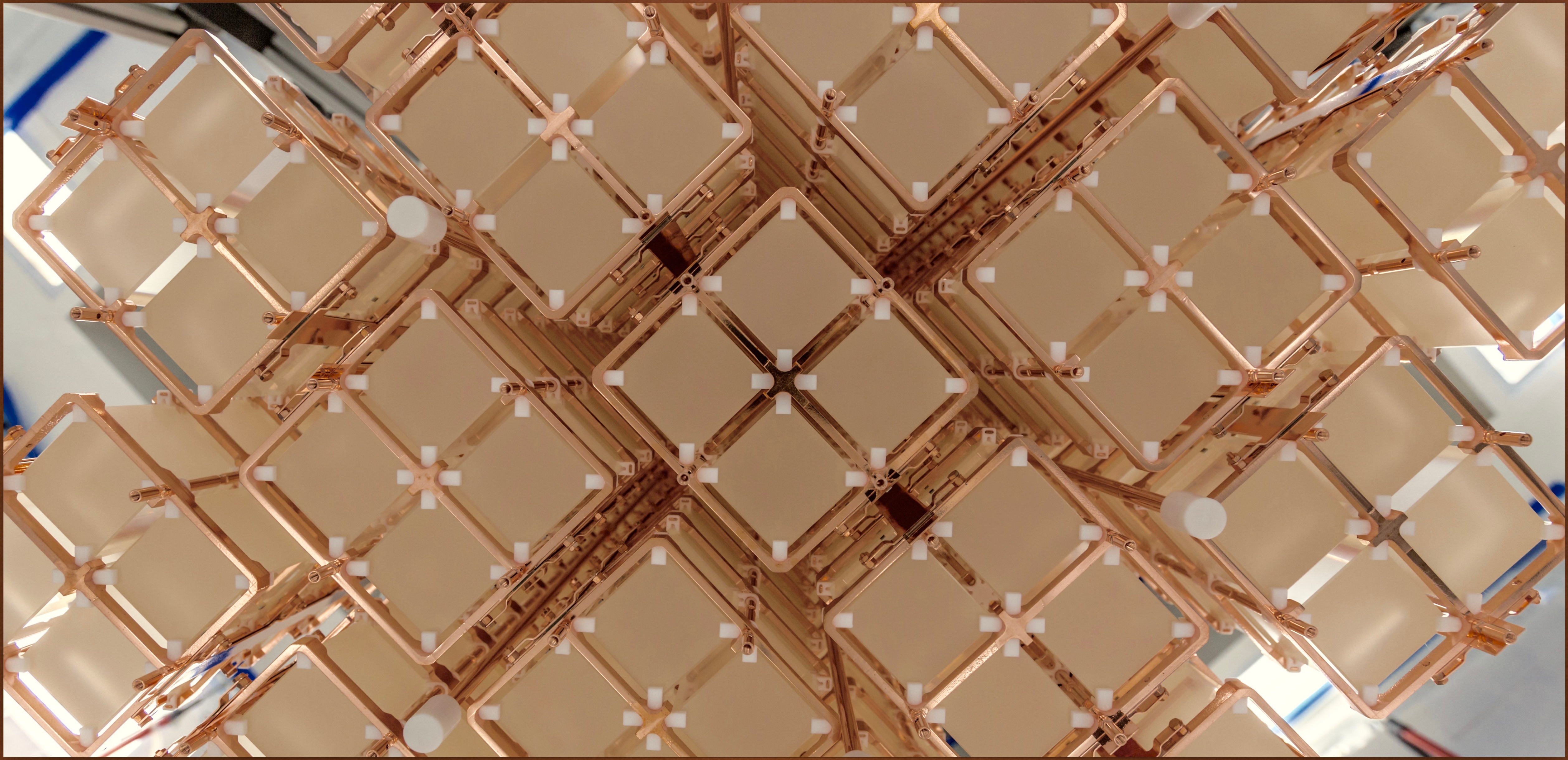
THE CUORE EXPERIMENT

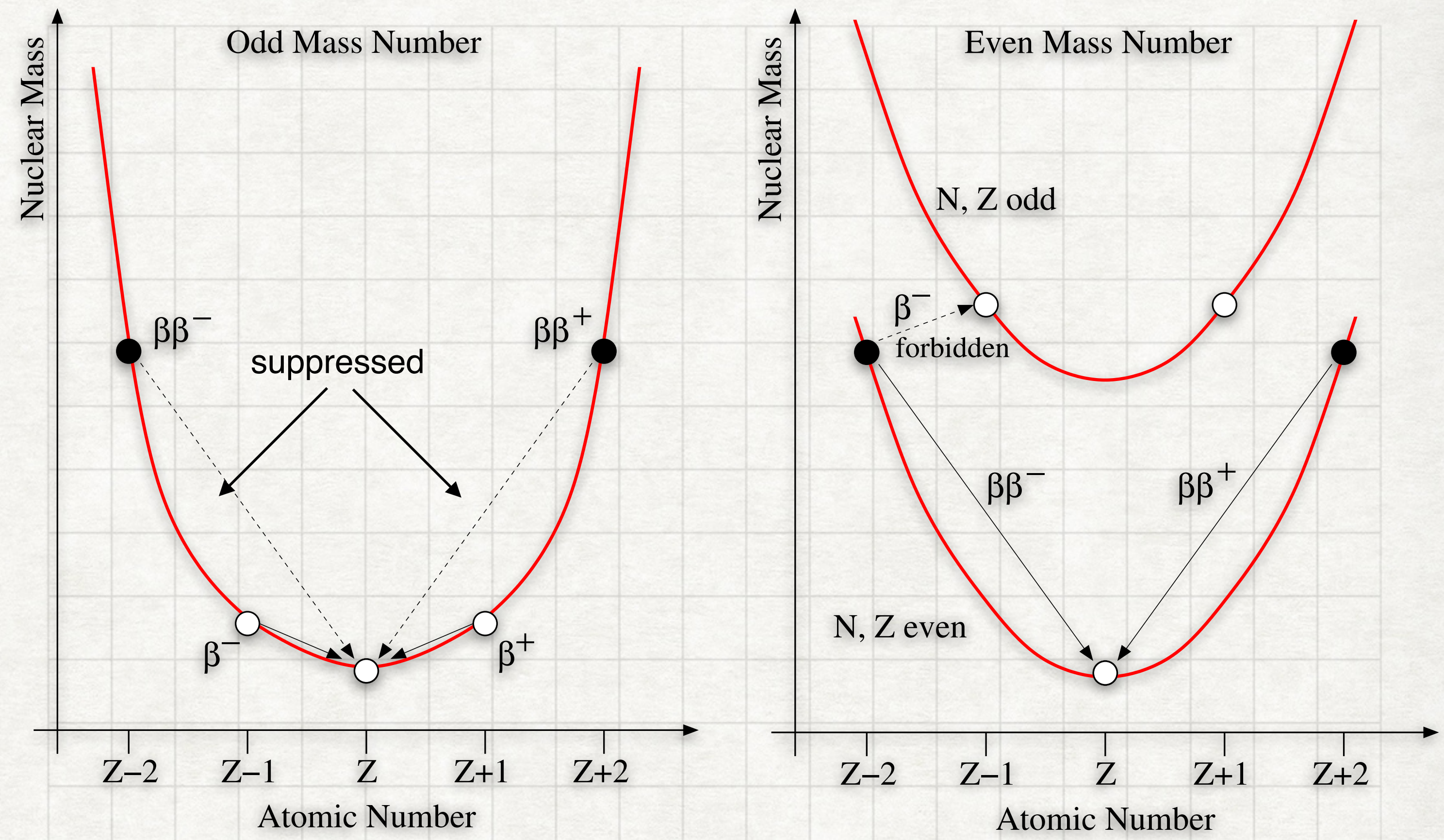
Laura Marini, Università degli studi di Genova and INFN
on the behalf of the Cuore collaboration

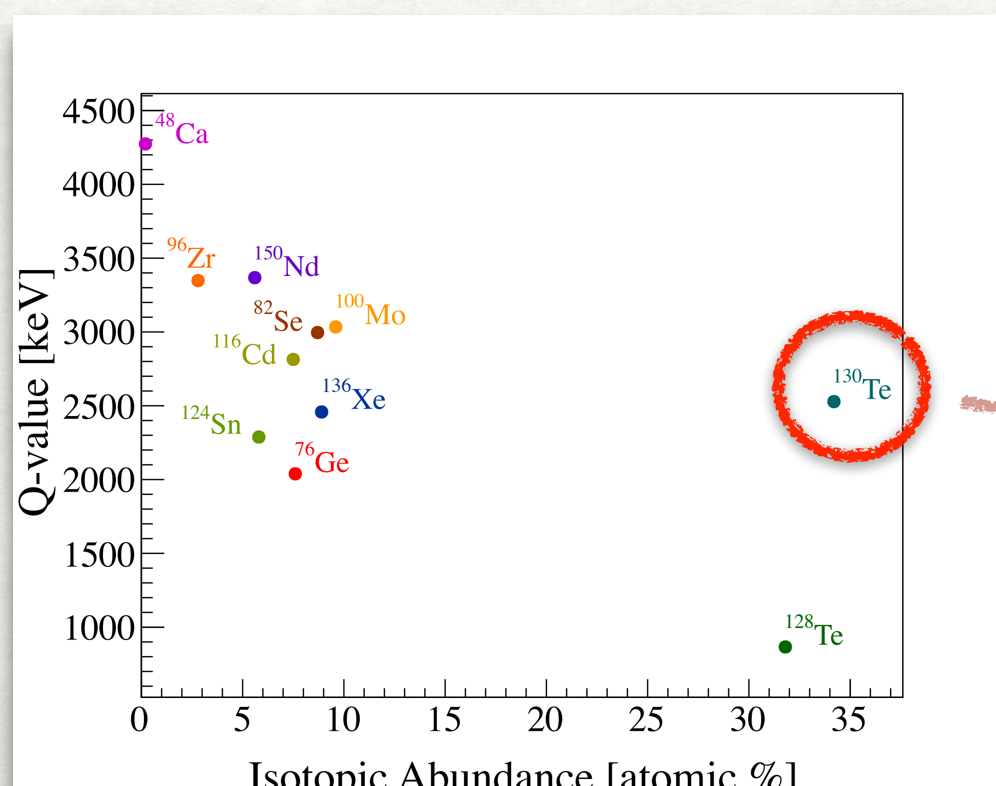


WHAT

DO WE WANT TO SEE

Double Beta Decay is a second order weak interaction, only directly observable for few nuclei, for which the standard Beta Decay is suppressed or forbidden (even - even nuclei)



