The CRESST-III Dark Matter Search

Status and Outlook

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on behalf of the CRESST collaboration

May 16, 2023

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The CRESST Collaboration

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Istituto Nazionale di Fisica Nucleare
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UNIVERSITY OF OXFORD

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HEPHY
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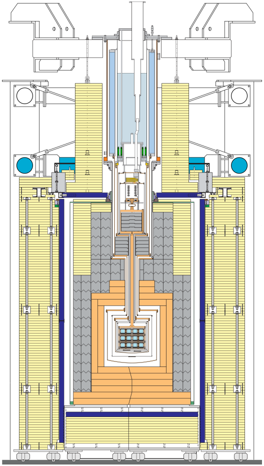
TU WIEN

The CRESST Experiment

Cryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers

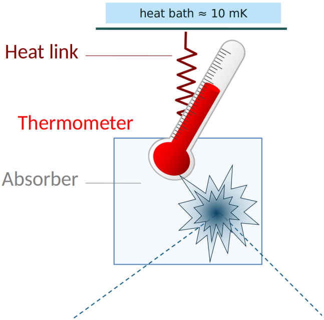


- Located in the LNGS underground laboratories
- Detects potential DM particles via scattering off target nuclei
- Uses Transition Edge Sensors (TES)
- Operates at $\sim$ 15 mK

Cryogenic calorimeters

- Basic setup: crystal equipped with TES
- A particle interaction causes an energy deposition in the crystal
- Calorimeter equation:

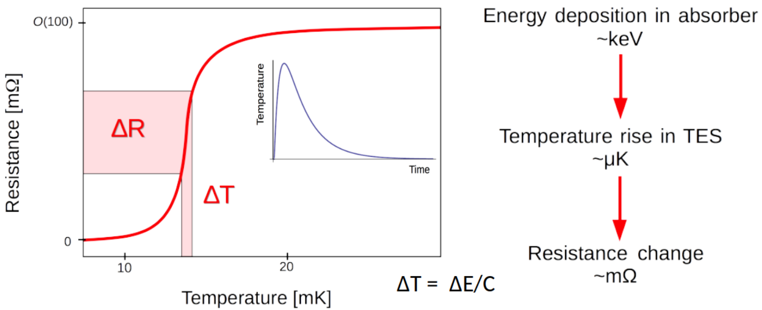
$$\Delta T = \frac{\Delta E}{C}$$



For low heat capacity (true at low temperatures)
$\Rightarrow$ low energy deposition can lead to significant temperature variation

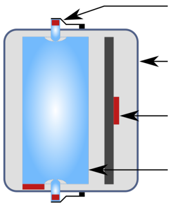
- Temperature variation is measurable with the TES

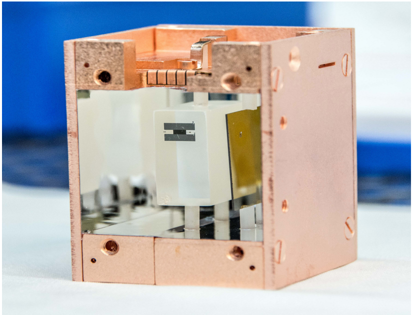
The Transition Edge Sensor



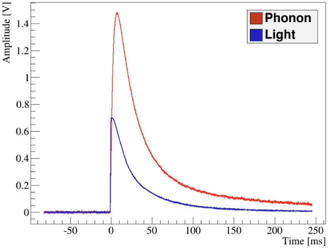
- Sensor is operated at transition between normal conducting and super conducting phase
- Very small temperature variations can be measured through resistance variations

CRESST III Detectors





- Main absorber: scintillating crystal with dimension (2x2x1) cm^3
- Additional light detector for background discrimination
- Reflective foil to optimize light collection
- Simultaneous readout of both channels

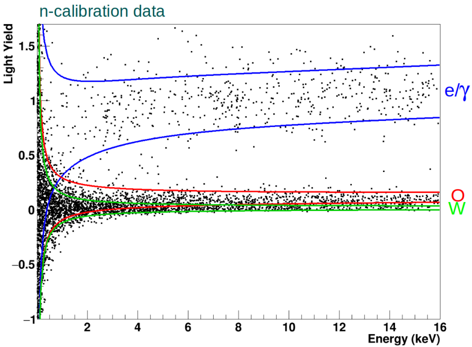


Event Discrimination

We can discriminate events depending on their light output:

$$\text{LightYield} = \frac{\text{Light signal}}{\text{Phonon signal}}$$

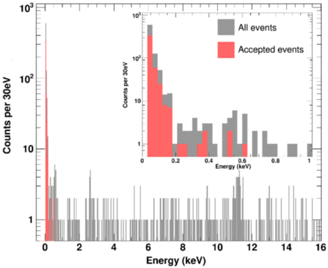
To define the region of the bands we perform a neutron calibration



