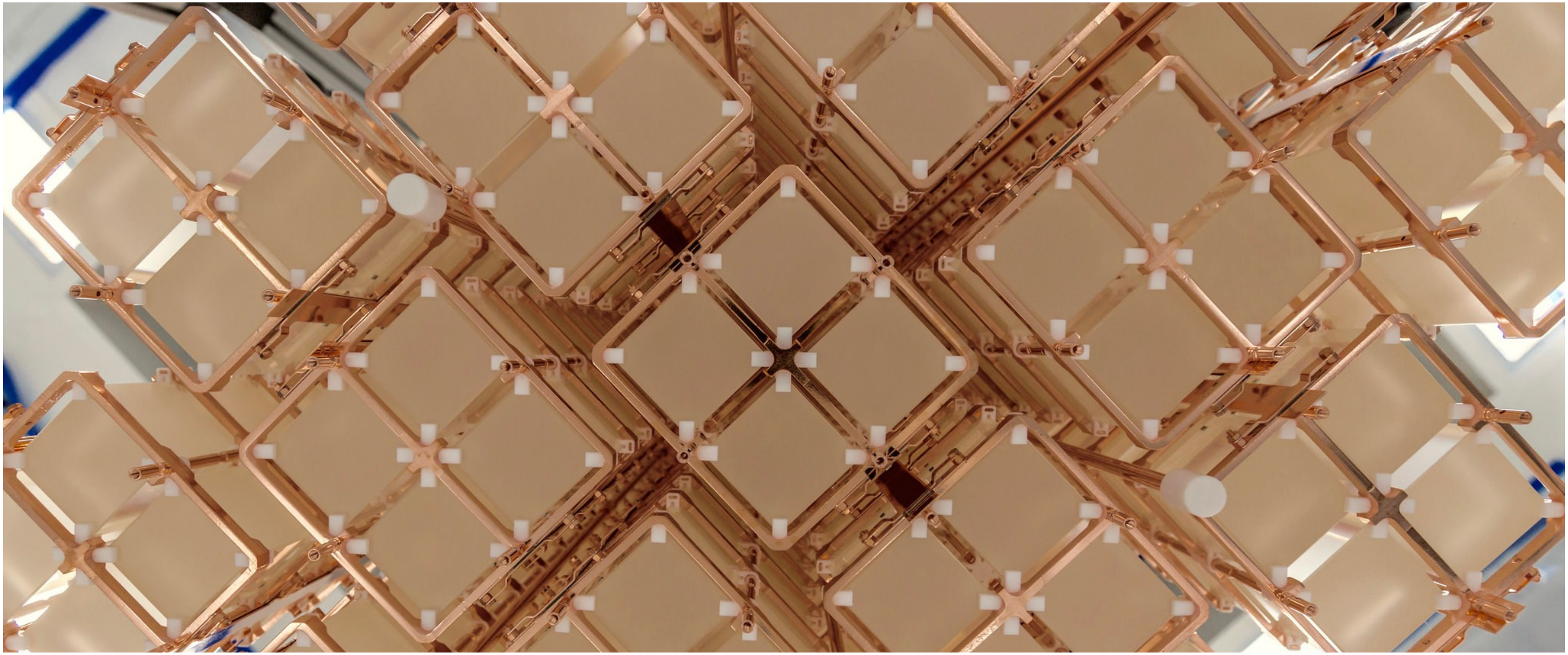


The CUORE experiment at LNGS

Stefano Pozzi
Università/INFN Milano-Bicocca

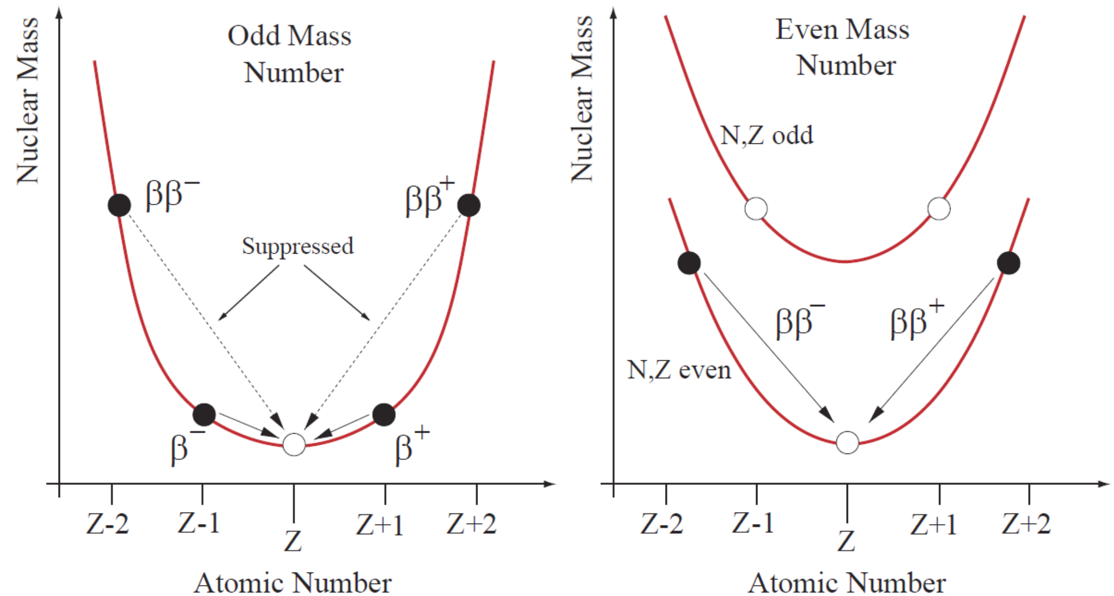
CUORE

INFN Istituto Nazionale di Fisica Nucleare

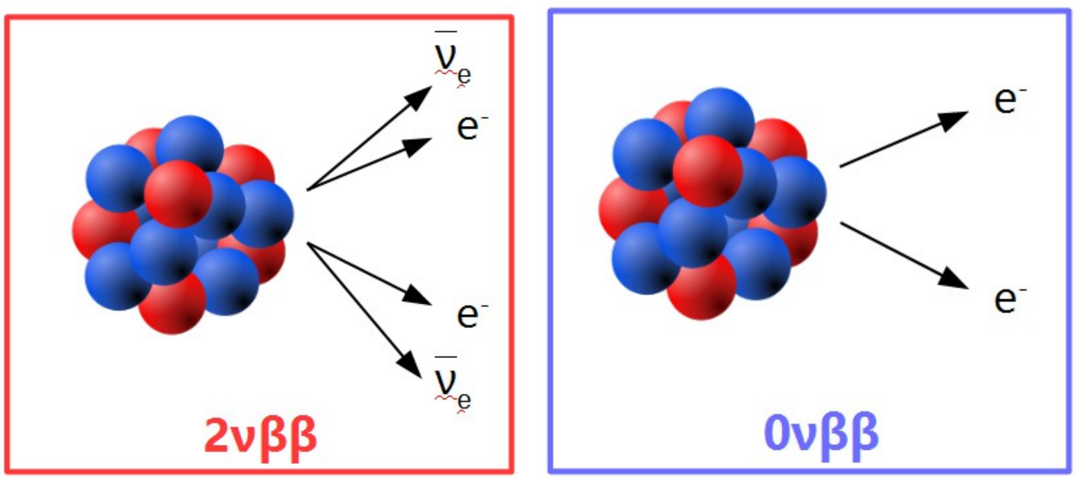
Neutrino Telescopes, 13-17 March 2017, Venice (Italy)

