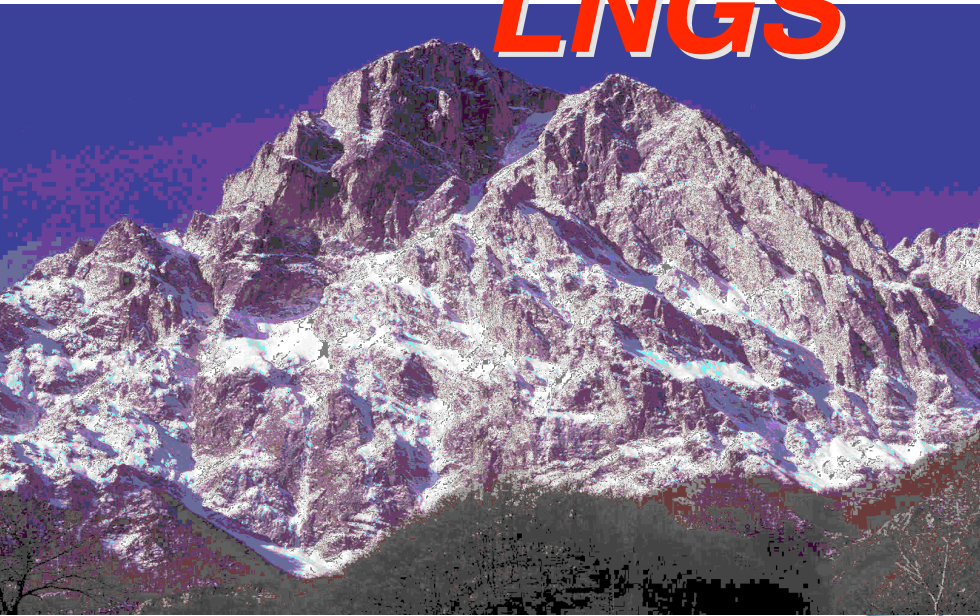


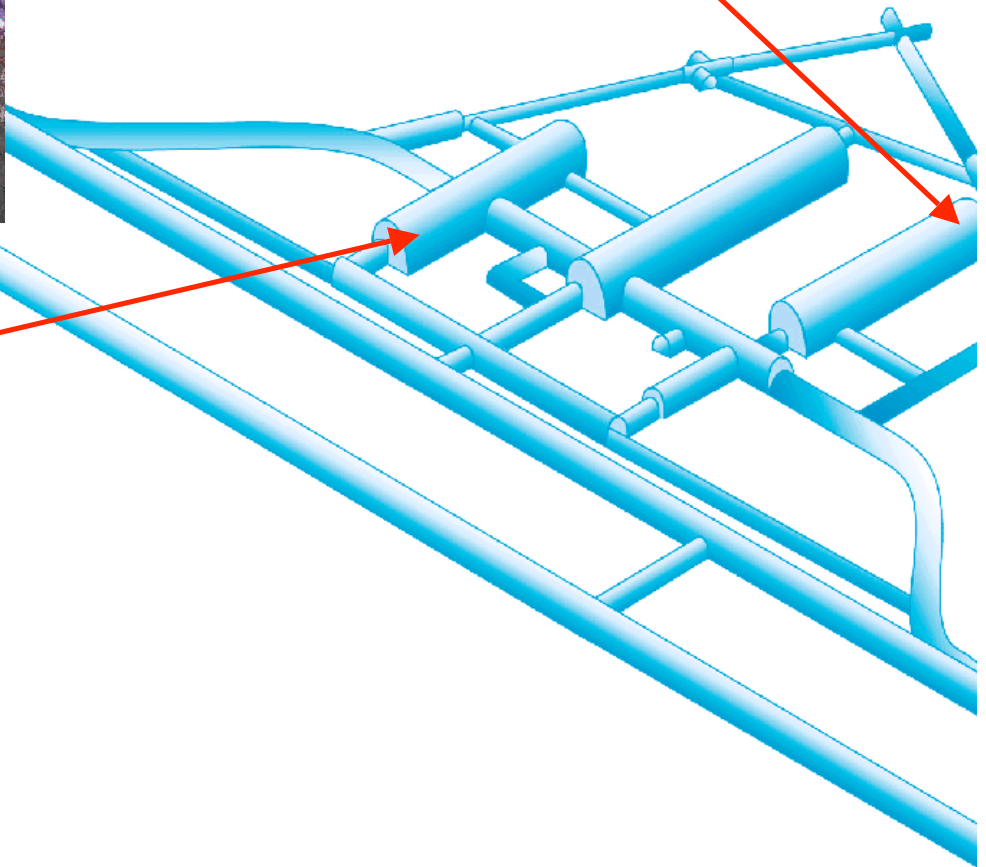


CUORicino @ LNGS

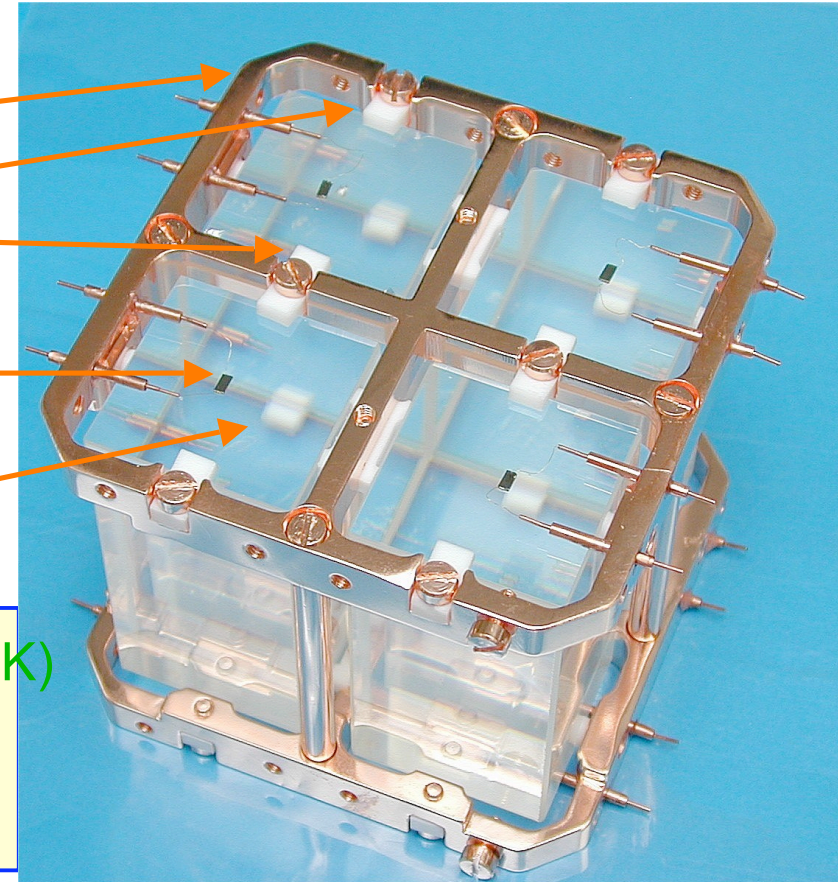
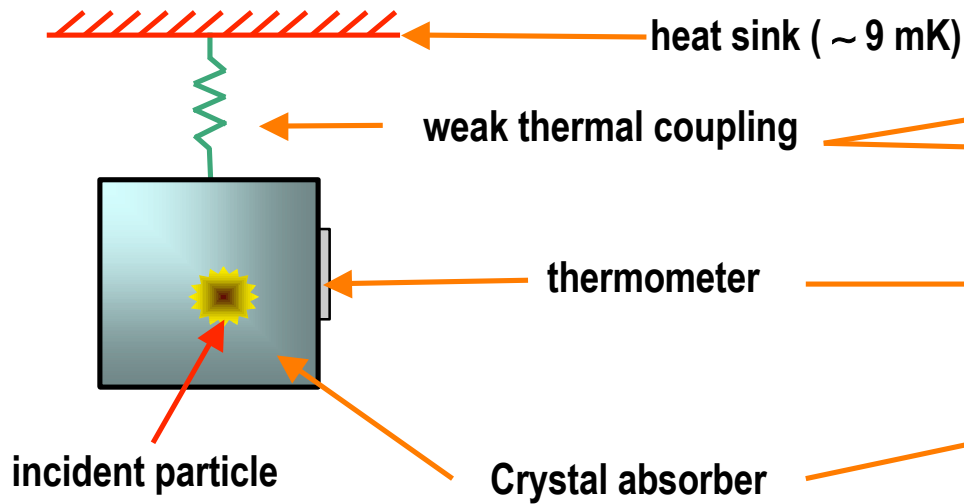