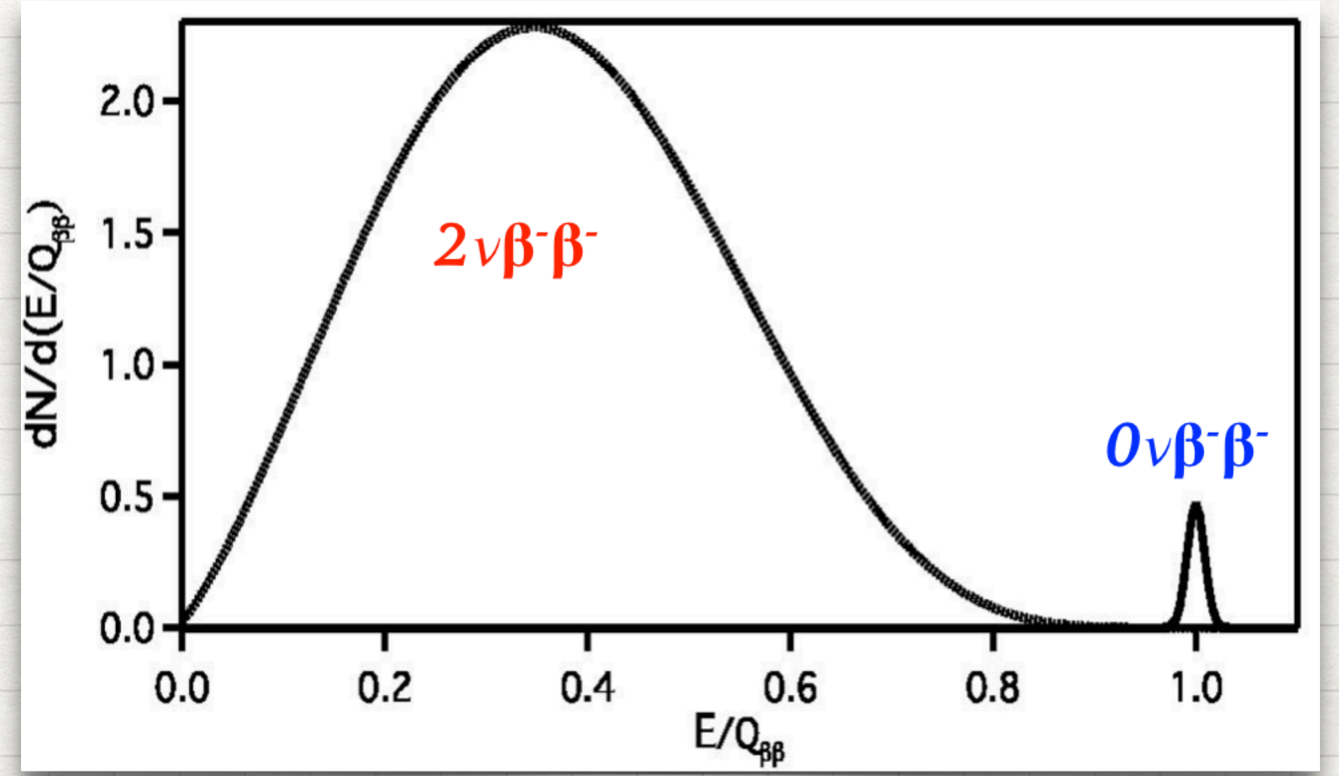


^{130}Te is chosen for:

- its high isotopic abundance (34.17%)
- ^{130}Te within the detector absorber of TeO_2 (high detection efficiency)
- Q-value of 2527.515 ± 0.013 keV in a region with low beta/gamma background
- reproducible growth of high quality crystals

WHAT

DO WE WANT TO SEE



Why 0vBB?

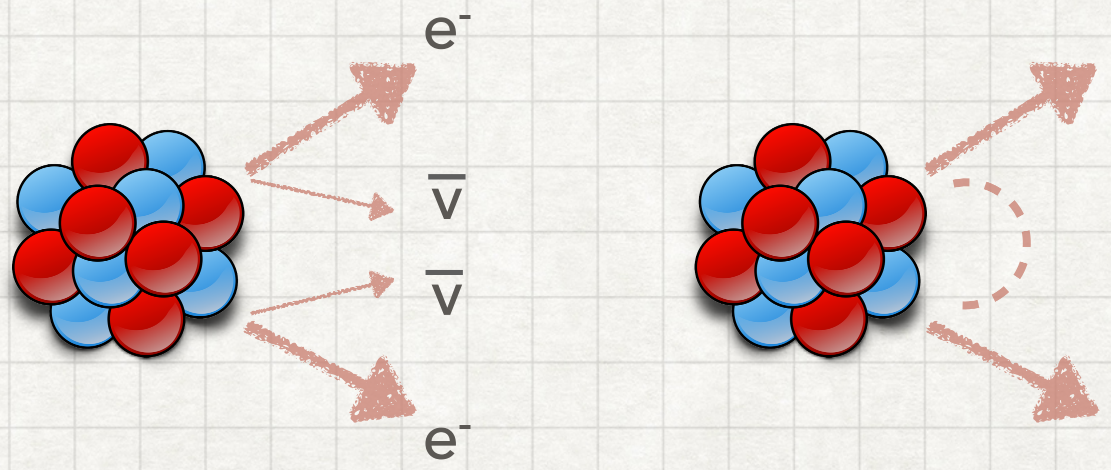
- lepton number violation
- Majorana nature of neutrinos
- constrain the absolute neutrino mass hierarchy and scale

Signature

- peak at the Q-value of ^{130}Te ßß decay (2527.515 ± 0.013)keV

Never observed to date

- Current 0vBB half-life lower limits are in the range $10^{22} - 10^{26}$ y



CUORE

CHALLENGES

$$T^{0\nu}_{1/2}(n_\sigma) = \frac{ln2}{n_\sigma}\frac{N_A\, i\, \varepsilon}{A}\, f(\Delta E)\sqrt{\frac{M\, t}{B\,\Delta E}}$$

big exposure (mass x time)

- 988 TeO_2 crystal with isotopic abundance of 34.167% for a total mass 206 kg of active material
- foreseen 5 years of data taking

Goal: 5 years

high energy resolution

- noise reduction techniques
- temperature stability
- fine tuning of detectors parameters to optimize the signal to noise ratio

Goal: 5 keV FWHM

low background

- strict radiopurity selection on materials
- low background assembly environment
- passive shields from external and cryostat radioactivity

Goal: 0.01 counts/keV/kg/yr

Goal $T_{1/2}$ (90% C.L.) > 9.5×10^{25} y
Goal $\langle m_{\beta\beta} \rangle$ 50 - 130 meV

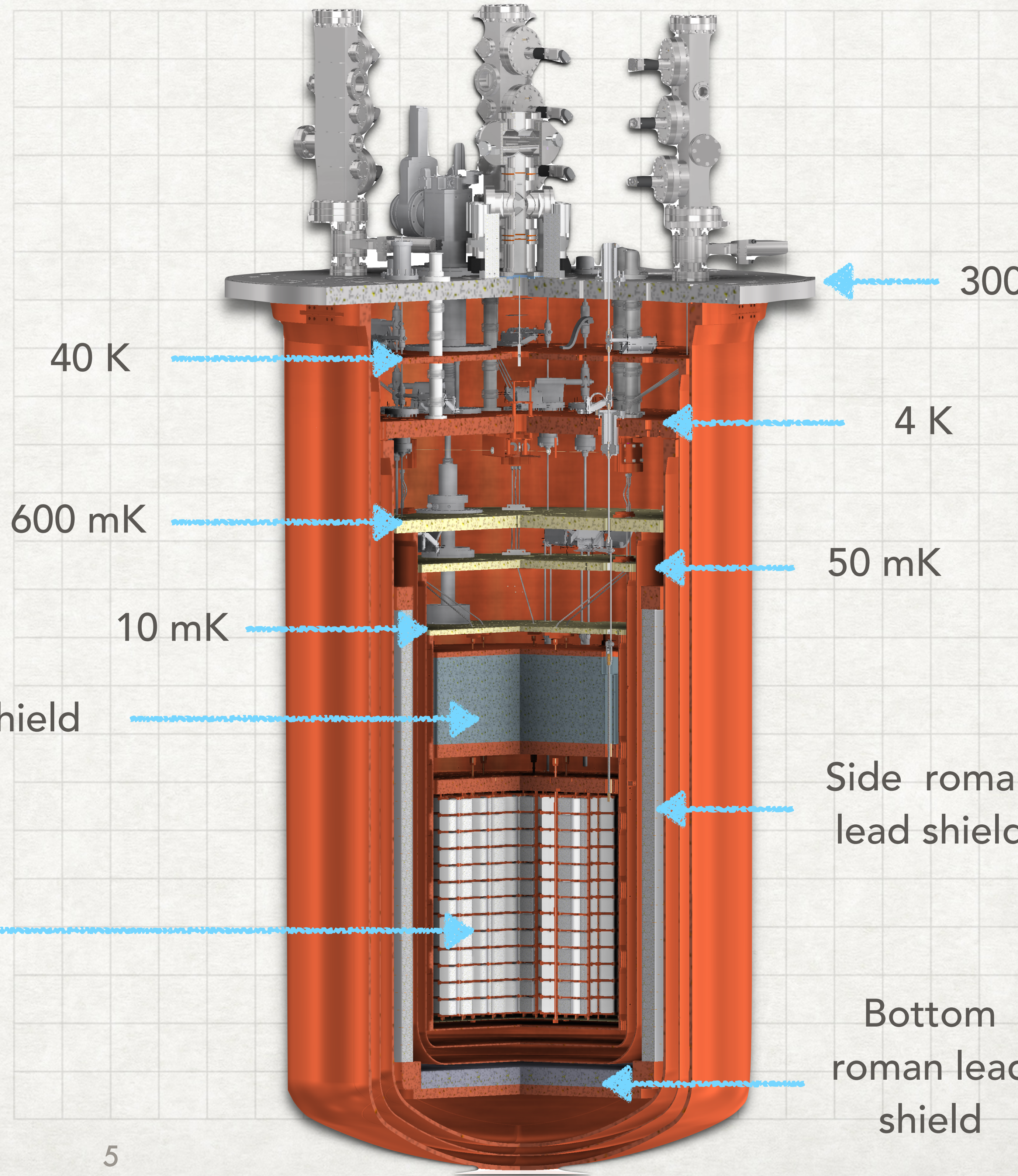
Advances in High Energy Physics
http://dx.doi.org/10.1155/2015/879871

