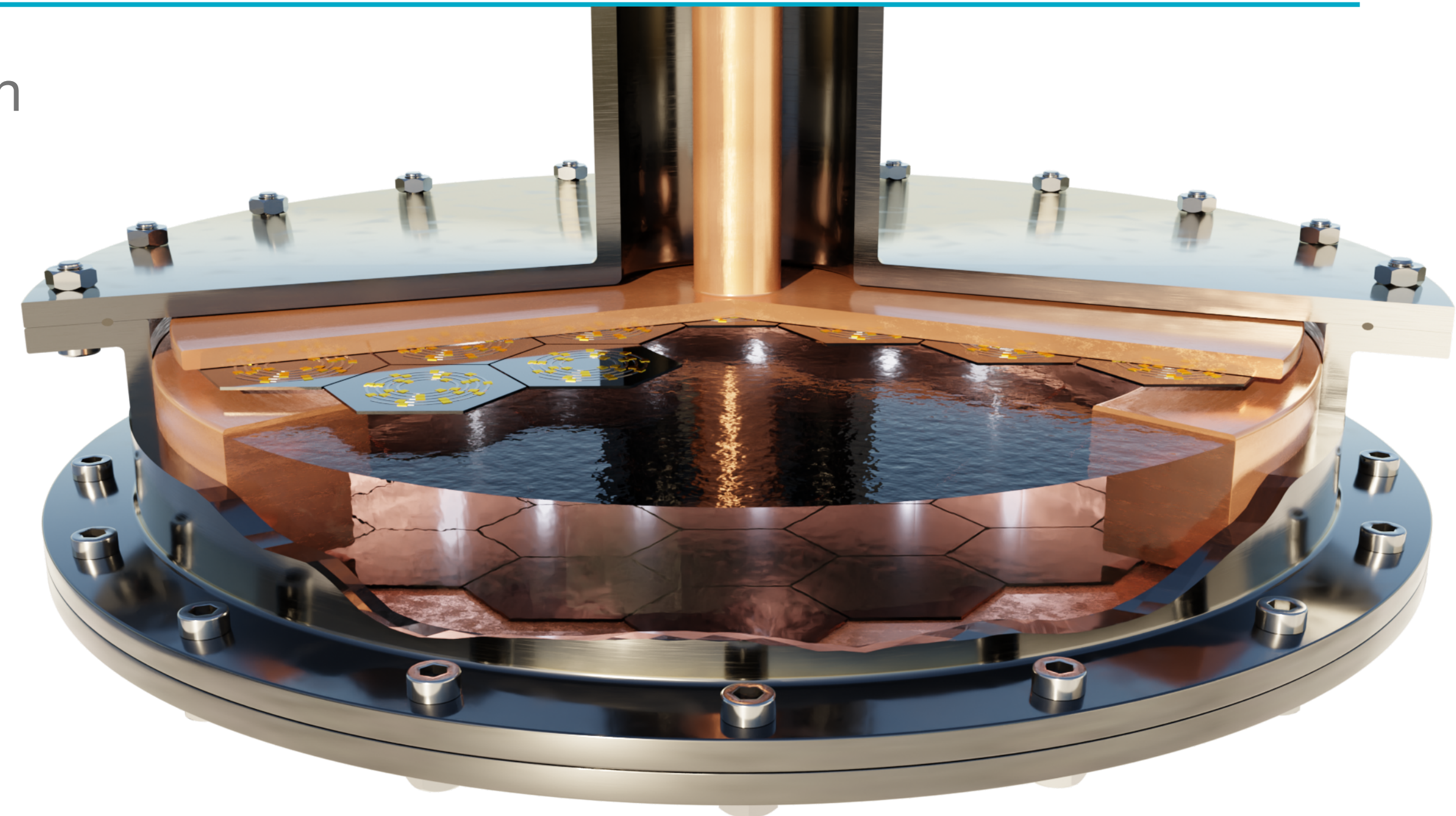




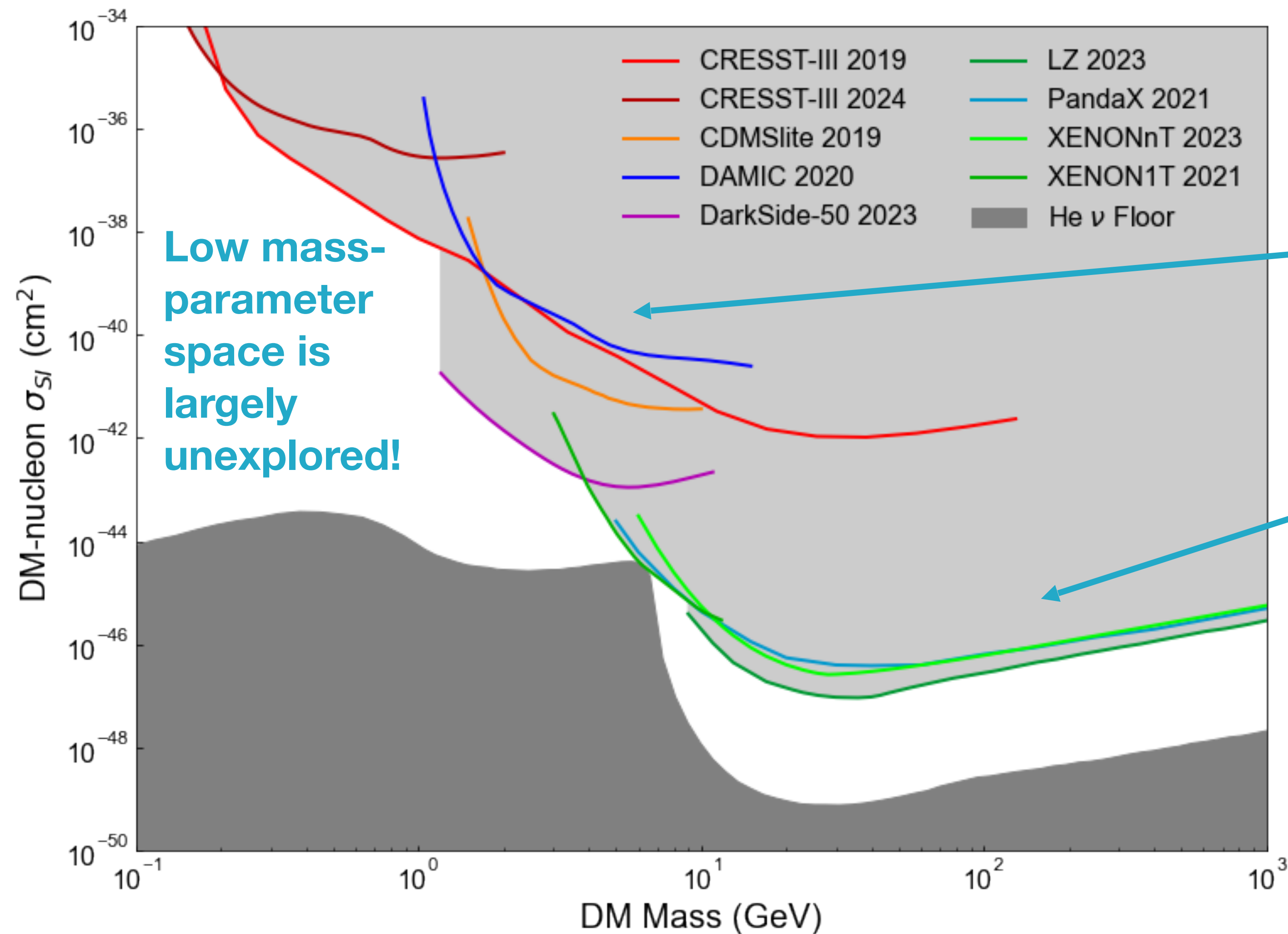
The Projected Sensitivity of the DELight Experiment

Eleanor Fascione on behalf of the DELight Collaboration
DPG-Herbsttagung Göttingen 08.09.2025

DELight



The Current SI-DM Landscape and Push to Low Mass



Various experimental efforts to reach sensitivity to $\sim \text{GeV}/c^2$ scale WIMPs

Heavy noble experiments constrain high-mass WIMP parameter space and push towards neutrino fog

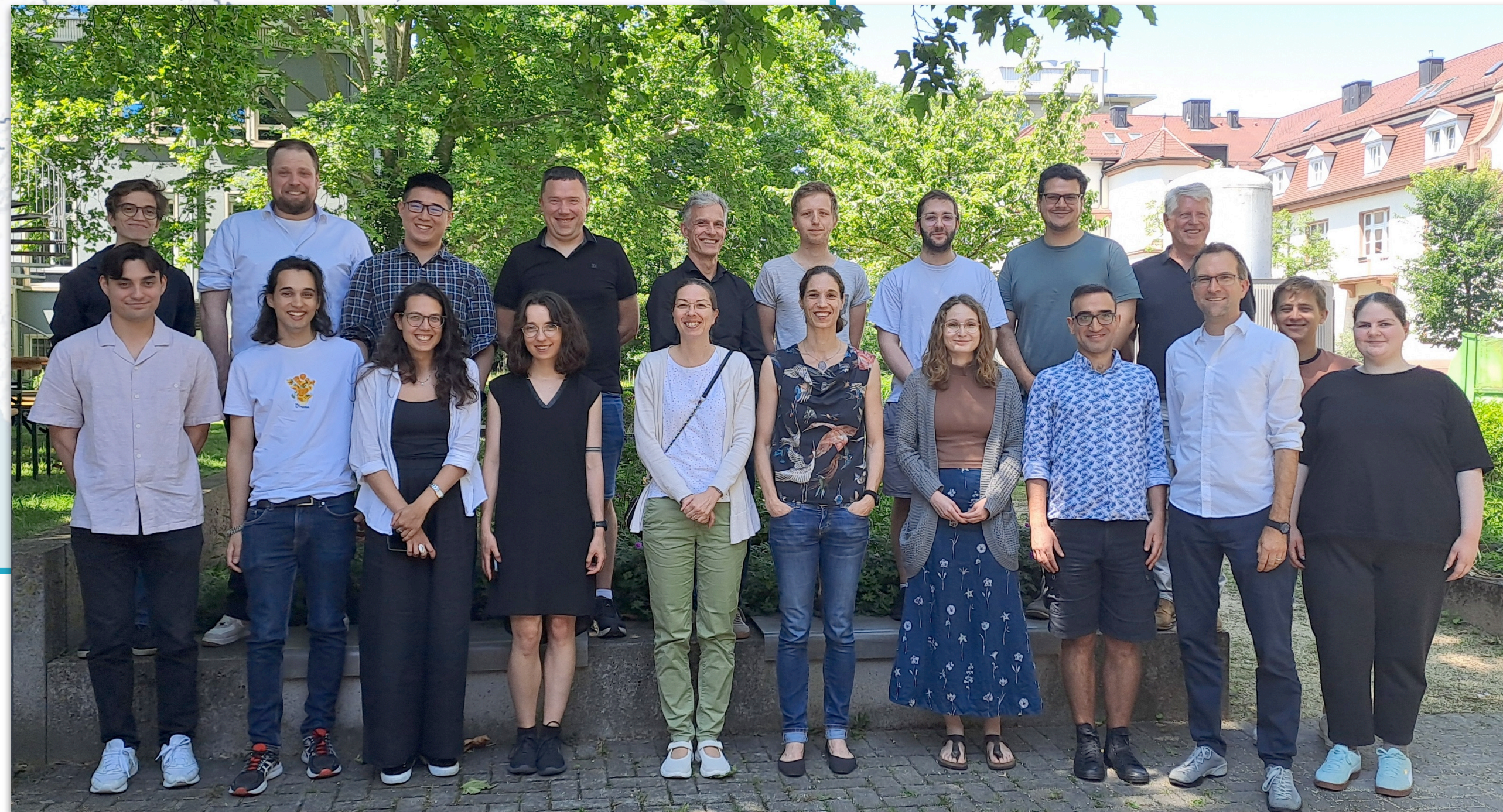
A Direct search Experiment for Light dark matter (DELight)



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An upcoming light dark
matter search using
superfluid helium-4



universität freiburg



DElight

A Direct search Experiment for Light dark matter (DELight)



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SEIT 1386

An upcoming light dark matter search using superfluid helium-4

universität freiburg

Upcoming talk by Francesco Toschi:

Shaping DELight: signal propagation in superfluid helium-4

T10.6 15:30



Upcoming talk by Axel Brunold:

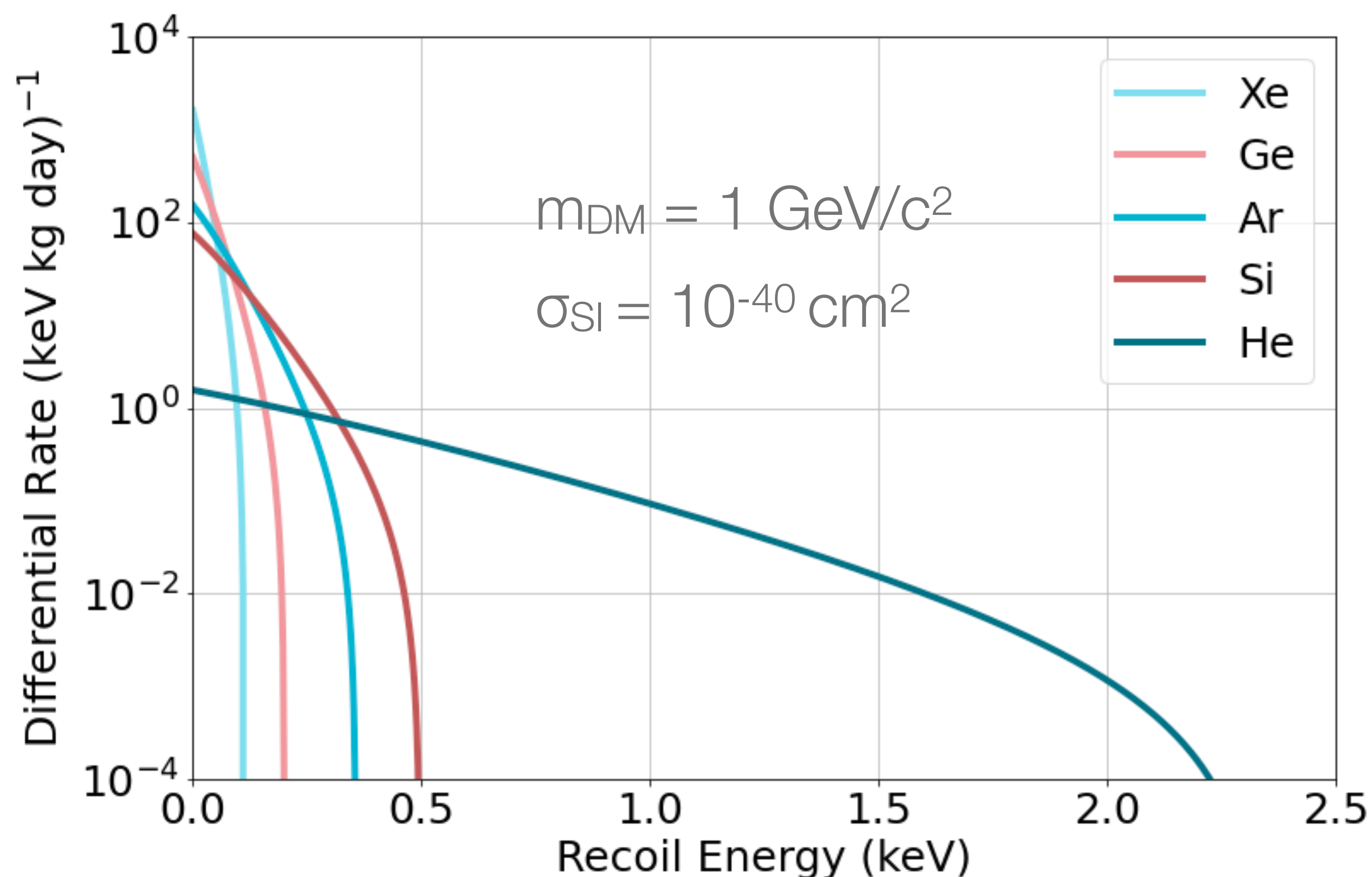
Towards dark matter detection with superfluid Helium: First results from the DELight Demonstrator

