SuperCDMS SNOLAB: status and prospects

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on behalf of the SuperCDMS Collaboration

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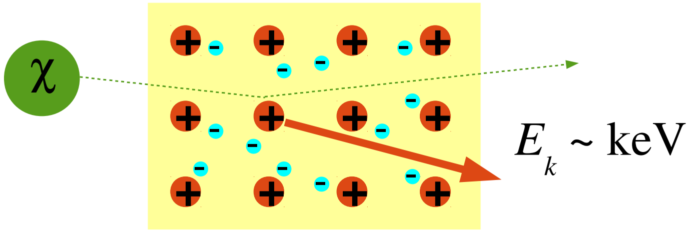
INTRODUCTION

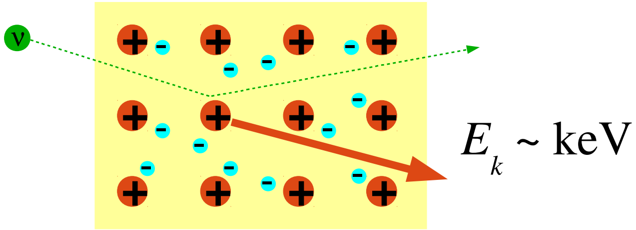
Purpose: detect **galactic WIMPs** using semiconductor (**Ge**, **Si**) crystal detectors

Ionization+***phonon*** *measurements* → ***Recoil energy***+***particle identification***

Signal: single **atomic nucleus** from crystal lattice, recoiling after a WIMP interaction



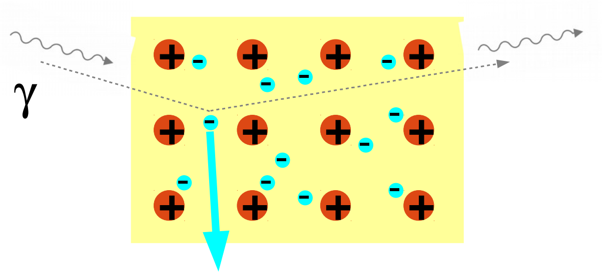
Coherent neutrino scattering (**CNS**) produces the **same signal** as WIMPs

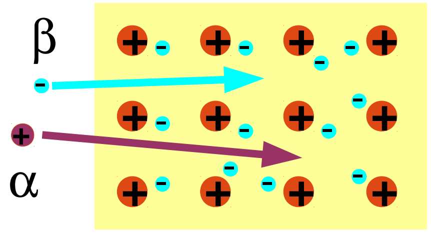


INTRODUCTION

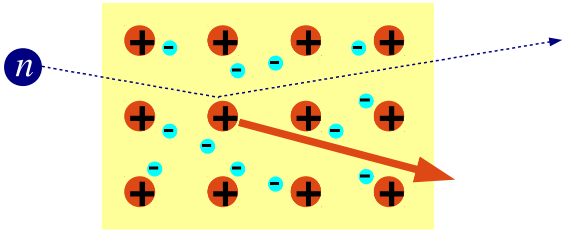
Backgrounds: from **environmental radioactivity** and **cosmic muons**:

1) **Electrons** from the crystal lattice, recoiling after X-ray or γ-ray interactions
2) **Charged particles** from nuclear disintegrations (mostly α and β decays)
3) **Atomic nuclei** from the crystal lattice, recoiling after neutron interactions





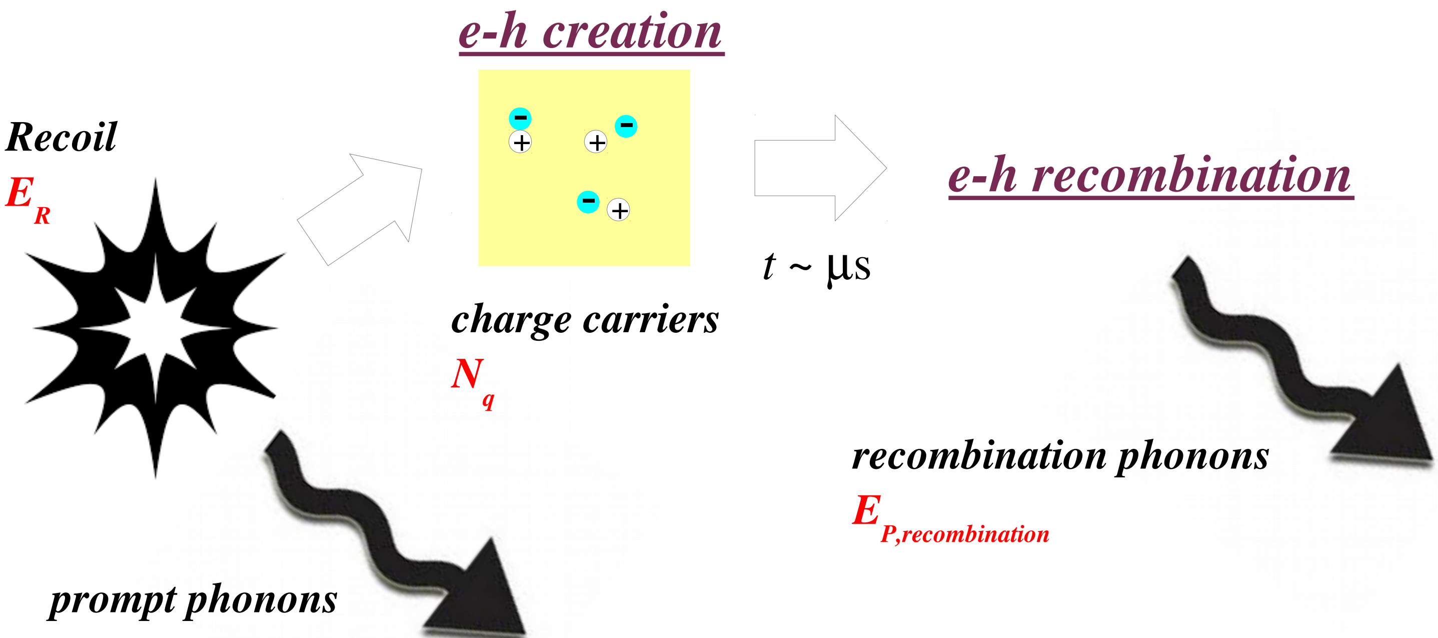
Small penetration if decay occurs outside the detector



