New results of CUORICINO on the way to CUORE

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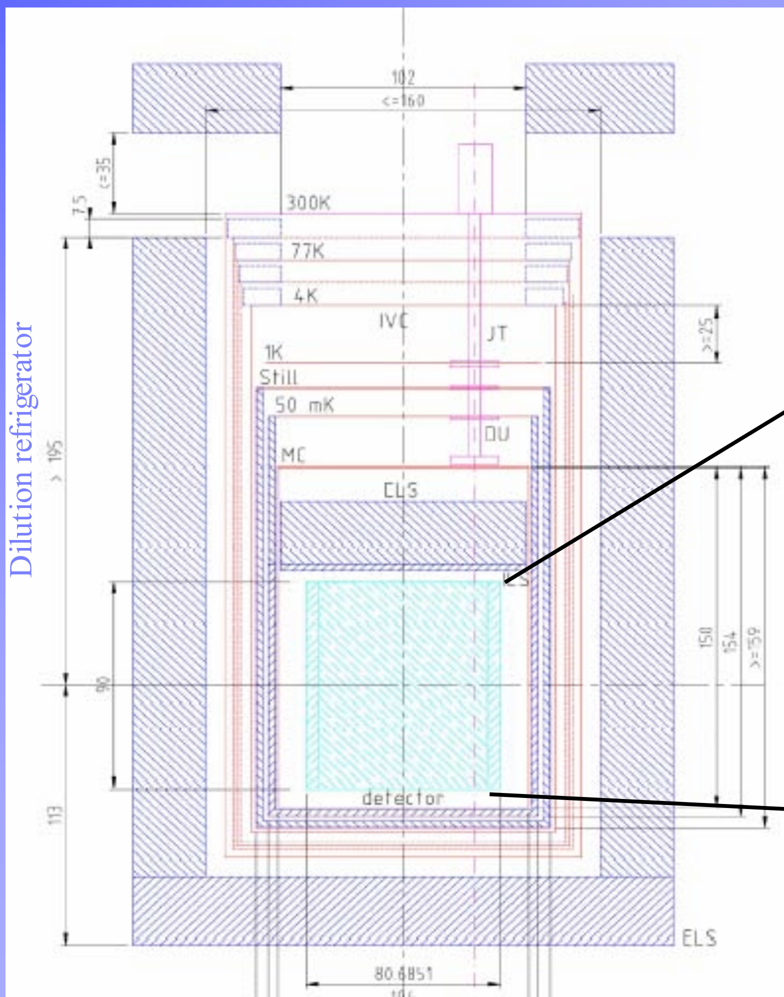
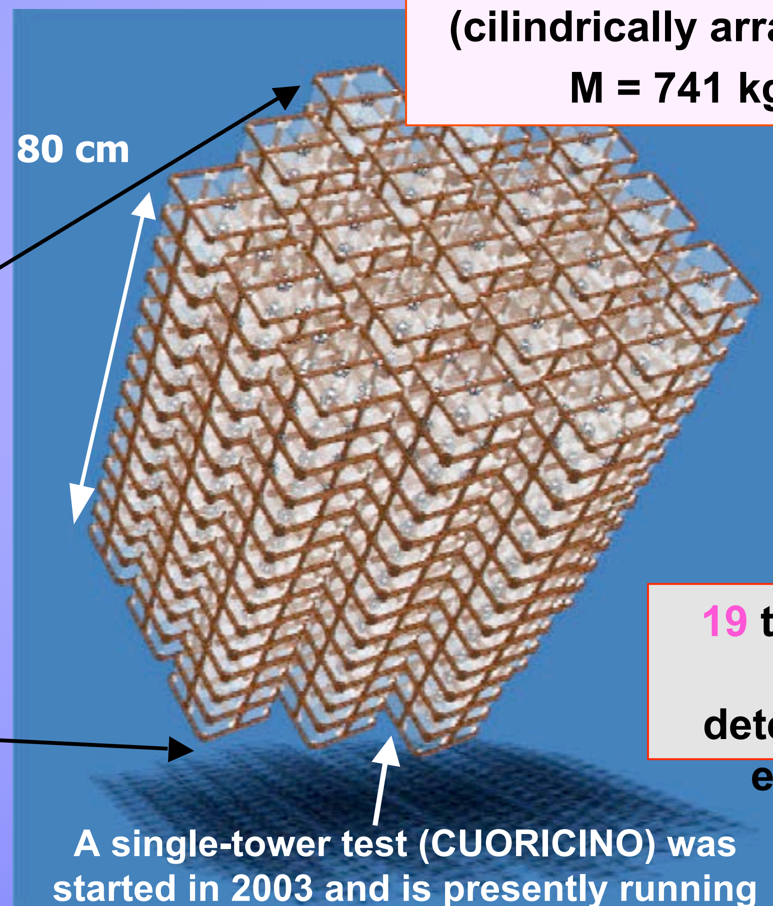
On behalf of the CUORE Collaboration

The CUORE experiment

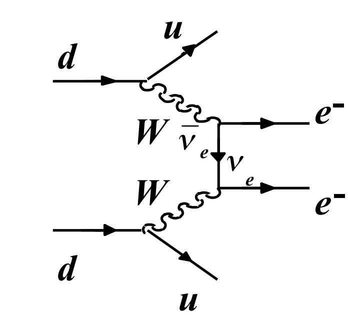
CUORE (Cryogenic Underground Observatory for Rare Events) is an experiment to search for the neutrinoless Double Beta Decay (DBD0ν) of the ^{130}Te with bolometric detectors to be installed in the Laboratori Nazionali del Gran Sasso





DBD-0ν of ^{130}Te

ββ-0 ν : (*A*, *Z*) → (*A*, *Z*+2) + 2e⁻



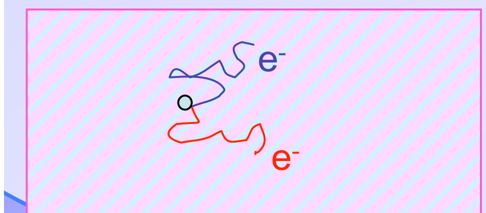
0ν - ββ decay

Expected lifetime:

$$\hat{o}^{-1} = G_{0i} \left|M^{0i}\right|^2 \left|\langle m_i \rangle\right|^2$$

- G_{0i}: **Phase space factor** ($\propto Q^5$)
- M^{0i}: **nuclear matrix element** → **uncertainties**
- $\langle m_i \rangle$: **Effective neutrino mass**

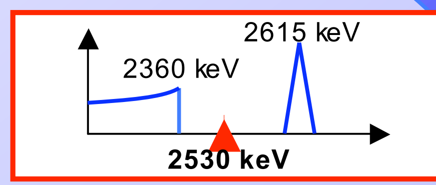
Cuoricino (and CUORE) are experiments for measuring 0ν-DBD of ^{130}Te, using bolometric detectors



Source ≡ Detector
(calorimetric technique)

Signature: an energy line is expected at the Q value of the reaction.