CUORE

CRYOGENIC UNDERGROUND OBSERVATORY FOR RARE EVENTS

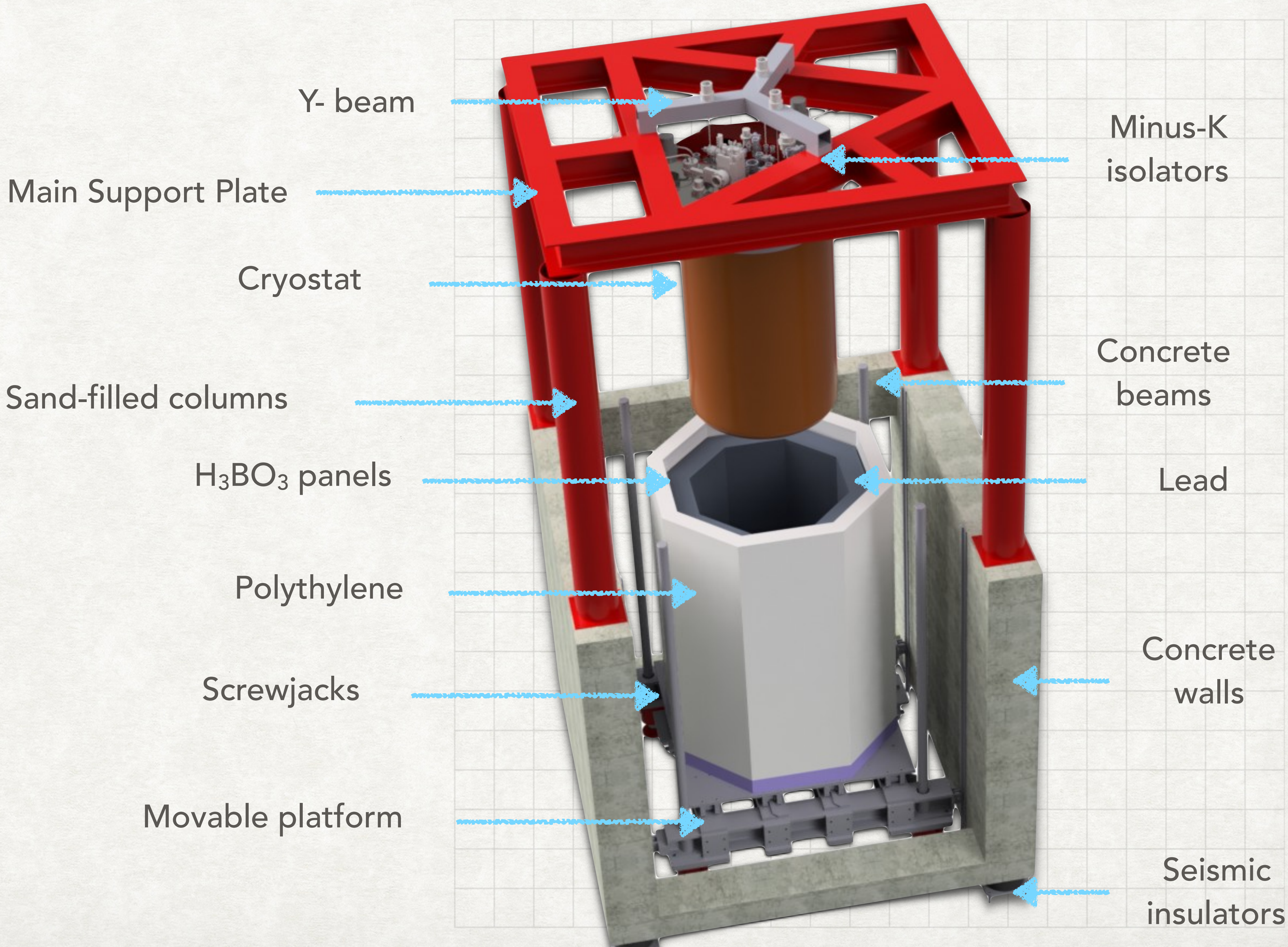
The CUORE detector is hosted in a cryogen free cryostat:

- Mass to be cooled < 4K: ~15 tons (Pb, Cu and TeO_2)
- Operating temperature 10 mK
- Designed to guarantee extremely low radioactivity and low vibrations environment



CUORE

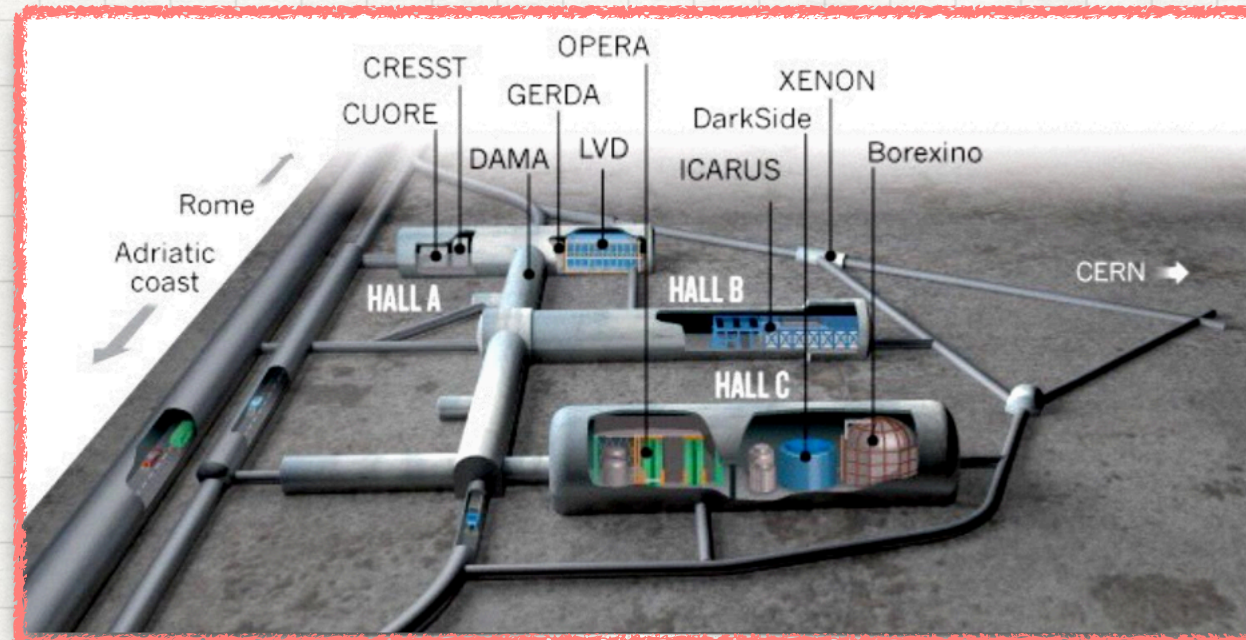
CRYOGENIC UNDERGROUND OBSERVATORY FOR RARE EVENTS

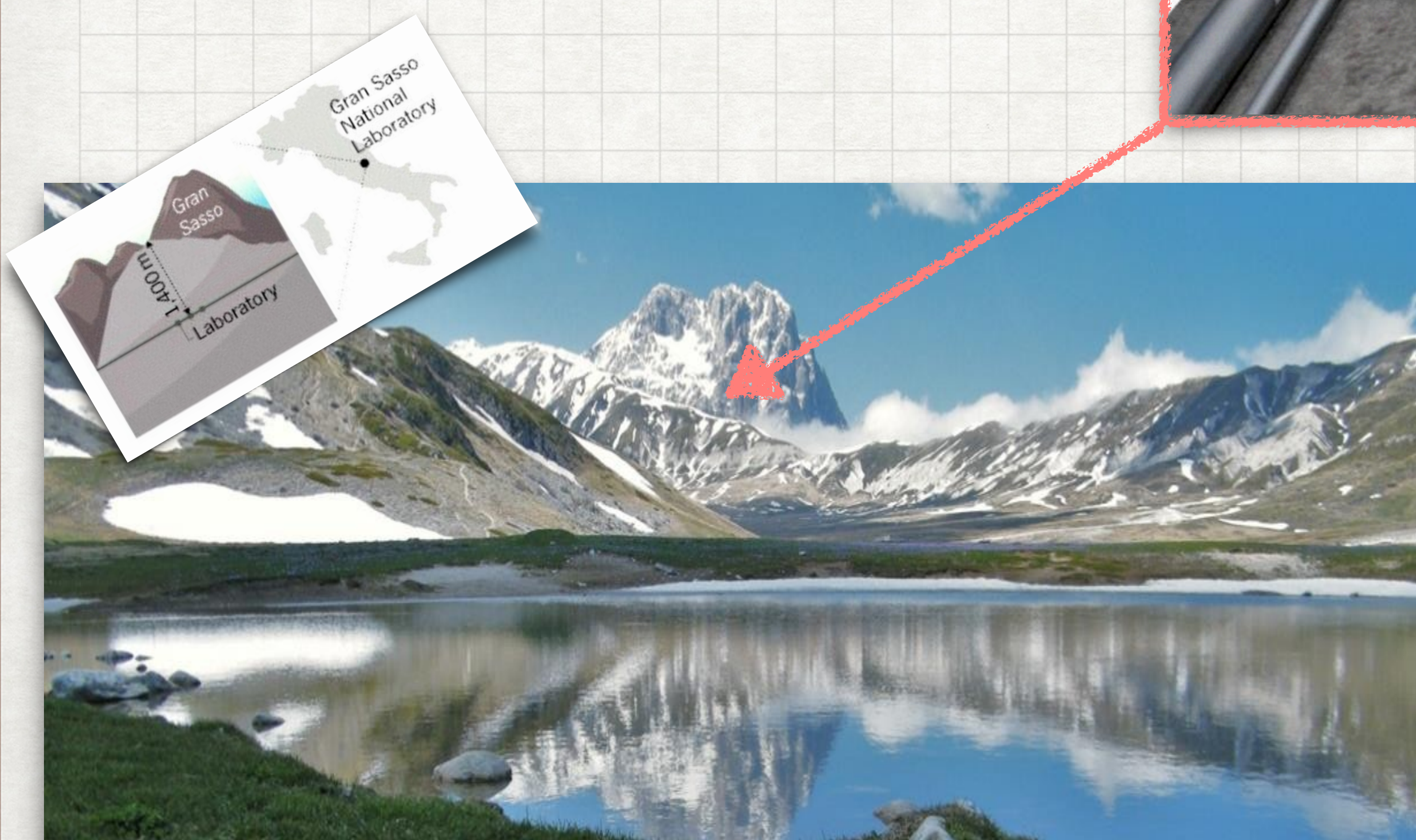


WHERE

LNGS - GRAN SASSO UNDERGROUND LABORATORY (ITALY)

