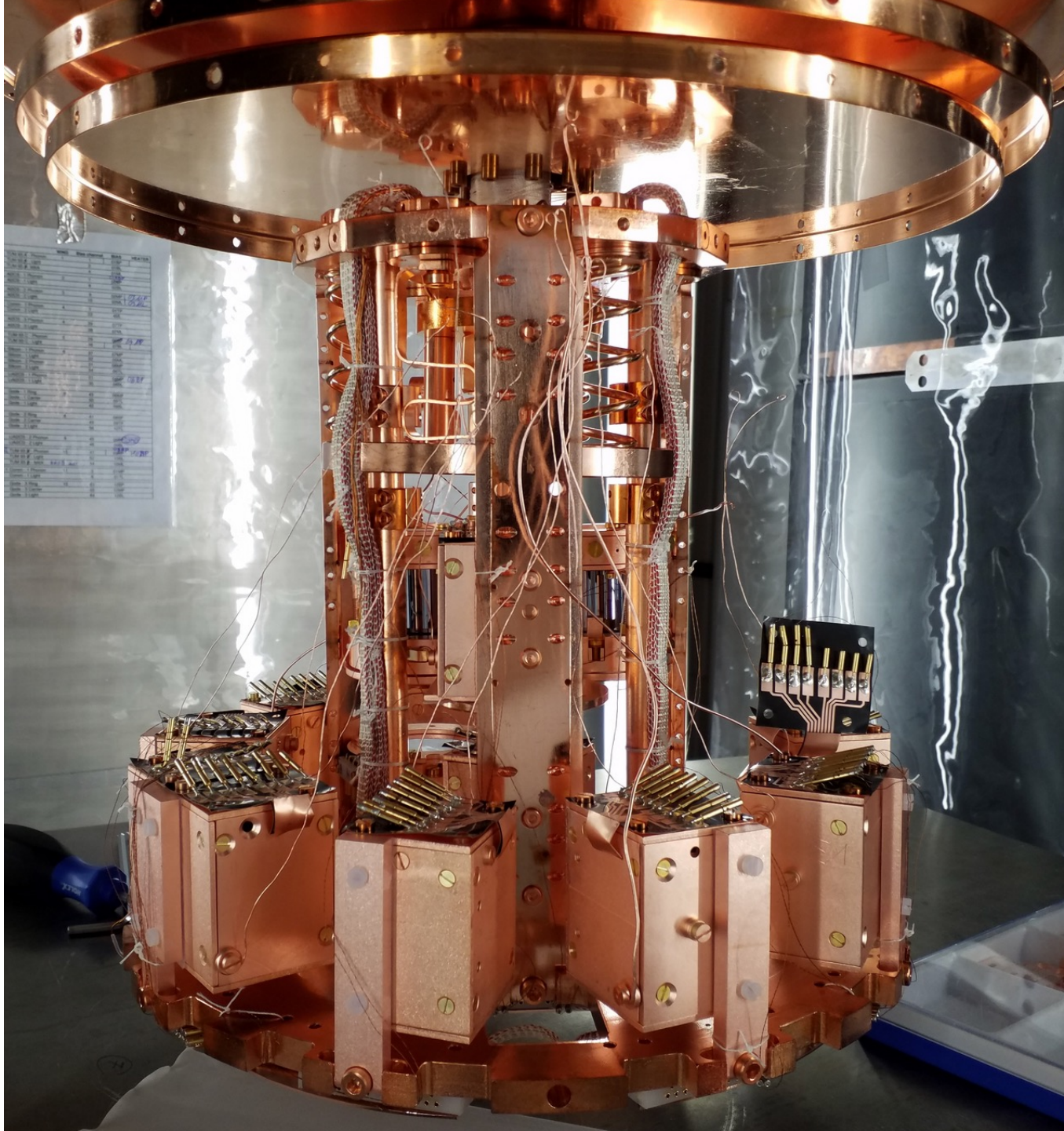
CRESST

Cryogenic **Rare Event Search**
with Superconducting Thermometers

The CRESST-III Dark Matter Search: Status and Outlook

Angelina Kinast
on behalf of the CRESST collaboration

angelina.kinast@tum.de



The CRESST collaboration

CRESST

Cryogenic **Rare Event Search**
with Superconducting Thermometers

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

MAX-PLANCK-INSTITUT FÜR PHYSIK

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

UNIVERSITAS COMENIANA BRATISLAVENSIS

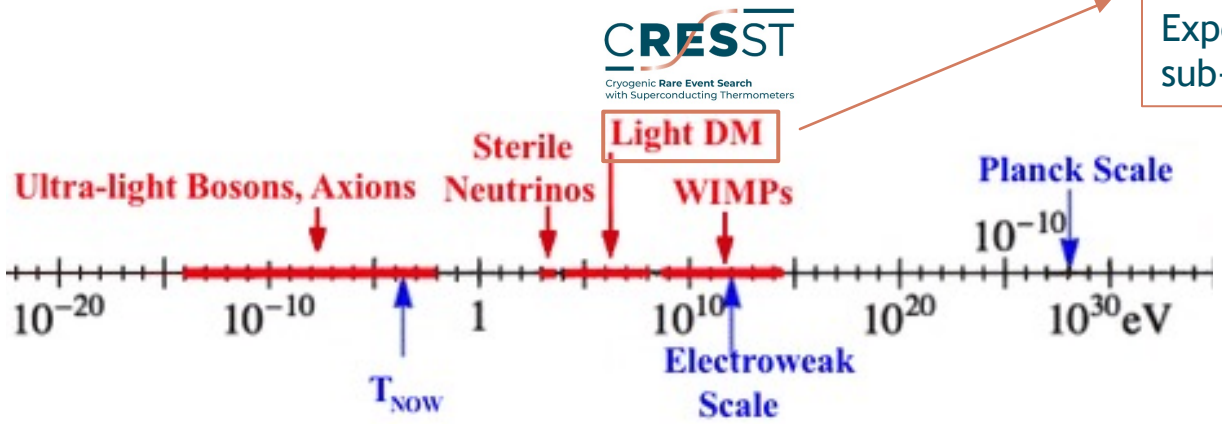
TU WIEN

UNIVERSITY OF OXFORD

HEPHY
INSTITUTE OF HIGH ENERGY PHYSICS

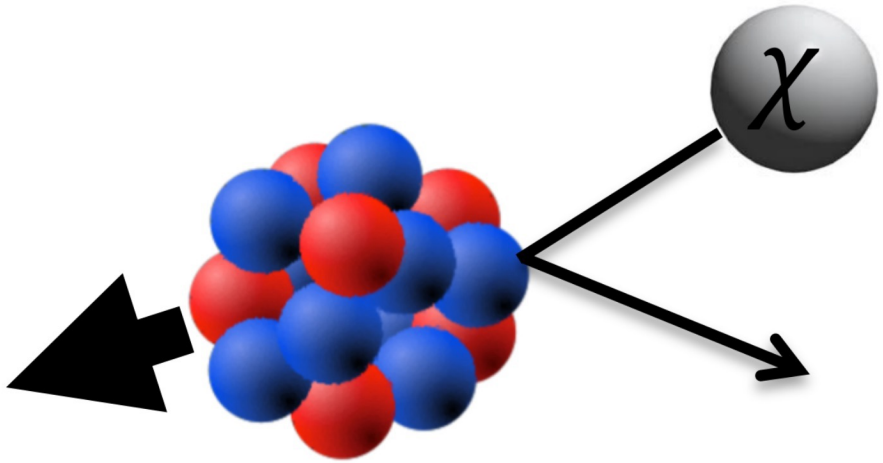
Dark Matter (DM) particle candidates

Cryogenic **Rare Event Search** with Superconducting Thermometers



Tuesday session:
Francisco Vazquez de Sola
Experimental Searches for sub-GeV Dark Matter

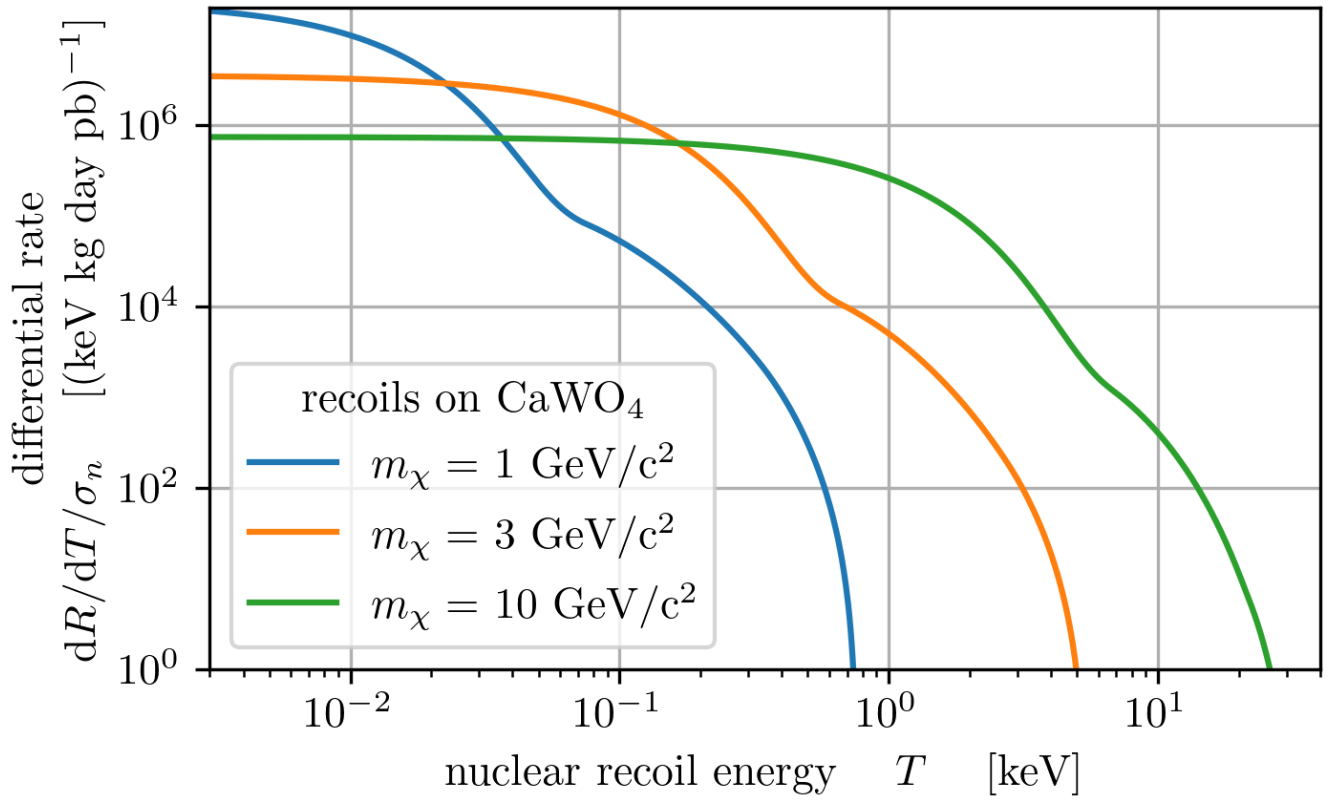
CRESST is looking for elastic recoil of light DM (sub-GeV) particles



