Searching for Light Dark Matter with Narrow-gap Semiconductors: The SPLENDOR Experiment

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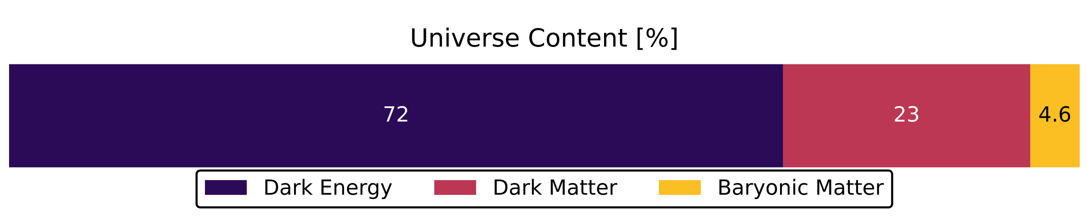
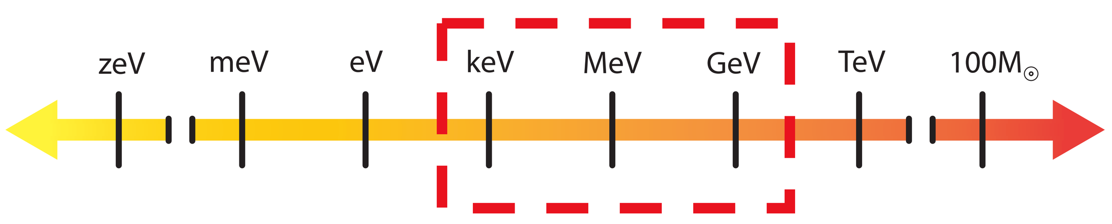
SPLENDOR

The SPLENDOR (**S**earch for **P**articles of **L**ight Dark Matt**er** with **N**arrow-gap Semicon**d**ucto**r**s) experiment is a search for light dark matter via the electron-recoil interaction channel, taking advantage of novel single-crystal narrow-bandgap (order 10-100 meV) semiconductors. Synthesized within the collaboration, the properties of these designer materials imply low dark counts when operated as ionization detectors at cryogenic temperatures. Using a readout scheme based on low-noise cryogenic high electron mobility transistors (HEMTs), the experiment is on track to achieve O(1) electron-hole pair resolution. This provides an excellent opportunity to probe new light dark matter parameter space: down to sub-MeV masses for fermionic dark matter and sub-eV masses for bosonic dark matter. This poster reviews the multidisciplinary R&D behind SPLENDOR, discusses the current status of the experiment, and presents projected sensitivities for a planned dark matter search.

Light Dark Matter

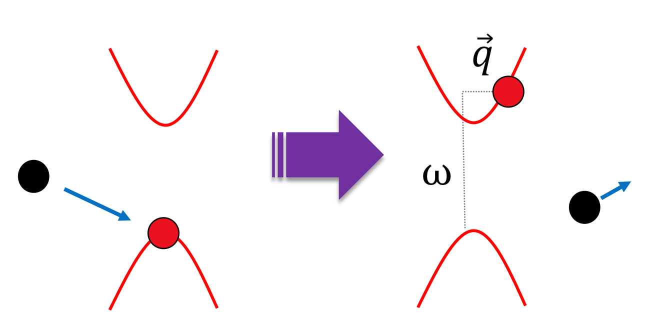




THE DARK SECTOR

- Kinematically-mixed dark photon
- Bosonic dark matter
- Asymmetric dark matter
- Freeze-in dark matter
- *Insert your favorite candidate here*

