CDMS

CRYOGENIC DARK MATTER SEARCH

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Summer 2010 REU
Texas A&M University
Cyclotron Group

Cyclotron Institute
Texas A&M University

Presentation

- Questions to Address:
  - What is Dark Matter?
  - Why do we Care?
  - How do we Detect Dark Matter?
  - What is A&M's Role?
  - What was my Role?
  - Conclusion

What is Dark Matter?

- Fritz Zwicky identified that galaxies tend to cluster by use of the first mountain top Schmidt Telescope
  - Photographs Galaxies Quickly
  - Virial Theorem
  - Rotational Motion
- Identification of "Unseen" mass
  - Gravitational Force was said to be incorrect if only visible matter is present.
  - Dark Matter Theory Proposed
- Zwicky mentioned the idea of dark matter, although the idea did not mean exactly what we do today.

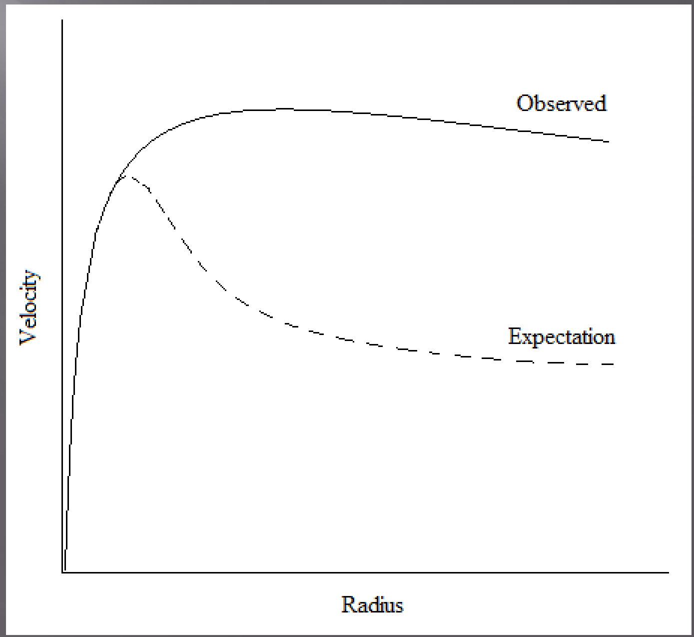
What is Dark Matter?

- Gravitational Effects on Visible Matter

Gravitation
al Force

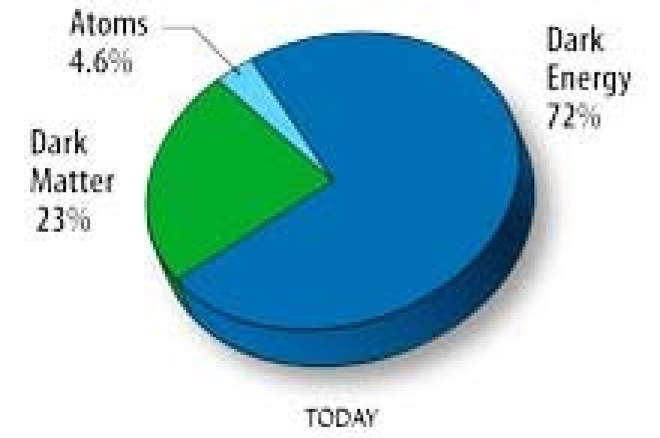
$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

Galactic Gravitational Force Plot

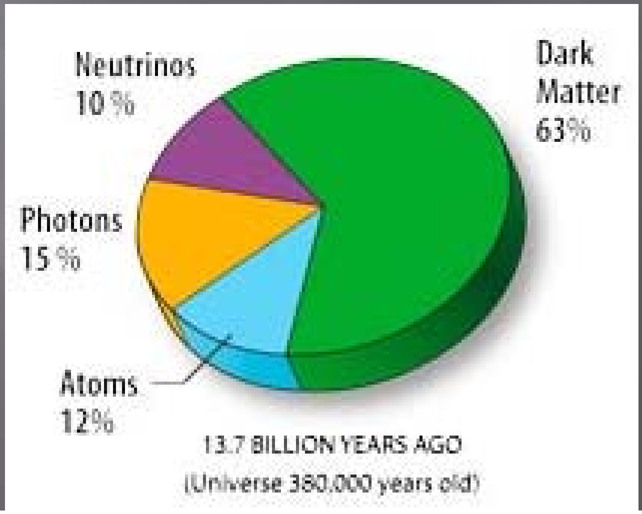


Why Do We Care?

