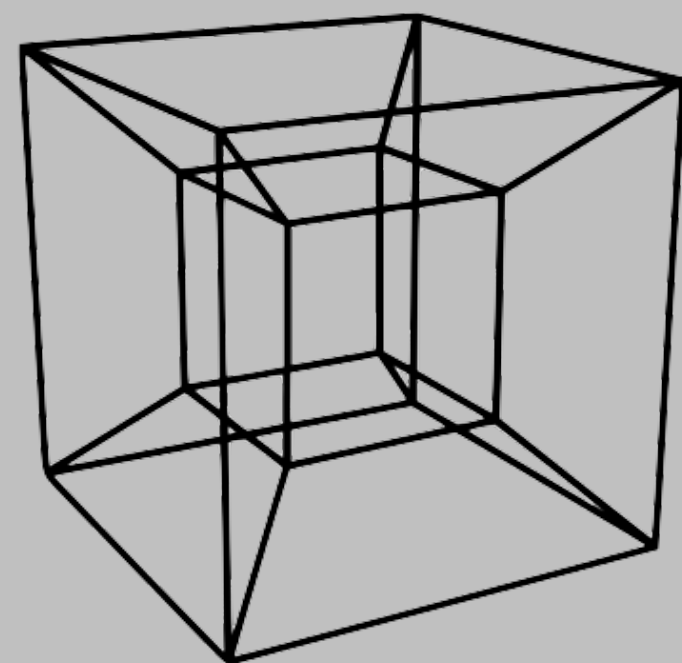


TESSERACT: status and progress towards sub-GeV dark matter detection

Valentina Novati

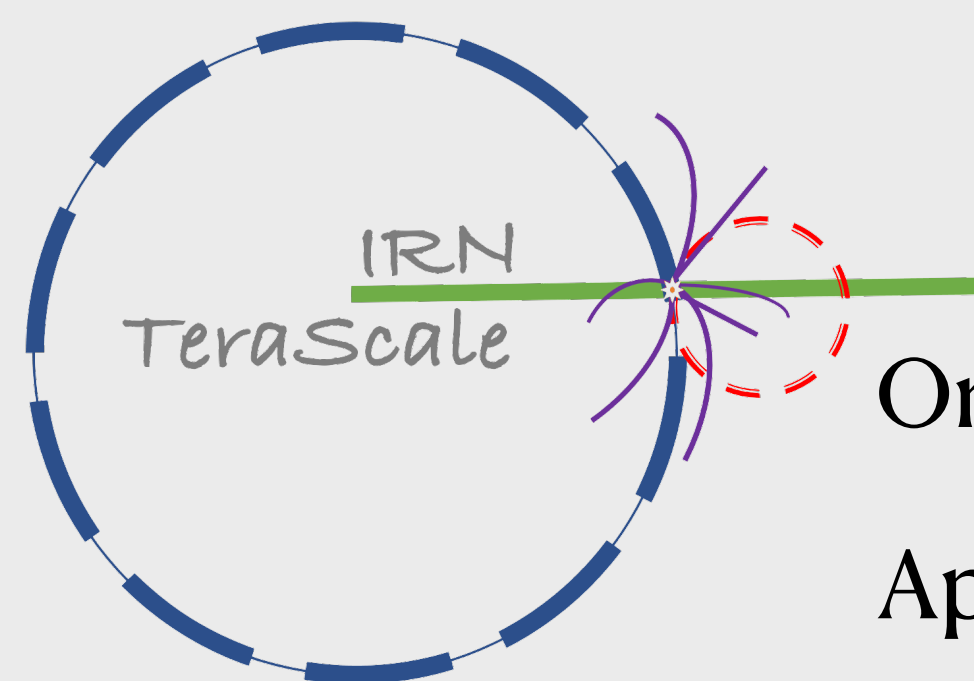
On behalf of the TESSERACT collaboration



TESSERACT

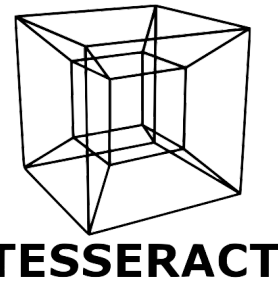


GRENOBLE | MODANE



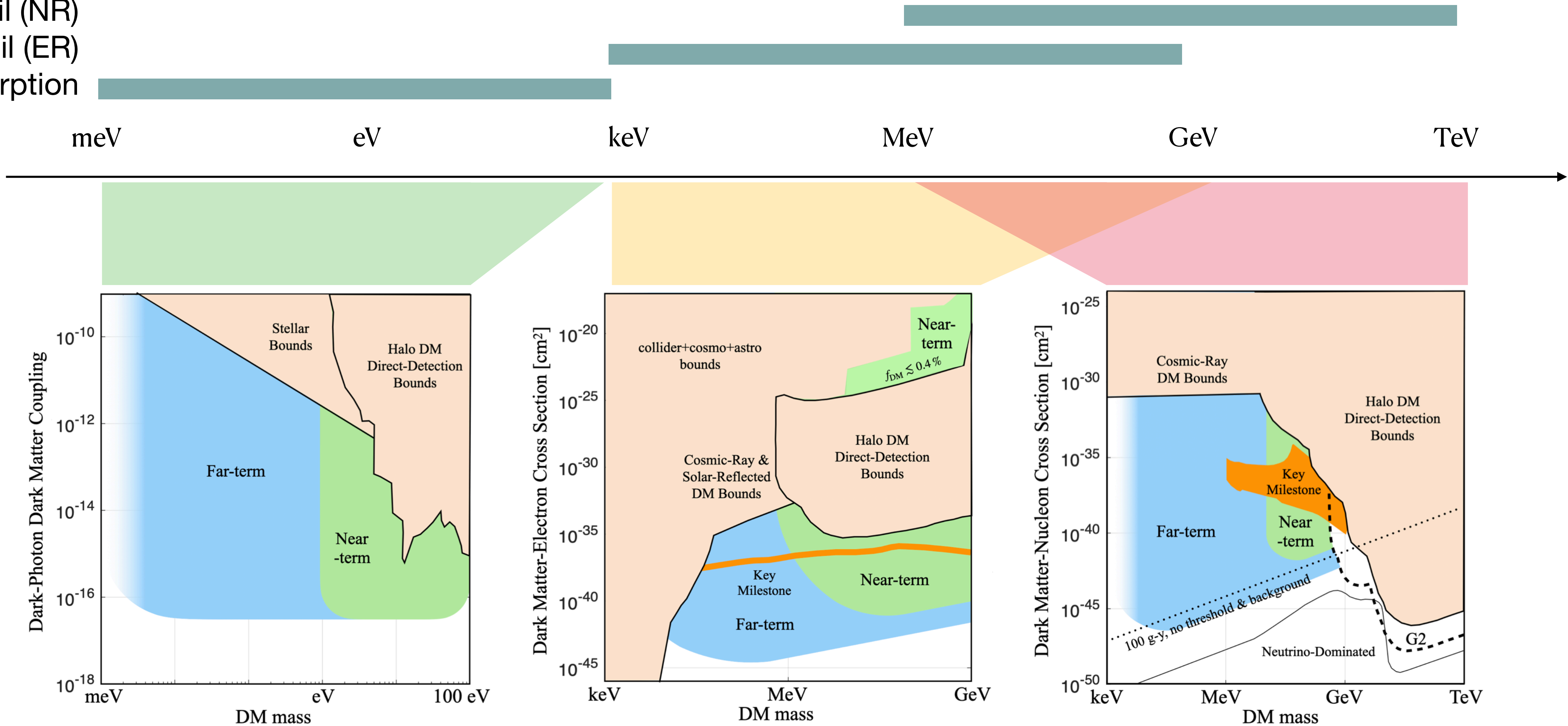
Orsay

April 22nd, 2026



Looking for a wide range of dark matter masses

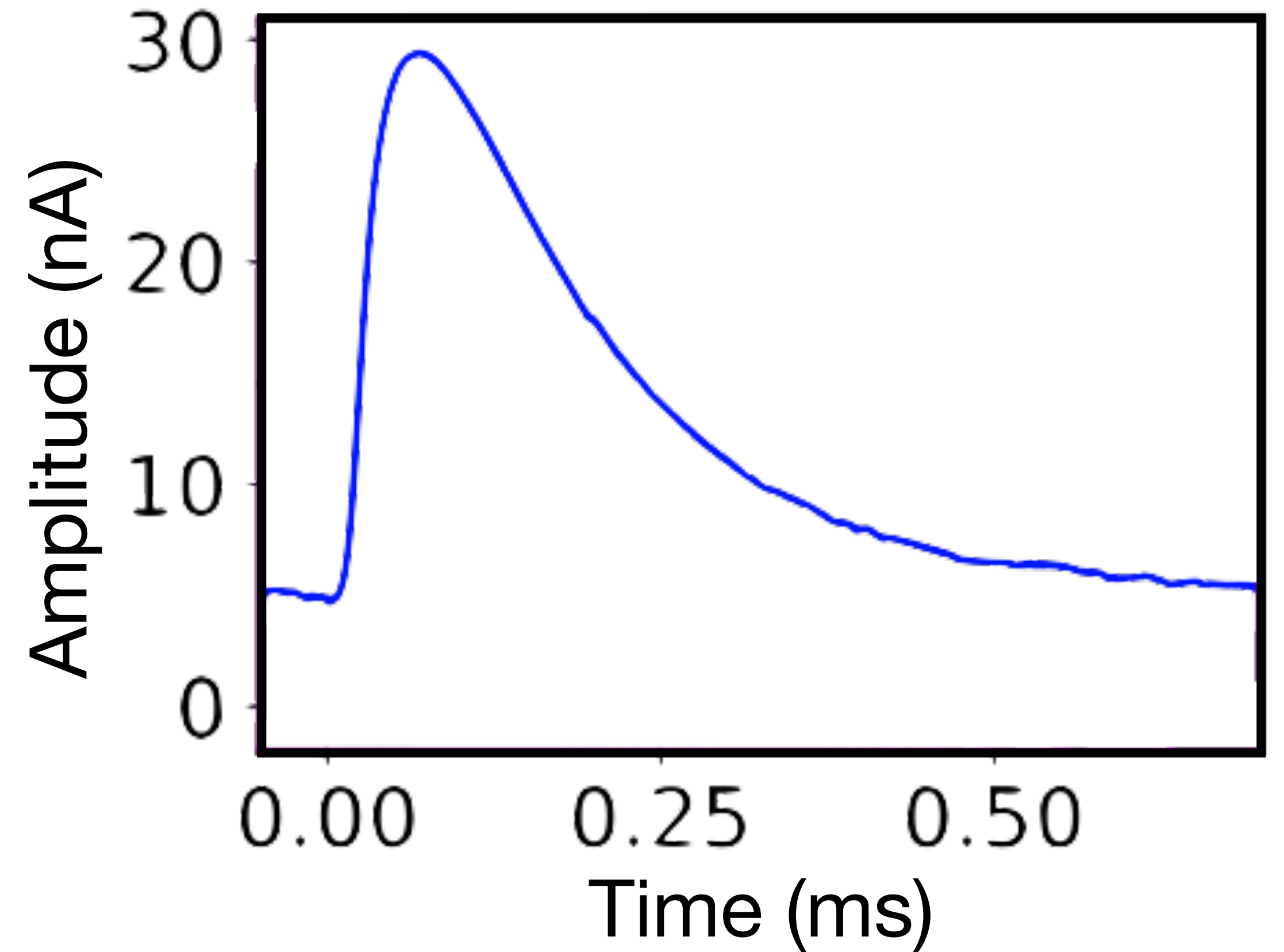
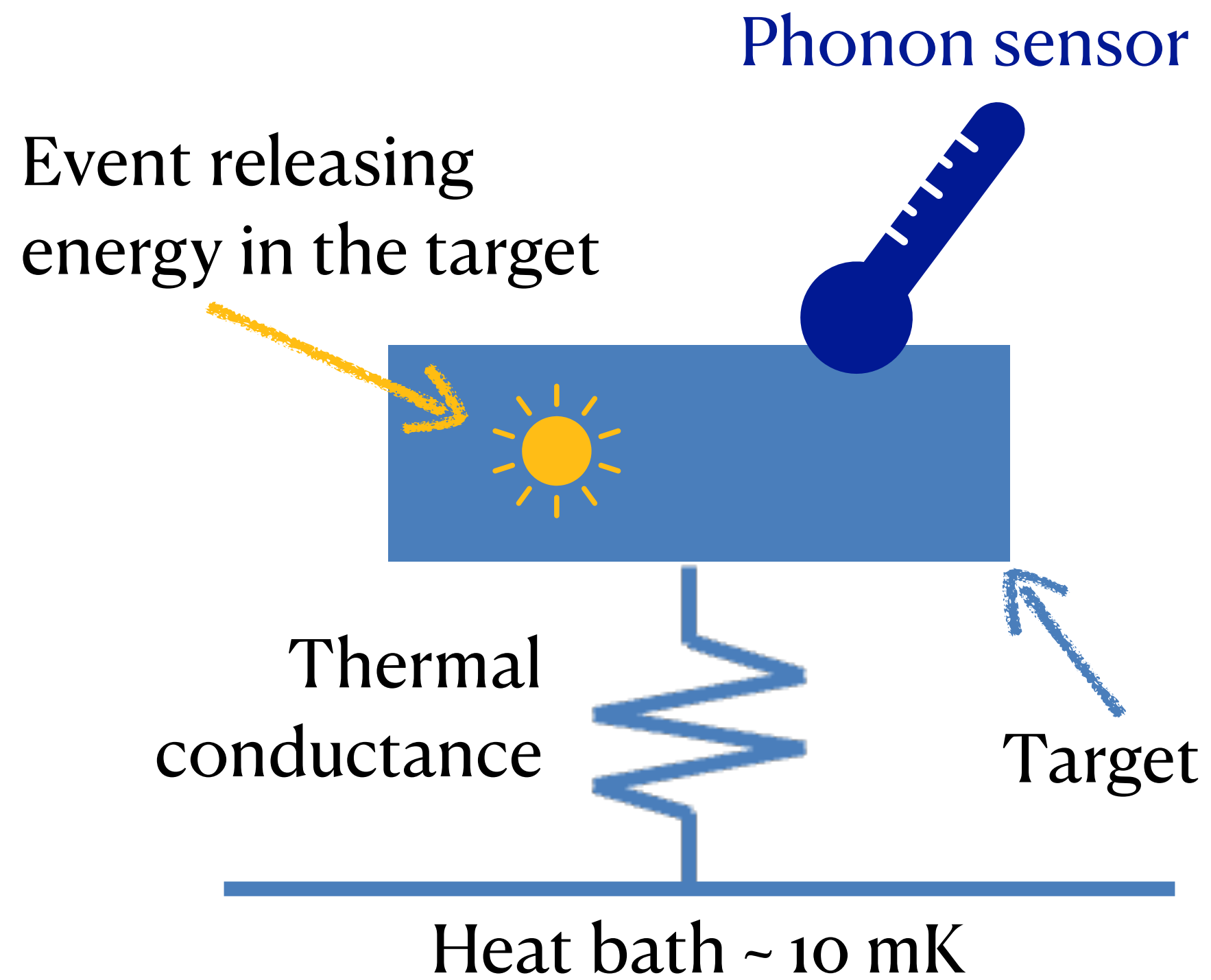
Nuclear recoil (NR)
Electron recoil (ER)
Absorption

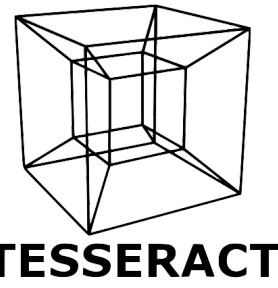


TESSERACT aims at extending the direct dark matter mass range from meV-to-GeV using phonon mediated cryogenic detectors

