CUORE:

high sensitive Double Beta Decay cryogenic Experiment

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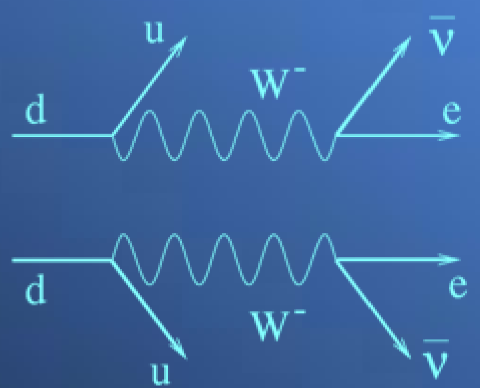
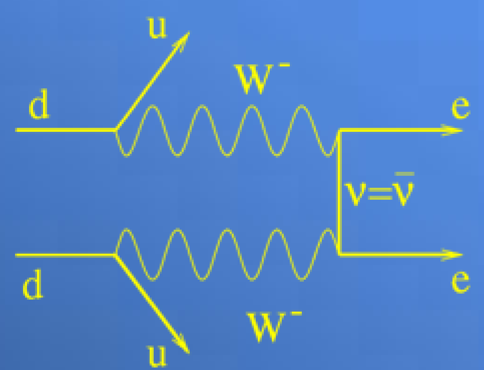
on behalf of the CUORE collaboration

Double Beta Decay

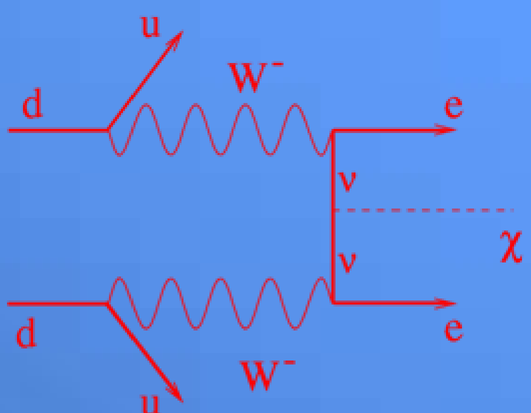
$(A,Z) \rightarrow (A,Z\text{-}2) + 2e + 2\bar{\nu}$



$(A,Z) \rightarrow (A,Z\text{-}2) + 2e$

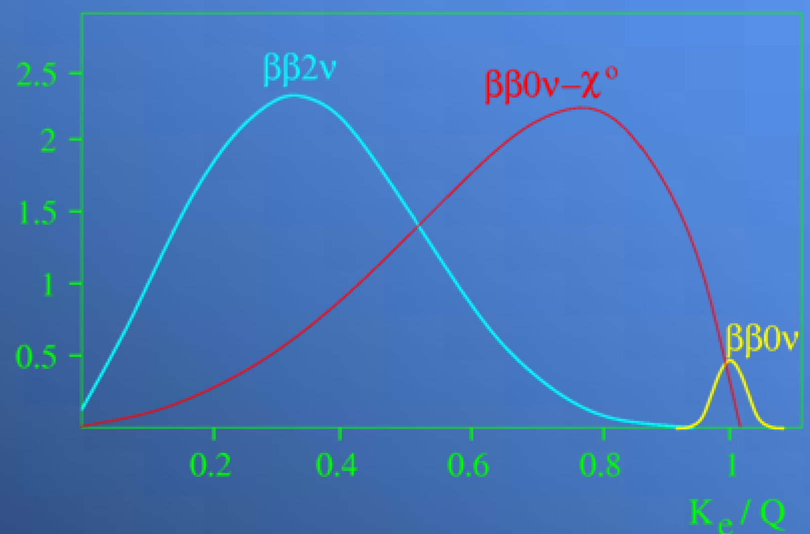


$(A,Z) \rightarrow (A,Z\text{-}2) + 2e + \chi$

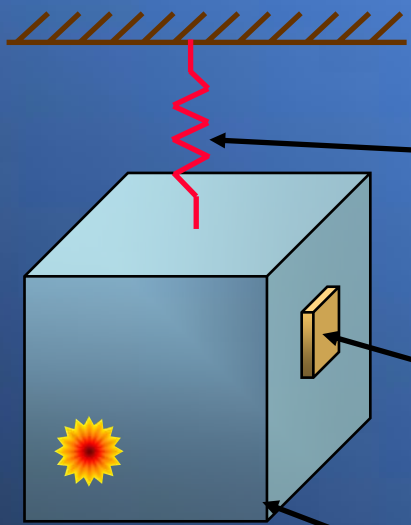


Allowed in SM
observed in several nuclei with
$\tau^{2\nu} \sim 10^{18} - 10^{21}$ y

- Leptonic number violation
- Majorana neutrino
- $\nu = \nu^c$
- $\mathbf{m_\nu \neq 0}$



Cryogenic Detectors

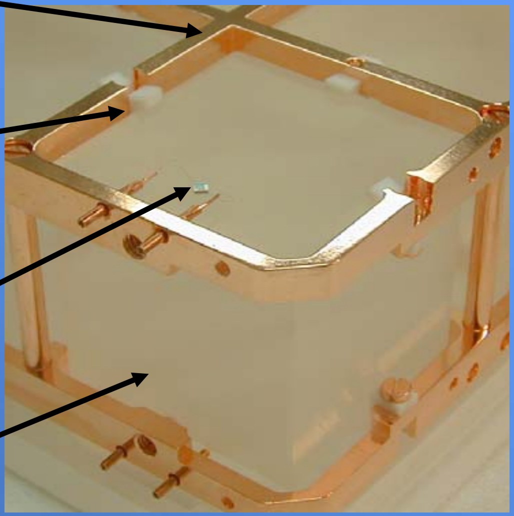


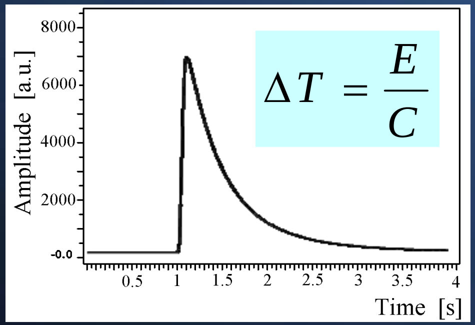
Heat bath (~8 mK)

Weak thermal coupling (G~4 pW/mK)

Thermometer (NTD Ge , R~100 MΩ)

Adsorber crystal (TeO_2, C~10^{-9} J/K)





Cryodet features

- ▲ wide choice of detector materials
- ▲ good energy resolution
- ▲ true calorimeters
- ▼ velocity

DDB-0ν Sensitivity

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

Detector mass (kg)

Measurement Time (y)

Isotopic abundance

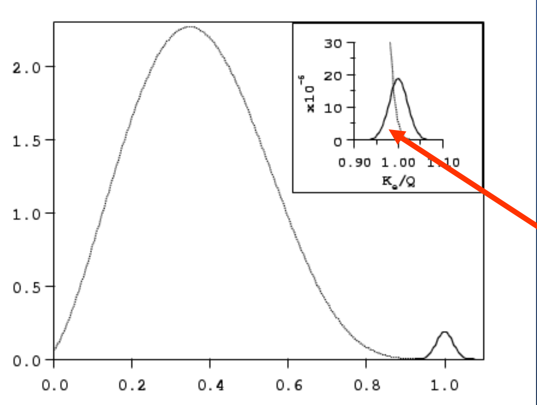
Efficiency

$$S^{0\nu} = \ln 2\, N_A \times \frac{a}{A} \left(\frac{M\,T}{b\,\Gamma} \right)^{1/2} \times \varepsilon$$

Energy resolution (keV)

Atomic mass

Background (counts/keV/kg/y)



sum electron energy / Q

Unavoidable background

$\propto Q\Gamma^6$

TeO_2 cryogenic detectors

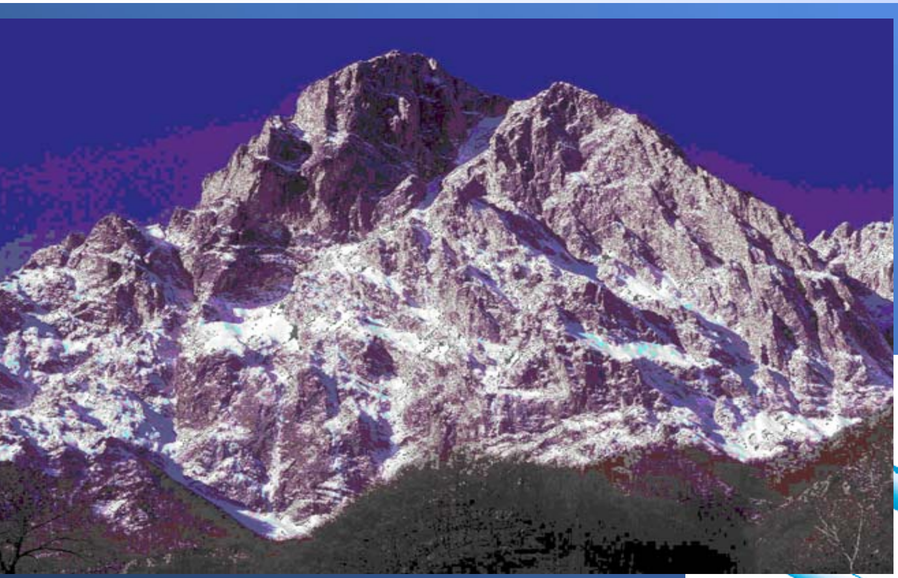
Active isotope ^{130}Te

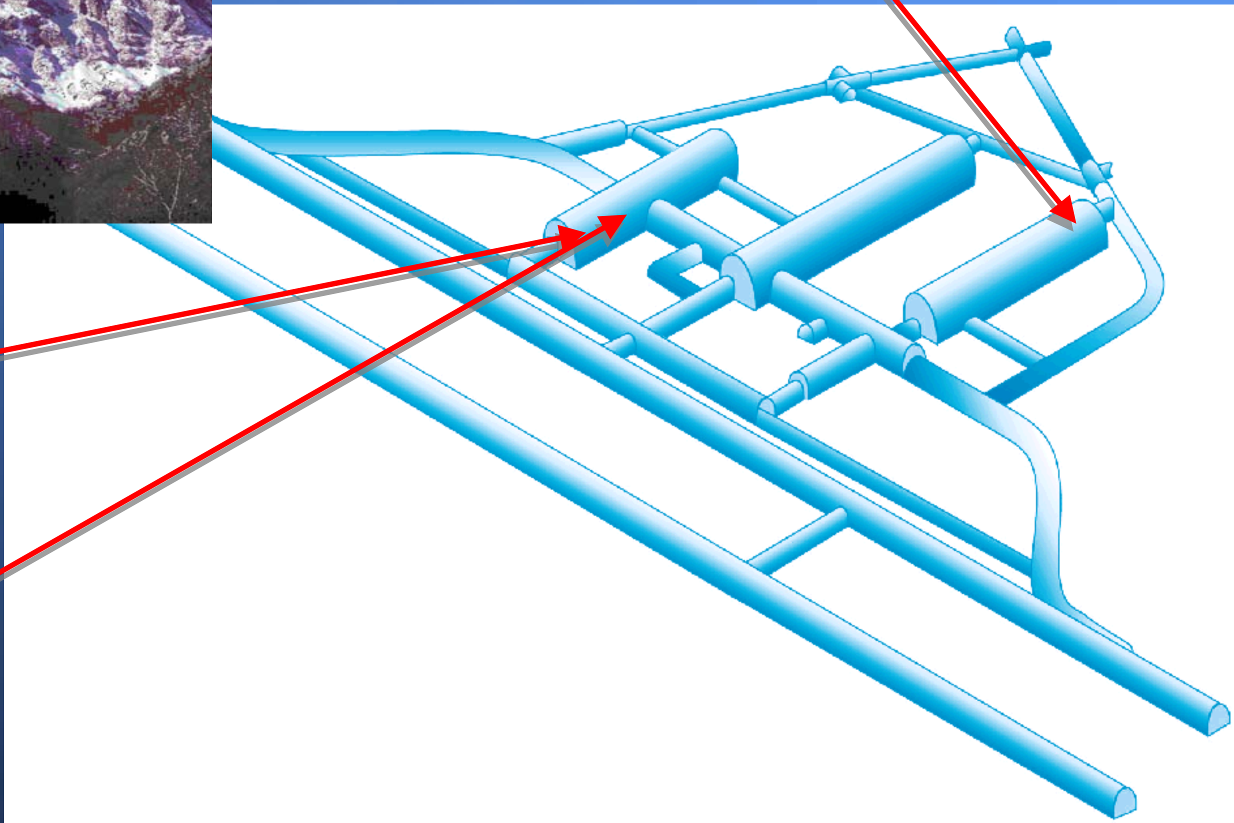
- high natural isotopic abundance: a = 33.4 %
- transition energy: Q = 2529 keV
- reasonable nuclear matrix element calculations

TeO_2 Absorbers

- low specific heat
- large crystals available
- radiopure

CUORE @ LNGS



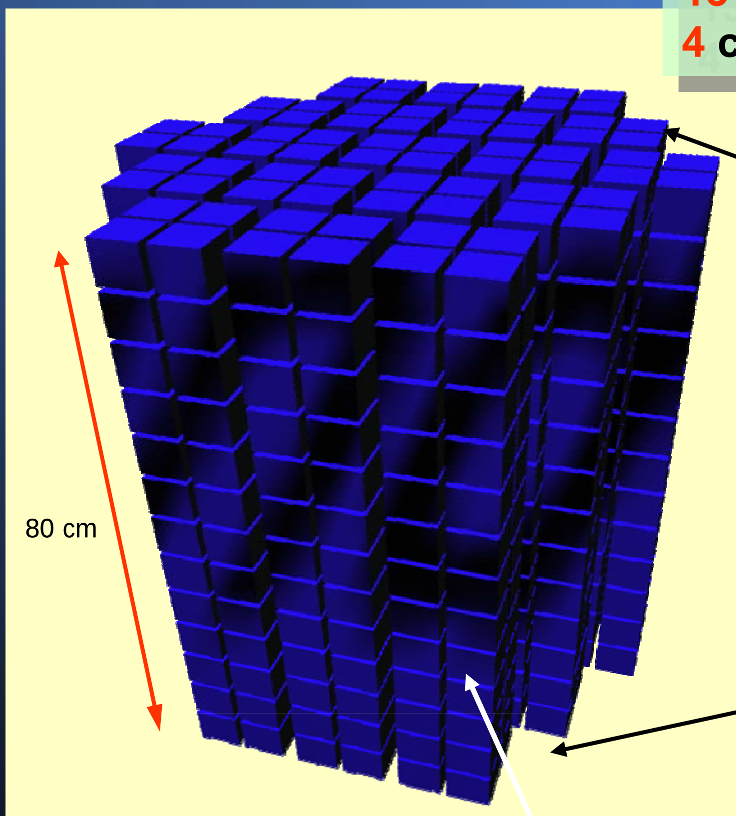


Cryogenic Underground Observatory for Rare Events

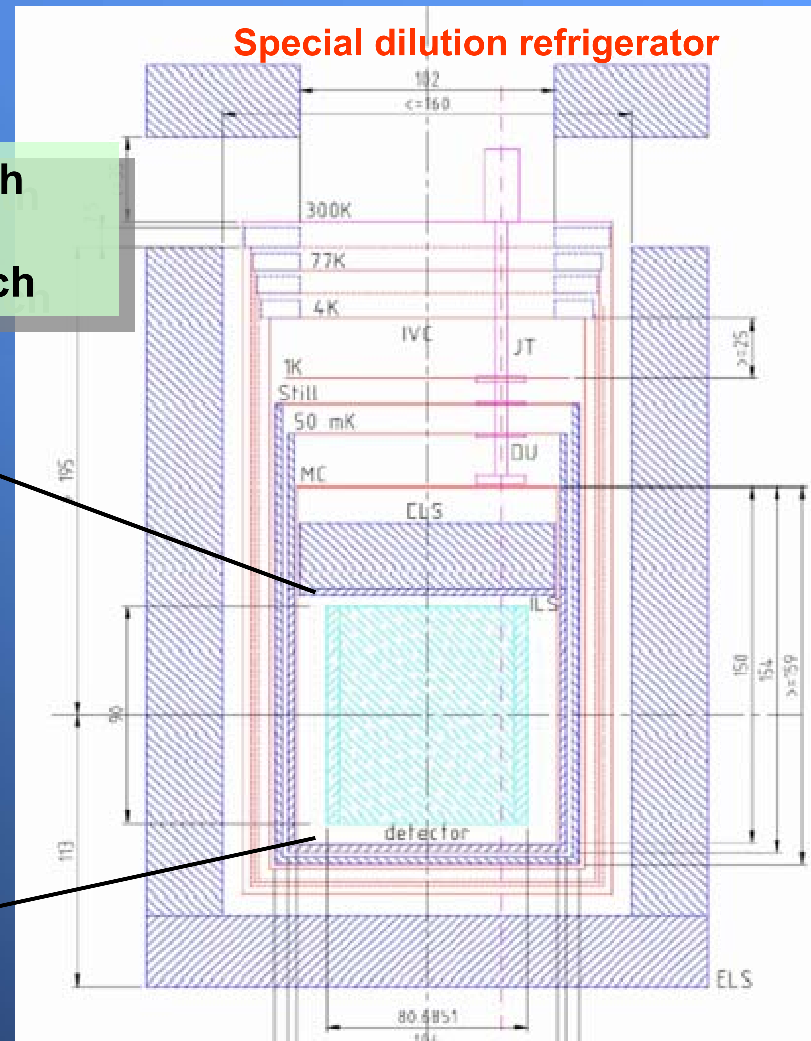
CUORE will be a closely packed array of 988 detectors

M = 741 kg of TeO_2

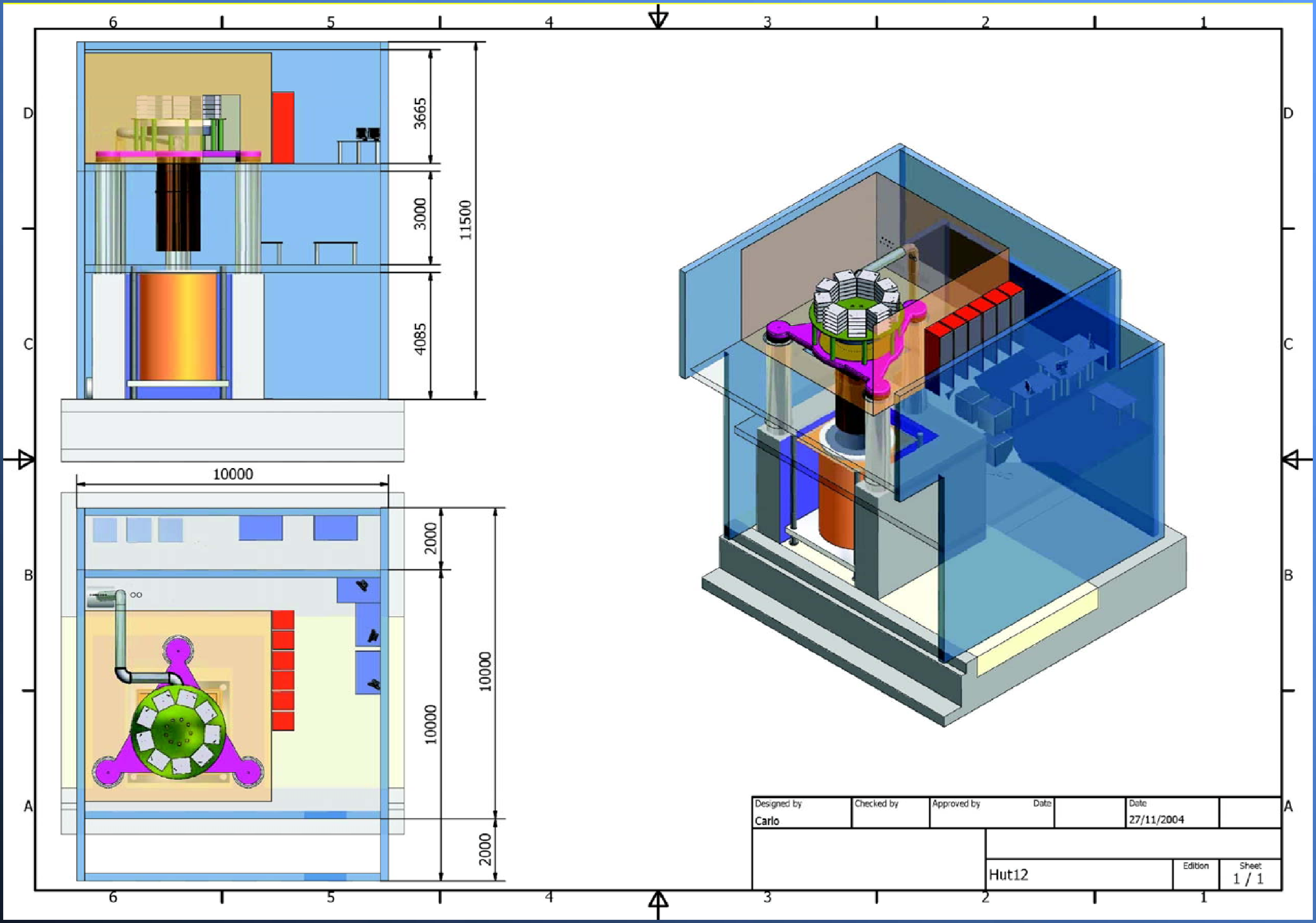
19 towers with
13 planes of
4 crystals each



19 CUORICINO-like towers

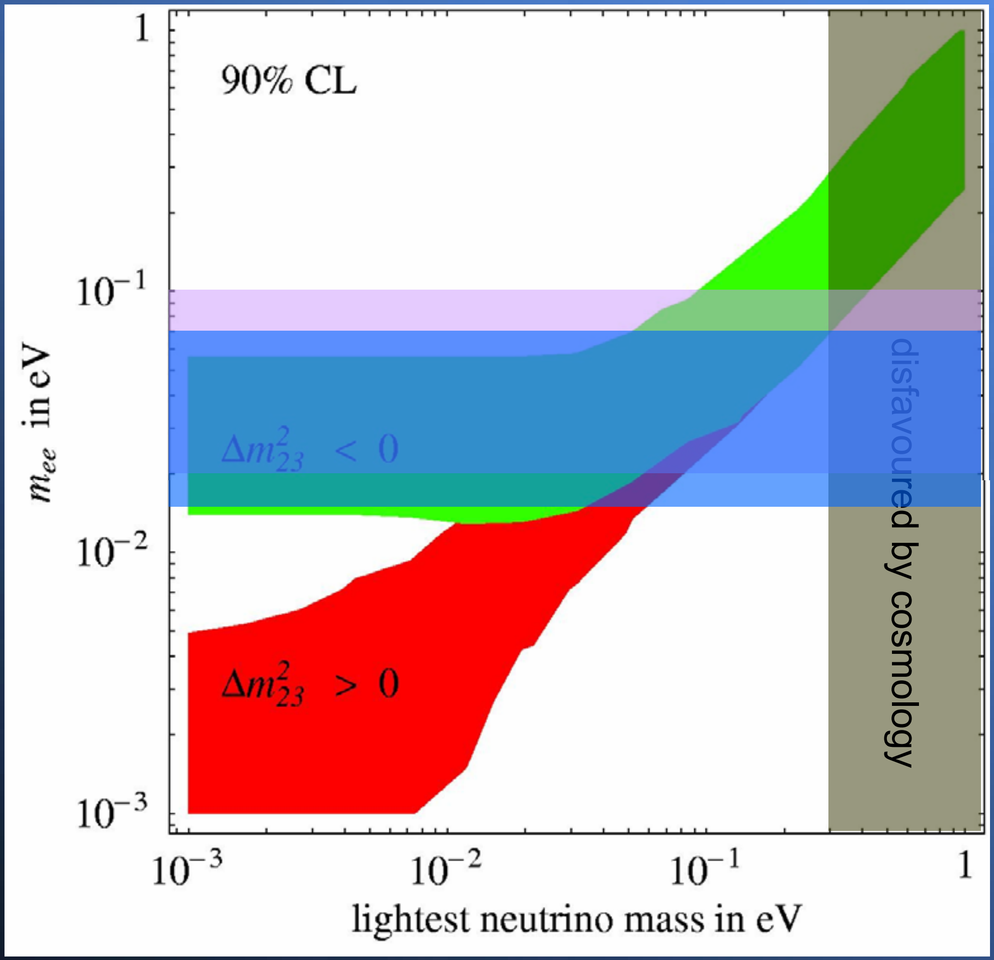


CUORE Hut


3665
3000
4085
11500
10000
2000
10000
10000
2000
Designed by
Carlo
Checked by
Approved by
Date
Date
27/11/2004
Hut12
Edition
Sheet
1 / 1

CUORE time schedule

CUORE expected sensitivity

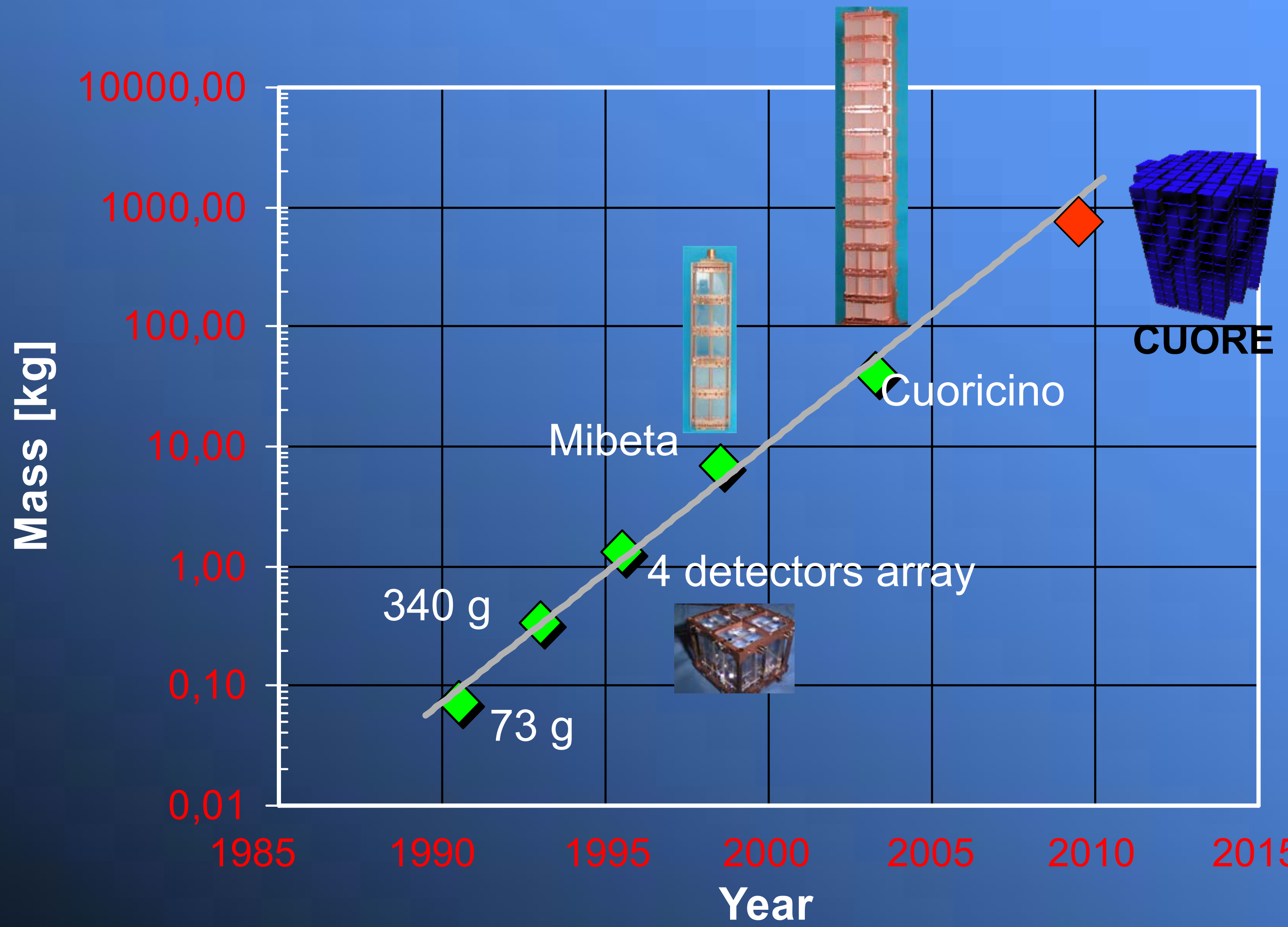


Strumia A. and Vissani F. hep-ph/0503246

In 5 years:

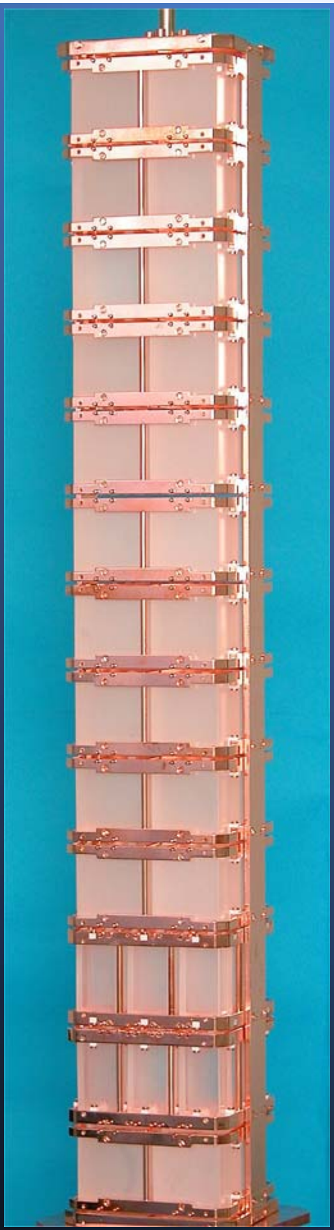
b (counts/keV/kg/y)	Γ [keV]	$T_{1/2}$ [y]	$\langle m_\nu \rangle$ [meV]
10^{-2}	5	2.1×10^{26}	19-100
10^{-3}	5	6.5×10^{26}	11-57

Moore's Law



Mass [kg]
10000,00
1000,00
100,00
10,00
1,00
0,10
0,01
1985
1990
1995
2000
2005
2010
2015
Year
CUORE
Cuoricino
Mibeta
4 detectors array
340 g
73 g

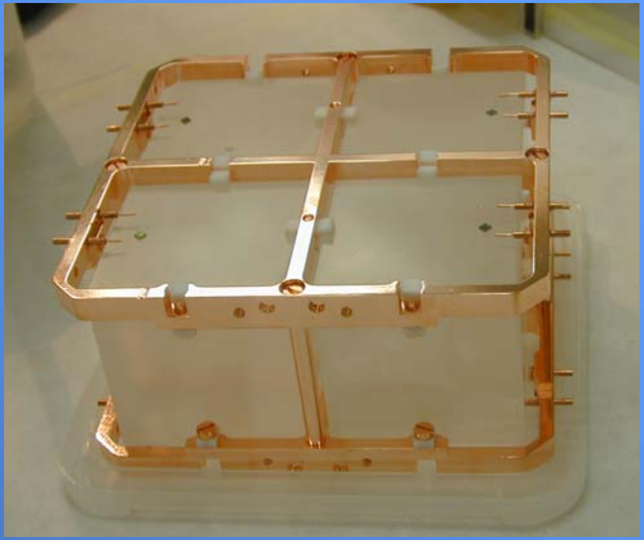
Cuoricino

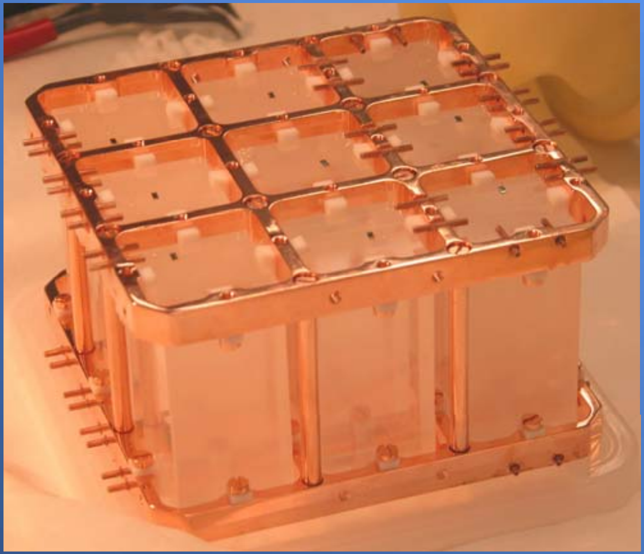


11 modules
4 detectors each
Dimension: 5x5x5 cm^3
Mass: 790 g

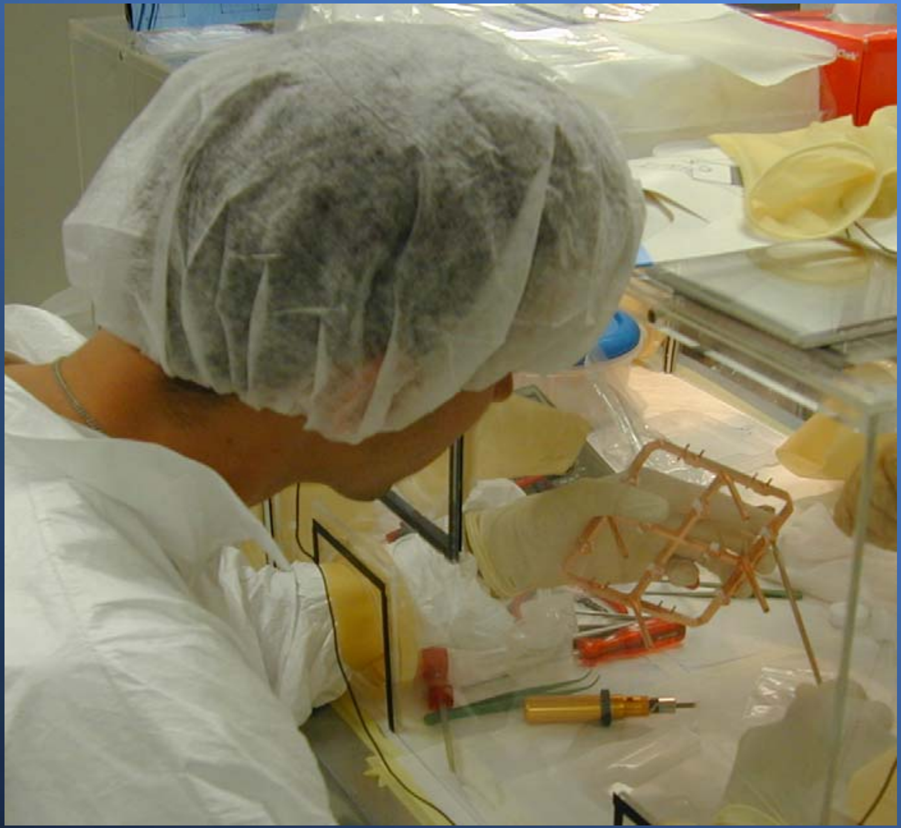
Total mass
40.7 kg

2 modules
9 detectors each,
Dimension: 3x3x6 cm^3
Mass: 330 g



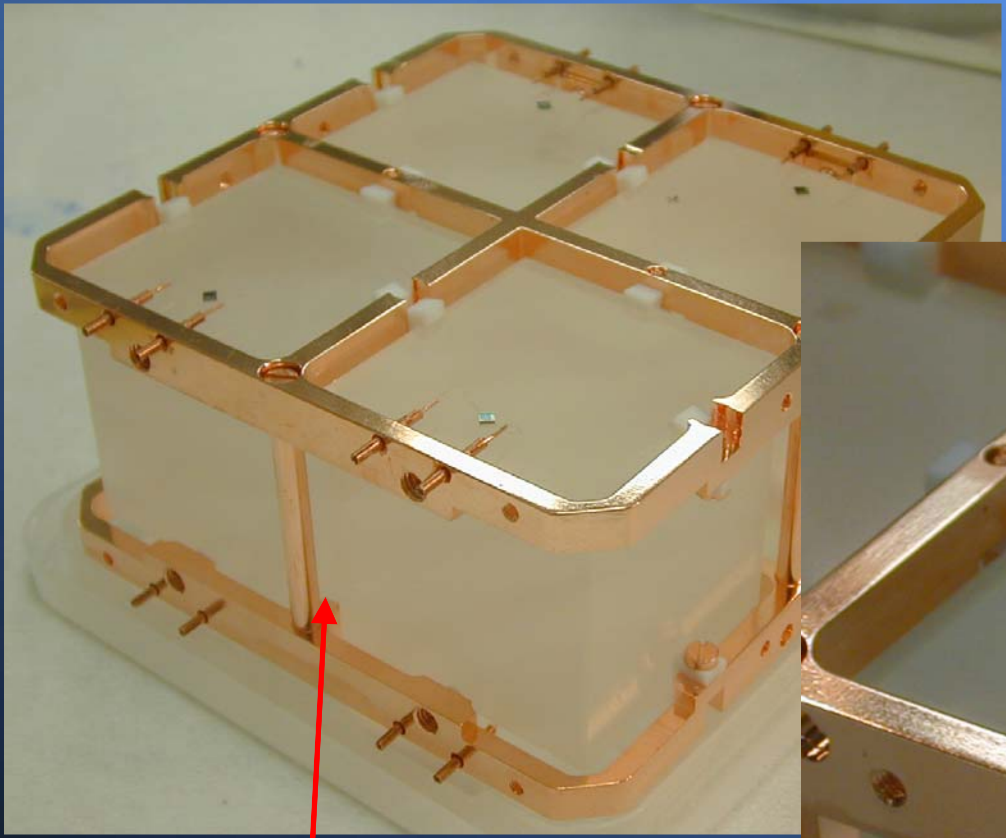


Detectors assembling



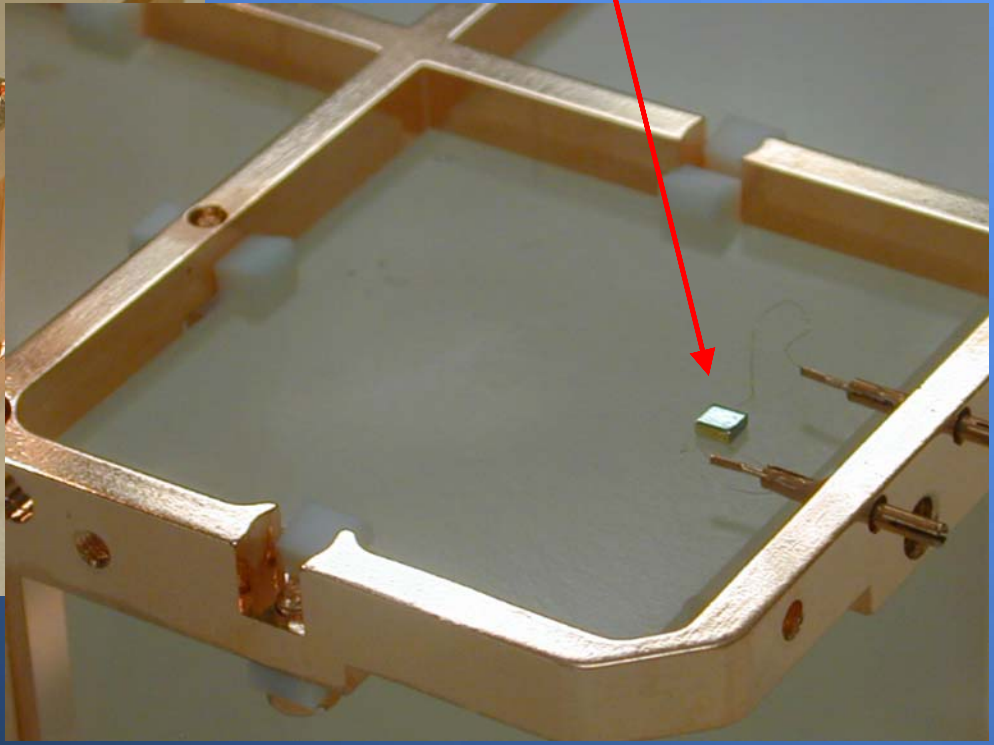
All the operations done in
Clean Room and
nitrogen atmosphere

Cuoricino module



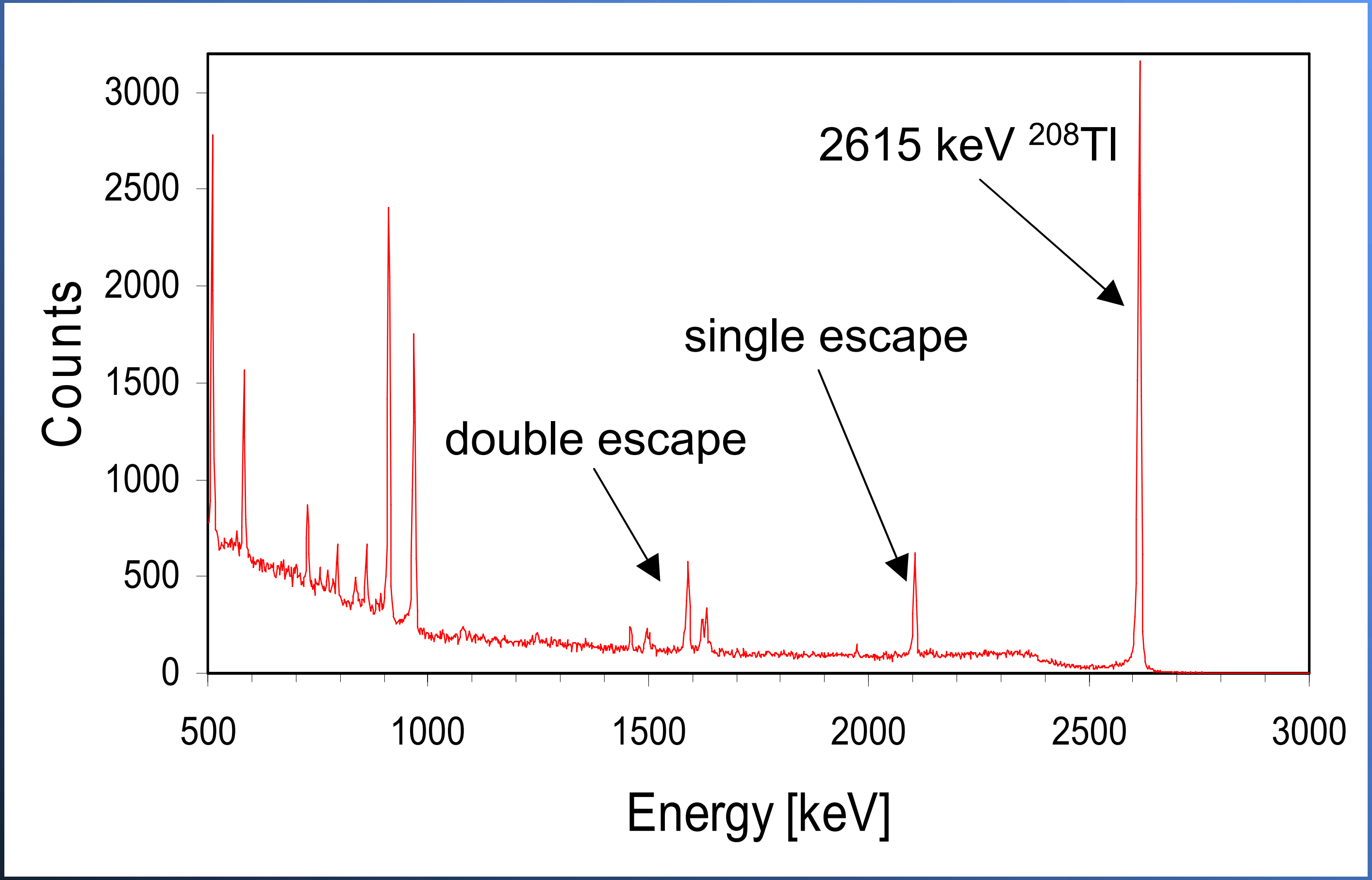
A Cuoricino module

Ge NTD thermistor



Tower assembling

^{232}Th Calibration



Sum spectrum of all the 5x5x5 cm^3 detectors

ΔE_{FWHM} = 7.5 keV @ 2615 keV

Live time

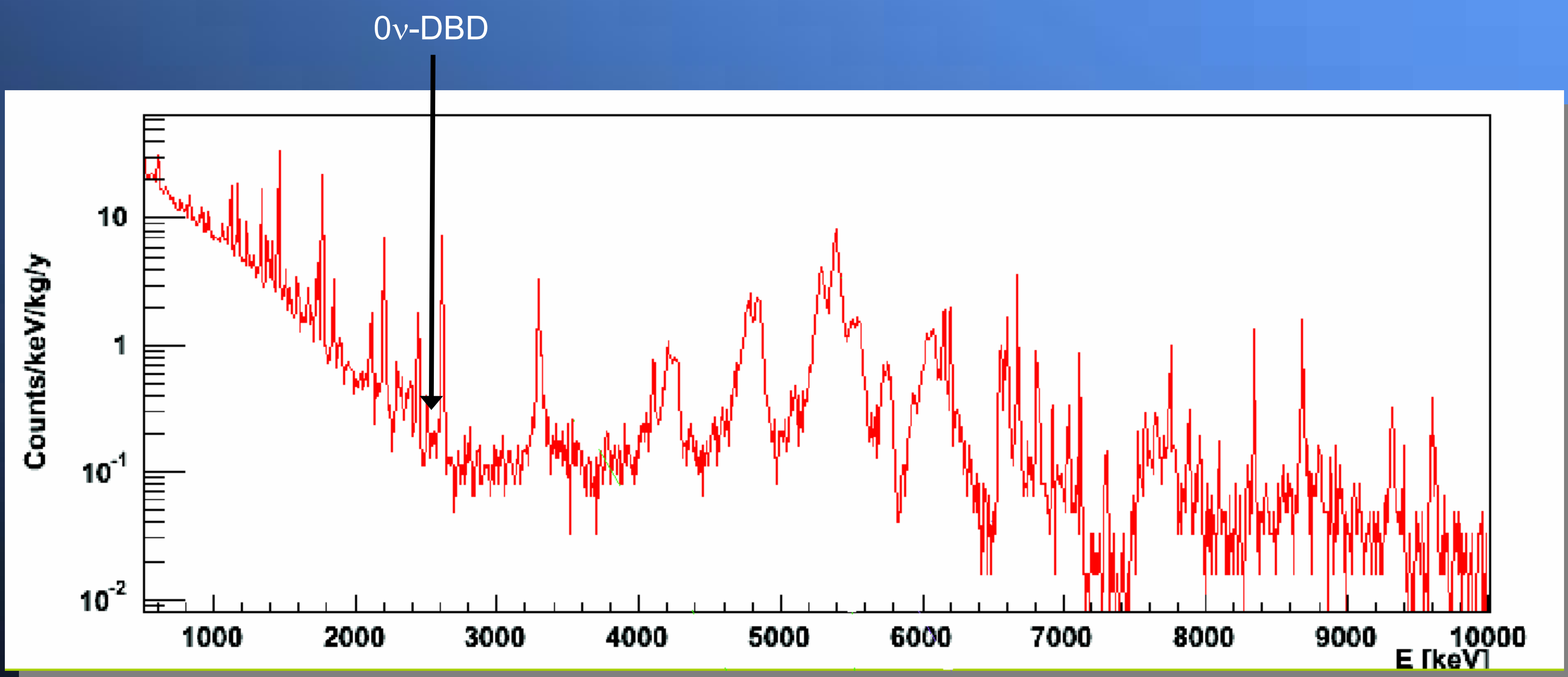
Run I
Cooldown: February 2003
Detectors: 14/62 detectors lost
Working detectors: 73%
Live Time: 23%

Upgrade: October 2003
- Wiring
- DAQ
- Temperature feedback
- Cryogenics (20 years old cryostat)

Run II
Cooldown: May 2004
Detectors: 2 detectors still dead + 2 with high noise
Working detectors: 94%
Live Time: 64% (+ ~ 10% calibrations time)

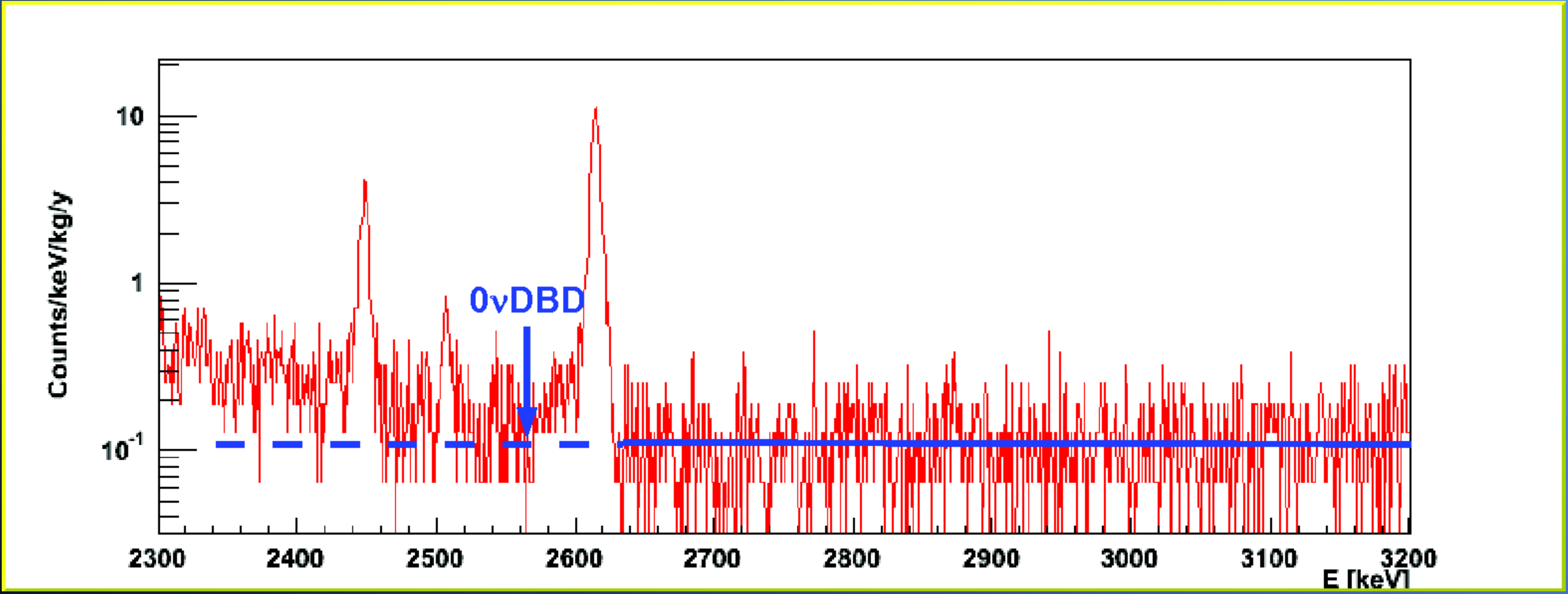
Background

- Contribution from ^{232}Th to DBD region ~ 40%
- Internal shielding far from optimal

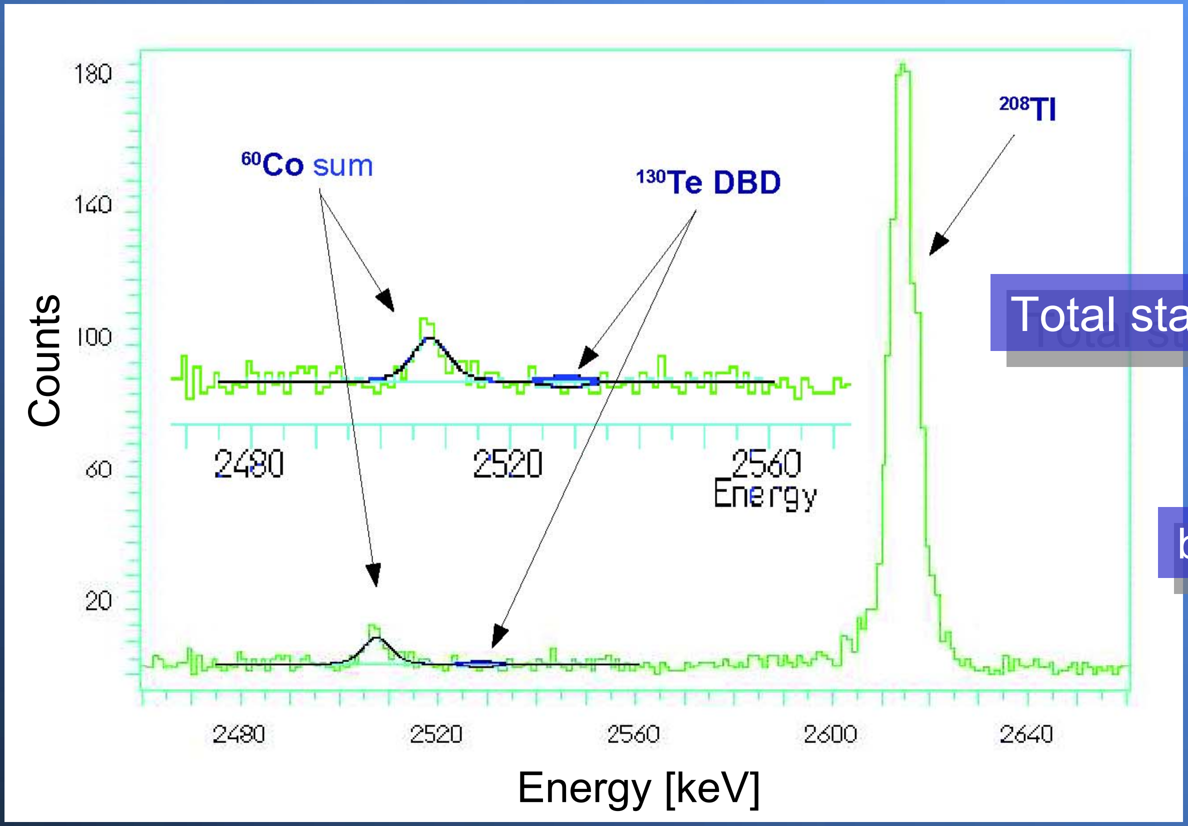


Background

- Flat background above 2615 keV
- Natural extrapolation below
- Contribution to the 0ν-DBD region: ~ 60%



Cuoricino result on ^{130}Te ββ–0u decay



Total statistic ~ 5.36 kg (^{130}Te) × y

b = 0.18 ± 0.02 c/keV/kg/y

Maximum Likelihood
flat background + fit of 2505 peak

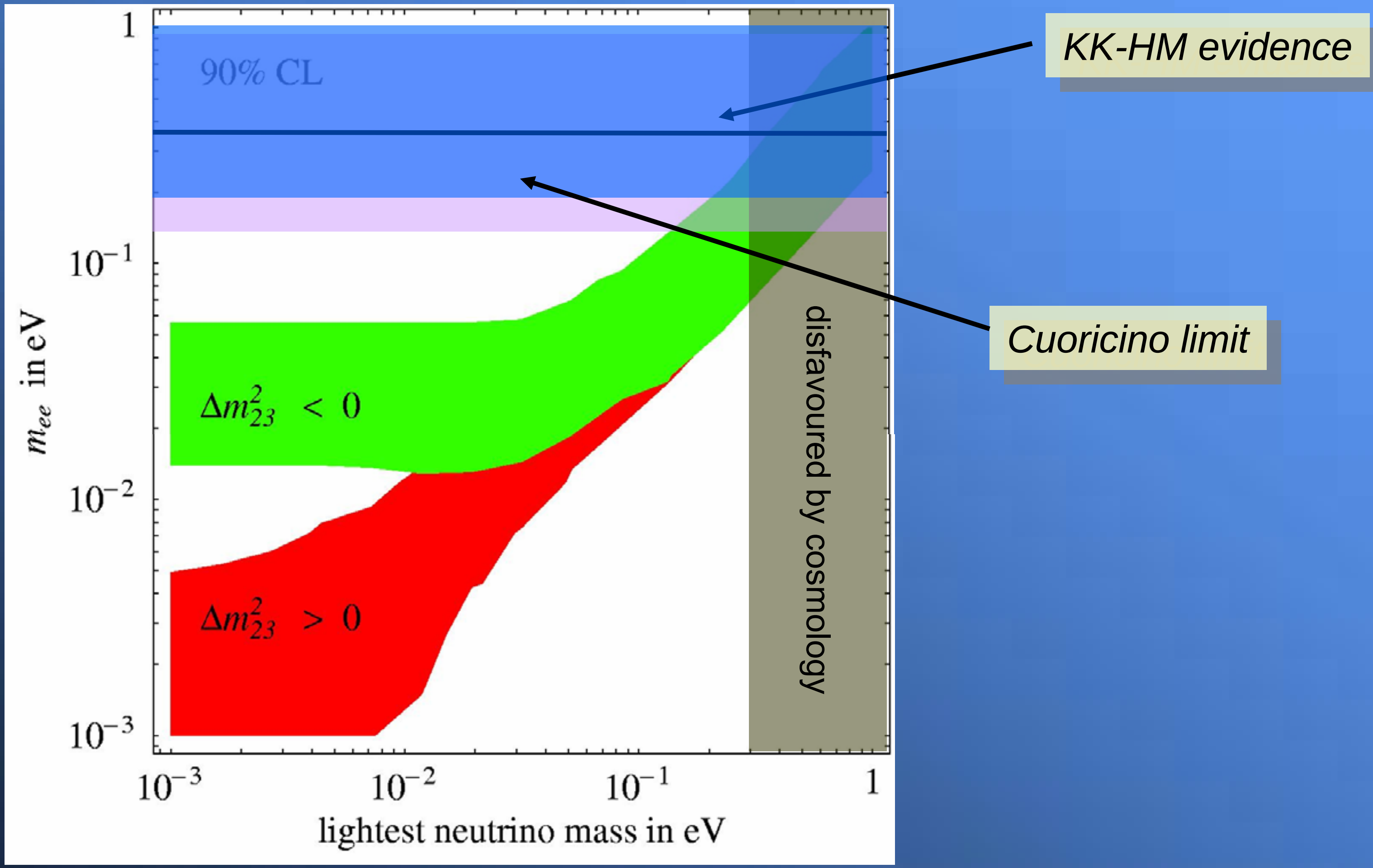
Anticoincidence background spectrum of the 5x5x5 cm^3 crystals around the ii-0u region

$$\boxed{\tau^{0\nu}_{1/2} \geq 1.86 \cdot 10^{24}\, y \left(90\%\, CL\right)}$$

$$\boxed{\left\langle m_\nu \right\rangle \leq 0.20 - 1.05\, eV^* \quad \left(90\%\ CL\right)}$$

* Dependent on the value for the nuclear matrix elements

Cuoricino result



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Cuoricino discovery potential

$\langle m_\nu \rangle$=50 meV – half lives for different nuclei and models [10^{26} y]

Staudt et al.

Nucleus	Ref.: (20)	(80)	(81)	(82)	(24, 83)	(84)
^{48}Ca	12.7	35.3	-	-	-	10.0
^{76}Ge	6.8	70.8	56.0	9.3	12.8	14.4
^{82}Se	2.3	9.6	22.4	2.4	3.2	6.0
^{100}Mo	-	-	4.0	5.1	1.2	15.6
^{116}Cd	-	-	-	1.9	3.1	18.8
^{130}Te	0.6	23.2	2.8	2.0	3.6	3.4
^{136}Xe	-	48.4	13.2	8.8	21.2	7.2
^{150}Nd$^{a)}$	-	-	-	0.1	0.2	-
^{160}Gd$^{a)}$	-	-	-	3.4	-	-

Elliot-Vogel 2002

$T_{1/2}(^{76}Ge)$ / $T_{1/2}(^{130}Te)$	**11.0**	**3.0**	**20.0**	**4.6**	**3.5**	**4.2**
Extrapolation Ge→Te half lives x 10^{24}	**1.06**	**4.0**	**0.6**	**2.6**	**3.4**	**2.8**

Conclusions

- Cuoricino is presently the most sensitive DBD-0ν running experiment, capable to confirm in a relatively short time the KK-HM “evidence”.

- Cuoricino demonstrate feasibility of a large scale bolometric detector with good energy resolution and background.

- The costruction of CUORE, a second generation detector, is started and we will start taking data in 5 years from now. CUORE will have the capability to explore the inverse hierarchy mass region.

The 790 g detectors

R&D on new detectors 5x5x5 cm^3 of TeO_2 (790 g)

The best 790 g detector:

1.5 keV FWHM @ 0.351 MeV

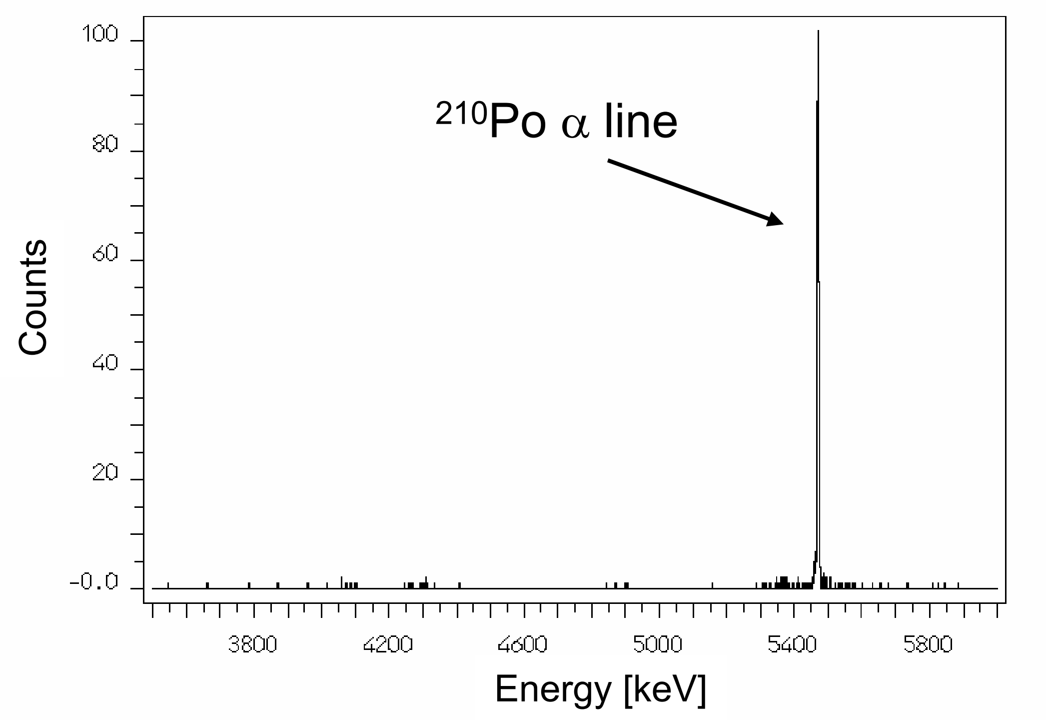
2.4 keV FWHM @ 0.911 MeV

3.8 keV FWHM @ 2.615 MeV

4.2 keV FWHM @ 5.407 MeV

(the best α spectrometer ever realized)

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



Better design of the 790 g detectors holder allows resolution better than 5 keV @ 2615 keV