Double-beta decay

- 2^{nd} order weak interaction, allowed only for a small set of nuclei

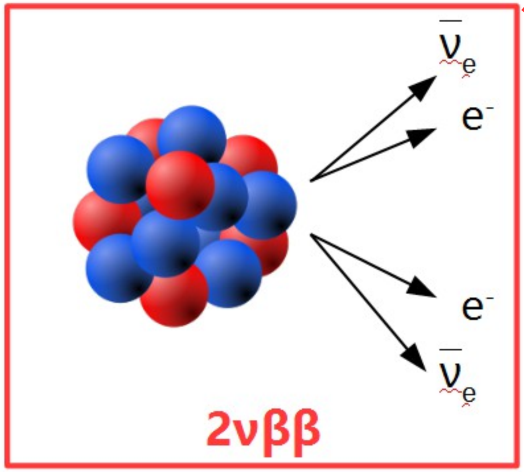


- SM-allowed
- Observed

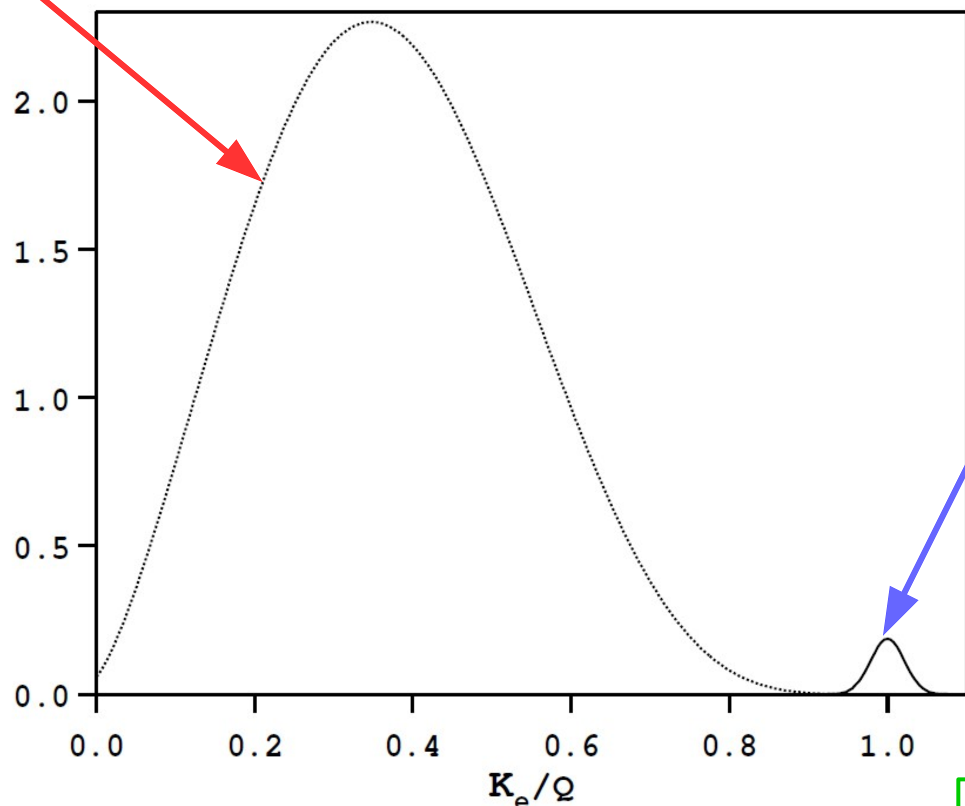


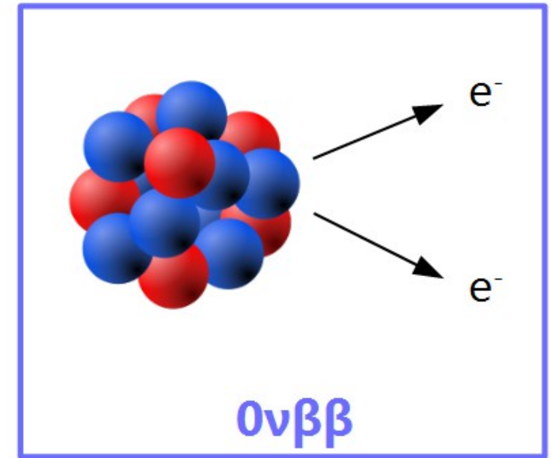
- Lepton number violation
- Neutrinos are their own antiparticle

Experimental signature



Continuum
0 - $Q_{\beta\beta}$





Peak at $Q_{\beta\beta}$

Sensitivity:

$$T^{0\nu}_{1/2}(n_\sigma) \propto \frac{1}{n_\sigma}\frac{\epsilon \cdot i.a.}{A}\sqrt{\frac{M \cdot t}{b \cdot \Delta E}}$$

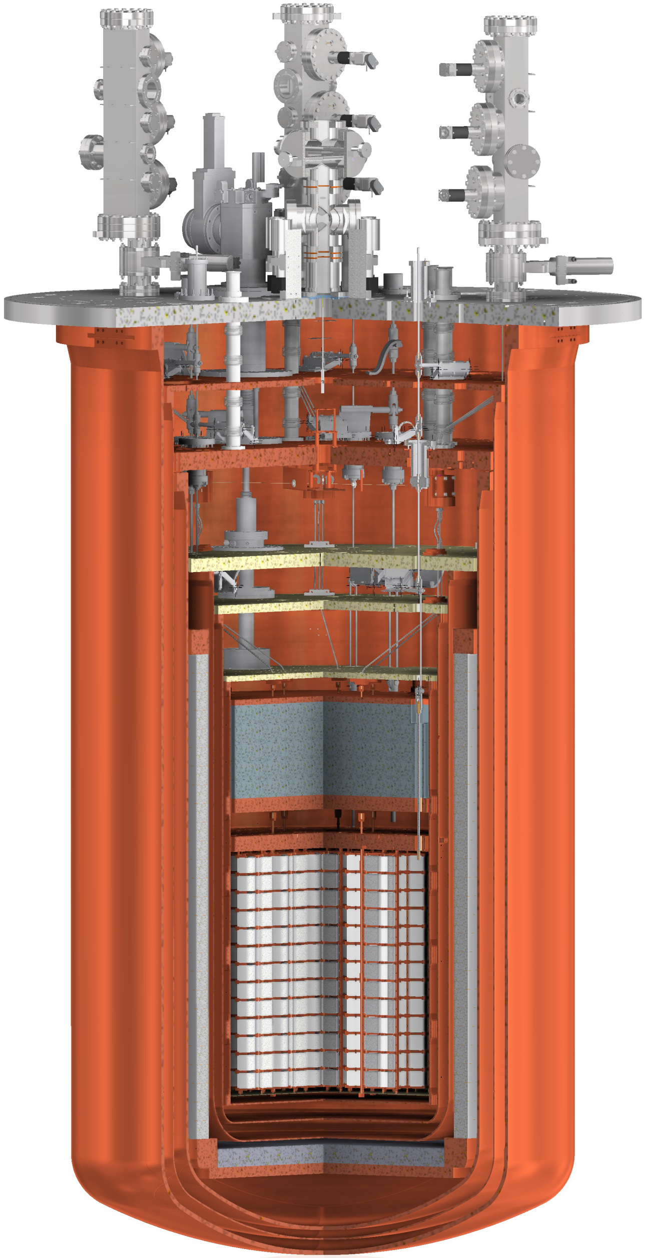
2νββ : unavoidable background to 0νββ

CUORE

CUORE

- **C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents
- Search for $0\nu\beta\beta$ in ^{130}Te
- Located at LNGS (Gran Sasso National Laboratory), in central Italy
  - Average depth: 3600 m.w.e.
  - $(2.58 \pm 0.3)\cdot 10^{-8}$ μ/s/cm^2
  - $4\cdot 10^{-6}$ neutrons/s/cm^2 (<10 MeV)
  - 0.73 γ/s/cm^2 (<3 MeV)

CUORE



- 988 TeO_2 crystals, 5x5x5 cm^3 each
- Total mass: 742 kg TeO_2 (natural Te)
- ^{130}Te mass: 206 kg
- Crystals operated as bolometers in a cryostat capable of reaching T < 10mK

$$T^{0\nu}_{1/2}(n_\sigma) \propto \frac{1}{n_\sigma} \frac{\epsilon \cdot i.a.}{A} \sqrt{\frac{M \cdot t}{b \cdot \Delta E}}$$

Goals

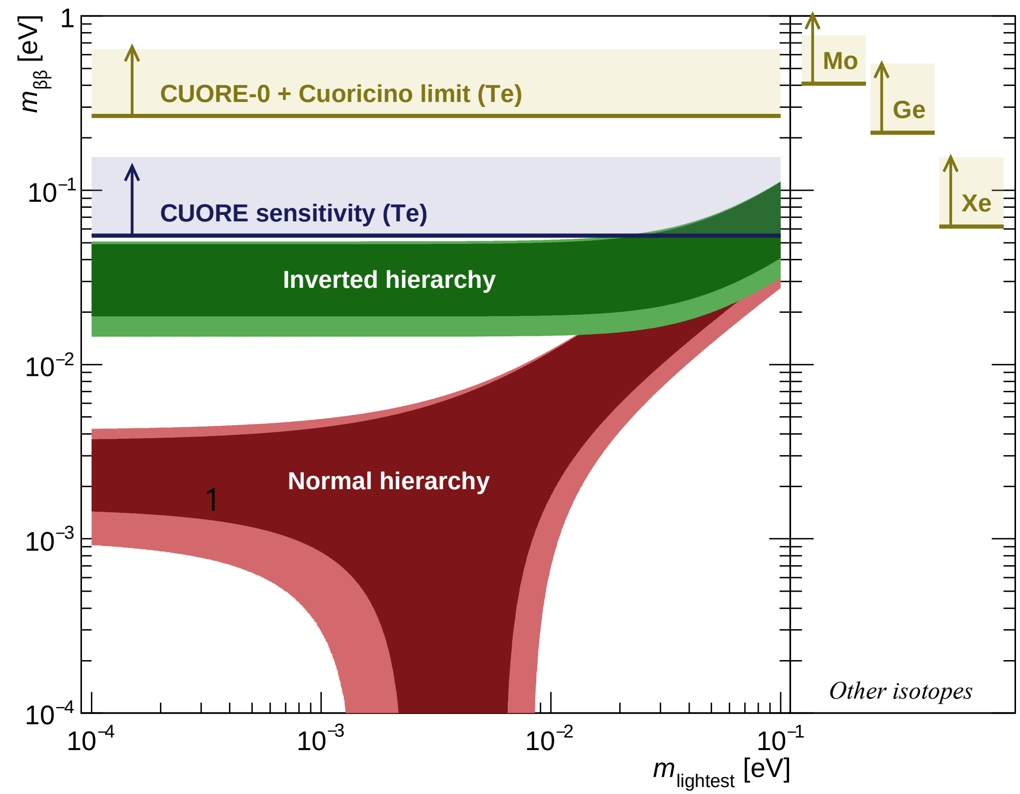
- ΔE : 5 keV FWHM @$Q_{\beta\beta}$
- *b* : 0.01 counts/(keV·kg·y)
- *t* : 5 years livetime

CUORE: sensitivity

$$[T^{0\nu}_{1_2}]^{-1} = G_{0\nu}|M_{0\nu}|^2\langle m_{\beta\beta}\rangle^2$$

Goals

- ΔE : 5 keV FWHM @$Q_{\beta\beta}$
- b : 0.01 counts/(keV·kg·y)
- t : 5 years livetime

