New wings give ICARUS flight for second neutrino hunt

July 5 2016, by Stefania Pandolfi

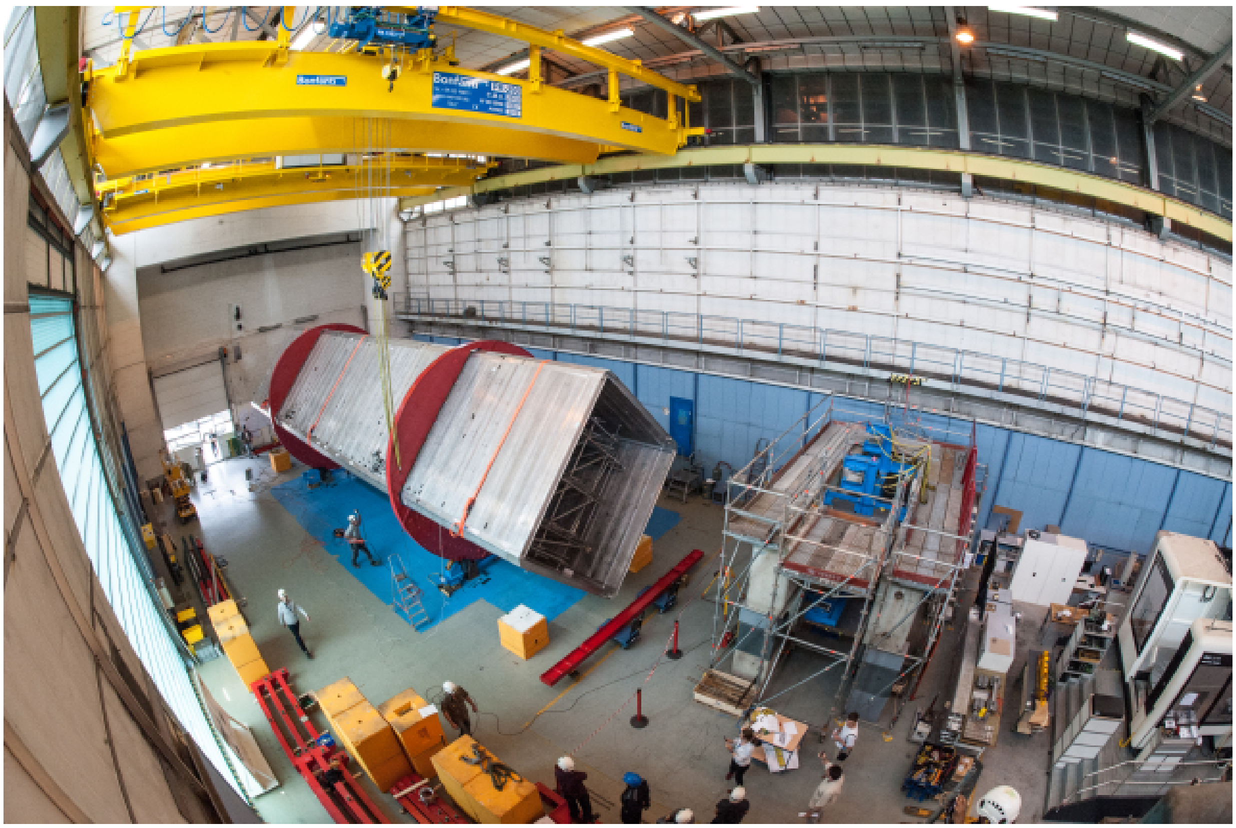
One of the ICARUS time projection chambers being refurbished at CERN in a clean room. Credit: Max Brice/CERN

It's a big shining box, 4 metres high, 20 metres long: this magnificent detector arrived at CERN 16 months ago and since then it is undergoing a complete refurbishing. ICARUS, a 760-ton detector filled with liquid argon (LAr) whose technology was first proposed by Carlo Rubbia in 1977, was used between 2010 and 2014 at the INFN Gran Sasso Laboratory in Italy to study neutrino oscillations using a beam of neutrinos produced at CERN. After its overhaul at CERN, which should last until the end of 2016, it will be shipped to Chicago to start a second life. It will be part of the Short Baseline Neutrino (SBN) programme at Fermilab, dedicated to the study of sterile neutrinos (see Box). The refurbishment is part of the CERN Neutrino Platform (CENF) project, started in 2014, to follow the recommendations of the European Strategy for Particle Physics, and it is done in collaboration with the INFN and Fermilab. "The Neutrino Platform pulls together a community that is scattered across the world," says Marzio Nessi, CERN Neutrino Programme project leader. "CERN has committed significant resources to support R&D in all aspects of neutrino research, and ICARUS's refurbishment is the first beneficiary of this programme."

