

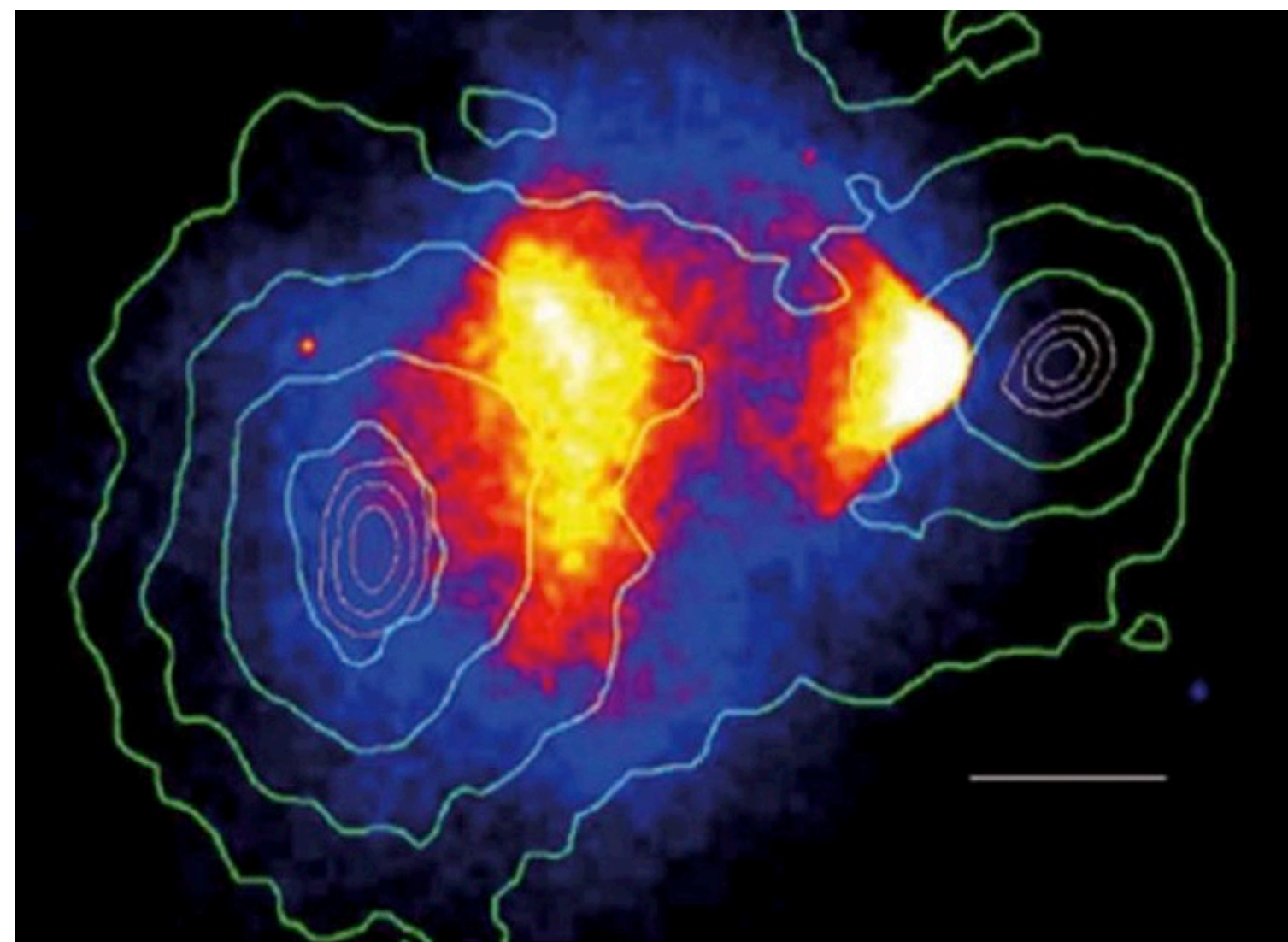
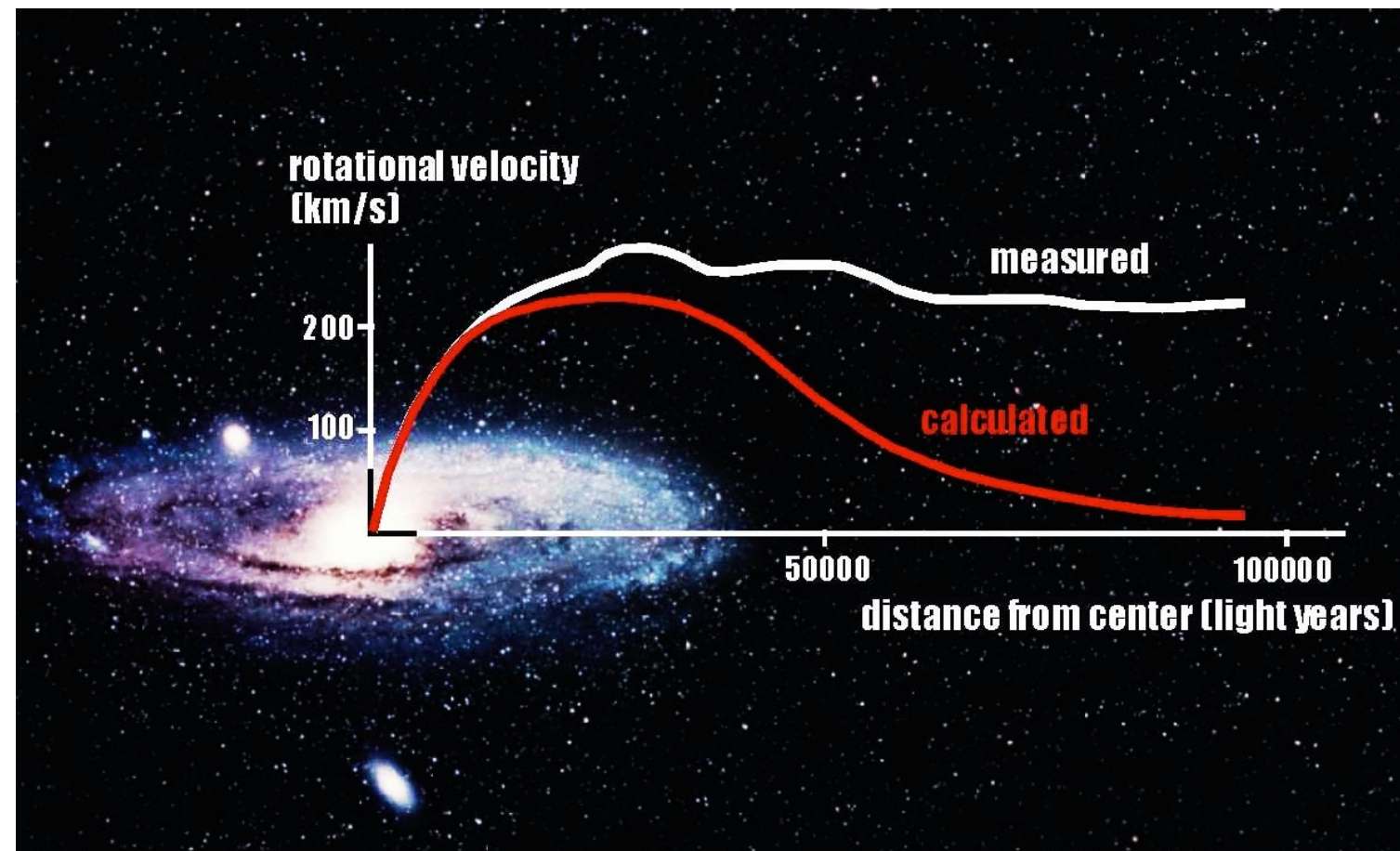


Current Status of the Direct Search Experiment for Light Dark Matter

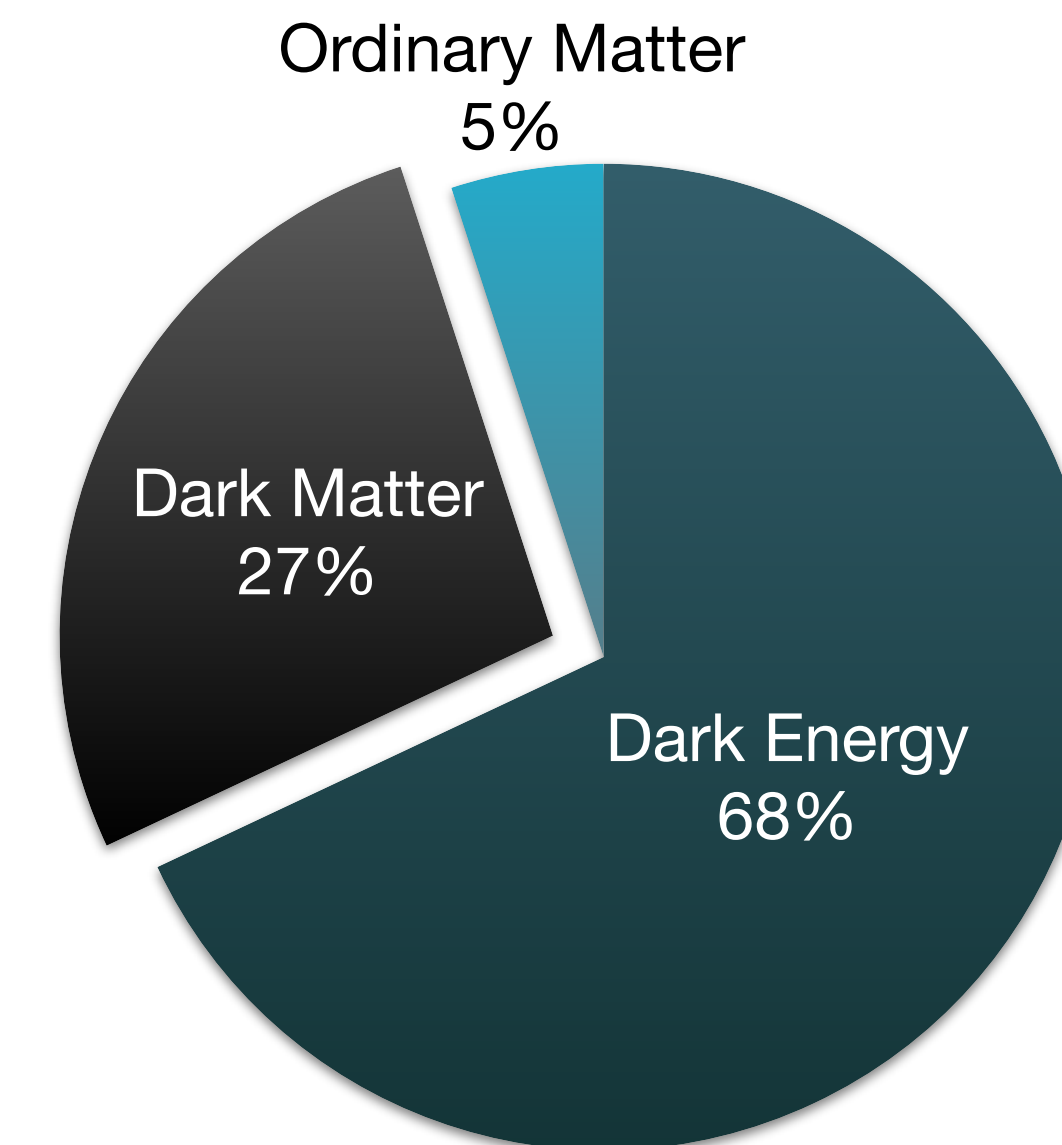
Eleanor Fascione on behalf of the DELight Collaboration
DPG Spring Meeting, Karlsruhe 2024/03/05



