

Selected highlights from the ANTARES neutrino telescope



Lake Louise Winter Institute
Lake Louise, Canada
February 2017



Timothée Grégoire
on behalf of the ANTARES collaboration

2500m depth

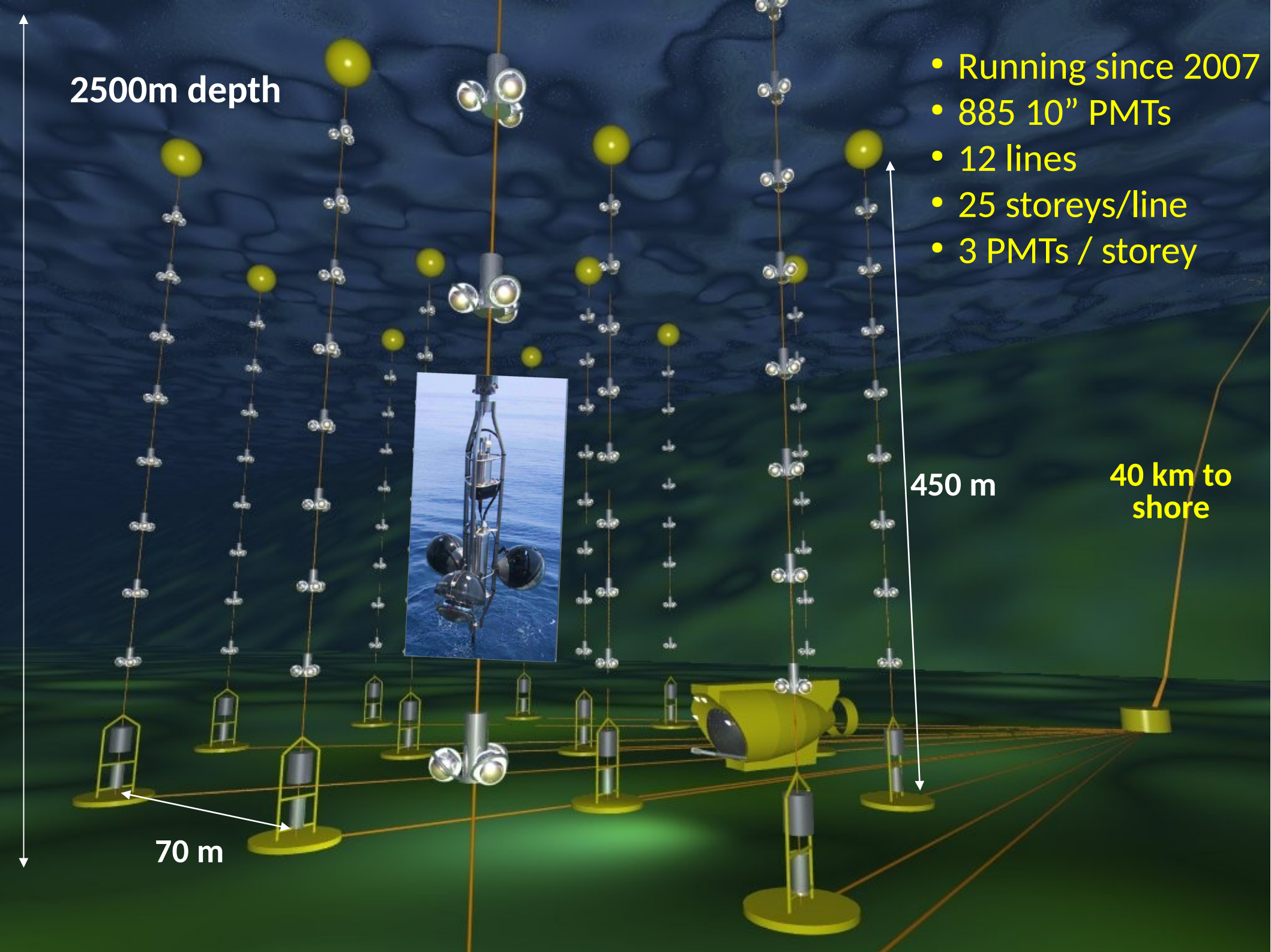
- Running since 2007
- 885 10" PMTs
- 12 lines
- 25 storeys/line
- 3 PMTs / storey



