Sanford Underground Research Facility

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Deep Thoughts

Notes from the underground by Communications Director Constance Walter

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Pushing the frontiers of science

Artwork by Sandbox Studio, Chicago, with Ana Kova courtesy Symmetry Magazine.

In the 1960s, Ray Davis Jr., a chemist from Brookhaven National Laboratory, began counting neutrinos deep underground at the Homestake Mine in Lead, S.D. As he began collecting data, he realized he was seeing only one-third the number of neutrinos that had been predicted. Nearly 30 years later, the answer to the so-called "solar neutrino problem" was discovered: neutrinos occasionally oscillate, or change flavors as they travel to detectors on earth.

"We know there are three flavors of neutrinos—electron, muon and tau," said Mark Thomson, a professor of physics at the University of Cambridge. When a neutrino interacts with matter, which happens very rarely, it produces one of those particles. However, when neutrinos are fired over very long distances, sometimes you see the "wrong" type of particle, which means the neutrino has changed flavor (for example, what starts out as a muon neutrino oscillates into an electron neutrino).

"Before the discovery of neutrino oscillation, we thought neutrinos were quite dull particles. We didn't believe they had mass and they didn't seem to do much," said Thomson, a co-spokesperson with DUNE (Deep Underground Neutrino Experiment). "Pretty much everything we know about neutrinos today comes from the discovery of this phenomenon," Thomson said.

Neutrinos are tiny, almost massless particles that behave very strangely, making them very difficult to study. Scientists with DUNE hope that by studying neutrino oscillation, they will learn more about the universe in which we live.

The universe is made up of matter, but it wasn't always that way. During the Big Bang, equal amounts of matter and anti-matter were created, annihilating each other as they collided. But somewhere along the line, matter became more prevalent, producing stars, planets, intergalactic gases and life.

"Neutrino physics could be the key to how that whole process happened," Thomson said. "We want to find conclusive evidence that neutrinos behave differently from their antimatter particles."

DUNE plans to shoot the most powerful beam of neutrinos ever produced 800 miles through the earth from Fermilab in Illinois to massive liquid argon detectors deep underground at Sanford Lab. That distance, Thomson said, is critical. "The greater the distance, the better you can study the properties of neutrinos."

The placement of DUNE nearly a mile underground, has other implications as well. If there were a core-collapse supernova in the Milky Way, DUNE could observe thousands of neutrinos, allowing us to see the formation of a neutron star and, potentially, the birth of a black hole. "We'd have to be pretty lucky to see that, actually," Thomson said. "But you never know. If we did, we'd learn a lot."

DUNE collaborators will also look for proton decay, an incredibly rare event that could open a window into a grand unified theory, in which three of the four fundamental forces of nature—electromagnetism, the weak force and the strong force—merge.

"Basically, that says we can treat all particles the same and all of the forces in one common way. They just manifest differently. We're building an experiment with more power and precision than has ever been done before," Thomson said. "We're pushing the frontiers of science. We could see something completely surprising."

Deeptalks *Science on the Road*

Mike Headley and Jaret Heise will discuss Big Science, Big Impacts at the Hill City School this evening at 7 p.m. On Feb. 9 at 6 p.m. at the Sanford Lab Homestake Visitor Center, Bryce Pietzyk will talk about underground access at the Sanford Lab.