Sensitivity and Physics Reach of CUORE

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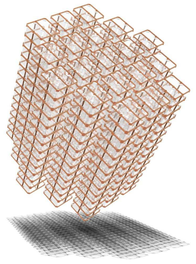
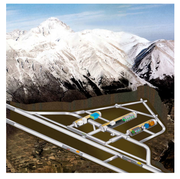
CUORE



CUORE tower array

- The Cryogenic Underground Observatory for Rare Events (CUORE) will search for $0\nu\beta\beta$ in ^{130}Te.
- 988 TeO_2 crystals as both the $0\nu\beta\beta$ sources and as bolometric detectors, with 206 kg of ^{130}Te mass.
- CUORE is also suitable for the direct dark matter search due to its low background and significant target mass.
- CUORE-0, the first tower from the CUORE assembly line, is operating as a standalone experiment and has been taking data since March 2013.
- The CUORE experiment is currently in the advanced stages of detector construction and scheduled to take data in 2015, with $\sim$ 5 years of expected data taking.

- Both CUORE and CUORE-0 are located underground at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. The average rock coverage of 1.4 km (3600 m.w.e) provides a factor of 10^6 reduction of the surface muon flux.

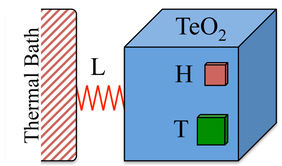


LNGS

CUORE hut

TeO_2 Bolometers for $0\nu\beta\beta$ Search

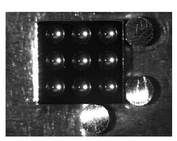
- ^{130}Te has relatively high Q-value of 2528 keV.
- ^{130}Te also has high natural isotopic abundance at 34.2% and enrichment of TeO_2 is not required.
- TeO_2 bolometers, which measure energy through a rise in the temperature of the detector, provide excellent energy resolution (0.2% at Q-value).
- Excelletn energy resolution of the detector helps identify the signal and suppresses intrinsic background from $2\nu\beta\beta$.



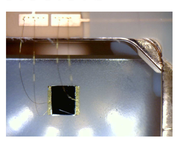
Schematic of a bolometer

CUORE Detector

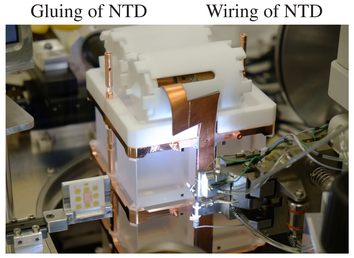
Bolometric Detectors



Gluing of NTD



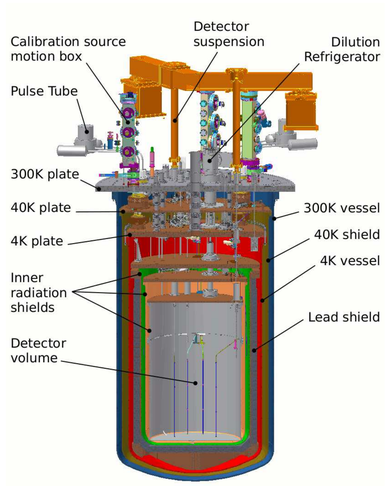
Wiring of NTD



Tower with a bonding machine

- CUORE consists of 19 towers, each tower is composed of 13 planes of four $5 \times 5 \times 5$ cm^3 TeO_2 crystals, mounted in a frame made of copper.
- Radiopure TeO_2 crystals are produced in collaboration with Shanghai Institute of Ceramics, Chinese Academy of Science and transported to LNGS by ground and sea transportation to minimize cosmogenic activation.
- Each crystal is instrumented with one neutron transmutation doped (NTD) Ge thermistor and one silicon Joule heater.
- Bolometer operating temperature is 10 mK.
- The detector assembly procedure is performed in a cleanroom environment.
- Flexible printed circuit board copper traces were bonded to the thermistors and heaters using 25 μm diameter gold wires.

