Status of CUORE

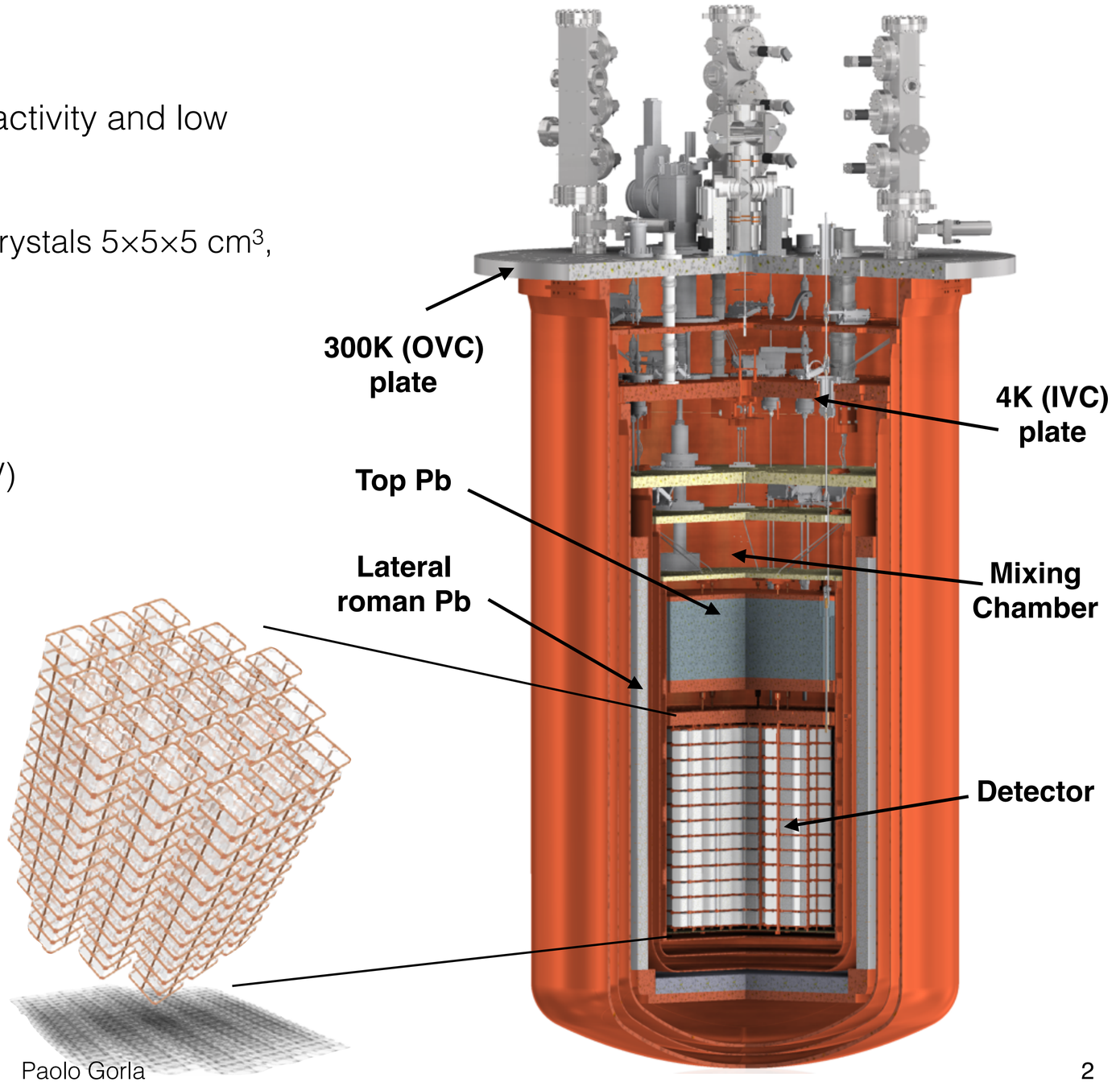
Paolo Gorla
Laboratori Nazionali del Gran Sasso

for the CUORE collaboration

The CUORE challenge

Operate a huge bolometric array, in an extremely low radioactivity and low vibrations environment, to detect 0νDBD of ^{130}Te

- Closely packed array of 988 TeO_2 crystals (19 towers of 52 crystals 5×5×5 cm^3, 0.75 kg each)
- Mass of TeO_2: 741 kg (~206 kg of ^{130}Te)
- Energy resolution: 5 keV @ 2615 keV [FWHM] ($Q_{\beta\beta}$=2527 keV)
- Stringent radiopurity controls on materials and assembly
- Operating temperature: ~ 10 mK
- Mass to be cooled < 4 K: ~ 15 tons (lead, copper and TeO_2)
- Background aim: 10^{-2} c/keV/kg/year
- $T_{1/2}$ sensitivity in 5 years (90% C.L.): ~ 9.5 x 10^{25} yr



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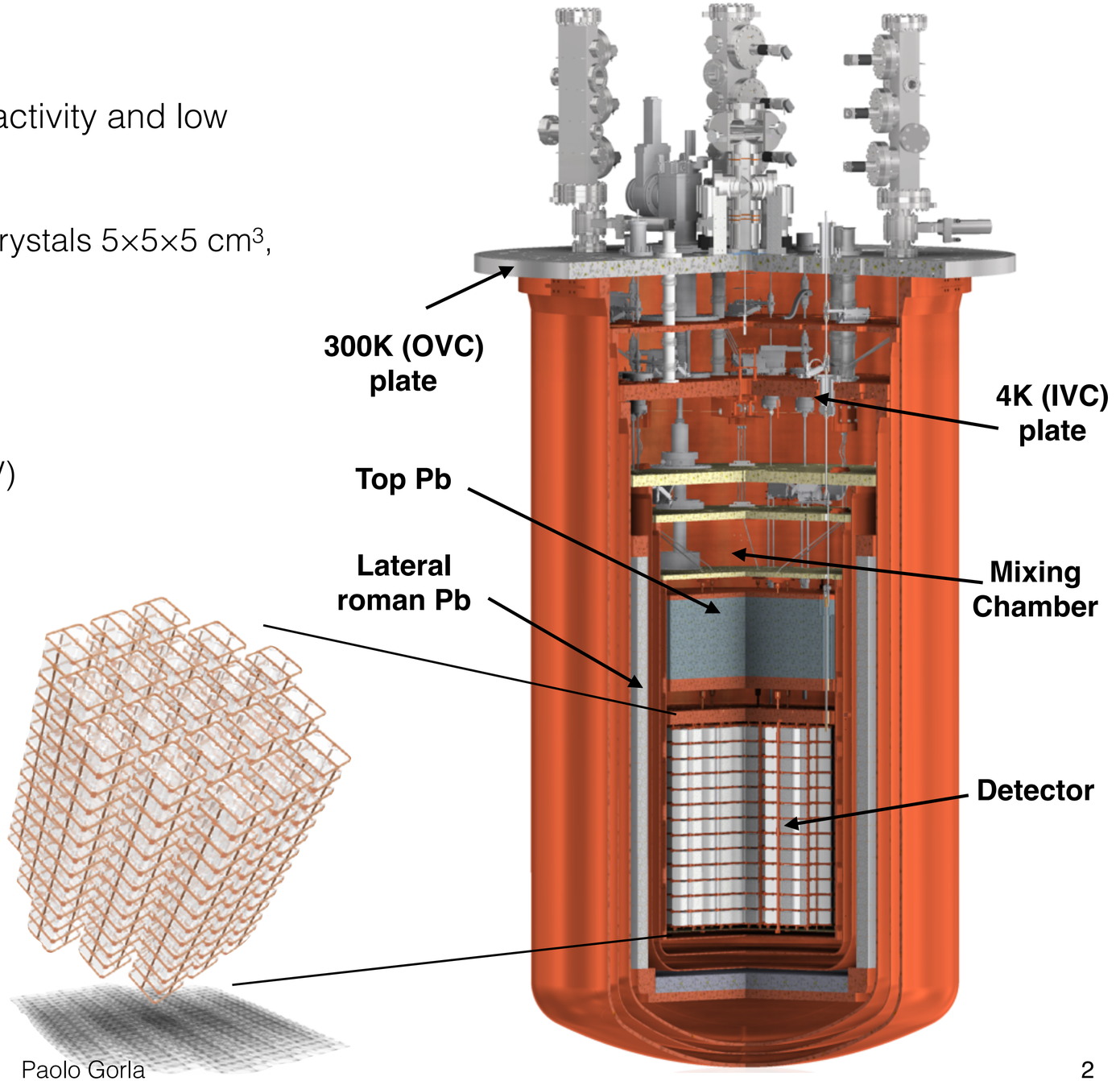

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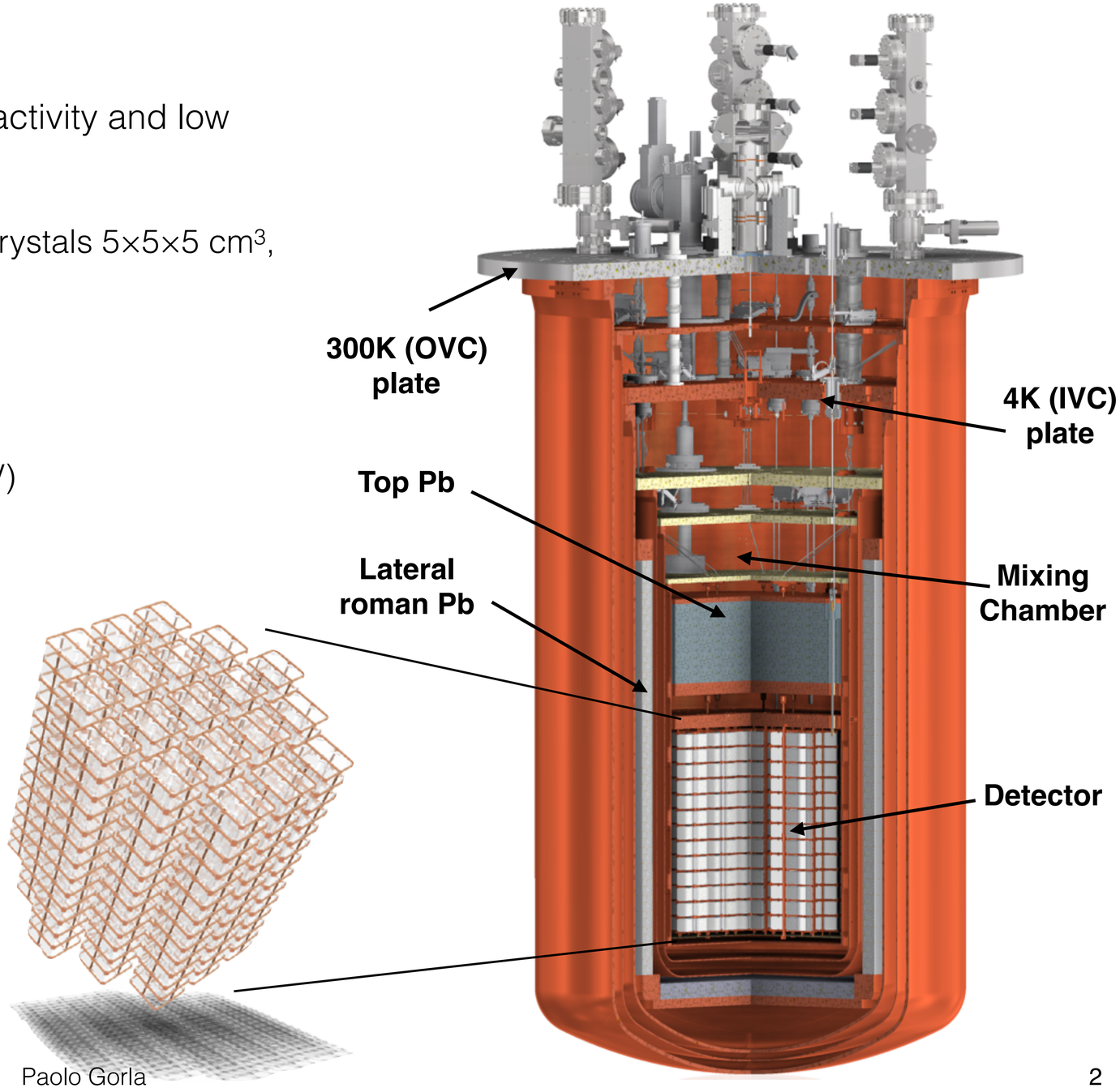
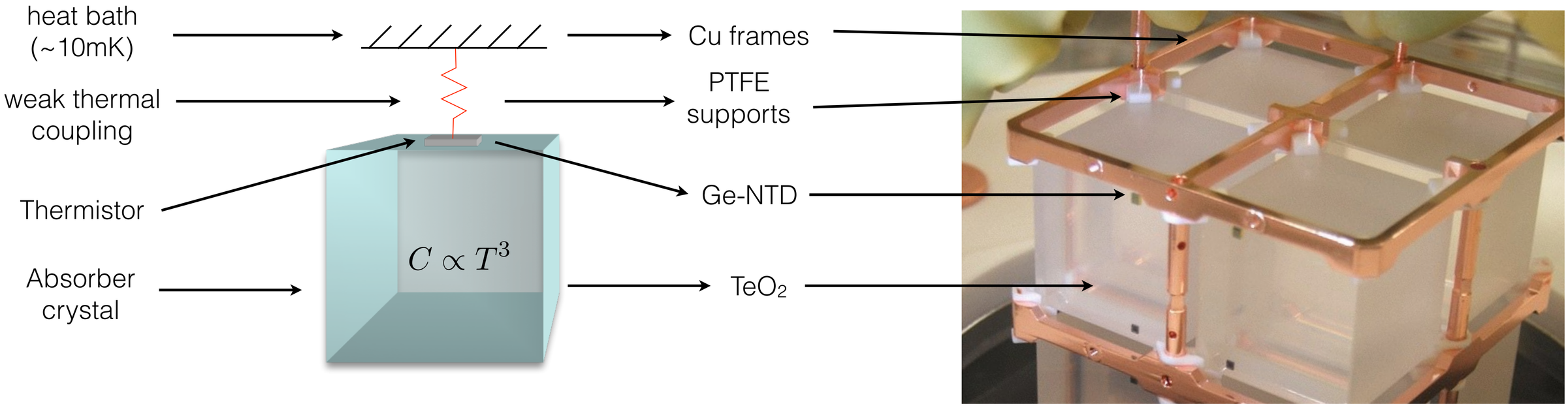
  - CUORE-0 results
  - CUORE commissioning

