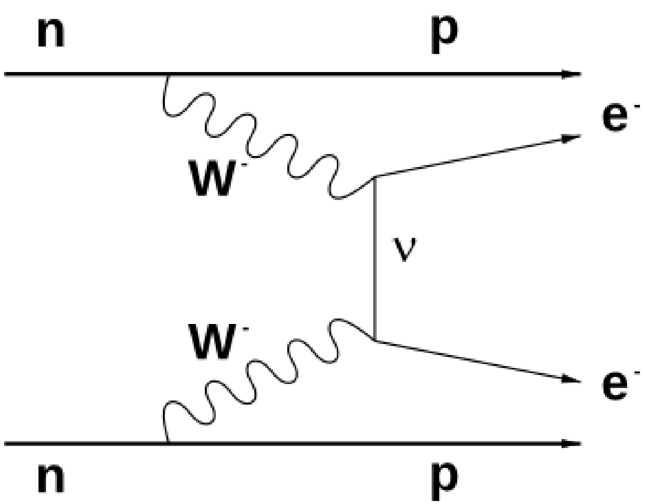
Recent Results from CUORE

Silvia Capelli
On behalf of the CUORE collaboration
Universita` e Sezione INFN di Milano Bicocca

Neutrinoless Double Beta Decay ($0\nu\beta\beta$)

- Channel for $\beta\beta$ decay **forbidden by SM** ($\mathbf{\Delta}L=2$)
- Extremely **rare** process ($T_{1/2} > 10^{22} - 10^{24}$ y)
- Its observation would prove **ν Majorana nature**



For **light** $\boldsymbol{\nu}_M$ exchange the **Decay Rate** is:

Nuclear Matrix Element
NUCLEAR PHYSICS

$$(T_{0\nu})^{-1} \propto G_{0\nu}(Q,Z)|M^{0\nu}|^2 \langle m_{ee} \rangle$$

Phase Space Factor
ATOMIC PHYSICS

Effective Majorana mass
PARTICLE PHYSICS

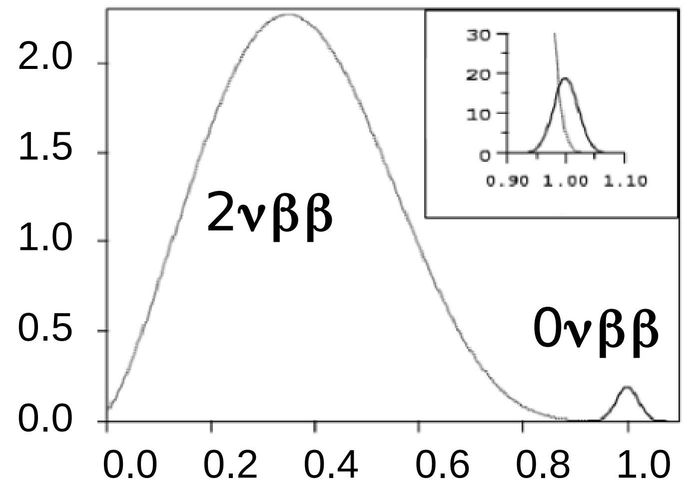
$$\langle m_{ee} \rangle = \left| \sum \left| U_{ei}^2 \right| m_i e^{i\alpha_i} \right|$$

2

Experimental search for 0νββ

(A,Z) --> (A, Z+2) +2e$^-$

Main signature:
Peak at Q-value over 2νββ tail enlarged only by detector resolution



Experimental sensitivity $S^{0\nu}$

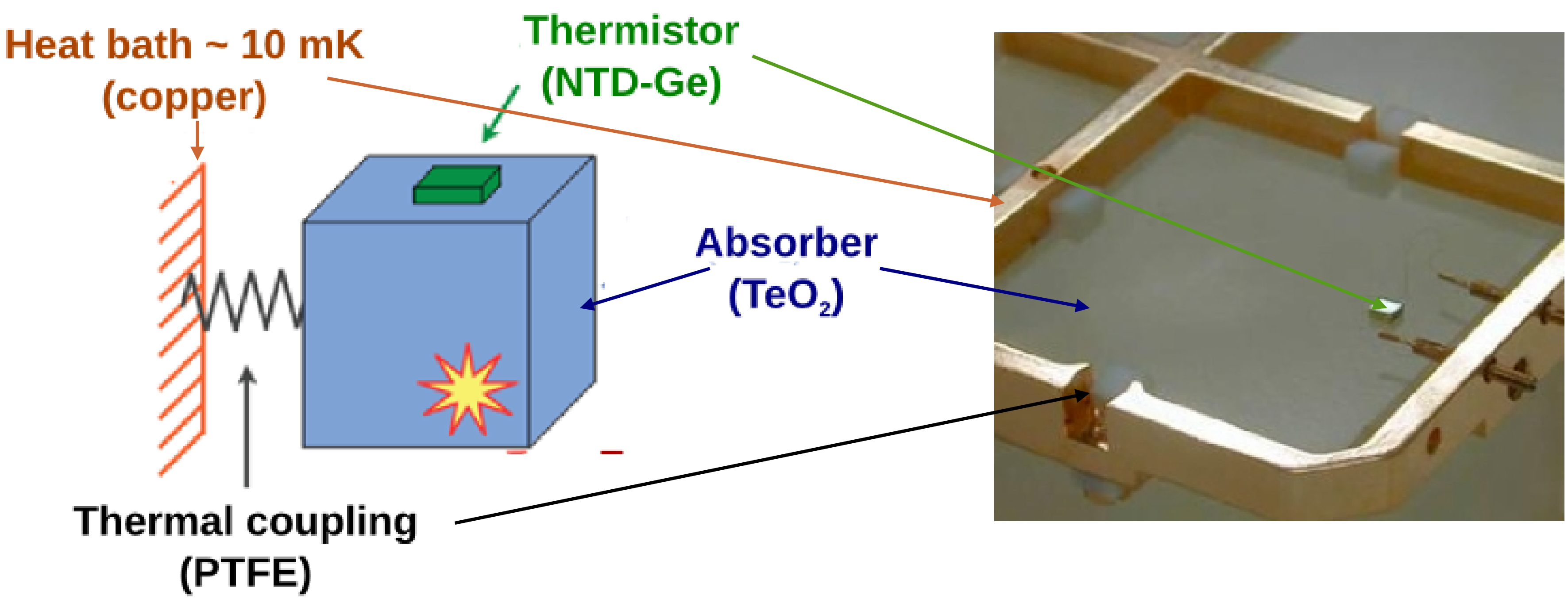
Lifetime corresponding to the minimum detectable number of events over background at a given C.L.

M: total active mass in kg
ε: detector efficiency
a.i.: isotopic abundance
b: background in c/keV/kg/y
ΔE: detector resolution @ ROI in keV
T:exposure time in y

$$S^{0\nu} \propto \frac{\epsilon\, a.i.}{A} \left(\frac{MT}{b\,\Delta E} \right)^{1/2} \qquad b \neq 0$$

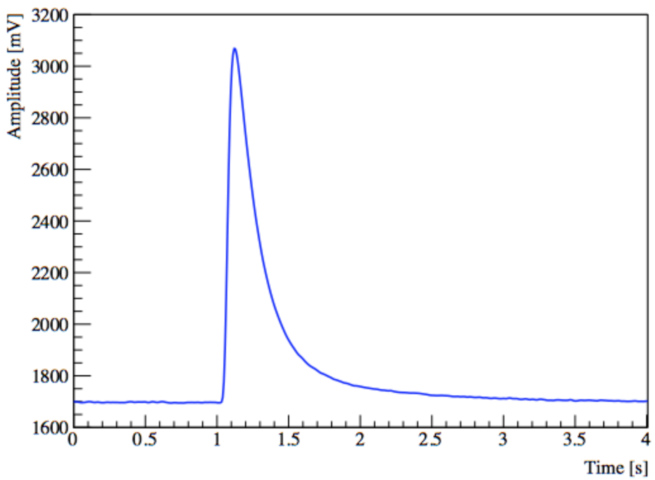
Qualitative expression in the Gaussian approximation
(not fully accurate for very low background experiments)

Bolometric technique



$$\Delta T = \frac{E}{C(T)}$$

$$\Delta t = \frac{C}{G}$$



Particle energy is converted into phonons by dielectric and diamagnetic absorbers whose heat capacity ($C \propto T^3$) is very low at low T.
(At T~10 mK ΔT ~300 mK @ 1 MeV)

- **Crystal Absorber (TeO_2):** E → **Δ**T
- **Biased T sensor (NTD-Ge):** **Δ**T → **Δ**V
- **Thermal link (PTFE+gold wires):** T_0~10 mK

0νββ research with TeO_2

^{130}Te is a **good 0νββ candidate** ($^{130}Te \rightarrow {}^{130}Xe + 2e^-$)

high natural **i.a. (34.2 %) -- NO enrichment** is needed

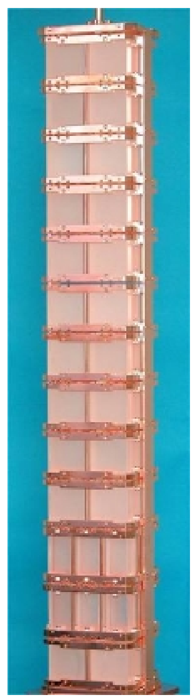
reasonably **high Q-value (Q~2528 keV) --** high G(Q,Z) and low background

MiDBD
1.8 kg ^{130}Te

1997-2001

$T_{1/2}^{0\nu}$ > 2.1 x 10^{23} y [21]

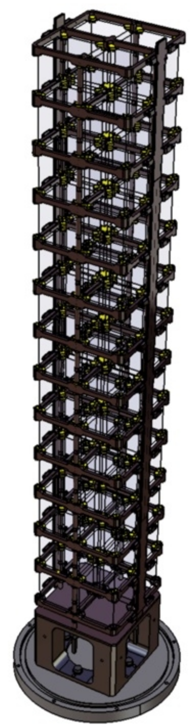
Cuoricino
11.3 kg ^{130}Te



2003-2009

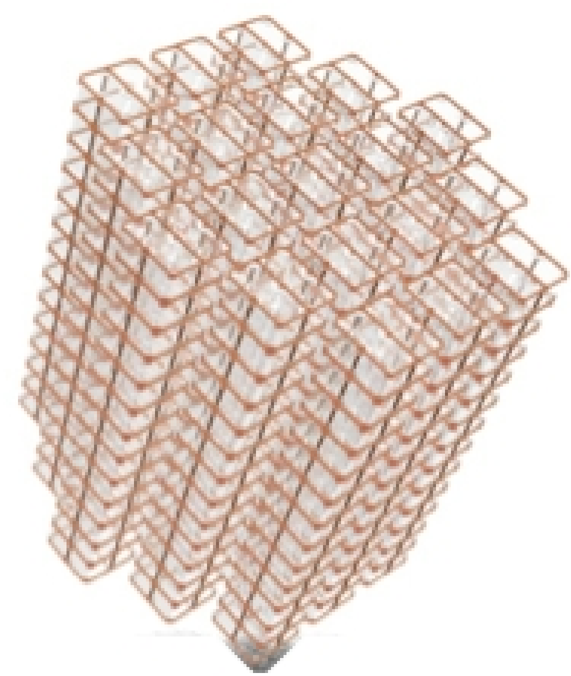
$T_{1/2}^{0\nu}$ > 2.8 x 10^{24} y [5]

CUORE-0
11 kg ^{130}Te



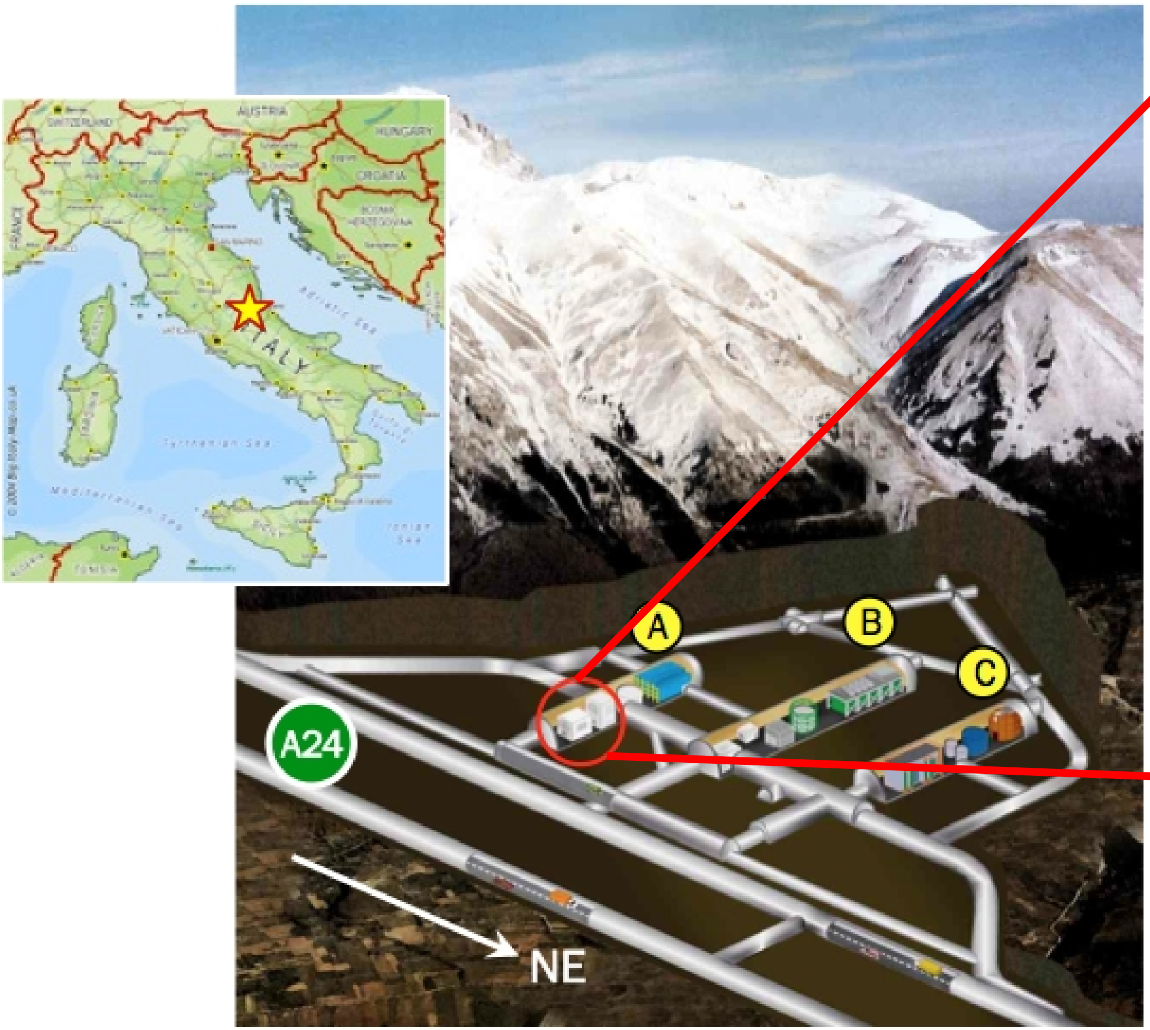
2012...2014

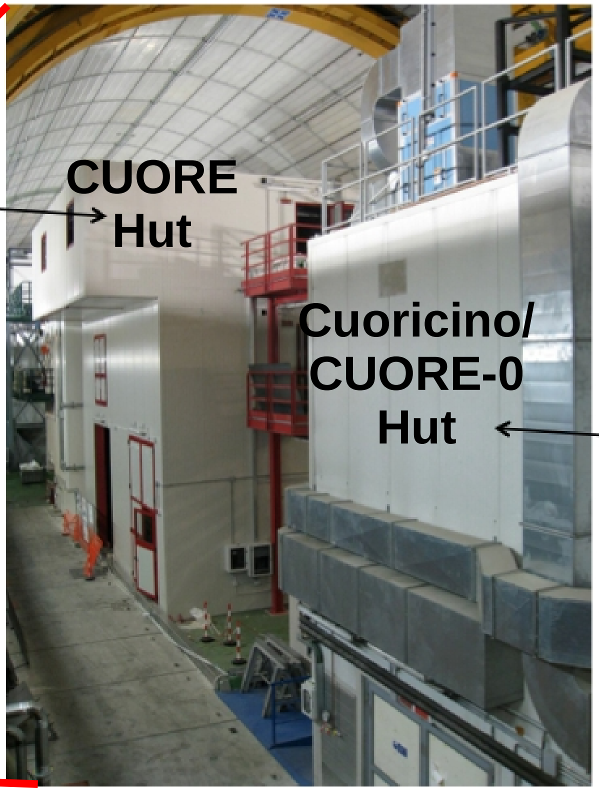
CUORE
206 kg ^{130}Te



2014...

Location





Average depth ~ 3650 m.w.e. [10]

μ flux: $(2.58 \pm 0.3)\cdot10^{-8}$ m/s/cm^2 [11]

n flux <10 MeV: $4\cdot10^{-6}$ n/s/cm^2 [12,13]

γ flux < 3 MeV: 0.73 g/s/cm^2 [14,15]

In A Hall of LNGS, Italy
(Laboratori Nazionali del Gran Sasso)

From Cuoricino to CUORE

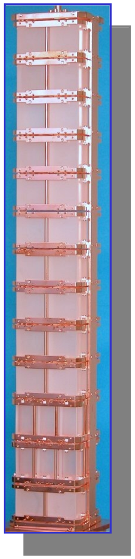
988 TeO_2 5x5x5 cm^3 crystals (750 g each)
Detector Mass: 741 kg TeO_2
^{130}Te mass (natural i.a.) : 206 kg of ^{130}Te
Array: 19 towers, each with 13 planes of 4 crystals each

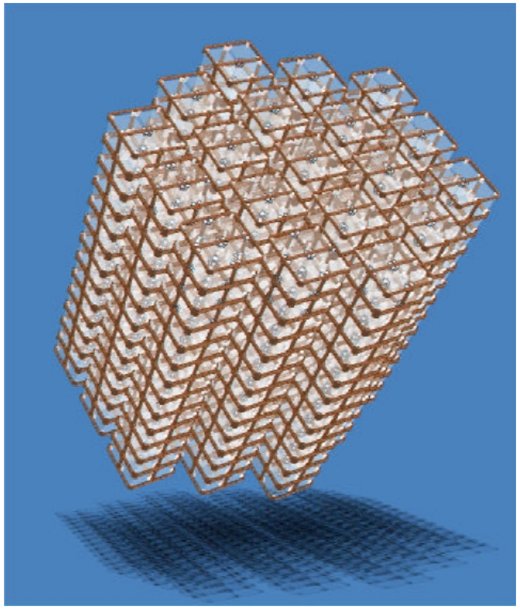
Sensitivity improvement:

$$S^{0\nu} \propto \frac{\epsilon\, a.i.}{A} \left(\frac{MT}{b\, \Delta E} \right)^{1/2}$$

(Mx20) + (ΔE/1.5) + (Tx2) + (b/20)

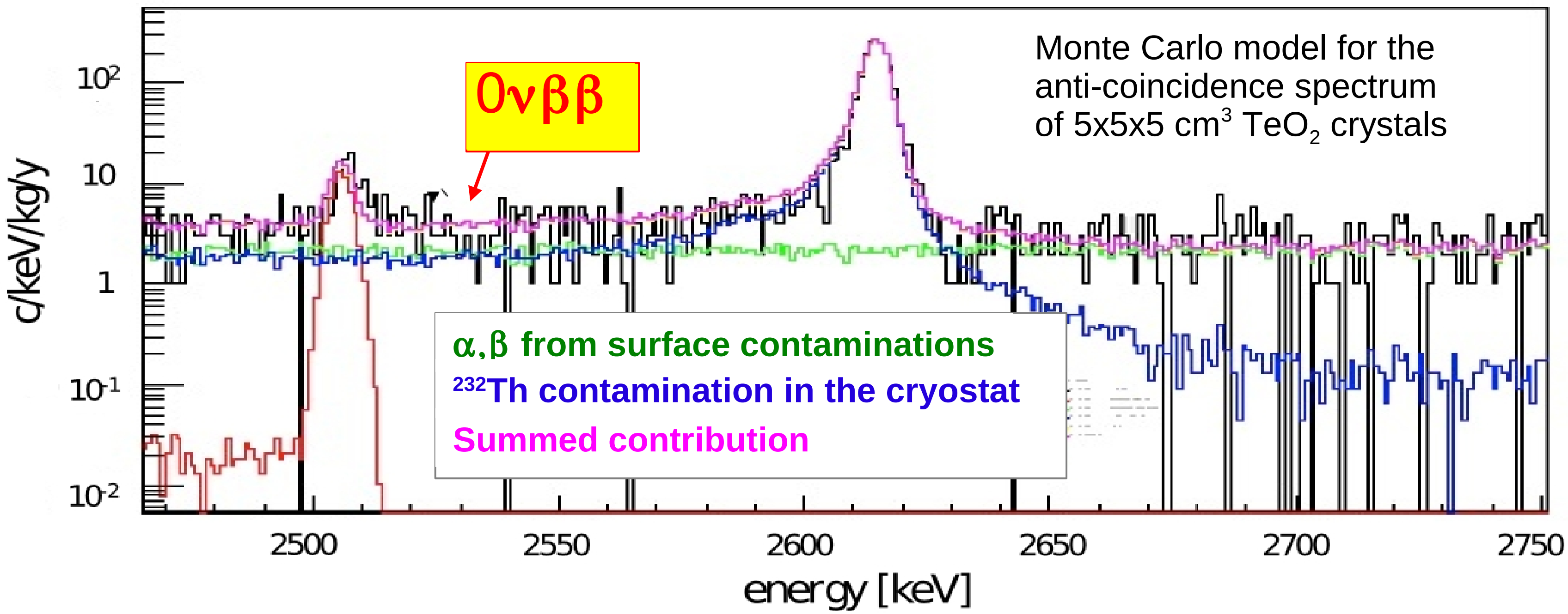
=> CUORE $S^{0\nu}$ ~ 35 Cuoricino $S^{0\nu}$





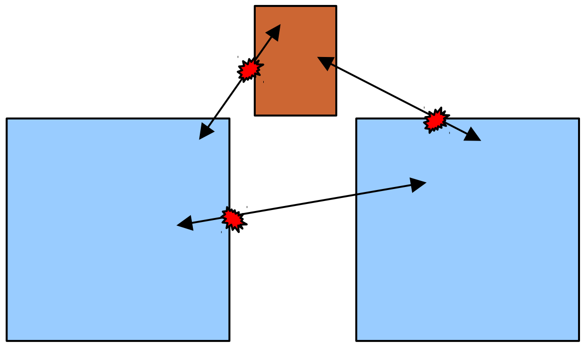
The most challenging issue is background reduction
GOAL: 0.01 counts/keV/kg/y

The Background in the Cuoricino ROI



b = 0.169 ± 0.006 c/keV/kg/y

^{232}**Th in the cryostat (γ)** [7,8]	**30 ± 10 %**
Contamination on **crystal surface** [7,8]	**10 ± 5 %**
Contamination on **Cu surface** [7,8]	**50 ± 20 %**



The main issue are degraded α and β from crystal and copper surfaces

The Background Issue

Background reduction

Passive methods adopted for CUORE while testing different active methods
(i.e. Surface sensitive bolometers, scintillating bolometers) for future improvements

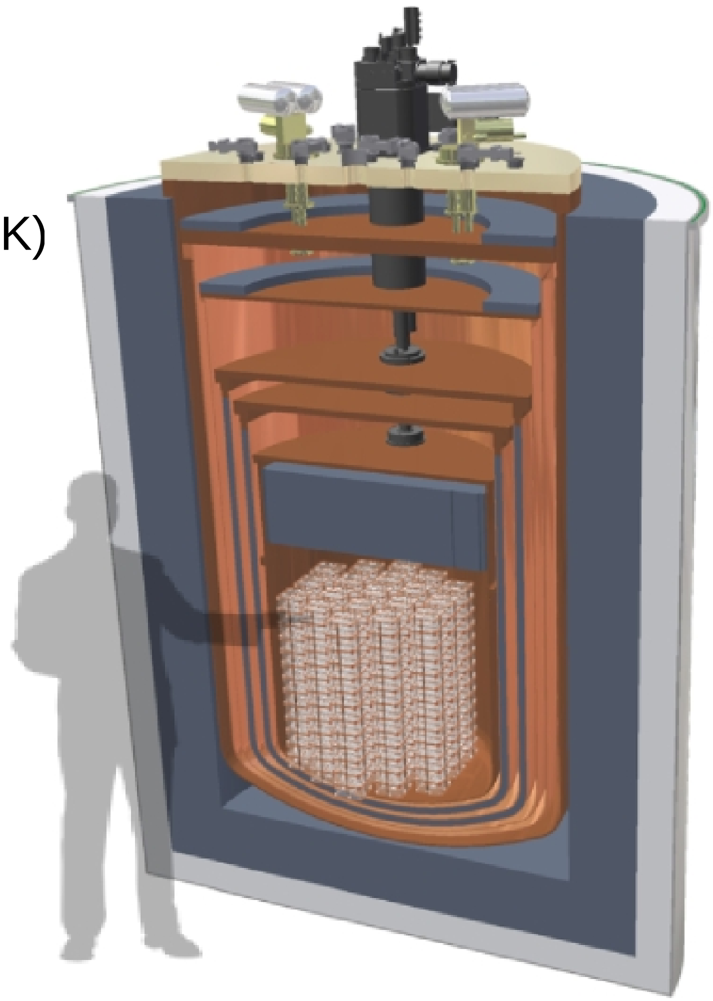
- **Detector granularity:** reduction thanks to anticoincidence between detectors
- Optimized **shields and materials selection**
- **New design of the detectors holder:** less amount of copper facing the crystals
- **TeO_2 crystals bulk contamination control**: strict protocol for TeO_2 production [20]
- **Crystals surface contamination reduction:** new treatment developed

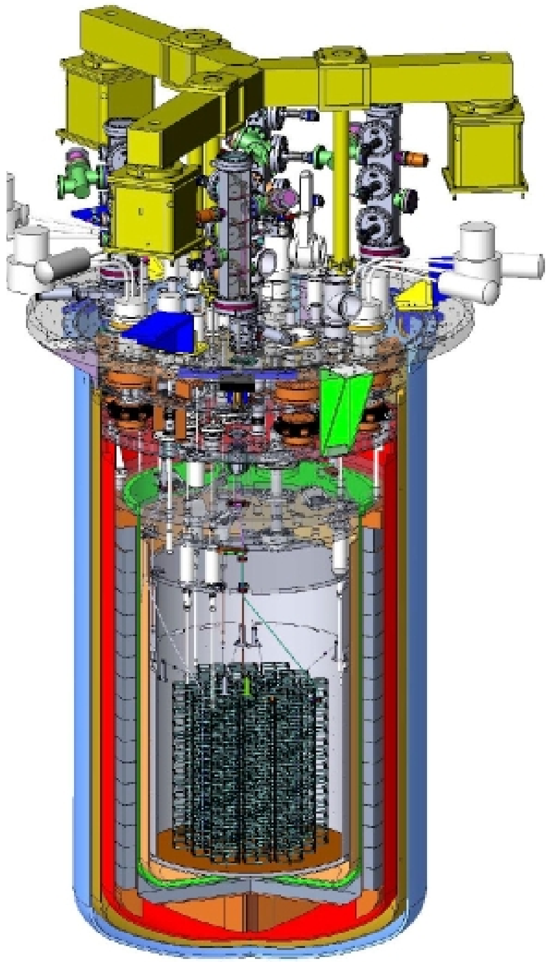
  => bolometric tests on 4 sample crystals from each batch: **CCVR [9] tests**
- **Surface contamination of the copper facing the crystals reduction:**
- => bolometric tests of three different surface treatments: **Three Tower Test (TTT)**

Environmental and cryostat background

Developed a low-radioactivity cryostat, provided with nested Cu/Pb shields

- **Careful material selection**
  => low radioactivity
- **6 nested copper vessels**
  (300K, 40K, 4K, 600mK, 50mK, 10mK)
- **External + Internal Pb shields**
  (~35 cm minimum thickness)
- **Shields for neutrons**
  (18cm PET + 2 cm H_3B0_3)



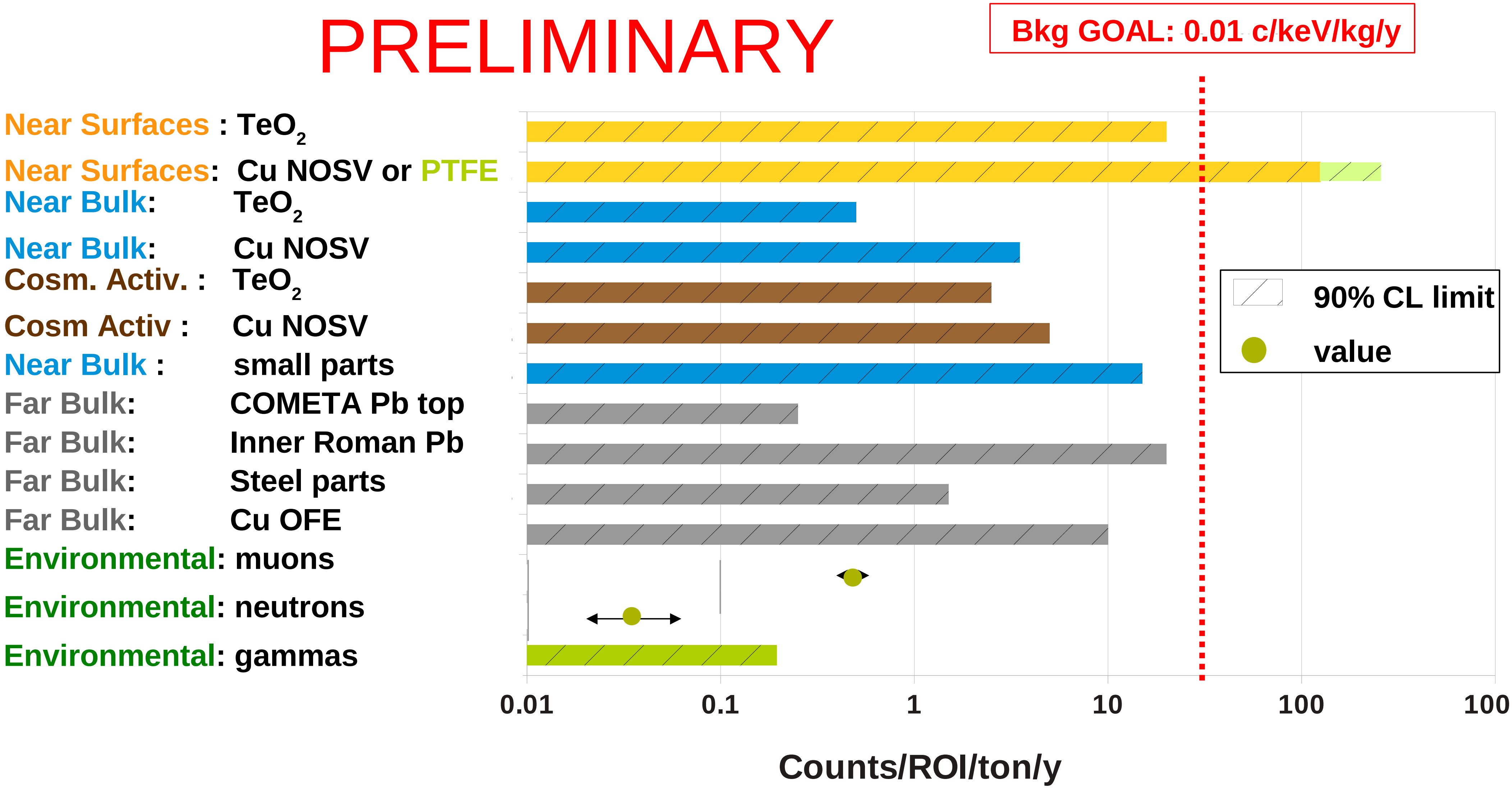


CUORE background budget

Contributions of the main background sources to the ROI of CUORE

The computation is performed by Monte Carlo simulations using in input the contamination limits/values obtained from measurements

PRELIMINARY



CUORE Status

Assembly clean room

Underground Storage Area

300 K shield installation

- **Hut and clean room:** fully equipped
- **Detector assembly line:** almost ready
- **Radon abatement system:** installed
- **Cryostat:** commissioning of first 3 vessels (of 6) on-going at LNGS
- **Cryostat Dilution Unit**: commissioning started, T<8 mK reached in stable conditions in a test cryostat
- **Calibration system:** construction started
- **Copper parts:** being machined and cleaned, delivered by end 2013
- **Crystals:** 95% stored underground at LNGS at the end of 2012
- **Thermistors:** production on-going, final delivering in early 2013

Dilution Unit Commissioning

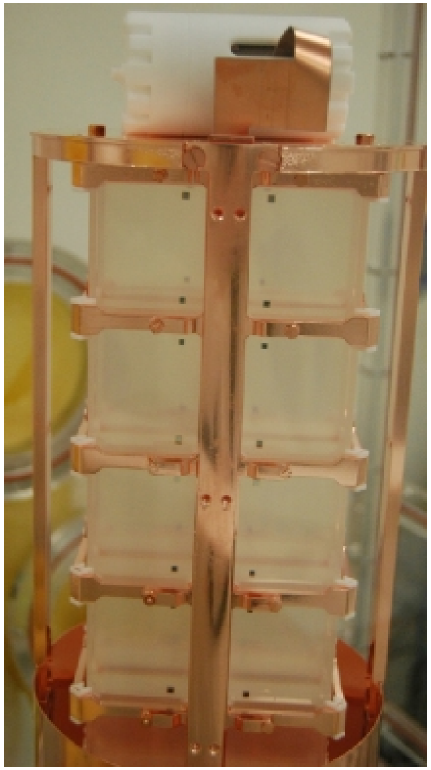
CUORE first phase: CUORE-0

1 CUORE-like tower of 13 planes - 4 crystals each
52 TeO_2 5x5x5 cm^3 crystals (750 g each)
Detector Mass: 39 kg TeO_2
^{130}Te mass (natural i.a.): 11 kg of ^{130}Te

- All detector components manufactured, cleaned and stored with protocols defined for CUORE
- Assembled with the same procedures foreseen for CUORE
- In the 25 years-old CUORICINO cryostat

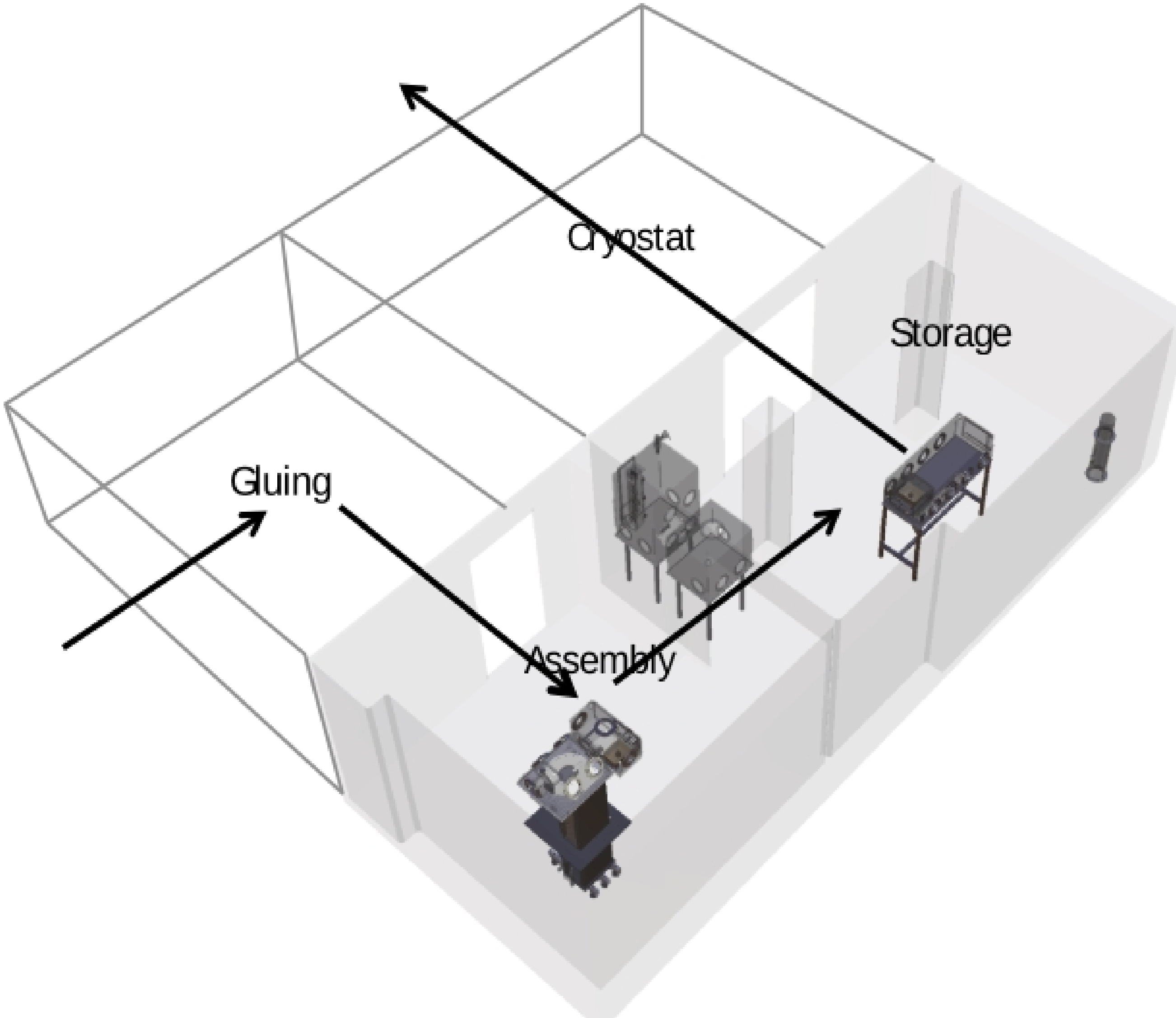
GOALS

- Proof of Concept for CUORE in all stages
- Test and debug the CUORE assembly line (thermistor gluing, signal wires bonding, tower assembly)
- Test of the CUORE DAQ and analysis framework
- Extend the physics reach beyond CUORICINO while CUORE is being assembled
- Demonstrate potential for DM and Axion detection



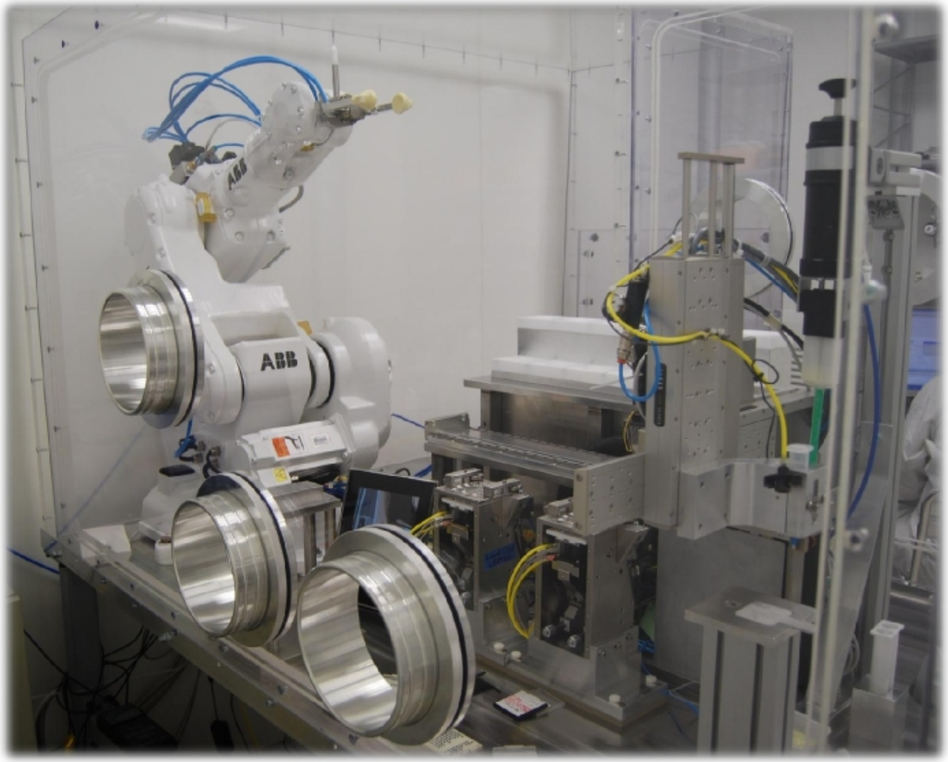
CUORE-0: assembly procedure

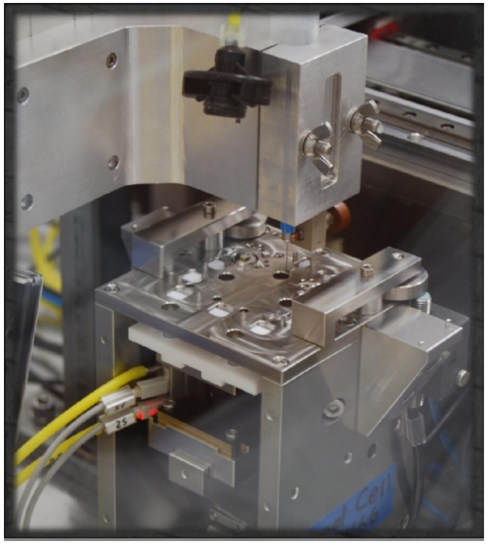
CUORE-0 assembly was performed in the new CUORE clean room following all the stages and using **all the equipment developed for CUORE**

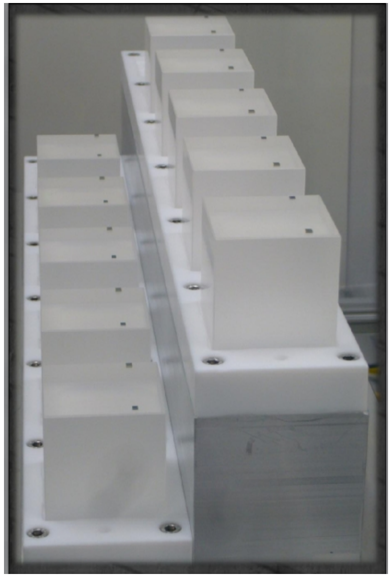


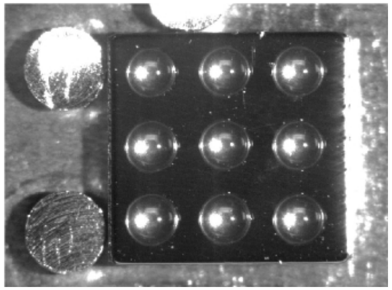
CUORE-0: thermistor gluing

The gluing of CUORE-0 thermistor to crystals was performed with the **new CUORE gluing semi-automatic machine** (in a N_2 flushed glove box): fast, operator independent, minimizes radioactive contaminations, makes this stage more reproducible thus improving detector uniformity.



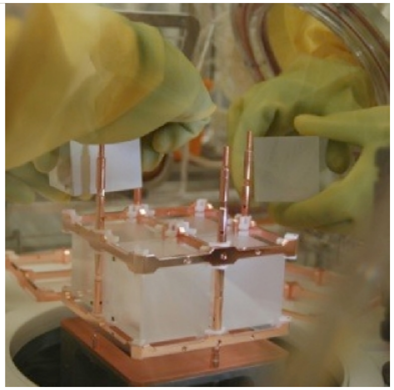


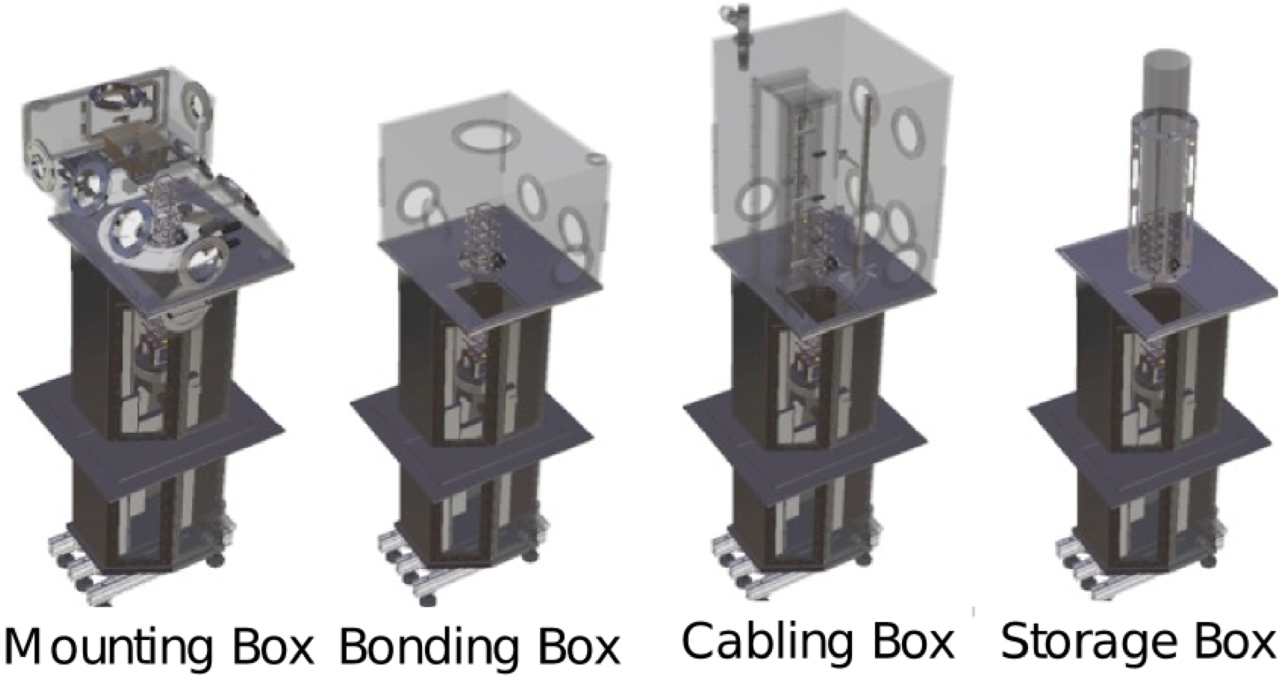


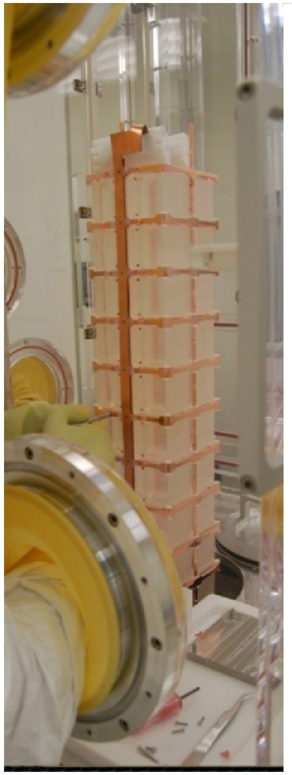


CUORE-0: tower assembly

The assembly of the tower was done with the **CTAL (CUORE Tower Assembly Line)** provided of a sealed and flushed stainless steel chamber (Garage) supporting a working plane where **4 different glove boxes** switch allowing 4 operations to be performed (mounting, cabling, bonding, and tower storage) with radioactivity control and reproducible protocols

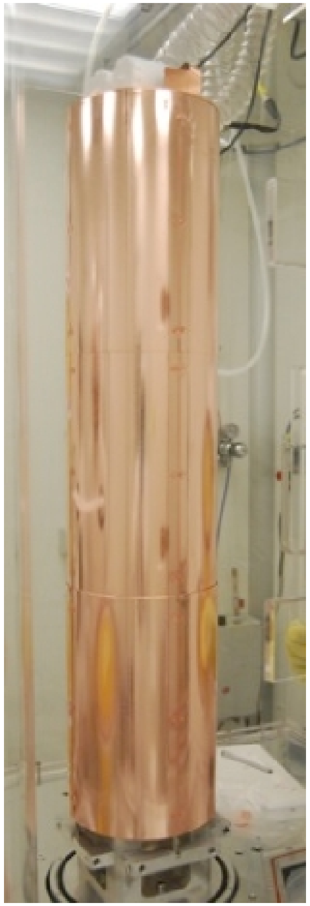






CUORE-0: shield installation and transportation

After shield installation the tower has been closed in a flushed Plexiglas box, then moved to the special opening door of the **CUORE clean room** with a trans-pallet. It has then been lifted with a fork-lift to the **CUORICINO clean room** where it has been joined to the cryostat dilution unit (operations not necessary for CUORE).



CUORE-0 status

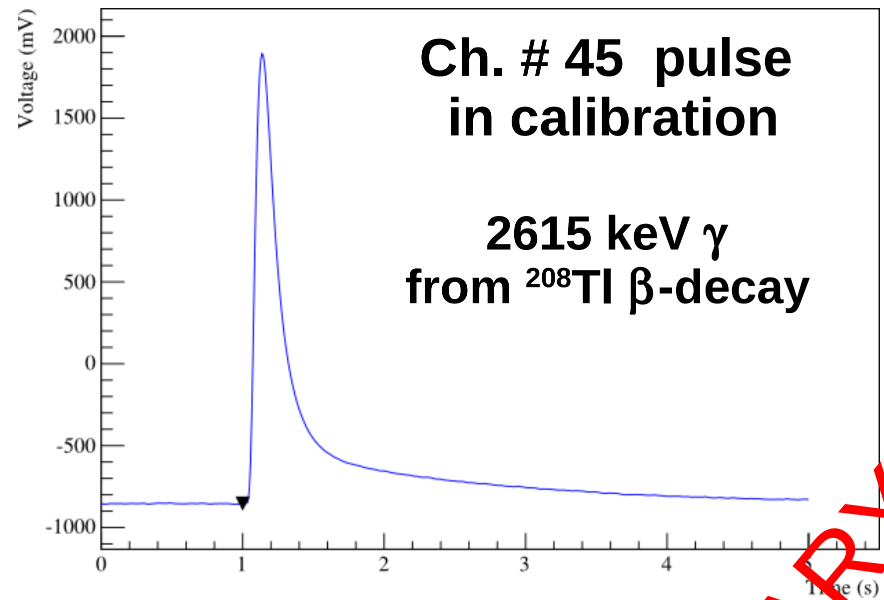
- CUORE-0 was **cooled down** to a base T **~ 8 mK** to start the pre-operation and optimization phase **in August 2012**
- Pre-operation was disturbed by **2 vacuum leaks** (the cryostat is ~25 years old) which deteriorated detector performances
- We were able to perform **calibrations** despite the leaks, showing reasonable detector performance
- The **second leak has been fixed** at the beginning of February
- **Pre-operation** and optimization phase is restarting

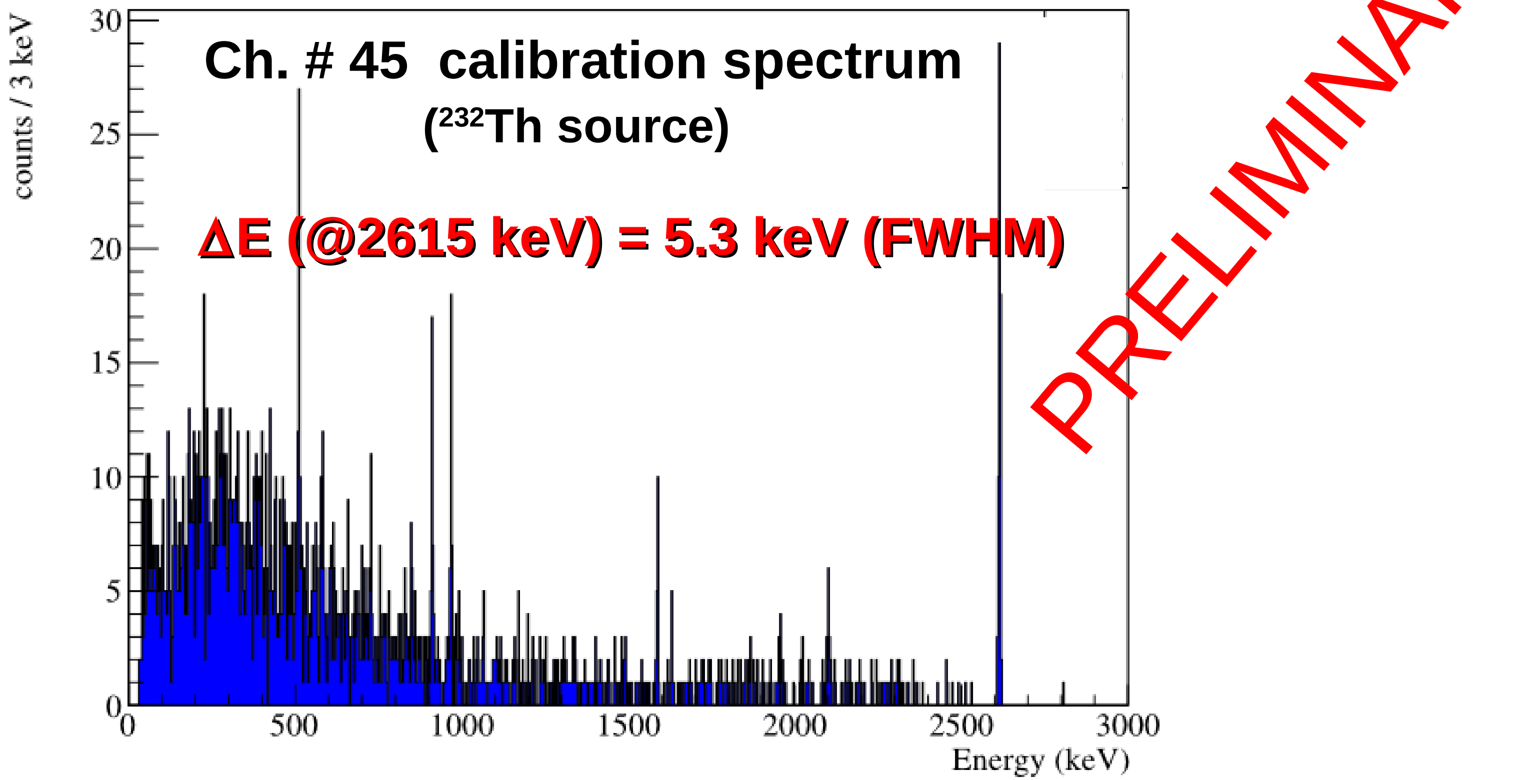
Detector performance

- **Successfully tested** and defined the CUORE **assembly procedures**

- Demonstrated that **a complete CUORE tower** can be assembled in **less than 4 weeks**

- **51 detectors alive** (out of 52)





CUORE-0 and CUORE sensitivity

Assumptions

	CUORE-0	CUORE
M [kg]	11 of ^{130}Te	206 of ^{130}Te
ΔE [keV] *	~5	~5
b [c/keV/kg/y] **	0.05	0.01
Live-T [y]	2	5

$$S^{0\nu} \propto \frac{\epsilon\, a.i.}{A}\left(\frac{MT}{b\,\Delta E}\right)^{1/2}$$

ε = 87.4% (Monte Carlo calculation)
i.a. (^{130}Te) = 34.2 % (ICP-MS)

* Data from Cuoricino [8] and CUORE-0
** Data from measurements + bkg model in the hypothesis that surface contaminations are negligible with respect to cryostat ones

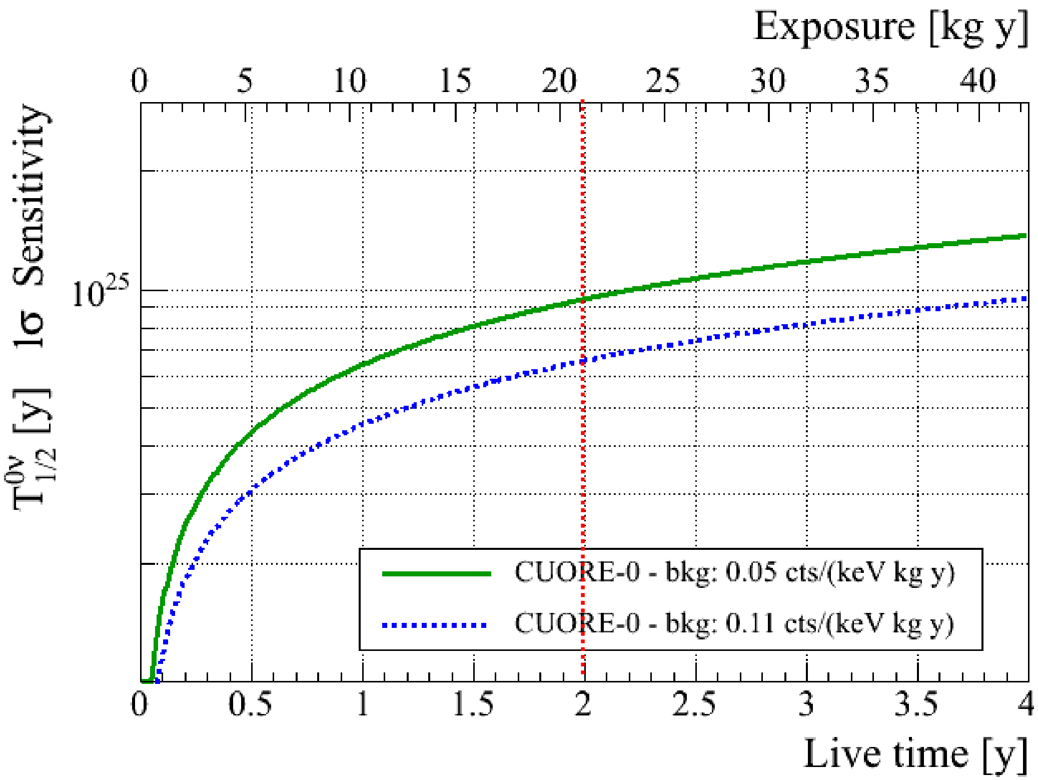
Sensitivity

		CUORE-0	CUORE
$T_{1/2}$	1σ CL	9.4×10^{24} y	1.6×10^{26} y
	90% CL	**5.9×10^{24} y**	**9.5×10^{25} y**
$\langle m_{ee}\rangle$ ***	1σ CL	162 – 422 meV	39 – 102 meV
	90% CL	**204 – 533 meV**	**51 – 133 meV**

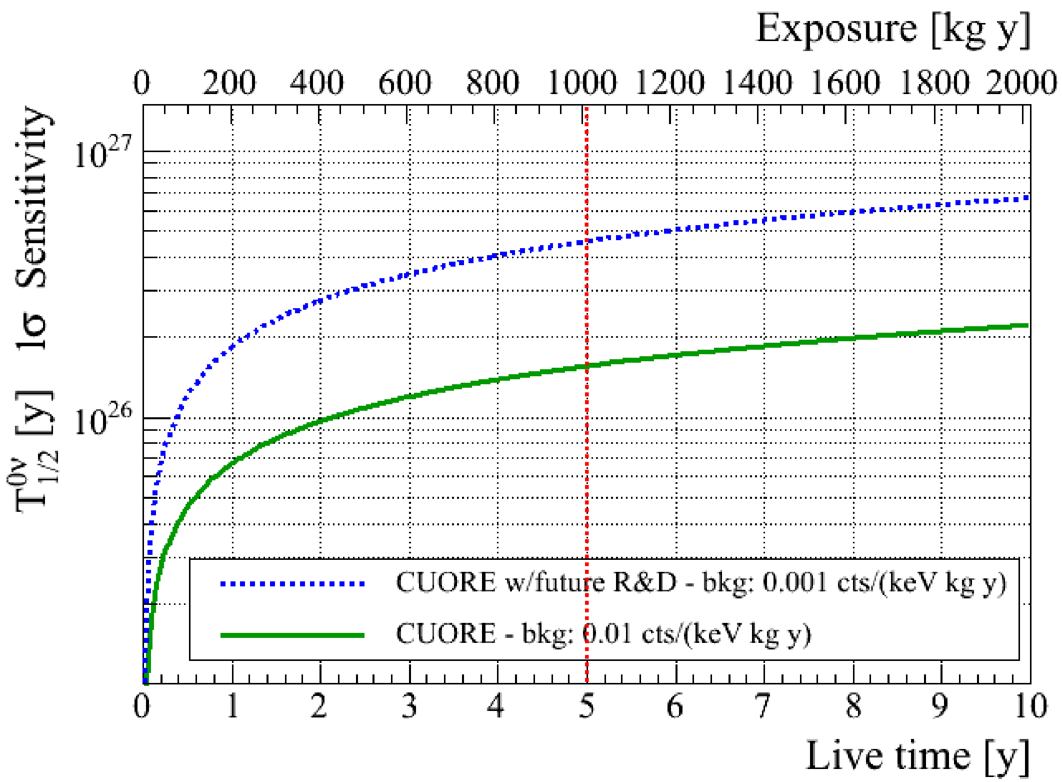
*** Computation performed with PSF and NME from [6]

$T_{1/2}$ sensitivity versus Time

CUORE-0



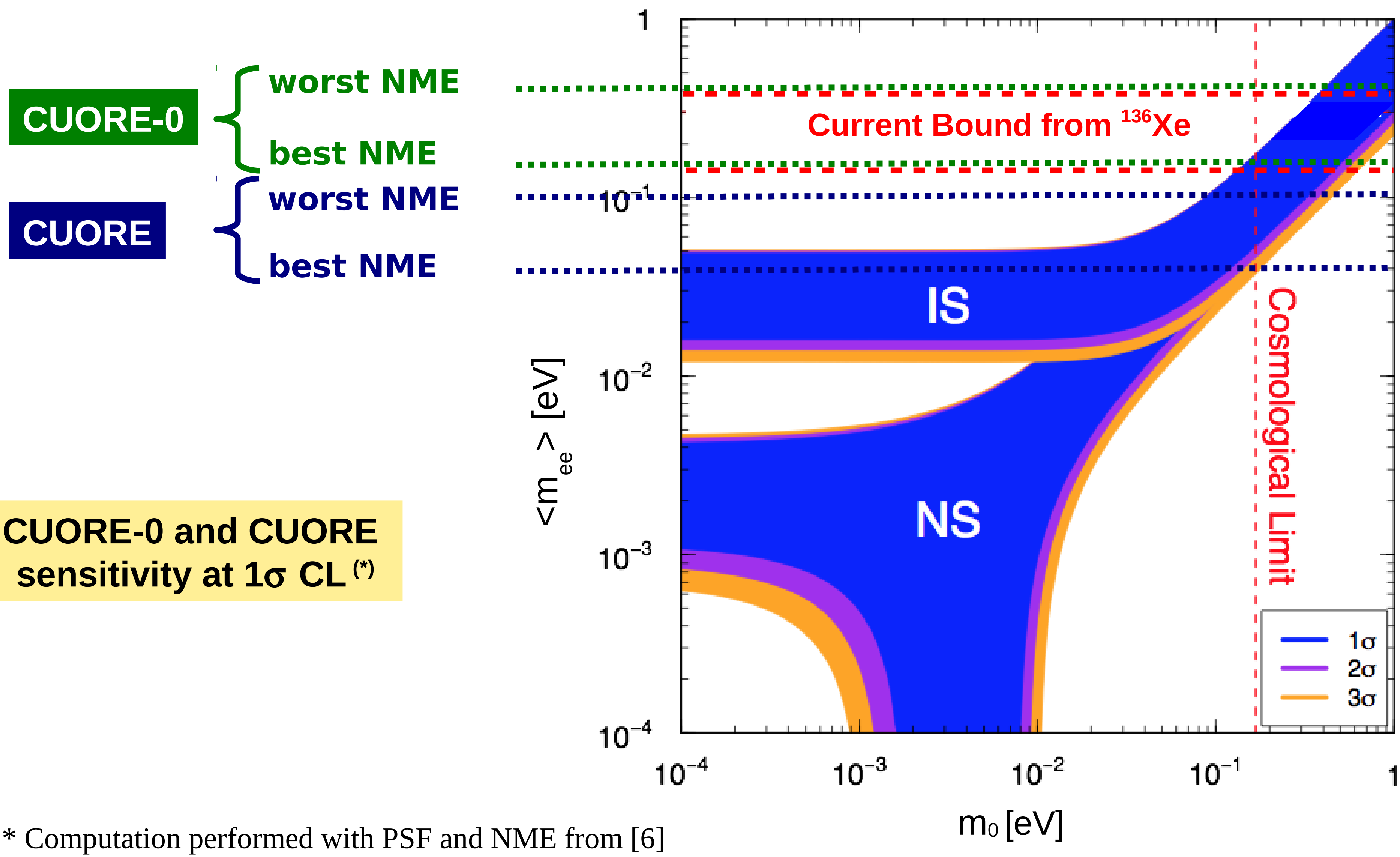
CUORE



- Bkg scaled from CUORICINO taking into account the improvement in the cleaning of surfaces
- Bkg in the hypothesis that surface contaminations are negligible with respect to cryostat contamination
- Bkg evaluated from measured values/limits for CUORE materials and geometry (bkg budget)
- Optimistic background

* Computation performed with PSF and NME from [6]

$<m_{ee}>$ sensitivity



CUORE-0 and CUORE sensitivity at 1σ CL (*)

* Computation performed with PSF and NME from [6]

Conclusions

- **TeO_2 bolometers** represent since many years a competitive detector for 0νββ research
- A strong R&D has been developed in order to reduce the background in the ROI

  (the **main challenge being surface contaminations** of detector and facing parts)
- The **CUORE goal of 0.01 c/keV/kg/y** is just **behind the corner**
- **CUORE** is **under construction**
- CUORE **cool down** is foreseen **by end 2014**
- **CUORE-0**, the first CUORE tower, was **successfully assembled** using CUORE assembly tools and procedures
- **Calibration** measurements performed in pre-optimization/optimization phase show **good detector performances**
- After some delay due to cryogenic problems, **CUORE-0 is restarting** operating in these days

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The CUORE Collaboration

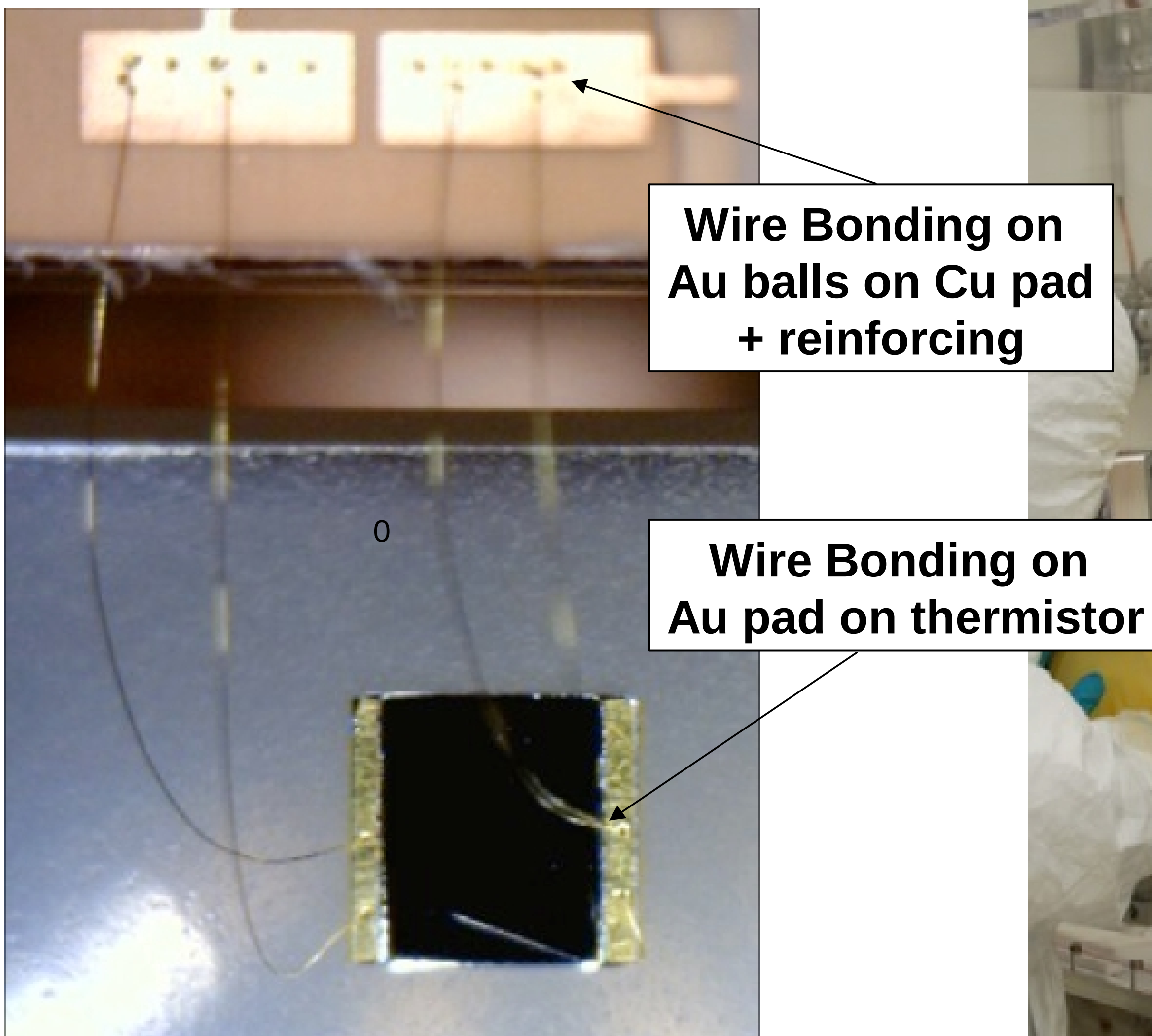
- INFN LNGS Laboratories
- INFN & University Milano Bicocca
- INFN Roma & Sapienza University
- INFN Roma Tor Vergata
- INFN & University Genova
- INFN & University Firenze
- INFN LNL Laboratories
- INFN LNF Laboratories
- INFN Padova
- INFN and University Bologna

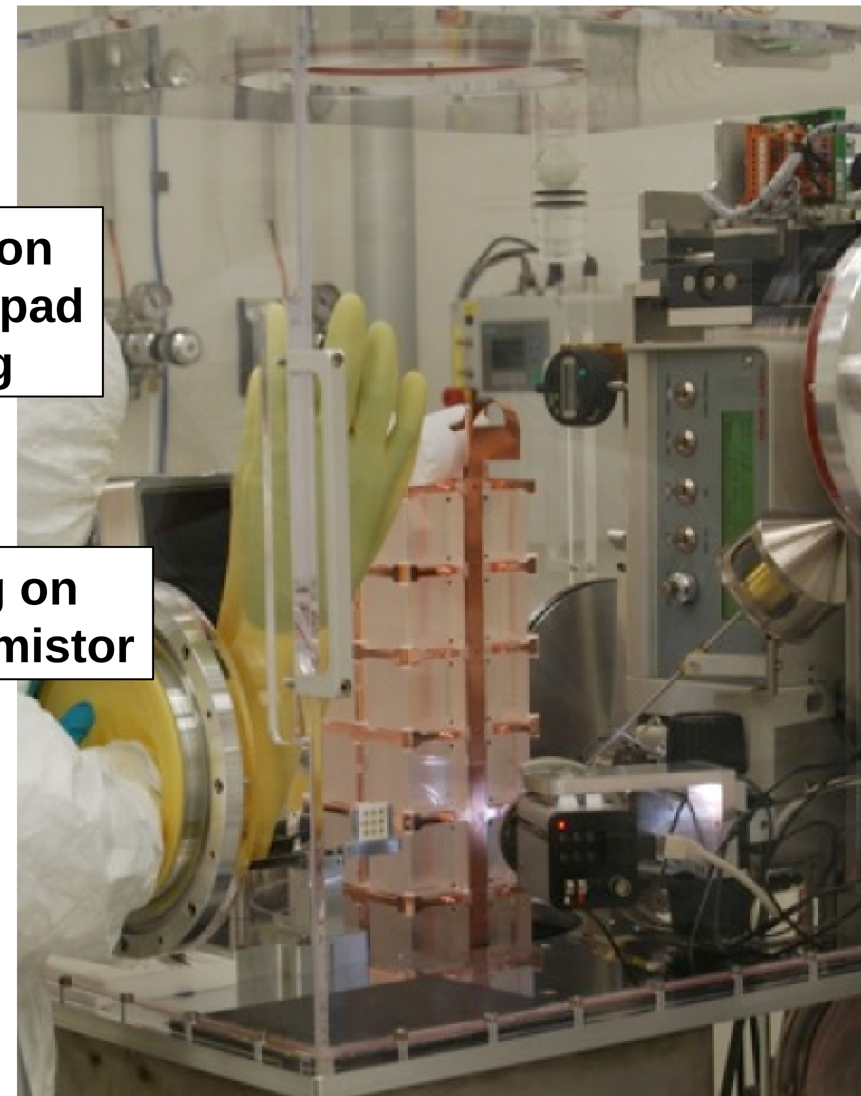
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- University of California Berkeley
- University of Califoria Los Angeles
- University of South Carolina
- California Politechnic state University
- University of Wisconsin Madison
- CNRS – CSNSM Orsay
- Shanghai Institute of Applied Physics
- University of Zaragoza

Back-up slides

CUORE-0: Signal wires connection

The signal readout is provided by **gold wires directly bonded** on the assembled tower in a N_2 fluxed glove box. The bonding proceeds in **3 main steps**: 1. ball bonding on a Au pad on the thermistor; 2. bonding of the wire on Au balls on a Cu pad; 3. reinforcing.



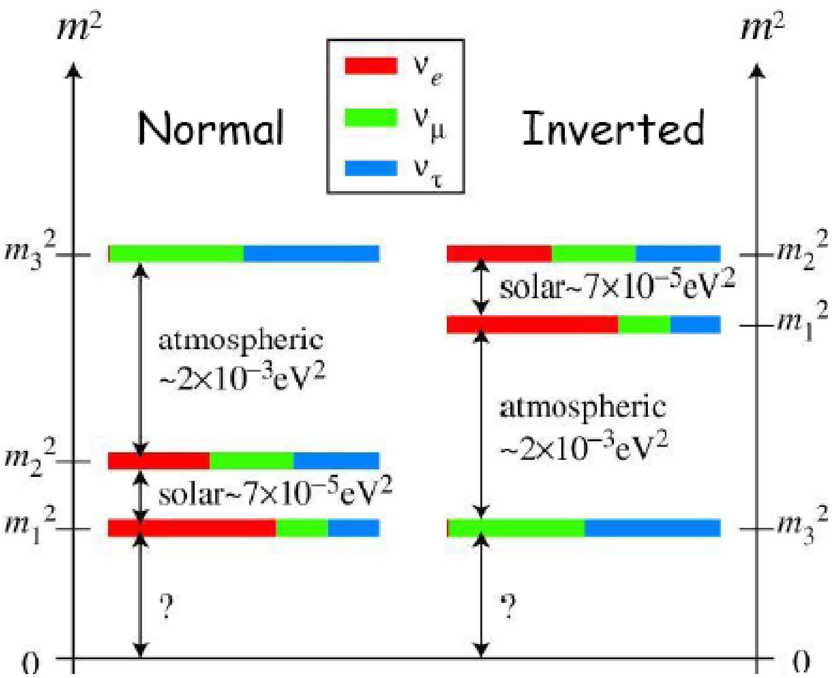


Why 0νββ is important ?

$$\langle m_e e \rangle = \left| \sum |U_{ei}|^2 \, m_i \, e^{i\alpha_i} \right| = f(\theta_{12}, \theta_{23}, \theta_{13}, \Delta m_{12}, \pm \Delta m_{23}, m_0)$$

- U_{ei}: neutrino mixing matrix
- m_i: neutrino mass eigenstates
- $e^{i\alpha_i}$: Majorana phases related to CP
- $\theta_{12}, \theta_{23}, \theta_{13}$: mixing angles
- $\pm \Delta m_{23}$: mass hierarchy
- m_0: absolute mass scale

in the 3-neutrino picture



The observation of 0νββ:

Is currently the only feasible method to establish:

- Majorana nature of the neutrino
  - Lepton number violation

Can give important information about:

- Absolute neutrino mass scale
  - Neutrino mass hierarchy
    - CP Majorana phases

Cuoricino final $0\nu\beta\beta$ result

Statistics: M T = 19.75 kg (^{130}Te)

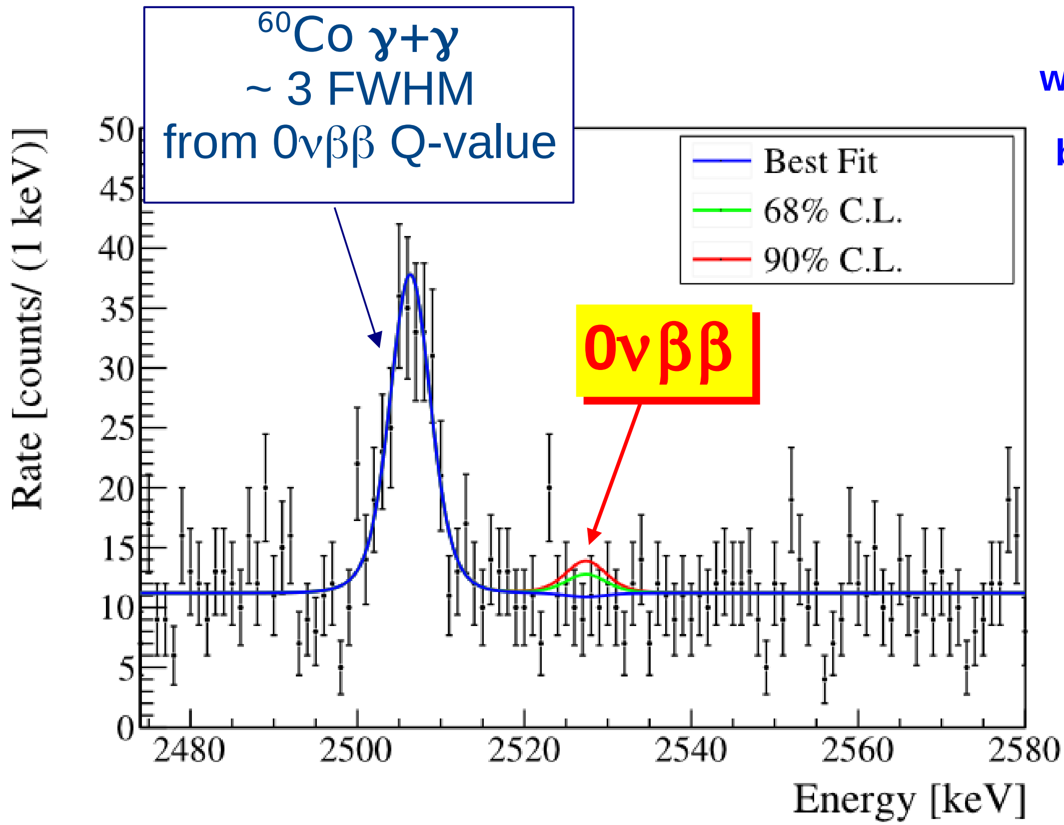
Energy resolution: **ΔE** = 6.3 ± 2.5 keV FWHM

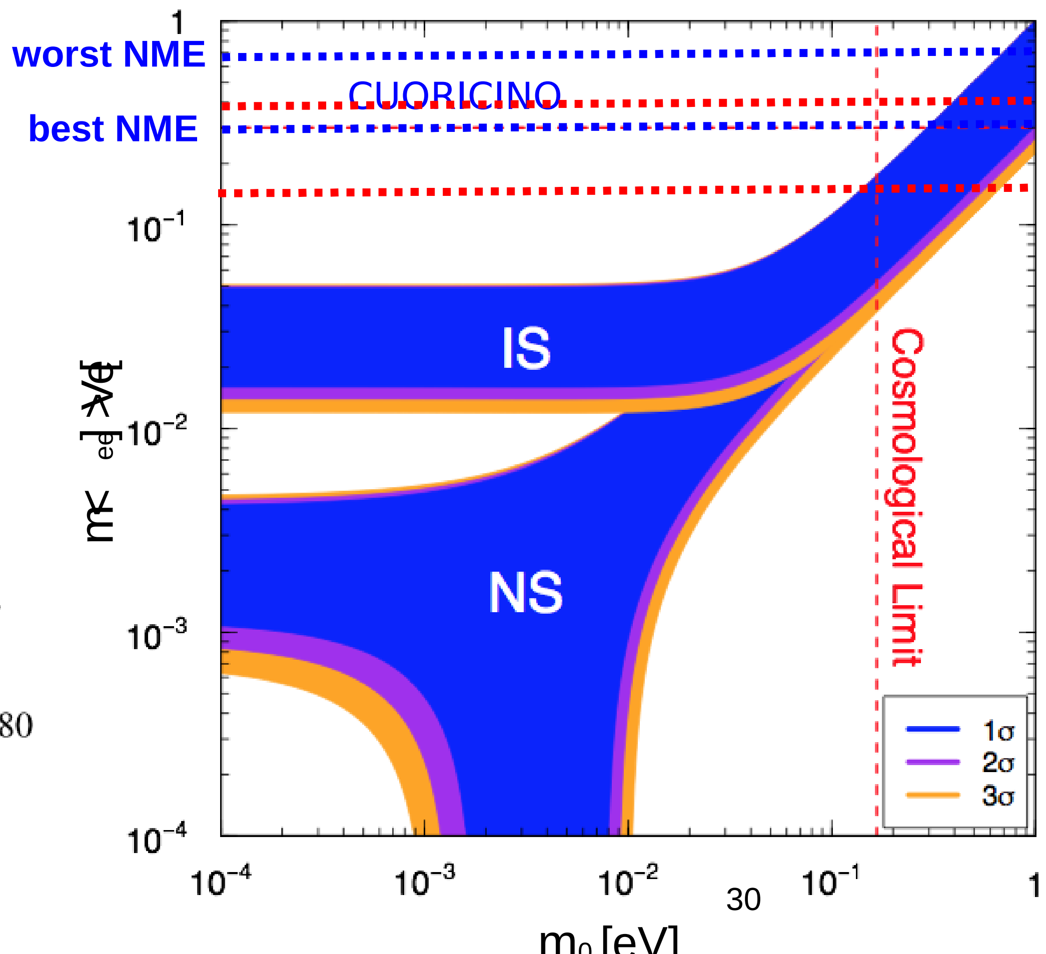
Backround Index (BI): b = 0.169 ± 0.006 c/keV/kg/y

$T_{1/2}^{0\nu} > 2.8 \times 10^{24}$ y [5]

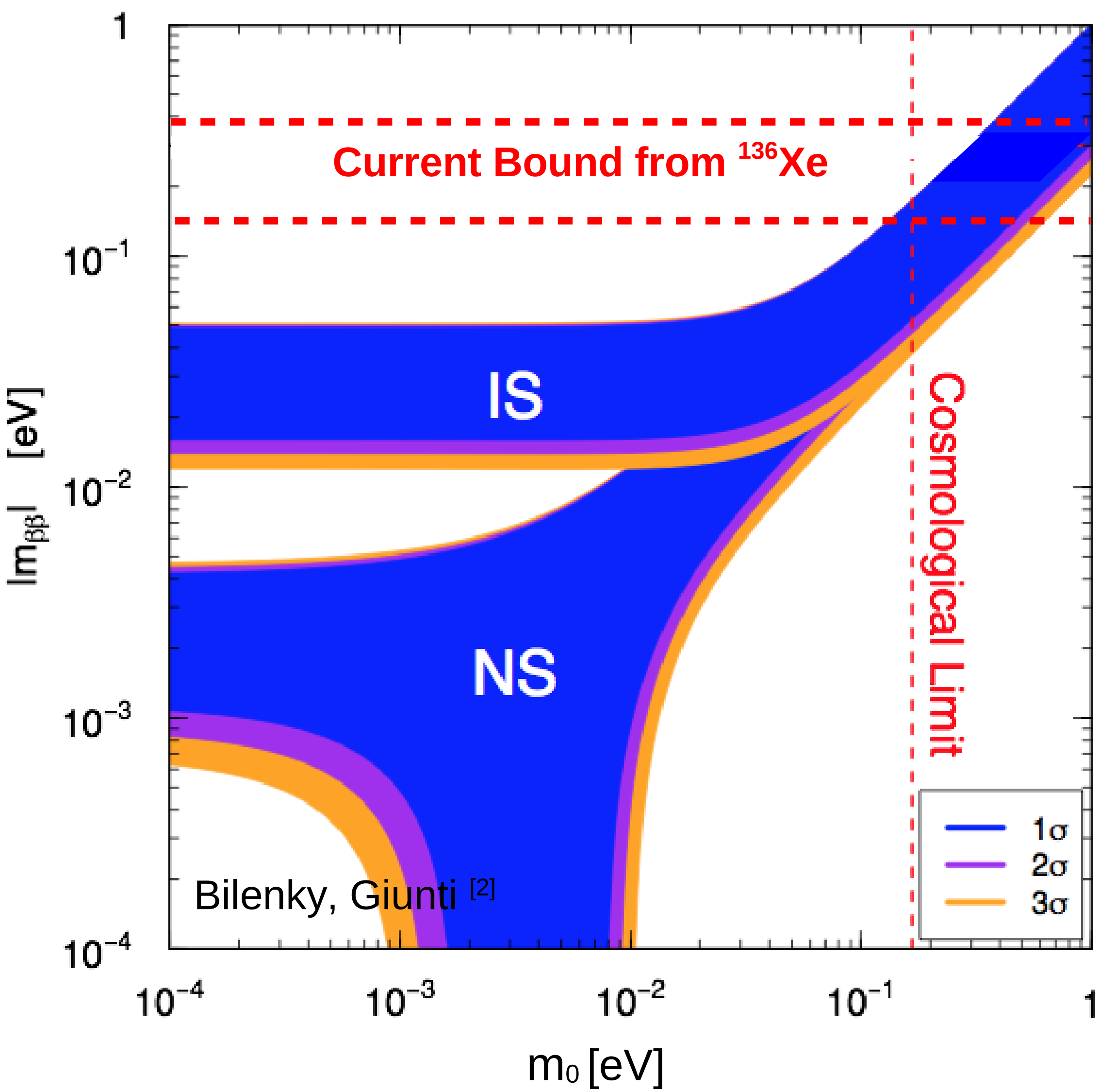
$\langle m_{ee} \rangle < (0.3 - 0.7)$ eV [5]

NME from [6]





0νββ status of the art



Most recent Results

Calculations are performed with QRPA and Shell Model

The range is due to NME uncertainties.

EXO-200: $<m_{ee}>$ < 0.15-0.36 eV [3]

Kamland-Zen: $<m_{ee}>$ < 0.25-0.60 eV [4]

Experimental Strategies

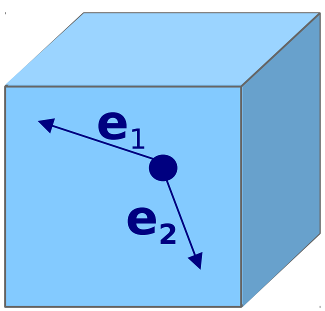
Additional signatures can be looked for:

Single electron energy spectrum
Angular correlation between the two electrons
Track and event topology
Time Of Flight
Daughter nuclear specie

Two main approaches: calorimetric (source = detector) or external-source detector

Calorimeters

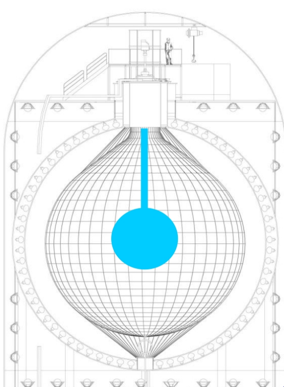
Solid



- High M possibles
- High efficiency
- High resolution
- Event topology/track (pixellated detectors)

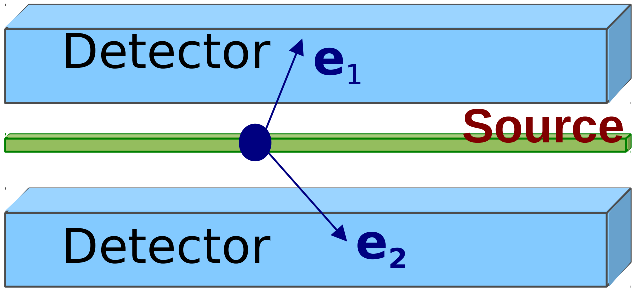
Liquid

- High M possibles
- High efficiency
- Re-use of existing exp.
- Event topology,particle ID (Xe TPC)



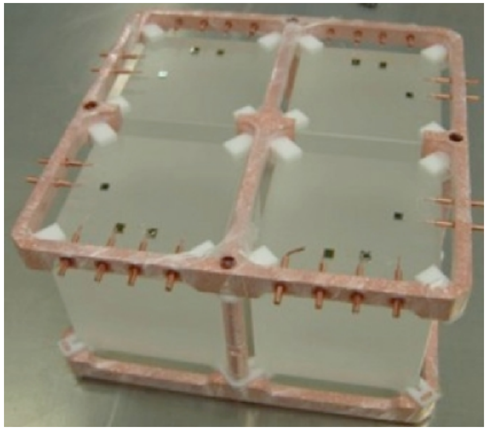
External-source detectors

- Event topology, particle ID
- More ββ candidates in same det.

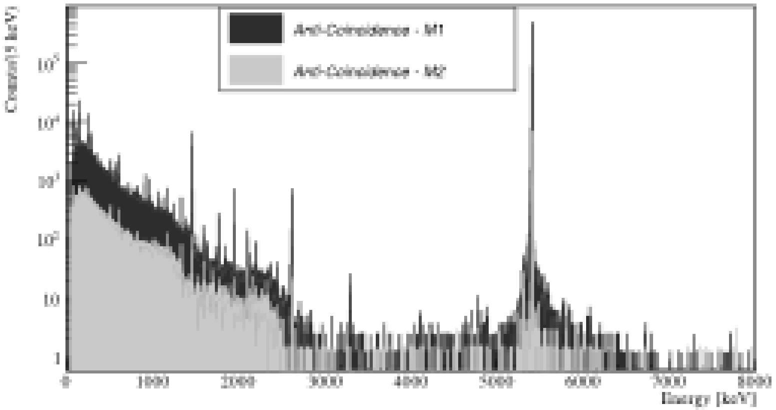


Background from TeO_2: CCVR test

CUORE Crystal Validation Run: a dedicated cryogenic setup in C Hall at LNGS to test crystal radioactivity and performances (4 crystal samples from each CUORE batch since 2008)



CCVR 1-5 sum spectra [9]



Background in the (2.7 ÷ 3.9) MeV region **reduced by a factor of ~2** with respect to CUORICINO

Bulk/surface activities within contract specifications

Bulk activity 90% C.L. upper limits:

8.4·10^{-7} Bq/kg (^{232}Th), 6.7·10^{-7} Bq/kg (^{238}U), 3.3·10^{-6} Bq/kg (^{210}Po)

Surface activity 90% C.L. upper limits:

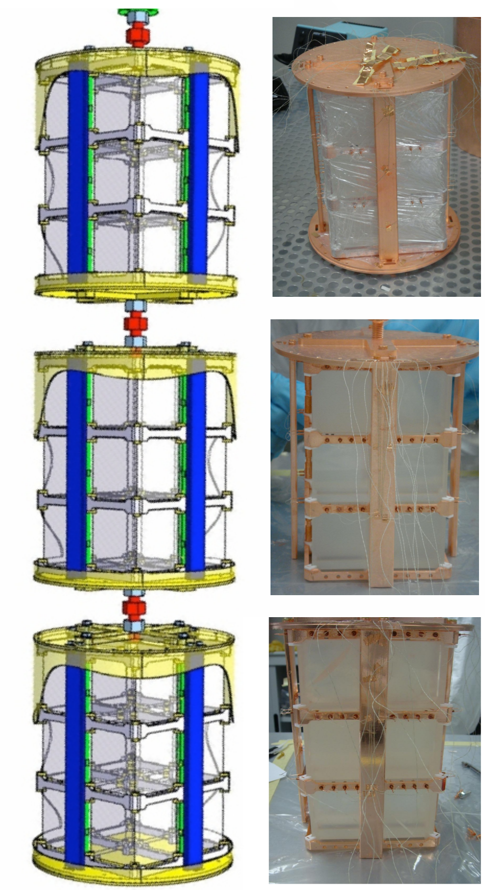
2·10^{-9} Bq/cm^2 (^{232}Th), 1·10^{-8} Bq/cm^2 (^{238}U), 1·10^{-6} Bq/cm^2 (^{210}Po)

More infos: https://wiki.hep.wisc.edu/cuore/CUOREOfficialNumbers?action=AttachFile&do=view&target=CCVR.ppt

Background from Cu: TTT test

Bolometric test to compare the effect in the ROI of **3 different copper surface treatments**

Crystals from Cuoricino array **fully reprocessed** according to the new CUORE standards

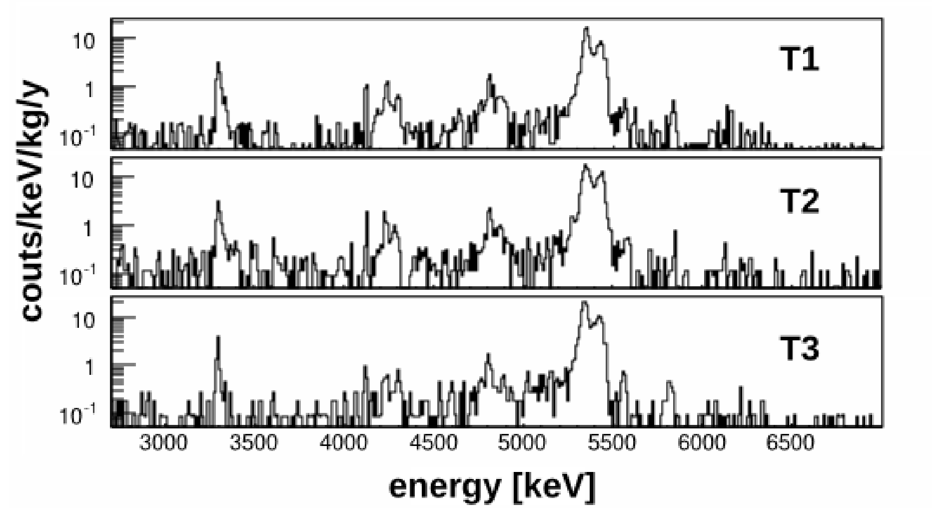


T1: Polyethylene
- Soap
- H_2O_2+ H_2O + citric acid
- 70 mm of polyethylene

T2: Chemical treatment
- Soap
- Electro-erosion
- Chemical etching
- H_2O_2+ H_2O + citric acid

T3: Plasma cleaning
- Tumbling
- Electro-polishing
- Chemical etching
- Magnetron Plasma etching

Total spectra (no anticoincidence applied)



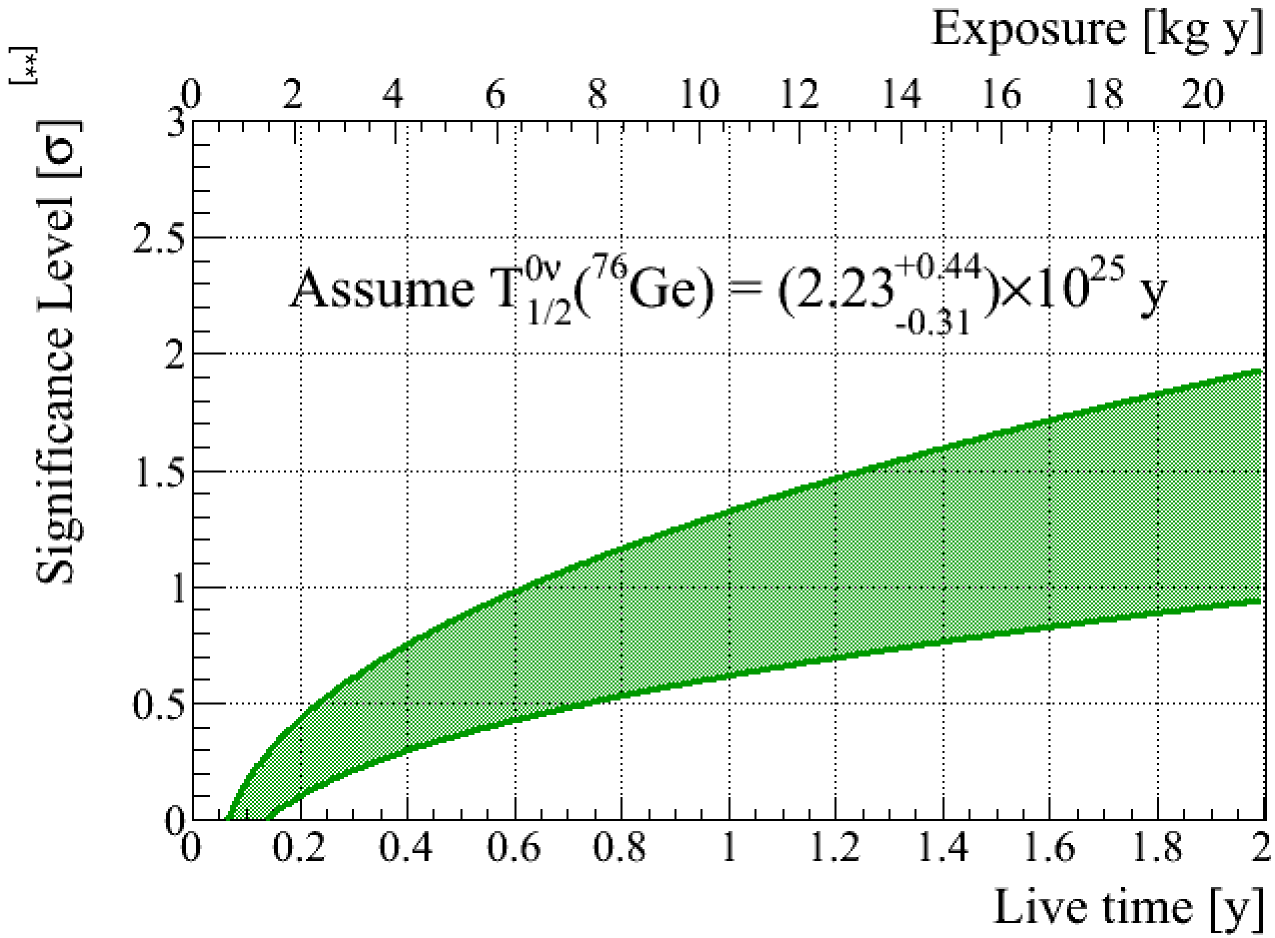
Best result obtained for T1 and T3

Bkg in the (2.7÷3.9) MeV region after anti-coincidence cut:

=> 0.052 ± 0.008 c/keV/kg/y

^{232}Th / ^{238}U on Cu: < $7 \cdot 10^{-8}$ Bq/cm^2

CUORE-0 Sensitivity to ^{76}Ge claim



Significance level at which CUORE-0 can observe a **ββ0ν signal consistent with the claim in ^{76}Ge** [*], with b=0.05 c/keV/kg/y

Spread due to the NMEs + the 1 σ error on the reported ^{76}Ge measurement

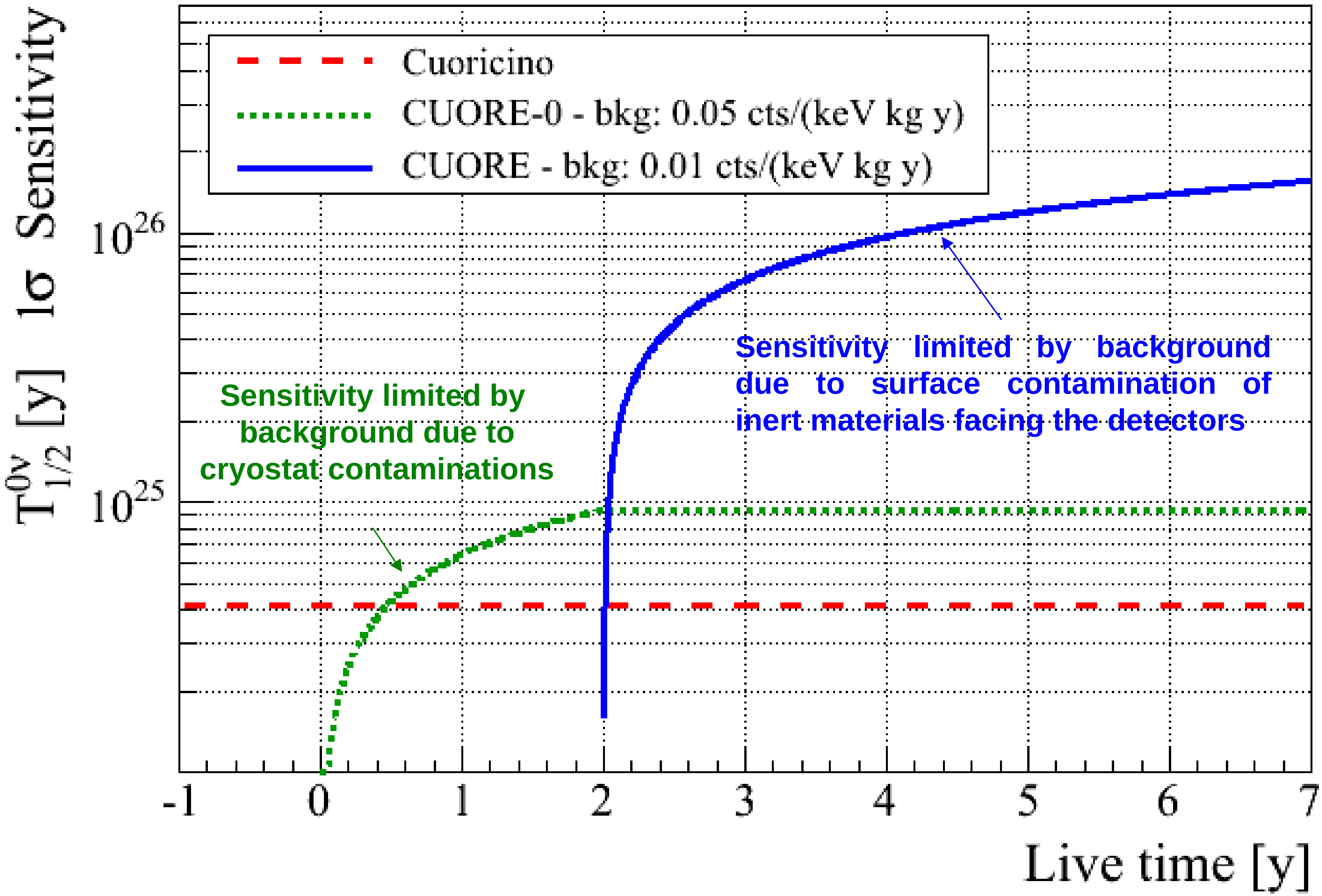
[*] *H.V. Klapdor-Kleingrothaus et al., Mod. Phys. Lett. A 21 (2006) 1547*
[**] *Computation performed with PSF and NME from [6]*

CUORE background budget

Source Element	Contamination level Bulk [Bq/kg]; Surf [Bq/cm^2]	Source Data	c/keV/kg/y
Environmental **γ**	0.73 γ/s/cm^2	LNGS Meas. [14] [15]	$< 3.9 \cdot 10^{-5}$ [15]
Environmental n	46 n/s/cm^2	LNGS Meas. [12] [13]	$(8.56 + 6.06) \cdot 10^{-6}$ [15]
Environmental **μ**	$3 \cdot 10^{-6}$ μ/s/cm^2	MACRO Meas. [11]	$(1.04+0.22) \cdot 10^{-4}$ [15]
Far bulk: Cu OFE	$< 6.4 \cdot 10^{-5}$ (Th), $< 5.4 \cdot 10^{-5}$ (U)	HPGe	$< 2 \cdot 10^{-3}$
Far bulk: Steel parts	$< 1 \cdot 10^{-2}$ (Th), $< 5 \cdot 10^{-3}$ (U)	HPGe	$< 3 \cdot 10^{-4}$
Internal Roman Lead	$< 4.3 \cdot 10^{-5}$ (Th), $< 4.6 \cdot 10^{-5}$ (U)	HPGe	$< 4 \cdot 10^{-3}$
Top disk COMETA Lead	$< 1.2 \cdot 10^{-4}$ (Th), $< 1.4 \cdot 10^{-4}$ (U)	HPGe	$< 5 \cdot 10^{-5}$

PRELIMINARY – GEOMETRY DETAILS NOT AT FINAL STAGE

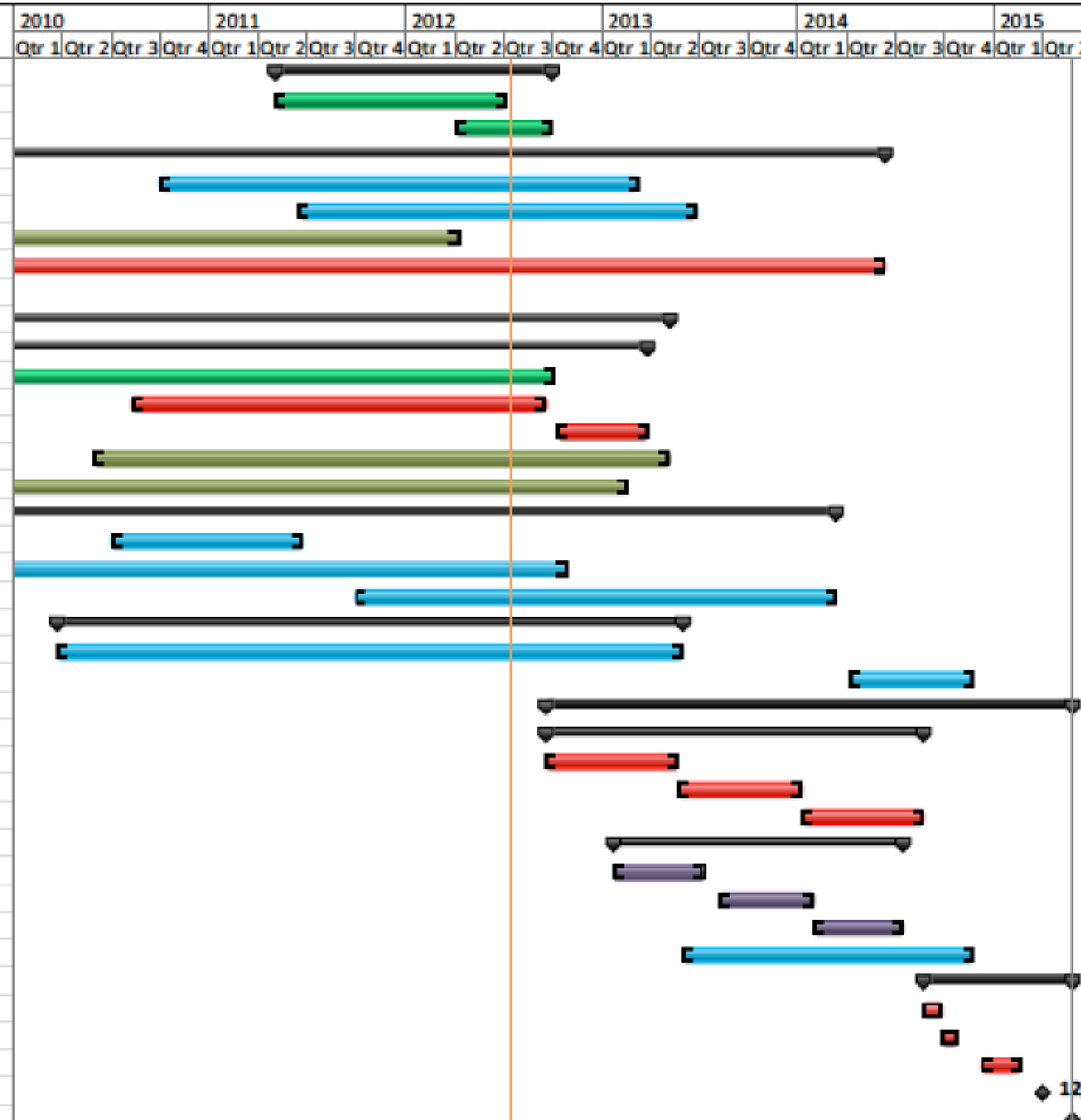
$T_{1/2}$ sensitivity versus Time (*)



* Computation performed with PSF and NME from [6]

CUORE schedule

ID	Task Name	Start	Finish	Est. Float
1	1.0 Hut	2/1/11	6/29/12	
2	Clean Room Radon Seal & Abatement	2/1/11	4/5/12	
3	Faraday Cage	1/2/12	6/29/12	20 mo
4	2.0 Detector	8/1/07	3/12/14	
5	Crystal Procurement	6/30/10	12/7/12	6 mo
6	Thermistors	3/16/11	3/25/13	2 mo
7	Structure - Design, Prod.	8/1/07	1/9/12	
8	Surface Cleaning	4/24/08	3/12/14	2 mo
9	3.0 Cryogenics	8/1/07	12/10/13	
10	3.1 Cryo Design & Construction	8/1/07	2/4/13	
11	Cryogenic Procurements	8/1/07	12/24/12	
12	Cooling Units and Test Dewar	8/1/07	7/2/12	2 mo
13	300K - 4K Chamber Fab	5/10/10	6/18/12	
14	600mK - MC Fab	7/10/12	12/24/12	
15	Detector Suspension	3/1/10	2/4/13	
16	Internal Lead Shielding	12/1/08	11/16/12	
17	3.2 Calibration System	4/23/09	12/10/13	
18	Finalize Calibration Design	4/1/10	3/23/11	
19	Calibration Prototypes	4/23/09	7/27/12	
20	Calibration Construction	7/1/11	12/10/13	
21	4.0 Electronics	12/22/09	2/28/13	
22	Elec. Production & Testing	12/22/09	2/28/13	7 mo
23	6.0 Data Analysis Tools	1/6/14	8/22/14	7 mo
24	7.0 Assembly Integration & Test	6/19/12	2/25/15	
25	Cryostat Integration Into Hut	6/19/12	5/22/14	
26	Initial Installation & 4K Test	6/19/12	2/18/13	
27	Base Tempurature Test - Partial Load	2/19/13	10/8/13	
28	Base Tempurature Test - Full Load	10/9/13	5/22/14	
29	7.3 Tower Assembly & Integration	10/23/12	4/14/14	2 mo
30	Assemble Towers 1 to 5	10/23/12	4/9/13	
31	Assemble Towers 6 to 11	5/9/13	10/29/13	
32	Assemble Towers 12 to 19	10/30/13	4/14/14	
33	7.4 Electronics Install & Commissioning	3/1/13	8/22/14	
34	7.5 Detector Insertion & Sys. Testing	5/23/14	2/25/15	
35	Open and prepare for installation	5/23/14	6/26/14	
36	Detector Insertion	6/27/14	7/24/14	1 mo
37	Initial Cooldown and System Check	9/9/14	11/20/14	1 mo
38	System Test Complete	12/30/14	12/30/14	2 mo
39	CD 4 - US Deliverables Complete	2/25/15	2/25/15	



No float left!

What beyond CUORE?

$$S^{0\nu} \propto \frac{\epsilon\, a.i.}{A} \left(\frac{MT}{b\,\Delta E} \right)^{1/2}$$

Extensions beyond CUORE are possible in order to increase sensitivity to cover the inverted hierarchy region of the neutrino mass spectrum

- Relatively inexpensive isotopic enrichment of ^{130}Te
- No change needed to the experimental infrastructure
- > 500 kg of ^{130}Te
- A factor 3 increase in i.a. => $S^{0\nu}_{enr} \sim 3\, S^{0\nu}_{nat}$

- Particle discrimination (R&D is being developed)

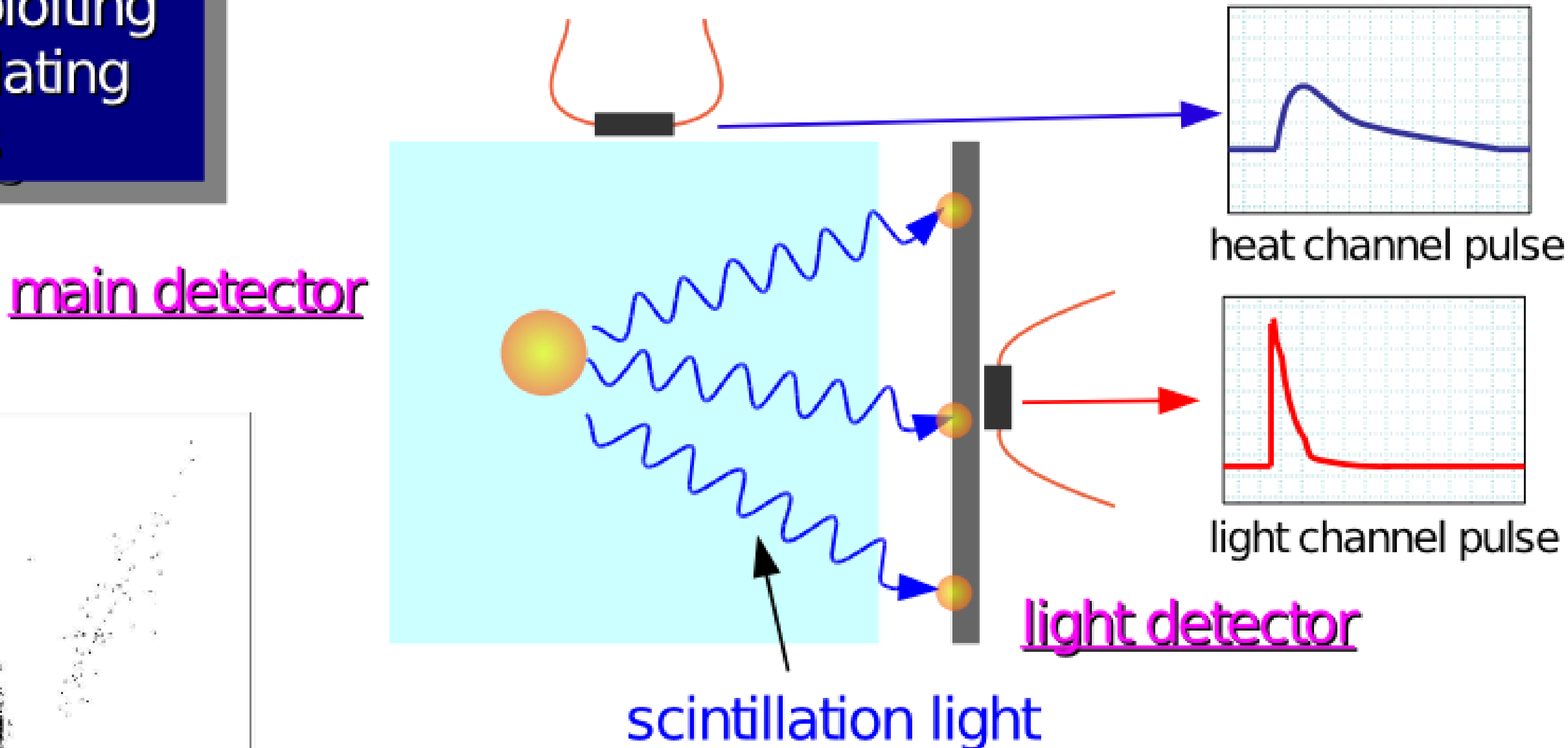
signal shape, surface sensitive detectors [16] , Cherenkov light detection [17]

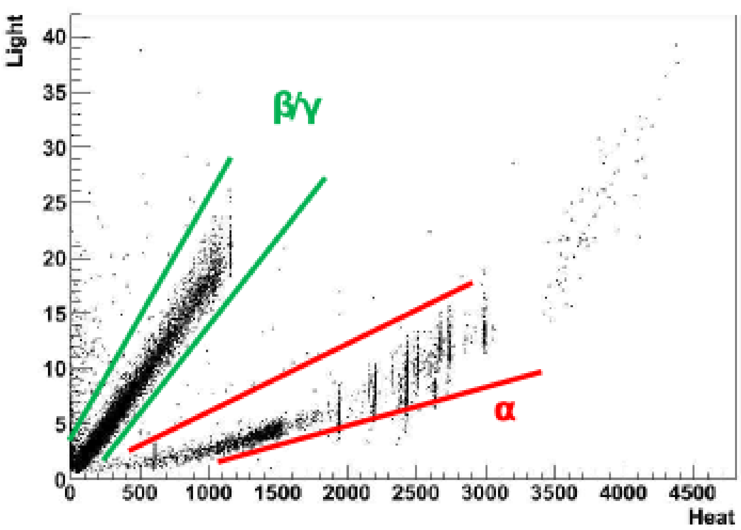
or scintillating bolometers (i.e. ZnSe, $CdWO_4$, $CdMoO_4$...)

Phonon+Light readout

Main idea: discriminate the dangerous alpha background exploiting different scintillating properties

Double read-out: simultaneous information from two thermal detectors to unravel the nature of the interacting particles





→ An old idea:
Alessandrello et al. PLB 420 (1998) 109

- use α vs. β/γ different light yield
- many **high** $Q_{\beta\beta}$ isotopes are available in scintillating crystals

TeO_2: phonon + Cerenkov light readout

$Q_{\beta\beta}$ (^{130}Te) = 2528 keV – i.a. = 34.2%

TeO_2 crystals (unfortunately!) do not scintillate...

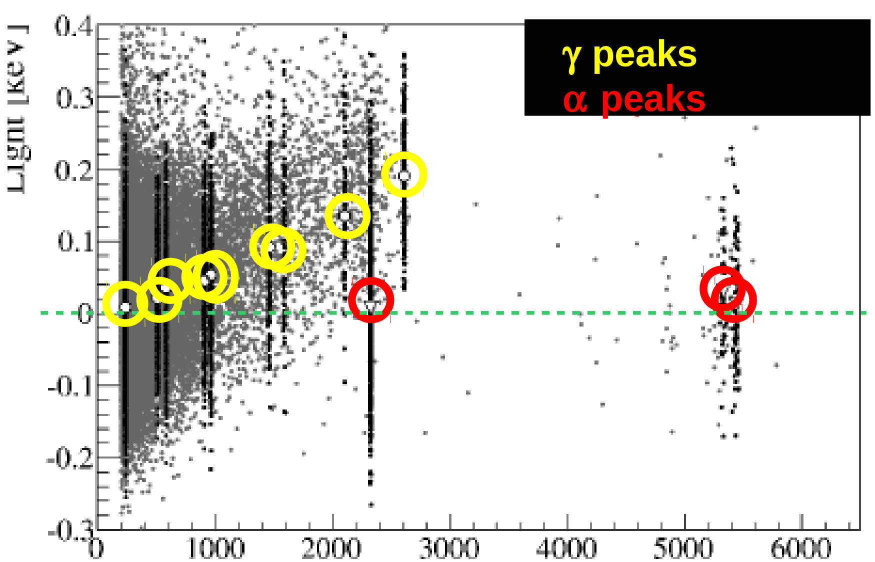
... but they have good optical properties.

Expected threshold for Cerenkov light emission:

- 50 keV for β/γ
- 400 MeV for α

T.Tabarelli de Fatis, EPJ C65 (2010) 359

Expected light emission: 140 eV/MeV ➡ **~ 350 eV for ^{130}Te 0νββ**



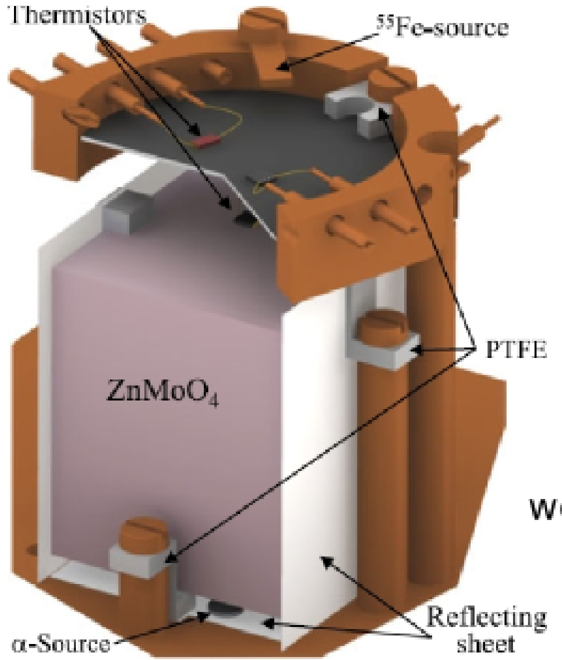
TeO2 crystal mass: 117 g

α vs β/γ discrimination power (DP):

$$DP = \frac{|(\mu_{(\beta/\gamma)} - \mu_{\alpha})|}{\sqrt{(\sigma^2_{(\beta/\gamma)} + \sigma^2_{\alpha})}} = 1.5$$

F. Bellini et al., AP 35 (2012) 558

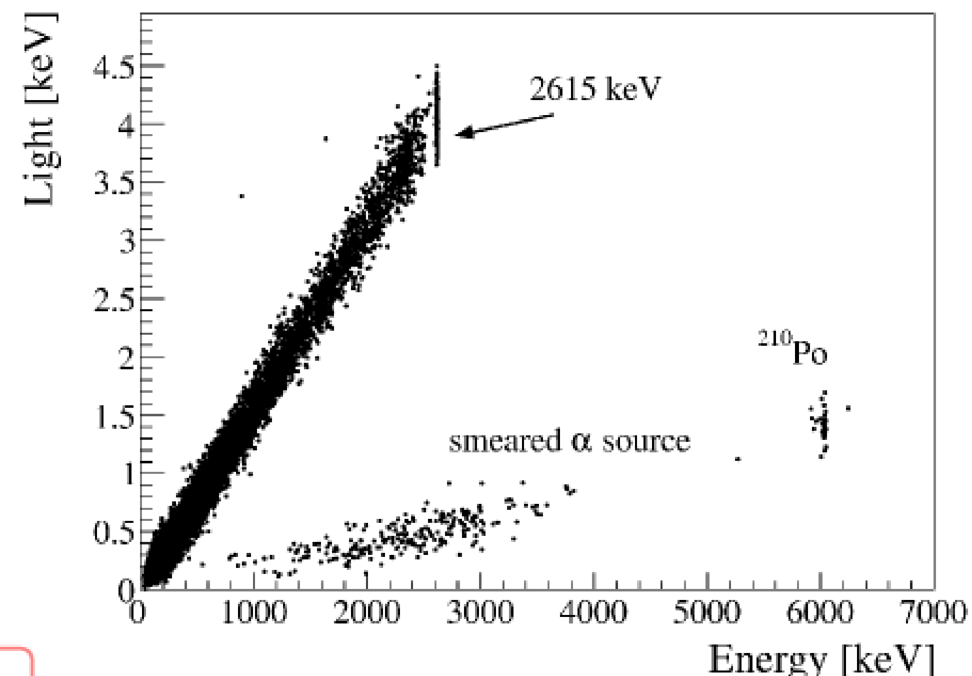
$ZnMoO_4$: Phonon+Scintillation Light readout

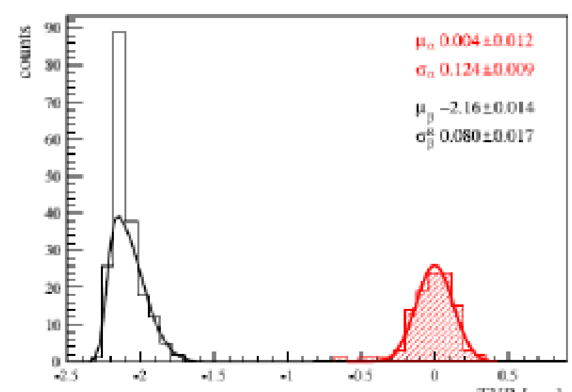


weight= 330 g

$Q_{\beta\beta}$ (^{100}Mo) = 3034 keV – i.a. = 9.6%

$ZnMoO_4$ scintillating crystal





@2615 keV:

ΔE_{FWHM} ~6 keV

α vs β/γ discrimination power (DP):

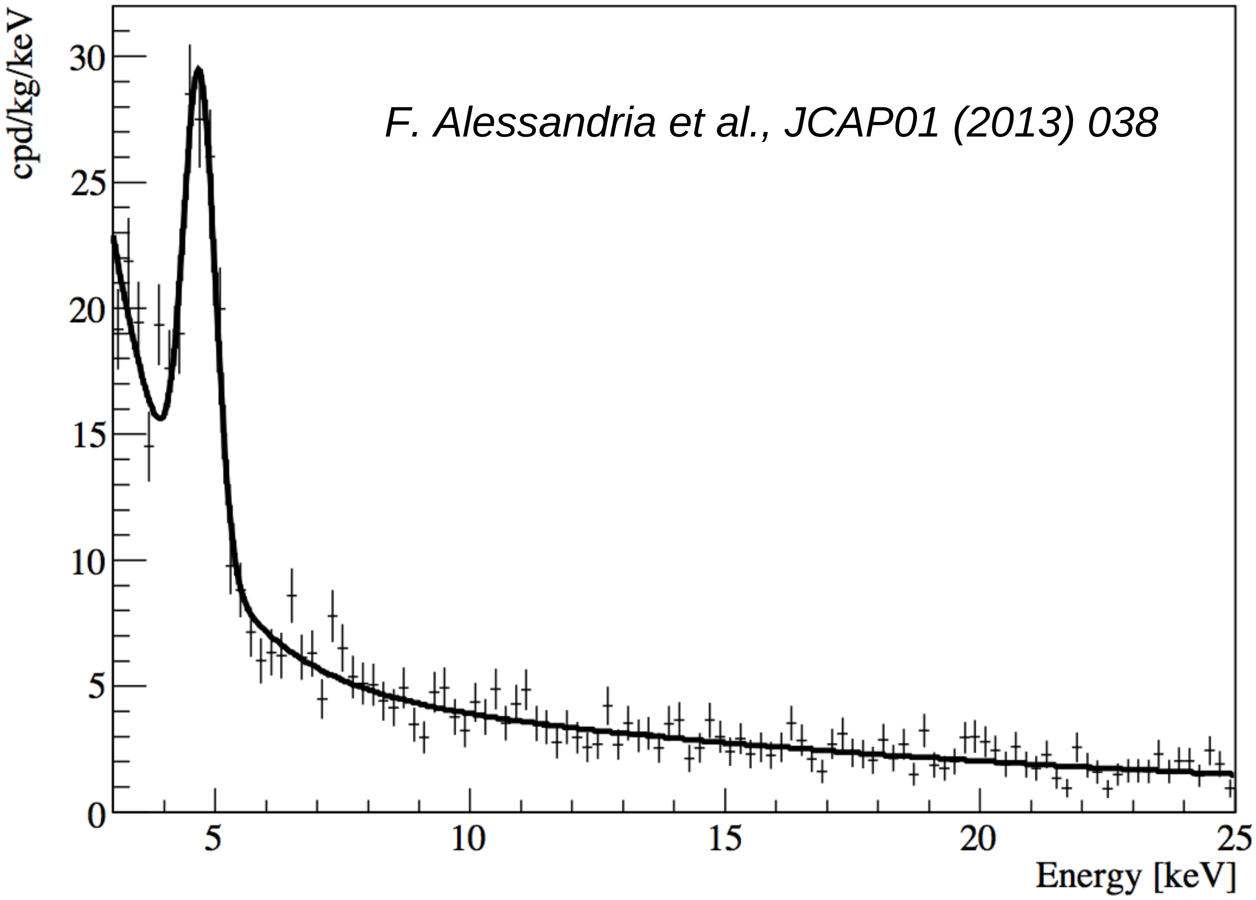
$$DP = \frac{|(\mu_{(\beta/\gamma)} - \mu_{\alpha})|}{\sqrt{(\sigma^2_{(\beta/\gamma)} + \sigma^2_{\alpha})}} = 19$$

DP = 14 on pulse shape

J.W. Beeman et al., EPJ C72 (2012) 2142

Sensitivity to DM (1)

The **background rate at low energy** (3-25 keV) of CUORE and CUORE0 was assumed equal to the one measured in a **CCVR** run in which a dedicated trigger algorithm was used to lower the threshold (=3keV) [*].



[*] *S. Di Domizio, F. Orio and M. Vignati, JINST 6 (2011) P02007*

Sensitivity to DM (2)

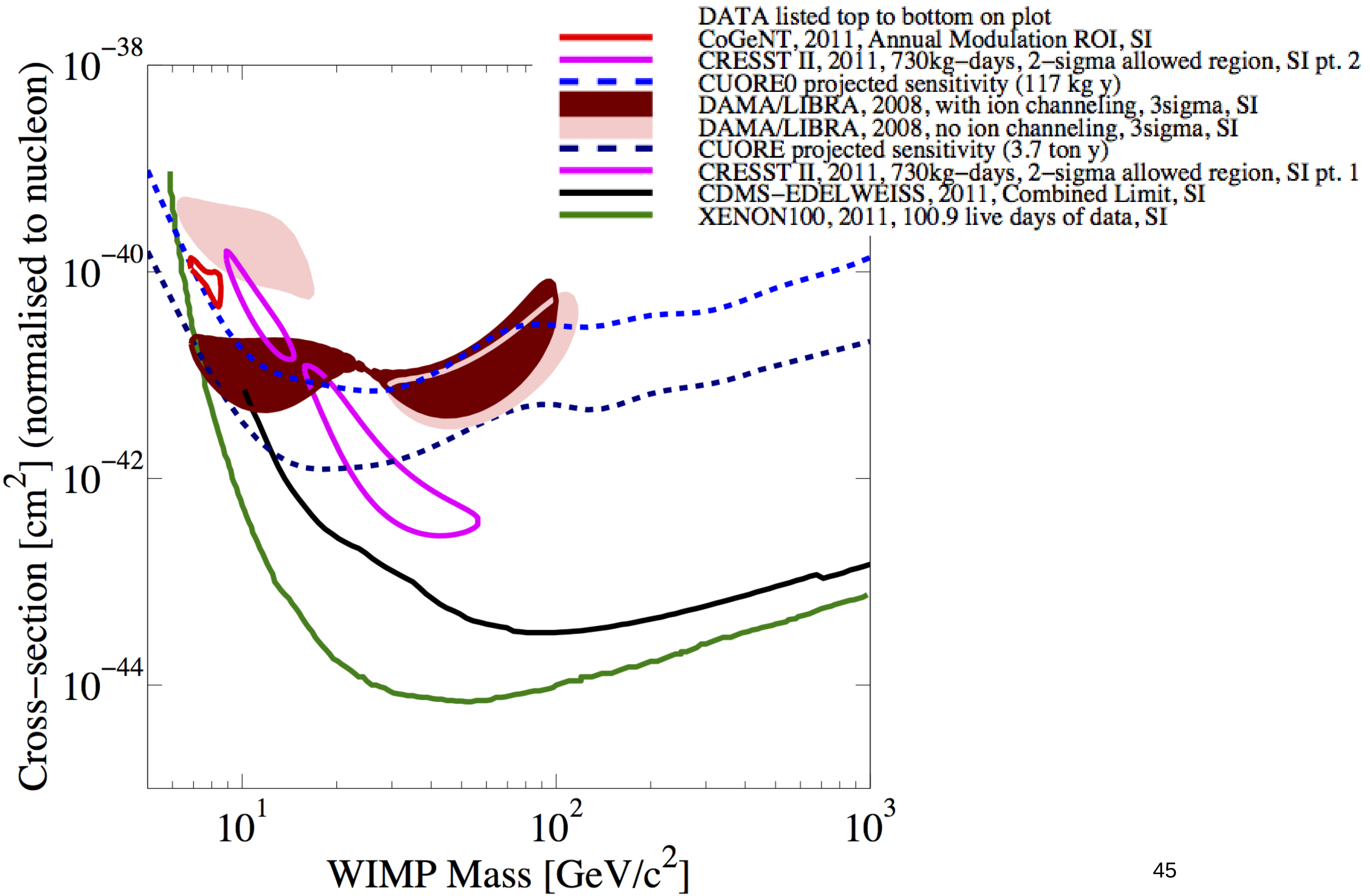
In order to evaluated CUORE-0 and CUORE sensitivity to DM **Toy Monte Carlo simulations** were performed generating background events according to the fit of the measured distribution, and WIMP events according to the theoretical distribution described in [*], using the following WIMP parameters: density $\rho_W = 0.3$ GeV/cm^3 , average velocity $v_0 = 220$ km/s and escape velocity from the Galaxy $v^{esc} = 600$ km/s [**]. A quenching factor for nuclear recoils in TeO_2 equal to 1 was used [***].

The **dependence of the WIMP interaction rate on the time in the year** was included.

As it can be seen from the plot in slide 3, CUORE could investigate the **same parameter space of the DAMA/LIBRA** experiment, and could be the only experiment other than DAMA/LIBRA looking for an **annual modulation** of dark matter interactions.

[*] *J. D. Lewin and P. F. Smithl, Astrop. Phys. 6 (1996), no. 1 87*
[**] *F. Alessandria et al., JCAP01 (2013) 038*
[***] *A. Alessandrello et. al., NIM.A 409 (May, 1998) 451*

Sensitivity to DM (3)



TeO_2 bolometer parameters

Detector working temperature: T ~ 10 mK

Mixing chamber temperature: T_{MC} ~ 5 mK

Heat capacity of crystal: C ~ 2 x 10^{-9} J/K

Thermal conductance of thermal coupling to heat bath: G ~ 2 x 10^{-9} W/K

Time constant of bolometer: t ~ C/G ~ 1 s

Rise time of pulse: ~ 50 ms

Decay time of pulse: ~ 200 ms

Resistance of thermistor: R ~ 100 MΩ

$R(T) = R_0 \bullet \exp[(T_0/T)_\gamma]$

R_0: nominal values ~0.9-1.2 Ω

T_0: nominal values ~3-4 K

γ is considered to be = 0.5

A representative set of reasonable parameters that reproduces R ~ 100 MΩ is: R_0 ~ 1.1 Ω, T_0 ~ 3.35 K, γ = 0.5

Detector Response:

$\Delta V_{thermistor}$ ~ 0.3 mV/MeV

$\Delta R_{thermistor}$ ~ 3 MΩ/MeV

$\Delta T_{thermistor}$ ~ 0.03 mK/MeV

$\Delta T_{crystal}$ ~ 0.1 mK/MeV