Low Energy Analyses with CUORE and a Search for Solar Axions

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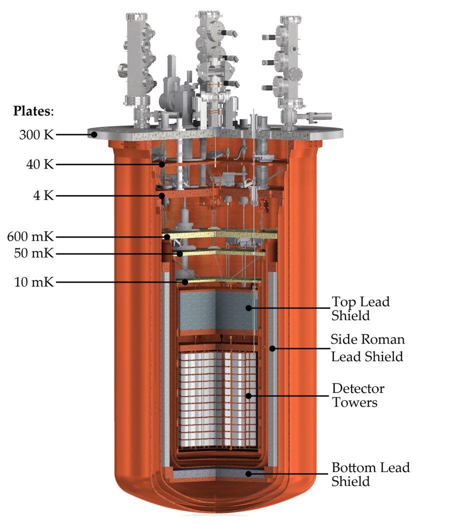
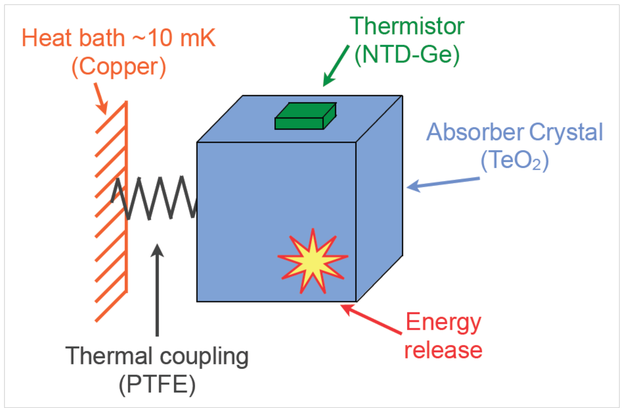
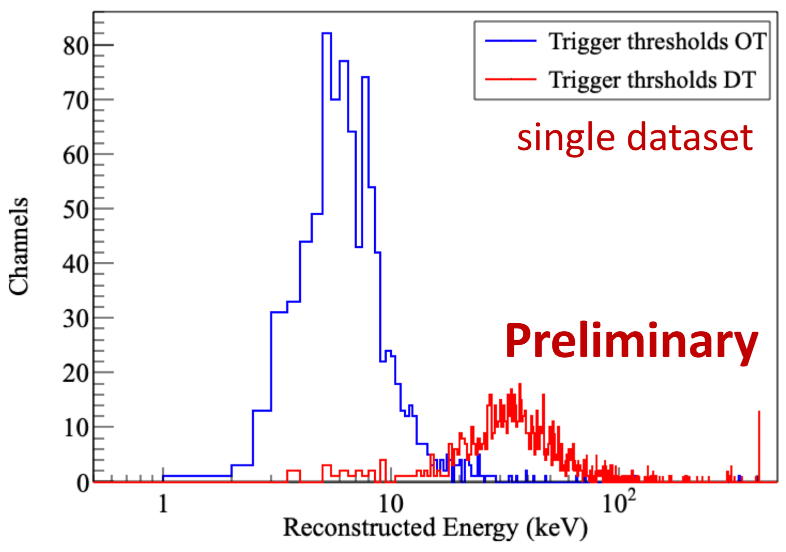
CUORE: The Cryogenic Underground Observatory for Rare Events





- 988 TeO_2 crystal cryogenic calorimeters operated at ~15 mK, which convert deposited energy from particles into heat
- Located at Laboratori Nazionali del Gran Sasso
- Collected and analyzed over 2 tonne·yrs of TeO_2 exposure

