Karlsruhe Institute of Technology

DELight

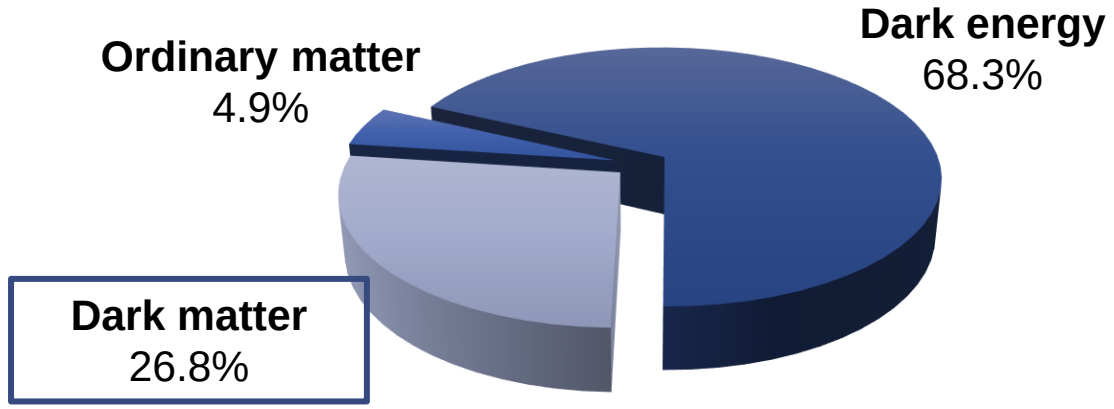
DELight: a **D**irect search **E**xperiment for **Light** dark matter with Superfluid Helium

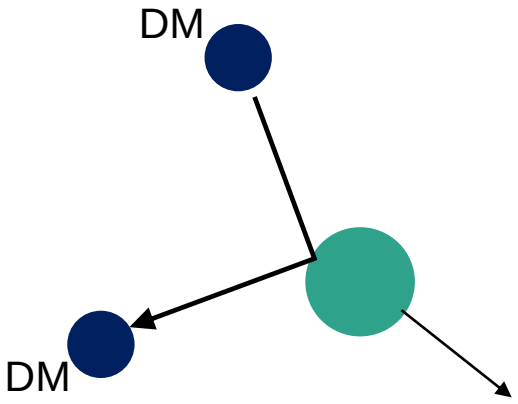
Francesco Toschi

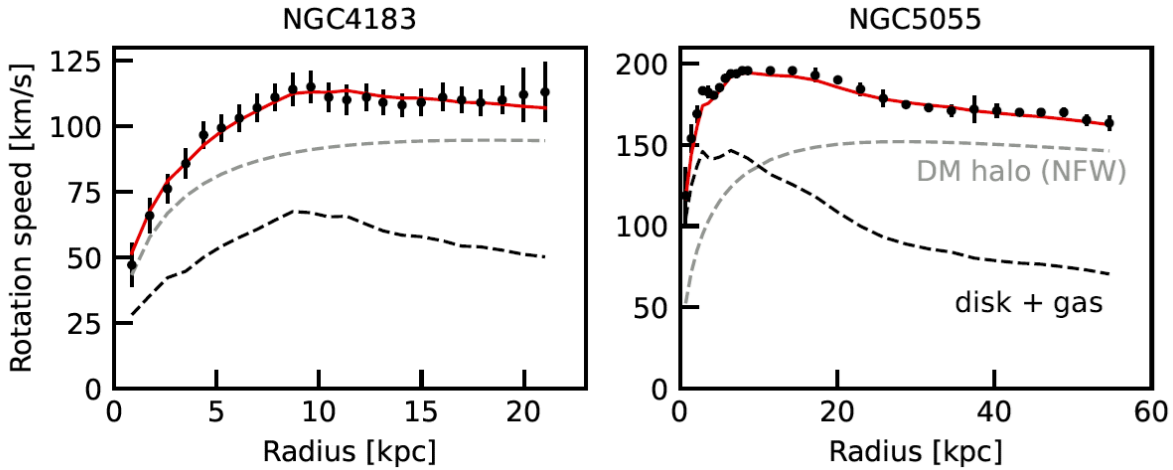
DPG Spring Meeting, Dresden – 20.03.2023

Dark Matter

- No electromagnetic interaction → **dark**;
- Evidences of gravitational nature → **massive**;
- No particle candidate in SM → **BSM physics**;
- Direct searches for DM-nucleus scattering.

