CUORE (Cryogenic Underground Osservatory for Rare Events) and CUORICINO

E.Fiorini, Neutrino 2004
Paris , June 17, 2004

For searches on neutrinoless ββ decay , WIMPs and axions interactions and on rare nuclear events

The collaboration

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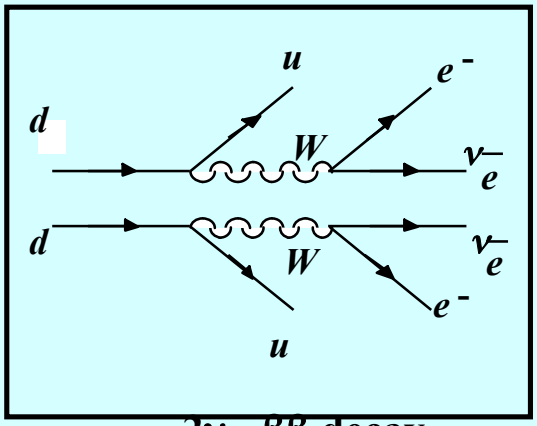
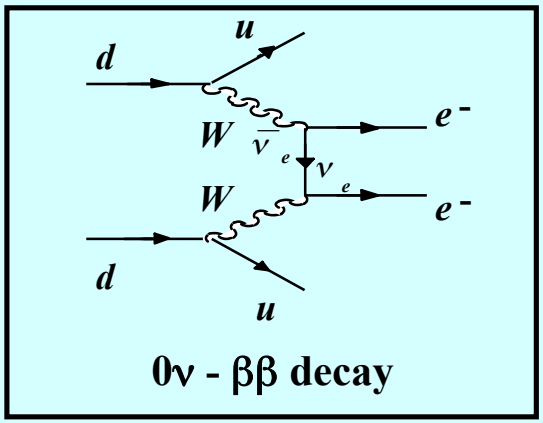
$(A,Z) \Rightarrow (A,Z+2) + 2\,e^- + 2\,\bar{\nu}_e$

$(A,Z) \Rightarrow (A,Z+2) + 2\,e^- + \chi\ (\ldots 2,3\,\chi)$

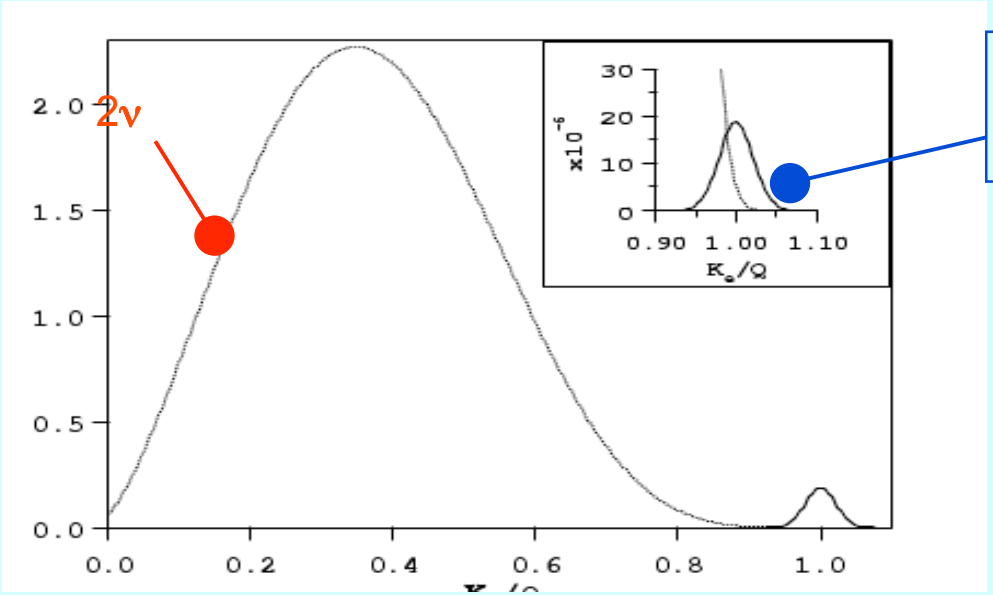
$(A,Z) \Rightarrow (A,Z+2) + 2\,e^-$



2ν - ββ decay

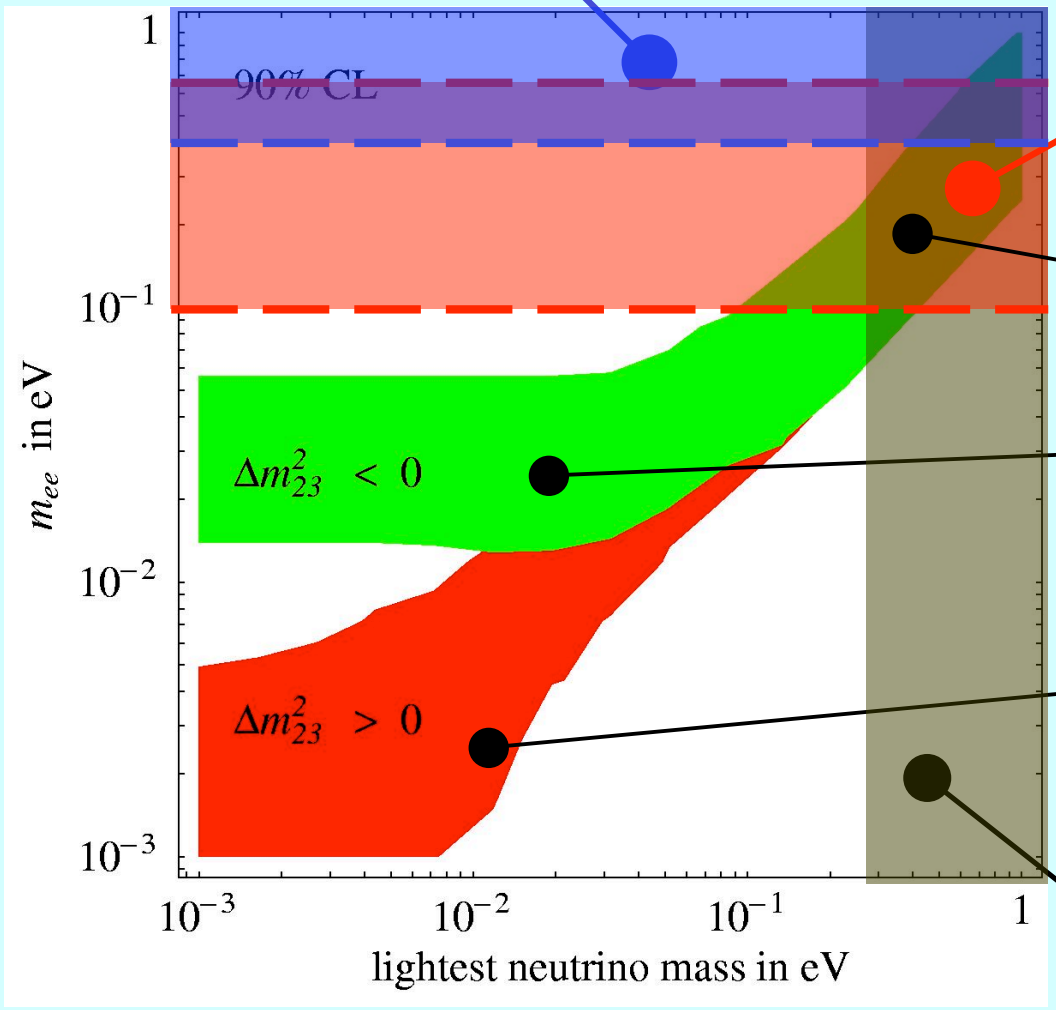


0ν - ββ decay



Neutrinoless ββ peak

Present Cuoricino region



Possible evidence (best value 0.39 eV)

"quasi" degeneracy
$m_1 \approx m_2 \approx m_3$

Inverse hierarchy
$\Delta m^2_{12} = \Delta m^2_{atm}$

Direct hierarchy
$\Delta m^2_{12} = \Delta$
m^2_{sol}

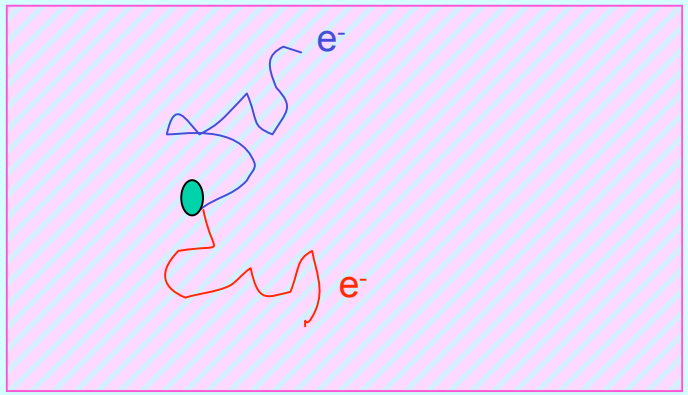
Cosmological disfavoured region (WMAP)