Trigger thresholds



Optimum Filter [1]

signal template

$$H(\omega_k) = h\frac{s^*(\omega_k)}{N(\omega_k)}e^{-j\omega_k i_M}.$$

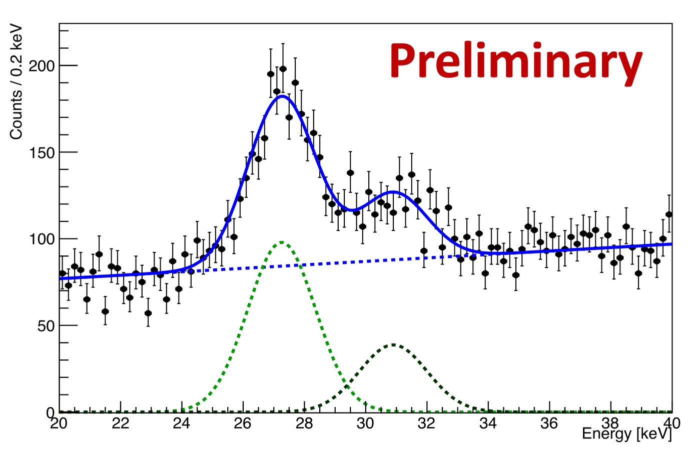
noise power spectrum

- Use an Optimum Trigger (OT) on data processed through an Optimum Filter, a matched filter to optimize the signal to noise ratio
- OT triggers are much lower than triggering on the derivative of raw waveforms (DT), enabling low energy searches

Low energy analysis methods

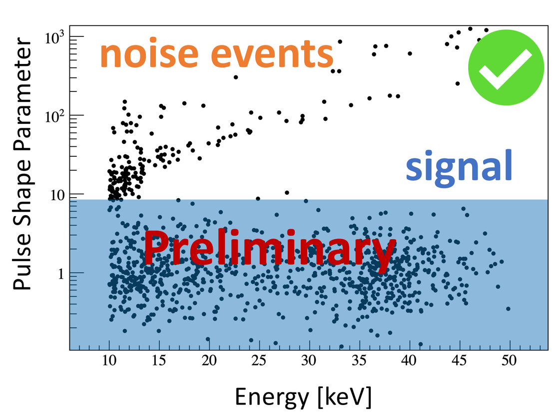
- 2 tonne·yr dataset of CUORE underwent additional processing for low-energy studies building off of CUORE-0 and CUORE techniques
- Te x-rays from calibration data are a tool for optimizing many methods
- Specific low-energy variables and event-level cuts developed for:
  - Multi-site events tagging
  - Dedicated pulse shape analysis to reject spurious events
  - Identifying pileup pulses

