

# LA-UR-24-24943

Approved for public release; distribution is unlimited.

**Title:** Building a better neutrino trap

**Author(s):** Del Mauro, Diana

**Intended for:** Lab social media  
Web

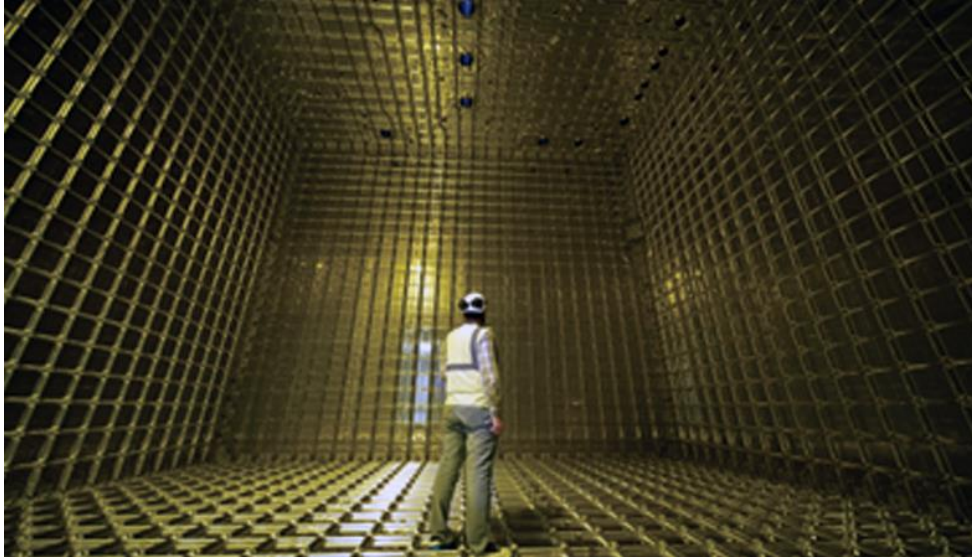
**Issued:** 2024-05-16



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

# Building a better neutrino trap

New detector technologies being tested to better understand elusive particle



The 770-ton particle detector pictured above, called ProtoDUNE, sits at the border of Switzerland and France to test the design and technologies for the Deep Underground Neutrino Experiment, or DUNE, which will be built a mile below ground in South Dakota to better understand neutrinos, a particle that's pervasive in the universe. Credit: CERN

First detected by Los Alamos researchers **Frederick Reines** and **Clyde Cowan** in a nuclear reactor in 1956, tiny particles dubbed neutrinos are so abundant they constantly pass through human bodies by the trillions. But despite decades of study, the neutrino's bizarre nature is still little understood.

Lab scientists are trying to rectify that.

As data streams in from two particle detectors at a prototype experiment in Switzerland, Los Alamos physicists are refining their instruments, which sit atop the detectors. Their laser calibration system will help researchers better understand signals coming from the elusive neutrino, aiding the quest to unlock the neutrino's secrets about the universe.

The prototype detectors, located at the European Center for Nuclear Research (CERN), will pave the way for a U.S.-based experiment of unprecedented scale called the Deep Underground Neutrino Experiment, which is under construction. With one detector in South Dakota and another in Illinois, DUNE aims to launch the most intense neutrino beam in the world. The Lab is a key player with more than 1,400 international collaborators.

"Building enormous experiments deep underground — imagine building a ship in a bottle — is both exciting and challenging at the same time, and there is a sense of adventure in what we do," said physicist **Sowjanya Gollapinni** (P-2).

Gollapinni is spearheading the calibration and cryogenic instrumentation for DUNE in her role as technical leader of the project. She also is the U.S. scientific coordinator for DUNE's second construction phase.



