Direct Detection

Summary and outlook

Jeremy Mardon, SITP, Stanford

GOALS/CHALLENGES

SENSITIVITY

low thresholds

BACKGROUNDS

1) measure, understand

2) control

EXPOSURE

scaling up

SIGNAL/BKGD DISCRIMINATION

long term stability for annual modulation

Directional sensitivity?

MORE ESTABLISHED

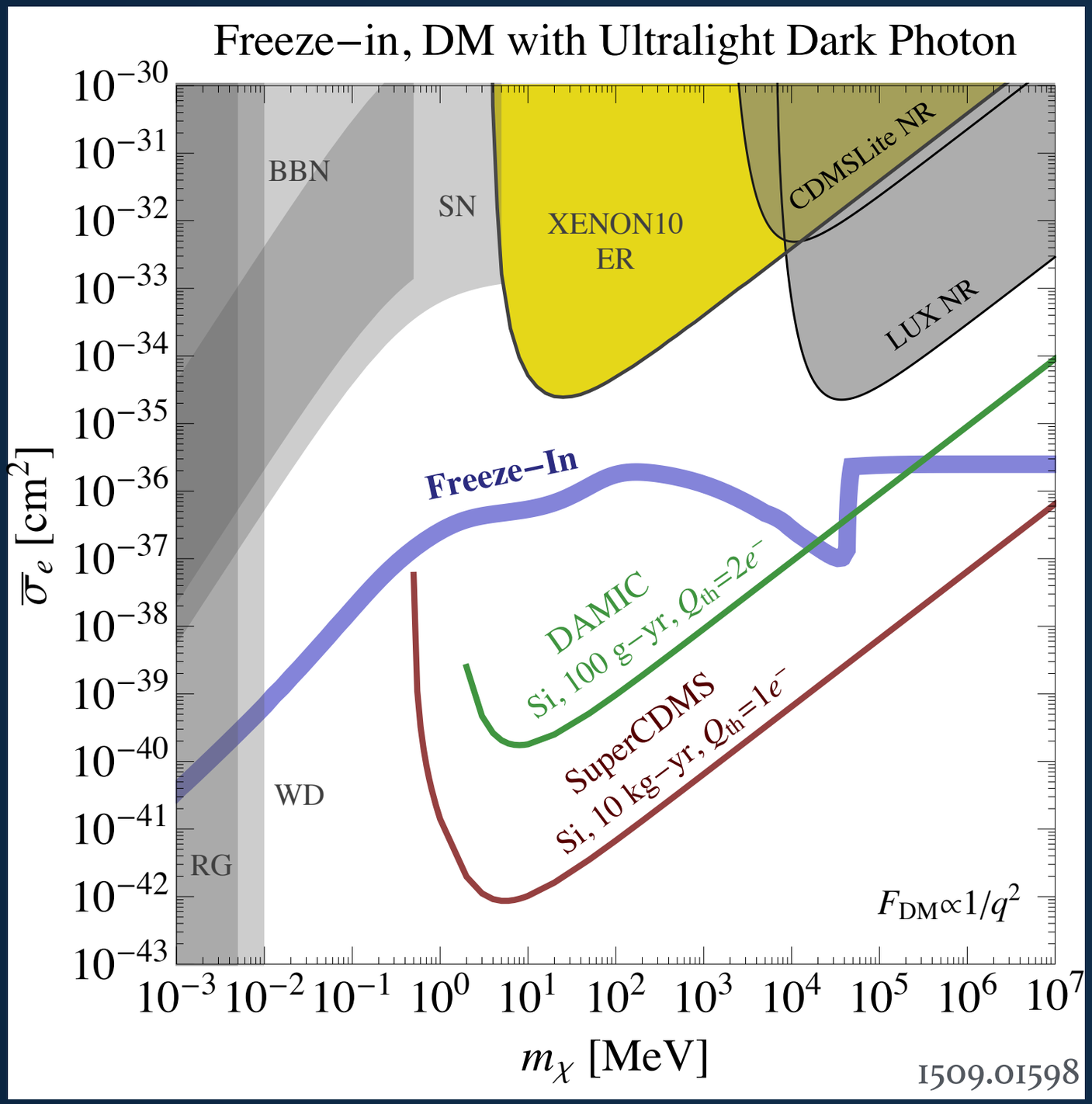
MORE SPECULATIVE

Models

Light mediators (photon/ hidden-photon / other?)

Heavy mediator: colliders better

e^- RECOIL



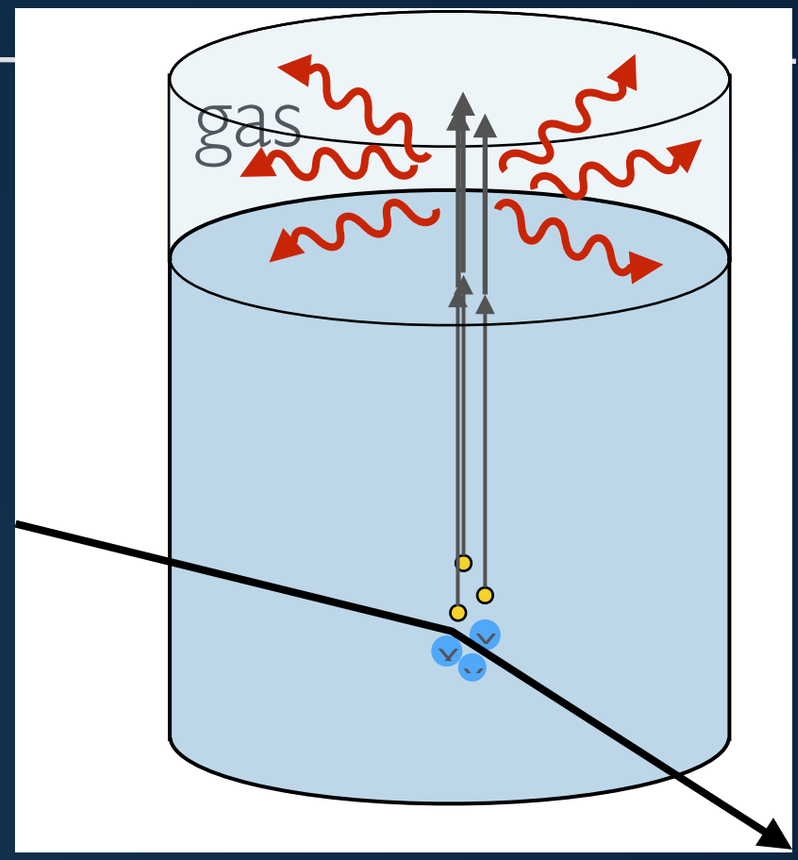
XENON10 bound improve with current LXe exps?

