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The KM3NeT Broadcast optical system network

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The optical data transport system of the KM3NeT neutrino telescope at the bottom of the Mediterranean Sea will provide more than 6000 optical modules in the detector arrays with a point-to point optical connection to the control stations onshore. This research infrastructure will house two detectors: ORCA and ARCA.

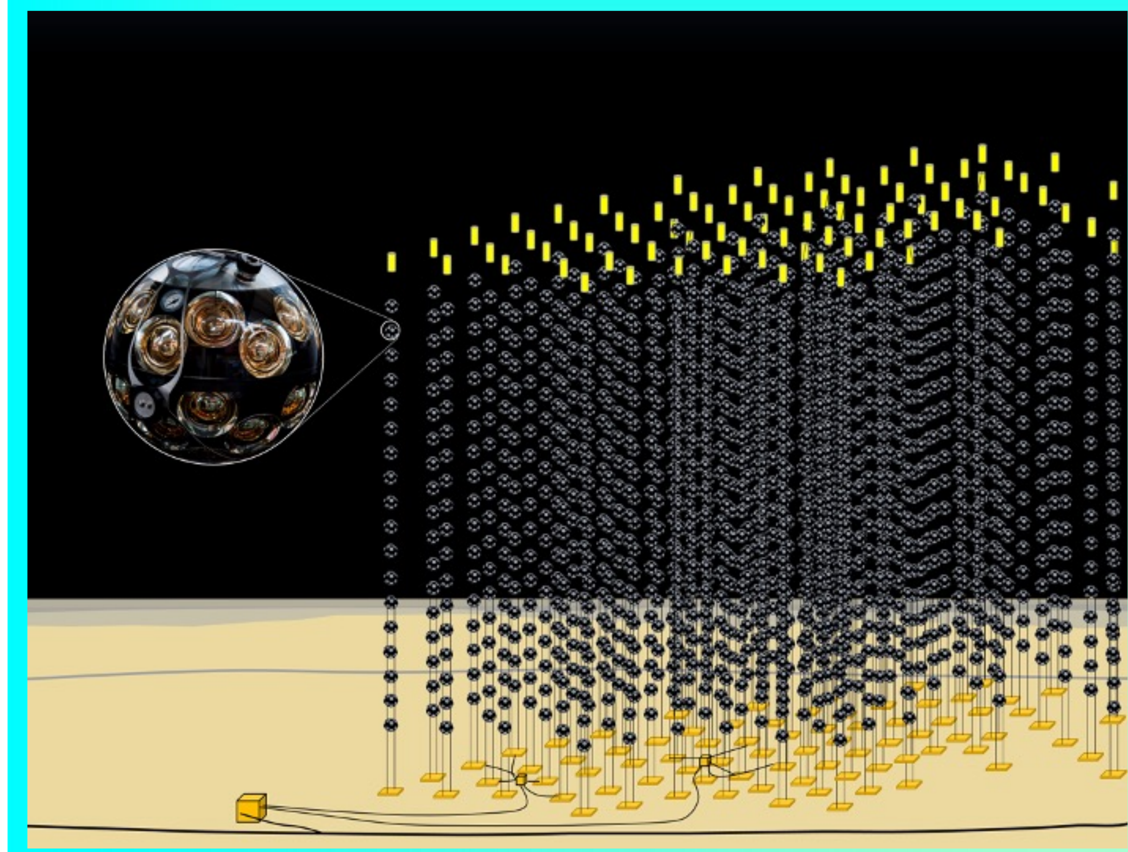

Fig. 1 — A sketch of the KM3NeT detector.

Both detectors have as scientific goal neutrino astronomy, in particular ORCA is mainly focused for the detection of atmospheric neutrinos with energies ranging from 1GeV-1 TeV and ARCA for the detection of cosmic neutrinos with energies above 1 TeV.
The telescope is densly instrumented by hundreds of Detection Units – vertical structures that support 18 optical modules linked by an electro-optical backbone.
Because the expected data rate is maximum 200 Mbps per optical module, the data transmission system of KM3NeT has to rely on an optical fibre physical layer. All data are transported through deep sea fibre optic cables using the Dense Wavelength Division Multiplexign technology for a more efficient use of fibres present in the system. Details of the optical data transfer system are presented.