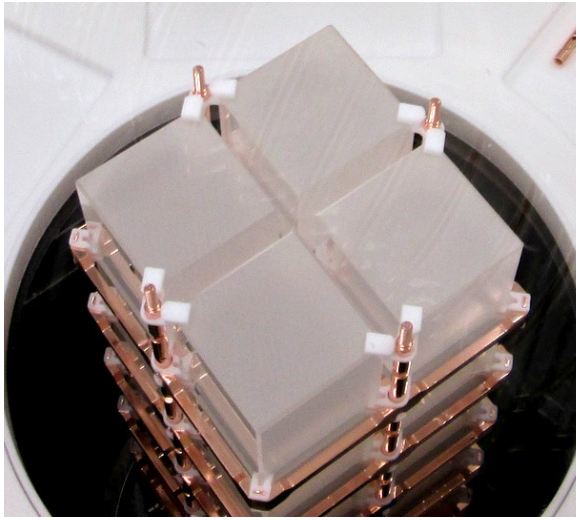


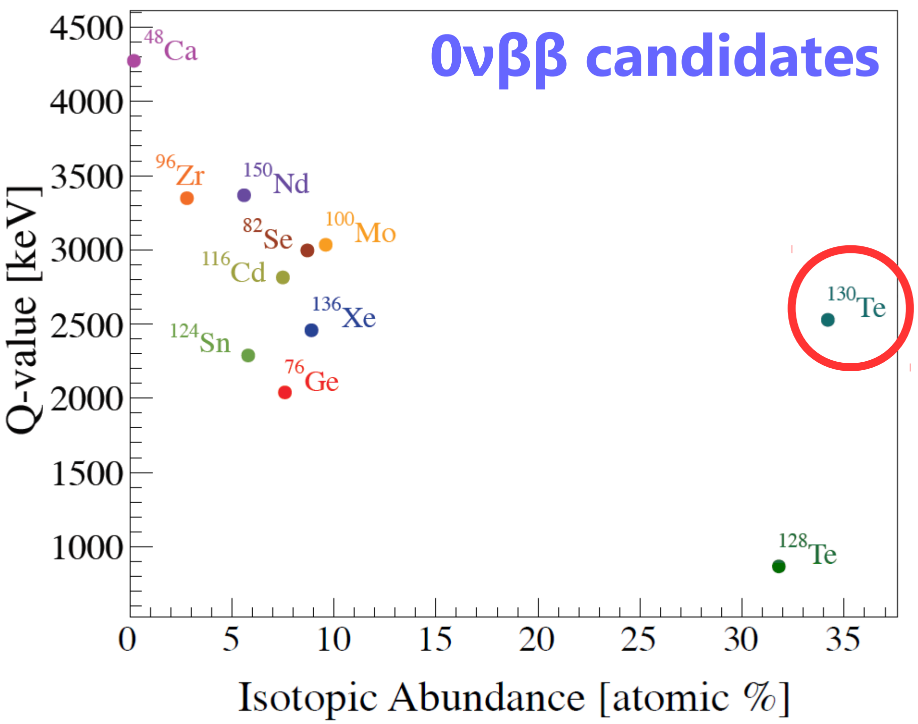
$T_{1/2}$ > 9.5 x 10^{25} yr (90% C.L.)

$m_{\beta\beta}$ < (50 – 130) meV

May come close to inspecting IH region, depending on NME

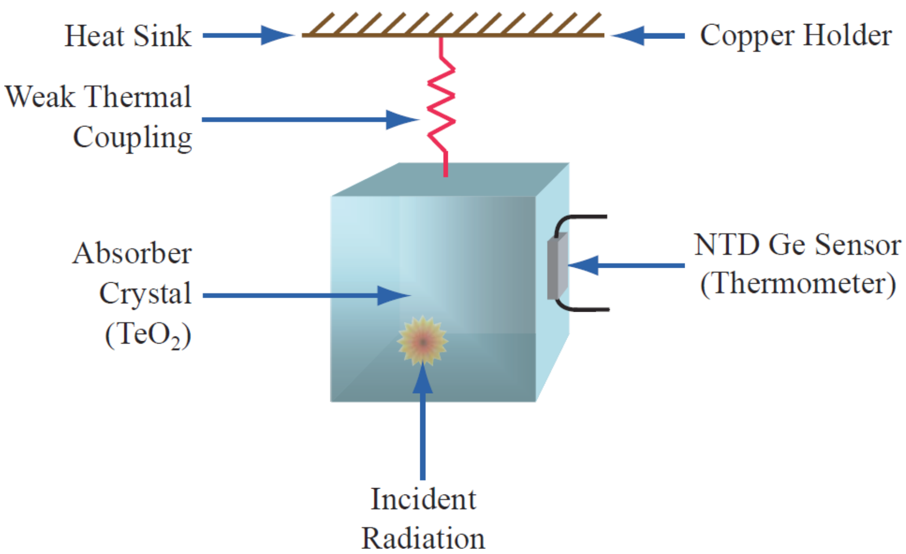
TeO_2

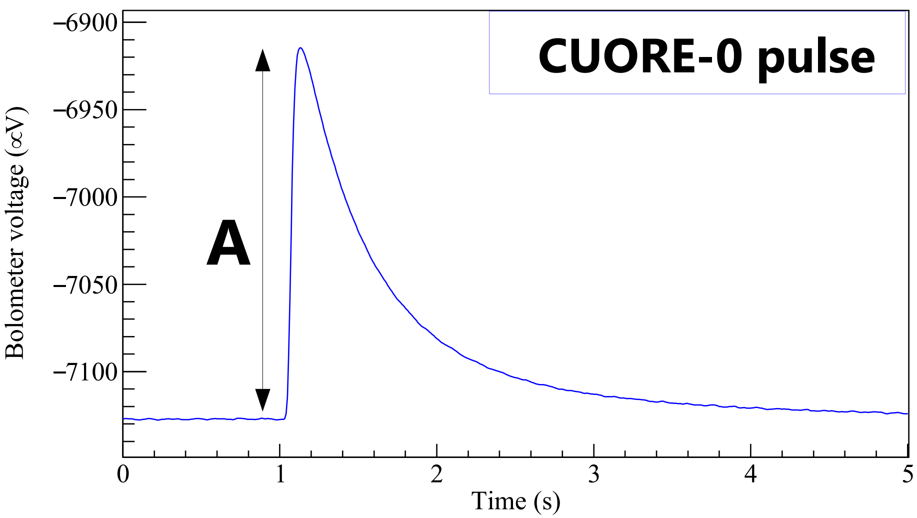




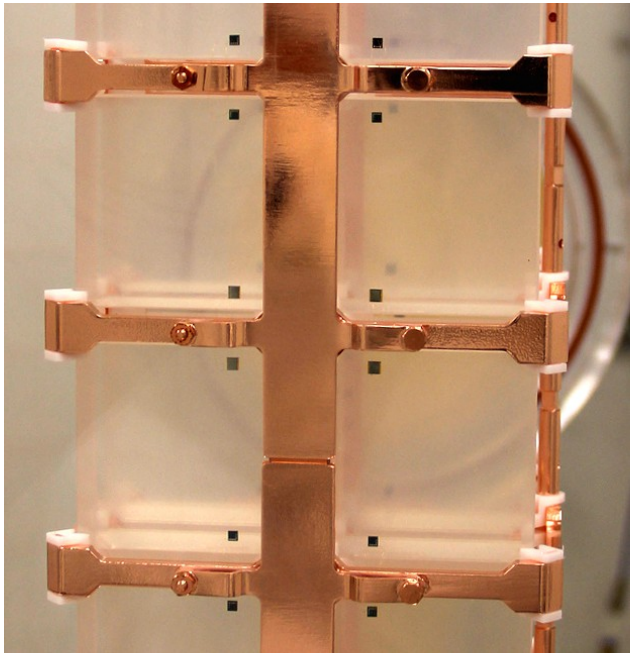
- High natural isotopic abundance of source isotope (^{130}Te)
- ^{130}Te included in the detector: high efficiency
- $Q_{\beta\beta}$ = 2527.5 keV, in a region with relatively low β/γ background
- Excellent energy resolution (5 keV FWHM @ $Q_{\beta\beta}$)
- Reproducible growth of high quality crystals

