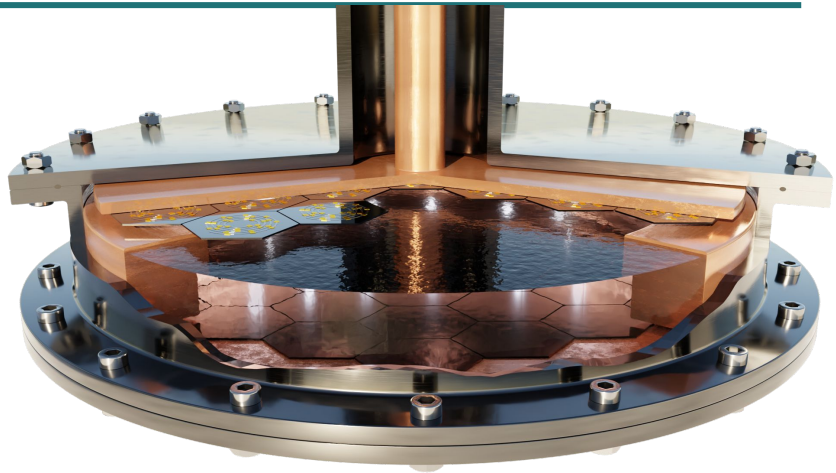
The DELight Experiment

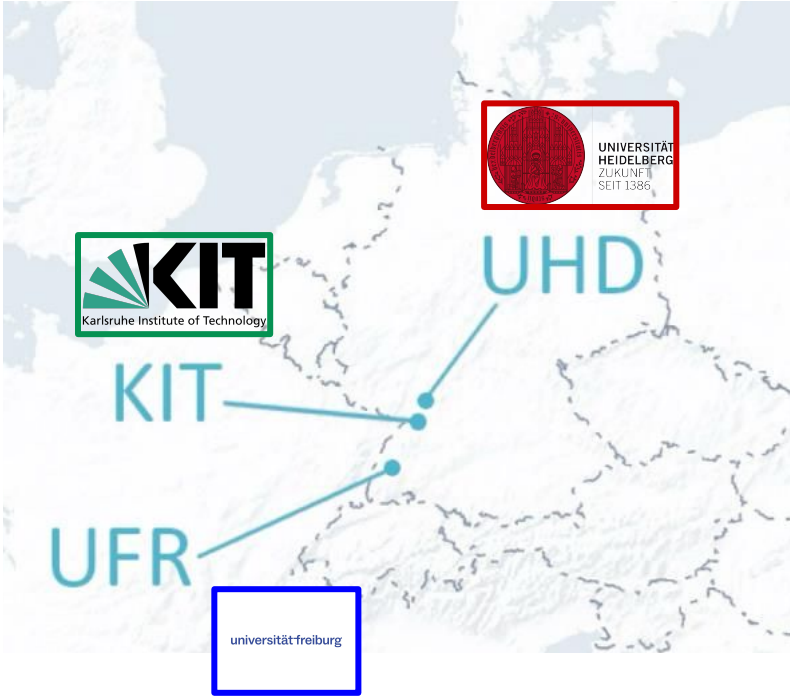
Overview and Perspectives



20th Patras Workshop on Axions, WIMPs and WISPs
September 26, 2025

Anna Bertolini
Heidelberg University
on behalf of the DELight Collaboration

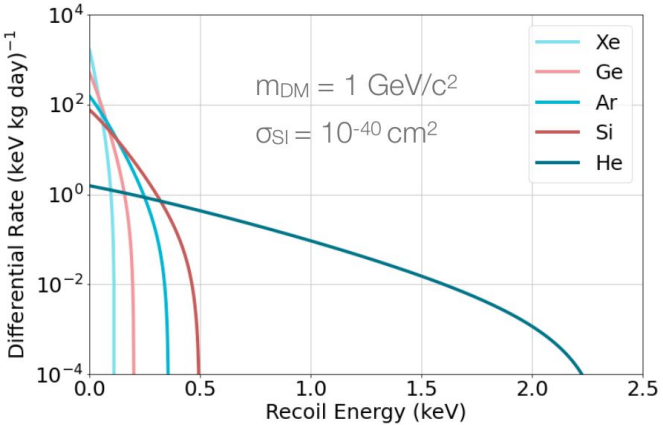
The Collaboration

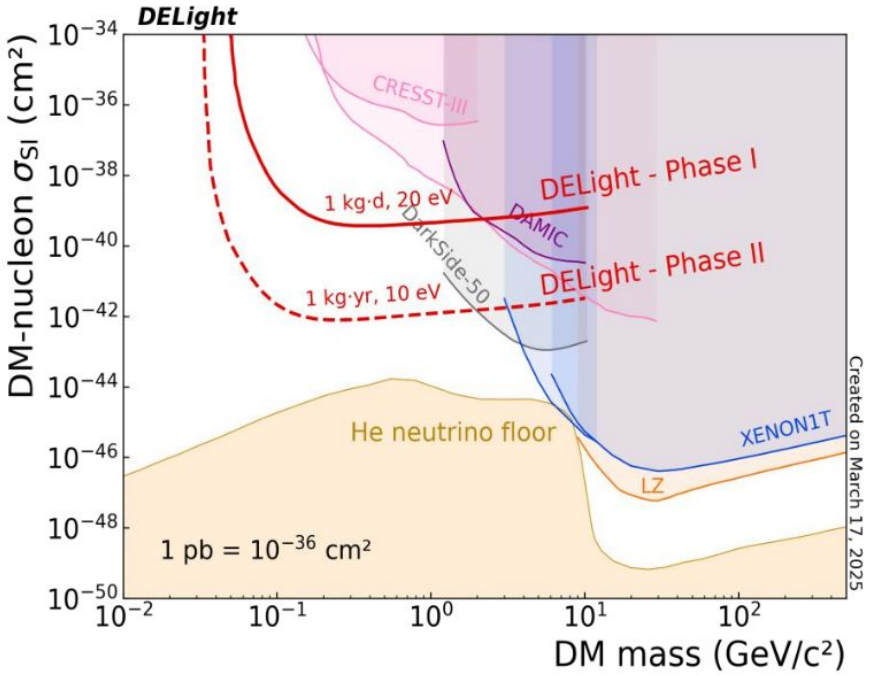


- Three institutions in Germany
- Designing future **Direct search Experiment for LIGHT dark matter**