The network

In order to share the same fibre between the different signal coming from each optical module, a fixed grid of frequencies is assigned with an offset of 50 GHz. A multi-stage multiplexing scheme is adopted at different levels onshore and offshore. All information related to clock synchronization and detector control commands are broadcasted by the data acquisition system onshore to the detection units and the data coming from the optical modules are routed to shore with an asymmetric usage of the bandwidth.
In order to have a clock distribution, with a resolution of a nanosecond, a White Rabbit switch fabric is present onshore. The asymmetric broadcast design implyes a different configuration of White Rabbit switches with respect to the standard design.

KM3NeT/ARCA detector

The ARCA (Astroparticle Research with Cosmic in the Abyss) is installed at a depth of about 3500 m and the distance to the control station is about 100 kilometers offshore Portopalo di Capo Passero in Italy. The detection units of ARCA are connected in a deep sea network infrastructure with a star configuration (Fig. 2). Up to twelve detection units are connected to a hub, the junction box. Junction Boxes are then connected to the main electro-optical cable final termination frame and the main electro-optical cable to the control station, where the data are acquired. A different number of fibres are used in each section.
When completed, the detector will consist of two blocks of 115 detection units about 700 m high.
The ARCA star topology foreseen the detection units connected to the junction boxes by means of two optical fibres. The system is composed of three types of signals:

- A channel for the slow control data (downstram);
- A base module control channel (upstream):
- Three channels for the junction box control and command (downstream and upstream);
- A channel for each optical module data (upstream).

