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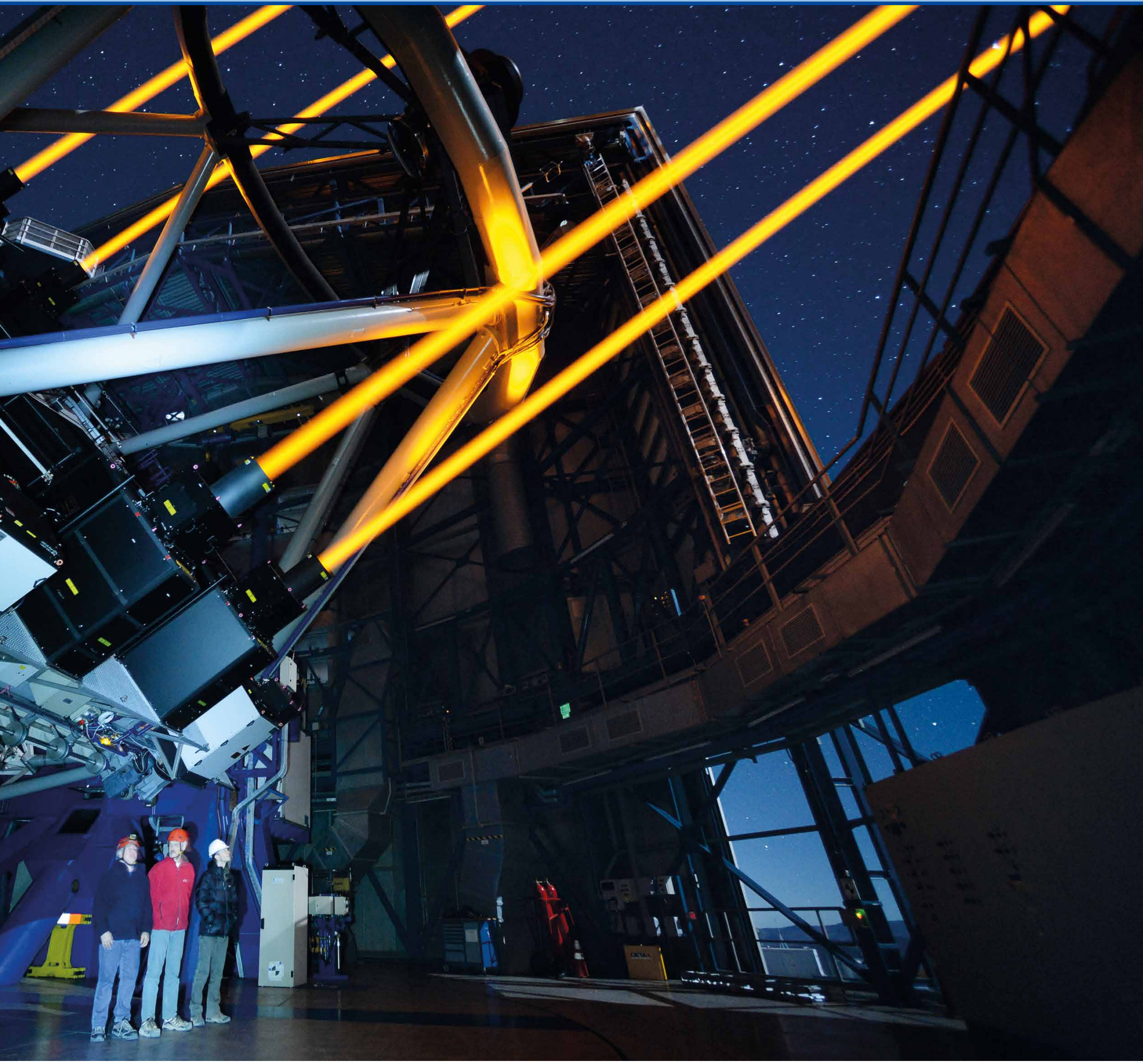

- THEME: ASTRONOMICAL SCIENCE INSTRUMENTATION
- INTERMEDIATE ROTARY STAGE FOR 200-MM WAFER SIZE COMPATIBILITY
- DSPE CONFERENCE ON PRECISION MECHATRONICS 2021 REPORT
- PRECISION FAIR 2021 PREVIEW

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DSPE
YOUR PRECISION PORTAL

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The main cover photo (the Very Large Telescope (VLT) with the laser guide stars in operation) is courtesy of ESO / Fred Kamphues. Read the article on page 5 ff.