R. Essig et al., ArXiv: 2203.08297

Cryogenic calorimeters

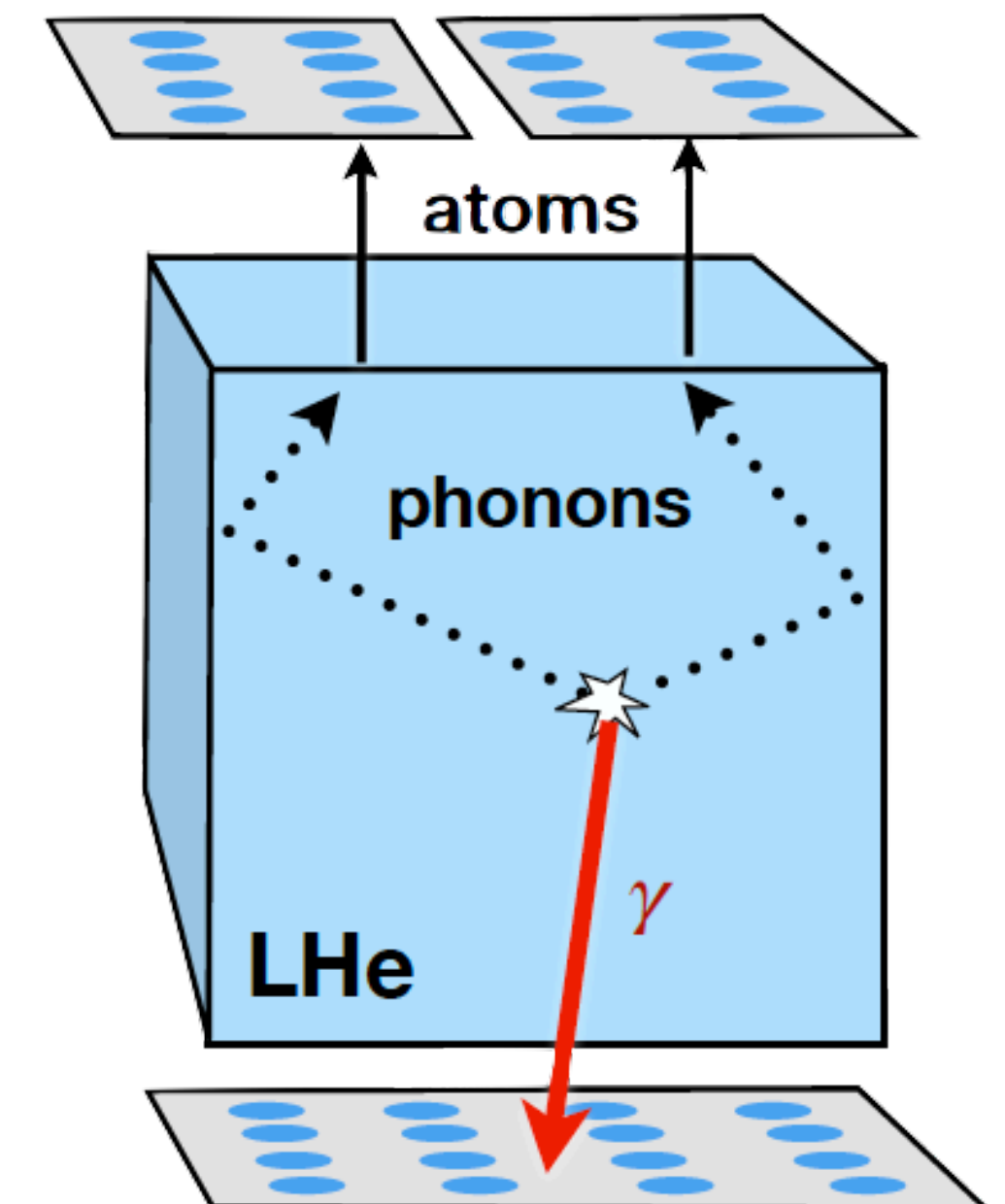
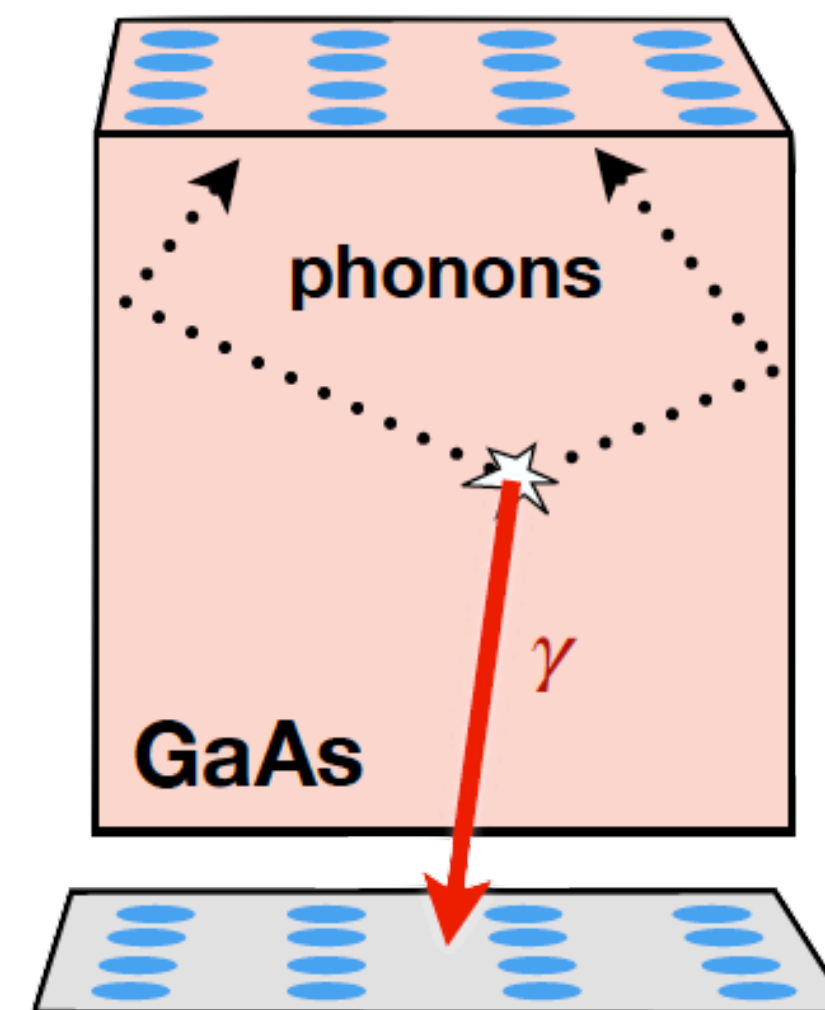
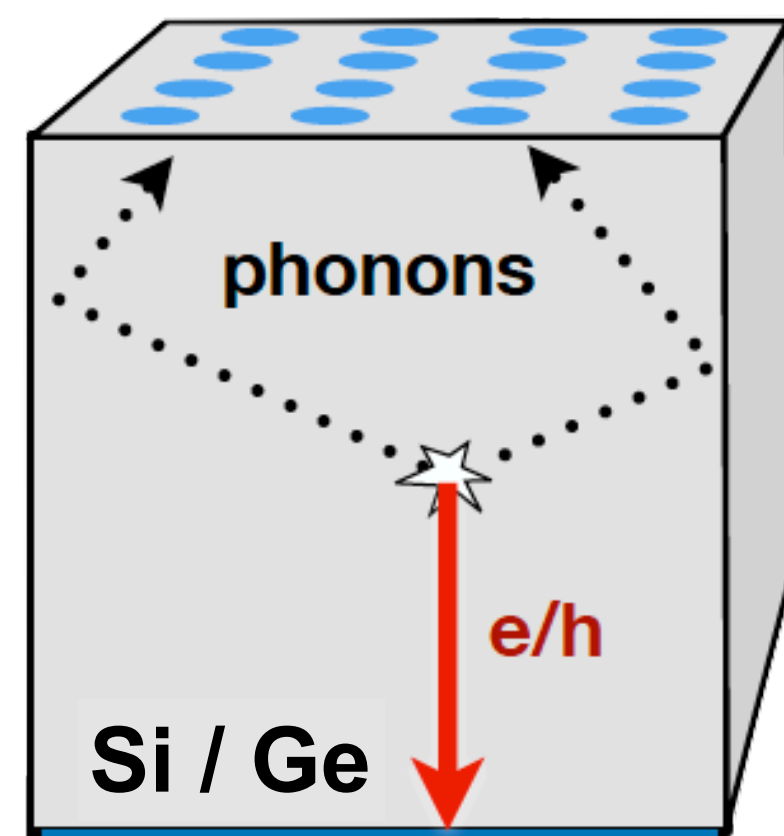
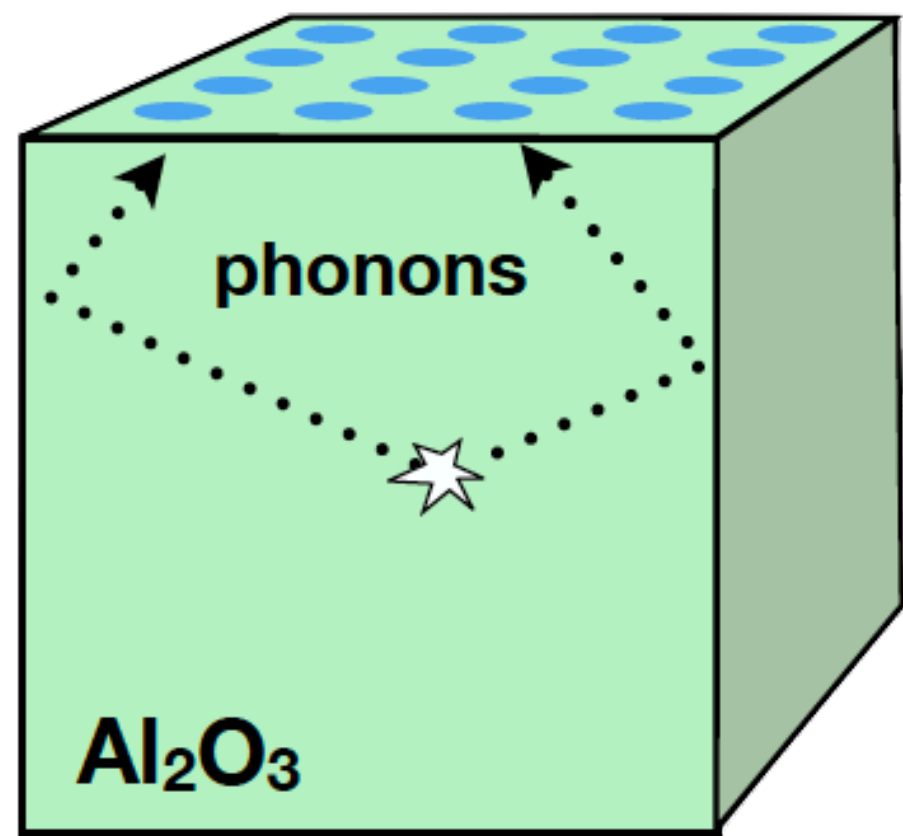


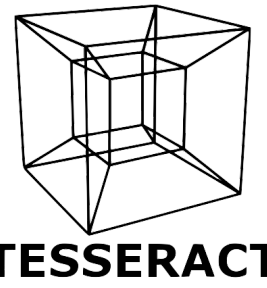


Target material

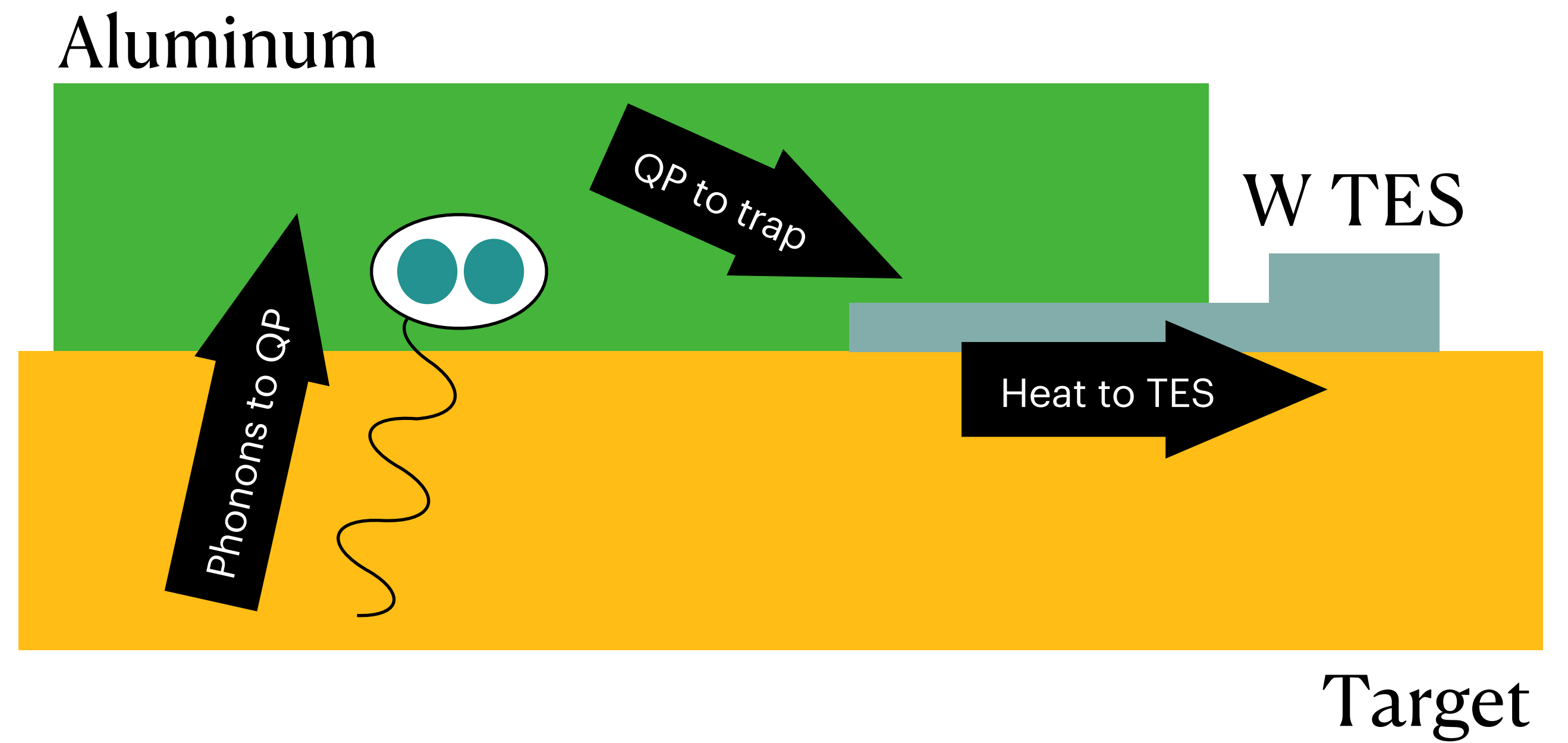
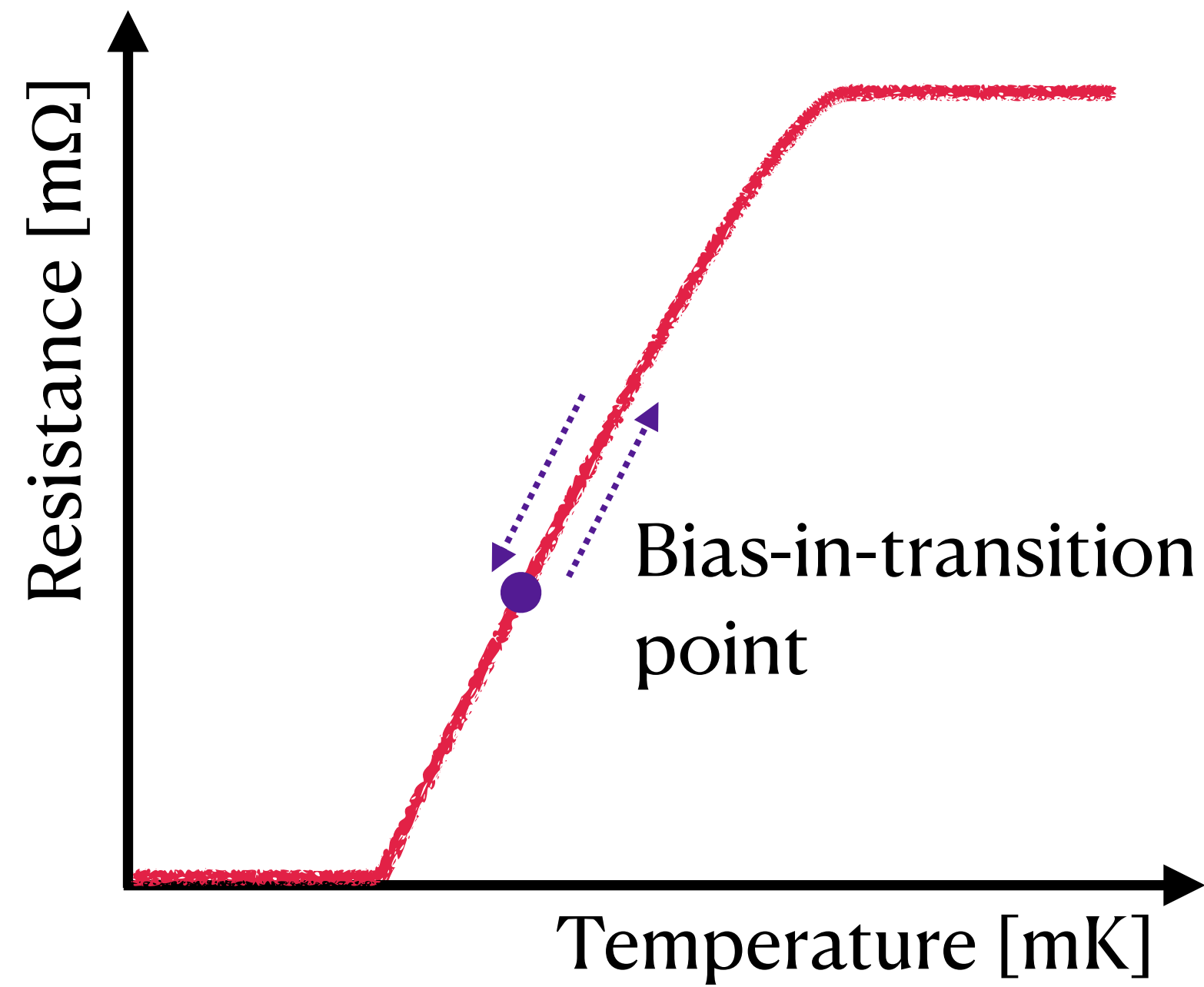
Five distinct target materials to maximize sensitivity to complementary dark matter couplings:

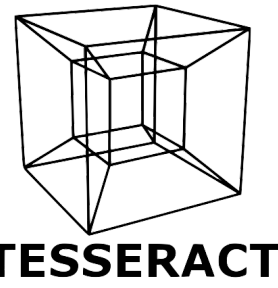
- Polar crystals: sapphire (Al_2O_3) and gallium arsenide (GaAs)
- Superfluid helium (LHe)
- Semiconductor crystals: germanium (Ge) and silicon (Si)





Phonon sensor





Low energy event excess

Observation of a strong Low Energy Event Excess (LEEE) in **ALL** low-threshold cryogenic experiments limiting their DM sensitivity.