Challenges for light DM search

Cryogenic **Rare Event Search** with Superconducting Thermometers

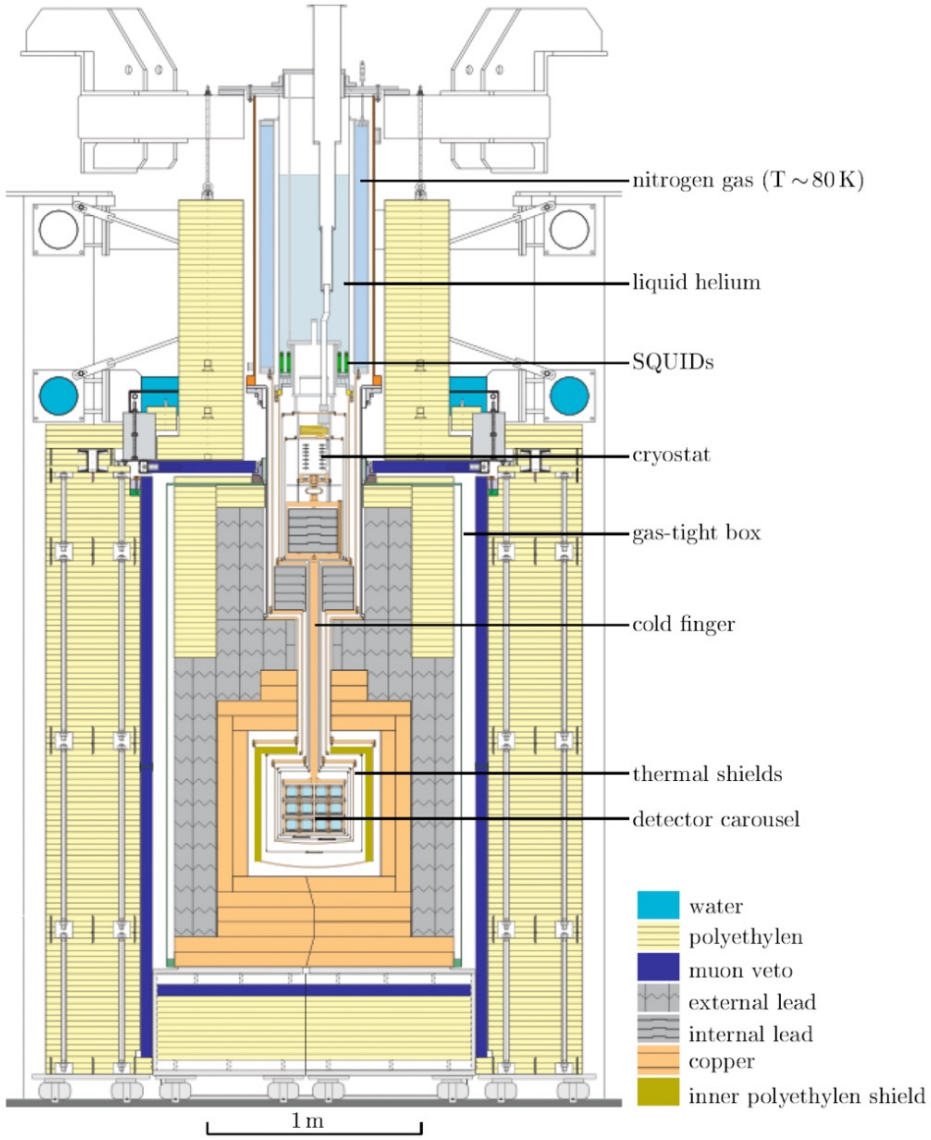
Recoil-spectra of $CaWO_4$ for different DM masses

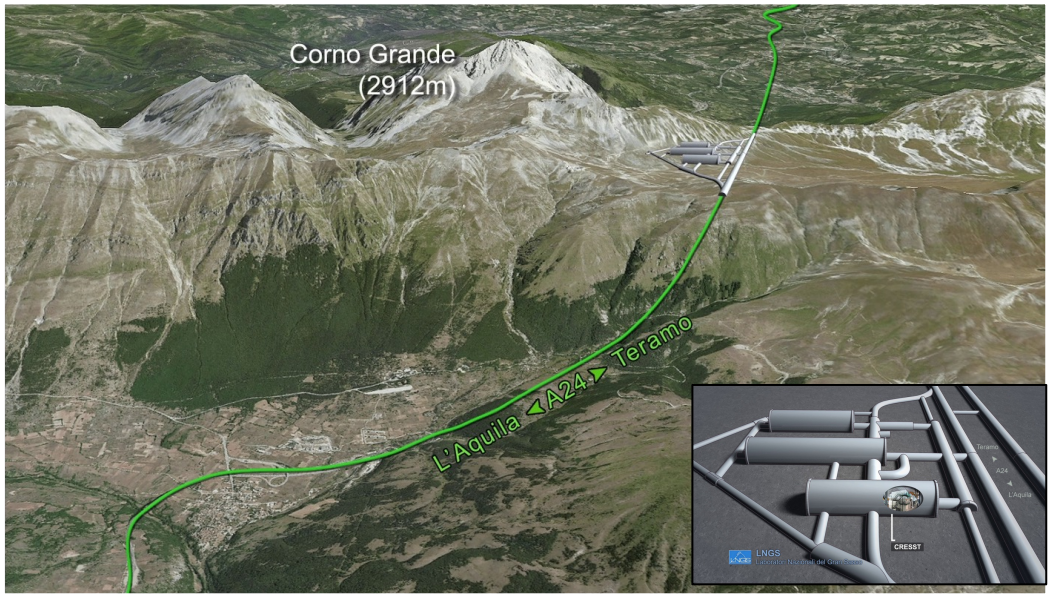


J. Rothe (2020), *Low-Threshold Cryogenic Detectors for Low-Mass Dark Matter Search and Coherent Neutrino Scattering,* http://mediatum.ub.tum.de/?id=1576351

- Small recoil energies → thresholds O(100eV)
- Low expected rate → low background

Background reduction





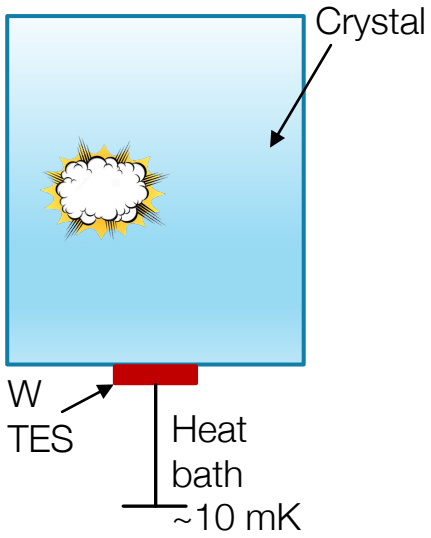
Shielding:
- 3600 m. w. e. of rock
- polyethylene / lead / copper

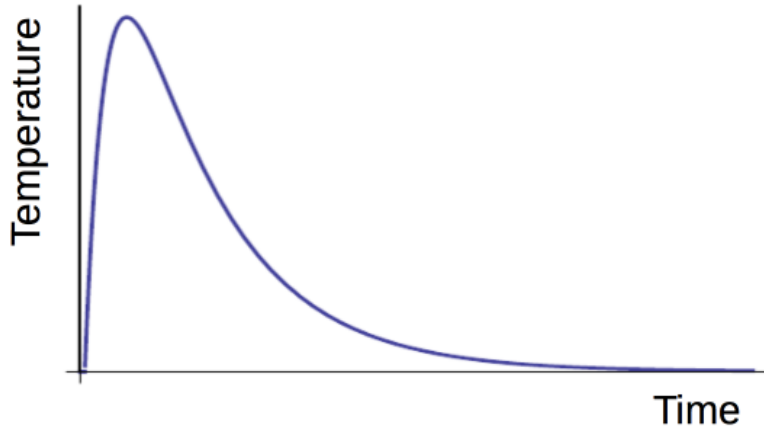
Specially selected target materials (High-purity $CaWO_4$ crystals grown in-house at TUM)

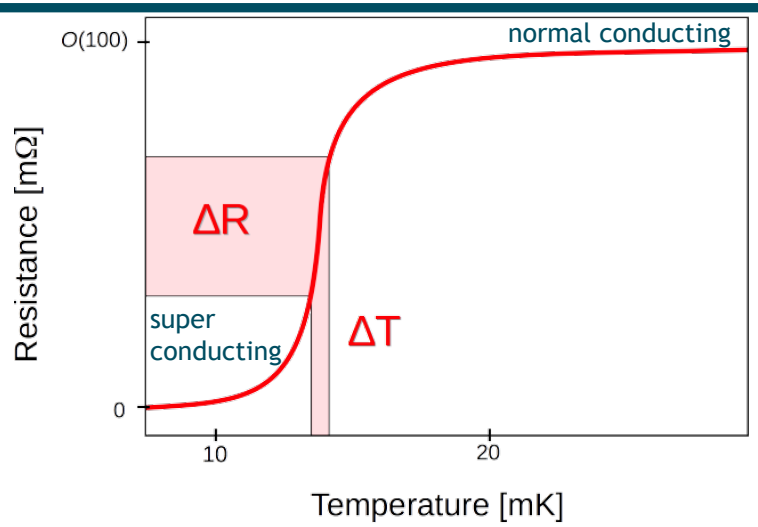
Background-rate in detectors:
~ 4 counts/keV/kg/day

Strauss, R., et al. "Beta/gamma and alpha backgrounds in CRESST-II Phase 2." *Journal of Cosmology and Astroparticle Physics* 2015.06 (2015): 030.

CRESST detector principle

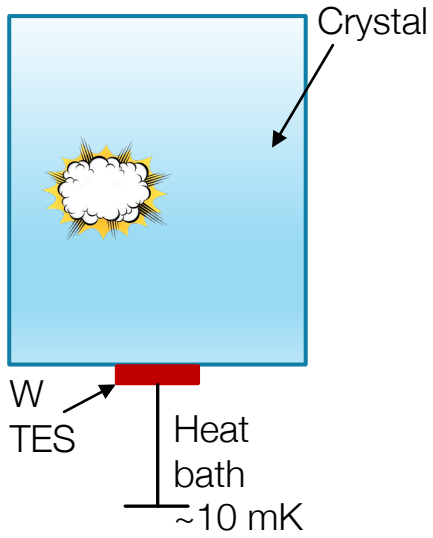


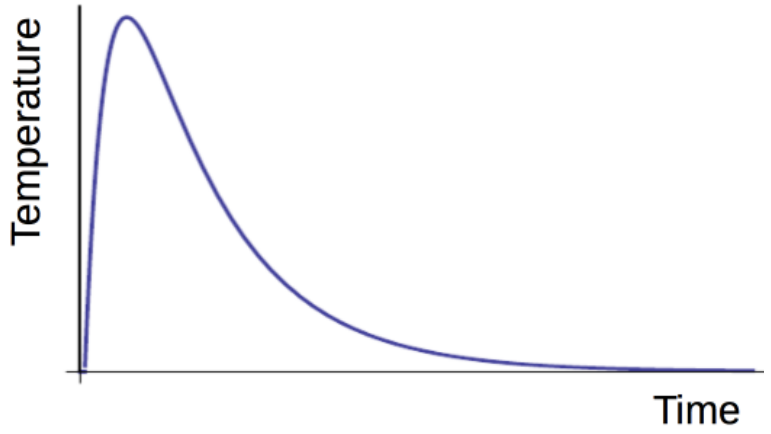


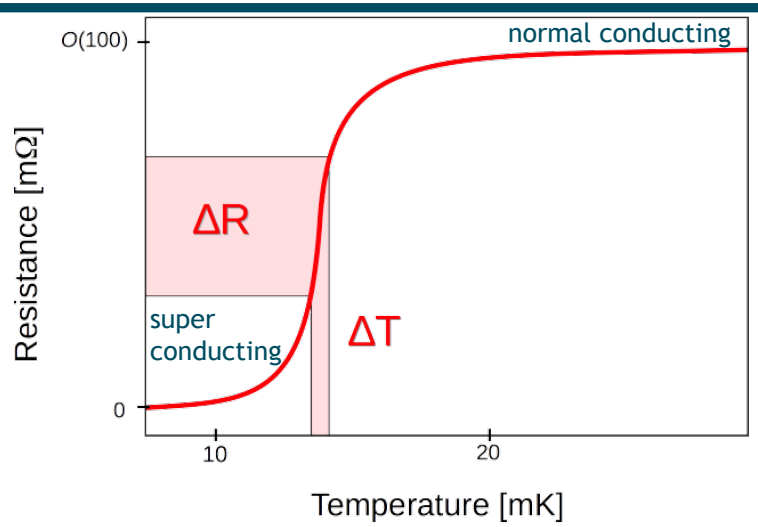


Energy deposition
ΔE O(100 eV) → Temperature rise ΔT O(μK) → Resistance change O(mΩ)