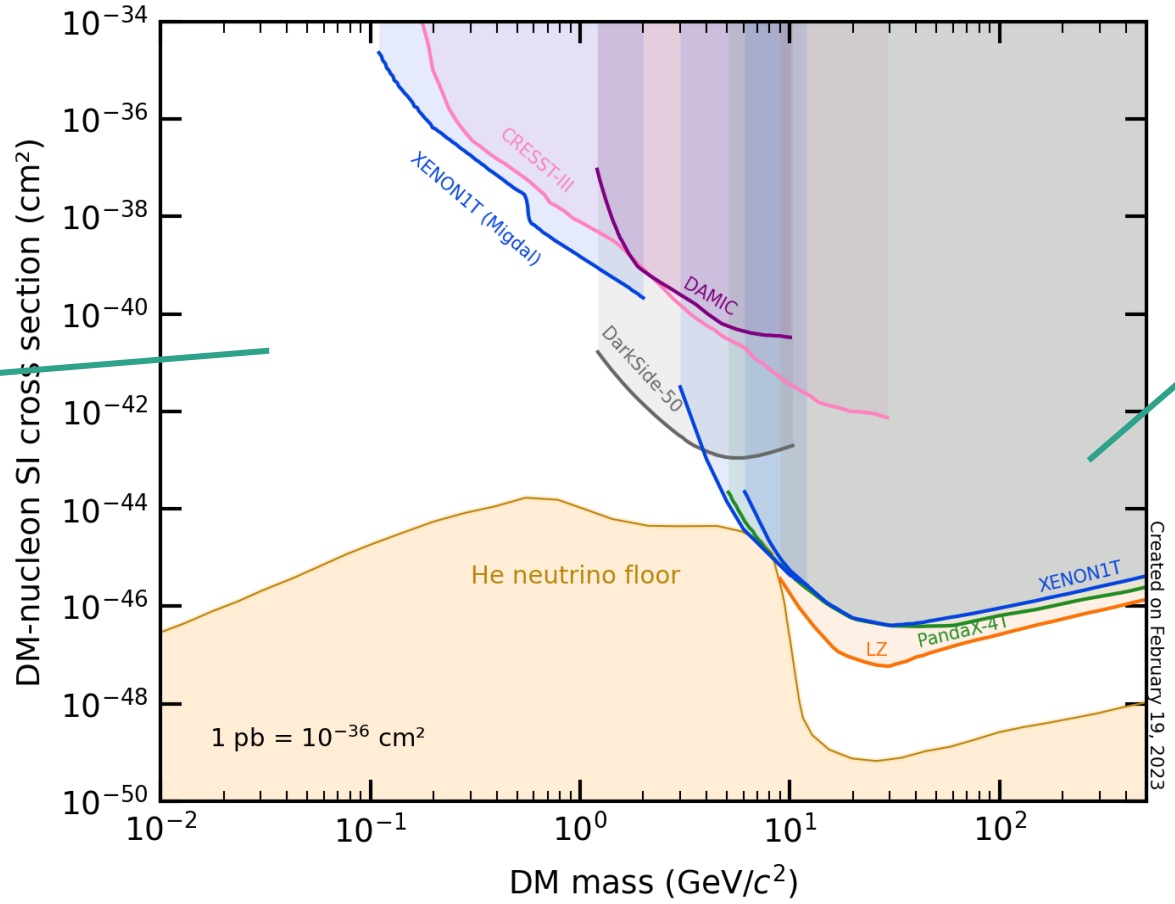






The Dark Matter landscape today

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

arXiv:2207.11966

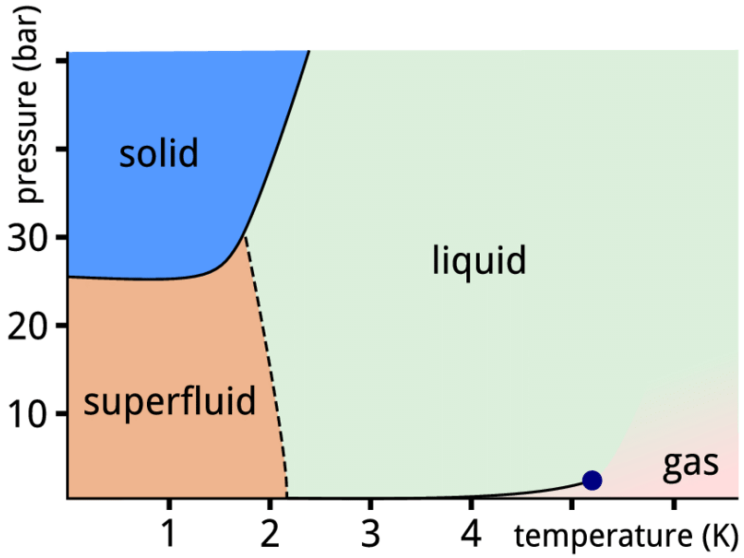
Phys. Rev. Lett. **121**, 111302 (2018)

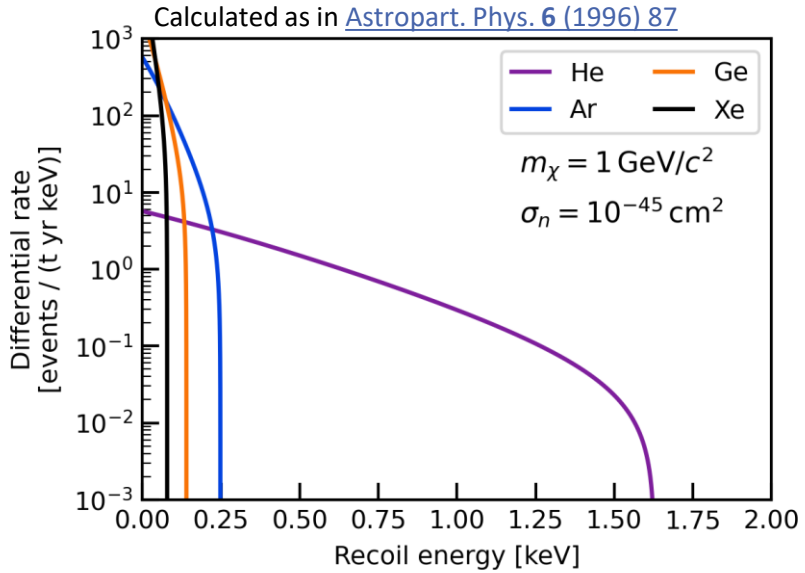
Technologies for LDM searches

- 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 ^{4}He** (e.g., DELight, HeRALD)

arxiv:2209.10950 Phys. Rev. D **100**, 092007 (2019)

Superfluid ^{4}He as target

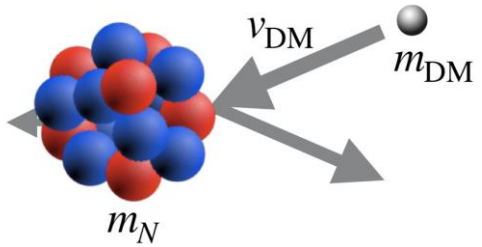




- Impurities freezing out (~20 mK)
- Multiple signals
- Unexpensive material and scalable technology

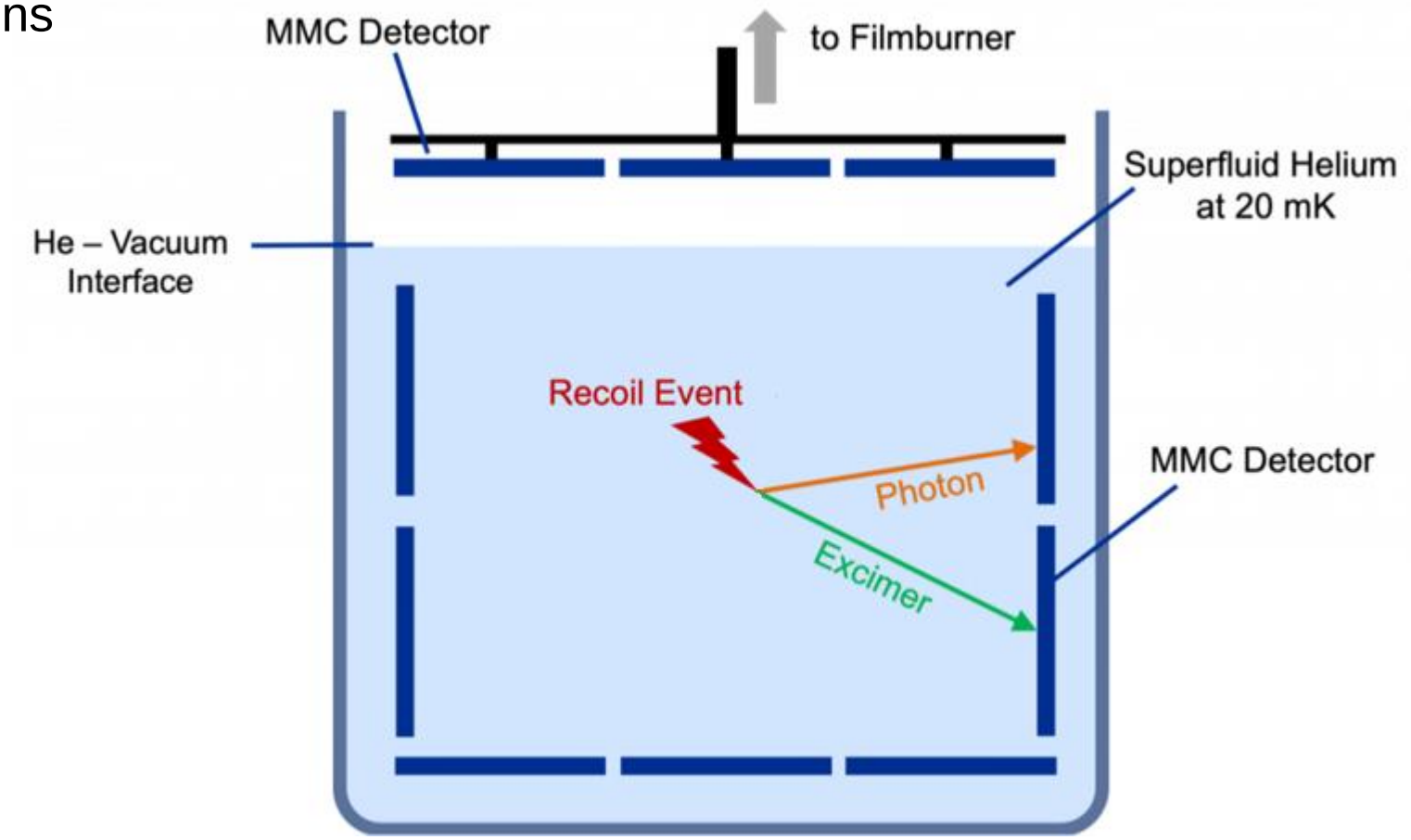
- Light nuclei maximize recoil energy for LDM

vs.



