



An update of Cuoricino results:

are we now able to confirm the HM claim of evidence?

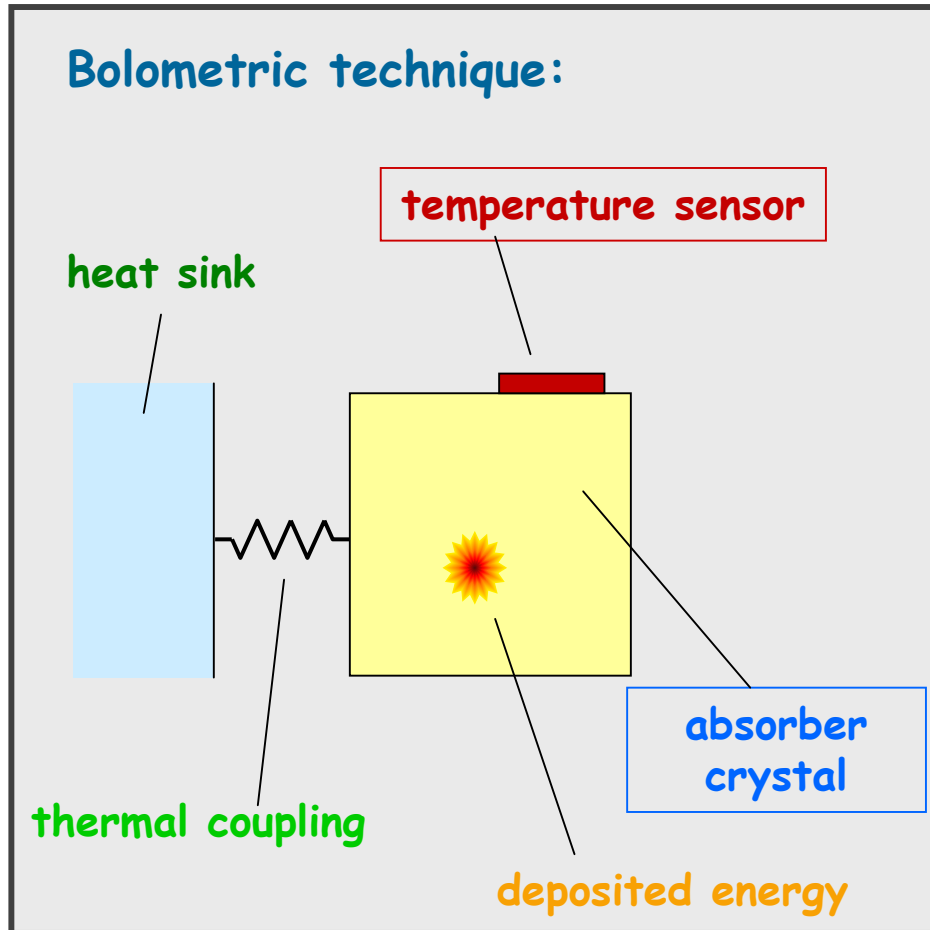
Claudia Nones

(on behalf of the CUORE collaboration)

Outline of the talk

- Basic principle of bolometric technique
- Why have we chosen the ^{130}Te as source of the OVDBD?
- Cuoricino experiment: the detector and the first results
- CUORE project
- Cuoricino prospects
- Conclusions

Basic principle of bolometric technique



From a very simple thermal model



$$\text{Signal: } \Delta T = E/C$$

In order to develop high pulses the detector has to work at low temperature (10mk)

Main advantages:

- high energy resolution
- wide versatility (few constraints on absorber material)
- the detector is fully sensitive (no dead layer)

Double Beta Decay Source

WHY ^{130}Te ?

- high natural isotopic abundance (33.87 %)
 - Sensitivities higher than 10^{26} y imply 10^{28} - 10^{29} nuclides



A few percent of isotopic abundance is unacceptable

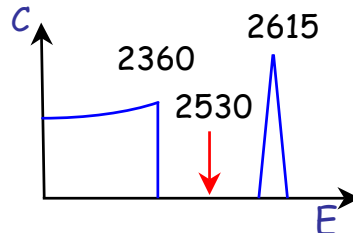
- high transition energy ($Q=2530.30 \pm 1.99$ keV)

- ↳ - this means large phase space for the decay
- ↳ - the Q-value is important with respect to the natural radioactive background

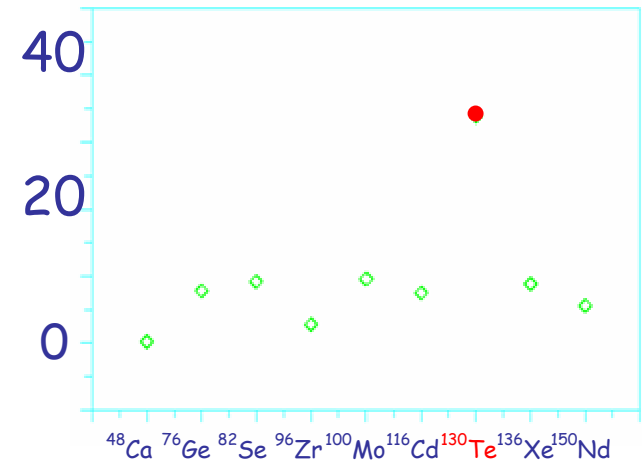


natural gamma background stops at 2615 keV (^{208}Tl , Th chain) but ^{130}Te is in a lucky position:

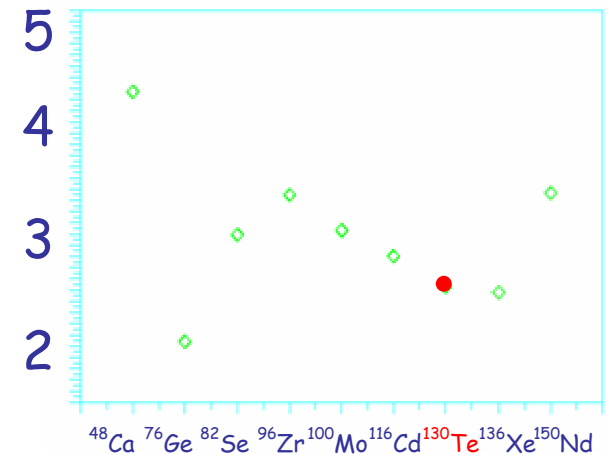
- outside the ^{238}U background
- between the full energy and the Compton edge of 2615 keV photon



