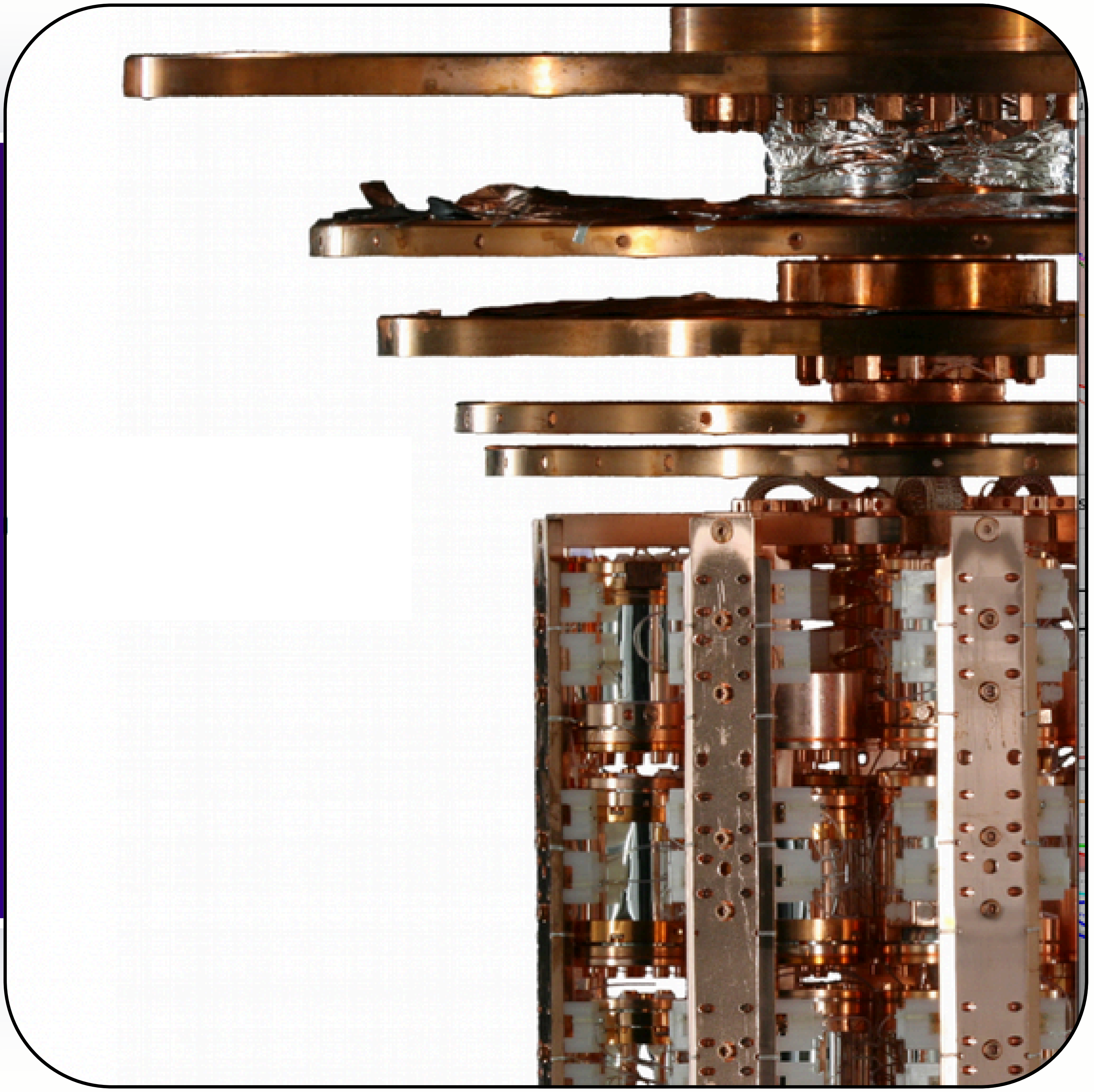
Cryogenic **Rare Event Search** with Superconducting Thermometers

LATEST RESULTS FROM CRESST

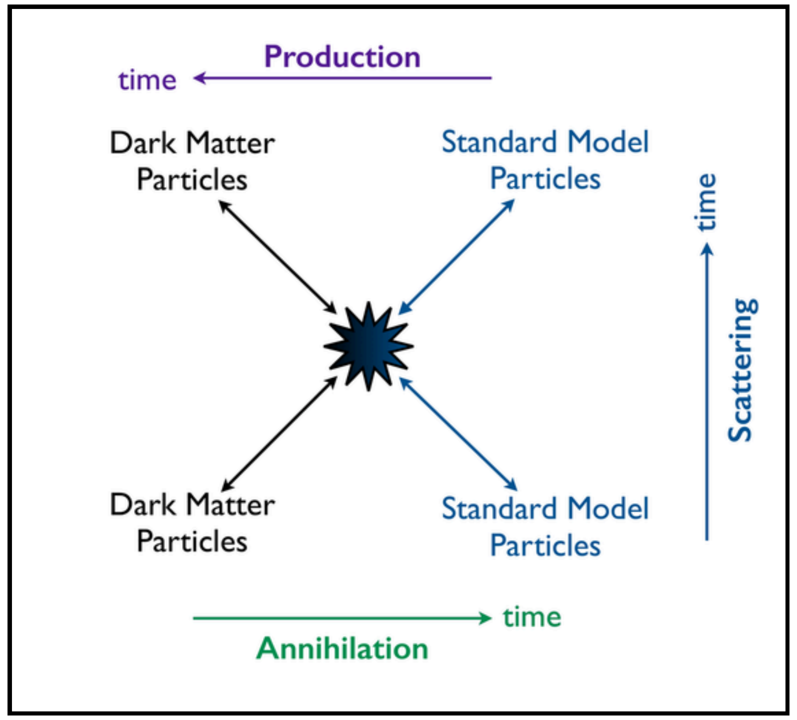


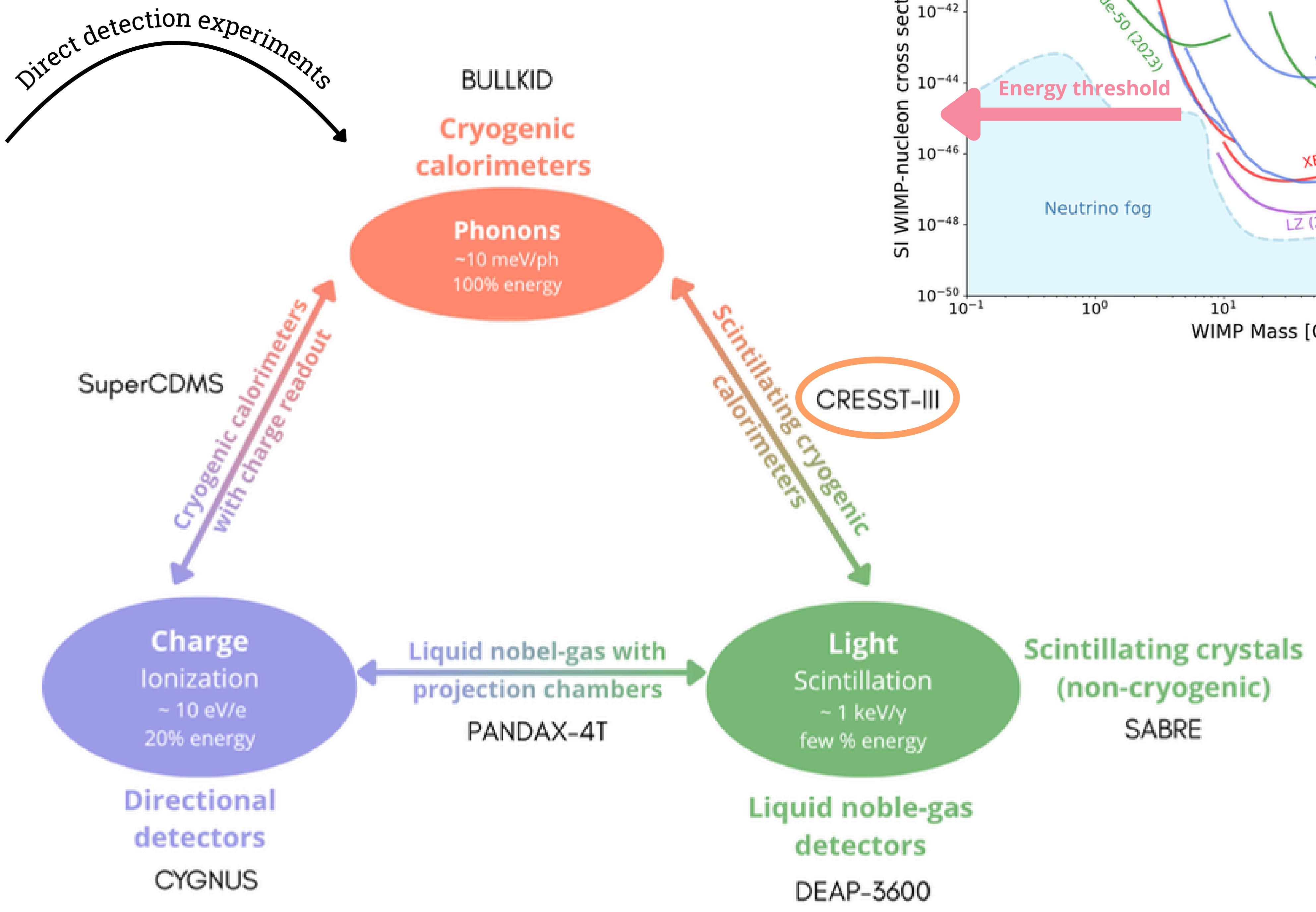
Presented by **Danaé Valdenaire**, on behalf of CRESST collaboration

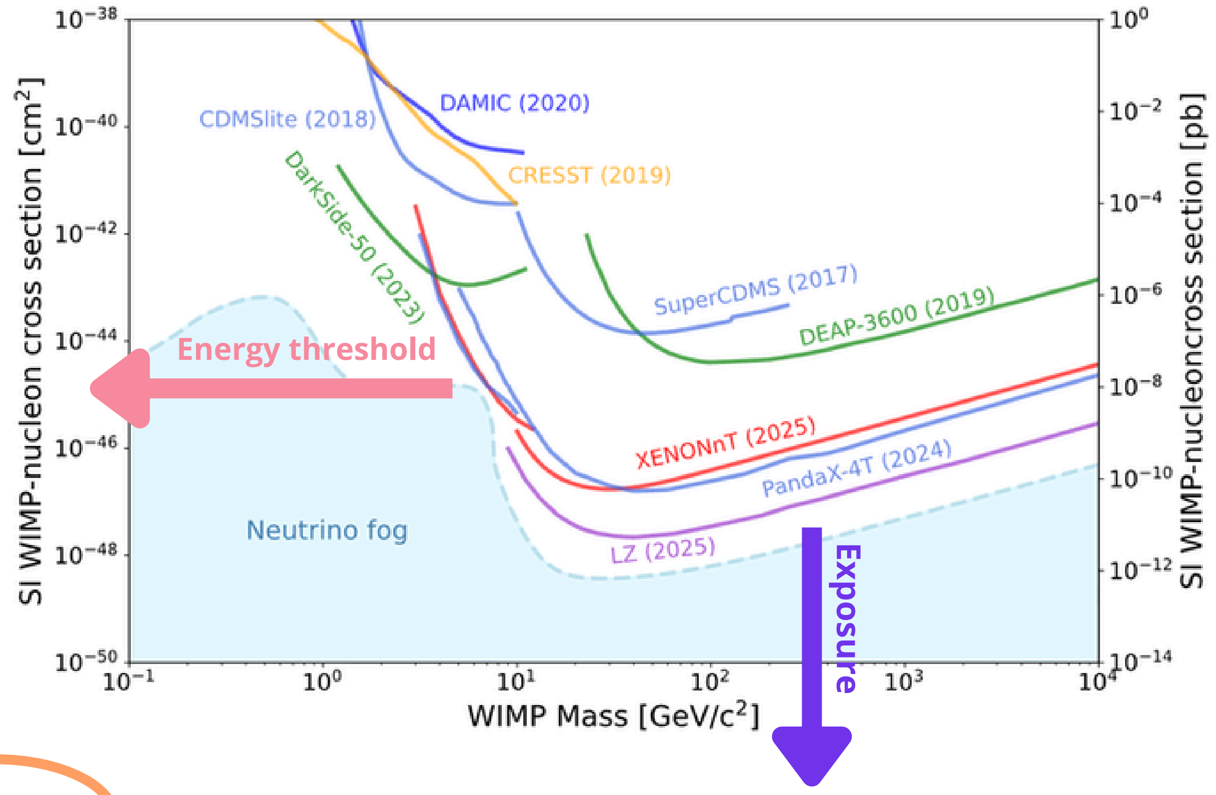
danae.valdenaire@oeaw.ac.at

DARK MATTER DIRECT DETECTION

How to detect dark matter?





