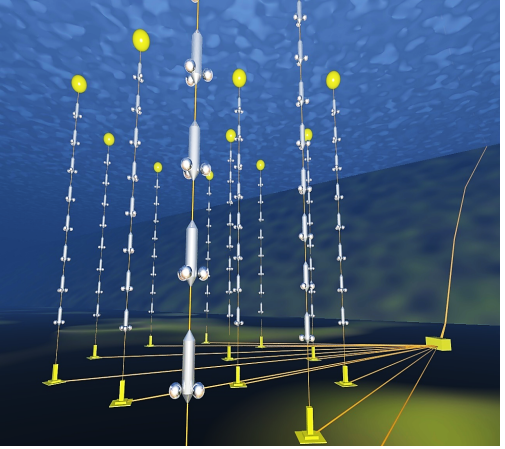


ANTARES

Largest underwater neutrino telescope running since 2007 (complete 2008)

Excellent view of galactic center region with high angular resolution

=> interesting constraints possible on Galactic component of IceCube signal

- **Neutrino astrophysics**
- **Multi-messenger observations**
- **Dark matter**
- **Atmospheric neutrinos (oscillations)**
- **Exotic particles search: nuclearites, monopoles**
- **Acoustic neutrino detection**
- **Earth and Sea sciences**

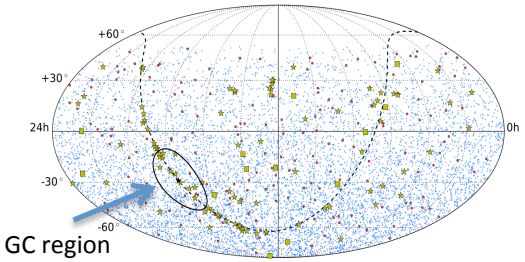
Astrophysics

Sensitive to **all neutrino flavours**

High resolution (3deg) for cascade signatures
-> contribute in point source search

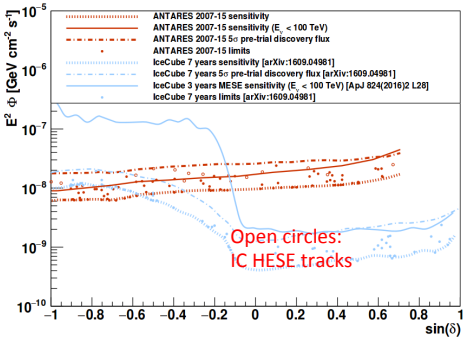
- 2007-2015(2424 days): 7629 tracks, 180 cascades
- Unbinned all-sky search
- 103 Candidate sources (including 13 IceCube HESE tracks)

- No significant excess
- Best limits for part of Southern Hemisphere
- Excellent sensitivity for E_ν <100 TeV



GC region

PRELIMINARY

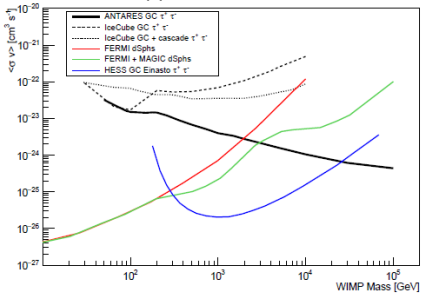


Particle physics

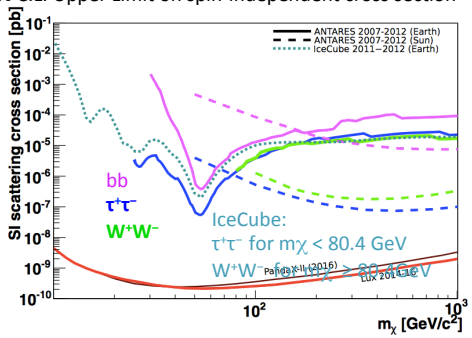
Competitive limits
In Dark Matter
searches

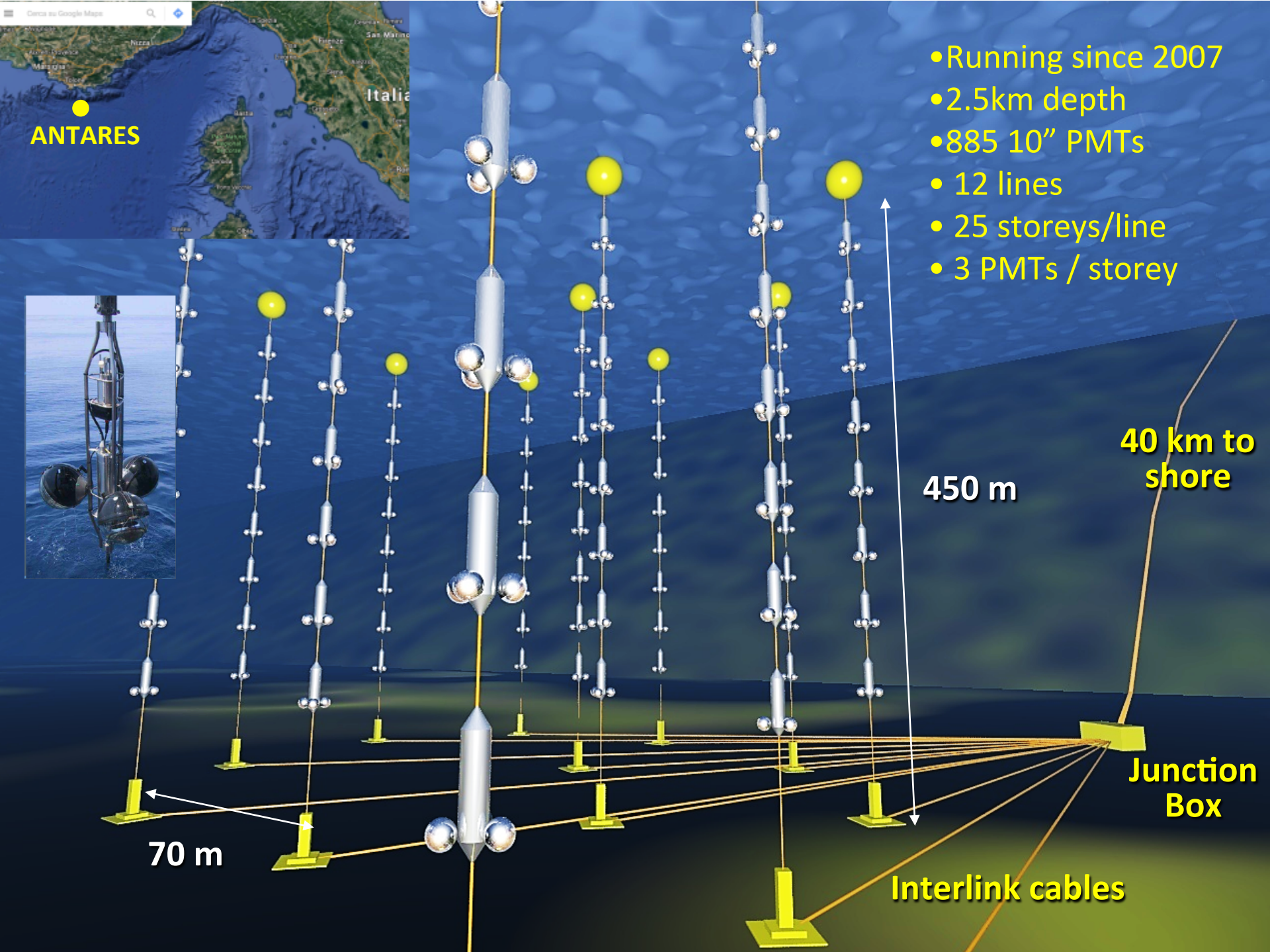
Galactic Center
Using track events from 9 years of data