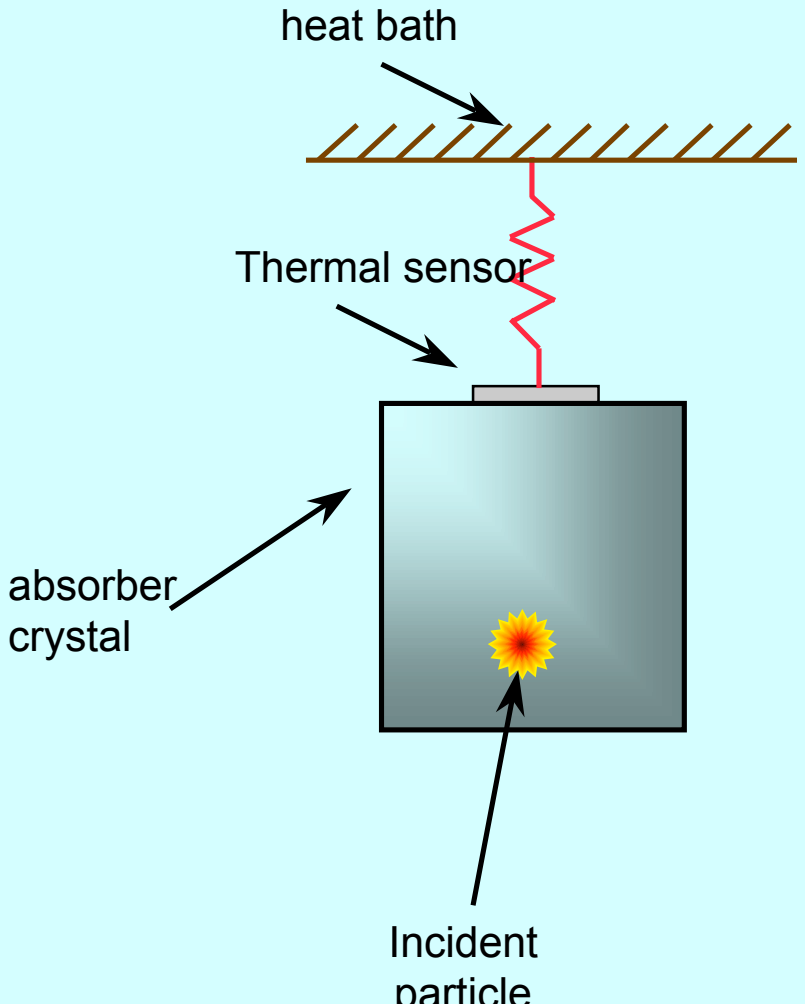
Feruglio F. , Strumia A. , Vissani F. hep-ph/0201291

Experimental approach

Thermal detectors

Source = detector (calorimetric)





Why thermal detectors

Flexibility in the choice of detectors

- uncertainty in nuclear matrix evaluation
- a ββ peak could be simulated by a radioactive signal. If found in two different regions

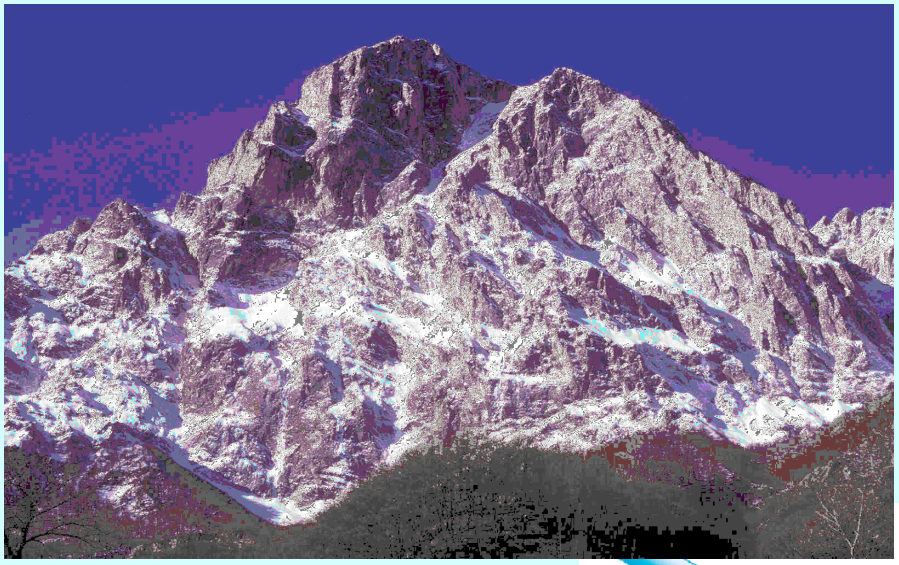
=> Clear indication

Excellent resolution <1 eV ~ 4 eV @ 6 keV
~10 eV ~keV @ 2 MeV

Present choice of ^{130}Te *due to*

- Good natural isotopic abundance (i.a. = 33.87 %)
  Importante per l'espansione a basso costo dei rivelatori futuri
- High transition energy (Q = (2528.8 ±1.3) keV)
  Spazio delle fasi grande, minor fondo radioattivo (valle tra l'en. piena ed il Compton edge del ^{208}Tl)
- observed with geo-chimical techniques ($T_{1/2\ incl} = (0.7 - 2.7) \times 10^{21}$ y)
  $m_{ee} \approx 0.1$ eV $\Leftrightarrow T_{1/2} \approx 10^{26}$ y

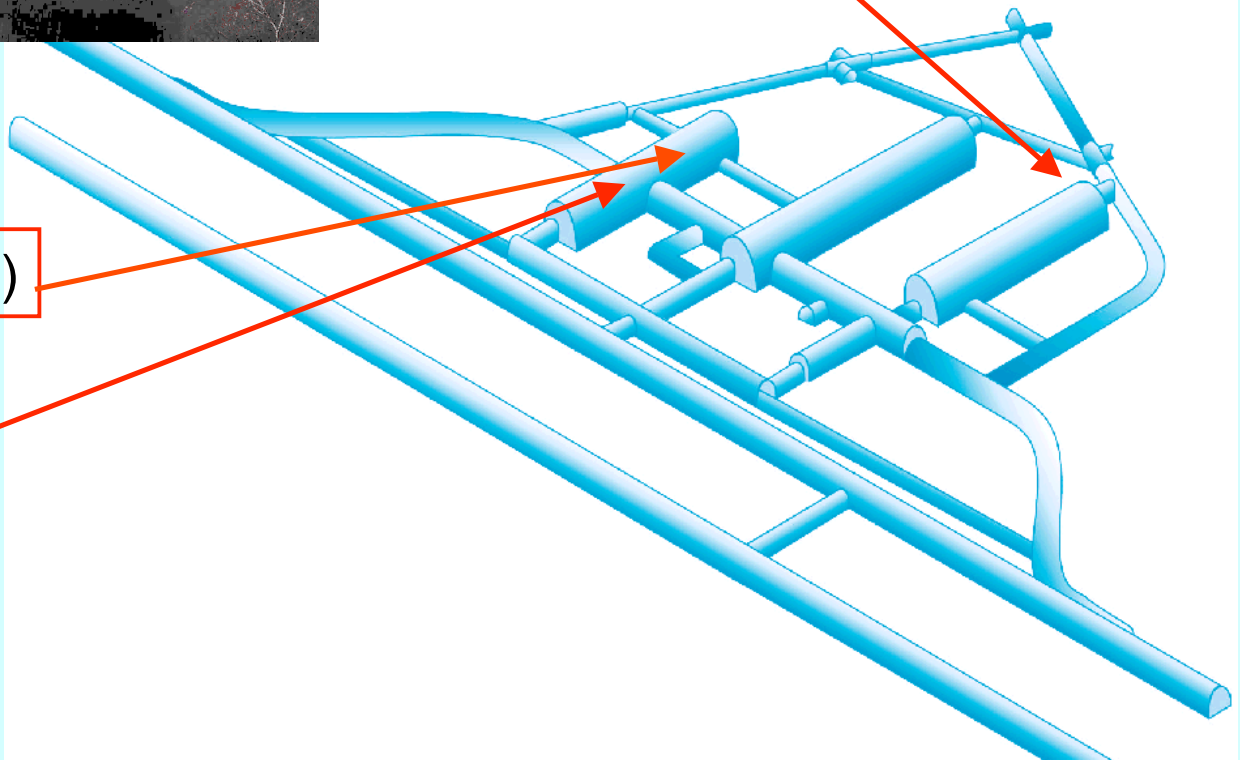
CUORE @ LNGS



CUORE R&D (Hall C)

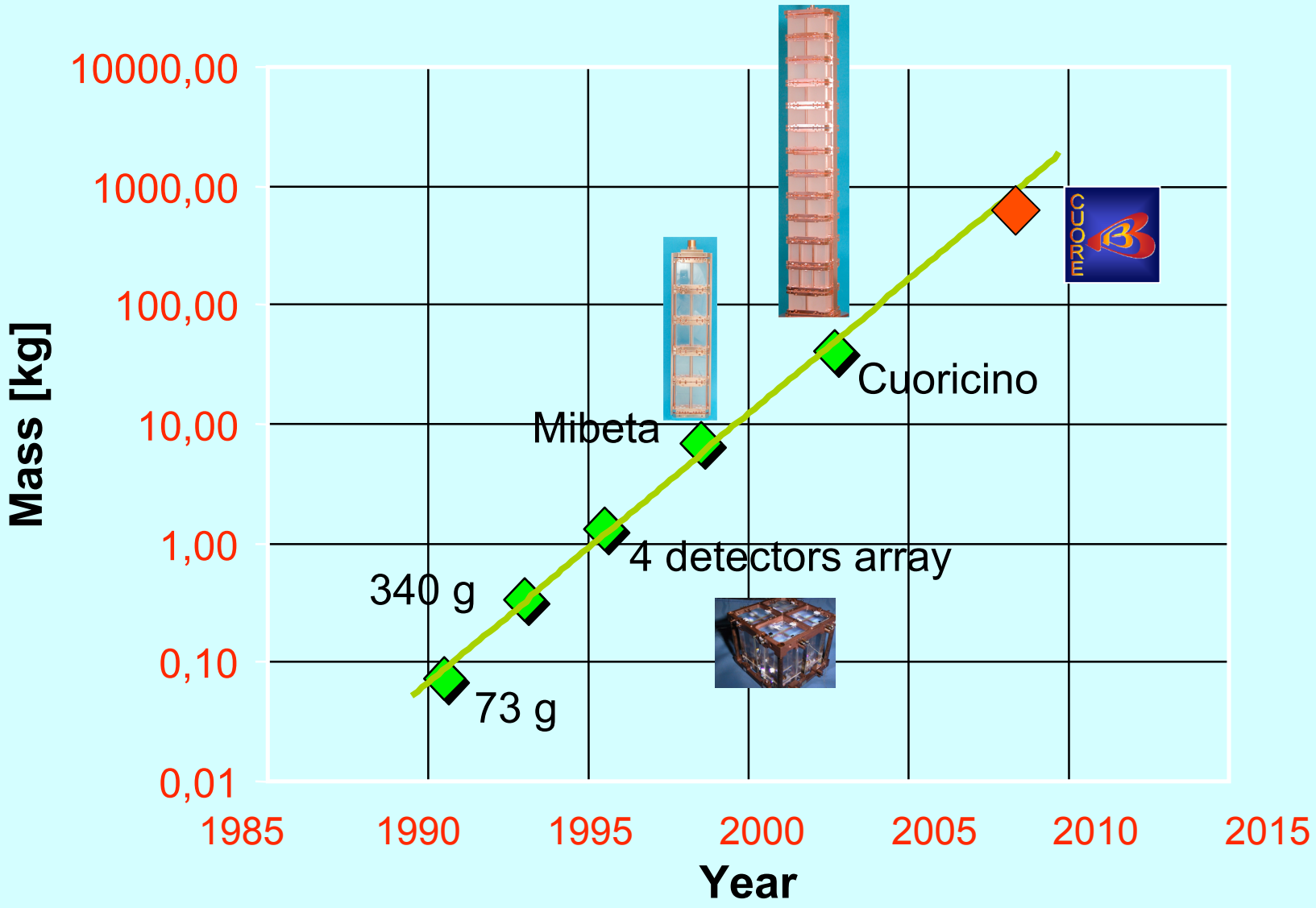
CUORE (Hall A)

