

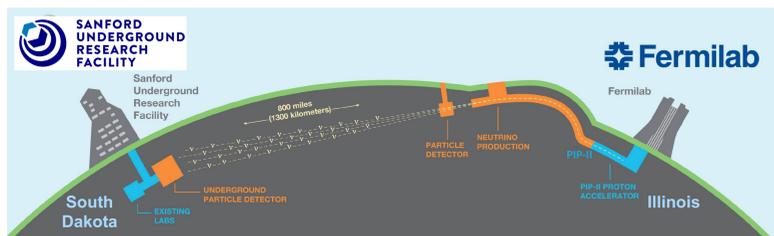
Ensuring High-Purity Liquid Argon for the LBNF FDC: Collaborative Cryogenics Research Between UNICAMP and Fermilab

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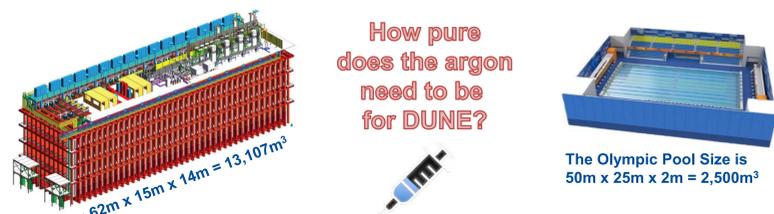
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Background

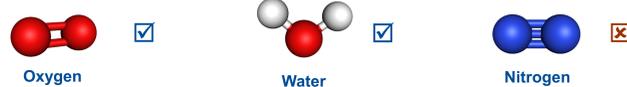
The Long-Baseline Neutrino Facility (LBNF), at the Sanford Underground Research Facility (SURF) in South Dakota, hosts the Deep Underground Neutrino Experiment (DUNE).



That's 17,500 tons of pure liquid argon per cryostat - roughly the volume of five Olympic swimming pools.



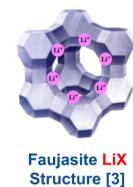
HD Detector <100ppt or ~1.4ml of oxygen equivalent VD Detector <50ppt or ~0.7ml of oxygen equivalent



Impurities like nitrogen (N₂), oxygen (O₂), and water (H₂O) affect results and must be kept low. Filters remove O₂ and H₂O, but **not** N₂, which must be limited in purchased argon. Over 1 ppm of N₂ can reduce light output by 20%.

Brazil-Fermilab Phase I Results:

N₂ Removal Media and Innovative Method



During Phase I, the State University of Campinas (UNICAMP) developed an innovative method using Li⁺ Faujasite (Li⁺-FAU) Zeolite to remove nitrogen (N₂) contamination from liquid argon. This media also captures water (H₂O), functioning similarly to 4A molecular sieves. The method was validated in collaboration with Fermilab through simulations and tested on two cryostats: PuLArC at UNICAMP and ICEBERG at Fermilab [1].

Liquid Argon Purification Experiments at Unicamp and Fermilab



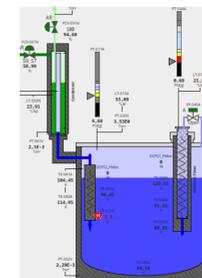
PuLArC Cryostat at UNICAMP 90 liters of LAr

Test Results: Li-FAU Zeolite for N₂ Removal [4]

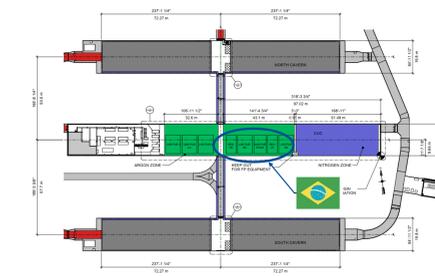
- PuLArC Cryostat at UNICAMP 90 L: 1.2 kg of Li-FAU reduced N₂ levels from 20-50 ppm to 0.1-1.0 ppm in 1-2 hours.
- ICEBERG Cryostat at Fermilab 2,596 L [2]: 3 kg of Li-FAU lowered N₂ from ~5 ppm to <1 ppm over 96-hour cycles, with no active circulation.

Results: these tests demonstrate the scalability and effectiveness of Li-FAU as a purification medium.

Planned Next Step: Test the performance of Li-FAU in a ProtoDUNE cryostat.



ICEBERG Cryostat at Fermilab 3,000 liters of LAr



Top view of underground level 4,850-foot level Argon Purification and Regeneration Systems VD/HD

The VD/HD Regeneration and Argon Purification Systems, located in the Central Utility Cavern, are illustrated in the top-view figure on the left.

