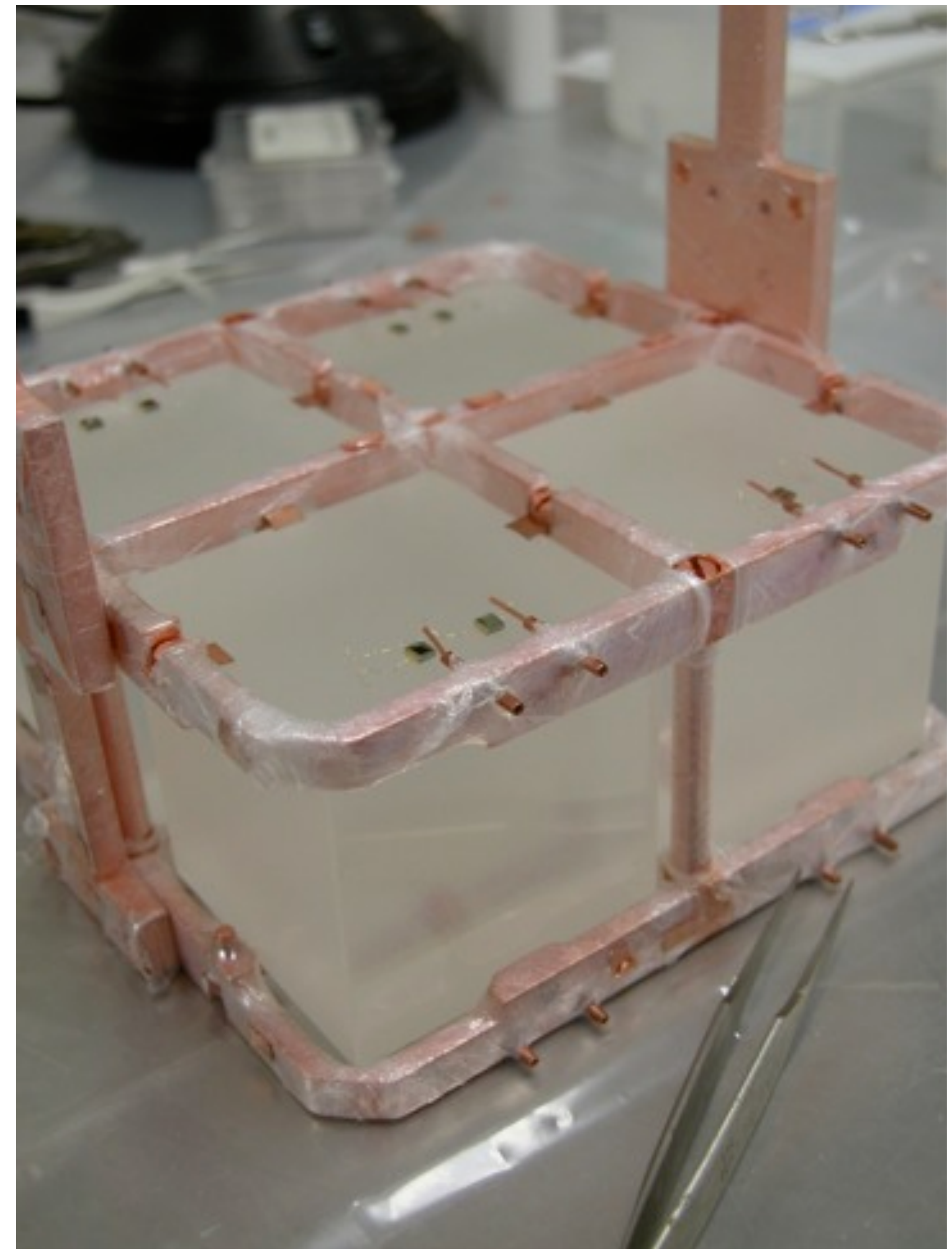
Macrobolometers for rare events physics: the 1000 crystals challenge and the fight for zero background



Paolo Gorla
INFN Roma Tor Vergata

Outline

- Macrobolometer: what is that and how does it work?
- Operation principles
- Rare events physic applications: advantages and disadvantages
- The 1000 detector challenge
- The fight against background and the zero background dream
- A scintillation approach for non scintillating macrobolometers.

Introducing Bolometers (I)

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3) How does it works?
The basic idea is to measure the energy deposited by a particle after it has been converted into heat with a T sensor.

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5) What is a Macrobolometer?
Bolometer with a mass in the 100 g -1 kg scale.

6) Which are the advantages?
Bolometers provide better energy resolution (~few per mil). Moreover a wide range of materials can be used for the absorber.

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8) When should I use a Macrobolometer?

Ideal applications in rare events particle physics in which the rate of events is very low but a very good energy resolution is needed.

Advantages of Bolometers over conventional devices for radiation spectroscopy

Bolometers are Phonon-Mediated particle detectors

Intrinsic Energy resolution

- ε: energy to produce an elementary excitation
- N = E/ε: number of elementary excitation
- $\Delta E = \varepsilon\ \Delta N = \varepsilon\ (N)^{1/2} = (\varepsilon E)^{1/2}$
  (RMS energy resolution due to Poisson fluctuations)

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ε:	100 eV	⇒	30 eV	⇒	3 eV	⇒	< 0.01 eV

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Moreover in a bolometer all the deposited energy is converted into phonons while in conventional devices the fraction of total energy that is converted in signal is small (30% in semiconductors, 15% scintillators,...)

Thermal and athermal phonons

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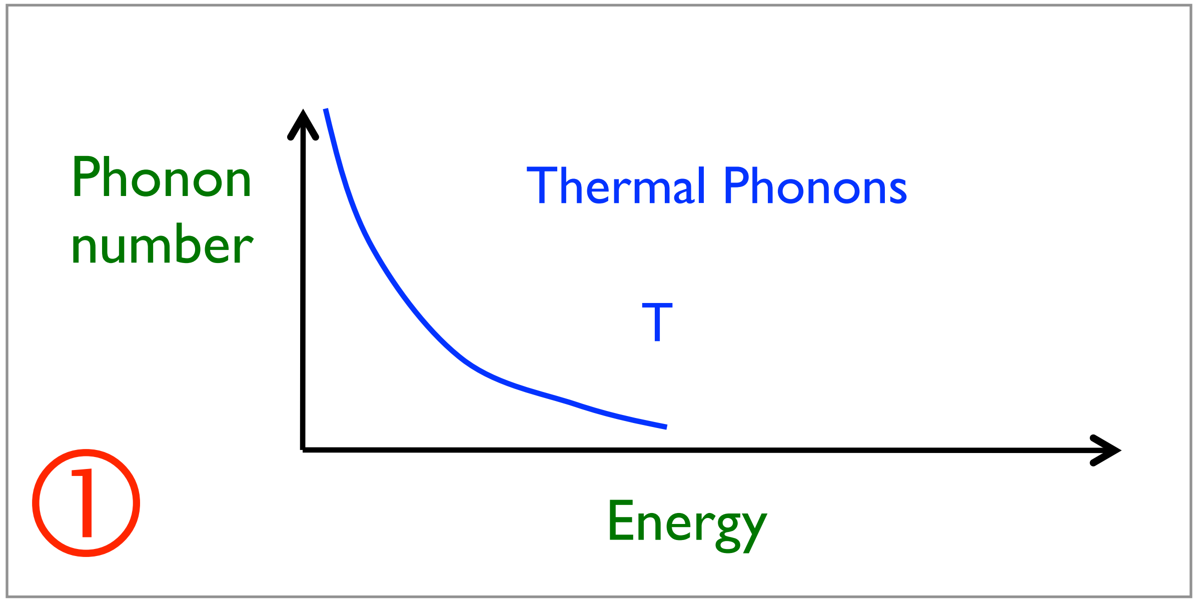
Before interaction



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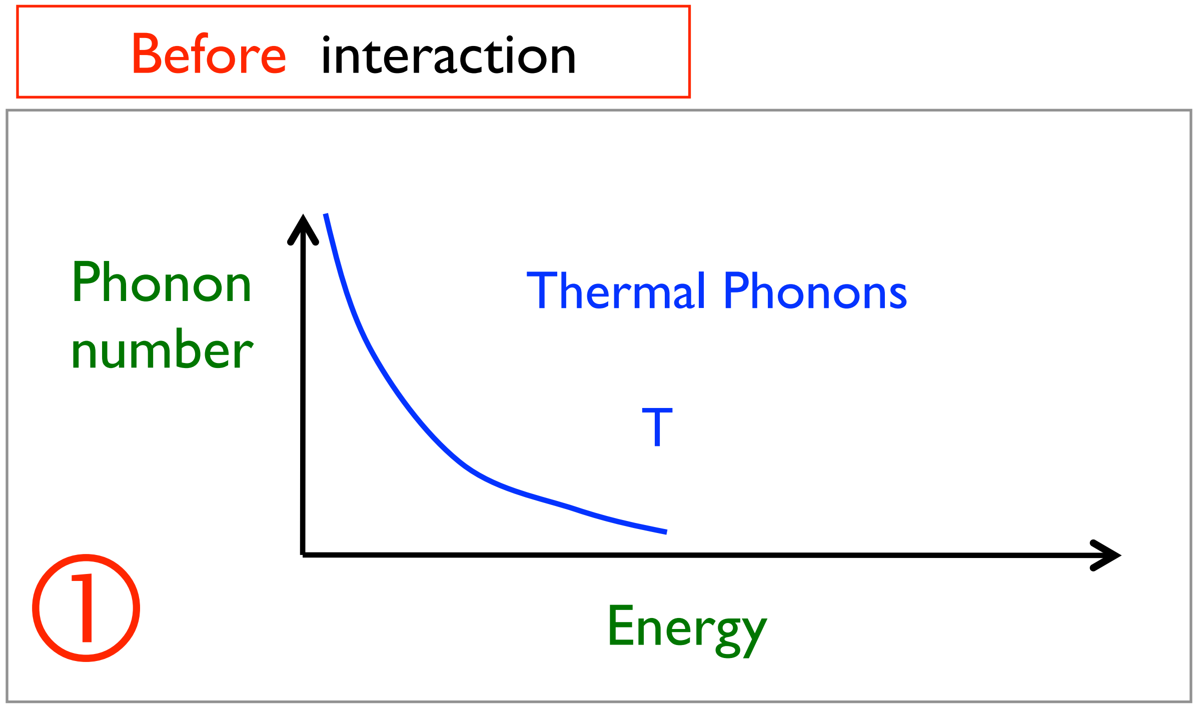

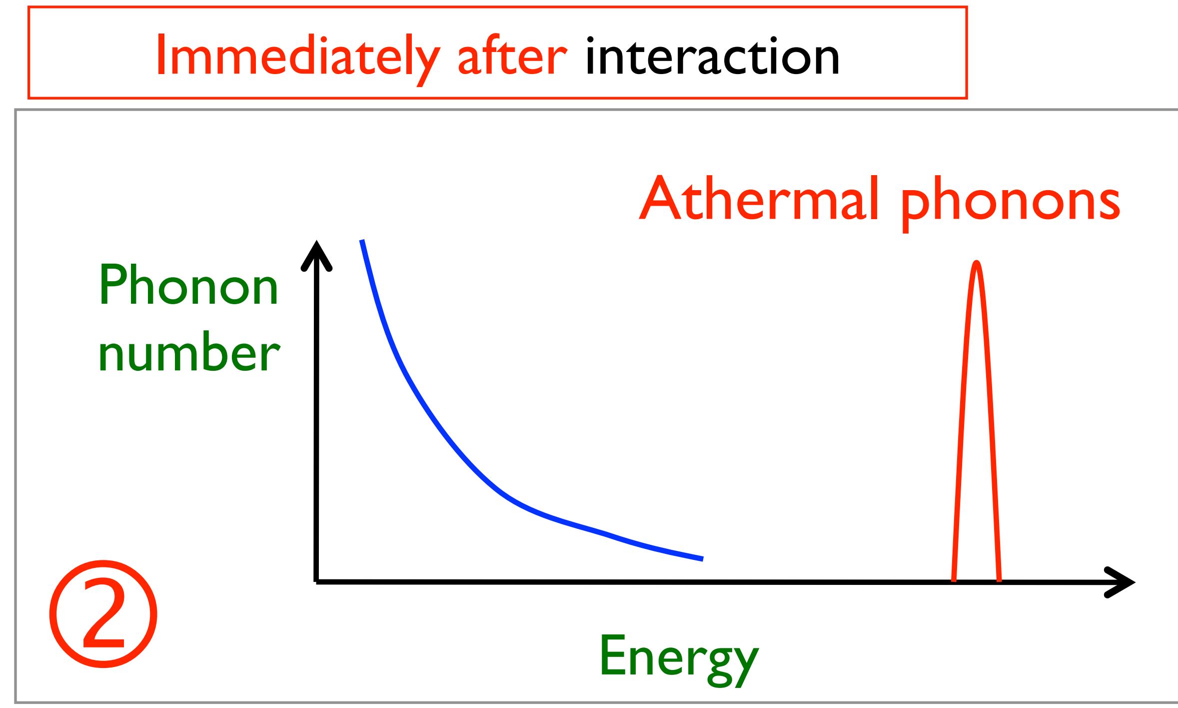

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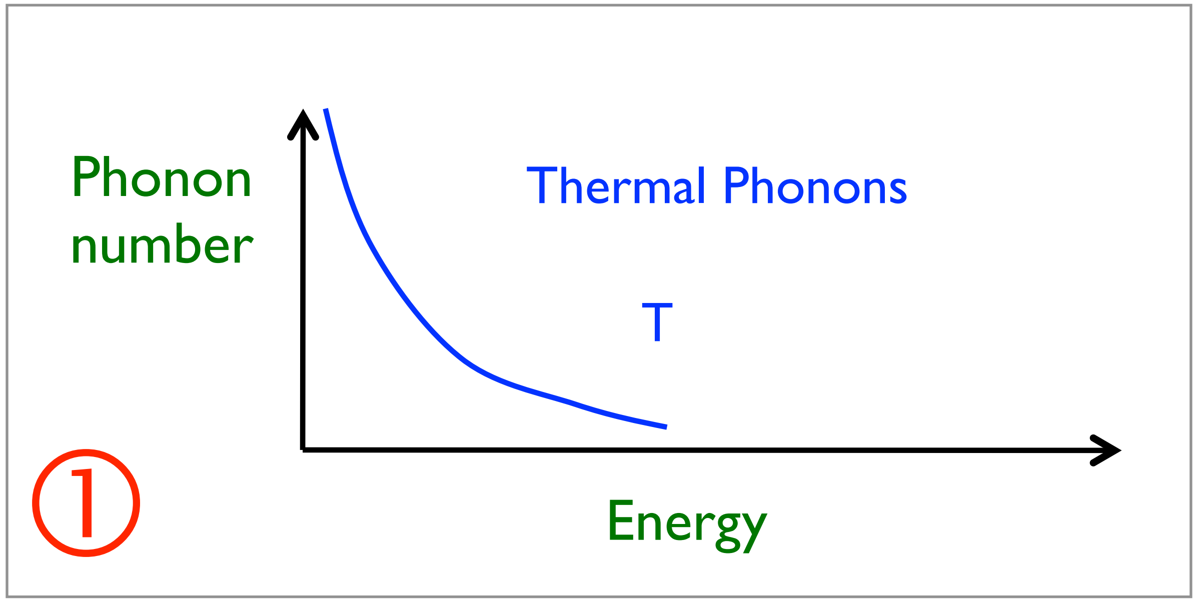
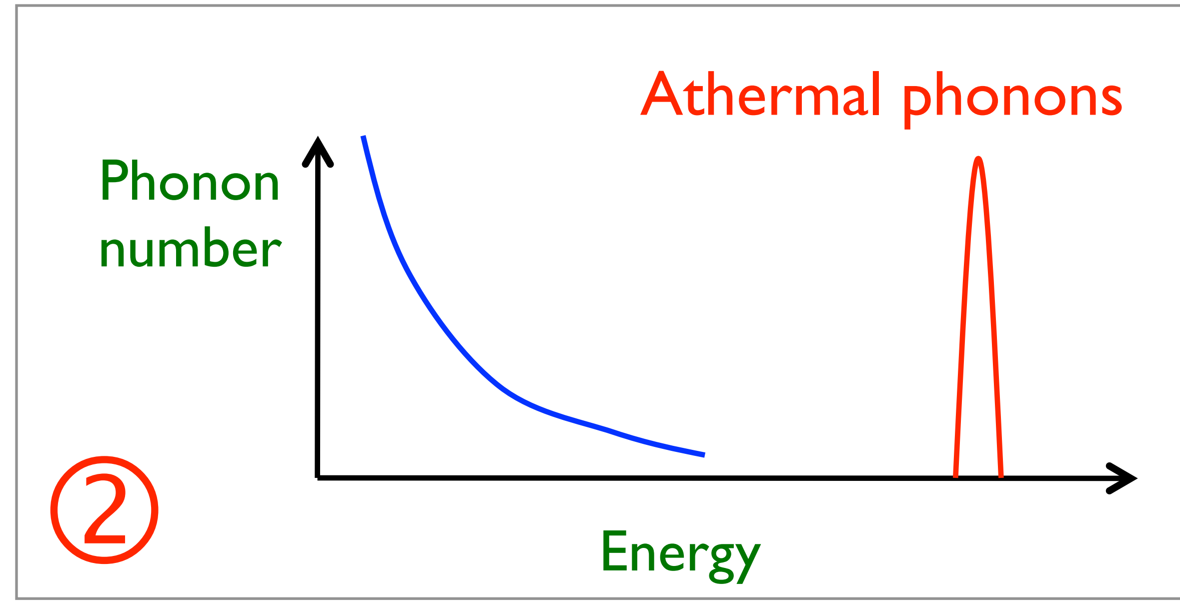
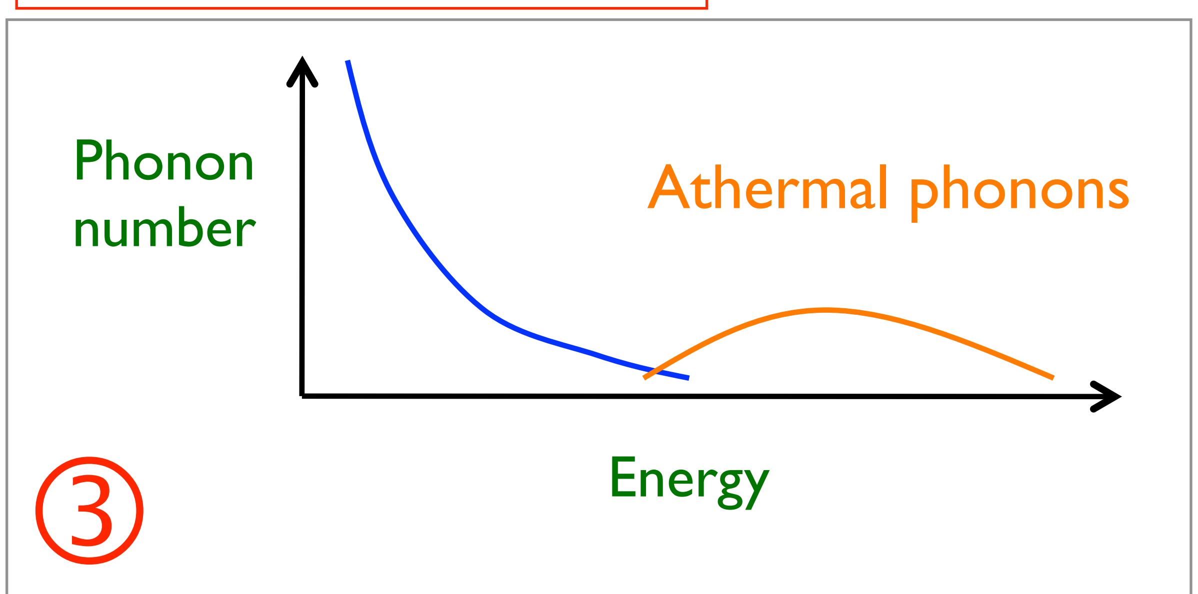


Immediately after interaction



Phonon energy degradation



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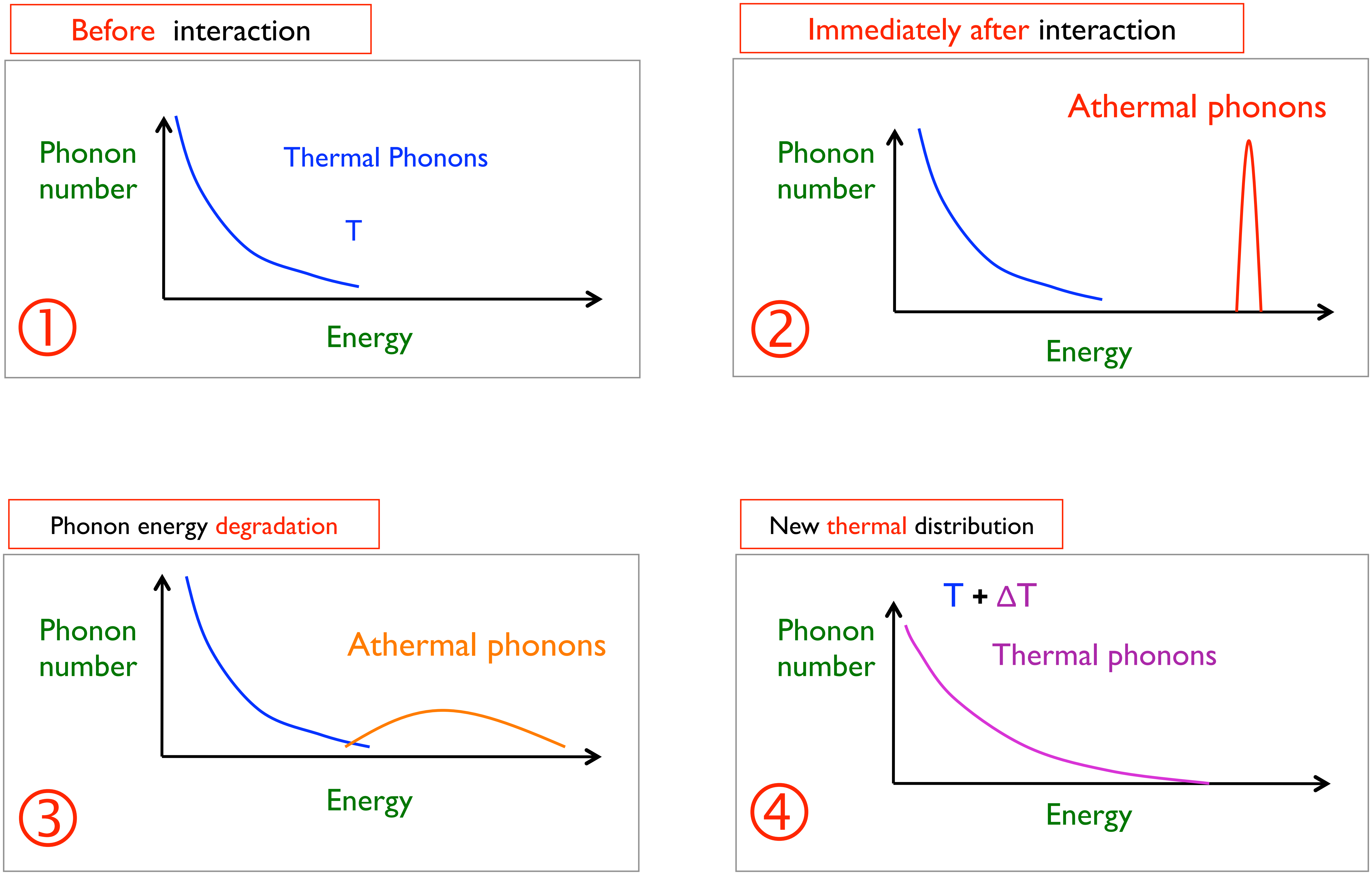

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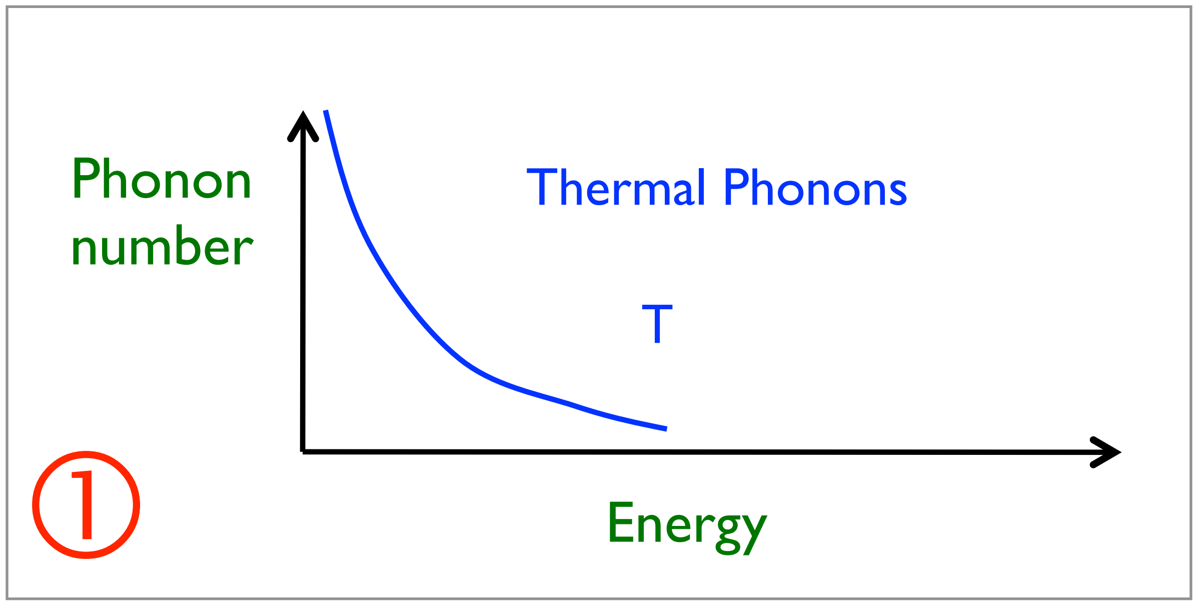

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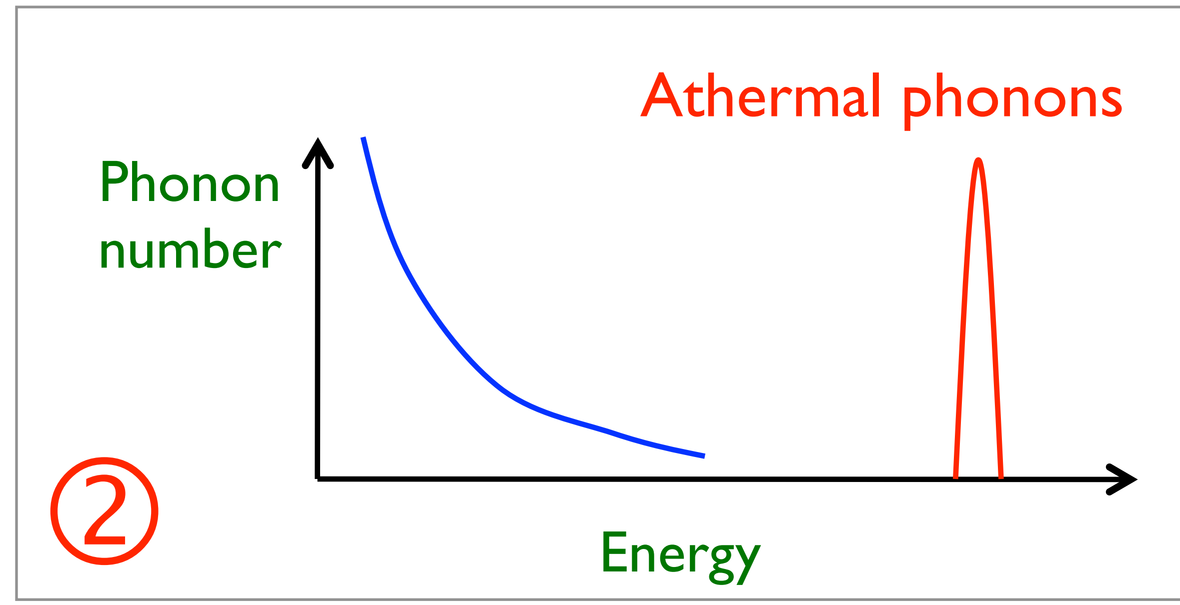
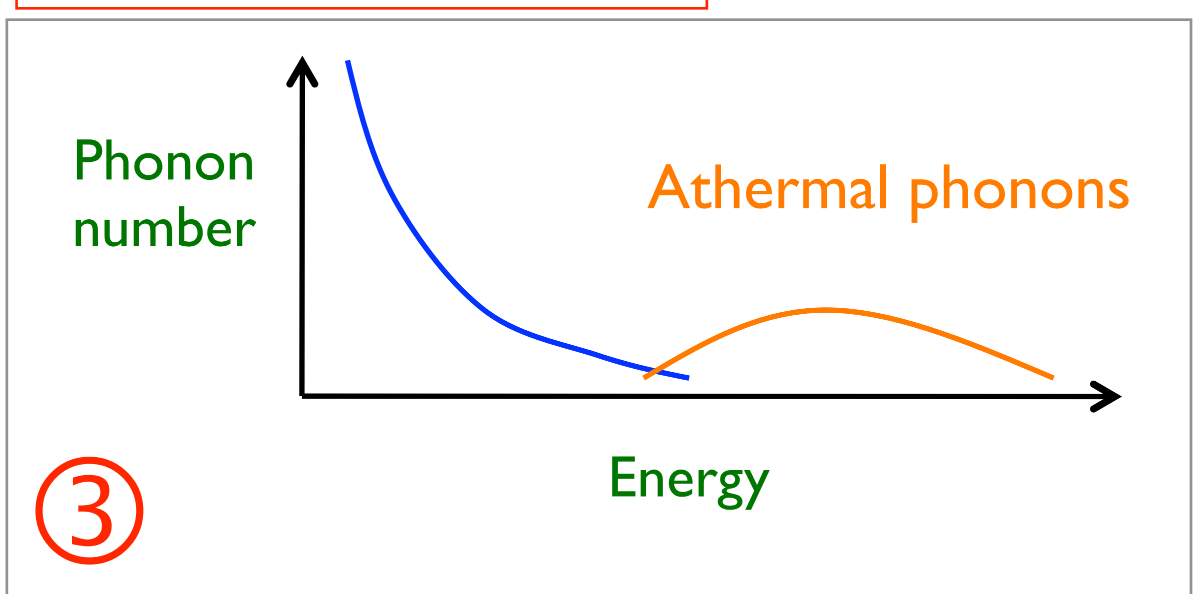
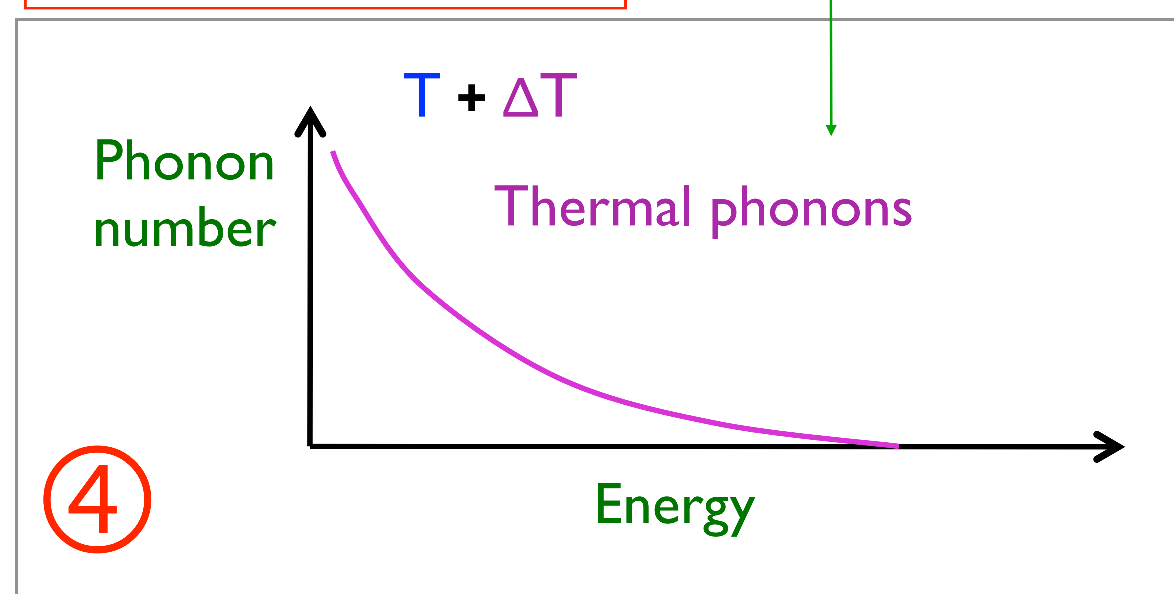


Detector operating here:
Perfect calorimeter
Energy

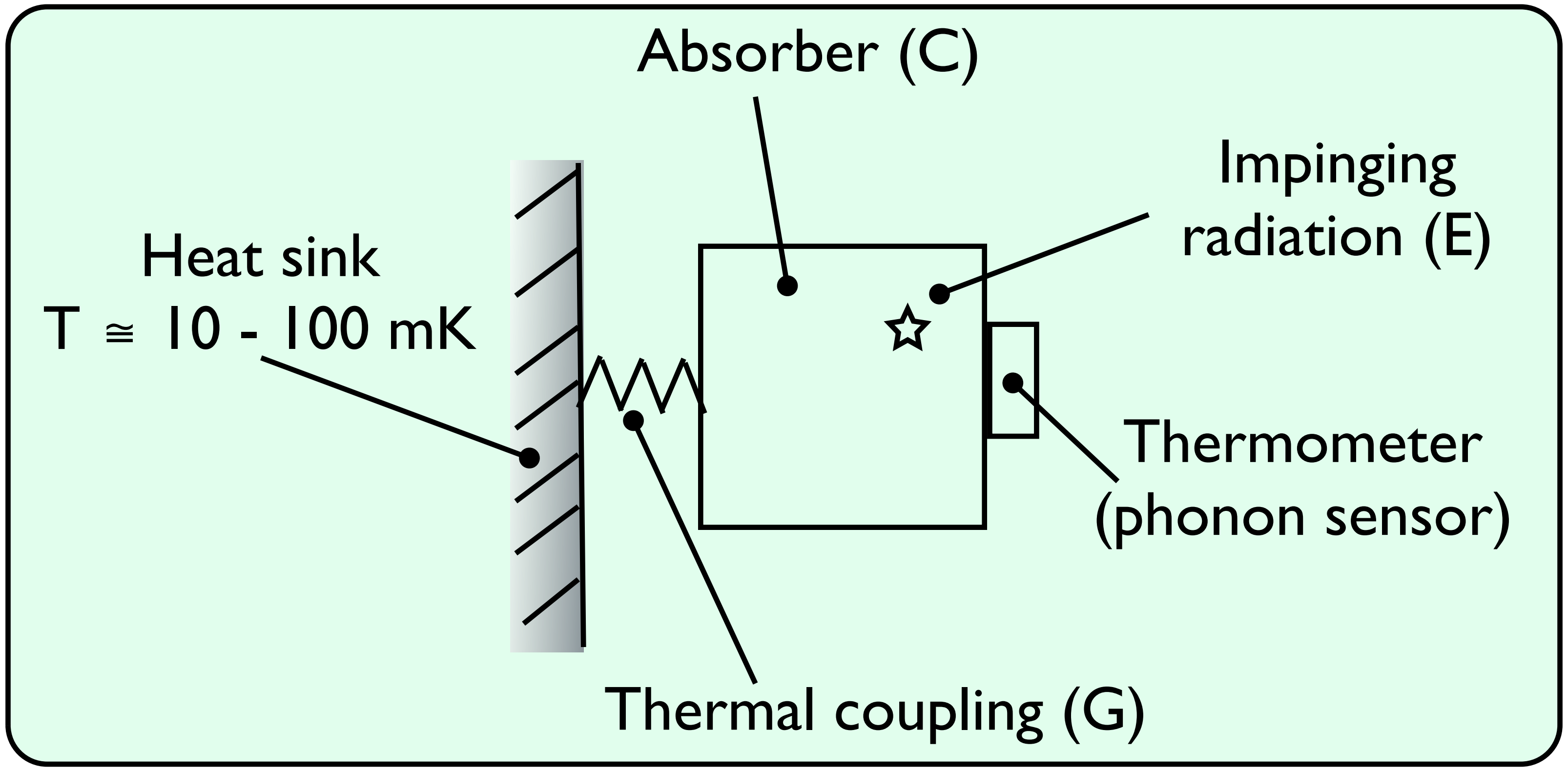
Phonon energy degradation



New thermal distribution



Perfect calorimeter



- The only relevant parameter for the energy absorber is the heat capacity C.
- The thermal conductance to the bath G enables the temperature recover.

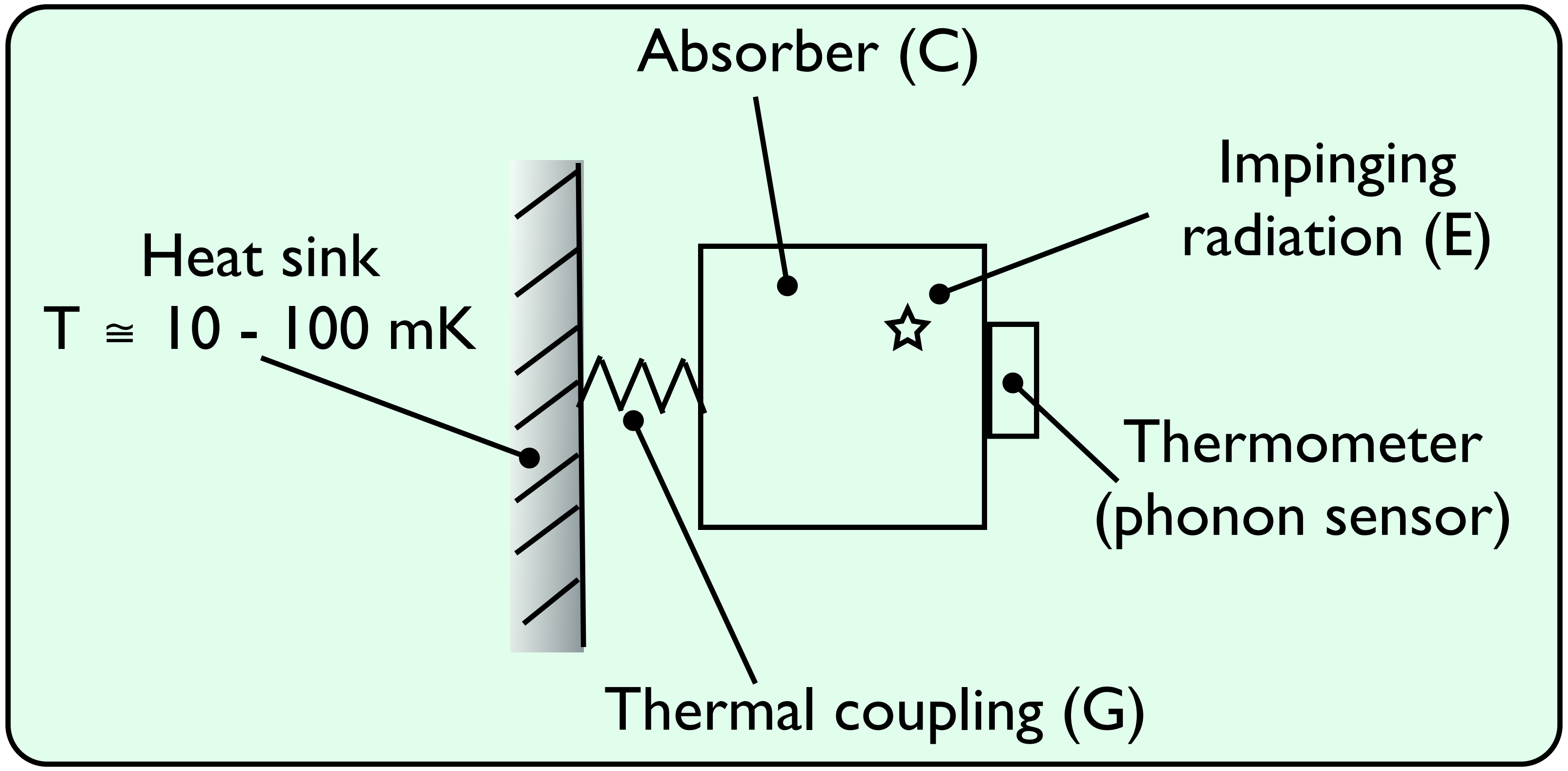
Signal amplitude

$$\Delta T = E/C$$

Relaxation time

$$\tau = C/G$$

Perfect calorimeter



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- Dielectric diamagnetic materials are preferred

$$C \propto (T/\Theta_D)^3 \text{ (Debye Law)}$$

Wide choice of materials!

Phonon sensor

A phonon sensor is a device that collects phonons and generates or modulates an electrical signal, proportional to the energy contained in the collected phonons. If the PMD is operated as a perfect calorimeter, the phonon sensor works as a thermometer.

In practical devices, there are two classes of phonon sensors extensively employed:

- Semiconductor Thermistors (ST)
- Transition Edge Sensors (TES)

There are in addition other devices that can be used as phonon/temperature sensors: Kinetic Inductance Detectors (KID), Superconductive Tunnel Junctions (STJ), Magnetic Micro-Calorimeters (MMC), ...

Semiconductor Thermistors (ST)

Doped semiconductors close to the Metal to Insulator Transition (MIT).
At low temperatures (< ~10 K), the resistivity is given by:

$$\rho(T) = \rho_0 \exp [(T_0/T)^{1/2}]$$

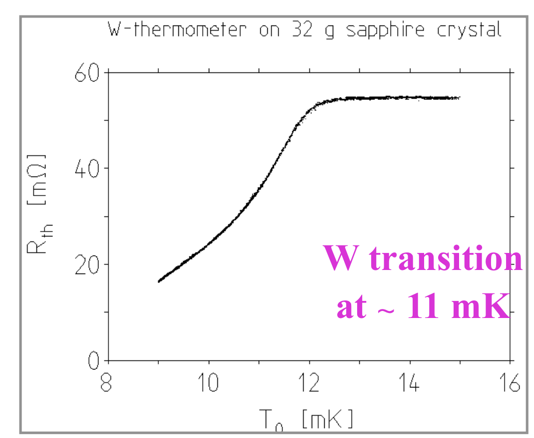
(Variable Range Hopping with Coulomb gap conduction regime)

T_0 depends on the doping level → it fixes ρ_0 and the sensitivity

① **Neutron Transmutation Doped** (NTD) **Ge** thermistors
② **Si-implanted** thermistors;

Transition Edge Sensors (TES)

TES is a superconductive film kept around T_C.
It exploits the steep temperature dependence of the resistance in these conditions



Low impedance thermistors ⇒ SQUID readout
Much higher S/N ratio with respect to ST

if we define the sensitivity as
$A \equiv |d \log R / d \log T|$

$A \cong 10$ for ST
$A \cong 1000$ for TES

Summary

Advantages:

- Very good energy resolution
- Wide choice of materials for the energy absorber
- Possibility of building big detectors (~kg scale)

Disadvantages:

- Very slow signal (50 msec - 2 sec)
- Need to work at low temperature
- No radiation identification (?)

Macrobolometers for rare events physics

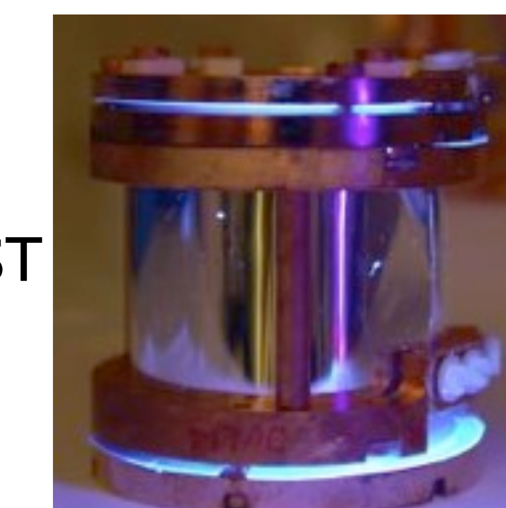
For many rare events physics applications, such as Neutrinoless Double Beta Decay (0νDBD), for which the slowness of the detector response is not a problem the very good energy resolutions guarantees the possibility of identifying the expected peak from the background.

CUORE

Moreover the possibility of choosing different isotopes for the absorber crystal is a good opportunity both for source=detector experiments (0νDBD, ...) and for source≠detector (Dark Matter search...)