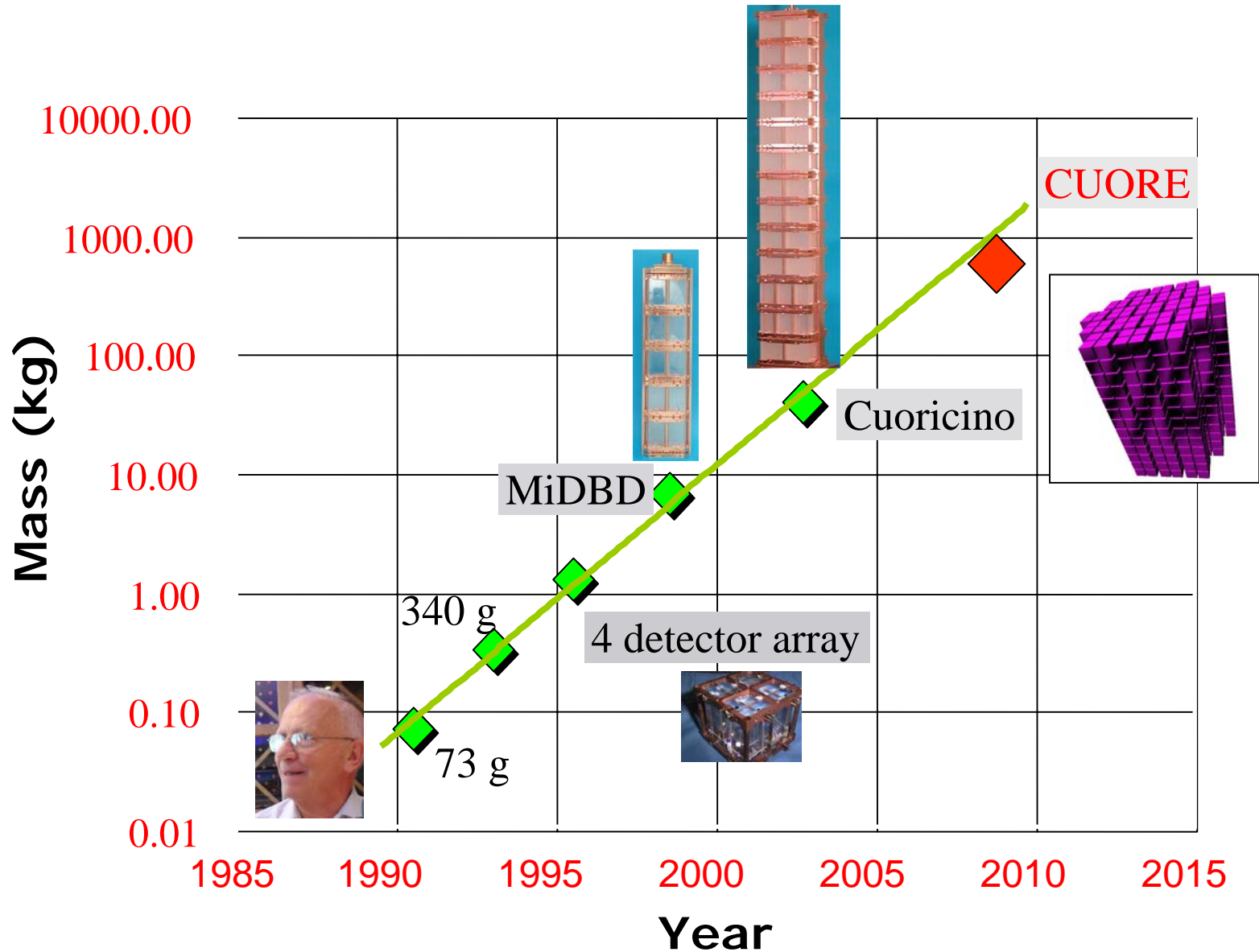
Isotopic abundance (%)



Transition energy (MeV)



