The search for a fourth neutrino

An international research program at Fermilab will probe one of the enduring mysteries of science: Are there only three types of ghostly particles known as neutrinos, or is a fourth type waiting to be discovered?

Three detectors, one program

Neutrinos are everywhere. They are among the most abundant particles in the universe, so understanding everything about them is critical to understanding the universe. Scientists discovered the third type of neutrino, called the tau neutrino, at Fermilab in 2000, and we know that the three types of neutrinos can transform into each other.

Theoretical models and data from previous experiments suggest there might be a fourth kind, one that may not follow the rules of neutrino interactions with matter as we know them. Searching for these so-called sterile neutrinos is the goal of more than 250 scientists from 50 institutions involved in Fermilab's Short-Baseline Neutrino Program. When construction is complete, a chain of three particle detectors—placed in a straight line about a third of a mile long—will probe a beam of muon neutrinos created by Fermilab's particle accelerators. The three detectors will each be filled with hundreds of tons of liquid argon to record the interactions of these mysterious particles.

Together these three detectors are powerful tools to investigate the evolution of neutrino oscillations over a short time and distance and thus explore whether the universe is even more complex than we think. This is the first time in history that several high-precision liquid-argon detectors have been strung together to conduct a neutrino physics experiment. The upcoming international Deep Underground Neutrino Experiment and Long-Baseline Neutrino Facility, hosted by Fermilab, will also use liquid-argon technology.

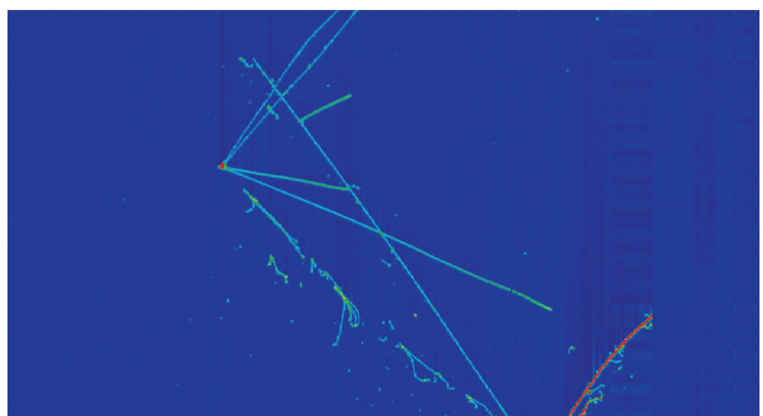
The ICARUS detector was installed in its Fermilab research hall in 2018.

ICARUS: high tech from Italy

In 2018, the largest of the three detectors, ICARUS, was installed inside its Fermilab research hall. Scientists previously operated the 760-ton ICARUS detector at Gran Sasso National Laboratory in Italy for four years before shipping it for upgrades to the CERN research center near Geneva, Switzerland. In 2017, the detector arrived at Fermilab. ICARUS is the world's first large liquid-argon neutrino detector. The liquid-argon technology yields the most precise 3-D images of the particle tracks created when neutrinos collide with atoms.

MicroBooNE: on the hunt

The detector at the center of the chain has been taking data since 2015. The 170-ton MicroBooNE detector will be the first to check an unexplained anomaly in the data of a previous neutrino experiment. This anomaly could indicate the presence of sterile neutrinos, but other explanations are also possible. MicroBooNE combines liquid-argon technology with state-of-the-art 3-D imaging processing to spot neutrino interactions.



This image shows the particle tracks resulting from the interaction of a neutrino with liquid argon inside the MicroBooNE detector.

SBND: closest to the source

The Short-Baseline Near Detector, which will sit closest to the source of the neutrino beam, also will employ high-precision liquid-argon technology. Scientists from Brazil, CERN, Switzerland and the United Kingdom are working with U.S. scientists on the design and construction of this 260-ton particle detector. Its function is a critical one in the the chain of detectors: measuring the purity of the muon neutrino beam produced by the Fermilab accelerators before it reaches MicroBooNE and ICARUS.