

**Cuoricino and CUORE
experiments:
the search for 0 ν DBD of
 ^{130}Te**



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Outline of the talk

- Why have we chosen the ^{130}Te as source of the $0\nu\text{DBD}$?
- Basic principle of bolometric technique
- Cuoricino experiment: the detector and the first results
- CUORE project
- A new idea to reduce the CUORE background

Double Beta Decay Source

WHY ^{130}Te ?

- high natural isotopic abundance (33.87 %)
Sensitivities higher than 10^{26} y imply $10^{28} - 10^{29}$ nuclides



A few percent of isotopic abundance is unacceptable

- high transition energy ($Q=2528.8 \pm 1.3$ keV)

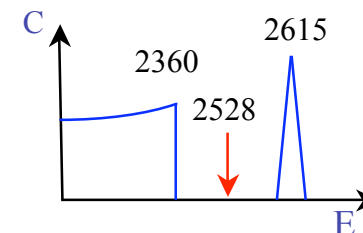
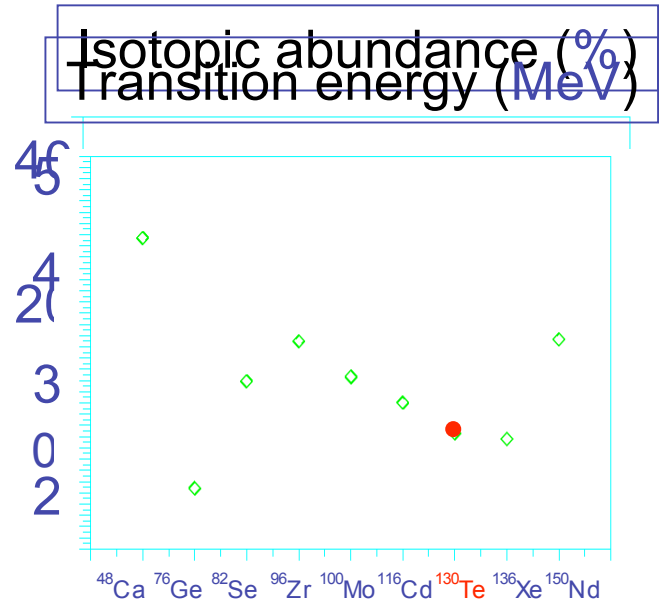


- this means large phase space for the decay
- the Q-value is important with respect to the natural radioactive background



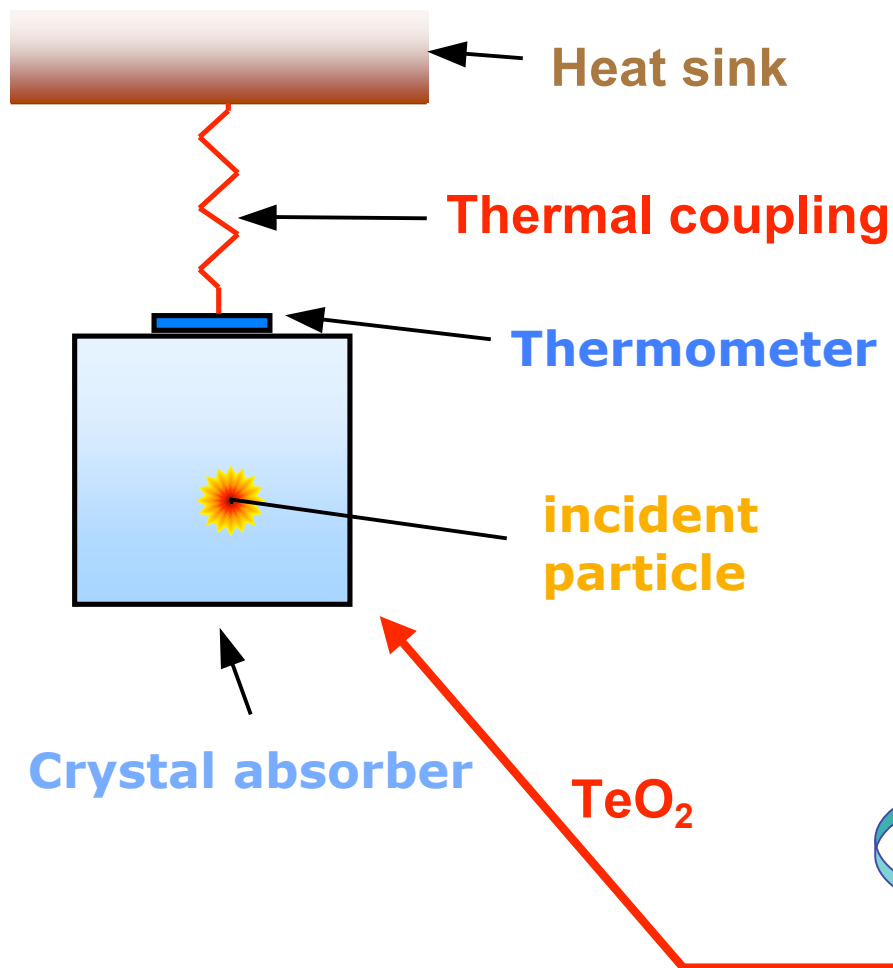
natural g background stops at 2615 keV
(^{208}Tl , Th chain) but ^{130}Te is in a lucky position:

- outside the ^{238}U background
- between the full energy and the compton edge of 2615 keV photon



Basic principle of bolometric technique

The original idea is very simple:



This technique measures **all** the energy deposited by particle in form of increase of temperature in the absorber

