



Christian Enss for the **DE**light Collaboration  
Heidelberg University

# DELight: Direct Search Experiment for Light Dark Matter

## A Superfluid Helium-based Detector



**DE**light



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<https://web.etp.kit.edu/~delight/index.html>

Lake Luise Winter Institute 2024



## HERON HELium-ROton detection of Neutrinos

A superfluid helium-based detector designed to investigate solar neutrinos

### HERON as Dark Matter detector

R. E. Lanou, H. J. Maris, and G. M. Seidel, PRL **58**, 2498 (1987).

J. Adams *et al.*, Proc. XXXIst Moriond Conference, p. 14, (1996) .

T. M. Ito, G.M. Seidel, PRC **88**, 025805 (2013).

### HERON-like Detectors for Dark Matter

W. Guo, D.N. McKinsey, PRD **87**, 115001 (2013)

H. J. Maris, G. M. Seidel, D. Stein, PRL **119**, 181303 (2017)

S. Hertel *et al.*, PRD **100**, 092007 (2019)

B. v. Krosigk *et al.*, SciPost Phys. Proc. **12**, 016 (2023)





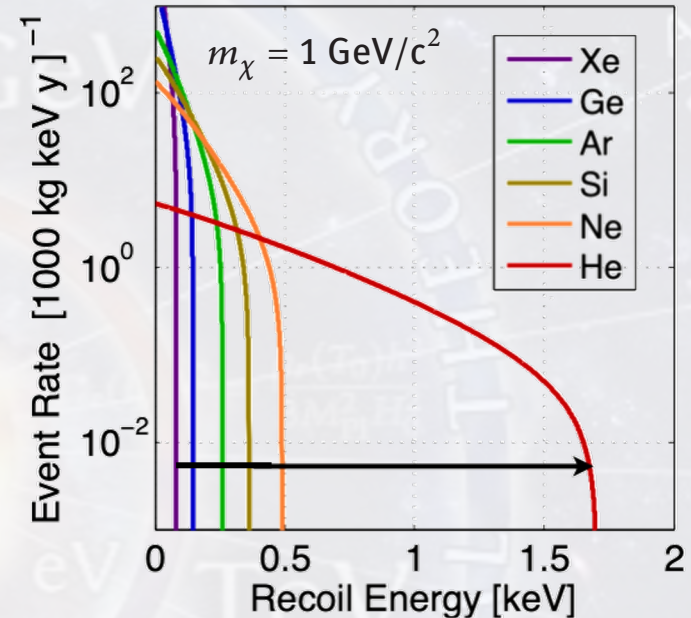
## Favourable properties of superfluid helium

- ▶ **light** baryonic target

$$E_{\text{nr}} = \frac{2 m_{\chi}^2 m_{\text{n}} v_{\chi}^2}{(m_{\chi} + m_{\text{n}})^2} \cos^2 \theta$$

10 GeV  $\rightarrow$  10 keV – 100 keV nuclear recoil energy

- ▶ **ultrapure** – **no internal background**
- ▶ **multiple signals**, quasiparticles, photons, excimers
- ▶ discrimination of **nuclear** and **electronic recoil**
- ▶ event location: **coded aperture array**
- ▶ **fiducialization** possible
- ▶ **directionality**
- ▶ helium **immune to muon spallation/capture**