CRESST detector principle



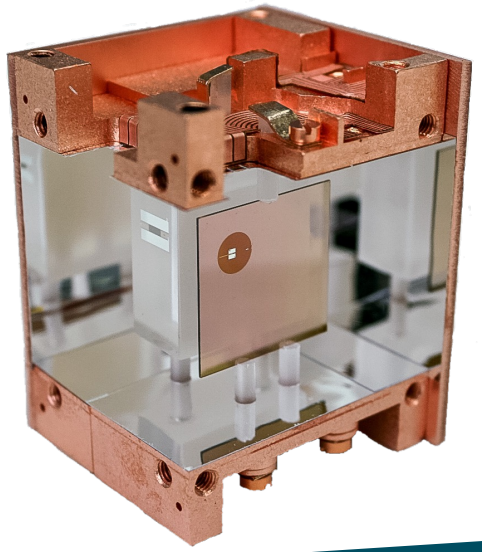


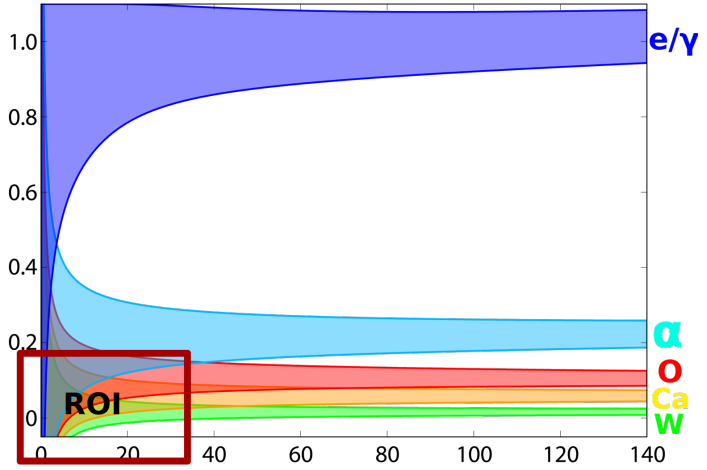


Energy deposition ΔE O(100 eV) → Temperature rise ΔT O(μK) → Resistance change O(mΩ)

Achievable thresholds: O(**10 eV**)

2 channel readout of scintillating crystals: particle discrimination event-by-event

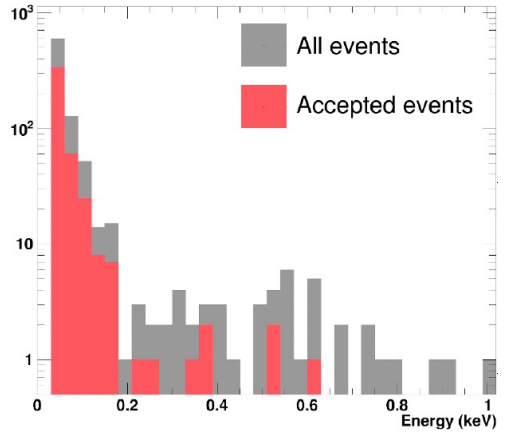




First Results of CRESST-III

Cryogenic **Rare Event Search** with Superconducting Thermometers

Leading limit for sub-GeV DM with nuclear recoil threshold of 30.1 eV



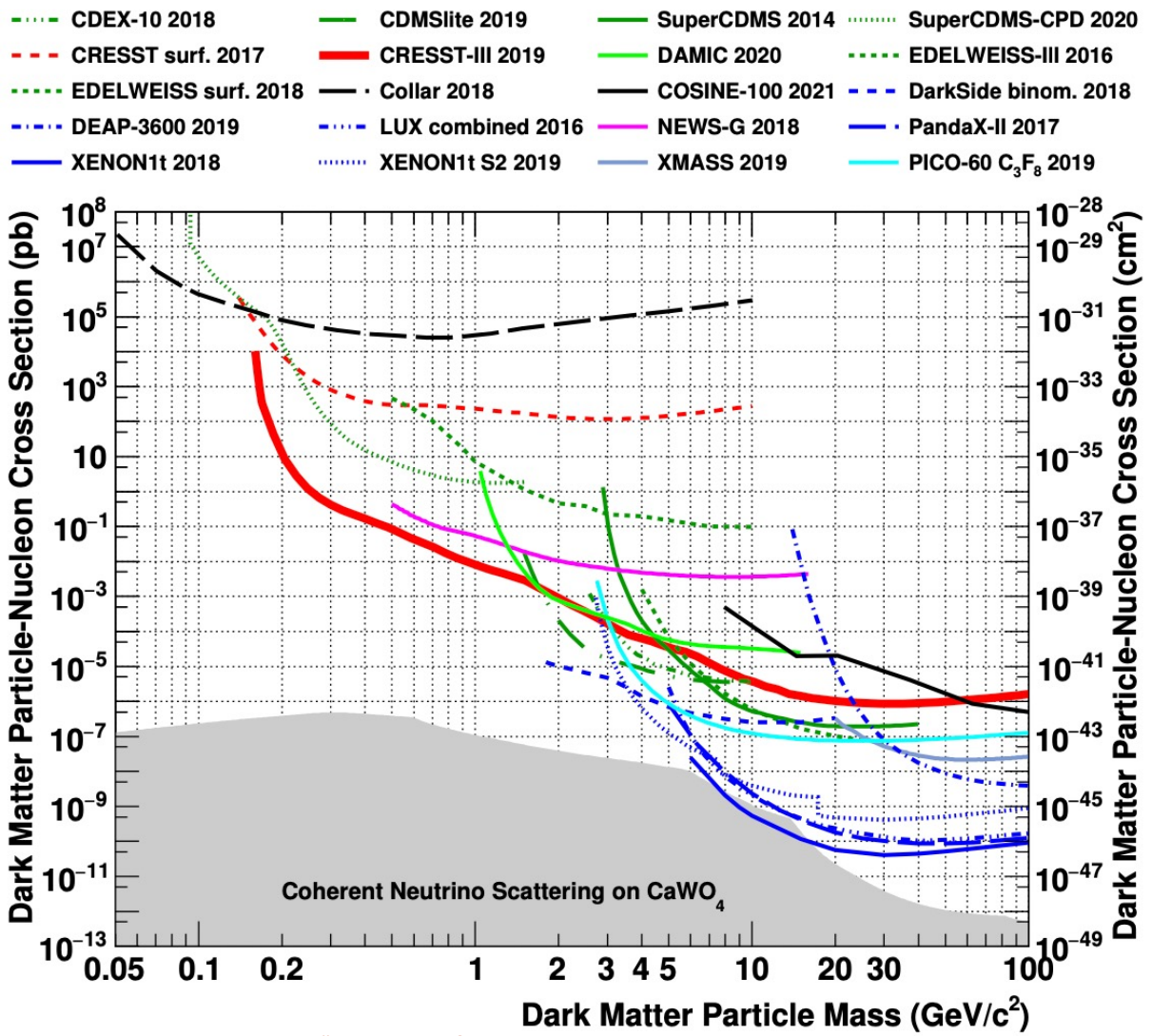
Excess of events below 200 eV measured

- Signal-like event shape (no noise events)
- Observed in all detectors with different rate

→ Main limiting factor for CRESST DM search

→ Also limiting for other low-threshold DM experiments → Joint workshop

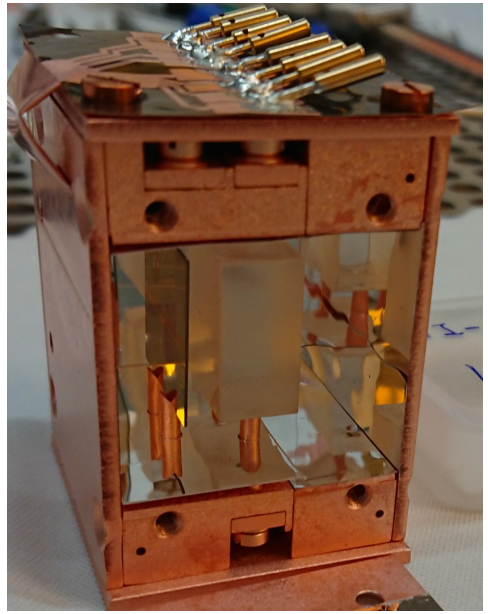
SciPost Phys. Proc. 9, 001 (2022) / arXiv:2202.05097v2



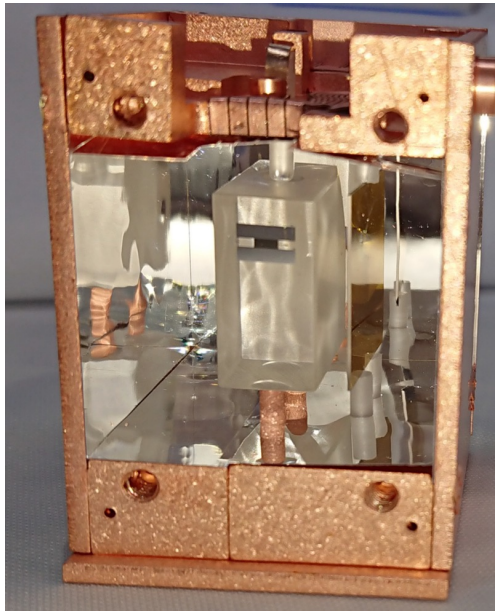
A. Abdelhameed et al., "First results from the CRESST-III low-mass dark matter program

Modification of detector modules

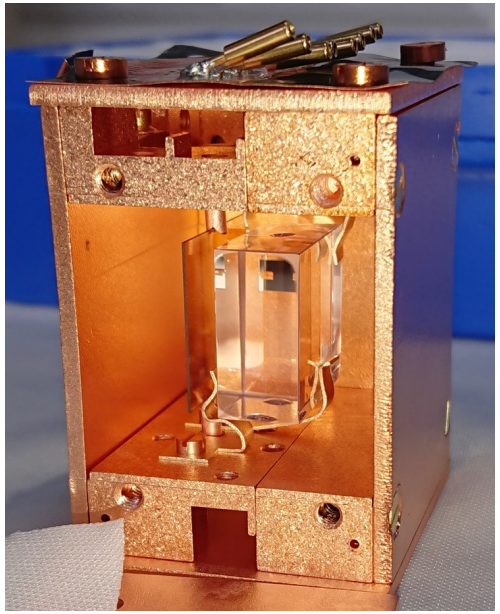
CRESST
Cryogenic **Rare Event Search** with Superconducting Thermometers



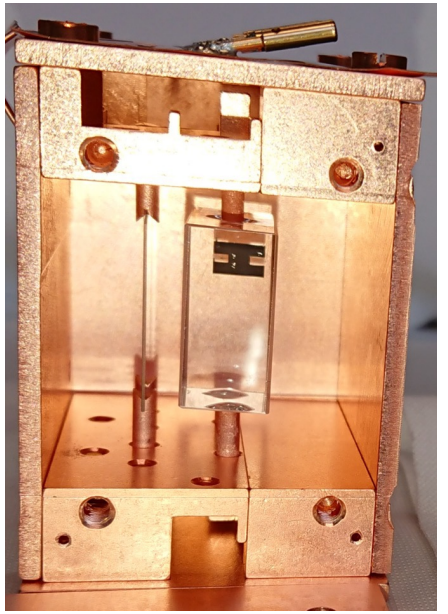
$LiAlO_2$



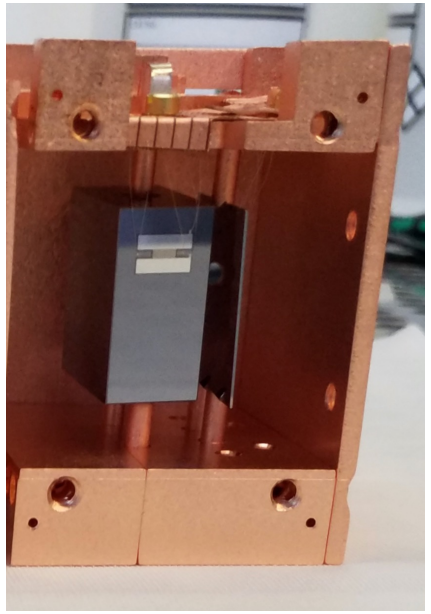
TUM – $CaWO_4$



Commercial – $CaWO_4$



Al_2O_3



Si

- Various target materials
- Detector holding
- Scintillating parts
- ^{55}Fe source for accurate energy calibration

