Search for a neutrino counterpart to the HAWC gamma-ray catalog with the ANTARES telescope

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on behalf of the ANTARES and HAWC Collaborations

Figure 1. The HAWC Observatory

The HAWC experiment [1] is a water Cherenkov detector located in Mexico. It observes the very-high- energy gamma-ray sky with large exposure and field of view, performing a high-sensitivity survey. ANTARES [2] is a neutrino telescope located in the Northern hemisphere, in the Mediterranean Sea. Due to its geographical location, reconstruction accuracy for all-flavor neutrino interactions and low energy threshold for neutrino detection, the ANTARES observatory can monitor with large exposure the Southern sky, and study neutrino source candidates in the Galactic plane.

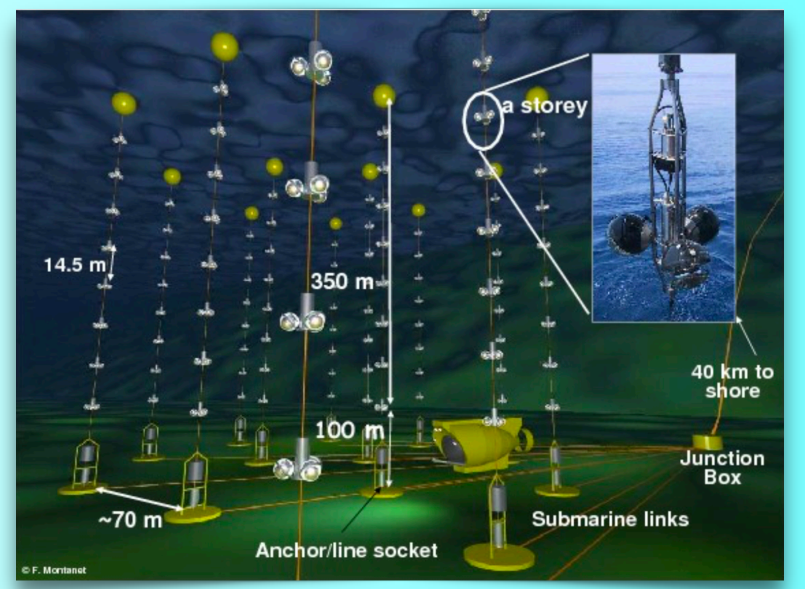

Figure 2. The ANTARES telescope

The ANTARES 2007-2017 (track and cascade events) dataset [3] is used to performe an **all sky** and a **Galactic Plane** search of an all-flavor neutrino emission in correlation with the $E^{-2.5}$ all energy [4] and to E^{-2} high energy [5] HAWC point-source sky maps above 3σ. The Villante et al [6] model is used to derive the neutrino flux. An energy cut-off on neutrino spectra at 100 TeV is considered.