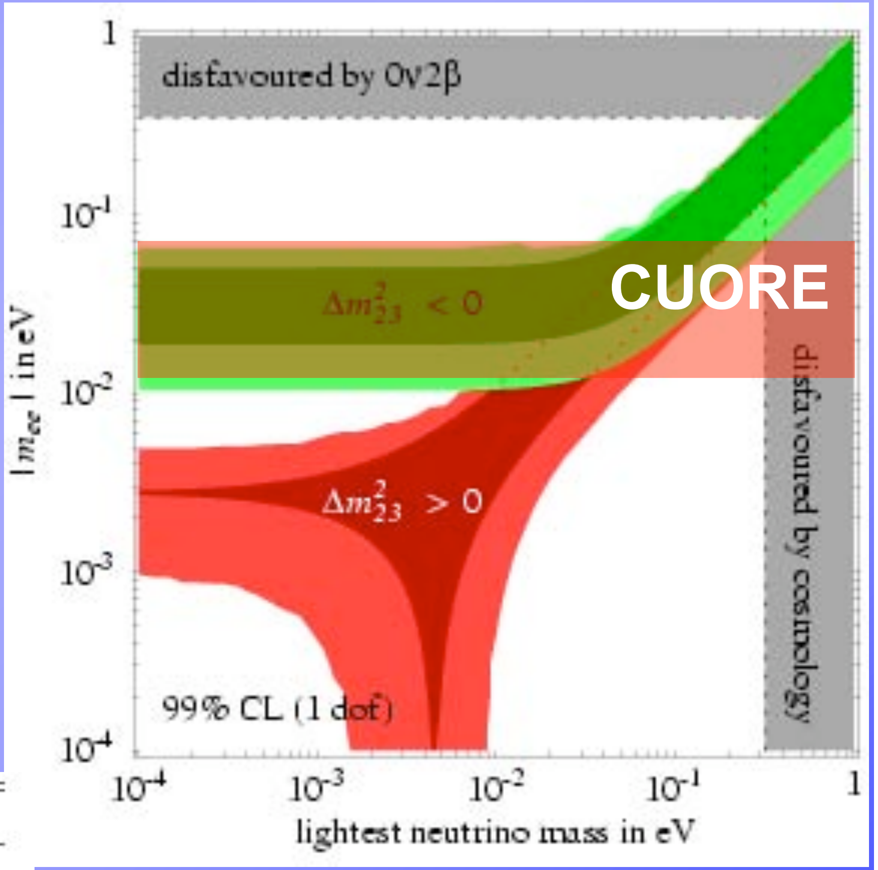
$Q(^{130}Te)$ = 2530.3 keV



- **High natural i. a. (33.87 %)**
- **High Q = 2528.8 keV**
- **Encouraging predicted DBD0v $t_{1/2}$ $\langle m_\nu \rangle \approx 0.3$ eV ⇔ $t^{1/2}_{0\nu} \approx 10^{25}$ years**

CUORE expected sensitivity

A.Strumia and F.Vissani.: hep-ph/0503246



CUORE ββ-0ν sensitivity will depend strongly on the background level and detector performance.

In five years:

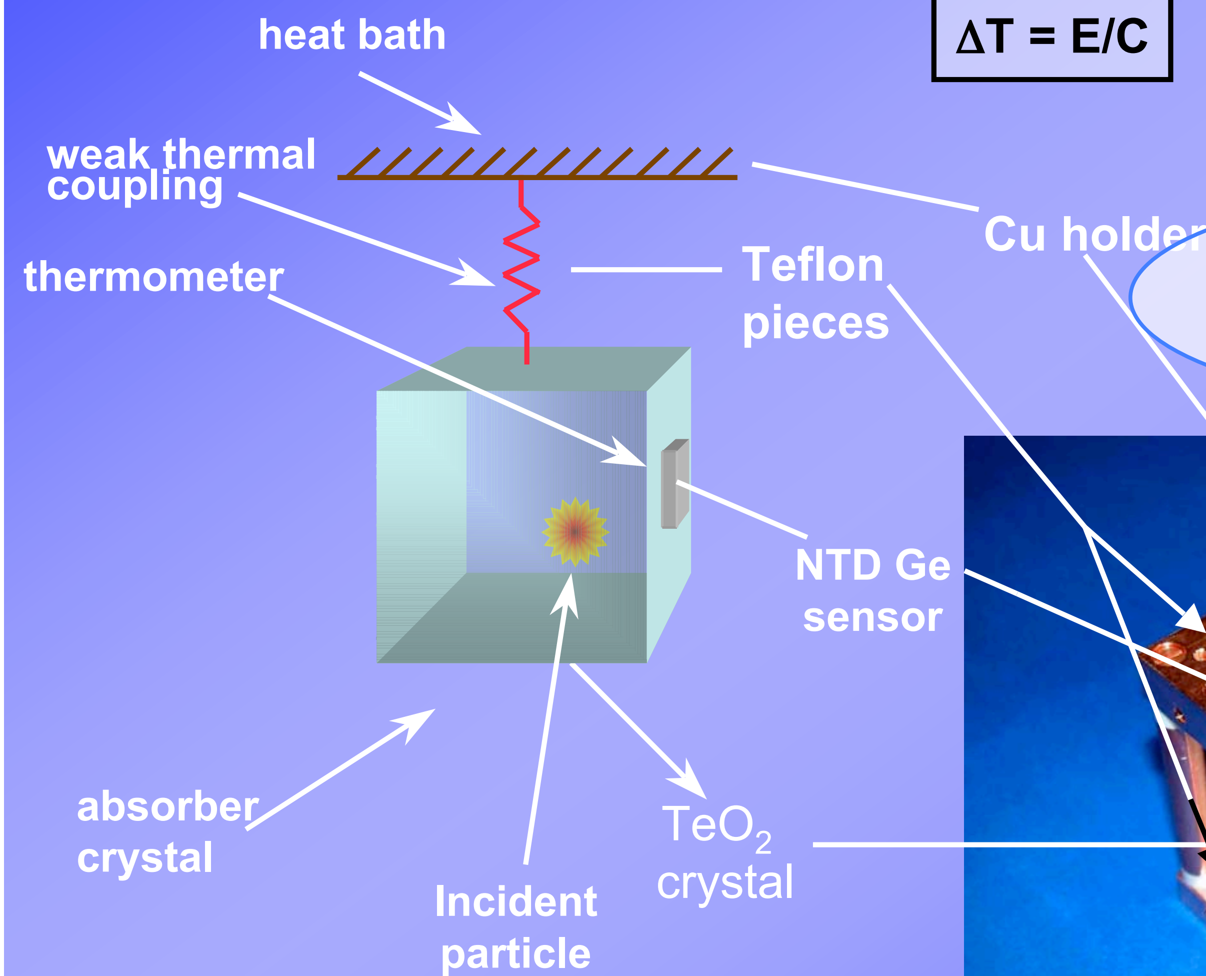
B(counts/keV/kg/y)	Δ(keV)	$T_{1/2}$(y)	$\lvert\langle m_\nu\rangle\rvert$ (meV)
0.01	10	1.5×10^{26}	23–118
0.01	5	2.1×10^{26}	19–100
0.001	10	4.6×10^{26}	13–67
0.001	5	6.5×10^{26}	11-57

