UNIVERSITÄT
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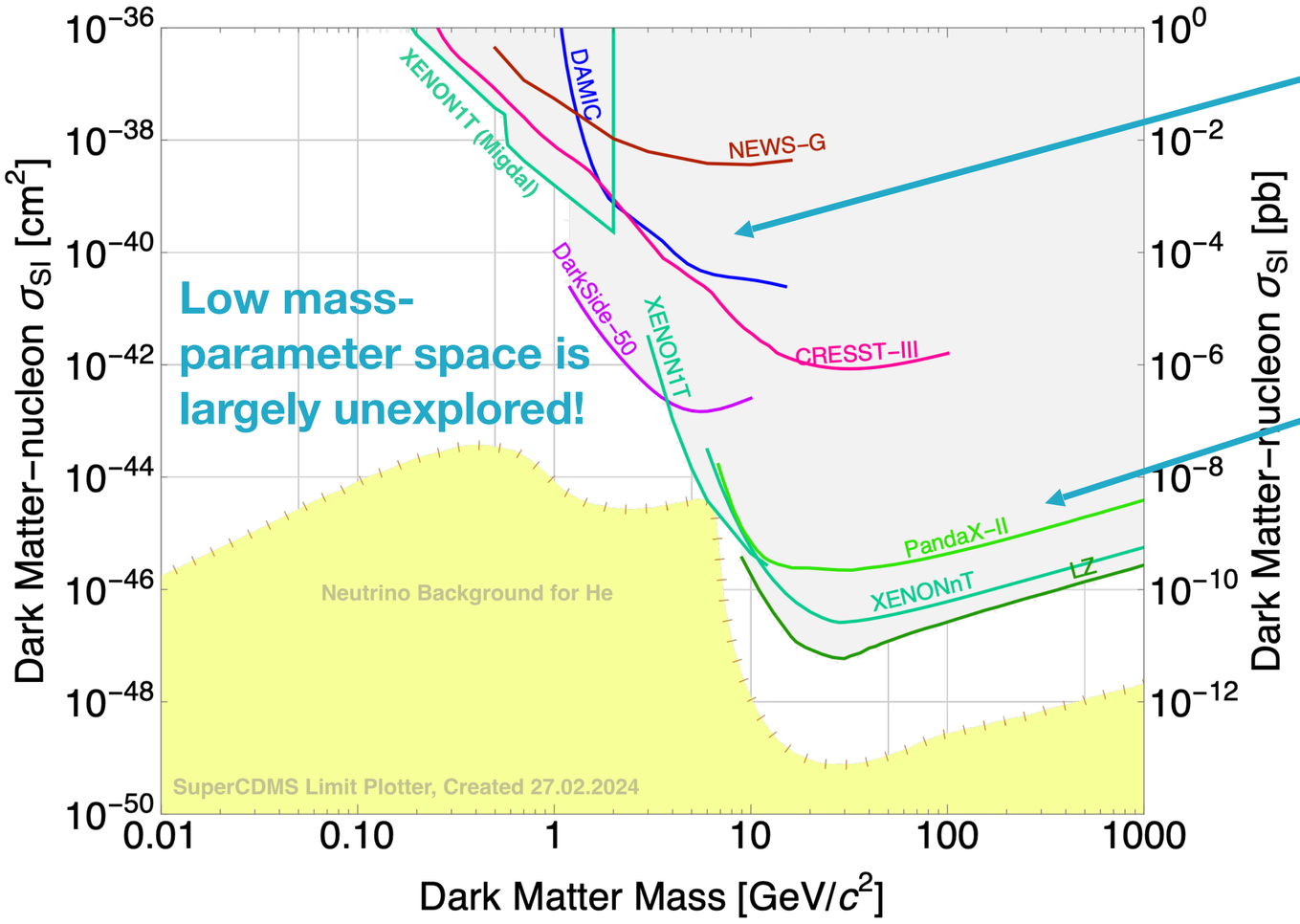
SEIT 1386

The Direct search Experiment for Light Dark Matter (DELight): Overview and Perspectives

