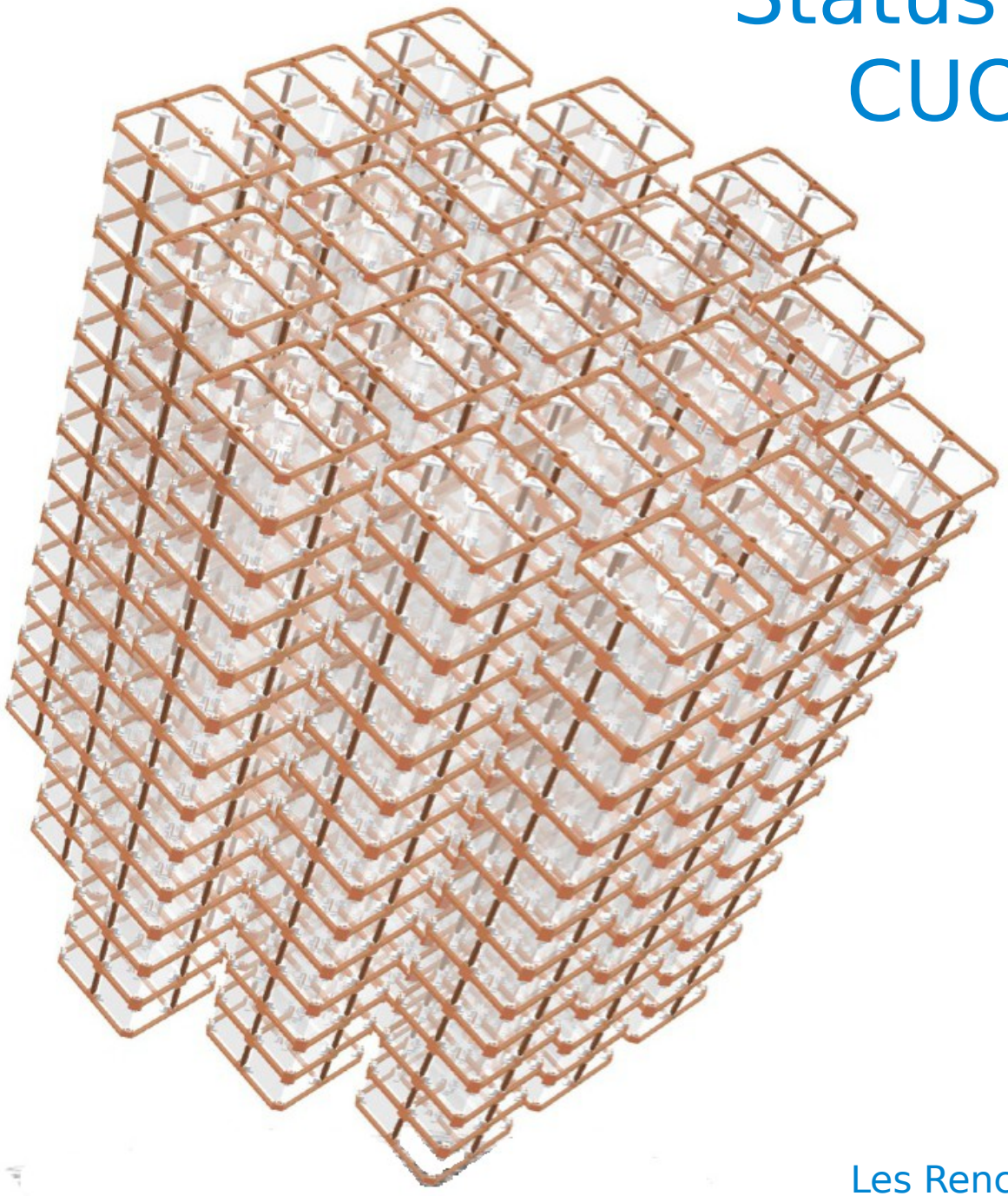


Status of the CUORE and CUORE-0 experiments at Gran Sasso

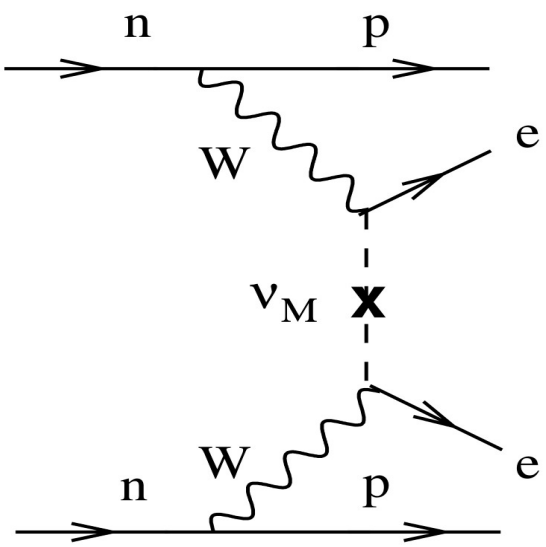
S. Di Domizio
INFN and University of Genova

for the CUORE collaboration

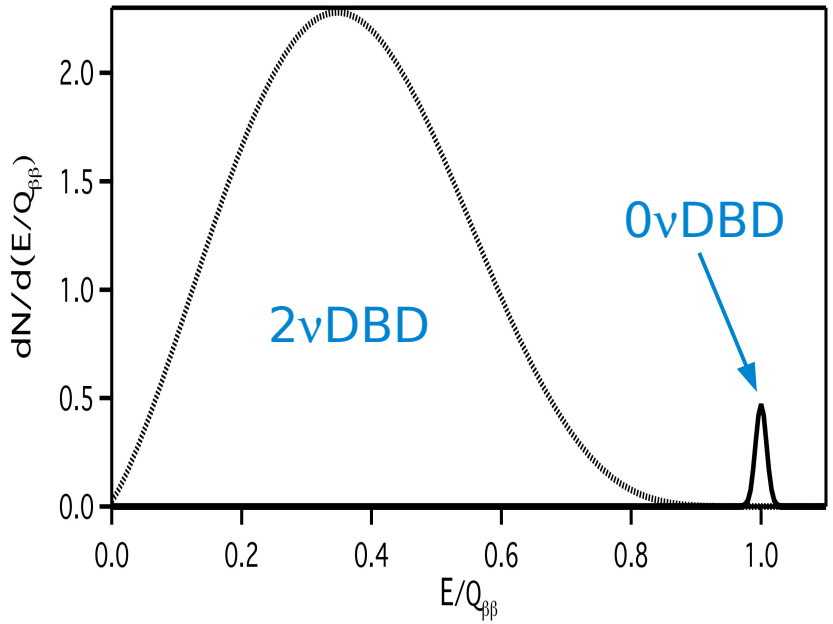
Les Rencontres de Physique de la Vallée d'Aoste
La Thuile, February 25 2014

Neutrinoless double beta decay

Decay diagram



Energy spectrum



Experimental sensitivity

$$S^{0\nu} \propto i.a.\ \varepsilon \sqrt{\frac{M\,t}{b\,\Delta E}}$$

Isotopic abundance

Detection efficiency

Detector mass

Measurement time

Background index counts/(keV kg y)

