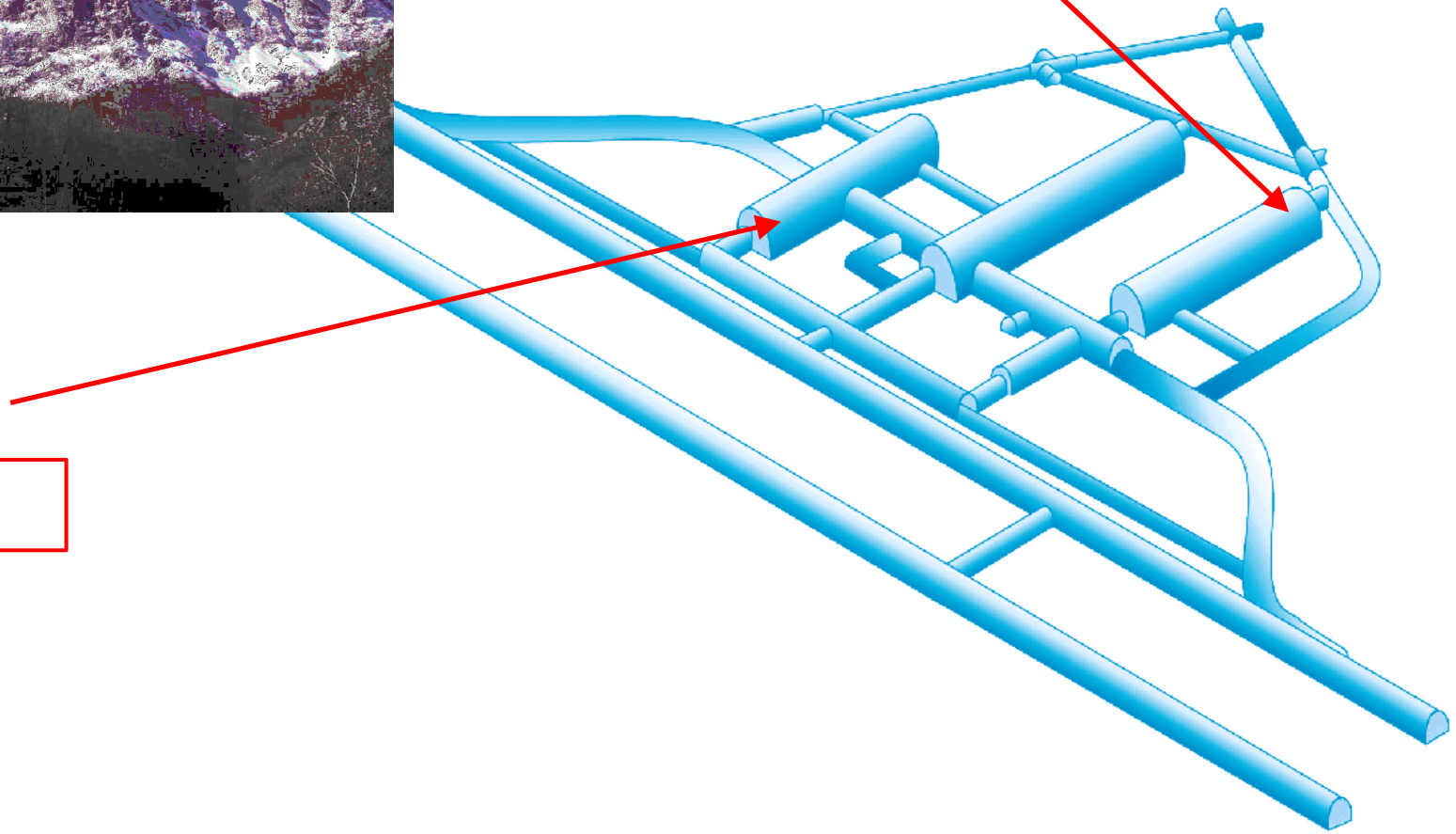
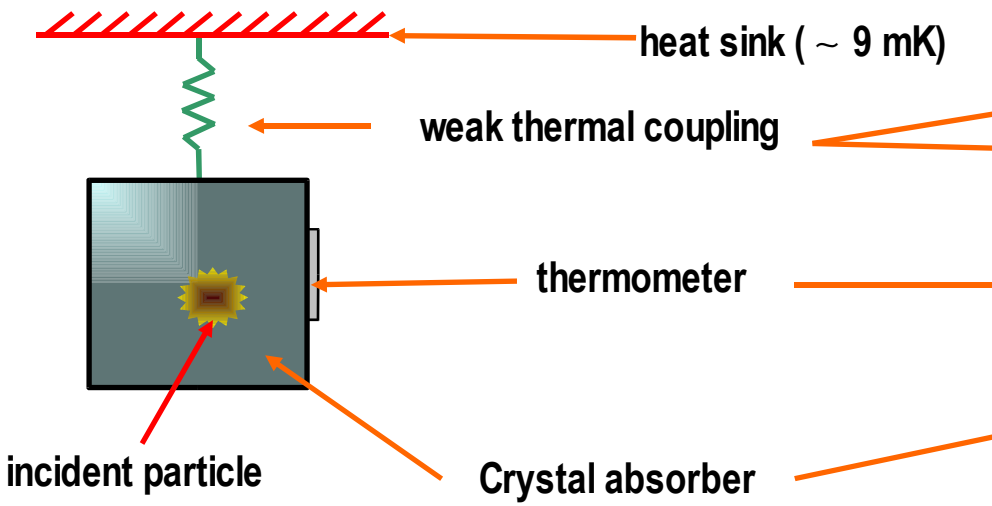
CUORicino @ LNGS

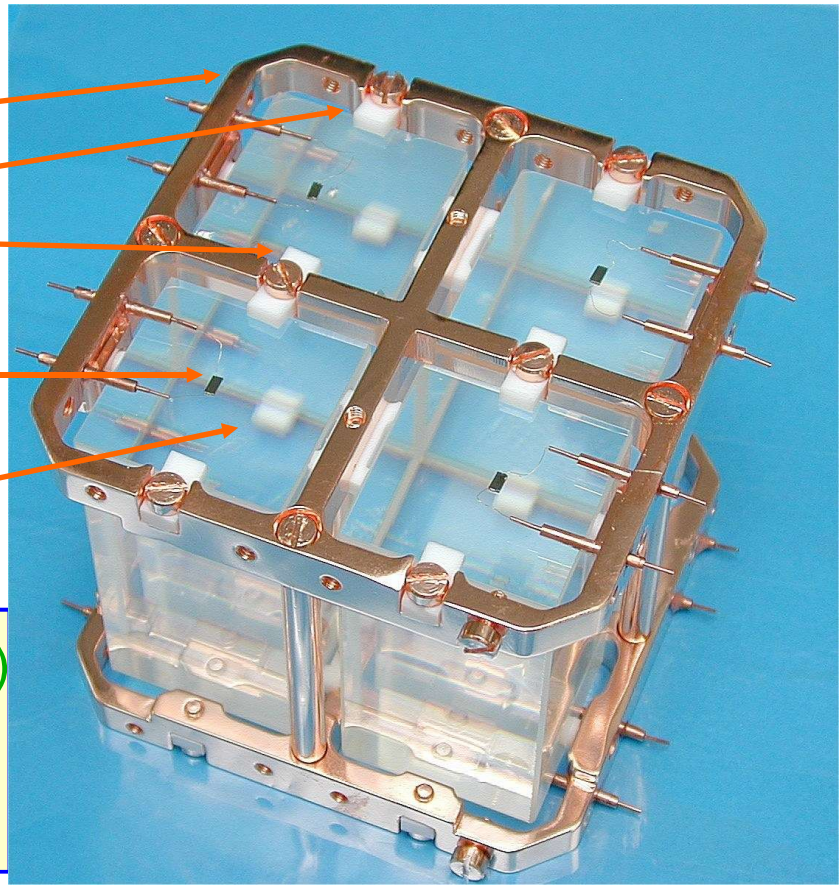
CUORE R&D (Hall C)

Cuoricino (Hall A)



Thermal Detectors

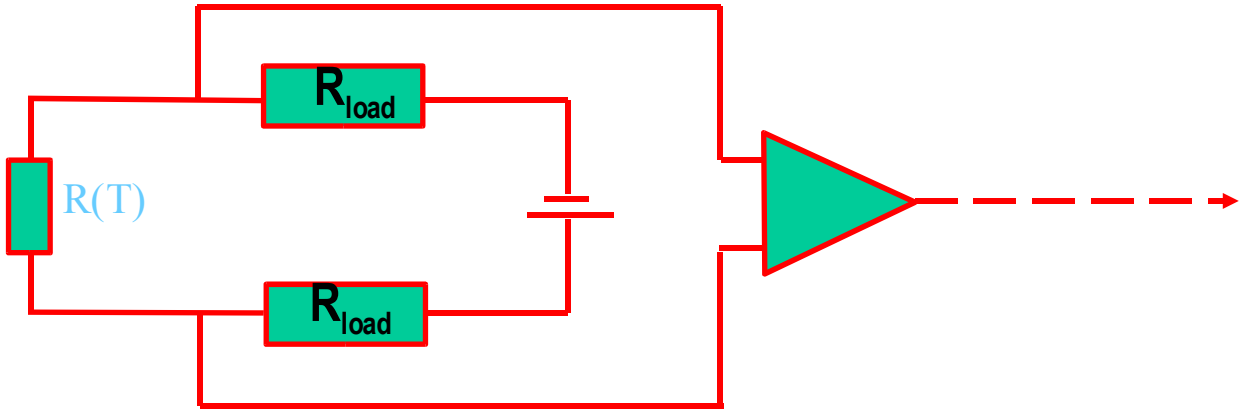


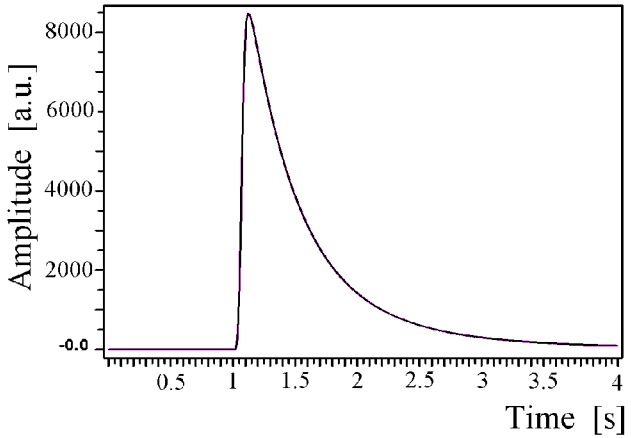


$\Delta T = E/C \div T^{-3} \Rightarrow \Delta T/\Delta E \cong 100\ \mu K/\ MeV$ (T=10 mK)