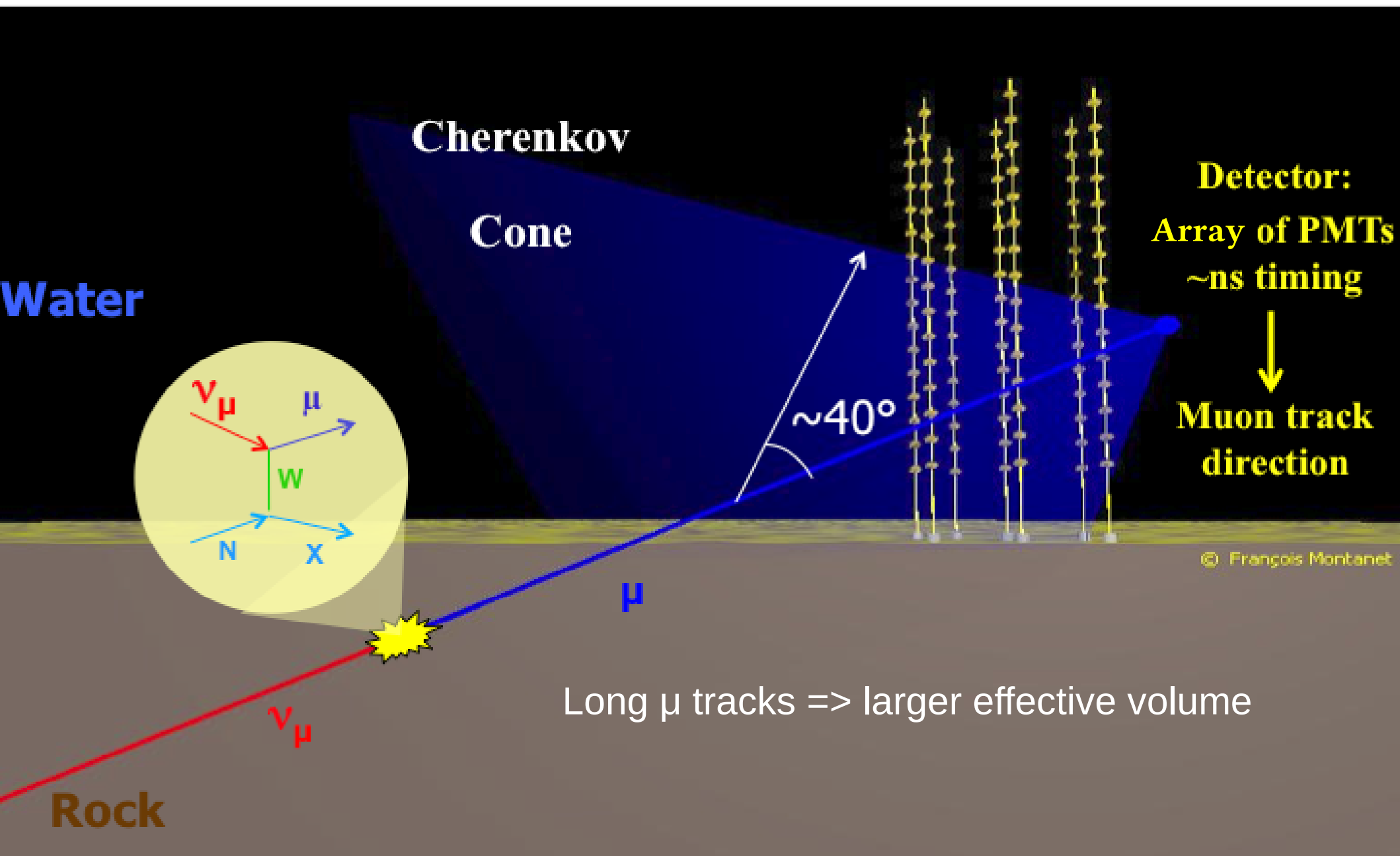
450 m

40 km to shore

70 m



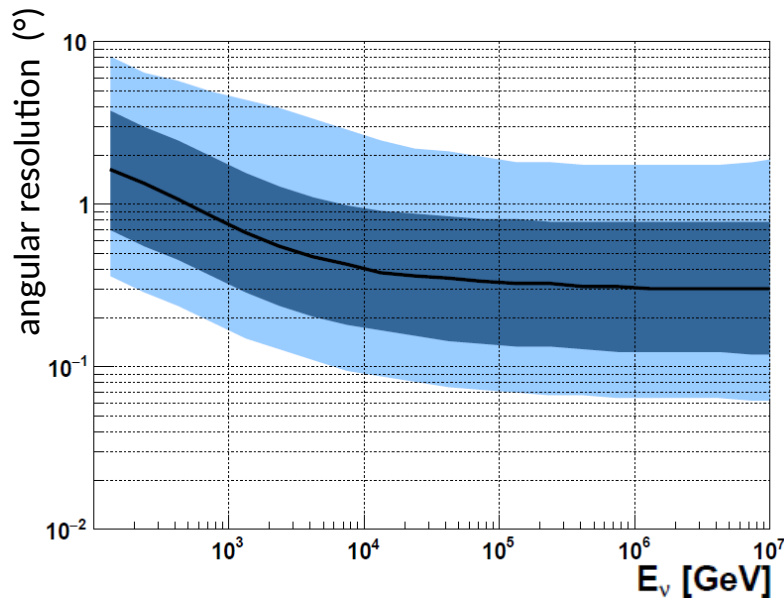
Detection principle



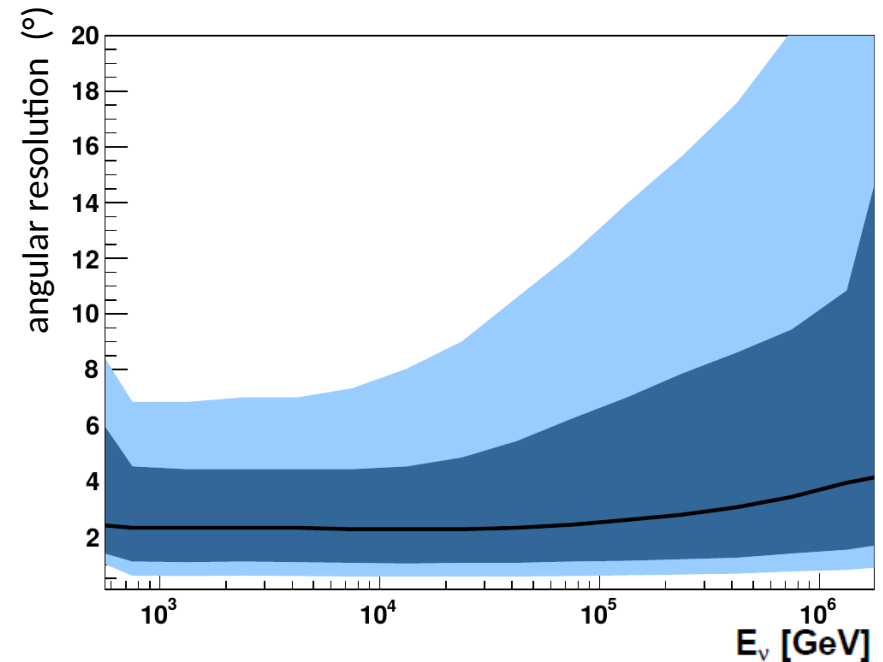
Long μ tracks => larger effective volume

Two type of events

- **Tracks:** CC $\nu_\mu/\nu_\tau \rightarrow \mu$
- Interaction can occur far from the detector
 - ➔ **Larger effective volume**
- Median **angular resolution:**
 - ➔ **<0.4°** above 10 TeV

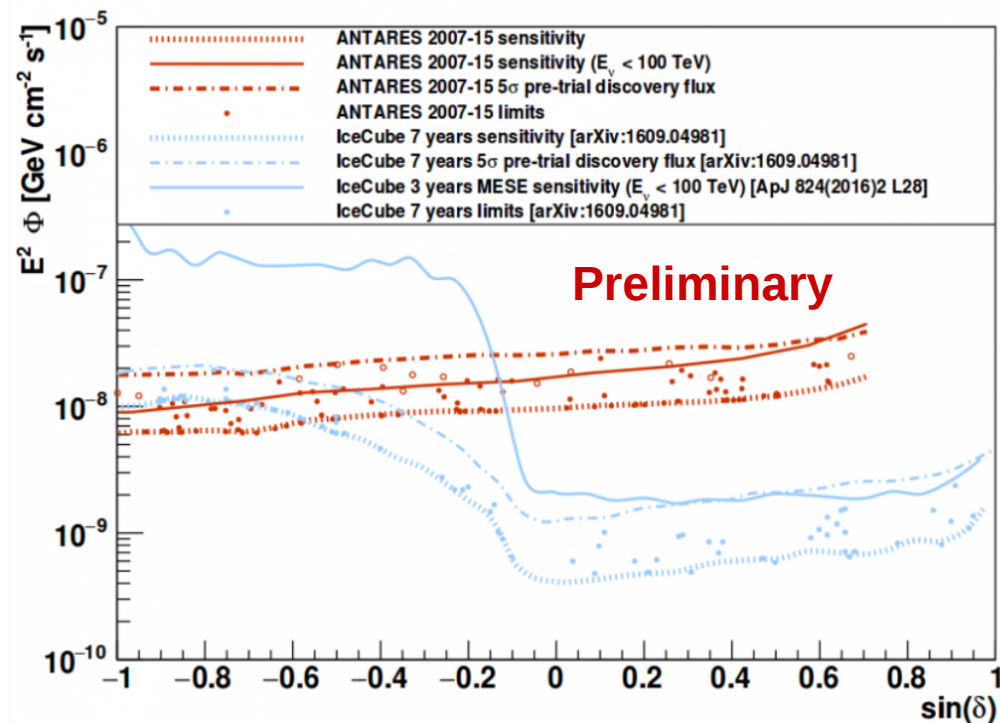
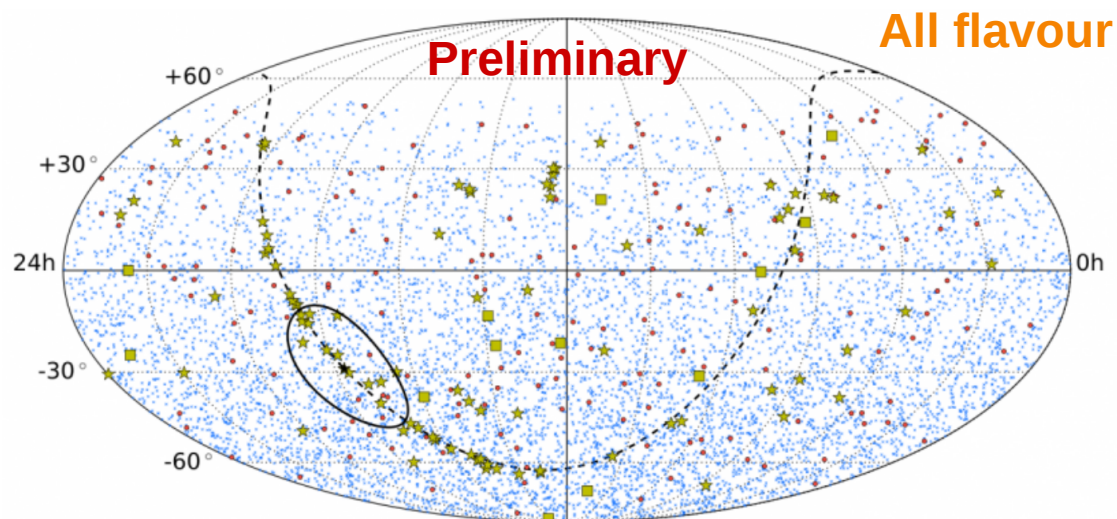