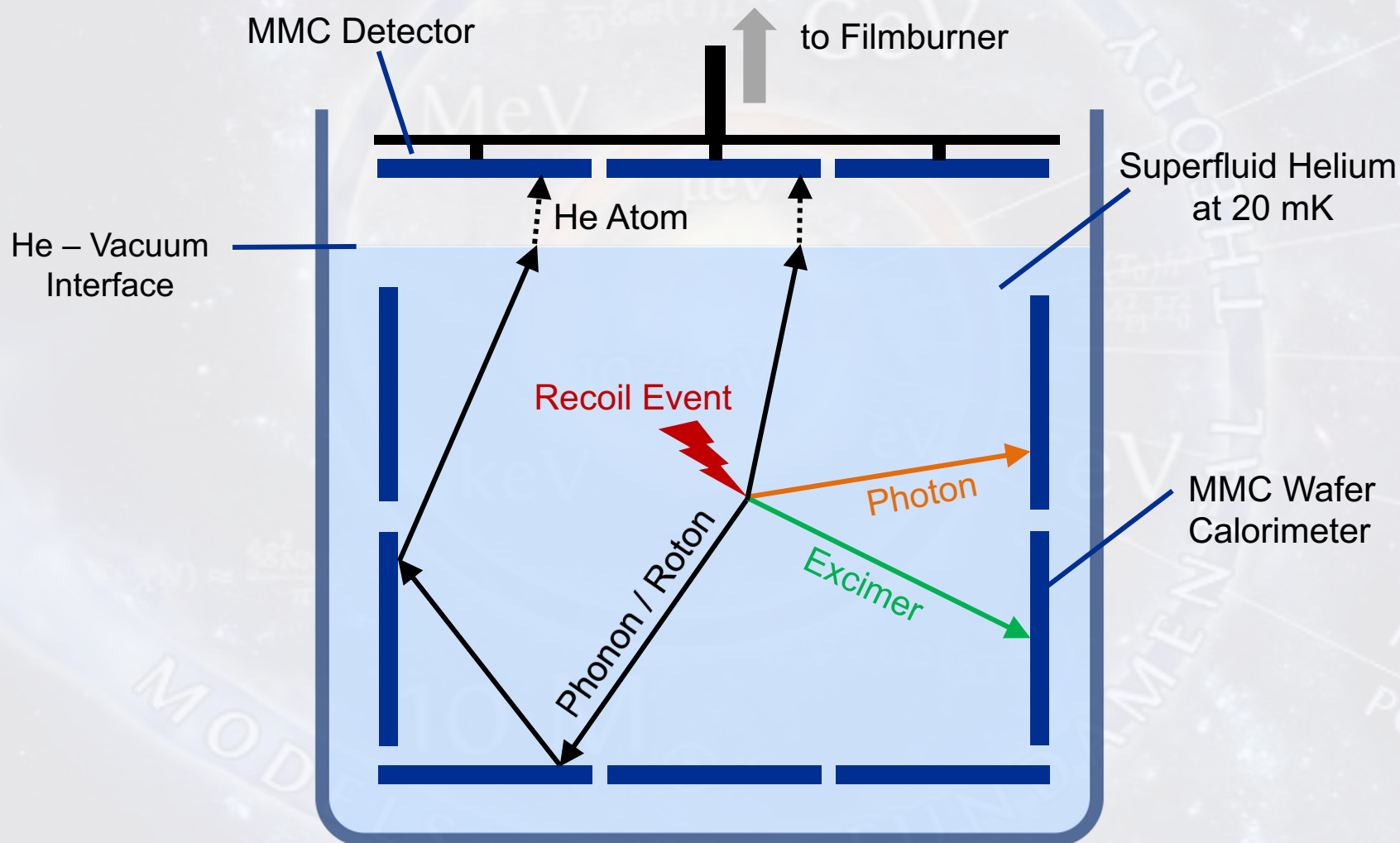


## Overall concept has been demonstrated

- S. Bandler *et al.* PRL **78**, 2429 (1992)
- C. Enss *et al.* Physica B **194-196**, 515 (1994)
- S. Bandler *et al.* PRL **74**, 3169 (1995)
- D.N. McKinsey *et al.* PRA **59**, 200 (1999)
- W. Guo *et al.* PRL **102**, 235301 (2009)
- F.W. Carter *et al.* JLTP **186**, 183 (2017)

