Fermilab scientists lead quest to find elusive fourth kind of neutrino

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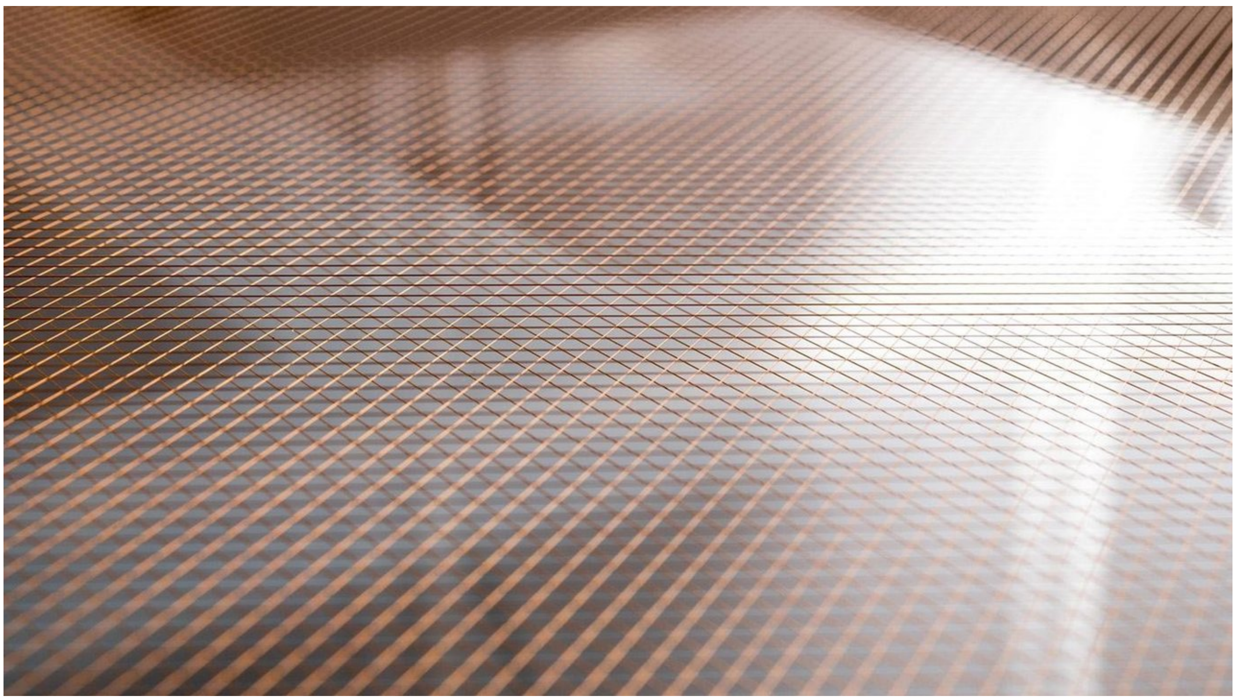


Close-up of the surface of one of the neutrino detector's assemblies, where thousands of wires spaced 3 millimeters apart detect the signals created by neutrinos passing through the detector. Credit: Reidar Hahn

Neutrinos, ghostly fundamental particles that are famously difficult to study, could provide scientists with clues about the evolution of the universe.

They are so difficult to catch, in fact, that it's possible there's a fourth type that's been hiding right under our noses for decades.

Scientists at the UChicago-affiliated Fermi National Accelerator Laboratory, site of the most extensive neutrino research in the world, are leading an international collaboration to explore the possibility of a completely new particle. Although three types of neutrino are known, scientists are searching for a possible fourth—the sterile neutrino, whose existence has been teased but never clearly confirmed.

Major components for the new neutrino experiment are arriving from around the world to be integrated into the upcoming Short-Baseline Near Detector, or SBND, at Fermilab.

"The short-baseline program aims to address interesting results from previous experiments that could be hinting at a new class of neutrinos, which would open up a completely new, unexpected area in neutrino physics," said David Schmitz, SBND co-spokesperson and assistant professor of physics at the University of Chicago. "But no matter what we find, the results should give us clarity on this long-standing puzzle."

At Fermilab, located about 45 miles west of Chicago, three detectors perch along a beam of neutrinos generated by Fermilab's particle accelerators. Of the three, the new detector will sit closest to the beam source, just 360 feet away. (The other two, MicroBooNE and ICARUS, are 1,500 feet and 2,000 feet from the source, respectively.)

