CUORICINO and CUORE

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On behalf of the CUORE Collaboration

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Experimental sensitivity to 0ν-DBD

sensitivity F lifetime corresponding to the minimum detectable number of events over background at a given (1 σ) confidence level

b: specific background coefficient **[counts/(keV kg y)]**

$b \neq 0$

source mass, live time, energy resolution

$$F \propto (MT / b\,\Delta E)^{1/2}$$

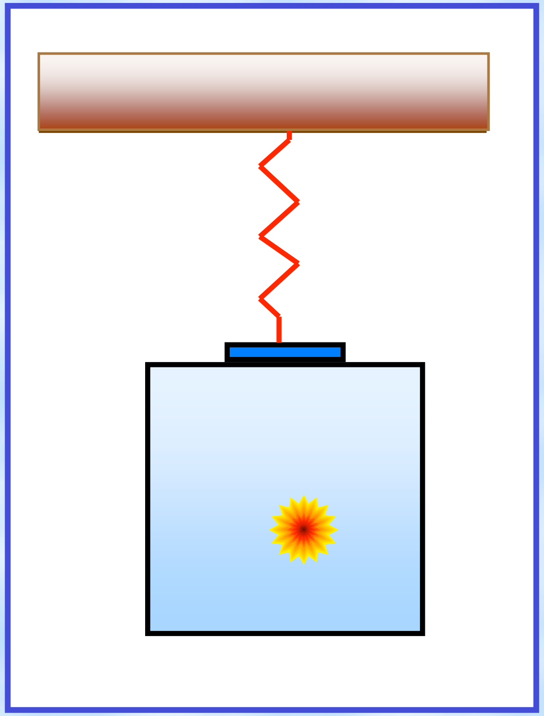
$b = 0$

$$F \propto MT$$

importance of the nuclide choice
(but large uncertainty due to nuclear physics)

$$\text{sensitivity to } m_{ee} \propto (F/Q\,|M_{nucl}|^2)^{1/2} \propto \frac{1}{Q^{1/2}\,|M_{nucl}|}\left(\frac{b\,\Delta E}{MT}\right)^{1/4}$$

Some basic concepts on bolometers



Signal: $\Delta T = E/C$

Time constant $= C/G$

↓

LOW TEMPERATURES

* All the energy deposited is measured
  (bulk and surface bkg are ≠)
* The detector is FULLY SENSITIVE
  (no dead layer)
* SOURCE = DETECTOR technique
  (Source mass optimization)
* Very good energy resolution
  (no 2ν backround)
* Wide material choice
  (Phase 2 or 3?)

The CUORICINO set-up

CUORICINO = tower of 11 modules, 4 detector (790 g) each
2 modules, 9 detector (330 g) each

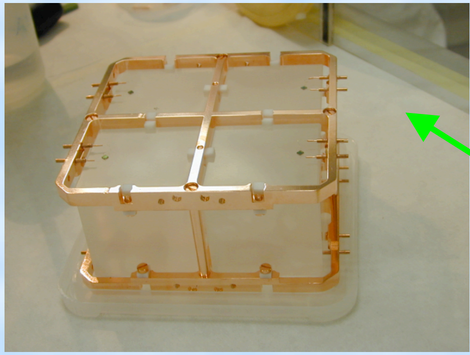
M = ~ 40.7 kg → ~ 5×10^{25} ^{130}Te nuclei

