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# Status of the ANTARES detector

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**Summary.** — ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) is currently the largest neutrino observatory in the Northern hemisphere. The detector has been designed to detect high energy muon neutrinos coming from both galactic and extra-galactic sources, via the identification of muons, produced as the final state of charged current interactions of muon neutrinos with the medium surrounding the detector. The main goal of the ANTARES experiment is the search for high energy neutrinos of astrophysical origin. Besides the search for point-like steady sources, other physics topics are relevant for a deep sea neutrino observatory. Some research topics that are presently pursued within the ANTARES Collaboration will be presented here.

PACS 95.55.Vj – Neutrino, muon, pion, and other elementary particle detectors; cosmic ray detectors.
PACS 95.85.Ry – Neutrino, muon, pion, and other elementary particles; cosmic rays.
PACS 98.70.Rz – $\gamma$-ray sources; $\gamma$-ray bursts.

## 1. – Introduction

The ANTARES Collaboration has completed in 2008 the construction of an underwater neutrino telescope 40 km off the coasts of Toulon, Southern France, at a depth of about 2500 m [1].

The apparatus is an array of photomultiplier tubes (PMTs), arranged on 12 detection lines, each comprising up to 25 triplets of PMTs. The main goal of the ANTARES experiment is the detection of high-energy muon neutrinos of astrophysical origin. This search is performed by looking for upward-going neutrino-induced muon tracks out of the huge amount of the down-going atmospheric muons, produced in interactions between primary cosmic rays and atmospheric nuclei. The shielding effect of the sea reduces the flux of atmospheric muons, which is however several orders of magnitude larger than the atmospheric neutrino flux.

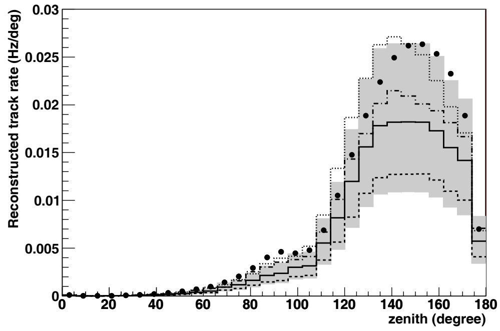


Fig. 1. – Zenith angle distribution of reconstructed tracks for data collected in 2007. Black points represent data, while solid, dotted, dashed and dot-dashed lines represent Monte Carlo events generated with different parametrizations for the flux of atmospheric muons [2]. The shaded areas include the systematic uncertainties, due to environmental and geometrical effects.

## 2. – Atmospheric muons

Atmospheric muons represent a dangerous background for track reconstruction as their Cherenkov light can mimic fake upward-going tracks: although they are a background for neutrino detection, the atmospheric muons are useful to verify the detector response. The main uncertainties concerning the identification of the atmospheric muons come from the production mechanisms (parametrization of the primary cosmic ray composition), the environmental parameters of the site were the telescope has been deployed and the geometrical description of the photomultiplier tubes (effective area and angular acceptance).

Results of a detailed study on systematics uncertainties that affect the detection and reconstruction of atmospheric muons are described in [2]. Figure 1 shows the distribution of reconstructed zenith angle for both data and Monte Carlo events, for the 2007 configuration (only 5 detection lines were active and collecting data): data (black points) are compared to Monte Carlo expectations obtained using different models (black curves). The shadowed band represents the systematic error on the simulation of the detector due to environmental and geometrical parameters: a systematic effect of about $\pm 30\%$ can be considered as due to the environmental and geometrical parameters.

The left plot in fig. 2 shows the distribution of the elevation for reconstructed events detected during 2007 and 2008: particles that are reconstructed with positive elevation are identified as down-going, then likely atmospheric muons, while particles reconstructed with negative elevation are up going particles.

## 3. – Neutrinos from astrophysical sources

The production of high-energy neutrinos (energies higher than some TeV) is expected to take place in the same sources that are able to accelerate cosmic rays up to ultra-high energies. The interactions of cosmic rays with radiation and matter surrounding the acceleration regions are then expected to lead to the production of charged pions and kaons, whose decays produce electrons and muon neutrinos. As an effect of the flavor oscillations, an equal amount of neutrinos of the three flavors is expected to reach the Earth.

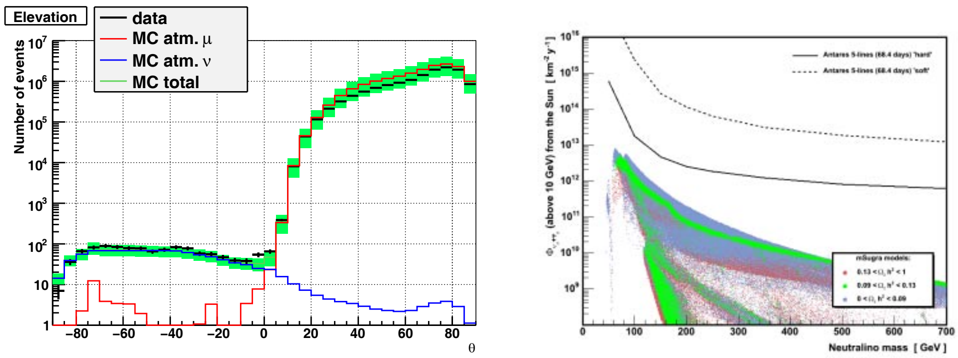


Fig. 2. – (Color online) Left plot: Zenith distribution of reconstructed tracks for 2007 and 2008 ANTARES data. The error band of the *total MC* curve takes for neutrinos a combined theoretical and systematic error of 30% and for atmospheric muons of 50%. Right plot: upper limit on the total $\nu_\mu$ and $\bar{\nu}_\mu$ flux from neutralino annihilation in the Sun, obtained with 2007 data [5], with 5 detection lines. Each colored point corresponds to a supersymmetric model and different observational constraints. Two annihilation models (hard, into W vector bosons and soft, into $\mathrm{b\bar{b}}$ quarks) have been studied.

Candidate sources of high energy neutrinos include both steady, *e.g.* Super Nova Remnants, micro-Quasars or Active Galactic Nuclei (AGN), and transient objects, such as Gamma-Ray Bursts (GRBs) or Core Collapse Super Novae (CCSN).

Transient sources offer a unique opportunity to detect high energy neutrinos, the background of atmospheric muons and neutrinos being reduced over the narrow time window. Two detection methods have currently been implemented within the Collaboration: the *triggered search* [3] and the *rolling search* [4] methods. While the former method relies on the information received by a satellite, the latter is such that the *golden* neutrino events are used to trigger the observation with a network of optical telescopes. The follow-up is necessary since an observation in neutrinos is not necessarily associated to a source: the candidate source has to be monitored for several days in order to investigate its transient nature and to compare its light curve to that of known classes of astrophysical objects, like CCSN.

Indirect search for dark matter can be performed in ANTARES by looking for a neutrino excess from celestial bodies like the Sun or the Galactic Center: neutrinos with energies below the TeV scale could be produced in the annihilation of weakly interacting massive particles, *e.g.* neutralinos, gravitationally trapped in celestial bodies. Current limits about the flux of muon neutrinos (and anti-neutrinos) from the Sun have been obtained from the 2007 data [5], as a function of the neutrino mass, and are shown in fig. 2.

## REFERENCES

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