

DELIGHT: a Direct search Experiment for Light dark matter

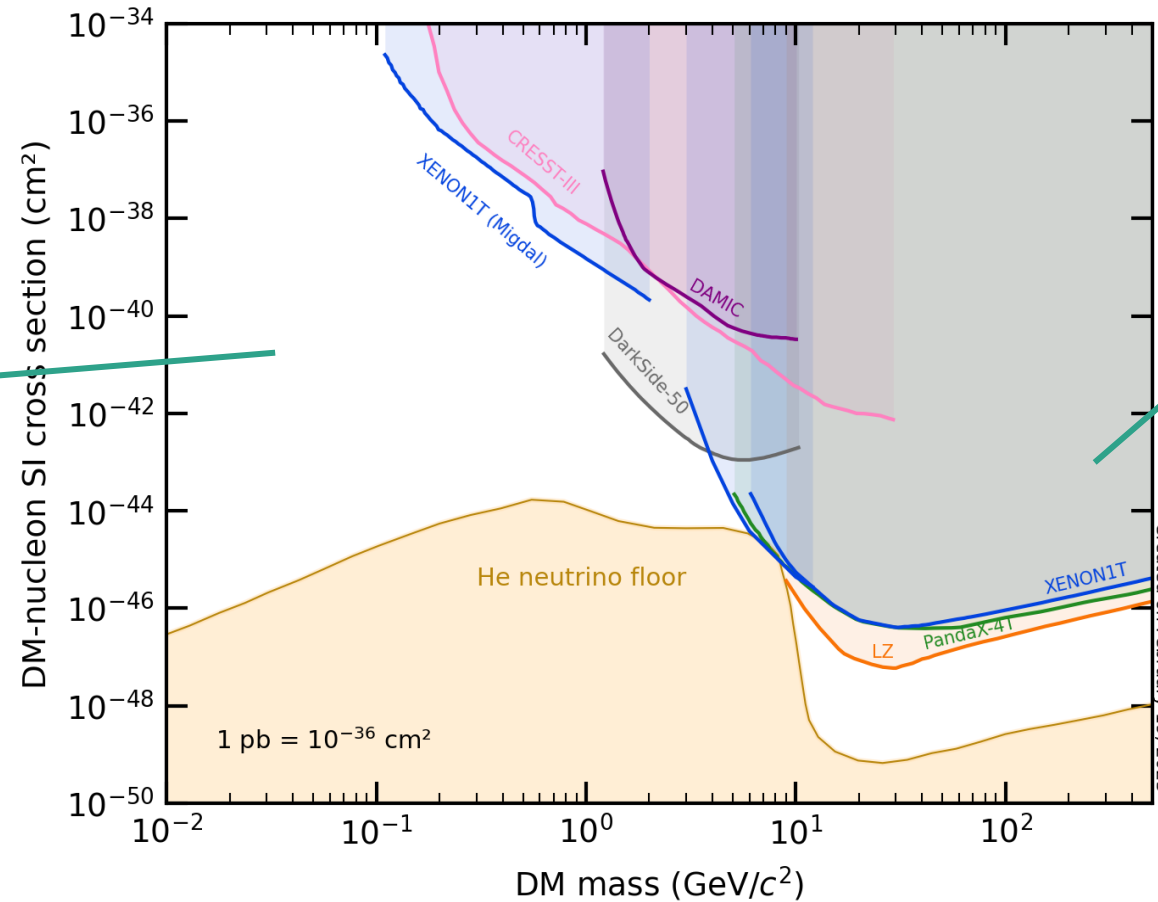
Francesco Toschi

Lake Louise Winter Institute – 21.02.2023



The Dark Matter landscape today

Phase space for Light DM (LDM) is mostly unexplored!



Noble liquid dual-phase TPCs constrain the phase space for large WIMP masses

[arxiv:2207.03764](https://arxiv.org/abs/2207.03764)

[arXiv:2207.11966](https://arxiv.org/abs/2207.11966)

[Phys. Rev. Lett. **121**, 111302 \(2018\)](https://doi.org/10.1103/PhysRevLett.121.111302)

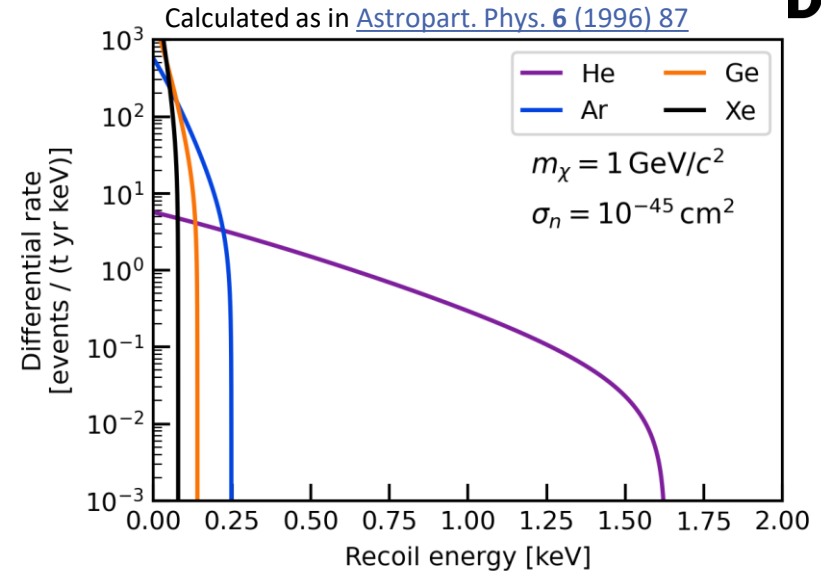
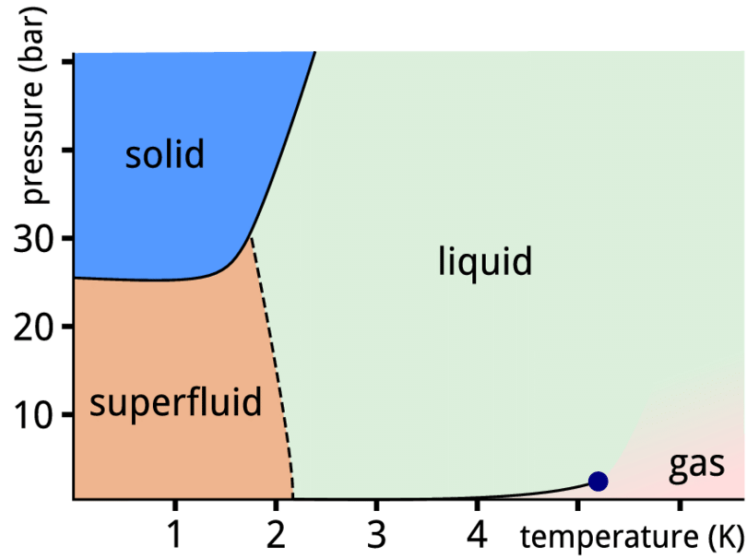
Technologies for LDM searches

