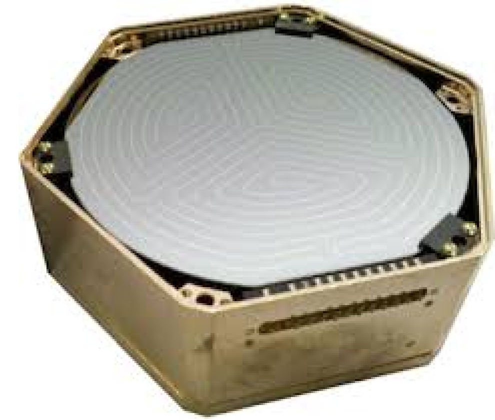


IDM 2018, BROWN UNIVERSITY, RI, USA

BELINA VON KROSIGK (bkrosigk@physics.ubc.ca)

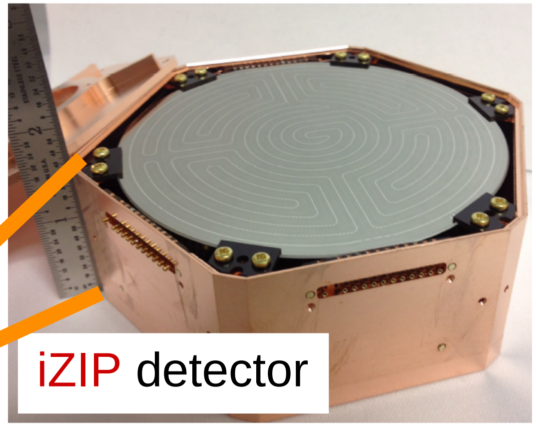
UNIVERSITY OF BRITISH COLUMBIA

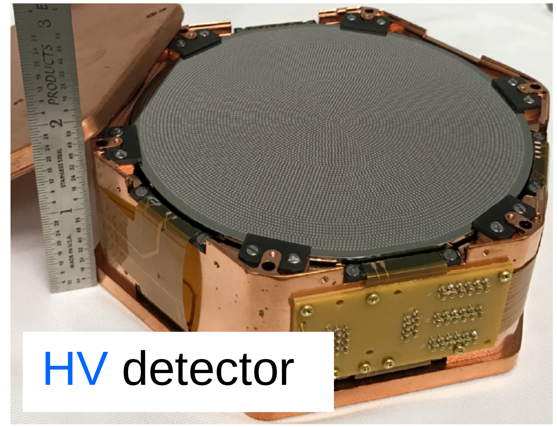
Dark Photon Searches with SuperCDMS Technology

ON BEHALF OF THE SuperCDMS COLLABORATION

SuperCDMS DETECTOR TECHNOLOGY

SuperCDMS DETECTORS



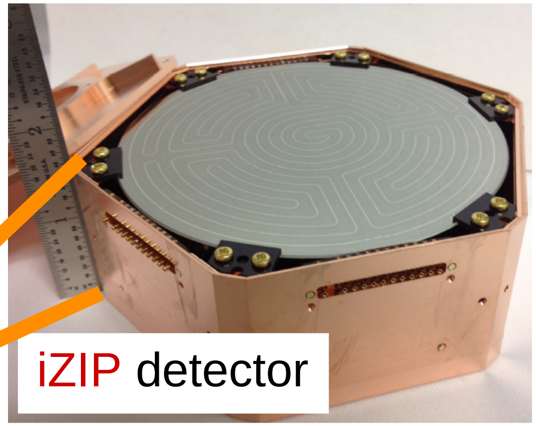


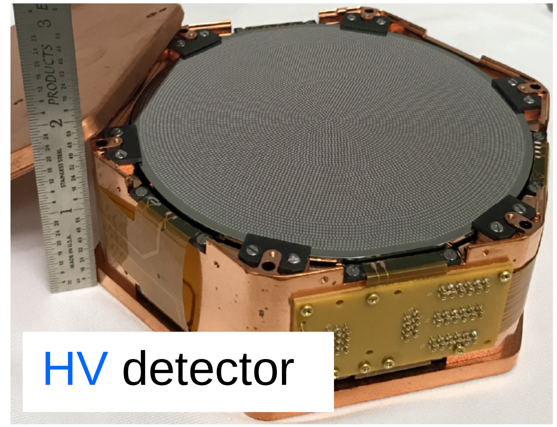
Talk by T. Aramaki:
"SuperCDMS Detector Performance and Early Science from CUTE"

Ge detectors, 1.4 kg each.
Si detectors, 0.6 kg each.
Total: Ge: ~ 25 kg.
Total: Si: ~ 3.6 kg.

- High-purity Ge and Si crystals.
- Measurement of phonon signal via transition edge sensors.
- Bias voltage:
  - **iZIP**: < 10 V
    => Phonon + ionization signal
    => Nuclear / Electron Recoil discrimination.
  - **HV**: ~ 100 V
    => Phonon amplification of ionization signal
    => Very low threshold.

SuperCDMS DETECTORS





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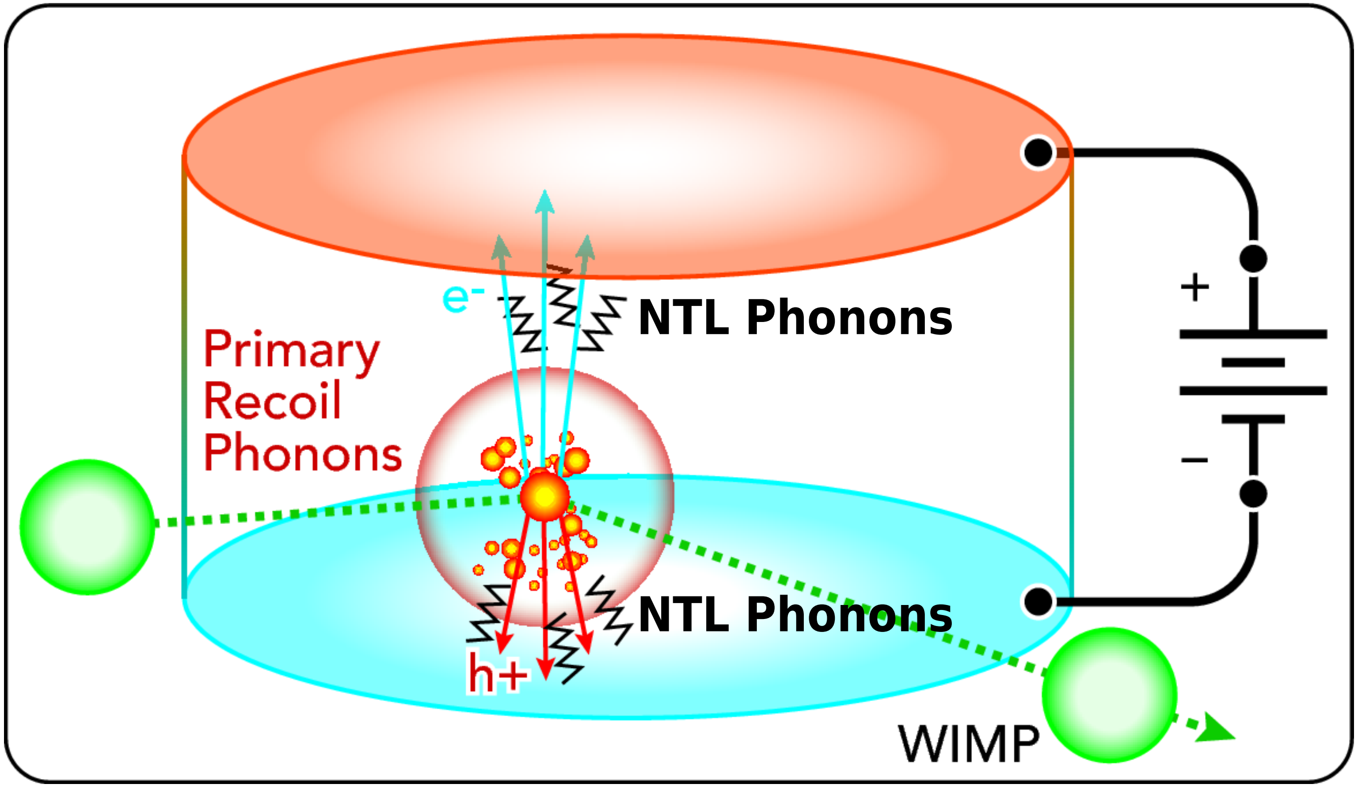
Neganov-Trofimov-Luke Effect