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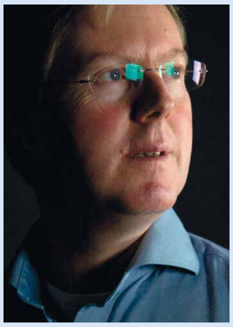
DUTCH INDUSTRY IN BIG SCIENCE


(Photo: Kimon Kodossis)

Dutch society is slowly emerging from the Covid-19 pandemic, which has had a major impact on our personal lives and the way we operate in business. Dutch industry has certainly had its problems, but fortunately many companies are as busy as ever, for example in the Big Science arena... and have been over the last couple of years.

VDL has won the contract to build the support structures for the European Extremely Large Telescope (ELT), the largest optical telescope on Earth when finished. This is a return on investment for the early involvement and joint development with TNO and NOVA. The situation at CERN has resulted in the Netherlands gaining a well-balanced status for supplies due to Boessenkool and Demaco winning large contracts and many other companies winning smaller contracts. Dutch companies are also well placed to secure the Dutch share of the Square Kilometre Array construction contracts. The first contract was signed recently, and the remaining contracts will follow in the next 12 months.

Many of the companies involved in Big Science see the benefit of supplying to Big Science in the way it triggers product innovation, convinces other parties of their capabilities or keeps their best employees interested and on board.

The Einstein Telescope (ET) Pathfinder facility in Maastricht (NL) will provide opportunities for industry in the coming decade. This facility is being built to push many technologies beyond the state-of-the-art. These innovations require the involvement of the high-tech industry. The Interreg-ET2SMEs project aims to find and partially fund companies that can collaborate in these efforts. The ultimate goal is to build the Einstein Telescope and explore the universe beyond our current horizon both in time and space.

The Low Frequency Array (LOFAR) radio telescope community, with its core in the north of the Netherlands, is still growing and work is being done to upgrade the LOFAR sensor network for even better performance. At the High Field Magnet Laboratory (HFML) in Nijmegen, the facilities are being continuously expanded and improved leading to new projects and tenders. In southern France, the construction of the International Thermonuclear Experimental Reactor (ITER) has continued in spite of Covid-19, although some delays have occurred.

To support Dutch industry in its efforts to be successful in the Big Science domain, the Dutch ILO-net focuses on finding matches between the key enabling technologies in which our companies are strong and the technology roadmaps of the Big Science organisations. To do this well, our network needs to keep expanding to include more companies with unique capabilities. The collaboration and support of Mikrocentrum, the independent knowledge and network organisation for the technical manufacturing industry, plays a pivotal role in these efforts.

One of Mikrocentrum's major events, the Precision Fair, is the main event on the ILO-net calendar offering an excellent opportunity to meet many companies, catch up with familiar ones and become acquainted with new ones. In addition, together with Mikrocentrum, we organise a programme of presentations from various Big Science organisations to inform visitors about new projects and technical achievements that serve as examples.

Apart from their tenders, some Big Science organisations have increased their efforts in the domain of knowledge transfer in order to trigger industry to benefit from developed technologies and know-how. To back those efforts, we aim to showcase the technologies of those organisations and we are planning to organise events focused on knowledge transfer.

The Big Science organisations can provide a fertile breeding ground for the sales of core technologies and potential innovations for those that are willing to find out whether there is a cultural and technical match between a Big Science organisation and their company. But only then does the work begin to keep up a sustained effort in maintaining a good relationship and finding the sweet spot that will provide the desired benefits.

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FOUNDATIONS AND HIGHLIGHTS

The Netherlands plays a prominent and long-standing role in astronomy. This is due in part to the Dutch expertise in systems engineering, precision optomechanics, mechatronics and control engineering. Dutch high-tech engineering companies and research institutes are active in the ongoing developments involved for each step in bringing an electromagnetic signal (photon, radio wave, etc.) from outer space to a detector. This article presents an overview and concludes with a number of highlights.