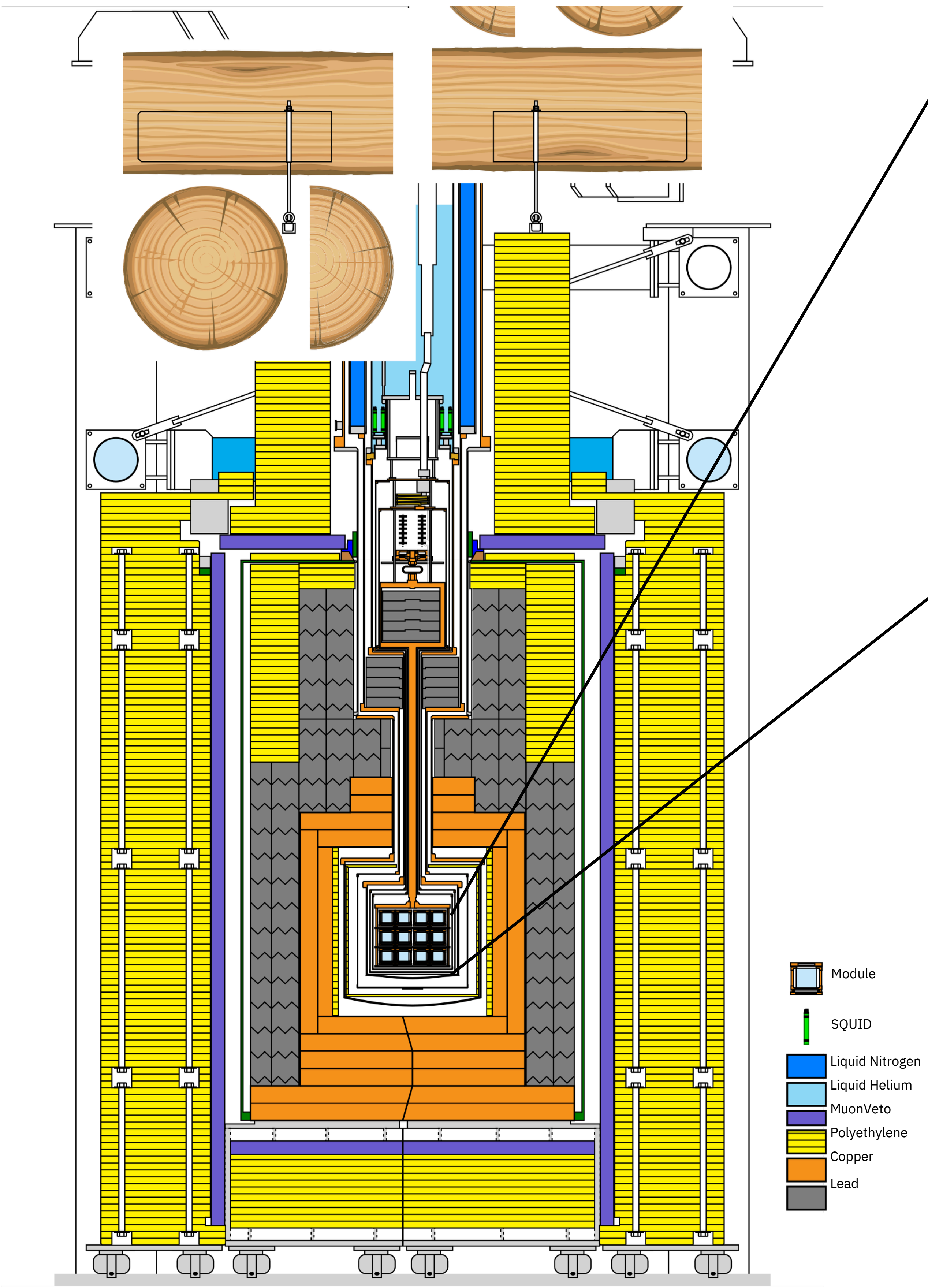


CRESST INFRASTRUCTURE

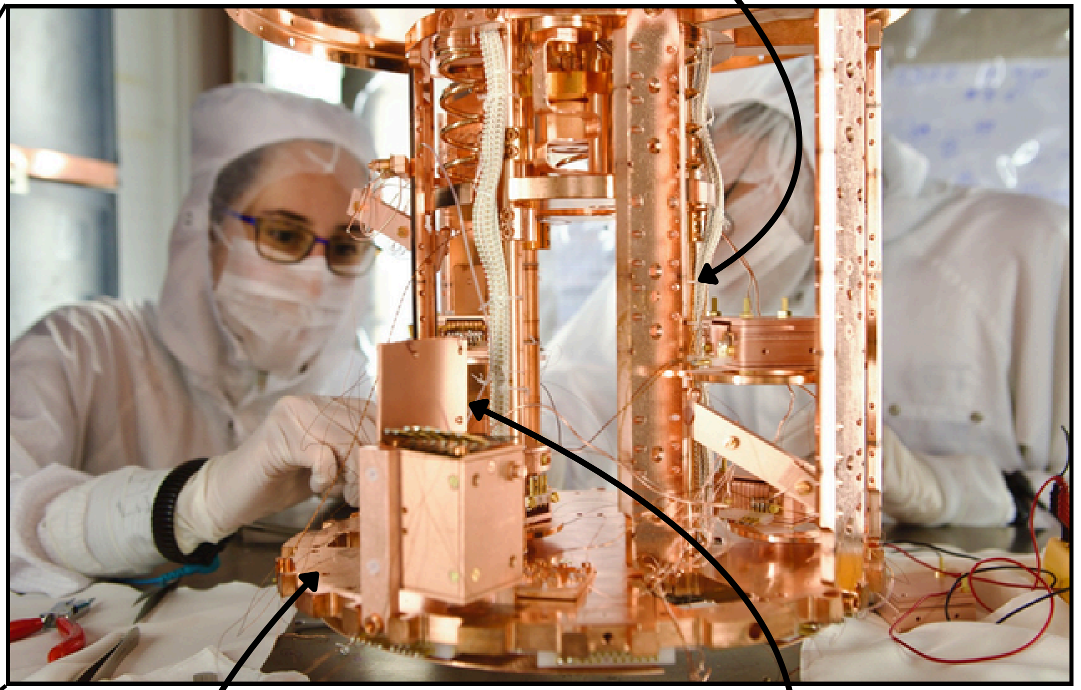
Laboratori Nazionali del Gran Sasso underground lab in Italy

→ 1400m of rock: μ flux by ~10^6

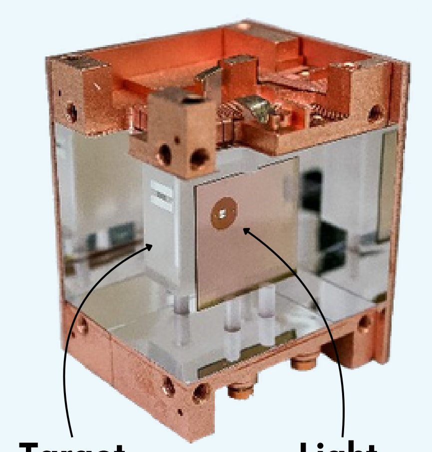
→ passive shieldings for radioactivity + active muon veto.



