# Hunting Dark Matter with SuperCDMS

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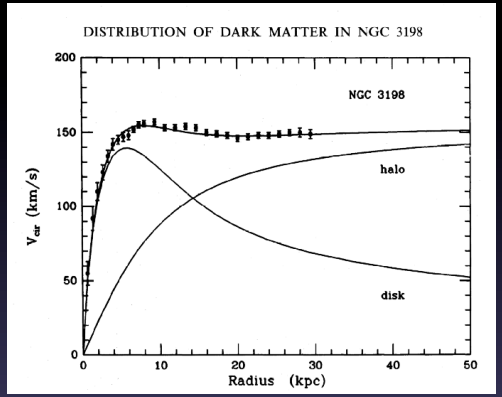
Rencontres de Blois 2013

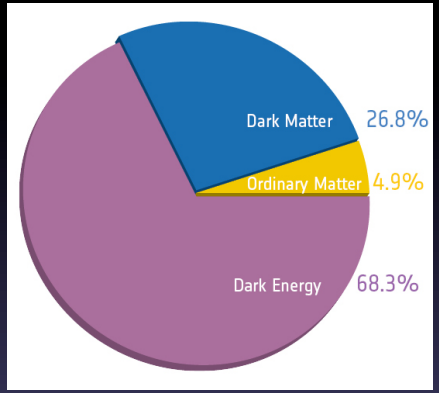
# The SuperCDMS Collaboration

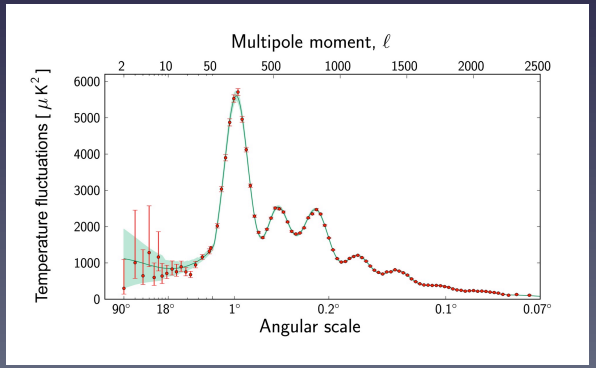
- California Institute of Technology
- Fermi National Accelerator Laboratory
- Massachusetts Institute of Technology
- NIST
- Pacific Northwest National Laboratory
- Queen's University
- Santa Clara University
- SLAC/KIPAC
- Southern Methodist University
- Stanford University
- Syracuse University
- Texas A&M
- University of British Columbia
- University of California, Berkeley
- University of California, Santa Barbara
- University of Colorado, Denver
- University of Evansville
- University of Florida
- FT-UAM CSIC and Universidad Autonoma de Madrid
- University of Minnesota

# Dark Matter

- Most of universe is 'dark'
- Evidence from multiple sources
  - CMB
  - Galactic rotation curves
  - Large scale structures
- Observations favor particle dark matter as opposed to large composite but dark objects (such as black holes)

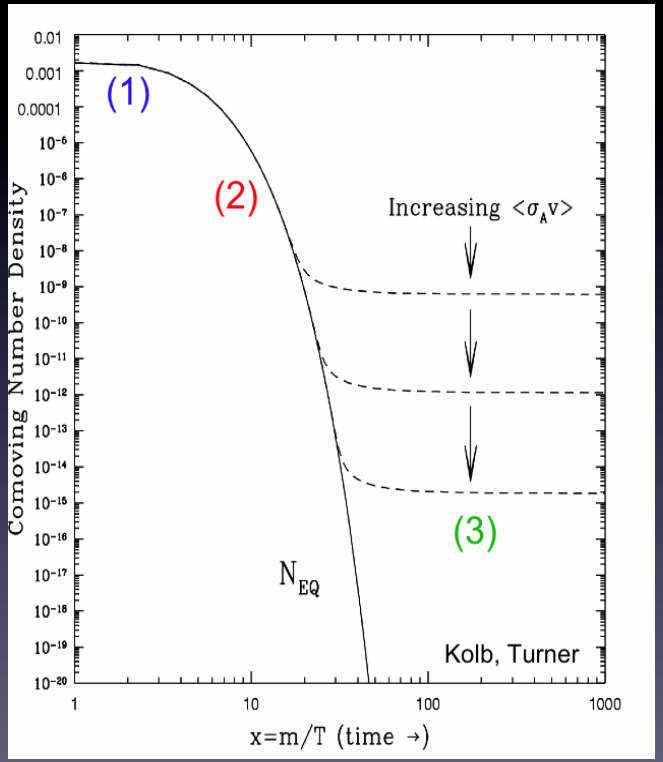


# Enter the WIMPs

- Particle dark matter must satisfy some strict requirements
- Weakly Interacting Massive Particles from super-symmetry
- So called 'WIMP miracle' motivated searches
  - Thermalized in early universe
  - Eventually freezes out
  - If one supposes Weak scale cross-section get correct relic density to match observations

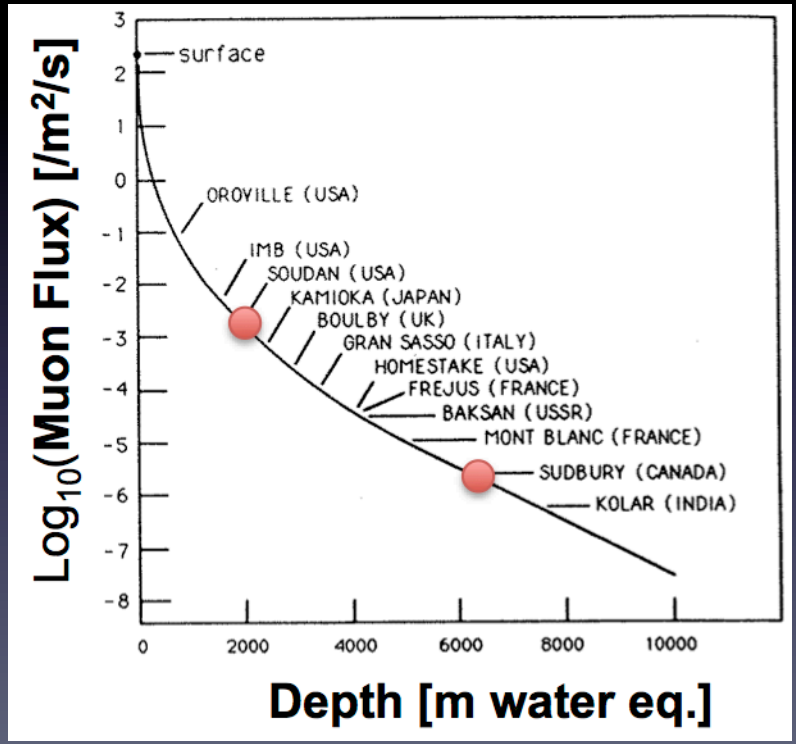


# Detection Strategy

- Weak interactions need very sensitive detectors
- Detectors will be sensitive to many backgrounds
- Several solutions exist to reduce backgrounds and SuperCDMS employs the following:
  - Go deep
  - Shielding
  - Discrimination
- Reducing or discriminating backgrounds allow us to observe rare events

