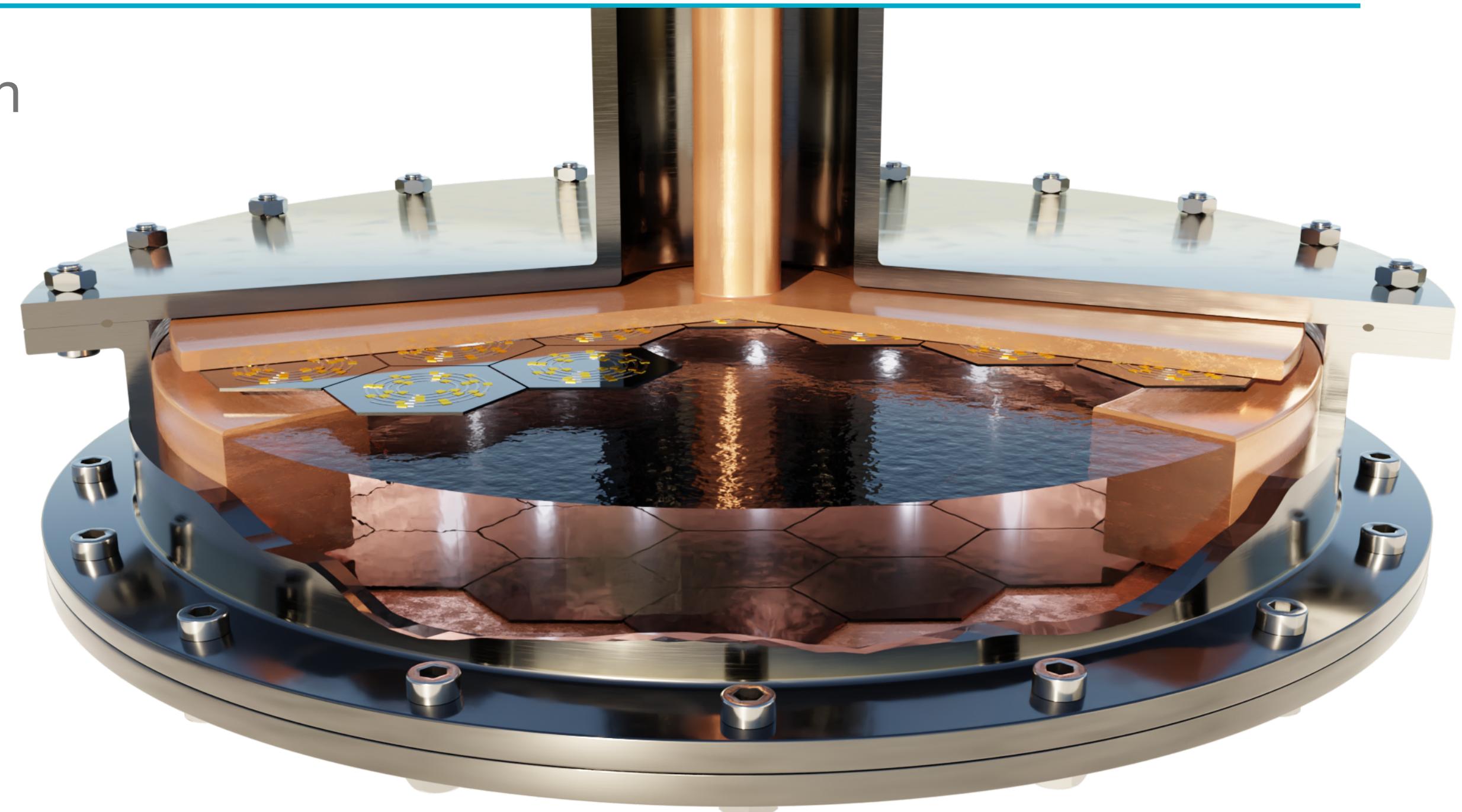
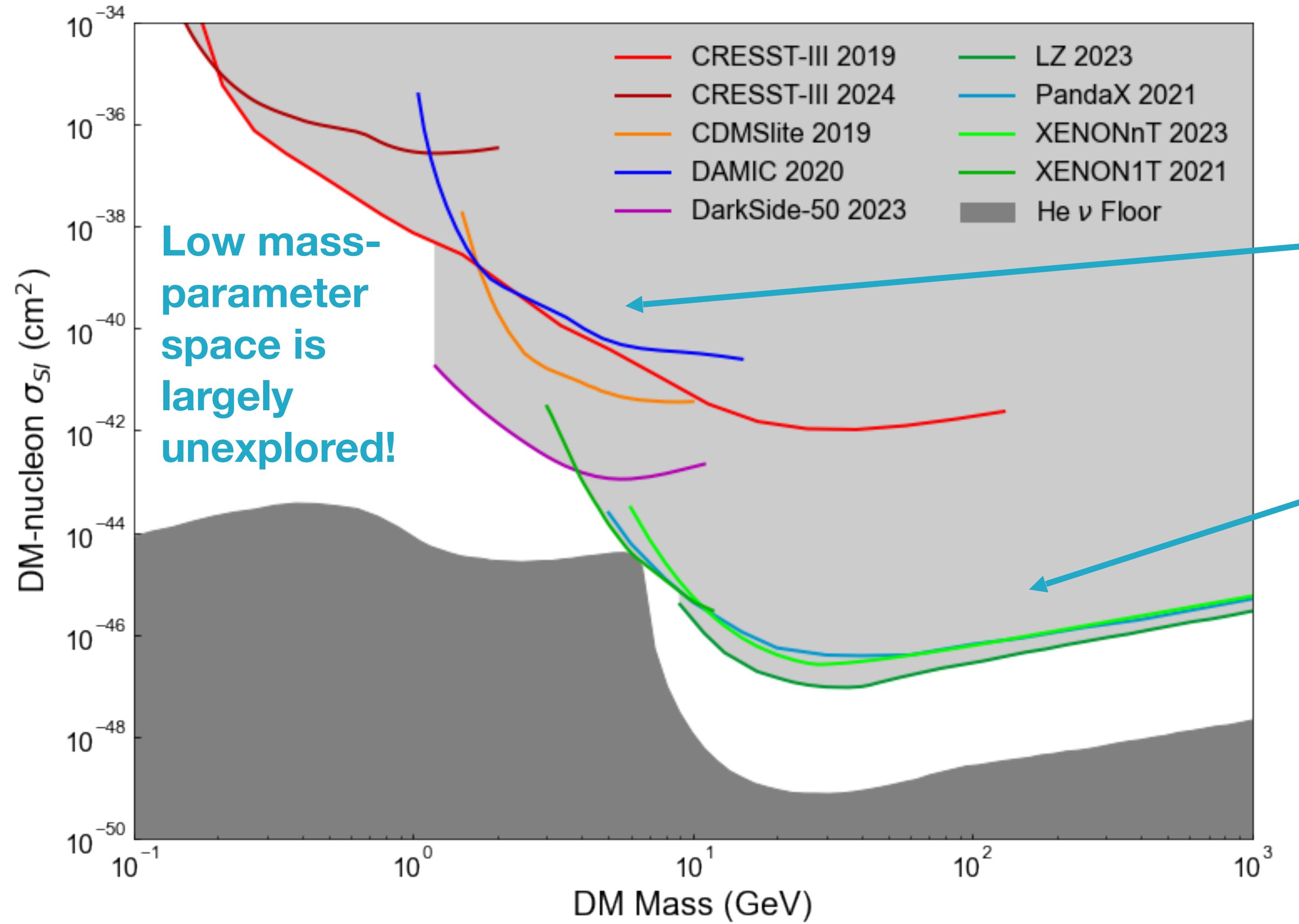


The Projected Sensitivity of the DELight Experiment

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



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

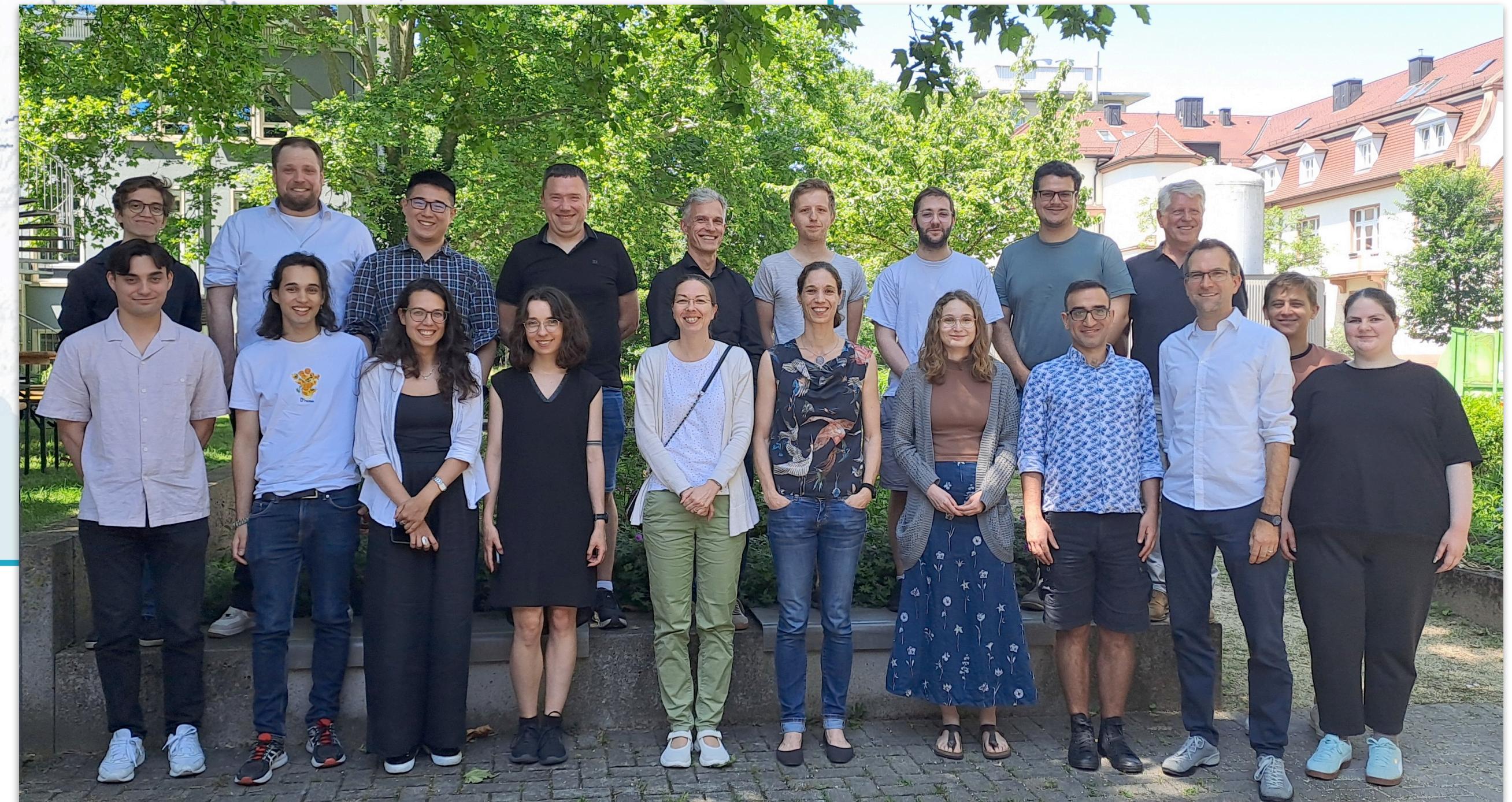


UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

The DELight Collaboration



An upcoming light dark matter search using superfluid helium-4



DElight



The DELight Collaboration



An upcoming light dark matter search using superfluid helium-4

Upcoming talk by Francesco Toschi:
Shaping DELight: signal propagation in superfluid helium-4

T10.6 15:30

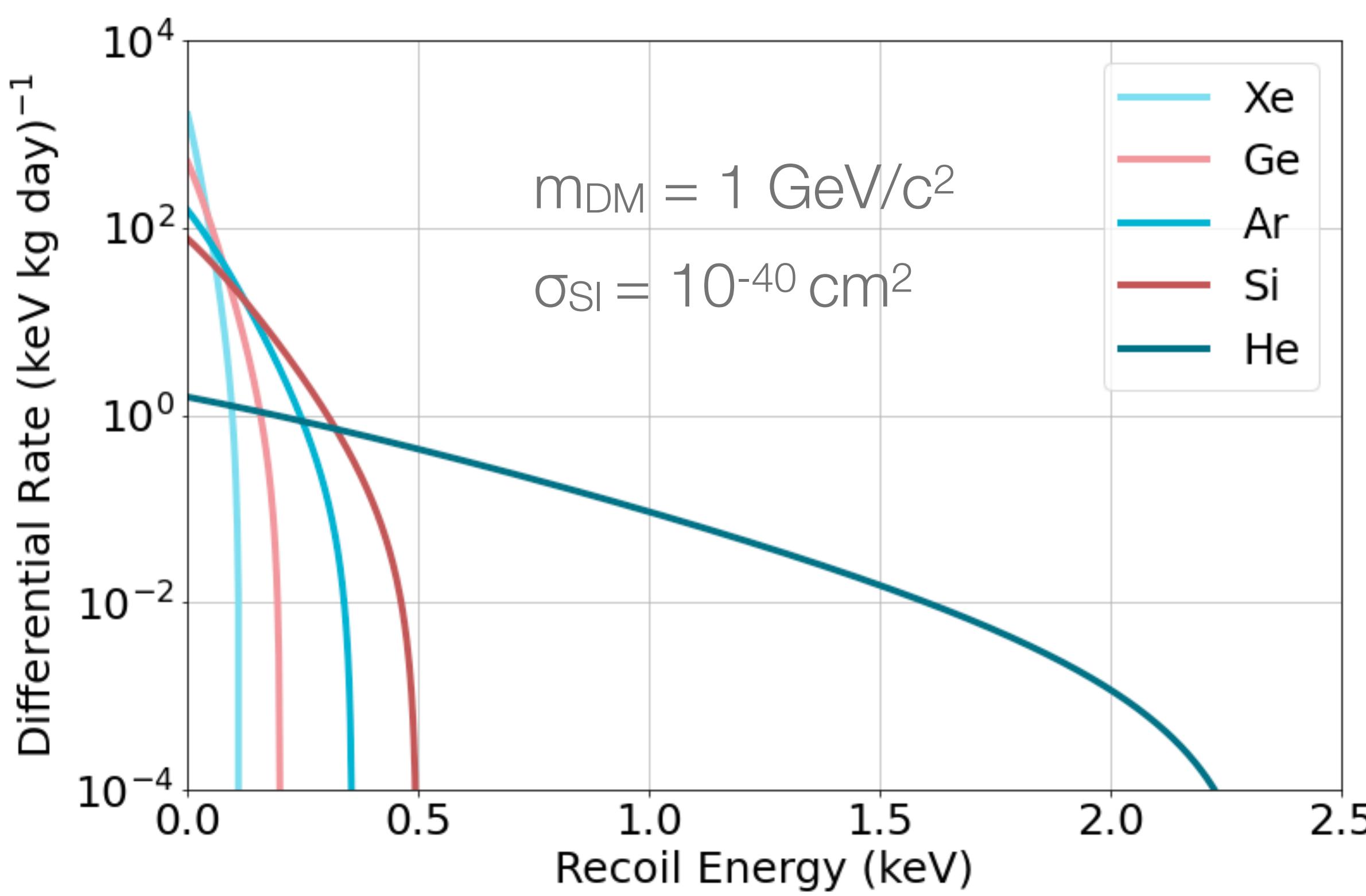
Upcoming talk by Axel Brunold:
Towards dark matter detection with superfluid Helium: First results from the DELight Demonstrator