The history of TeO_2 bolometers



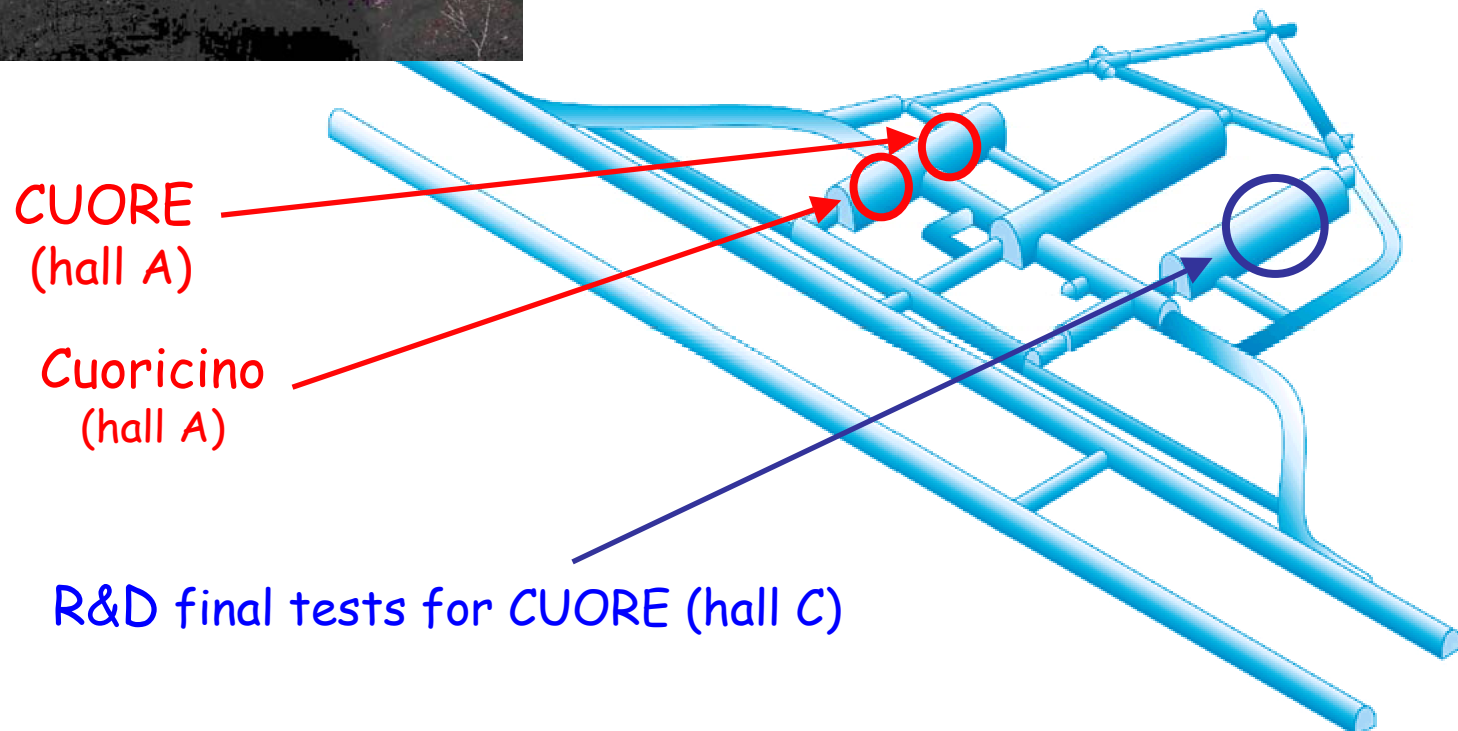
Cuoricino and CUORE Location



Cuoricino experiment is installed in

**Underground National Laboratory
of Gran Sasso
L'Aquila - ITALY**

the mountain providing a **3500 m.w.e. shield** against cosmic rays



The Cuoricino detector

It is a self-consistent experiment is giving significant results on **Double Beta Decay**.

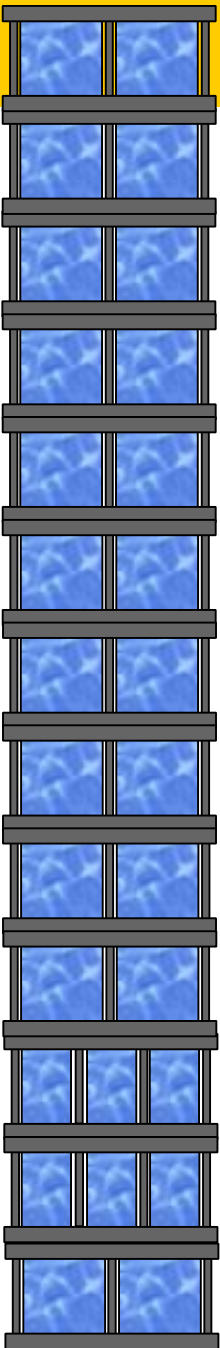
Total number of detectors: 62

- 11 modules with 4 *big* detectors
 - ▼ 44 TeO_2 crystals
 - ▼ $5 \times 5 \times 5 \text{ cm}^3 \Rightarrow 790 \text{ g}$
 - ▷ TeO_2 mass $\Rightarrow 34.76 \text{ kg}$