$\Delta T \rightarrow \Delta R \Rightarrow \Delta R/\Delta T \cong 100\ k\Omega/\mu K$

$\Delta V = I \times dR/dT \times \Delta T \Rightarrow \Delta V/\Delta E \cong 1\ mV/MeV$ (I $\cong$0.1 nA)





Phases of the experiment

Past, present and future:

1997 The first large mass array of bolometers was operated.
20 crystals × 340 g = 6.8 kg (Mi DBD - I experiment)

1998-2001 Tests on larger crystals (760 g) were successfully carried on aiming at more powerful experiments (hall C)

2001 The 20 crystal array is rebuilt with improved BKG features (Mi DBD - II experiment)

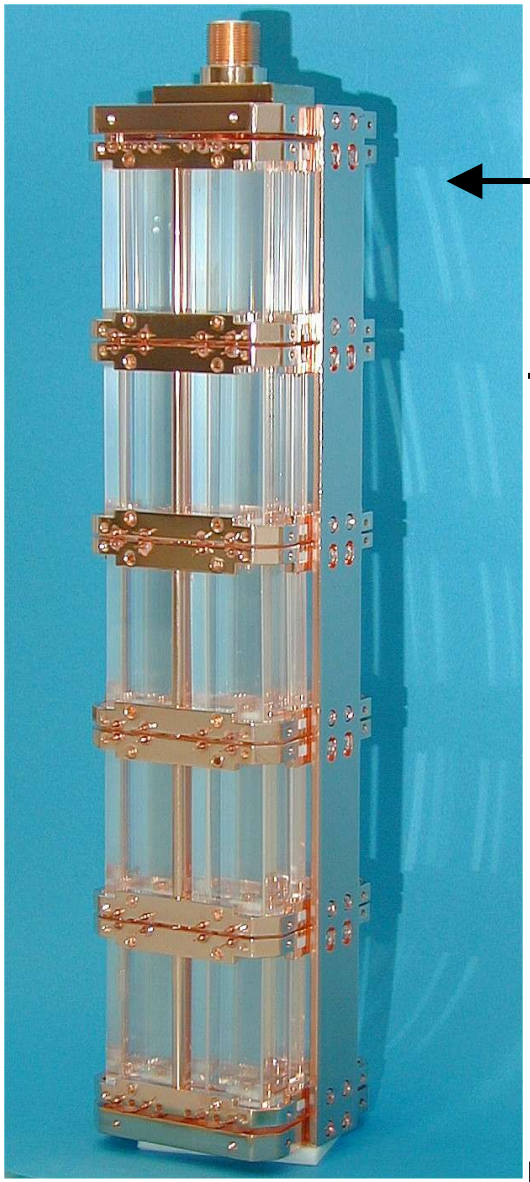
2001 A new, larger mass array is in preparation.
44 crystals × 760 g
18 crystals × 340 g
≈ 40 kg (CUORICINO experiment)

2003-... Full data taking of CUORICINO

July 2004-2009 Construction of a second generation array
1000 crystals × 760 g = 760 kg (CUORE experiment)

The Mi DBD - II: experimental set-up

(a general test for the CUORICINO set-up)

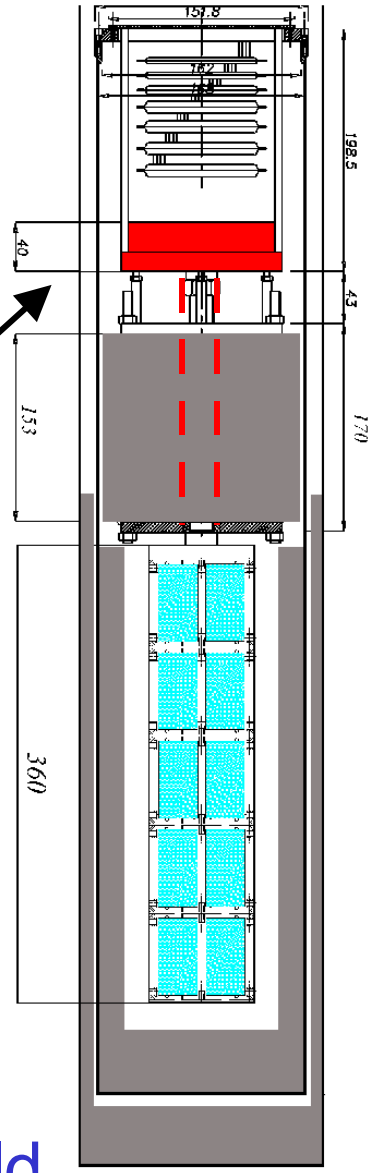


5 modules, 4 detector each, are arranged in a tower-like compact structure (6.8 kg)

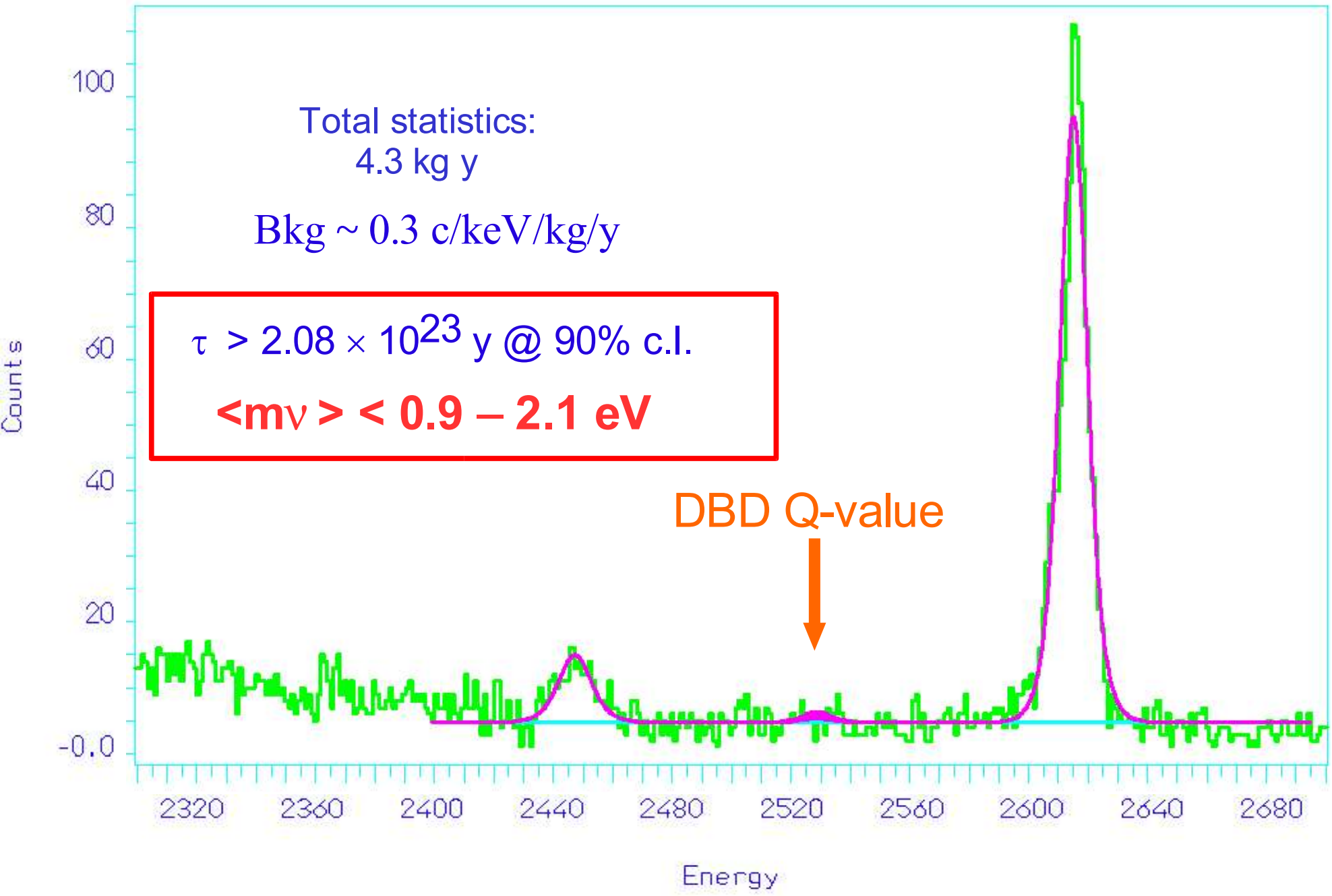
The tower is mounted inside a dilution refrigerator