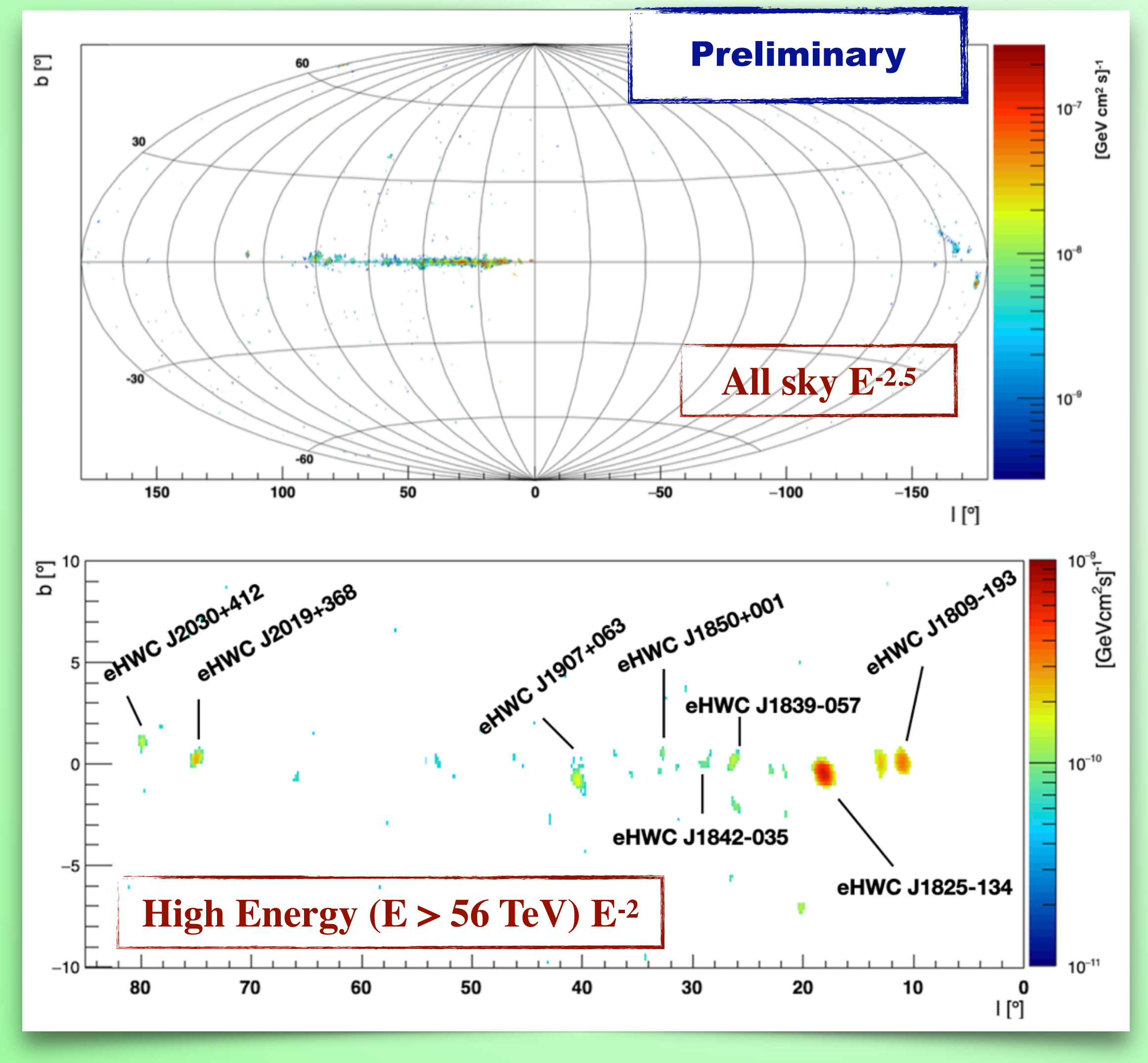

Figure 3. Upper (lower) panel expected neutrino sky map proportional to $E^{-2.5}$ (E^{-2}) HAWC signal as modelled by [6].

The neutrino maps are the template sky maps for the search of neutrinos coming from the same direction in the sky. In the search method, based on a maximum likelihood approach, the template maps and the ANTARES data are used to build the likelihood function of signal and background events.

$$L_{sig+bkg} = \prod_{\tau\in(tr,sh)} \prod_{i\in\tau} \left[\mu^{\tau}_{sig} \cdot pdf^{\tau}_{sig}(E_i, \alpha_i, \delta_i) + \mu^{\tau}_{bkg} \cdot pdf^{\tau}_{bkg}(E_i, \delta_i)\right]$$

$$pdf^{\tau}_{sig}(E_i, \alpha_i, \delta_i) = M^{\tau}_{sig}(\alpha_i, \delta_i) \cdot \epsilon^{\tau}_{sig}(E_i, \alpha_i, \delta_i)$$

$$pdf^{\tau}_{bkg}(E_i, \delta_i) = M^{\tau}_{bkg}(\delta_i) \cdot \epsilon^{\tau}_{bkg}(E_i, \delta_i)$$