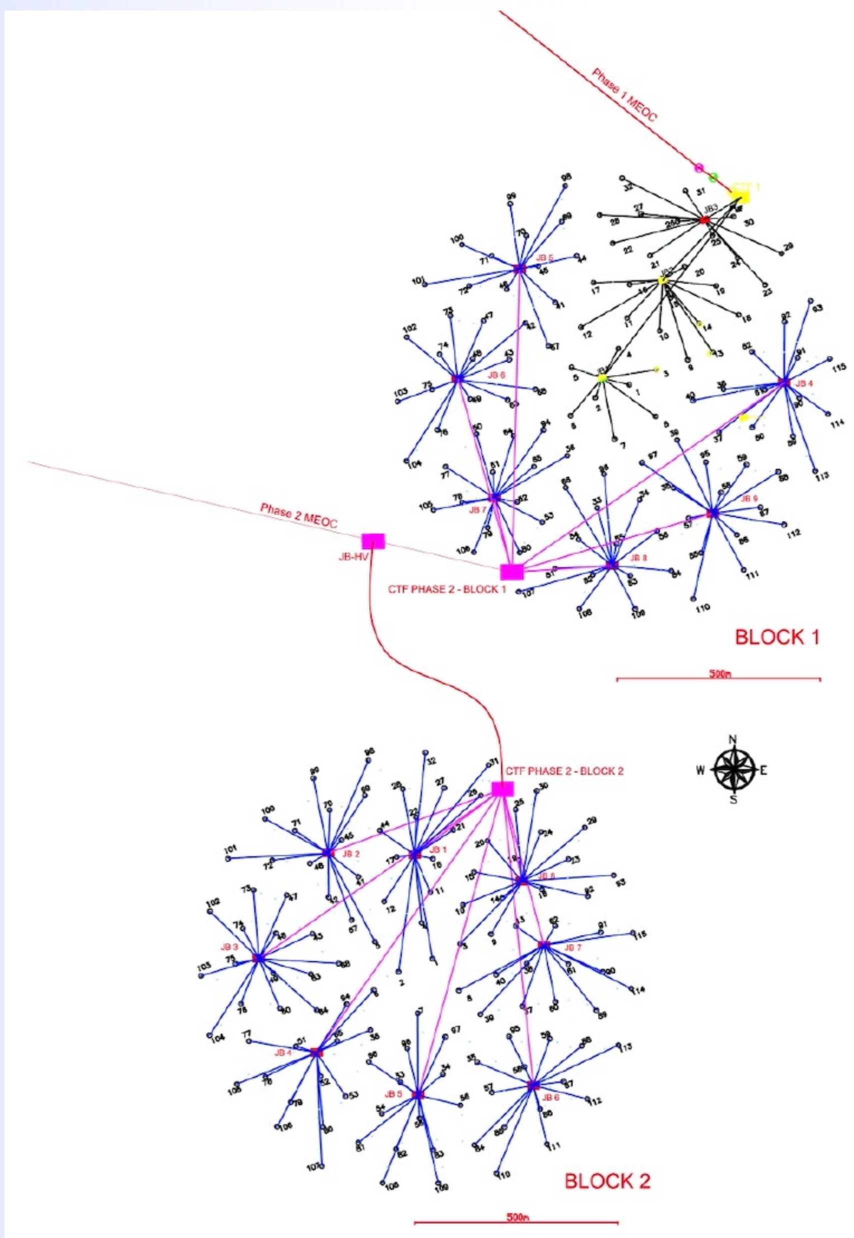

Fig. 2 — Layout of ARCA network

The slow control channel, the base module channel and the junction box channels travel together bidirectionally sharing the same fibre in the main electro-optical cable and go through two stages of amplification, one inside the junction box and the other in the control station. After the amplification, the junction box control signals are routed to the Monitor and Control Unit and the base module channels to the White Rabbit fabric for the data synchronization.
The data signals are preamplified only in the control station, separated using a 72 channel demultiplexer and then managed by the avalanche photodiode SFPs hosted in the front end switches.
At the junction box level the control channels and the optical amplification are redundant in order to be compliant with the reliability studies carried out by the collaboration to maintain the 20 years life span. In particular, the optical amplifier can be switched by means of an optcal switchover logic board (Fig. 3).