Result

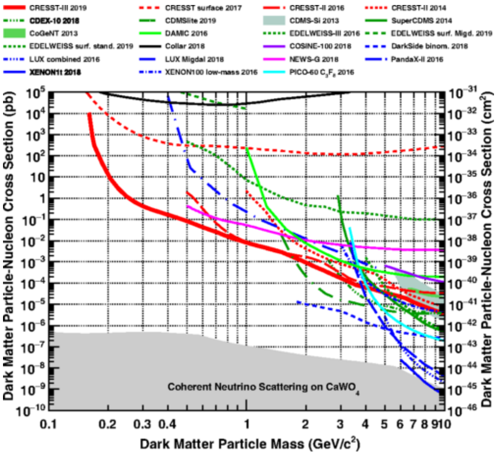
Excellent discrimination between **nuclear recoils** (signal) and **electron/photon interactions** (background)

First Results from CRESST III (2019)



Detector A

mass	23.6 g
data taking	Oct 16 - Jan 18
baseline resolution	4.6 eV
energy threshold	30.1 eV



[Phys. Rev. D 100, 102002]

First observation of a Low Energy Excess (LEE)

First ideas about LEE

What we knew:

- unknown rise of particle events
- energy range of 30 eV - 200 eV

Possible origins:

- excess might be related to the target material ($CaWO_4$)
- could be caused by stress of the holder
- might be related to the scintillating foil

Dedicated modifications to probe the LEE

- different target materials
- changes to the holding structure of the crystal
- remove scintillating components

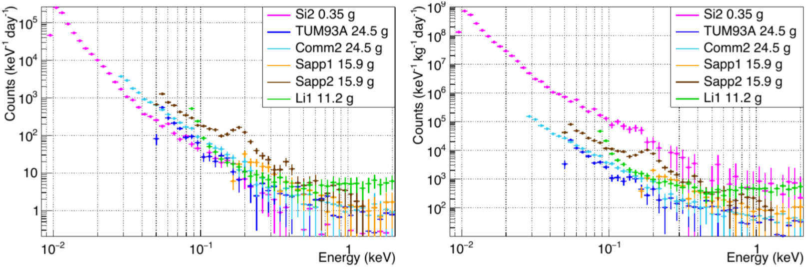
Current Measurement Campaign

- The main goal of this run was to understand the LEE
- We kept the data blind to allow for DM searches
- At the end of the run we performed a neutron calibration
- The run was followed by a set of tests for LEE studies

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	no	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

Observations on LEE

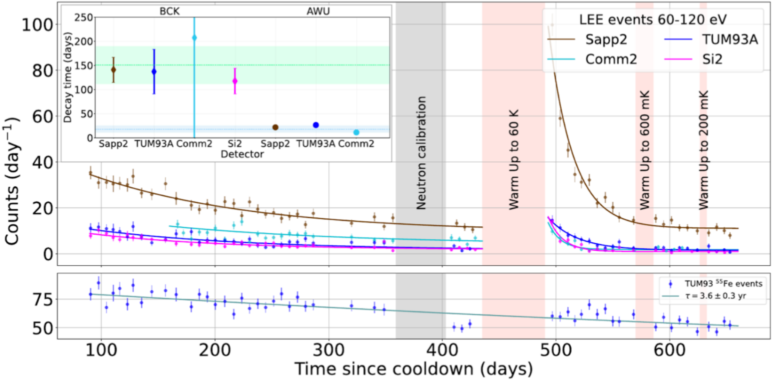
- Excess is observed in every material and geometry
- Rate does not scale with mass (right plot)



[arxiv:220709375v2]

We therefore exclude a DM origin

Time Dependence of the LEE



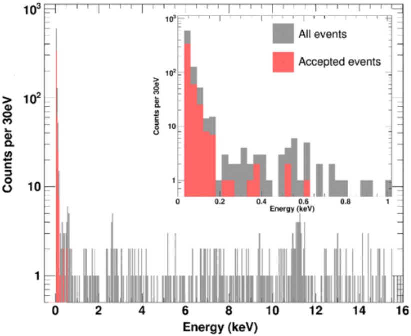
[arxiv:220709375v2]

- LEE decreases over time with similar decay time in all detectors ($\sim$ 150 d)
- Neutron calibration has no effect on the LEE rate
- Warm-up to 60 K leads to an increase of the rate, which then decreases with a faster rate ($\sim$ 15 d)
- Warm-up to 200 mK and 600 mK do not affect the LEE rate