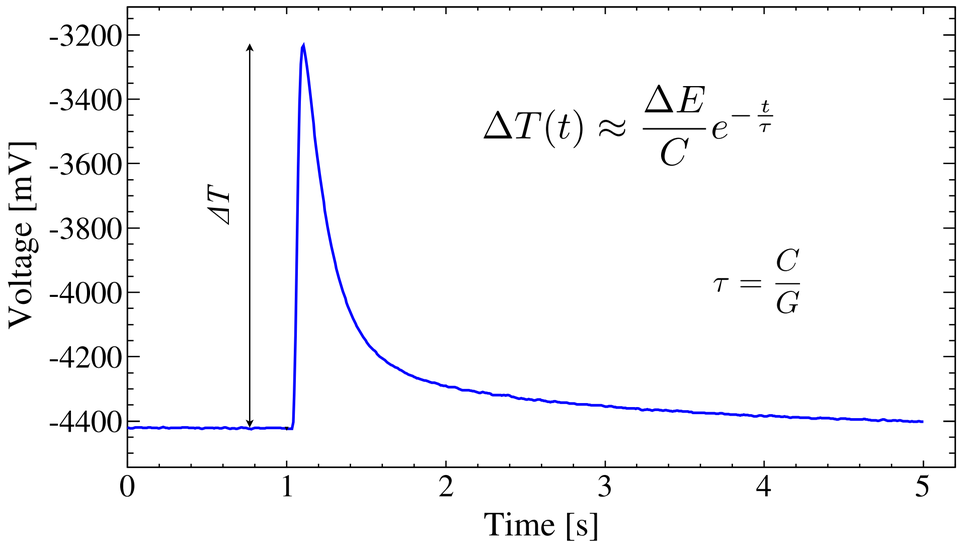


Thermal Detectors

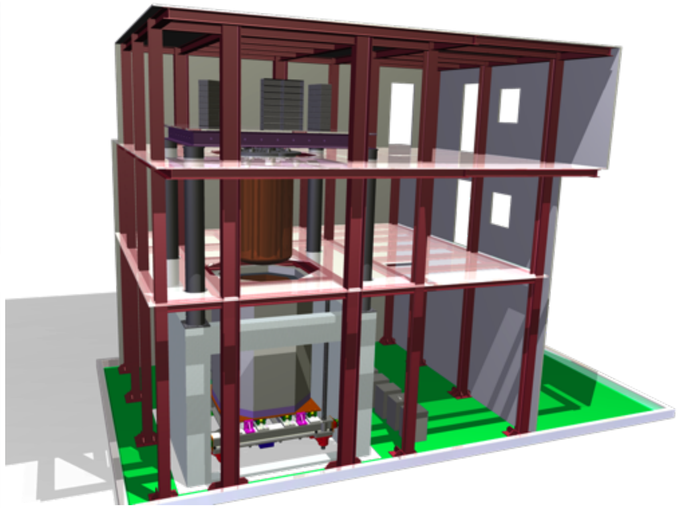


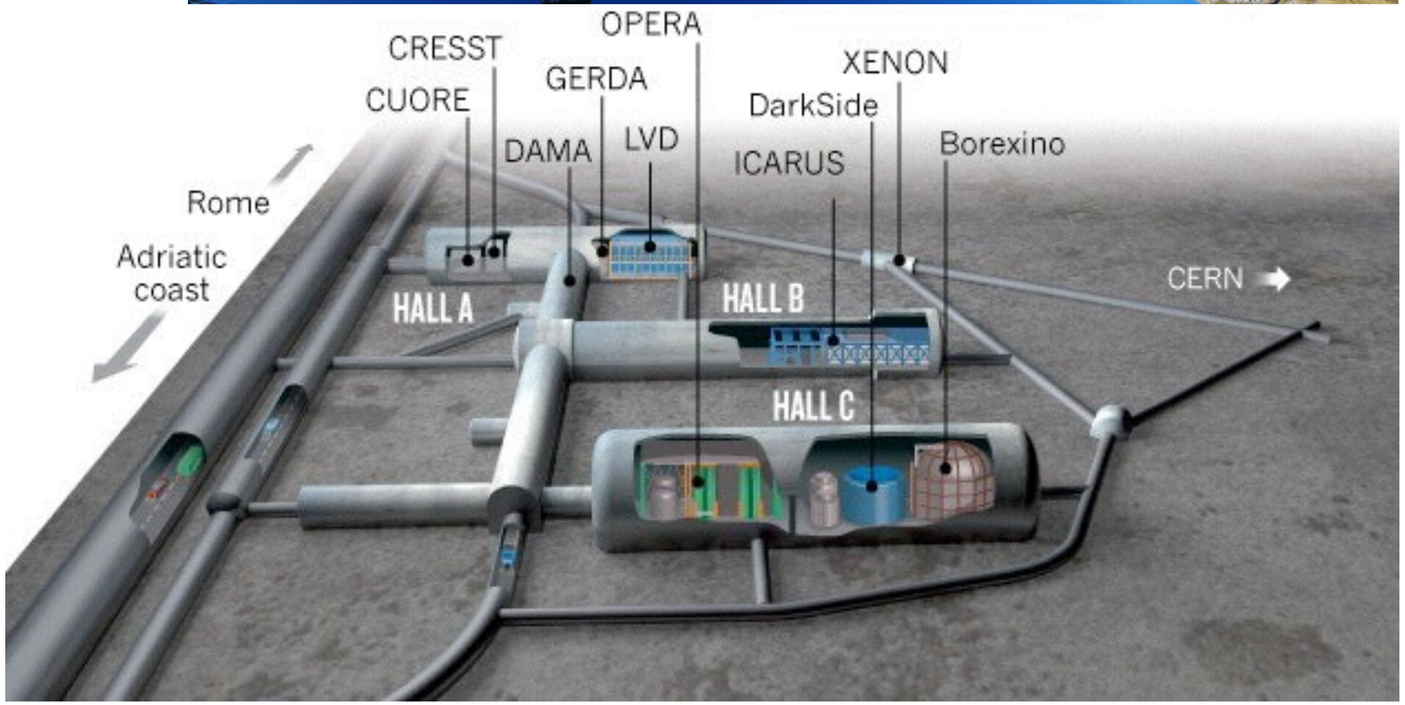
- low heat capacity @ T_{work}
- excellent energy resolution (~1 ‰ FWHM)

  huge number of energy carriers (phonons)
- equal detector response for different particles
- slowness (suitable for rare event searches)



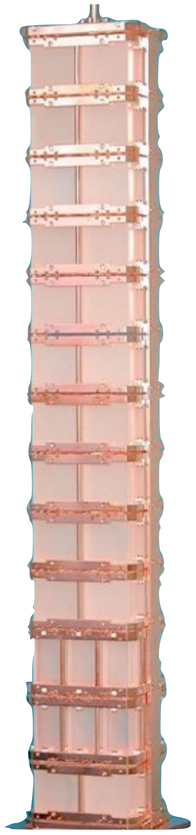
CUORE @ Gran Sasso





- ~3800 m.w.e. deep
- μs: ~3x10^{-8}/(s cm^2)
- γs: ~0.73/(s cm^2)
- neutrons: 4x10^{-6} n/(s cm^2)

The CUORE program

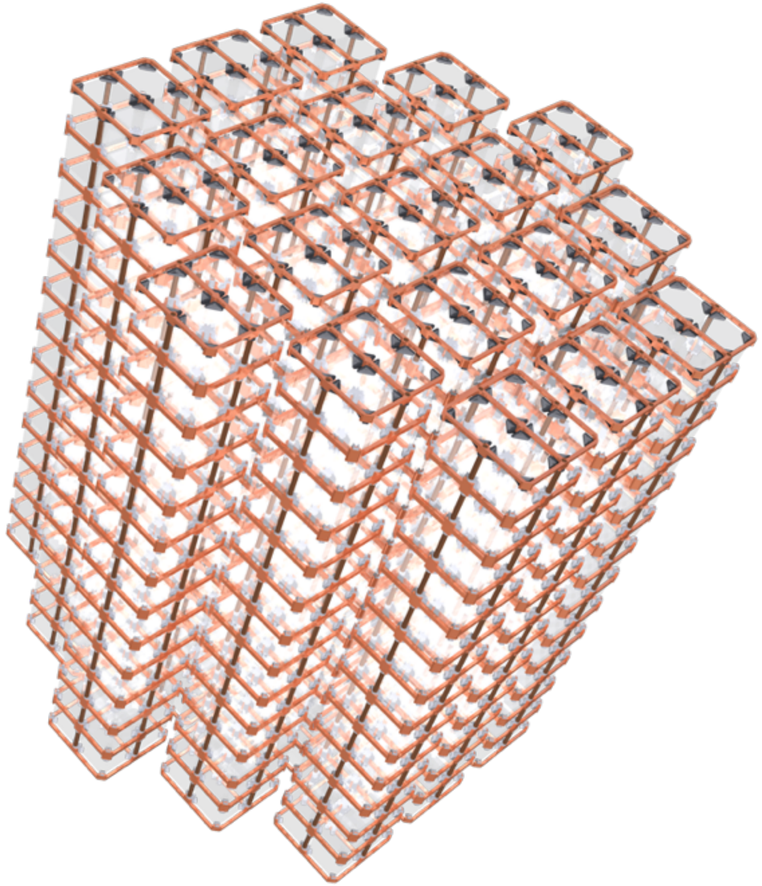


CUORICINO
(2003-2008)

COMPLETED

CUORE-0
(2012- 2015)

COMPLETED



CUORE
2016

Ready for detector installation

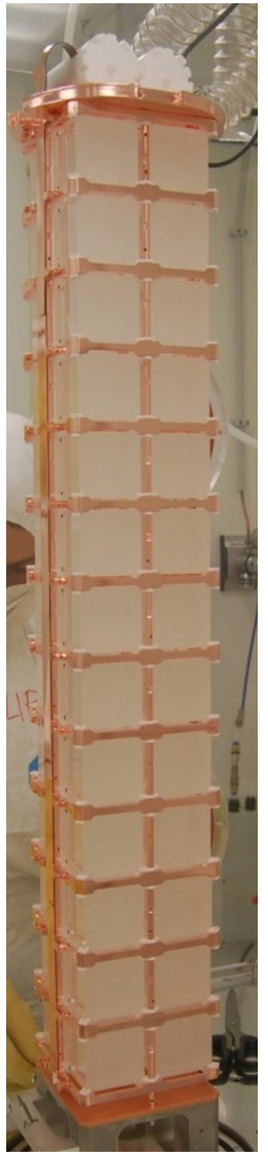
CUORE-0

CUORE-0 was the first tower produced out of the CUORE assembly line.

- 52 TeO_2 5x5x5 cm^3 crystals (~750 g each)
- 13 floors of 4 crystals each
- total detector mass: 39 kg TeO_2 (10.9 kg of ^{130}Te)

CUORE-0 took data from March 2013 to September 2015 in the 25 years old Cuoricino cryostat.

- Proof of concept of CUORE detector in all stages
- Test and debug of the CUORE tower assembly line
- Test of the CUORE DAQ and analysis framework
- Check of the radioactive background reduction
- Sensitive 0vDBD experiment