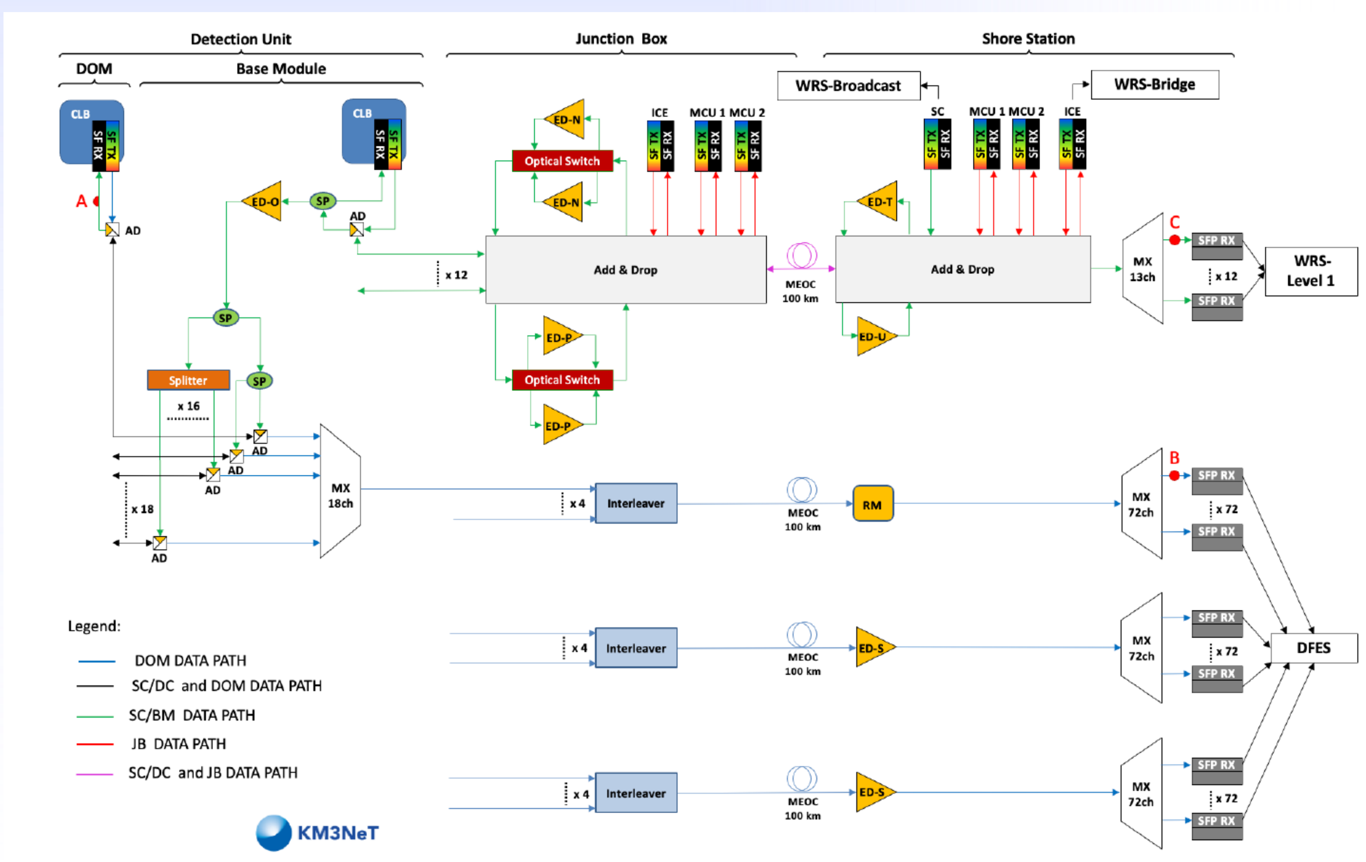

Fig. 3 — The ARCA optical system

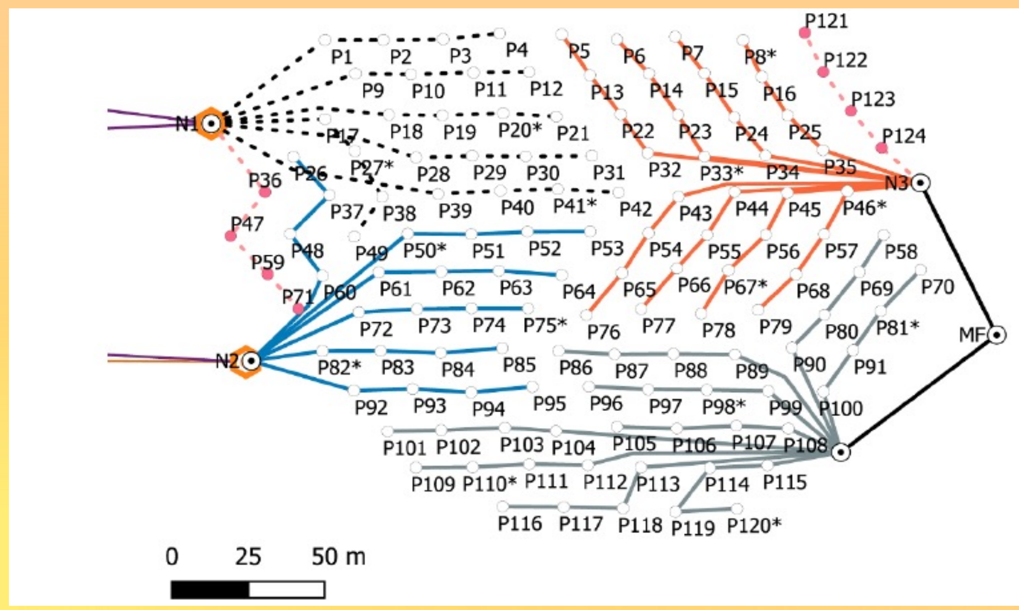

Fig. 4 — Layout of ORCA network

KM3NeT/ORCA detector

The ORCA (Oscillation Research with Cosmic in the Abyss) is installed at a depth of about 2500 m, 40 kilometers offshore the Toulon coast in France. The network design has a daisy chain configuration connecting groups of four detection units to each other, each daisy chain is then connected to a hub, the node (Fig. 4). The nodes are linked to the control station on shore through the main electro-optical cable. A different number of fibres are used in each section. ORCA will comprise one block of 115 detection units about 200 m high.
Due to the daisy chain configuration, ORCA foresees different stage of signal splitting ratios between the data coming from the base modules in order to equalise the optical power levels (Fig. 5) between them.
In particular, the system foreseen three type of signals:

- A channel for the slow control data (downstream);
- A channel for the base module control data (downstream and upstream);
- A channel for each optical module data (upstream).

