Low Energy Excess Studies in the CRESST Experiment

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CRESST Experiment

CRESST (**Cryogenic Rare Event Search with Superconducting Thermometers**) is a **direct dark matter** (DM) **detection** experiment located in the LNGS. **Nuclear recoil events** are detected using crystals equipped with **Transition Edge Sensors (TES)** and **detection thresholds of below 10 eV** have been achieved.

The Low Energy Excess (LEE)

The LEE is a **background of unknown origin** and has been observed in every CRESST detector module. Its two main characteristics are: the **rise in event rate below 200 eV** and the **decreasing event rate in time**. Further, the LEE rate can be re-enhanced by a thermal cycle to above 10 K [3].

Detector Modules

The standard CRESST detector module consists of a **bulk** (20x20x10) mm^3 and a **wafer** (20x20x0.4) mm^3 **detector**, denoted by 0 and 1 respectively.

In the **previous run (2020-2024)**, each crystal was equipped with **one TES sensor** and held inside the housing either by clamps (Comm2) or by sticks. The target materials included $CaWO_4$ (Comm2, TUM93A), Al_2O_3 (Sapp2) and Si (Si2).

In the **current run (2024 – today),** a new detector design, the **doubleTES** detector ($CaWO_4$ and Silicon-on-Sapphire (SOS)), is operated. Every crystal is equipped **with two identical TES sensors** and is held by a gravity-assisted holding scheme. This sensor scheme is applied to five $CaWO_4$ bulk and four stacked SOS wafer detectors (also called Stack).

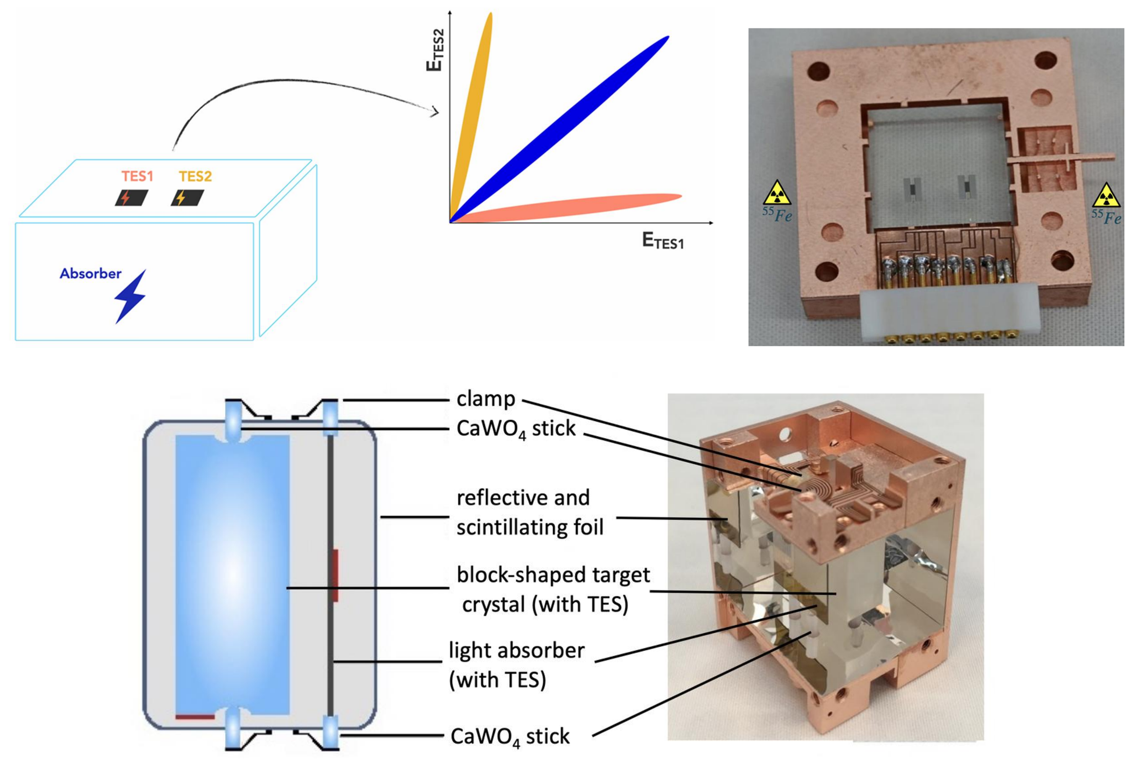

Figure 1: CRESST detector modules: a single TES detector module (bottom) [1] and a doubleTES detector module with event discrimination: events detected by one (orange and pink) and by both (blue) TES sensors (top) [2].