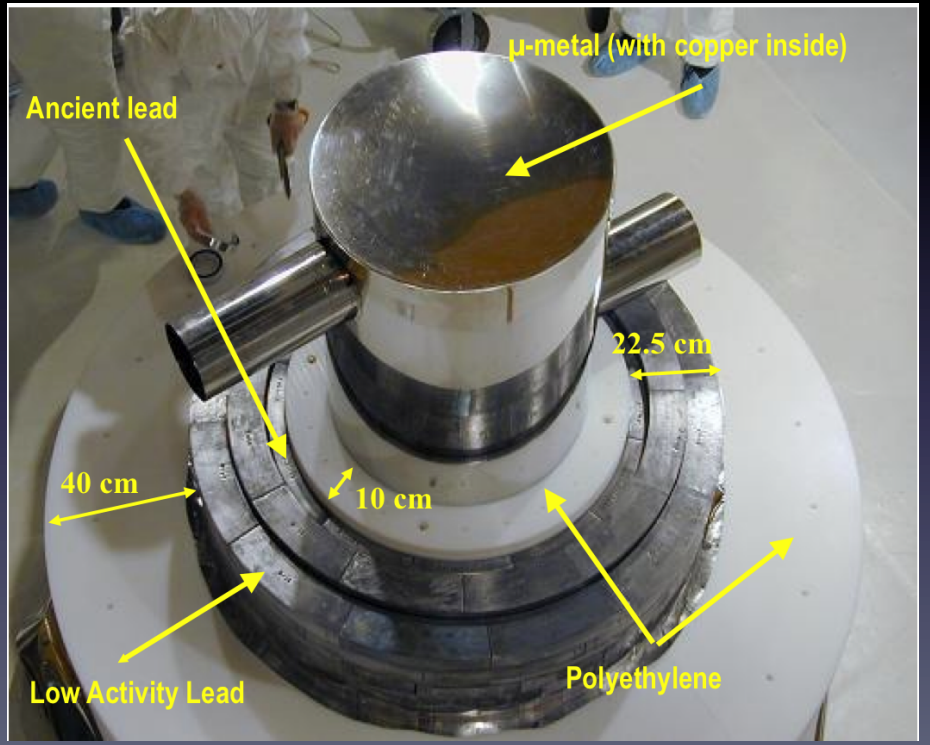
# Backgrounds

- Currently operating SuperCDMS at Soudan Underground Laboratory
- Depth of ~ 800 m (2000 m water equivalent)
  - Reduces surface muon flux by 5 orders of magnitude
- Future plans for SNOLAB



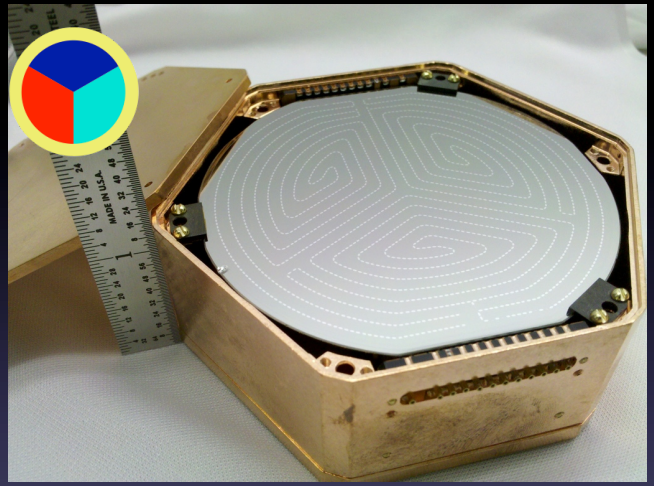
# Background Shielding

- SuperCDMS employs various shielding method
  - Active muon veto
  - Polyethylene for neutron moderation
  - Lead and old lead layers to moderate gammas
  - Additional low activity copper shielding



# Detectors

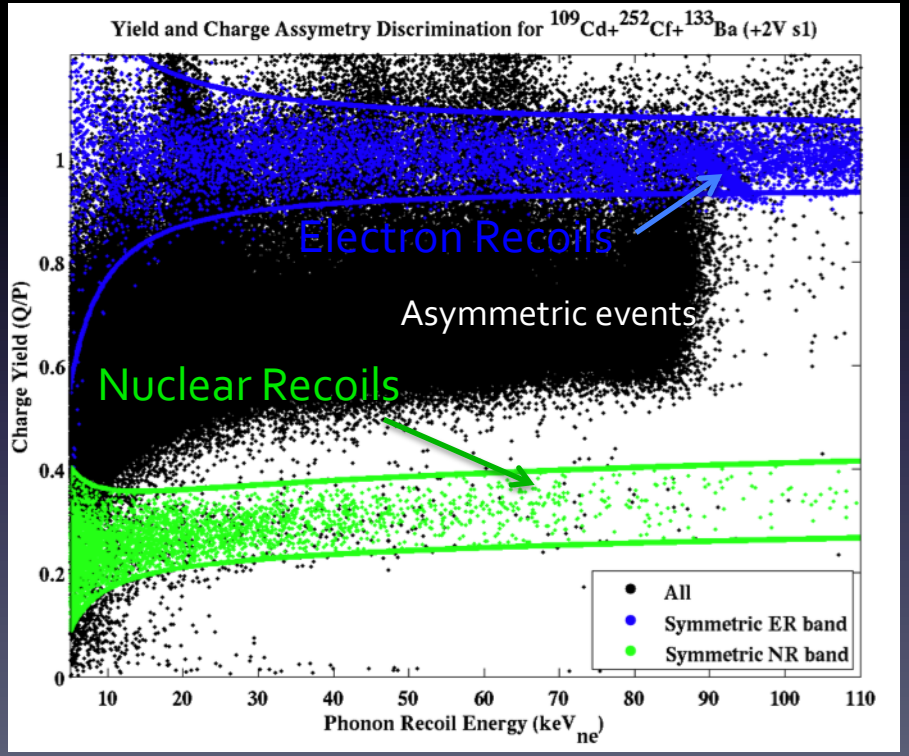

- CDMS-II oZIP
- Ge and Si
- 0.239 kg and 0.106 kg respectively
- 76 mm diameter x 10 mm thickness
- 4 phonon channels on one side
- 2 Ionization on opposite



- SuperCDMS @ Soudan
- New detectors: iZIP
- 0.6 kg mass
- 76 mm diameter x 25 mm thickness
- Outer ring phonon channel
- Interdigitated Phonon and ionization on both sides
- Ge only