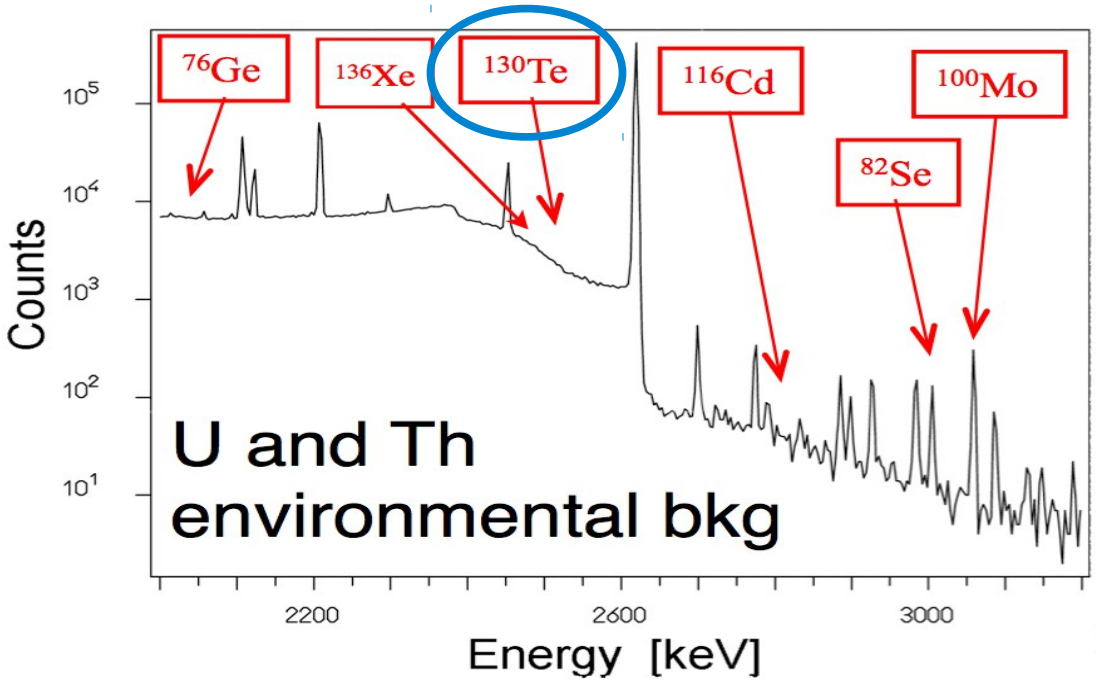
Energy resolution

Neutrinoless double beta decay: ^{130}Te

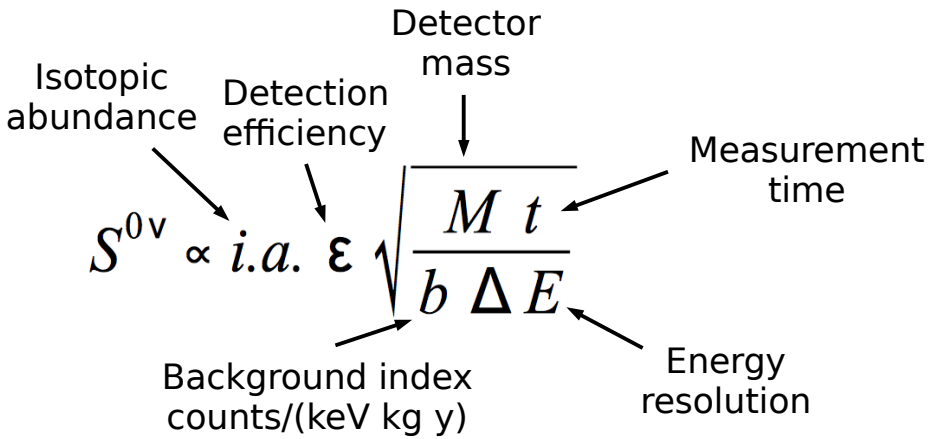
Interesting isotopes

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

Q-values and gamma background



Experimental sensitivity



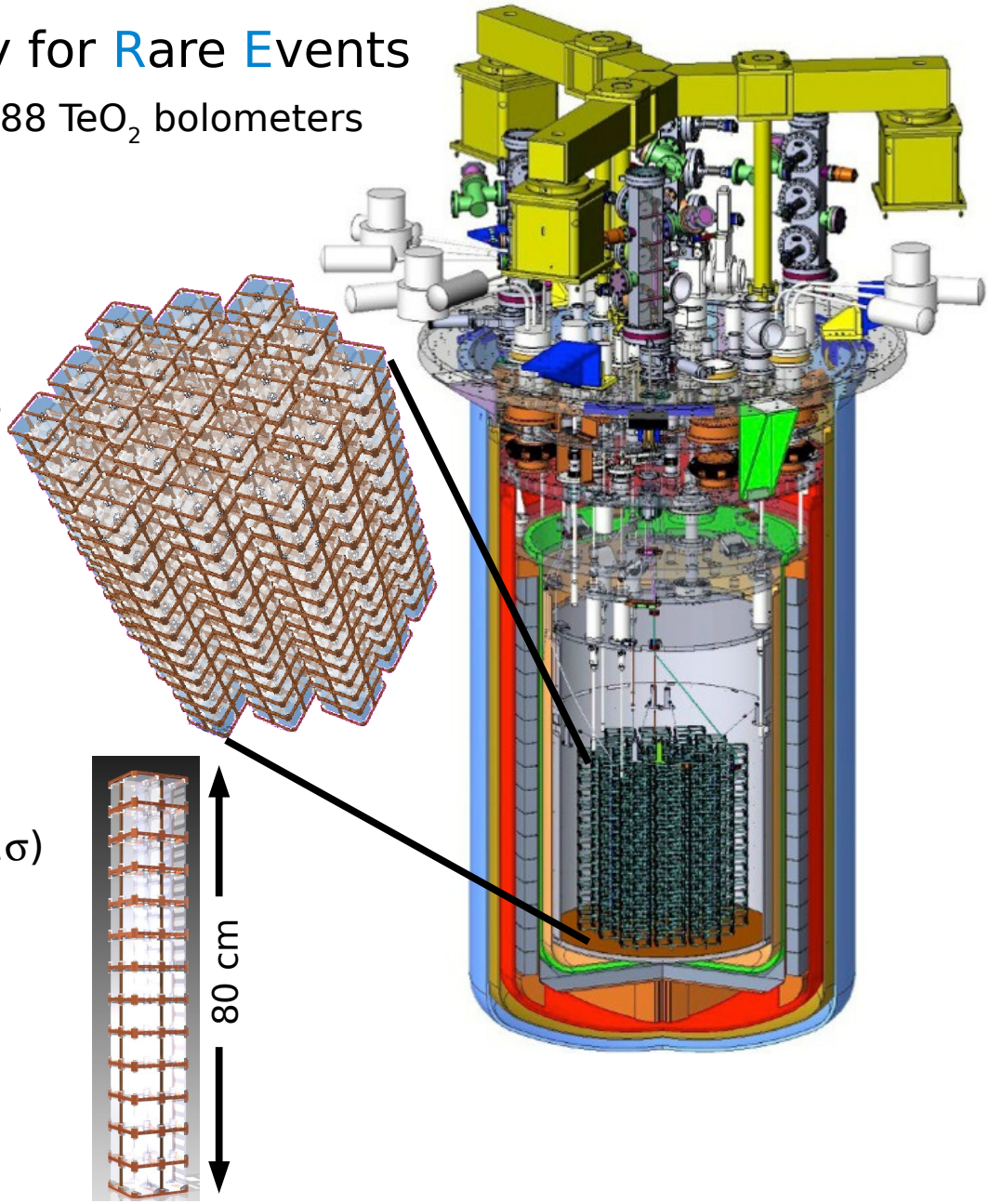
CUORE

Cryogenic Underground Observatory for Rare Events

Neutrinoless double beta decay in ^{130}Te with 988 TeO_2 bolometers

Detector

- ^{130}Te mass: 206 kg (~10^{27} nuclei)
- TeO_2 mass: 741 kg
- 988 TeO_2 bolometers arranged in 19 towers
- Single crystal: 5x5x5 cm^3 (0.75 kg)



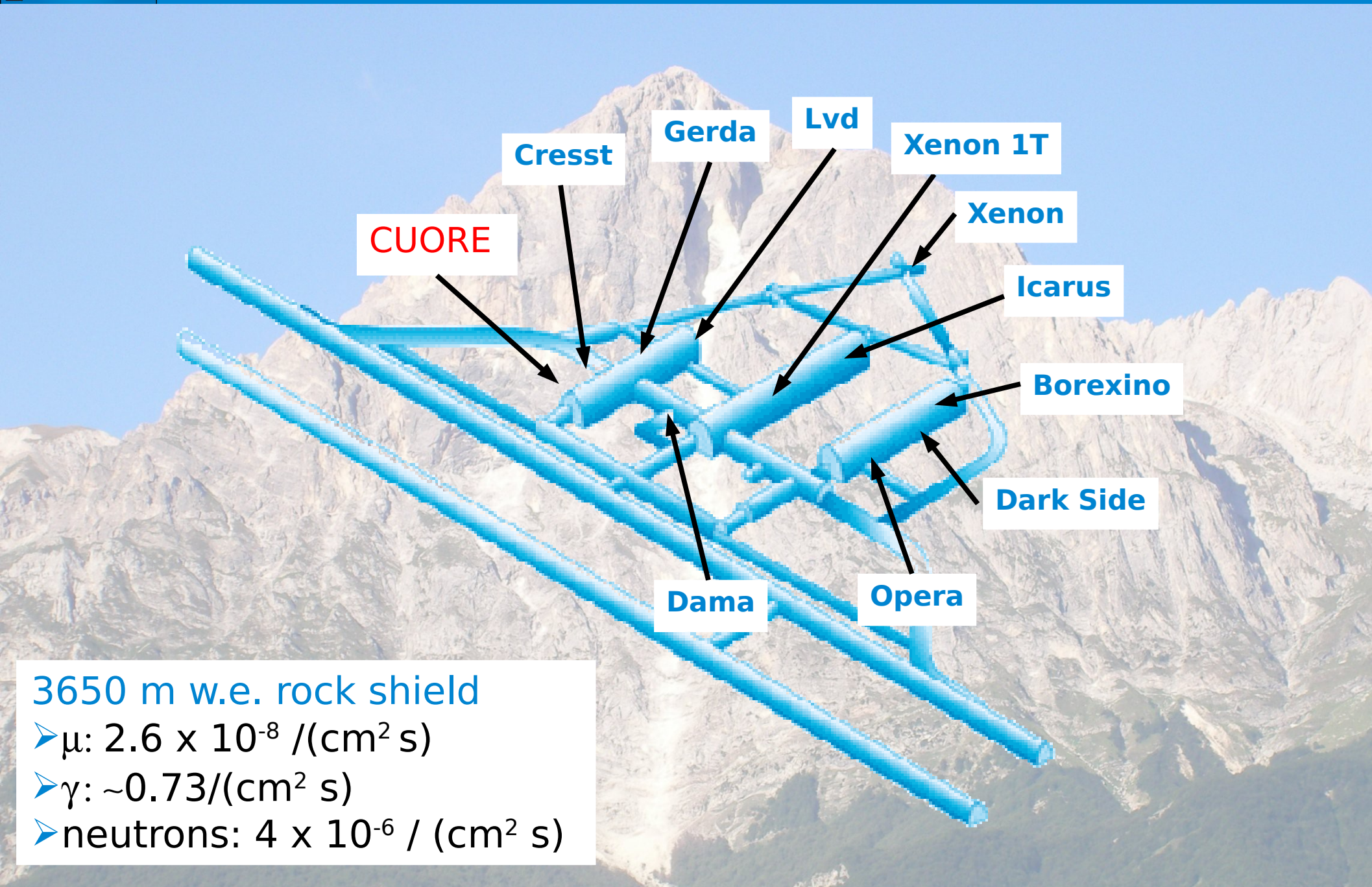
Goals

- Resolution: 5 keV FWHM at 2.5 MeV
- Bkg: 0.01 counts/(keV kg y)
- Half life sensitivity: 1.6 x 10^{26} y (1σ)
- Majorana mass sensitivity: 39 – 102 meV (1σ)

Detector cool down:

- beginning of 2015

LNGS Underground laboratories

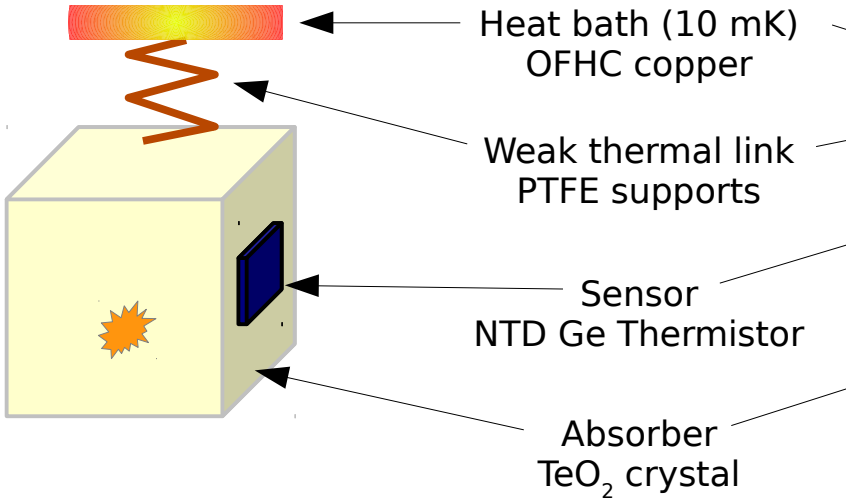


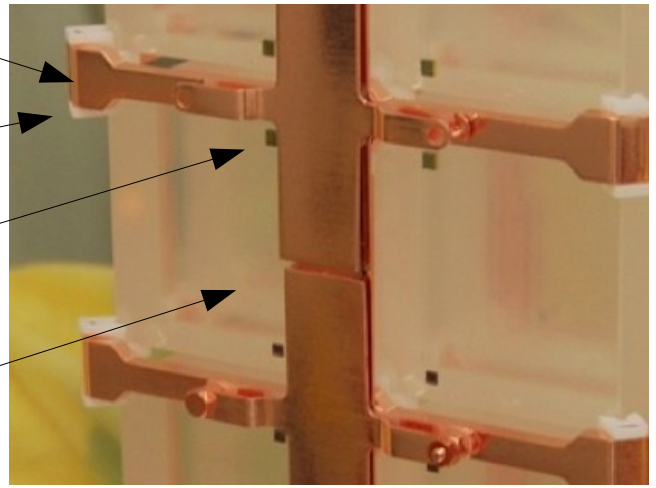
3650 m w.e. rock shield

- μ: 2.6 x 10^{-8} /(cm^2 s)
- γ: ~0.73/(cm^2 s)
- neutrons: 4 x 10^{-6} / (cm^2 s)

CUORE single module

Energy release measured as a temperature rise of the absorber crystal: $\Delta T = \frac{E}{C}$



