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Overview of Collaborative Research Between UNICAMP in Brazil and Fermilab in Cryogenics

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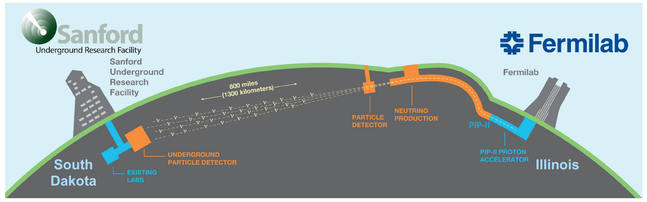
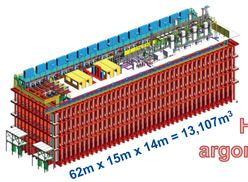
Background

The Long-Baseline Neutrino Facility (LBNF), located at the Sanford Underground Research Facility in Lead, South Dakota, hosts the Deep Underground Neutrino Experiment (DUNE).



The cryostats contain 17,500 metric tons of ultra-pure liquid argon (LAr) each. It is like 5 Olympic pools



How pure should the argon be for the experiment?

The Olympic Pool Size is 50m x 25m x 2m = 2,500m³

Detector 1 <100ppt or ~1.4ml of oxygen equivalent

Detector 2 <50ppt or ~ 0.7ml of oxygen equivalent

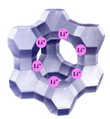
Oxygen ☑

Water ☑

Nitrogen ☒

Contaminants in argon, such as nitrogen (N_2), oxygen, and water, significantly affect experimental results. It is crucial to keep them low. The argon is purified using media, which capture O_2 and water. As the filters can't remove N_2, it must be kept low in the argon purchasing specification.

Purification Media and Innovative Method



Faujasite LiX

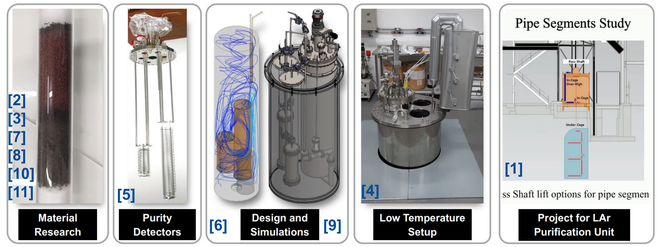
A systematic study incorporating collaborative materials, methods, and research [3], [8], simulation models [6], [9], and experimental results [10] have revealed that zeolite Li-FAU is an effective adsorbent for removing nitrogen and water impurities during liquid argon circulation.

Collaboration with Brazil

Brazil State University of Campinas (UNICAMP) focuses on advanced argon purification and photodetection for LBNF/DUNE.

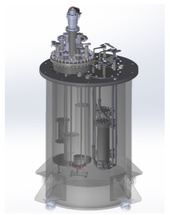
During Phase I worked on:

- Filtration materials research,
- Purity monitors/detectors,
- Design and process simulations,
- Cryostat for purification media testing,
- Equipment delivery and installation.



Brazilian Team Science and Technology Development Focus During Phase I of the Agreement

Liquid Argon Purification Experiment at Unicamp



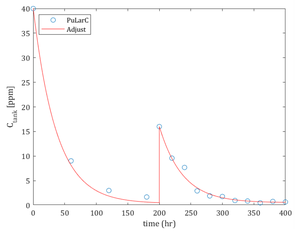
PuLArC Cryostat at UNICAMP 90 liters of LAr

UNICAMP constructed a test facility, the Purification Liquid Argon Cryostat (PuLArC), to study argon purification [4].

Testing at the PuLArC facility demonstrated:

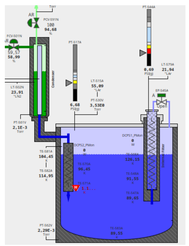
1.2 kg of Li-FAU zeolite adsorbent showed a reduction of the N_2 contamination from 20-50 ppm to 0.1-1.0 ppm within 1-2 hours of active circulation time for several runs [10].

PuLArC Cryostat Filtration Process



Two cycles of simulation, The media is not saturated

Liquid Argon Purification Experiment at Fermilab



ICEBERG Cryostat at Fermilab 3,000 liters of LAr

Testing at the Integrated Cryogenic Experiment for Beam Energy Research and Generation (ICEBERG) Cryostat in Fermilab's Noble Liquid Test Facility (NLTF), confirmed the effectiveness:

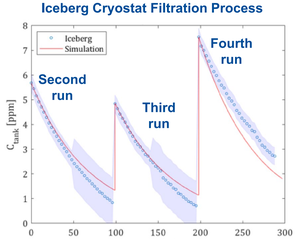
3 kg of Li-FAU zeolite reduced N_2 contamination from ~ 5 ppm of injected N_2 to less than 1 ppm over 96-hour cycles without active circulation [12].

A calibrated gas analyzer was connected to the Iceberg cryostat to monitor N_2 dissolved in LAr.

The cryostat was filled with 2,596 liters of LAr.

Several controlled amounts of N_2 were flushed into the cryostat (15-25 liters each).

Iceberg Cryostat Filtration Process



N_2 concentration as a function of time for selected injections [12]

Tests	Time = 0 hr	Time = 96 hr
Run 2	5.68 ± 0.10	0.84 ± 0.04
Run 3	4.84 ± 0.07	0.71 ± 0.03
Run 4	7.54 ± 0.14	2.50 ± 0.07

The table contains the mean values of the initial and final N2 concentrations

Conclusion

The successful testing of Li-FAU as an effective adsorbent for N_2 impurities marks a significant advancement for neutrino experiments, improving LAr quality. Promising results from the PuLArC and Iceberg cryostats suggest that Li-FAU could be a viable alternative to Molecular Sieve 4A in large-scale LAr cryostats. This collaboration highlights the power of international scientific research in advancing neutrino experiments.

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