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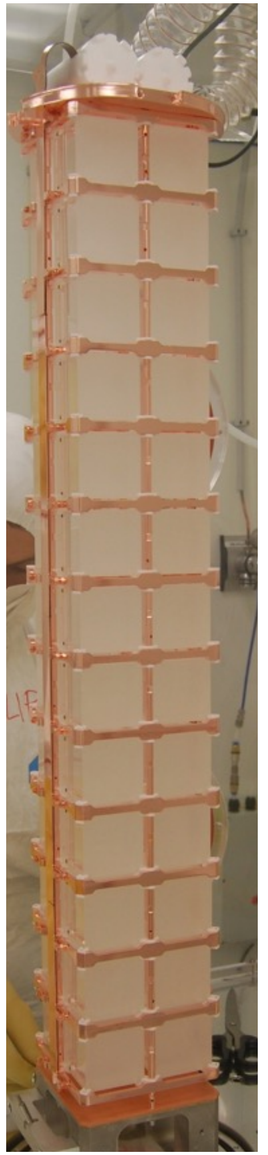
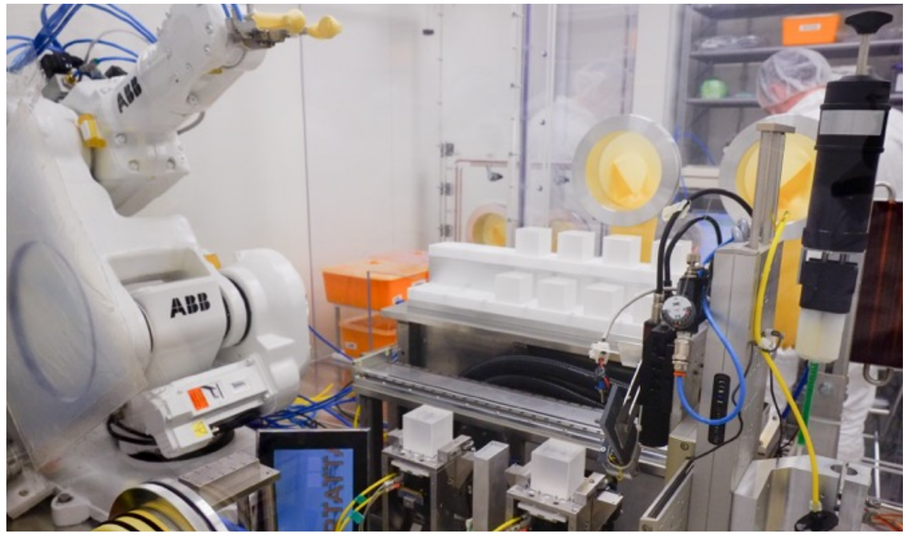
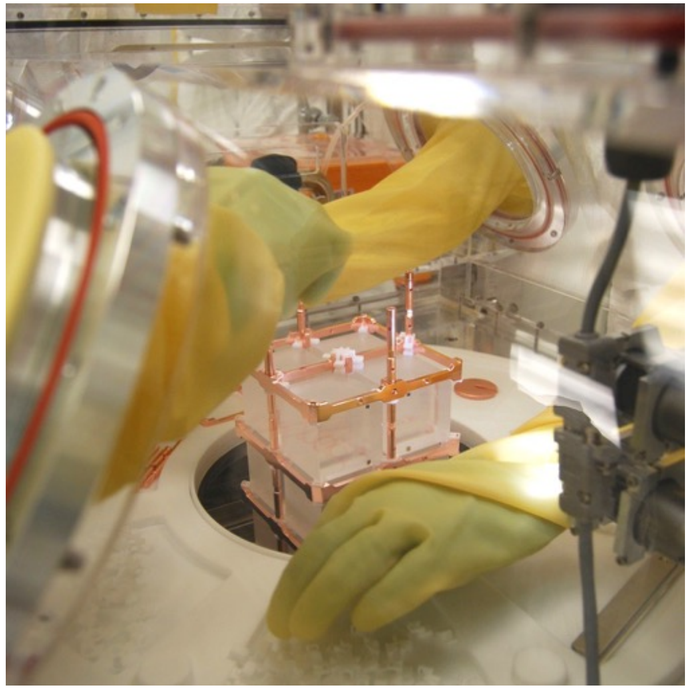
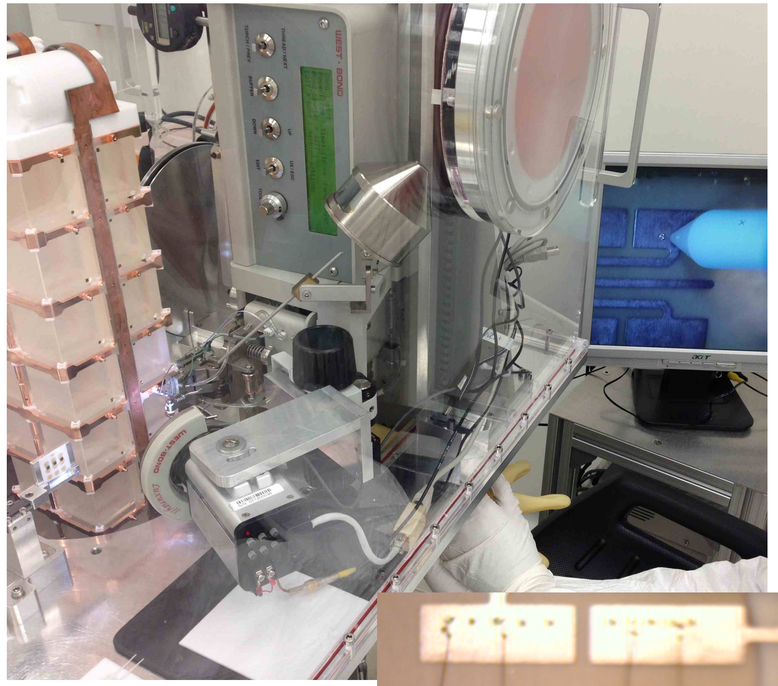


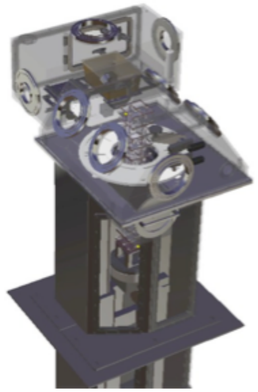
CUORE-0 Assembly & Bonding

No-touch approach: all the operations carried out in N2 atmosphere

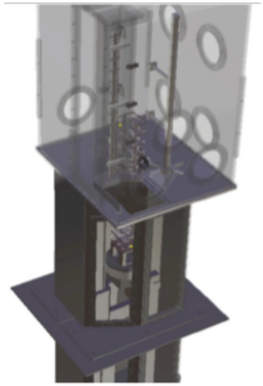




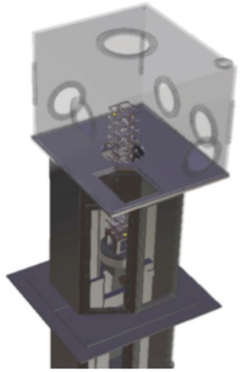




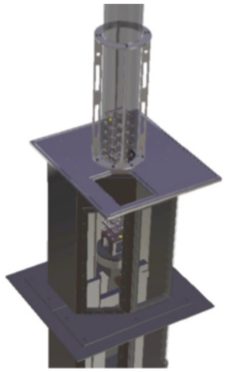
1. Assembly box



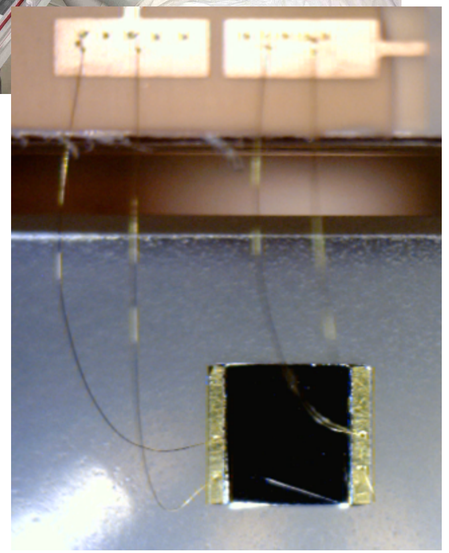
2. Cabling box



3. Bonding box

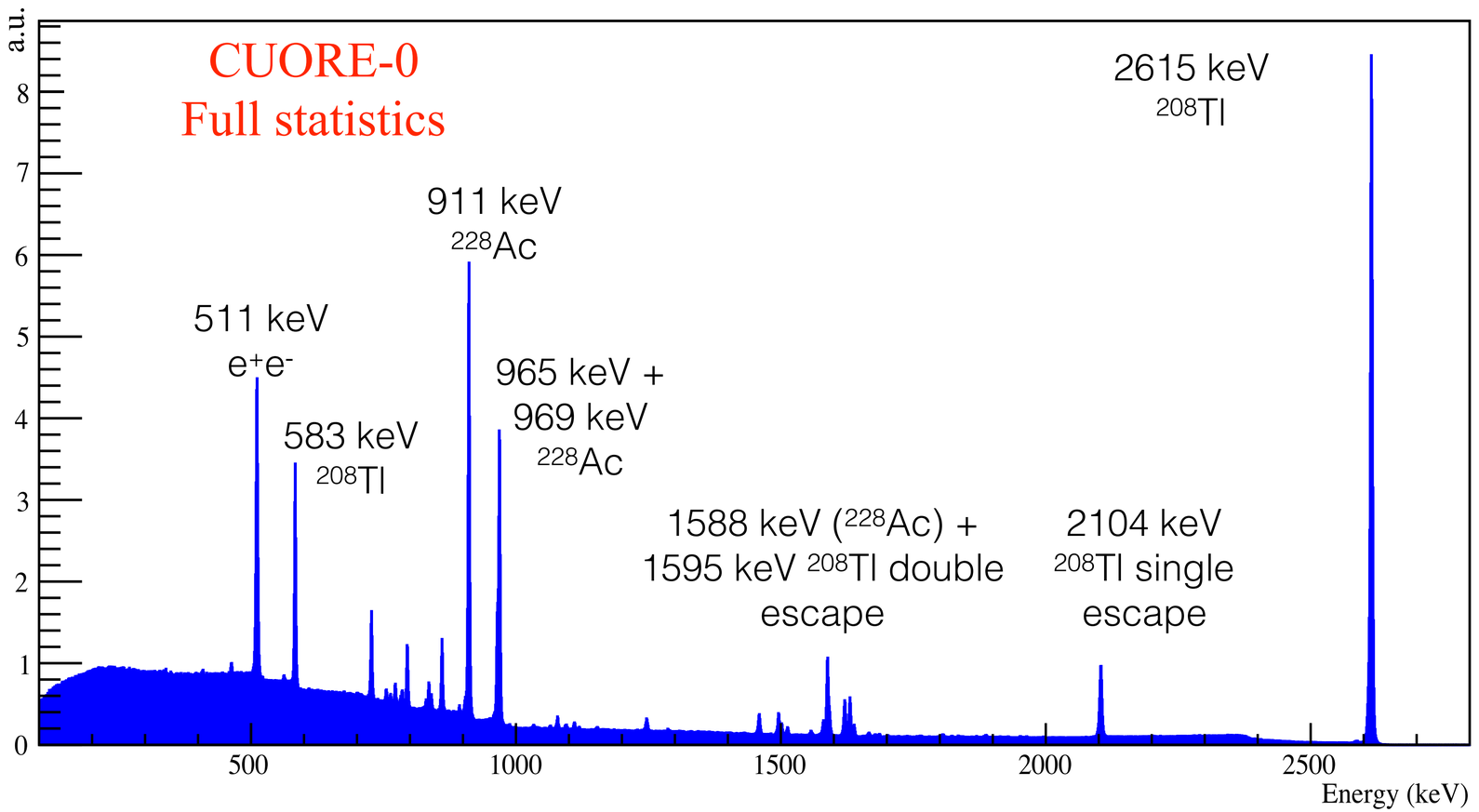


4. Storage box



CUORE-0 ^{232}Th calibration and resolution

CUORE-0 total calibration energy spectrum



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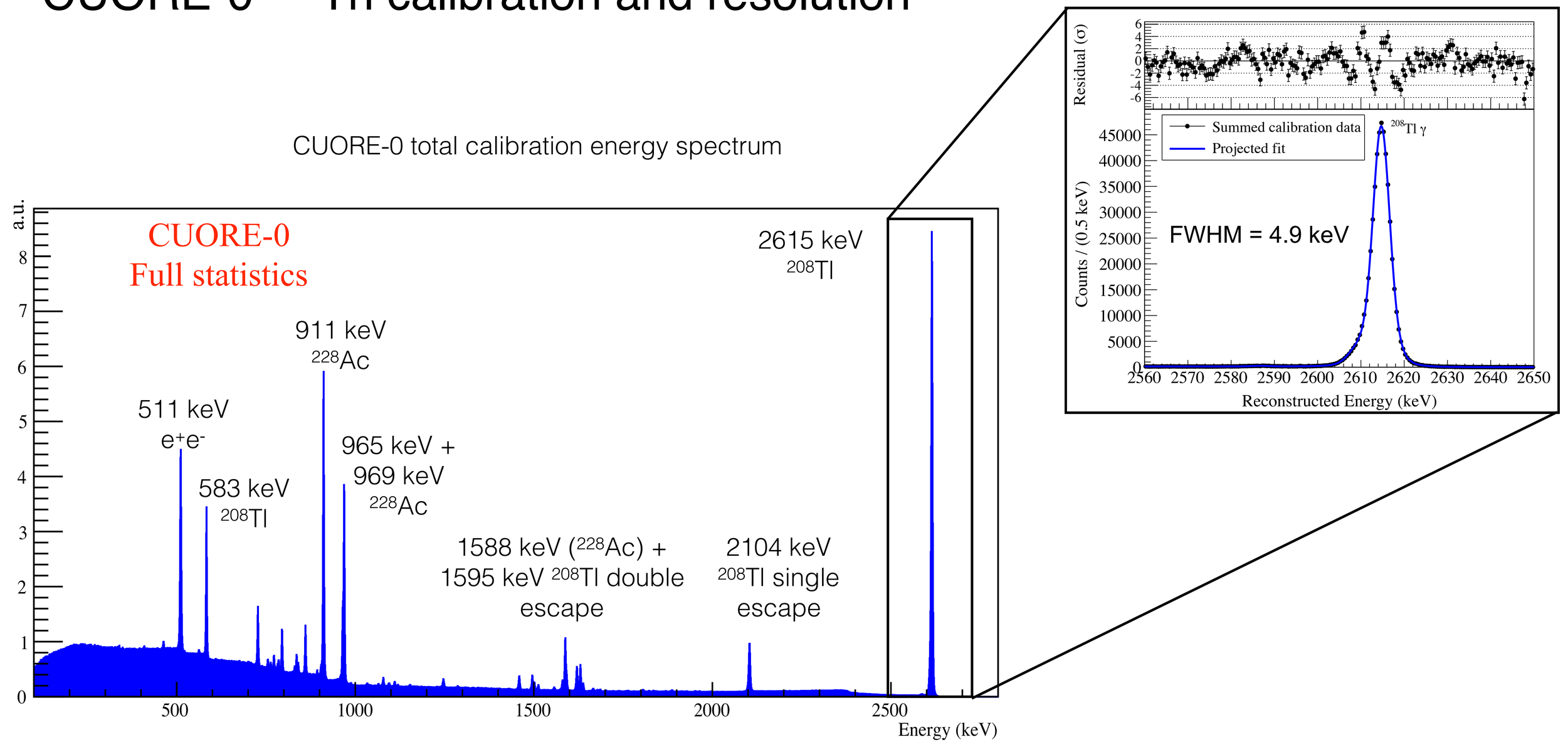

