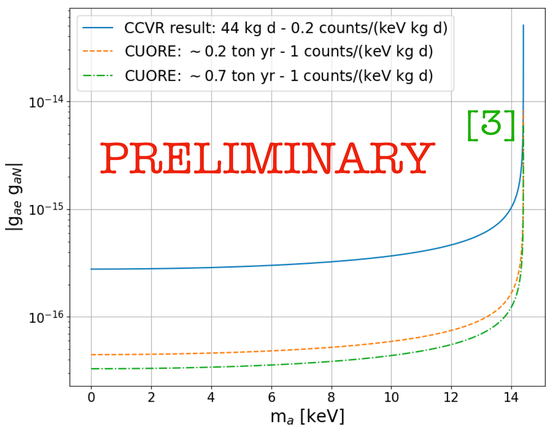
Recent progress on dark matter searches in CUORE

Solar Axions

The Axion is a light dark matter candidate originally predicted to explain the non-observation of a charge-parity violation in strong interactions



1. produced by the nuclear transition of ^{57}Fe excited state (thermally populated in the core of the Sun)
2. converted to electrons via axio-electric effect: monochromatic peak at 14.4 keV

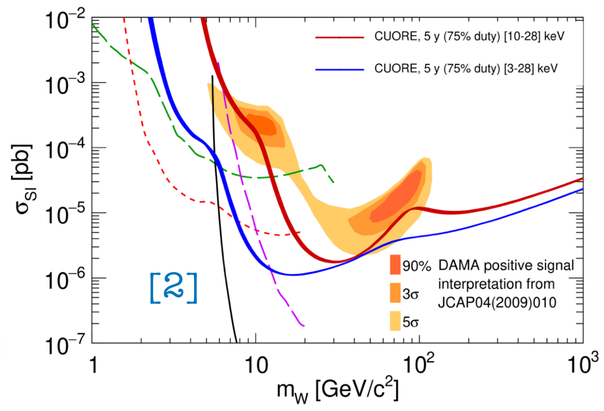
➡ This search is sensitive to Axions coupling to electrons and nuclei

WIMPS

Weakly Interacting Massive Particles are largely studied dark matter candidates thermally produced in the early universe and still present as a relic due to universe expansion.

1. Interact via nuclear recoil in CUORE crystals. TeO_2 provides both light and massive nuclei
2. Search for an annual modulation due to Earth's motion

➡ Low mass (<100 GeV) WIMPS targeted because of larger modulating amplitudes

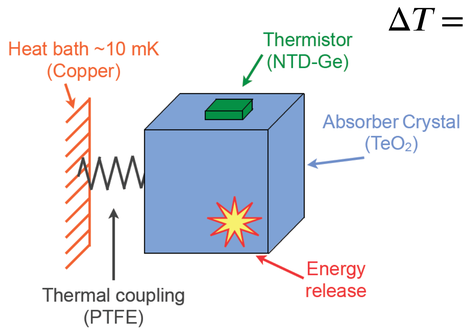


The CUORE Experiment

CUORE consists of 988 TeO_2 cubic crystals working as cryogenic calorimeters.

➡ convert particles energy release into heat
➡ temperature increase read by a thermistor (NTD-Ge)

$$\Delta T = \frac{\Delta E}{C(T)} \rightarrow C(T) \propto T^3$$

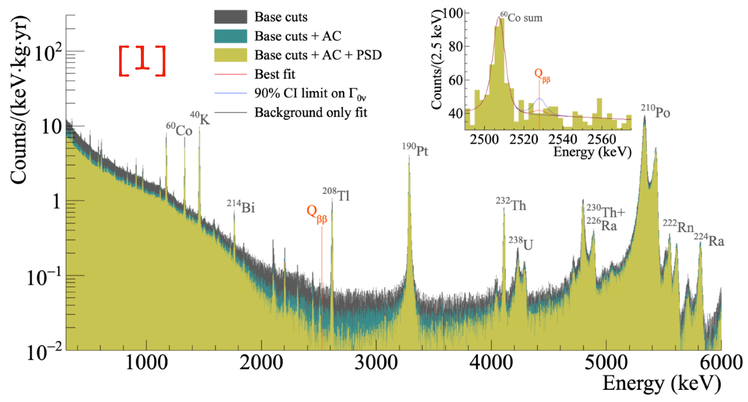


- Needs very low temperatures (~ 10 mK)
- Excellent energy resolution (~ 1 keV Noise RMS)

- Operated underground (@ Laboratori Nazionali del Gran Sasso) to shield against cosmic rays
- Built with low radioactivity materials and strict cleaning procedures

The first ton-scale bolometric detector operated in a Cryogen-free cryostat able to guarantee over a 5 years live-time