Coldest point and cold finger

The tower is surrounded by an inner lead shield, (Roman lead) and all the refrigerator by a 20 cm thick outer lead shield



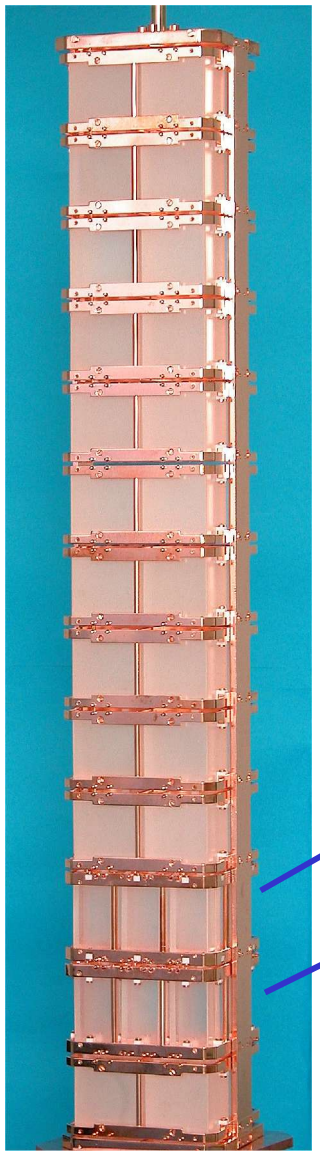
Mi DBD: limits on 0nDBD



The CUORICINO set-up

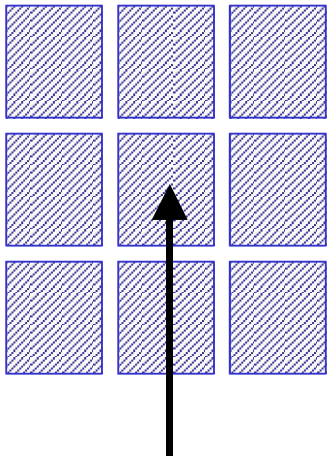
11 modules
4 detector each,

Crystal dimension 5x5x5 cm^3
Crystal mass 790 g



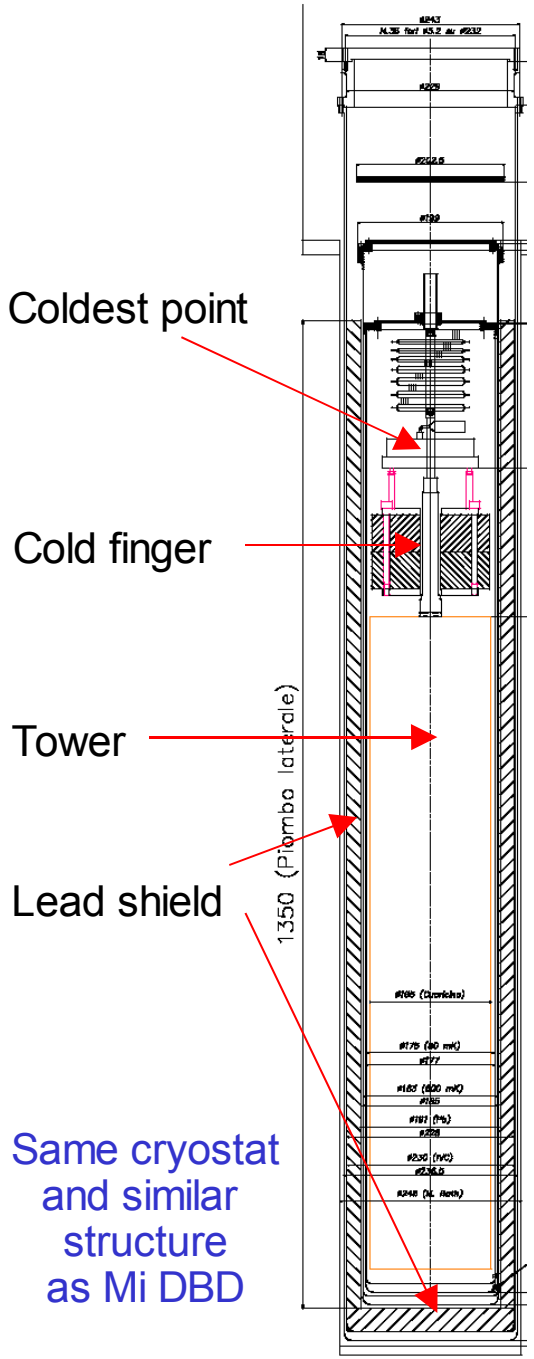
2 modules
9 detector each,
Crystal dimension
3x3x6 cm^3
Crystal mass
340 g

Plane section



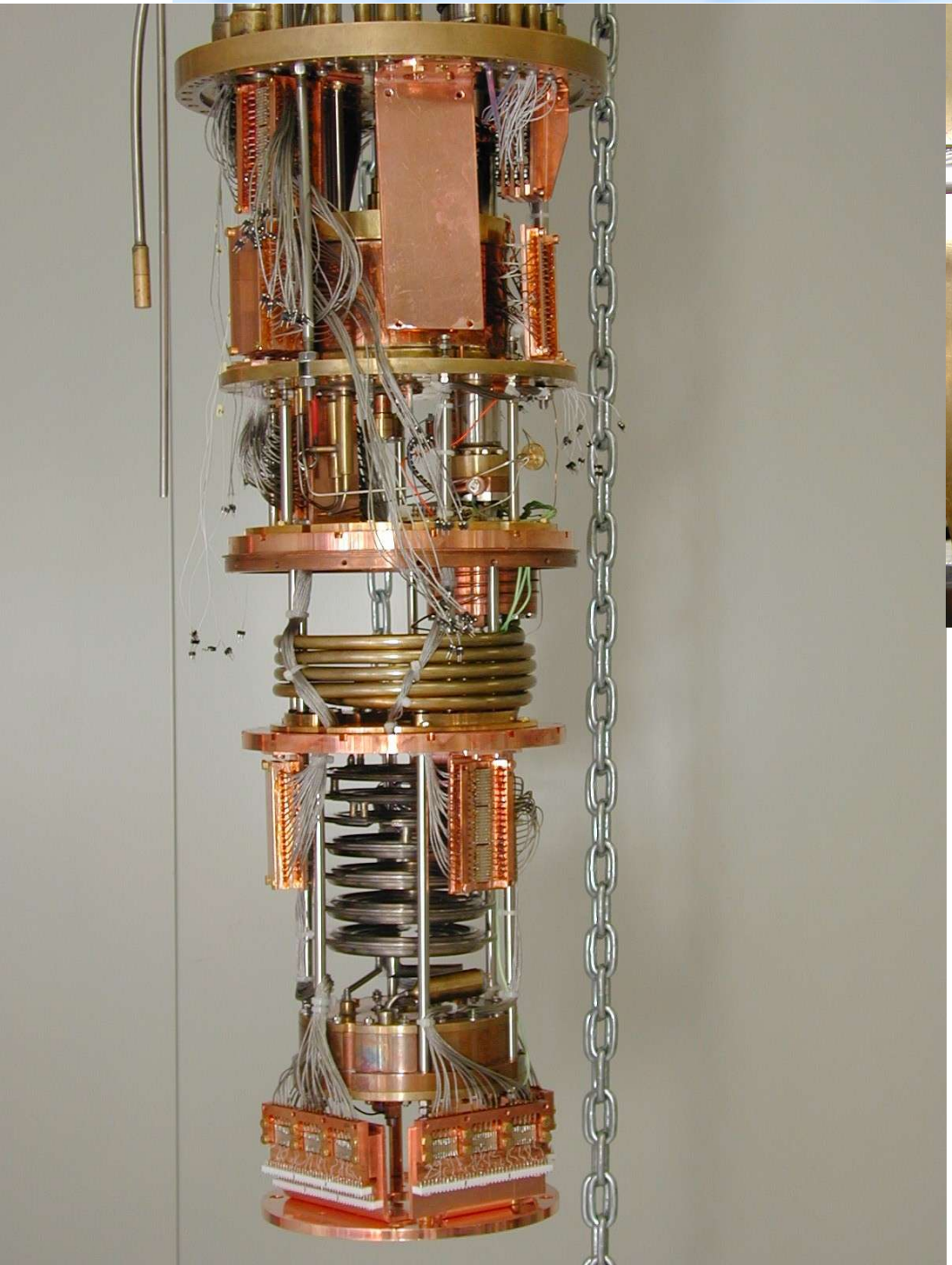
This detector will be completely surrounded by active materials.
Substantial improvement in BKG reduction