Eleanor Fascione on behalf of the DELight Collaboration
DPG Göttingen 2025

DELight

The Current SI-DM Landscape and Push to Low Mass



Various experimental efforts to reach sensitivity to ~GeV/c^2 scale WIMPs

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

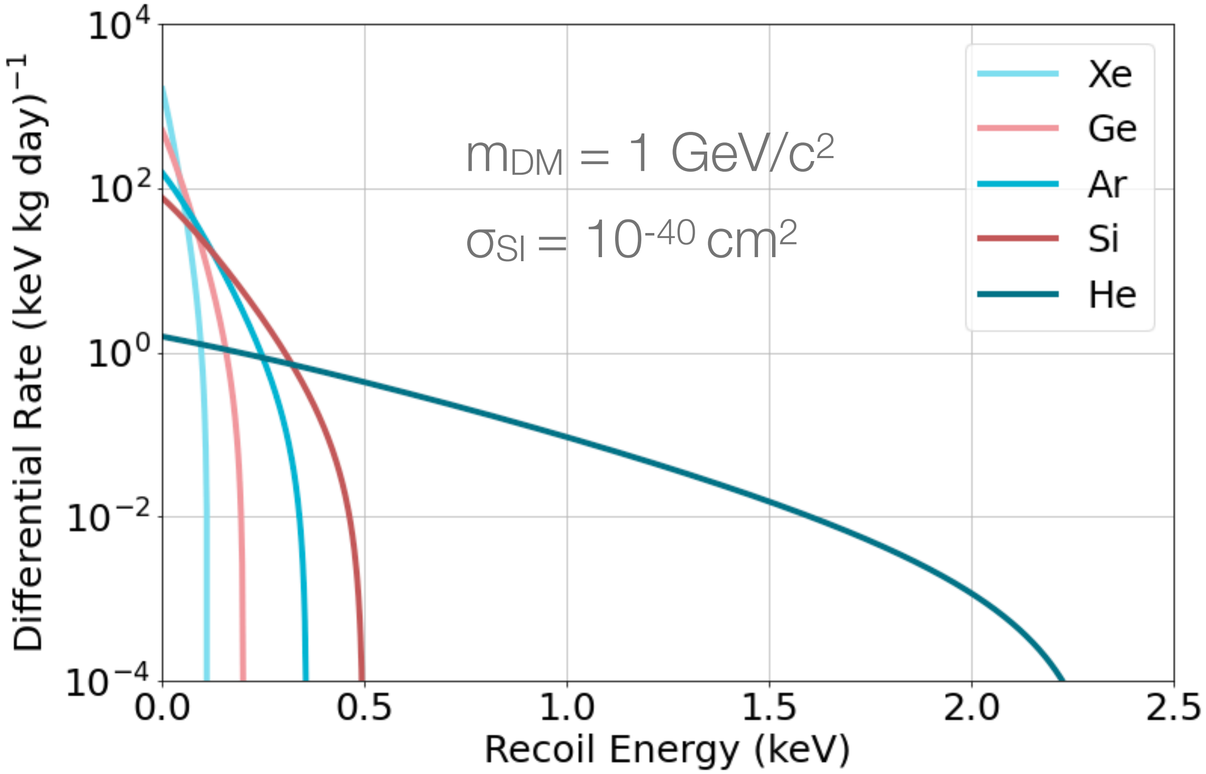
The DELight Collaboration

An upcoming light dark matter search using superfluid helium-4

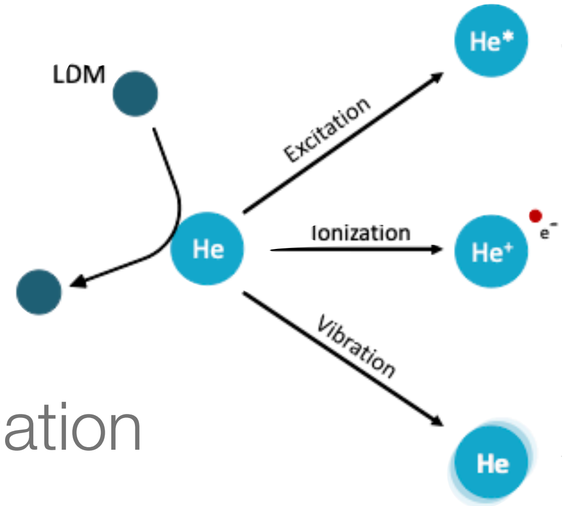
E. Fascione, DPG Göttingen 31.04.2025

Superfluid Helium-4 Target

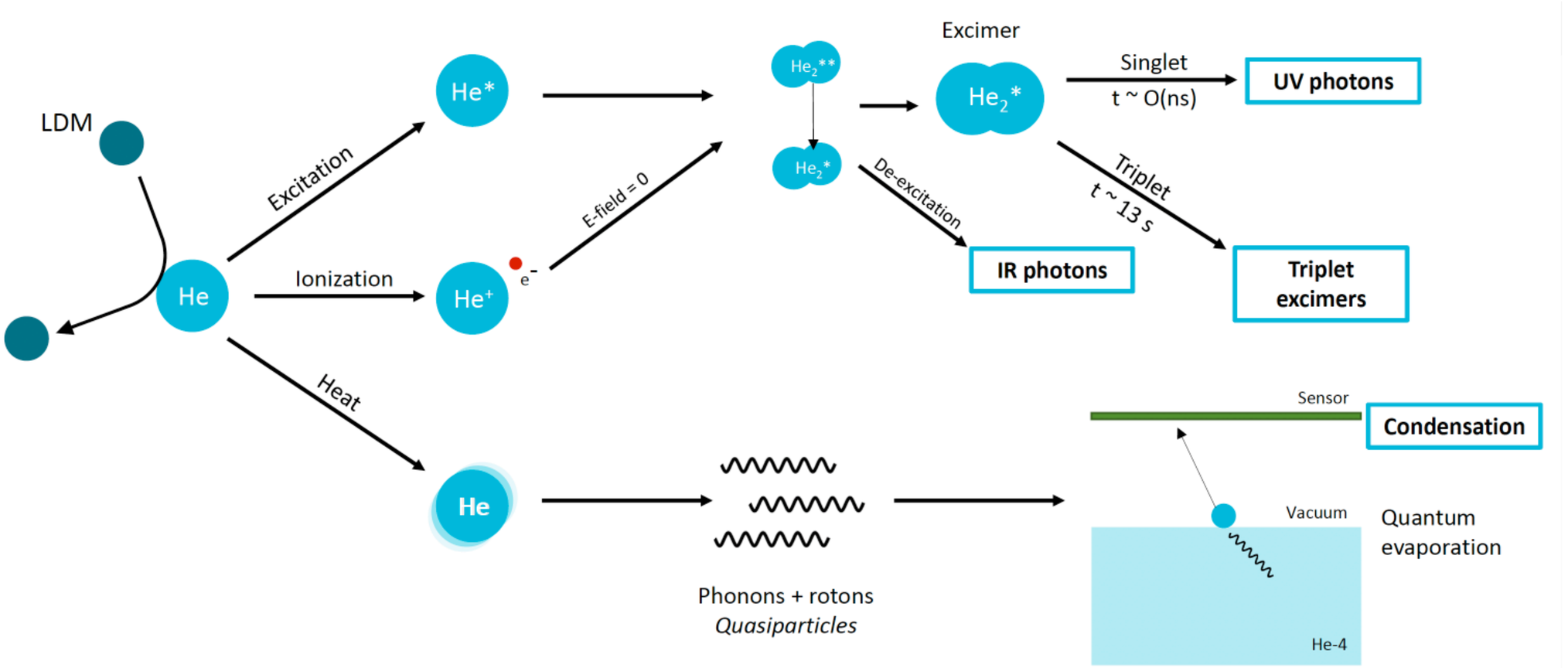
- Light nucleus ideal for LDM search



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



Signals in Superfluid He-4



Signals in Superfluid He-4

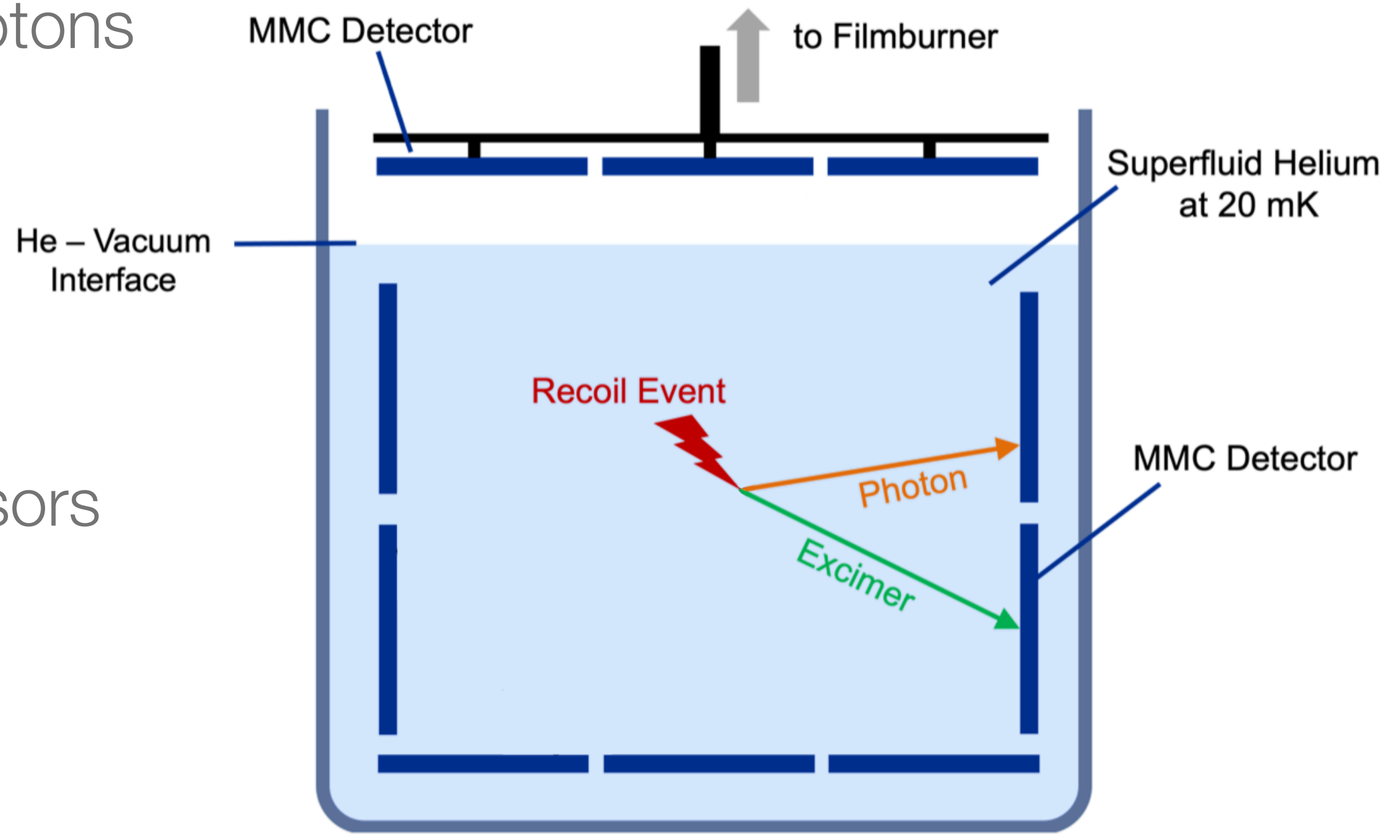
See next talk by F. Toschi:

Signal partitioning in superfluid ^{4}He: A Monte Carlo approach

T19.2 17:00

DELight Detector - Interactions in Superfluid Helium-4

- Prompt signal from UV and IR photons
- Triplet excimer
  - Ballistic O(m/s) speed
  - 13s lifetime
  - Very delayed arrival time at sensors