The mountain of Gran Sasso naturally protect the experiment from cosmic rays



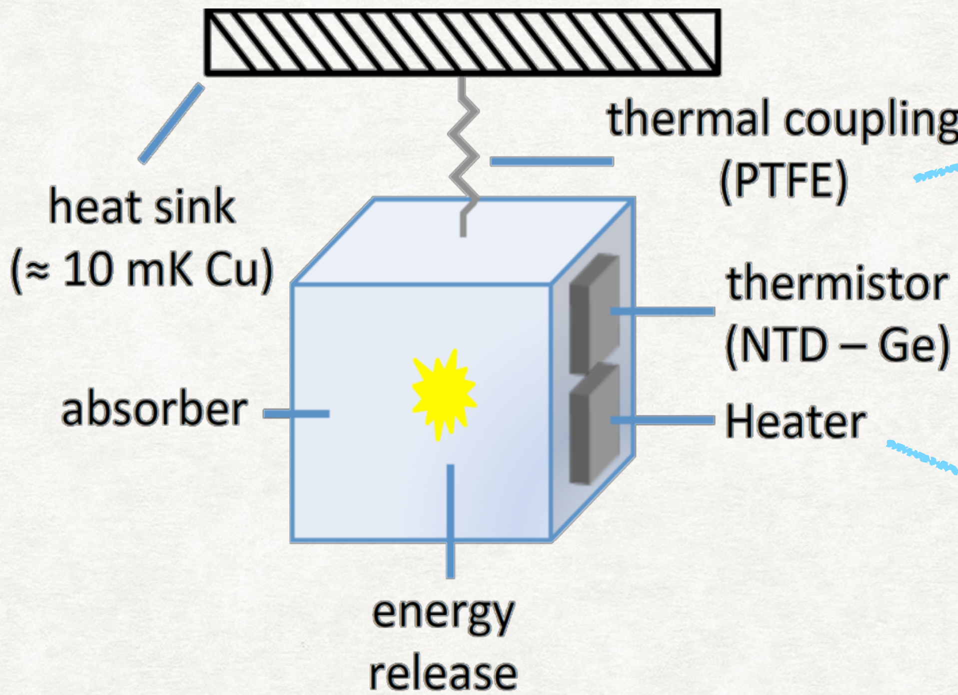


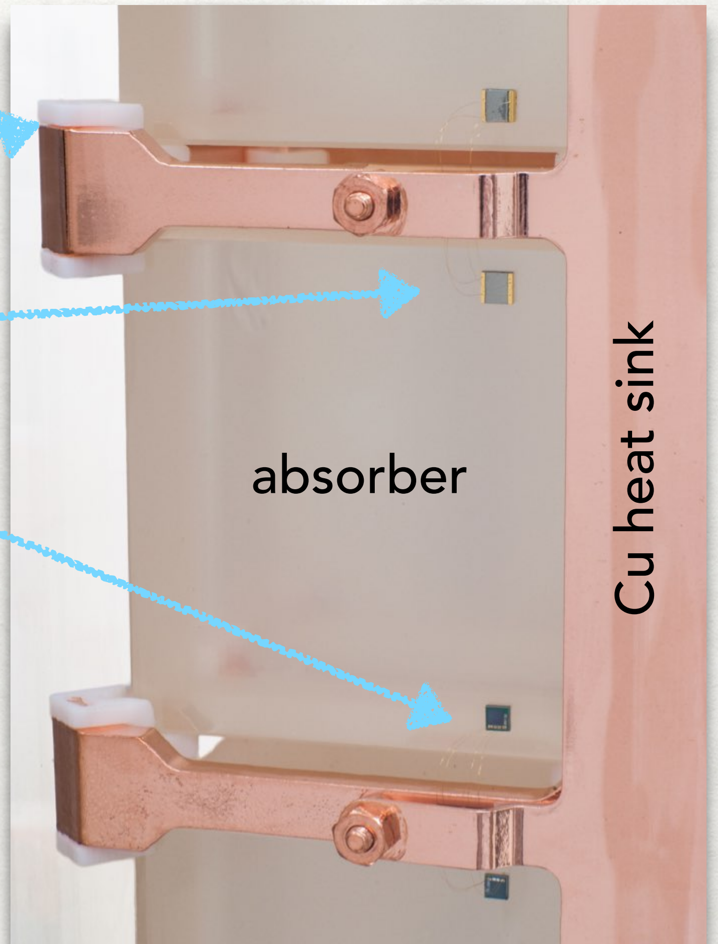
- 3600 m.w.e. deep
- μs: $3\times10^{-8}/(s\ cm^2)$ - 10^{6}. less than on the surface
- γs: $0.73/(s\ cm^2)$
- neutrons: $4\times10^{-6}\ n/(s\ cm^2)$

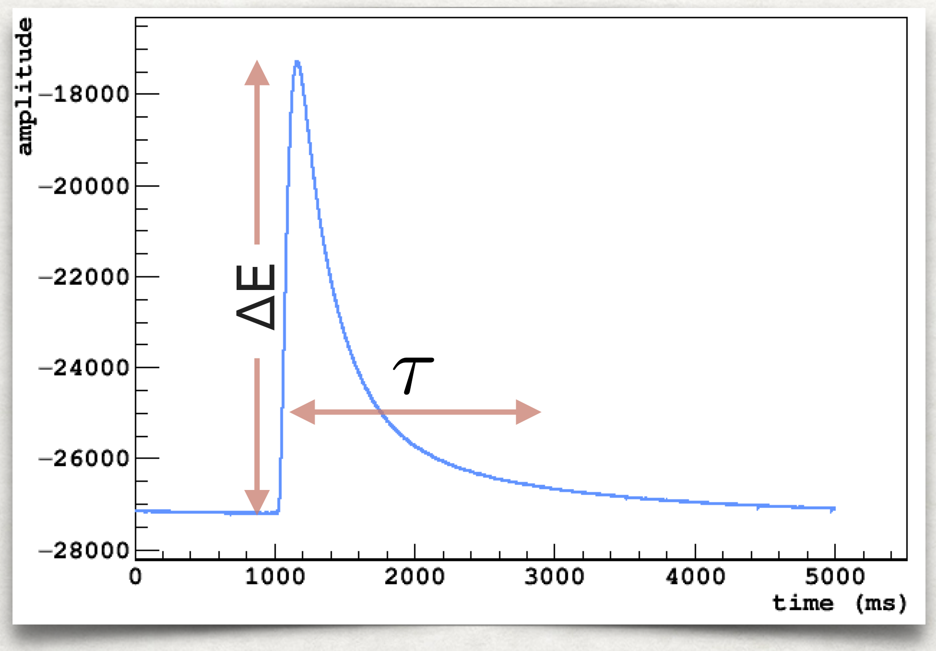
HOW

WE MEASURE PARTICLE INTERACTION WITH BOLOMETERS

A particle interaction in the absorber causes an increase in temperature, measured by the thermistor







$$\Delta T = \frac{\Delta E}{C} \sim \frac{100\mu K}{MeV}$$

$$\tau = \frac{G}{C} \sim 1s$$

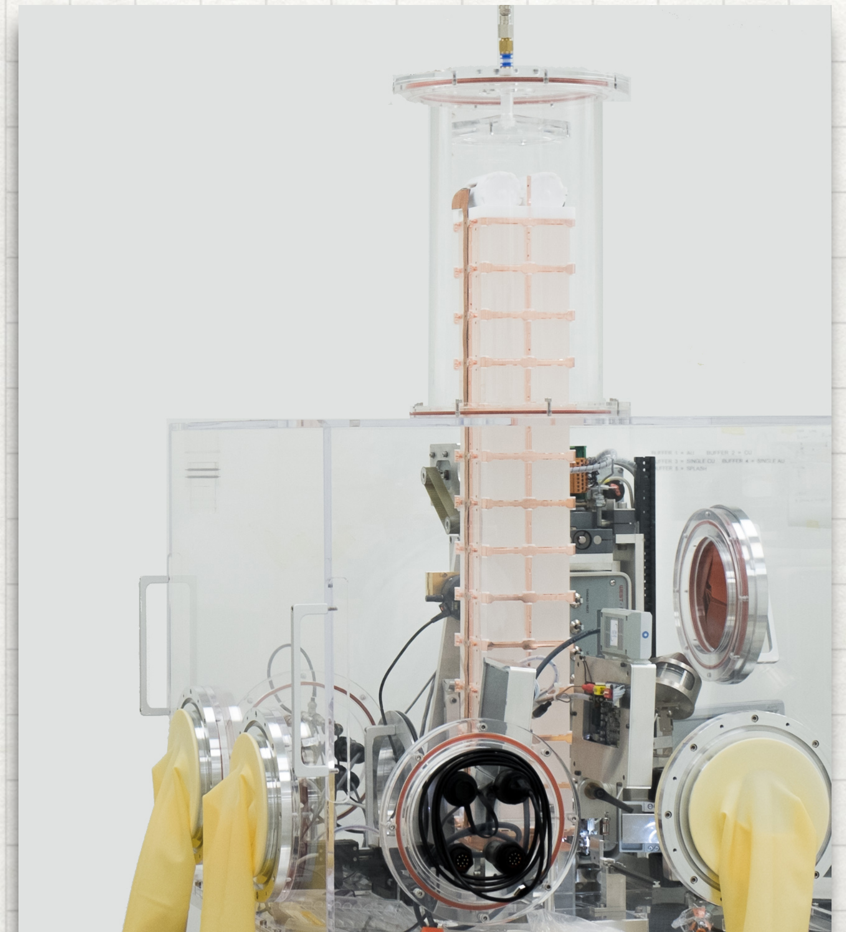
$$C(T) \propto T^3$$

$$R(T) = R_0 e^{\sqrt{T_0/T}}$$

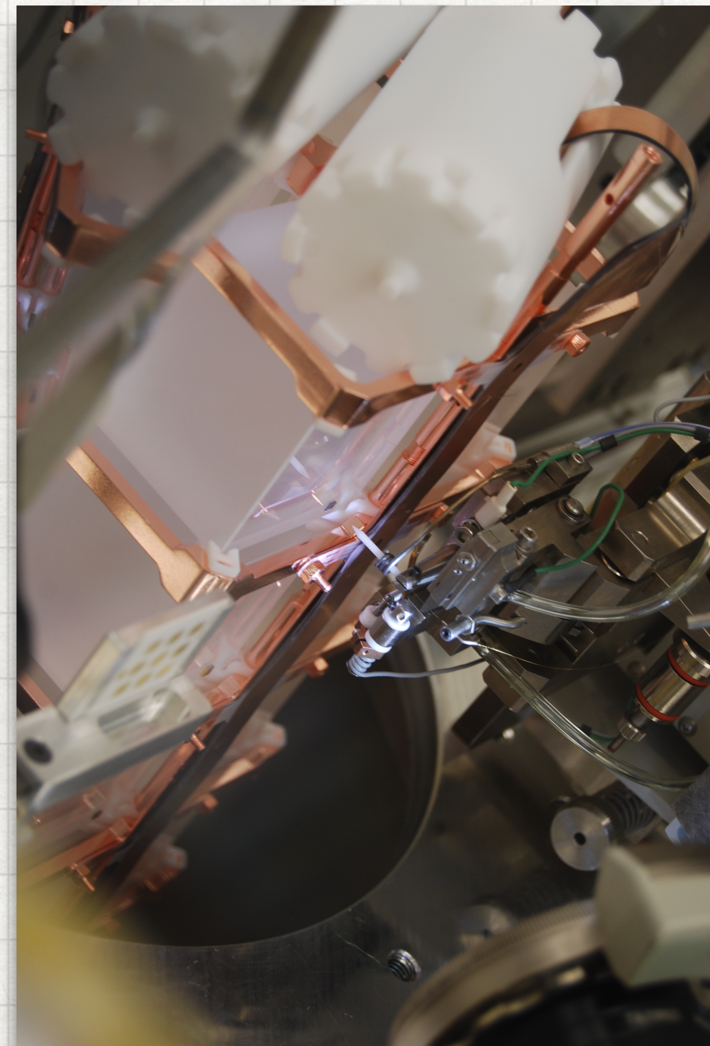
C: absorber capacity
ΔT: temperature variation
ΔE: energy deposition
G: thermal conductance
t: signal decay time