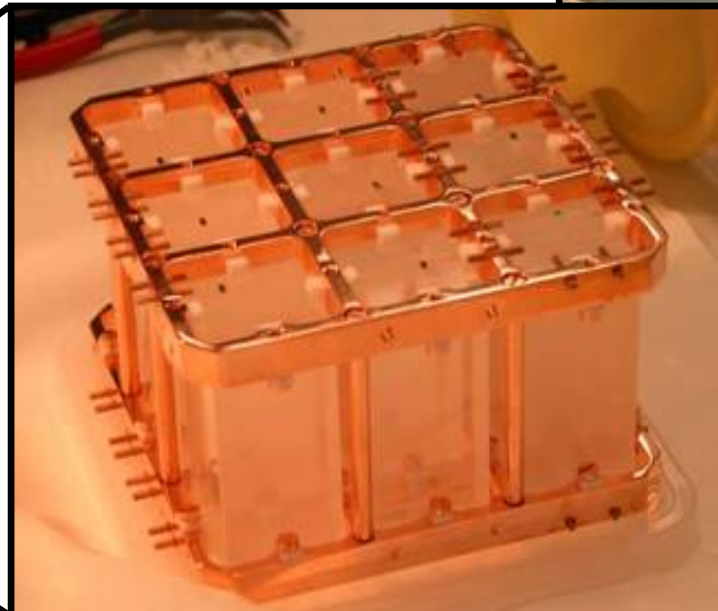
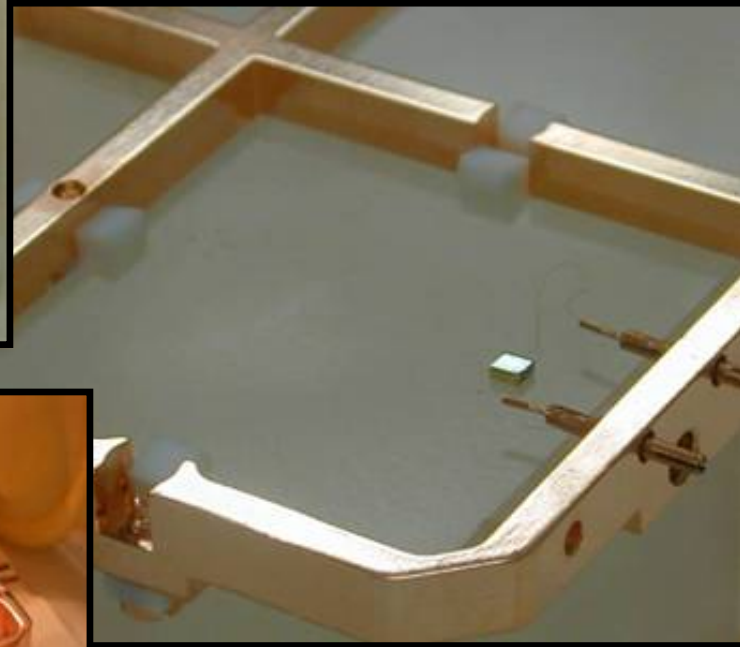
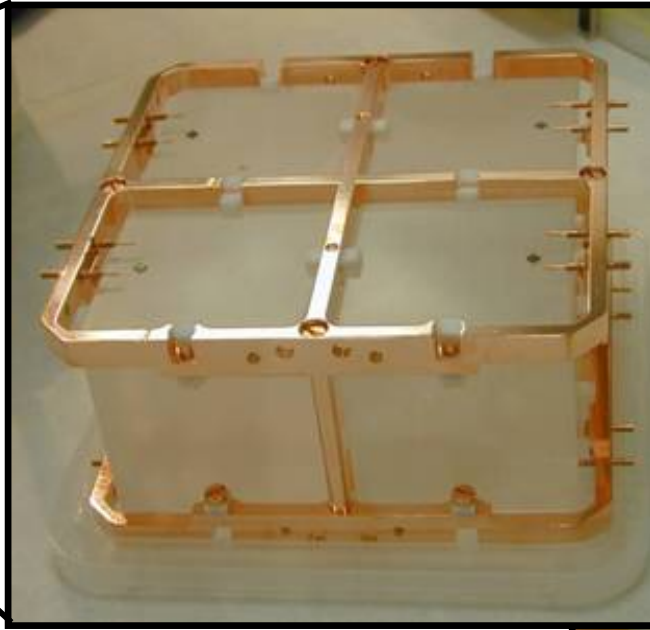
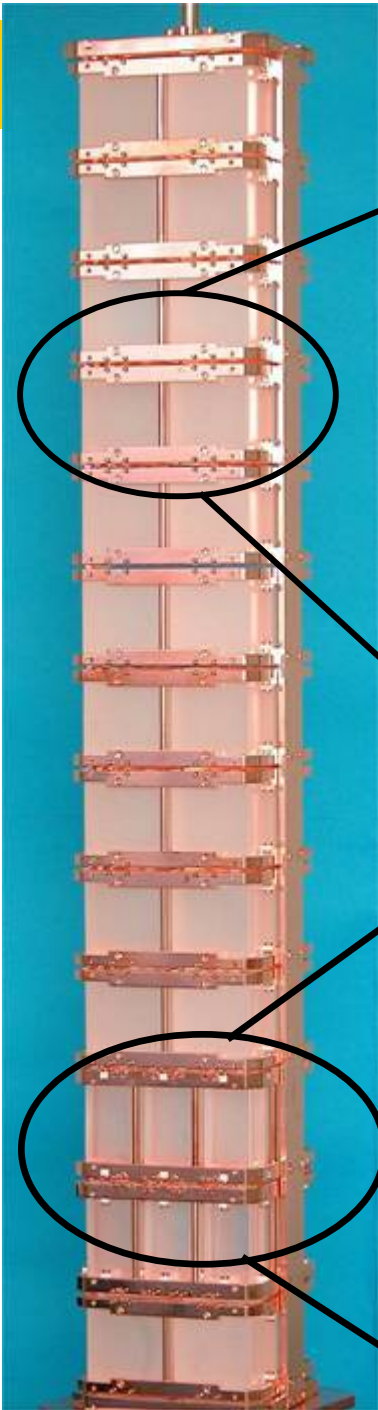
- 2 modules with 9 *small* detectors
 - ▼ 18 TeO_2 crystals
 - ▼ $3 \times 3 \times 6 \text{ cm}^3 \Rightarrow 330 \text{ g}$
 - ▷ TeO_2 mass $\Rightarrow 5.94 \text{ kg}$
 - 4 crystals are enriched
 - ▼ $2 \times {}^{130}\text{TeO}_2 + 2 \times {}^{128}\text{TeO}_2$

