About 1,000 scientists from more than 160 institutions in 30 countries collaborate on the Deep Underground Neutrino Experiment. Collaborators encourage and anticipate further international participation.

Why are neutrinos important?

Neutrinos are among the most abundant particles in the universe, a billion times more abundant than the particles that make up stars, planets and people. Each second, a trillion neutrinos from the sun and other celestial objects pass through your body. Although neutrinos are all around us, they interact so rarely with other matter that they are very difficult to observe.

The latest developments in particle accelerator and detector technology make possible promising new experiments in neutrino science. The Deep Underground Neutrino Experiment collaboration, which comprises about 1,000 scientists from 30 countries are building a world-leading neutrino experiment that involves construction at both Fermi National Accelerator Laboratory (Fermilab), located in Batavia, Illinois, and the Sanford Underground Research Facility (Sanford Lab) in Lead, South Dakota.

What do we know about neutrinos?

Neutrinos are elementary particles that have no electric charge. They are among the most abundant particles in the universe. They are very light. A neutrino weighs at least a million times less than an electron, but the precise mass is still unknown.

Neutrinos are difficult to observe in nature, they are produced in great quantities in the sun and in smaller quantities in the Earth. In the laboratory, scientists can make neutrino beams with particle accelerators.

Neutrinos pass harmlessly right through matter, and only very rarely do they collide with other matter particles.

There are three types of neutrinos: electron neutrinos, muon neutrinos and tau neutrinos.

The laws of quantum mechanics allow a neutrino of one type to turn into another one as the neutrino travels long distances. And they can transform again and again. This process is called neutrino oscillation. Understanding neutrino oscillations is the key to understanding neutrinos and their role in the universe.

The distance between Fermilab and Sanford Lab is 800 miles (1300 kilometers). This is ideal for examining neutrino oscillations with the Deep Underground Neutrino Experiment. Scientists also will use DUNE to look for neutrinos coming from the explosion of a star—a supernova—to discover the formation of a neutron star or black hole.

Mysterious neutrinos

Neutrinos may provide the key to answering some of the most fundamental questions about the nature of our universe. The discovery that neutrinos have mass, contrary to what was previously thought, has revolutionized our understanding of neutrinos in the last two decades while raising new questions about matter, energy, space and time. Neutrinos may play a key role in solving the mystery of how the universe came to consist of matter rather than antimatter. They could also unveil new, exotic physical processes that have so far been beyond our reach.
The LBNF neutrino beamline at Fermilab

What is LBNF?
The Long-Baseline Neutrino Facility will use Fermilab’s particle accelerators to create neutrinos and send them through the earth to a new, large, cutting-edge neutrino detector located almost a mile underground at the Sanford Underground Research Facility. The neutrinos will travel the 800 miles from Illinois to South Dakota straight through the earth – no tunnel is needed for these particles.

The LBNF neutrino beamline at Fermilab

At Fermilab, scientists have operated neutrino-producing facilities for more than 30 years. The LBNF neutrino beamline will steer protons from Fermilab’s Main Injector accelerator up a small hill (see graphic below) and then point the beam into the ground, toward the Sanford Lab. The protons will smash into a piece of graphite. The particles that emerge from these collisions will go into a 680-foot-long tunnel and generate neutrinos that travel in the same direction as the protons. Scientists would also build a state-of-the-art underground hall for the near detector of the Deep Underground Neutrino Experiment. The detector will measure the composition of the neutrino beam as it leaves the Fermilab site.

Traveling at close to the speed of light, the neutrinos will leave the Fermilab site at a depth of about 200 feet, continue straight through the earth and arrive at the Sanford Lab in South Dakota within a fraction of a second. Because neutrinos can travel through rock and all other matter, no tunnel is necessary for this 800-mile trip.

More information

- LBNF website: lbnf.fnal.gov
- DUNE website: dunescience.org
- Fermilab website: www.fnal.gov

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Or send e-mail to the LBNF/DUNE project team: lbnf-communication@fnal.gov

The DUNE particle detector at Sanford Lab

How will DUNE revolutionize neutrino research?
The Deep Underground Neutrino Experiment aims to transform our understanding of neutrinos and their role in the universe. In particular, scientists want to discover whether neutrinos are the reason the universe is made of matter. DUNE also will look for neutrinos coming from the explosion of a star to record the formation of a neutron star or a black hole in real time. And DUNE could move us closer to realizing Einstein’s dream of a unified theory of matter and energy by observing the rare process of a proton spontaneously decaying into other particles.

The neutrino detector at Sanford Lab

The DUNE neutrino detector at the Sanford Underground Research Facility will reside in a large underground complex to be excavated by the LBNF project on the 4850-foot level, near the Ross shaft. This deep location will shield the detector from the cosmic rays that bombard the Earth, increasing the detector’s capability to identify rare interactions of neutrinos and other particles.

The detector will be filled with almost 70,000 tons of liquid argon, a material similar to helium, but heavier. Like helium, argon must be cooled to remain liquid. Cryogenic equipment will be installed in the cavern to cool argon to minus 350 degrees Fahrenheit. The particle detector will record the arrival of the neutrinos from Fermilab or a distant star explosion by measuring the rare interactions between neutrinos and the argon atoms. It will transmit the signals to computers for storage and analysis. It will take about a decade to collect enough data to make the hoped-for discoveries that will revolutionize our understanding of the universe.

More information

- LBNF website: lbnf.fnal.gov
- DUNE website: dunescience.org
- Fermilab website: www.fnal.gov

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