NEGANOV-TROFIMOV-LUKE AMPLIFICATION

NTL: Neganov-Trofimov-Luke



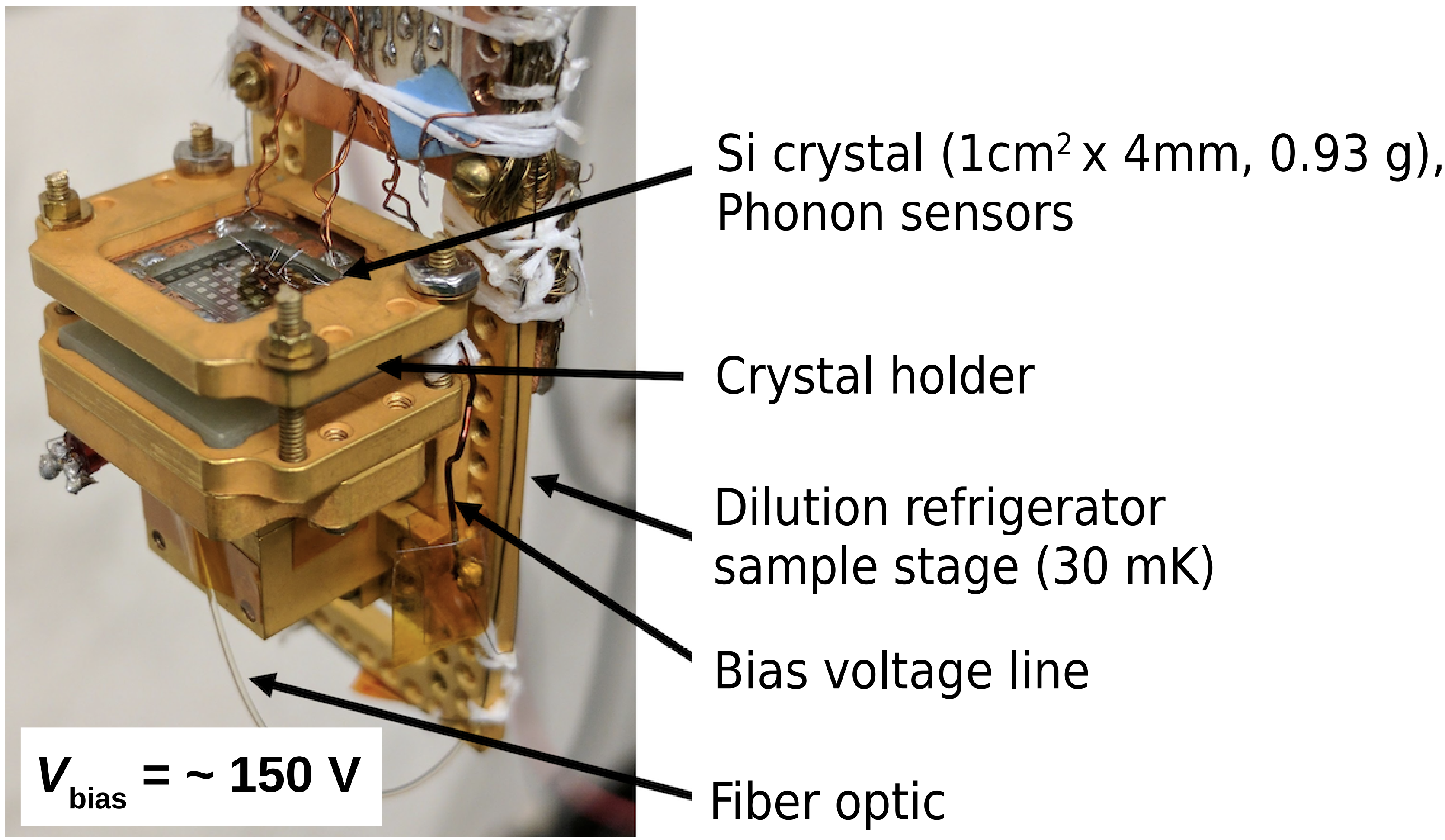
$V_{bias} \sim 100$ V

Observed Phonon Energy = E_{Recoil} + $\mathbf{E_{NTL}}$

PROTOTYPE HVeV DETECTOR

Talk by N. Kurinsky:
“Sub-GeV Dark Matter Search with a SuperCDMS HVeV Detector”

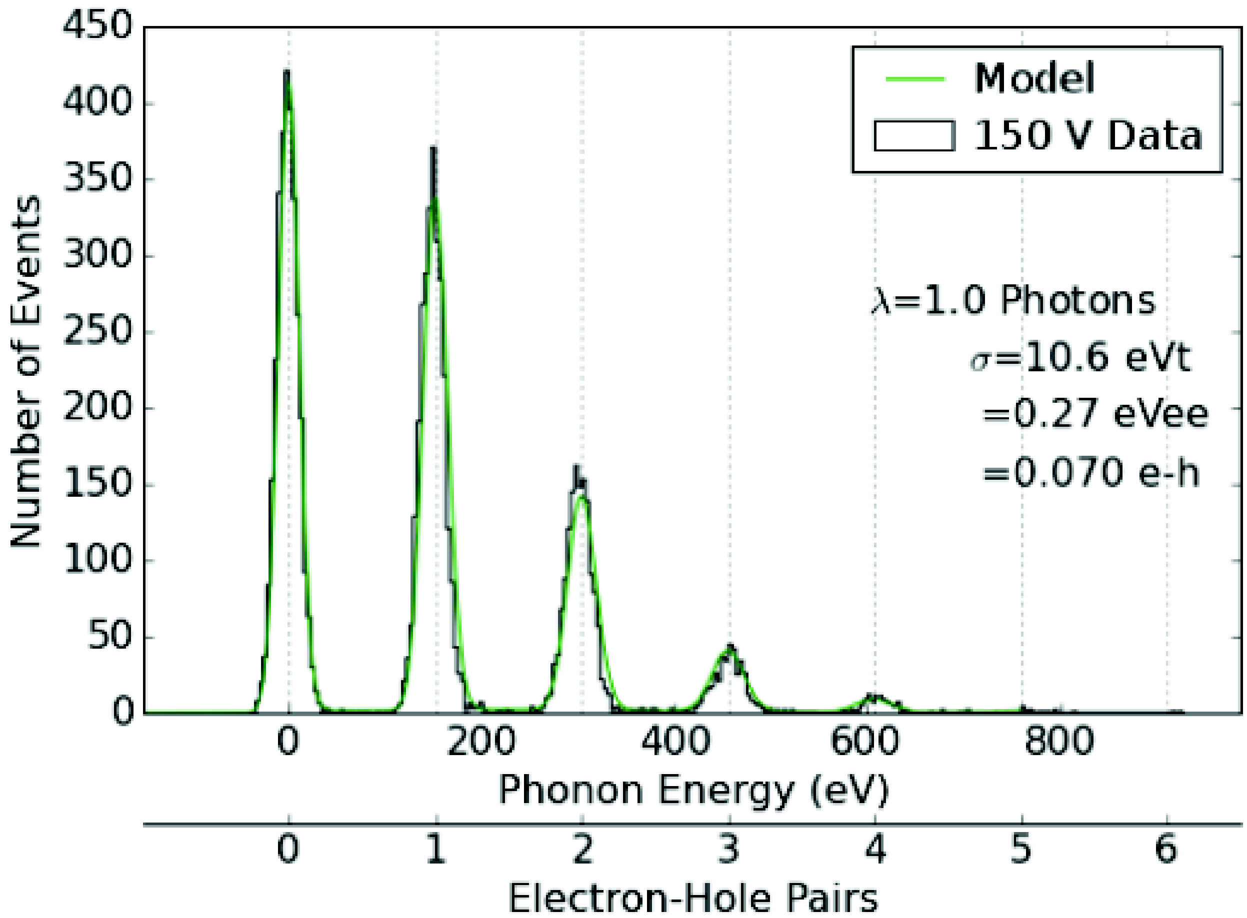
R.K. Romani et al.,
Appl.Phys.Lett. 112 (2018) 043501



- Strong NTL amplification of e^-h^+ pairs.
- Detector operated on surface at Stanford.

PROTOTYPE HVeV DETECTOR

- Si band gap: ~ 1.2 eV.
- Calibration data with pulsed 650 nm laser => 1.91 eV photons.



Sensitivity to single e^-h^+ pairs in Si crystal with a phonon sensor!

SuperCDMS DARK MATTER SEARCHES

Nuclear Recoil

↓

$$\frac{\text{Number of } e^{-}h^{+} \text{ pairs}}{\text{Primary Phonons}} = \textbf{small}$$

↓

Primary SuperCDMS DM search event class for default detectors.

↓

- Elastic WIMP-nucleon scattering.

Electron Recoil

↓

$$\frac{\text{Number of } e^{-}h^{+} \text{ pairs}}{\text{Primary Phonons}} = \textbf{large}$$

↓

Particularly interesting for HVeV detector!

↓

- Absorption of relic dark photons or relic ALPs.
- Light DM-electron scattering.
- ...

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Particularly interesting for HVeV detector!

