CUORE (Cryogenic Underground Osservatory for Rare Events) and CUORICINO

E.Fiorini, Washington , July 13, 2004

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

U.S.contribution so far:

Berkeley Production and tests of the thermistors , nuclear physics, radioactivity

U.S.C. (since 30 years!) Study of ββ decay, background evaluation and reduction, D.M. (Wimps and axions) searches, operation underground etc.

The collaboration

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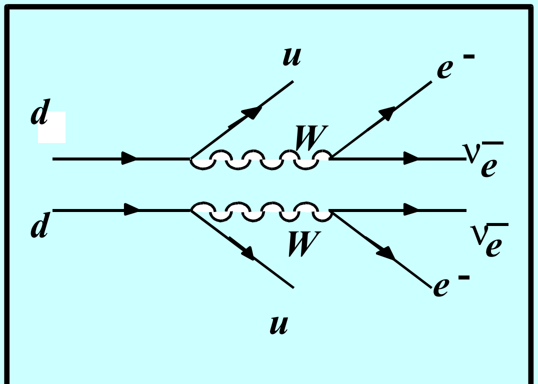
* To be confirmed

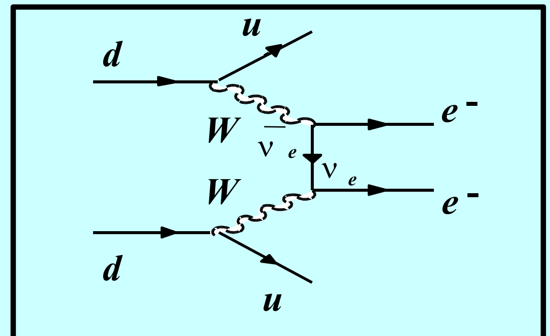
$(A,Z) \Rightarrow (A,Z+2) + 2\,e^- + 2\,\bar{\nu}_e$