Spread in $<m_\nu>$ from **nuclear matrix element uncertainty**

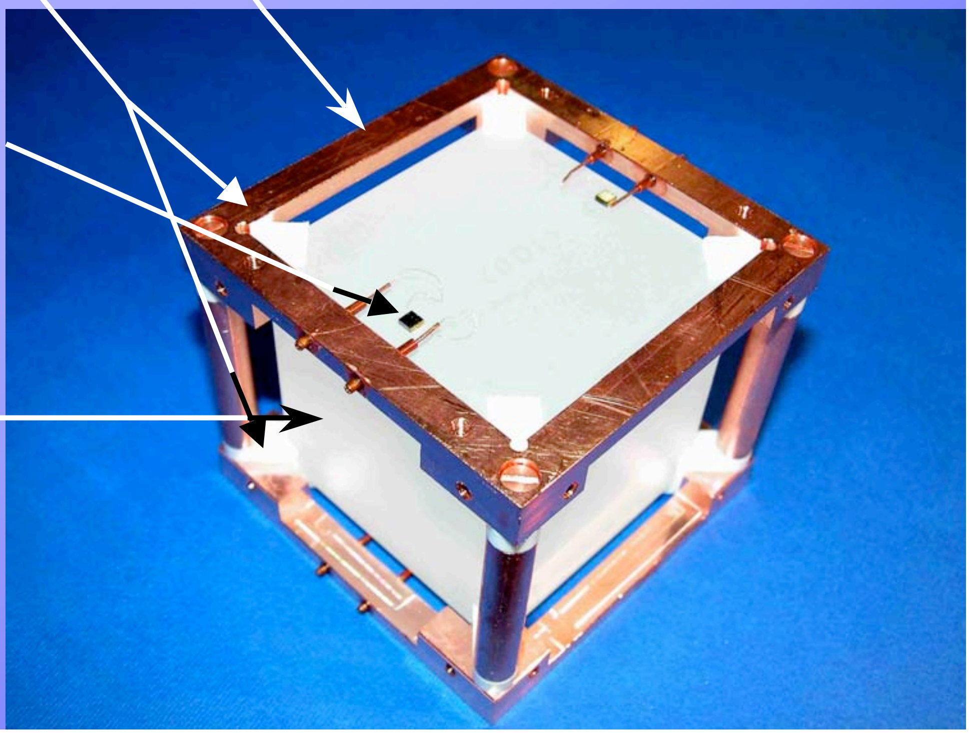
Experimental approach

Bolometer operating principles:

$\Delta T = E/C$ ⇒ **Low Temperature**



Absorber material TeO_2 low heat capacity large crystals available radiopure



Improving sensitivity

Sesitivity: half life corresponding to the minimal number of detectable events above background, for a given C.L.:

$$S^{0\nu}_{n\sigma} = \frac{\text{cost.} \times N_A \times}{\alpha_n} \frac{a}{A} \left(\frac{M\,T}{b\,\Delta E} \right)^{1/2} \times \varepsilon$$

From CUORICINO to CUORE we will increase sensitivity by a factor $(741/40)^{1/2}$ =4.5. Further improvements are very difficult with present technology.

Detector mass (kg)

Isotopic abundance

Measurement time (y)

Efficiency

Difficult to modify. In the case of ^{130}Te one can gain a factor 3 in sensitivity but economic and R&D efforts are needed

Atomic mass

Background (counts/keV/kg/y)

If CUORE will take data for 5 years further improvements will be impossible (20 years more to gain a factor 2).

Energy resolution (keV)

Given

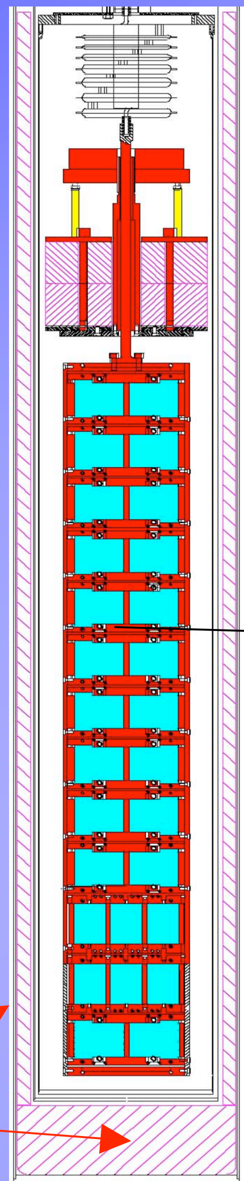
10-20% improvements are possible: negligible contribution to sensitivity

This is the only tunable parameter to act on for improving sensititvity.