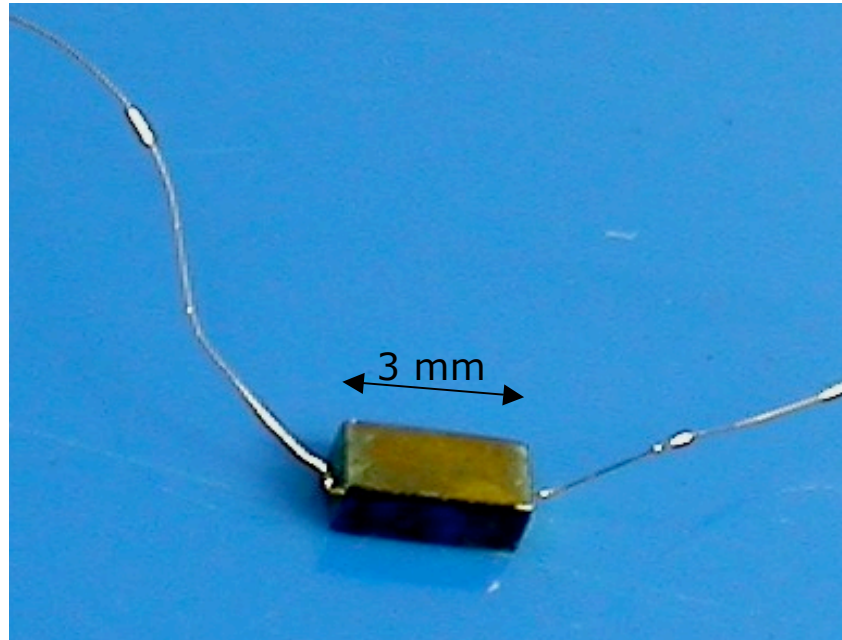
Absorber $\equiv$ DBD source

$$\text{Signal: } \Delta T = E/C$$
$$\text{Time constant} = C/G$$

Low heat capacity

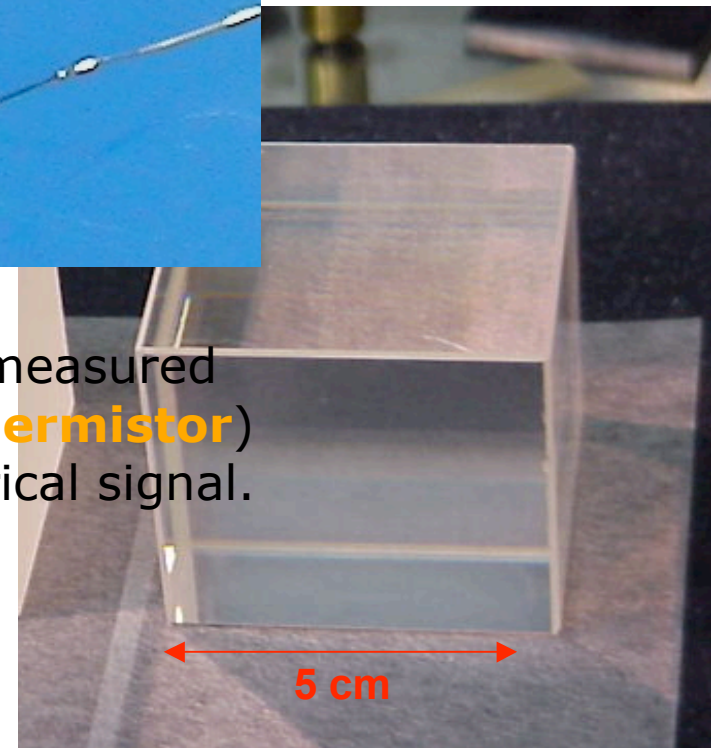
- Low temperatures
- Dielectric diamagnetic materials

Thermometer and absorber



e of TeO_2 crystal

The thermal signal is measured by the thermometer (**thermistor**) that generates an electrical signal.



Chronology of experiments

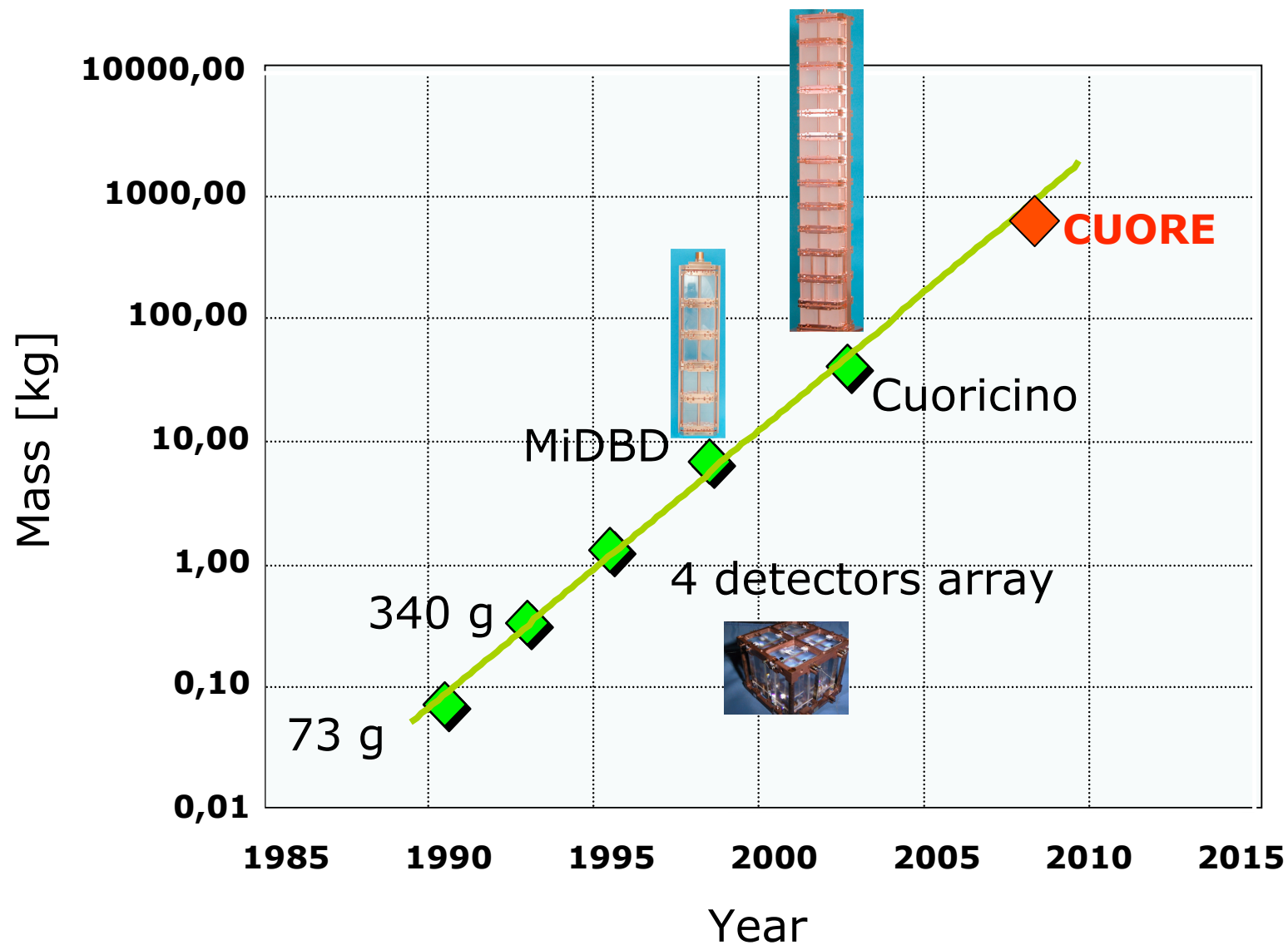
- 1997 Start of **MiDBD - I** experiment at LNGS
20 crystals $\times$ 340 g = 6.8 kg
- 2001 MiDBD detector reassembled to improve the background
and to test the first prototype of Cuoricino single module
- 2002 Stop of **MiDBD**
- MiDBD**

1998- 2003 Tests on large mass crystals (760 g) in order to develop more sensitive experiments

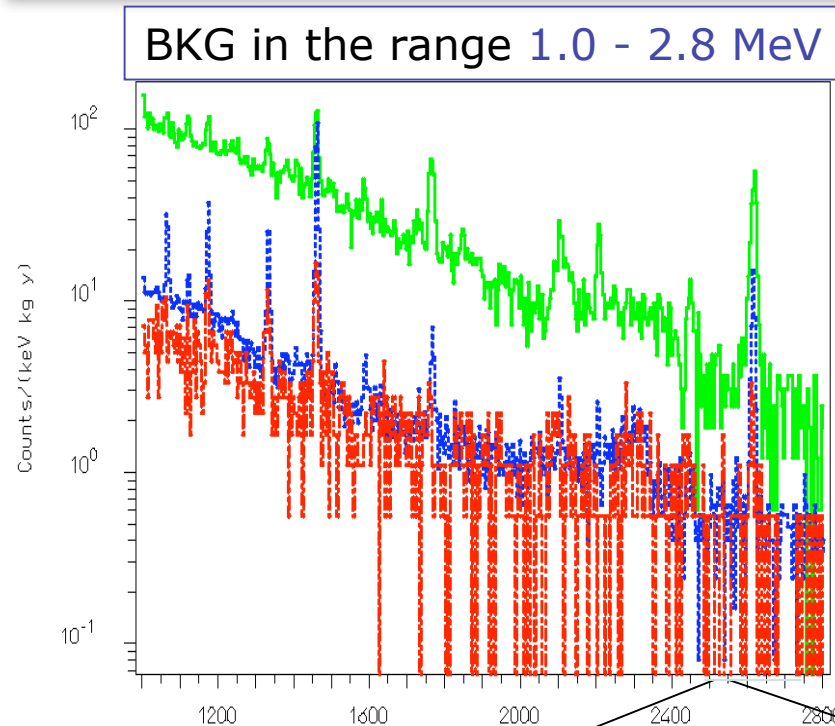
- 2001-2002 Construction of the Cuoricino detector
44 crystals $\times$ 790 g
18 cristalli $\times$ 340 g
- 2003 Start of the Cuoricino experiment
- Cuoricino**