total active mass

- TeO_2 : 40.7 kg
- ${}^{130}\text{Te}$: 11.3 kg
- ${}^{128}\text{Te}$: 10.5 kg

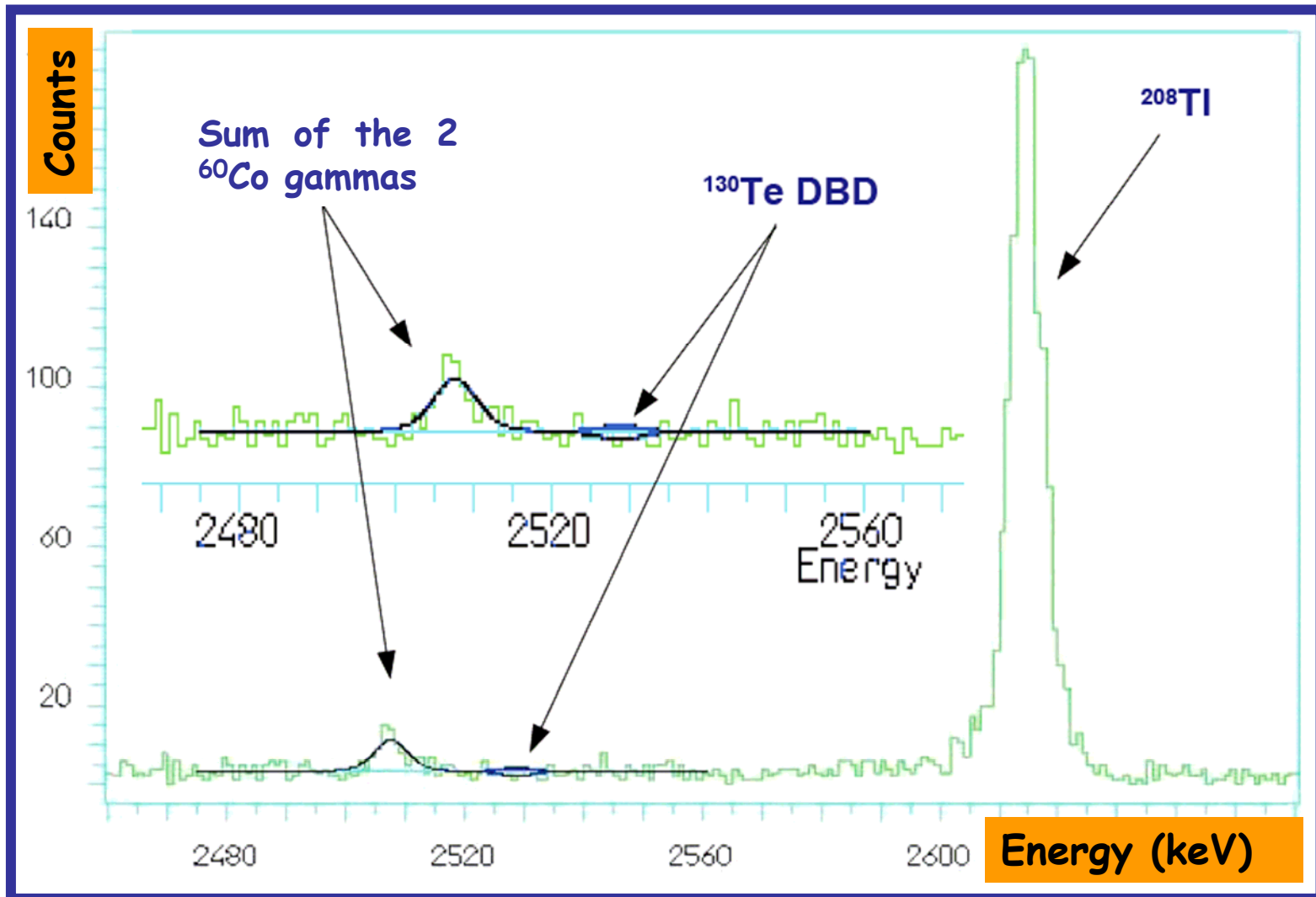


The Cuoricino detector



Neutrinoless DBD results (1)

Background sum spectrum of all the detectors in the DBD region



Neutrinoless DBD results (2)

CURRENT RESULTS:

$$MT = 7.09 \text{ kg } ^{130}\text{Te} \times y$$

$$\tau_{1/2}^{0\nu} (y) > 2.2 \times 10^{24} y$$



$$m_{ee} < 0.2 - 1.1 \text{ eV} \quad (90\% \text{ c.l.})$$

$$\text{Bkg} = 0.18 \pm 0.02 \text{ c/keV/kg/y}$$

$\langle \Delta E \rangle$ @ 2615 keV

790 g crystals $\sim 7.5 \pm 2.9 \text{ keV}$

330 g crystals $\sim 9.6 \pm 2.5 \text{ keV}$

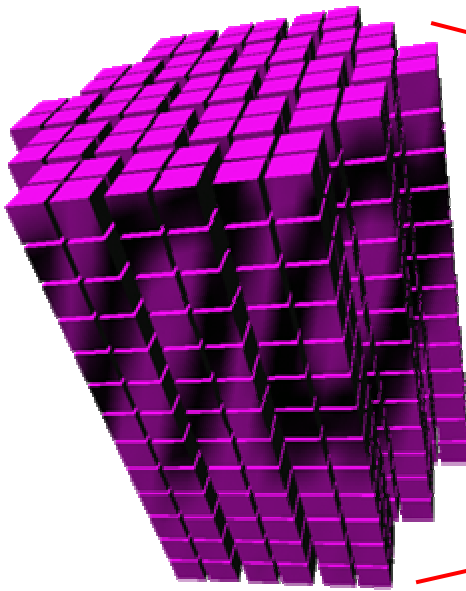
Are we now able to scrutinize the HM claim of evidence?

... we will see in the last part of the talk!!!

CUORE

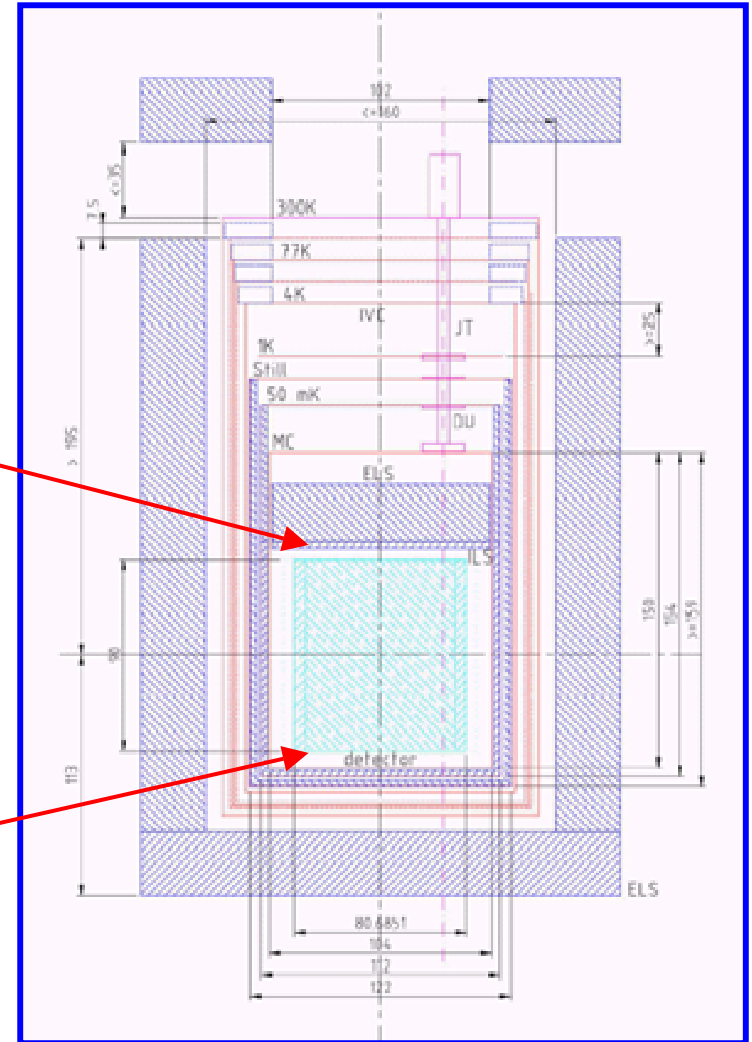
Cryogenic Underground Observatory for Rare Events

Array of 988 detectors:
19 Cuoricino-like towers.
→ $M = 0.74$ ton di TeO_2



90 cm

19 CUORICINO-like towers



Special dilution refrigerator

Cuoricino prospects

Are we able now to scrutinize the HM claim of evidence?