- Electronic or hadronic **showers:**
 - ➔ CC ν_e/ν_τ and NC
- **Contained** in the detector
 - ➔ **Better energy estimation**
- Median **angular resolution:**
 - ➔ **~3°**



Search for neutrino Point-like Sources

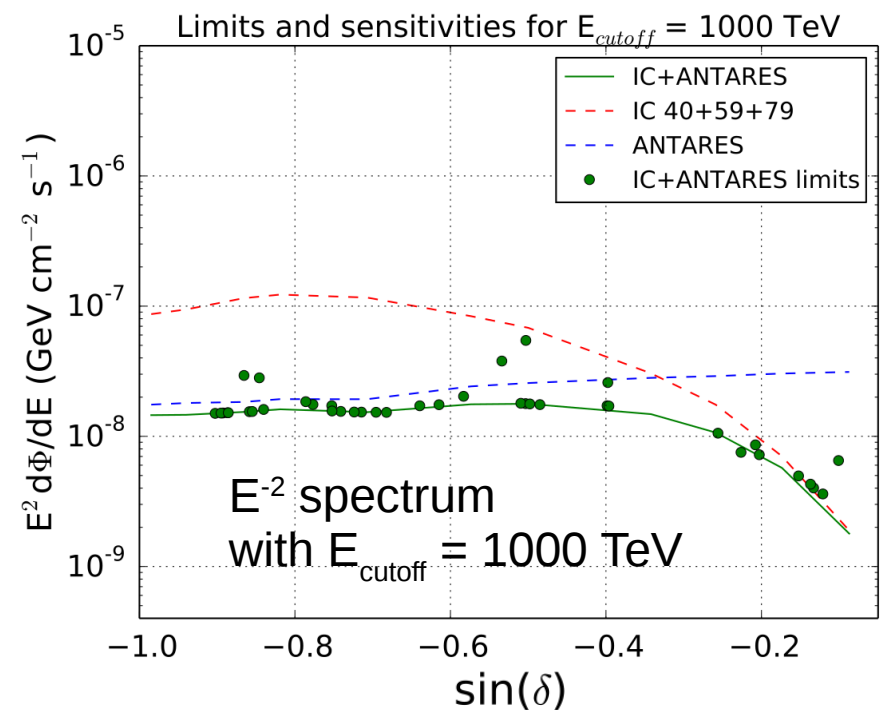
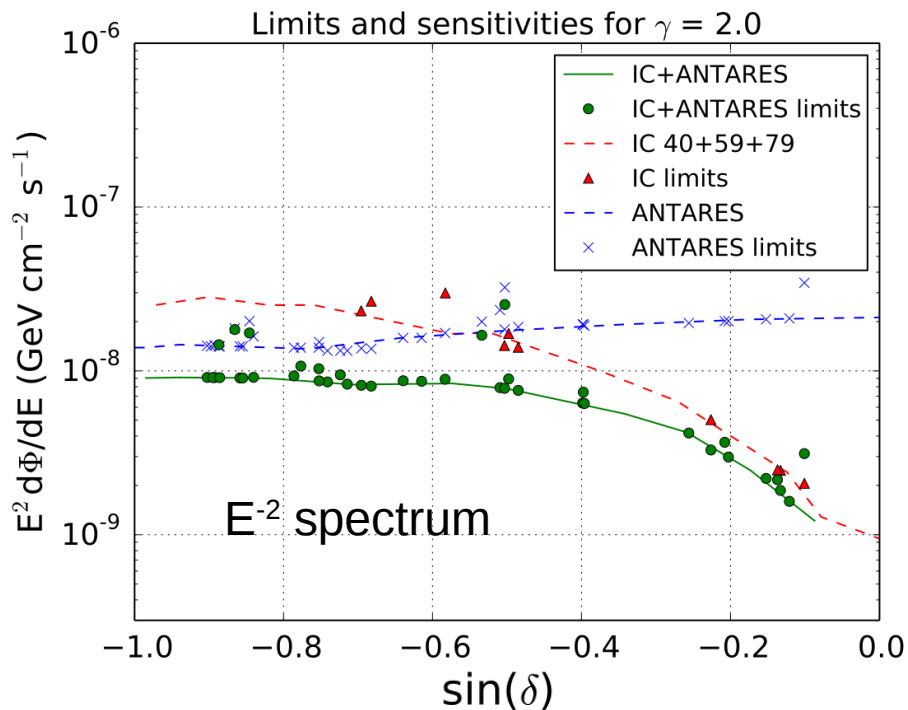
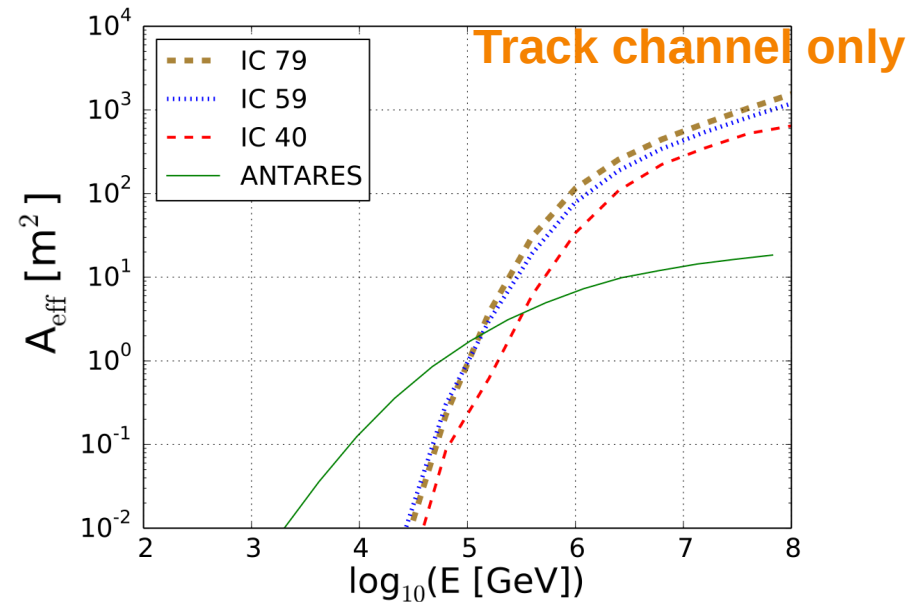
- 9 years of ANTARES data using tracks and **showers**
→ **All flavour**
- Use of a **likelihood ratio** in three ways:
 - **Full sky search**
 - Search around the **galactic plane**
 - **Candidate list search**
- **No significant excess found**
- Plan to combine with IceCube