CAROUSEL



~mK temperature



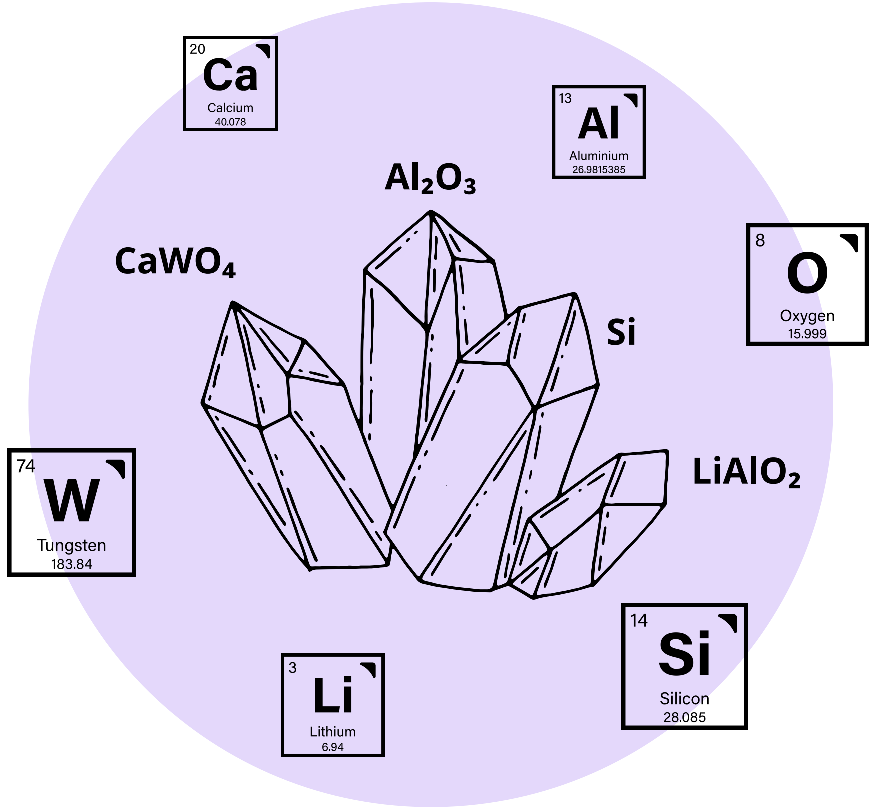
CRESST-III standard detector

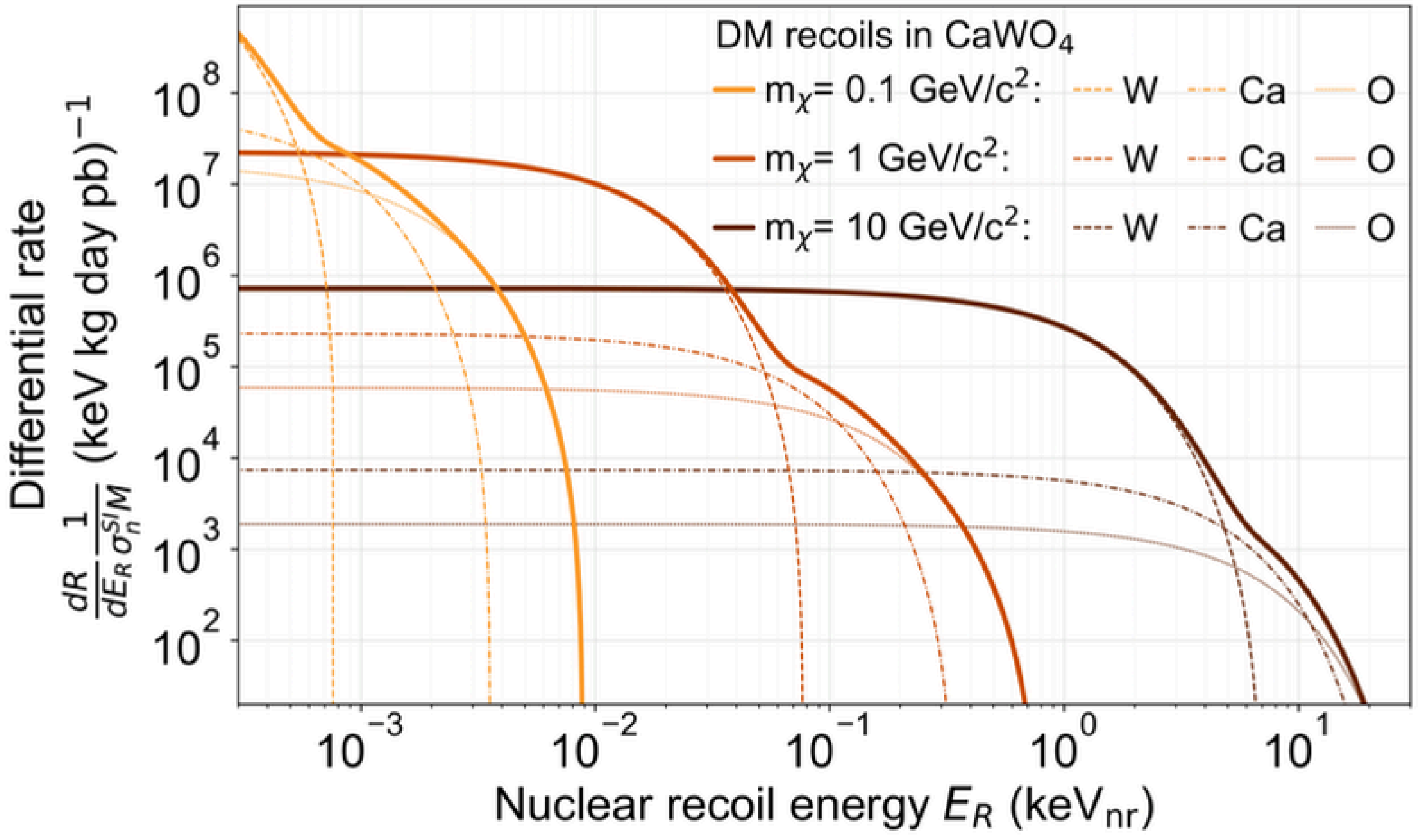
TARGET MATERIAL

$$\frac{d\sigma_{SI}}{dE_R} = \frac{m_N}{2v^2}\frac{\sigma_n}{\mu_n^2}A^2F^2(E_R)$$

$$\frac{d\sigma_{SI}}{dE_R} \propto A^2$$

Heavy nuclei are favored



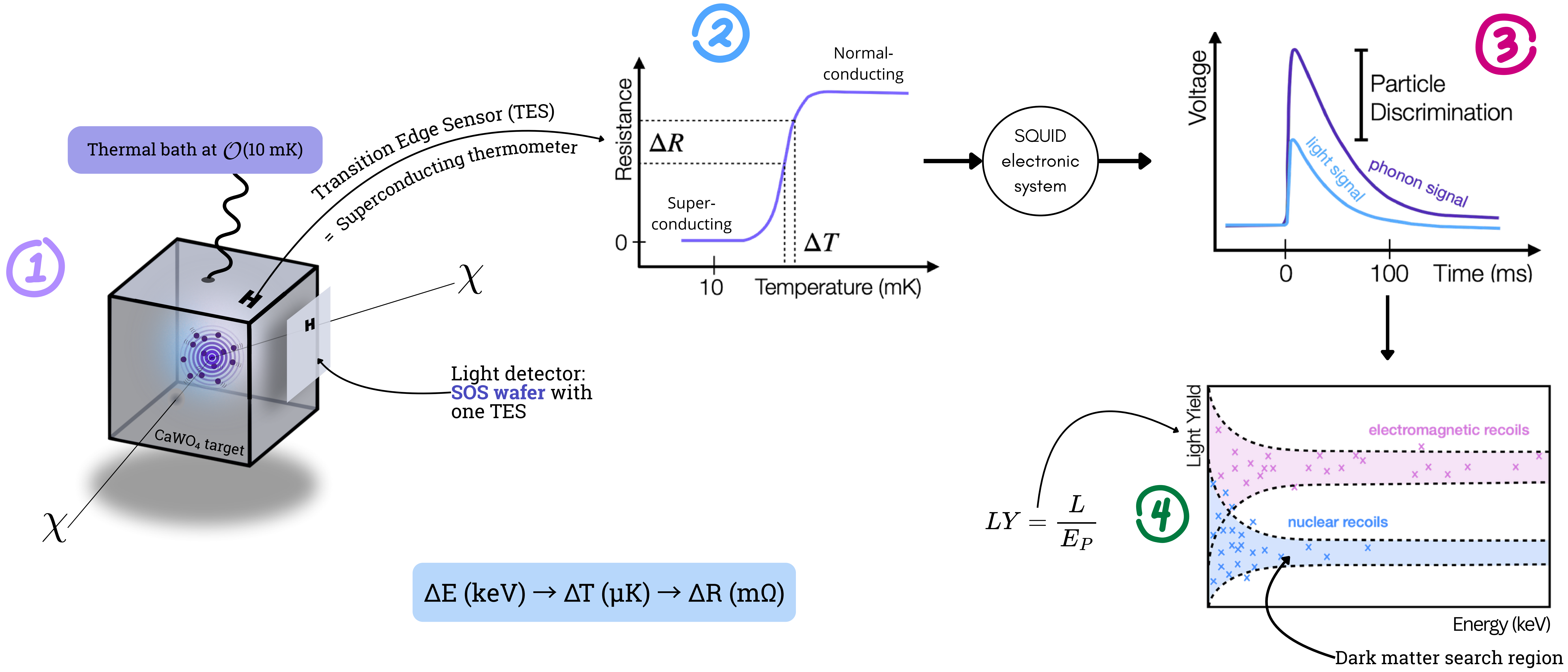


However, **light nuclei** are necessary to access low DM mass!

+

Scintillating crystals

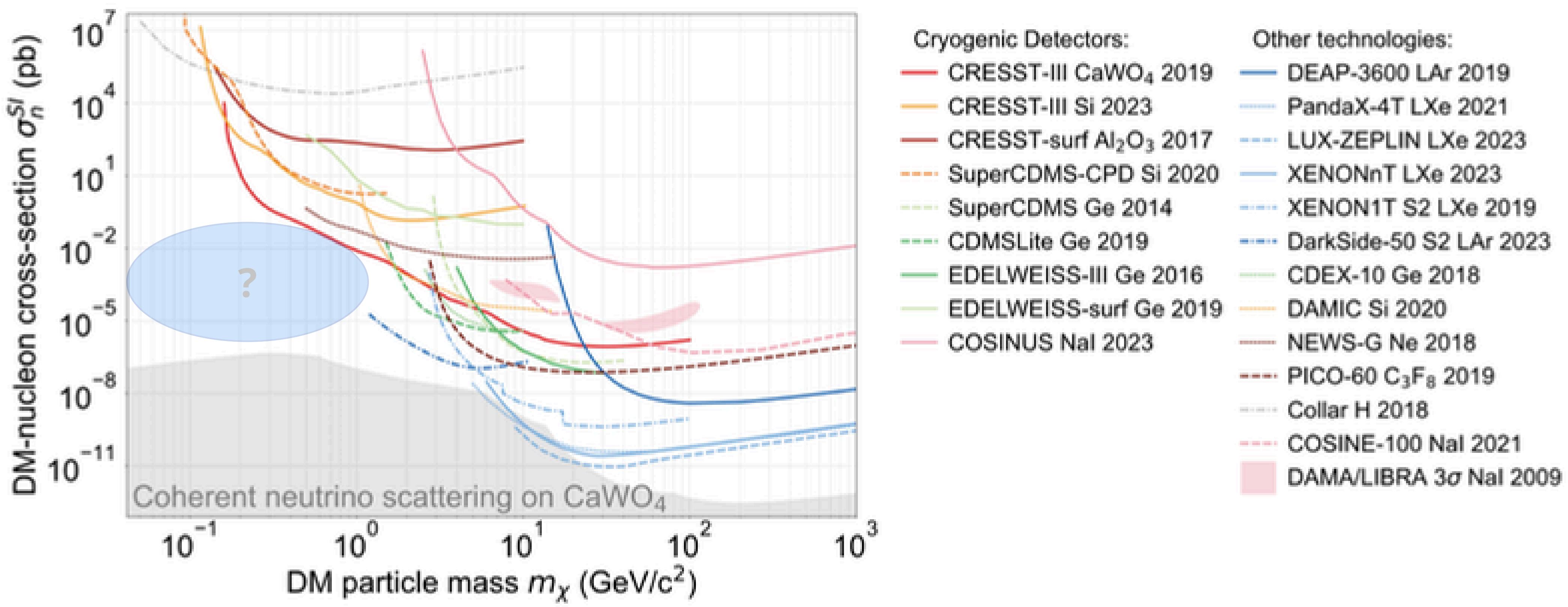
DETECTION PRINCIPLE



ΔE (keV) → ΔT (μK) → ΔR (mΩ)

CRESST SCIENTIFIC GOAL

M. Kaznacheeva and K. Schaeffner, J. Adv. Instrum. Sci. 2024, 1 (2024)



CRESST-II **CRESST-III** detectors are optimised for low mass (< few GeV) DM searches

	2012	2014	2016	2019	2024	2026
Crystal	**$CaWO_4$**	**$CaWO_4$**	**$CaWO_4$**	**$CaWO_4$**	**SOS-wafer**	
Crystal mass	m = 300 g	m = 249 g	m = 300 g	m = 24 g	m = 0.6 g	**Current run**
Energy threshold	E_{th} = 10 keV	E_{th} = 600 eV	E_{th} = 307 eV	E_{th} = 30.1 eV	E_{th} = 6.7 eV	

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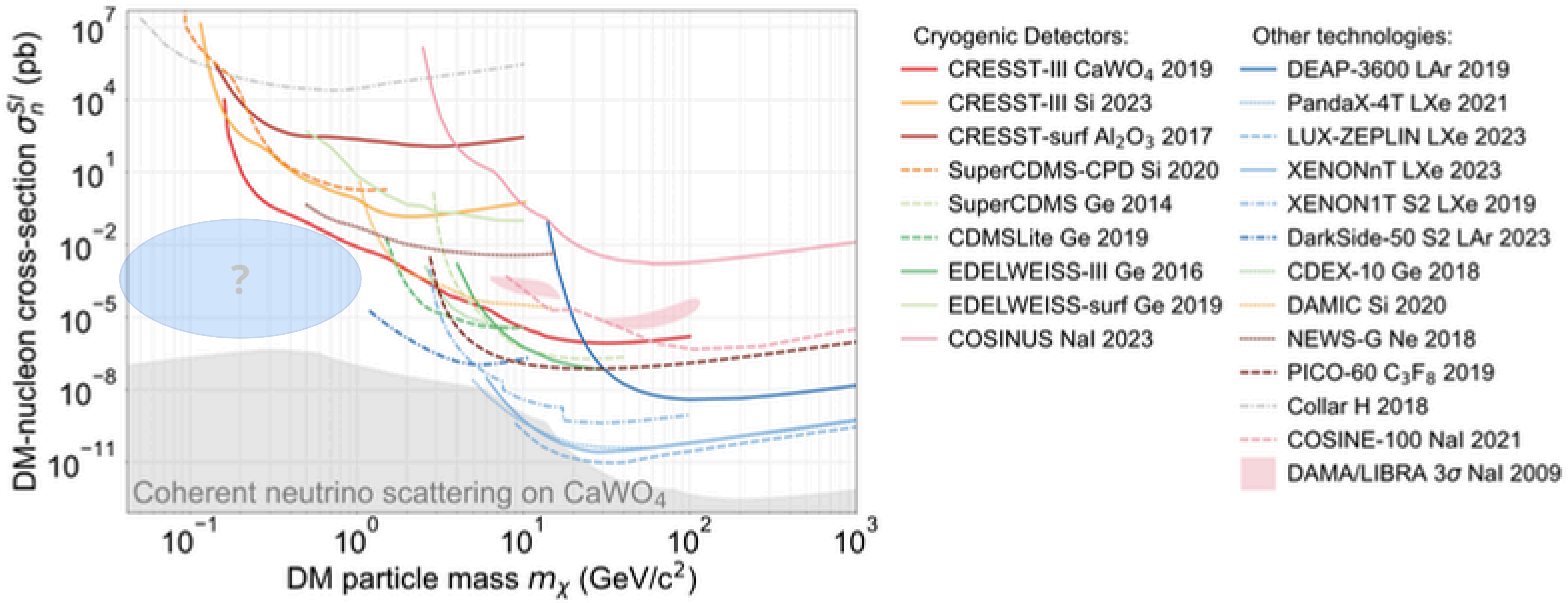