CDMS

CRESST



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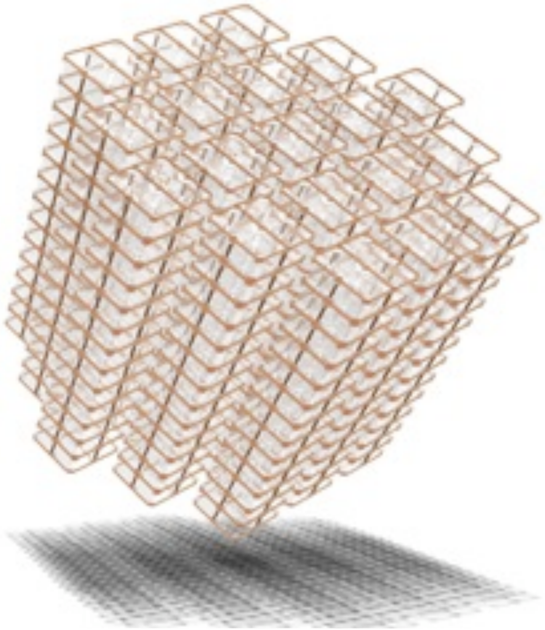
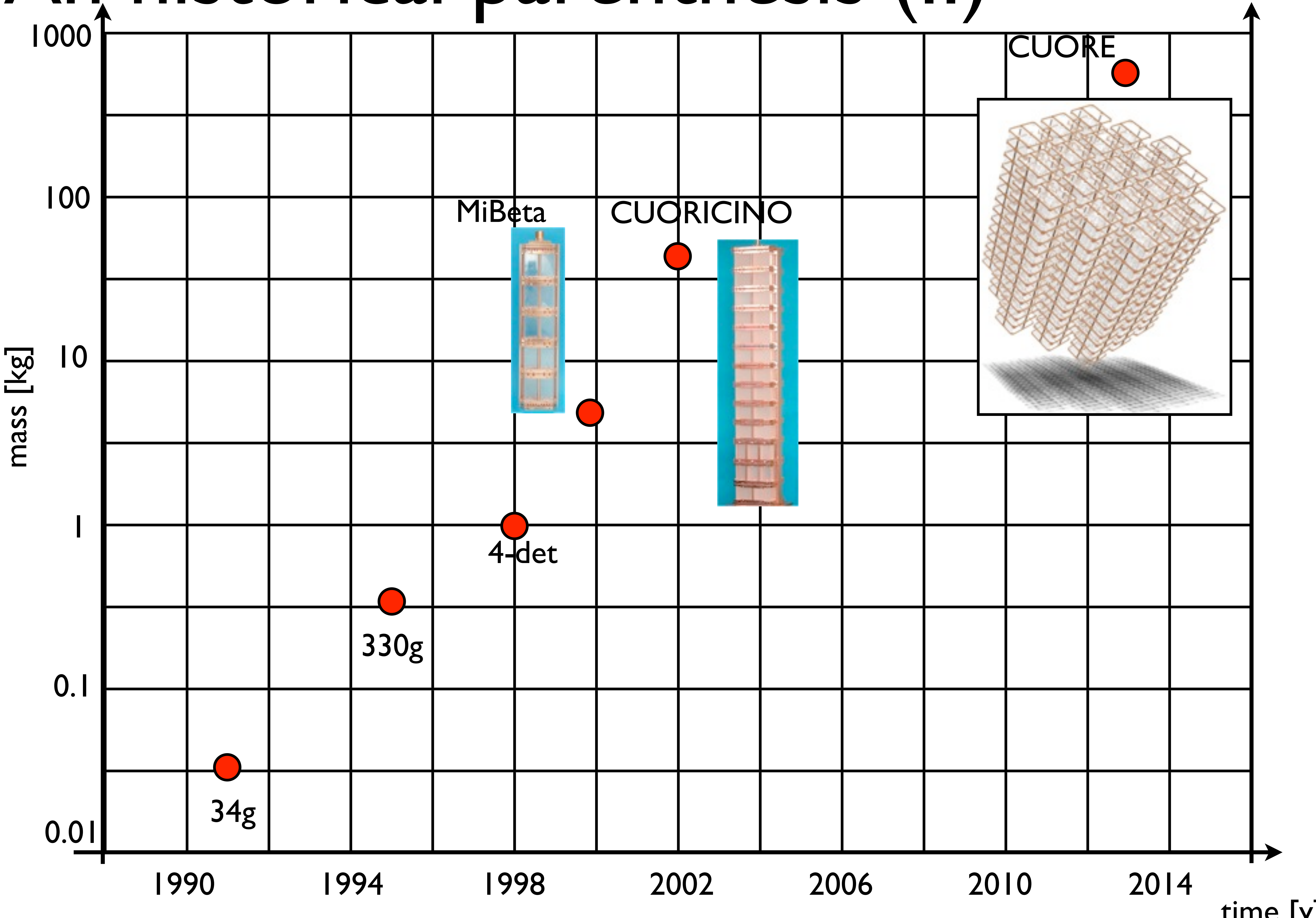


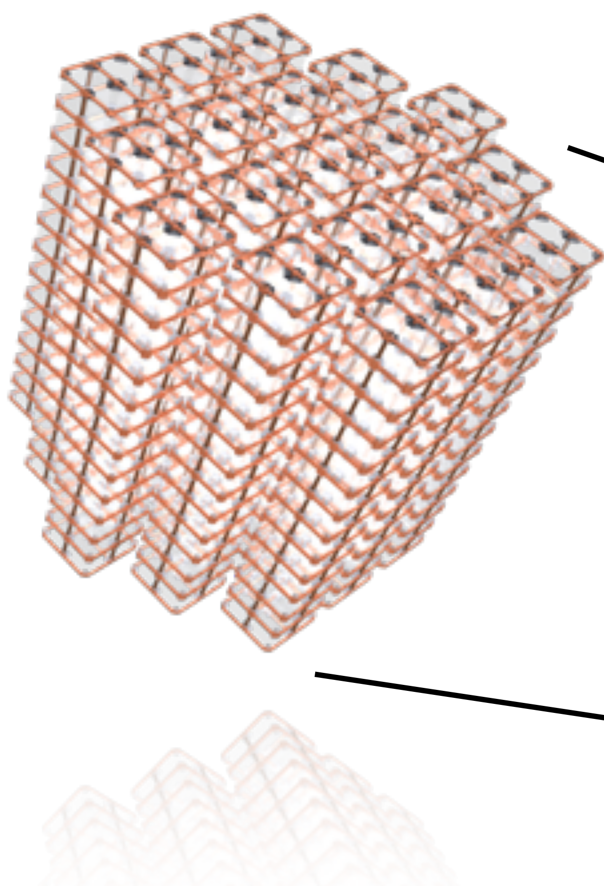
2009: CUORE starting the construction phase - 0.78 tons!

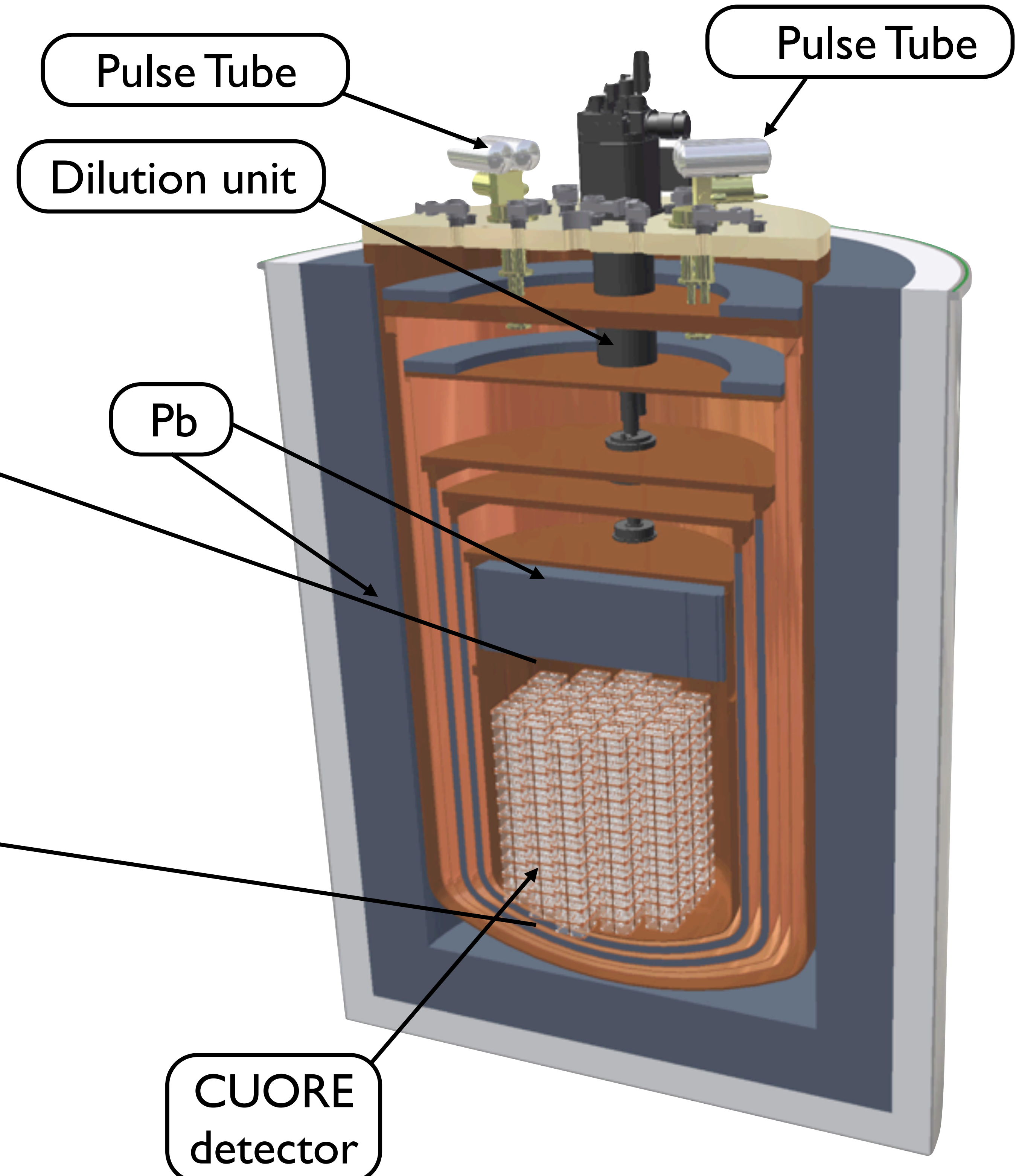
An historical parenthesis (II)



CUORE: Cryogenic Underground Observatory for Rare Events

Array of 988 detectors. 19 CUORICINO-like towers M = 0.741 ton of TeO_2 (200 kg ^{130}Te) to measure 0ν-DBD of ^{130}Te with bolometric detectors at Laboratori Nazionali del Gran Sasso.





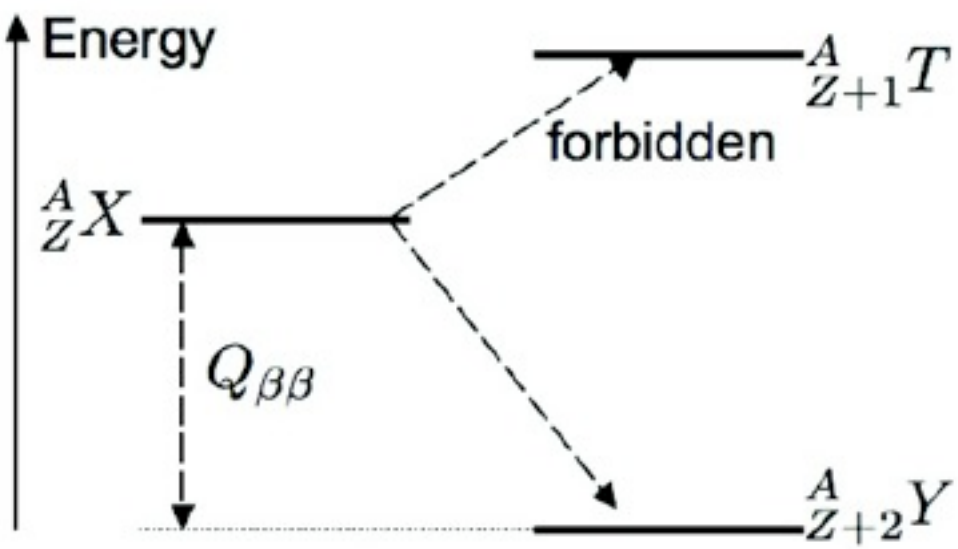
Sensitivity (5 y): $T^{1/2} = 2.1 \cdot 10^{26}$y

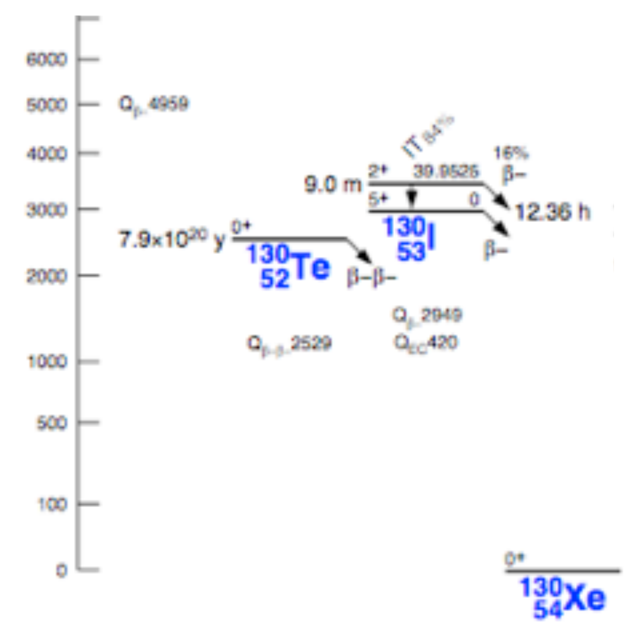
m_ν = 35 - 82 meV

NME from F.Simkovic et al. Phys.Rev. C77 - J.Suhonen et al. Int.Jou.Mod.Phys. E17 - J.Menendez et al. Nucl. Phys. A818 - J.Barea et al. Phys. Rev. C79

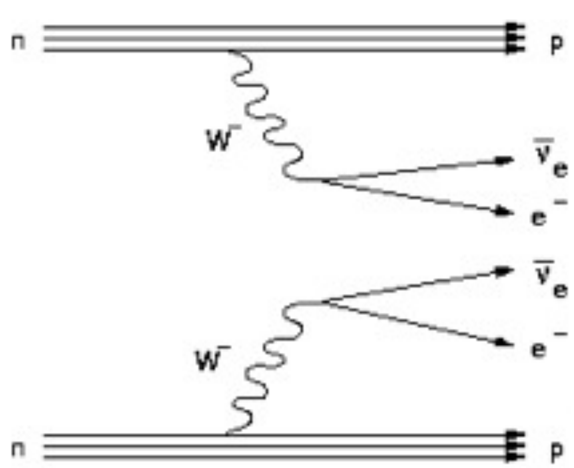
Double Beta Decay (I)

2ν-DBD (M.Goeppert-Mayer, 1935) is an extremely rare second order process allowed by SM. It take place when both the parent and the daughter nuclei are more bound than the intermediate one (or the transition on the intermediate one is strongly suppressed). Because of the pairing term, such a condition is fulfilled in nature for a number of even-even nuclei.





2ν-DBD: (A,Z) → (A,Z+2) + 2e$^-$ + 2ν



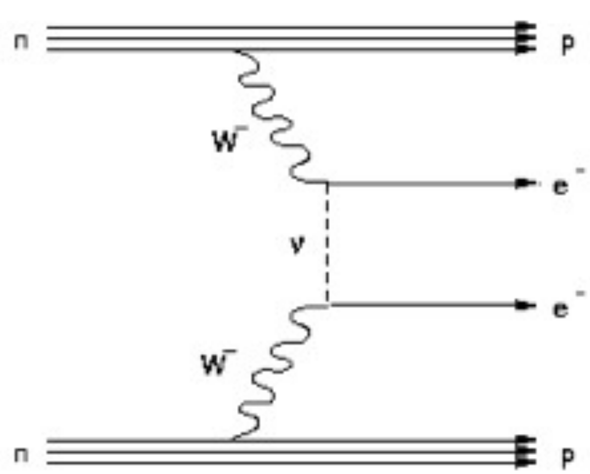
- Extremely rare second order process allowed by SM
- Observed for several nuclei
- Process: $\tau^{0\nu} \sim 10^{19}$-10^{21} y

Double Beta Decay (II)

0ν-DBD (W.H.Furry, 1939) is a lepton number violating (ΔL=2), not allowed by the Standard Model. The 0νDBD can occur only if two requirements are satisfied: i) the neutrino has to be a Majorana particle, and ii) the neutrino has to have a non-vanishing mass.

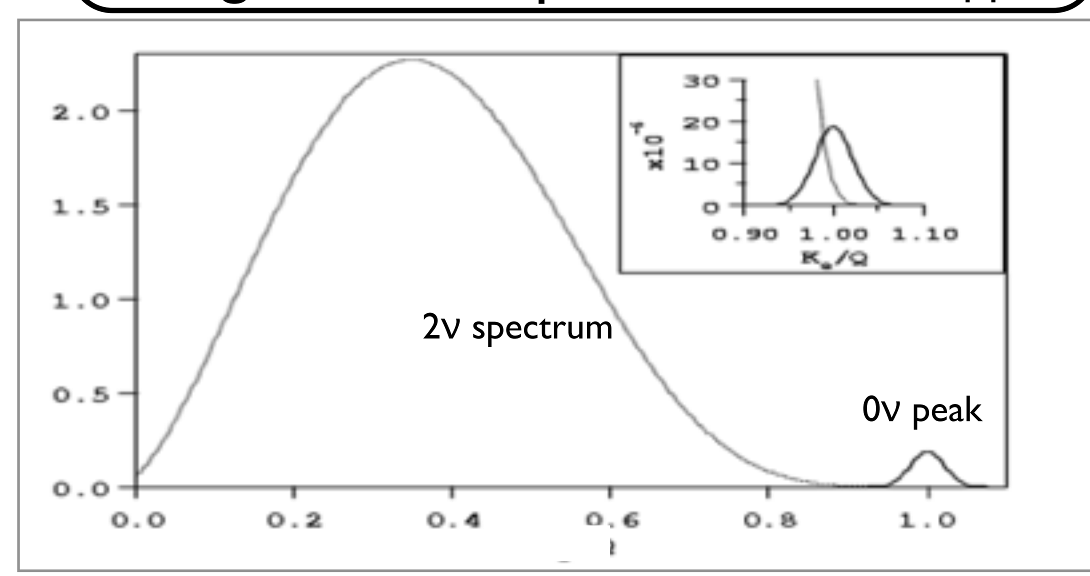
This is the crucial process for neutrino physics since can solve the puzzle of the Majorana nature of the neutrino

0ν-DBD: $(A,Z) \rightarrow (A,Z+2) + 2e^-$ ⟶ implies physics beyond SM



- 0ν-DBD is an extremely rare
- process: $\tau^{0\nu} > 10^{24}\text{-}10^{25}$ y
- β radiation

For $2e^-$ sum energy, expected signature is a peak with $E \equiv Q_{\beta\beta}$



If 0ν-DBD is observed: neutrino is a Majorana particle and m_ν is measured

Schetcher, Valle Phys. Rev. D25 2951 1982

Double Beta Decay (III)

$$(T^{0\nu}_{1/2})^{-1} = G(z,Q)|M|^2\langle m_\nu\rangle^2$$

Atomic physic: phase space term $O(Q^5)$

Nuclear physic: nuclear matrix elements (big uncertainties!)

Particle physics: neutrino mass (neutrino propagator)

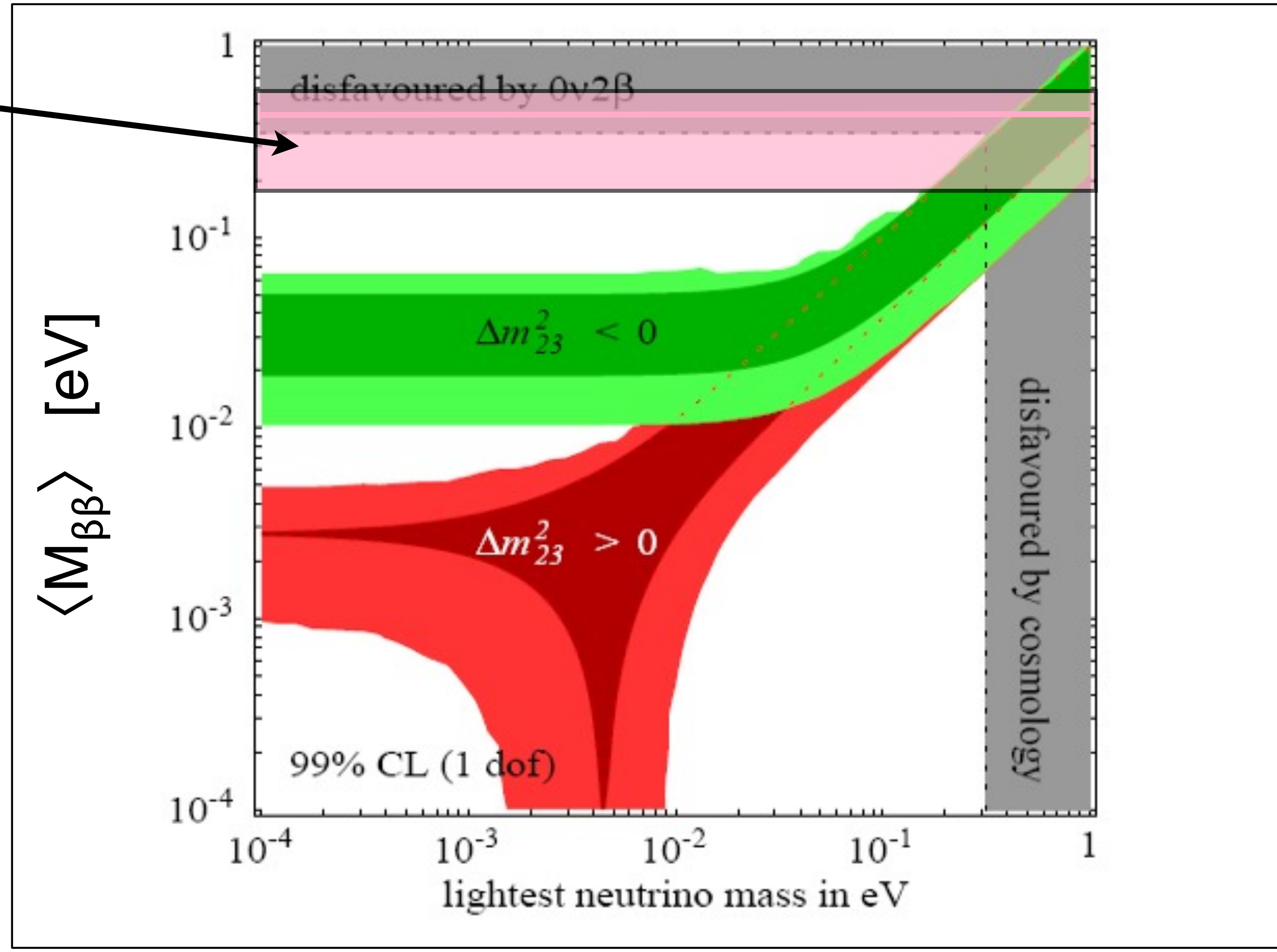
$$|\langle m_\nu\rangle| = |\ m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{i\alpha} + m_3 |U_{e3}|^2 e^{i\beta}\ |$$

Majorana phases

Parameterizing
$$m_2 = \sqrt{\Delta m^2_{sol} + m_1^2}$$
$$m_3 = \sqrt{\Delta m^2_{atm} + m_1^2}$$
$$\Rightarrow \quad |\langle m_\nu\rangle| = f(m_1)$$

Present strategies

HM-KK evidence (best value 0.32)



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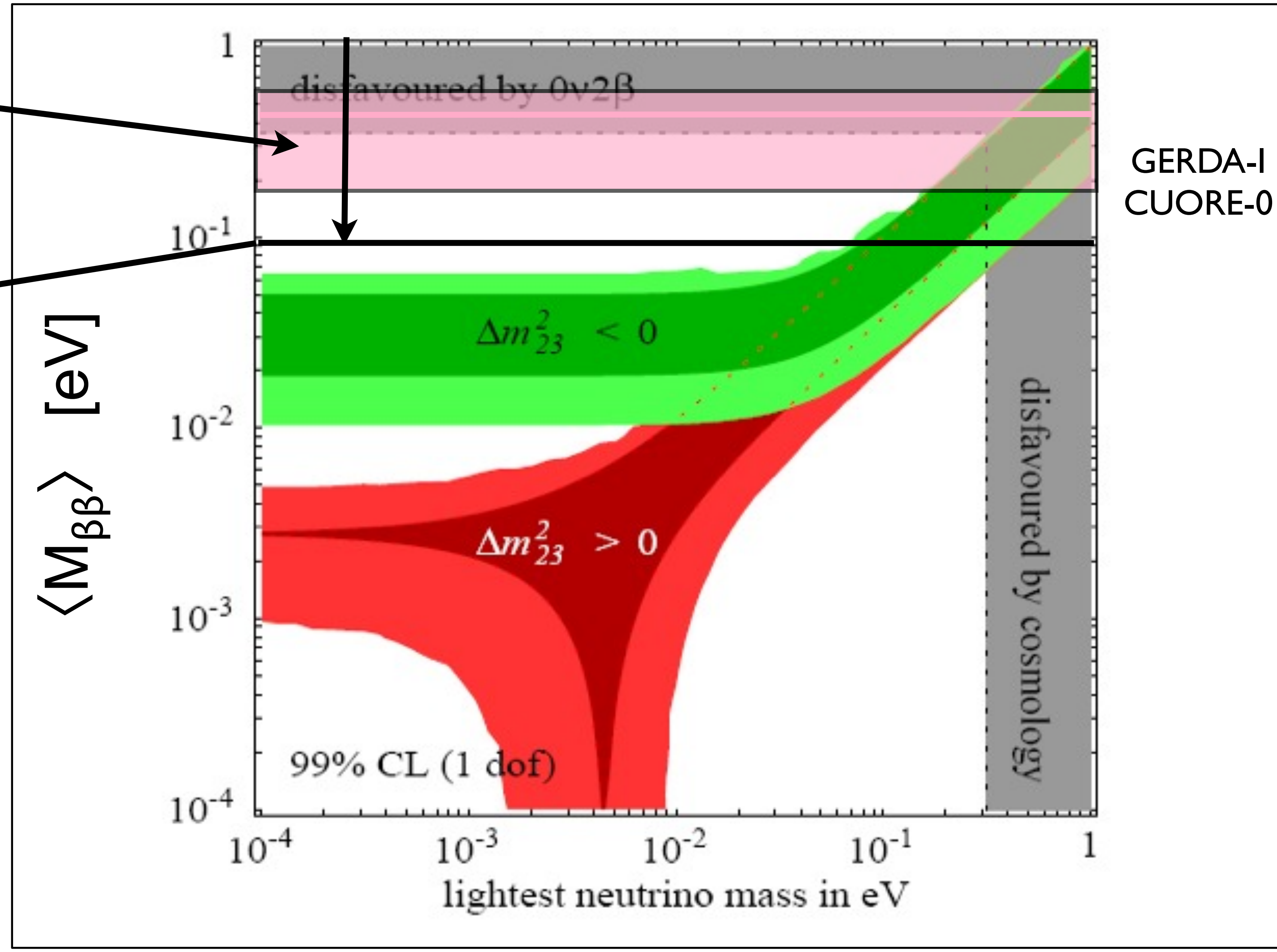
Phase I: scrutinize HM-KK evidence



GERDA-I
CUORE-0

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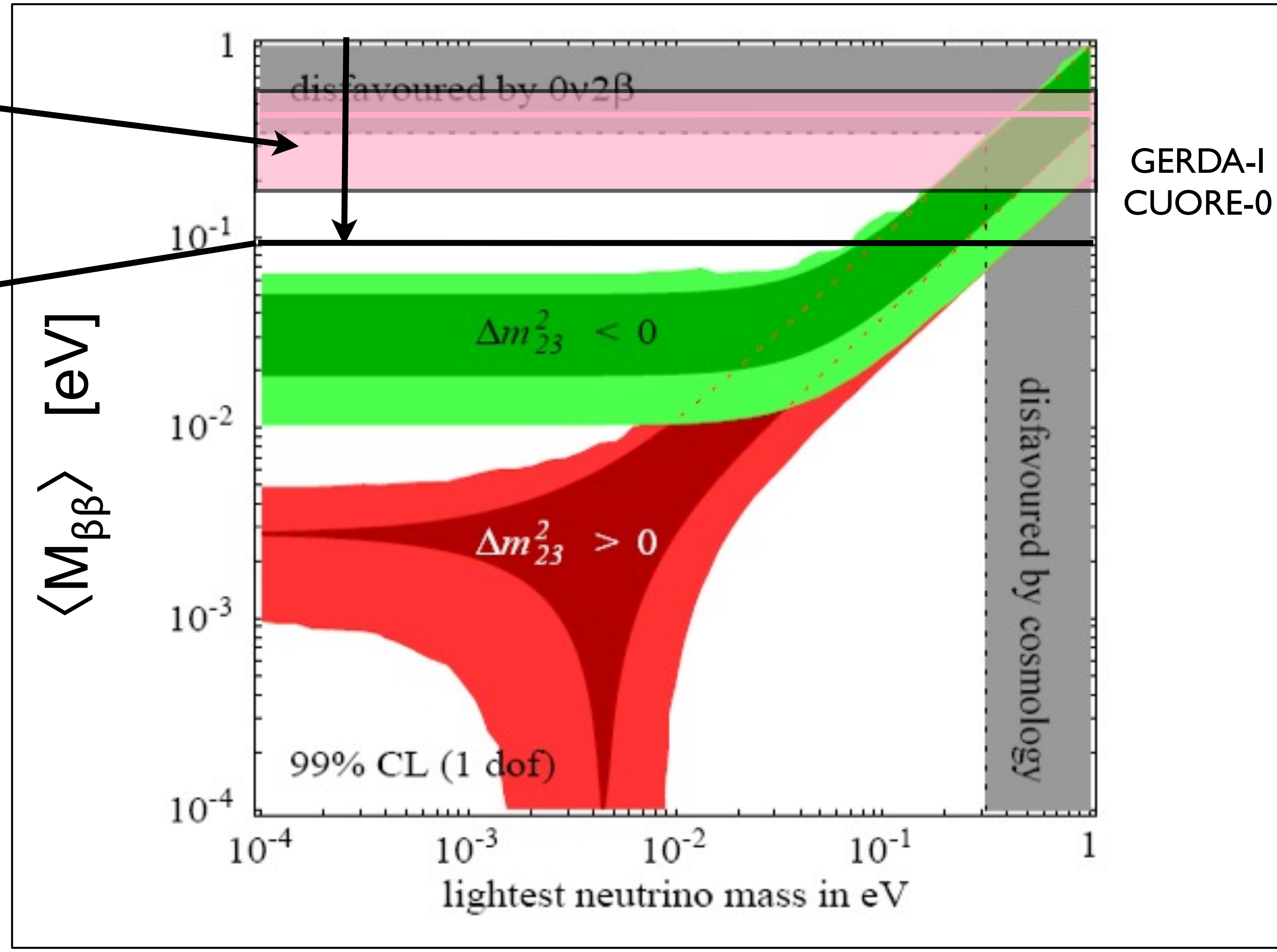
confirmed

Phase II: cross confirm with observation in several different nuclei



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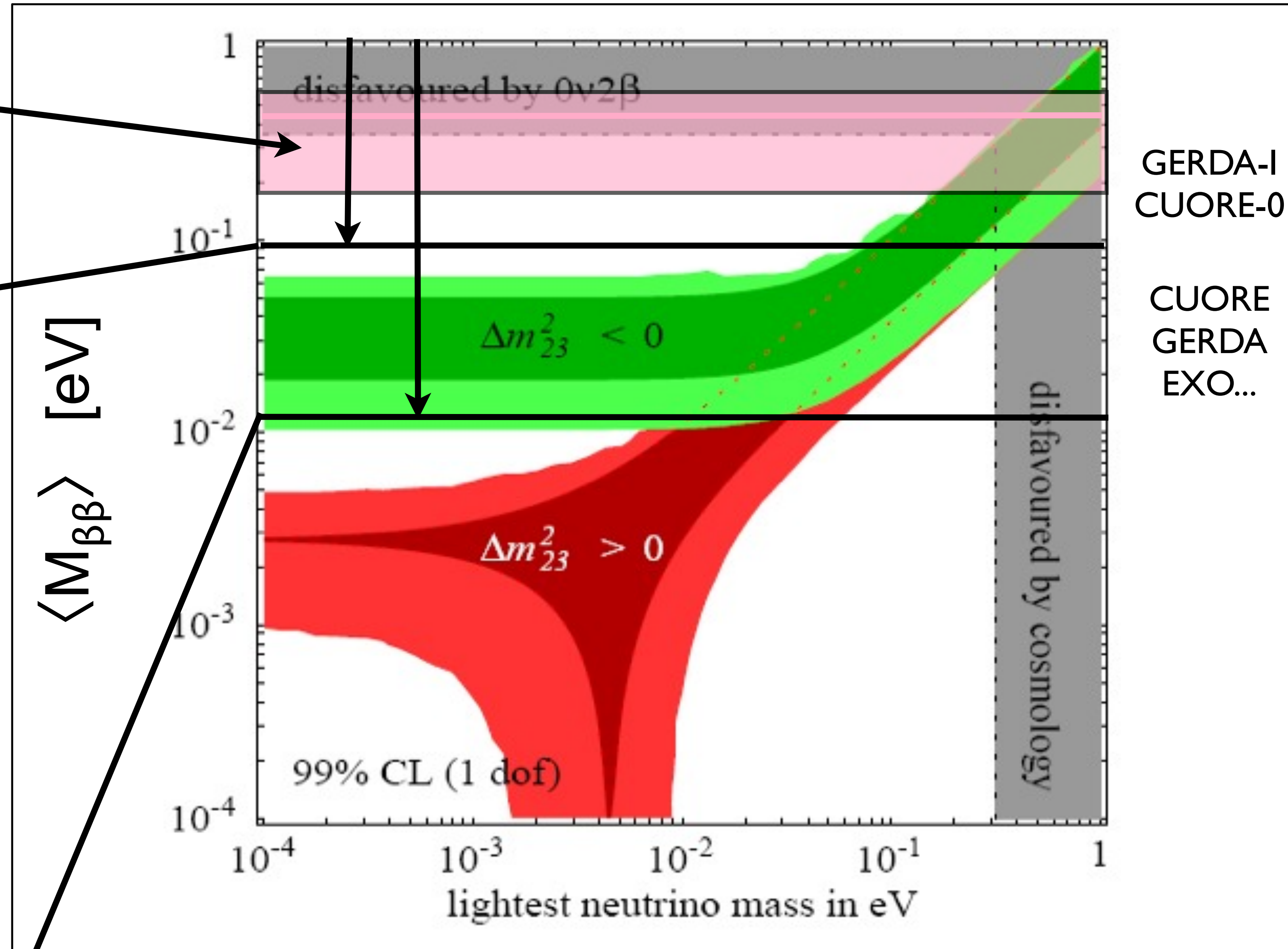
Phase II: explore the Inverted Hierarchy (IH) option



GERDA-I
CUORE-0

CUORE
GERDA
EXO...

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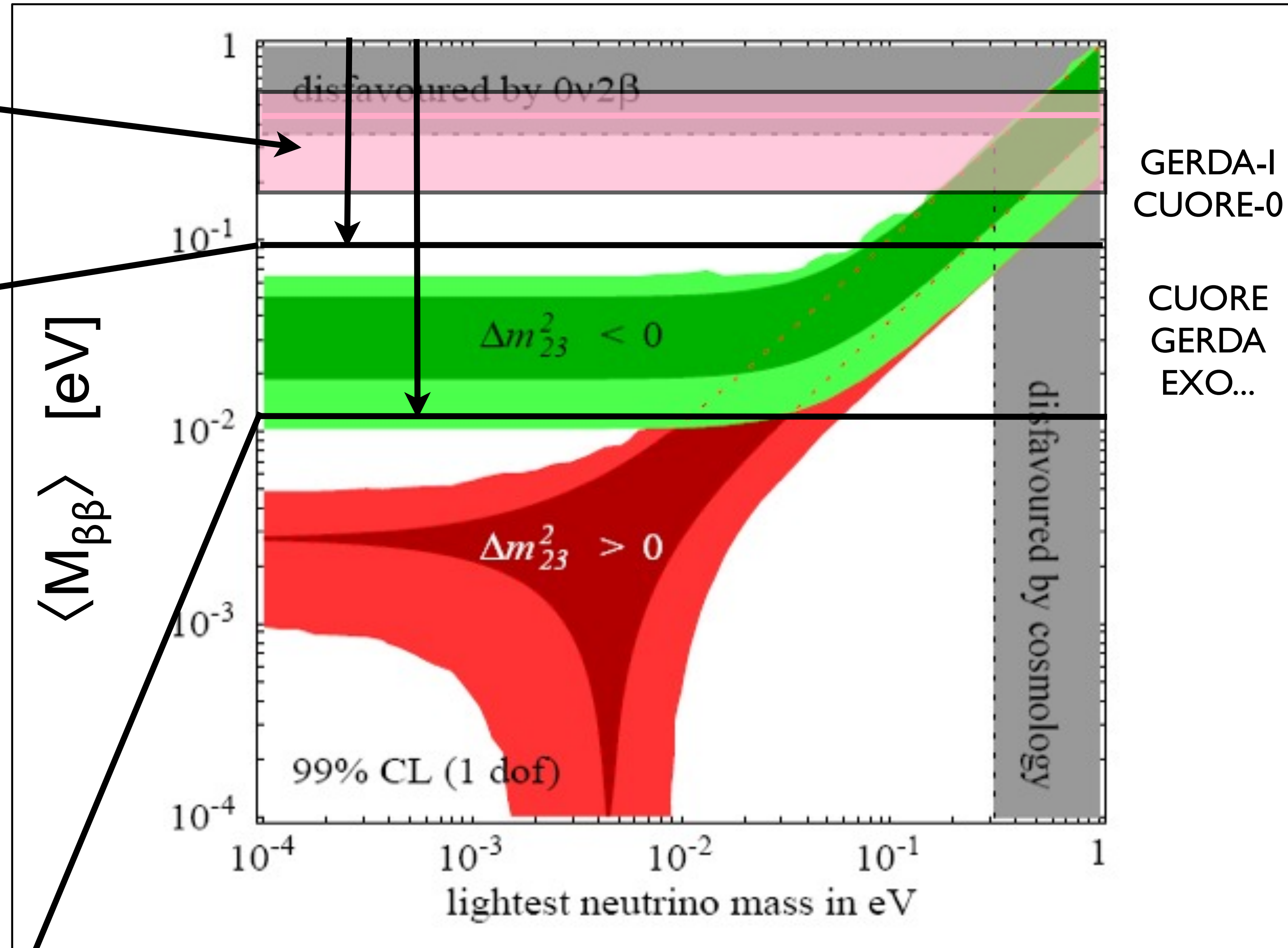
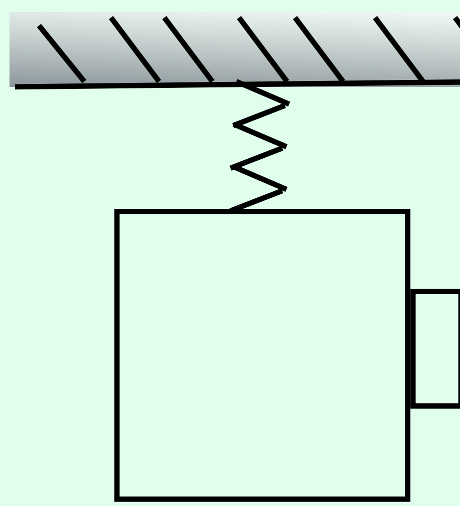
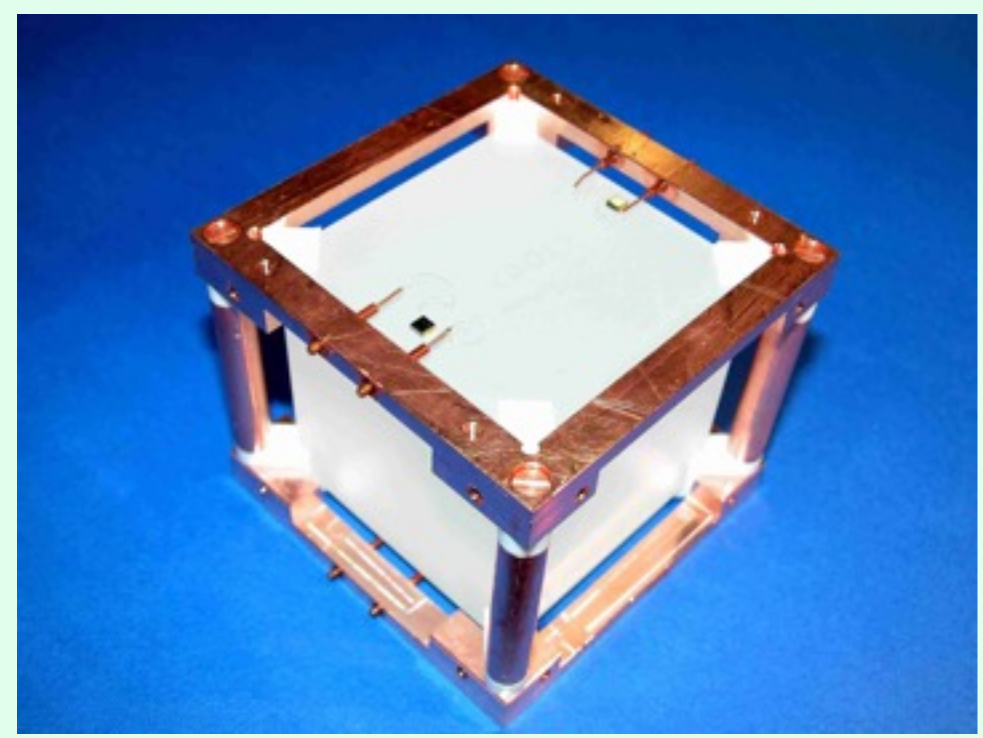


e.g.: ~ 10^{27} atoms of isotope, 5 keV resolution, 5y, <0.01 c/keV kg y

TeO_2 bolometers (I)

TeO_2 bolometers designed for ^{130}Te 0νDBD search:





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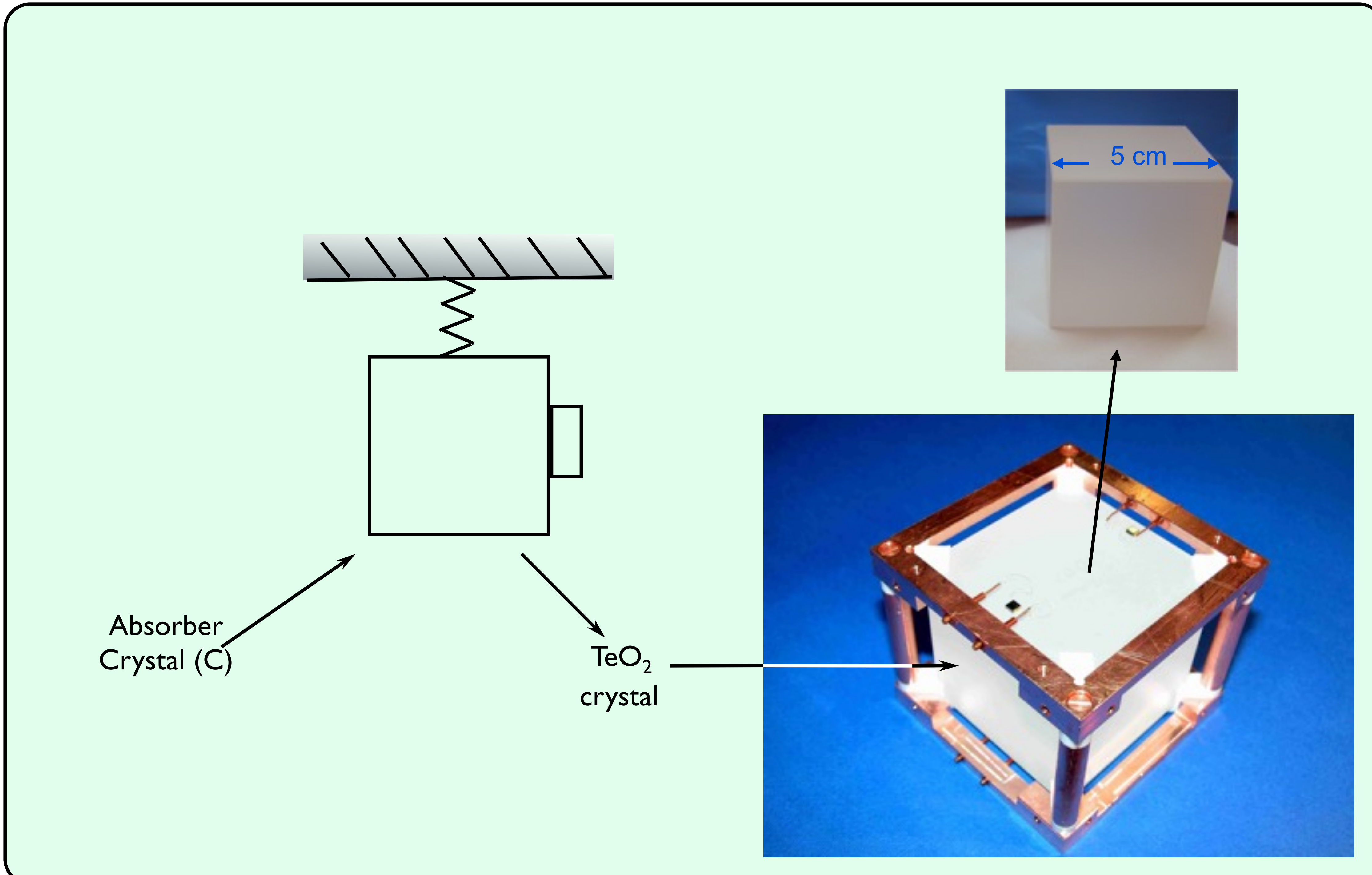

