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Flashback to the Future

IceCube Captures its First Two Neutrino Events

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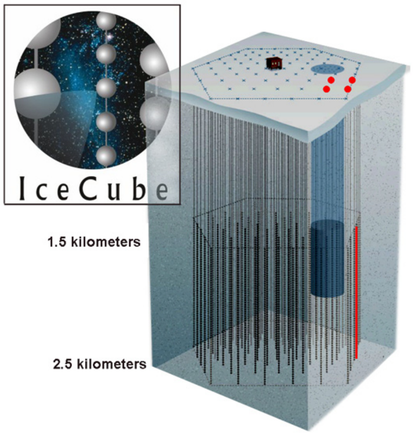


IceCube is an observatory for studying high-energy neutrinos. With its light-detecting gear buried more than a mile beneath the Antarctic ice cap, IceCube uses planet Earth to filter out the noise of unwanted particles.

More than 100 researchers representing 26 scientific institutions from the United States, Europe, Japan, and New Zealand are building IceCube, a huge neutrino observatory at the South Pole that has already registered its first two catches.

"This shows that the hardware and electronics are working as designed, and, in some areas, considerably better than called for in the design specifications," says Spencer Klein, an astrophysicist who heads the physics analysis team for Lawrence Berkeley National Laboratory, one of the institutions participating in the IceCube collaboration.

The high-energy neutrinos IceCube is designed to study are subatomic particles with very small mass and no electrical charge, originating in exploding stars, black holes, and other high-energy sites in the Milky Way and beyond. Because neutrinos travel to Earth virtually unobstructed, they can be used by scientists to "see" into regions of space otherwise obscured by dust or other matter.

Such observations should provide new insight into the nature of dark matter, the origin of cosmic rays, the source of gamma-ray bursts, and other cosmic issues. With the few detector strings now in place, IceCube has already proved it can catch neutrinos; when completed in 2011, IceCube will feature more than 75 strings, each two and a half kilometers long. Each string consists of an electrical cable connecting 60 digital optical modules (DOMs) with the surface, operating at depths from 1,450 to 2,450 meters deep. Distributed throughout more than a cubic kilometer of Antarctic ice, the DOMs will be able to measure neutrino energies ranging from 100 billion to a quadrillion or more electron volts.

A DOM consists of a pressurized glass sphere the size of a basketball, housing an optical sensor called a photomultiplier tube that can detect photons and convert them into electronic signals. Equipped with onboard control, processing, and communications hardware and software, each DOM acts like a minisatellite. Berkeley Lab scientists designed the unique electronics packages inside the DOMs, which enable IceCube to pick out the rare signal of a high-energy neutrino colliding with a molecule of water.

Digital Optical Modules (DOMs) detect signals generated by neutrino collisions in the ice.

IceCube will detect particles of many kinds coming from all directions, but since neutrinos are the only ones able to pass untouched through the entire planet, Earth serves as a filter to screen out all the other kinds coming from below.

Innumerable neutrinos pass through the Earth each second like ghosts, interacting with nothing. Once in a rare while, though, a neutrino will collide with an atom. This generates a muon, a subatomic particle resembling a heavy electron.

If the collision happens in ice or water the muon emits blue light called Cherenkov radiation, since it is travelling faster than the speed of light in water. IceCube's DOMs can detect this radiation through the clear South Pole ice.

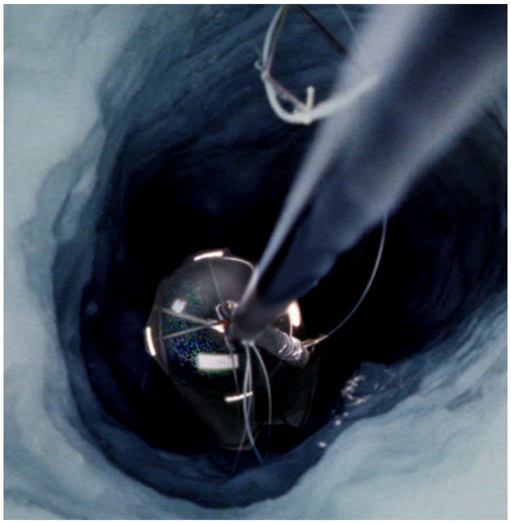
By measuring the intensity and arrival time of the light flashes as the muon travels through the array of detectors, scientists can reconstruct its direction and energy. Knowing the direction is critical for separating a muon generated by a cosmic neutrino from the million-times more numerous downward-traveling muons generated by cosmic rays in the atmosphere.

