Surface induced background in CUORE

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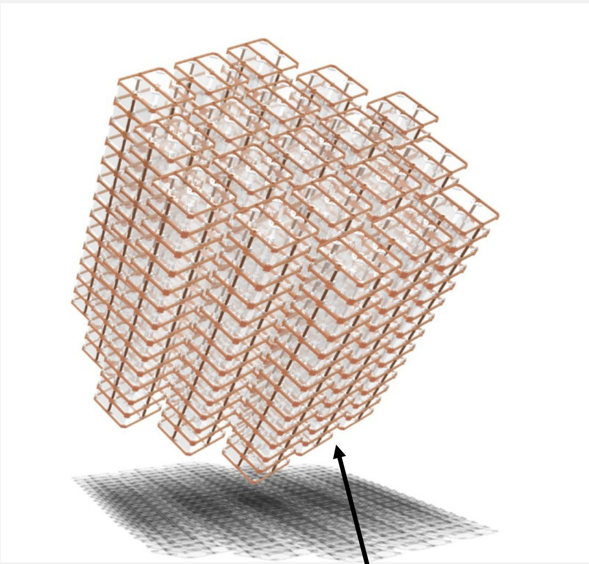
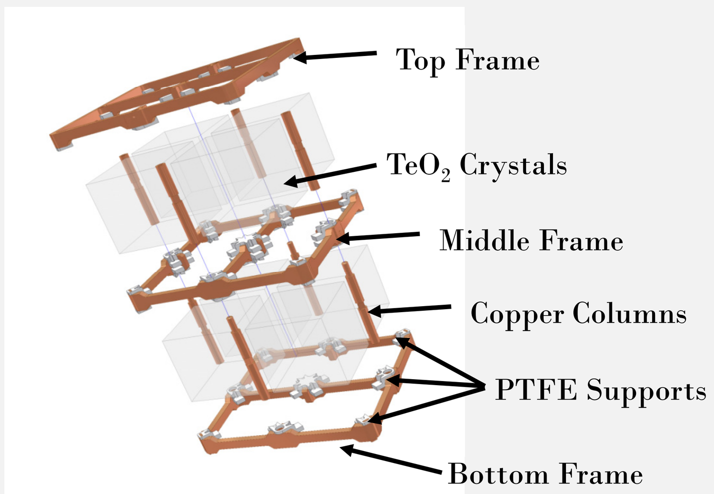
Cryogenic Underground Observatory for Rare Events

The CUORE experiment aims to search for neutrinoless Double Beta Decay (0νDBD) of ^{130}Te (Q~ 2528 keV, isotopic abundance ~34%) with TeO_2 bolometers. Discovery of 0νDBD will provide outstanding insight into neutrino mass and nature (Dirac or Majorana).

CUORE is a tightly-packed array of 988 bolometers

- operated at Laboratori Nazionali del Gran Sasso (Italy)
- base temperature: ~10 mK
- total detector mass: 741 kg (206 kg of ^{130}Te)





19 tower, with 52 detectors each

CUORE shielding

- A ~25 cm thick lead layer outside the cryostat shields the detector from γ radiations coming from the bottom and from the sides.
- Outside the external lead shield an 18 cm thick polyethylene layer will be added in order to thermalize environmental neutrons that will then be absorbed by a 2 cm layer of H_3BO_3 powder.
- The entire array will be surrounded by a 6 cm thick Roman lead shield operated at about 10 mK and a further thickness of 30 cm of low activity lead will be used to shield from the dilution unit and from the environmental radioactivity.
- Alpha background due to crystal surface contaminations is highly reduced by operating the detectors in anticoincidence.

CUORE Background Model

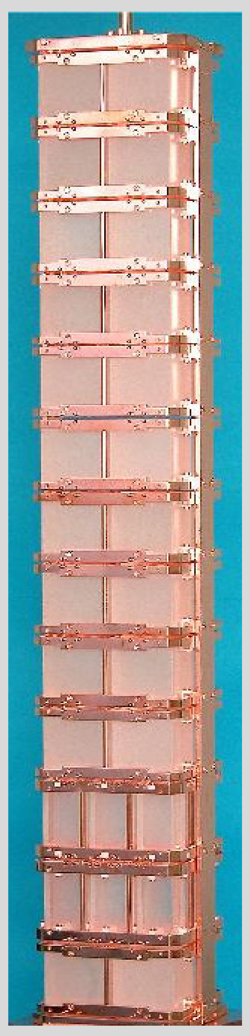
The CUORE background model is based mainly on the knowledge acquired on the bolometric technique thanks to Cuoricino.

Source	Rate in the region of interest counts/keV/kg/y
^{238}U in the Cu elements	$<0.7\cdot10^{-3}$
^{232}Th in the Cu elements	$<1.5\cdot10^{-3}$
^{232}Th in the Roman lead shield	$<4\cdot10^{-3}$
TeO_2 surface activity	**$<4\cdot10^{-3}$**
Copper and PTFE surface activity	**$<(2\text{-}6)\cdot10^{-2}$**

Main background contributions in CUORE. Only elements with an expected contribution larger than $1\cdot10^{-3}$ counts/keV/kg/y are listed.

