Universität Zürich[UZH]

TESSERACT

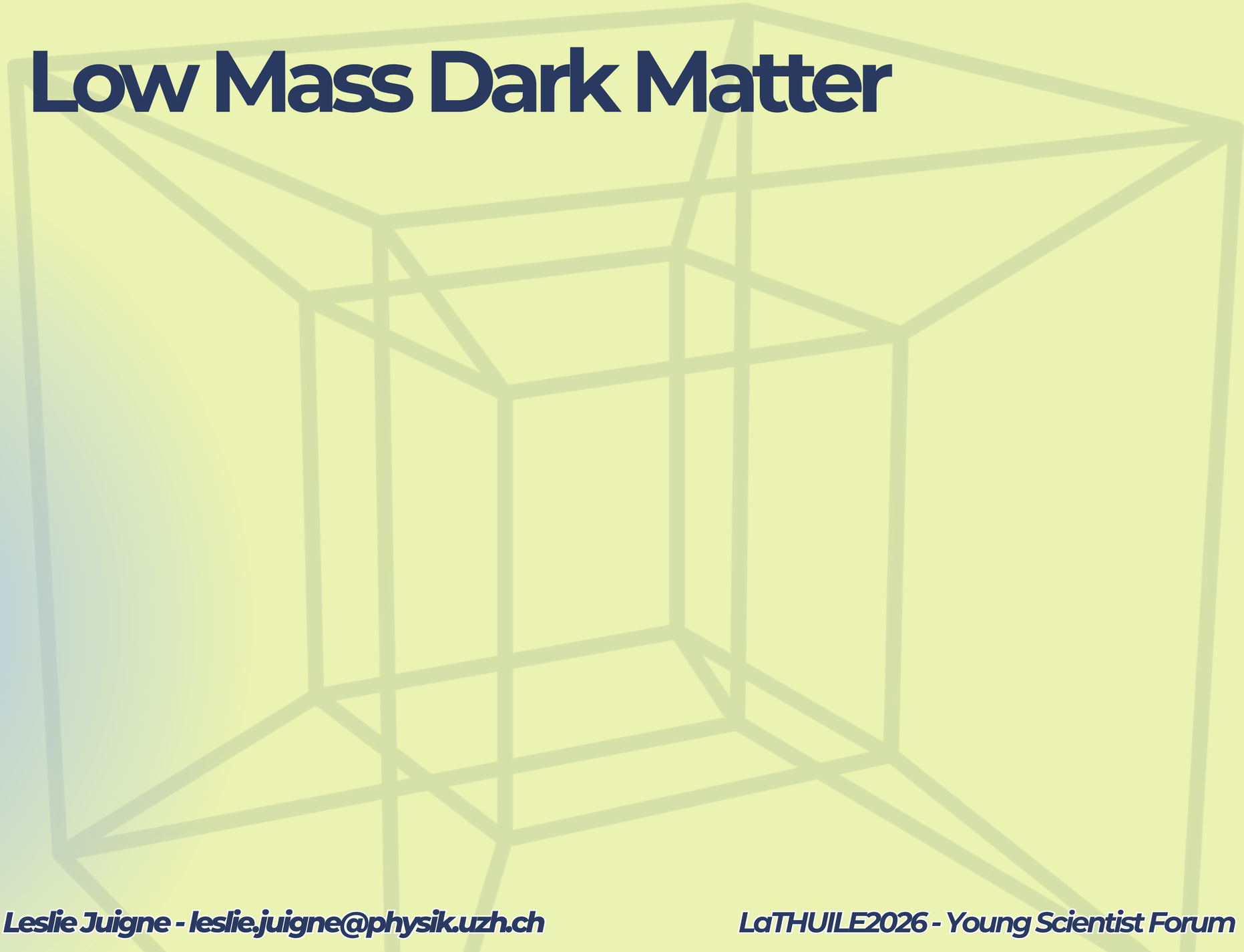
Search for light dark matter using a multi-target approach with the TESSERACT Experiment

LA THUILE 2026 - Young Scientist Forum

02 March 2026

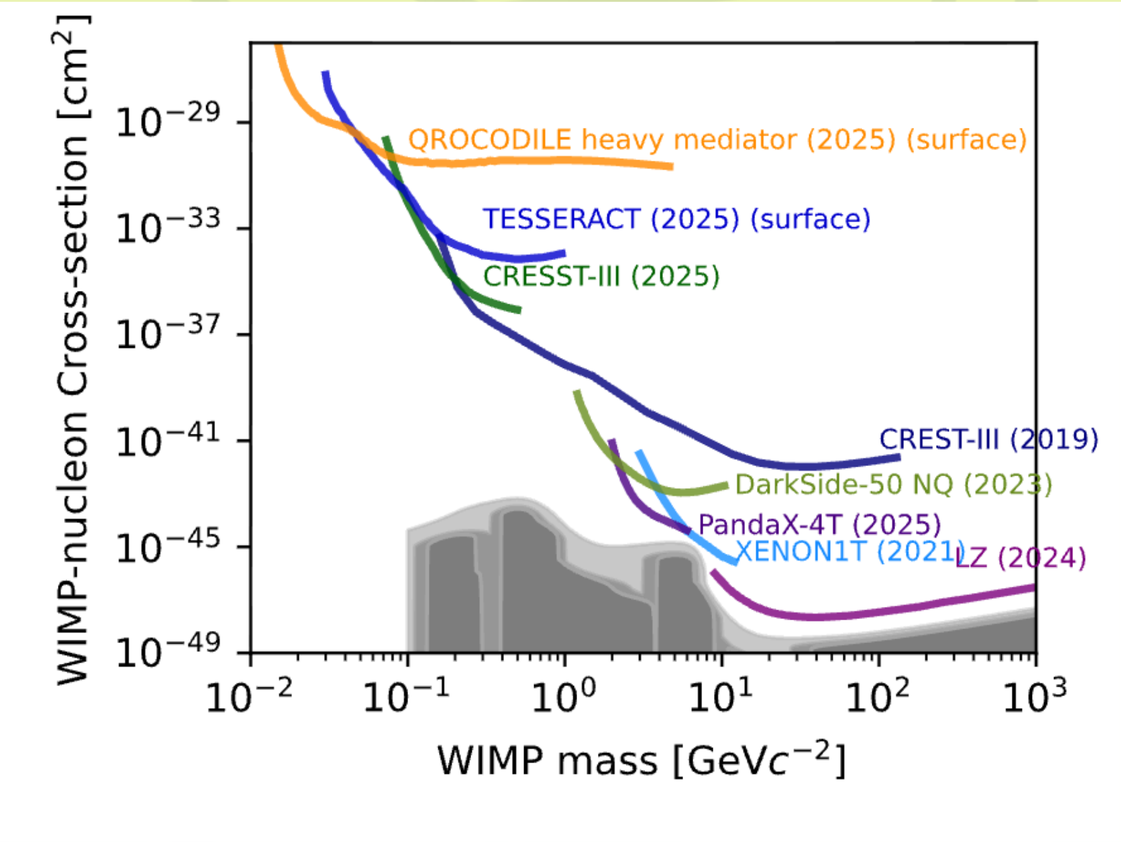
Leslie Juigne | leslie.juigne@physik.uzh.ch

Low Mass Dark Matter



Leslie Juigne - leslie.juigne@physik.uzh.ch

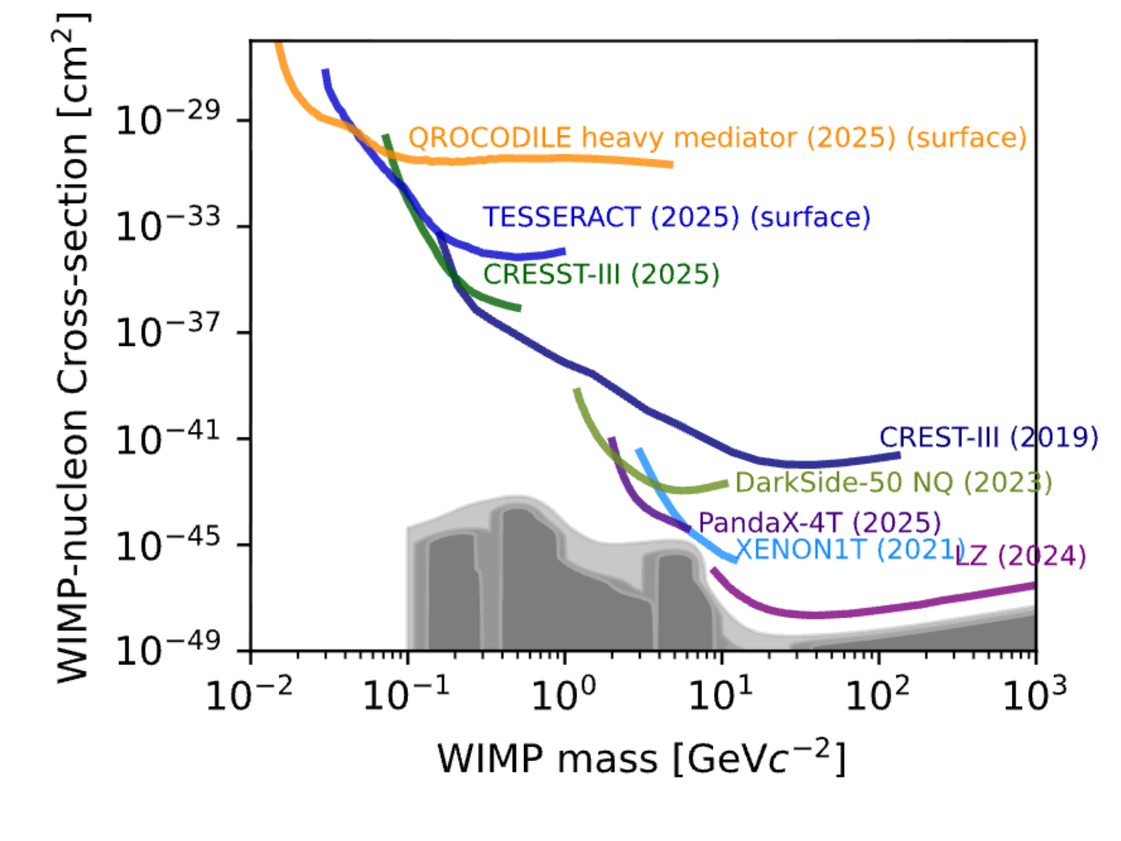
Low Mass Dark Matter



Dark matter limits highlighting the TESSERACT limits - Credit Knut Dundas Morå

- Low mass DM **much less constrained**
  - Several order of magnitude difference with the current WIMPs limits

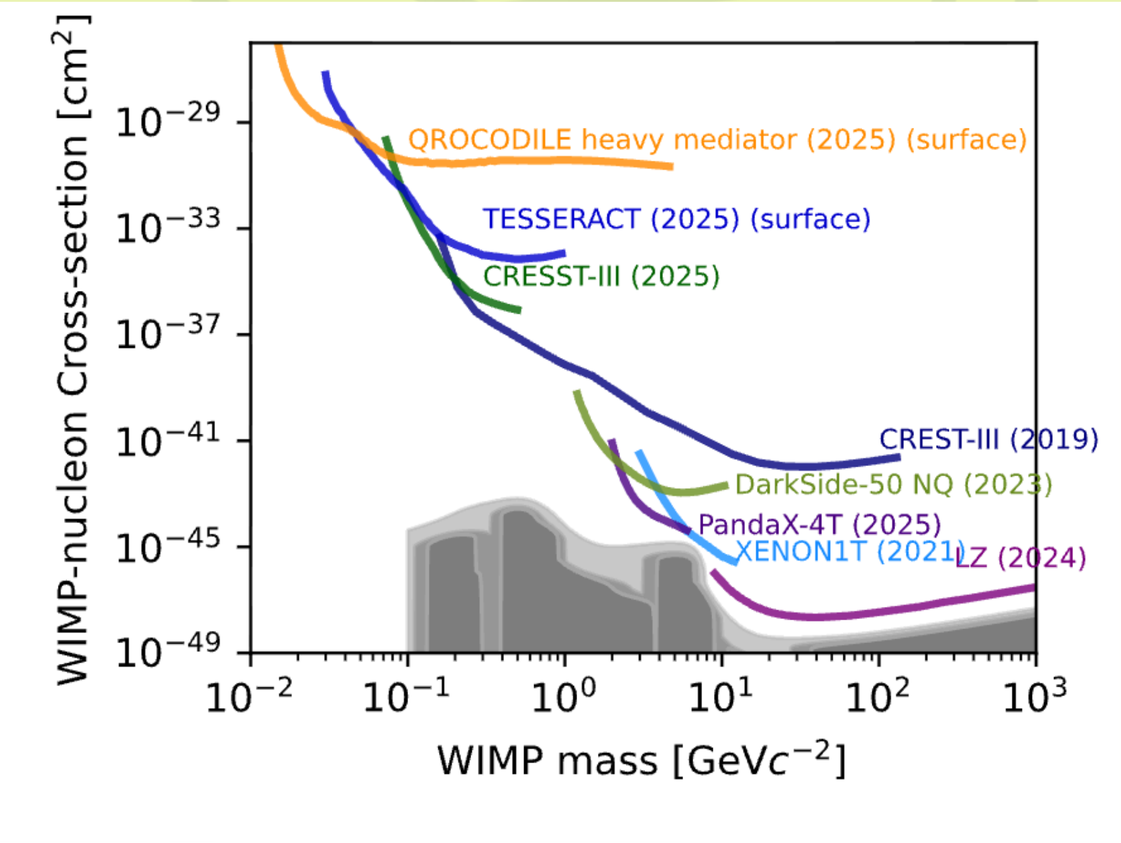
Low Mass Dark Matter



Dark matter limits highlighting the TESSERACT limits - Credit Knut Dundas Morå

- Low mass DM **much less constrained**
  - Several order of magnitude difference with the current WIMPs limits
- **Lower E threshold** → meV -keV

Low Mass Dark Matter

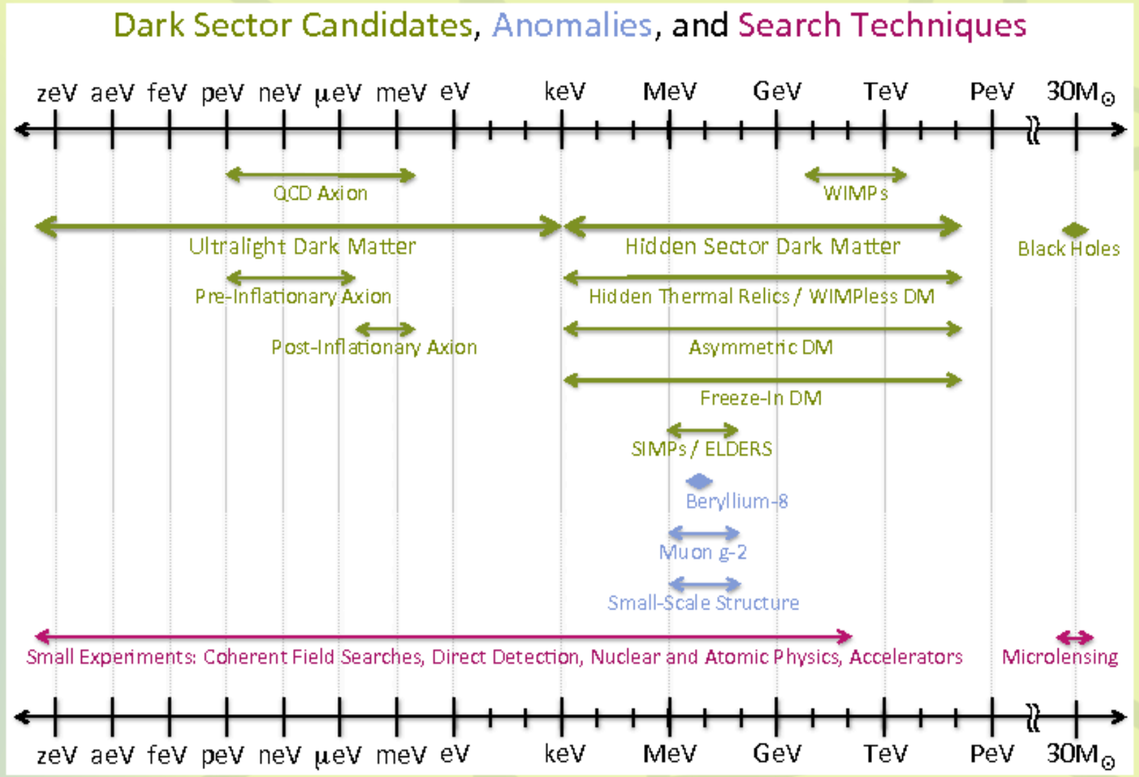


Dark matter limits highlighting the TESSERACT limits - Credit Knut Dundas Morå

- Low mass DM **much less constrained**
  - Several order of magnitude difference with the current WIMPs limits

- **Lower E threshold** → meV -keV
- **Lighter targets**

Low Mass Dark Matter

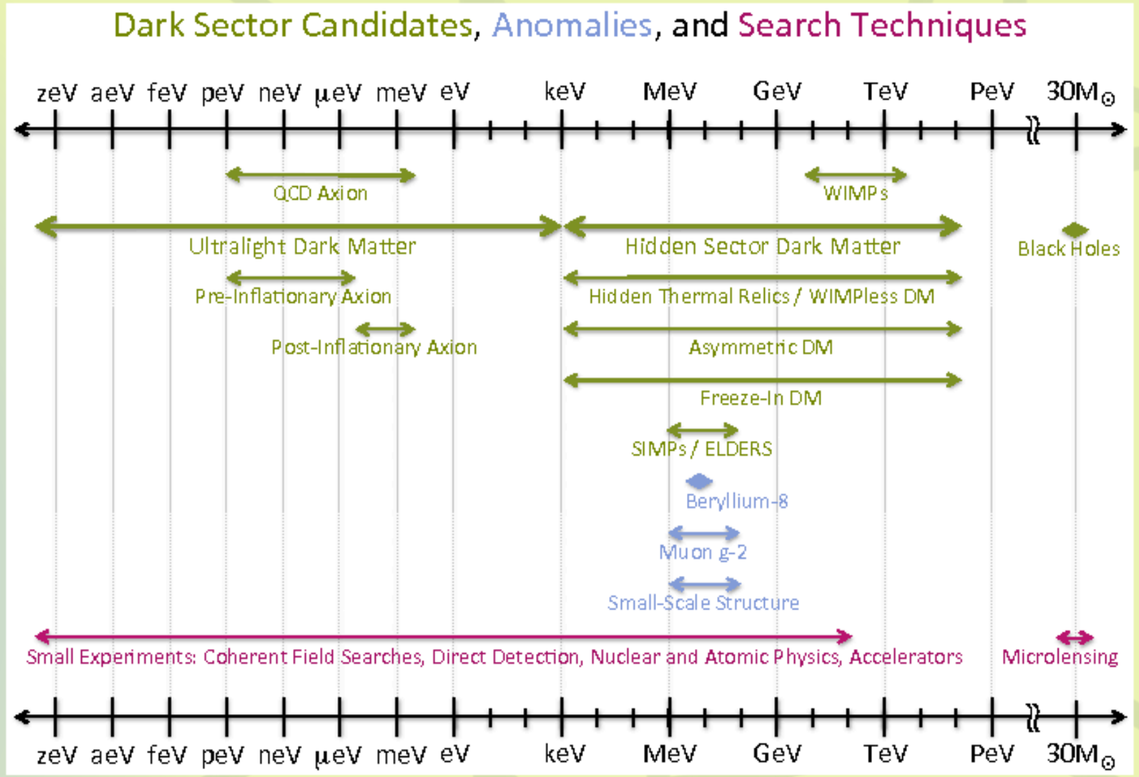


Dark matter limits highlighting the TESSERACT limits - Credit Knut Dundas Morå

- Low mass DM **much less constrained**
  - Several order of magnitude difference with the current WIMPs limits

- **Lower E threshold** → meV -keV
- **Lighter targets**
- **LDM Signatures** :
  - Electron & Nuclear Scatter
  - Absorption
  - Lighter masses : no ionisation but coherent excitation of the target