Cuoricino (Hall A)



Increase of the detector mass

②

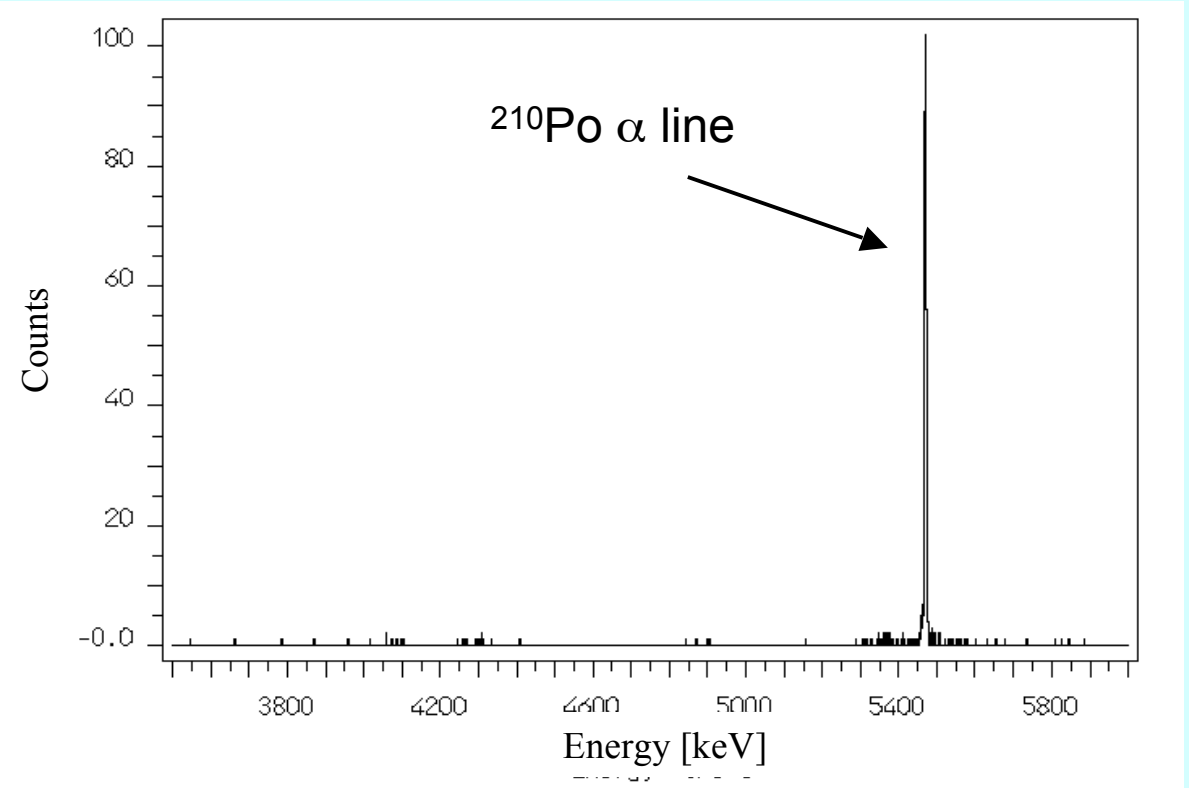


Resolution of the 5x5x5 cm^3 (~ 760 g) crystals

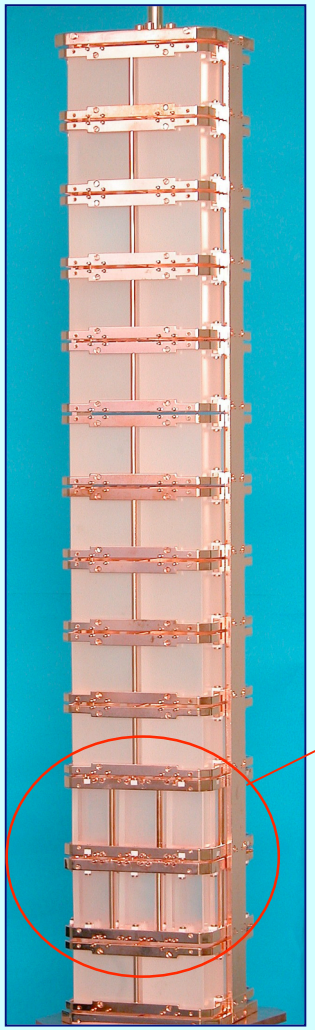
:

0.8 keV FWHM @ 46 keV
1.4 keV FWHM @ 0.351 MeV
2.1 keV FWHM @ 0.911 MeV
2.6 keV FWHM @ 2.615 MeV
3.2 keV FWHM @ 5.407 MeV

(the best α spectrometer ever realized)



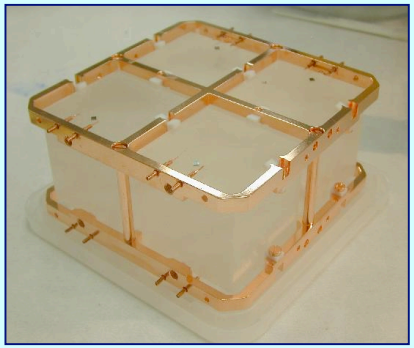
CUORICINO



- ✓ Search for the $2\beta|_{0\nu}$ in ^{130}Te (Q=2529 keV) and other rare events
- ✓ At Hall A in the Laboratori Nazionali del Gran Sasso (LNGS)
- ✓18 crystals 3x3x6 cm3 + 44 crystals 5x5x5 cm3 = 40.7 kg of TeO2
- ✓Operation started in the beginning of 2003 => ~ 4 months
- **✓Background .19±.02 c /kev/ kg/ a**
- ✓ **$T_{1/2}^{0\nu}$ (^{130}Te) > 7.5 x 10^{23} y** **$\langle m_\nu \rangle$ .3 -1. 6**

Klapdor 0.1 – 0.9

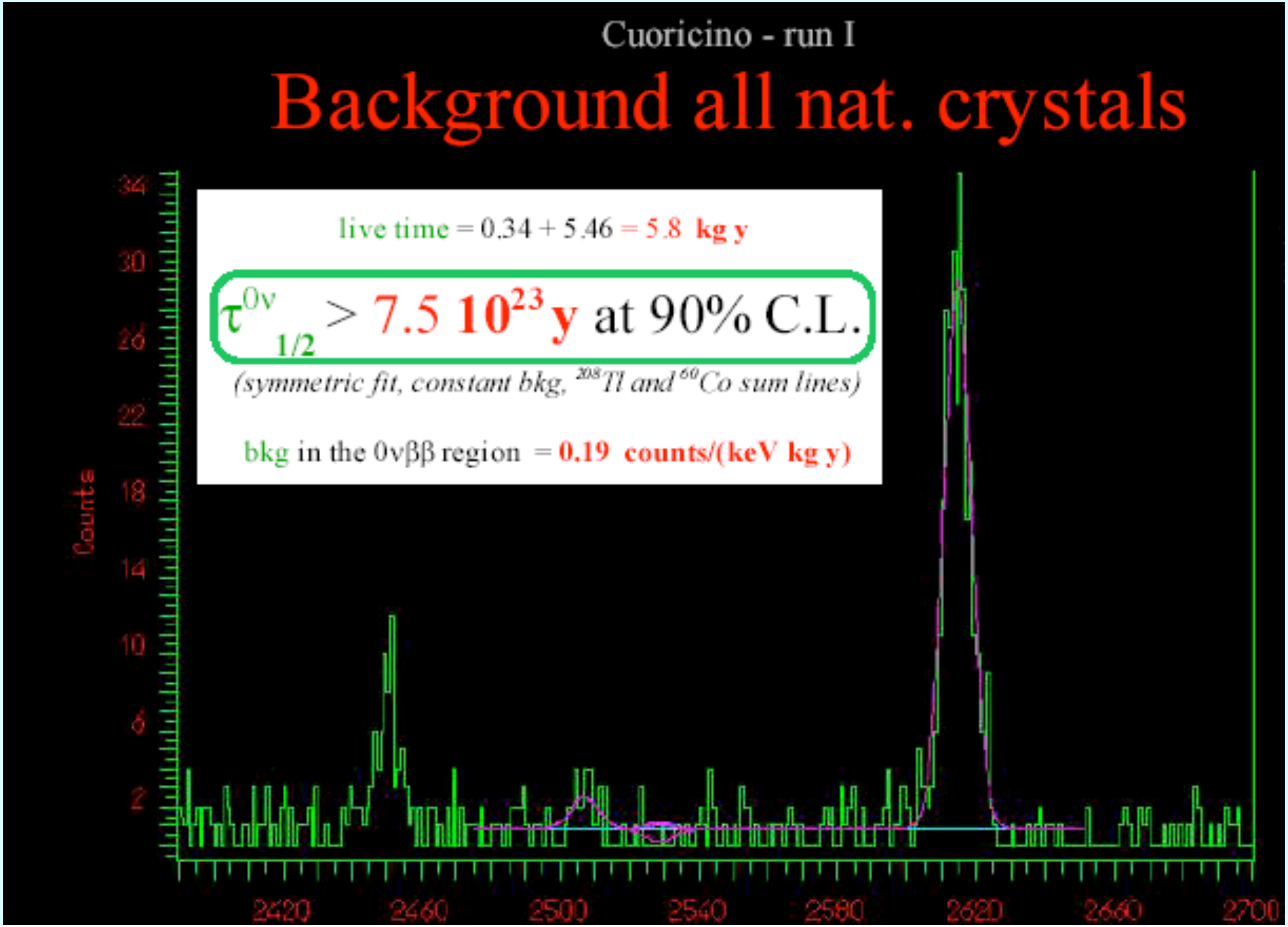
2 modules, 9 detector each,
crystal dimension 3x3x6 cm^3
crystal mass 330 g