Detector principle



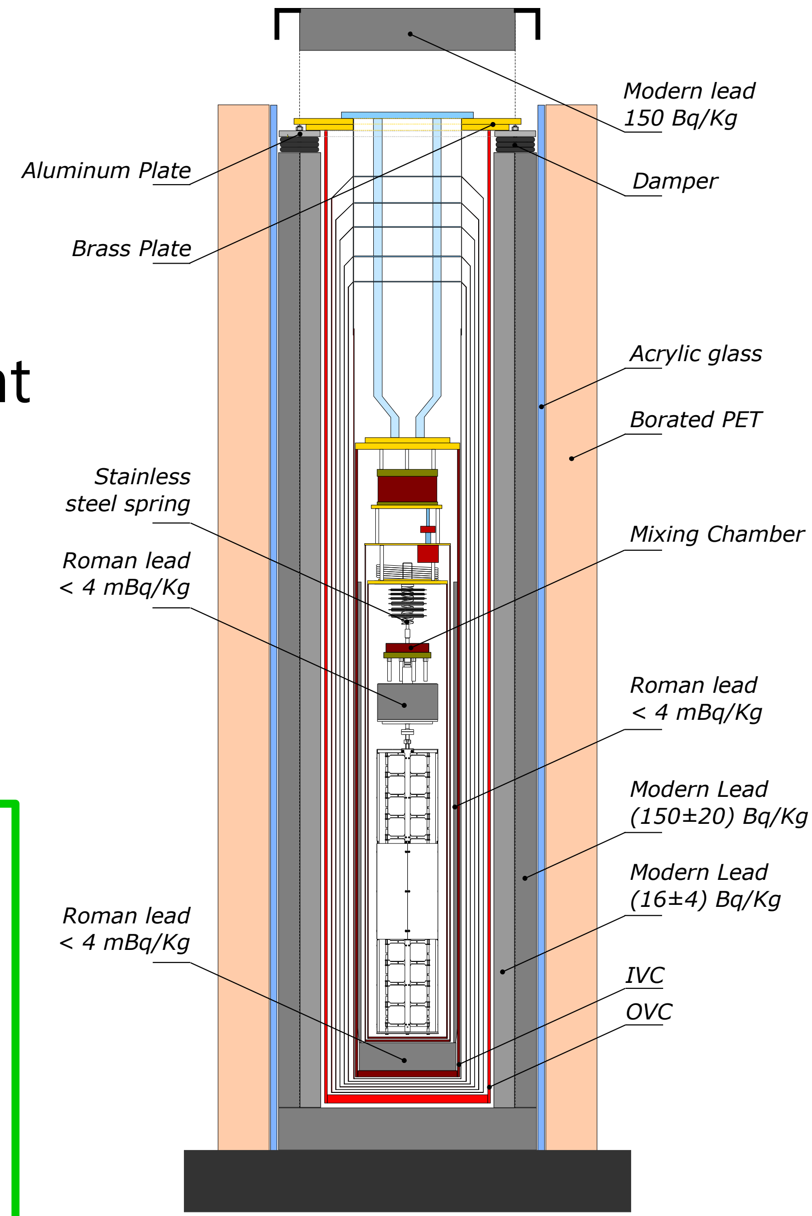


- Energy deposition converted into a temperature rise: $\mathbf{A \propto E/C(T)}$
- Need to work at extremely low temperature, as $\mathbf{C(T) \propto T^3}$
- Signal readout with an NTD Ge sensor
  $\mathbf{R_{NTD} \propto exp(\ 1/T^{1/2}\ )}$
- Heat dissipated to the Cu holder; base temperature restored in a few seconds



CUORE-0

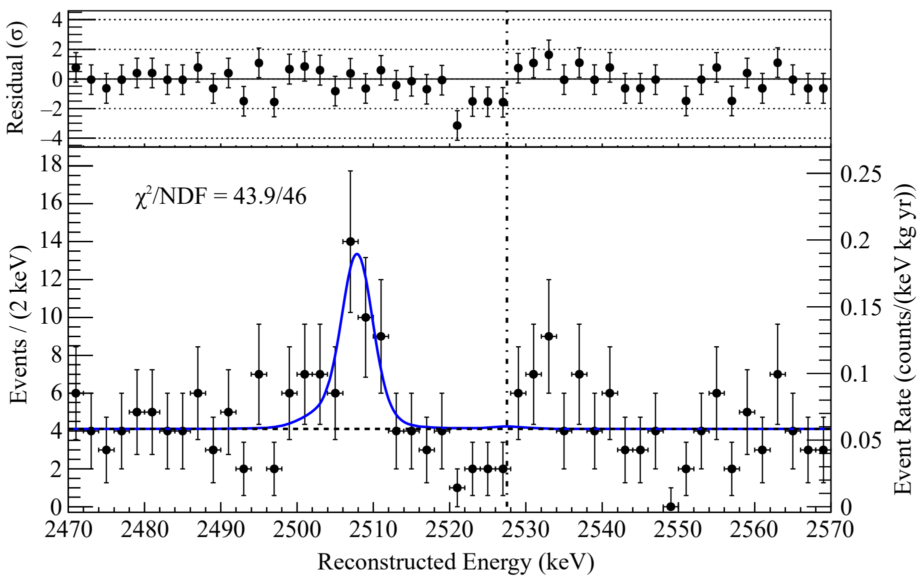
- First tower built by the CUORE tower assembly line
- 52 TeO_2 (10.9 kg ^{130}Te) crystals operated in the old Cuoricino cryostat
- 9.8 kg·y ^{130}Te exposure
- Test of material selection & surface cleaning

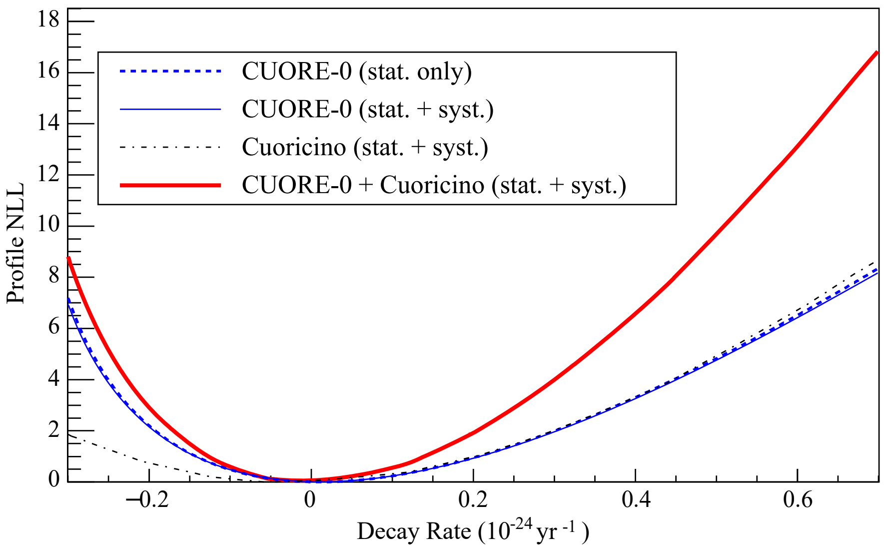


- ✔ Most stringent limit on $0\nu\beta\beta$ half-life in ^{130}Te
- ✔ Most precise measurement of $2\nu\beta\beta$ half-life in ^{130}Te

(2016) JINST 11 P07009

CUORE-0 : 0νββ





- ΔE_{FWHM} = 5.1±0.3 keV @ 2528 keV
- Bkg = 0.058 ± 0.004 ± 0.002 counts/(keV·kg·y)

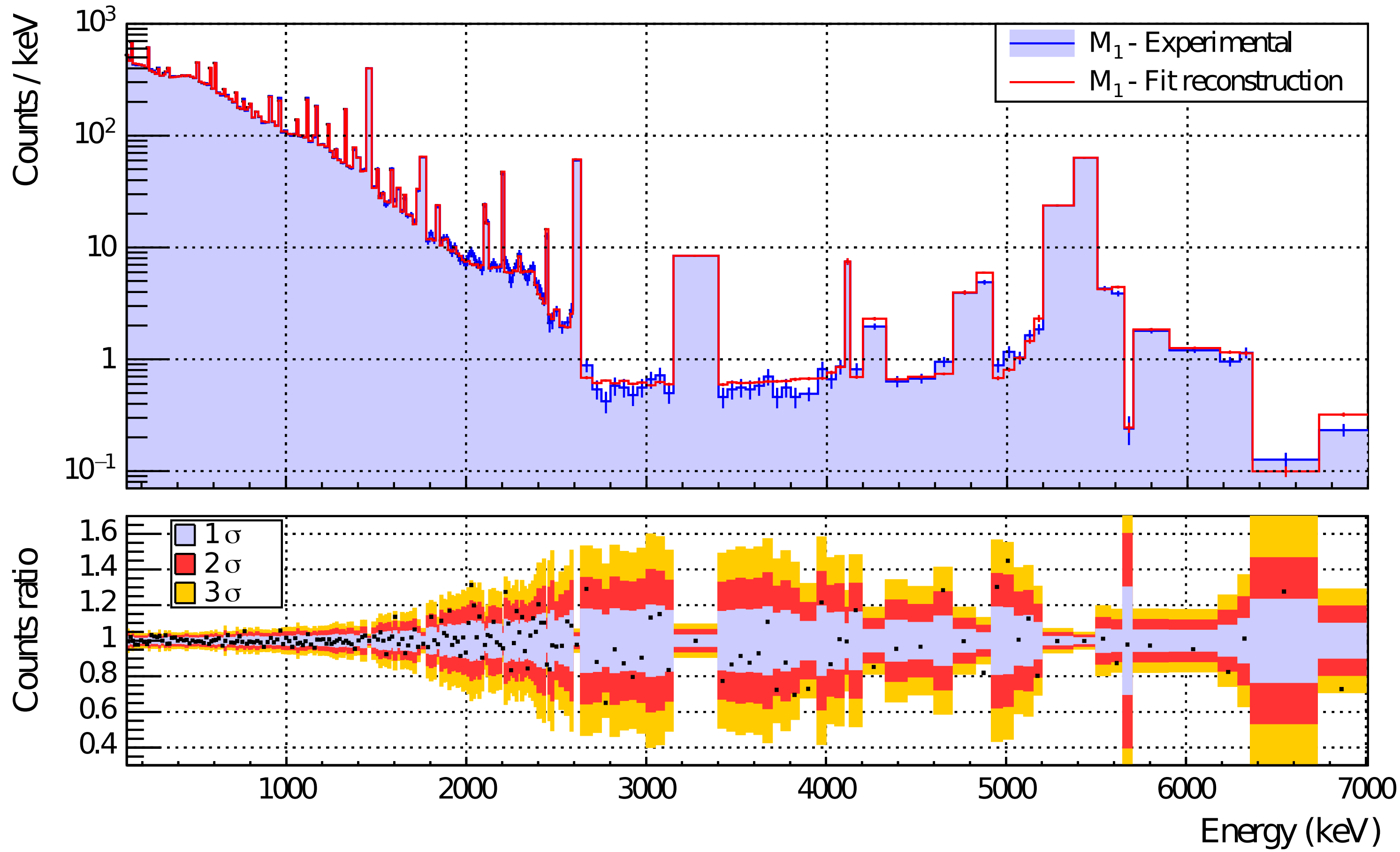
Mostly from the old Cuoricino cryostat

Combination with Cuoricino (90% C.L.)