Semiconductors surpass LXe sensitivity?

e⁻ RECOIL IN LIQUID XE

~10 MeV mass threshold for 1 e⁻
Established sensitivity

(LARGE?) BACKGROUNDS from:
e⁻ trapping at surface / on impurities?
e⁻ emission from cathode?



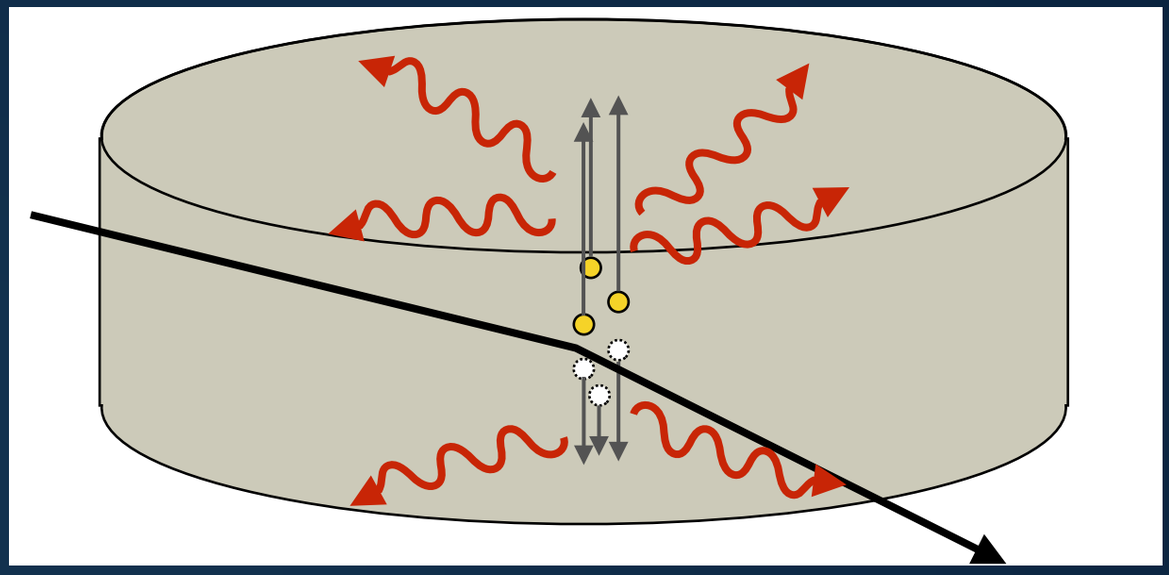
Xenon100, LUX, LZ/XenonnT challenges:
Reproduce Xenon10's purity & low trapping rate
Reduce Bkd with timing cuts (tradeoff vs deadtime)

Dedicated Exp?
small scale, less deep, optimized for few-e⁻ search

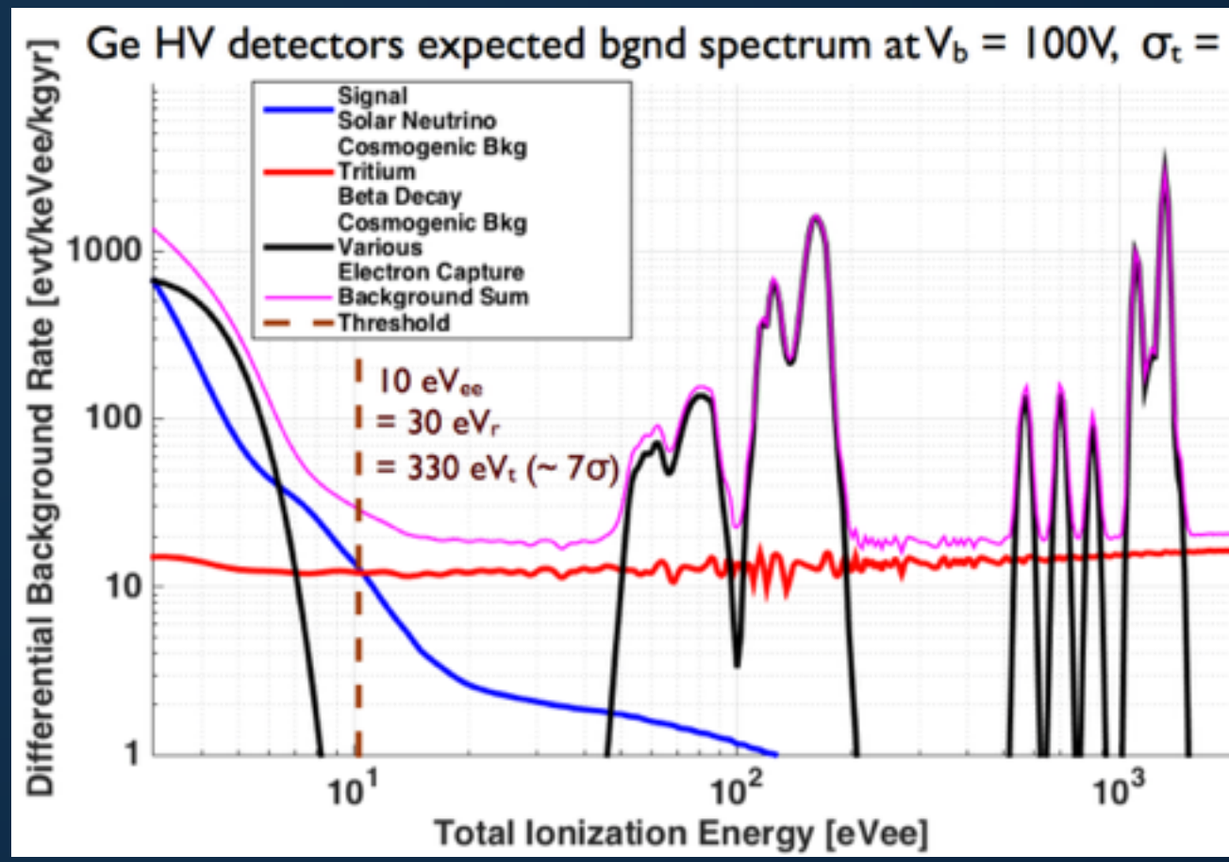
e^- RECOIL IN GE/SI

~1 MeV mass threshold for 1 e^-

Si/Ge: CDMSlite & DAMIC
Working towards 1 e- sensitivity
Path laid out, ~ 2yr timescale?



BACKGROUNDS from:
leakage current?
radioactive bkd: ~few per year
other new bkds?

