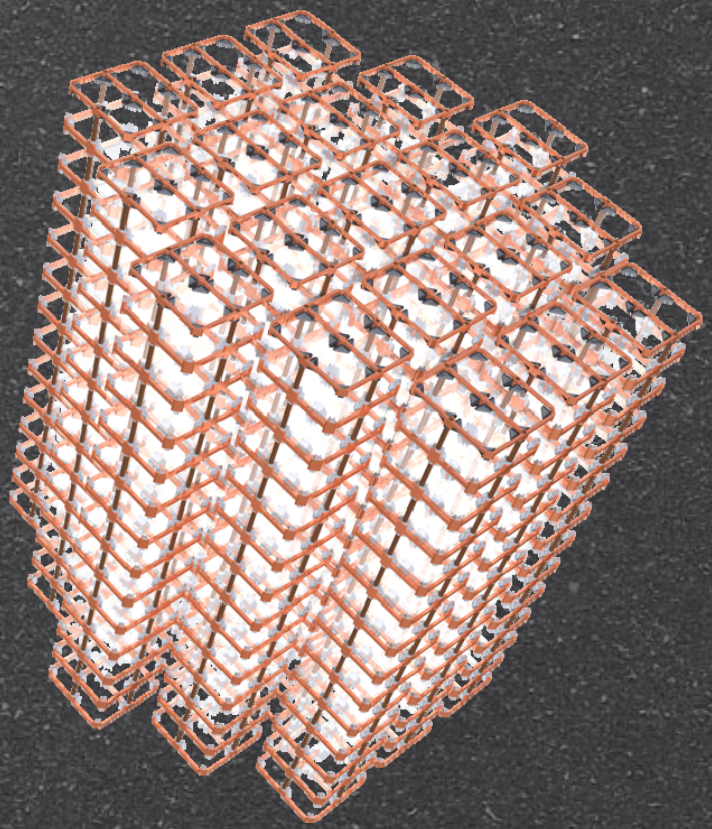
XIV International Workshop on "Neutrino Telescopes"
Venice, March 15-18, 2011

CUORICINO, CUORE-0 AND CUORE: AN UPDATE



C. Brofferio, University of Milano Bicocca
on behalf of the CUORE Collaboration

THE BOLOMETRIC WAY TO DBD

The key point when using a bolometer is that you can:

FIRST choose the isotope **THEN** define the compound

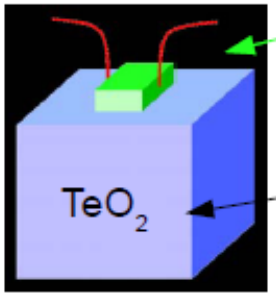
^{130}Te :

High isotopic abundance = 34% **NO ENRICHEMENT**

High Q-value = 2527 keV **LOW GAMMA BACKGROUND**

Good F_N: $\tau_{1/2}^{0\nu} = 1 \div 6\ 10^{26}$ y when $m_{ee} = 50$ meV

TeO_2 bolometers: source=detector approach



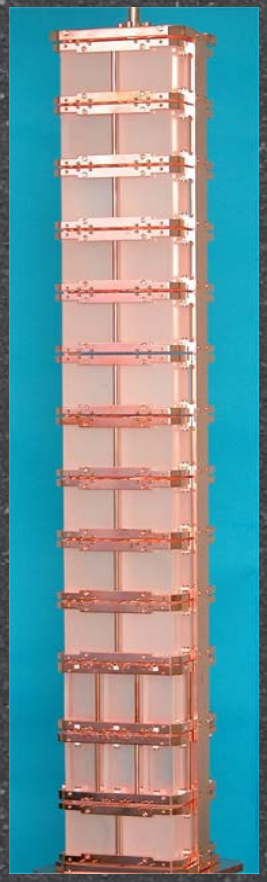
Temperature sensor: $\Delta T \rightarrow \Delta V$