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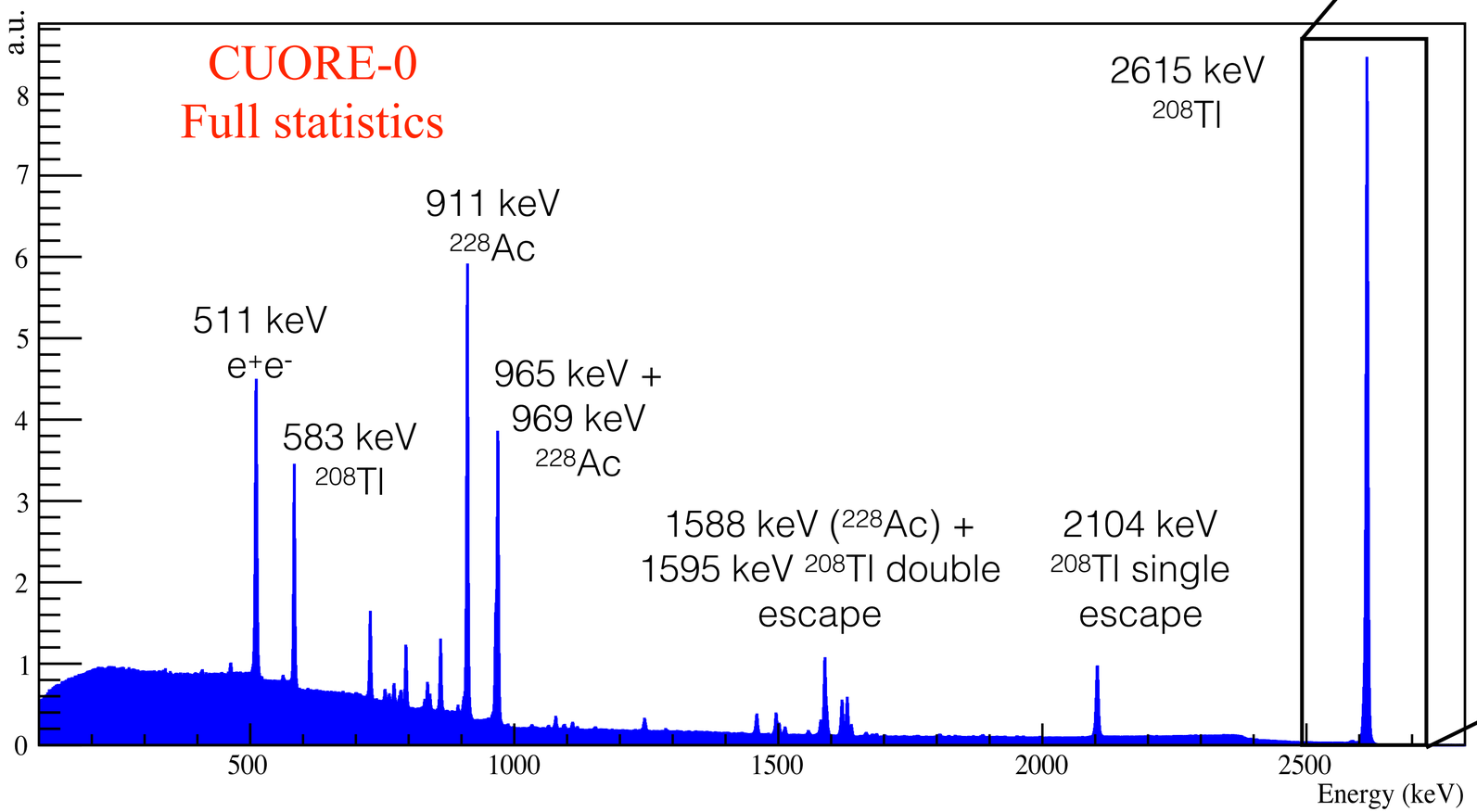
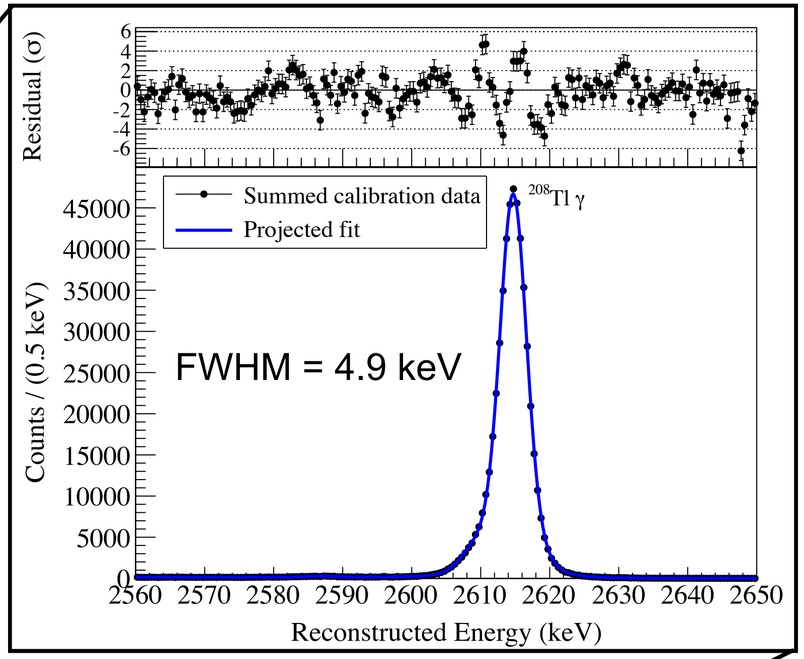




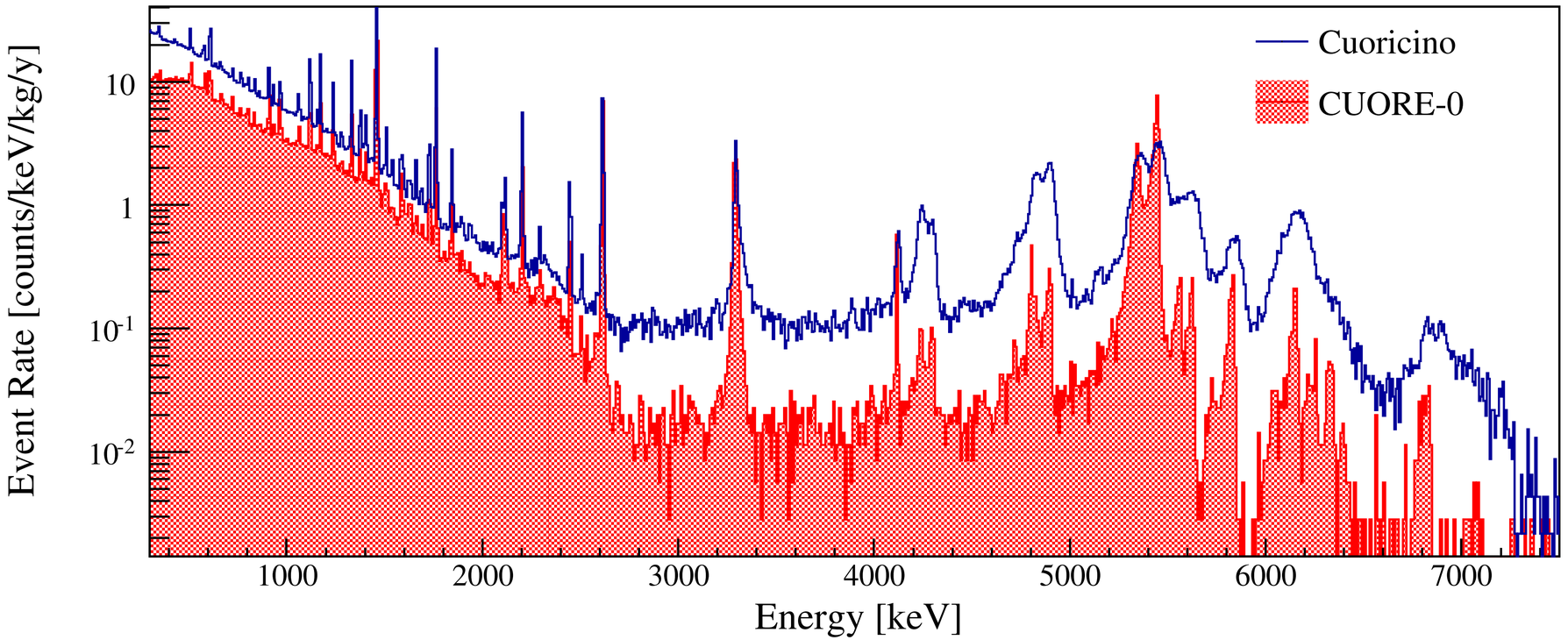
The 5 keV CUORE goal has been reached

Physics-exposure-weighted harmonic mean

@ 2615 keV	Average FWHM [keV]
Cuoricino	5.8
CUORE-0	4.9

CUORE-0 background

Comparison of the total background spectrum
in CUORE-0 and Cuoricino



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

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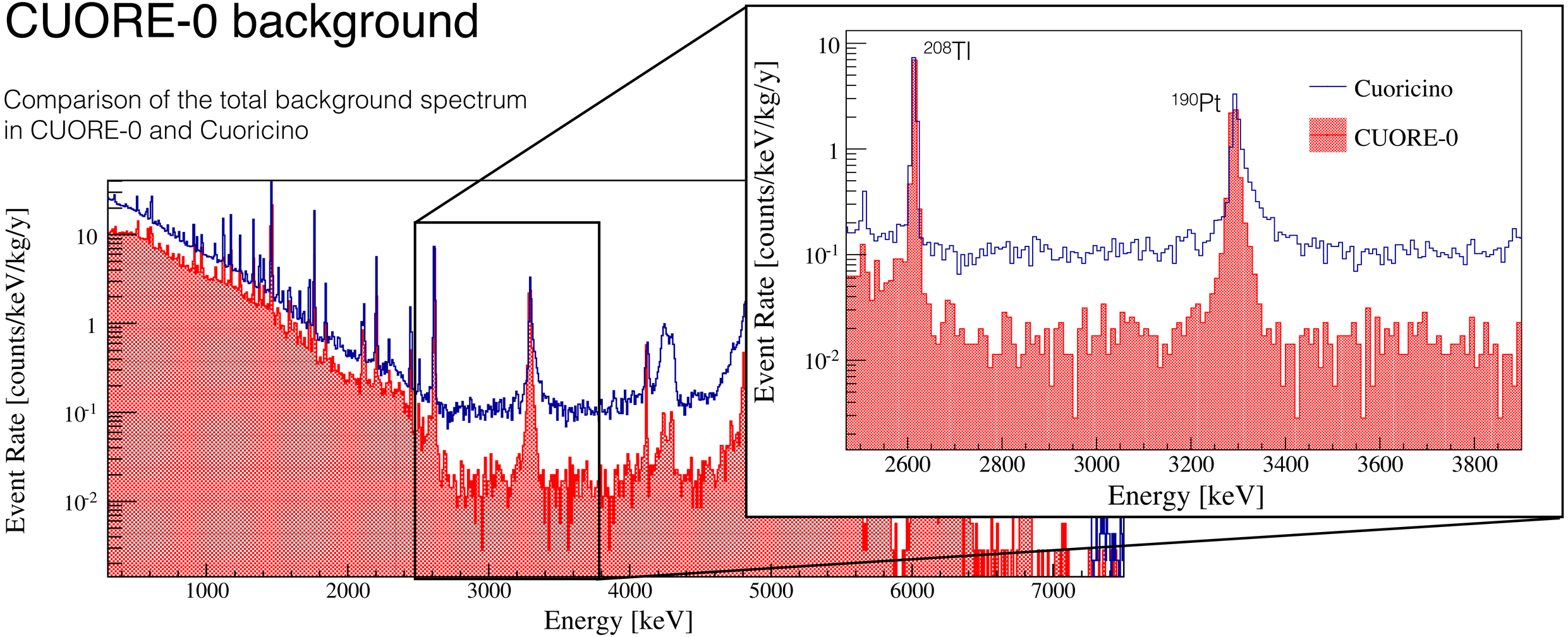

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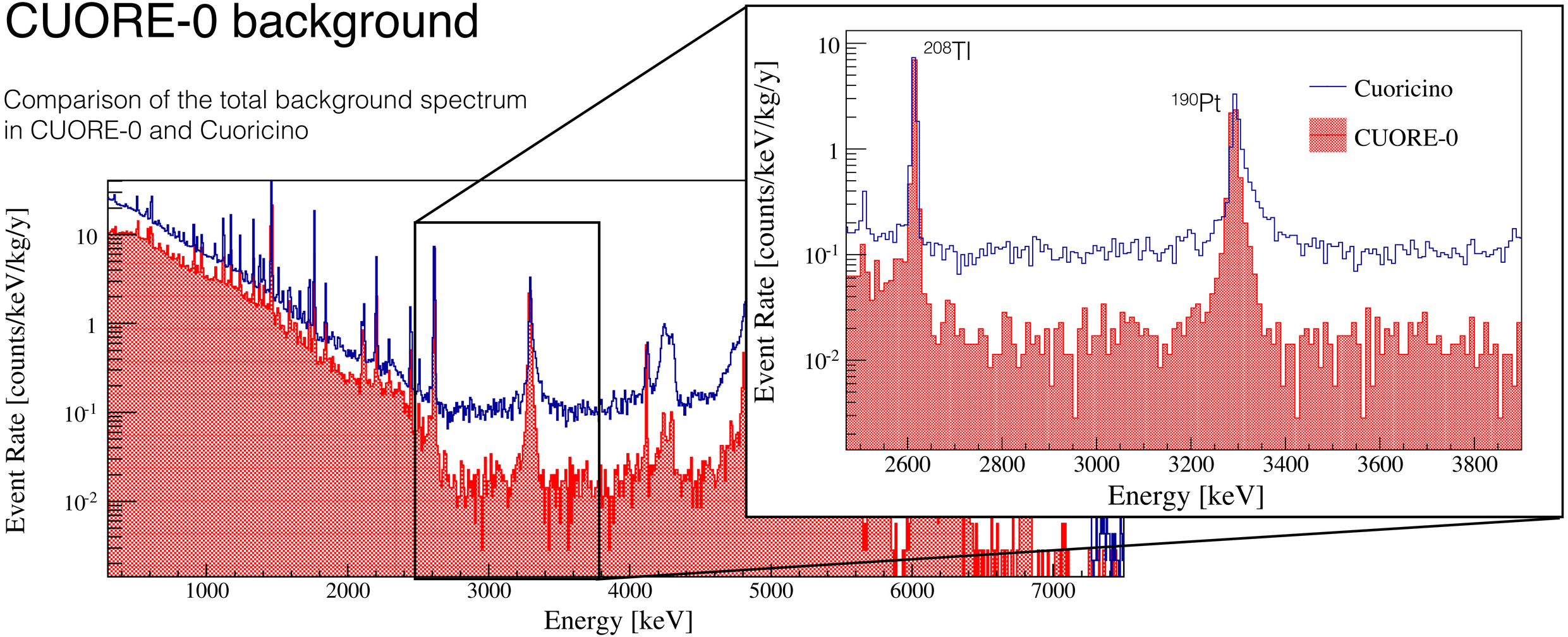