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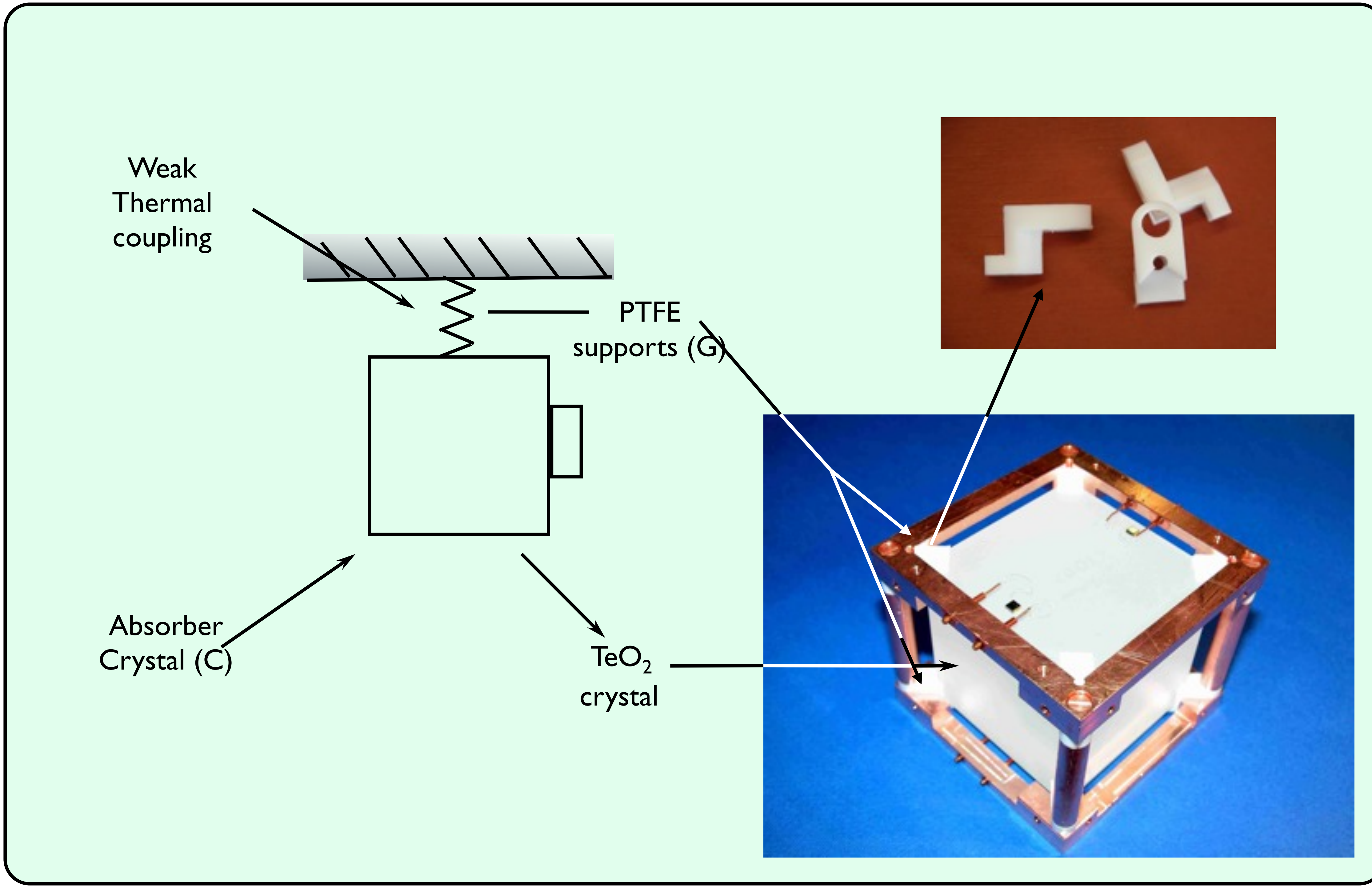

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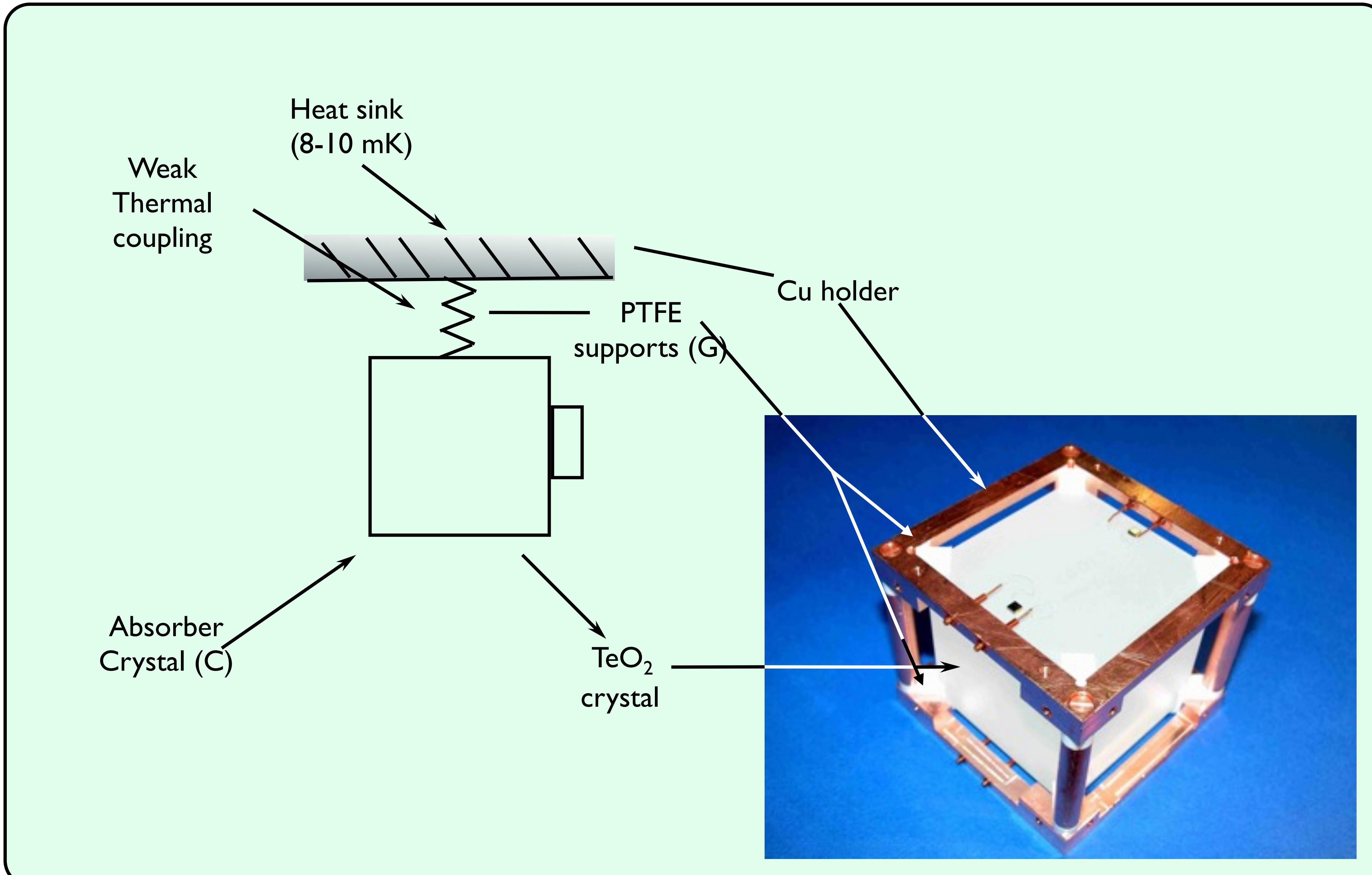

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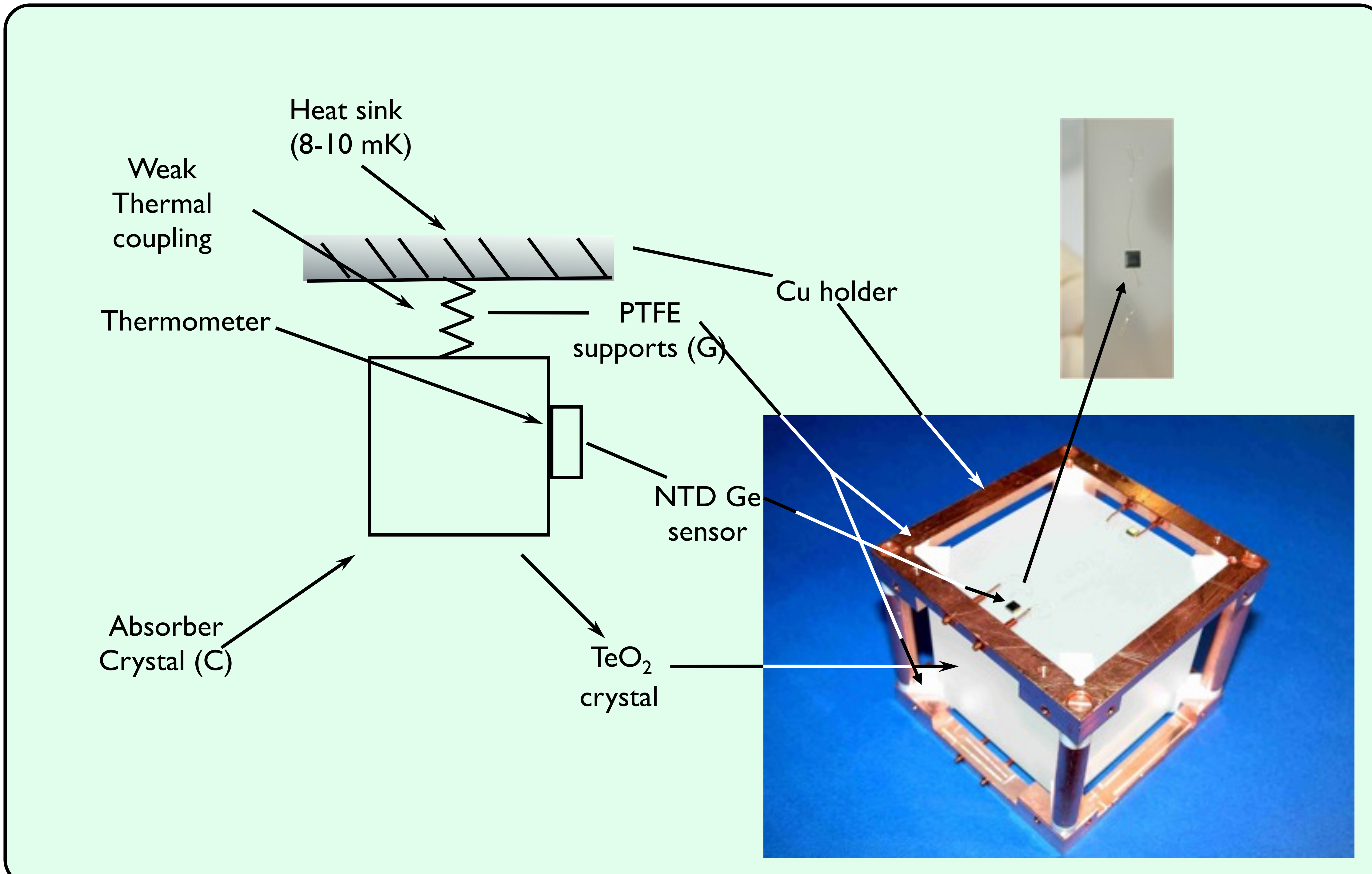

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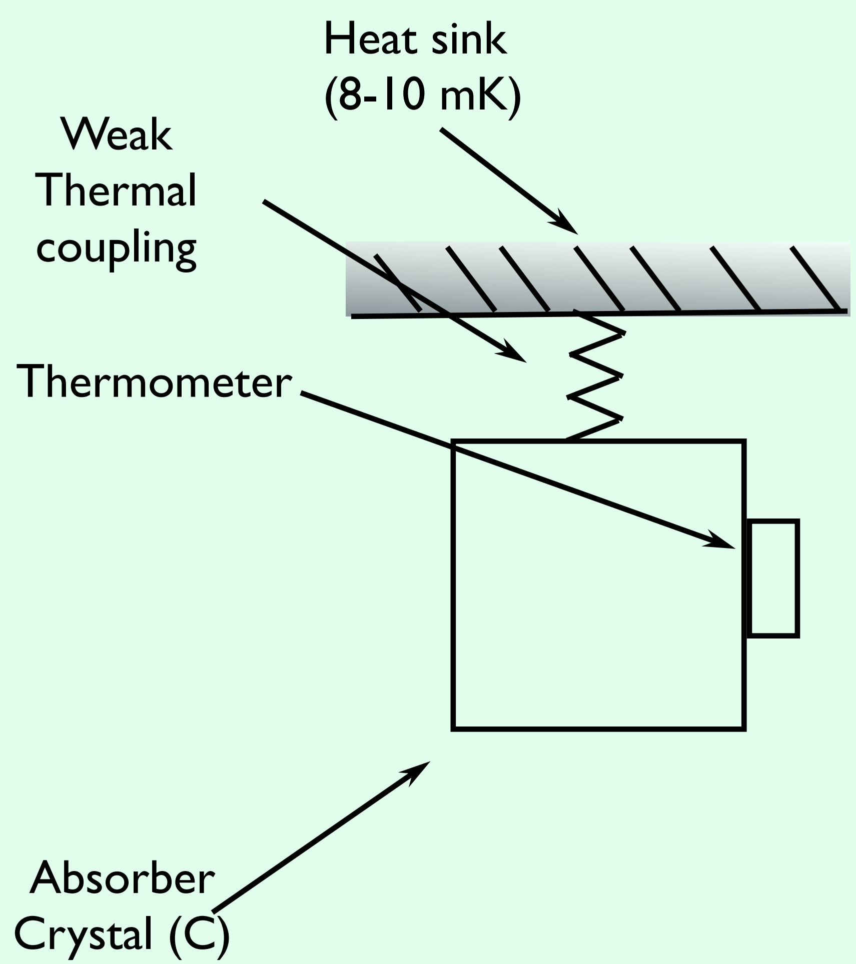

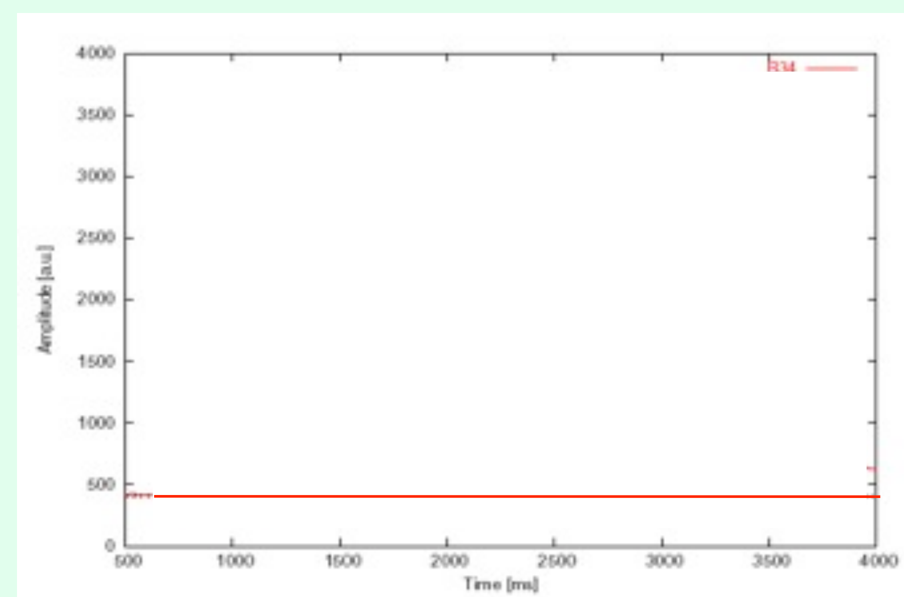

19

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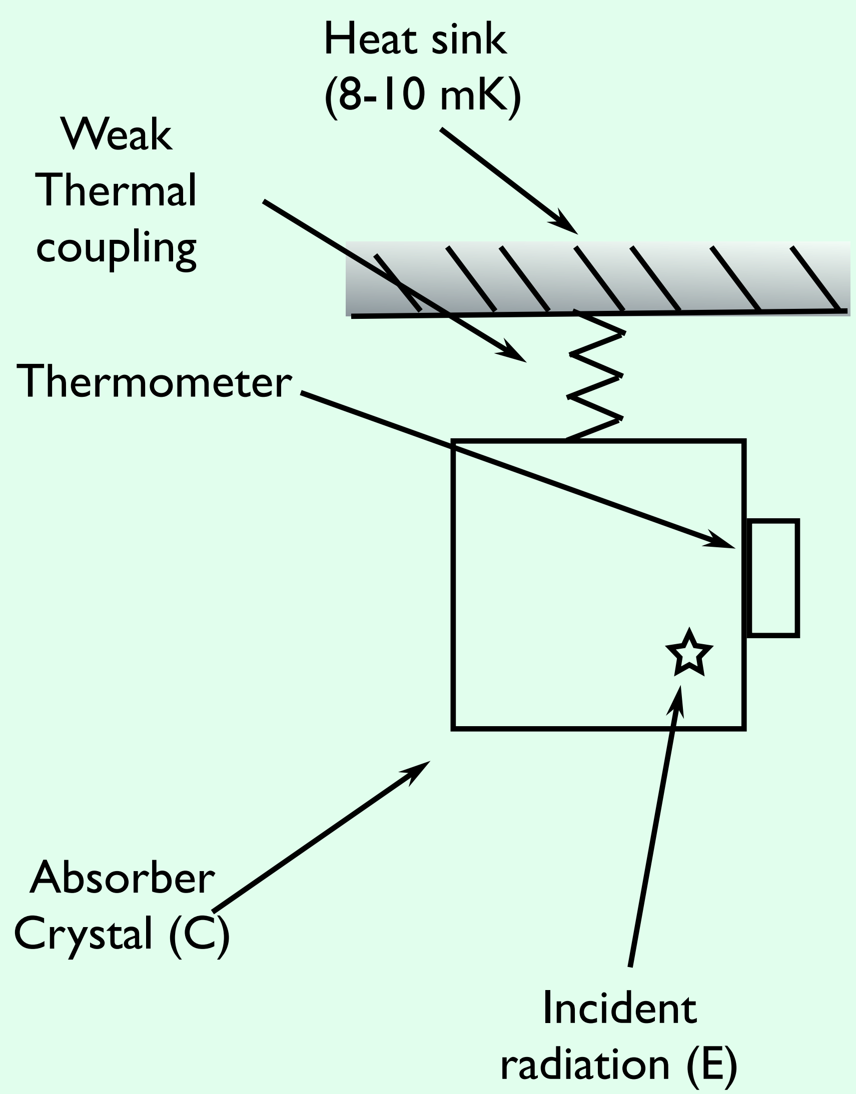

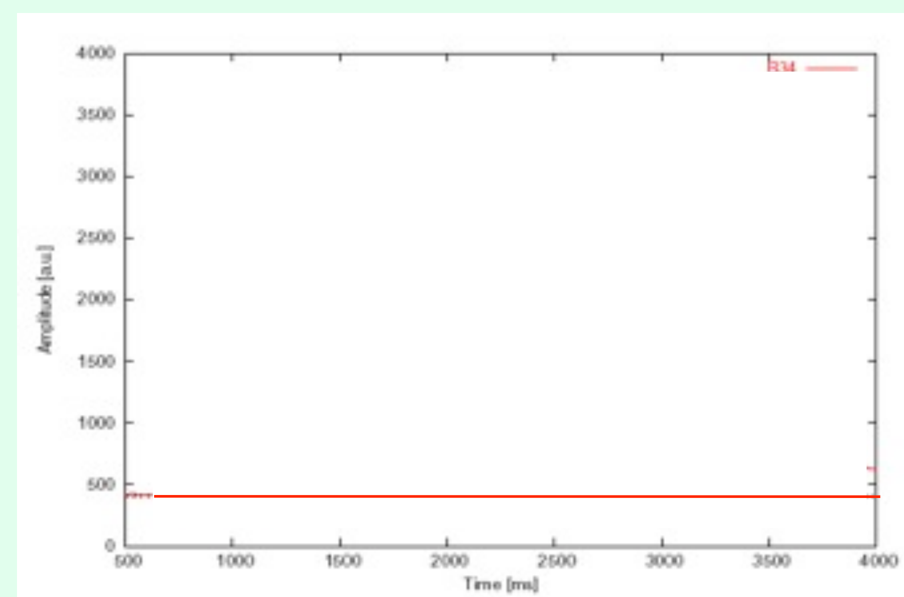

19

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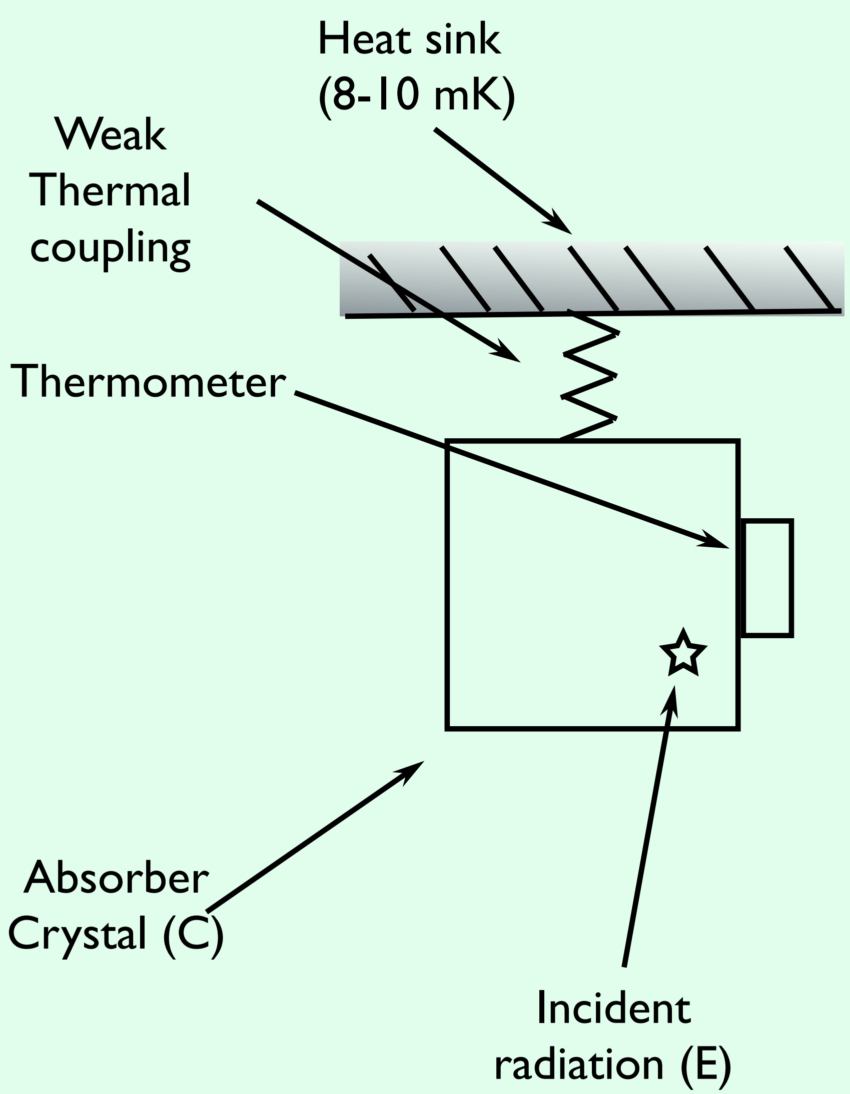
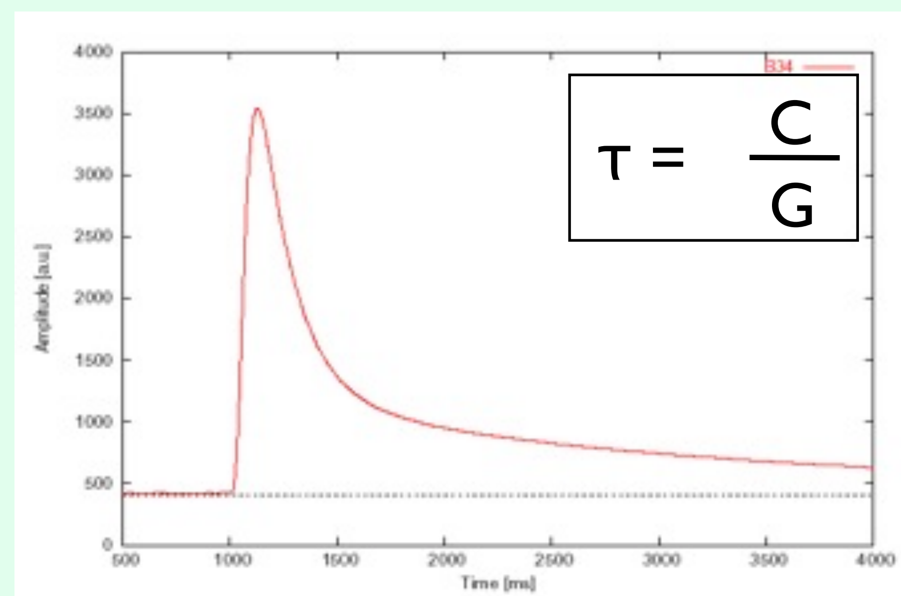


$$\Delta T = \frac{E}{C}$$



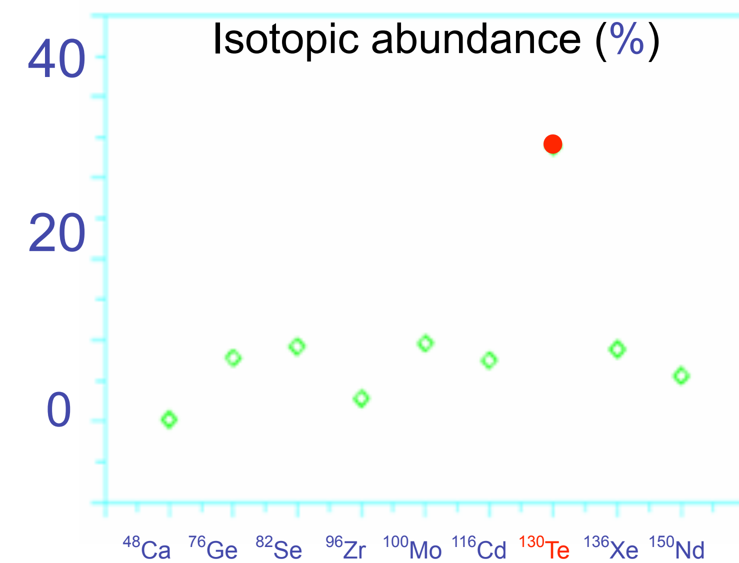
$$\tau = \frac{C}{G}$$

19

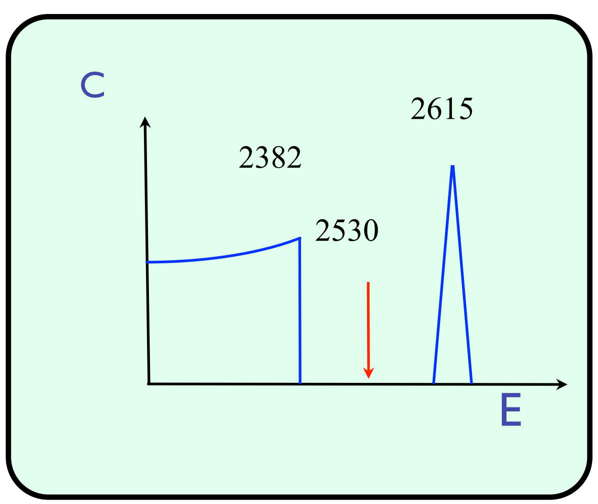
TeO_2 bolometers (II)

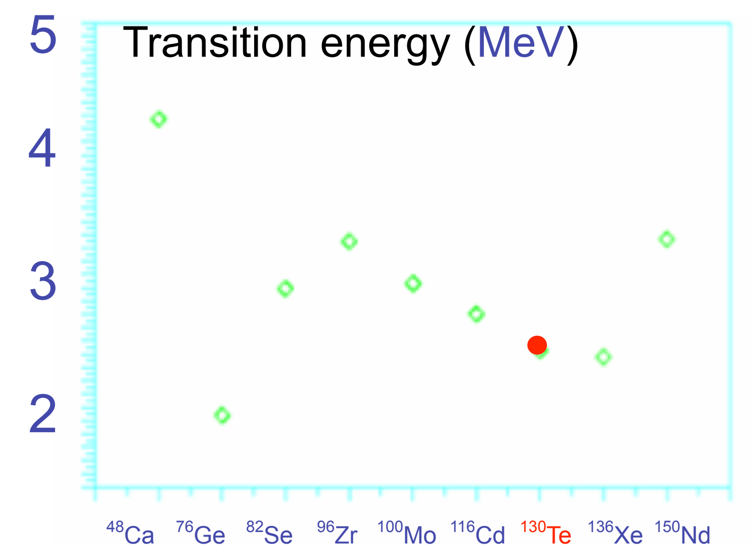
In CUORICINO and CUORE experiments we use TeO_2 because it contains ^{130}Te, but why ^{130}Te?

- high natural isotopic abundance (33.87 %)



- high transition energy (Q=2530 keV)





The choice of TeO_2 guaranties good mechanical properties and low radioactive contaminations.

TeO_2 bolometers (III)

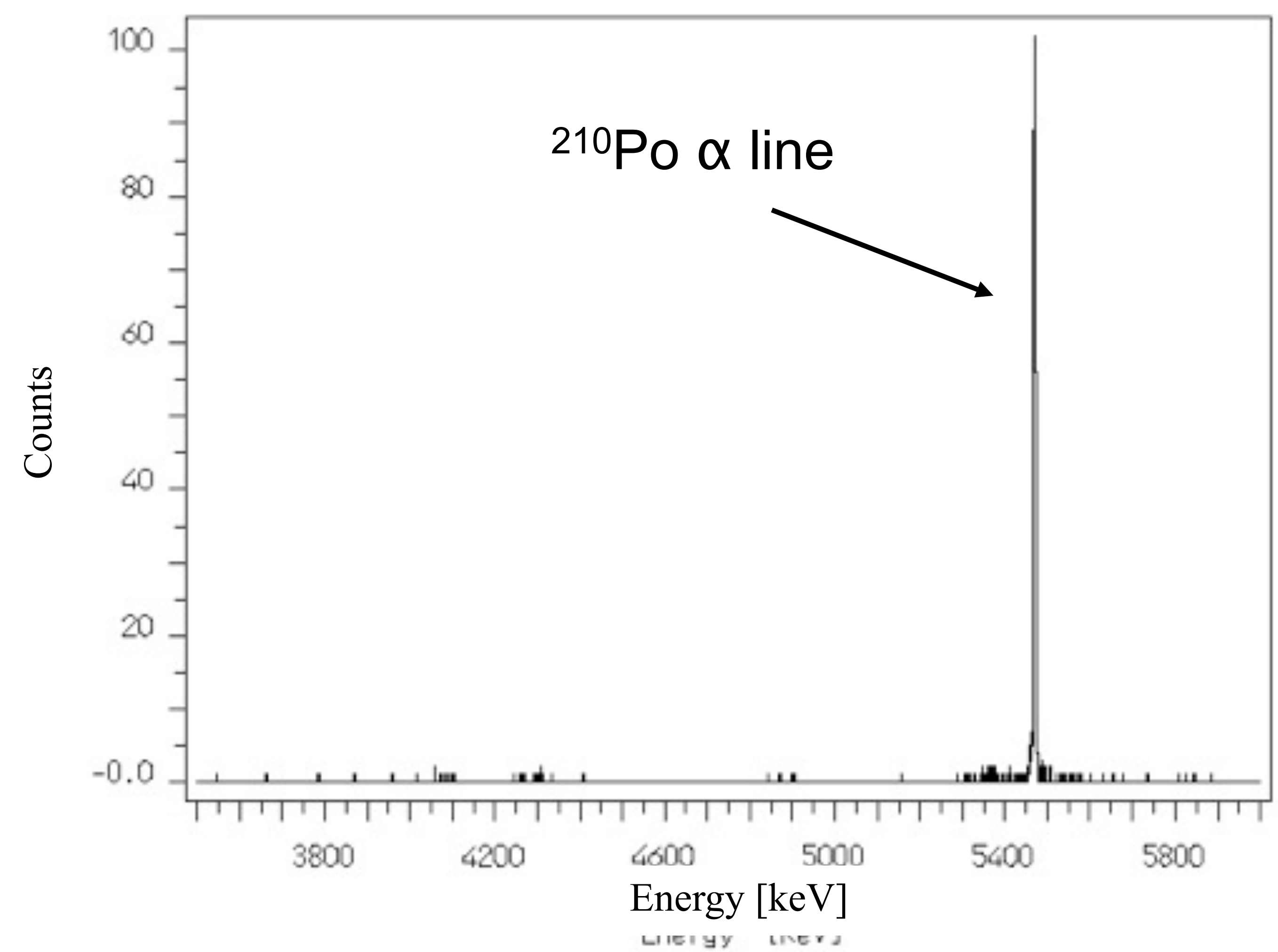
Performances: 5x5x5 cm^3 TeO_2 (790 g) showed to have very good energy resolution (≤‰).

best 780 g detector:

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

Best alpha measurement ever performed

A.Alessandrello et al, NIM A440 (2000) 397-402



Nevertheless resolution is far from intrinsic limit: dominated by different phenomena

Sensitivity (I)

Half-life corresponding to the maximum signal n_B that could be hidden by the background fluctuations at a given statistical C.L.

$$S_{0\nu} \propto i.a. \cdot \sqrt{\frac{M \cdot T}{\Gamma \cdot b}}$$

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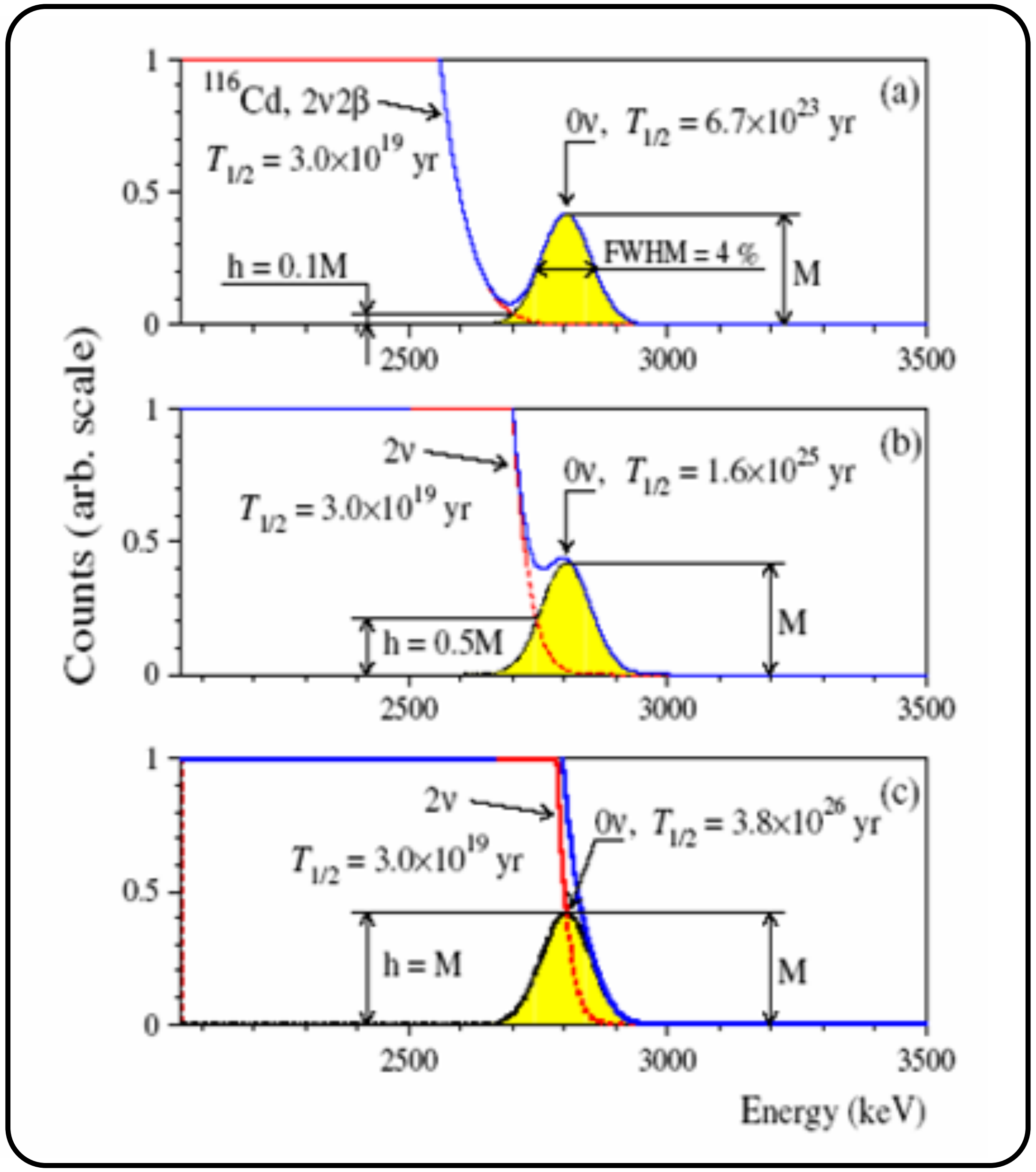
Background: currently this is the ONLY tunable parameter to push sensitivities of order of magnitudes.

Sensitivity (II): discovery potential



Yu.G. Zdesenko, F.A. Danevich and V.I. Tretyak
J.Phys. G: Nucl. Part. Phys. 30 (2004) 971

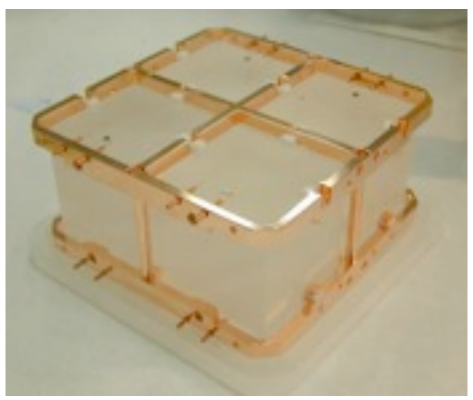
2νDBD is an unavoidable background for any 0νDBD (neutrino tagging?).

Energy resolution is a crucial parameter for any experiment aiming to measure 0νDBD and not just increasing the sensitivity on the not observed process.