NTD thermistor
$R = R_0 \exp(T/T_0)^{\gamma}$ → high sensitivity

Absorber: $E \rightarrow \Delta T \sim E/C(T)$

TeO_2 crystals
Low heat capacity
High radio-purity
Large size crystals available

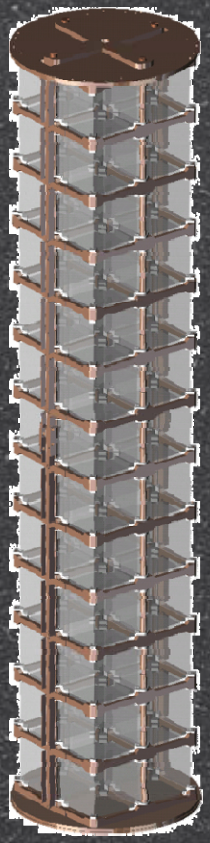
1997: START OF THE CUORE PROGRAM



Cuoricino

2003–2008

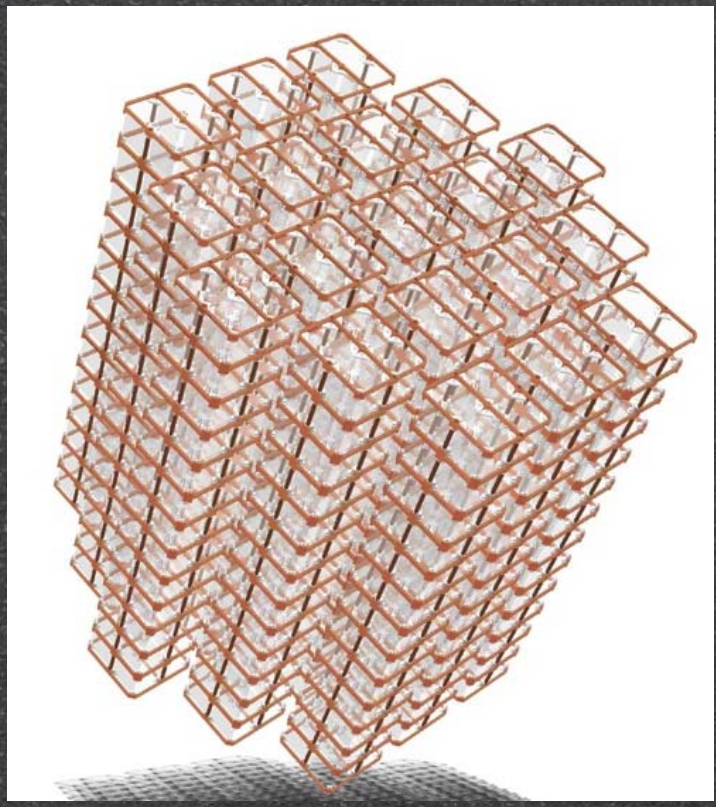
~11 kg ^{130}Te



CUORE-0

2011–2014

~11 kg ^{130}Te



CUORE

2013–2018

~200 kg ^{130}Te

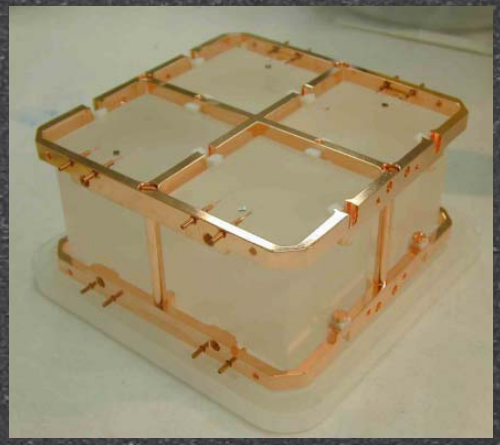
2003 – 2008: CUORICINO

Still the largest bolometric experiment ever realized

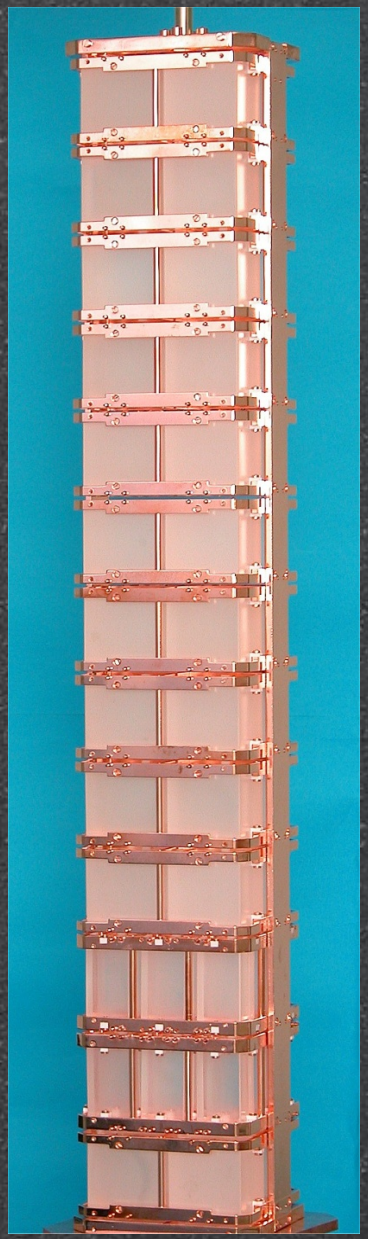
Total TeO_2 mass 40.7 kg

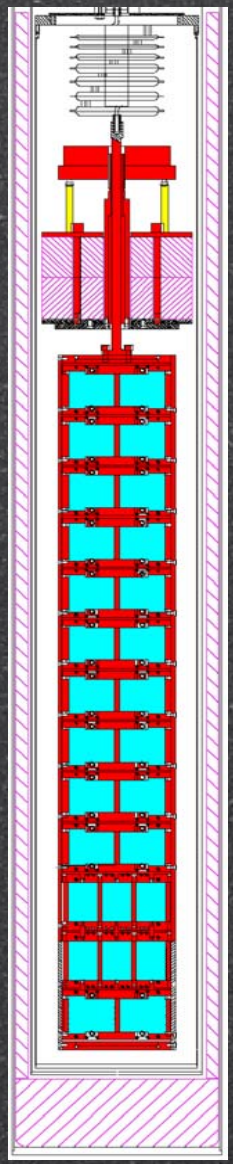
Total ^{130}Te mass 11.2 kg

11 modules of 4 TeO_2 crystals
5x5x5 cm^3 → 790 g

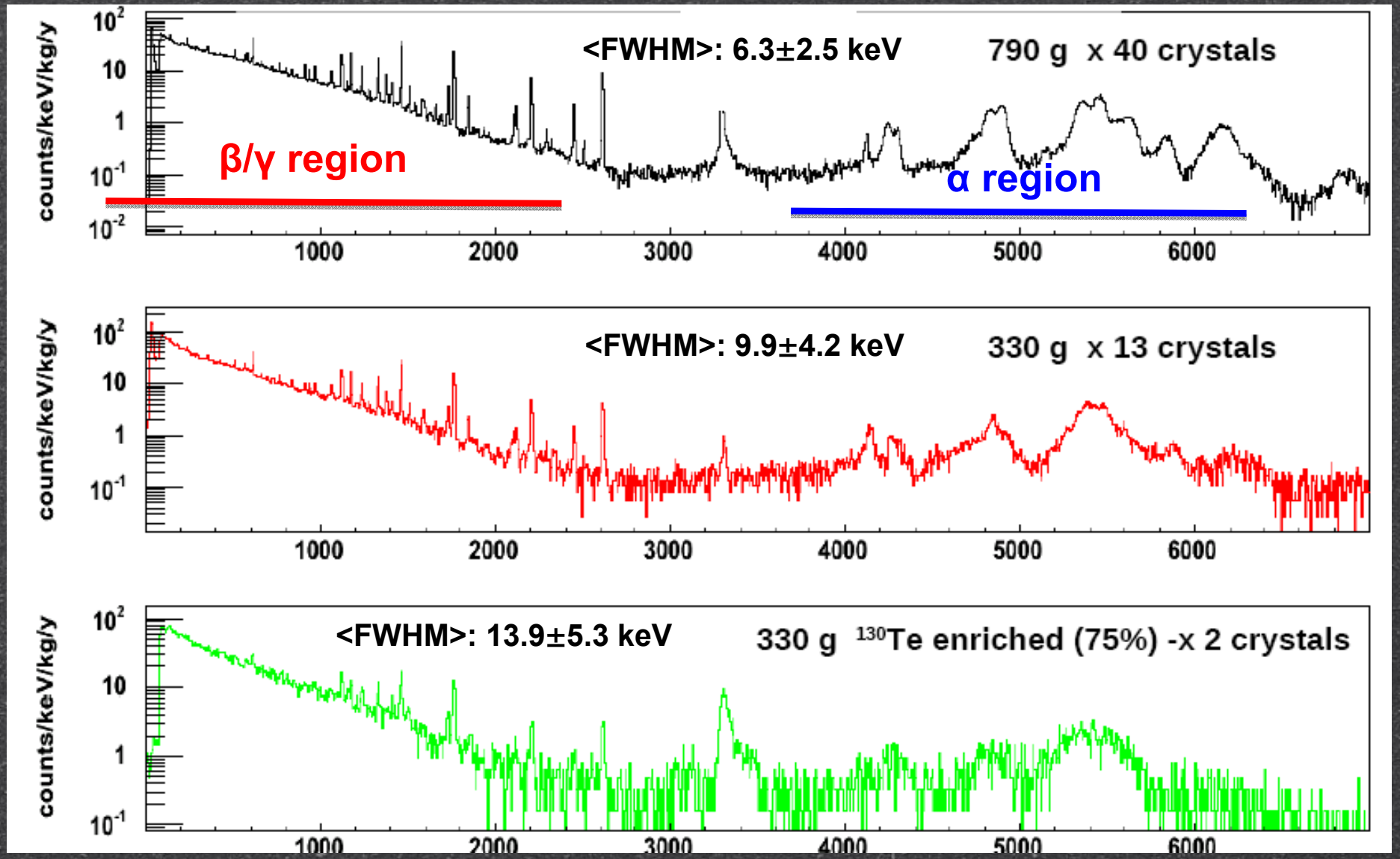


2 modules of 9 TeO_2 crystals
4 enriched (2x^{130}Te - 2x^{128}Te)
3x3x6 cm^3 → 330 g



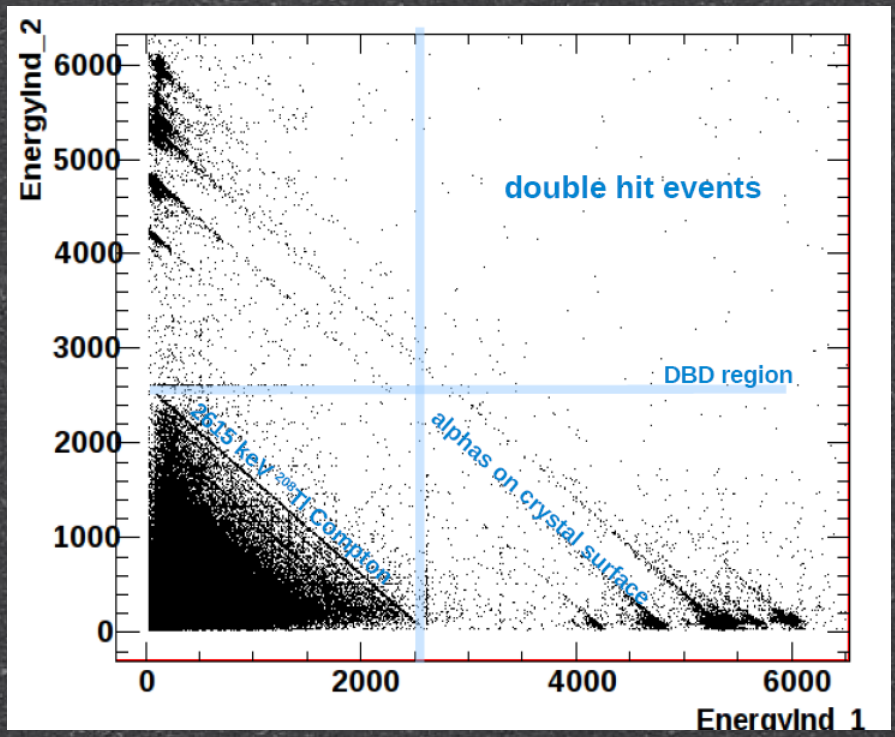


CUORICINO DATA

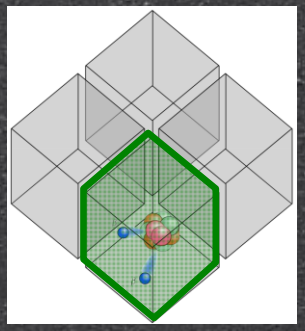


COINCIDENCE STUDIES

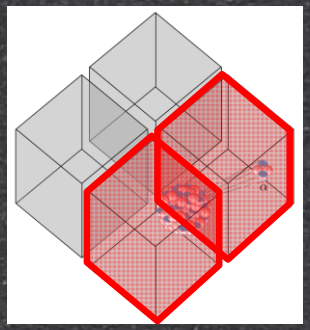
- Background reduction (0νDBD)
- Background study (source identification)
- Study of complex processes (Physics)



- Discarding multi-site events reduced background by 10-15% aprox. in the region of interest
- Surface contaminations on crystals are clearly visible



Single Crystal Event

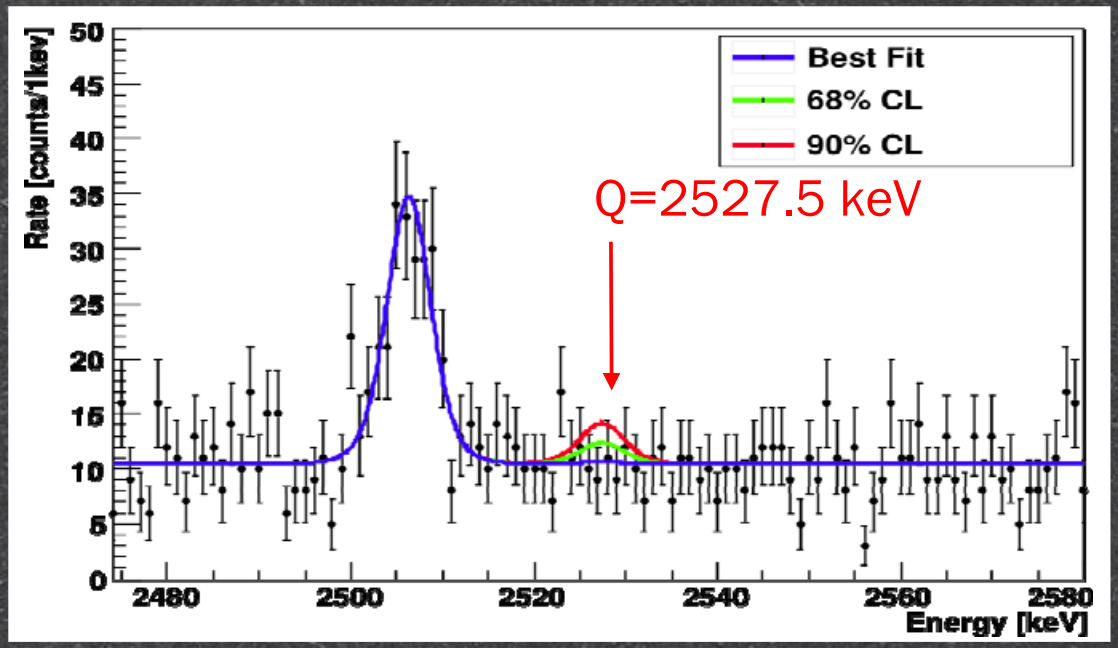


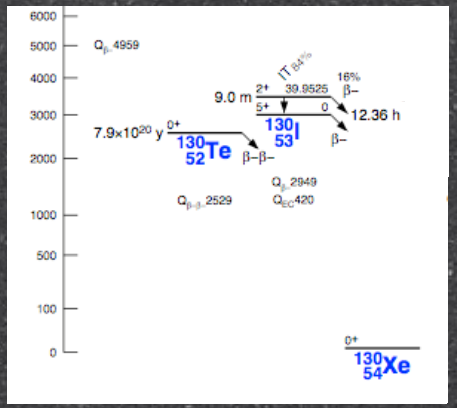
Multiple Crystal Event

CUORICINO: 0νDBD RESULT

Astropart. Phys. (2011), doi:10.1016/j.astropartphys.2011.02.002

TOTAL: **19.6 kg · yr** ^{130}Te exposure
collected in 2 runs (2003-2004, 2004-2008)
(II Run, Big Crystals alone: 15.8 kg · y)





NME bibliography:

1 Šimkovic et al.,
PRC 77 (2008) 045503
2 Civitarese et al.,
JoP:Conference series
173 (2009) 012012
3 Menéndez et al.,
NPA 818 (2009) 139
4 Barea and Iachello,
PRC 79 (2009) 044301

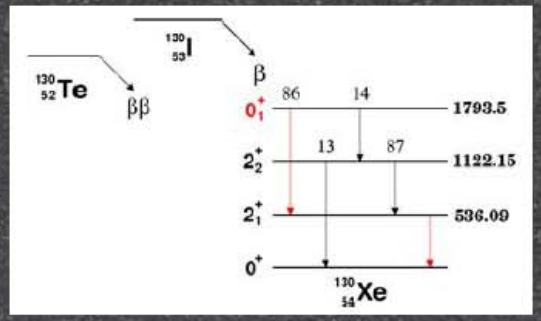
Background Big Crystals, II run: 0.153 ± 0.006 counts/keV/kg/y

Lower limit, half-life: $T_{1/2}^{0\nu}$ (^{130}Te) > 2.8 × 10^{24} y (90% C.L.)

Upper limit, Majorana mass: m_{ν_e} < 0.3 – 0.7 eV

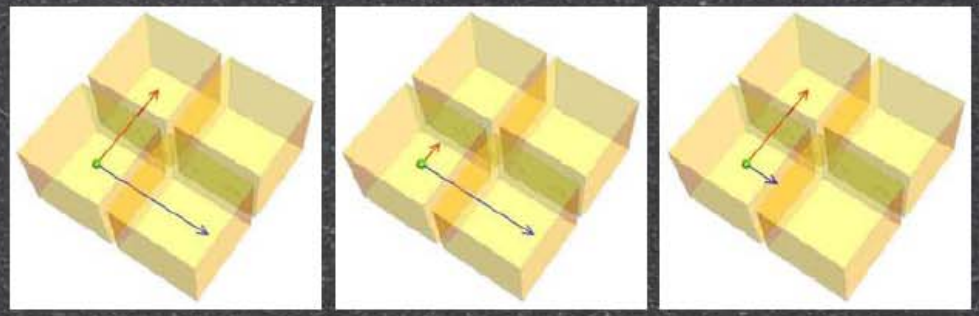
CUORICINO: ββ ON EXC. STATES

PAPER IN PREPARATION



Coincidence based analysis:

study of complex processes



	hit1 [keV]	hit2 [keV]	hit3 [keV]
scenario1	0-734	1257	536
scenario2	536-1270	1257	X
scenario3	1257-1991	536	X

CALCULATIONS AND PAST EXP.

Theor: $T_{1/2}(2\nu\beta\beta^*) = (5.1 - 14) \times 10^{22}$ y

Exp: $T_{1/2}(2\nu\beta\beta^*) > 2.3 \times 10^{21}$ y, 90% CL

Theor: $T_{1/2}(0\nu\beta\beta^*) = 1.4 \times 10^{26}$ y

Exp: $T_{1/2}(0\nu\beta\beta^*) > 2.5 \times 10^{22}$ y, 90% CL

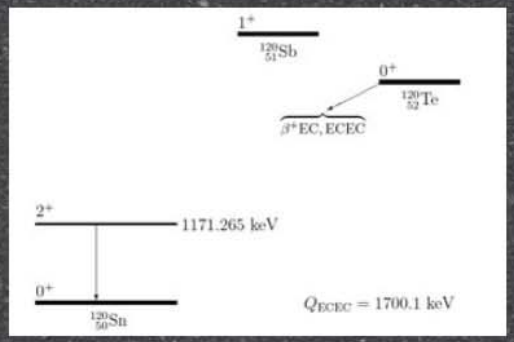
$T_{1/2}(0\nu) > 1.0 \times 10^{24}$ y (9 CL)

$T_{1/2}(2\nu) > 1.4 \times 10^{23}$ (90% CL)

PRELIMINARY

CUORICINO: β^+/EC DECAY OF ^{120}Te

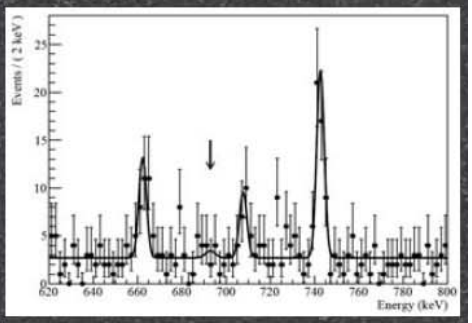
Astroparticle Physics 34 (2011) 643-648

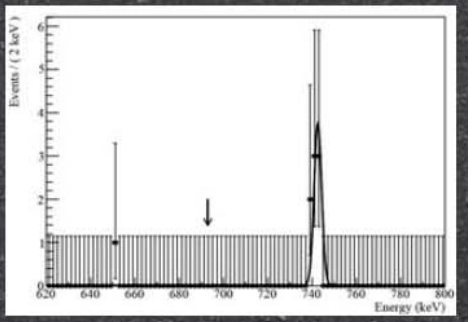


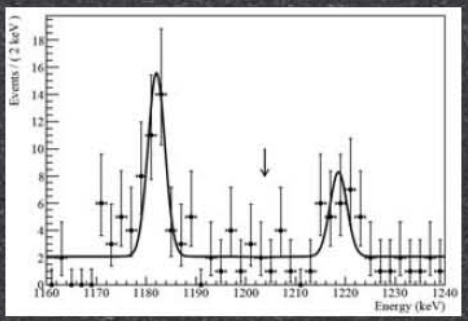
Again: a coincidence based analysis

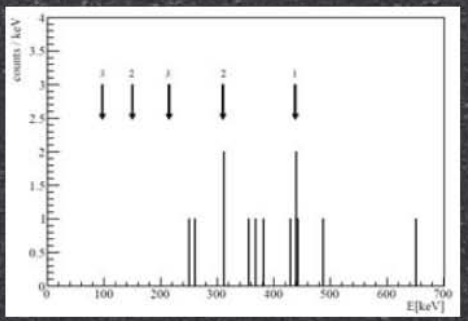
Exposure:
0.0573 kg y of ^{120}Te

Signature (0v)	Signature (2v)	Mult	Efficiency [%]
692.8 keV	(30.5 - 692.8) keV	1	3.00 ± 0.02
692.8 ⊕ 511 keV	(30.5 - 692.8) keV ⊕ 511 keV	2	3.40 ± 0.02
692.8 ⊕ 511 ⊕ 511 keV	(30.5 - 692.8) keV ⊕ 511 keV ⊕ 511 keV	3	0.45 ± 0.01
1203.8 keV	(541.5 - 1203.8) keV	1	16.28 ± 0.04
1203.8 ⊕ 511 keV	(541.5 - 1203.8) keV ⊕ 511 keV	2	6.23 ± 0.03
1714.8 keV	(1052.5 - 1714.8) keV	1	10.04 ± 0.03







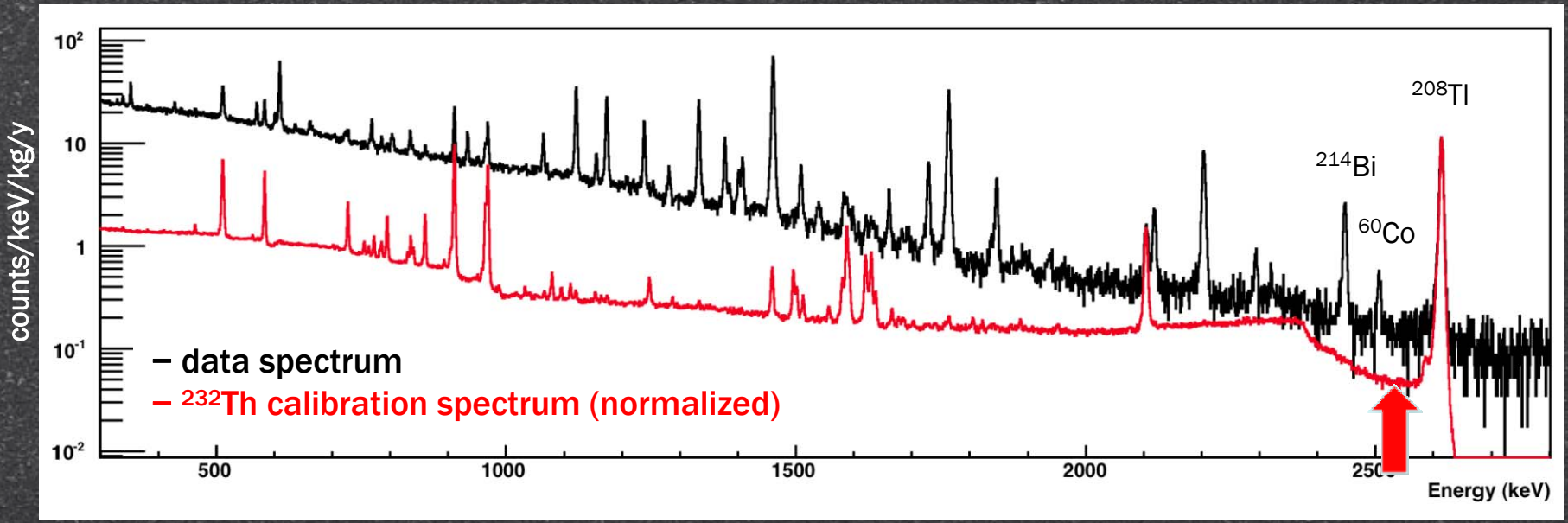


0v mode: $T_{1/2}(0\nu) > 1.9 \cdot 10^{21}$ y @ 90% C.L
(4 orders of magnitude improvement)

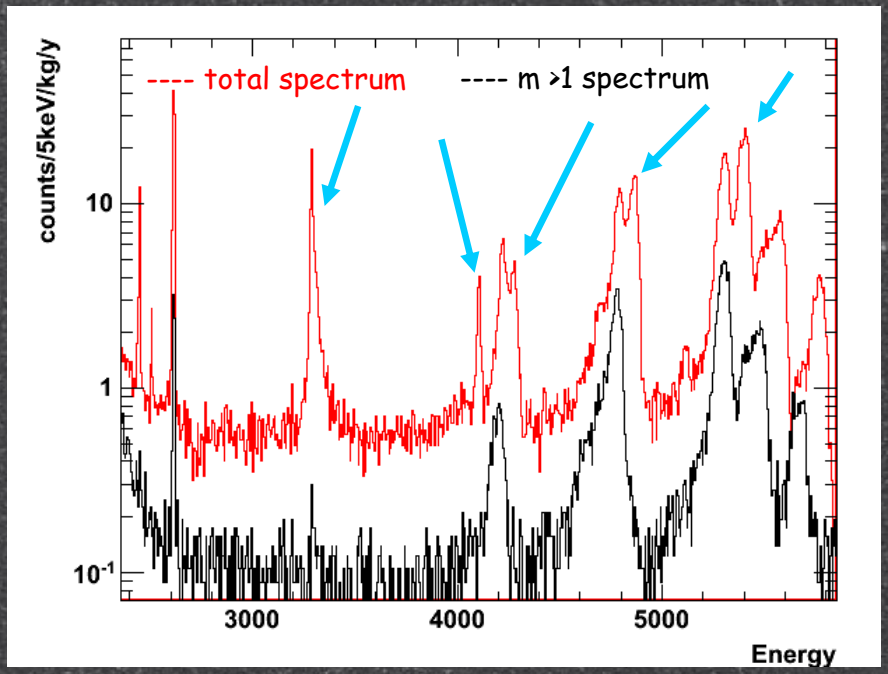
2v mode: $T_{1/2}(2\nu) > 0.9 \cdot 10^{20}$ y @ 90% C.L
(3 orders of magnitude improvement)

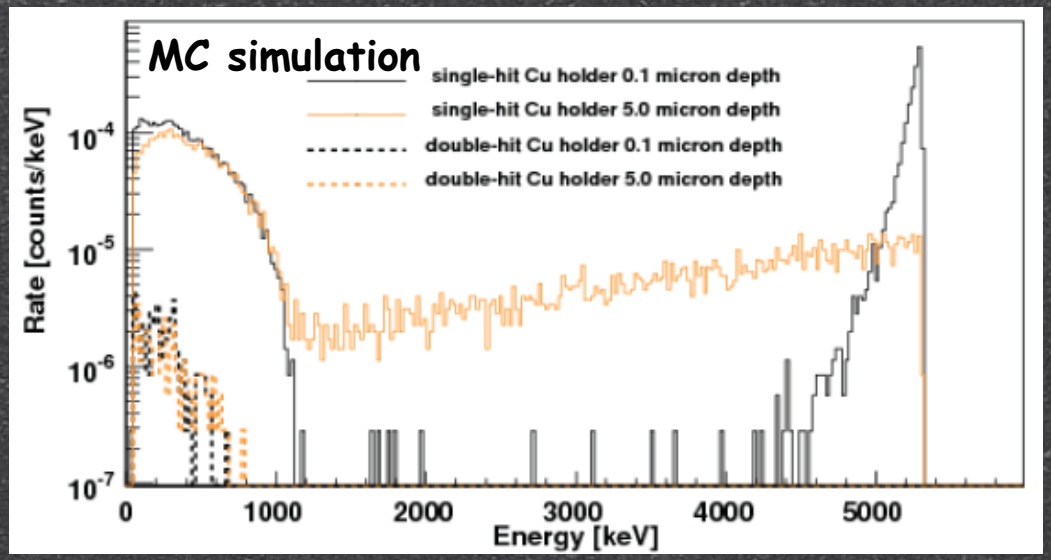
IDENTIFICATION OF POSSIBLE BACKGROUND SOURCES

- There are three main sources of background in the **region of interest (2474–2580 keV):**
  - **(~40%)** Compton events from 2615 keV peak of ^{208}Tl, from ^{232}Th cryostat contamination
  - **(~50%)** Degraded alphas from ^{238}U and ^{232}Th on copper surfaces
  - **(~10%)** Degraded alphas from ^{238}U and ^{232}Th on crystal surfaces
- The 2505 keV ^{60}Co peak is likely due to cosmic-ray activation of the copper



CUORICINO BKG: LET'S ZOOM-IN...





THERE IS CLEARLY A **FLAT BKG** COMING FROM ALPHA REGION

NOT DUE TO CRYSTAL **BULK** CONTAM. (sharp peaks, no continuum, E = Q)

CAN COME FROM **SURFACE** CONTAMINATIONS

CRYSTALS: m>1 SPECTRUM (degraded peaks if partially implanted)

SURROUNDING MATERIALS: a continuum with more or less structures

CUORE DETECTOR AND SET-UP

988 TeO_2 crystals arranged in 19 towers

Mass 741 kg (~ 200 kg of ^{130}Te)

Energy resolution 5 keV @ 2615 keV (FWHM)

Background aim: 10^{-2} c/keV/kg/years

MAIN CONCEPTS:

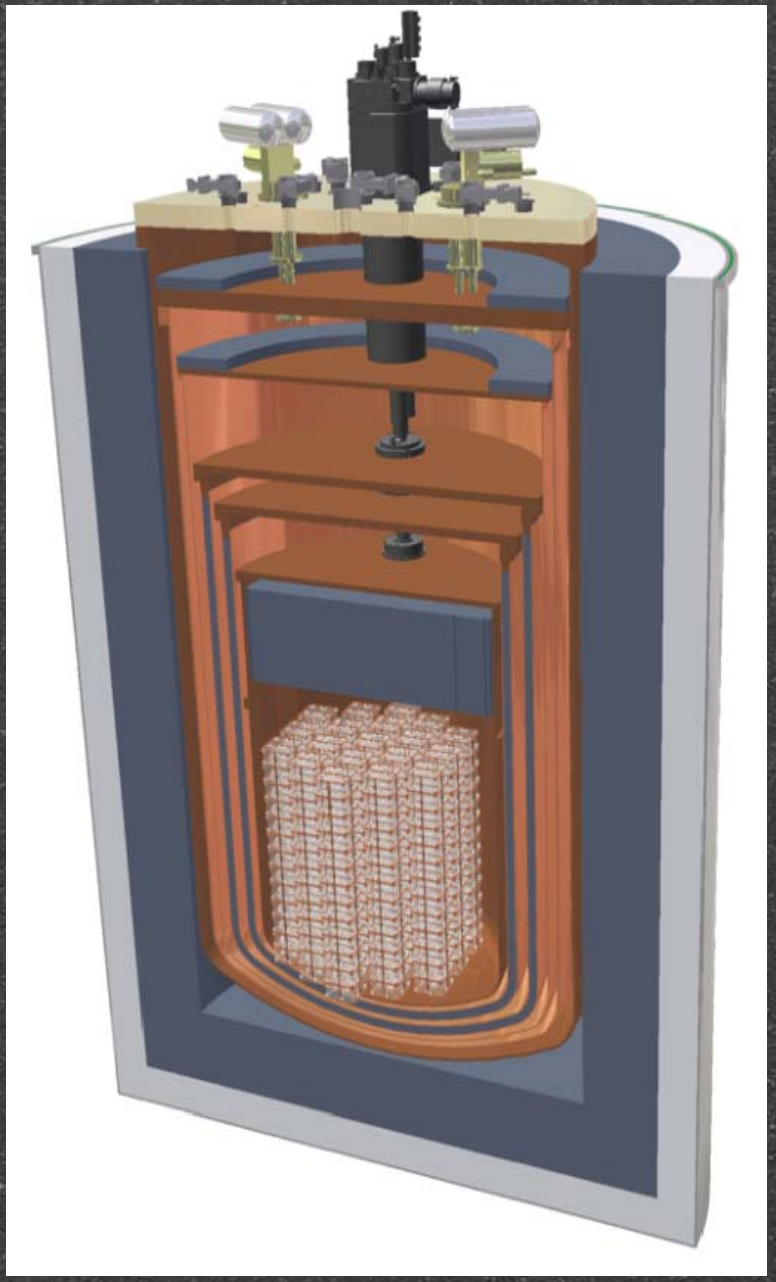
- ~20 times the mass of CUORICINO
- stringent controls on radioactivity of materials and on the assembly protocol
- heavy shielding (36 cm Pb min.)
- tightly packed array with a high efficiency in background rejection thanks to the use of anticoincidence

  n bkg suppressed by ~30

  μ bkg suppressed by ~ 20

  (Astrop. Phys. 33 (2010) 169)

  crystal surface bgk suppressed by ~ 4



CUORE CRYSTALS VALIDATION

~1000 crystals ordered to SICCAS (China)

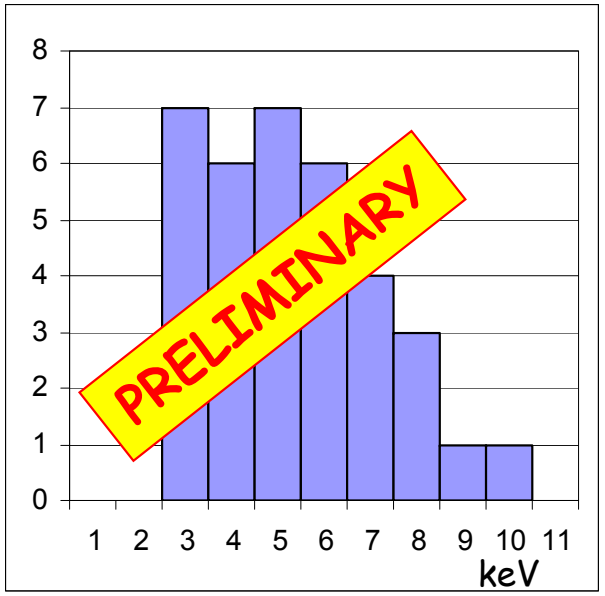
* 560 crystals ordered by INFN (now in LNGS)

* 500 crystal ordered by DoE will follow:
  91 already in LNGS, end in sept 2012

for each production batch, 2 or more crystals are tested in hall C cryostat:

Single cell similar to CUORE
New electronics and DAQ as CUORE
All material cleaned CUORE like

35 CUORE BOLOMETERS



<FWHM>: 4.89±1.86 keV

PURPOSE OF THE TEST

check performances as bolometers

check bulk contaminations

check surface contaminations

bulk: <6 10^{-14} g/g in U, <8 10^{-14} g/g in Th
----------> ββ bkg < 5 10^{-5} c/keV/kg

surface: ~ nBq/cm^2
----------> ββ bkg <2 10^{-3} c/keV/kg/y

PRELIMINARY

CUORE RADIOACTIVITY TEST

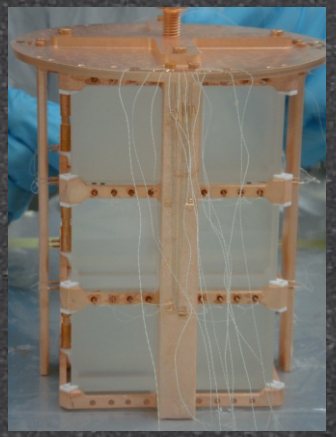
THE THREE TOWERS TEST

Measurement was done in Hall A cryostat: same as Cuoricino

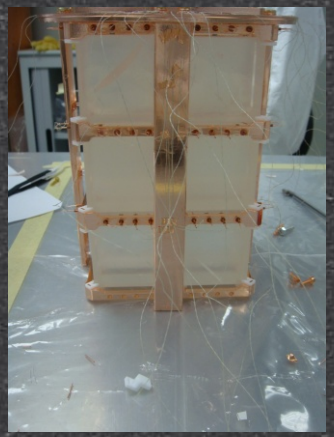
Crystals were dismounted from Cuoricino detector and repolished on surfaces

Three different types of copper cleaning were tested to evaluate the surface contribution to background

T1
Chemical etching with polyethylene wrapping



T2
More complex chemical treatment



T3
Legnaro T.E.C.M.

TTT BACKGROUND

Without Efficiency correction

Tower c/keV/kg/y	2700-3900 MeV (excluded Pt peak)	Error (1σ)	4-5 MeV (U/Th)	Error (1σ)	5-6 MeV (Po/Pb)	Error (1σ)
T1-Pirro	0.058	[illegible]	0.227	0.011	1.063	0.023
~~T2-Gorla~~	~~0.087~~	~~0.008~~	~~0.260~~	~~0.014~~	~~1.334~~	~~0.032~~
T3-LNL	0.061	0.006	0.218	0.013	1.531	0.034

PRELIMINARY

To be compared with Cuoricino background in the same region:

0.122 ± 0.001 c/keV/kg/y

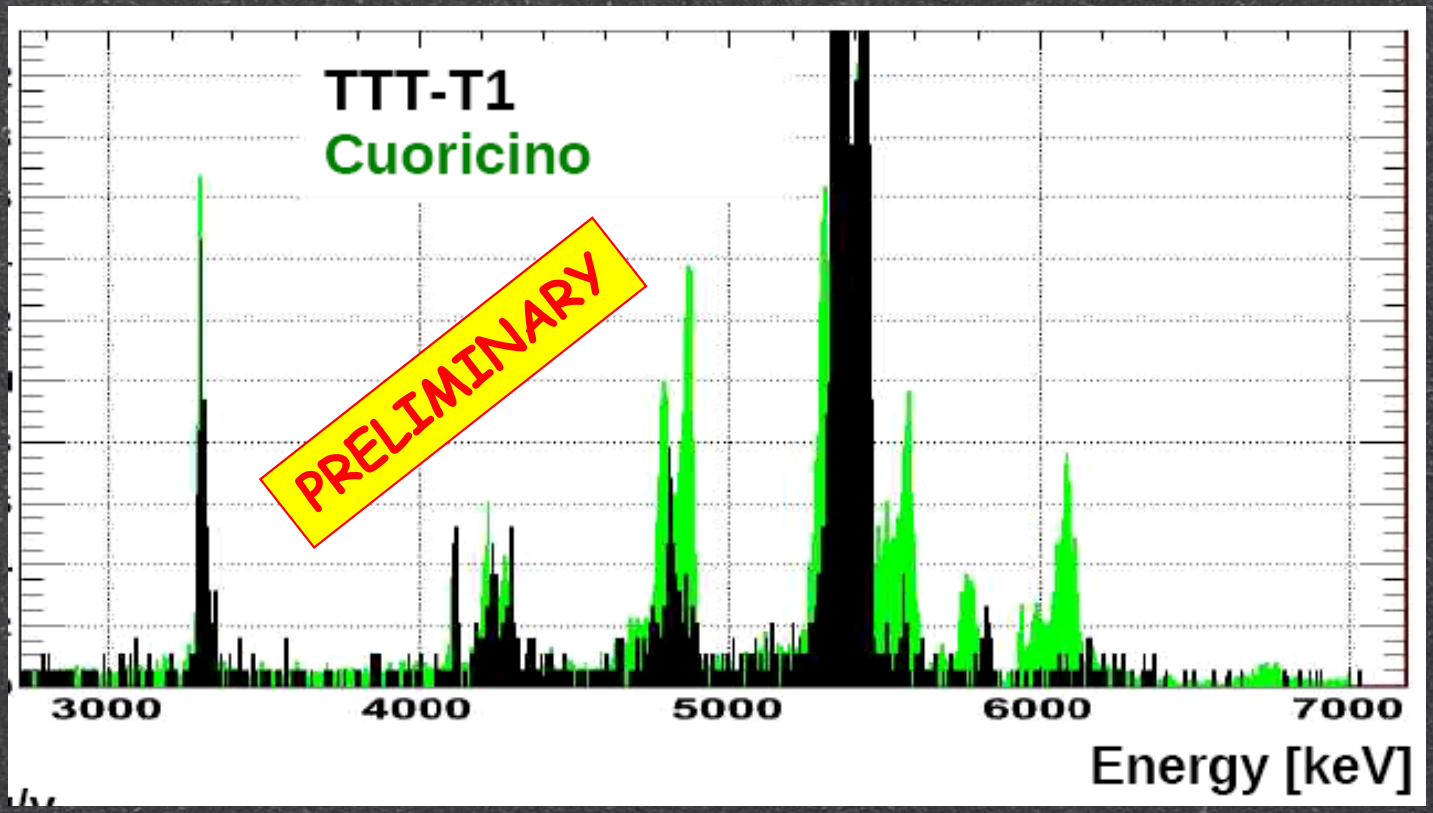
The flat component that contributed for ~60% to CUORICINO background (and that we consider the more important source limiting CUORE background) is reduced by a factor ~2 !

TTT CRYSTALS: RECONTAMINATION

TTT crystals are re-polished Cuoricino crystals

We improved much on the surface contamination...

...BUT clearly recontaminated them with ^{210}Pb

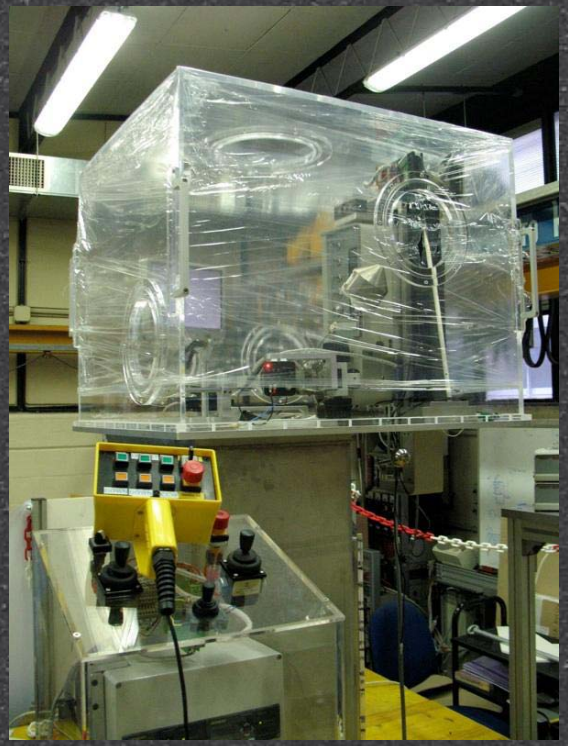


RECONTAMINATION RISKS

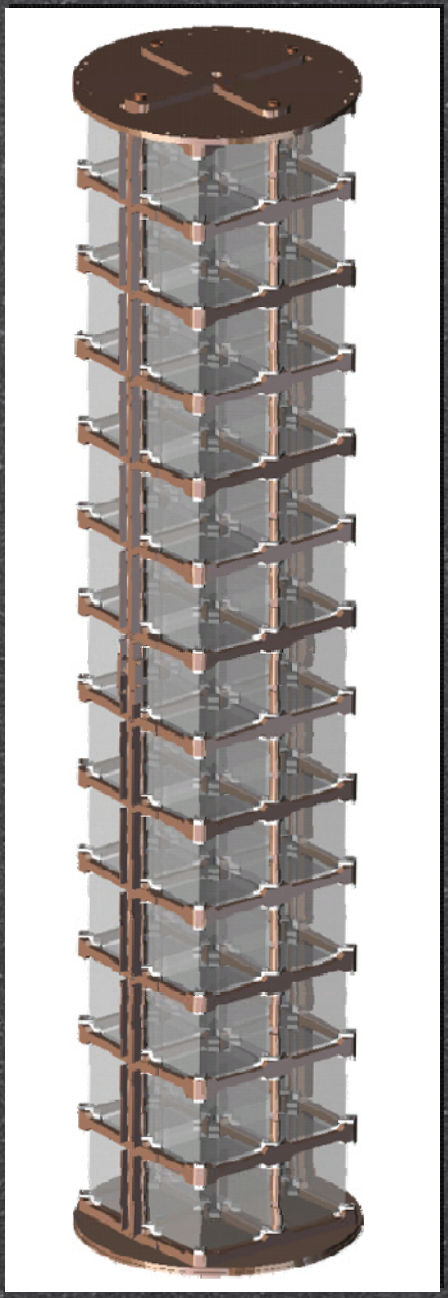
FIGHTING RECONTAMINATION:
A NEVERENDING STORY

ALL MATERIALS, AFTER CLEANING, ARE PACKED UNDER VACUUM, STORED UNDERGROUND AND KEPT UNDER N_2 FOR YEARS...

THE TOWER ASSEMBLY LINE IS BASED ONLY ON NITROGEN FLUSHED GLOVE BOXES



THE NEAR FUTURE: CUORE-0



A single tower realized with the same procedure of CUORE
- crystals from the same production line
- same copper and PTFE
- CUORE-like copper surface cleaning
- same assembly line

CUORE-0 will be installed in HallA cryostat
- same as Cuoricino

Many aspects will be analyzed with CUORE-0:
- detector performances with high statistics
- radioactive background (in Cuoricino cryostat)

CUORE-0 will be assembled in the next months
and then put into operation before the end of the year

...STAY TUNED!!

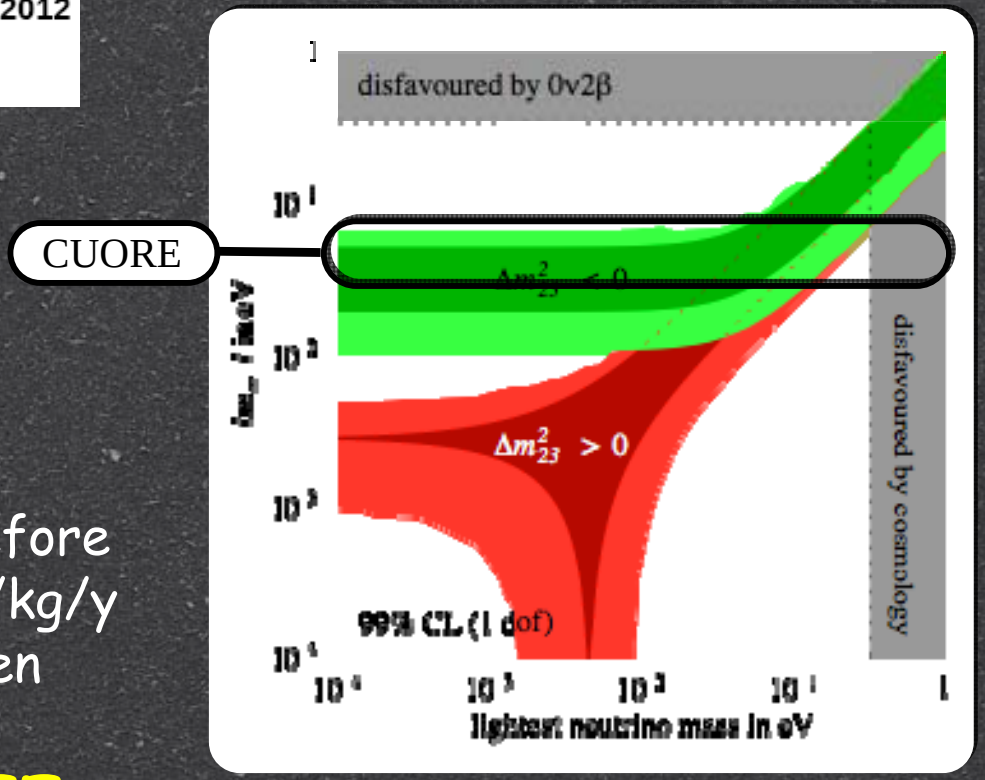
CUORE: THE REAL CHALLENGE

Background [c/kev/kg/y]	FWHM [keV]	$T_{1/2}^{0\nu}$ [y] @ 68%C.L.	$\langle m_{\beta\beta} \rangle$ [meV]			
			R(QRPA)[1]	pn(QRPA)[2]	ISM[3]	IBM-2[4]
0.01	5	2.1×10^{26}	35÷66	41÷67	65÷82	41
0.001	5	6.5×10^{26}	20÷38	23÷38	37÷47	23

1 Šimkovic et al., PRC 77 (2008) 045503
2 Civitarese et al., JoP:Conference series 173 (2009) 012012
3 Menéndez et al., NPA 818 (2009) 139
4 Barea and Iachello, PRC 79 (2009) 044301

Based on our studies and knowledge we foresee for CUORE a background of 0.01 c/keV/kg/y

But other CUORE-like detectors are being proposed and under study, therefore the possibility to reach a 0.001 c/keV/kg/y or even better in the future is still open



JUST WAIT AND WE'LL SEE...