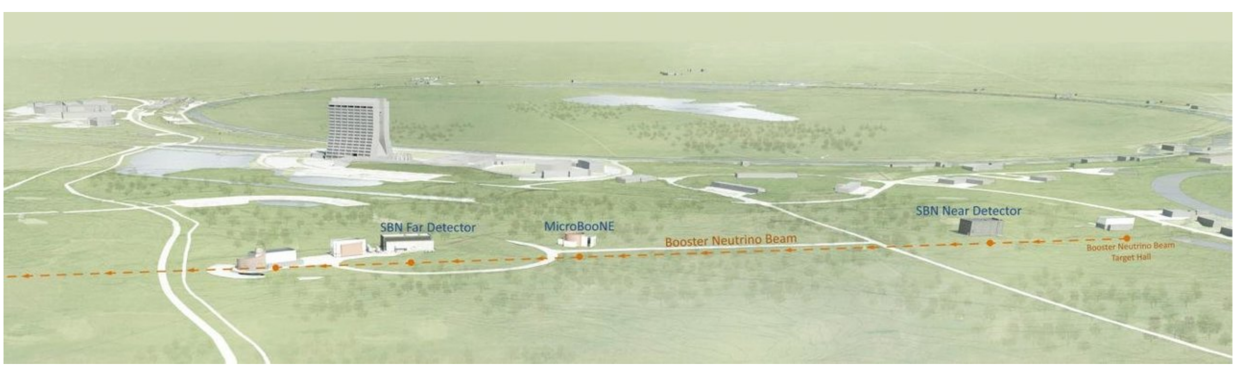
"The reason you have three detectors is that you want to sample the neutrino beam along the beamline at different distances," said Fermilab neutrino scientist Ornella Palamara, the other spokesperson for the project.

As neutrinos pass through one detector after the other, some of them leave behind traces in the detectors. Scientists will analyze this information to search for firm evidence of the hypothesized but never seen member of the neutrino family.

Making a (dis)appearance

Neutrinos come in one of three "flavors": electron, muon and tau. They change from one flavor into another as they travel through space, which is called oscillation. Neutrinos are known to oscillate in and out of the three flavors, but only further evidence will help scientists determine whether they also oscillate into a fourth type—a sterile neutrino.

If these sterile neutrinos exist, they don't interact with matter at all. (The neutrinos we're familiar with do interact, but only rarely.) Results from other experiments have hinted at the possibility of the sterile neutrino's existence, but so far, no one has confirmed it.



Three detectors perch along a beam of neutrinos generated by Fermilab's particle accelerators, each checking the stream for evidence of a possible fourth type of neutrino. Credit: Fermilab

SBND, as the first detector in the beam, will record the number of electron and muon neutrinos that pass through it before oscillation can occur. The vast majority of them—about 99.5 percent—will be muon neutrinos. By the time of their arrival at the far detectors, MicroBooNE and ICARUS, a few out of every thousand muon neutrinos may have converted into electron neutrinos.

Two possible outcomes could indicate the existence of the new particle.

One is that the far detectors see more electron neutrinos than expected. This could be evidence that sterile neutrinos are also present: The neutrinos could be converting into and out of sterile neutrino states in a way that produces an excess of electron neutrinos. The other is that the far detectors see fewer muon neutrinos than expected—the muon neutrinos spotted in SBND "disappear"—because they converted into sterile neutrinos.

"Having a single experiment where we can see electron neutrino appearance and muon neutrino disappearance simultaneously and make sure their magnitudes are compatible with one another is enormously powerful for trying to discover sterile neutrino oscillations," said Schmitz. "The near detector substantially improves our ability to do so."

Components from three continents

The first of four anode plane assemblies, highly sensitive electronic components, came to Fermilab in October. More are on their way.

The anode plane assemblies, four in all, are part of a 4-by-4-by-5-meter detector that will be suspended inside a cryogenic tank filled with liquid argon at -300 degrees Fahrenheit. Each assembly is a huge frame covered with thousands of delicate sense wires, designed to track particles that come off neutrinos colliding with argon atoms in the tank.

SBND will also be a testing ground for some of the technologies, including the anode plane assemblies, that will be used in the international Deep Underground Neutrino Experiment, known as DUNE, a megascience experiment hosted by Fermilab that is currently under construction in South Dakota.

Institutions in Europe, South America and the United States are helping build SBND's various components. In all, more than 20 institutions on three continents are involved in the effort. Another dozen are collaborating on software tools to analyze data once the detector is operational, Schmitz said.

"Being part of an international collaboration is great," Palamara said. "Of course, there are challenges, but it's fantastic to see people coming from all around the world to work on the program. Having pieces of the detector built in different places and then seeing everything come together is exciting."

Assembly of SBND is expected to finish in fall 2019, after which the detector will be installed in its building along the accelerator-generated neutrino beam. SBND is scheduled to begin receiving neutrinos by the end of 2020.

Provided by University of Chicago