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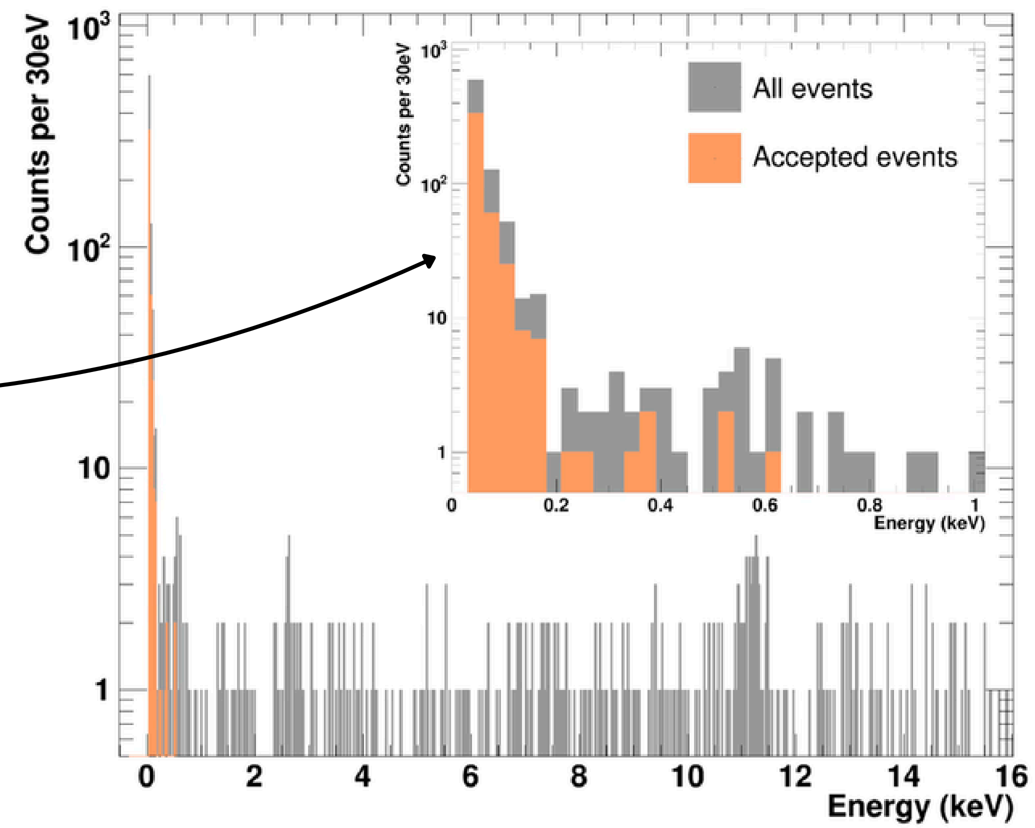
Something showed up in the data here...

THE LOW-ENERGY EXCESS

The **Low Energy Excess** is a rise in event rate looking like particle events below 200 eV.

CRESST sensitivity is limited because of the presence of the low-energy excess

CRESST first observation of LEE in 2019



Phys. Rev. D 100, 102002

→ Decay with time and repopulated with thermal cycles.
→ Rate and spectral shape variation among detector modules
→ Dark matter origin or external radioactivity is excluded

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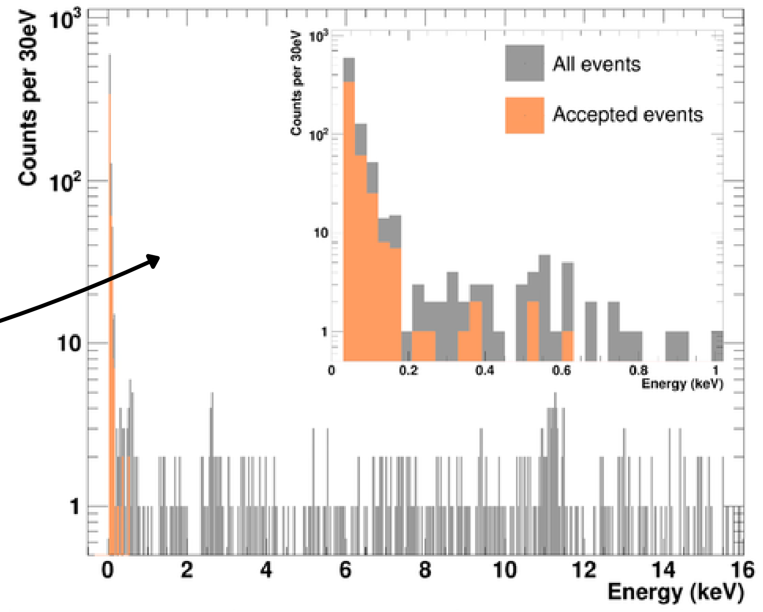

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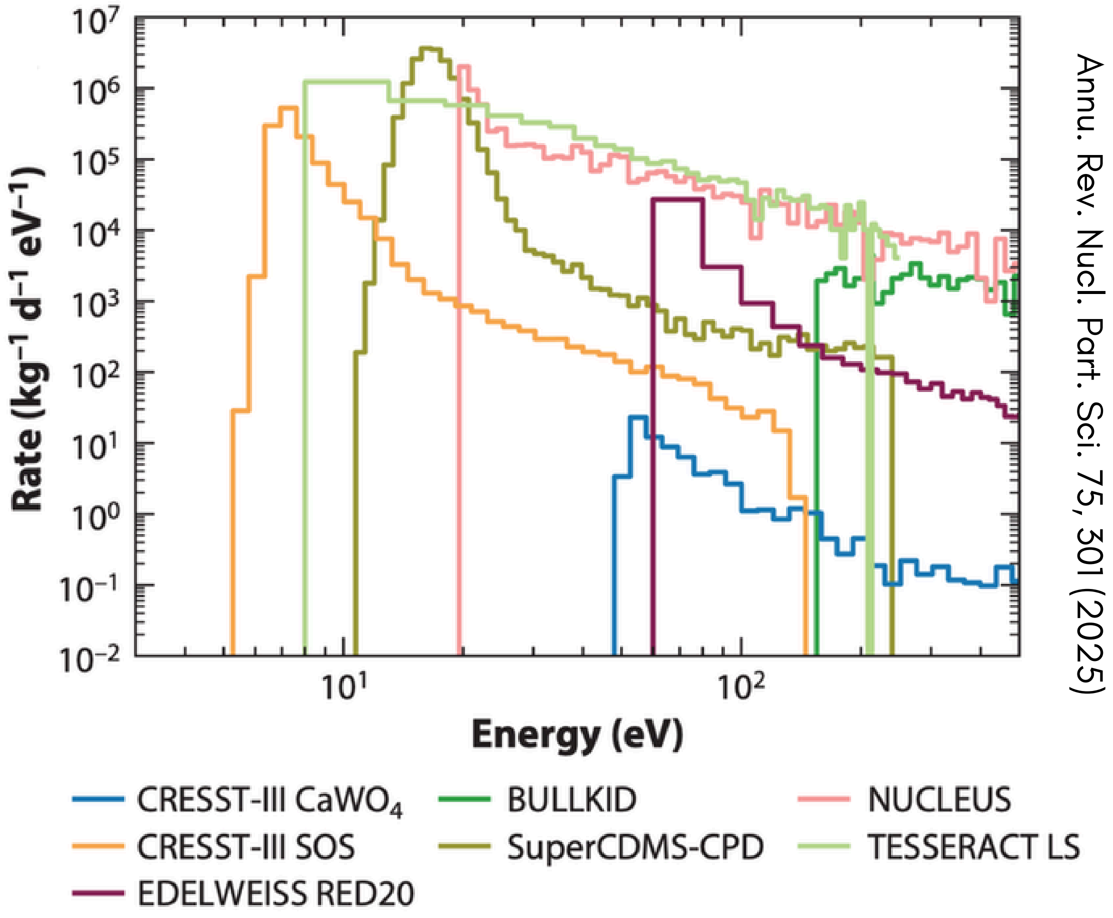


Annu. Rev. Nucl. Part. Sci. 75, 301 (2025)

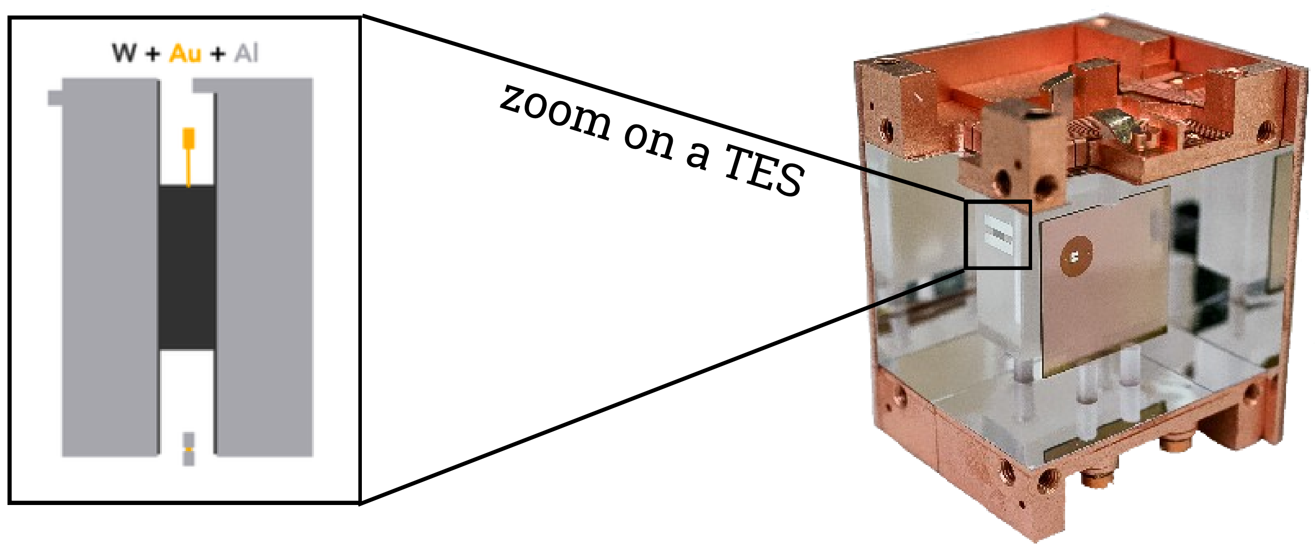
→ Observed by different collaborations: SuperCDMS, Nucleus, EDELWEISS, ...
→ 2021: own dedicated workshop @EXCESS.
→ Edition 2026: 14 different collaborations.

THE LOW-ENERGY EXCESS

Hypothesis

A part of LEE events could come from a **stress release at the interface** of the crystal and the TES, or within the TES itself, while **real particle events** are generated in the **bulk**.

→ We need to **discriminate bulk events** from **interface** events.