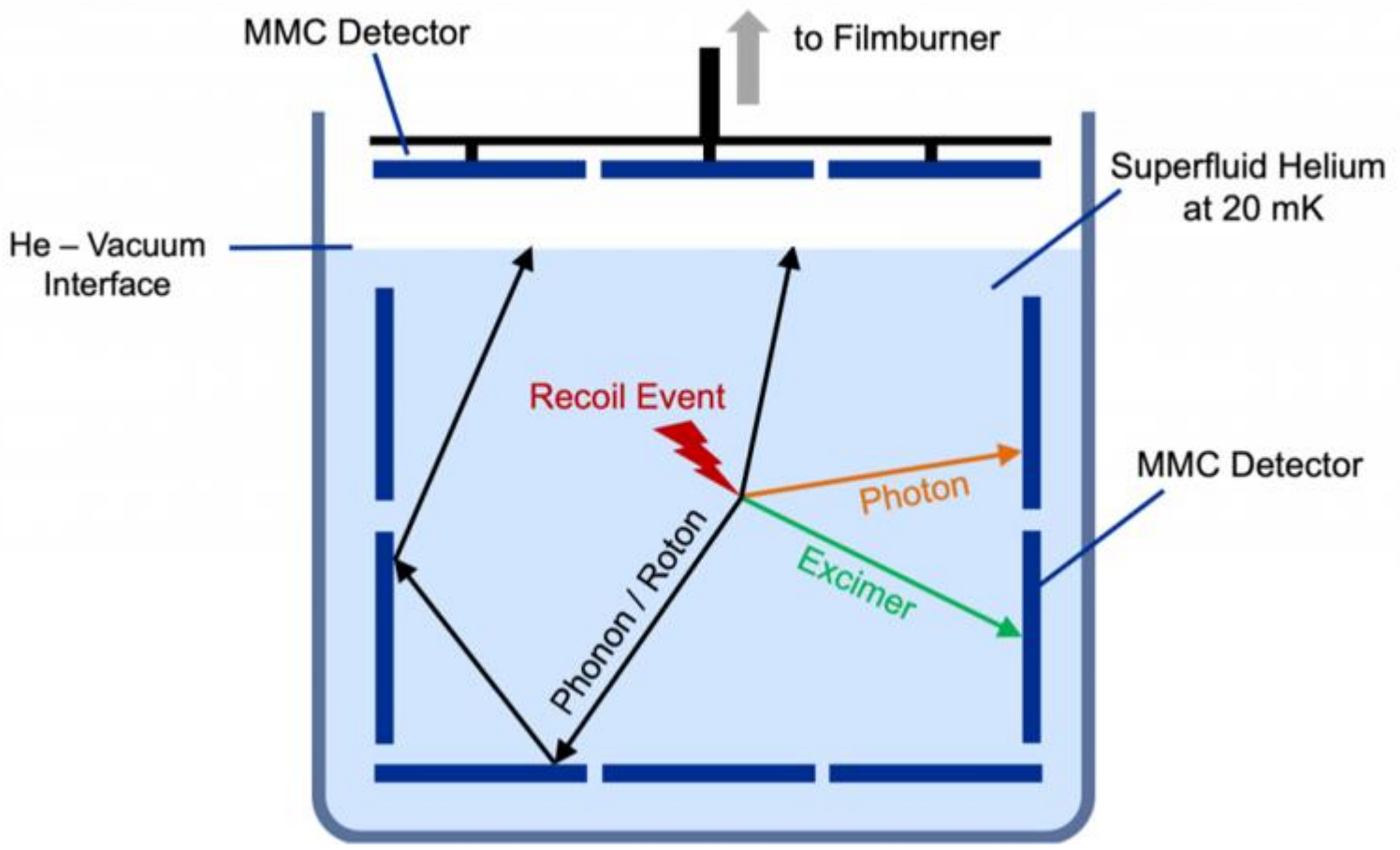
DELight detection principle

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



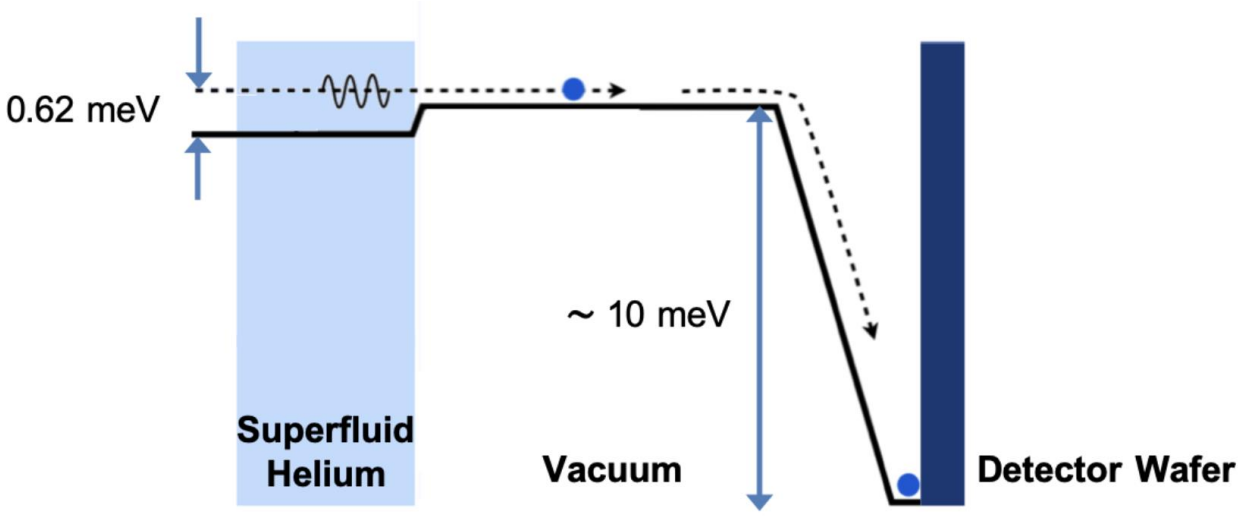
DELight detection principle

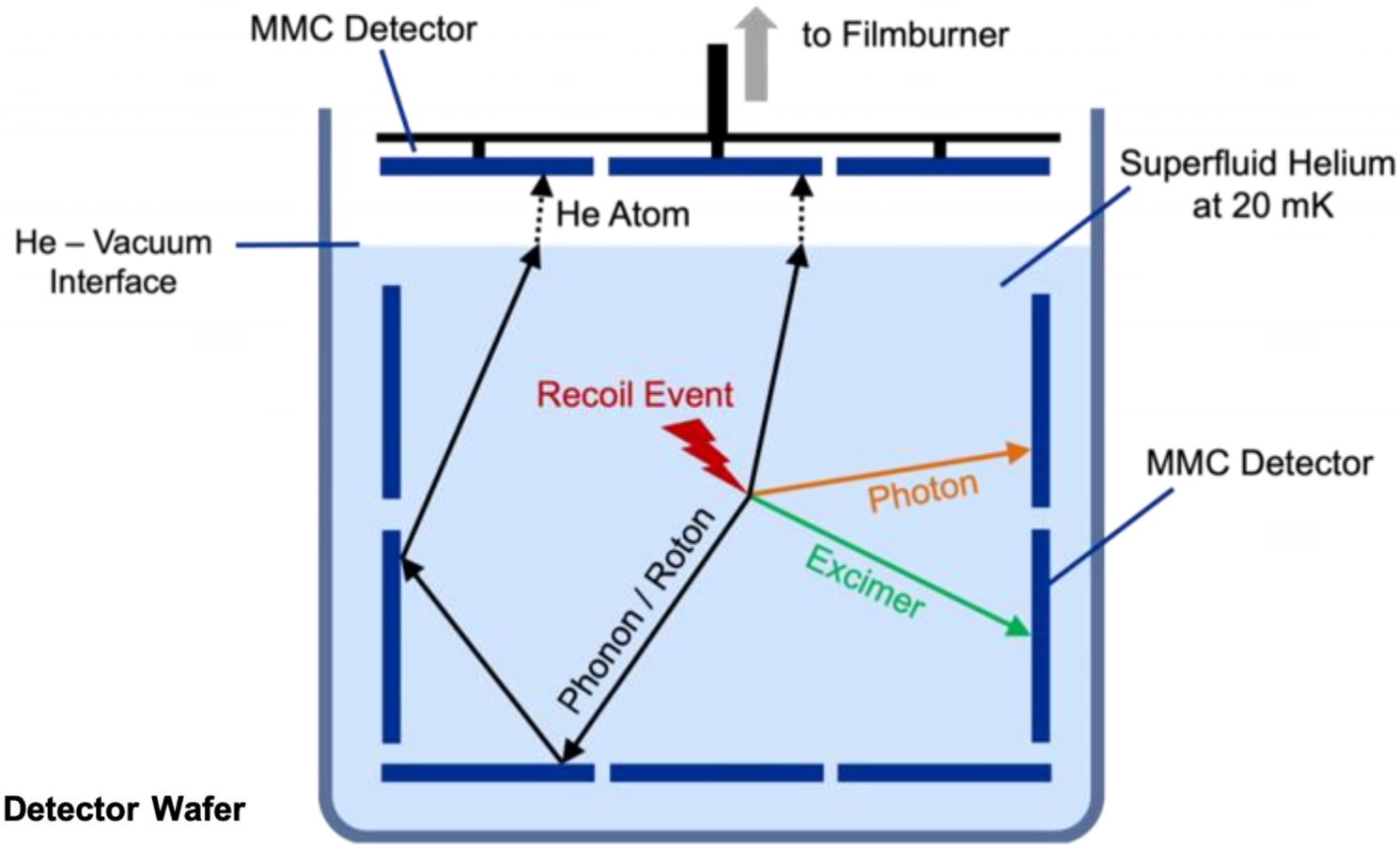
- Quantum of collective excitation (phonon) as additional signal
- *Quasiparticles* propagate ballistically within the He target and are reflected at the interface with solid



DELight detection principle

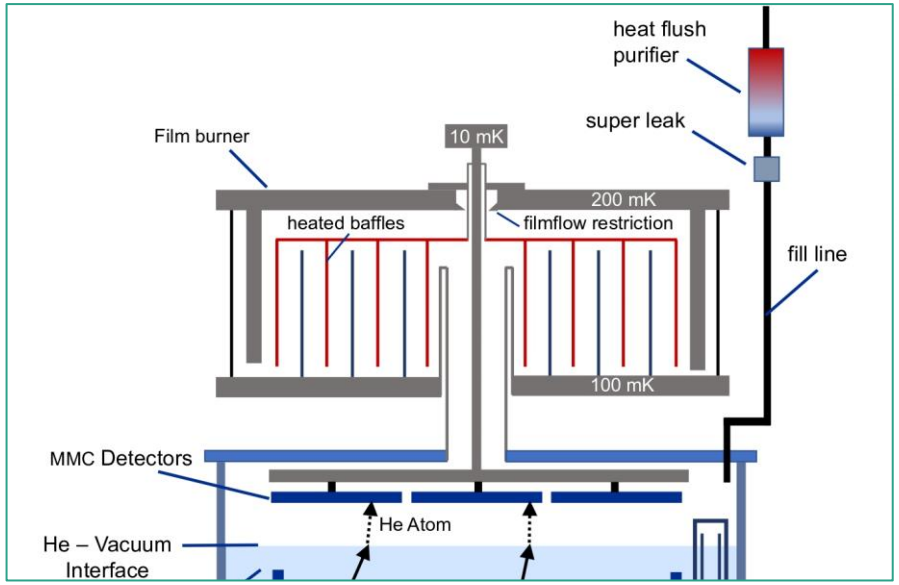
- Noise-free gain $\gtrsim$10 in deposited energy within the MMC detector as binding energy He-He is smaller than He-absorber