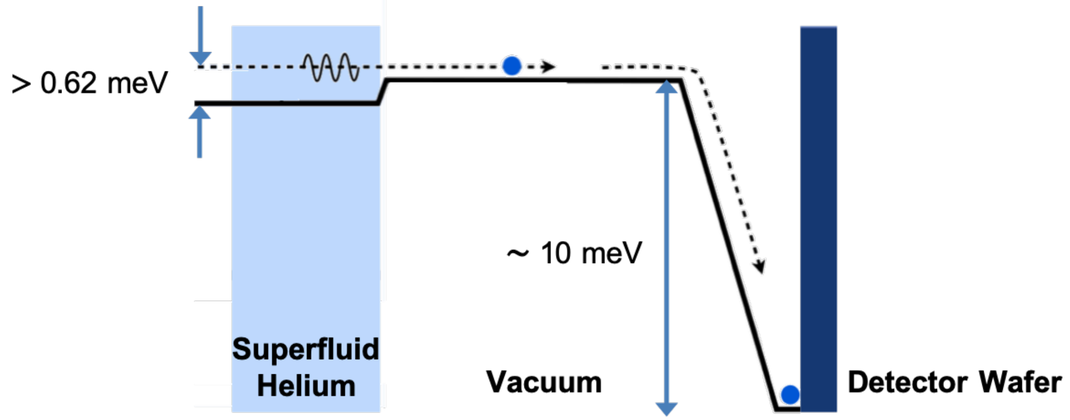
DELight Detector - Interactions in Superfluid Helium-4

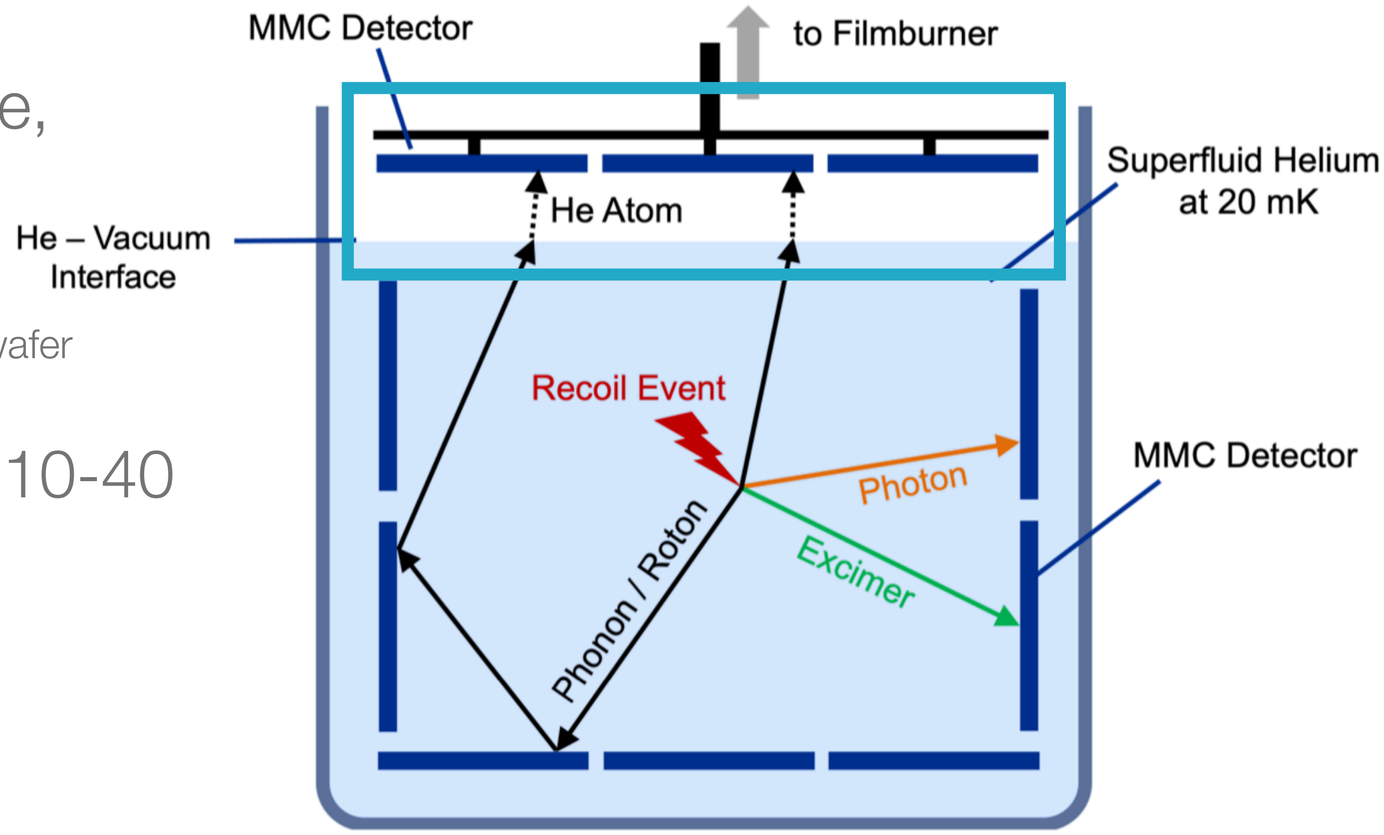
- Quasiparticles (phonon and rotons) propagate ballistically within the LHe, bouncing off of surfaces

Quasiparticle → Free He atom → He atom on wafer

Quantum evaporation Condensation

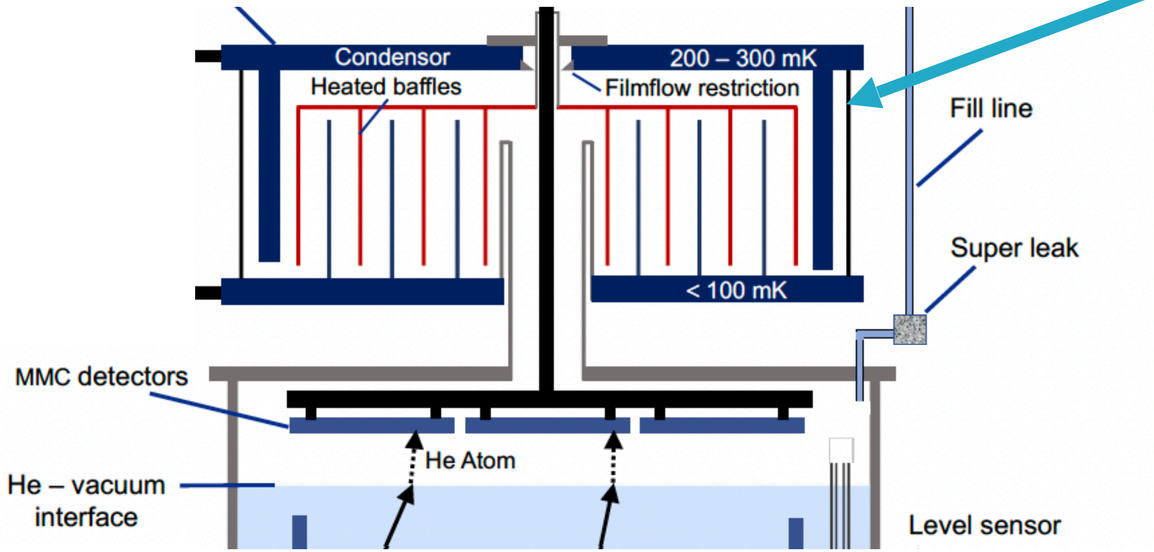
- Noise free amplification of factor of 10-40