CUORE R&D (Hall C)

Cuoricino (Hall A)



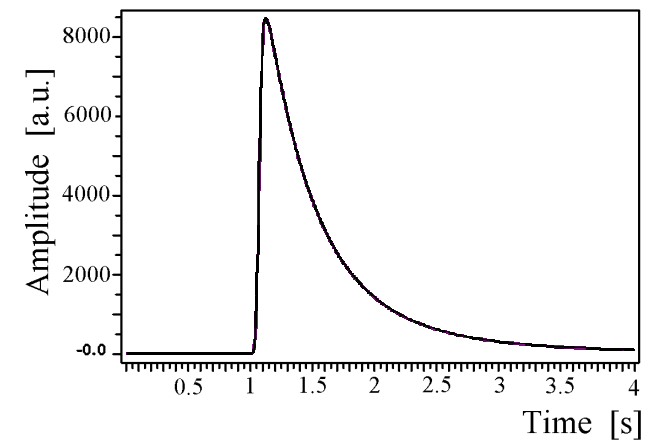
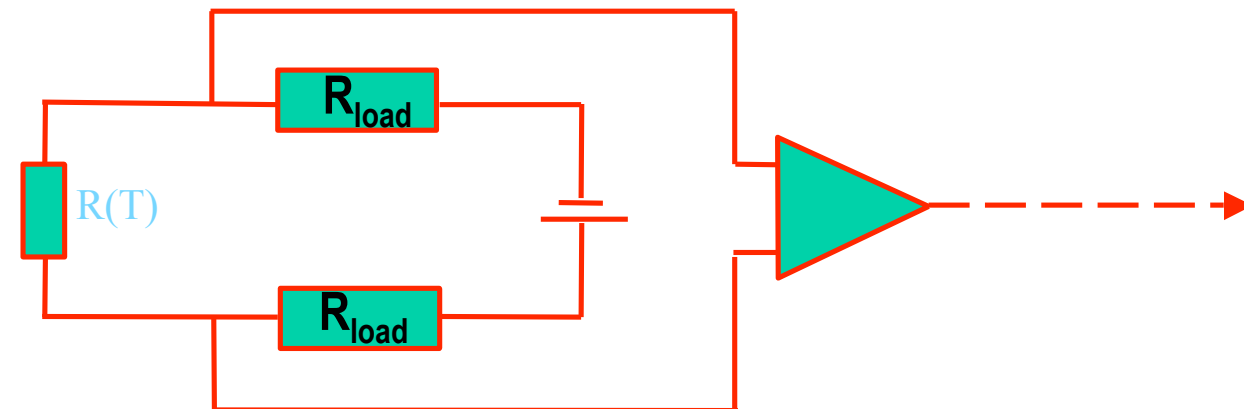
Thermal Detectors



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

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

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





Phases of the experiment

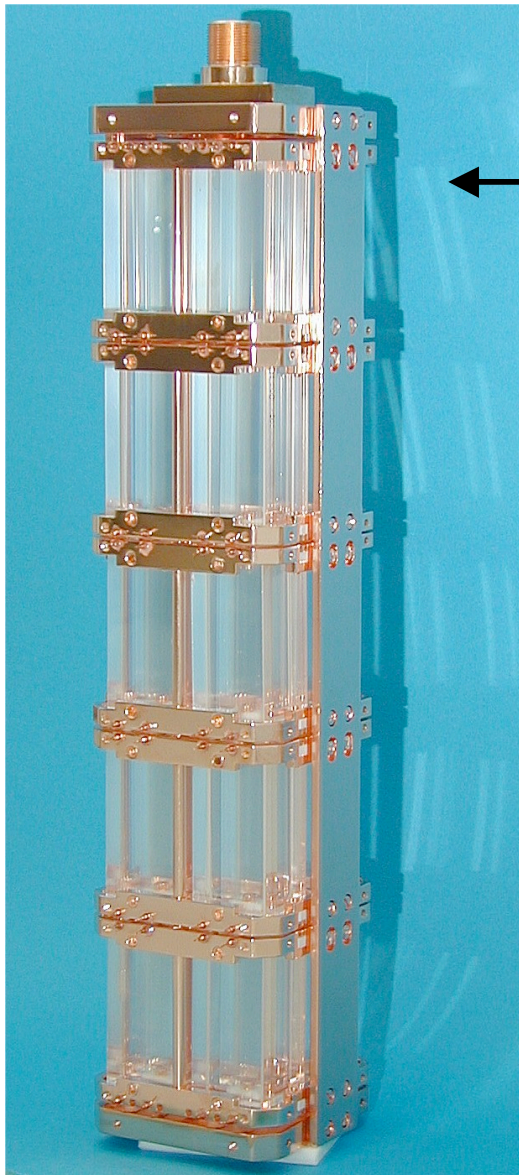
Past, present and future:

- 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 $\approx$ 40 kg (CUORICINO experiment)
18 crystals _ 340 g
- 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)



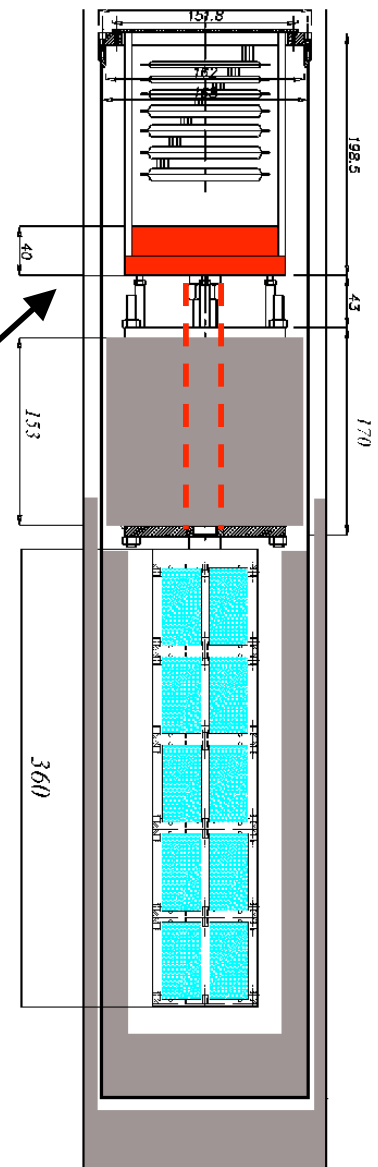
5 modules, 4 detector each,
are arranged in a tower-like
compact structure (6.8 kg)