The significance of the signal is estimated trough a *hypothesis test TS*

$$TS = logL_{sig+bkg} - logL_{bkg}$$

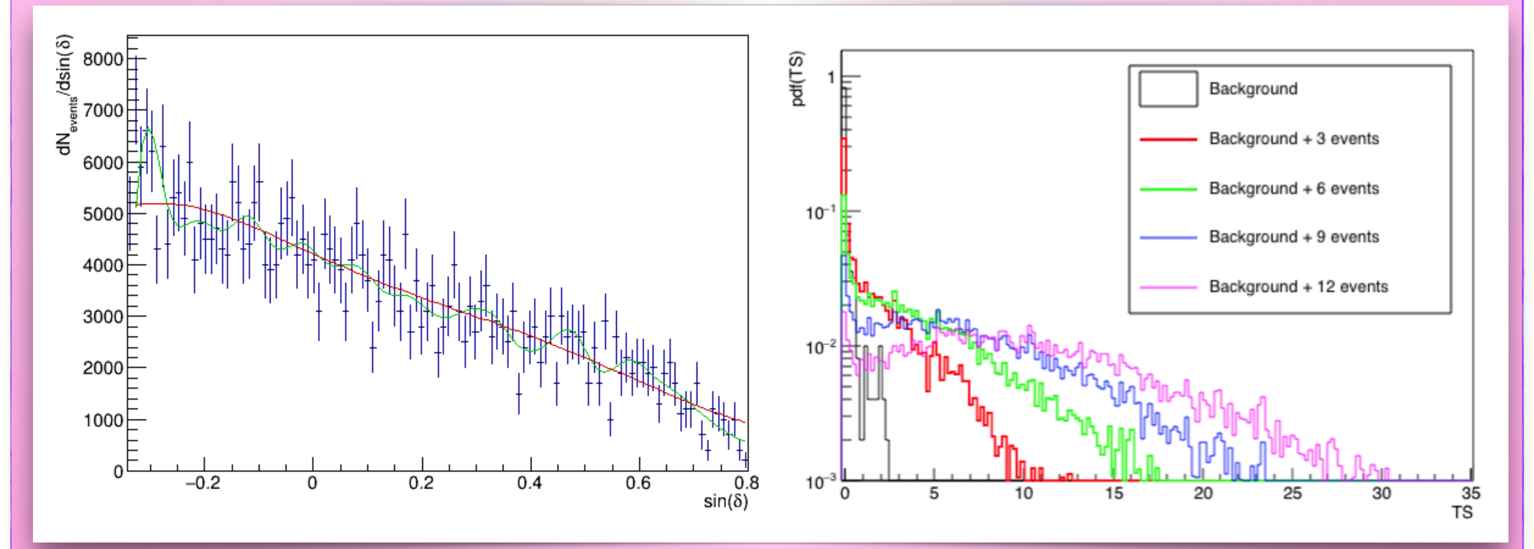

Figure 4. On the left the M_{bkg} for track-like events. On the right the TS distribution for the only background case and for the background plus 3, 6, 9, 12 signal events.

The results of the **all sky** and **Galactic Plane** searchers are reported in Tab. 1 and the sensitivities are presented in Fig. 5. The sensitivity of the all sky and Galactic Plane searchers is a factor **4.8** above the the neutrino flux predicted using the Villante et al. method. For comparison the ANTARES sensitivities presented in [7] and [8] are also shown.

	N_{tr}	N_{sh}	n_{90}	$(n_{90}/N_s)\cdot\Phi_\nu$
All sky neutrino search ($E^{-2.5}$ sky map)	0.92	0.55	7.1	4.8
Galactic Plane search (HE sky map E^{-2}, E > 56 TeV)	0.60	0.42	5.0	4.8

Tab 1. For the two searches the number of reconstructed track (N_{tr}) and cascade (N_{sh}) events, the number of signal events (n_{90}) at the 90% confidence level and the fraction of the neutrino flux modelled by [6] to which ANTARES is sensitive are specified.