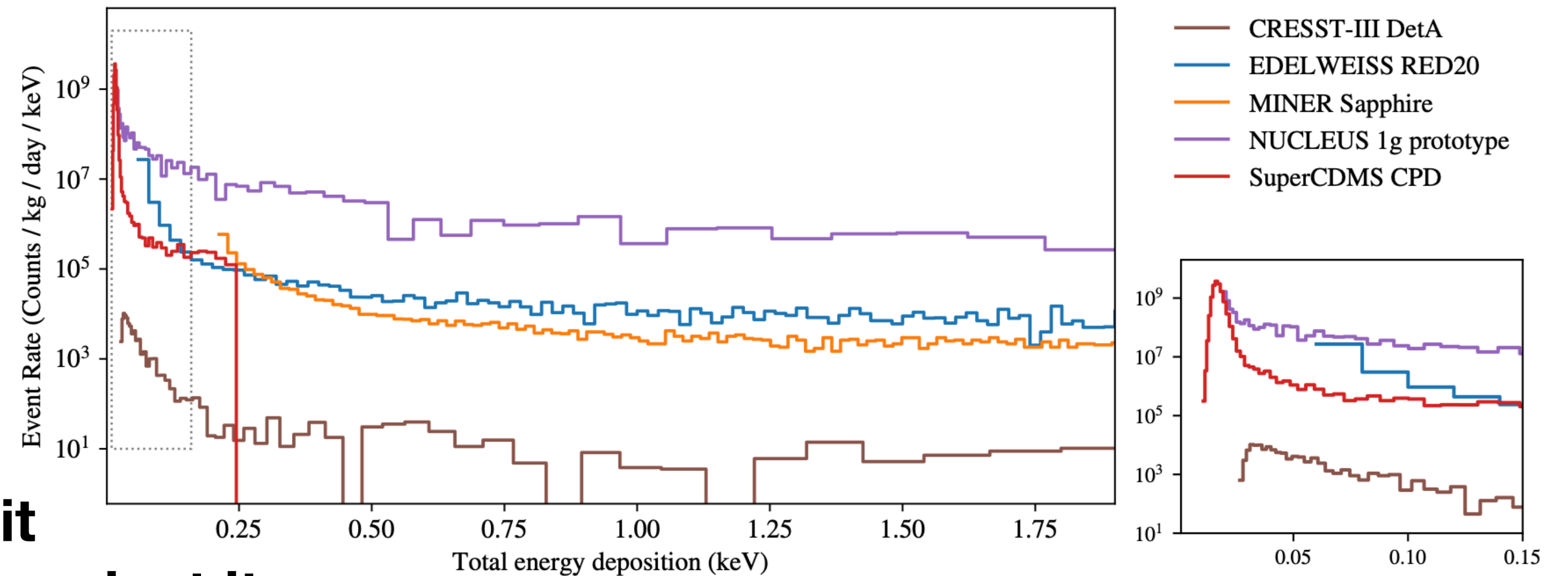
The LEEE is the dominating background at the lowest energies

LEEE characteristics:

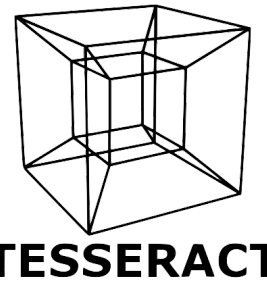
- time dependent,
- non-ionising,
- mostly independent of sites

Design driver of TESSERACT:

- **find the origin of the LEEE to mitigate it**
- **develop detector technologies that can reject it**



P. Adari et al., SciPost Phys. Proc. 9, 001 (2022)
D. Baxter et al., Annu. Rev. Nucl. Sci. 75:301–26, 2025

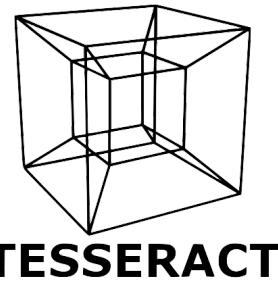


TESSERACT: low energy event excess

1. Discrimination of LEEE by multi-sensor detection

2. Discrimination of LEEE by coincident charge or photon

3. Discrimination of LEEE by coincident evaporation



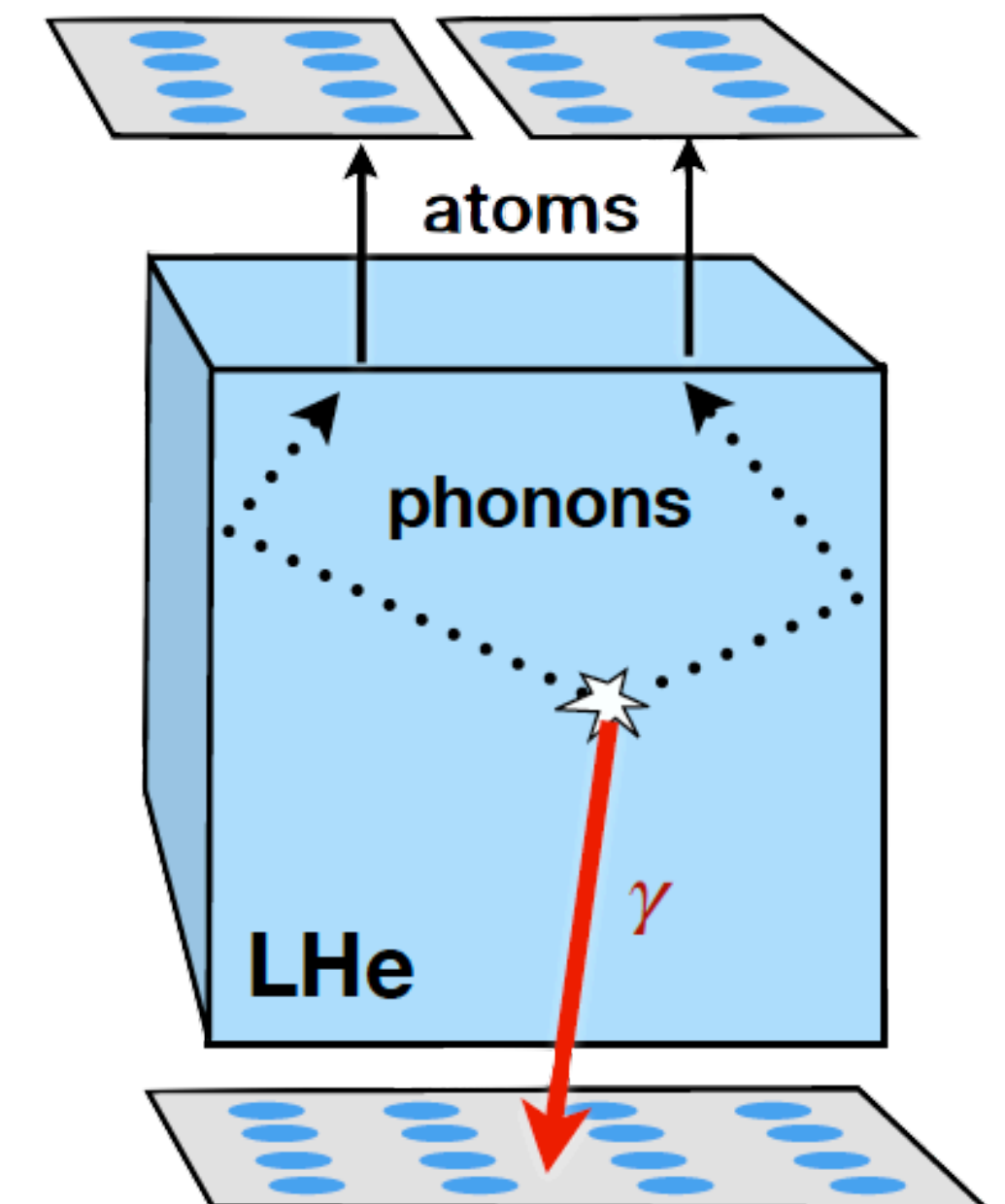
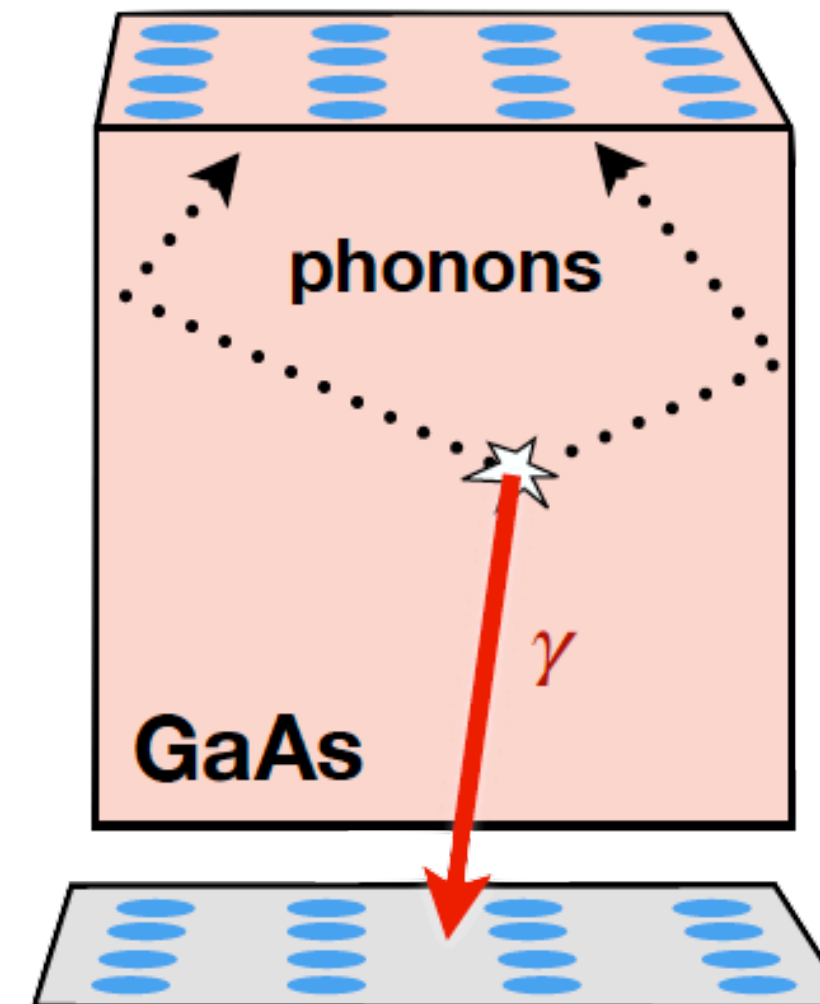
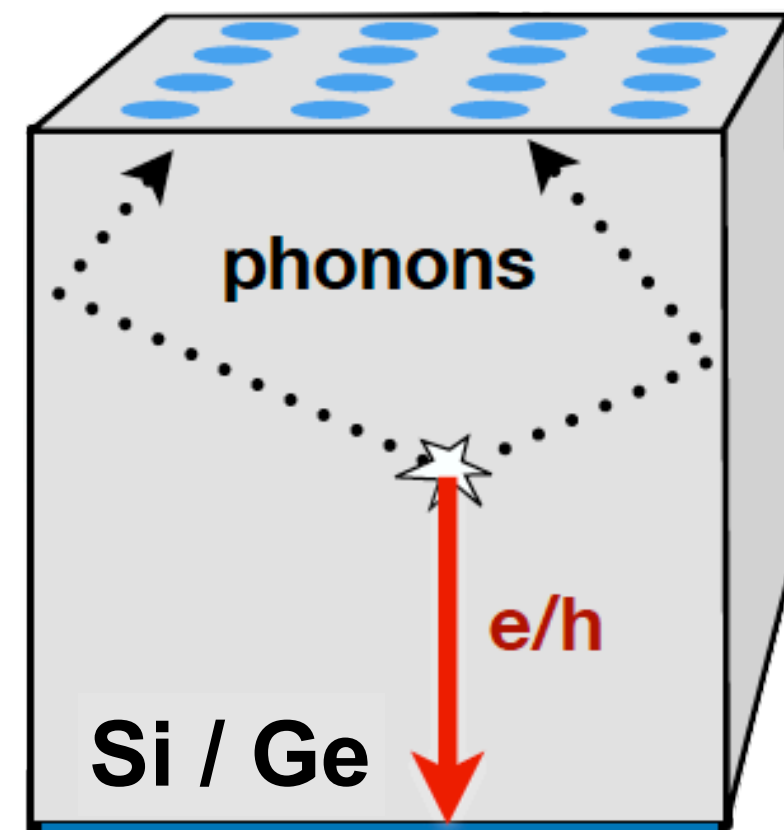
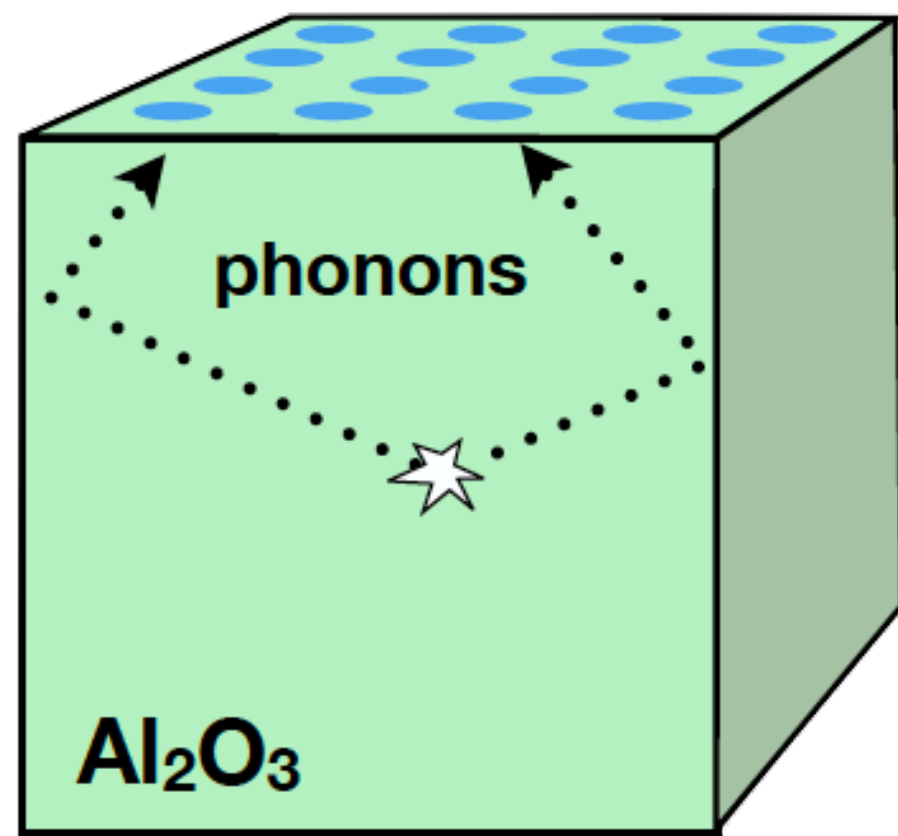
TESSERACT: low energy event excess

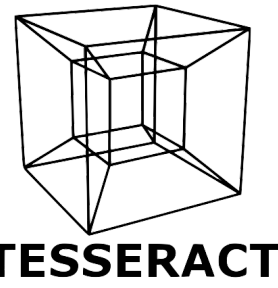
1. Discrimination of LEEE by multi-sensor detection

A dark matter signal in the target will be detected by different phonon sensors in coincidence.