See also the poster by Danaé Valdenaire:
„CRESST Double-TES Detector: a design and sensitivity study"

Energy Spectra of single and double TES Modules

The **doubleTES** detectors provide a possibility for event identification: based on all detected events the shared events, which have a similar detected energy in both TES sensors, can be identified. Due to this differentiation, the doubleTES design provides a **better distinguishability from noise events**. Therefore, the energy spectrum of the shared events has a lower event rate towards threshold. If comparing a single to a double TES module with similar performance, the **detection threshold of 1 NT/kg-day is considerably lower** (NT: noise trigger). When compared to the previous single TES detectors, **no significant LEE reduction is observed**.

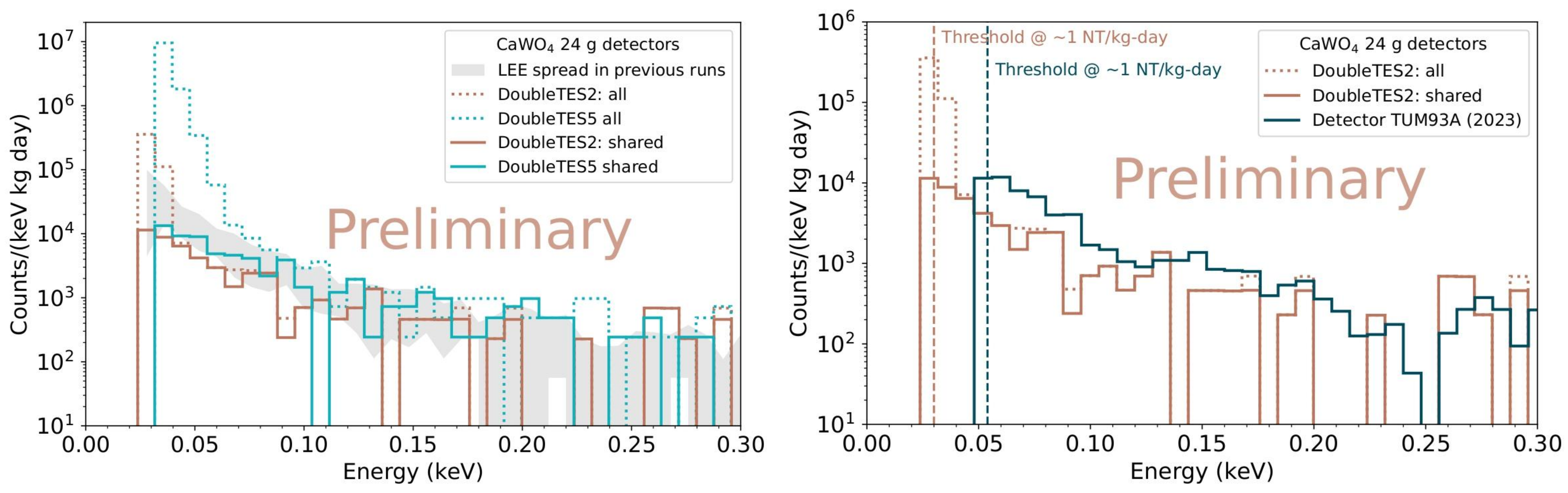

Figure 2: On the left, the energy spectra of doubleTES 2 (blue) and 5 (orange) are shown for all (dashed line) and only shared events (solid line). The grey band represents the spread of the LEE energy spectra in previous runs. On the right, the energy spectrum of doubleTES 2 (orange) and TUM93A (blue) is shown.

Spectral Shape of the LEE

Above 40 eV the most consistent model is a single power law: $\mathbf{A_P\ E^{-\varepsilon} + A_C}$ with the spectral shape parameter ε. Below 40 eV a change in spectral shape is observed and still under investigation.