T10.7 15:45

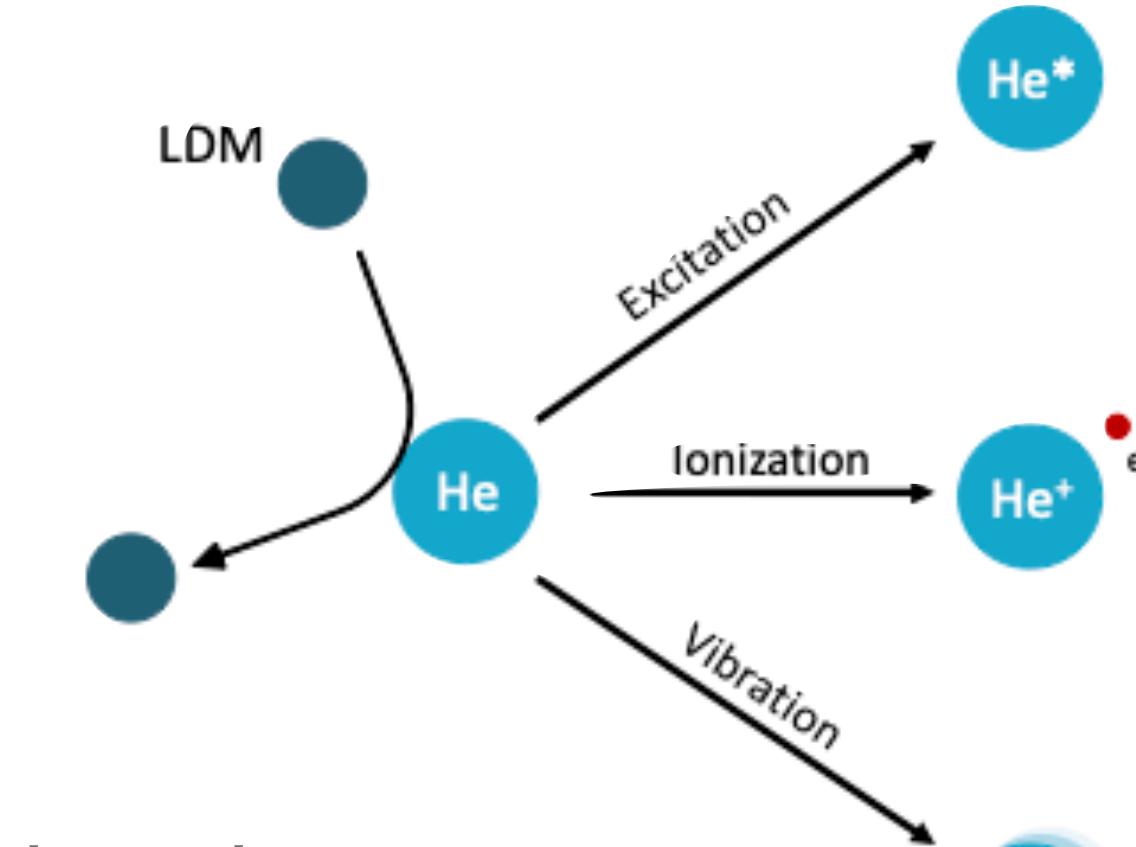


Superfluid Helium-4 Target

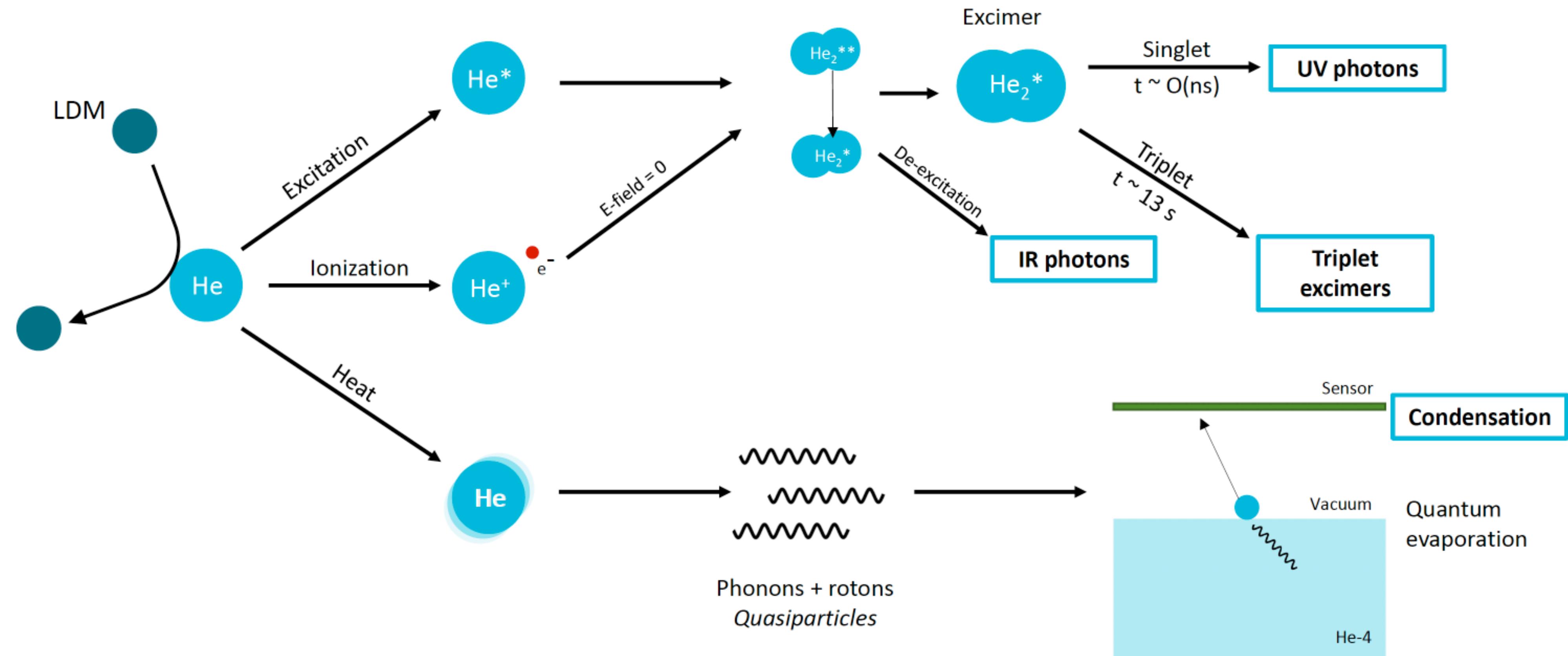
→ Light nucleus ideal for LDM search



- No intrinsic long-lived backgrounds
- Contaminants freeze-out
- Inexpensive
- Scalable
- Multiple signals:
- ER/NR discrimination