	2.7-3.9 MeV [counts/keV/kg/y]	ROI [counts/keV/kg/y]
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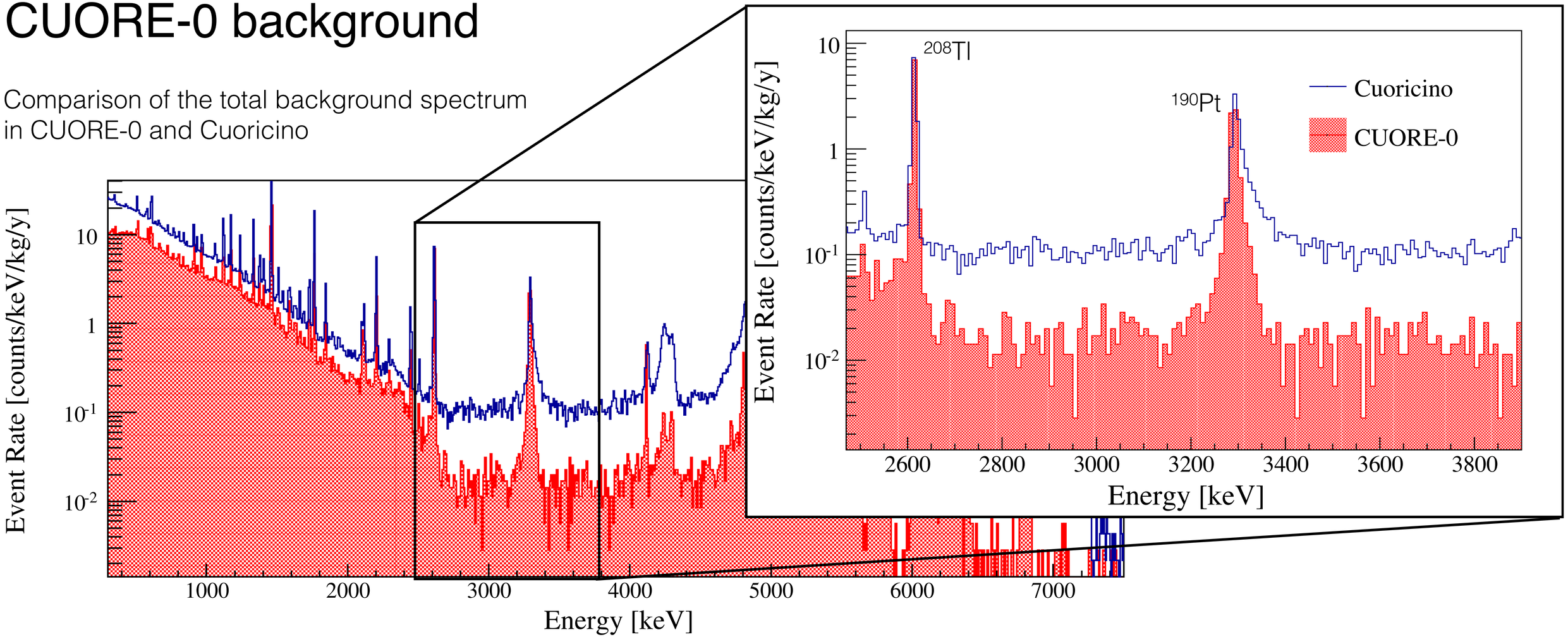

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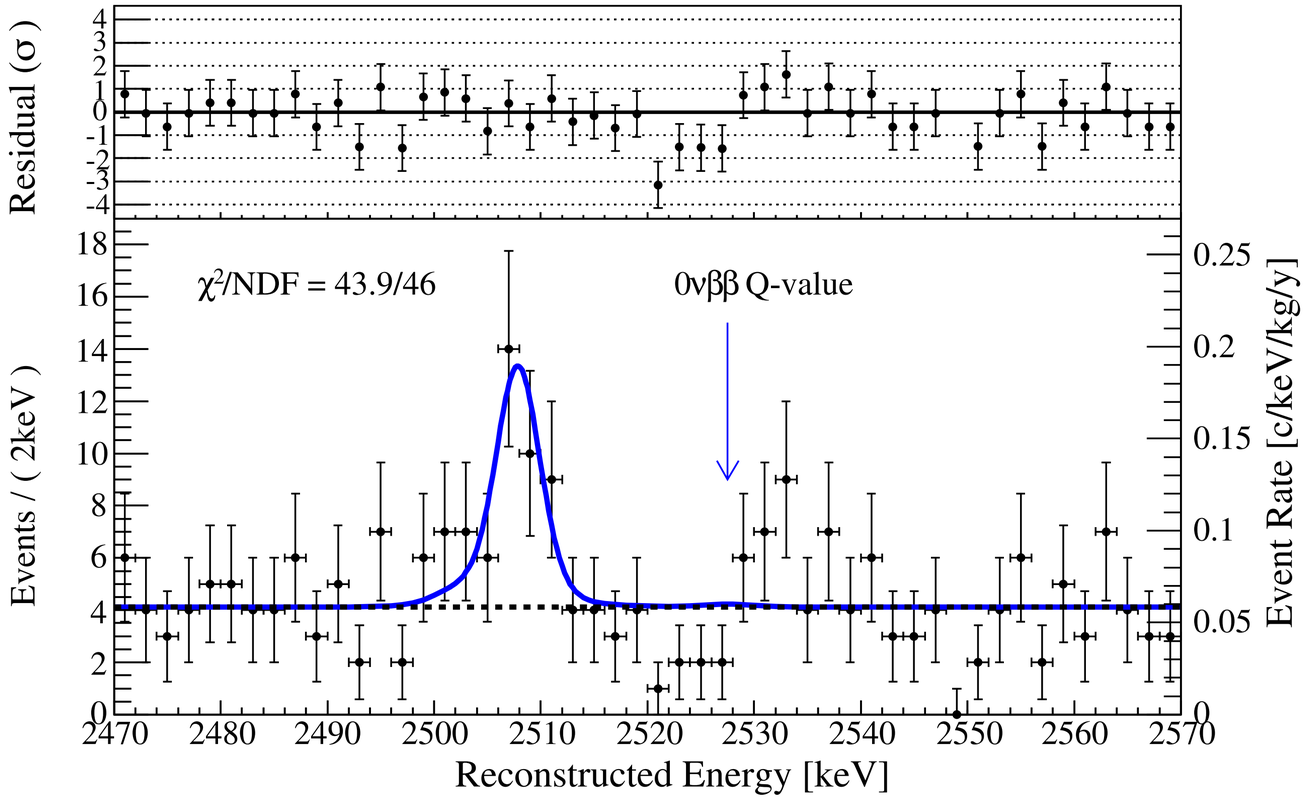
~ factor 7 reduction in the alpha continuum region

CUORE-0 results



Exposure: 9.8 kg·yr ^{130}Te

Best Fit Decay Rate: $\Gamma^{0\nu\beta\beta}$ (130Te) = 0.01 ± 0.12 (stat.) ± 0.01 (syst.) × 10^{-24} yr^{-1}

- Combination of the CUORE-0 result with the existing 19.75 kg · yr of ^{130}Te exposure from Cuoricino
- The combined 90% C.L. limit is $T_{1/2} > 4.0 \times 10^{24}$ yr.

Phys. Rev. Lett. 115, 102502

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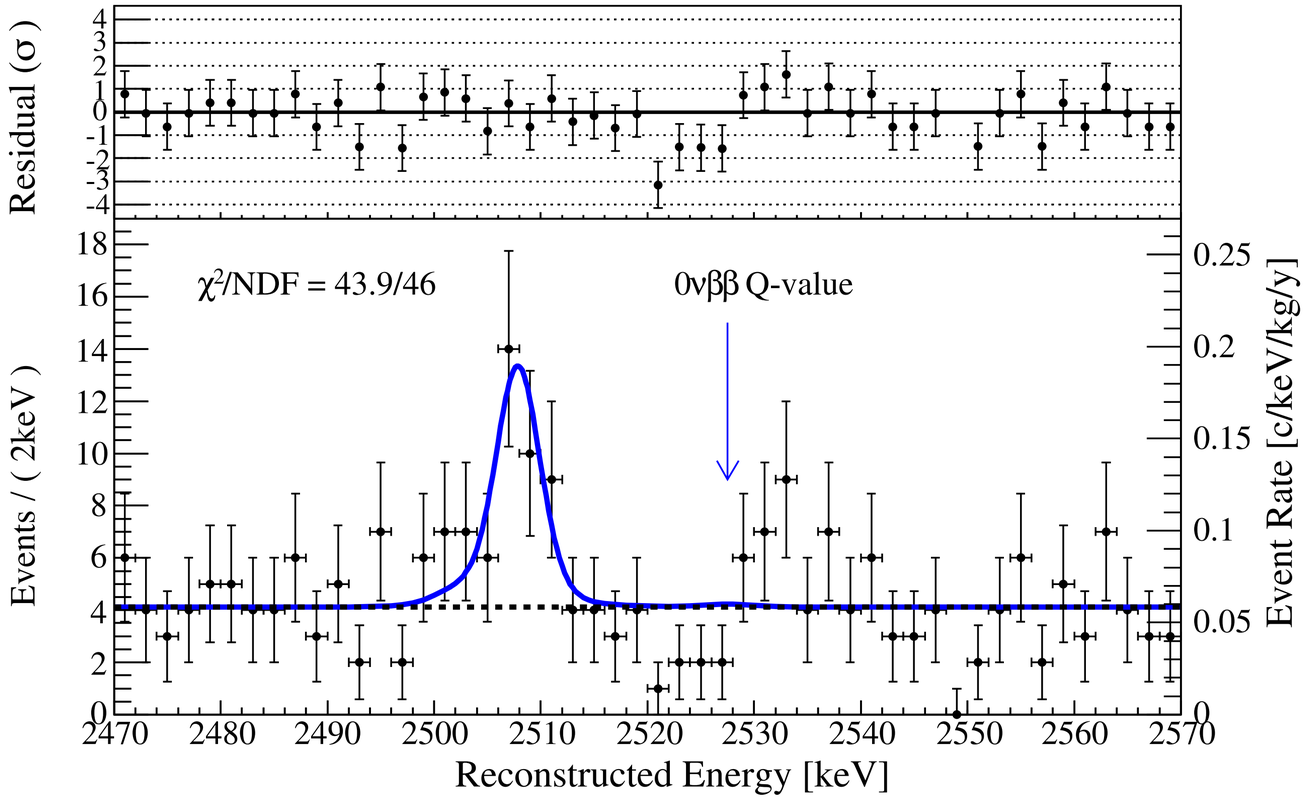