2004-2009 Preparation of a second generation experiment
1000 crystals $\times$ 760 g = 760 kg (**CUORE**)
CUORE is scientific approved but not yet fully founded

Temporal law for mass increase of TeO_2 detectors



History of the background in Mi DBD experiment



— BKG obtained with
single 340 g detector

Operation in clean conditions



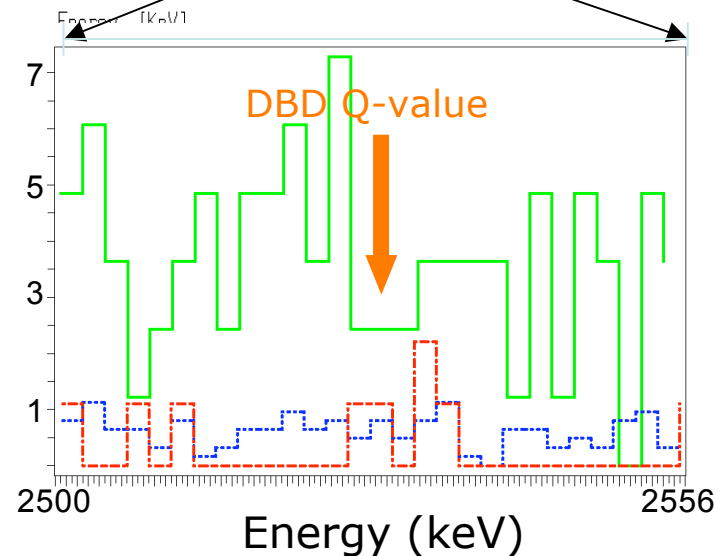
..... BKG obtained with
Mi DBD - I

*Polishing, etching and passivation of copper
Lapping of crystals with ultra-pure powder*



- - - BKG obtained with
Mi DBD - II

Counts
keV kg y



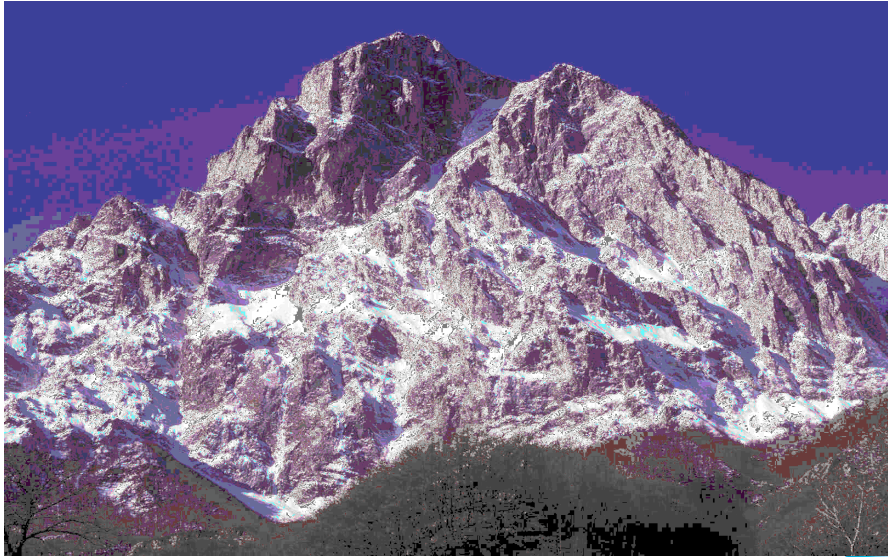
Before crystal and Cu treatment

0.59 ± 0.06 c/kev/kg/y

After crystal and Cu treatment

0.33 ± 0.11 c/kev/kg/y

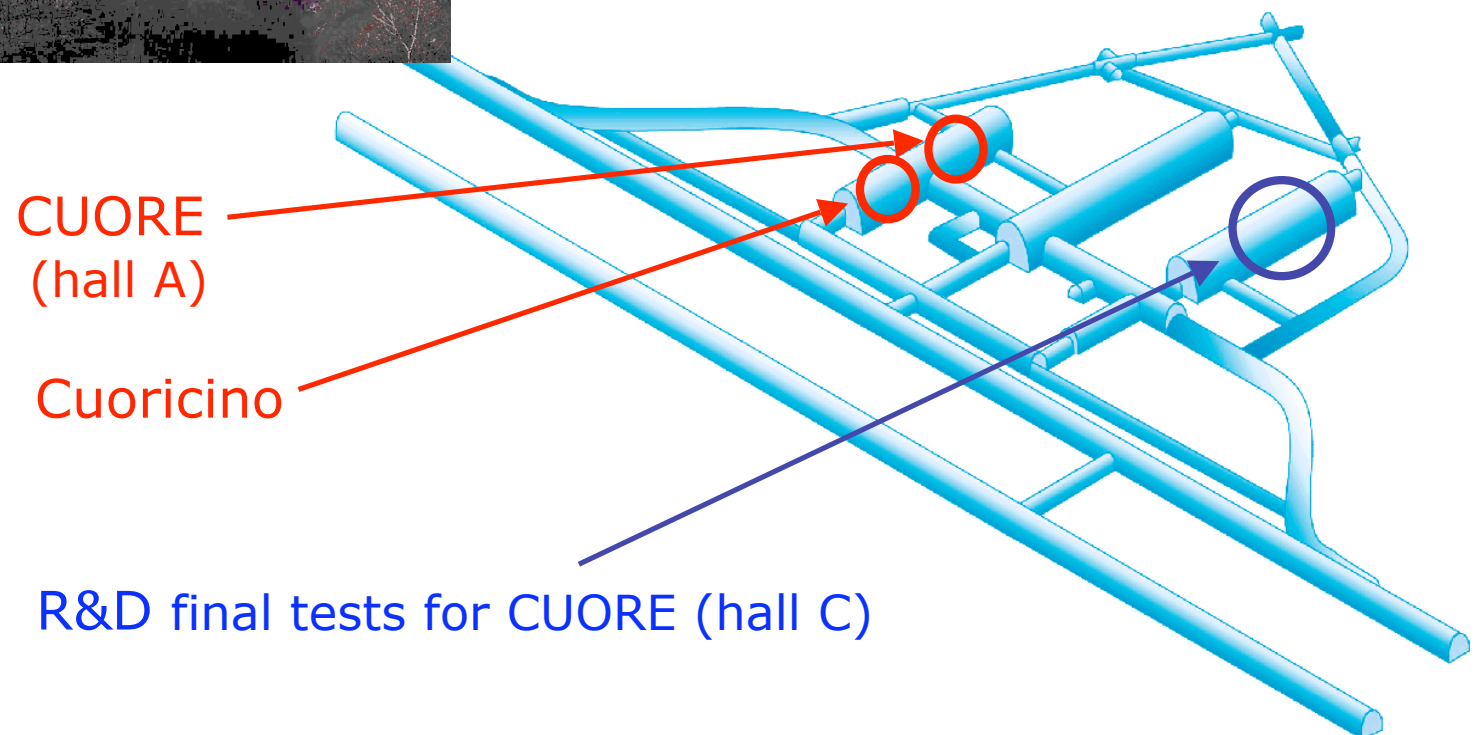
Cuoricino and CUORE Location



Cuoricino experiment is installed in the

**Underground National Laboratory
of Gran Sasso
L'Aquila – ITALY**

the mountain providing a **3500 m.w.e. shield** against cosmic rays



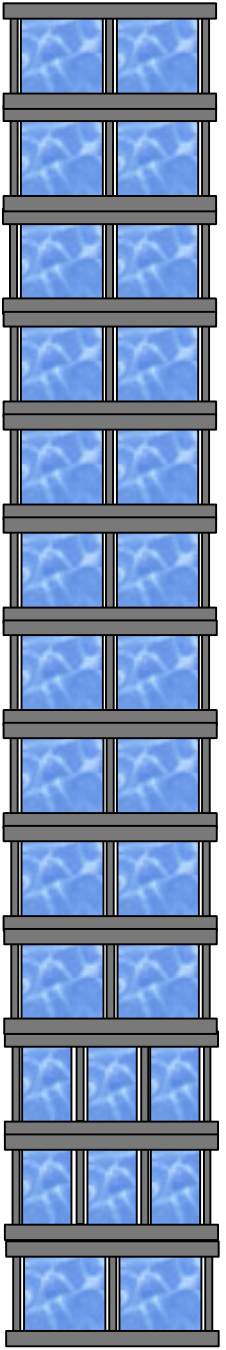
Cuoricino Detector

The Cuoricino detector has a tower-like structure and contains

44 TeO_2 crystals $5 \times 5 \times 5 \text{ cm}^3$ + 18 TeO_2 crystals $3 \times 3 \times 6 \text{ cm}^3$.

The first ones are displaced in 4 crystals modules while the other ones are displaced in 2 planes of 9 crystals modules (11th and 12th planes). The total detector weight is 41 kg.