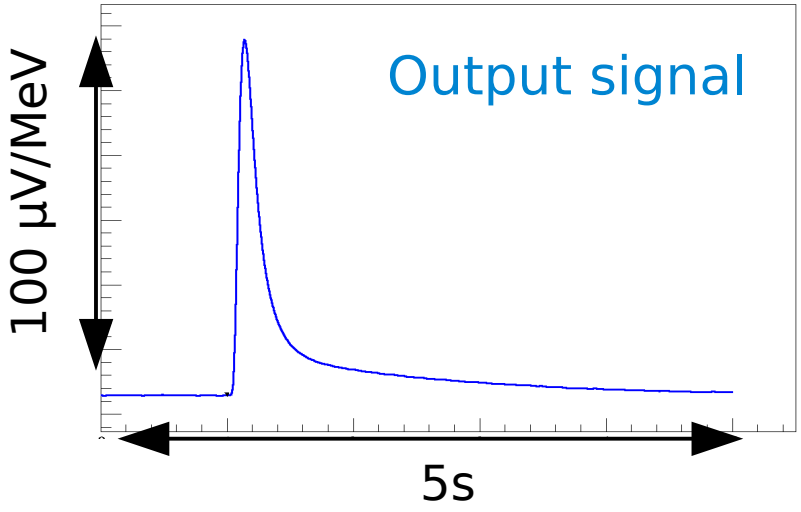


Absorber

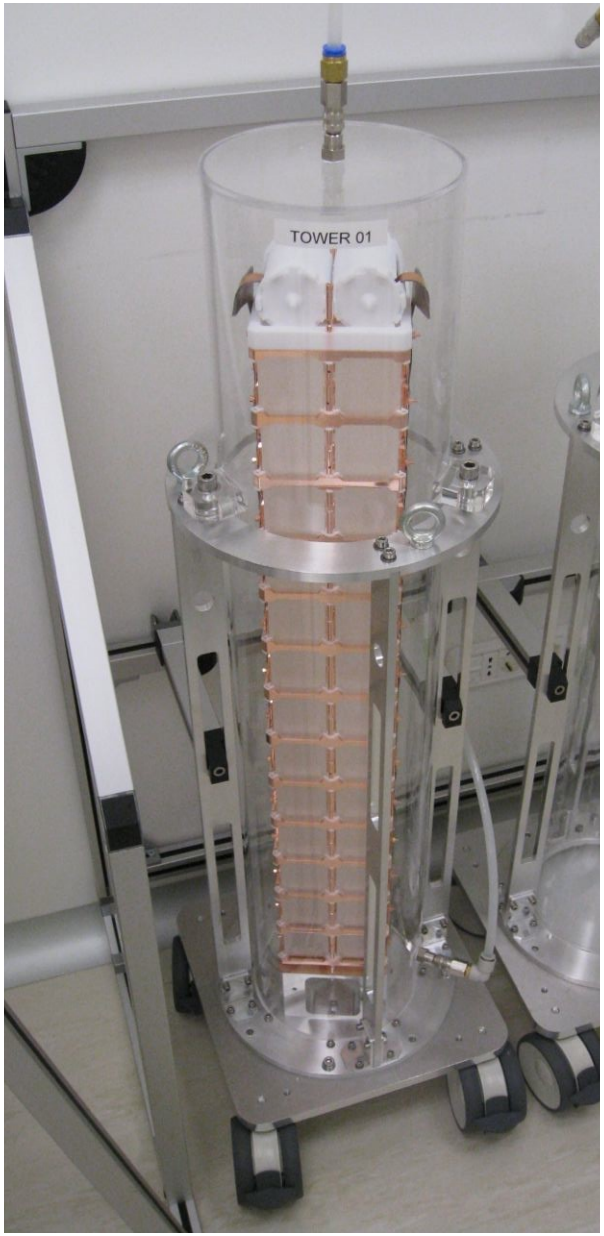
- Dimension: 5x5x5 cm^3
- Mass: 0.75 kg
- Heat capacity: 10^{-9} J/K
- $\Delta T/\Delta E \sim 100$ μK/MeV

Sensor

- $R = R0 \exp[(T_0/T)^{1/2}]$
- $R \sim 100$ MΩ
- $\Delta R/\Delta E \sim 3$ MΩ/MeV



CUORE status and schedule



Detector assembly: complete by June 2014

- Crystals for 16 towers glued with heaters and thermistors
- 14 towers assembled
- 12 towers already bonded and put to storage

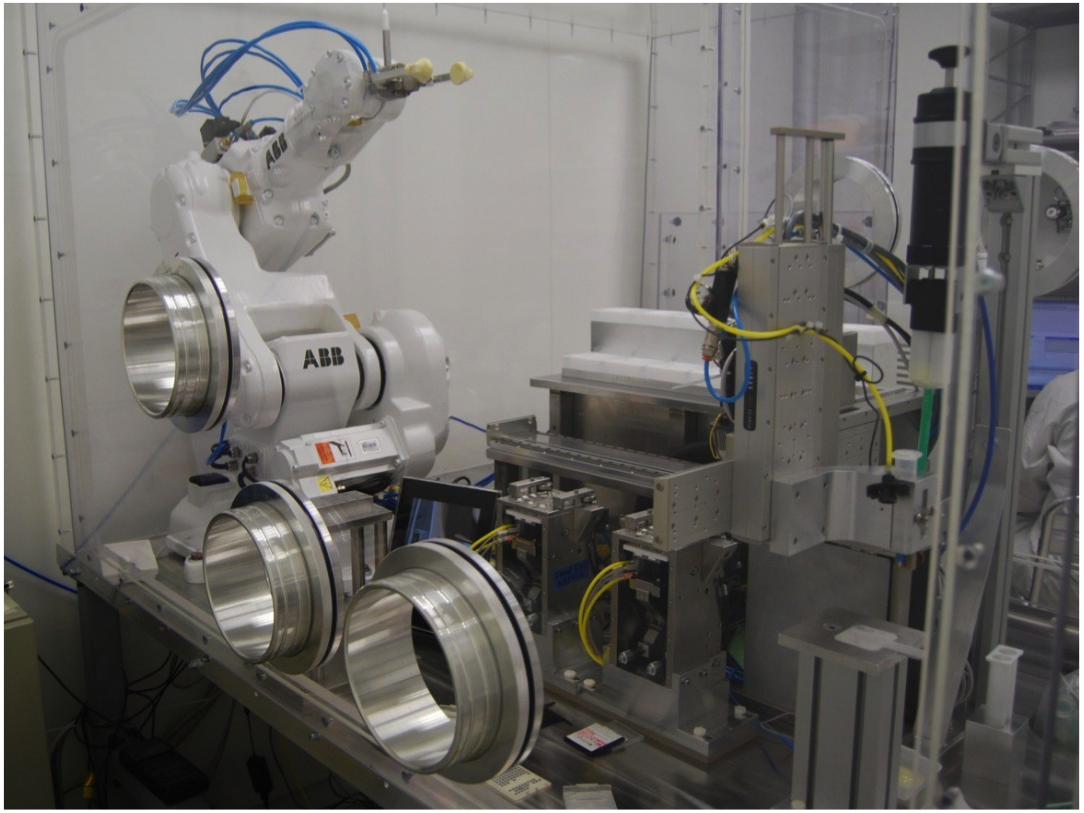
Cryostat commissioning: complete by fall 2014

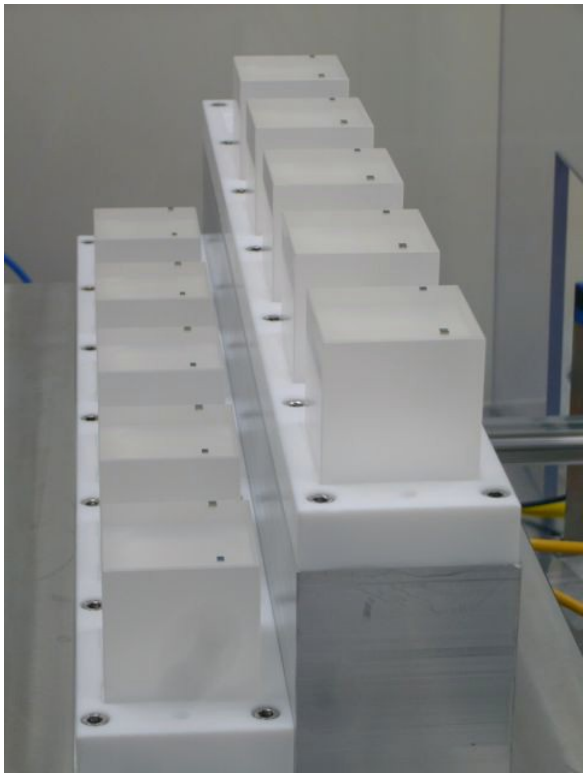
- 4K test passed
- First bolometric test to start in few weeks

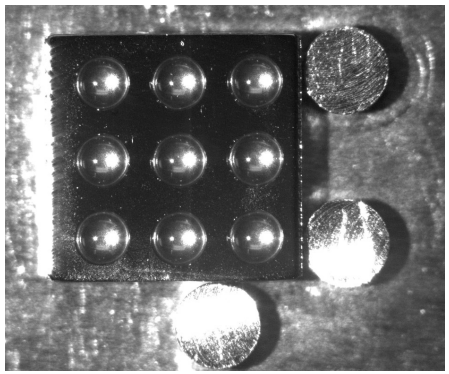
Detectors installation and commissioning: starting in fall 2014