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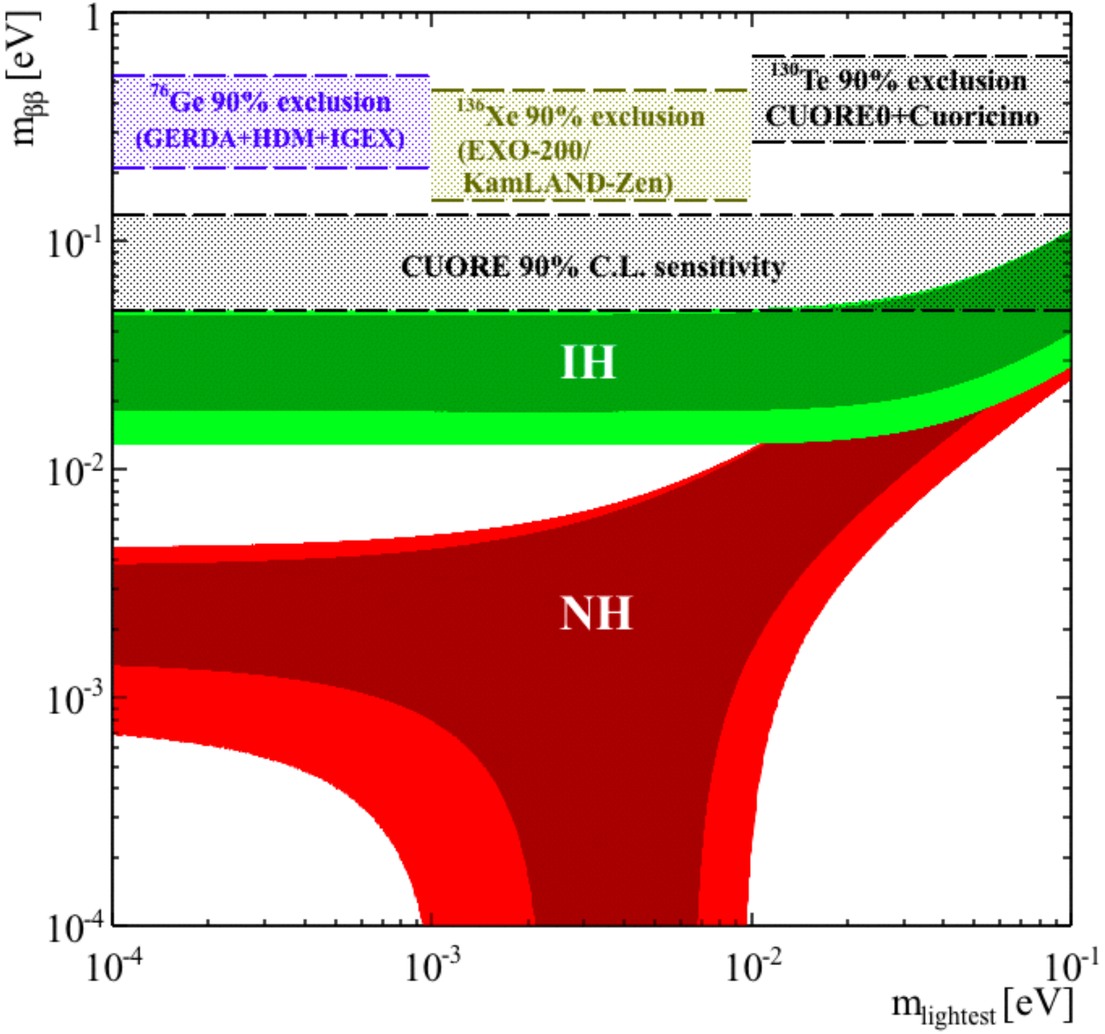

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- $\langle m_{\beta\beta} \rangle <$ (270-650) meV

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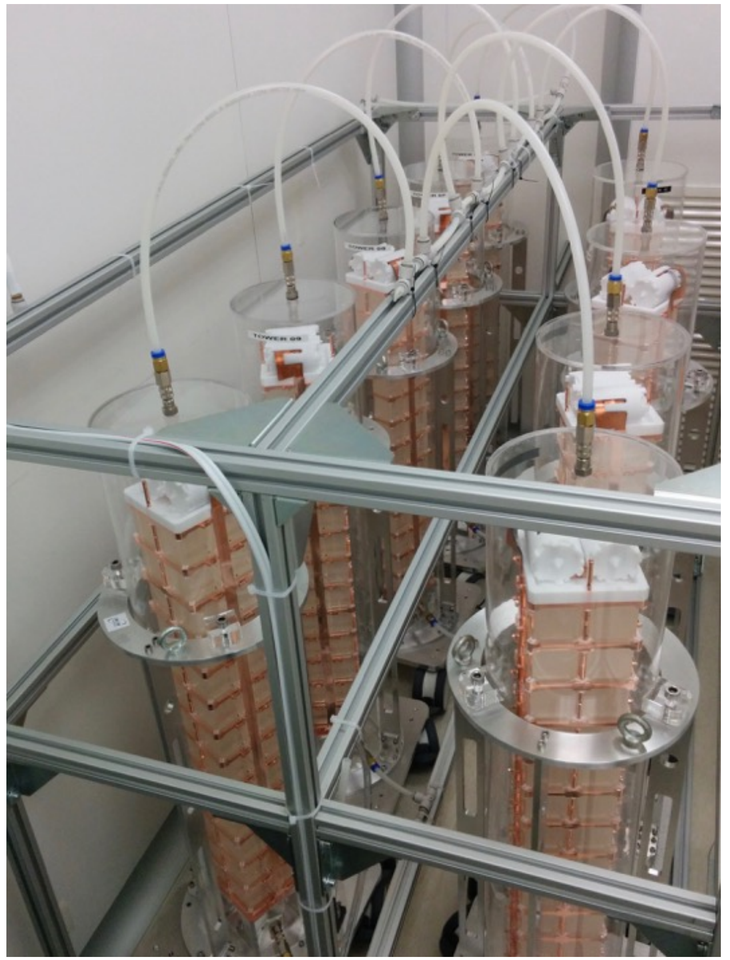
CUORE Towers Assembly

- Assembly of all the 19 CUORE towers completed in 2014



Assembly line improved after CUORE-0

CUORE-0

51/52 NTD connected

51/52 heaters connected

CUORE

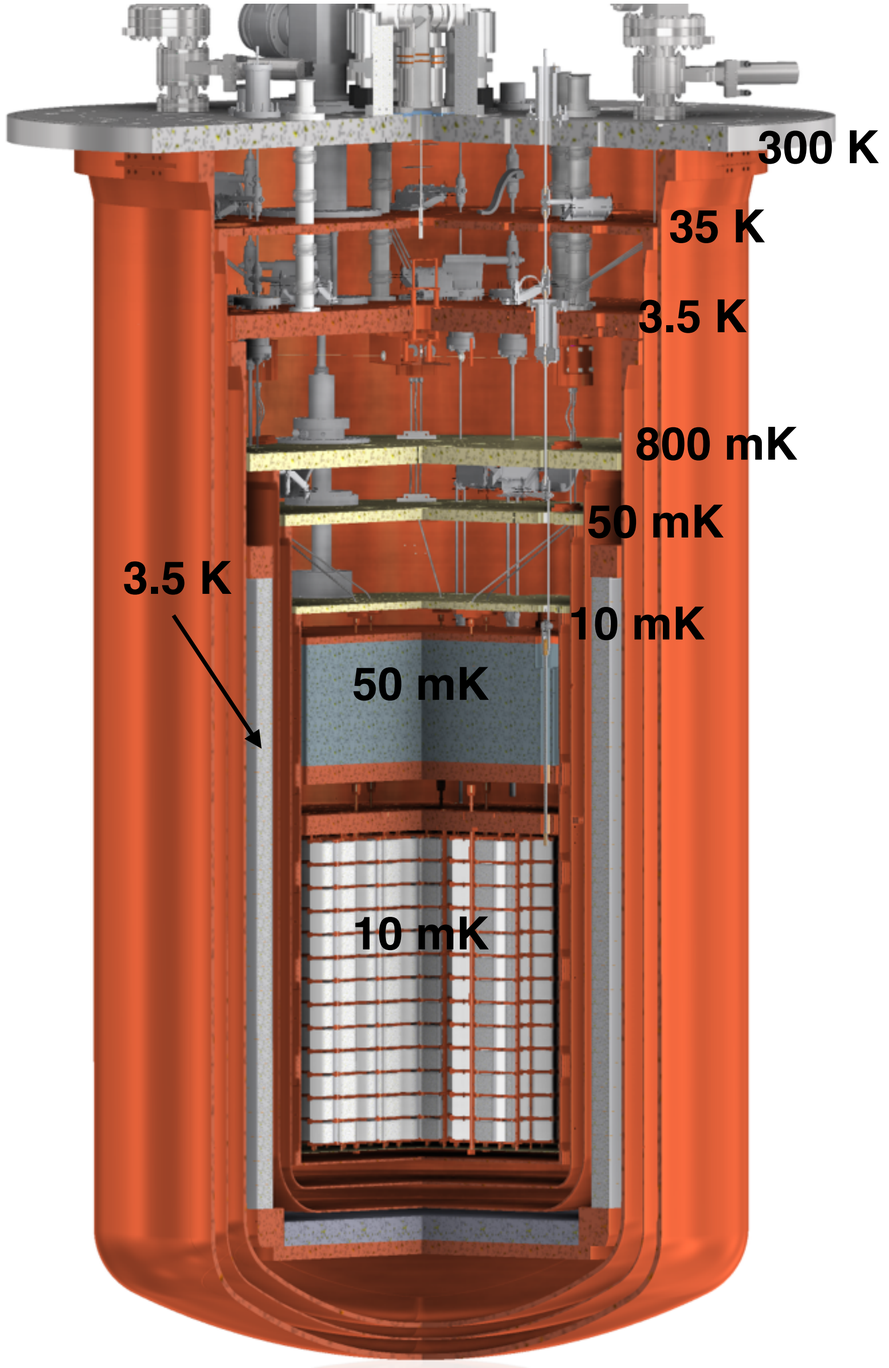
988/988 NTD connected

988/988 heaters connected

- Also a mockup tower for the Detector installation phase and a minitower to be used during the cryostat commissioning runs were produced

Cryogenic system commissioning

Goal was to develop a cryogenic system capable to deliver stable base T (~10 mK) together with reduced vibrations (baseline RMS at few keV) and a radio clean environment (selected material, cold Pb shields).



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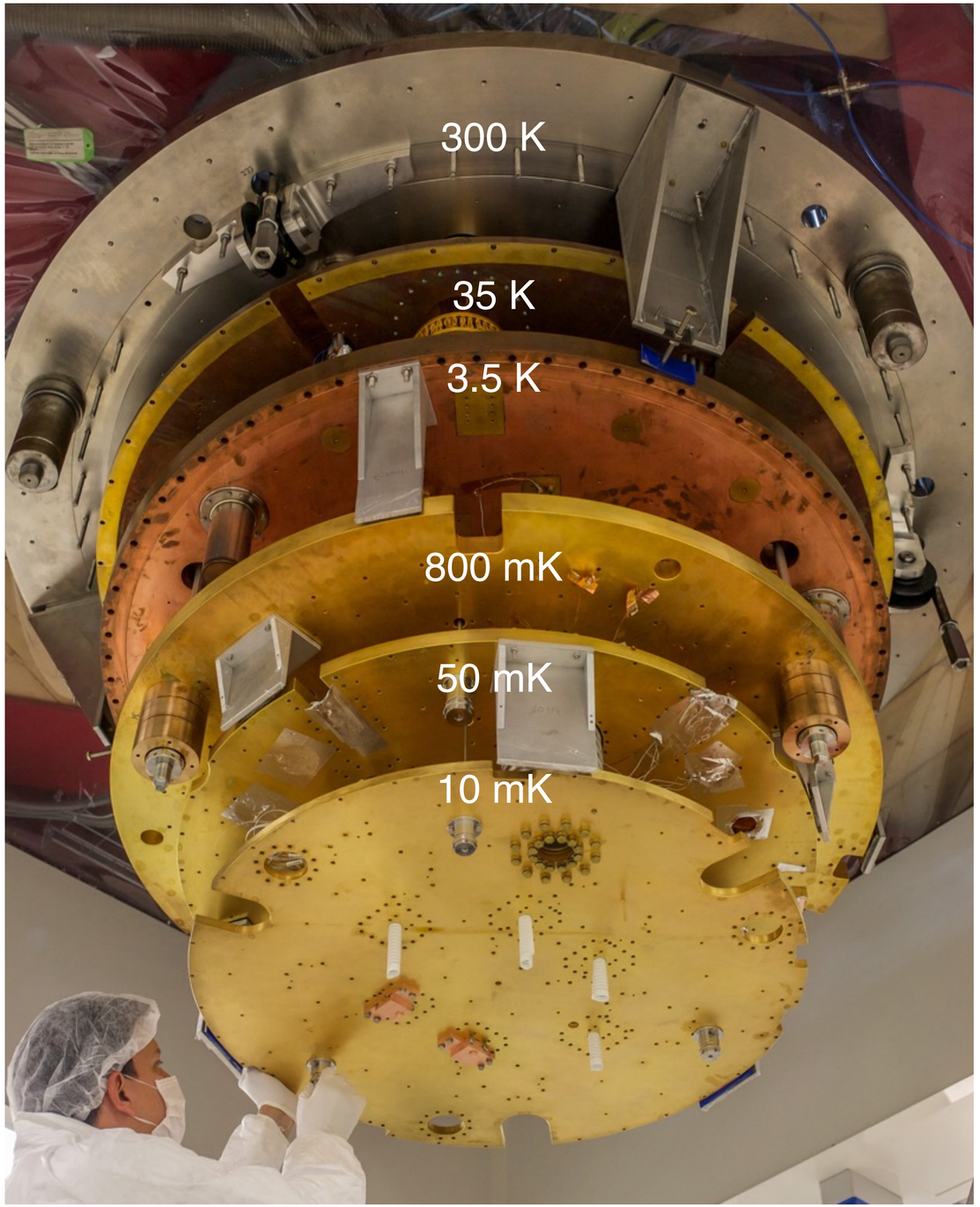