Search for neutrino Point-like Sources

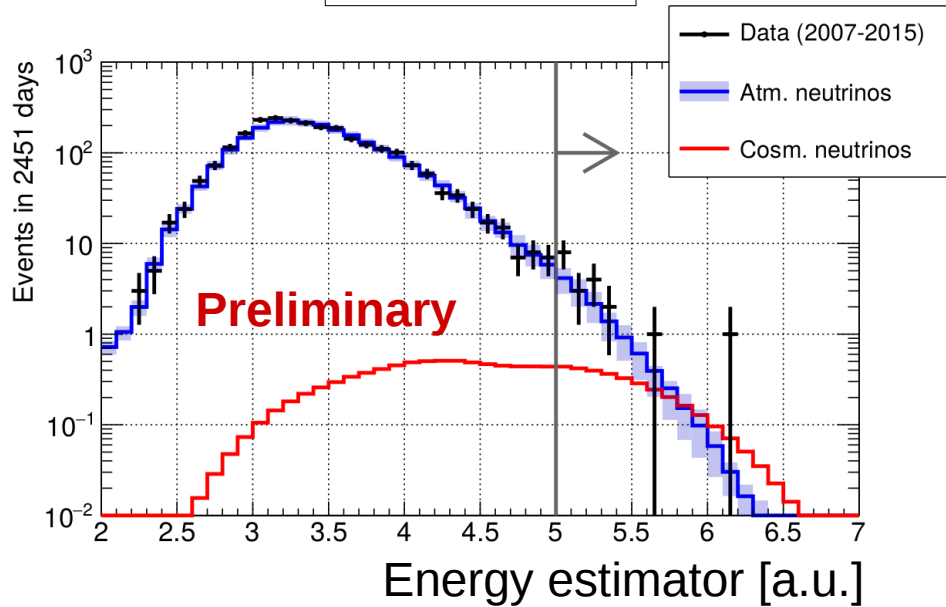
Astrophys.J. 823 (2016) no.1, 65

- **Combined** search with IceCube
 - ➔ ANTARES: 6 years; IceCube: 4 years of data
- Southern hemisphere
- **No significant excess** found



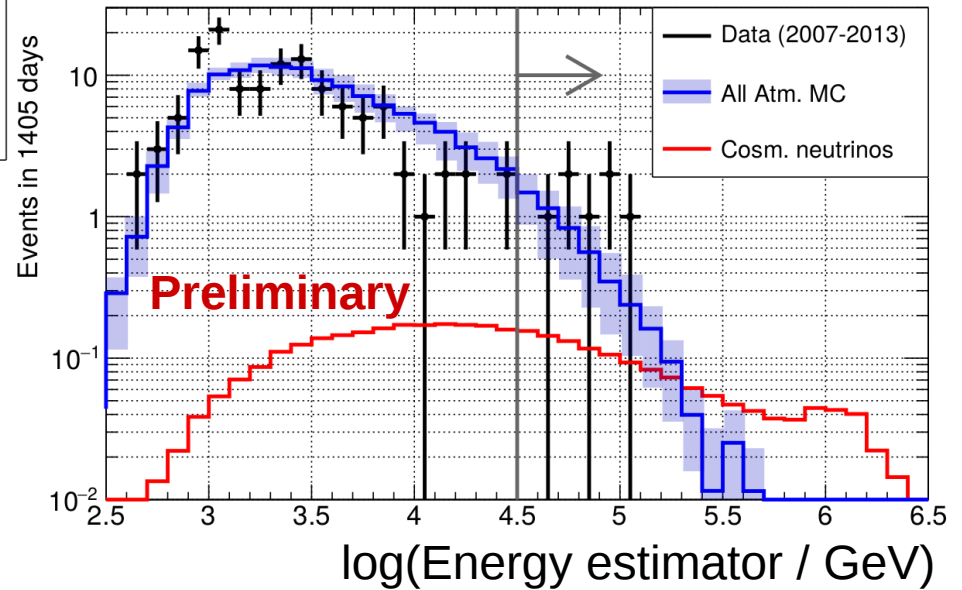
Search for neutrino Diffuse flux

Track events



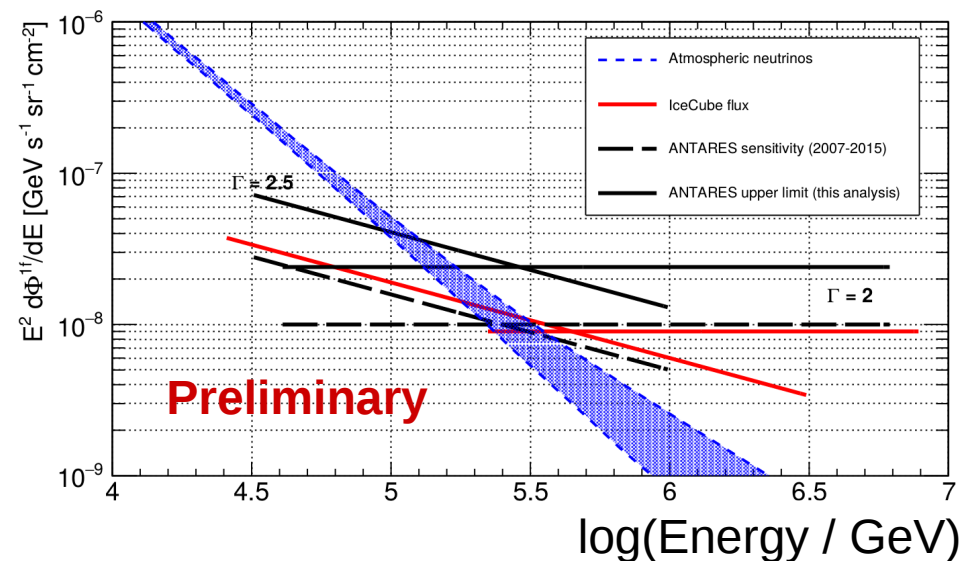
Shower events

All flavour



- All sky neutrino search
- Look for excess **above** a certain **energy threshold**
- 9 (7) years of data for tracks (showers)