$T^{0\nu\beta\beta}_{1/2}$ **> 4.0 x 10^{24} yr**

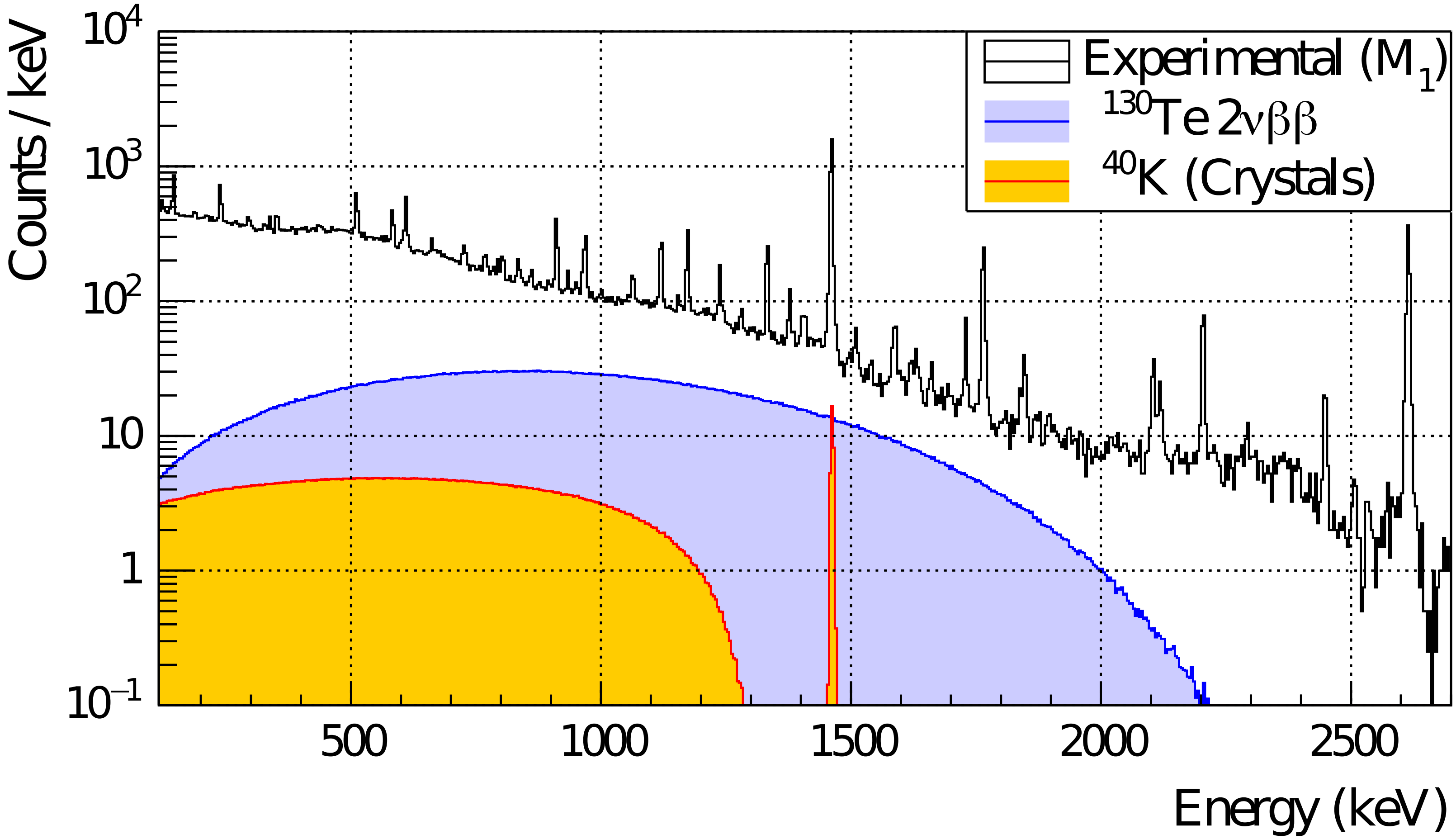
(2015) Phys. Rev. Lett. 115, 102502
(2016) Phys. Rev. C 93, 045503

CUORE-0 : Background model



Previous knowledge (HPGe measurements, cosmogenic activation) + CUORE-0 data (α/γ lines, coincidence analysis) = Full reconstruction of background sources

CUORE-0 : 2νββ

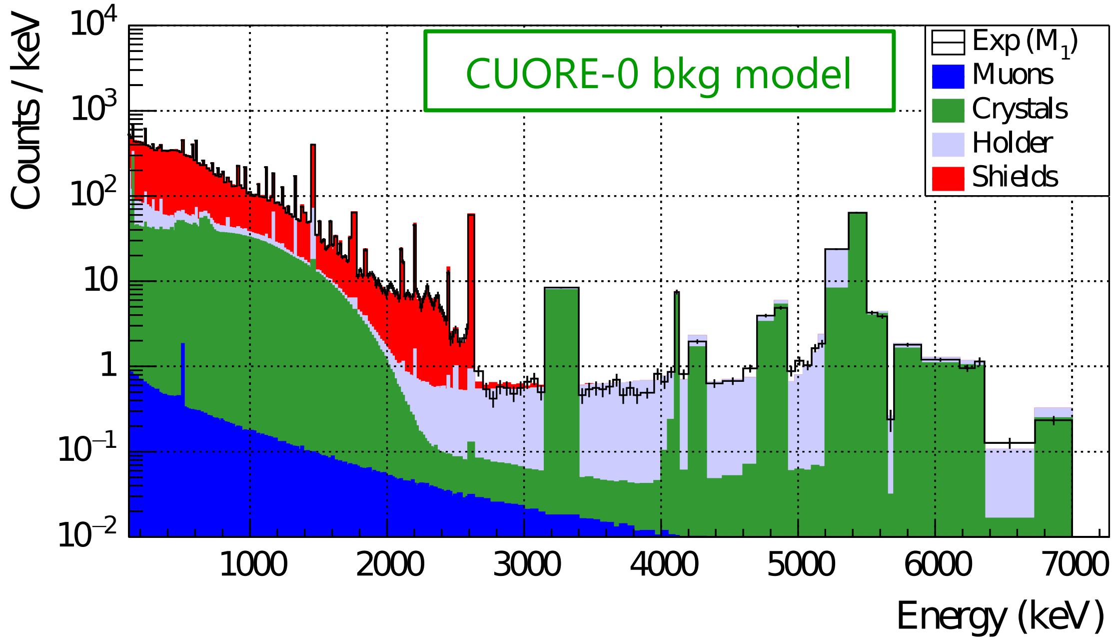


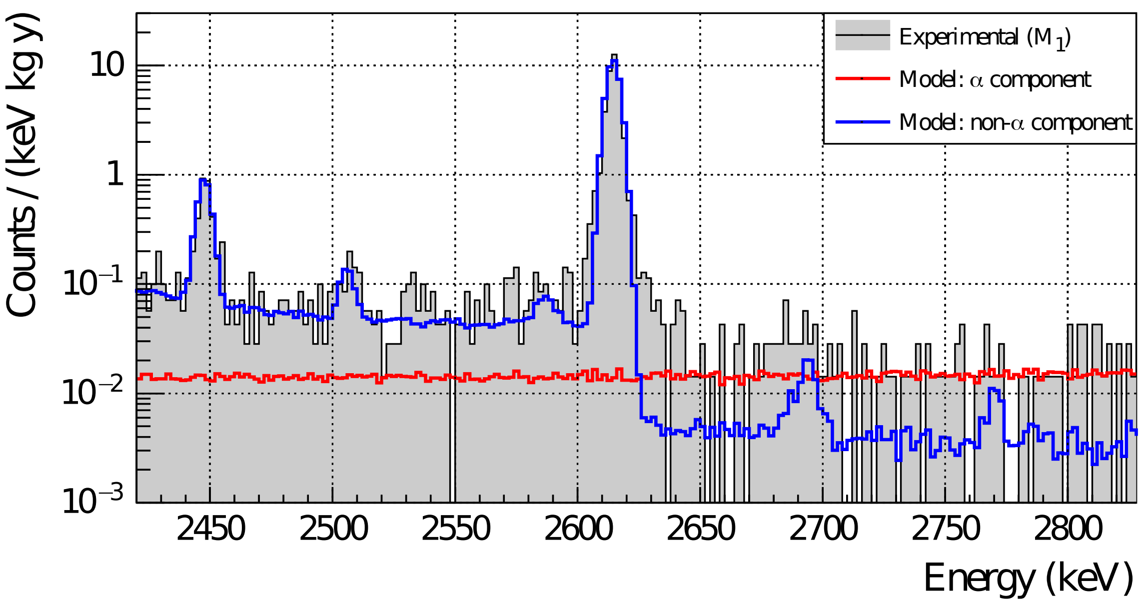
From the background model, we extract the ^{130}Te 2νββ half-life

$$T_{1/2}^{2\nu\beta\beta} = (\,8.2 \pm 0.2\ (\text{stat.}) \pm 0.6\ (\text{syst.})\,) \times 10^{20}\ \text{yr}$$