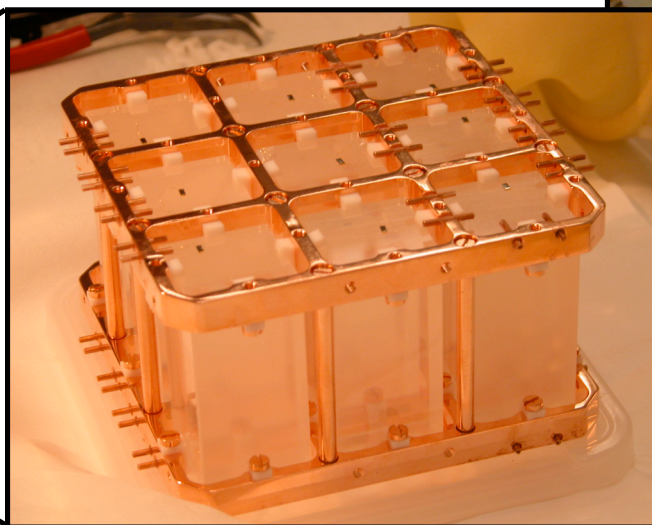
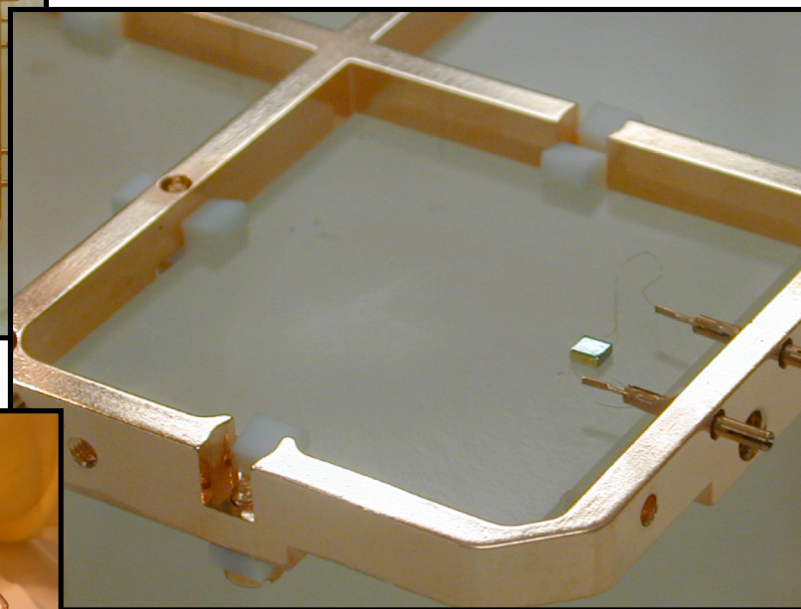
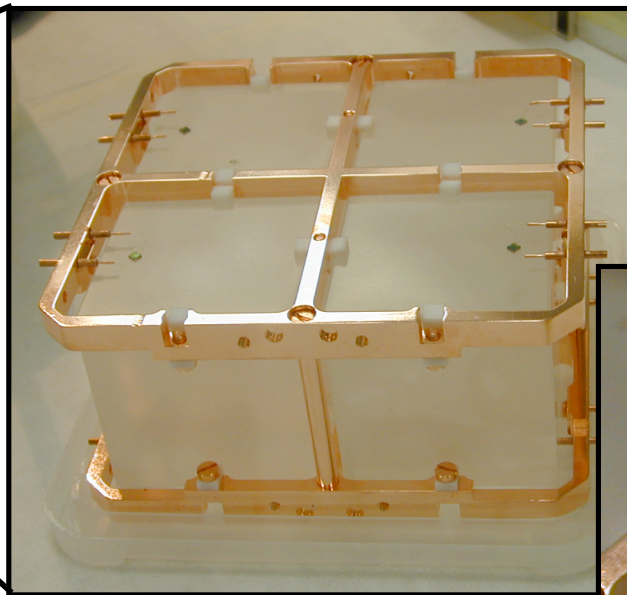
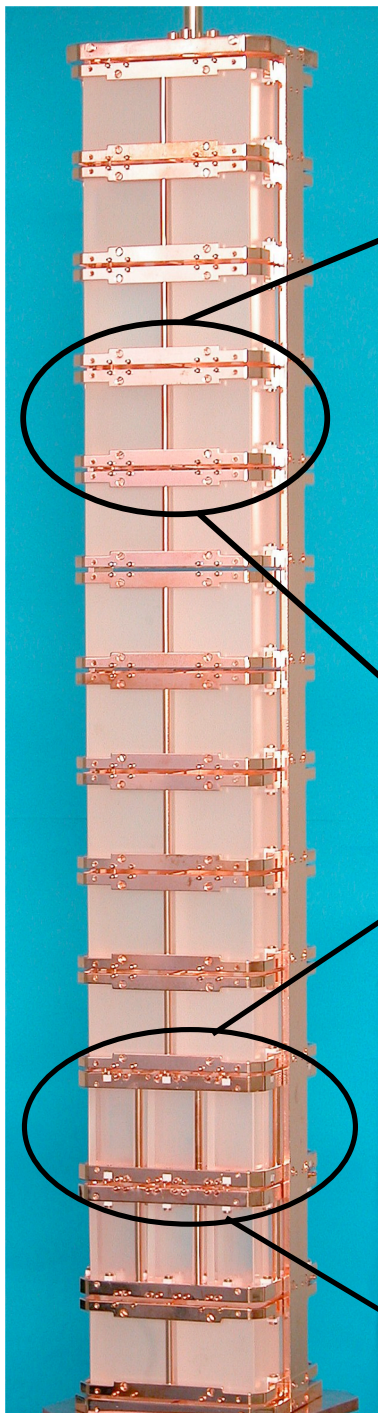
It is a self-consistent experiment that should give significant results on **Double Beta Decay**.



9 crystals modules

The diagram shows a vertical tower-like structure of the Cuoricino detector. It consists of a central column of blue rectangular crystals, each divided into four smaller quadrants by thin vertical lines. These crystals are held together by horizontal grey bands. At the bottom of the tower, two blue arrows point to the 11th and 12th modules from the top, which are labeled as '9 crystals modules'.