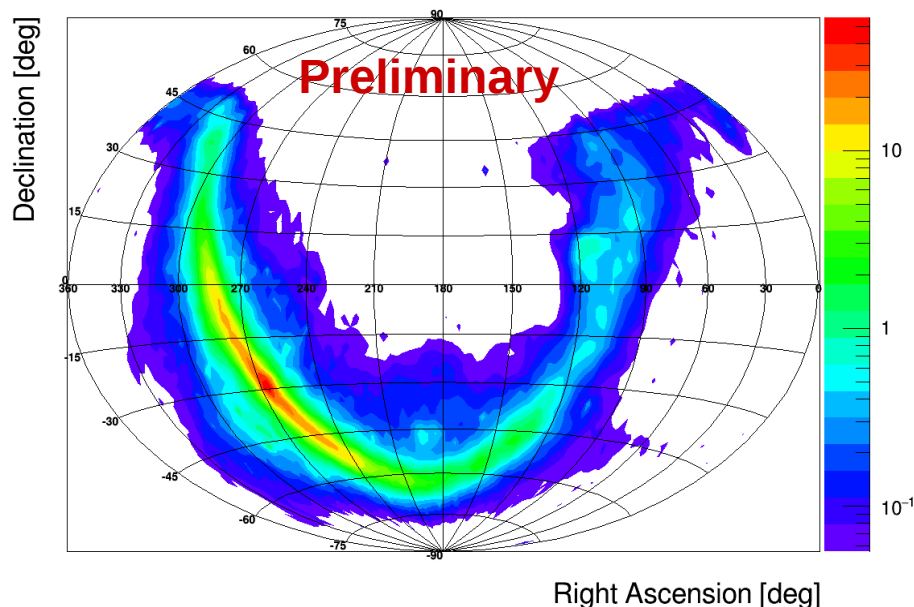
	Background expectation	Signal expectation	Number of events measured
Tracks	13±3	3	19
Showers	5±2	1.5	7



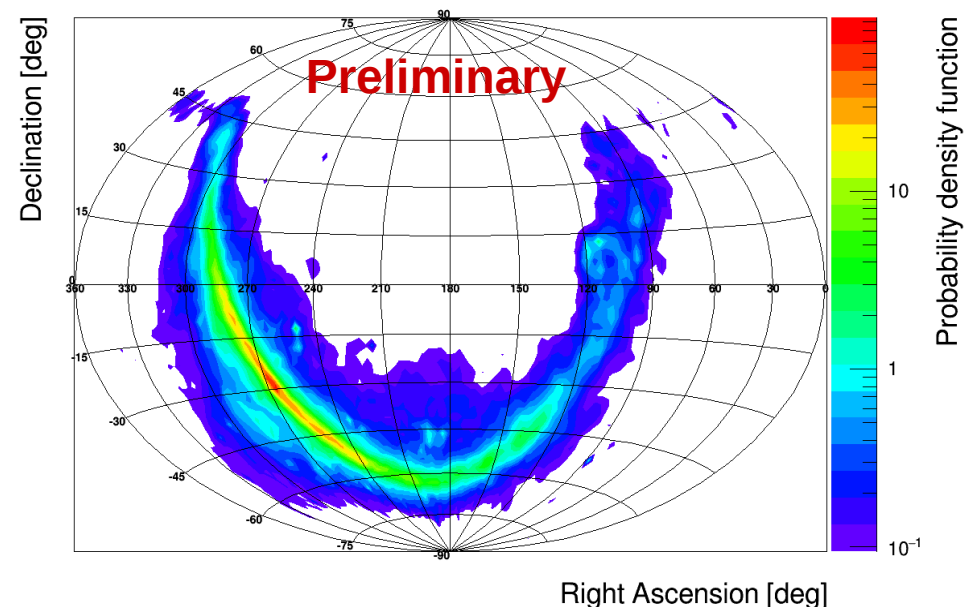
Galactic Plane analysis

All flavour

- Testing **KRA γ** model (Astroparticle Physics 55 (2014) 37-50)
- Phenomenological model of **Cosmic Ray diffusion** in the Galaxy
 - **Radial dependence** of the slope of the **diffusion coefficient** and the **advective wind**
- 9 years of ANTARES Data
- Predicts the ν energy and spatial distribution on the sky



Shower events



Track events

Galactic Plane analysis

All flavour

Search method:

- **How likely** our data contain some **signal** with the **KRA γ** characteristics?

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

- **Weight** this **against** the likelihood to have only **background**:
likelihood ratio
- **Fit** the **number of signal** events by maximising the likelihood ratio

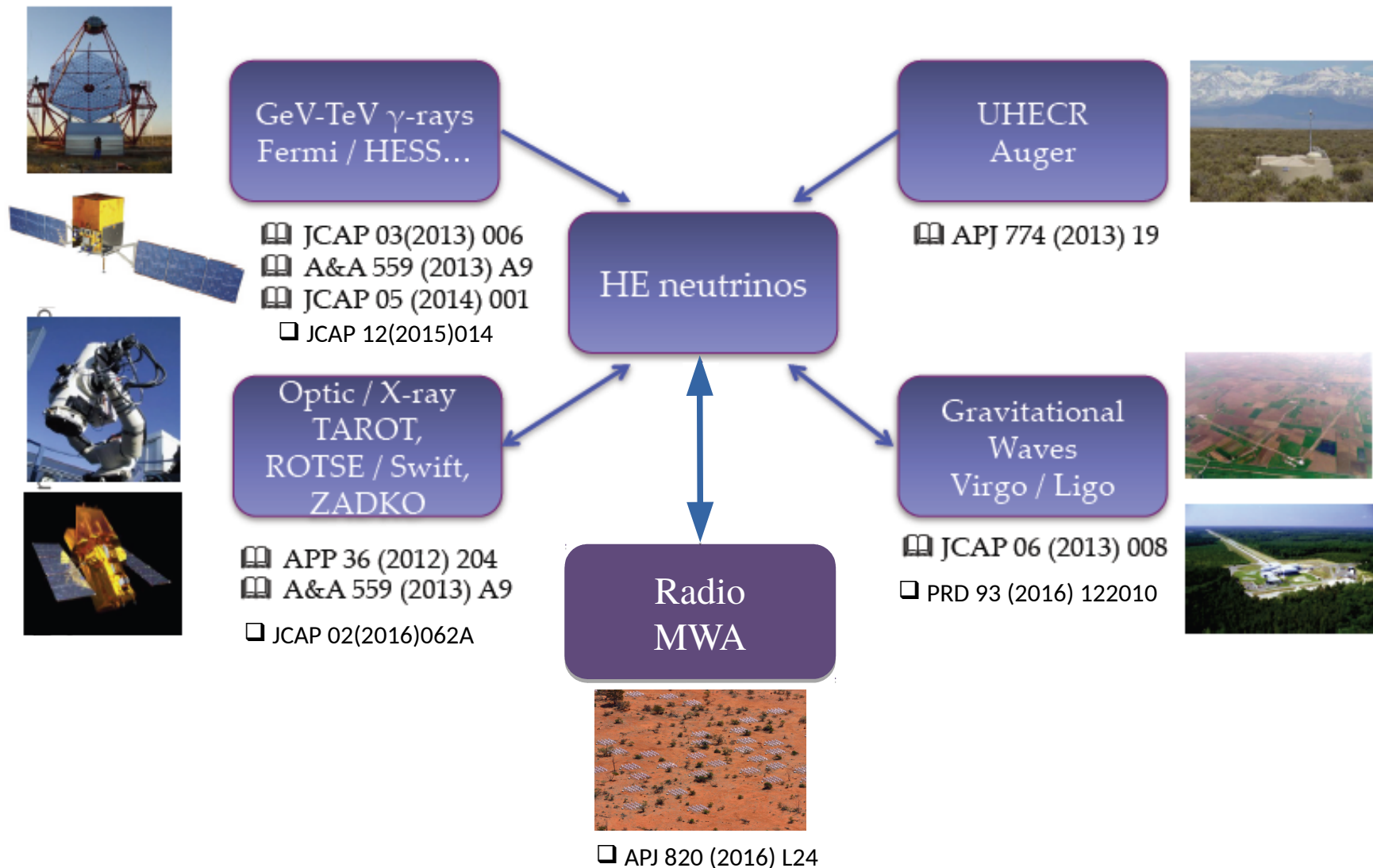
Results:

- **Sensitivity:** median Upper Limit (90% CL) = **1.1 $\Phi_{KRA\gamma}$**
- **Upper Limit** = **1.3 $\Phi_{KRA\gamma}$**
- **P-value** = **0.5**

To come:

- **Combination** with **IceCube**

The multi-messenger program



- **Increase** the detector **sensitivity** (suppression of the uncorrelated background)
- Better understand the **related physics mechanisms**

Gravitational wave follow-up

Track channel only

Physical Review D 93 (2016) n°12

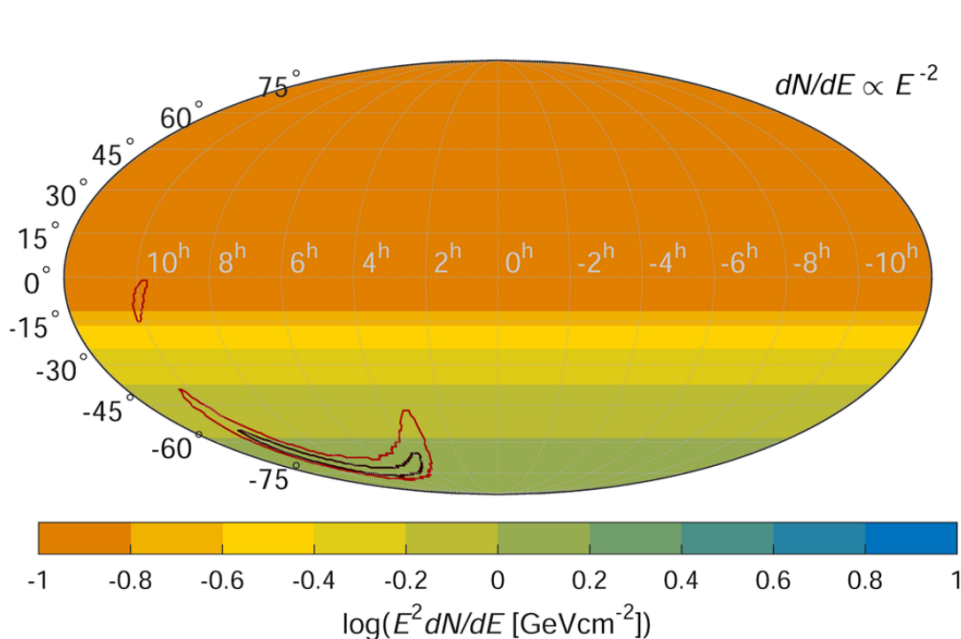
- Joint analysis with IceCube

- $E_{\nu, \text{tot}}^{\text{ul}} = 5.4 \cdot 10^{51} - 1.3 \cdot 10^{54} \text{ erg}$

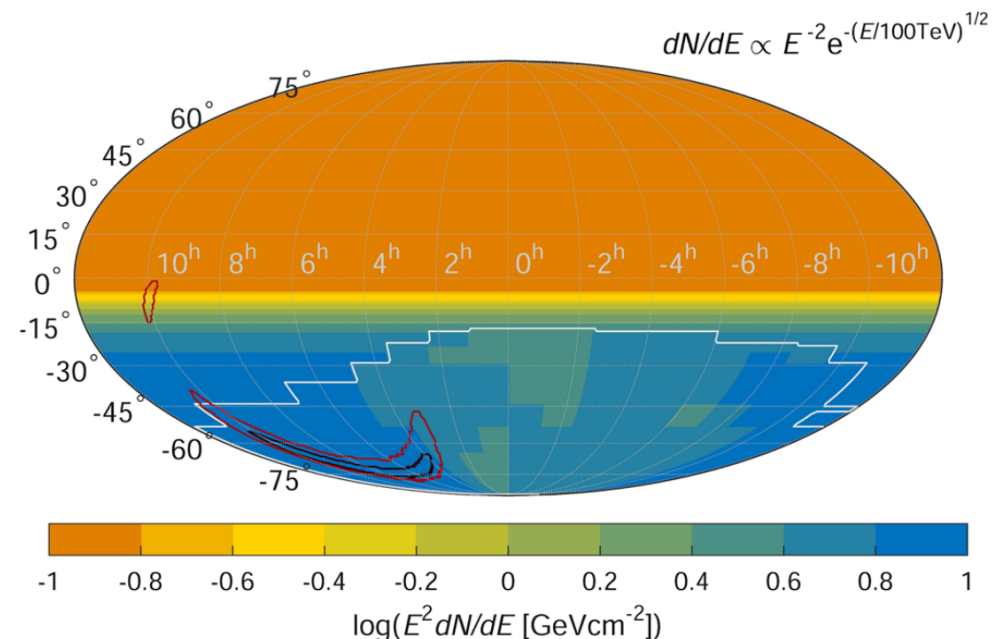
- $E_{\nu, \text{tot}}^{\text{ul (cutoff)}} = 6.6 \cdot 10^{51} - 3.7 \cdot 10^{54} \text{ erg}$