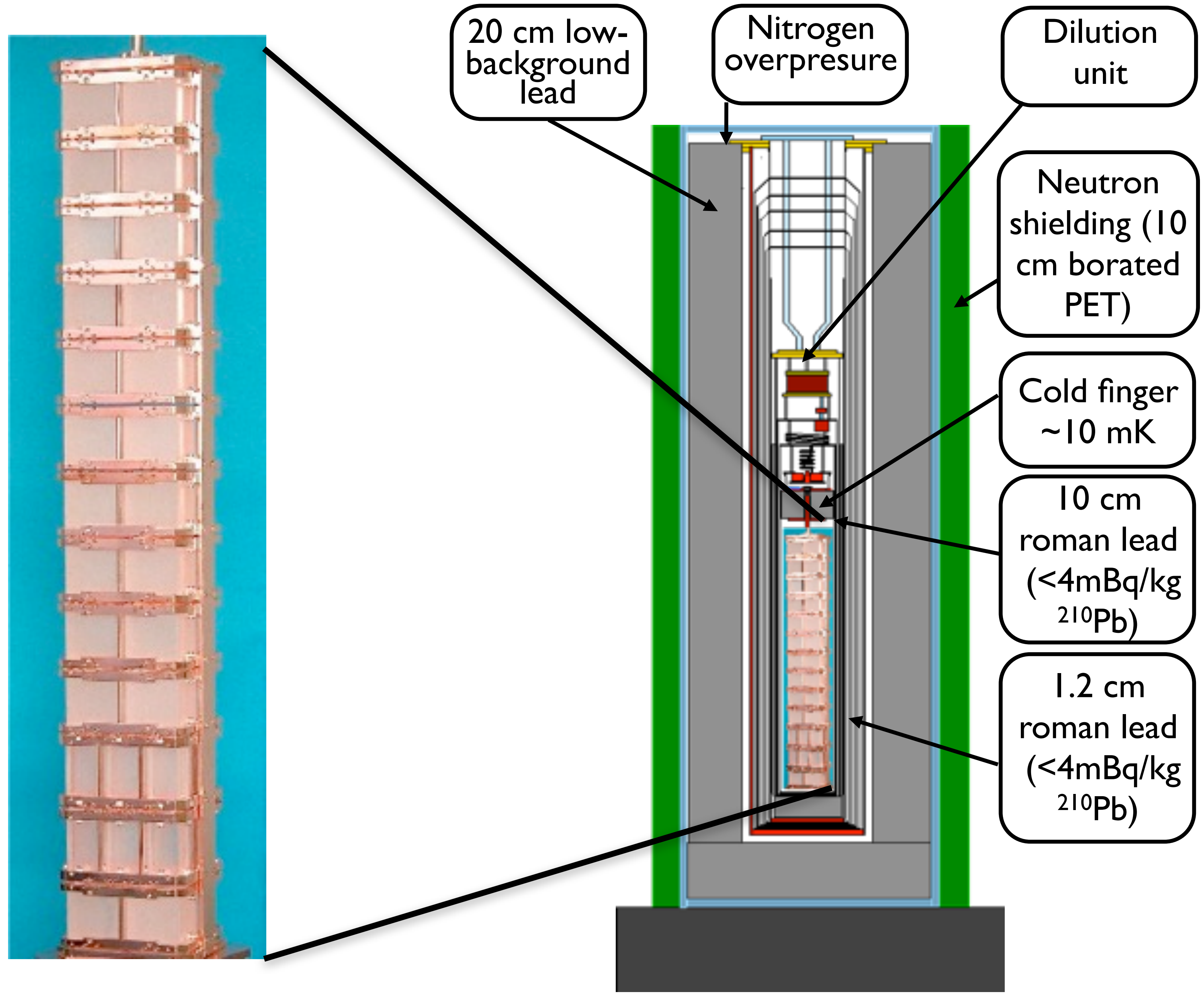
A starting point: the CUORICINO prototype

The largest bolometric experiment up to now, operated from March 2003 to June 2008.
CUORICINO is a tower 62 TeO_2 bolometers with a total mass 40.7 kg of TeO_2 (11.34 kg ^{130}Te)

11 modules, 4 detector each
Crystals: 5x5x5 cm^3, 790 g

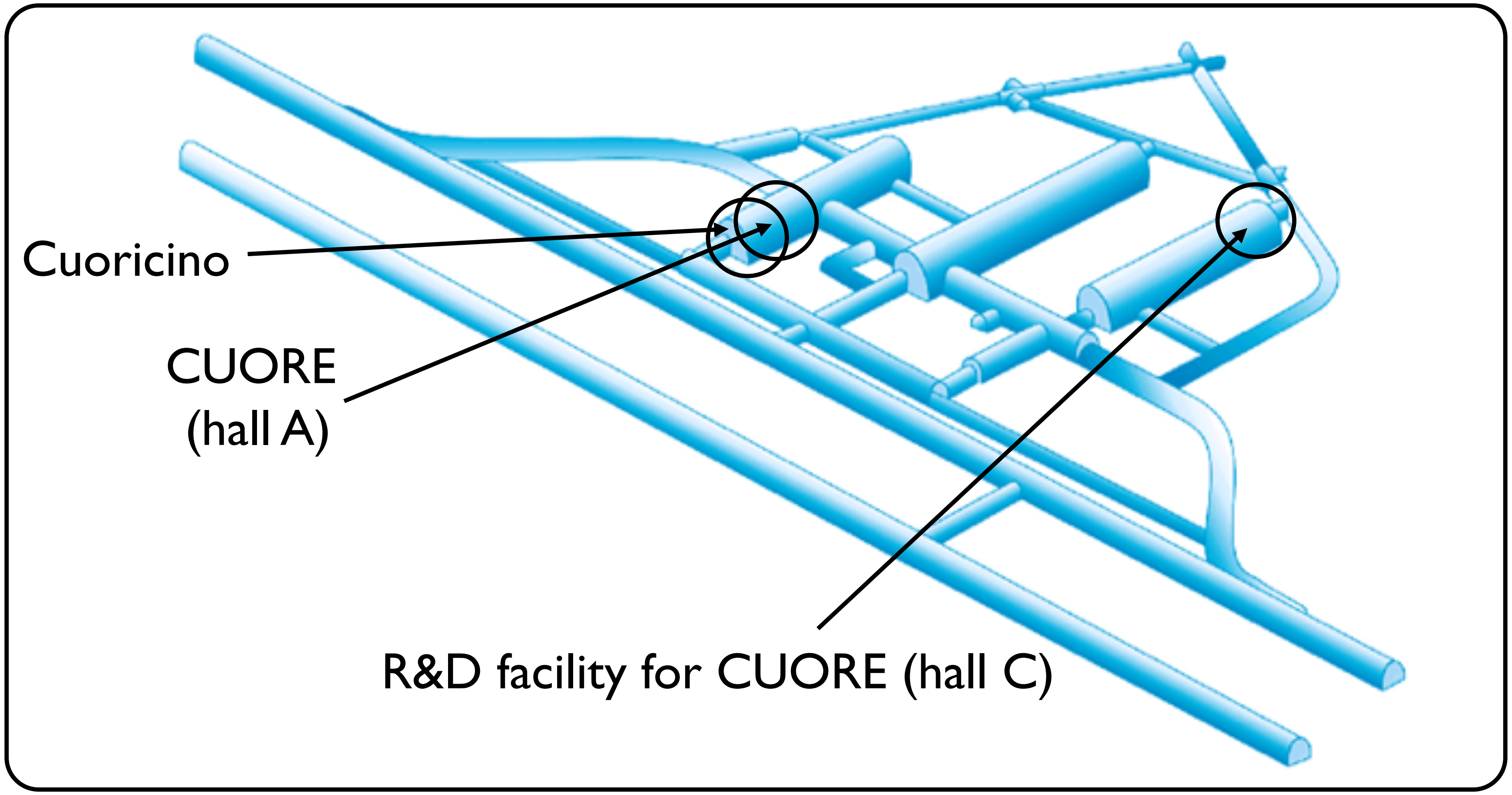


2 modules, 9 detector each
Crystals: 3x3x6 cm^3, 330 g
2 enriched in ^{128}Te (82.3%)
2 enriched in ^{130}Te (75%)



CUORICINO @ LNGS

Installed in the Laboratori Nazionali del Gran Sasso INFN (Italy) undrground location



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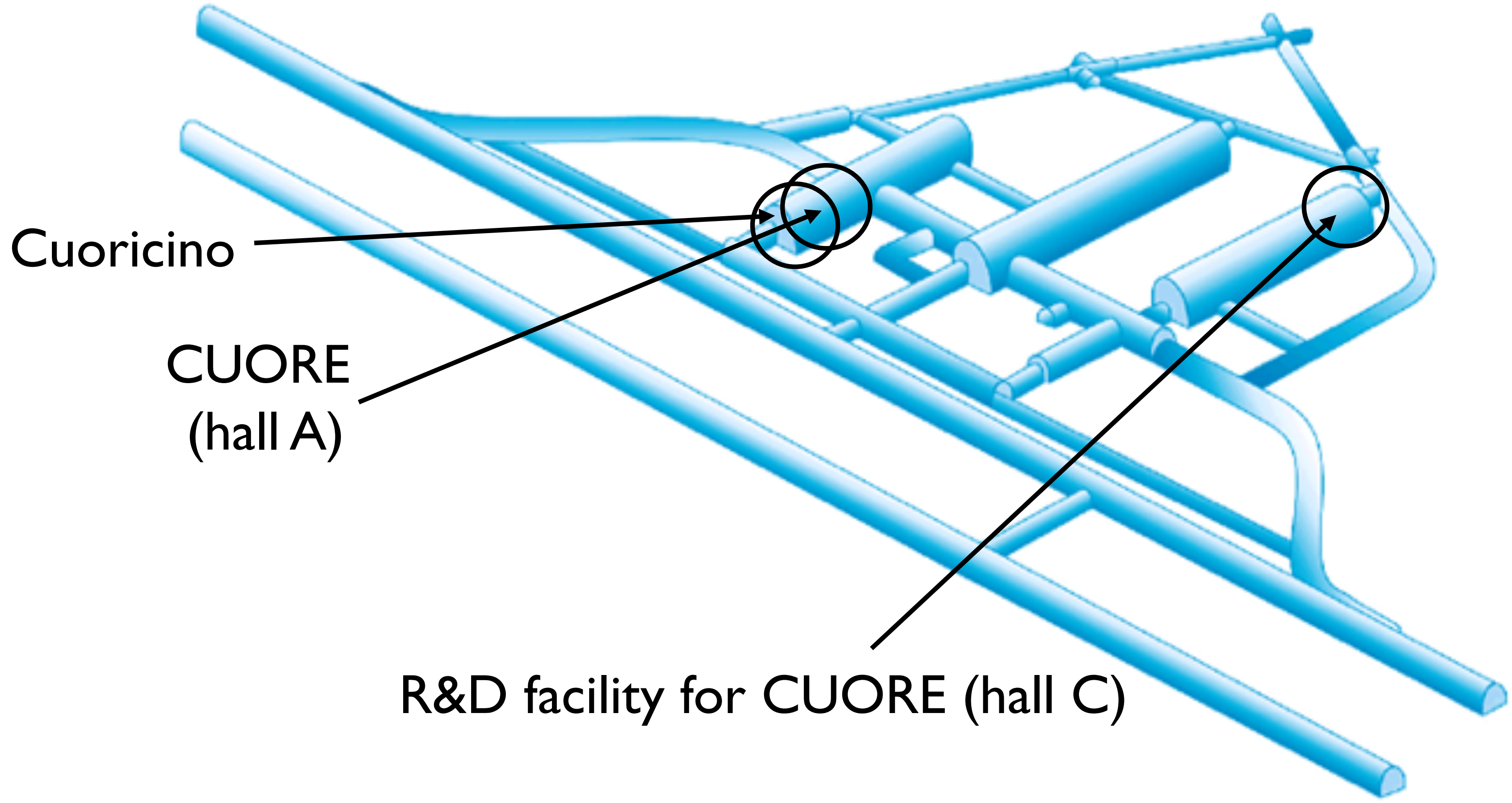
the rock overburden provides a 3500 m.w.e. shield against cosmic rays



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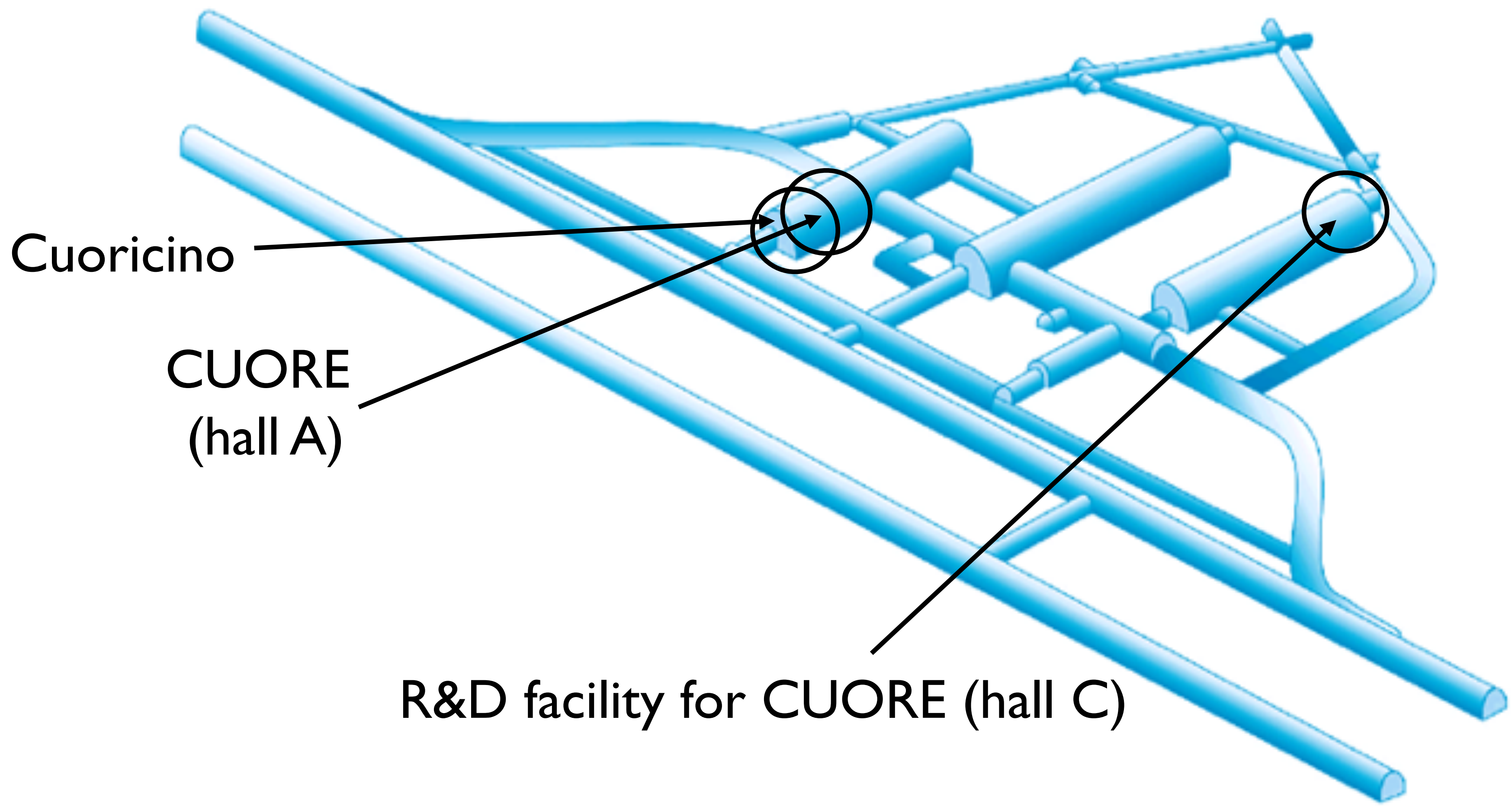
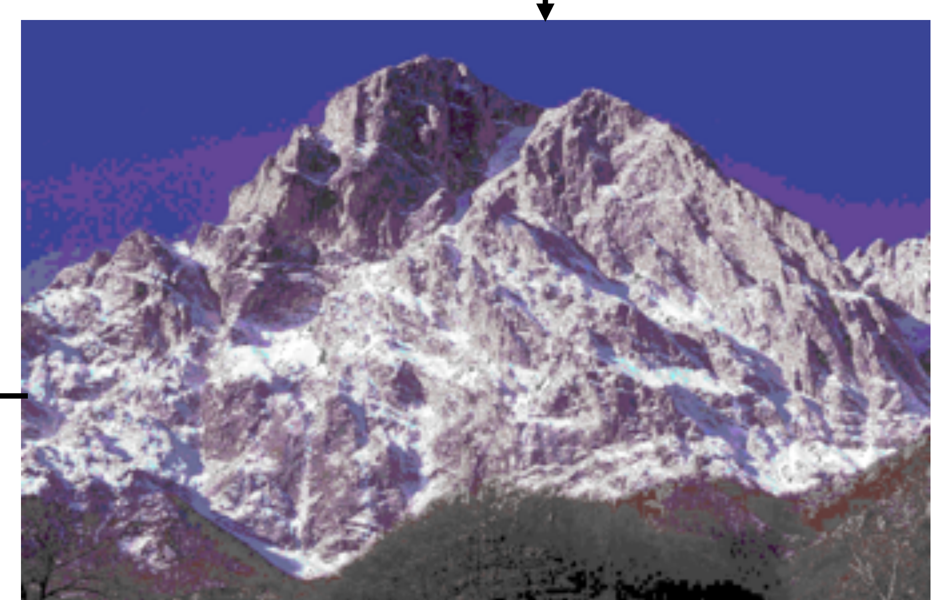
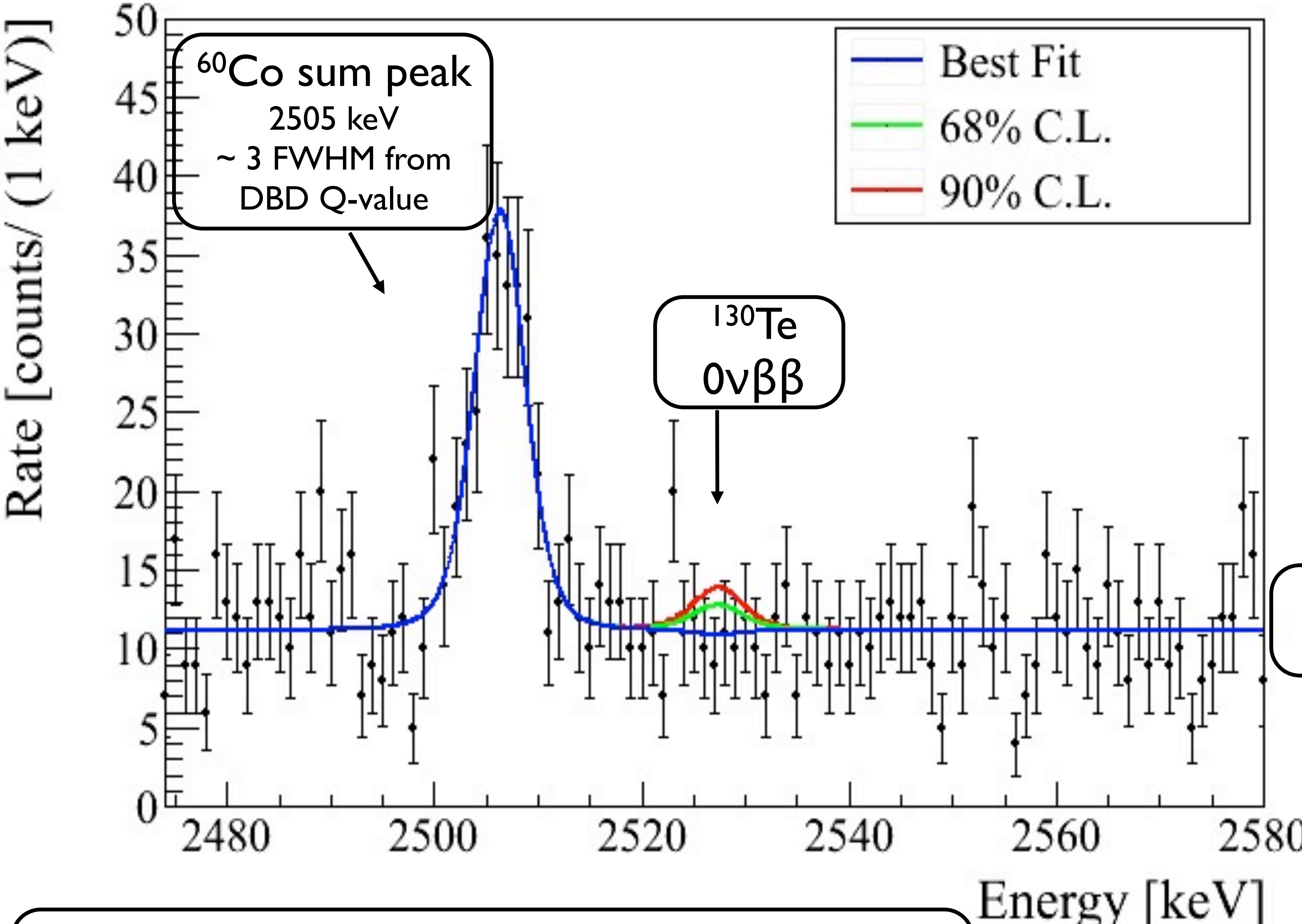




CUORICINO results



19.75 kg · y of ^{130}Te total exposure
$Q_{\beta\beta}$ = 2527 keV

So far no evidence of 0νDBD was found

$\tau_{1/2}$ >2.8x10^{24} year @ 90% C.L.

UPPER LIMITS ON m_ν (meV):

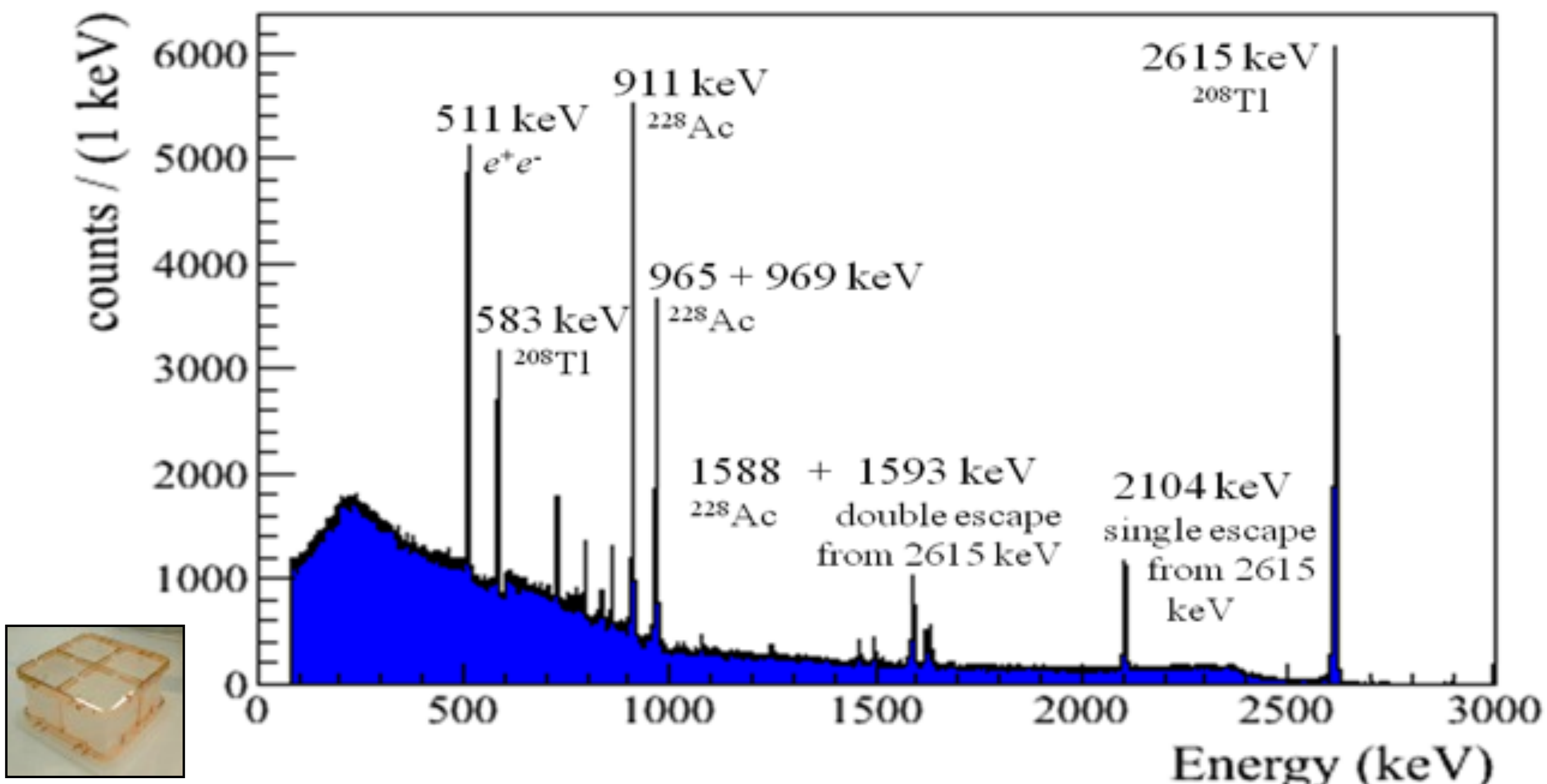
- 300-570 (QRPA) F. Simkovic et al., Phys. Rev. C 77, 045503 (2008)
- 360-580 (QRPA) O. Civitarese and J. Suhonen, J. Phys.: Conf. Ser. 173,(2009)
- 570-610 (SM) J. Menendez et al., Nucl. Phys. A 818, 139-151 (2009)
- 350-370 (IBM) J. Barea and F. Iachello, Phys. Rev. C 79, 044301 (2009)

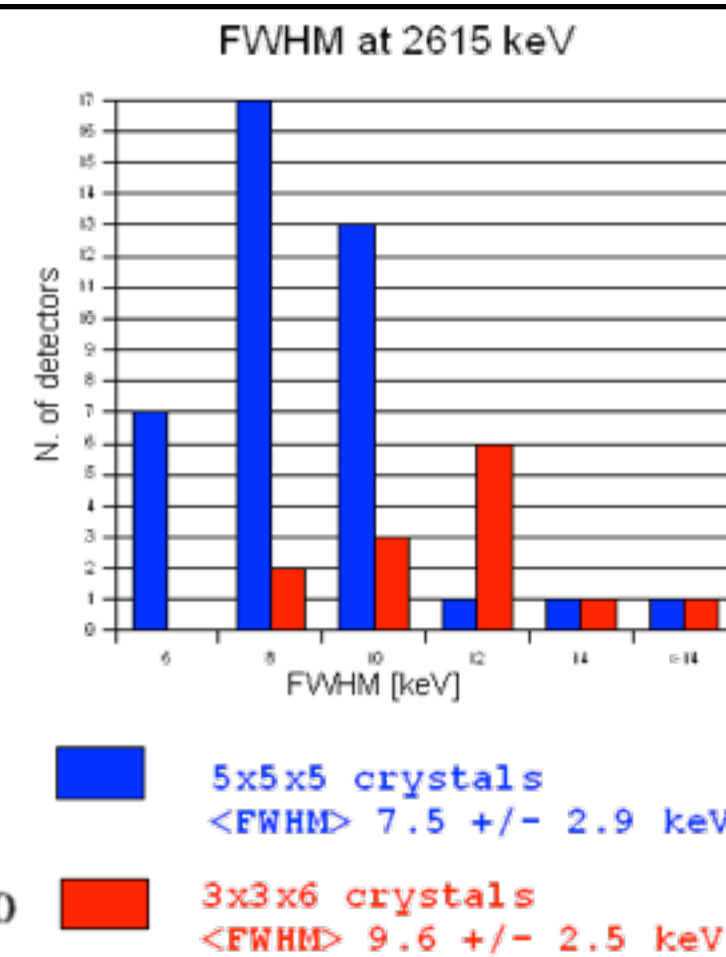
CUORICINO performances

Duty cycle ~ 60%

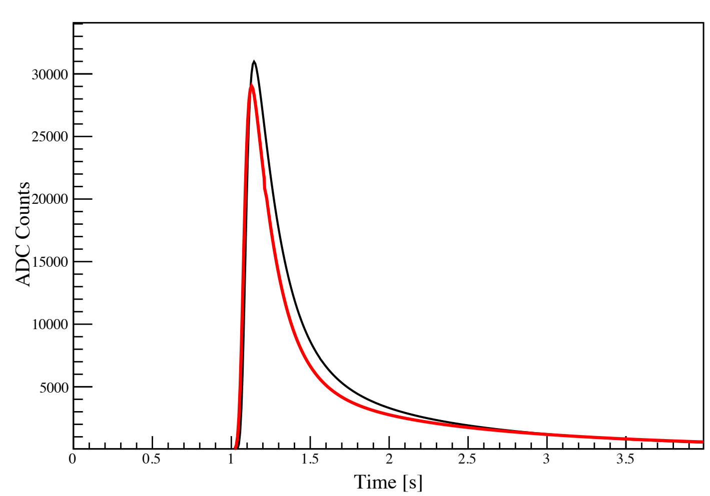
Average FWHM resolution @ 2615 keV :
~ 7.5 keV (5x5x5 cm^3 crystals)

Typical calibration spectra (^{232}Th)





Reproducibility of the detector performance



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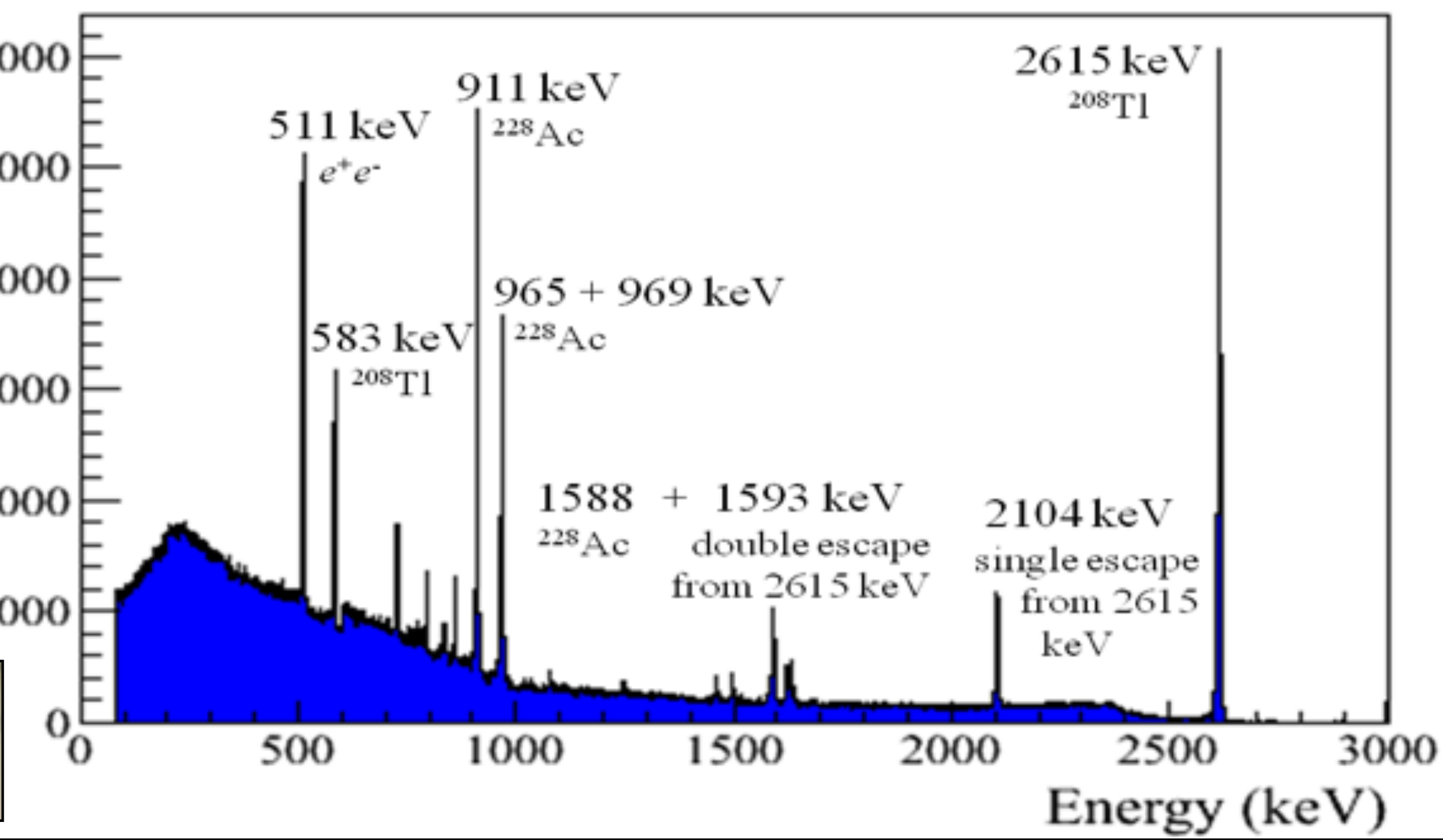

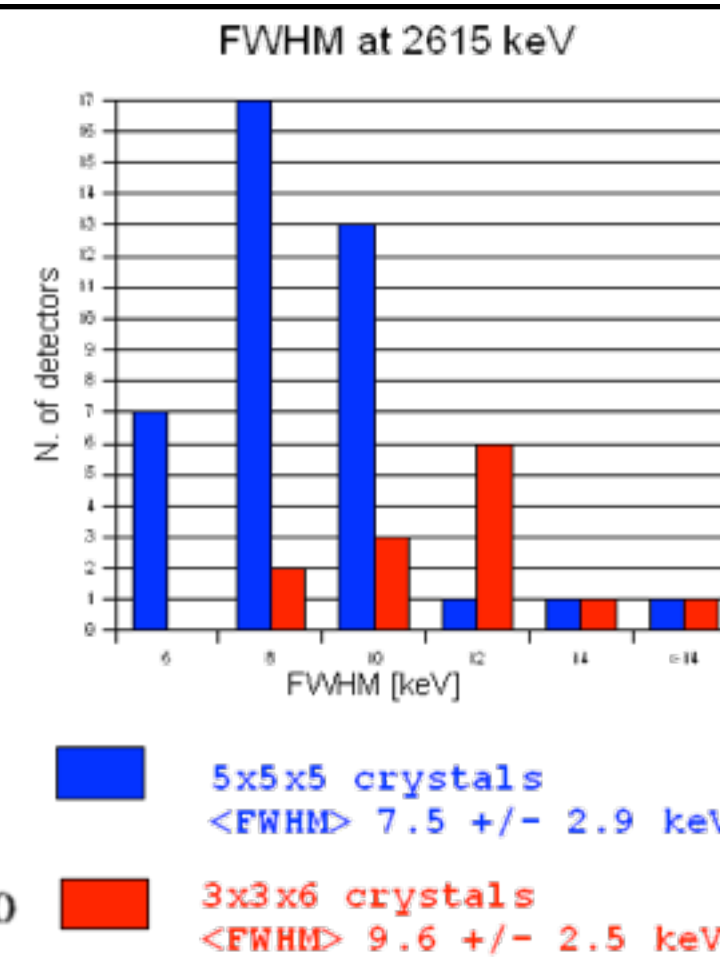

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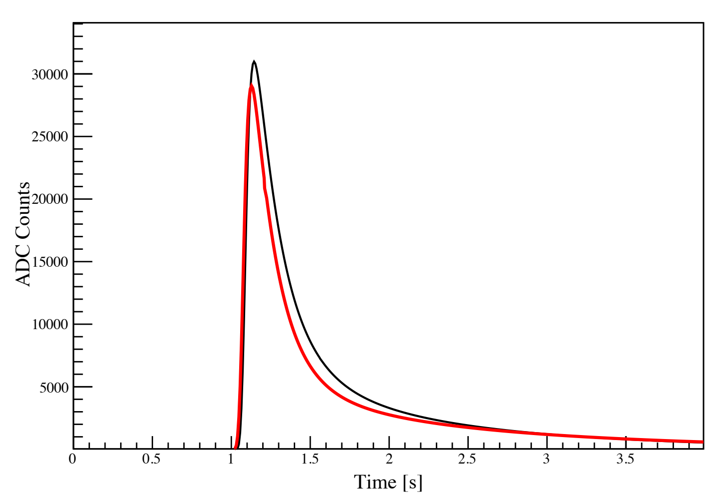
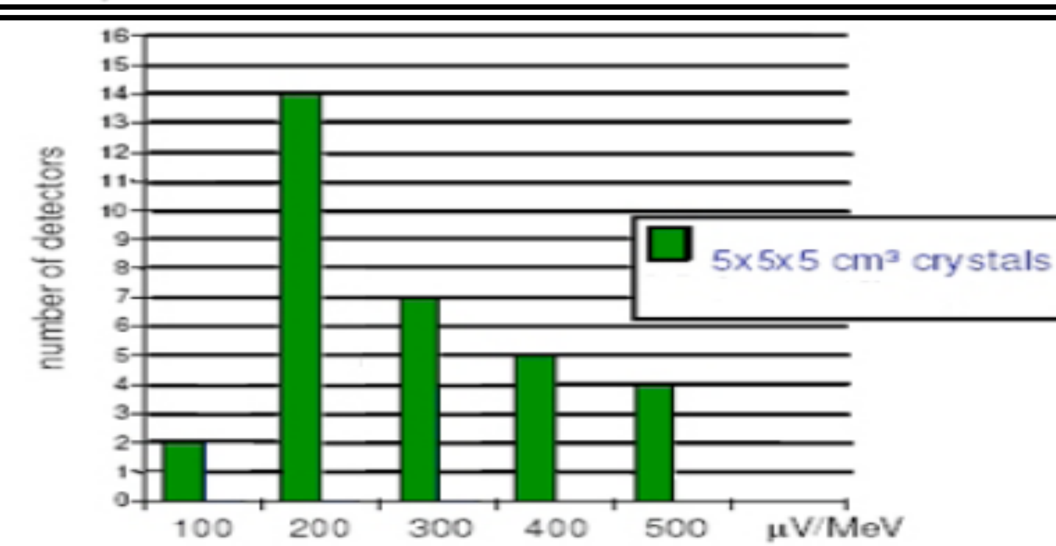
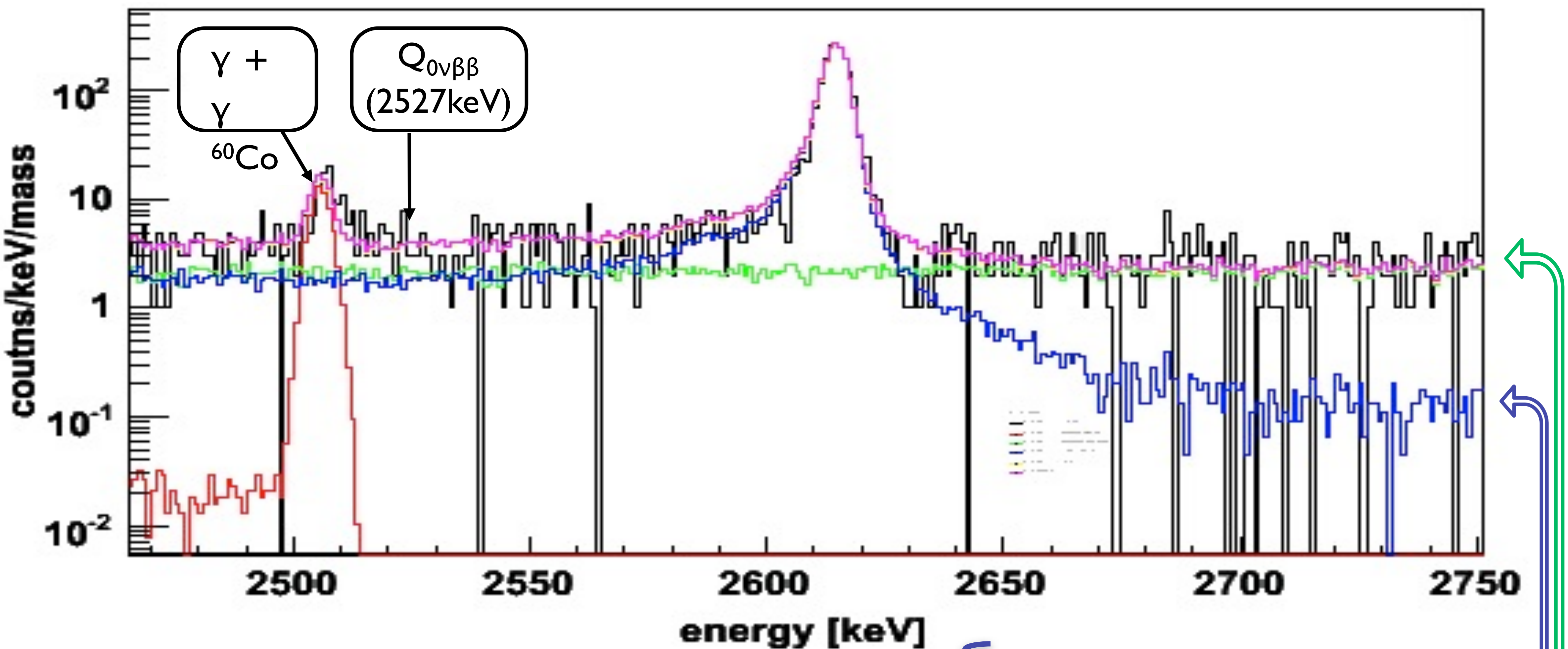




CUORICINO background

In the 0νDBD region:



Bkg @ 0νDBD region = 0.18±0.01 c/keV/kg/y (ainticoincidence spectrum, 5x5x5 cm^3 crystals)

30 ± 5 % ^{232}Th in cryostat (γ)

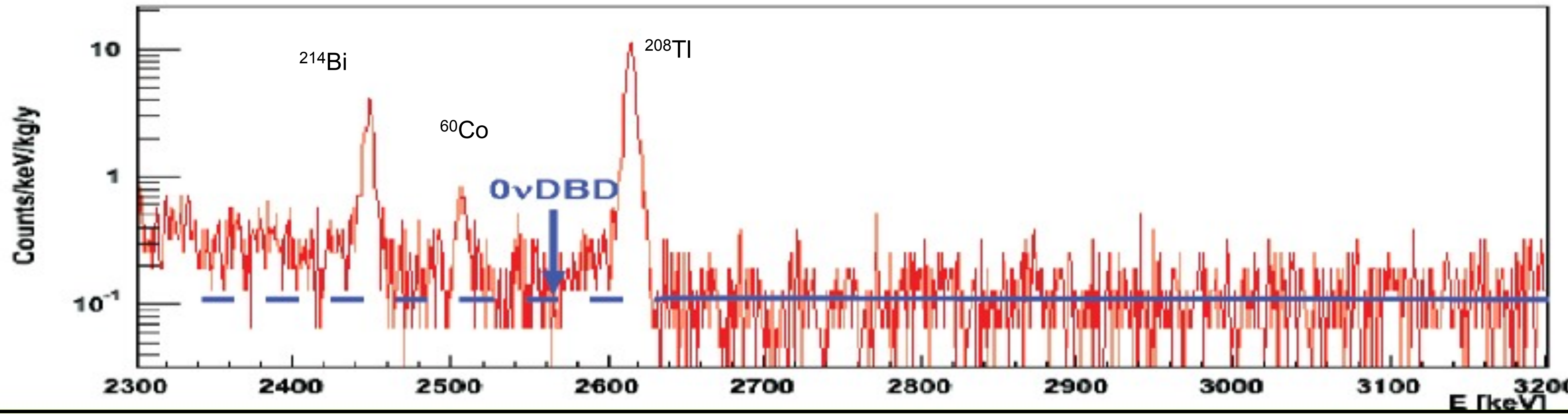
20 ± 5 % TeO_2 surface (α)

50 ± 10 % Cu surface (α)

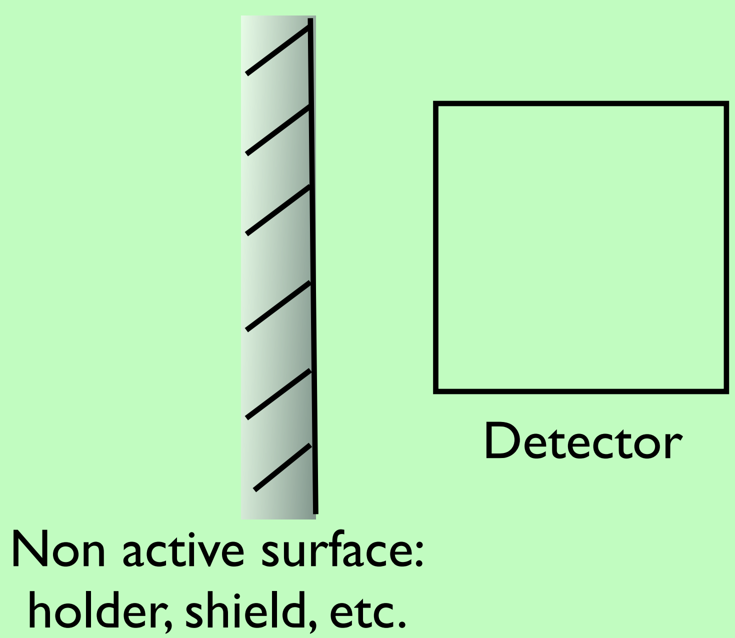
Flat background in the energy region above the ^{208}Tl 2615 keV line: contribution to the counting rate in the 0νDBD region: ~ 70% . Origin: degraded alpha particles.

Degraded alpha background

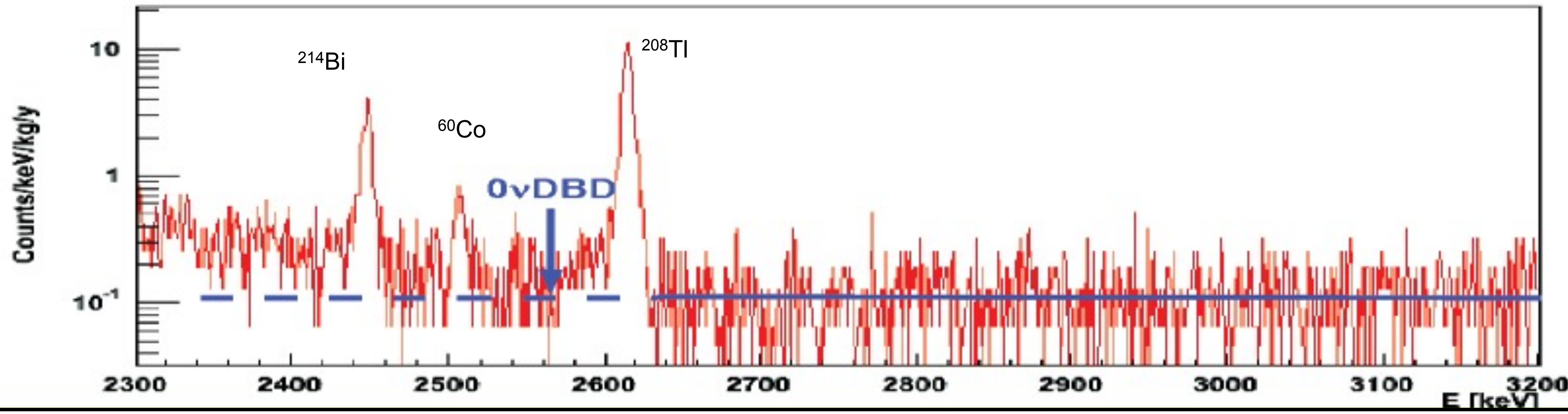
Degraded alpha background



A well know bkg source in DBD experiments are degraded α particles:



Degraded alpha background



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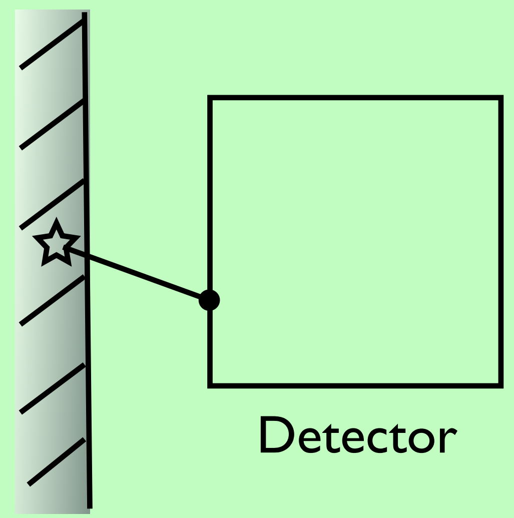
α produced near the surface will loose part of its energy in the material an part on the detector



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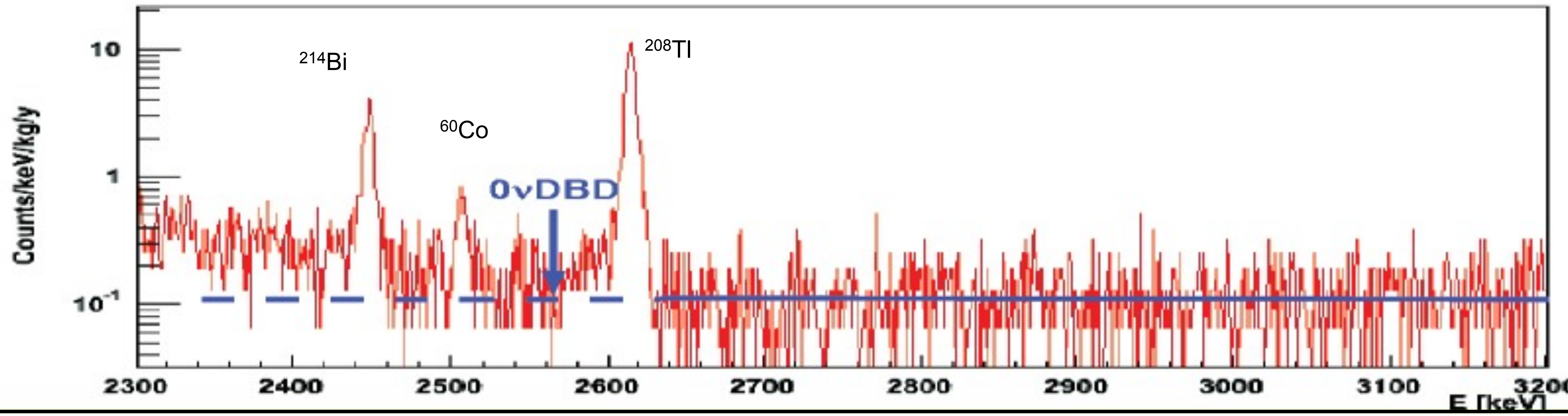

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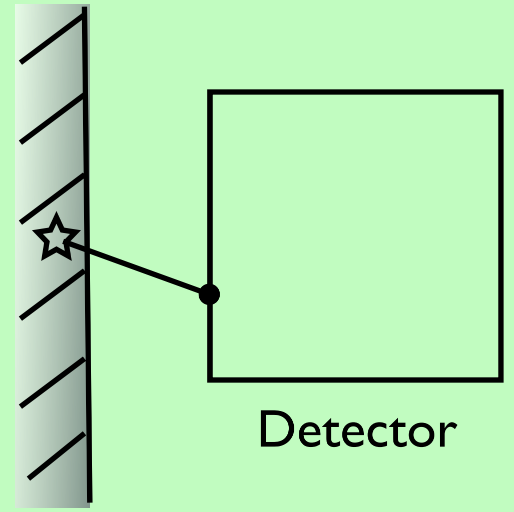


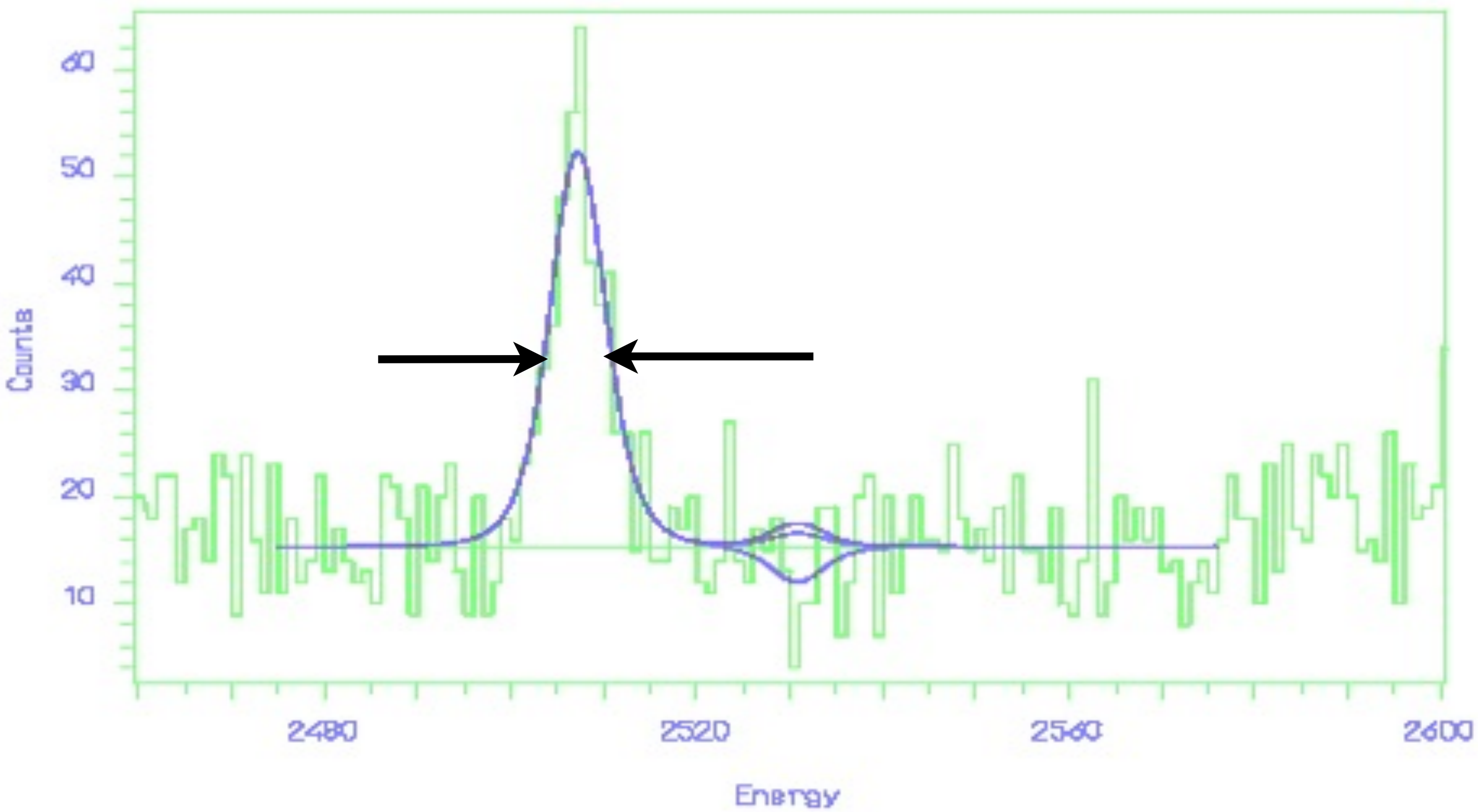
→ Continuum of events at all energies

CUORE R&D

- Detector behavior improvement:
    - Resolution
    - Reproducibility
- Degraded alpha background reduction:
    - TeO_2 crystals surface cleaning
    - Cu surface cleaning

Detector behavior

Detector behavior improvement



In CUORICINO the resolution (FWHM) is ~7.5 keV @ 2500 keV

Energy of the mediator (phonon) ~ 0.01 eV. We are far from intrinsic resolution. The broadening of the peak is dominated by other phenomena: thermal noise.

