Detection of atmospheric neutrinos with the first detection units of KM3NeT-ARCA

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KM3NeT [1] is a research infrastructure that will host a net of underwater neutrino detectors which are currently being constructed in the Mediterranean Sea. KM3NeT will consist of two different detector configurations: ARCA and ORCA. ORCA will exploit neutrinos (~GeV) generated in the Earth's atmosphere to study fundamental neutrino properties. ARCA will be used for the search of high energy neutrinos (>TeV) from distant astrophysical sources such as blazars, GRBs and colliding stars.
When completed, ARCA will consist of 2 building blocks of 115 Detection Units (DUs) covering an instrumented volume of ~1km^3. A DU hosts 18 Digital Optical Modules (DOMs), each housing 31 3'' PMTs providing a 4π coverage. Data from ~53 days with 2 operational DUs and ~207 days with one operational DU have been analyzed.

The aim of this analysis, which is an extension of [2], *is to detect atmospheric neutrinos from the first data demonstrating the capability of the ARCA detector.*

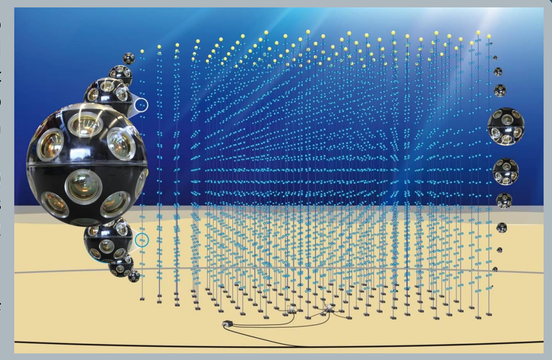


Figure 1. Artistic view of the KM3NeT building block.

The zenith angle distribution is shown in fig.2 for all reconstructed events (data - black). As expected, the contribution from atmospheric muons dominates the observed rate (atm.muon MC - blue). Atmospheric neutrinos (atm.neutrino MC - red) are isotropically distributed, while atmospheric muons are expected to have a downward going track direction.

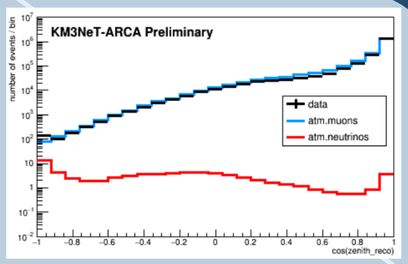


Figure 2. Distribution of the cosine of the zenith angle for all reconstructed events.

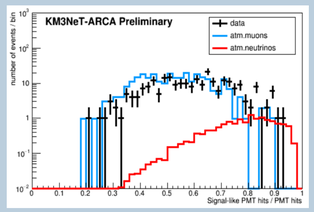


Figure 3. Ratio of the signal-like PMT hits over all PMT hits in an intermediate level of the analysis.

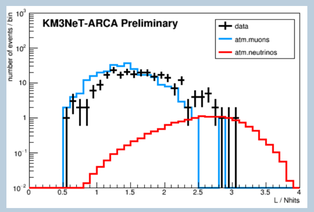


Figure 4. Distribution of the likelihood over the number of hits used for the muon track reconstruction in an intermediate level of the analysis.

In order to reject mis-reconstructed atmospheric muons, selection requirements were applied based on quality criteria. The distributions of two of the quantities used for event selection are shown for an intermediate step of the analysis. Events with more than 70% of signal-like hits (fig.3) and with L/Nhits ≥ 2.0 (fig.4) have been selected.

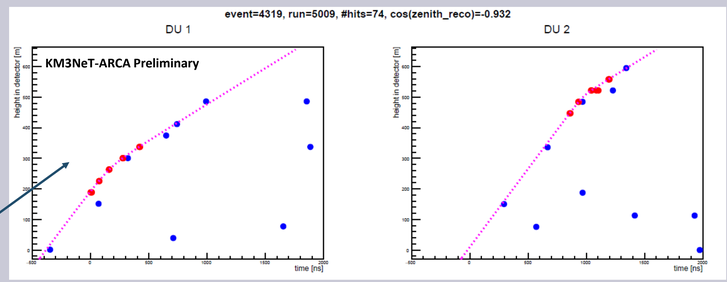


Figure 8. Height in the detector vs time of the recorded PMT hits for a selected event in ARCA DU1 & DU2 configuration.

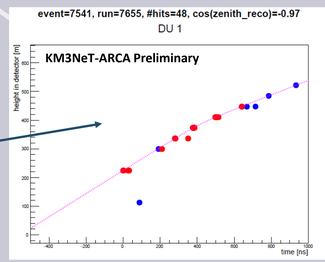


Figure 9. Height in the detector vs time of the recorded PMT hits for a selected event in ARCA DU1 configuration.