WOUTER JONKER AND RAMON NAVARRO

"Preserving knowledge is easy. Transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth."
Ahmed Zewali, winner of the Nobel Prize in Chemistry (1999)

Introduction

The development of instruments for astronomy is an inspiring subject where science and society meet engineering and business. The science of astronomy addresses important societal topics, seeking to address big questions about our understanding of the Universe and our place in it, such as the hunt for exoplanets where life might be possible. It fosters international collaboration and advances human knowledge in the broad sense.

1
Professor Jan Hendrik Oort, the Dutch pioneer in the field of radio astronomy, and H.M. Queen Juliana at the opening of the radio telescope in Dwingeloo (NL) in 1956. (Image credit: Oort archives)

At the same time, it offers goals for the high-tech industry: astronomy requires the development of optical and optomechanical instruments for ultimate precision, which boosts the expertise of the involved companies, creating visibility on the world stage and offering potential for series production. The development of such instruments brings deep technical knowledge and conceptual solutions that also find their application in neighbouring domains such as aerospace, optical satellite communication, medical instruments, defence and ICT.

For such a relatively small country, the Netherlands plays a prominent and long-standing role in astronomy (Figure 1). Dutch inventors and astronomers are credited with such achievements as: the invention of the microscope and the telescope; the discovery of Saturn's rings and its largest moon, Titan, and the Oort Cloud and Kuiper Belt structures in the solar system; finding the first hints of the existence of dark matter; and major new insights in cosmology. Frits Zernike was awarded the Nobel prize in the field of Optics and, as recently as 2018, Dutch astronomer Ewine van Dishoeck won the prestigious Norwegian Kavli Prize for astrophysics for her work on the origin of stars and planets (Figure 2).

AUTHORS' NOTE

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Ramon Navarro is the Dutch industrial liaison officer for ESO and program manager at SRON, the Netherlands Research School for Astronomy. NOVA is the alliance of the astronomical institutes of the Dutch universities of Amsterdam, Groningen, Leiden and Nijmegen.

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Professor Ewine van Dishoeck receiving the Kavli Prize for astrophysics from H.M. King Harald V of Norway. (Image credit: Fredrik Hagen / NTB scanpix)

The Dutch precision engineering industry is solidly world class in areas of expertise such as systems engineering, precision optomechanics, mechatronics and control engineering. As it stands, the Netherlands is ideally positioned to both benefit from, and contribute to, the science of astronomy (Figure 3).

From starlight to signals

In its path from outer space to a photon detector in a telescope, light is reflected off several optical surfaces to collect it and bring it into focus. The blurring effect of the atmosphere is corrected before the light is fed into the main science instruments that measure the desired properties. Dutch high-tech engineering companies and research institutes are active with the ongoing developments for each of these steps. Below is a quick overview of the steps in going from starlight to signals, followed by a few illustrative highlights.

Mirrors and support structures

The first component that starlight encounters in a big astronomical telescope is the primary mirror. Polished and finished down to an accuracy of single-digit nanometers, the mirrors are kept in that near-perfect shape using statically determined mirror support structures. Active mechanisms in these can compensate for the known, relatively slow effects of the temperature gradients that occur throughout the night, and for the changing gravity vector as the telescope pointing angle varies between horizon and zenith. The largest modern telescopes (Figure 4) have segmented primary mirrors, while the secondary, tertiary and further mirrors in the optical train can also be actively positioned, pointed and often 'warped'.

Turbulence

The only remaining significant disturbances to the image then come from outside the observatory dome, in the form of atmospheric turbulence. Turbulence varies depending on the time of day, the location on Earth and the altitude in the sky. The turbulent mixing of air layers with different temperatures distorts the optical wavefront. The typical distance over which the wavefront can still be considered 'flat' is called the Fried parameter R0 ('R-naught'), which can range from 5 cm on a typical day in the Netherlands to 20 cm on a clear night on Mauna Kea (Hawai'i, USA), one of the world's most favourable observational locations.