Low Mass Dark Matter



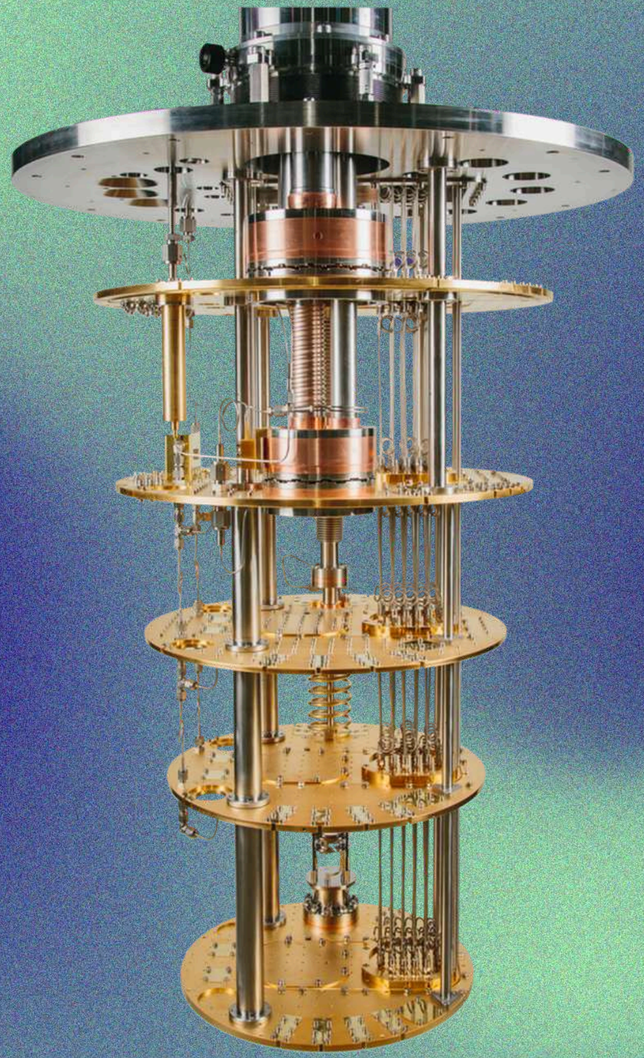
Dark matter limits highlighting the TESSERACT limits - Credit Knut Dundas Morå

- Low mass DM **much less constrained**
  - Several order of magnitude difference with the current WIMPs limits

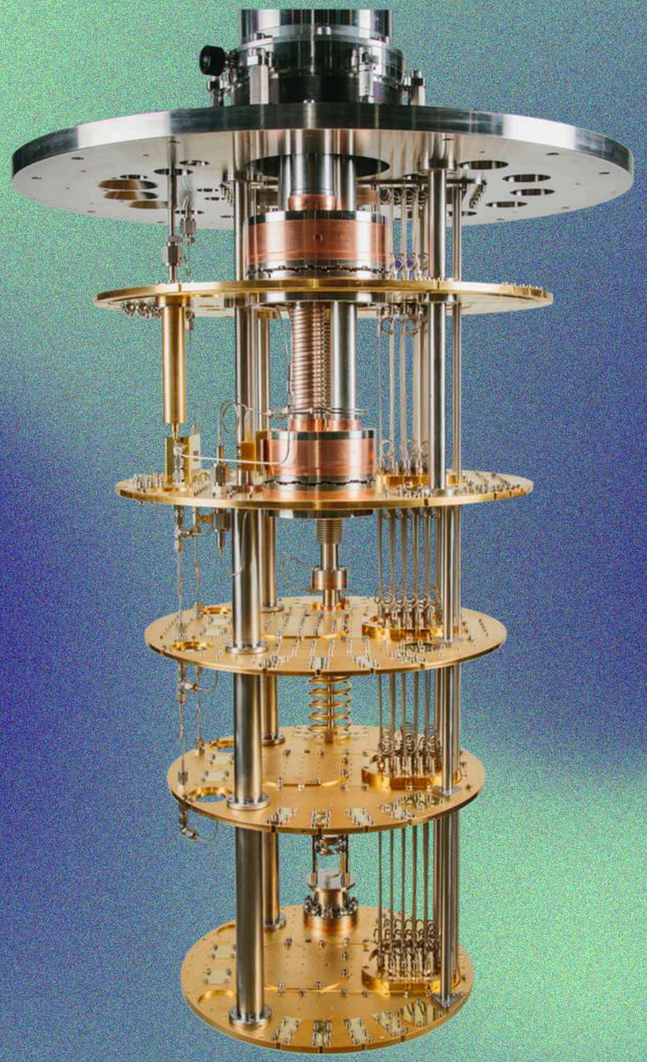
- **Lower E threshold** → meV -keV
- **Lighter targets**
- **LDM Signatures** :
  - Electron & Nuclear Scatter
  - Absorption
  - Lighter masses : no ionisation but coherent excitation of the target

- **Low Energy Excess** or LEE

Multi-Targets Approach

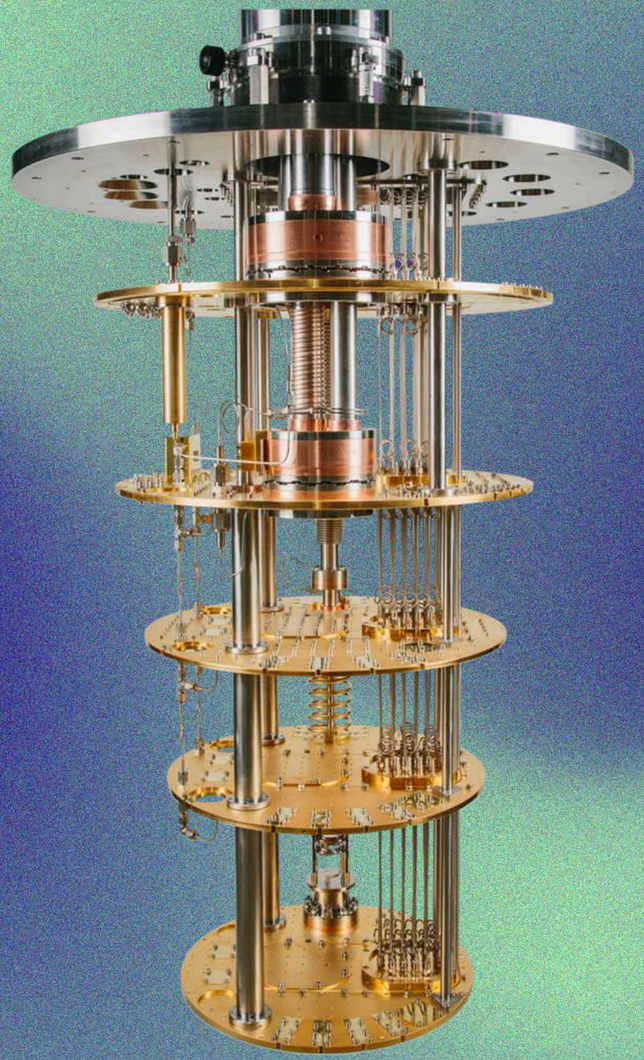


Multi-Targets Approach

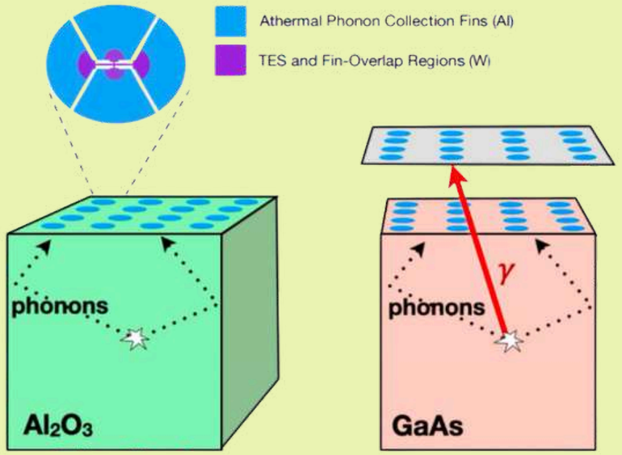


- 4 distincts target materials with the same sensors (TESs)

Multi-Targets Approach

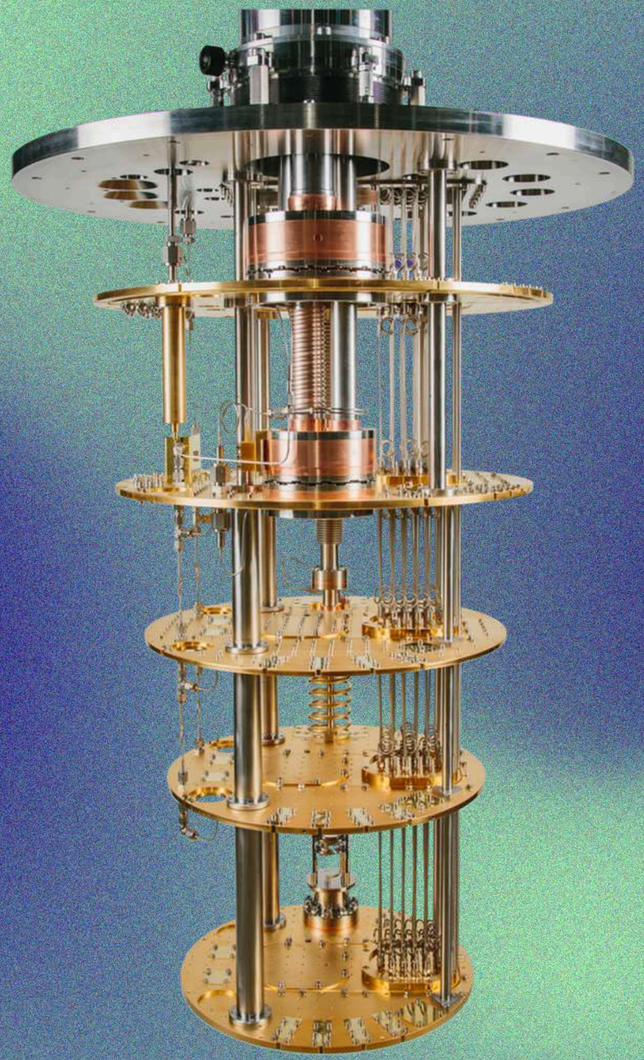


- **4 distincts target materials with the same sensors (TESs)**
  - Solid State detectors : Sapphire and GaAs

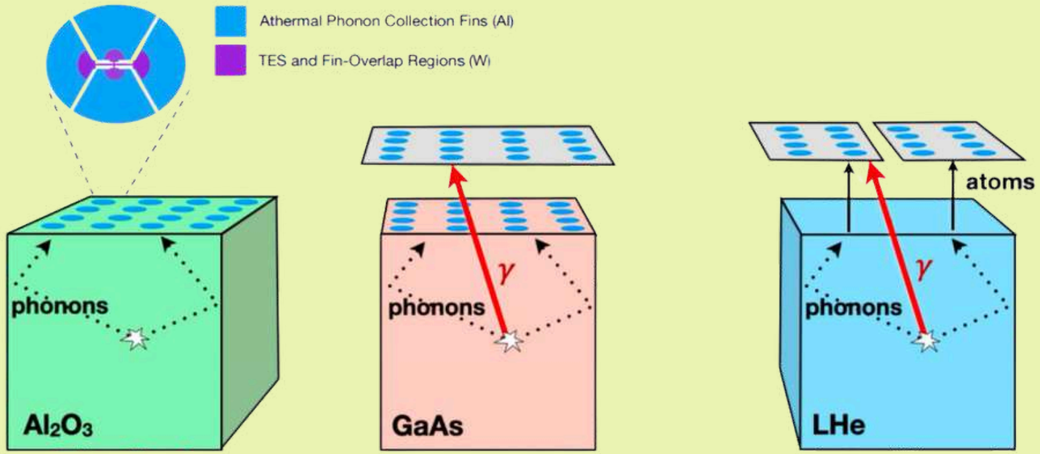


Leslie Juigne - leslie.juigne@physik.uzh.ch

Multi-Targets Approach

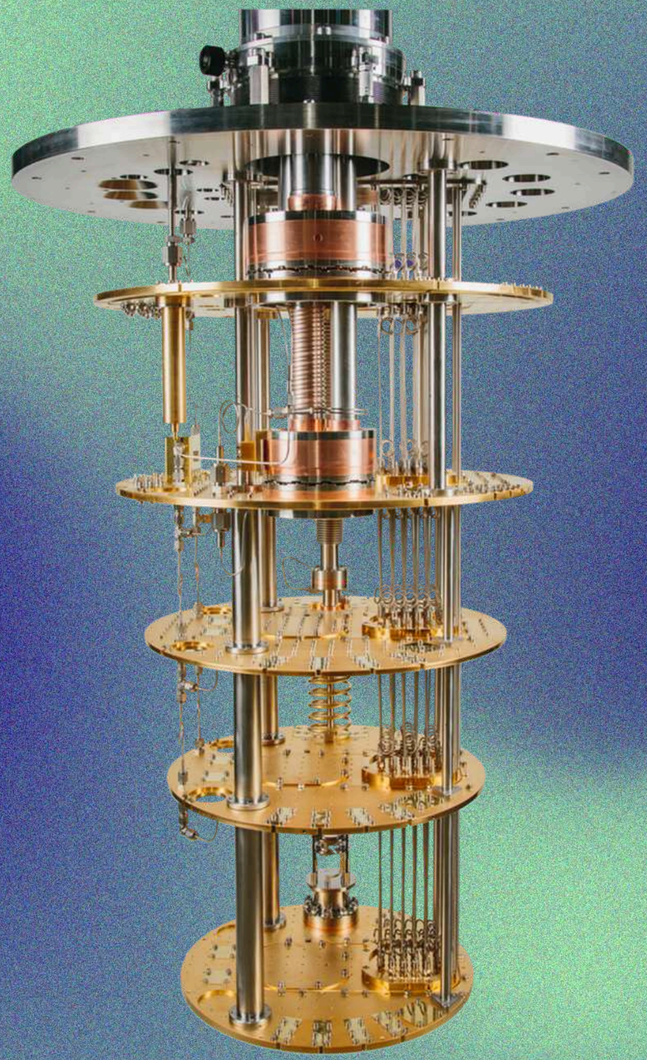


- **4 distincts target materials with the same sensors (TESs)**
  - Solid State detectors : Sapphire and GaAs
  - Helium in the superfluid state

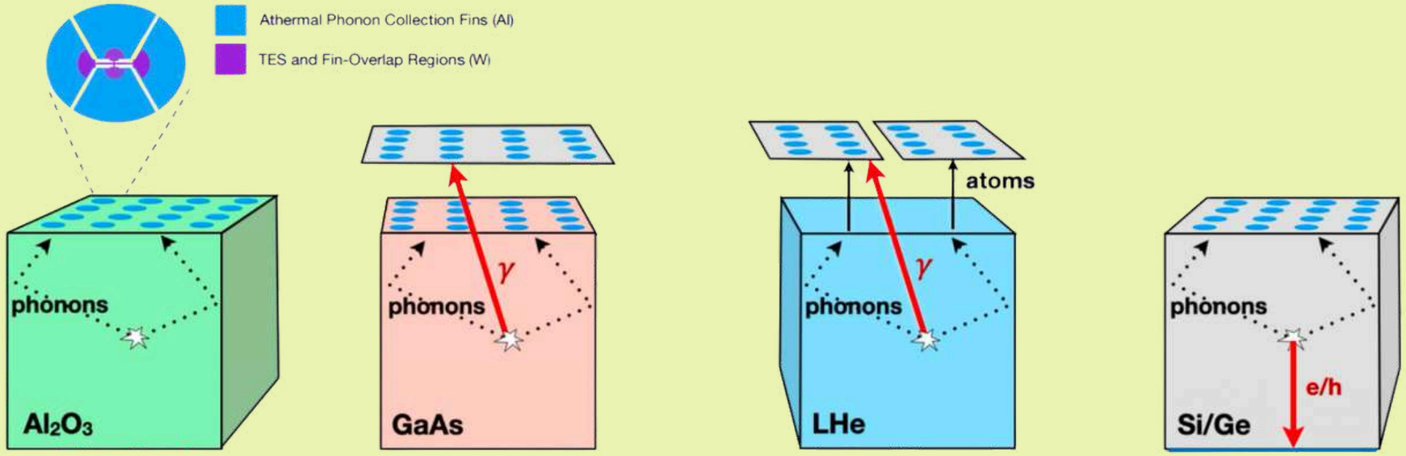


Leslie Juigne - leslie.juigne@physik.uzh.ch

Multi-Targets Approach

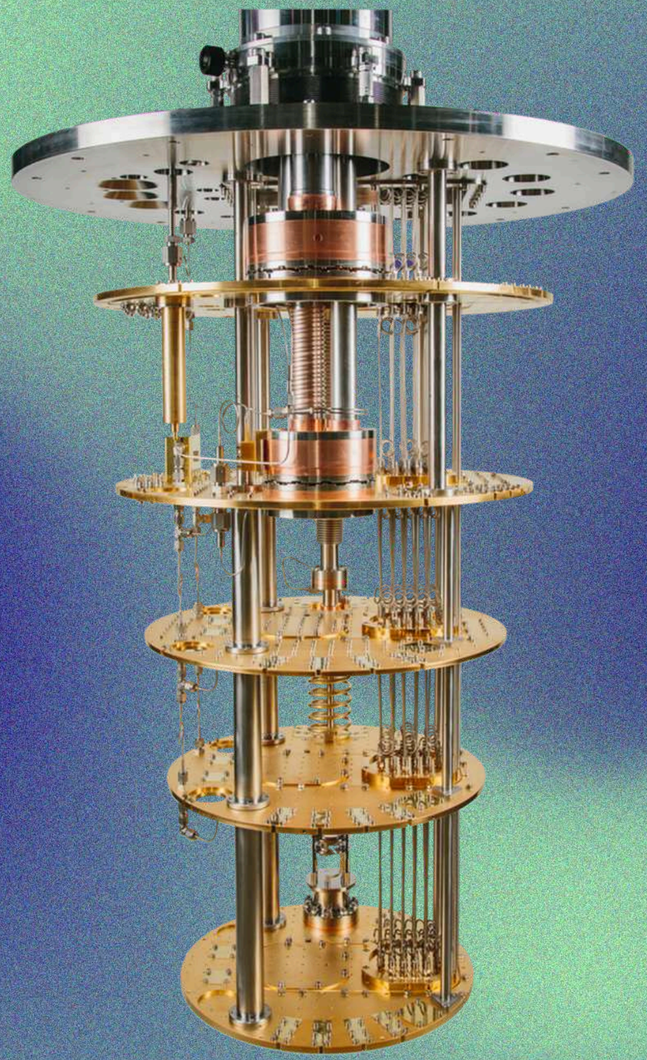


- **4 distincts target materials with the same sensors (TESs)**
  - Solid State detectors : Sapphire and GaAs
  - Helium in the superfluid state
  - Semiconducting Bolometers : Ge/Si Bolometers

