Overview of collaborative research between UNICAMP in Brazil and Fermilab in cryogenics

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Abstract. The Long-Baseline Neutrino Facility (LBNF) situated at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, serves as the host for the Deep Underground Neutrino Experiment (DUNE), employing cryostats with nearly 70,000 metric tons of high purity liquid argon (LAr). The integrity of LAr quality is pivotal in determining the electron lifetime within DUNE, directly impacting its signal-to-noise ratio. Specifically, Far Detector 1 (FD-1) in cryostat 1 requires an electron lifetime over 3 ms within its 3.5 m drift, corresponding to less than 100 parts-per-trillion (ppt) Oxygen equivalent contamination. Far Detector 2 (FD-2) in cryostat 2 demands over 6 ms electron lifetime within its 6.0 m drift, corresponding to less than 50 ppt Oxygen equivalent contamination. Nitrogen (N_2) absorption of LAr scintillation light, known as quenching, necessitates N_2 contamination in LAr to remain below 1 ppm to minimize photon loss and enhance energy reconstruction. Studies indicate that at 1 ppm N_2, approximately 20% of scintillation light is lost, highlighting the importance of minimizing N_2 contamination.

Brazil State University of Campinas's (UNICAMP) contribution to LBNF focuses on developing argon purification and regeneration for DUNE FD-1 and FD-2.

To that effect, they constructed a test facility to perform studies on LAr purification at a smaller scale, the Purification Liquid Argon Cryostat (PuLArC) with approximately 90 liters of LAr. One of the filtration materials was considered and tested Li-FAU molecular sieve.

Value engineering on argon purification media was conducted, leading to the identification of Li-FAU zeolite's ability to effectively capture N_2 impurities during LAr circulation. Testing at UNICAMP's PuLArC facility demonstrated that 1 kg of Li-FAU is capable of reducing N_2 contamination from 20-50 ppm to 0.1-1.0 ppm within 1-2 hours of circulation.

In October 2023, testing at the Iceberg cryostat in Fermilab's Noble Liquid Test Facility (NLTF), with approximately 2,625 liters of LAr, confirmed the efficacy of 3 kg of Li-FAU in reducing N_2 contamination

from ~ 5 ppm of injected N_2 down to less than 1 ppm over 96-hour cycles, showcasing its potential for larger-scale LAr cryostats. Further tests are planned to validate Li-FAU's use as a possible alternative to Molecular Sieve 4A in LBNF-DUNE and related liquid argon experiments.

This contribution will describe how the research was performed and present the test setups and results in detail.

This advancement not only has the potential to enhance DUNE's precision but also to elevate liquid argon experiments globally, showcasing the power of international scientific collaboration.

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Submission category: ICEC 14.

Presentation type: Oral.