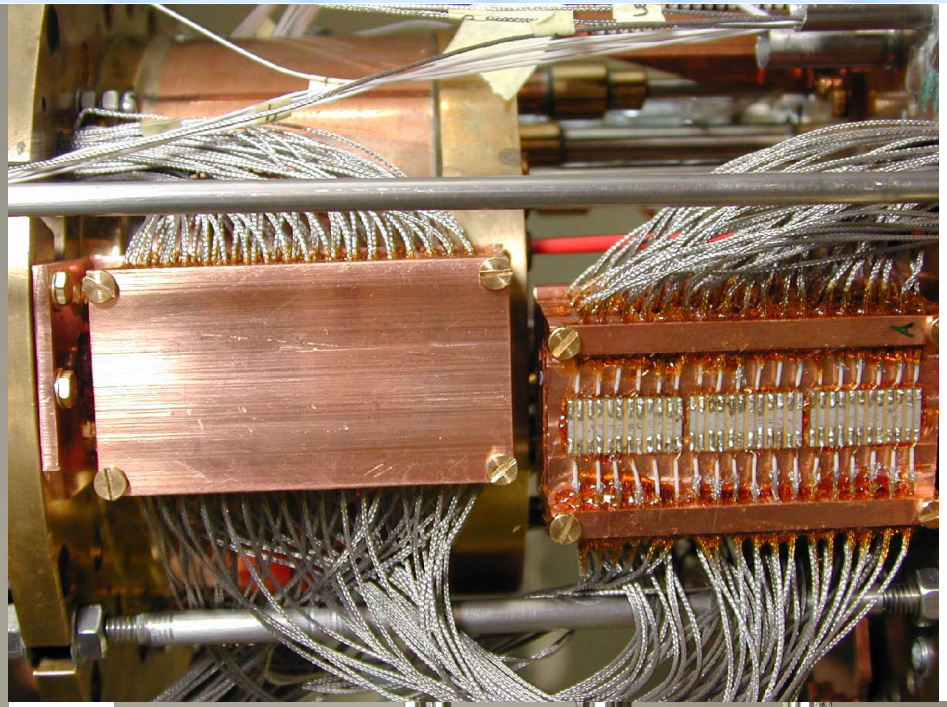
Total mass
40.9 kg

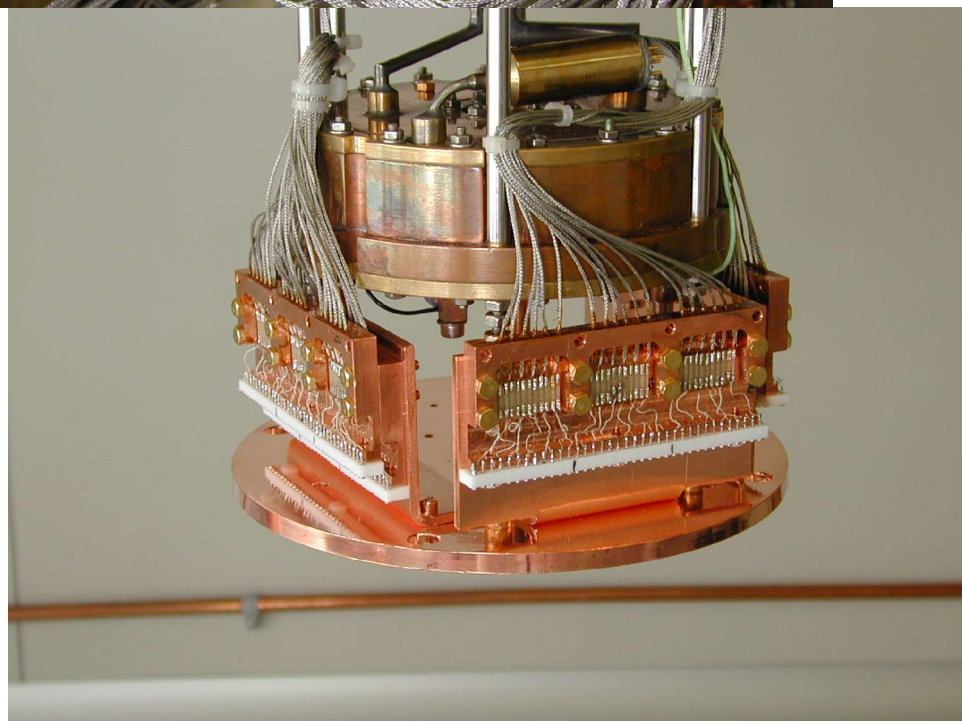


Same cryostat and similar structure as Mi DBD

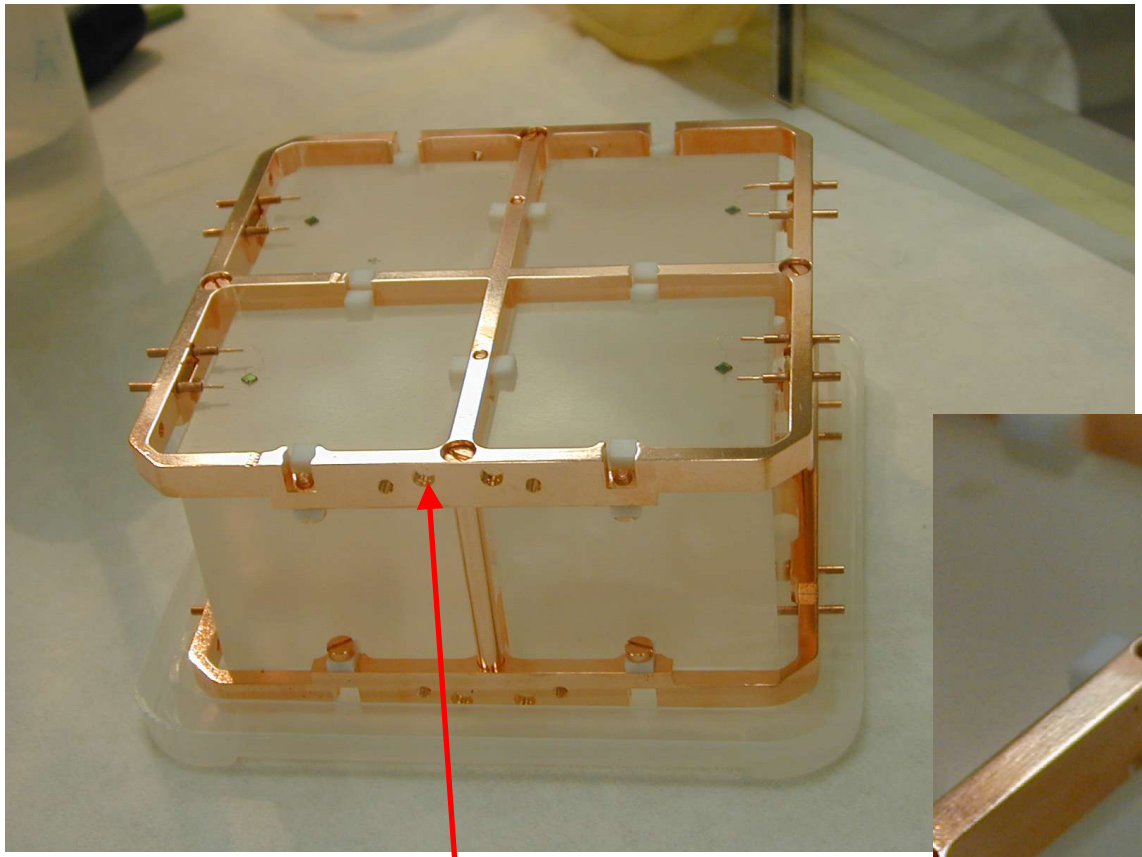
CUORICINO: criostat & wiring





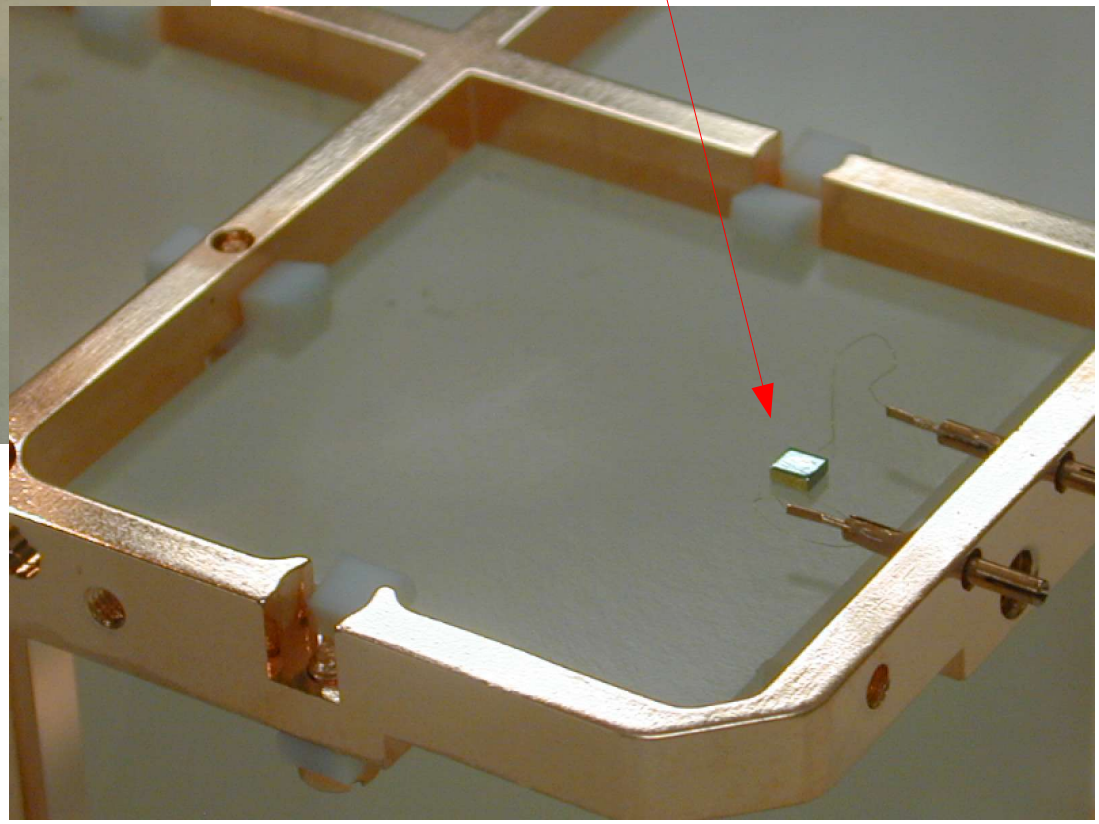


Cuoricino Single Module



A Cuoricino module

Ge NTD thermistor



Collected data : 1st run

- *cooling:* **january 2003**
- *tests and optimization:* **from january to april**
- *data acquisition:*
  - ☺ **from april 19 to june 21** *(72% live time)*
    - ☹ **stop due to the interruption of the water supply**
  - ☺ **from July 9 to July 21**
    - ☹ **stop due to a problem with the He liquefier**
  - ☺ **from September 4 to October 30**
    - ☹ **stop due to undergo operations of manteinance and improvements**