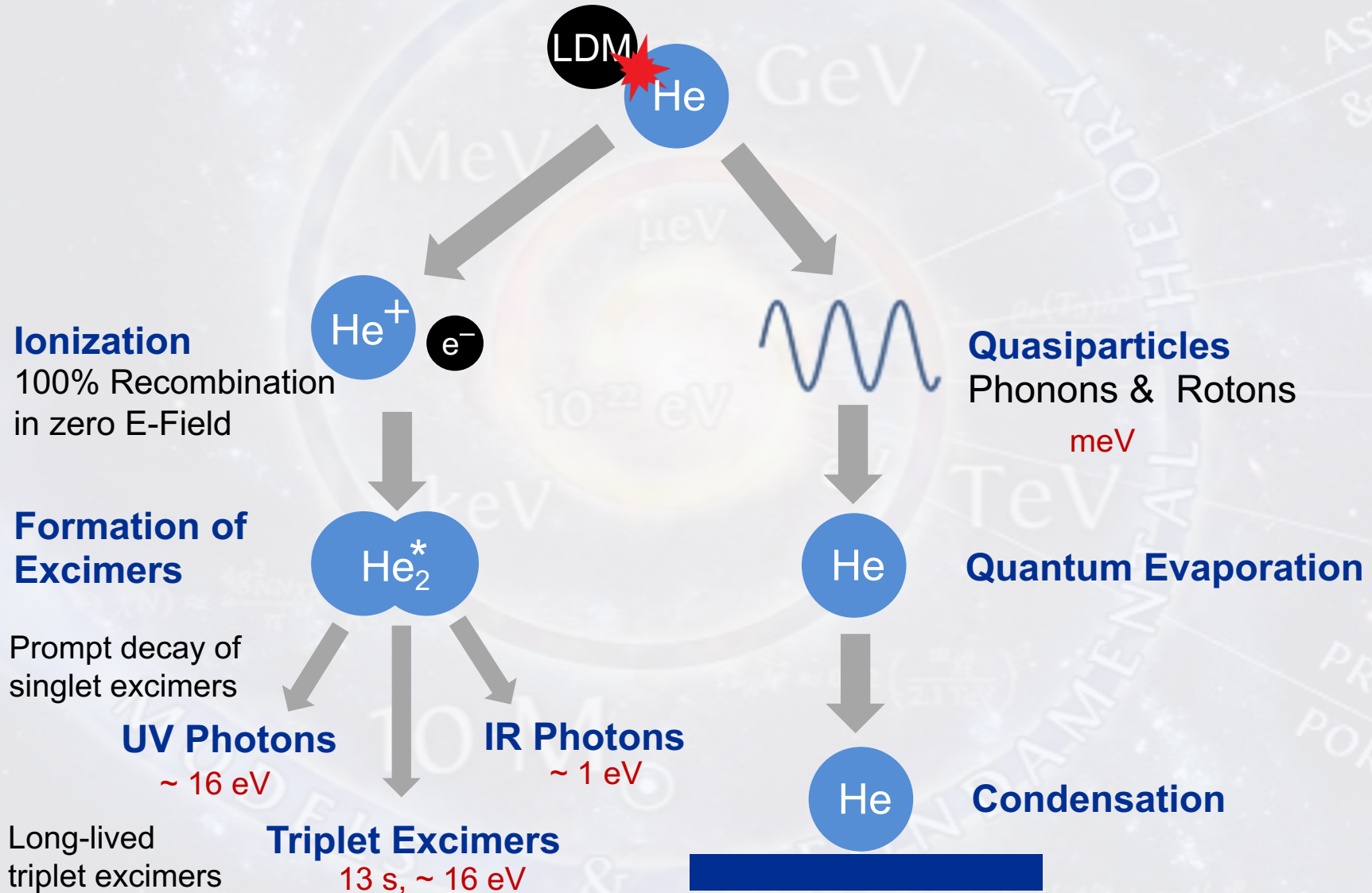


# Basic Concept and Available Signals



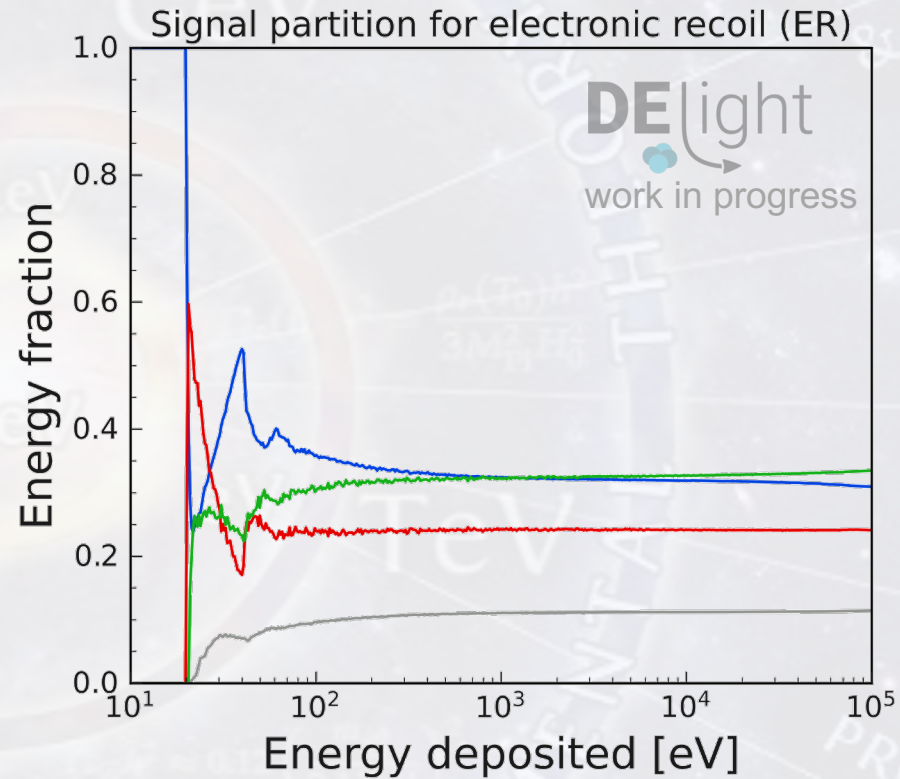


# Multiple Signals and Signal Chains





# Discrimination of ER and NR



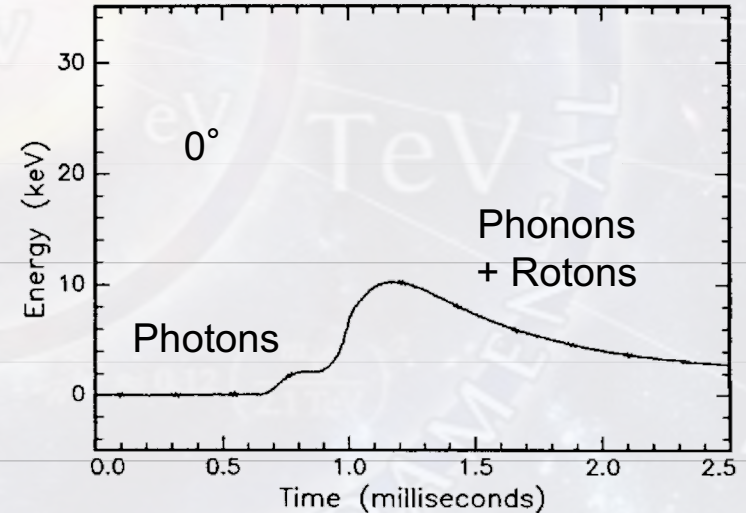
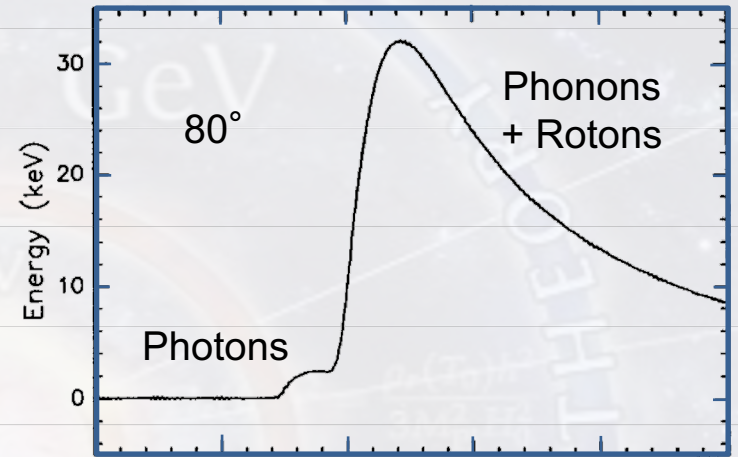
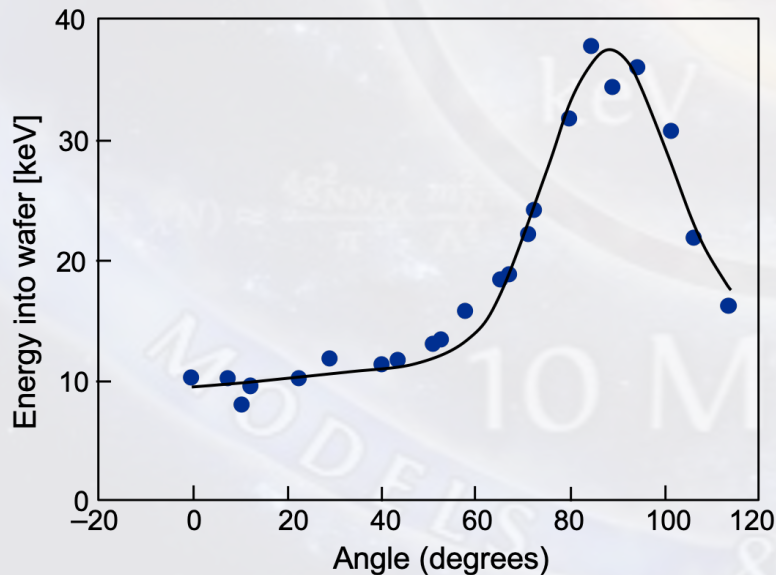
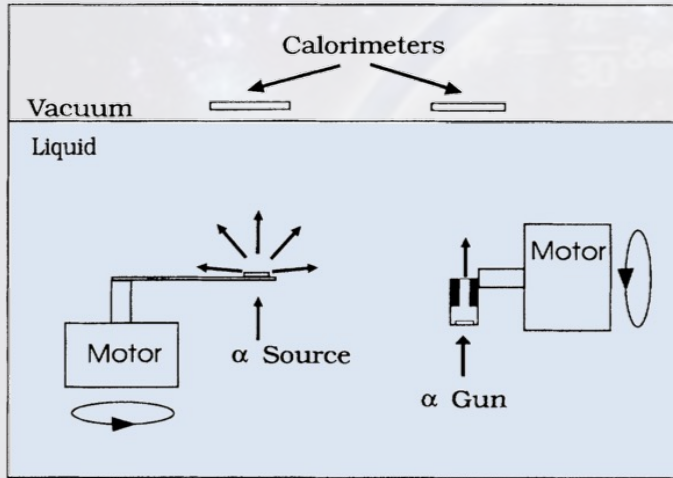
F. Toschi *et al.* to be published