2. Discrimination of LEEE by coincident charge or photon

3. Discrimination of LEEE by coincident evaporation

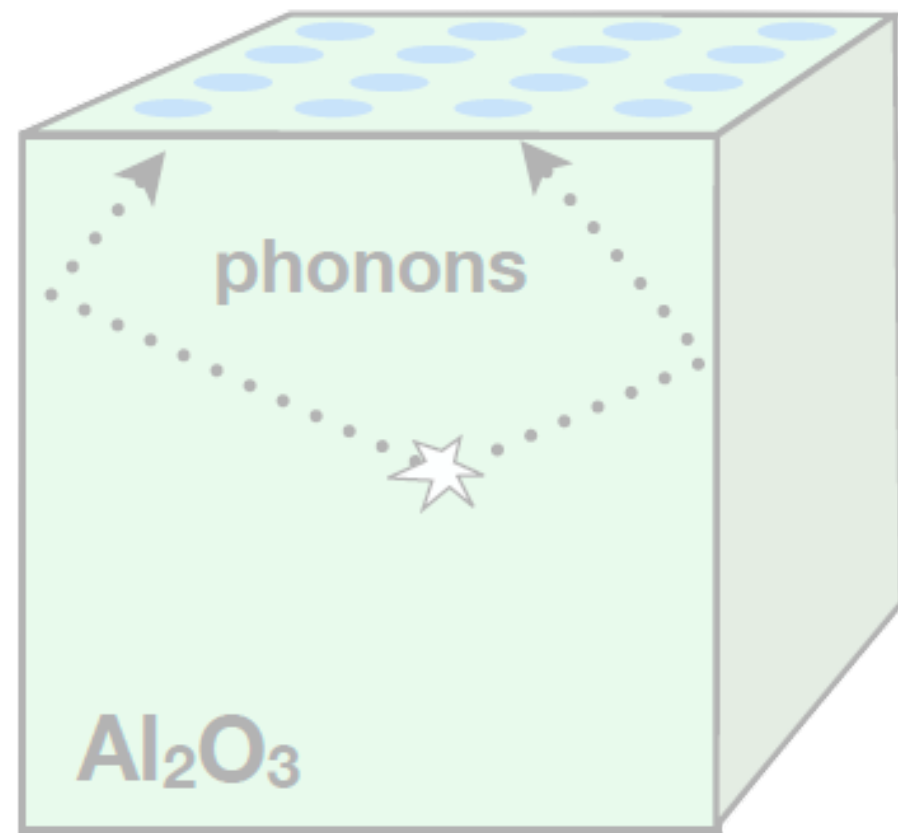




TESSERACT: low energy event excess

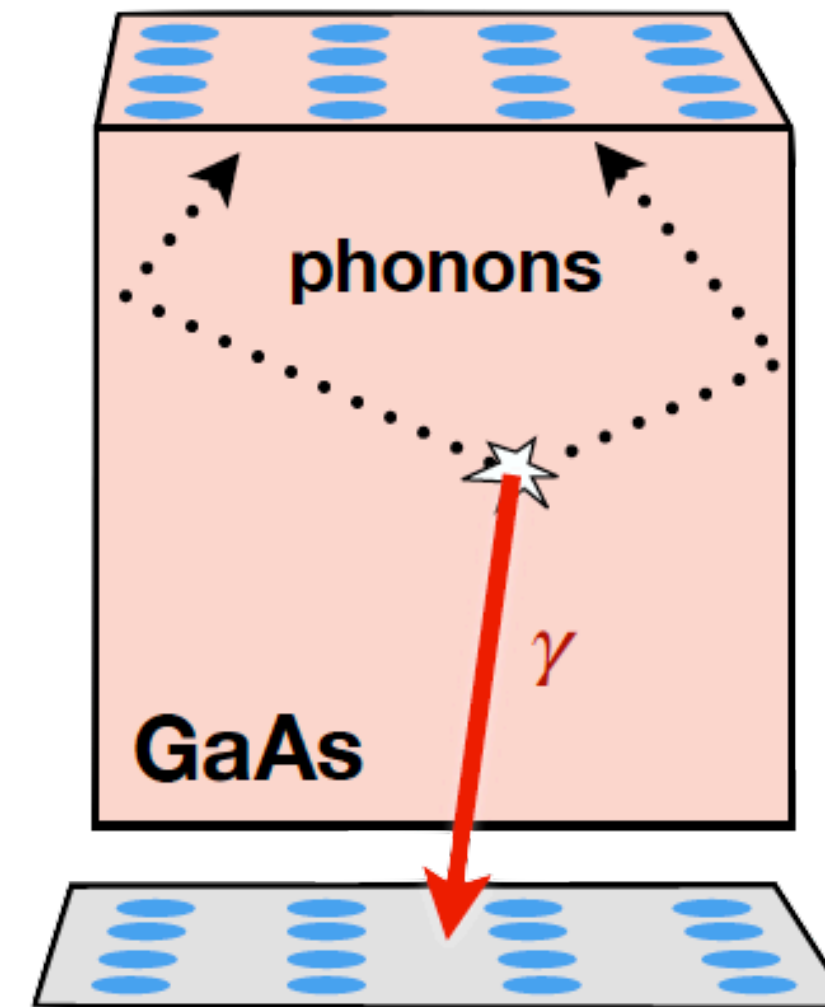
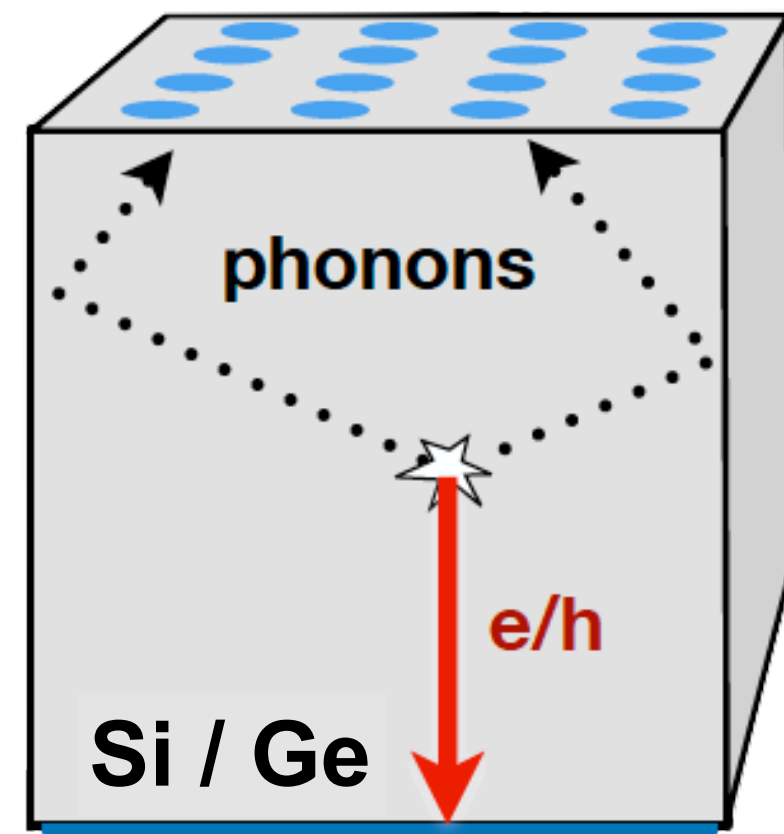
1. Discrimination of LEEE by multi-sensor detection

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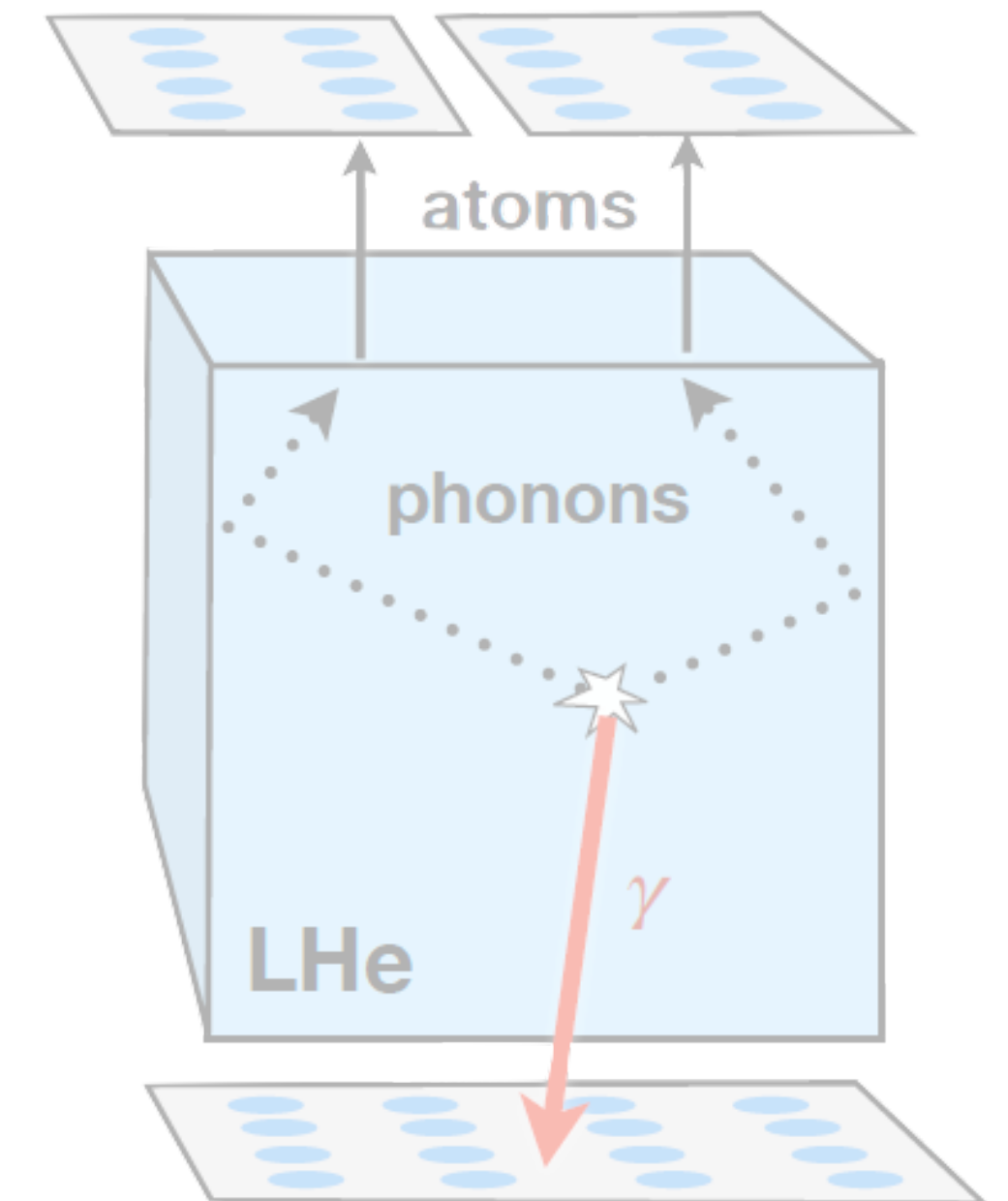


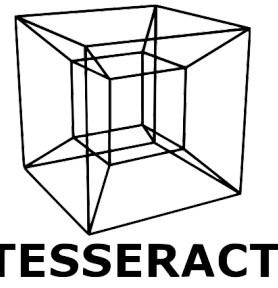
2. Discrimination of LEEE by coincident charge or photon

LEEE is “phonon-only”, entirely free of electronic excitation. DM signal can be tagged by its electronic excitation. (*semiconductor and scintillator efforts*)