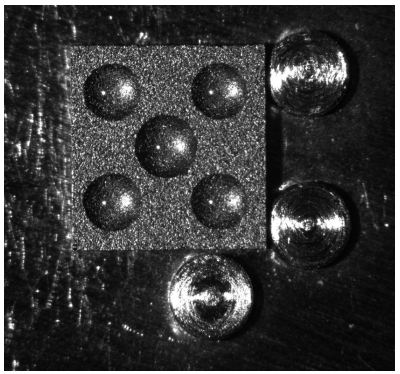
Detectors cool down: 2015

CUORE gluing







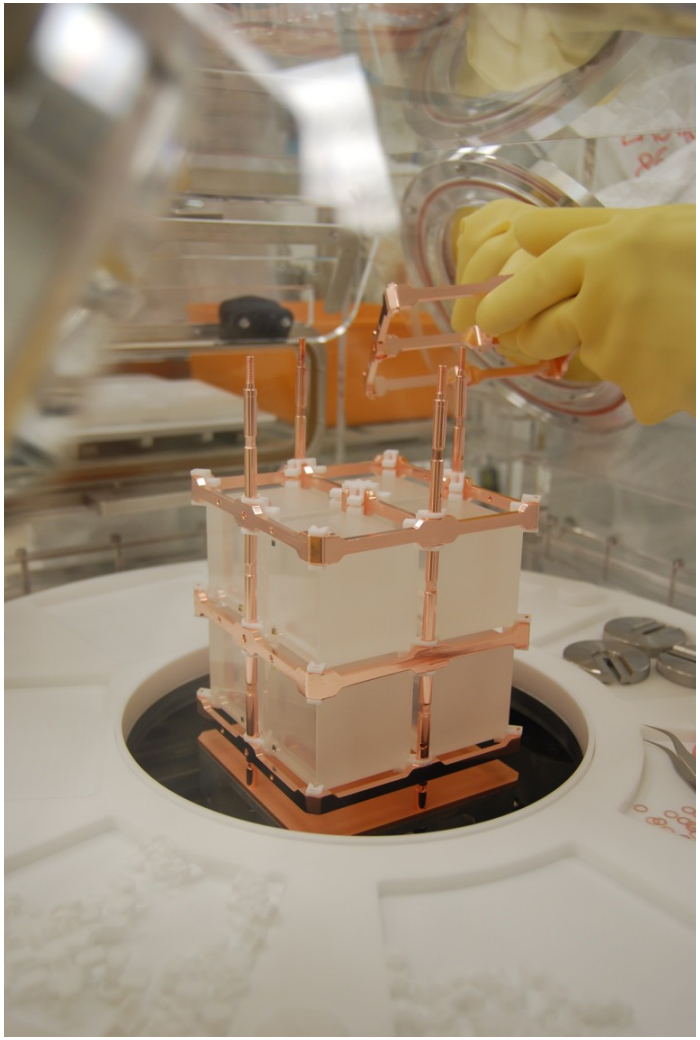


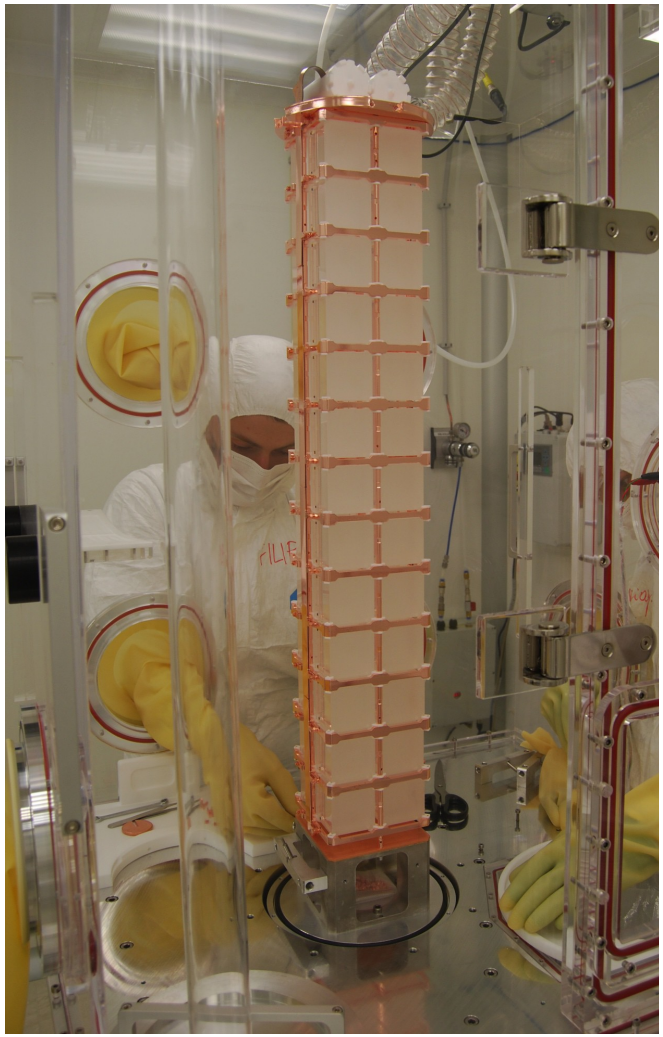
Semi-automatic gluing system to improve the reproducibility of detector performances

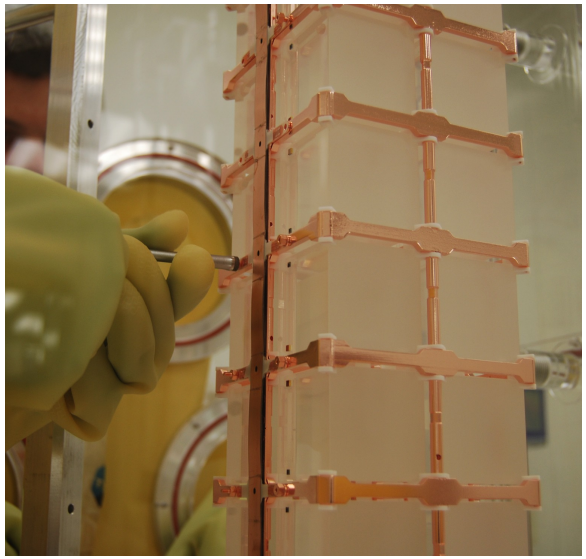
- NTD sensors
- Joule heaters (for detector gain calibration)

All operations performed in glove boxes to avoid radon recontamination

CUORE assembly



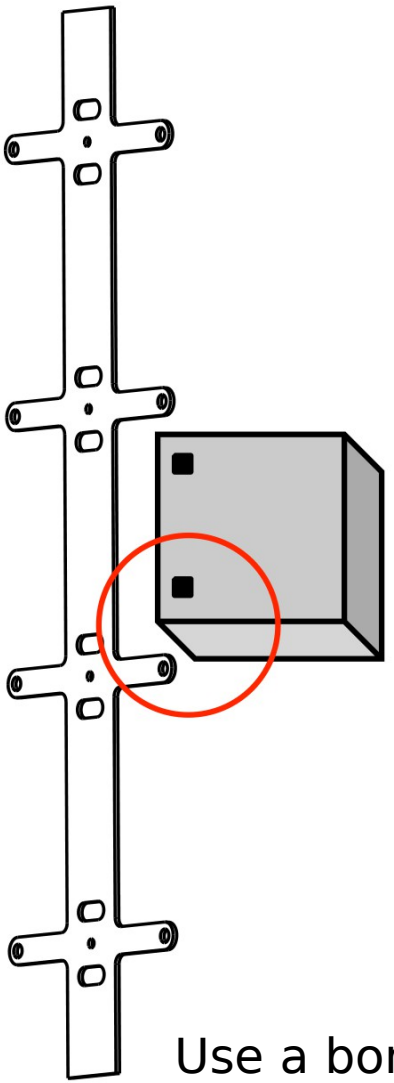


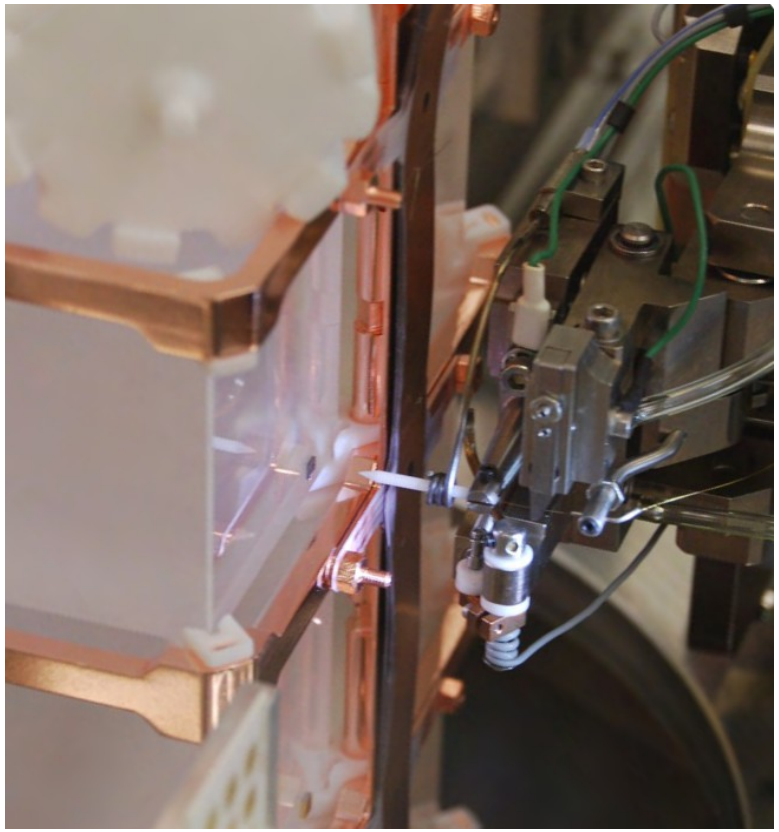


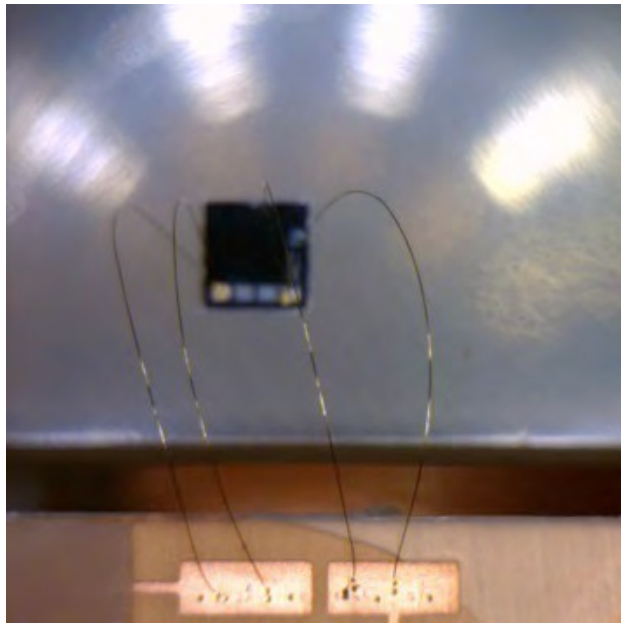
- Copper support structure
- Teflon supports
- Crystals
- PEN-Cu tapes for signal readout

All operations performed in glove boxes to avoid radon recontamination

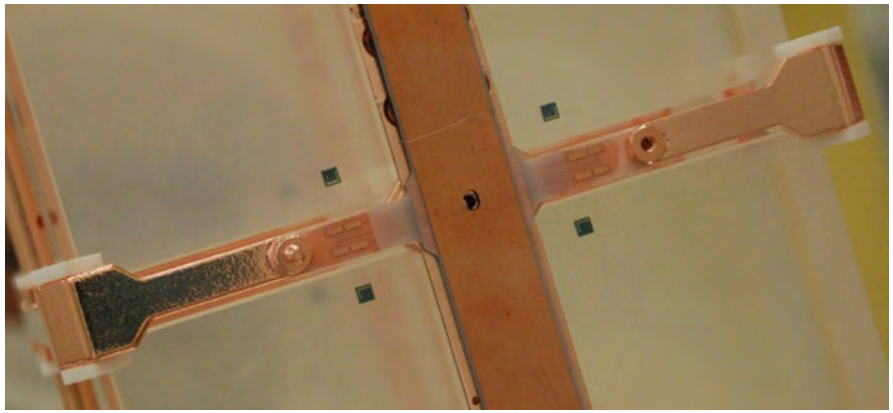
CUORE bonding







Use a bonding machine to connect the sensors and the heaters to the wire tray pads with gold wires