- The Estimates Today:



- Dark Matter Compared to Known Matter:



Why Do We Care?

- Astronomers Seek out Answers to the Possible Beginning and End of the Universe.

- Particle Physicists Seek Out Further Knowledge of Particle Interactions.

A Couple of the Possible Approaches

MACHO'S

- Massive Astrophysical Compact Halo Object
  - Ordinary Matter
    - Composed of Quarks
  - Large Scale
    - Stars
    - Black Holes
  - Baryonic Matter

WIMP'S

- Weakly Interactive Massive Particle
  - Unordinary Matter
  - Small Scale
    - Subatomic Particles
  - Non-Baryonic Matter

How Do We Detect Dark Matter?

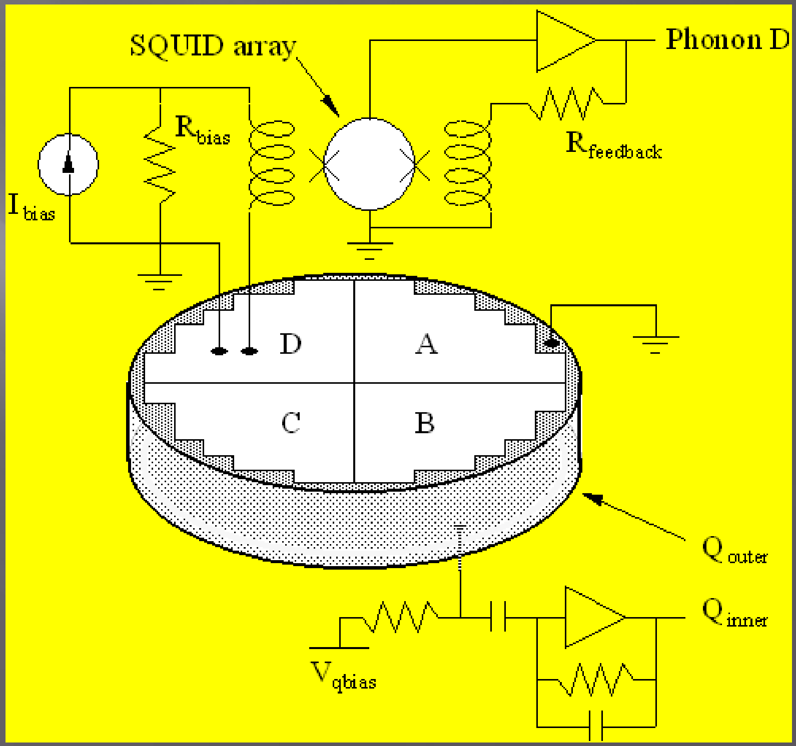
- A Few of the Many Experiments Designed to Investigate Dark Matter:
  - LUX Experiment:
    - Xenon
  - CoGeNT:
    - P-type point contact germanium detectors
  - COUPP:
    - Bubble Chambers
  - CDMS:
    - Germanium and Silicon Detectors

CDMS

- Cryogenic Dark Matter Search
  - Approaches the Problem Using the Idea of WIMP Interactions
  - Uses Ge and Silicon Detectors
  - And Like All Dark Matter Experiments with a Focus on WIMP Interactions, CDMS is Designed to Exclude All Interactions, but those of WIMPS
    - A Series of Cuts are Used
    - Several Layers Of Shielding