DM-ELECTRON SCATTERING



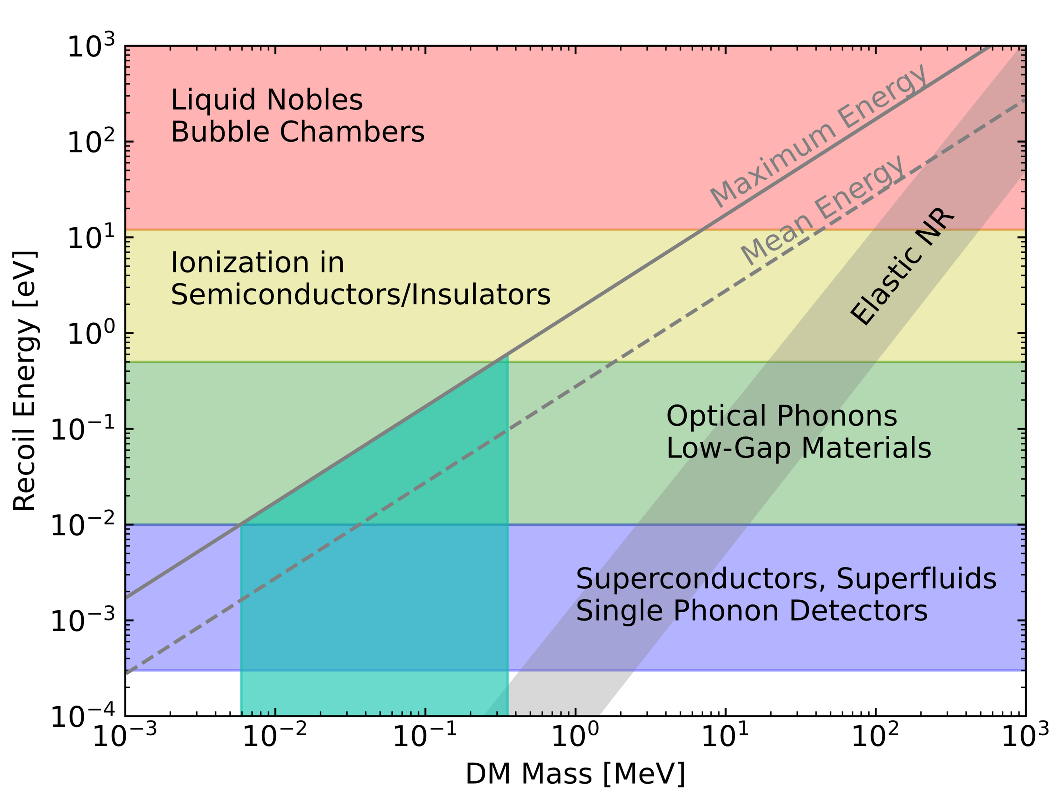
- Inelastic scattering process
- Can be formulated in terms of the experimentally measurable and theoretically calculable **Loss Function**

$$\Gamma(\mathbf{v}_\chi) = \int \frac{d^3\mathbf{q}}{(2\pi)^3} |V(\mathbf{q})|^2 \left[2\frac{q^2}{e^2} \mathrm{Im}\left(-\frac{1}{\varepsilon(\mathbf{q},\omega_\mathbf{q})}\right)\right]$$

$$\mathcal{W}(\mathbf{q},\omega) \equiv \mathrm{Im}\left(-\frac{1}{\varepsilon(\mathbf{q},\omega)}\right)$$

Y Hochberg *et al*, *Phys. Rev. Lett.* ***127***, 151802 (2021).

WHY NARROW BANDGAPS?



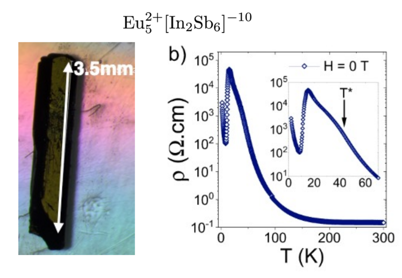
Recoil energy scales and detection technology. Adapted from arXiv:2203.08297

- Light dark matter searches via DM-electron scattering are fundamentally limited by bandgap
- With novel materials with small (order 10-100 meV) bandgaps, we can search for sub-MeV fermionic dark matter and sub-eV bosonic dark matter