Single neutron scatters mimic signal

SEMICONDUCTOR DETECTORS

Deposited energy splitted between **electron-hole pairs** and **prompt phonons**



*Eventually all the recoil energy is released as phonons (**heat**)*

$$N_q = Y\frac{E_R}{\epsilon}, \quad \epsilon(\mathrm{Ge}) = 3.0\ eV$$

$$E_P = E_{P,prompt} + E_{P,recombination} = E_R$$

	Ionization yield (*Y*)
Recoiling electron	1
Recoiling Ge nucleus	~0.3

SEMICONDUCTOR DETECTORS

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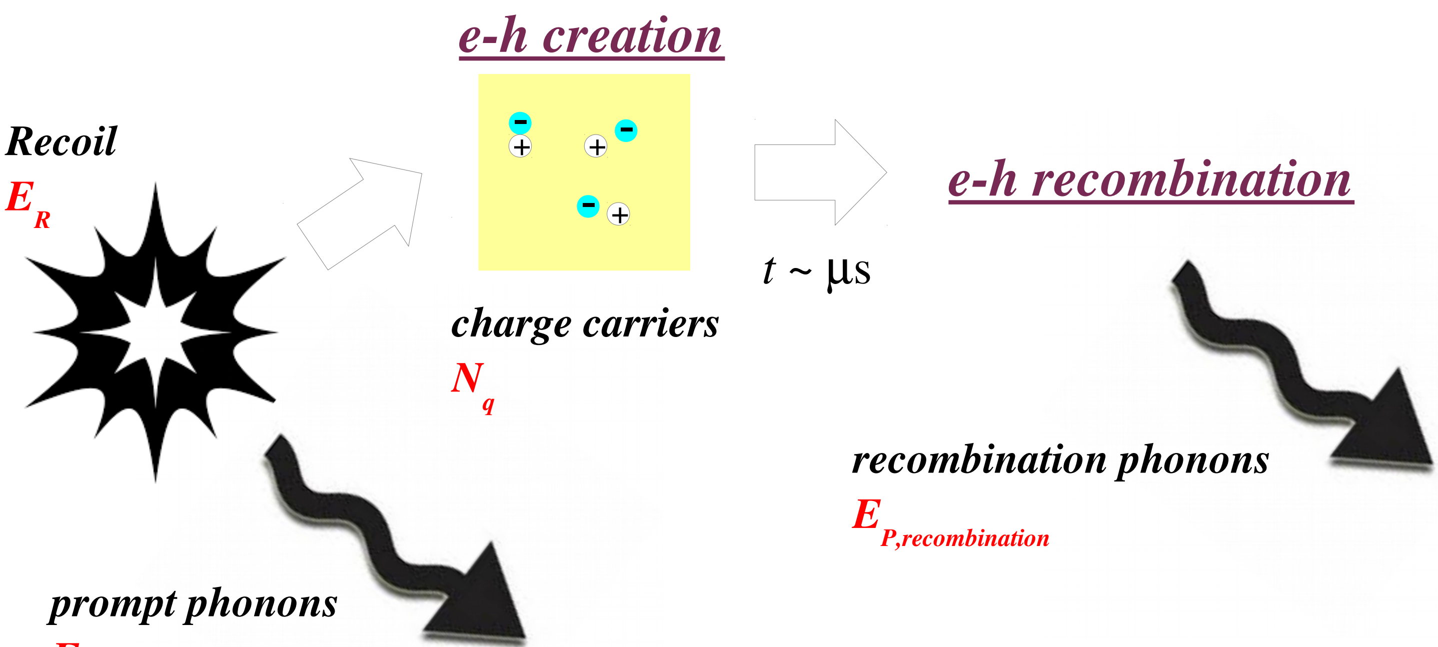

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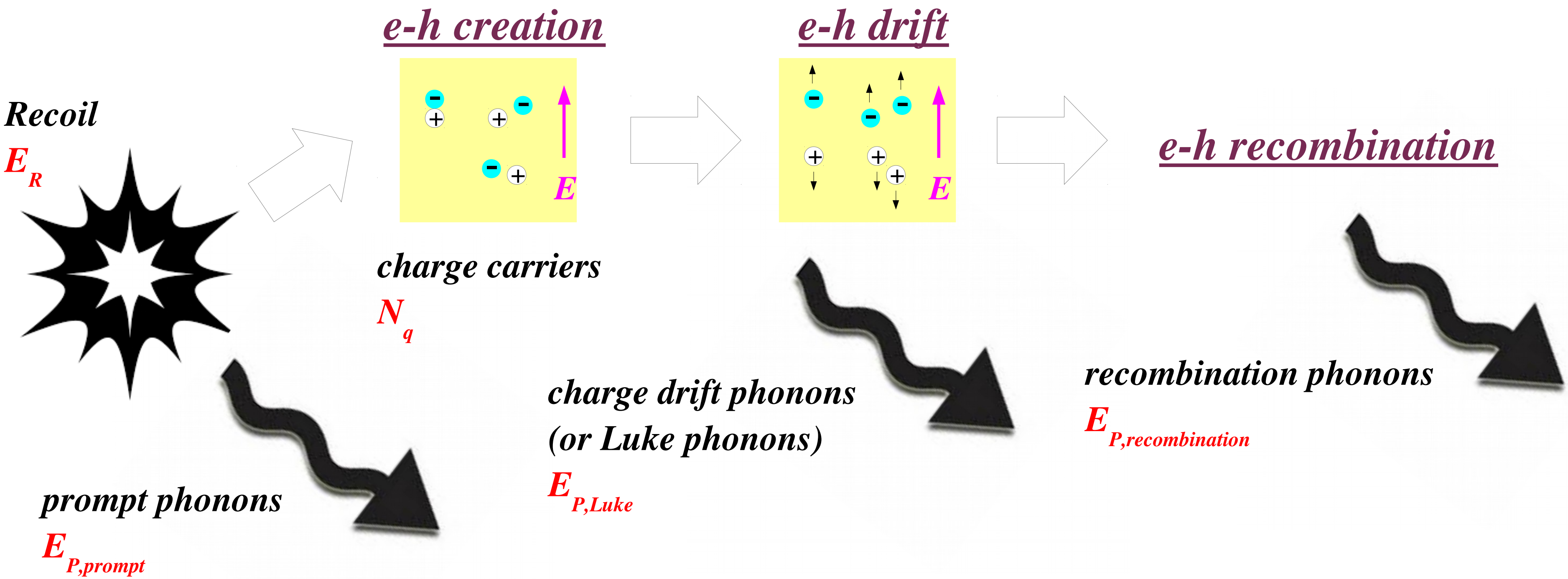
*Ionization yield (Y) enables **particle identification***