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

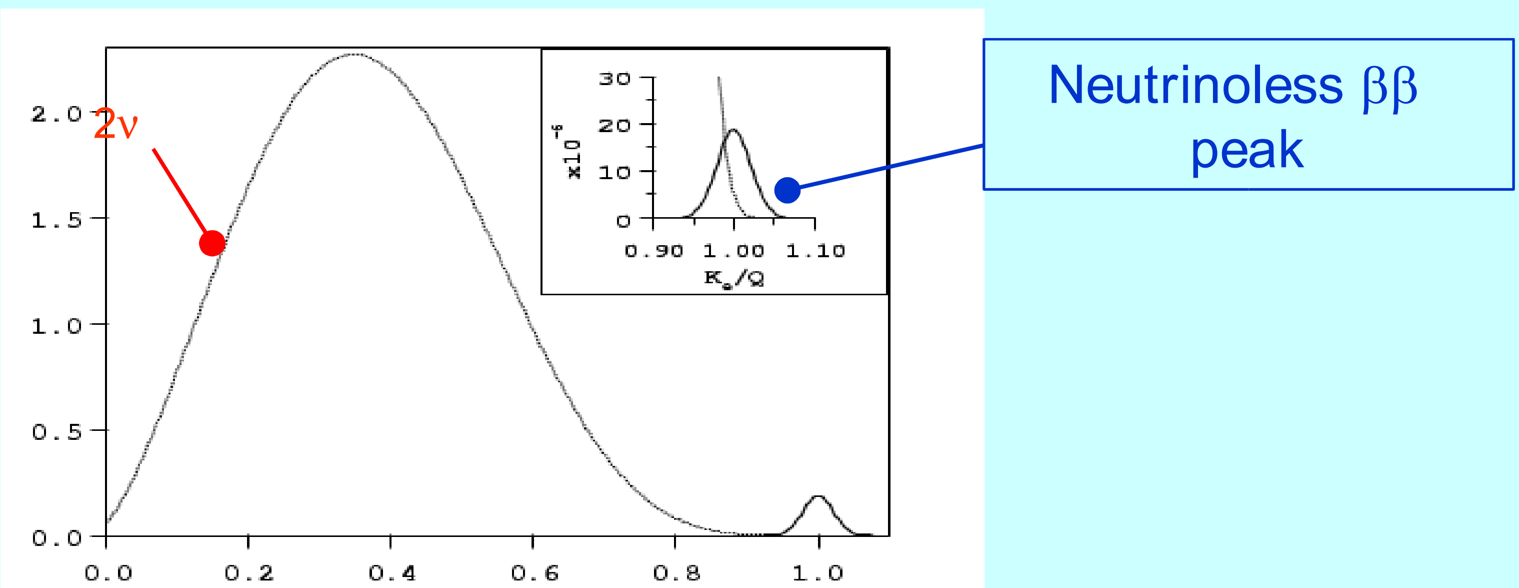
$(A,Z) \Rightarrow (A,Z+2) + 2\,e^-$



2ν - ββ decay



0ν - ββ decay

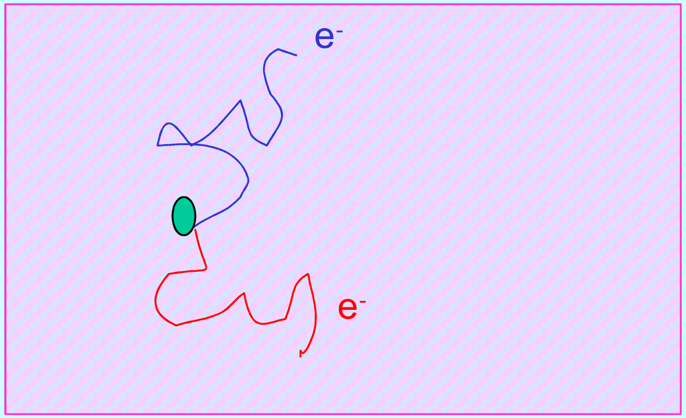


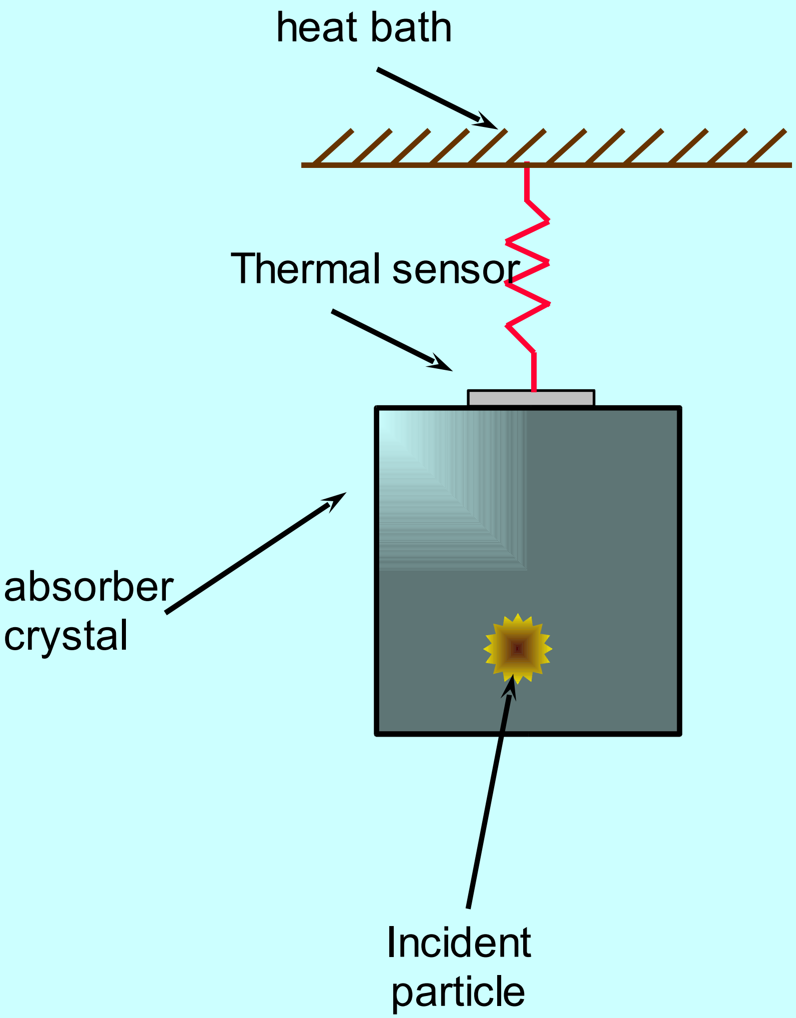
sum electron energy / Q

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

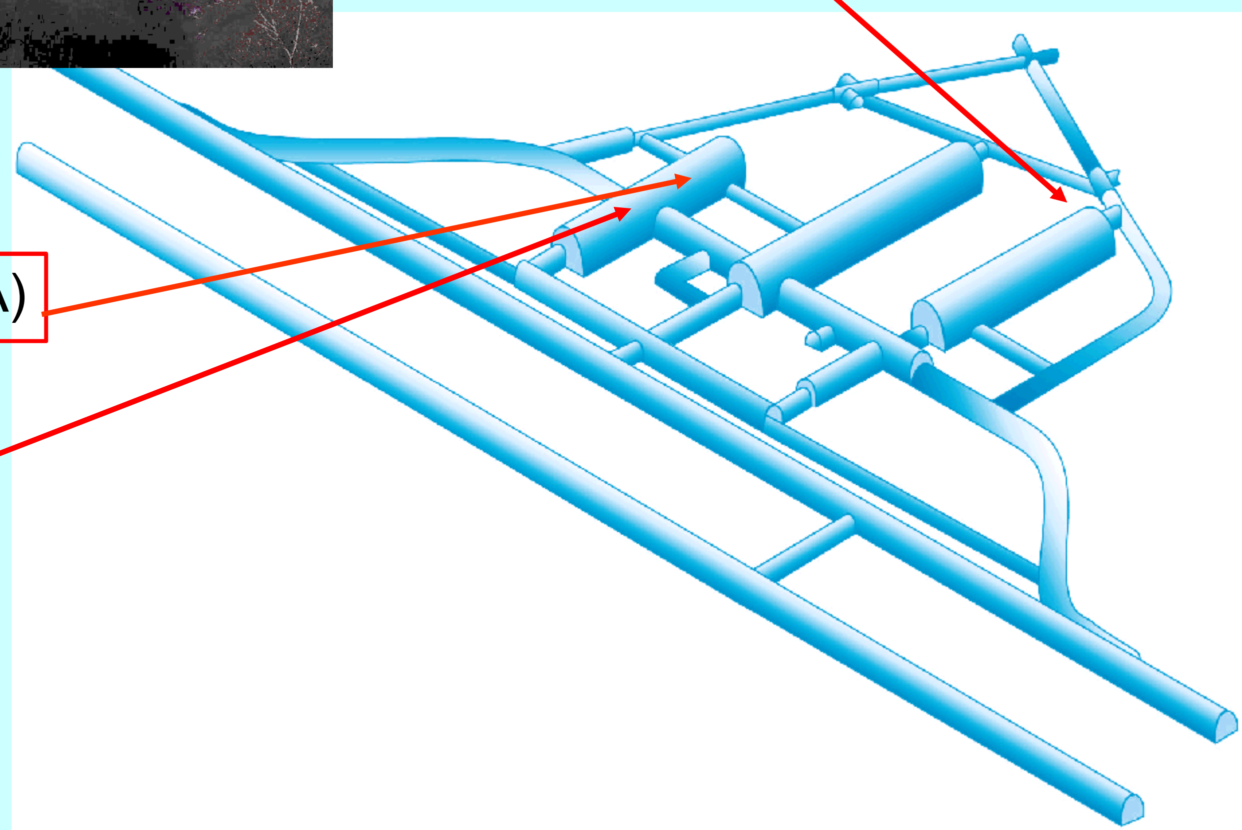
Excellent resolution <1 eV ~ 4 eV @ 6 keV