Cuoricino mass: 1st run

Detectors:

4x11 = 44 large size crystals (~5x5x5 cm^3 av. mass = 790g) — 32 working

9x2 = 18 small size crystals (~3x3x6 cm^3 av. mass 330 g) — 16 working

Active mass:

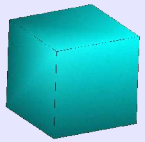
32 x 0.790 = 25.28 kg
12 x 0.330 = 3.96 kg
} 29.24 kg = 9.9 kg ^{130}Te

2 (^{130}Te-enriched) x 0.330 = 0.660 kg = 0.495 kg ^{130}Te

2 (^{128}Te-enriched) x 0.330 = 0.660 kg = 0.543 kg ^{128}Te

10.4 kg ^{130}Te

Detector performances: 1st run



32 *5x5x5 crystals* are **read-out** but:

2 have cross-talk

1 has high noise

29 really used

17 *3x3x6 crystals* are **read-out** but:

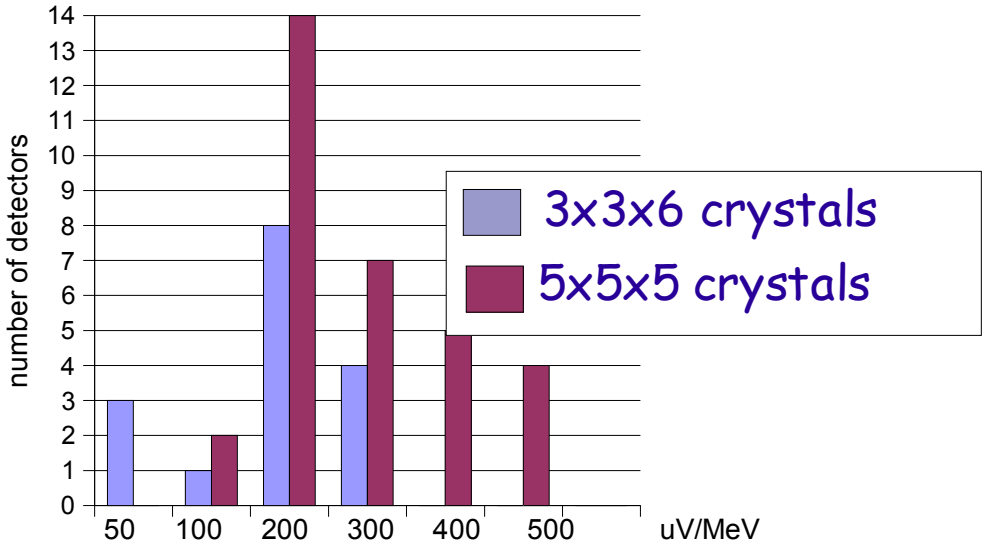
1 has no Si heater (one of the two central crystals)

1 lost the Si heater during the run

15 really used
11 natural
4 enriched

Pulse height distribution μ V/MeV

(normalized to 1 kg of TeO_2)



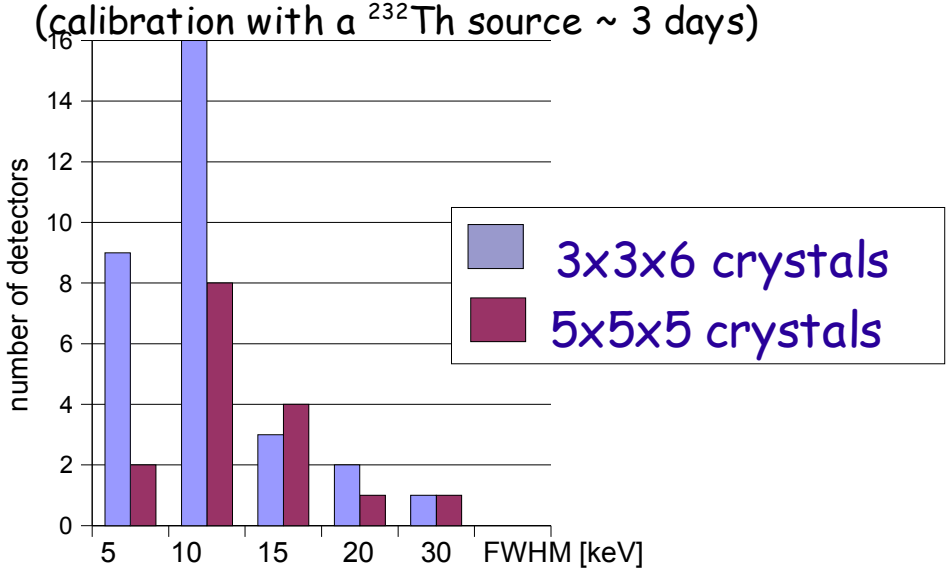
average for 5x5x5 crystals =340 μ V/MeV

average for 3x3x6 crystals = 440 μ V/MeV

Energy resolution

FWHM [keV] of the 2615 keV gamma line of ^{208}Tl

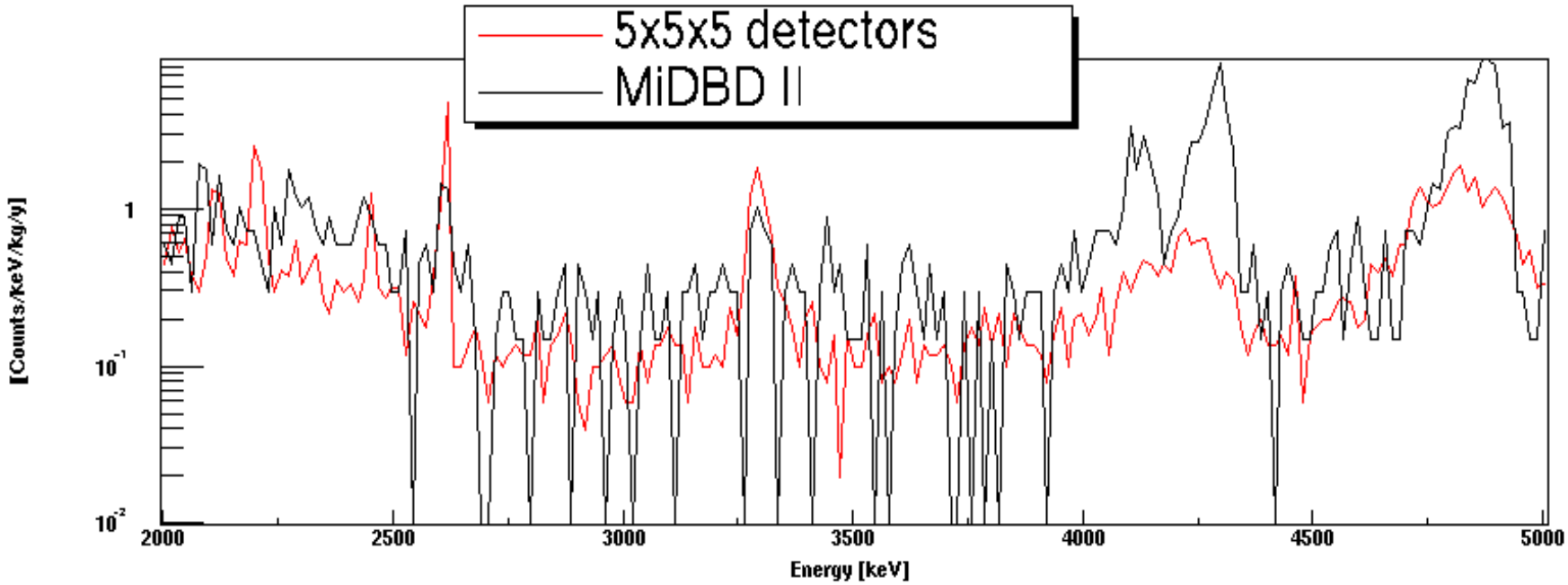
(calibration with a ^{232}Th source ~ 3 days)