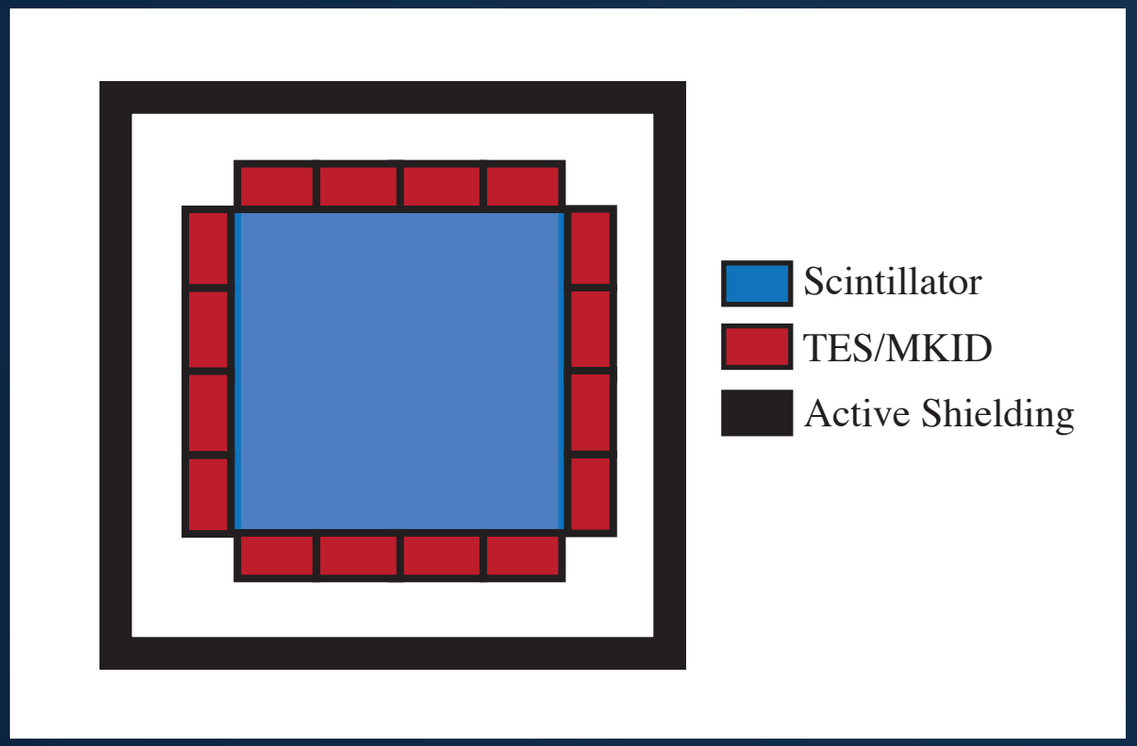


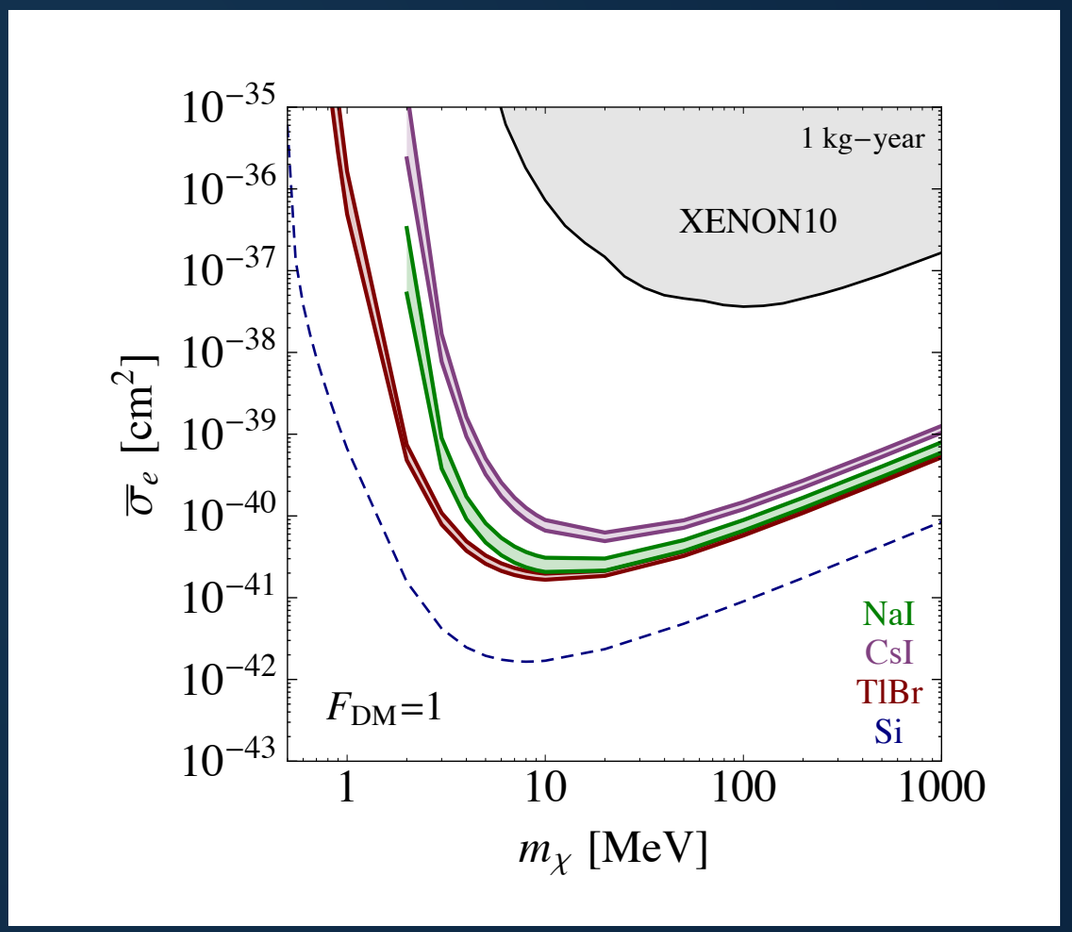
Golwala talk at DM2016

Scintillators

Single photon detection (TES? MKID?)

No E-field (lowers bkd?)