↓

- Absorption of relic dark photons or relic ALPs.
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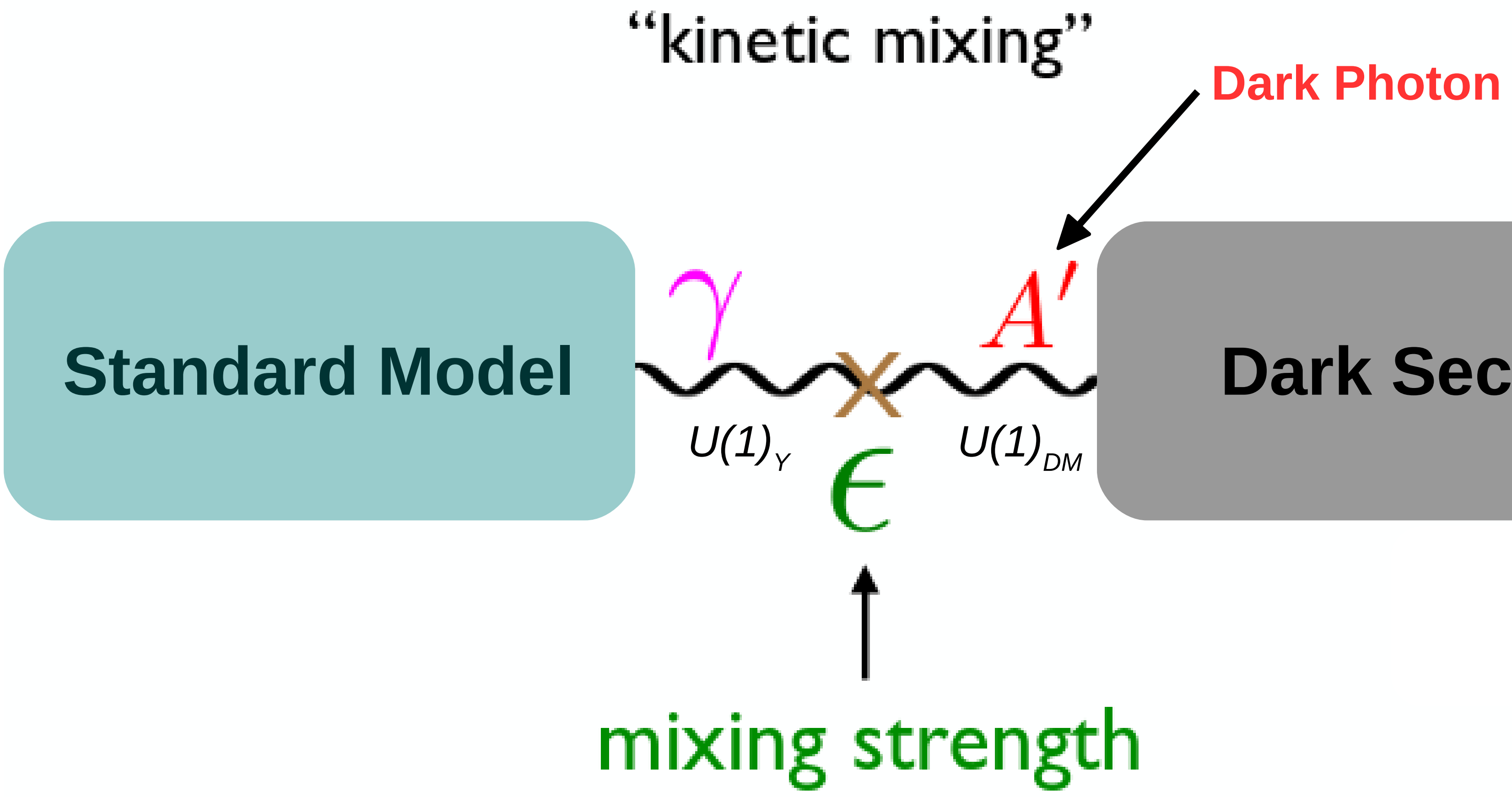
- ...

DARK PHOTON

SEARCH

MINIMAL VECTOR PORTAL



The *U(1)* vector mediators kinetically mix with kinetic mixing parameter ε.

DARK PHOTON ABSORPTION

- Analogous to photoelectric absorption, but with a **dark photon A'** of mass $\boldsymbol{m_{A'}}$ being absorbed.

Absorption Rate:

$$R \sim \rho_{\mathrm{DM}}\, \varepsilon_{\mathrm{eff}}^{2}\, m_{A'}^{-1}\, \sigma_{\mathrm{p.e.}}(E=m_{A'})$$

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with:

$$\varepsilon_{\mathrm{eff}}^2 = \varepsilon^2 \cdot \frac{m_{A'}^4}{[m_{A'}^2 - \mathrm{Re}\Pi]^2 + [\mathrm{Im}\Pi]^2}$$

≠1 for $m_{A'} < \sim 100$ eV

≈1 for $m_{A'} > \sim 100$ eV

Π: In-medium polarization tensor. Depends on $\sigma_{p.e.}$ as well.

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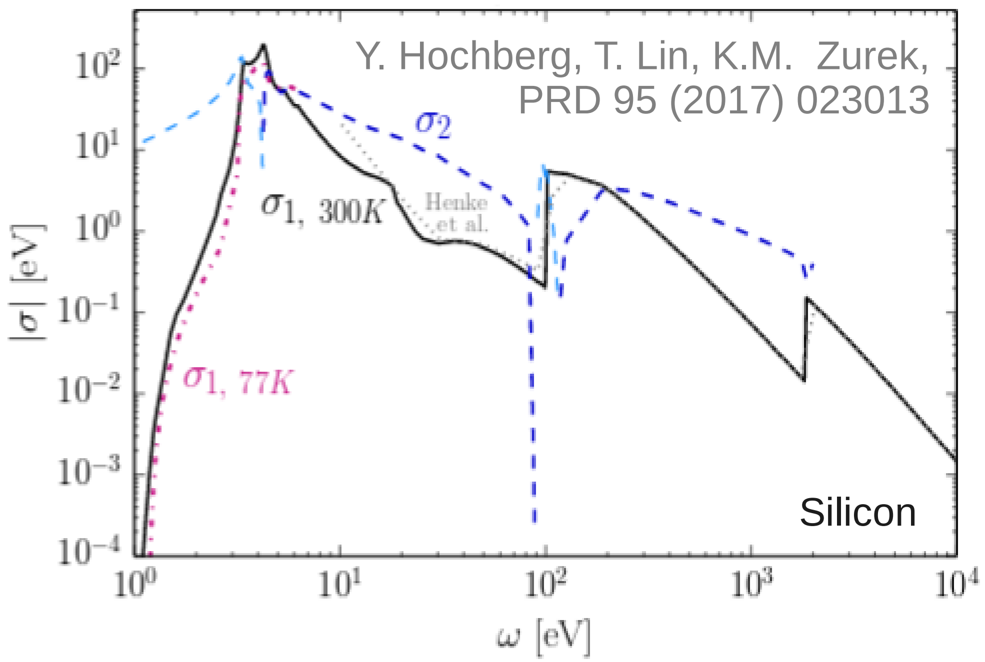
PHOTOELECTRIC ABSORPTION

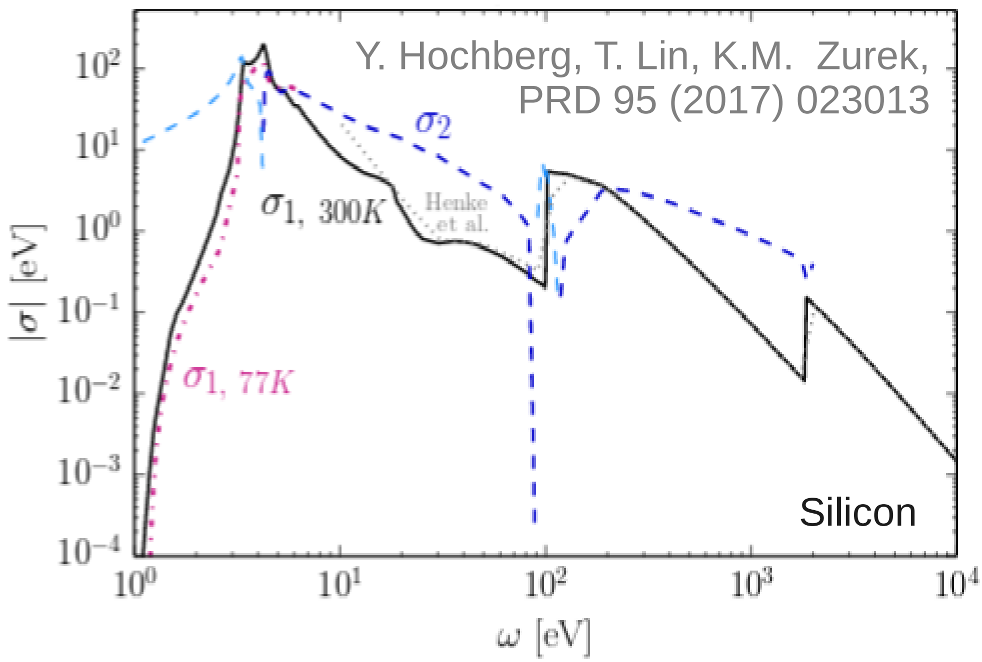


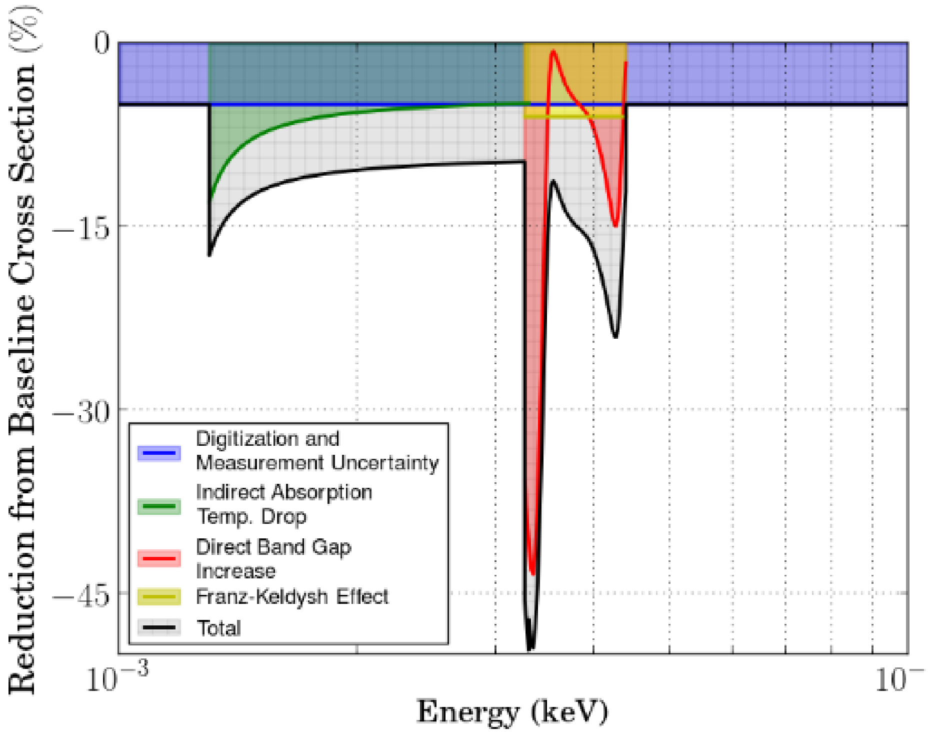
- $\sigma_1 \hat{=} \sigma_{p.e.}$ always needed.
- σ_2 needed for in-medium correction.