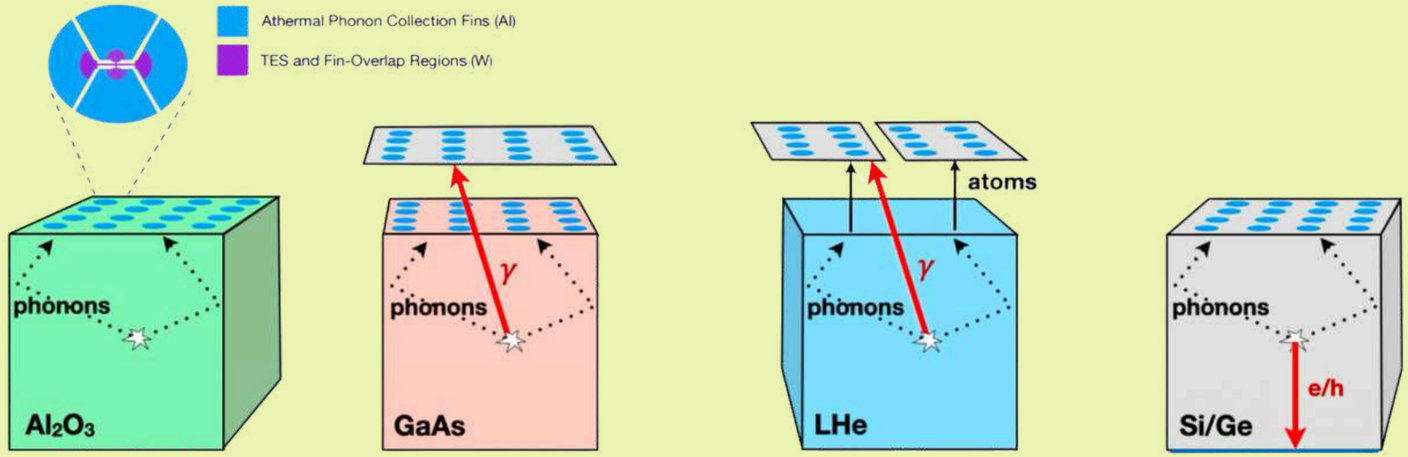


Leslie Juigne - leslie.juigne@physik.uzh.ch

Multi-Targets Approach

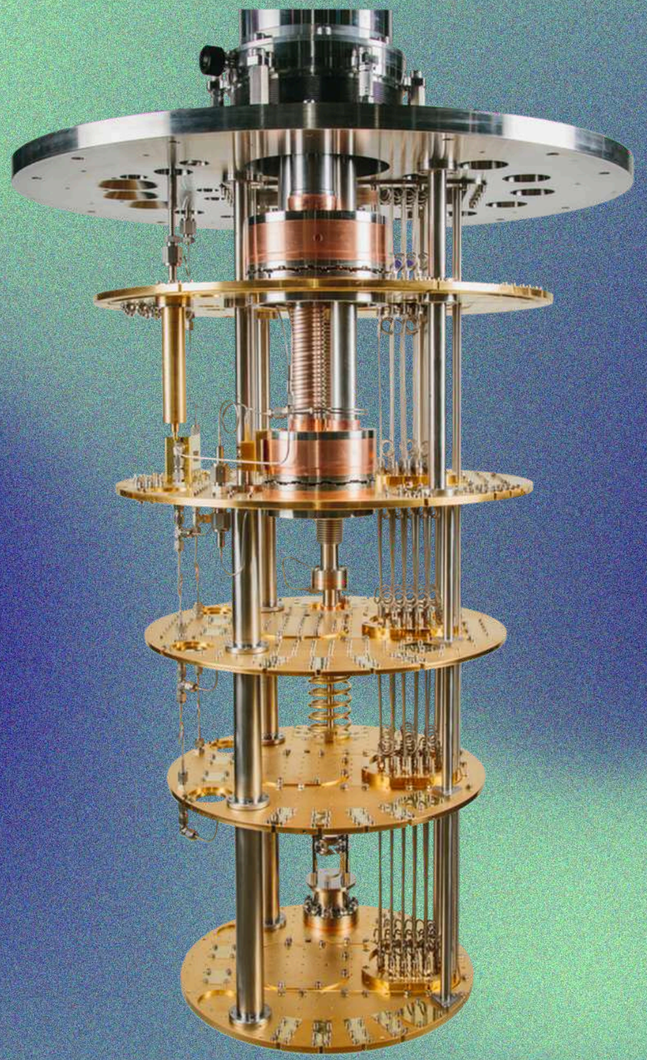


- **4 distincts target materials with the same sensors (TESs)**
  - Solid State detectors : Sapphire and GaAs
  - Helium in the superfluid state
  - CryoCubes : Ge/Si Bolometers
- **Maximize sensitivity** to multiple DM candidates

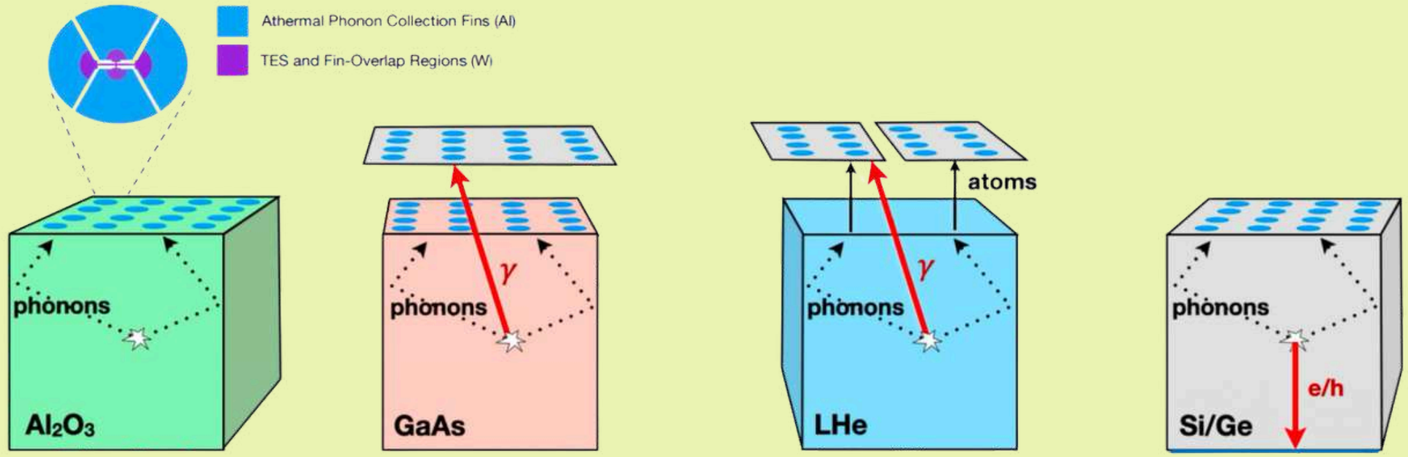


Leslie Juigne - leslie.juigne@physik.uzh.ch

Multi-Targets Approach

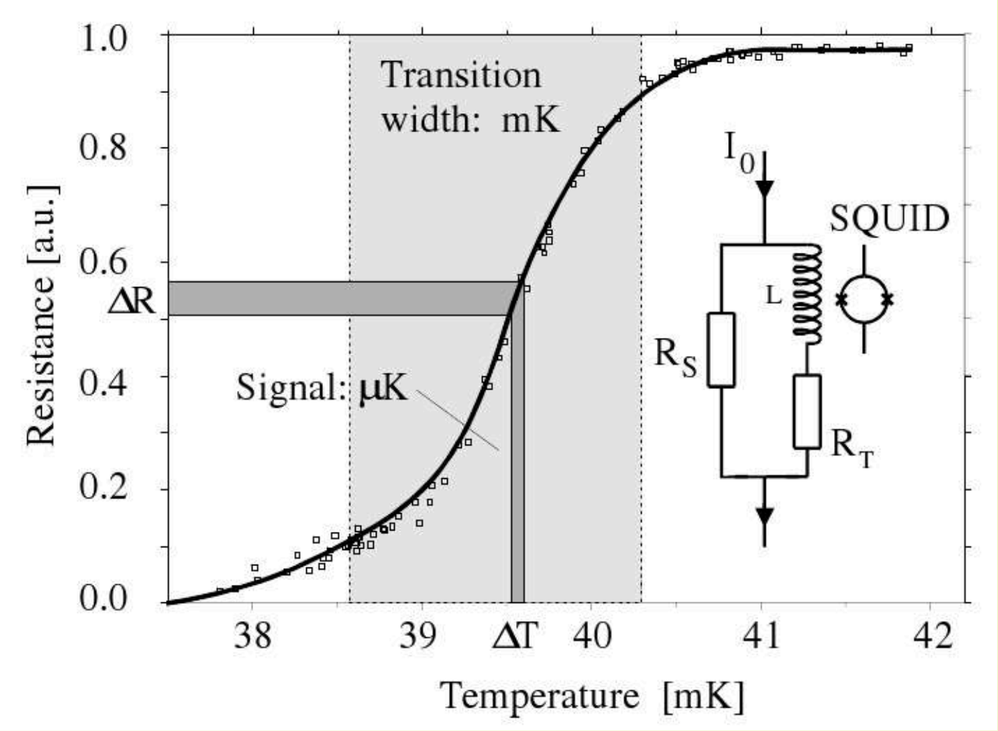


- **4 distincts target materials with the same sensors (TESs)**
  - Solid State detectors : Sapphire and GaAs
  - Helium in the superfluid state
  - CryoCubes : Ge/Si Bolometers
- **Maximize sensitivity** to multiple DM candidates
- **Discriminate** and **identify** backgrounds



Leslie Juigne - leslie.juigne@physik.uzh.ch

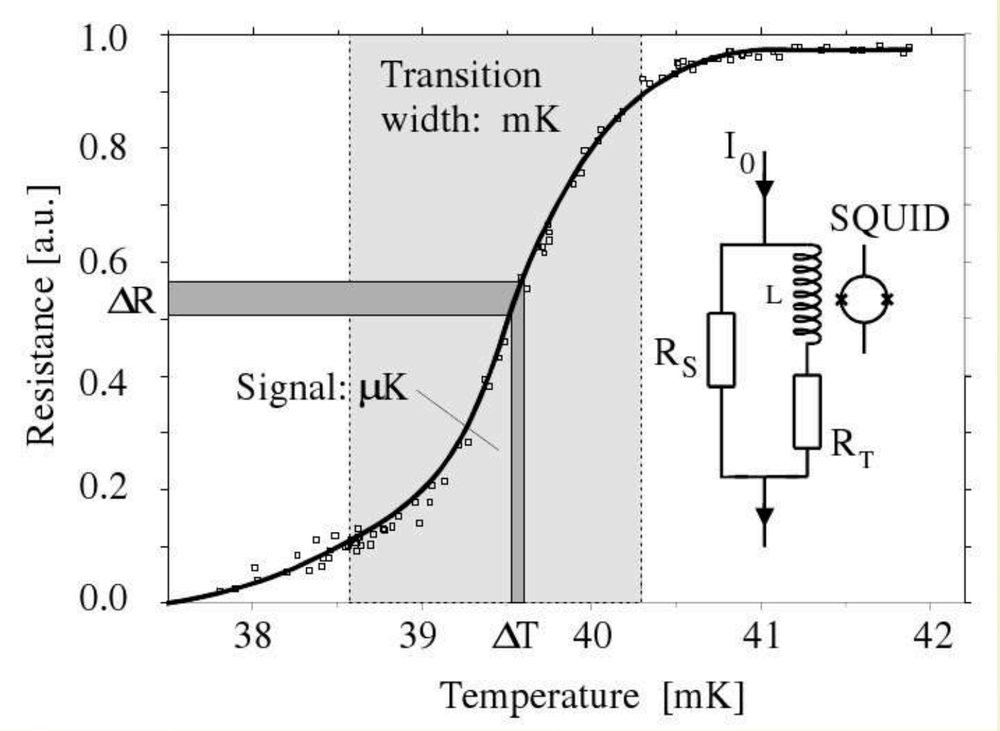
TESs Technology



Transition curve of a transition-edge sensor (TES)

TESs Technology

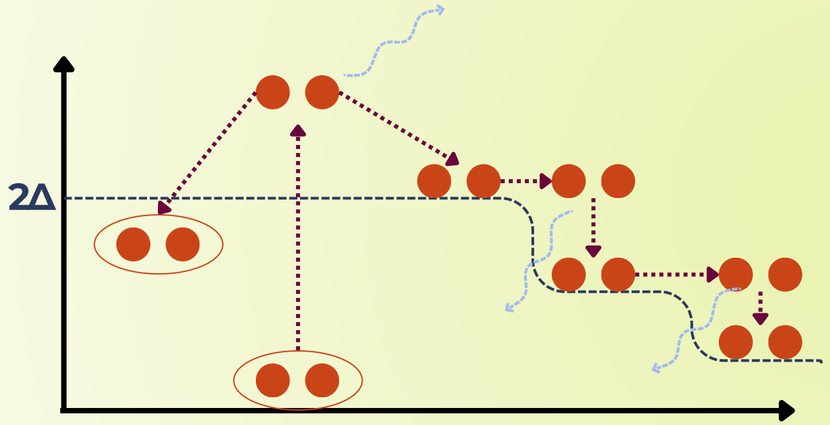
- TES : **Transition Edge Sensors**
  - Superconducting sensors
  - mK temperatures
  - Phonon collection efficiency ~50%

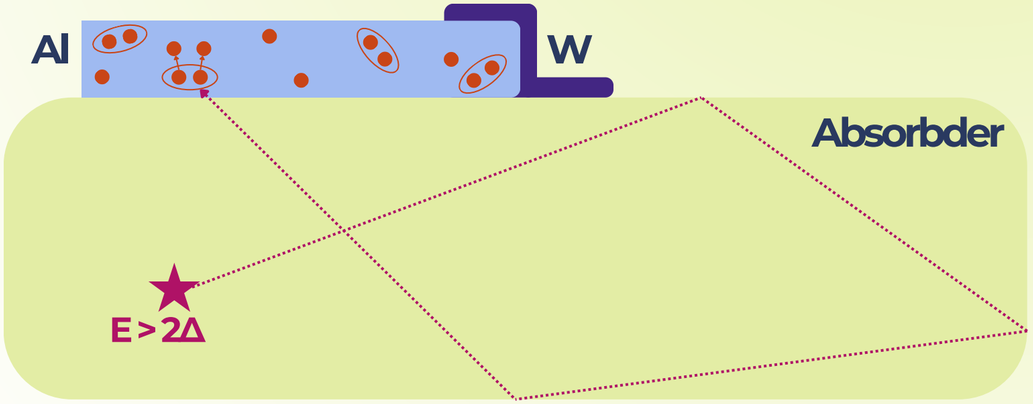


Transition curve of a transition-edge sensor (TES)

TESs Technology

- TES : **Transition Edge Sensors**
  - Superconducting sensors
  - mK temperatures
  - Phonon collection efficiency ~50%
- **Athermal Calorimeter**
  - Uses quasiparticle Trapping
  - Aluminium fins collect the phonons
    - TES smaller → better **energy resolutions**



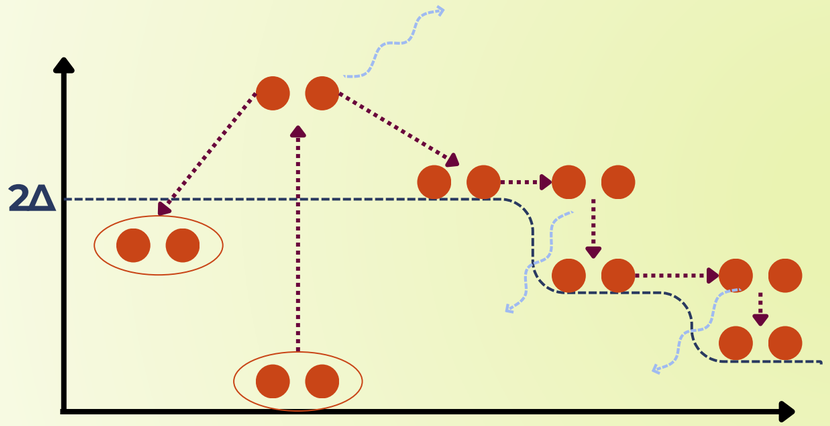


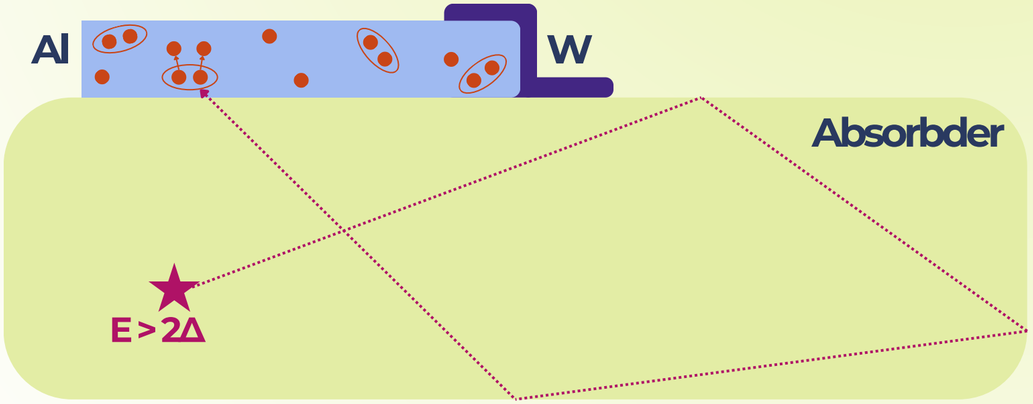
Schematic of a QET - Credit Caleb Wade Fink

TESs Technology

- TES : **Transition Edge Sensors**
  - Superconducting sensors
  - mK temperatures
  - Phonon collection efficiency ~50%
- **Athermal Calorimeter**
  - Uses quasiparticle Trapping
  - Aluminium fins collect the phonons
    - TES smaller → better **energy resolutions**

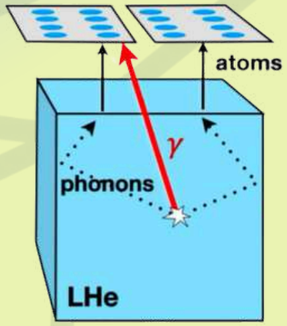
- **Our TESs have the world leading energy resolution with 273meV**





Schematic of a QET - Credit Caleb Wade Fink

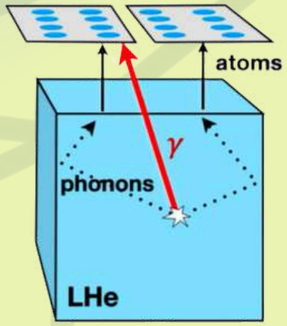
Multi-targets technologies



01. Superfluid Helium Cell

Multi-targets technologies

HeRALD Experiment

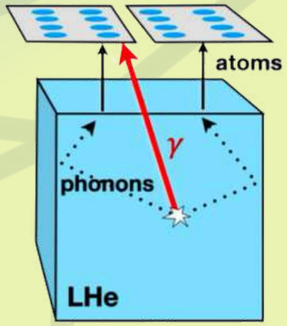


01. Superfluid Helium Cell

- **Helium as target**
  - R&D with the **HeRALD Experiment**

Multi-targets technologies

HeRALD Experiment

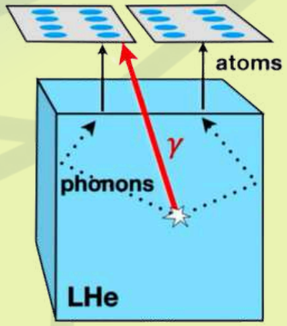


01. Superfluid Helium Cell

- **Helium as target**
  - R&D with the **HeRALD Experiment**
  - Radiopure
  - ER/NR discrimination via photon/roton ratio

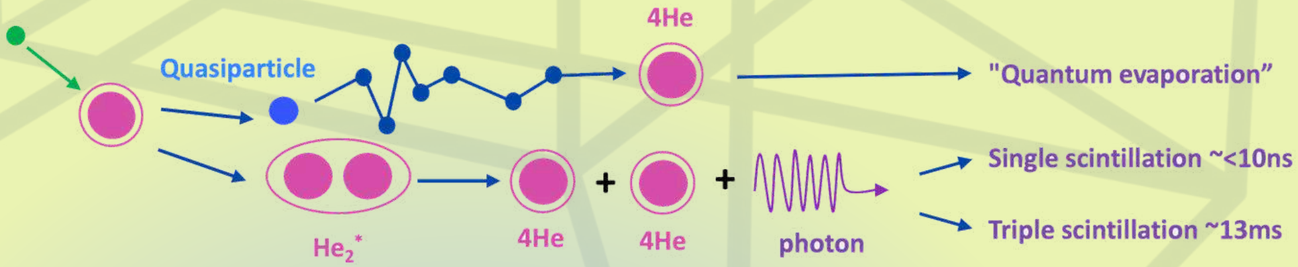
Multi-targets technologies

HeRALD Experiment



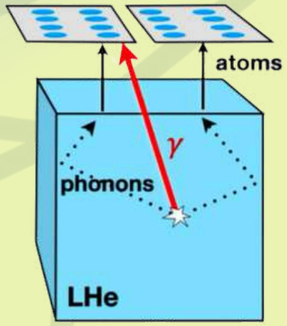
01. Superfluid Helium Cell

- **Helium as target**
  - R&D with the **HeRALD Experiment**
  - Radiopure
  - ER/NR discrimination via photon/roton ratio
  - Unique multiple signals
    - allows signal/background discrimination
    - gain mecanism