Materials Approach

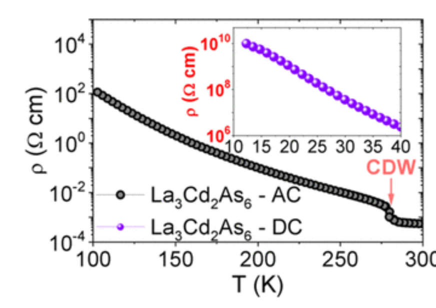
IN-HOUSE MATERIALS DISCOVERY

Electron count/Zintl phases



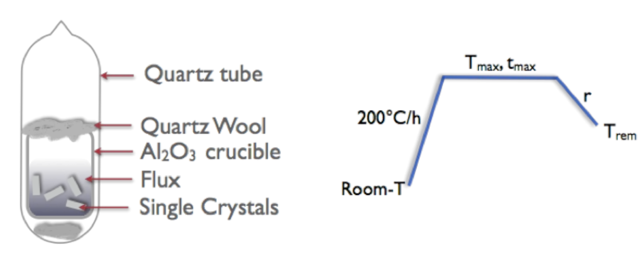
PFS Rosa *et al*, *npj Quantum Materials* **5**, 52 (2020).

Charge density wave

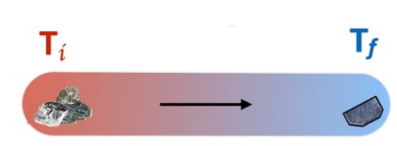


MM Piva *et al*, *Chem. Mater.* ***33***, 11, 4122 (2021).