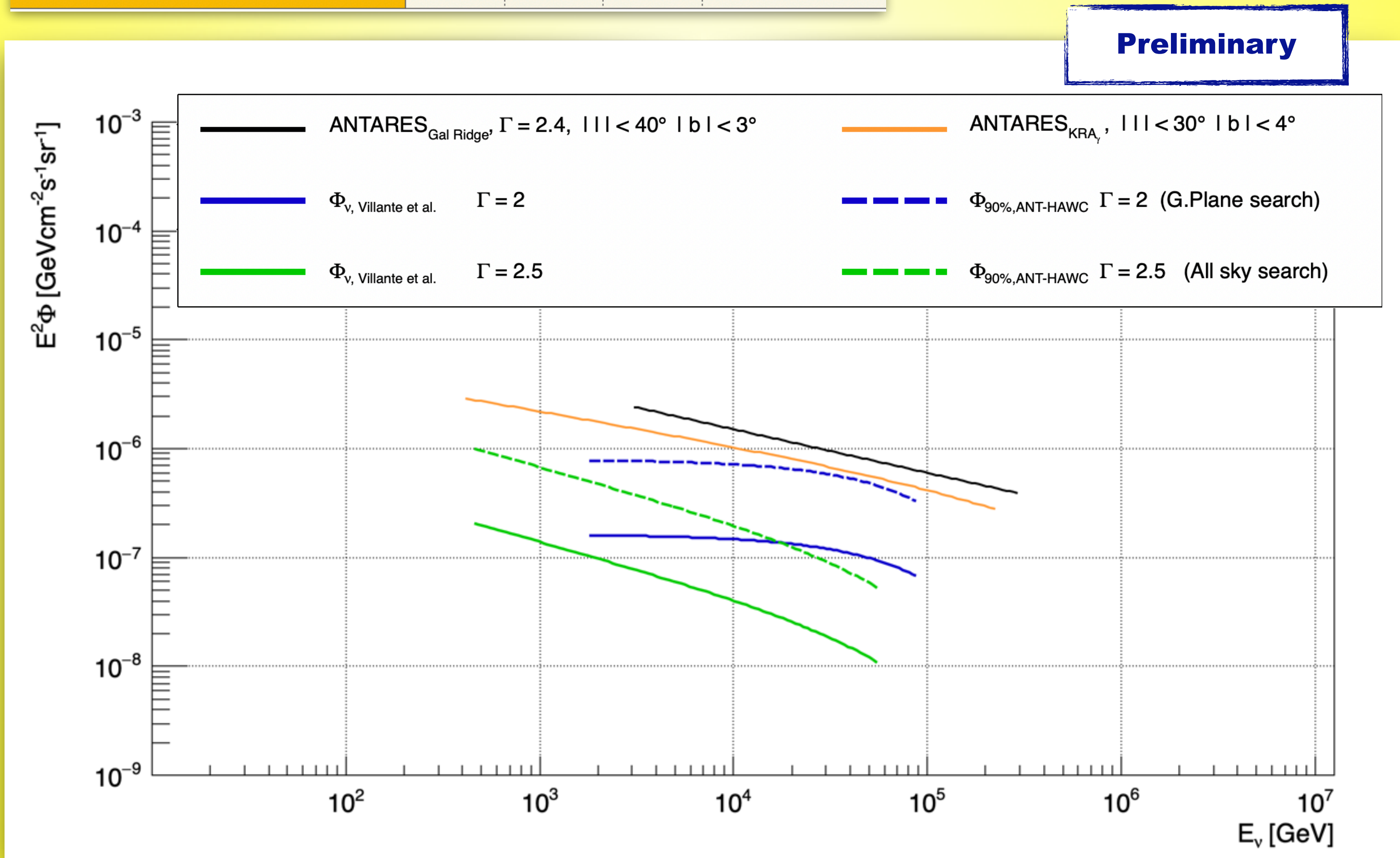

Figure 5. ANTARES sensitivities of the all sky (dashed green line) and Galactic Plane (dashed blue line) searches. For comparison the ANTARES sensitivities presented in [7] and [8] are reported.

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