The motivation for modelling the LEE is to potentially treat the LEE as a "known background" and to possibly find the LEE's origin.

Time Behaviour of the LEE

In time, the most consistent model is an exponential function: $\mathbf{A_E \exp\left(-\frac{t}{\tau}\right) + A_C}$ with the decay constant τ.

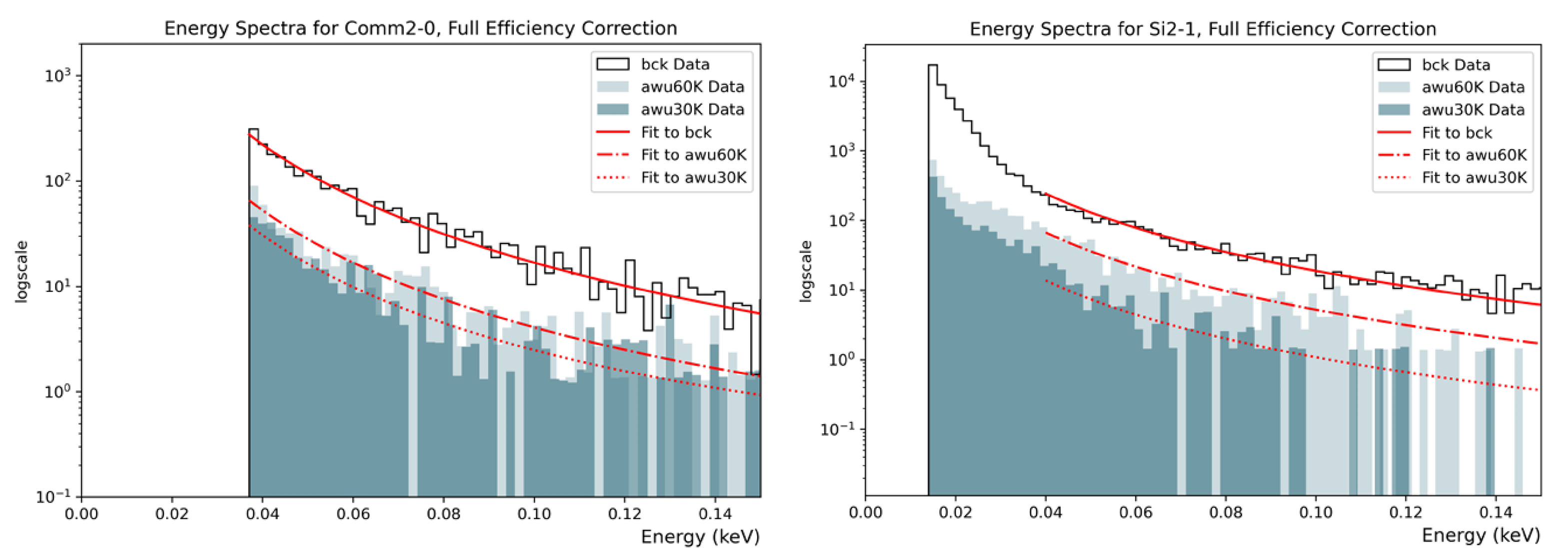

Figure 3: The energy spectra of different data sets (different blue shades) with a power law fit of a $CaWO_4$ bulk detector (left) and a Si wafer detector (right) are shown. Above 40 eV the power law is a consistent description, whilst below 40 eV a change in spectral shape is observed (right) [4].