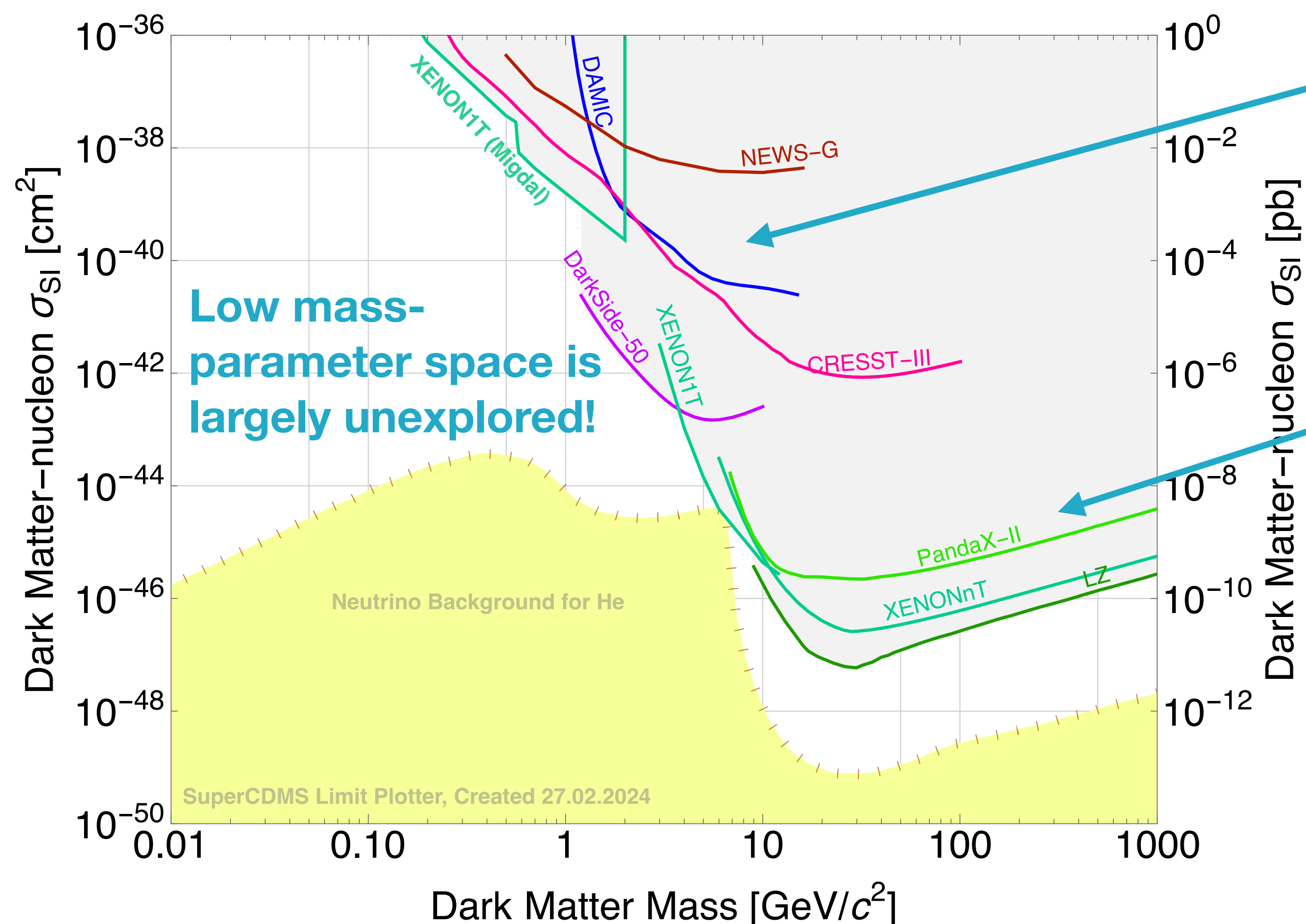
Dark Matter (DM)



- 85% of matter is **non-luminous, non-baryonic**, and **non-relativistic** dark matter
- Direct searches for interactions of DM with normal matter
- The WIMP is one of the favoured candidates
- Search for nuclear scatters



The Current SI-DM Landscape and Push to Low Mass



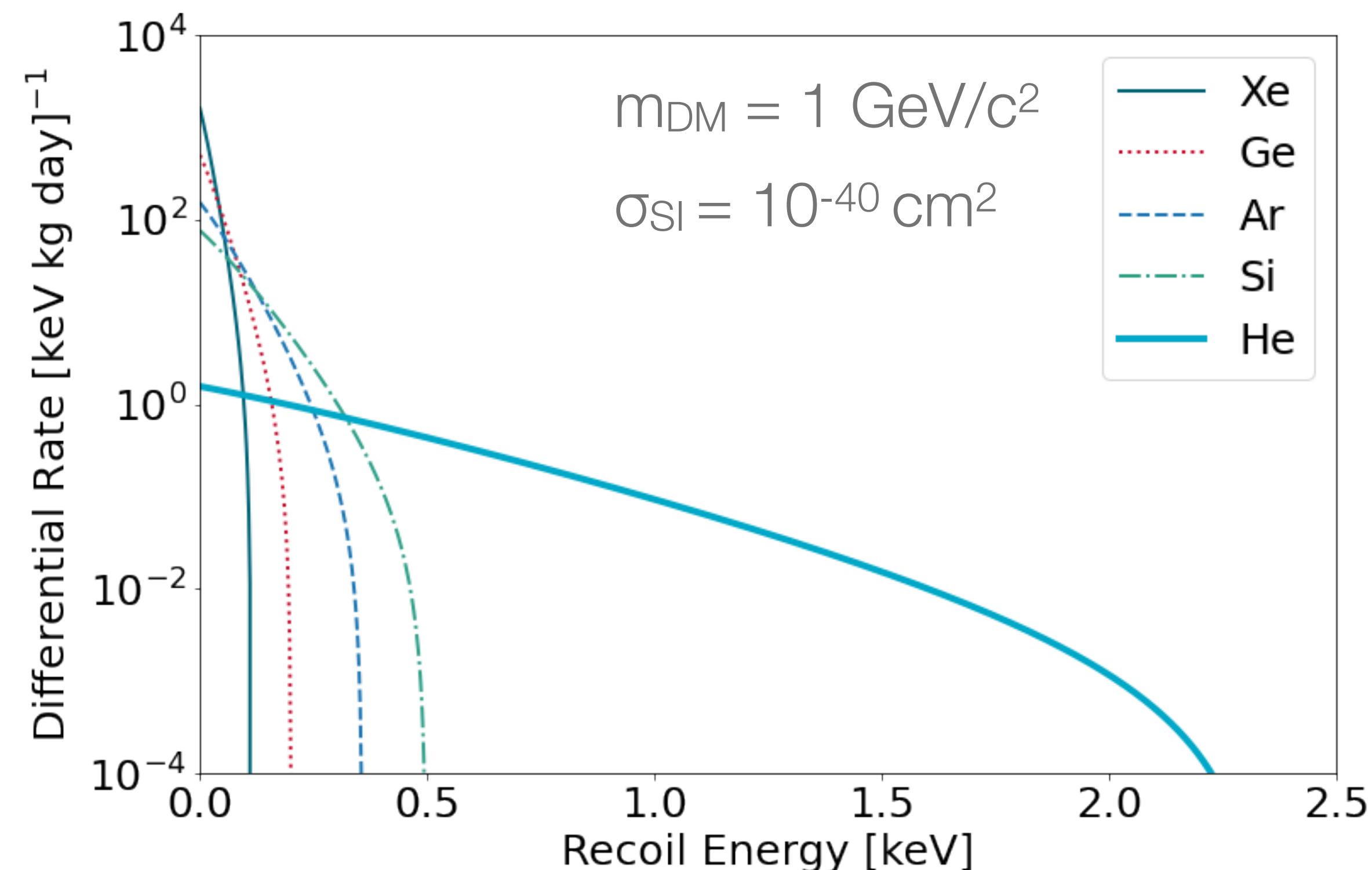
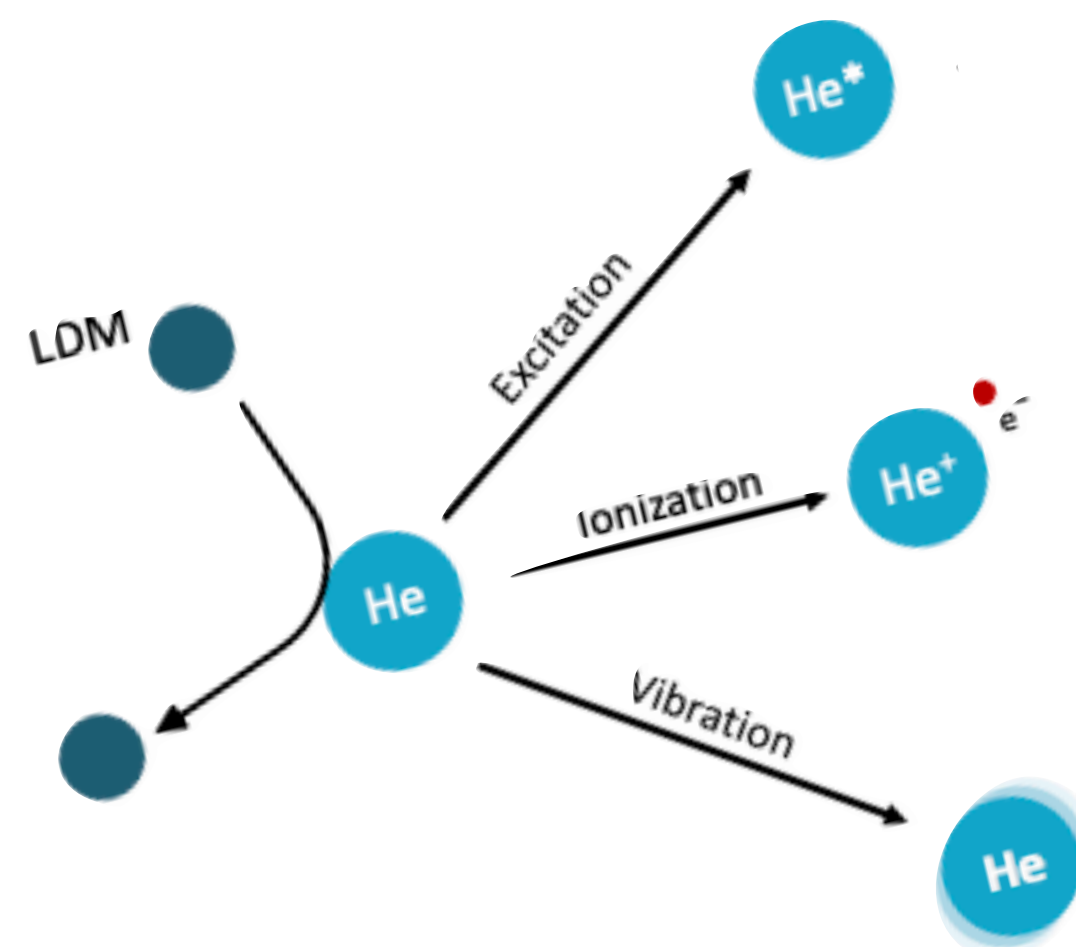
Various experimental efforts to reach sensitivity to $\sim$ GeV/c² scale WIMPs

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

1. J.I.Collar, Phys. Rev. D 98, 023005 (2018)
2. Arnaud et al., Astroparticle Physics 97, p.54--62 (2018)
3. Qiuhong Wang et al. (PandaX-II Collaboration) 2020 Chinese Phys. C 44 125001
4. Aalbers et al., Phys. Rev. Lett. 131, 041002 (2023)
5. Aprile et al., Phys. Rev. Lett. 131, 041003 (2023)
6. Aprile et al. Phys. Rev. Lett. 126, 091301 (2021)
7. Aprile et al., Phys. Rev. Lett. 123, 241803 (2019)
8. A. Aguilar-Arevalo et al., Phys. Rev. Lett. 125, 241803 (2020)
9. P. Agnes et al. (DarkSide), Phys. Rev. Lett. 130, 101001 (2023)
10. Abdelhameed, A. Physical Review D 100.10 (2019)

