Exploring Analysis Optimization Strategies for Dark Matter Detection with the SuperCDMS Experiment

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Overview

1. Introduction to Dark Matter and the SuperCDMS Experiment
2. Sensitivity Estimations using Rudimentary versions of CDMS Predictions and approximate versions of Previous Analysis Techniques
3. Does combining detectors differently affect the sensitivity?
4. Does the method of combining detectors affect how we optimize the analysis?
5. Conclusions
Good evidence that the Universe (including Milky Way) is filled with dark matter.

Assuming it’s a new kind of particle, our goal is to discover it and study its nature.

We believe Earth is swimming through dark matter.

Figure: Artist’s Rendition of Milky Way’s Dark Matter Halo Illustration: CXC/M.Weiss
SuperCDMS Goals

- SuperCDMS is the Cryogenic Dark Matter Search.
- Detectors record important data from interaction events (mostly photons, but hopefully Dark Matter).
- Sensitivity is the expected upper limit on the interaction cross section between dark-matter and atomic-matter that we would be able to measure.
For our study, we do not use real data, just approximations for backgrounds and acceptances (not equal to arXiv:1402.7137)

We use standard methods (Boosted Decision Tree or BDT) to distinguish dark matter from background.
- Background-like closer to -1.0
- Dark Matter-like closer to 1.0

Simple Analysis: select events with a BDT value above a specific threshold for each detector.

To estimate the sensitivity, we consider the expected number of background events and the response to dark matter (acceptance) as a function of BDT threshold.

Figure: BDT training data
Questions

- The plot on the following pages use **rudimentary and incomplete** CDMS analysis methods to represent the effect of changing analysis methods.
- Previous method used 7 detectors, treated them all as a single experiment; optimized BDT thresholds on the combined background/acceptance.
- New questions we are asking:
  - Is the overall sensitivity improved by treating the detectors as separate experiments?
  - Does this change affect the choice of BDT thresholds used to optimize sensitivity?
Is the SuperCDMS experiment more sensitive as one giant experiment or many smaller ones, using previously optimized thresholds?

- Exposures, acceptances, and backgrounds are different.
- Each detector does not contribute equally to the combined limit.
Example 1-bin vs. 7-bin Sensitivities

- Start with a fixed set of BDT thresholds to estimate sensitivity.
- Old method (1-bin green): combine backgrounds and acceptances as if it were one giant detector with the combined expected sensitivity.
- New Method (7-bin blue): Find the expected sensitivity of each detector individually and combine using Markov-chain Monte Carlo to find the overall sensitivity.
- The rudimentary and incomplete data indicates that the new method improves sensitivity by up to 1.66, but varies as a function of Dark Matter mass.
Example Optimization Results

- The new method improves sensitivity, but would changing BDT thresholds help even more?
- Estimate expected limit in three ways:
  - (individual) Only consider one detector as we vary its BDT threshold
  - Old method (total), vary only one detector’s BDT threshold
  - New method (7-bin), vary only one detector’s BDT threshold
- Repeat for all detectors.
- No evidence that the new method would have optimized the BDT thresholds differently.
We have studied the optimization and analysis strategies for improving the overall sensitivity to Dark Matter with SuperCDMS detectors.

We compared the current strategy of treating the detectors as a single experiment vs. treating them as separate experiments.

We found no evidence that the previous method of optimization needs changing.

Our findings indicate that treating the detectors as separate experiments does improve the overall sensitivity.

Looking forward to SuperCDMS SNOLab data.
Thanks to Adam Anderson, Raymond Bunker, Jorge Morales, Kristi Schneck, Stephen Yellen, and for all of their help in creating this talk.
The new method utilizes PyMC, a Markov Chain Monte Carlo library written in Python. This technique makes integrating the uncertainties of certain values into a model simpler.