Results from the first ARCA and ORCA detector units

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on behalf of the KM3NeT Collaboration

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Abstract: *KM3NeT will be the largest underwater neutrino telescope employing the Cherenkov detection technique in the deep Mediterranean Sea. The infrastructure will consist of three detector building blocks: large 3D arrays of optical sensor modules arranged on vertical detection units anchored on the seabed. Two building blocks for KM3NeT/ARCA are optimised for the detection of TeV-PeV neutrinos in order to discover cosmic neutrino point sources, and one building block for KM3NeT/ORCA is optimised for the detection of few-GeV atmospheric neutrinos in order to determine the neutrino mass hierarchy. The construction of the ARCA and ORCA detectors has started. Results from the first two ARCA detection units and the first ORCA detection unit are shown.*

KM3NeT is a neutrino research infrastructure under construction in the Mediterranean Sea. It aims to measure both high-energy neutrinos ("KM3NeT/ARCA") to identify cosmic high-energy neutrino sources, and low-energy atmospheric neutrinos ("KM3NeT/ORCA") to determine fundamental neutrino parameters, most importantly the neutrino mass ordering. The acronyms stand for "Astroparticle/Oscillation Research with Cosmics in the Abyss". Both detectors consist of Digital Optical Modules (DOMs): pressure-resistant glass spheres each housing 31 3-inch photomultiplier tubes (PMTs) to detect Cherenkov light emerging from the neutrino interaction.

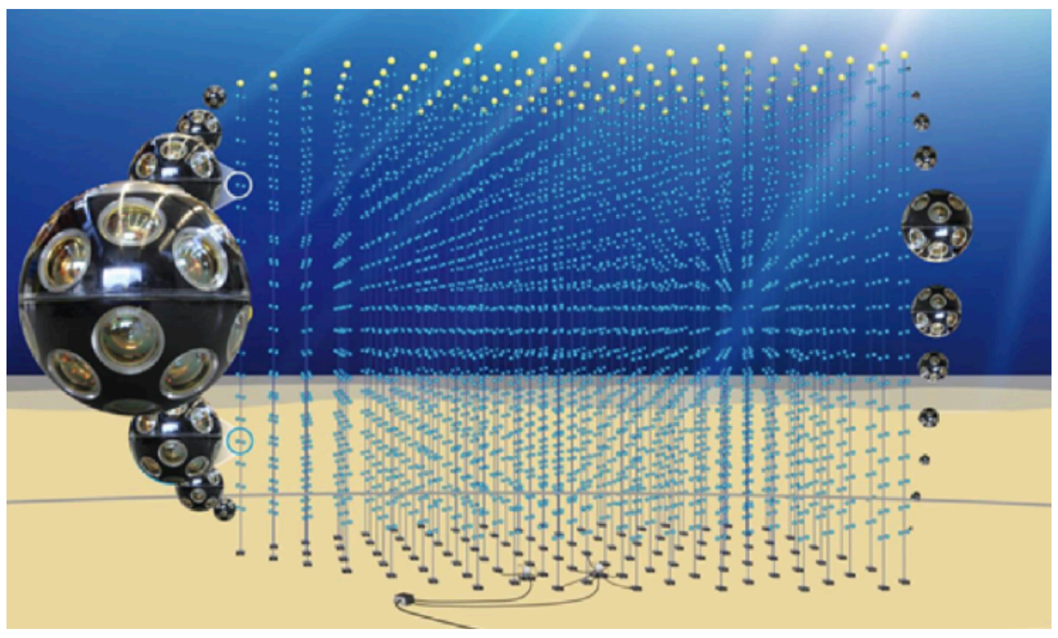

Fig. 1: A sketch of the KM3NeT detector

The DOMs are mounted on vertical lines called Detection Units (DUs) or "strings" in groups of 18. The vertical spacing between DOMs is 36 m for the ARCA layout, while 9 m for the ORCA layout to optimise for low-energy neutrino interactions. The first two fully functional ARCA DUs were deployed in December 2015 (ARCA-DU1) and May 2016 (ARCA-DU2) at the Italian KM3NeT site at Capo Passero, Sicily. Both DUs took data continuously till April 2017. The first DU of the ORCA detector was deployed at the France KM3NeT site in the Bay of Toulon, in September 2017 and operated till December 2017.

