INTRODUCTION

The DUNE-LBNF project requires the construction of four very large membrane cryostats at SURF, in Lead, SD, USA, about 1.5 km underground. Each crystal contains 12,100 m³ of liquid argon, equivalent to 17.1 kton. To qualify design changes and to validate the performance of the detectors, crystals and associated cryogenic systems, to ensure that the required purity of 100 ppm oxygen equivalent, corresponding to 3.0 ms electron lifetime, is achieved.

The 30 ton prototype at Fermilab was already operated cryogenically without a detector and it is now being equipped with single phase TPCs in early 2016. The W(12)x12 e is being constructed this summer at CERN and will be operational with a dual phase TPC at the end of 2016.

The preliminary design of the support structures of all other crystals is almost completed. A feasibility study for each membrane cryostat will be awarded to a membrane cryostat vendor in the next months. It will feed back eventual modifications to the design, if needed. At that point, the final engineering of the support structure and the engineering of the membrane cryostat by the manufacturer start.

The prototypes involving the following membrane cryostats:

- WA105 1x1x3: containing about 19 m³ of liquid argon to be constructed at CERN
- Short-Baseline Near Detector (SBND): containing about 189 m³ of liquid argon. It will serve as near detector for the Short-Baseline Near Detector program at Fermilab.
- DUNE Single Phase: containing about 485 m³ of liquid argon. It will be located on the H4 beam line extension in the CERN CRIB area.
- WA105 6x6x4: containing about 485 m³ of liquid argon (with a different configuration detector than the previous one). It will be located on the H5 beam line extension in the CERN CRIB area.

Memburent cryostat technology is widely used by Liquefied Natural Gas (LNG) transportation and storage, with over 100 operating vessels that could now be as large as 250,000 m³ in volume. The structural part of a membrane cryostat is the surrounding outer support structure. Steel in the case of these prototypes, but it can also be concrete as in the 35 ton prototype at Fermilab. The corrugated membrane contains the liquid argon. The pressure is transferred through the insulation to the support structure.

A membrane cryostat is built from the outside in (Figure 1). First the support structure with its vapor barrier. The membrane is an integral part of the support structure and is developed in a similar way. Large openings for installation of the membrane cryostat by the manufacturer start.

The design also allows air to flow underneath the cryostat to maintain the temperature of the bottom part of the vessel without evacuation. With a liquid argon filtration system composed by a molecular sieve and copper filters, it can create its own vacuum.

After commissioning, the DUNE TPC will detect and study neutrinos from a new improved beam line from Fermilab. The Deep Underground Neutrino Experiment (DUNE) – Long-Baseline Neutrino Facility (LBNF) project envisions using a membrane tank technology for a large liquid argon detector with the start of construction in the 2020 time frame and operations in 2024. The current detector configuration has a total fiducial mass of 40,000 tons of ultra pure liquid argon (less than 100 parts per trillion of oxygen equivalent contamination) to be located at the 400fts of the Sanford Underground Research Facility (SURF) in Lead, SD, USA. The experiments are being developed in a phased approach, which is to total four identical crystals of about 12,100 m³ of total liquid argon each, each one instrumented with Three Projection Chambers (TPCs). The initial phase is to include two crystals, with the corresponding required cryogenic system. The remaining crystals will come at a later date.

To qualify the membrane technology for future very large-scale and underground implementations, a strong prototyping effort is ongoing: several smaller detectors of growing size with associated prototypes and cryogenic systems will be designed and built in the next 1-2 years in order to be operationally available to low energy. It will take data with single-phase detector in early 2016. A similar size prototype with a dual-phase detector is being constructed at CERN and will be operational next year. In the coming years three more membrane cryostats will be constructed: a 260 ton crystal with single-phase detector at Fermilab and in parallel two 670 ton prototypes at CERN. The DUNE Single Phase and the DUNE TPC phase prototypes will be ready by 2016.

Purity of 100 ppm oxygen equivalent, far exceeding the level of purity for the liquid argon required by these detectors, will be achieved. It will be located on the H4 beam line extension in the CERN CRIB area. The experiments are being developed in a phased approach, which is to total four identical crystals of about 12,100 m³ of total liquid argon each, each one instrumented with Three Projection Chambers (TPCs).

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After commissioning, the DUNE TPC will detect and study neutrinos from a new improved beam line from Fermilab. These cryostats will be engineered, constructed, commissioned, and qualified by an international engineering team.

Development of Membrane Cryostats for Large Liquid Argon Detectors


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