3. Discrimination of LEEE by coincident evaporation

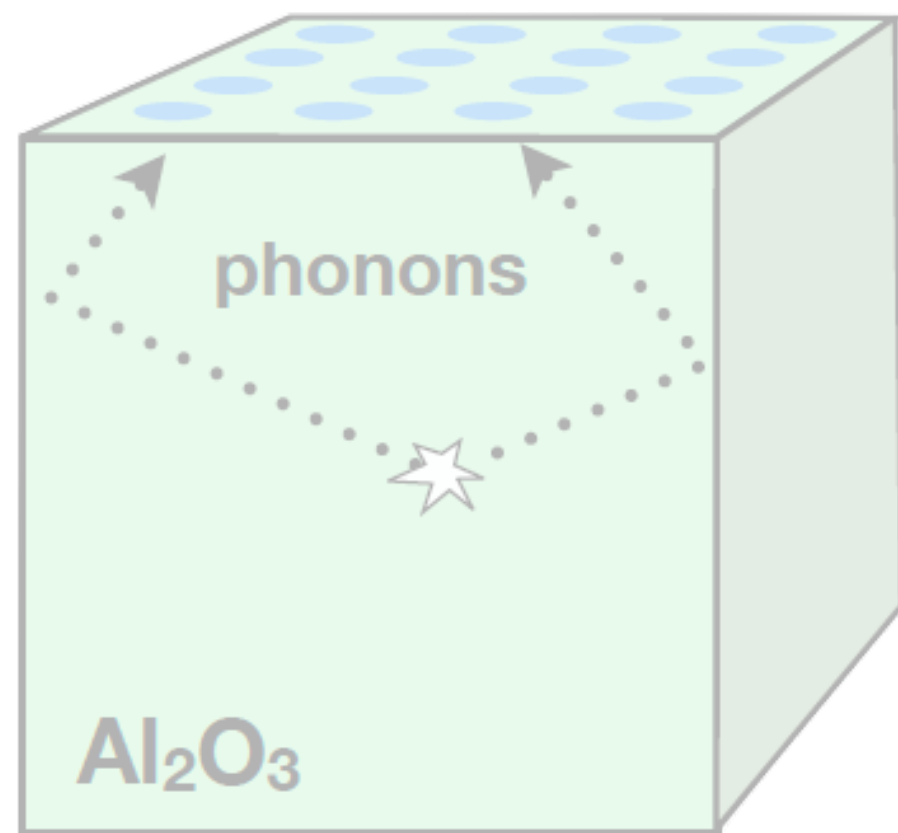




TESSERACT: low energy event excess

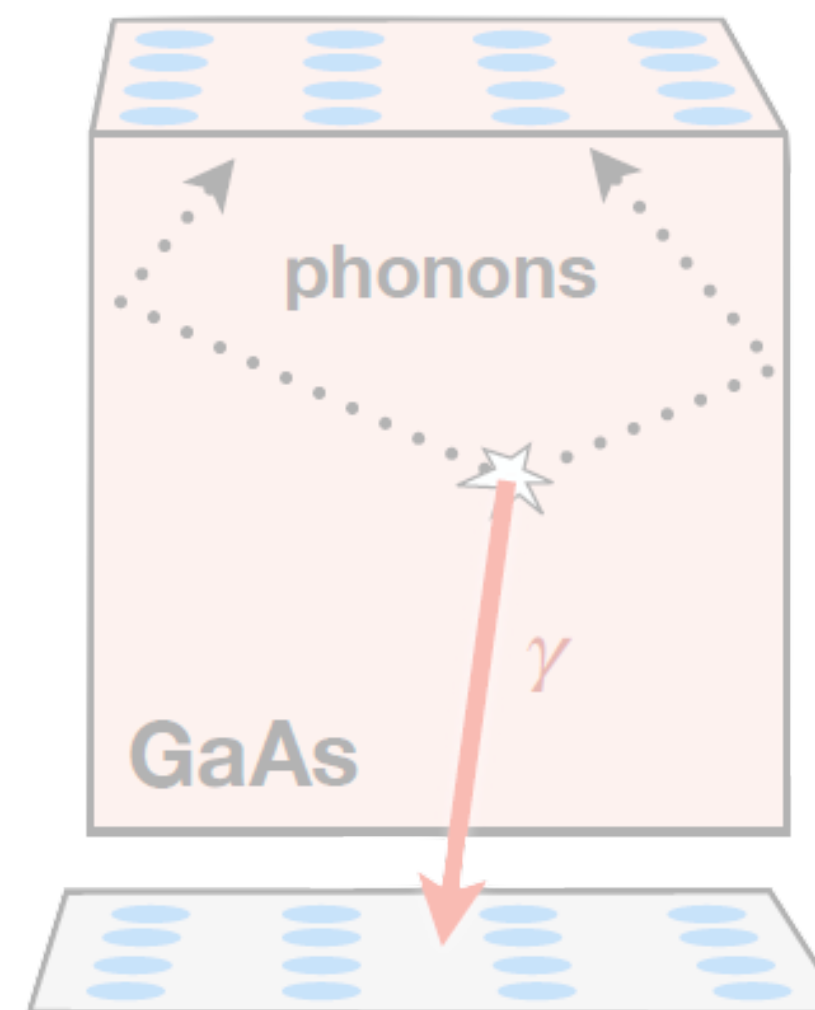
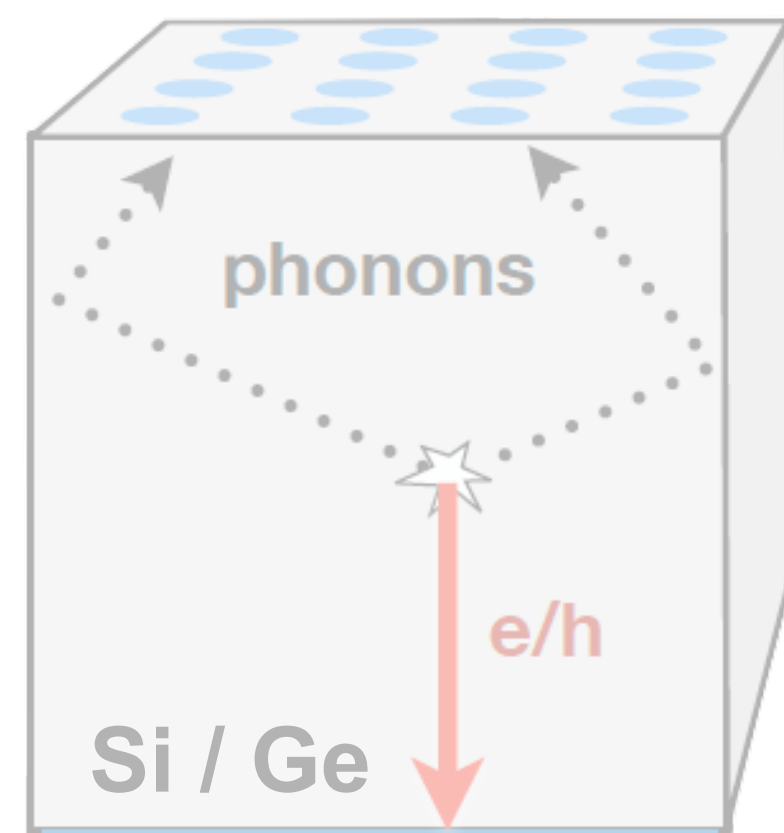
1. Discrimination of LEEE by multi-sensor detection

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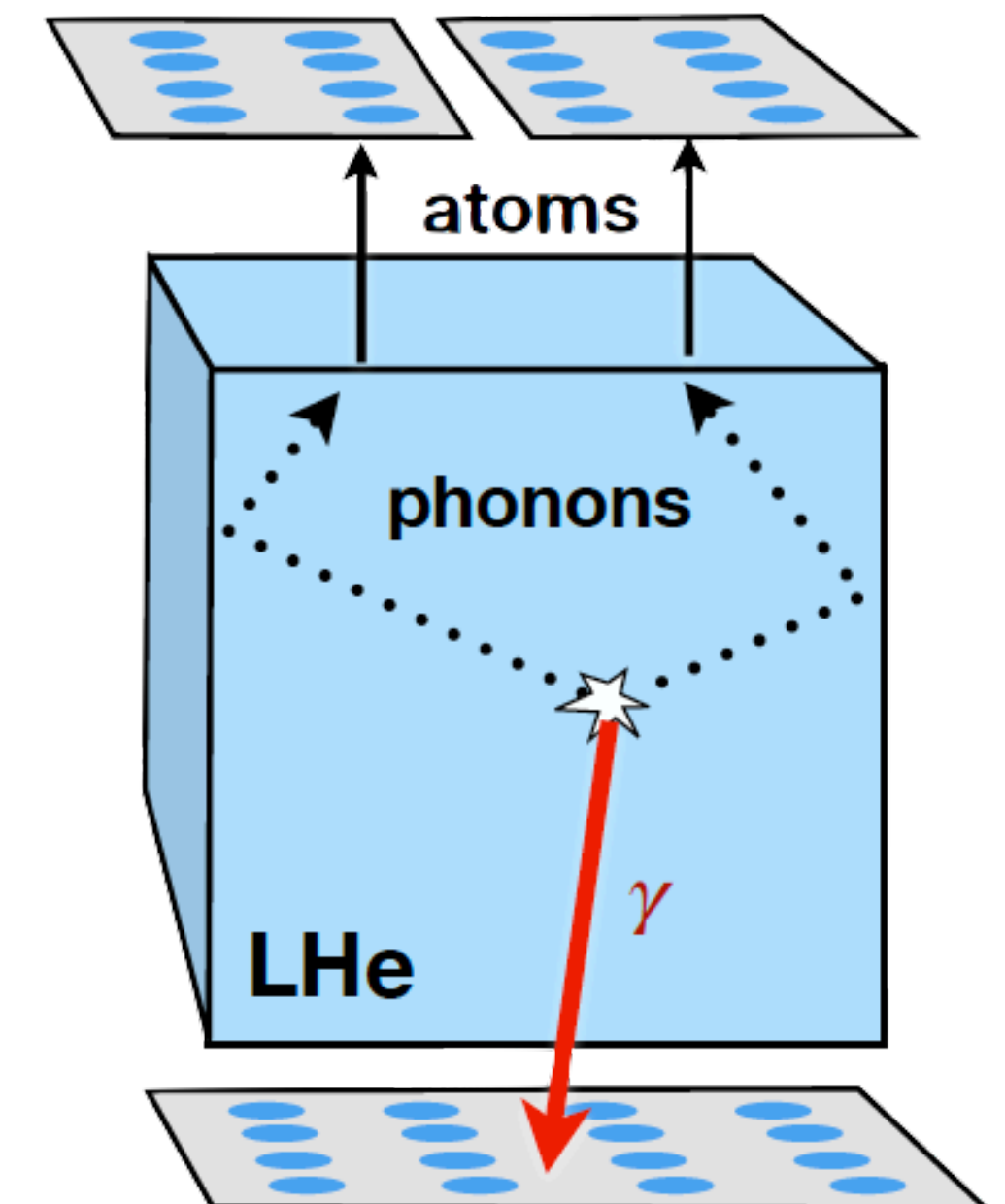
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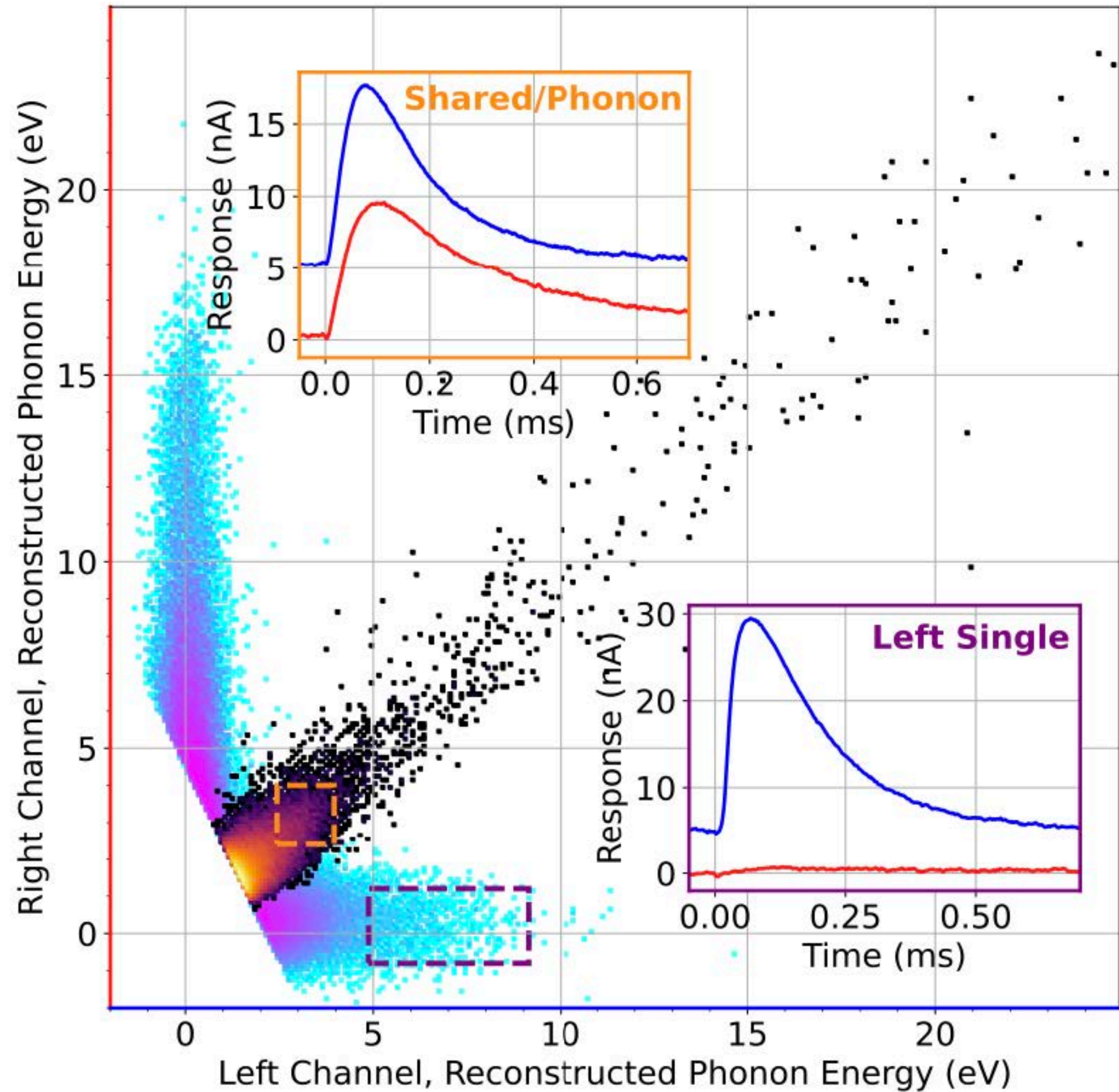


3. Discrimination of LEEE by coincident evaporation

Superfluid target: free of LEEE. Evaporation signals are multi-channel; LEEE is single-channel.



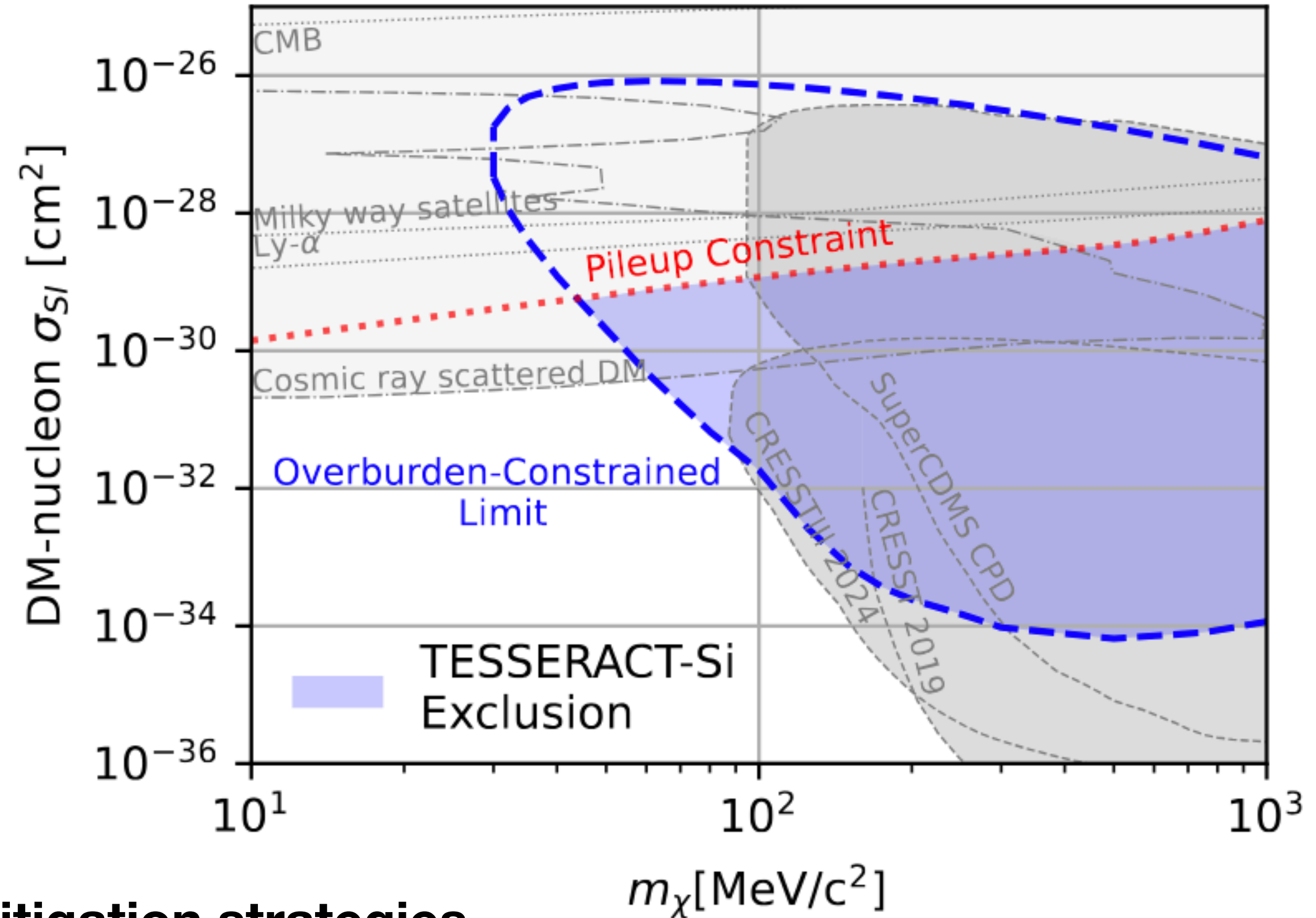
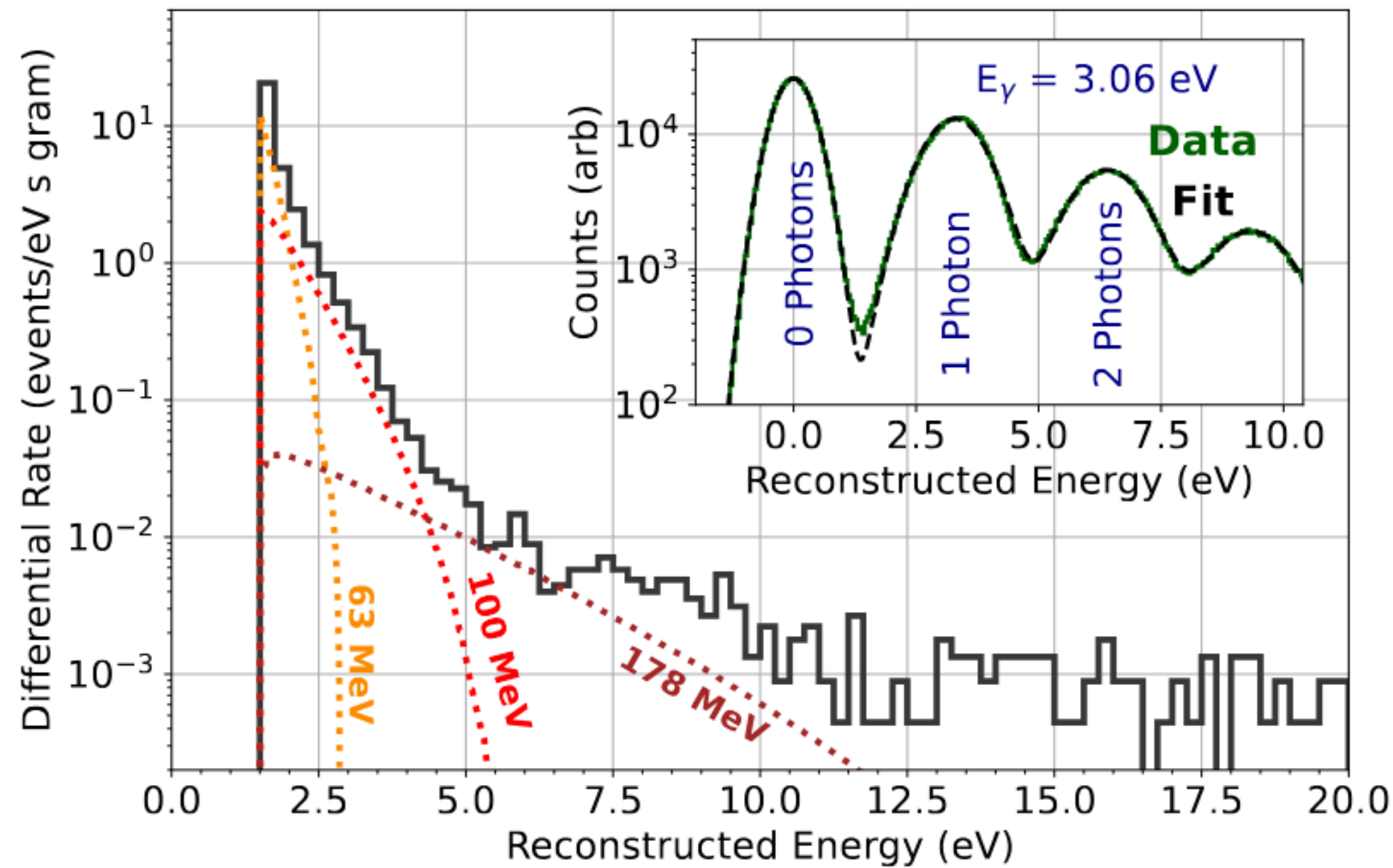
TESSERACT: low energy event excess