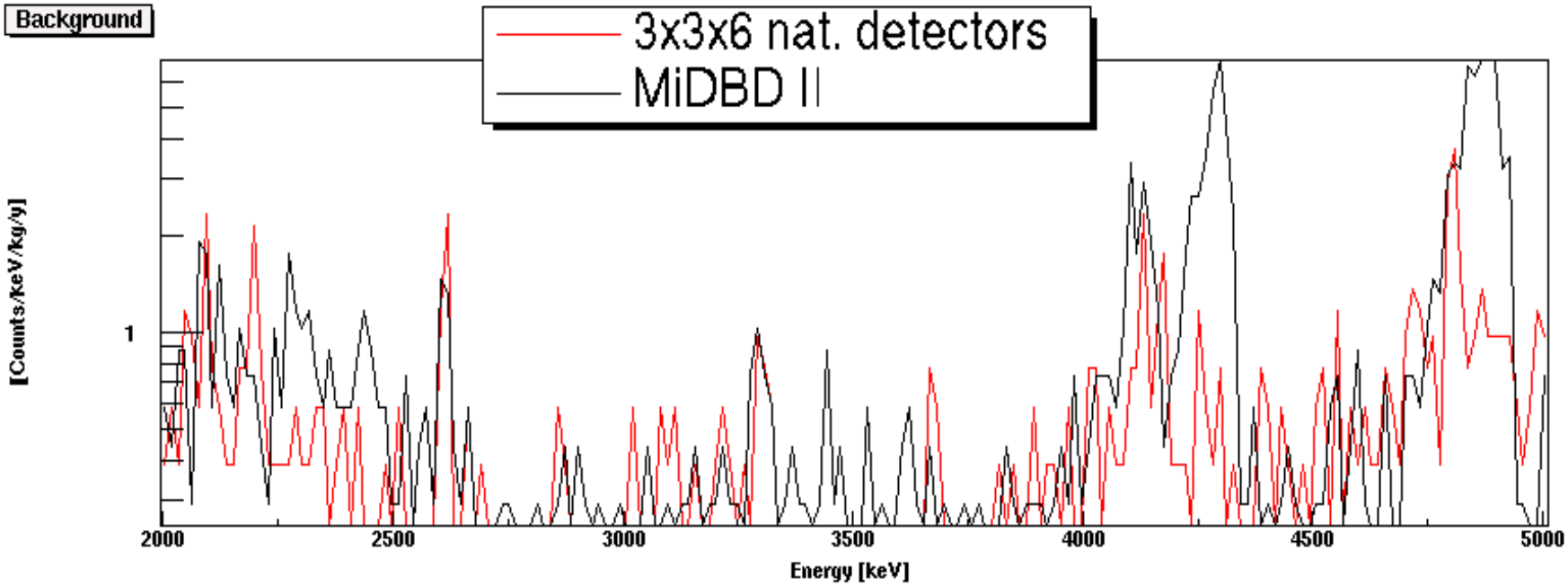


average 5x5x5 cm^3 crystals ~ 7 keV

average 3x3x6 cm^3 crystals ~ 9 keV

Background big and small crystals: comparison with MiDBD II





Background 1st run: integrals

counts/keV/kg/y	1-2 MeV	2-3 MeV	3-4 MeV	4-5 MeV	2510-2580
MiDBD II	3.21 ± 0.08	0.61 ± 0.04	0.29 ± 0.02	1.88 ± 0.06	0.4 ± 0.1
3x3x6 crystals	3.18 0.11	0.36 0.04	0.23 0.03	0.77 0.05	0.21 0.11
5x5x5 crystals	3.25 ± 0.09	0.39 ± 0.01	0.21 ± 0.01	0.56 ± 0.01	0.19 ± 0.03
MiDBD II / 3x3x6	1.01	1.69	1.26	2.44	1.9
3x3x6 / 5x5x5	0.98	0.92	1.1	1.38	1.1

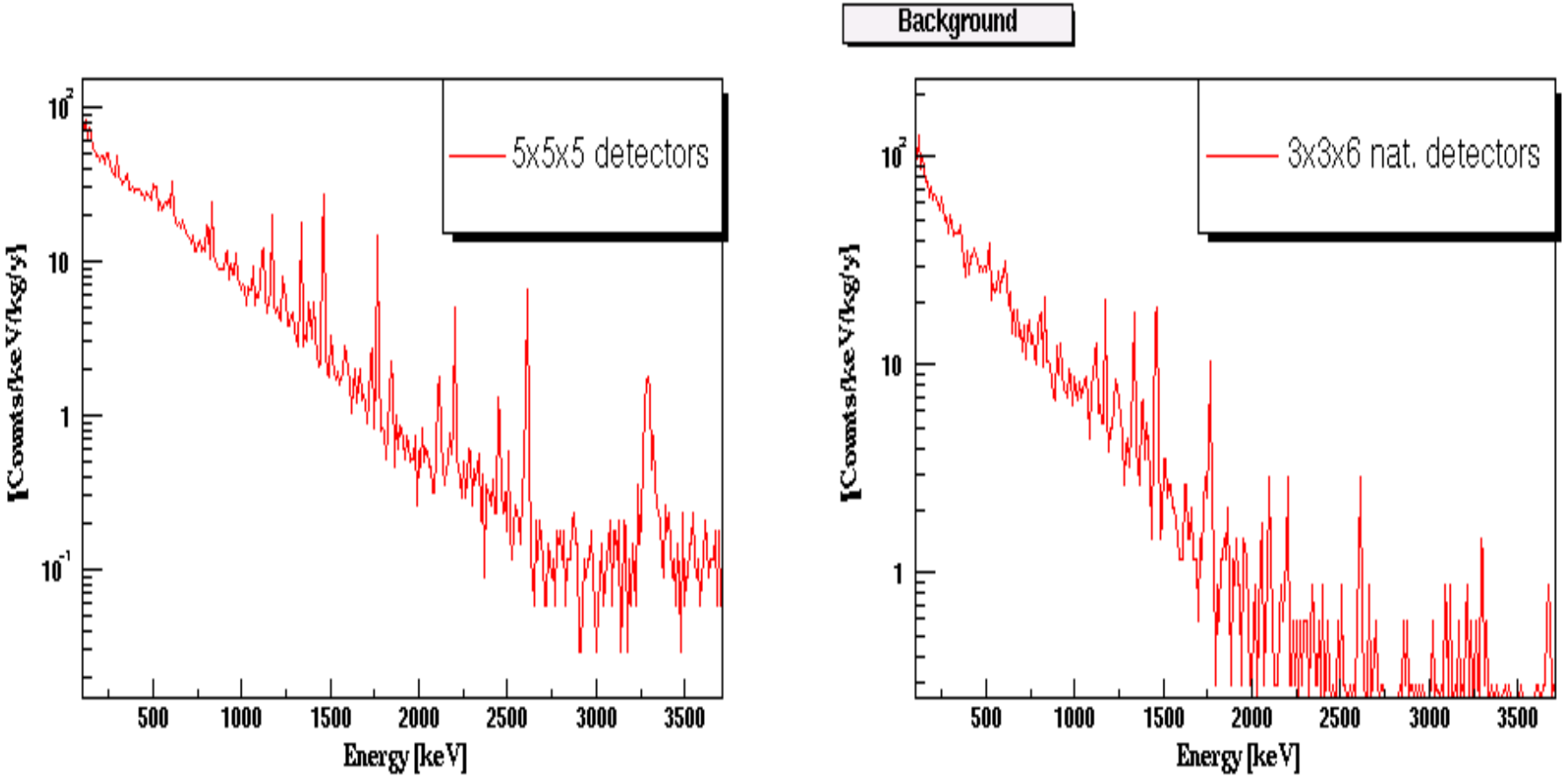
- reduction in the 2-3 MeV region despite the reduced internal lead shield
- notable reduction in the alpha region and in the DBD region
- Pt190 peak present in the 3-4 MeV region

Background 1st run: gamma peaks

2615 keV ^{208}Tl
1764 keV ^{214}Bi
} 3 times higher in 5x5x5 than in 3x3x6 → detector efficiency

V ^{40}K → same intensity in 5x5x5 and in 3x3x6

332 keV ^{60}Co → higher in 3x3x6 crystals



Cuoricino - run I

Background 5x5x5 crystals

live time = **5.46 kg y**

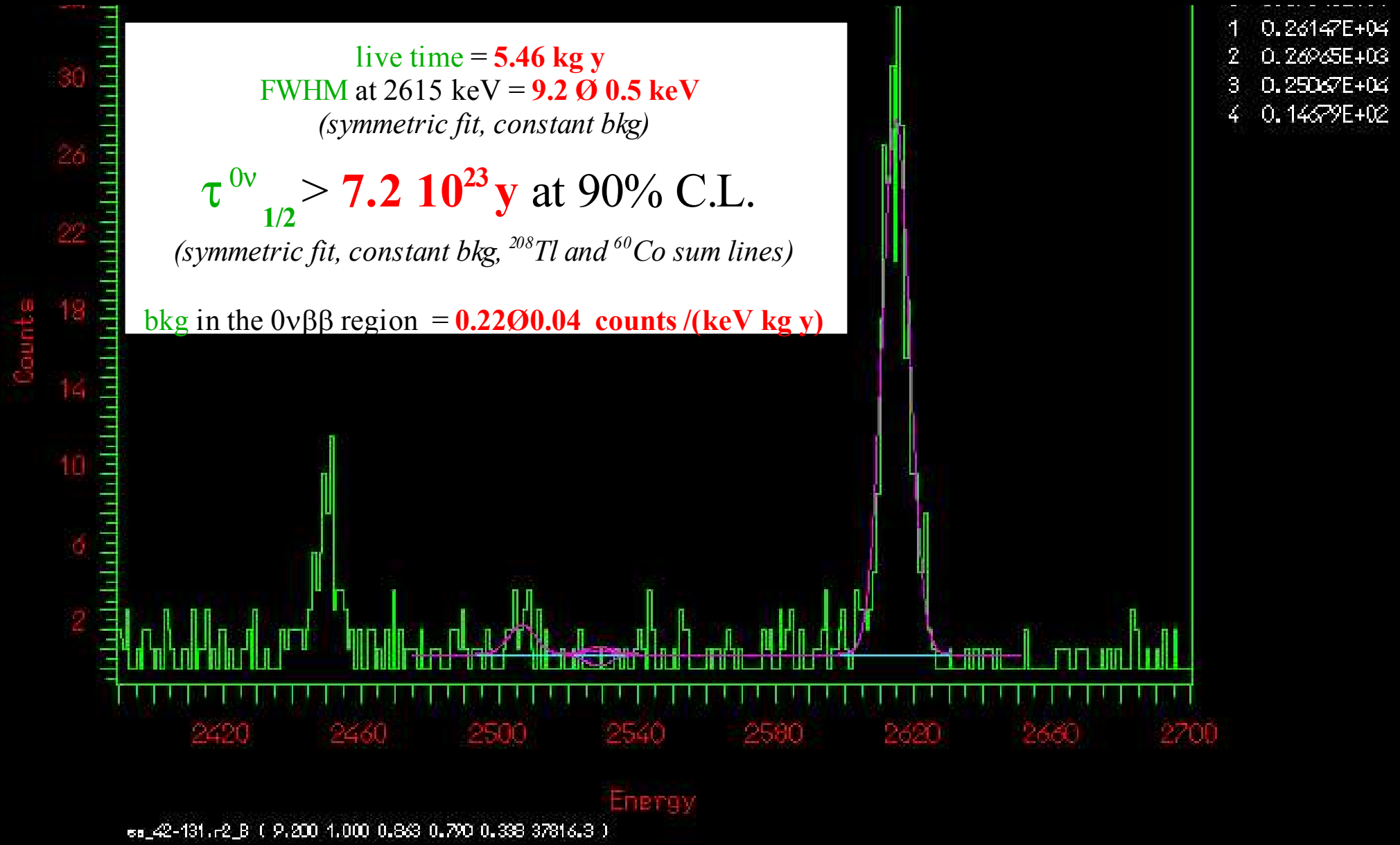
FWHM at 2615 keV = **9.2 Ø 0.5 keV**

(symmetric fit, constant bkg)

$\tau^{0\nu}_{1/2} > 7.2\ 10^{23}$ **y** at 90% C.L.