T10.7 15:45



Superfluid Helium-4 Target

➔ Light nucleus ideal for LDM search



➔ No intrinsic long-lived backgrounds

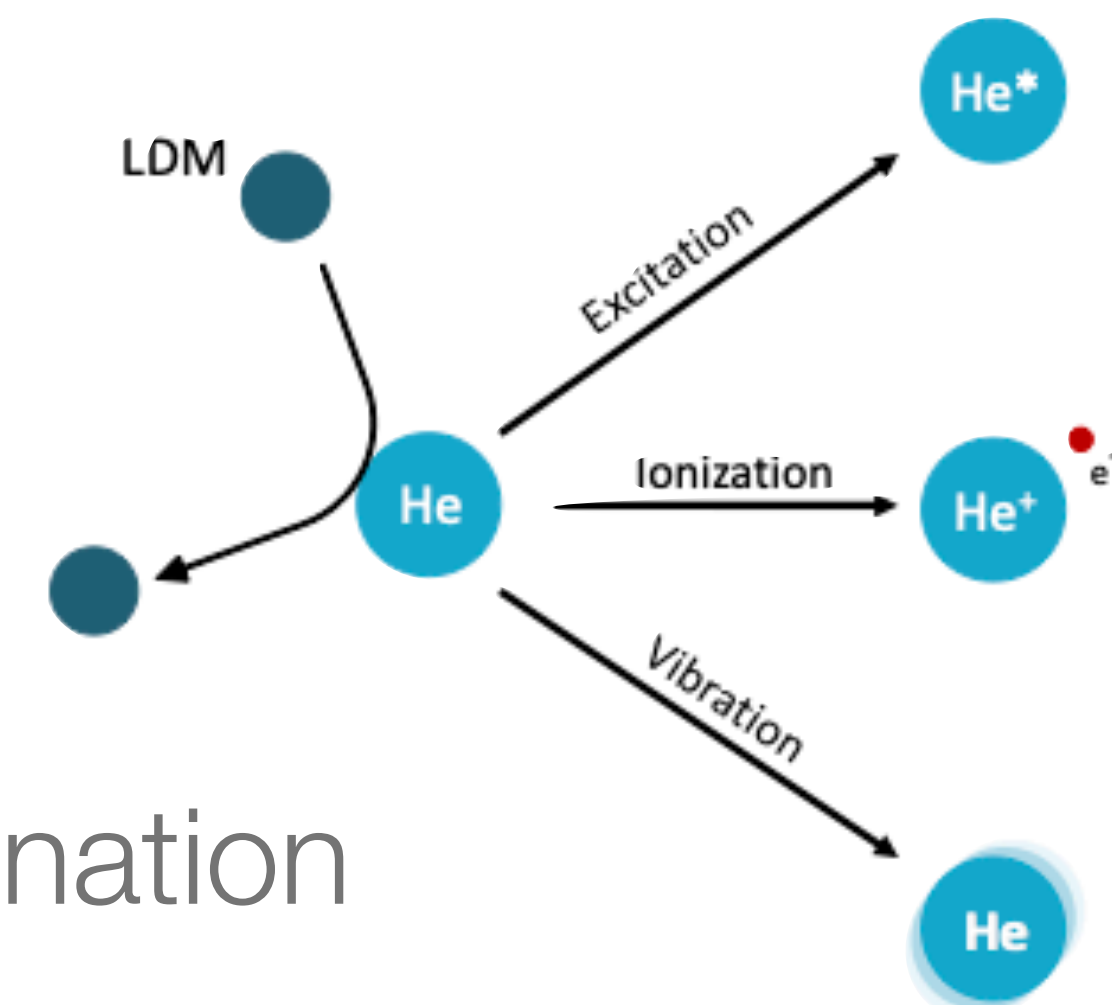
➔ Contaminants freeze-out

➔ Inexpensive

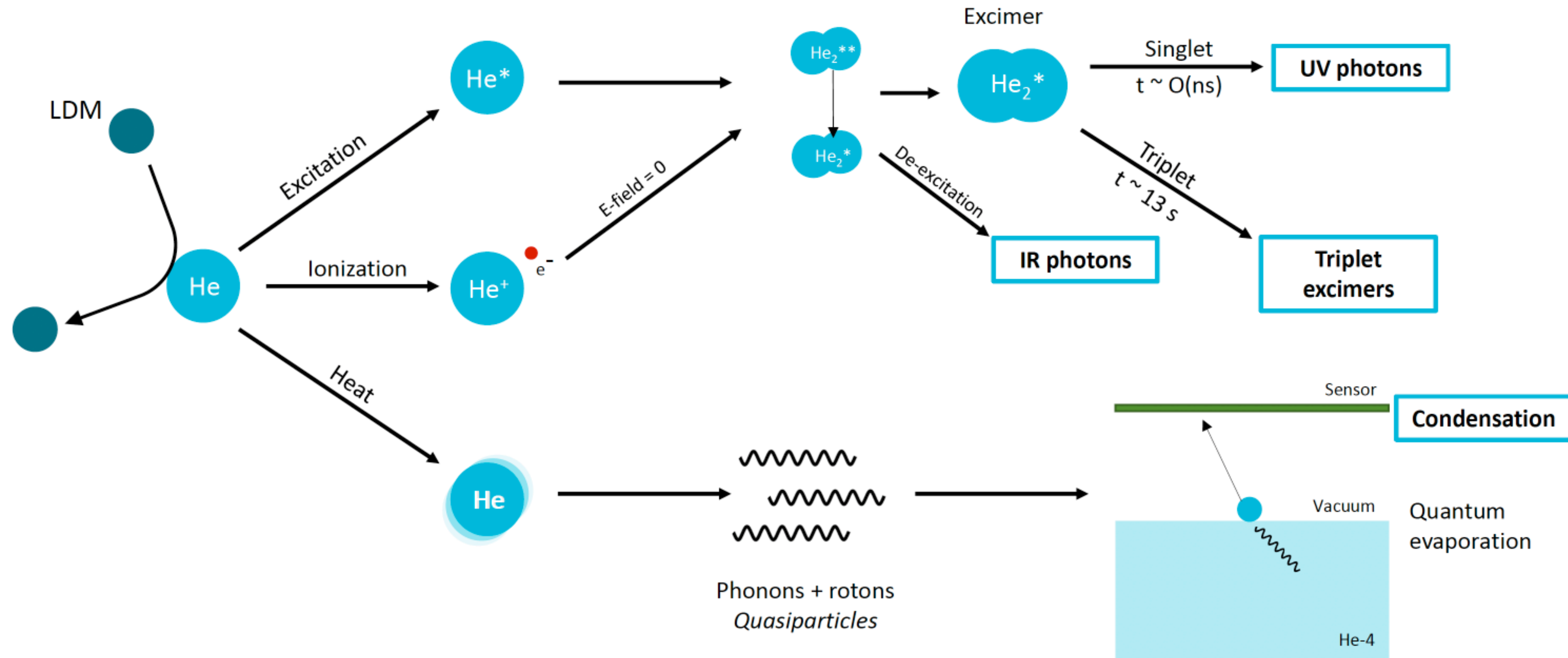
➔ Scalable

➔ Multiple signals:

➔ ER/NR discrimination



Signals in Superfluid He-4



DELIGHT Detector - Interactions in Superfluid Helium-4

→ UV and IR photons

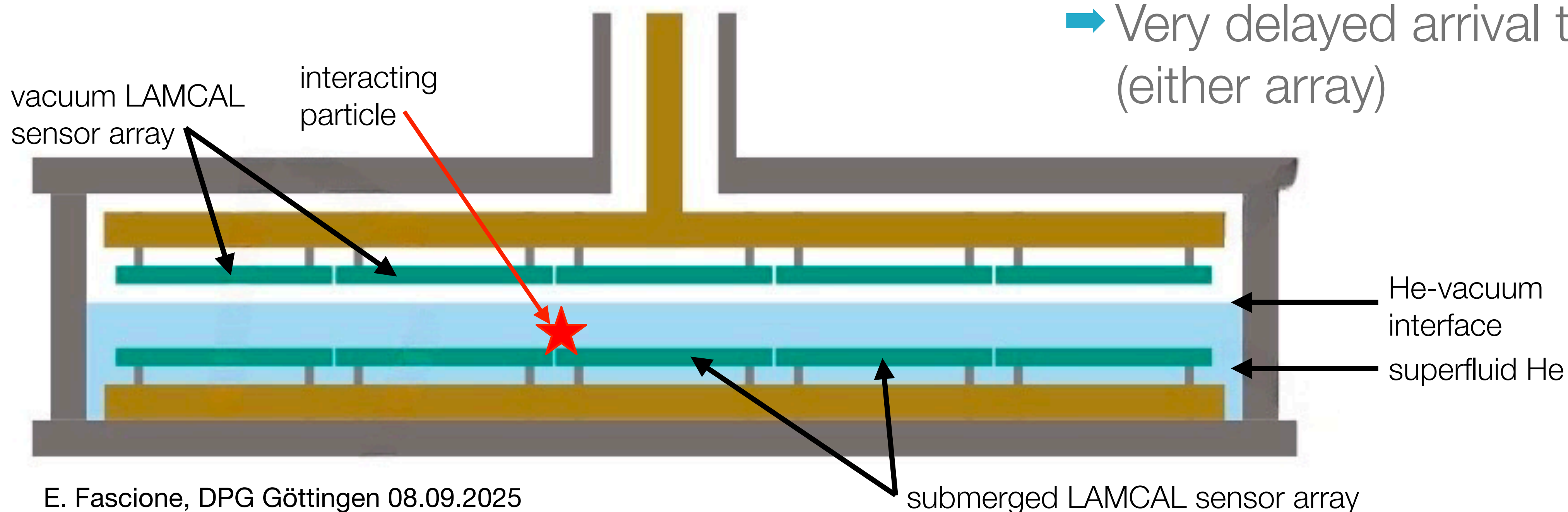
→ Prompt arrival at sensors (either array)

→ Triplet excimer

→ Ballistic $O(m/s)$ speed

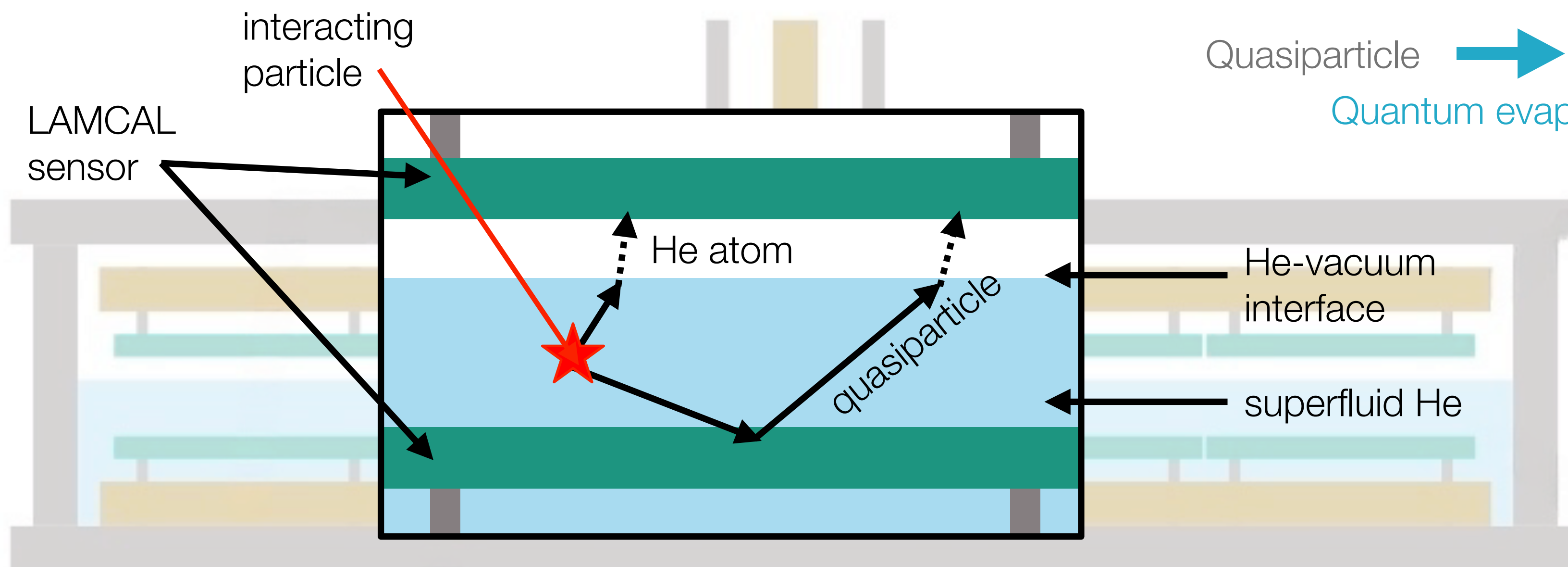
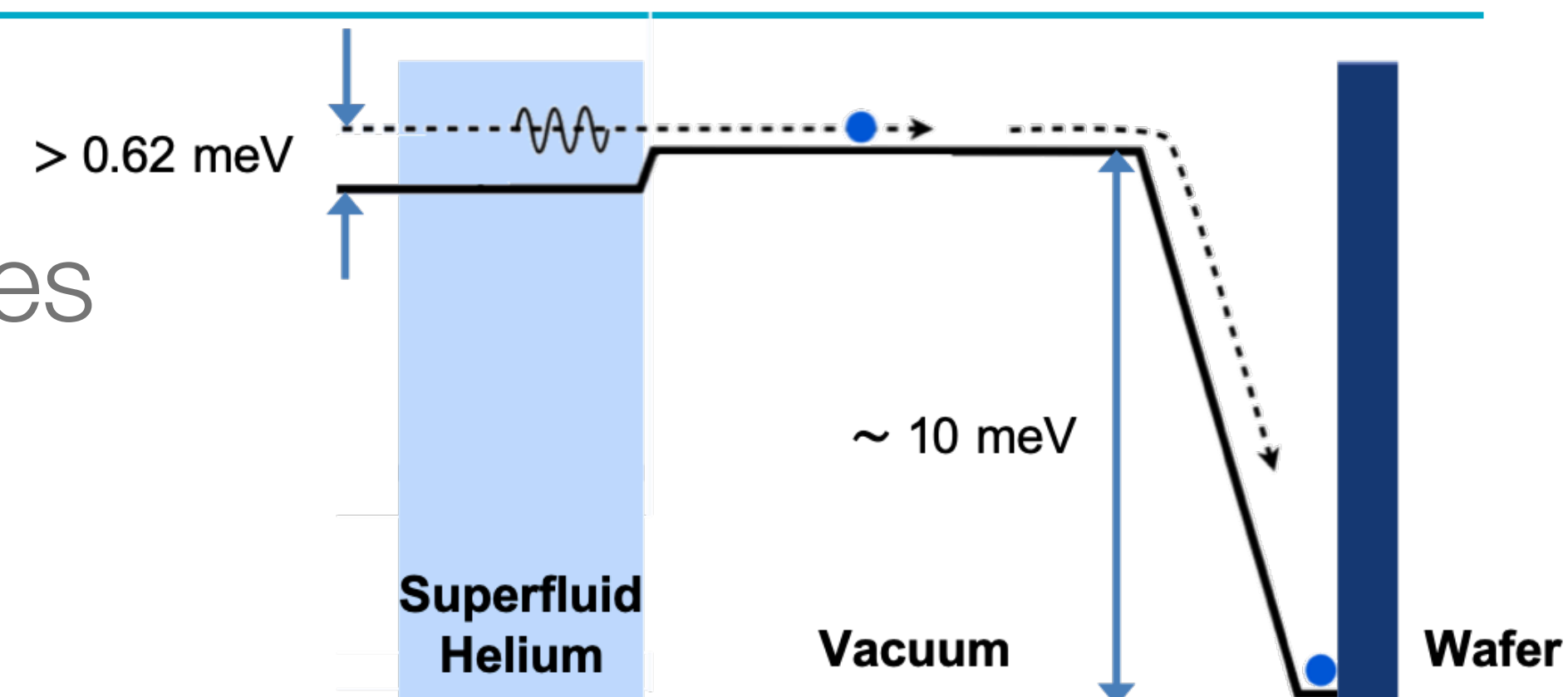
→ 13s lifetime