One of the TESSERACT techniques to mitigate the LEEE employs two TESs on the same target.

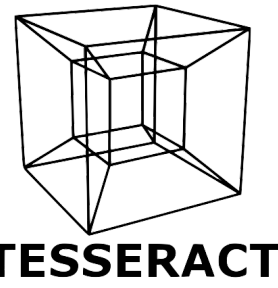
This allowed us to remove LEEE events triggering a single channel.

First surface dark matter search



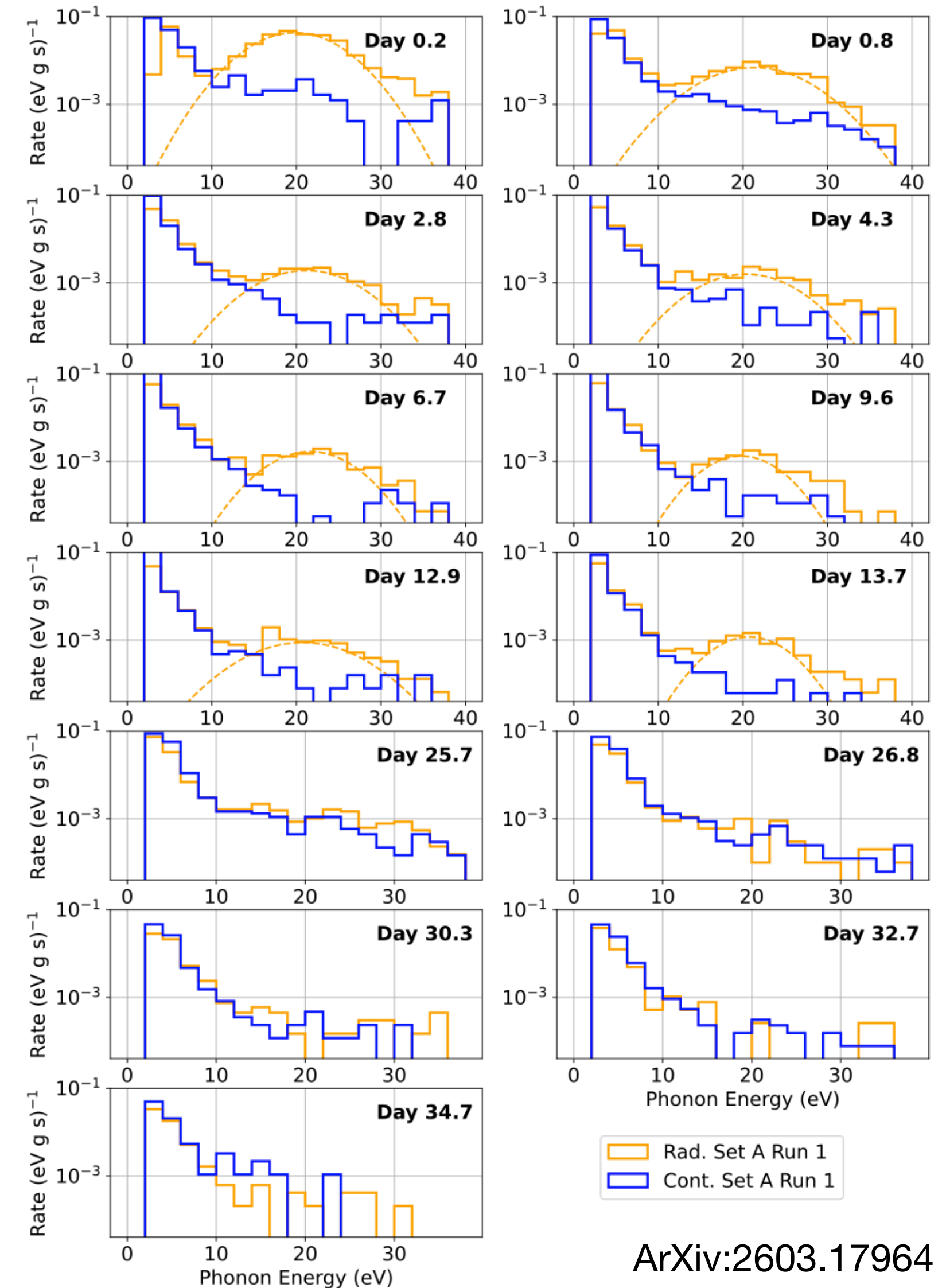
Leading between 44 MeV and 87 MeV
 Limited by the LEEE at the lowest energies
Need LEEE discrimination techniques and mitigation strategies

T.K. Bui et al., Phys. Rev. Lett. 135, 161002, 2025



TESSERACT: low energy event excess

- The LEEE rate scales with volume for the TESSERACT detectors
- Hypothesis: LEEE are induced by neutron damages from cosmic rays.
- Expose detectors to neutrons (DD generator + AmBe source) and measure the rate at low energy
- Excess of events around 20 eV (Frenkel pair formation energy) but different spectral shape
- → the LEEE is not dominated by neutron damages



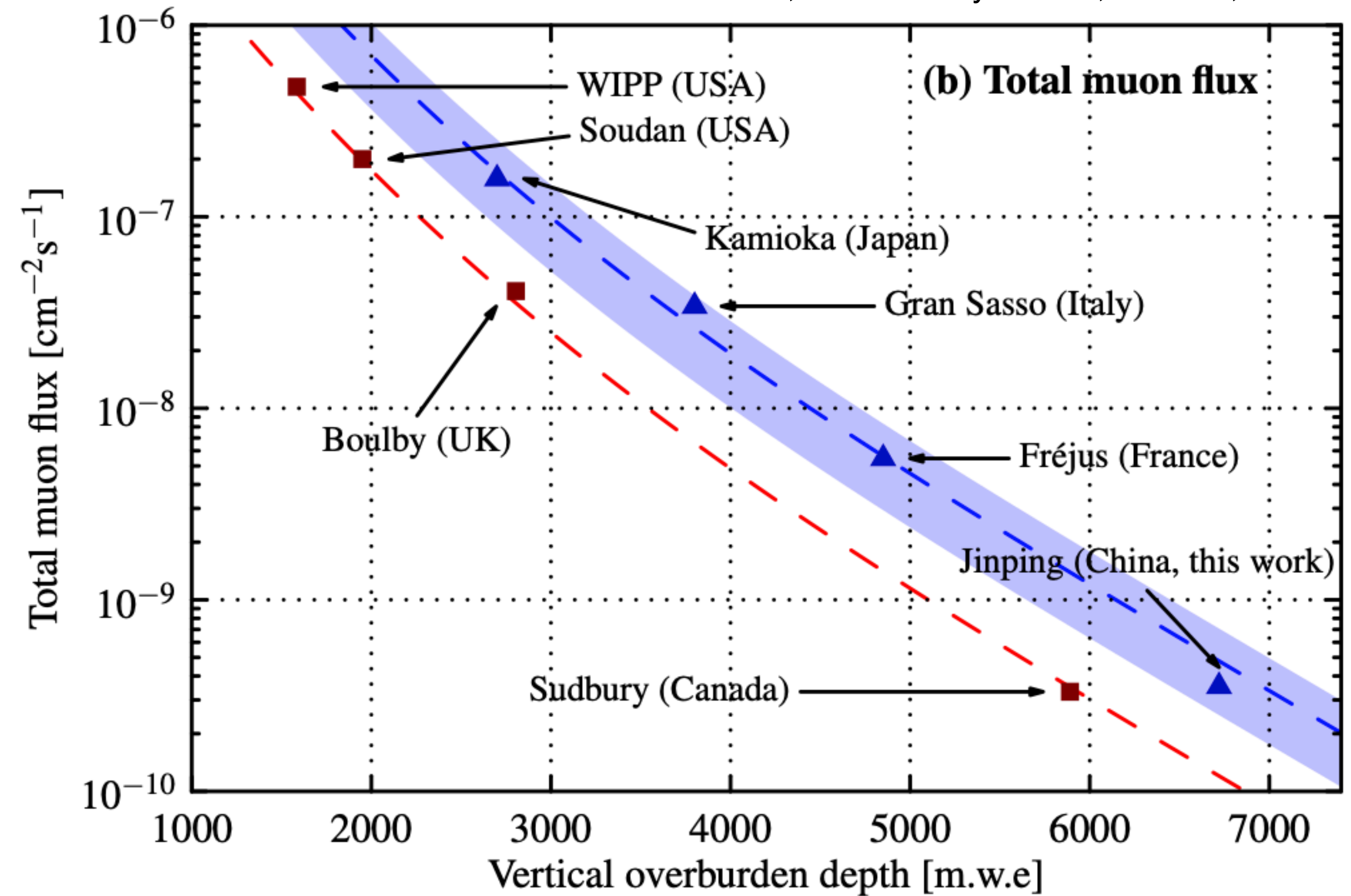
ArXiv:2603.17964

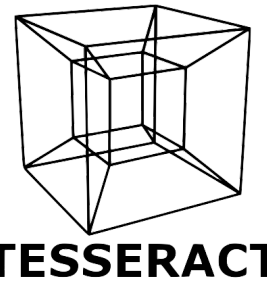
Environmental backgrounds

The TESSERACT experiment will be hosted in the laboratories souterraine de Modane (LSM), the deepest underground laboratory in Europe.

The LSM will provide shielding for cosmogenic backgrounds thanks to a 10^6 reduction of the muon flux provided by the rock.

Z. Guo et al., Chinese Phys. C 45, 025001, 2021



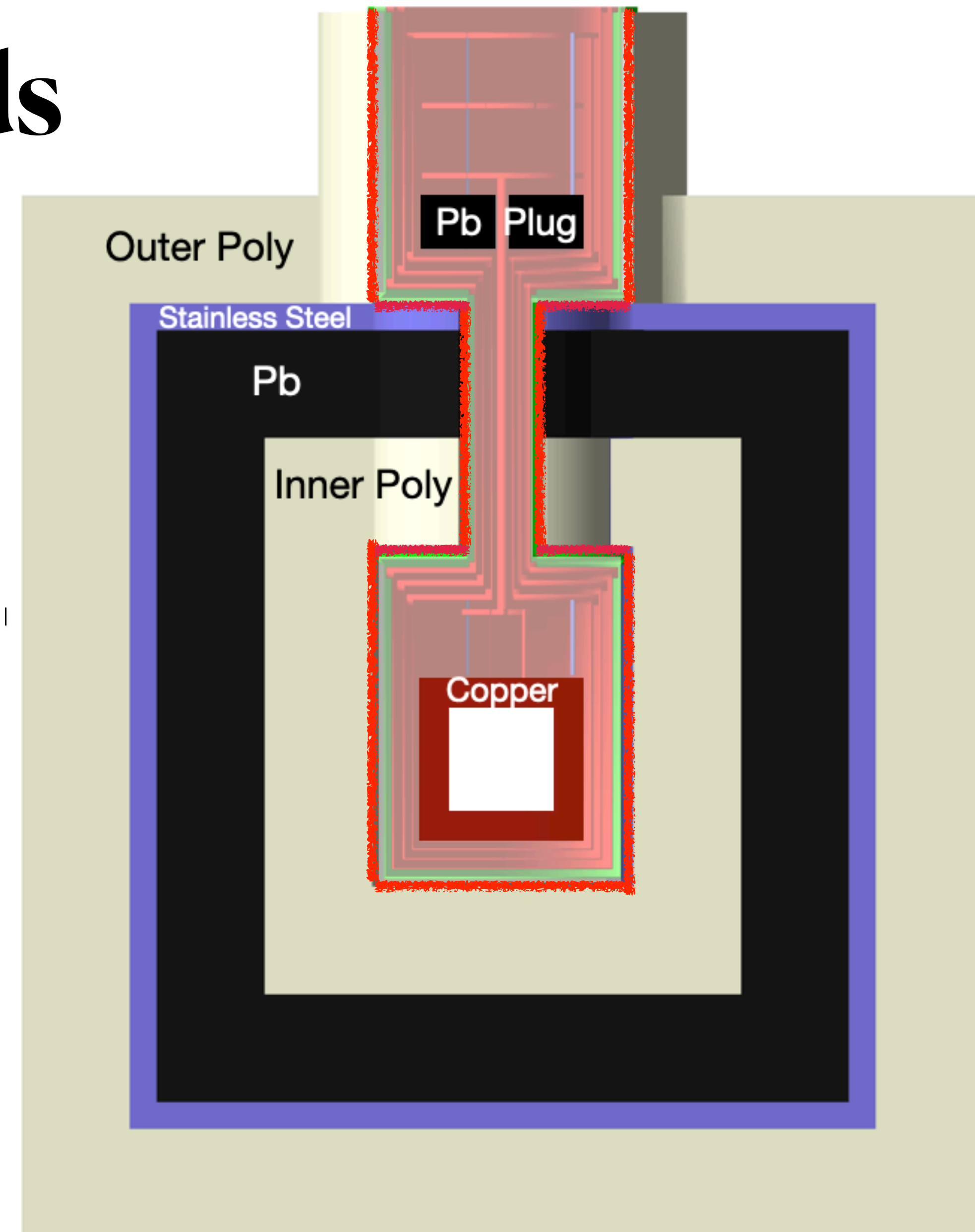


Environmental backgrounds

The dilution refrigerator will have a dumbbell shape to better surround the detectors with the external shielding.

The dilution refrigerator is designed around commercial cryostat with a vertical layout.