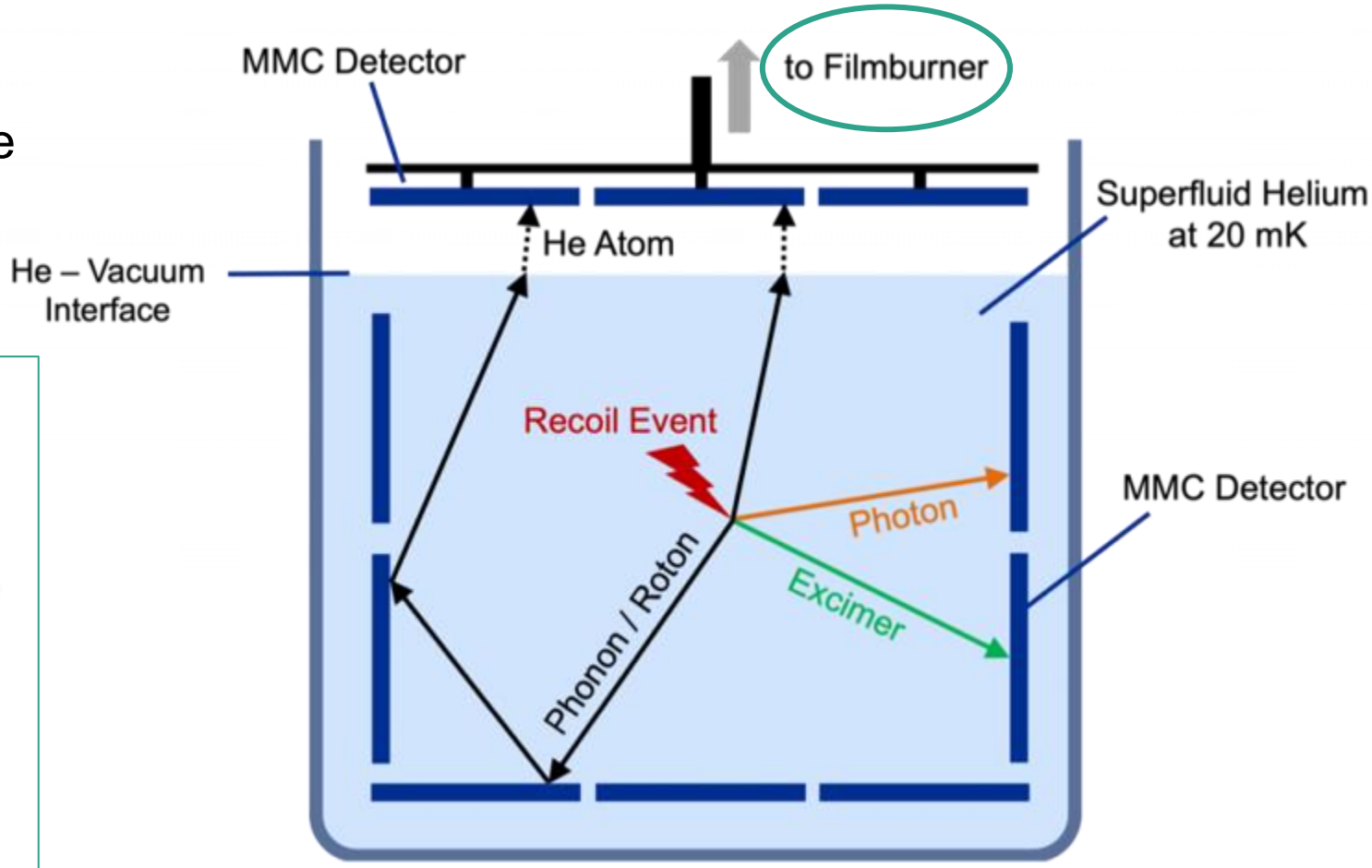




DELight detection principle

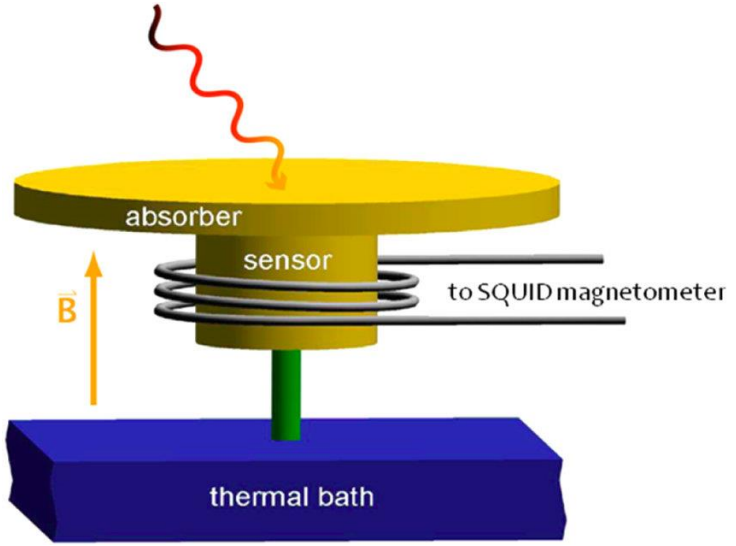
- He absorption happens for a „dry“ sensor surface → need to remove the creeping film of superfluid helium

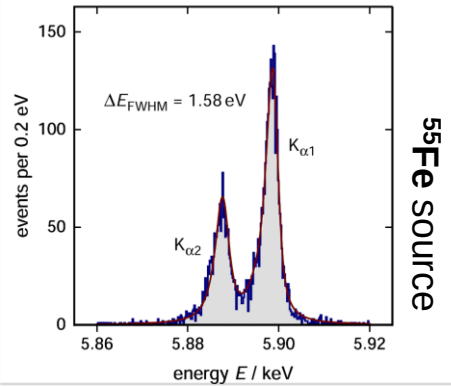


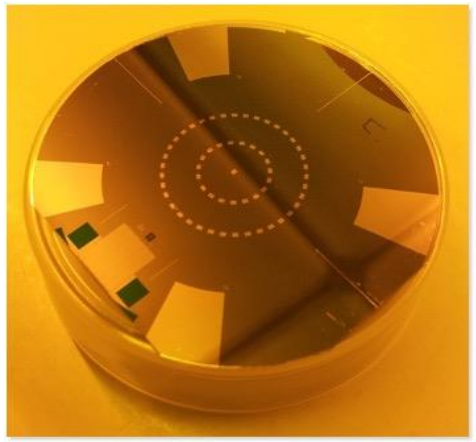


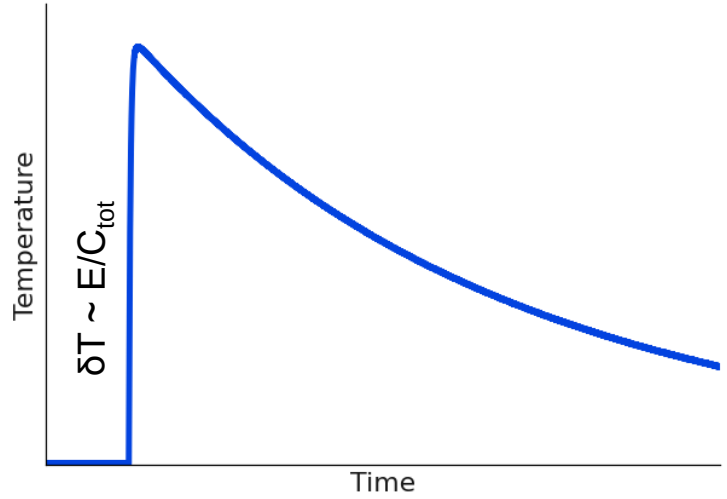
Magnetic Micro-Calorimeters (MMCs)

- Energy deposit in an *absorber* leads to a temperature increase δT changing the magnetization of the *paramagnetic* sensor δM ∝ δT