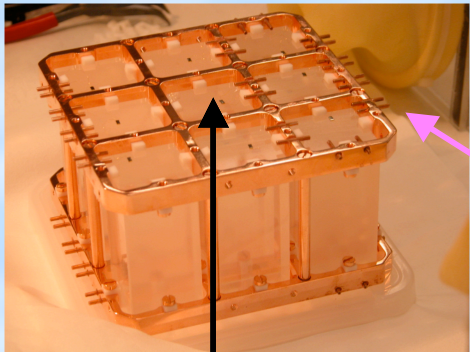
I run :	29	5x5x5
	15	3x3x6

TOTAL ^{130}Te MASS
59 moles

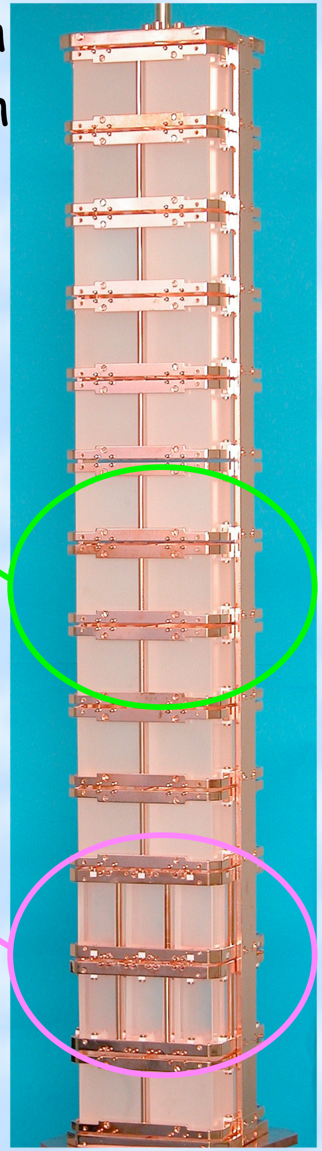
II run :	42	5x5x5
	18	3x3x6

TOTAL ^{130}Te MASS
83 moles



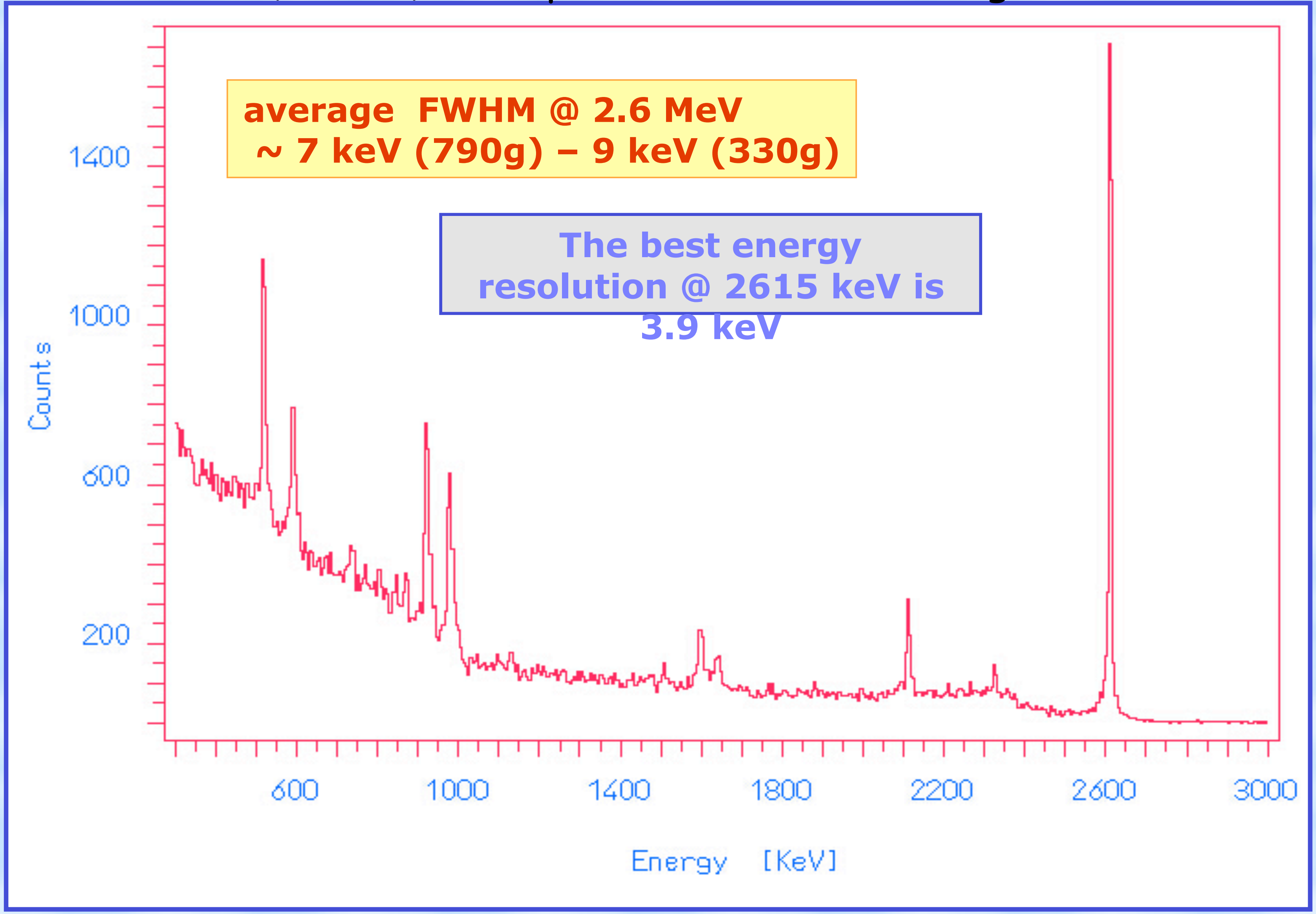


This detector is completely surrounded by active materials.
Useful for BKG origin models