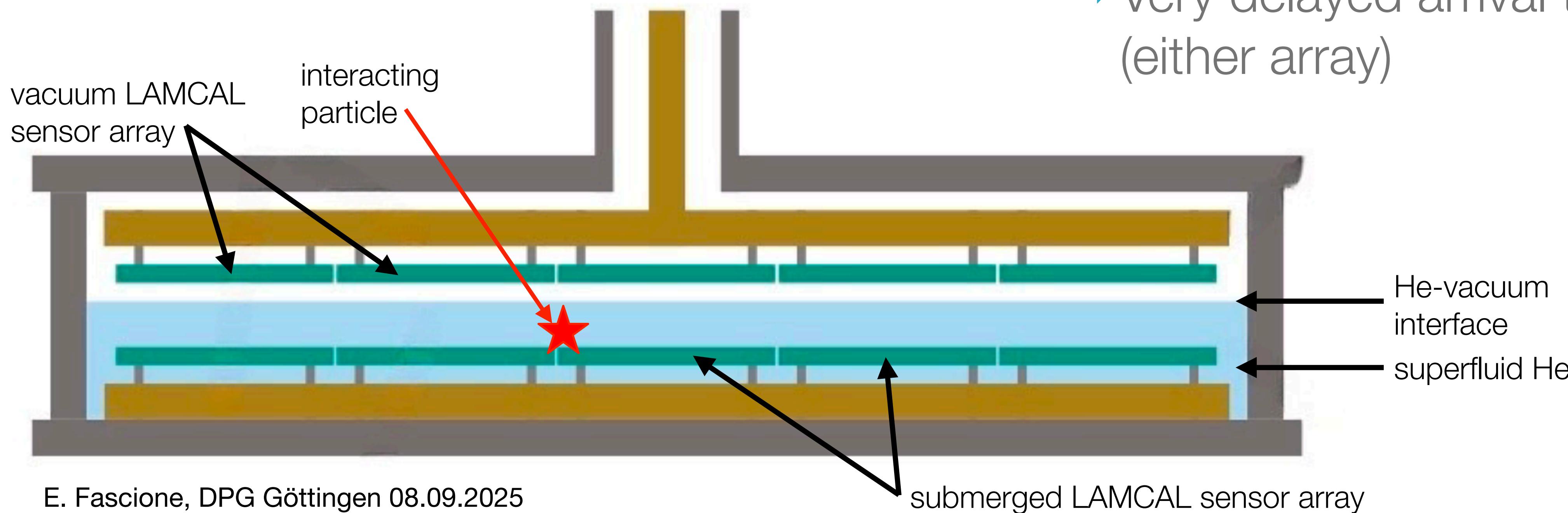


Signals in Superfluid He-4



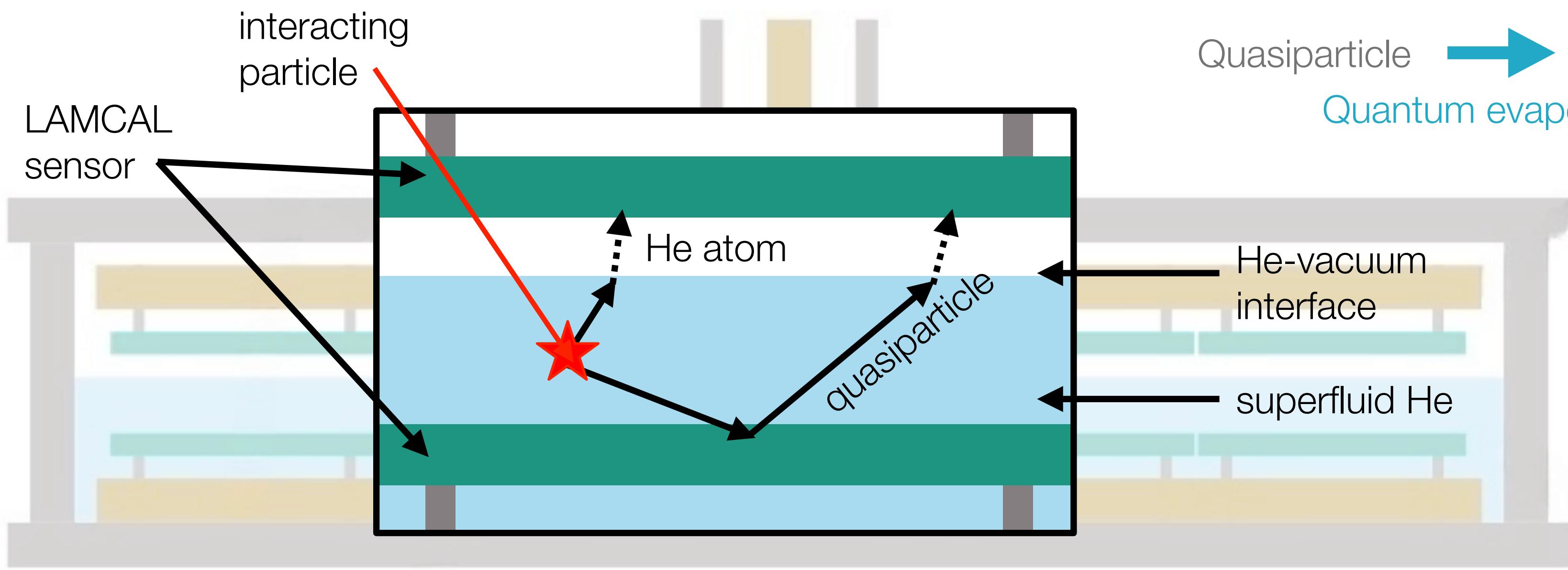
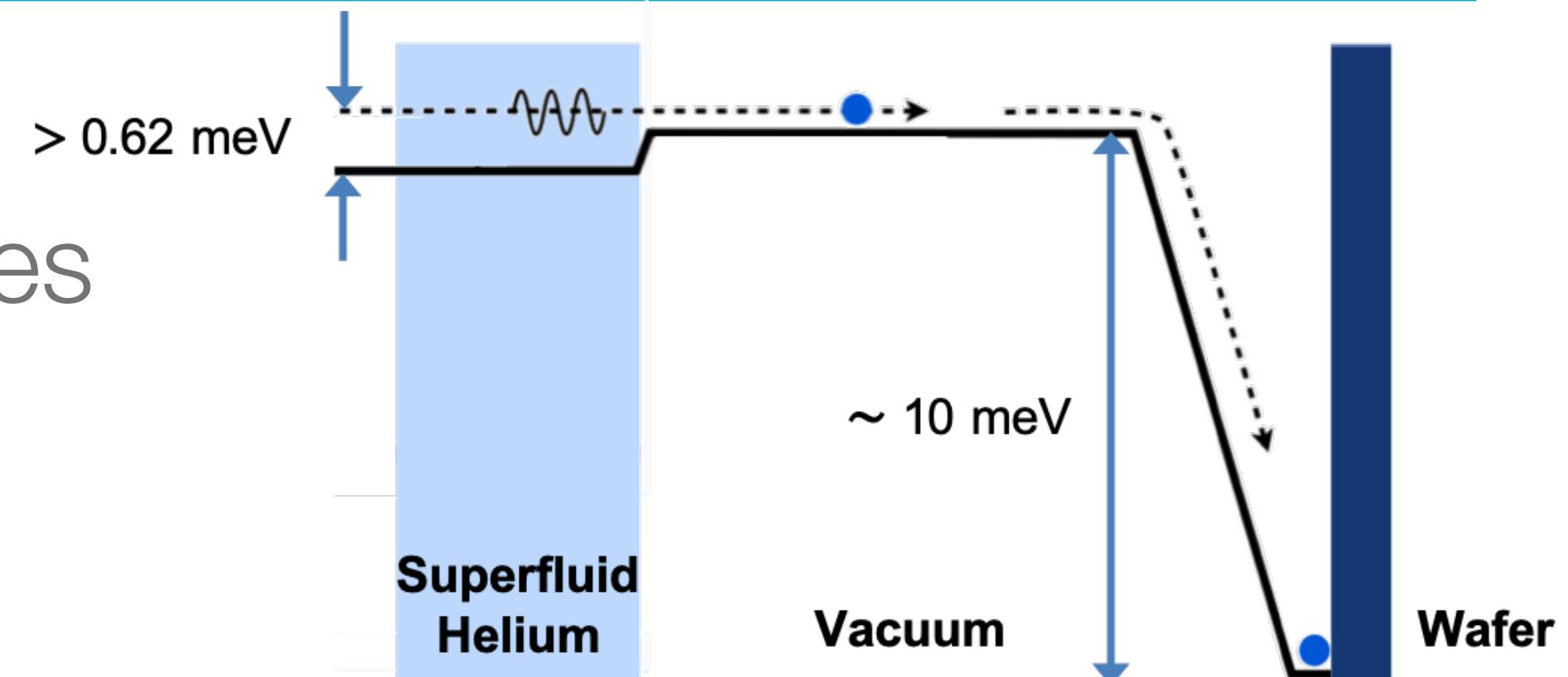
DELight Detector - Interactions in Superfluid Helium-4

- 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

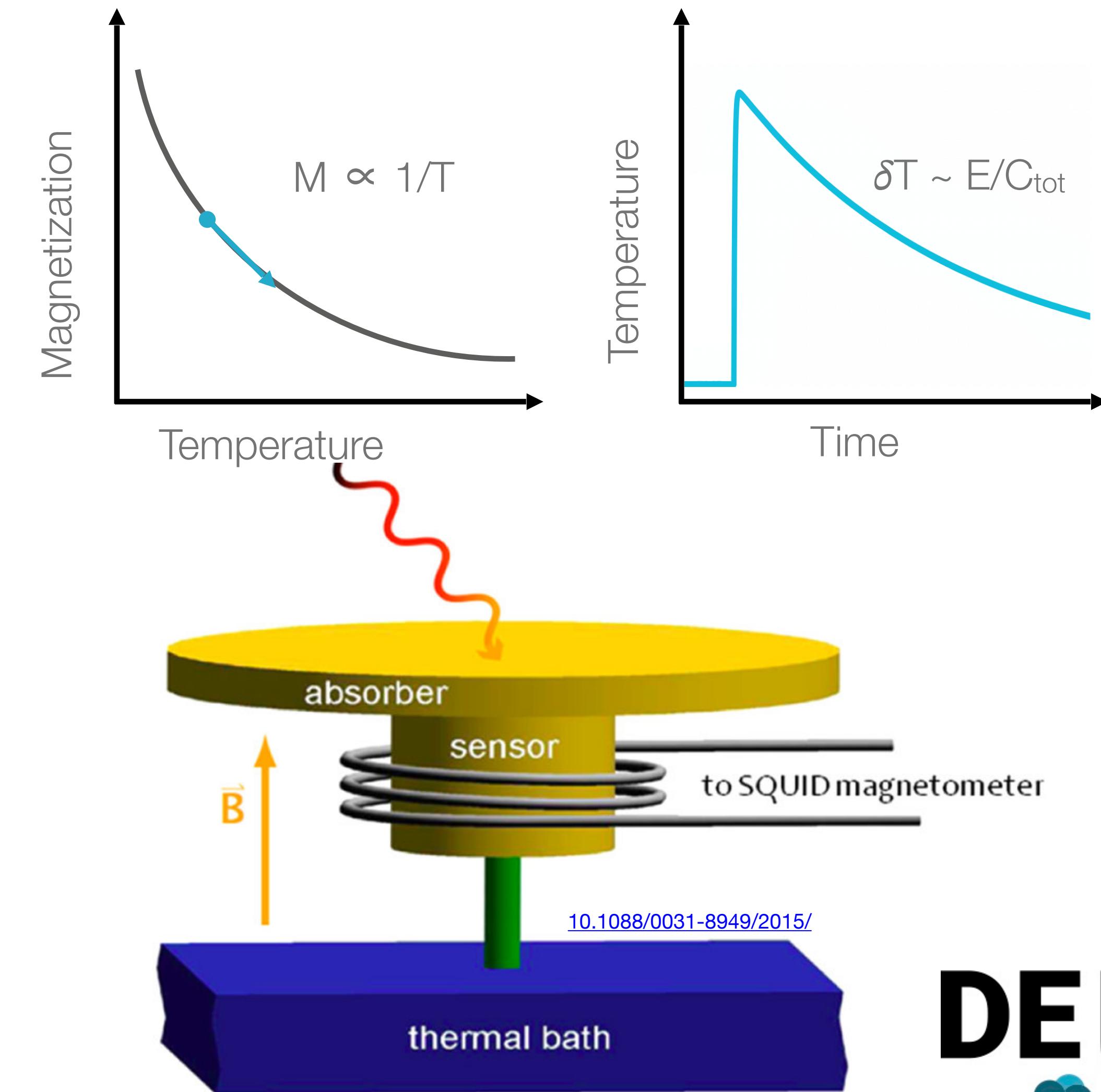
- Quasiparticles (phonon and rotons) propagate ballistically within the LHe, bouncing off of surfaces
- Noise free amplification of factor of 10-40



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

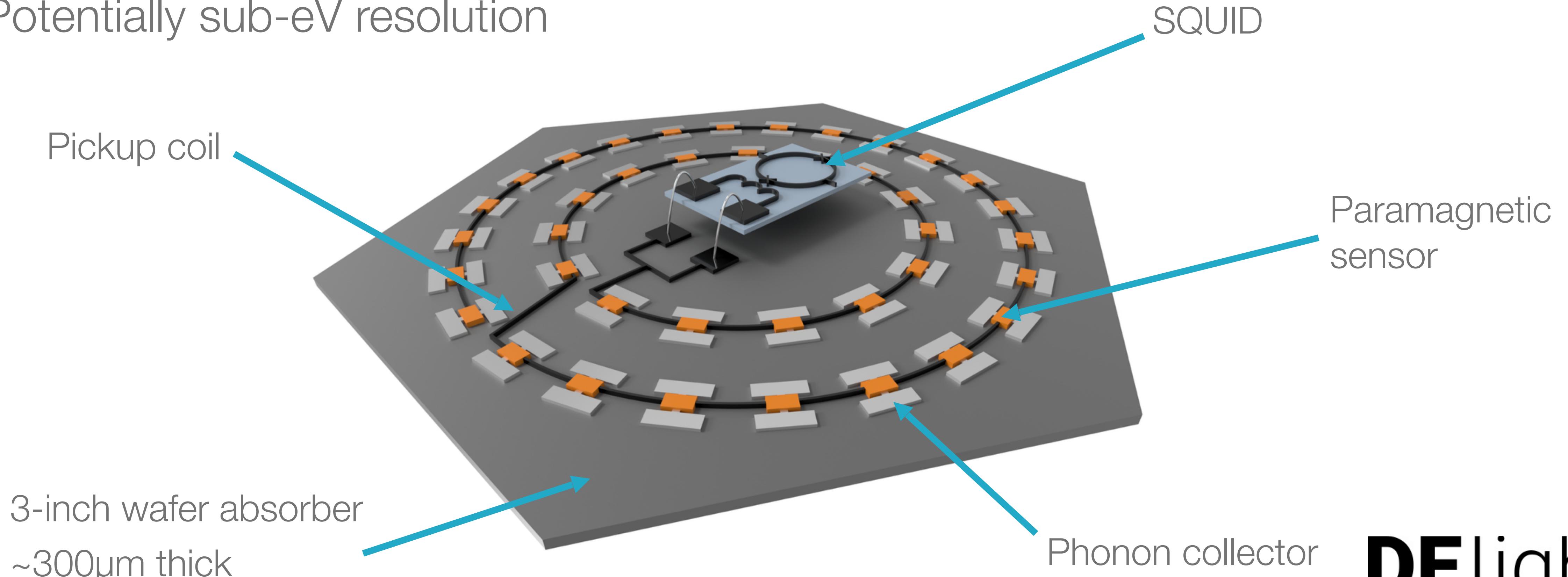
Magnetic MicroCalorimeters (MMCs)

