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The ANTARES detector

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ANTARES is a neutrino telescope under construction in the Mediterranean Sea at the depth of 2500 m, about 40 km off the French coast. A short review of its design and expected performances is presented as well as the status of the project.

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1. Introduction

Neutrino astronomy represents a new tool to explore the far Universe and to investigate possible mechanisms for cosmic ray acceleration. High energy neutrinos could be produced inside cosmic accelerators like Supernovae Remnants, Active Galactic Nuclei and microquasars via the so called "astrophysical beam dump" mechanism, according to which neutrinos result from the decay of mesons (π and K) produced in pp or pγ interactions. The weak nature of their interactions allows neutrinos to travel enormous distances without being absorbed, scattered and deflected, delivering direct information on their production sites. On the other hand, the extremely small neutrino cross section and the low fluxes predicted by various models require large mass detectors and suggest the use of sea water or polar ice as natural Cherenkov radiators. Upward-going muons, produced by neutrinos interacting near the detector after having crossed the Earth, emit Cherenkov light, in water or ice, that is detected by an array of photomultipliers tubes (PMTs). Arrival times and amplitudes of the PMT signals allow the reconstruction of the muon direction and energy.

The ANTARES Collaboration [1], formed by scientists from many European countries, plans to build and deploy a neutrino telescope in the Mediterranean sea, about 40 km off-shore Toulon (France) $(6^o10'E, 42^o50'N)$ at a depth of 2500 m. Its sky coverage is 3.5 π sr and is complementary to that of AMANDA [2]. The instantaneous sky overlap of the two experiment is 0.5 π sr. Moreover, the location of ANTARES allows the observation of the Galactic centre for about 2/3 of the day.

*see Ref. [1] for a list of the ANTARES Collaborators

2. The ANTARES detector: physics goals and performances

The detector, see Fig. 1, will consist of 900 PMTs arranged in 12 strings at a distance of $\sim$ 70 m from each other, anchored to the seabed. Starting at 100 m from the seabed, 25 storeys will be mounted along each string at a distance of 14.5 m; they will be connected by an electro-optical-mechanical cable. Each storey will hold 3 optical modules (OM) [3] and a water-tight titanium box containing the electronic components. Each OM will house, in a pressure resistant glass sphere, a 10" Hamamatsu R7081-20 PMT mounted at 45^o with respect to the downward vertical direction. Optical beacons and acoustic transponders distributed all along

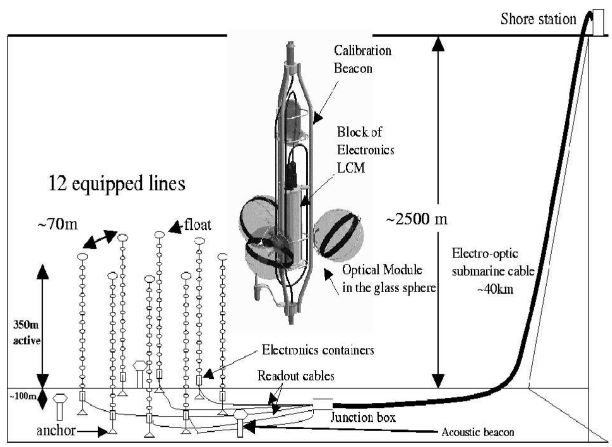

Fig. 1. Schematic view of the ANTARES detector

the strings will be used for timing calibration and position measurements. Each string will be coupled to a junction box that will distribute the electric power and the control signals and will transmit data to a shore station via a main electro-optical cable. A special instrumented line, monitoring environmental parameters like salinity, sound velocity, sea current velocity and hosting devices for oceanographic, biological and seismological studies, will complement the detector.

The main ANTARES objective is the detection of neutrinos of astrophysical origin coming from point-like sources or as a diffuse flux. The diffuse neutrino signal can be detected above the background due to atmospheric neutrinos thanks to the harder spectrum expected from cosmic accelerators at high energy ($\geq$ 10 - 100 TeV). On the other hand, the knowledge of direction and time will help to suppress this background in the search for point-like, persistent or transient sources.

An extensive simulation activity has been performed to define the sensitivity of the detector through the study of some important parameters.

The neutrino effective area, defined as the ratio of the detected muons relative to the incident neutrino flux, is about $7 \cdot 10^{-3}$ m^2 at 1 TeV, 3 m^2 at 100 TeV and approaches a saturation value of 30 m^2 due to the Earth opacity to very high energy neutrinos.

The intrinsic angular resolution, defined as the median of the angle between the direction of the reconstructed muon and the parent neutrino for simulated events, is an important parameter for the detection of point-like sources. Below 10 TeV it is dominated by neutrino interaction kinematics, while for $E_\mu > 10$ TeV it is $\sim 0.2^o$. The muon energy is estimated exploiting the features of muon energy losses for $E_\mu \gtrsim 500$ GeV. Following the methods presented in [4] *the energy resolution* is a factor between 2 and 3 for $E_\mu \gtrsim 1$ TeV.

3. Status of the ANTARES project

A long R & D phase allowed the measurement of the relevant environmental parameters of the detector site showing that they are well suited for building a Cherenkov detector: the absorption length is 60 m at a wavelength of 470 nm and the effective scattering length is larger than 200 m [5]. The sea current velocity is 5 - 15 cm/s and the loss of transparency of a downward looking sphere is about 1.5 % after one year and tends to saturation [6].
In 1999 a test line with 7 optical modules was deployed. The zenith angle distribution of reconstructed muons is in good agreement with the expected one. In 2003 a prototype line with 5 storeys and a reduced version of the instrumented line were deployed and connected to the junction box. The deployment, connection and recovering of the lines were successful. Data were recorded for about 100 days. A failure in the clock transmission prevented to get a ns precision level. Nevertheless, the tiltmeters and the compass along the string showed that the line moves coherently as a solid. Moreover, the counting rates of OM's gave information on the background due to short-lived peaks of bioluminescence superimposed to a baseline from ^{40}K decay and bacteria [7]. Correlations with the sea currents have been observed.

4. Conclusions

After the successful deployment, connection and recovery of two prototype lines, the ANTARES detector entered the construction phase. The objectives for the next months are the redeployment of a prototype line and the launching of the mass production of components. The completion of the detector is foreseen by 2007.

References

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