An Overview of the LUX-ZEPLIN (LZ) Dark Matter Experiment

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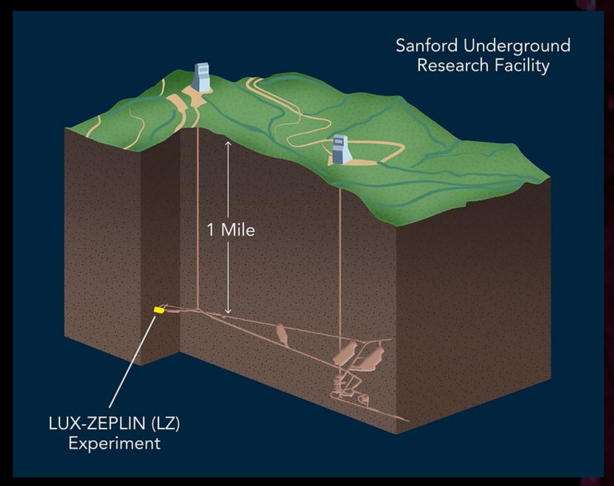
Introduction

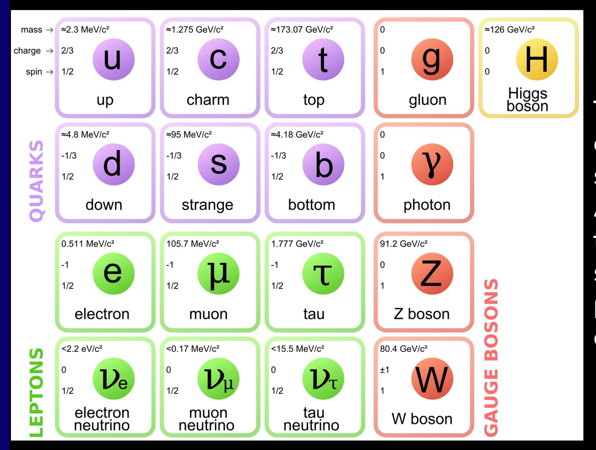
- 85% of all matter in the universe is made up of Dark Matter, the other 15% makes up everything we can see. The LUX-ZEPLIN (LZ) is an ongoing experiment conducted at the Sanford Underground Research Facility (SURF) in Lead, SD. It is hosted approximately 1 mile underground in the Davis Campus.

The Davis Campus' name pays homage to Ray Davis. This is an image of him standing inside his LUX underground neutrino experiment which he ultimately won a nobel prize for.

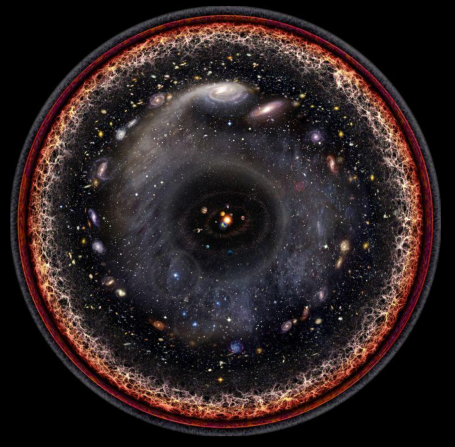


3D Image of SURF depicting where the LZ experiment is held 4850 feet underground.

- This experiment attempts to directly detect Weakly Interacting Massive Particles (WIMPs) in order to find evidence of Dark Matter. This type of matter does not interact with light, hence the term Dark Matter. If experimentally discovered, a WIMP would show that there is physics beyond the current standard model of particle physics.