→ Very delayed arrival time at sensors (either array)



DELight Detector - Interactions in Superfluid Helium-4

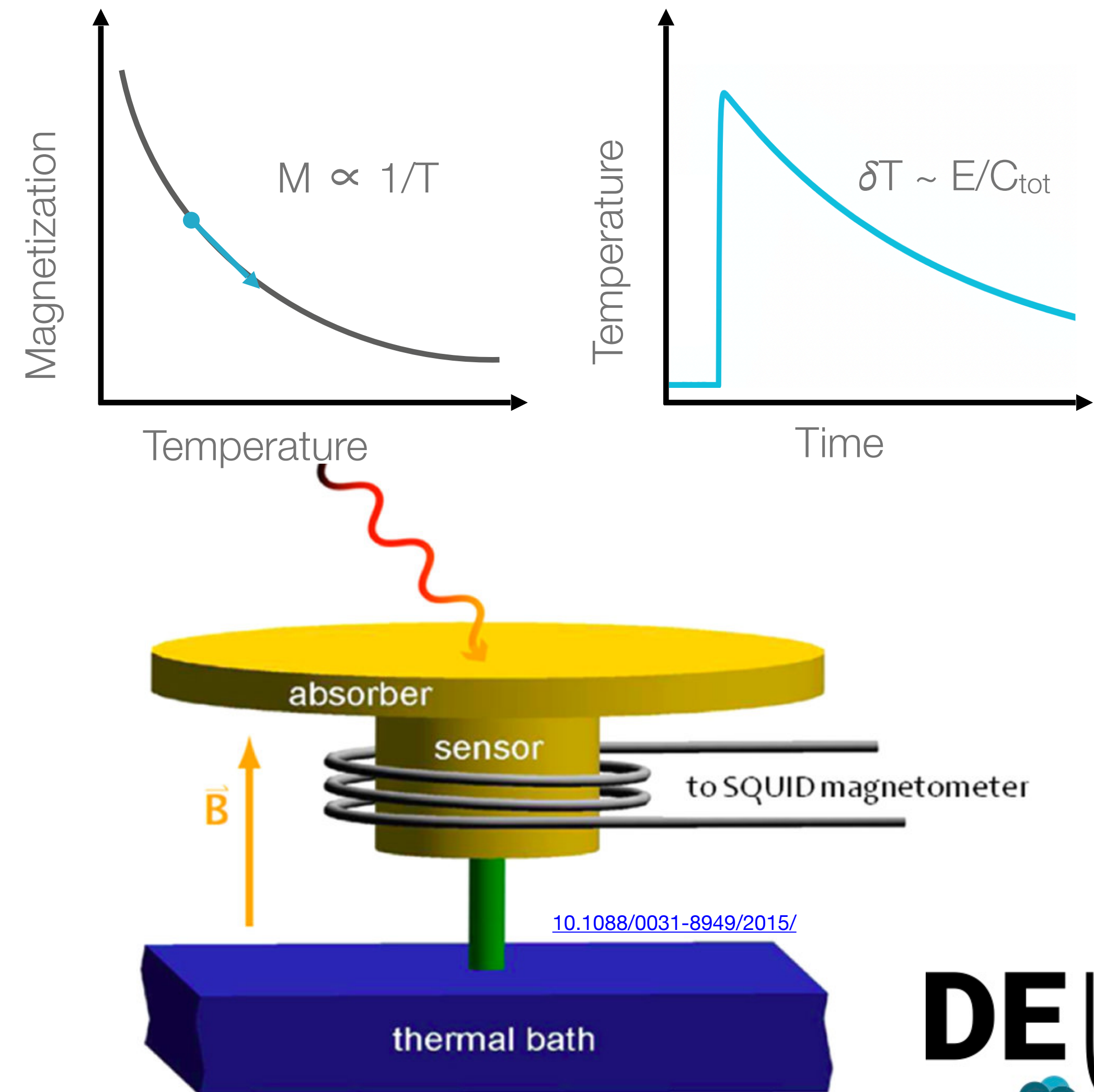
- Quasiparticles (phonon and rotons) propagate ballistically within the LHe, bouncing off of surfaces
- Noise free amplification of factor of 10-40



Quasiparticle → Free He atom → He atom on wafer
Quantum evaporation Condensation

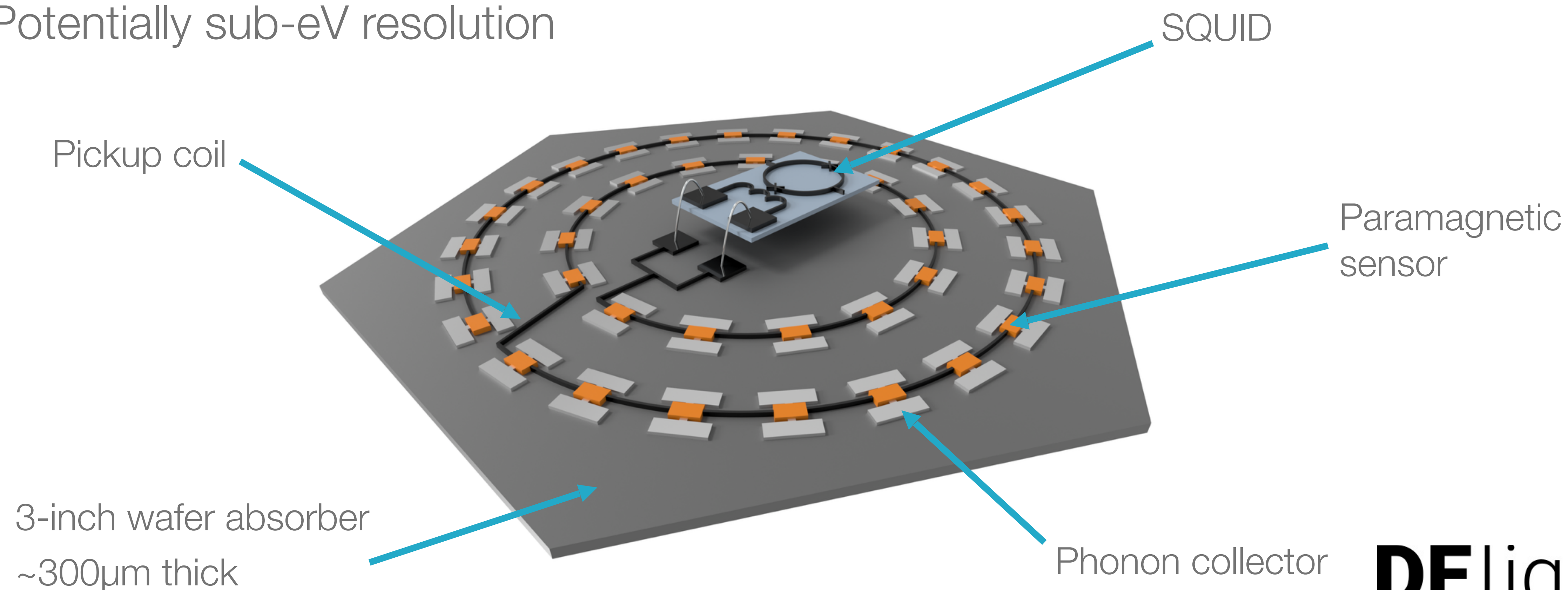
Magnetic MicroCalorimeters (MMCs)

- Energy deposition in absorber → increase in temperature δT → decrease in magnetization of paramagnetic sensor $\delta M \propto \delta T$
- δM read out via SQUID
- Best MMC resolution to date with optimum-filter analysis of ^{55}Fe calibration peaks
- **$\Delta E_{\text{FWHM}} = 1.25 \text{ eV at } 5.9 \text{ keV}$**



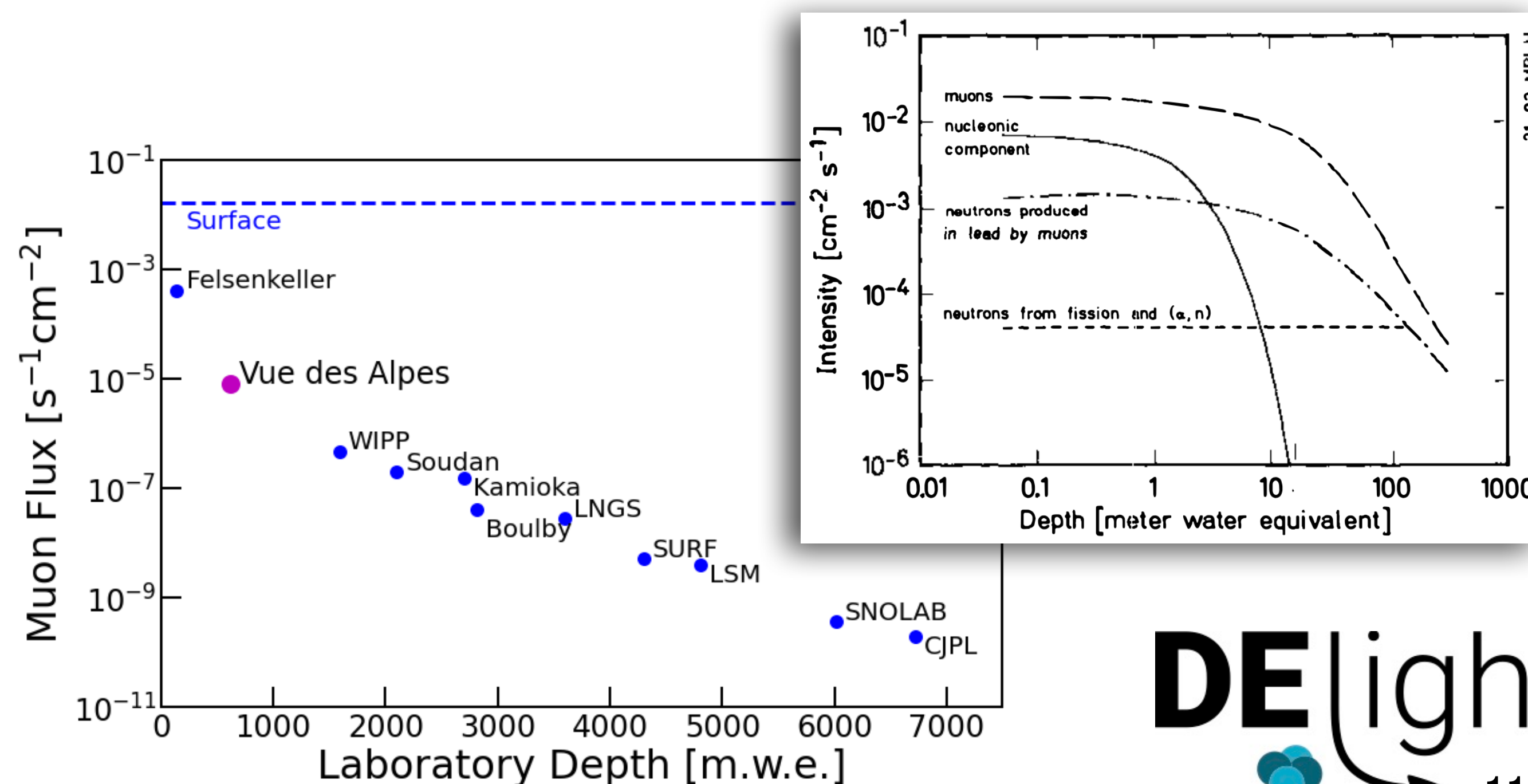
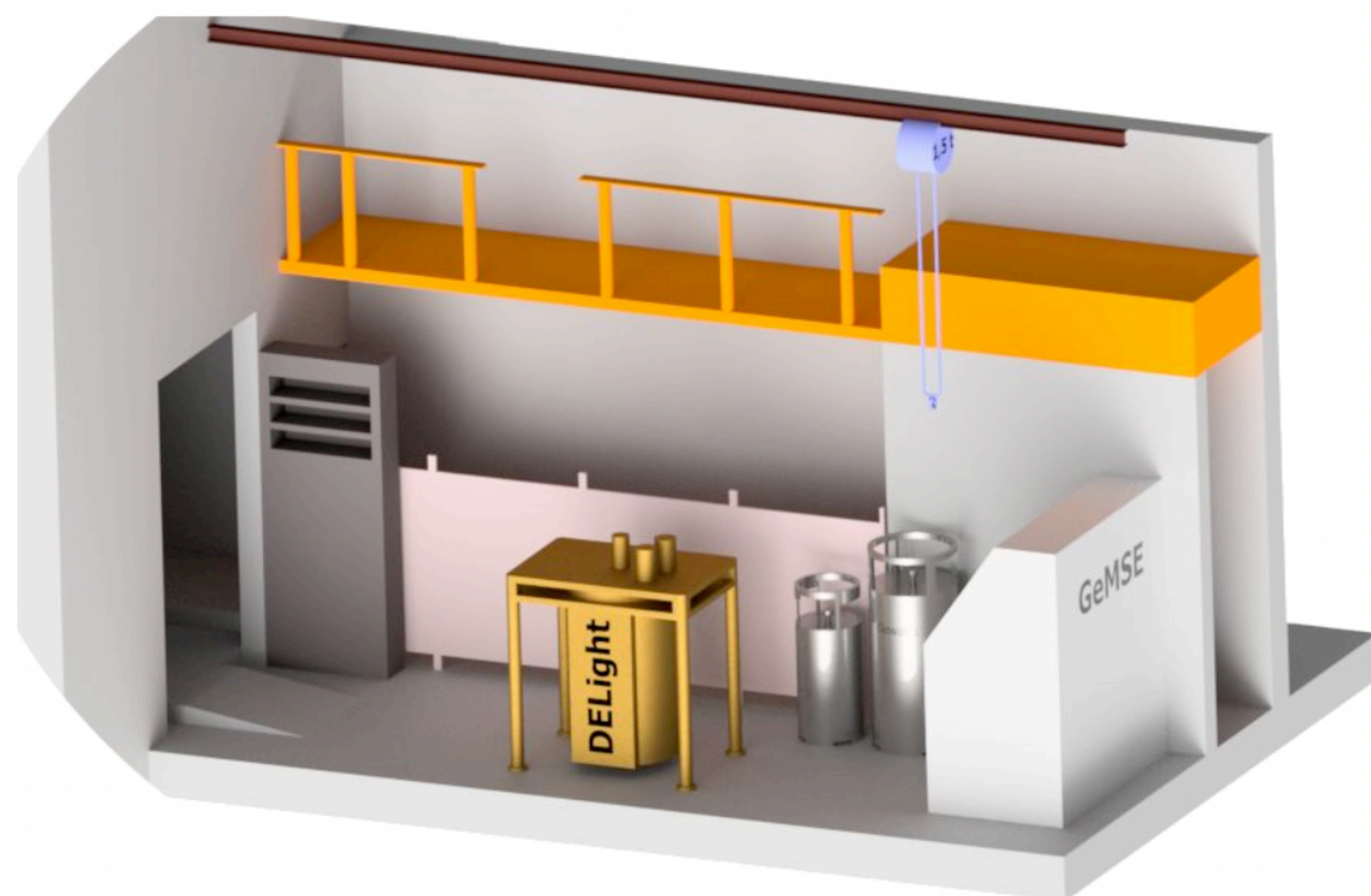
Possible DELight Sensor Design

