In former gold mine, scientists lie in wait for dark matter

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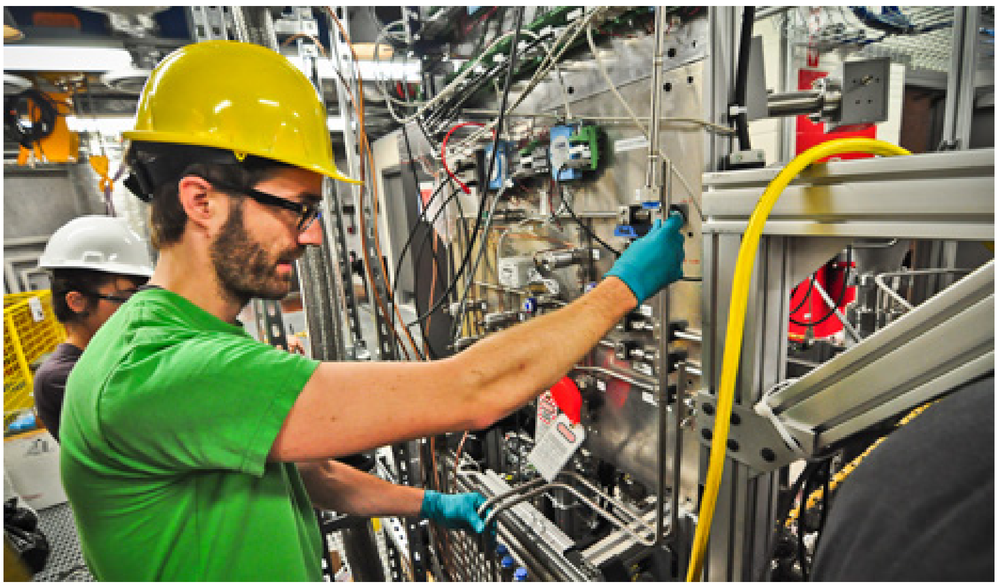

Scientists are hunting for dark matter deep underground in South Dakota. Here, Yale postdoctoral researcher Markus Horn works on the LUX collaboration's xenon gas system, part of an elaborate experiment to capture dark matter particles for the first time. Credit: C.H. Faham/Brown University

(Phys.org) —Nicole Larsen, a fifth-year graduate student at Yale, couldn't talk by phone. "I'm 4,850 feet below the surface," she said, by Skype, on a recent afternoon.

Over the summer Larsen, a particle physicist, spent most of her daylight hours at the bottom of an old gold mine in the Black Hills of South

Dakota, 50 miles northwest of Mount Rushmore and a 30-minute drive from the nearest supermarket. She was helping to hunt for dark matter, a mysterious substance estimated to make up as much as 85% of the universe's total matter.

Scientists have inferred dark matter's existence, but never detected it directly. Teams of researchers around the world are racing to be the first, including Larsen's, a collaboration known as the Large Underground Xenon dark matter experiment, or LUX.

"Knowing more about dark matter will give us ideas about the future of our planet, galaxy, and universe," she said from the former Homestake gold mine, nearly a mile inside Earth. "This search has implications for how the universe got to be the way it is and for what's going to happen to us in the future as well."

About a dozen Yale researchers are now involved in LUX. The full collaboration involves more than 100 researchers from 17 institutions. Daniel McKinsey, an associate professor of physics at Yale and one of LUX's senior scientists, leads the Yale contingent and serves as the collaboration's co-spokesman. On Oct. 30 LUX plans to release its first results.

"Dark matter is one of the huge mysteries of modern science," McKinsey said. "Its effects are widespread in the universe. Knowing its properties would be revolutionary for particle physics."

Less than 15% of the universe is made up of conventional matter—protons, neutrons, electrons. Most of the rest is thought to be dark matter, which cannot be seen or felt, and seems to interact weakly, if at all, with conventional matter. (Hence the nickname for dark matter particles—WIMPs, or weakly interacting massive particles.) Identifying the raw material of the universe is a high priority for physicists and astronomers.

Scientists have inferred its existence from the behavior of known entities, such as galaxies. Conventional matter cannot explain the ability of galaxies to keep their form while rotating at current speeds, for example. Dark matter may provide the extra mass that would make this possible.

In a one-of-a-kind laboratory at the bottom of the Homestake mine, in Lead, S.D., the LUX scientists have designed and built a sophisticated device for taking dark matter's fingerprint. It's about the size of a telephone booth and called a liquid xenon detector.

Xenon is one of the noble (or rare) gases. Its high density in liquid form is useful for catching subatomic particles moving at high speeds, as dark matter is believed to be. A vat of liquid xenon equipped with arrays of ultra-sensitive light detectors sits in a tank of water. The researchers believe that dark matter particles, which can penetrate deep into the earth, will collide with xenon atoms and bounce off their nuclei, jarring the xenon and generating a fluorescence the detector has been designed to notice.

The layers of rock surrounding the lab are intended to help minimize interference by various particles that endlessly bombard earth's surface. These particles, such as high-energy neutrons and muons, would make it harder for scientists to discern the presence of dark matter particles—a difficult task as it is.

"It's like trying to spot a single snowflake in a blizzard or hear a single voice in Times Square," said McKinsey. "You're digging a signal out of a lot of noise."

And digging for something akin to physics gold: "Because the dark matter particle would be a 'new' particle," McKinsey said, "it would also be the first particle discovered outside of the Standard Model of particle physics," the prevailing theory that describes the fundamental particles of matter and how they interact.

McKinsey's group has played an important role in the collaboration, with primary responsibility for several of the detector's major components, including the all-important xenon gas circulation, purification, and recovery systems. "We need the xenon to be exceptionally pure—sub part-per-billion levels of impurity," he said recently. Much of the team's work has taken place in South Dakota, and nearly every member has worked in the mine's lab, known as known as the Sanford Underground Research Facility, or at a surface lab nearby. Important projects have also been carried out in New Haven, where the team invented some essential technologies from scratch. McKinsey and his squad of postdocs, graduate students, and undergraduates shuttle back and forth between coastal Connecticut and South Dakota's Black Hills.

To reach the two-story subterranean lab at Lead, researchers ride an elevator they call "the cage." Wearing coveralls, hard hats, and steel-toe boots, they load into it at 7:15 a.m. for a prompt 7:30 departure. The ride takes about 10 minutes. When they exit at bottom, a glance to the left reveals a dark, muddy hole, an abandoned passageway for the gold miners of yesteryear. The scientists all go right, into a high-grade science lab flooded in fluorescent light.

"Once we detect dark matter, assuming we one day do, there's a gazillion other experiments we can do to understand it better," said McKinsey. "The key is seeing it first."

Provided by Yale University