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



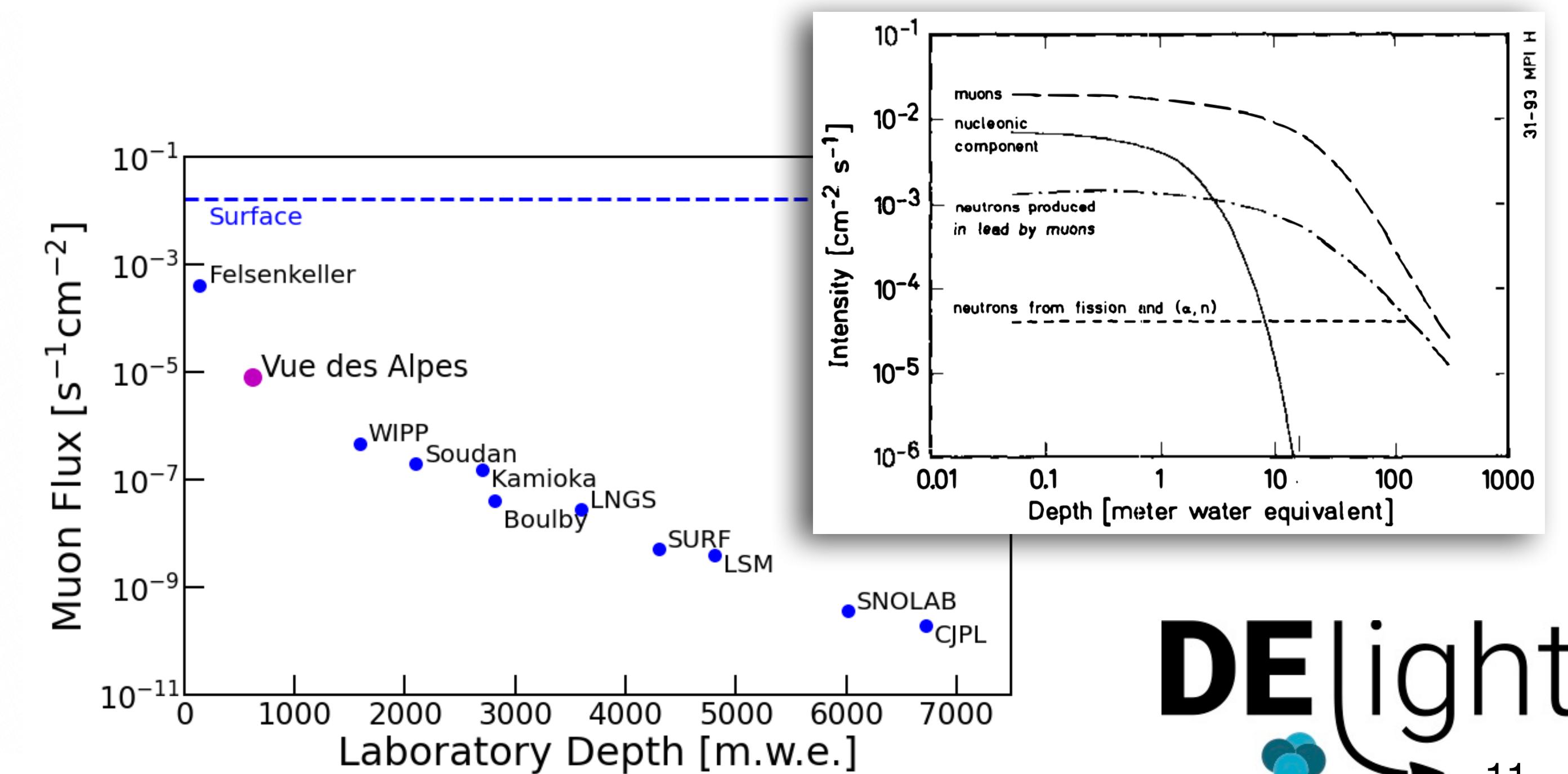
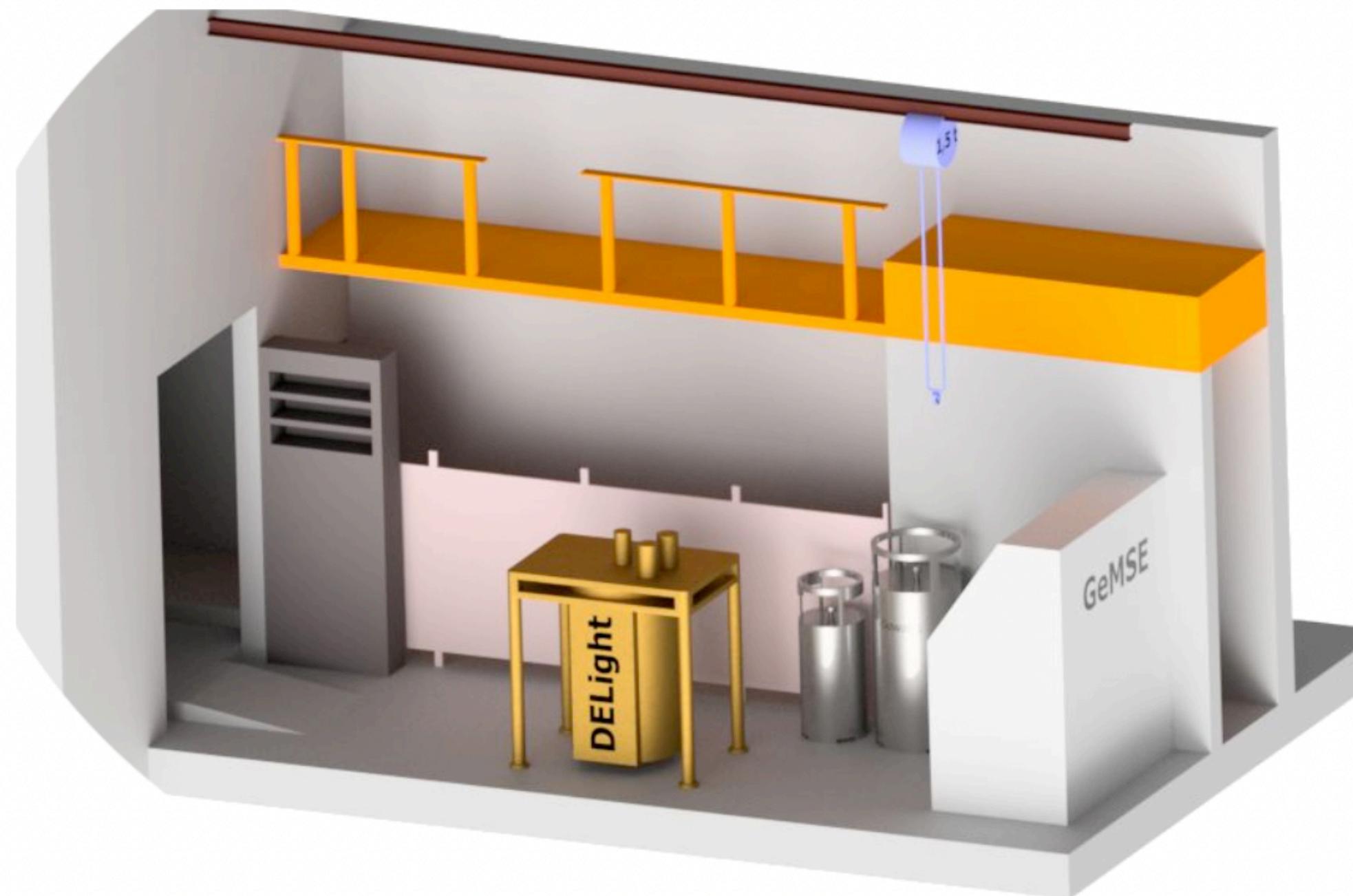
Possible DELight Sensor Design

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



Vue-des-Alpes Underground Lab

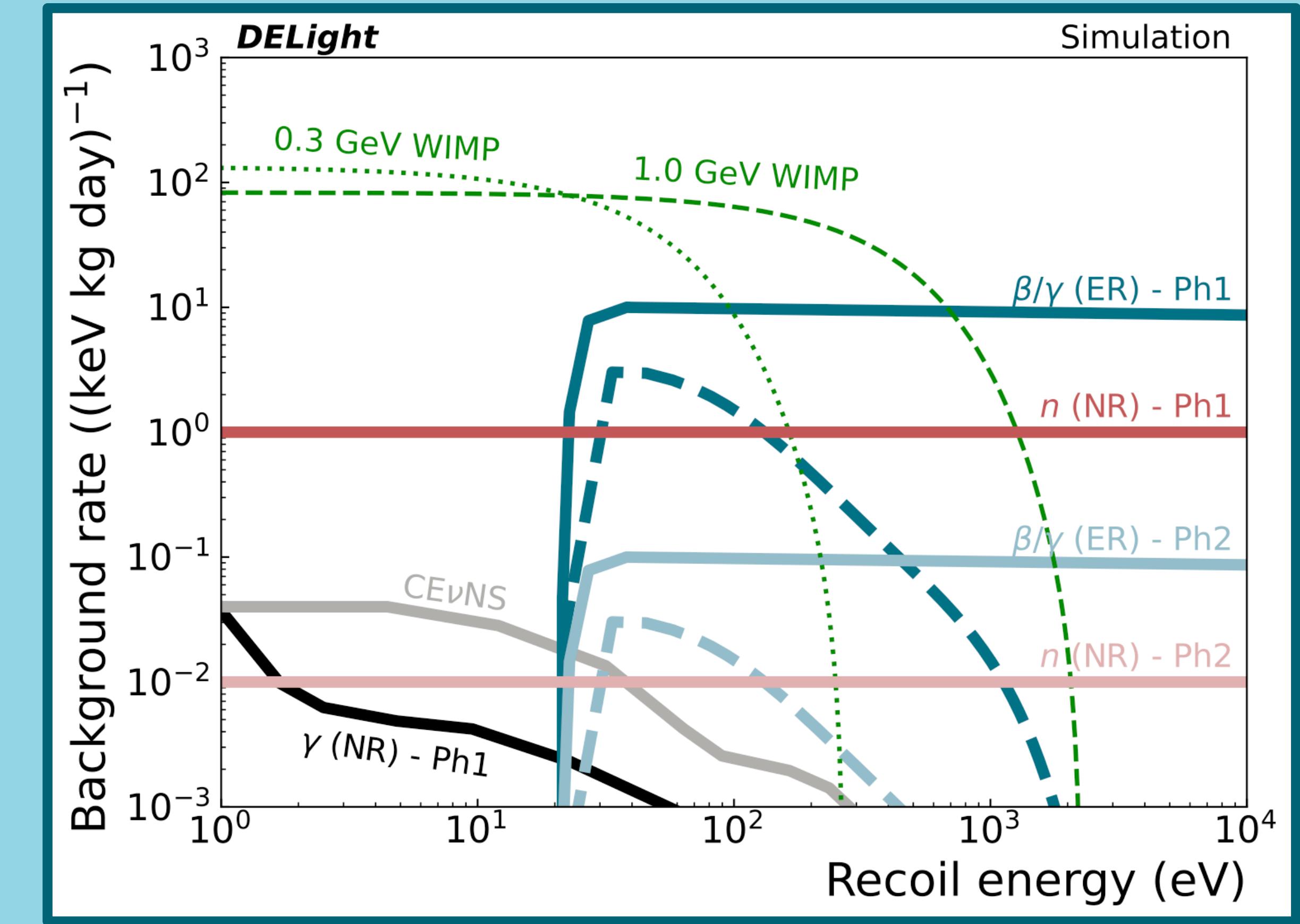
- Shallow underground lab in Switzerland, operated by University of Freiburg
- Hosts GeMSE gamma spectrometer for material assay
- Reduced cosmic background with 230m rock overburden (620m.w.e)



Projecting Sensitivities

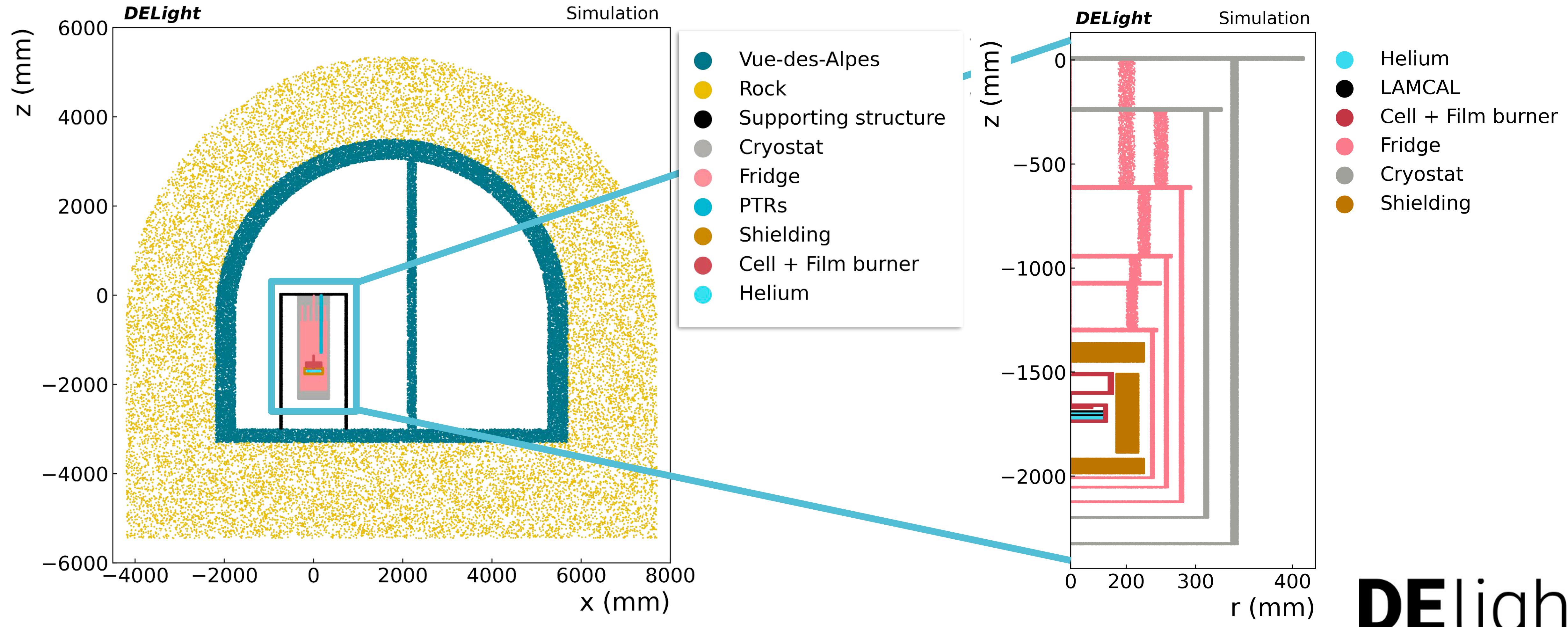
- Background model
- Signal model
- Detector response
- Limit method

DElight



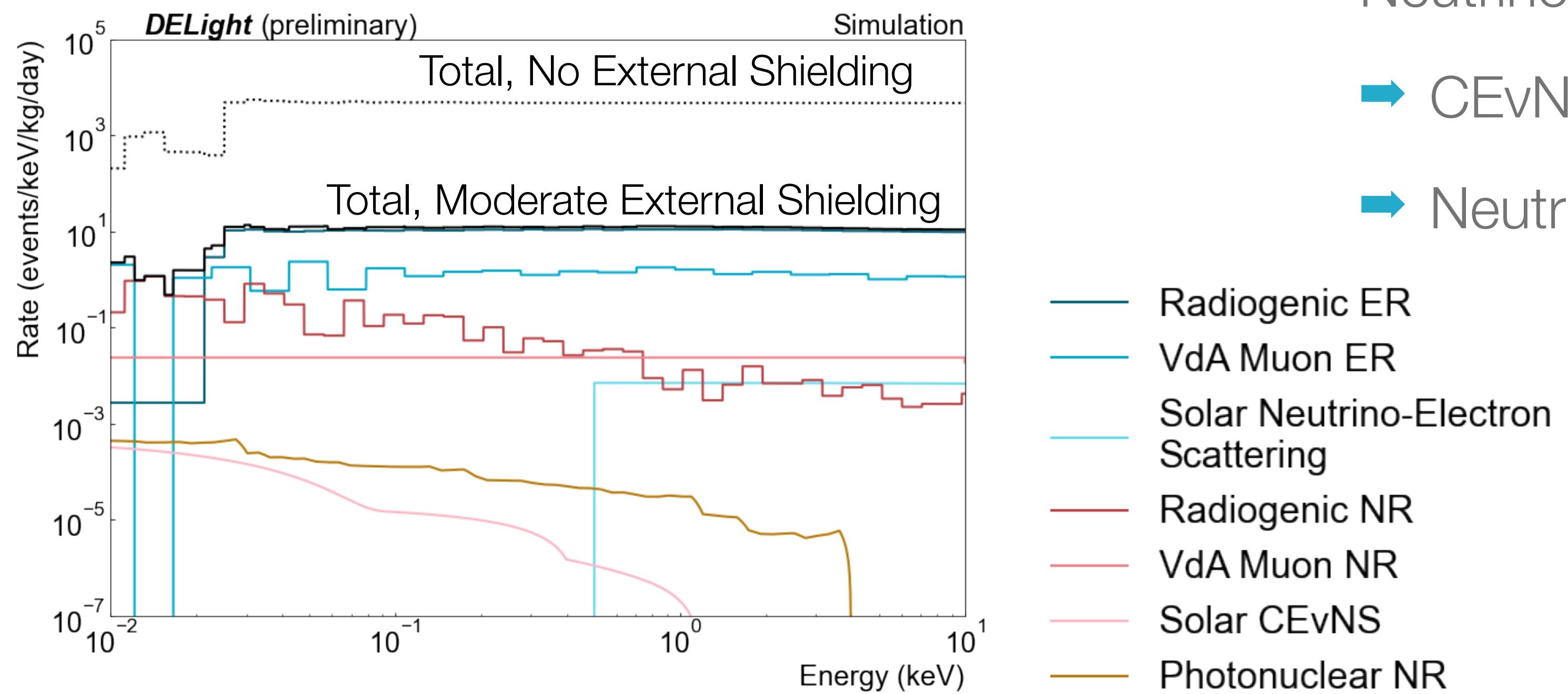
Starting point: a simple assumption of a background goal