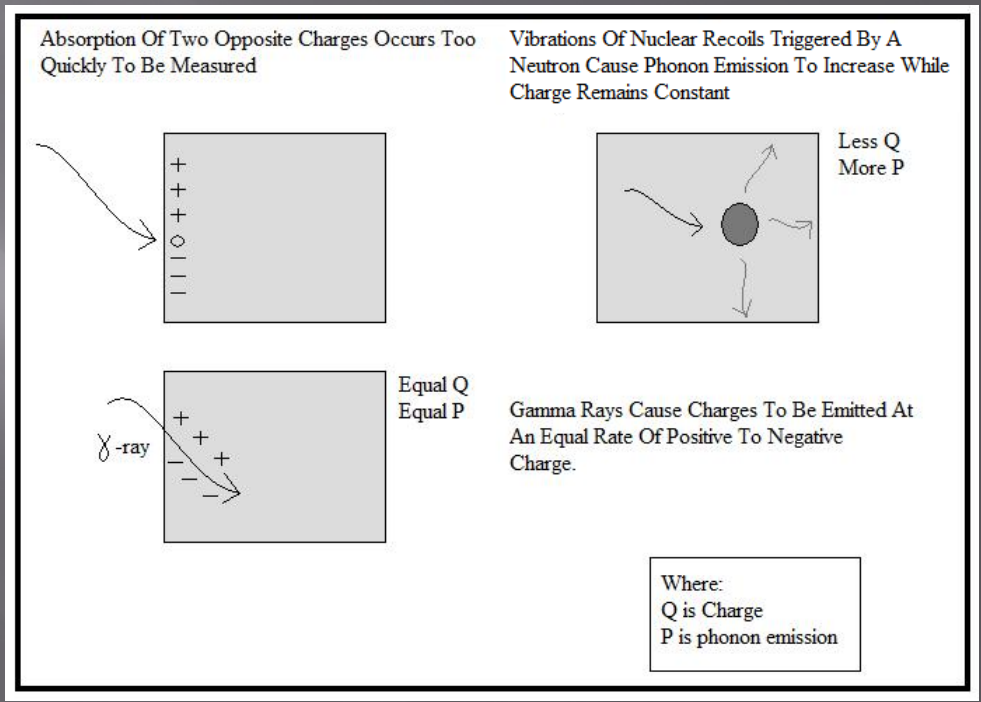
CDMS Detector

- CDMS detector composed primarily of Ge and Si.
- 4 Quadrant Detector



Electromagnetic Interactions vs Nuclear Recoils

- Electromagnetic Interactions
  - Electromagnetic Interactions Occur Causing Equal Charge and Equal Photon Detection
- Nuclear Reactions
  - Nuclear Reactions Result in More Photon Detection and Less Charge Detection



- Possible Approaches To Obtain Acceptable Data
  - Shielding
  - Rejection

Shielding

- Types of Shielding
  - Climate Shielding
  - Exterior Shielding
  - Veto Cut

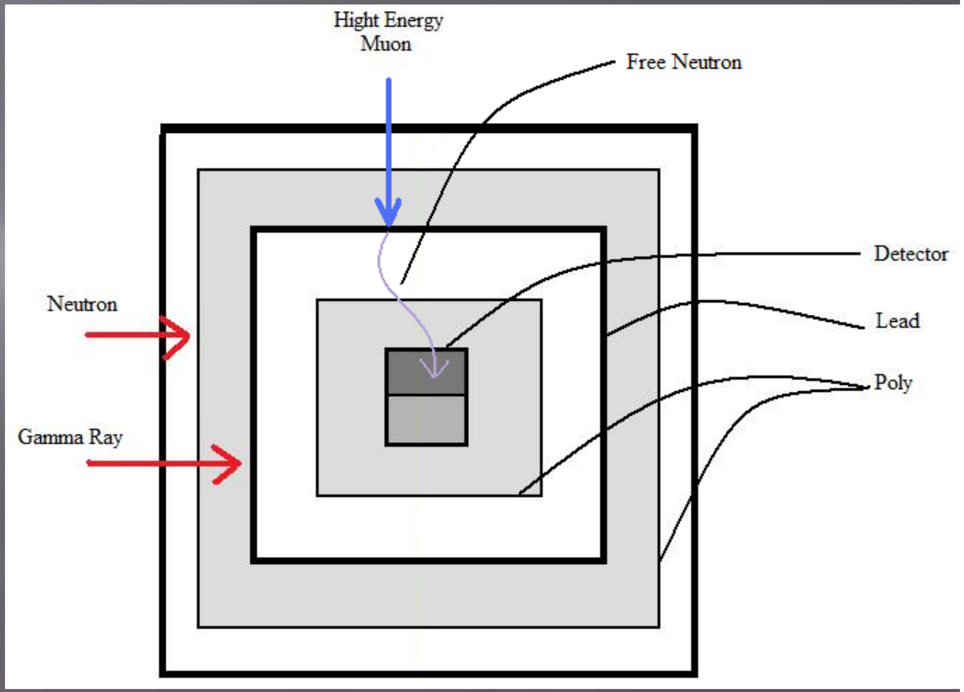
CDMS at Soudan
(cdms.berkeley.edu/…/science/soudan.shtml)