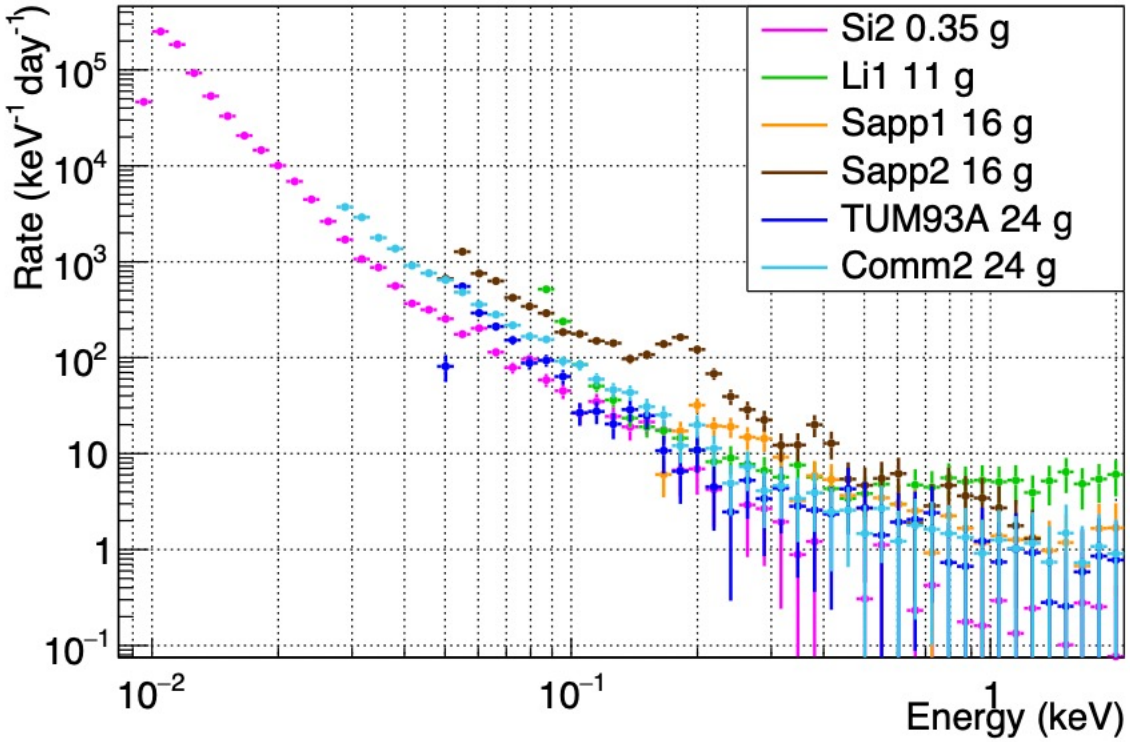
Data-taking ongoing since November 2020

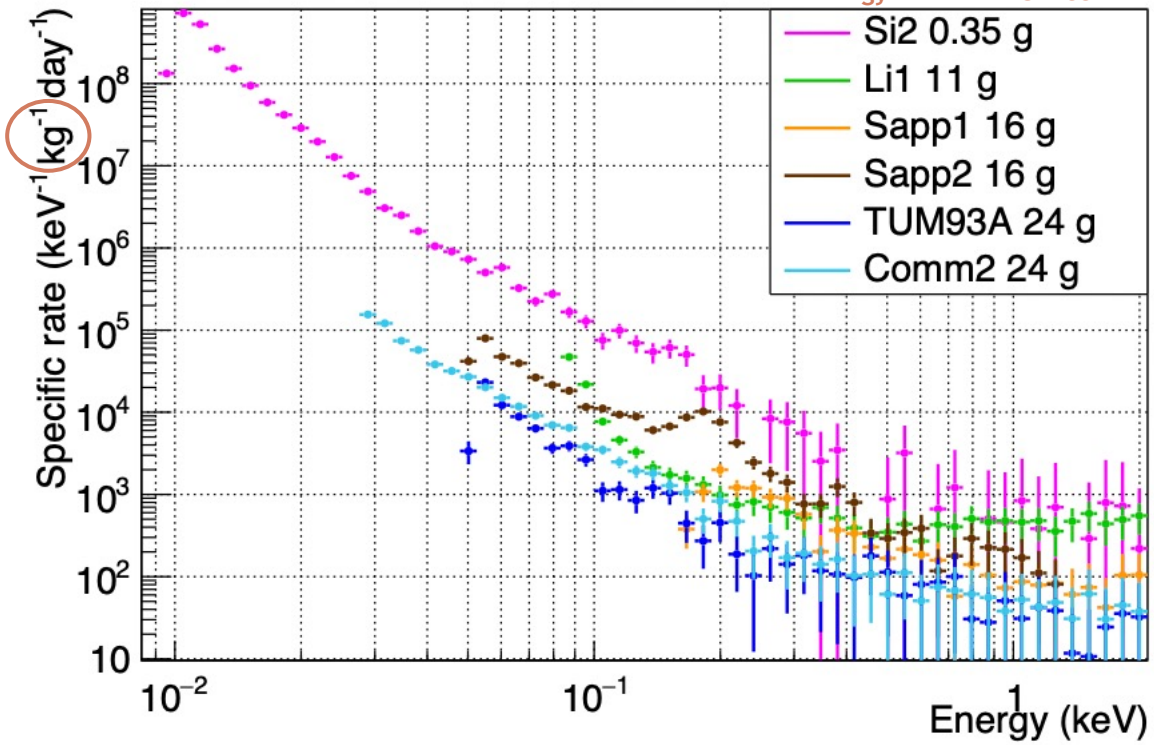
Low-energy spectra

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

New Results!

arXiv:2207.09375
Latest observations on the low energy excess in CRESST-III





- Excess observed in all detectors, same shape, different thresholds
- Rate of Excess does not scale by mass and is observed in all materials with varying rate

→ **Excludes** external origins like **DM** or external radioactivity

Time Dependence

Cryogenic **Rare Event Search** with Superconducting Thermometers

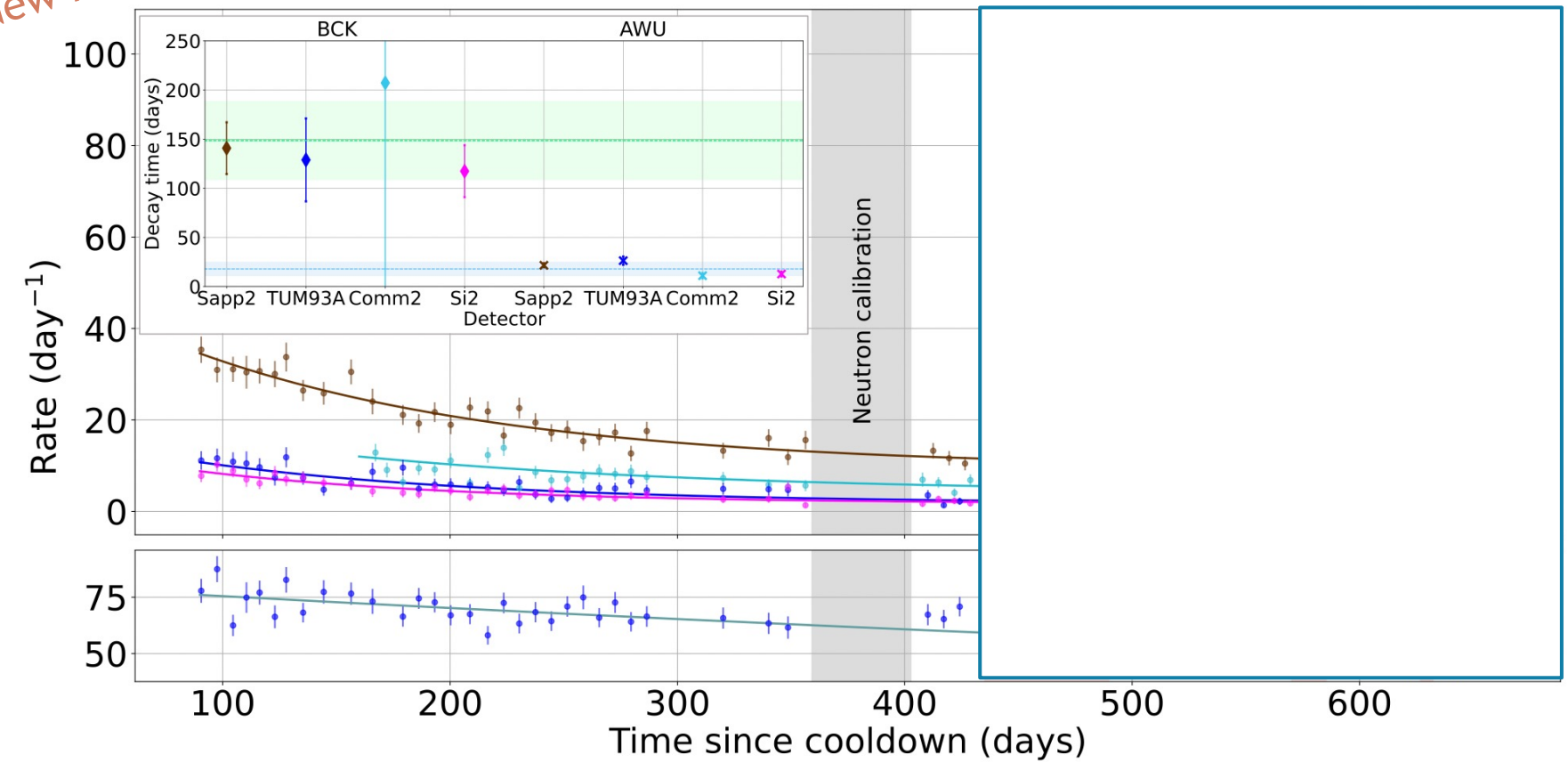
arXiv:2207.09375

Latest observations on the low energy excess in CRESST-III

Observations:
Rate decays with similar decay time for all detectors

- Decay time ~150 days
- No influence of neutron calibration

New Results!