DETECTOR

SENSOR GLUING, TOWER ASSEMBLY AND SENSORS BONDING



Tower assembly done inside a clean room in glove boxes under N_2 atmosphere



Bonding

The 19 towers have been stored in dedicates cases under N_2 atmosphere

Nuclear Instruments and Methods A 768, 130-140 (2014)
arxiv:1405.0852

CUORE-0

FIRST CUORE TOWER

Single CUORE tower in Cuoricino cryostat:

- Validation of the assembly procedure
- Test of the design
- Measure the background
  - Low background level achived
- Measure the energy resolution

Total detector mass: 39kg of TeO_2 (11 kg of ^{130}Te)

Data taking from March 2013 to September 2015

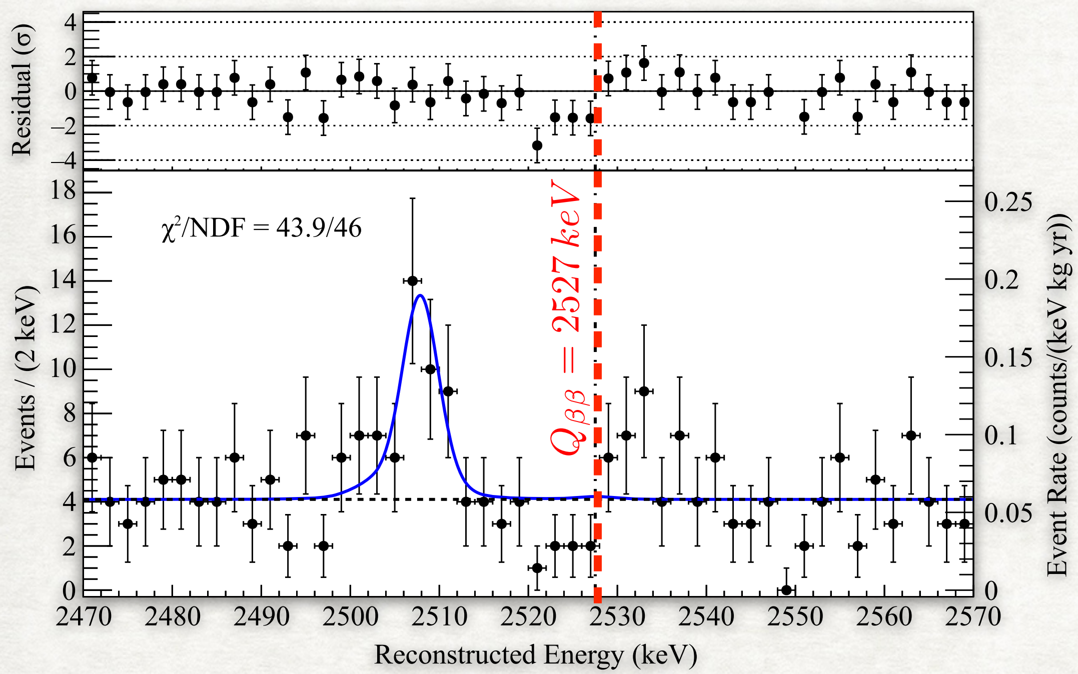
^{130}Te Exposure: 9.8 kg yr

Reached the CUORE energy resolution:

5.1 ± 0.3 keV   FWHM @ 2615keV

CUORE-0

$0\nu\beta\beta$ RESULTS



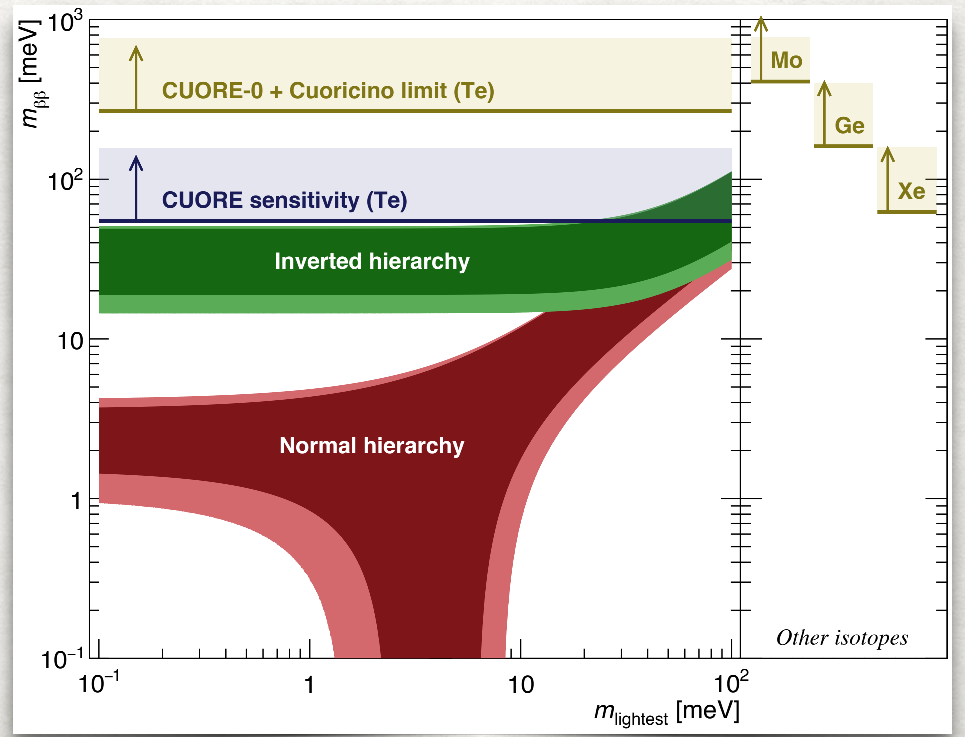
Fit function in the energy region 2470-2570keV

- signal peak at the Q-value of the transition
- a peak at 2507keV from ^{60}Co double-gammas
- smooth continuum background– multiscatter Compton events from ^{208}Tl and surface decays

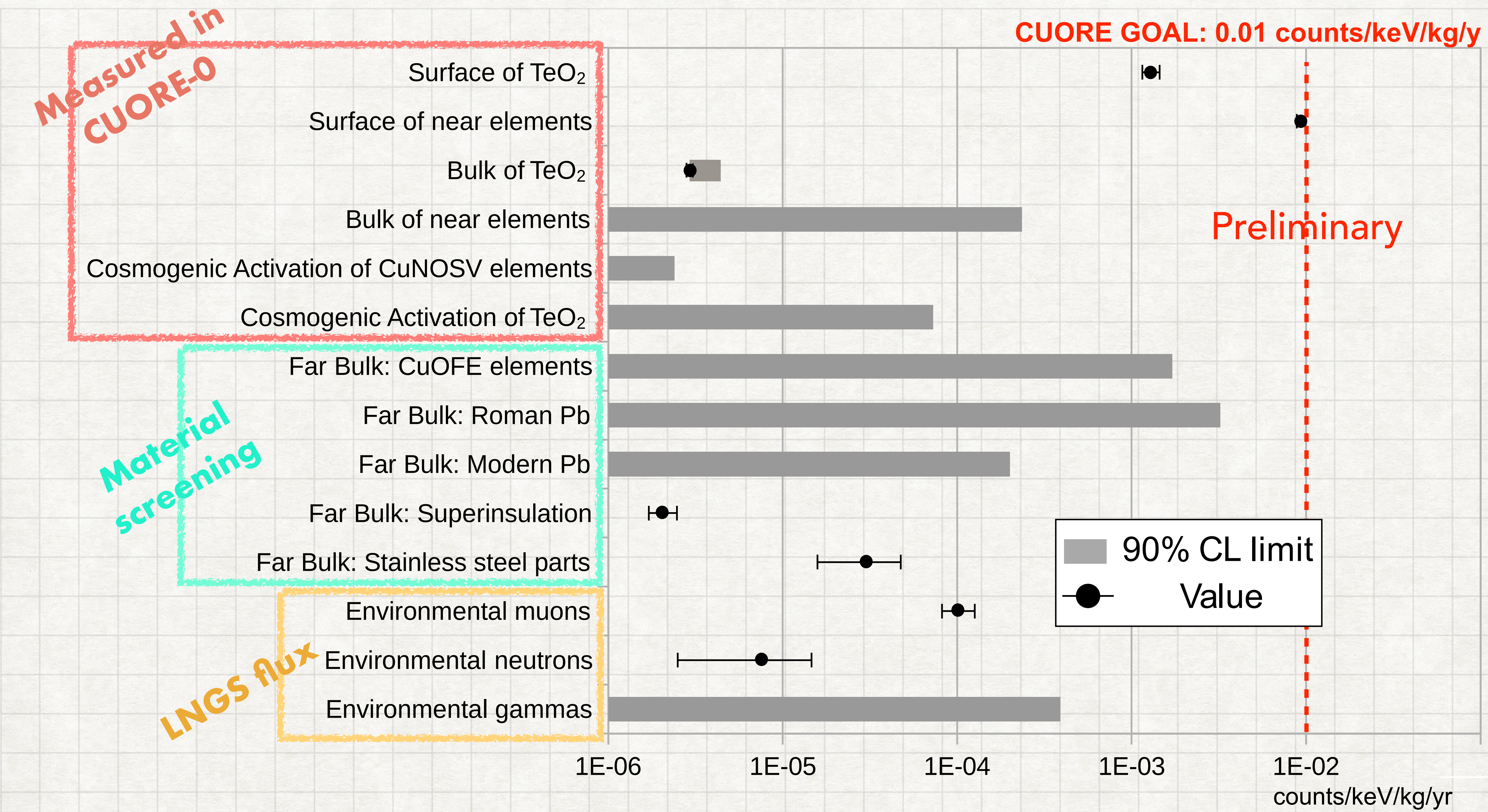
Phys. Rev. Lett. 115 (2015) no.10, 102502
Phys. Rev. C 93, 045503 (2016)