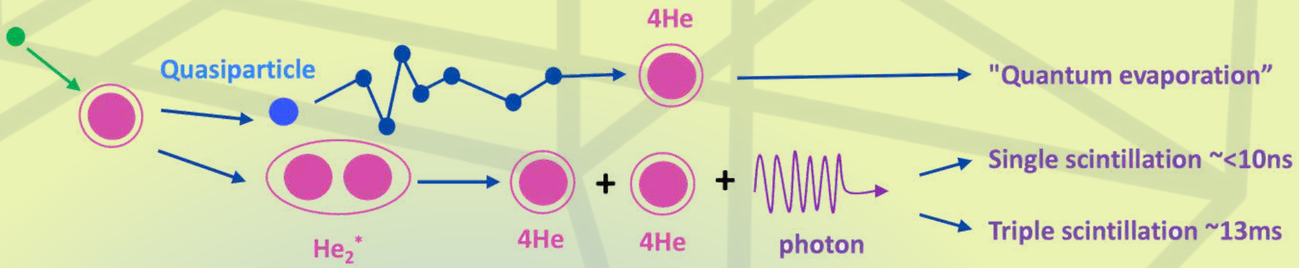
Multi-targets technologies

HeRALD Experiment



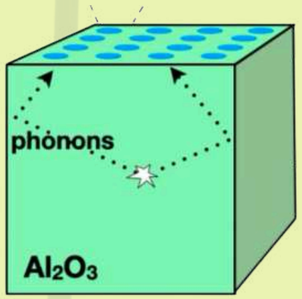
01. Superfluid Helium Cell

- **Helium as target**
  - R&D with the **HeRALD Experiment**
  - Radiopure
  - ER/NR discrimination via photon/roton ratio
  - Unique multiple signals
    - allows signal/background discrimination
    - gain mecanism
  - no stress related to LEE backgrounds



Multi-targets technologies

01. Superfluid Helium Cell

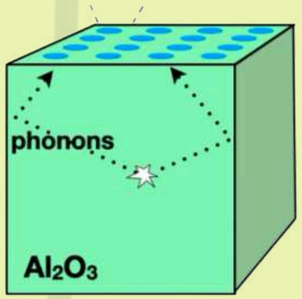


02. Solid State Detectors Sapphire & GaAs

Multi-targets technologies

SPICE Experiement

01. Superfluid Helium Cell



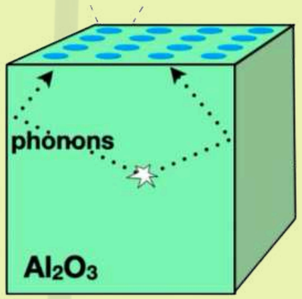
02. Solid State Detectors Sapphire & GaAs

- **Sapphire (Al2O3)**
  - R&D with the **SPICE Experiment**

Multi-targets technologies

SPICE Experiement

01. Superfluid Helium Cell



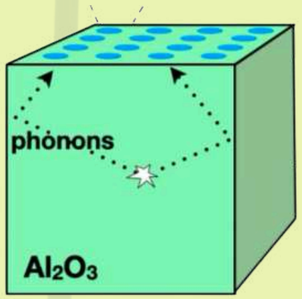
02. Solid State Detectors Sapphire & GaAs

- **Sapphire (Al2O3)**
  - R&D with the **SPICE Experiment**
  - **Many optical phonon modes** and well matched to low-mass DM

Multi-targets technologies

SPICE Experiement

01. Superfluid Helium Cell



02. Solid State Detectors Sapphire & GaAs

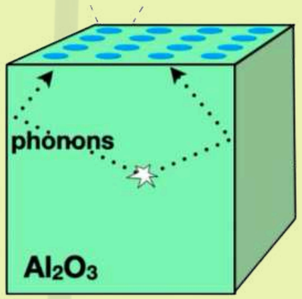
- **Sapphire (Al2O3)**
  - R&D with the **SPICE Experiment**
  - **Many optical phonon modes** and well matched to low-mass DM
  - Coupling to E&M → **Dark-photon sensitivity**

Multi-targets technologies

SPICE Experiement

01.

Superfluid Helium Cell

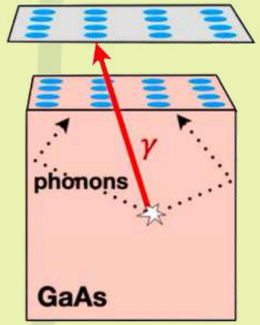


02.

Solid State Detectors Sapphire & GaAs

- **Sapphire (Al2O3)**
  - R&D with the **SPICE Experiment**
  - **Many optical phonon modes** and well matched to low-mass DM
  - Coupling to E&M → **Dark-photon sensitivity**
  - LEE background → reduced using **2-channels TESs coincidences**

Multi-targets technologies

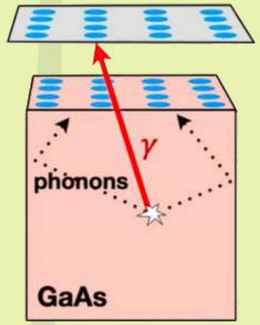


01. Superfluid Helium Cell

02. Solid State Detectors Sapphire & GaAs

Multi-targets technologies

SPICE Experiement



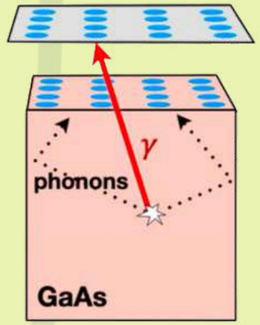
01. Superfluid Helium Cell

02. Solid State Detectors Sapphire & GaAs

- **Gallium Arsenide (GaAs)**
  - R&D with the **SPICE Experiment**

Multi-targets technologies

SPICE Experiement



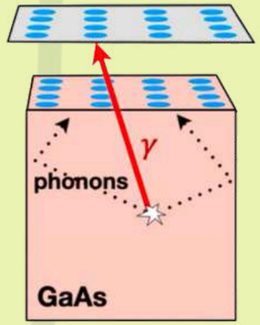
01. Superfluid Helium Cell

02. Solid State Detectors Sapphire & GaAs

- **Gallium Arsenide (GaAs)**
  - R&D with the **SPICE Experiment**
  - **Polar crystal & bandgap** well matched to kinematic region of low-mass DM

Multi-targets technologies

SPICE Experiement



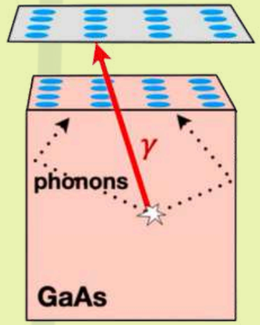
01. Superfluid Helium Cell

02. Solid State Detectors Sapphire & GaAs

- **Gallium Arsenide (GaAs)**
  - R&D with the **SPICE Experiment**
  - **Polar crystal & bandgap** well matched to kinematic region of low-mass DM
  - **Background discrimination** via photon/phonon ratio

Multi-targets technologies

SPICE Experiement



01. Superfluid Helium Cell

02. Solid State Detectors Sapphire & GaAs

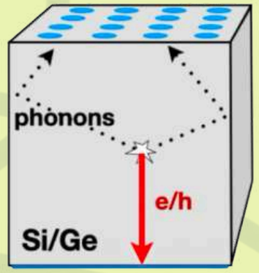
- **Gallium Arsenide (GaAs)**
  - R&D with the **SPICE Experiment**
  - **Polar crystal & bandgap** well matched to kinematic region of low-mass DM
  - **Background discrimination** via photon/phonon ratio
  - LEE background reduced : **phonon/phonon & γ/γ coincidence**

Multi-targets technologies

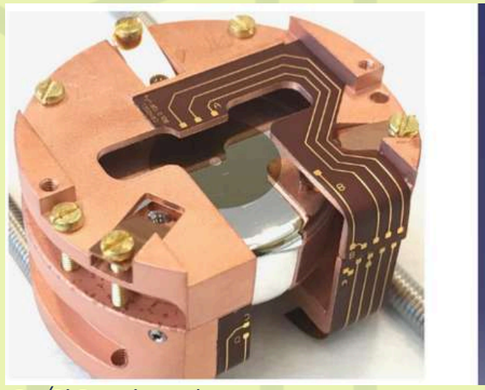
01. Superfluid Helium Cell

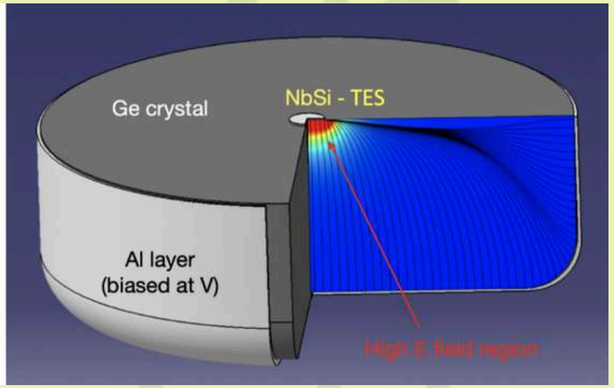
02. Solid State Detectors Sapphire & GaAs

03. Si/Ge Targets



Multi-targets technologies

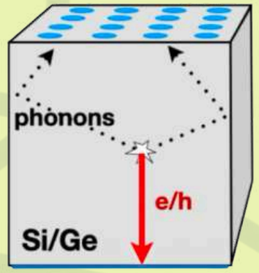




Ge/Si Semiconductors

01. Superfluid Helium Cell

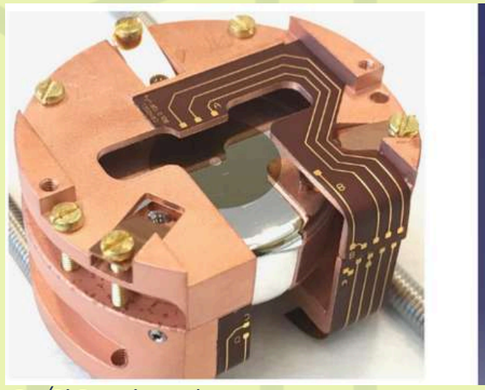
02. Solid State Detectors Sapphire & GaAs

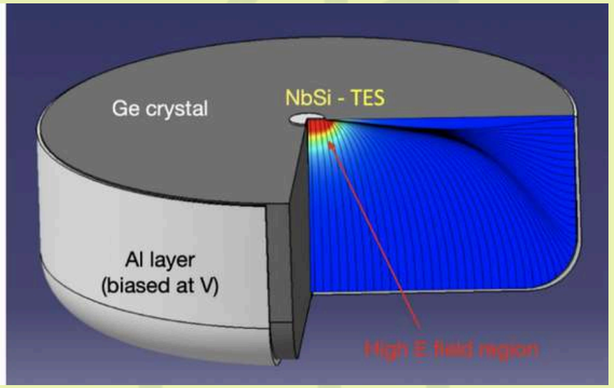


03. Si/Ge Targets

- **CryoCube (Ge/Si)**
  - 2-Channels : Heat & ionization
  - Luke Boost : $E_{total} = E_{recoil} + E_{luke}$

Multi-targets technologies

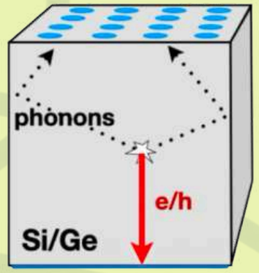




Ge/Si Semiconductors

01. Superfluid Helium Cell

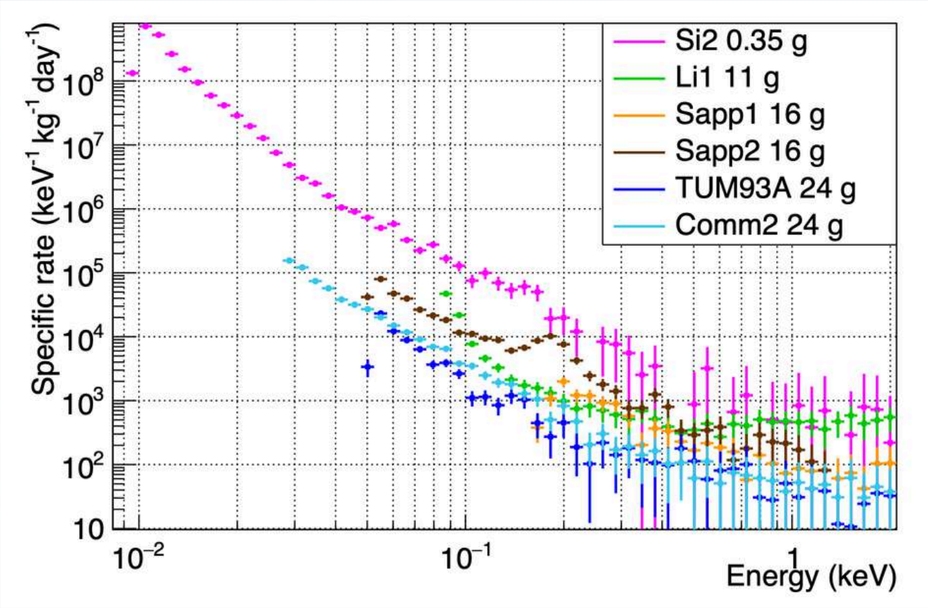
02. Solid State Detectors Sapphire & GaAs



03. Si/Ge Targets

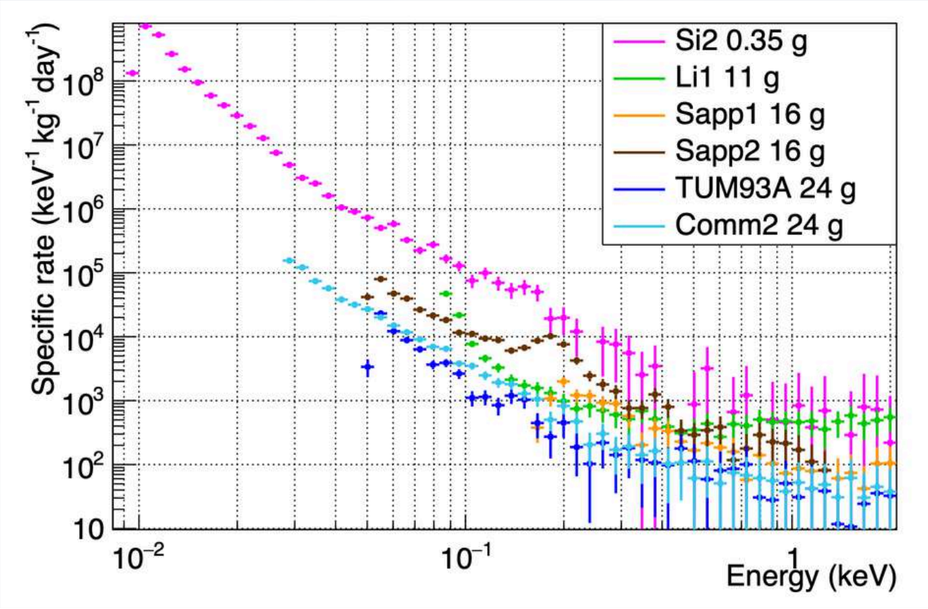
- **CryoCube (Ge/Si)**
  - 2-Channels : Heat & ionization
  - Luke Boost : $E_{total} = E_{recoil} + E_{luke}$
  - LV & HV modes → Allow ER/NR discrimination
    - LEE background dsicrimination with the LV mode

LEE - Low Energy Excess



LEE study for different detector modules - CRESST Collaboration

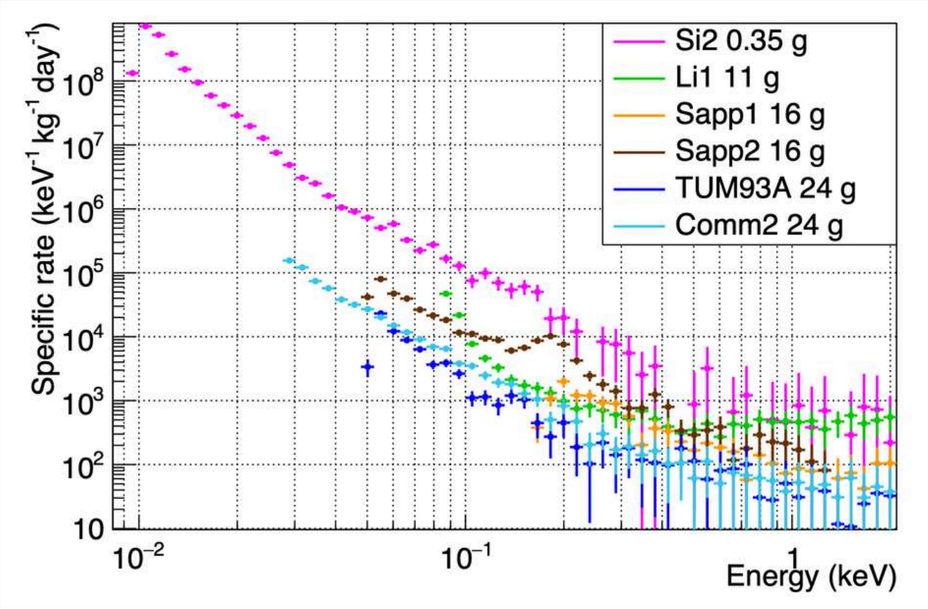
LEE - Low Energy Excess



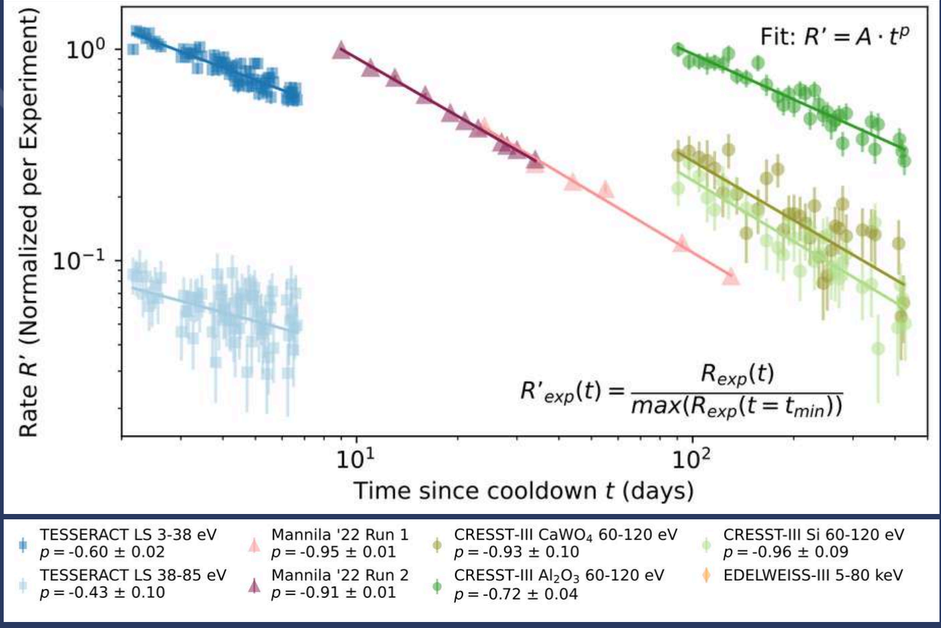
LEE study for different detector modules - CRESST Collaboration