Cuts

- External Cuts
  - Cooling the System
  - Shielding of Different Types of Radiation
    - Lead, Poly, and a Half Mile of Solid Earth of Overhead, Shields the Detector Resulting in x50 000 Less Muons
    - Some Types of Shielding Such as Pb May in Turn be a Source of Events

Shielding

- Veto Cut
  - A muon may trigger a false event both inside and outside of the detector.
    - The Muon is Not the Cause of the Event, but Rather a if a Neutron is Freed and Collides with the Detector an Event is Said to Have Occurred
  - Gamma Radiation may cause false events
  - Incident Neutrons may cause false events
  - The Veto Cut excludes these False Nuclear Interactions With the Detector

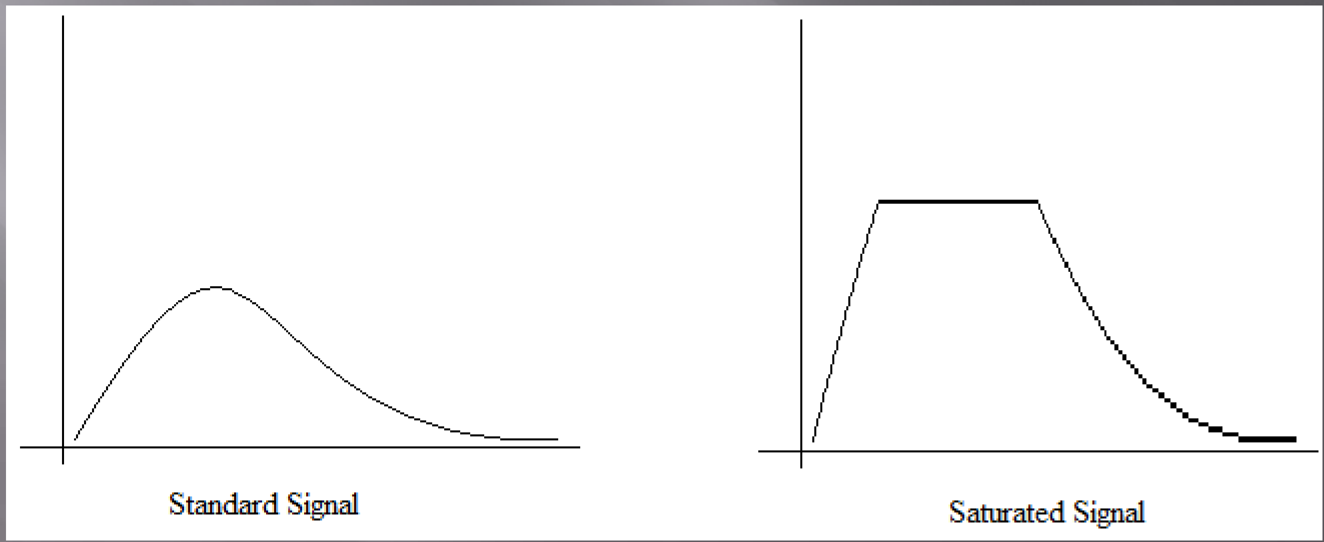


Backgrounds Cuts

- Background Particles
  - Distinguishing Between Nuclear Recoils and Electron Recoils
- Applying Cuts
  - Data Quality Cut
  - Q-Inner Cut
  - Q-Threshold Cut
  - Single Scatter Cut