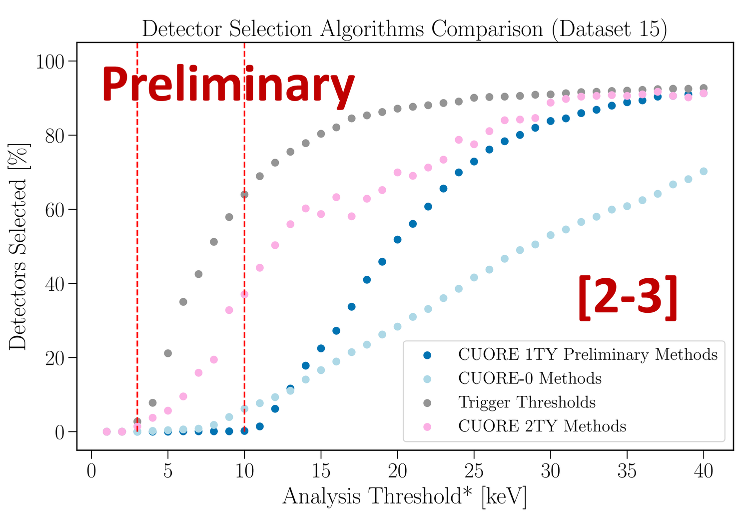
Te x-ray fits



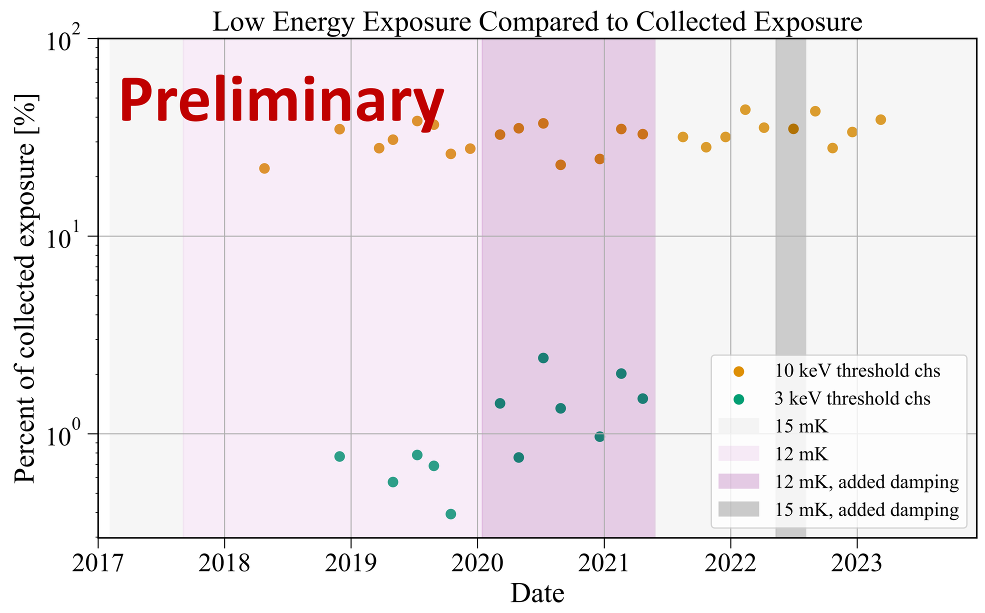
Sensitivity optimizing detector selections

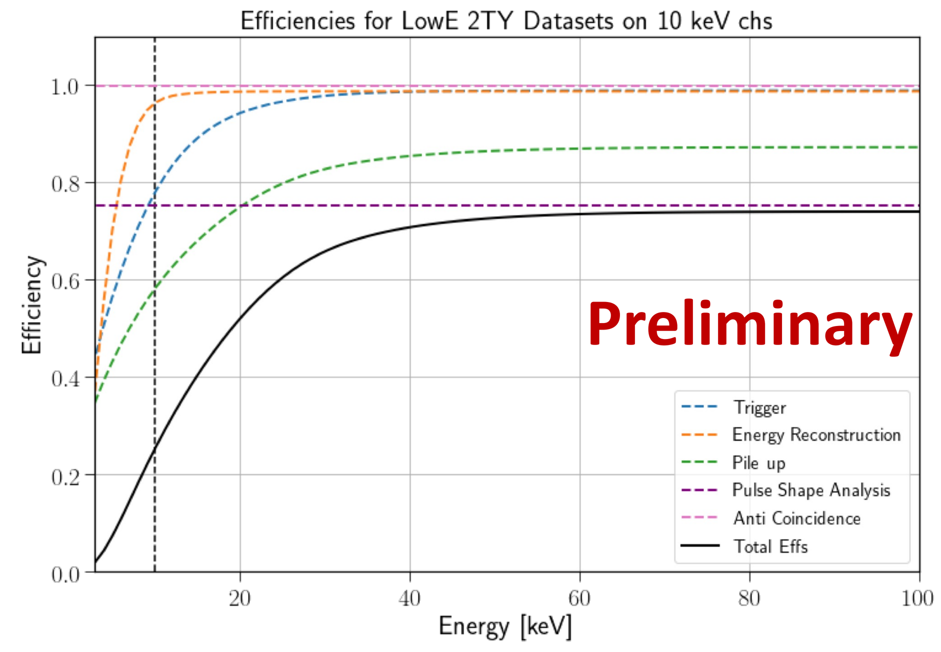
- Study pulse shape and events rate to select the best performing detectors of the array
- Greatly increased exposure compared to previous methods