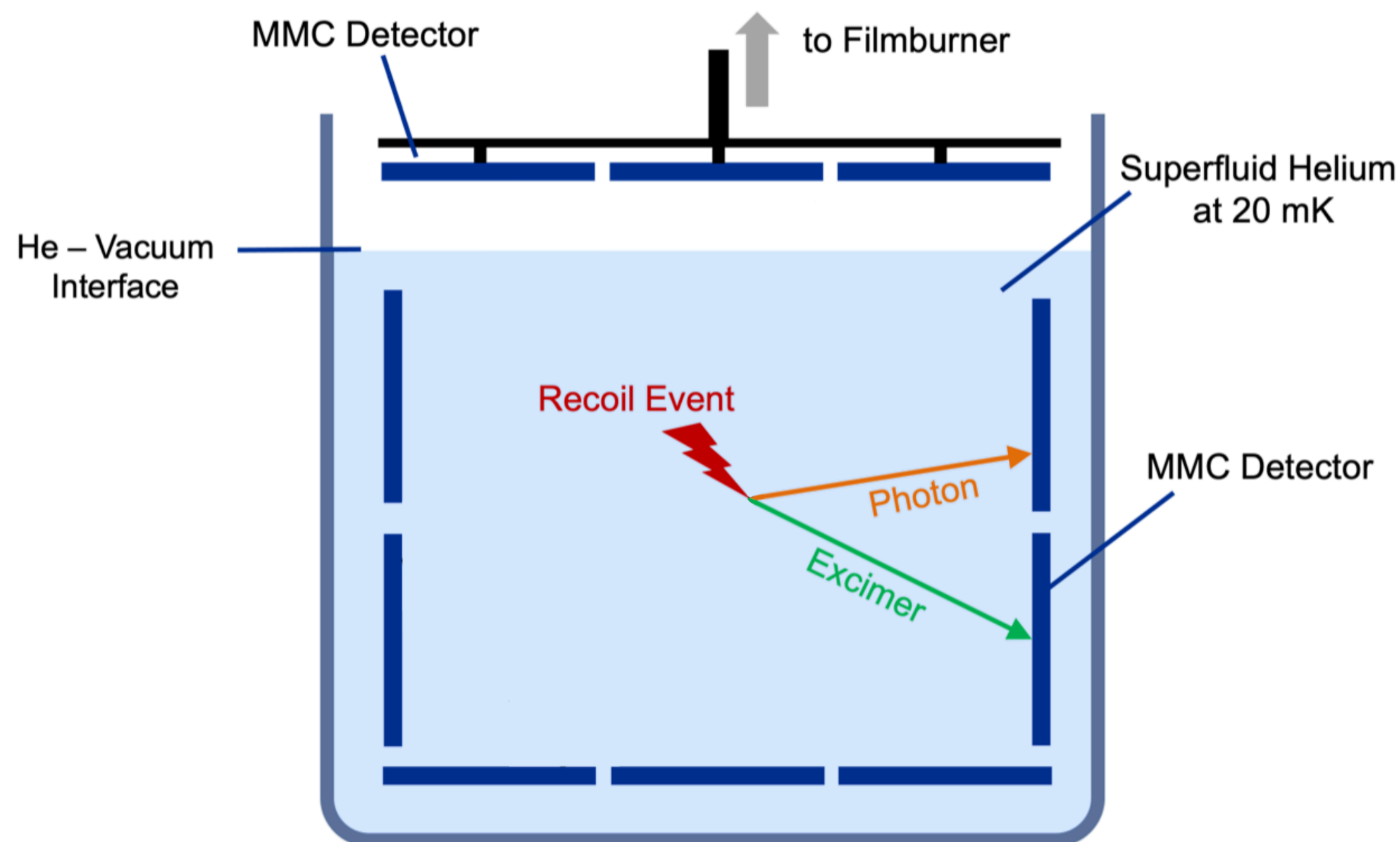
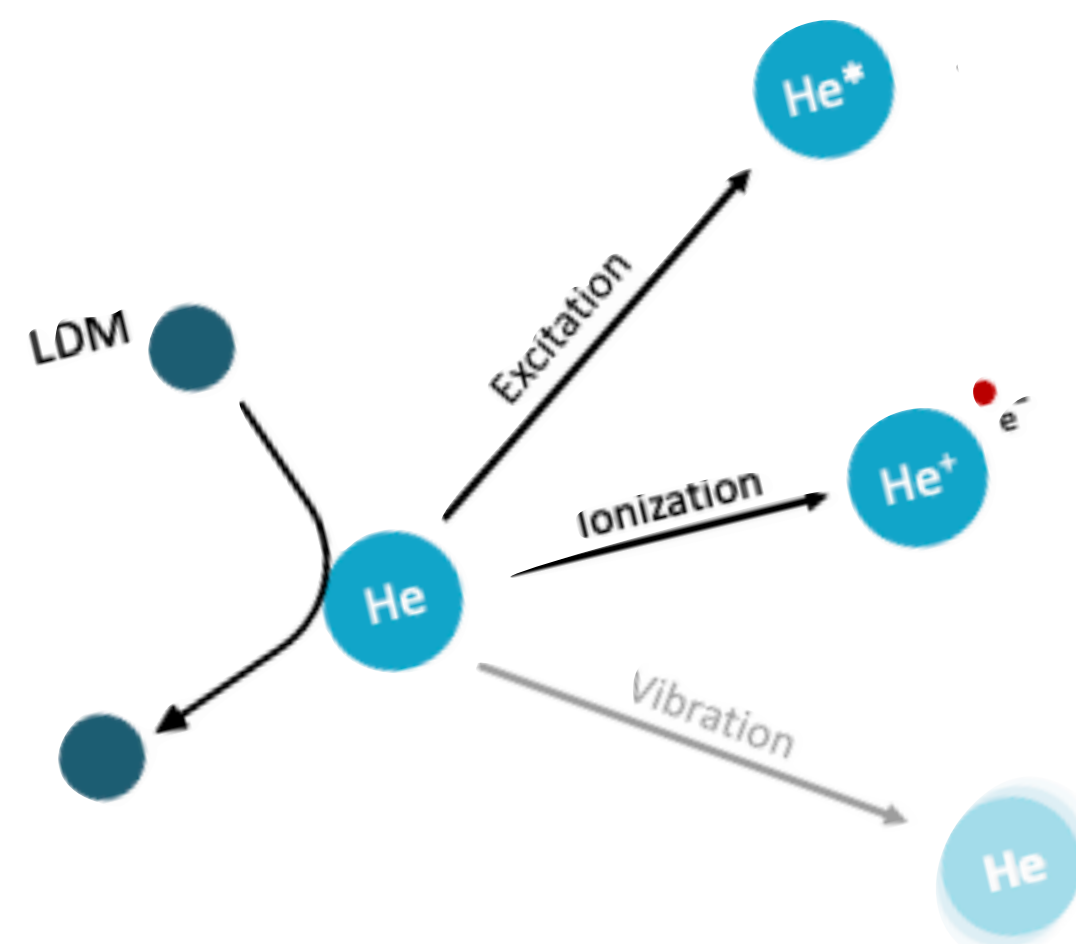
Superfluid Helium-4 Target

- Light nucleus ideal for LDM searches
- No intrinsic long-lived backgrounds
- Contaminants freeze-out
- Inexpensive compared to other targets
- Multiple signals



DELIGHT Detector - Interactions in Superfluid Helium-4

- Prompt signal from UV and IR photons
- Triplet excimer
- Ballistic O(m/s) speed
- 13s lifetime

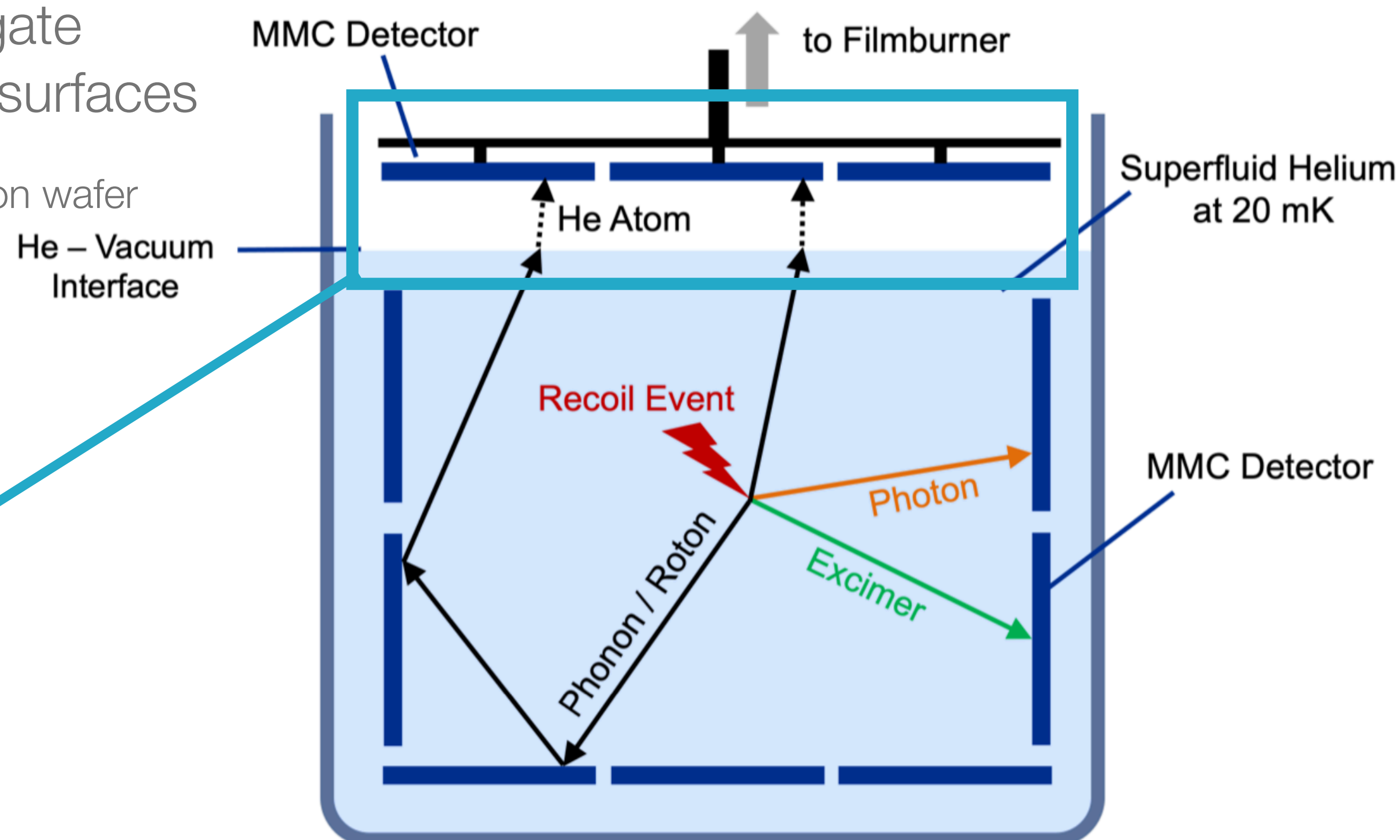
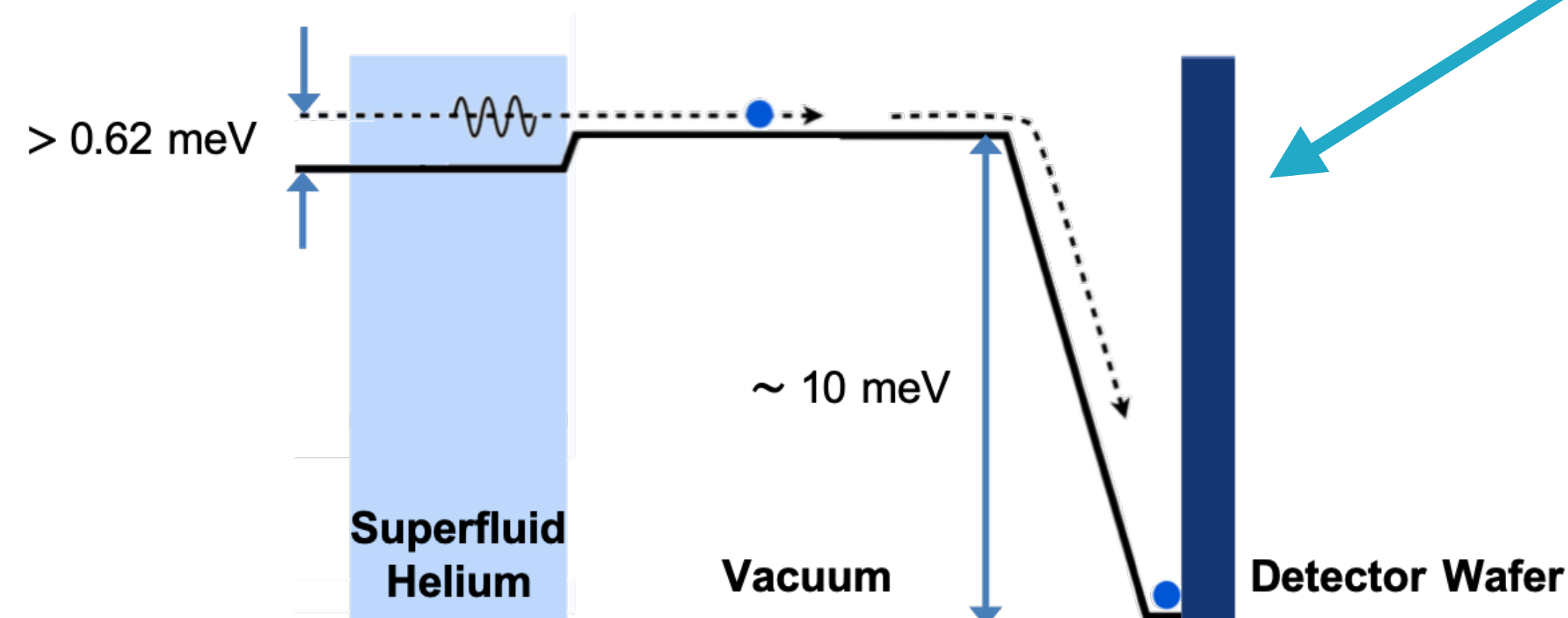


