Recent results from the second CDMSlite run and overview of SuperCDMS SNOLAB project

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on behalf of the SuperCDMS collaboration

U.S. DEPARTMENT OF ENERGY Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

The SuperCDMS Collaboration

California Inst. of Tech. | CNRS-LPN | Durham University | FNAL | Mass. Inst. of Tech.

NIST Inst. of Tech. | PNNL | Queen's University | SLAC | Southern Methodist U.

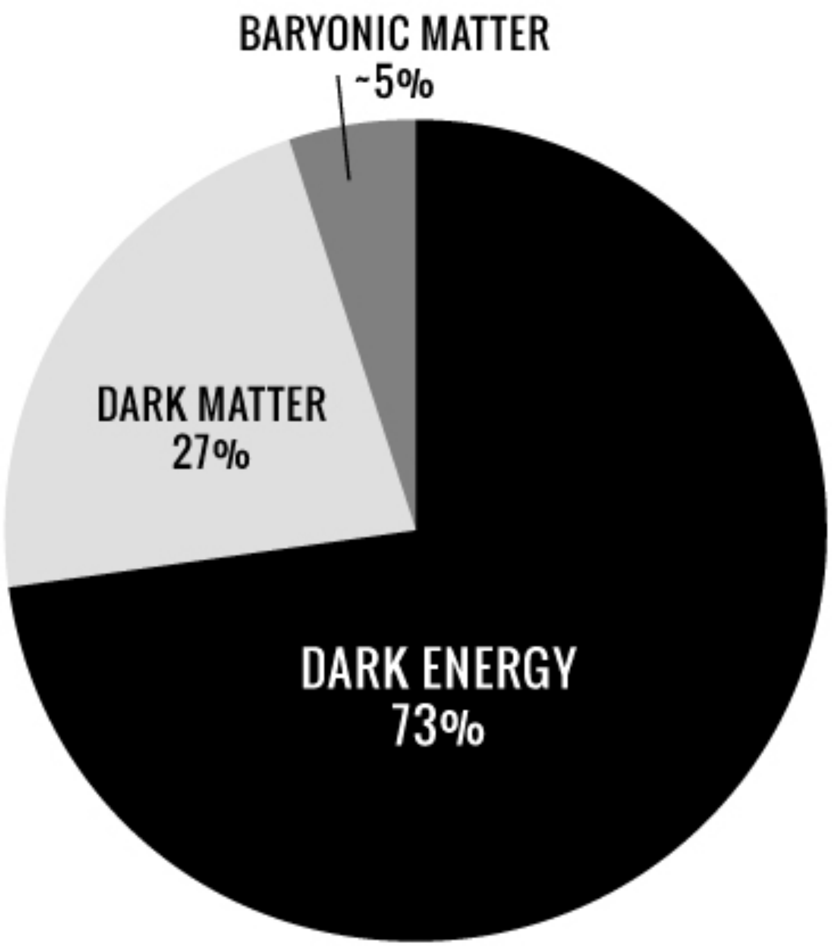
Santa Clara University | South Dakota SM&T | Stanford University | Texas A&M University | U. British Columbia

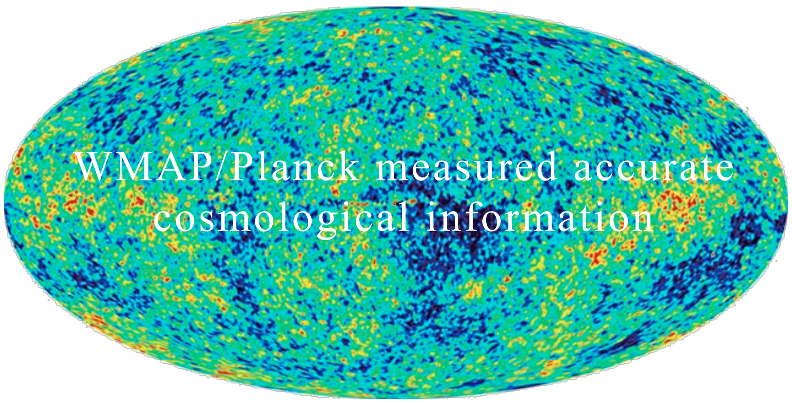
U. California, Berkeley | U. Colorado Denver | U. Evansville | U. Florida | U. Minnesota | U. South Dakota

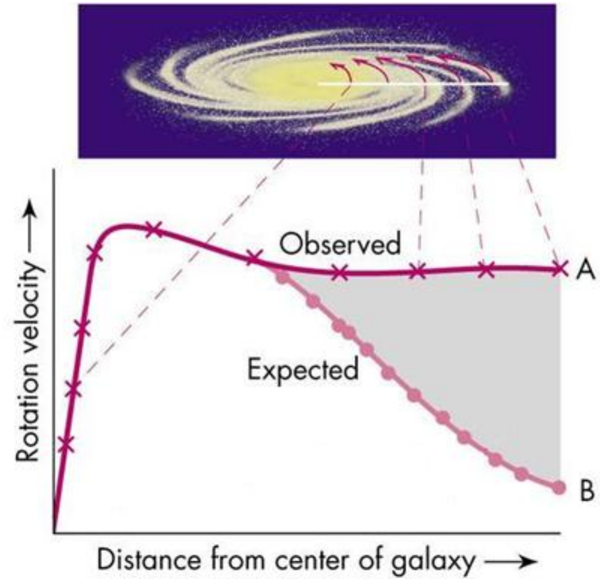
Outline

- Introduction
- SuperCDMS Soudan
  - Detection concept
  - Detector design
  - CDMSlite second run result
- SuperCDMS SNOLAB
  - Project overview
  - Detector design
  - Projected sensitivity