Eur. Phys. J. C (2017) 77: 13

CUORE background budget





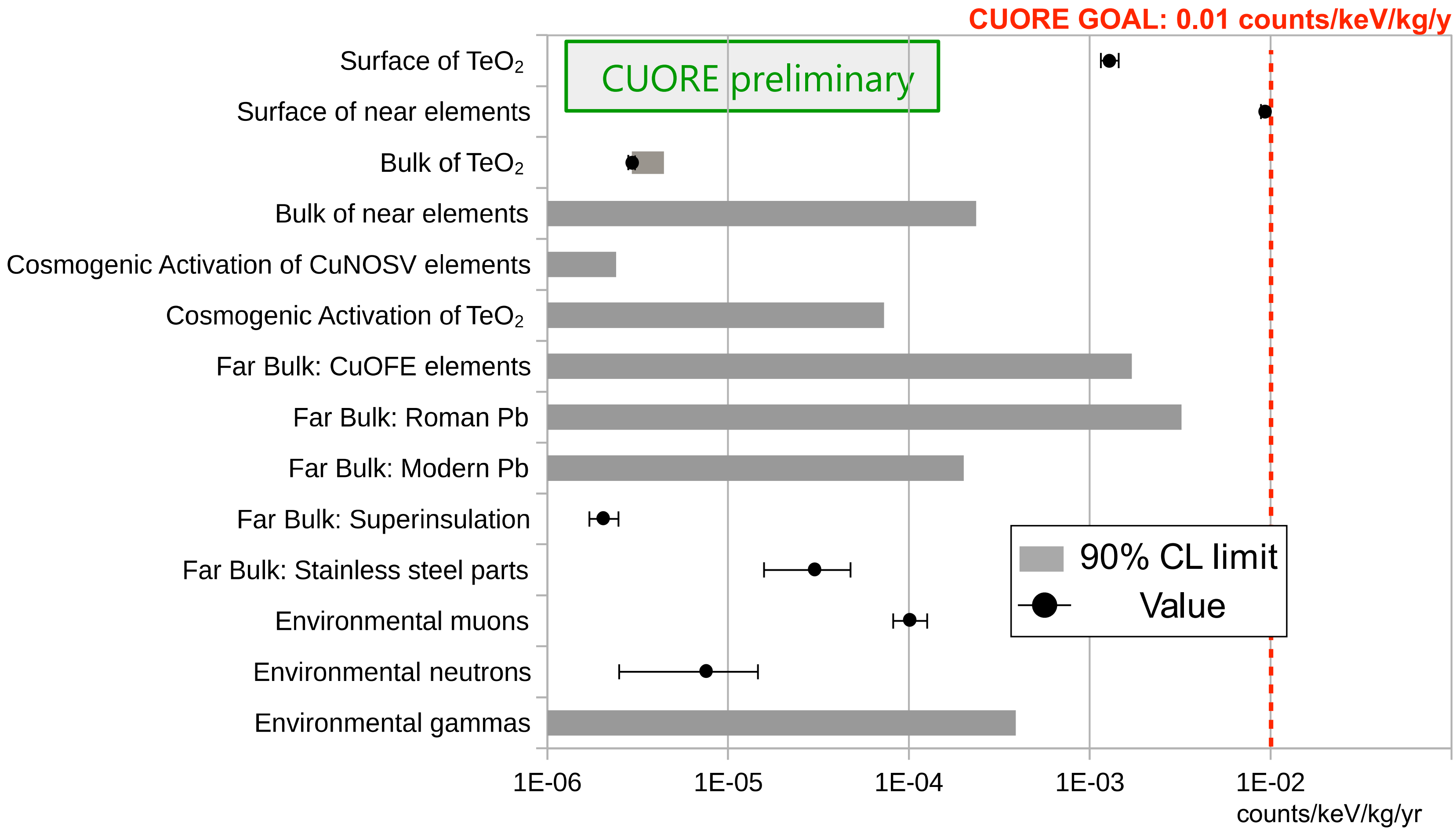
Main background components in the 0νββ ROI

Component	Fraction [%]
Shields	74.4 ± 1.3
Holder	21.4 ± 0.7
Crystals	2.64 ± 0.14
Muons	1.51 ± 0.06

Expected lower background in CUORE

- New, cleaner cryostat
- More granular detector improves multiplicity analysis
- Towers are exposed to lower amounts of copper

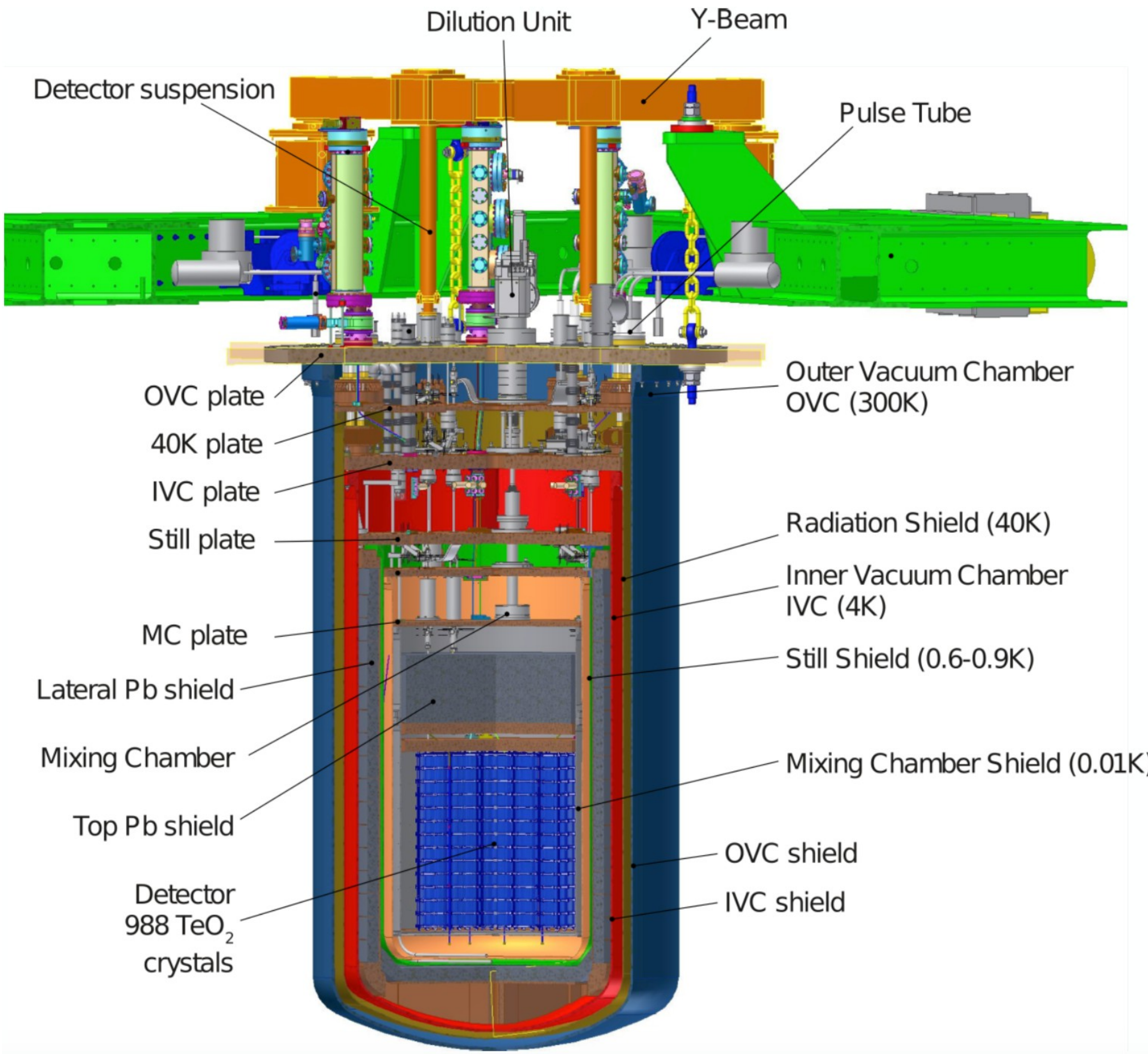
CUORE background budget



Extrapolation of CUORE-0 background model to CUORE
Dominated by surface contaminations

