

IceCube expands neutrino search to spot fainter signals

A major upgrade to the 15-year-old detector will aid in the study of neutrino oscillations.

By **Jenessa Duncombe**



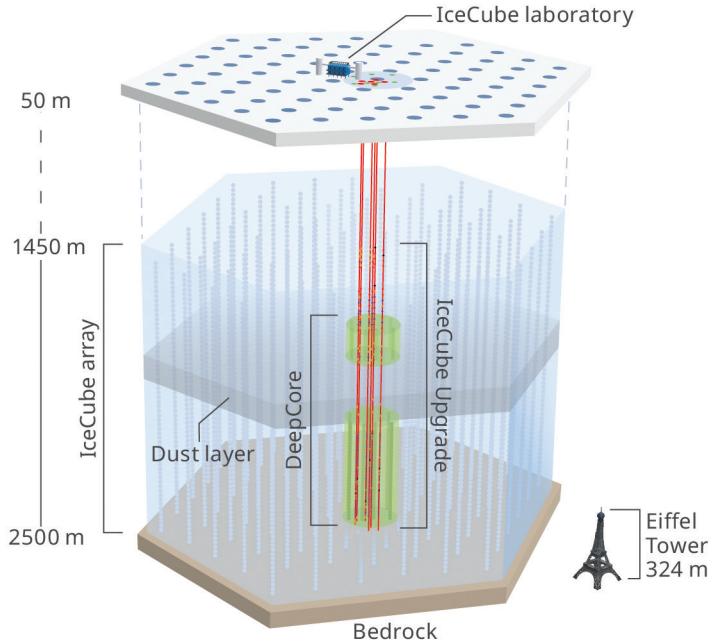
▲ The Sun rises over the IceCube Upgrade drill camp near the Amundsen–Scott South Pole Station in Antarctica. (Photo by Ilya Bodo, IceCube/NSF.)

Originally built for measuring energetic neutrinos from distant galaxies, the IceCube Neutrino Observatory has been fitted with more than 600 new sensors for detecting lower-energy neutrinos from closer to home. The

\$55 million IceCube Upgrade, which was completed in February, will enable researchers to closely analyze the flavor oscillations of neutrinos that are produced when cosmic rays collide with nuclei in Earth's atmosphere.

IceCube is a 1 km³ Cherenkov

detector near the geographic South Pole. Its more than 5000 photosensors are buried in the ice roughly 1.5–2.5 km deep. At such depths, no air bubbles cloud the ice. Collisions of neutrinos with atoms in the ice produce energetic muons, electrons, or tau leptons and other



◀ IceCube's new sensor array, called IceCube Upgrade, is located at the center of the detector. Six new vertical strings, shown in red, have more than 600 sensors that are two to three times more sensitive to light than IceCube's older ones. (Image by the IceCube Collaboration.)

particles that result in flashes of blue-tinted Cherenkov radiation propagating through the icy darkness.

The closer together and more sensitive the sensors, the lower the energy of the original neutrino that IceCube can detect. DeepCore, IceCube's most densely spaced sensor array, detects roughly 100 atmospheric neutrino events per day at energy levels above 5 GeV. The new sensor array and DeepCore together should enable the detection of about 600 events per day at energy levels above 1 GeV. "With the upgrade, we will not only see more events, but we will have a much better chance to analyze them and determine the neutrino's direction, energy, and flavor correctly," says Albrecht Karle, the lead scientist for IceCube's upgrade.

As neutrinos travel, they oscillate between flavors: tau, muon, and electron. Studying the oscilla-

tions can reveal deeper truths about the particles, including the relative sizes of the three mass eigenstates that contribute to the three observed flavors. Two of the masses are close in size, and it's unclear whether the third mass is larger or smaller than the other two. This is known as the neutrino mass-ordering problem.

Tau neutrinos are hypothesized to appear at different levels in IceCube's detector depending on the mass-ordering solution. Karle says IceCube could publish its first mass-ordering result after three years of data collection. (See *PT*'s 2025 story "Next-generation underground neutrino detector in China up and running" to read about another mass-ordering experiment.)

At least 90% of IceCube's new sensors have frozen into the ice, says Karle, and the others will soon. The new sensors are two to three times as sensitive to light as Ice-

Cube's older ones. He expects regular data collection to begin midyear.

NSF contributed about 70% of the funds for the update; additional support came from Germany, Japan, South Korea, and Sweden. IceCube is operated by the University of Wisconsin–Madison and has more than 450 collaborators across 14 countries. (To read about IceCube's broader scientific goals, see the 2008 *PT* feature "Astronomy and astrophysics with neutrinos," by Francis Halzen and Spencer Klein.)

"We passed our entrance exam with the successful deployment of the upgrade," says Francis Halzen, the head scientist of IceCube. Now he's awaiting NSF's decision on initiating a much bigger build-out. Called IceCube-Gen2, the \$500 million proposed project would enlarge IceCube's effective volume 10-fold and expand its search for extremely high-energy neutrinos. **PT**