~10 eV ~keV @ 2 MeV

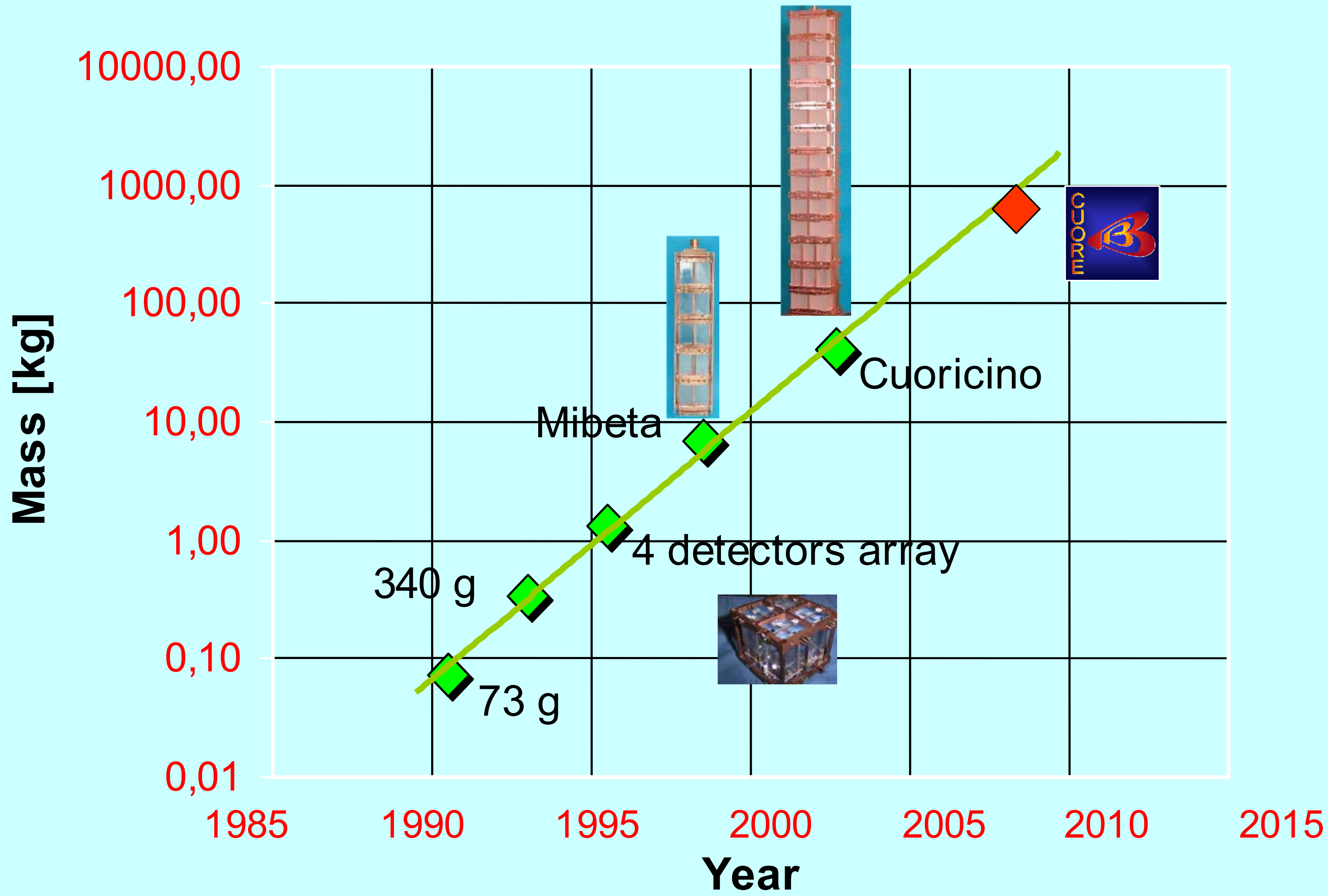
Present choice of ^{130}Te due to

- 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) × 10^{21} y) → $m_{ee} \approx 0.1$ eV $\Leftrightarrow T_{1/2} \approx 10^{26}$ y

CUORE @ LNGS



Increase of the detector mass



Resolution of the 5x5x5 cm³ (~ 760 g) crystals

:

0.8 keV FWHM @ 46 keV

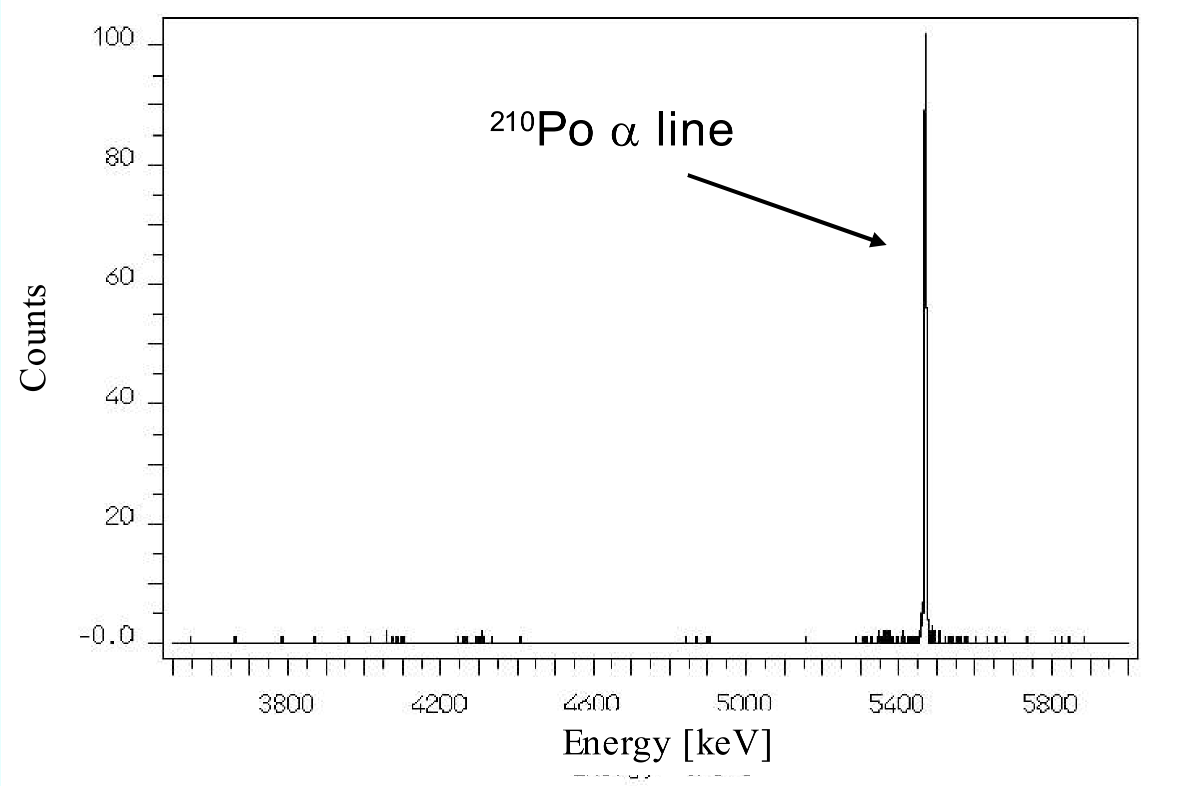
1.4 keV FWHM @ 0.351 MeV

2.1 keV FWHM @ 0.911 MeV

2.6 keV FWHM @ 2.615 MeV

3.2 keV FWHM @ 5.407 MeV

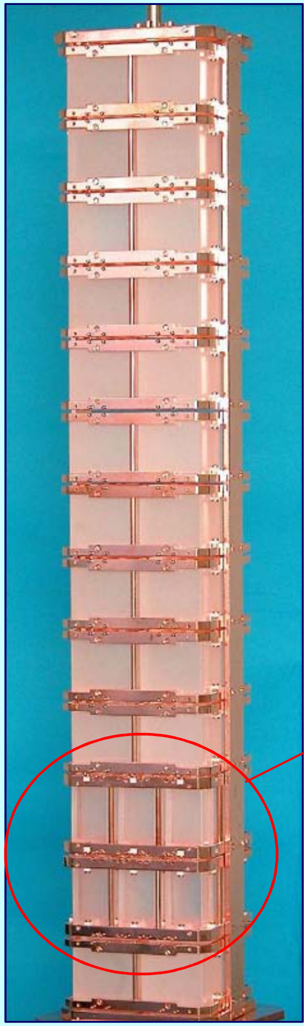
(the best α spectrometer ever realized)