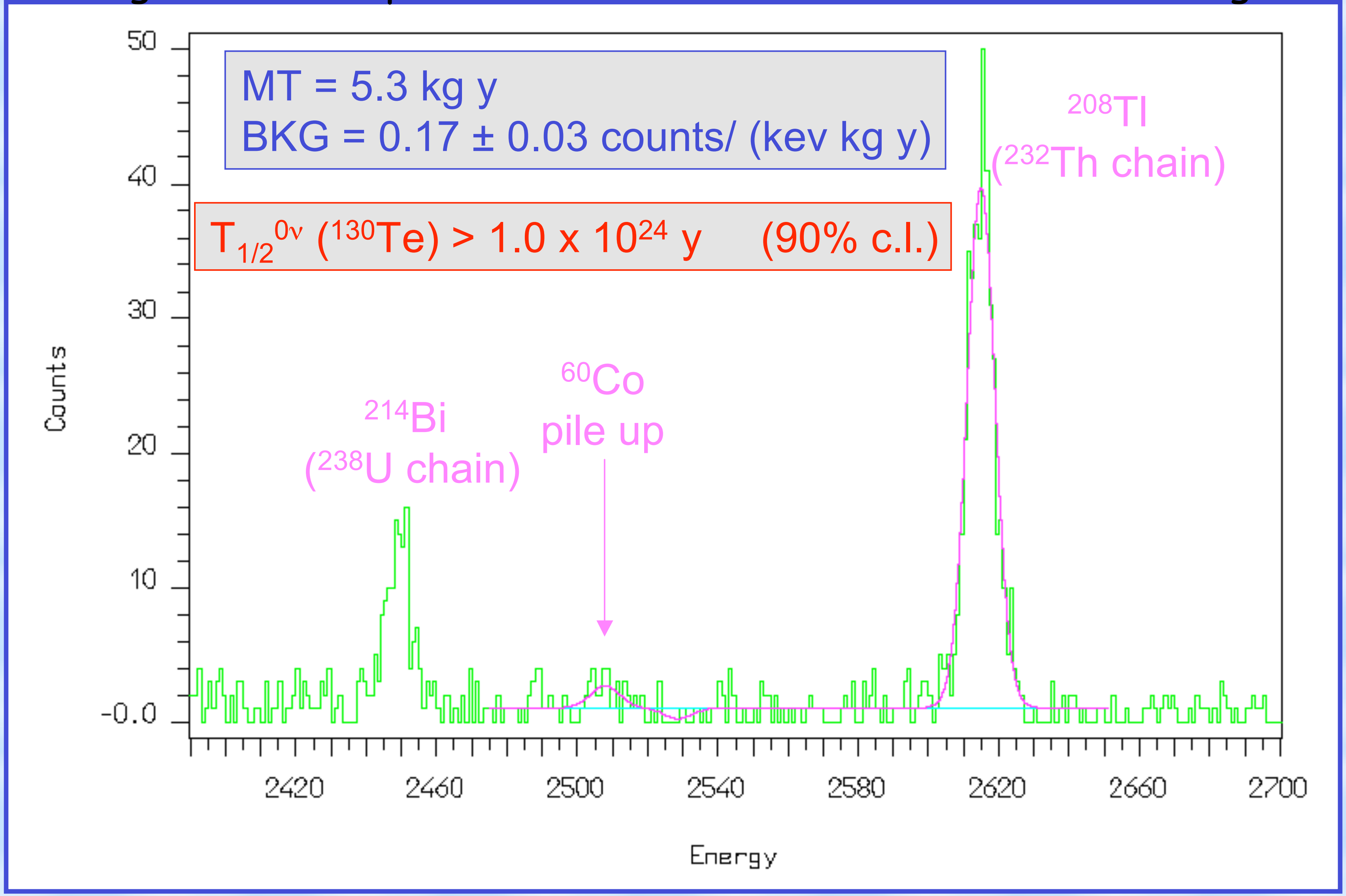
CUORICINO results (1)

Calibration (U + Th) sum spectrum of all the 790g detectors



CUORICINO results (2)

Background sum spectrum of all the detectors in the DBD region



CUORICINO prospects (1)

Is CUORICINO able to scrutinize the HM experiment claim?

m_{ee} = 50 meV – half life for different nuclei and models [10^{26} y]

Elliot Vogel 2002

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	-	-

$T_{1/2}$ (^{76}Ge)/$T_{½}$(^{130}Te)	11.3	3.0	20.0	4.6	3.5	4.2	
expected $T_{½}$(^{130}Te) (units: 10^{24} y)	1.06	4.0	0.6	2.6	3.4	2.8	limit: > 1.0

CUORICINO prospects (2)

Staudt et al. (above Ref. 82)

Expected event number in 3 y in a 13 keV energy window (1.5xFWHM: 92% of signal)

1 σ BKG fluctuation = $(0.17 * 13 * 40 * 3)^{0.5}$ = 16

Ref.:	(20)	(80)	(81)	(82)	(24,83)	(84)
Expected event number	**115**	**30**	**204**	**47**	**36**	**43**
S/N ratio (σ)	**7.2**	**1.9**	**13**	**2.9**	**2.3**	**2.7**