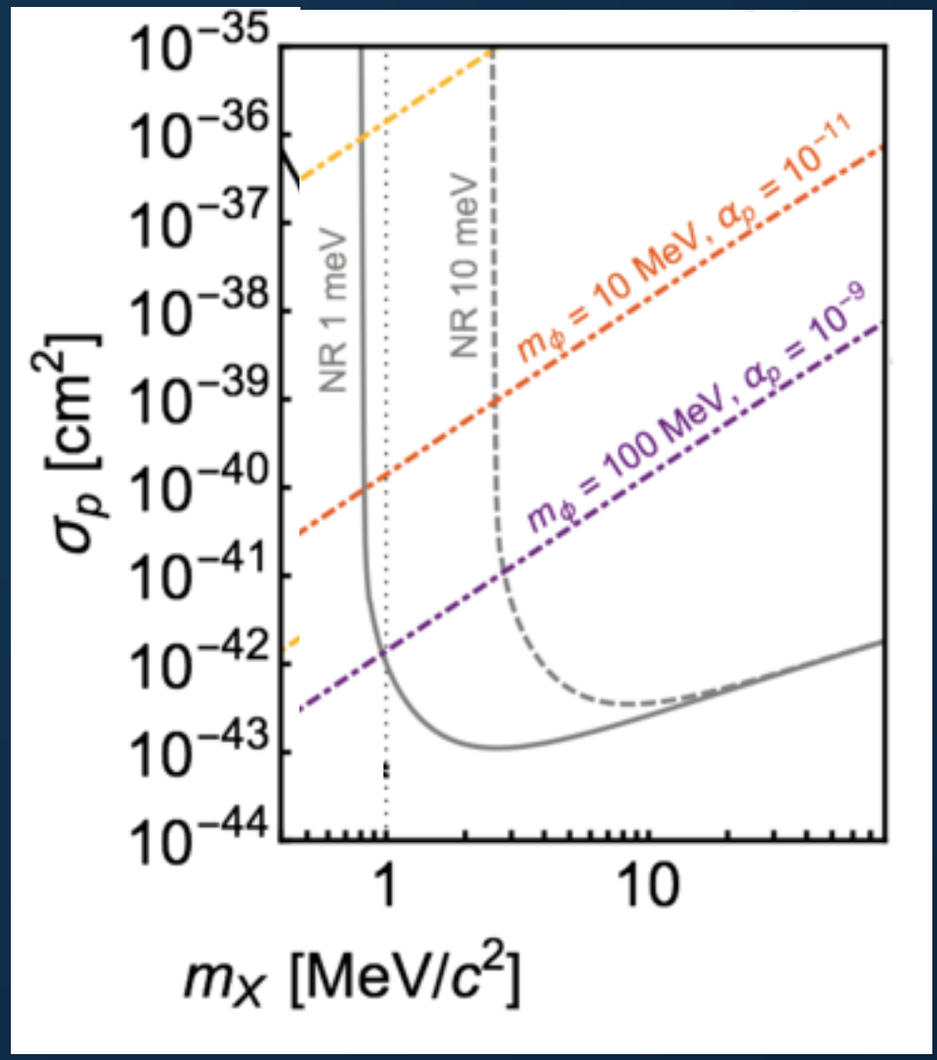
NR in Liquid Helium

Nuclear recoil ⟶ quasiparticle production

ballistic atoms from liquid surface

energy gain in detector

~10 meV threshold?
few MeV DM mass

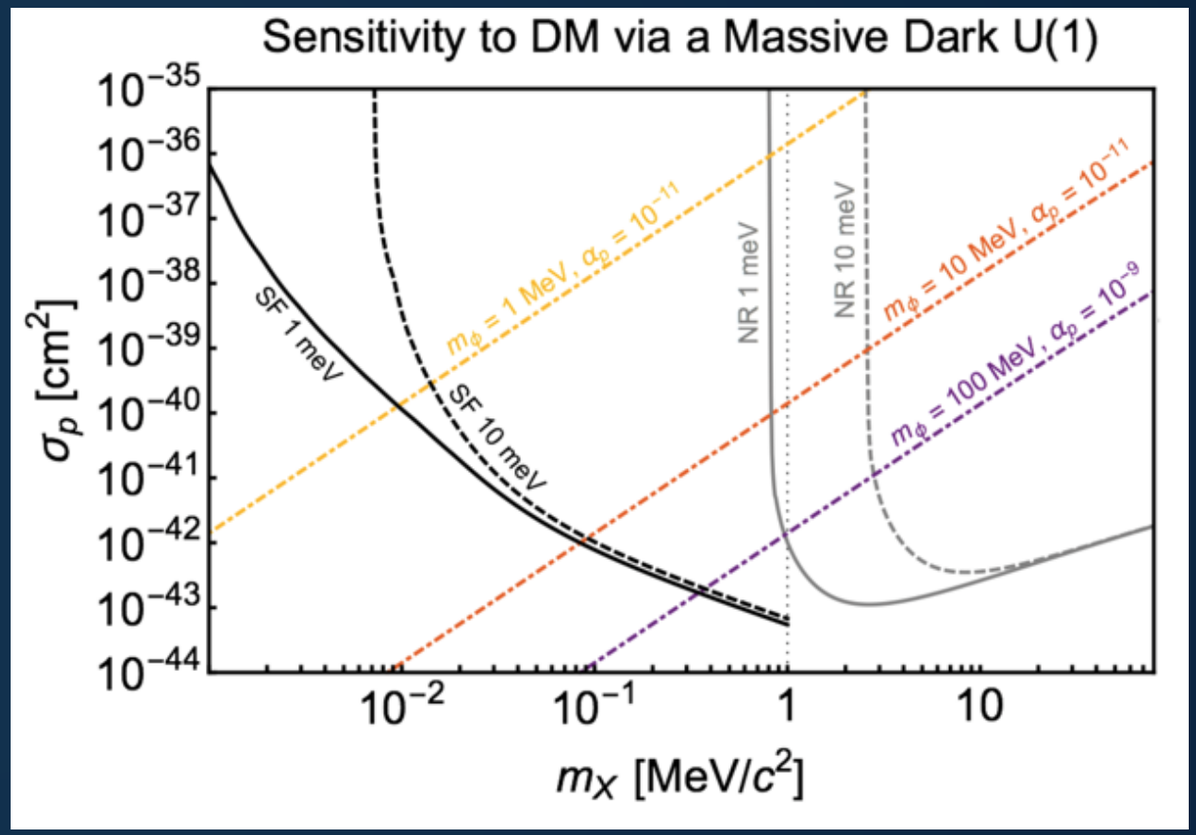


NR in Superfluid Liquid Helium

Nuclear recoil ⟶ 2-phonon production

purpose of superfluid:
collection of quasiparticles
(no thermalization)

Reach to ~keV scale DM mass?