The ICARUS detector is made up of two modules; each module is filled with high-purity liquid argon, it has a cathode plane in the middle and a wire chamber at each side forming a Time Projection Chamber (TPC). When an energetic particle passes inside the volume, it creates ionizing radiation along its track. The electrons thus created drift towards the sides of the detectors, where three layers of parallel wire planes register the arrival time and the position of the drifted electrons. By combining these position data with the drift time – established also thanks to photomultipliers placed after the wire planes – one can reconstruct a three-dimensional image of the event.

A thorough refurbishment of the ICARUS detector

The renovation campaign concerns many parts of the experiment. New-generation, more efficient photomultipliers have been installed. They are critical components as the Fermilab neutrino beam – which will be sending neutrinos to the chain of detectors of the SBN – will be pulsed at the microsecond level, but the electron drift time in the chamber is of the order of milliseconds. During this time, other particles, such as cosmic rays particles, can cross the detector and accumulate in the read-out system. The photomultipliers will be able to discard the unwanted, out-of-beam time events.



The ICARUS cryostat is being rotated so that aluminium welding can always be done in a flat position. Credit: M.Brice/CERN

Moreover, as the quantity of electrons released by the ionizing particle is extremely small, high-quality electronics are essential to distinguish them from background noise. The electronics have been completely redesigned in the INFN laboratories, with new signal amplifiers and a better signal-to-noise ratio.

Furthermore, the metallic cathode plane in the middle of the detector has been smoothed at the millimetre level to ensure a perfectly uniform electrical field. This is important to perform momentum measurements via multiple scattering of the very energetic particles escaping the detector.

Finally, the argon recirculating and purifying system has also been improved. To prevent ionization electrons recombining with circulating impurities (mostly oxygen, carbon dioxide and water molecules), a high degree of purity is required, at a level better then 0.1 part per billion. ICARUS has a double recycling system that has been revamped by the cryogenic group at CERN. "Improving the performances of a detector already successfully operating in the Gran Sasso underground laboratory has been extremely challenging in many respects" says Claudio Montanari, ICARUS Technical Coordinator. "Indeed, in order to make it fully functional to operate on the surface, many different aspects including data acquisition, background rejection, timing and event reconstruction needed to be rethought."

A real challenge: high-quality aluminium welding of the cryostat

A second, fundamental part of the renovation project is the engineering of the cryostat. It was decided that it would be built in aluminium, mainly for logistics reasons, but this decision brought many challenges. Aluminium welding is generally more difficult than a stainless steel one, as it must be done in a flat position to maximise its effectiveness. Secondly, the welding must be of a very high-quality, to avoid introducing additional, unwanted, impurities. Finally, the cryostat module is just barely bigger than the detector: over a length of 20 meters, the tolerance is of the order of a few millimetres. The

Mechanical & Materials Engineering group at CERN, led by Francesco Bertinelli, is pre-assembling the 4x4 meter extruded panels, juxtaposing and tack welding them with a few supporting ribs. To have clean, high-quality welding, the team is going to rotate the entire pre-assembled cryostat like a giant roaster, in order to weld always in a flat position. This process will last several months, at the end of which the cryostat is ready to host the detector. "The cryostat's assembly engineering is an excellent example of how team work is conducted at CERN," says Bertinelli. "We have a group made up of people with various backgrounds and skills, different nationalities, cultures and languages, but we are closely working together towards our common goal."

When the cryostat will be ready it has to be moved out of its current building, brought in front of the clean room where the detector is, and the two parts will be assembled. At the beginning of 2017, an exceptional load transport will carry it all the way to Fermilab to start its new adventure.

The Short Baseline Neutrino (SBN) programme

The SBN programme has been approved after, in the past decades, the Liquid Scintillator Neutrino Detector (LSND) and MiniBooNE experiments obtained, some unexpected results, showing tensions with the standard model of particle physics in which there are only three types ('flavours') of neutrinos. Indeed, LSND reported hints of the existence of a fourth type of neutrino; MiniBooNE, which used the same beam line at Fermilab that will be used for the SBN programme, found an excess of low-energy particles events. Some theories ascribe this apparently strange neutrino behaviour to the presence of a fourth, sterile, neutrino flavour. The suite of experiments of the SBN programme are meant to cast light on this mystery.

Provided by CERN