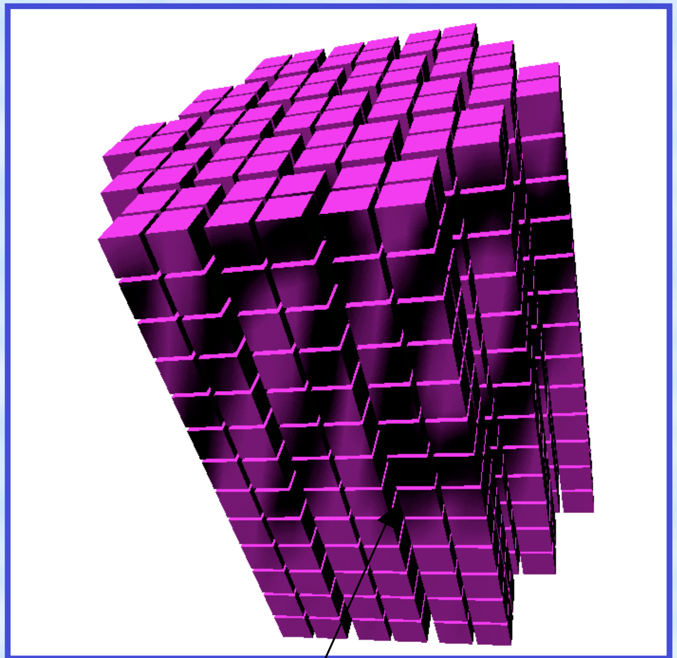
(to be compared with **28.75** events of the HM claim, with a **BKG** level which is 0.11 / 0.17 = **0.65 lower** in HM and with an energy **resolution** which is **3x better** in HM)

good chance to have a positive indication

cannot falsify HM if no signal is seen

From CUORICINO to CUORE

CUORE is a closely packed array of
988 detectors (cylindrical option)
M = 741 kg

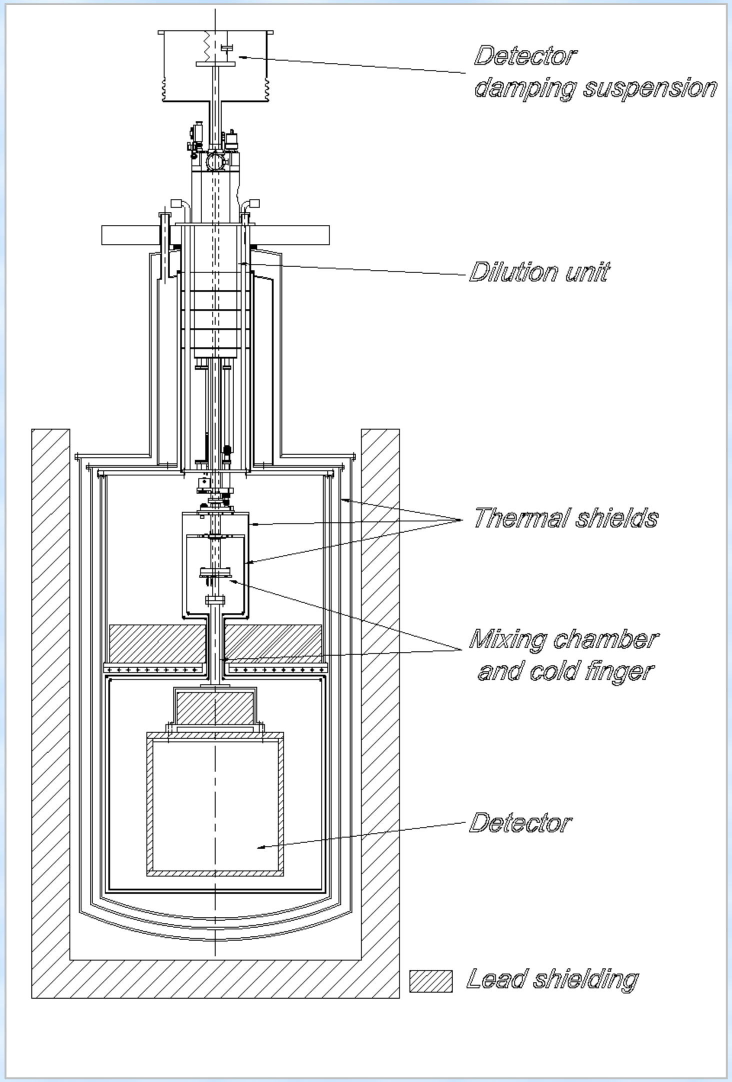


19 towers with

13 planes of

4 crystals each

Each tower is a CUORICINO-like detector



Special dilution refrigerator

CUORICINO background model (1)

PRELIMINARY !

