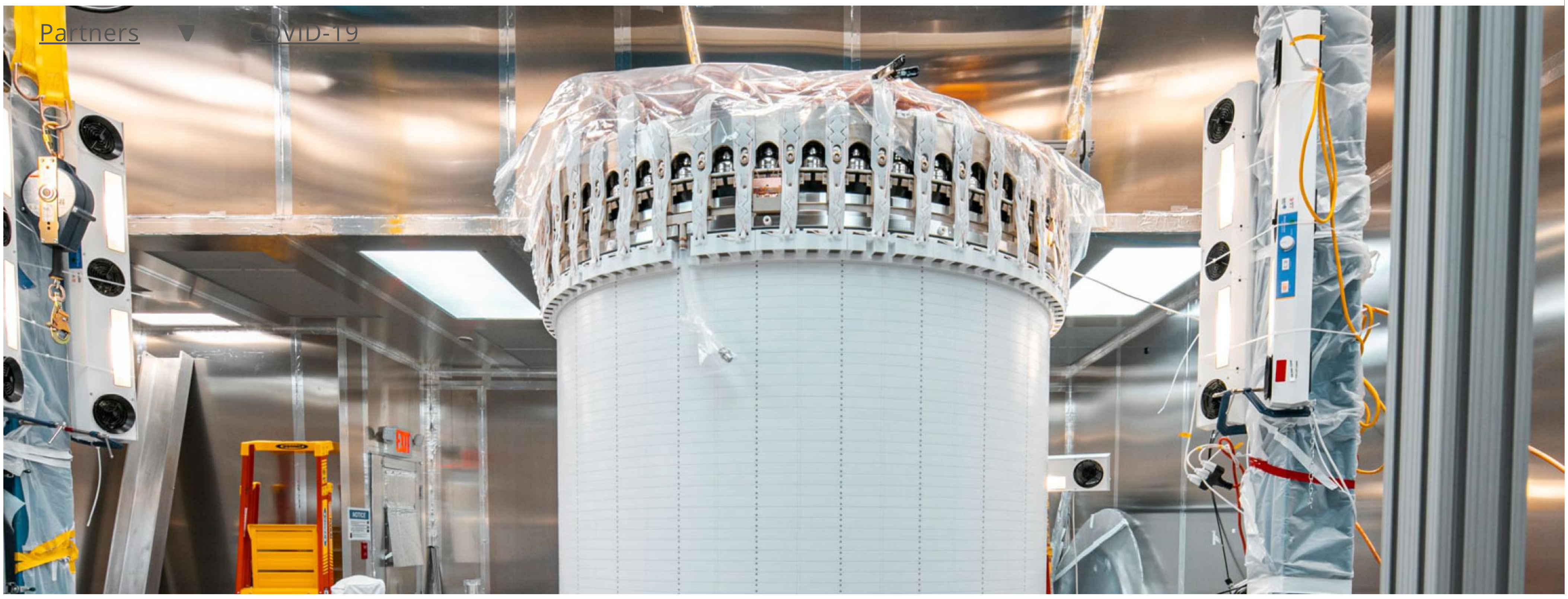

News

Dark matter detector completes startup operations

The LUX-ZEPLIN experiment, which includes Penn State researchers, has completed its initial run and is poised to detect the mysterious particles

7 July 2022

Deep below the Black Hills of South Dakota in the Sanford Underground Research Facility (SURF), an innovative and uniquely sensitive dark matter detector—the LUX-ZEPLIN (LZ) experiment—has passed a check-out phase of startup operations and delivered its first results. The LZ experiment, which is designed to observe the mysterious and as-yet-undetected phenomenon known as dark matter, is led by Lawrence Berkeley National Lab (Berkeley Lab) in conjunction with an international team of 250 scientists and engineers from over 35 institutions including Penn State.

“Dark matter is a fundamental part of the universe, but because it does not emit, absorb, or scatter light, it cannot be observed in conventional ways,” said **Carmen Carmona-Benitez**, assistant professor of physics and the LZ principal investigator at Penn State. “I’m thrilled to see this complex detector ready to address the long-standing mystery of what dark matter is made of. The LZ team now has in hand the most ambitious instrument to do so!”