The tower is mounted inside
a dilution refrigerator

Coldest point
and cold finger

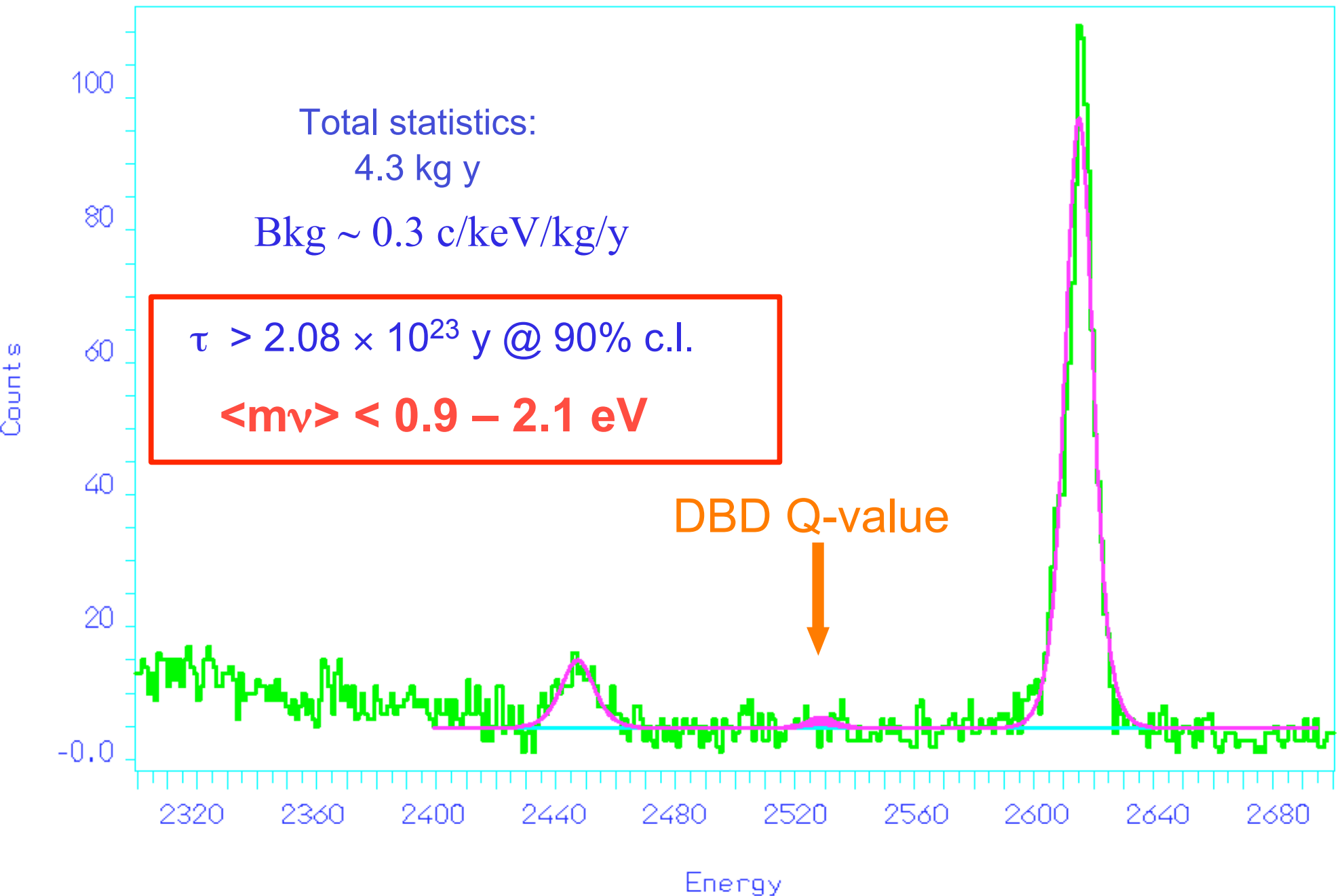
The tower is surrounded by
an inner lead shield,
(Roman lead)
and all the refrigerator

by a 20 cm thick outer lead shield





Mi DBD: limits on 0ν DBD





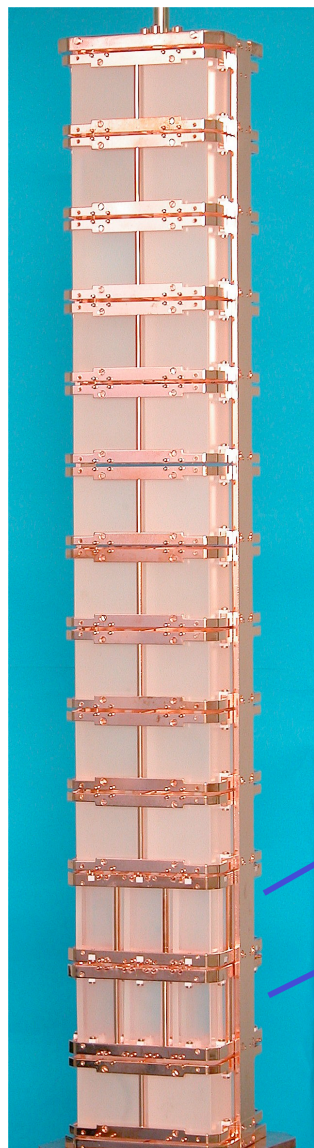
The CUORICINO set-up

11 modules

4 detector each,

Crystal dimension $5 \times 5 \times 5 \text{ cm}^3$

Crystal mass 790 g



2 modules

9 detector

each,

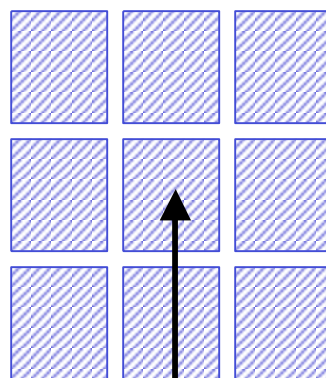
Crystal dimension

$3 \times 3 \times 6 \text{ cm}^3$

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

Coldest point

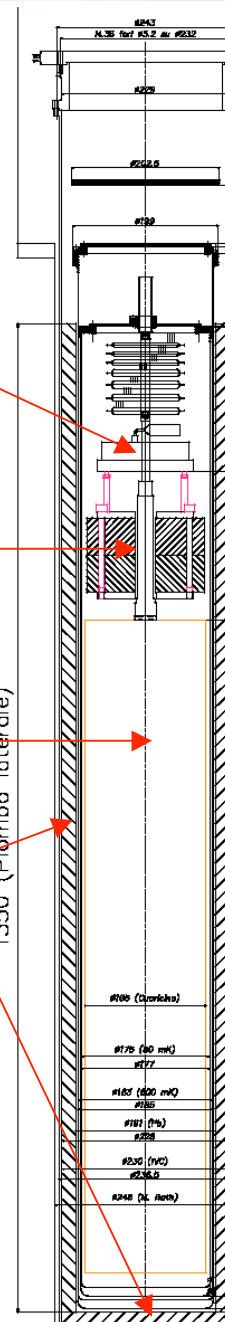
Cold finger

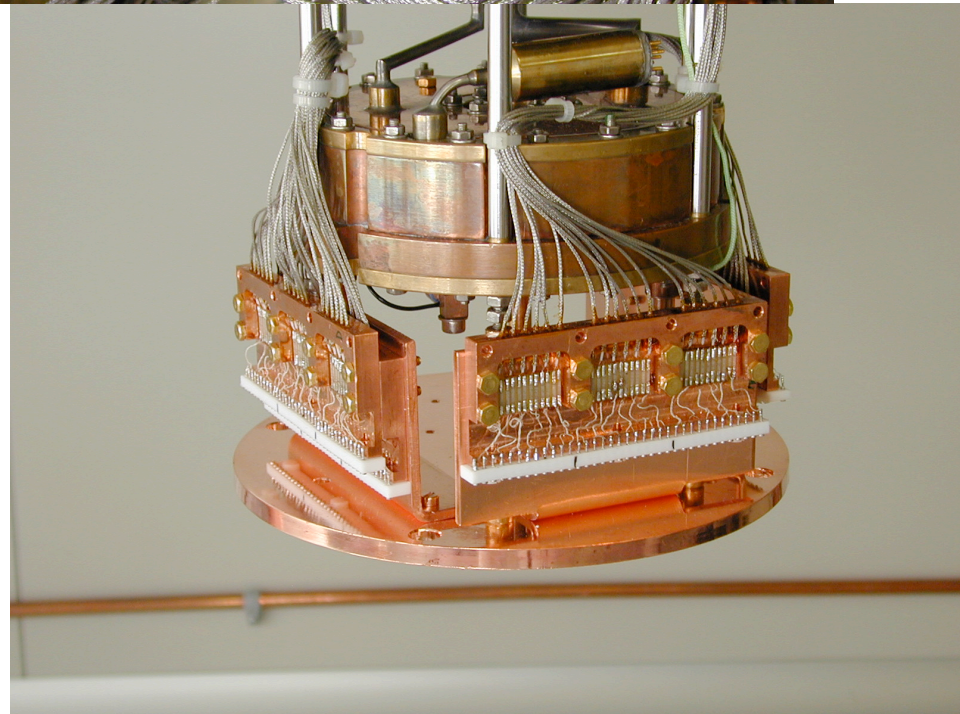
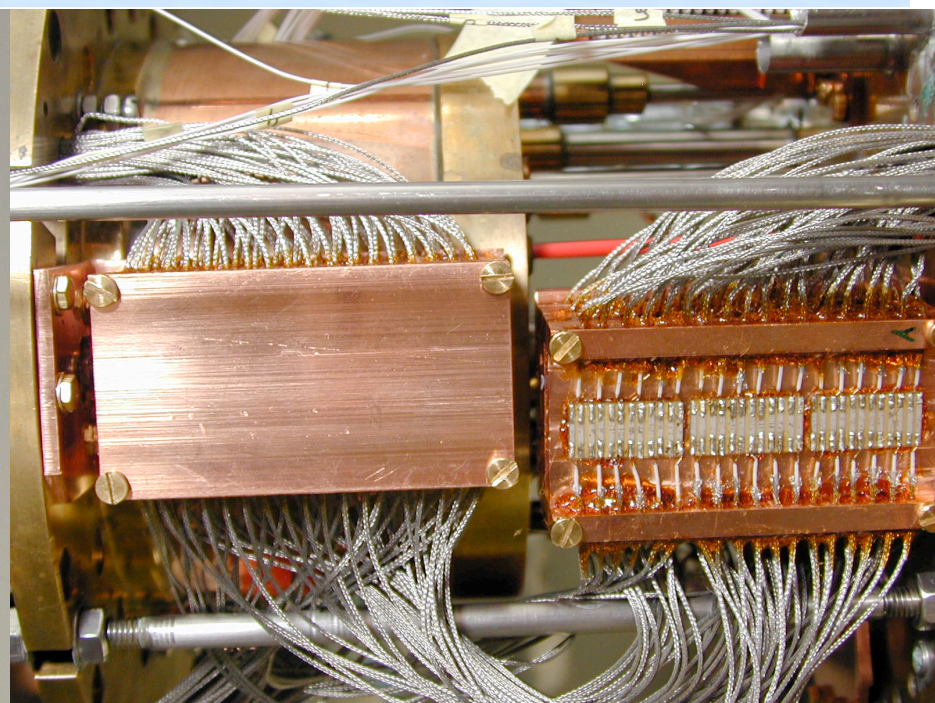
Tower

