Brown - Cryogenic Dark Matter Search (CDMS) - Experimental Group

Summary

The CDMS Experiment is looking for the very occasional interactions of WIMP particle dark matter in sensitive Ge and Si detectors, operated at 20 mK and housed in a deep underground laboratory. The expected rates for WIMP scattering range from 1 event per kg per week to 1 event per 100 kg per year! This signal is in competition with many types of backgrounds. Our studies, aimed at understanding and eliminating these backgrounds, are outlined in this poster. (For details see http://cdms.brown.edu)

Understanding Detector Response

Our analysis involves trying to understand how the CDMS detectors, called ZIPs, respond to particle events.

Understanding the ZIPs' behavior to energy deposition from WIMPs and types of radioactive backgrounds, is of paramount importance in an experiment looking for rare events.

It is also necessary to understand how the ZiPs act in special cases, such as with events occurring close to their surface.

Particle Discrimination

A WIMP event interacts by scattering from the nucleus of an atom. Electrons and gammas differ in that they interact with the atomic electrons. This difference in the interaction mechanisms allows us to discriminate between WIMP and electromagnetic events.

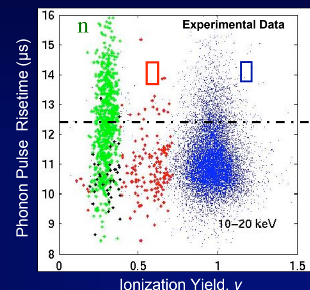
Neutrons also scatter from nuclei. However, we can identify them because they often multiply scatter in the detectors.

It is important for us to be able to correctly identify all particles that are *not* Dark Matter so that the extremely rare WIMP interactions can be picked out.

Gamma Discrimination

Beta Discrimination

Neutron Discrimination



Beta Electron Rejection

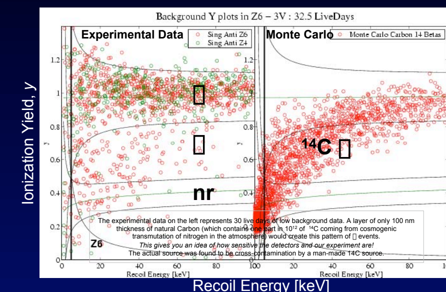
Background is also caused by low energy electrons coming from the beta decay of radioactive isotopes near the detectors. The electrons preferentially interact in the surface of the ZIP detectors. As outlined in the Gamma Rejection section, the ionization yield discrimination is less effective at the surface.

However these events can be discriminated by the additional use of the phonon pulse **rise time**.

By rejecting all pulses which have a rise time of less then 12 μs, we eliminate:

-- **85% of beta events** but keep
-- **55% of neutrons**

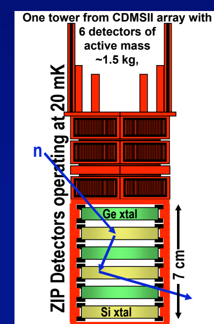
Coupled with rejection based on the ionization yield, total beta rejection is around 98% efficient.



The above figures show event recoil energy versus ionization yield for experimental data from detector ("Z6") on the left, and a Monte Carlo simulation on the right. The simulated data was created in order to study whether this detector was surface contaminated with ^{14}**C**.

It can be seen on the left that the experimental data from the detector (Z6, red circles) has significantly more events between the gamma band (marked □) and nuclear recoil band (marked nr), than a second detector (Z4, green circles).

It was concluded that Z6 has a small amount of ^{14}C (marked □) contamination, a simulation of which is shown on the right. Developing an accurate simulation of the detector required us to develop a very detailed understanding of the detector dead layer, and the surface scattering of electrons.



Background Neutrons

Neutrons give a background, in the CDMS experiment, that appears very similar to the expected signal of WIMPs, since both scatter by **nuclear recoil**.

Eliminating sources of neutron background is vitally important and is the reason why CDMS II is under 2500 ft of rock at the Soudan Mine in Minnesota! High energy cosmic muons create neutrons through spallation processes (the disintegration of nuclei). The rock overburden at Soudan reduces the muon flux by a factor of 100,000.

Any residual neutron flux can be identified since the neutrons will tend to scatter in more than one detector. Given how low the WIMP interaction cross section is the chance of a given WIMP scattering twice in our detectors is negligible.

Experimental neutron calibration data is combined with Monte Carlo simulations to design neutron shielding, and to give a better understanding of the residual expected nuclear recoils rates.

WIMPs and Supersymmetry

WIMPs are not part of the Standard Model of particle physics. They are made up of some type of 'exotic' matter, which is non-Baryonic.

Supersymmetry includes WIMPs in a very natural way. The lightest (and therefore most easily observable) supersymmetric particle is almost always an excellent candidate for a dark matter particle.

The **lightest supersymmetric particle**, or **LSP**, is most likely some combination of the supersymmetric states of the W boson, B boson, and two of the Higgs bosons. i.e. the Wino, Bino, and neutral Higgsinos. This particle is also referred to as the **neutralino**.

Whichever form the LSP takes, it is almost guaranteed that it will be a good candidate for Dark Matter.

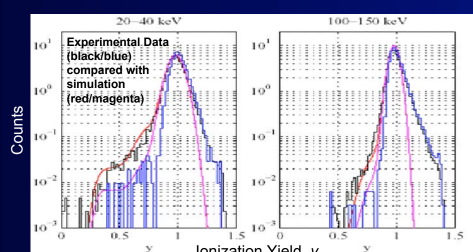
Conversely, the discovery of a WIMP would be a significant 'thumbs-up' for Supersymmetry.

Gamma Response

The main discrimination parameter used to determine the type of background is the **ionization yield**, the ratio of the ZIP's charge and phonon collection channels. Gammas and betas interact with ZIPs by the process of **electron recoil**, which produces a higher ionization yield value than that produced by the **nuclear recoil** of neutrons and WIMPs.

Correct gamma identification in CDMS ZIPs is better than **99.95% efficient**. Incomplete charge collection in the top ~1 μm of the surface of the ZIPs is responsible for the small fraction of gamma events that are misidentified.

Accurate Monte Carlo simulation of gamma backgrounds, and experimental comparison have enabled our group at Brown to study this dead layer effect in detail and produce new models of its behaviour.



Shown above are histograms of the ionization yield, *y*, for a ^{60}Co gamma source calibration of a ZIP detector. Events are in the range (left) 20-40 keV, and (right) 100-150 keV. Gamma interactions are expected to have a *y*~1. Nuclear recoil interactions have *y*~0.4. The black and blue lines are experimental data, the red and magenta are simulations. Within each pair, the lines are for single and multiple detector scatter events.

Background Sources

Understanding the sources of the CDMS backgrounds represents a significant challenge, and an important goal. Invaluable in this search are **Monte Carlo simulations** and their comparison with real data taken from the experiment.

Our group at Brown uses Monte Carlo techniques as a tool to better understand the detector response due to backgrounds, and to identify the existence of radioactive contaminants causing the backgrounds.

Known background contaminants include:

Carbon-14, Thorium-232, Uranium-238, Lead-210, Potassium-40, Tritium

Radon-222 (present in the air) **Cosmic Ray Muons**

Cosmogenics **Muon-induced Neutrons**

Identifying and eliminating these sources is quite a challenge!

Experimental Particle Astrophysics Group
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