- ➔ Large Area MMC (LAMCAL) for full surface coverage - sapphire wafer
- ➔ Potentially sub-eV resolution



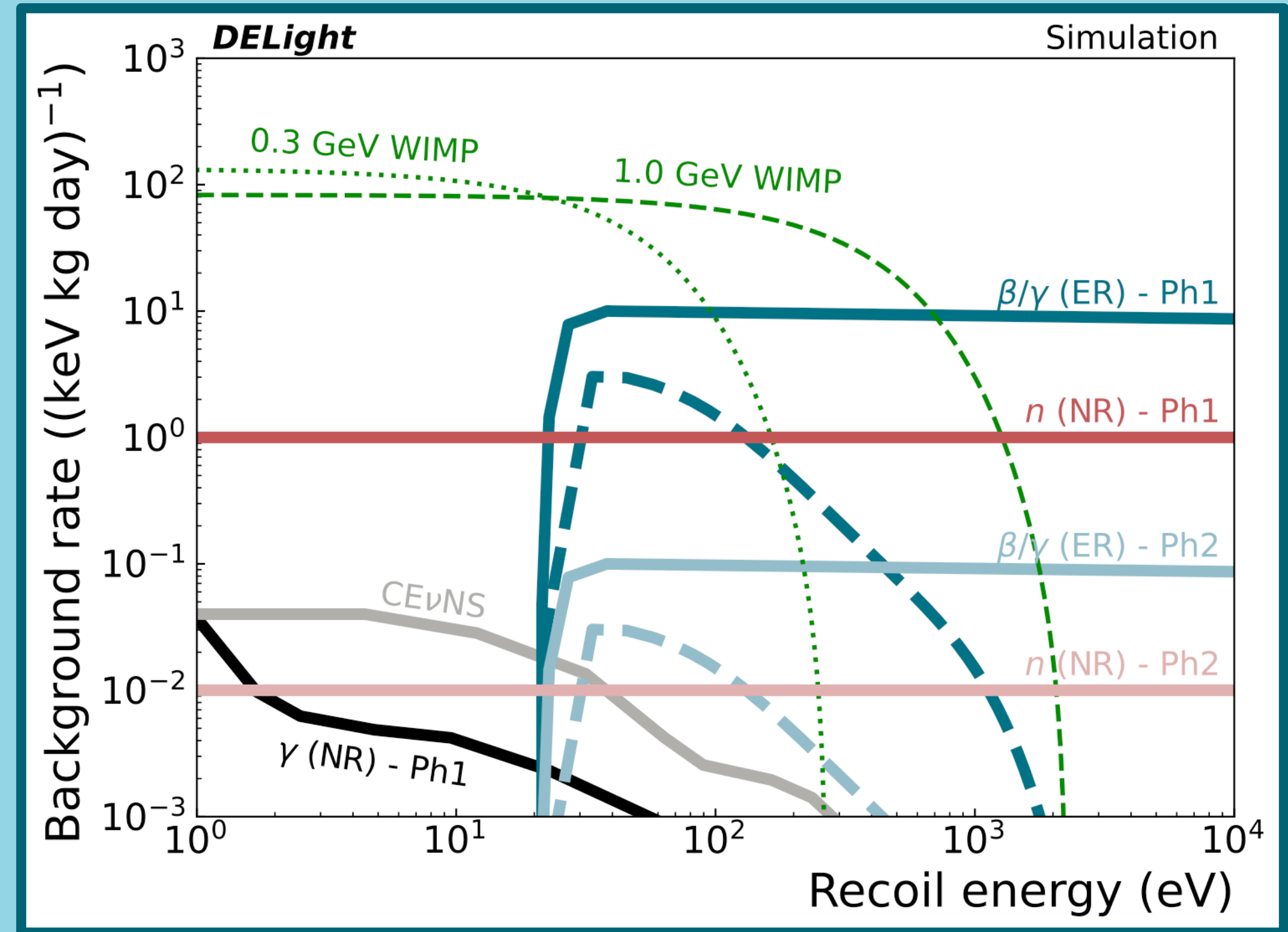
Vue-des-Alpes Underground Lab

- Shallow underground lab in Switzerland, operated by University of Freiburg
- Hosts GeMSE gamma spectrometer for material assay
- Reduced cosmic background with 230m rock overburden (620m.w.e)



Projecting Sensitivities

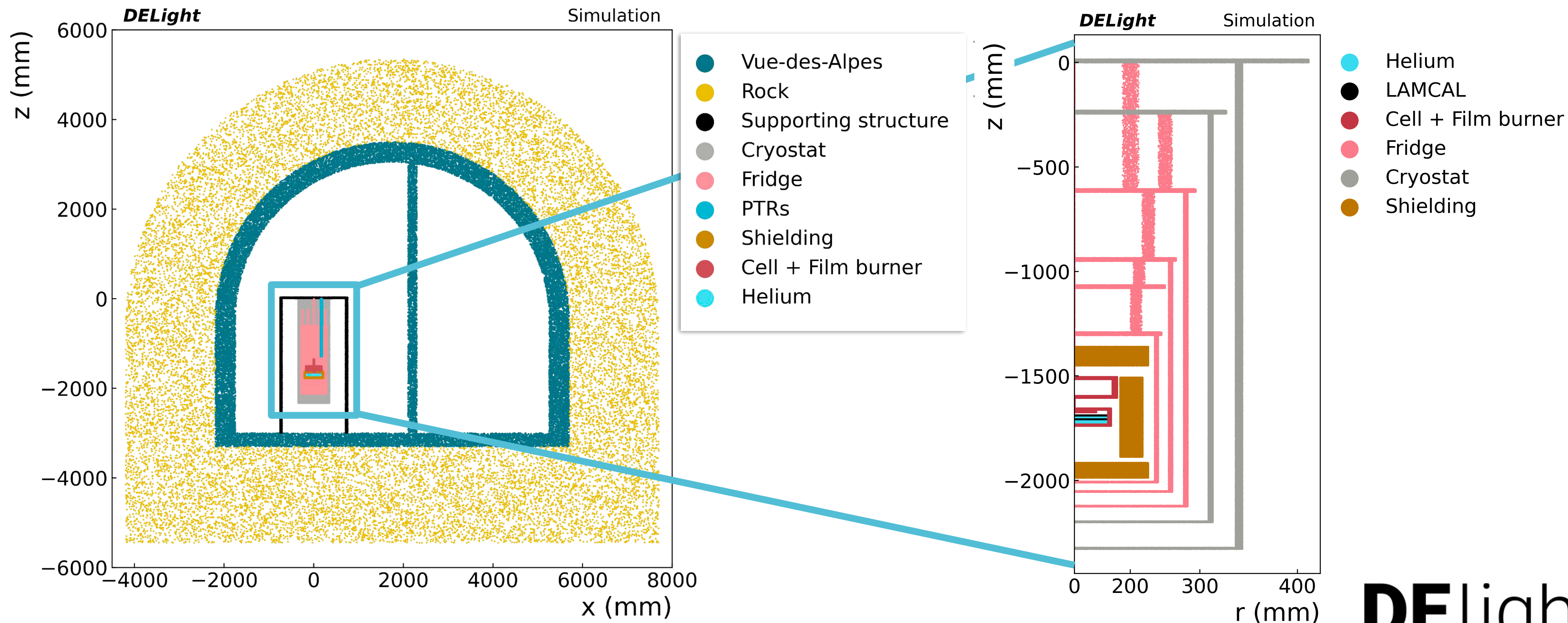
- Background model
- Signal model
- Detector response
- Limit method



Starting point: a simple assumption of a background goal



DELight Background Model: Geant4 Simulation Geometry



DELight Background Model: Background Components

→ Backgrounds are split by recoil type

→ Electron recoil (ER): distinguishable background

→ Nuclear recoil (NR): signal-like background

→ Radiogenic material contamination

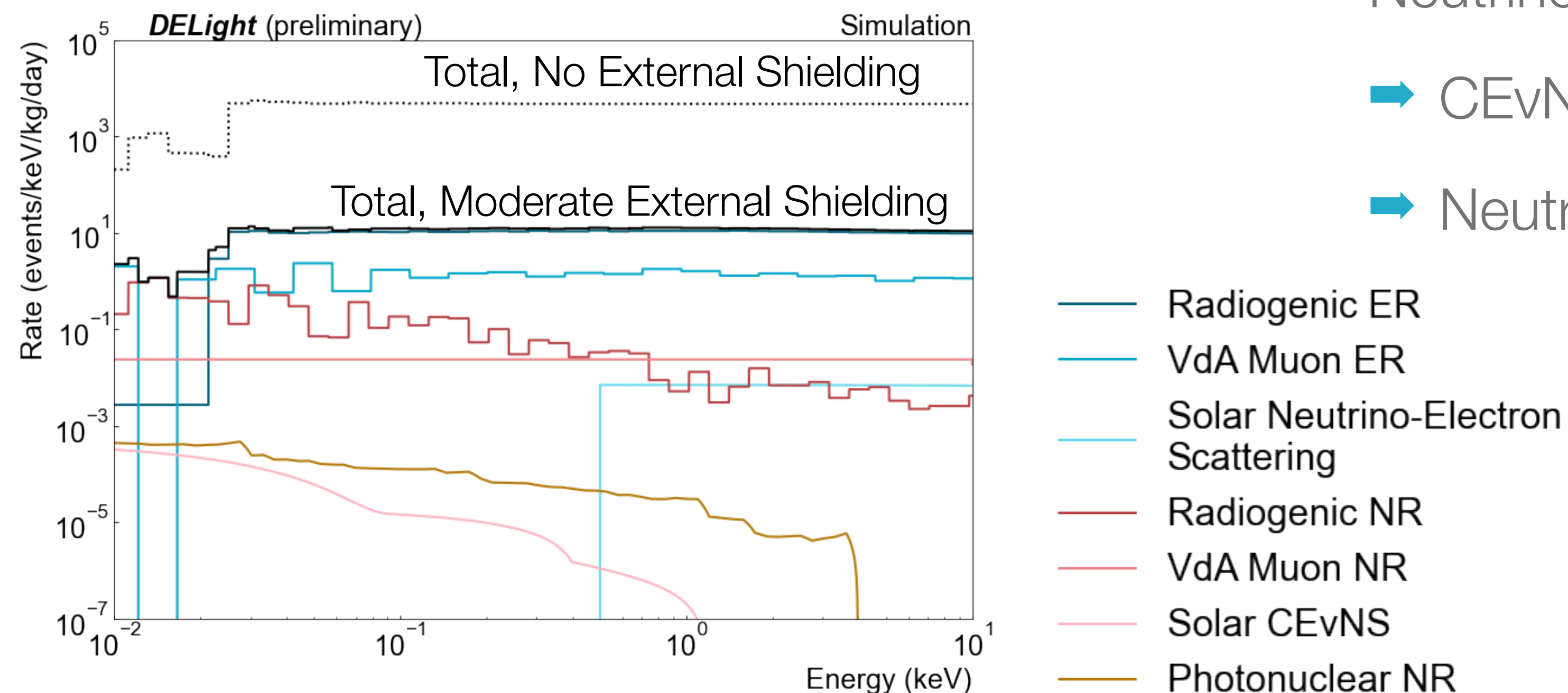
→ ^{40}K , ^{60}Co , ^{137}Cs , ^{232}Th , ^{235}U , ^{238}U