Cuoricino

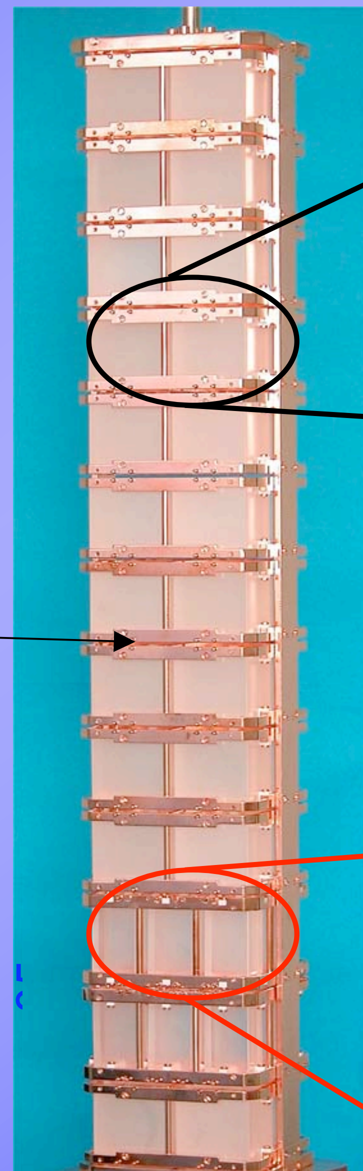
Cuoricino: 62 detectors array.
11 modules of 4 detectors
2 modules of 9 detectors

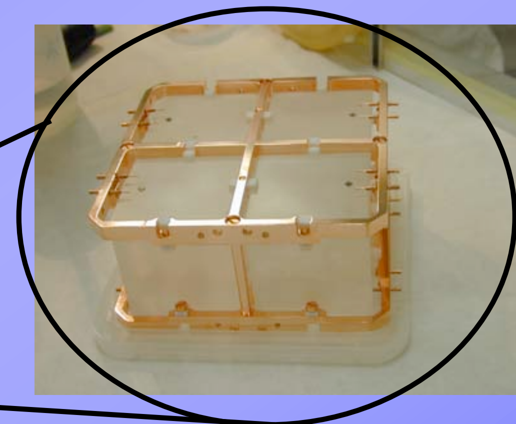
Total active mass
TeO_2 ~~ 40.7 kg
^{130}Te ~ 11.3 kg