HM experimental results:

$$T_{1/2}^{0\nu} (\gamma) = (0.69-4.18) \times 10^{25} \text{ (3}\sigma \text{ range)}$$

Best value: $1.19 \times 10^{25} \text{ y}$

REF. Klapdor et al., Physics Letters B 586 (2004) 198-212

$$m_{ee} = 0.24 - 0.58 \text{ eV (3}\sigma \text{ range)}$$

Nuclear matrix element of Muto-Bender-Klapdor

What I have done...

$$T_{1/2}^{0\nu} \text{ (Klapdor)}$$

Choose a nuclear model

$$T_{1/2}^{0\nu} ({}^{130}\text{Te})$$

$$T_{1/2}^{0\nu} ({}^{130}\text{Te}) = \frac{T_{1/2}^{0\nu} (\text{Klapdor})}{\frac{G_{130\text{Te}}^{0\nu}}{G_{76\text{Ge}}^{0\nu}} \cdot \left| \frac{M_{\text{refA}({}^{130}\text{Te})}^{0\nu}}{M_{\text{refA}({}^{76}\text{Ge})}^{0\nu}} \right|^2}$$

Ref.	Method	r_0 [fm]	g_{pp}	g_A	$M^{0\nu}$									
					^{76}Ge	^{82}Se	^{96}Zr	^{100}Mo	^{116}Cd	^{128}Te	^{130}Te	^{136}Xe	^{150}Nd	
Without higher order terms of nucleon current														
Differences understandable														
EVZ-88	QRPA	1.1	β	1.0	1.3	1.0	0.8	1.8	2.4	2.2	1.0			
MBK-89	QRPA	1.1	β	1.25	3.84	3.59		1.94	3.93	3.18	1.45	5.57		
T-91	QRPA	1.1	1.0	1.0	2.86	2.59		3.14	2.55	2.22	1.27	3.47		
					1.25	3.97	3.60		4.30	3.53	3.07	1.74	4.80	
SKF-91	QRPA	1.1	1.0	1.00	3.37	2.72			3.17	2.94	1.71			
					1.25	4.55	3.71		4.24	3.95	2.31			
PSVF-96	QRPA	1.1	1.0	1.25	3.04	2.23	2.41	1.09	0.94	2.48	2.33	1.55		
SPVF-99	RQRPA	1.1	1.0	1.00	4.05	3.82	2.24	4.58	2.86	3.38	2.87	1.20	5.15	
					1.25	3.60	3.40	1.99	4.12	2.58	2.96	2.50	1.02	4.51
present	QRPA	1.1	$2\nu\beta\beta$	1.25	3.35	2.95		1.83	2.32	1.98	1.30	3.10		
Results discussed														
SK-01	QRPA	?	$2\nu\beta\beta$?	4.45	3.60	4.16	5.37	3.99	4.84	4.73	1.69		
					1.71	1.71	2.75	3.81	2.85	3.43	3.77	1.35		
					3.74	4.30	3.01	4.36	3.61	4.29	4.55	1.57		
AS _{WS} -98	QRPA	1.1	β	1.00	1.87	2.70	2.72	3.40	3.39	2.83	3.00	1.02		
					1.25	5.30	4.93	3.85	2.93		6.15	3.34		
AS _{AW S} -98	QRPA	1.1	β	1.00	4.85	3.61	3.70		3.97		3.81	2.15		
					1.25	6.44	4.82	3.96	5.25		5.05	2.84		
CS-03	QRPA	?	β	1.25	3.33	3.44	3.55	2.97	3.75		3.49	4.64		
With higher order terms of nucleon current														
SPVF-99	RQRPA	1.1	1.0	1.25	2.80	2.64	1.49	3.21	2.05	2.17	1.80	0.66	3.33	
present	QRPA	1.1	$2\nu\beta\beta$	1.00	2.48	2.10	0.40	1.24	1.31	1.47	1.36	0.94	1.96	
					1.25	2.68	2.36	0.04	1.28	1.56	1.73	1.55	1.03	2.25
					RQRPA	1.1	$2\nu\beta\beta$	1.00	2.30	1.91	0.43	1.12	1.22	1.37
				1.25	2.40	2.12	0.31	1.16	1.43	1.60	1.47	0.98	2.05	

Rodin, Faessler, Simkovic, Vogel
nucl-th/0503063

$$T^{1/2} = \frac{1}{G^{0\nu} \cdot |M^{0\nu}|^2 \cdot \left(\frac{\langle m_\nu \rangle}{m_e}\right)^2}$$

No univoque definition
of $G^{0\nu}$ and $M^{0\nu}$!!!

$$G^{0\nu} = \begin{cases} 7.93 \times 10^{-15} \text{ y for } ^{76}\text{Ge} \\ 55.4 \times 10^{-15} \text{ y for } ^{130}\text{Te} \end{cases}$$

$$\frac{G^{0\nu} (^{130}\text{Te})}{G^{0\nu} (^{76}\text{Ge})} = 6.99$$

Cuoricino limit in 3 y:

Cuoricino limit: 2.2×10^{24} y

4.3×10^{24} y

Nuclear models

With higher order terms of nucleon current

Results discussed by the authors

Without higher order terms of nucleon current

0,1

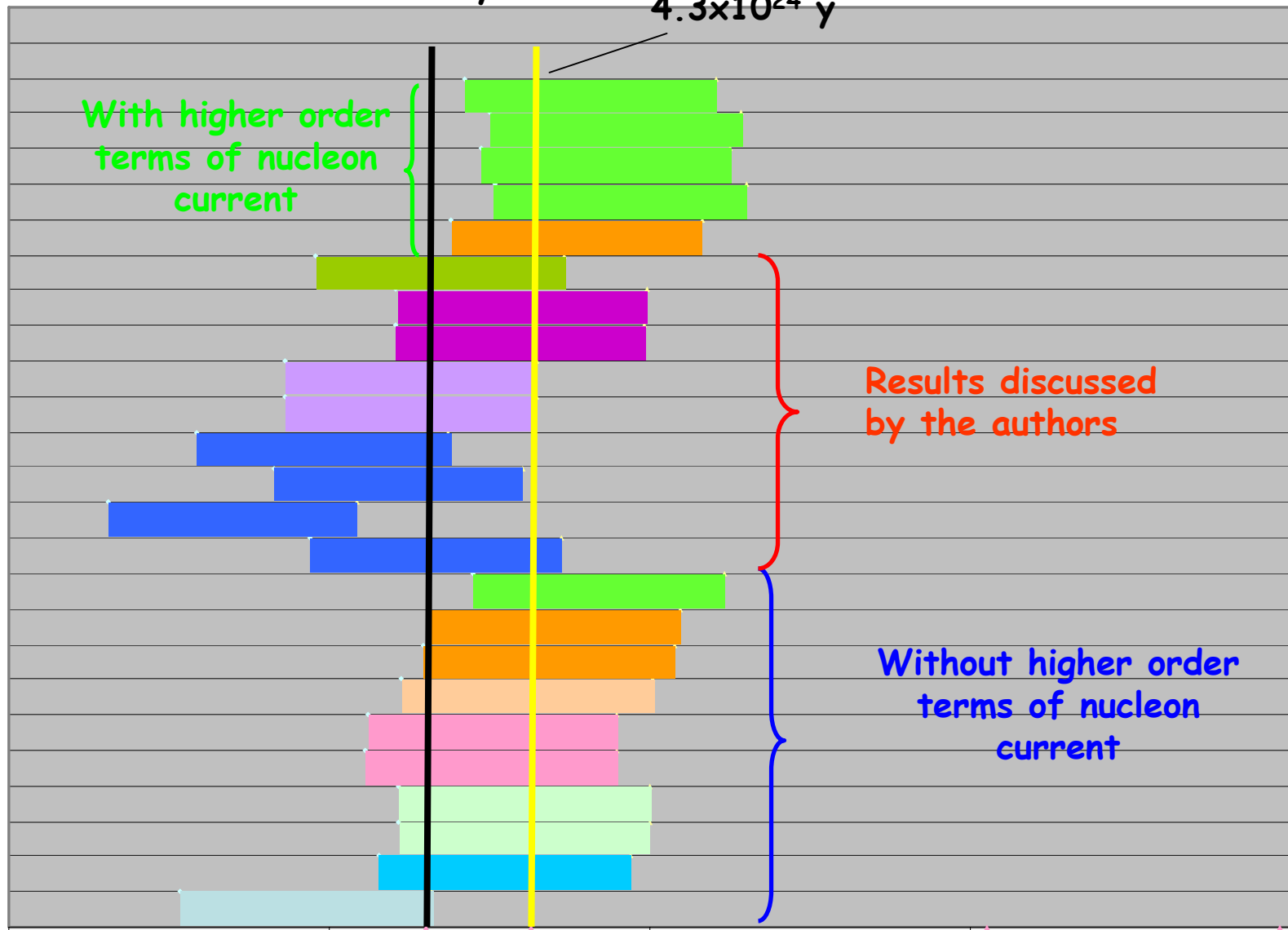
1

10

100

1000

$T^{1/2} \times 10^{24}$ y for ^{130}Te

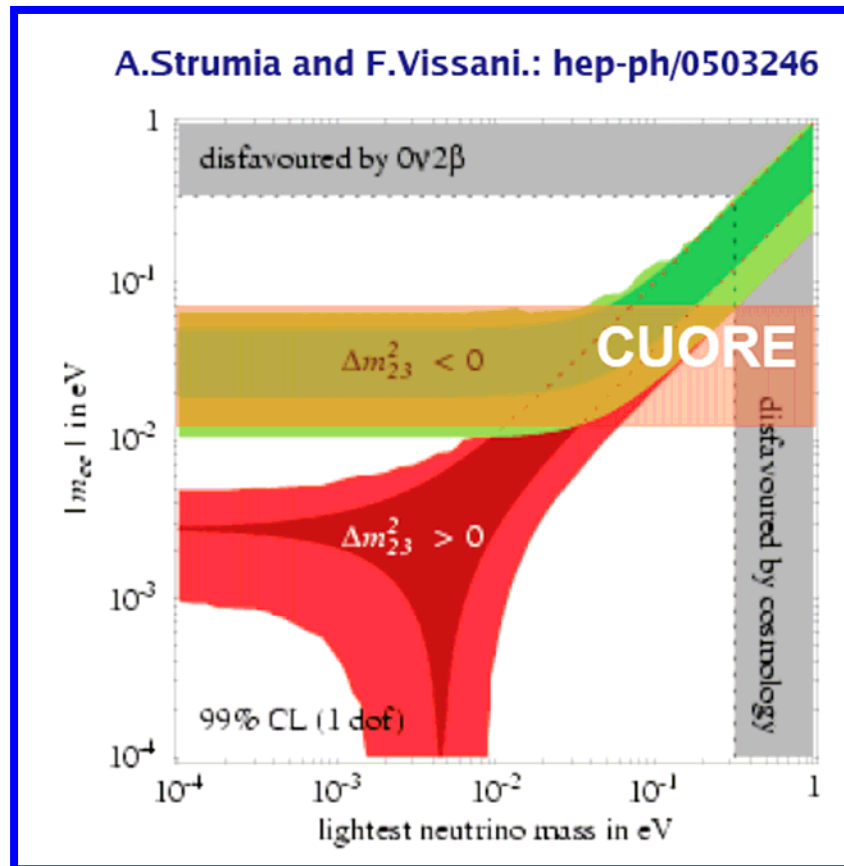


And what about CUORE? (1)