Exposure and efficiencies



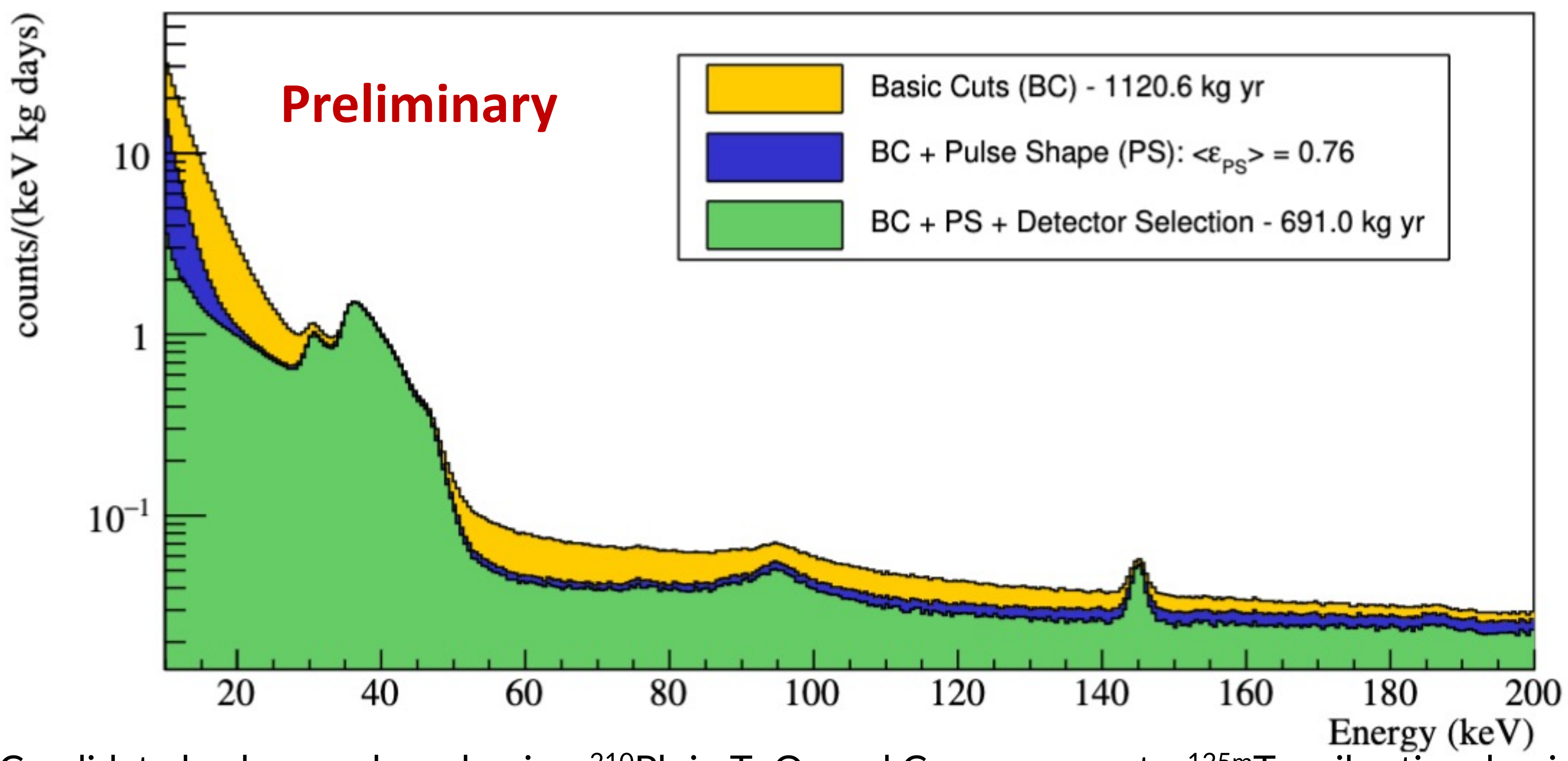


Total TeO_2 exposure at:
- 3 keV: ~ 10 kg·yrs
- 10 keV: ~ 690 kg·yrs

- Accessible exposures affected by operational temperature, vibrational controls, and time of year (See S. Quitadamo's poster)

- Efficiencies on coincident events and pulse shape analysis were evaluated from ^{40}K and Te x-ray peaks at 27-31 keV, respectively
- Detection efficiencies were calculated from low-energy, thermal events injected into CUORE crystals using heaters