Introduction

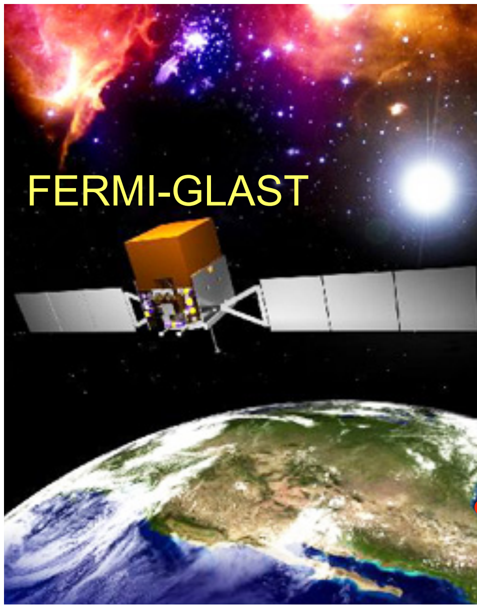




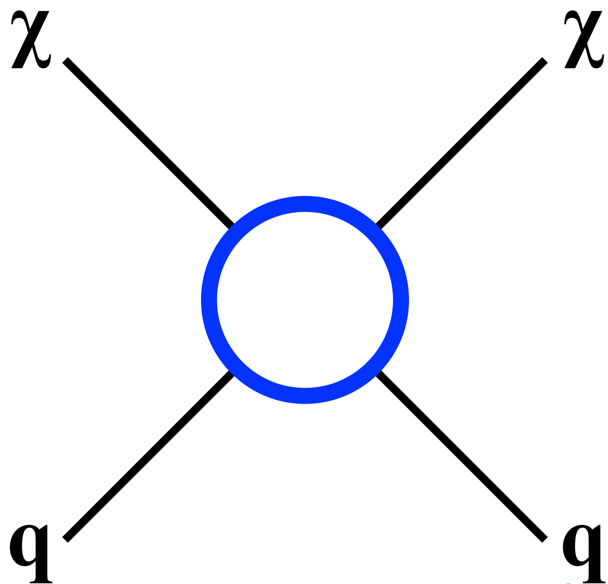


Galactic rotational curve

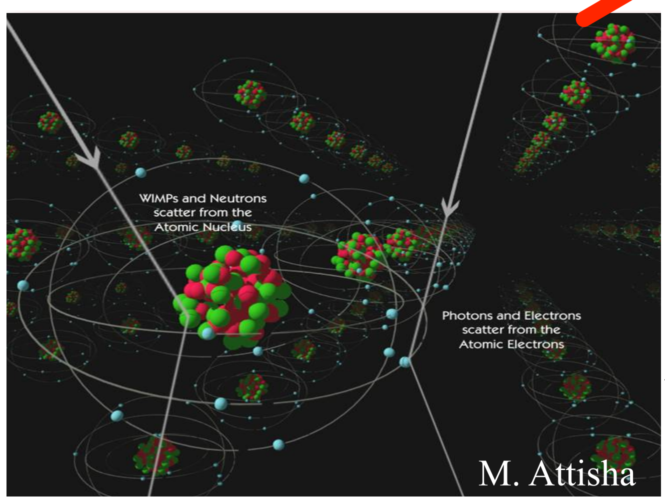
DM search



Indirect Search
DM annihilation



Collider Search
Man-made production



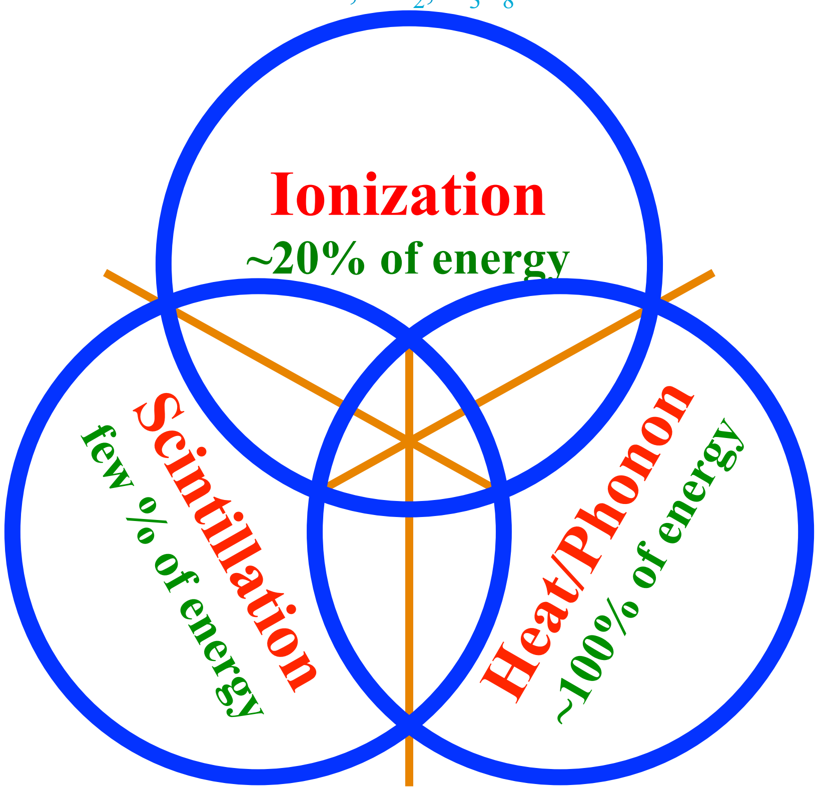
Direct Search
Nuclear elastic scattering