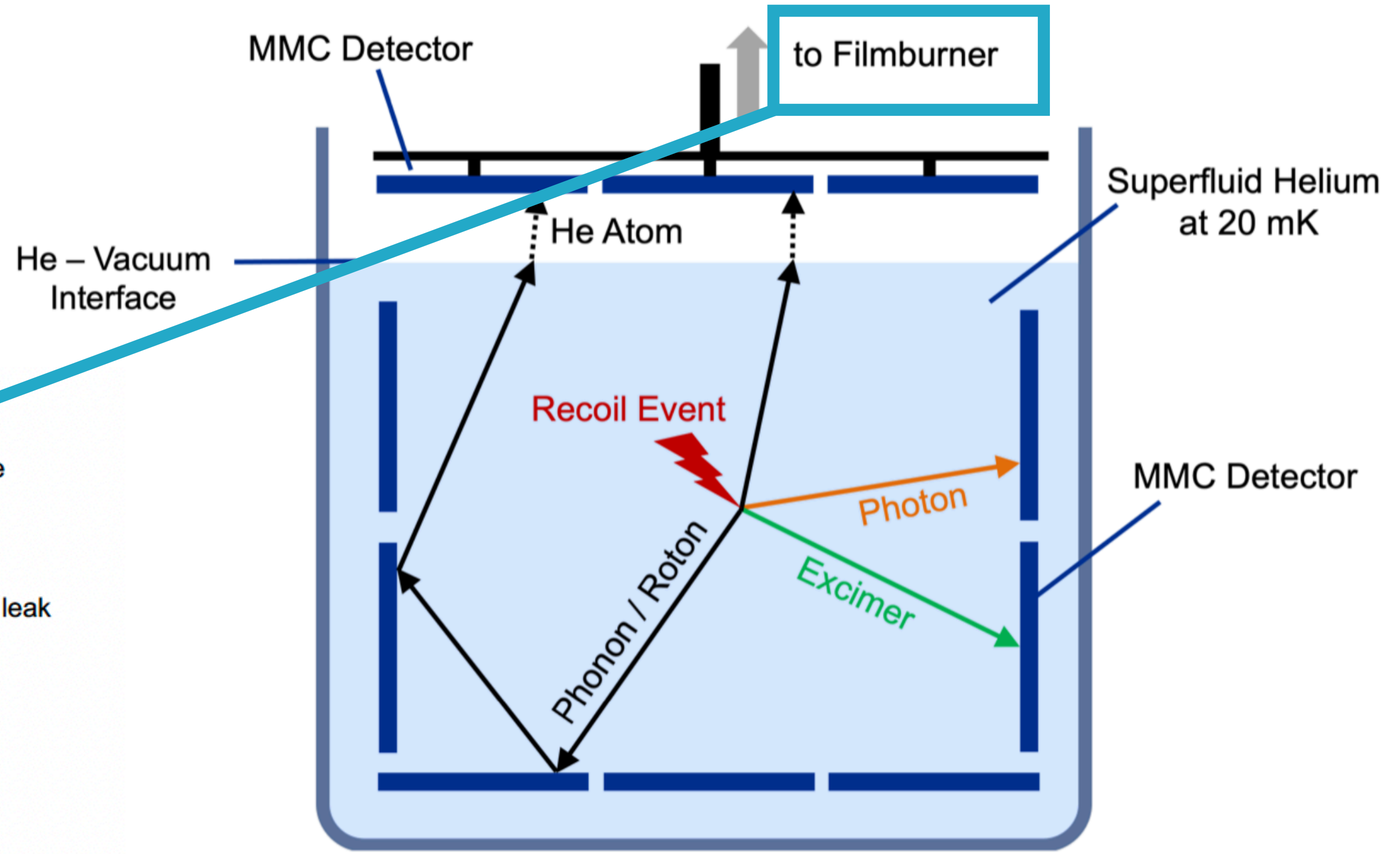




DELight Detector - Film Burner

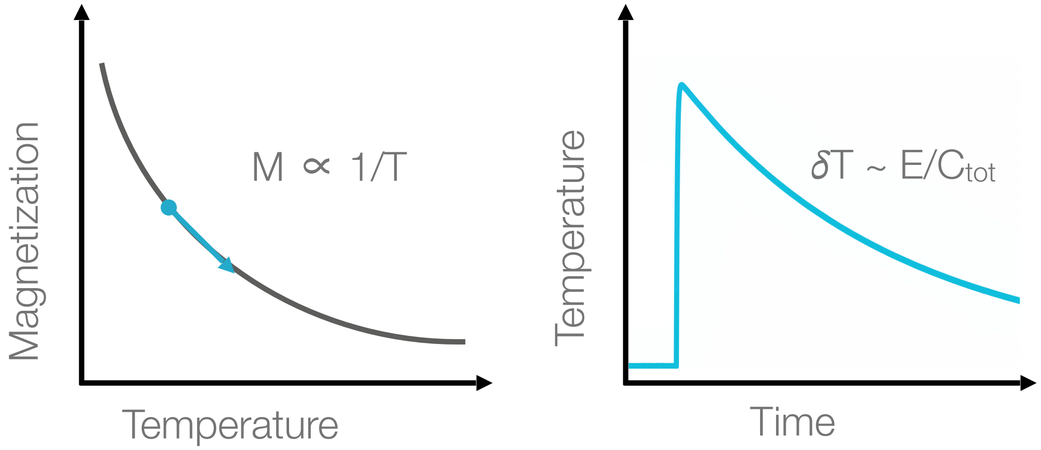
- Must keep sensors free of He film to maintain amplification factor
- Implement a film burner

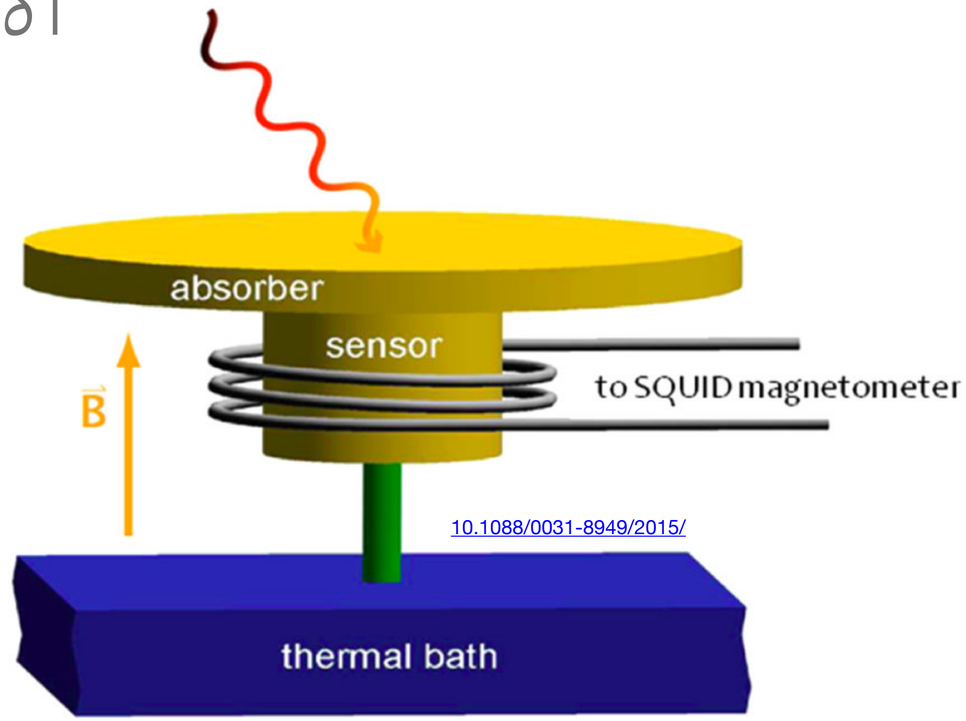




Magnetic MicroCalorimeters (MMCs)

- Energy deposition in absorber → increase in temperature δT and decrease in magnetization of the paramagnetic sensor $\delta M \propto \delta T$
- Change in magnetization read out via SQUID