11 modules, 4 detector each,
crystal dimension 5x5x5 cm^3
crystal mass 790 g

Cuoricino - run I

Background all nat. crystals

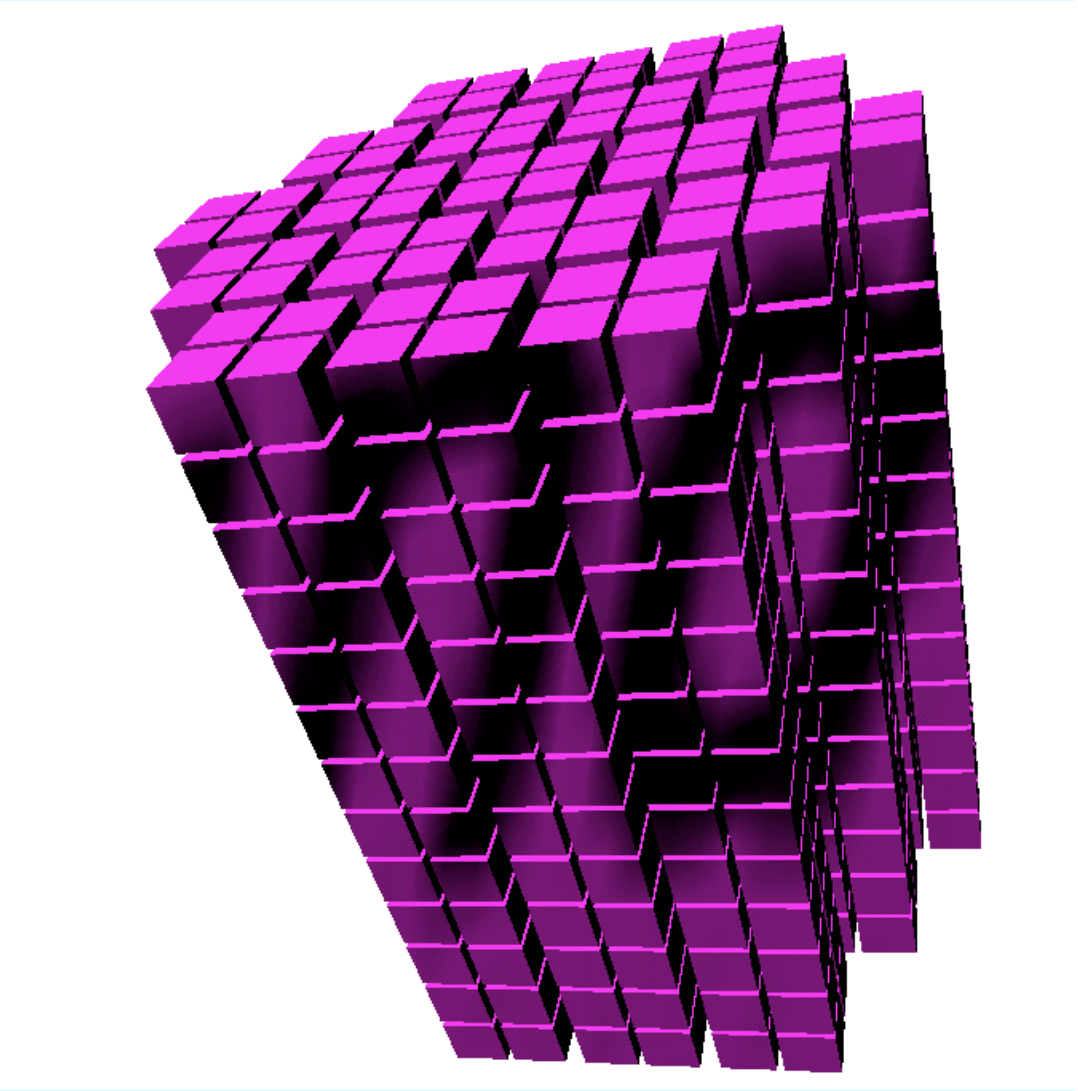


IL PROGETTO CUORE

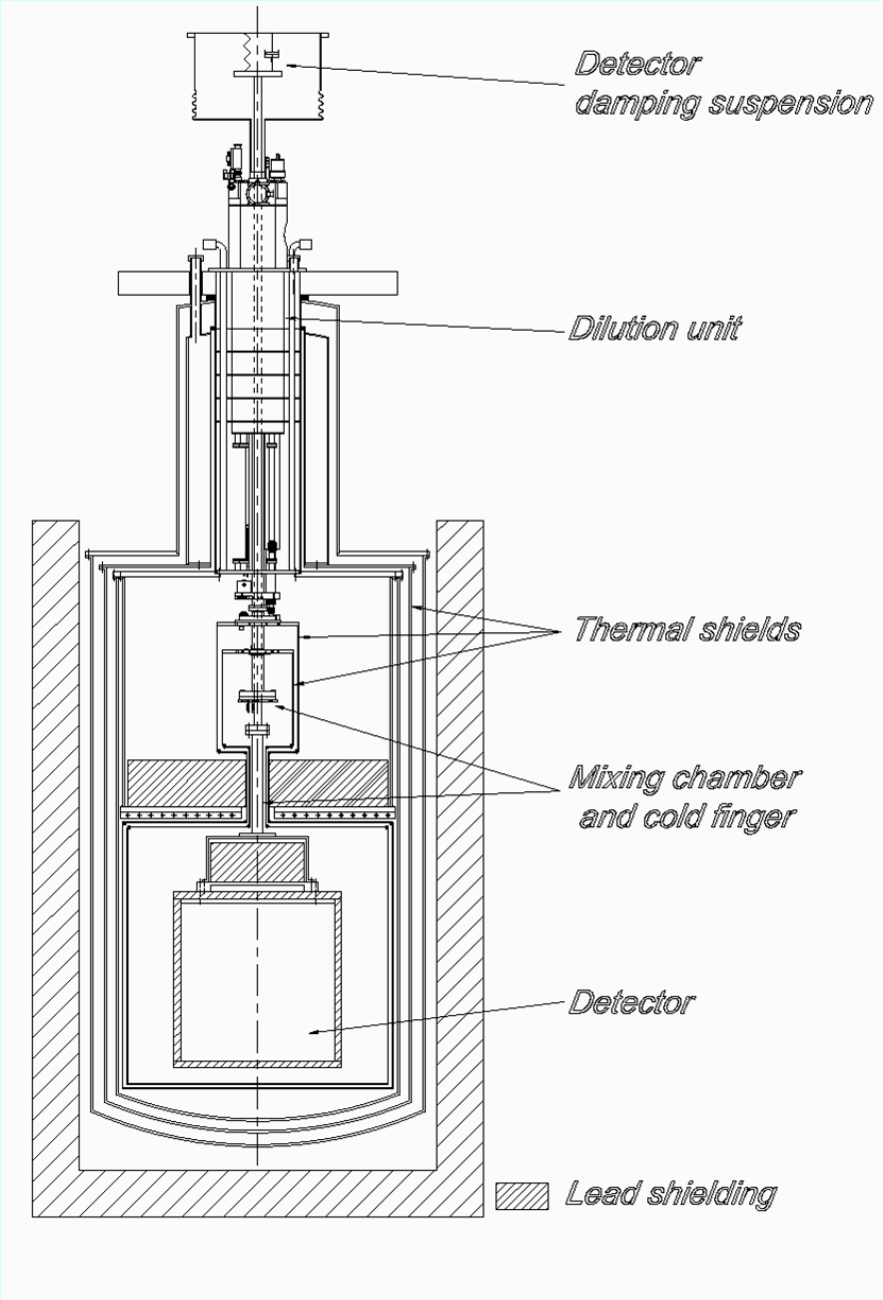
CUORE is an array of **988** bolometers grouped in **19** colums with **13** flours of **4** crystals

750 kg TeO_2 => 600 kg Te
=> **203 kg ^{130}Te**

Crystals are separated by a few mm, only, with little material among them



Progetto di set-up per CUORE



External shiled

Roman Pb (< 4 mBq/kg)

Modern Pb (~16 Bq/kg)

Common Modern Pb (~160 Bq/kg)