Temperature dependence

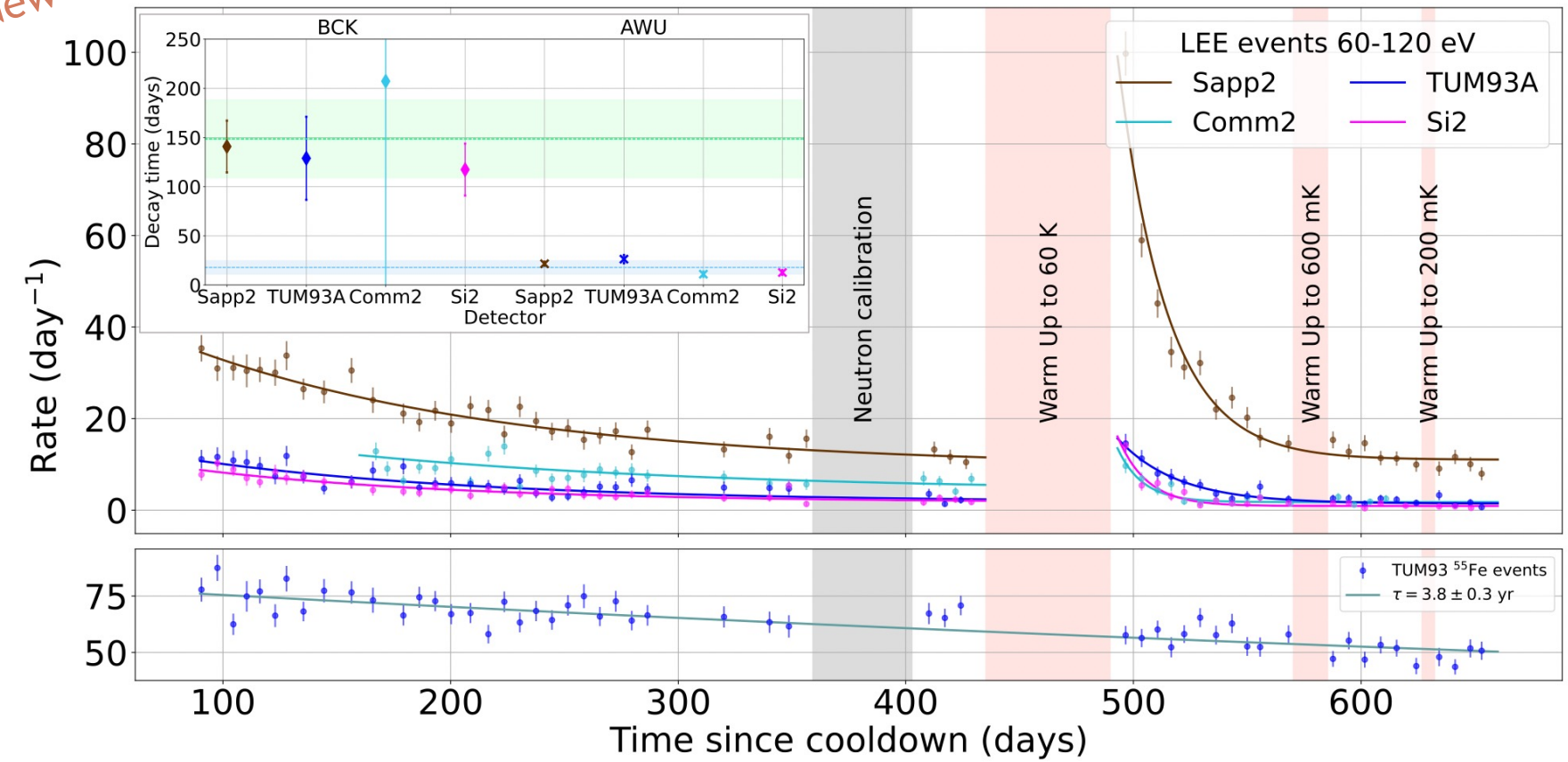
CRESST
Cryogenic **Rare Event Search** with Superconducting Thermometers

New Results!

arXiv:2207.09375
Latest observations on the low energy excess in CRESST-III

Observations:
Rate decays with similar decay time for all detectors

- Decay time ~150 days
- No influence of neutron calibration
- Rate resets after warm-up to 60 K (no effect at 200 mK and 600 mK)
- Decay time after warm-up ~20 days



Excludes external and intrinsic radioactivity and DM as origin!
Hints towards **solid-state effect**

R&D ongoing!

Further options under study:

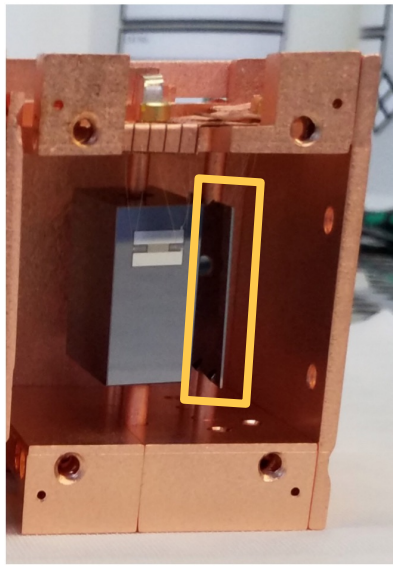
- Sensor related effects
- Holding induced stress

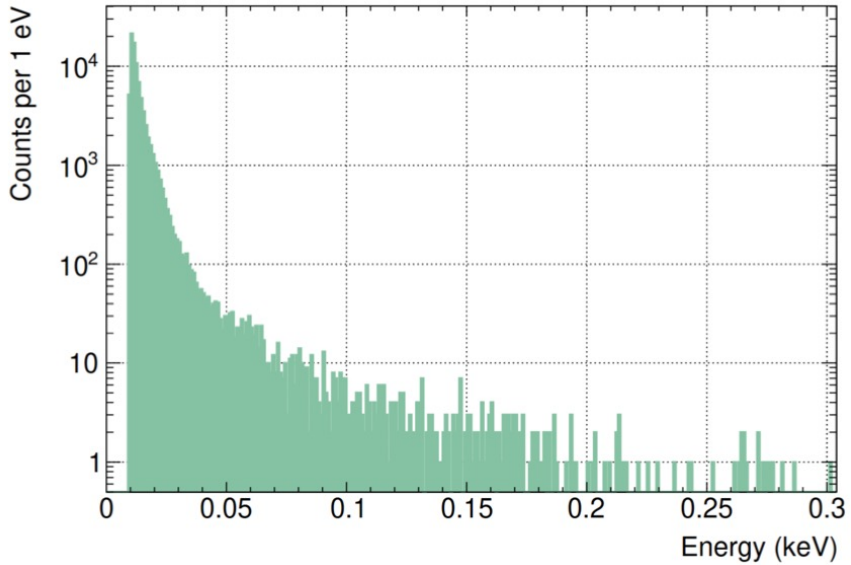
Spin-independent DM results

Cryogenic **Rare Event Search** with Superconducting Thermometers

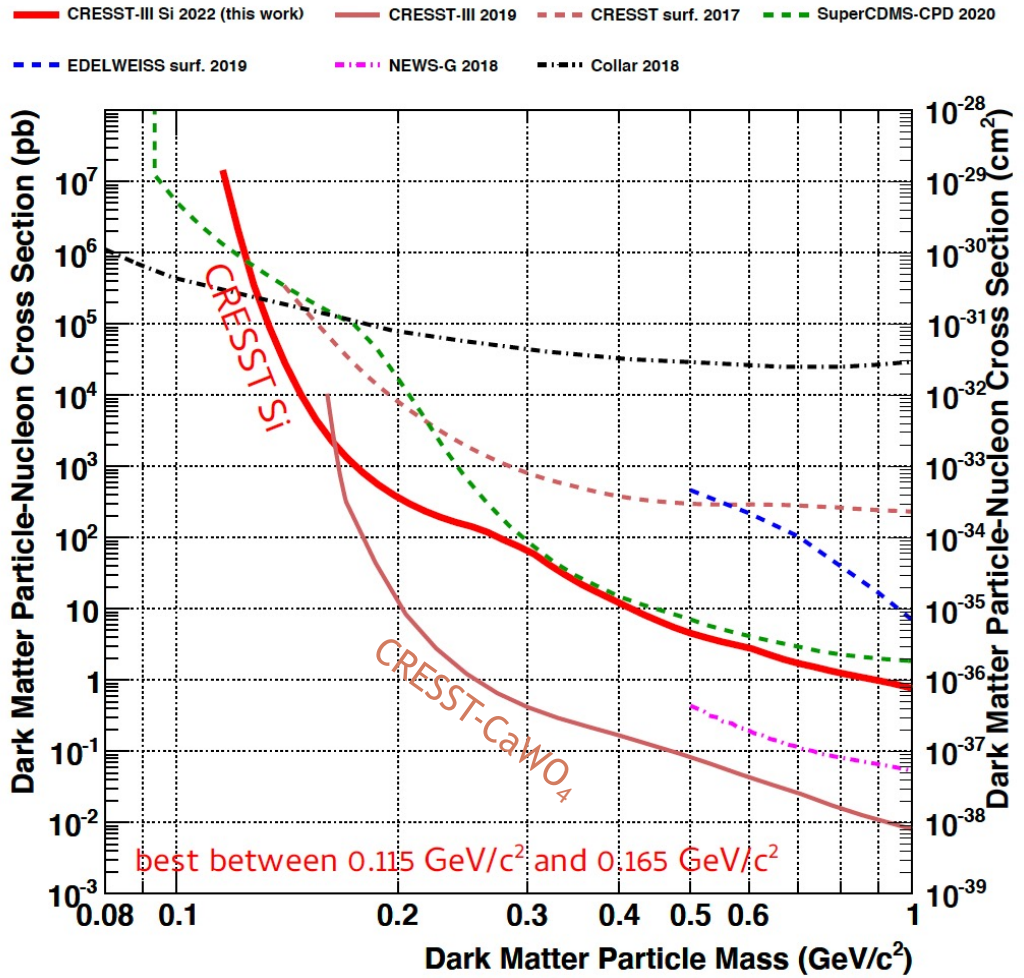
Si-Wafer detector with threshold of 10 eV
Energy Resolution: 1.36 eV
Data taking: Nov 2020 – Aug 2021
Exposure: 55.06 g d

Best DM exclusion limit between 115 and 165 MeV/c^2





New Results!



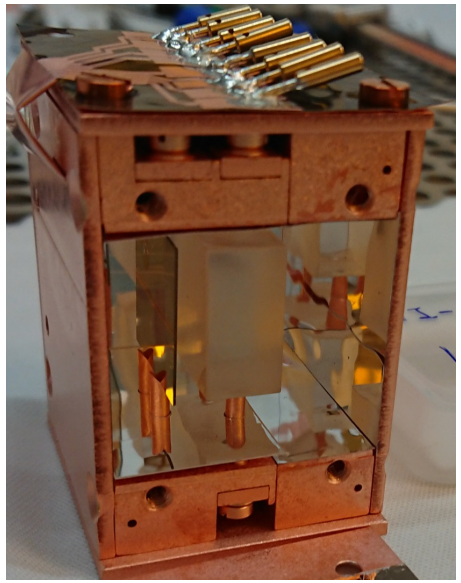
Spin-dependent DM results

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

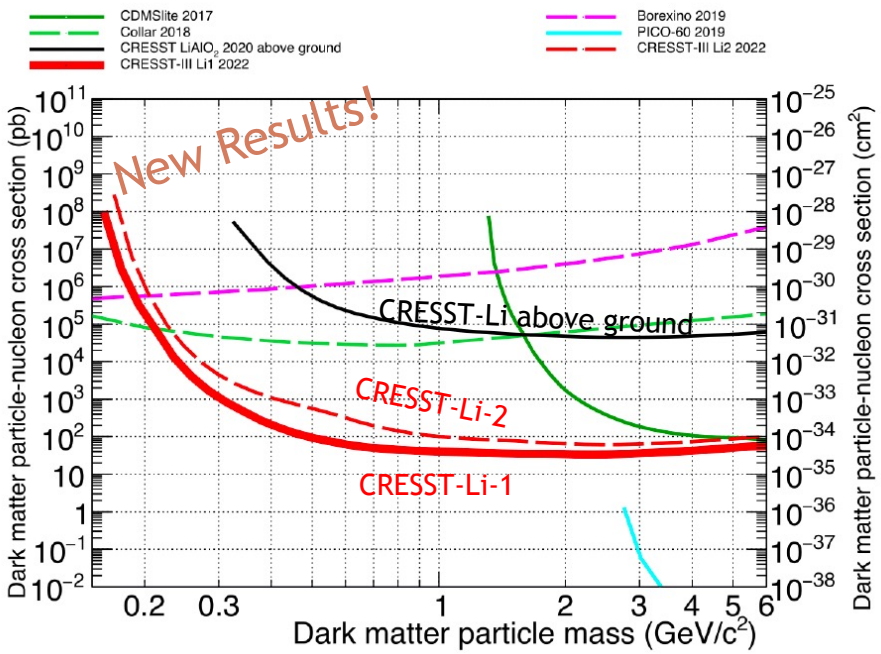
$LiAlO_2$ detector threshold **83.6 eV**
Data taking: Nov 2020 – Aug 2021
Exposure: 1.161 kg d