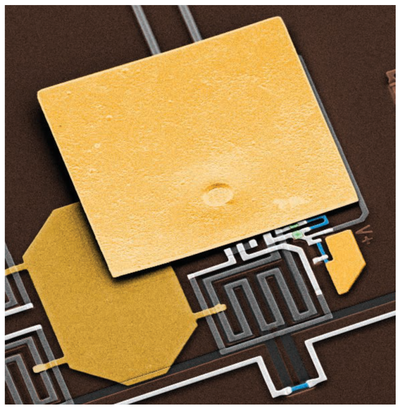


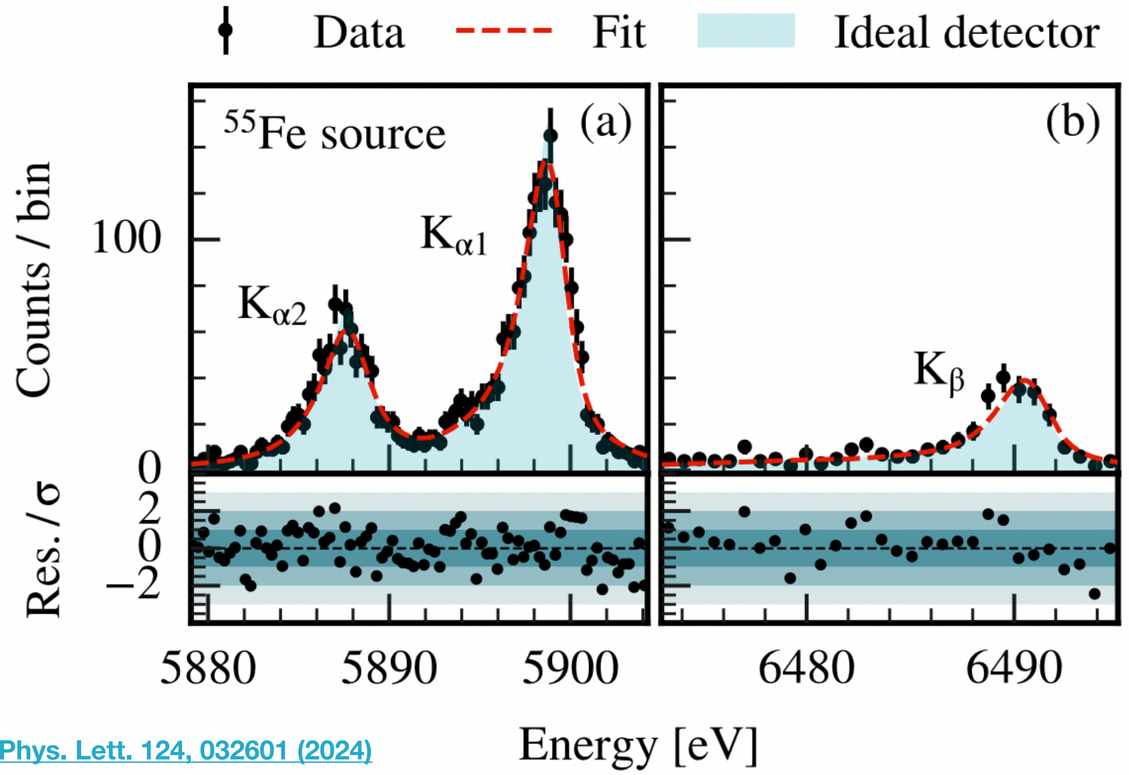


10.1088/0031-8949/2015/

R&D - MMC Energy Resolution

- New MMCs achieved best resolution to date with optimum-filter analysis of ^{55}Fe calibration peaks
  - **ΔE_{FWHM} = 1.25 eV at 5.9keV**
  - Amplitude fit to K_α data
  - Validated by reconstructing K_β



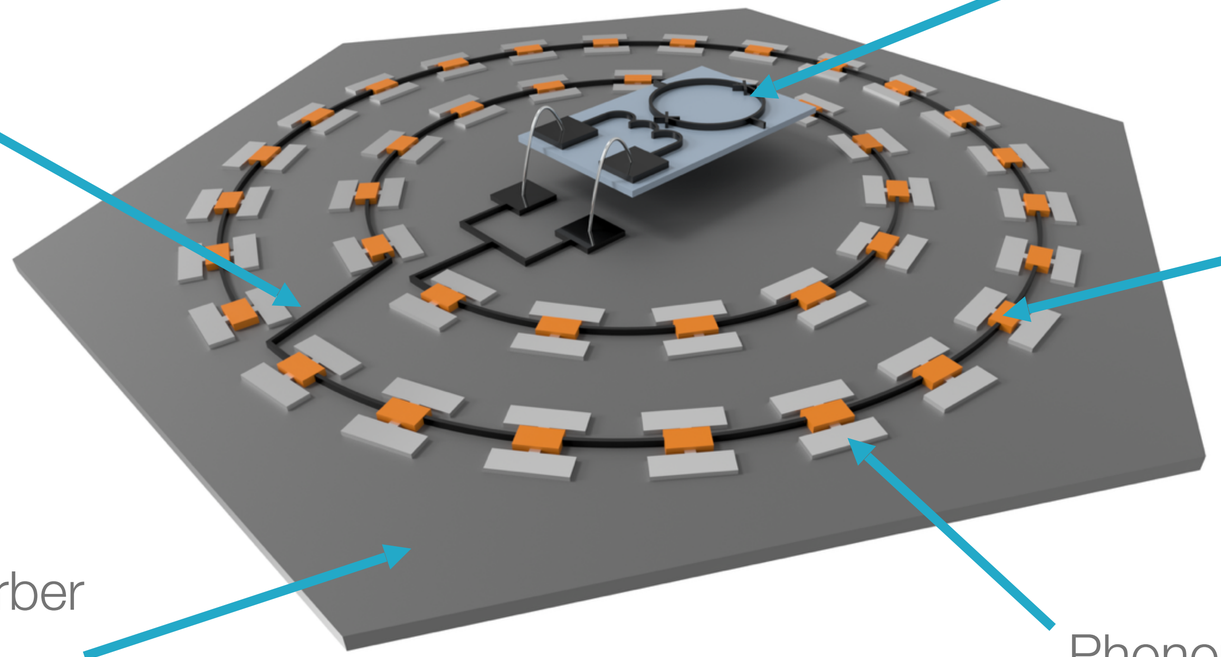


Appl. Phys. Lett. 124, 032601 (2024)

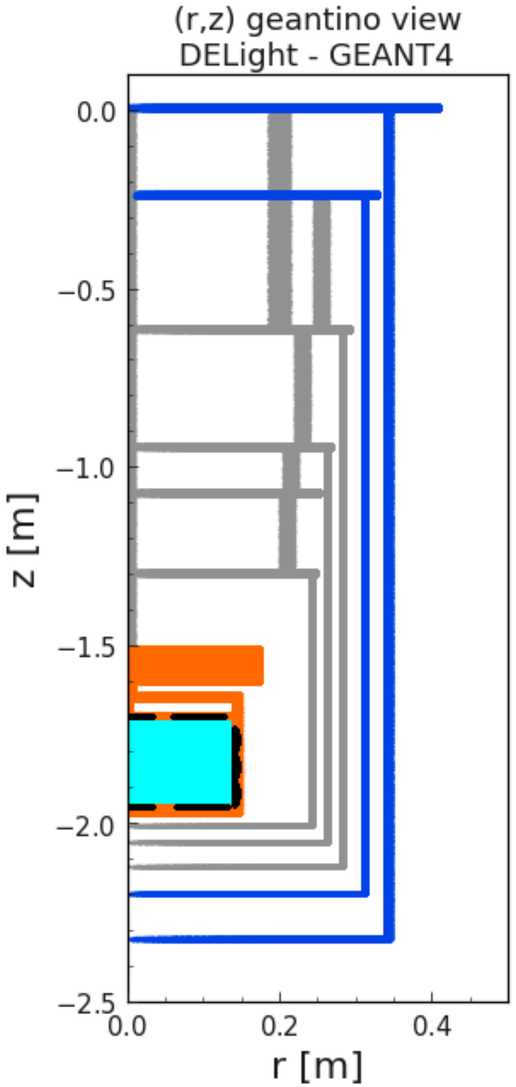
Phys. Rev. D 109, 043035 (2024)

Possible DELight MMC Design

- Large area MMC for full surface coverage - silicon or sapphire wafer
- Potentially sub-eV resolution



Simulations



- Geant4 model of preliminary DELight geometry implemented
- Quasiparticle physics implemented
- Ongoing background modelling
- Waveform simulations