Best-fit values:

- Background index in ROI: 0.058±0.004(stat)±0.002(syst) counts/keV/kg/yr
- Limit on effective Majorana neutrino mass <mBB>: 270-760 meV
- Decay rate = 0.01 ± 0.12(stat)±0.01(syst) × $10^{-24}yr^{-1}$
- Halflife $T^{0\nu}_{1/2}$ > 2.7 x 10^{24} yr at 90% C.L. (CUORE-0)
  $T^{0\nu}_{1/2}$ > 4.0 × 10^{24} yr at 90% C.L. (Cuoricino + CUORE-0)



BACKGROUND BUDGET



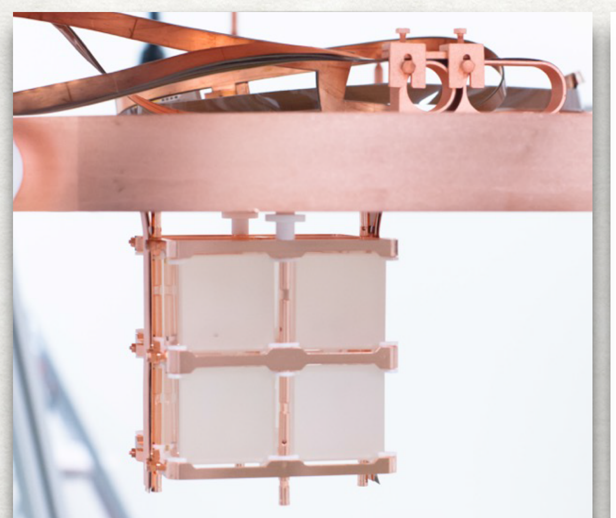
“The projected background for the CUORE experiment” on arXiv:1704.08970v1 (28 Apr 2017)

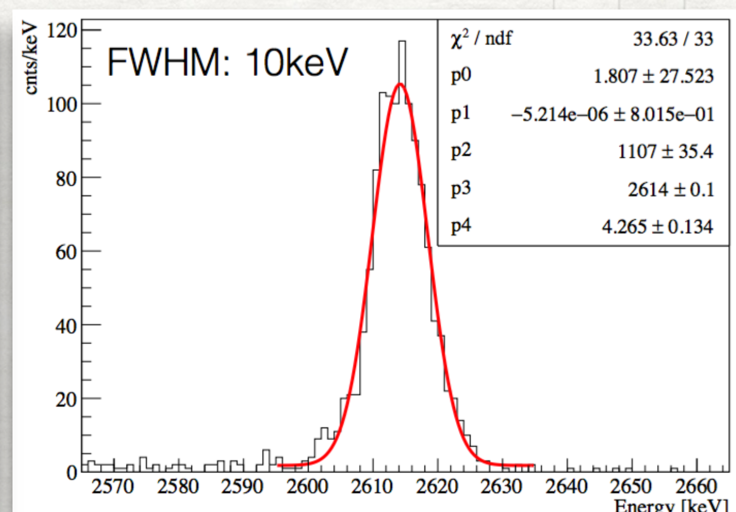
CUORE COMMISSIONING

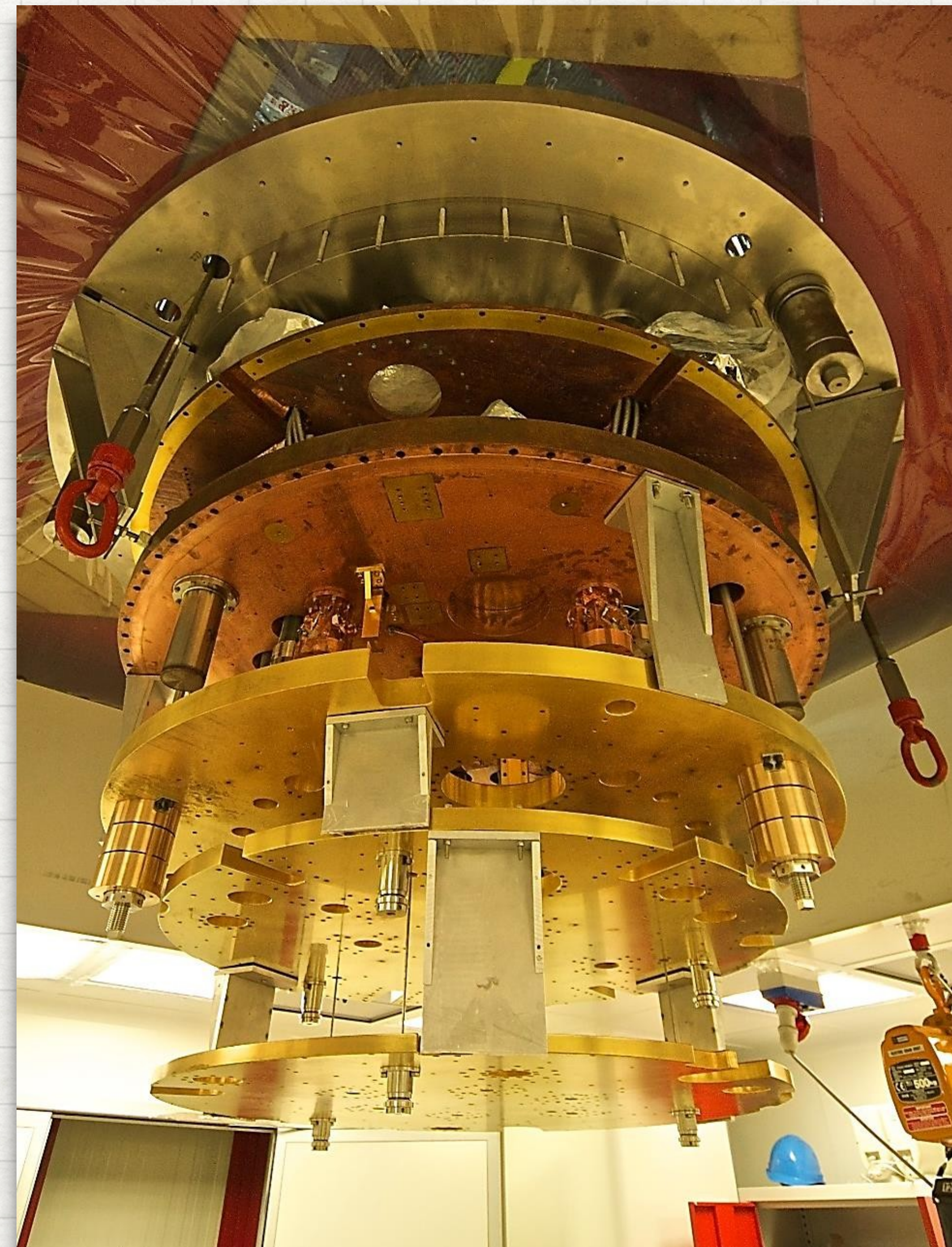
CRYOGENIC SYSTEM

Commissioning completed in March 2016:

- Stable base temperature @ 6.3mK
- Cooling power: > 3μW @10mK
- Test of the full detector readout chain (electronics, DAQ) and temperature stability with the Mini-tower (8 crystal tower)







Note: the resolution of the minitower was obtain without any detector or electronic optimization

CUORE COMMISSIONING

ROMAN LEAD SHIELD

Lateral and bottom shielding with 6cm - thick ^{210}Pb - depleted roman lead

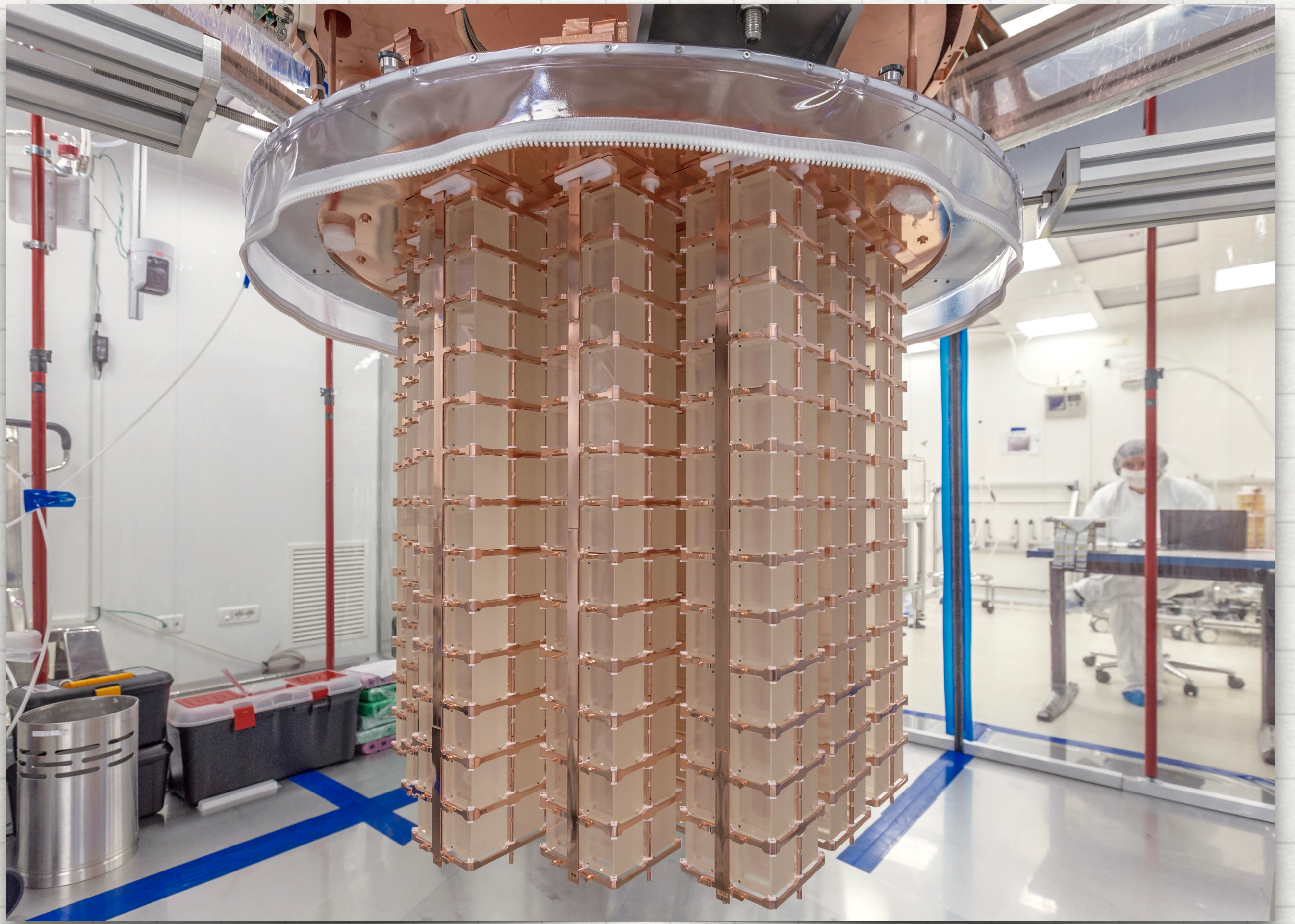
The ingots stayed under water for centuries, loosing most of their radioactive component (es. cosmogenic activated lead isotops)

The ingots have been melted in a clean envirnoment without the use of any additive during the melting process that could have contaminated the lead

CUORE COMMISSIONING

TOWERS INSTALLATION

towers installation
July - August 2016



The 19 towers were installed in a
radon free clean room.
It took about one month.