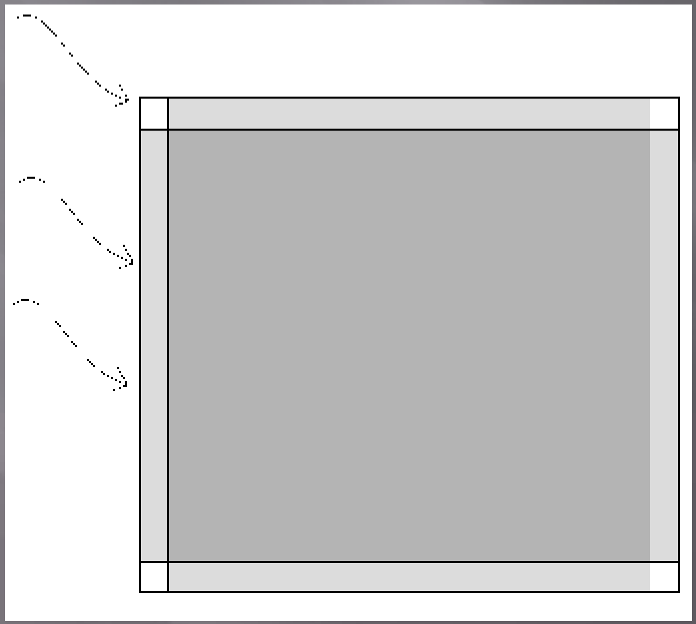
Cuts

- Data Quality Cut
  - Signals are Expected Within 10keV-100keV range
  - Above that Threshold is Considered Higher Energy Than That of Possible WIMPs
  - Only High Quality Events May be Considered as Possible Dark Matter Events



Cuts

- Q-Inner Cut
  - Incoming ray triggers a possible event at a boundary, but nothing occurs on the inside
  - Exclusion of the Corners and Edges

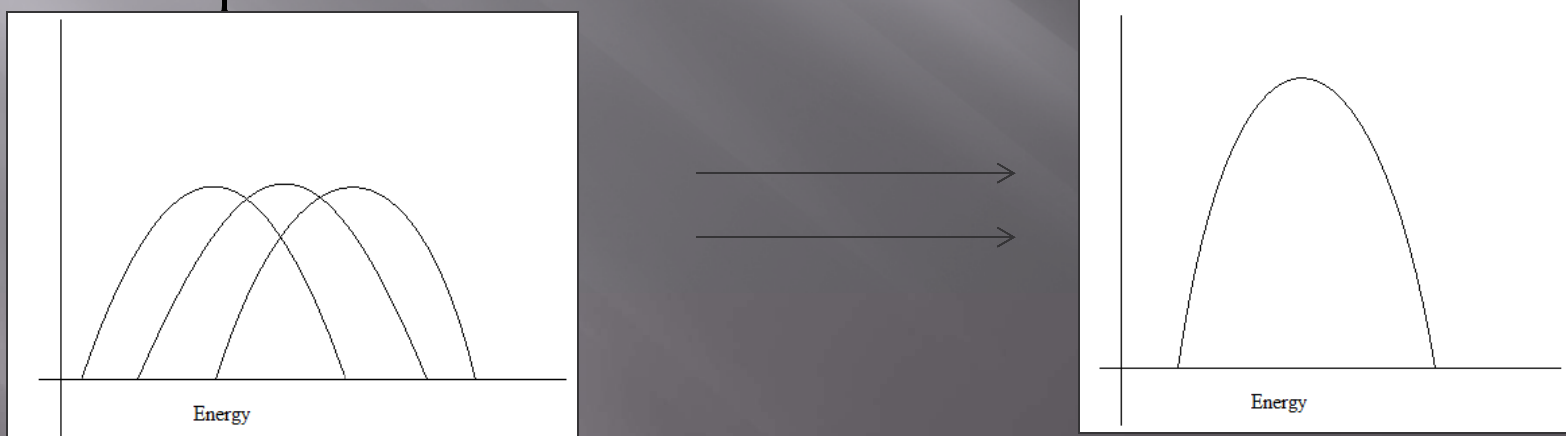


Cuts

- Q-Threshold Cut
  - Have Readings Begin at a Particular Point to Avoid Noise
  - The Measurement of Any Signal Must be Several Sigma Above the Mean of The Noise
  - This Produces a Clear Phonon and Charge Signal Rather Than Being Interfered with Unwanted Background