- Change in magnetization measured by a coupled SQUID as change in current δI ∝ δT
- Measured resolution of **1.6 eV** (@ 5.9 keV)



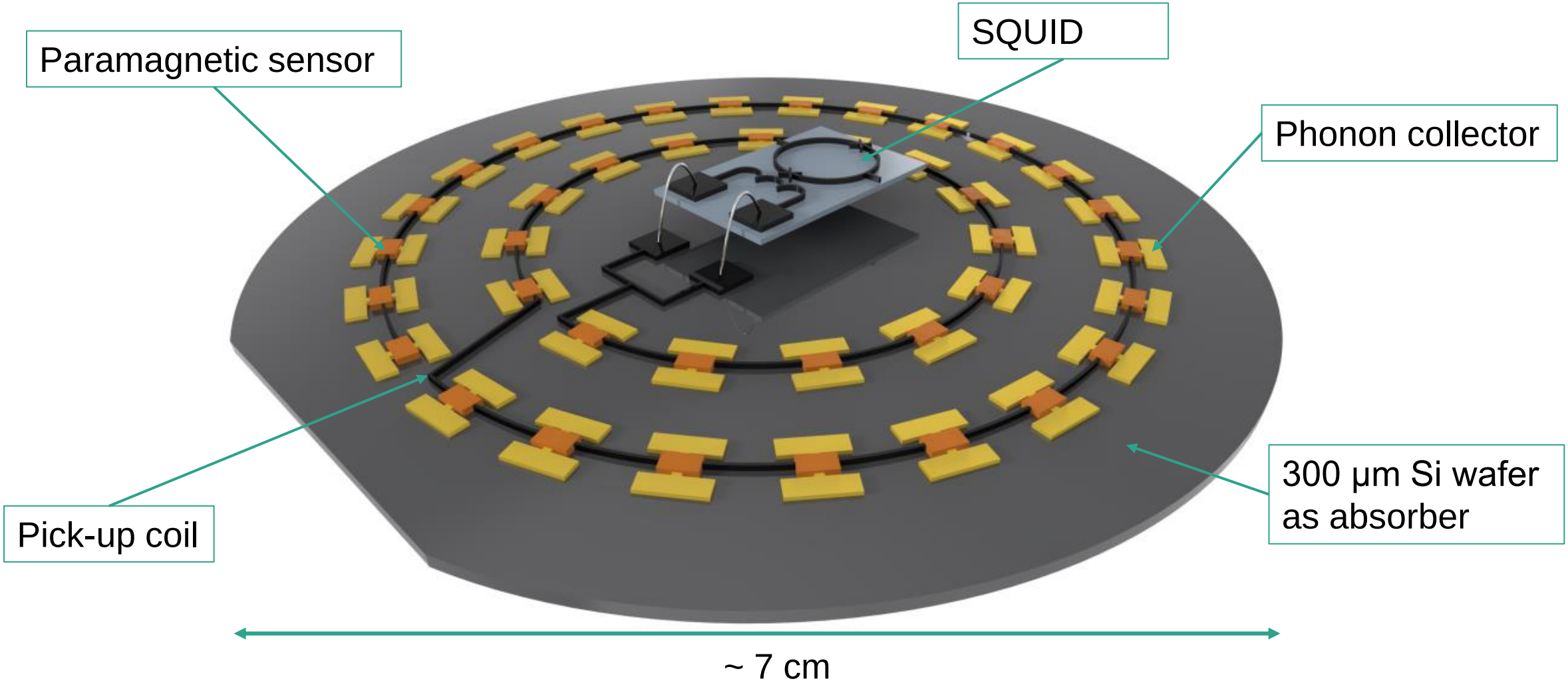






J. Low Temp. Phys. 193, 365-379 (2018)

DELight MMCs



J. Low Temp. Phys. 193, 365-379 (2018)

The present of DELight

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

B. von Krosigk[1⋆], K. Eitel[1], C. Enss[2,3], T. Ferber[4], L. Gastaldo[2], F. Kahlhoefer[5], S. Kempf[6,3], M. Klute[4], S. Lindemann[7], M. Schumann[7], F. Toschi[1,7] and K. Valerius[1]

