# Update on KM3NeT Detector Construction and Commissioning

Daan van Eijk
for the KM3NeT Collaboration

## KM3NeT Detector and Physics Goals

*The KM3NeT Digital Optical Module*

The KM3NeTneutrino detector [1] is currently under construction at two separate geographical locations in the deep waters of the Mediterranean Sea.

The so-called ORCA (Oscillation Research with Cosmics in the Abyss) detector is located 40 km off the French coast. This densely instrumented detector has a volume of roughly 0.01 $km^3$ and is dedicated to neutrino oscillation studies by detecting low-energy (GeV) atmospheric neutrinos from all directions.

The second detector site is situated 100 km off the Sicilian coast. This detector is called ARCA (Astrophysics Research with Cosmics in the Abyss) and will cover a larger, though more sparsely instrumented volume of roughly 1 $km^3$, optimized for the detection of high-energy (TeV and higher) astrophysical neutrinos.

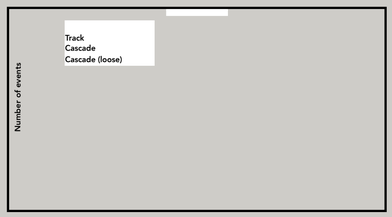
Both ORCA and ARCA use the same neutrino detection technology. Cherenkov light emitted as a result of neutrino interactions is detected by so-called Digital Optical Modules (DOM) that contain 31 three-inch PMTs [2] each. This novel multi-PMT design allows for a more isotropic view, larger photocathode area per module and better background suppression.

Both ORCA and ARCA detection units (DU) contain 18 DOMs each, arranged on vertical strings that are anchored to the sea bottom and held upright by the buoyancy of the DOMs and an additional buoy on top. ORCA (ARCA) DUs are roughly 200 (700) m long and DUs are spaced roughly 20 (90) m apart.

## ORCA Construction and Commissioning

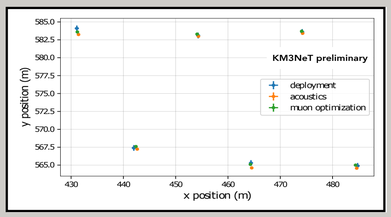
Currently, six ORCA DUs are installed at the sea bottom, taking data continuously since January 2020.

The **position** of the DU anchors is first determined during deployment. During data-taking, the position of all DOMs and anchors is measured continuously using acoustic beacons, placed on the sea bottom and a selection of anchors, as source and hydrophones, mounted on all anchors and in all DOMs, as receivers. As a cross-check, in quiet sea conditions, these positioning results can be compared to average (x,y)- coordinates of DOMs from a muon track residual analysis.

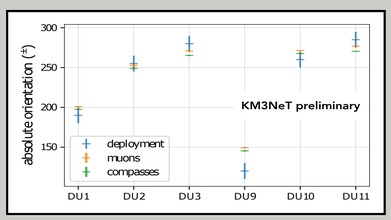



*Left: accumulated event rates as a function of time for various event classes in the ORCA detector with 6 installed DUs*

*Right: (x,y)-coordinates for the six deployed ORCA DUs, measured or calculated using three independent methods*




The **orientation** of the DU anchors is first determined during deployment by comparing ROV footage to the ROV internal compass. During data-taking, the orientation of both the anchor and all DOMs is measured continuously using compasses mounted on the central logic boards (CLB) in all DOMs and DU bases. Again, as a cross-check, in quiet sea conditions, these orientation results can be compared to average DOM orientations from a muon track residual analysis.

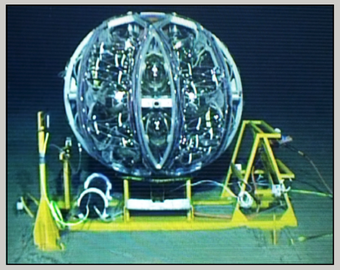



*Azimuthal orientation for the six deployed ORCA DUs, measured or calculated using three independent methods. The DU number (1, 2, 3, 9, 10, 11) indicates its position in the seafloor network*

Inter-PMT, inter-DOM and inter-DU **timing** is calibrated using $^{40}K$ [4] or muon coincidences and by flashing LEDs that are mounted in every DOM during dedicated calibration runs.

## Deployment Technology

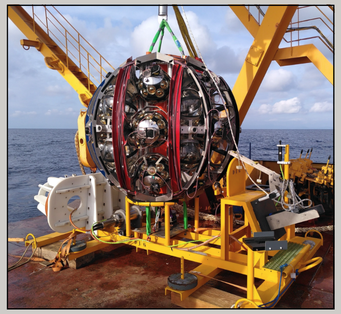
In preparation of deployments, KM3NeT DUs are wound on 2.2 m diameter spherical aluminum structures called Launchers of Optical Modules (LOM). A loaded LOM is then mounted on the anchor frame and the entire stack is lowered to the sea bottom from a ship using a heavy winch cable. Using acoustic positioning, the anchors can be horizontally positioned with a precision better than 1 m.



*An ORCA DU ready for unfurling on the sea bottom as seen from the ROV*

A remotely operated underwater vehicle (ROV) connects the DU to the electro-optical network on the sea bottom. After a DU functional test and release of the lift cable, the ROV triggers the release of the buoyant LOM to start its ascent to the sea surface, unfurling the DU in the process.

While the ROV visually inspects the unfurled DU and its DOMs, the LOM resurfaces and is recovered for use in next deployments.



*An ORCA DU loaded on a LOM waiting for deployment. Note the three visible DOMs on the front side of the LOM*

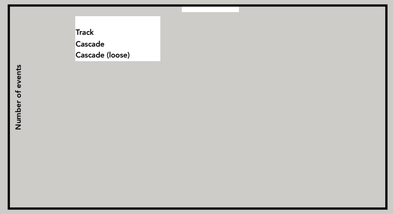
*Watch a LOM unfurl on YouTube: www.youtube.com/watch?v=tAA3Hat6XfY*

## ARCA Construction: Status and Outlook

Currently, two ARCA DUs are installed at the sea bottom. One has experienced a power failure and will be recovered during the next sea operation.

The other one has been recording data for several consecutive months but is currently not operational. Data-taking will restart in fall 2020 when an upgrade of the shore station is completed.

Pending a design upgrade of the junction boxes to be installed in the ARCA seafloor network, DU production is proceeding, aiming for a deployment of 5 additional ARCA DUs in early 2021 and 18 more by the end of 2021.




*Accumulated event rates as a function of time for various event classes in the ARCA detector with 1 operating DU*

## Summary

The KM3NeT neutrino detector is under construction in the Mediterranean Sea. Currently, 6 ORCA detection units are installed and taking data continuously since January 2020. 1 ARCA detection unit is installed and waiting to resume data-taking.

By the end of 2020, 3 additional ORCA DUs and 5 additional ARCA DUs are expected to be ready for deployment.

The full ORCA and ARCA detectors are expected to be completed by 2025 (115 DUs) and 2026 (230 DUs), respectively.

## References

[1] S. Adrián-Martínez et al., *J. Phys. G: Nucl. Part. Phys. 43* (2016) **084001**
[2] S. Aiello, et al., *JINST13* (2018) **P05035**
[3] M. Ageron et al., *Eur. Phys. J. C 80* (2020) **99**
[4] S. Biagi et al, poster #306, this conference