We have identified 4 possible sources for the residual BKG in the DBD region:

- Neutrons ← Excluded since adding B-polyethilene shield had no effect
- Energy degraded 2615 keV photons
- Degraded α from TeO_2 surface
- Degraded α from Cu frame and plate surface

The alpha continuum extends down to the DBD region

CUORICINO ~ 0.2 counts/ keV kg y

Source	^{208}Tl	$\beta\beta(0\nu)$ region	3-4 MeV region
TeO_2 ^{238}U and ^{232}Th surface contamination	-	20$\pm$ 15%	20$\pm$ 10%
Cu ^{238}U and ^{232}Th surface contamination	$\sim$15%	50$\pm$ 20%	80$\pm$ 10%
^{232}Th contamination of cryostat Cu shields	$\sim$85%	30$\pm$ 10%	-

CUORICINO background model (2)

In the ANTICOINCIDENCE bkg spectrum

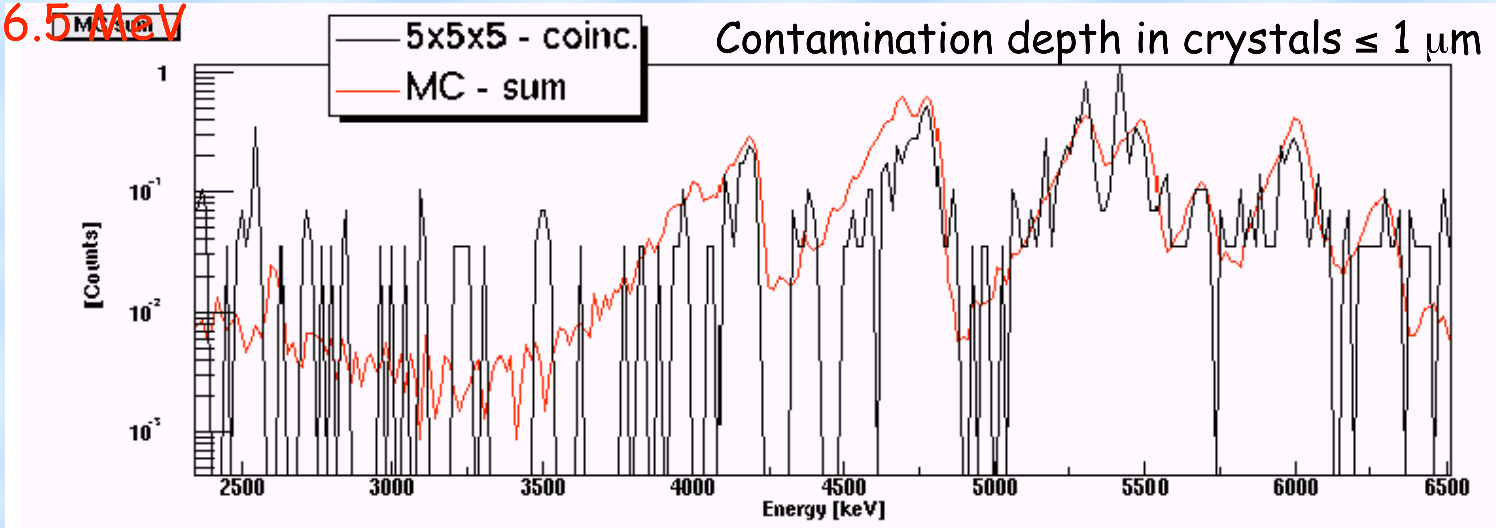
Crystal bulk contaminations determine gaussian peaks

Surface contaminations determine peaks with tails (shape depending on contamination depth)

In the COINCIDENCE spectrum only CRYSTAL SURFACE contam. contribute

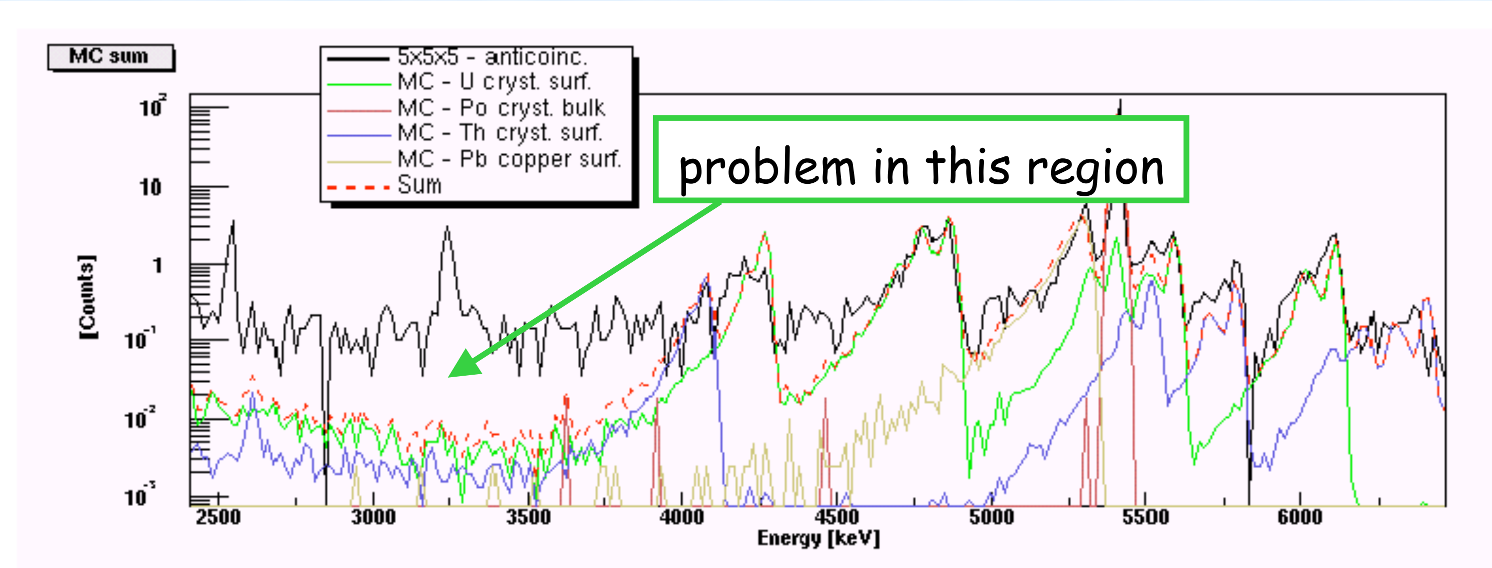
① Fix the U and Th crystal cont. levels and depth through MC reconstruction of the COINCIDENCE spectrum in the spectral region 2.5 – 6.5 MeV