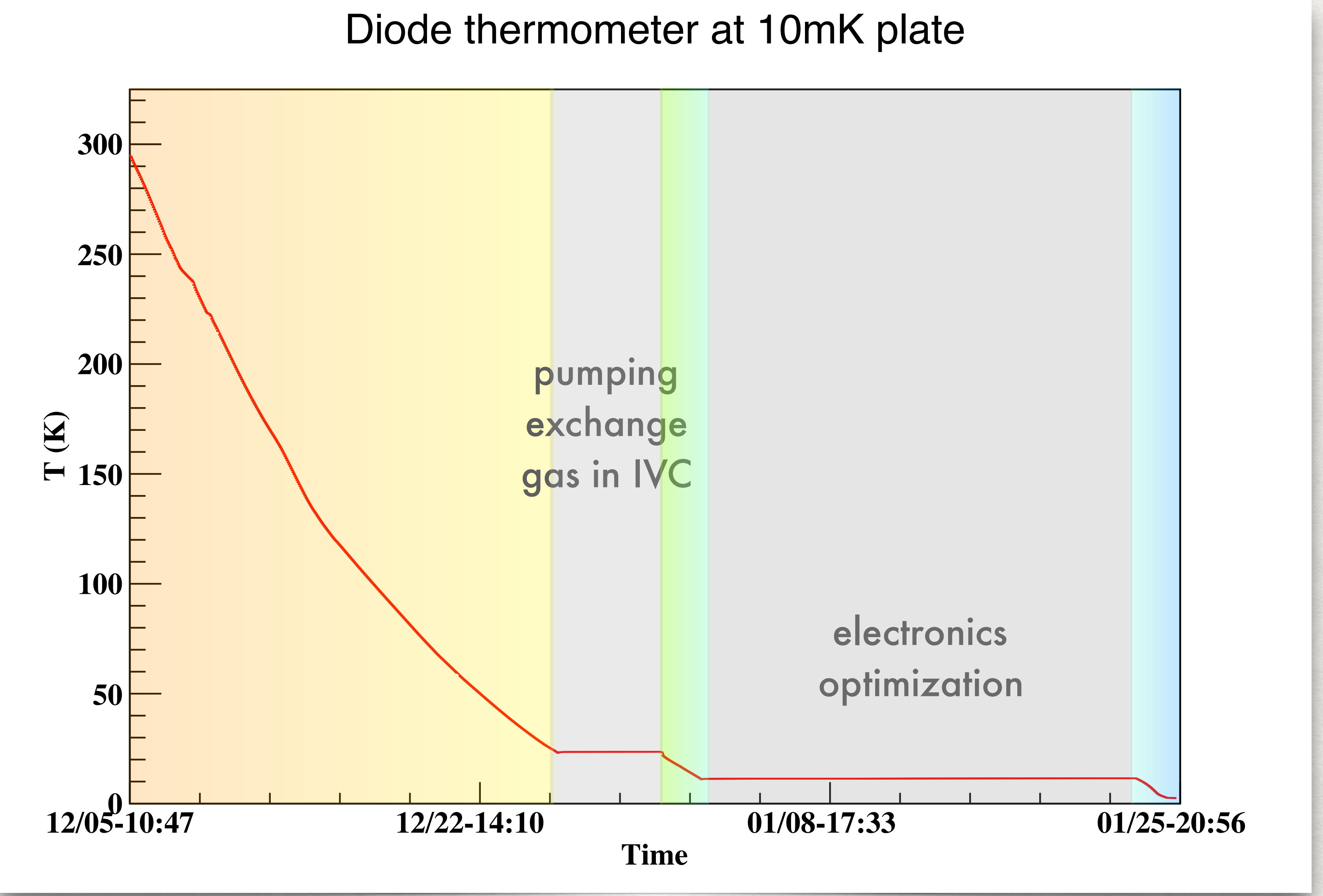
CUORE COOL DOWN

The cool down of the cryostat started in December 2016

First phase using helium exchange gas, then fast cooling and pulse tubes, then pulse tubes only

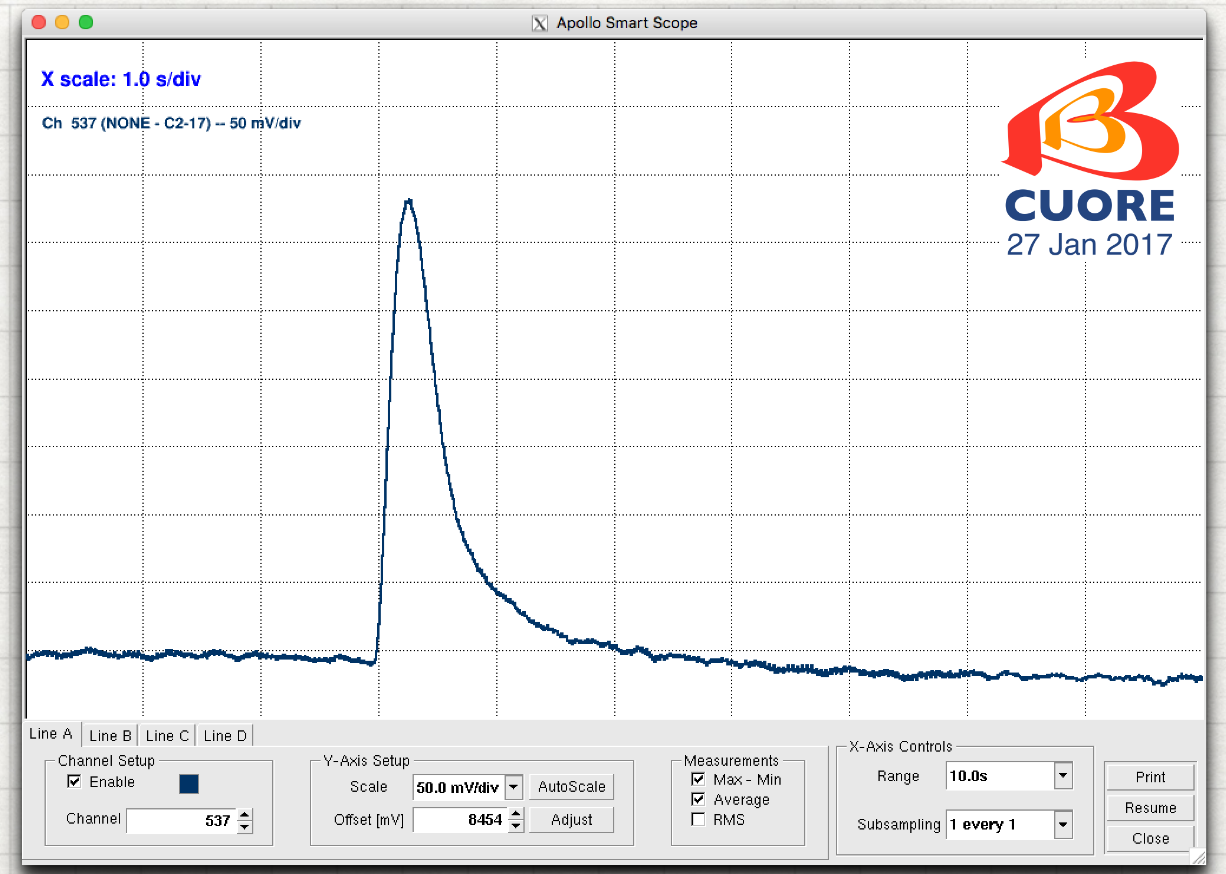
Last phase after the pause dedicated to electronics optimisation was achieved with the dilution unit, down to base temperature (~7mK)

26.01.2017
Base temperature 7 mK



END OF COMMISSIONING

AND BEGINNING OF DATA TAKING



27.01.2017
observation of the first CUORE pulse!

From 27.01.2017 (first pulse) up to now many achievements were obtained in different areas:

Noise optimization:

- Electronics noise attenuation
- Vibrations reduction (detector must be mechanically isolated)
- Pulse tube relative phase shift tuning

END OF COMMISSIONING

AND BEGINNING OF DATA TAKING

Temperature scan around base temperature to choose the one that optimise the signal and at the same time allow to work with the designed thermistor resistance

Working point scan to choose the best bias current to feed to each channel thermistor:

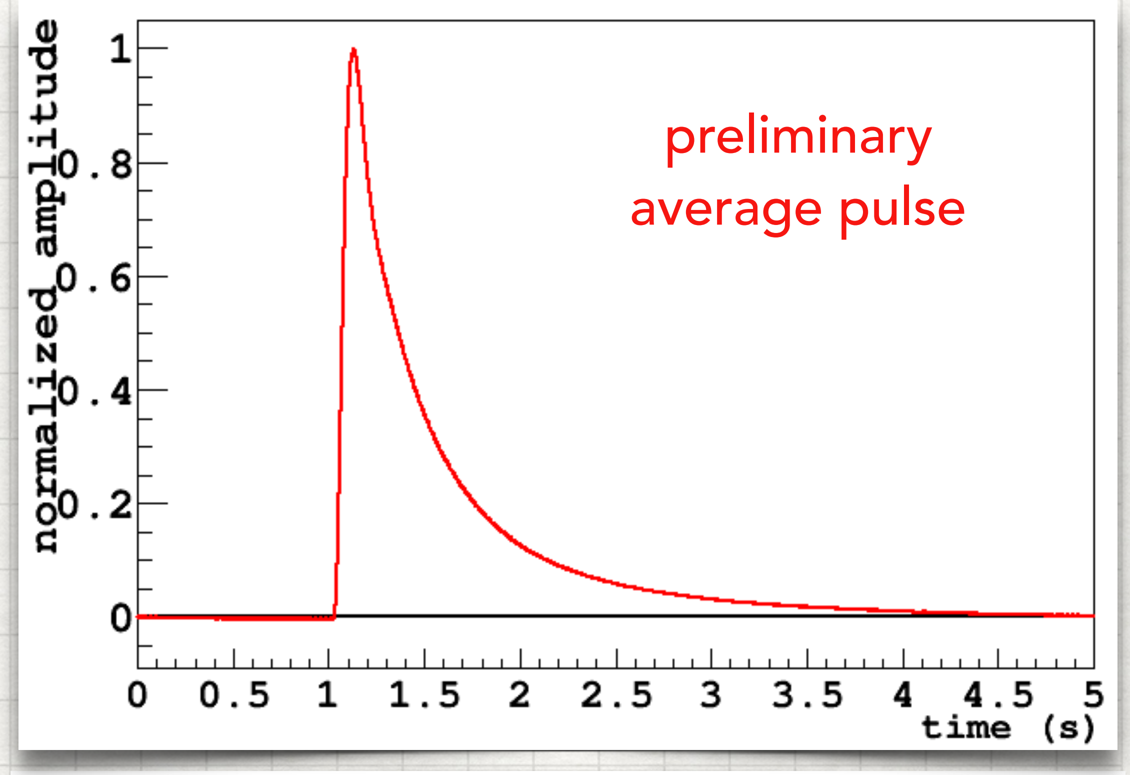
- linear behaviour for small temperature variations
- maximisation of signal to noise ratio
- optimization of pulse amplitude