previous work by HERON  
HeRALD

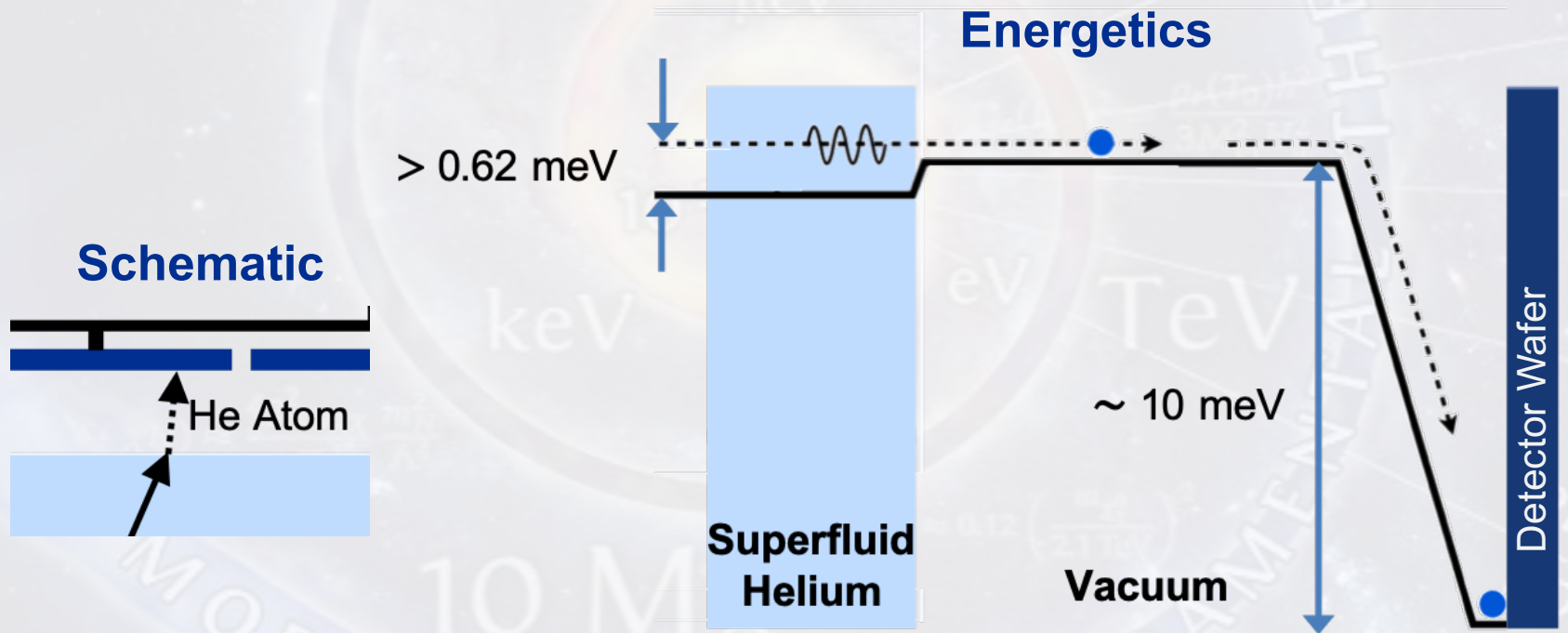
T.M. Ito, G.M. Seidel, PRC **88**, 025805 (2013)  
S. Hertel *et al.*, PRD **100**, 092007 (2019)