Contamination depth in crystals ≤ 1 μm



CUORICINO background model (3)

② Reconstruct the ANTICOINC. spectrum in the spectral region 2.5 – 6.5 MeV

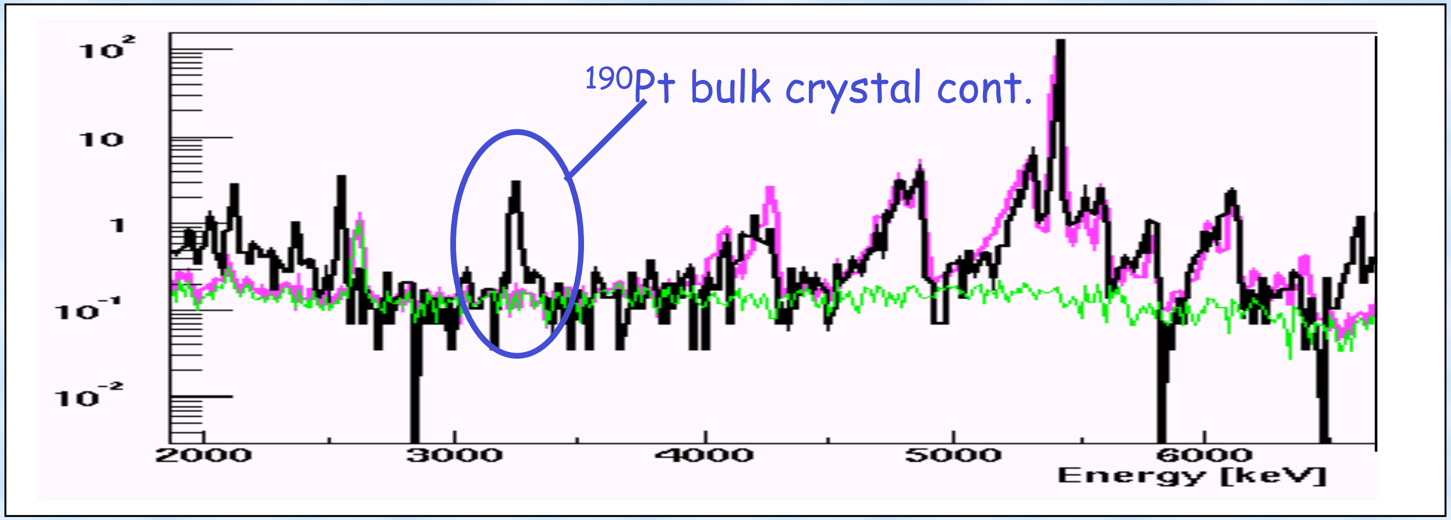


INGREDIENTS:

- ^{210}Po bulk contamination of the crystals (5.4 MeV gauss. Peak, decaying)
- ^{210}Pb surface contamination of the Cu + crystal (5.3+5.4 MeV constant peak)
- U + Th crystal surface contam. (fixed through the coincidence spectrum)

CUORICINO background model (4)

③ Introduce ^{238}U or ^{232}Th surface contamination level and depth profile due to the Cu structure facing the detectors



surface contamination level: ~ 1 ng/g vs bulk c.l. : < 1 (0.1) pg/g for Cu (TeO_2)

contamination depth: ~ 5 μm in agreement with direct measurement on Cu

The CUORE background

Full Montecarlo simulation on the basis of the CUORICINO and Mi DBD background analysis

- Bulk contamination of Cu and TeO_2 ⇒ < 0.004 counts / kev kg y
- Contamination in the cryostat shields ⇒ can be made negligible by the granular structure and more Pb
- Surface contamination as it is ⇒ 0.04 counts / kev kg y
  (reduction due to decrease of Cu area and different geometry, but not enough)