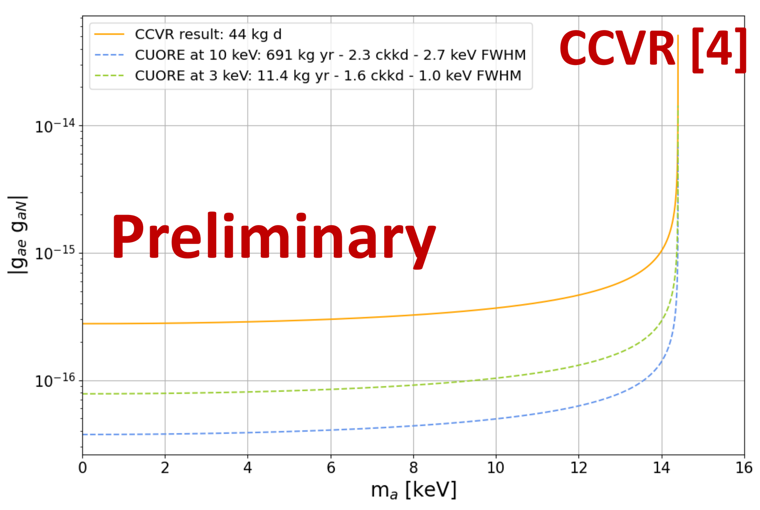
Low energy spectrum for selected channels at 10 keV



- Candidate backgrounds and noise: ^{210}Pb in TeO_2 and Cu components, ^{125m}Te, vibrational noise from microseism events
- Energy resolution: ~ 2-3 keV FWHM at 30 keV

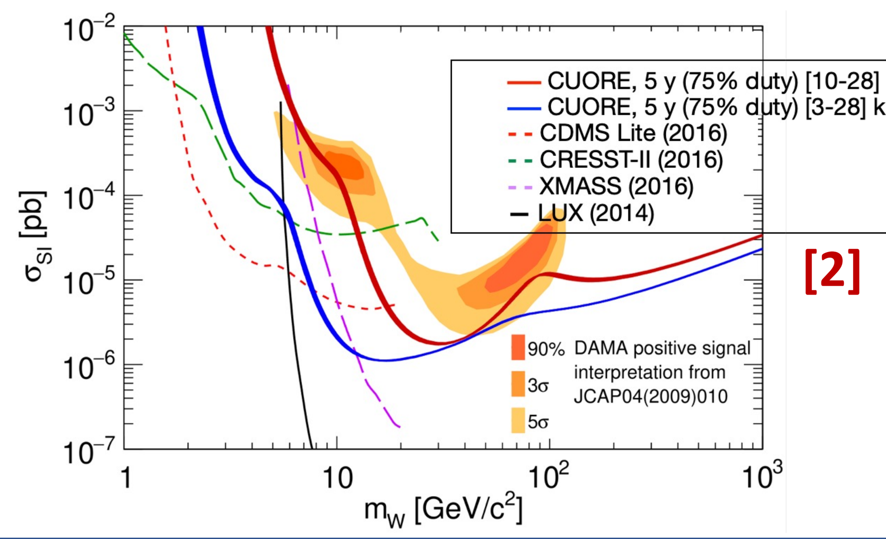
Solar axion search

- Axions and Axion-like Particles (ALPs) are dark matter candidates
- Multiple solar axion searches are possible with CUORE
- Ongoing search for solar axions produced from an M1 transition of ^{57}Fe in the sun and detected by the axio-electric effect



WIMP search

- Weakly Interacting Massive particles (WIMPs) are well-motivated dark matter candidates by particle physics and astrophysics
- Search for annual modulation of events throughout the year
- Sensitivity estimated using results from CUORE-0



References

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[2] Low energy analysis techniques for CUORE: EPJ C (2017) 77: 857
[3] Performance of the low threshold Optimum Trigger on CUORE data: A . Branca et al. Journal of Physics: Conference Series (2020) 1468(1):012118
[4] Search for 14.4 keV solar axions from M1 transition of 57Fe with CUORE crystals: JCAP05 (2013) 007

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