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# Unlocking the keV frontier of the CUORE experiment


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## 介绍 Introduction

**C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents

First ton-scale cryogenic calorimeter:
- large exposure (> 2 ton yr)
- excellent energy resolution via thermal phonons detection

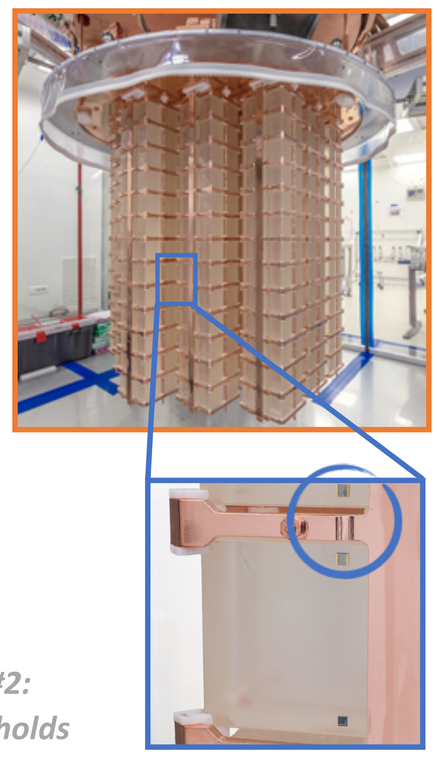
Excellent performance at MeV-scale to search for neutrinoless double beta decay ($0\nu\beta\beta$)

Neutron Transmutation Doped Germanium (NTD-Ge) thermistors:

- Detect temperature rise due to particles interaction
- Reliable on a large scale: 988 operated in CUORE
- Working on a wide energy range

★ Can explore physics down to the keV scale!

插图 *Figure #1: CUORE and a close-up*



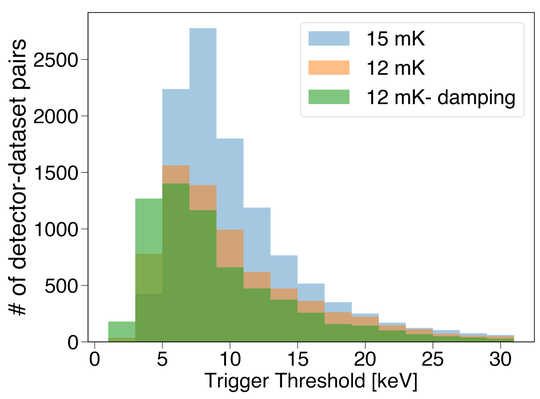



插图 *Figure #2: Trigger thresholds distribution*

Accessible threshold improves:
- at lower operation temperature
- with optimal vibration damping configuration

~ 60% below 10 keV
~ 1% below 3 keV

Challenges at low energy:
- Poor signal-to-noise ratio spoils pulses reconstruction
- Cryogenic Calorimeters are susceptible to spurious events like vibration, thermal stresses, electronic spikes

## 实验方法 Methods

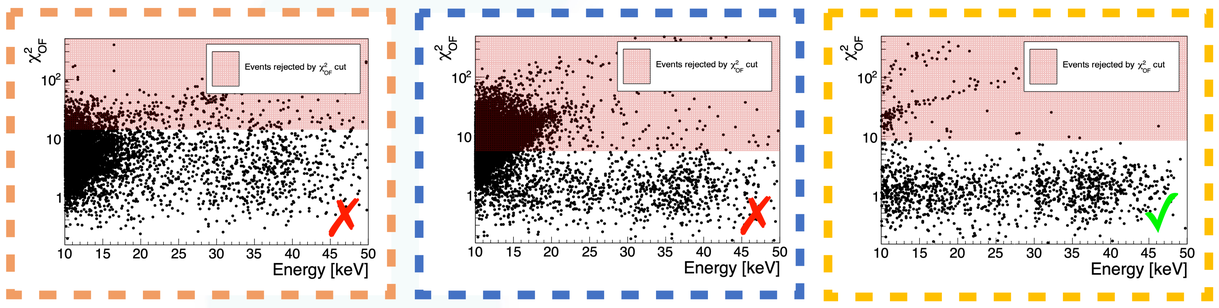



插图 *Figure #3: Pulse shape vs energy examples*

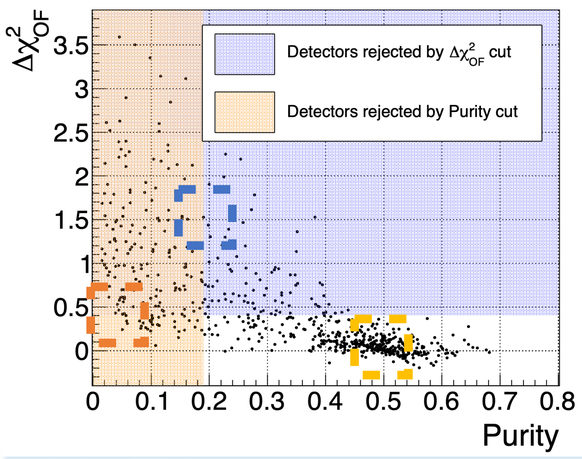



插图 *Figure #4: Low Energy quality parameters for each detector*

1. Define an energy threshold we aim to reach (e.g. 10 keV)

2. Apply detector-by-detector optimised pulse shape cut
   - $\chi^2_{OF}$ variable: similarity with template average pulse