Background goal completely within reach

CUORE Cryostat

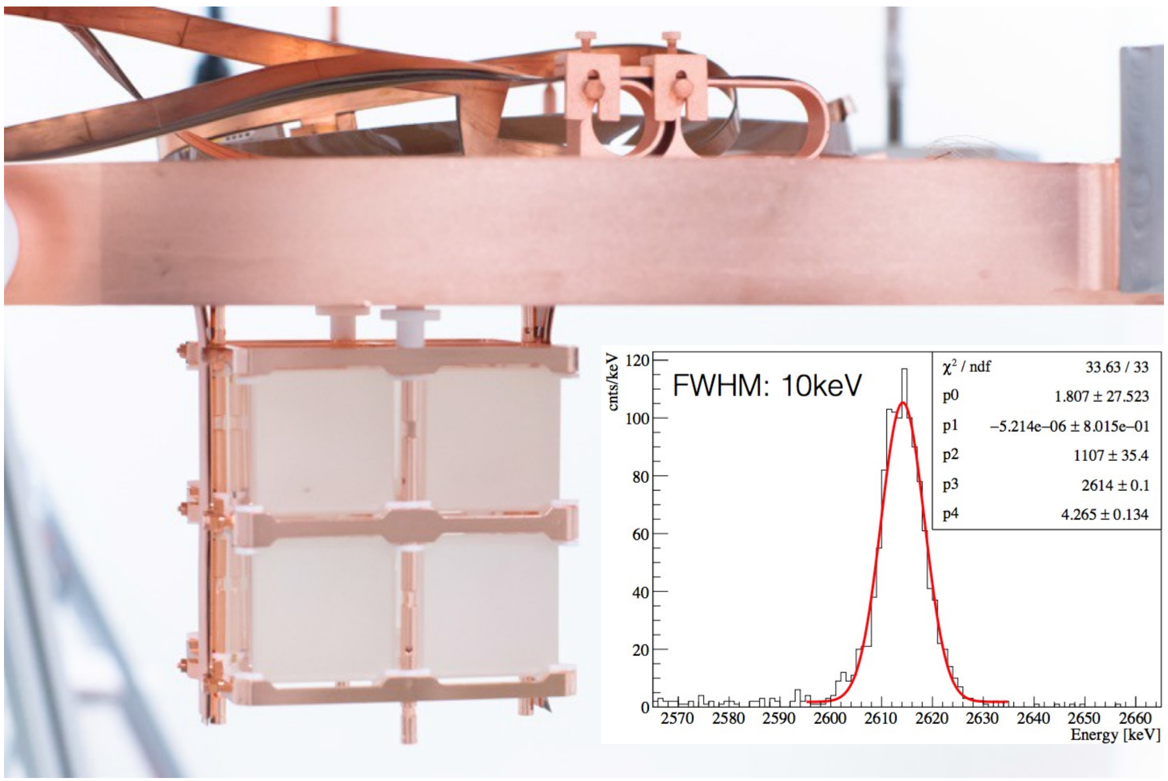


- Material selection driven by thermal/mechanical properties and radio-purity
- Special surface cleaning procedures for elements close to the detector
- Shielding: 25 cm Pb @300K + 6 cm roman Pb @4K
- Extremely low vibrations (suspensions)
- Stable, ultra-low temperature

Cryostat commissioning

Cryostat commissioning: series of cooldowns with increasingly complete system

Mini-tower test: 8 crystals array, last commissioning run

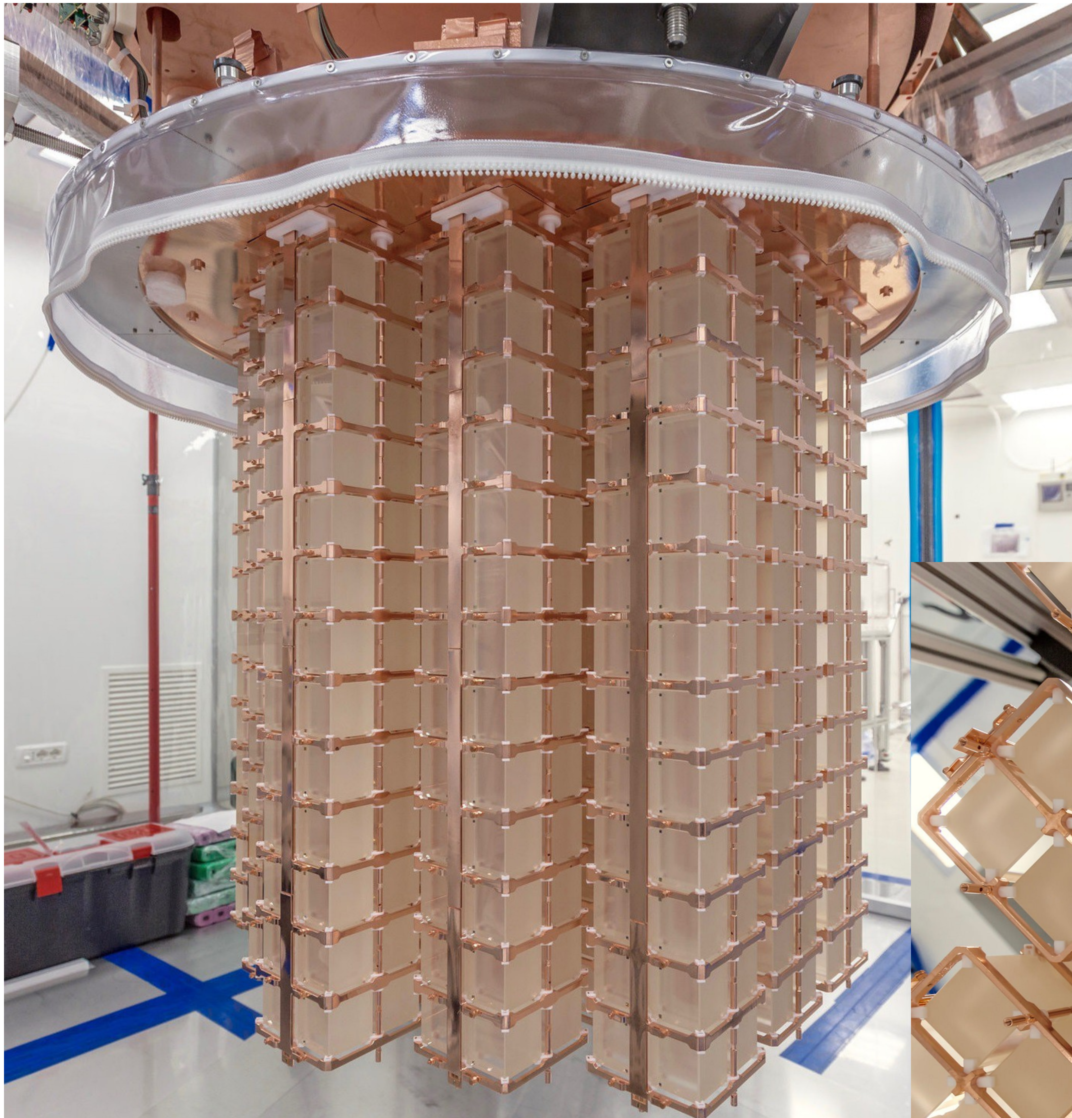


- ✔ Stable base temperature: 6.3 mK
- ✔ Successful test of detector calibration system, electronics, DAQ, temperature stabilization
- ✔ No unaccounted sources of background found

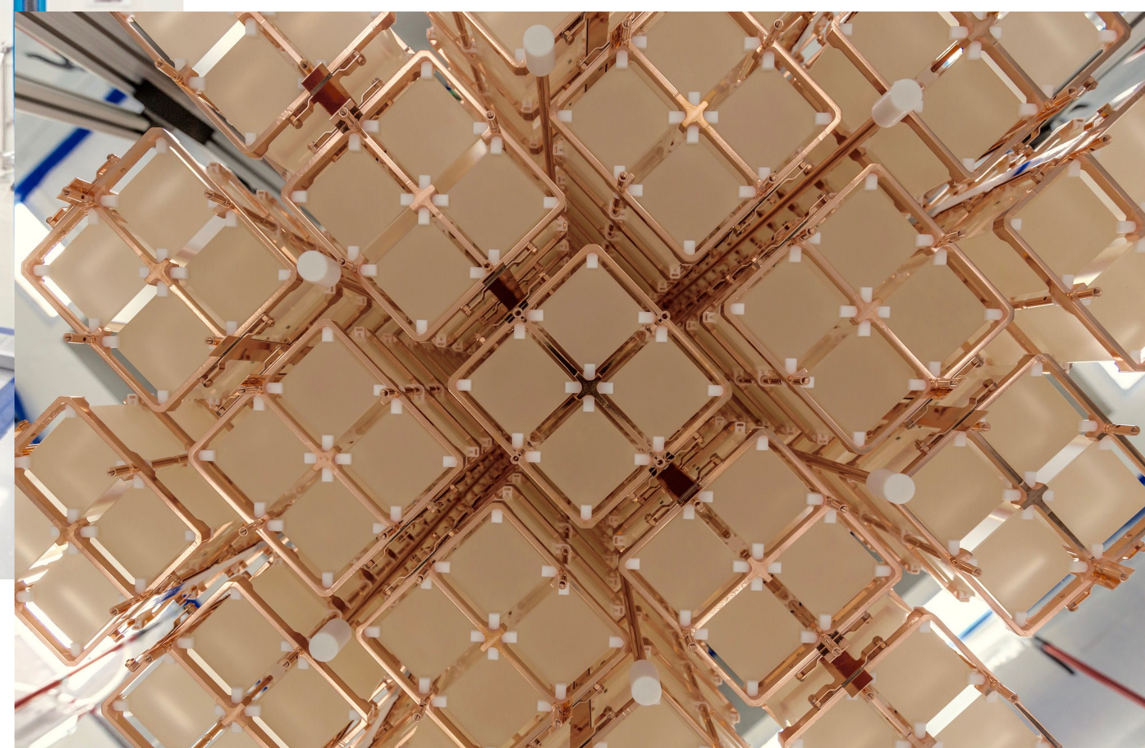
See poster from S. Copello

“The commissioning of the CUORE experiment: the mini-tower run”