Lead shield

1350 (Piombo laterale)

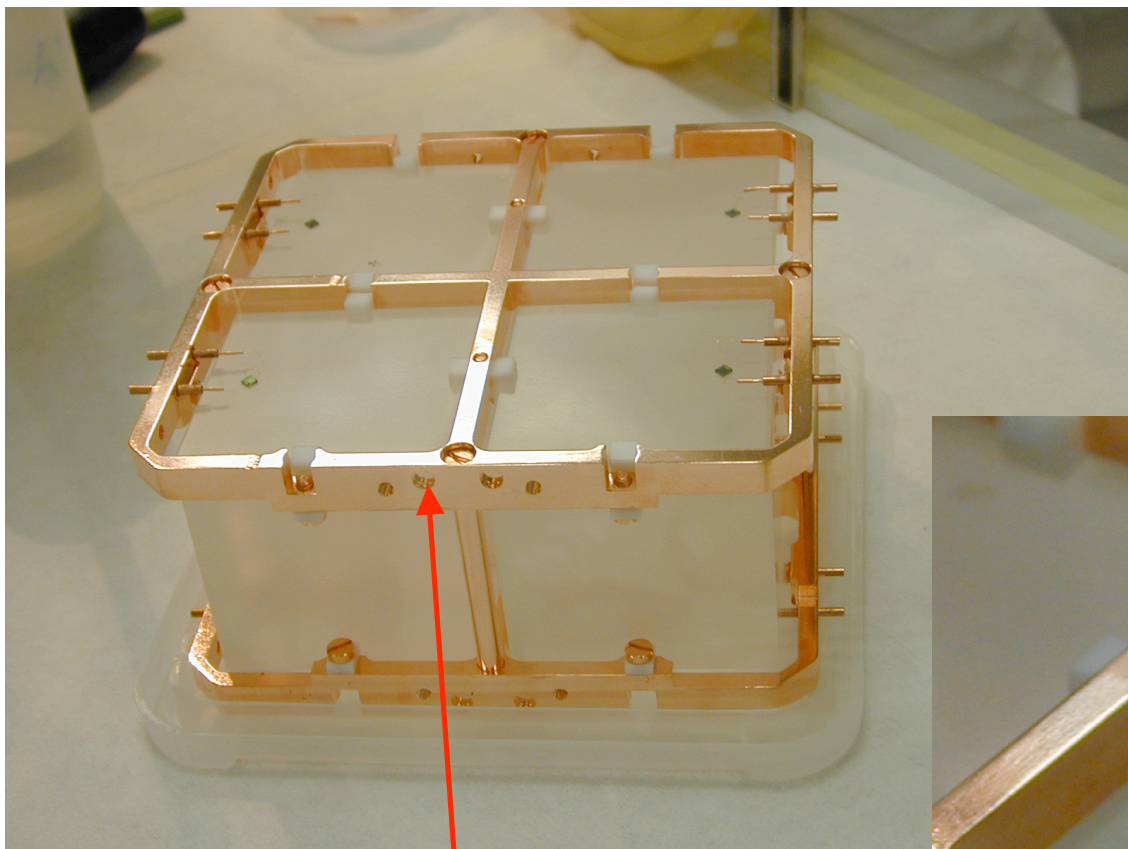
Same cryostat and similar structure as Mi DBD





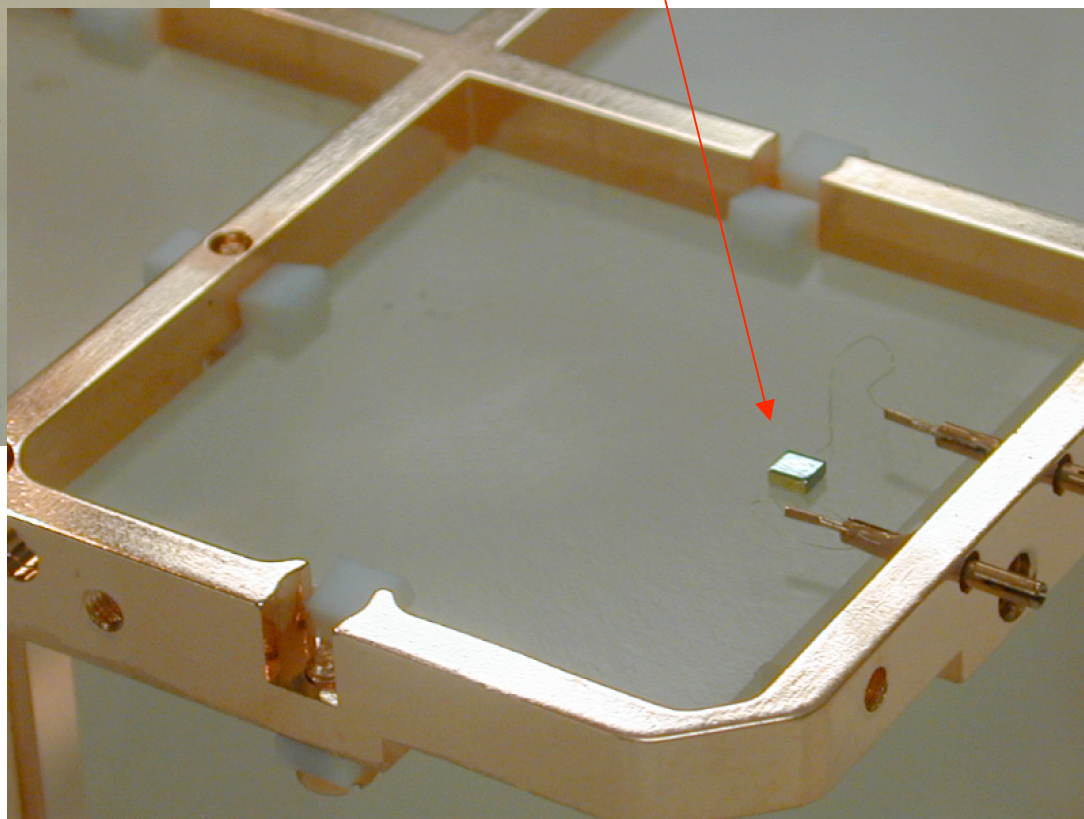


Cuoricino Single Module



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 maintenance and*



Cuoricino mass: 1st run

Detectors:

4x11 = 44 large size crystals ($\sim 5 \times 5 \times 5 \text{ cm}^3$ av. mass = 790g) 32 working
9x2 = 18 small size crystals ($\sim 3 \times 3 \times 6 \text{ cm}^3$ av. mass 330 g) 16 working

Active mass:

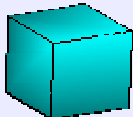
$$\begin{aligned} 32 \times 0.790 &= 25.28 \text{ kg} \\ 12 \times 0.330 &= 3.96 \text{ kg} \end{aligned} \quad \left. \begin{array}{l} 25.28 \text{ kg} \\ 3.96 \text{ kg} \end{array} \right\} 29.24 \text{ kg} = 9.9 \text{ kg } ^{130}\text{Te}$$

$$\begin{aligned} 2 (^{130}\text{Te-enriched}) \times 0.330 &= 0.660 \text{ kg} &= 0.495 \text{ kg } ^{130}\text{Te} \\ 2 (^{128}\text{Te-enriched}) \times 0.330 &= 0.660 \text{ kg} &= 0.543 \text{ kg } ^{128}\text{Te} \end{aligned}$$

$$10.4 \text{ kg } ^{130}\text{Te}$$



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)

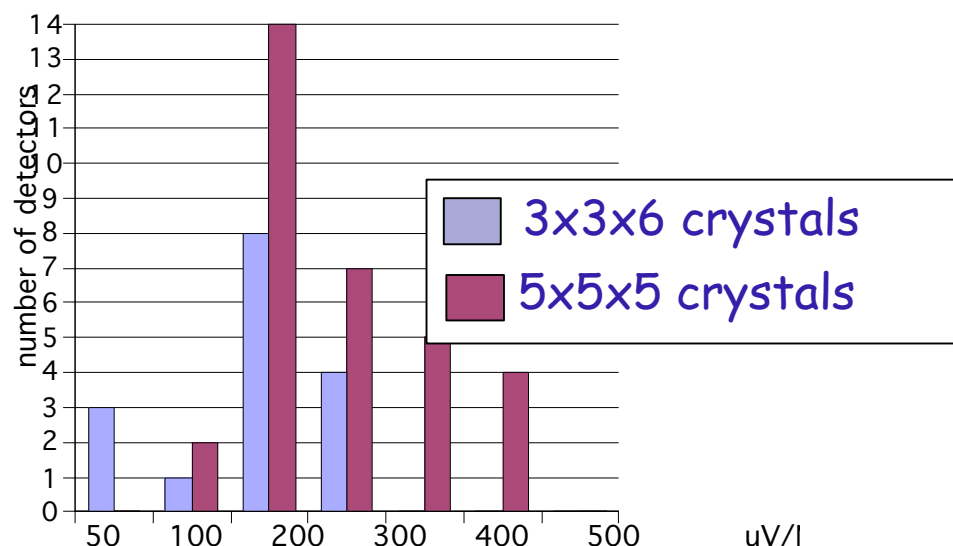
15 really used

11 natural

4 enriched

Pulse height distribution $\mu\text{V}/\text{MeV}$

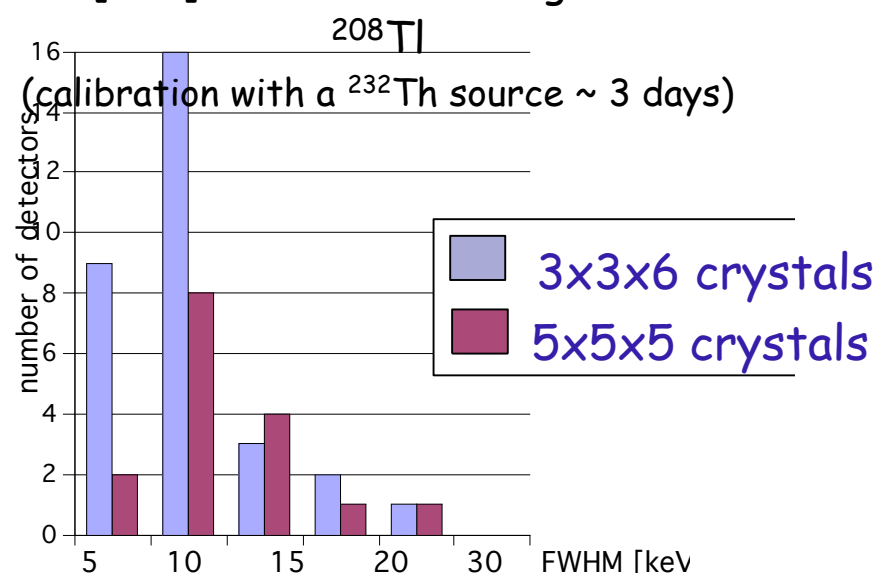
(normalized to 1 kg of TeO_2)



average for 5x5x5 crystals = 340 $\mu\text{V}/\text{MeV}$
 average for 3x3x6 crystals = 440 $\mu\text{V}/\text{MeV}$

Energy resolution

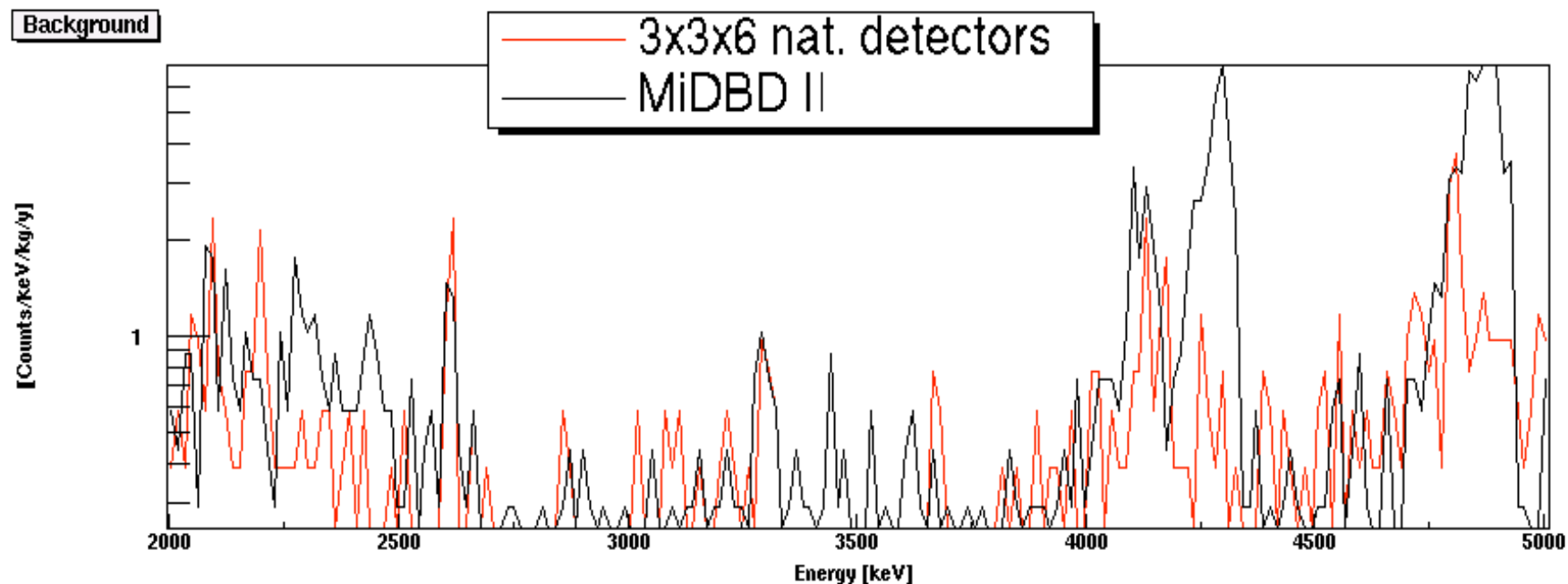
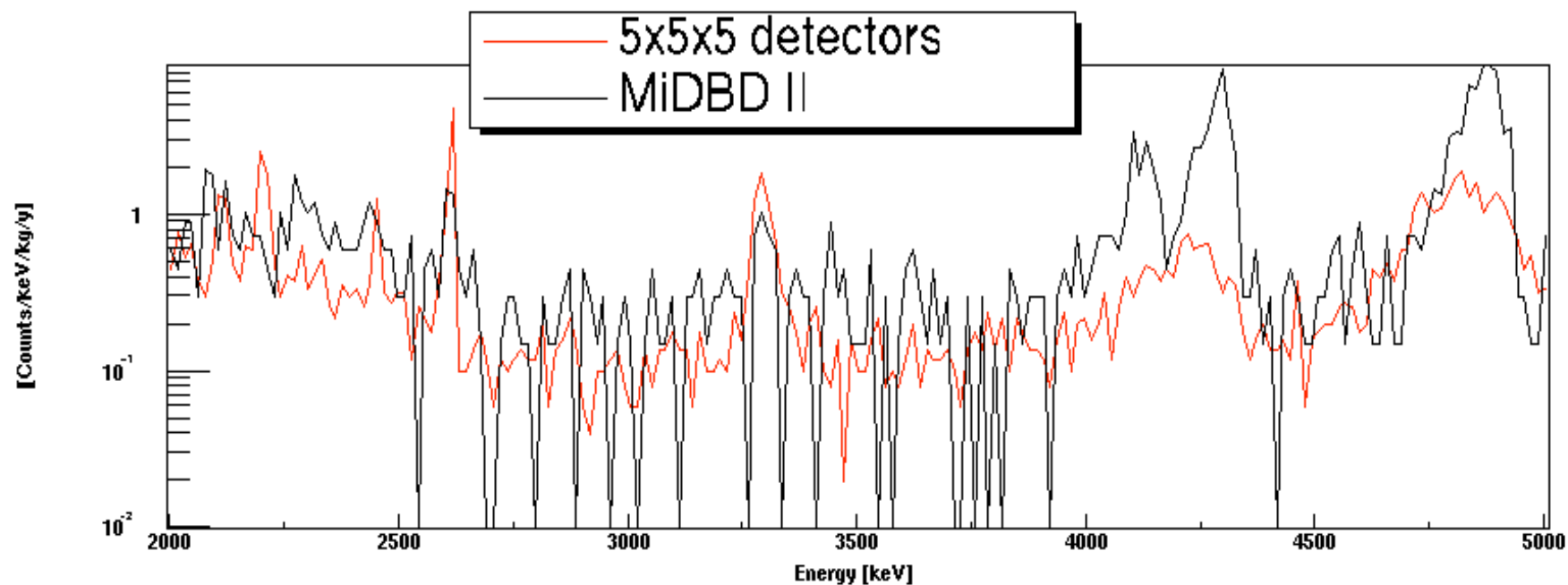
FWHM [keV] of the 2615 keV gamma line of



