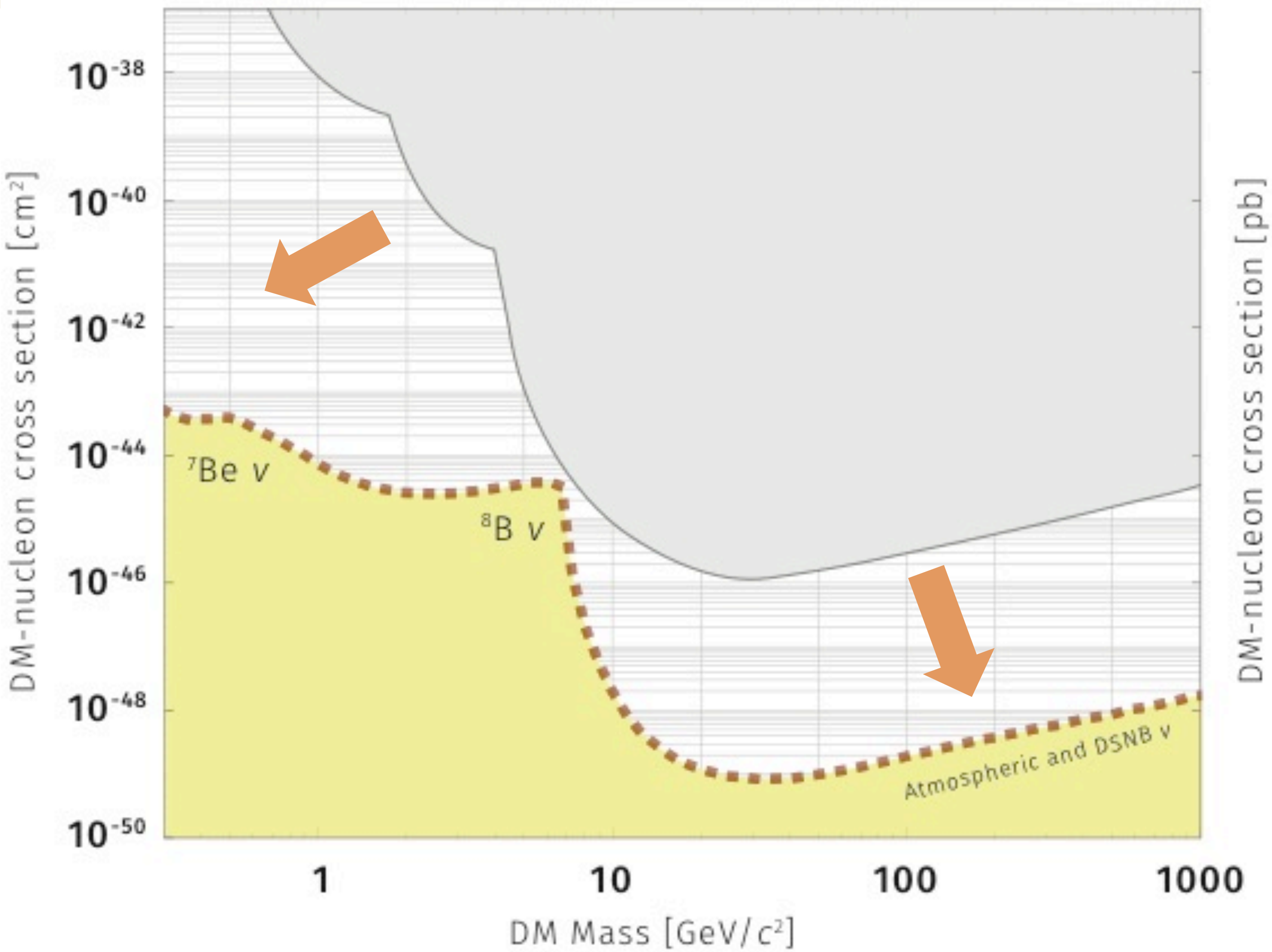
Recent Results and Current Status of SuperCDMS

TSUGUO ARAMAKI
SuperCDMS Collaboration
SLAC NATIONAL ACCELERATOR LABORATORY

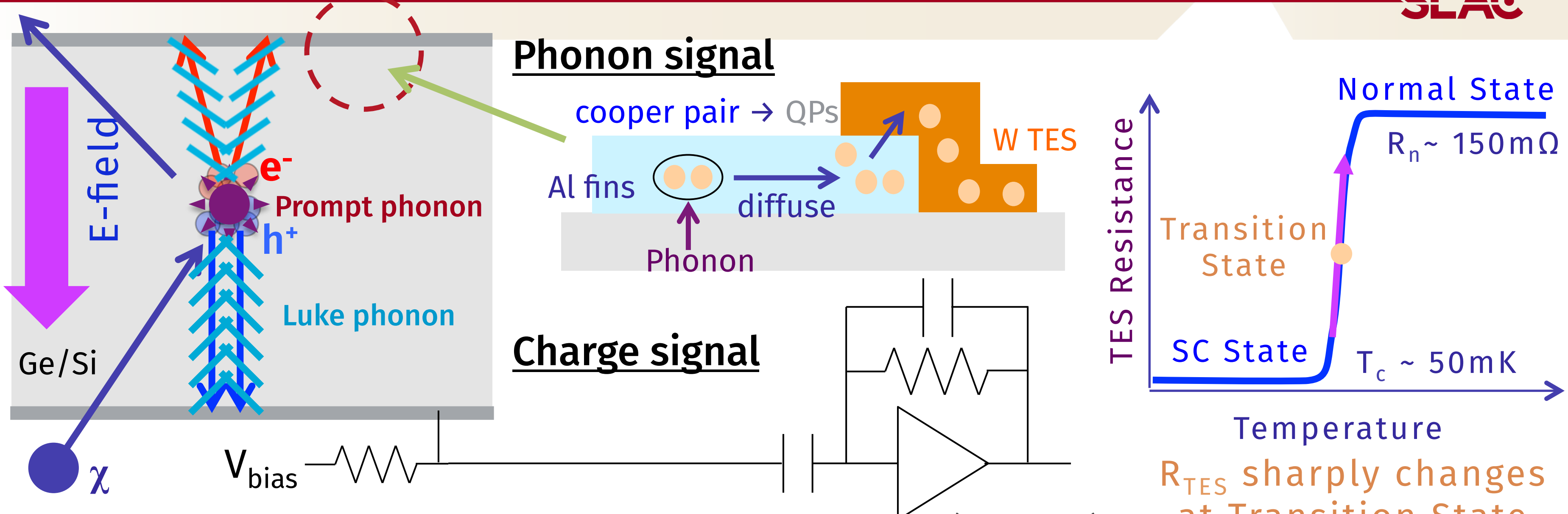
U.S. DEPARTMENT OF ENERGY
Office of Science