Direct DM search

DRIFT
DAMIC
CoGeNT
PICO
Ge, CS_2, C_3F_8

ZEPLIN II, III
XENON10,100,1T
WARP
ArDM
Darkside
LUX
PandaX
Xe, Ar, Ne

SuperCDMS
~~EDELWEISS~~
Ge, Si

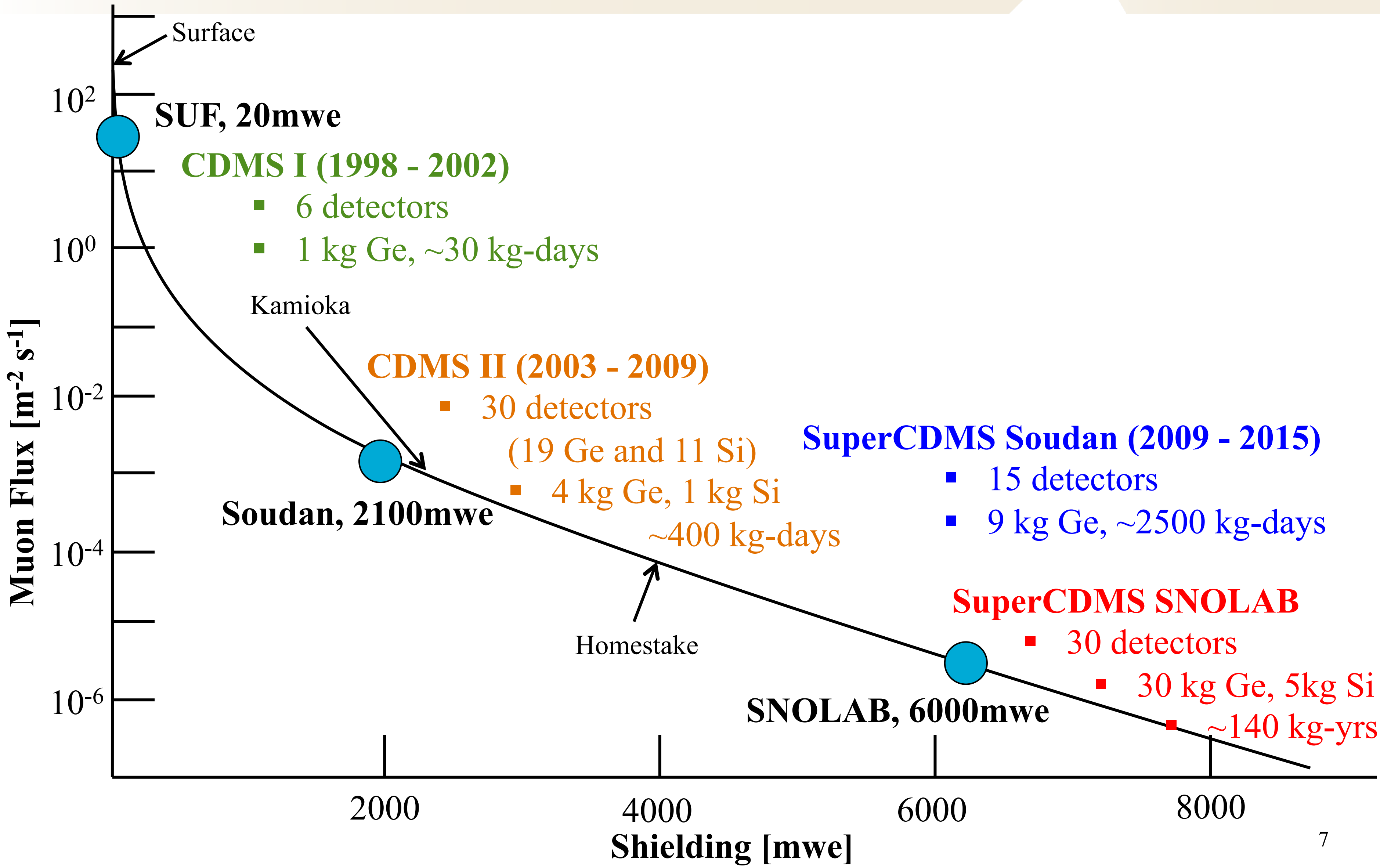


NAIAD
ZEPLIN I
DAMA/LIBRA
KIMS
DMice
XMASS
DEAP/CLEAN
NaI, CsI, Xe, Ar, Ne

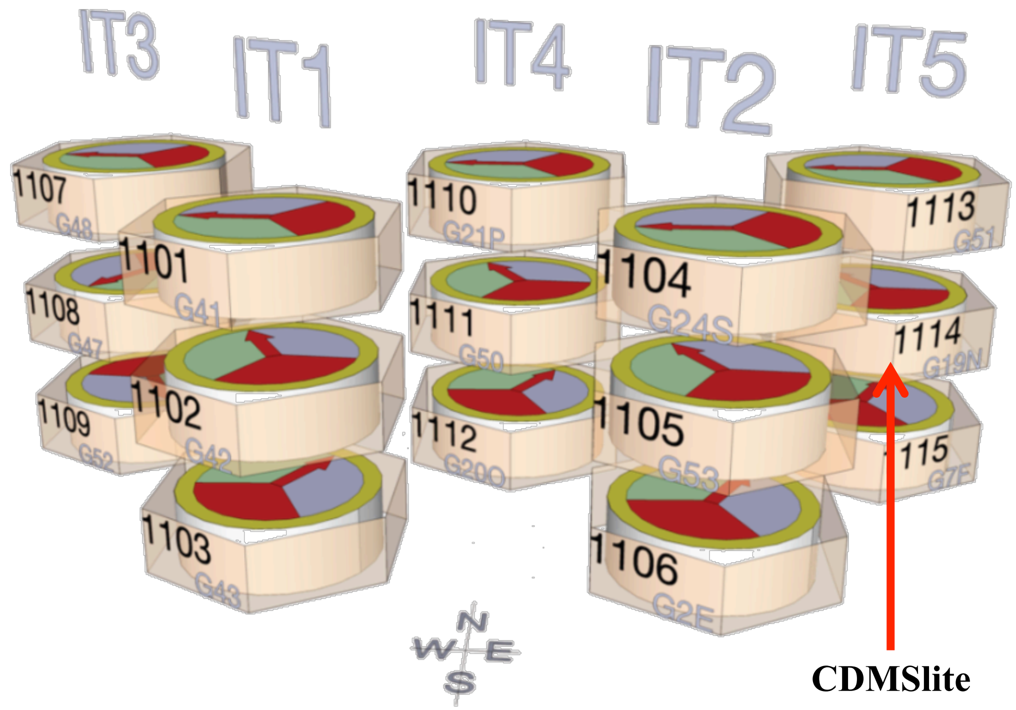
CRESST II
ROSEBUD
$CaWO_4$, BGO, $ZnWO_4$, Al_2O_3

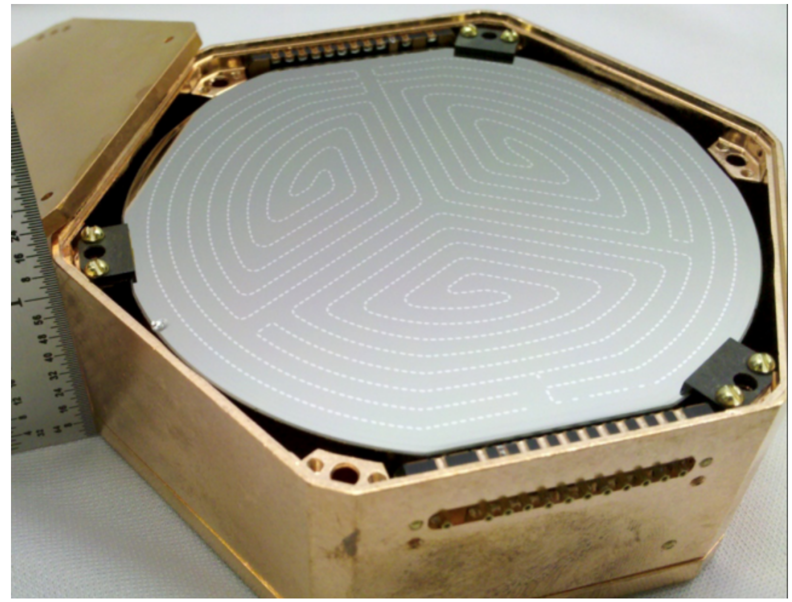
CRESST I
Al_2O_3, LiF

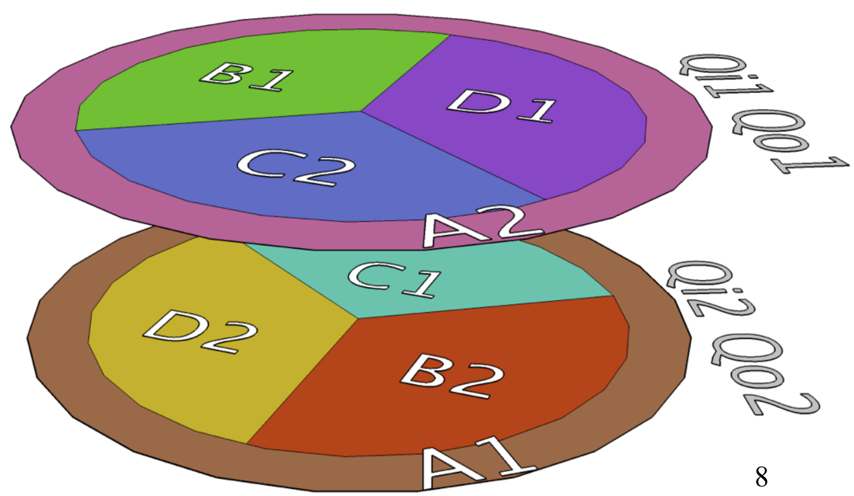
CDMS project history



SuperCDMS Soudan

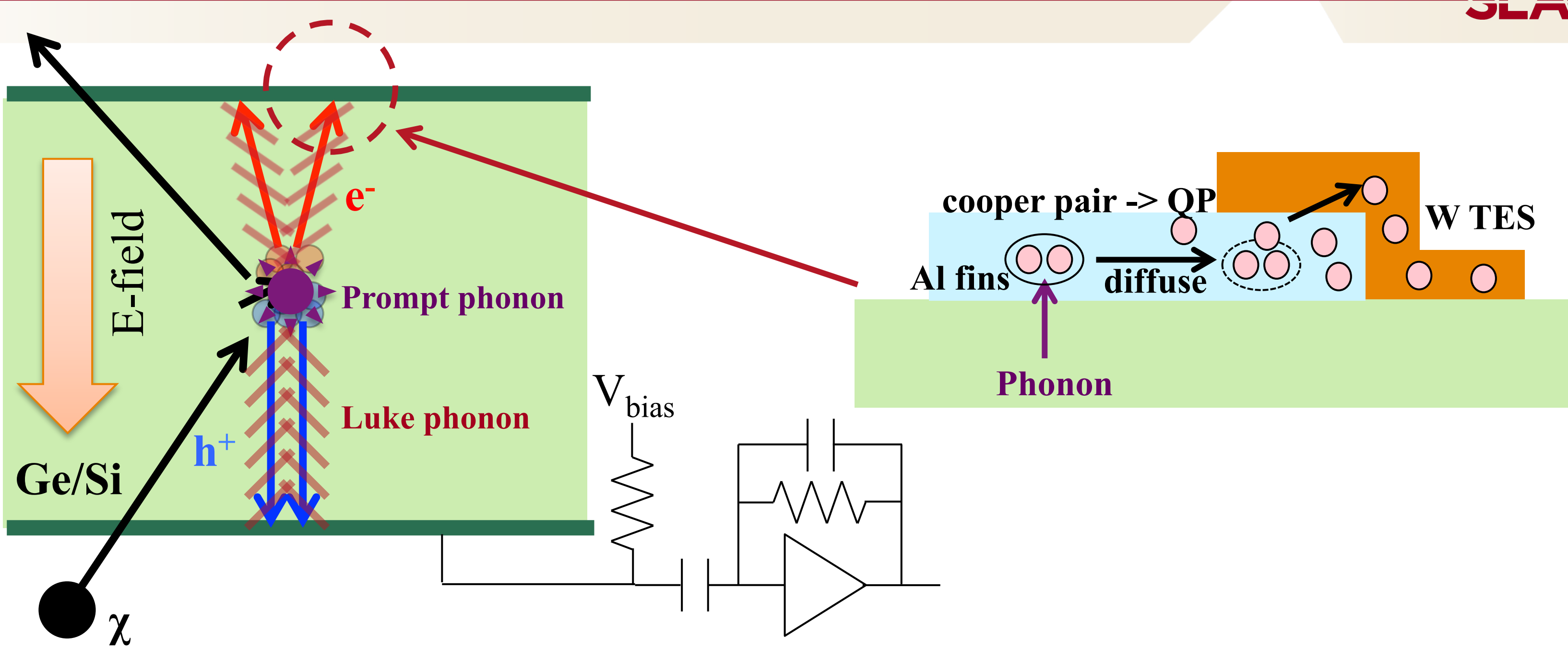






- There are 5 towers, 3 detectors each
- 3 inch diameter, 2.5 cm thick, 600g Ge crystal (CDMS II: 240g)
- 4 phonon and 2 charge channels/side