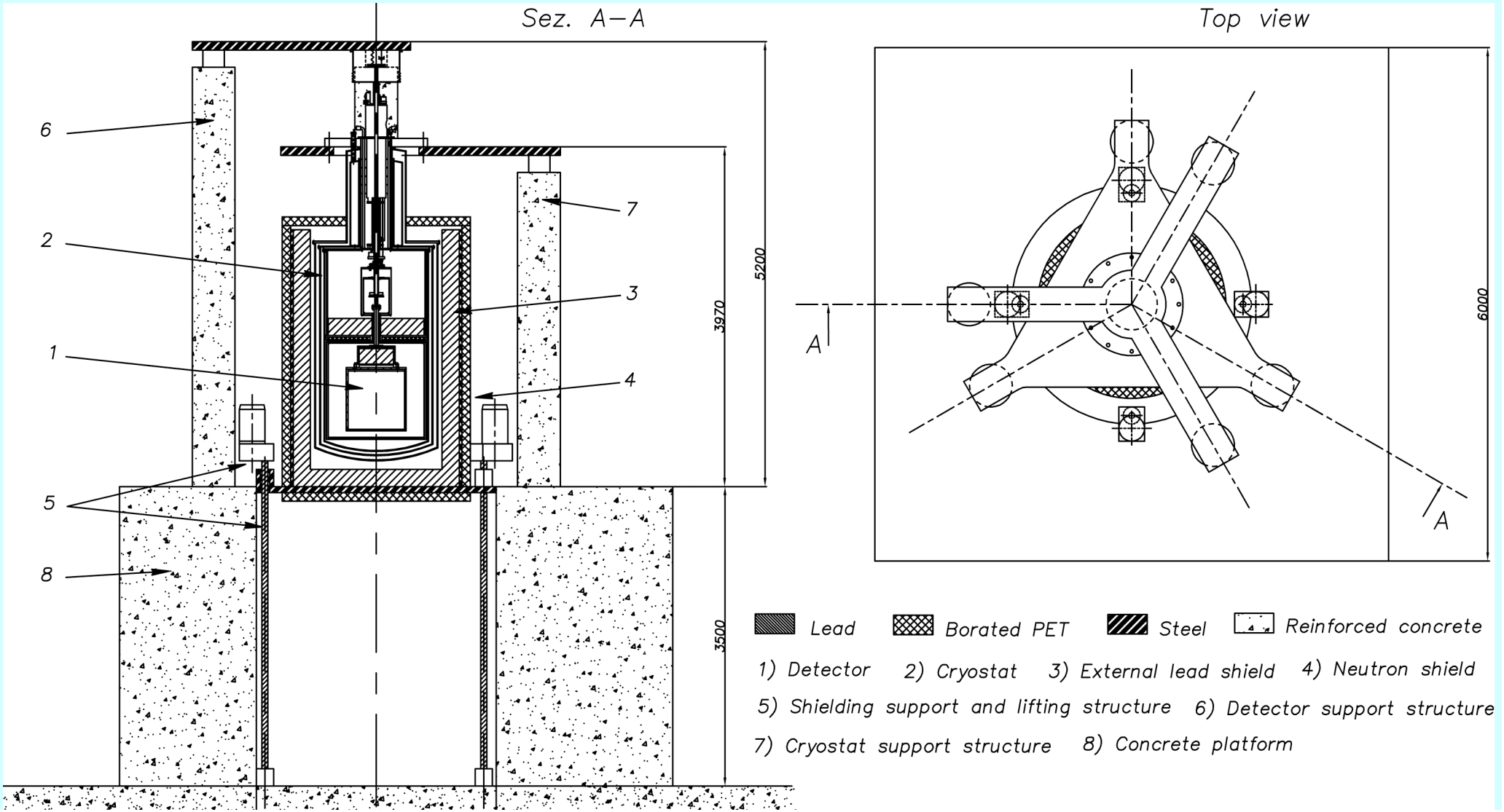
External shield in B-PET

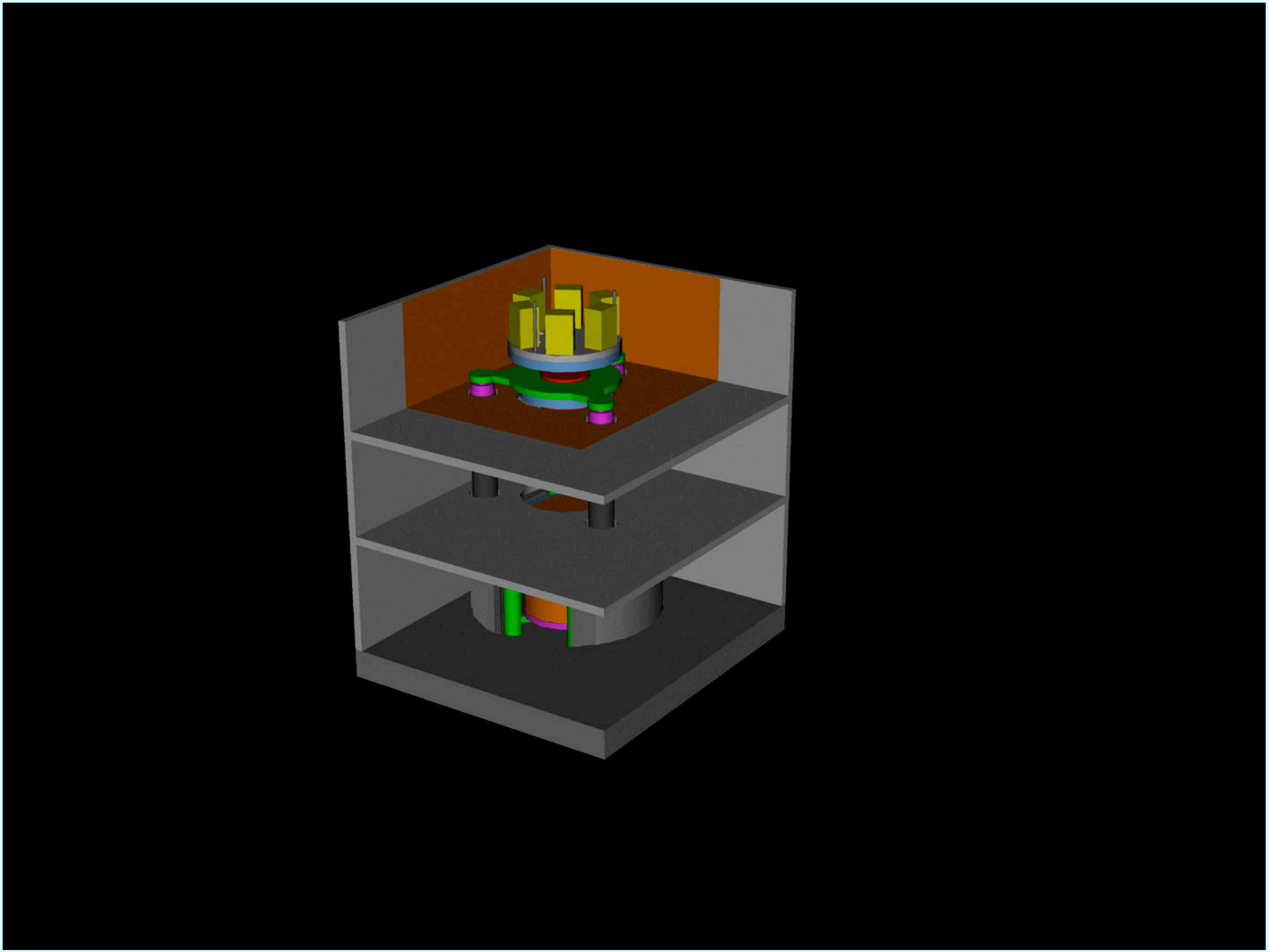
Anti-Rn box with flux of N_2

Suspension system of CUORE

The detector is suspended in an INDEPENDENTfrom the cryostat

A mobile platform allows opening the cryostat disassemnling the shielding





CUORE sensitivity

b = 0.01 - Γ = 5 keV $F^{0\nu} = 9.4 \times 10^{25} \times (T[y])^{1/2}$ **| < m > |(0.024- 0.13 eV in 5 y)**

$F^{0\nu} = 3 \times 10^{26} \times (T[y])^{1/2}$ **| < m > |(0.016- 0.09 eV in 5 y)**

b = 0.001 - Γ = 5 keV

CUORE Background in the neutrinoless ββ region

Monte Carlo results , supported by CUORICINO

Bulk crystal (<.1 pg/g) and external activity negligible

a. **γ cryostat activity** (thermal shield larger in in CUORICINO then MIDBD)
Increased Roman lead and no thermal shileds < .0038 counts/keV/kg/year

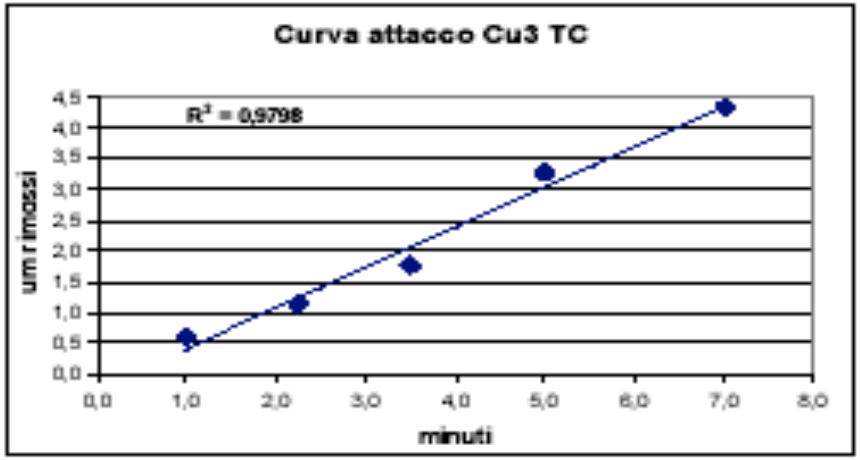
b. **α & β surface activity from Copper structure**
(Monte Carlo => ~ 0.1 ng/g v.s. < 1 pg/g internal) proved!