90% C.L. Upper Limit on annihilation cross section



Earth
90% C.L. Upper Limit on spin-independent cross section

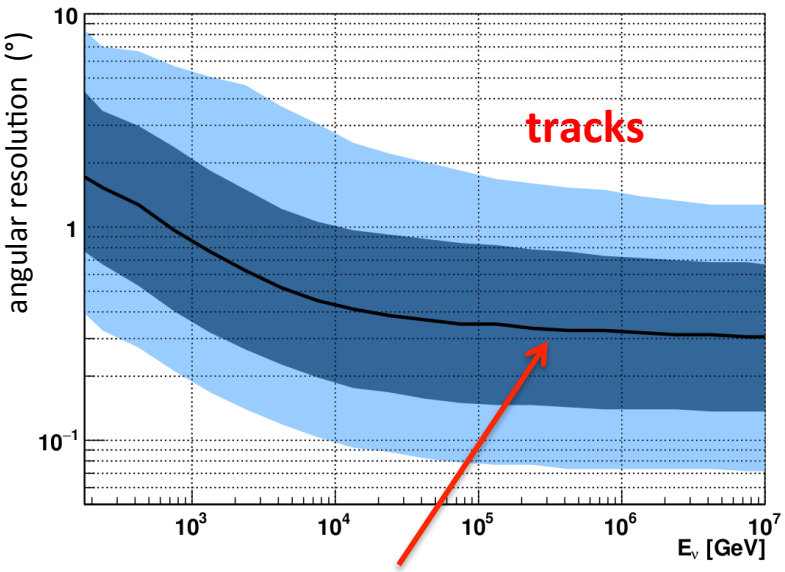



ANTARES
•Running since 2007
•2.5km depth
•885 10” PMTs
• 12 lines
• 25 storeys/line
• 3 PMTs / storey
450 m
40 km to shore
Junction Box
70 m
Interlink cables

ANTARES performance

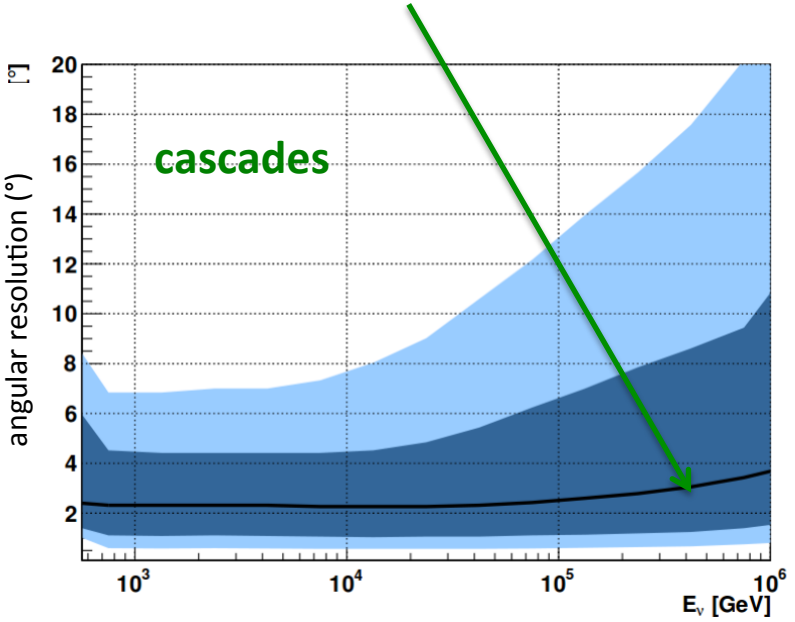
- Upgoing track events (ν_μCC)
- Angular resolution <0.4° for E_ν>10 TeV
- 90% purity

Angular resolution vs E_ν



median resolution

- Upgoing cascade events (ν_e/ν_t CC, NC)
- Angular resolution < 3°
- Energy resolution for ν_eCC better than 10%



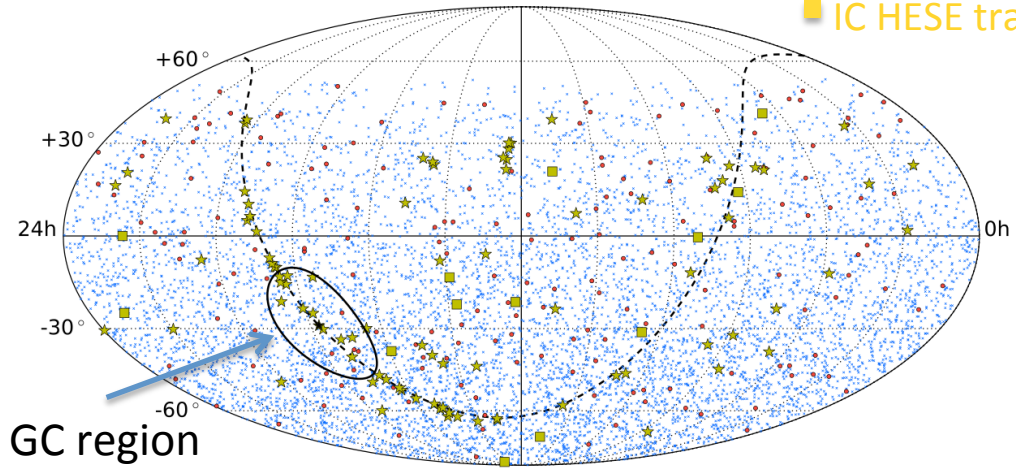
All flavour point source search

- 2007-2015(2424 days):
  7629 tracks, 180 cascades
- Unbinned all-sky search
- 103 Candidate sources (including 13 IceCube HESE tracks)