Cryogenics and Calibration System

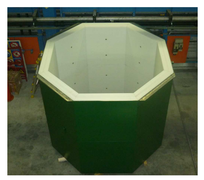


CUORE cryostat

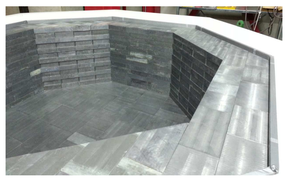
Test installation and cooldown

Shields

Ancient Roman lead discovered by a scuber diver



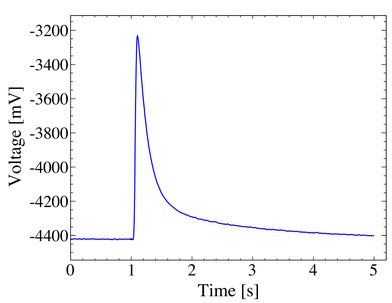
External neutron shield (PE + H_3BO_3)



External γ-ray shield (Lead)

Electronics, Data Acquisition, and Analysis Software

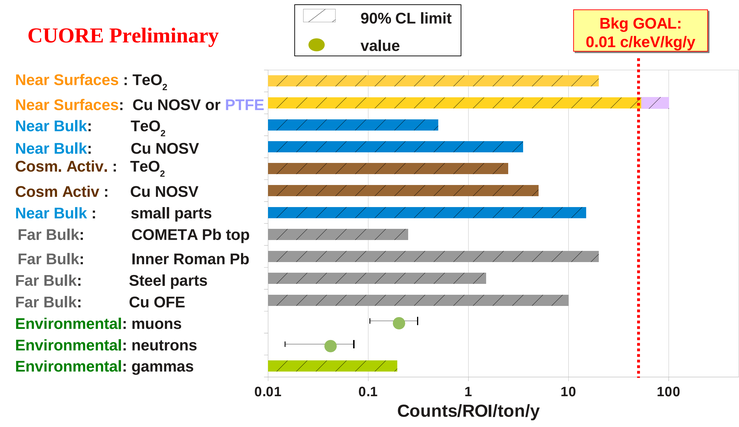
- The bolometer signals are amplified and then filtered with six-pole Bessel low-pass filters.
- The signals are digitized by National Instruments 18-bit digitizers with a 125 S/s sampling rate.
- DAQ software package designed to read signals from $\sim$ 1000 bolometers will digitize the analog waveforms, run trigger algorithms, and store data for offline analysis.
- Continuous data collection and off-line triggering allow for multiple physics analyses by applying different energy thresholds in software.
- Raw data will be processed with C++ based software framework for the analysis.



An example of a bolometer signal

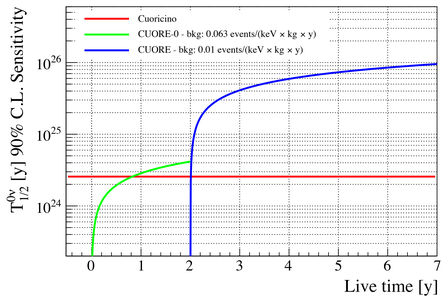
Prospects of CUORE

Background Budget

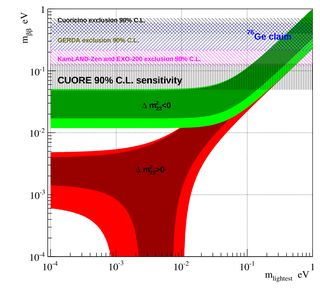


- CUORE-0 experiment demonstrated that surface background mitigation was successful.
- The CUORE background goal is 0.01 events/(kg $\times$ keV $\times$ yr).
- In addition, the low background rate allows for a precise measurement of the $2\nu\beta\beta$ half-life and a search for dark matter with CUORE.

Sensitivity to $0\nu\beta\beta$



Projected 90% C.L. half-life sensitivity



90% C.L. sensitivity to $m_{\beta\beta}$ vs m_{lightest} (5y)

- CUORE-0 is expected to surpass Cuoricino upper limit of 2.8×10^{24}yr in 1 year of live time.
- With a background rate of 0.01 events/(kg $\times$ keV $\times$ yr), 5 keV FWHM region of interest resolution, and 5 years of live time, we expect a 90% C.L. sensitivity of :
- $T^{0\nu}_{1/2} = 9.5 \times 10^{25}$ y ($\langle m_{\beta\beta} \rangle$ = 0.05–0.13 eV).

Dark Matter Perspective

- With 3 keV energy threshold for all detectors, the same background rate measured from the CUORE Crystal Validation Run II in the region of interest, and 5 years of live time, CUORE is sensitive to the regions allowed by DAMA, CoGeNT, and CRESST.

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