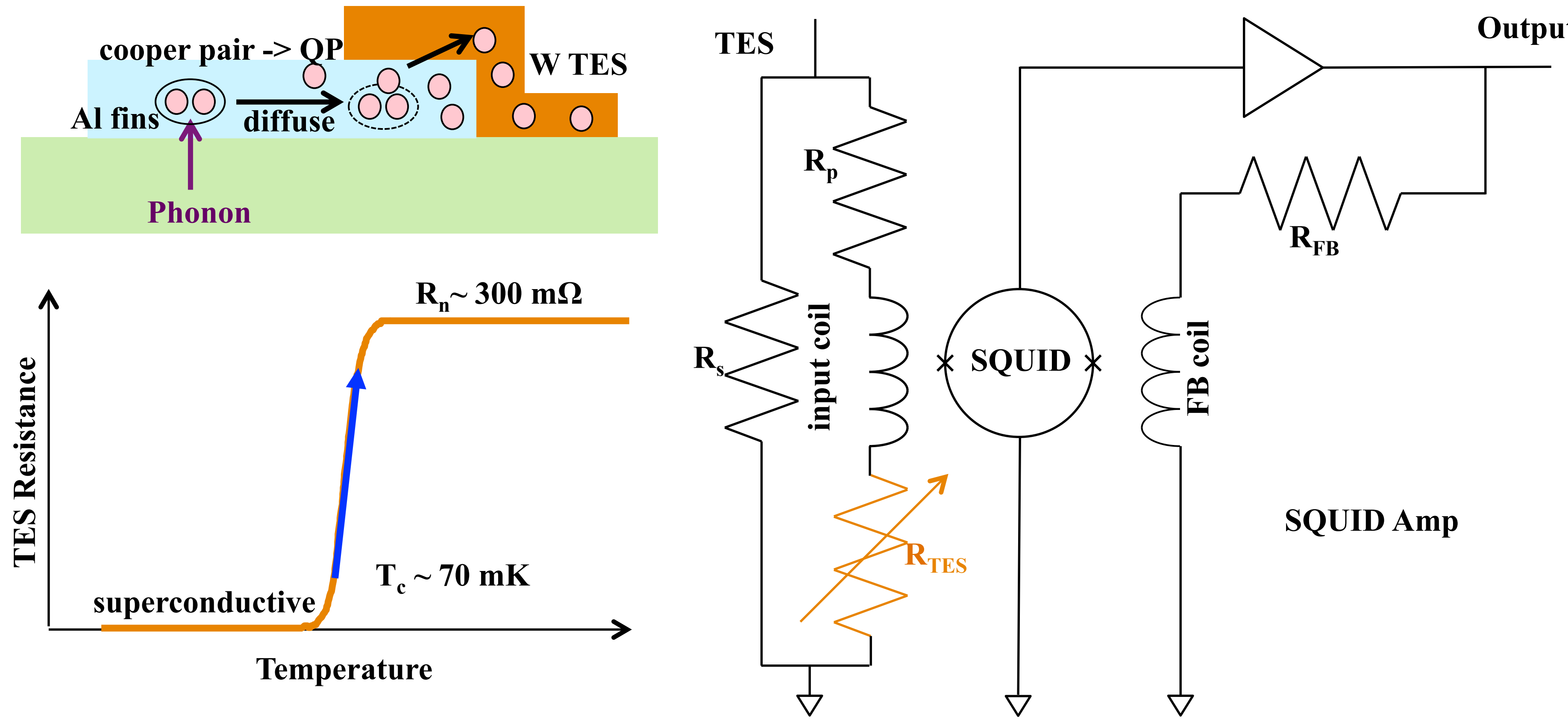
Detection technique – phonon & charge signals



- DM scatters off a target nuclon (Ge/Si)
  -> creates **prompt phonons** & **e**-**h** pairs
- e^-/h^+ are separated by E-field and drift to electrodes
  -> creates **Luke phonon** due to the Naganov-Luke effect
- e^-/h^+ are read out with the charge sensitive amplifier
- Phonons break cooper pairs in Al fins, create quasi-particles (QPs)
- QPs are collected in W Transition Edge Sensors (TESs)