Upward going atmospheric neutrino candidates have been selected. Neutrino candidates recorded by ARCA DU1 & DU2 and ARCA DU1 configurations are shown in fig.8 and fig.9, respectively. All DOMs with hits are represented by blue circles while red circles represent the DOMs having triggered hits. The magenta line shows, for direct Cherenkov photons, the arrival time to the DOM as expected from the track reconstruction.

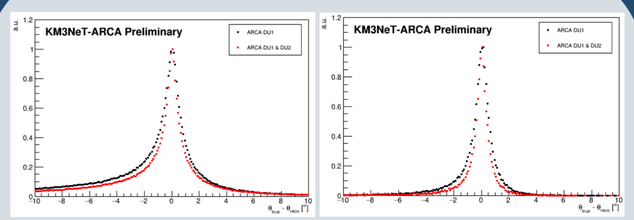


Figure 5. Zenith angle resolution for all reconstructed events (left) and for events surviving the selection criteria (right), separately for the two ARCA detector configurations studied.

The muon zenith angle resolution is shown separately for the two ARCA periods in fig.5 (left) for all reconstructed events and in fig.5 (right) for the events surviving the selection criteria. For the period with one DU (DU1 - black) and with two DUs (DU1 and DU2 - red) in operation, a zenith angle resolution of 1.4^o and 1.1^o is obtained respectively for all reconstructed events.
After the selection requirements applied, the corresponding muon zenith angle resolutions are 1^o and 0.7^o.

The distribution of the zenith angle is shown in fig.6 for events fulfilling the final selection criteria.
15 neutrino candidates are found with reconstructed cos(zen) < 0 in the data sample of ~260 days of effective livetime, while 8.1 events are expected from the atmospheric neutrino simulations and 1 event is expected from atmospheric muon background.
The energy spectrum for upward going simulated neutrino events satisfying the final selection criteria is shown in fig.7 where a detection energy threshold of ~200 GeV is observed.

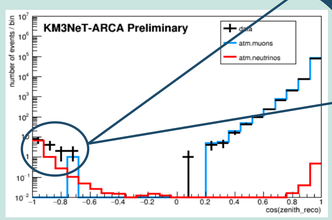


Figure 6. Distribution of the cosine of the zenith angle for events surviving the neutrino selection criteria.

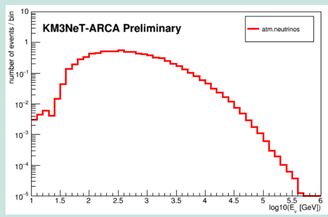
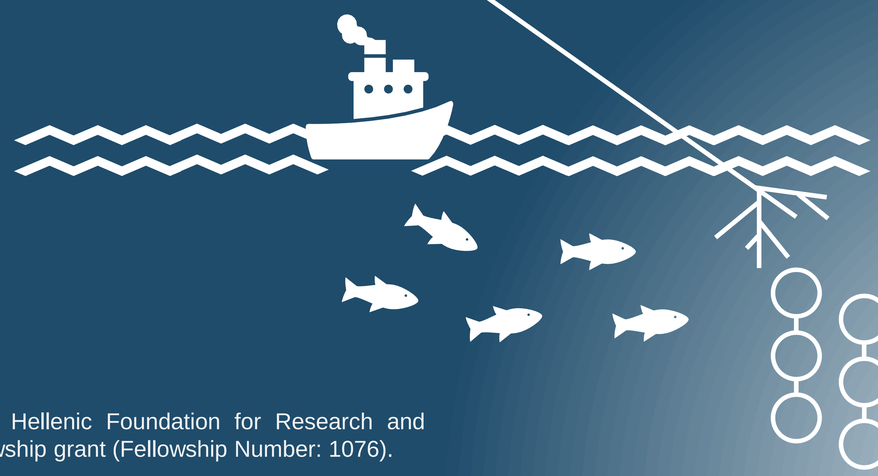


Figure 7. Distribution of the true (MC) neutrino energy for events with cos(zen) < 0 expected to fulfill the selection criteria.



References :

[1] S. Adrián-Martínez et al. (KM3NeT Coll.), Letter of intent for KM3NeT 2.0, J. Phys. G: Nucl. Part. Phys 43 (2016) 084001.
[2] Rosa Coniglione, Jannik Hofestädt, Anna Sinopoulou, Ekaterini Tzamariudaki, Dmitry Zaborov , on behalf of the KM3NeT Collbaoration, "Atmospheric Neutrinos Detected with the First KM3NeT Detection Units of ARCA and ORCA", 36th International Cosmic Ray Conference -ICRC2019.

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