- Cryogenic bolometers (e.g., SuperCDMS, CRESST)
- Migdal effect in dual-phase TPCs (e.g., XENONnT, LZ, DarkSide)
- Charge-Coupled Devices (e.g., SENSEI, DAMIC)
- Gaseous proportional counters (e.g., NEWS-G, DarkSphere)
- ...
- **Superfluid ^4He** (e.g., DELight, HeRALD)

[arxiv:2209.10950](https://arxiv.org/abs/2209.10950)

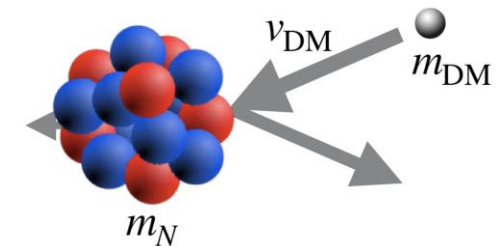
[Phys. Rev. D **100**, 092007 \(2019\)](https://doi.org/10.1103/PhysRevD.100.092007)

Superfluid ^4He as target



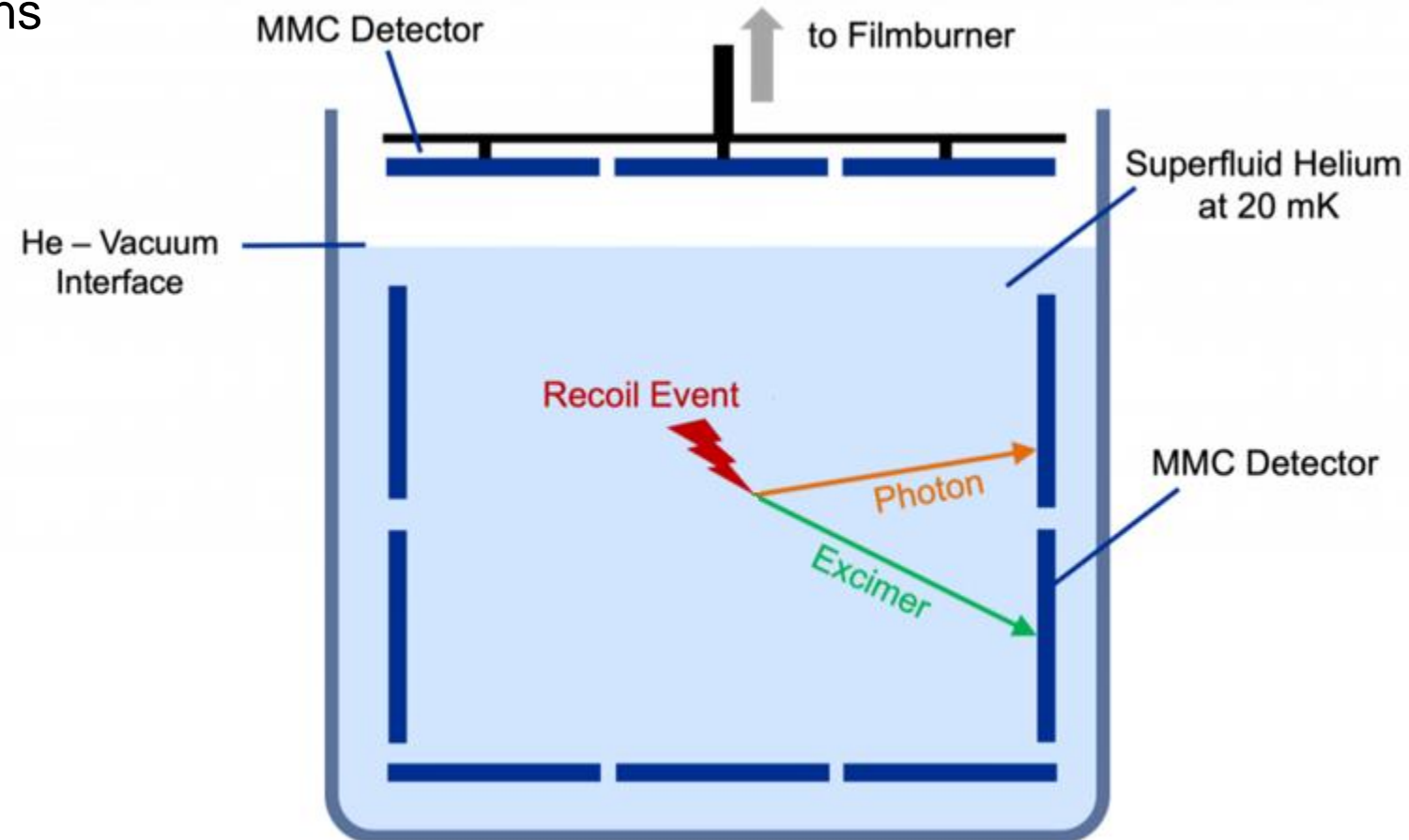
- Impurities freezing out (~ 20 mK)
- Multiple signals
- Unexpensive material and scalable technology

