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The KM3NeT project: status and perspectives

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Abstract

KM3NeT is an international consortium involving more than 300 scientists from 10 EU countries. Its main objective is the construction of a multi-km³ high-energy neutrino telescope in the Mediterranean Sea that will also host an interdisciplinary observatory to marine sciences. KM3NeT has been included in the roadmap of the European Strategy Forum of Research Infrastructures (ESFRI). Very high energy neutrinos are important messengers to study non-thermal phenomena in the Universe. The pioneering ANTARES, NEMO and NESTOR underwater neutrino telescope projects include the extensive R & D knowledge base behind the KM3NeT project. A Technical Design Report has been published which describes the technological solutions chosen for the detector. The present status of the project is presented.

1 Introduction

Neutrinos are the perfect probe to explore the far Universe. They have no electrical charge, are insensitive to gravitational and magnetic fields and interact only weakly. This means they can travel huge distances from their production sites before reaching a detector on the Earth, transporting direct information on mechanisms acting inside cosmic accelerators. The discovery of astrophysical neutrinos will open a new perspective of astronomy and astrophysics, complementing present gamma ray astronomy and cosmic ray studies.

The same properties that make them unique messengers of high energy processes, represent a severe limitations to their detectability. Very large detection volumes, at least 1 km³, are required in order to have an unambiguous signal due to astrophysical neutrinos together with an effective shield against the overwhelming background due to atmospheric muons, residuals of the high energy cosmic ray showers. A km³ size neutrino telescope is currently in data taking at the South Pole, IceCube (Abbasi et al., 2012). However, its sensitivity to sources in the southern sky, which includes most

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oceans, where seawater represents simultaneously the target, the shield and the active detection volume. A lattice of very sensitive optical detectors is deployed at a large depth under water (or ice). Time, position and charge information of signals due to Cherenkov photons are registered and processed with dedicated algorithms, allowing the reconstruction of the charge particle direction. Though the telescope is sensitive to all neutrino flavors, it is optimized to neutrino induced muons. Identifying upward going tracks allows the rejection of the overwhelming background of atmospheric muons. The angle between the neutrino and the muon directions is less than 1° for neutrino energy larger than a few 100 GeV (Fig. 4). An excess of tracks over the expected background of atmospheric neutrinos is hint for a cosmic source. The study of the energy spectrum of neutrinos reaching the detector can also provide indication of a diffuse flux of cosmic origin, if the measured spectrum does not follow the expected power law for atmospheric neutrinos ($\gamma = -3.7$).

3 Sites

A suitable site to host this kind of infrastructure must fulfill several requirements among which the most relevant are: sufficient depth in order to provide an effective shielding to the penetrating atmospheric radiation component, proximity to coast to facilitate deployment operations and to reduce the cable connection cost, high water transparency, low level of bioluminescence, low rate of biofouling and sedimentation on optical devices, low sea current velocity and low risk of catastrophic events, like slope failures and significant earthquakes.

The KM3NeT project is based on the joined efforts of three European collaborations, ANTARES, NEMO and NESTOR, which, since a long time, have been performing accurate activities of site characterization. They have identified three different sites that have been recognized as optimal sites for hosting such an infrastructure. Their locations are indicated in Fig. 5. For the time being, as available fundings are strictly connected to

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et al. (2012). This will extend knowledge of some physical processes of the ocean and their interactions with biology and climate. Real time tracking of bio-acoustic emissions will be possible. The system will also provide continuous observations to investigate the behavior of hazardous events such as earthquakes and might contribute to the regional tsunami early warning system under ICG/NEAM with better performance than data buoys currently being deployed. The Earth and Sea Science component will practice a multidisciplinary approach and will form the basis of the Mediterranean section of the EU plan for long-term monitoring of the ocean margin environment around Europe and is part of the Global Monitoring for Environment and Security (GMES) system, complementing oceanographic networks such as GOOS (Global Ocean Observing System), EuroGOOS and DEOS (Dynamics of Earth and Ocean Systems). In addition, close cooperation will be pursued with EMSO (European Multidisciplinary Seafloor Observa-
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6 Conclusions

A short description of the KM3NeT project is given. After years of study, a detailed design for large infrastructure including a km³ size neutrino telescope and a marine science observatory in the Mediterranean Sea has been prepared. In addition, the experience of the ANTARES telescope has demonstrated the feasibility of this technique. Some initial funding has been made available to start its construction in Capo Passero and Toulon sites. This is only the first step, but represents a fundamental progress towards the full realization of the project.