DELight Background Model: Geant4 Simulation Geometry



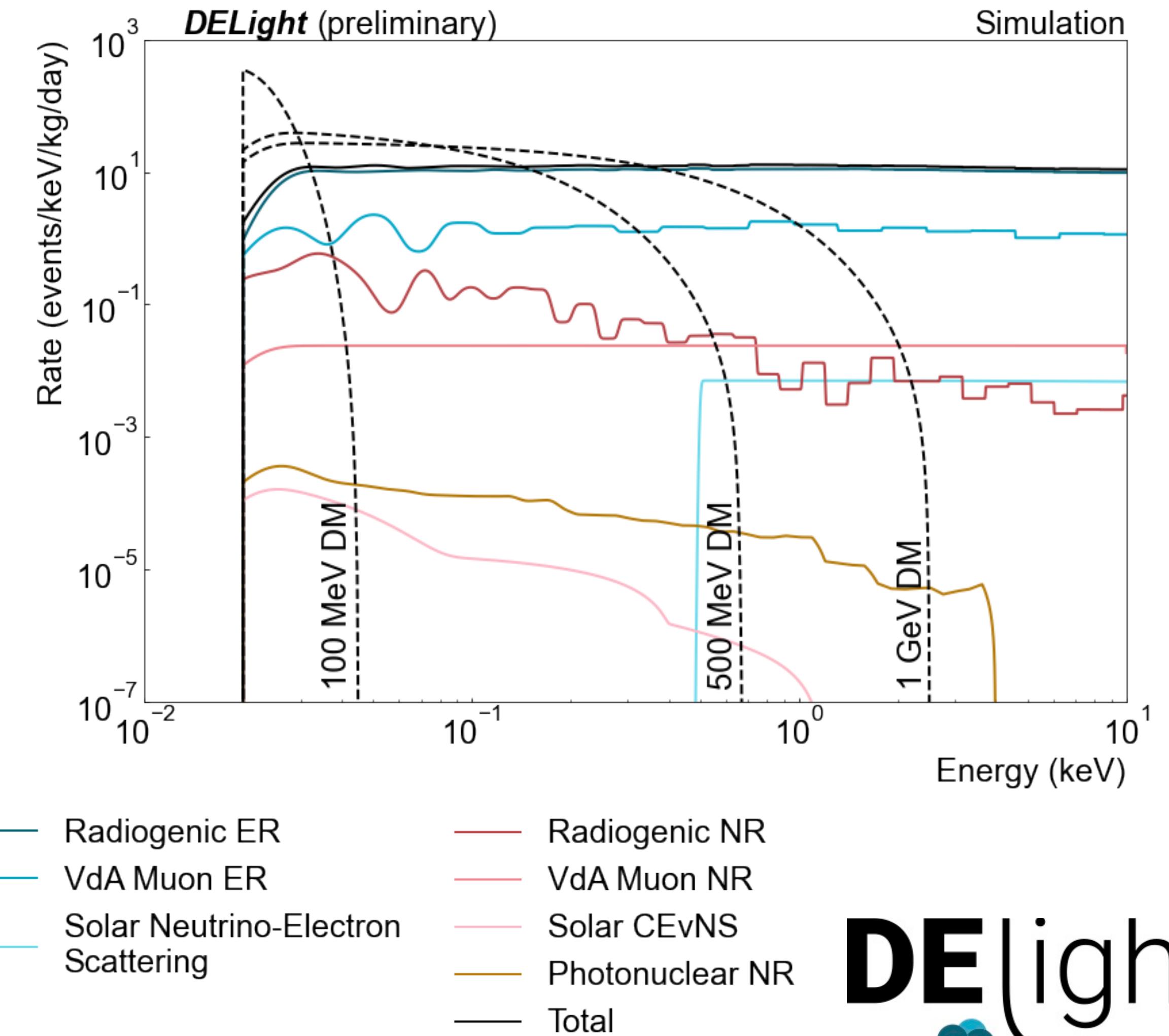
DELight Background Model: Background Components

- 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



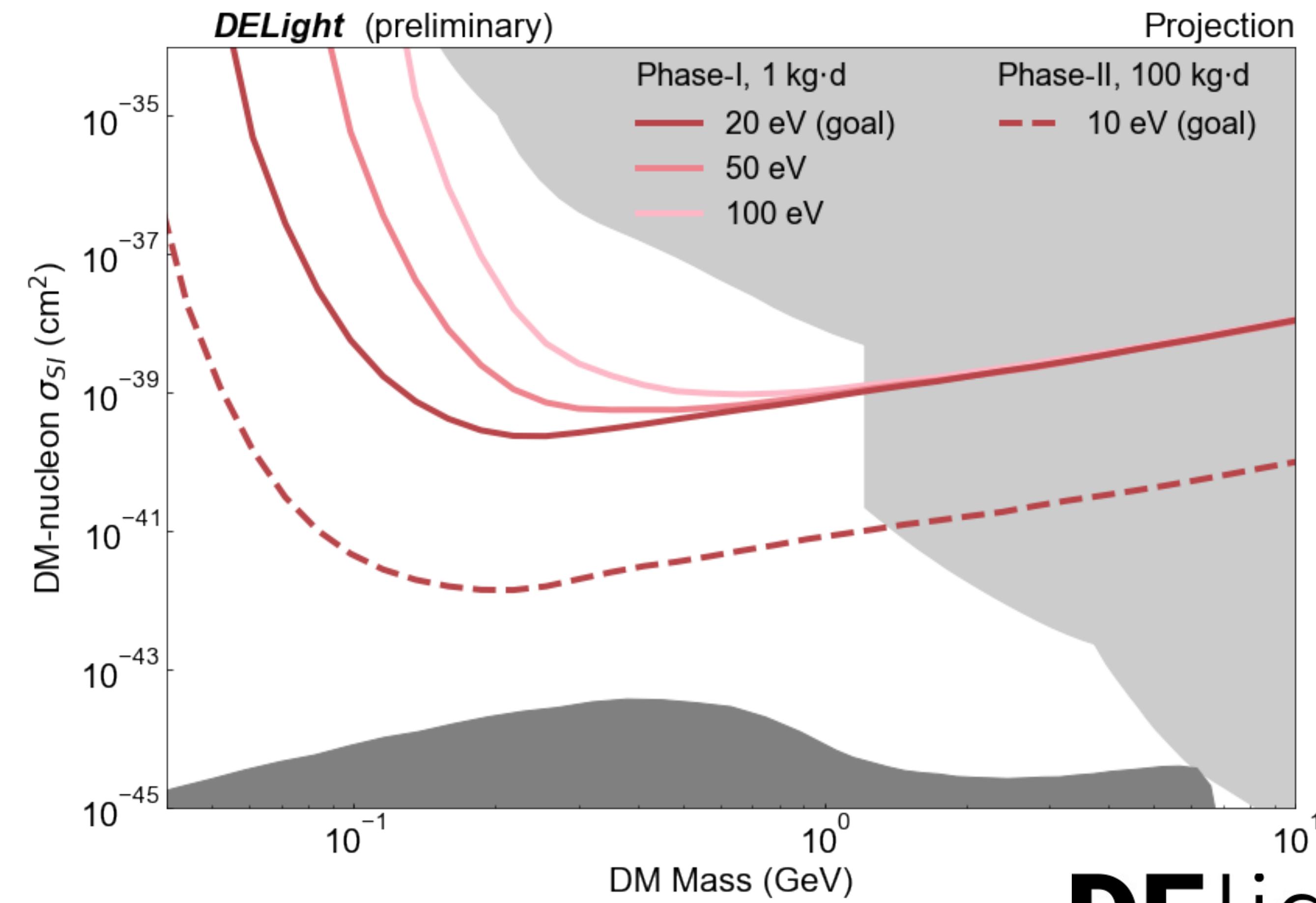
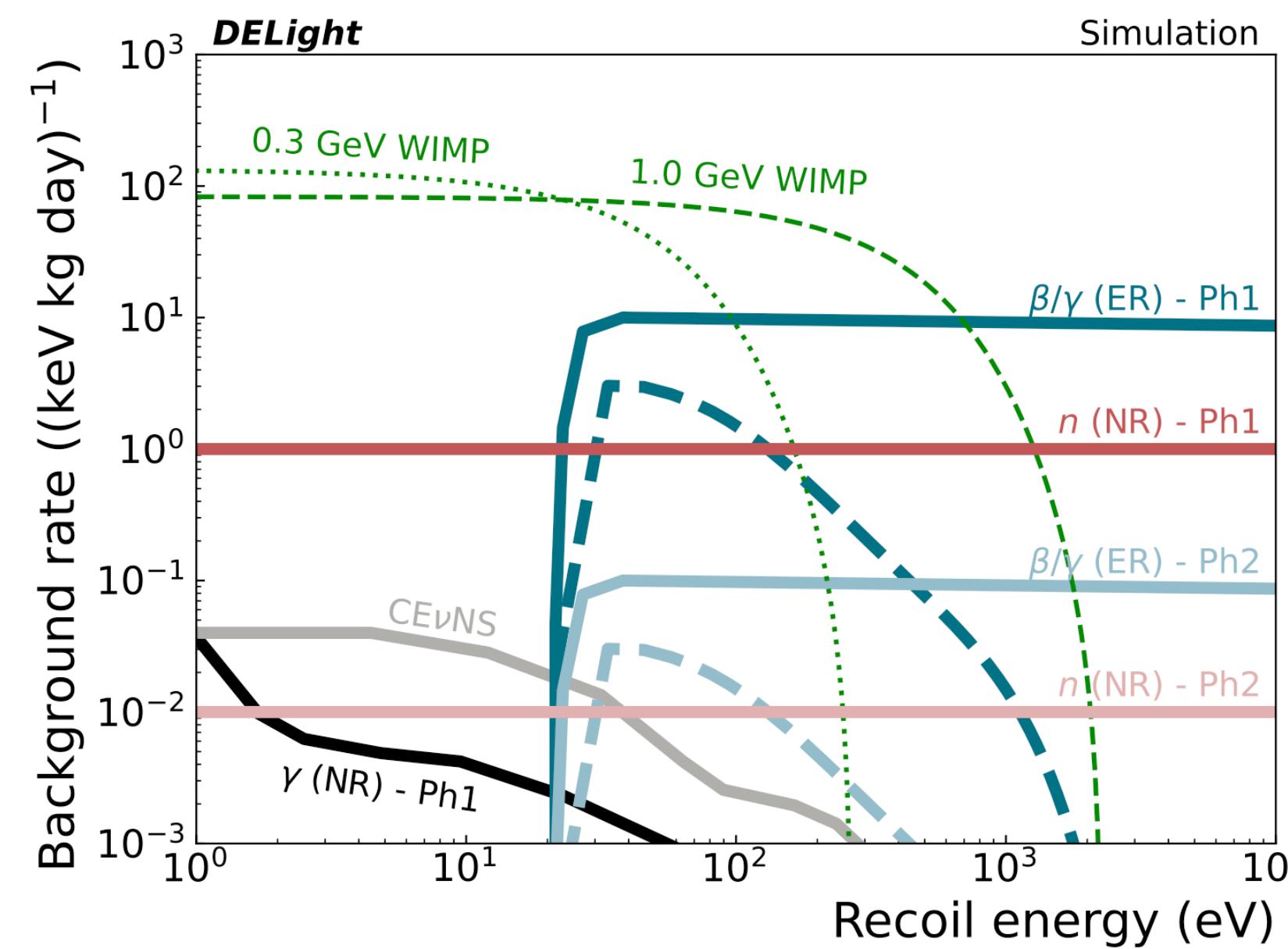
Projection Methodology