The Liquid Xenon Time Projection Chamber (TPC), the heart of the LZ detector, in the clean room before assembly inside the titanium cryostat. Credit:

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Dark matter's presence and gravitational pull are fundamental to our understanding of the universe. For example, the presence of dark matter, estimated to be about 85 percent of the total mass of the universe, shapes the form and movement of galaxies, and it is invoked by researchers to explain what is known about the large-scale structure and expansion of the universe.

Dark Matter particles have never actually been detected—but perhaps not for much longer. The countdown may have started with results from LZ's first 60 "live days" of testing. These data were collected over a three-and-a-half-month span of initial operations beginning at the end of December. This was a period long enough to confirm that all aspects of the detector were functioning well.

In a paper posted online July 7 on the **experiment's website** and the online preprint archive arXiv.org, LZ researchers report that with results from the initial run, LZ is the world's most sensitive dark matter detector.

"We plan to collect about 20 times more data in the coming years, so we're only getting started," said LZ Spokesperson Hugh Lippincott of the University of California Santa Barbara. "There's a lot of science to do and it's very exciting!"

An underground detector

A variety of cosmic particles collide with the Earth on a regular basis, and LZ is designed to detect theorized dark matter particles known as weakly interacting massive particles (WIMPs). The experiment is located about a mile underground to protect it from cosmic radiation at the Earth's surface that could drown out dark matter signals.

Carmen Carmona-Benitez, assistant professor of physics and the LZ principal investigator at Penn State, and Luiz de Viveiros, assistant professor of physics, one mile underground at the start of construction of the Sanford Underground Research Facility (SURF) where the LZ detector is located. Credit: Simon Fiorucci, Berkeley Lab.

The heart of the LZ dark matter detector is comprised of two nested titanium tanks filled with ten tons of very pure liquid xenon. When particles collide with xenon atoms, they produce visible scintillation or flashes of light, which are recorded by two arrays of photomultiplier tubes (PMTs), explained Aaron Manalaysay from Berkeley Lab who, as LZ physics coordinator, led the collaboration's efforts to produce these first physics results, including calibration, understanding of the detector response, and sensitivity.

"Considering we just turned it on a few months ago and during COVID restrictions, it is impressive we have such significant results already," Manalaysay said.

The collisions will also knock electrons off xenon atoms, sending them to drift to the top of the chamber under an applied electric field where they produce another flash permitting spatial event reconstruction.

"The characteristics of the light signals help determine the types of particles interacting in the xenon, allowing us to separate backgrounds and potential dark matter events," said **Luiz de Viveiros**, assistant professor of physics at Penn State, whose team is responsible for modeling and monitoring background signals in the detector.

