LIAISING WITH THE STARS

Dutch universities and research institutes such as ASTRON, DIFFER, Nikhef and SRON are involved in large research infrastructures to perform experimental physics research. This inherently includes the construction of various high-tech equipment for CERN, ITER, ESO, ESA, etc., the so-called Big Science organisations, whose research requires large-scale facilities. The various domains of research each have their own approach to working with industry. However, with the size of these facilities increasing over the last decades, the involvement of industry has become indispensable and fundamental, especially in the engineering domain and for the production of parts in large numbers.

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In the Dutch ILO-net, industrial liaison officers (ILOs) work towards establishing links between Dutch industry and the Big Science organisations to find opportunities for companies from three angles. The first is working together in developing new equipment. The second is finding the right company that can bid competitively with tenders. And last, but not least, showcasing the technologies available for commercialisation from these organisations. To these ends, the individual ILOs work together to increase their common network, organise events, and visit companies and research facilities.

AUTHOR'S NOTE

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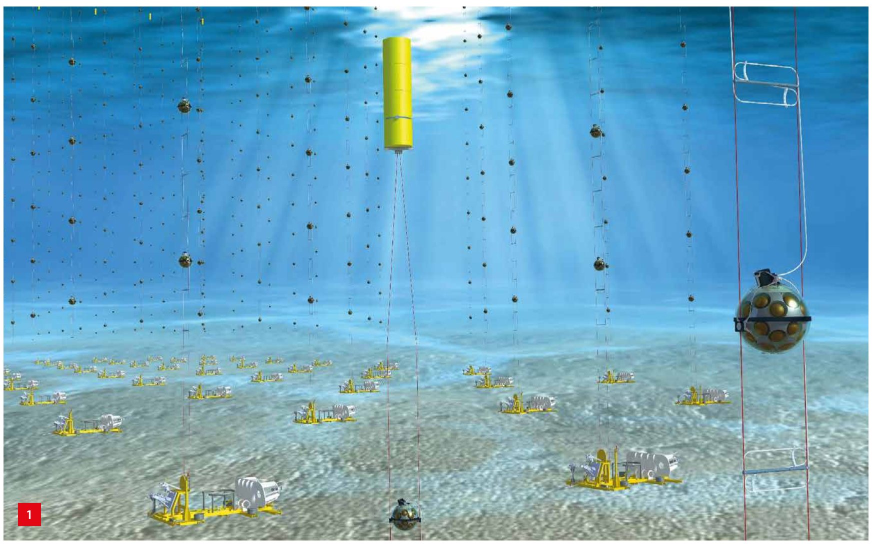
To give an impression of what has been accomplished, what is being done and which opportunities will be arising in the future, three projects in the astronomy domain are highlighted to demonstrate how the collaboration between industry and Big Science can be established. This involves:

- Km3NeT: the development, engineering and construction of the oil-filled cables for the neutrino telescope in the Mediterranean Sea, in collaboration with MCAP;
- ProtoDUNE: the construction of valve boxes for the neutrino experiment at CERN, by Demaco;
- ETpathfinder: the challenges that need to be tackled with industry in the coming years in this research facility, which is being built in Maastricht (NL) to develop the technologies required for the underground Einstein Telescope to study gravitational waves.



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Artist's impression of the KM3NeT telescope at the bottom of the seafloor, comprising several thousands of spheres, equipped with photomultiplier tubes.

KM3NeT

Despite the fact that neutrinos represent one of the most abundant forms of cosmic radiation, their detection is extremely difficult. This is due to the nature of these elementary particles: a neutrino has no charge and cannot interact with its surroundings through the electromagnetic force. Indeed, it is the mysterious aspect of these particles that makes them a desirable object of study and hence many physics experiments have been carried out to elucidate their properties. Moreover, as our Universe is filled with neutrinos, the study of cosmic neutrinos will contribute to our understanding of the Universe. A new experiment, KM3NeT, will allow us to observe high-energetic cosmic neutrinos from various astrophysical objects.