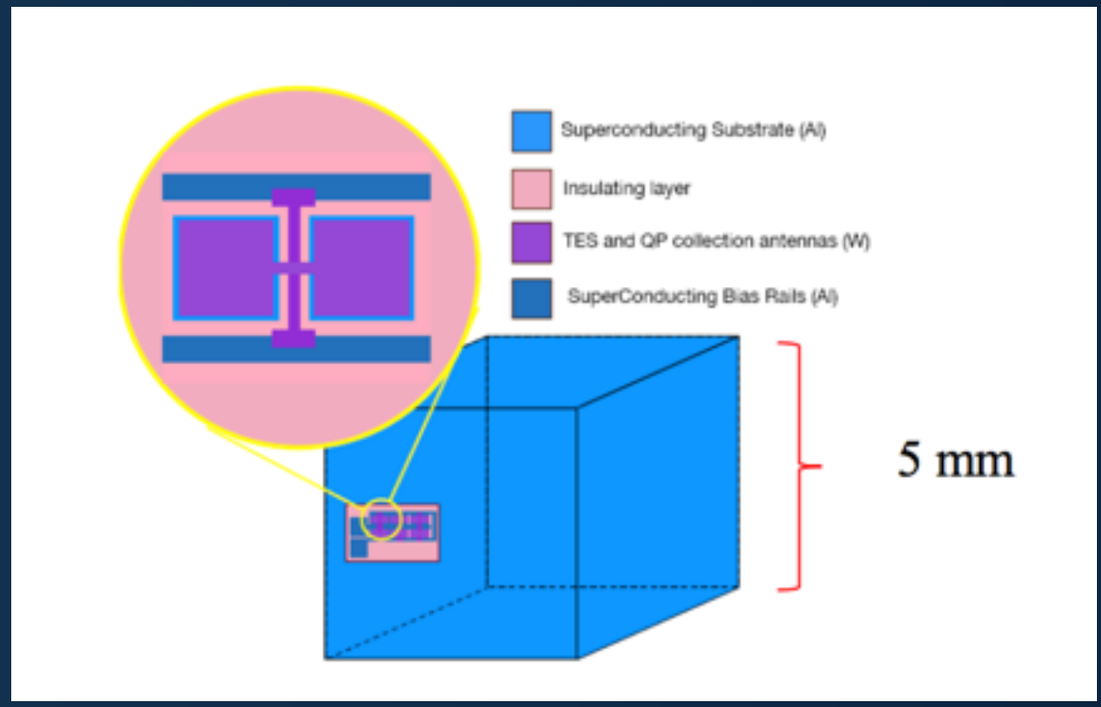
Theory issue:
form-factor suppresses coupling through hidden-photon mediator or DM with EM dipole.

SUPERCONDUCTOR

e- recoil ⟶ quasiparticle production

purpose of super~~fluid~~ conductor:
collection of quasiparticles
(no thermalization)

Reach to ~keV scale DM mass?



Theory issue:
in medium-effects suppress scattering through hidden photon mediator
BBN & cooling constraints

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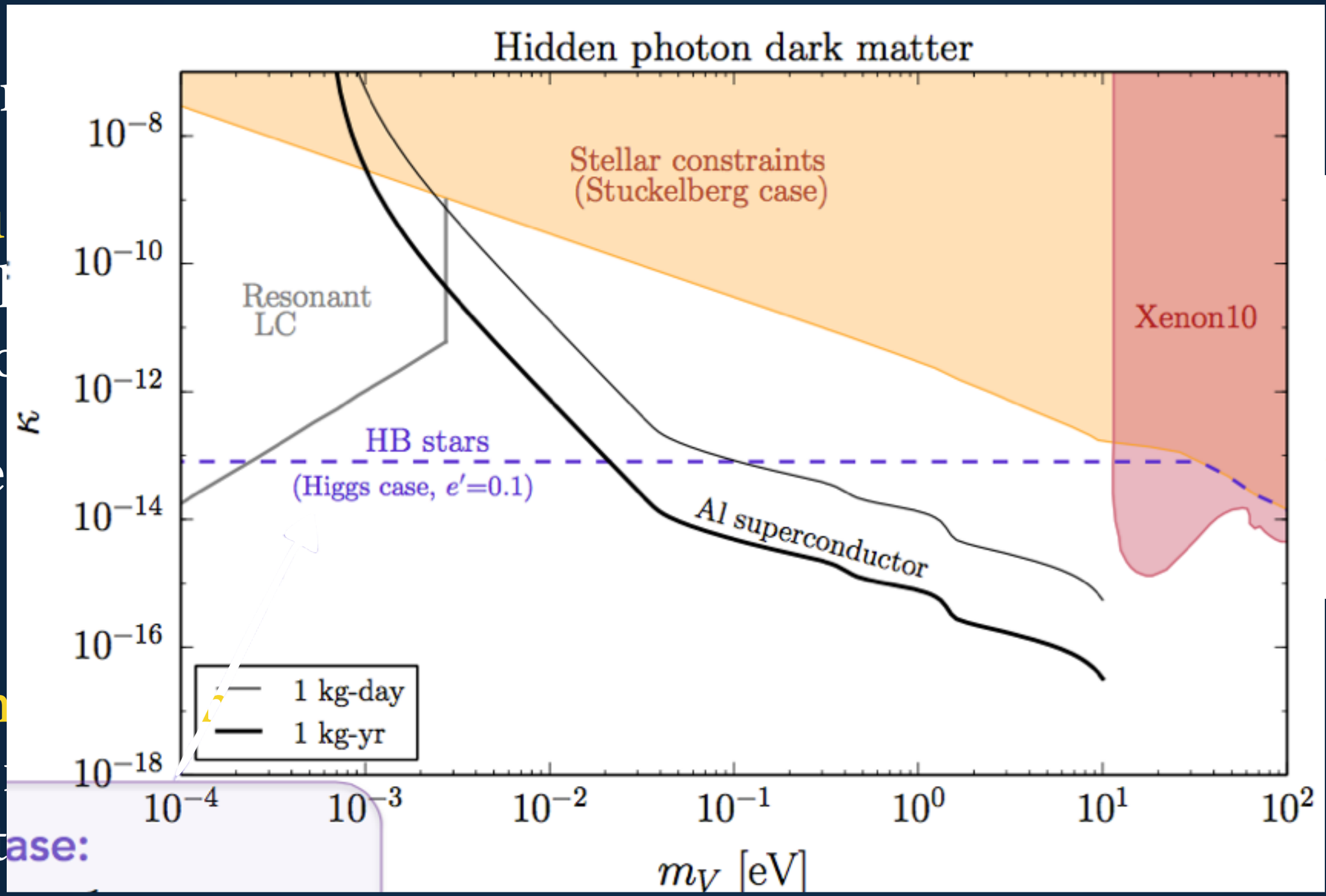