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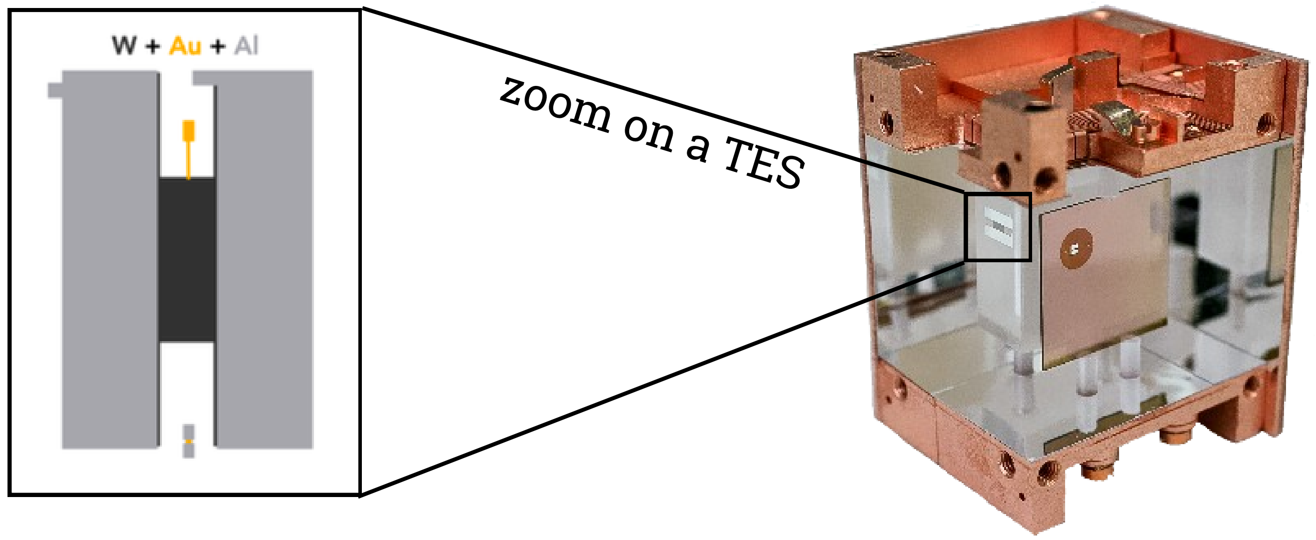
Proposition

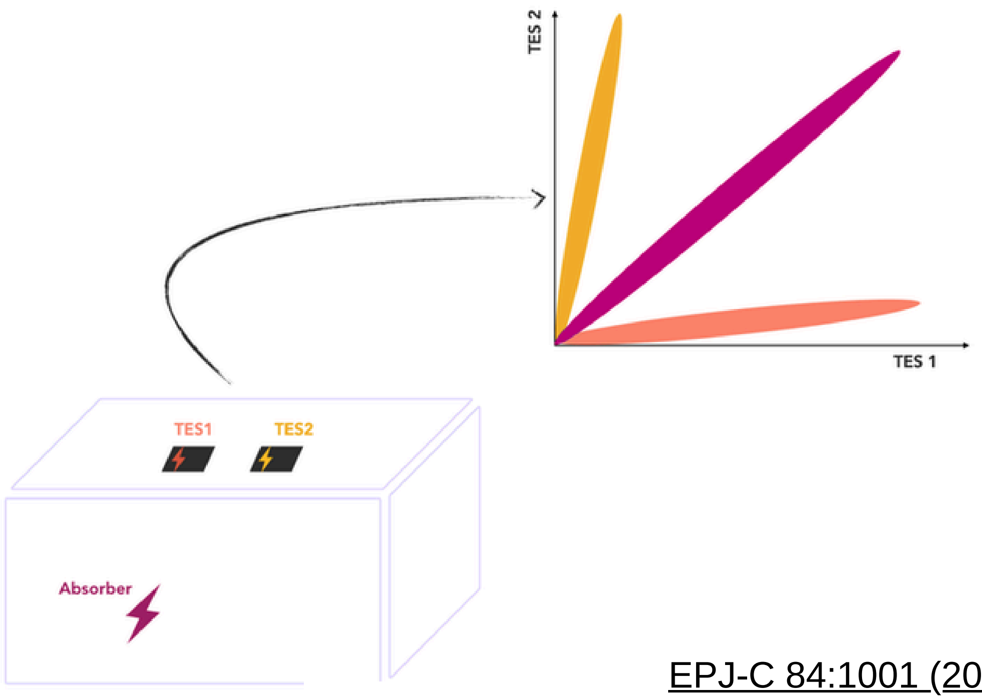
Separate bulk from interface events using a **second TES** on the crystal.

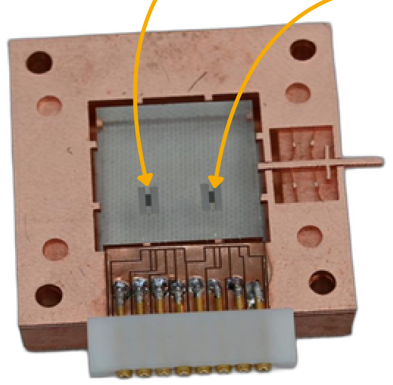


DOUBLE-TES DETECTORS

New detector design

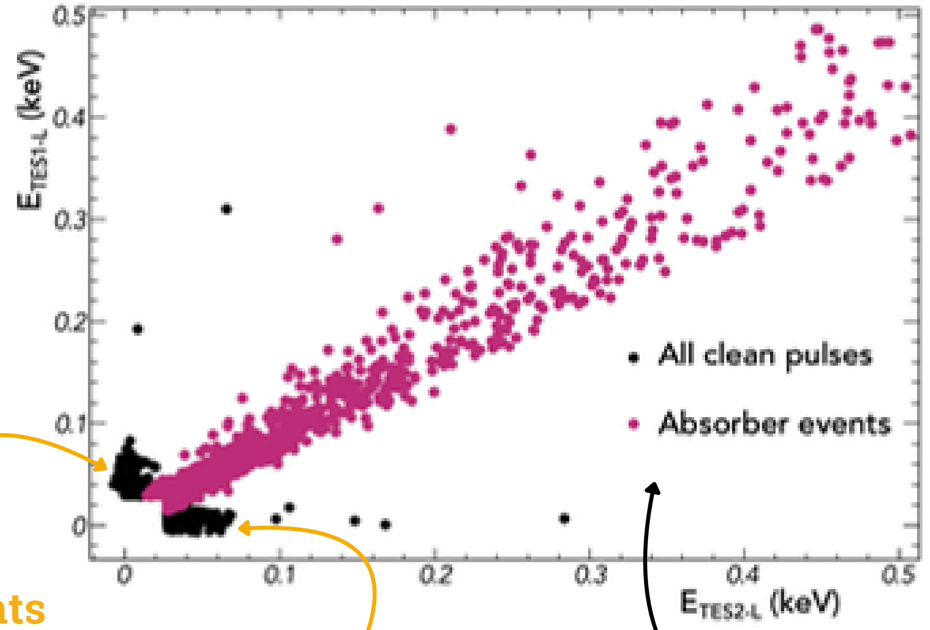
Above ground measurement





20x20x10 mm³ $CaWO_4$ target	
New gravity-assisted stress free holding	
m = 24 g	
Baseline resolution TES1 = (27.1 ± 0.3) eV	Baseline resolution TES2 = (29.6 ± 0.3) eV

EPJ-C 84:1001 (2024)



Single events of TES1

Single events of TES2

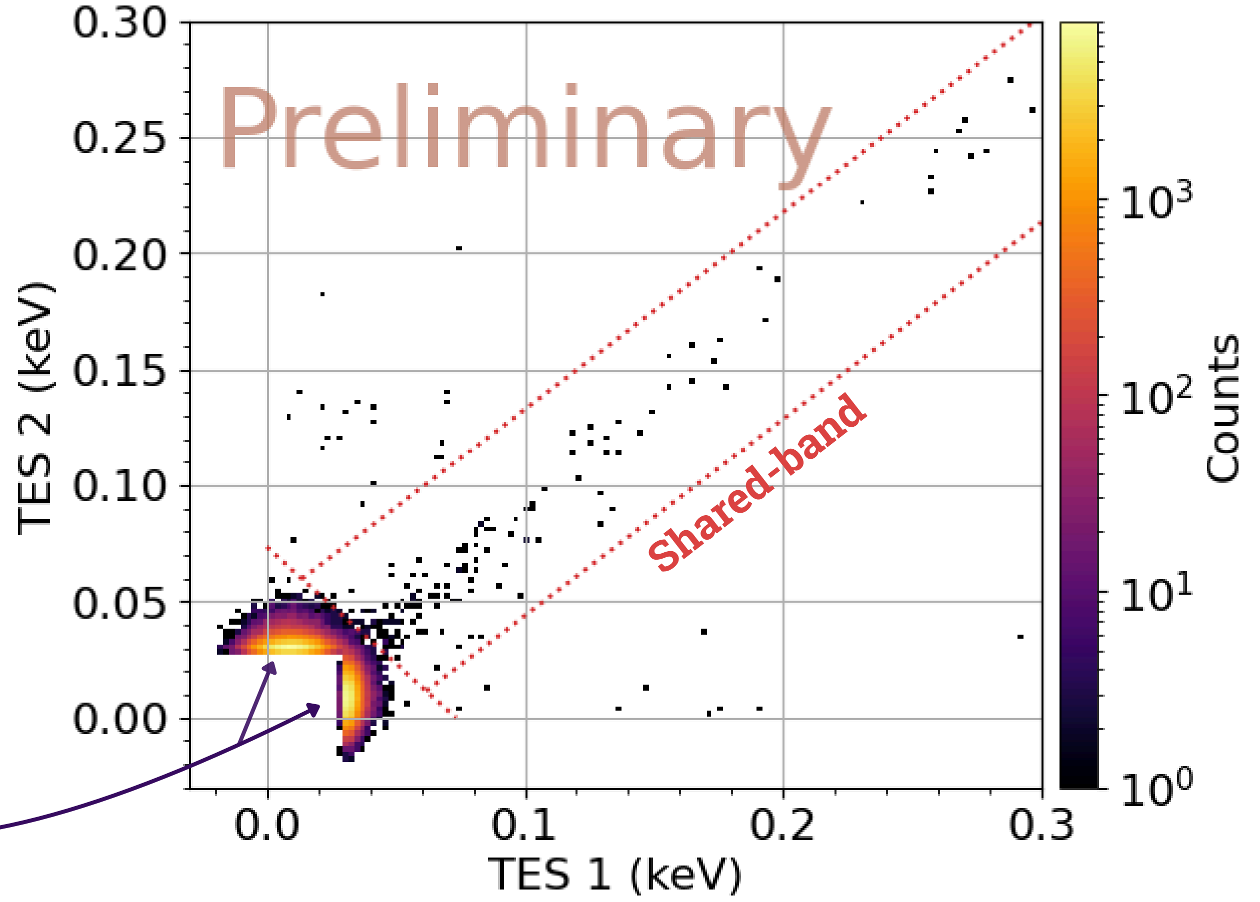
Particle events in the bulk → propagate to the two TESs
→ **shared band event**