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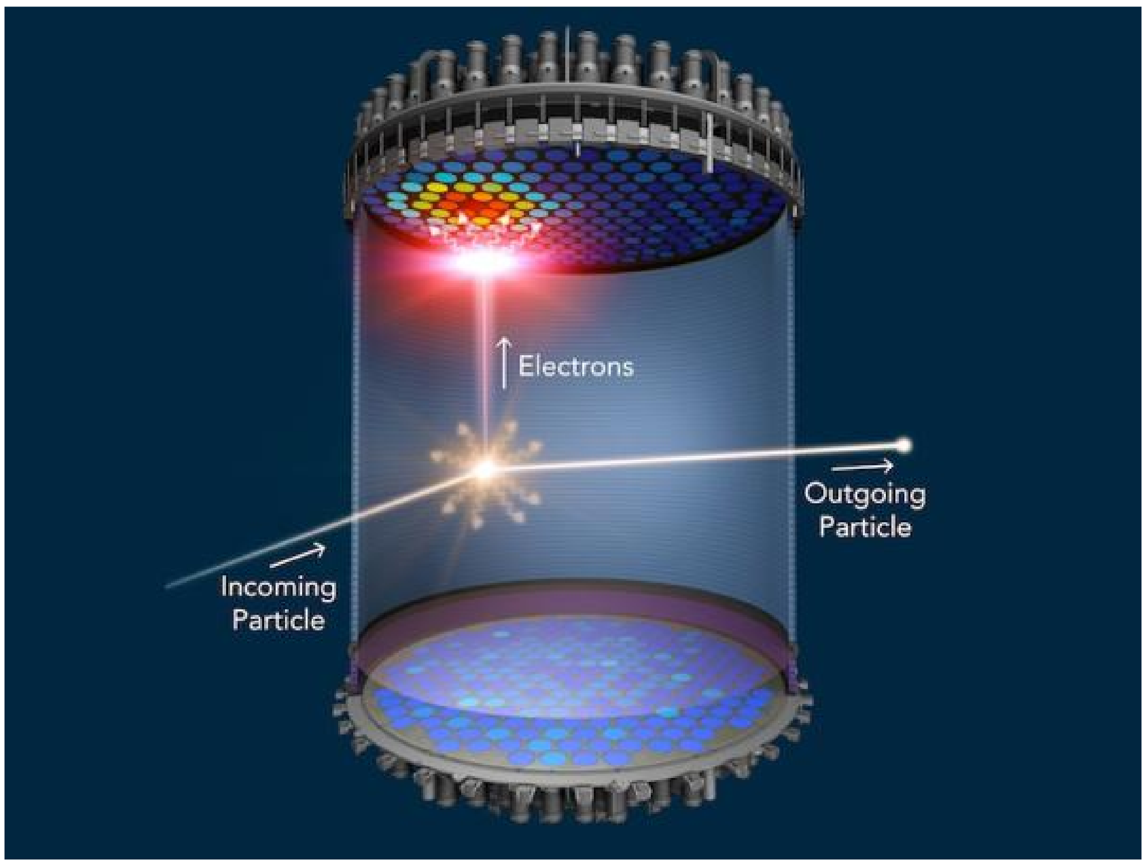

Diagram of Event in the LZ detector. An incoming particle interacts with a xenon atom, producing a small flash of light and electrons, which are extracted at the top of the detector and produce additional light. The flashes of light are detected by the top and bottom photomultiplier tube (PMT) arrays and provide clues as to the incoming particle's makeup. Credit: LZ/SLAC

A successful start

“Lots of subsystems started to come together as we started taking data for detector commissioning, calibrations and science running. Turning on a new experiment is challenging, but we have a great LZ team that worked closely together to get us through the early stages of understanding our detector,” said **David Woodward**, assistant research professor of physics at Penn State and the experiment run coordinator.

The take home message from this successful startup: “We’re ready and everything’s looking good,” said Berkeley Lab Senior Physicist and past LZ Spokesperson Kevin Lesko. “It’s a complex detector with many parts to it and they are all functioning well within expectations,” he said.

Carmen Carmona-Benitez, assistant professor of physics and the LZ principal investigator at Penn State, and David Woodward, assistant research professor of physics and the experiment run coordinator, working on LZ components in the cleanroom of the Penn State lab. Credit: Gavin Cox, Penn State

The design, manufacturing, and installation phases of the LZ detector were led by Berkeley Lab project director Gil Gilchriese. The LZ operations manager, Berkeley Lab’s Simon Fiorucci, said the onsite team deserves special praise at this startup milestone, given that the detector was transported underground late in 2019, just before the onset of the COVID-19 pandemic. He said with travel severely restricted, only a few LZ scientists could make the trip to help on site. The team in South Dakota took excellent care of LZ.

"I'd like to second the praise for the team at SURF and would also like to express gratitude to the large number of people who provided remote support throughout the construction, commissioning and operations of LZ, many of whom worked full time from their home institutions making sure the experiment would be a success and continue to do so now,” said Tomasz Biesiadzinski of the SLAC National Accelerator Laboratory and the LZ detector operations manager.

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With confirmation that LZ and its systems are operating successfully, Carmona-Benitez said, it is time for full-scale observations to begin in hopes that a dark matter particle will collide with a xenon atom in the LZ detector soon!

LZ is supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics and the National Energy Research Scientific Computing Center, a DOE Office of Science user facility. LZ is also supported by the Science & Technology Facilities Council of the United Kingdom; the Portuguese Foundation for Science and Technology; and the Institute for Basic Science, Korea. Over 35 institutions of higher education and advanced research provided support to LZ. The LZ collaboration acknowledges the assistance of the Sanford Underground Research Facility.

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