The First Two Years

Francis Halzen, a University of Wisconsin-Madison professor of physics who is the principal investigator for IceCube, says the first string of DOMs performed “like a Swiss watch” in their first full year. Despite a 10-day delay at the start of the 2005-2006 austral season, which runs from November to mid-February, eight more strings were added, bringing the total to 540.

Holes in the ice 2,500 meters deep are made by five-megawatt hot water drills. In the 2005-2006 season two drill towers were used, enabling the drilling teams to start work on the next hole within three days of completing the previous one. By the end of the season the team was drilling a hole every four days. At that rate, and with an earlier start, 14 or more strings could be deployed in 2006-2007.

“Drilling eight new holes this past season was a significant achievement because it shows that we can drill and instrument holes at production speeds,” said Robert Stokstad, of Berkeley Lab’s Nuclear Science Division, who heads the Institute for Nuclear and Particle Astrophysics and is the leader of Berkeley Lab’s IceCube effort. “This was a key point in demonstrating the success of IceCube as a construction project.”

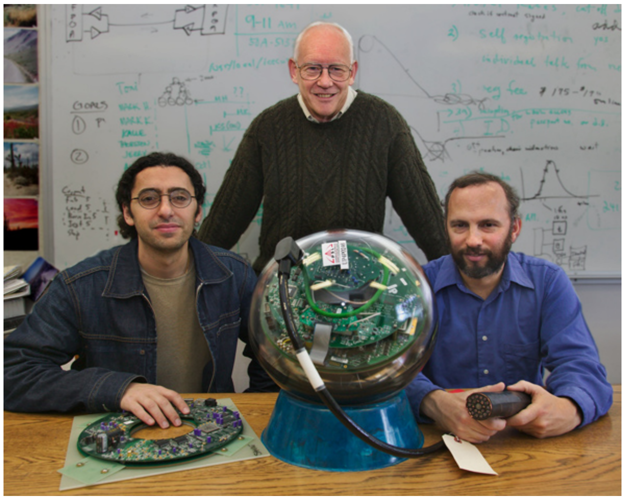


IceCube’s DOMs are connected in long strings of 60 each via an electrical cable, then lowered into holes drilled into the ice down to depths of 2.5 kilometers.

Construction of IceCube is projected to cost $272 million. The National Science Foundation will provide $242 million for the project, with an additional $30 million from Germany, Sweden, Belgium, Japan, New Zealand, the Netherlands, and the Wisconsin Alumni Research Foundation.

In addition to Berkeley Lab and the University of Wisconsin-Madison, other IceCube collaborating institutions from the United States are the University of California at Berkeley, the University of Maryland, Pennsylvania State University, the University of Wisconsin-River Falls, the University of Delaware, the University of Kansas, Clark Atlanta University, Southern University, the University of Alaska, and the Princeton Institute for Advanced Study.

More than 30 Berkeley Lab scientists and engineers have been involved in the project. Leaders include Klein; Stokstad; astrophysicist and IceCube Operations manager Azriel Goldschmidt of the Nuclear Sciences Division; William Edwards of the Engineering Division, who is the Berkeley Lab project manager; and David Nygren of the Physics Division, an expert in particle detection. Nine Berkeley Lab researchers traveled to the South Pole during the 2005-2006 season to participate in IceCube’s deployment and testing; in addition to Klein and Edwards they were Keith Beattie, David Hayes, Arthur Jones, Chuck McParland, Jerry Przybylski, Mike Solarz, and John Jacobsen, representing the Nuclear Science, Physics, Engineering, and Computational Research divisions.



Azriel Goldschmidt, Bob Stokstad, and Spencer Klein (photo Roy Kaltschmidt, CSO)

This is an edited version of an article appearing in the March, 2006 edition of Science@Berkeley Lab, the online science magazine of Lawrence Berkeley National Laboratory. The full-length version, including links to further information, may be accessed at http://www.lbl.gov/Science-Articles/Archive/sabl/2006/Mar/07-IceCube.html.