- Leading proton limits between 0.25 and 2.5 GeV/c^2
- Leading neutron limits between 0.16 and 1.5 GeV/c^2

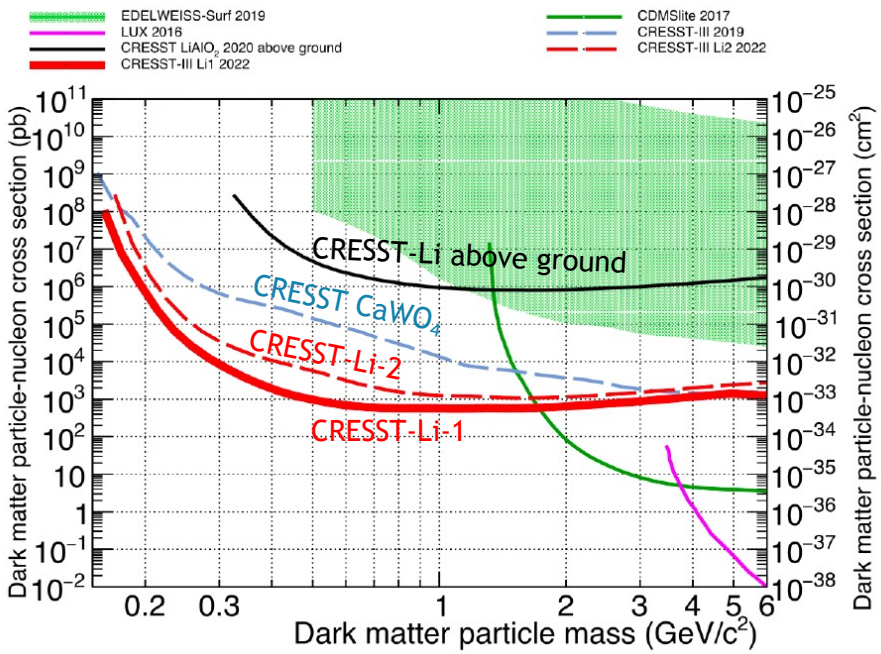
arXiv:2207.07640
Testing spin-dependent dark matter interactions with lithium aluminate targets in CRESST-III



Proton

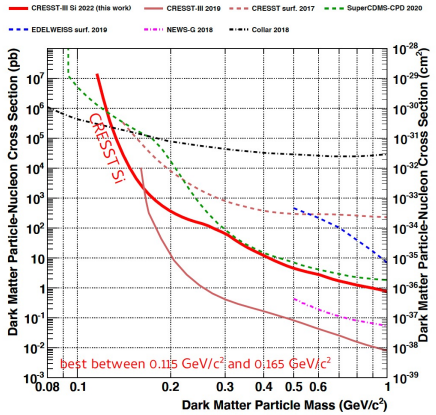


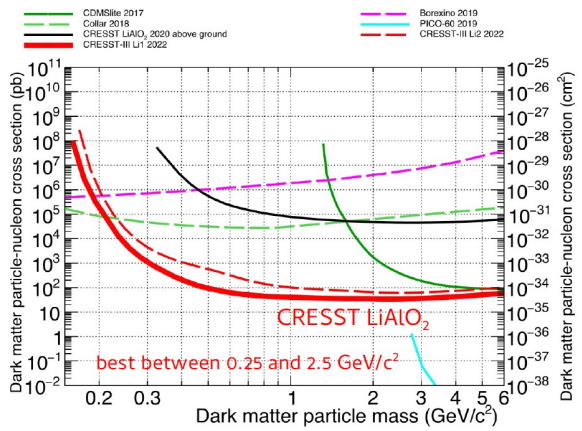
Neutron



Summary:

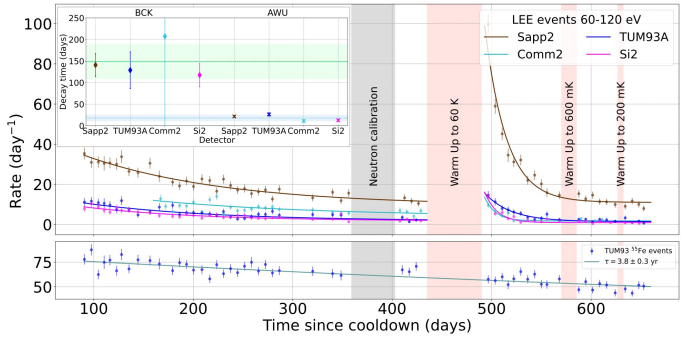
New **leading exclusion limits** for both spin-dependent and spin-independent DM search





Dedicated study of the excess ongoing

- First results **exclude** a particle-like origin and **DM**
- Hint towards solid-state process i.e. **stress related effects**



Outlook:

Excess studies ongoing, other temperature cycles are planned

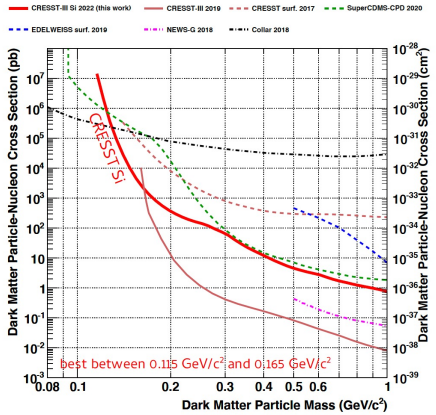
Detector R&D

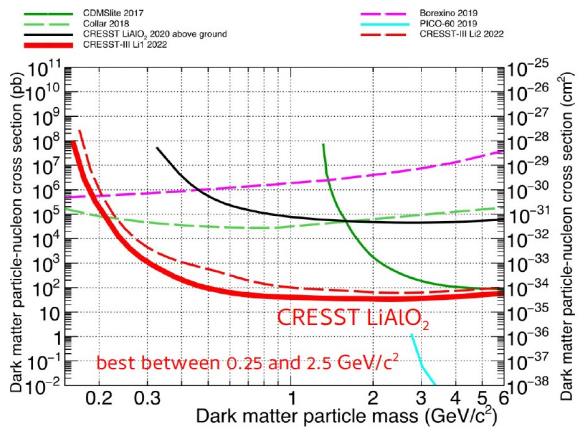
- Study stress as a source of the excess
- Lower thresholds of detectors

Upgrade of the CRESST setup planned afterwards to increase number of available channels to 288

Summary:

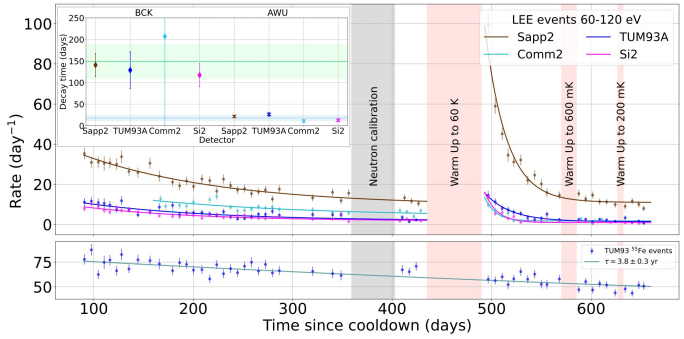
New **leading exclusion limits** for both spin-dependent and spin-independent DM search





Dedicated study of the excess ongoing

- First results **exclude** a particle-like origin and **DM**
- Hint towards solid-state process i.e. **stress related effects**



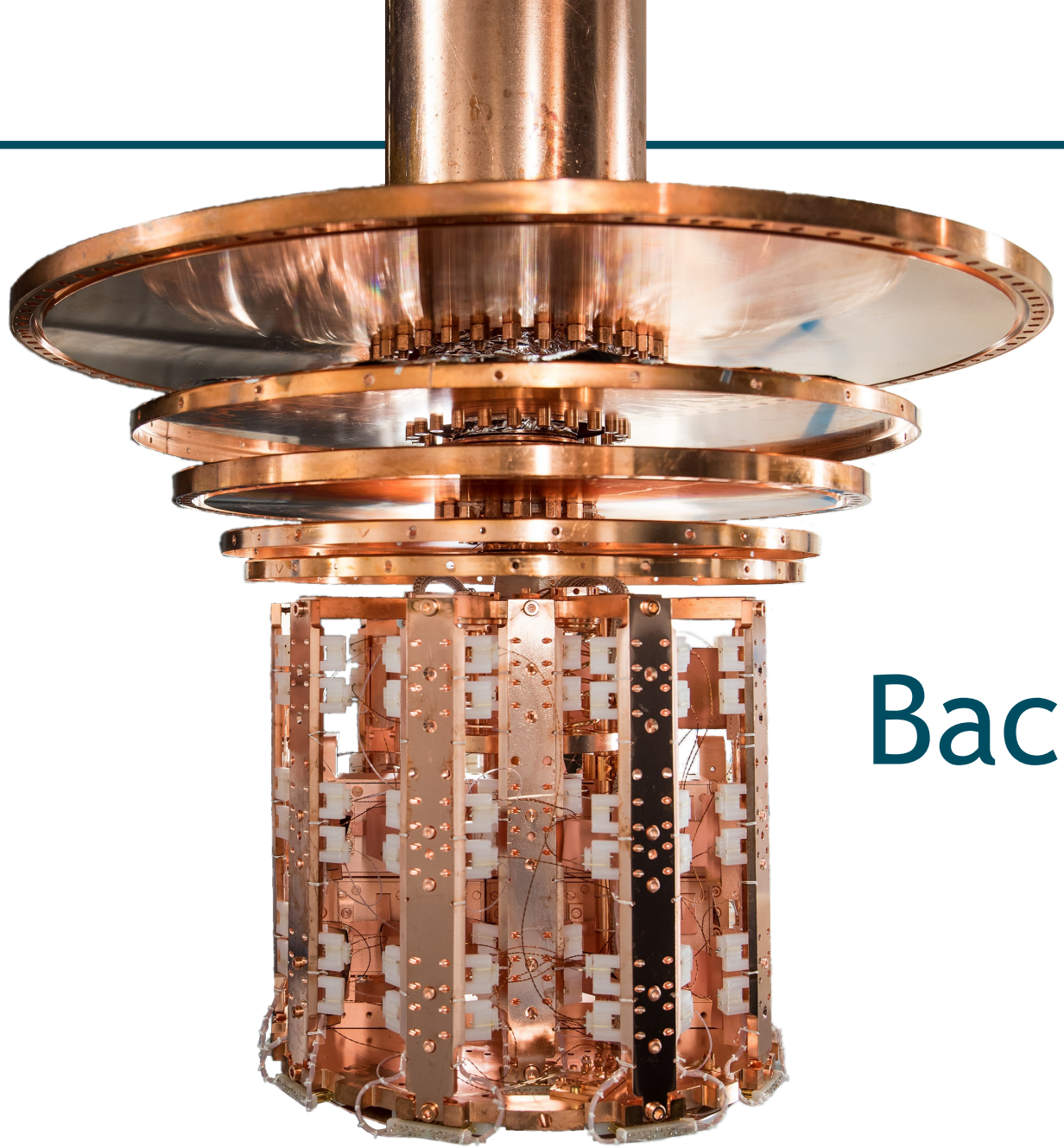
Outlook:

Excess studies ongoing, other temperature cycles are planned

Detector R&D

- Study stress as a source of the excess
- Lower thresholds of detectors

Upgrade of the CRESST setup planned afterwards to increase number of available channels to 288