A small telescope with a diameter comparable to R0 will always see a more-or-less flat wavefront and so its image will be relatively unaffected. However, a large mirror can fit many times this R0 distance across its diameter. Despite the increased resolution that theoretically comes from having a larger mirror ('diffraction limit'), the practical resolution of a telescope is therefore still limited to that of a ~20-centimeter telescope due to turbulence ('seeing limit').

3

The Milky Way rises over the BlackGEM telescope array in La Silla, Chile. A joint project by NOVA (Netherlands Research School for Astronomy), Radboud University (NL) and KU Leuven (Belgium), it is designed to observe the optical counterpart to neutron-star and black-hole mergers. (Image credit: Zdeněk Bardon / ESO).

4

Artist's rendering of the completed Extremely Large Telescope at Cerro Armazones, Chile; red truck for scale. (Image credit: ESO)

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.

JAN VISSER

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.

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.

AUTHOR'S NOTE

Jan Visser, coordinator industrial contacts at Nikhef, is industrial liaison officer for CERN and ET, and coordinator of ILO-net. He acknowledges the input by institutes and companies.

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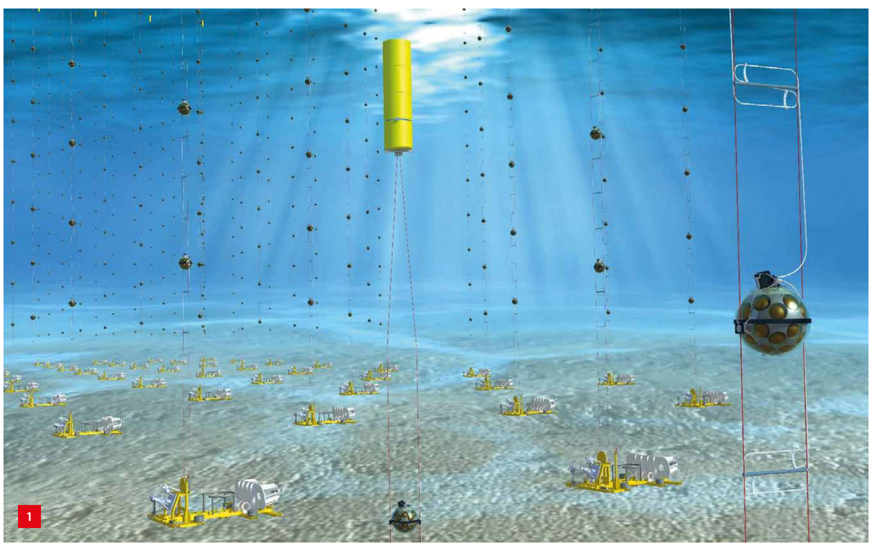

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Artist's impression of the KM3NeT telescope at the bottom of the seafloor, comprising several thousands of spheres, equipped with photomultiplier tubes.

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.

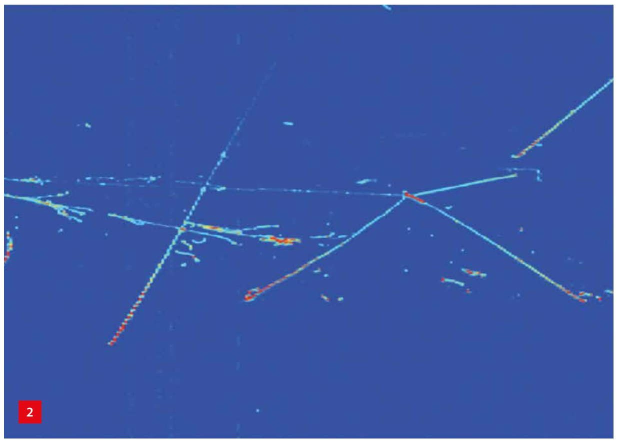
After the successful deployment of a limited number of strings with detection units, and hence a limited neutrino flux, sufficient neutrinos have now been detected to extract the first results on the quantum-mechanical properties of neutrinos, known as neutrino oscillations.

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.