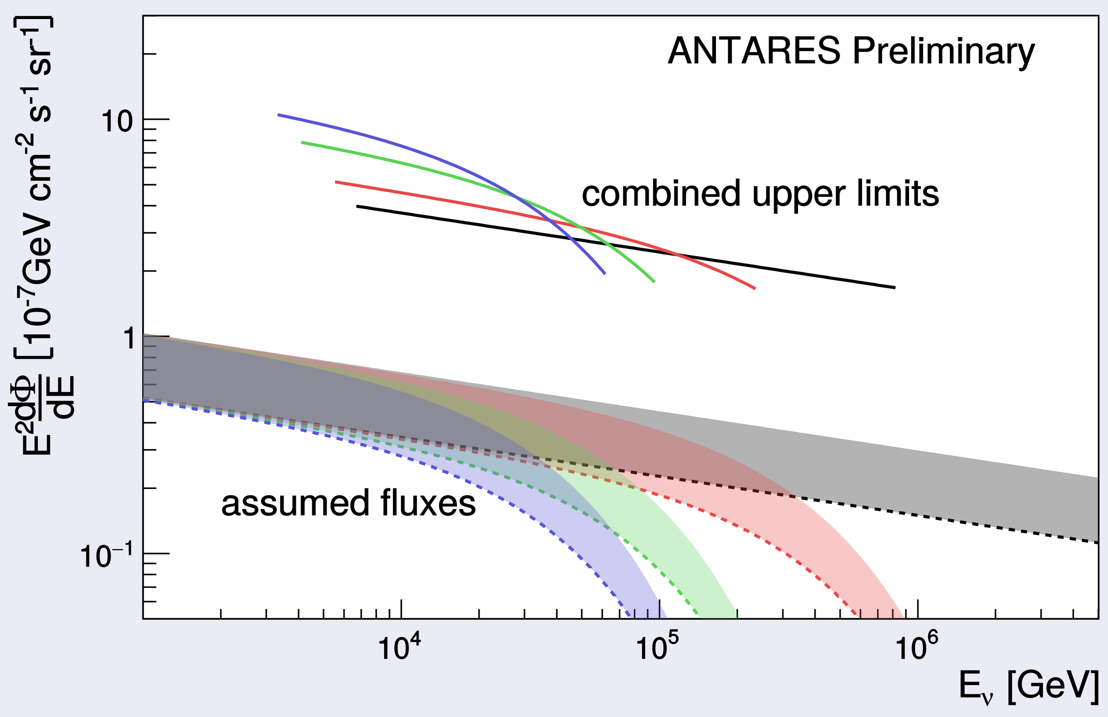


Combined flux upper limits

The on- and off-zone counts in the two analyses are combined to derive limits on the signal flux using 90% Feldman&Cousins upper bounds $\mu_{90\%}$ [12, 13]:

$$\Phi_{90\%} = \Phi_{\mathrm{model}} \times \frac{\mu_{90\%}\left(N_{\mathrm{on,\,t}}+N_{\mathrm{on,\,s}} \mid \overline{N}_{\mathrm{off,\,t}}+\overline{N}_{\mathrm{off,\,s}}\right)}{s_{\mathrm{t}}+s_{\mathrm{s}}}$$

Cutoff [TeV]	none	500	100	50
Simulated signal showers s_s	0.90	0.75	0.55	0.44
Simulated signal tracks s_t	1.23	0.94	0.59	0.42



Due to the small excesses observed in both channels, the resulting upper limits are an order of magnitude above the assumed test fluxes. The future KM3NeT telescope will be able to reach a comparable sensitivity within one year of data taking [14].

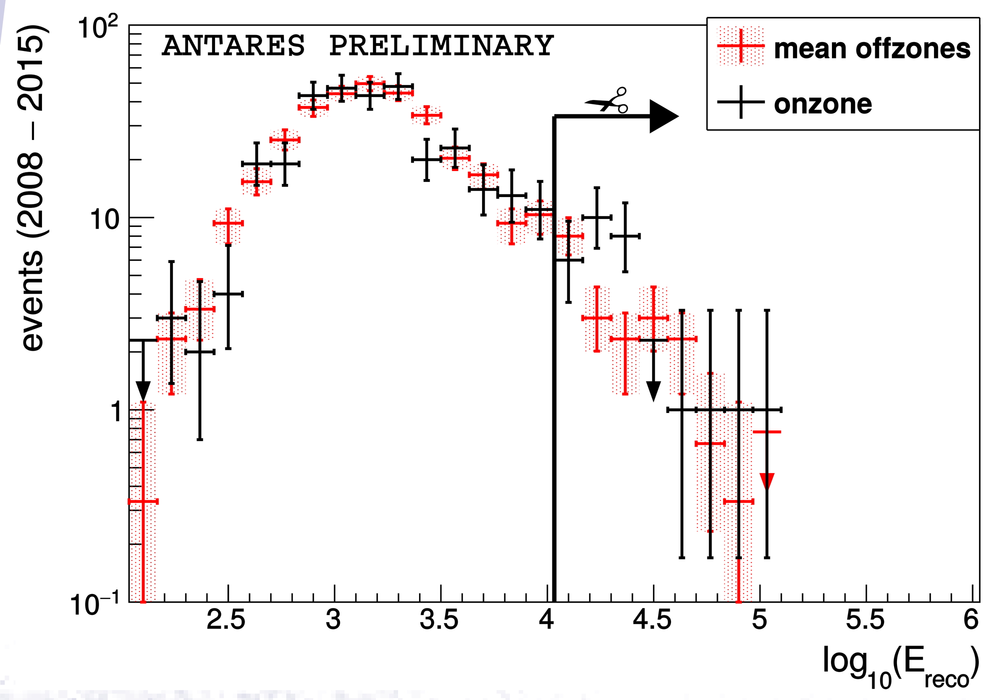
Track-like signatures

- Mar 2008 – Dec. 2015 data already analysed previously [3].
- Analysis cuts optimised for E^{-2} neutrino spectrum to obtain most stringent average upper limit.

Event selection:

→ De-selection of shower-like events
→ Angular error estimate < 1°
→ Cut on reconstruction quality
→ Energy estimated by neural net: track energy **> 10.7 TeV**

Measured background: 19.7 events per off-zone
On-zone measurement: 28 events
→ Non-significant excess (1.5σ) [11]



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IMPRS physics of light

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