Direct DM Search: Current Status



→ **SuperCDMS focuses on Low-Mass DM**

CDMS Detection Technique: Phonon and Charge



1. Dark Matter scatters off target nucleus (Ge/Si)
   → *Prompt phonons* & *e*-*h* pairs produced
2. *e-*/*h+* separated by *E-field* and drifted to electrodes
   → *Luke phonons* produced due to Neganov-Luke effect
3. *e-*/*h+* read out with charge sensitive amplifiers
4. Phonons break *Cooper pairs* in Al fins, create *quasi-particles* (*QPs*)
5. *QPs* collected in *Tungsten (W) Transition Edge Sensors* (*TESs*)
6. Current change due to R_{TES} change read out by SQUID amplifiers

SuperCDMS SOUDAN

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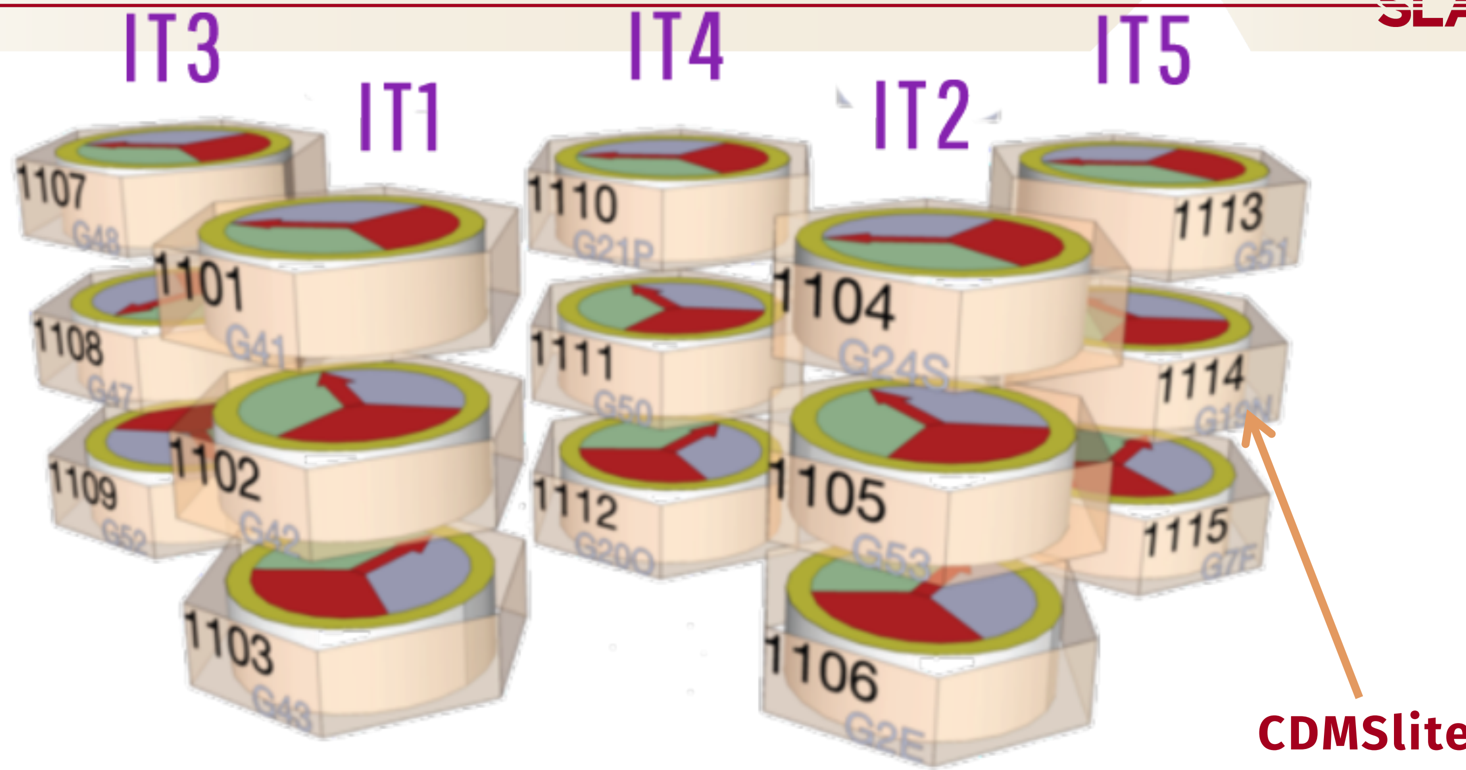
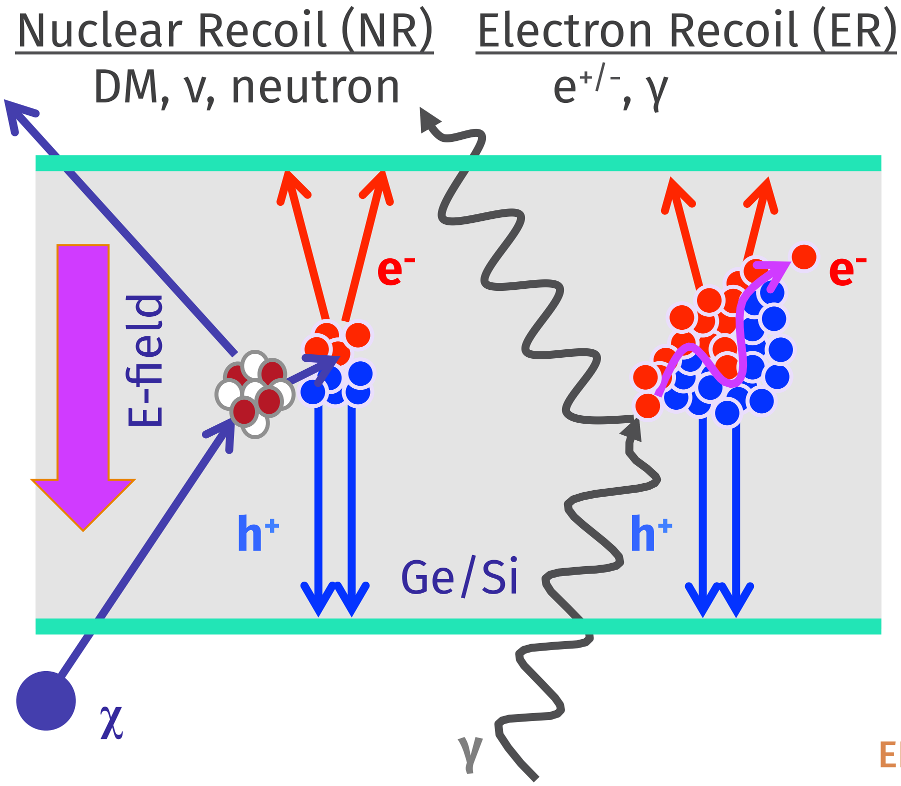