- Light nuclei maximize recoil energy for LDM



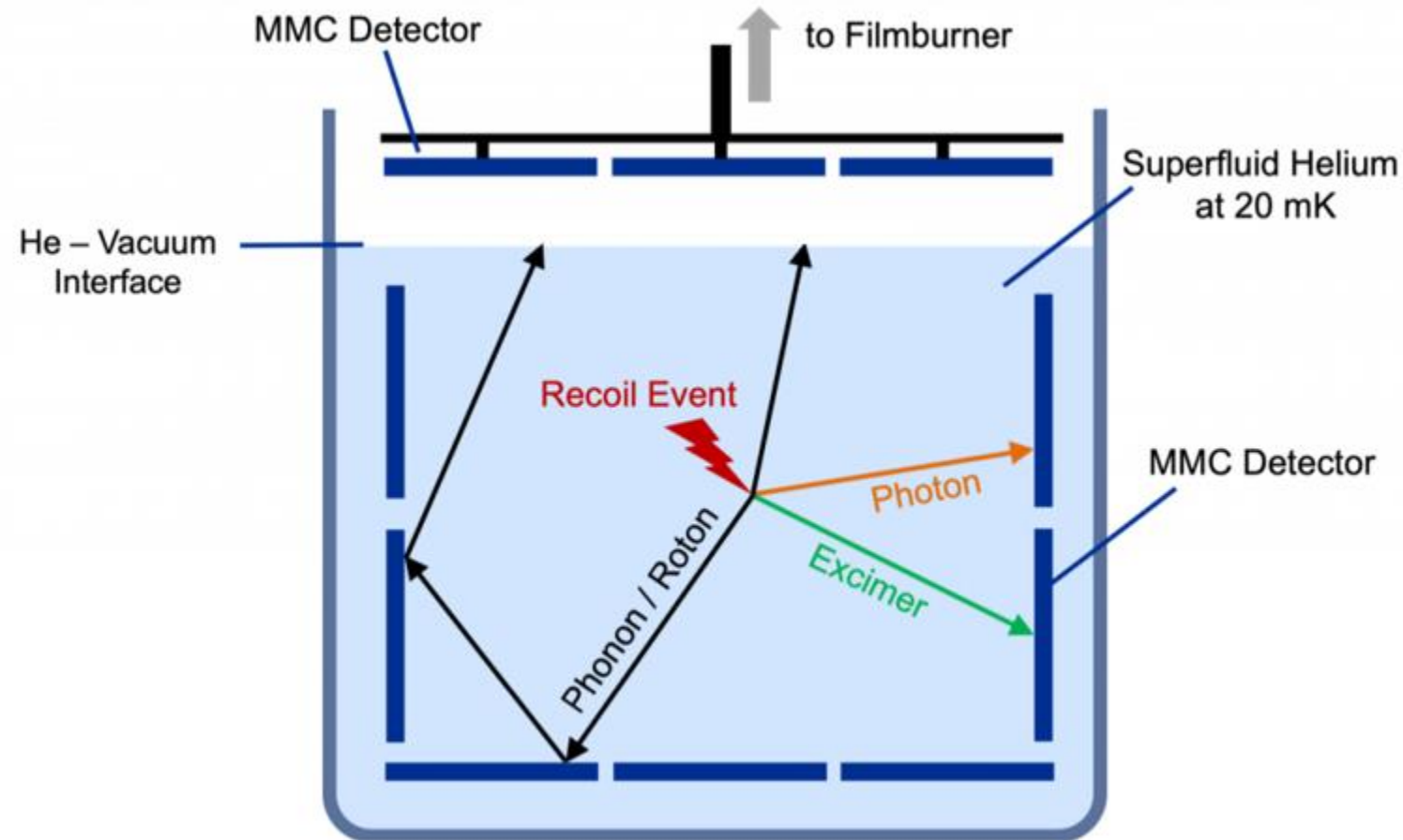
DELIGHT detection principle

- Prompt detection of UV and IR photons
- Ballistic triplet excimer:
 - 13 s lifetime
 - O(m/s) speed
 - Detected when in contact with MMC



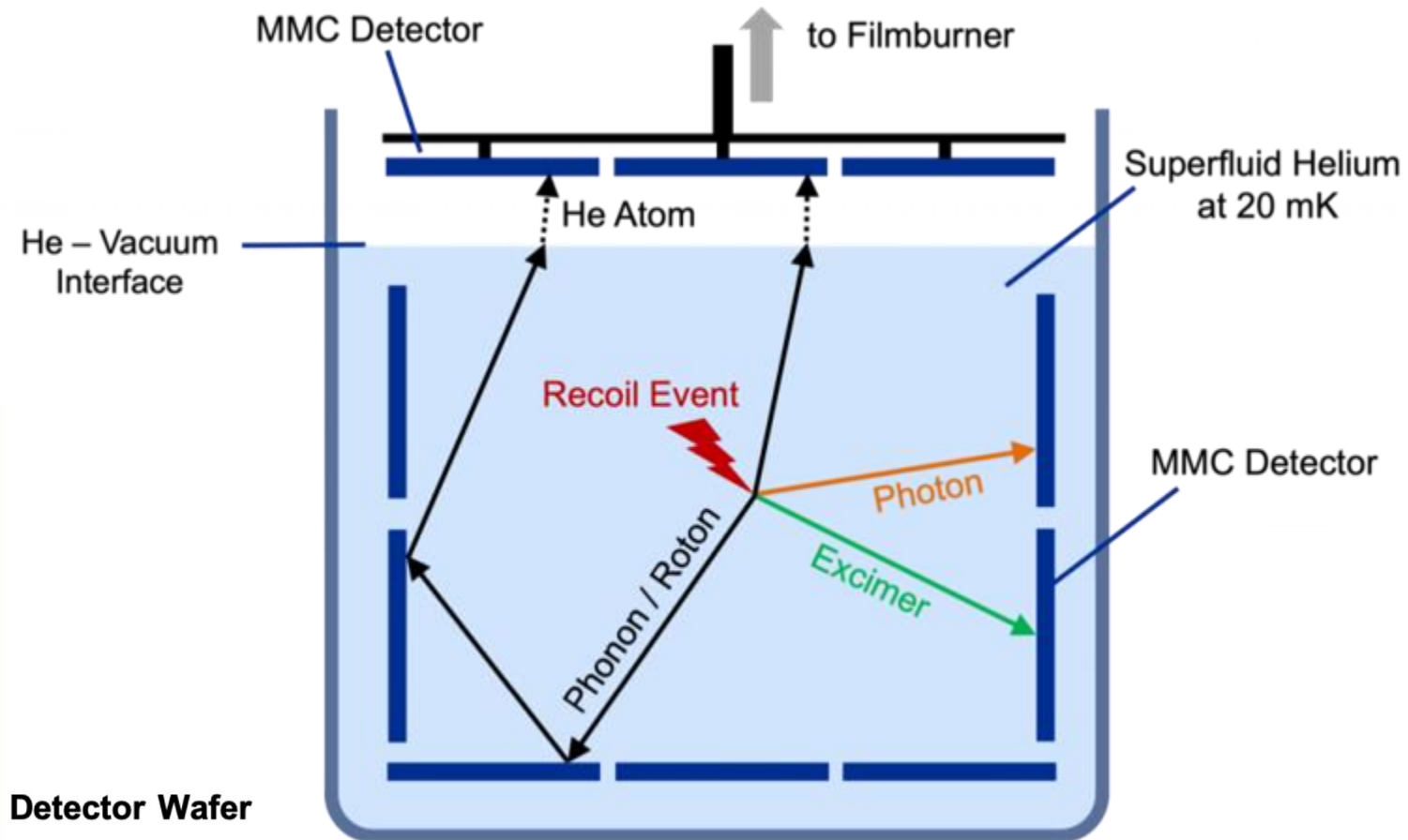
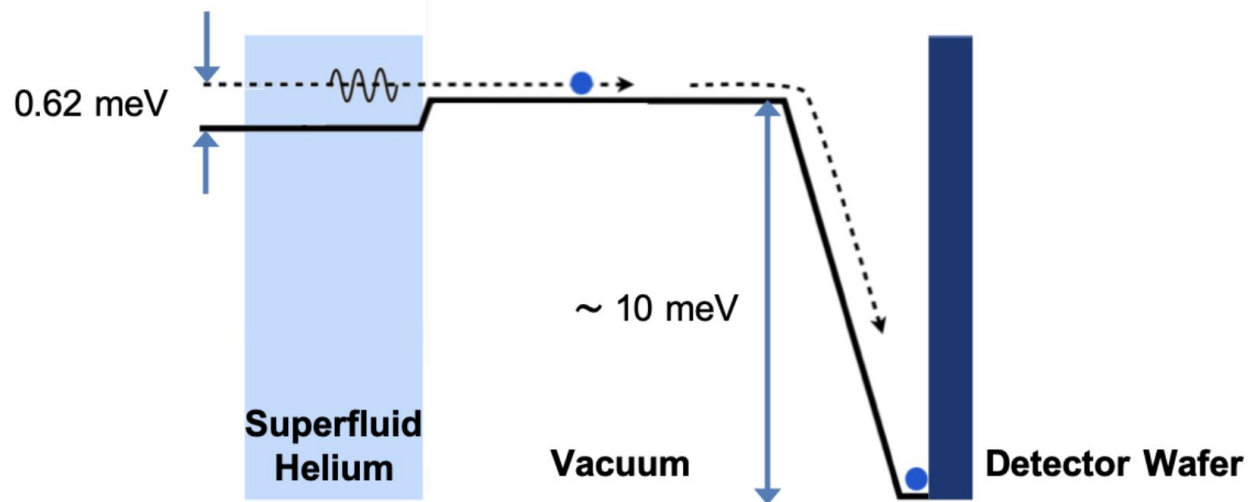
DELIGHT detection principle