Detection technique – TES

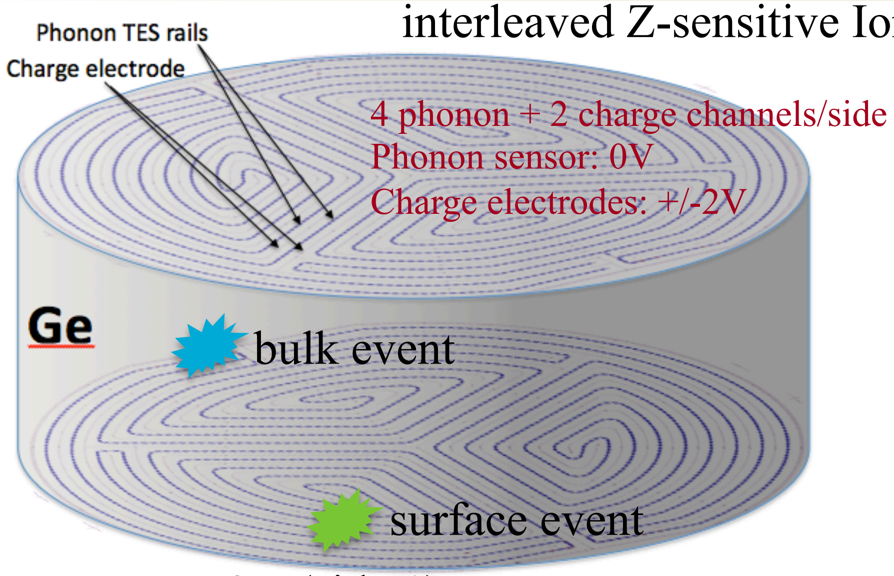
SLAC

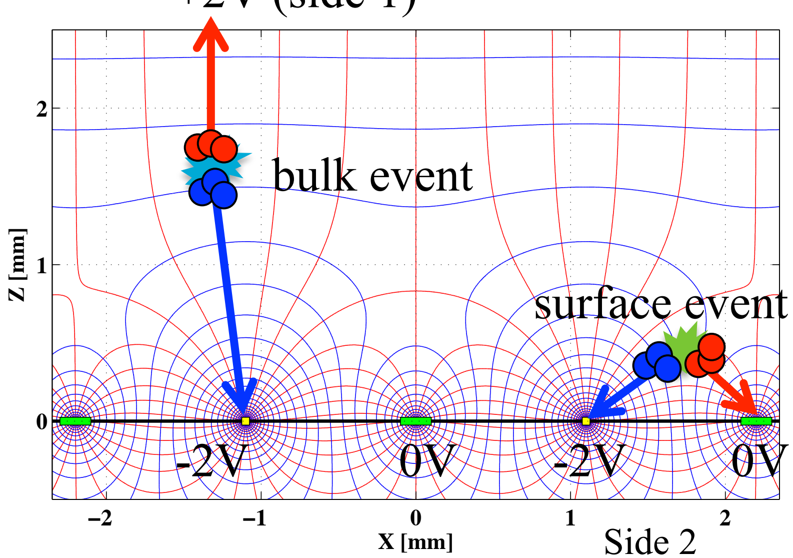


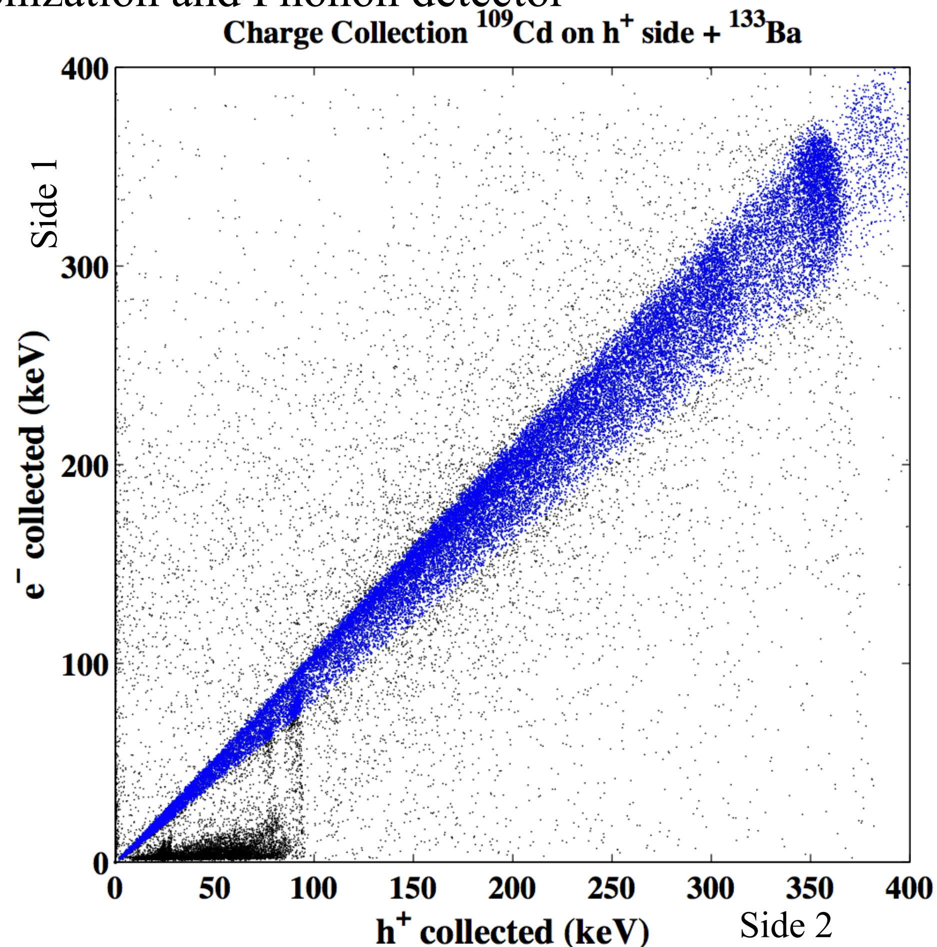
- TES resistance sharply increases as warmed up
  -> current changes in the input coil
- SQUID amplifier reads the induced magnetic flux in the input coil