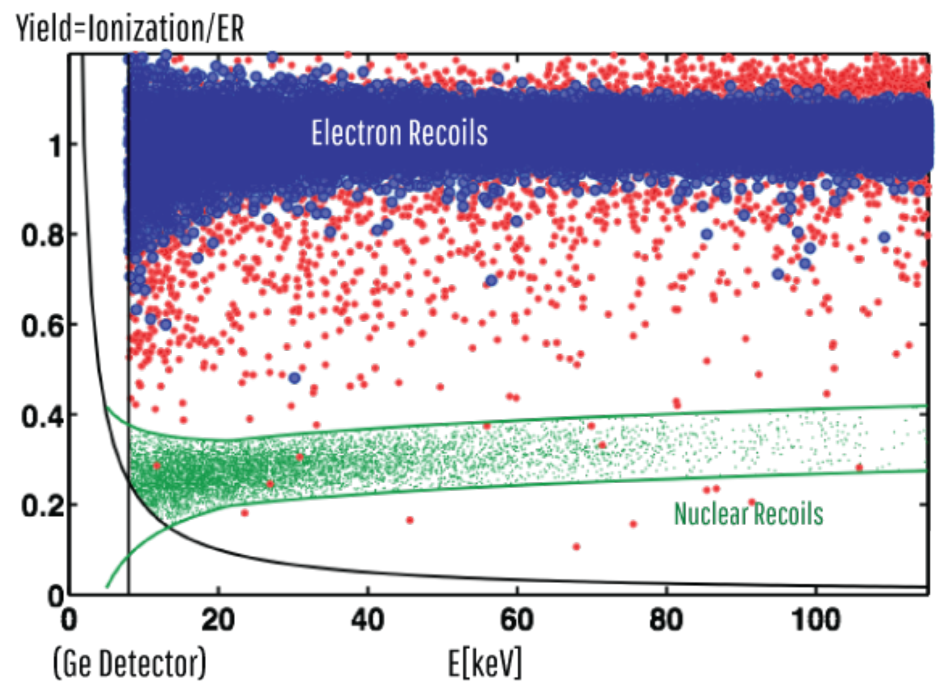
Operated at Soudan Mine, Minnesota

- 5 towers deployed, 3 detectors per tower
    - 75mm diameter, 2.5cm thick, 600g Ge crystals
- iZIP *interleaved Z-sensitive Ionization Phonon* Detector introduced
- One detector operated with a high-voltage bias mode

    → **CDMSlite (low-ionization threshold experiment)**

iZIP Detector: NR/ER Event Discrimination





ERs and NRs can be clearly separated with Ionization Yield

- Both phonon and charge signals measured
- **Ionization Yield: ratio of *charge E* to *recoil E* ($Y = E_Q/E_r$)**
- NRs create less *e*-*h* pairs compared to ERs for same recoil energy

  → Y ~ 0.3 for NRs, ~ 1 for ERs
- Discrimination factor for ER and NR events: ~ 10^6