Some Pictures



Active mass during this run:

$$42 \times 0.790 = 33.18 \text{ kg}$$

$$17 \times 0.330 = 5.61 \text{ kg}$$

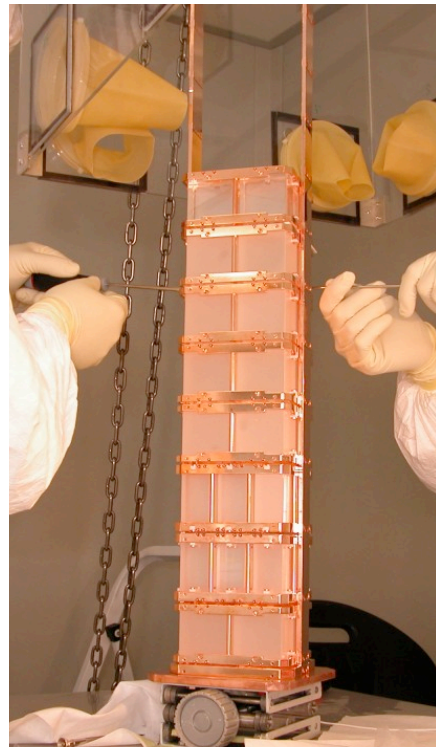
➡ **$\sim 13 \text{ kg } ^{130}\text{Te}$**

Cuoricino detector preparation



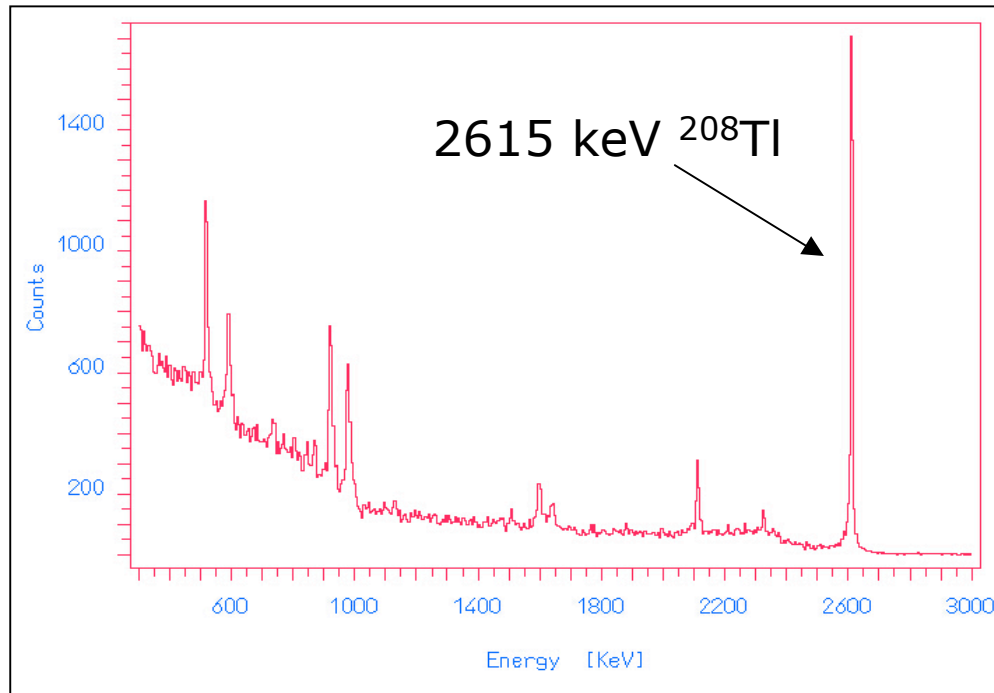
Assembling of the detector modules...

... the assembling of the tower ...



... the connection of the tower to the MC of dilution refrigerator.

Detector Performance



spectrum obtained
with a calibration

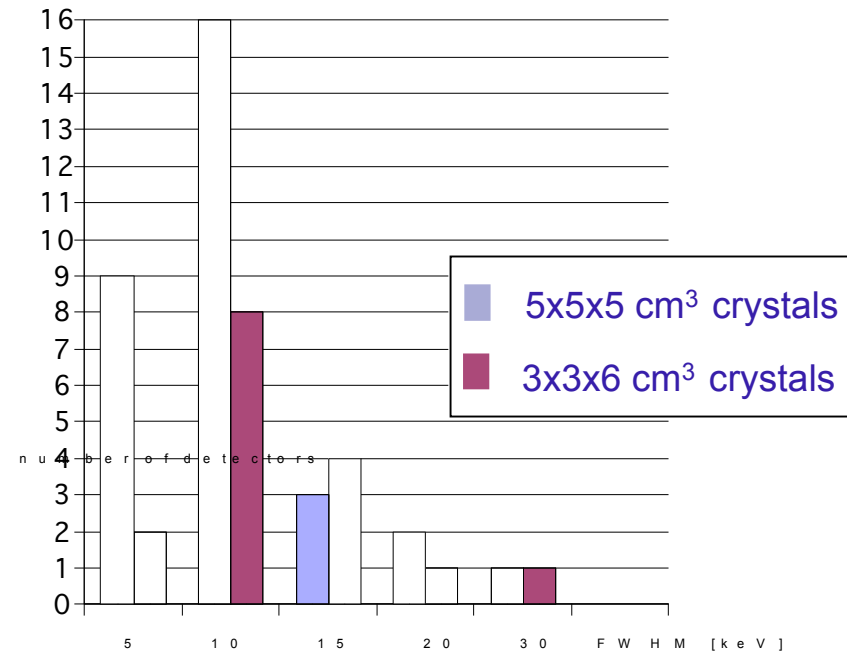
The calibration is performed periodically (every 2 weeks) using a mixed U and Th source paced outside the cryostat but inside the external lead shield

FWHM [keV] of the 2615 keV gamma line of ^{208}Tl (calibration with a ^{232}Th source ~ 3 days)

**average $5 \times 5 \times 5 \text{ cm}^3$ crystals $\sim 7 \text{ keV}$
average $3 \times 3 \times 6 \text{ cm}^3$ crystals $\sim 9 \text{ keV}$**

**The best energy resolution
@ 2615 keV is 3.9 keV**

Energy resolution FWHM



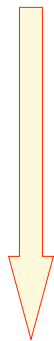
First Results

Cuoricino is taking data since April 2003 (MT = 3.8 kg y):

Background $\beta\beta$ region (anticoincidence spectrum, only 5x5x5 crystals)