→ Cosmic muons

→ Neutrinos

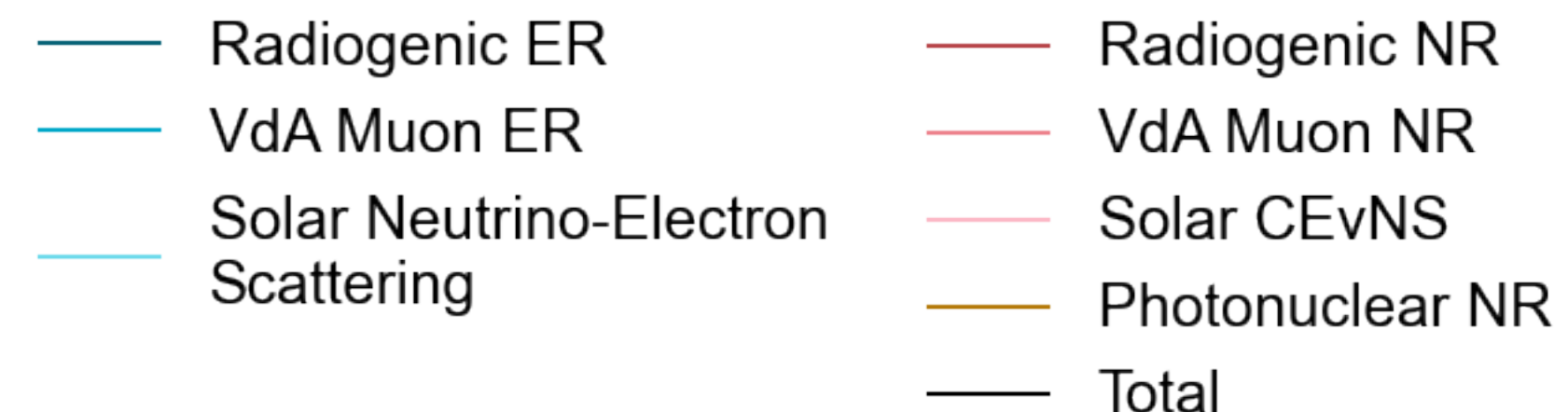
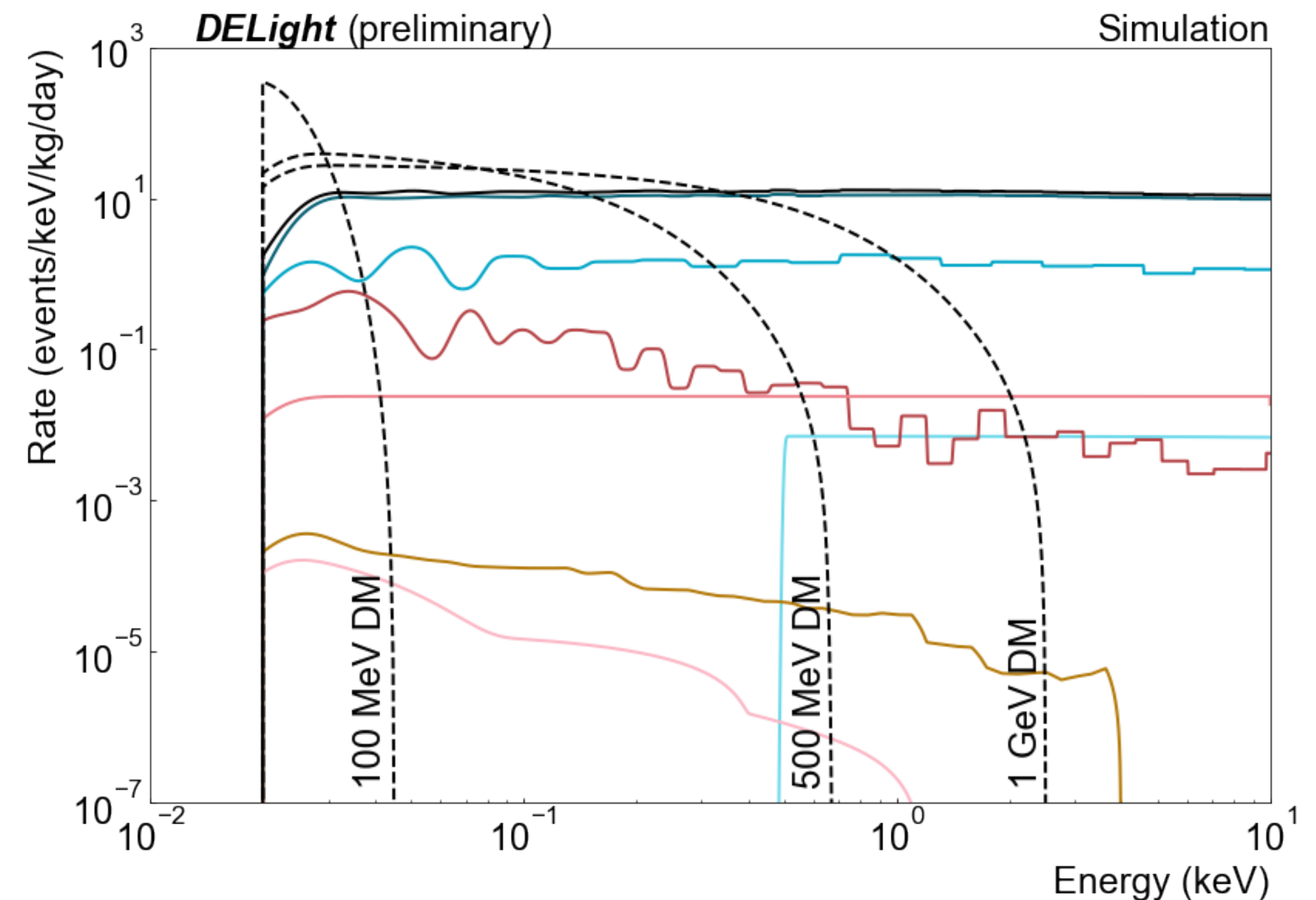
→ CEvNS

→ Neutrino-electron scattering



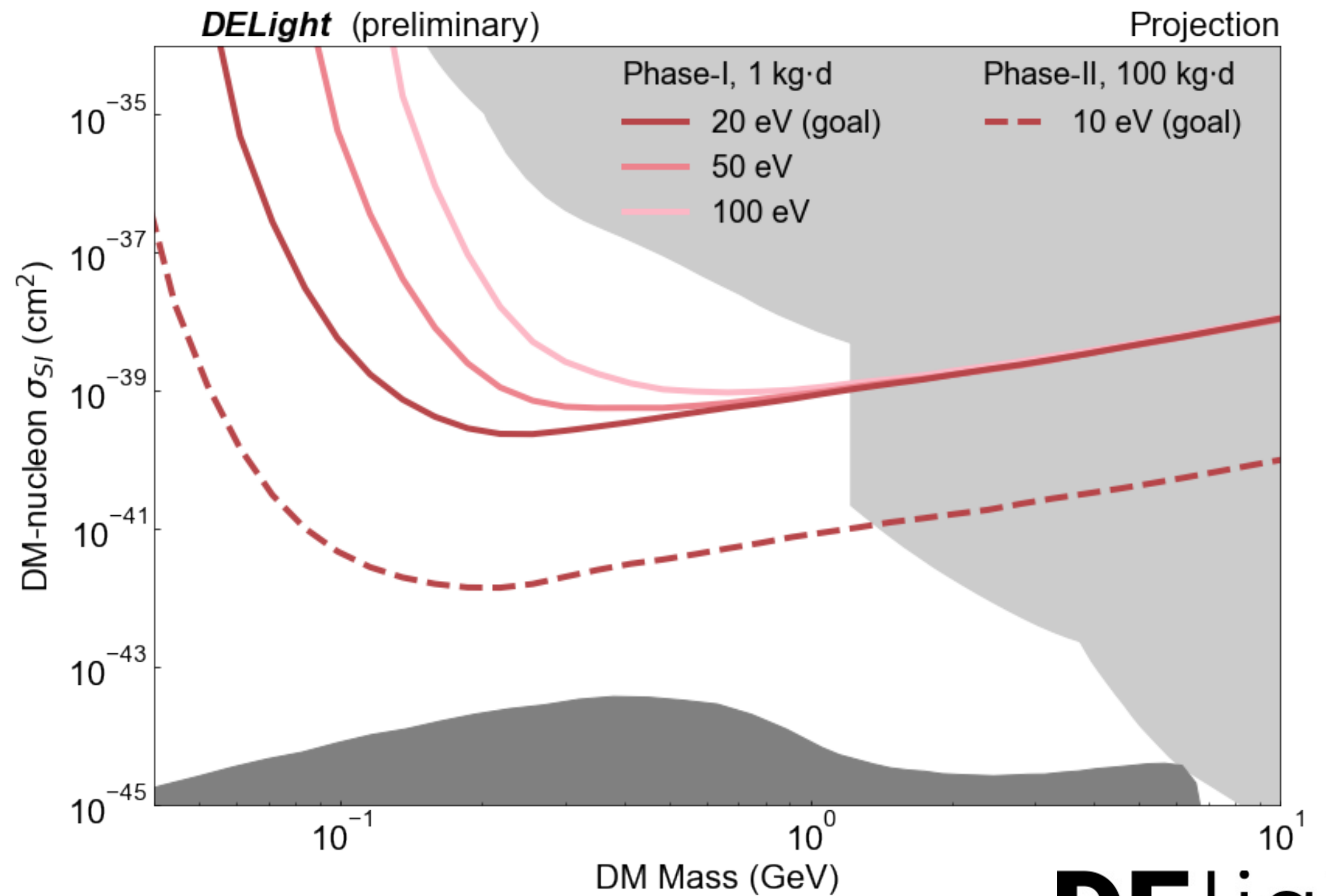
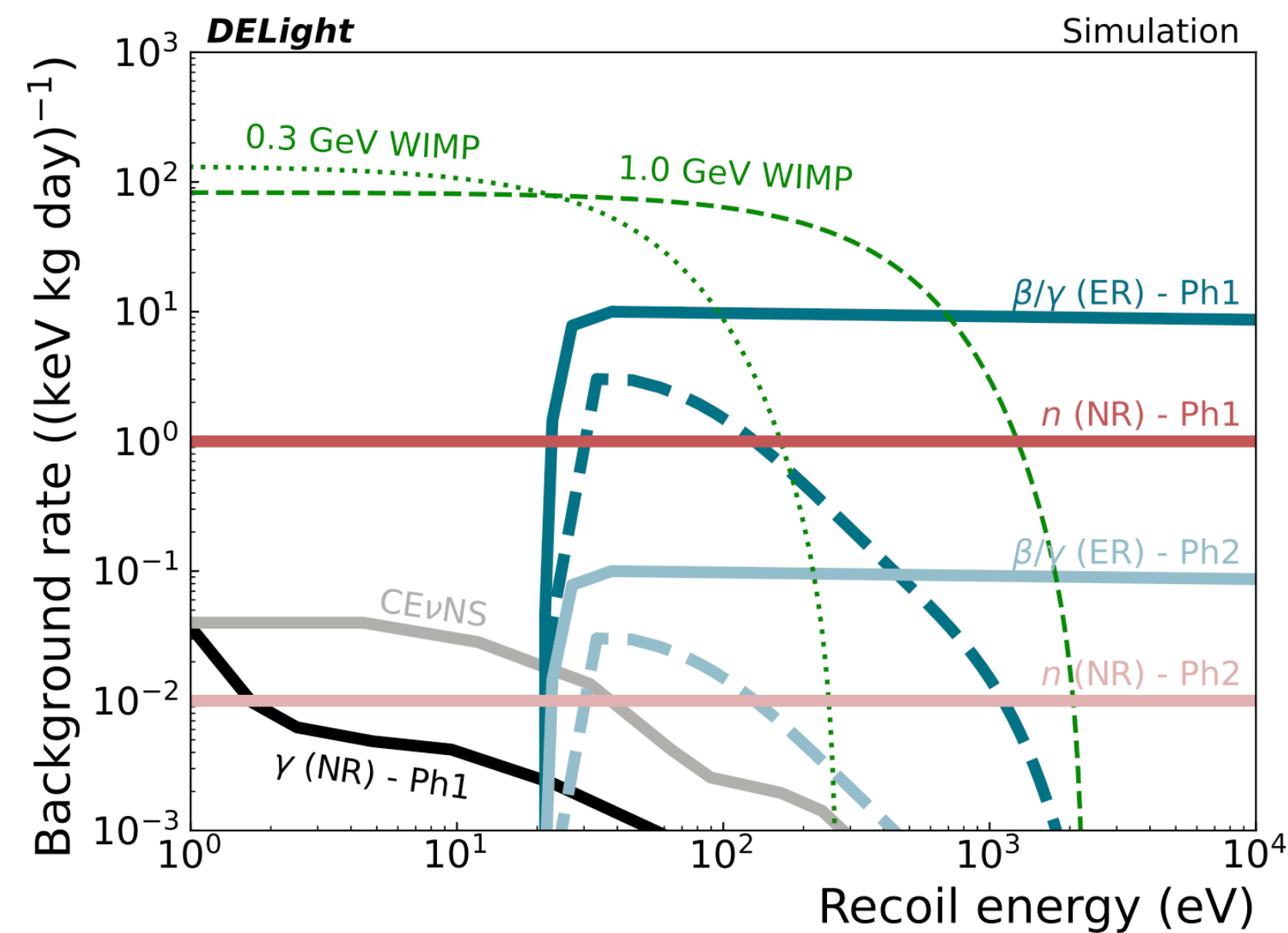
Projection Methodology

- ➔ Build background and signal models
- ➔ Apply detector response model
 - ➔ Energy resolution smearing
 - ➔ Trigger efficiency
- ➔ Profile likelihood ratio (PLR) method
 - ➔ Simulate large number of background-only experiments based on desired exposure
 - ➔ Calculate 90% upper limit on cross section for each test mass
 - ➔ Median of cross sections taken as projected sensitivity



