

PHD FIRST YEAR ANNUAL REPORT – CARLO GUIDI

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During the first year of the PhD in Physics my work took place on several fronts:

- 1) Simulations of the acoustic positioning system for the KM3NeT submarine cosmic neutrino detector.
- 2) Analysis of KM3NeT Raw acoustic data
- 3) Implementation of an offline and online monitoring system for good signal reception by KM3NeT acoustic detectors
- 4) Analysis of the acoustic data of the Whalesafe project, aimed at detecting sperm whales.
- 5) Course attendance and related study in view of the associated exam tests

1)

KM3NeT is an underwater neutrino telescope located at two different sites in the Mediterranean Sea, one in France (ORCA, at 2500 m depth), offshore the coast of Toulon, and one in Italy, offshore Capo Passero (ARCA, at 3500m depth). The detectors will consist of several hundreds detection units installed at the seabed at high depths. A detection unit is a vertical structure with Digital Optical Modules (DOMs) attached. Each DOM is equipped with photomultipliers to detect Cherenkov light and a piezo sensor for acoustic signals detection. To precisely reconstruct neutrino events a time resolution of about 1 ns is needed for the KM3NeT detectors. Such temporal resolution corresponds to 20 cm of light/muon path length in water. So, relative positioning of each element of the detection unit should be known at this level in order not to spoil the angular resolution of the detector.

The KM3NeT acoustic positioning system consists of three autonomous emitters (Acoustic Beacons), positioned outside the detection volume and not synchronized with the master clock of the detector, a hydrophone at the base of each line and a piezoelectric acoustic receiver on each DOM in the line. Each beacon emits regularly a different acoustic pattern in order to be recognized.

To estimate the position accuracy that can be reached with such a system a numerical simulation study has been performed. For this, a function is defined to reconstruct the position of the various elements. It depends on the time of emission (ToE), the time of flight (ToF) and the time of arrival (ToA) of the various pings emitted by the acoustic beacons and detected by the hydrophones and piezos.

The function is minimized in order to find the positions of the beacons and the base of the detection units that better fit the measured ToAs. In addition, the timing resolution of the detected signals is taken into account to finally provide the estimated positions of the components with their improved uncertainty.

2)

An analysis of the Raw acoustic data recorded from three DOM on 20/03/2019 between 06:00 (UTC) and 12:00 (UTC) was carried out. Some existing analysis programs have been used and new acoustic data analysis programs have also been implemented in Python. For each binary file of acoustic data, the waveform as a function of time, the Power Spectral Density and the spectrogram have been represented. Furthermore, a preliminary analysis of the submarine background noise was carried out.

3)

The work necessary for the implementation of an offline or online monitoring system for the reception of the acoustic signal emitted by the Beacons by the acoustic receivers (Piezos and hydrophones) was started. The most delicate part consists in filtering the acoustic data in order to recognize the signal from the noise. A Quality Factor is used as a parameter, which represents the maximum of the Cross Correlation function between the measured signal and the expected one (known and different for each beacon). It was necessary

to set a threshold on the Quality Factor, distinct for each receiver/emitter pair, based on a series of successive filters. For each RUN, all the thresholds will be calculated and used in the next RUN to establish the quality of the signal and separate noise and signal.

4)

Whalesafe is a project aimed at the acoustic revelation of the sperm whales in the Ligurian Sea, inside the Pelagos cetacean sanctuary.

The measurement system includes two buoys at a certain distance from the coast. The first buoy supports the equipment designed to transmit the signal to the ground. At the second buoy is attached a structure that supports four hydrophones placed in a tetrahedron and lowered to a depth of about 70 m. These receivers have to record the sounds emitted by the sperm whales that pass in the surrounding area.

The acoustic data for June and July 2018 was analysed. In particular two days, 12 and 13 July, were identified, in which numerous sources of sperm whales were revealed. An offline analysis program has been created that is able to calculate the 3D position and speed of the animal over time using the information of the arrival angle of the direct wave and the reflected wave. The effect of the sound velocity profile in water on the curvature of the sound beam (depending on pressure, temperature and salinity) has also been considered.

5)

Attended courses:

- Gravitational Waves (Master's degree course)
- Nuclear astrophysics and neutrinos (Zavatarelli – Corvisiero, Cavanna)
- Electronics and data acquisition (Fontanelli - Musico)
- ISAPP summer school 2019 – The Dark Side of the Universe, May 28 – June 4, 2019

Passed exams:

- Nuclear astrophysics and neutrinos (Zavatarelli – Corvisiero, Cavanna)
- Electronics and data acquisition (Fontanelli - Musico)
- ISAPP summer school 2019 – The Dark Side of the Universe, May 28 – June 4, 2019

The examination of gravitational waves will be taken by November 2019

Partecipation at local shift for ANTARES and KM3NeT in Toulon, France (16-23 May 2019)

Partecipation at conferences and workshops:

- Talk at KM3NeT Workshop on simulation and data analysis in Genova, Italy (January 2019)
- Talk at KM3NeT Collaboration meeting in Nantes, France (10-14 June 2019)
- Participation at KM3NeT Workshop on KM3NeT Positioning System in Catania, Italy (11-13 September 2019)
- Talk at MarSS 2019: The International Workshop on Marine Sensors and Systems in Granada, Spain (22-25 October 2019)

Proceedings:

- “Simulation of the performance of the acoustic positioning system of the underwater KM3NeT neutrino telescope” for MarSS 2019: The International Workshop on Marine Sensors and Systems in Granada, Spain