It is possible to know E_R and Y from E_P and N_q

SEMICONDUCTOR DETECTORS

An **applied electric field** (*E*) is required to separate the charge carriers



$$N_q = Y\frac{E_R}{\epsilon}, \quad \epsilon(\mathrm{Ge}) = 3.0\ eV$$

$$E_P = E_R + \boxed{q_e V N_q} = E_R(1 + Y\frac{q_e V}{\epsilon})$$

$E_P > E_R$ *if voltage bias (V) is applied*

$E_P = g(V)\,E_R$

SEMICONDUCTOR DETECTORS

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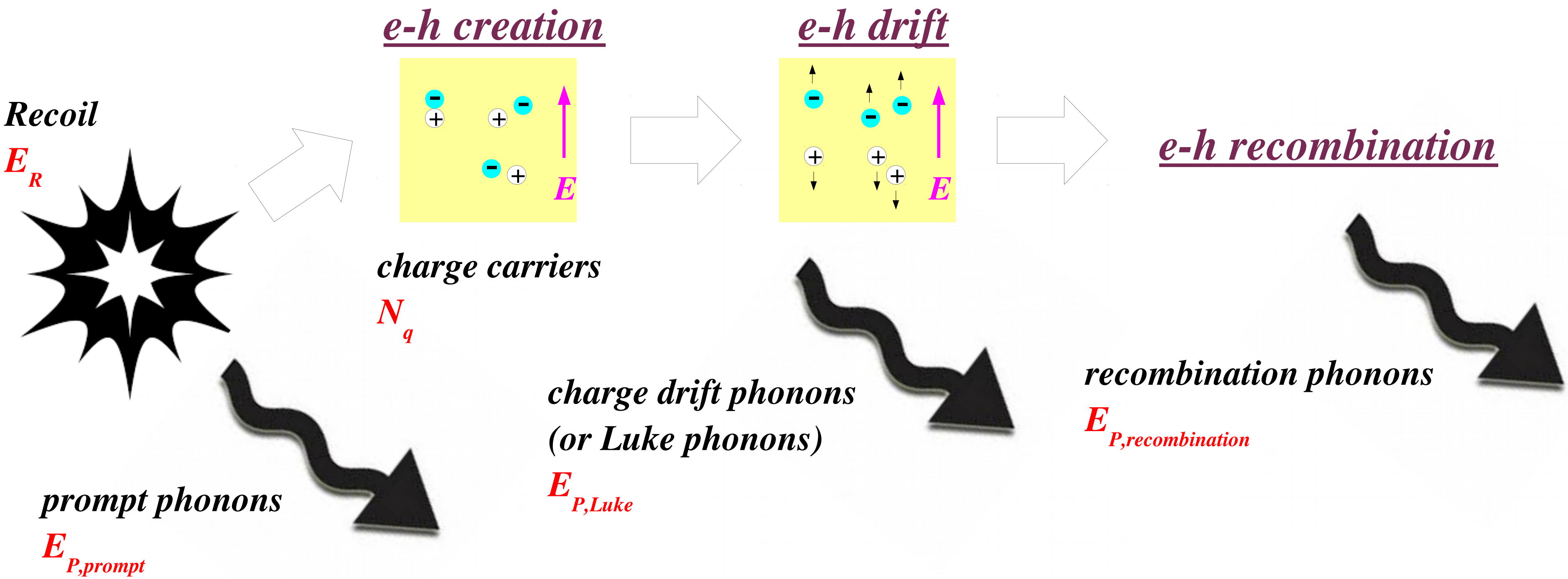

$$\boxed{N_q} = \boxed{Y}\frac{\boxed{E_R}}{\epsilon}, \qquad \epsilon(\mathrm{Ge}) = 3.0\ eV$$

$$\boxed{E_P} = E_R + q_e V N_q = \boxed{E_R}(1 + \boxed{Y}\frac{q_e V}{\epsilon})$$

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It is possible to know E_R and Y from E_P and N_q

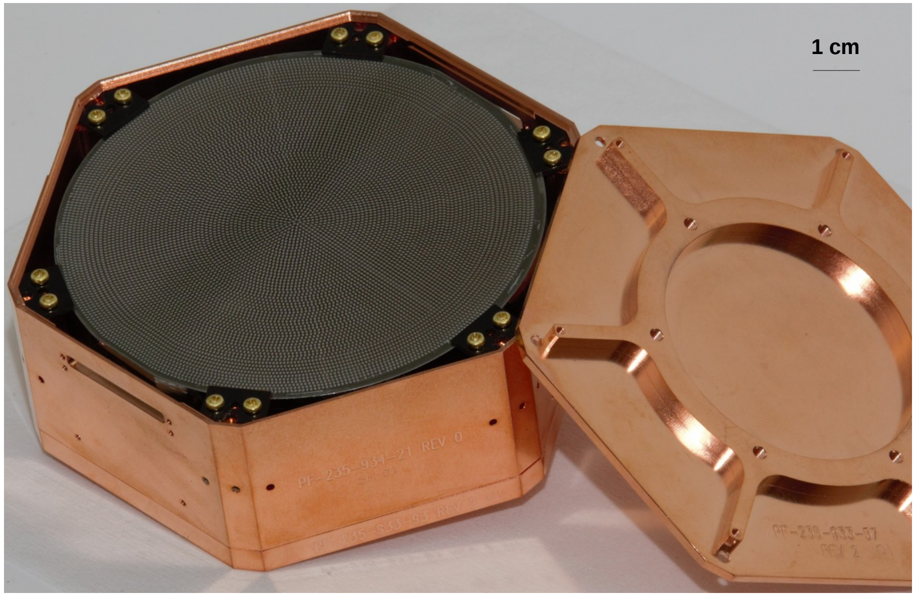
SUPERCDMS SNOLAB

Project proposal:

- Detectors with **full background rejection** capabilities (***iZIP***): **10 Ge**, **2 Si**
- Detectors with **lowered energy thresholds** (***HV***): **8 Ge**, **4 Si**

Project ***approved by US DoE*** *as a low-mass WIMP search experiment*

First ***Ge HV detector*** *prototype (+copper housing)*



SUPERCDMS SNOLAB

Project proposal:

- Detectors with **full background rejection** capabilities (***iZIP***): **10 Ge**, **2 Si**
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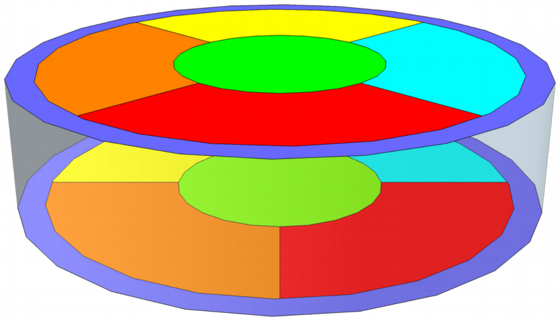
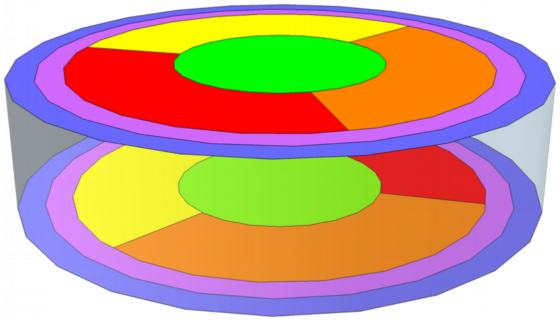
Detector mass: ***1.39 kg (Ge)****,* ***0.61 kg (Si)***

iZIP *detector*



- ***Charge+phonon*** *measurements*
- ***Particle identification***
- ***Full fiducialisation***

HV *detector*



- ***High voltage bias*** *(70-100 V)*
- ***Phonon*** *measurements only*
- ***Radial fiducialisation***

SUPERCDMS SNOLAB

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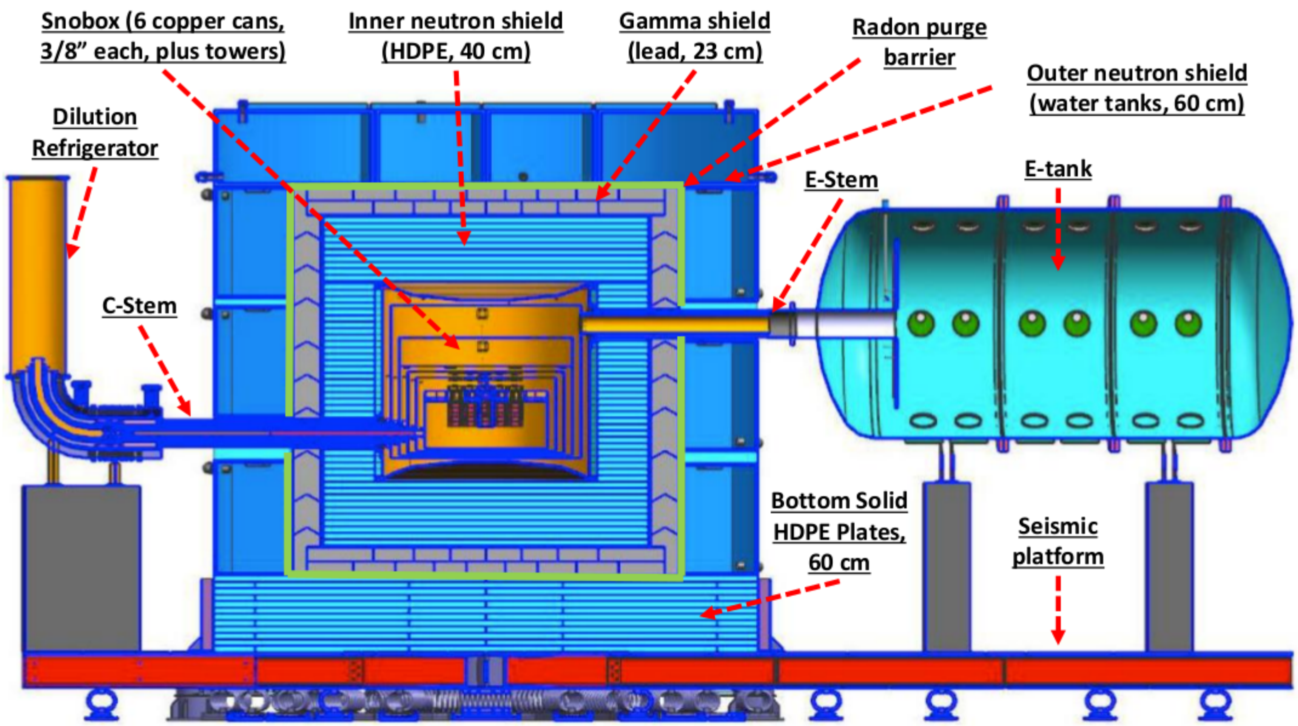
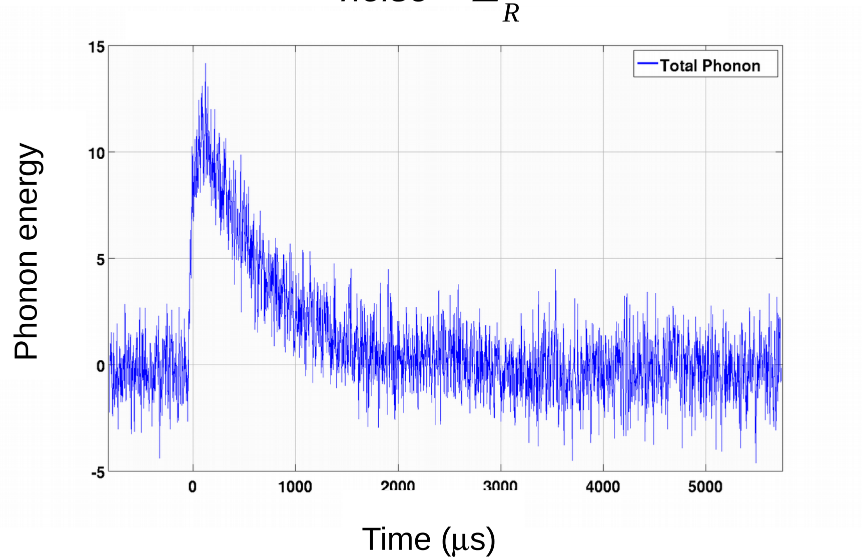
*Operating at **cryogenic temperatures** (< 15 mK)*