Goal of the DELight Experiment

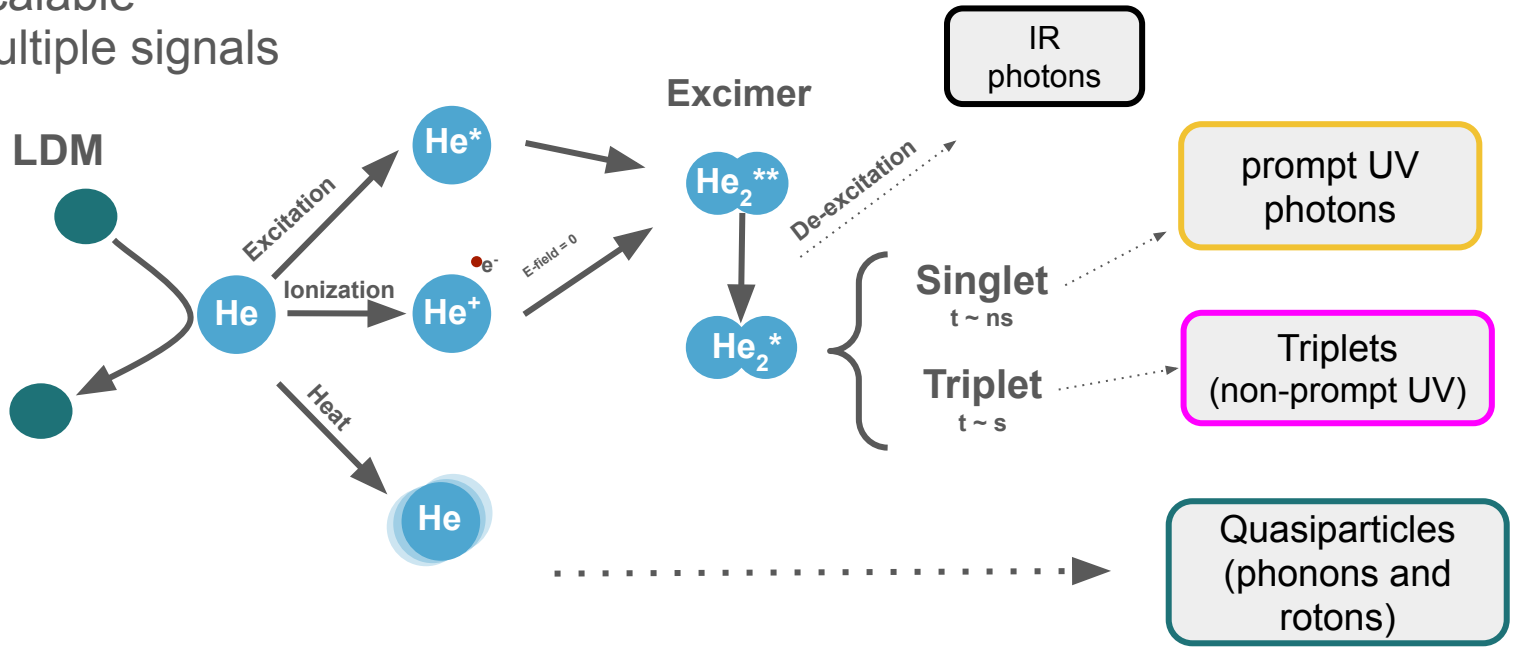
- Goal: probe **Light Dark Matter** → DM-nucleon interaction
- Use superfluid ^{4}He as target material
- No Low-Energy-Excess expected in the liquid
- Light nuclei → ideal for LDM search





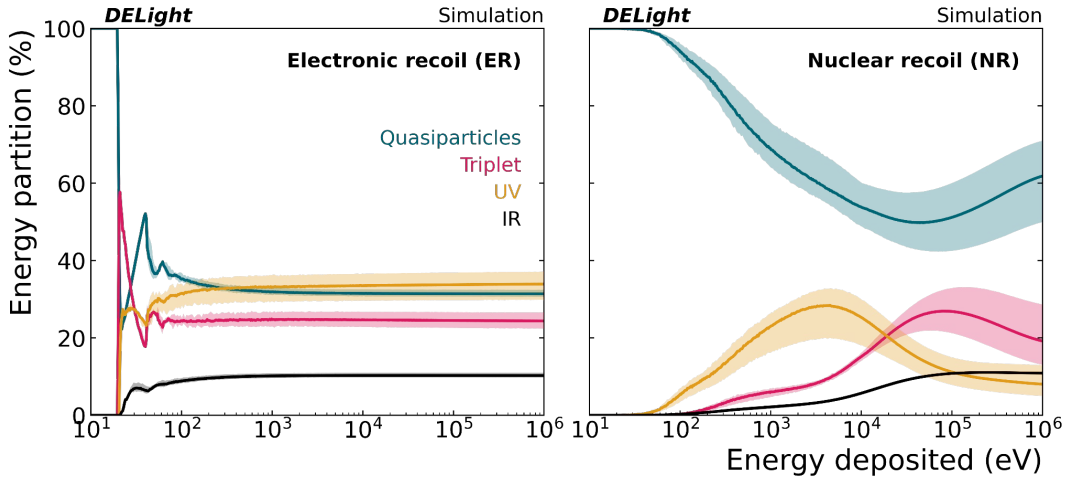
Superfluid ^{4}He as Target Material

- No intrinsic long-lived backgrounds
- Contaminants freeze-out
- Scalable
- Multiple signals