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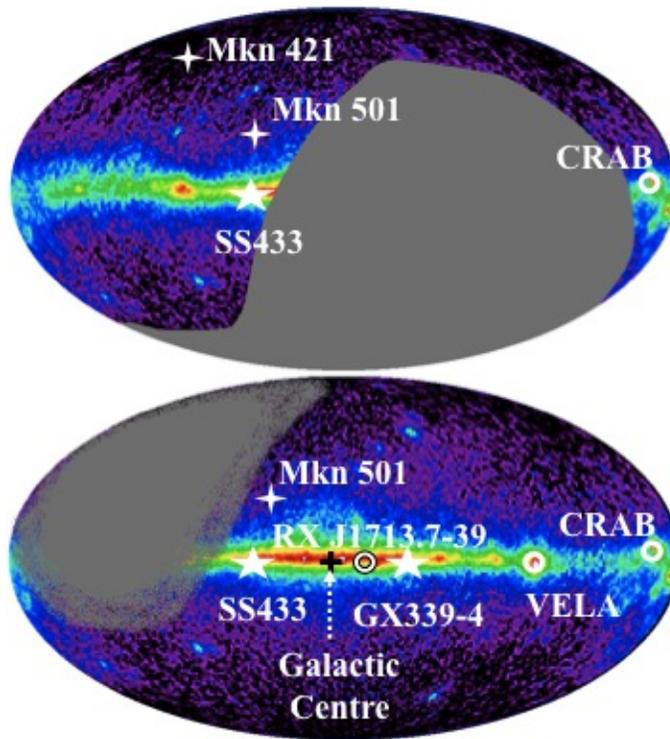


Fig. 1. Visible sky for a detector at the South Pole (top panel) and in the Mediterranean Sea (bottom panel).

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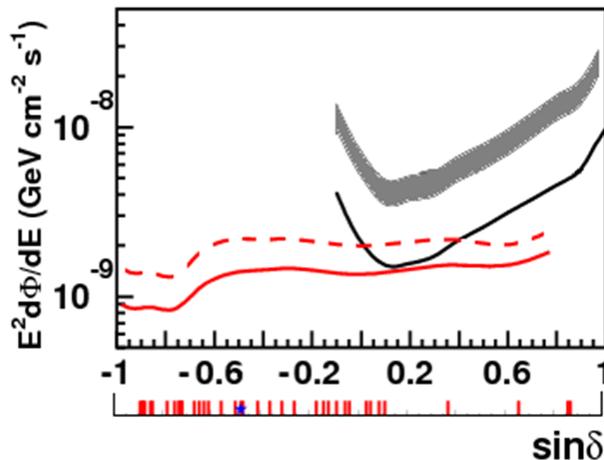


Fig. 2. Sensitivity of the KM3NeT detector to neutrino point sources with an E^{-2} spectrum for one year of observation, as a function of the source declination. The red lines indicate the flux sensitivity (90 % CL; full line) and the discovery flux (5σ , 50 % probability; dashed line). The full black line is the IceCube sensitivity for one year, the shaded band indicates the IceCube's discovery flux (5σ , 50 % probability), spanning a factor 2.5 to 3.5 above the flux sensitivity. The red ticks show the positions of Galactic gamma ray sources, the blue star the position of the Galactic Centre.