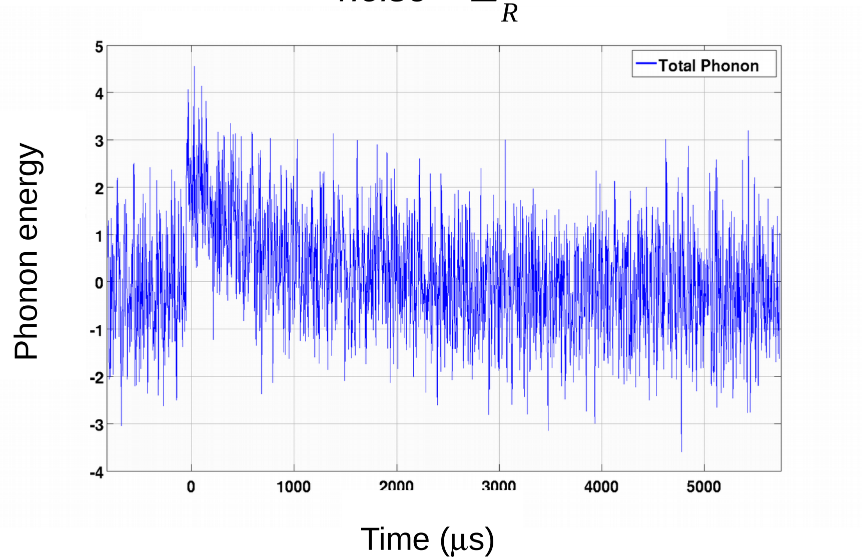
HIGH-VOLTAGE (HV) DETECTORS

Noise limits the lowest accessible E_R

noise < E_R



noise ~ E_R



However: **Phonon signal can be amplified by increasing the voltage bias**

HIGH-VOLTAGE (HV) DETECTORS

Total phonon energy in presence of **voltage bias** (***V***):

$$E_P = E_R + \boxed{q_e V N_q} = E_R(1 + Y\frac{q_e V}{\epsilon}) = g(V)E_R$$

*contribution from the applied **electric field***

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contribution from the applied ***electric field***

$g(V) > 1$

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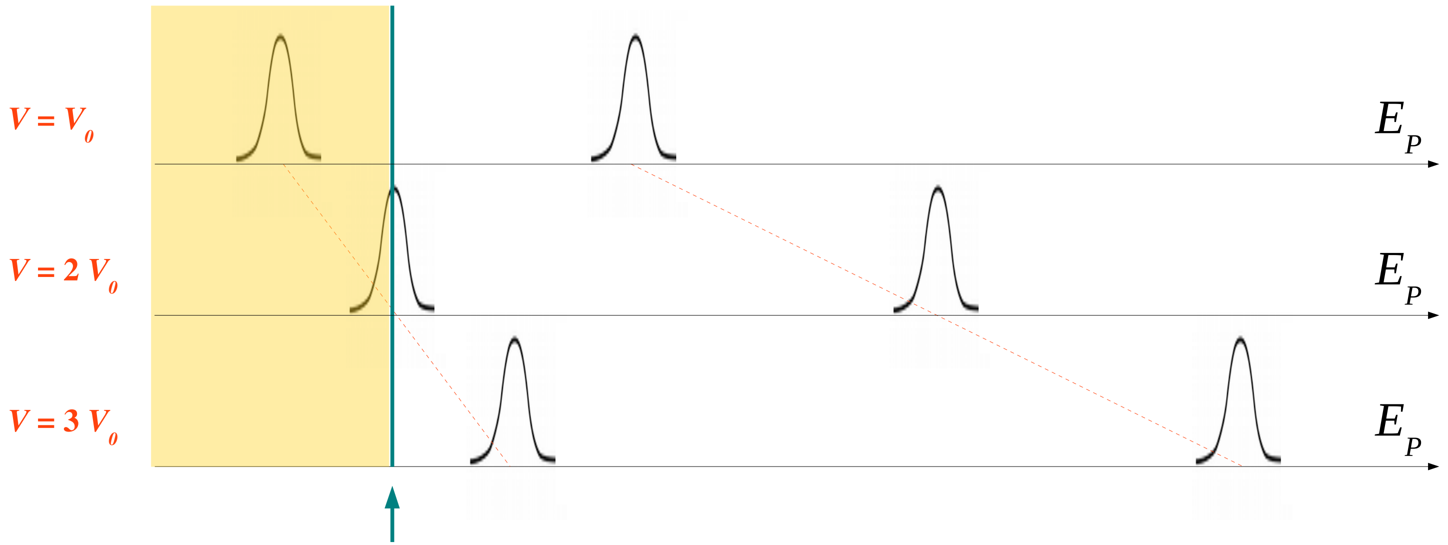

Phonon threshold (~typical noise fluctuations)

HIGH-VOLTAGE (HV) DETECTORS

Total phonon energy in presence of **voltage bias** (***V***):

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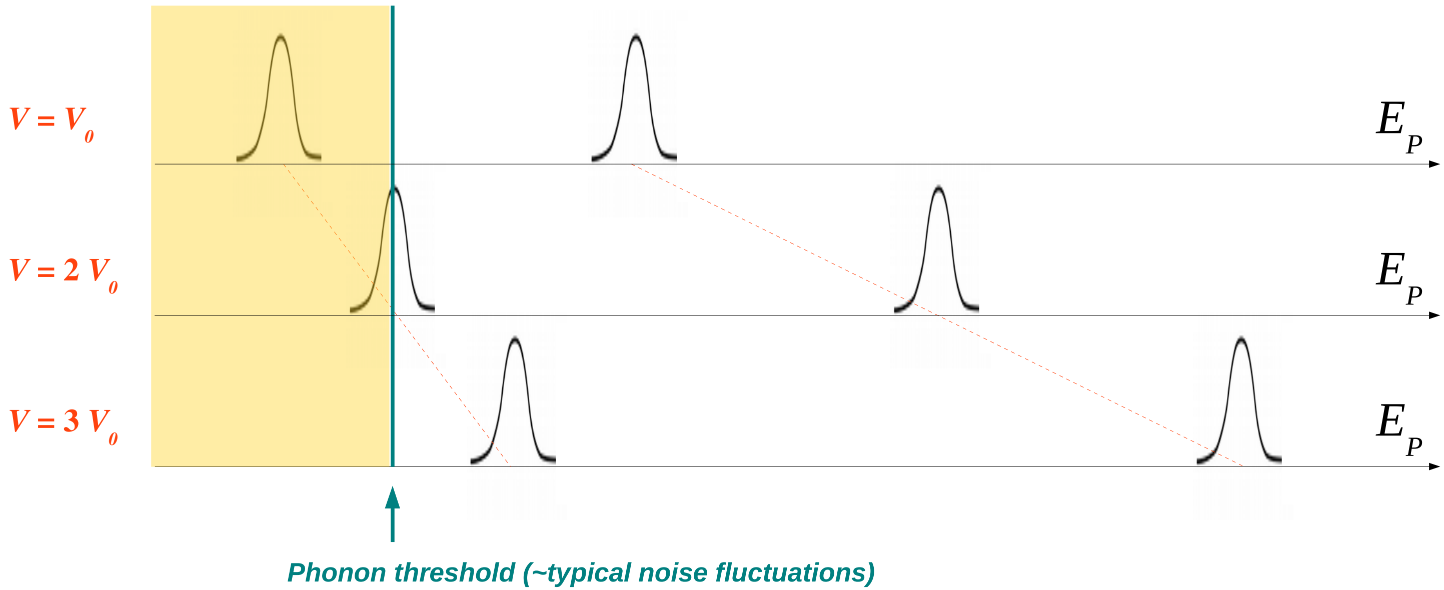


