Fermilab

The Science of NOνA

Neutrinos are everywhere!

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. Unimaginably large numbers of neutrinos from the first moments of the universe are still present today.

Neutrinos help to shape our universe

Nuclear reactions make the sun shine, producing neutrinos. Neutrinos shaped the evolution of galaxies and the distribution of galaxies throughout the cosmos. To understand the universe, we must understand neutrinos.

The Neutrino Revolution

Science often proceeds slowly, but the past 20 years have brought a revolution in neutrino physics including:

- The observation that neutrinos change, or oscillate, from one type to another
- The discovery that neutrinos have mass
- The observation of neutrinos from a supernova explosion
- A consistent understanding of the number of neutrinos coming from the sun

The Fundamental Questions

Neutrino Oscillations
We now know that neutrinos oscillate, but we have not yet observed and understood the full spectrum of oscillations. Unknown factors that govern neutrino oscillations have significant implications for our understanding of the universe.

Neutrino Mass
One of the most fundamental questions in particle physics today is why elementary particles have the masses that they do. The observation of neutrino mass has great significance for answering this question. We know that neutrinos have mass and we know that the masses are very, very small. However, we still do not know the masses of the different neutrino types, and we do not have complete knowledge of the neutrino mass ordering; that is, which neutrino is the lightest and which is the heaviest.

Symmetry Between Matter and Antimatter
The big bang should have created equal amounts of matter and antimatter, yet today, there is only matter. Some scientists believe that this puzzling phenomenon is tied to the properties of neutrinos.

The NOνA Experiment

The NOνA experiment is designed to answer fundamental questions in neutrino physics:

1. Can we observe the oscillation of muon neutrinos to electron neutrinos?
2. What is the ordering of neutrino masses?
3. What is the symmetry between neutrinos and antineutrinos?

NOνA is the only proposed experiment that can determine the neutrino mass ordering, and it will be the best experiment for addressing the first question, and for starting us on the road to answering the third one.

The NOνA Detectors

NOνA consists of a 200-ton detector on the Fermilab site (near detector) and a 15,000 ton detector in Northern Minnesota (far detector). The neutrinos that reach the far detector must pass through the earth before emerging in Minnesota. The far detector is located along the last East-West road before the Canadian border, to obtain the longest distance possible for neutrinos to travel between detectors. This long baseline increases NOνA's sensitivity to the neutrino mass ordering.

NOνA uses liquid scintillator contained in rigid, highly reflective PVC cells to detect neutrino interactions. The charged particles produced by the neutrino interaction inside the detector cause the liquid scintillator to produce light that is captured by optical fibers and carried to light-sensitive detectors.