Thermal noise (Thermo-phononic noise): baseline fluctuation due to thermal energy (phonons) dissipations in the detector. Main source: mechanical vibrations converted in to heat via friction.

Sensitivity to noise: [resolution broadening]/[vibration intensity]

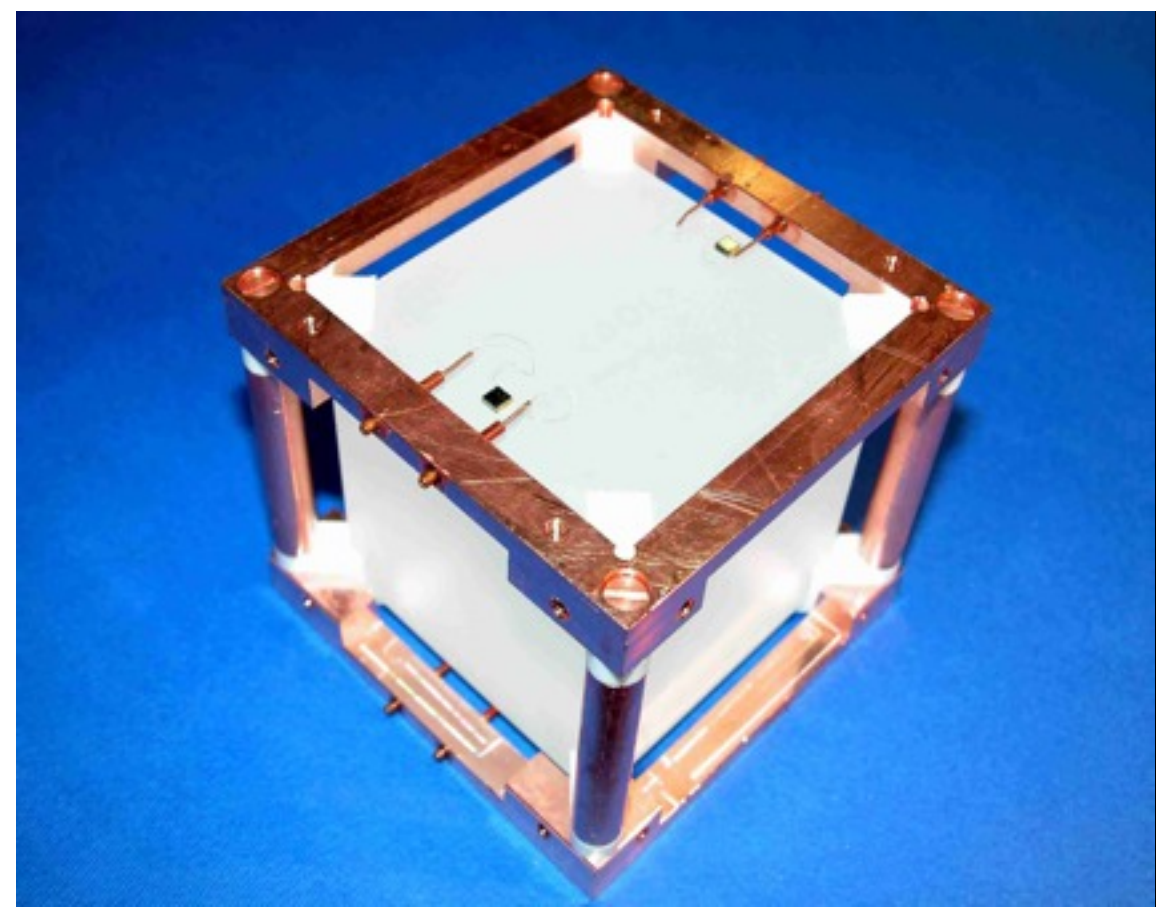
+

Intrinsic Thermal effects (ballistic phonons? position effects?)

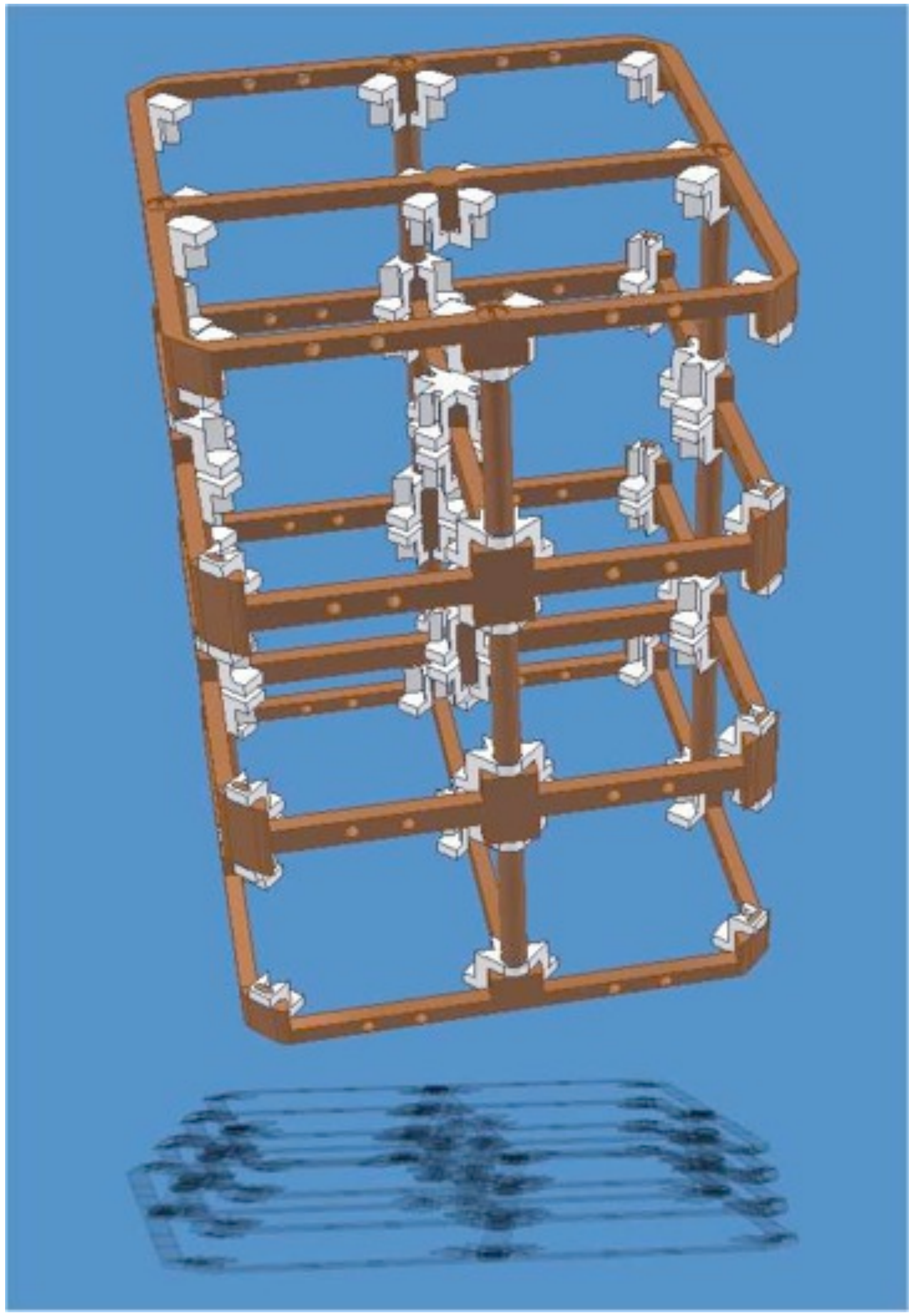
Goal: reduce sensitivity to noise

A new design

Studying the thermal contraction of the different materials and their elasticity (Young module) a new prototype of copper and PTFE supports was designed to minimize the possibility of relative movements of the different parts (friction).



Results



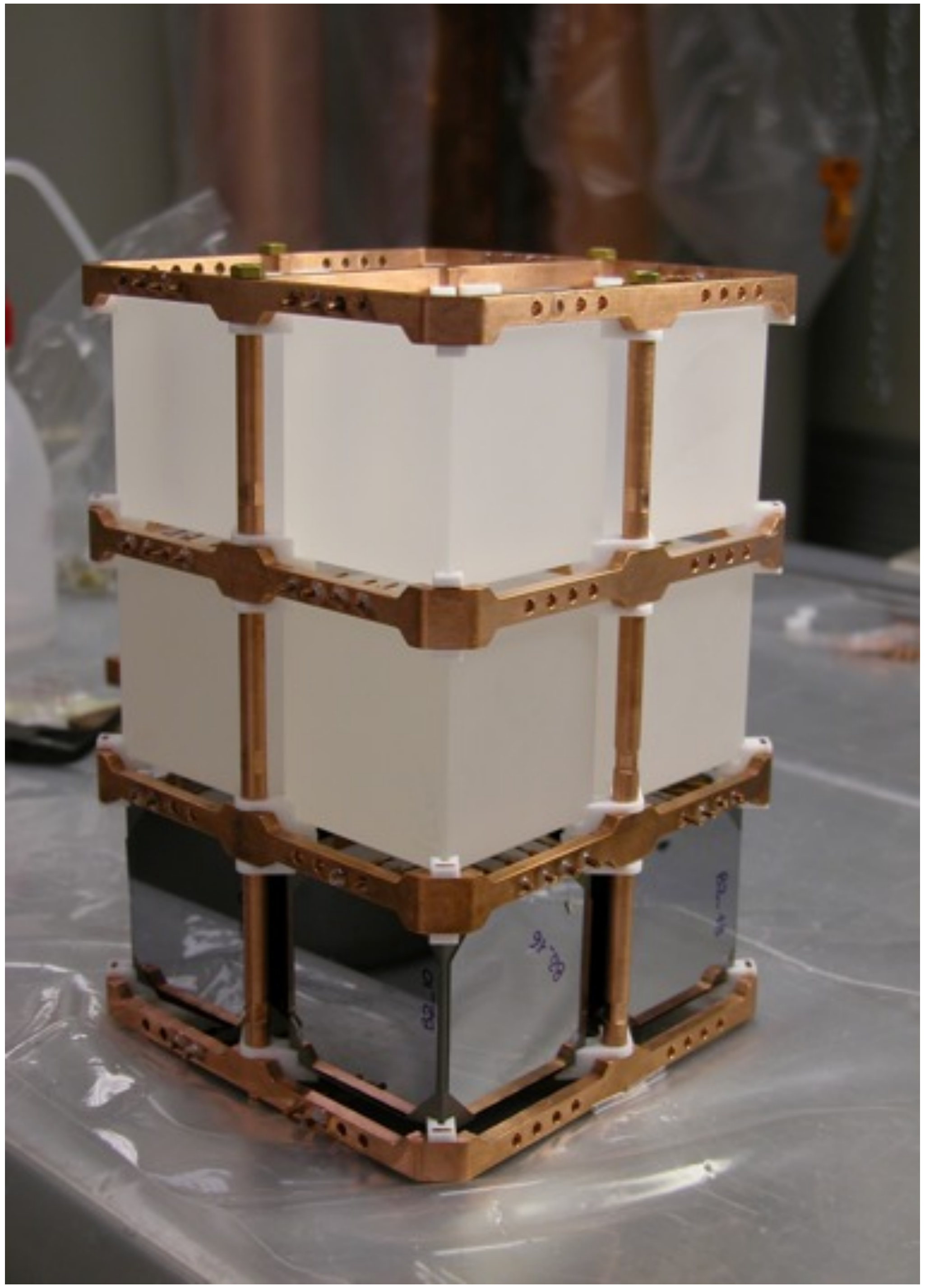
A three floor tower was projected and designed, in a way that at least 1 floor is in a tower-like situation.

ΔE_{ave} = 5.7 +/- 1.0 keV

$\Delta E_{CUORICINO}$ = 7.5 +/- 2.8 keV

This result was confirmed in other 4 12-detectors tests and the new setup was adopted by the collaboration

Results



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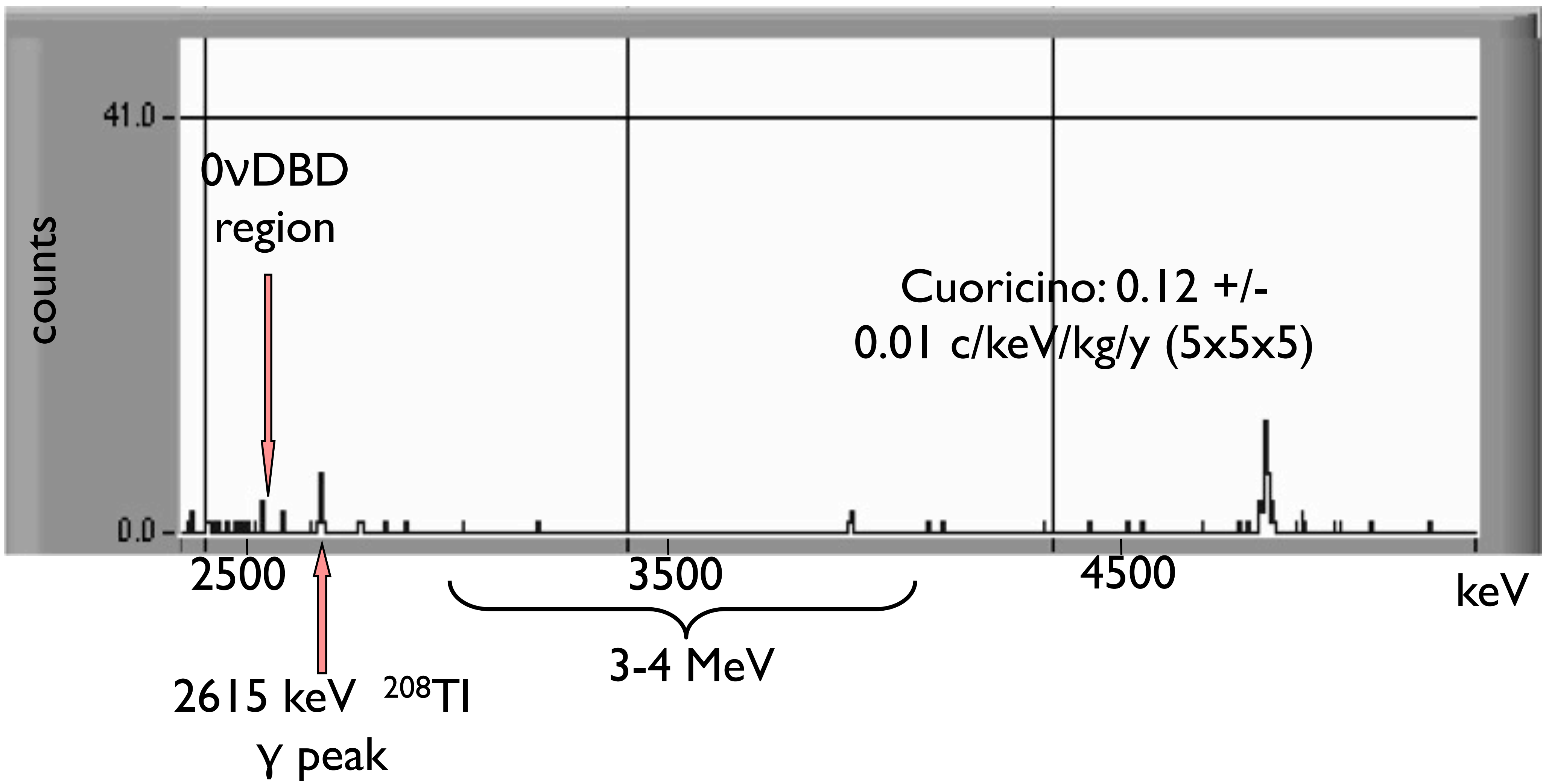
Background reduction

Estimation method

Measuring very low background in the 0νDBD region (100 keV) will need extremely long measurements: to measure 0.01 c/keV/kg/y with an accuracy of 10% it will take years. Since the continuous background is the same above 2615 keV we can estimate it in that wider region



~ 3 counts/day on 10 Kg detector for the CUORICINO bkg, but we want to measure 10 times less

A big background reduction in this region will confirm our capability to reduce the background in the DBD0ν region

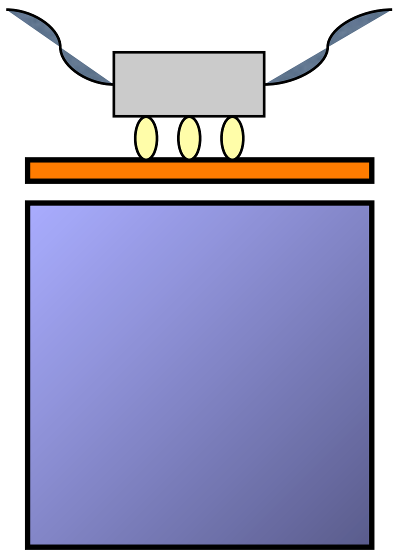
Crystal cleaning

Two different approaches:

Crystal cleaning

Two different approaches:

① Crystal etching with ultra pure Nitric acid: the acid remove the contaminants but leave a layer of molecules that generates a thermal interface between crystal and thermistor. → Irreproducible pulse shapes, bad behavior.



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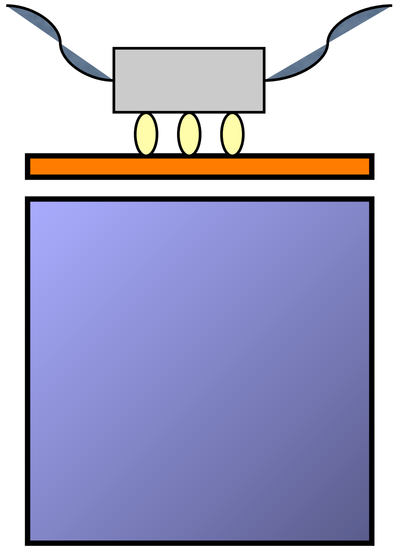

② Lapping crystals with 2μ SiO_2 radio-pure powder does not leave material on the surface, but mechanically acting part of the contaminants are re-implanted in the crystal (a few μ).

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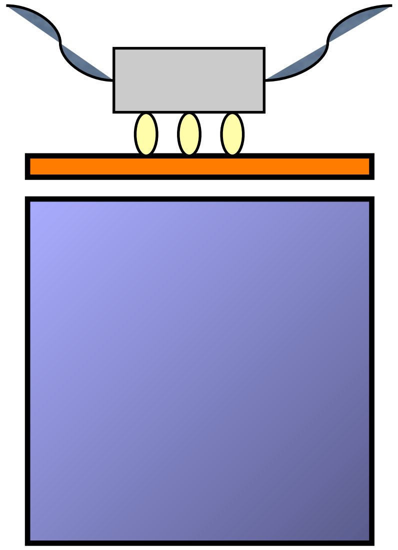

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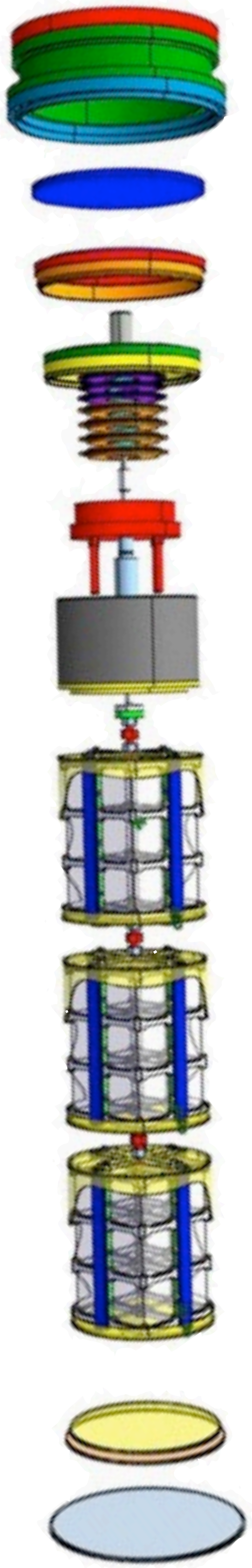
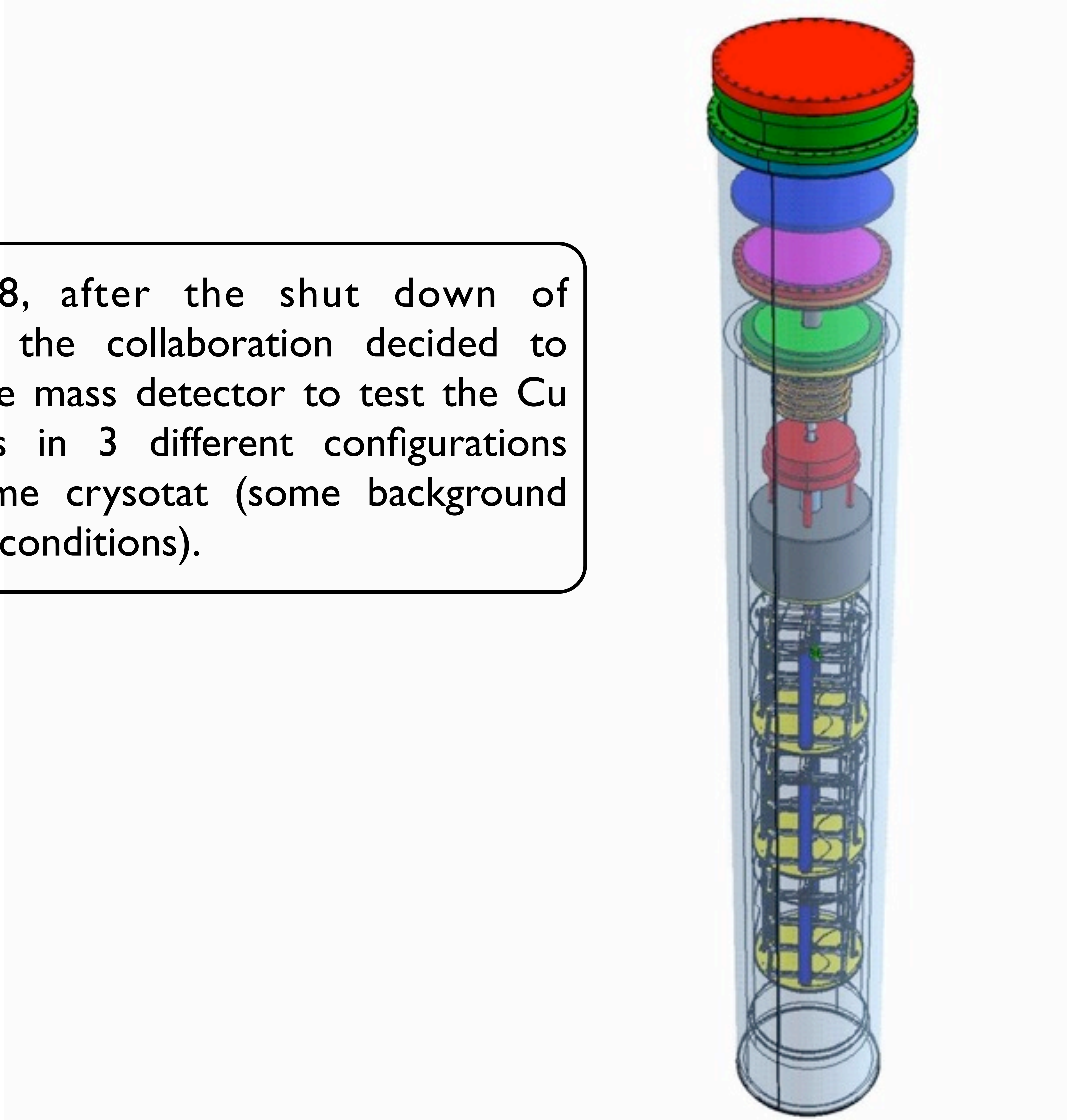
Combining the two approaches we obtained clean crystal without thermal conduction limitations.

A final test: the three towers

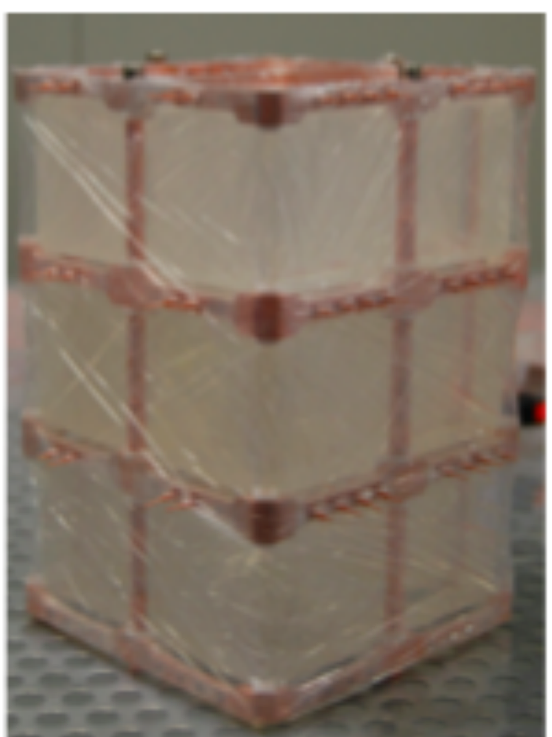


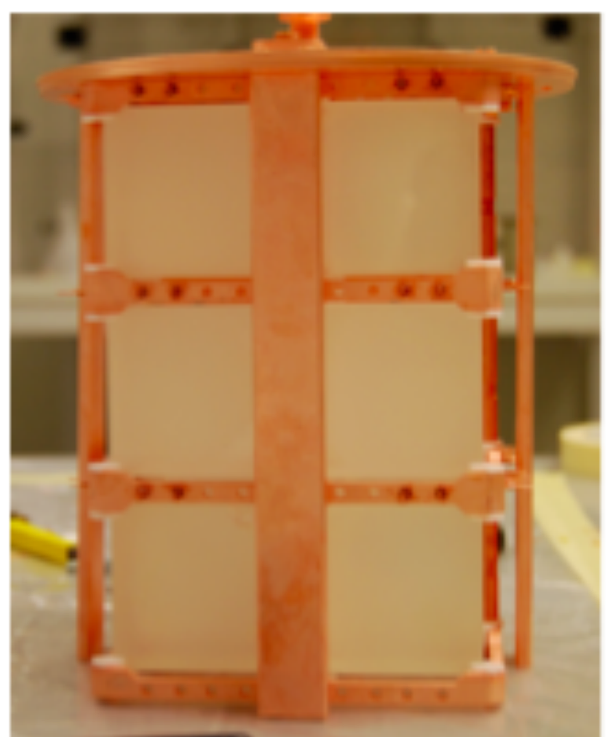
In June 2008, after the shut down of CUORICINO, the collaboration decided to prepare a large mass detector to test the Cu contaminations in 3 different configurations inside the same crysotat (some background and operation conditions).

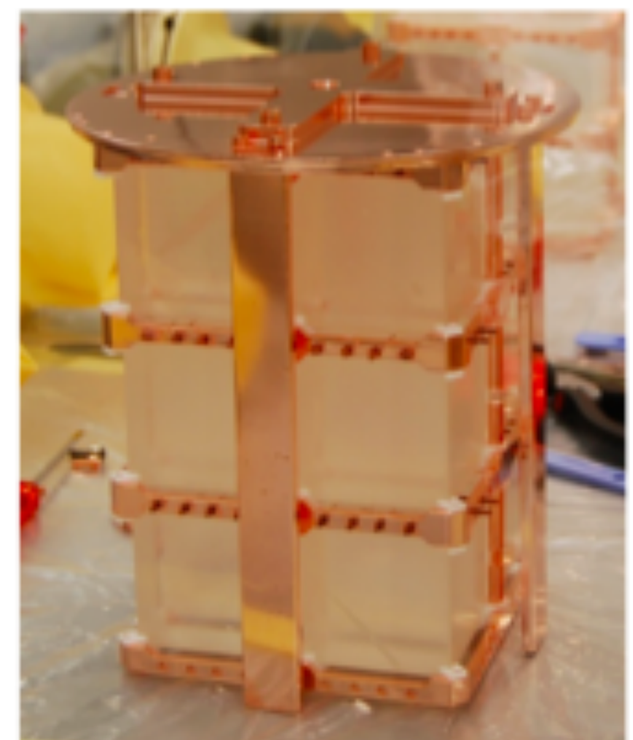


The three towers (I)

T1	T2	T3
Polyethylene Cleaning: • Soap • H_2O_2 + H_2O + Citric acid Polyethylene: 7 layers Complete coverage	Chemical New Cleaning: • Soap • Electro erosion: 85% phosphoric acid, 5% butanol, 10% H_2O • Etching: Nitric acid •Passivation: H_2O_2 + H_2O + Citric acid	Plasma cleaning Chemical and electrochemical + plasma cleaning







The three towers (II)

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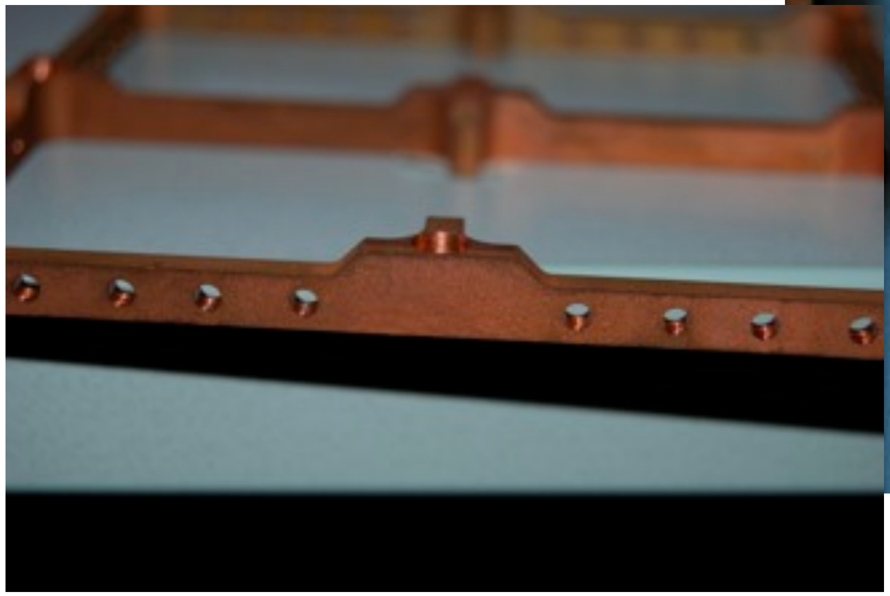

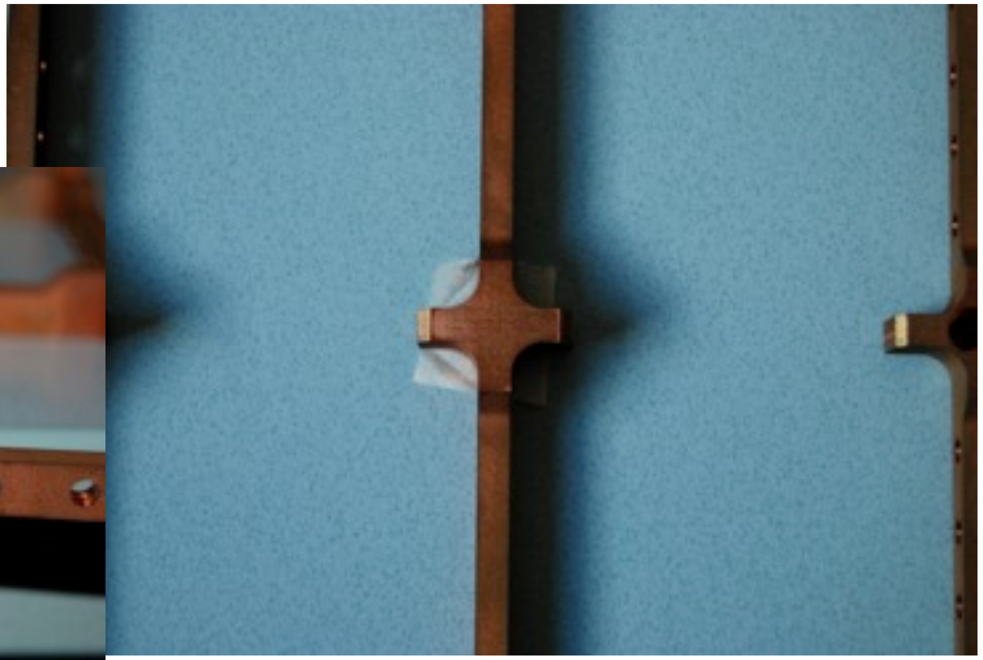

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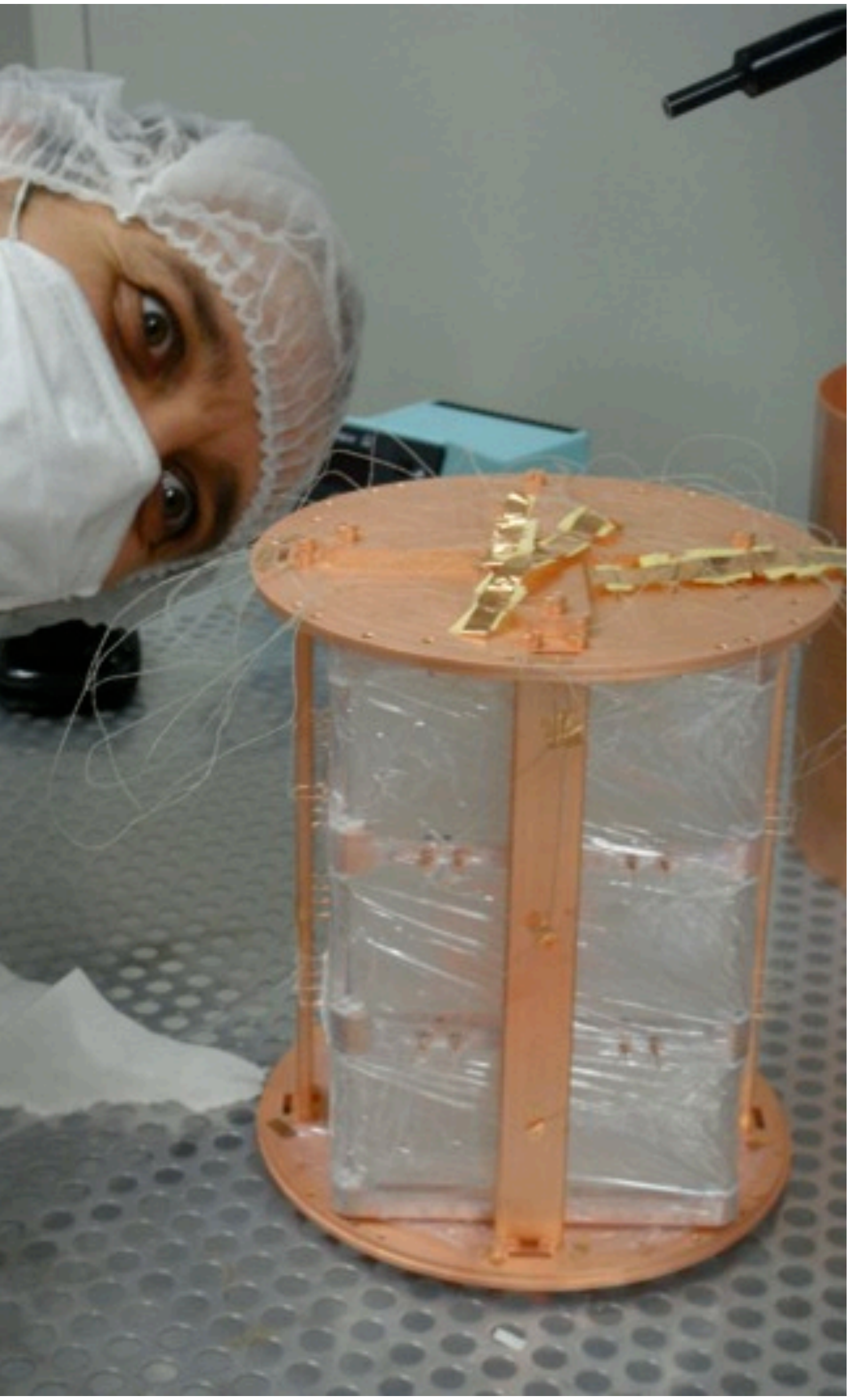

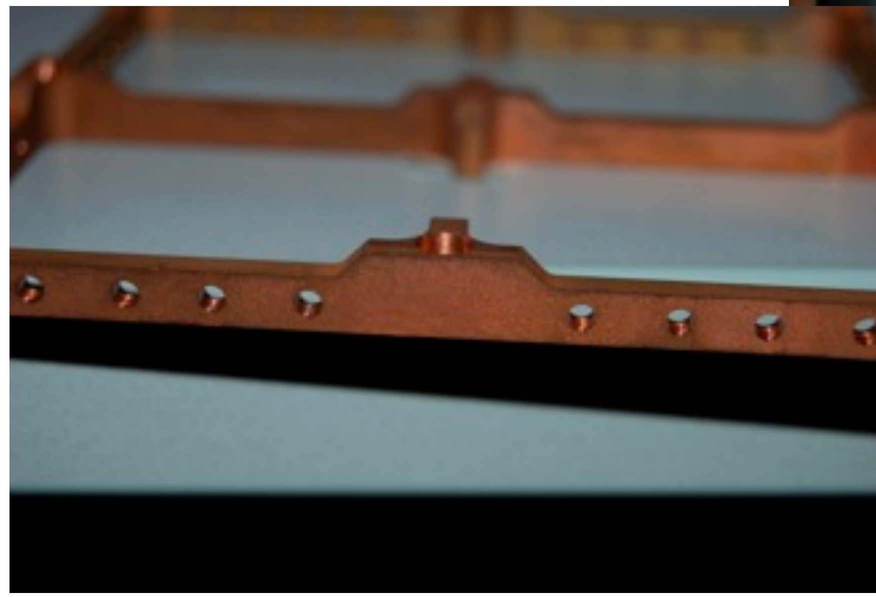

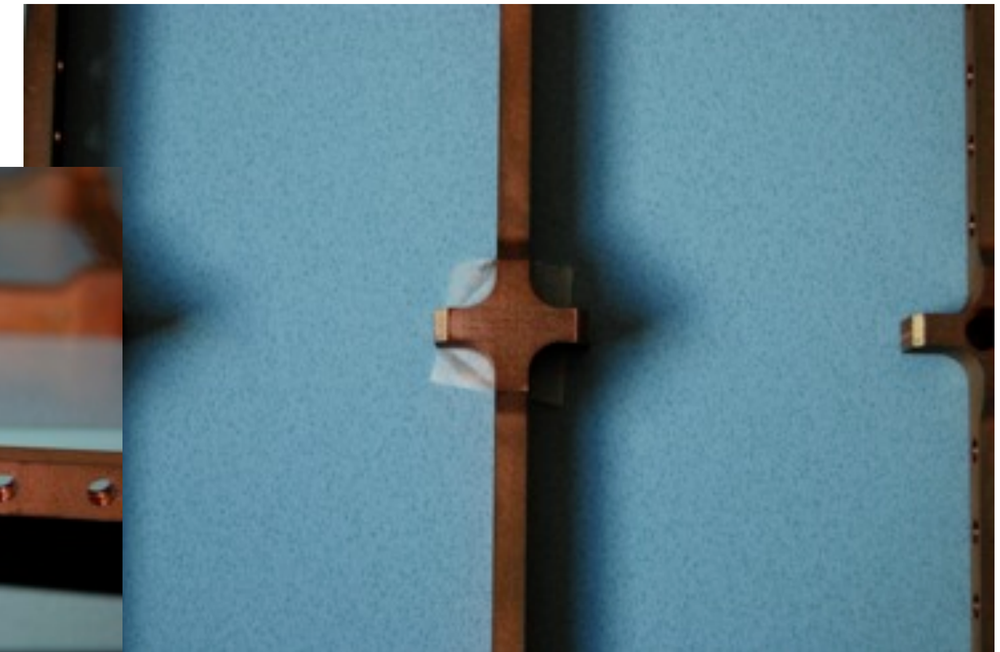

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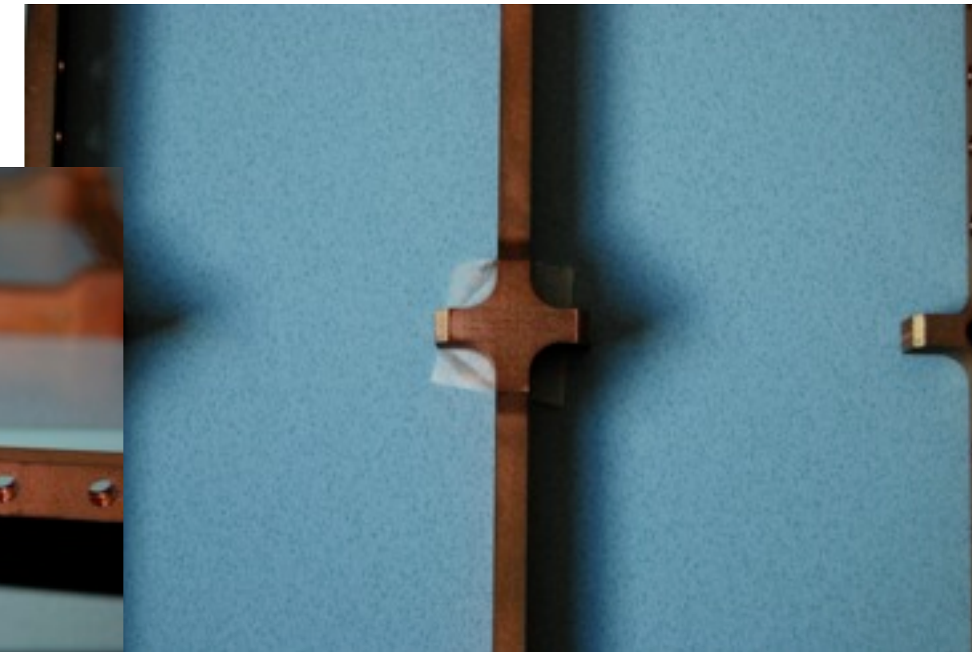