- Quantum of collective excitation (phonon) as additional signal
- *Quasiparticles* propagate ballistically within the He target and are reflected at the interface with solid

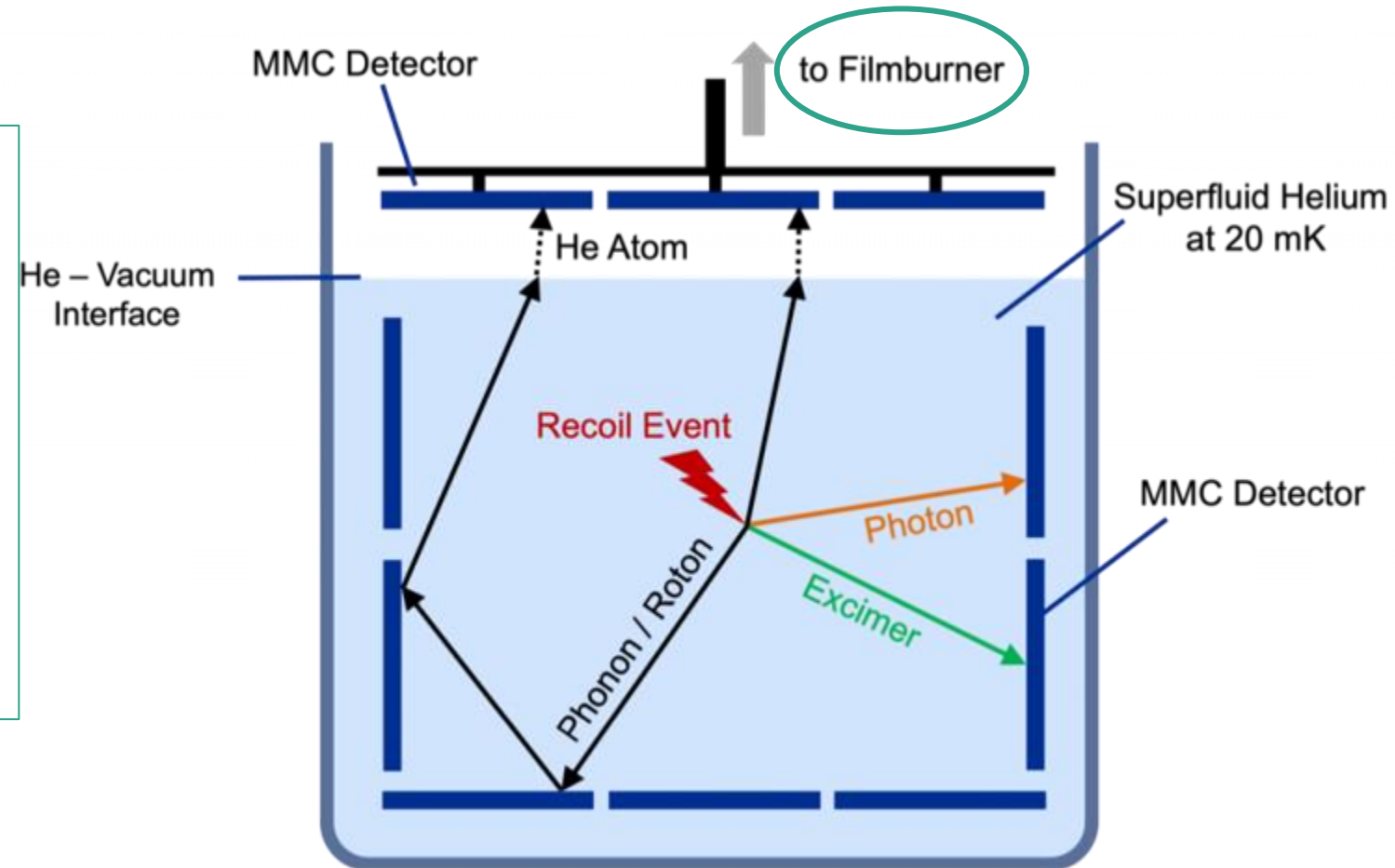
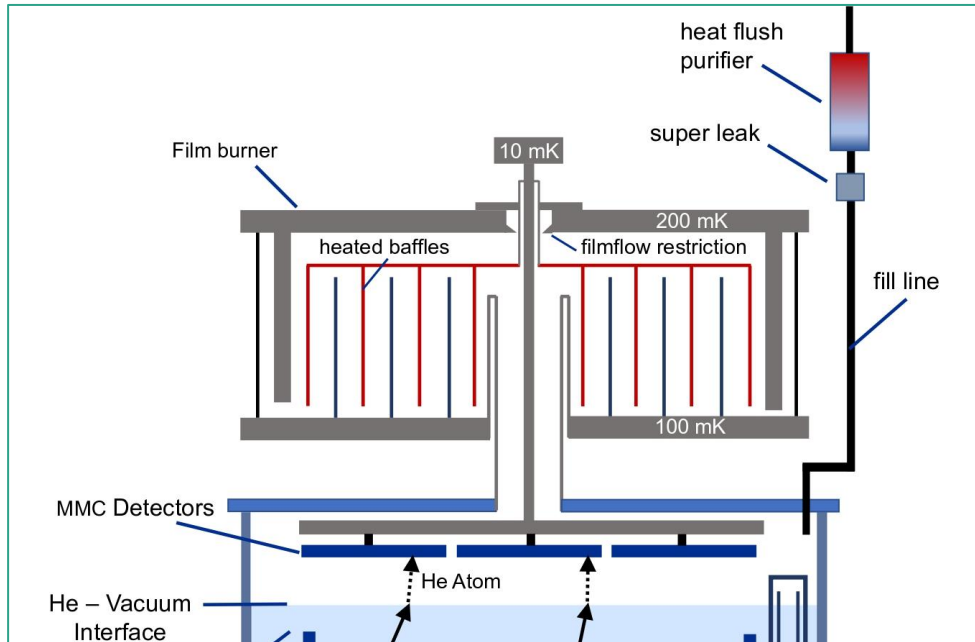


DELIGHT detection principle

- Noise-free gain ≥ 10 in deposited energy within the MMC detector as binding energy He-He is smaller than He-absorber