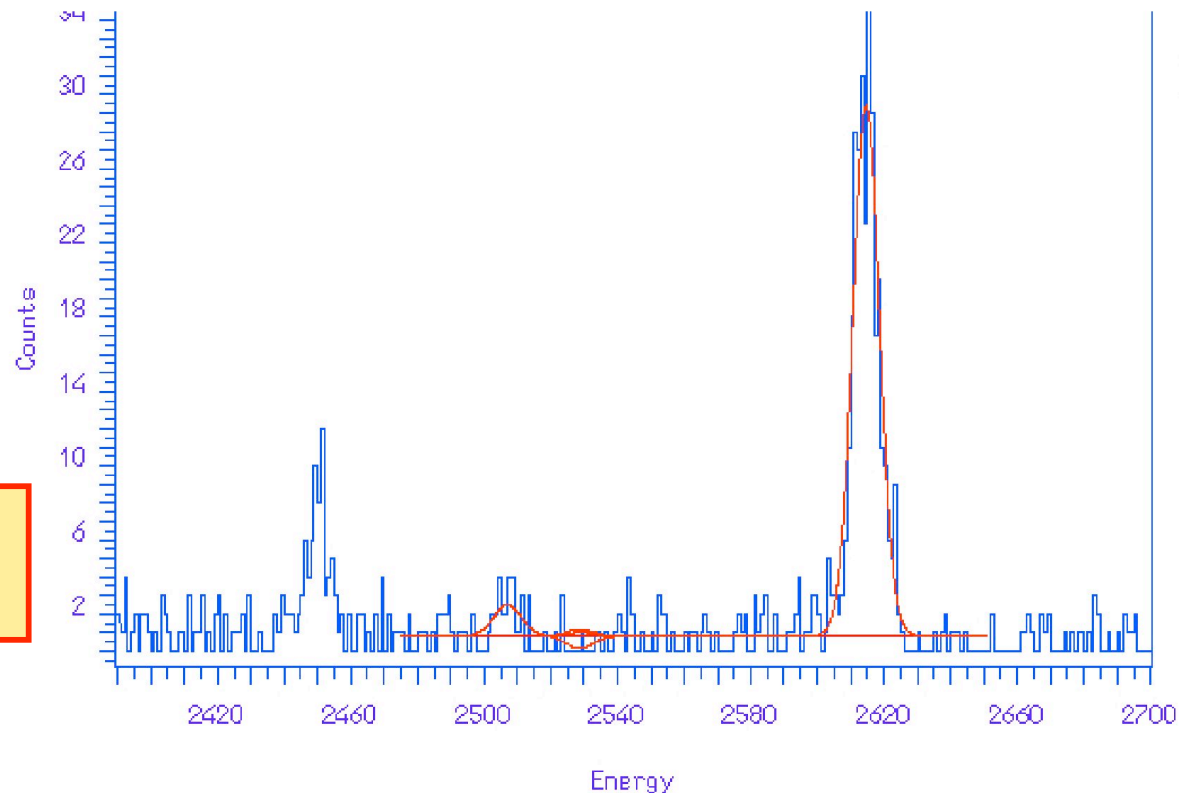
$$= 0.19 \pm 0.02 \text{ c/keV/kg/y}$$

Dominated by degraded alphas interacting on the surface



**Total results for life time
and Majorana mass:**

$$T_{1/2}^{0\nu} (^{130}\text{Te}) > 7.5 \times 10^{23} \text{ y}$$
$$m_{ee} < 0.3 - 1.6 \text{ eV}$$



Cuoricino Sensitivity

$$F^{0\nu} = 4.17 \times 10^{26} \times \frac{a}{A} \times \left(\frac{M T}{b \Gamma} \right)^{1/2} \times \varepsilon$$

Diagram illustrating the factors influencing Cuoricino sensitivity, with arrows pointing to the corresponding terms in the equation:

- Isotopic abundance points to a
- Atomic mass points to A
- Detector mass points to M
- Running time points to T
- Background points to b
- Energy resolution points to Γ
- Detector efficiency points to ε

3 year of Cuoricino run:

$$F^{0\nu} = 1 \times 10^{25} \text{ y} \quad \langle m_{ee} \rangle \approx 0.16 - 0.38 \text{ eV}$$



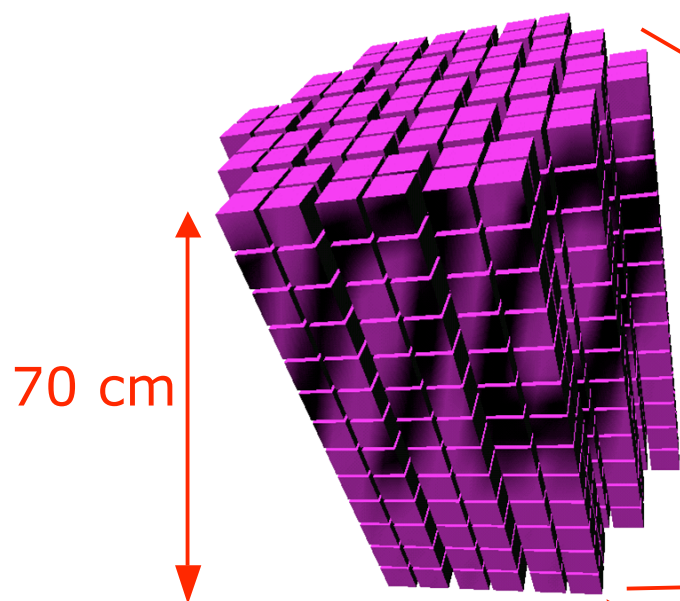
Cuoricino can confirm the Klapdor results if the nuclear matrix elements are good as expected;
If they are not, unfortunately Cuoricino can not disprove the Klapdor results

Cryogenic Underground Observatory for Rare Events

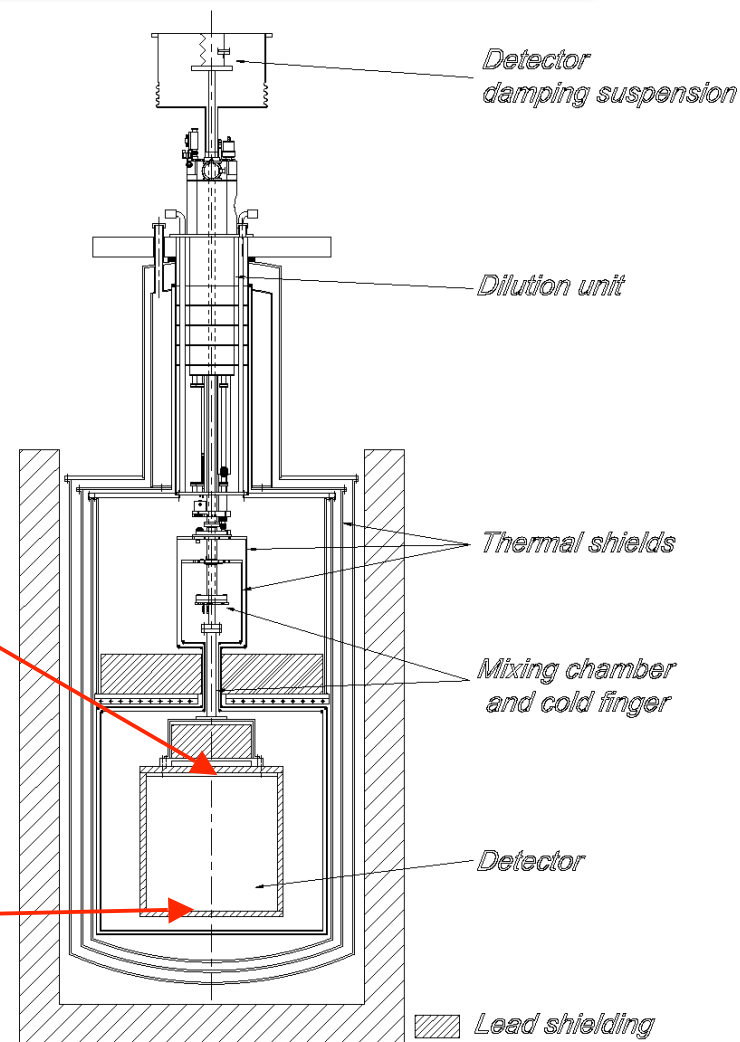
Array of 1000 detectors:

25 Cuoricino-like towers.

→ $M = 0.78 \text{ ton di TeO}_2$



25 towers CUORICINO-like



CUORE Sensitivity

Summarizing the BKG contributions:

- ◆ Bulk contamination is not a problem $\Rightarrow \sim 0.001$ counts/keV/kg/y
- ◆ main BKG contribution is due to the Surface contamination from passive materials, as the Cu surfaces facing the detector. We have to make a big R&D work to reduce this contaminations by a factor 10-100 with respect to now $\Rightarrow \sim 0.01 - 0.001$ counts/keV/kg/y