# Detection

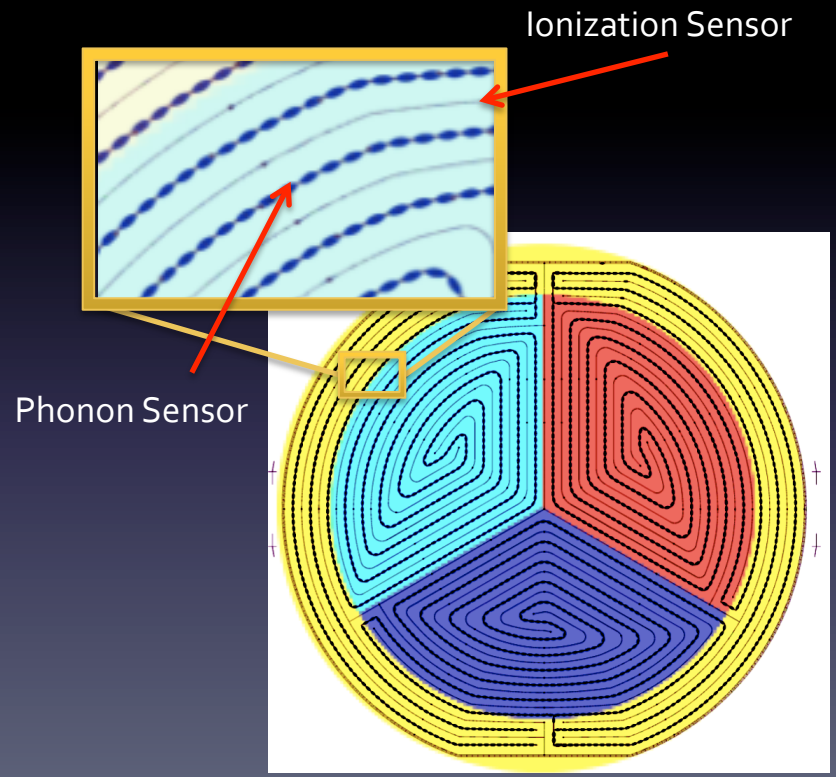
- Measure ionization
- Collect athermal phonons via transition edge sensors (TES)
- Electron Recoils (betas, gammas)
- Nuclear Recoils (neutrons, WIMPs)
- Discrimination quantity called Yield
  - Ratio of charge to phonon recoil energy
  - Use calibration sources ($^{133}$Ba for ER and $^{232}$Cf for neutron)



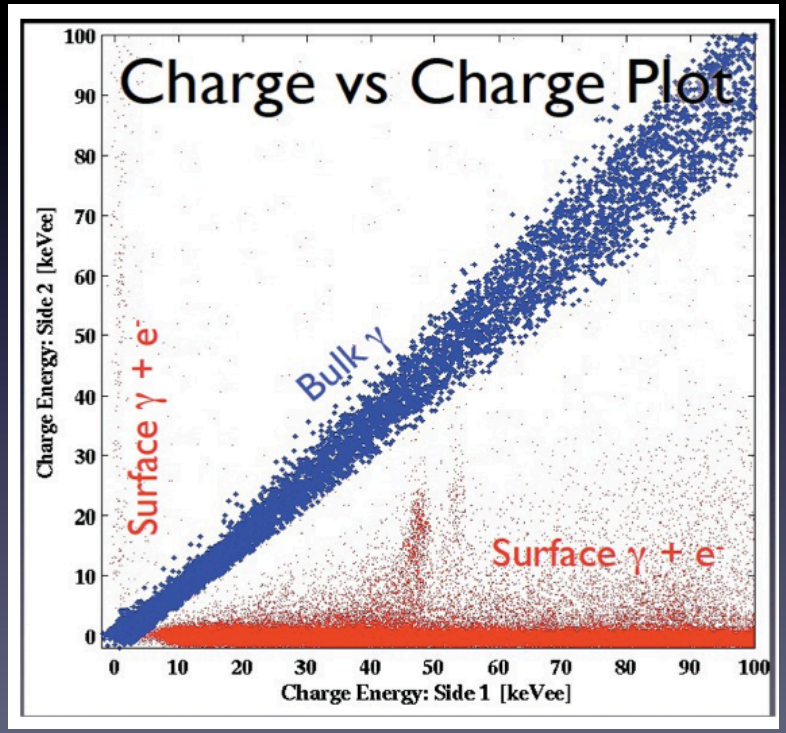

Surface Test Facility Data (UCB)

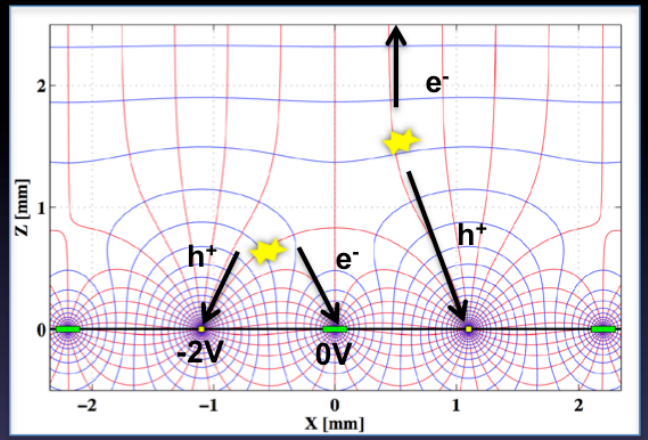
# Why the iZIP?

- A dominant background in CDMS-II was surface events
- These occur near the surface dead layer of the detector
- Poor charge collection results in lower yield
  - These events 'rain' into the NR band
  - CDMS-II used various pulse shape timing parameters to discriminate
- The iZIP can do better