ARCA

The multi-PMT DOM allows the selection of atmospheric muons over the optical background by looking for local coincidences between PMTs. In Fig. 2 the rates of local coincidences in a time window of 25 ns are shown for the lowest and the highest DOM of the ARCA-DUs. MonteCarlo (MC) simulations of atmospheric muons and contributions

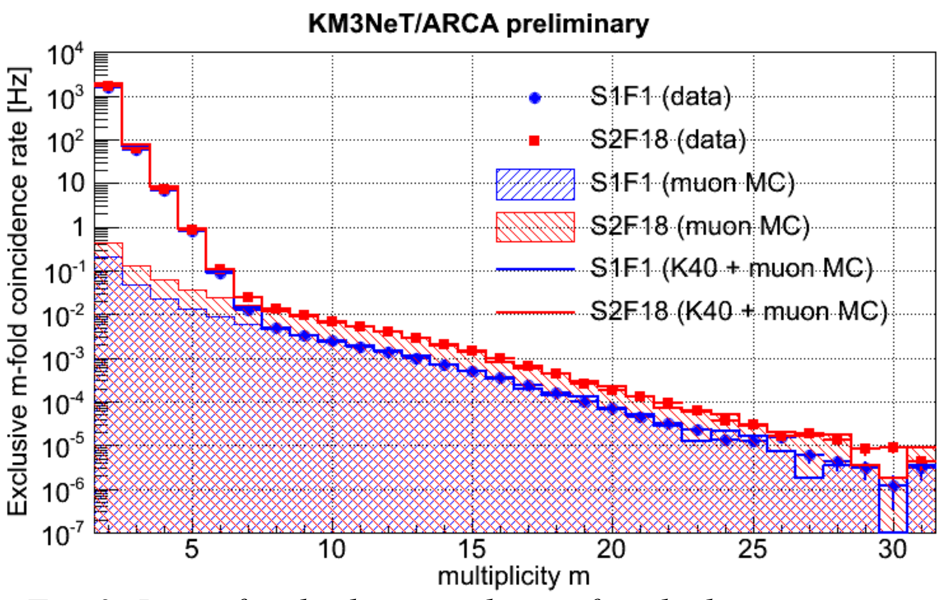

Fig. 2: Rate of multiple coincidences fort the lowermost DOM (DOM1) of ARCA-DU1 and for the uppermost DOM (DOM18) of ARCA-DU2.

from optical background produced by ^{40}K decays in the sea water are also reported.

The expected depth dependence of the high-multiplicity coincidence rates due to the decrease of the atmospheric muon flux along the first two KM3NeT/ARCA DUs has been measured. This result shows that the ≥8-fold coincidence rates decrease by roughly a factor 2 along the approximately 630 m depth difference between the top and bottom DOMs. The data-MC comparison is shown in Fig. 3. The red dashed line shows the base expectation from an ideal MC with uniform PMT efficiencies which neglects the differences between individual PMTs as determined from in-situ calibration. The black points show the uncorrected data. The blue points show the data corrected for the effect of the PMT efficiencies. Statistical errors bars are included but are too small to be visible over the markers.

The data-MC comparison displays that the MC simulation is able to reproduce the characteristics of the selected data, indicating that the detector is well calibrated and the systematics are kept under control.