arxiv:2209.10950

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

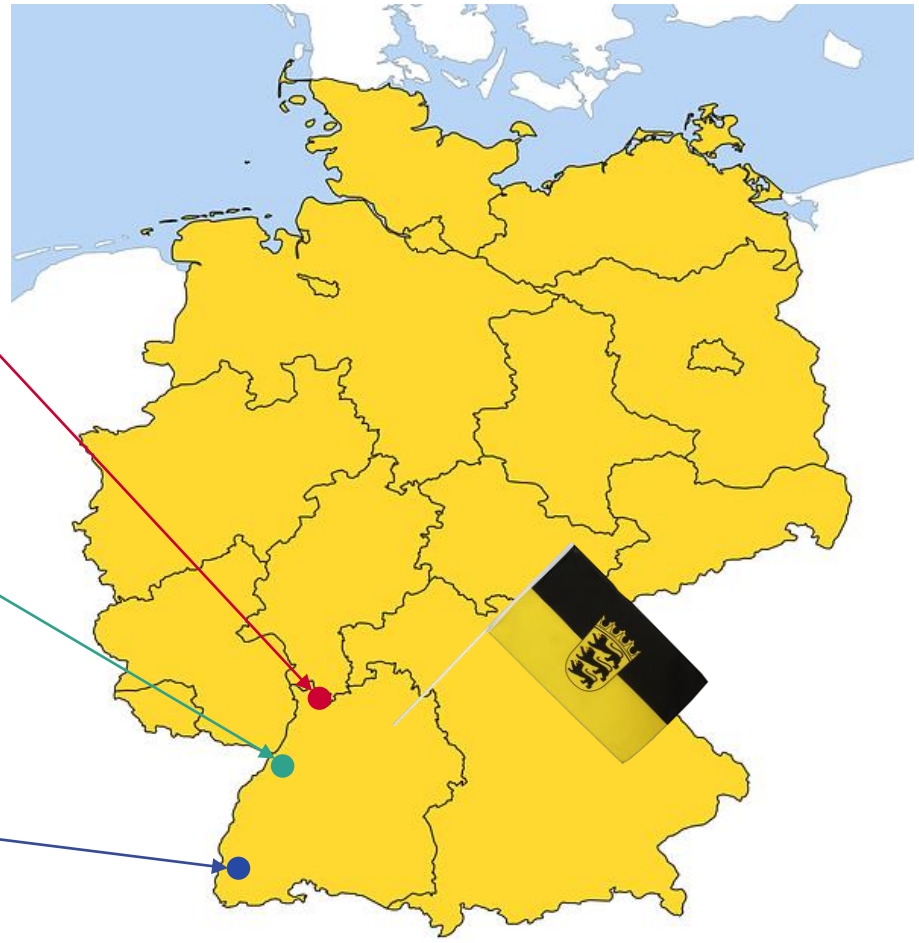
UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

- MMC R&D
- MC simulations

Karlsruher Institut für Technologie

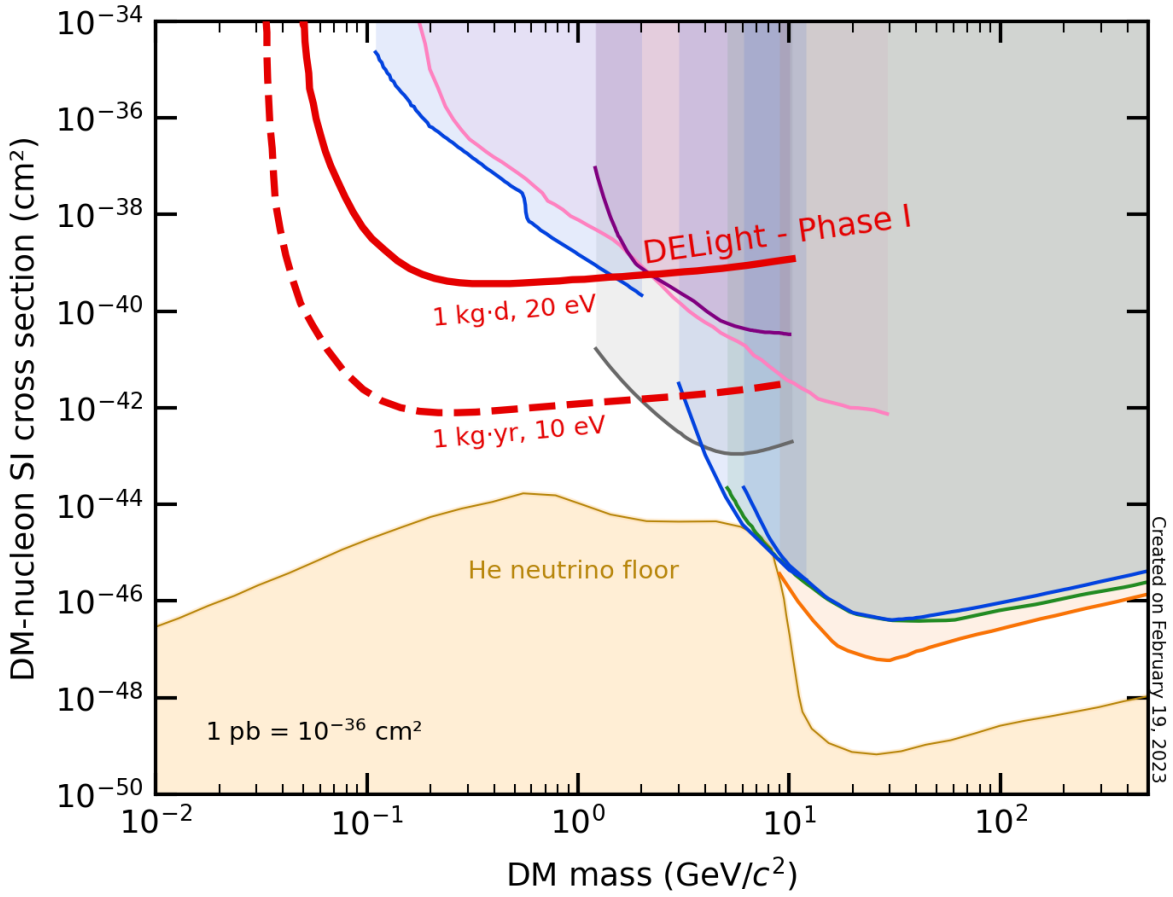
- UG laboratory (Vue des Alpes, CH)
- Low-radioactivity techniques