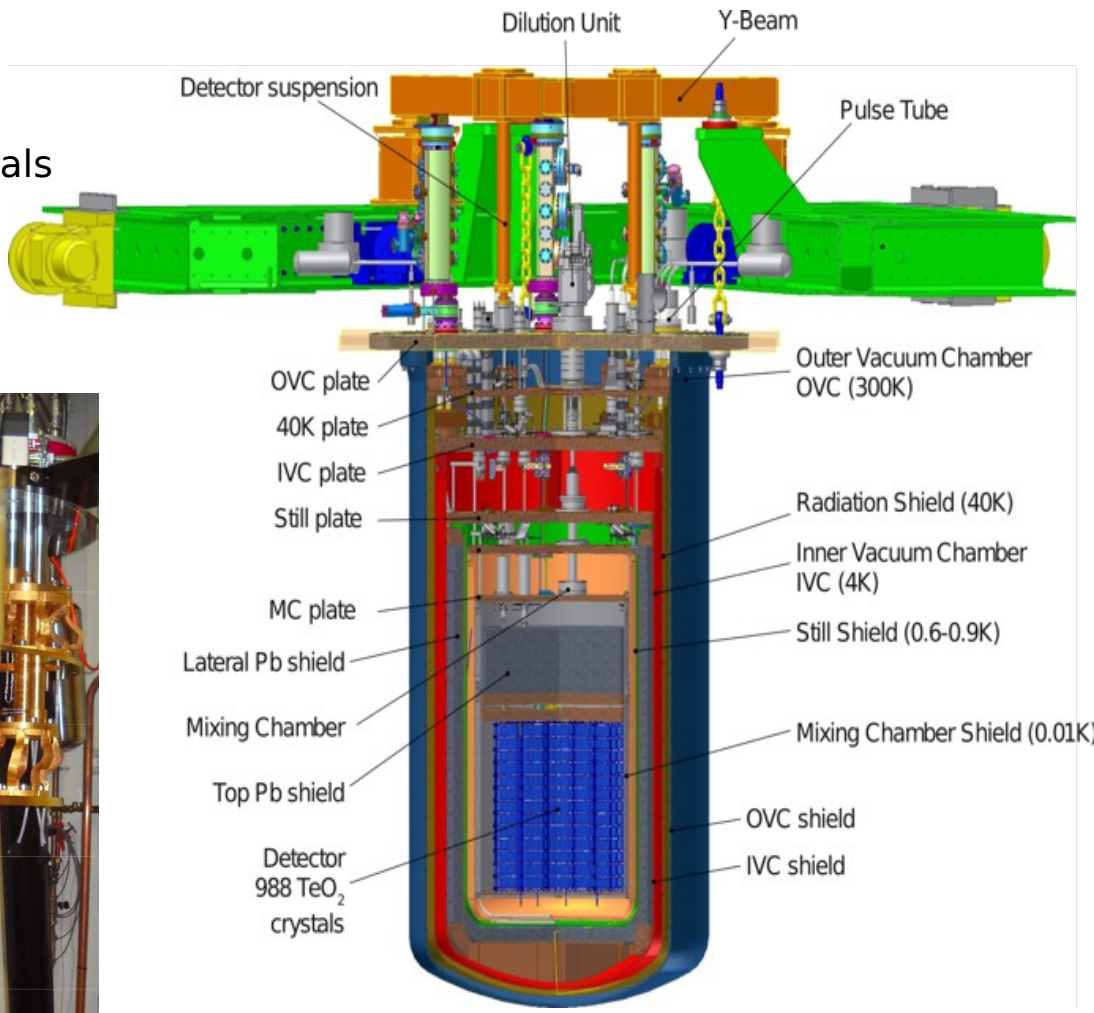


All operations performed in glove boxes to avoid radon recontamination

CUORE cryogenic apparatus

Custom dilution refrigerator

- No cryogenic liquids
- ~1 ton of detector cooled down to 10 mK
- ~20 tons of material at low temperature
- Stringent radioactivity constraints on the materials

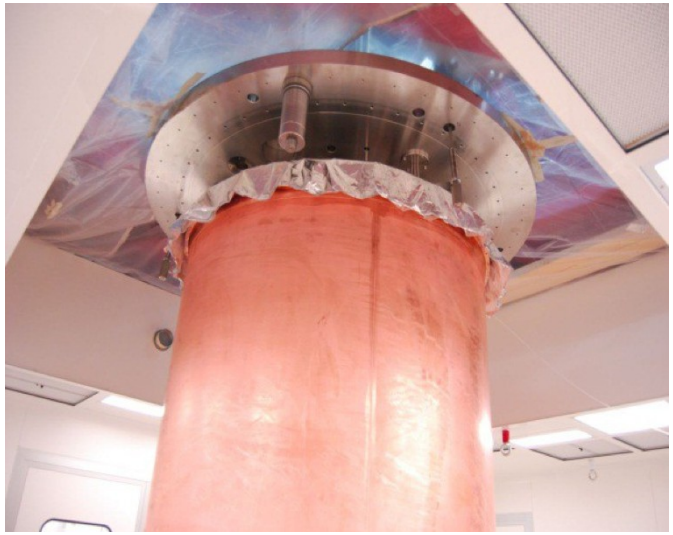


Suspension

- Multi stage suspension system
- Detectors suspension mechanically decoupled from the cryostat

Calibration

- periodic insertion of ^{232}Th source wires between the CUORE towers

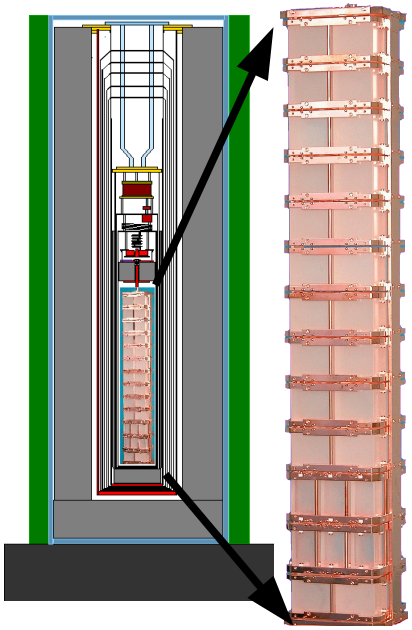


Cryogenic system underwent tests at LNGS

- IVC stable at 3K
- Dilution unit: ~5 mK reached
- Calibration system passed 4 K test

CUORICINO

Took data at LNGS between 2003 and 2008

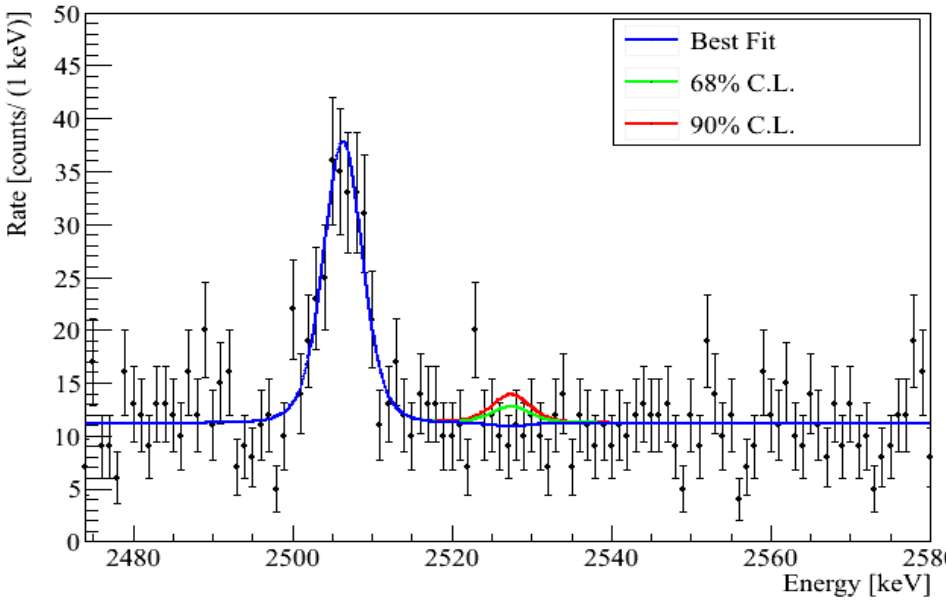


- 62 TeO_2 bolometers
- 41 kg (11.3 kg in ^{130}Te)
- Statistics: 19.75 kg y in ^{130}Te
- Resolution: 6.3 keV FWHM
- Bkg: 0.15 counts/(keV kg y)
  (790g crystals only)

$$T^{0\nu}_{1/2} > 2.8 \times 10^{24}\ y\ @\ 90\%\ CL$$

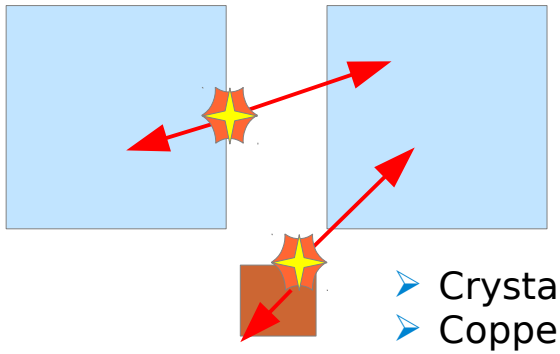
$$m_{\beta\beta} < 0.30 \div 0.71\ eV$$

Astropart. Phys. 34 (2011) 822–831



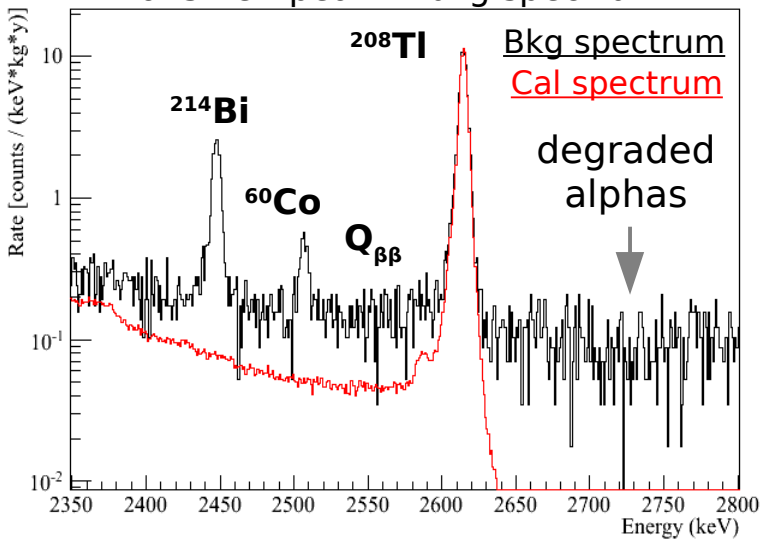
Main background contributions

- Gammas from ^{208}Tl (^{232}Th cont. in cryostat shields): (30±10)%
- Radioactive contaminations from crystal surfaces: (10±5)%
- Radioactive contaminations from Cu holders surfaces: (50±20)%

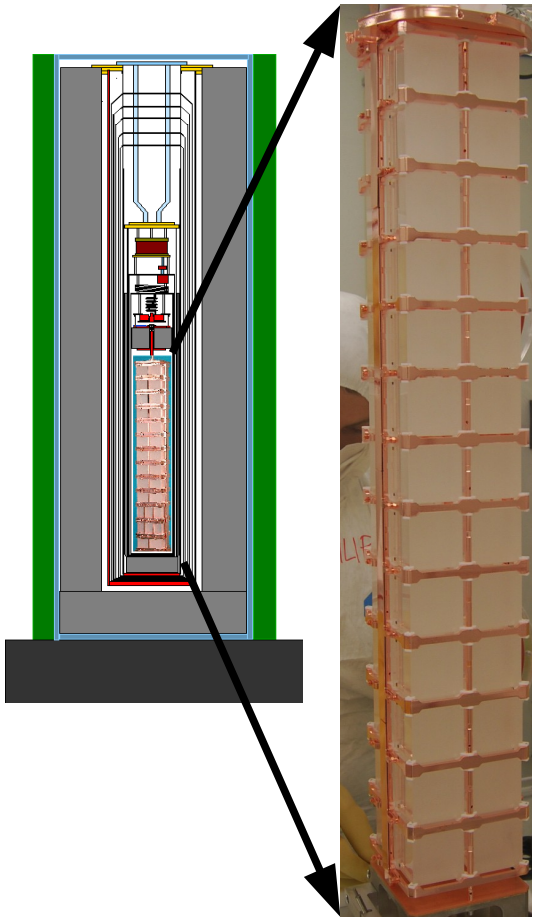


- Crystal contamination: double hit
- Copper contamination: single hit

Cal. spectrum normalized on 2615 keV peak in bkg spectrum



CUORE-0



A single CUORE-like tower

- 52 5x5x5 cm^3 natural TeO_2 bolometers
- Test CUORE cleaning procedures
- Test CUORE assembly procedures
- A sensitive 0vDBD experiment