What we have learned about the LEE

Observations:

- present in different materials
- does not scale with size
- rate decays with time
- rate increases after a warm-up



[J. Phys.: Conf. Ser. 1342 012076]

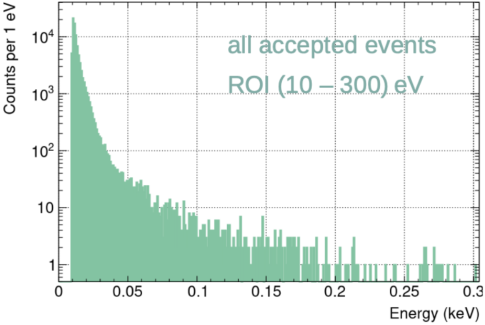
Open possibilities:

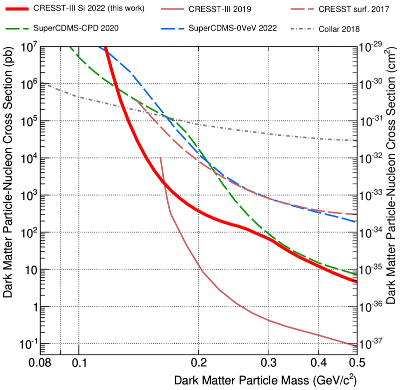
- LEE might originate from stress
- LEE might be related to the sensor

Results from a Si Wafer Detector

Si wafer detector

mass	0.35 g
data taking	Nov 20 - Aug 21
baseline resolution	1.36 eV
energy threshold	10.0 eV





[arXiv:2212.12513, accepted at Phys. Rev. D]

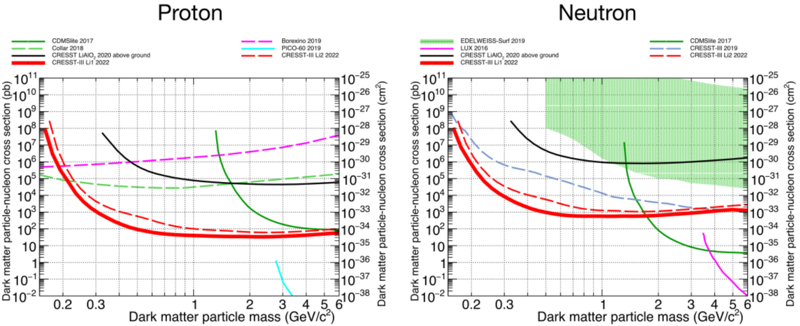
The wafer detector was used as target and the crystal as veto

Spin Dependent Limits with $LiAlO_2$ Detectors

Lithium aluminate detector

mass	11.2 g
data taking	Nov 20 - Aug 21
baseline resolution	12.8 eV
energy threshold	83.6 eV

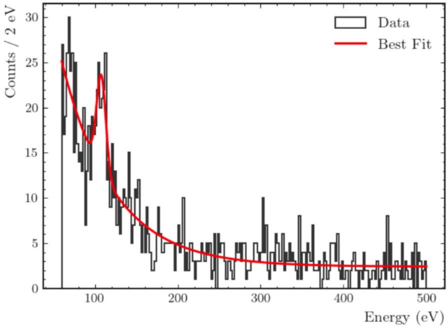
Lithium aluminate contains three isotopes sensitive to spin-dependent DM interactions:
Li-6, Li-7, Al-27



[Phys. Rev. D 106, 092008]

Recoil Peak in Neutron Calibration

- Sub-keV calibration is challenging: it is difficult to find a low energy source and it generates additional background
- Radiative capture of thermal neutrons could provide a good energy calibration at around 100 eV [CRAB collaboration arXiv:2011.13803]
- In $CaWO_4$ this effect should be visible as a 112 eV peak



[arXiv:2303.15315]

Our neutron calibration data show a peak at $\sim$ 110 eV in multiple detectors
$\rightarrow$ we could adopt this calibration method
$\rightarrow$ confirms our energy calibration method

Plans for the future

- Perform additional warm up tests to study the LEE
- Ongoing detector R&D e.g. new detector designs and stress free holdings
- Preparation of a new run for excess studies at end of the year
- Preparation for upgrade of read-out system to 288 channels, aiming to reach 1 tonne day exposure

Summary

- With the current run (Nov 2020 - ongoing) CRESST released new dark matter results:
  - extension to lower DM masses with 10 eV energy threshold
  - competitive spin-dependent DM limits
- We performed warm-up test to study the origin of the LEE
  - excess decreases over time
- Neutron source might be used for low energy calibration
- Ongoing preparation of a new run with new detector designs