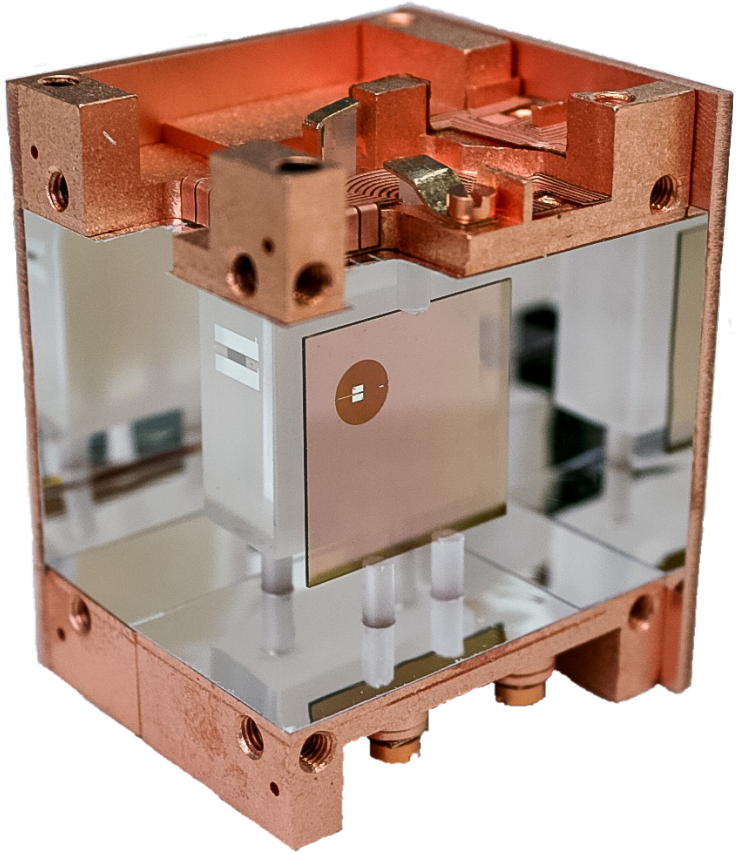


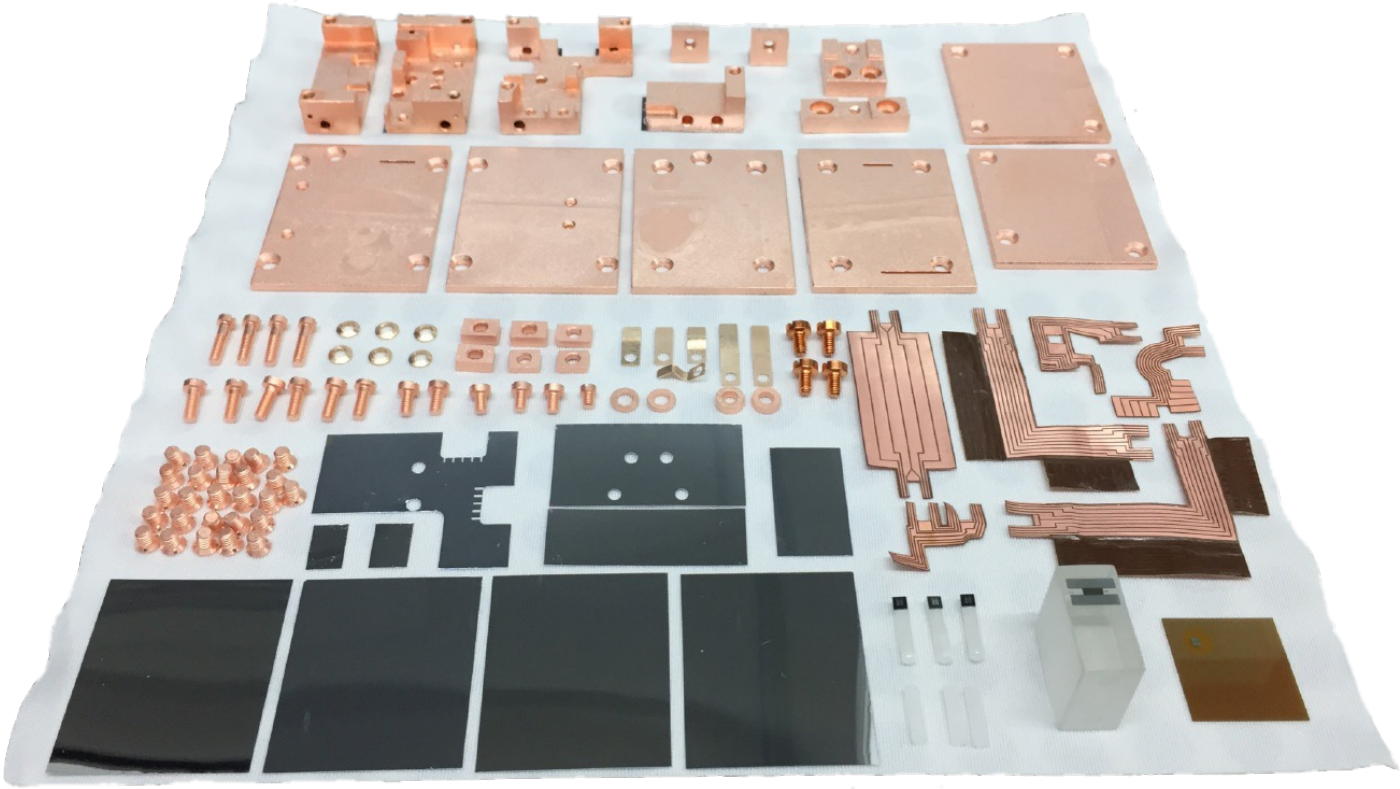
Backup

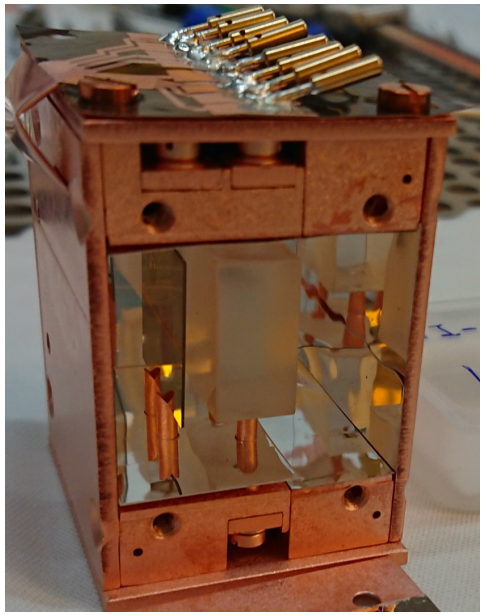
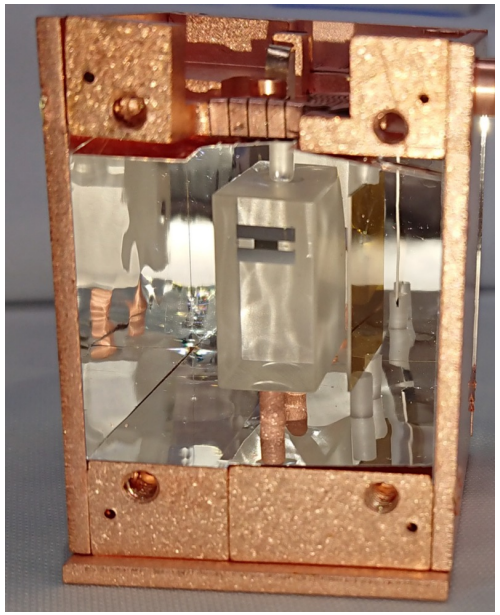
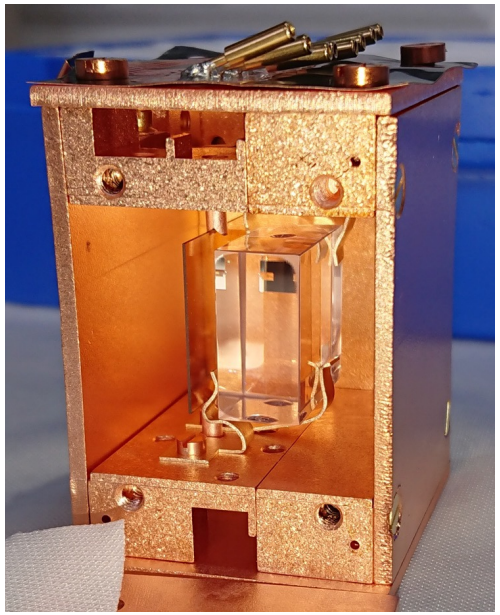
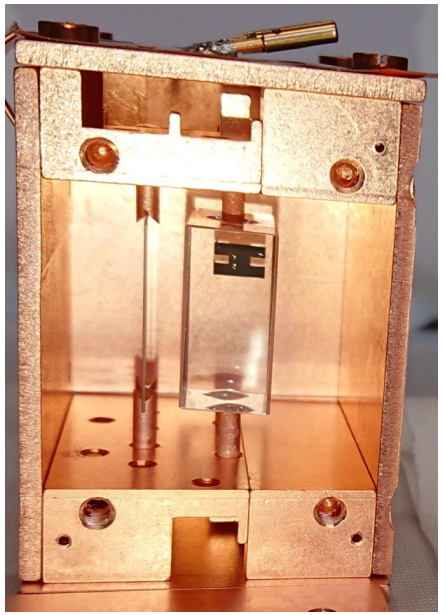
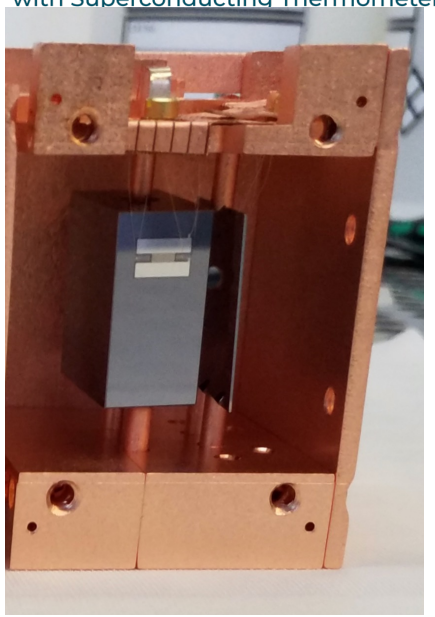
CRESST Detectors