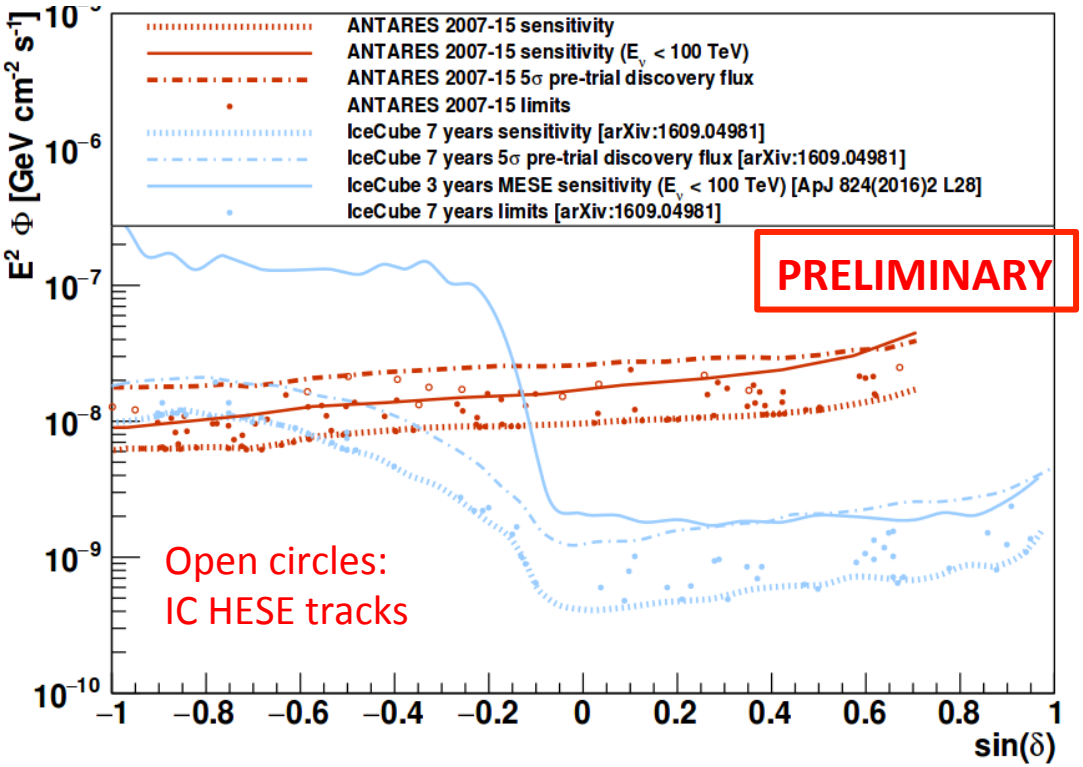
- No significant excess
- Best limits for part of Southern Hemisphere
- Excellent sensitivity for E_ν <100 TeV