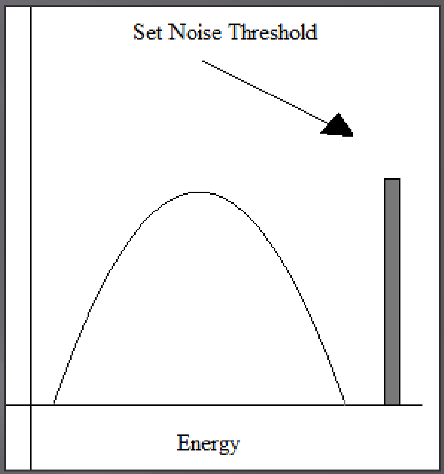
Noise

- Noise Is Unavoidable
  - Instruments
  - Fitters
  - Electricity
- Compound Noise



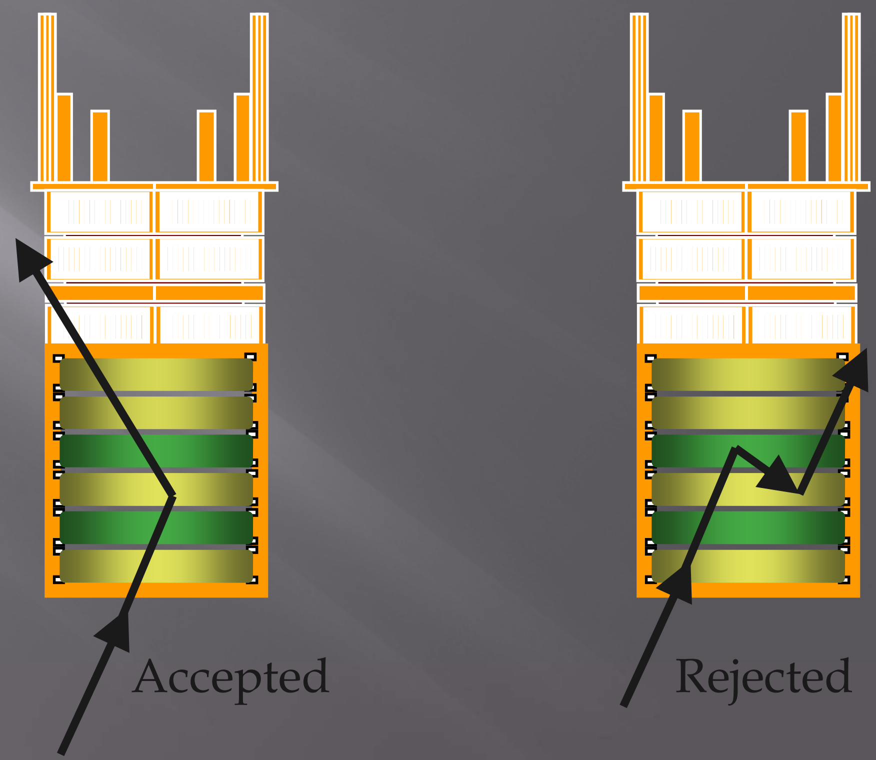
Setting A Threshold

- Charge Threshold Cut
  - Set a threshold to avoid reading noise in as an event
  - Setting Threshold Problems
    - Setting the Threshold Too High Creates a Potential Loss of Signal, Because Possible Signals Are in turn Ignored
    - Setting the Threshold Too Low Creates a Potential loss of Signal, Because of Interference