Dedicated study in
Ancillary file to arXiv:1804.10697,
SuperCDMS Collaboration

- Depends on:
  - **Temperature** (SuperCDMS at ≤ 30 mK),
  - **E-field strength** (detectors are biased),
    - Franz-Keldysh Effect [B.O. Seraphin, N. Bottka, PR 139 A 560],
- Effects particularly prominent near band gap.

PHOTOELECTRIC ABSORPTION





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DARK PHOTON ABSORPTION SIGNAL

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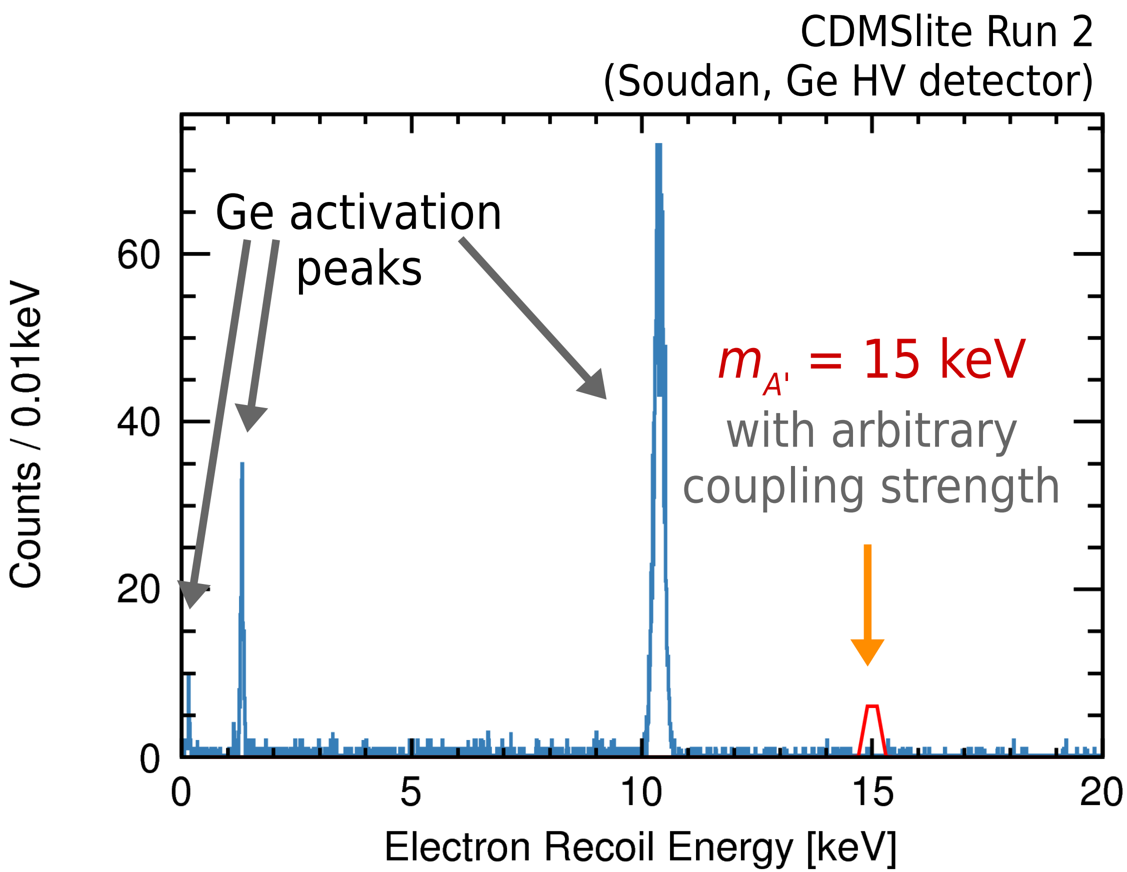
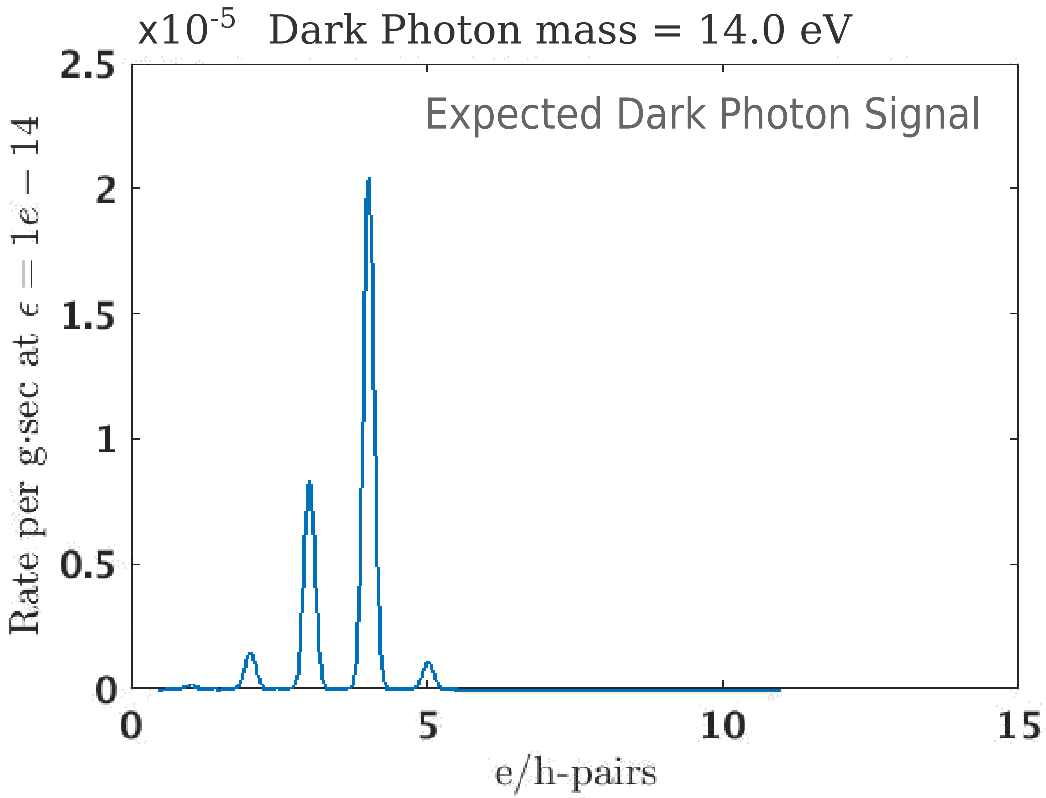


Expected signal: **Peak at electron recoil energy corresponding to $m_{A'}$**

DARK PHOTON ABSORPTION SIGNAL IN QUANTIZATION LIMIT



Ionization model:

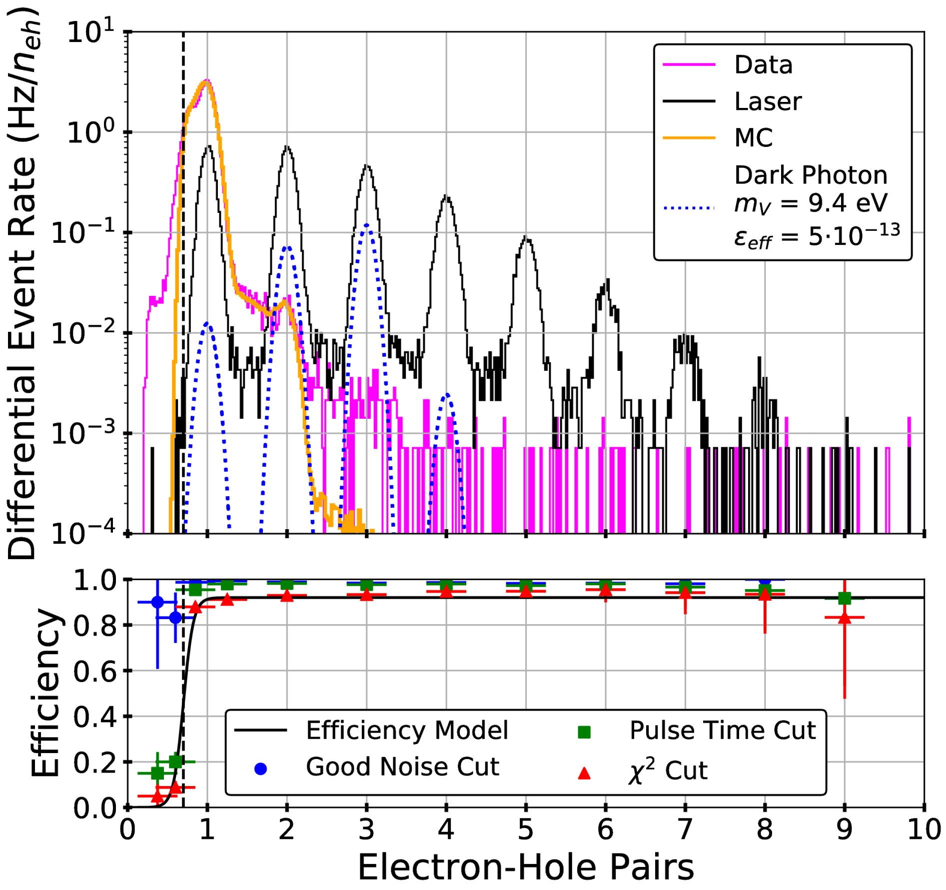
$$\langle n_{eh}(E_\gamma)\rangle = \begin{cases} 0 & E_\gamma < E_{gap} \\ 1 & E_{gap} < E_\gamma < \epsilon_{eh} \\ E_\gamma/\epsilon_{eh} & \epsilon_{eh} < E_\gamma \end{cases}$$