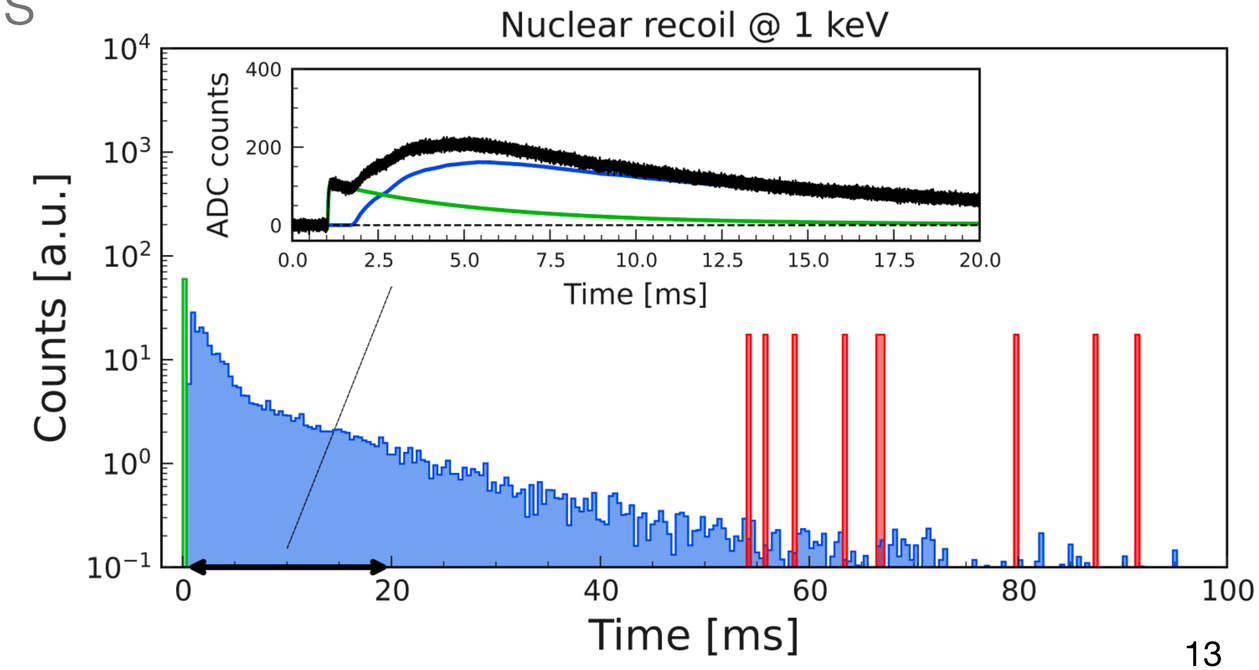
Fridge

Cryostat

Cell+film burner

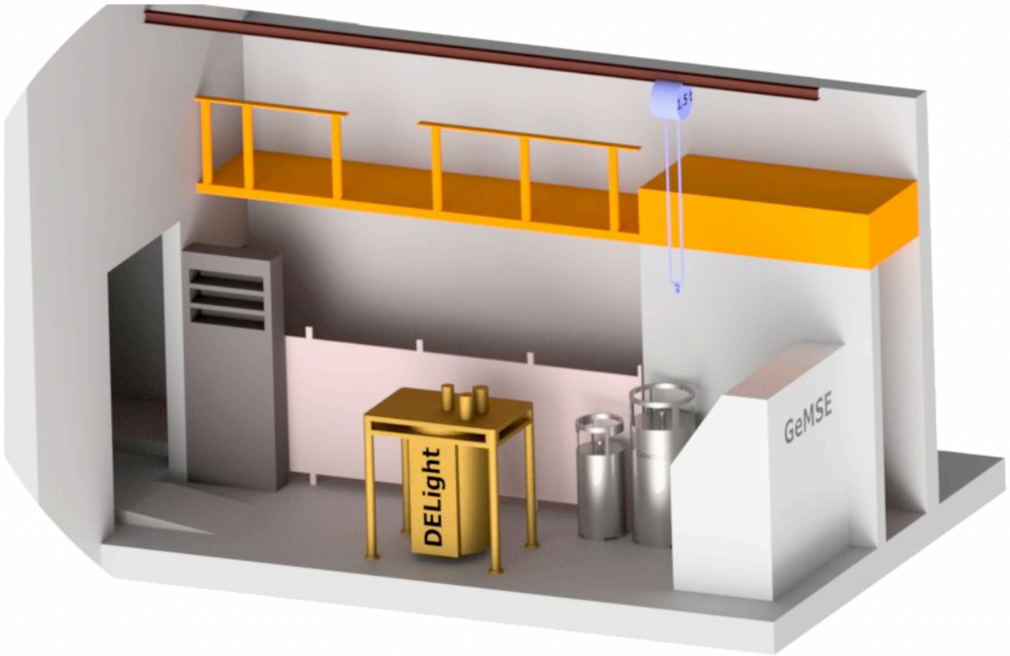
^{4}He

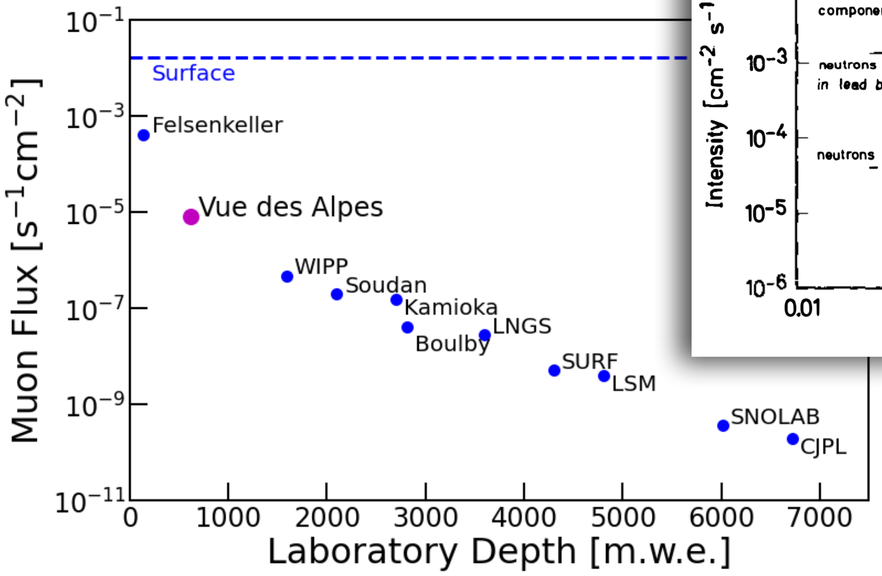
MMC

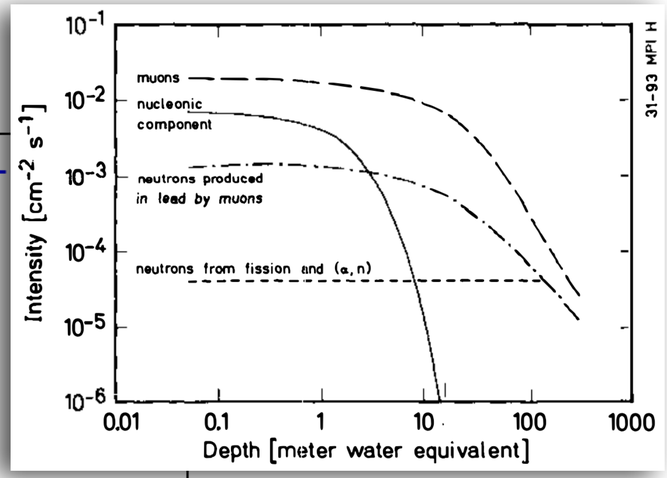


Vue-des-Alpes Underground Lab

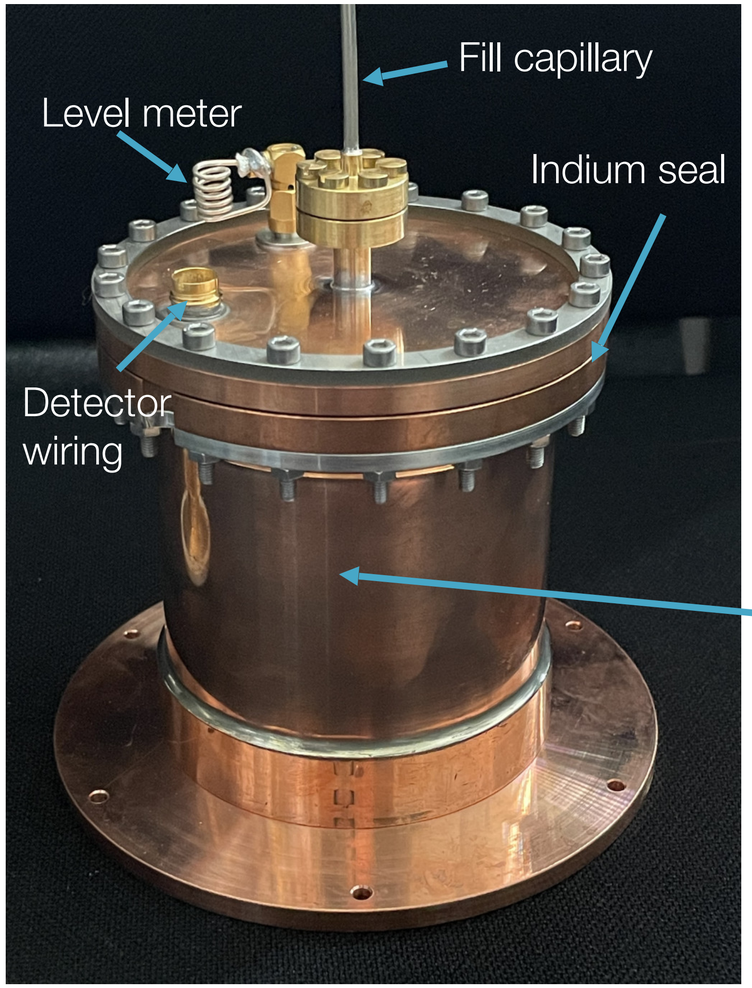
- Shallow underground lab in Switzerland, operated by University of Freiburg
- Hosts GeMSE gamma spectrometer for material assay