# Why the iZIP?

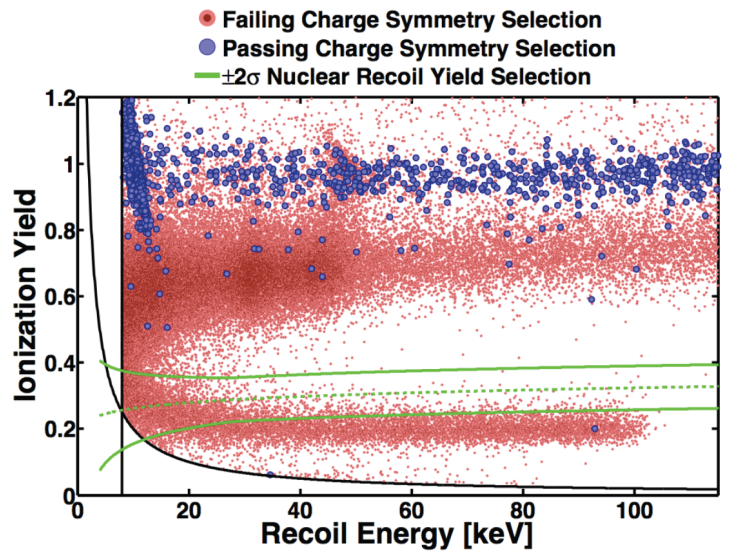


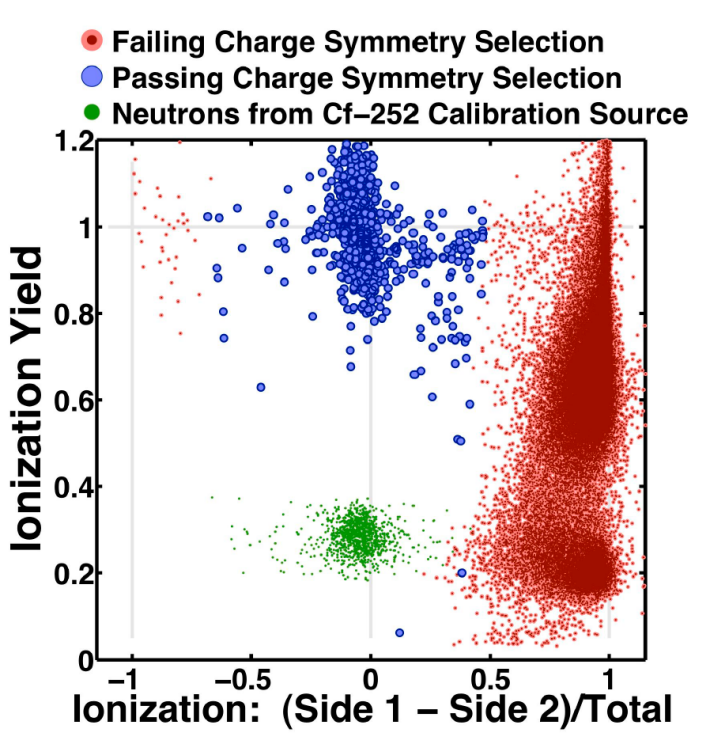




- Complex surface field
- Bulk events produce charge on both faces
- Surface events only on one side!

# Charge Discrimination

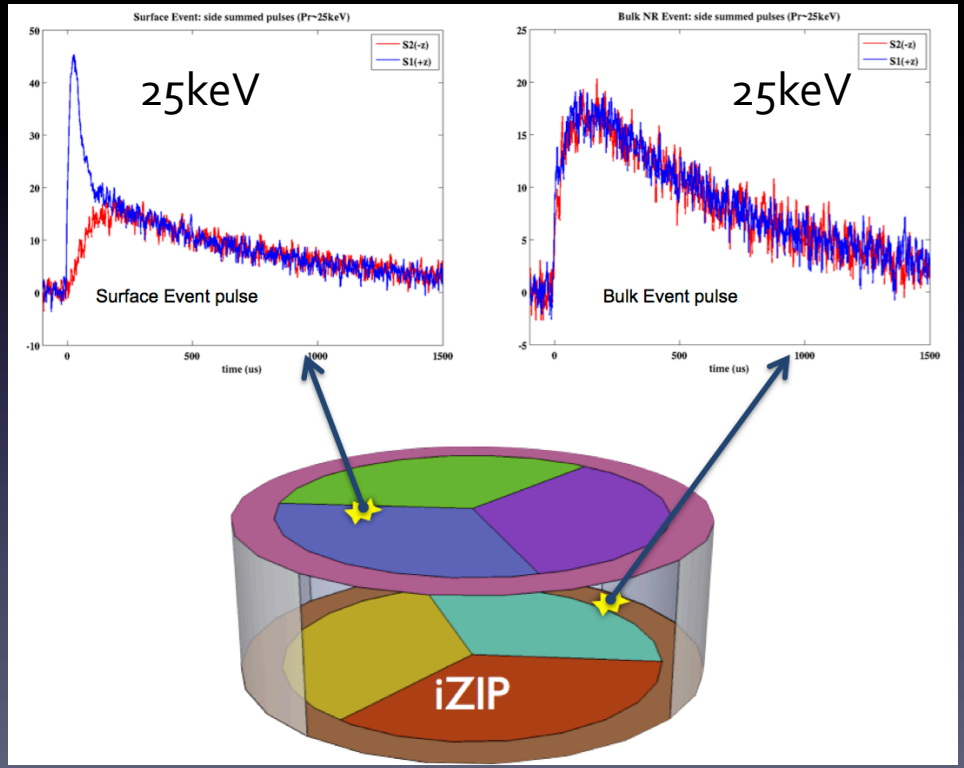
- Implanted $^{210}Pb$ sources adjacent to 2 detectors to study surface event rejection
- Currently have statistics limited rejection fraction of $1.7 \times 10^{-5}$ (http://arxiv.org/abs/1305.2405 )



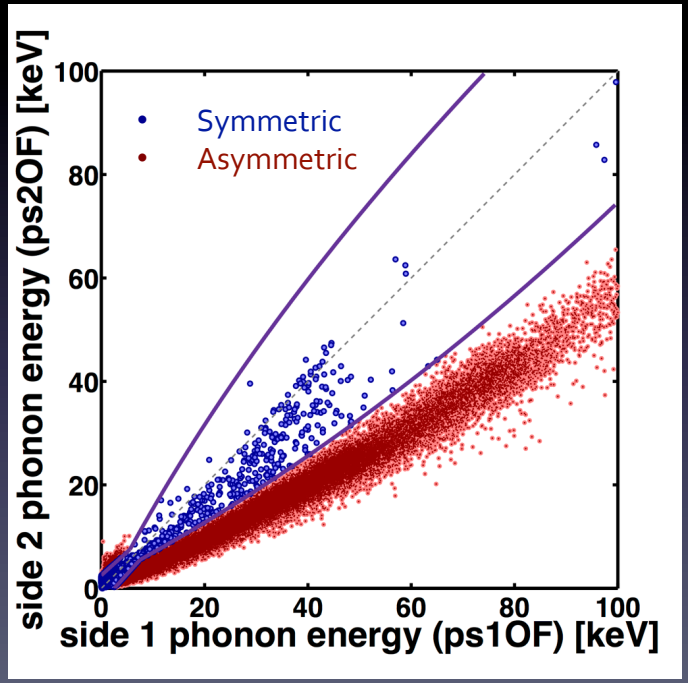
# Phonons

- Phonon based surface event discrimination possible
- Events near surface look different than those in bulk



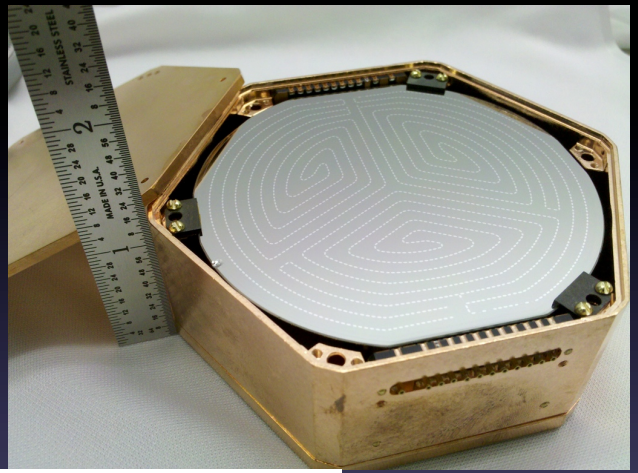
# Phonon Discrimination

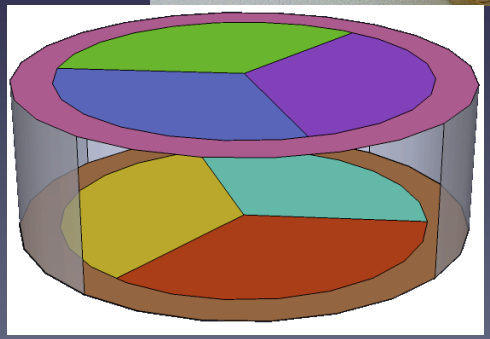
- Phonon based symmetry performs better than ionization at low energy
  - Lower intrinsic noise
- Can use in conjunction with ionization
- $4.54 \times 10^{-4}$ surface event discrimination observed for phonons
- Outer phonon channel allows for removal of side-wall events
  - So called 'zero-charge' events