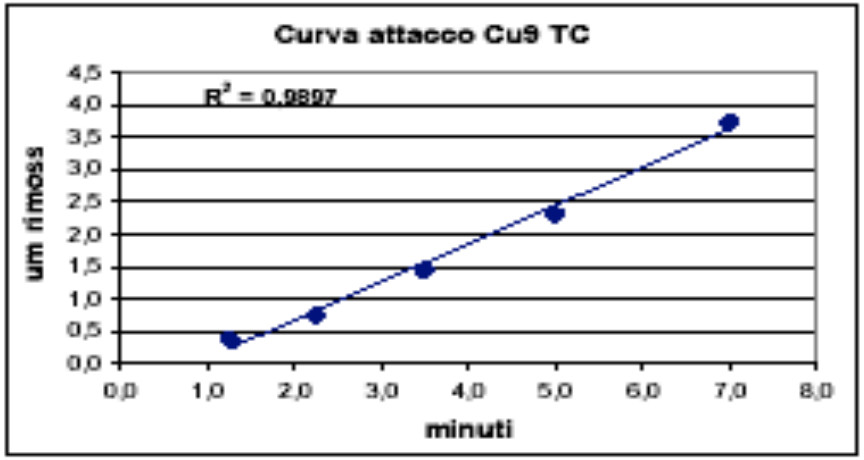
c. **α & β surface activity of crystals** (Monte Carlo ~ 0.1 ng/g v.s. < .1 pg/g internal)