IN-HOUSE MATERIALS GROWTH

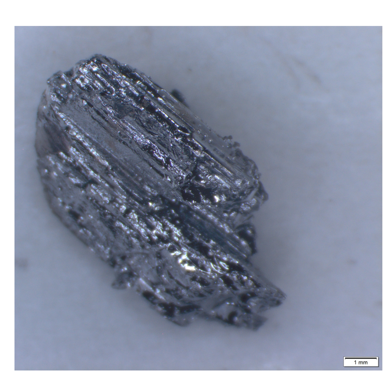


Flux Growth

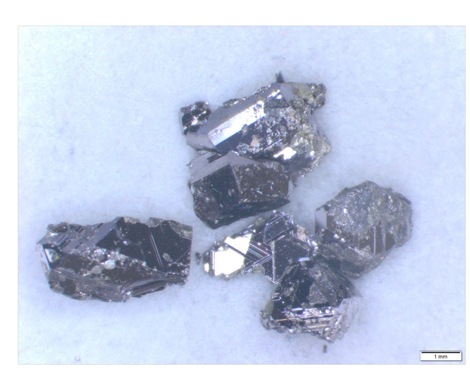


Chemical Vapor Transport

SOME CANDIDATE MATERIALS

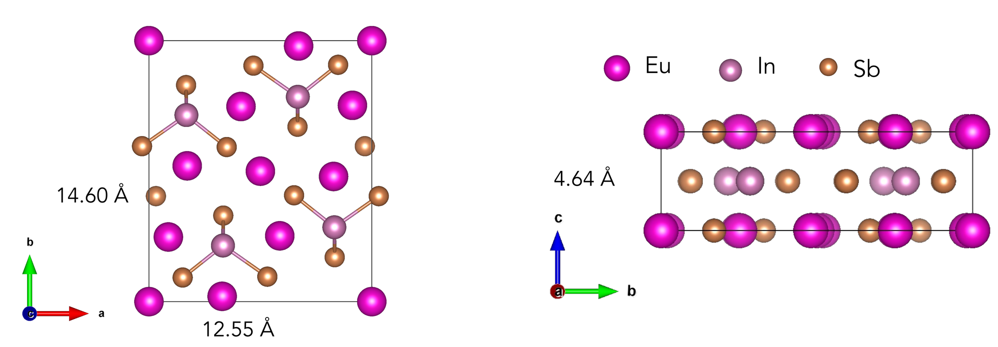


$Eu_5In_2Sb_6$



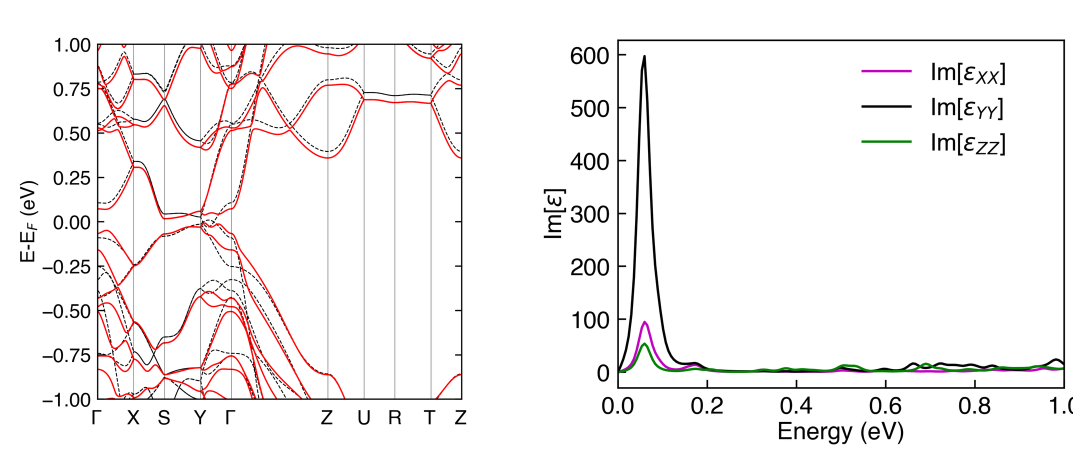
$EuZn_2P_2$

$Eu_5In_2Sb_6$: A Case Study

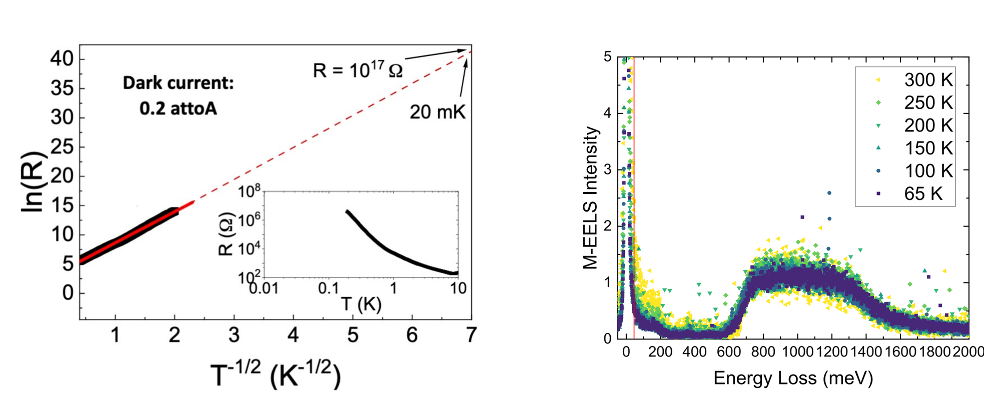


MATERIALS THEORY

- Use many-body perturbation theory to calculate loss function from **first principles**