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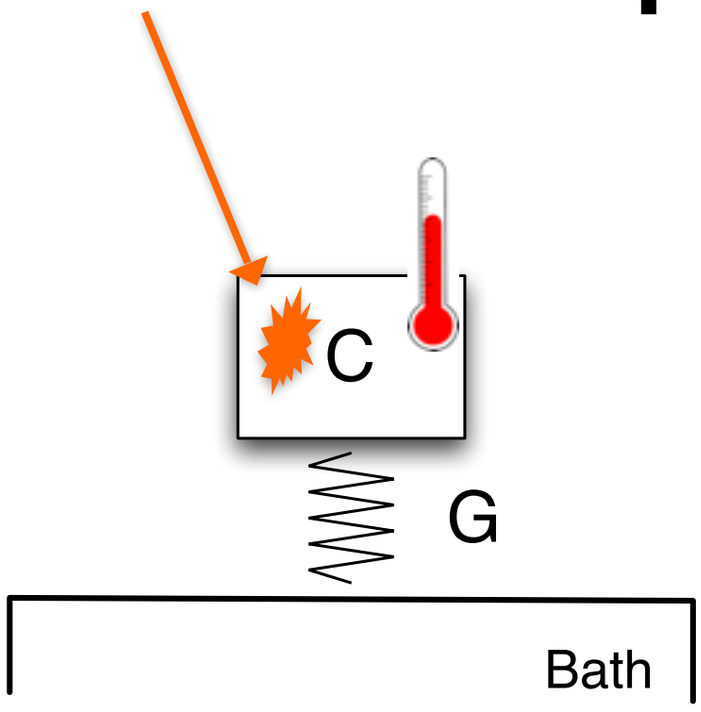
TES:
Today / Tomorrow

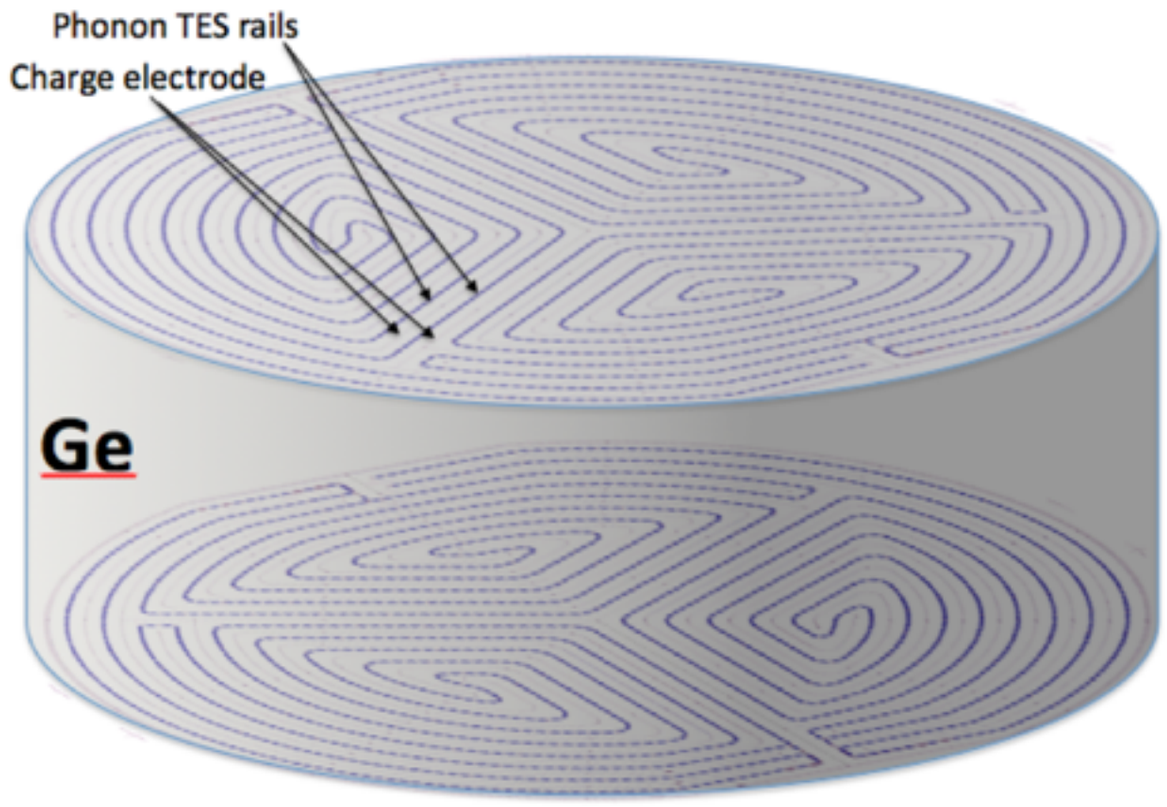
TES: Current Status



TES	Tc	Volume	$\sqrt{S_p}$ [W/$\sqrt{Hz}$]	σ_E [meV]
W	125	25x25x25	$5x10^{-18}$	120
Ti	100	6x0.4x56	$4.2x10^{-19}$	47
MoCu	110	100x100x200	$4.2x10^{-19}$	296

SuperCDMS

- Tc = 52 mK
- σ_{pt} ~ 50eVt



TES: Sensitivity Scaling Laws

$$\sigma^2_{<E>} \propto \sqrt{VT^3}$$

Theoretically: Sensitivity can be significantly improved

Engineering Challenges:

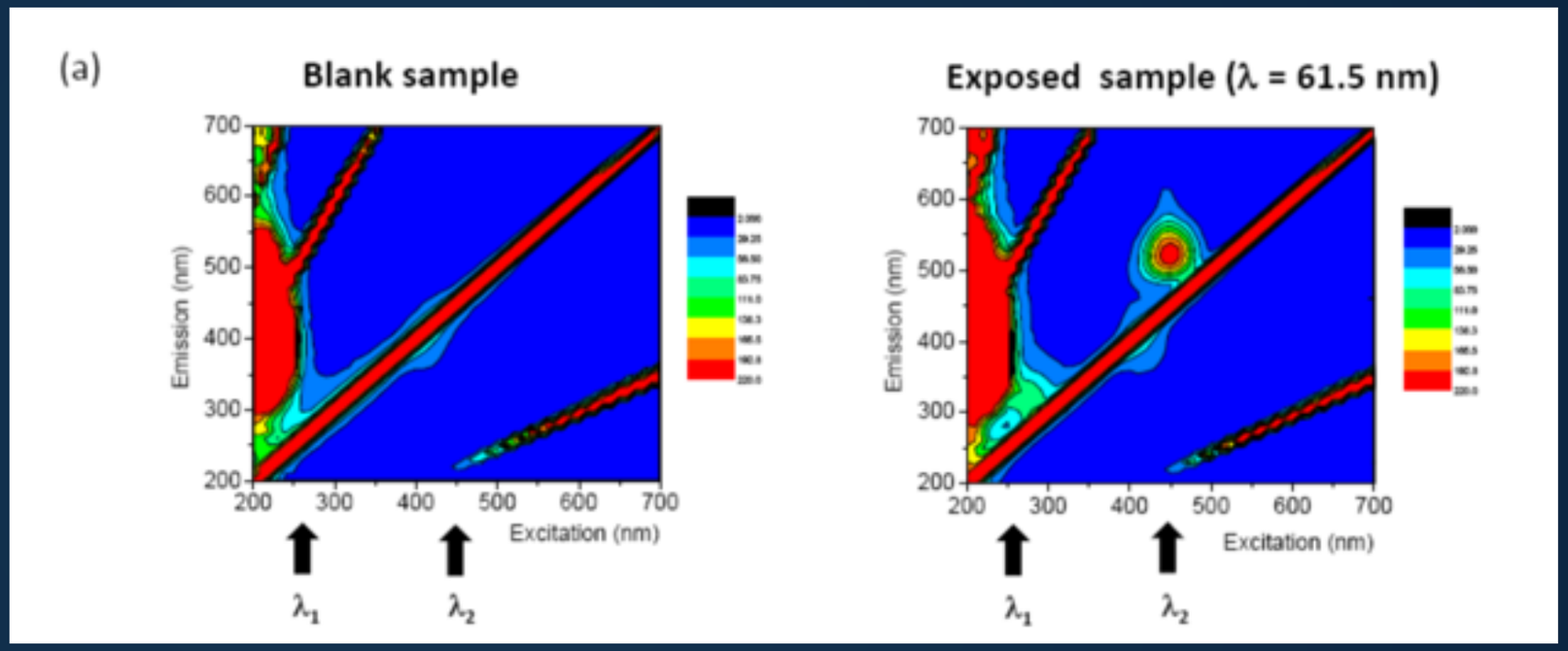
- Parasitic Power: Vibrations
- Parasitic Power: EMI
- Low T_c Superconducting Films

Most TES R&D over past decade orthogonal to greater baseline sensitivity

Similar scaling laws from MKIDs

Color Centers

Nuclear recoil ⟶ lattice dislocation



10's eV threshold ⟶ 30-100 MeV DM masses

Very new technology, active R&D at Weizmann

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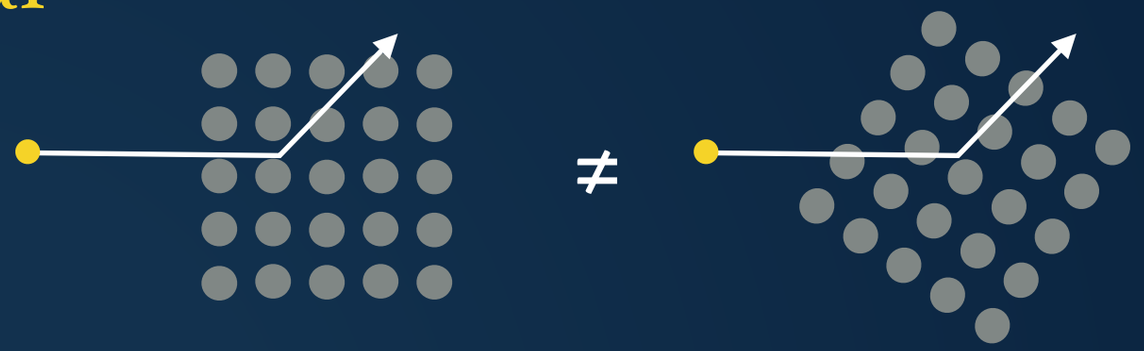
Directional Sensitivity

Semiconductors ARE directional

- Si/Ge too symmetric
  (<1% directional variation)
- Other crystals targets?



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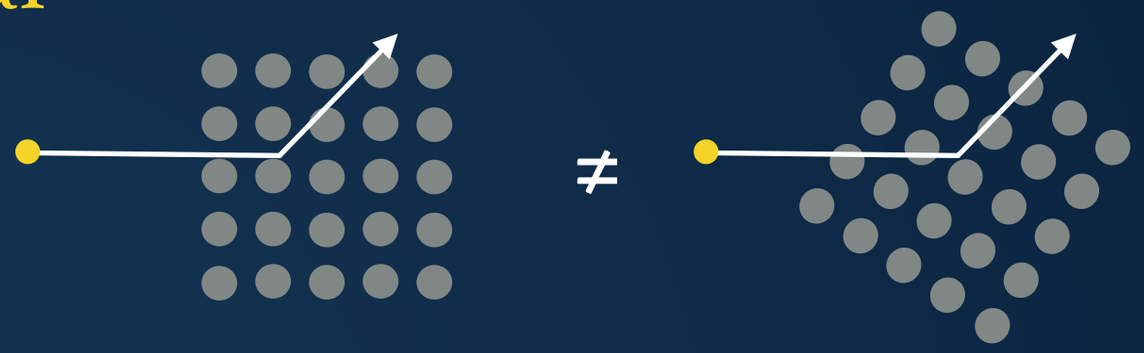

Graphene sheets

e^- ejection out of surface
Directional IF e^- direction is measured
Ptolemy exp. to search for CνB: ~0.5 kg graphene, detects ejected e-
Use for LDM search first?
Is it technologically feasible?