- Reduced cosmic background with 230m rock overburden (620m.w.e)

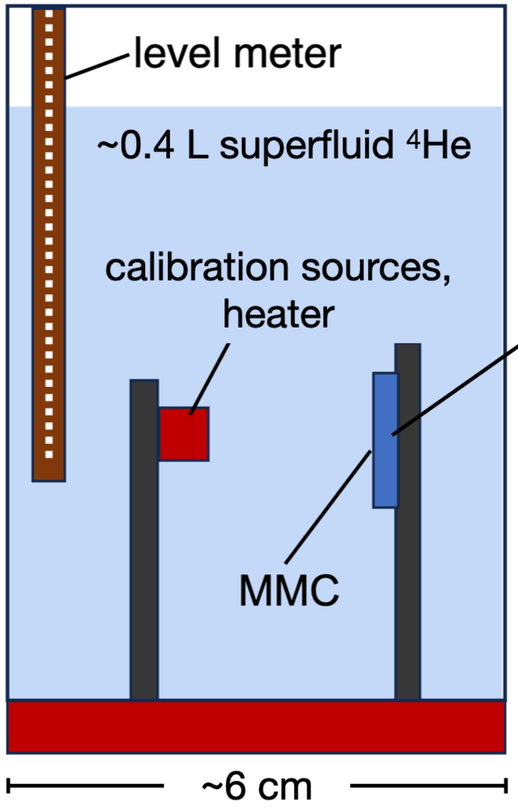


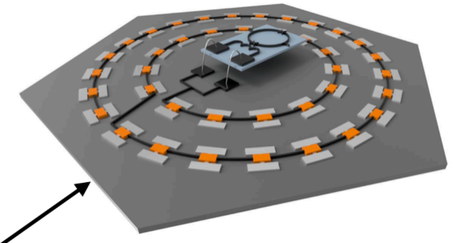




Small Scale “DELight Demonstrator” for R&D

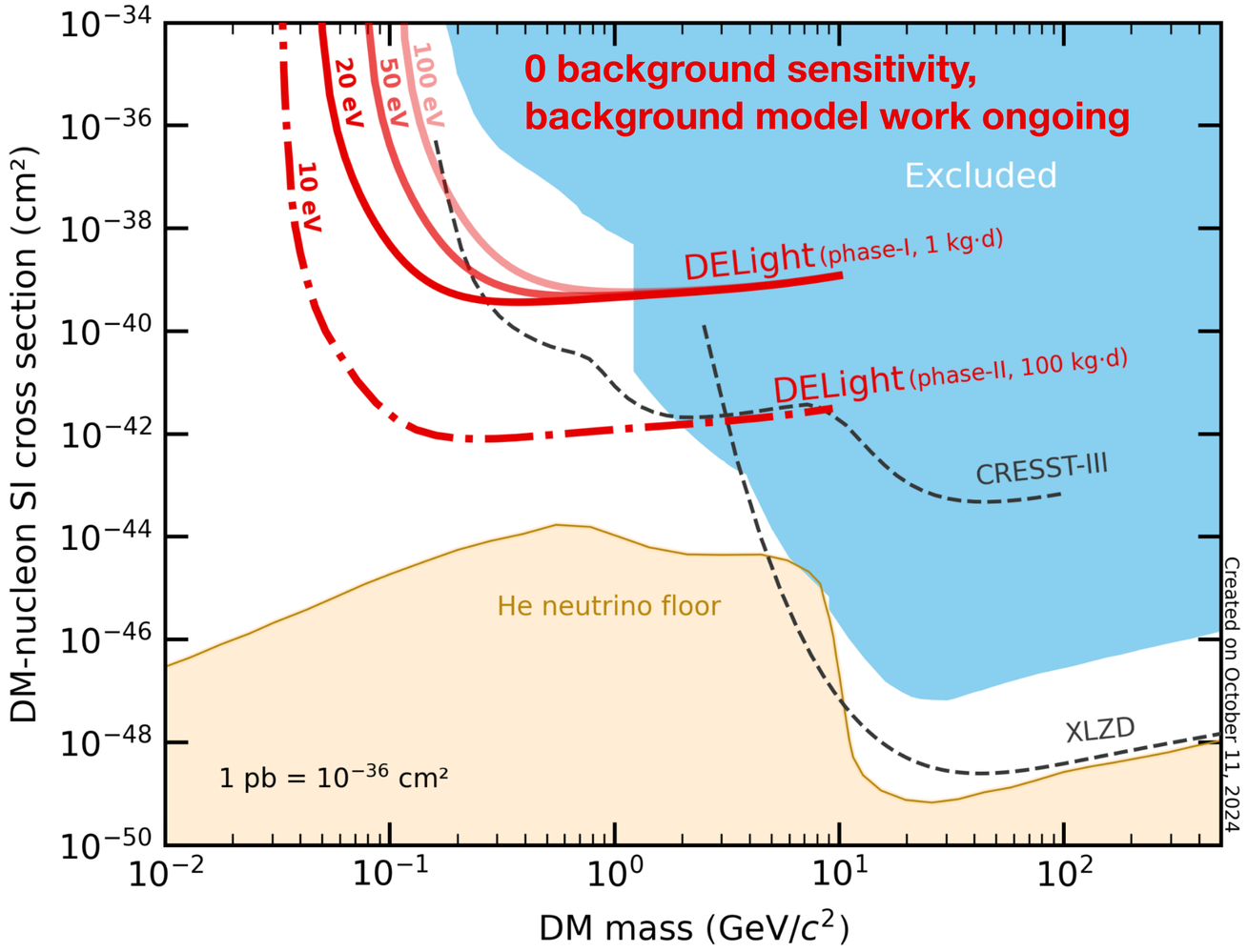






- MMC testing, athermal and thermal sensor characterization
- Direct quasiparticle measurements
- Background modelling
- DAQ
- Event reconstruction