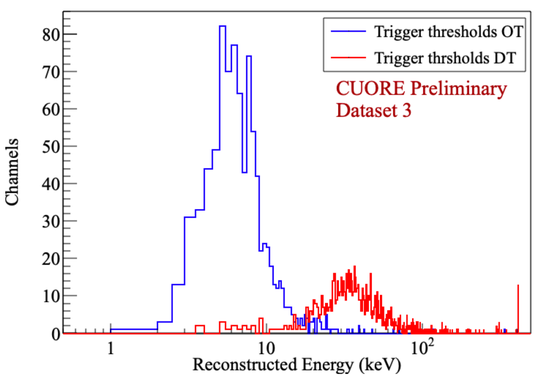
See new results in K. Alfonso talk



CUORE is designed to search for $0\nu\beta\beta$, but its significant achievements open the door to further new physics searches

- Over 2 ton yr of raw exposure
- Background index of 1.49 ·10^{-2} counts/(keV kg yr) at ^{130}Te $0\nu\beta\beta$ Q-value (2528 keV)
- Best limit on ^{130}Te $0\nu\beta\beta$ half-life: 2.2 ·10^{25} yr

Lowering the energy threshold



We apply an offline trigger on the filtered waveforms.
The (Optimum) filter transform function is made to suppress the frequencies most affected by the noise:

$$H(\omega) = k\frac{S^*(\omega)}{N(\omega)}e^{i\omega t_{peak}}$$

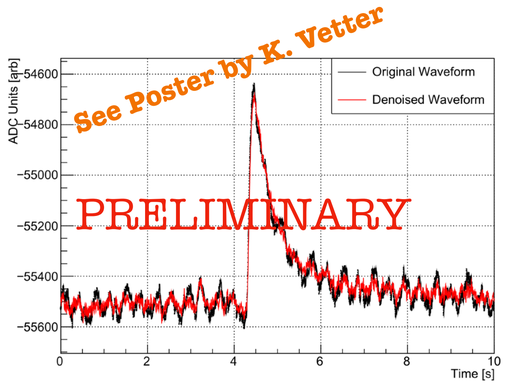
Signal template

Noise template

This pushes at lower energies the trigger energy threshold set to be at 90% of the trigger efficiency.

- More than 50% of the CUORE channels have a trigger threshold lower than 10 keV

See Poster by K. Vetter

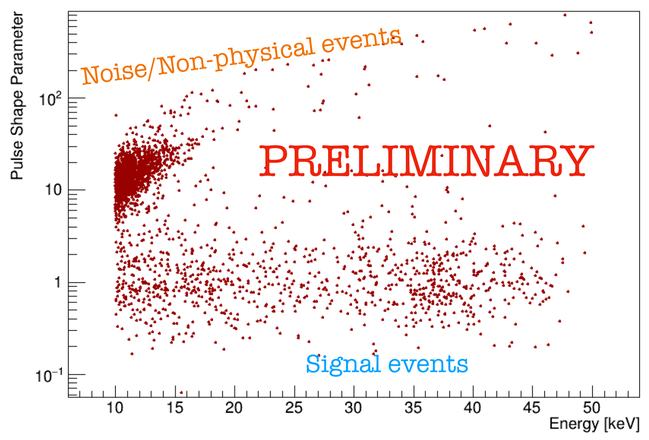


To further improve the noise level, in the 2 ton yr data release, waveforms will be denoised.

- De-correlate noise of bolometric channels with the one of auxiliary devices (accelerometers, microphones, antennas)

Low Energy Techniques

Tower vibrations, electronic noise or energy deposits in the thermistors can mimic signal pulses leaking in the low energy spectrum. We aim to reject such non-physical events



We quantify how an event is close to the ideal pulse shape:

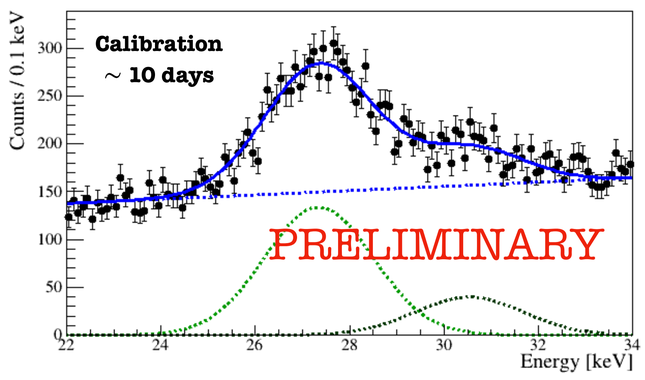
Signal Events:
➡ constant band at lower values

Noise/Non-physical events:
➡ increasing with energy
➡ clustering at lower energies

CUORE detects X-rays from Te atoms excited by an external source used for calibration.
Overall 8 lines spanning from about 27 to 31 keV, mostly detected in coincidence with a higher energy gamma.

We can use them to:

- Check energy calibration
- Estimate efficiencies
- Optimize signal-to-noise ratio for
  - Pulse Shape cuts
  - Anti-coincidence cut



[1] CUORE latest results: Nature volume 604, pages 53–58 (2022)

[2] CUORE-0 Low Energy Techniques: EPJC volume **77**, 857 (2017)

[3] Solar Axions search with TeO_2 Crystals: JCAP 05 (2013) 007

Alberto Ressa for the CUORE collaboration

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