- Now: online follow-up

See Imre Bartos' talk



No energy cut-off



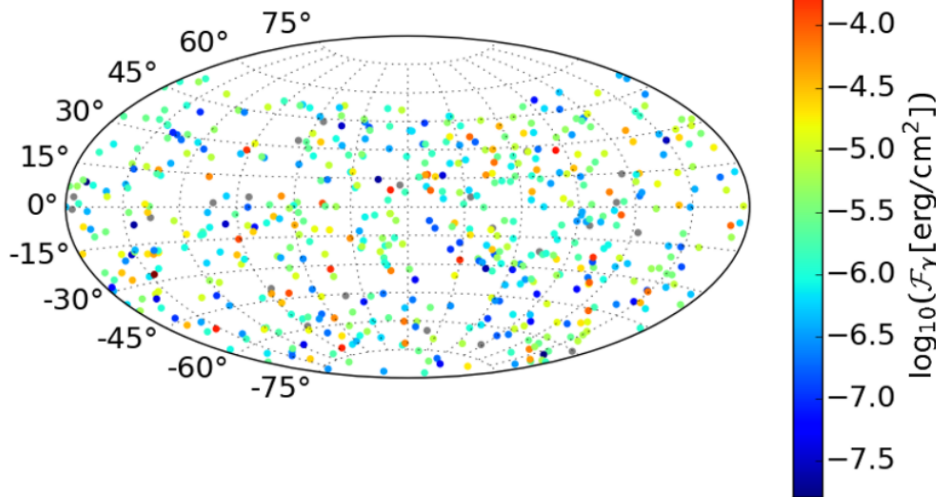
With energy cut-off

Multimessenger: GRBs

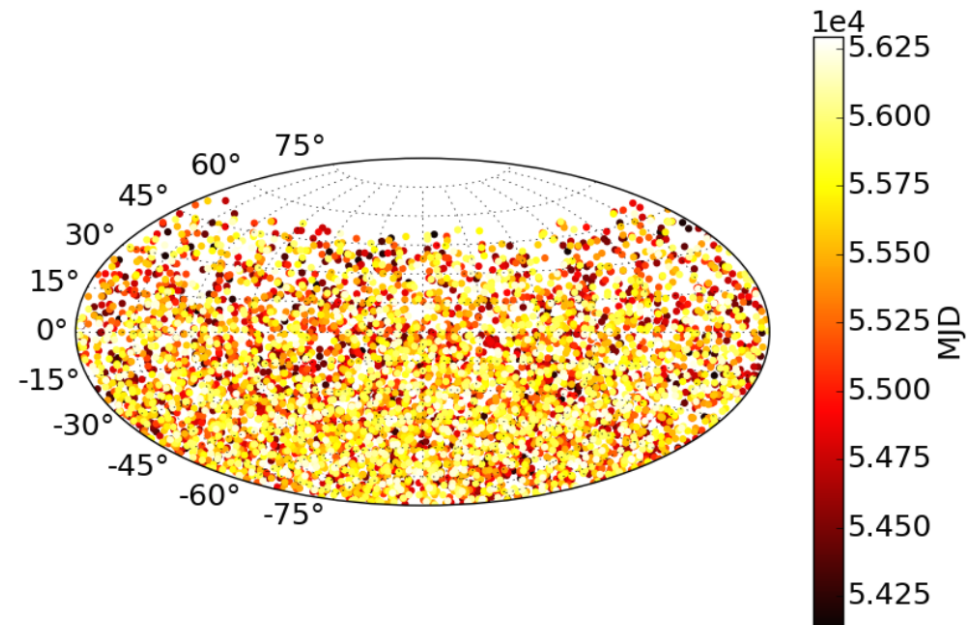
Track channel only

Eur.Phys.J. C77 (2017) no.1, 20

- 1488 Gamma Ray Bursts
- Many models predict **time-shifted neutrino signals**
 - ➔ Search for **ν within 40 days** of the Gamma Ray Bursts
- 6 years of ANTARES data and 1 year of IceCube
- **No coincidence** found, UL (sensitivity) = **1 detectable ν / 100 GRBs**



Selected GRBs

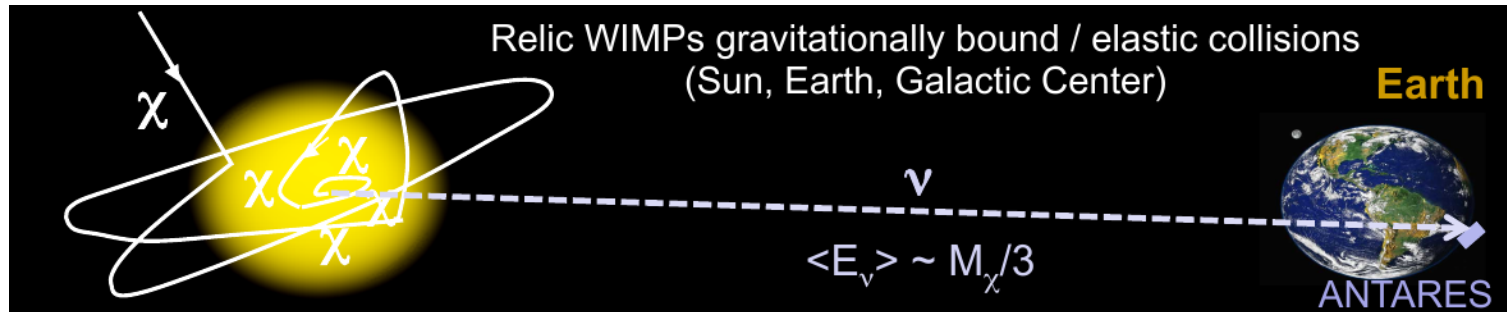


Recorded neutrino candidates from ANTARES

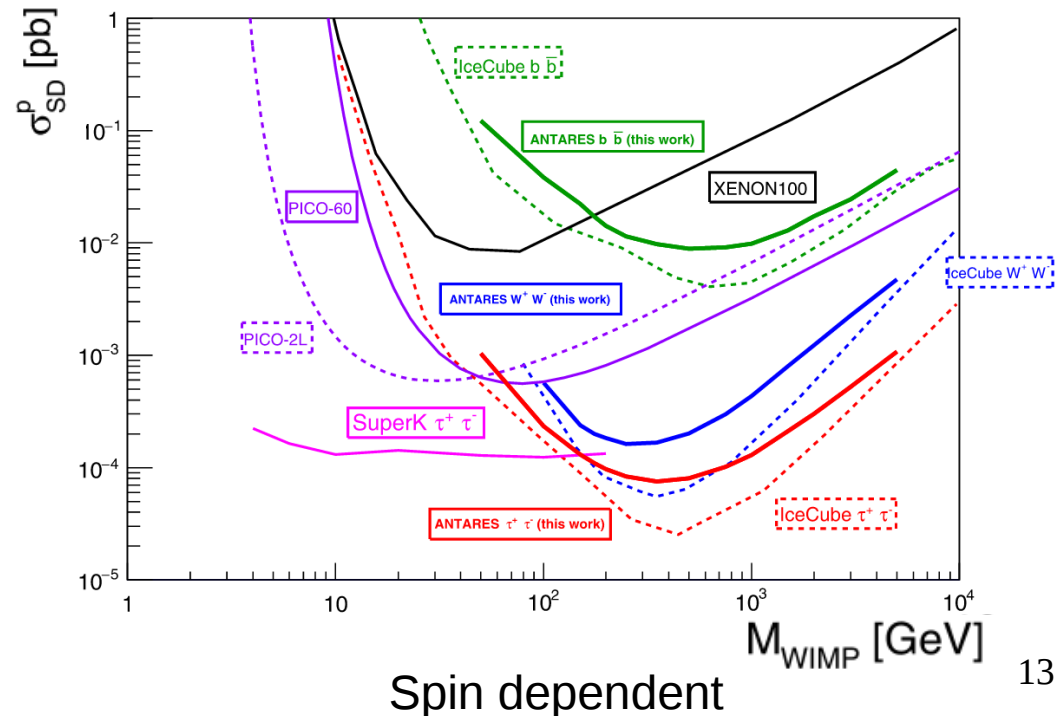
Dark Matter from the Sun

Physics Letters B 759 (2016) 69-74

Track channel only



- WIMP annihilations in the **Sun**
- **WIMP + WIMP**
 $\rightarrow b\bar{b}, \tau^+\tau^-, W^+W^-$
 $\rightarrow \dots \rightarrow \nu$
- 6 years of ANTARES data
- **No significant excess found**