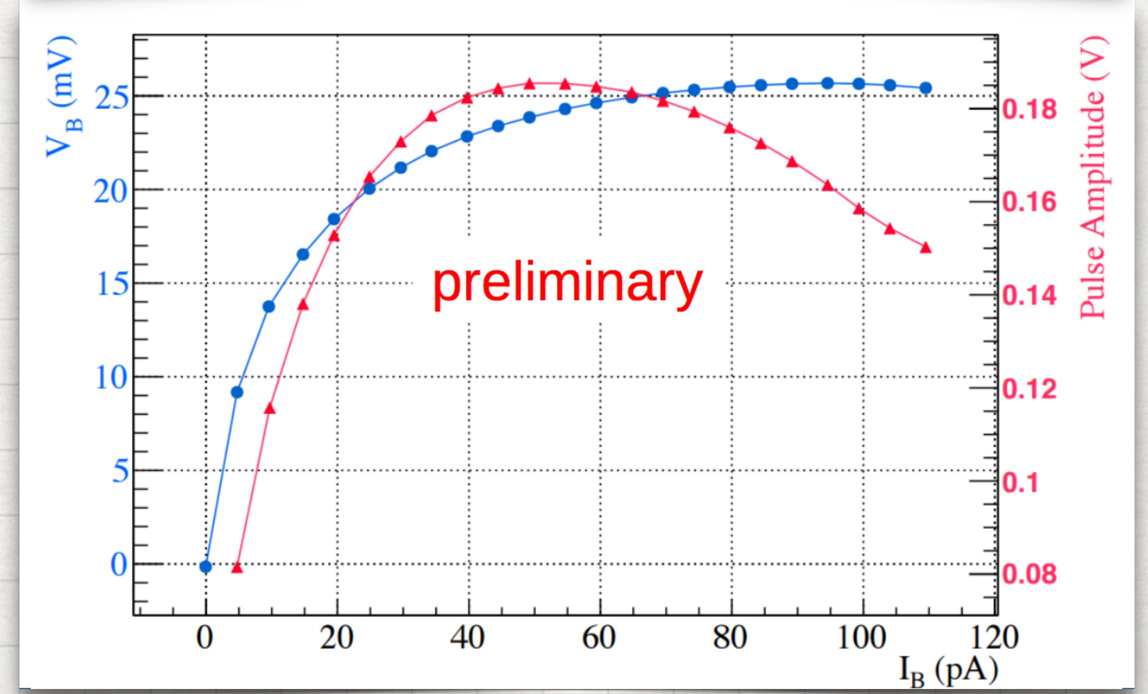
External lead shield raising

Calibration sources deployed (April 2017):

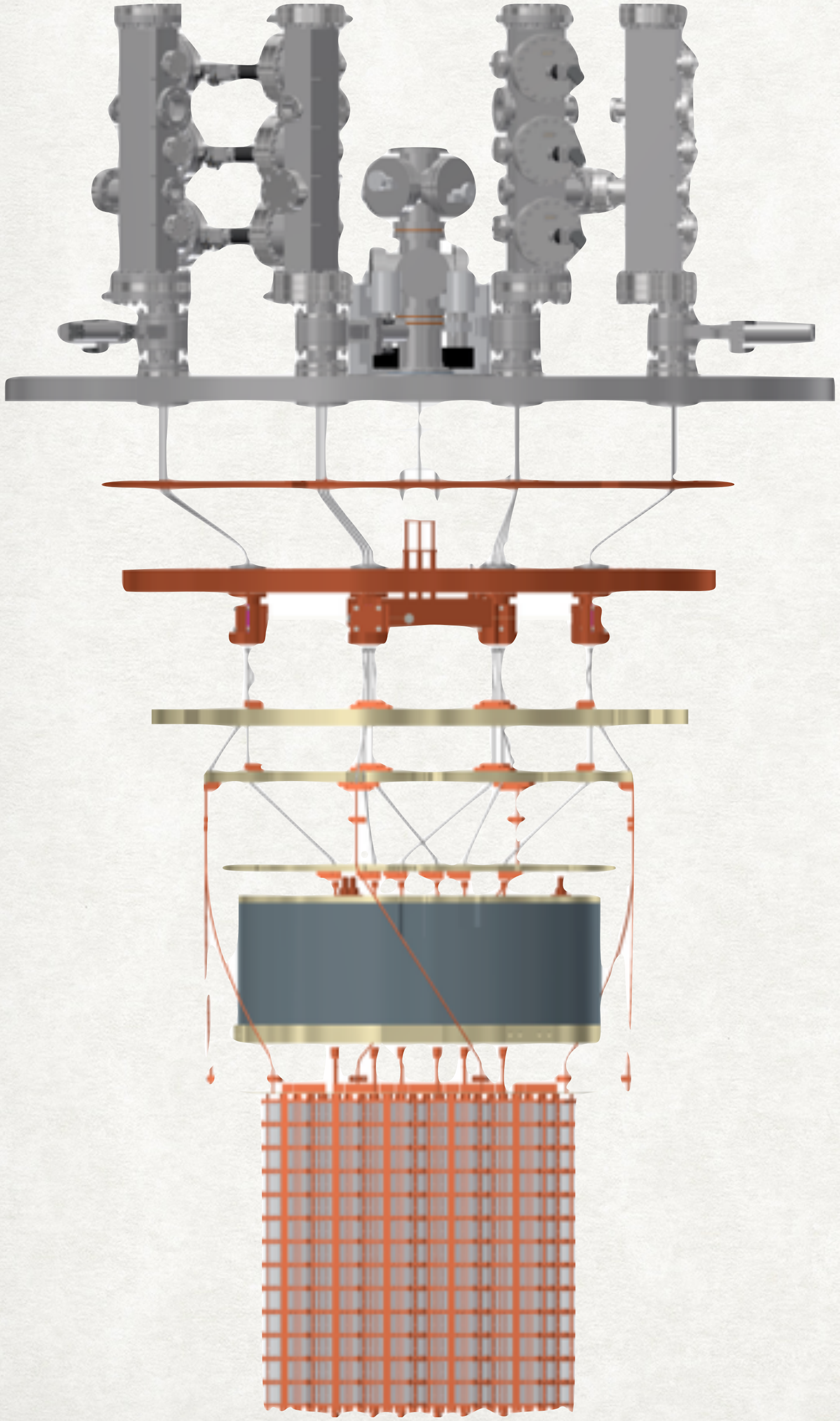
- deployment of 12 thoriated strings facing the detector
- preliminary energy calibration using the main peaks of ^{232}Th

Beginning of data taking (April 2017)



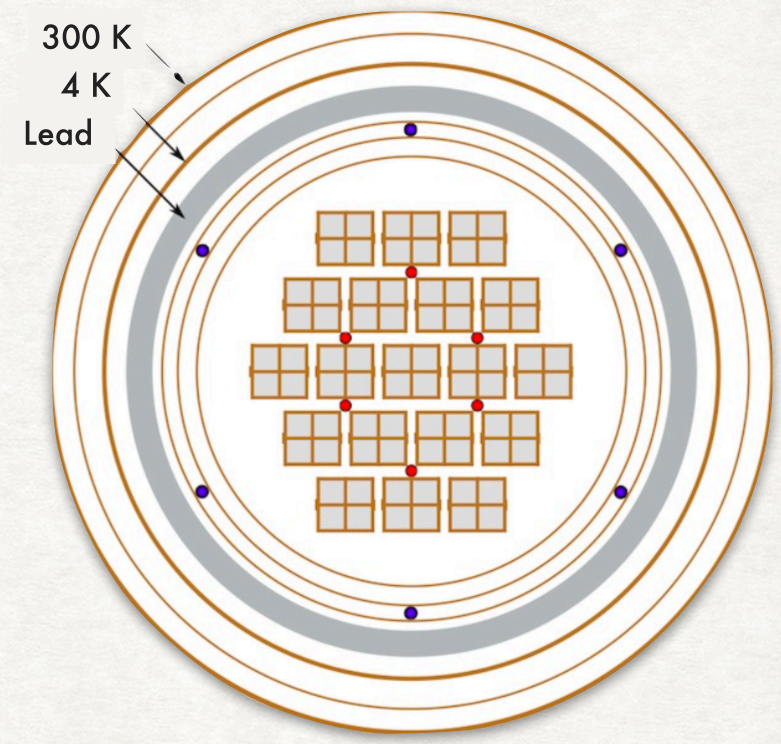


CALIBRATION SYSTEM



A series of tubes in the cryostat guide 12 strings that can be inserted within the detector towers.

- the strings contain ^{232}Th γ-ray sources that produce peaks from 239 keV to 2615 keV
- Usually these strings are kept outside the detector and lowered once a month for calibration
- Outer strings have an higher activity in order to compensate for the two inner cryostat Cu vessels



Nucl. Instrum. Methods A 844 (2017) 32-44 arXiv:1608.01607v2

CONCLUSION

In conclusion the CUORE commissioning was successful:

- CUORE cryostat commissioning March-April 2016
- CUORE towers installation July-August 2016
- CUORE cryostat close-out November 2016
- CUORE cooldown and start of pre-operation December 2016
- First CUORE pulses starting from January 2017
- First deployment of calibration system April 2017
- Beginning first data-taking April 2017

In April 2017 the CUORE commissioning ended and CUORE data-taking began

PHYSICS DATA COMING SOON... STAY TUNED!

THANK YOU

THE CUORE COLLABORATION