The main goal of CUORE is to test the inverse hierarchy

$$m_3 \ll m_1 \approx m_2$$

$$|m_{ee}| = (19 - 50) \text{ meV}$$



And what about CUORE? (2)

a: isotopic abundance

A: atomic mass

ε : efficiency

$$F^{0\nu} \sim \frac{a \cdot \varepsilon}{A} \sqrt{\frac{M \cdot T}{b \cdot \Gamma}}$$

M: active mass [kg]

T: live time [y]

b: background [c/keV/kg/y]

Γ : energy resolution [keV]

CUORE_conservative

b=0.01 - Γ =10 - T=3y

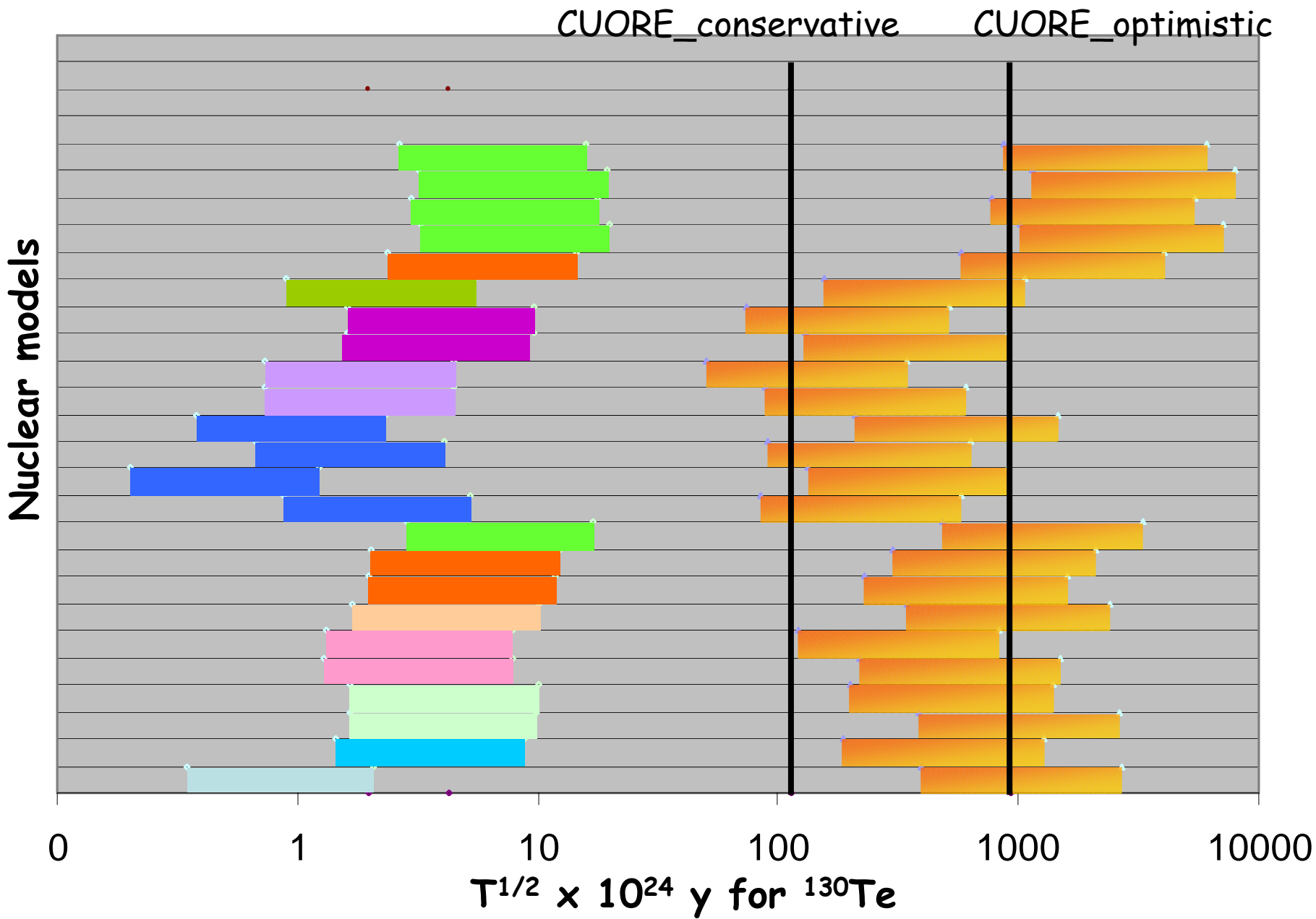
CUORE_optimistic

b=0.001 - Γ =5 - T=10y

$F^{0\nu} = 1.13 \times 10^{26} \text{ y } (1\sigma)$

$F^{0\nu} = 9.25 \times 10^{26} \text{ y } (1\sigma)$

CUORE and the inverse hierarchy



Summarizing

For each nuclear model, if we assume that:

- 1) Cuoricino is setting a correct limit on the value of $T^{1/2}$
- 2) Klapdor has measured a right value of $T^{1/2}$

with our present limit, we can exclude two models, EVZ-88 and SK-01 while in the next 3y (@60% of lived time) Cuoricino can proceed with the exclusion of other models and start to investigate new models with higher order terms of nucleon current!

...if Cuoricino will see no signals it cannot exclude Klapdor's result;

BUT

If CUORE will see no signal or the signal is in the region of inverse hierarchy

- ❑ Klapdor's claim of evidence is wrong, or
- ❑ there are some problems with the nuclear models (due to the fact that Ge and Te are very different nuclides)

If CUORE will see a signal @ $\sim 10^{25}$ y (region between degenerate and inverse hierarchy)

- ❑ Klapdor's claim of evidence could be correct but
- ❑ only few nuclear models are able to predict it

Conclusion

- ✓ Cuoricino is presently the most sensitive $0\nu\text{DBD}$ running experiment, capable to confirm the KK-HM "evidence".
- ✓ Cuoricino demonstrates the feasibility of a large scale bolometric detector (CUORE) with good energy resolution and bkg on many detectors.
- ✓ CUORE, a second generation detector developed on this new approach, will be built and start up in the next 4 years.
- ✓ Recent results on background suppression confirm the capability to explore the inverse hierarchy mass region.