average 5x5x5 cm³ crystals ~ 7 keV
 average 3x3x6 cm³ 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	0.1	0.36	0.04	0.23	0.03	0.77	0.05	0.21	0.05
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

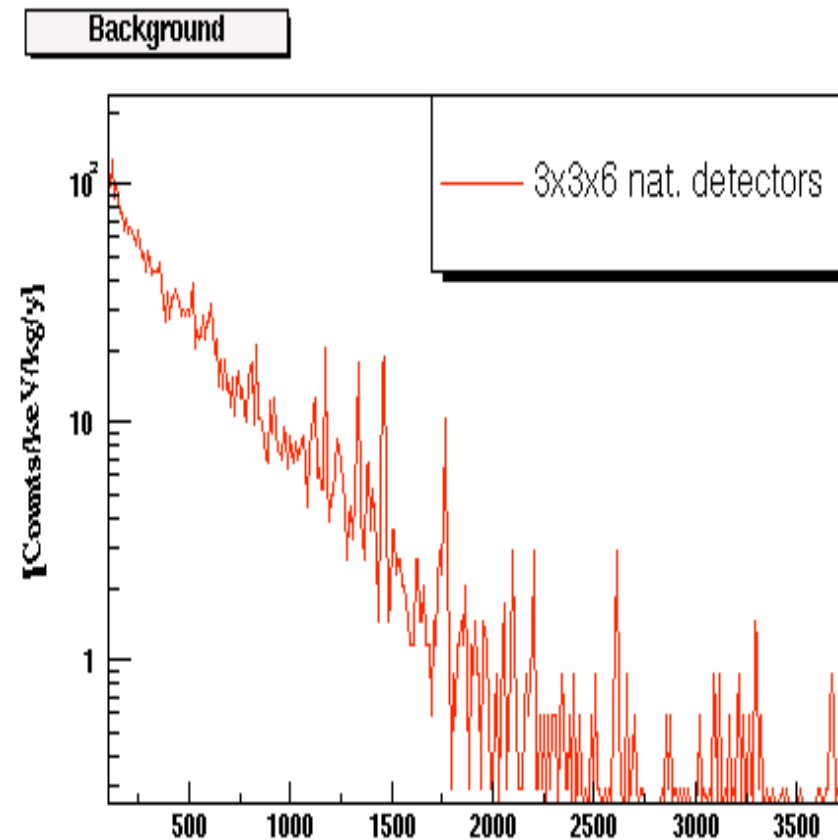
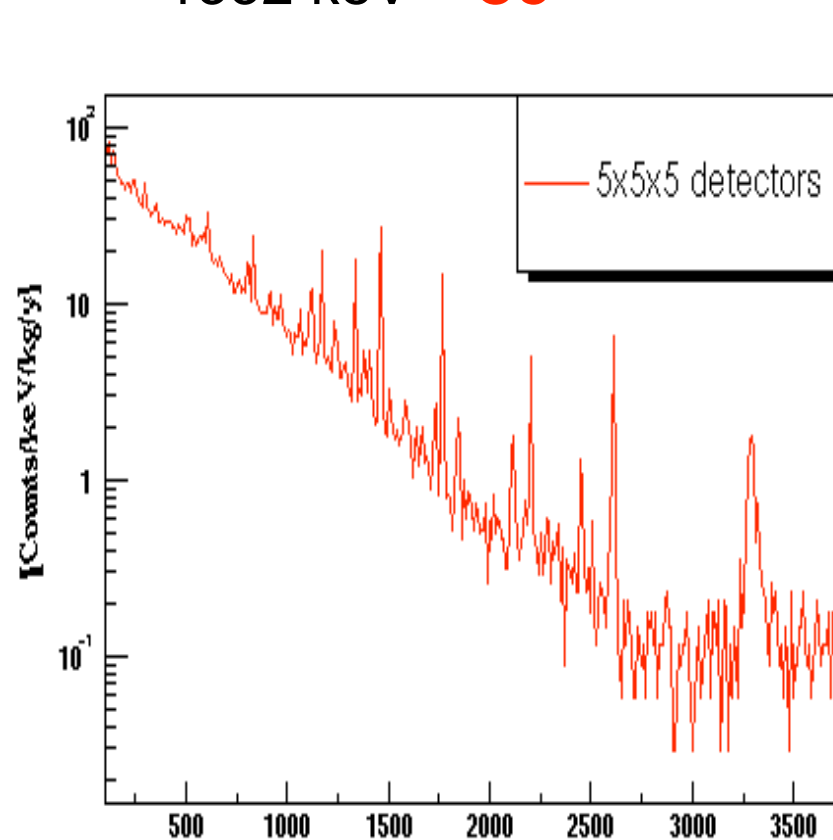