Superfluid ^{4}He as Target Material

- No intrinsic long-lived backgrounds
- Contaminants freeze-out
- Scalable
- Multiple signals
  → **potential ER/NR discrimination**



Phys. Rev. D 111, 032013

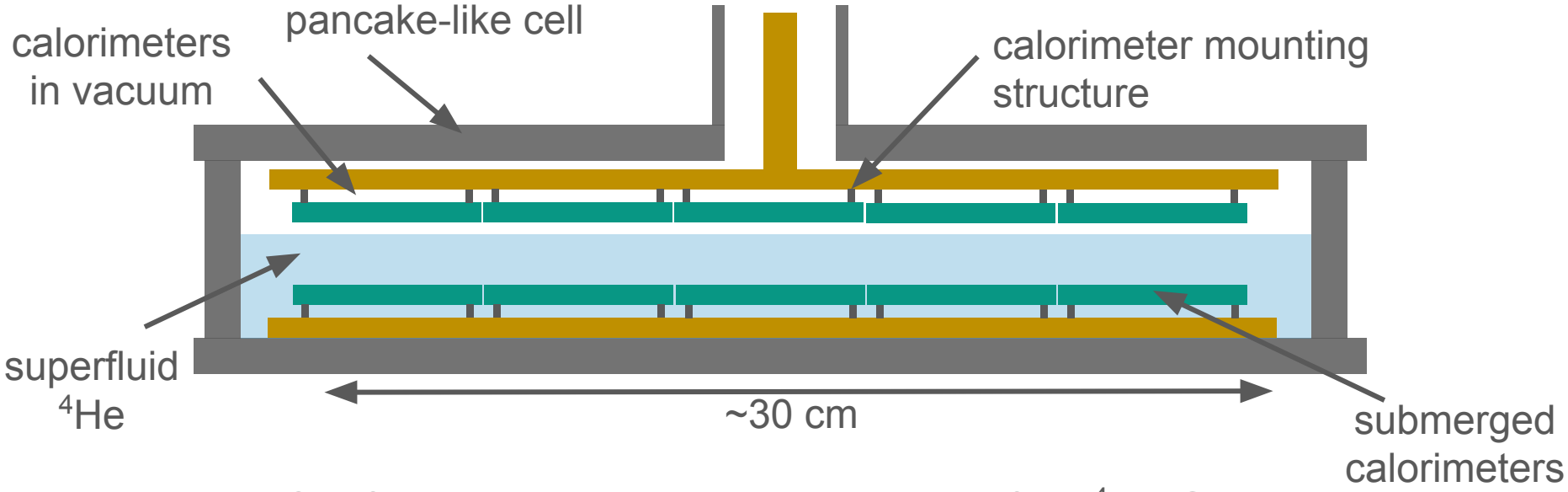
IR photons

prompt UV photons

Triplets (non-prompt UV)

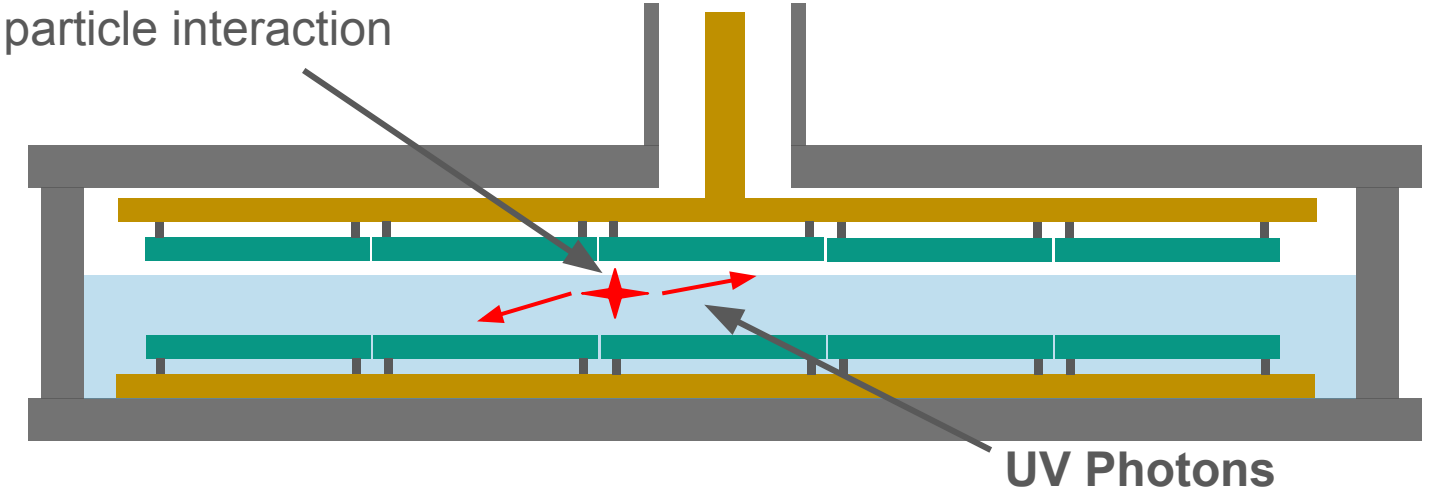
Quasiparticles (phonons and rotons)