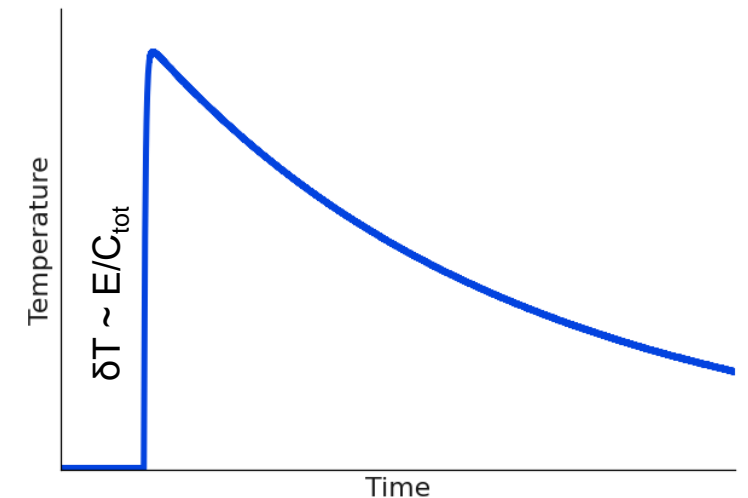
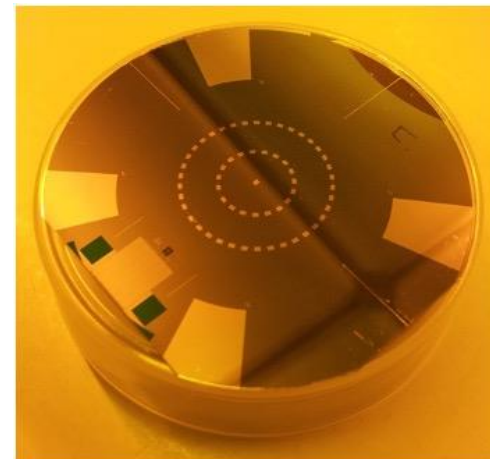
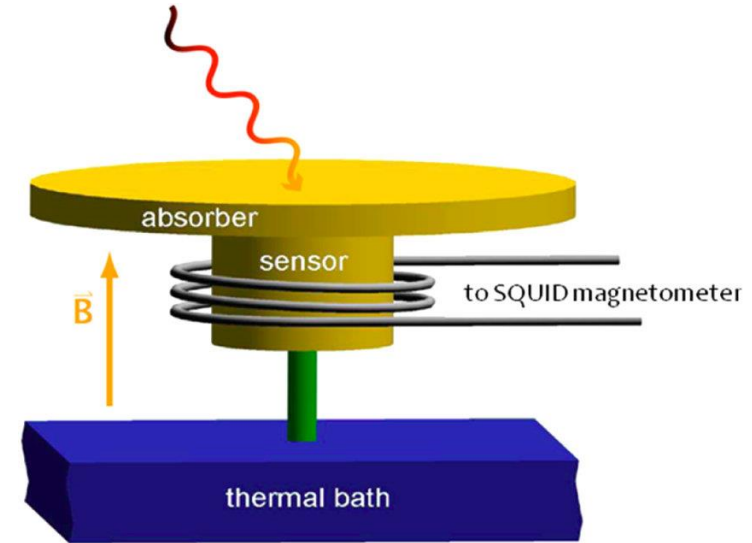


DELIGHT detection principle

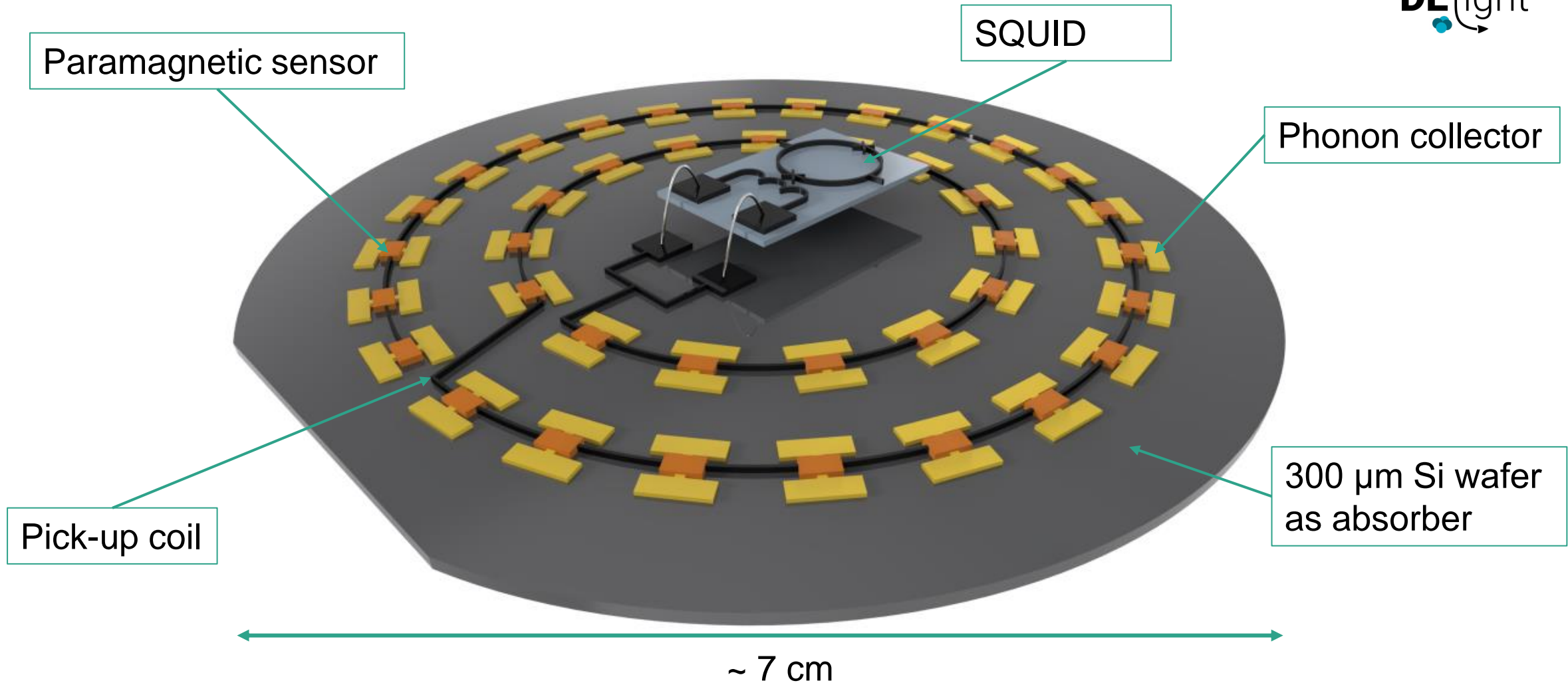


Magnetic Micro-Calorimeters (MMCs)