# Detector Utilization

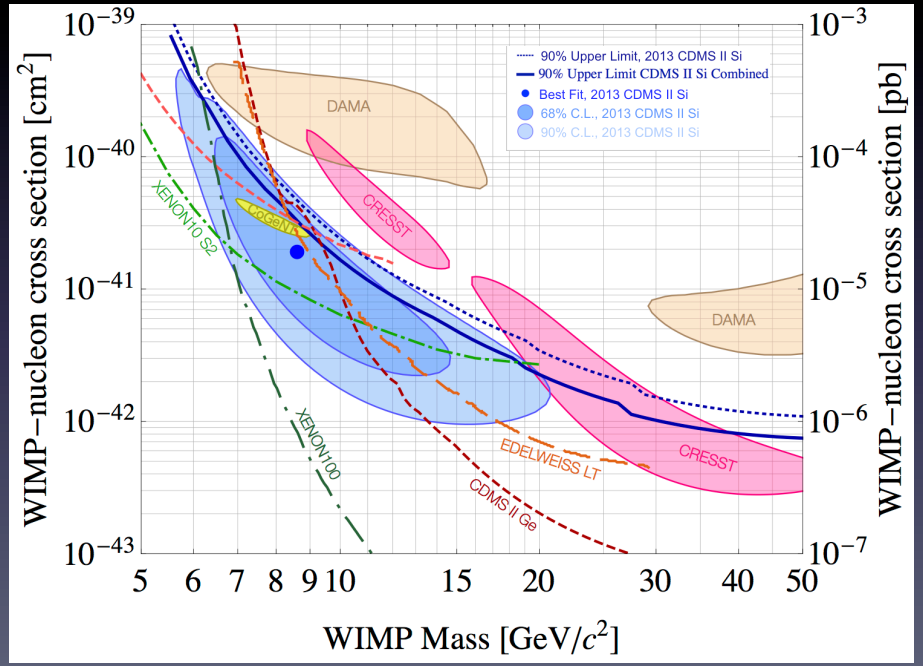
- SuperCDMS at Soudan uses 15 Ge iZIPs
  - Improved discrimination
  - Increased acceptance
- Lets us perform high and low mass WIMP searches





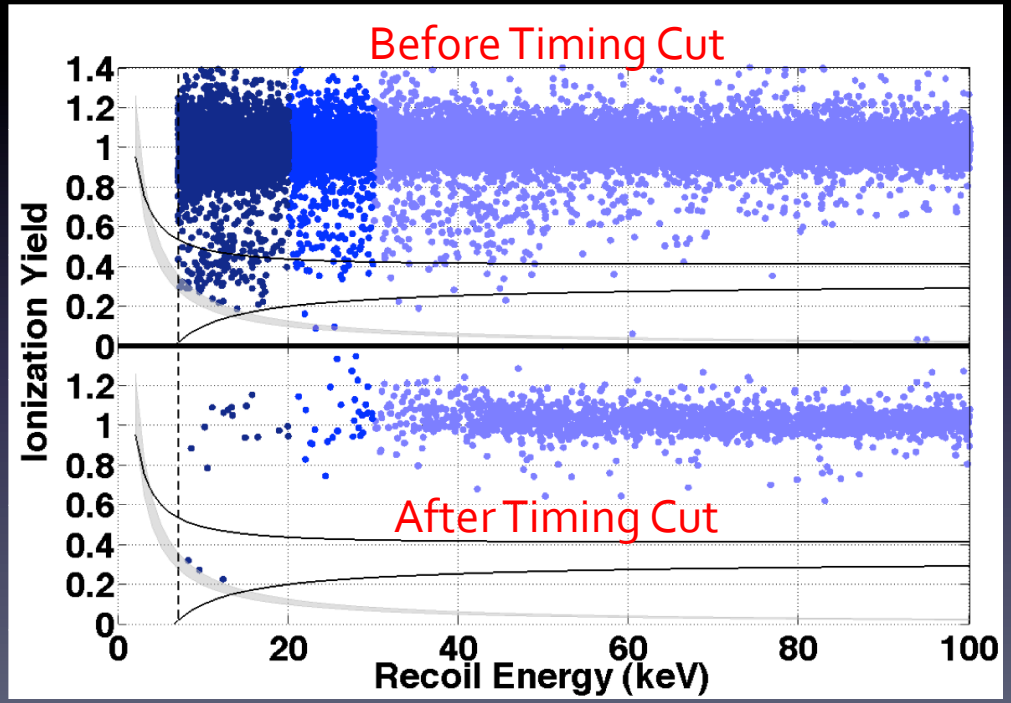
# Low Mass WIMPs

- Low mass search possibilities
- Recent experiments have had intriguing hints in the low mass region
- CDMS-II Si results quite interesting and can motivate further study
  - http://arxiv.org/abs/1304.4279



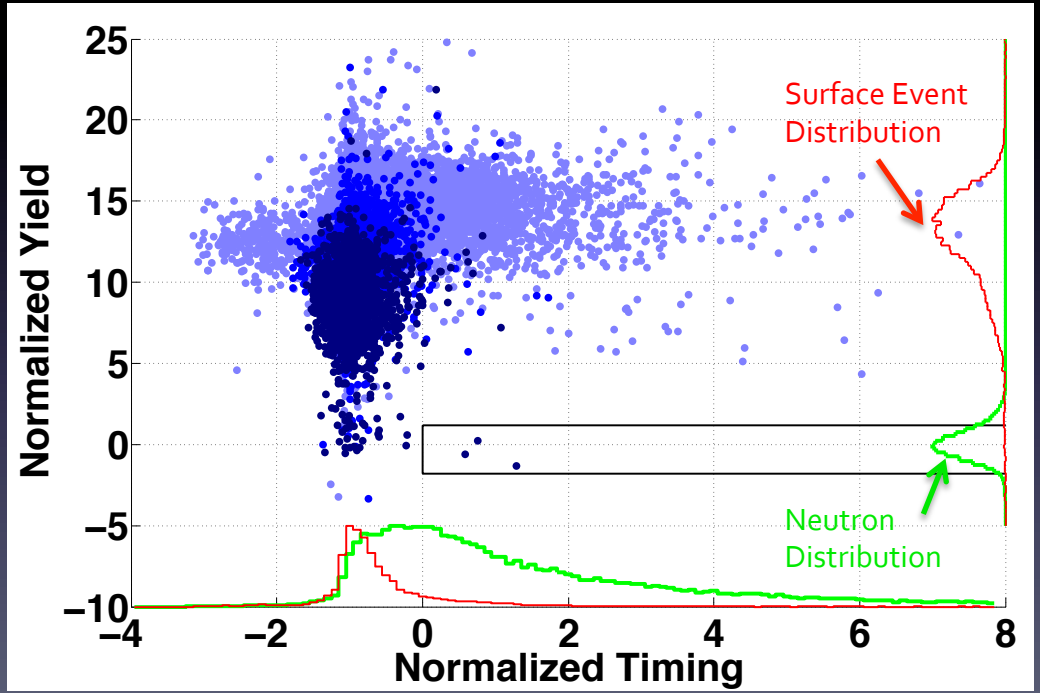
# CDMS-II Si Result

- 140.23 kg-days in 8 Si detectors
- Timing parameter cut based on phonon pulse shape
- Rejects surface event rain seen in yield