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

- 20x20x10 mm phonon detector
- 20x20x0.5 mm light detector



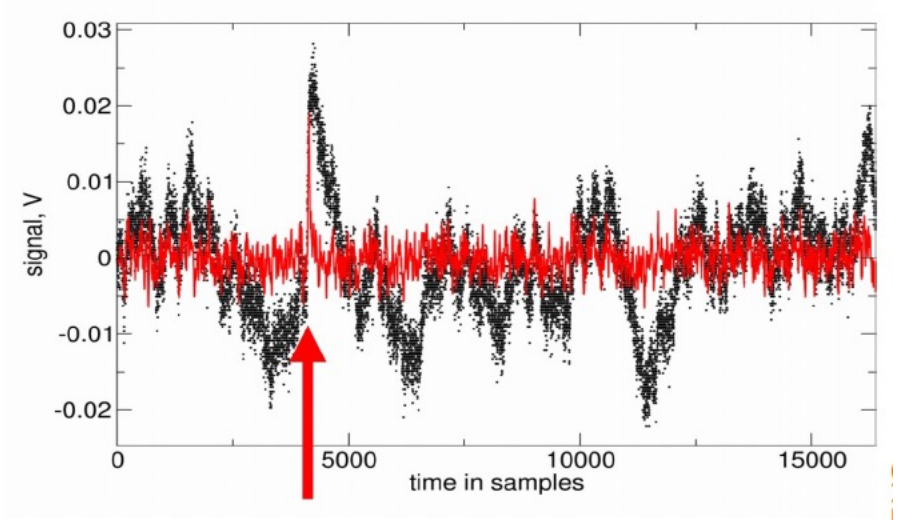


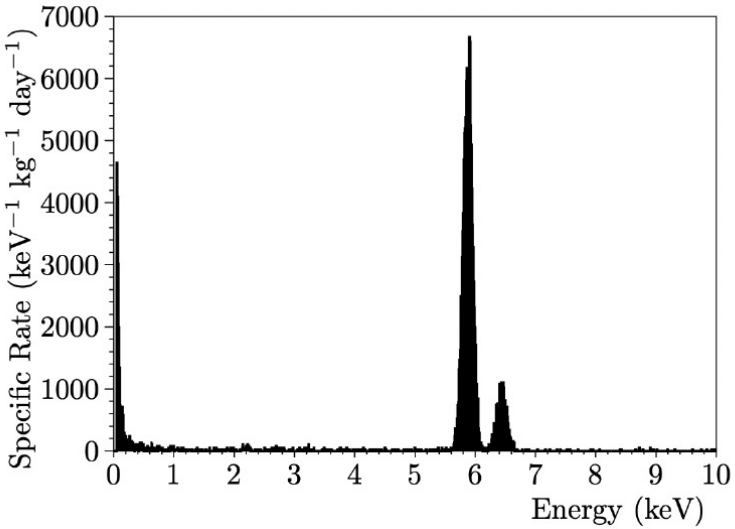






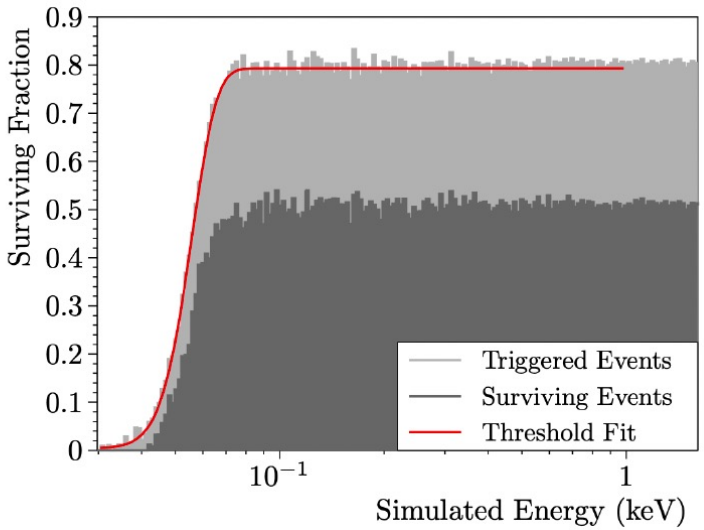
Name	Material	Holding	Foil	Mass	Threshold
Comm2	$CaWO_4$	bronze clamps	no	24.5 g	29 eV
TUM93A	$CaWO_4$	2 Cu + 1 $CaWO_4$	yes	24.5 g	54 eV
Sapp1	Al_2O_3	Cu sticks	no	15.9 g	157 eV
Sapp2	Al_2O_3	Cu sticks	yes	15.9 g	52 eV
Li1	$LiAlO_2$	Cu sticks	yes	11.2 g	84 eV
Si2	Si	Cu sticks	no	0.35 g	10 eV

Analysis

- Continuous DAQ
- Energy calibration via ^{55}Fe source



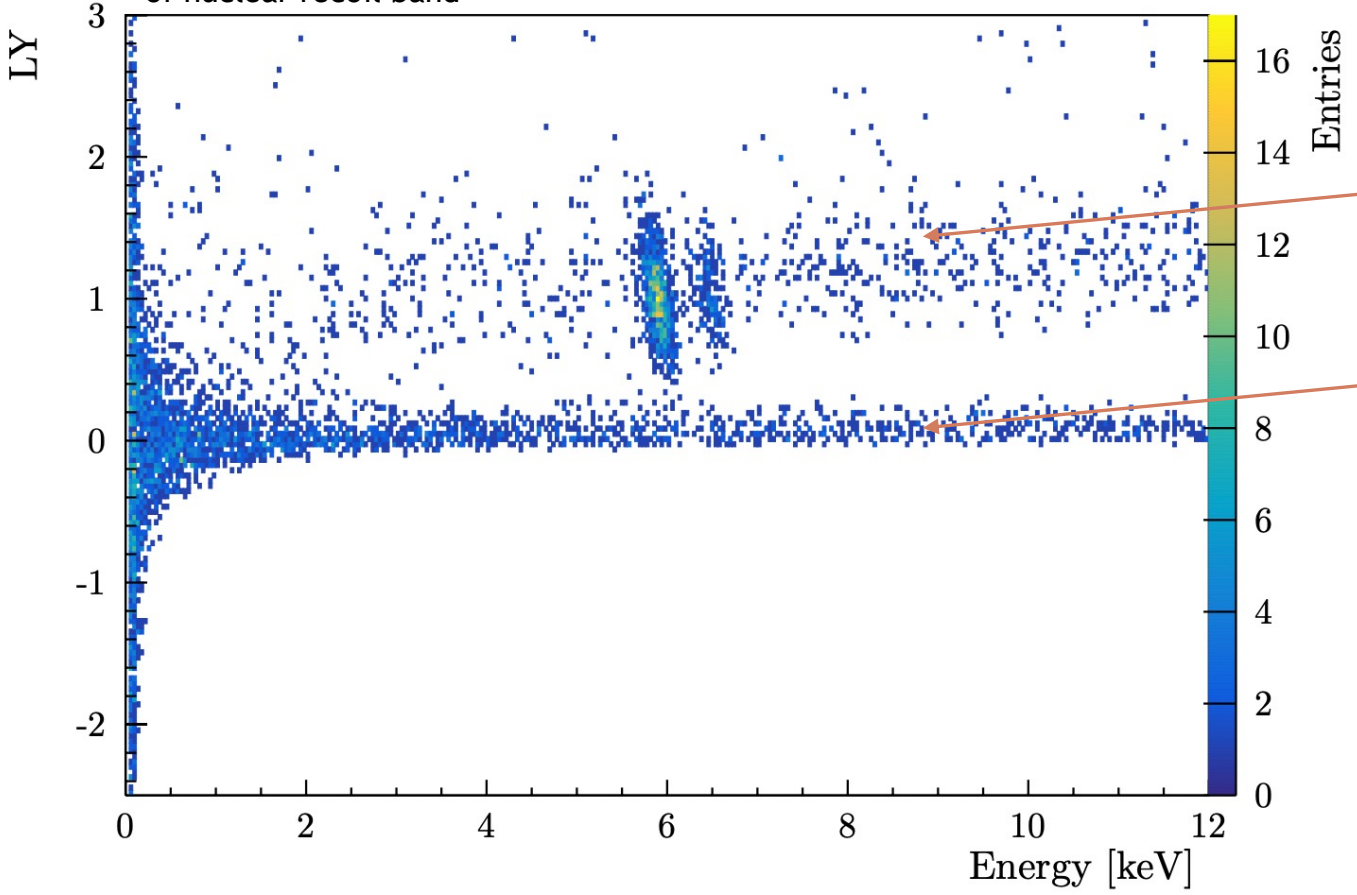




Event Discrimination

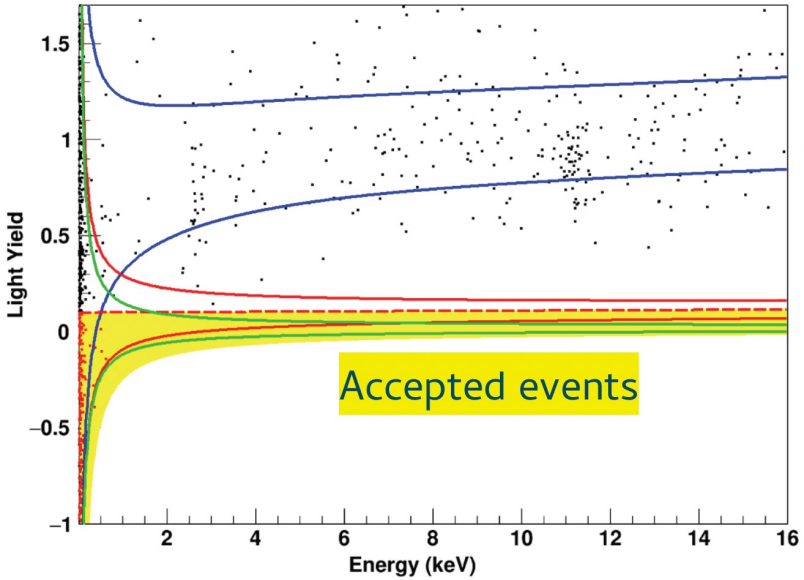
Cryogenic **Rare Event Search** with Superconducting Thermometers

Neutron Calibration for definition of nuclear recoil band



e/gamma recoils

nuclear recoils



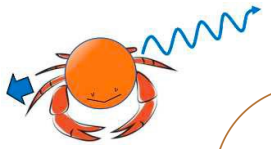
DetA 2019

Nuclear Recoil Calibration at 100eV scale

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

https://arxiv.org/abs/2211.03631

New!! Published Nov. 8 on arXiv



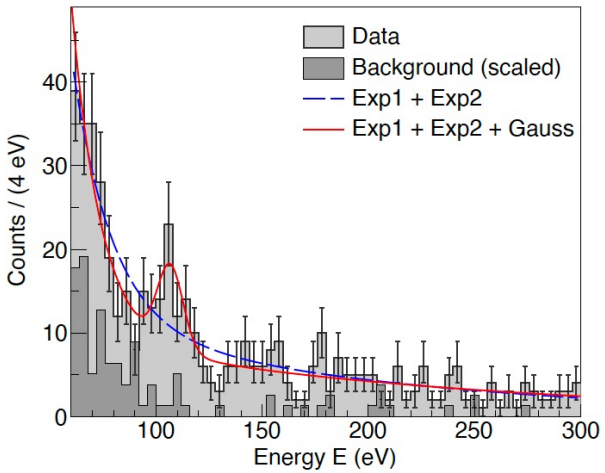
nucleus EXPERIMENT

Observation of a nuclear recoil peak at the 100 eV scale induced by neutron capture

H. Abele,[1] G. Angloher,[2] A. Bento,[2,3] L. Canonica,[2] F. Cappella,[4] L. Cardani,[4] N. Casali,[4] R. Cerulli,[5,6] A. Chalil,[7] A. Chebboubi,[8] I. Colantoni,[4,9] J.-P. Crocombette,[10] A. Cruciani,[4] G. Del Castello,[4,11] M. del Gallo Roccagiovine,[4,11] D. Desforge,[7] A. Doblhammer,[1] E. Dumonteil,[7] S. Dorer,[1] A. Erhart,[12] A. Fuss,[1,13] M. Friedl,[13] A. Garai,[2] V. M. Ghete,[13] A. Giuliani,[14] C. Goupy,[7] F. Gunsing,[7] D. Hauff,[2] F. Jeanneau,[7] E. Jericha,[1] M. Kaznacheeva,[12] A. Kinast,[12] H. Kluck,[13] A. Langenkämper,[2] T. Lasserre,[7,12] A. Letourneau,[7] D. Lhuillier,[7] O. Litaize,[8] M. Mancuso,[2] P. de Marcillac,[14] S. Marnieros,[14] T. Materna,[7] B. Mauri,[7] A. Mazzolari,[15] E. Mazzucato,[7] H. Neyrial,[7] C. Nones,[7] L. Oberauer,[12] T. Ortmann,[12] A. Ouzriat,[7] L. Pattavina,[12,16] L. Peters,[12] F. Petricca,[2] D. V. Poda,[14] W. Potzel,[12] F. Pröbst,[2] F. Reindl,[1,13] R. Rogly,[7] M. Romagnoni,[15] J. Rothe,[12] N. Schermer,[12] J. Schieck,[1,13] S. Schönert,[12] C. Schwertner,[1,13] L. Scola,[7] O. Serot,[8] G. Soum-Sidikov,[7] L. Stodolsky,[2] R. Strauss,[12] M. Tamisari,[15,17] L. Thulliez,[7] C. Tomei,[4] M. Vignati,[4,11] M. Vivier,[7] V. Wagner,[12] and A. Wex[12]

(CRAB Collaboration)*

(NUCLEUS Collaboration)†



neutron-capture-induced nuclear recoil peak

CRESST publication to the same topic in internal review, on arXiv soon!