Note that **only E_P can be amplified**, but not N_q

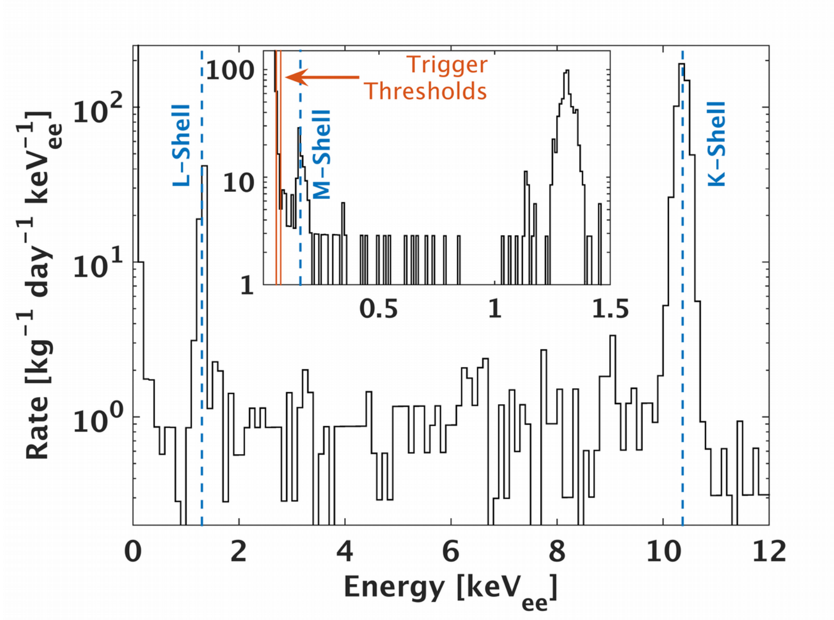
Particle identification & fiducialisation compromised, E_R reconstruction requires assumptions on Y

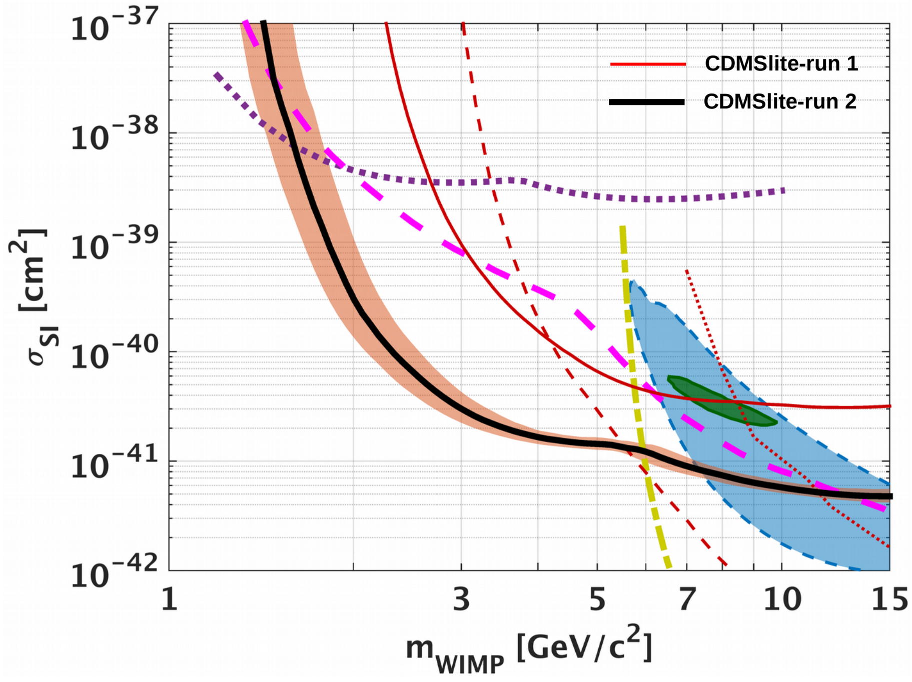
HIGH-VOLTAGE (HV) DETECTORS

HV technology successfully tested at **SuperCDMS Soudan** (***CDMSlite***)