PRELIMINARY

Blue: Tracks
Red: Cascades
Candidate Sources
IC HESE tracks

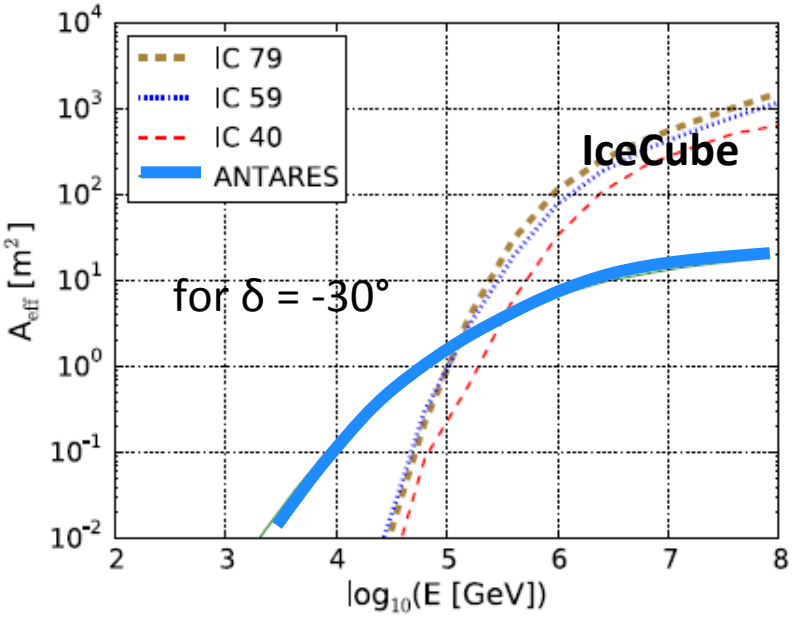


GC region

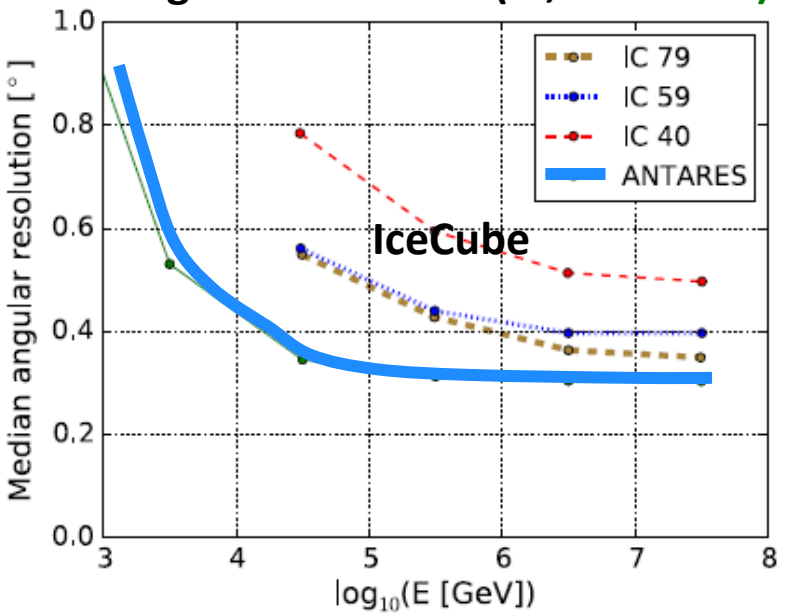


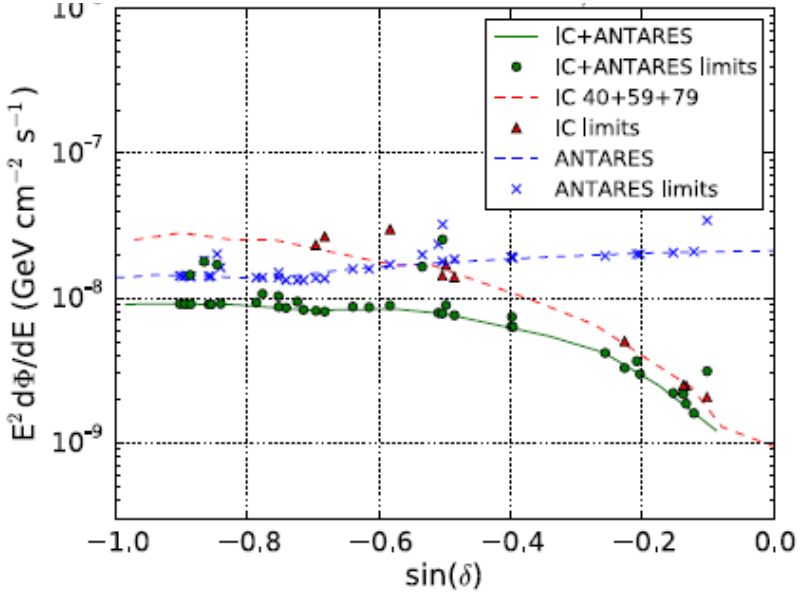
Combined ANTARES-IceCube PS search

Effective areas (IC, ANTARES)



Angular resolution (IC, ANTARES)





- IC 79 & IC59 & IC40 + 6 years of ANTARES
- Combined sensitivities (green line) and 90% CL limits (points) for E^{-2} spectrum.
- Blue (Red) curves/points indicate ANTARES (IceCube) sensitivities/limits

Astrophys.J. 823 (2016) no.1, 65

Probing neutrino emission from the Galactic Plane

Previously: Signal/off-zone analysis

2007-2013 data, track events

no excess found

PLB 760, 143 (2016)

New all-flavour analysis

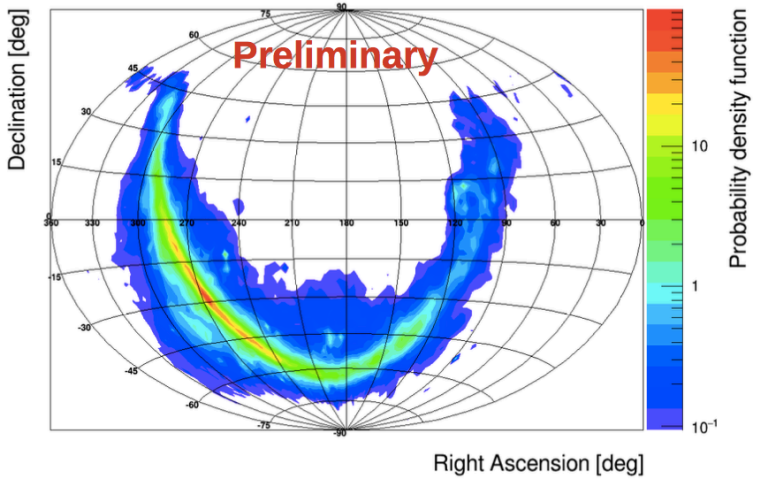
2007-2015 data, track&cascade events

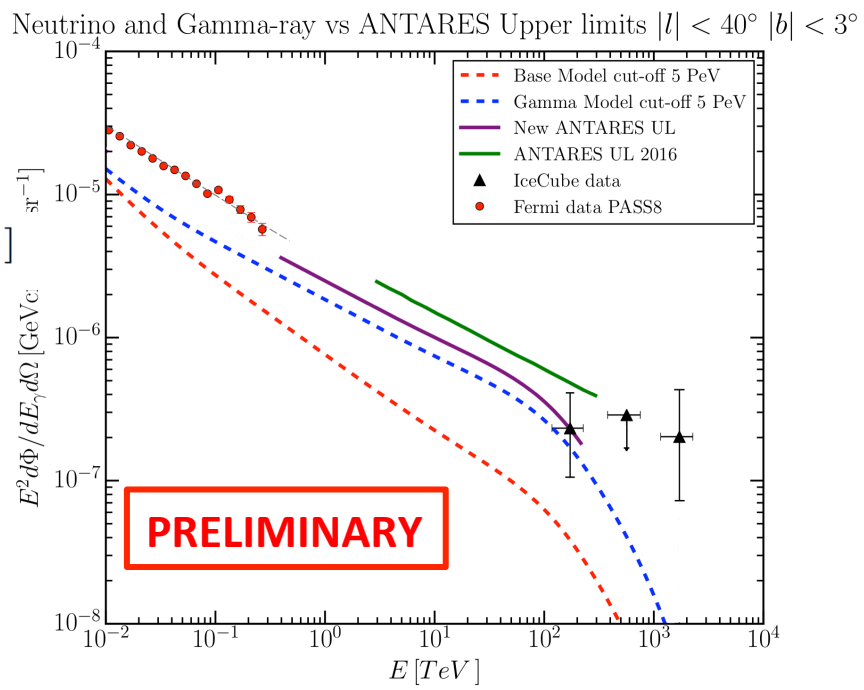
Likelihood approach probing KRAγ model

Limit at 1.3*KRAγ model

$$L_{sig+bg} = \prod_{evt} \left[n_{sig} \cdot pdf_{sig}(\alpha^{evt}, \delta^{evt}, E^{evt}) + n_{bg} \cdot pdf_{bg}(z^{evt}, \delta^{evt}, E^{evt}) \right]$$