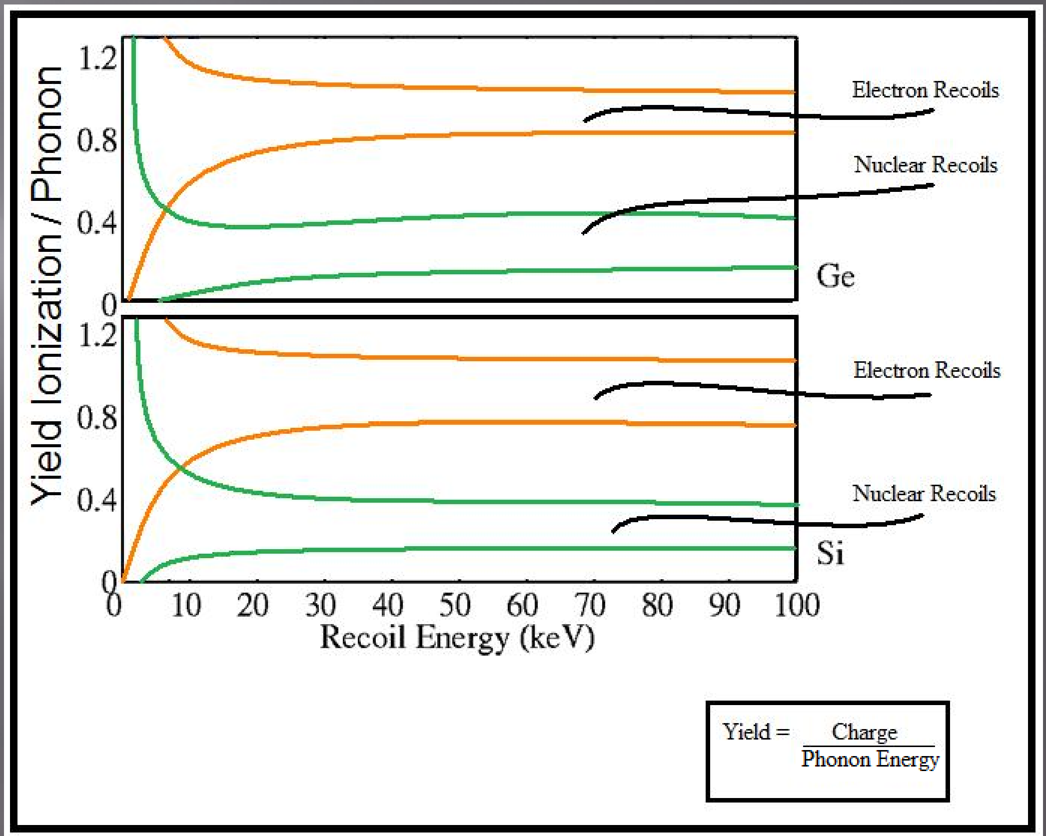
Single Scatter Cut

- The Interaction of a Signal Amongst the Stacked Detectors Must Not Scatter Multiple Times
- WIMPs Will Not Scatter in Multiple Detectors While Backgrounds May



Energy Plot

- Electron Recoils are Backgrounds
- Nuclear Recoils are Possible Events



Signal

- A Detector's Sensitivity to WIMPs is Proportional to the Product of the Detector Mass Times How Long the Detectors Look for WIMPs
- Detectors Are Already Running at Their Optimal Time Period. Detector Mass Must be Increased In Order to Maximize Signal Production
- This Has Been a Problem In the Past
  - Detectors Are 'Hand Crafted' in Time Intensive R&D Style Processes
  - Testing Detectors is a Time Strenuous Issue
  - Consistency is an Issue with 'Hand Crafted' Detector

What is A&M's Role?

- Increasing Production
  - Texas A&M University is Working on Increasing the Production Rate CDMS Detector by Industrializing the Method of Production Using Silicon Valley Production Techniques.
  - The Mass Production of Detectors Increases the Sensitivity of the Experiment, and With Any Luck, the Success of the Experiment Along With It.
- Increasing Consistency
  - Improving the Reproducibility of Results of the CDMS Detector
- Take Over Stanford's Process
  - Allows Stanford To Pursue Theoretical Approaches to Bettering Their Detector

What is A&M's Role?