*Used **~70 V** voltage bias*

***Energy spectrum** from CDMSlite-run 2*



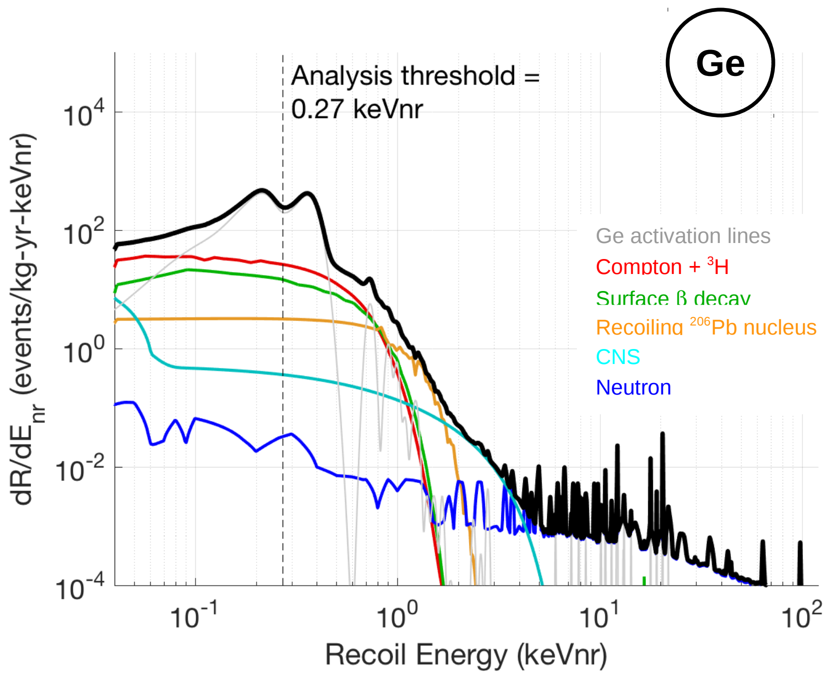


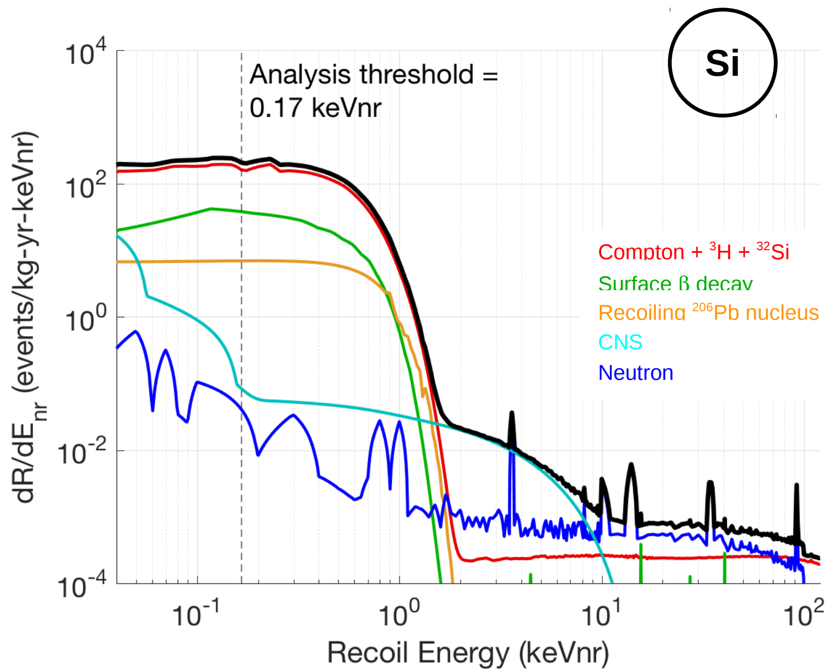
*Exclusion limit calculated by **assuming all events in signal region to be WIMPs***

PREDICTED EVENT RATE (iZIP DETECTORS)

*From **arXiv: 1610.00006***

Event selection: recoiling nucleus+single scattering+full fiducialisation



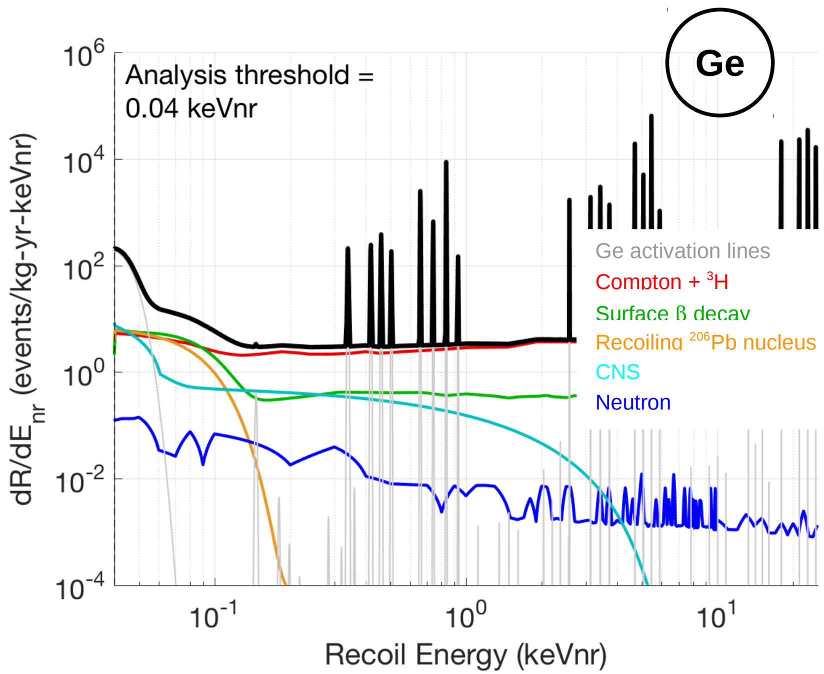


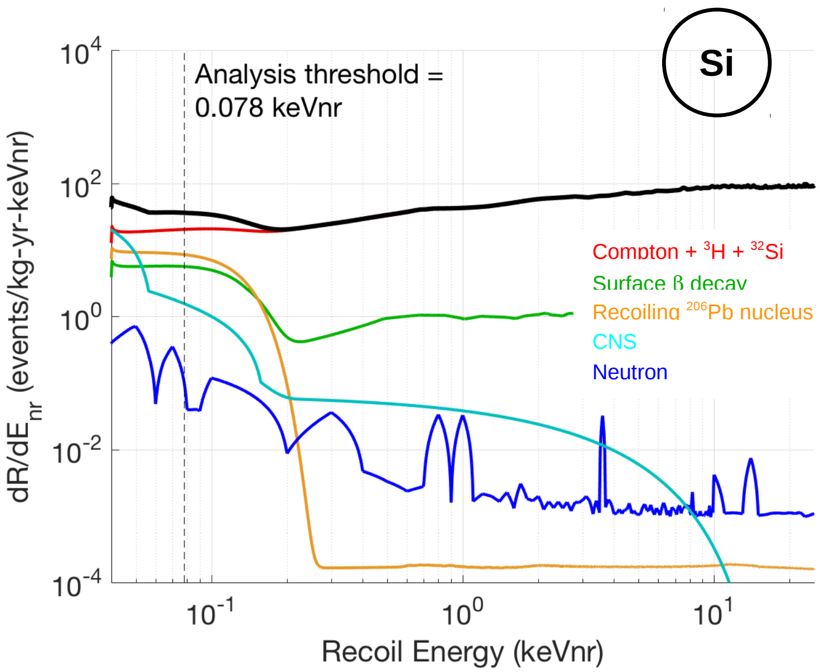
***~0.5 events** predicted in Si iZIP detectors between 2 and 10 keV for 5 years live time*

PREDICTED EVENT RATE (HV DETECTORS)