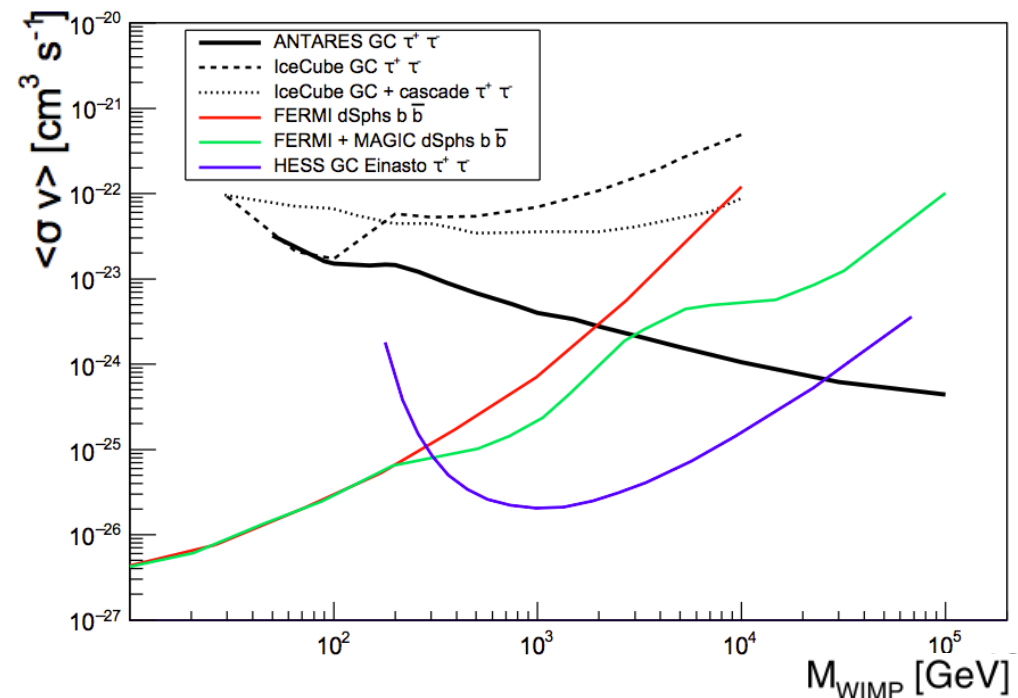
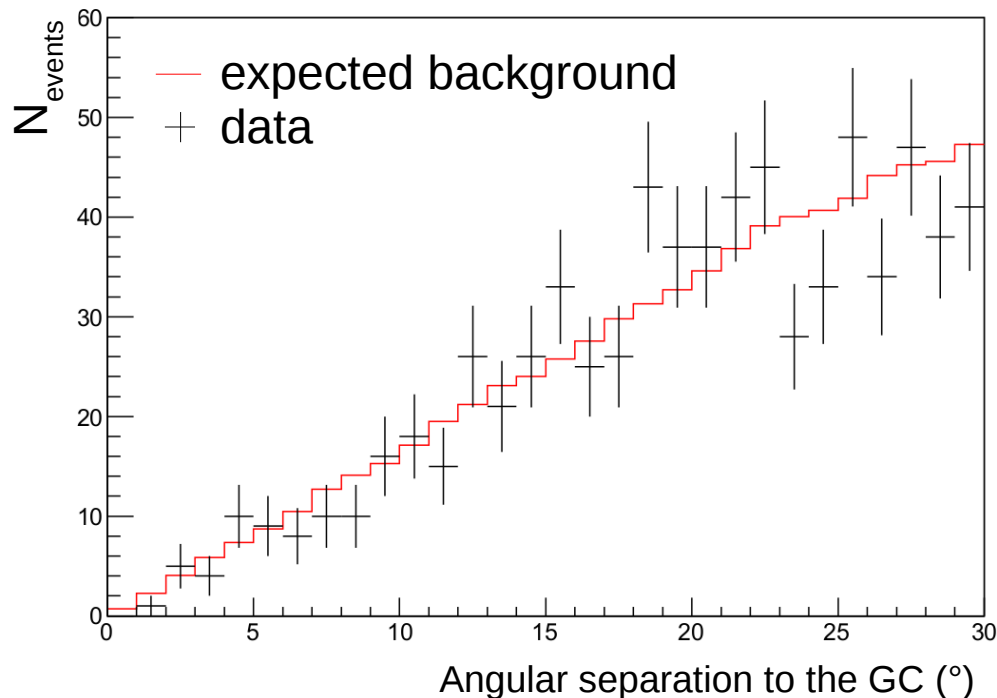


Dark Matter from the Galactic Center

arXiv:1612.04595

Track channel only

- **WIMP + WIMP** $\rightarrow b\bar{b}, \tau^+\tau^-, W^+W^-, \mu^+\mu^-, \nu\bar{\nu} \rightarrow \dots \rightarrow \nu$
- Search for an **excess** of ν close to the **Galactic Center**
- 9 years of ANTARES data
- **No significant excess** found
- **Limit** on the thermally averaged **annihilation cross section** $\langle\sigma v\rangle$



Summary and perspectives

- **All flavor** sensitivity by including shower events
- Excellent **angular resolution**...
 - ...even for the **showers**
- **Best sensitivity** on a large part of the **Southern sky**...
 - ...especially for **E < 100 TeV**
- Physics reach from **cosmic sources** to **dark matter**

Improvements to come:

- Include **showers** in all analyses which use only tracks
- Next generation neutrino telescope: **KM3NeT**
 - Talk from **Paschal Coyle**



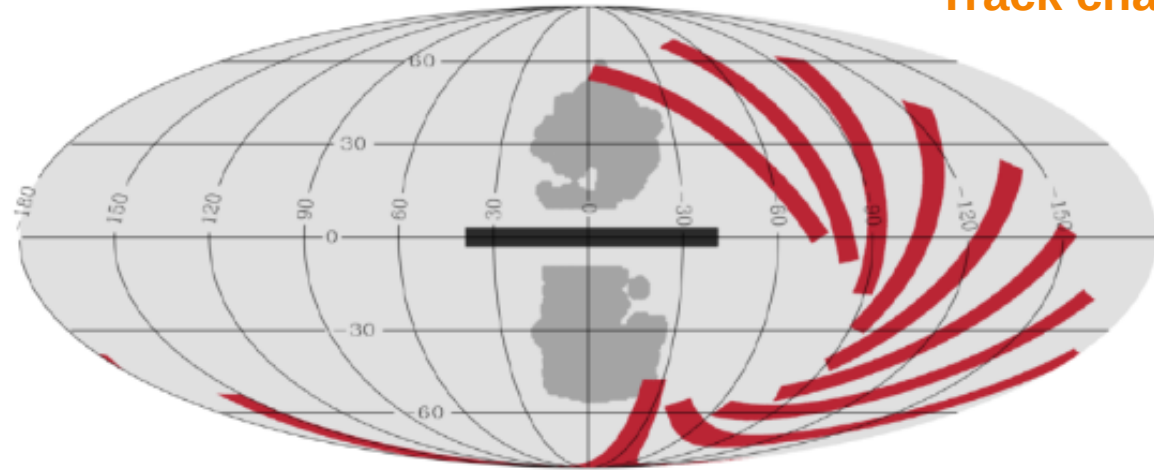
Thank you !

Backup slides

On-off Galactic Ridge study

Track channel only

PLB 760 (2016) 143



- Search region
→ $|l| < 30^\circ$, $|b| < 4^\circ$
- Comparing galactic plane with equivalent **background regions**
- **No excess** in the HE neutrinos
- 90% CL upper limits: **< 3 IceCube HESE events** coming from this region for $E_\nu < 300$ TeV