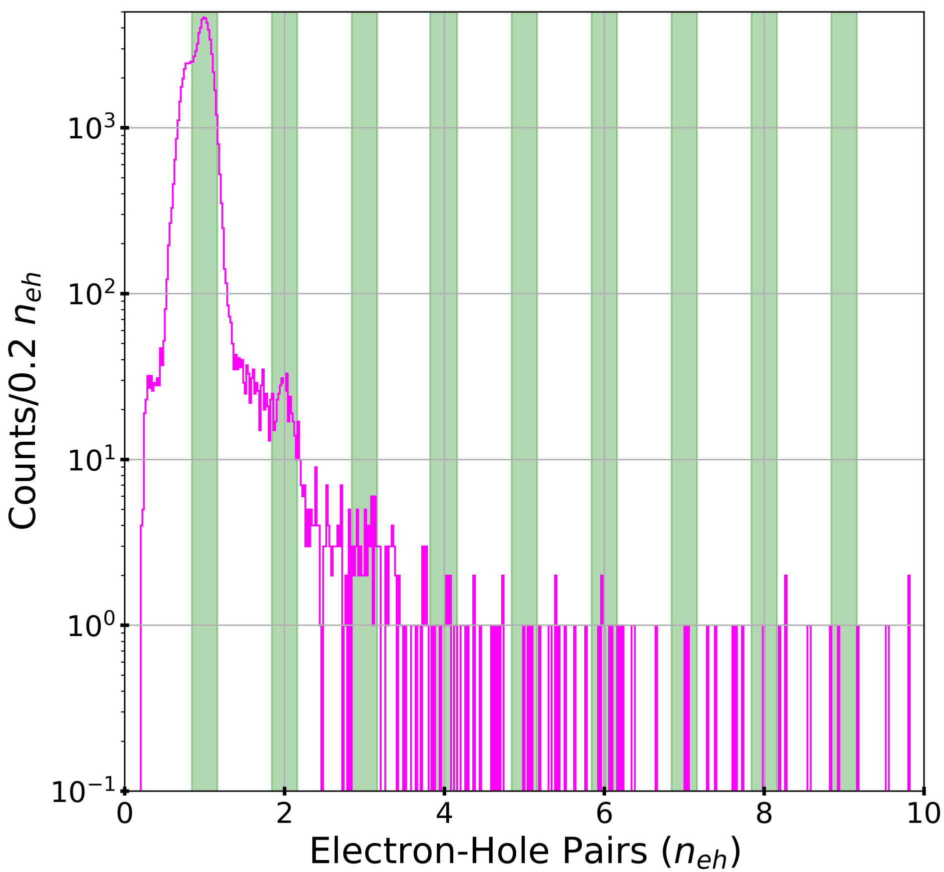
Quantization of peak at electron recoil energy corresponding to $m_{A'}$

DARK PHOTON SEARCH ON HVeV DATA

SuperCDMS Collaboration, arXiv:1804.10697
accepted by PRL

0.49 g-day exposure after data selection cuts.

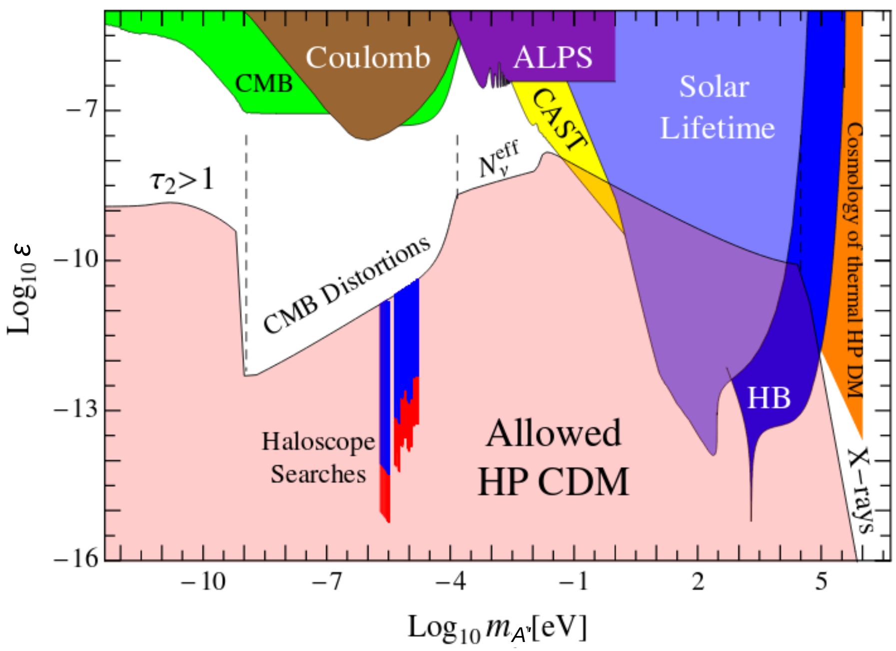




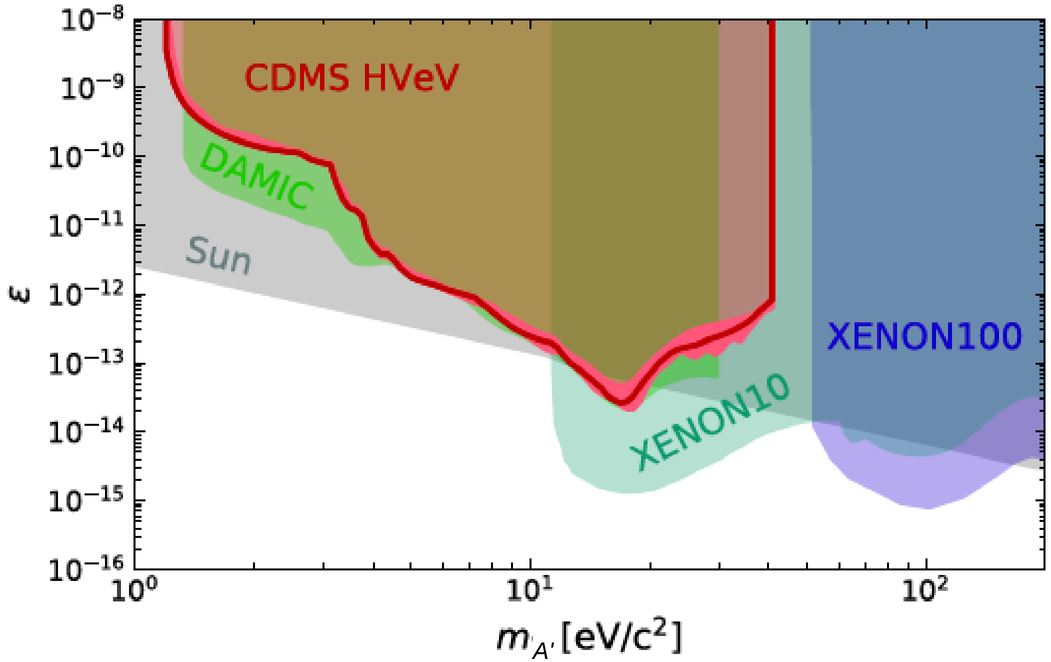
Region of Interest: +/- 2 σ quantization peak regions.

90% C.L. KINETIC MIXING LIMIT

P. Arias, D. Cadamuro, M. Goodsell, J. Jaeckel, J. Redondo, A. Ringwald, JCAP 1206 (2012) 013



SuperCDMS Collaboration, arXiv:1804.10697 accepted by PRL



Reaching existing limit despite order of magnitude smaller exposure.

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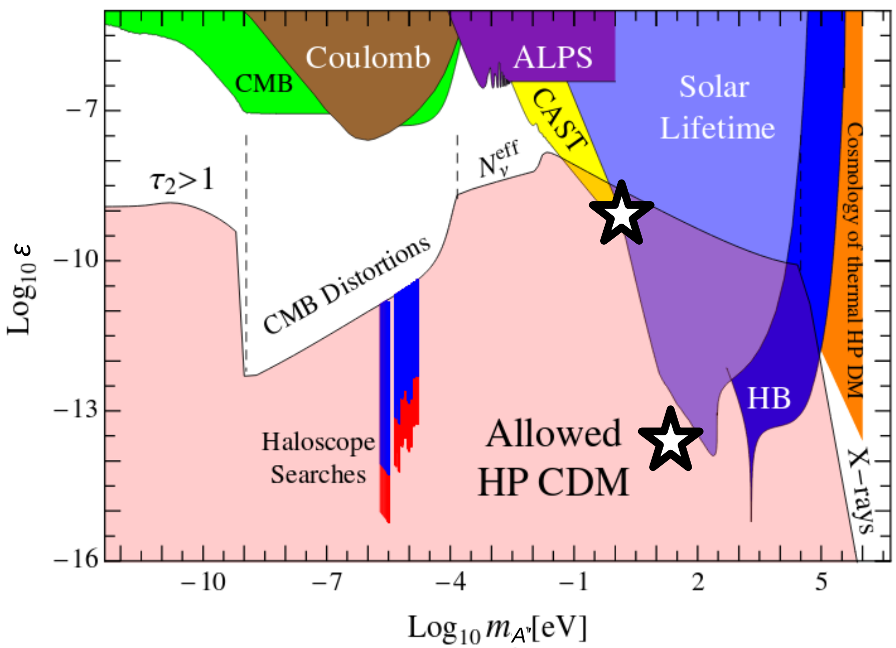