Roman Pb shield

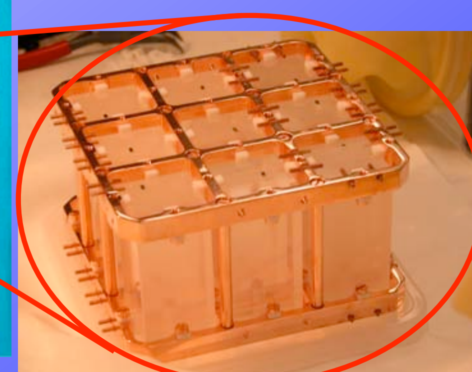
Cuoricino *tower*: 62 TeO_2 crystals



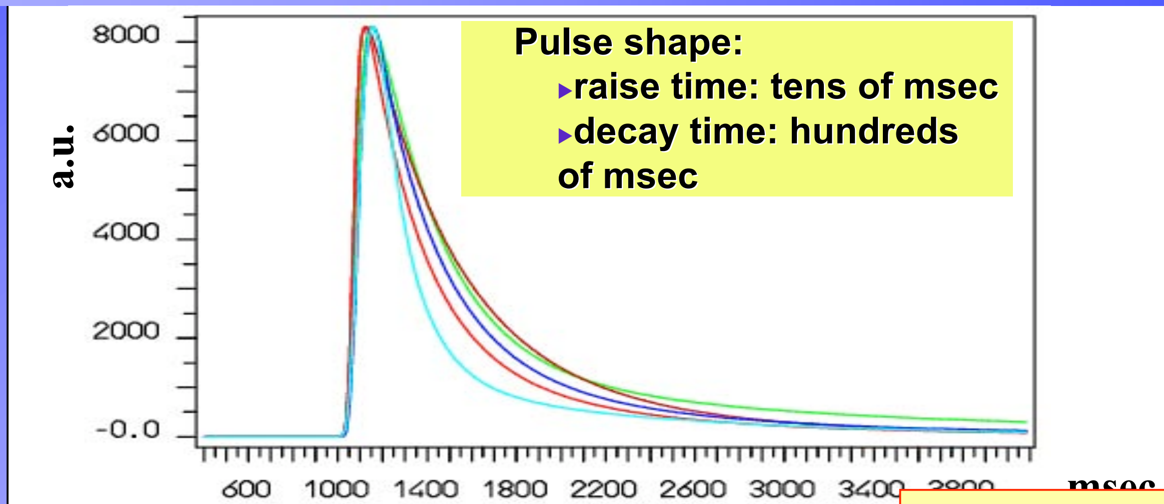


4 detectors 5x5x5 cm^3, 790 g each

9 detectors 3x3x6 cm3, 330 g each



Detector Behavior

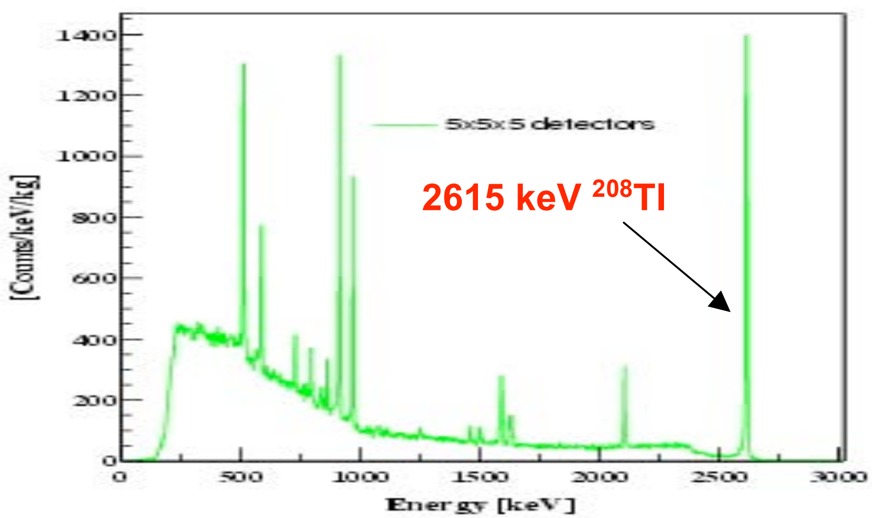


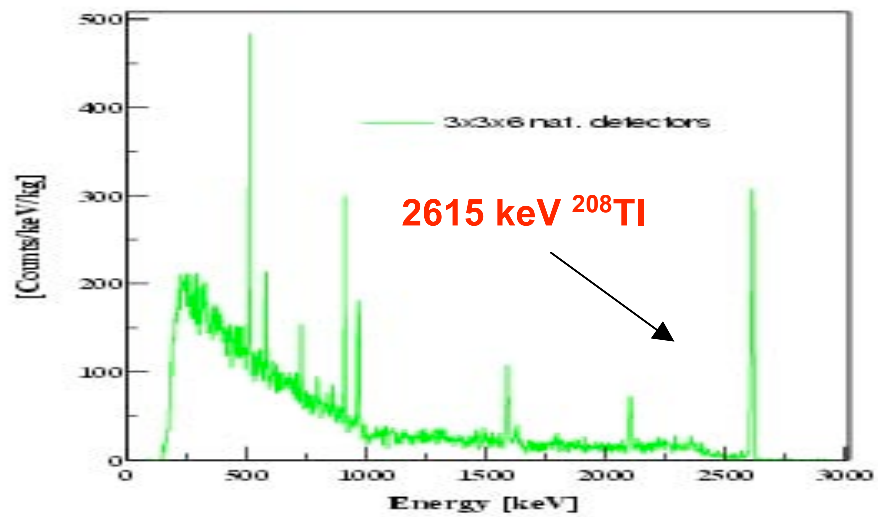
ΔE @ 2615 keV

790 g crystals ~ 7.5+/-2.8 keV

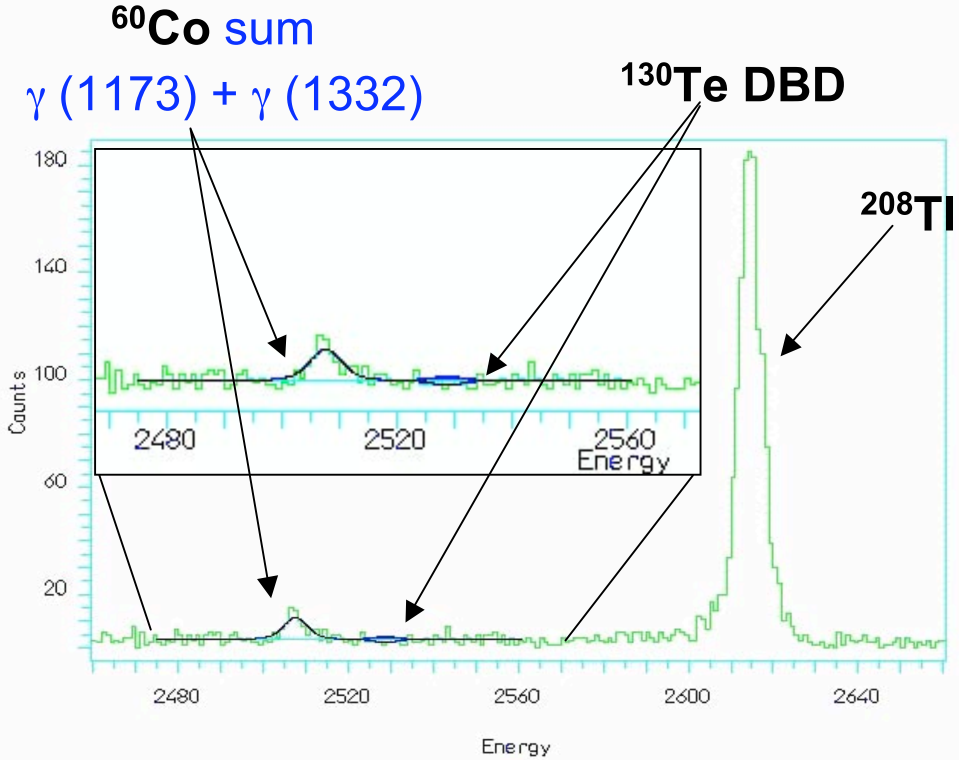
330 g crystals ~ 9.6+/-2.5 keV

Calibration with ^{232}Th γ-sources external to the cryostat





Cuoricino results



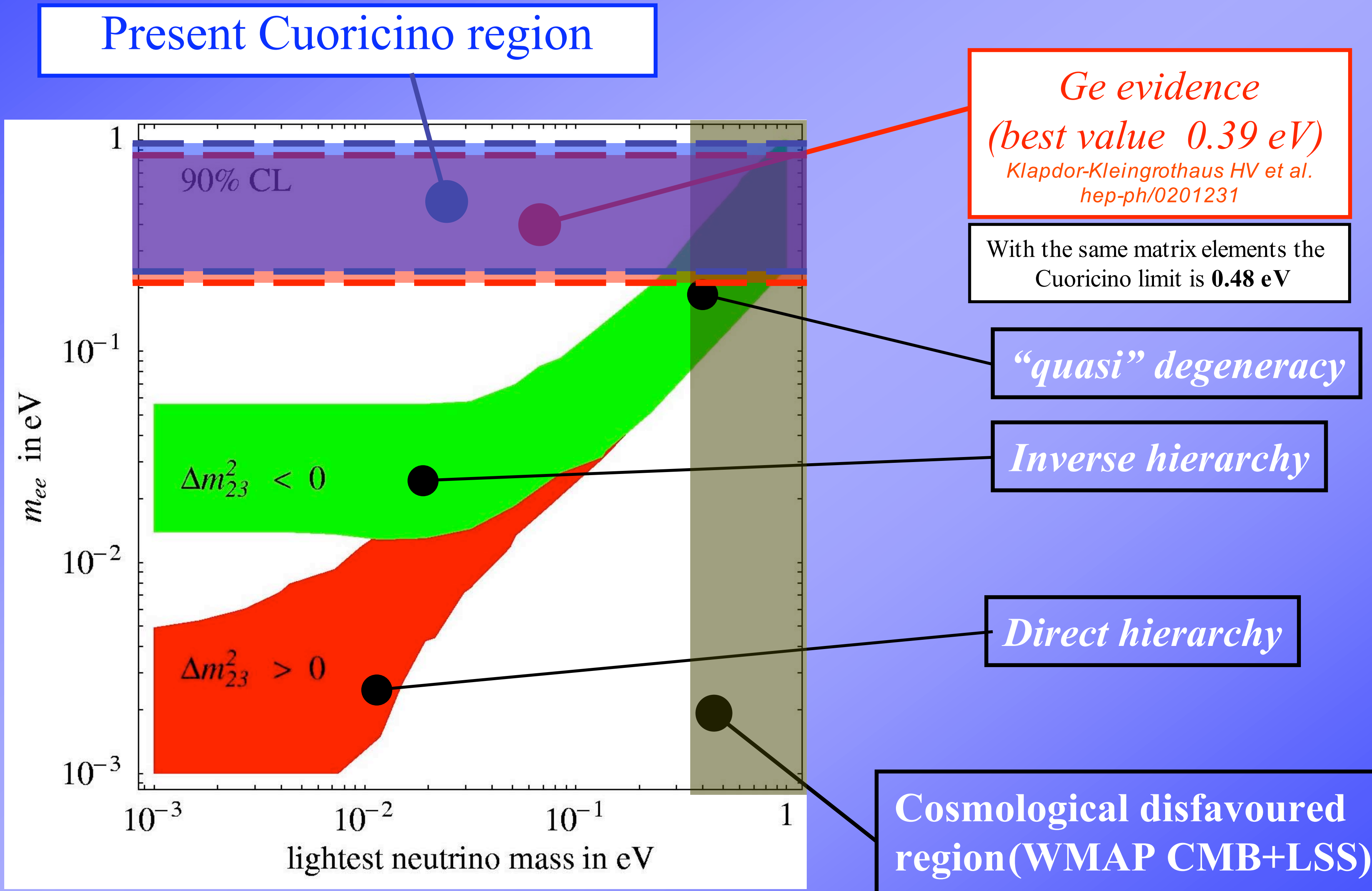
STATISTICS:

- **anticoincidence spectrum detector efficiencies: 86.4% (790g) and 84.5% (330g)**
- **run I + run II = 7.09 kg (^{130}Te) x year**
- **No peak is observed at the 0νDBD transition energy (2528.8 keV)**
- **Bkg counting rate in the 0 νDBD region = 0.18 ± 0.02 c/keV/kg/y**

$t^{1/2} > 2.2\ 10^{24}$ y at 90% C.L. **$<m_\nu> < [0.19 \div 0.98]$ eV**

- **~5% variation of the limit when changing the energy region, the bkg shape (linear or flat) and when including/excluding the 2615 keV peak**

CUORICINO sensitivity



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

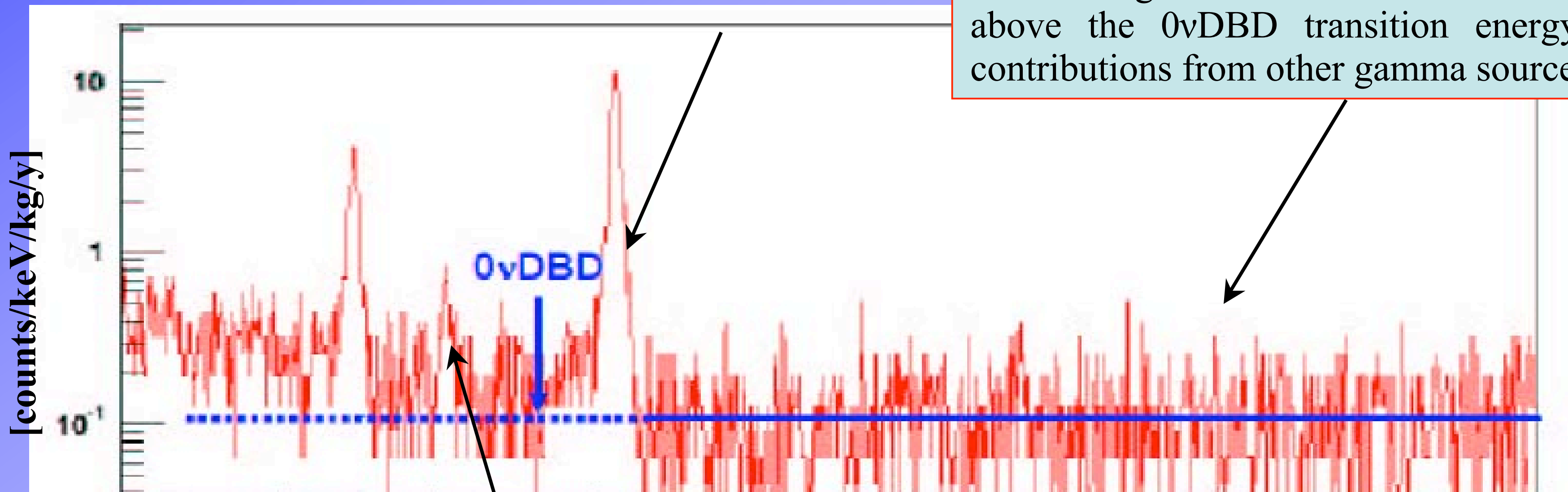
Background Origin (I)

2615 keV Tl line: contribution to the DBD bkg due to a Th contamination (multicompton).

➢ Most probable location: in between the inner Roman lead shield and the external lead shield.

➢ Th (Tl) contribution to DBD background: **~ 40% (prelimin**

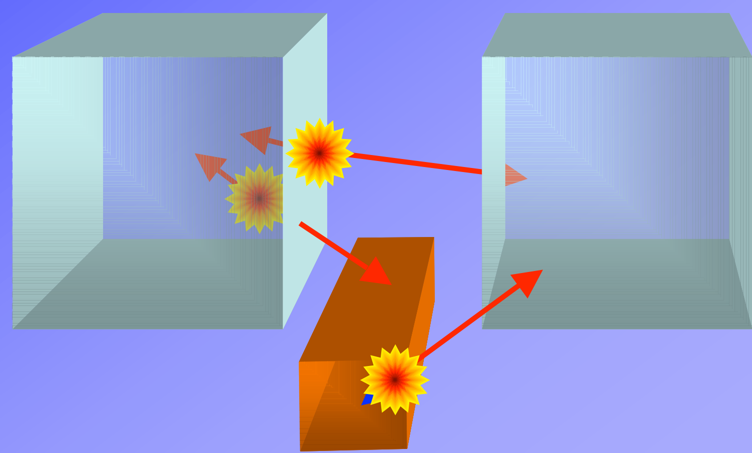
No other gamma lines identified near or above the 0νDBD transition energy no contributions from other gamma sources.

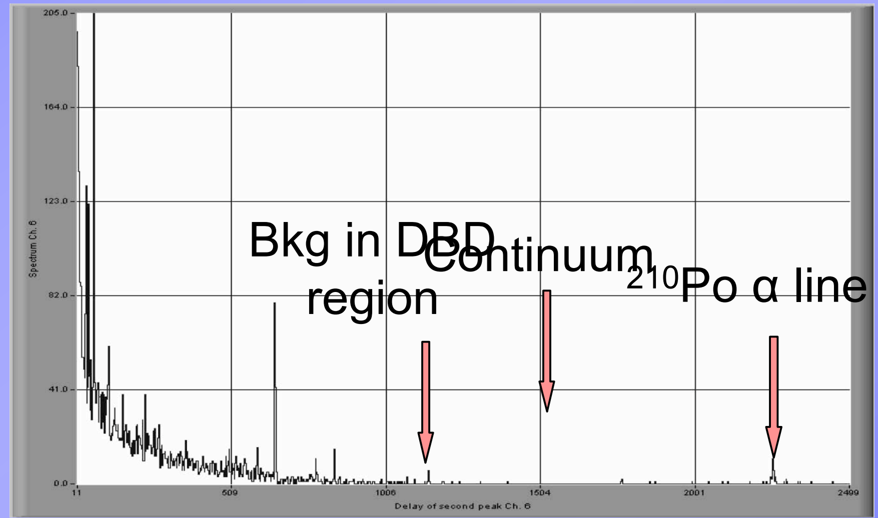


Flat background in the energy region above the ^{208}Tl 2615 line

- Natural extrapolation to the region below the 2615 keV peak
- Contribution to the counting rate in the 0νDBD region: ~ 60% (preliminary)
- Origin: degraded alpha particles

Background Origin (II)





3-4 MeV background

Cuoricino **0.122+/- 0.003 c/keV/kg/y**

bkg model (*Cuore Proposal 2004) :*

(20 +/- 10) % crystal surface contamination

*(80 +/- 10) % "Cu" surface contamination ~ **0.10 c/keV/kg/y***

CUORE goal: 0.01 c/kev/kg/y

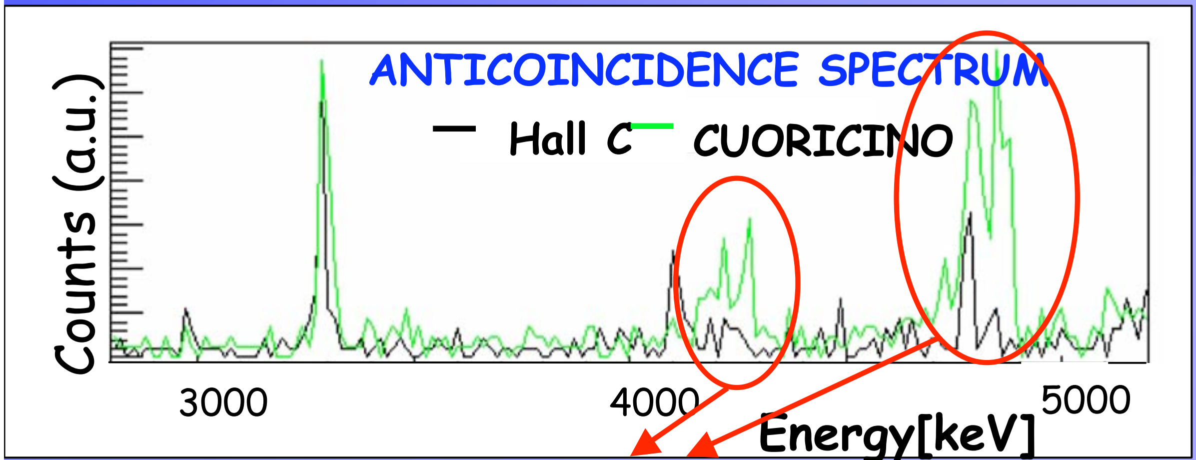
Two tests were planned:

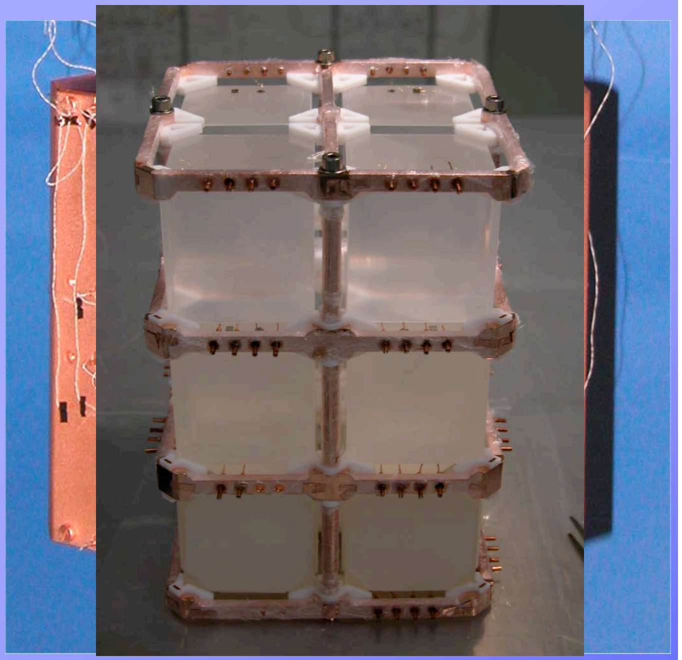
① **Crystal and copper surface cleaning to reduce the background.**

② **Covering the cupper surface with ultraclean polyethylene foil**

CUORE background

Array of 8 Detectors: cleaned with ultra-radiopure materials and procedures





- **Reduction of a factor ~ 4 on crystal surface contaminations: CUORE milestone for this task reached**
- **Reduction of a factor ~ 2 on copper surface contaminations**