Background 1st run: gamma peaks

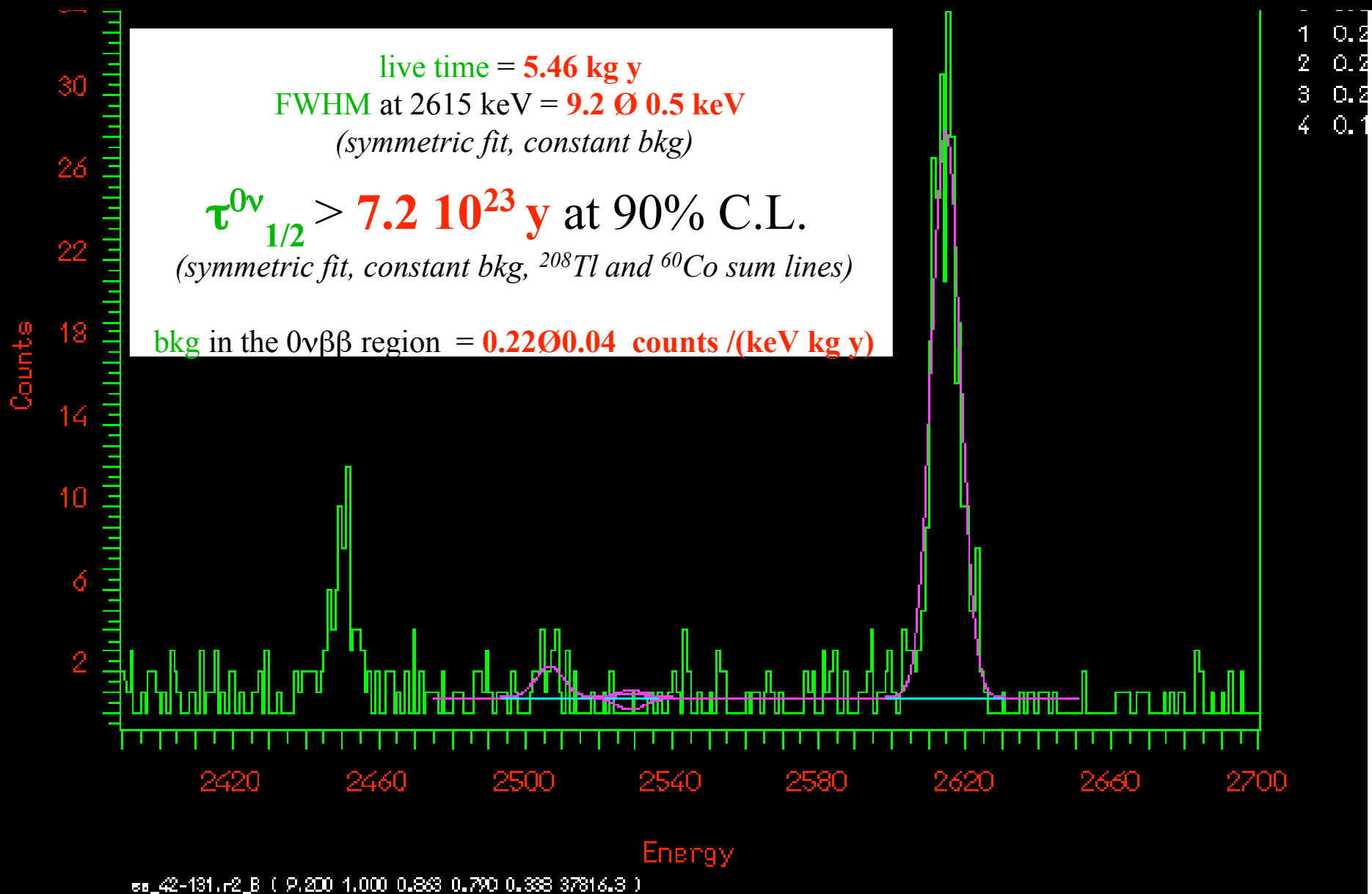
2615 keV ^{208}Tl
1764 keV ^{214}Bi } 3 times higher in 5x5x5 than in 3x3x6 → detector efficiency

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

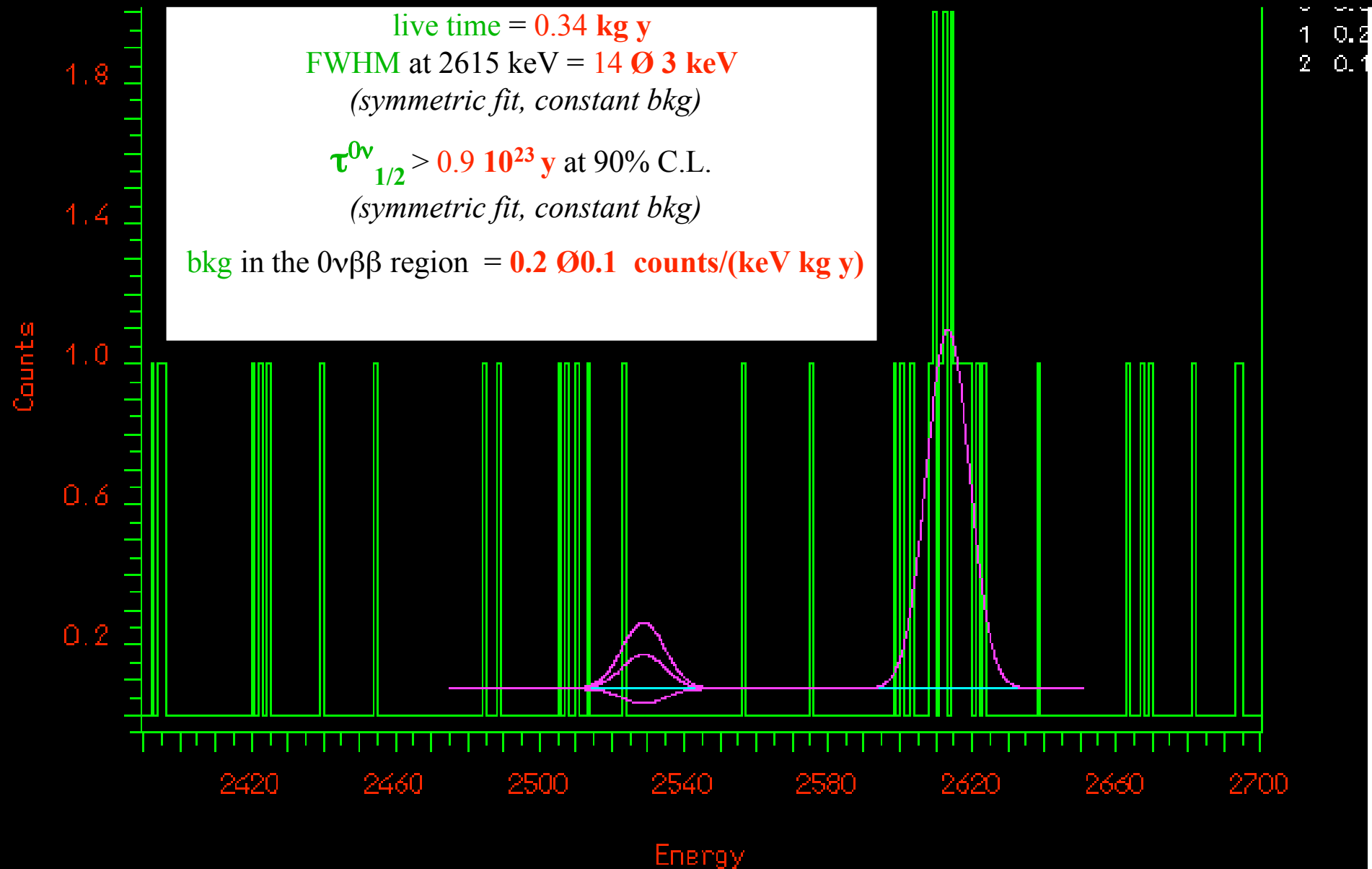
1332 keV ^{60}Co → higher in 3x3x6 crystals