universität freiburg



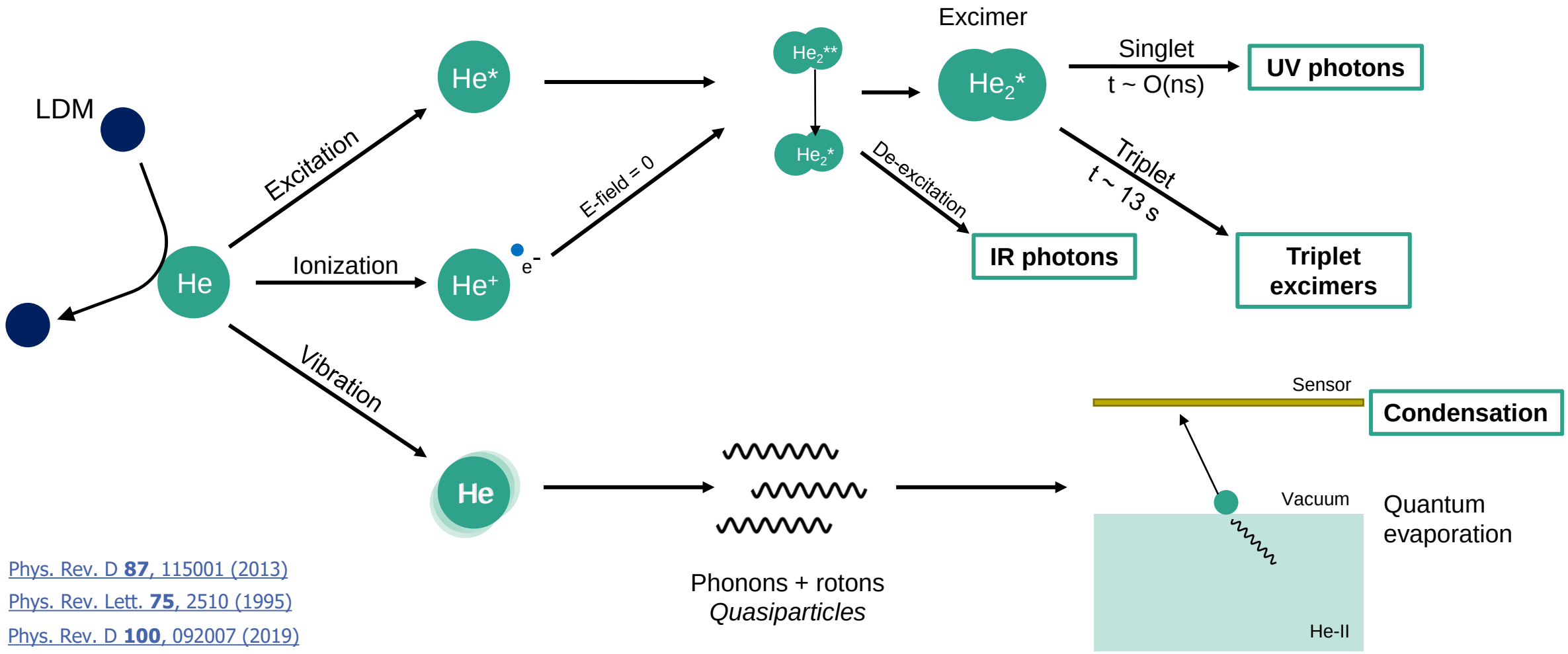
The future of DELight

- 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

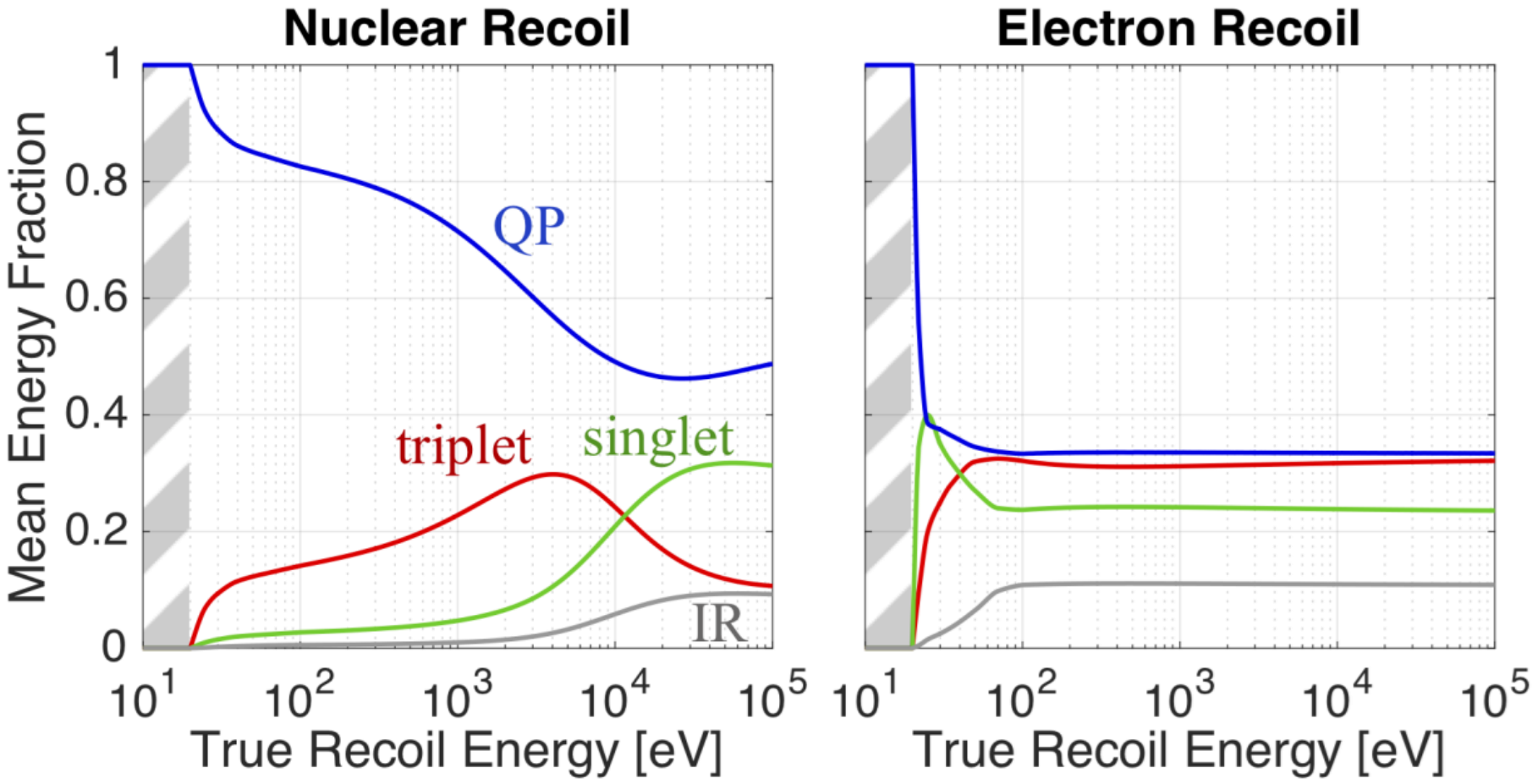


Phys. Rev. D **87**, 115001 (2013)

Phys. Rev. Lett. **75**, 2510 (1995)