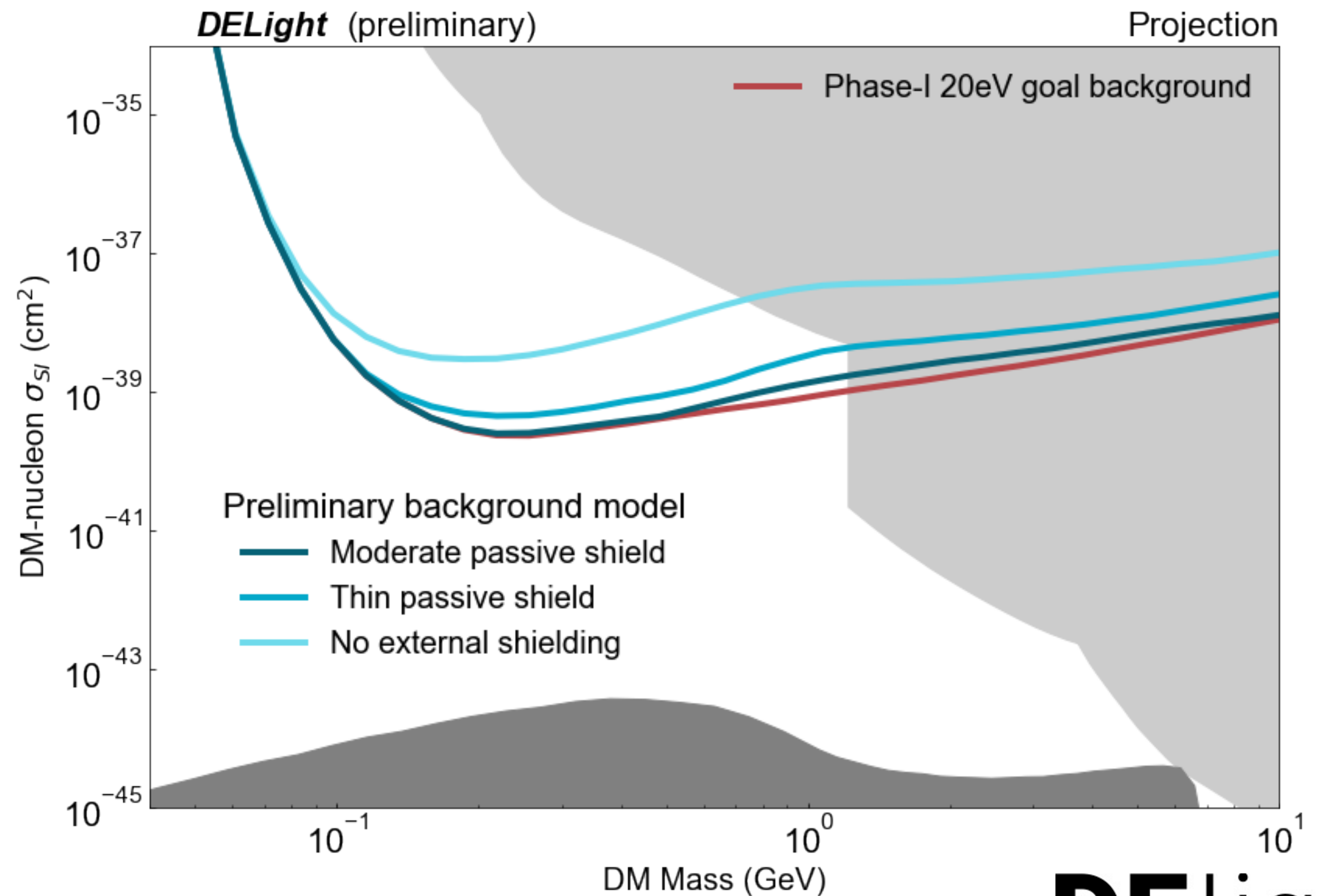
Projected Sensitivity: Threshold and Exposure

- ➔ Simple flat background model
- ➔ Studying impact of threshold and exposure

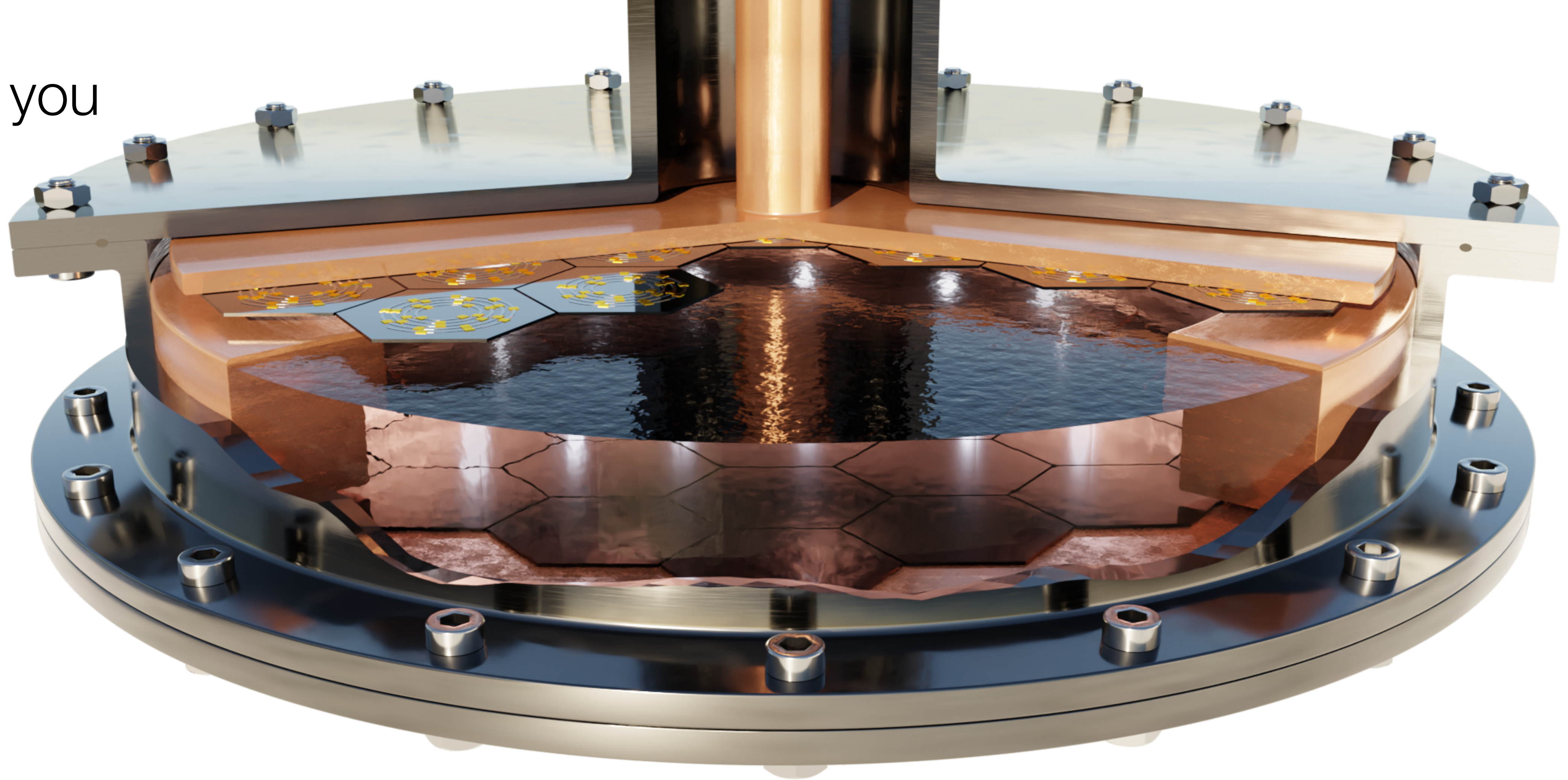


Projected Sensitivity: Background Model

- ➔ Phase-I: 1kg·d exposure
 - ➔ Realistic background model under different assumptions of external shielding
 - ➔ With moderate passive shielding - we reach the background goals
- ➔ Significant parameter space reach



Thank you

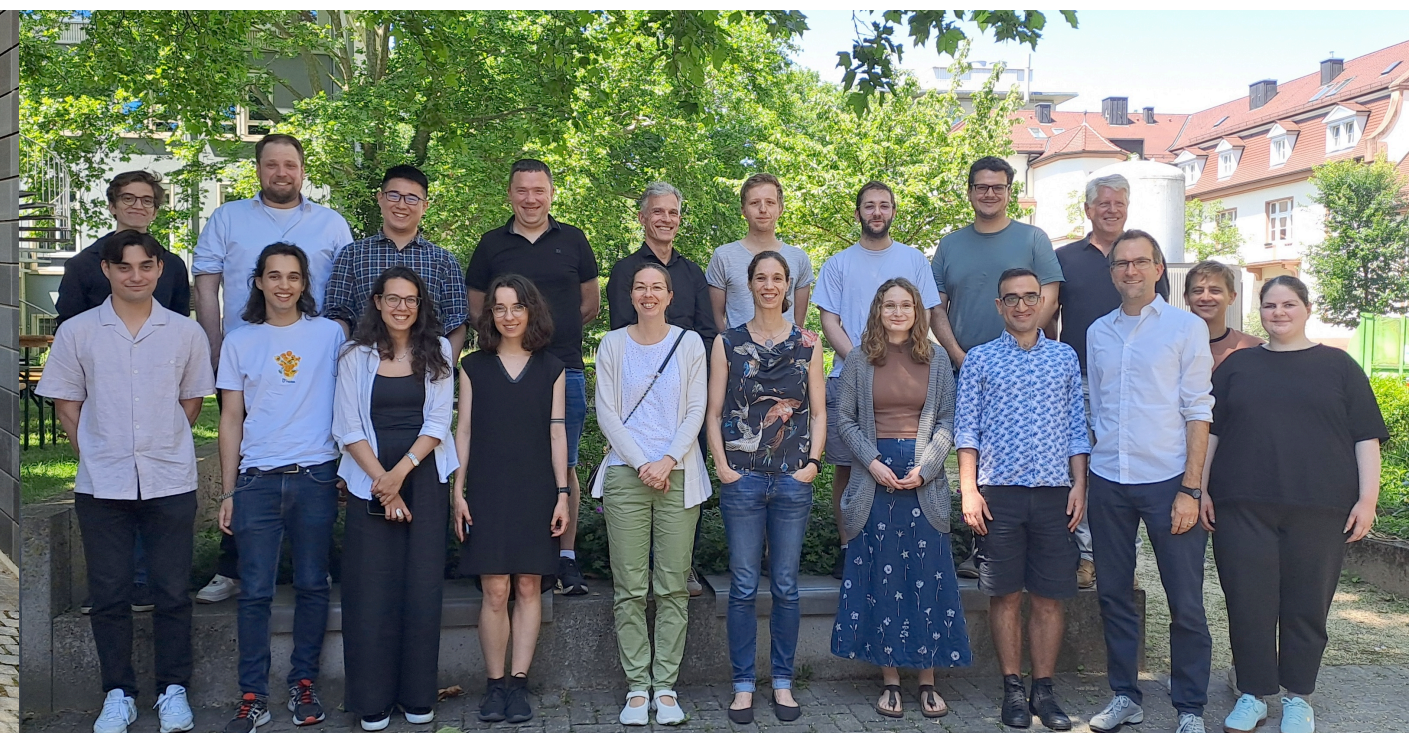


2023@HD

2024@KIT

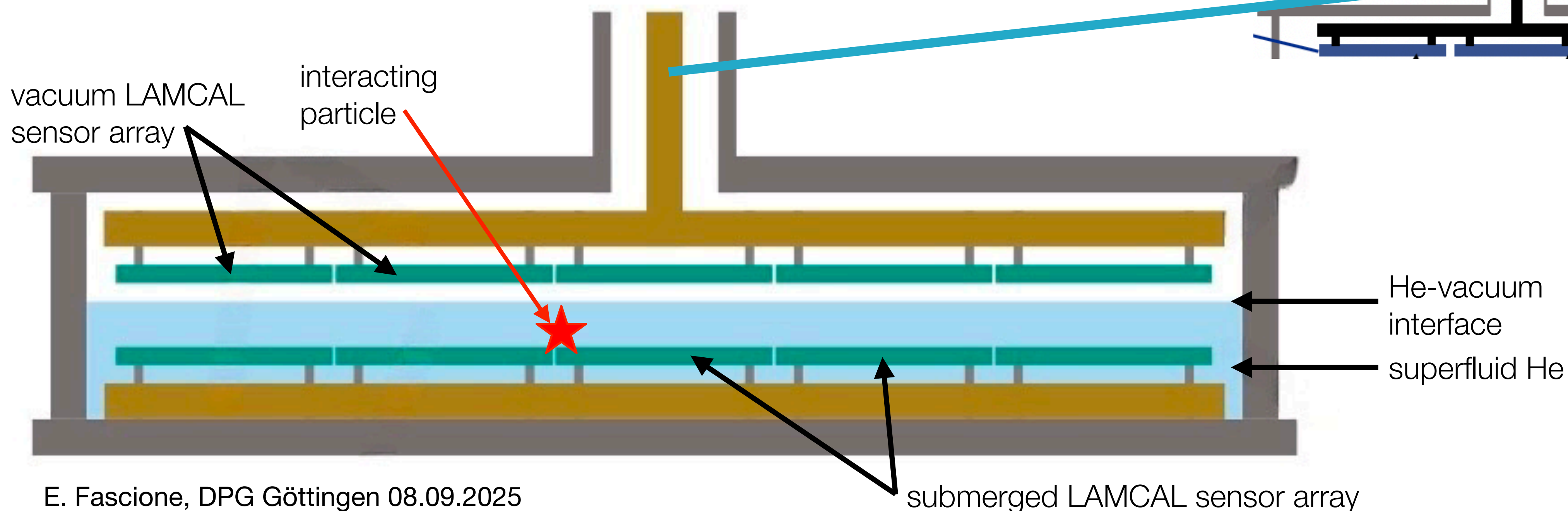
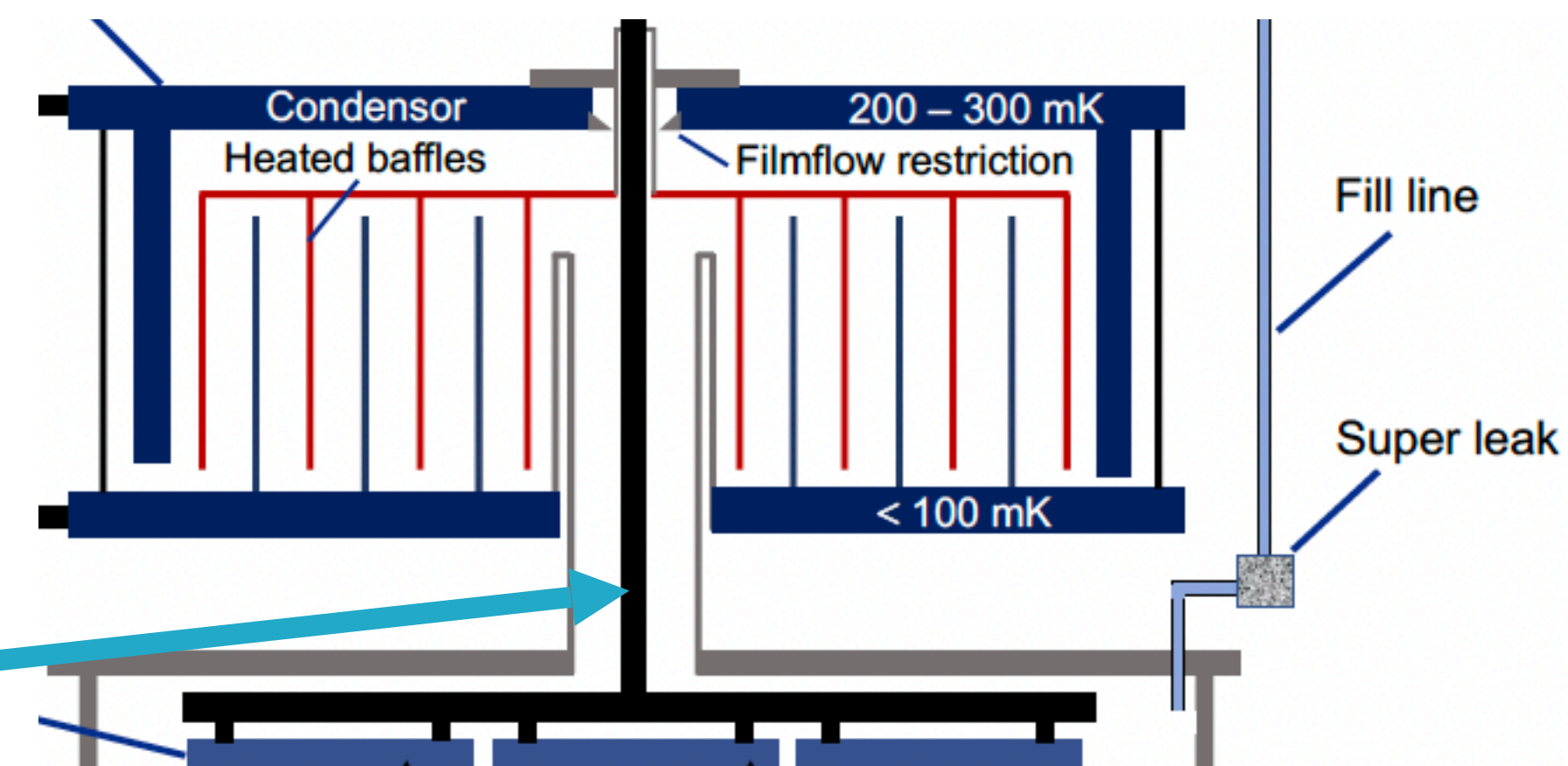
2024@HD