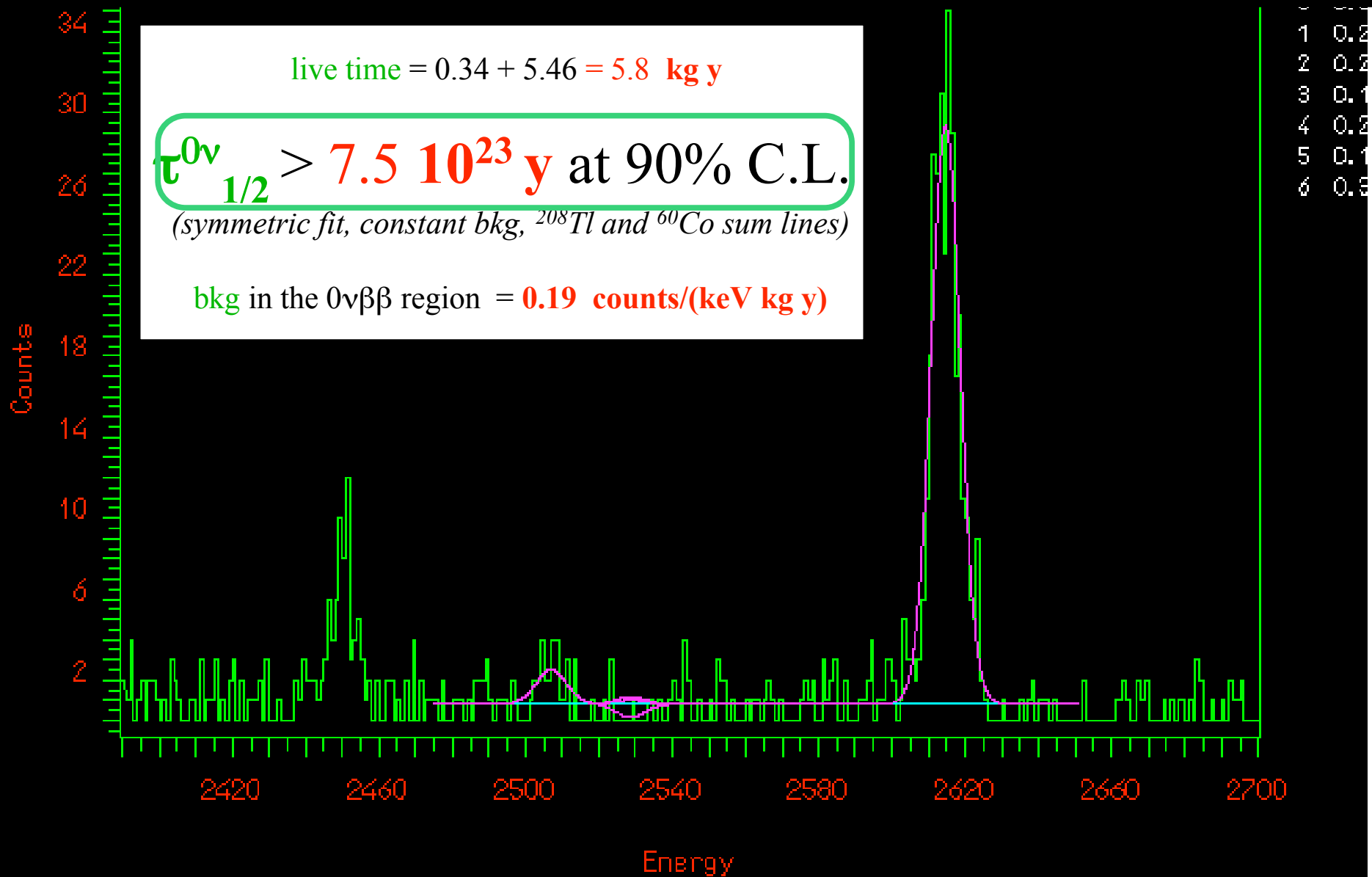
Background 5x5x5 crystals



Background 3x3x6 nat. crystals



Background all nat. crystals



sa_42-131.r2_B (2.200 1.000 0.863 0.790 0.338 37816.3)
 sa_71-131.r2_X (14.000 1.000 0.845 0.380 0.388 9093.5)



CUORICINO sensitivity

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

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

Isotopic abundance → a
Atomic mass → A
Detector mass (kg) → M
Running time (y) → T
BKG (counts/keV/kg/y) → b
Energy resolution (keV) → Γ
Detector efficiency → ε

For: $b = 0.2$ and $\Gamma = 9$ 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 maintenance 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

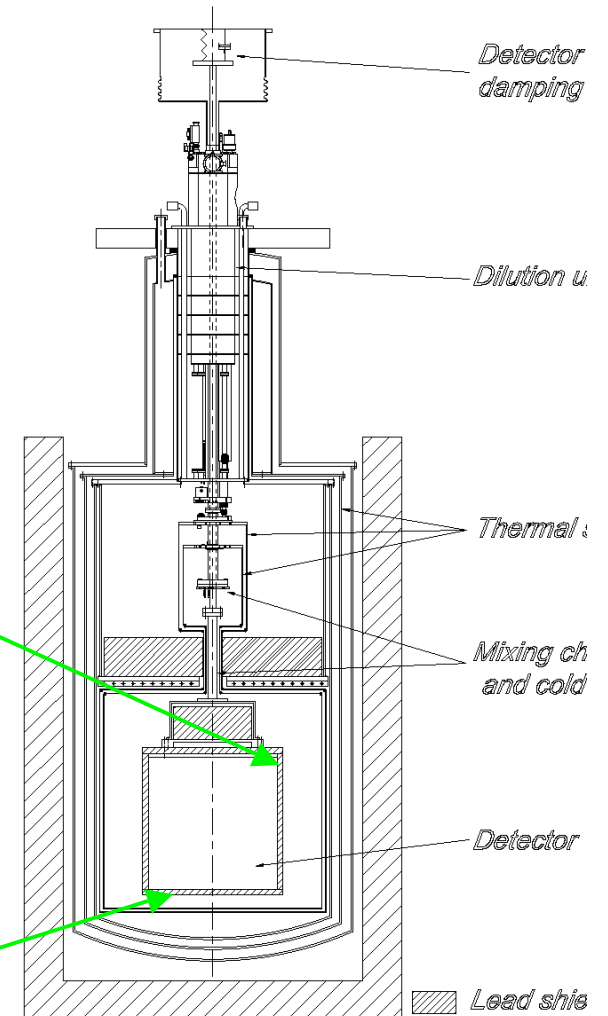
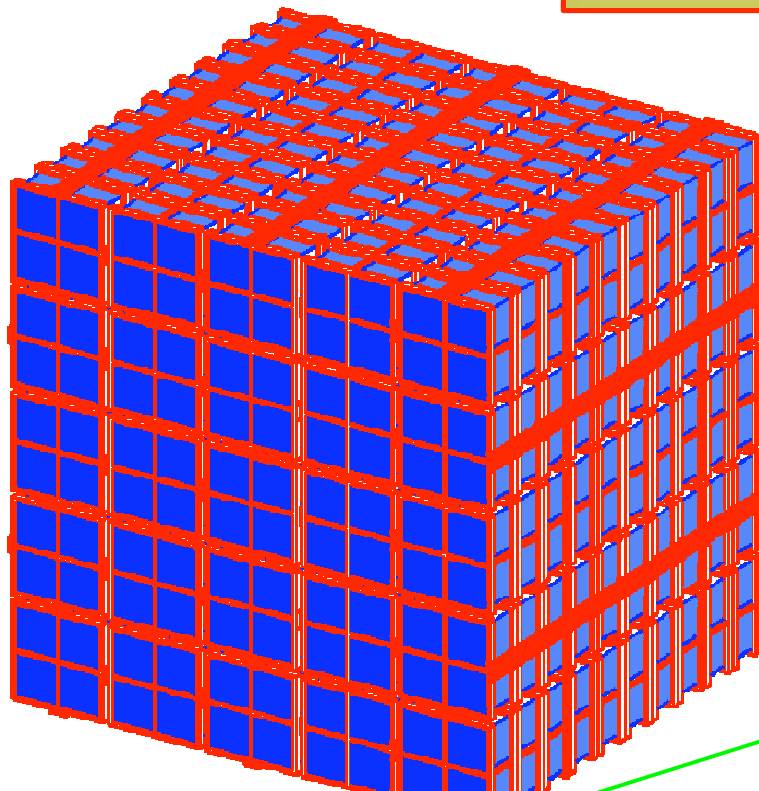
CUORE: Array of 1000 detectors:

25 towers - 10 modules/tower - 4 detectors/module

APPROVED

$M = 0.75 \text{ ton}$

70 cm





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 estimated 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 dimensions
 - primary milestone of CUORE R&D is a reduction by a factor 10 of the surface contaminations

Sensitivity:

Minimal expectation :

$b = 0.01$ and $\Gamma = 10$ keV

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

(68% CL)

After appropriate R&D :

$b = 0.001$ and $\Gamma = 10$ keV

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

(68% CL)