- The narrow “neck” region covered with a lead plug cooled down to 1K
- A thick copper canister will surround detector region



Environmental backgrounds

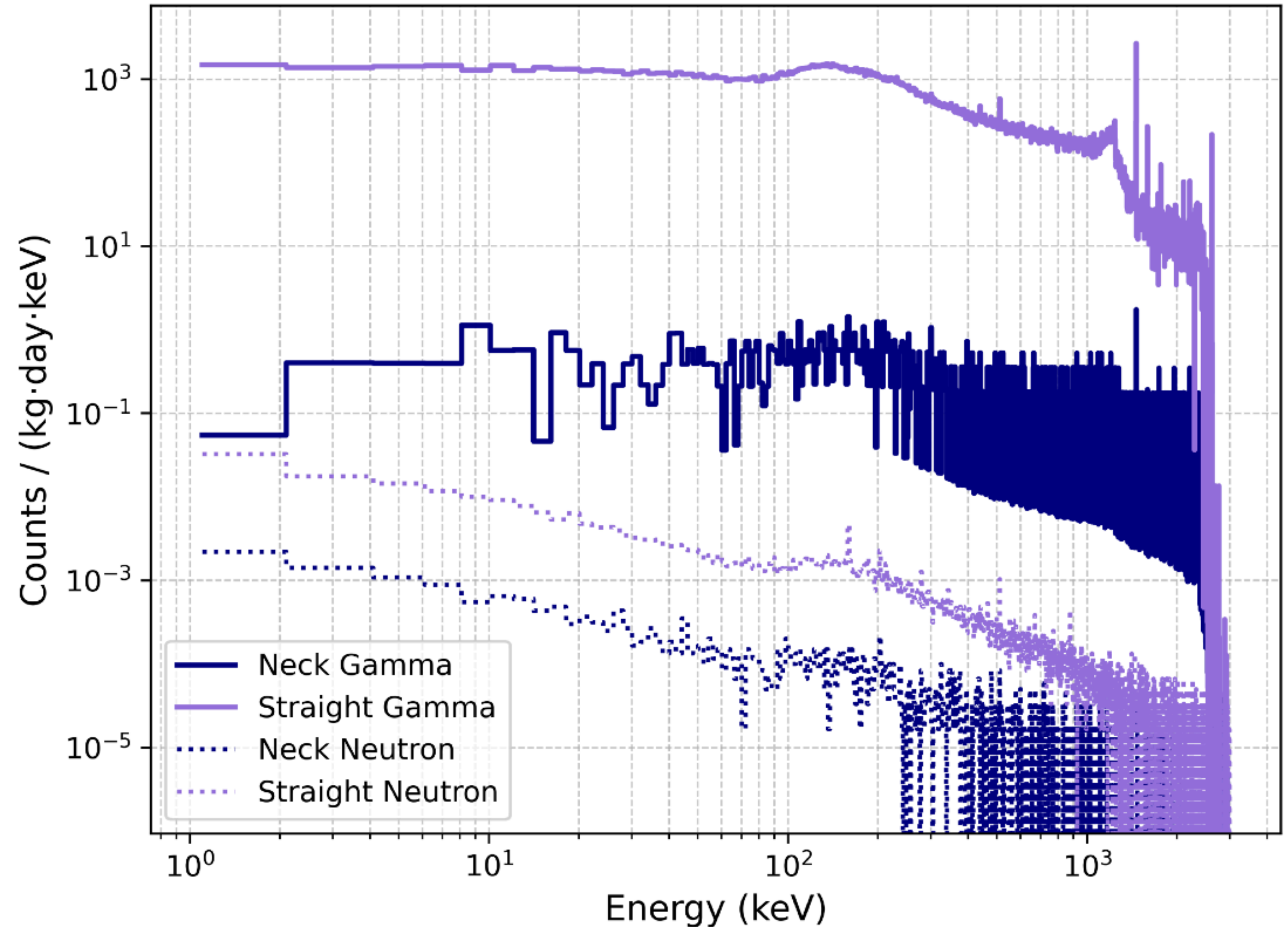
Credit J. Blé (PhD)

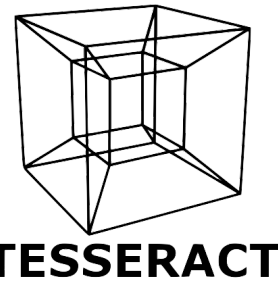
Material screening at LSM ongoing.

Simulations for a dilution refrigerator with a neck predict:

- ~ 1 DRU (electron recoils)
- $< 10^{-3}$ DRU (nuclear recoils)

for a dilution refrigerator with a “neck”



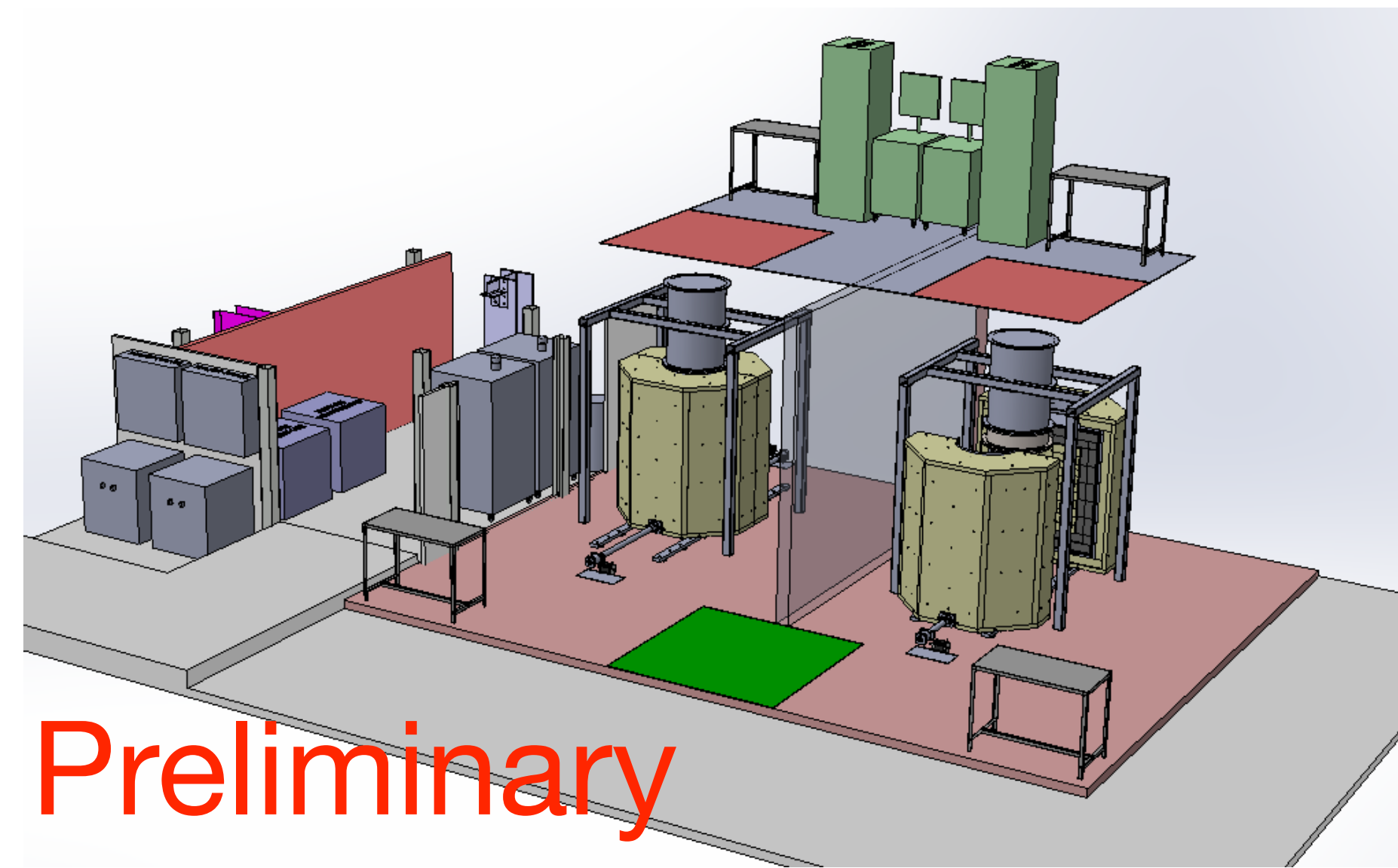


Getting ready for LSM

Two copies of the setup at LSM, for enabling both:

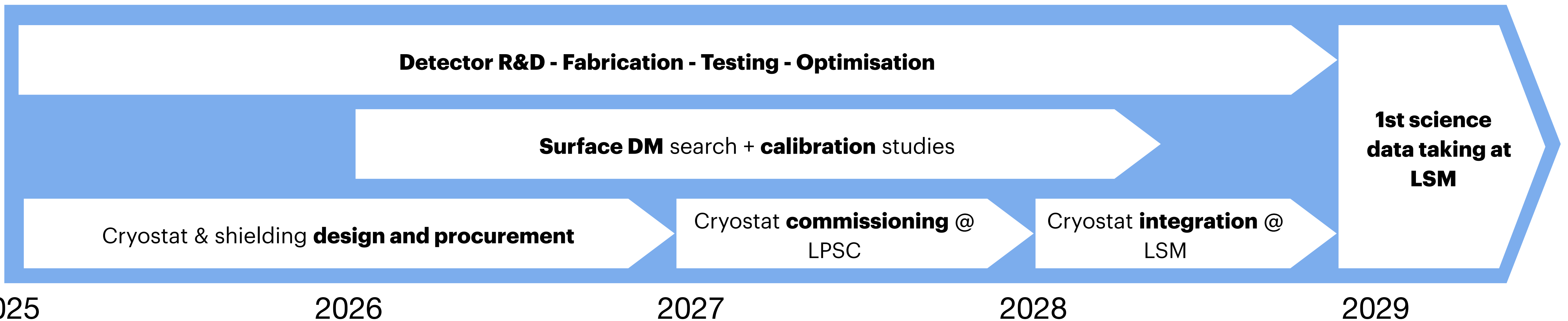
- underground R&D and detector optimisation
- DM science data taking in parallel

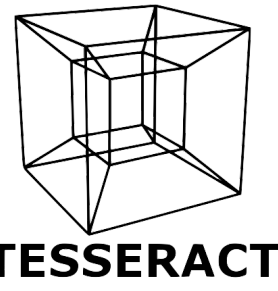
Target background levels < 10 event/ (kg keV day)



Preliminary
(Clean room not shown)

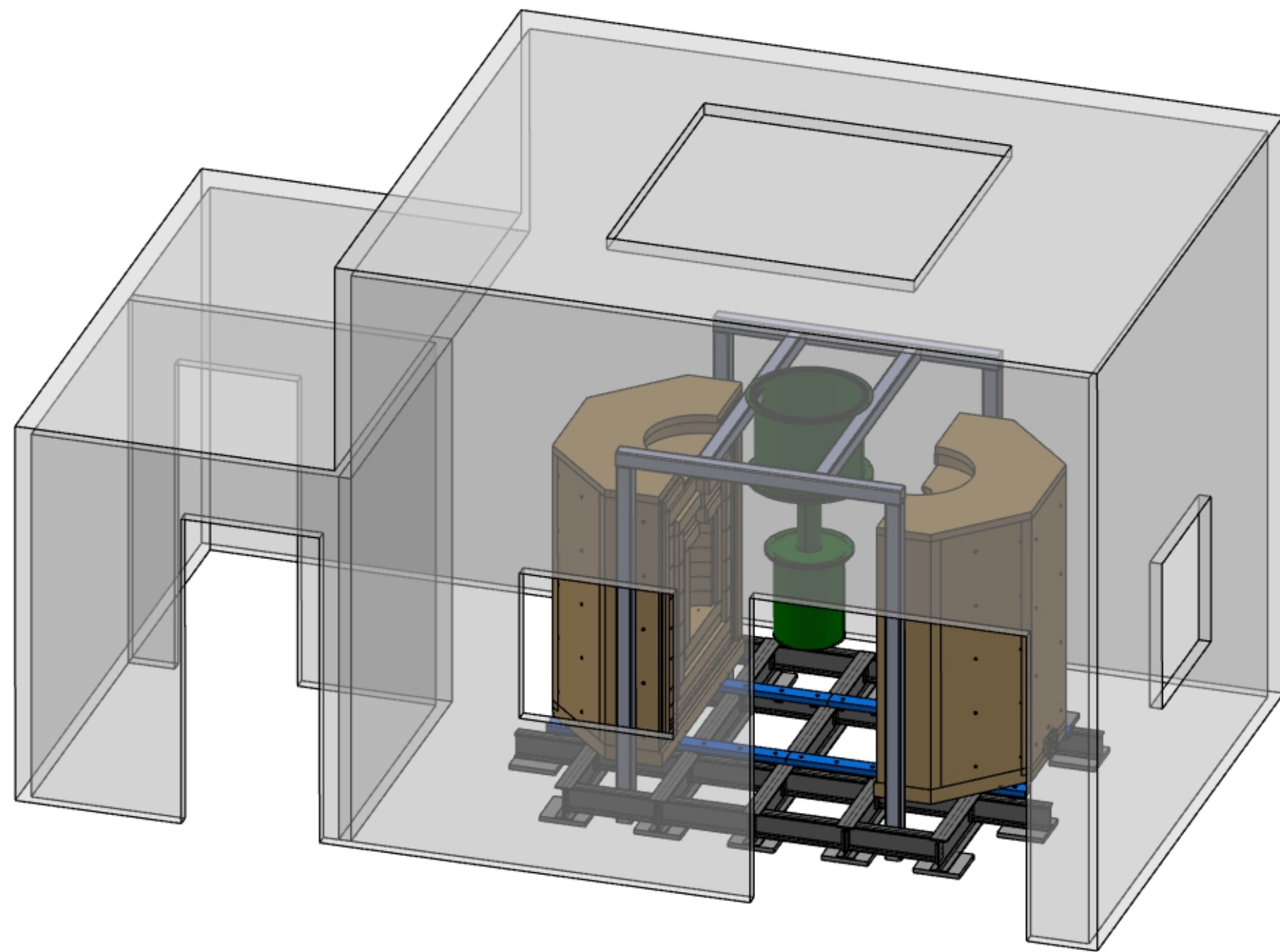
Integration at LSM planned in 2028 for first DM science data in 2029

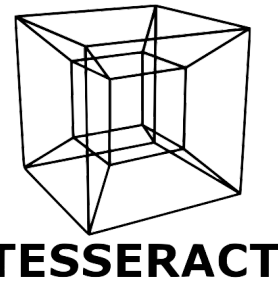




Getting ready for LSM

Dedicated clean room at LPSC ready to host the first TESSERACT fridge for its surface commissioning including: cryogenics, vibration levels, EMI mitigation, detector integration operation and optimisation, and **surface DM science** !