PDF for track events according to KRAγ model





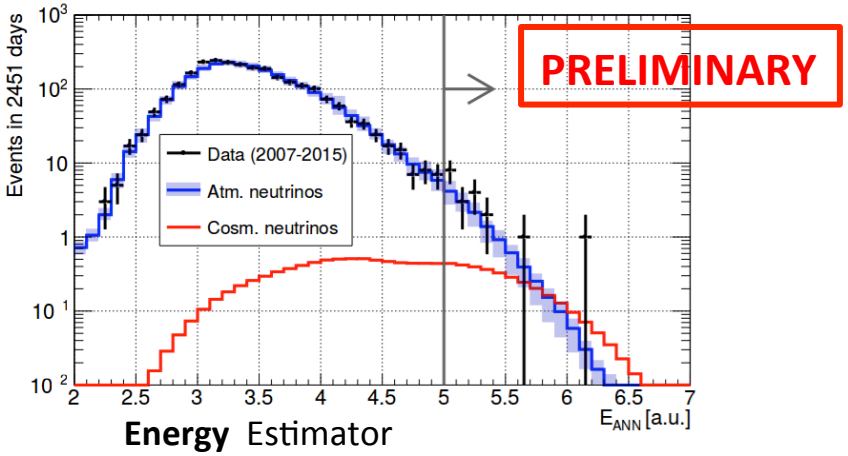
Diffuse flux (all flavour analysis)