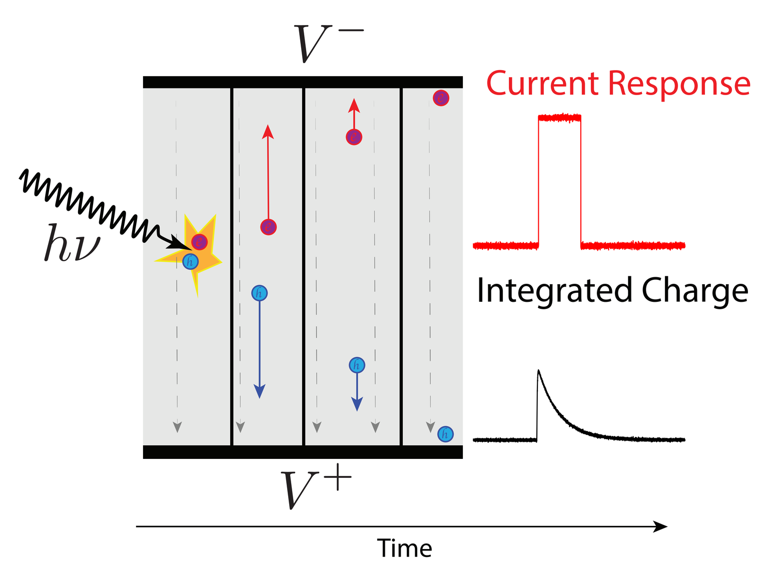
MATERIALS EXPERIMENT



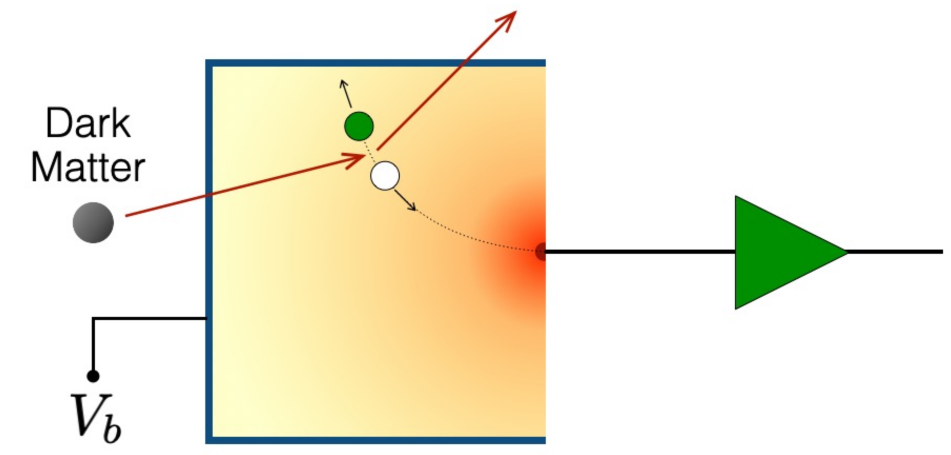
- Resistivity measurements indicate gaps of order 100 meV and very low dark counts
- EELS measurements allow direct measurement of loss function via experiment, and for direct comparison to theory

Detection Scheme

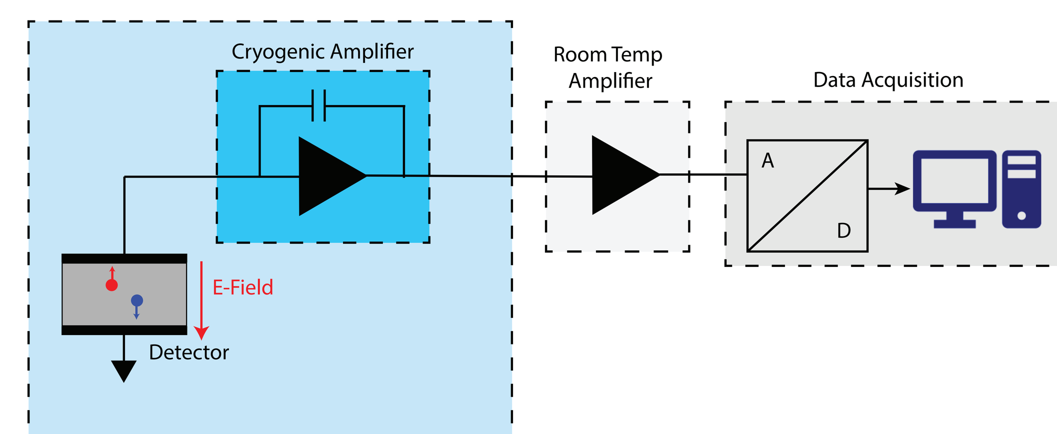
CHARGE AMPLIFICATION PRINCIPLES



- Use well-known point-contact style detector design



READOUT CHAIN

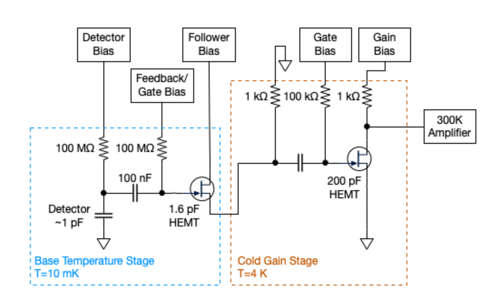


$$\sigma_E \sim E_{gap} \times \sigma_V \times (C_{detector} + C_{input} + C_{parasitic})$$

charge resolution
(goal: $\sigma_{e^-} \sim O(1)\, e^-$)