At the node a splitter is used to combine 24 base module data channels which are boosted to the control station before being routed to the main electro-optical cable. At the control station onshore, a 26 channel demultiplexer divides the signal coming from the base modules and then will be routed to the White Rabbit fabric for the data synchronization.
The data coming from the optical modules are preamplified at the control station, demultiplexed and managed by the avalanche photodiode SFP hosted in the front end switches.
The node control and command signals do not share the same fibre of the slow control and base module channels.

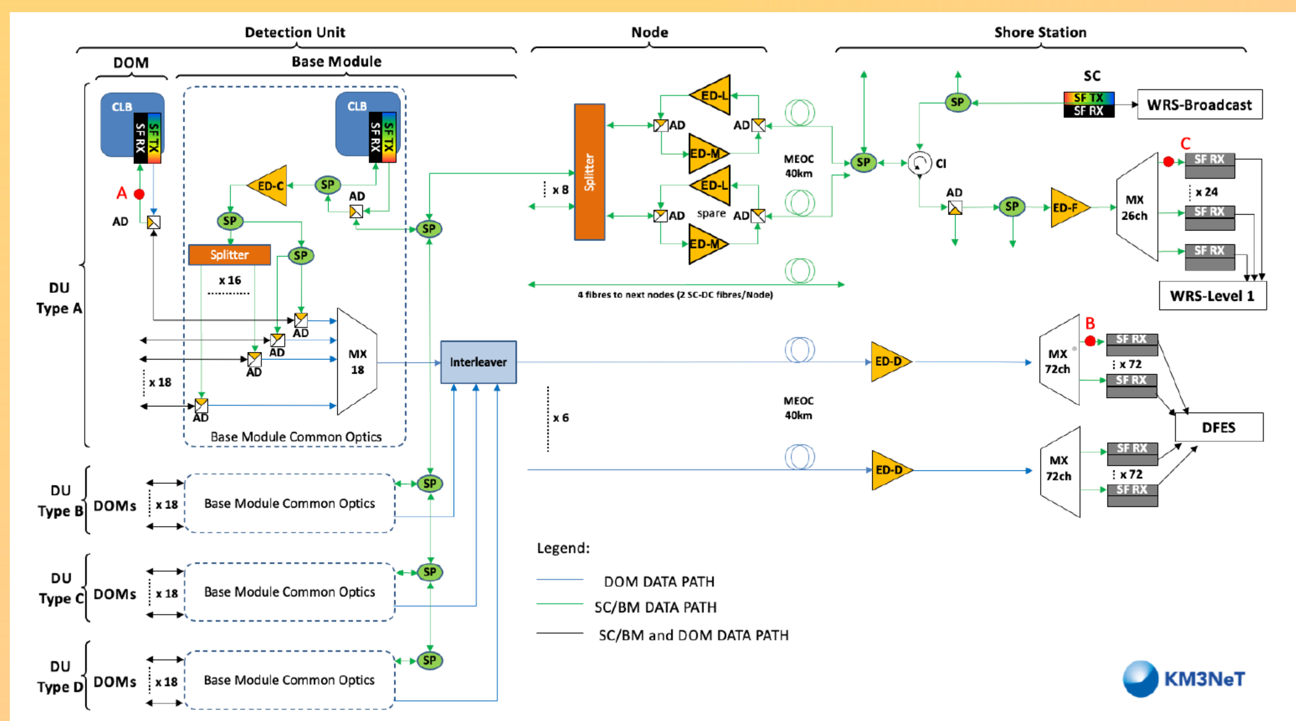

Fig. 5 — The ORCA optical system

[1] S. Aiello et al 2023 KM3NET broadcast optical data transport system, JINST **18** T02001.