iZIP Detector: Surface Event Rejection

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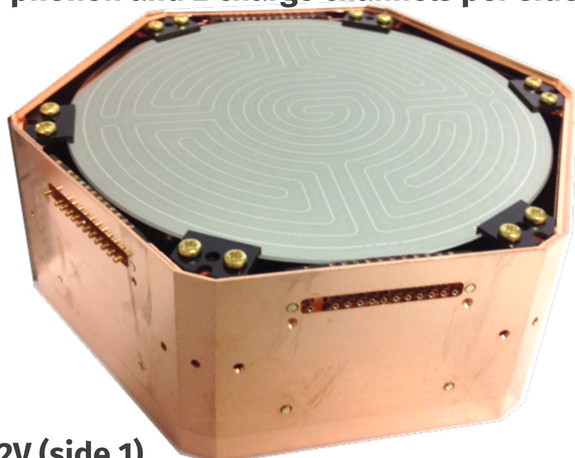
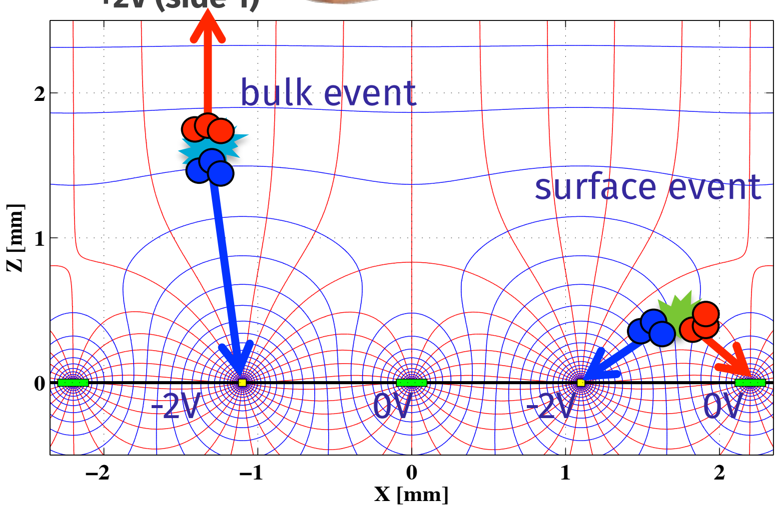
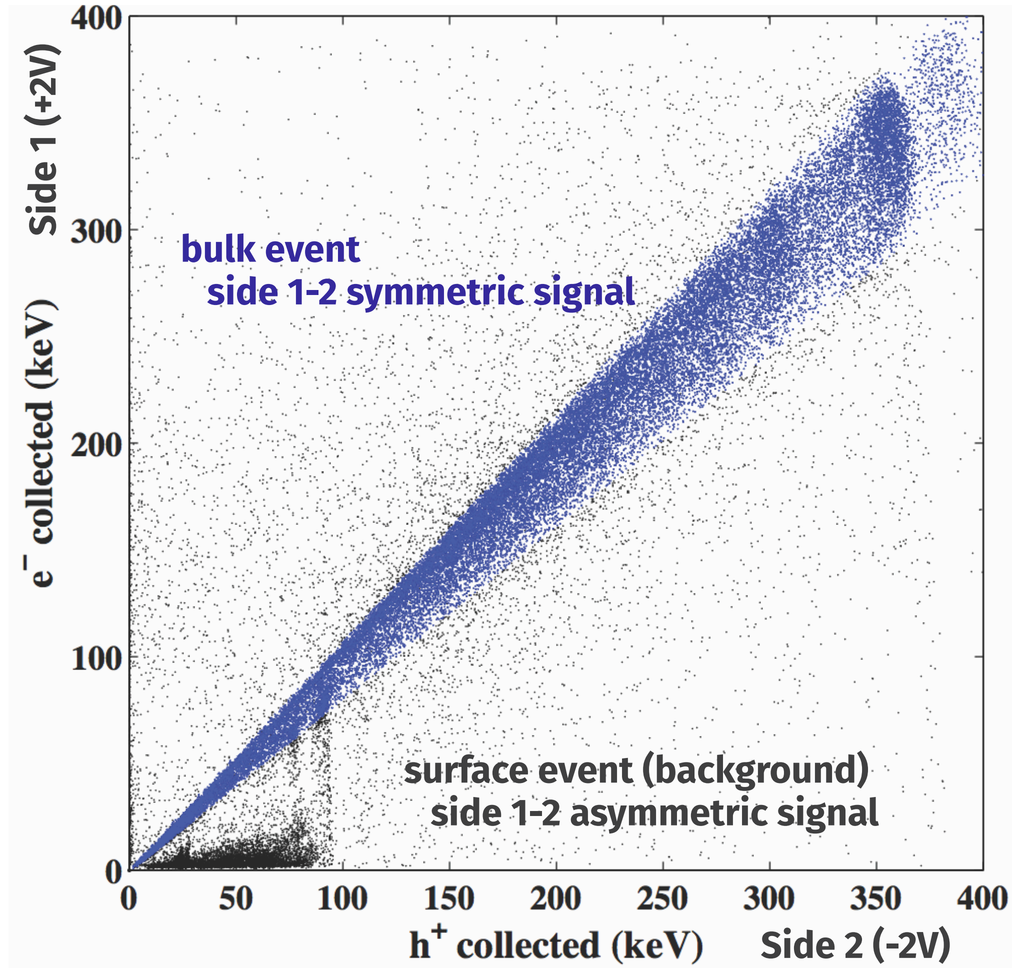
4 phonon and 2 charge channels per side







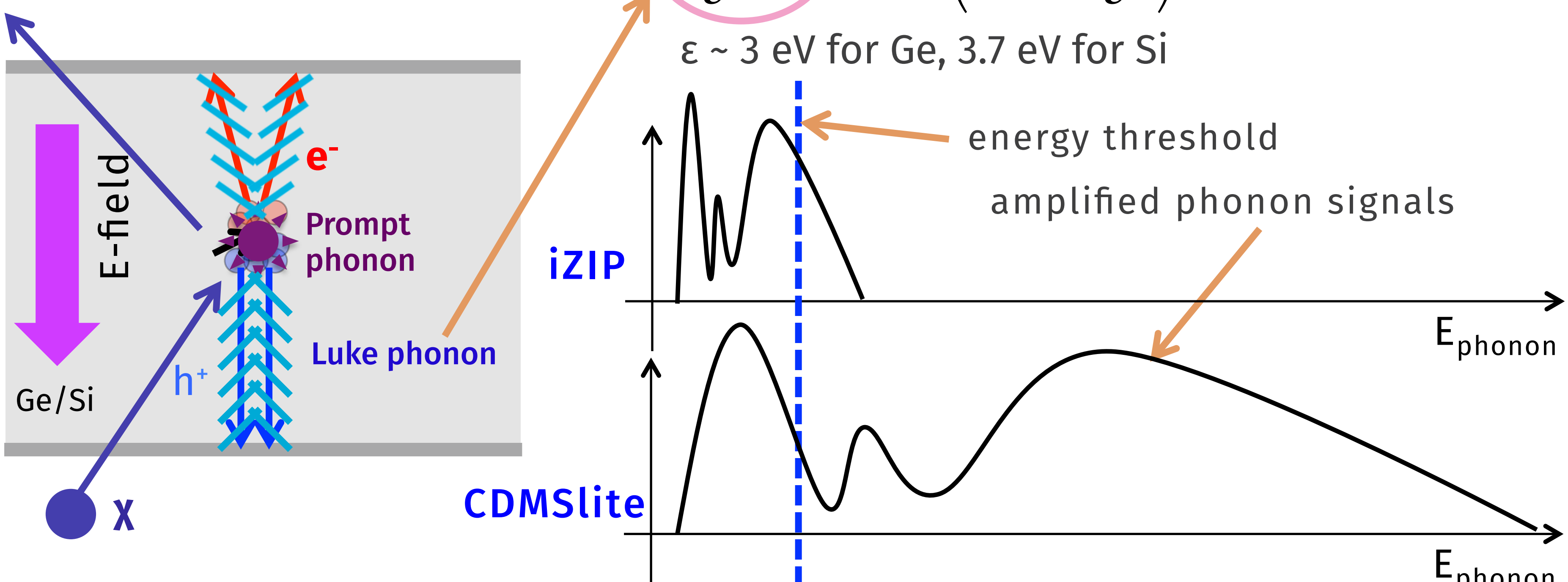
- TES rails (0V) and charge electrodes (+/-2V) interleaved with each other