- Rate excess observed in **all low-threshold cryogenic experiment**

LEE - Low Energy Excess



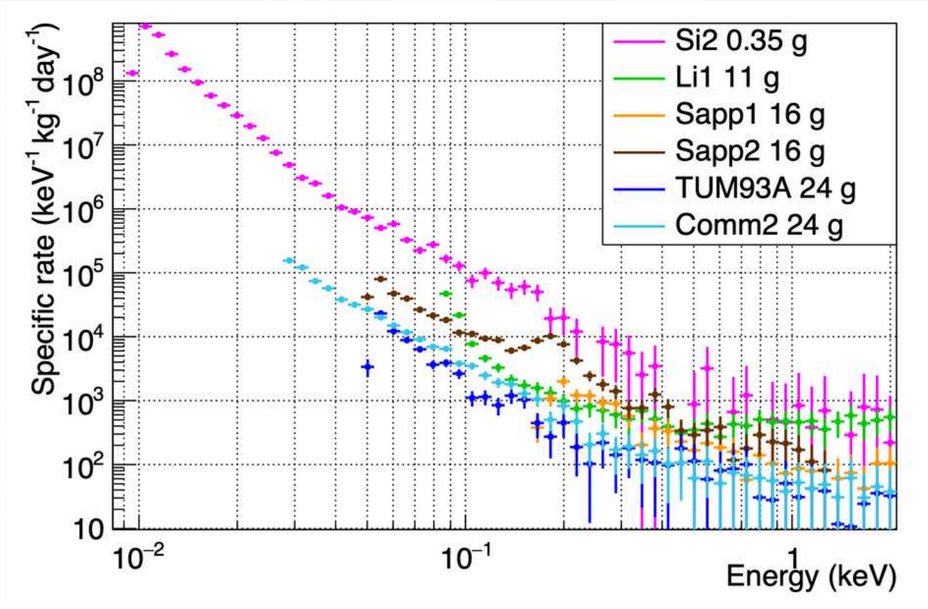
LEE study for different detector modules - CRESST Collaboration



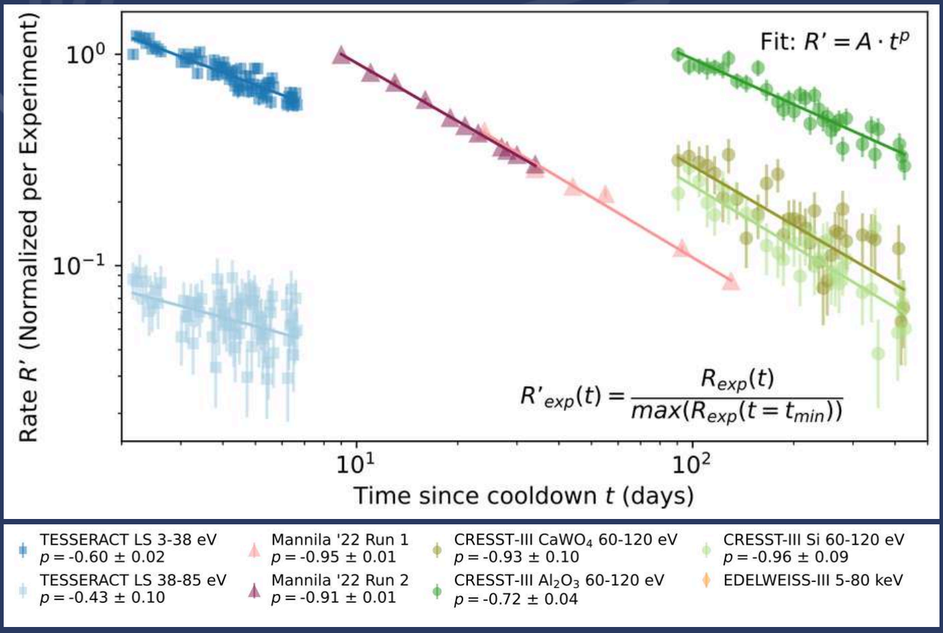
LEE rate evolution with time

- Rate excess observed in **all low-threshold cryogenic experiment**
- **What we know :**
  - Time dependant
  - Non ionising
  - Could be cause by Stress or defect in the materials

LEE - Low Energy Excess



LEE study for different detector modules - CRESST Collaboration

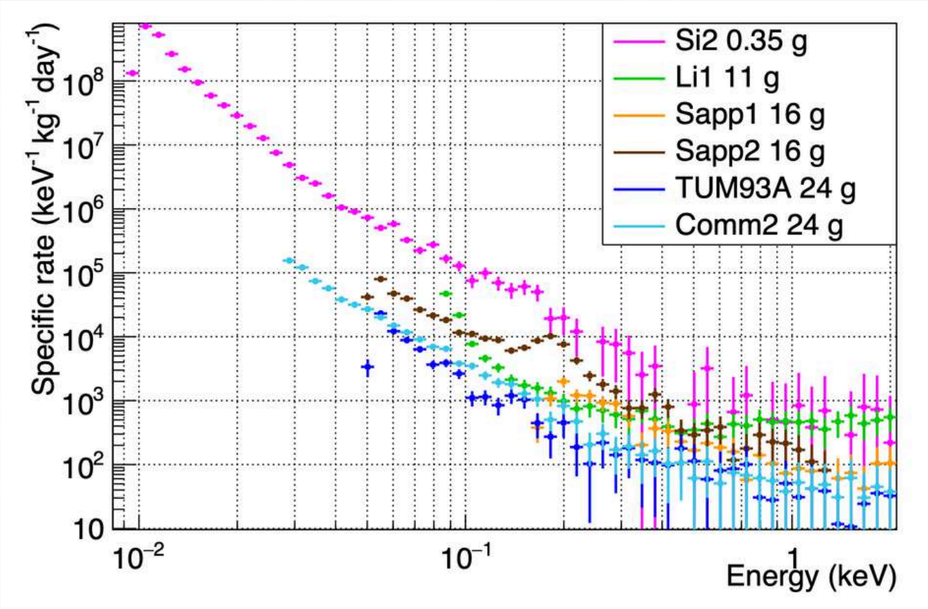


LEE rate evolution with time

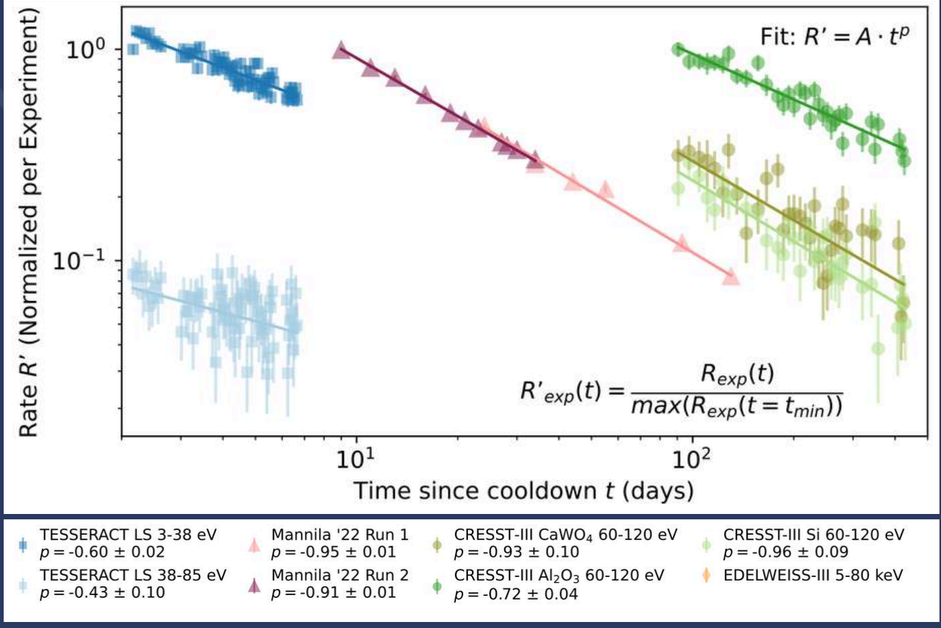
- Rate excess observed in **all low-threshold cryogenic experiment**
- **What we know :**
  - Time dependant
  - Non ionising
  - Could be cause by Stress or defect in the materials

- **Largest background at lowest energy and limiting our phonon baseline energy resolution**

LEE - Low Energy Excess



LEE study for different detector modules - CRESST Collaboration

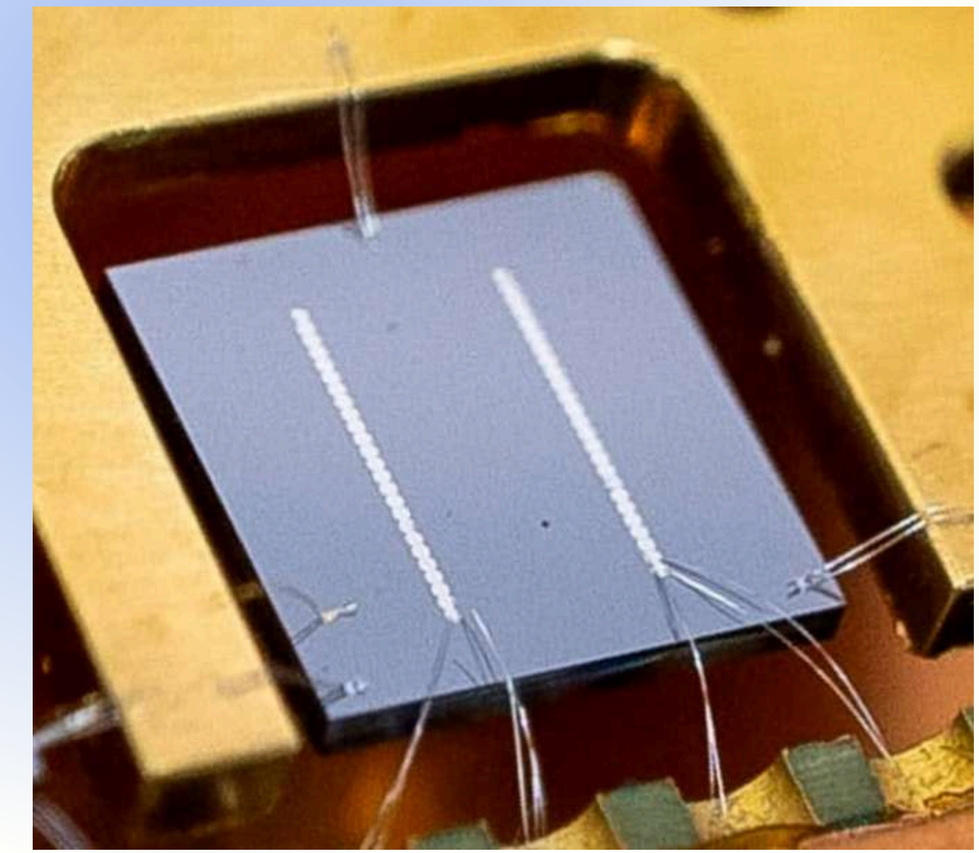


LEE rate evolution with time

- Rate excess observed in **all low-threshold cryogenic experiment**
- **What we know :**
  - Time dependant
  - Non ionising
  - Could be cause by Stress or defect in the materials

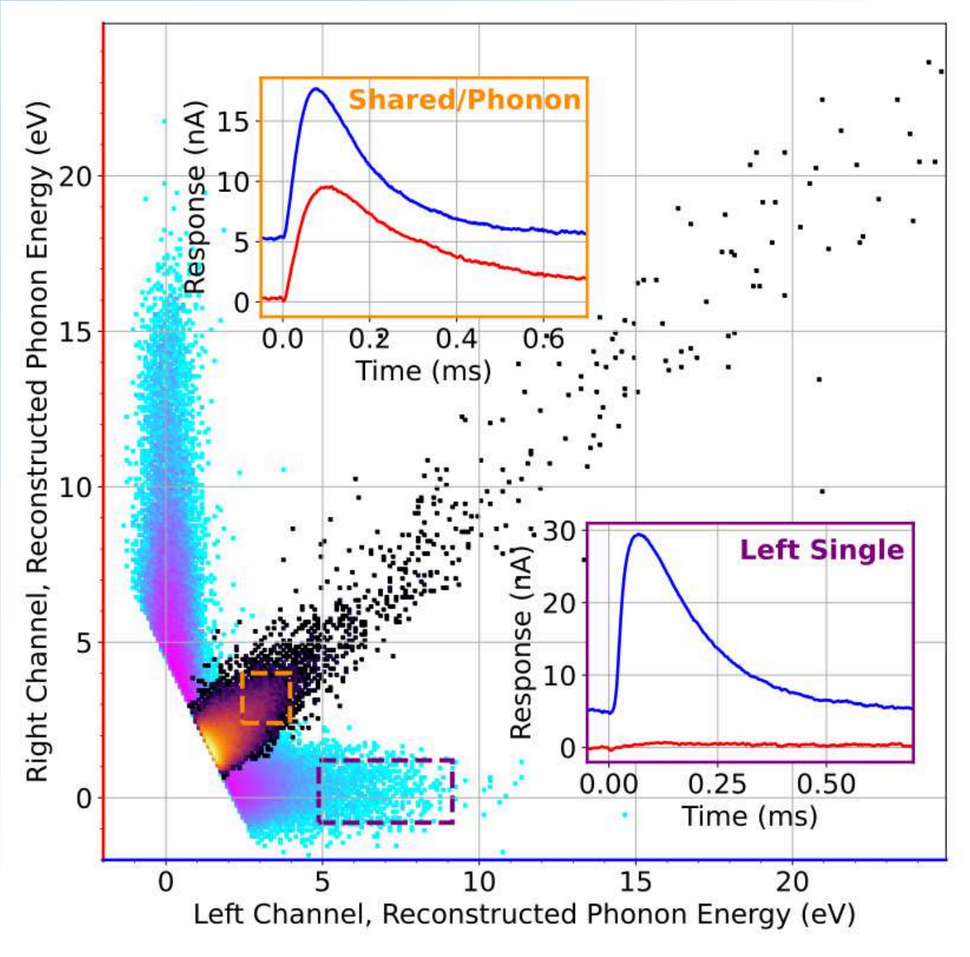
- **Largest background at lowest energy and limiting our phonon baseline energy resolution**
- **TESSERACT Experiment :**
  - finding the origin of the LEE
  - developing technologies to reject it

First Results



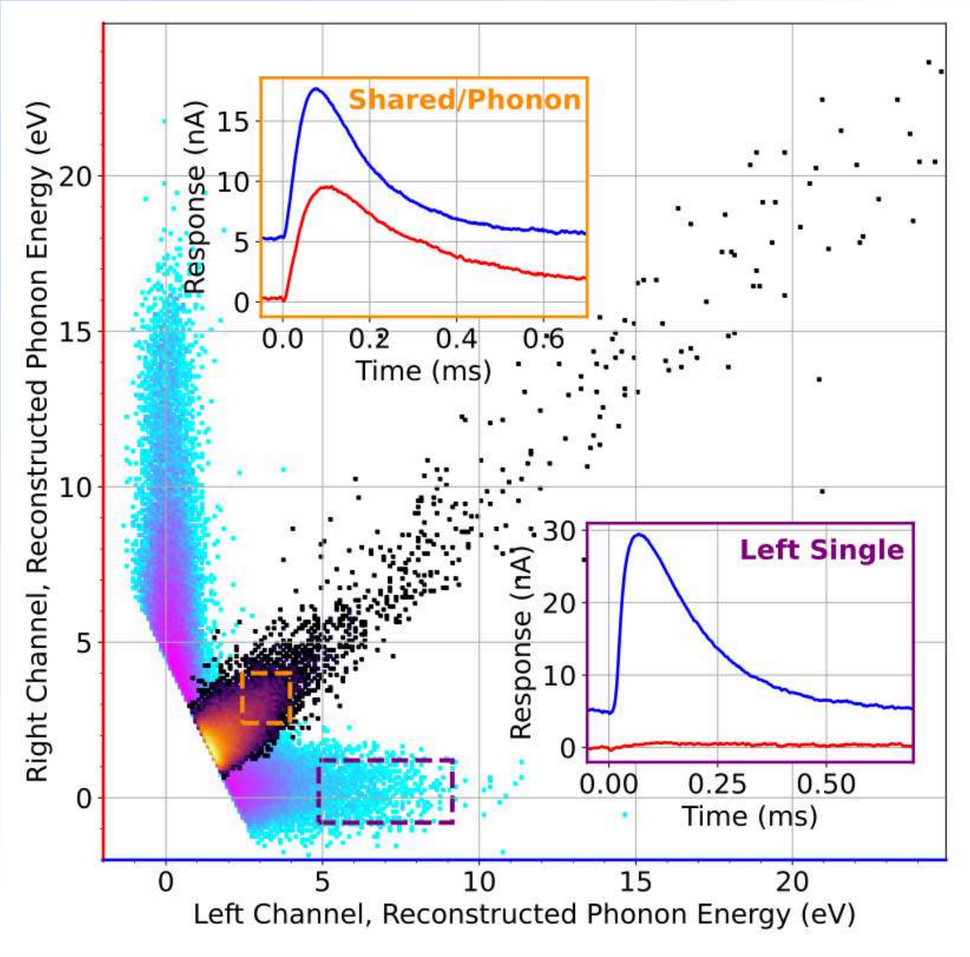
- Detector with **two readout channels** coupled to **the same target**

First Results



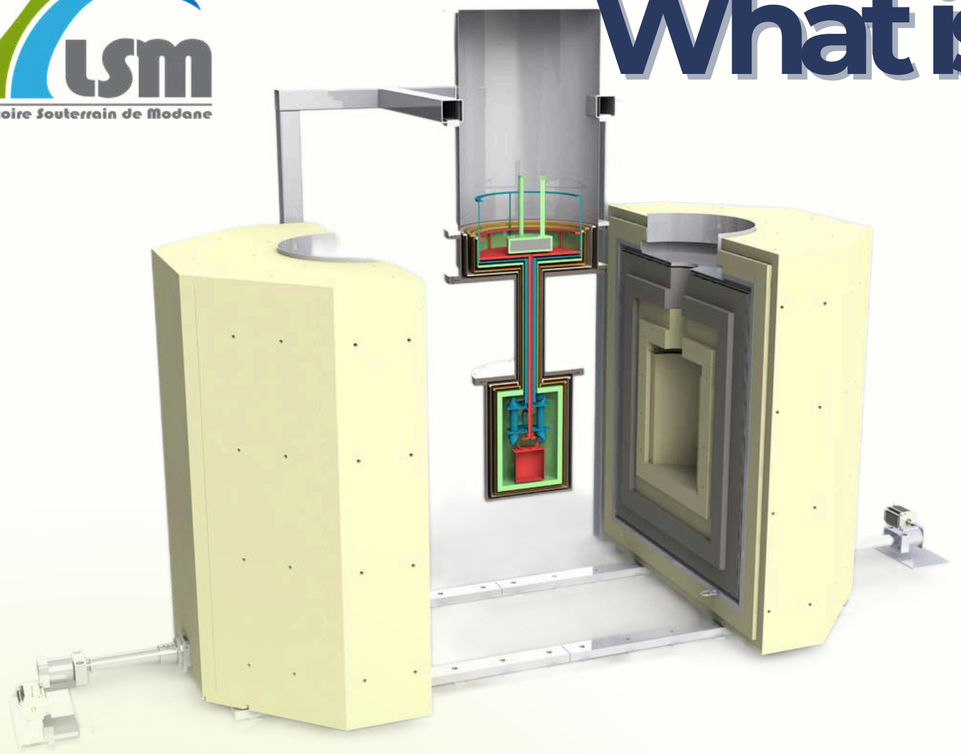
- Detector with **two readout channels** coupled to **the same target**
- Allow **background discrimination** based on **the energy partionning** between the channels