Same detector mass as CUORICINO

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

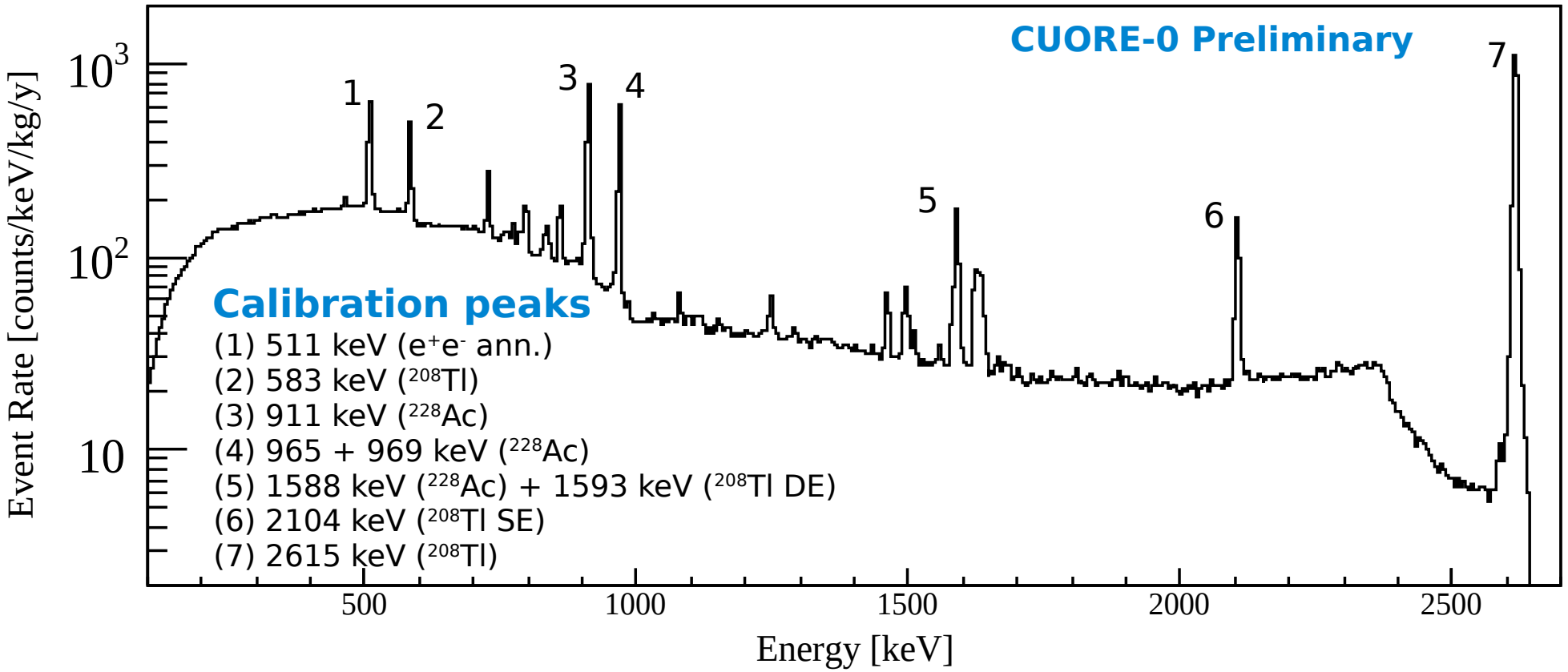
Shielding

- Internal and external lead shield
- Borated pohlyethylene shield
- Anti radon box

Started data taking in March 2013

Operated in the CUORICINO cryostat:
γ background not expected to change → study background due to near surface contaminations

CUORE-0 calibration: ^{232}Th

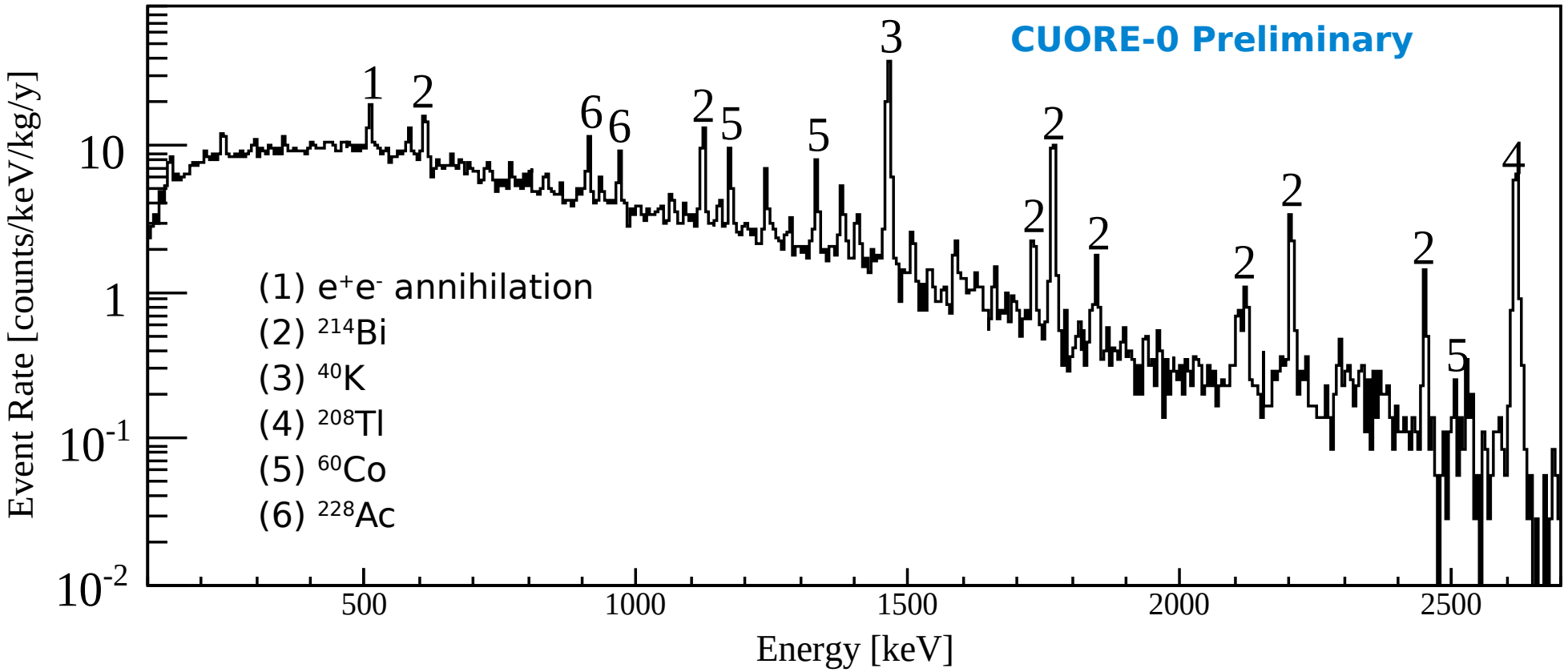


Calibration

Periodic insertion of a ^{232}Th source between the cryostat and the external lead shield

Average energy resolution: 6.3 keV FWHM

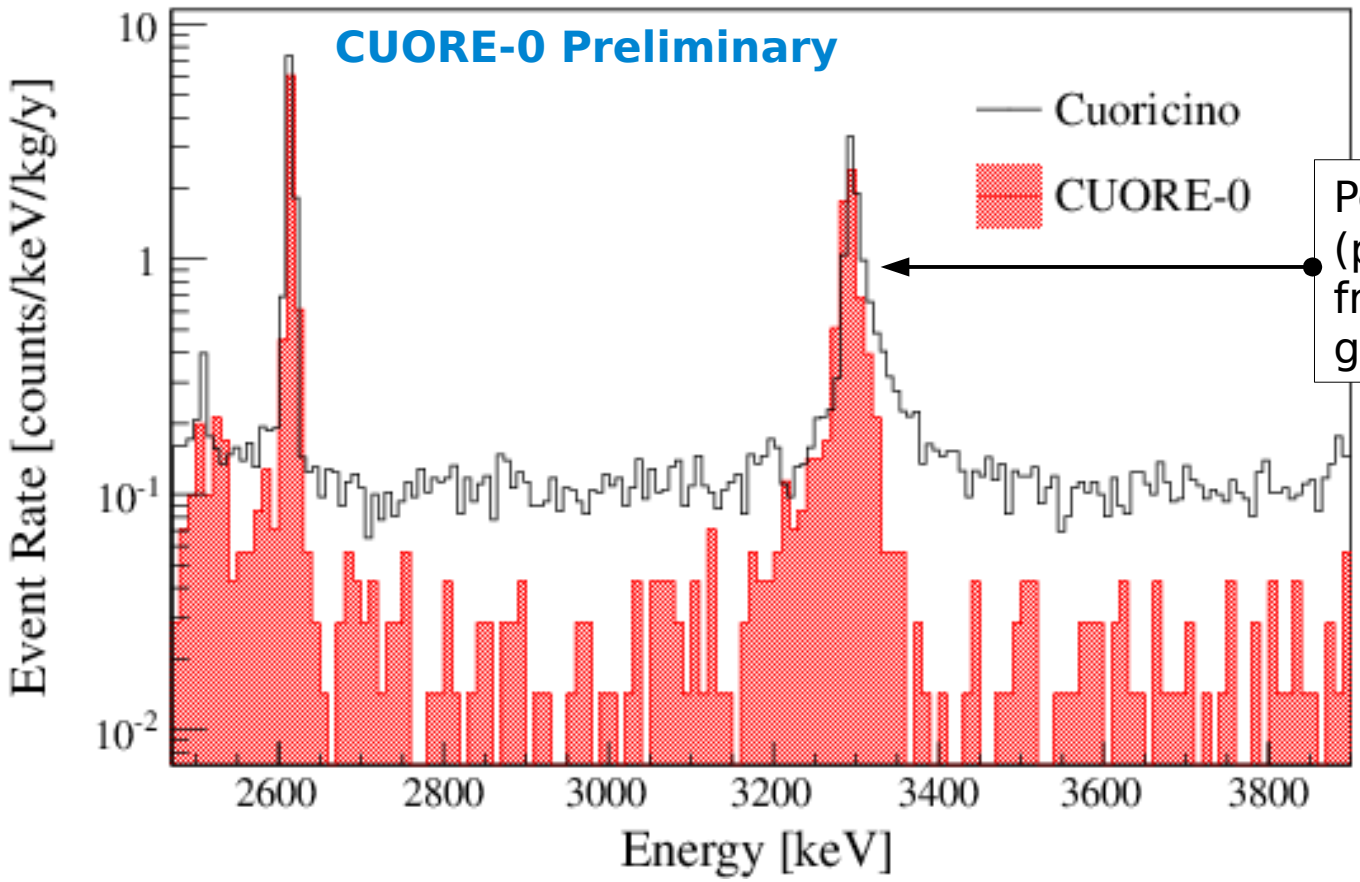
CUORE-0 background – γ region



- Energy resolution: 5.7 keV FWHM @2.6 MeV
- TeO_2 exposure: 7.1 kg y
- arXiv:1402.0922 (submitted to EPJC)