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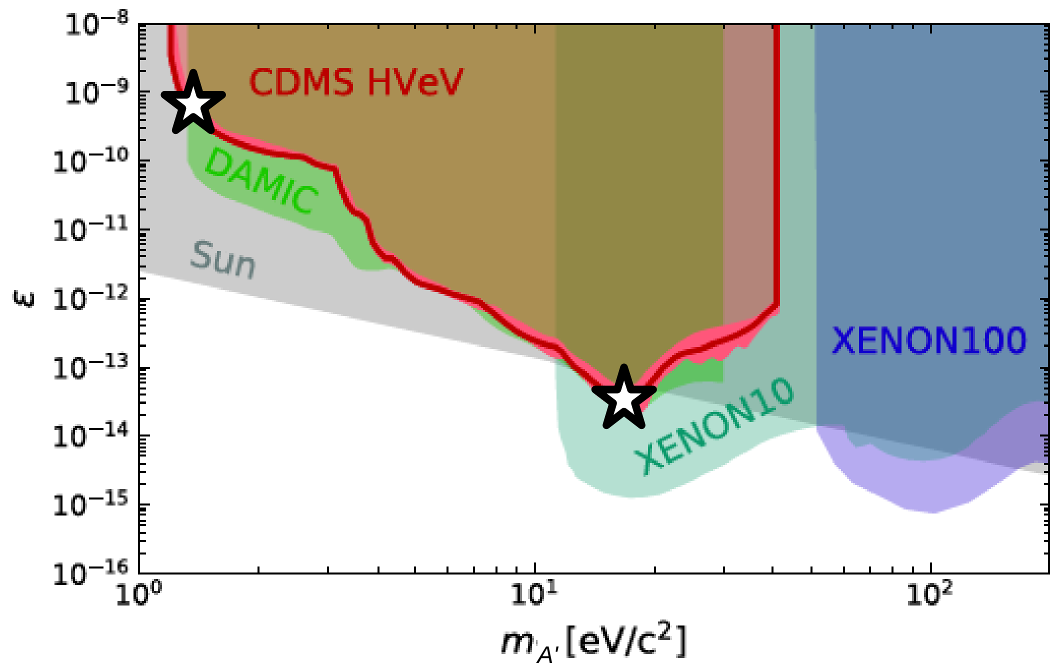


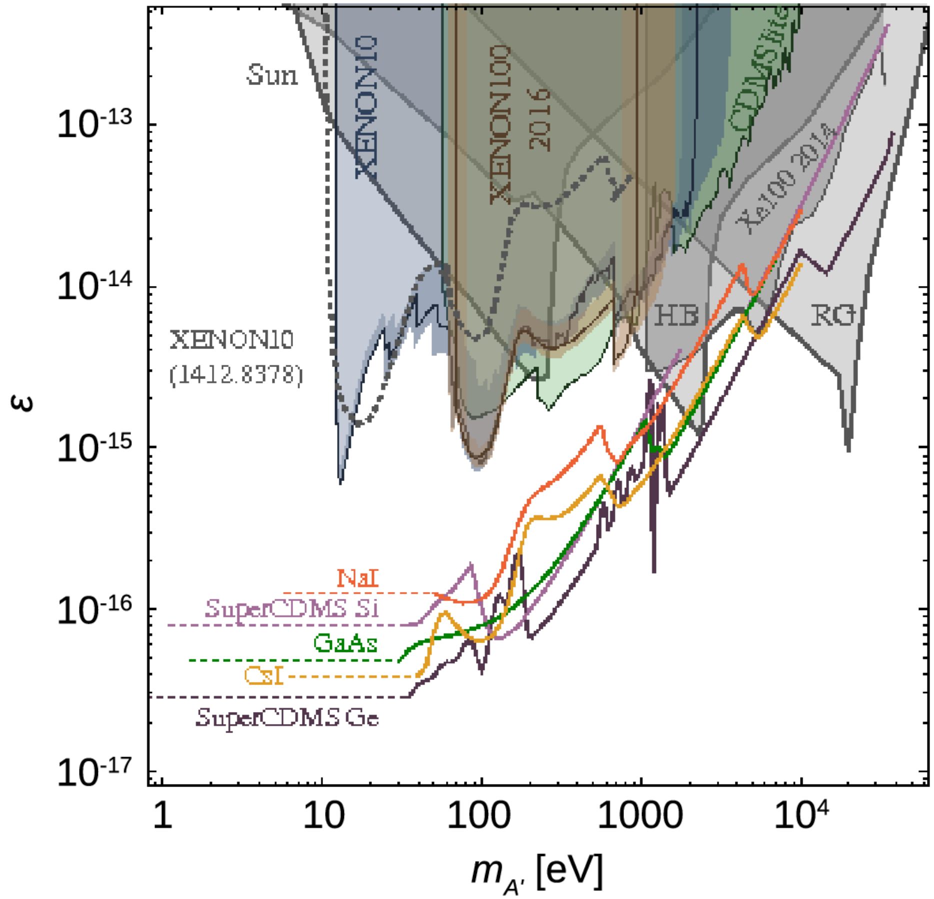
Reaching existing limit despite order of magnitude smaller exposure.

OUTLOOK

SuperCDMS SNOLAB PROJECTIONS

SuperCDMS HV detectors with 20 kg-yrs (Ge) and 10 kg-yrs (Si) exposure.

I. Bloch, R. Essig, K. Tobioka, T. Volansky, T. Yu
JHEP 1706 (2017) 087



- Commissioning of SuperCDMS SNOLAB in 2020.
- Starting to take data end of 2020!

Talk by R. Schnee:
"Status and Expected Sensitivity of SuperCDMS SNOLAB"

THE 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	U. Colorado Denver	U. Evansville	U. Florida	
	U. Montréal	U. Minnesota	U. South Dakota	U. Toronto	

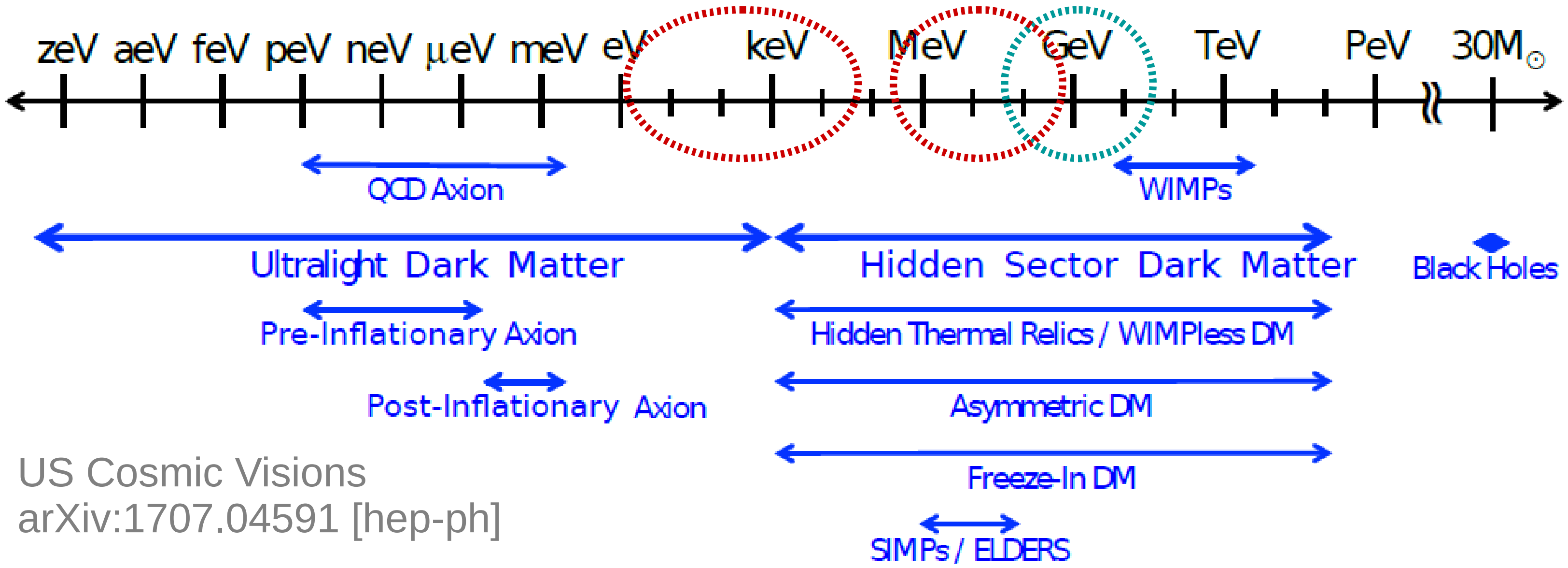
* Associate members

SUPPLEMENTARY MATERIAL

DM DETECTION CHANNELS - Electron Recoil

SuperCDMS DM Search
(Electron Recoil)

SuperCDMS WIMP Search
(Nuclear Recoil)



US Cosmic Visions
arXiv:1707.04591 [hep-ph]