(symmetric fit, constant bkg, ^{208}Tl and ^{60}Co sum lines)

bkg in the 0νββ region = **0.22Ø0.04 counts /(keV kg y)**



Background 3x3x6 nat. crystals

live time = 0.34 **kg y**

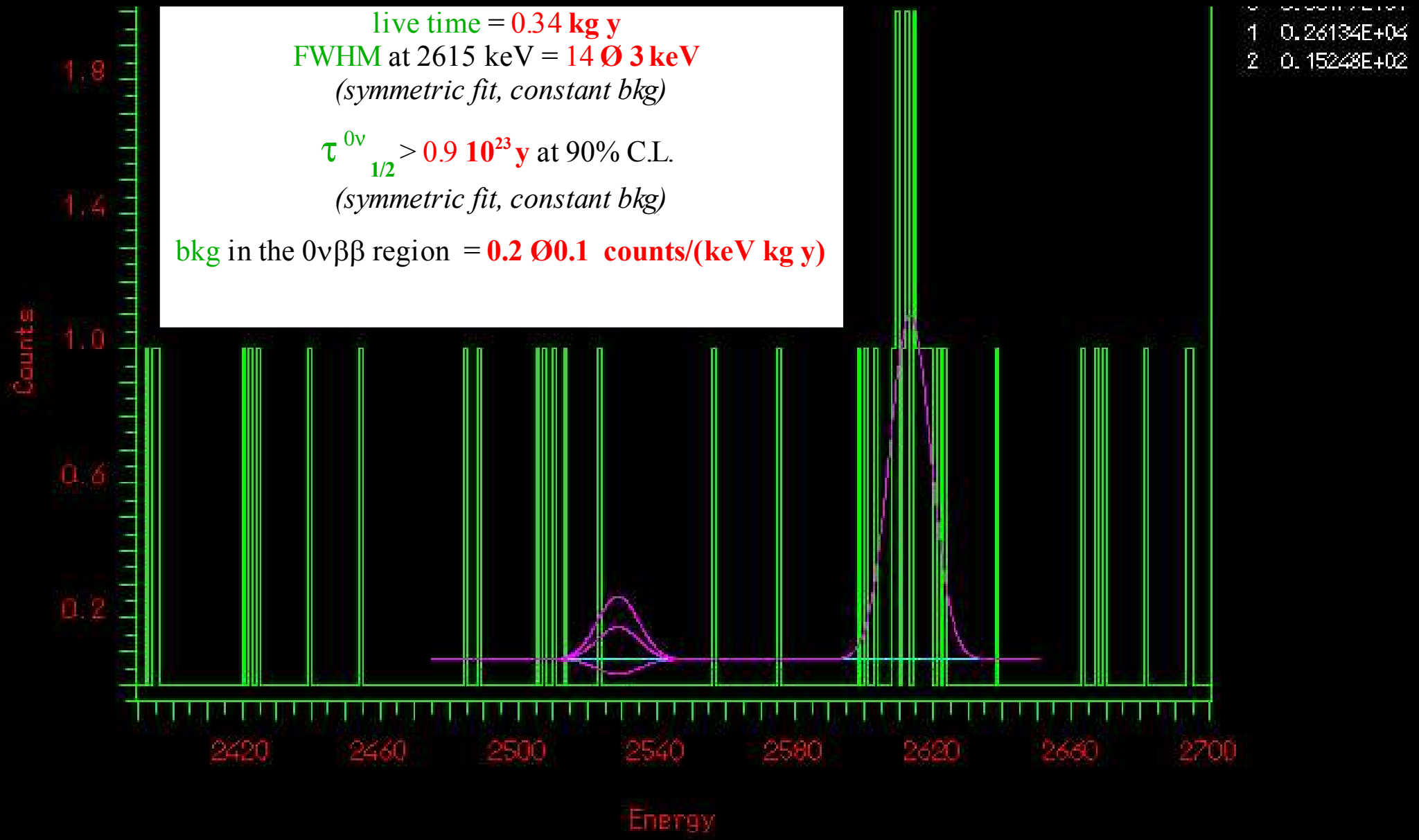
FWHM at 2615 keV = 14 **Ø 3 keV**

(symmetric fit, constant bkg)

$\tau^{0\nu}_{1/2} > 0.9\ \mathbf{10^{23}\ y}$ at 90% C.L.

(symmetric fit, constant bkg)

bkg in the 0νββ region = **0.2 Ø0.1 counts/(keV kg y)**



ea_71-131.r2_X (14.000 1.000 0.845 0.380 0.338 9088.5)

Cuoricino - run I

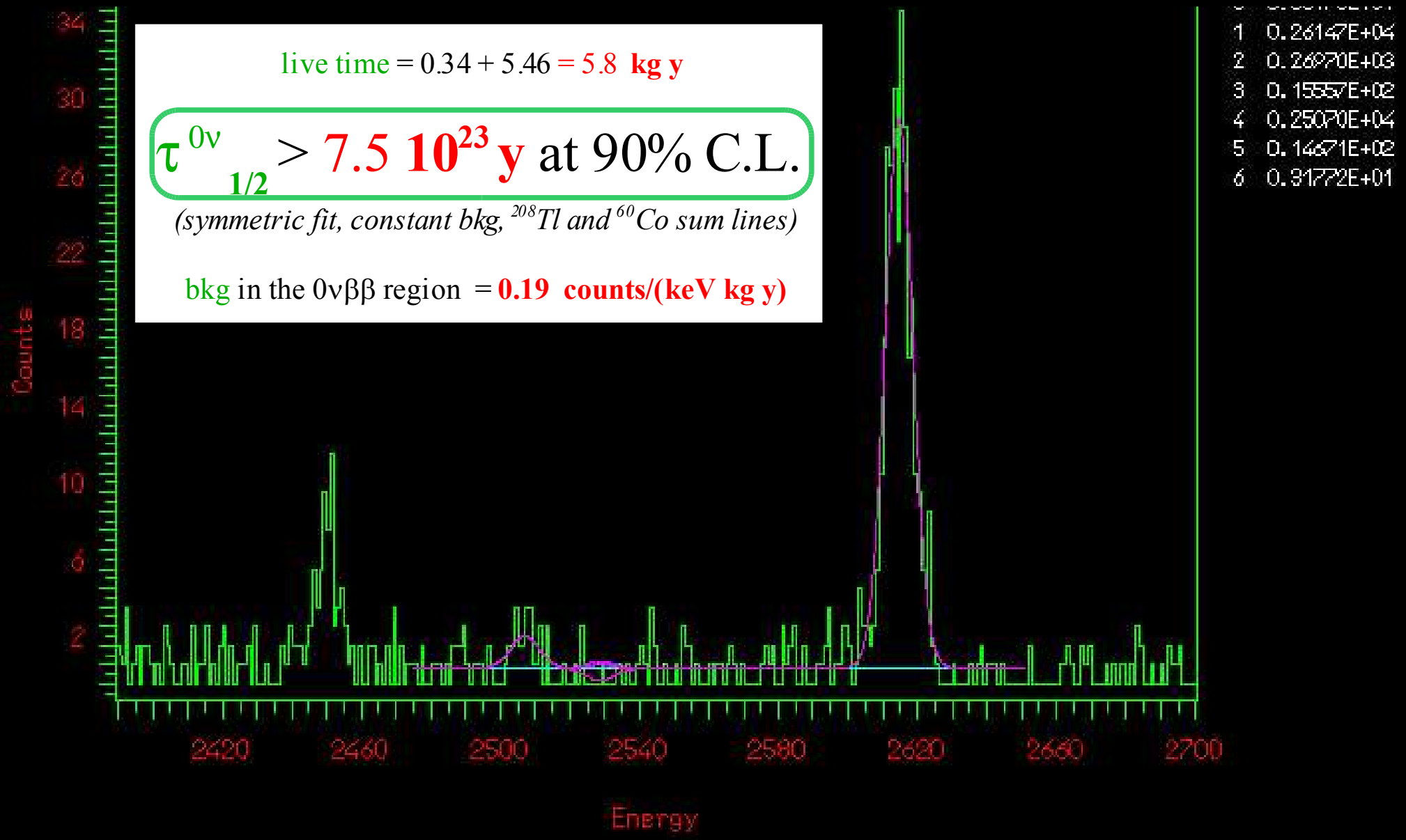
Background all nat. crystals

live time = 0.34 + 5.46 = 5.8 **kg y**

$\tau^{0\nu}_{1/2} > 7.5\ \mathbf{10^{23}\ y}$ at 90% C.L.