# HERON Detector: Directionality



C. Enss *et al.*, *Physica B* **194-196**, 515 (1994)  
S. Bandler *et al.* *PRL* **74**, 3169 (1995)



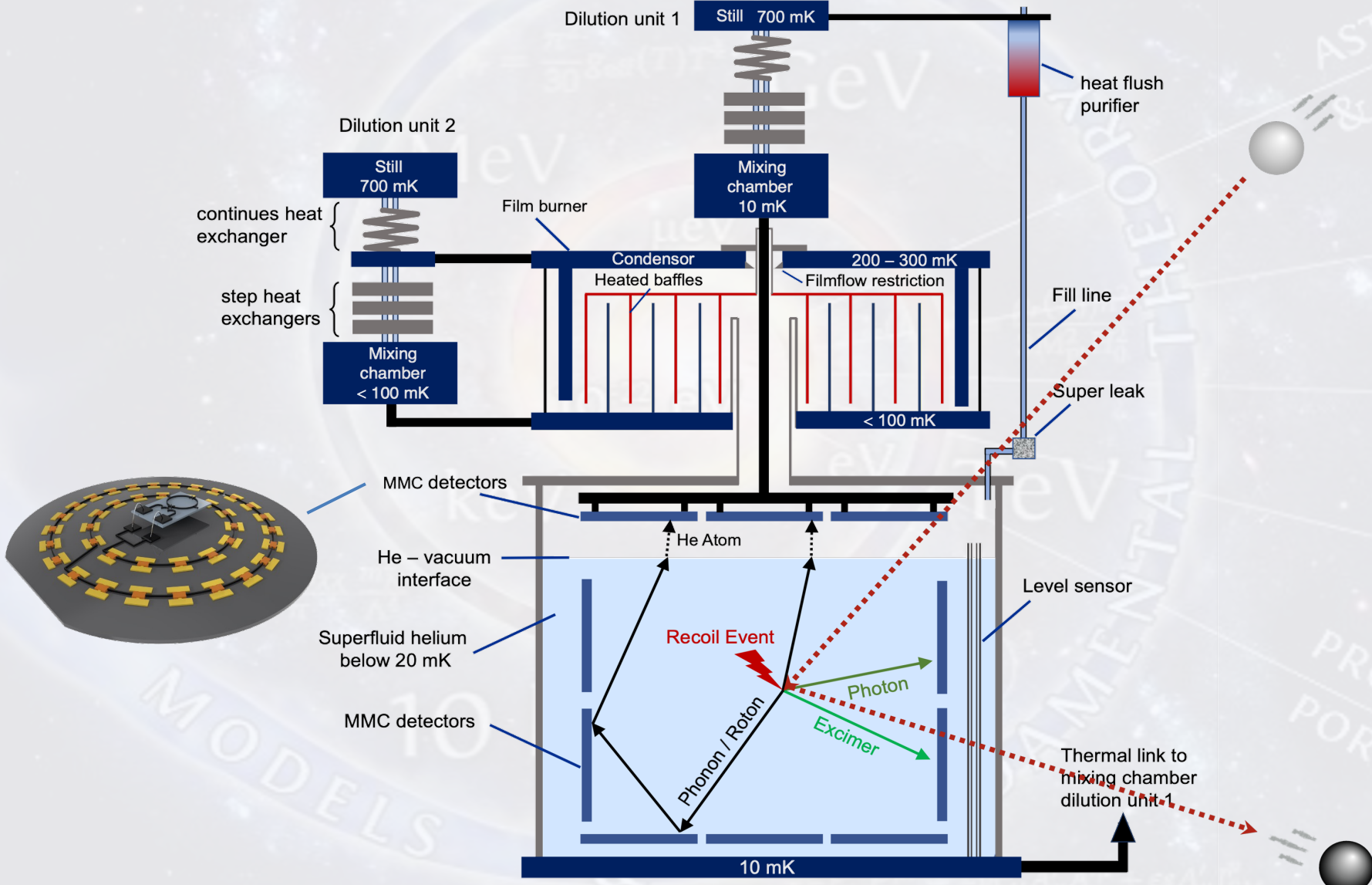
► noise-free signal **gain** by a factor **10 to 40**

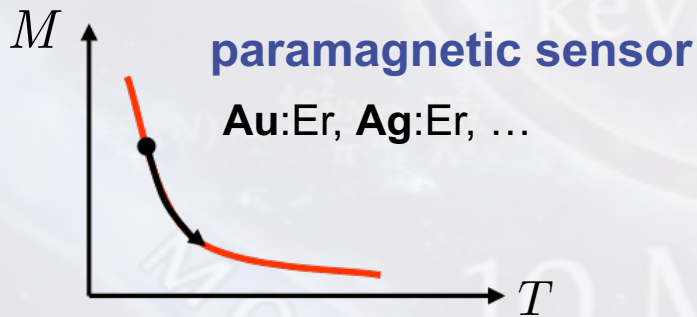
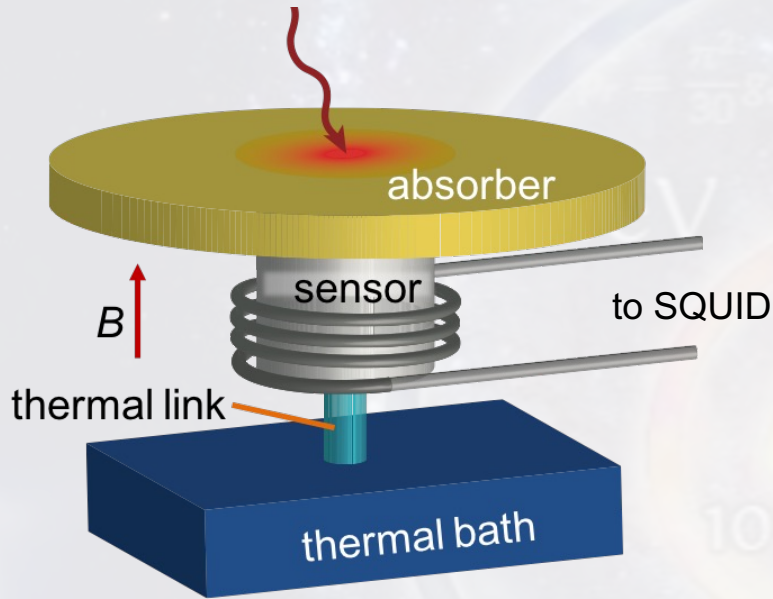