- 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



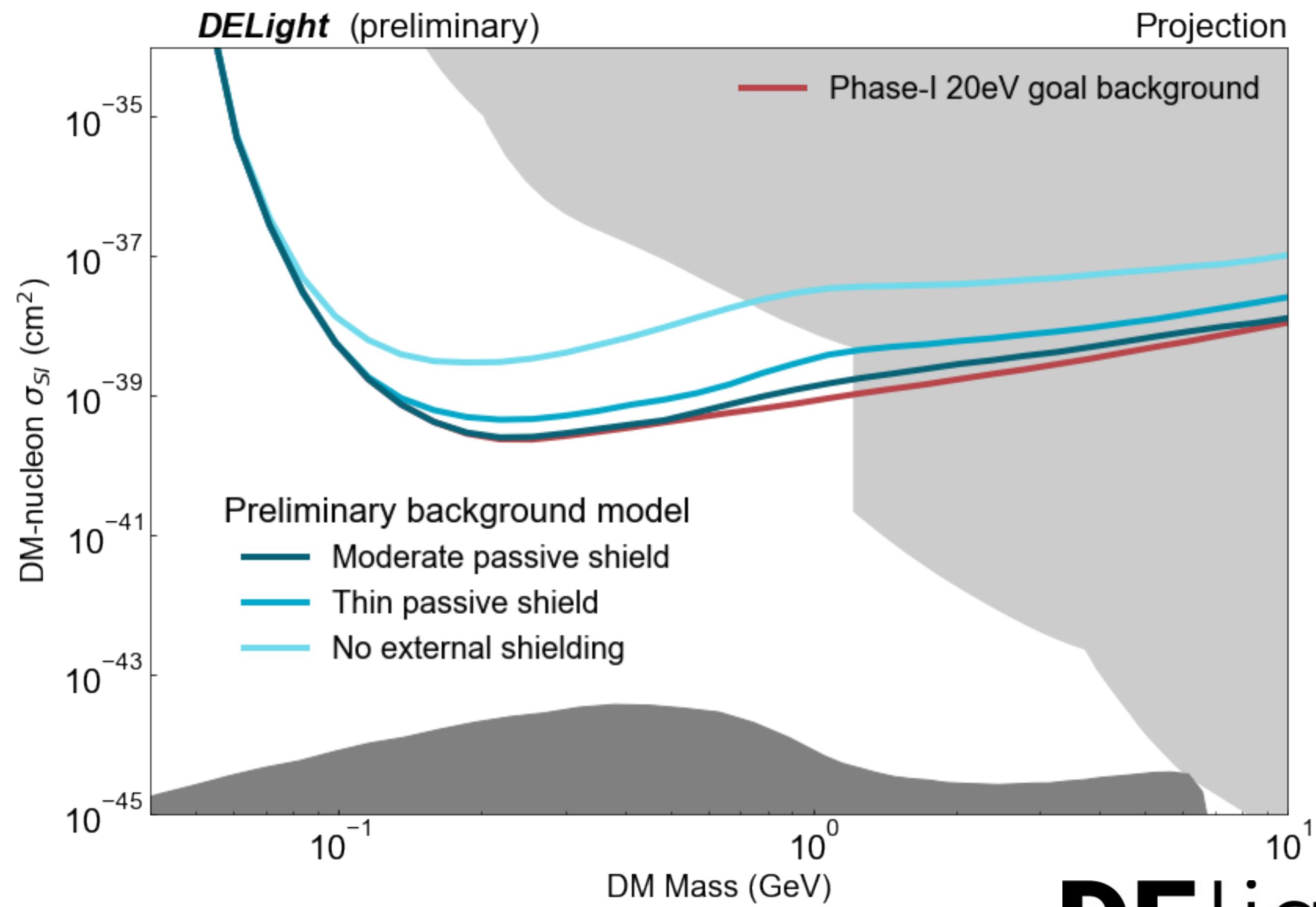
Projected Sensitivity: Threshold and Exposure

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

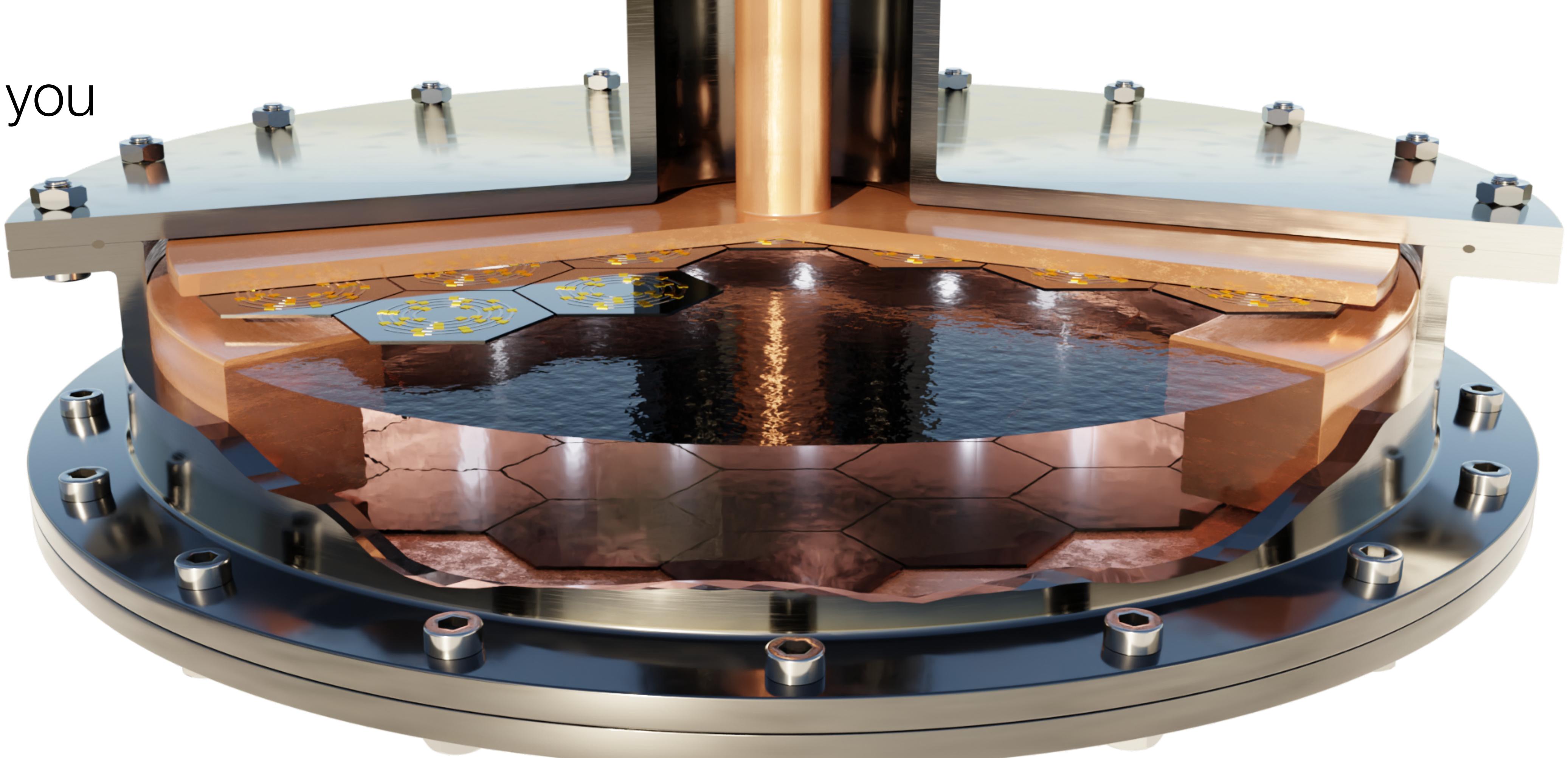


Projected Sensitivity: Background Model

- 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



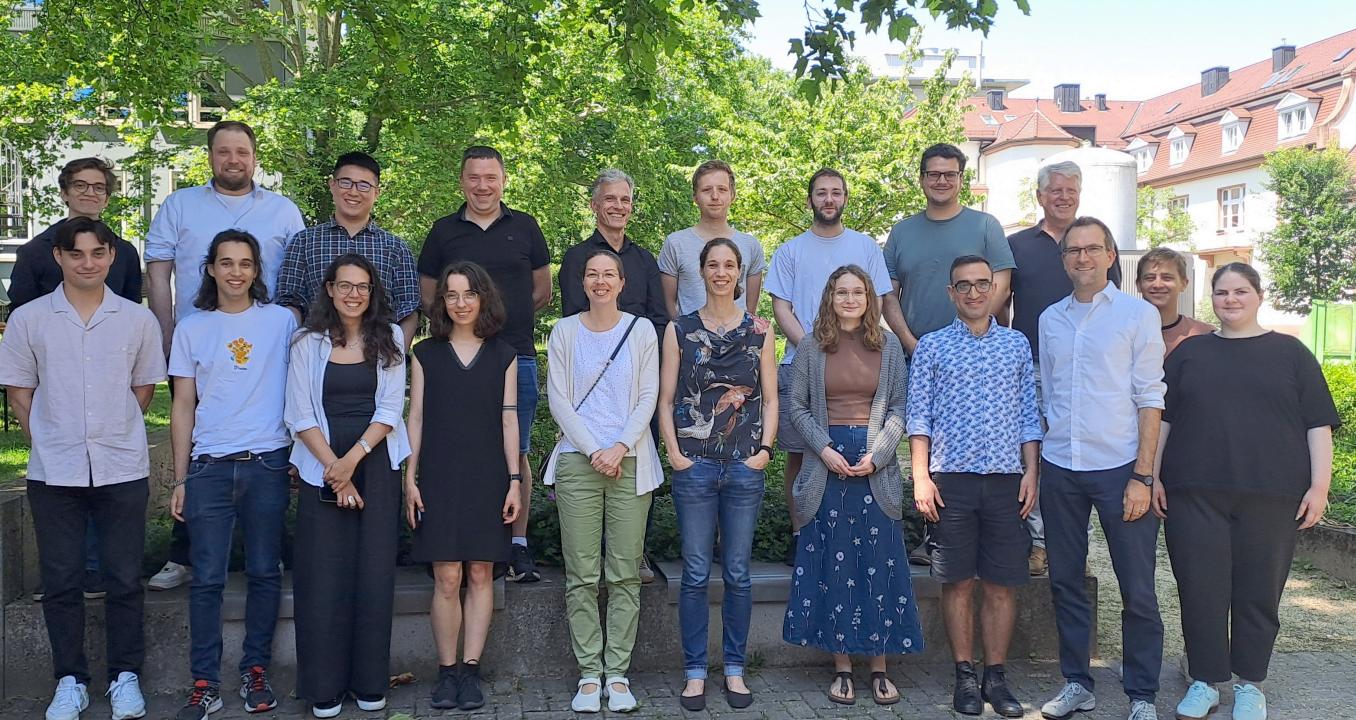
2024@KIT



2024@HD

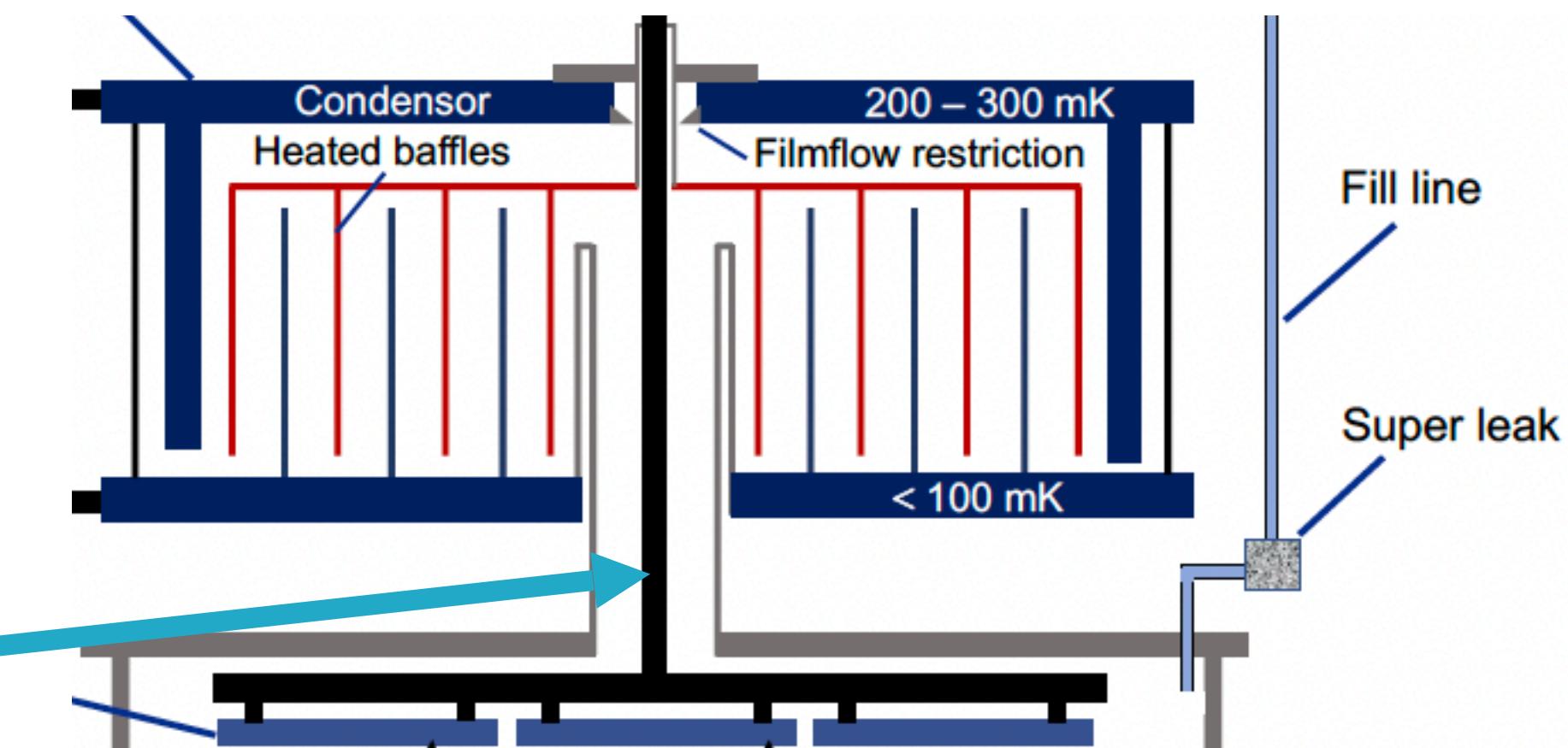
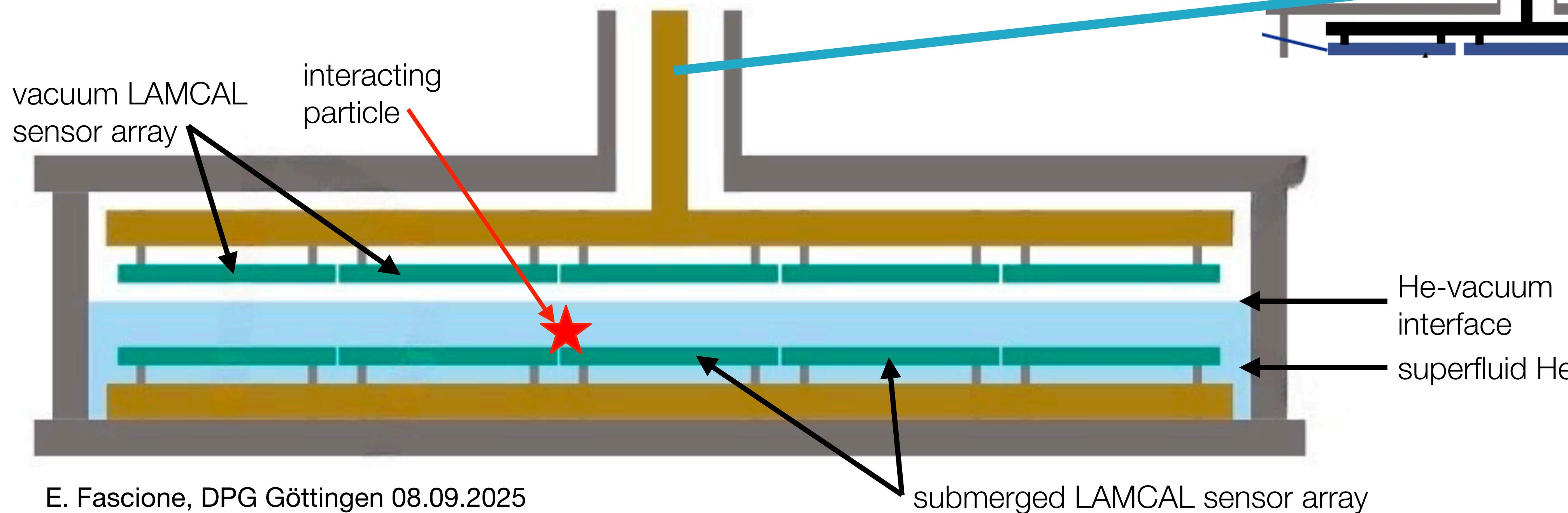