*From **arXiv: 1610.00006***

Event selection: single scattering+radial fiducialisation





PREDICTED SENSITIVITY

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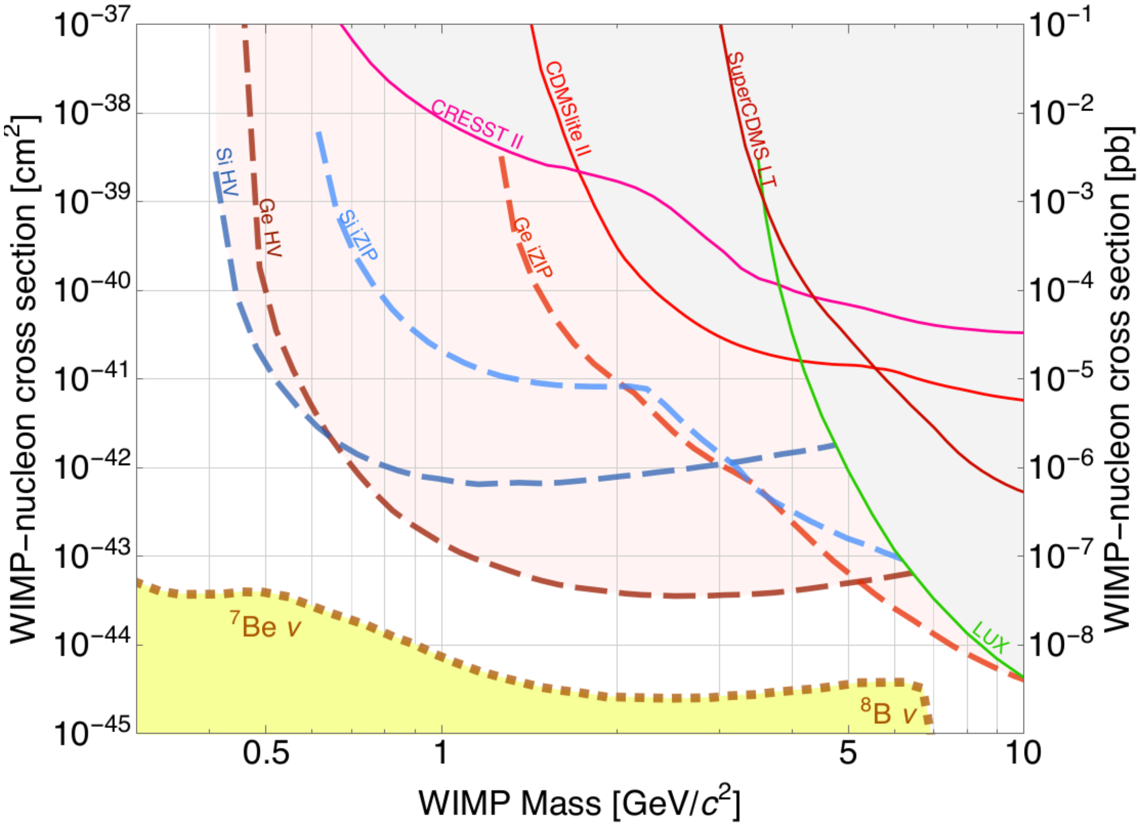
Initial program: **5 years** of operation (**2020-2024**), **80% live time**



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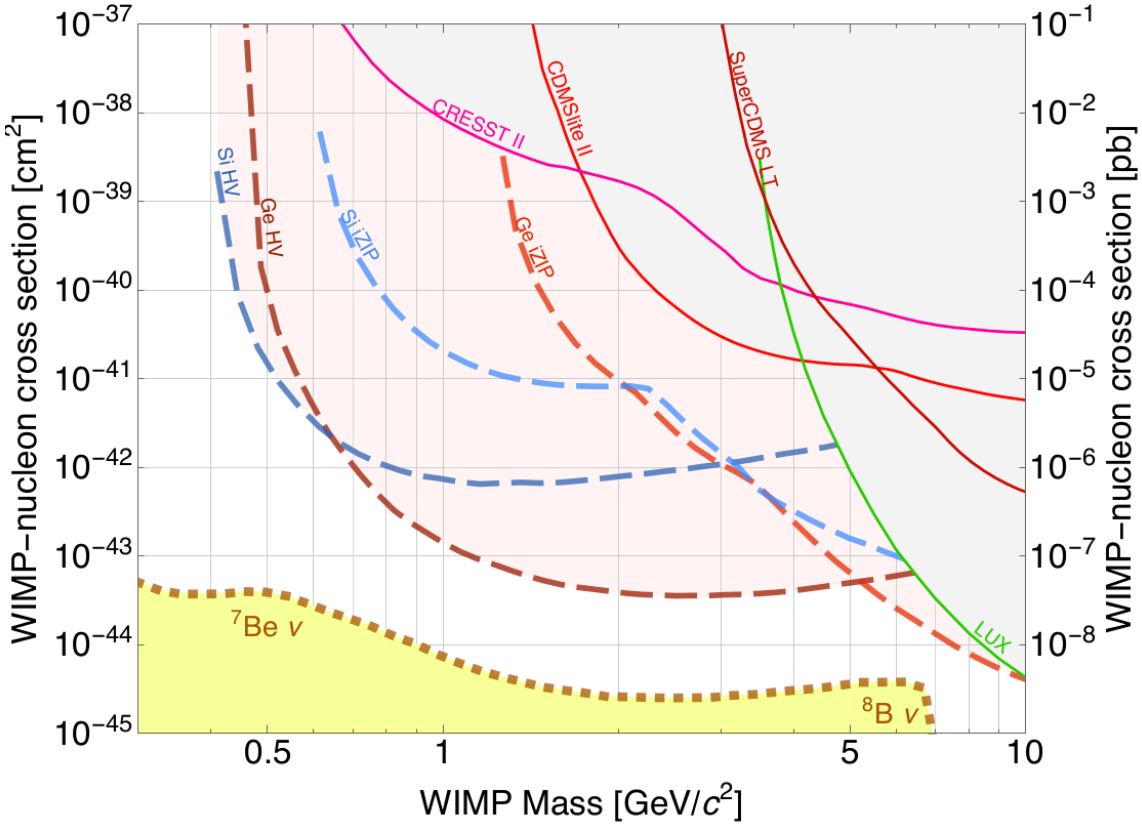

*Aiming towards **reaching the CNS floor** from solar neutrinos in future stages of the experiment*

SUMMARY

- **SuperCDMS SNOLAB using semiconductor detectors (Ge, Si)**
- **Payload: 25 kg (Ge), 3.6 kg (Si)**
- **2 operation modes: iZIP (full discrimination), HV (lower threshold)**
- **First program: 5 years of operation (2020-2024)**
- **CNS dominating some spectrum intervals in iZIP detectors**
- **Plan to reach CNS floor from solar neutrinos in future stages of the experiment**

THANK YOU…