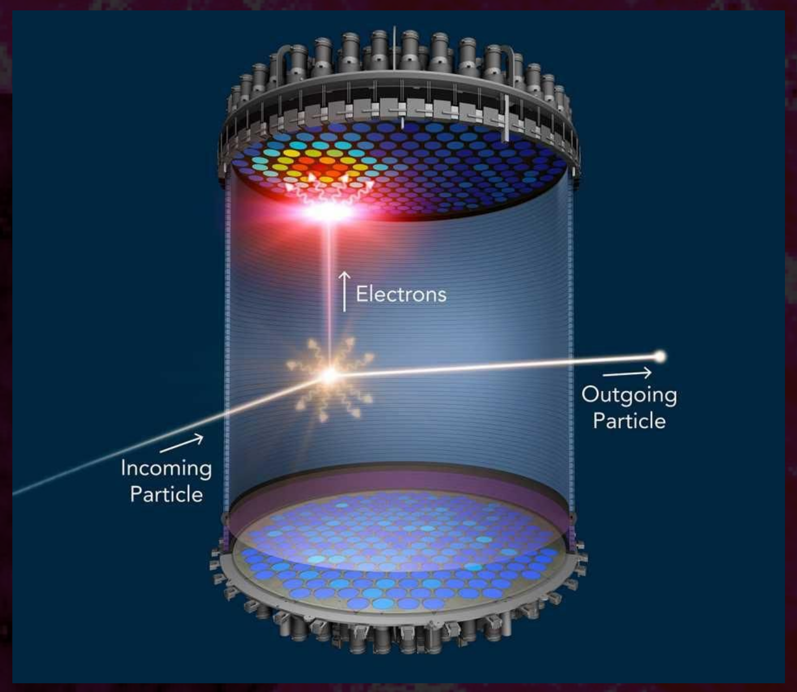
This is a chart of all known elementary particles dubbed the standard model of particle physics. A WIMP discovery would show that there is physics beyond this standard model, a very exciting possible outcome for the experiment .



A better understanding of Dark Matter will give us a greater idea of what will happen with our universe in the future and what has already happened to it in the past. Depicted here is an artist's rendition of the observable universe by Pablo Carlos Budassi.

How the LUX-ZEPLIN (LZ) Experiment Works

- The TPC sits in the heart of the detector and will contain 7 tonnes of active liquid xenon. Here, a WIMP is expected to interact with a xenon nucleus through nuclear recoil. This creates a burst of light called a scintillation (S1 signal). Which is then followed by another scintillation (S2 signal) that comes from an electric charge after going through an electroluminescence process.



This is an animated image of the TPC. Here, the S1 and S2 signals will be captured by PMT's (seen on the top and bottom of the TPC). S1 comes from a light signal produced by a nuclear recoil and S2 comes from the electric charge created by the collision of the WIMP and xenon nucleus.

- In order to stop neutrons from creating false positive signals, the TPC is surrounded by an Outer Detector (OD) to act as a "neutron net." One piece of the OD is the acrylic vessels (AVs). They contain liquid scintillator loaded with Gadolinium, GdLS (#2), that is necessary to detect neutron radiation which, left undetected, would mimic a WIMP's signal.
- The OD is comprised of a 25' diameter 20' tall water tank (#4). The water is put in place to shield the xenon in the TPC from gamma rays which would otherwise be picked up as background radiation. The reason this experiment is being done nearly a mile underground is also to shield from background radiation, mainly cosmic radiation, which the detector is sensitive to.