KM3NeT is a neutrino telescope presently under construction at the bottom of the Mediterranean Sea at a depth of 2.5 km (Figure 1). Using a large number of photomultiplier tubes, Cherenkov light will be observed emanating from the interactions triggered by cosmic neutrinos passing through the seawater. As the expected interaction rate is low, a neutrino telescope should be large to guarantee observation of a sufficiently large neutrino flux. This is the very reason why the experiment is being built in the depths and darkness of the Mediterranean Sea; here a large volume of seawater can act as a detection medium. The KM3NeT collaboration consists of a large number of (mostly European) universities and research institutes. The realisation of KM3NeT is now on a steady course. In dedicated sea campaigns the building blocks of the

KM3NeT experiment are being deployed in the deep sea. This is an extremely large and challenging endeavour. The deployment of the detection units is a complex process, but has proven to be a successful method to create a 3D grid of photosensitive sensors.

Building detection units (domes) that operate at a depth of 2.5 km and can communicate with a coastal station presents huge challenges. The two main challenges are the connections from the domes to the outside world and to have fibres operational under an enormous pressure of around 250 bar. The design of the connector to feed in electrical power and to extract the signals via an optical fibre required a lot of work and tests to get it right.

Nikhef engineers worked closely together with MCAP, a Dutch company specialised in cable and glass fibre assemblies. In this collaboration, an oil-filled cable was developed, providing KM3NeT with a solution that enables the fibre to correctly transmit the light back to shore. MCAP obtained new knowledge that it has put to good use in other products to expand its customer base.

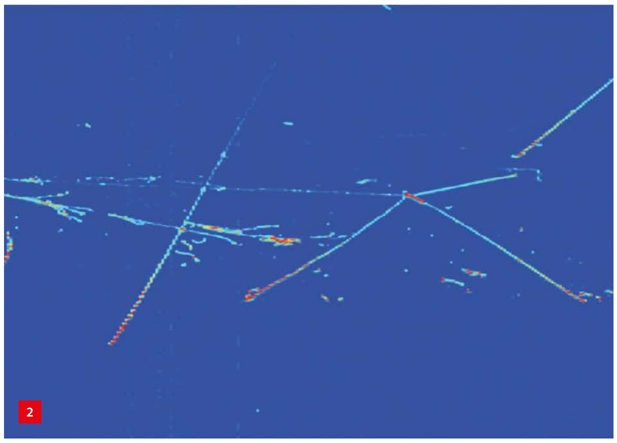
After the successful deployment of a limited number of strings with detection units, and hence a limited neutrino flux, sufficient neutrinos have now been detected to extract the first results on the quantum-mechanical properties of neutrinos, known as neutrino oscillations.

ProtoDUNE

ProtoDUNE is a precursor for the planned Deep Underground Neutrino Experiment (DUNE) and has already detected neutrinos in 2018. This international experiment is aimed at studying neutrinos to answer a number of fundamental physics questions about the nature of matter. One of the scientific goals is to study the explosions of supernovae and subsequent formation of neutron stars and black holes in real time by detecting the neutrinos fleeing from these explosions. A possible additional goal is to find an answer in the quest for the reason why the Universe is made of matter.

To this end, neutrinos are generated at Fermilab National Accelerator Laboratory in Batavia, Illinois, USA, and detected 1,300 km away at the Sanford Underground Research Laboratory in Lead, South Dakota, USA. Here, the difference in behaviour of neutrinos and antineutrinos is the key. Another topic to study is the possible proton decay that would shed light on the relation between the stability of matter and the envisioned Grand Unification Theory for the fundamental forces.

The ProtoDUNE experiment at CERN is a liquid argon Time Projection Chamber (Lar TPC) that has excellent neutrino detection capabilities providing 3D tracks of the interactions (Figure 2). Neutrinos are never detected directly, but via their interaction with argon. The system at CERN contains 770 tonnes of liquid argon in an active detection volume of 7.2 m x 6.1 m x 7.0 m.