To Conclude: The DELight Forecast

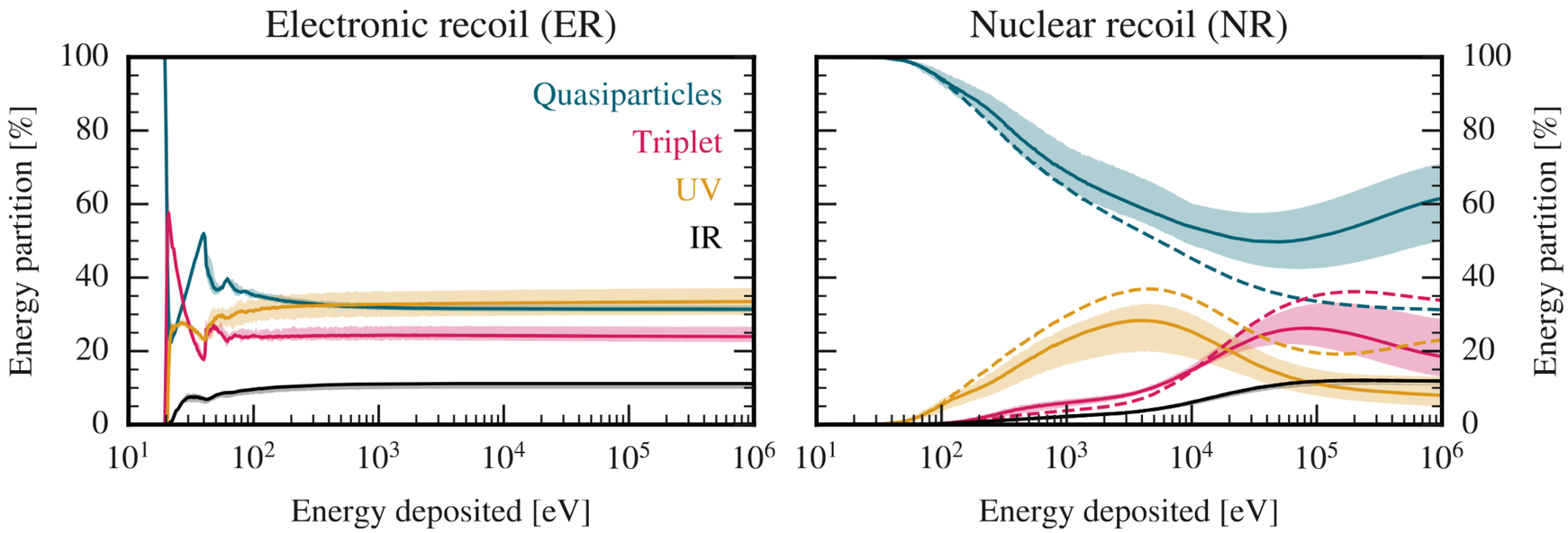


- Phase-I/Phase-II
  - 10L target
  - Shallow lab
- Long range plan
  - Larger cell + O(kg·yr) exposure, <10eV threshold
  - Deep lab


Thank you

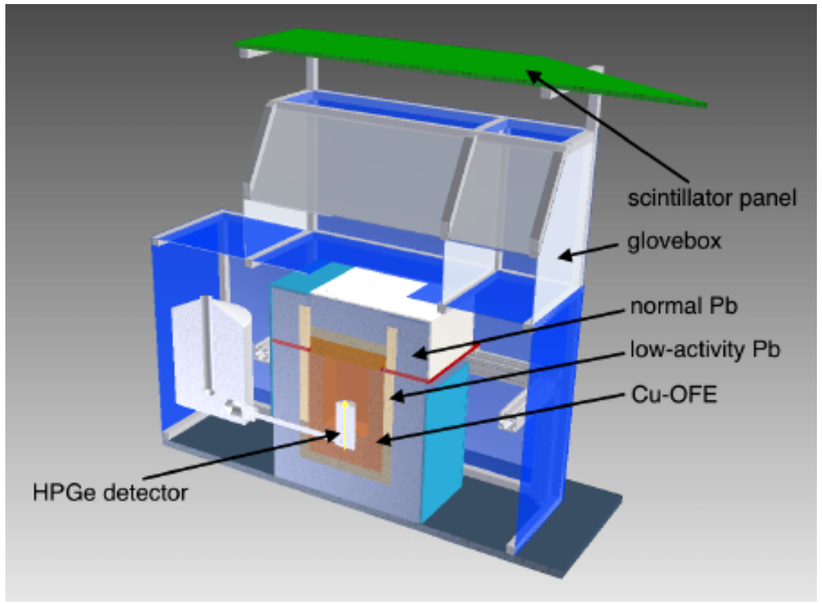
Signal Formation in Superfluid Helium

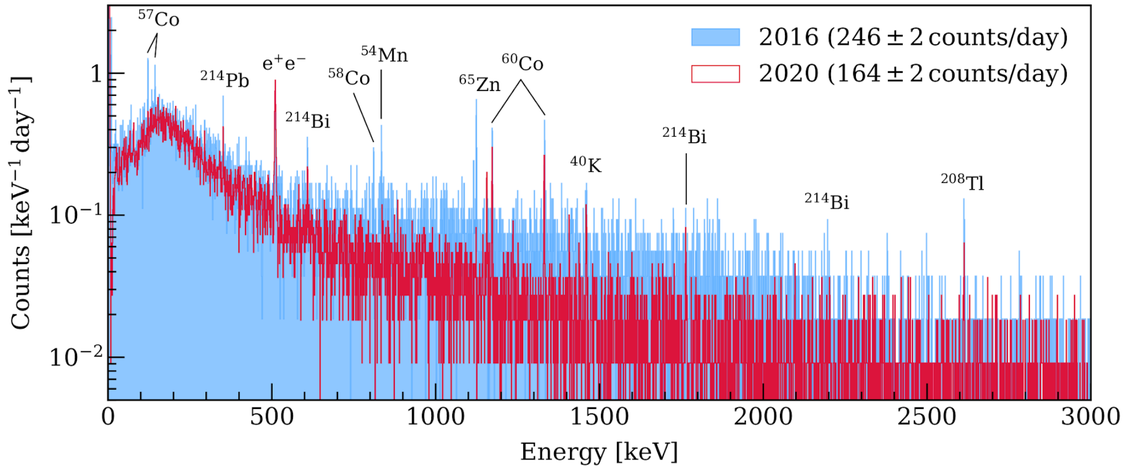
- Developed a Monte Carlo-based approach to estimate signal partitioning
  - **Signal partitioning in superfluid 4He: a Monte Carlo approach**, paper accepted by PRD, arXiv:2410.13684

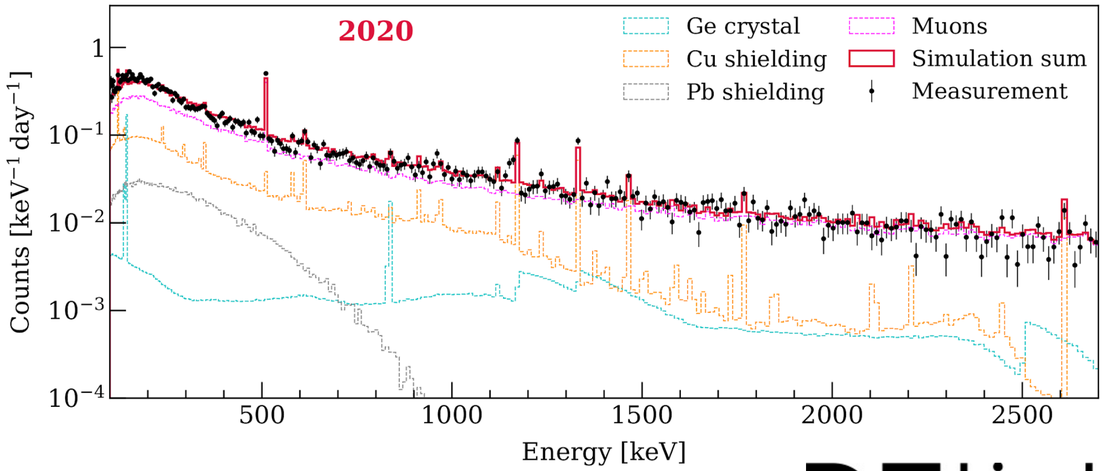


GeMSE

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







GeMSE HPGe spectrometer. JINST 17, P04005 (2022)