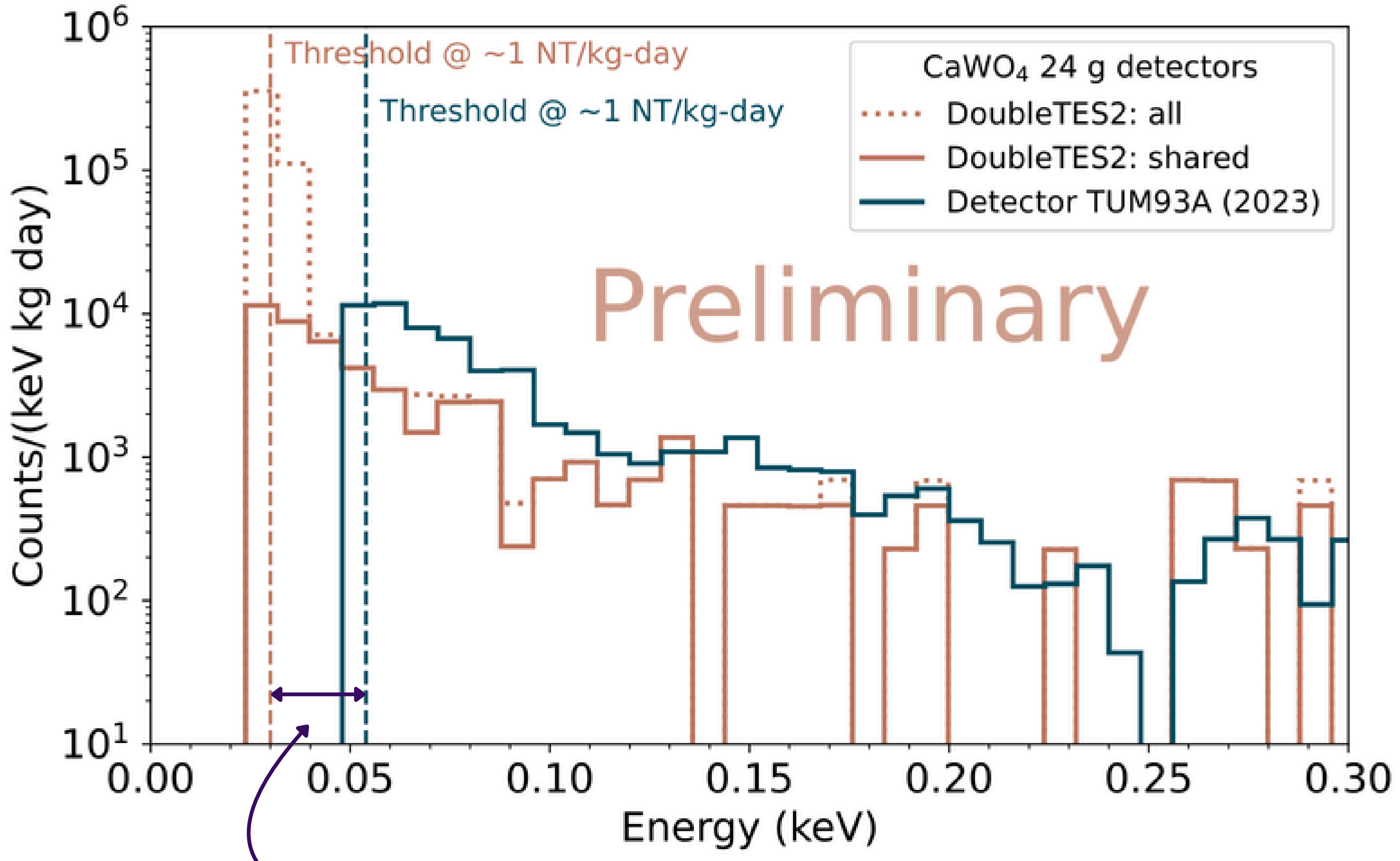
interface events should propagate to one TESs only
→ **single events**

This first above-ground measurement demonstrates the **double-TES ability to discriminate between bulk and surface events.**

DOUBLE-TES DETECTORS: LATEST RESULTS

Energy threshold of 35 eV





Threshold improvement

→ Clear separation of single and double TES events.

→ BUT two different LEE population: a shared and a single TES component

→ Needs more investigation

Double-TES2
20x20x10 mm³ $CaWO_4$ target
m = 24 g
Baseline resolution of both **TES ~ 7 eV**

→ Significantly lower threshold with double TES

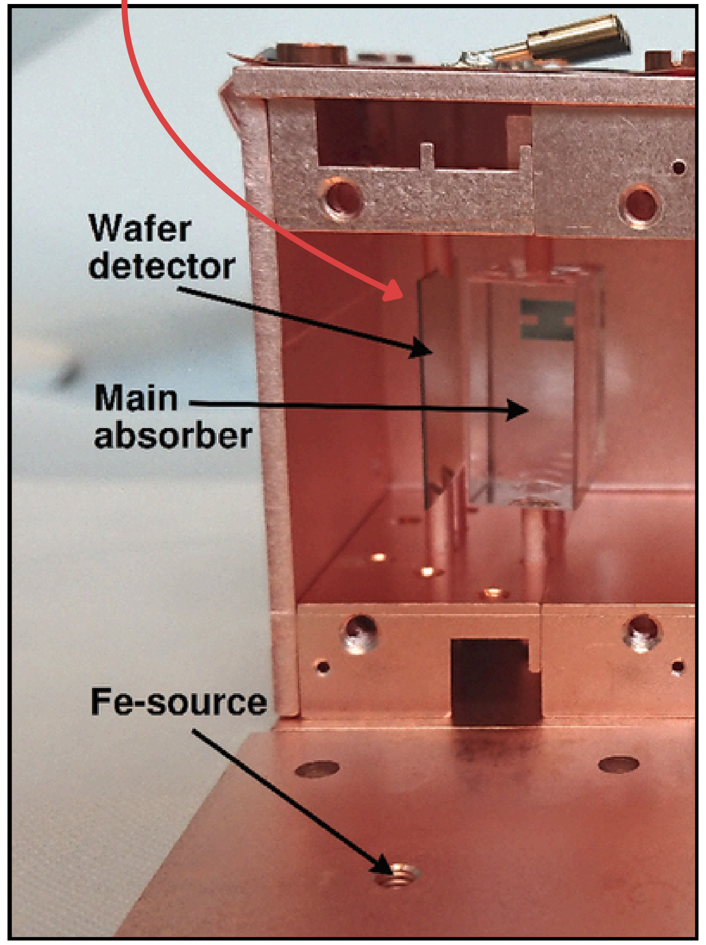
→ Currently collecting blind data for new dark matter analysis!

MORE DARK MATTER RESULTS

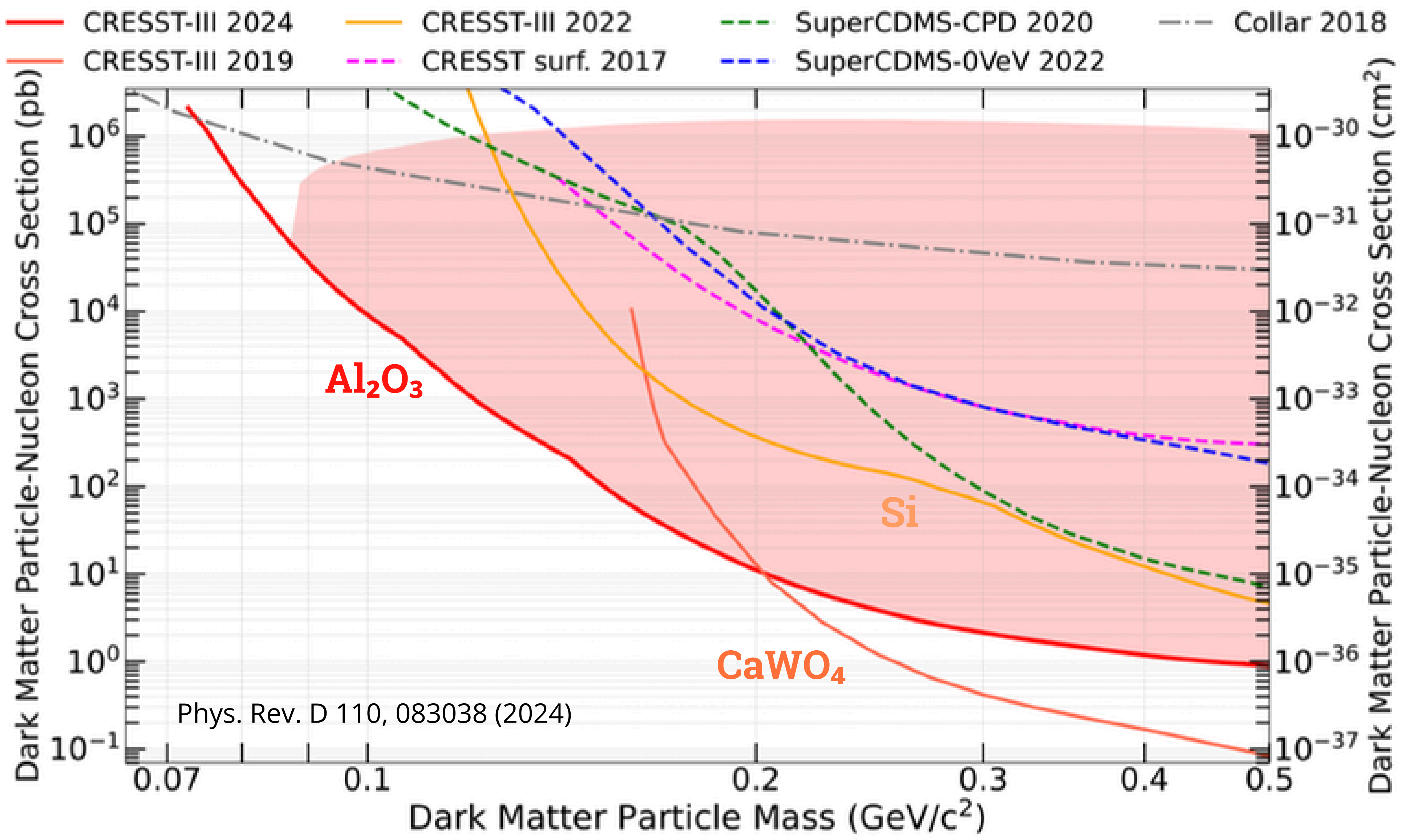
Light detector used as a target

Al_2O_3 target
m = 0.6 g
Energy threshold = 6.7 eV

Incredibly low threshold



Spin-independent interactions

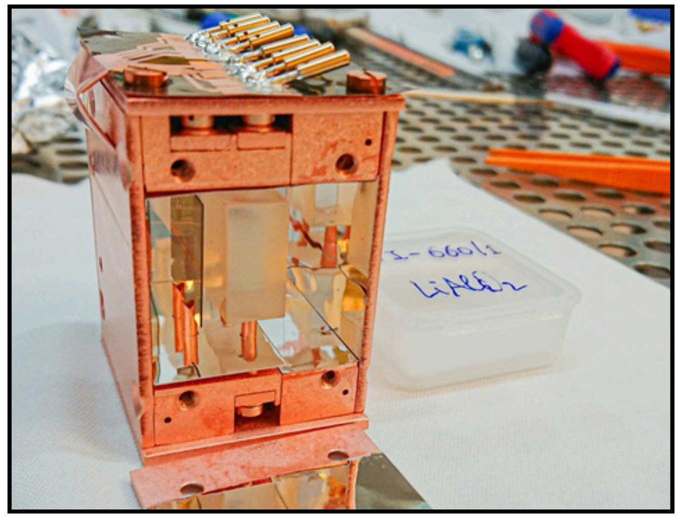


Data campaign: Nov 2020 – Aug 2021

MORE DARK MATTER RESULTS

Phys. Rev. D 106, 092008 (2022)