Directional Sensitivity

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Si/Ge

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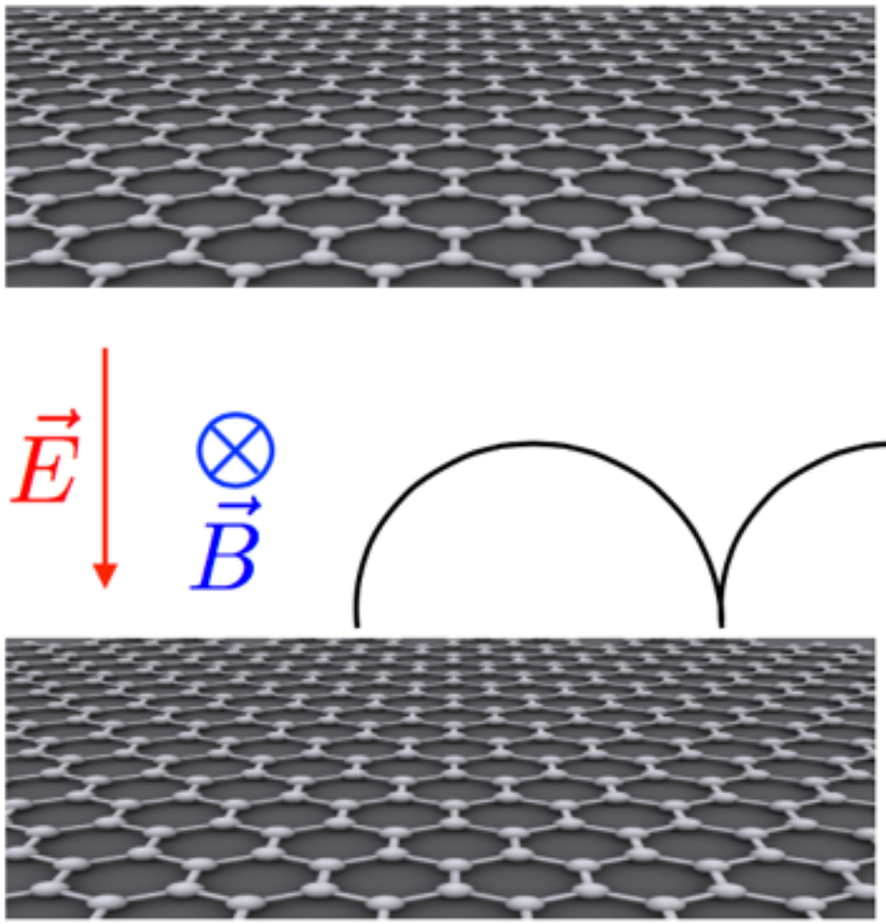

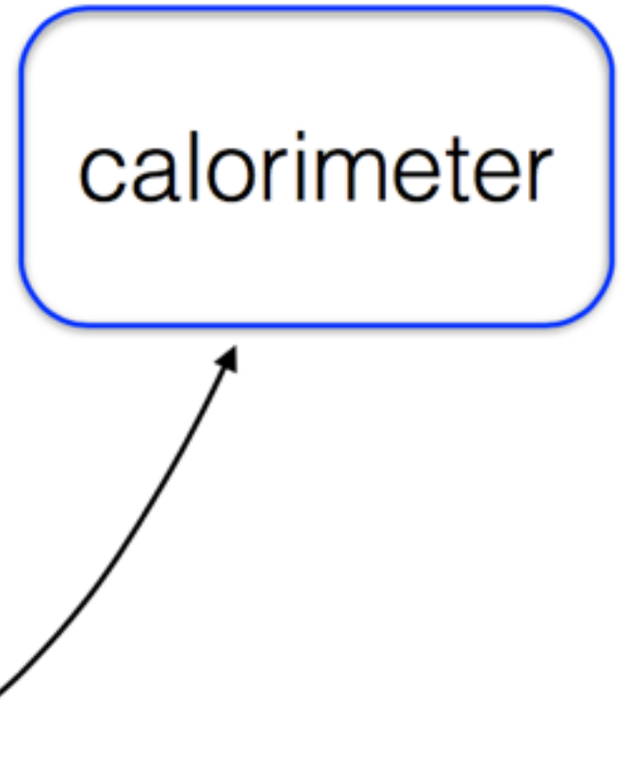

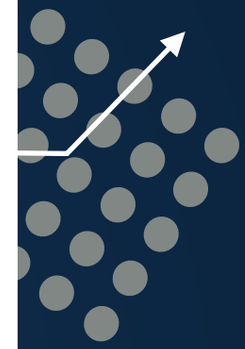

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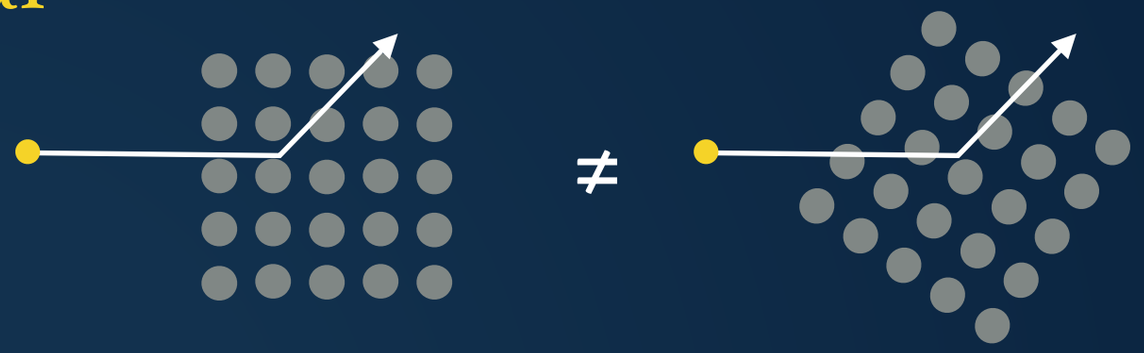
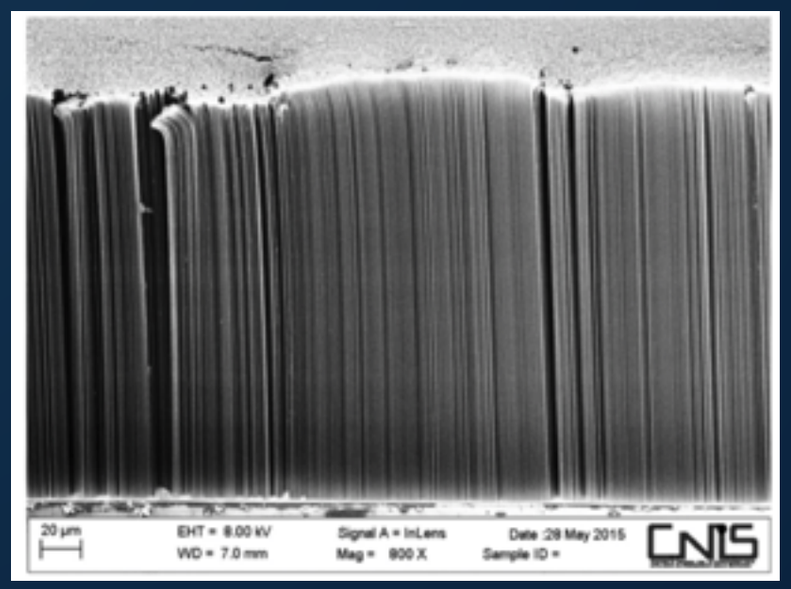


Graphene sheets

- e^- ejection out of surface
- naturally directional
- Ptolemy exp. to search for CνB: ~0.5 kg graphene, detects ejected e-
- Use for LDM search first?
- Is it technologically feasible?



Carbon nanotubes targets?

- Also naturally directional
- Produce in volume in coherent structure?

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OUTLOOK

Technology : several directions, very promising

Signal vs. Bkd discrimination: big challenge

Viable models below ~MeV?