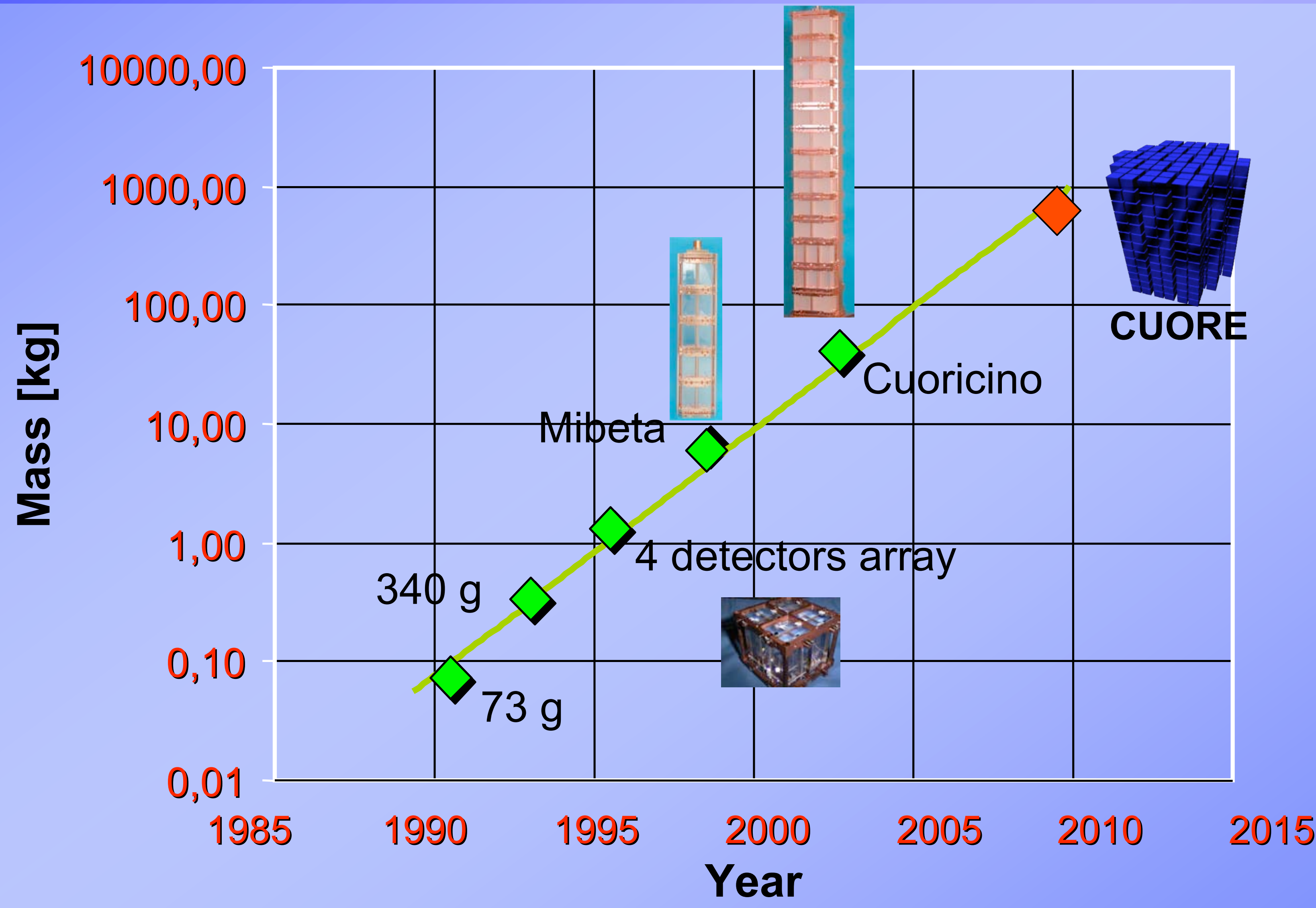
Preliminary

Crystal surface contaminations in CUORE	< 3 x 10^{-3} c/kev/kg/y
Crystal internal contaminations in CUORE	< 8 x 10^{-5} c/kev/kg/y
Copper surface contaminations in CUORE	< 5 x 10^{-2} c/kev/kg/y
New structure with red...	< 2.5 x 10^{-2} c/kev/kg/y

CUORE goal: 0.01 c/kev/kg/y

New development presently tested @LNGS

TeO_2 Bolometers

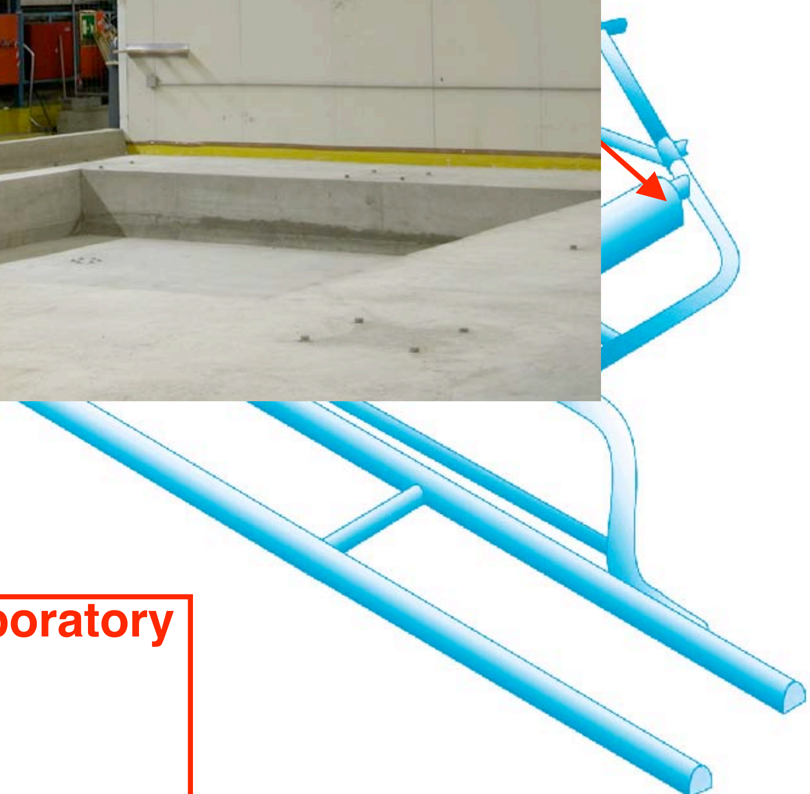


CUORE @ LNGS

CUORE R&D (Hall C)

CUORE location (Hall A)

Cuoricino (Hall A)



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Conclusion

- Cuoricino is presently the most sensitive DBD-0ν running experiment, capable to confirm the KK-HM "evidence".
- Cuoricino demonstrate feasibility of a large scale bolometric detector (CUORE) with good energy resolution and bkg on many detectors.
- Recent results on background suppression confirm the capability to explore the inverse hierarchy mass region.
- CUORE, a second generation detector developed on this new approaches, will be build and start up in the next 5 years.