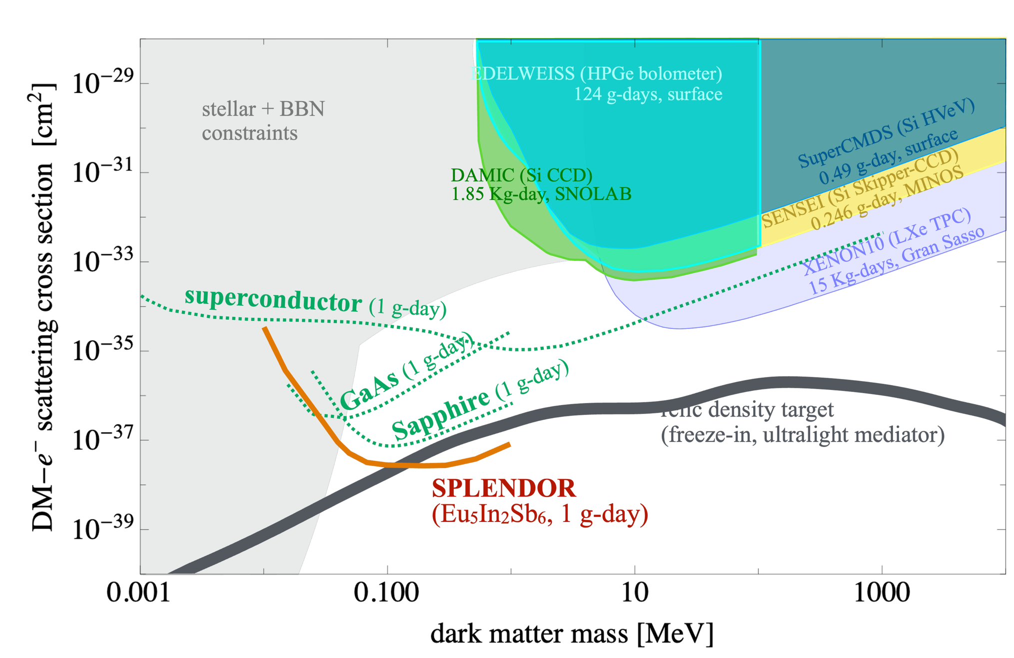
Main Design Challenge: Minimization of parasitic capacitance

Solution: Two-stage HEMT design

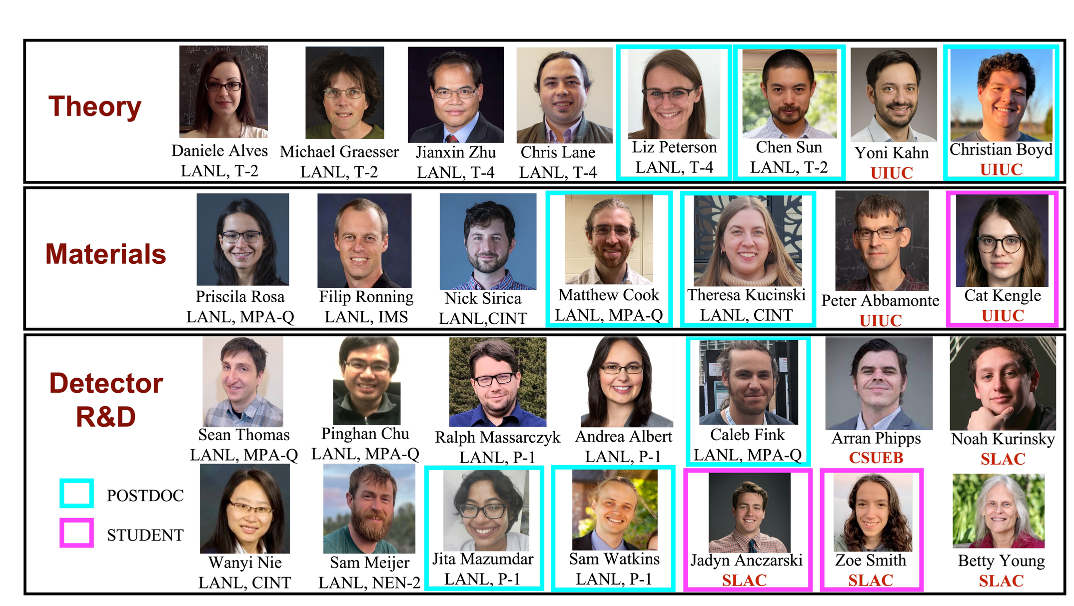


Estimated Sensitivity

Assuming a light mediator, with a preliminary dielectric function, SPLENDOR's 90% C.L. sensitivity with no background



THE SPLENDID TEAM



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