THE SuperCDMS SNOLAB EXPERIMENT

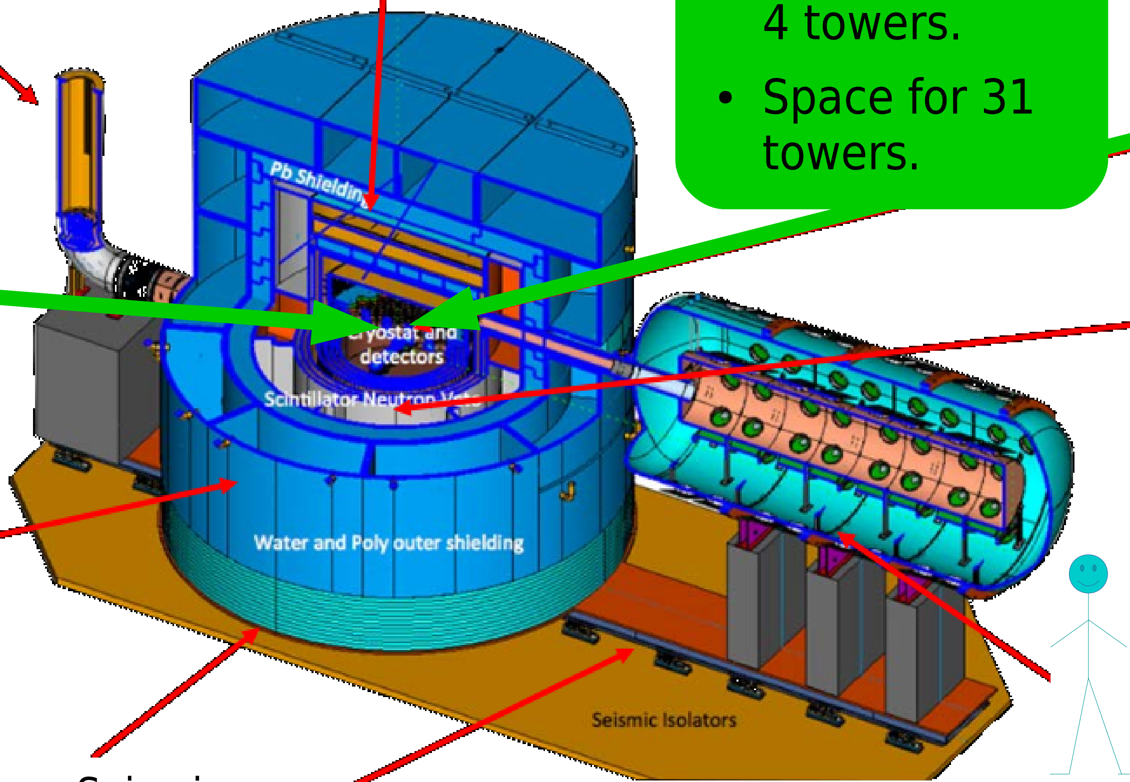
Gamma shield (Pb)

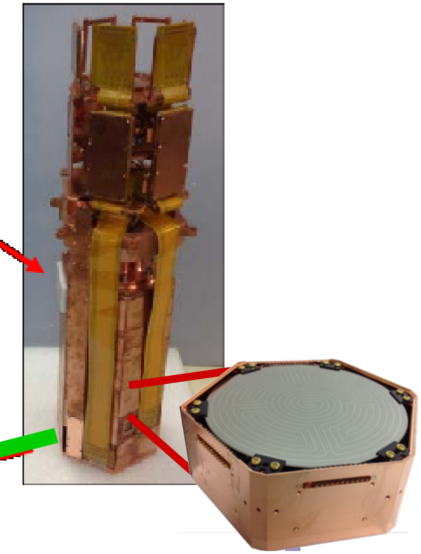
Fridge to provide
<15 mK at the detectors

6 detectors
→ 1 tower

- Starting with 4 towers.
- Space for 31 towers.

15 mK





Inner neutron
shield (PE)

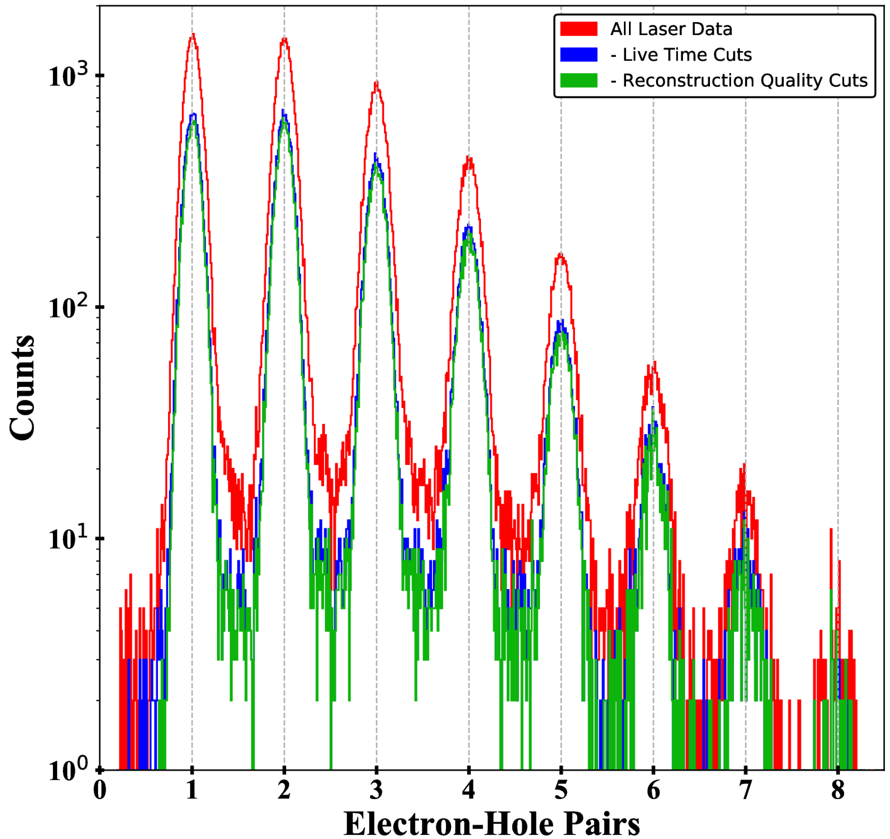
Outer neutron
shield (water, PE)

Seismic
platform

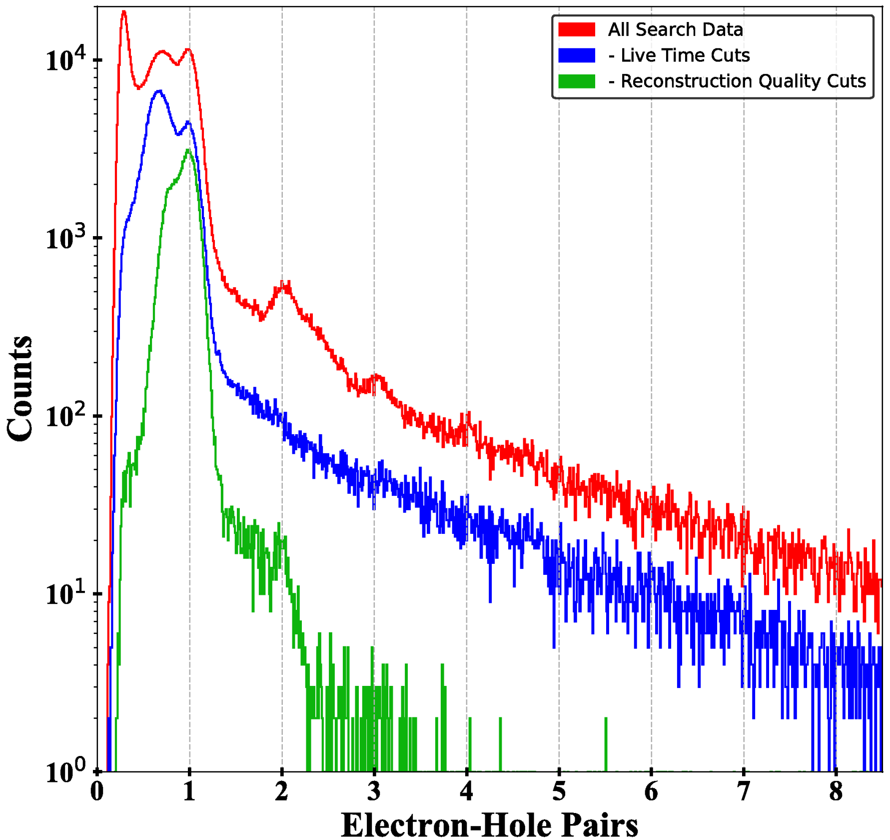
Signal vacuum
feedthroughs

0.49 GRAM-DAYS OF SCIENCE DATA

Calibration Laser Data



DM Search Data



- Live Time Cuts:
  - Low-frequency noise, surface leakage, system stability.
- Reconstruction Quality Cuts:
  - Pre-trigger noise, reconstructed pulse start time, pulse shape.

DARK PHOTONS: IN-MEDIUM EFFECTS

Absorption rate:

$R \sim \rho_{DM}\, \varepsilon_{eff}^{2}\, m_V^{-1}\, \sigma_{p.e.}(E=m_V)$

with:

$$\varepsilon_{\text{eff}}^2 = \varepsilon^2 \cdot \frac{m_V^4}{[m_{V'}^2 - \text{Re}\Pi]^2 + [\text{Im}\Pi]^2}$$

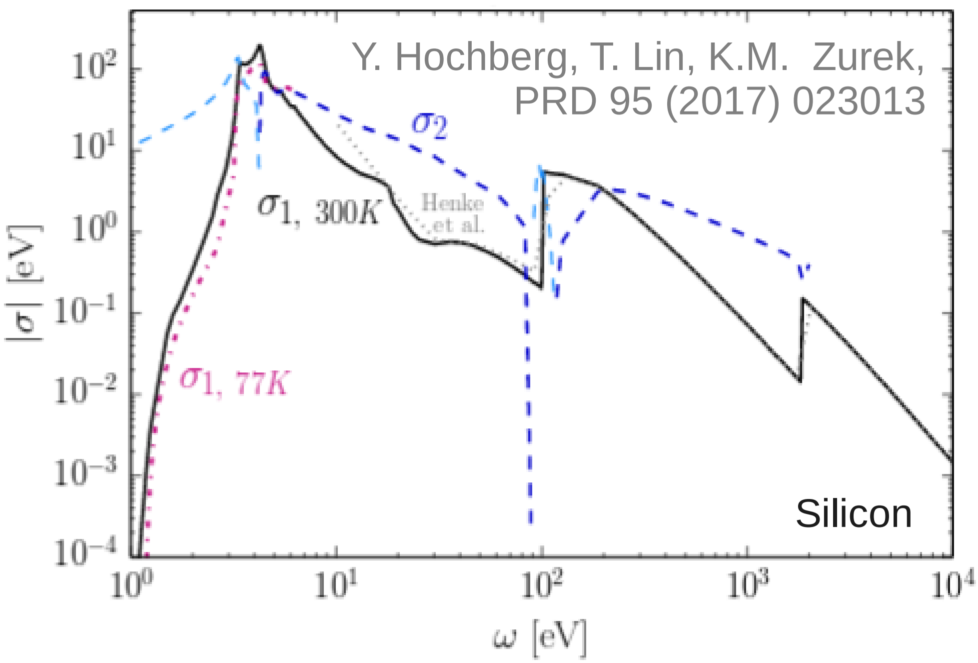
In-medium polarization tensor:

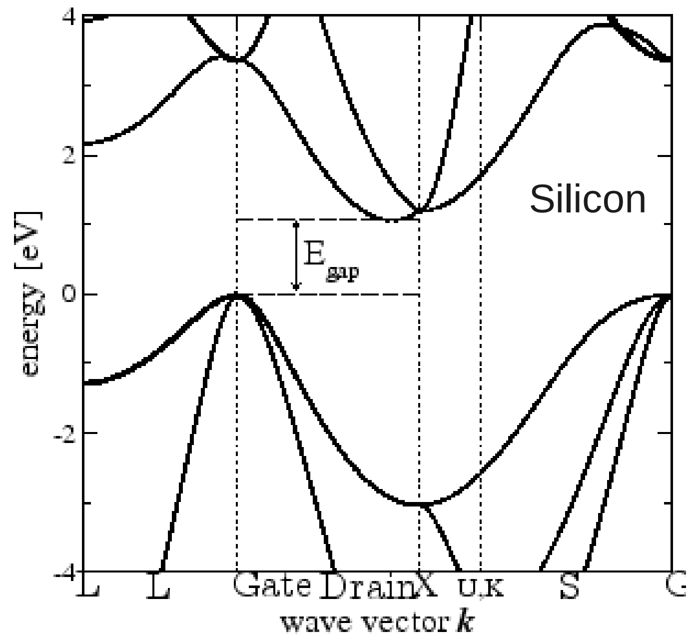
$$\Pi(E_\gamma = m_{V'}c^2) \approx -i \cdot \hat{\sigma} \cdot m_{V'}c^2$$

Conductivity:

$$\hat{\sigma} \equiv \sigma_1 + i\sigma_2$$

PHOTOELECTRIC ABSORPTION



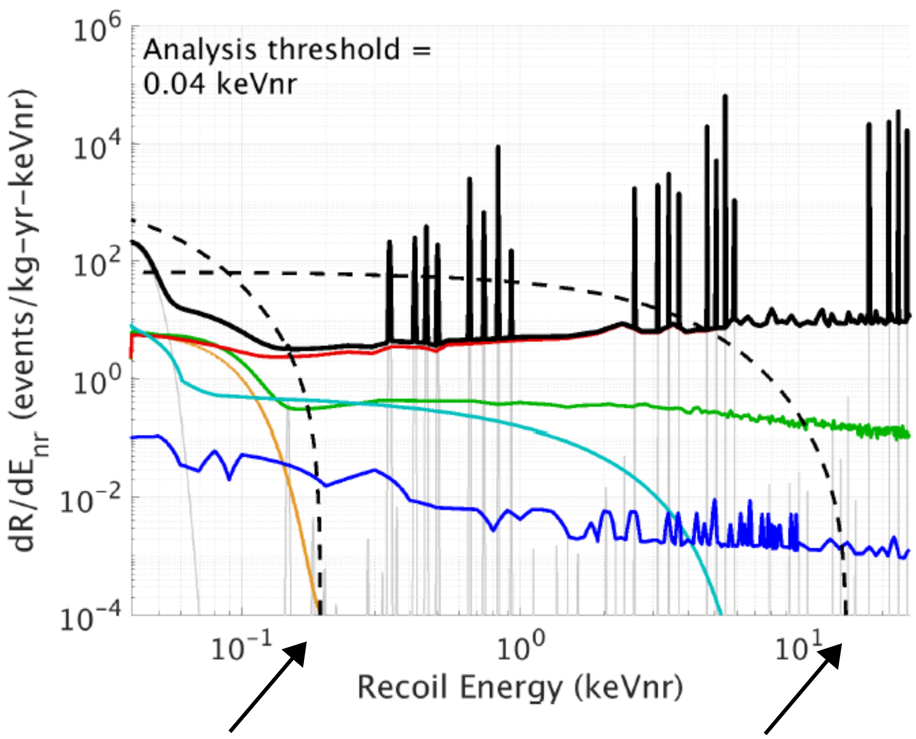


- $\sigma_1 \hat{=} \sigma_{p.e.}$ always needed.
- σ_2 needed for in-medium correction.

WIMP-NUCLEON SCATTERING

- **Spin-independent (SI) elastic WIMP-nucleon scattering.**
  - **Primary Dark Matter search.**
- Spin-dependent (SD) elastic WIMP-nucleon scattering.
- Dominant backgrounds have Electron Recoil signature.

Prediction in
Ge HV detectors
after fiducial cuts:

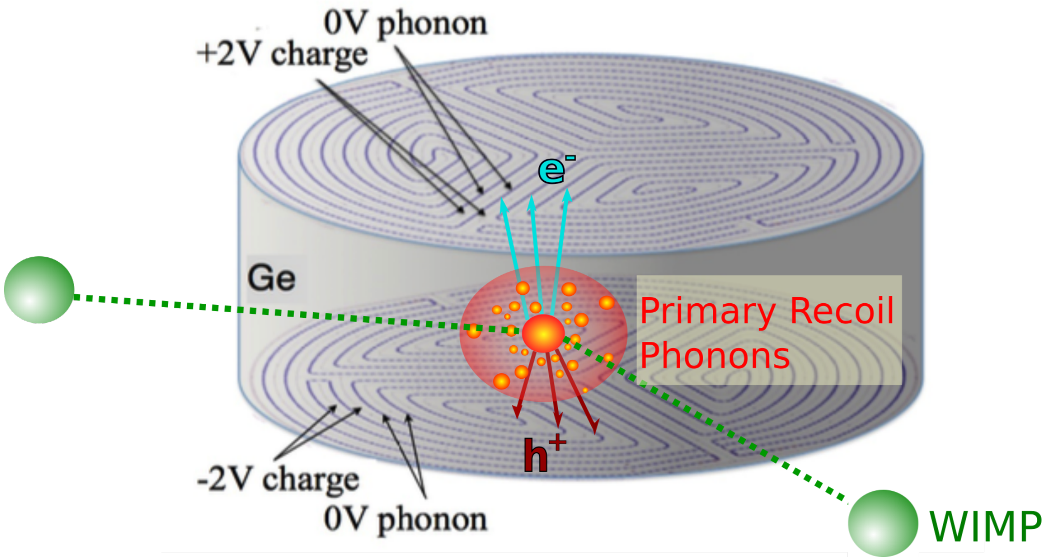


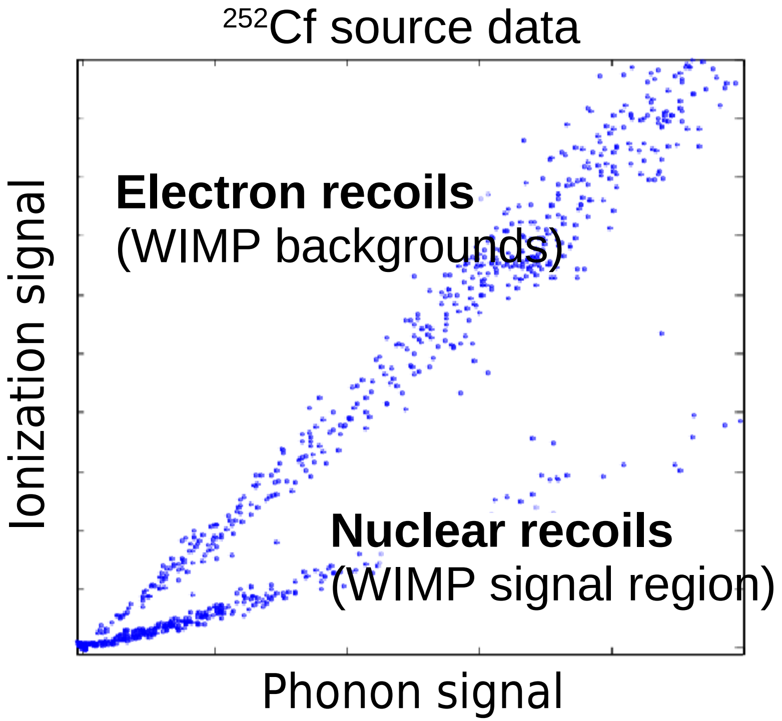
Total
^{3}H and Comptons
Ge activation
Surface betas
Surface ^{206}Pb
Coherent neutrinos
Neutrons

1 GeV WIMP 10 GeV WIMP with $\sigma = 10^{-42}$ cm^{2}.

DETECTION PRINCIPLE – iZIP MODE

interleaved **Z**-Sensitive **I**onization and **P**honon detectors.





- **Phonon signal**: Heat / energy deposition.
- **Ionization signal**: e^-/h^+ pair production.
  - Reduced for nuclear recoil.
- **Combination**: Efficient discrimination between nuclear and electron recoil events.

SYSTEMATIC EFFECT OF FANO TERM