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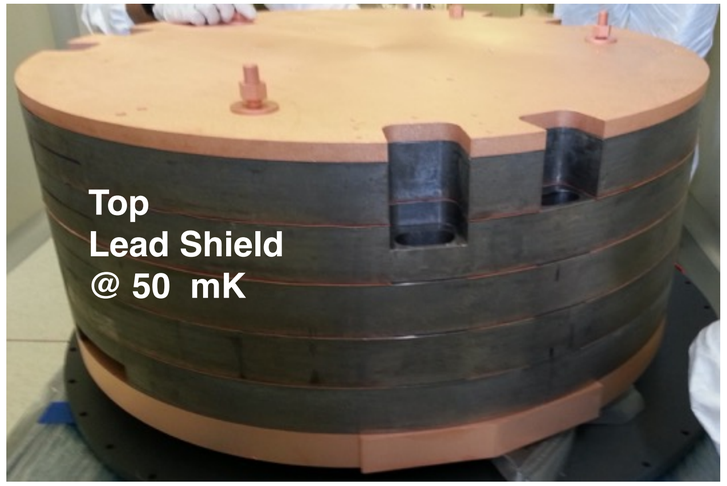
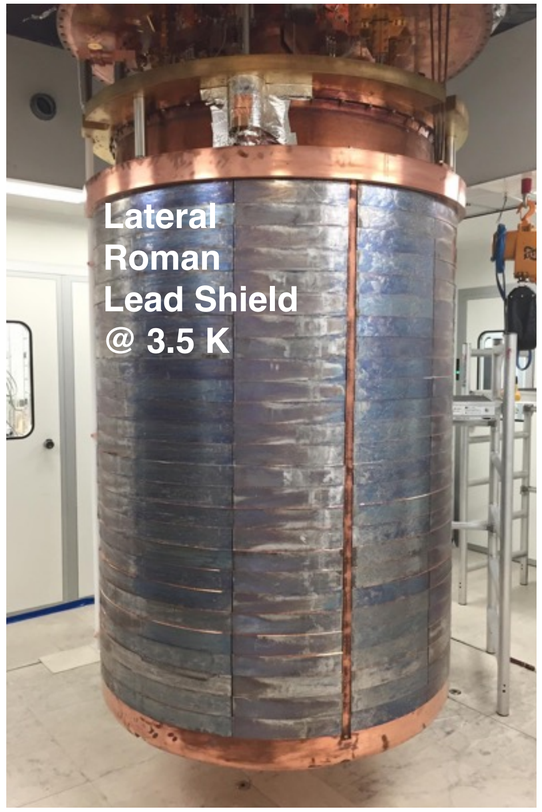
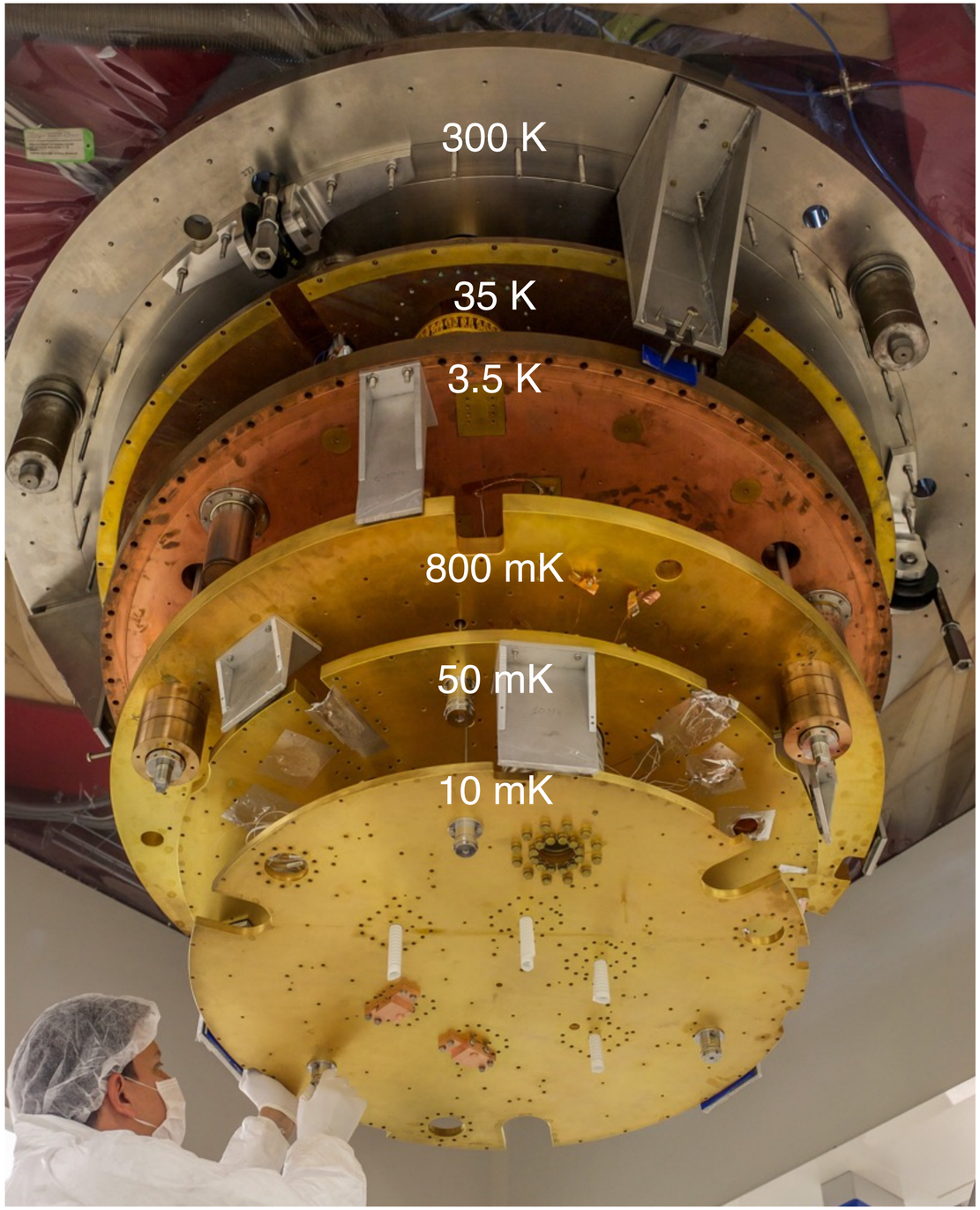
Goal was to develop a cryogenic system capable to deliver stable base T (~10 mK) together with reduced vibrations (baseline RMS at few keV) and a radio clean environment (selected material, cold Pb shields).

- All the cryostat components well thermalized at the different stages (including 2.5 tonnes top Pb shield @ 50 mK and lateral 5 tonnes roman Pb shield @ 3.5 K).

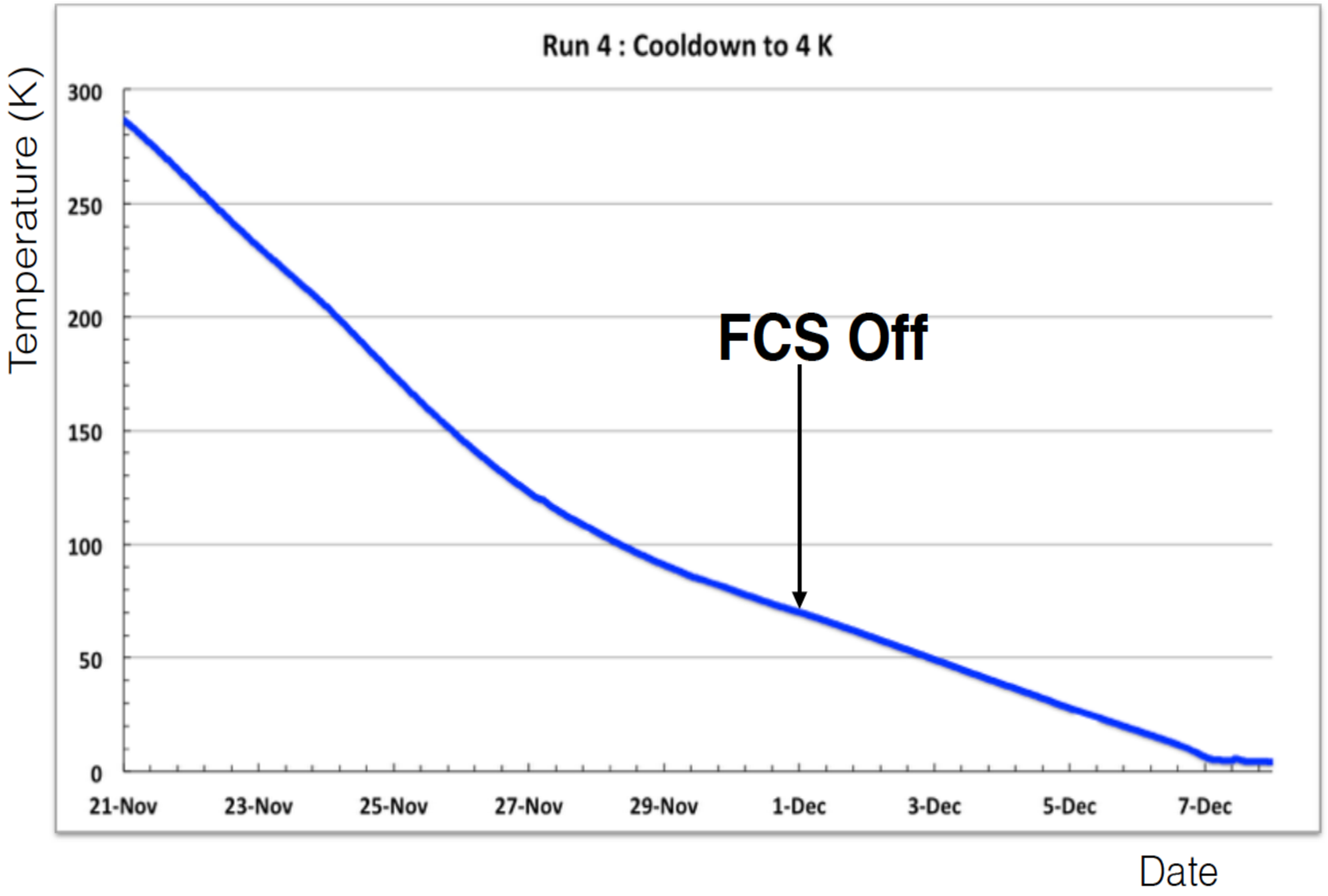
- No evident temperature gradient or heat leak is observed.



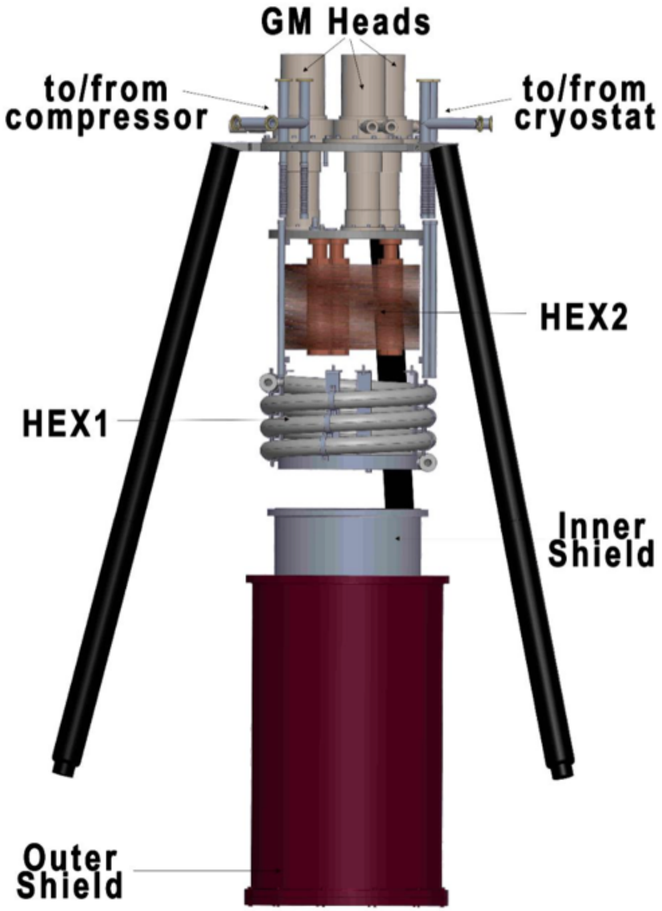




Cool down

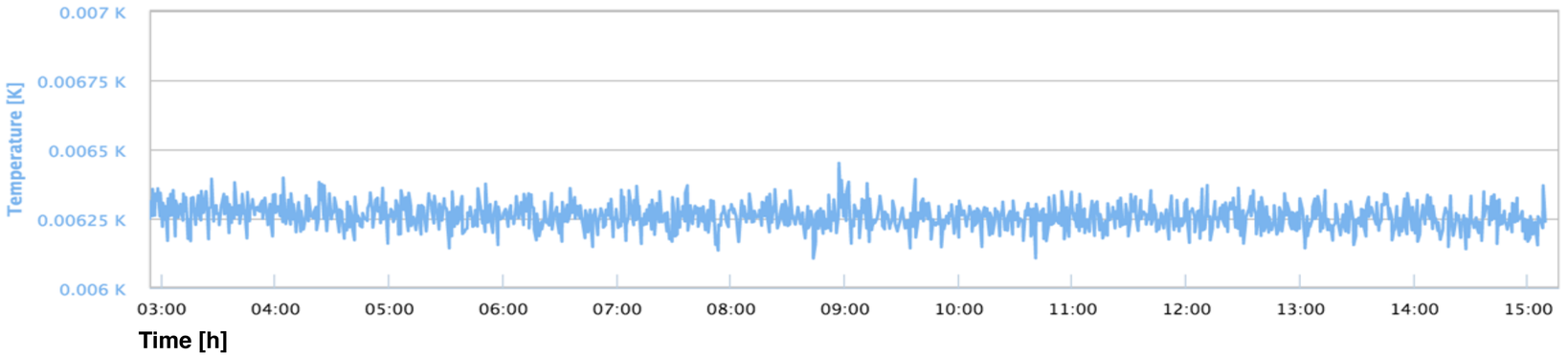


- Cool down to 4 K of about 15 tonnes was performed in 17 days
- Fast cooling was used up to ~ 75 K



Base T stability

- Cool down from 3.5 K to base temperature was performed in ~ 1 day
- Stable base temperature -that allows CUORE bolometers operation- **6.3 mK**. Base T stable for more than 70 days.