Cuoricino background and surface contaminations

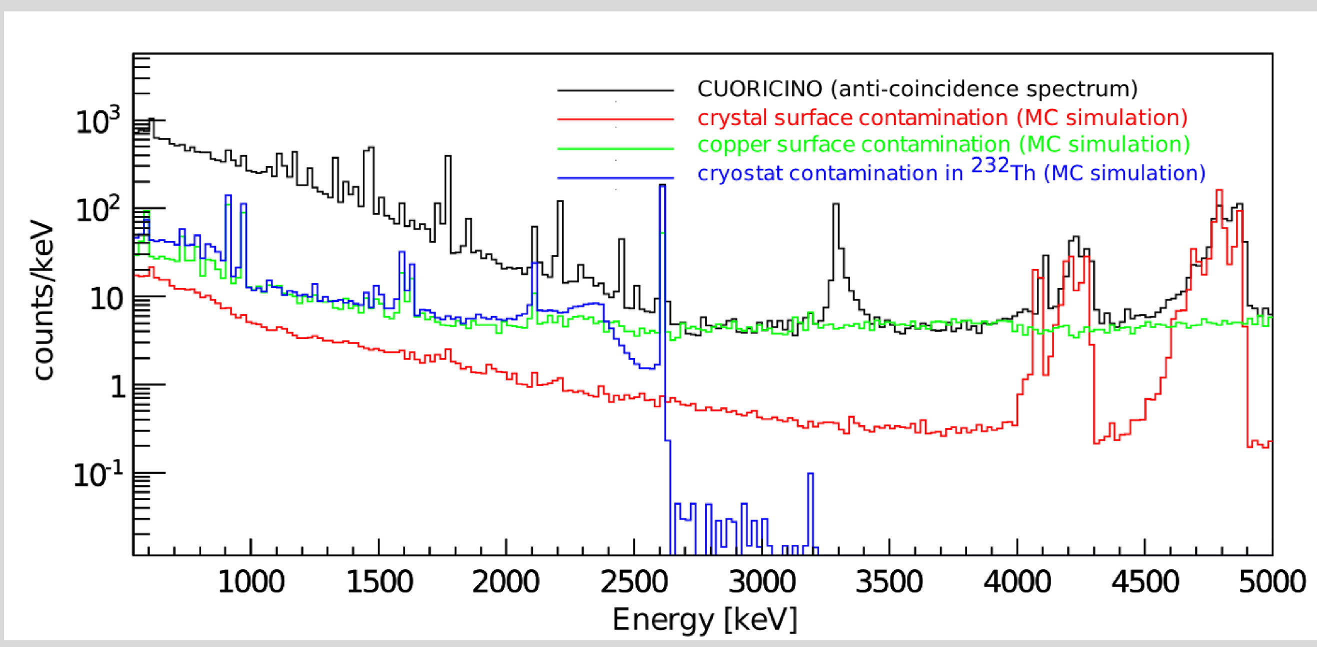
The Cuoricino experiment (2003-2008, total statistics 19.75 kg·y) consisted of an array of 62 TeO_2 bolometers with a total mass of 40.7 kg. The Cuoricino detector was built as a prototype for the CUORE experiment. Cuoricino allowed to reach excellent background level of 0.169±0.006 c/keV/kg/y at the Q-value (anti-coincidence between detectors).



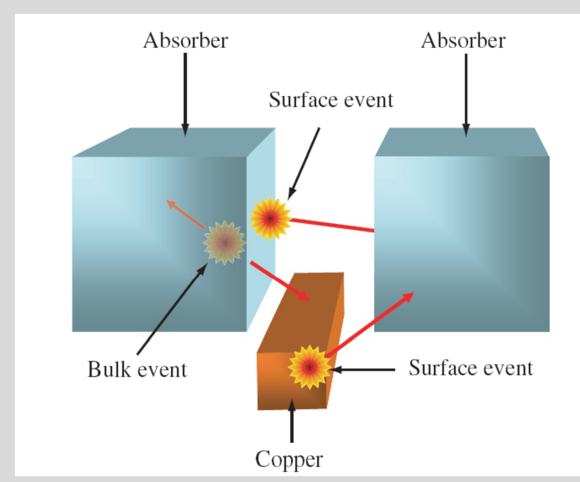
Cuoricino Background Model

Cuoricino counting rate in the region of interest:

- (10±5)% of the measured rate is ascribed to **surface contaminations** of the TeO_2 crystals in ^{238}U and ^{232}Th;
- (30±10)% to multi-Compton events of the 2615 keV gamma ray from ^{208}Tl contaminations of the cryostat and shields;
- (50±20)% to **surface contaminations** of inert materials surrounding the crystals, most likely copper.