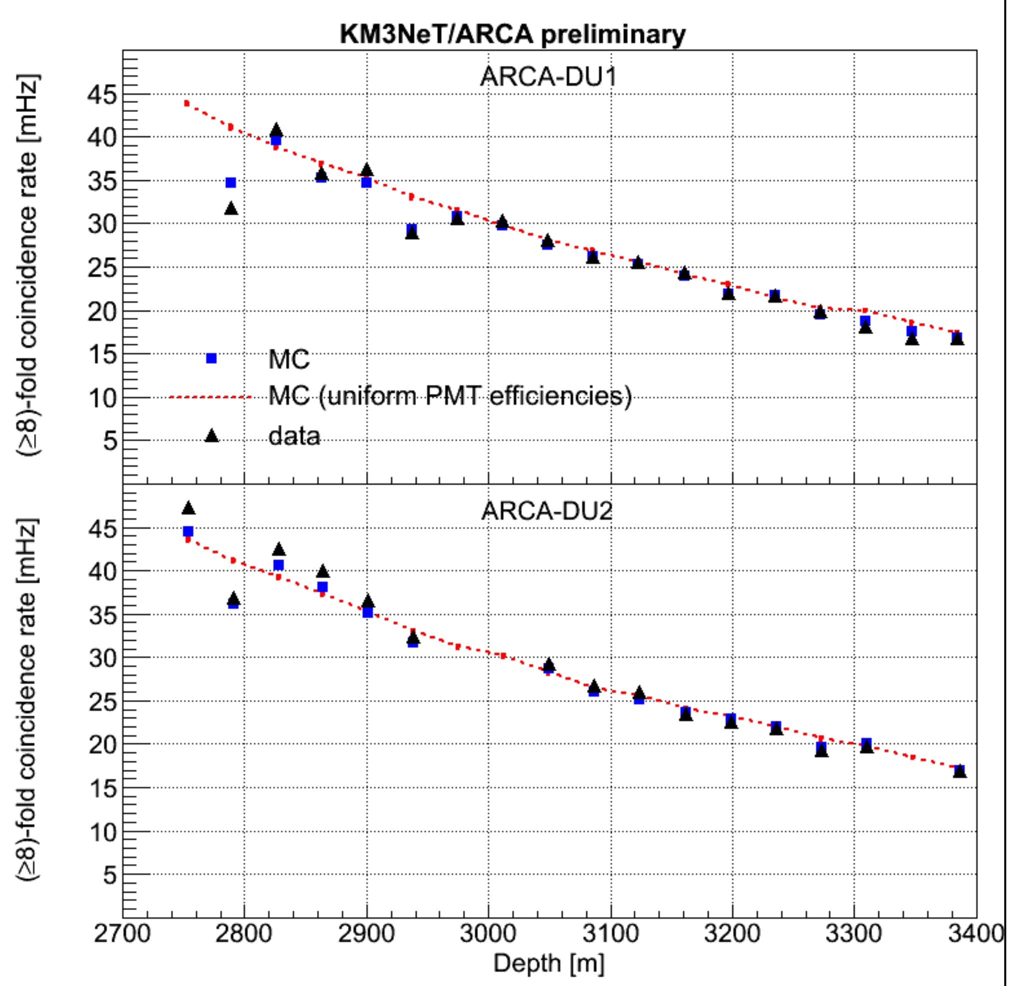

Fig. 3: Rate of ≥ 8 PMT coincidences in the DOMs as function of depth for ARCA-DU1 and ARCA-DU2.

ORCA

The dense instrumentation of the ORCA detector allows for the detection of atmospheric neutrinos with a threshold of $E_\nu \sim 5$ - 10 GeV. Using the default track reconstuction, dedicated analysis cuts are devised to guarantee a selection of a clean neutrino candidate sample. With the available livetime of 82 days, 13 upgoing neutrino candidate events are observed, agreeing well with MC prediction of 8.3 ± 2.9 (stat.) atmospheric neutrinos plus 1 ± 1 (stat.) atmospheric muon events. The reconstructed zenith angle distribution is shown in Fig. 4. The observed distribution is in good agreement with MC predictions.

- → Already 82 days of data of a single ORCA DU allows to select a neutrino candidate sample.
- → This verifies the KM3NeT technology and illustrates the capacity of the future ORCA detector.

An advantage of operating a large volume in deep-sea water is the favourable optical properties of seawater. Due to the large scattering length, most photons arrive