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Particle tracks in the LAr TPC.

Two ProtoDUNE set-ups at CERN form a test facility for developing liquid argon detector technologies. The core of the logistics of the liquid argon was designed, produced and installed by Demaco and consists of 38 valve boxes (Figure 3) and 90 transfer lines. Demaco designed and built the valve boxes, which are an integral part of the Neutrino Platform Proximity Cryogenics project in which four cryogenics systems are linked to four cryostats.

The valve boxes are fundamental in turning over the liquid argon every five days through a set of filters to reduce the water and oxygen impurity concentration to at least no more than 100 ppt oxygen equivalent (ppt = parts per trillion (10^{12})). This is a requirement to reach the desired electron lifetime for the operation of the TPC; generally, less than 40 ppt is achieved.

3

Demaco's valve boxes.

The main challenge of the project was to minimise the effect of the temperature of the surroundings and deal with the various coefficients of expansion of the different materials, each at their own temperature, in the chain during the cooling-down process. Each of the 38 valve boxes has a specific functionality requiring the careful selection of equipment such as control valves, heaters, pressure and temperature sensors, flow transmitters, purification equipment (mole-sieve and active copper), safety valves and others.

In the process, Demaco gained experience concerning argon purification and series production; both very useful for future projects. As the DUNE collaboration consists of many international partners, getting to know them will lead to new projects.

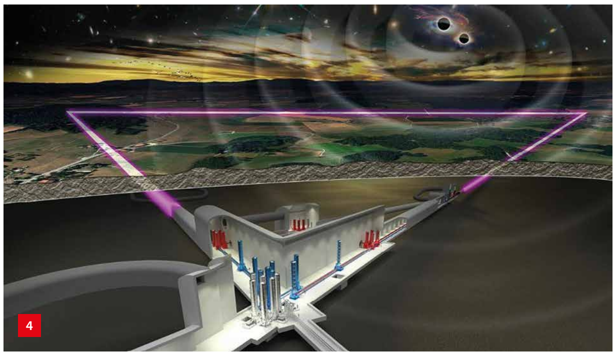
ETpatfinder

The Einstein Telescope is the proposed European next-generation gravitational-wave detector (Figure 4). In 2015, the existing gravitational-wave detectors reported the first detection. This demonstrated the power of laser interferometry in translating the miniscule vibrations in space-time into a measurable signal and then reducing the noise. This had been a decades-long endeavour of designing, creating, testing, improving and finetuning the hardware and data-analysis software. This first result in 2015 was awarded the Nobel Prize in Physics in 2017.

The current systems detect about one event per week. The aim is now to extend the physics knowledge that can be obtained from gravitational-wave detections by increasing the sensitivity for events by decreasing the noise and increasing the frequency range of the detector. From the existing infrastructures it has been learned how and where to improve.

The plan on how to improve requires ground-breaking innovations in mirror technology: composition, manufacturing and highly uniform coatings over large areas. The cooling system needs to be vibration-free, while laser requirements are narrow linewidth, high stability and high power at a wavelength of 2,090 nm. For the 120-km-long vacuum system, alternatives are being investigated for the standard stainless-steel pipes. Options are different kinds of steel with coatings. Most important for the facility is the low tolerance for residual water and hydrogen in the vacuum system.

Several of these intended developments can be tested in the ETpathfinder facility in Maastricht, in the Dutch province of Limburg. There, a vacuum system is being built in a cleanroom environment for testing prototypes, materials and procedures for their applicability in the full Einstein Telescope infrastructure. It is clear that all these innovations require close involvement from industrial partners. As this is easier said than done, the ETpathfinder organisation is reaching out to companies by regularly organising events, searching for those that have particular skills that can be useful in these developments, and inviting interested parties to get in touch.



Artist's impression of the Einstein Telescope in the landscape of Limburg (NL).

INFORMATION
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