- Energy deposit in an *absorber* leads to a temperature increase δT changing the magnetization of the *paramagnetic* sensor $\delta M \propto \delta T$
- Change in magnetization measured by a coupled SQUID as change in current $\delta I \propto \delta T$
- Measured resolution of **1.6 eV** (@ 5.9 keV)



DELIGHT MMCs



The present of DELight

DELight: a Direct search Experiment for Light dark matter with superfluid helium

B. von Krosigk^{1*}, K. Eitel¹, C. Enss^{2,3}, T. Ferber⁴, L. Gastaldo², F. Kahlhoefer⁵, S. Kempf^{6,3},
M. Klute⁴, S. Lindemann⁷, M. Schumann⁷, F. Toschi^{1,7} and K. Valerius¹

[arxiv:2209.10950](https://arxiv.org/abs/2209.10950)

- He cell + filmburner R&D
- DELight lab this year



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

- MMC R&D
- MC simulations



- UG laboratory (Vue des Alpes, CH)
- Low-radioactivity techniques



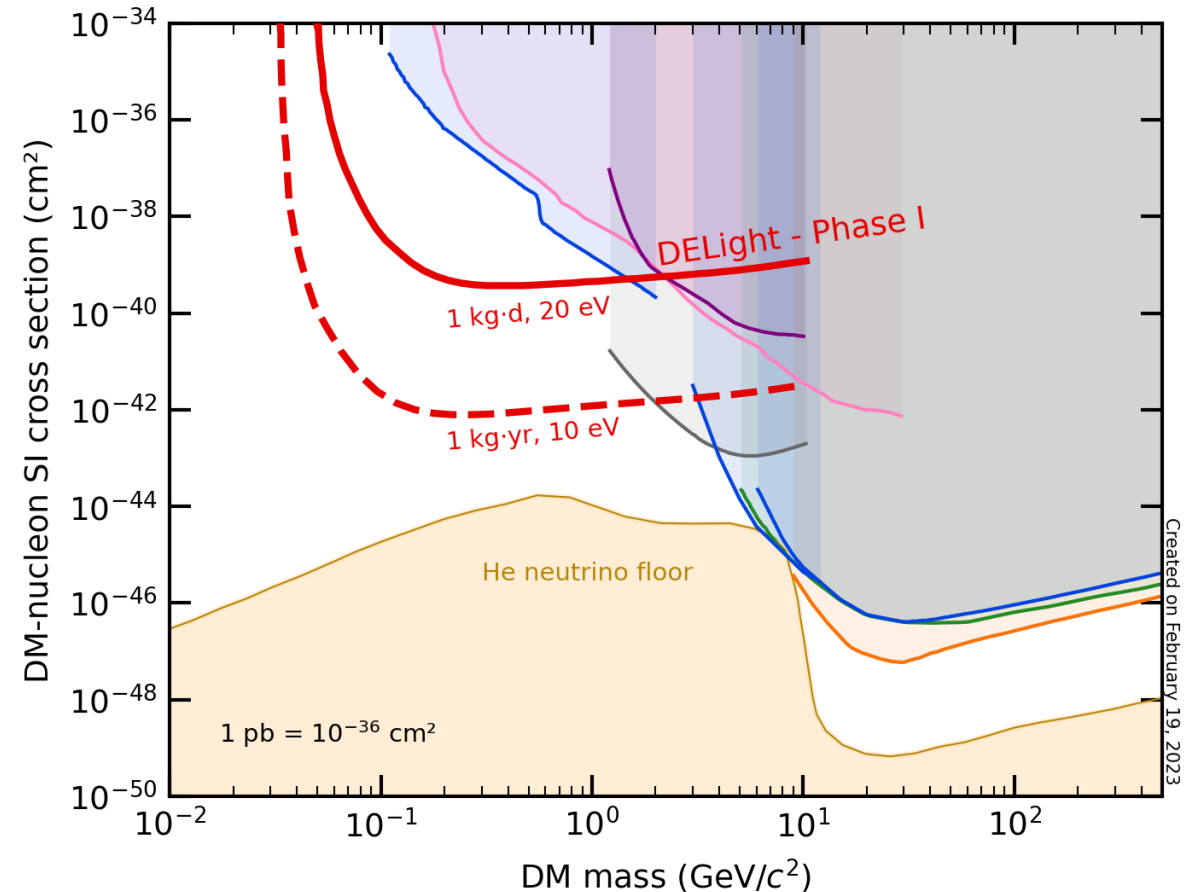
The future of DELight



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

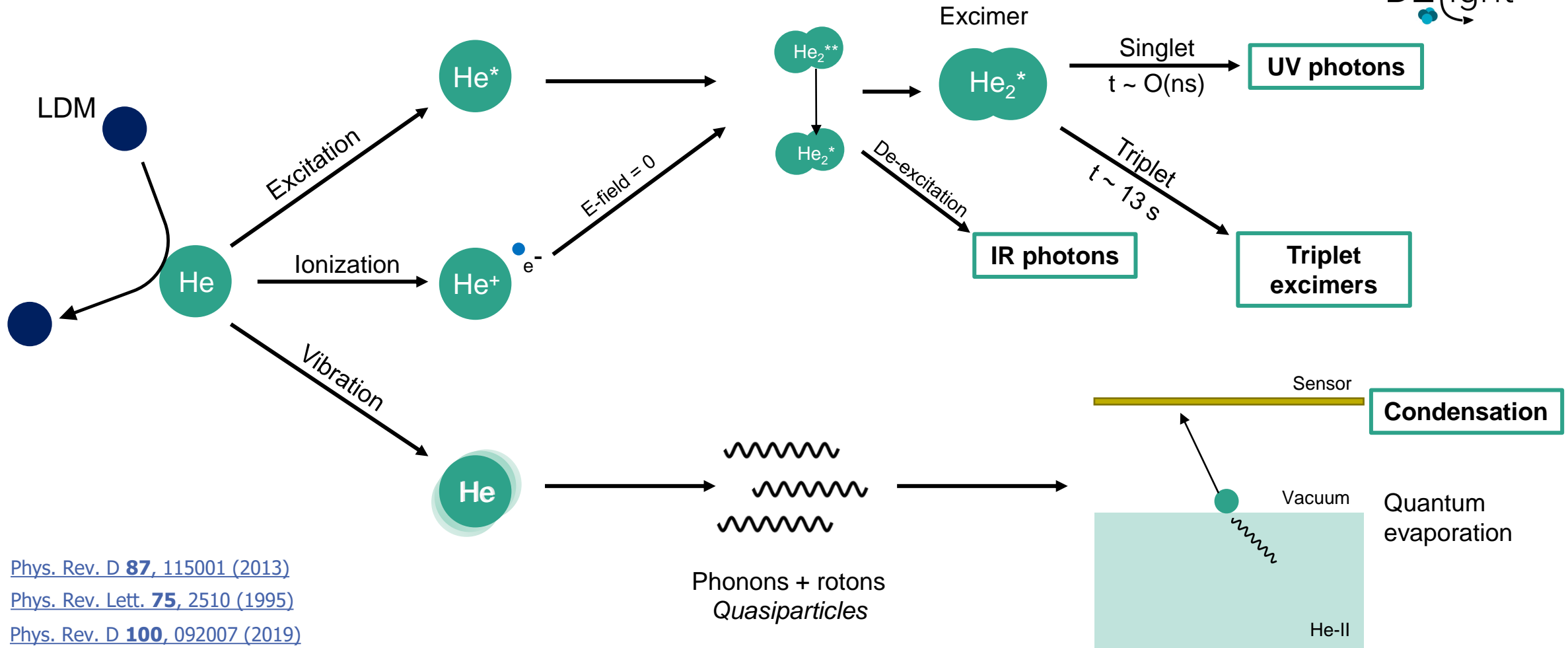


- First phase can already probe new parameter space with limited exposure:
 - 10 liters (~1 kg)
 - O(kg·d) exposure
 - 20 eV threshold
- Long term plan:
 - Up to 200 liters in UG lab
 - O(kg·yr) exposure
 - <10 eV threshold