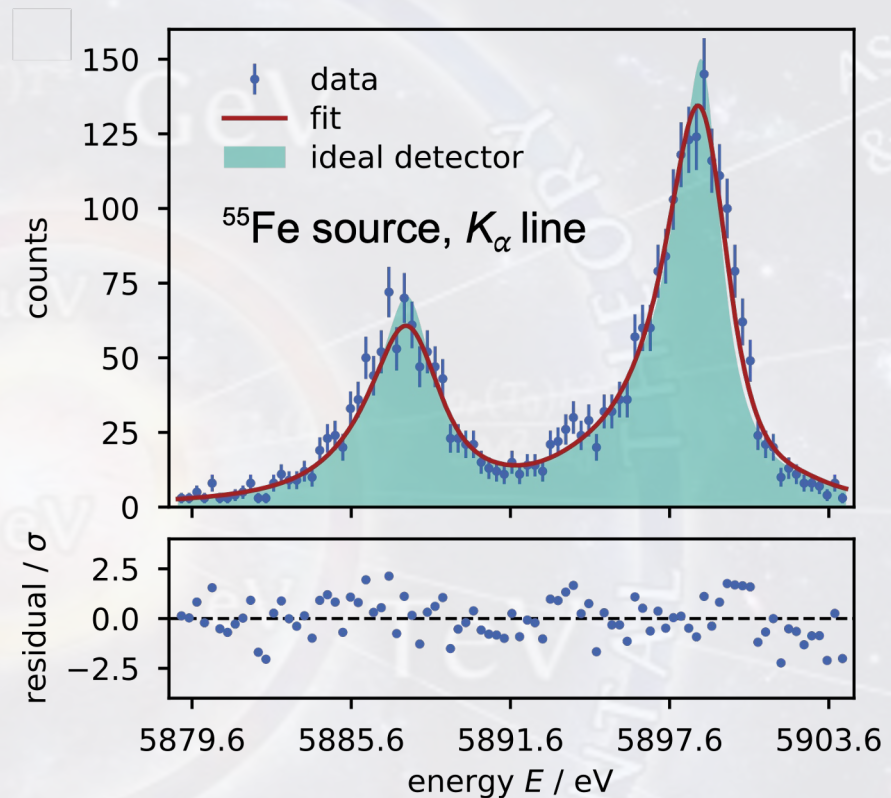
# DELIGHT Detector Concept

DELIGHT



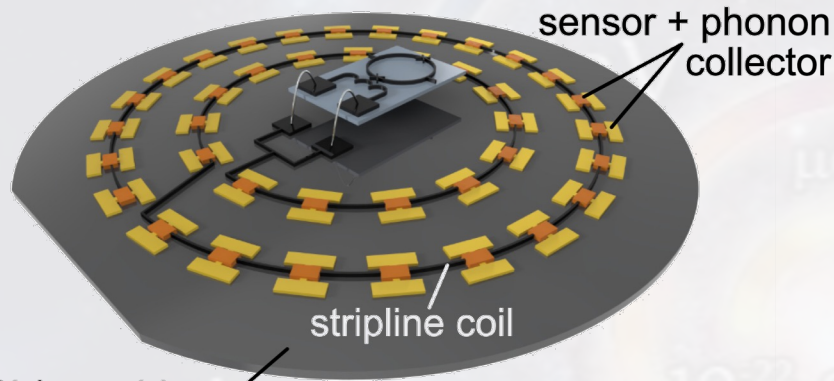


$$\delta M = \frac{\partial M}{\partial T} \delta T = \frac{\partial M}{\partial T} \frac{E}{C_{\text{tot}}}$$

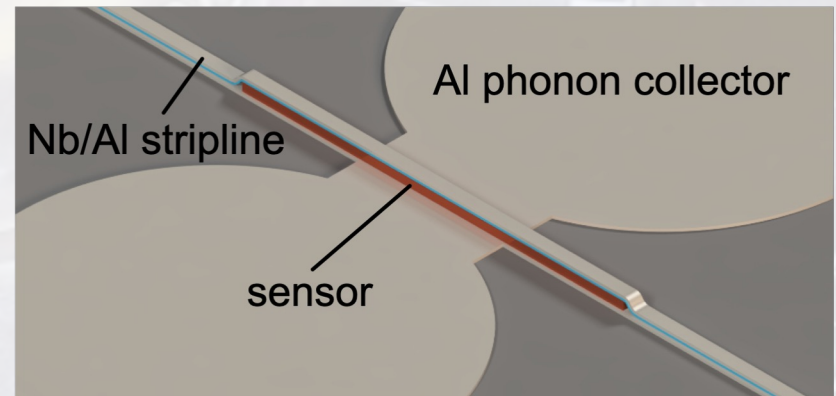
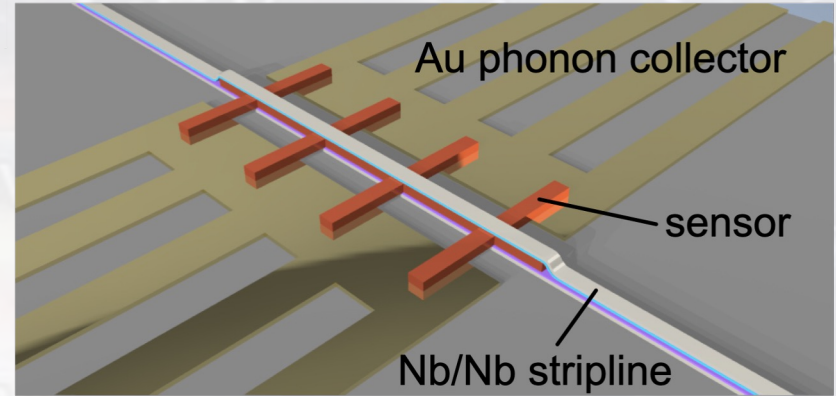
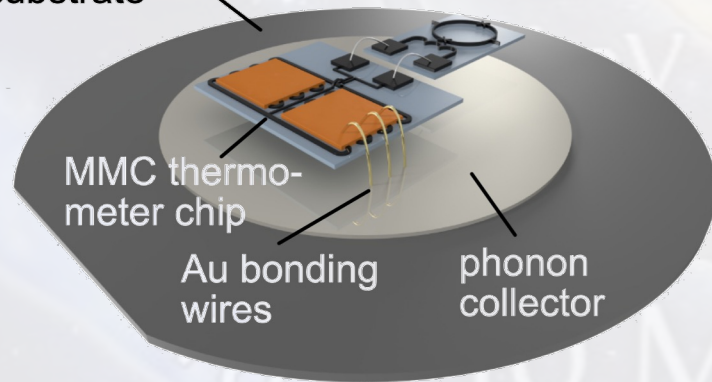


- ▶ 150  $\mu\text{m}$  x 150  $\mu\text{m}$  x 3  $\mu\text{m}$  absorber
- ▶ quantum efficiency at 5 keV is 98%
- ▶ energy resolution  $\Delta E_{\text{FWHM}} = 1.25 \text{ eV}$  at 6 keV
- ▶ resolving power  $E/\Delta E = 4712$