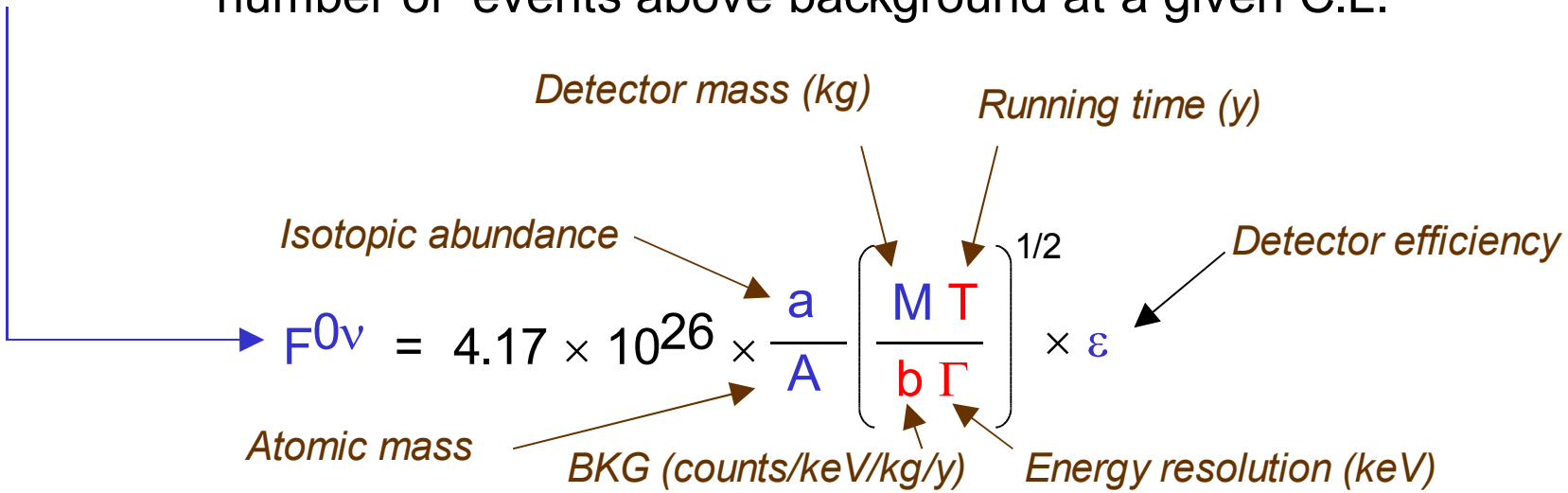
(symmetric fit, constant bkg, ^{208}Tl and ^{60}Co sum lines)

bkg in the 0νββ region = **0.19 counts/(keV kg y)**



CUORICINO sensitivity

Sensitivity: Lifetime corresponding to the minimum detectable number of events above background at a given C.L.



For: b = 0.2 and Γ = 9 keV

$$F^{0\nu} = 3.5 \times 10^{24}\ T^{1/2}\ \text{(68\% CL)}$$

$$\langle m_\nu \rangle < 0.1 - 0.5\ \text{eV}$$

5 anni

Status of Cuoricino

At the end of October Cuoricino was stopped to undergo operations of manteinance and improvements:

- 42/44 of the 5x5x5 crystals are working
- All the 3x3x6 crystals are working (one is without the heater)

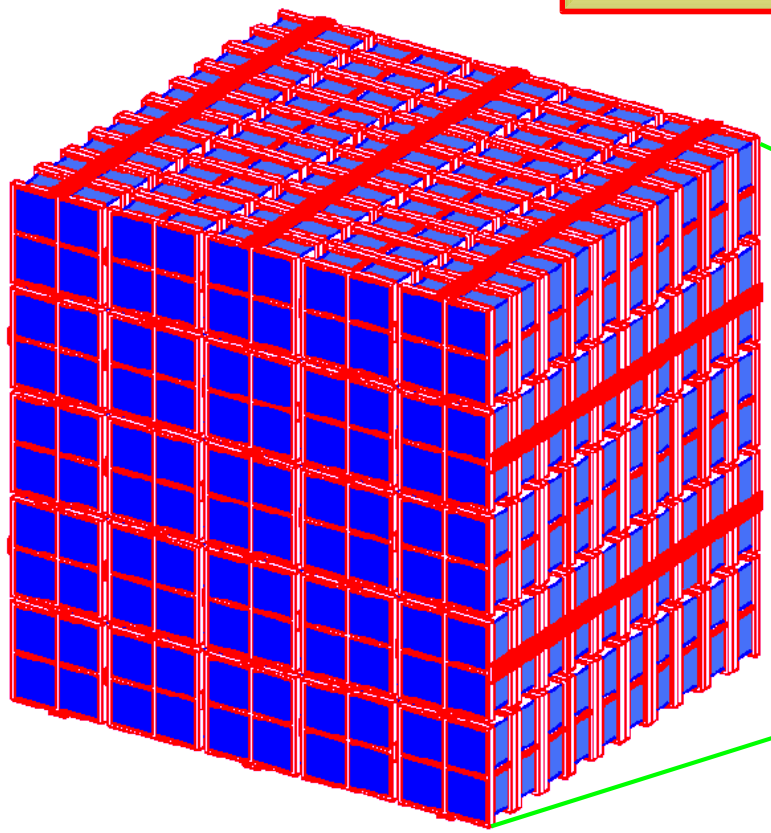
It's now full data taking

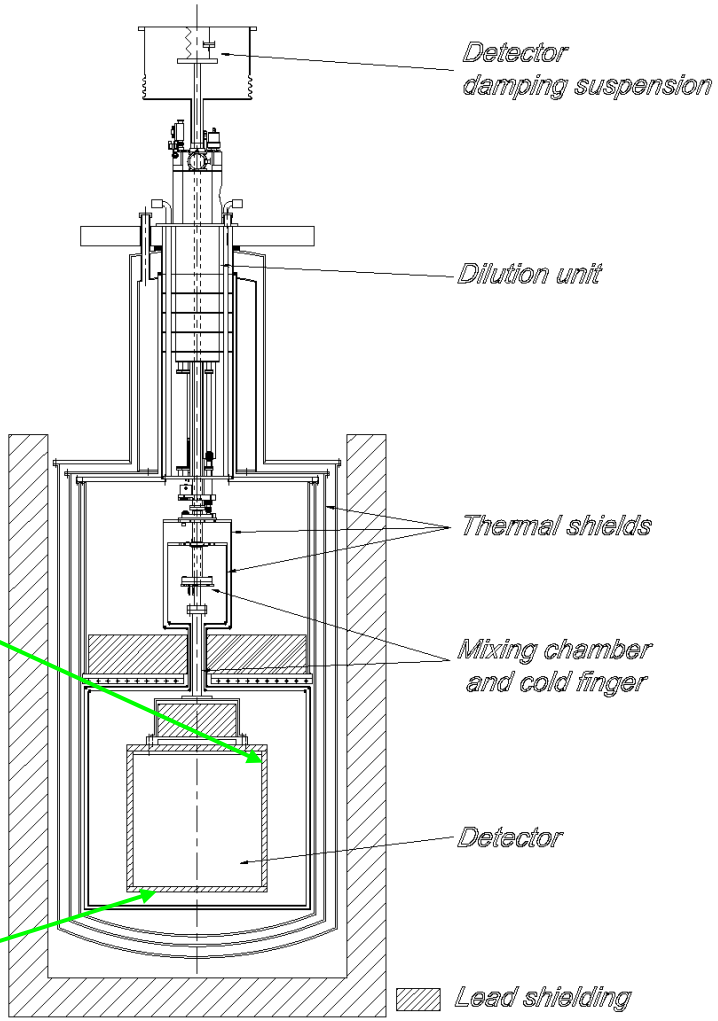
The CUORE project

CUORE: Array of 1000 detectors:
25 towers - 10 modules/tower - 4 detectors/module

APPROVED

M = 0.75 ton





From Cuoricino to CUORE

CUORICINO proves:

- the feasibility of a large bolometric array with the tower-like structure
- that detector performances (signal rise and decay time, pulse height, energy resolution) are not affected by the increase in crystal size (from 340 g to 790 g)

Cuoricino can't be a direct test of Cuore feasibility for what concerns bkg but:

- The tightly closed structure of CUORE should give a strong reduction of the bkg operating with the detector in anticoincidence
- The lead shield designed for CUORE will be optimized in order to practically cancel the outside bkg
- R&D activities as respect to surface cleaning and material selection will give an additional reduction in the bkg contribution in the DBD region

CUORE sensitivity

According to a Montecarlo simulation of the CUORE detector based on the Cuoricino contamination levels we have extimated a bkg in the DBD region around 7×10^{-2} c/keV/kg/y (mainly due to surface contaminations)

Goal of CUORE:

- Minimal expectation (present cuoricino bkg) : b=0.01 c/keV/kg/y
- After appropriate R&D we can expect a reduction of a factor 20: b=0.001 c/keV/kg/y:
  - improvements of a factor 1.5-2 are expected by possible reduction of the copper mounting structure dimentions
  - primary milestone of CUORE R&D is a reduction by a factor 10 of the surface contaminations

Sensitivity:

Minimal expectation :

b = 0.01 and Γ = 10 keV

$$F^{0\nu} = 6.5 \times 10^{25}\ T^{1/2}$$

(68% CL)

After appropriate R&D :

b = 0.001 and Γ = 10 keV

$$F^{0\nu} = 2.1 \times 10^{26}\ T^{1/2}$$

(68% CL)