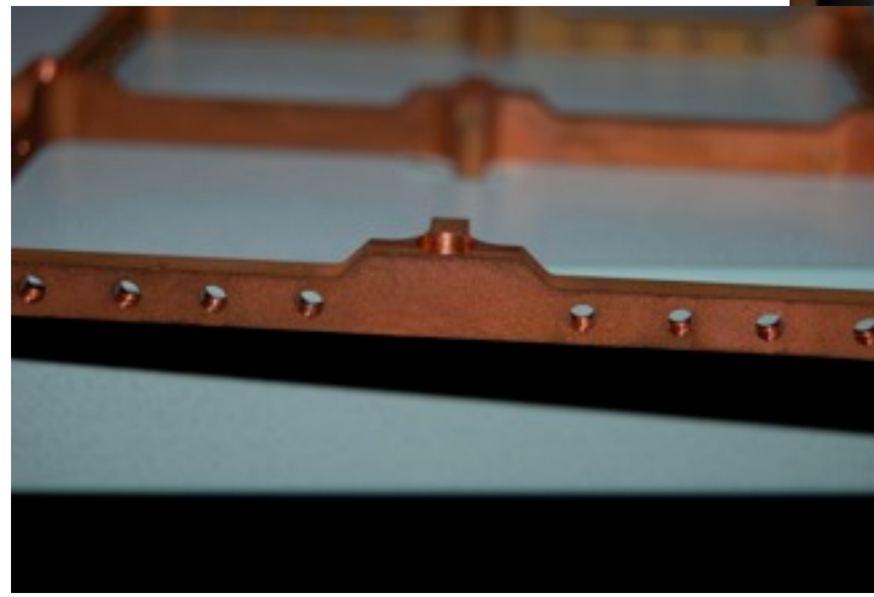

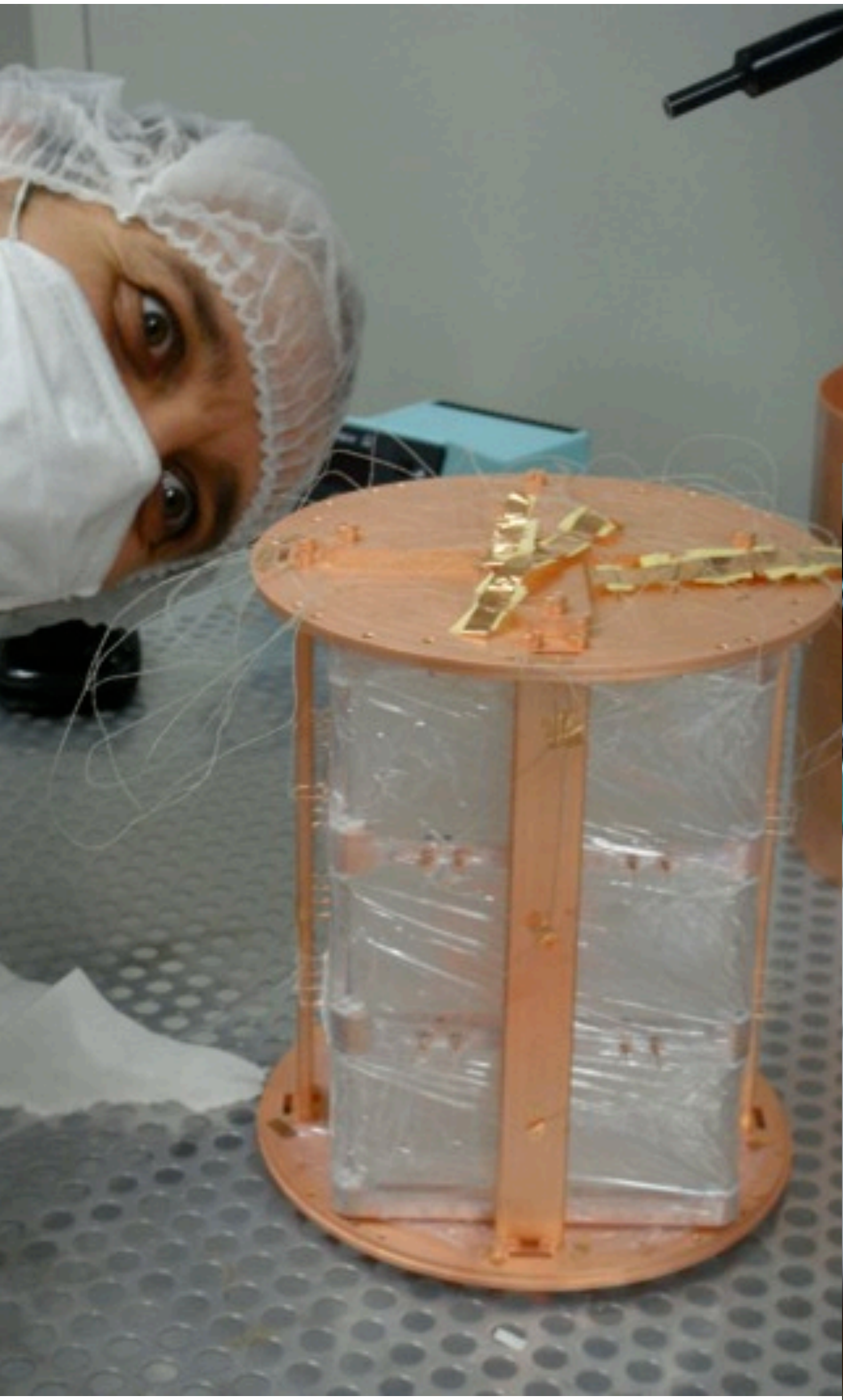

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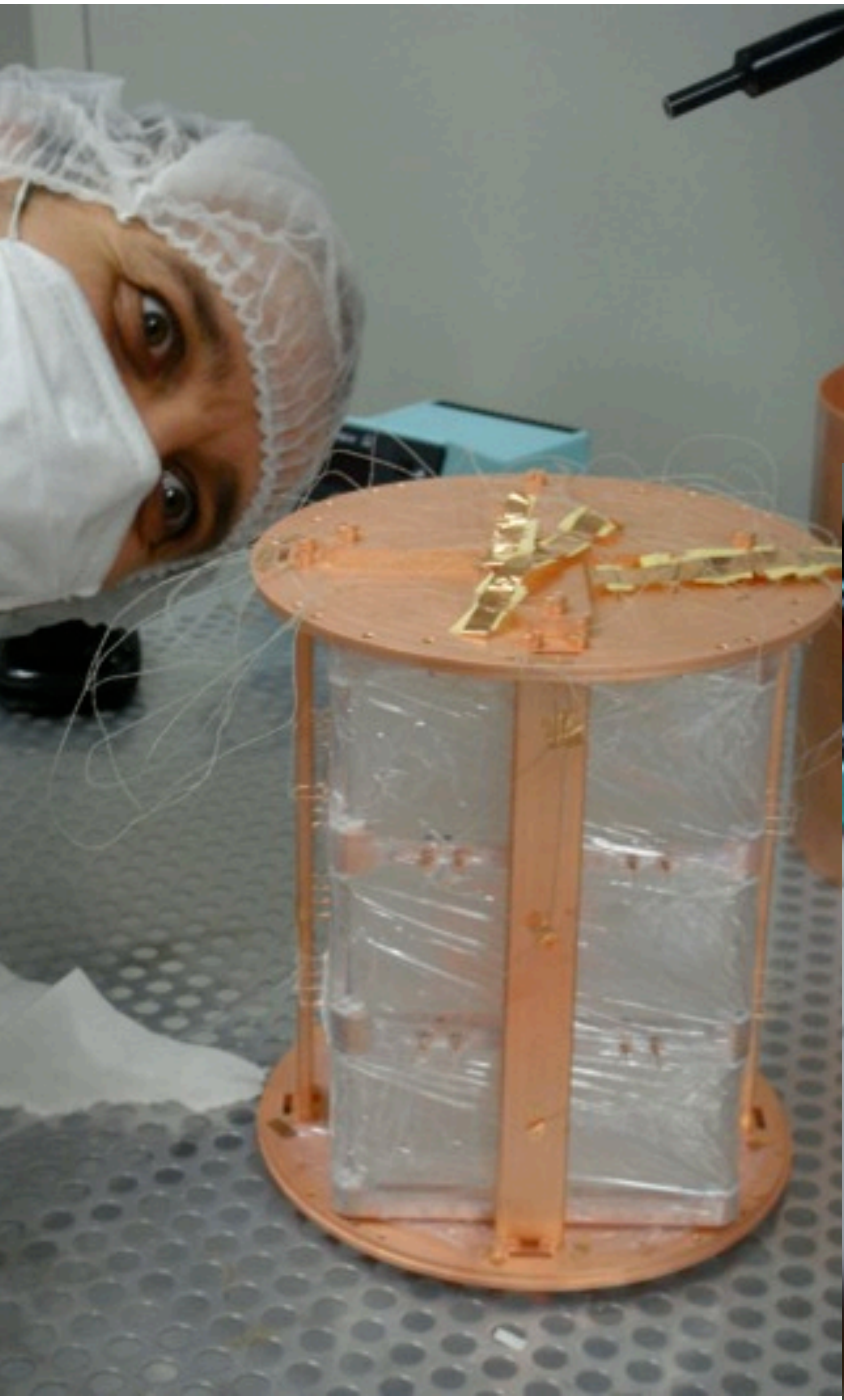

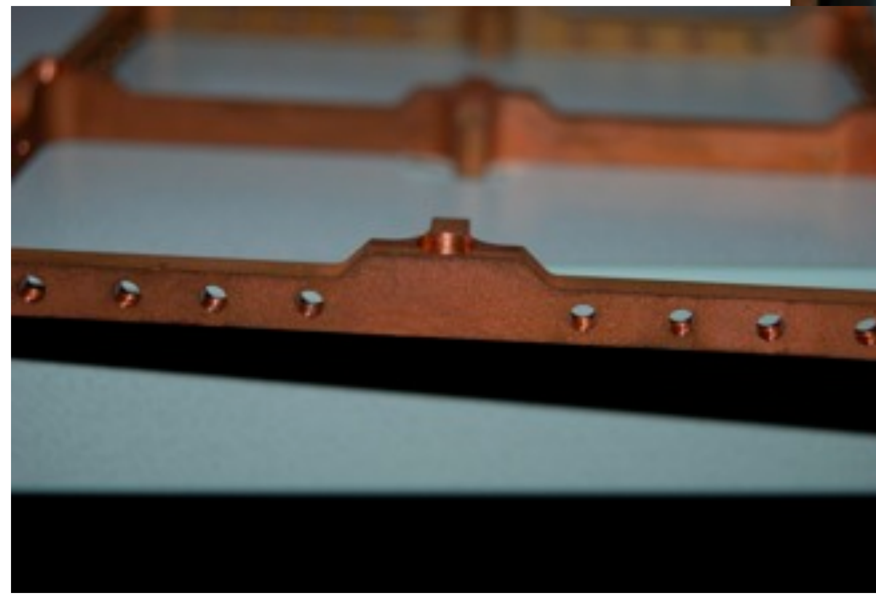

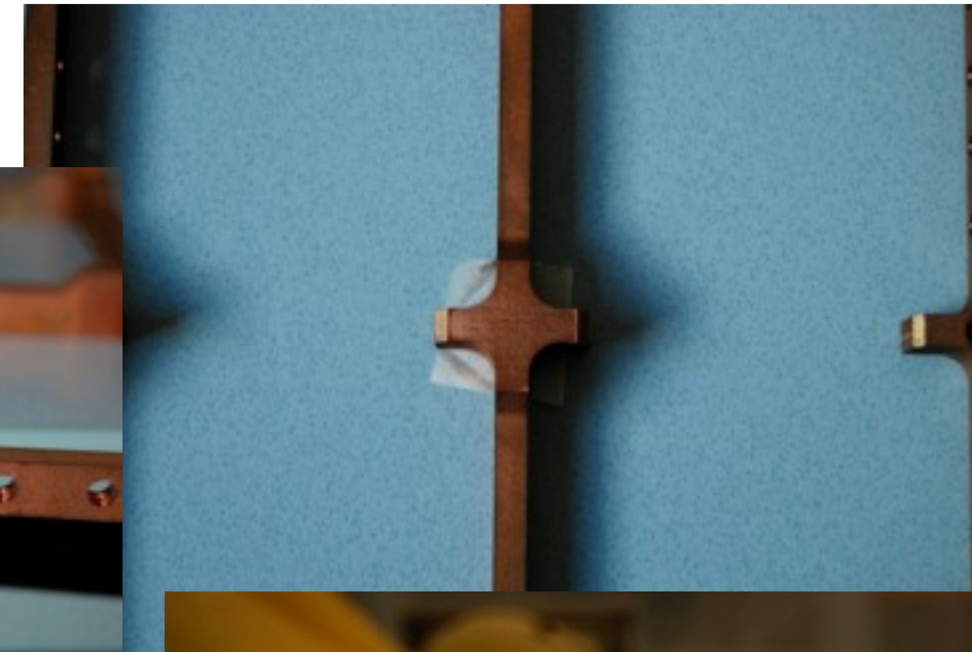

The three towers (III)

T3T is a Rn suppressed
test

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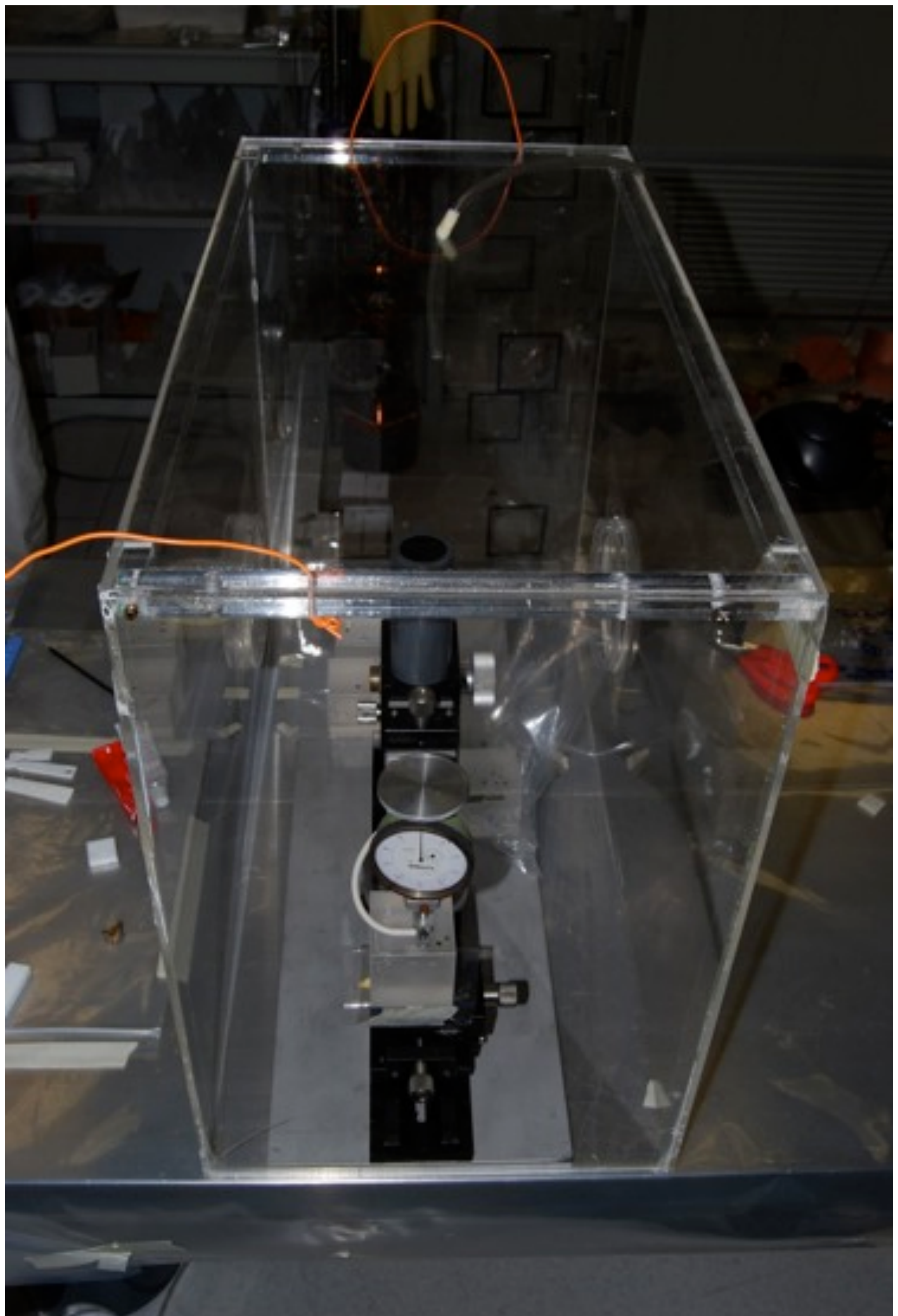

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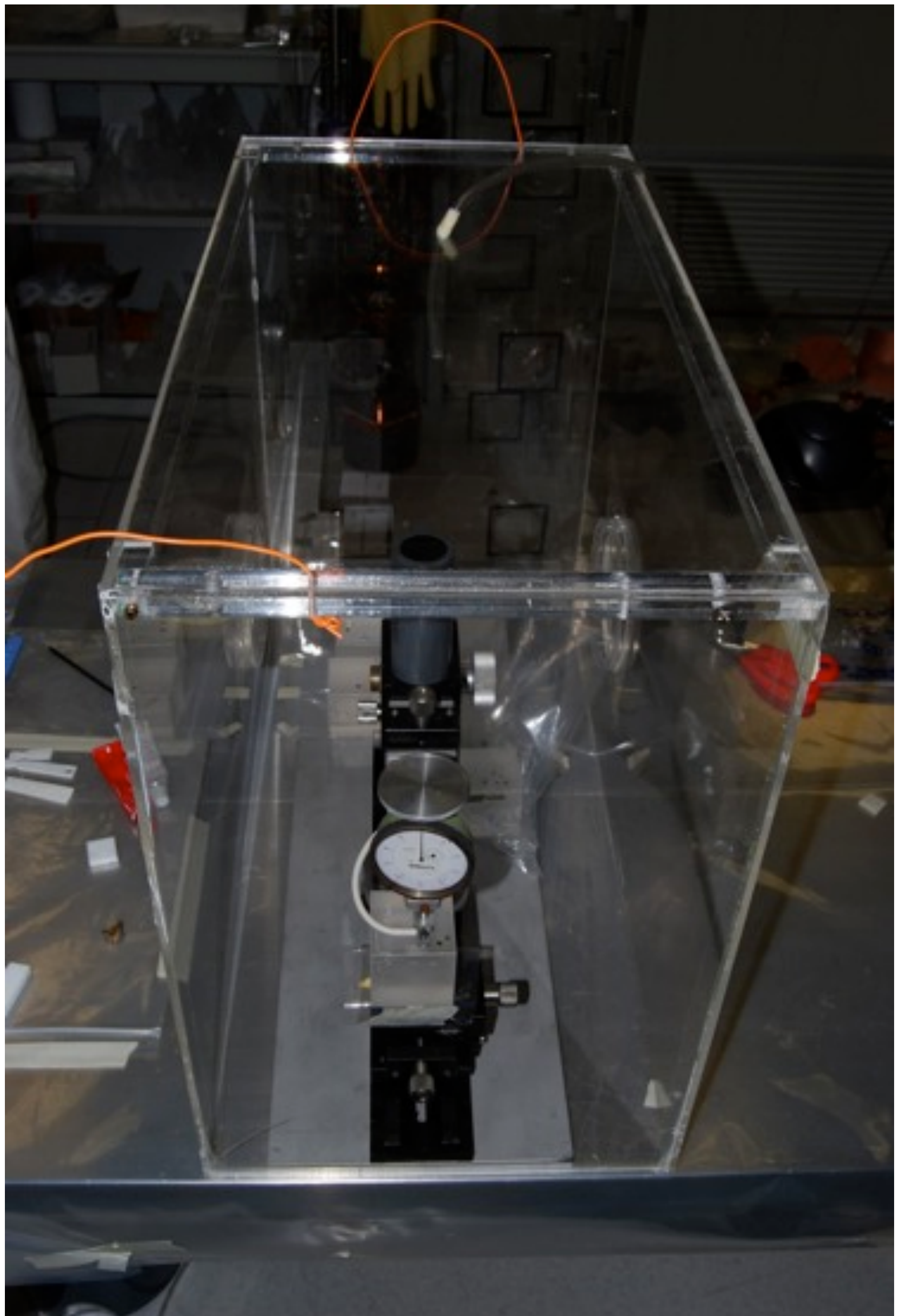

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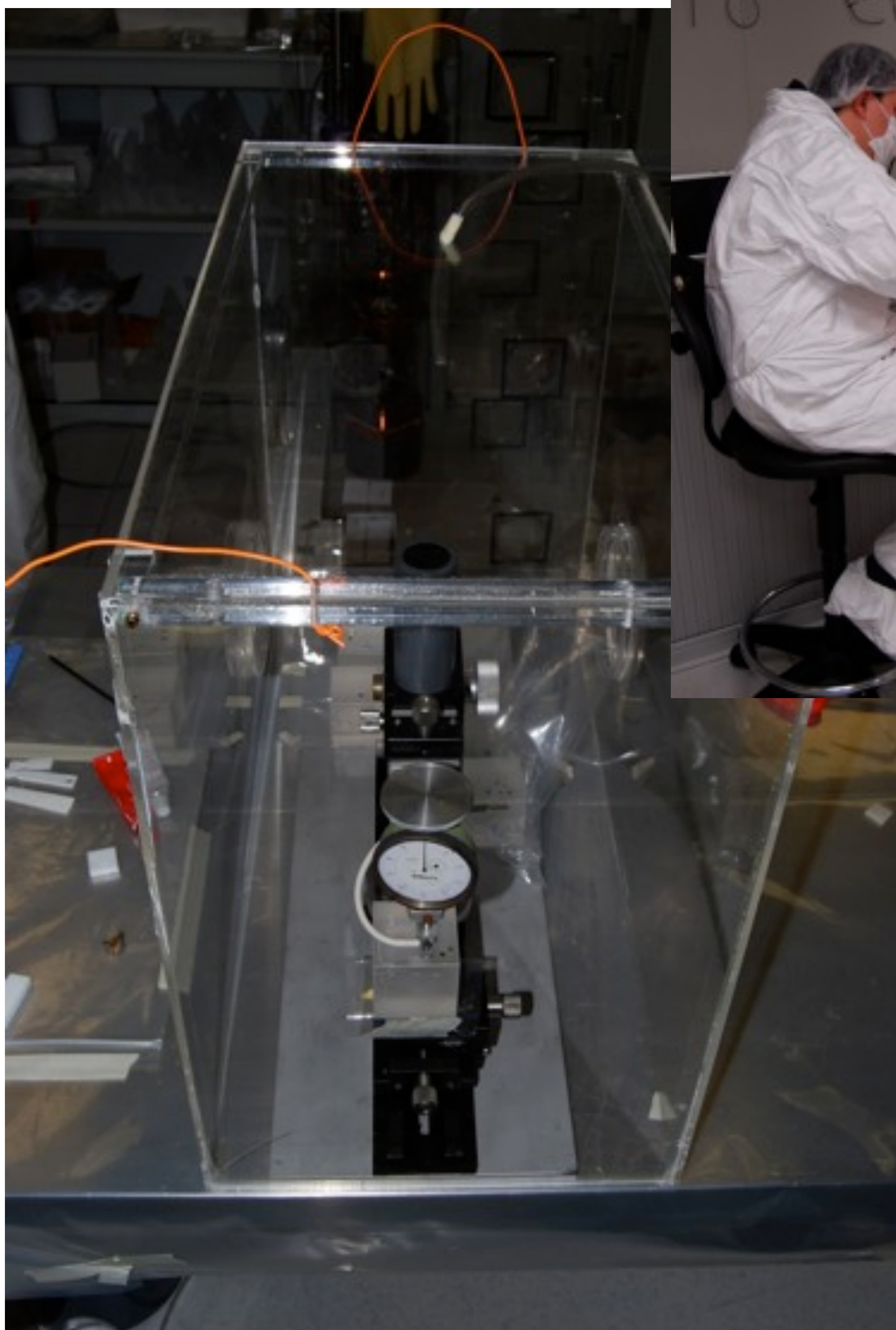

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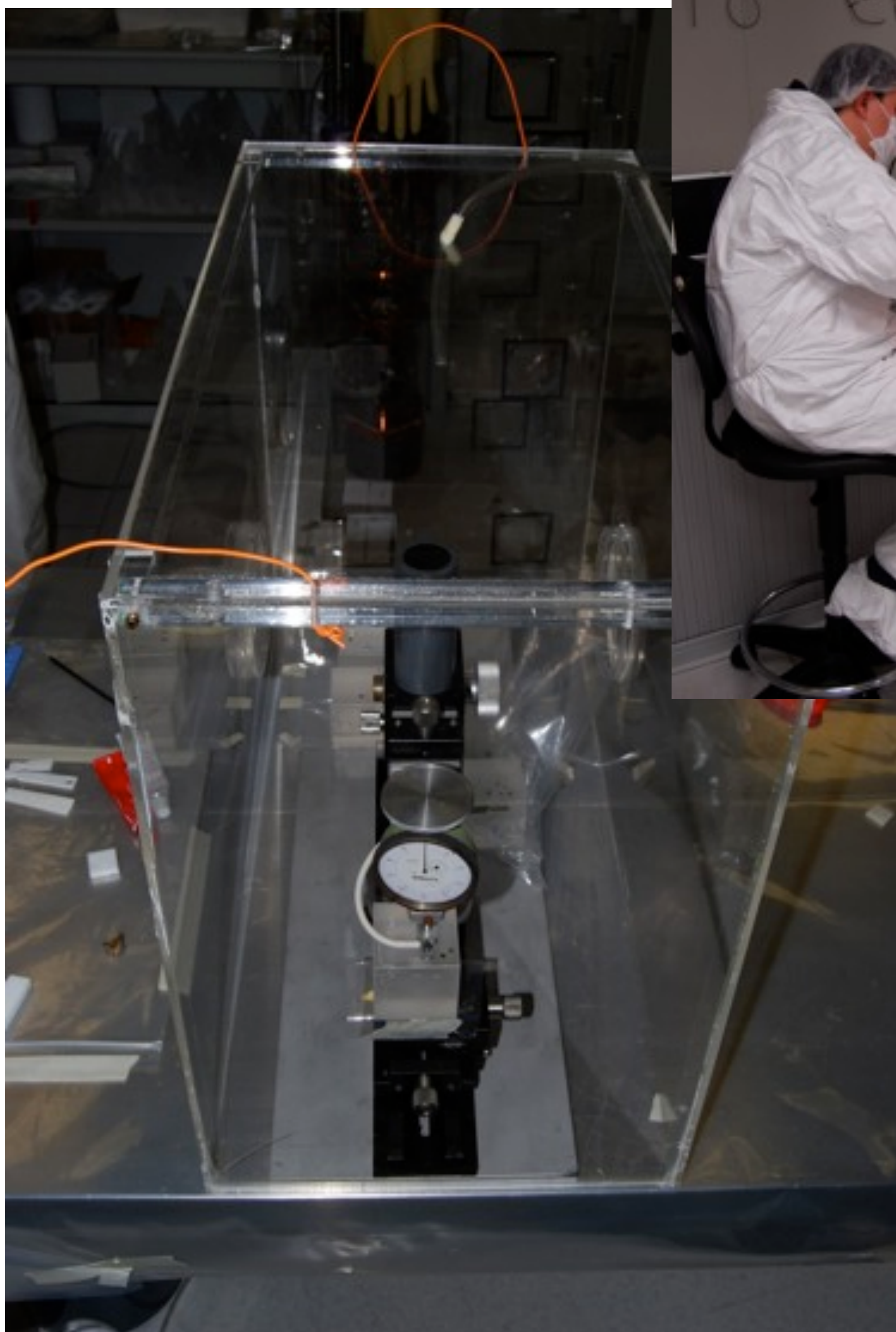

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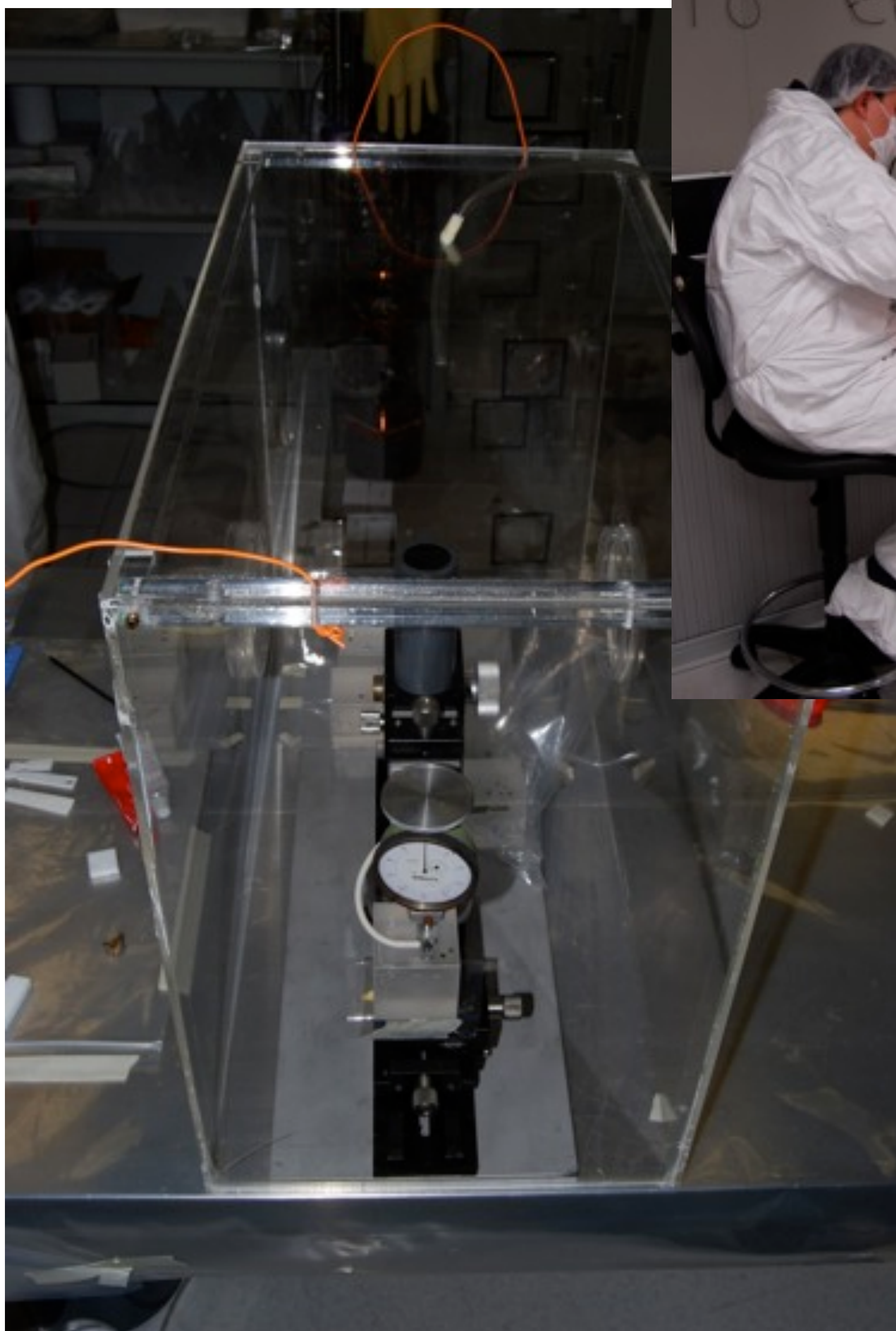
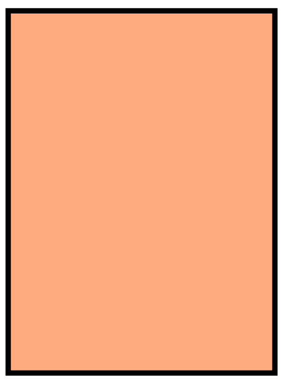
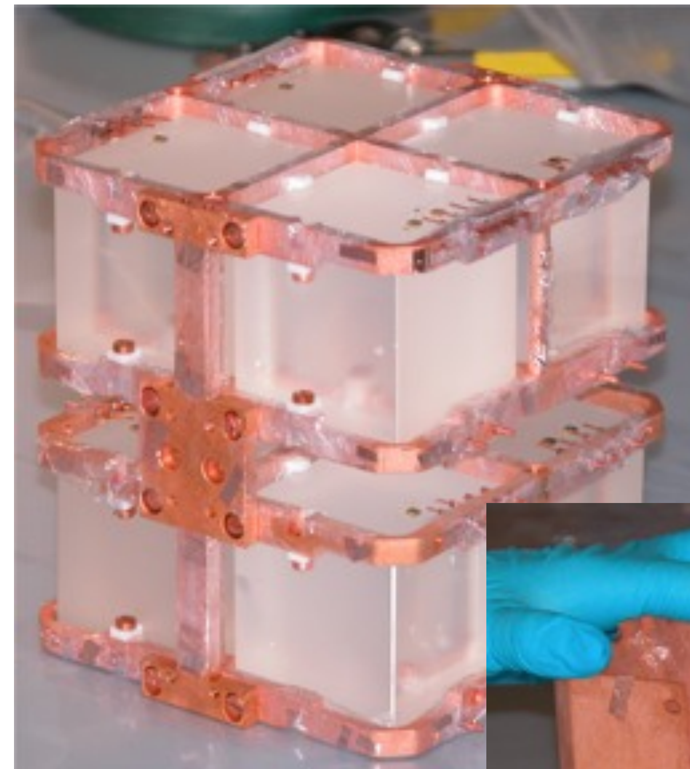


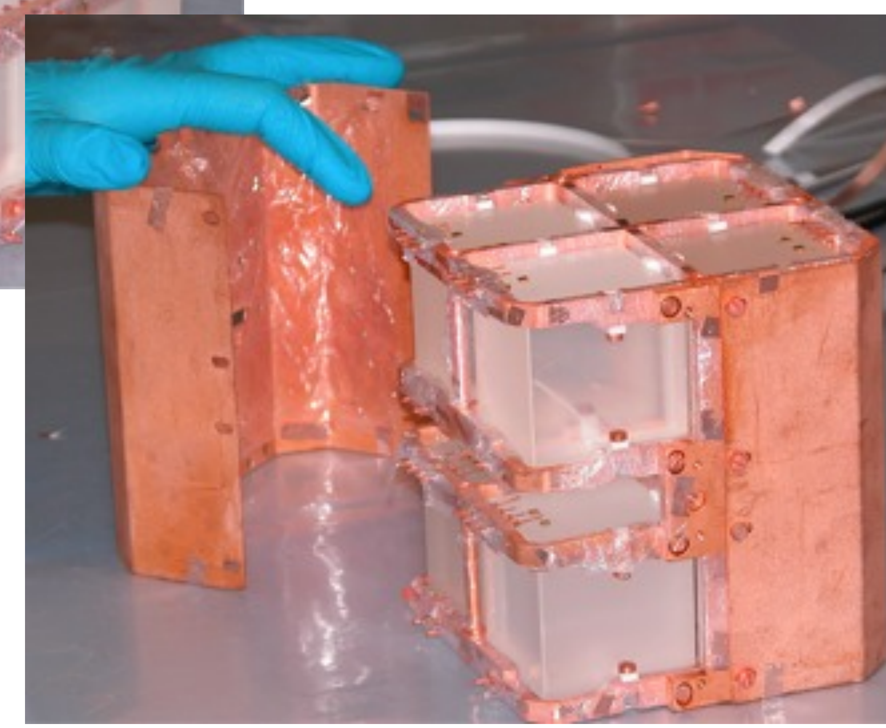
Total air exposure: less than 2 days

The polyethylene

Copper completely covered by a polyethylene foil to shield alpha particles







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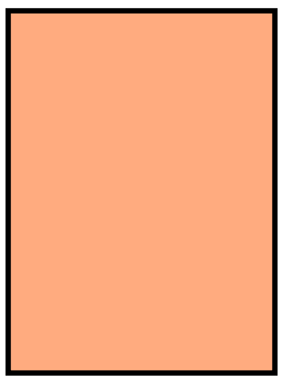

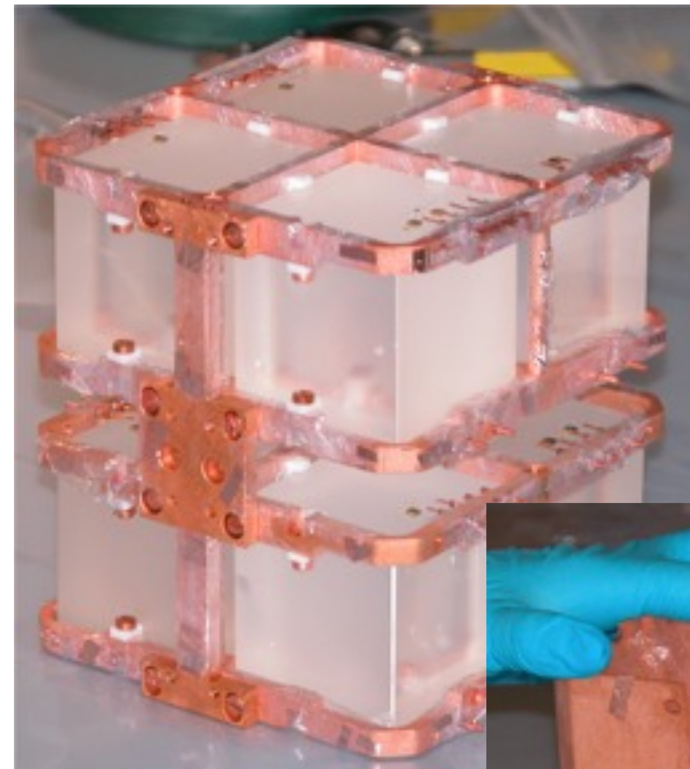

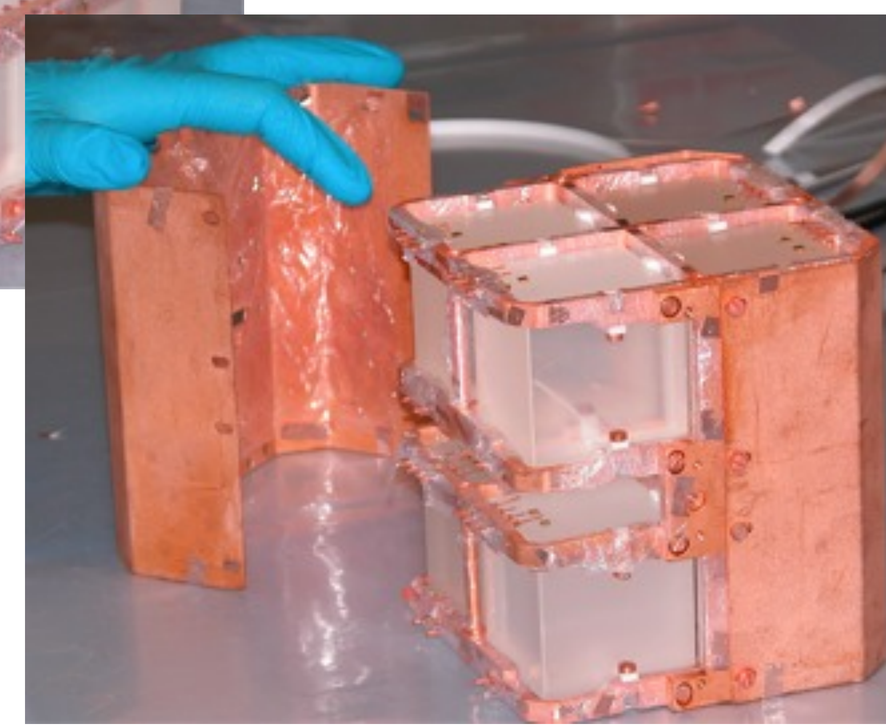

Measuring contamination from a Cu sample the Surface to Volume ration (S/V) is very small. With standard detectors (HPGe) is difficult/impossible to see these contaminations. For the 12 µm polyethylene foil S/V is in favor of S so the HPGe measurement is a surface contamination measurement

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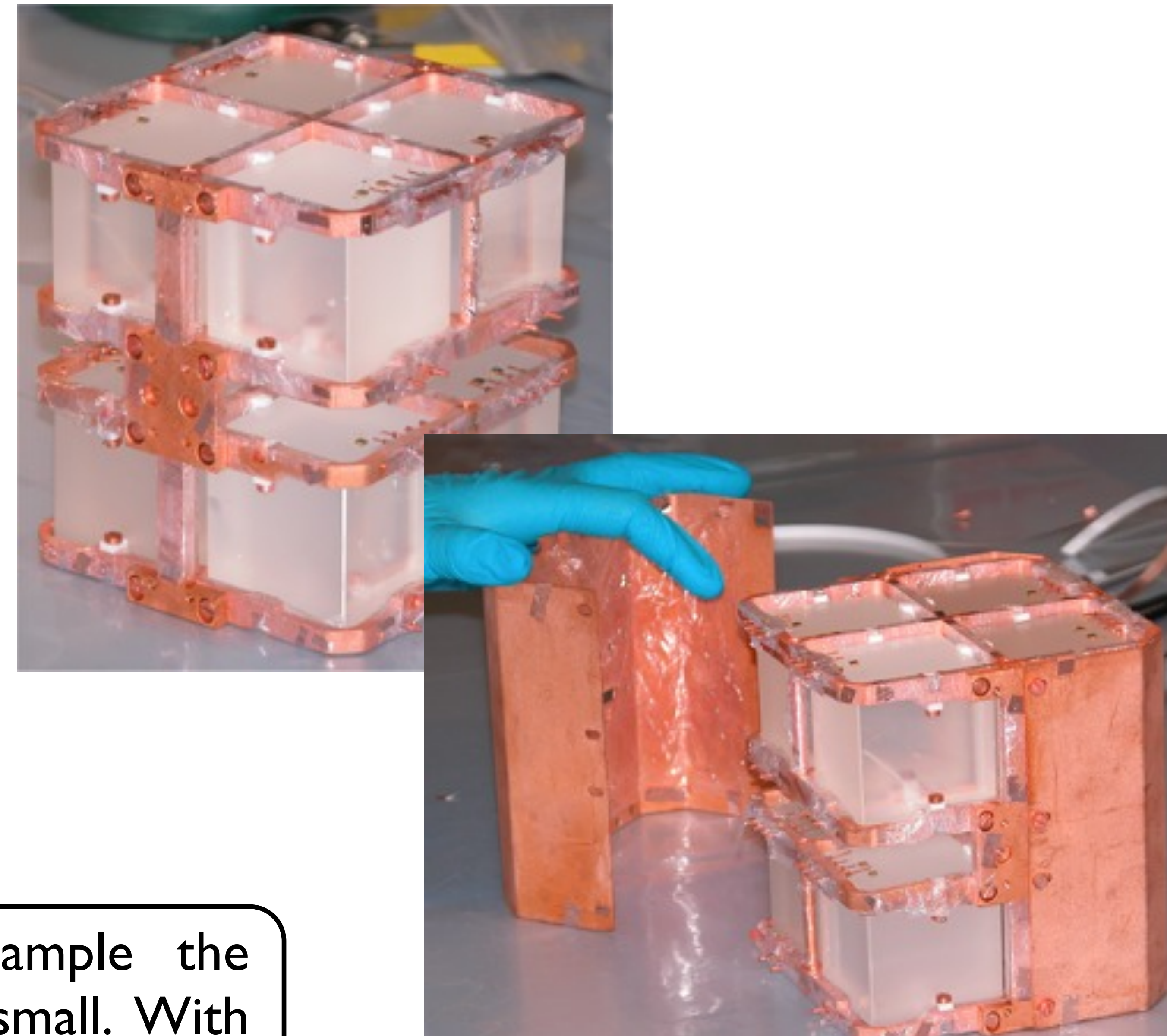