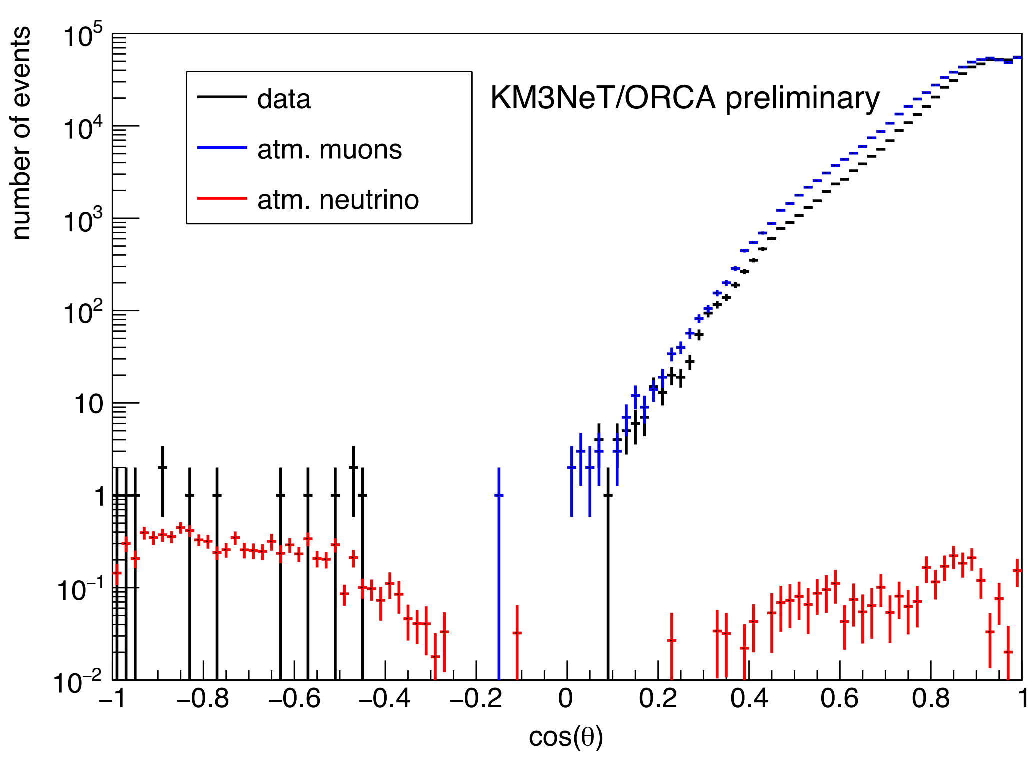

Fig. 4: Distribution of reconstucted zenith angle θ for data (back), atmospheric neutrino MC (red) and atmospheric muon MC (blue).

at the PMTs without scattering and therefore 'on time'. The time residual distribution is shown in Fig. 5. Also the tail of 'late' hits from scattered photons is well described by the MC predictions.

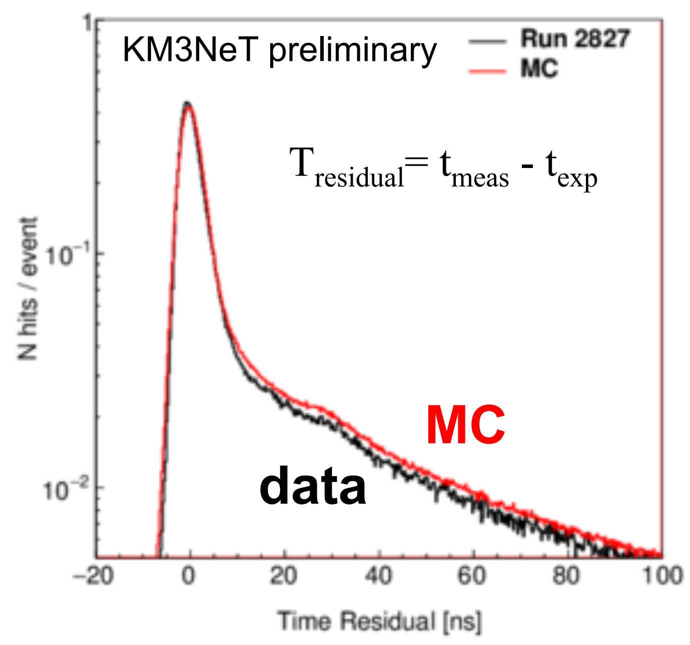

Fig. 5: Distribution of time residual between measured and expected hit time for data (black) and atmospheric muon MC (red).

[1] S. Adrián-Martínez et al. (KM3NeT collaboration), Journal of Physics G: Nuclear and Particle Physics, 43 (8), 084001, 2016
[2] S. Adrián-Martínez et al. (KM3NeT Collaboration), The prototype detection unit of the KM3NeT detector, Eur. Phys. J. C (2016) 76: 54
[3] M. Jongen (for the KM3NeT Coll.), PoS(ICRC2017)1018.