M. Krantz *et al.*, *Appl. Phys. Lett.* **124**, 032601 (2024)



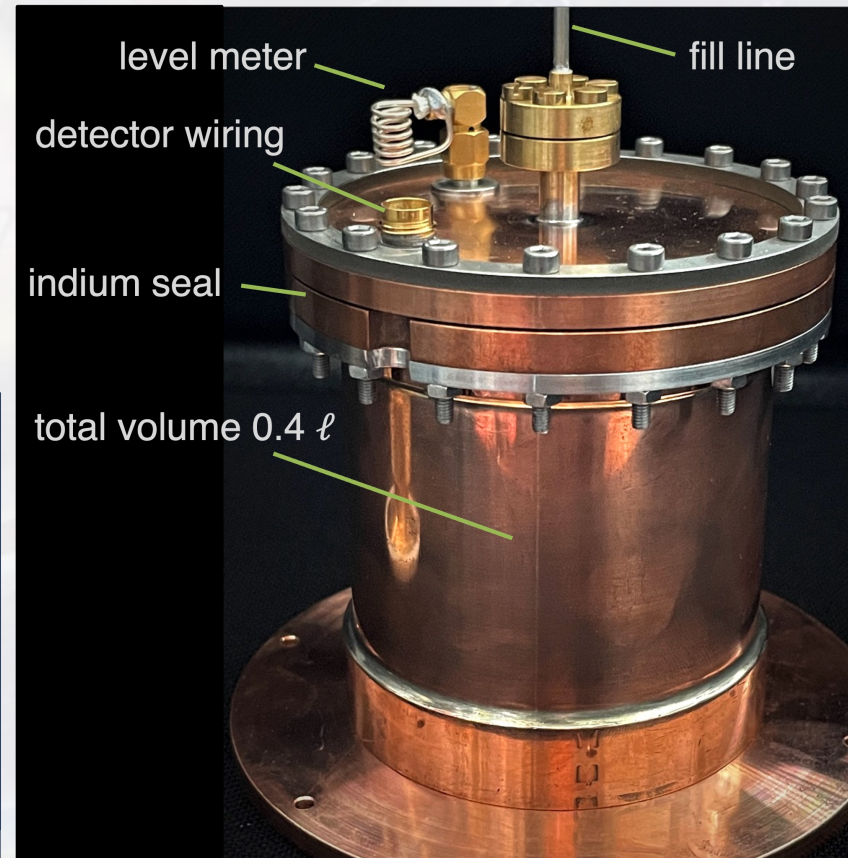
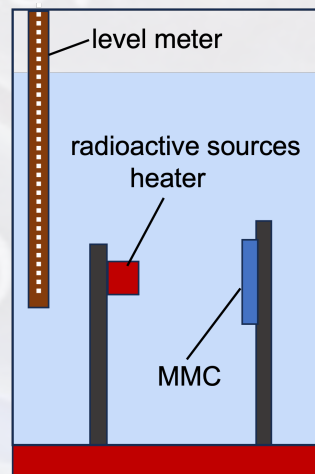
Si / sapphire substrate





## in liquid characterization with MMCs:

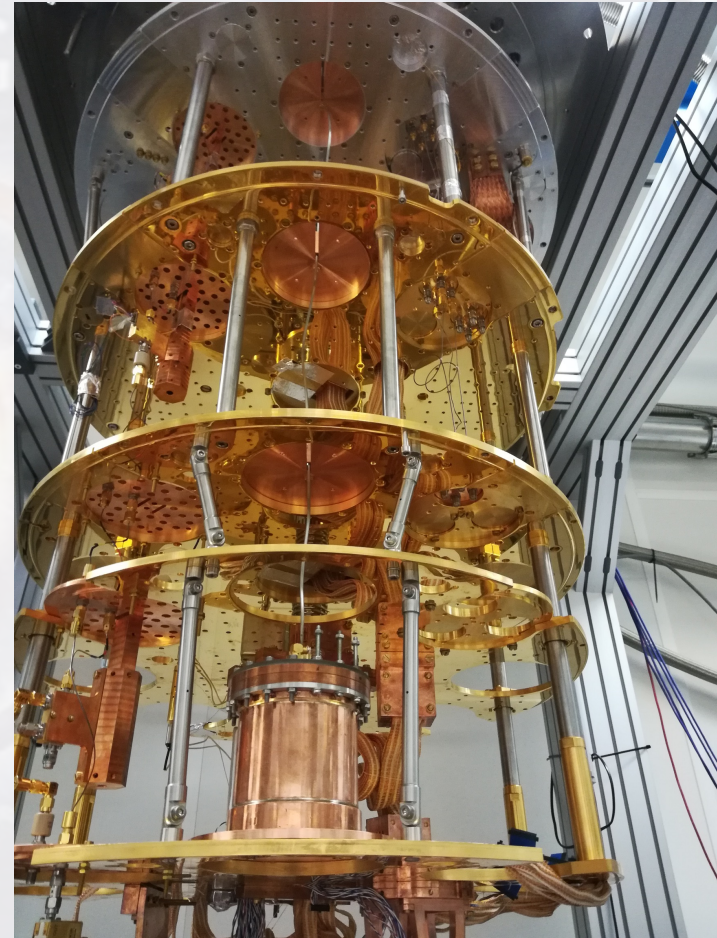
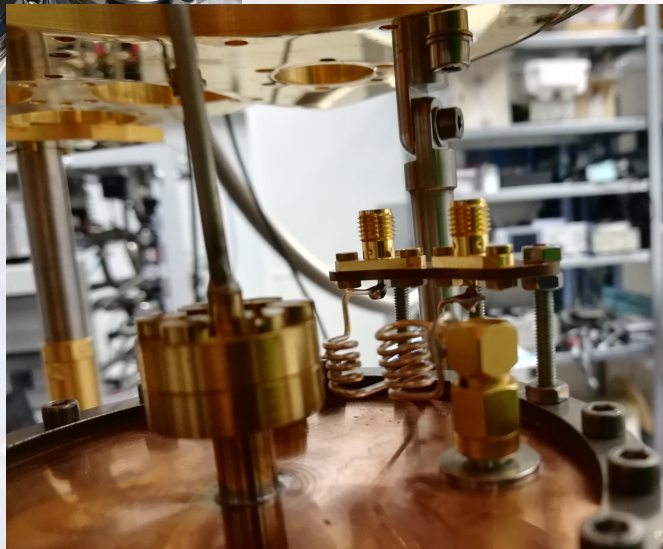
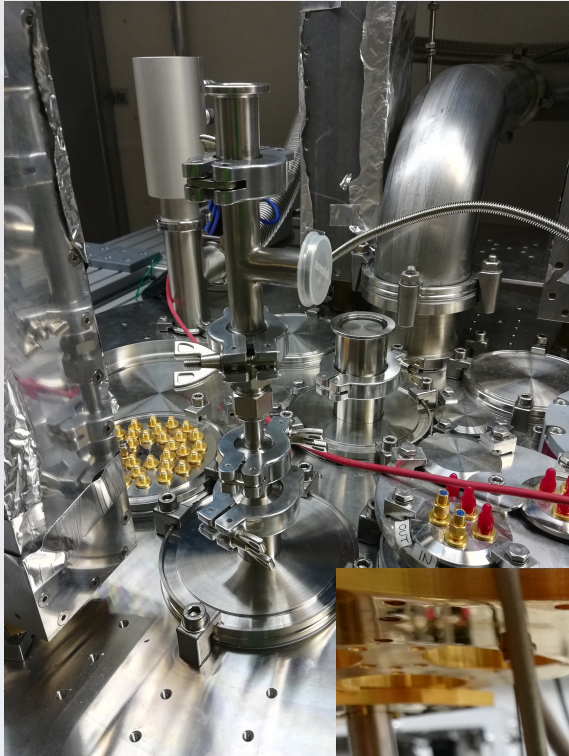
- ▶ sensitivity test for **MMCs in liquid**
- ▶ search for **quasiparticle signals** within liquid
- ▶ test for new-type **level meter** (has been tested with air)
- ▶ test for **purification** system
- ▶ test for **filling** system
- ▶ test superconducting **motors**
- ▶ detection of **uv-photon**
- ▶ detection of delayed **triplet signal**
- ▶ test knife-edge flow restrictions
- ▶ measure roton reflectivity
- ▶ ...