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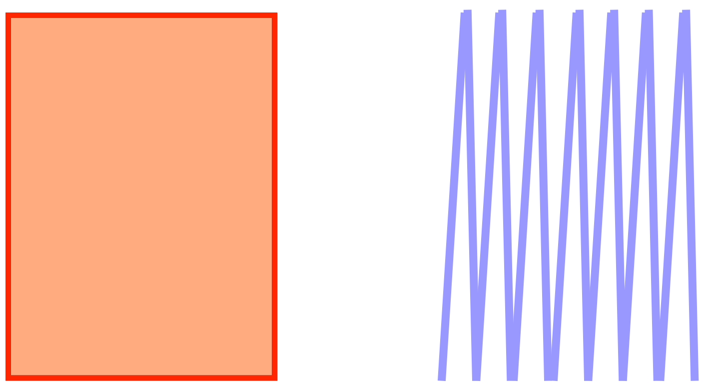

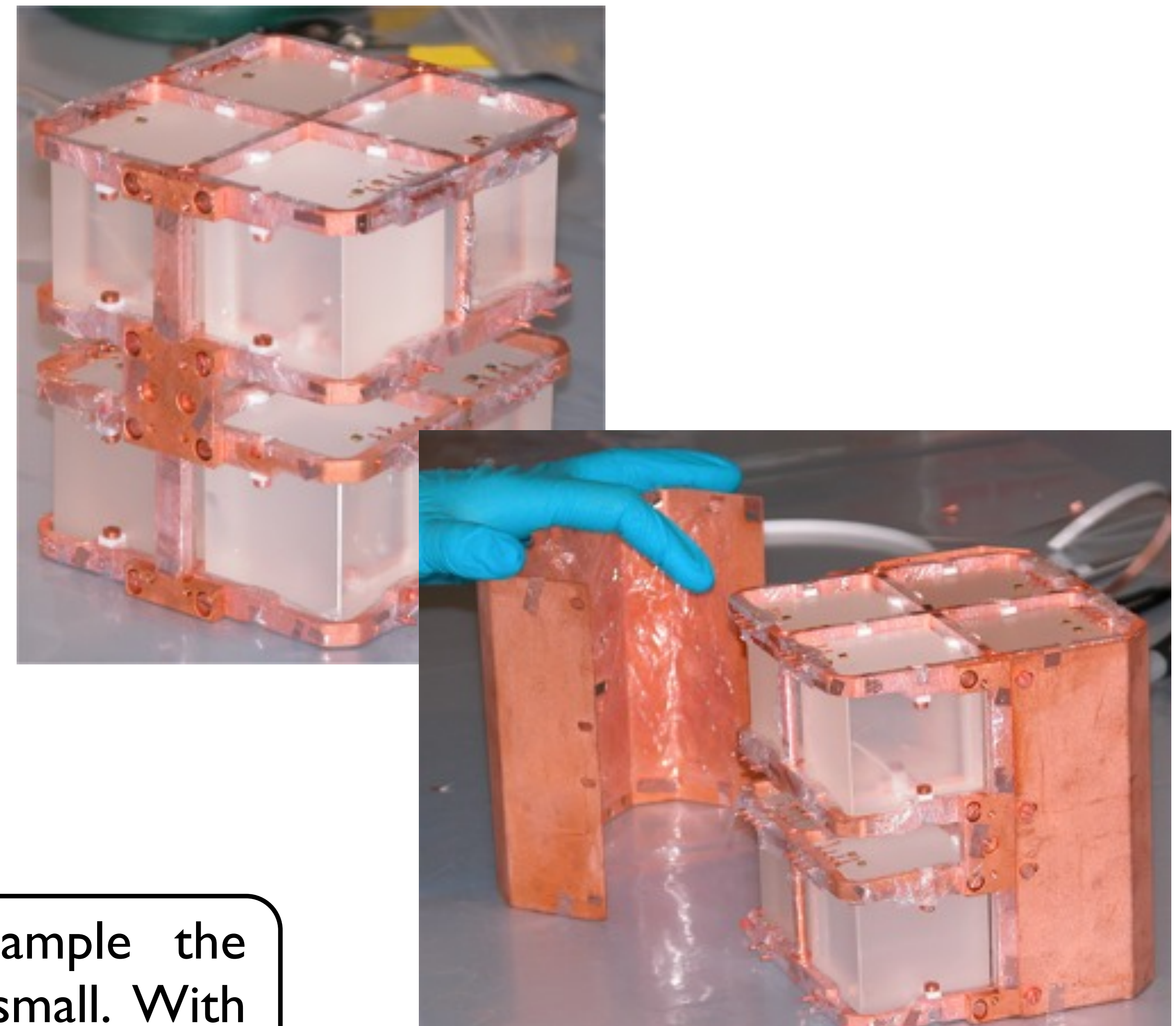

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The three towers (IV)

- 8 months full time activity (30 scientist)
- complete disassembling of CUORICINO
- 3 independent tower built
- 36 bolometers built
- complete reprocessing of all CUORICINO crystals according to CUORE standards
- 72 thermistor + 36 heaters glued

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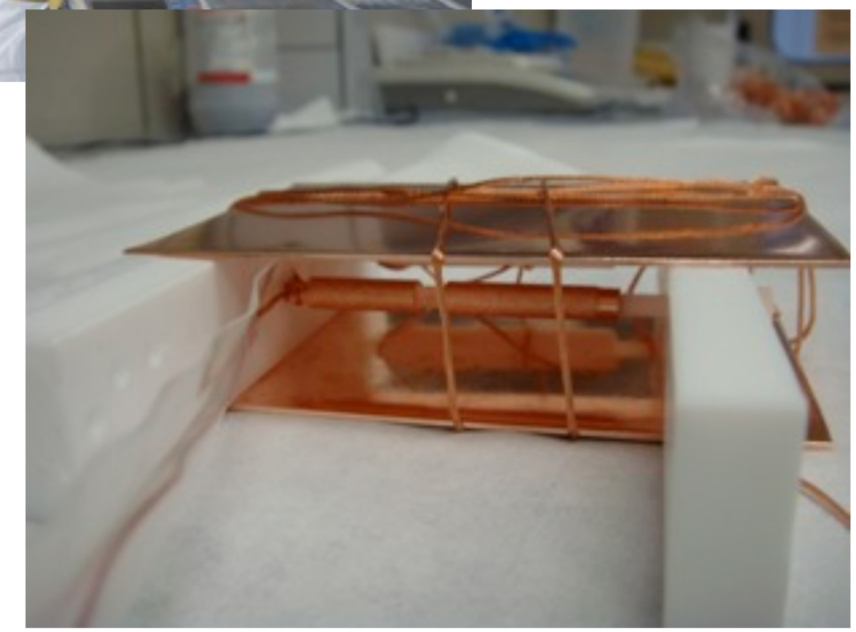

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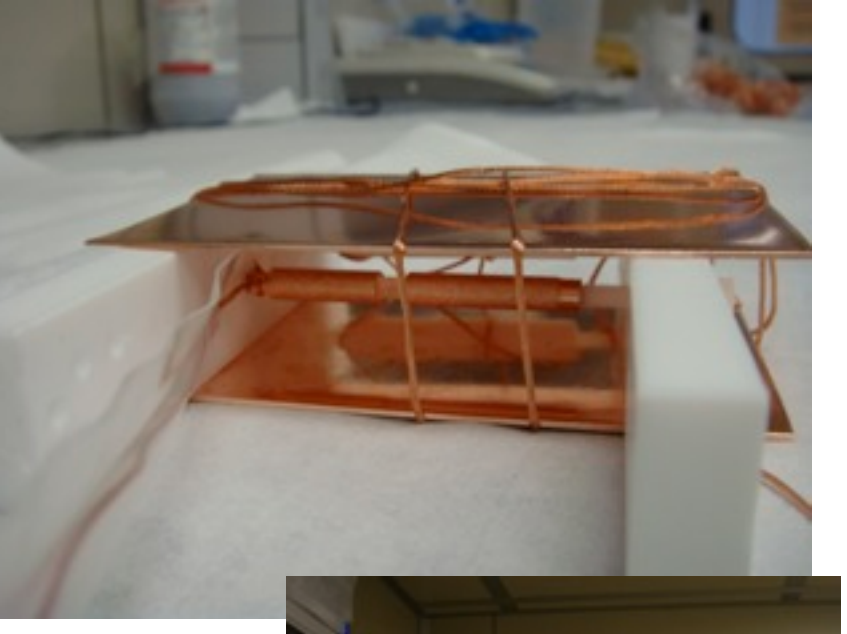

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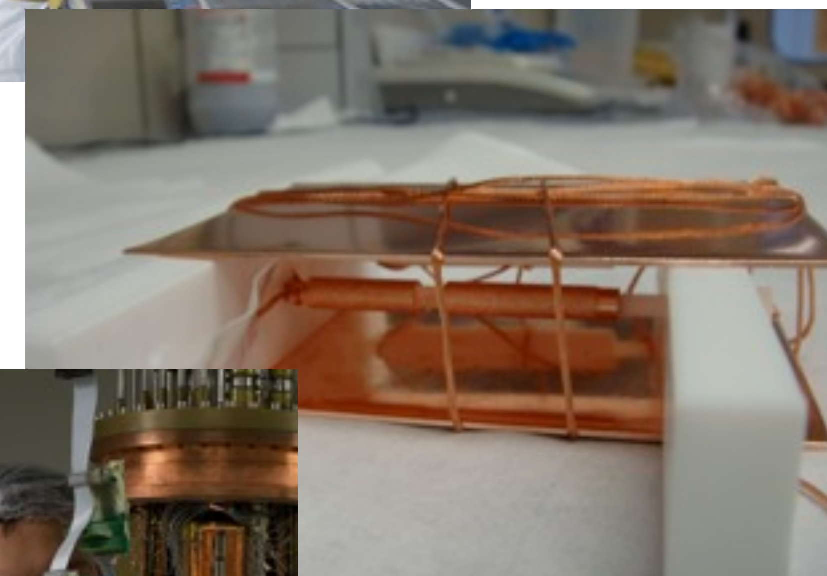

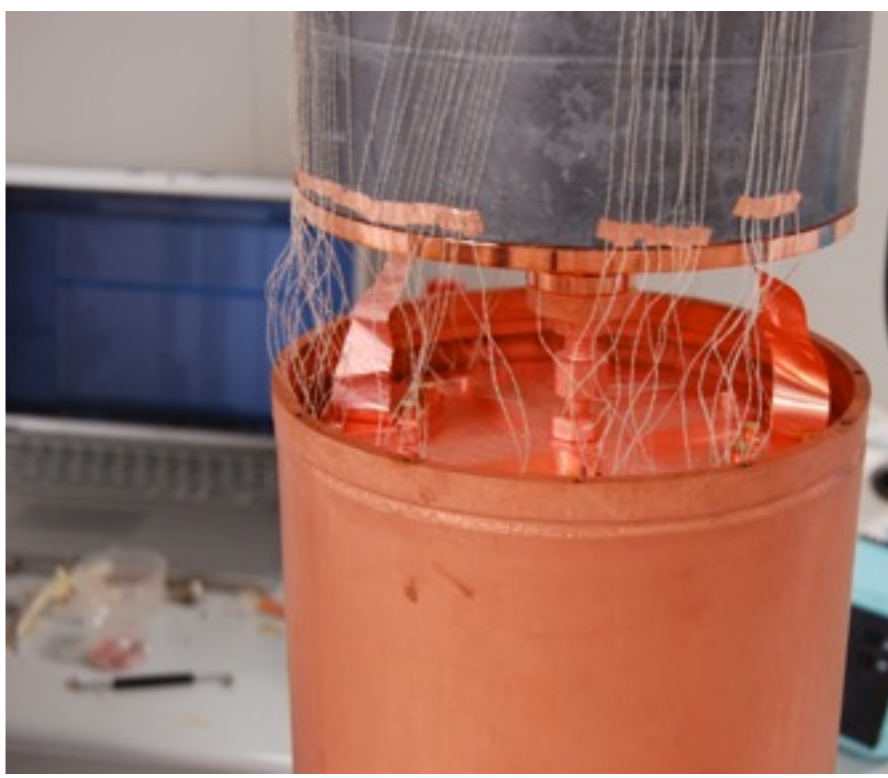

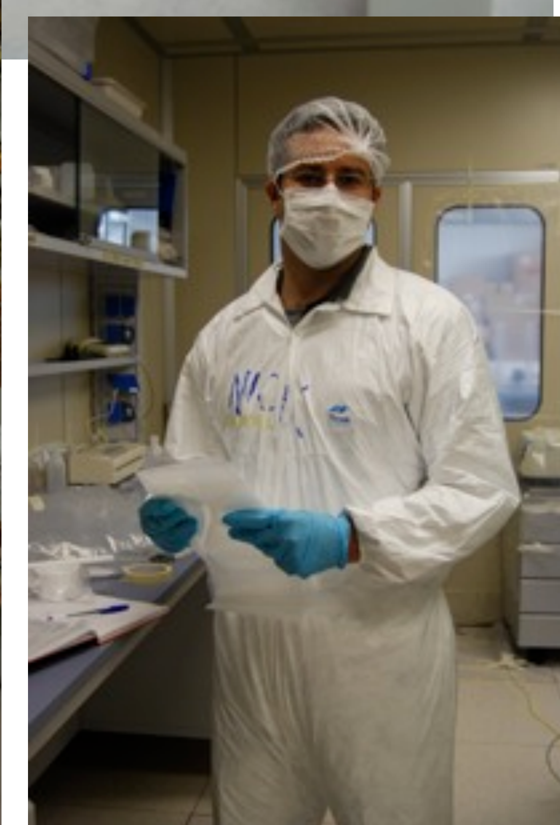

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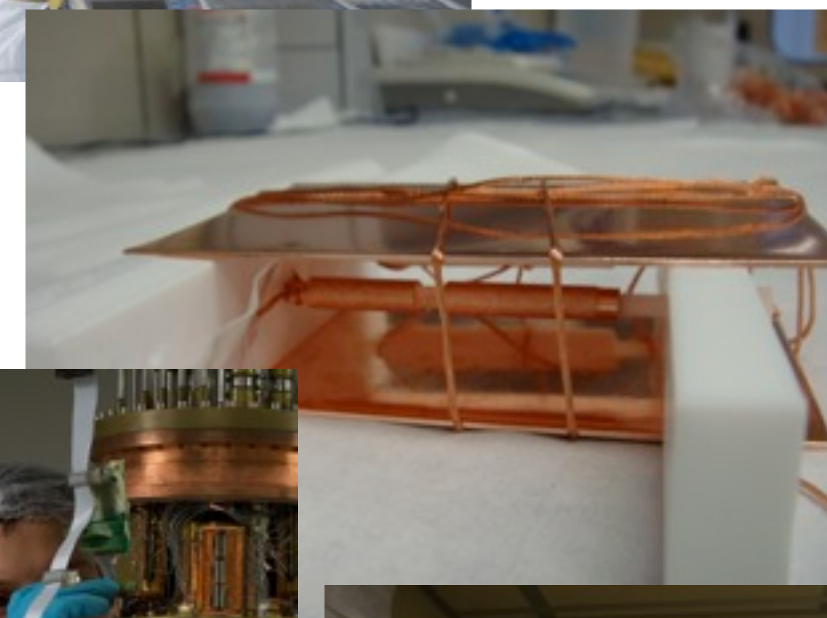

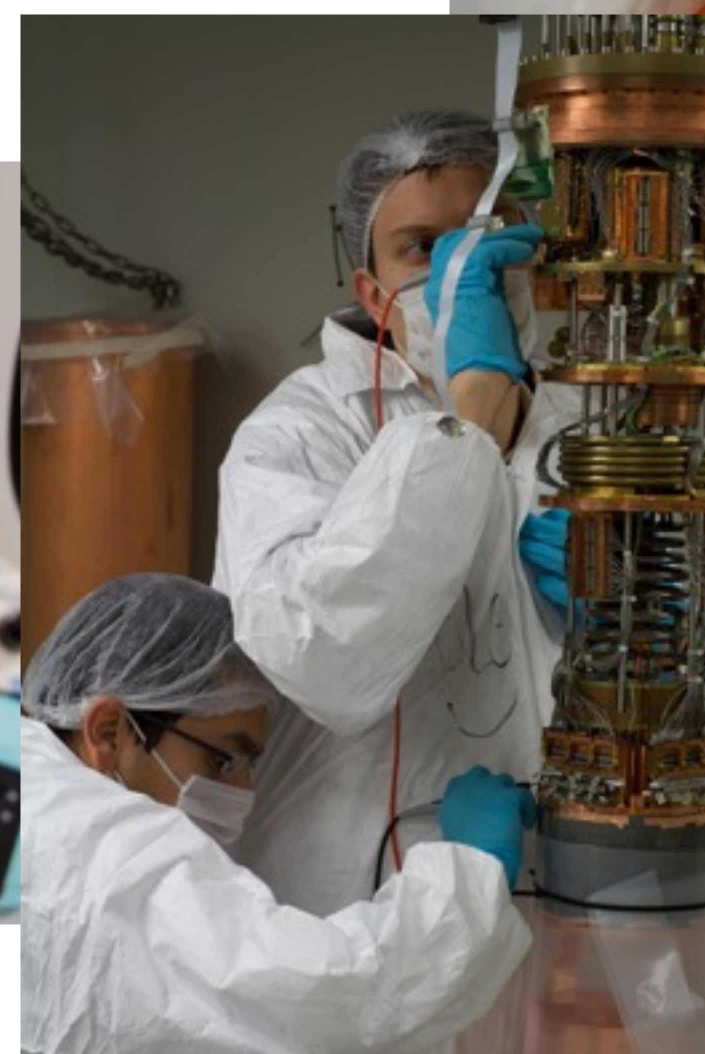

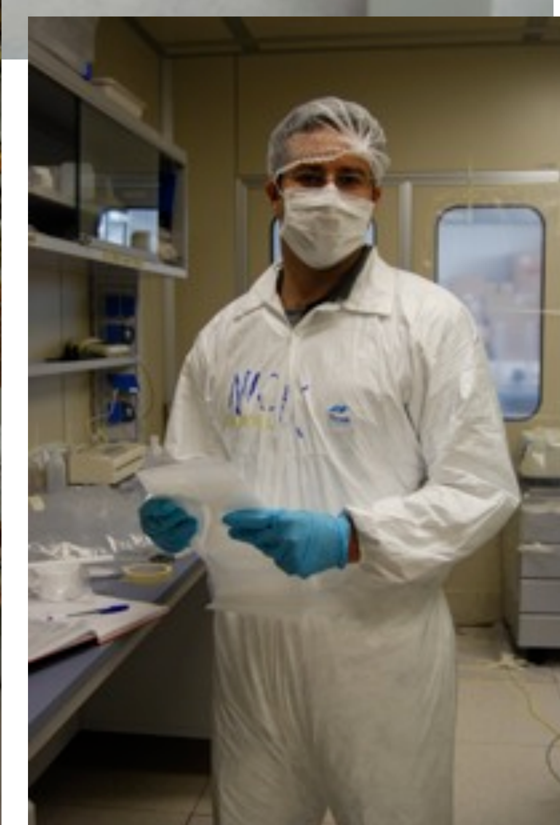

CUORE prospects

$$S_{0\nu} \propto \sqrt{\frac{M \cdot T}{\Gamma \cdot b}}$$

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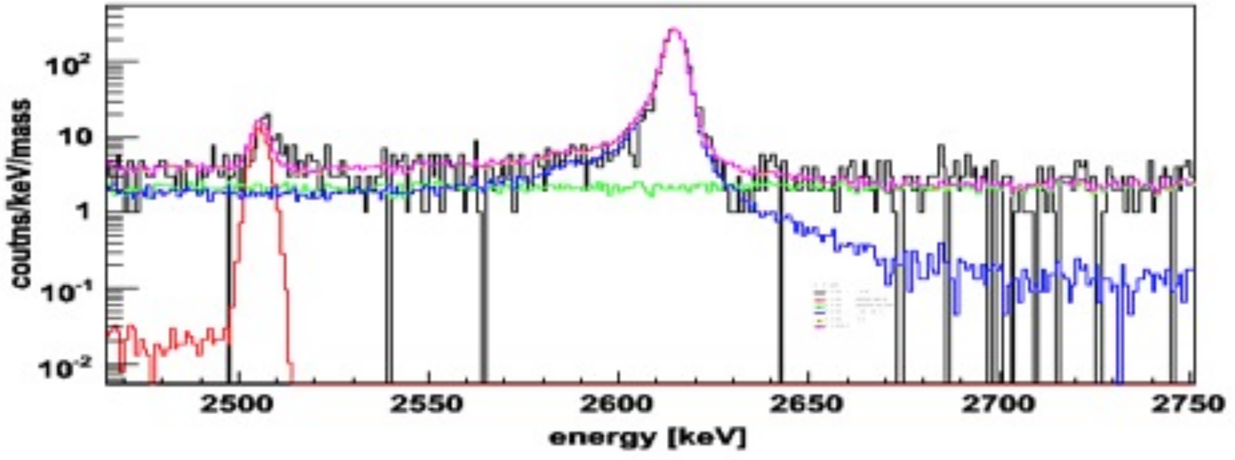
Background?

$b_{CUORICINO}$ = 0.18 c/keV/kg/y



^{232}Th in cryostat: reduced with selected matherials and better shielding

CUORE Tl line bkg = < 10^{-3} c/keV/kg/y

TeO_2 surface: proper surface treatments

Hall C measured contamination < 3 10^{-3} c/keV/kg/y

Surfaces facing detectors: work ongoing

TTT measured contamination ~ 3-4 10^{-2} c/keV/kg/y.

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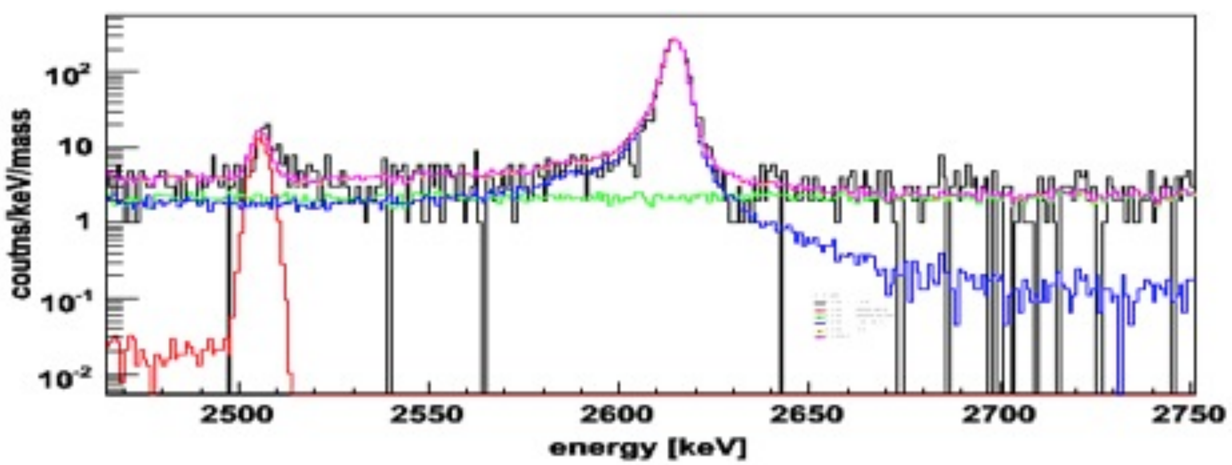

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Background	Sensitivity	Effective Majorana Mass
0.01 c/keV/kg/y (realistic)	$T_{1/2}^{0\nu} = 2.1 \cdot 10^{26}$ y	19-100 meV

Status of the CUORE experiment

The CUORE Collaboration

M. Barucci, L. Risegari, and G.Ventura
Dipartimento di Fisica dell' Università di Firenze e Sezione di Firenze dell' INFN, Firenze I-50125, Italy
S.Di Domizio1,2, A.Giachero1,3, P. Ottonello1,2, M.Pallavicini1,2 and D.Torazza1,2
1 Dipartimento di Fisica dell'Universita' diGenova e
2 Sezione di Genova dell'INFN, Genova I-16146, Italy
3 Laboratori Nazionali del Gran Sasso, I-67010, Assergi (L'Aquila), Italy
M. Balata, C. Bucci, P. Gorla, S.Nisi, D.Orlandi, E.L.Tatananni, C.Tomei, and C.Zarra
Laboratori Nazionali del Gran Sasso, I-67010, Assergi (L'Aquila), Italy
E.Andreotti, L.Foggetta, A. Giuliani, M. Pedretti, C.Rusconi and C.Salvioni
Dipartimento di Fisica e Matematica dell'Università dell'Insubria e
Sezione di Milano dell' INFN, Como I-22100, Italy
A.De Biasi, G. Keppel, V. Palmieri and V. Rampazzo
Laboratori Nazionali di Legnaro, Via Romea 4, I-35020 Legnaro (Padova)
F. Alessandria
Sezione di Milano dell'INFN, Milano I-20133, Italy

C.Arnaboldi1,2, C. Brofferio1,2, S. Capelli1,2, L. Carbone2, M.Carrettoni1,2, M.Clemenza1,2,
O. Cremonesi2, E. Ferri1,2, E. Fiorini1,2, L.Gironi1,2, S.Kraft1,2, C.Maiano1,2, C.Nones1,2,
A. Nucciotti1,2, L. Pattavina1,2, M. Pavan1,2, G. Pessina2, S. Pirro2, E. Previtali2,
D.Schaeffer1,2, M. Sisti1,2 and L.Zanotti1,2
1 Dipartimento di Fisica dell'Università di Milano-Bicocca e
2 Sezione di Milano dell'INFN, Milano I-20126, Italy
R. Ardito and G. Maier
Dipartimento di Ingegneria Strutturale del Politecnico di Milano, Milano I-20133, Italy
F.Bellini, C.Cosmelli, I.Dafinei, R.Faccini, F.Ferroni, C.Gargiulo, E.Longo, S. Morganti,
M. Olcese and M.Vignati
Dipartimento di Fisica dell'Universita' di Roma La Sapienza e
Sezione di Roma dell'INFN, Roma I-00185, Italy
M.M.Deninno, N.Moggi, F.Rimondi, and S.Zucchelli
Dipartimento di Fisica dell'Universita' di Bologna e Sezione di Bologna dell'INFN, Bologna I-40126, Italy
M.Martinez
Lab. of Nucl. and High Energy Physics, University of Zaragoza, 50009 Zaragoza, Spain
A. de Waard adnG. Frossati
Kamerling Onnes Laboratory, Leiden University, 2300 RAQ, Leiden, The Netherlands
J. Beeman1, A.Bryant2,3, M.P.Decowski2,3, S.J.Freedman2,3, E.Guardincerri2,
E.E. Haller1,4, R.Kadel5, L.Kogler2,3, Yu.G.Kolomensky3,5, A.R. Smith2 and N. Xu2
1Materials Science Division, Lawrence Berkeley National Laboratory,Berkeley, CA 94720
2Nuclear Science Division, Lawrence Berkeley National Laboratory,Berkeley, CA 94720
3Department of Physics, University of California, Berkeley, CA 94720, USA
4Department of Materials Science and Engineering,U. of California at Berkeley, CA 94720 USA
5Nuclear Science Division, Lawrence Berkeley National Laboratory,Berkeley, CA 94720
M.J. Dolinski1,3, K.Kazkaz1, E.B. Norman1,2 and N.D.Scielzo1
1 Lawrence Livermore National Laboratory, Livermore, CA 94550 USA
2 Department of Nuclear Engineering, University of California, Berkeley, CA 94720
3 Department of Physics, University of California, Berkeley, CA 94720, USA
H.Z. Huang, S.Trentalange, C.Whitten Jr.
Department of Physics and Astronomy, University of California, Los Angeles, CA 90095-1547.
T.D. Gutierrez
California Polytechnic State University, San Luis Obispo, CA 93407 USA
F.T.Avignone III, I. Bandac, R.J. Creswick, H.A. Farach, C.Martinez, L.Mizouni and C. Rosenfeld
Department of Physics and Astronomy, University of South Carolina, Columbia S.C. 29208 USA
L.Ejzak, K.M.Heeger, R.H.Maruyama and S.Sangiorgio
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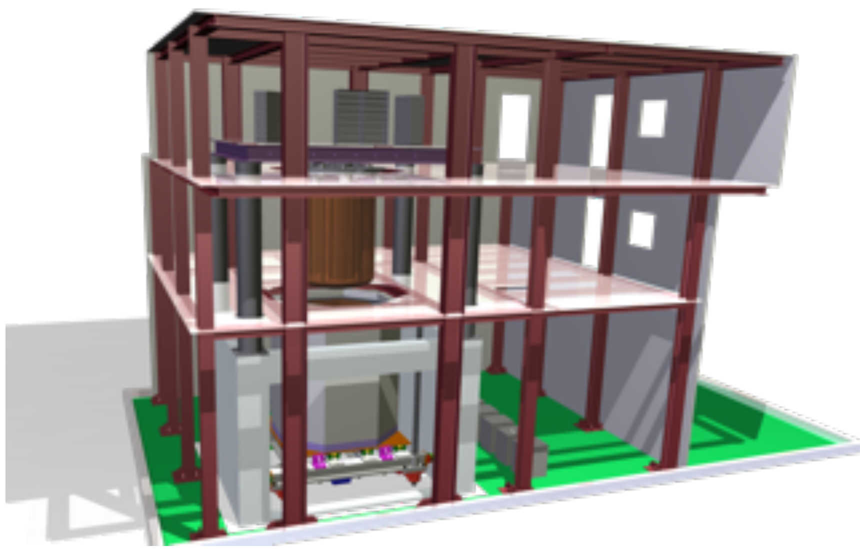
Y.Ma, X.Cai, D.Fang, W.Tian and H.Wang
Shanghai Institute of Applied Physics (Chinese Academy of Sciences), Shanghai, China

CUORE status

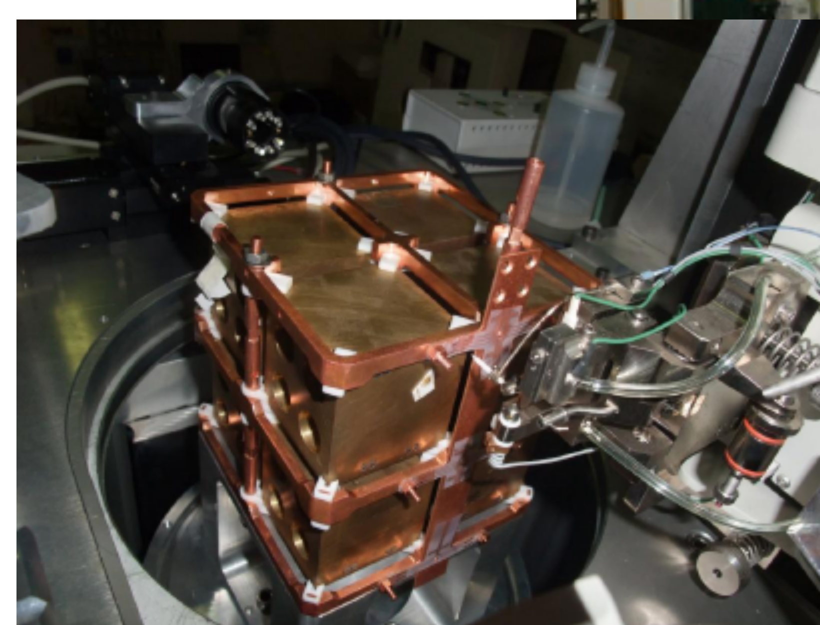


CUORE has a dedicated site in LNGS: building and clean room completed.

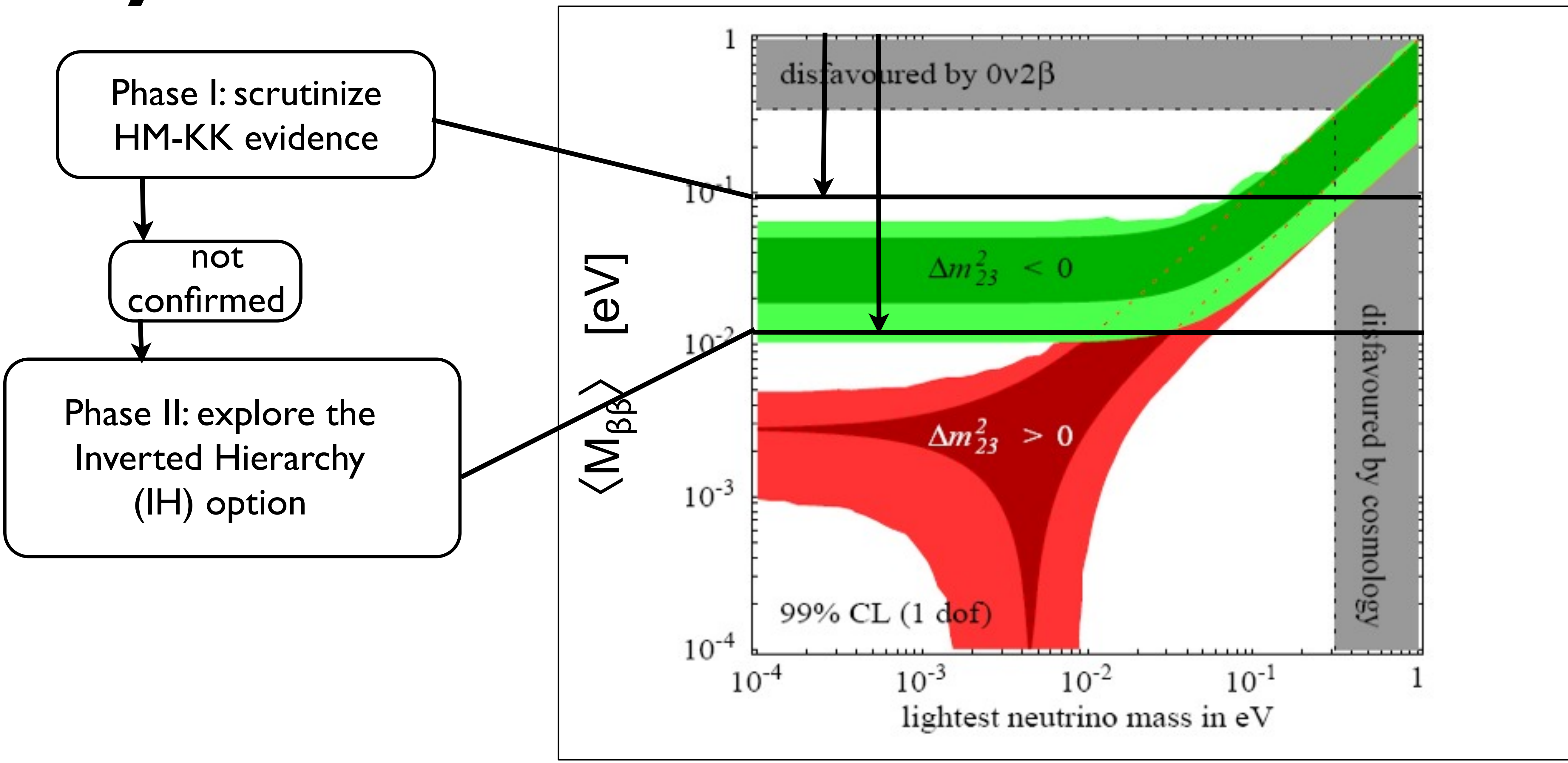
Summer 2011: first CUORE tower assembled in Gran Sasso (CUORE-0 prototype)

Late 2011: cryostat commissioning.

Dec 2011: start the assembly of all the CUORE detectors



Beyond 1 ton?


Phase I: scrutinize HM-KK evidence
not confirmed
Phase II: explore the Inverted Hierarchy (IH) option
disfavoured by 0ν2β
$\Delta m^2_{23} < 0$
$\Delta m^2_{23} > 0$
disfavoured by cosmology
99% CL (1 dof)
$\langle M_{\beta\beta} \rangle$ [eV]
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
lightest neutrino mass in eV

Beyond 1 ton?

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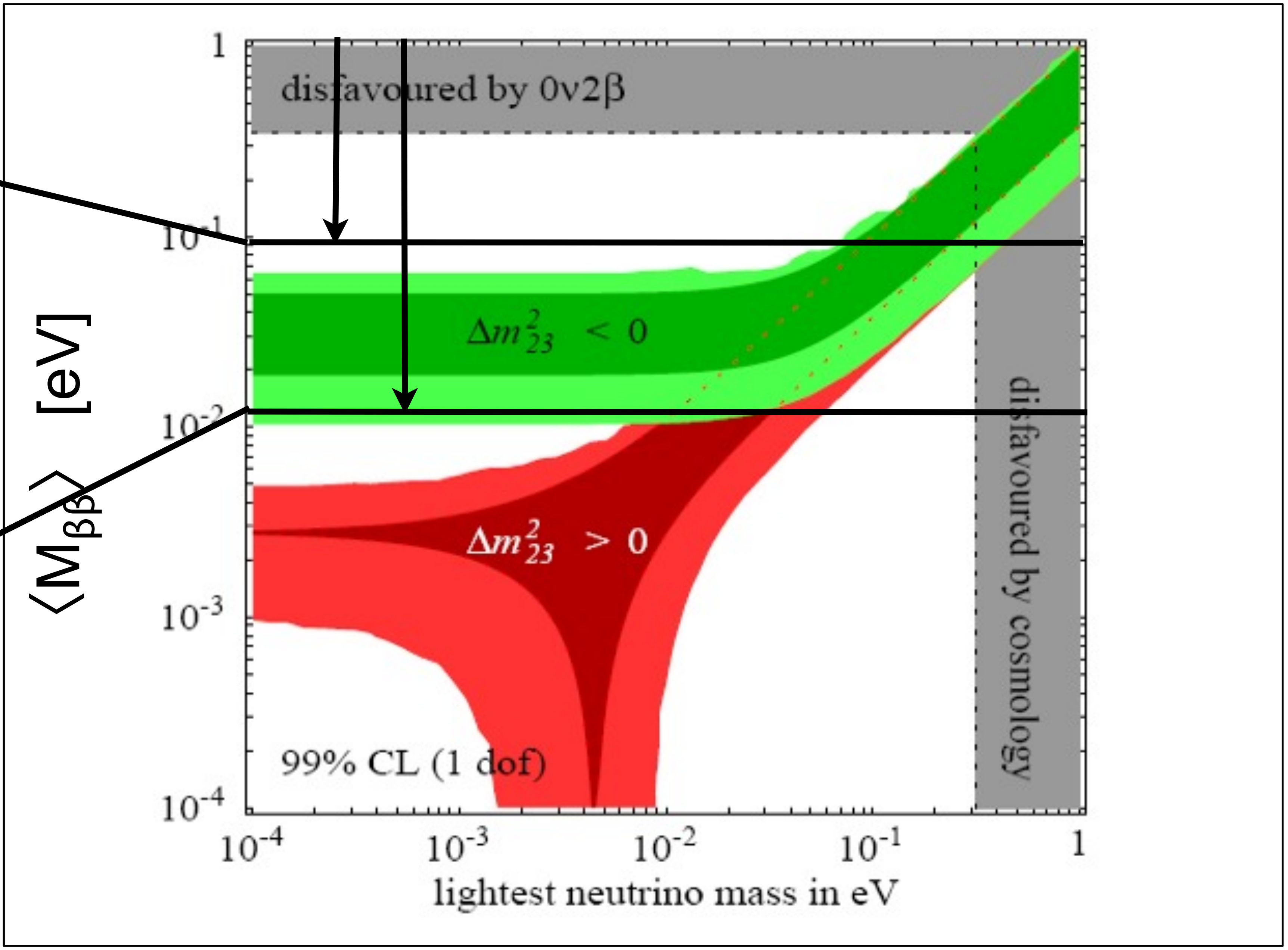
If m_ν is in the 100-50 meV region

A lot of evidences to come in next 10 years!