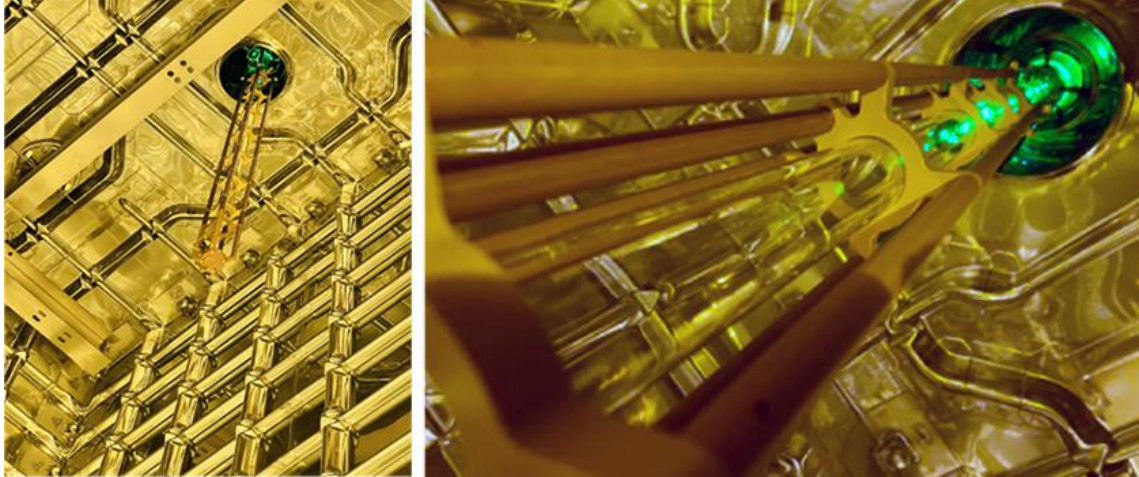
Earlier this year in South Dakota, crews carved out the future home of particle detectors for the international Deep Underground Neutrino Experiment. Installation of the four neutrino detectors — each one about the size of a seven-story building — is expected to begin soon to record the rare interaction of neutrinos with liquid argon. Credit: Fermilab

## Getting it right, on a small scale

Designing a better neutrino trap is challenging because this subatomic particle rarely interacts with matter, exhibits no electrical charge and is nearly weightless. That's why before the real experiment happens in the United States, the two scaled-down detectors in Europe, called ProtoDUNEs, are testing technologies under development.

Laser calibration instruments designed and built at Los Alamos in collaboration with the Laboratory of Instrumentation and Experimental Particle Physics (LIP) in Portugal were installed on the experiment in late January, and Gollapinni's team is busy validating their performance.

"We are primarily involved in developing calibration instruments required to extract charge and light signals in the detectors with precise spatial and energy resolution. We use innovative techniques that involve class-IV ultraviolet lasers and neutron radiation to develop these systems and validate the designs in the ProtoDUNE experiment at CERN," Gollapinni said.



Shown above are views of the laser calibration system developed by Los Alamos, viewed from inside the ProtoDUNE liquid argon detector. The green light at the top is from a laser used for alignment of the beam during commissioning of the system. Credit: DUNE Collaboration

## **Extremely cold liquid could be key to better data**

Liquid argon is a cryogenic liquid with a boiling point of -303 degrees Fahrenheit, or -186 degrees Celsius. It is a relatively new medium for this high-energy physics research, and the hope is this extremely cold environment will enable more precise measurements when DUNE experimentalists study how neutrinos transform their identity.

Recently, the first ProtoDUNE detector was filled with liquid argon, which took almost two months because the vast chamber is about three stories tall. "When a neutrino interacts with argon, it produces charged particles that ionize the atoms, allowing scientists to detect and study neutrino interactions," according to a recent [report from CERN](#).

"But argon also consists of 40 nucleons (22 neutrons and 18 protons), presenting a complicated nuclear physics environment," Gollapinni said. "We actively collaborate with LANL theorists for input on the nuclear physics that happens inside the argon nucleus and tie that into our experimental investigations."

Can neutrinos explain why the universe is made of matter — stars, galaxies, atoms and life — and why most antimatter disappeared after the Big Bang? This is a question DUNE wants to explore.



In late January, Sowjanya Gollapinni and her team, which includes international collaborators, installed their laser calibration system on top of ProtoDUNE detectors in Europe. Top row: Jan Boissevain (LANL), Sowjanya Gollapinni (LANL), Eric Renner (LANL), Rui Alves (LIP). Bottom row: David Rivera (LANL), Jose Maneira (LIP). Credit: DUNE Collaboration

The Los Alamos team will analyze particle interactions with the argon nucleus in ProtoDUNE to learn how particles such as neutrons and protons propagate in liquid argon. "These scattering measurements provide key inputs to analyses aiming to address the matter-antimatter asymmetry puzzle in DUNE," Gollapinni said.

The Los Alamos DUNE team also includes postdoctoral researcher **David Rivera** (P-2); engineers **Eric Renner** (P-3), **Jan Boissevain** (P-2), **Walter Sondheim** (P-3) and **Adam Martinez** (P-2); and post-bac students **Leon Tong** (P-2) and **Daniel Xing** (P-2).

Neutrino studies tend to be tied to fundamental science questions, but they could have national security science implications, too.