DELight Detector - Interactions in Superfluid Helium-4

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

Quasiparticle $\rightarrow$ Free He atom $\rightarrow$ He atom on wafer
 Quantum evaporation Condensation

- Noise free amplification of factor of 10



DELIGHT Detector - Interactions in Superfluid Helium-4

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

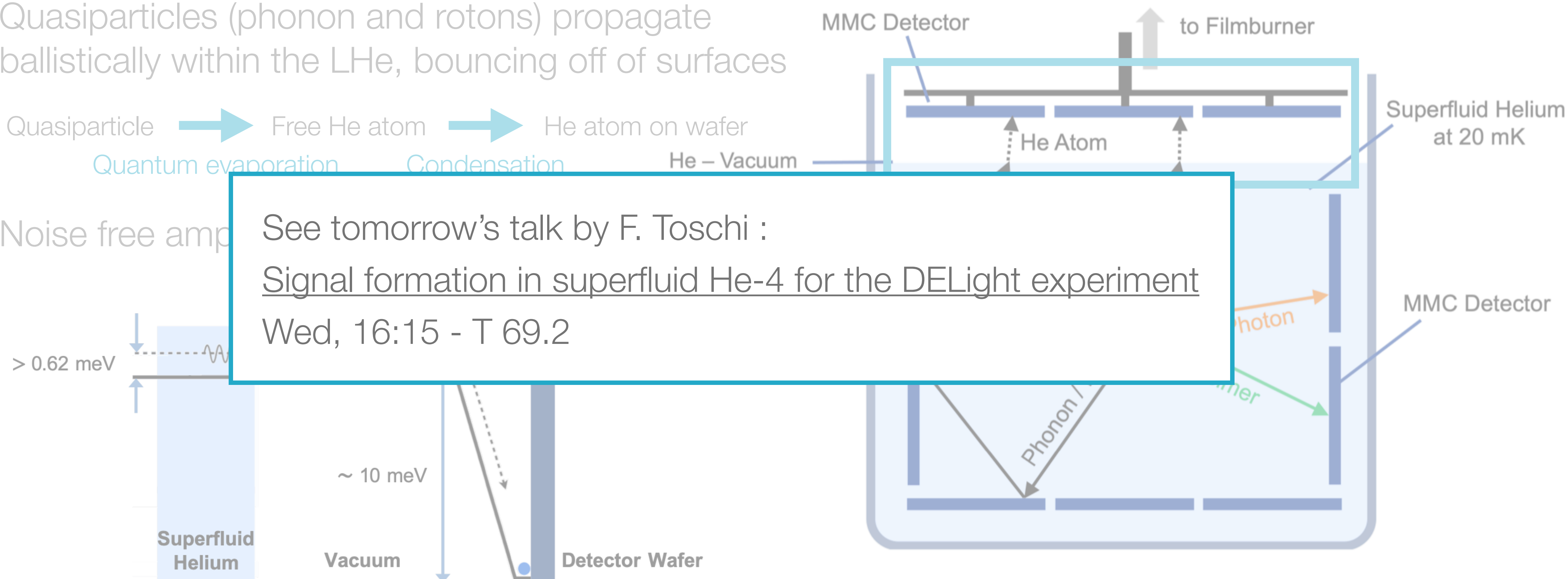
Quasiparticle $\rightarrow$ Free He atom $\rightarrow$ He atom on wafer
 Quantum evaporation Condensation He - Vacuum

- Noise free amp

See tomorrow's talk by F. Toschi :

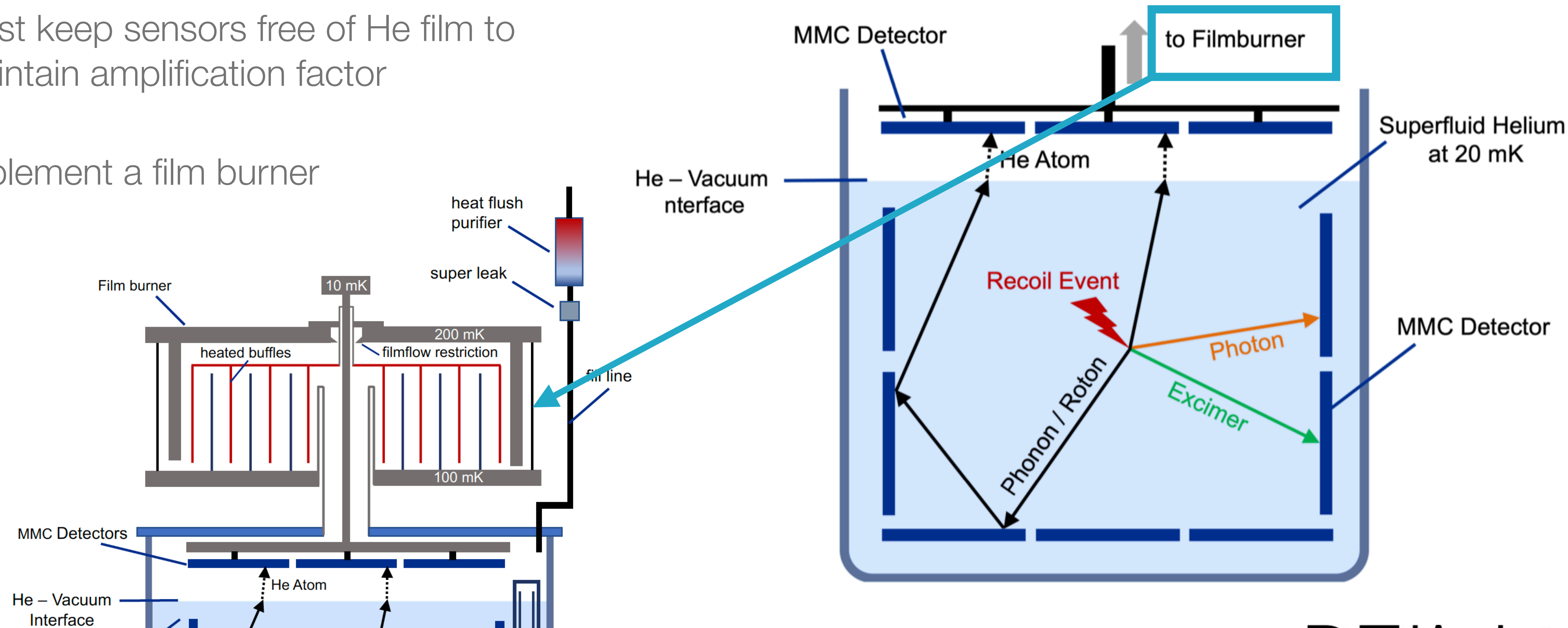
Signal formation in superfluid He-4 for the DELight experiment

Wed, 16:15 - T 69.2



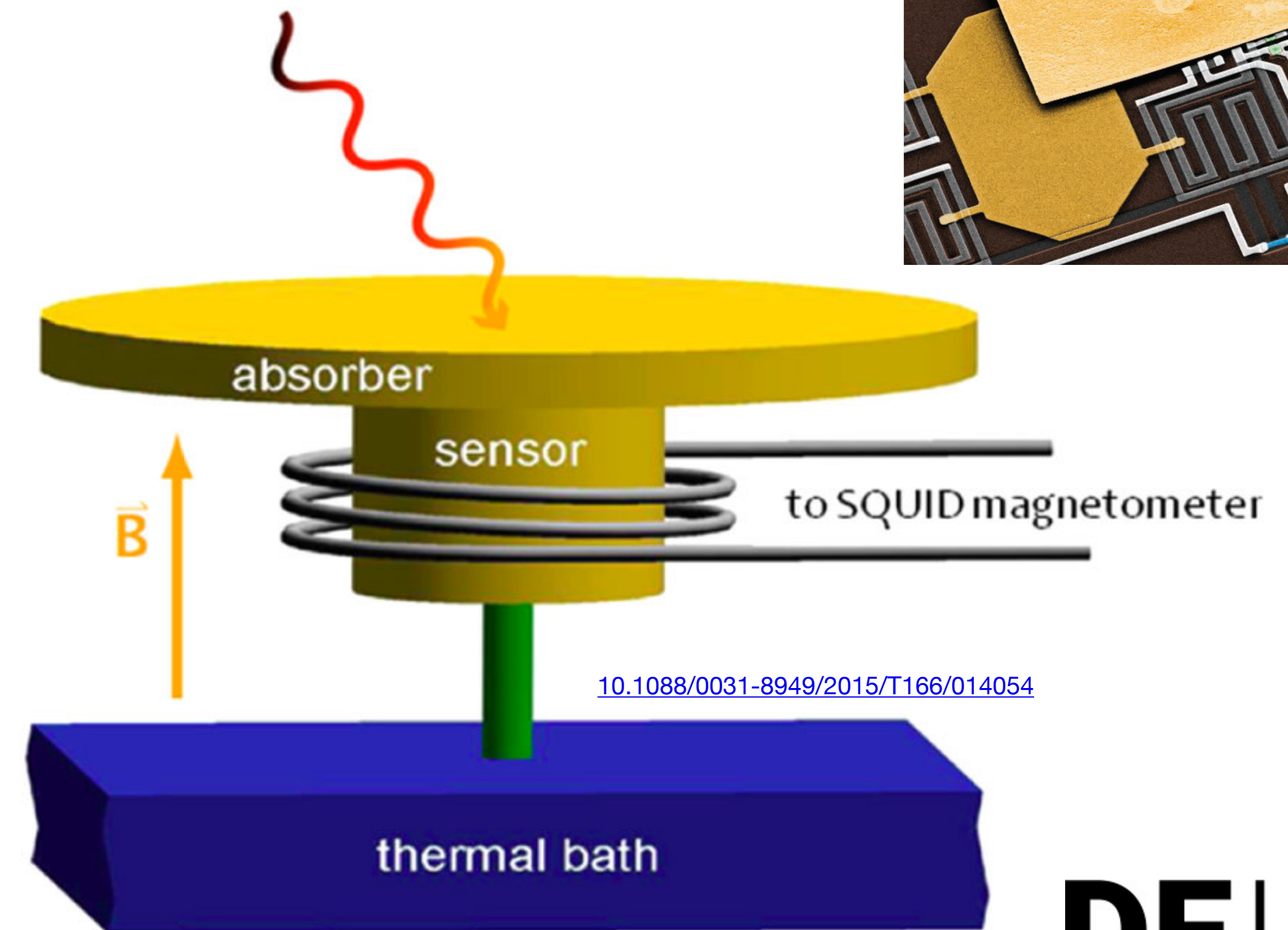
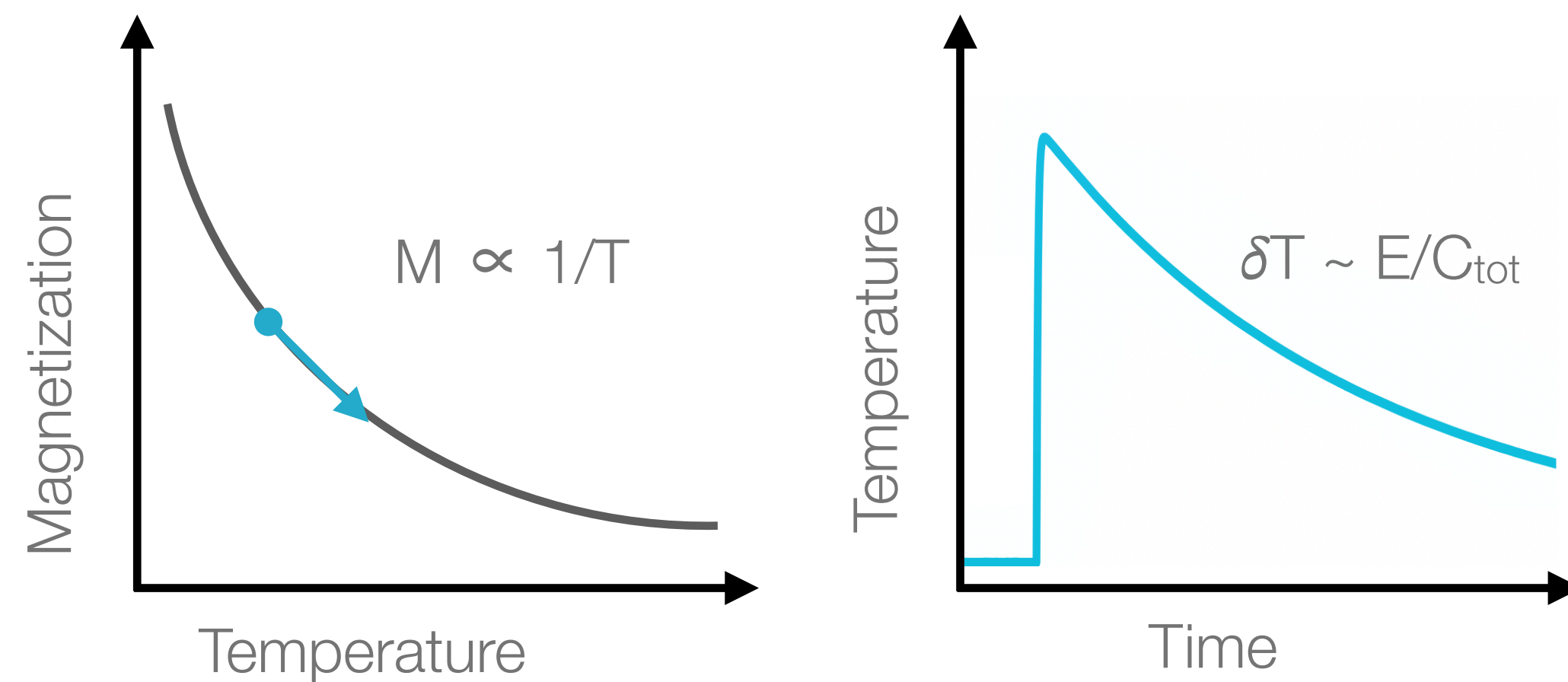
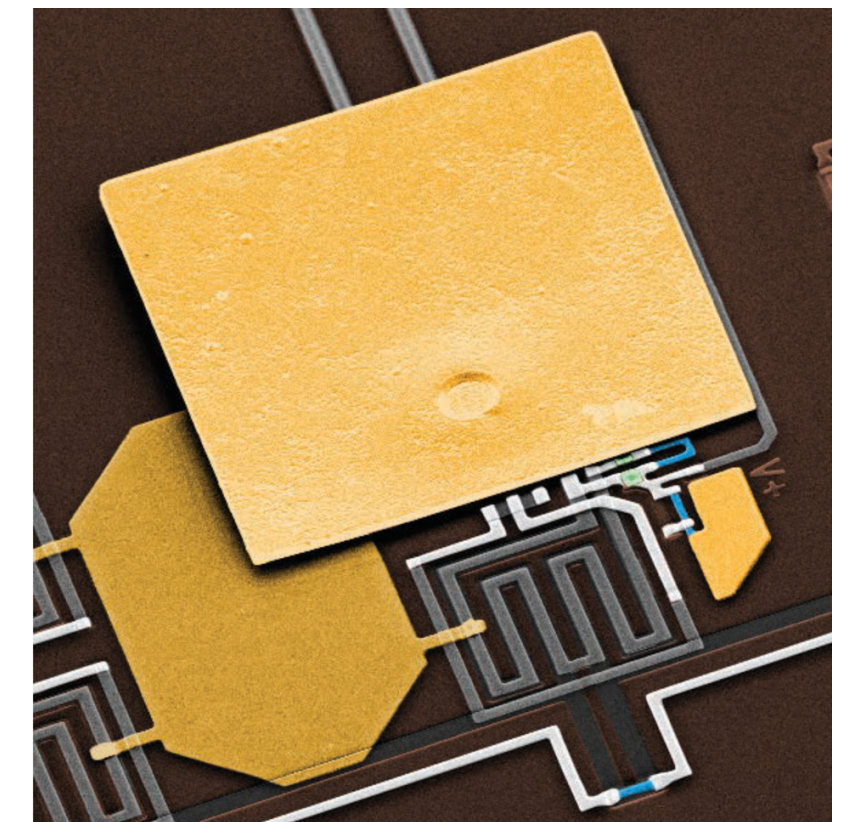
DELight Detector - Film Burner

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



Magnetic MicroCalorimeters (MMCs)

- Energy deposition in the absorber causes an increase in temperature δT and decrease in magnetization of the paramagnetic sensor $\delta M \propto \delta T$
- Change in magnetization is read out by a SQUID

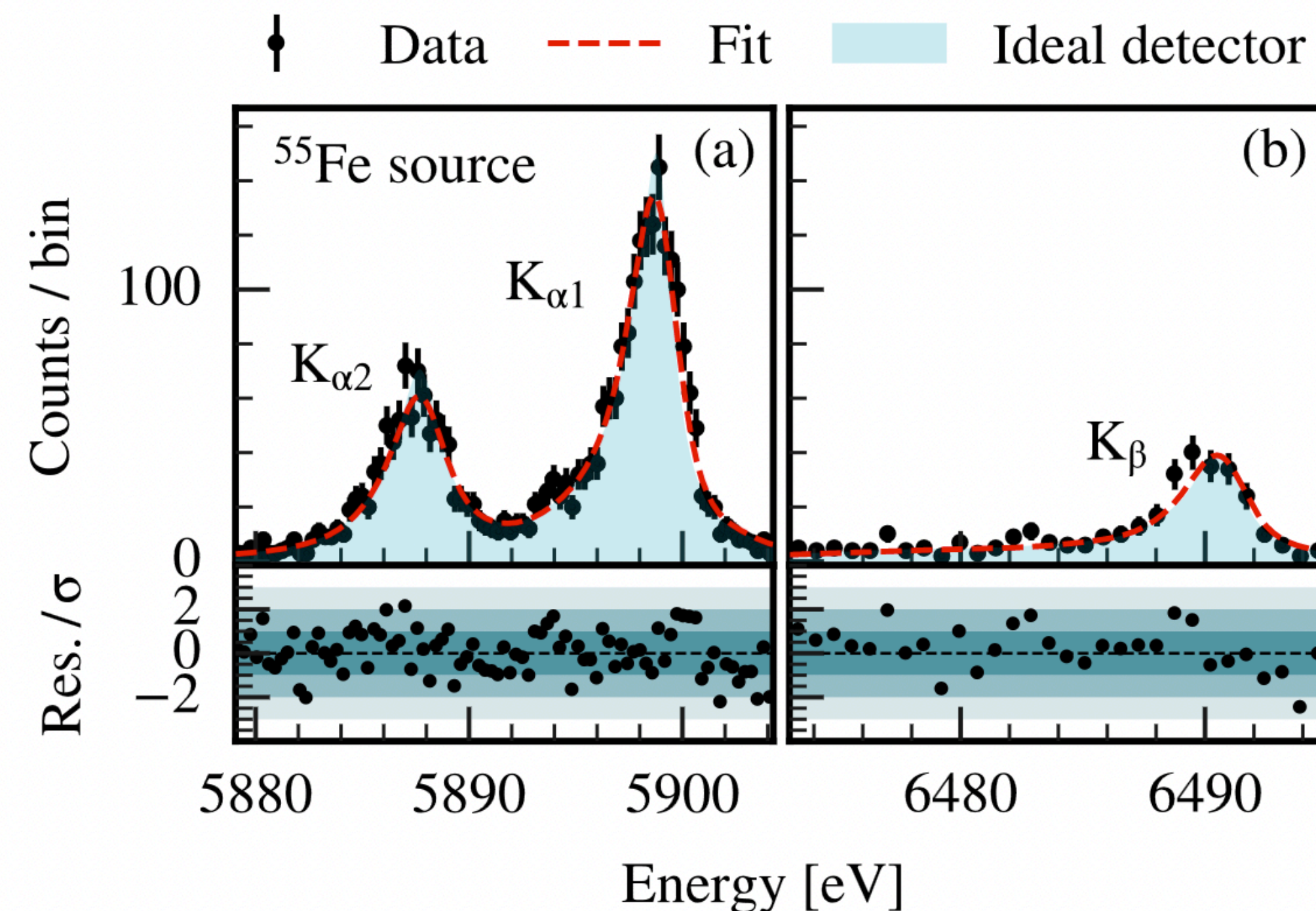


R&D - MMC Energy Resolution and Fabrication

- Previous best MMC resolution $\Delta E_{\text{FWHM}} = 1.58 \text{ eV}$ at 5.9keV
 - J. Low Temp. Phys. 193, 365-379 (2018)
- New MMCs described in **Appl. Phys. Lett. 124, 032601 (2024)**
 Matthäus Krantz, Francesco Toschi, Benedikt Maier, Greta Heine, Christian Enss, Sebastian Kempf
- Achieved best resolution to date **$\Delta E_{\text{FWHM}} = 1.25 \text{ eV}$ at 5.9keV**
 - Optimal filter analysis of ^{55}Fe calibration peaks
 - Amplitude fit to K_{α} data, calibration parameters validated by reconstructing K_{β}

- Paper published Phys. Rev. D 109, 043035 (2024)**

Francesco Toschi, Benedikt Maier, Greta Heine, Torben Ferber, Sebastian Kempf, Markus Klute, and Belina von Krosigk



R&D - MMC Energy Resolution and Fabrication

- Previous best MMC resolution $\Delta E_{FWHM} = 1.58$ eV at 5.9keV

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

- New MMC (2024)

MMC fabrication technology and sensor layout under development, see Monday's talk by S. Kempf:

- Achieved

Wafer calorimeter development for the Direct Search Experiment for Light Dark Matter with Superfluid Helium (DELIGHT)

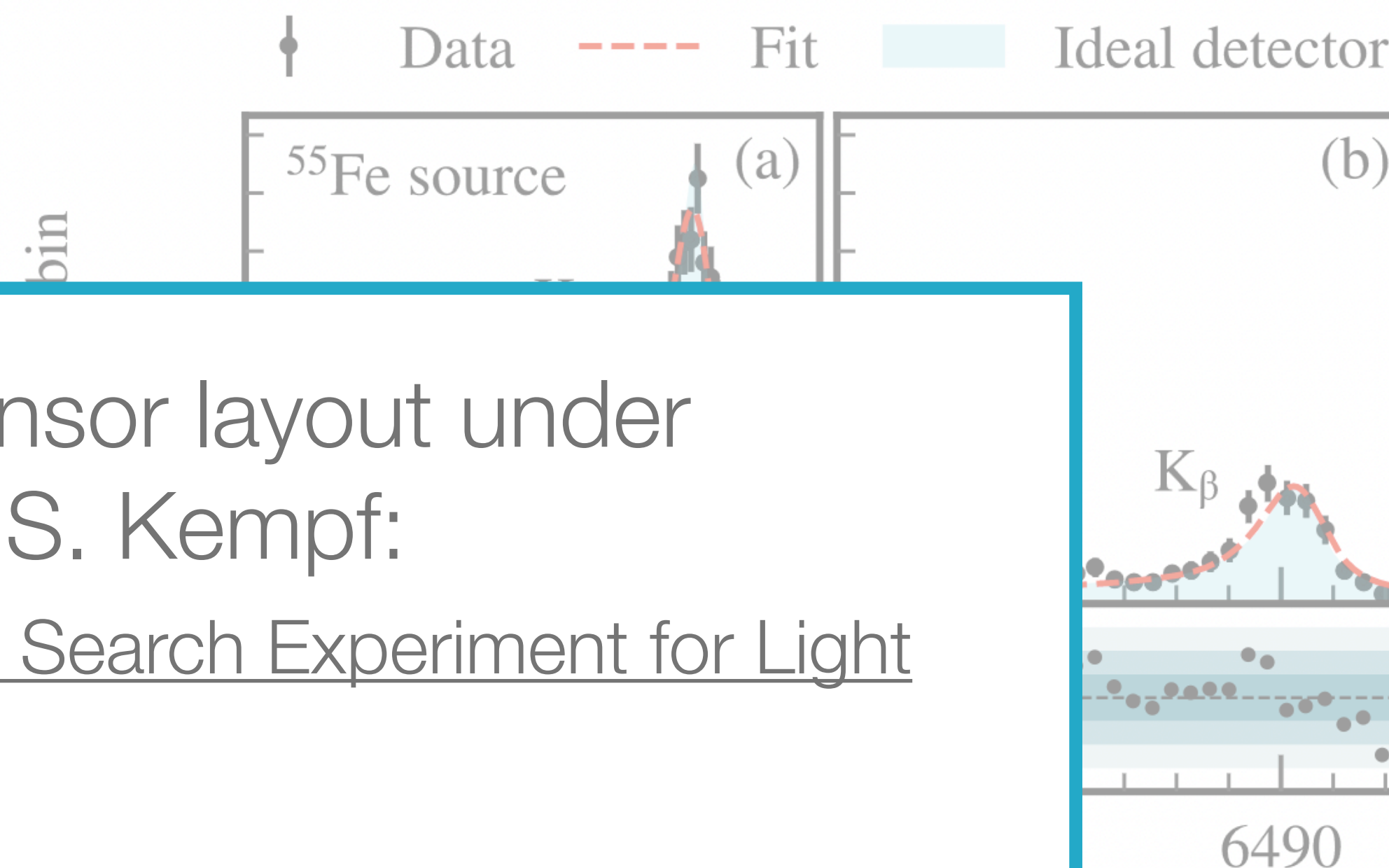
- Optim

Mon, 16:00 - T 18.1

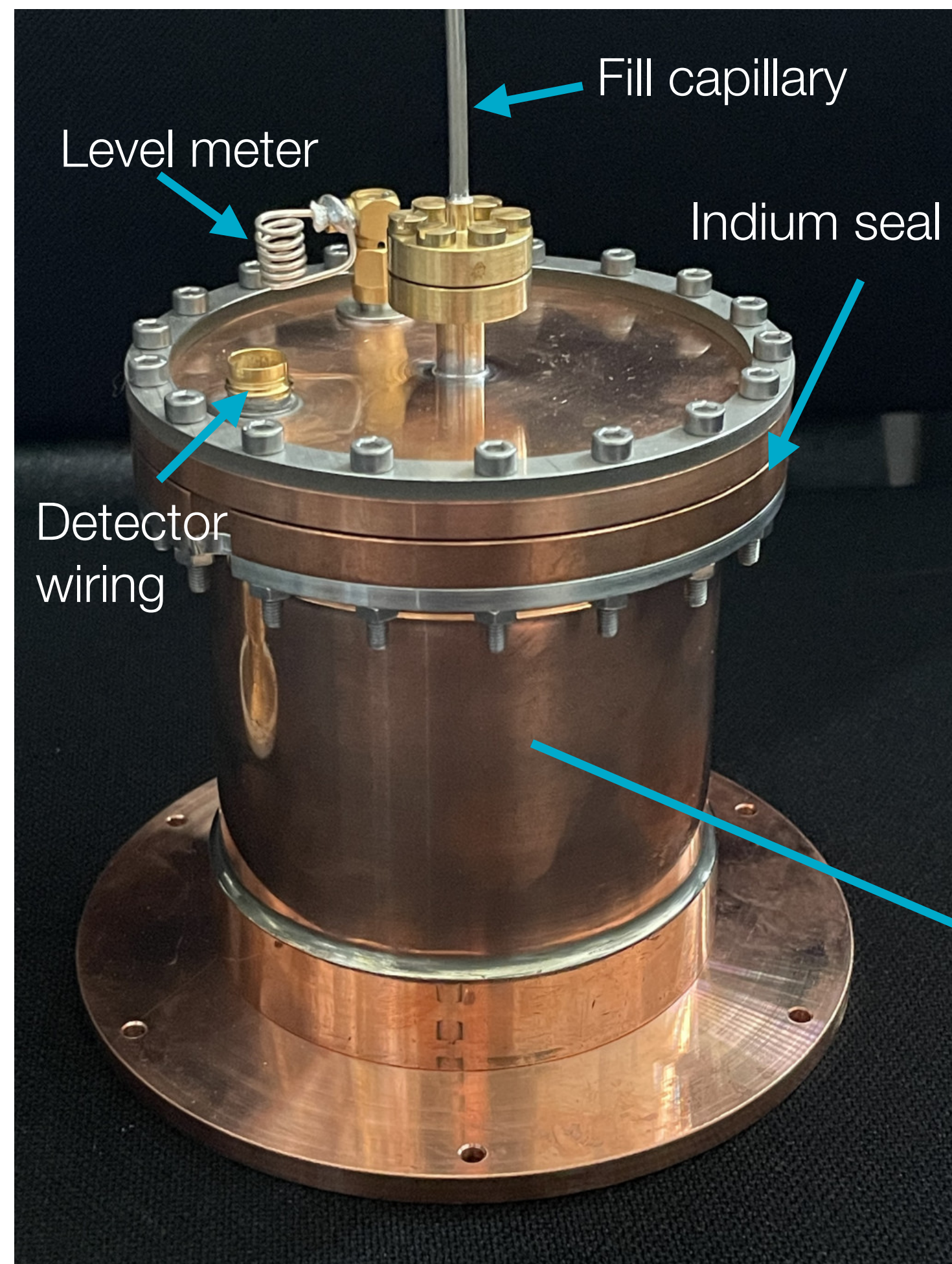
- Amplitude fit to K_{β} data, calibration parameters validated by reconstructing K_{β}

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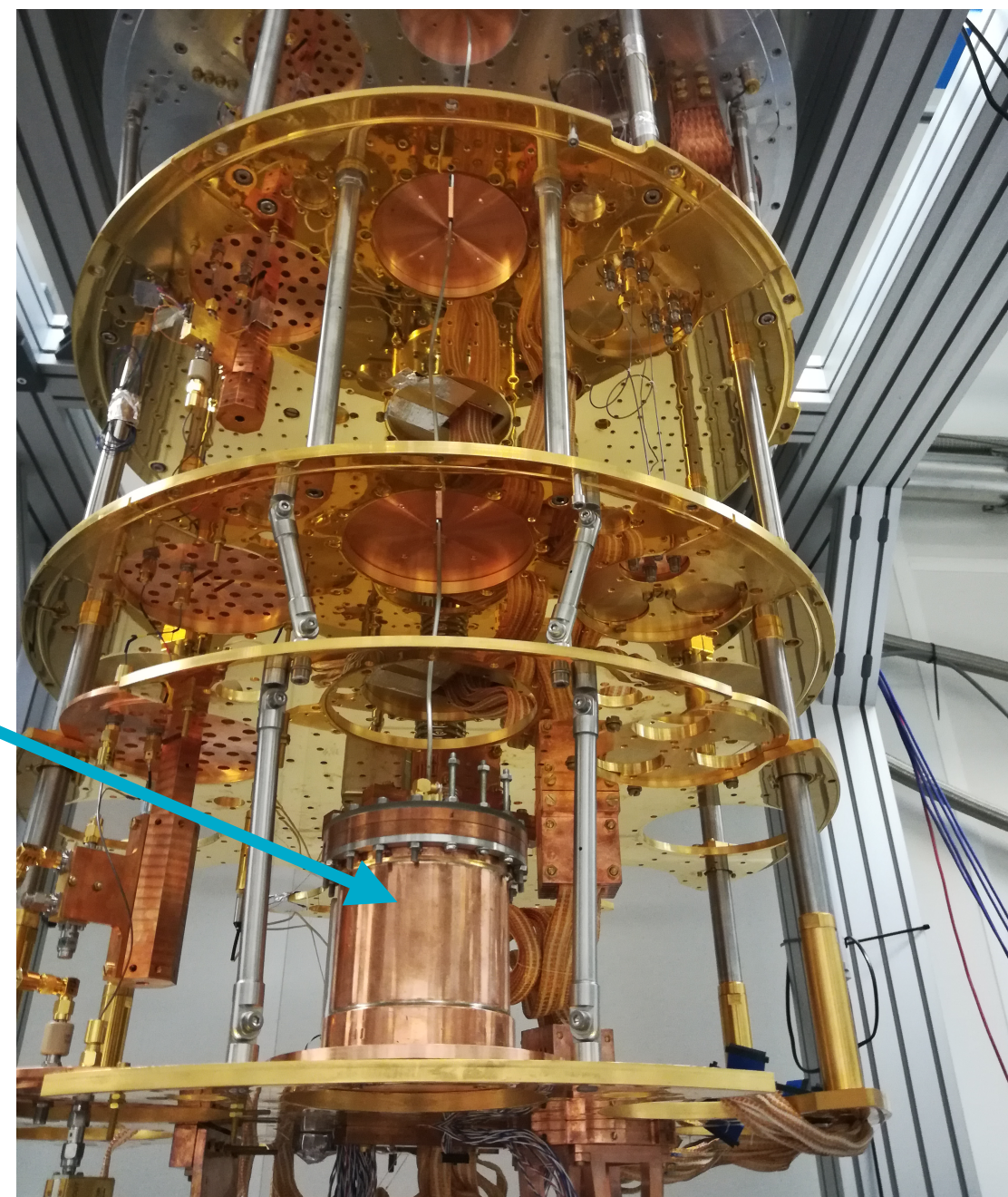
Francesco Toschi, Benedikt Maier, Greta Heine, Torben Ferber, Sebastian Kempf, Markus Klute, and Belina von Krosigk



R&D - Proto-cell Testing



- A 280mL test cell with He level meter and 12 channel wiring
- Operating in the ECHo experiment cryostat at Heidelberg University

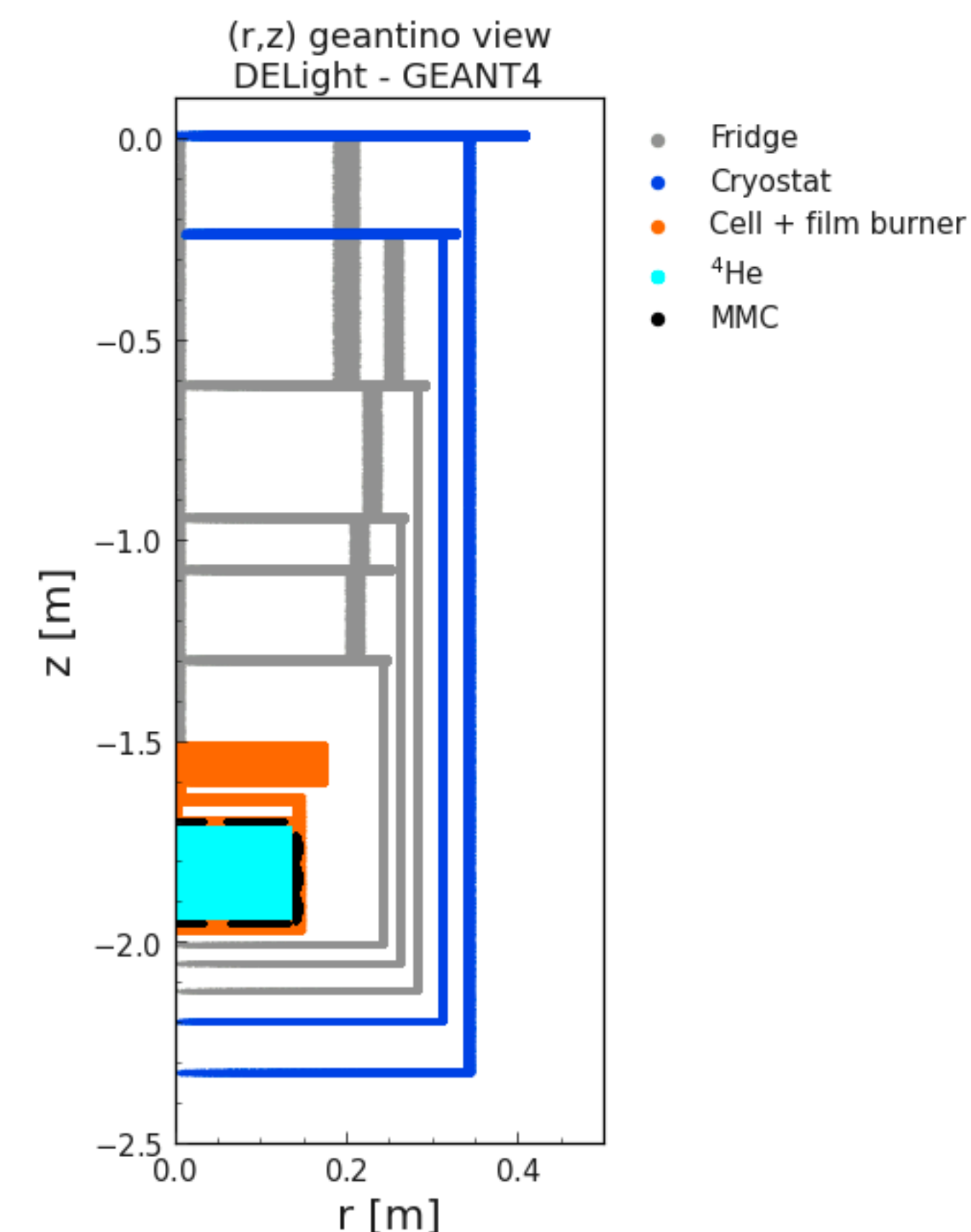


- Planned/ongoing tests
 - MMC sensitivity submerged in LHe
 - Direct quasiparticle measurements
 - UV/triplet detection
 - ...

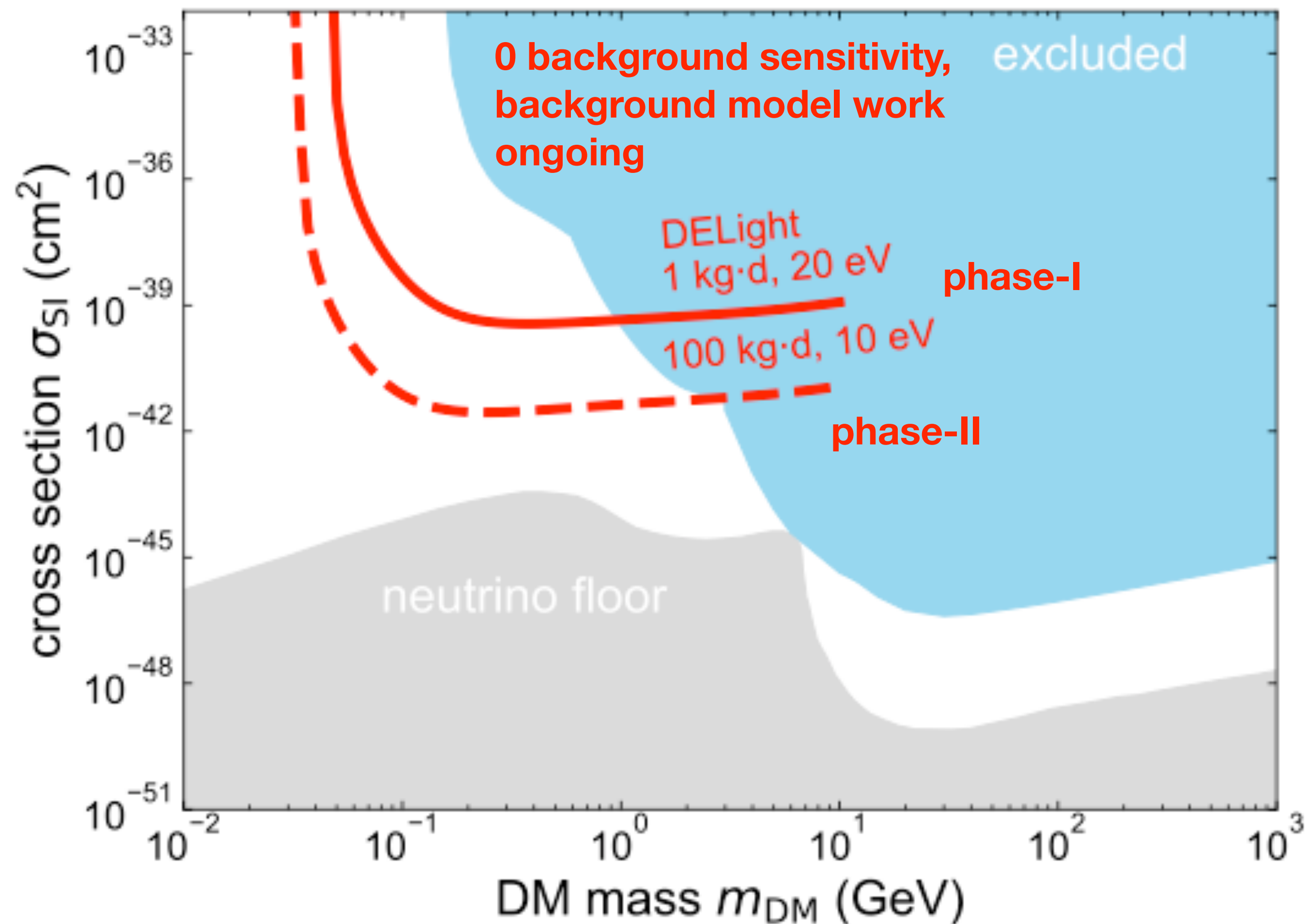


R&D - Backgrounds and Simulations

- Simulation framework updates
 - Geant4 model of detector geometry implemented
 - Triplet (done) and phonon (ongoing) physics implementation in Geant4
 - ER/NR partitioning implemented
 - Background simulations used to guide internal shielding considerations
- Background model work is ongoing
- GeMSE gamma-screening facility for background measurements of experiment components



The DELight Forecast

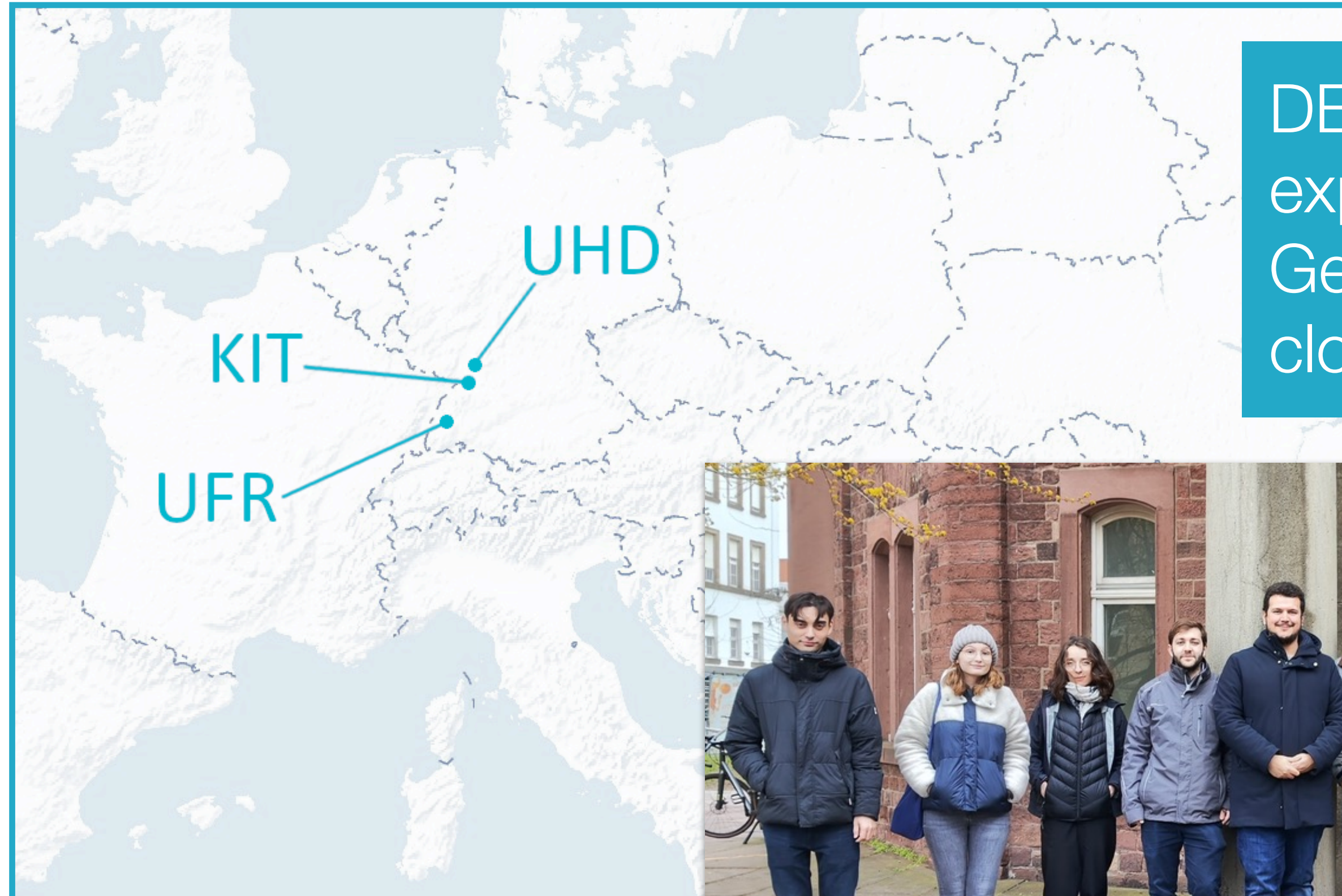


- Phase-I
 - 10L target volume
 - 20 eV threshold, ~kg day exposure
 - Surface or shallow lab
- Phase-II
 - 5-10eV threshold, ~100 kd day exposure
 - Shallow lab
- Long range plan
 - Larger cell + O(kg·yr) exposure
 - <10eV threshold
 - Underground lab

The DELight Collaboration



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386



DELight combines expertise from three German institutions in close proximity



universität freiburg



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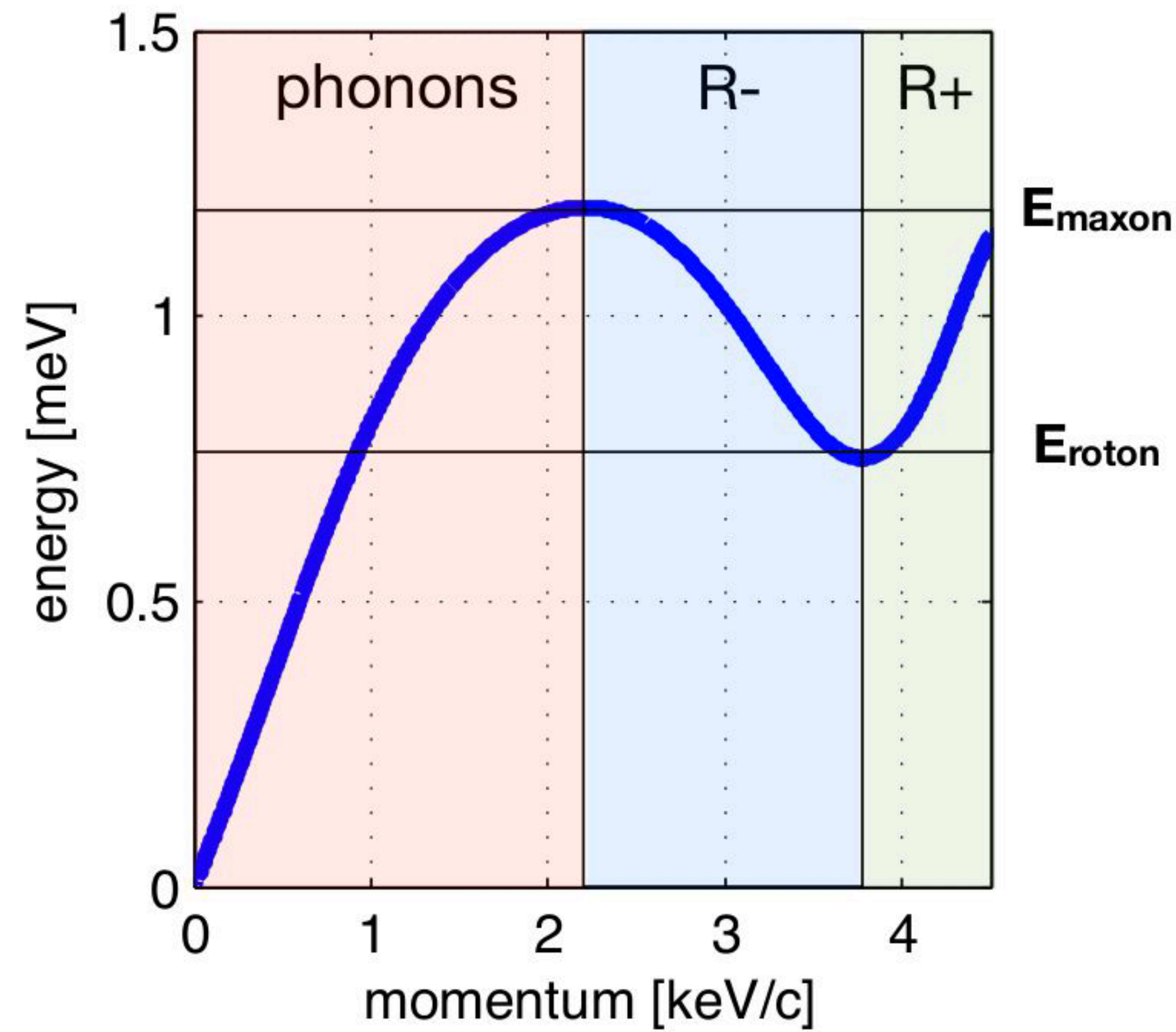


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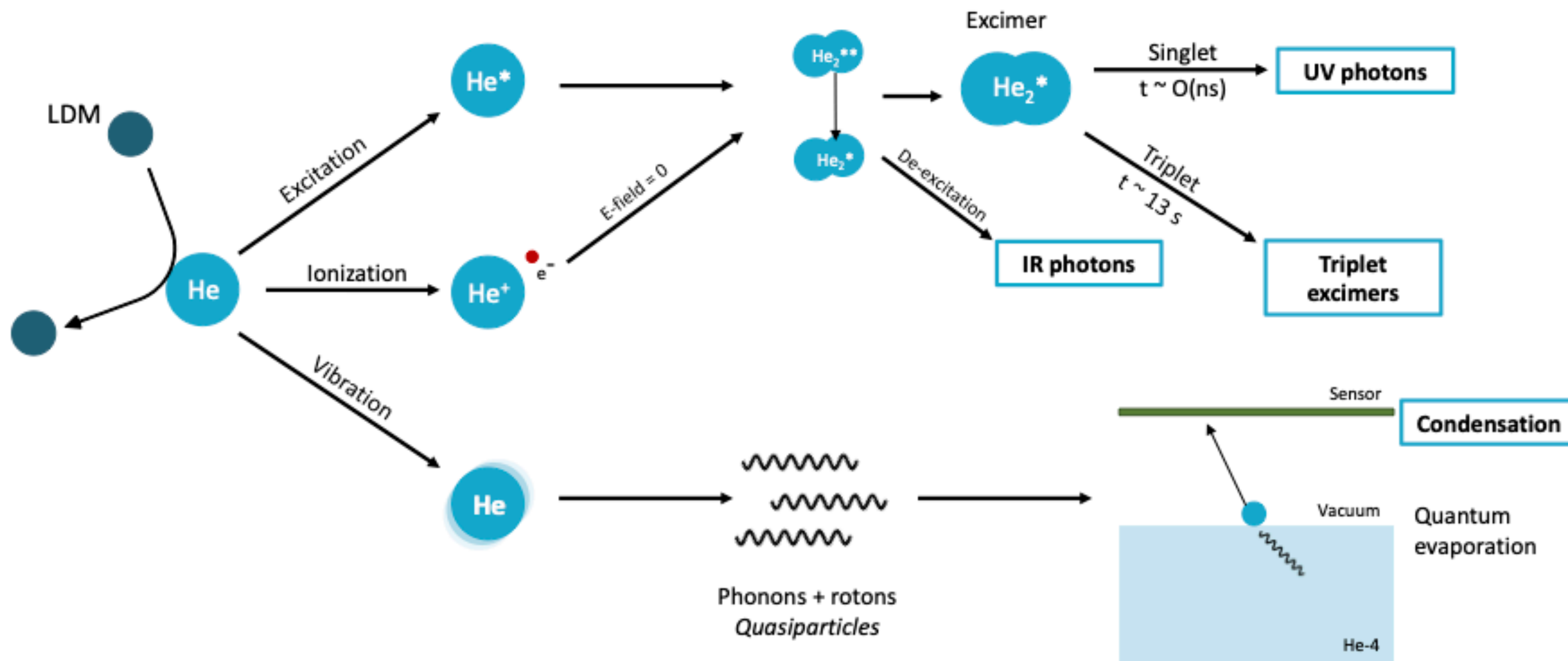
Backup Slides



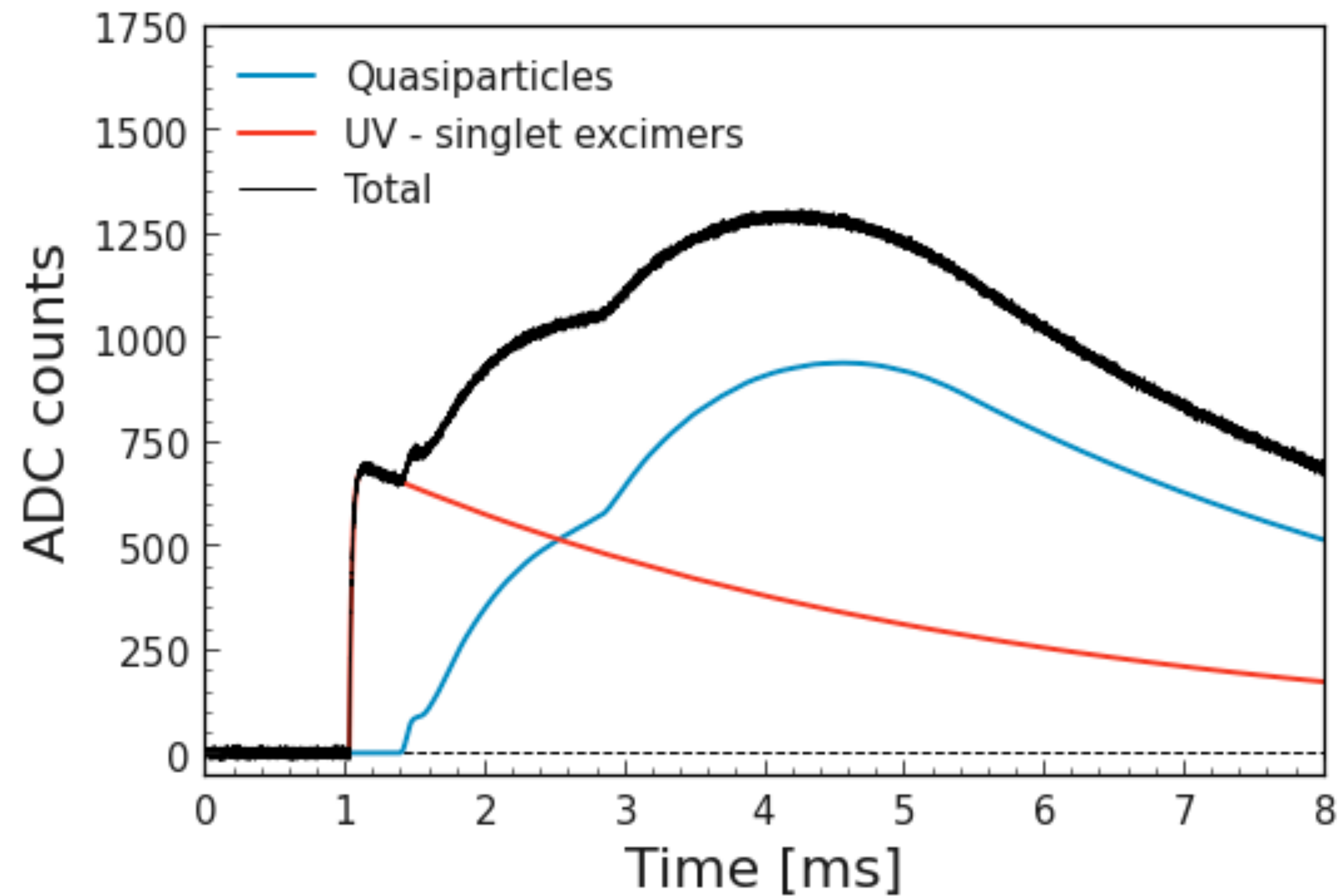
Quasiparticle Dispersion Relation in Superfluid He-4



Signals in Superfluid He-4



Event Signal Shape



Integrated DELight MMC Design