# CDMS-II Si Result

- In middle of signal event distribution
- In tail of Surface Event distribution
- Each event is likely single scatter
- Profile likelihood favors WIMP +background hypothesis over known backgrounds (3σ)

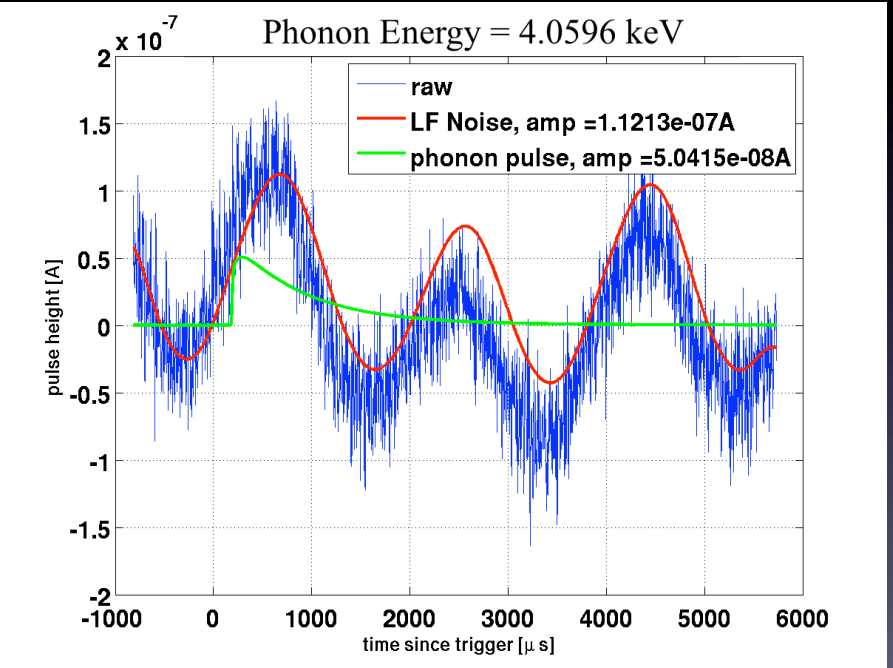


# Low Mass WIMPs

- iZIP detectors are suited for a low mass search
- Low mass WIMPs impart low energy into detectors
- Requires low trigger thresholds
  - Pay a livetime penalty due to noise triggering excessively
- Implement bandpass filters to take advantage of signal power in low frequency domain over usual noise
  - Allows lower trigger threshold

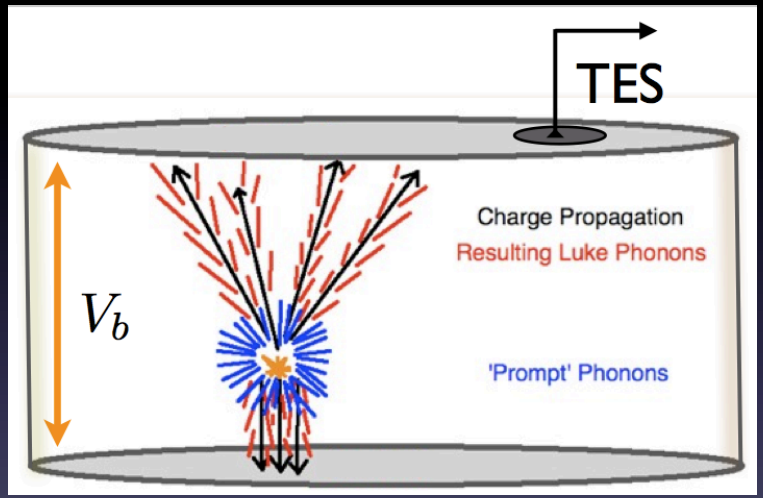
# Low Mass Backgrounds

- Low frequency noise is problematic
- Reconstructs to low energy pulses
- Can get around this with LF noise templates
- Fits LF noise better than standard pulse template allowing us to discriminate
  - Currently under study



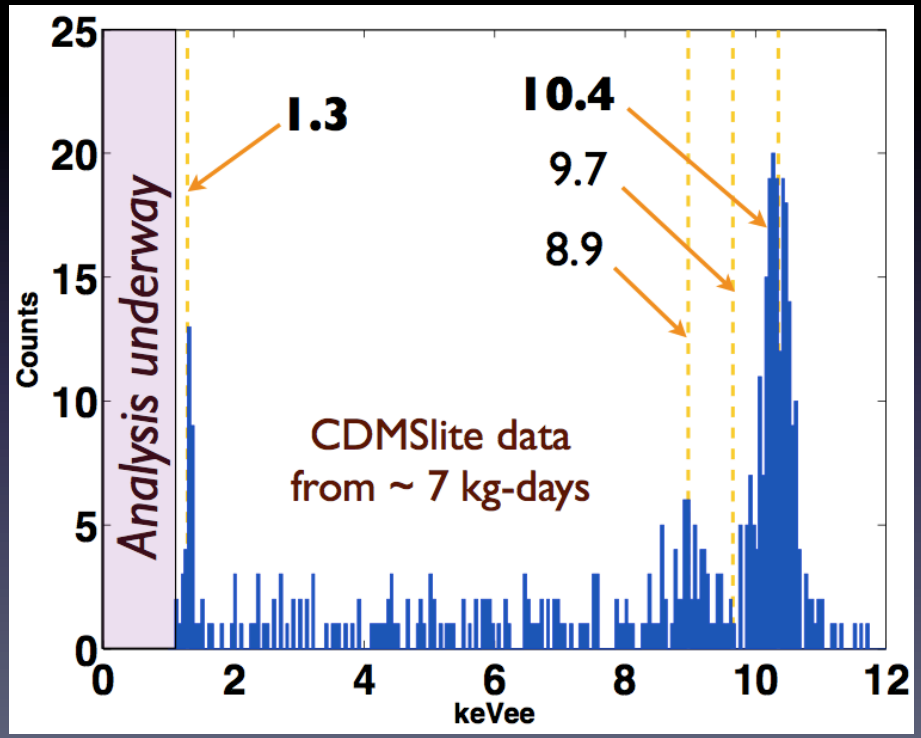
# CDMSLite

- Can explore low mass WIMPs via alternative running mode
- CDMSLite utilizes Luke phonons
- Standard detectors are biased at +/- 2V
- $E_{luke} = N_{e/h} \times eV_b$
- Luke energy scales as bias voltage and noise remains constant until breakdown