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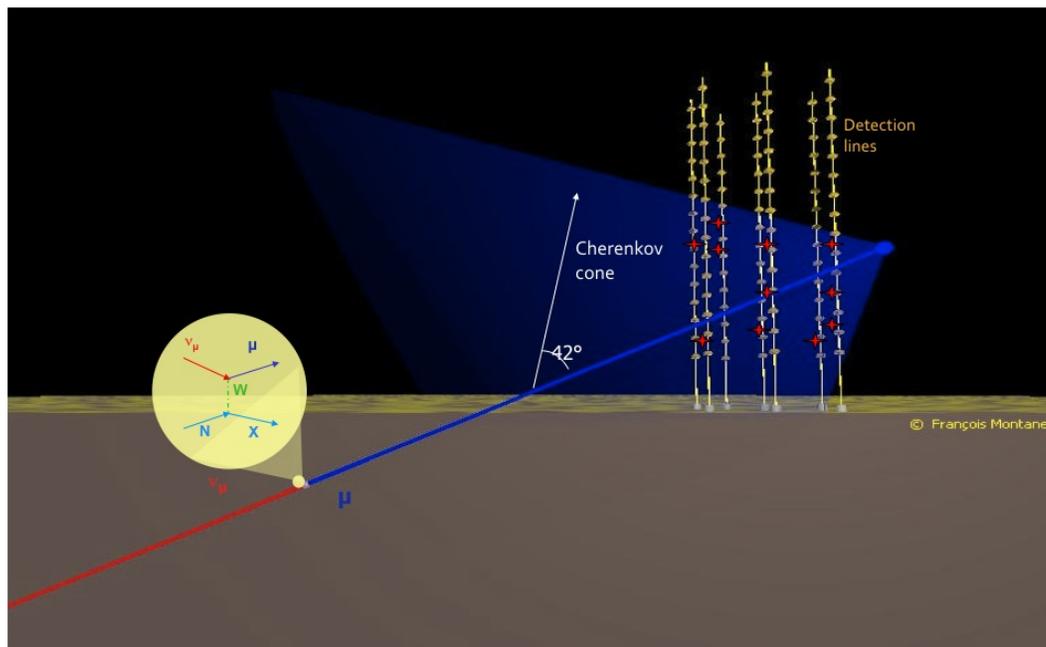
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Fig. 3. Detection principle of neutrino induced charged particles with an underwater telescope.

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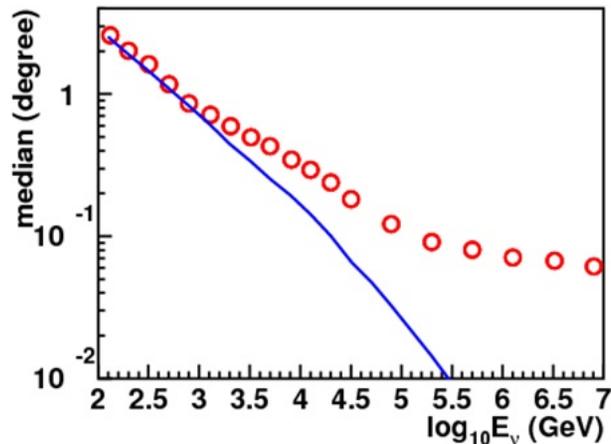
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Fig. 4. Median of the distribution of the angle between the neutrino and the reconstructed muon (red points). The blue line is the median of the intrinsic angle between neutrino and muon directions, driven by the dynamics of deep-inelastic neutrino-nucleon scattering and kinematics.

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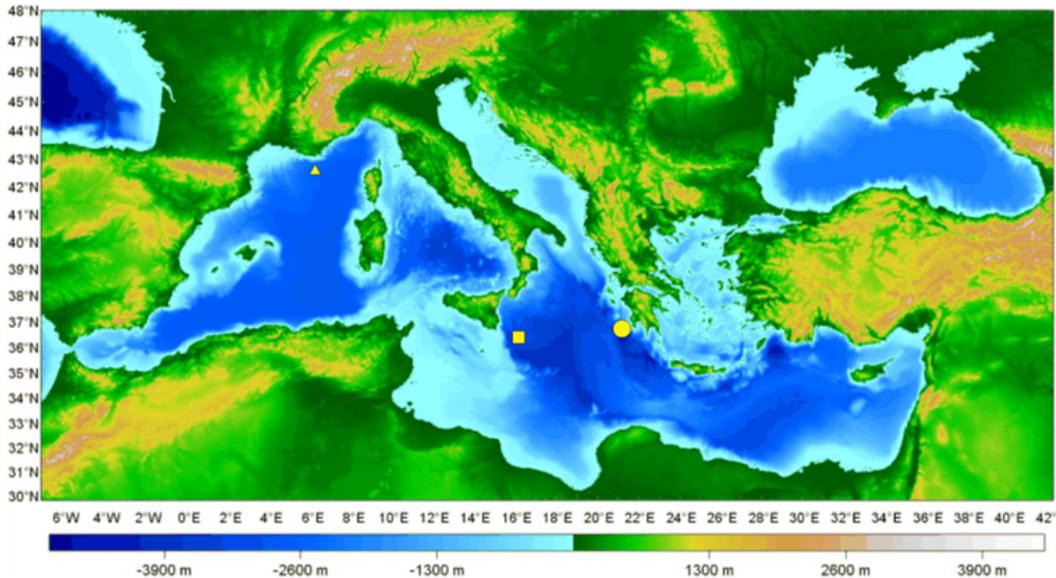
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Fig. 5. Bathymetry of the Mediterranean sea with the site locations marked. Triangle marks the Toulon site, ANTARES Collaboration, (Amram et al., 2003), the square the Capo Passero site, NEMO Collaboration, (NEMO coll., 2002) and the circle contains four possible sites near Pylos, NESTOR Collaboration, (Trimonis and Rudenko, 1992).