→ **Surface event rejection with E-field near surface**

CDMSlite: HV Detector

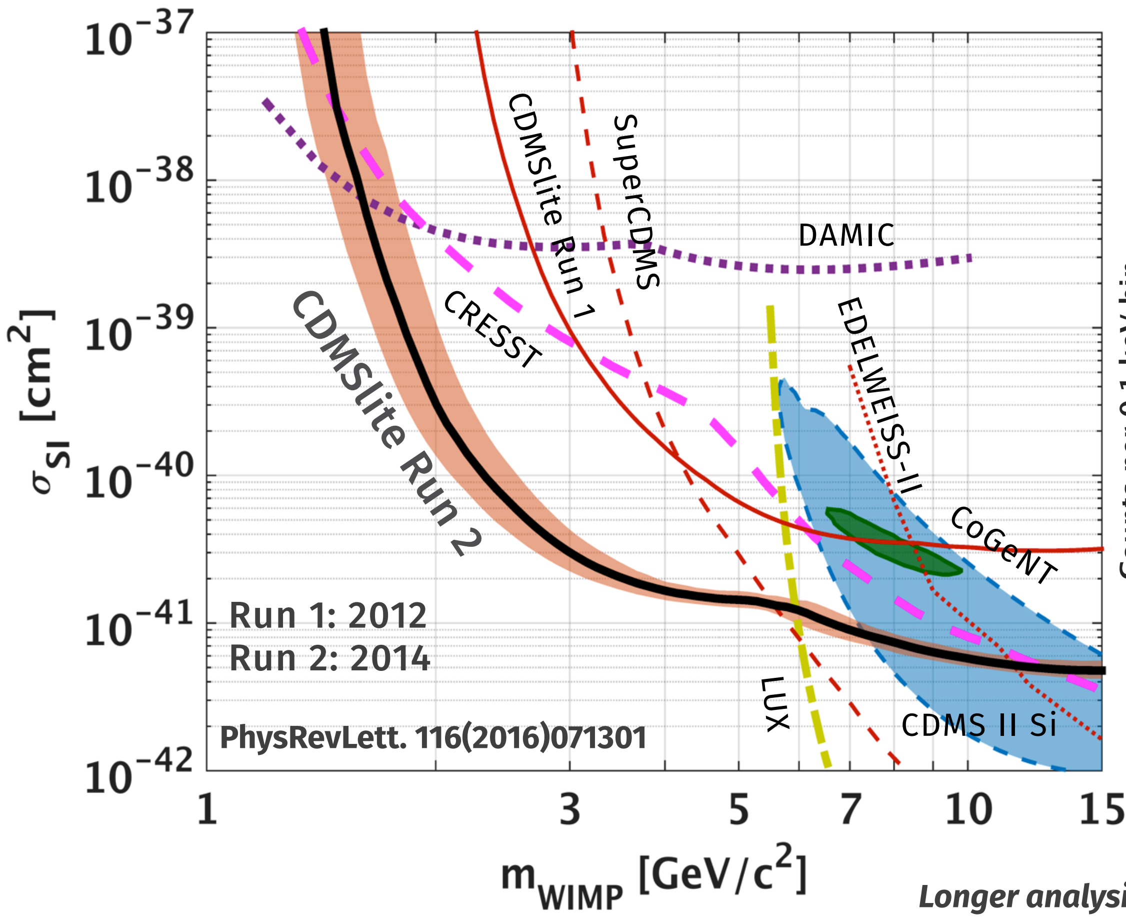
$$E_{\text{phonon, total}} = E_r + \frac{E_r Y}{\varepsilon} qV = E_r \left(1 + Y \frac{qV}{\varepsilon}\right)$$

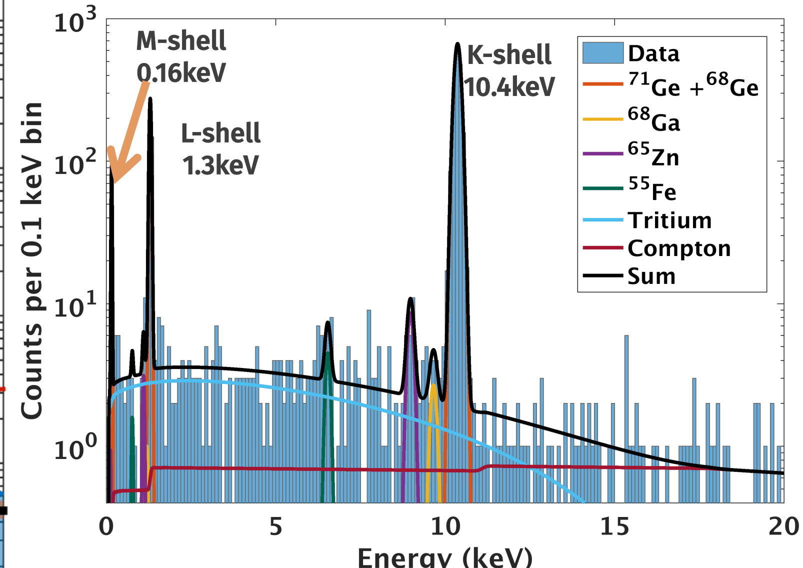
ε ~ 3 eV for Ge, 3.7 eV for Si



- Phonon signals amplified with Neganov-Luke effect
  - → **Eventually very low energy threshold achieved**
  - → **Ideal for low E_r from low-mass DM**
- No capability of ER/NR discrimination

CDMSlite: Sensitivity





^{71}Ge activation lines clearly seen, used for calibration

Longer analysis paper just submitted to PRD: arXiv: 1707.01632

- Run 2: 70-kg day exposure (side 1 = 0V, side 2 = -70V)