30% Preliminary Design Review was successfully completed in April 2025.

Purification Systems in Neutrino Platform – LBNF/DUNE Prototypes

Four prototype systems have been successfully designed, manufactured, installed, and have operated reliably for several years in international experiments.

These include ICARUS and SBND at Fermilab (USA) and ProtoDUNE-SP and ProtoDUNE-DP at CERN (Switzerland).

Their configurations and performance [3] are summarized in the reference table.

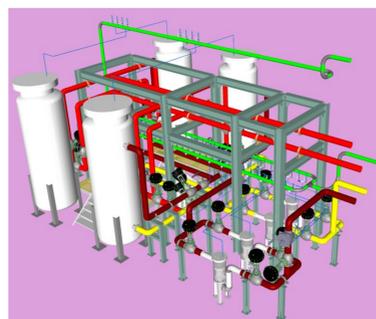
Prototypes and LBNF/DUNE Filtration Systems Sizes

Cryostat	ICARUS-T600 NP-01 Fermilab	SBND NP-03 Fermilab	ProtoDUNE-SP NP-04 CERN	ProtoDUNE-DP NP-02 CERN	LBNF/DUNE VD/HD Fermilab
Cryostat Volume, liters	543,000	200,000	570,775	570,775	12,544,800
4A Mol Sieve, liters	150	150	115	115	84
CU-0226 S Copper Oxide, liters	960	960	370	370	4,918
Total media, liters	1,110	1,110	485	485	5,002
Active Circulation	Yes	Yes	Yes	Yes	Yes
LAr Filtration Rate, kg/s	1.0	1.25	1.6	1.6	10.0
Required Purity, ms	3	3	3	3	3 and 6
Achieved purity	Yes	Yes	Yes	Yes	TBD
Measured lifetime	8.5 ms	20 ms	100+ ms	30+ ms	TBD

LBNF/DUNE Brazil In-Kind Contribution - Phase II Initiated

Argon Purification and Regeneration for VD and HD Modules

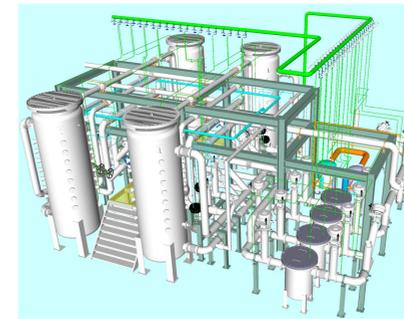
UNICAMP has begun engineering the Liquid Argon (LAr) and Gaseous Argon (GAR) purification and Regeneration systems for the Vertical Drift (VD) and Horizontal Drift (HD) Far Detector modules at the Far Site. The system is based on Fermilab's reference design and informed by the successful prototyping experience outlined above. To lead the execution phase, UNICAMP contracted the industrial engineering firm Akaer Engenharia S.A. in December 2024. The company formed a professional working group.



3D Model by Akaer Argon Gas Purification System

The Argon Gas skid (left figure) will be used exclusively during the cryostat's filling process, estimated to take about 8.5 months for the VD cryostat and approximately 13.5 months for the HD cryostat fill.

In collaboration with Fermilab and UNICAMP, Akaer established a baseline schedule, initiated package designs, and 3D modeling, clarified interfaces, and identified potential component vendors with proper ASME certification.



3D Model by Akaer – Typical Liquid Argon Purification System

Acknowledgment

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References

- [1] Technical Notes CRYOFRABR 001/2021 – 012/2024 listed in references in Poster ID 259 Tue-Po-1.3 from CEC/ICEM, presented at the 29th International Cryogenic Engineering Conference/ Geneva, Switzerland/ Jul. 22-26, 2024.
- [2] Exploring N₂ Capturing in Liquid Argon using Li-FAU Mol Sieve in the Iceberg, Pedro Bianchi Neto et al., LIDINE, Sao Paulo, Brazil/ Aug. 26-27, 2024.
- [3] Lessons from the commissioning of the cryogenic system for the Short-Baseline Neutrino Detector at Fermilab. Paper ID: 0008. FERMILAB-CONF-25-0005-PPD, presented at the 18th Cryogenics 2025, IIR Conference / Prague, Czech Republic / Apr. 7-11, 2025.
- [4] Exploring N₂ Capturing in Liquid Argon using Li-FAU Mol Sieve, D. Noriler, et al., European Congress of Chemical Engineering (ECCE) Lisbon, Portugal/ Sep. 8-10, 2025.