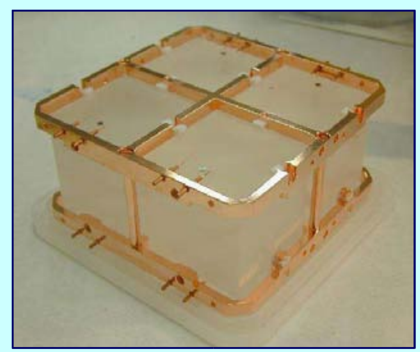
CUORICINO

- ✓ 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**

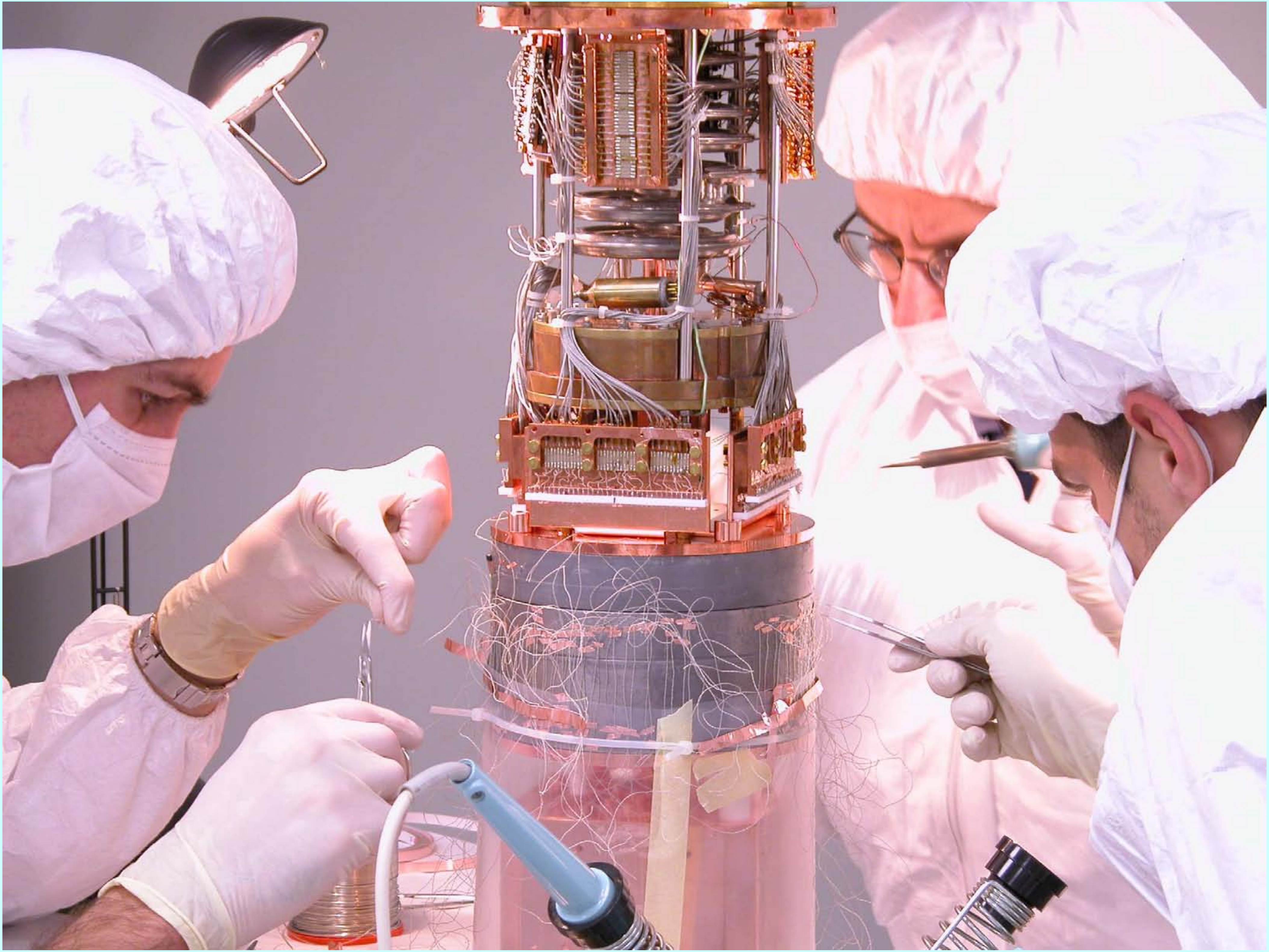
Klapdor 0.1 – 0.9



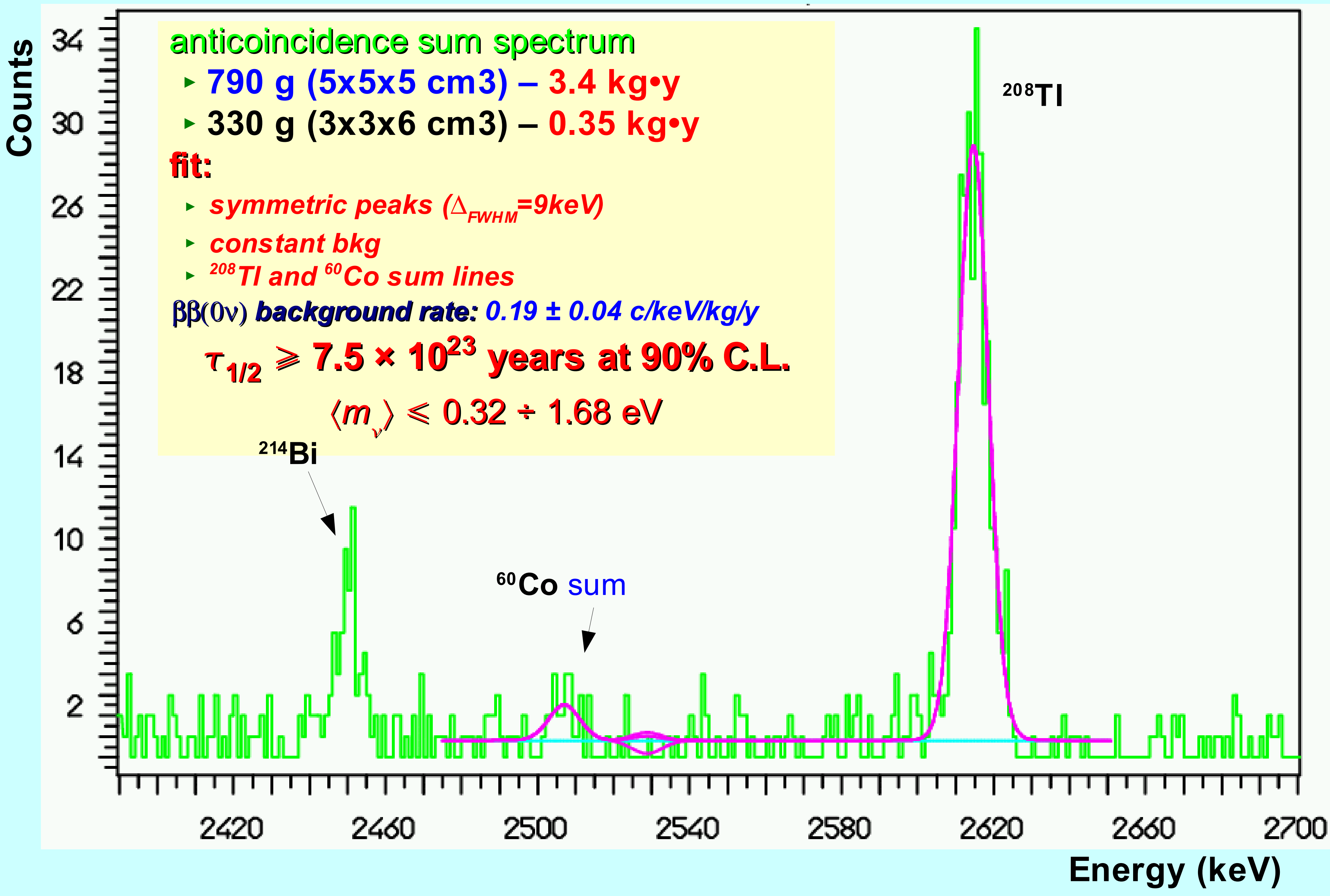
2 modules, 9 detector each,
crystal dimension 3x3x6 cm^3
crystal mass 330 g