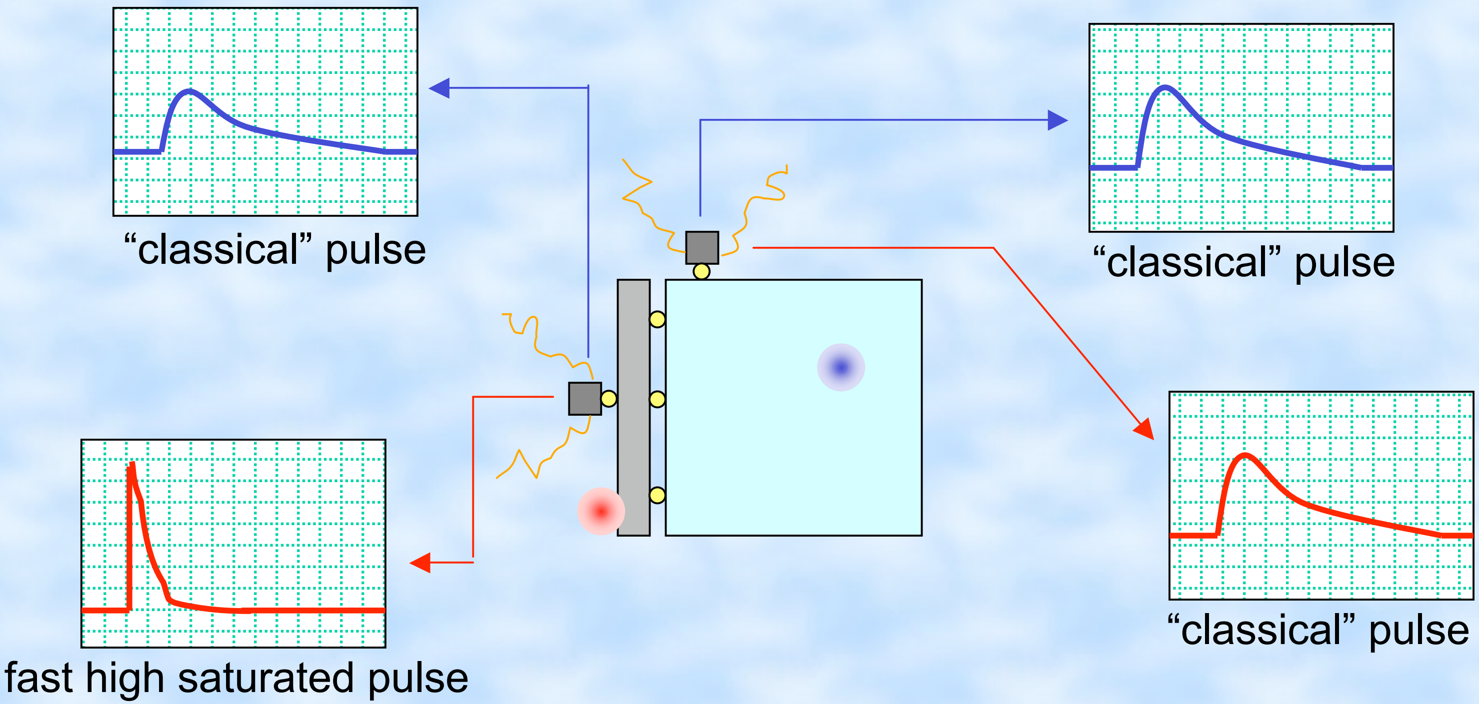
A reduction by a factor 10 in Cu surface contamination and by a factor 4 in TeO_2 surface contamination would correspond to a FULL success of CUORE

Copper cleaning procedure by chemical etching and surface passivation under development

Development of surface-sensitive bolometers

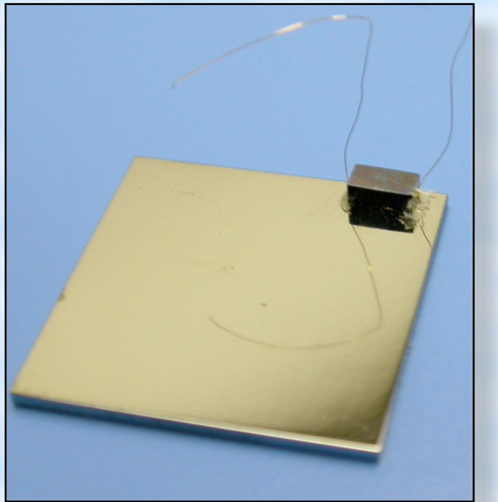
Use a thin Ge (or Si) crystal to make a composite bolometer

Energy deposited in the TeO_2 crystal (DBD-like event)