- Excludes new parameter space with DM mass = 1.6 - 5.5GeV/c^2

- Run 3 analysis ongoing

SuperCDMS SNOLAB: Overview

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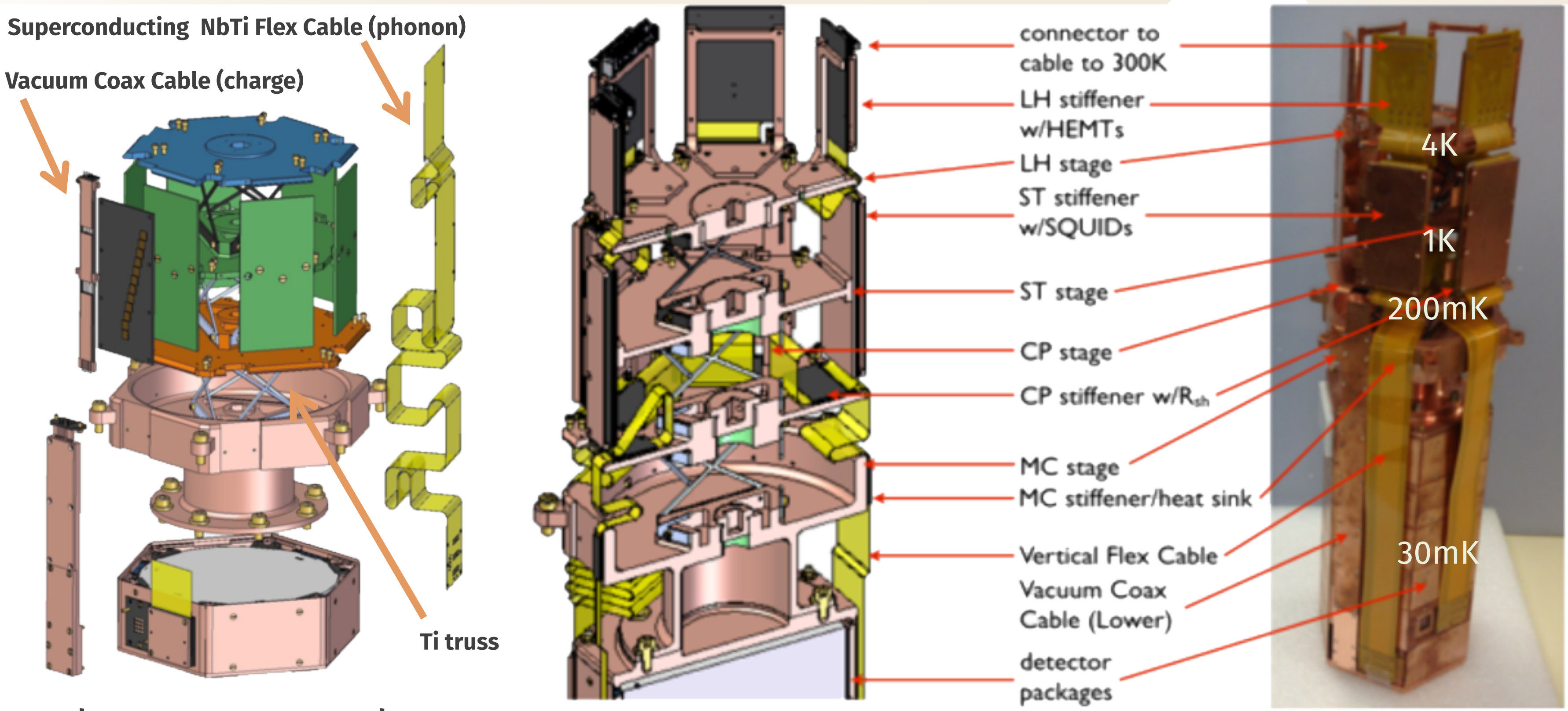
- A DOE/NSF G2 DM program: focuses on low-mass DM (< 10GeV/c^2)
  - **complementary targets (Ge, Si), detection techniques (iZIP, HV)**
- 100mm diameter, 3.3cm thick Ge (Si) crystals: 1.4kg (0.5kg)
- 4 detector towers: 31 tower capacity for future upgrades
  - Tower 1: 6 Ge iZIP
  - Tower 2: 4 Ge HV + 2 Si HV
  - Tower 3: 4 Ge HV + 2 Si HV
  - Tower 4: 4 Ge iZIP + 2 Si iZIP

TWIN:
Fabricated/Assembled at the same time
Similar Cosmogenic Activation/Radon Exposure Time

Tower 4 background info will be shared with Tower 3

- Lower background expected: **x200 lower ER background**
  - Radio-pure materials, less cosmic-rays at deeper underground
  - minimize cosmogenic activation/radon exposure time
- Improved energy resolution
  - optimized TES design, lower T_c, new readout electronics
- **Full operation will start in 2020**

Detector Tower Design



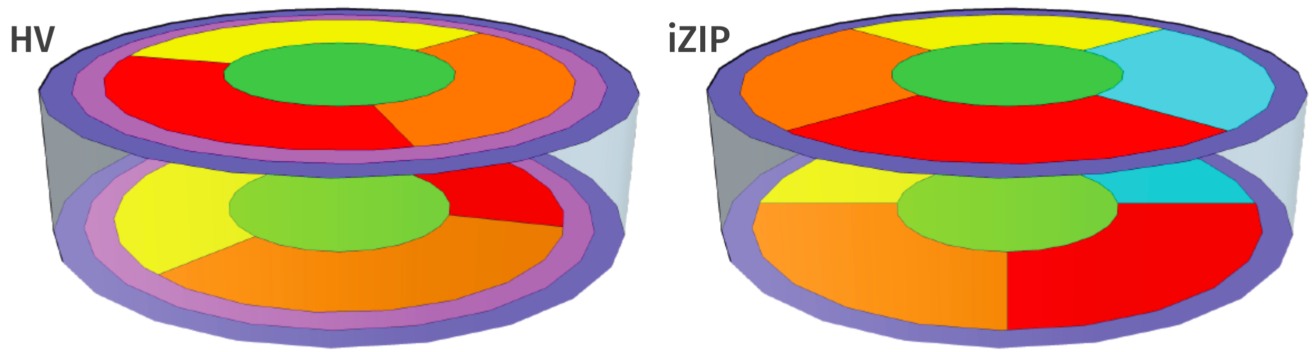
- 6 detectors and 4 stages per tower
  - LH = 4K, ST = 1K, CP = 200mK, MC = 30mK
  - each stage separated/supported with SC Ti or CF trusses
  - SC flex cable used to avoid thermal shorts between stages

Tower 1 will be available this fall

Detector Design: HV and iZIP

iZIP detector

- Performed well in Soudan, targeting *higher-mass DM (> 5GeV/c^2)*
- 6 phonon, 2 charge channels per side → **ER/NR discrimination**
- Expected background: *< 1 event during 5 years operation*
- Energy resolution: 50eV$_t$ for phonon, 160eV$_{ee}$ for charge