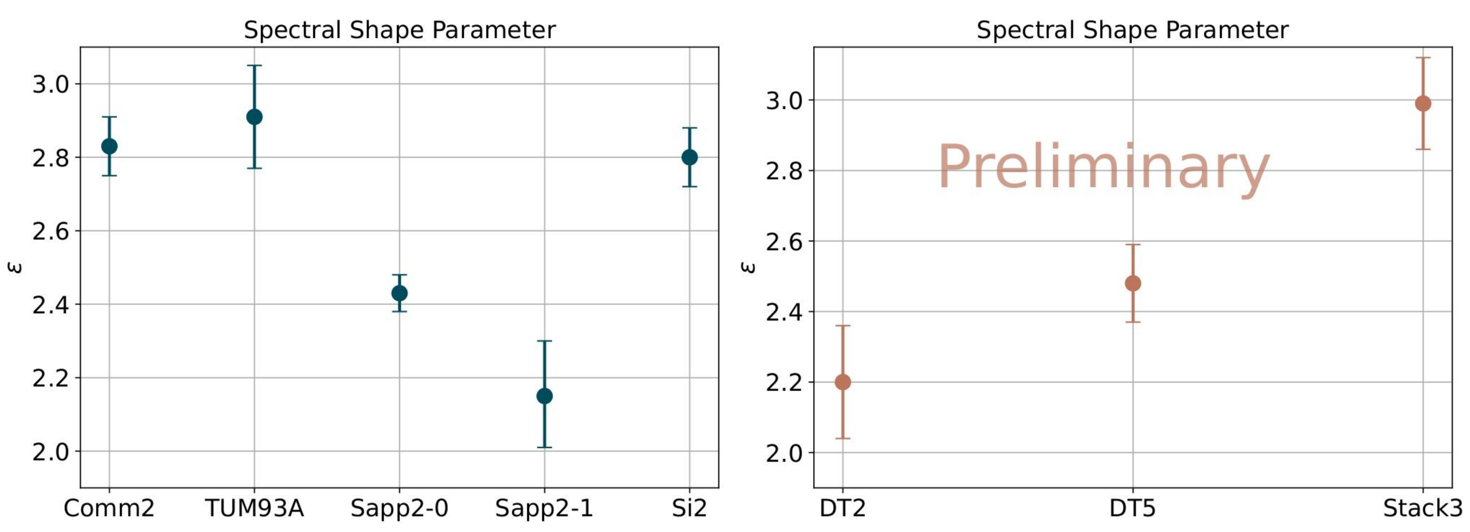

Figure 4: A comparison between the spectral shape parameters (left: previous run [4]; right: current run; the wafer detectors are Sapp2-1, Si2 and Stack3). The parameters are very similar between detectors and runs.