2025@UFR



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



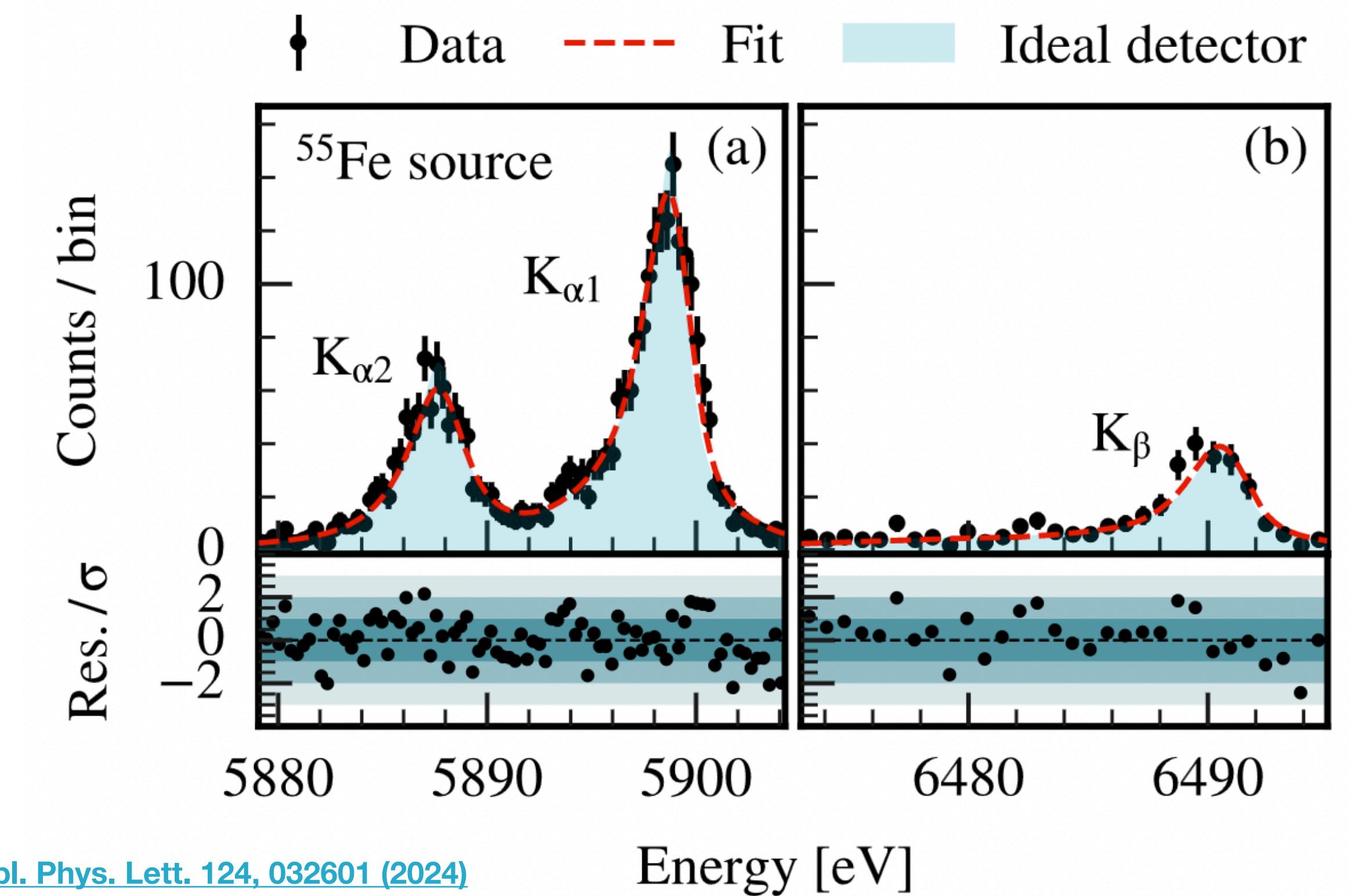
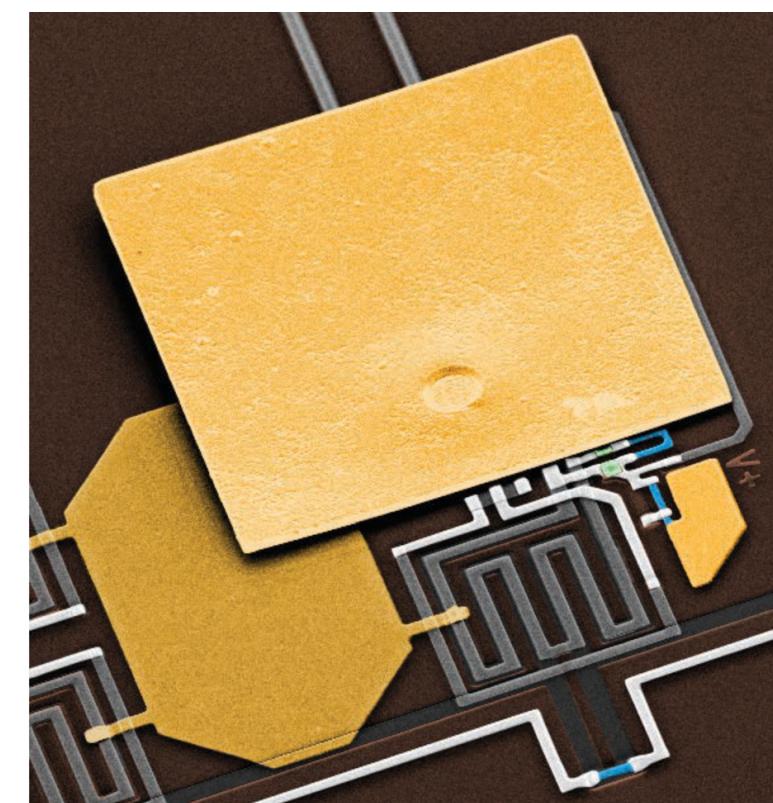
R&D - MMC Energy Resolution

→ 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}

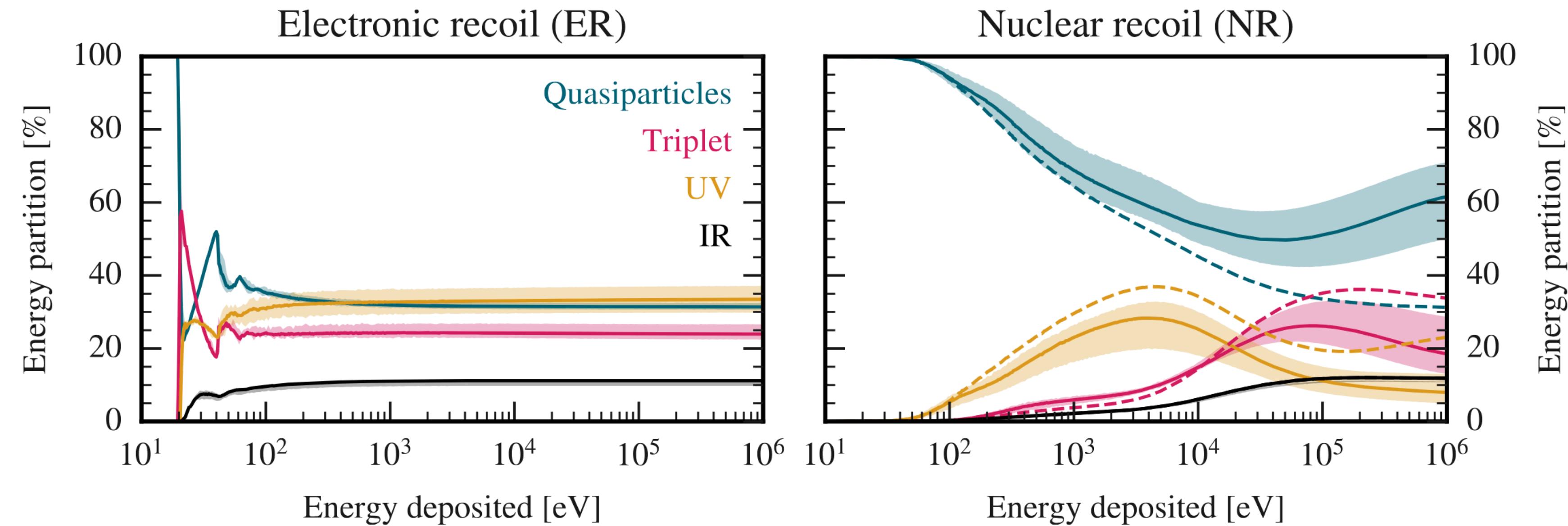


[Appl. Phys. Lett. 124, 032601 \(2024\)](#)