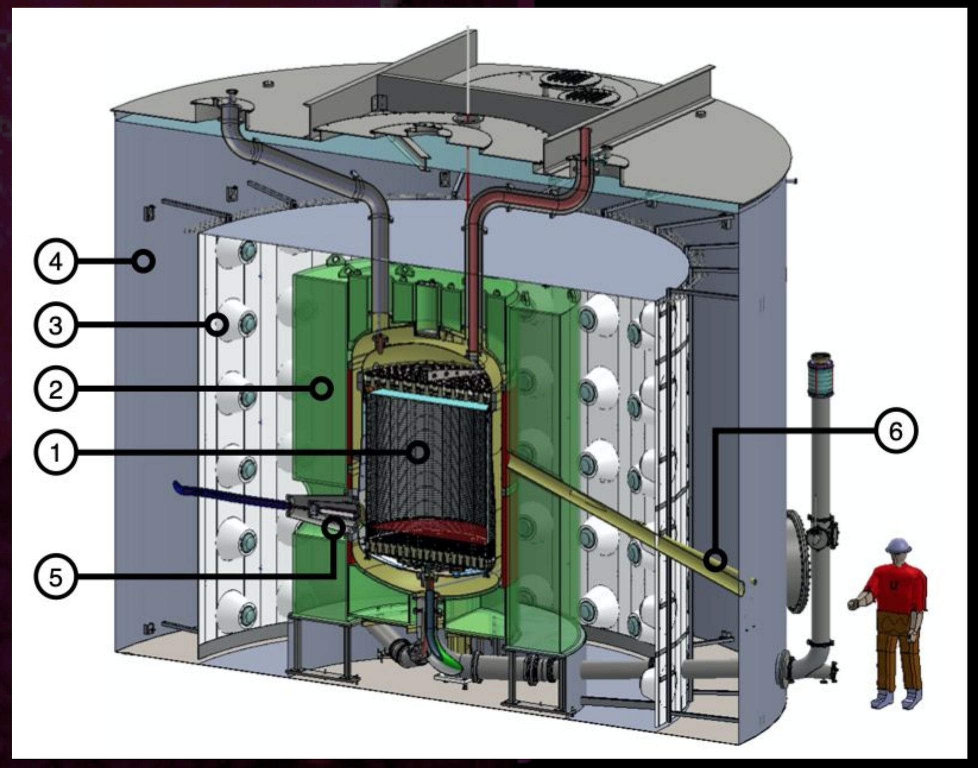


Image of the the LZ detector cut in half. 1) TPC where liquid xenon is stored. 2) Gadolinium liquid scintillator used to tag neutrons. 3) Photomultiplier tubes used to capture light from reactions. 4) Water tank for gamma/neutron shielding.

References

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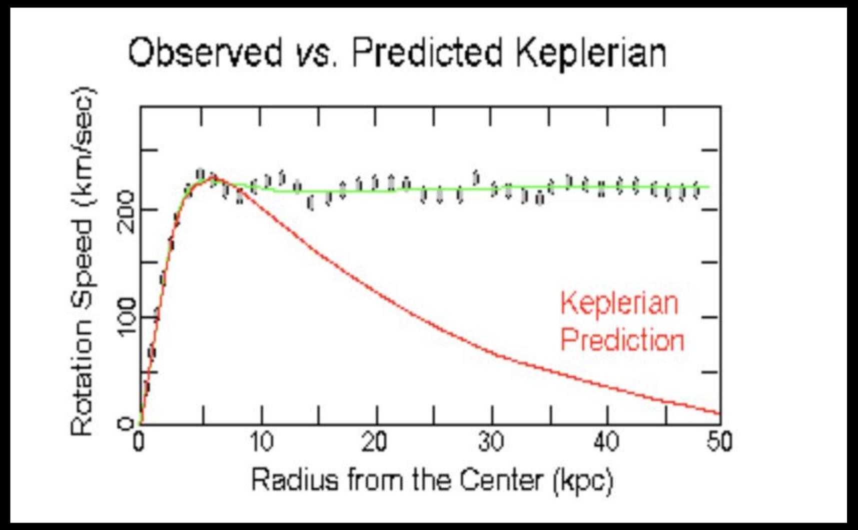
Evidence of Dark Matter

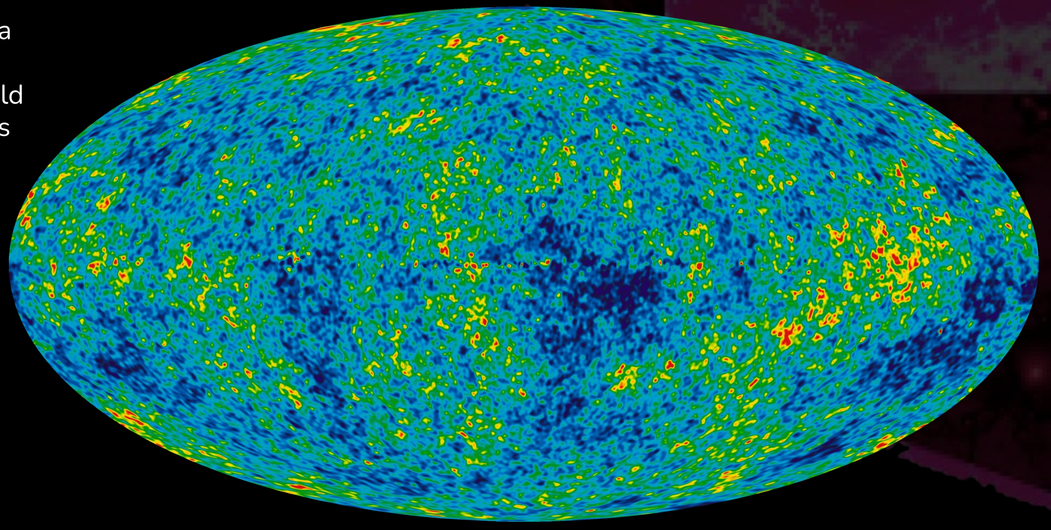
- In 2004, the strongest evidence we have on dark matter was found within the Bullet Cluster. The Bullet Cluster consists of two different galaxy clusters that collided. (Image to the right). Most of the mass in the collision in not interacting. This non-interacting matter is what we call a WIMP.