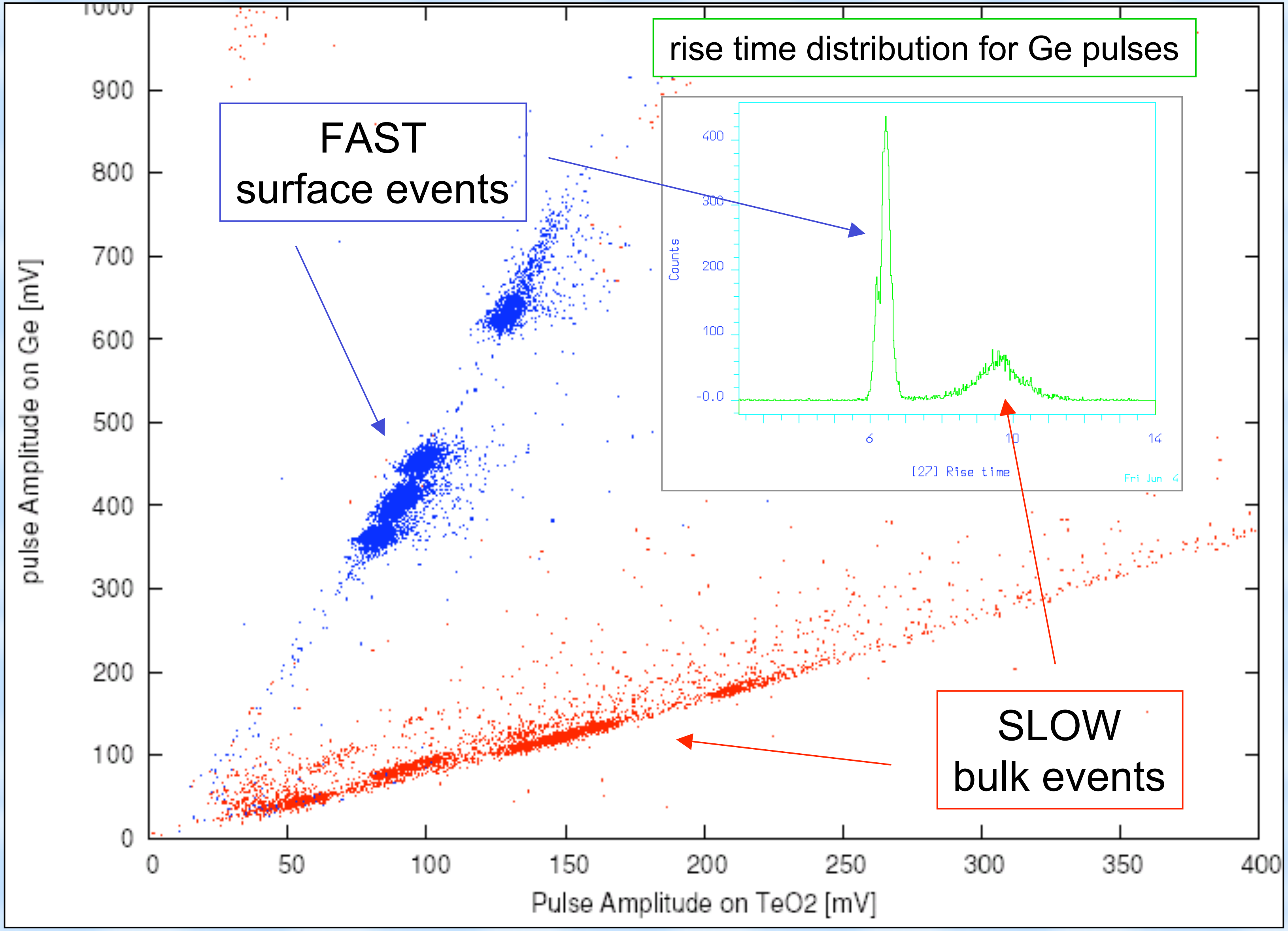


Energy deposited in the Ge crystal (degraded alpha event)

Development of prototypes



Preliminary very encouraging results



CUORE background and sensitivity

- Montecarlo simulations of the background show that

  $b \sim 0.001$ counts / (keV kg y)

  can be reached with the present bulk contamination of det. materials

- The problem is the surface background (alpha, beta energy-degraded):

  ↳ it MUST be reduced by a factor 10 – 100

10 y sensitivity with pessimistic	10 y sensitivity with optimistic
b = 0.01 counts/(keV kg y)	b = 0.001 counts/(keV kg y)
Γ = 10 keV	Γ = 5 keV
$F^{0\nu} = 2.1 \times 10^{26}$ y	$F^{0\nu} = 9.4 \times 10^{26}$ y
$m_{ee} < 24 - 133$ meV	$m_{ee} < 11 - 62$ meV
	$m_{ee} < 7 - 38$ meV

enriched CUORE

Conclusions

- Cuoricino experiment may confirm the HM claim soon, provided the nuclear matrix elements are reasonably favourable
- A full Montecarlo simulation for CUORE has been developed, on the basis of the CUORICINO and Mi DBD background analysis
- A big R&D work is going on to reduce the BKG, in order to permit to CUORE experiment to investigate the inverse hierarchy region of the neutrino mass pattern