2025@UFR



DELight Detector - Interactions in Superfluid Helium-4

- Must keep sensors free of He film to maintain amplification factor for quasiparticle signal
- Implement a film burner



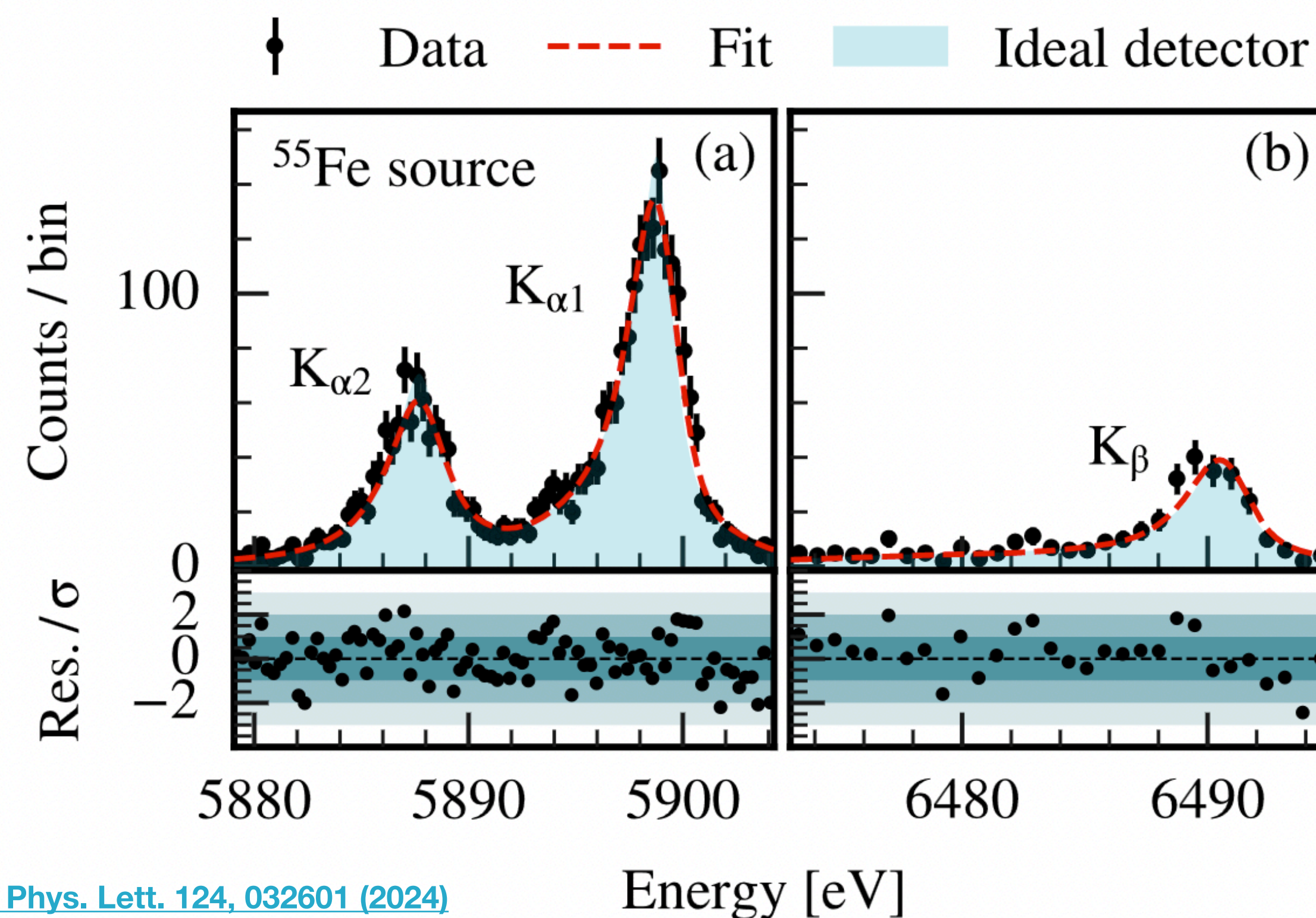
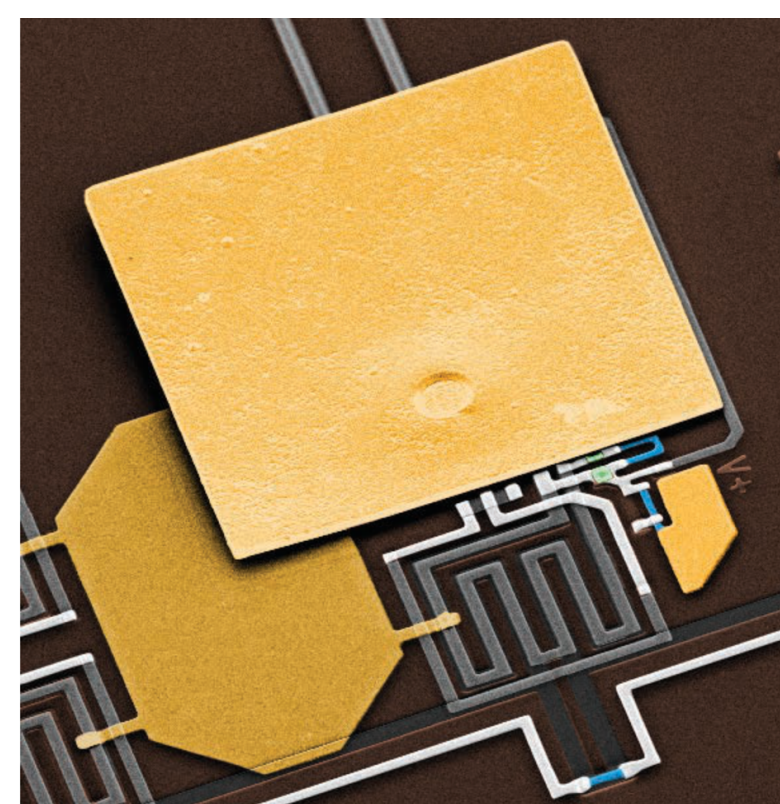
R&D - MMC Energy Resolution

➔ New MMCs achieved best resolution to date with optimum-filter analysis of ^{55}Fe calibration peaks

➔ $\Delta E_{\text{FWHM}} = 1.25 \text{ eV at } 5.9\text{keV}$

➔ Amplitude fit to K_{α} data

➔ Validated by reconstructing K_{β}

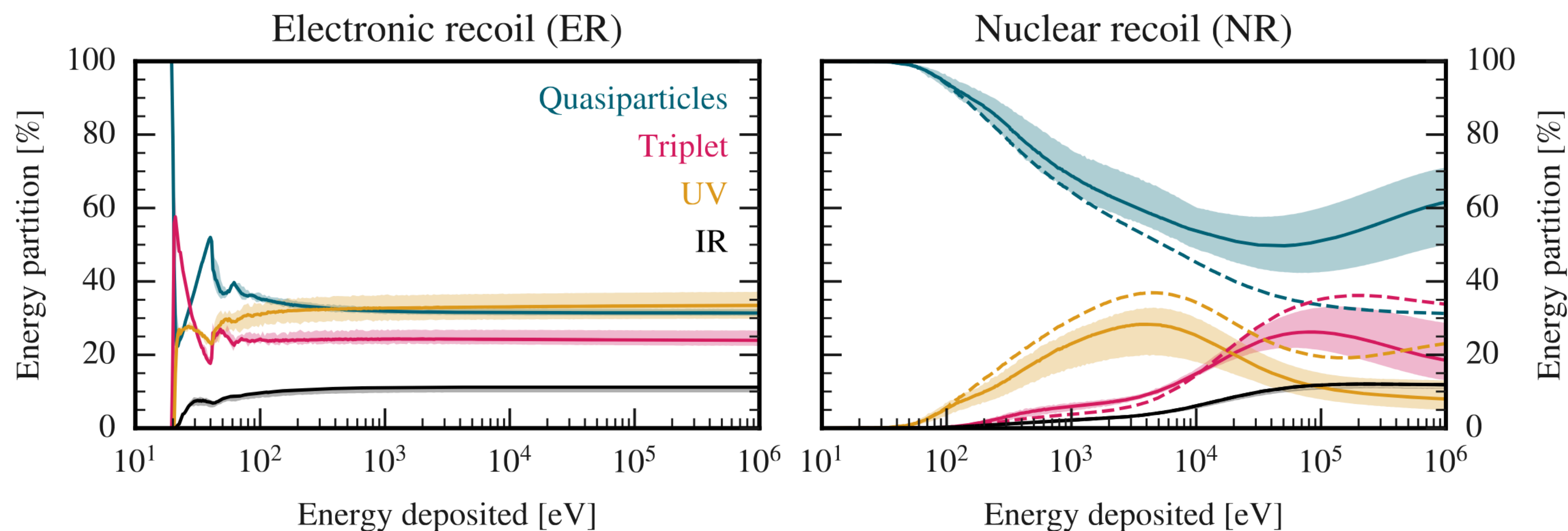


[Appl. Phys. Lett. 124, 032601 \(2024\)](#)

[Phys. Rev. D 109, 043035 \(2024\)](#)

Signal Formation in Superfluid Helium

- Developed a Monte Carlo-based approach to estimate signal partitioning
- **Signal partitioning in superfluid 4He: a Monte Carlo approach**, paper accepted by PRD, [arXiv:2410.13684](https://arxiv.org/abs/2410.13684)