Alpha surface contaminations

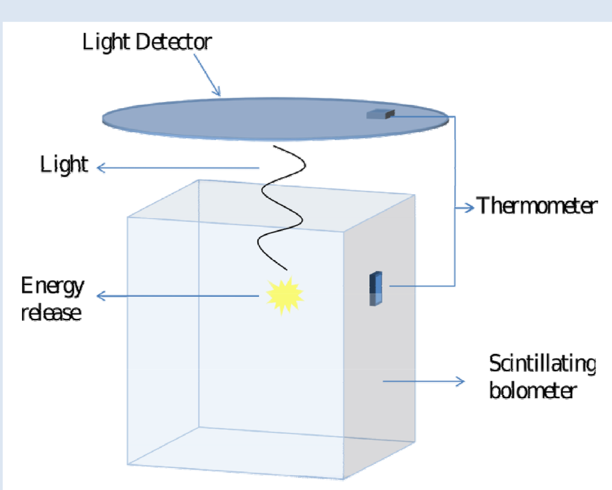


The kinetic energy of α particles emitted by U and Th daughters are always far above the region of interest for 0νDBD. Therefore α particles give contributions only if they loose a limited fraction of their energy in the bolometer. This condition happens whenever the contamination is localized on the surface of the crystal or of the material facing the detector.

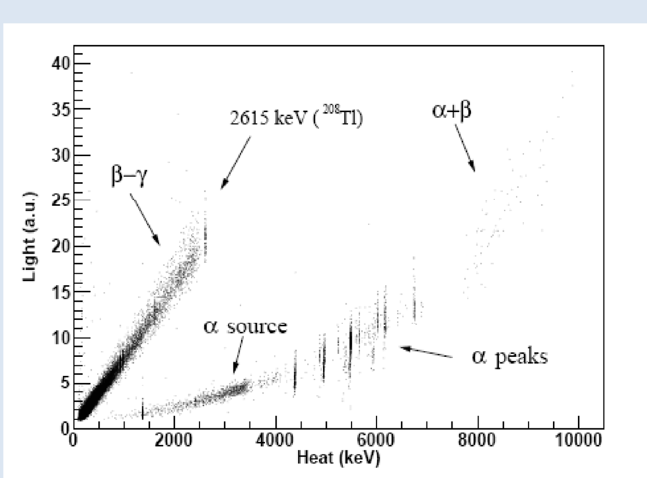
Surface contaminations studies with scintillating bolometer

Working principle of scintillating bolometers

Scintillating bolometer: a bolometer coupled to a light detector. The first consists of a scintillating absorber thermally linked to a phonon sensor while the latter can be any device able to measure the emitted photons.



The leading idea: to combine the two available information (heat and scintillation light) to distinguish the nature of the interacting particles, exploiting the different scintillation yield of β/γ, α and neutrons.



Example of scatter plot obtained with scintillating crystals.

Thanks to the capability to recognize the nature of the interacting particles, scintillating crystals can be used for diagnostic purposes, e.g. to study surface contaminations of materials faced to the detector.
Compared to conventional techniques used for surface contaminations studies (i.e. Si surface barrier detectors), scintillating bolometers can reach much higher sensitivity on surface contaminations.

	Scintillating Bolometer	Si surface barrier detector
Energy resolution (FWHM)	5-10 keV	25-30 keV
Background between 3-8 MeV	0.001 count/h/cm^2	0.05 count/h/cm^2
Active detector surface	> 100 cm^2	10 cm^2

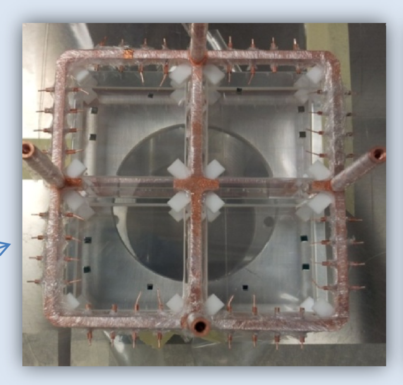
The BGO array

Usually, a scintillating bolometer has to be surrounded by a reflector in order to properly collect the scintillation light and therefore it cannot be directly faced to a given sample to study its radioactive emission. However, if a crystal with a very high light yield is chosen, it is possible to carry out a measurement without the reflecting sheet.
BGO crystals ($Bi_4Ge_3O_{12}$) are particularly suitable because of their very high light yield and commercial availability.

Array of 4 BGO crystals (5x5x5 cm^3) + Light detector (Ge, Ø=6.6 cm)

2 thermistors for crystal

CUORE-like frames covered with polyethylene



The assembly is the same (except for the light detector) of the one used for studies of surface contaminations done with TeO_2 crystals.

Surface inert material ≈ 450 cm^2

Live time = 1364 h

α background (3-8 MeV) ≈ 0.0001 count/h/cm^2

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P7 - Experimental Systems without Accelerators