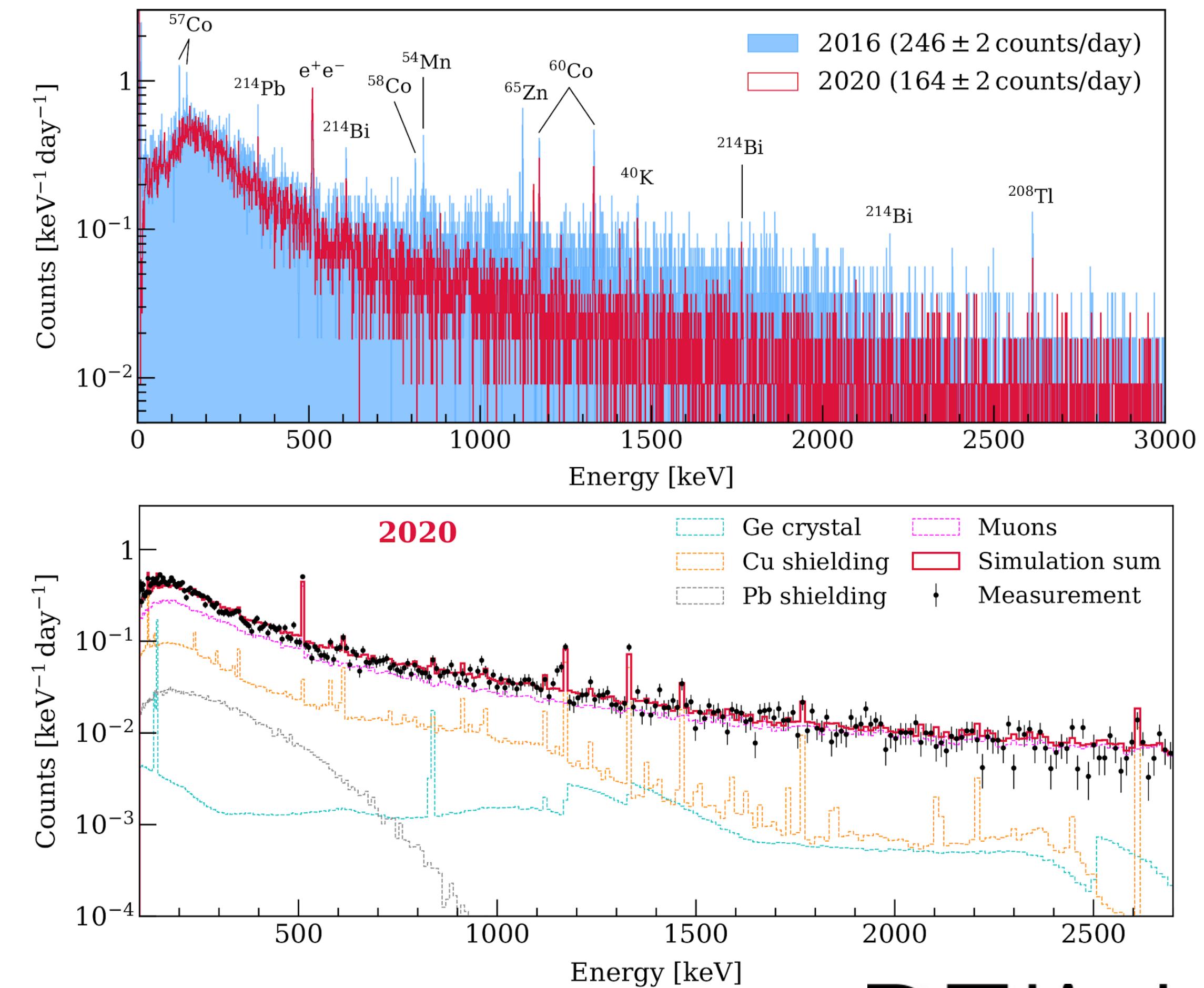
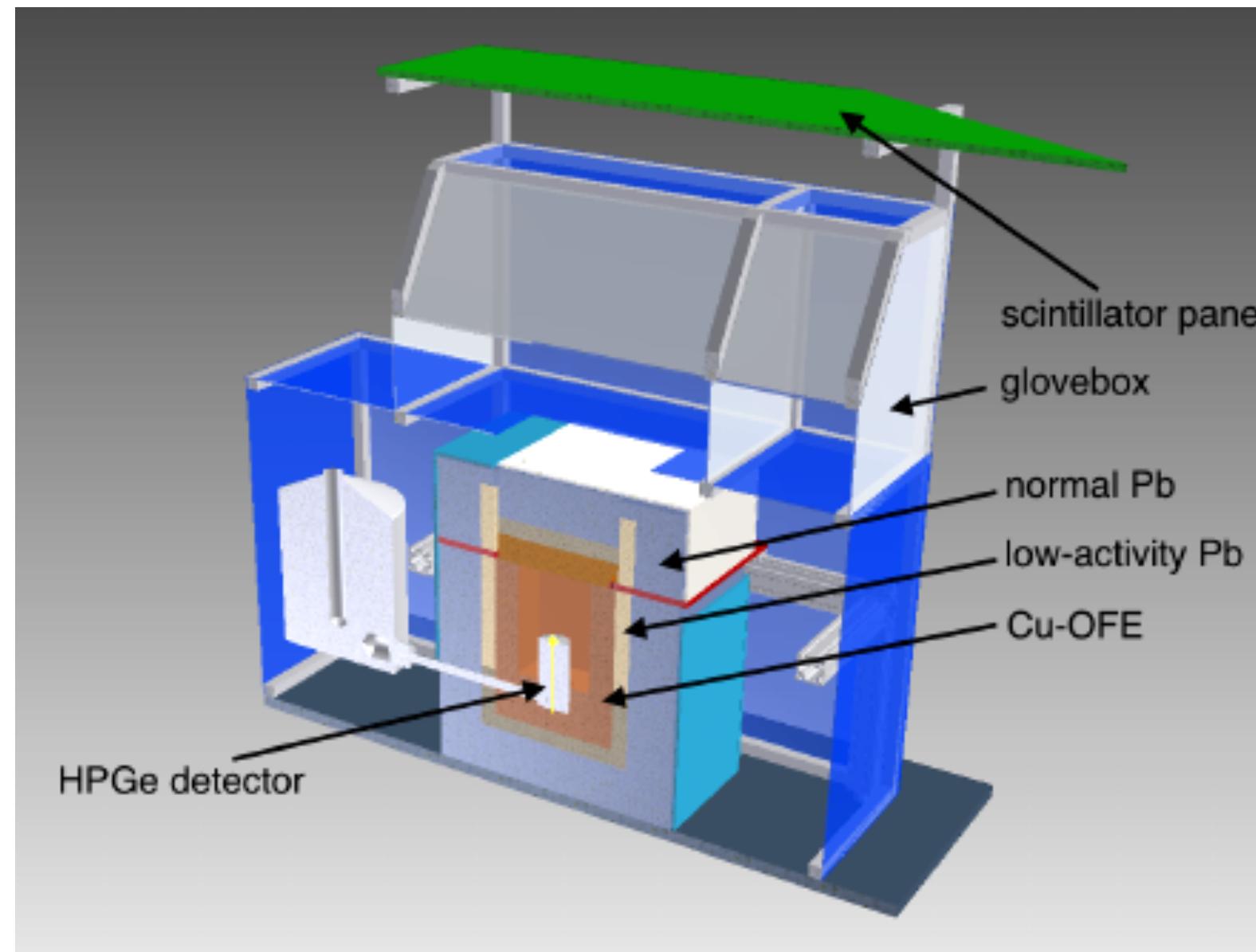
[Phys. Rev. D 109, 043035 \(2024\)](#)

Signal Formation in Superfluid Helium

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

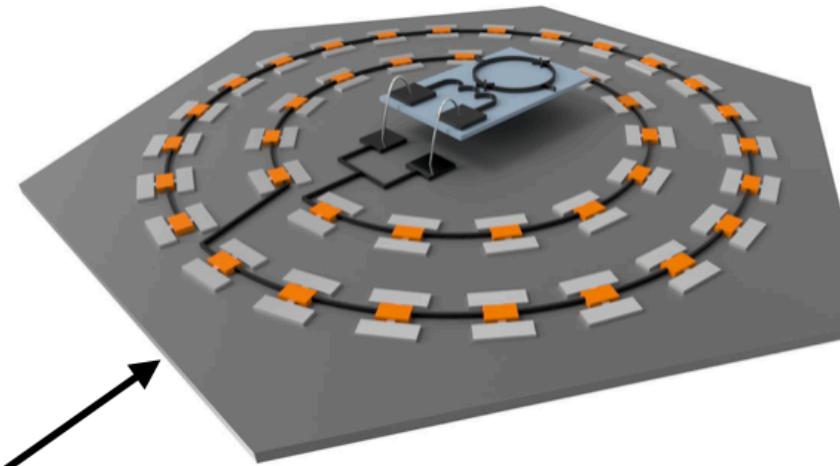
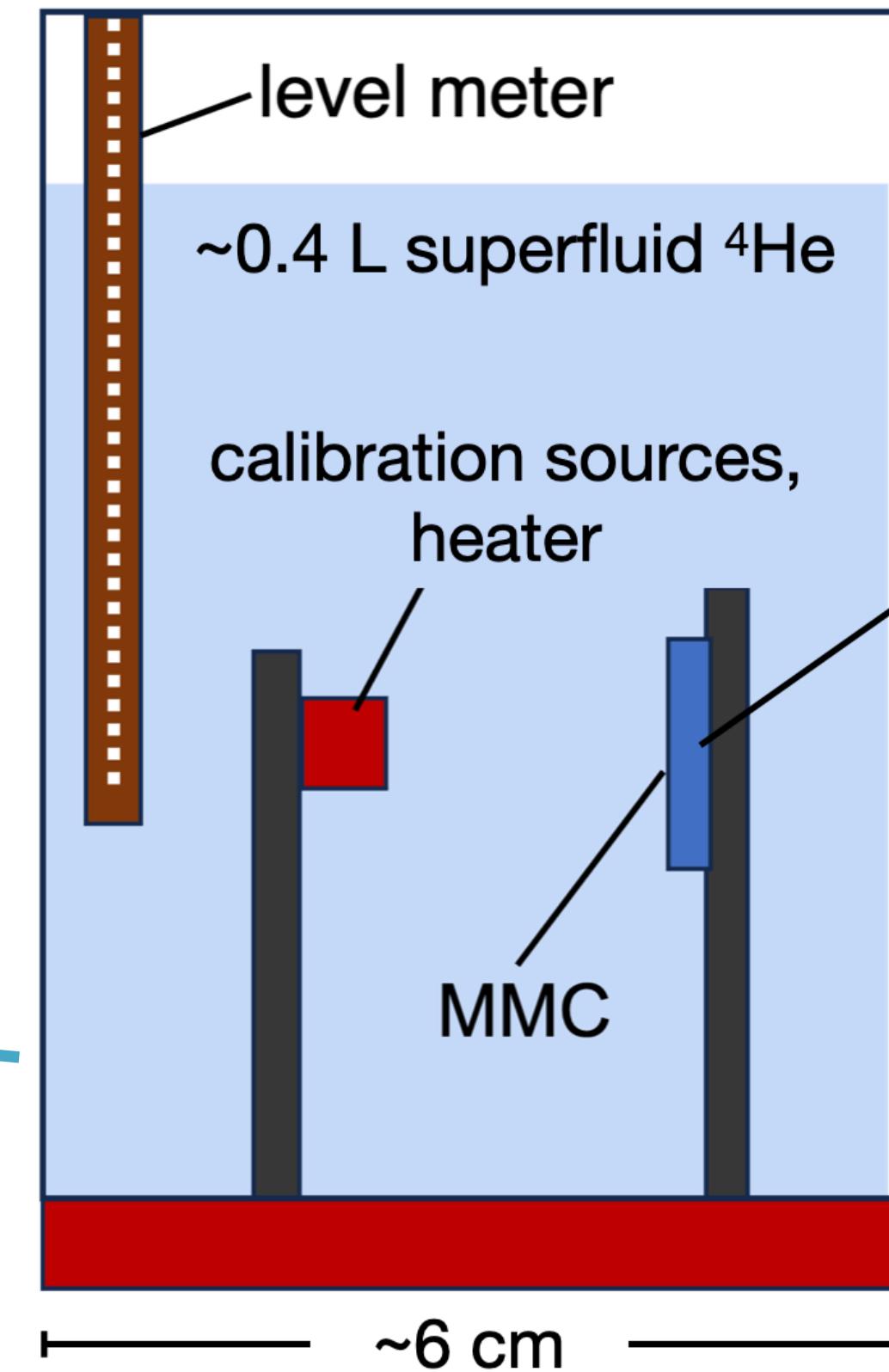
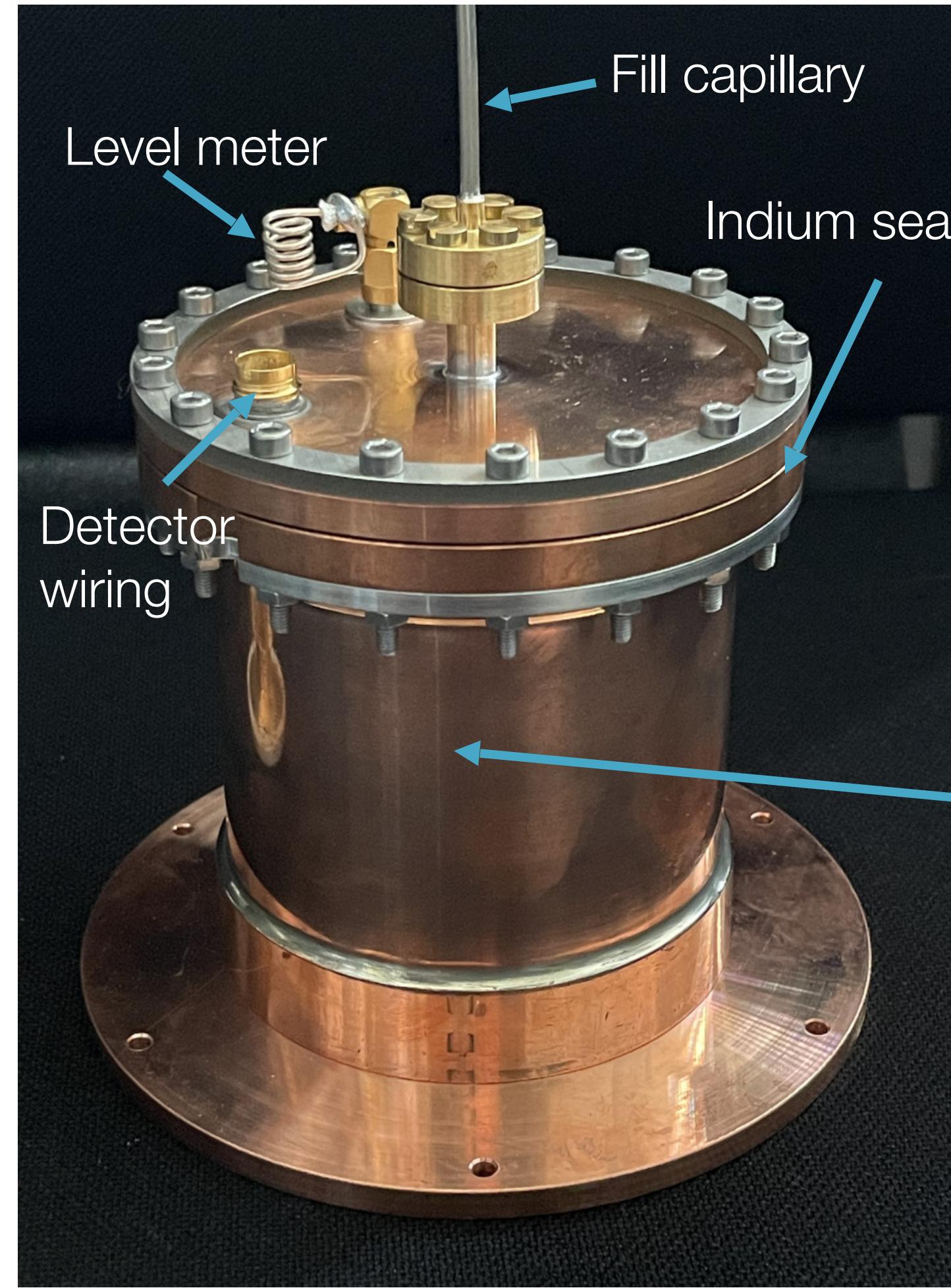


- Low background HPGe crystal gamma spectrometer @ VdA
- Material selection campaign for experiment components



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