iZIP detector – surface rejection with charge

interleaved Z-sensitive Ionization and Phonon detector



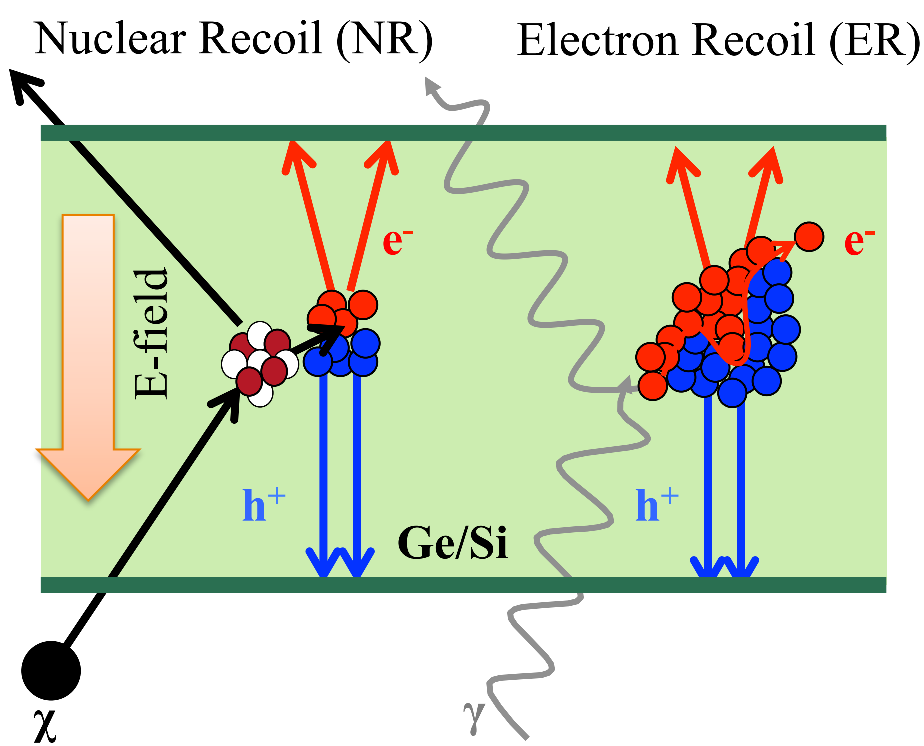


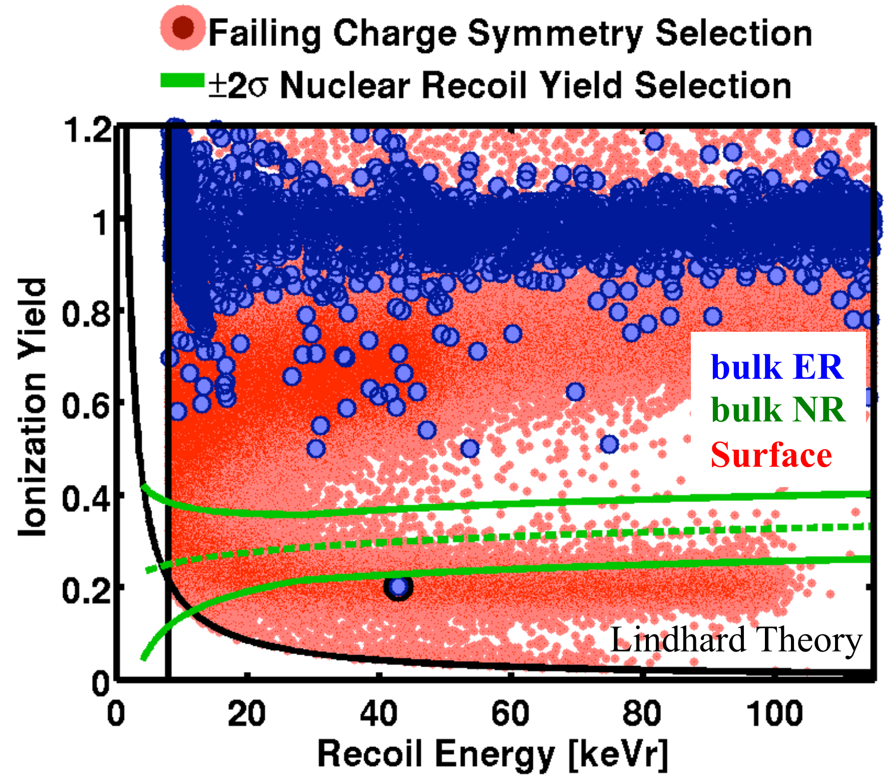


side1- 2 symmetric: bulk event

side1- 2 asymmetric: surface event

iZIP detector – ionization yield



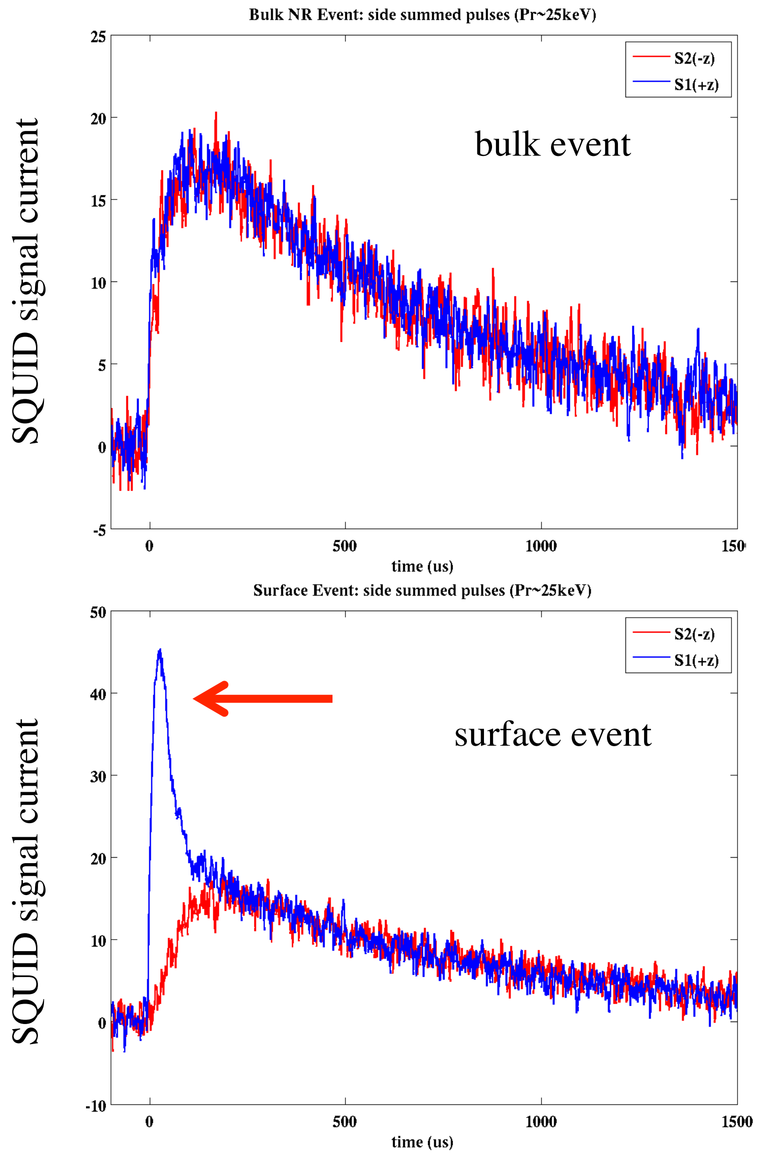


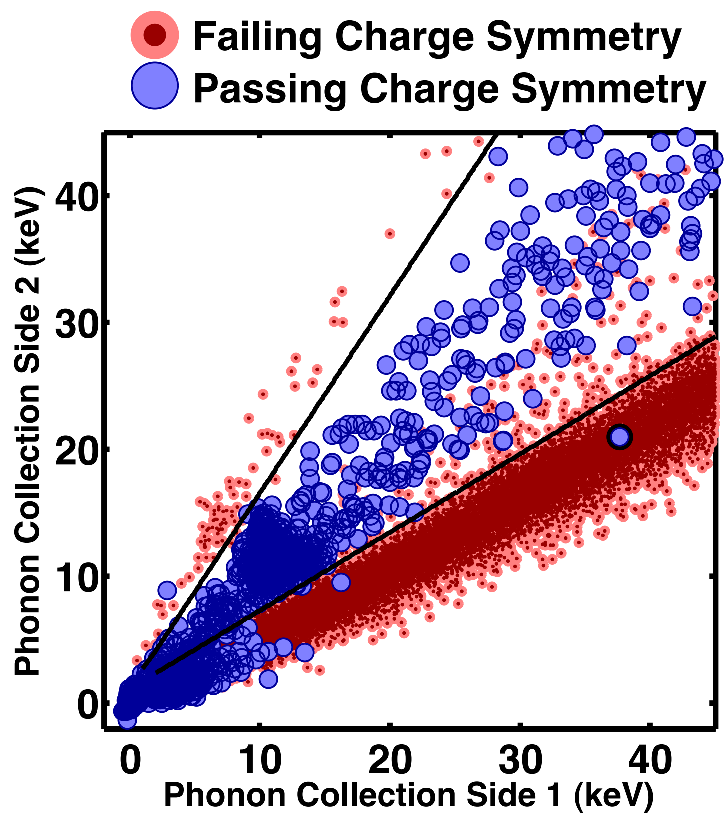
- Ionization yield: $Y = E_Q/E_{recoil}$
- NR events creates less e-h pairs, compared with ER for same E_r

Y ~ 1 for ER, ~ 0.3 for NR

-> NR events are distinguishable from ER with ionization yield

iZIP detector – surface rejection with phonons



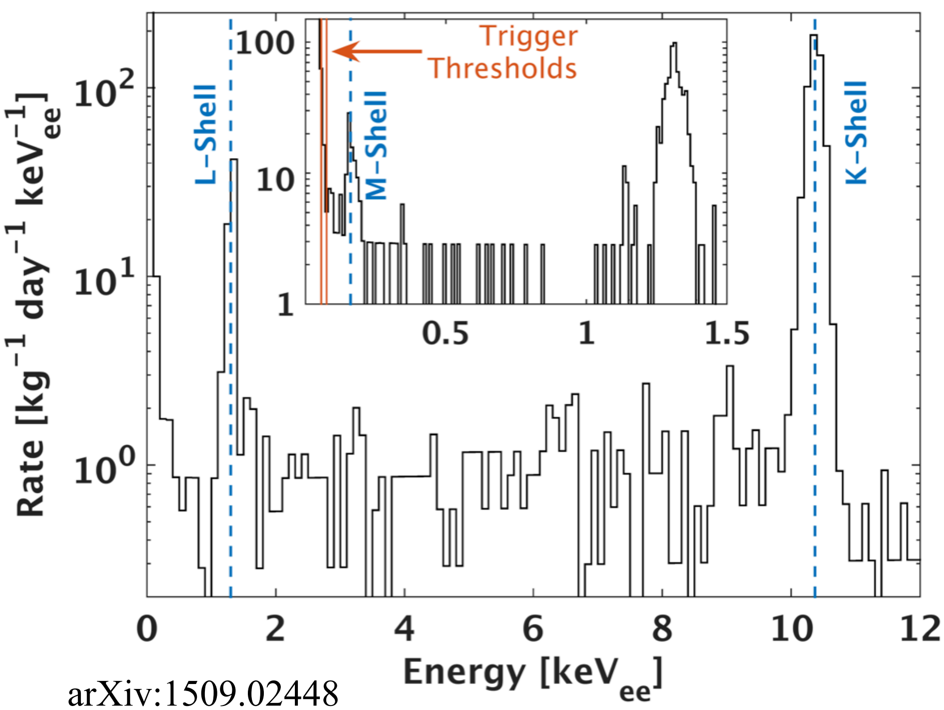


- Phonon pulse shapes are different between surface and bulk events

HV detector – CDMSlite

CDMS low-ionization threshold experiment

- One SuperCDMS iZIP detector was operated in HV mode
  - side 1: 0V, side 2: 70V
  - Read phonon signals at side 1
- Phonon signals are enhanced due to the Naganov-Luke effect