First Results

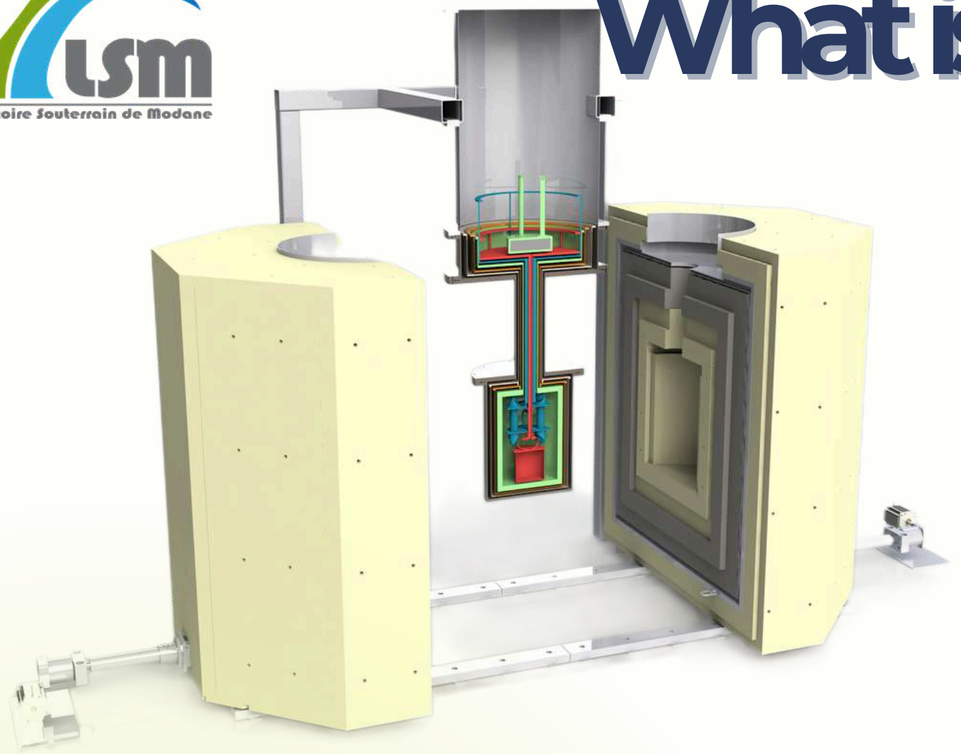


- Detector with **two readout channels** coupled to **the same target**
- Allow **background discrimination** based on **the energy partionning** between the channels
- Reached **new sensitivity limits** for **DM-nucleus scattering** down to masses **44MeV/c^2**

What is next? Deployment @ LSM

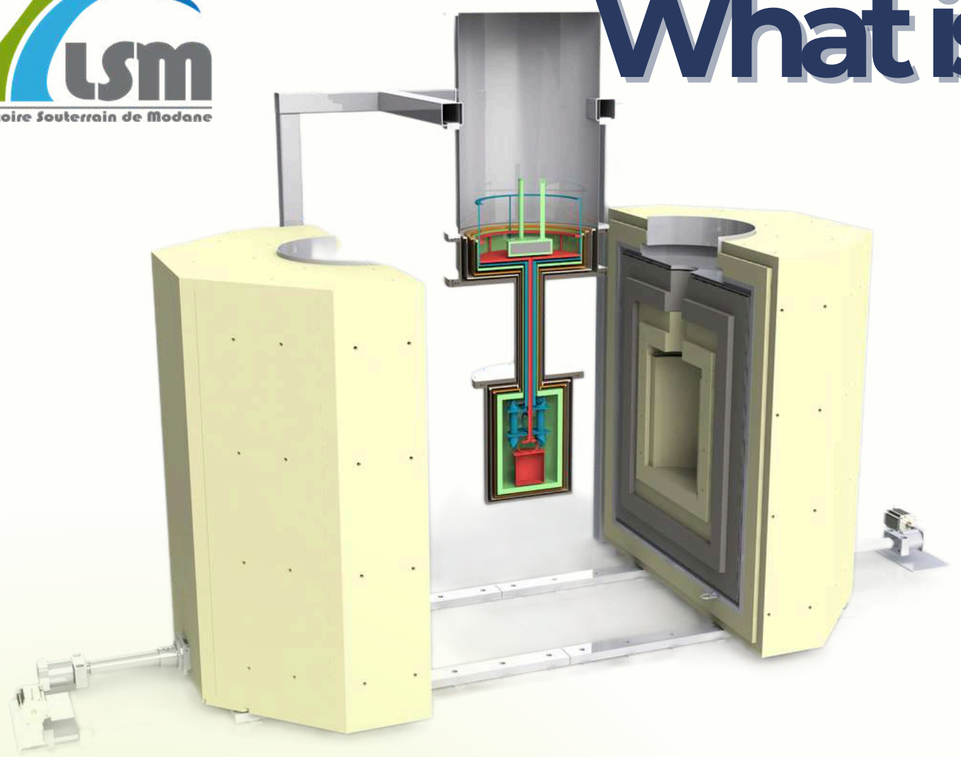


What is next? Deployment @ LSM



- **2 Experimental setups**
  - Data taking in parallel
- **Background level target :** 5 evt/kg/keV/day

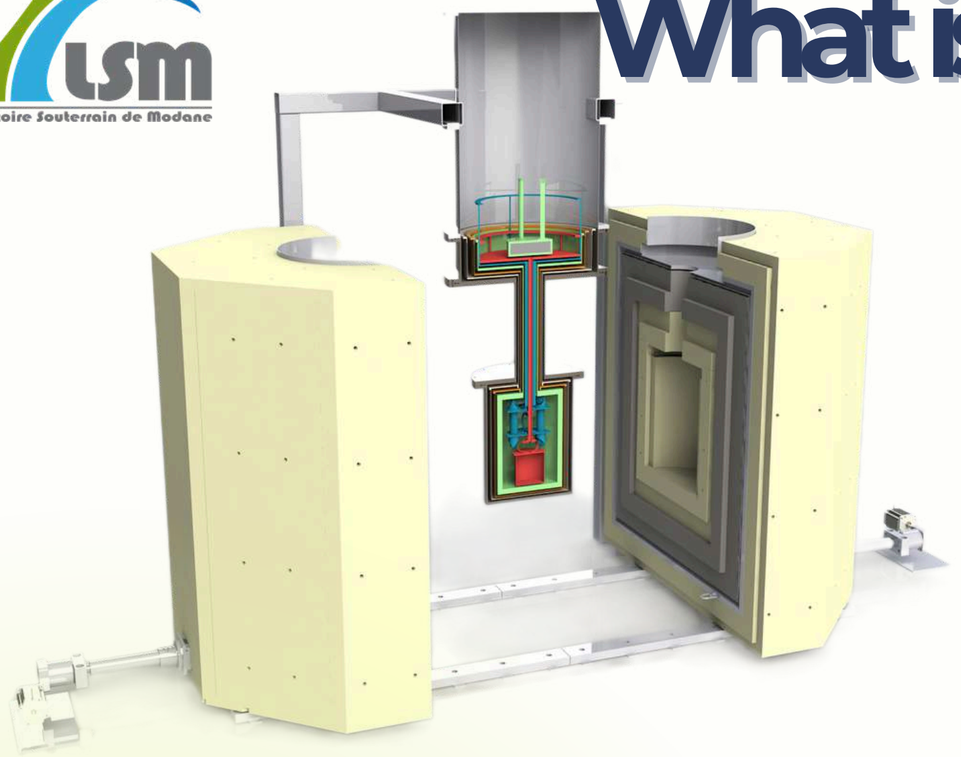
What is next? Deployment @ LSM



- **2 Experimental setups**
  - Data taking in parallel
- **Background level target :** 5 evt/kg/keV/day

2025	2026	2027	2028	2029
Detectors R&D - Fabrication - Testing - Optimization - Surface Science				
Cryostat&Shielding Design	Surface Cryostat Commissioning		Underground Installation	Science Run

What is next? Deployment @ LSM



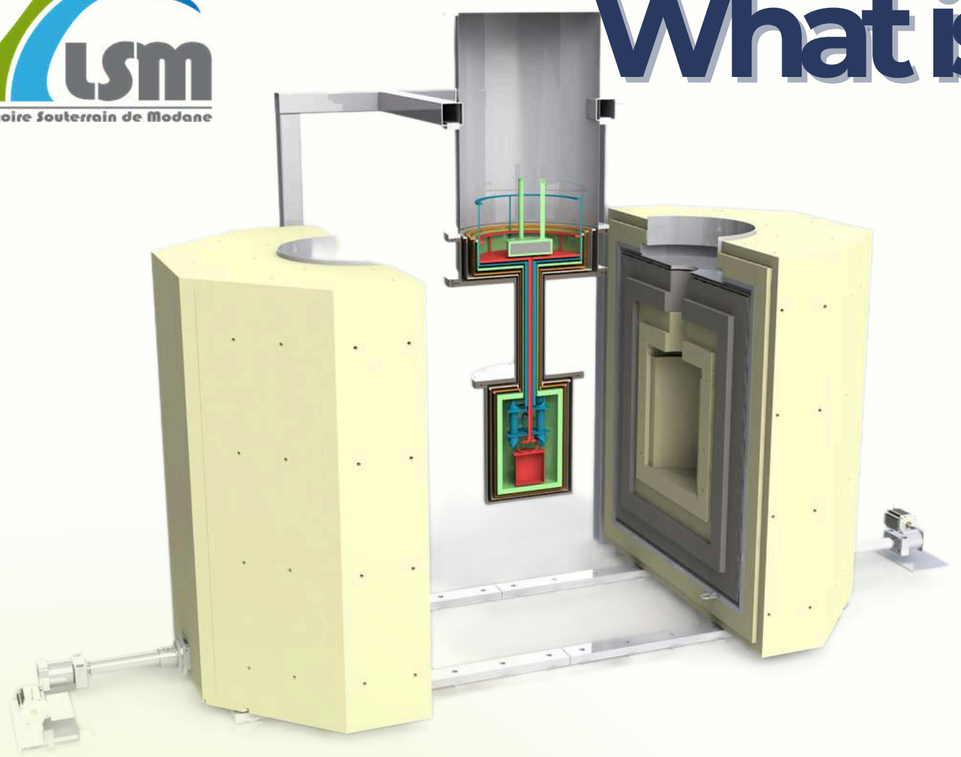
- **2 Experimental setups**
  - Data taking in parallel
- **Background level target :** 5 evt/kg/keV/day
- Integration at LSM in 2028

2025 2026 2027 2028 2029

Detectors R&D - Fabrication - Testing - Optimization - Surface Science

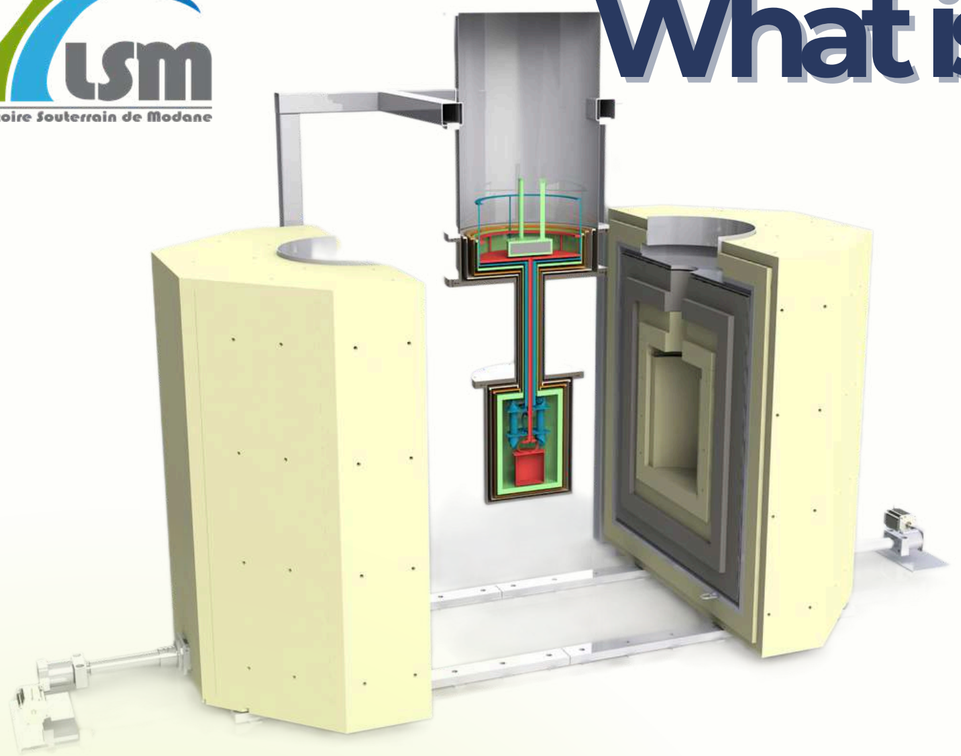
Cryostat&Shielding Design | Surface Cryostat Commissioning | Underground Installation | Science Run

What is next? Deployment @ LSM



- **2 Experimental setups**
  - Data taking in parallel
- **Background level target :** 5 evt/kg/keV/day
- Integration at LSM in 2028
- First DM science in 2029

What is next? Deployment @ LSM



- **2 Experimental setups**
  - Data taking in parallel
- **Background level target :** 5 evt/kg/keV/day
- Integration at LSM in 2028
- First DM science in 2029

we are here!

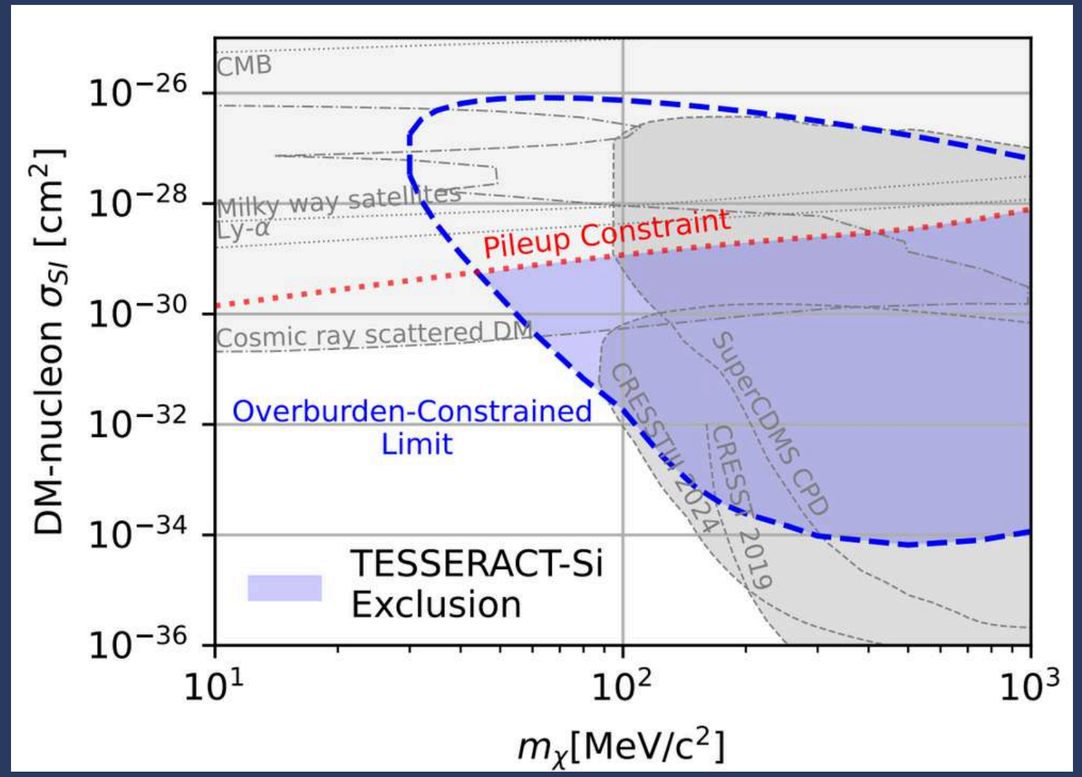
2025 | 2026 | 2027 | 2028 | 2029

Detectors R&D - Fabrication - Testing - Optimization - Surface Science

Cryostat&Shielding Design | Surface Cryostat Commissioning | Underground Installation | Science Run

conclusions.

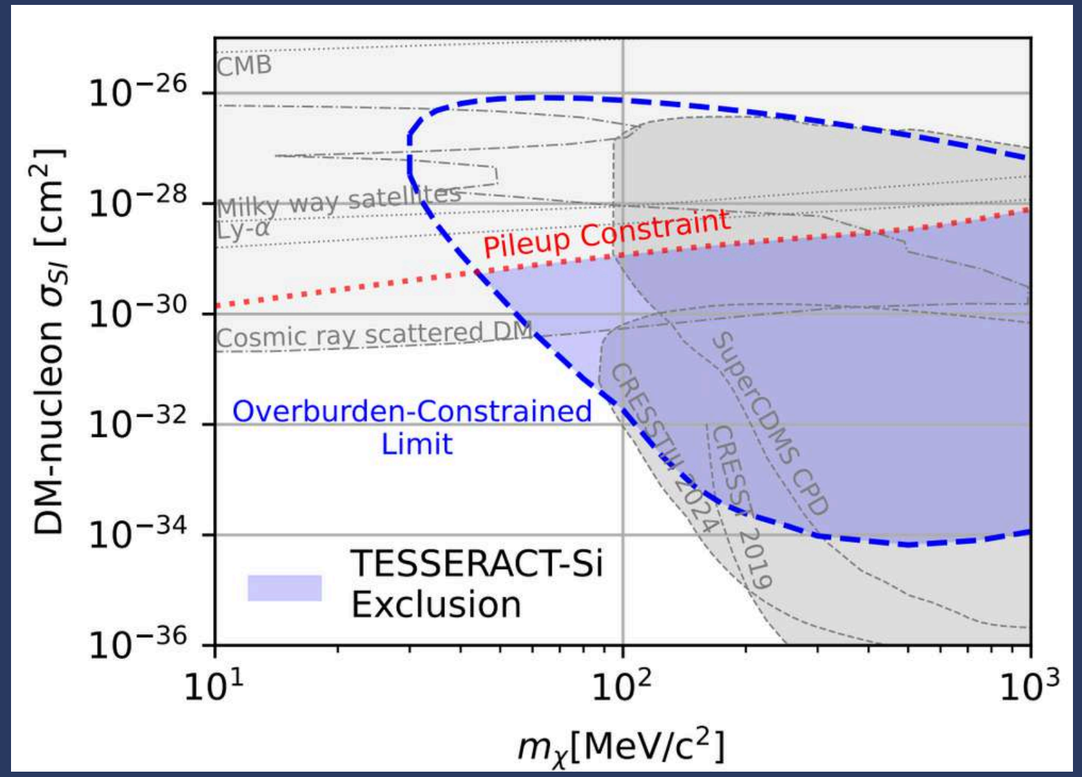
- The TESSERACT Team spread over the **US (DOE),** in **France (CNRS-IN2P3)** and in **Switzerland (SNF)**



Leslie Juigne - leslie.juigne@physik.uzh.ch

conclusions.

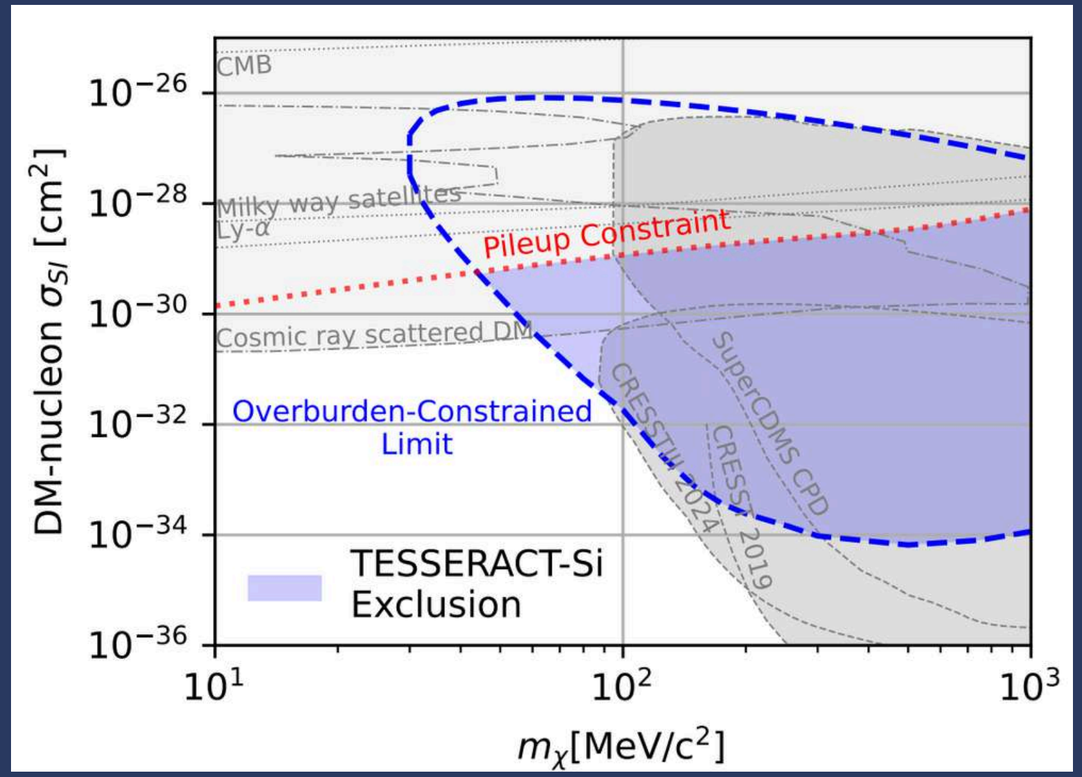
- The TESSERACT Team spread over the **US (DOE),** in **France (CNRS-IN2P3)** and in **Switzerland (SNF)**
- **Multi-targets materials** approach to explore different **DM candidates** and **backgrounds discrimination**



Leslie Juigne - leslie.juigne@physik.uzh.ch

conclusions.