Detector installation



The 19 towers were completely installed in August 2016 in a specially constructed, radon-free clean room



Detector installation

10 mK shield

Roman Pb radiation shield @4K

Installation of thermal and radiation shields, electronics and DAQ completed between Sep. and Nov. 2016

See poster from P.Carniti

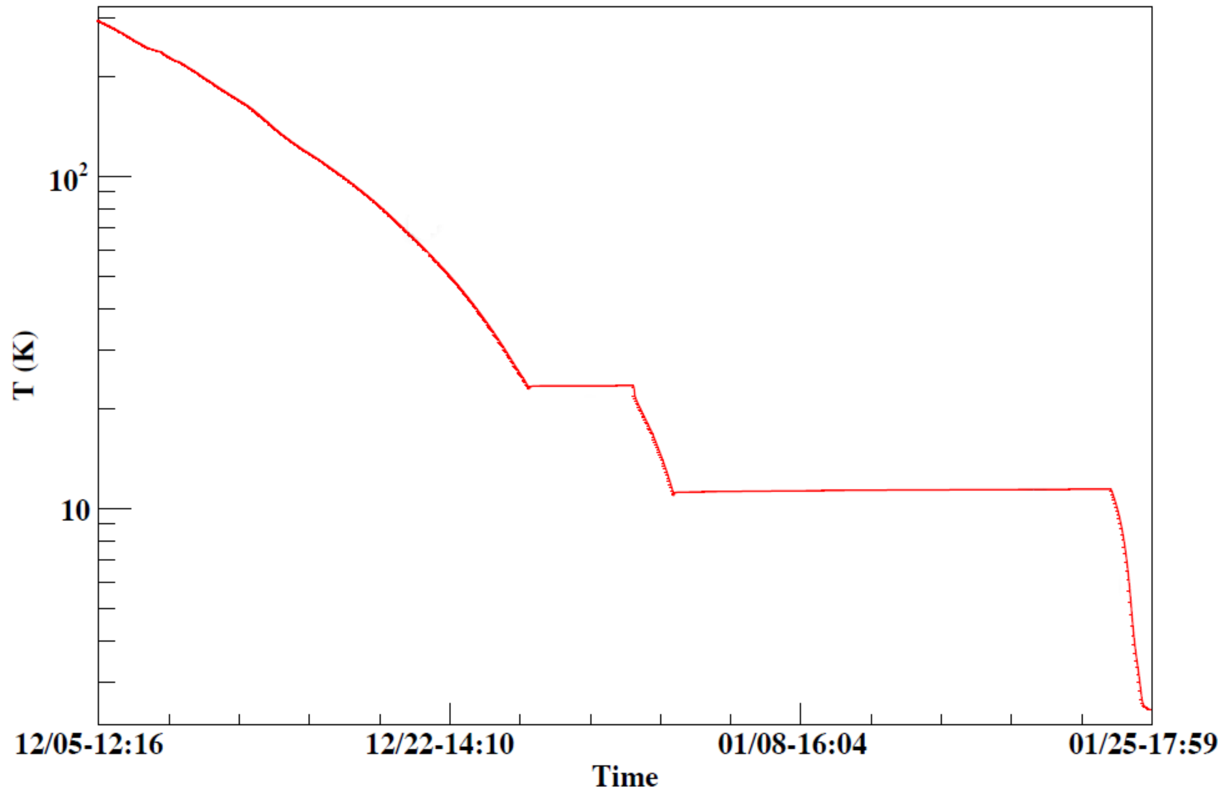
"Front-end electronics for large arrays of macro-bolometers"

Cryostat cooling

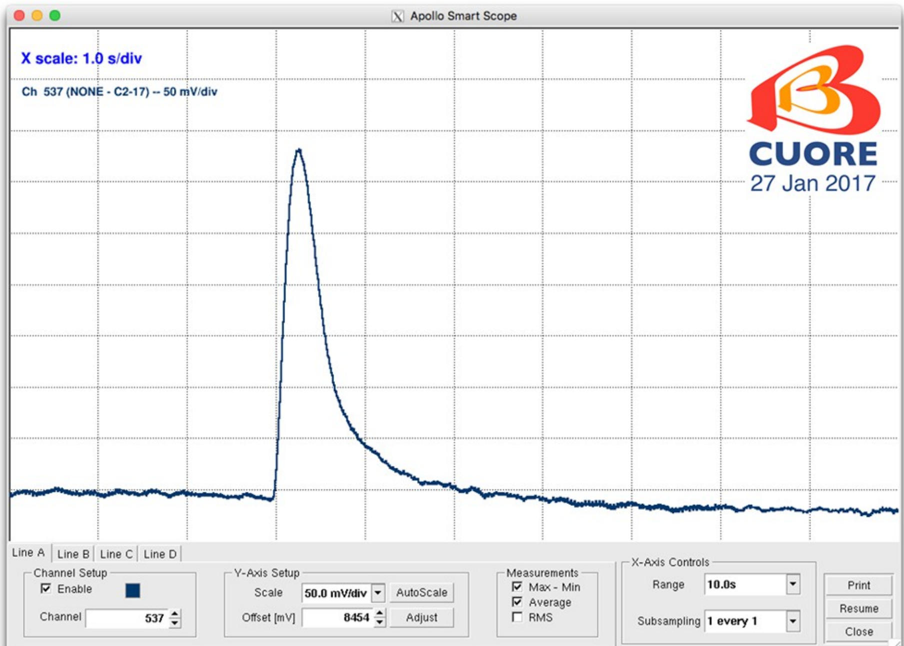
Cooling of the cryostat started in Dec. 2016

After a couple of stops to optimize the system, it reached base temperature (~8 mK) on Jan. 25th

Diode thermometer at 10mK plate



Current activities



First pulses recorded on Jan. 27th

- Gradually turned on all the 988 channels
- Optimization of the DAQ and data analysis software
- Improvement of noise, both from electronics and from vibrations (pulse tubes)
- Determination of the optimal working point for each crystal

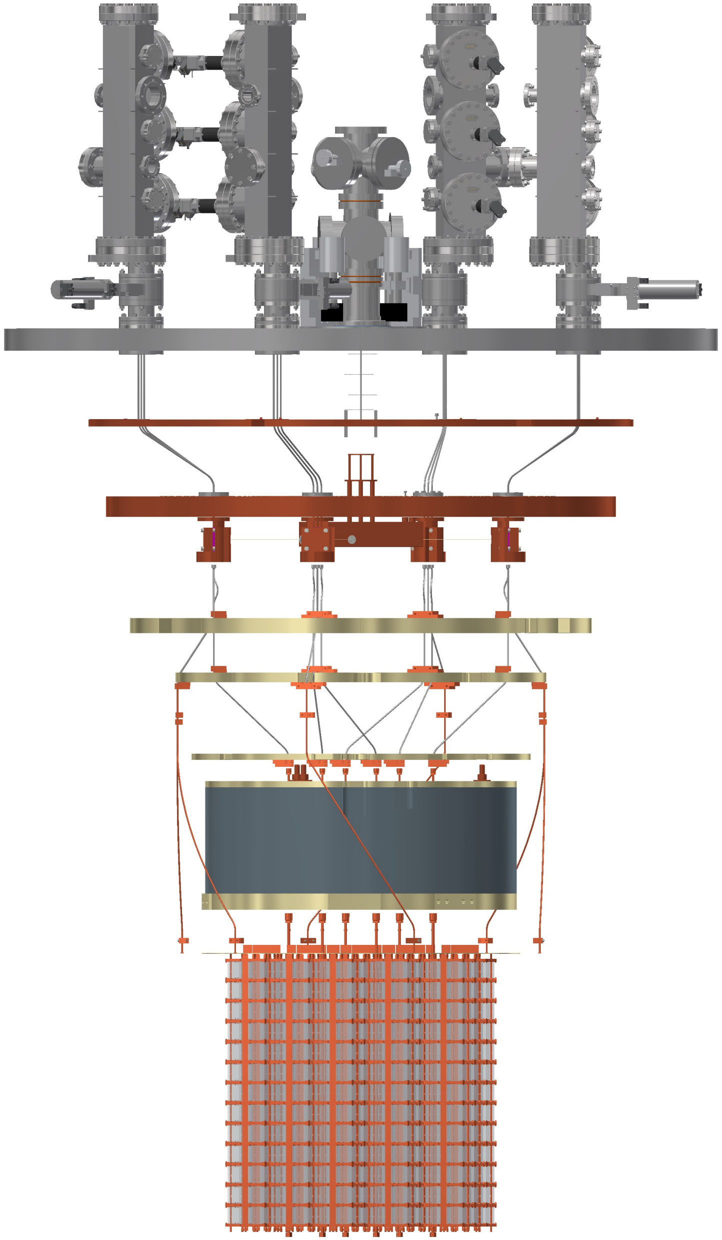
Calibration and background data

- The detector calibration system (DCS) consists of 12 strings, loaded in ^{232}Th, that can be lowered to detector level
- The strings are guided through tubes and positioned as to illuminate evenly all 19 towers
- Tested successfully during the mini-tower run

Calibration of the full detector will be performed in the following weeks

Background data will follow

Nucl. Instrum. Methods A 844 (2017), 32-44



Summary

- All CUORE towers have been installed and the cryostat is completely functional
- The cryostat has been successfully cooled down to ~8 mK
- Noise optimization operations are advancing rapidly
- Calibration measurements are on the way, and background data will soon follow