arXiv:1509.02448

$$E_{\text{phonon, total}} = E_r\left(1 + Y\frac{qV}{\varepsilon}\right)$$

ε ~ 3 eV for Ge, 3.7 eV for Si

-> x10 lower threshold for ER

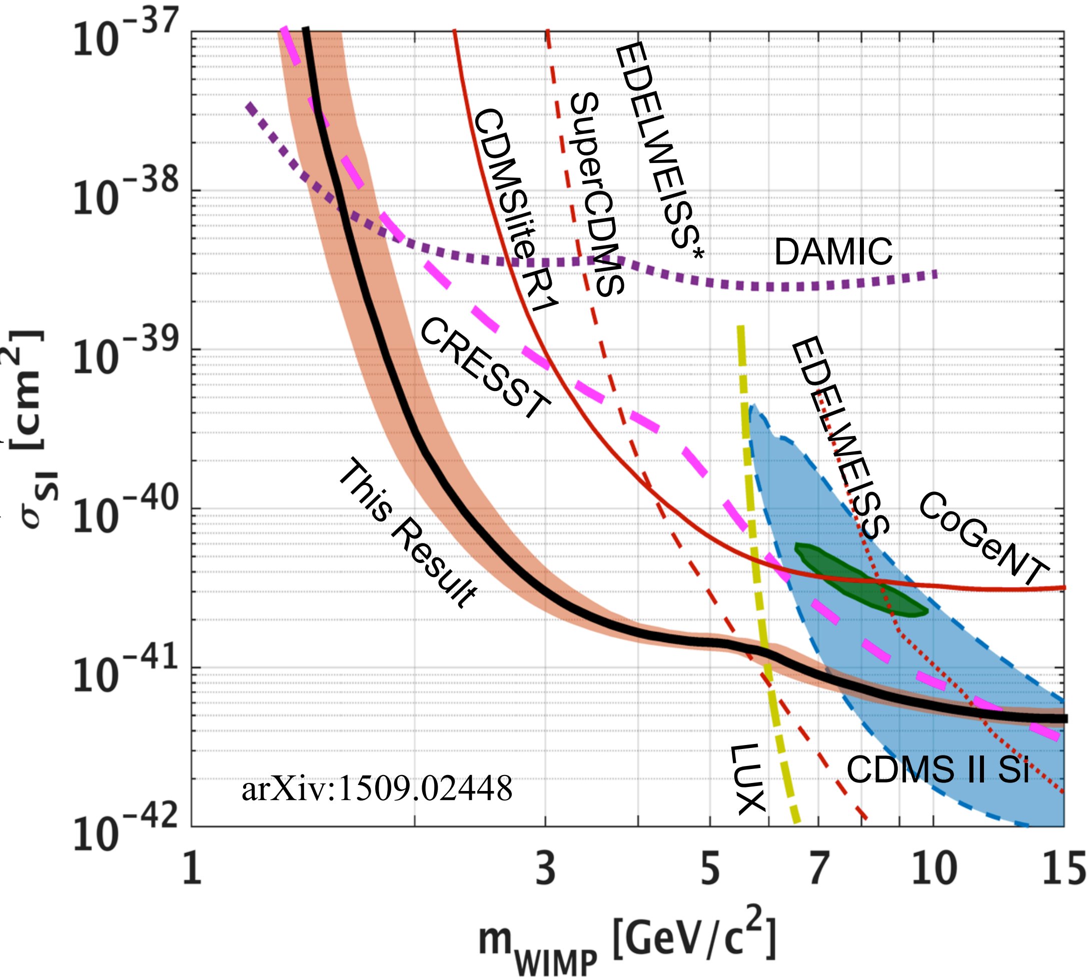
observed ^{71}Ge activation lines (0.16 keV, 1.3 keV, 10.4 keV)

-> x5 dilute background

- Similar phonon noise performance
- No ER-NR discriminations

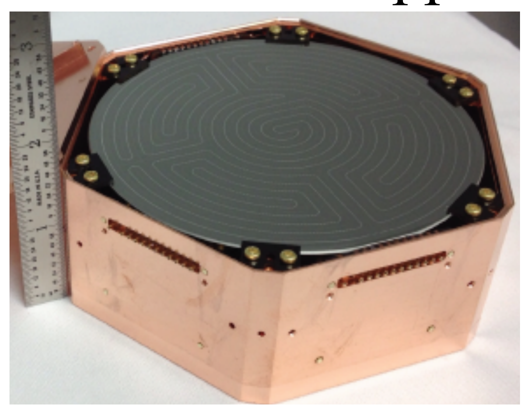
CDMSlite – recent upper limits

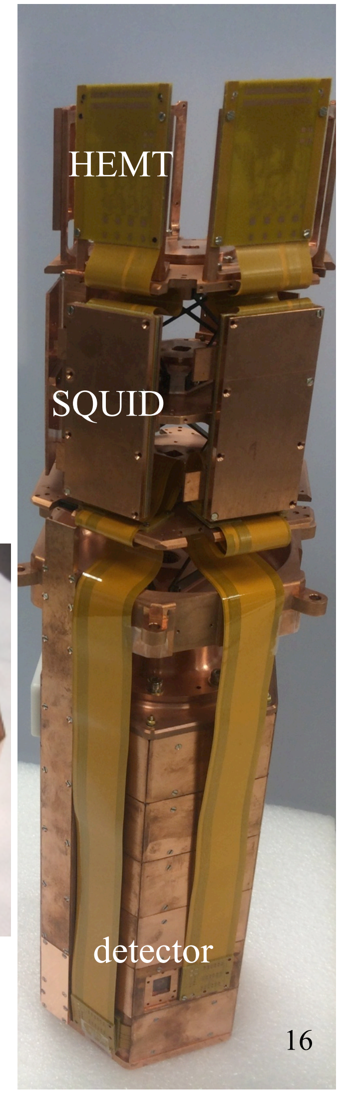
- First Run in 2013
  - 6.5 kg-days
  - 170 eV_{ee} threshold
- Second Run in 2014
  - install vibration sensor
  - better LF noise rejection
  - better energy calibration
  - new radial fiducial cut
  - 70 kg-days
  - ~ 56 eV_{ee} threshold



SuperCDMS SNOLAB – overview

- Selected as DOE/NSF 2nd-generation direct dark matter search
- Larger Ge/Si crystals: 1.4 kg for Ge, 0.5 kg for Si
  - 4 inch diameter, 3.3 cm thick
- 5 towers: 6 detectors/tower
  - 3 Ge iZIP, 1 Si iZIP, 1 HV (4 Ge + 2 Si) towers
  - Up to 31 towers are deployable
- Lower background
  - Lower bulk gamma background with cleaner copper
  - Lower Radon exposure
  - Lower cosmogenic activation
  - Lower muon flux at deeper site
- Improved signal readout
  - Phonon: new SQUIDs
  - Charge: FET -> HEMT (7mW -> 0.1 mW/device)
- Improved resolution with lower T_c



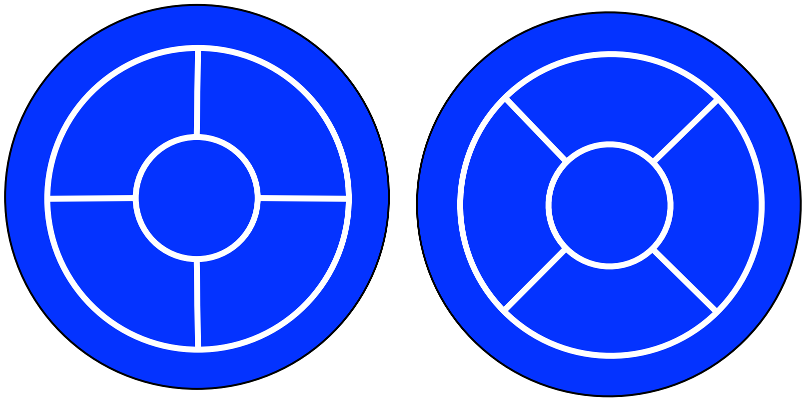


SuperCDMS SNOLAB – detector design

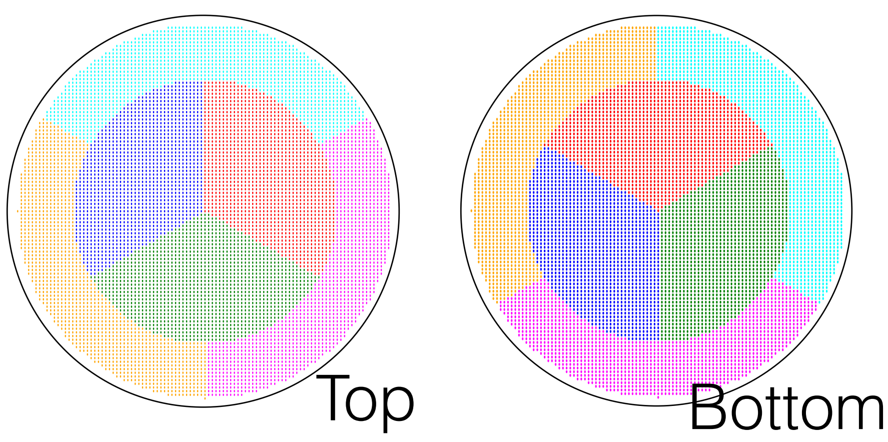
- iZIP detector
  - 6 phonon + 2 charge channels/side
- HV detector
  - side 1: +50V, side 2: -50V
  - 6 phonon channels/side