Data shown here:
March-September 2013

CUORE-0 background – α region



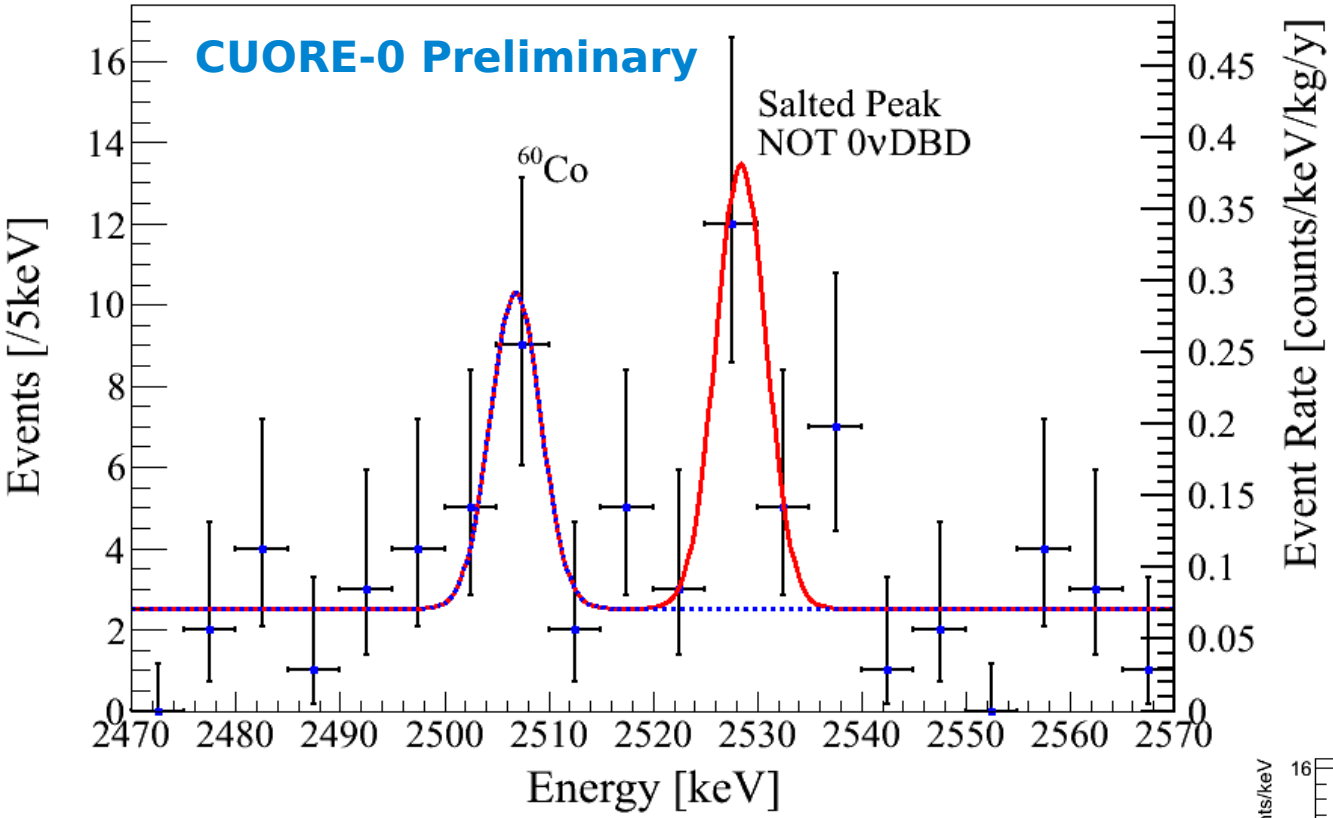
Peak from ^{190}Pt α decay (platinum contaminations from the crucibles used to grow crystals)

Data shown here:
March-September 2013

Flat background index: 0.019 ± 0.002 counts / (keV kg y)

Flat "alpha" background index evaluated in the regions
(2.7 – 3.1) MeV + (3.4 – 3.9) MeV (exclude the ^{190}Pt peak)

CUORE-0 background: DBD region (blinded)



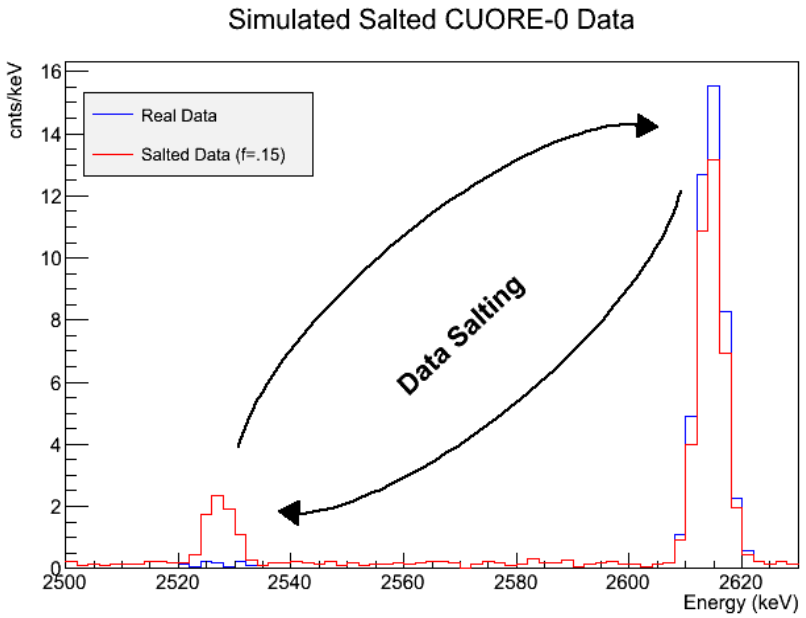
Data shown here:
March-September 2013

Flat background in ROI

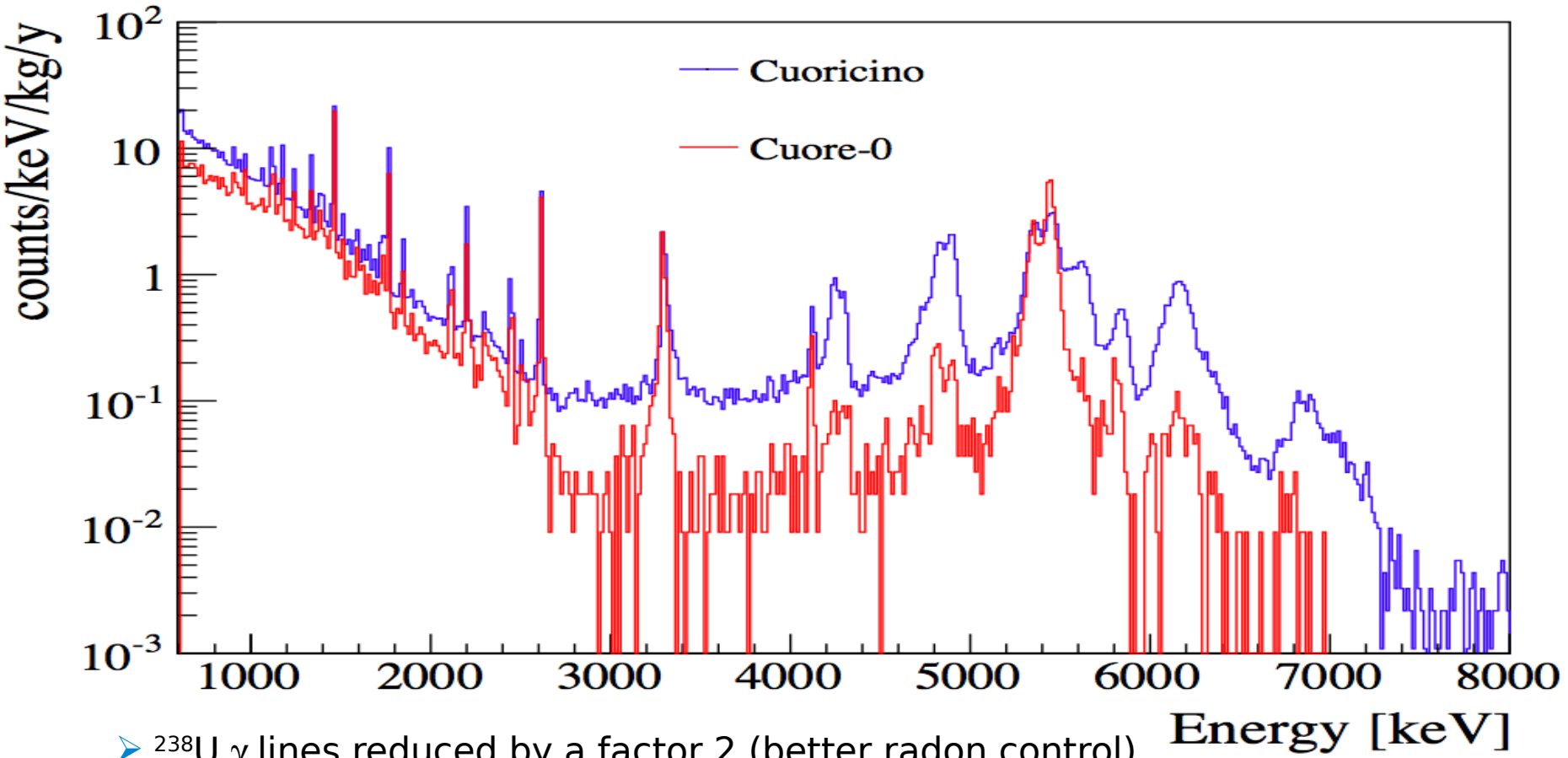
0.071 ± 0.011 cts/(keV kg y)

Blinding procedure

Exchange a small (blinded) fraction of ^{208}Tl events (2615 keV) with events in the 0νDBD region, producing a fake peak



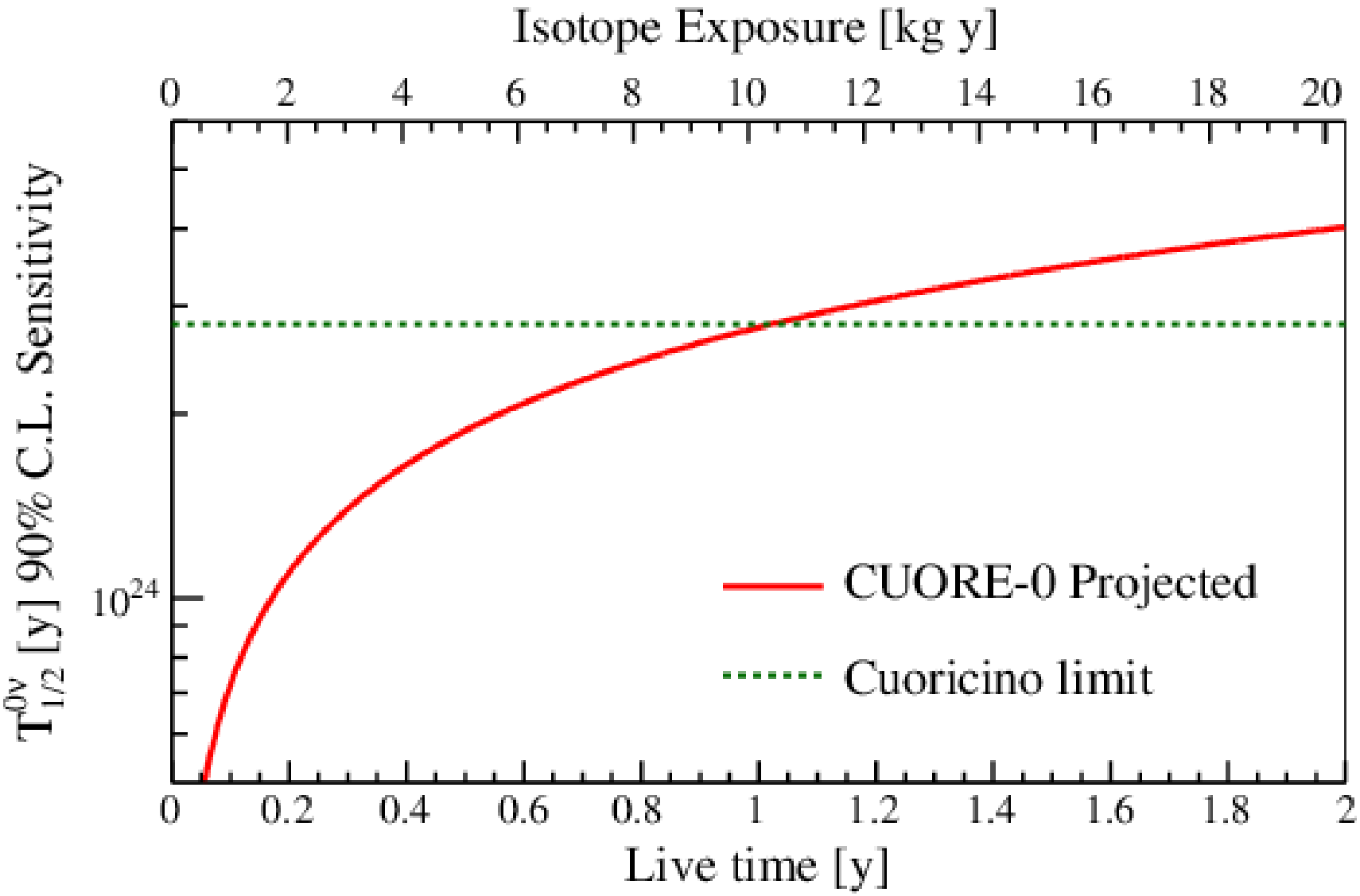
CUORE-0 vs Cuoricino



- ^{238}U γ lines reduced by a factor 2 (better radon control)
- ^{232}Th γ lines unchanged (originate from the cryostat)
- ^{238}U and ^{232}Th α lines reduced (improved detector surface cleaning)