Composite image of Bullet Cluster made from Hubble, Magellan, and Chandra images.



The calculations of Rubin and Kent show that there is not nearly enough mass in a galaxy for it to 'stick' together in a Keplerian fashion. Observations show us that as distance from the center of a galaxy increases, the rotation speed starts to flatline after ~5 kpc. With all the matter we see in the Milky Way, the rotation rate should decrease with increasing distance. This begs the question, where is the the extra mass, and why does it hold the galaxy in a specific way?

- Before the Bullet Cluster, in the 1970's, American astronomers Vera Rubin and W. Kent Ford found evidence for Dark Matter. They noticed that the mass of the visible stars in a typical galaxy made up only about 10% of the mass required to keep the stars in orbit around the center of the galaxy.
- The Cosmic Microwave Background (CMB) can be mapped across the sky as a picture of the early universe. The temperature density of this map is not uniform, and the effects of dark matter are seen after calculations.



Calculations from the CMB show that 4.9% of the universe is made of ordinary atoms, 26.8% is made of dark matter, and dark energy makes up 68.3%.

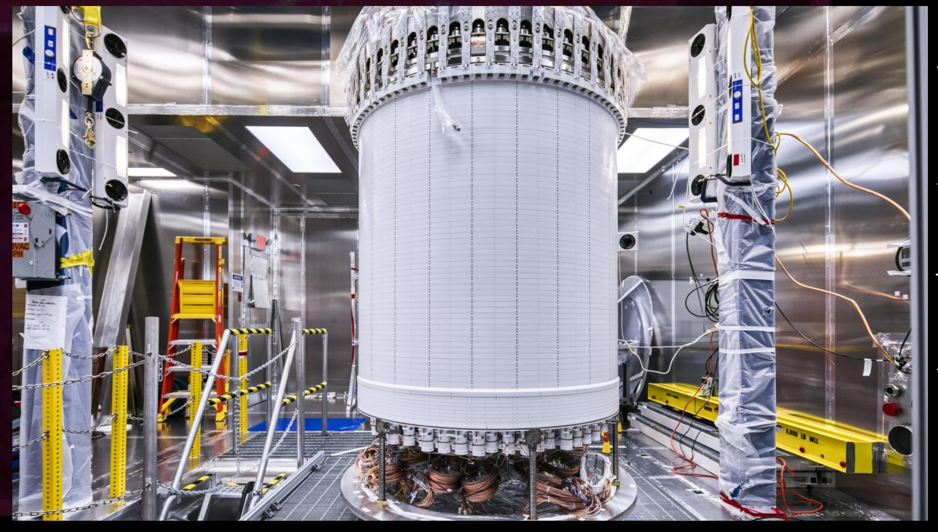
Work in the Davis Campus

- We were present during an assembly phase of LZ. It was our main job to assist in the commissioning of the outer detector. We also were given shifts to monitor and record values of different equipment running on the detector.
- Work commissioning the outer detector included helping out in the water room and the liquid nitrogen room. We were trained on how to run the water system which circulated purified water in and out of the detector. The liquid nitrogen room was where the filling of GdLS into the AVs took place. It was our job to deliver barrels weighing about 50 kg to a clean room where they could be emptied.

This is a photo taken at the 4850 level of the Big X, dubbed this because of two criss crossing pathways. We would meet here at the beginning of the day to discuss underground operations and safety protocols.

Jax Wysong in the Xenon Room. As the name implies, this is where all the xenon gas is staged that will eventually be moved into the TPC and condensed into liquid form. LZ uses about 10% of the world's annual production of xenon!

This was taken on the ground level of SURF right before our first trip underground. Behind us is the cage which lowers us to the 4850 level. Pictured from left to right is Keegan Harrison, Jake Booth, and Jax Wysong.



This is photo of the TPC before its implementation into the tank. Liquid xenon being kept in here is just waiting for a Dark Matter particle to interact with it. (Photo taken from Sanford Underground Research Facility website).

Jake Booth inside the liquid nitrogen room handling barrels of GdLS.