Questions and Answers for DNR CDMS Tours:
The Cryogenic Dark Matter Search

Q: What are you guys doing down there?
A: We are particle astrophysicists engaged in an experiment called CDMS (the Cryogenic Dark Matter Search) which is designed to look for the missing mass of the universe, also know as the “dark matter”. The basic idea is that tiny neutral particles may have been produced in the “big bang” which nearly fill space and pass right through us without being noticed. (By neutral, we mean the particles have no electric charge, otherwise they would be easily detected.) These particles could exist in sufficient numbers and have enough mass, equivalent to the mass of, say, a single iron atom, that they could account for most of the matter in the universe. Their total mass would be the dominant source of gravity that keeps stars orbiting around the centers of galaxies, our sun included. Part of what make this mystery so intriguing is that, surprisingly, the stuff that makes up everything we are familiar with, from the air we breath and the food we eat to the stars that shine in the night sky, is composed of the well-known particles named protons, neutrons and electrons. While other particles are known to exist, such as the neutrinos studied by our MINOS neighbors, and even more exotic ones can be made at Fermilab (the supplier of MINOS’ neutrinos), none of these could be the dark matter. So at the same time that we are searching for the missing mass – stuff that is responsible for the how the largest objects in the universe developed and evolve – we may also learn about the smallest objects yet studied, the subatomic particles known as WIMPs.

Q: Why is the experiment called CDMS?
A: CDMS stands for the Cryogenic Dark Matter Search. The ‘Dark Matter Search’ part of our name is described above, but why ‘Cryogenic’? The word cryogenic refers to things that are very cold. For us, this refers to our particle detectors, which must be operated at extremely cold temperatures to function properly, very close to ‘absolute zero’. Nowadays, a particle detector is any number of a variety of devices that detects particles using some sort of detector medium and some sort of sensor that provides an electrical signal that is typically recorded by a computer. One of the simplest types of particle detectors is the Geiger Counter, in which a thin wire (the sensor) is threaded in the center of a sealed metal tube filled with gas (the medium). A high voltage is applied to the wire so that when the particle to be detected collides with and ionizes gas atoms, a large electrical signal occurs. A CDMS detector works in a similar way, except that the medium is made of a solid (silicon or germanium) and one of the sensors is a very sensitive thermometer which detects the minuscule amount of energy that appears as heat when the particle to be detected collides with a single electron or atomic nucleus in the medium.

Q: What is the Dark Matter?
A: The dark matter refers to any and all of the stuff in the universe whose presence can be inferred through the effects of its gravity, but that can’t be seen directly because it does not emit or absorb light (or other forms of radiation). In some sense, the planet Pluto was once dark matter – before it was directly seen in a telescope, astronomers inferred its
existence because it exerted a gravitational tug on the orbit of Uranus. Over 70 years, the astronomer Fritz Zwicky, a contemporary of Edwin Hubble (discoverer of the expanding universe which led to the Big Bang theory), was studying the motion of galaxies. He found that they were moving much more rapidly than could be accounted for by the total strength of their mutual gravity. Simply put, it appeared that they should be flying apart, given how fast they were moving and how little matter was present to provide the gravity. In comparison, the gravity provided by the mass of the Sun is sufficient to account for the strength of gravity required to keep our planet Earth moving in its yearly orbit. So dark matter need not be invoked to account for the motion of the planets in our Solar System, but on larger scales – from our Milky Way Galaxy to large cluster of tens of thousands of galaxies similar to those studied by Zwicky, dark matter appears to be a very necessary ingredient.

Q: What is a WIMP?
A: WIMP is short for Weakly-Interacting Massive Particle, which refers to a hypothetical class of subatomic particles that have mass, and could therefore be the dark matter, but only have weak interactions. Only particles that interact more strongly, for example charged particles like protons and electrons, or particles that experience the so-called ‘strong force’ which keeps the atomic nucleus bound together, could collect and clump and form stars or other objects that can be seen in telescopes. The collective gravity of the mass of the WIMPs – if in fact they exist and there are enough of them – could account for the dark matter but their weak interactions would account for why they are so difficult to detect. Hopefully, WIMPs are plentiful enough and our detectors sensitive enough that we will be able to “see” them…

Q: Why do you think the Dark Matter is made of WIMPs?
A: We have very solid evidence that the universe is expanding and that in the past it was much more dense, compressed and hotter than today. We also have very good evidence that the same laws of physics that we study in the laboratory seem also to apply to our understanding of what took place when the universe was in this hot dense state. For example, based on nuclear physics that can be studied in controlled experiments in the laboratory, predictions were made as to how much of various nuclei such as hydrogen, helium and other light elements were synthesized in the early universe. Subsequent observations show that these predictions agree with the data. Based on the hypothetical properties of WIMPs – namely their mass and the weakness of their interactions – similar calculations can be done and show that a wide range of values can lead to a significant amount of dark matter. Moreover, the range of values corresponds to independent theoretical predictions from particle physics theories that address a set of issues completed unrelated to the question of dark matter.