Montecarlo simulation

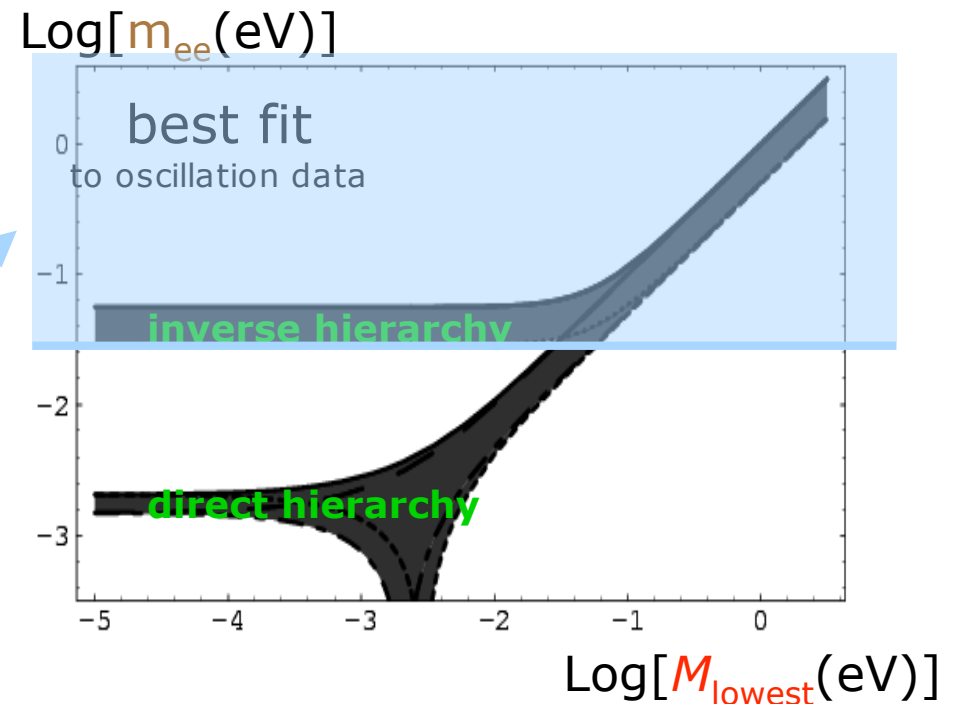


→ 5 y sensitivity:

$$b = 0.001 - \Gamma = 5 \text{ keV}$$

$$F^{0\nu} = 7 \times 10^{26} \text{ y}$$

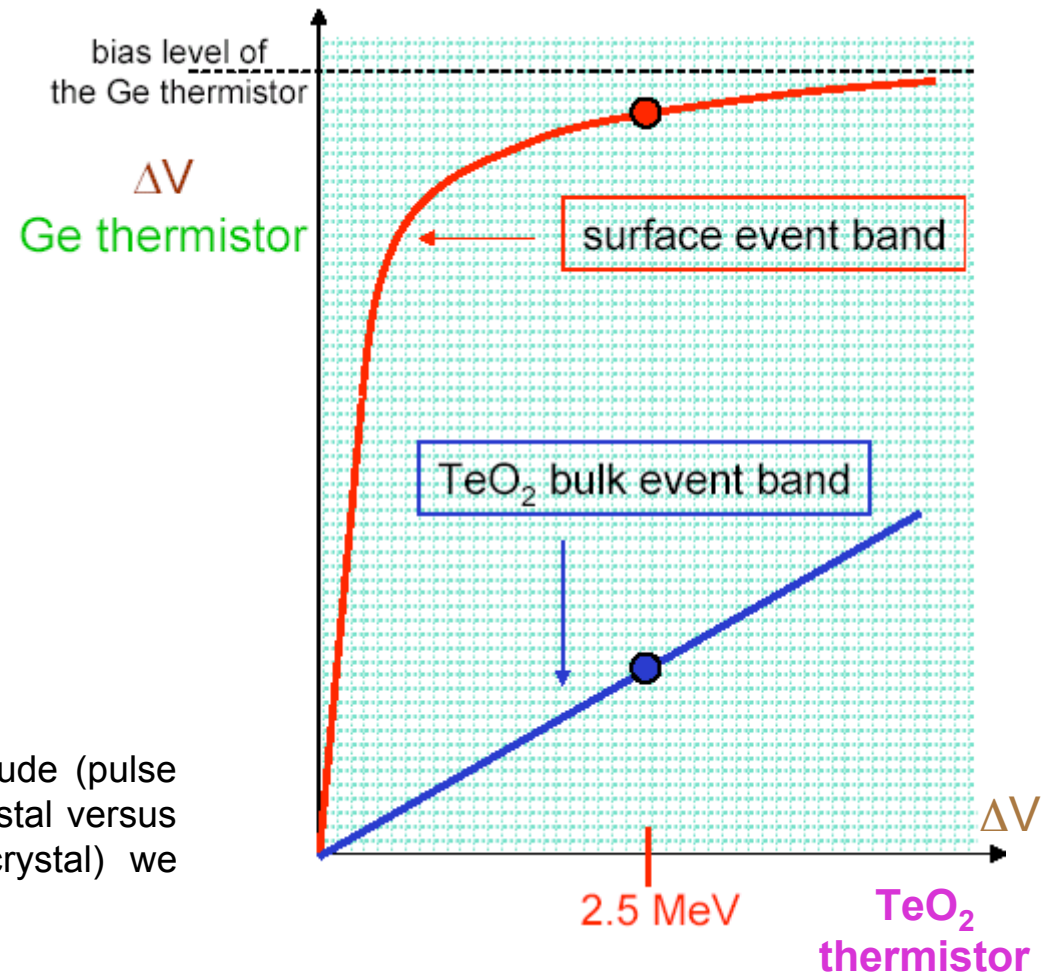
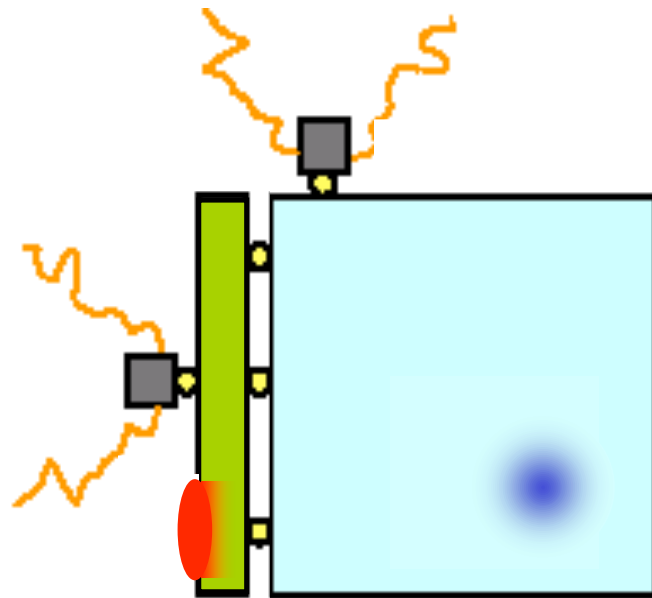
$$m_{ee} < 27 - 55 \text{ meV}$$



