Latest Results in the Search for Dark Matter
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Astronomical observations from telescopes, satellites and measurements of the cosmic microwave background have led scientists to believe that most of the matter in the universe neither emits nor absorbs light. This dark matter would have provided the gravitational scaffolding that caused normal matter to coalesce into the galaxies we see today. In particular, we think our own galaxy is embedded within an enormous cloud of dark matter. As our solar system rotates around the galaxy, it moves through this cloud.

Particle physics theories suggest that dark matter may be composed of Weakly Interacting Massive Particles (WIMPs). Scientists expect these particles to have masses comparable to, or perhaps heavier than, the masses of atomic nuclei. Although such WIMPs would rarely interact with normal matter, they could occasionally scatter from an atomic nucleus like billiard balls, leaving a small amount of energy that might be detectable under the right conditions.

The Cryogenic Dark Matter Search (CDMS) experiment, located a half-mile underground at the Soudan mine in northern Minnesota, uses 30 detectors made of germanium and silicon in an attempt to detect such WIMP scatters. The detectors are cooled to temperatures very near absolute zero. Particle interactions in the crystalline detectors deposit energy in the form of heat, and in the form of charges that move in an applied electric field. Special sensors detect these signals, which are then amplified and recorded in computers for later study. A comparison of the size and relative timing of these two signals, heat and charge, allows the experimenters to tell whether the particle that interacted in the crystal was a WIMP-- or one of the numerous known particles that come either from radioactive decays or from space in the form of cosmic rays. These background particles must be almost entirely filtered out if we are to see a WIMP signal. Layers of shielding materials, as well as the half-mile of rock above the experiment, are used to provide such background suppression.

The CDMS experiment has been searching for dark matter at Soudan since 2003. Previous data have not yielded evidence for WIMPs, but have provided assurance that the backgrounds have been suppressed to the level where as few as one WIMP interaction per year could have been detected.

We are now reporting on a new data set taken in 2007- 2008, which approximately doubles the sum of all past data sets. With each new data set, we must carefully evaluate the performance of each of the detectors, excluding periods when they were not operating properly. Detector operation is assessed by frequent exposure to sources of two types of radiation: gamma rays and neutrons. Gamma rays are the principal source of normal matter background in the experiment. Neutrons are the only type of normal matter particles that interact with germanium nuclei in the billiard-ball style that WIMPs would, although neutrons frequently scatter in more than one of our detectors. This calibration data is carefully studied to see how well a WIMP-like signal (produced by neutrons) can be seen over a background (produced by gamma rays). The expectation is that no more than one background event would be expected to be visible in the region of the data where WIMPs should appear. Since background and signal regions overlap somewhat, achievement of this low background level required us to throw out roughly 2/3 of the data that might contain WIMPs, because these data would contain too many background events.

All of the data analysis is done without looking at the data region that might contain WIMP events. This standard scientific technique, sometimes referred to as “blinding”, is used to avoid the unintentional bias that might lead one to count as WIMPs events having some of the characteristics of WIMP interactions but that are really from background sources. After all of the data selection criteria have been completed, and detailed estimates of background “leakage” into the WIMP signal region are made, we “open the box” and see if there are any WIMP events present.

In this new data set we indeed see two events with characteristics consistent with those expected from WIMPs. However, there is also a chance that both events could be due to background particles. Scientists have a strict set of criteria for determining whether a new discovery has been made. The ratio of signal to background events must be large enough that there is no reasonable doubt. Typically there must be fewer than one chance in a thousand of the signal being due to background. In this case, a signal of about five events would have met those criteria. We estimate that there is about a one in four chance to have seen two backgrounds events, so we can make no claim to have discovered WIMPs. Instead we say that the rate of WIMP interactions with nuclei must be less than a particular value that depends on the mass of the WIMP. The numerical values obtained for these interaction rates from this data set are more stringent than those obtained from previous data for most WIMP masses predicted by theories. Such upper limits are still quite valuable in eliminating a number of theories that might explain dark matter.

What comes next? While the same set of detectors could be operated at Soudan for many more years to see if more WIMP events appear, this would not take advantage of new detector developments and would try the patience of even the most stalwart experimenters (not to mention theorists). A better way to increase our sensitivity to WIMPs is to increase the number (or mass) of detectors that might see them, while still maintaining our ability to keep backgrounds under control. This is precisely what CDMS experimenters (and many other collaborations worldwide) are now in the process of doing. By summer of 2010, we hope to have about three times more germanium nuclei sitting near absolute zero at Soudan, patiently waiting for WIMPs to come along and provide the perfect billiard ball shots that will offer compelling evidence for the direct detection of dark matter in the laboratory.

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