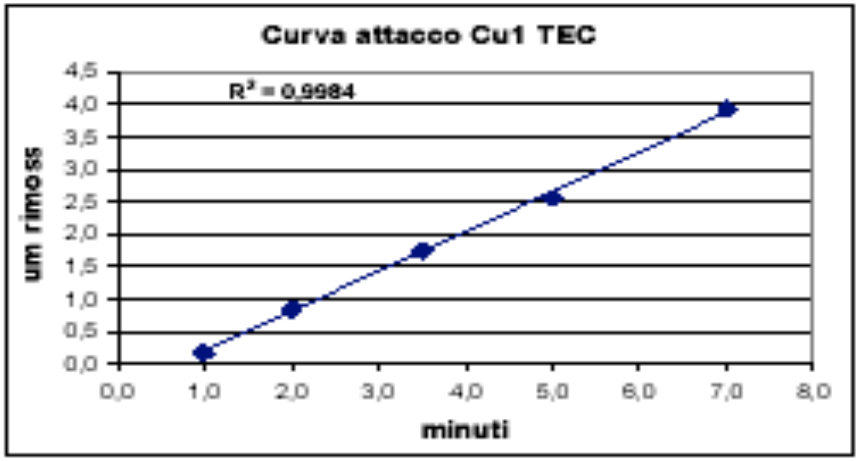
Corrosion rate of copper in HNO_3

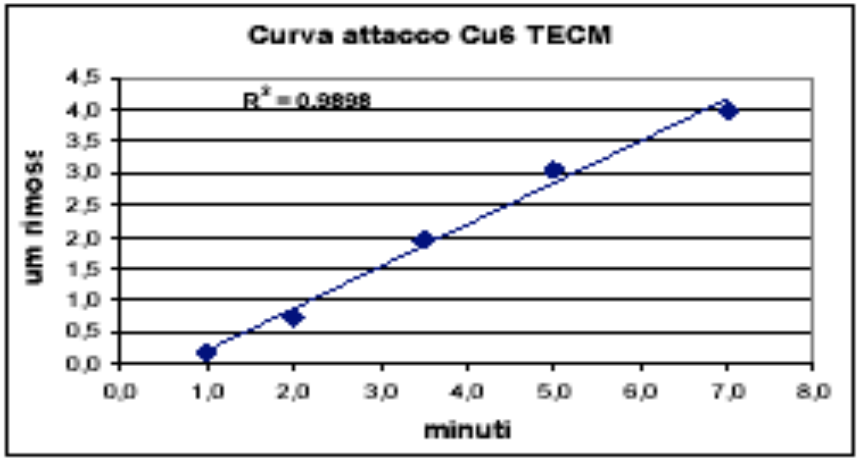
2,5 % HNO3 at 45°C

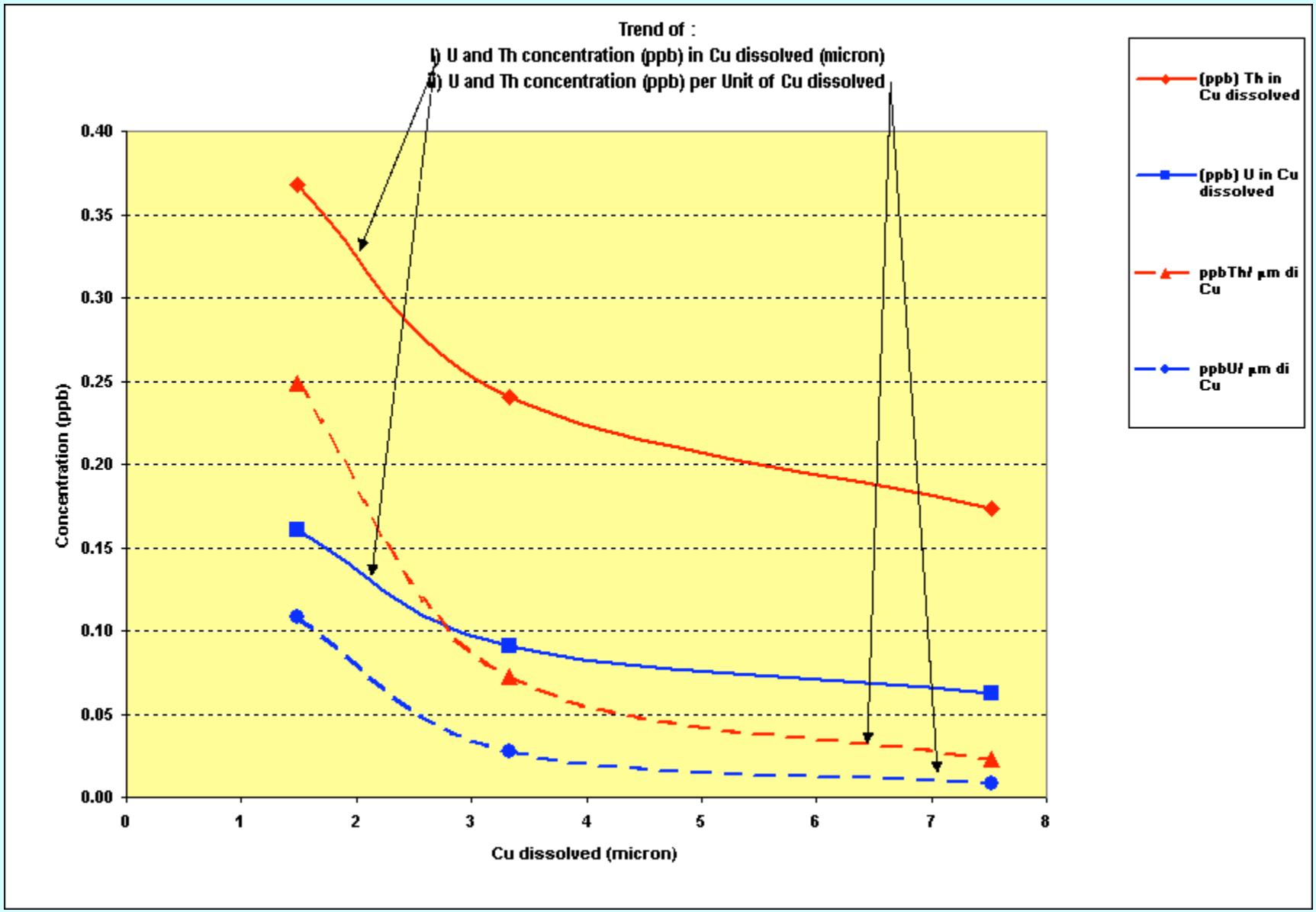
Second batch





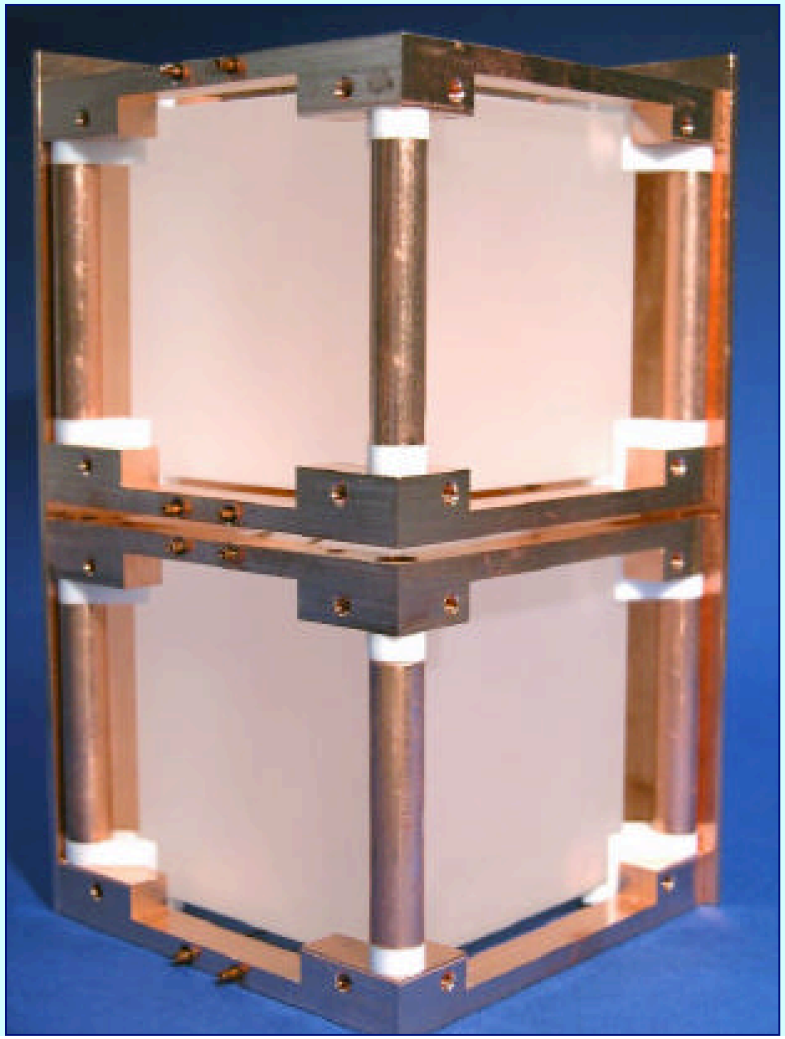


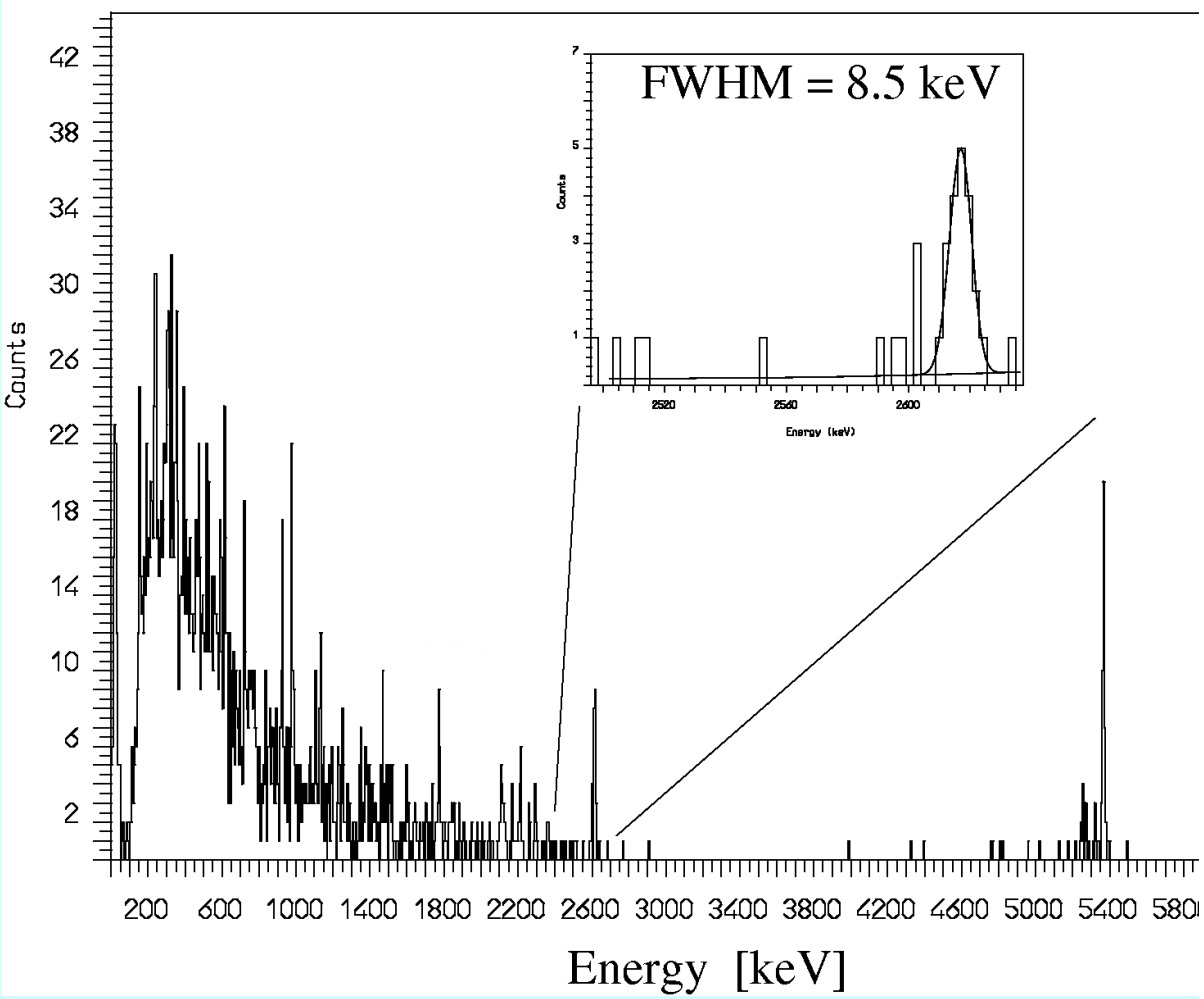



Trend of :
i) U and Th concentration (ppb) in Cu dissolved (micron)
ii) U and Th concentration (ppb) per Unit of Cu dissolved
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (ppb)
0
1
2
3
4
5
6
7
8
Cu dissolved (micron)
(ppb) Th in Cu dissolved
(ppb) U in Cu dissolved
ppbTh/ µm di Cu
ppbU/ µm di Cu

Larger crystals (6x6x6 cm^3 => 1.3 kg)