9 x 2 x 0.33 = 5.94 kg of TeO_2



11 modules, 4 detector each,
crystal dimension 5x5x5 cm^3
crystal mass 790 g
4 x 11 x 0.79 = 34.76 kg of TeO_2

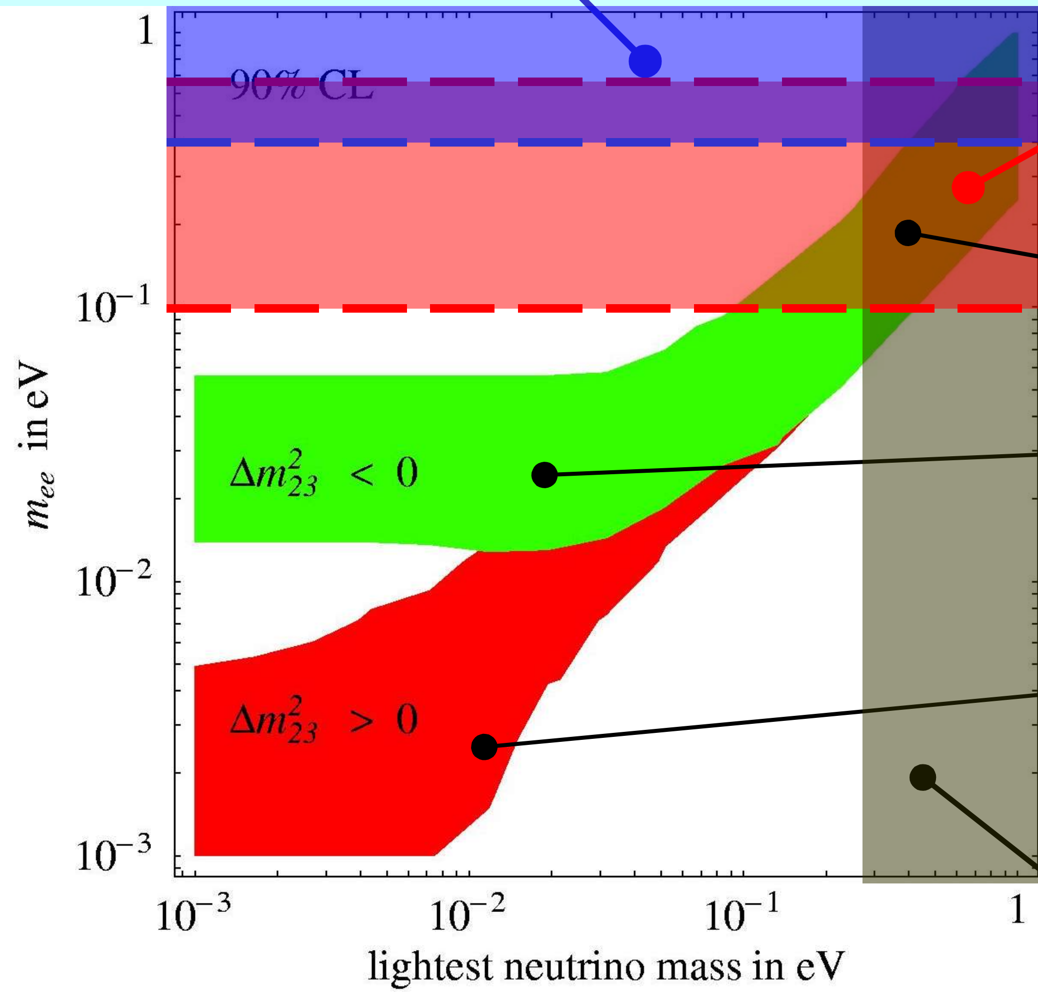


CUORICINO I: Natural TeO_2 crystals background spectrum



Present Cuoricino region

Possible evidence (best value 0.39 eV)