"How to use advancements in neutrino detection for nuclear security, especially nonproliferation and arms control, is an active area of research that sits at the interface of fundamental and applied sciences," Gollapinni said. "The connection comes from the fact that nuclear reactors, which are fission sources, produce neutrinos in large quantities through a process called nuclear beta decay that happens inside the atomic nucleus."



The ProtoDUNE team

recently filled one detector with liquid argon. Credit: CERN

## Many questions, many experiments

Lying in wait to catch a neutrino is a painstaking endeavor. There are many different experiments and approaches in the quest to answer questions about these particles, which can morph into different varieties.

The prototype experiments at CERN only run at certain times a year. Gollapinni will collect data from ProtoDUNE's upcoming run this summer. She'll also analyze data from other liquid argon experiments, such as MicroBooNE and the Short-Baseline Near Detector at Fermi National Accelerator Laboratory (Fermilab) near Chicago.

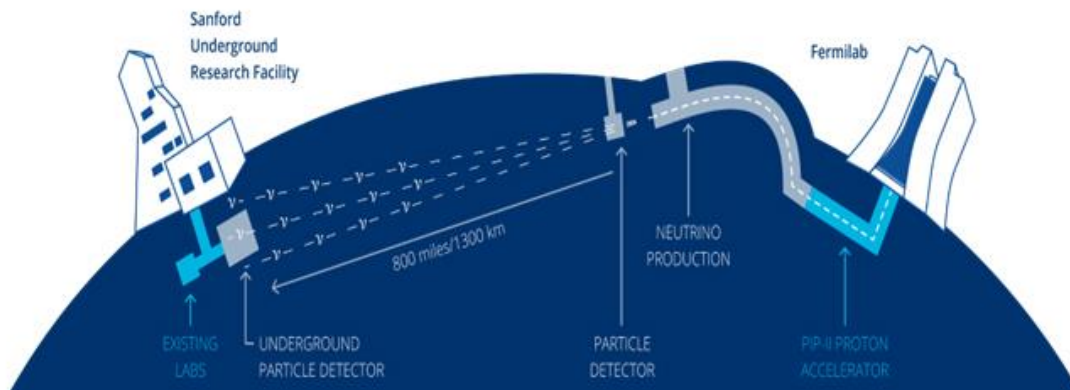
"At MicroBooNE and SBND, my team and I focus on measurements that explore the sterile neutrino question — in other words, is there a new type of neutrino? We also focus on physics processes where neutrinos serve as a portal to the dark sector (a mix of dark matter and dark energy) that constitutes 95% of the total mass-energy content in the universe," Gollapinni said.

Gollapinni's team while working on MicroBooNE and SBND includes postdoc **Mark Ross-Lonergan** (P-2), P-2 post-bac students Tong and Xing, and undergraduate student **Kevin Tanner** (P-2).

One of DUNE's detectors will be located at Fermilab, the place where Gollapinni found the inspiration for her career.

"I learned how neutrinos can be incredible probes to explore many unexplained phenomena in the universe, and I thought the biggest discoveries during my career will come from neutrino physics. So, I switched to the neutrino field as a postdoc," she said. "It was the best decision of my life, and I thoroughly enjoy the work that I do."

In 2022, Gollapinni received the Lab's Distinguished Performance Award for her accomplishments on DUNE and the Short-Baseline Neutrino program.



A schematic of the [DUNE experiment](#). Credit: Fermilab

### 5 takeaways from a century of neutrino research

Neutrinos are everywhere but you'll never see one. Here's what you need to know, according to the DOE Office of Science, which supports experiments and U.S.-hosted international facilities dedicated to understanding these building blocks of matter.

- Neutrinos are the most abundant particles that have mass in the universe, yet no one has been able to precisely measure their mass because neutrinos are so lightweight and difficult to study.
- Neutrinos are everywhere. Every time atomic nuclei come together (like in the sun) or break apart (like in a nuclear reactor), they produce neutrinos. Even a banana emits neutrinos — they come from the natural radioactivity of the potassium in the fruit. Once produced, these ghostly particles almost never interact with other matter.
- Tens of trillions of neutrinos from the sun stream through your body every second, but you can't feel them.
- Three types of neutrinos have been discovered so far: the electron neutrino, muon neutrino and tau neutrino. Sterile neutrinos are hypothetical particles.
- Neutrinos have the potential to resolve profound science questions, including how the universe came into existence and its composition at an elemental level.

Learn more about these elusive particles on the [DOE Office of Science](#) and [Fermilab](#) websites.

Also read about the hunt for [sterile neutrinos](#). On this episode of the Lab's "Down to a Science" [podcast](#), listen to Sowjanya Gollapinni discuss her work.