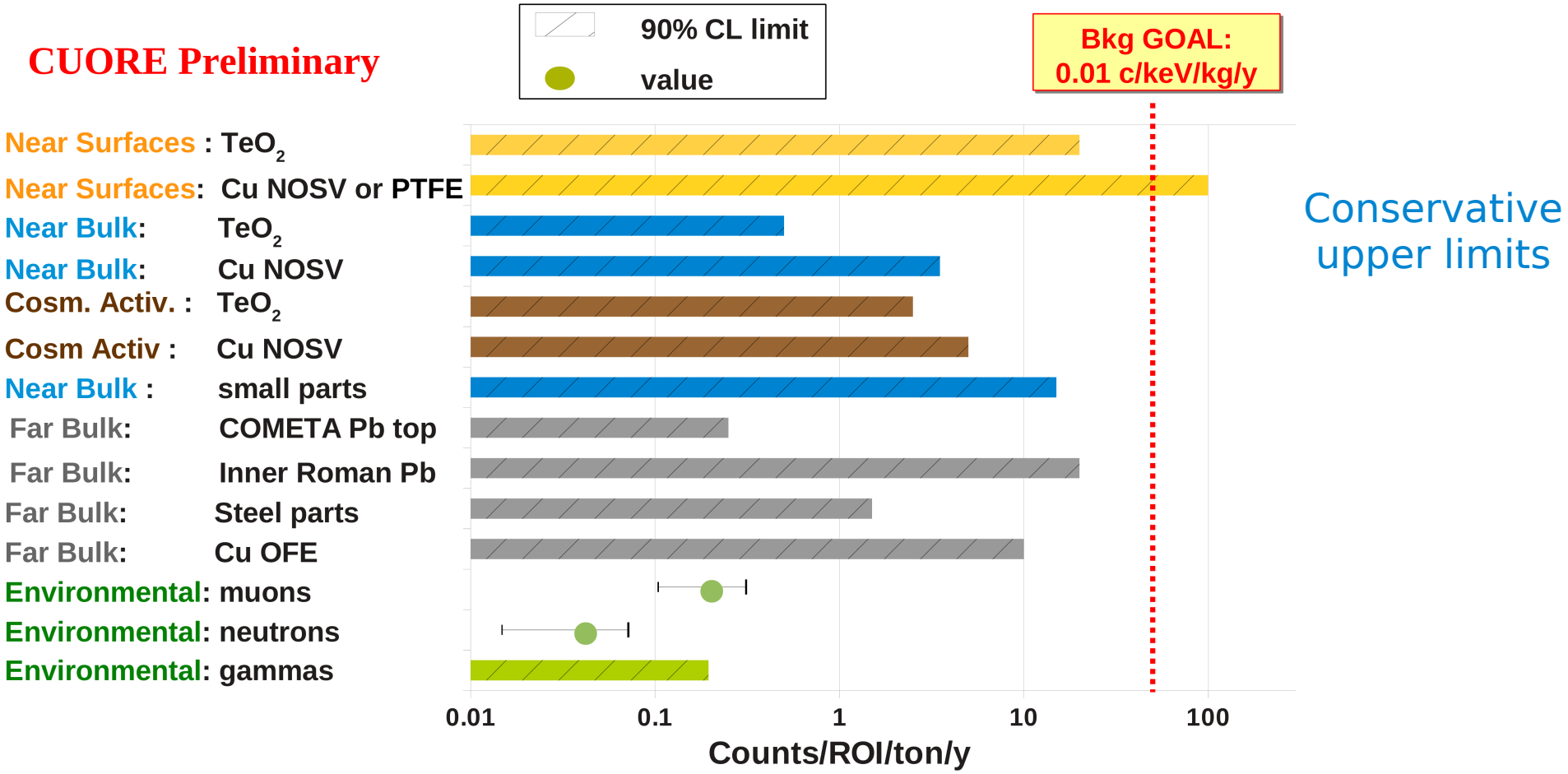
Flat background	Avg flat bkg [counts/(keV kg y)]		Signal efficiency [%]
	0vDBD region	2.7 – 3.9 MeV region	(detector + cuts)
CUORICINO	0.153 ± 0.006	0.110 ± 0.001	82.8 ± 1.1
CUORE-0	0.071 ± 0.011	0.019 ± 0.002	80.4 ± 1.9

CUORE-0 sensitivity



CUORE background

- New cryostat with radio-pure materials: γ contributions are made negligible
- Less copper surface facing the crystals: α bkg from copper surfaces can be reduced
- More crystal surfaces facing each others: more effective anticoincidence, negligible α bkg from crystal surfaces



Conservative upper limits

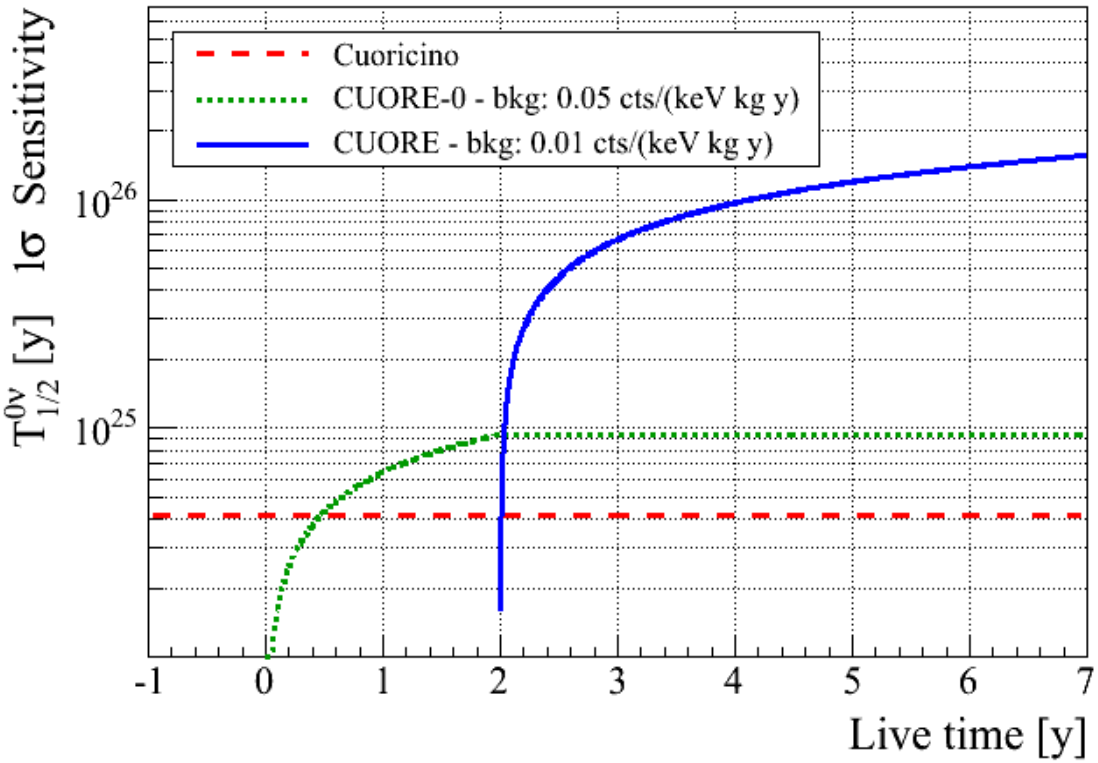
CUORE sensitivity

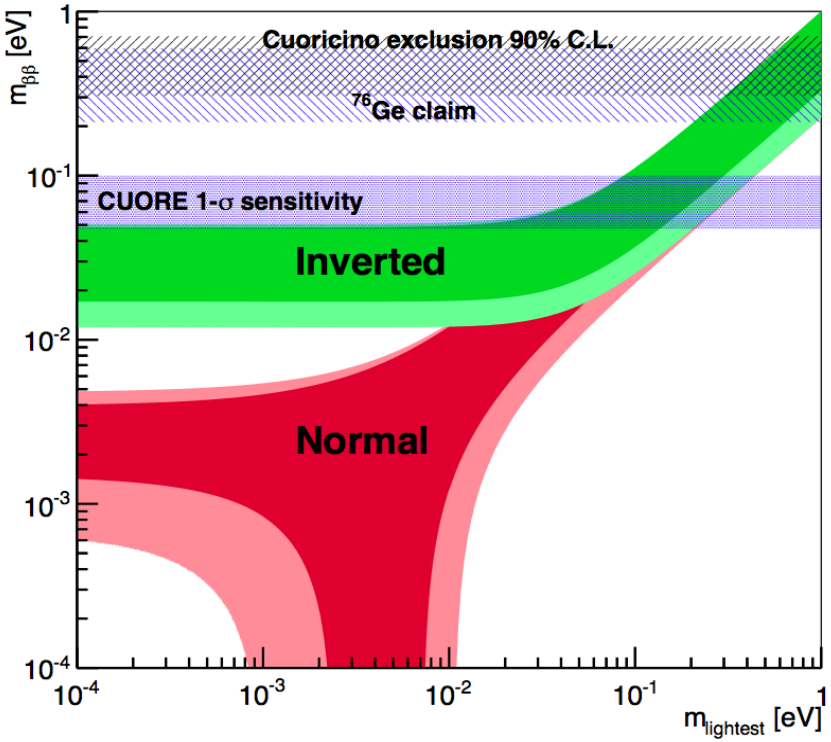
CUORE 0vDBD half life sensitivity

- 1σ: 1.6 x 10^{26} y or $m_{\beta\beta}$ < 39 – 102 meV
- 90% CL: 9.5 x 10^{25} y or $m_{\beta\beta}$ < 51 – 133 meV

Assumptions

- Background: 0.01 counts/(keV kg y)
- Resolution: 5 keV FWHM
- Live time: 5y





Conclusions

CUORE-0

- Successful test of the CUORE assembly procedure
- Started data taking in March 2013
- Resolution: 5.7 keV FWHM at 2.6 MeV
- Bkg in the α region: 0.019 cts/(keV kg y)

CUORE

- Commissioning in progress
- Cool down and data taking in 2015