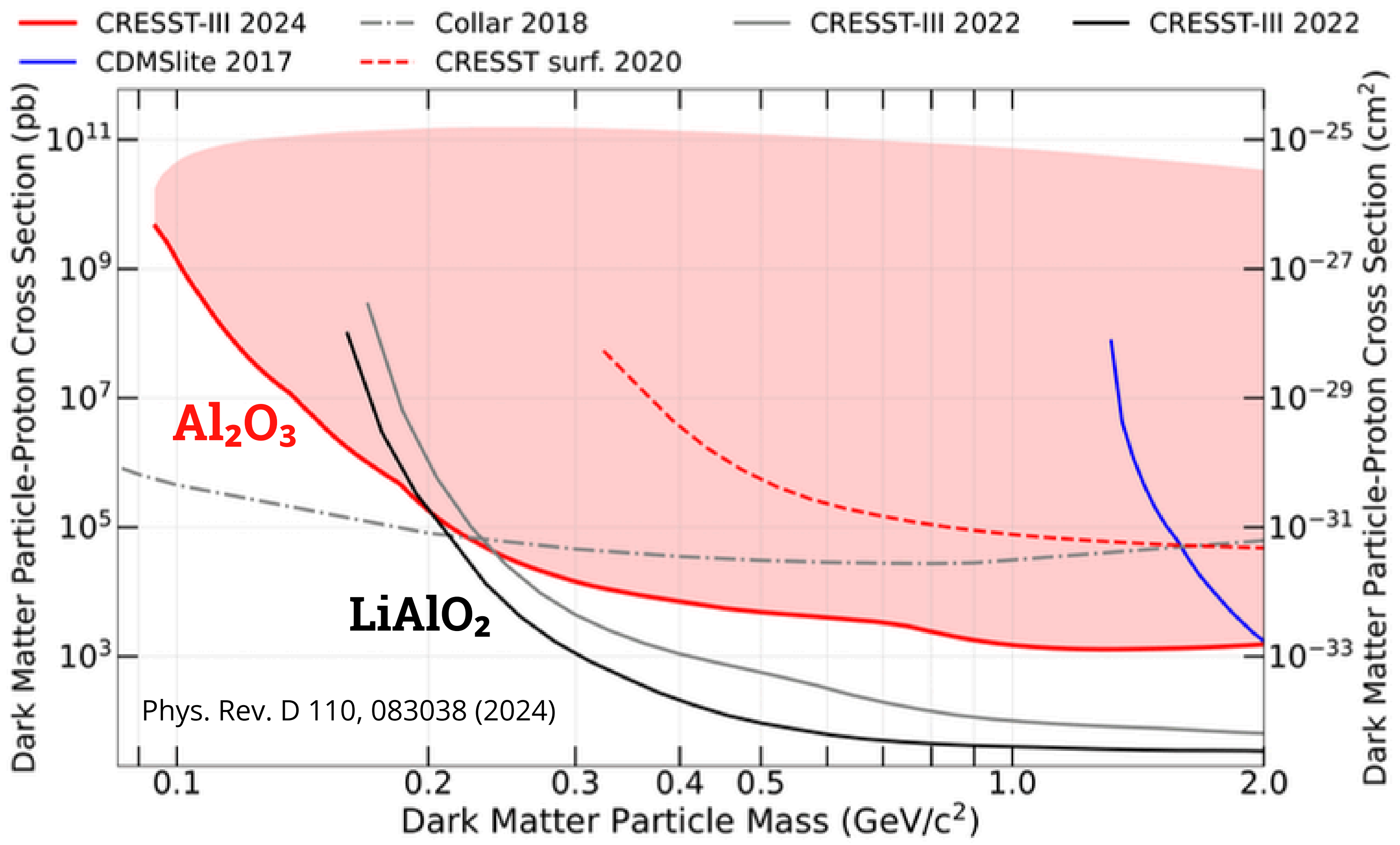
$LiAlO_2$
m = 11.2 g
Energy threshold = 83.6 eV

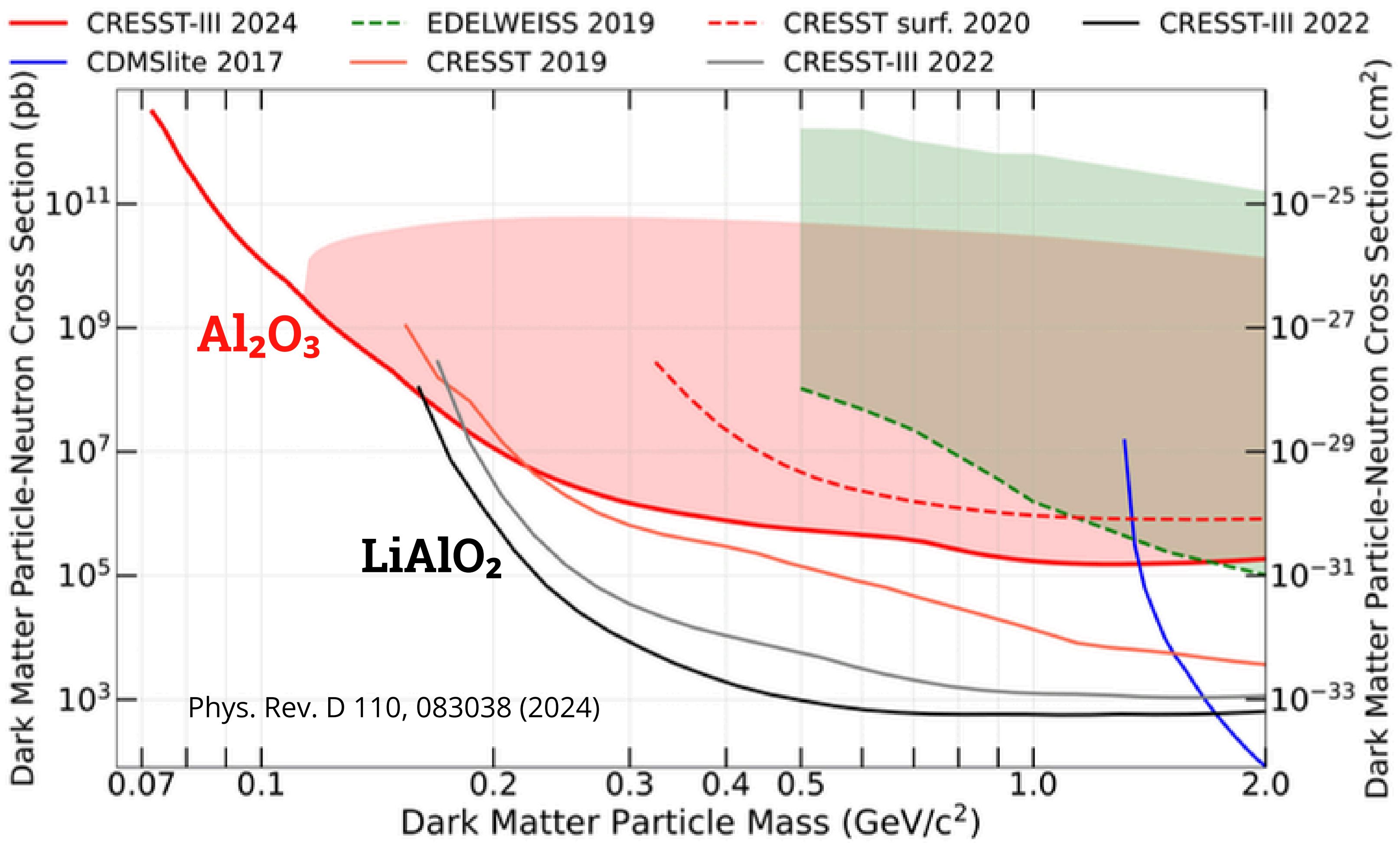


Spin-dependent interactions

Proton

Neutron





$LiAlO_2$ data taken from February and August 2021

CONCLUSION

- CRESST **energy thresholds** allow for deep exploration of **light DM mass** region below 1 GeV. **Blind data** taking is ongoing!

- **Double-TES** feature is a powerful tool to **reduce the LEE** while **pushing** the detector **threshold** to **lower** energies.

- The capability to adapt the technology to **multiple target crystals** allows the investigation of both **spin-dependent** and **spin-independent** interactions

CRESST
Cryogenic **Rare Event Search**
with Superconducting Thermometers

THANK YOU FOR YOUR ATTENTION!