Tracks

Data: 2007-2015 **(2451 livedays)**

Above E_{cut}: Bkg: 13.5 ± 3 evts, IC-like signal: 3 evts

Observed: **19 evts**

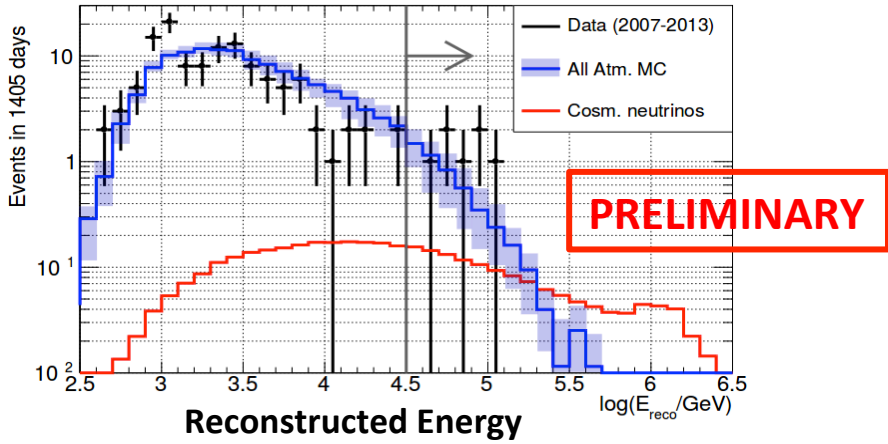


Cascades

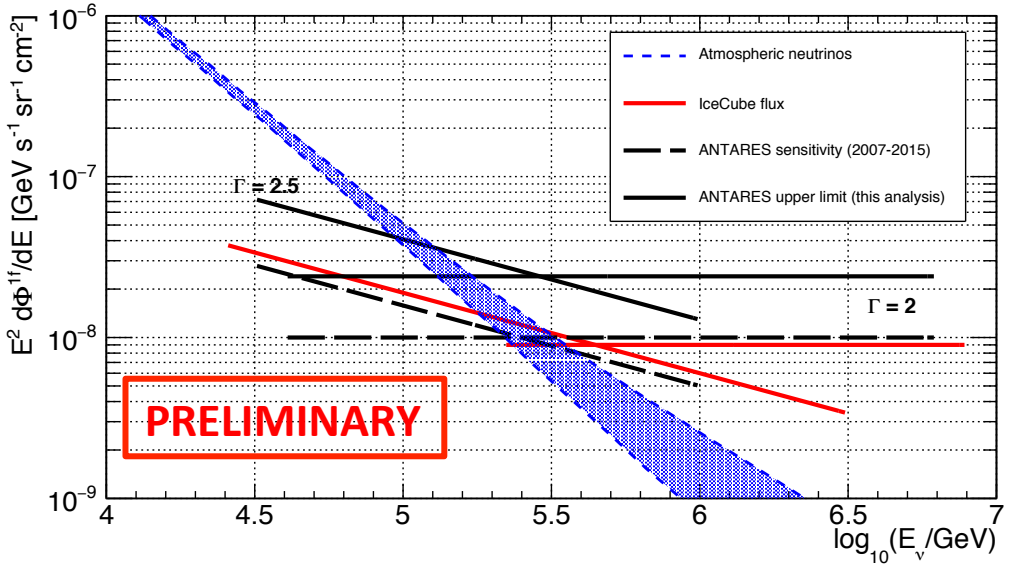
Data: 2007-2013 **(1405 livedays)**

Above E_{cut}: Bkg: 5 ± 2 evts, IC-like signal: 1.5 evts

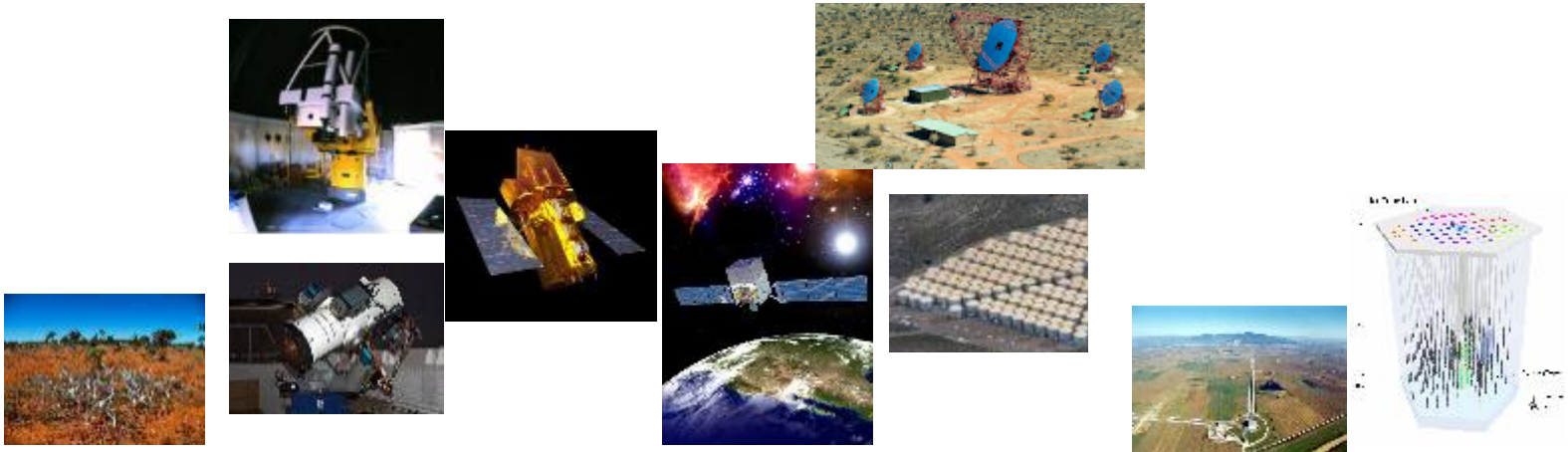
Observed: **7 evts**



ANTARES combined upper limits and sensitivities (2007-2015) tracks + cascades



Multimessenger program



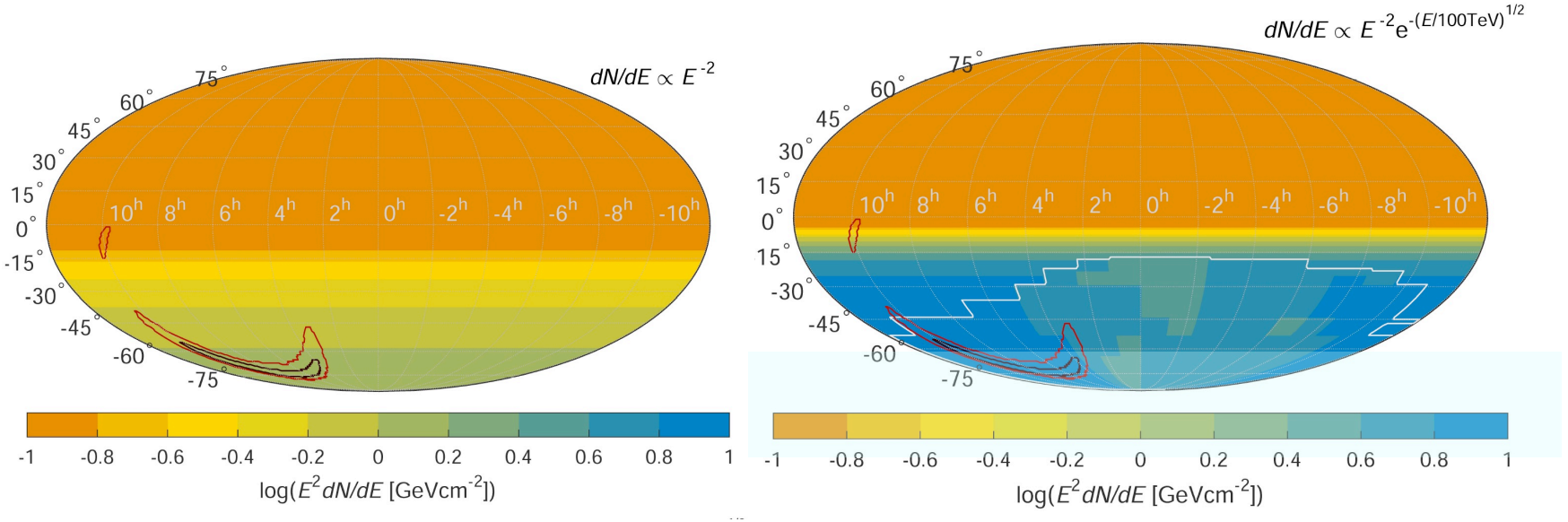
Multi wavelength follow-up of neutrinos

	Radio	Visible	X-ray	GeV-ray	TeV-ray	GW	ν
	MWA	TAROT ZADKO MASTER	Swift	Fermi-LAT	HESS HAWC	Ligo Virgo	IC
Alerts	12/yr	30/yr	6/yr	(Offline)	(1-10/yr)	(Offline)	

ANTARES following up Parkes alerts on Fast Radio Bursts (FRBs) since end of 2015

Neutrino follow-up of GW150914

joint ANTARES/IceCube/LigoSC/Virgo. Phys.Rev. D93 (2016), 122010



- Within ±500 s:
  - No ANTARES events (0.015 expected)
  - 3 IceCube events (not in GW location, 4.4 expected)
- Limits from ANTARES dominates for Eν < 100 TeV
- U.L. from IC dominate Eν > 100 TeV
- Limits on total energy radiated in neutrinos: <10% GW
- Future: Receive / send alerts in real time

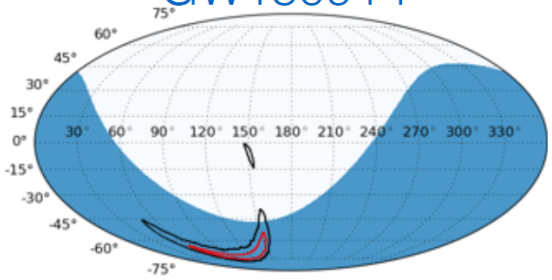
Neutrino follow-up of GWs

3 alerts sent by LIGO during the run 01 (2015/09 → 2016/01):

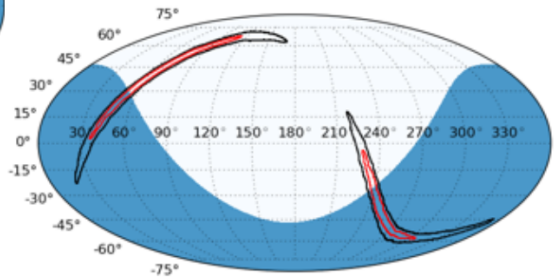
- GW150914: merging of 2 BHs (M= 36/29 M_s - 410 Mpc - 5.1 σ) **published**
- LVT151012: merging of 2 BHs (M= 23/13 M_s - 1000 Mpc - 1.7 σ)
- GW151226: merging of 2 BHs (M= 14/7 M_s - 440 Mpc - >5 σ)

Paper in preparation

GW150914

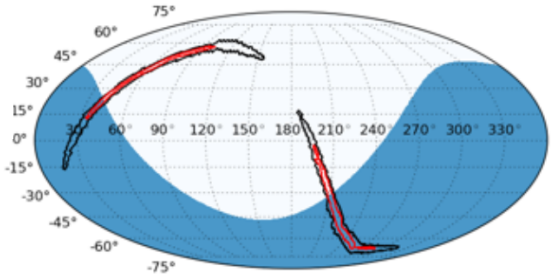


LVT151012



ANTARES visibility

GW151226



Limits for four bright GRBs

GRB 080916C, GRB 110918A, GRB 130427A ,GRB130505A *arXiv 1612.08589*

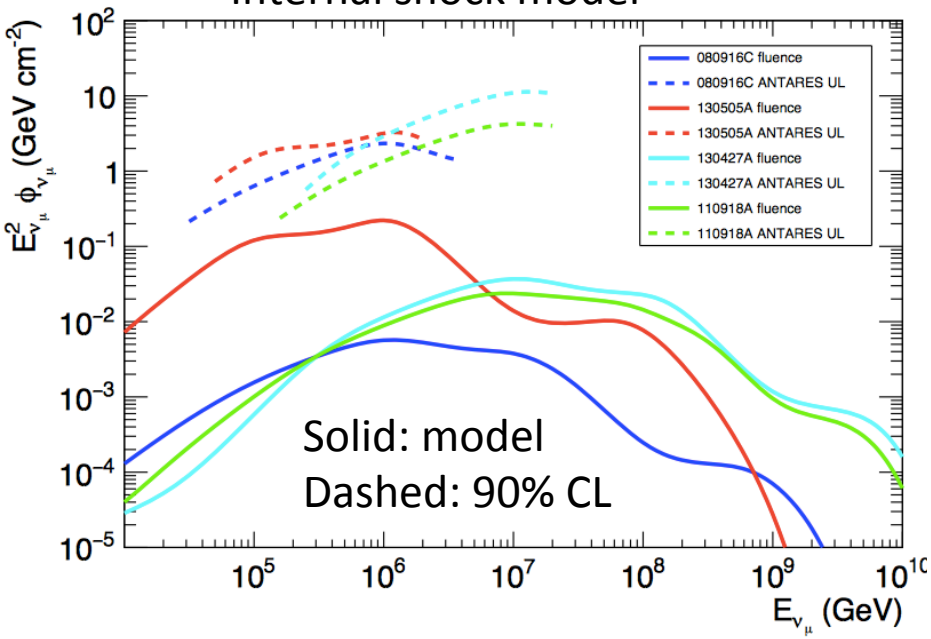
Special data taken over 200s after GRB trigger, no data filtering
(available for GRB 130427A and GRB 130505A)

Models probed:

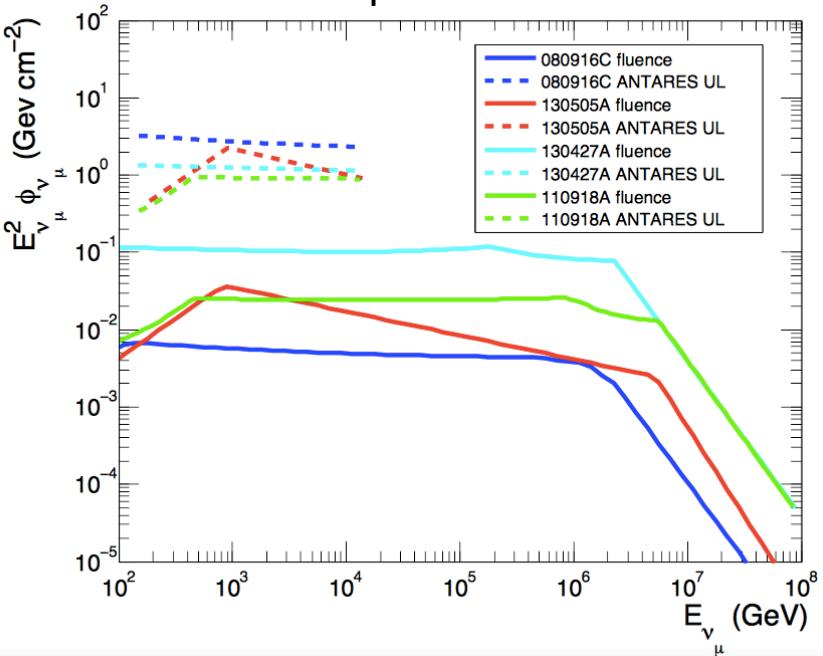
Internal Shock model -> regular event reconstruction

Photospheric model -> lower energies, unfiltered data samples with dedicated low energy reconstruction used

Internal shock model



Photospheric model



Dark Matter in the Sun and Galactic Center

Accumulation and annihilation in massive objects

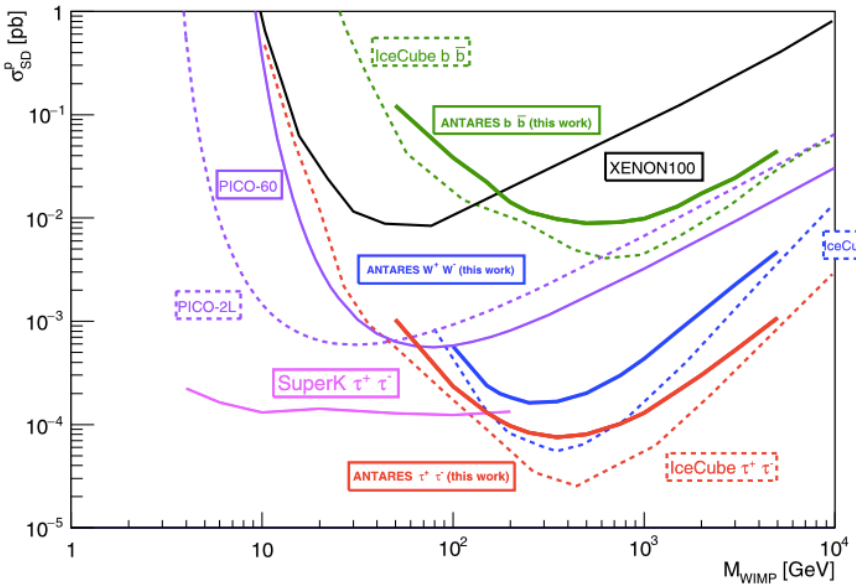
$$X_{\mathrm{WIMP}}\bar{X}_{\mathrm{WIMP}} \rightarrow \nu\bar{\nu},\ \mathrm{b\bar{b}},\ \mathrm{W^{-}W^{+}},\ \tau^{-}\tau^{+},\ \mu^{-}\mu^{+}$$

Selection cuts tuned separately for different channels and WIMP masses

Sun

Using track events from 6 years of data

90% C.L. Upper Limit on spin dependent cross section

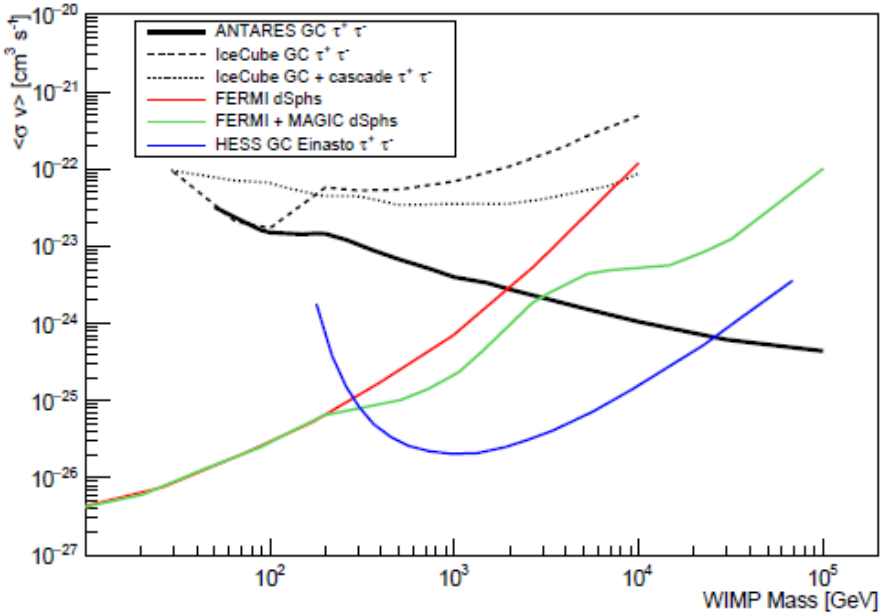


PLB 759, 69 (2016)

Galactic Center

Using track events from 9 years of data

90% C.L. Upper Limit on annihilation cross section

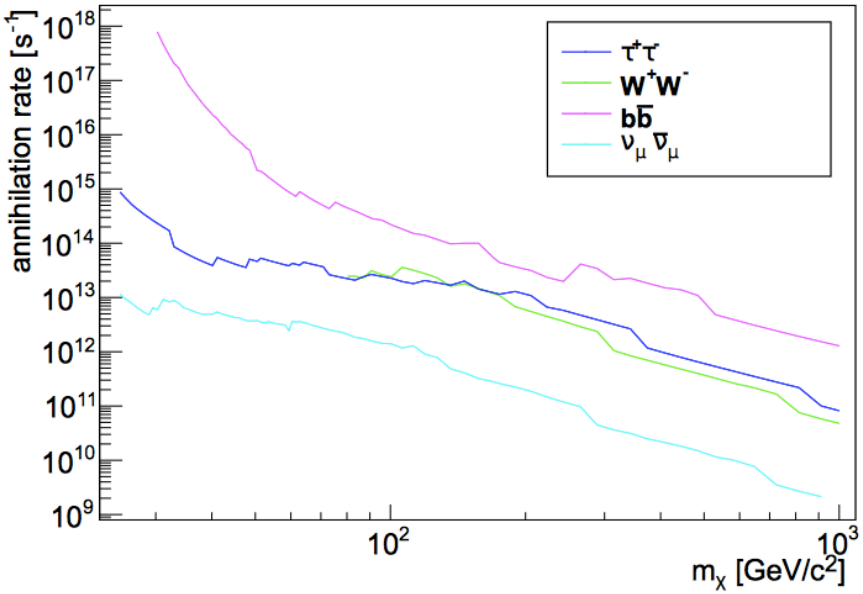


arXiv 1612.04595

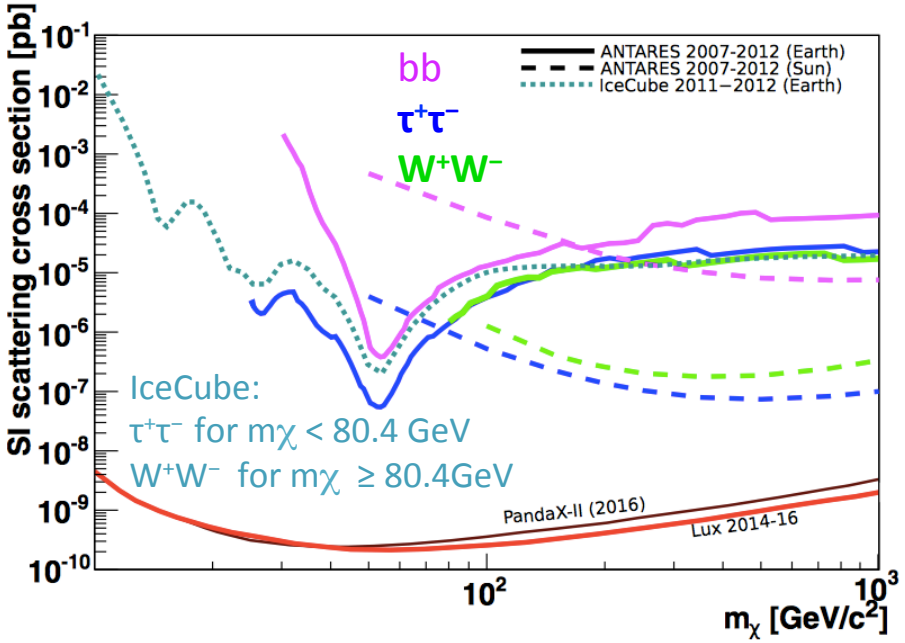
Dark Matter in the Earth

- Looking for almost vertically upward going tracks
- 1192 days live time (2007-2012)
- Selection optimized separately for different WIMP masses

90% C.L. Upper limit on annihilation rate



90% C.L. Upper Limit on spin-independent cross section



arXiv 1612.06792

Summary and outlook

ANTARES is delivering a variety of interesting physics results

- Unprecedented angular resolution of 3 degrees for cascades achieved,
  => All flavour neutrino interactions (to be) included in analyses
- Several results on the possible neutrino emission from the Southern sky
  => constraining origin of the IceCube signal
- Competitive sensitivity in Dark Matter observations
- Combined analyses with IceCube performed and in the works
  => optimal sensitivity on neutrino fluxes (point sources, galactic plane, dark matter)
- Many multi-messenger results exploiting also information from external observatories and also sending neutrino alerts for follow-up

Demonstration of the great potential of deep-sea Neutrino Telescopes