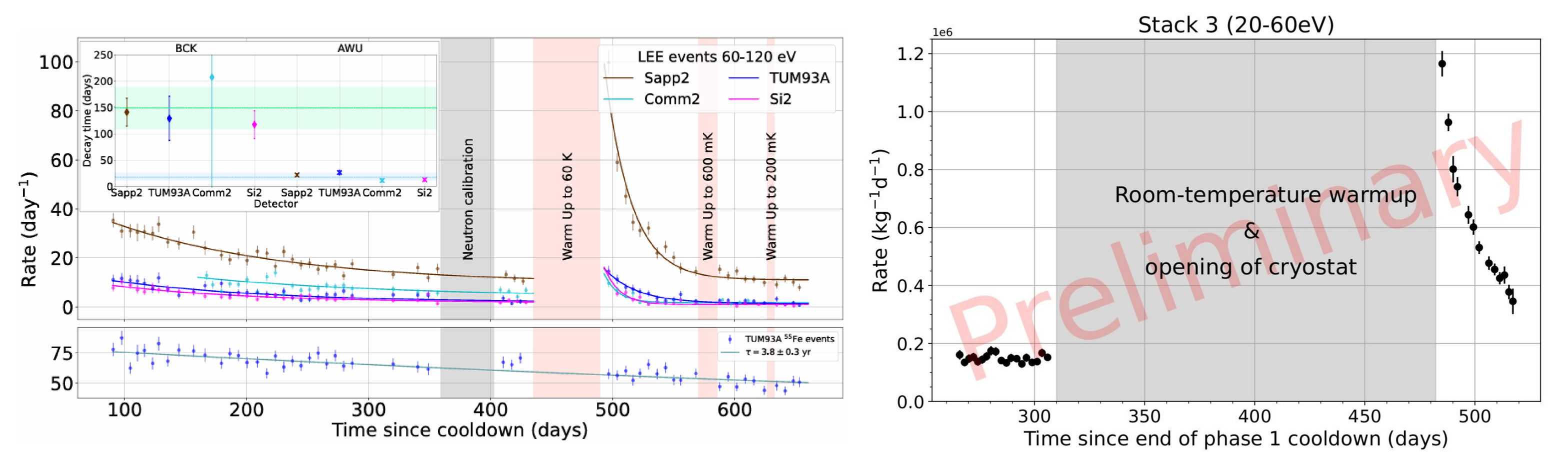

Figure 5: Previous run (left) [3]: The LEE for different detector modules (only wafer detector: Si2) is shown. The decay times are given in the inset plot for before and after the warm-ups (awu; the whole run included warm-ups to the following temperatures: 60 K, 600 mK, 200 mK, 4 K, 30 K, 11 K and 130 K). The decay time of the ^{55}Fe source is given in the bottom plot. For the current run (right) the rate of a wafer detector is shown.

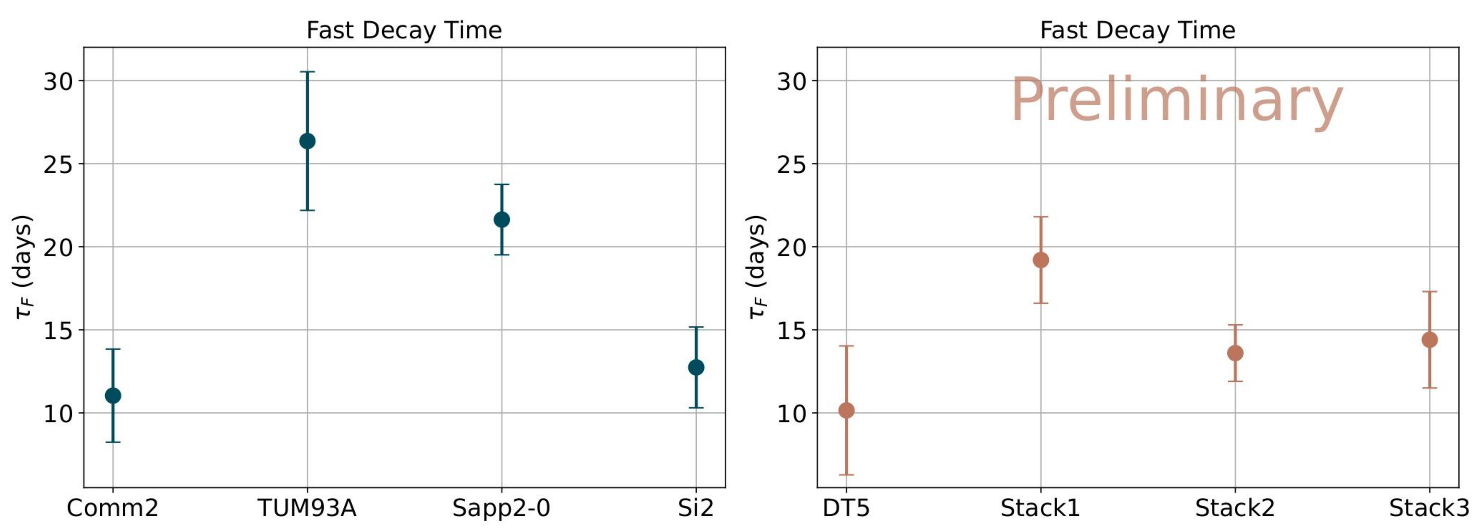

Figure 6: A comparison between the fast decay times (left: Fig. 5 previous run awu data; right: current run; the wafer detectors are Si2 and Stack1, 2 & 3). The parameters are very similar between detectors and runs.

References

[1] G. Angloher et al. "The CRESST experiment: towards the next-generation of sub-GeV direct dark matter detection". Comm. Phys. 9, 163 (2026)

[2] G. Angloher et al. "DoubleTES detectors to investigate the CRESST low energy background: results from above-ground prototypes". Eur. Phys. J. C (2024) 84:1001

[3] G. Angloher et al. "Latest observations on the low energy excess in CRESST-III". SciPost Phys. Proc. 12, 013 (2023)

[4] S. Kuckuk. "An Extensive Description of the Low-Energy Excess in CRESST-III". PhD thesis. Eberhard Karls Universität Tübingen, 2025

The CRESST Collaboration

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