Q: How can WIMPs be detected?
A: If WIMPs were produced in sufficient number in the early universe then their properties are limited to a certain range. These properties give us clues as to how to design our search experiments. The basic idea is that occasionally individual WIMPs will occasionally collide with individual nuclei that make up one of our detectors, that is, they
can collide with a germanium or silicon nucleus, just a like when a billiard ball is struck by the cue ball. Since the recoiling nucleus is charge, it slows down and stops within the detector and its kinetic energy is dissipated in the detector and appears as both a heat signal and a charge signal. By comparing the two types of signals, recoils due to WIMPs can be distinguished from recoils due to other types of particles. Now, since the WIMPs would only interact very rarely, we also have to shield the detectors from other sources of particles, or background sources. To reduce the rate from backgrounds we surround the detectors with a variety of different shielding materials. Also, all of the materials that we use have been screened to make sure they have very low radioactive contamination. Background reduction is the reason that we like to do our experiments underground because at the surface the rate of cosmic rays – high-energy charged particles coming down from space – would cause a very high background rate of particles entering our detectors. The 2000-feet of rock between the mine cavern and the surface act as a natural shield against the cosmic rays.

Q: Why does CDMS need to be housed in a large metal box?
A: The CDMS detectors produce very small signal that are subject electrical interference. The metal box, called a Faraday cage, provides a shield against such interference. We also use the box to create a “clean room” similar to the types of facilities used to manufacture computer chips and other devices that can be ruined by the presence of dust. In CDMS we are concerned about dust because it tends to be radioactive. You may be familiar with the household hazard of radon gas that emanates from the foundation into the basement. Radon gas in the mine, along with its radioactive decay products can be attracted to dust particles. If this dust lands on the detectors, it leads to a high background rate that can hide a WIMP signal.

Q: What other crazy things have you had to do to get your experiment working?
A: Some of the lead shielding is made from ballast material that was recovered from a two-hundred year old sunken ship off the coast of France. Ordinary lead makes a good shield against natural radioactivity from the cavern environment. But the ordinary lead also itself contains a small but noticeable amount of a radioactive isotope of lead that takes about a hundred years to decay away. By using old lead for the innermost parts of the shield we can reduce the background from the ordinary lead. The old lead has also been used with high-purity tin to make low-activity solder, which is used for all of the electrical connections near the detectors.

Q: How long have you been working on the experiment and when will it be finished?
A: The development of the detector and the low-background cryogenic systems began in the 1980’s. These new technologies were developed expressly for use in the dark matter search, but related developments have also come up in other areas, such as optical and x-ray astronomy, biological physics, and x-ray spectroscopy using in materials analysis.

Q: How many people are involved and where are they from?
A: CDMS involves around 40 physicists from about 10 institutions across the country. Some of the groups based at universities and are led by Professors and include fulltime PhD researchers as well as graduate students that are earning their PhDs by working on
the experiment. Other groups are led by Staff Scientists at national laboratories, where they have access to large teams of engineers, technicians and machine shops. Typically, each member institution brings a particular expertise or capability to the experiment. By organizing themselves and working together they can accomplish a much more challenging scientific goal than if they each worked independently.

**Q: How much does the experiment cost and where does the money come from?**
**A:** The experiment costs about $15 million dollars to build over a period of about 4 years plus additional operating and personnel expenses for additional running periods. The project is jointly funded by the National Science Foundation’s Division of Math and Physical Sciences and the Department of Energy’s Office of Science. Ultimately, the money comes from the US taxpayer.

**Q: What practical value does this experiment have and how might it affect my life?**
**A:** Some of the funds that are spent will bring dollars to the local economy. Beyond this direct impact on the region, the information that we learn from this experiment may one day end up in a science textbook. Indeed, much of the information in scholastic textbooks and much of what we know about the physical world is due to the efforts of scientific research. Sometimes this leads simply to answering questions that human beings have been curious about since the beginning of recorded history, and perhaps before then. Other times the answers to these questions lead to practical devices or knowledge, for example, biomedical imaging or radiation therapy to treat cancer patients owe their roots to fundamental research in particle physics. As we continue our explorations, who knows what new things we will learn? It is impossible to say, but the above are some of the examples that have come about as a result of humanities pursuit of basic questions about nature.

**Q: Will this experiment aid the national defense?**
**A:** What we learn in this specific experiment probably won’t directly aid the defense of our country, but there are several ways in which the scientific enterprise of which we are a part has and will continue to have a positive impact in a variety of ways. Some of the students and other researchers that are trained in and help develop new measurement instruments and techniques needed to carry out the experiment may choose to work in defense technologies. It’s important to remember that the detectors that we use are among the most sensitive radiation and particle detectors ever made. Innovations and innovators in radiation detection are in an excellent position to launch technology “spin-offs”, from battlefield measurements to verification and detection of nuclear weapons materials.

*CDMS FAQ vers. 1.0 - prepared by Dan Akerib, Case Western Reserve University*  
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