The Surface Sensitive Bolometers

background discrimination

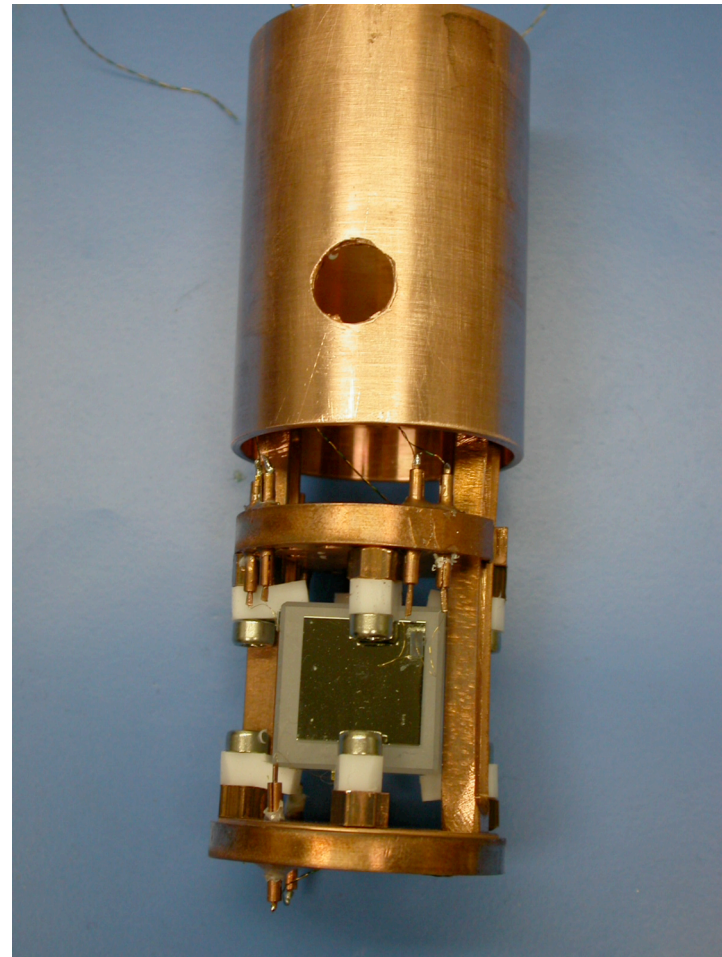
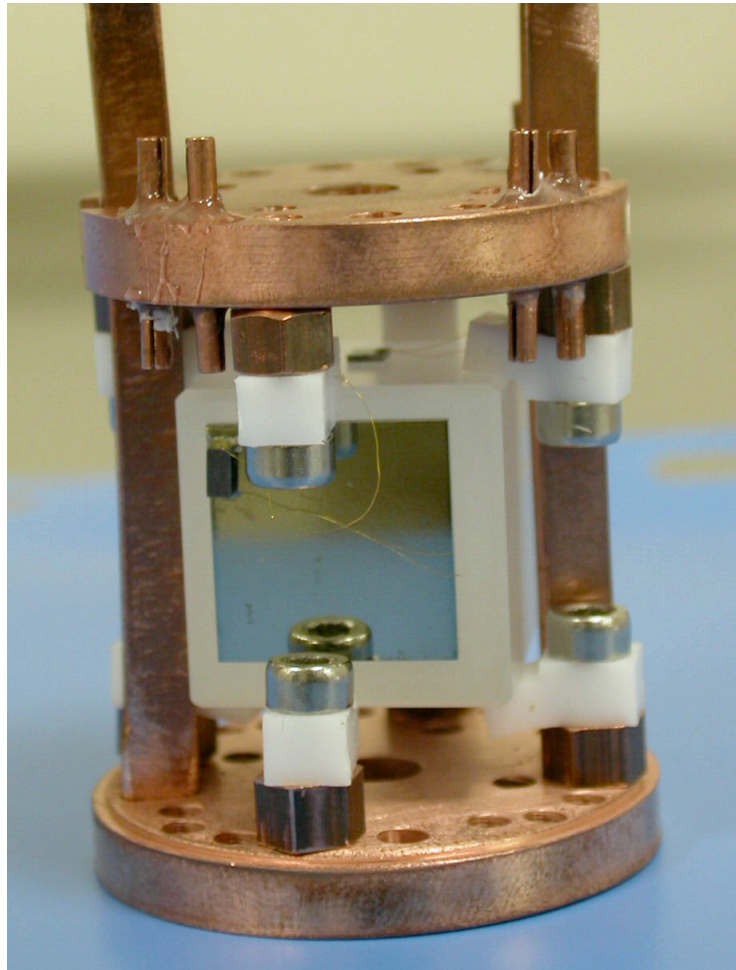
The idea is to use auxiliary thin Ge bolometers to control surface contamination



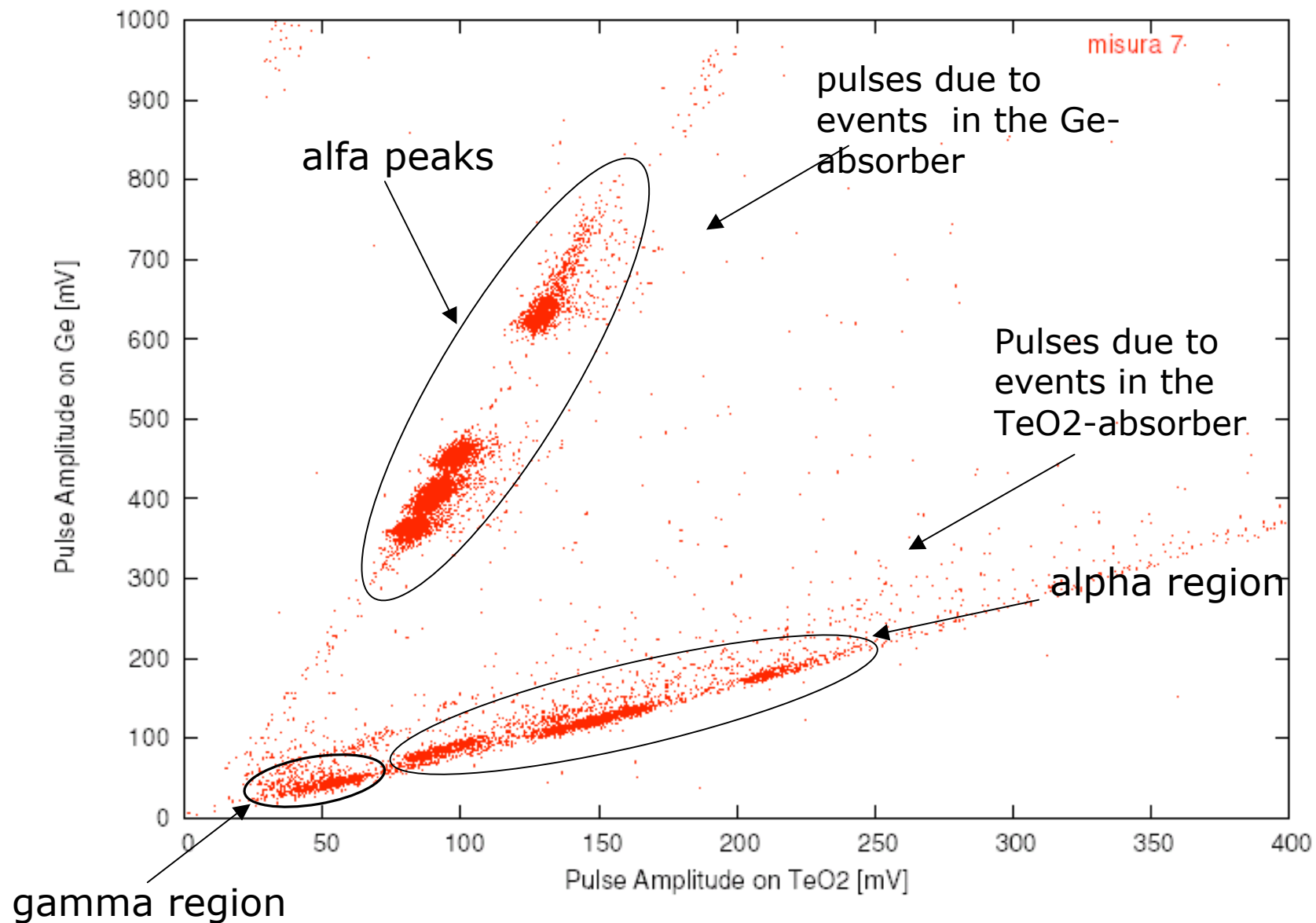
If we make a scatter plot of the pulse amplitude (pulse amplitude obtained with thermistor on Ge crystal versus those obtained with thermistor on TeO₂ crystal) we obtain two well separated behaviours

The Surface Sensitive Bolometers

First Run



Experimental Scatter Plot



Conclusions

- ◆ In order to have an experiment with an high sensitivity to the $0\nu\text{DBD}$
 - large masses
 - high energy resolutions
 - low backgroundare needed
- ◆ Cuoricino experiment could scrutinize the HM experiment claim if the nuclear matrix elements are good
- ◆ CUORE is a second generation experiment that will cover the whole Majorana mass region indicated by the ^{76}Ge result
- ◆ A big R&D work is needed to reduce the BKG in order to permit to CUORE experiment to investigate the inverse hierarchy region of the neutrino masses pattern
- ◆ We are working on a new idea for the CUORE background reduction