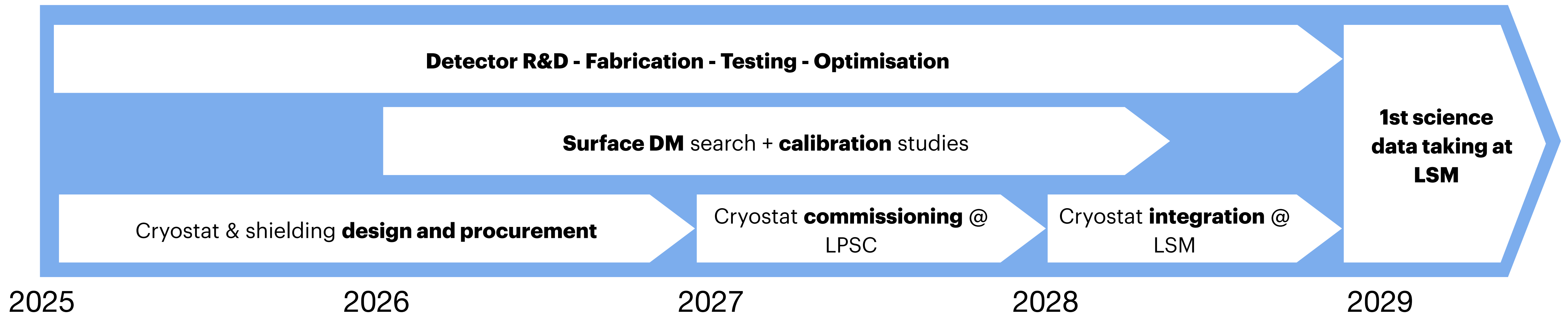


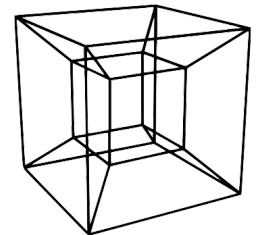


Conclusions and outlook

The TESSERACT experiment

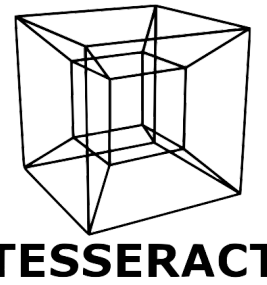
- will use diverse target materials sensitive to complementary dark matter couplings
- with sub-eV energy thresholds and state-of-the-art background rejection capabilities
- will be hosted in an ultra quiet underground cryogenic infrastructure at LSM





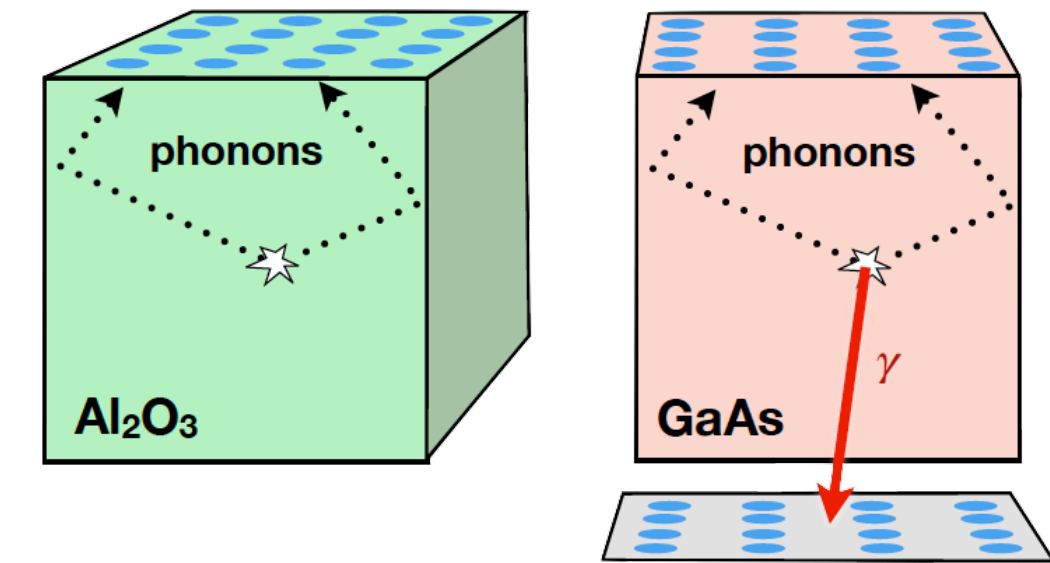
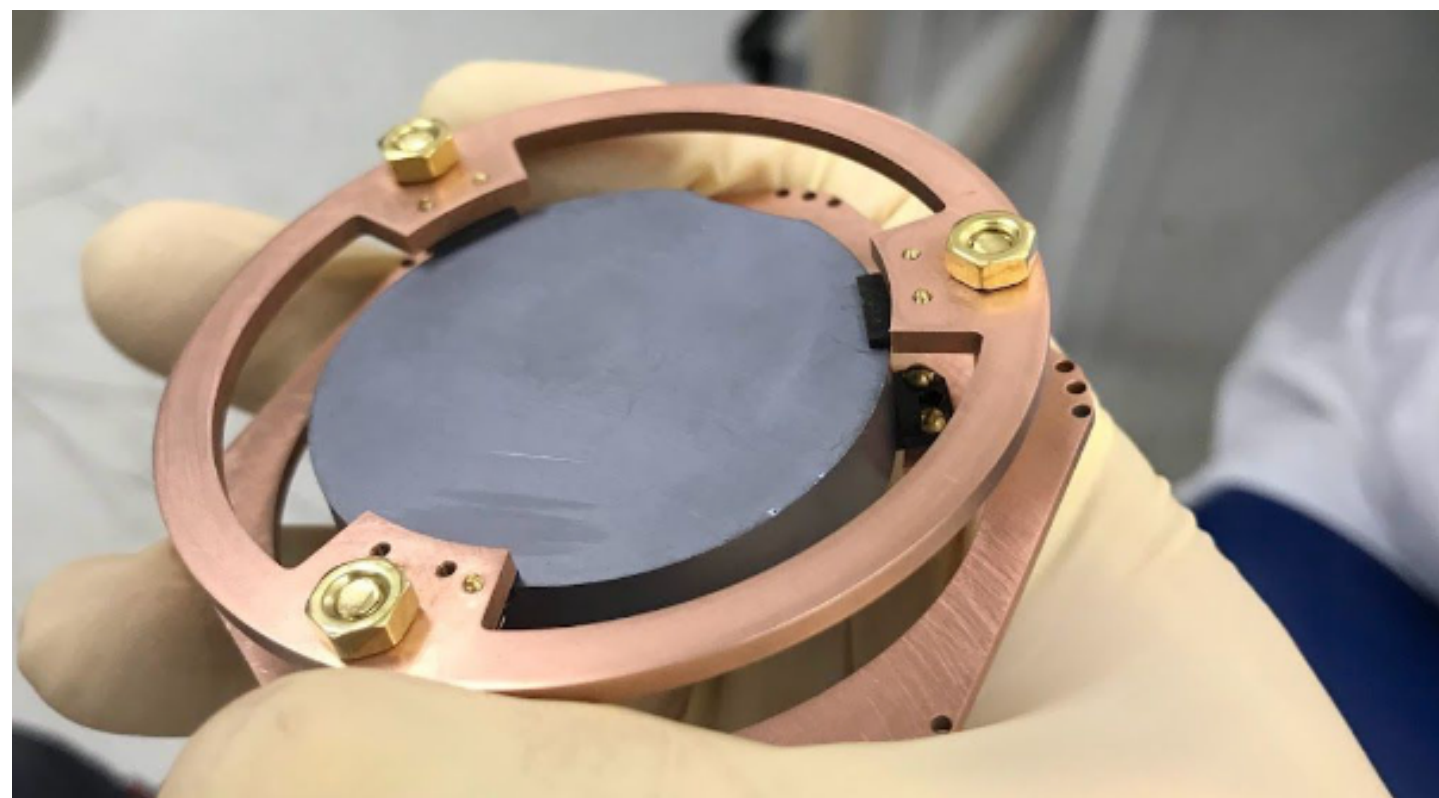
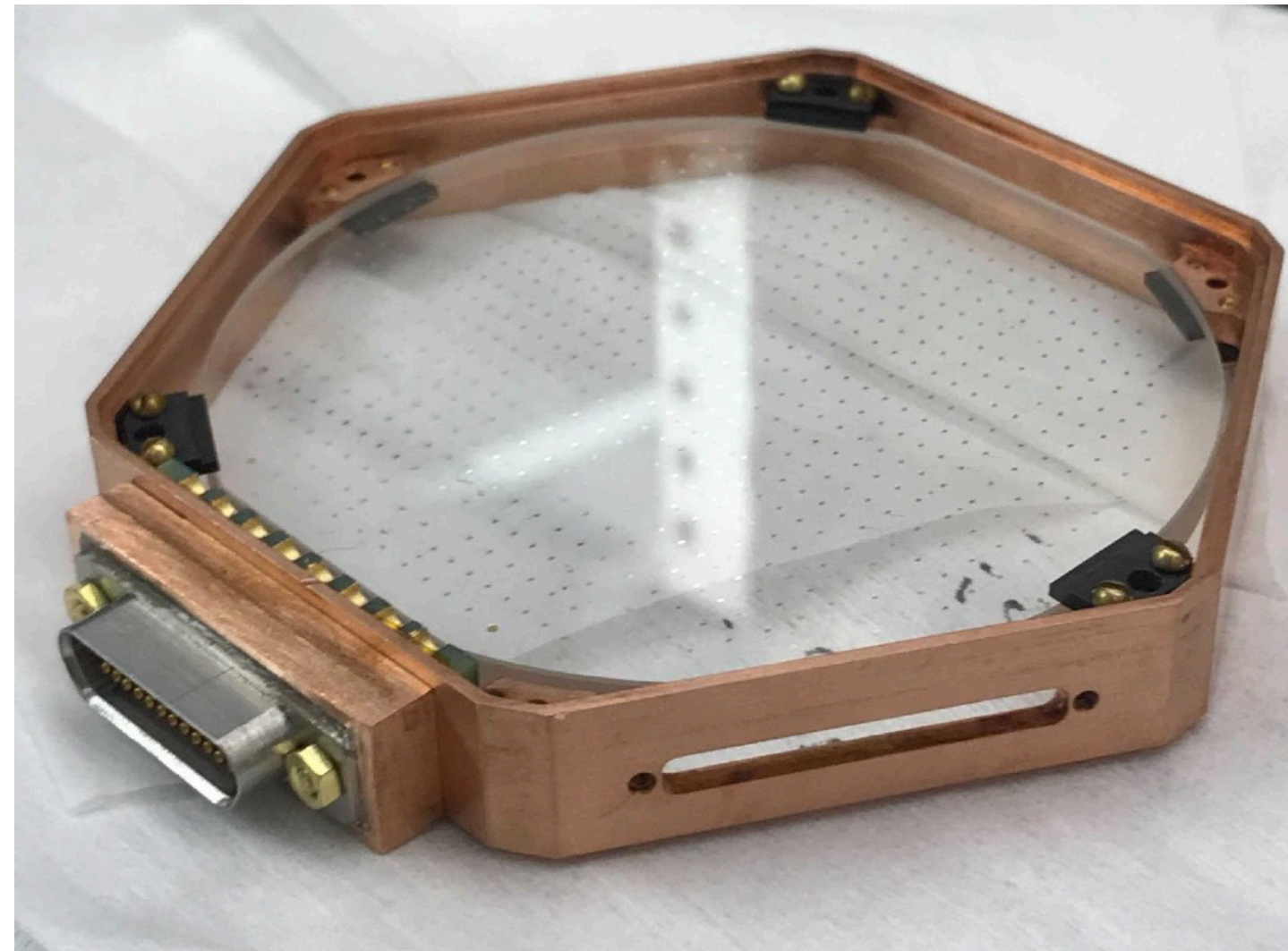
TESSERACT

Bonus

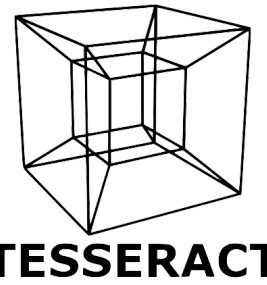


TESSERACT: SPICE

Sub-eV Polar Interactions Cryogenic Experiment

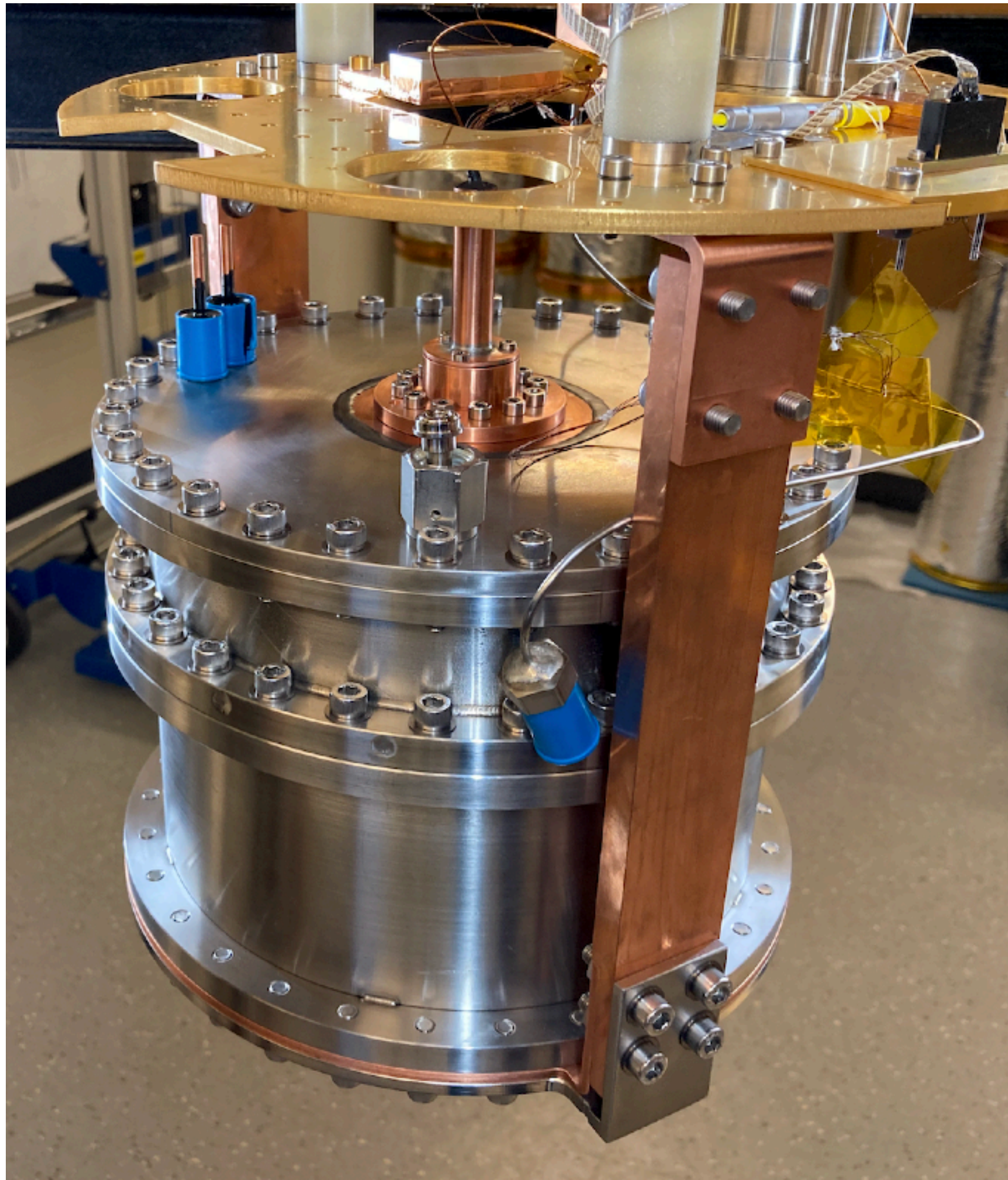
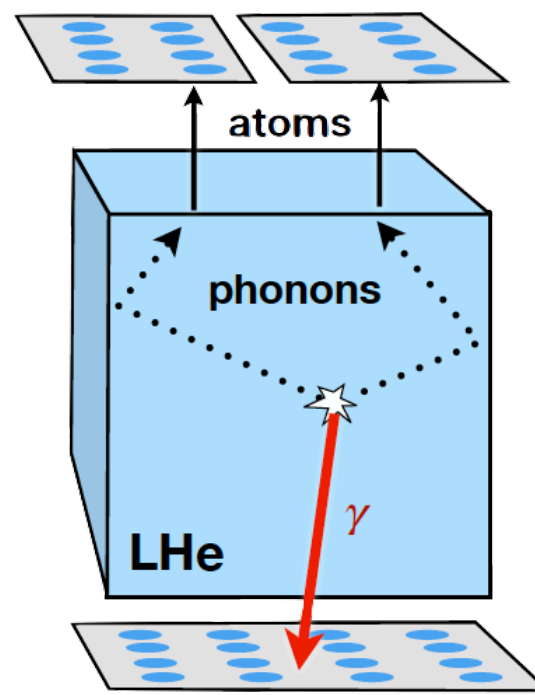


- Sapphire supports many optical phonon modes.
 - Optical phonons kinematically well-matched to low-mass DM → effective energy transfer
 - Coupling to E&M-like inputs due to electric dipole → dark photon sensitivity
 - Use of two TES-channels to suppress part of the LEEE
-
- Polar crystal & bandgap well matched to kinematic region of low mass DM
 - Background discrimination using phonon/photon ratio
 - Photon-photon and phonon-phonon coincidence can reduce instrumental backgrounds (LEEE)



TESSERACT: HeRALD

Helium Roton Apparatus for Light Dark matter



- Well kinetically matched to GeV-scale DM
- Easy to purify, intrinsically radio pure
- LHe cell operated at 20-50 mK with wafer-like cryogenic detectors with TES suspended in vacuum
- UV/IR photons and He atoms from qp induced evaporation
- First evidence of ER/NR discrimination @10 keV
- Already achieved ~ 170 eV threshold on He recoils (300 MeV DM)
- Multi-channel evaporation readout to reject LEEE via coincidences

R. Anthony-Petersen et al. Phys. Rev. D 110, 072006, 2024