- CDMS at A&M:
  - Wet Lab
    - Dektak
    - Spin Coater
    - Contact Alignment
    - Etching Process

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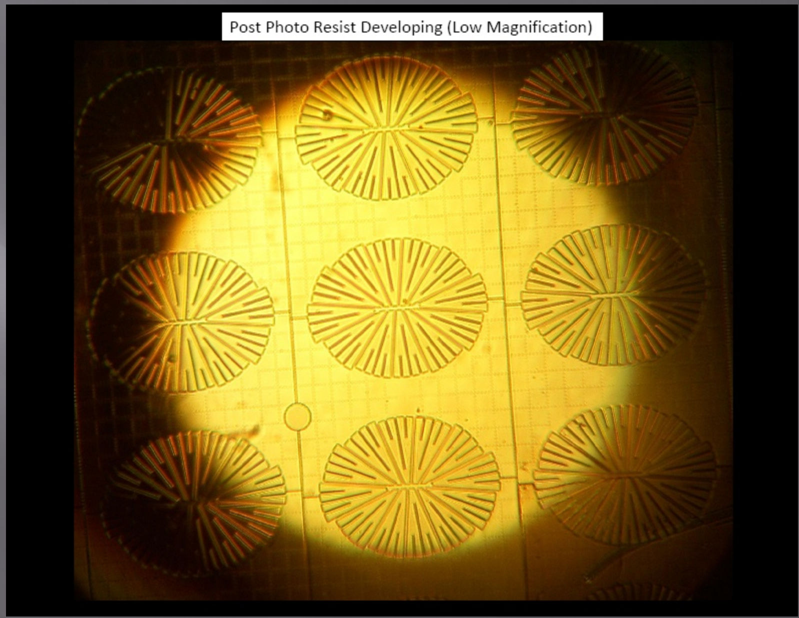

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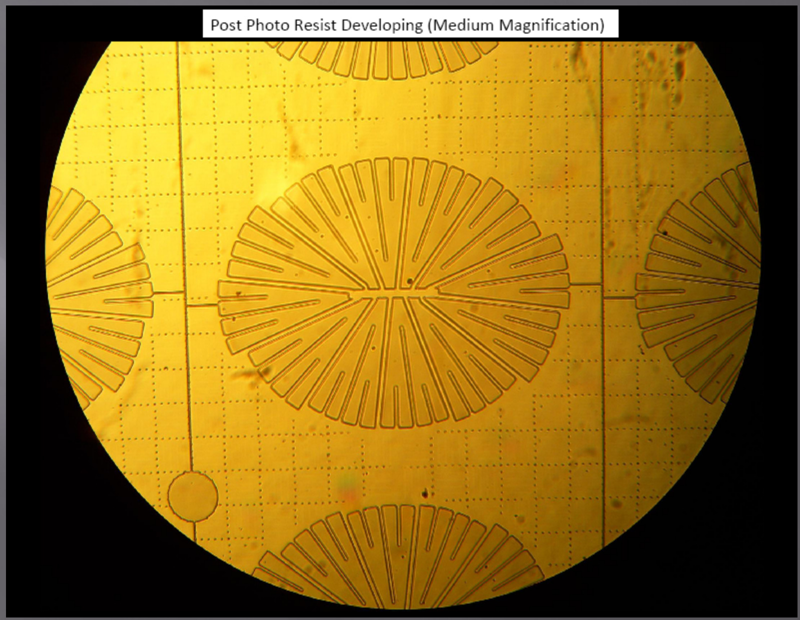

What Was My Role?

- In the Process of Commissioning a Second Laboratory My Role Has Become Very Broad Consisting of:
  - Sputtering System
  - Dektak
  - Ventilation
  - Spin Coater
  - Trouble Shooting
  - Equipment Installation

Conclusion

- CDMS is an Ongoing Experiment With Much to Look Forward to in the Future.
- Future of CDMS at Texas A&M:
  - Repair Sputtering System
  - Find Recipe To Match Desired Results
    - Possibly Introduce Oxygen
    - Possible Introduce Other Gas Components
  - Bring Online Polisher
    - Acquire More Space
  - Continue to bring online second laboratory:
    - Acquire and Install Spin Coater
    - Automate Oven Operation
    - Harness Contact Alignment Skill
    - Gain Further Knowledge of Etching Process
  - Continue on to Thicker Substrates.

Works Cited

- Works Cited
  - cdms.berkeley.edu/.../science/soudan.shtml

- Special Thanks
  - Texas A&M University
  - Cyclotron Institute
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  - And the Rest of The CDMS Team