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

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

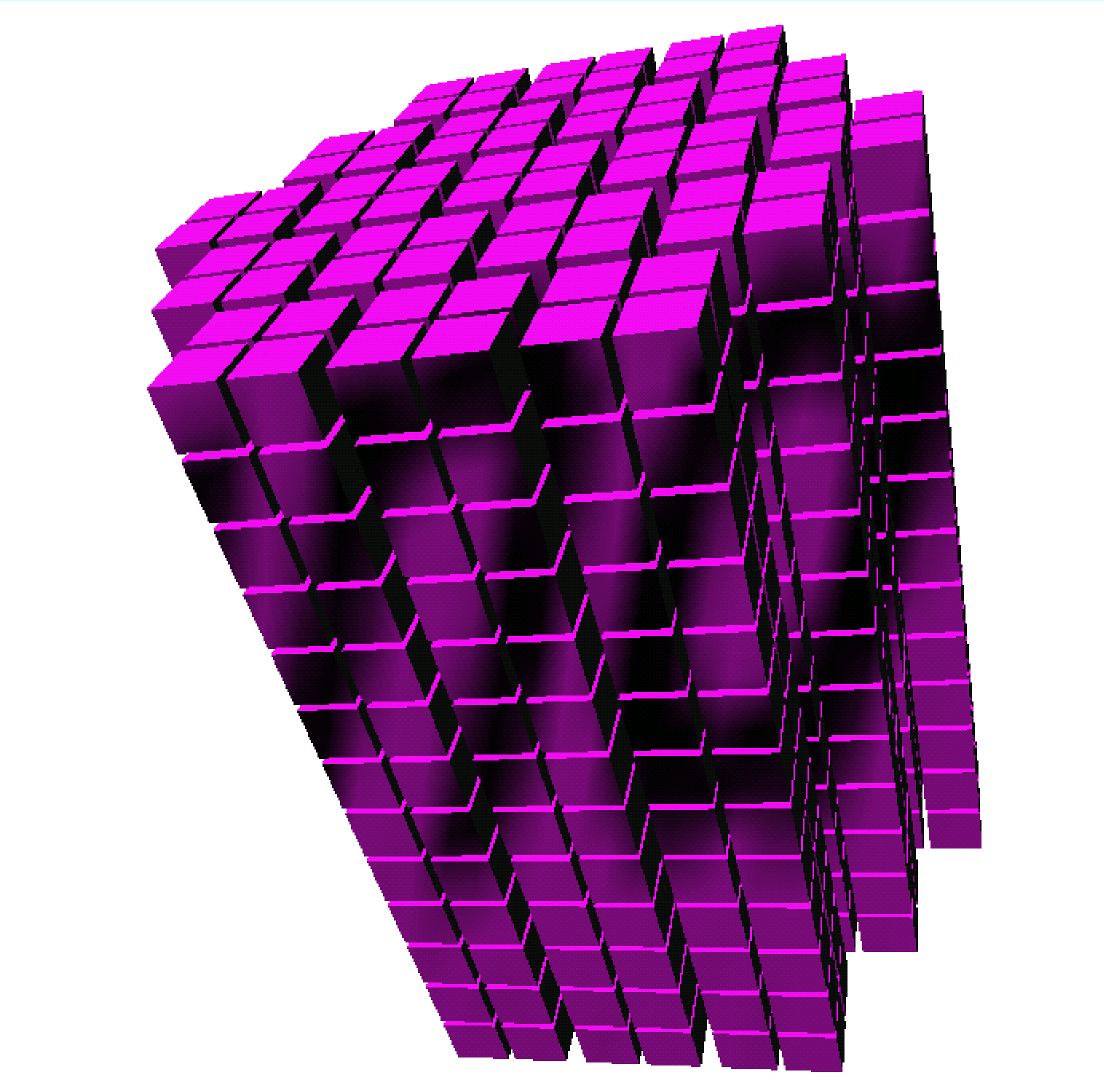
Inverse hierarchy
$\Delta m^2_{12} = \Delta m^2_{atm}$

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

Cosmological disfavoured region (WMAP)