Back-up slides

Superfluid Helium as target



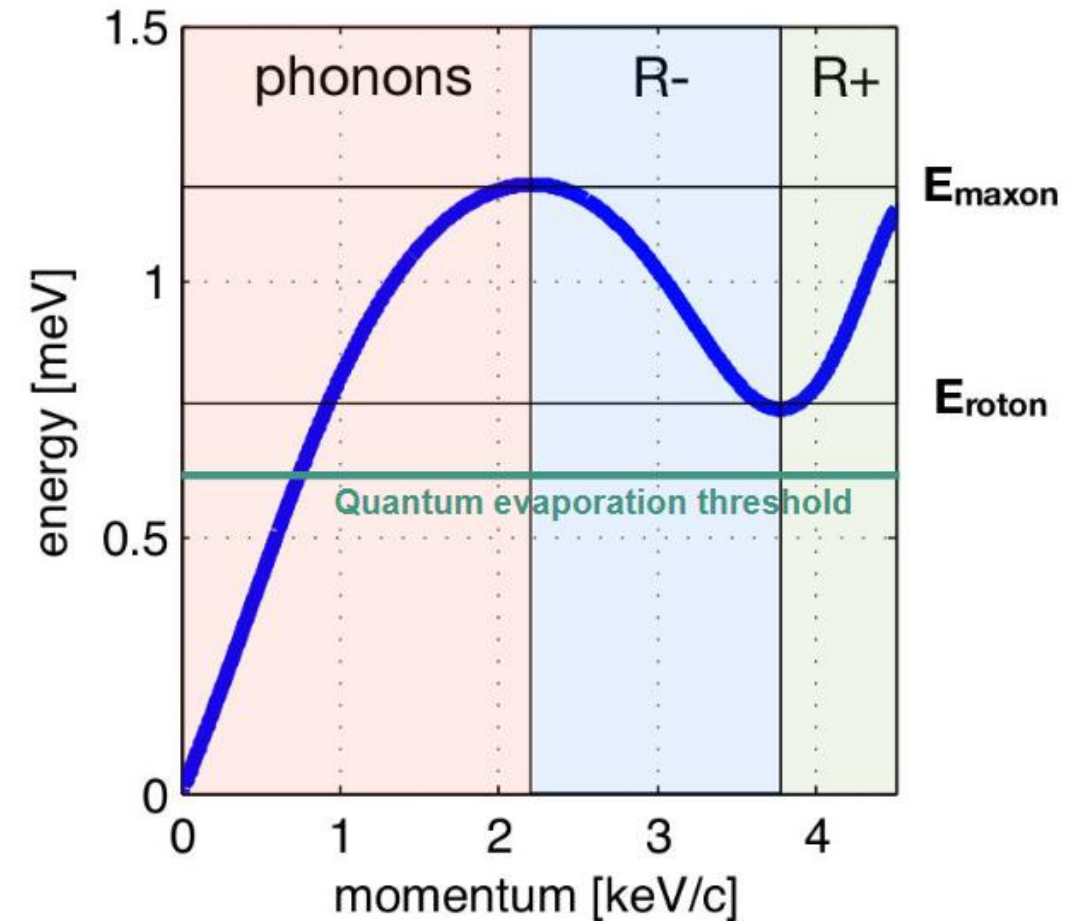
[Phys. Rev. D **87**, 115001 \(2013\)](#)

[Phys. Rev. Lett. **75**, 2510 \(1995\)](#)