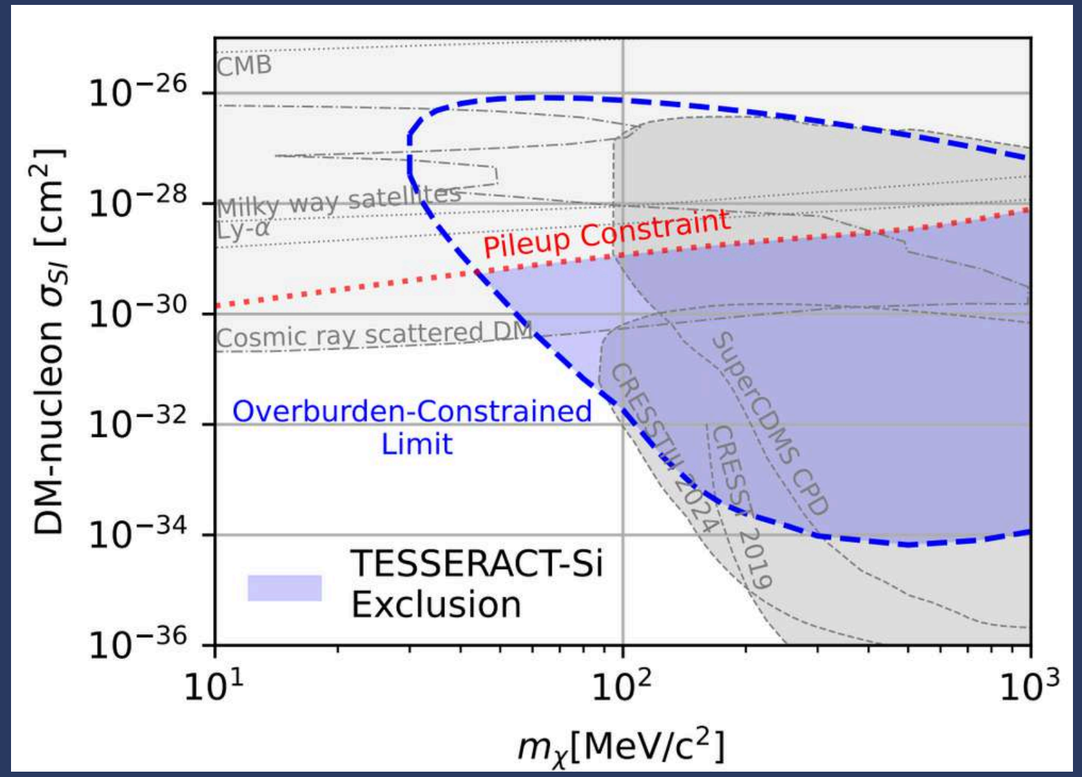
- The TESSERACT Team spread over the **US (DOE),** in **France (CNRS-IN2P3)** and in **Switzerland (SNF)**
- **Multi-targets materials** approach to explore different **DM candidates** and **backgrounds discrimination**
- **Surface experiment** has shown the success of all the targets and **prob new phase space**



Leslie Juigne - leslie.juigne@physik.uzh.ch

conclusions.

- The TESSERACT Team spread over the **US (DOE),** in **France (CNRS-IN2P3)** and in **Switzerland (SNF)**
- **Multi-targets materials** approach to explore different **DM candidates** and **backgrounds discrimination**
- **Surface experiment** has shown the success of all the targets and **prob new phase space**
- TESSERACT is now in **Project phase** and is expected to be moving **in Modane in 2028**



Leslie Juigne - leslie.juigne@physik.uzh.ch

Thank you for your attention!

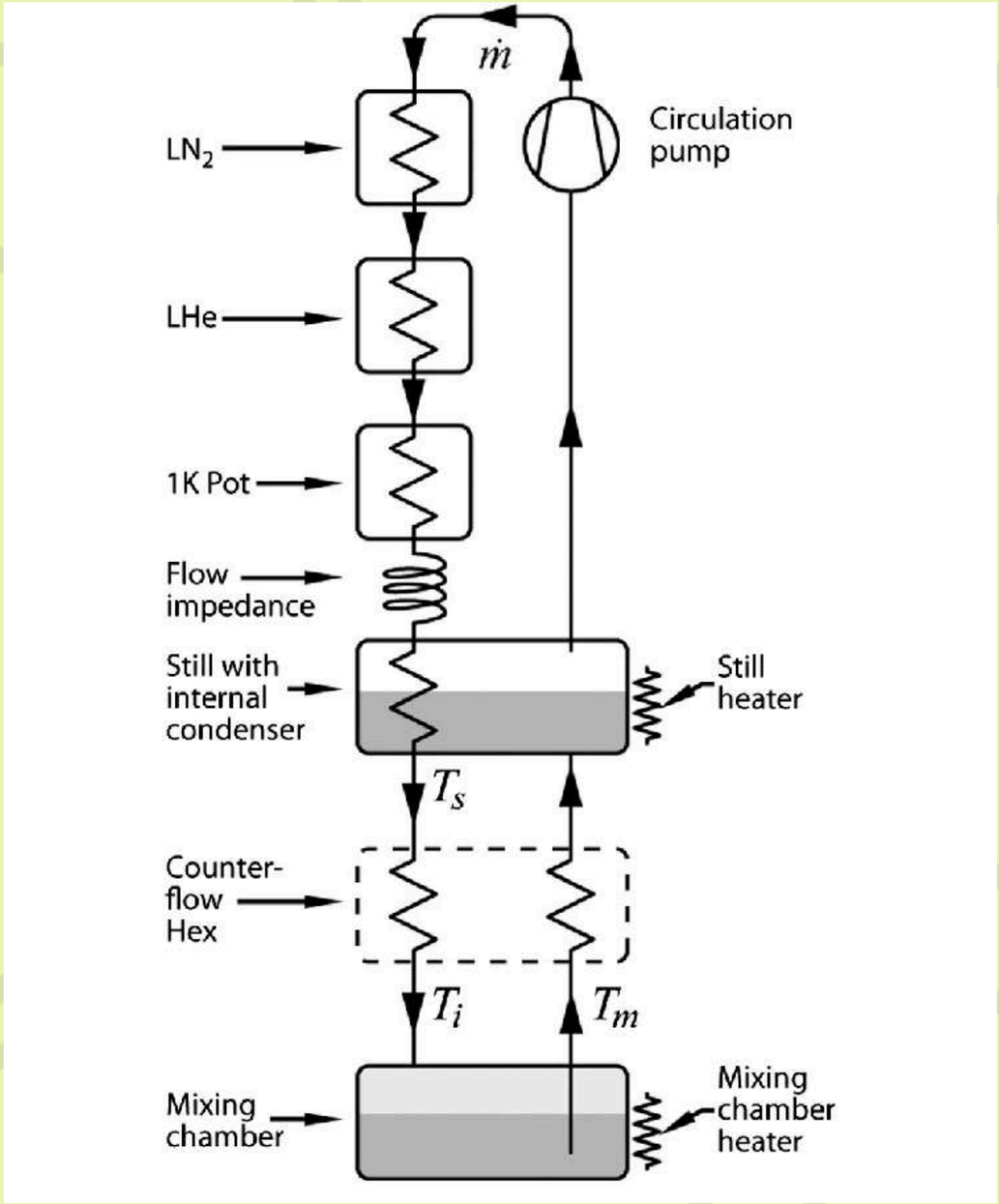
Low mass DM @UZH

- **UZH strongly involved in DM research**
- Low mass DM → TESSERACT and QROCODILE Experiment
- Experimental setups :
  - **R&D for TESSERACT**

1. Latest observations on the low energy excess in CRESST-III
2. Low-Energy Backgrounds in Solid-State Phonon and Charge Detectors
3. First Limits on Light Dark Matter Interactions in a Low Threshold Two Channel Athermal Phonon Detector from the TESSERACT Collaboration
4. Two facets of the x-ray microanalysis at low voltage: the secondary fluorescence x-rays emission and the microcalorimeter energy-dispersive spectrometer
5. A Gram-Scale low-T c Low-Surface-Coverage Athermal-Phonon Sensitive Dark Matter Detector

resources.

Leslie Juigne - leslie.juigne@physik.uzh.ch

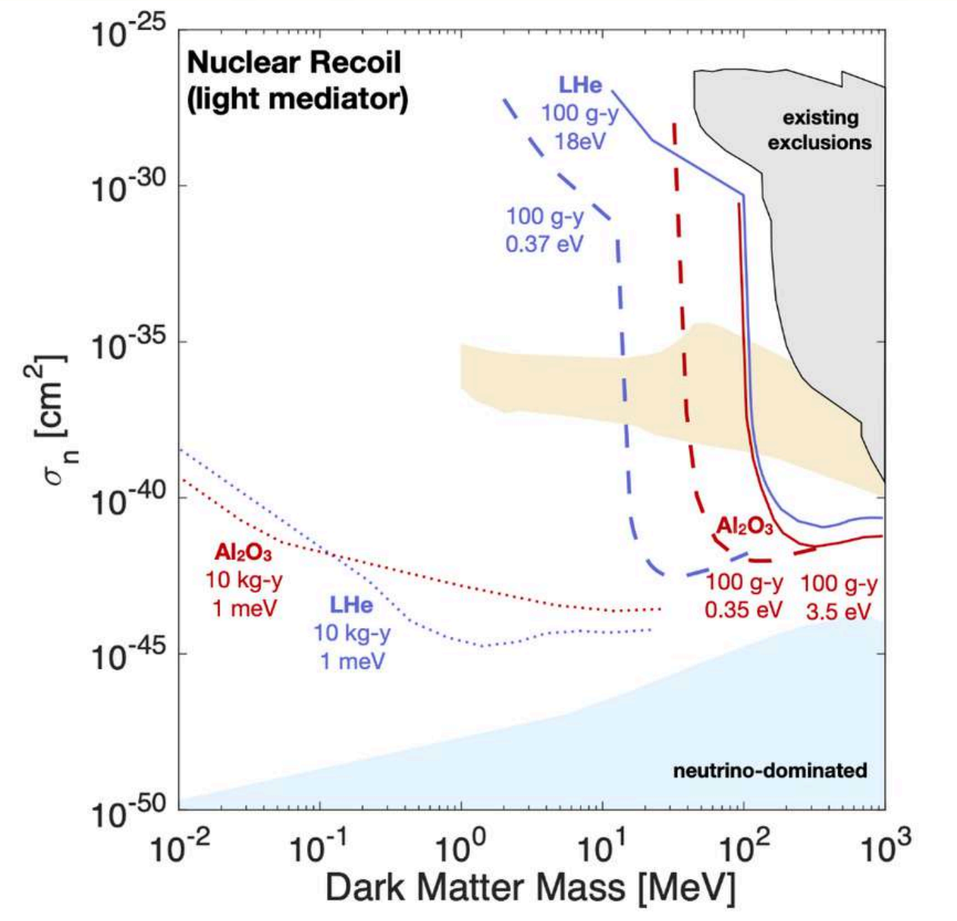


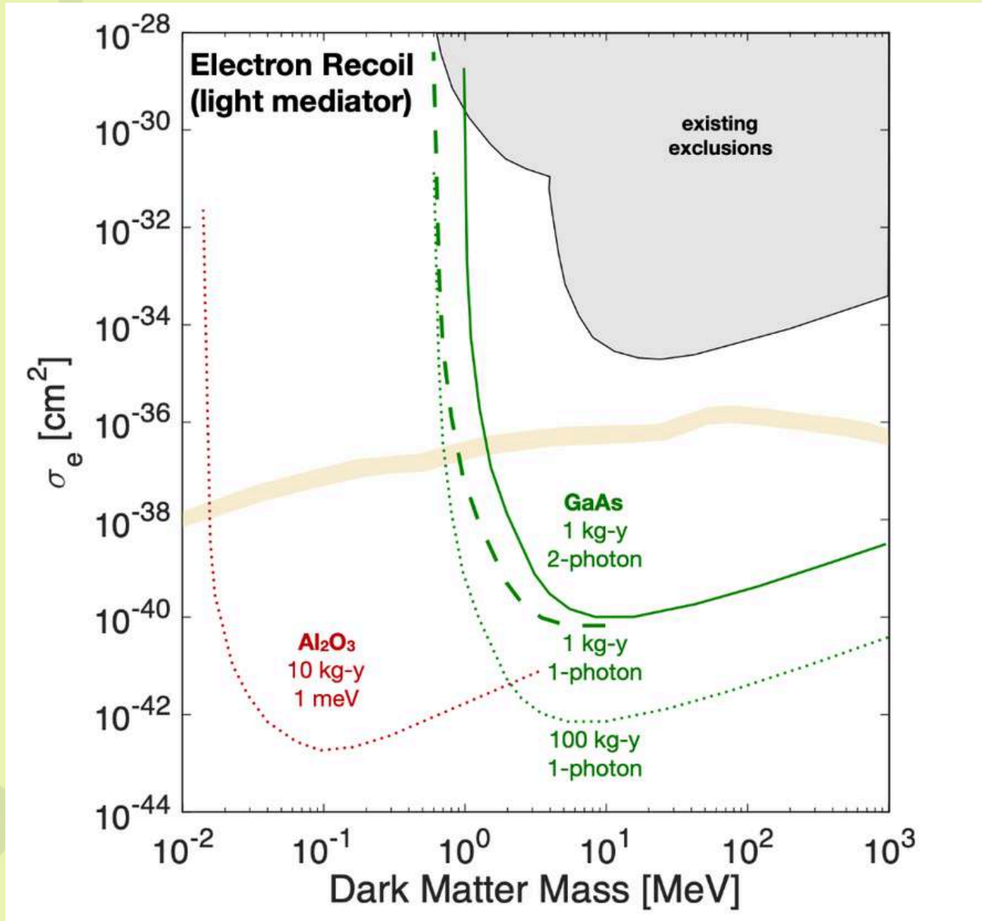
Dilution Fridge

- 4He is a boson
  - Bose-Einstein condensation
  - Superfluid ~2K
- 3He is a fermion
  - Not super fluid in this case

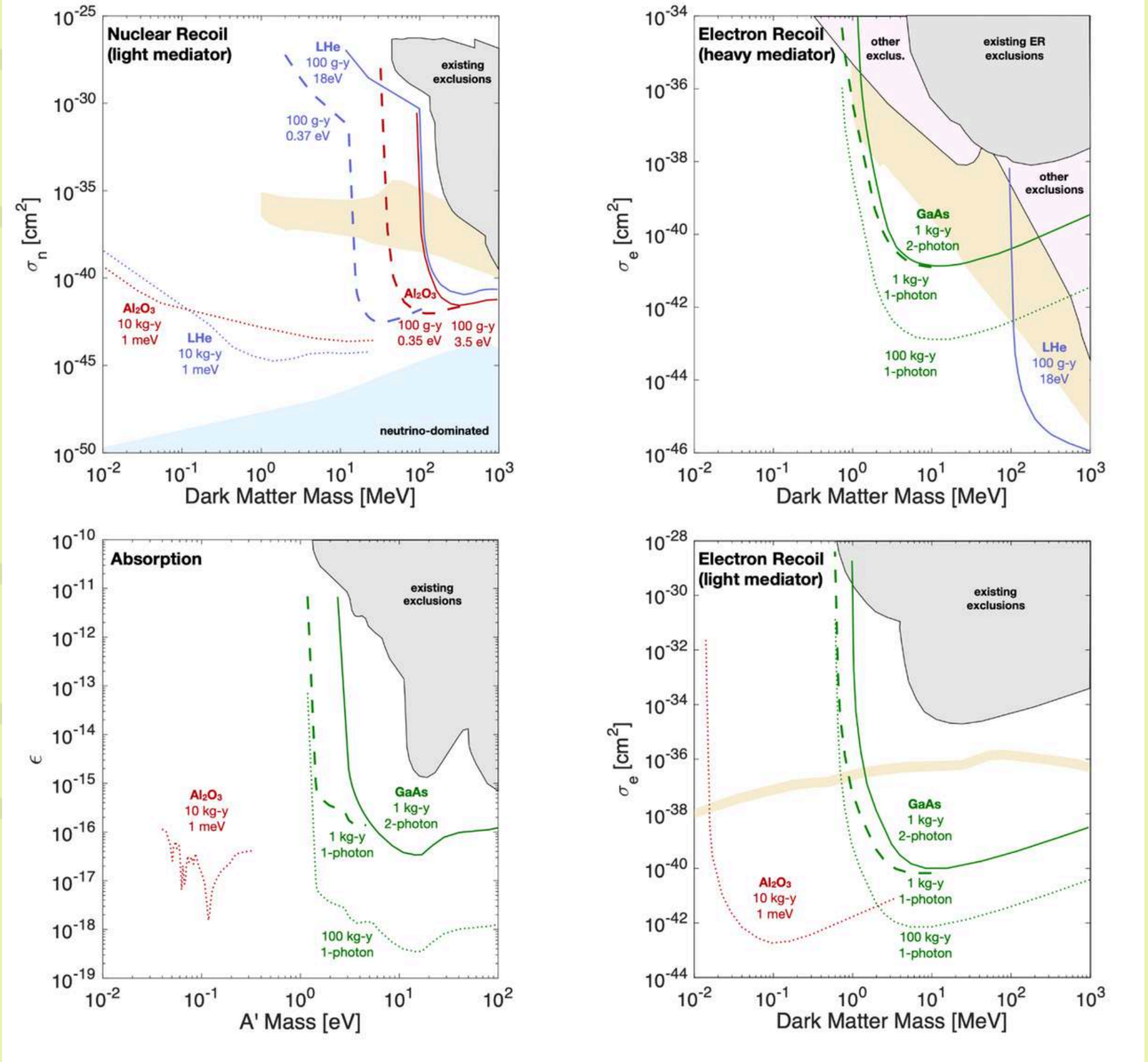
- ~0.87K
  - 3He/4He mixture separate in 2 phases
    - Concentrated 3He phase
    - Dilute phase of 93% 4He & 7% 3He
  - Enthalpy of 3He in dilute phase larger than the concentrated phase
  - In the mixing chamber the 3He is diluted and flows from the concentrated phase to the dilute phase
  - Cooling of the fridge from the energy needed to flow betweent the phases