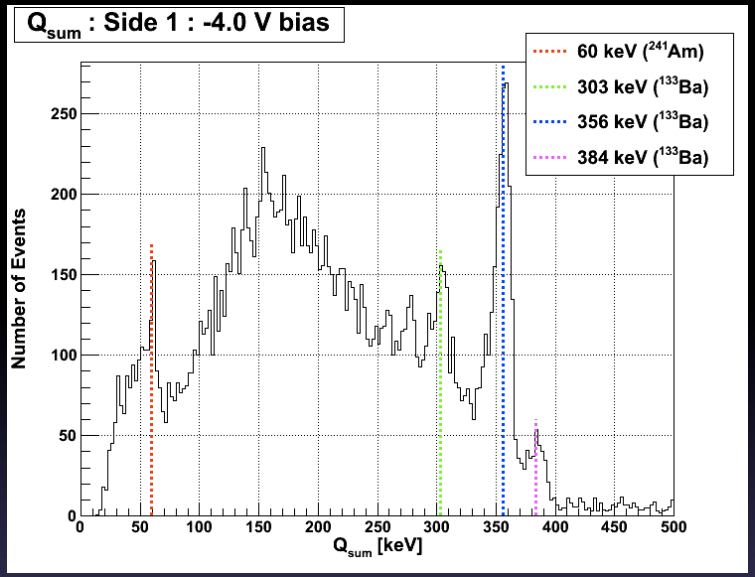
# CDMSLite

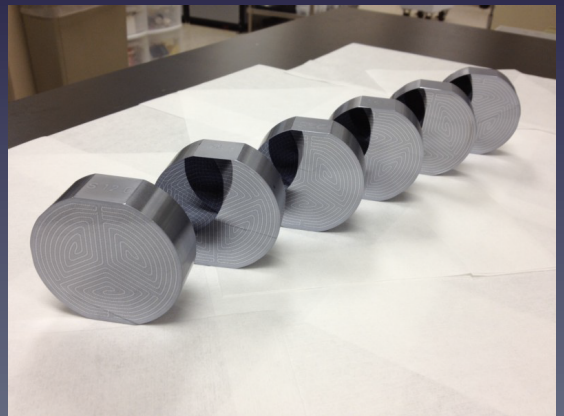
- As a result of amplified Luke signal has excellent energy resolution ~ 13 eVee
- Can resolve various Ge activation lines

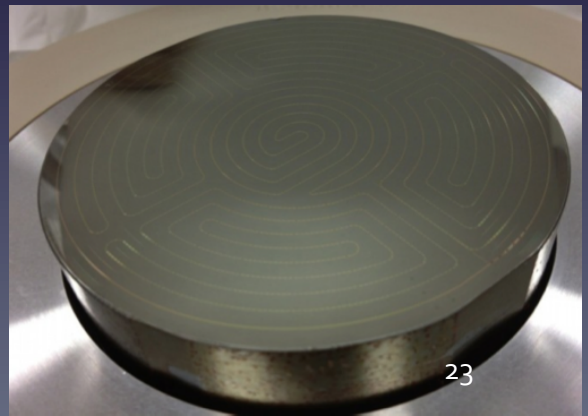


# Future

- Future plans include a 200kg payload in SNOLAB
- Will consist of larger iZIP detectors (100mm diameter)
  - 73% fiducial volume
- HEMT based ionization readouts
- Possible lower Tc TES sensors
  - Can help improve energy resolution