The CUORE project

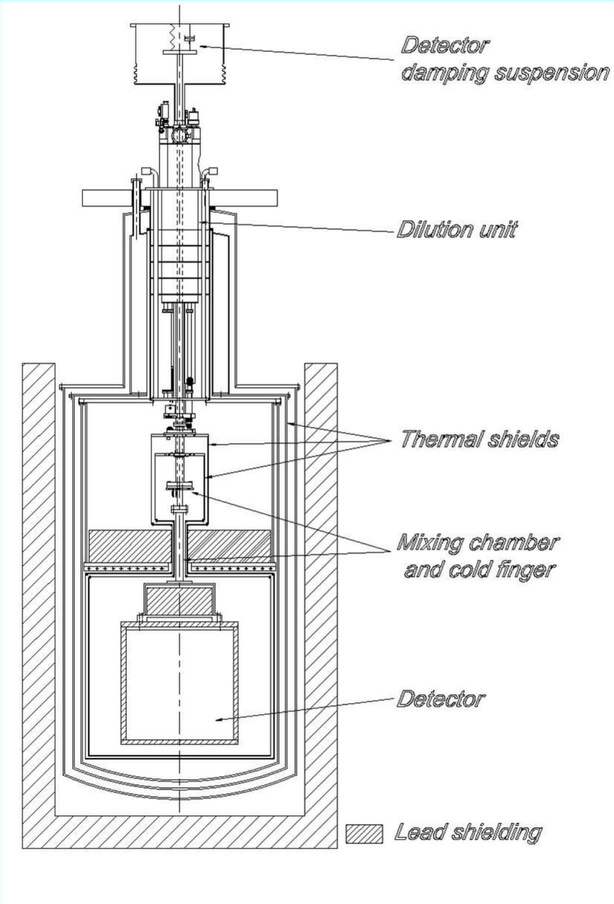
CUORE is an array of 988 bolometers grouped in 19 colums with 13 flours of 4 crystals



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

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

CUORE set-up design



External shield

Roman Pb (< 4 mBq/kg ^{210}Pb)

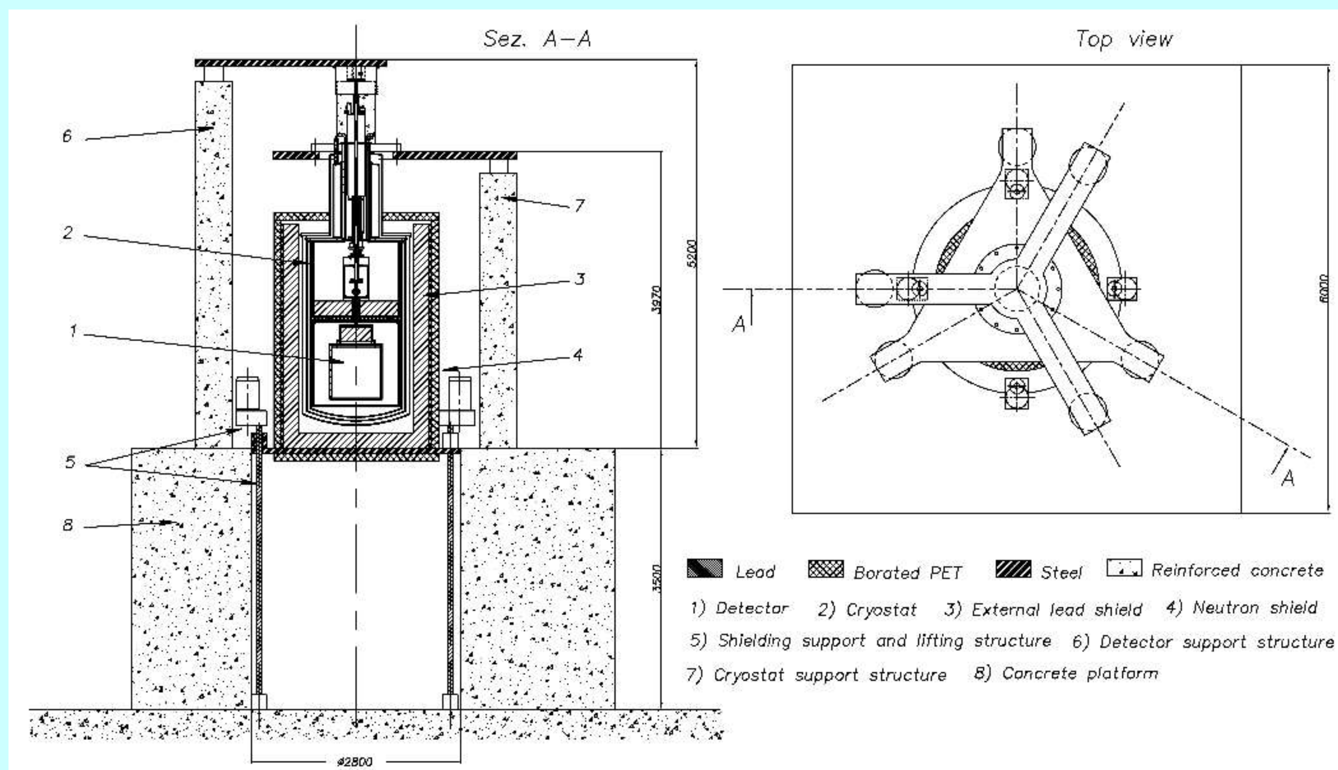
Modern Pb (~16 Bq/kg ^{210}Pb)

Common Modern Pb (~160 Bq/kg^{210}Pb)

External shield in B-PET

Anti-Rn box with flux of N_2

The detector is suspended in an INDEPENDENT way from the cryostat



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)**

b = 0.001 - Γ = 5 keV $F^{0\nu} = 3 \times 10^{26} \times (T[y])^{1/2}$ **| < m > | (0.016- 0.09 eV in 5 y)**

CUORE Background in the neutrinoless ββ region

Monte Carlo results , supported by CUORICINO

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

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

η. **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)

Conclusions

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

Compound	Isotopic abundance	Transition energy
$^{48}CaF_2$	.0187 %	4027 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

- CUORE could be ready before other major ββ experiments

- Performance of CUORE, amply tested with CUORICINO

- CUORE has been approved and has already an underground location