Channel layout optimized for event position identification

HV detector

- Concept proven with CDMSlite, targeting *low-mass DM (< 5GeV/c^2)*
- 6 phonon channels per side, signals read from both sides
- Main backgrounds: ^{3}H and ^{32}Si in crystals, line-of-site backgrounds
- Energy resolution: 10eV$_t$

Currently testing prototype detectors

SuperCDMS SNOLAB Sensitivity

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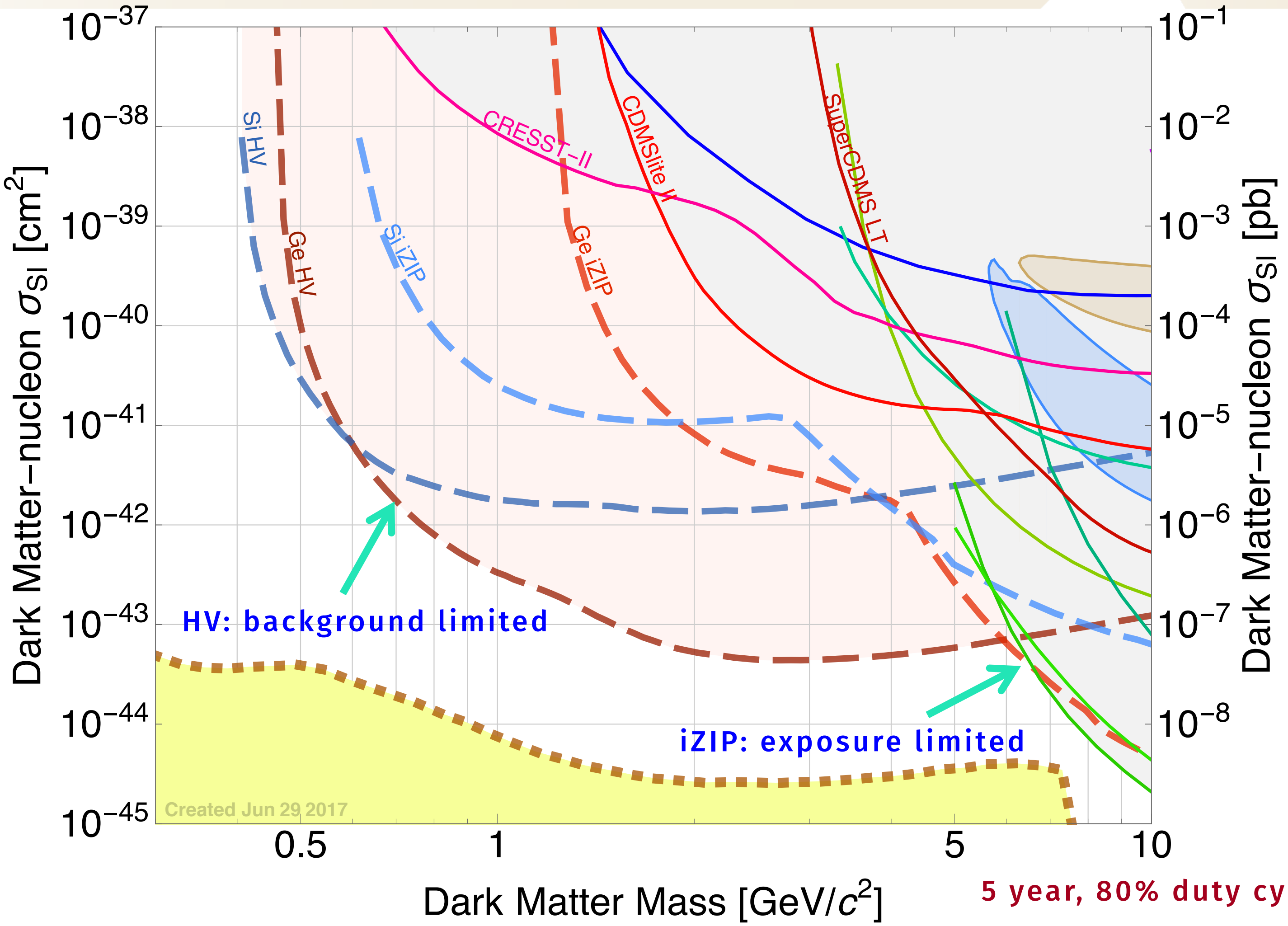

5 year, 80% duty cycle

- SuperCDMS can deeply probe low-mass DM models
- SuperCDMS SNOLAB expected to start data taking in 2020