# DELight-0: Mini-Cell

DELight

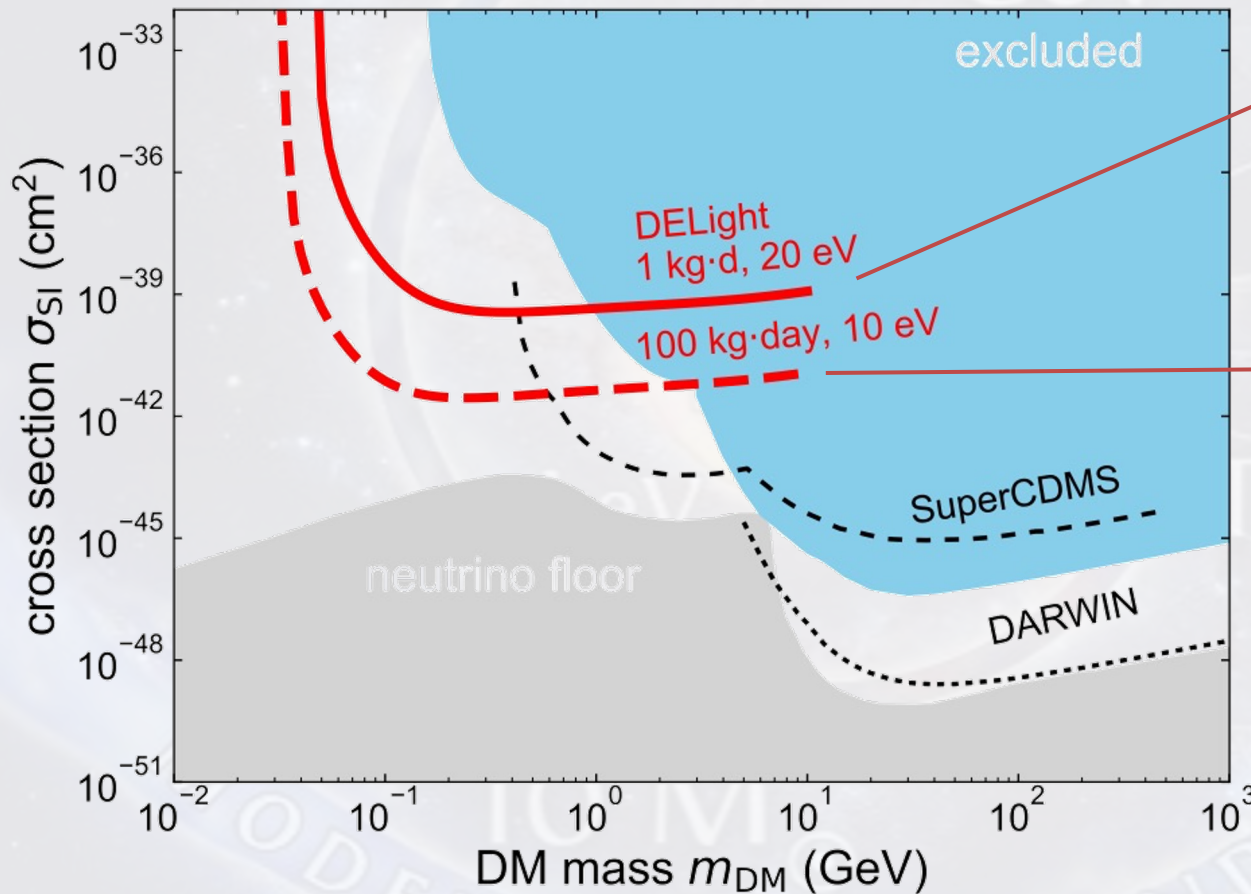




# DELight Phases I + II



Spin-independent cross section



**Phase I:**  
10 ℓ cell on surface or in shallow u-lab  
O(kg·d) exposure  
20 eV threshold

**Phase II:**  
20 ℓ cell in shallow u-lab  
O(100 kg·d) exposure  
10 eV threshold

**Long term plan:**  
100 ℓ cell in deep u-lab  
O(kg·yr) exposure  
< 10 eV threshold



Superfluid helium-based dark matter experiments have enormous potential for **light dark matter** searches

DElight is a **new project** to realize such an experiment

# Thank you!

**Freiburg University**  
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## Heidelberg University

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Collaboration meeting Summer 2023 in Heidelberg