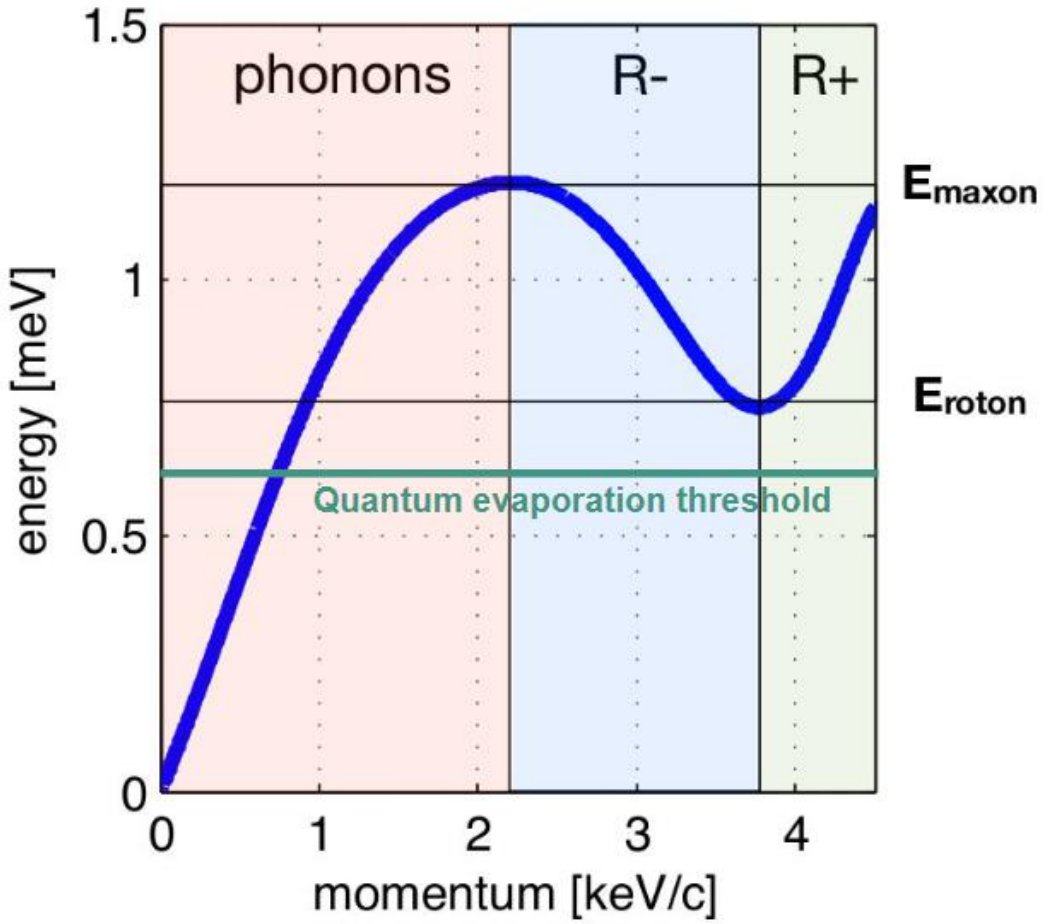
Phys. Rev. D **100**, 092007 (2019)

Signal partition



Phonon in superfluid Helium

- Rotons ≃ high momentum phonons

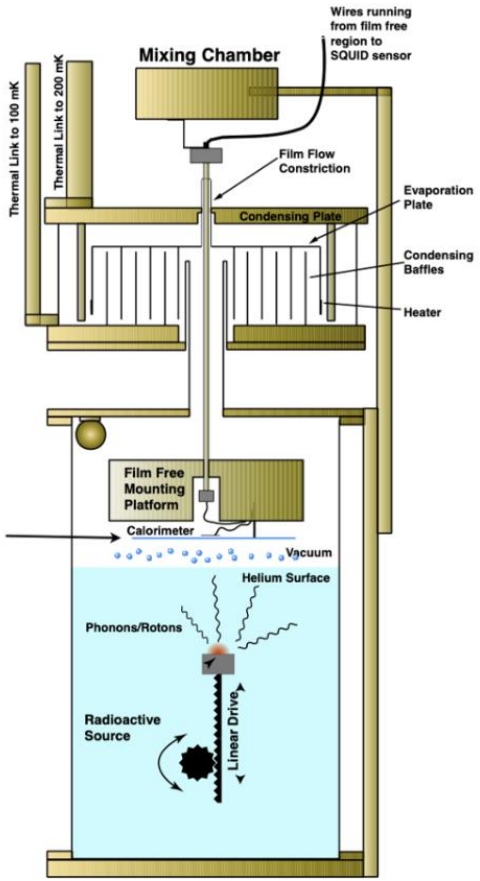


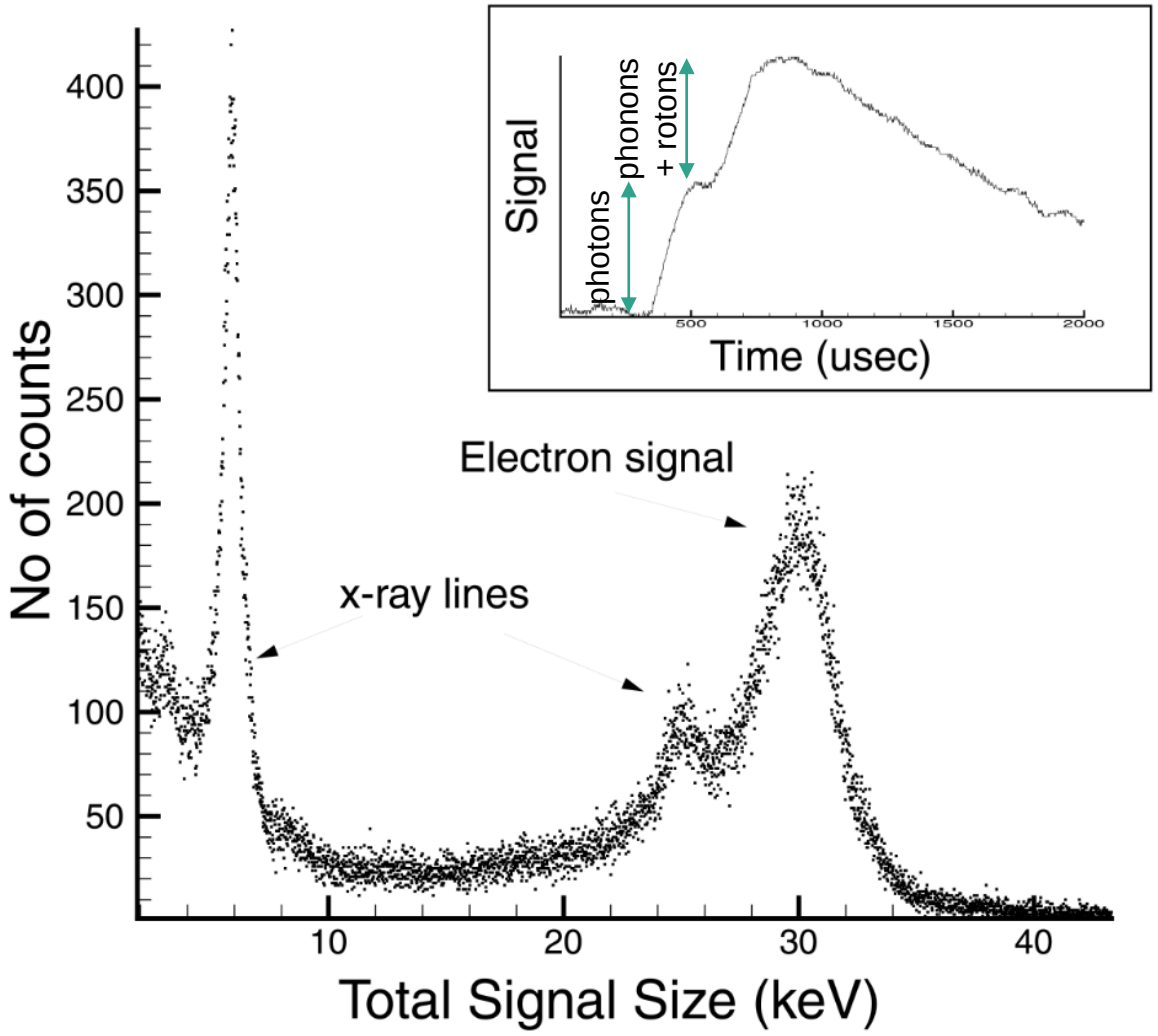
HERON

He film burner

wafer calorimeter

kg-scale
LHe mass





MMCs performance