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Deep-sea data transfer at the KM3NeT neutrino telescope

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KM3NeT is a future cubic kilometre-scale neutrino telescope for the deep Mediterranean. Several hundred vertical detection lines, each containing up to 100 optical modules with photomultipliers will be anchored to a sea floor power and data transport network. Data acquisition will minimize offshore electronics, reducing difficult and expensive maintenance operations. No off-shore triggering or filtering combining signals from multiple optical modules is foreseen; all signals passing internal criteria (e.g. charge threshold) will be uploaded via a fibreoptic telecommunications cable at an overall data rate of˜ 100Gb/s. Various options for front-end digitization and data transport, including colour multiplexing, are discussed

Summary

Summary: for presentation in the Optoelectronics and Links session

The KM3NeT data acquisition and transit system will collect analogue signals from photomultipliers (PMTs) contained in optical modules (OMs - based on pressure resistant glass spheres) arranged on several hundred tethered detection lines rising hundreds of metres from the seabed (2500 - 4000m depth) and tensioned by submerged buoys. The PMTs are sensitive not only to Cherenkov light from muon tracks generated in neutrino interactions, but also to high levels of optical background from bioluminescence and decays of radioactive potassium 40 present in sea salt.

While local coincidence triggering between nearby photomultipliers could be used to reduce these backgrounds, the central strategic approach is to maximize reliability in the difficult-to-maintain deep-sea hardware by keeping the electronics to a minimum. No off-shore triggering or filtering combining signals from multiple OMs is foreseen; all signals passing certain OM-internal criteria (e.g. charge threshold) will be uploaded to shore. An total effective photocathode area of around 50m2 will generate an overall data rate (signal + background) of˜ 100Gb/s, based on 8 bytes (including timestamp) per recorded photon. This data rate to shore can be accommodated on a small number of optical fibres within a single, standard fibreoptic deep-sea telecommunications cable using either coarse or dense wavelength division multiplexing (CWDM or DWDM) transfer protocols.

The long distance from the deep-sea site to shore (30-100 km) forces the use of single-mode optical fibres. The conversion of the electrical signals to optical signals can be implemented at different locations along the detection lines, or at other points in the local seabed network. One possible solution is to convert the electrical signals close to the PMTs, making each OM an end-node in the fibreoptic network. In this scheme, wavelength multiplexing would be used to limit the number of descending fibres in each detection line: an all optical star network would be constructed based on passive optical multiplexers. An alternative solution could be based on a network in which the star consists of an active switch array with connections to the OMs or groups of OMs implemented as a copper links running part-way or all the way down the detection line to the sea bed.

The copper-to-fibre transition point is determined not only from considerations of length/bandwidth capabilities for the two media but also from the relative reliability of the deep-sea mateable connectors that are required for remotely-operated submarine interconnection of the bases of the detection lines to the junction boxes that will relay data onto the main site-to-shore fibreoptic telecommunications cable. Such deep-sea connectors have been developed for the oil industry and military applications and can be mated in seawater at ambient pressures of more than 400 bar. They exist in electrical, optical or hybrid (electro-optic) configurations. Experience from the ANTARES neutrino telescope has shown hybrid electro-optic deep-sea mateable connectors to have an unfavourable reliability/cost quotient among sea-bed infrastructure components. While the technology of deep-sea mateable connectors continues to evolve rapidly, their relative cost and reliability in electrical, optical or hybrid configurations may determine whether the copper-to-fibre backbone transition occurs near the OMs, at the bases of the detection lines or within the junction boxes attached to the site-to-shore cable.

The sea-bed data network which connects the detection lines to the site-to-shore cable should allow for a progressive enlargement of the apparatus through successive deployments of detection lines (implying the passive acceptance of extra added colours), while maintaining data path redundancy at all stages of the telescope evolution. It is probable the detection lines will connect to a series of satellite junction boxes in a radial (star) configuration, while these junction boxes will themselves be circumferentially interconnected in a ring allowing for redundant data flow and powering pathways. The use of standard deep sea telecommunications cable branching and junction box node technology is under investigation. Straightforward deployment from cable ships carrying standard cable repair and handling plant will also be a major cost motivator in the configuration of the sea floor layout of the future KM3NeT neutrino telescope.

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