3. Reject detectors with unwanted behaviour as a function of energy
   - Increasing number of events density (lower "Purity")
   - Increasing pulse shape variable (higher $\Delta\chi^2_{OF}$)

Optimise low energy background level and signal efficiency over loss in exposure

## 实验成果 Results

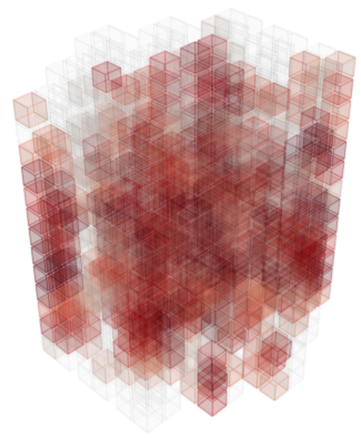
We focused on two possible thresholds:
- 10 keV: enough for several new physics searches, optimal exposure
- 3 keV: lowest achievable, of interest for $^{123}$Te EC search, optimal performances

| Energy Threshold | 10 keV | 3 keV |
|---|---|---|
| Selected exposure | 691 kg yr | 11 kg yr |
| FWHM | 2.5 keV | 1.2 keV |
| Background | 2 d.r.u. | 16 d.r.u. |
| Efficiency | 50% | 26% |

Best detectors:
- Central floors → lower vibration
- Less resistive NTD → lower thermal noise

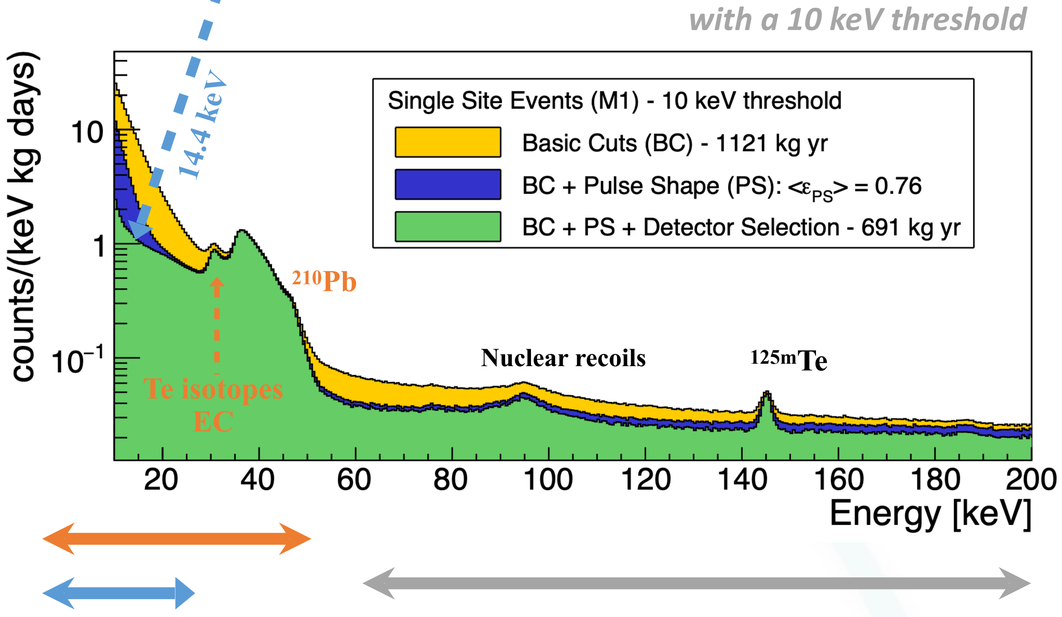
The selection of a detector depends also on data taking conditions, resulting in a different exposure for each of them.

插图 *Figure #4: Selected detector in CUORE array for a 10 keV threshold*




Proof of principle for dark matter search via monochromatic signature.
$^{57}$Fe nuclear de-excitation in the Sun to produce axions
Coming Soon!

插图 *Figure #5: low energy spectrum of CUORE with a 10 keV threshold*




New Physics:
- Solar Axions spectrum
- WIMPs annual modulation

Background Modelling:
- $^{123}$Te EC: never observed!

Well known spectrum features

## 实验结论 Conclusions

★ CUORE for the first time operated ~ thousand cryogenic sensors simultaneously, exploring more than 3 orders of magnitude of energy spectrum.

★ We minimised spurious events contribution with dedicated analysis techniques, highlighting data taking and detectors feature to improve energy threshold.

★ Opportunity to run a Phase II of CUORE for dark matter search subsequent to facility's vibration environment improvement for CUPID (CUORE's successor)

相关介绍Bibliography