The CRESST collaboration

TU WIEN
TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

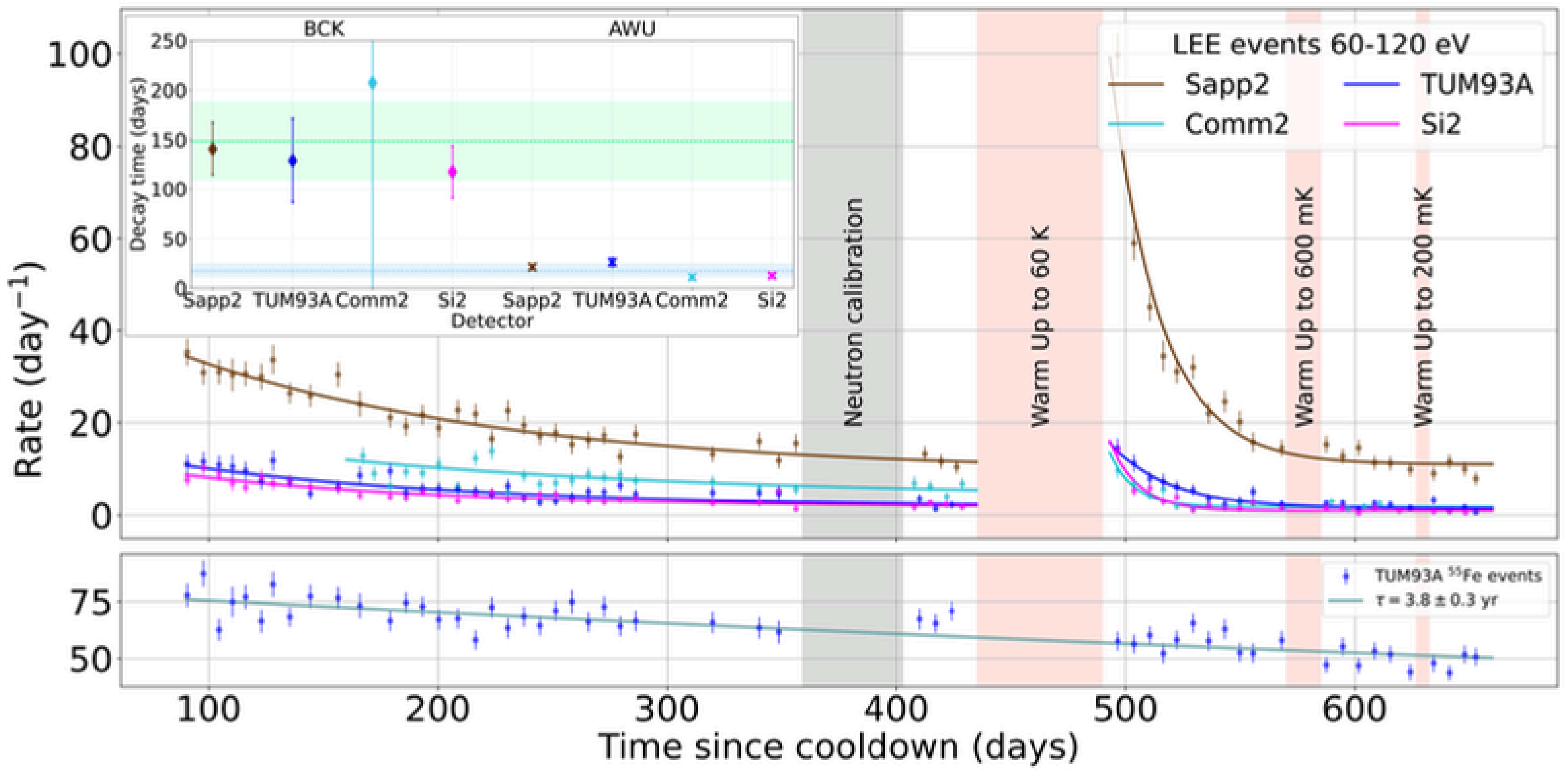
ÖAW

MBI

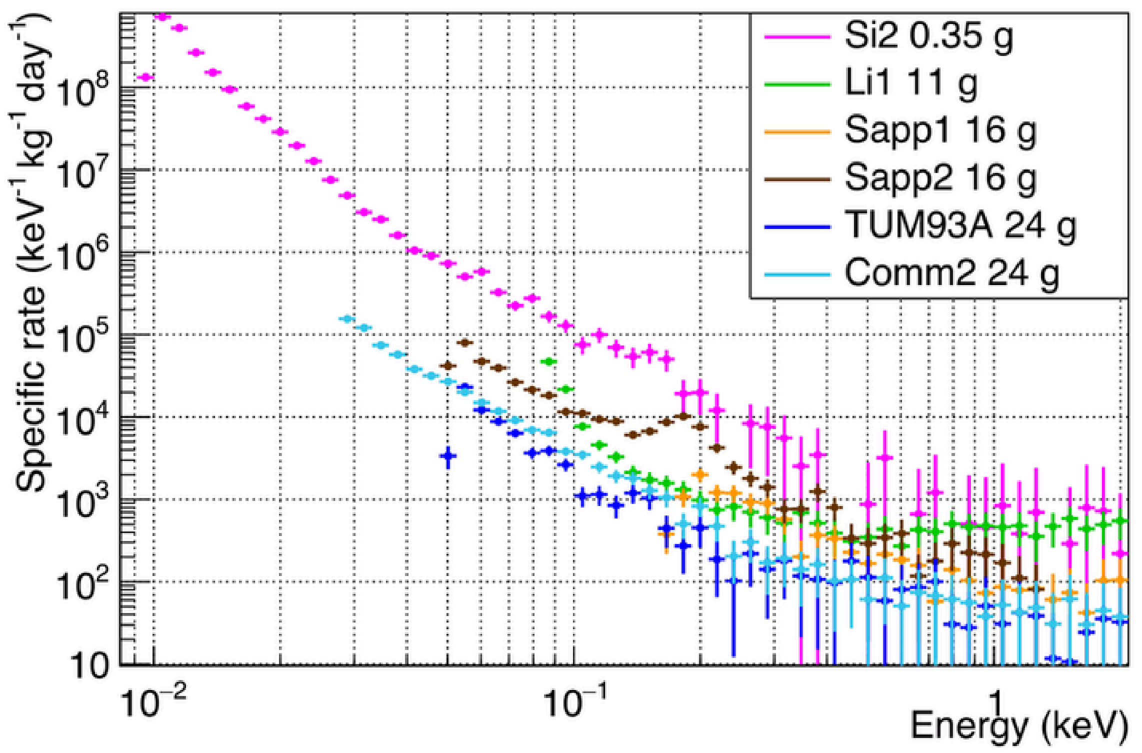
BACK-UP SLIDES

LOW ENERGY EXCESS

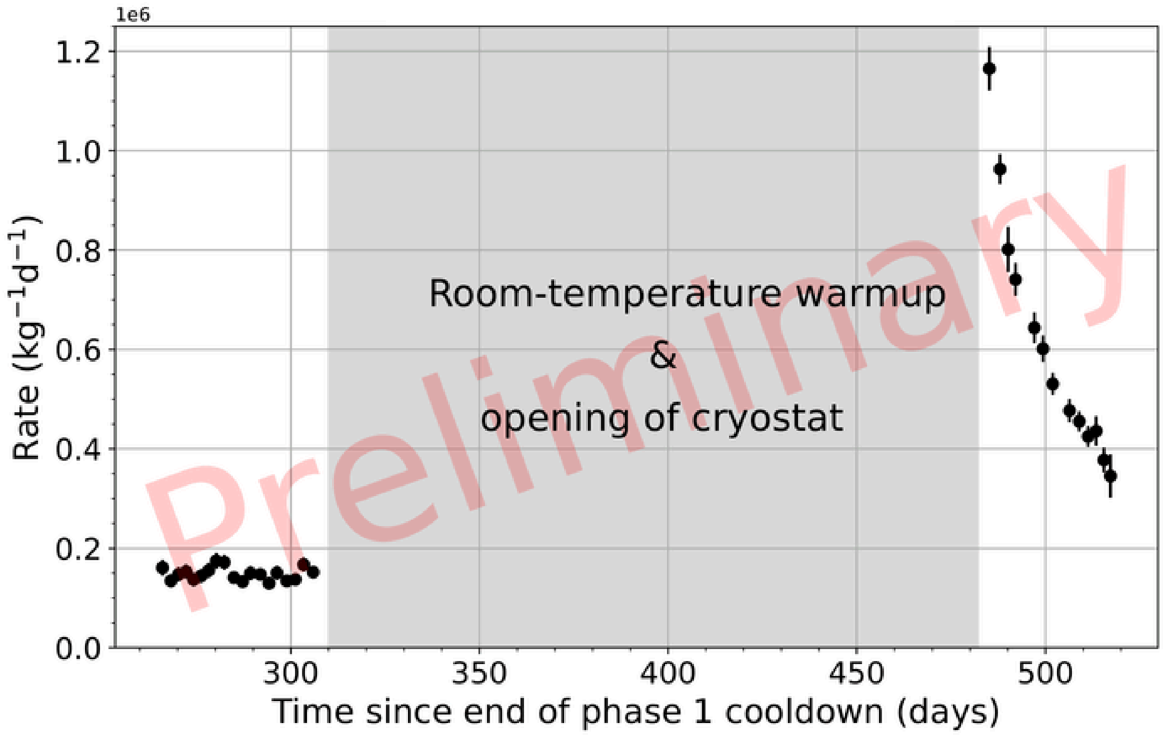
Time dependency of the LEE measured by CRESST

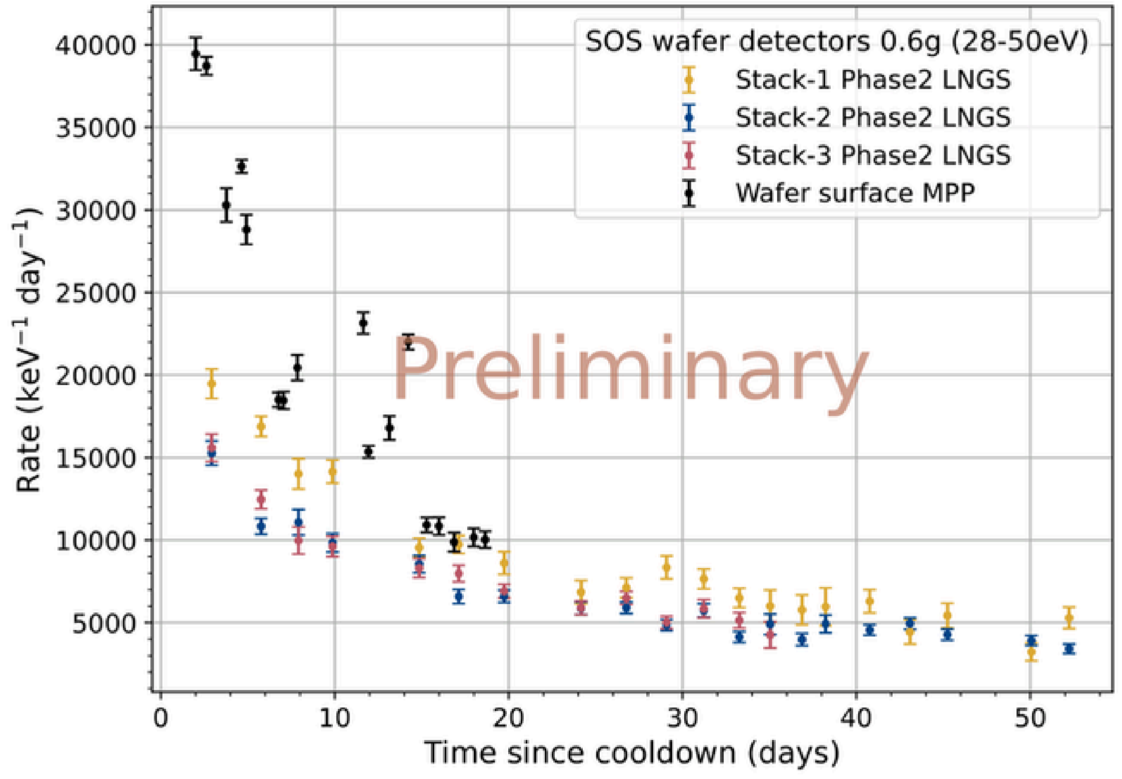


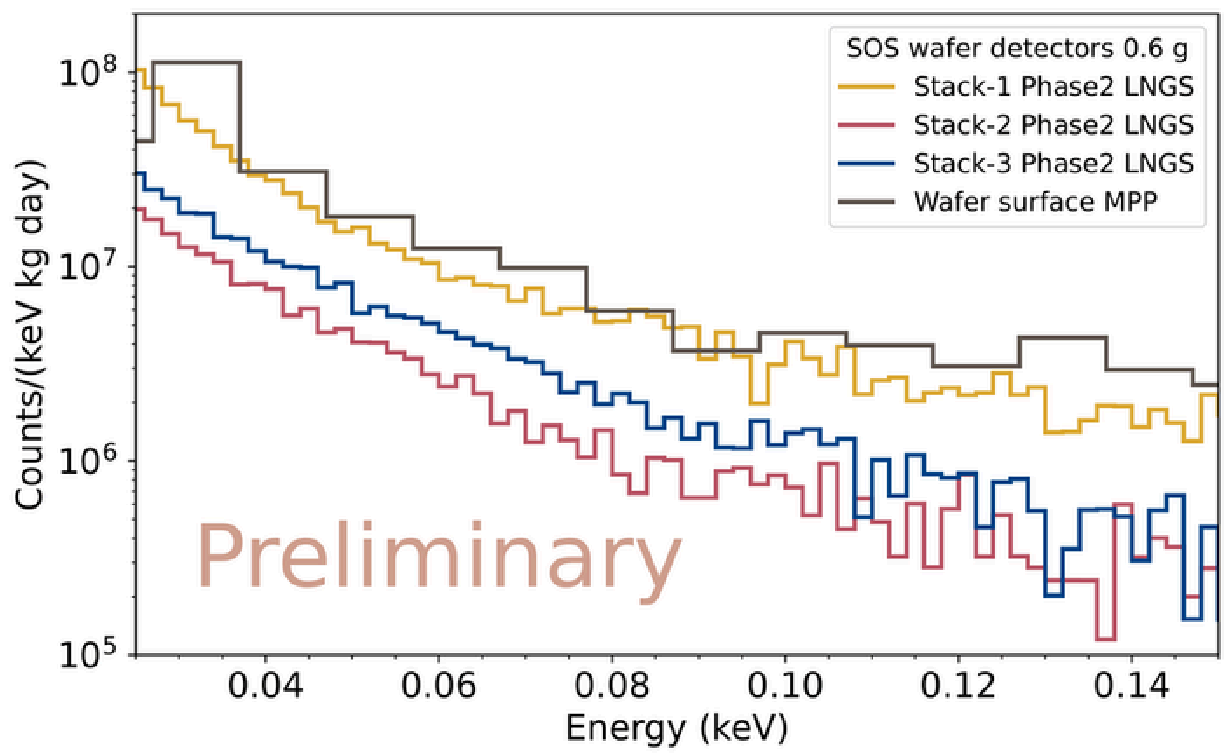
Rate of the LEE measured by CRESST



SciPost Phys. Proc. 12, 013 (2023)







SPIN-DEPENDENT, SPIN-INDEPENDENT

A. Spin-independent interactions

(a) *Recoil rate:* the differential recoil rate of spin-independent elastic DM-nucleus interactions is expressed as [29]:

$$\frac{\mathrm{d}R_\chi}{\mathrm{d}E_\mathrm{R}} = \sum_T f_T N_T \frac{\rho_\chi}{m_\chi} \frac{m_T}{2\mu_\mathrm{N}^2} A^2 \sigma_\mathrm{N} F^2(q) \mathcal{I}(v_\mathrm{min}) \quad (2)$$

$$\sigma_0 = \sigma_\mathrm{N} \cdot A^2 \cdot \frac{\mu_T^2}{\mu_\mathrm{N}^2}$$

B. Spin-dependent interactions

(a) *Recoil rate:* the differential recoil rate of spin-dependent interactions of DM with protons/neutrons only, denoted as p/n, is expressed as [29]:

$$\frac{\mathrm{d}R_\chi}{\mathrm{d}E_\mathrm{R}} = \sum_T f_T N_T \frac{\rho_\chi}{m_\chi} 2m_T \frac{(J_T+1)}{3J_T} \frac{\langle S_{\mathrm{p/n},T} \rangle^2}{\mu_{\mathrm{p/n}}^2} \sigma_{\mathrm{p/n}} \mathcal{I}(v_\mathrm{min})$$

$$\sigma_0 = \frac{4}{3} \cdot \frac{\mu_T^2}{\mu_{\mathrm{p/n}}^2} \sigma_{\mathrm{p/n}} \cdot \frac{J_T + 1}{J_T} \cdot \langle S_{\mathrm{p/n},T} \rangle^2$$