Projected limits for TESSERACT

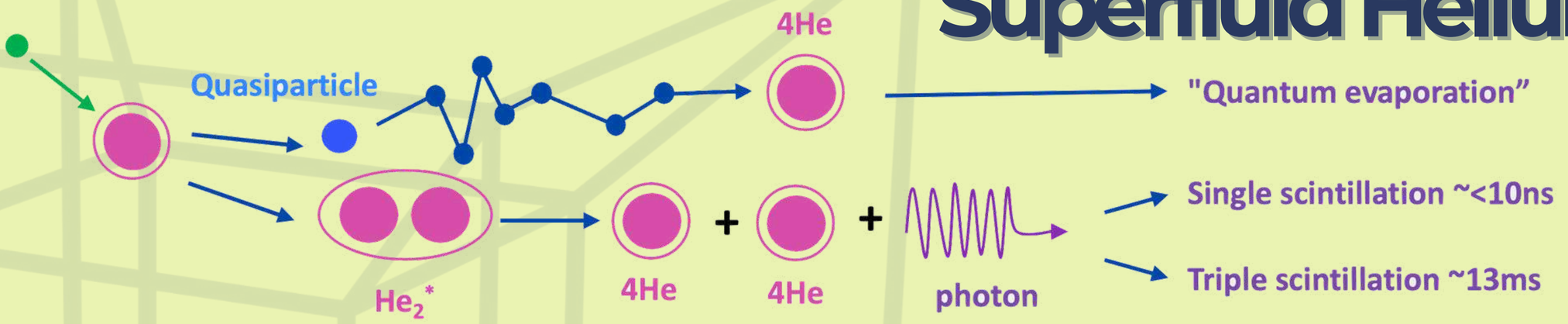


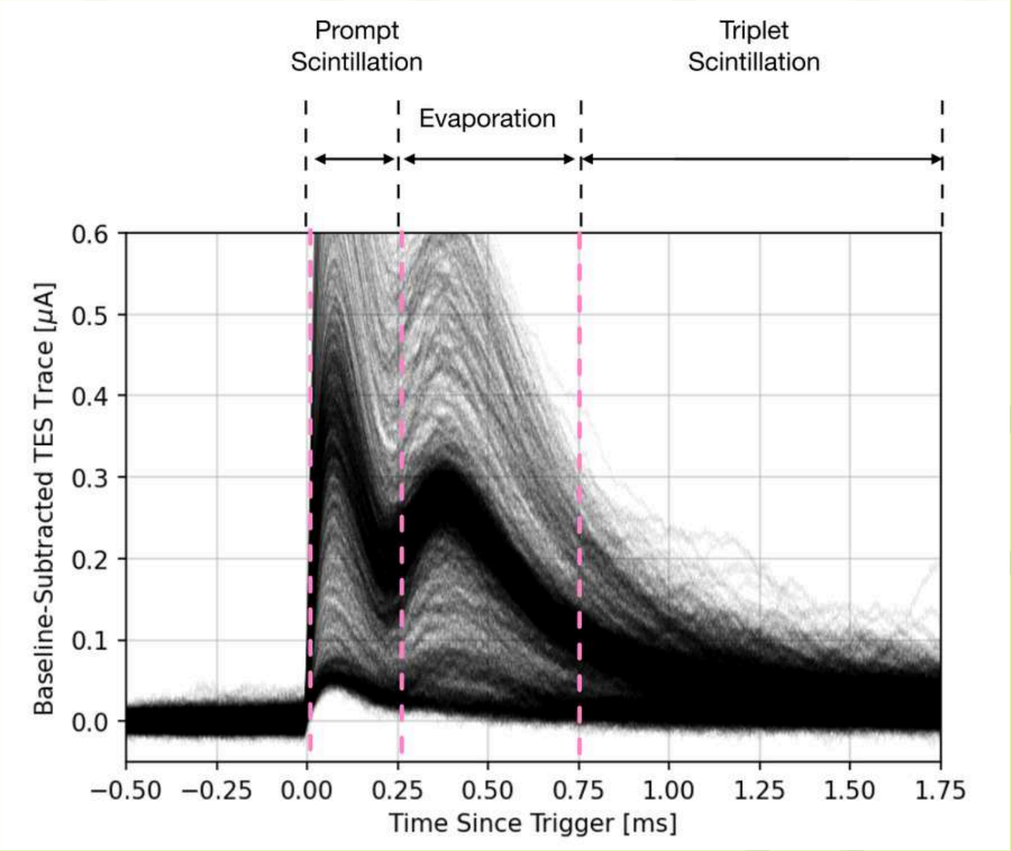


Projected limits for TESSERACT



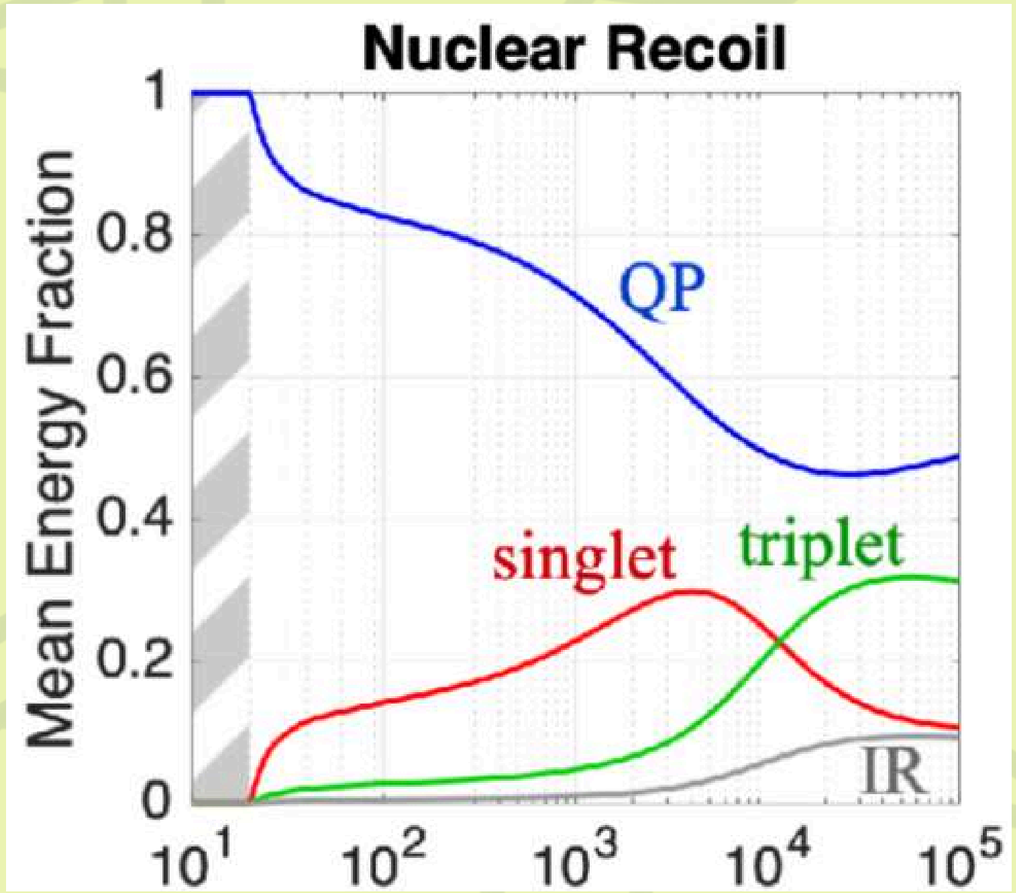
Superfluid Helium

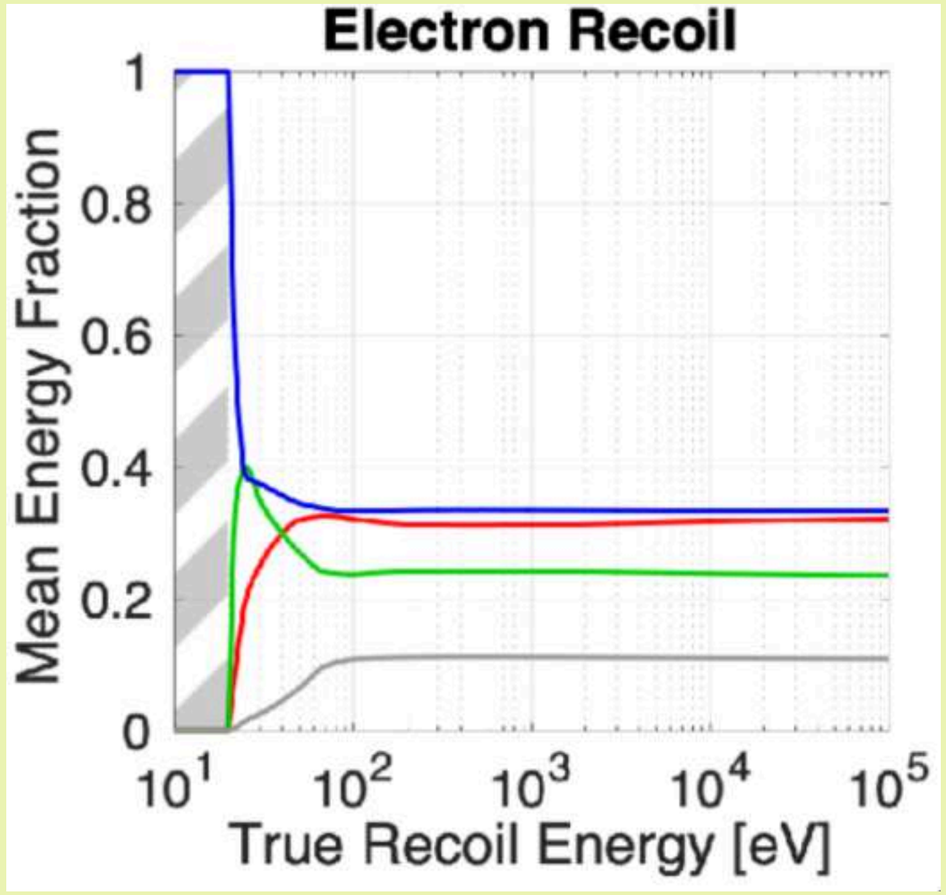




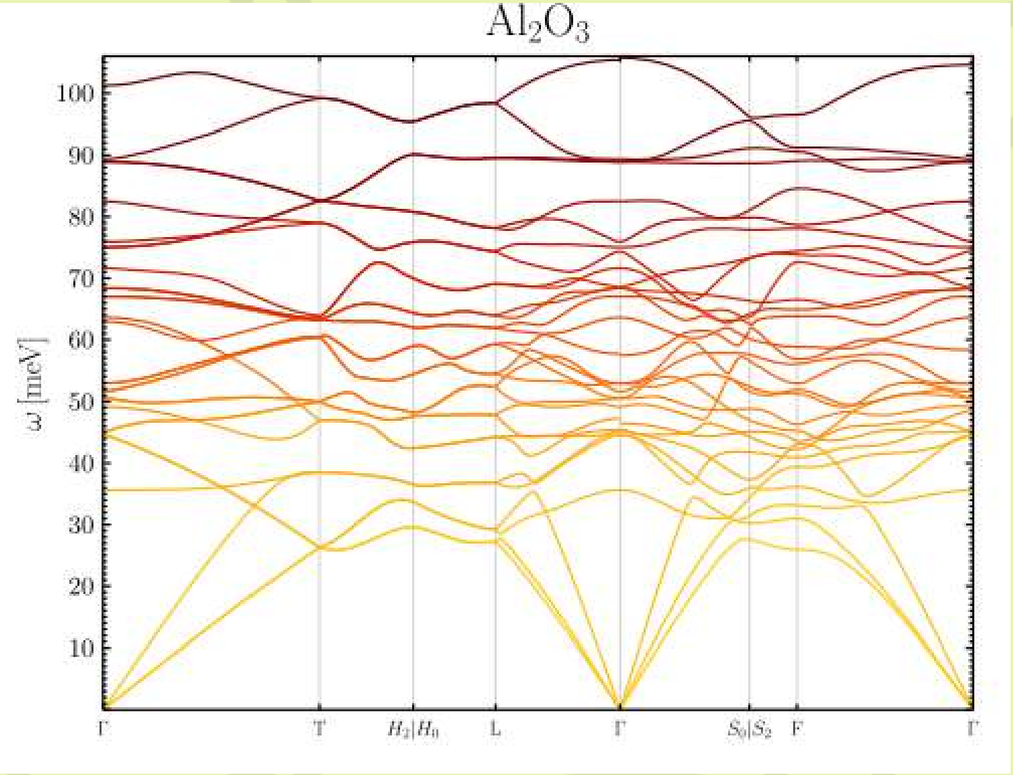
- Scintillation in VUV & IR
- Prompt decay ~16eV
- Triplet : ballistic propagation
- Quantum evaporation
  - 4He atom released and hit the calorimeter

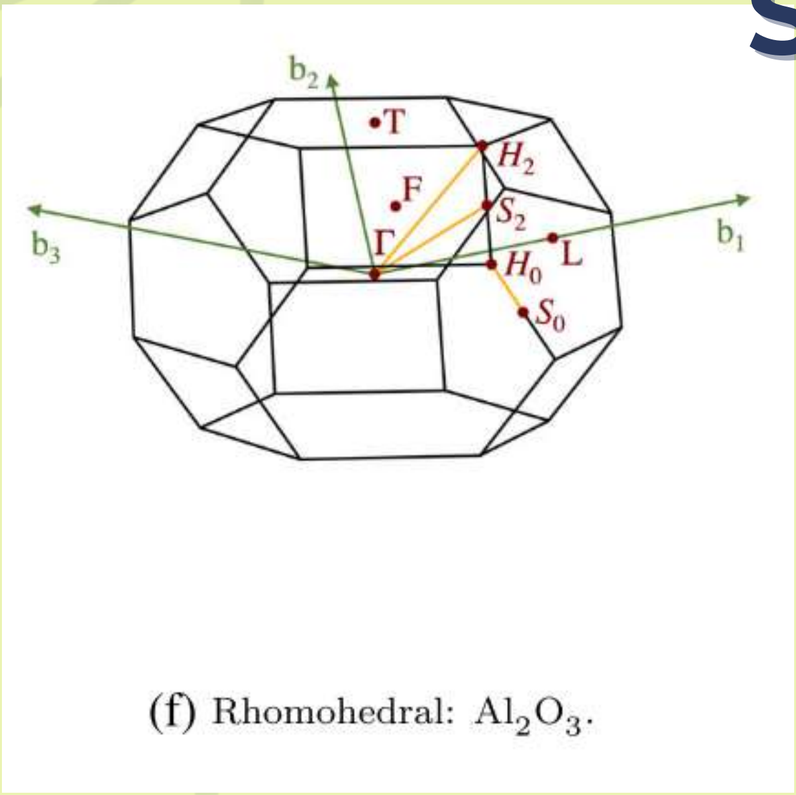
Superfluid Helium





Sapphire



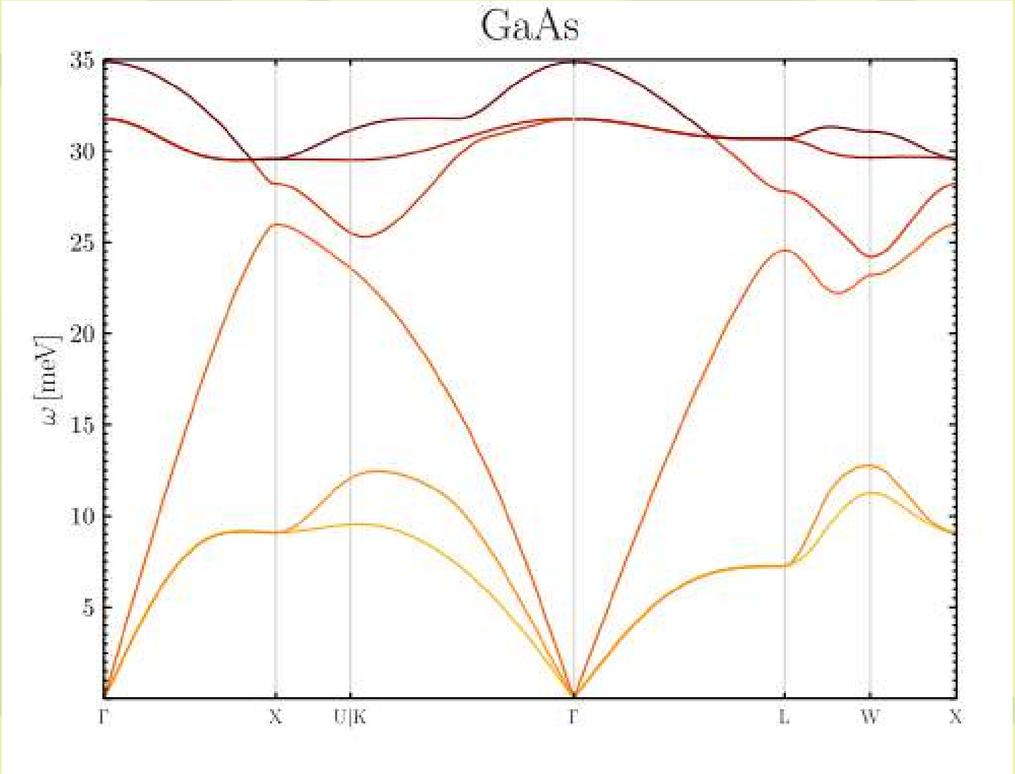


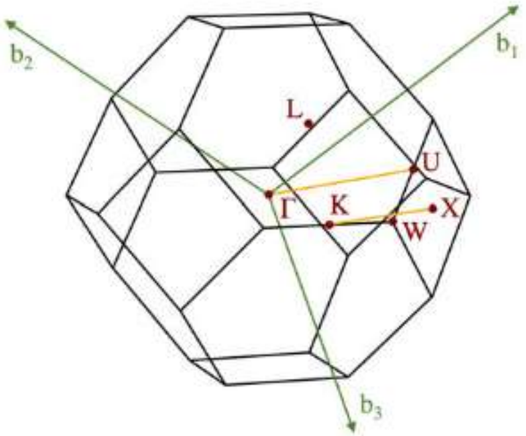
(f) Rhomohedral: Al_2O_3.

Dark photon in Sapphire :

- ion create internal electric dipole
- dark photon passing through the crystal
- **kinematic mixing** creates a oscillating E&M
  - create an optical phonon

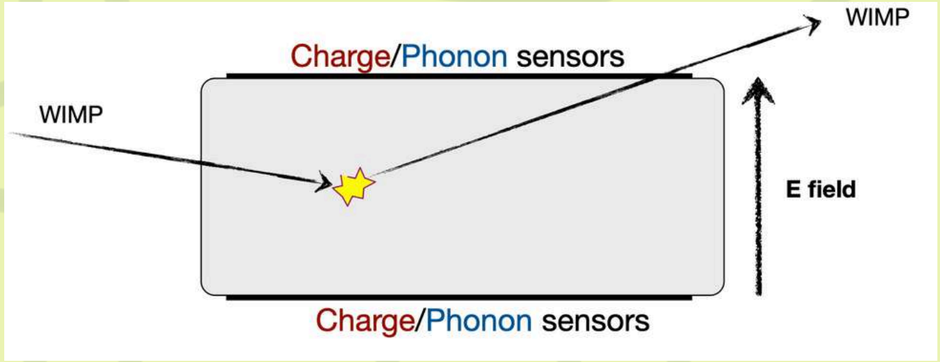
GaAs

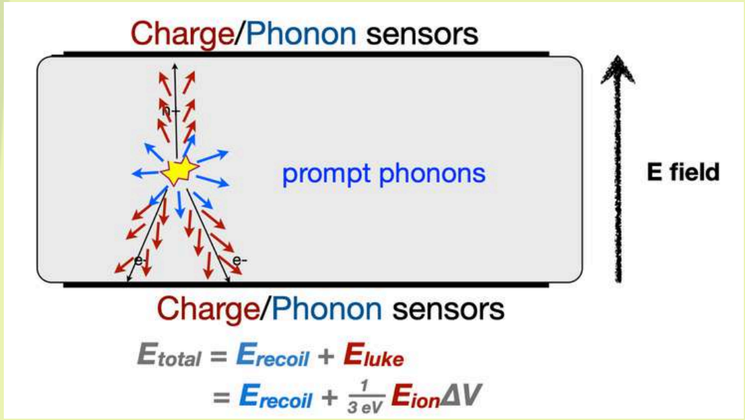




(b) Face centered cubic: Diamond, Si, Ge, GaAs, InSb, GaSb, ZnS, NaCl, MgO, LiF, NaF, NaI, PbS, PbSe, PbTe, CaF_2.

Signal in the cryocubes:





Luke Boost: