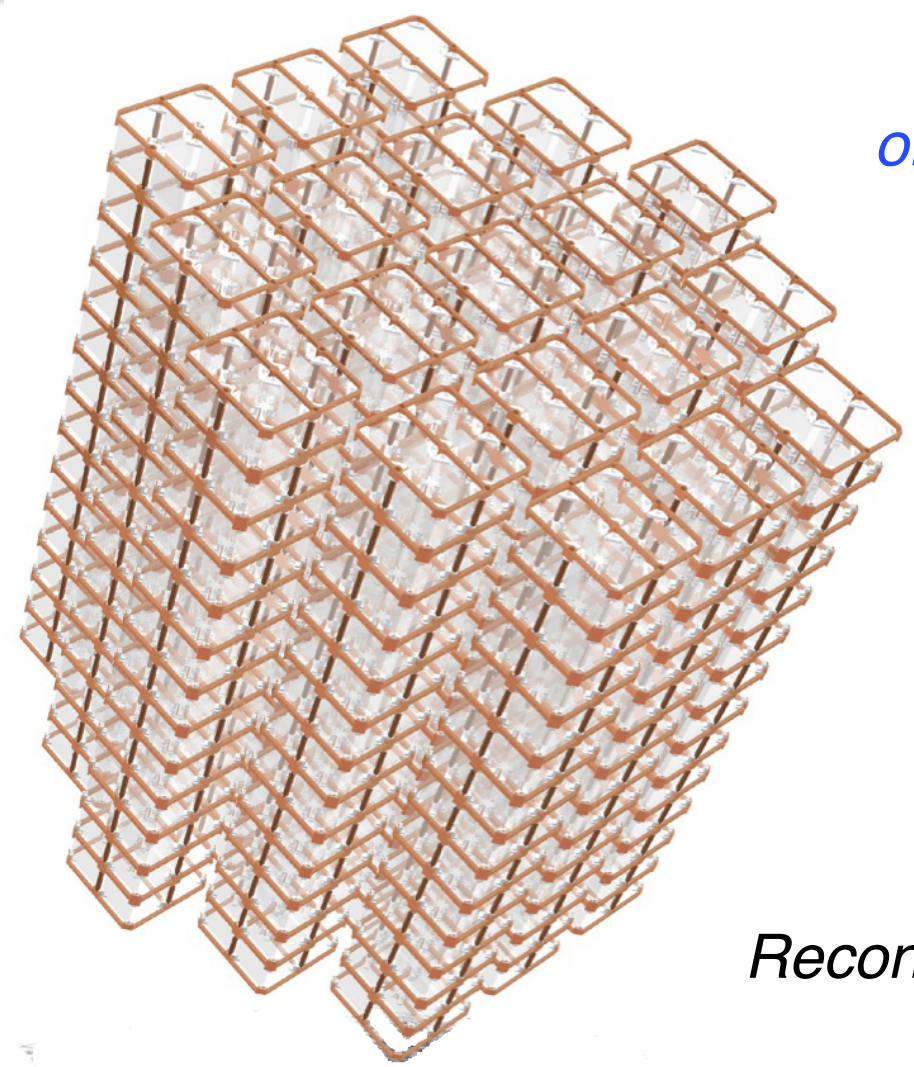
Status of CUORE and CUORE-0 experiments at Gran Sasso



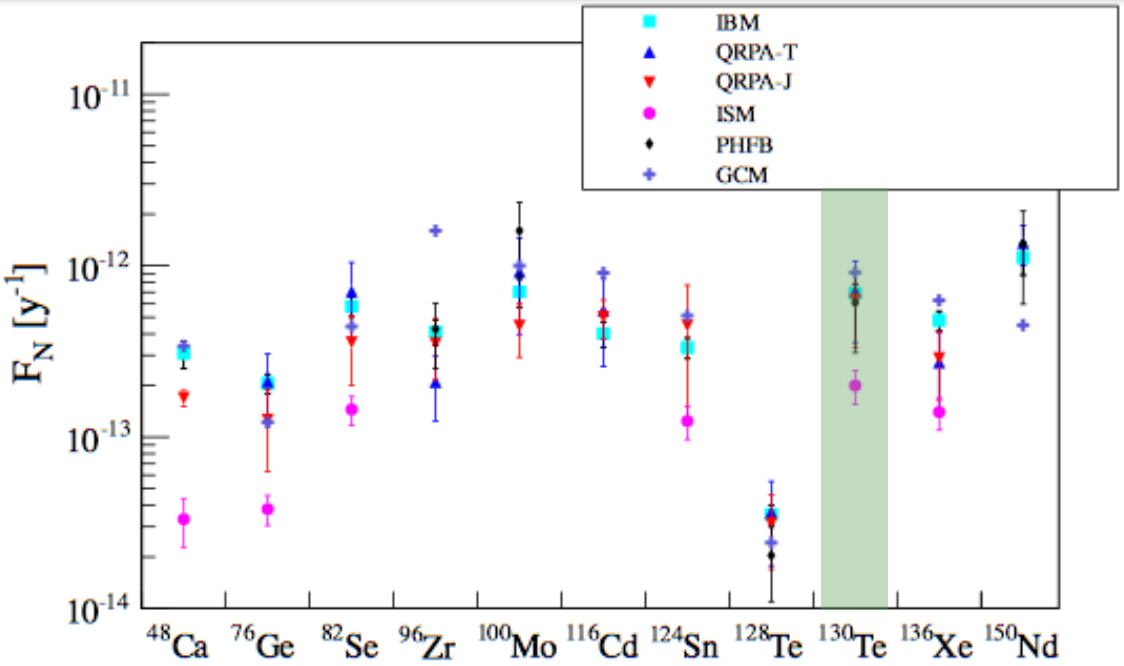
Fabio Bellini
on behalf of the CUORE Collaboration

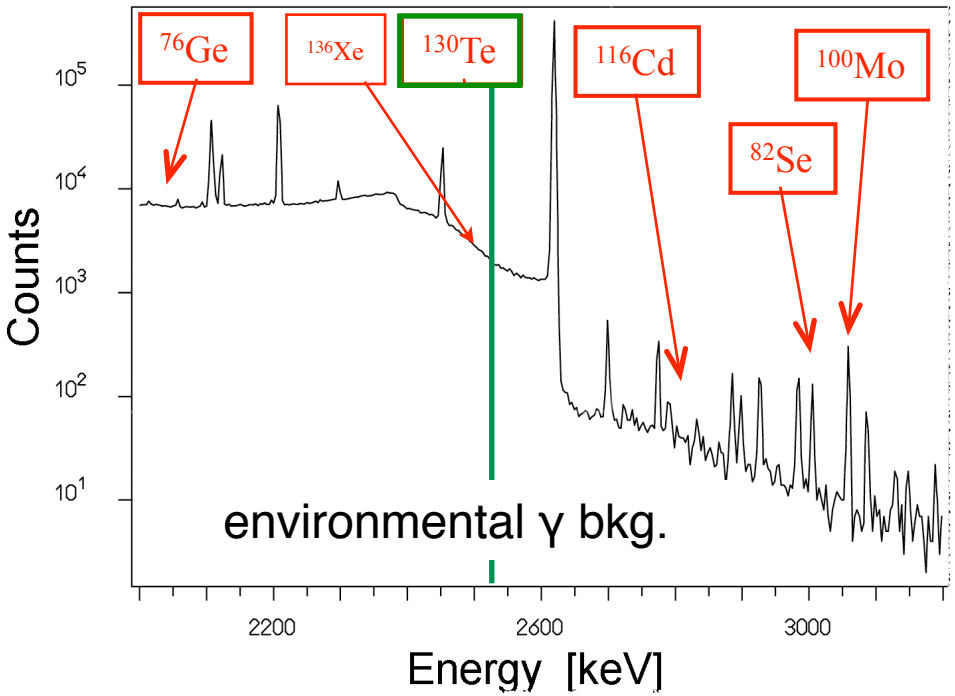
Recontres de Moriond La Thuile, 17/03/2014

Double beta decay with Tellurium

Sensitivity to the Majorana mass $m_{\beta\beta}$ goes as:

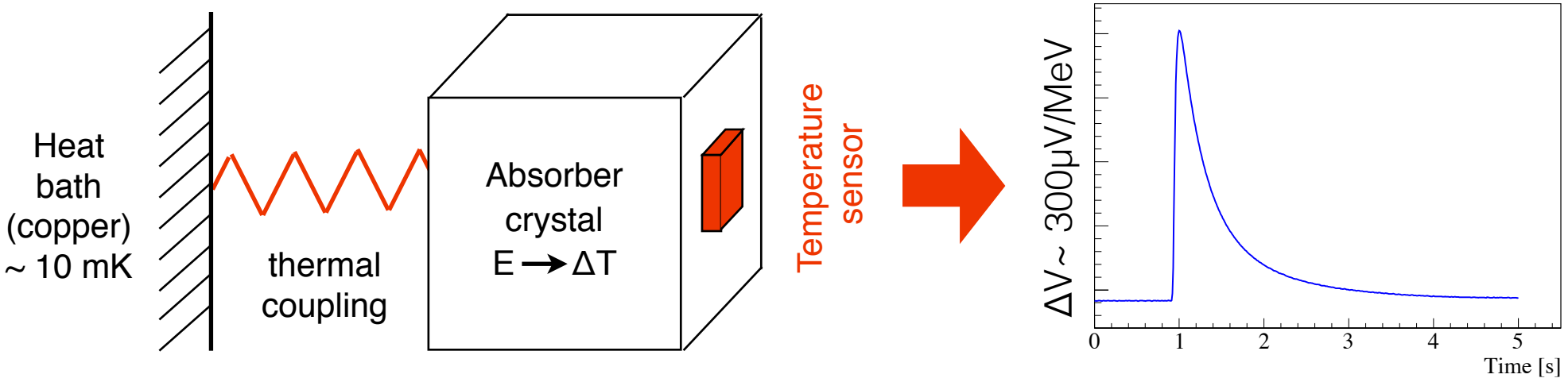
$$\frac{1}{|m_{\beta\beta}|^2} \sim F_N \cdot \text{I.A.} \times \sqrt{\frac{\text{Mass} \cdot \text{livetime}}{\text{bkg.} \cdot \Delta E}}$$



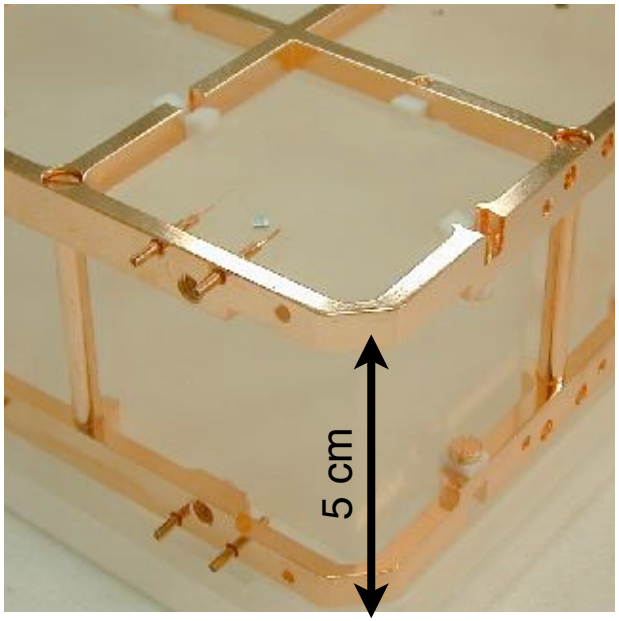


$\beta\beta$ Decay Reaction	Isotopic Abundance [atomic %]	Q-value [keV]
^{48}Ca→^{48}Ti	0.2	4274
^{76}Ge→^{76}Se	7.6	2039
^{82}Se→^{82}Kr	8.7	2996
^{96}Zr→^{96}Mo	2.8	3348
^{100}Mo→^{100}Ru	9.6	3034
^{116}Cd→^{116}Sn	7.5	2814
^{124}Sn→^{124}Te	5.8	2288
^{128}Te→^{128}Xe	31.8	866
^{130}Te→^{130}Xe	34.2	2528
^{136}Xe→^{136}Ba	8.9	2458
^{150}Nd→^{150}Sm	5.6	3368

Bolometric technique in CUORE



- 0.75 Kg $^{nat}TeO_2$ crystals:
  - C~10^{-9} J/K → ΔT/ΔE~100μK/MeV
- NTD-Ge thermistor: $R=R_0 \exp(T_0/T)^{1/2}$
  - R~ 100 MΩ → ΔR/ΔE~3MΩ/MeV



- Resolution @$0\nu\beta\beta$ energy (2528 keV): ΔE_{FWHM} = 5-7 keV

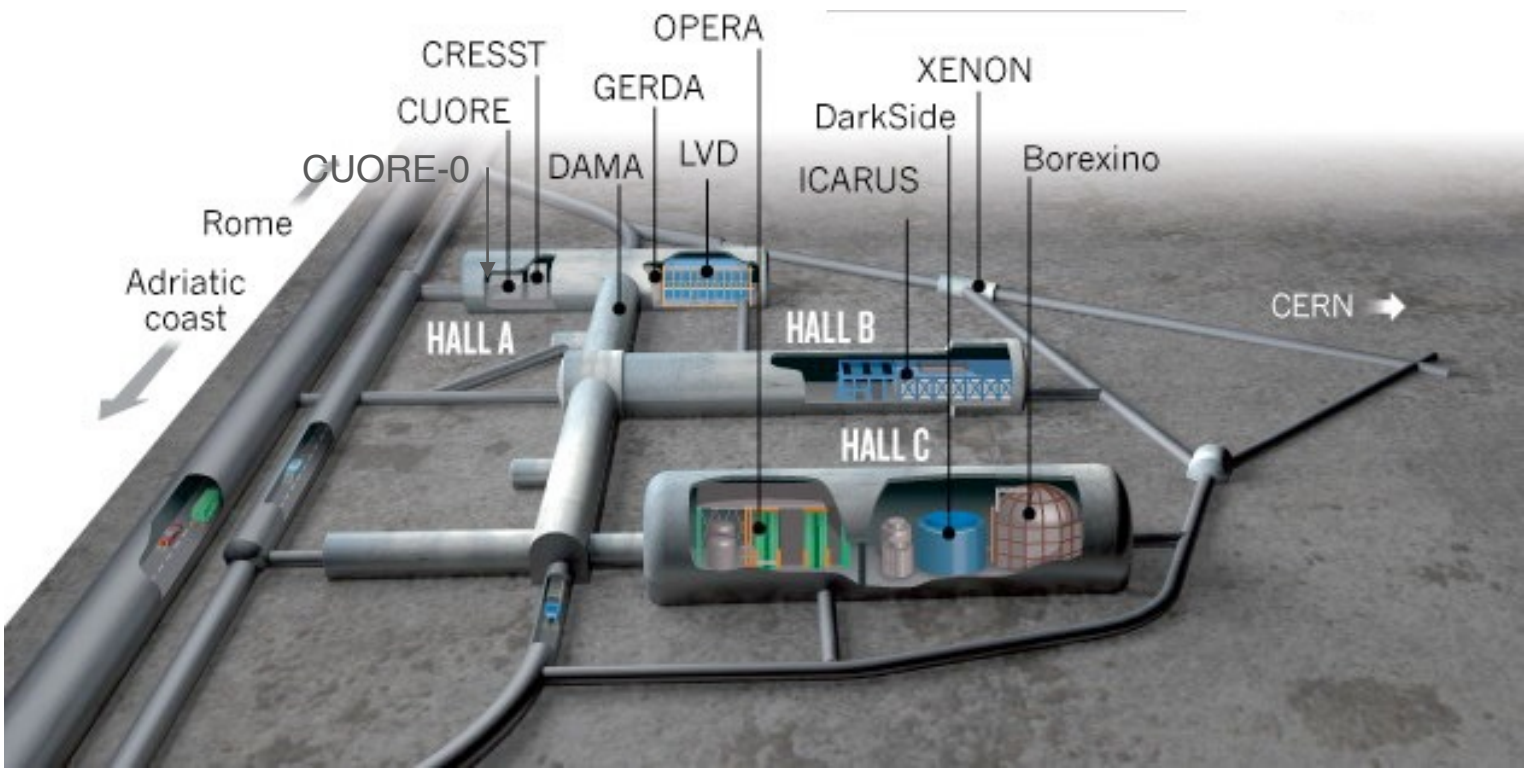
Gran Sasso lab in Italy

3650 m.w.e. deep

μs: 2.58×10^{-8}/(s cm^2)

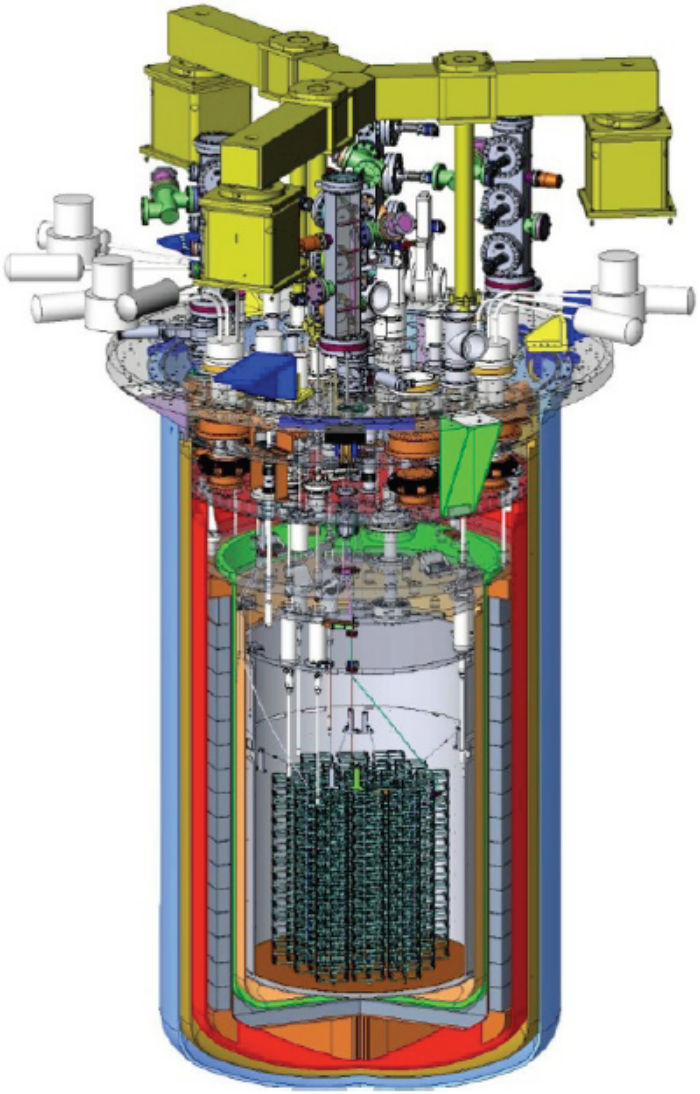
γs: ~0.73/(s cm^2)

neutrons: 4×10^{-6} n/(s cm^2)



CUORE: main challenges

988 TeO_2 bolometers
^{130}Te mass: 206 kg
TeO_2 mass: 741 kg

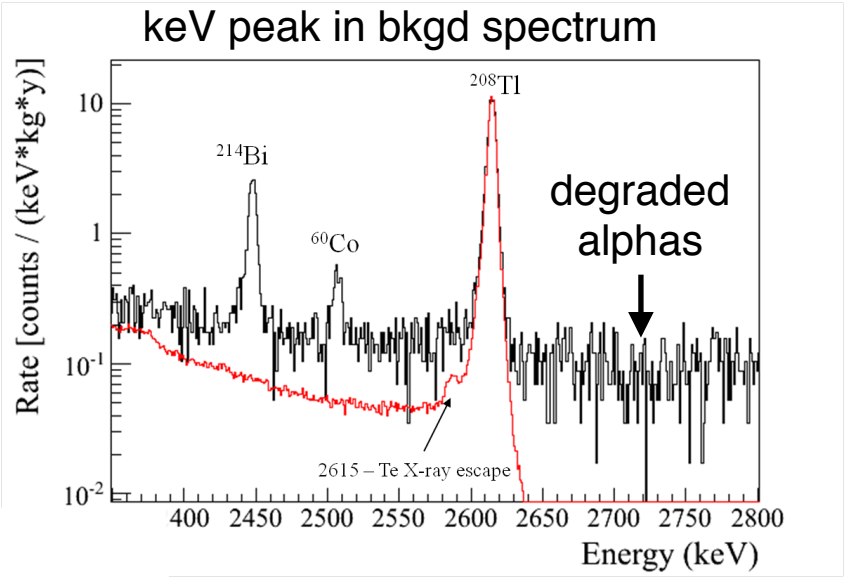


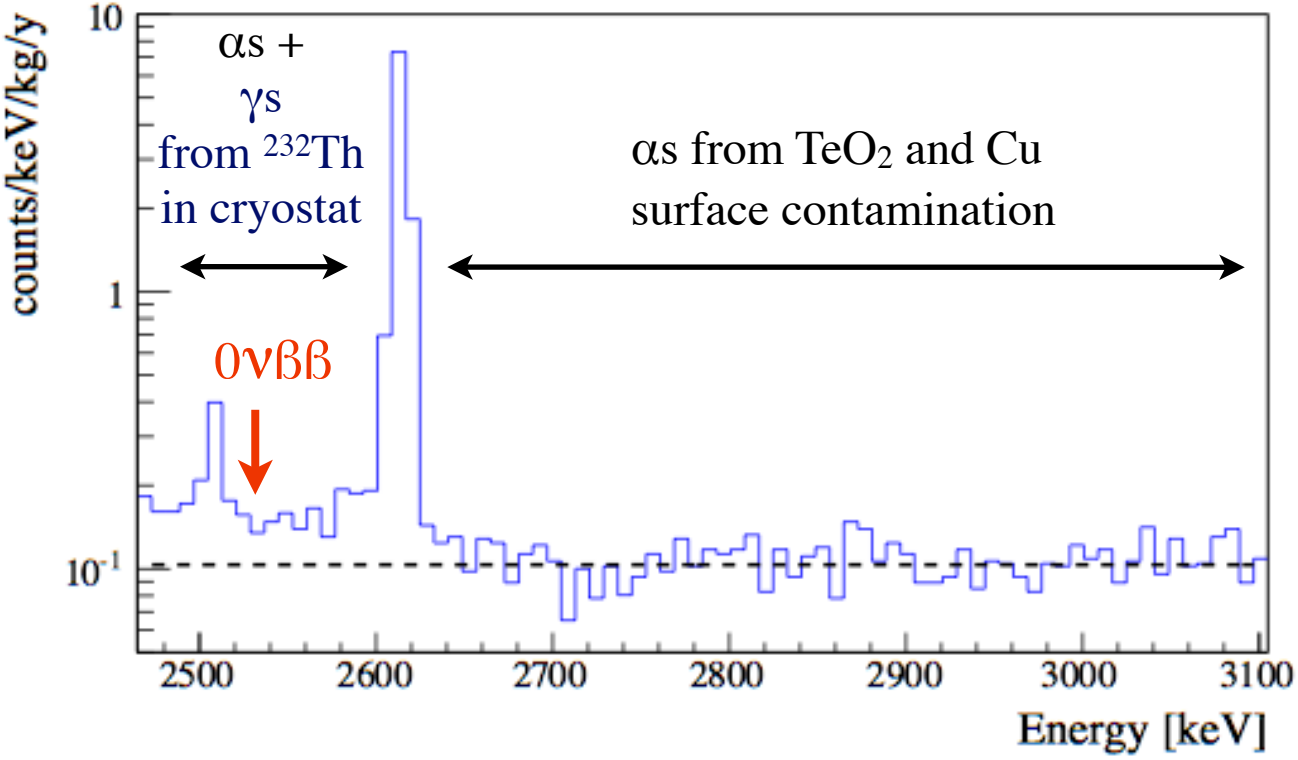
- Cryostat:
  - Custom pulse tube dilution refrigerator and cryostat. Technologically challenging: ~1 ton of detectors at 10 mK (~20 tons at various low temperature stages)
  - Stringent radioactivity constraints on materials and clean assembly
  - Independent suspension of the detector array from the dilution unit
- Cleaning
  - Strict radio-purity control protocol to limit bulk and surface contaminations in crystal production
  - TECM (Tumbling, Electropolishing, Chemical etching, and Magnetron plasma etching) cleaning for copper surfaces

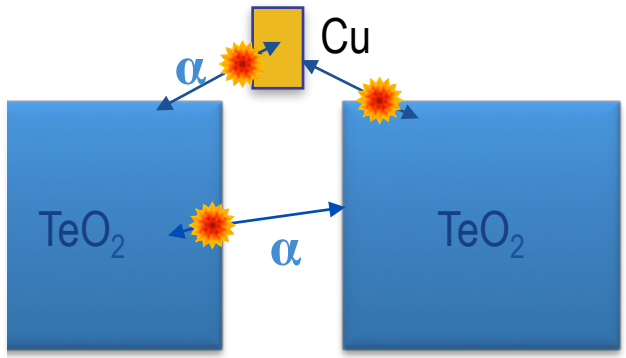
The CUORICINO experience

- 44x790g + 18x330g bolometers: 19.75 kg·y in ^{130}Te
- $T^{0\nu}_{1/2} > 2.8\times10^{24}$ years (90% CL)
  $\langle m_{\beta\beta}\rangle < 300\sim710$ meV
- Background level (790g only): 0.15 counts/keV/kg/year

Cal. spectrum normalized to 2615 keV peak in bkgd spectrum







CUORE-0

A single CUORE-like tower to test the cleaning and assembly techniques of CUORE

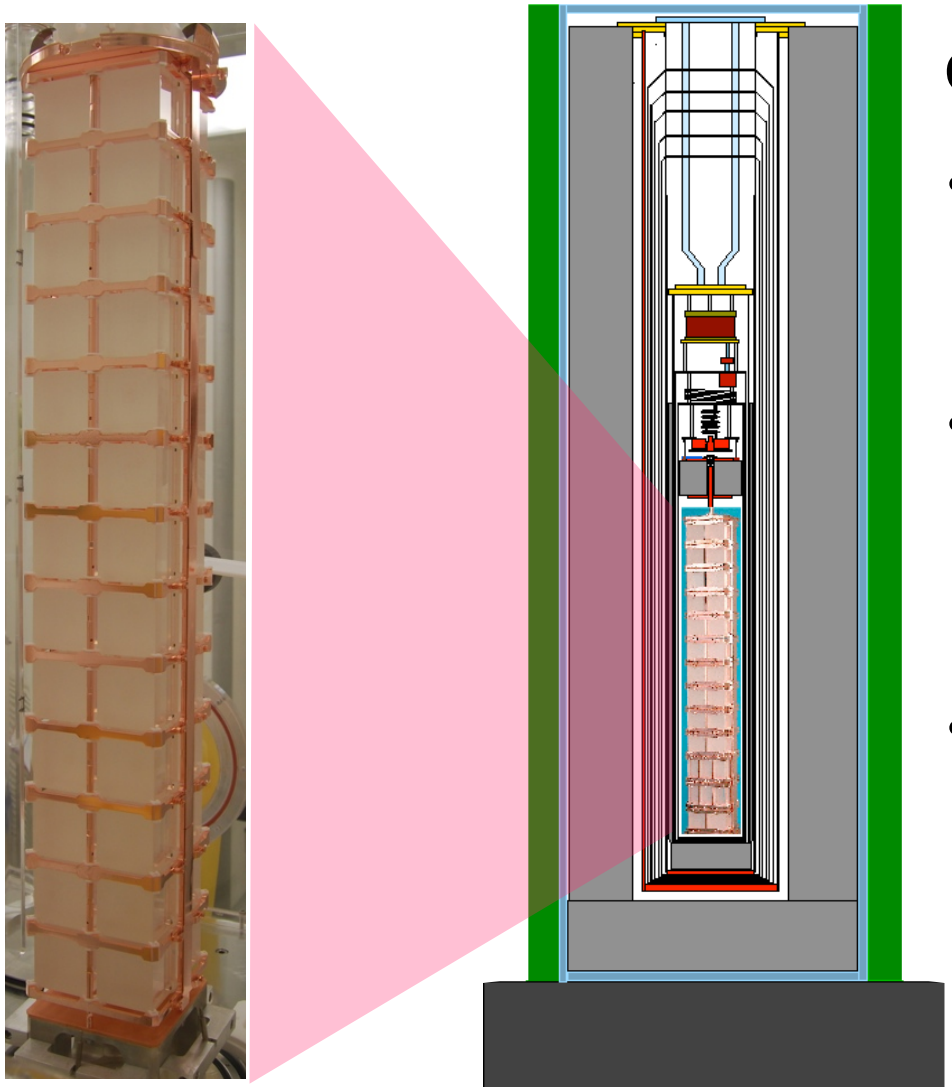
Size similar to CUORICINO:

- 52x750g bolometers
- 13 floor of 4 crystals each

Active mass:

- TeO_2: 39 kg
- ^{130}Te: 11 kg

Data Taking started on March 2013



Cryostat:

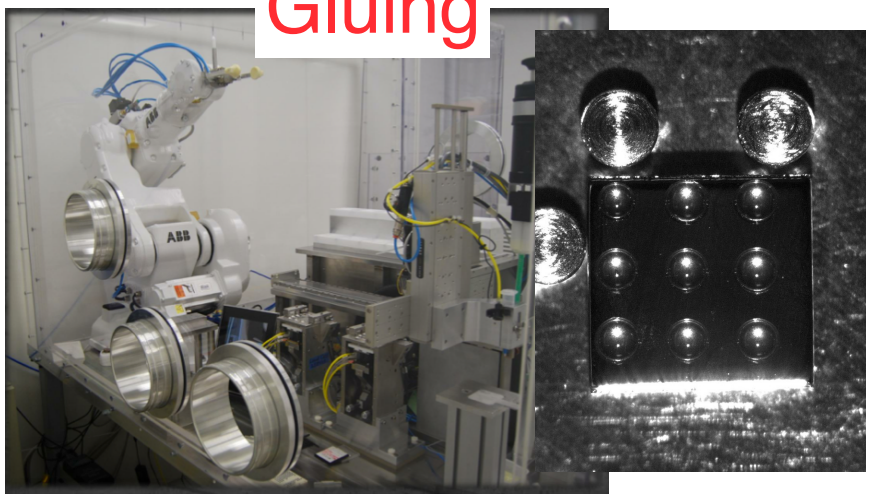
- Inner shield: 1cm Roman Pb A (^{210}Pb) < 4 mBq/Kg
- External Shield: 20 cm Pb 10 cm Borated polyethylene
- Nitrogen flushing to avoid Rn contamination.

Same cryostat as CUORICINO:

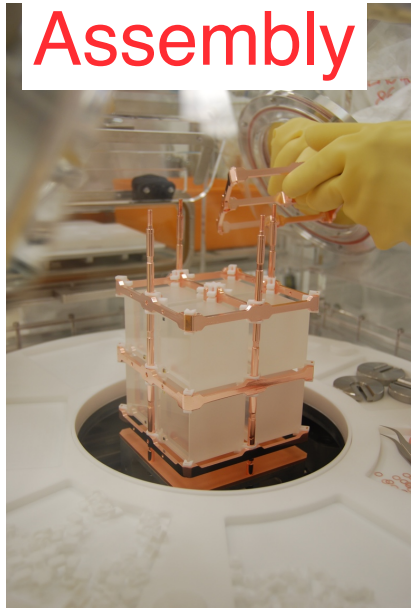
γ background (^{232}Th) not expected to change ⇒ test the α background

CUORE-0 construction

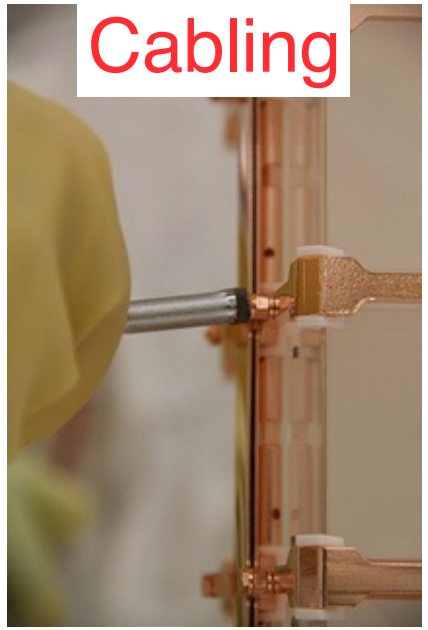
Gluing



Assembly

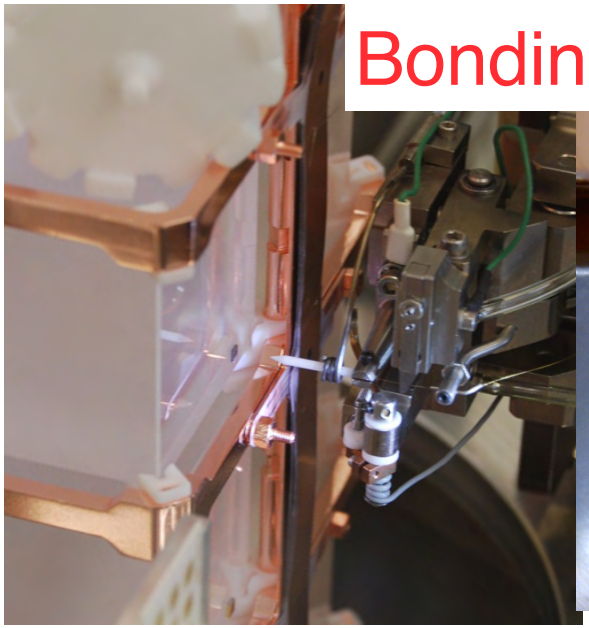


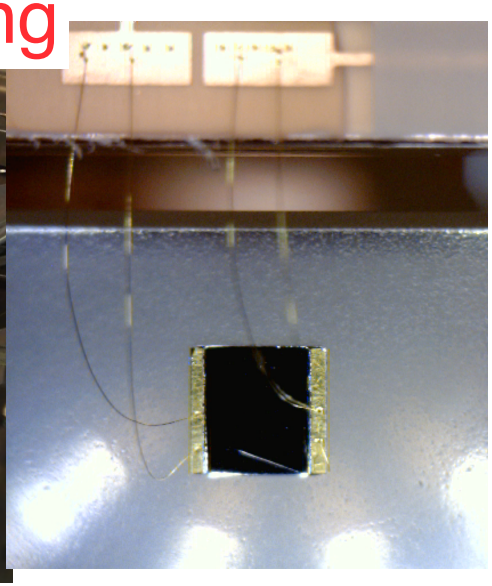
Cabling



Clean room

Bonding

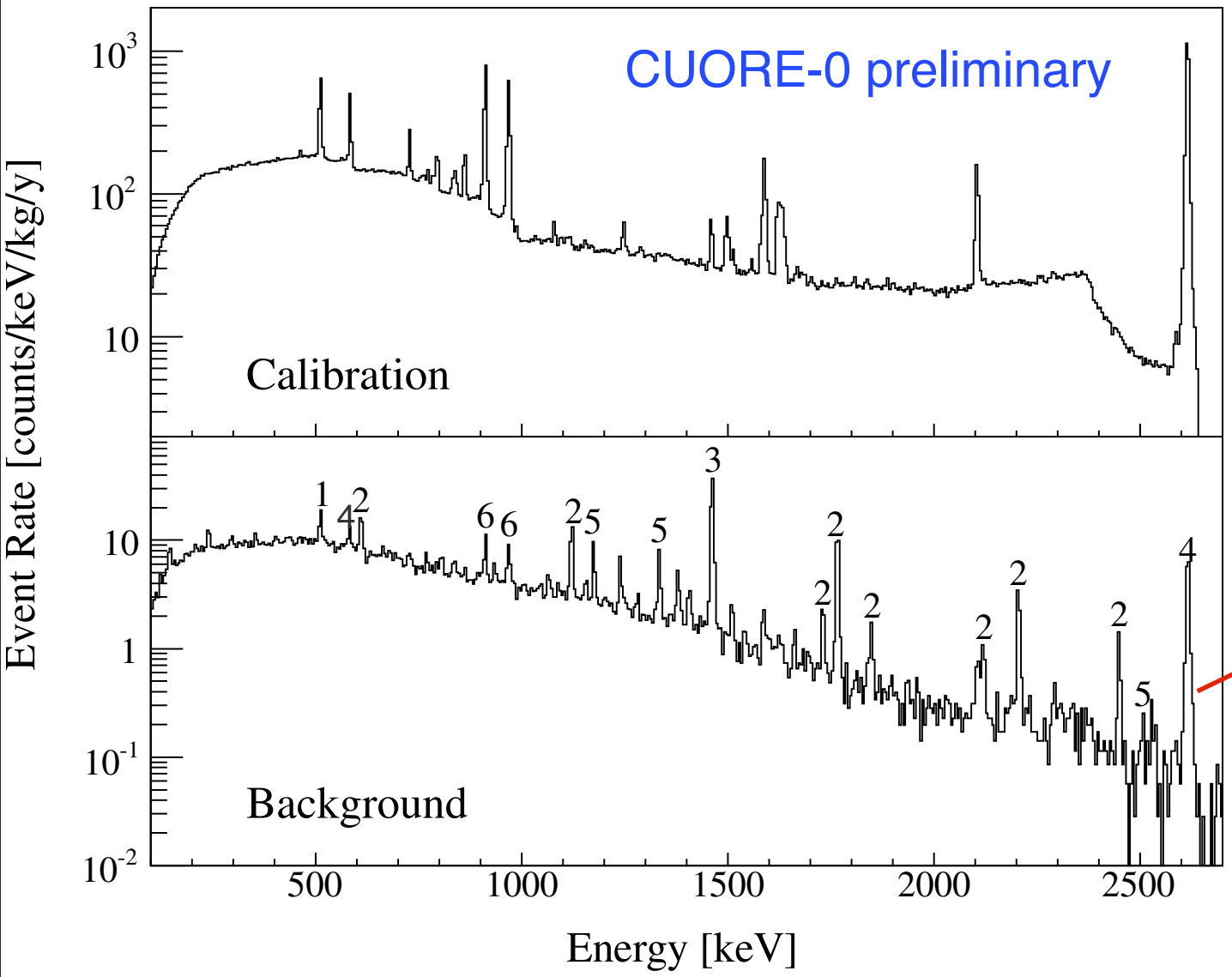




All steps of the assembly performed under nitrogen atmospheres inside glove boxes

CUORE-0 Performances

C.P.Aguirre et al., *Initial performance of the CUORE-0 experiment*, http://arxiv.org/abs/1402.0922, submitted to EPJC

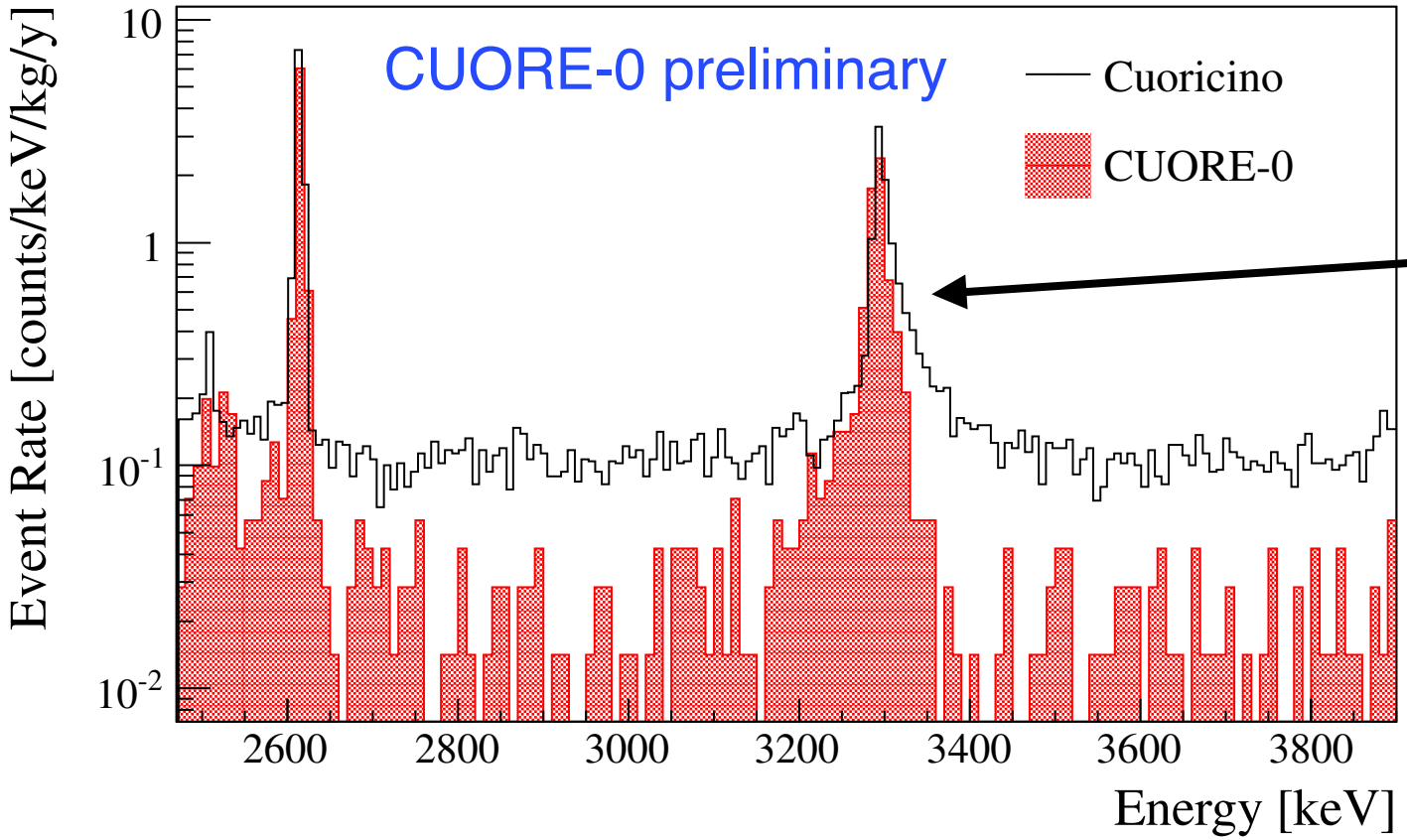


Data shown:
March-Sep 2013
2.0 kg·y in ^{130}Te

FWHM of ^{208}Tl γ line @2615 keV in the overall bkgd spectrum: 5.7 keV

(1) e^+ e annihilation
(2) ^{214}Bi
(3) ^{40}K
(4) ^{208}Tl
(5) ^{60}Co
(6) ^{228}Ac

CUORE-0 bkgd: α region

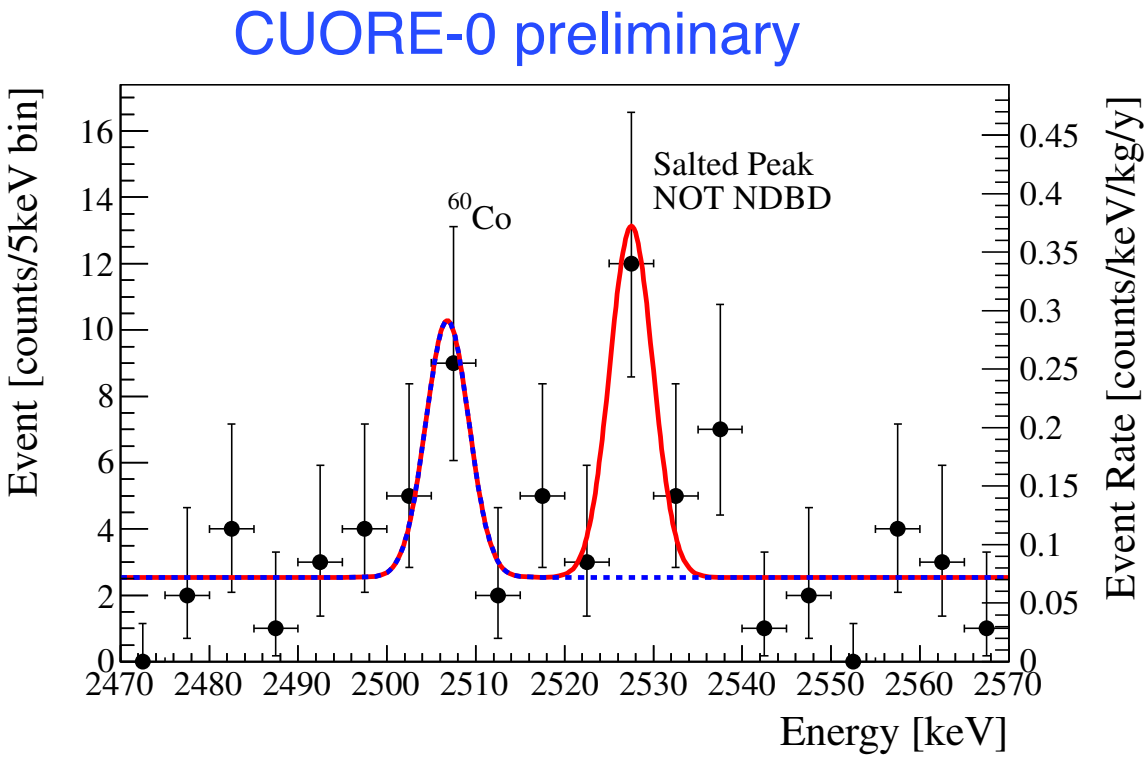


^{190}Pt alpha peak, due to platinum inclusions from the crucible used to grow crystals

Bkgd in α region evaluated in the intervals (2.7-3.1)MeV + (3.4-3.9)MeV (excluding ^{190}Pt peak)

0.019±0.002 counts/keV/kg/y⟹reduction of a factor 6 wrt CUORICINO

CUORE-0 bkgd: DBD region(blinded)

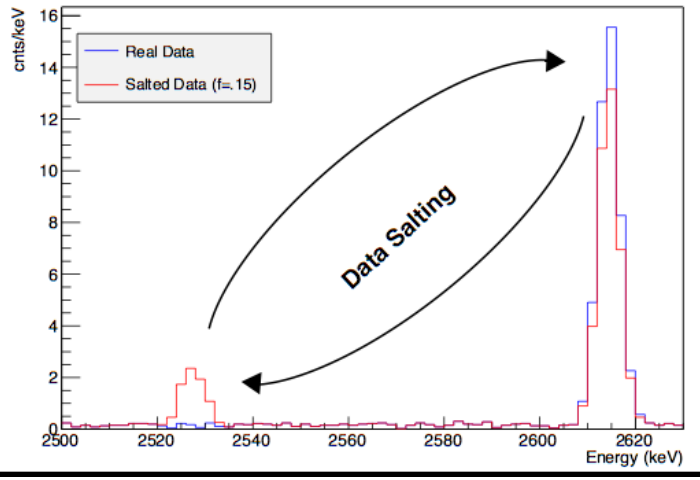


Flat background in ROI:

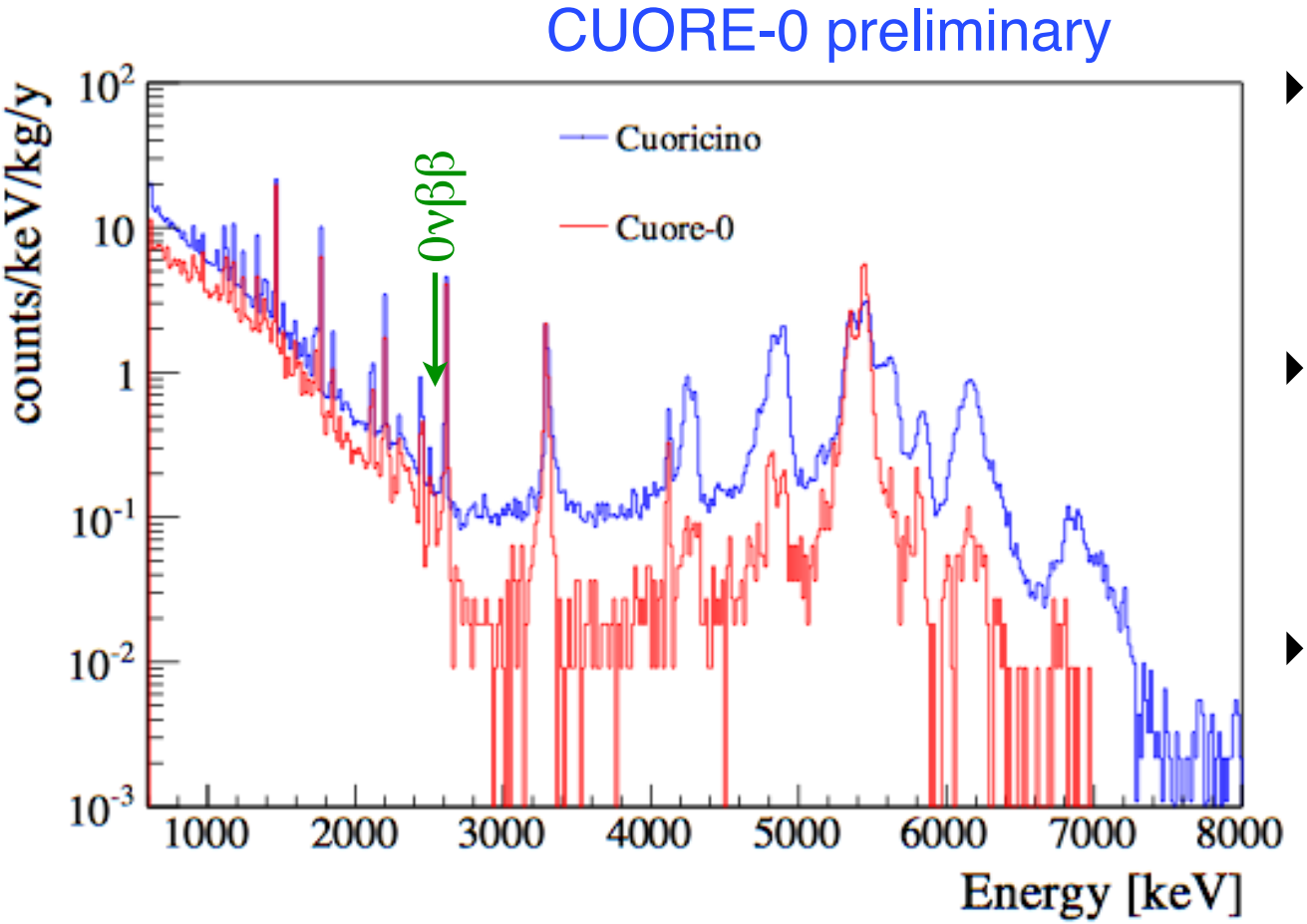
0.071±0.011 counts/keV/kg/y

Our way of blinding is to salt the data:

exchange a small (and blinded) fraction of ^{208}Tl events (2615 keV) with events in the $0\nu\beta\beta$ region, producing a fake peak.



CUORE-0 vs CUORICINO

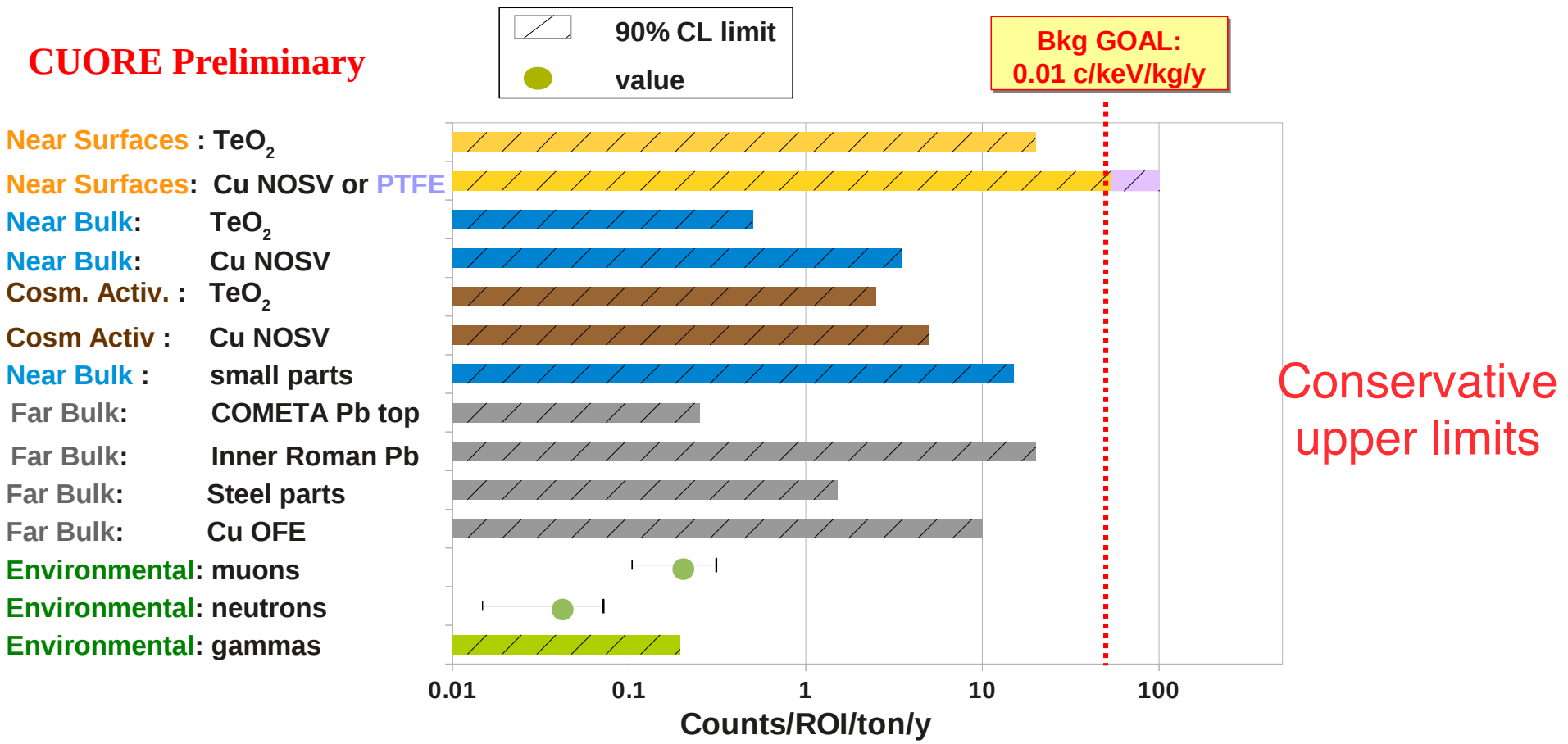


- ^{238}U γ lines reduced by a factor 2 (better radon control)
- ^{232}Th γ lines not reduced (originate from the cryostat)
- ^{238}U/^{232}Th α lines reduced (new detector surface treatment)

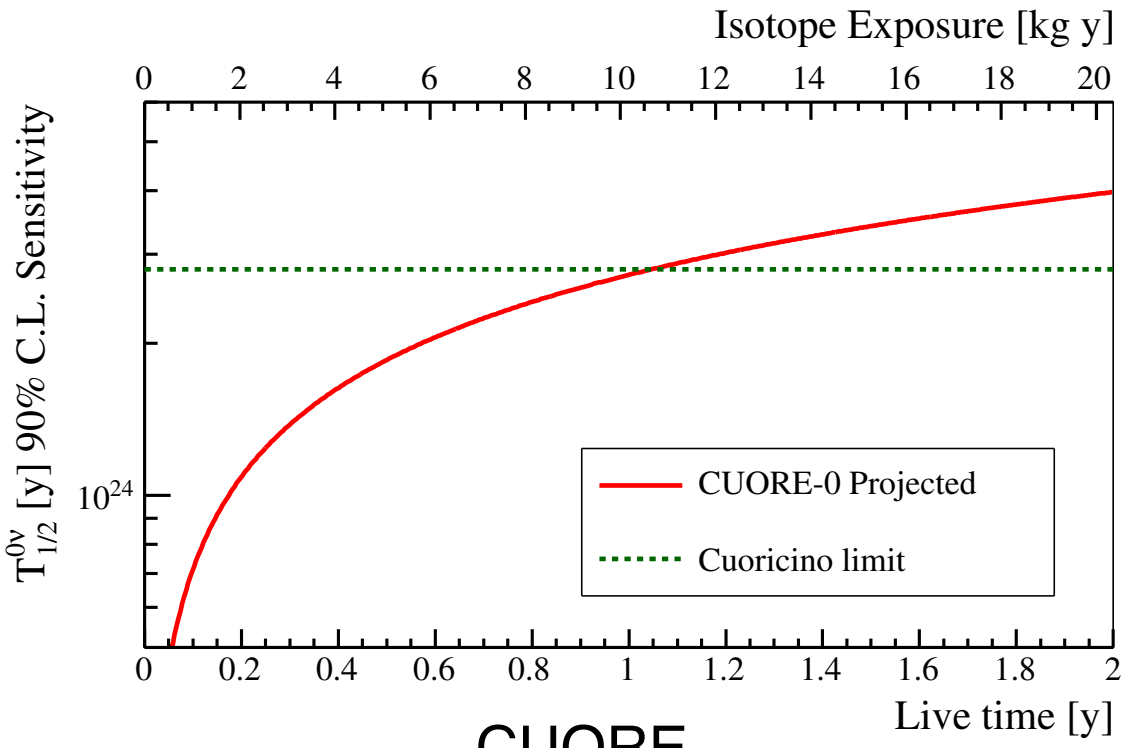
	Avg. flat bkg. [counts/keV/kg/y]		signal eff. [%] (detector+cuts)
	$0\nu\beta\beta$ region	2700-3900 keV	
CUORICINO	0.153 ± 0.006	0.110 ± 0.001	82.8±1.1
CUORE-0	0.071 ± 0.011	0.019 ± 0.002	80.4±1.9

CUORE Background

- New cryostat with radio-pure materials: γ contribution negligible
- Less copper facing the crystals: α from Cu surface reduced
- Enhanced granularity: negligible α bkgd from crystals surface



CUORE-0 and CUORE sensitivity



CUORICINO sensitivity reached in about a year of live time

CUORE

Background: 0.01 counts/keV/kg/y

FWHM resolution: 5 keV

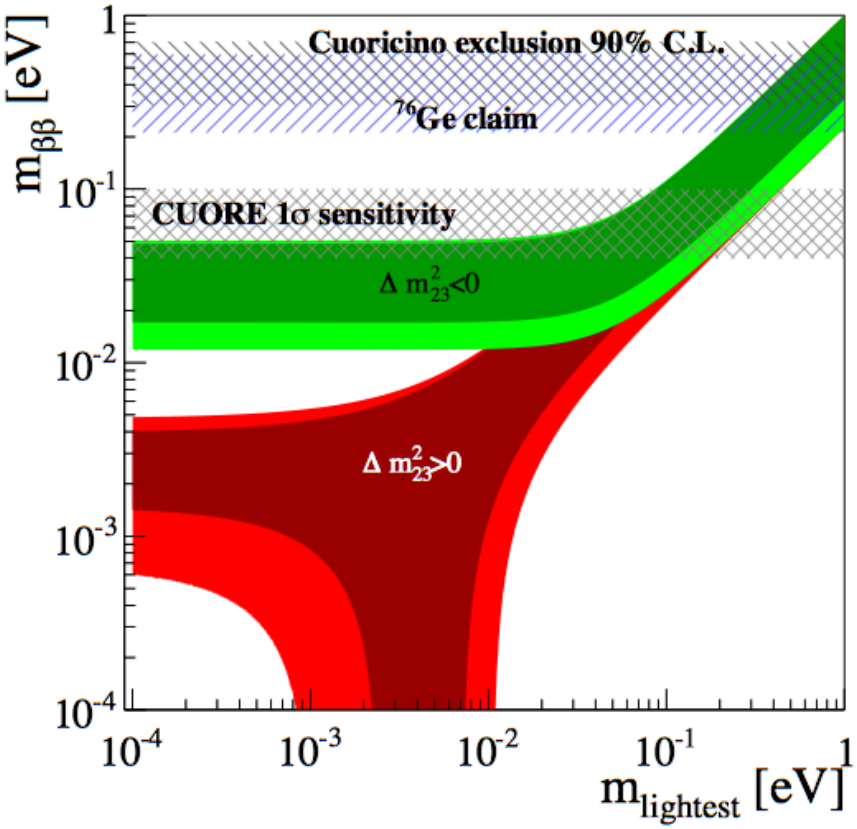
Live time: 5 y

Projected half-life sensitivity:

$9.5 \cdot 10^{25}$ y (90 % C. L.)

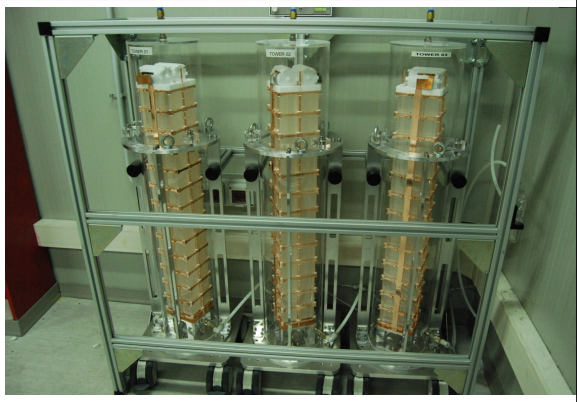
Effective Majorana neutrino mass sensitivity:

50 - 130 meV (90 % C. L.)



CUORE Status

- Detector assembly: completed by June 2014
  - Crystals for 17 towers glued with thermistors
  - 13 towers bonded and put in storage
- Cryostat commissioning: completed by fall 2014
  - 4K test passed
  - Dilution unit reached 5 mK in test setup at LNGS
  - First bolometric test to start in few weeks
- Detectors installation and commissioning:
  - starting in fall 2014
- Detectors cool down: 2015



Conclusions

- CUORE-0
  - Bkgd from surface contamination 0.019±0.002 counts/keV/kg/y ~ 6 times smaller than in CUORICINO
  - FWHM energy resolution: 5.7 keV
  - CUORE assembly and cleaning techniques validated
  - CUORE-0 will overcome the CUORICINO sensitivity in about a year of live time.
- CUORE:
  - CUORE towers installation and commissioning by the end of 2014.
  - Data taking will start in 2015.