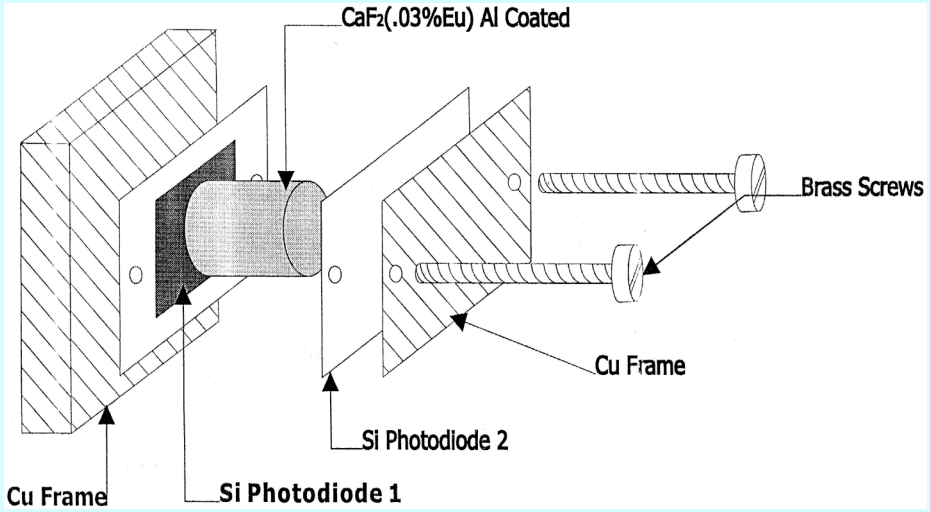
Reasonably good , but fragile

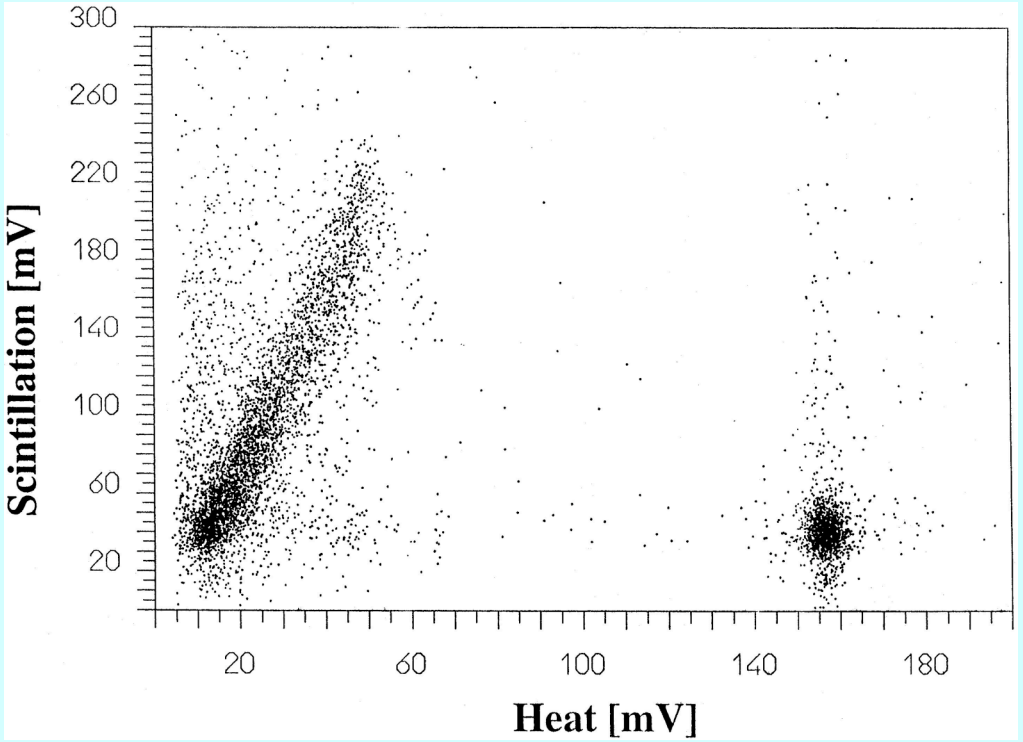


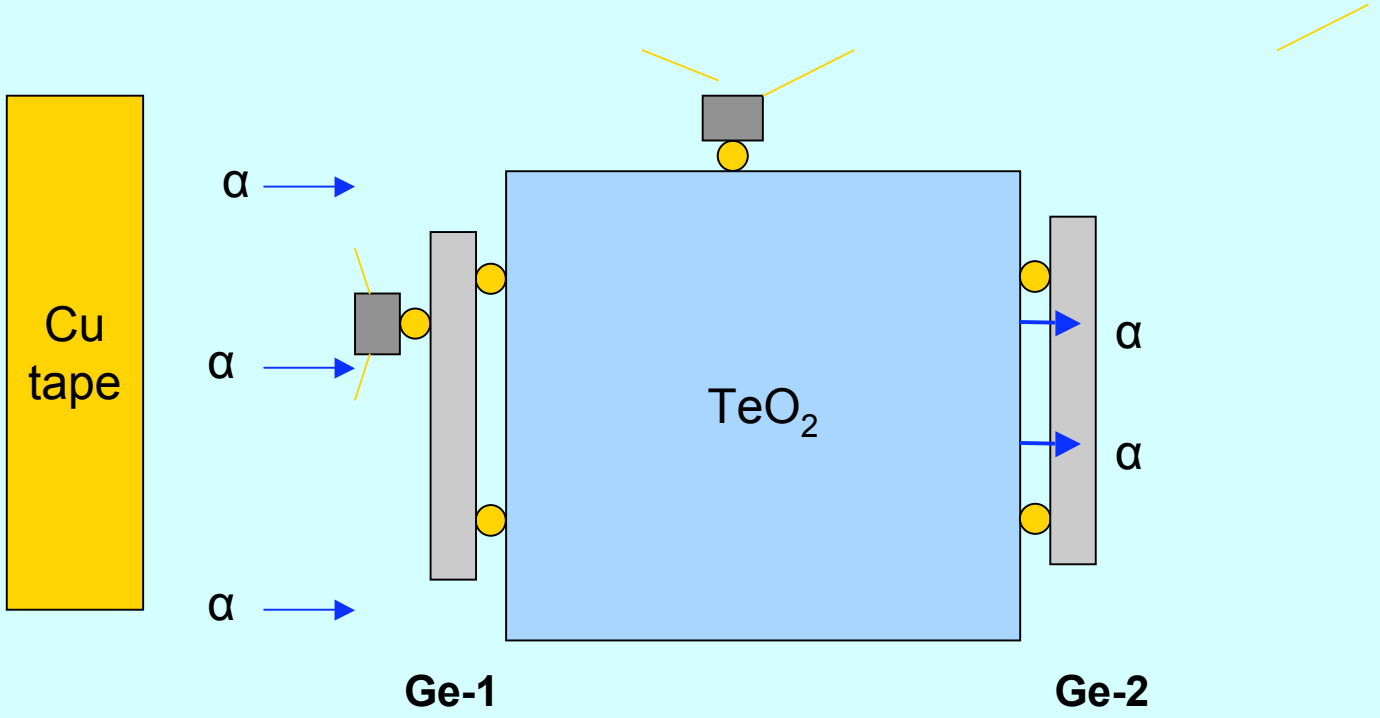


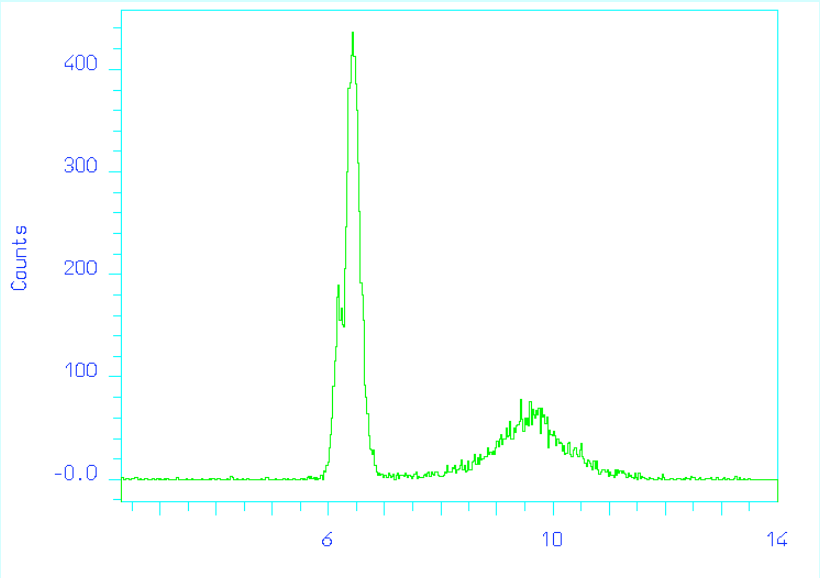
Active reduction of surface activity

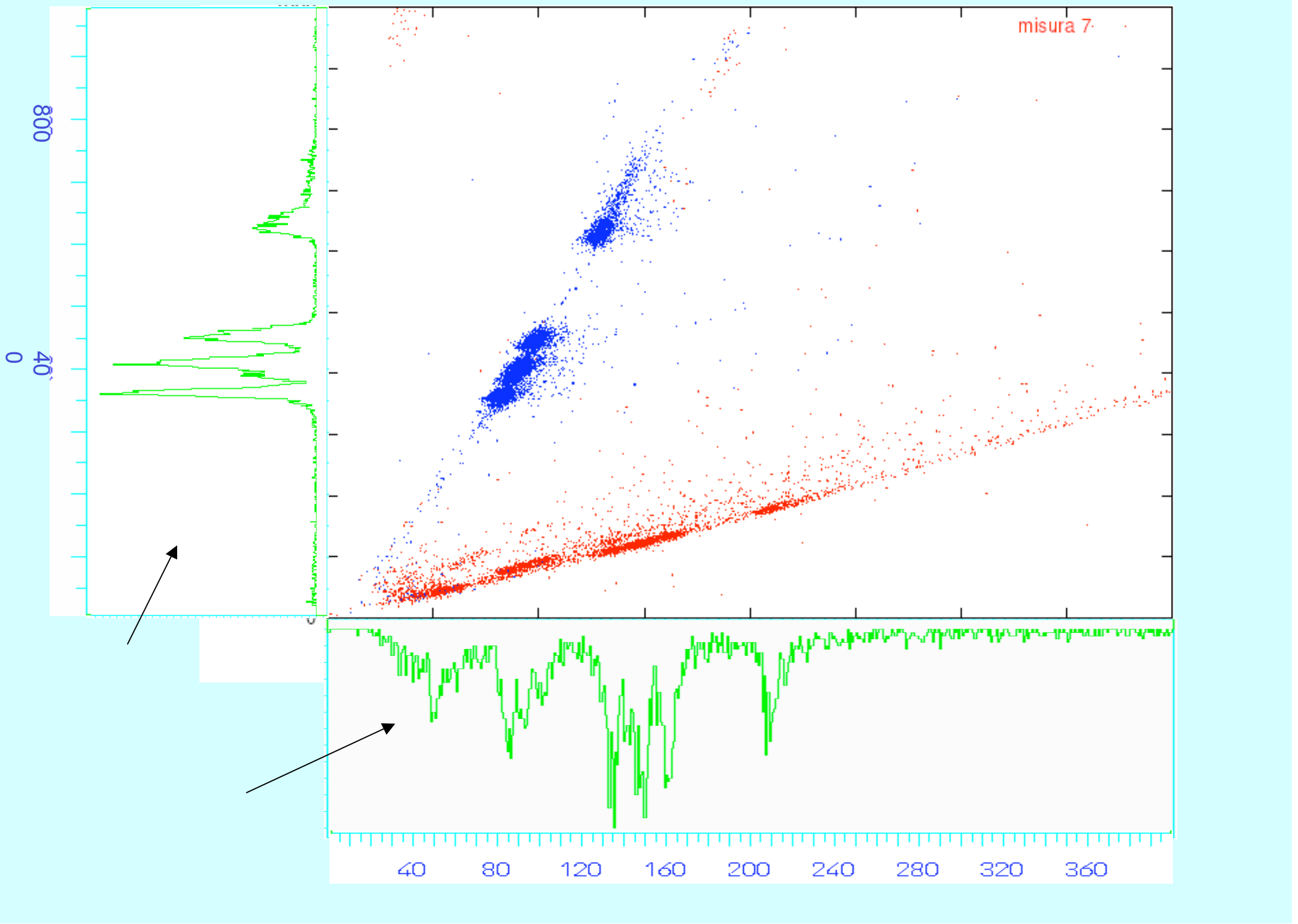
The scintillating bolometer
Proved for CaF_2 being studied for TeO_2






Cu
tape
α
α
α
TeO2
α
α
Ge-1
Ge-2


400
300
200
100
-0.0
Counts
6
10
14


misura 7
800
40
0
40
80
120
160
200
240
280
320
360

Start date: 1st July 2004	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5		US	INFN
Crystals	US								
Material Selection									
Procedure setting									
Growth and preparation									
	25	100	1400	2800			4325	4325	
Thermistors	US								
R&D and Ge irradiation									
Decay period									
Production									
	50	50	250	250			600	600	
Detector structure	INFN								
Design									
Material Selection									
Production									
	50	120	200	150	150		670		670
Cleaning									
	25	125	300	125	125		700		700
Cryostat & cryogenics	INFN								
Design and material selection									
Construction									
Installation and test									
	10	1000		100			1110		1110
Shieldings	INFN								
Design and material selection									
Construction									
		100		250	250		600		600
Underground Laboratory	INFN								
Design									
Installation									
	25	25	500	300			850		850
Electronics	US								
Design and test									
Production									
Installation									
	20	40	200	240		30	590	590	
Data Acquisition	INFN								
R&D and prototyping									
Final design									
DAQ SW development									
Production									
Installation									
	5	20	80	150	150	120	525		525
CUORE assembly	INFN/US								
Installation				50	50	900	1000	500	500
On-site Staff	Double the cost of the equipment contribution								
Contingency (25% for US)	150	375	750	675	600	450	3000	1500	1500
							13870		
Total cost	360	1955	3740	5090	1325	1500	13970	7515	6455

Conclusions

- Thermal detectors are very flexible, and allow to study different nuclei

Compound	Isotopic abundance	Transition energy
$^{48}CaF_2$	.0187 %	4272 keV
^{76}Ge	7.44 "	2038.7 "
$^{100}MoPbO_4$	9.63 "	3034 "
$^{116}CdWO_4$	7.49 "	2804 "
$^{130}TeO_2$	34 "	2528 "
$^{150}NdF_3$ $^{150}NdGaO_3$	5.64 "	3368 "

-^{130}Te has high transition energy and 34% isotopic abundance => enrichment non needed and/or very cheap. Any future extensions are possible

-Performance of CUORE, amply tested with CUORICINO

- CUORE has been approved and has already an underground location