Fig. 6. Multi-PMT optical module, containing 31 PMTs with 3" diameter photocathode in a large glass sphere.

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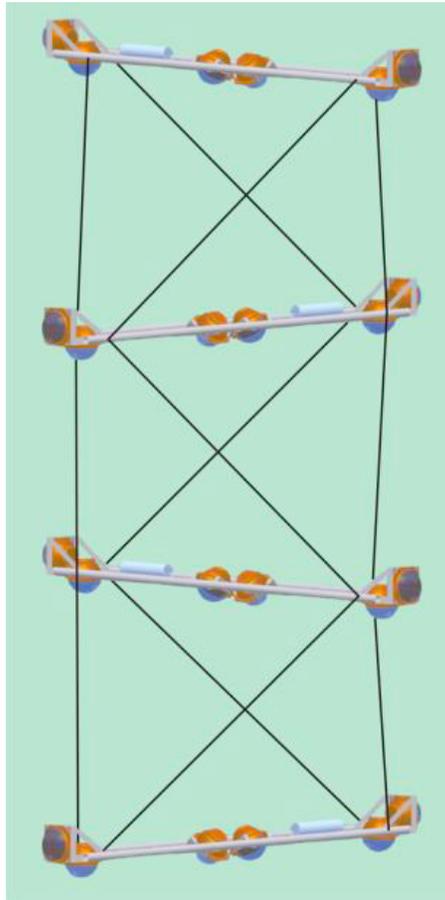


Fig. 7. A few of storeys with interconnecting ropes for the Bar detection unit (vertical scale is reduced).

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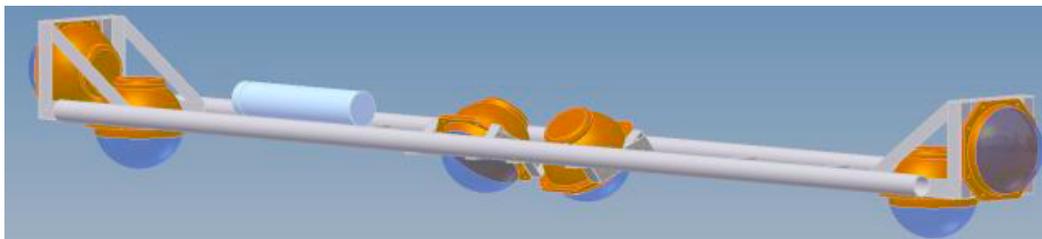
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Fig. 8. The storey for the Bar detection unit.

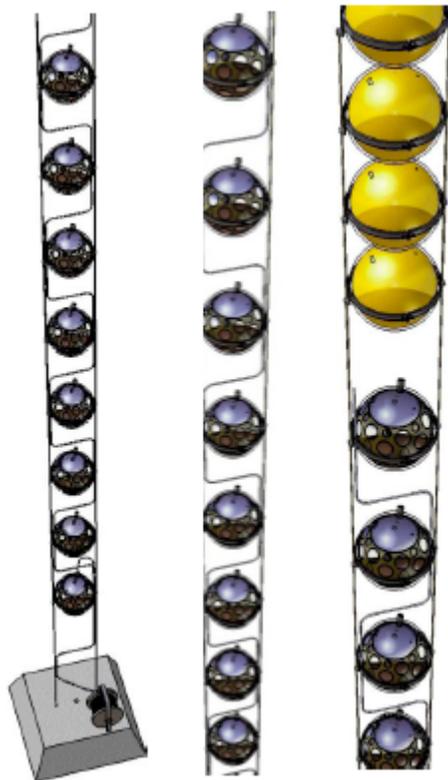


Fig. 9. Schematic layout of the String Detection Unit (from bottom at left to top at right).

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