MeV DM Search with DM-Electron Interactions

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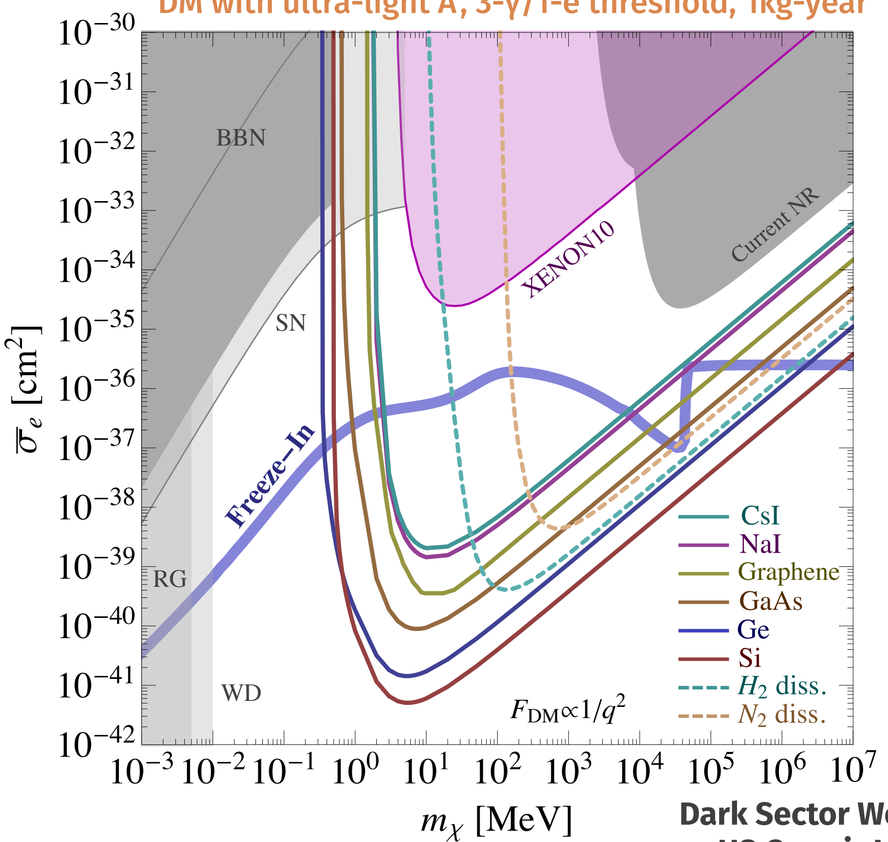
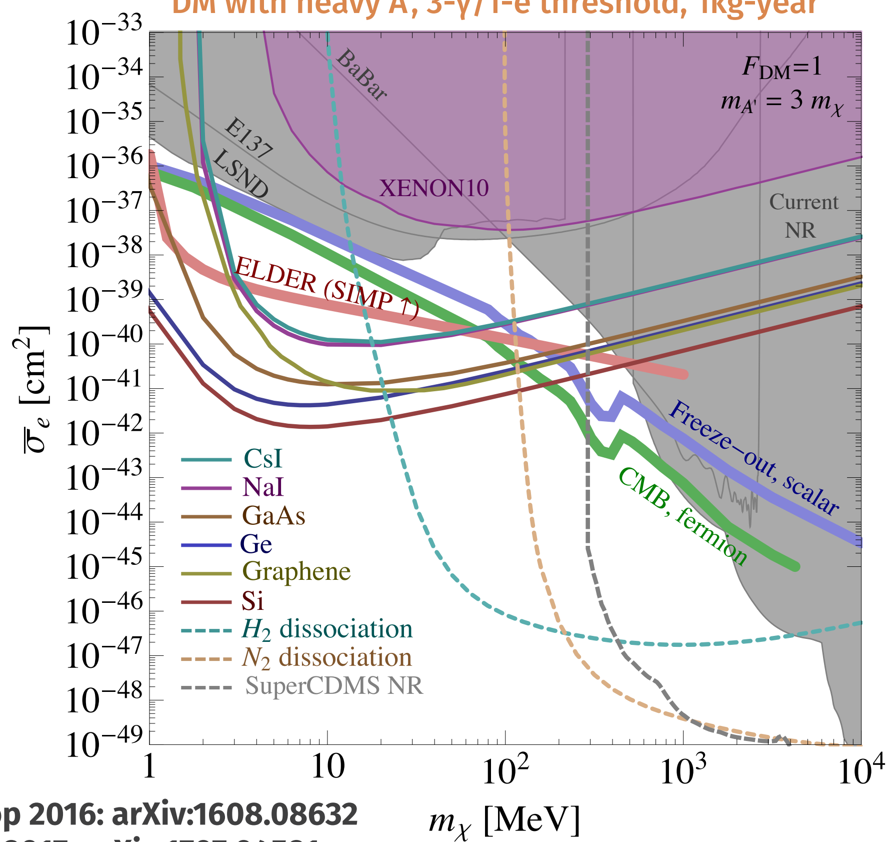
SuperCDMS SNOLAB/Next Generation (G2+)

DM with ultra-light A', 3-γ/1-e threshold, 1kg-year



DM with heavy A', 3-γ/1-e threshold, 1kg-year



Dark Sector Workshop 2016: arXiv:1608.08632
US Cosmic Visions 2017: arXiv:1707.04591

- Low-mass DM-electron interaction thru a dark-photon mediator
- Excellent energy resolution and very low backgrounds required
- **SuperCDMS (G2/G2+) could deeply explore MeV DM models**

Summary and Conclusion

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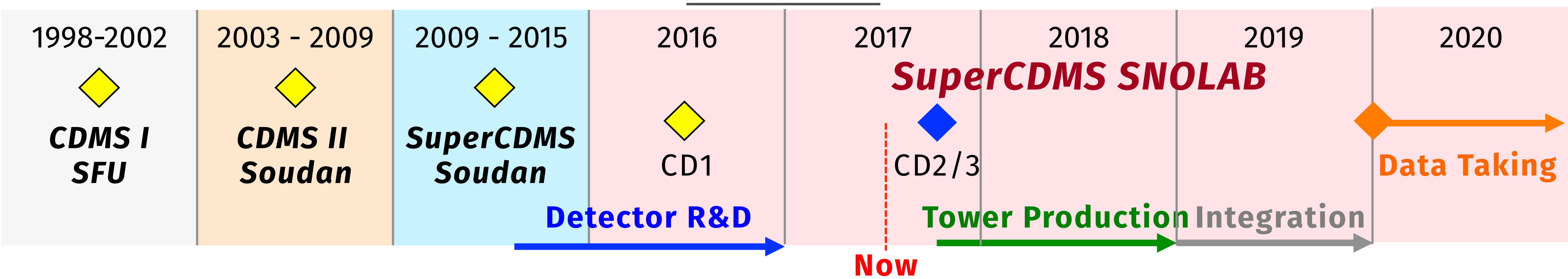
Timeline



- The SuperCDMS collaboration has been one of the leading direct DM search experiments for more than a decade.
- The CDMSlite Run 2 result excludes new parameter space for low-mass DM (1.6-5.5GeV/c^2). Run 3 analysis is ongoing.
- We are now moving forward with SuperCDMS SNOLAB CD2/3 reviews and production will start as soon as they are approved.
- Lower T_c, lower backgrounds and lower threshold detectors in SuperCDMS SNOLAB will allow us to uniquely and deeply probe the DM parameter space, especially for low-mass DM models.
- Full operation will start in 2020.

SuperCDMS Collaboration

California Inst. of Tech.
CNRS-LPN*
Durham University
FNAL
NISER
NIST*
Northwestern
PNNL
Queen's University
Santa Clara University
SLAC
South Dakota SM&T
SMU
SNOLAB
Stanford University
Texas A&M University
TRIUMF
U. British Columbia
U. California, Berkeley
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U. Evansville
U. Florida
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U. Toronto

* Associate members