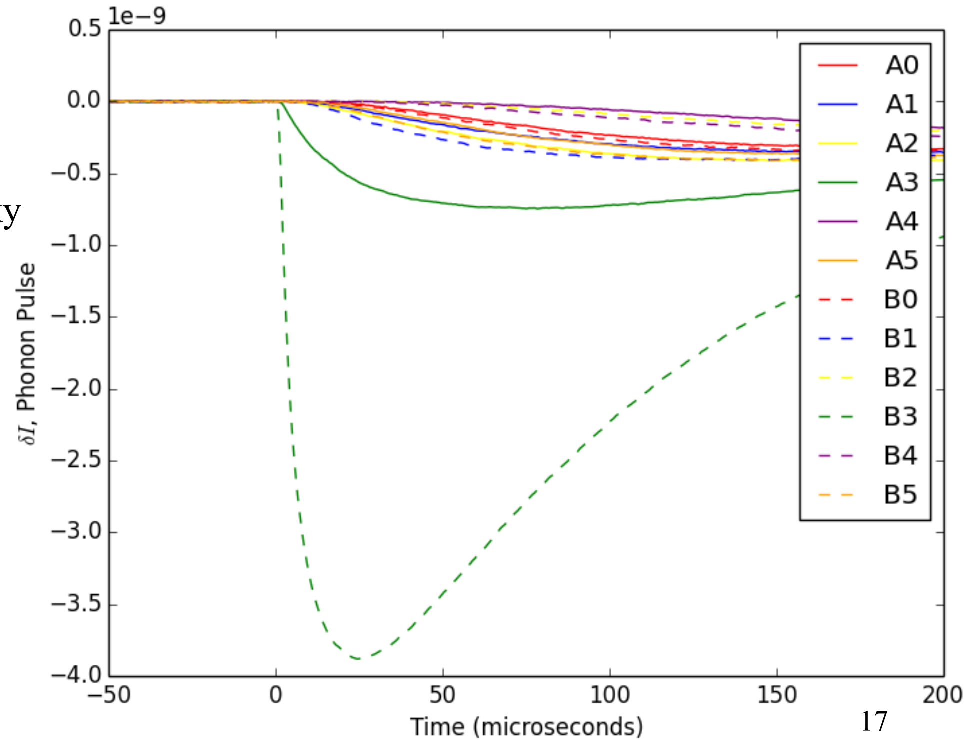
    -> surface rejection

    (z- and radial-fiducial cut)

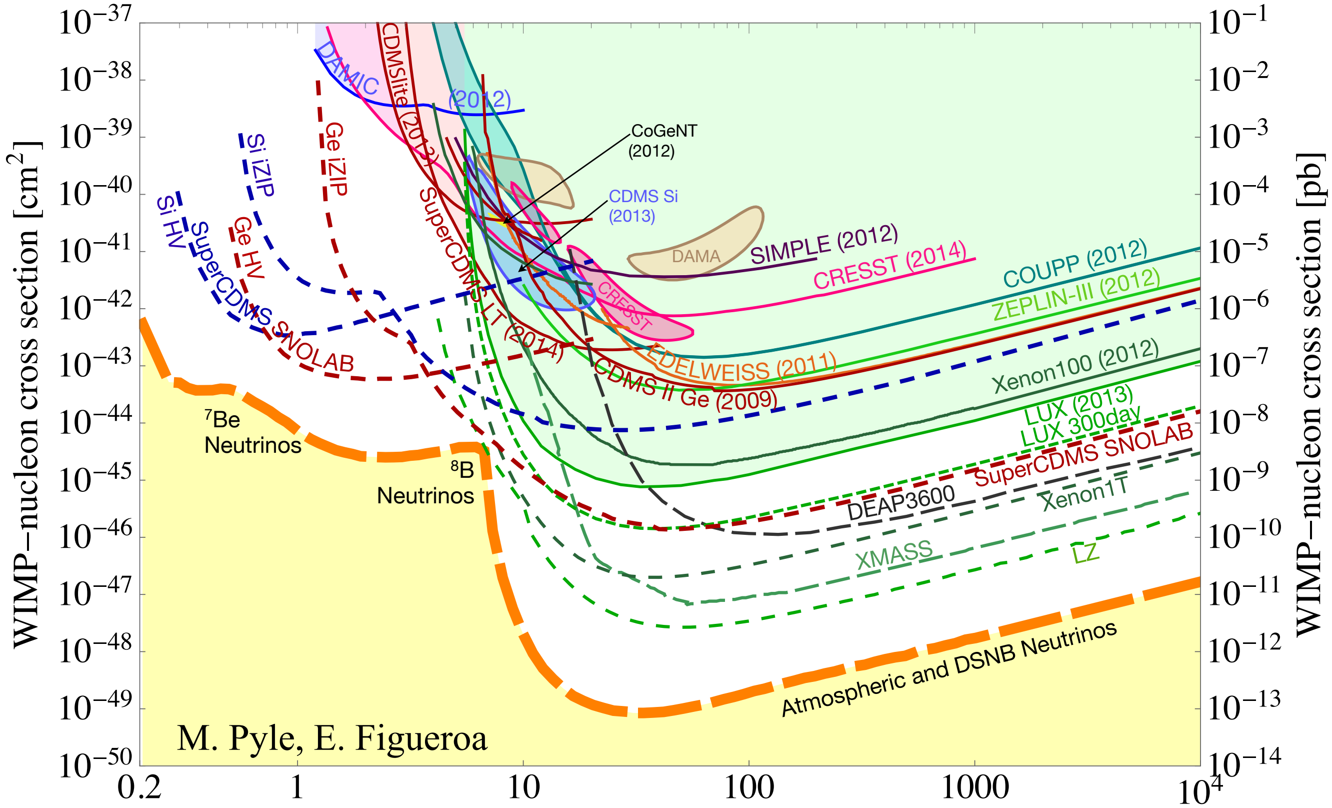


Preliminary studies, N. Kurinsky





SuperCDMS SNOLAB – projected sensitivity



- SuperCDMS SNOLAB can uniquely probe low mass DM, m < 5 GeV
- Ge and Si targets will allow us to study non-standard interaction
- Ge iZIP will detect ~ 15 ^{8}B solar neutrinos

Summary/Conclusion

- CDMS has been leading the direct dark matter search experiment for the past 15 years.
- The recent results of 70kg-days exposure in the second CDMSlite run excluded new parameter space for low-mass dark matter particles, in the dark matter mass range of 1.6 - 5.5 GeV.
- The SuperCDMS collaboration is moving forward with the design and construction of the SuperCDMS SNOLAB project.
- Lower backgrounds, lower threshold and improved detector resolution in SuperCDMS SNOLAB will allow us to uniquely and deeply probe the DM parameter space, especially for low-mass DM models.
- We will also be able to detect ^{8}B solar neutrinos