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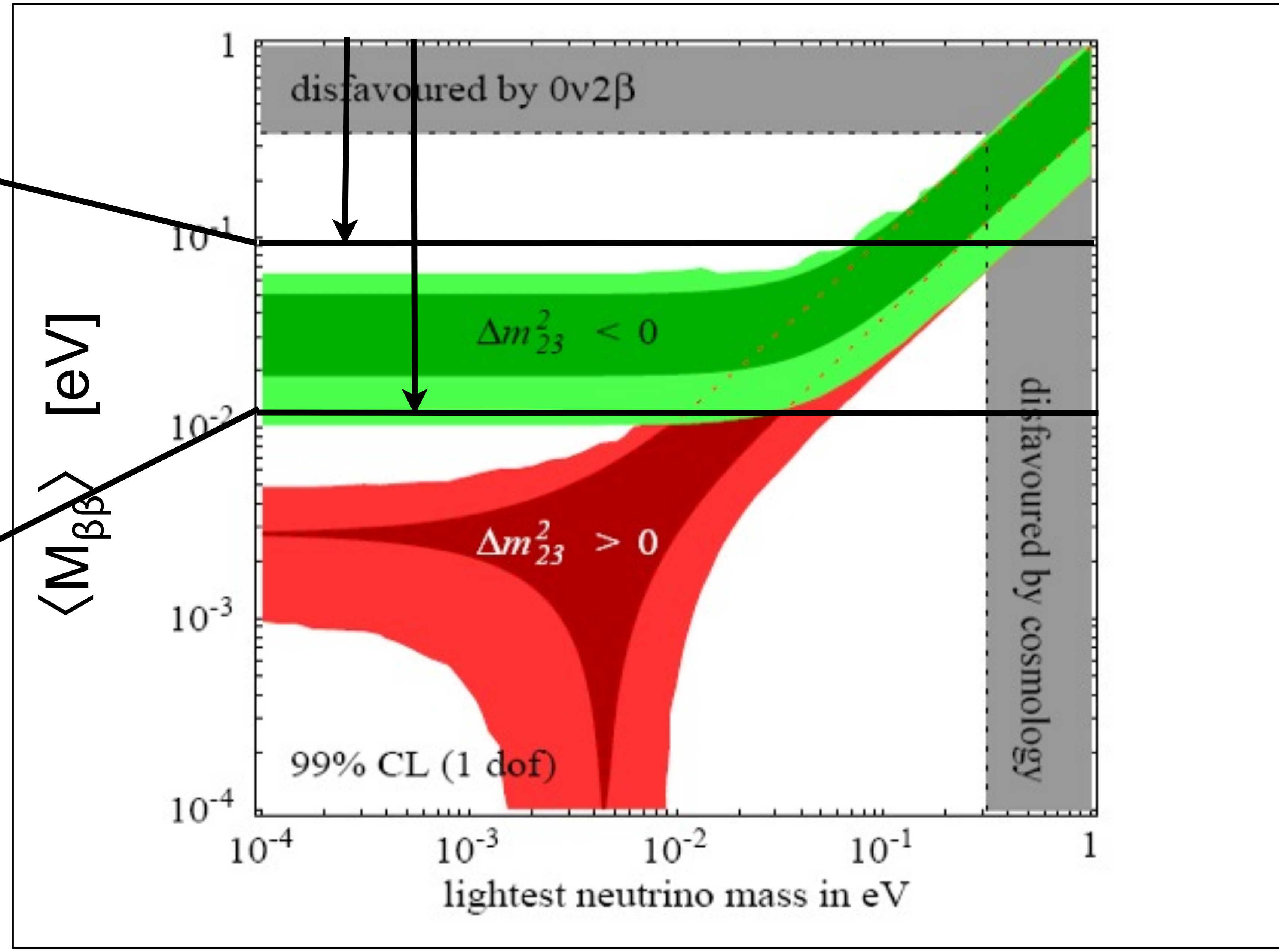
No evidence



The golden experiment (enriched scintillating CUORE, high resolution Ba+ tagging EXO, ...): a ton scale enriched experiment with "0 background" and good energy resolution → exclude the IH region

The zero background challenge

"Zero background" (0B) experiments:
experiments in which the background level B is so low that the expected number of background events in the region of interest along the experiment life is of order of unity: $b \cdot M \cdot T \cdot \Gamma \simeq O(1)$In this case the sensitivity equation assumes a simplified form in which the finale square root is substituted by MT/n_L where n_L is a constant depending on the chosen CL and on the actual number of observed events.

$$S_{0\nu} \propto i.a. \cdot \epsilon \cdot M \cdot T$$

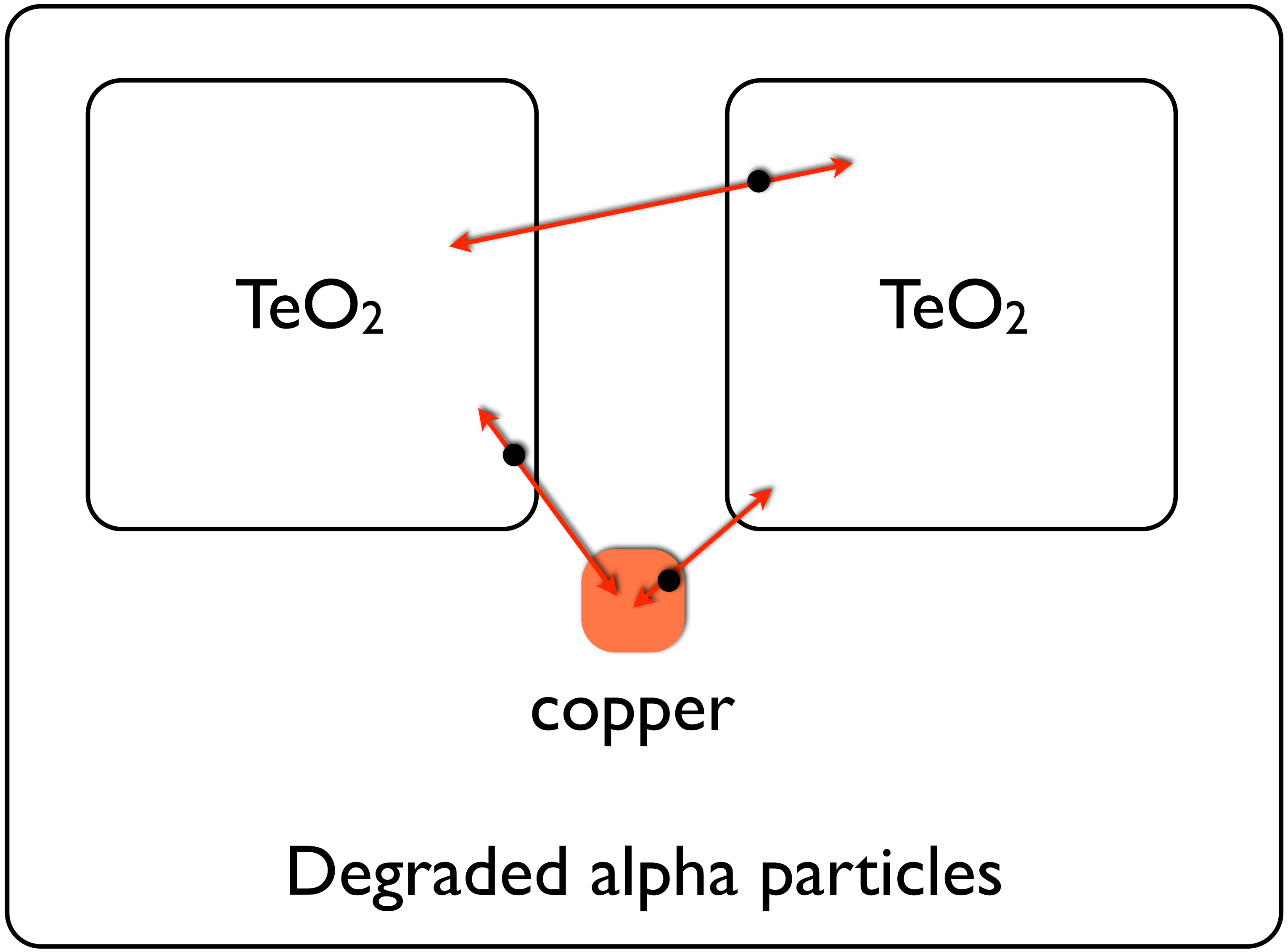
In a CUORE like experiment I need to push b from ~0.01 to > 10^{-3}-10^{-4} counts/keV/kg/y

CUORE background

- Degraded alpha is our nightmare
- IF our understanding is correct removing/tagging surface events will convert 0.001 dream to reality

Component	Background in DBD region (10^{-3} c/keV/kg/y)	Ratio to minimal goal
Environmental gamma	< 1	< 0.1
Apparatus gamma	< 1	< 0.1
Crystal bulk	< 0.1	< 0.01
Crystal surfaces	< 3	< 0.3
Close-to-det. material bulk	< 1	< 0.1
Close-to-det. material surface	~ 20 – 40	~ 2 – 4
Neutrons	~ 0.1	~ 0.01
Muons	~ 0.1	~ 0.01

Active discrimination techniques (I)

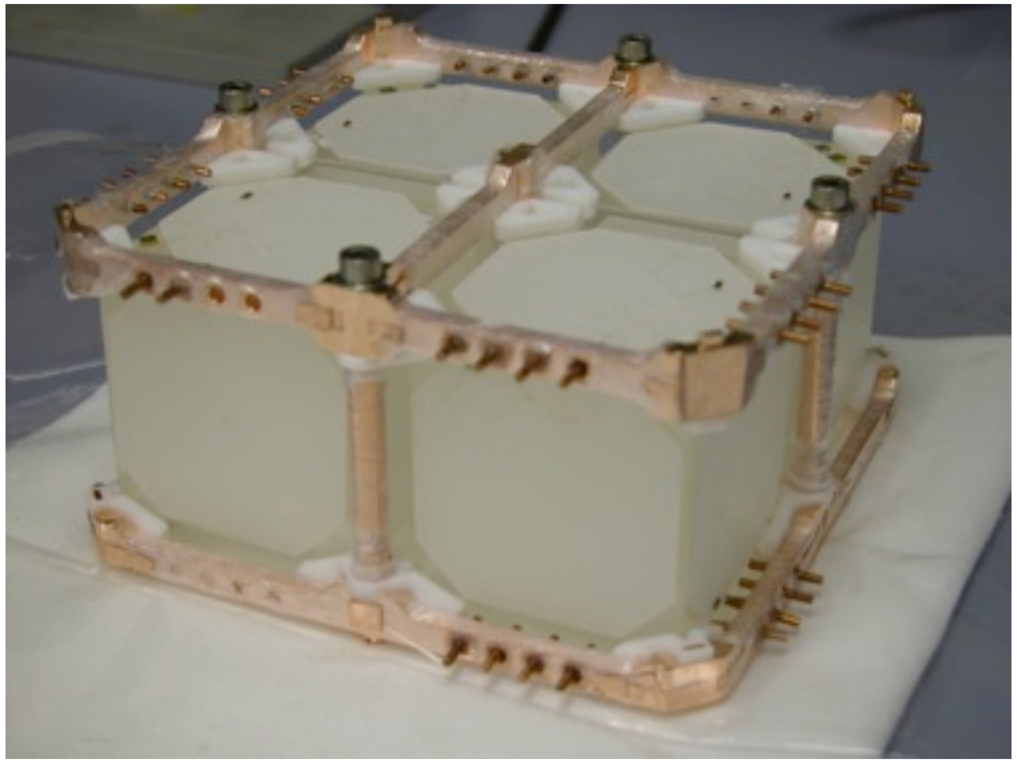


Possibilities

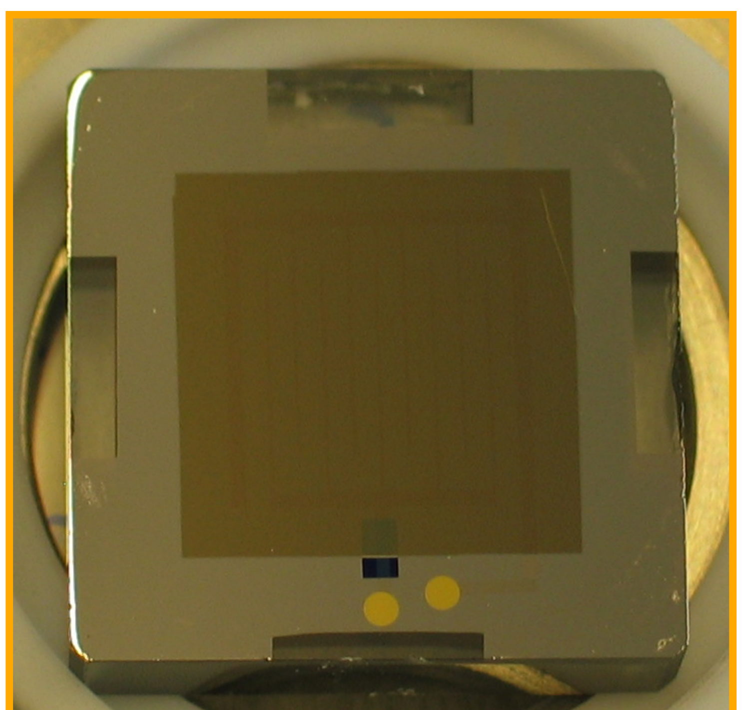
- alpha/beta
- surface event

Active discrimination techniques (II)

Surface event tagging

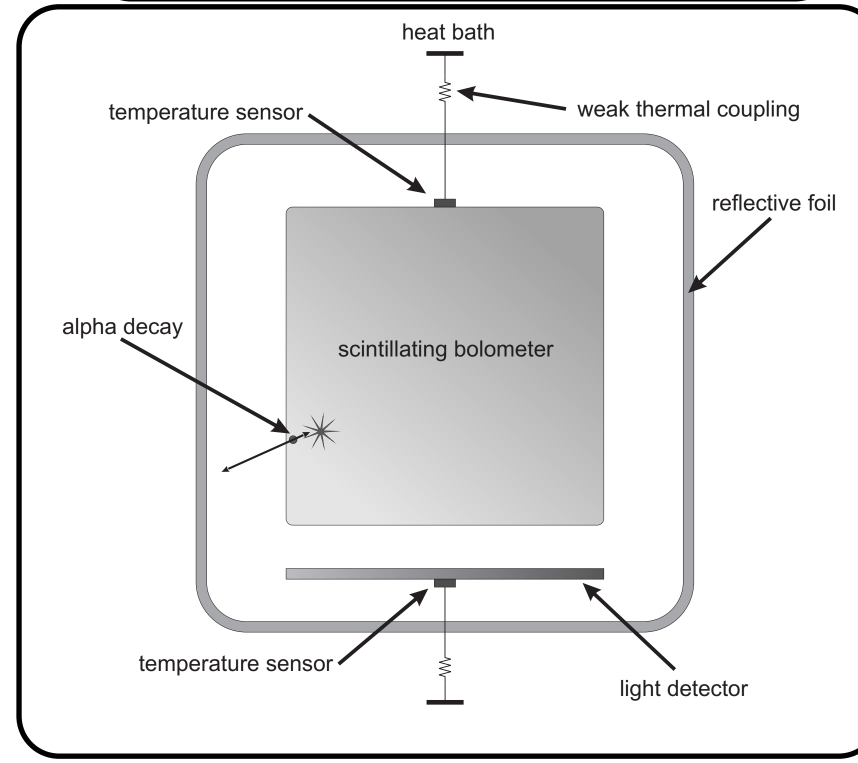


Surface
Sensitive Bolometers

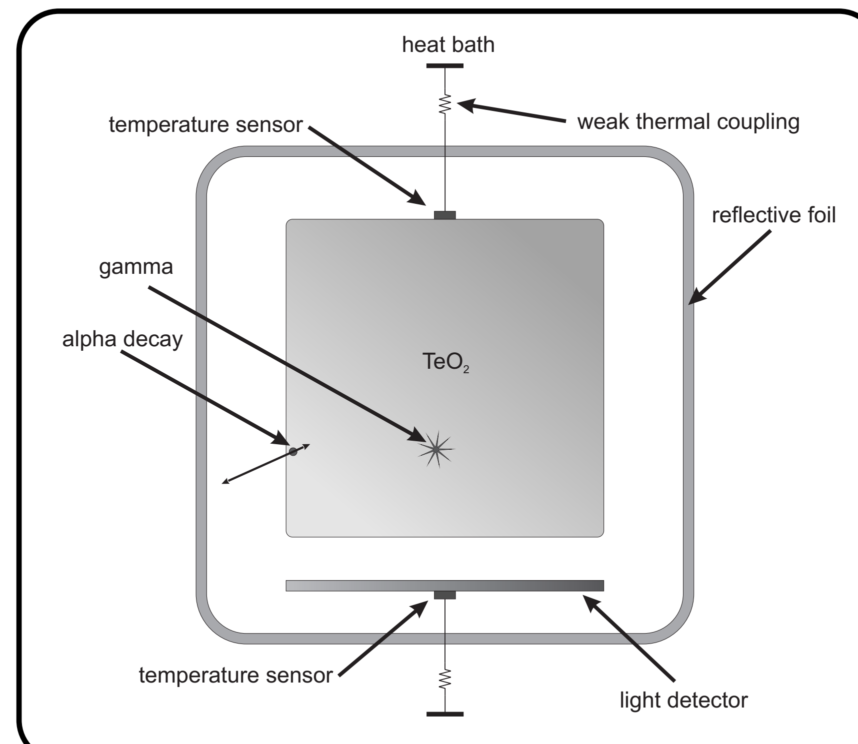


NbSi deposition

alpha/beta discrimination



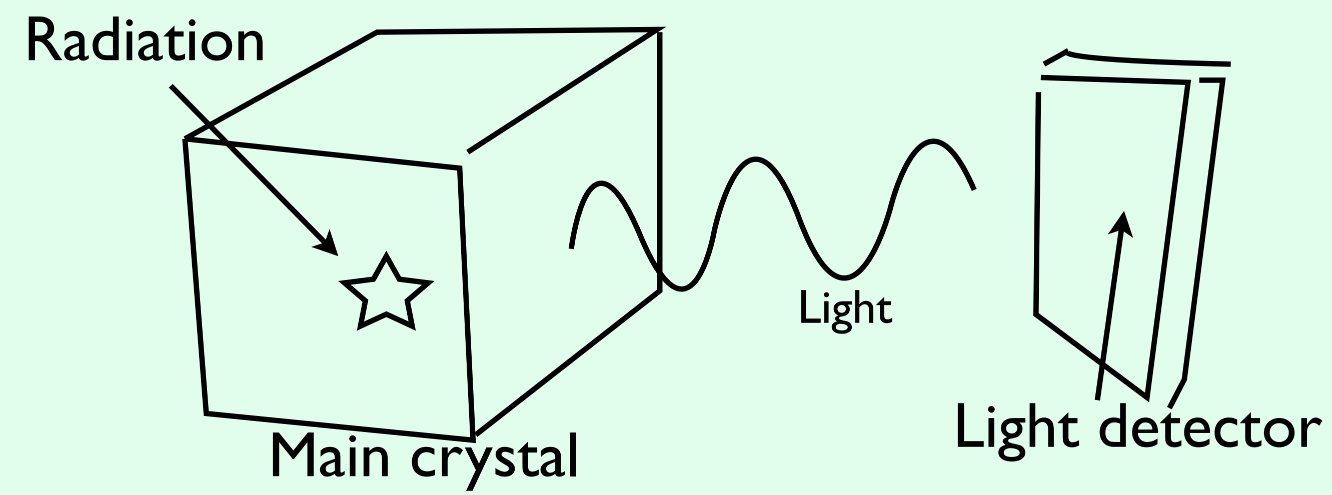
Scintillating Bolometer



Cerenkov

Scintillating Bolometer for 0ν-DBD search

AS in many DM experiments the use of combined detectors (scintillating bolometer) allows background rejection. Measuring the different light emission for different radiation allows background rejection.



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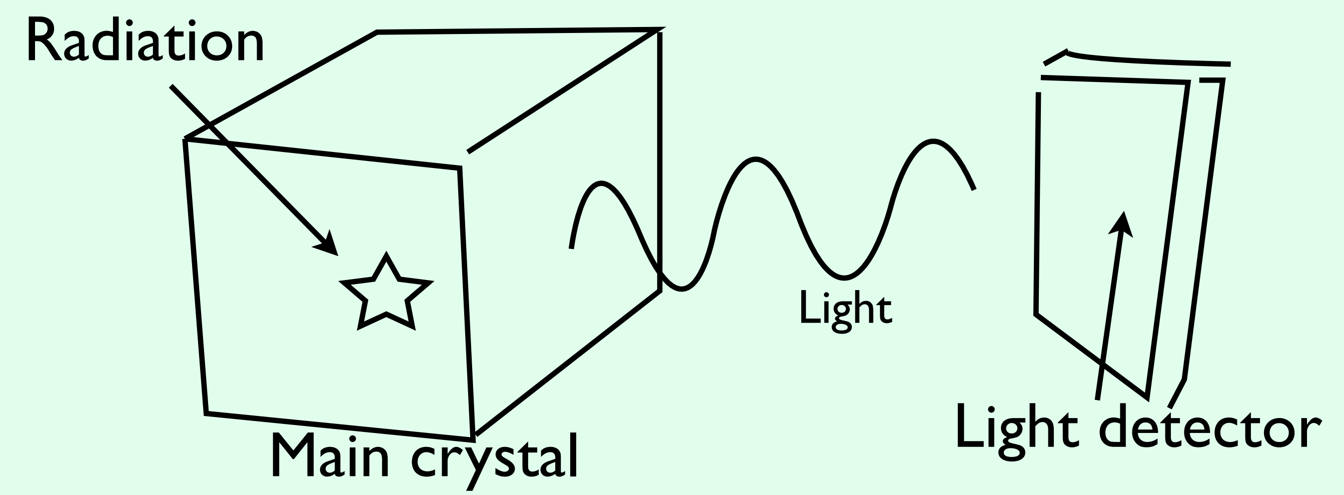

Bolometer:

- Good energy resolution
- Many DBD emitters available (^{48}Ca, ^{100}Mo, ^{116}Cd, ^{96}Zr,...)

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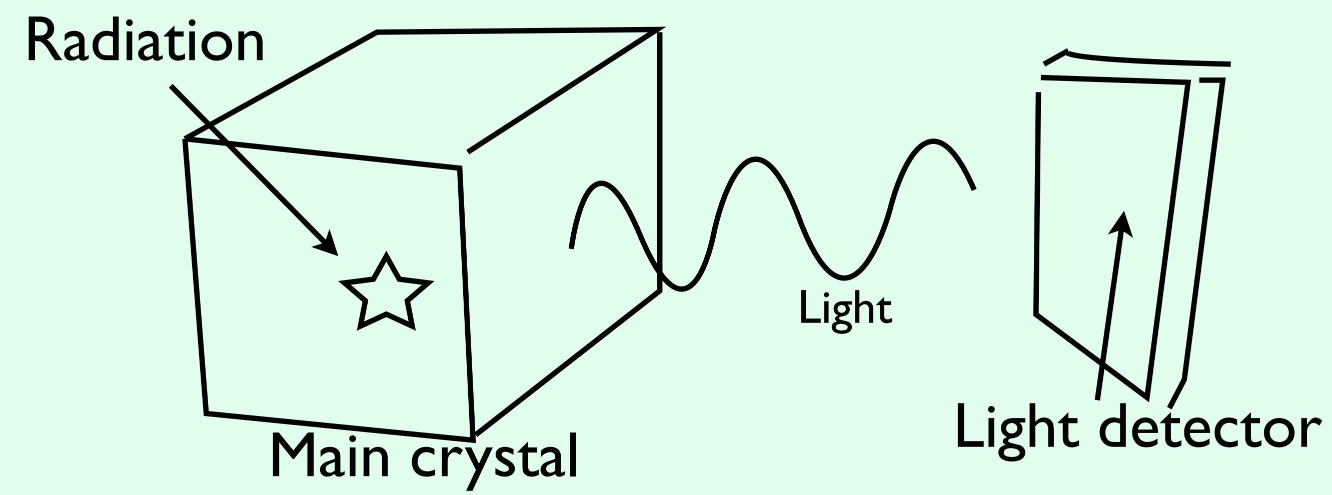

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Bolometer (as in DM experiments):
- Must work at few mK
- Easy operable, low radioactive contaminations

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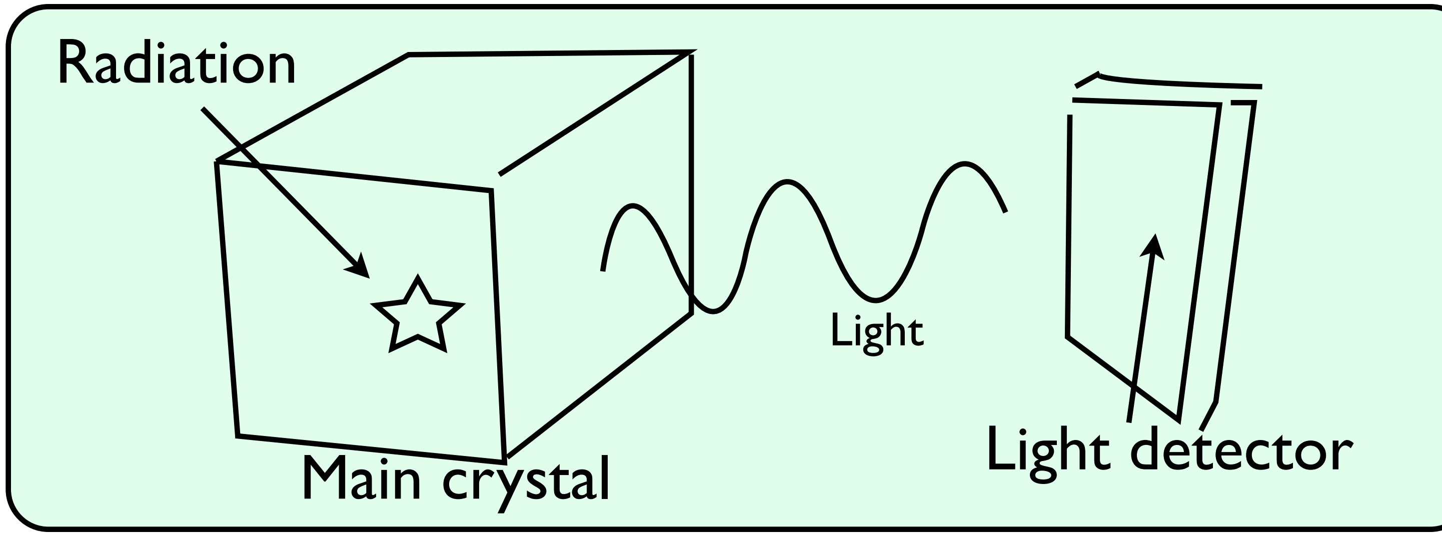

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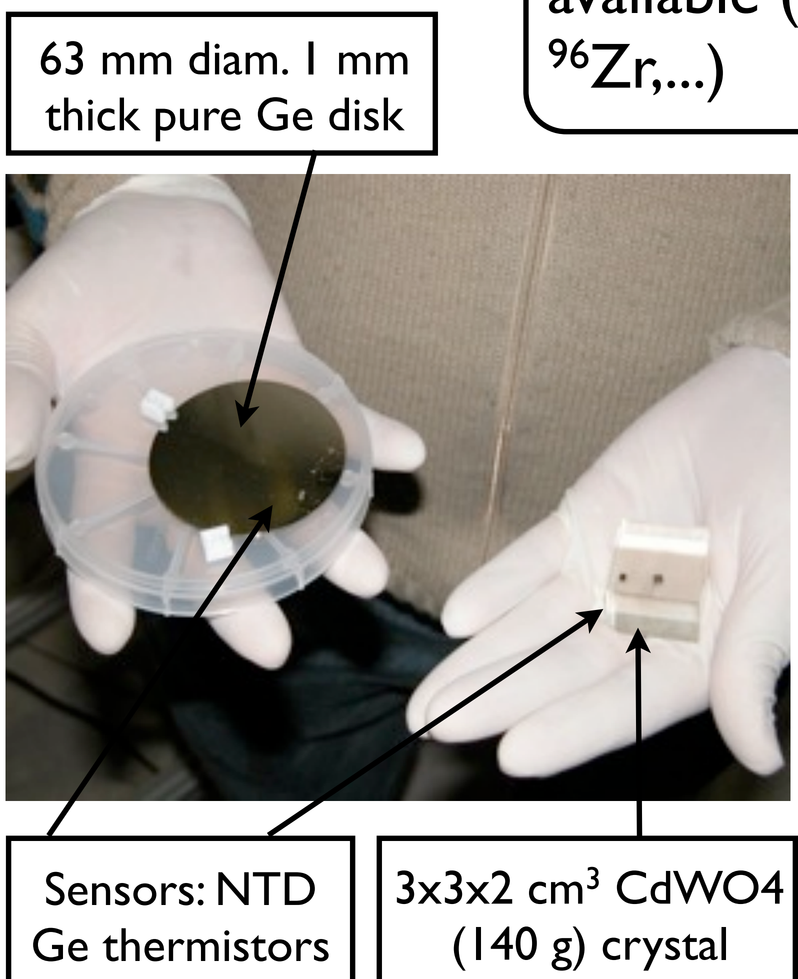
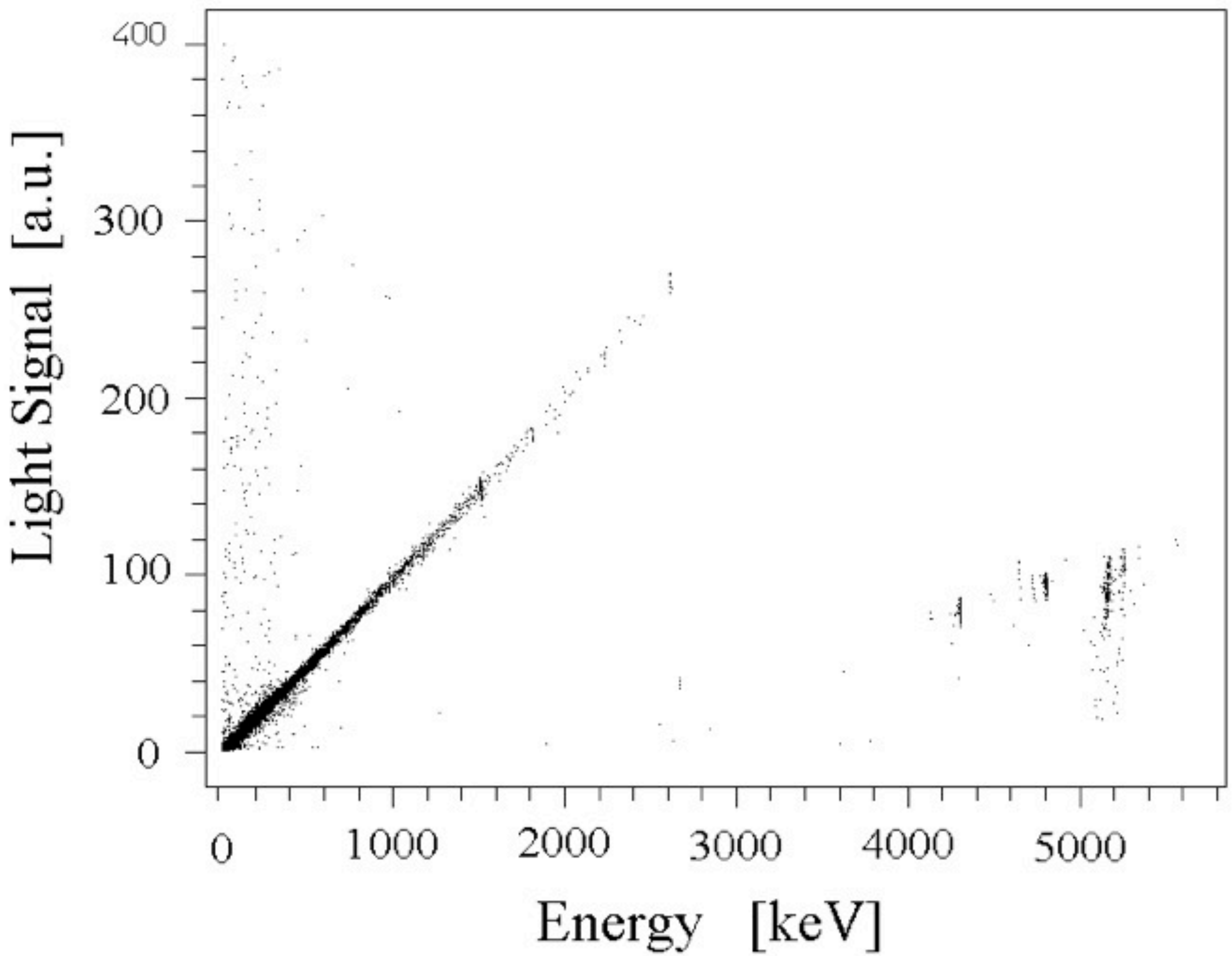
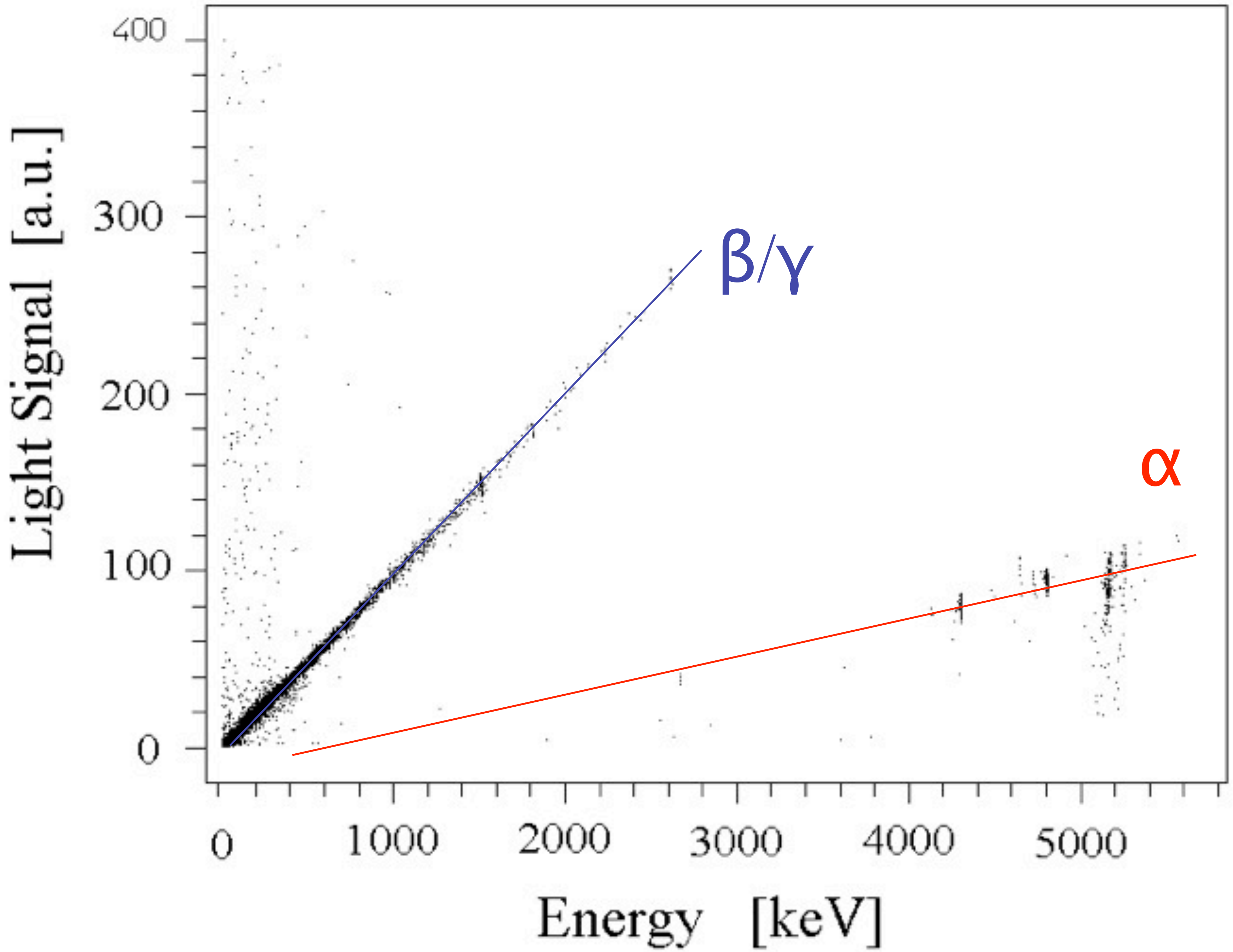


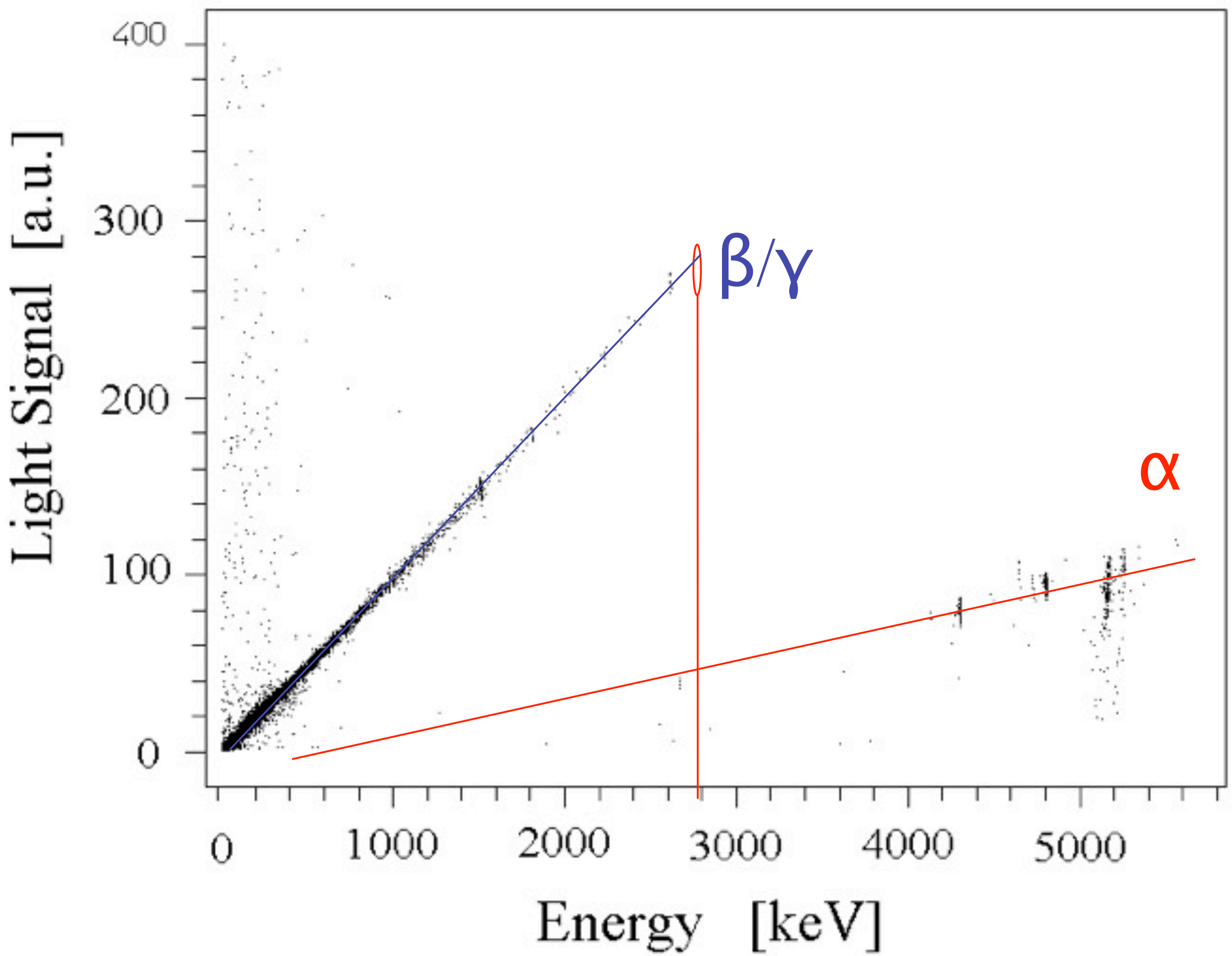
Scintillating Bolometer for 0ν-DBD search (II)



Scintillating Bolometer for 0ν-DBD search (II)



Scintillating Bolometer for 0ν-DBD search (II)



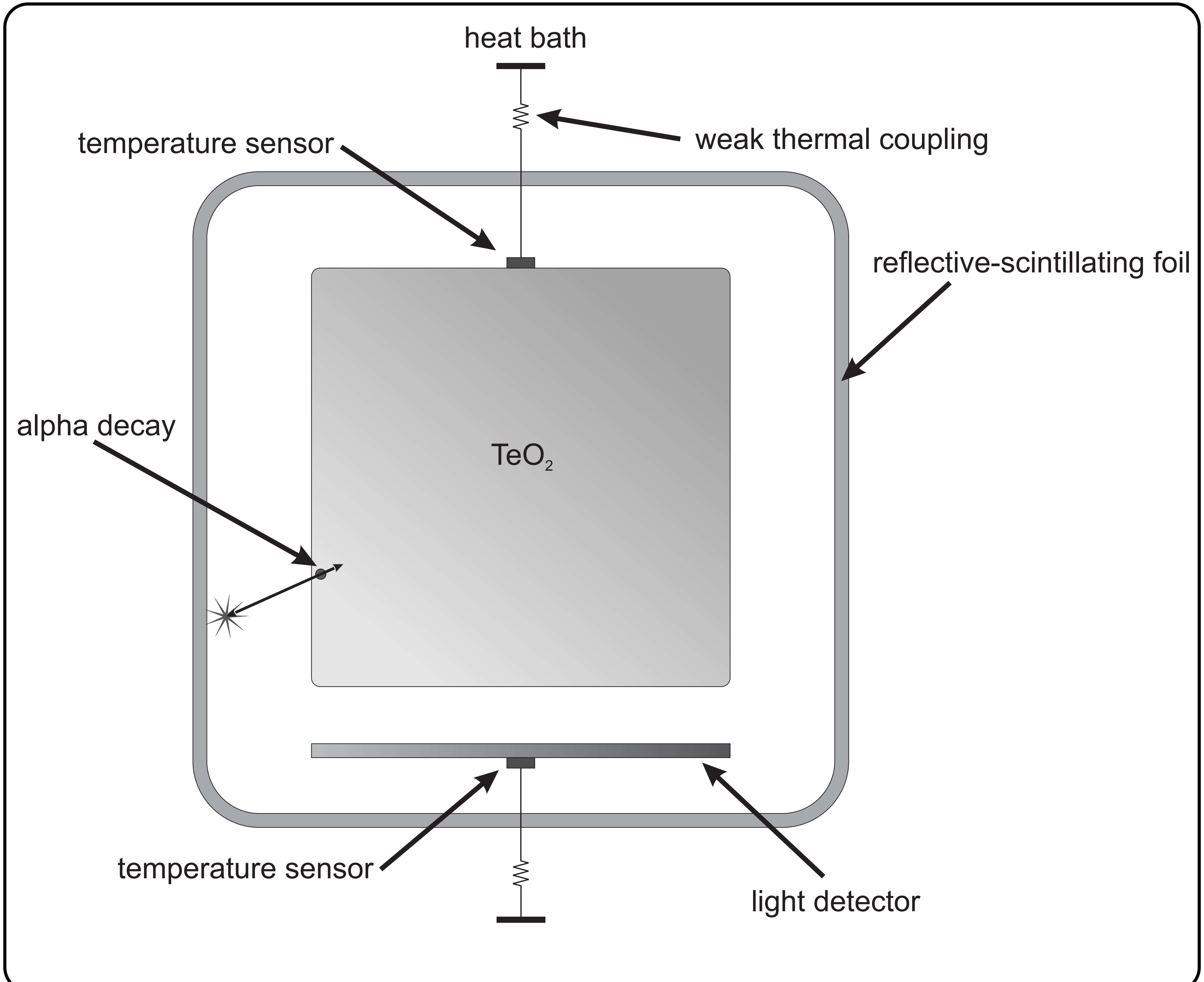
440 h live time measurement

$Q_{\beta\beta}(^{116}Cd)$ = 2805 keV

Scintillating bolometer vs Cerenkov

- The setup is the same
- The big advantage of Cerenkov is that works also on TeO_2 !!
- The big problem is the extremely good light detector needed
  - about 350 eV EMITTED as Cerenkov photons
  - taking into account self-absorption, total reflection and light collection a light threshold better than 100 eV is needed: extremely challenging!
  - Bolux (DBD-R&D) light detector has something between 250 and 500 eV
  - CRESST has about 50 eV

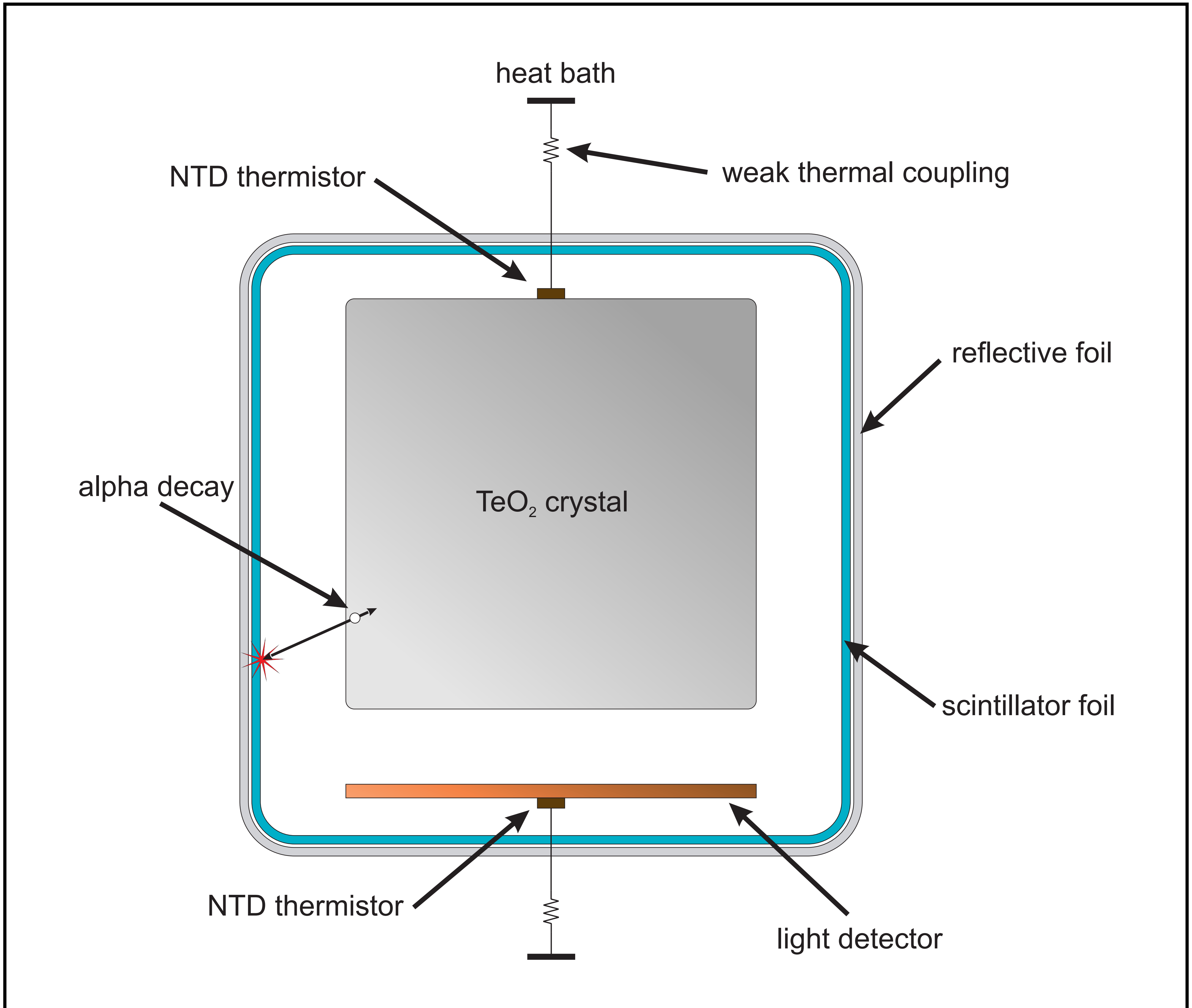
Proposed Technique



How much light?

- From ^{55}Fe calibration of the light detectors we derive that an alpha of 5.3 MeV produce about 1 keV of photons
- We need to tag alpha which release 2.5 MeV on the TeO_2 crystal
- The alpha decay with lower energy belonging to natural chains is the ^{232}Th that have a Q-value of 4.01 MeV
- We need to detect down to 1.5 MeV alphas
- Plastic scintillators are extremely non linear for alpha particles

Proposed Technique (upgraded)



A proper plastic scintillators should guarantee about 10 times more light

Summary

- Applies also on TeO_2
- Does not need a extremely low threshold light detector
- Alphas coming from copper are fully stopped by the foil
- The foil contaminations are tagged as well

- Next Step: Test!

Conclusions

- In the past 20 years bolometers became a actual alternative to conventional radiation detectors for rare events applications.
- CUORE is a neutrinoless Double Beta Decay experiment that aims to start exploring for the first time the inverted hierarchy mass region.
- CUORICINO has operated @ LNGS from March 2003 to June 2008 with excellent performances, demonstrating the feasibility of a large scale bolometric detector.
- The R&D results confirm the feasibility of an high sensitivity 0νDBD experiment.
- CUORE is the only second generation 0νDBD experiment in construction phase. The first data is expected in 2012.
- The future of the technique is in composite detectors: adding a scintillator around TeO_2 crystals we can put together the advantage of the CUORE detectors with a powerful bkg reduction technique.
- The race for a zero bkg experiment is started!