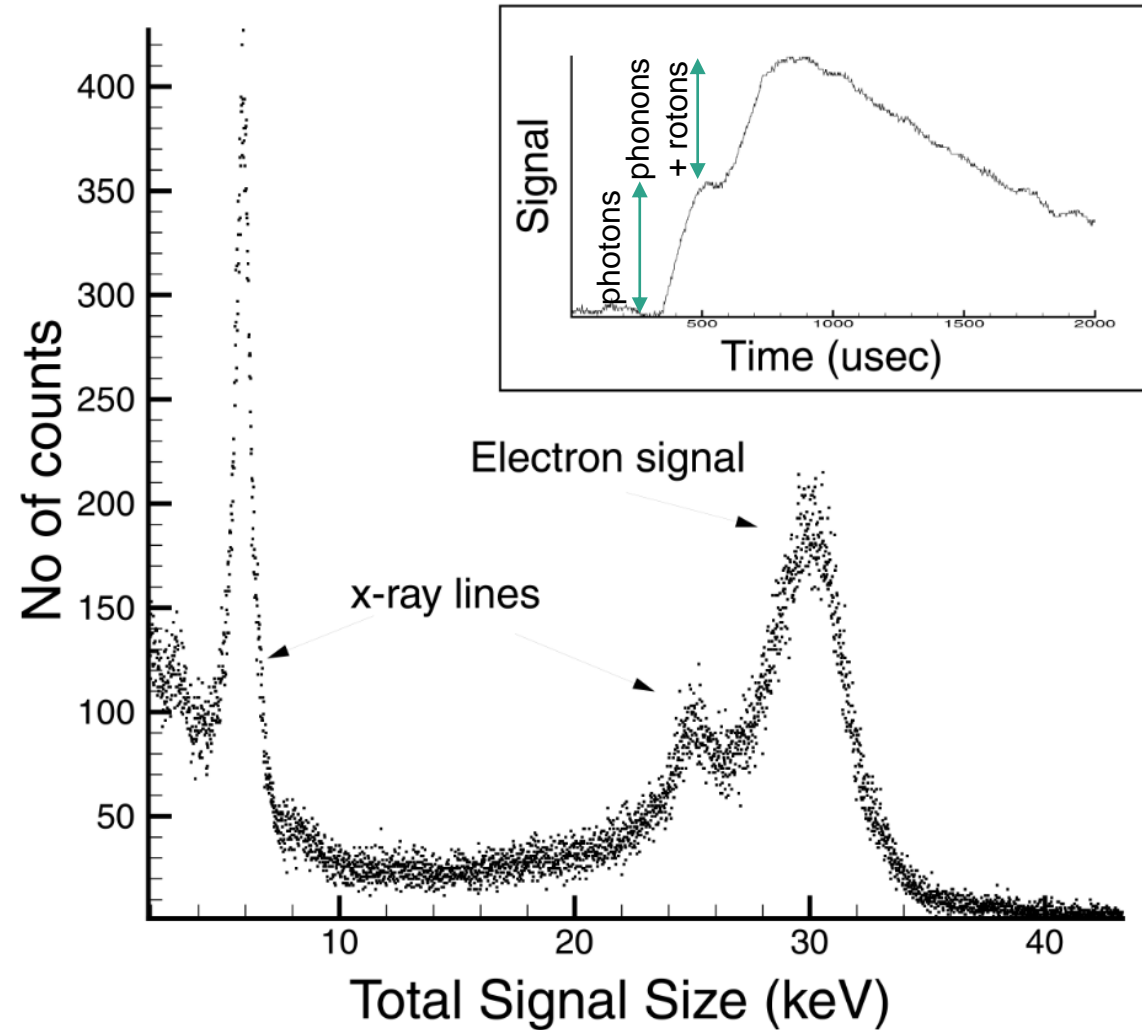
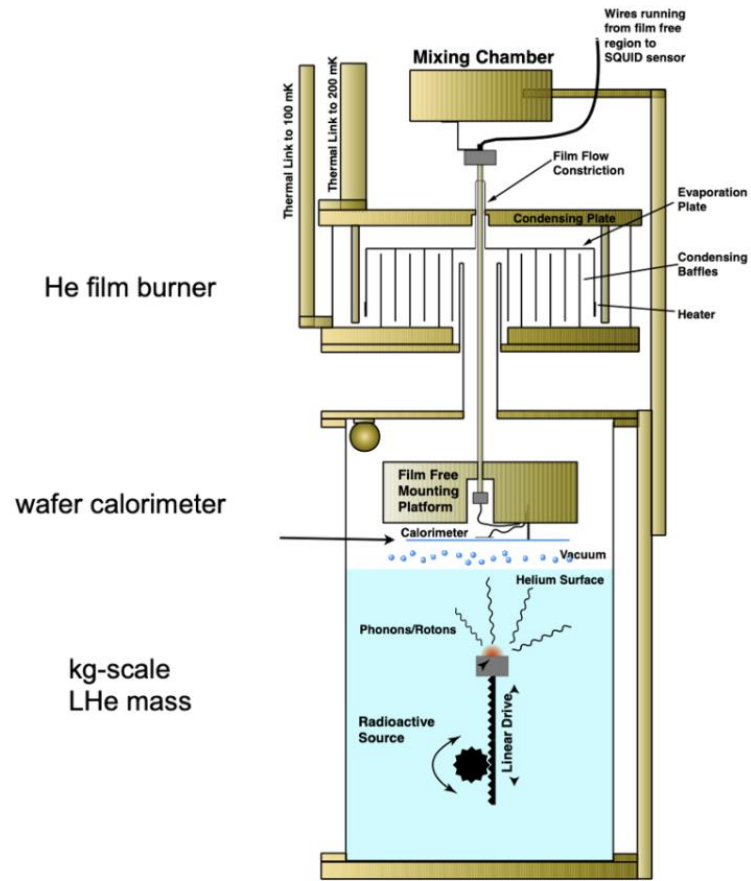
[Phys. Rev. D **100**, 092007 \(2019\)](#)

Phonon in superfluid Helium

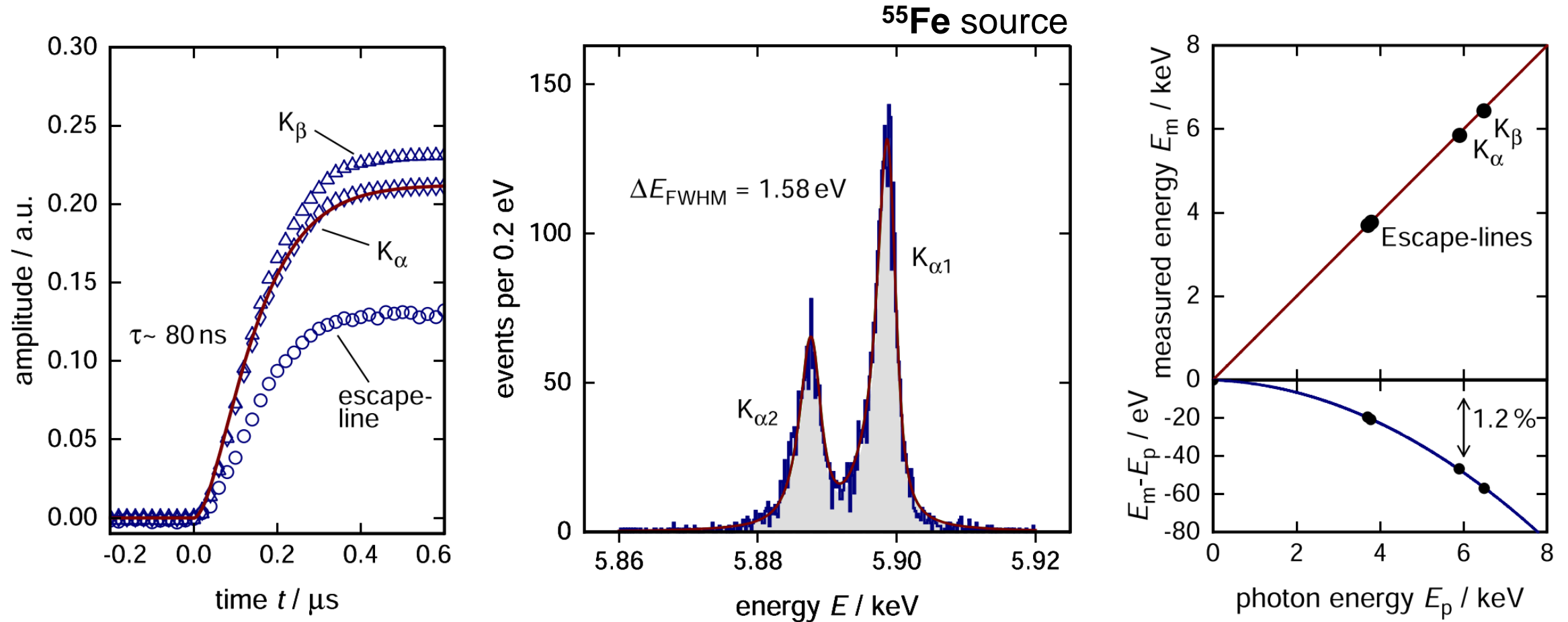
- Rotons \simeq high momentum phonons



HERON



MMCs performance



Vue-des-Alpes UG laboratory

- Situated in Vue-des-Alpes (Swiss Jura Mountains), easily accessible via car
- Rock overburden of 620 m.w.e. ($>10^3$ cosmic μ reduction)
- GeMSE HPGe gamma screening facility available