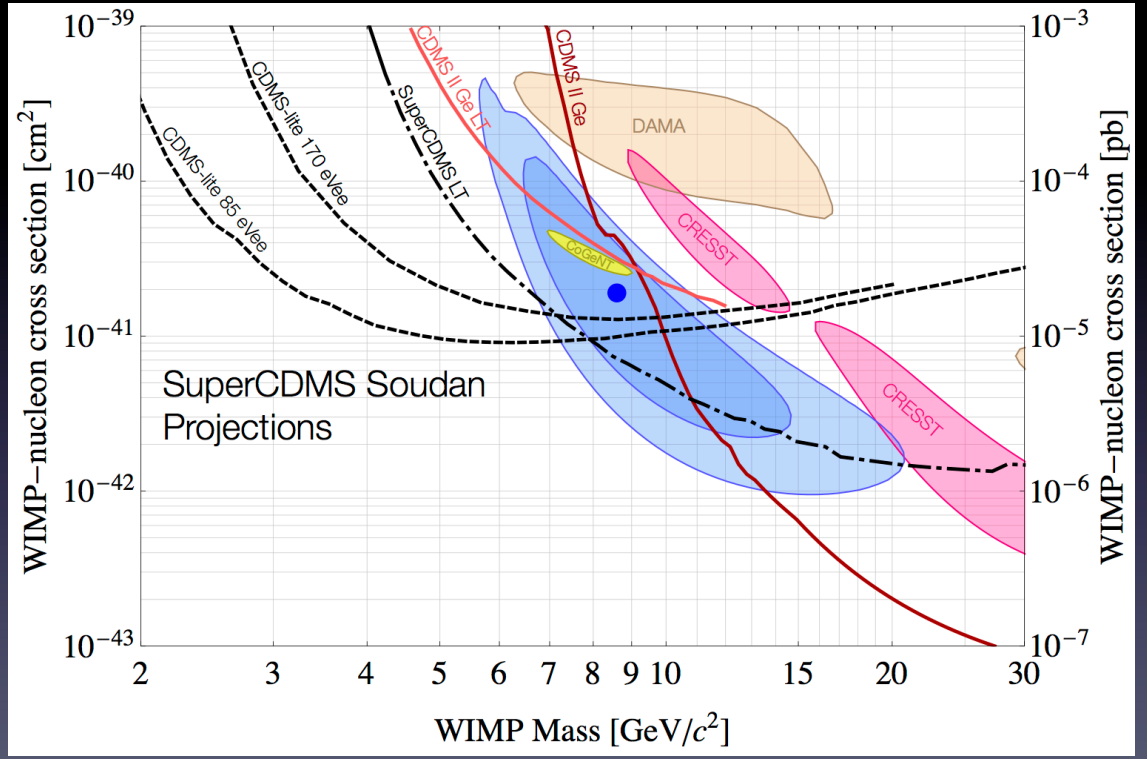




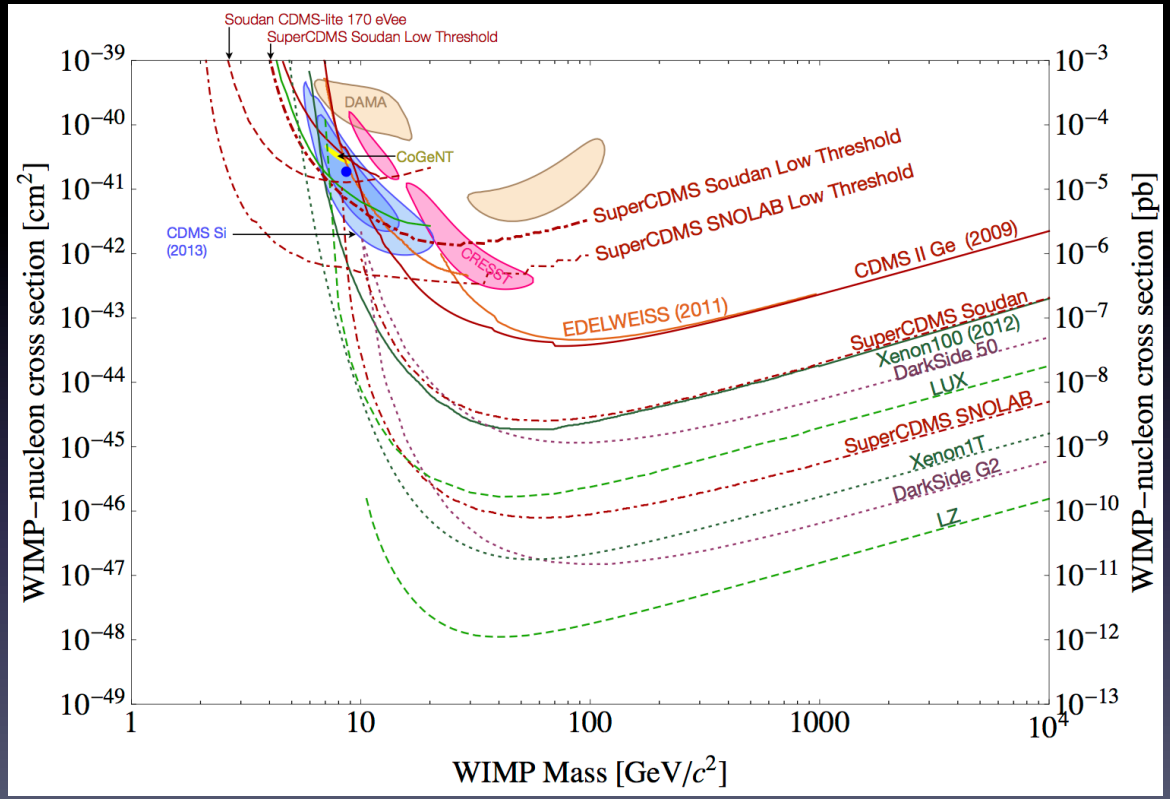
# Summary

- iZIP detectors offer improved background discrimination
- Competitive high and low mass searches
- CDMSLite shows promise for leading low mass cross-section limits



# Summary

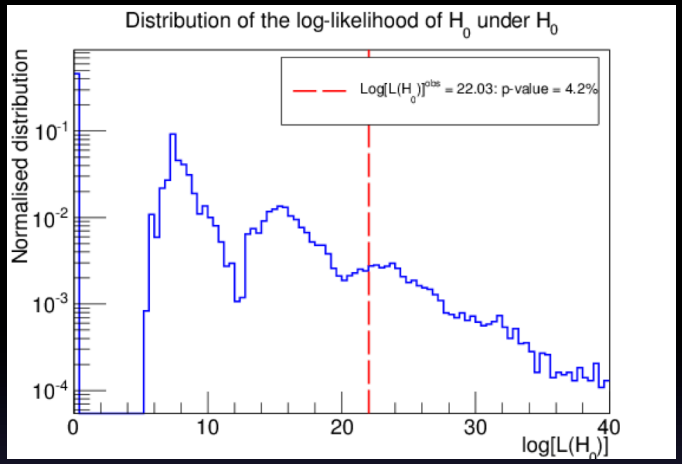
- Expect Soudan results from low mass and high mass WIMP searches later this year!
- SuperCDMS SNOLAB will have better sensitivity and explore interesting parameter space

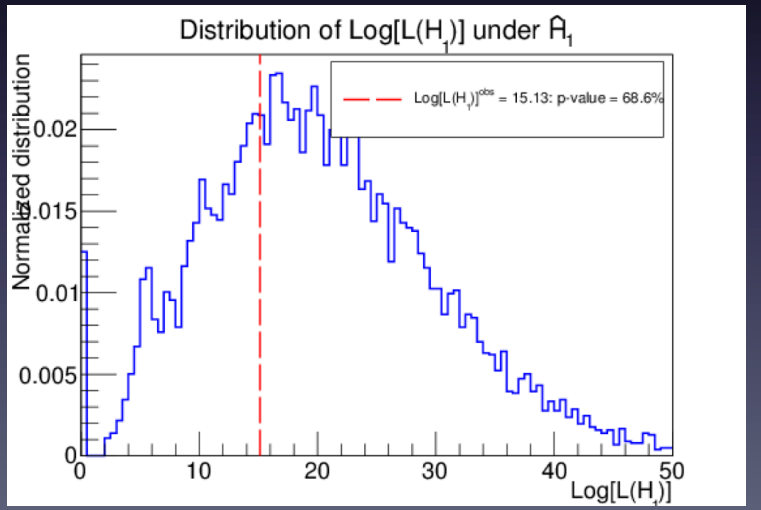


# Backup

# Goodness of fit

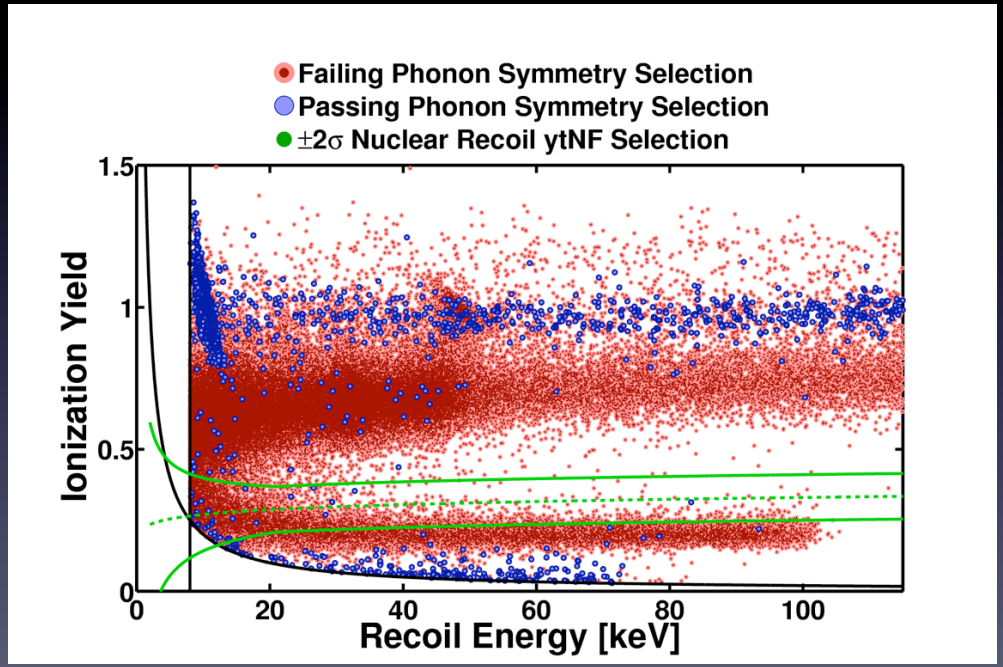
- Profile fits data well
- Goodness of fit for known background only is 4.2%
- Goodness of fit for WIMP +background is 68.6%



# Phonon Discrimination

- Make similar yield plot
  - Phonon symmetry instead of ionization
- Very good rejection seen



# Charge Symmetry

- Definition of Charge symmetry cut
- Gamma line from Ba source seen