DELight Design



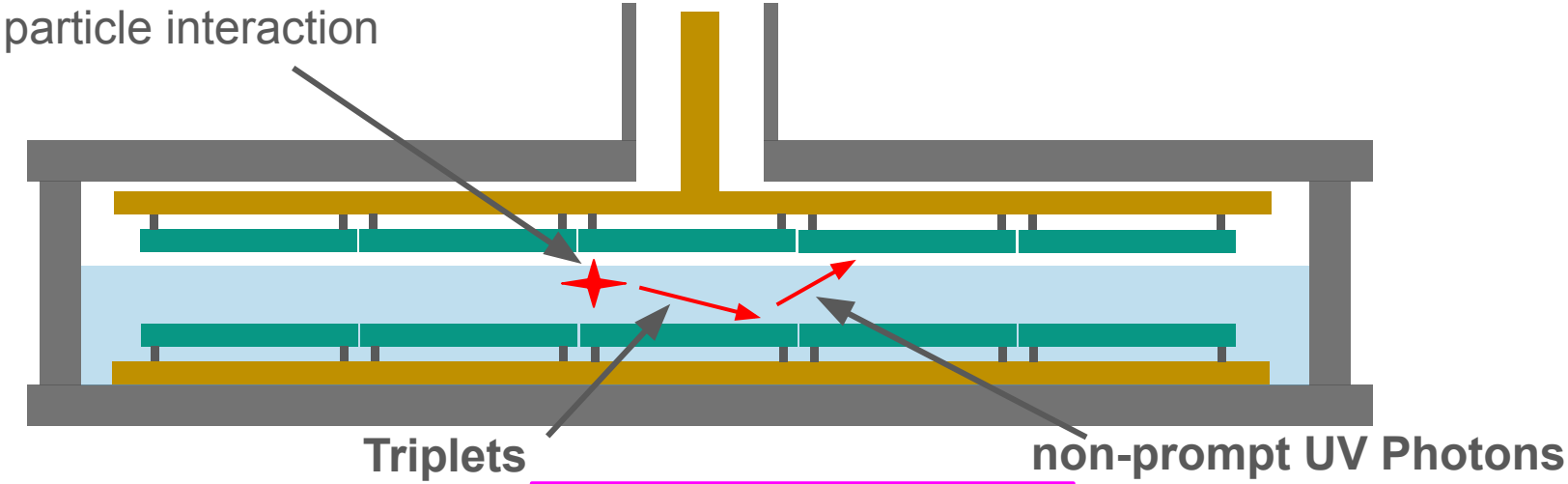
- Cell filled partially (1-10 liters) with superfluid ^{4}He @20 mK
- Calorimeters (sensor arrays) positioned in liquid and in vacuum
  → measure energy of scintillation and quasiparticles

DELight Design



- Singlet → UV photons
- First excited state in ^{4}He at ~20eV → Liquid transparent to UV photons
- Detection in both sensor arrays

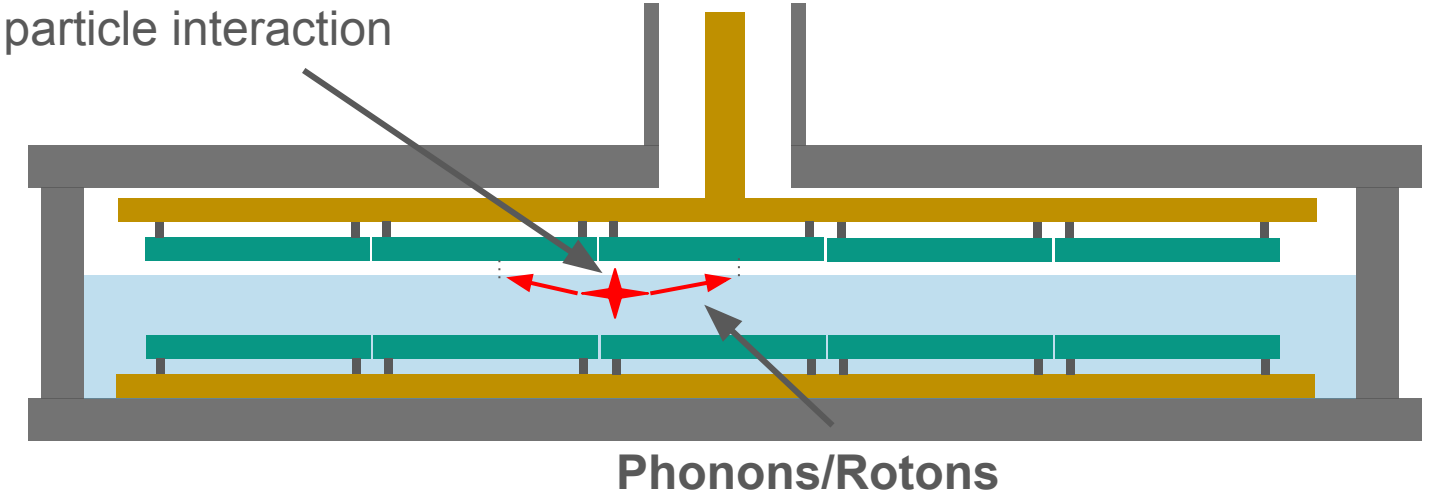
DELight Design



- Singlet → UV photons
- First excited state in ^{4}He at ~20eV → Liquid transparent to UV photons
- Detection in both sensor arrays

- Triplets lifetime→ 13s
- De-excite when reaching a surface
- UV photos delayed at calorimeter

DELight Design

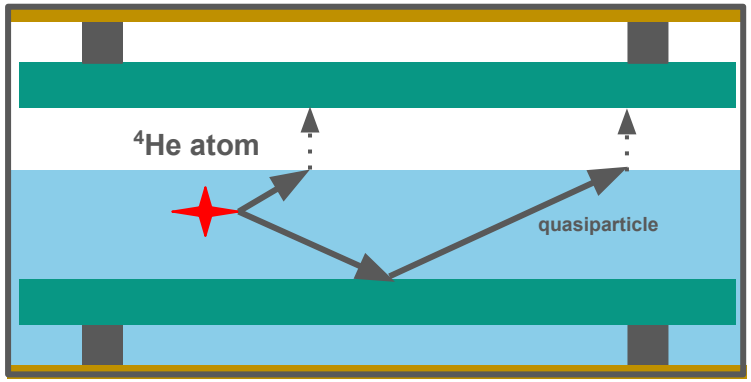


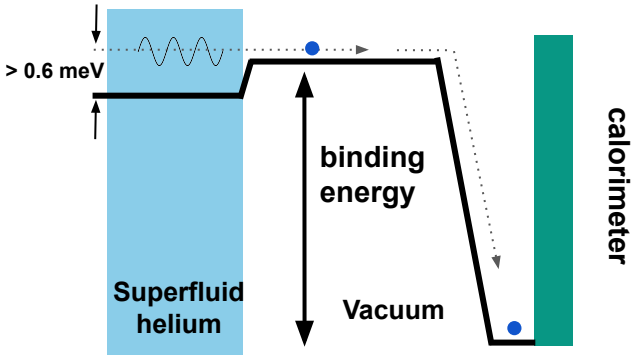
- Singlet → UV photons
- First excited state in ^{4}He at ~20eV → Liquid transparent to UV photons
- Detection in both sensor arrays

- Triplets lifetime→ 13s
- De-excite when reaching a surface
- UV photos delayed at calorimeter

- Quasiparticles propagate ballistically
- Evaporate He atoms at liquid surface → quantum evaporation

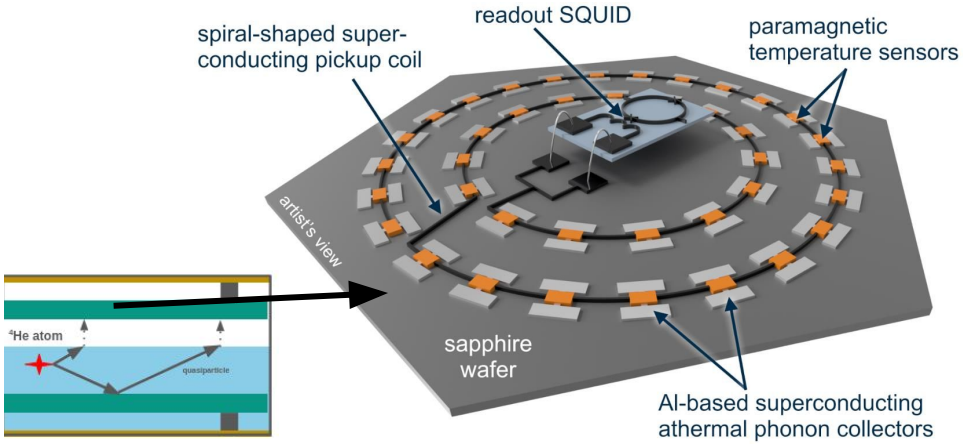
Quantum Evaporation





- Released He atoms condense on the sensor in vacuum
- Adsorption energy onto sapphire wafer ~20x binding energy → effective **signal amplification**
- Sensor in vacuum must be free from He film → Film burner

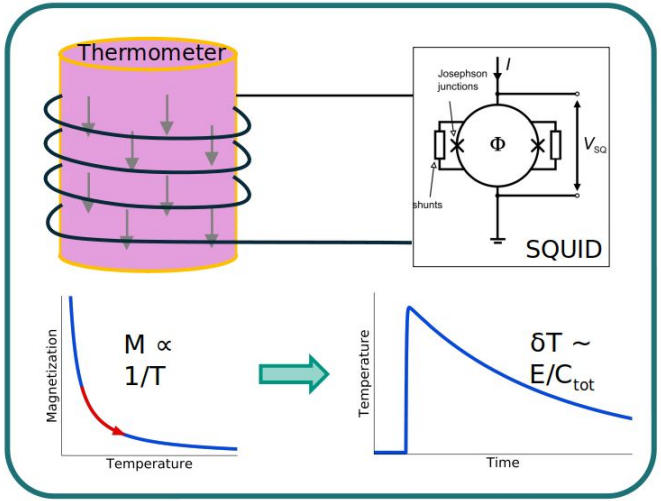
Calorimeters: LAMCALs



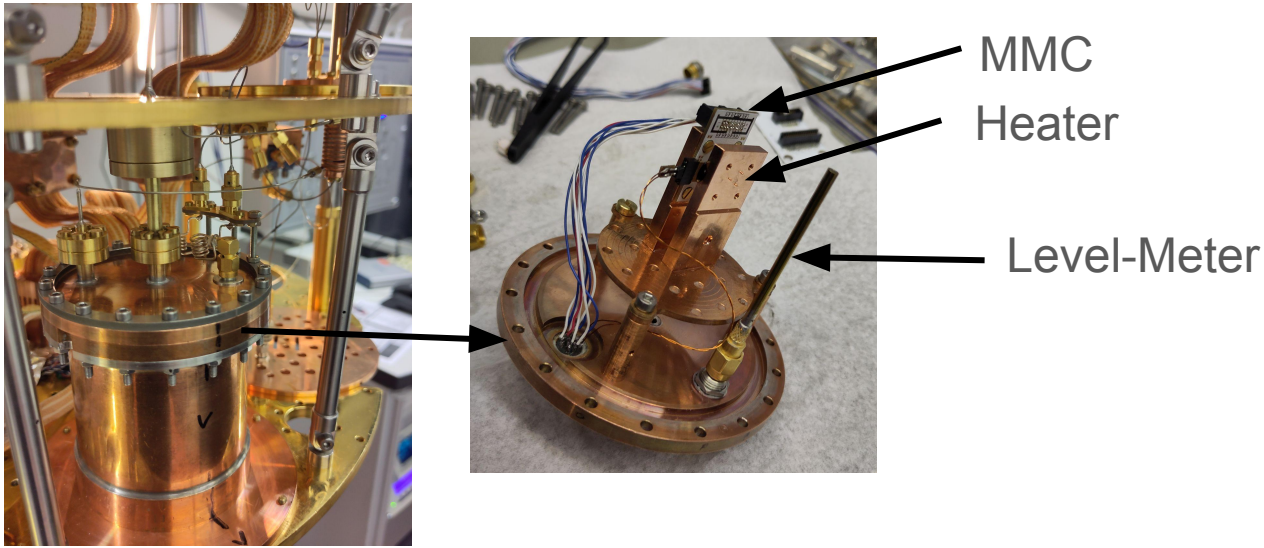
- Large Area cryogenic Micro-CALorimeter
- Sapphire-wafer as absorber
- Expected baseline resolution ~1eV

MMC

Temperature variation measured as a change in magnetization



Current Status - Demonstrator



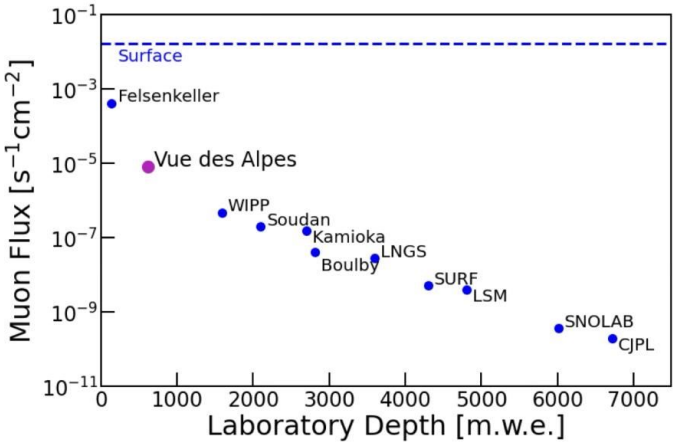
- R&D cell in operation in Heidelberg
- Cell filled with liquid helium @15 mK, level meter in function
- Equipped with MMC and heater

First Experimental Site

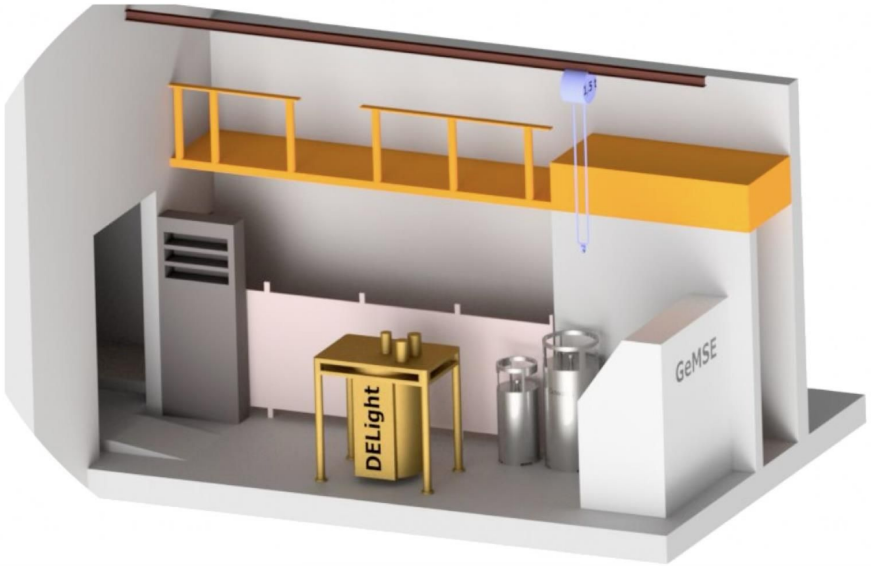
- Shallow underground lab

  → **230 m** rock overburden

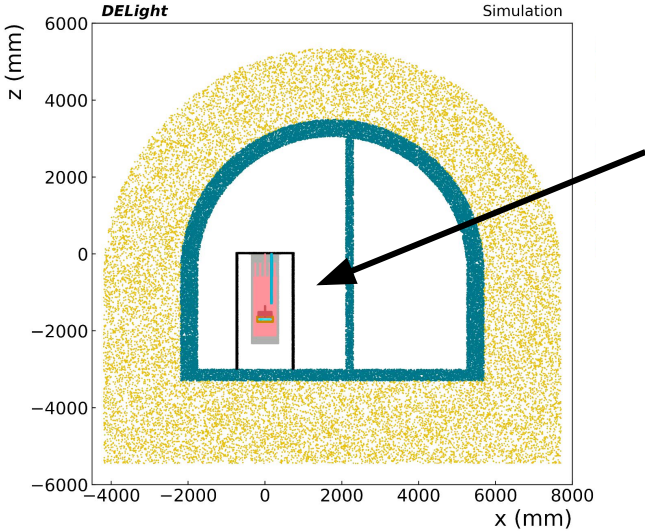
- Located in Switzerland
- Hosts GeMSE gamma spectrometer for material screening

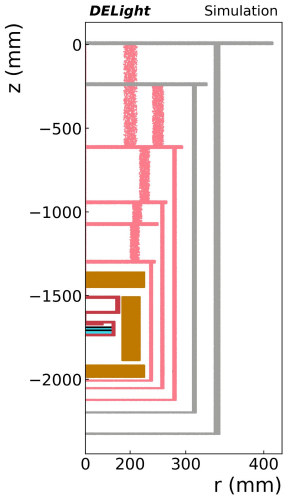


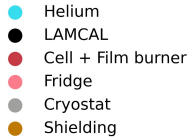
Vue-des-Alpes

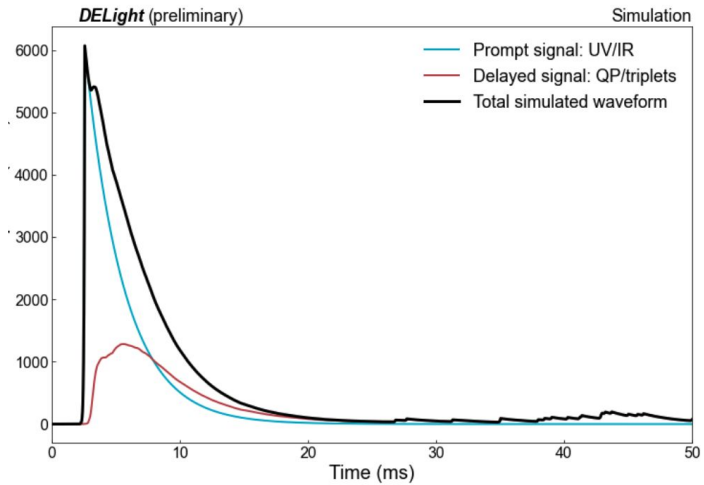


Simulations





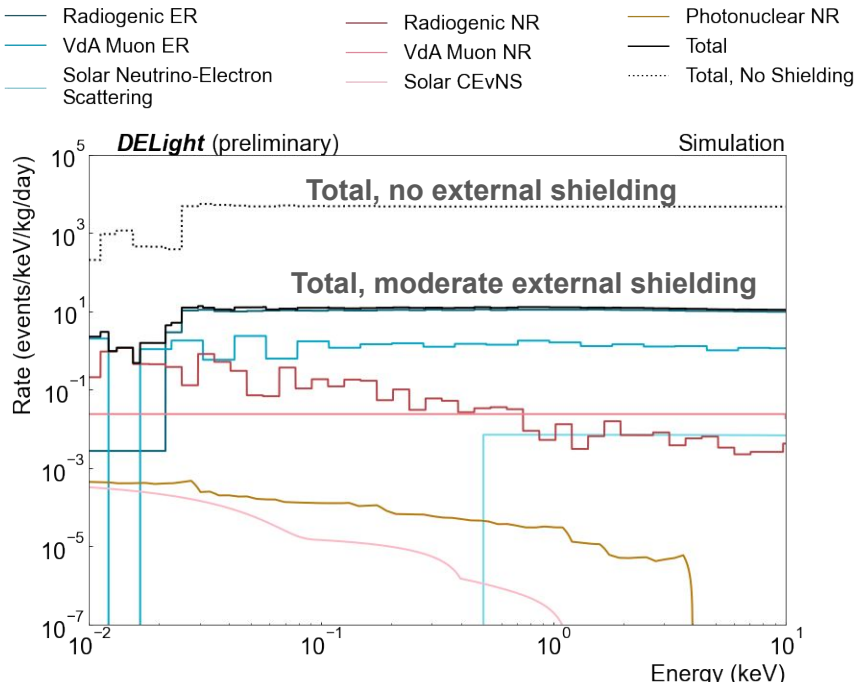




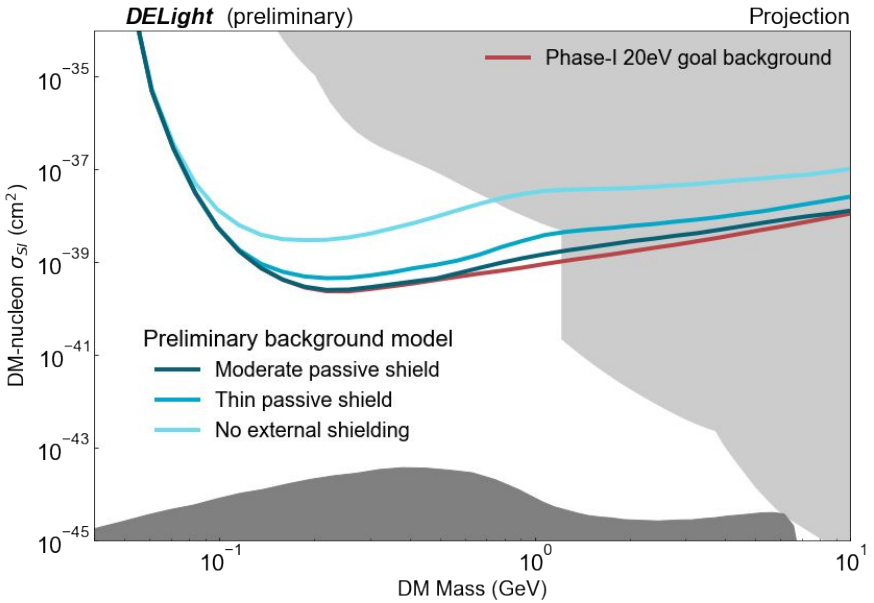
- Preliminary geometry implemented in Geant4
- Signal simulation (including quasiparticles) + waveform simulation
- Full background model (Vue-des-Alpes as experimental site)

Sensitivity Projections

Background model used for sensitivity projections

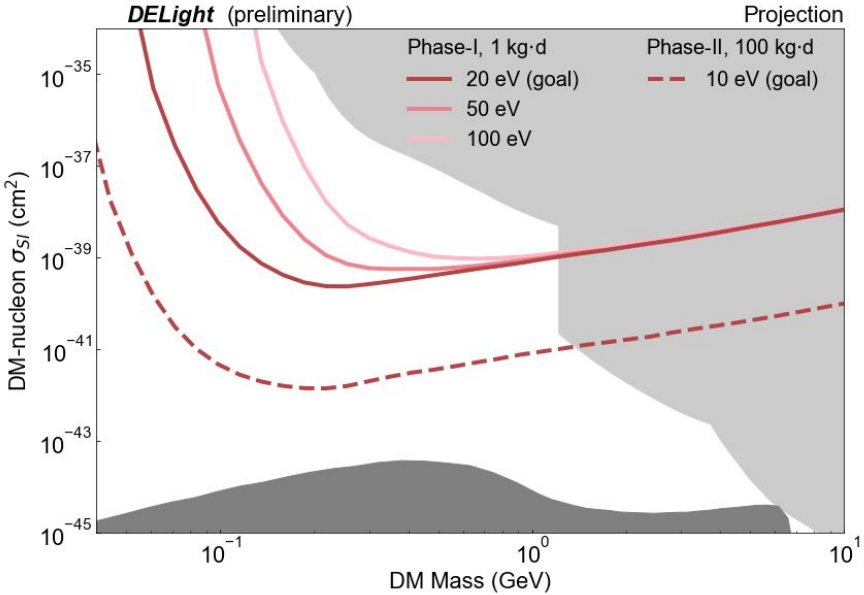


Phase-I 1 kg·d exposure



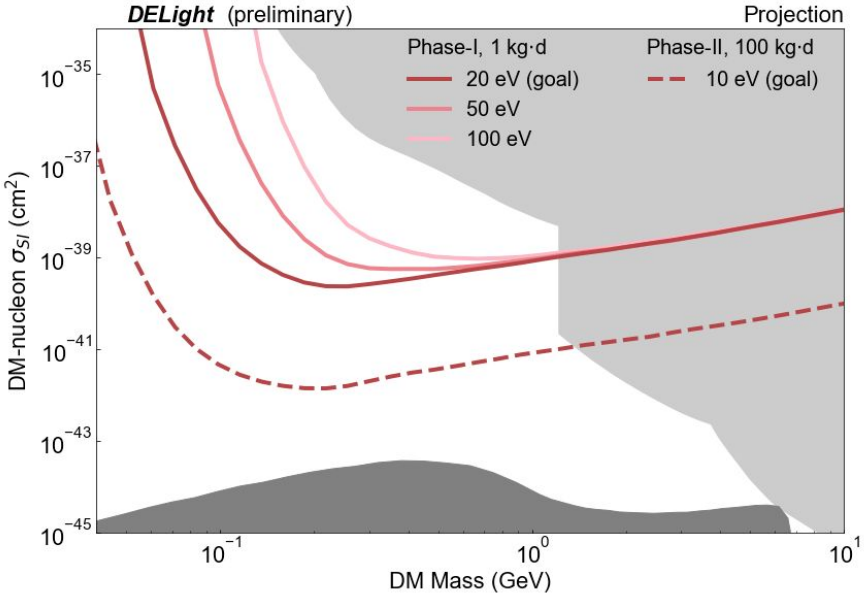
Summary and Outlook

- DELight is in its design phase
  → currently operating demonstrator
- First measurement will be at VdA
  - Phase-I: 20 eV threshold and 1 kg·d exposure
  - Phase-II: 10 eV thresholds and 100 kg·d exposure
- Long range plan:
  - deep underground laboratory
  - 200 L of liquid helium
  - threshold <10 eV and kg·year exposure



Summary and Outlook

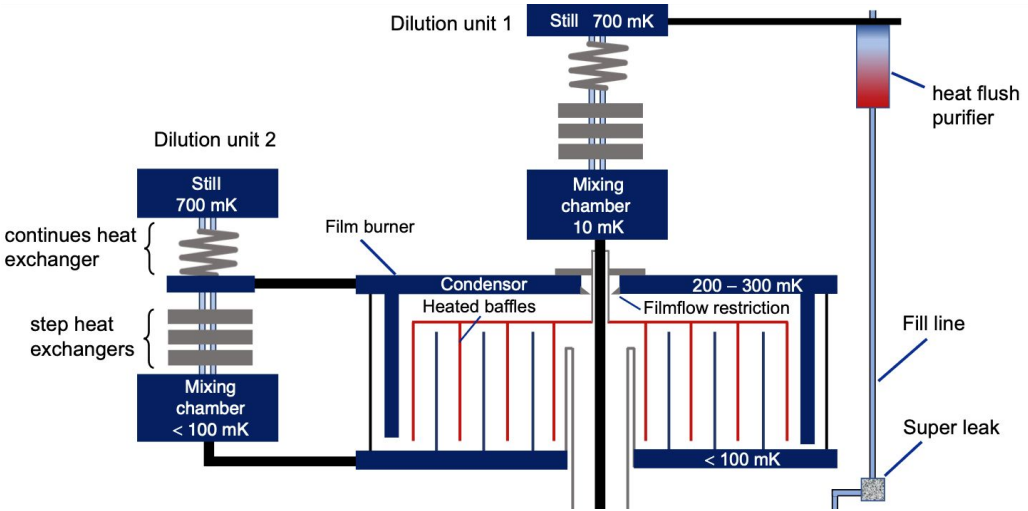
- DELight is in its design phase
  → currently operating demonstrator
- First measurement will be at VdA
  - Phase-I: 20 eV threshold and 1 kg·d exposure
  - Phase-II: 10 eV thresholds and 100 kg·d exposure
- Long range plan:
  - deep underground laboratory
  - 200 L of liquid helium
  - threshold <10 eV and kg·year exposure



Thank you!

Backup

Film Burner



- Additional structure close to the helium cell
- Needed against superfluid helium moving up to upper calorimeters
- Already tested by HERON collaboration