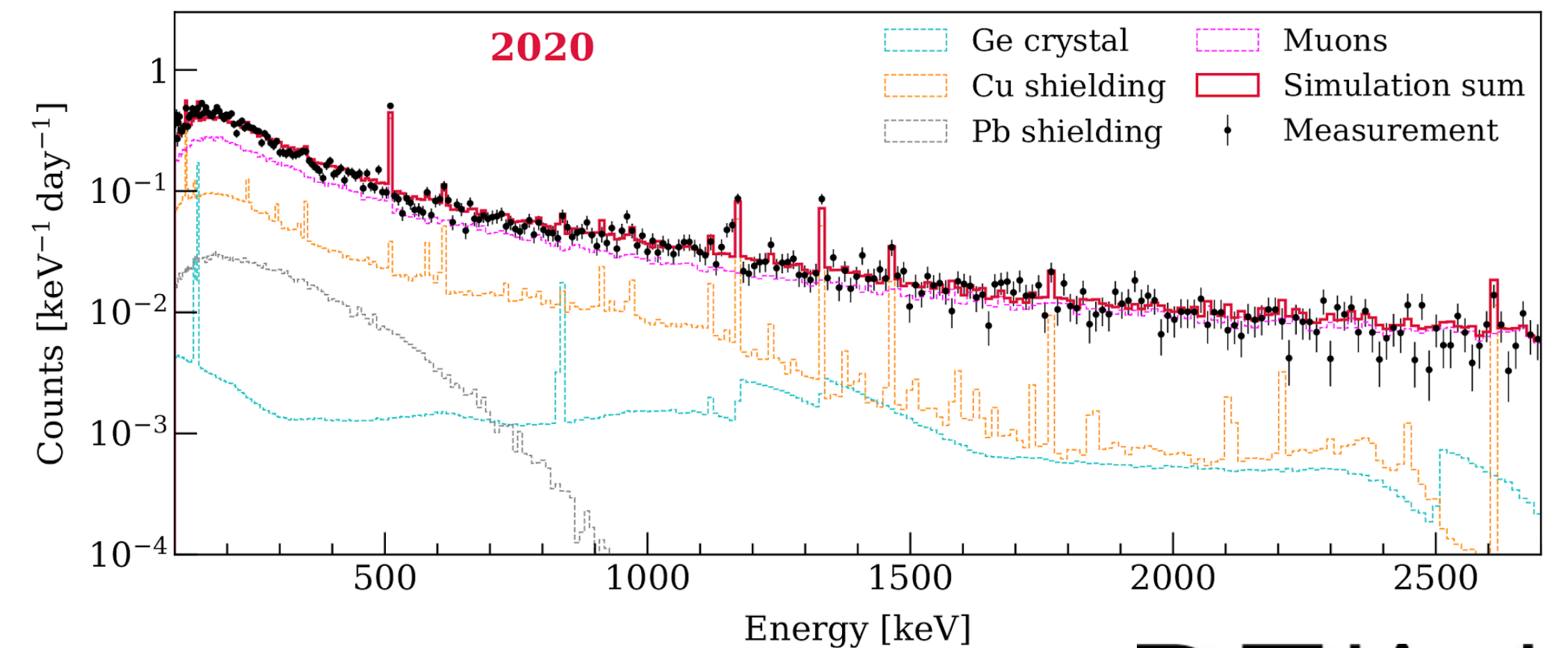
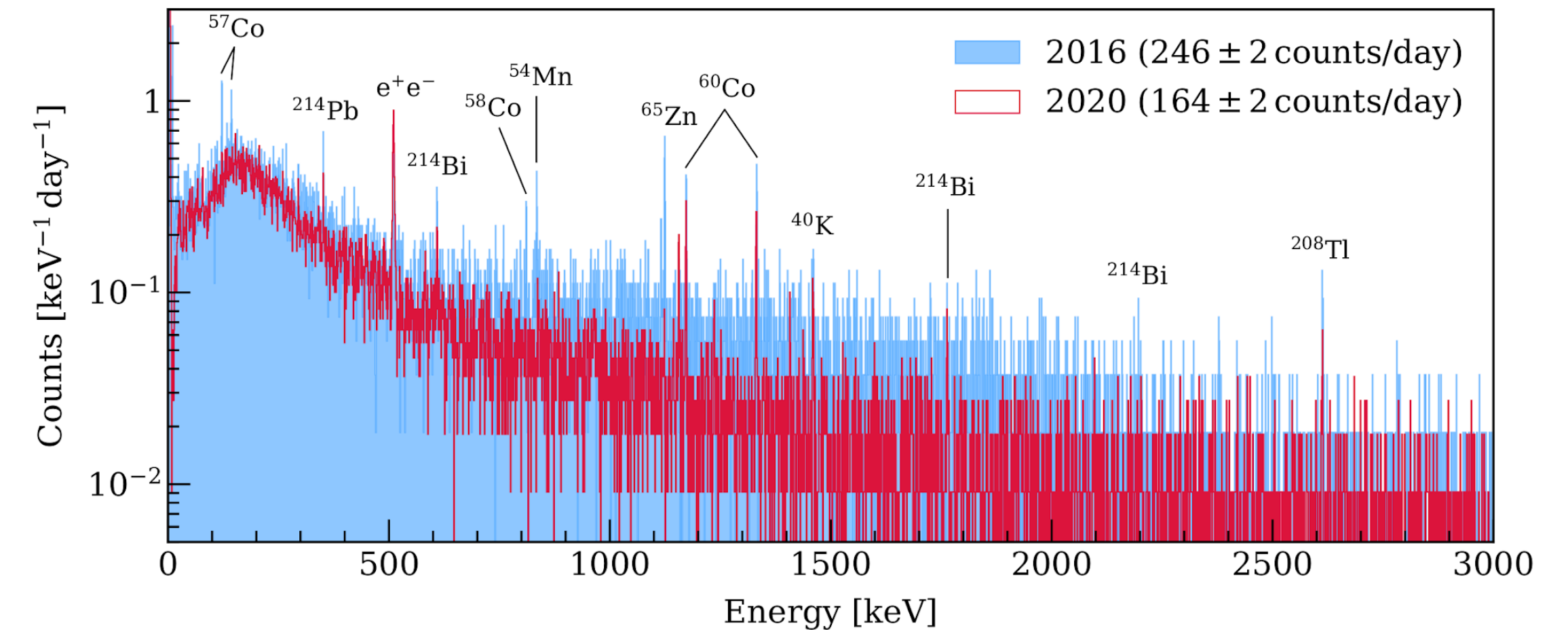
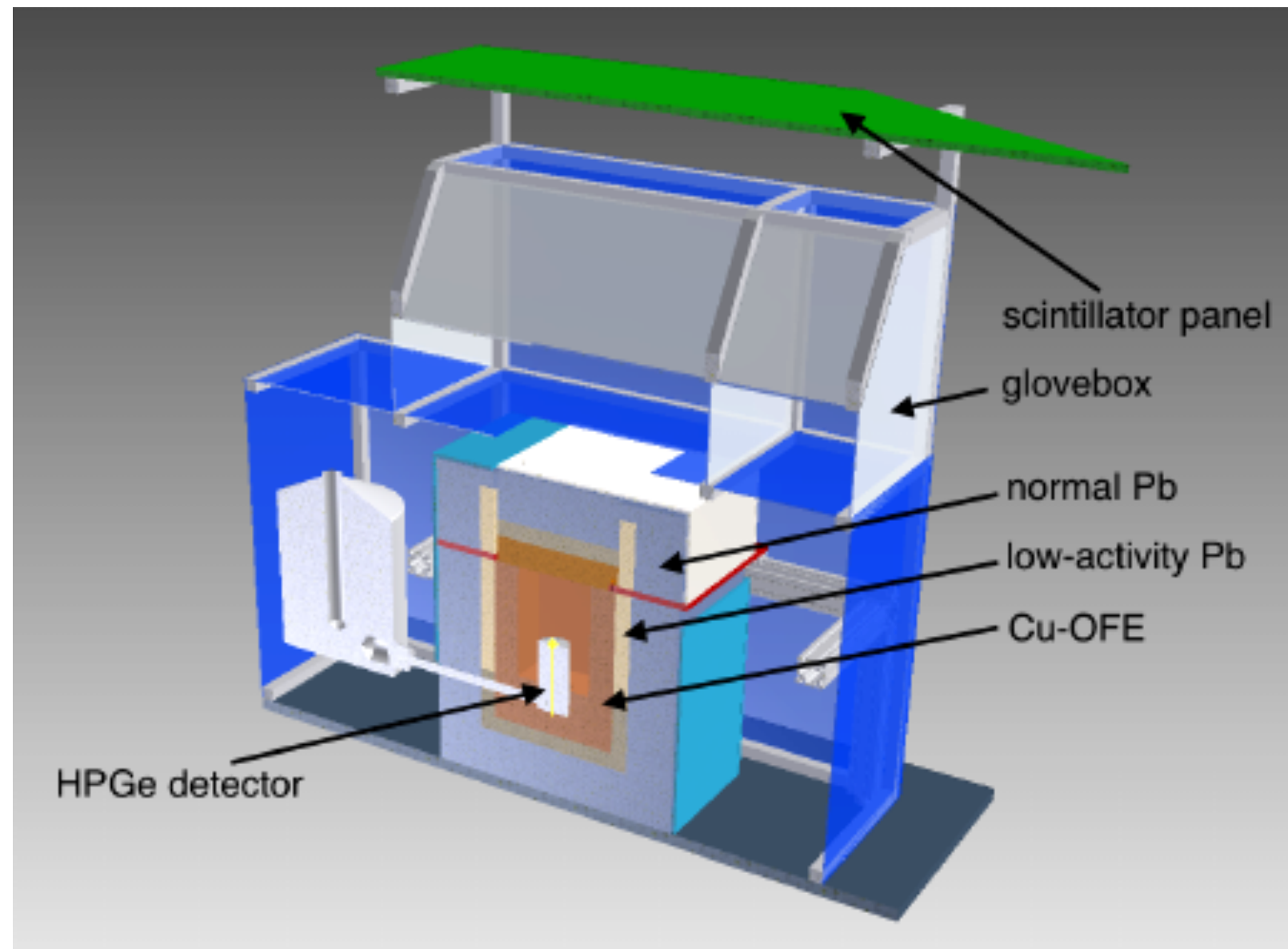


GeMSE



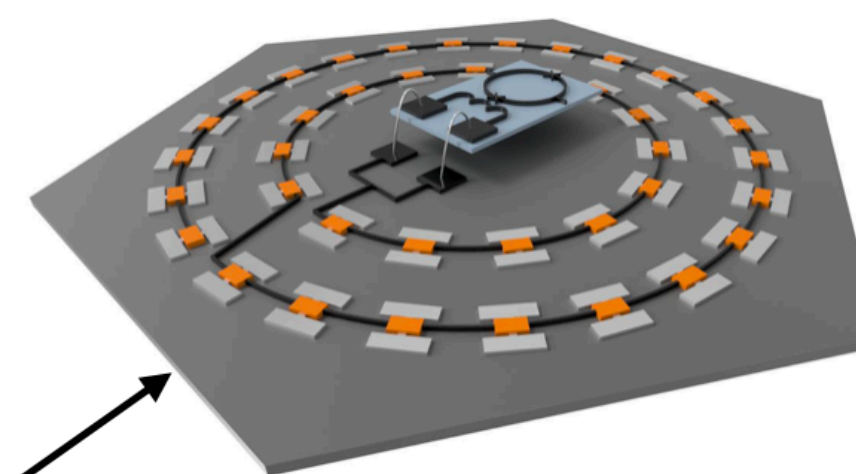
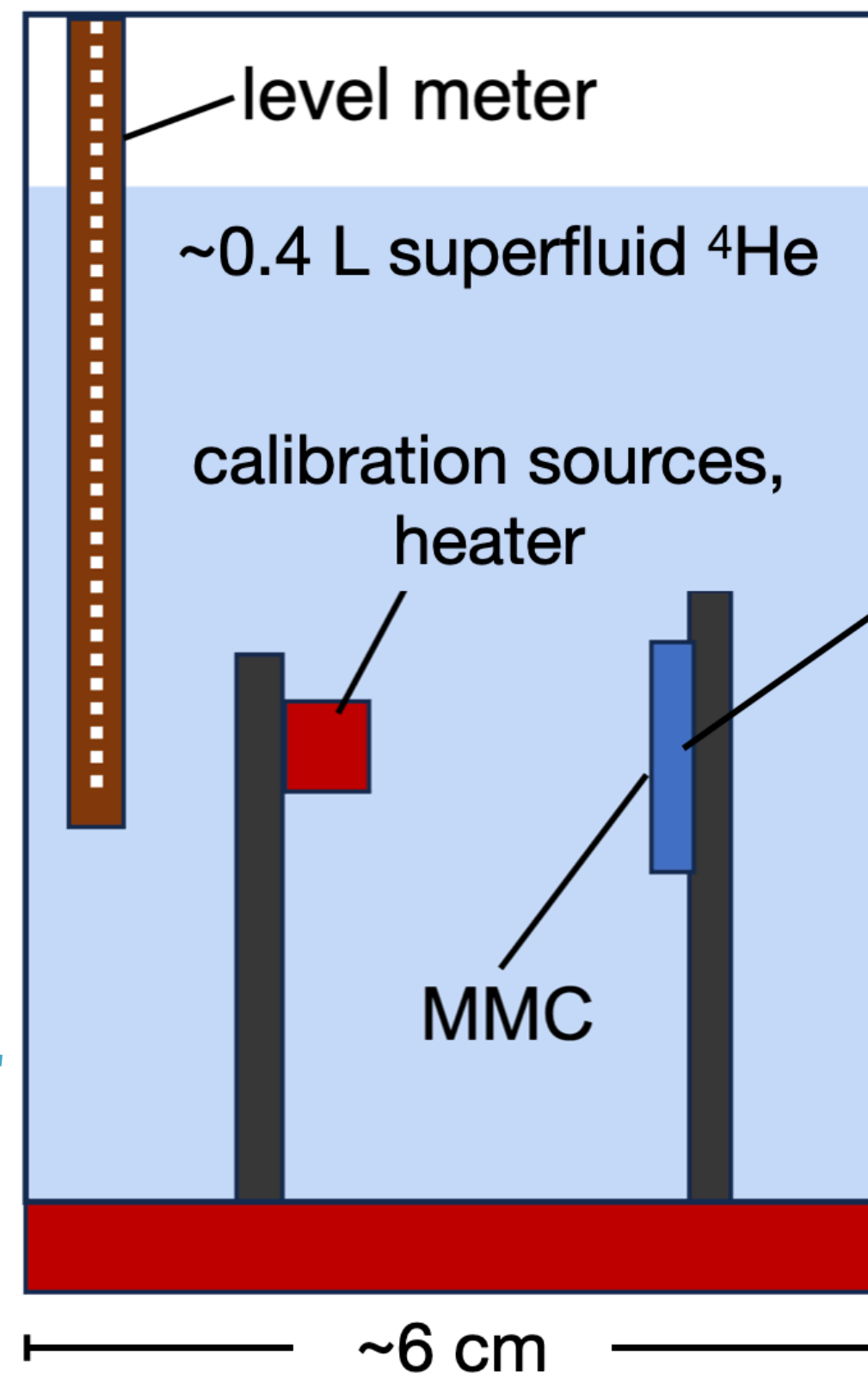
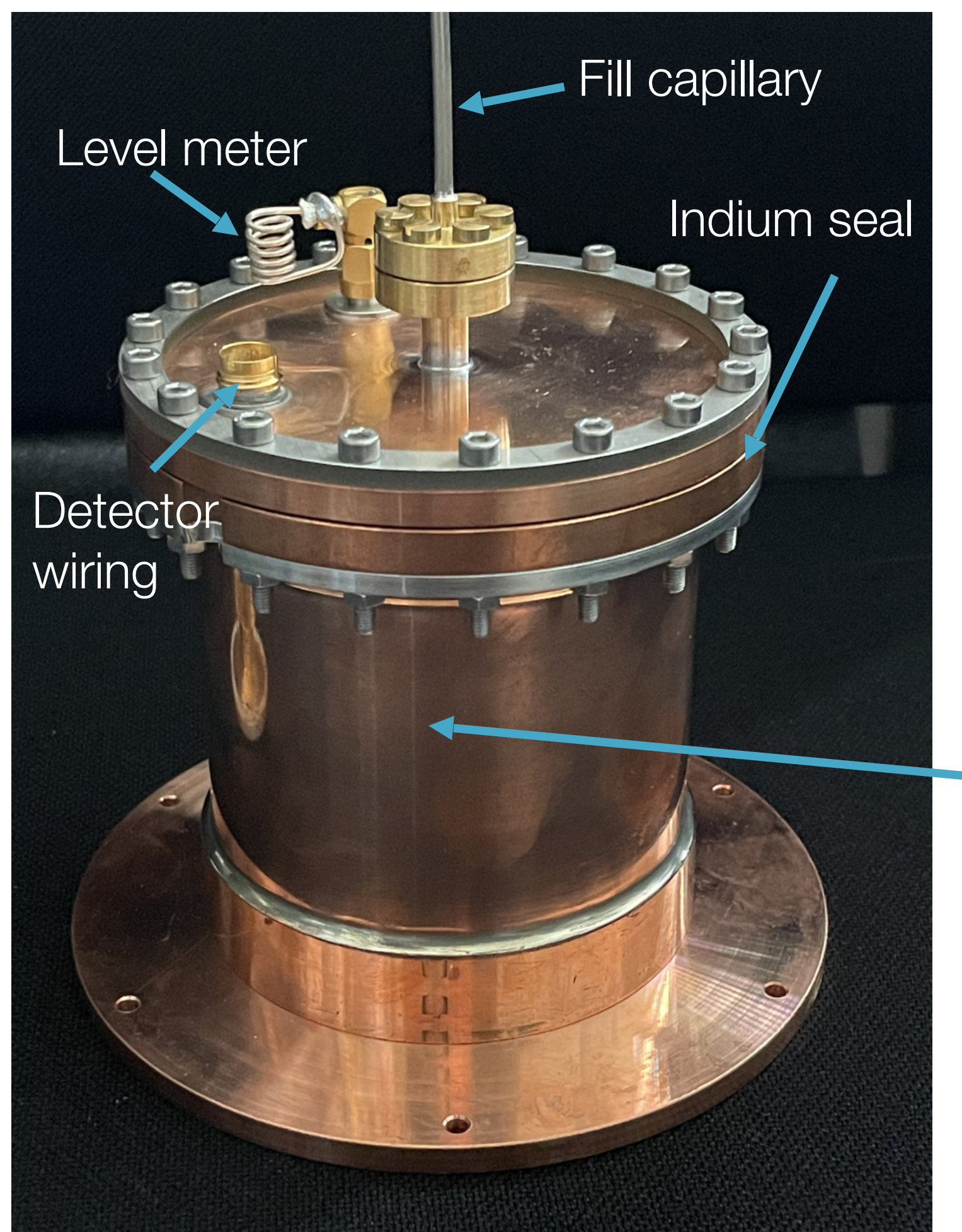
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- ➔ Low background HPGe crystal gamma spectrometer @ VdA
- ➔ Material selection campaign for experiment components



GeMSE HPGe spectrometer. JINST 17, P04005 (2022)

Small Scale “DELIGHT Demonstrator” for R&D



- ➔ MMC testing, athermal and thermal sensor characterization
- ➔ Direct quasiparticle measurements
- ➔ Background modelling
- ➔ DAQ
- ➔ Event reconstruction