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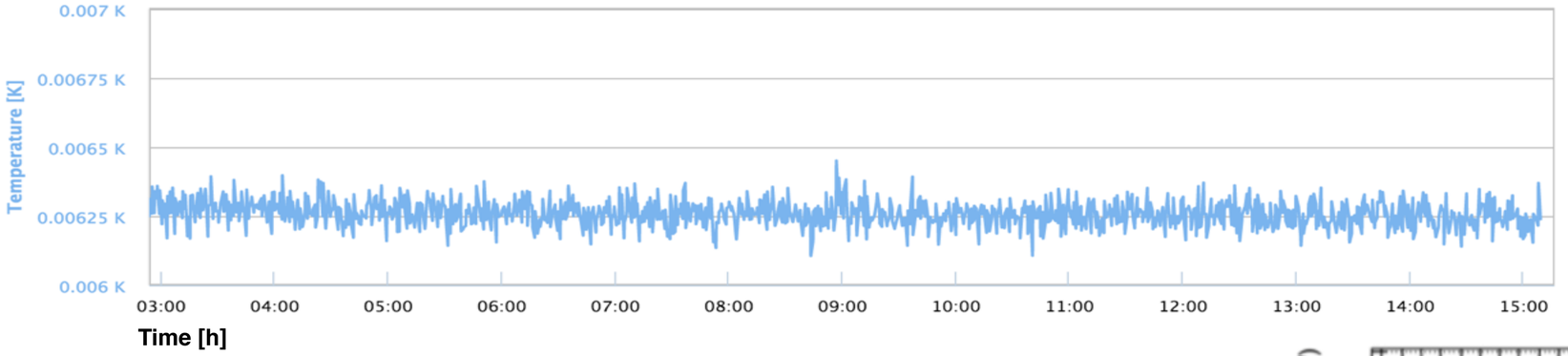
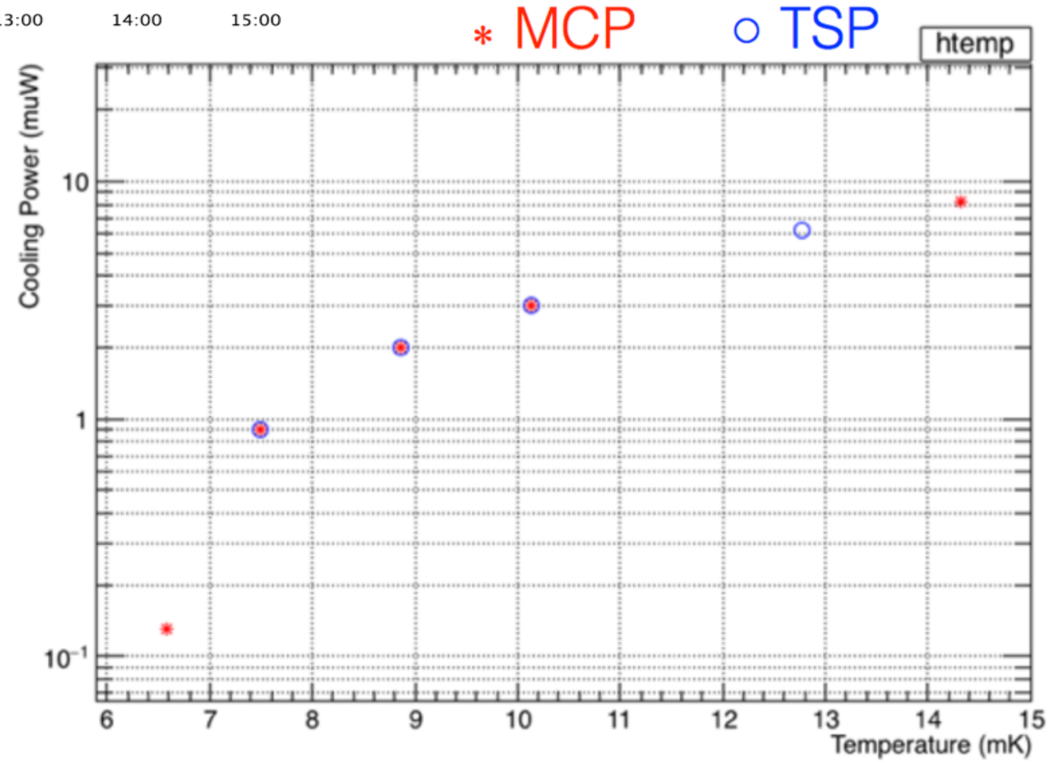


- Proved nominal cooling power: **3 μW @ 10 mK**.

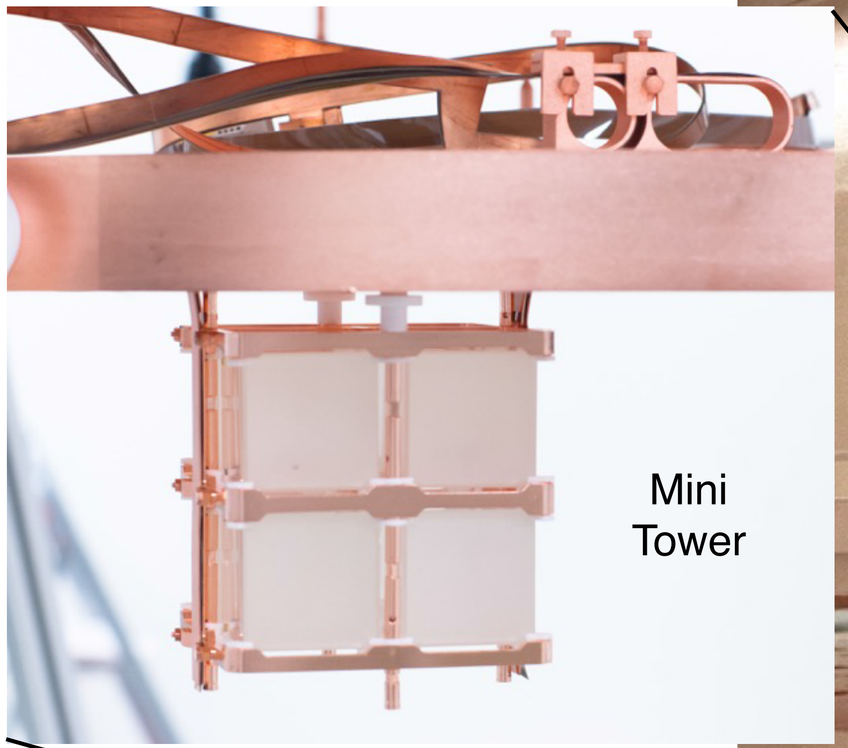
- Base temperature allows to stabilise operating temperature around 10 mK for a stable detector response.

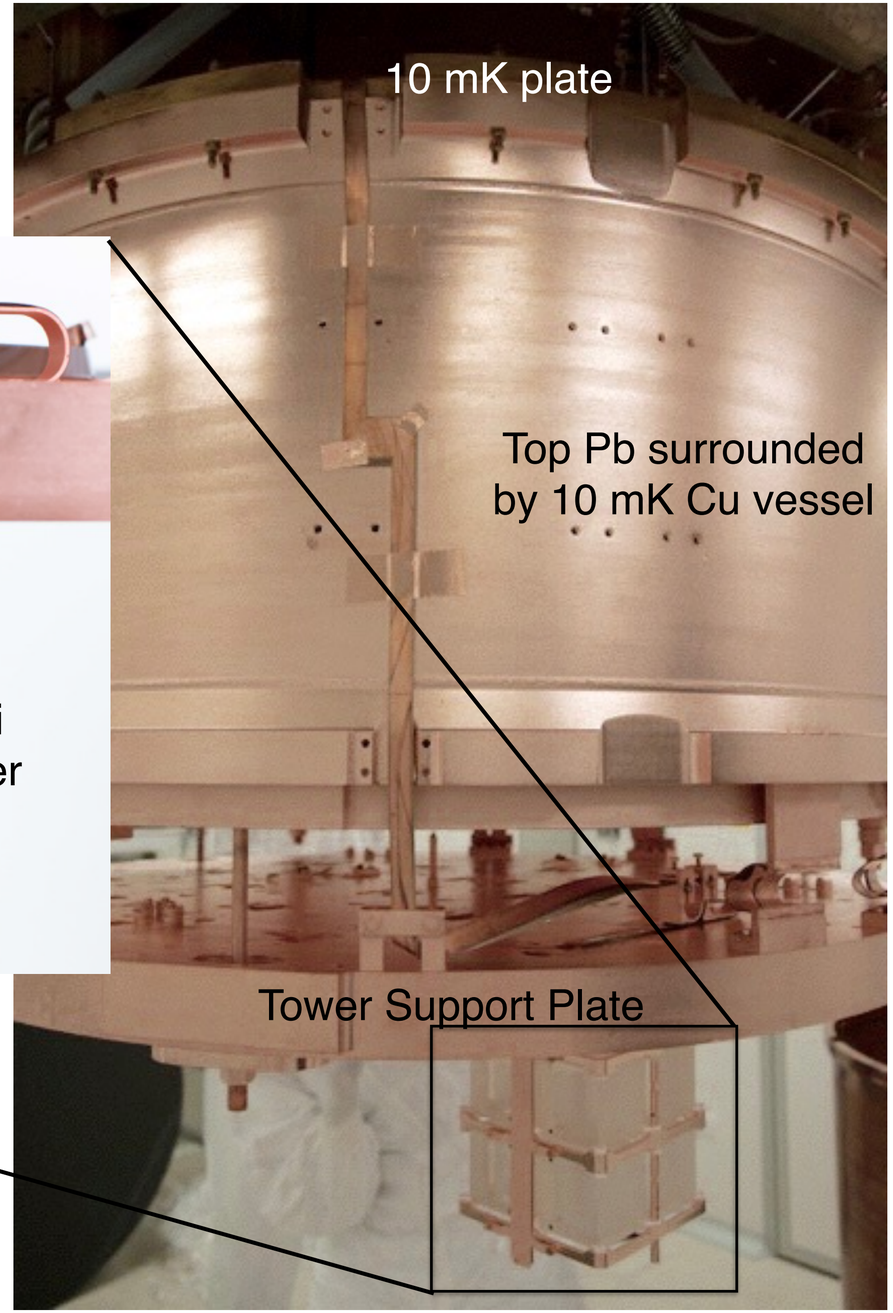


Bolometers and readout commissioning

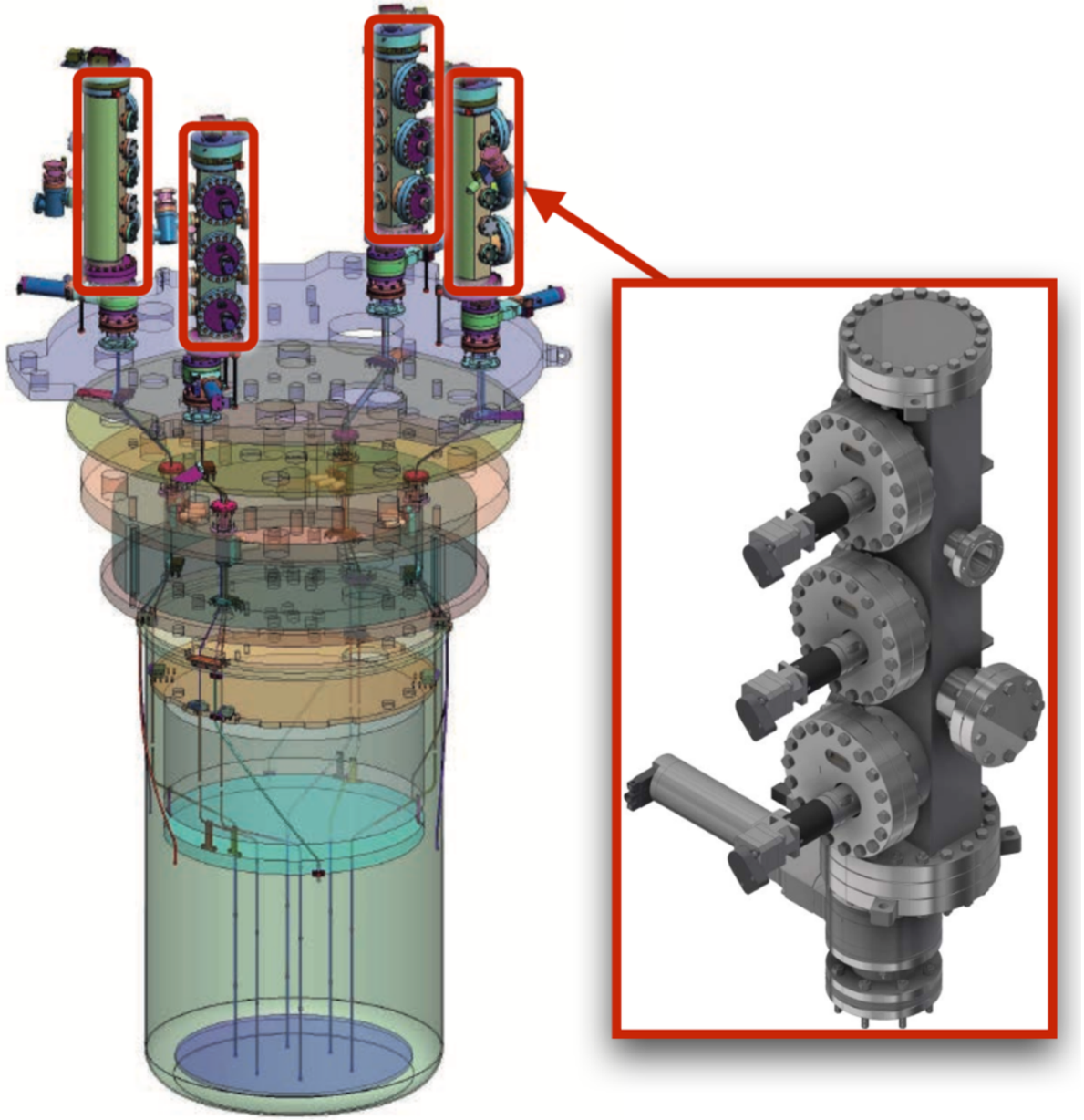
Bolometers and readout commissioning

- Encouraging detector performance (energy resolution) on 8 detectors array (Mini-Tower)
- Commissioned electronics, DAQ, temperature stabilization, and detector calibration systems

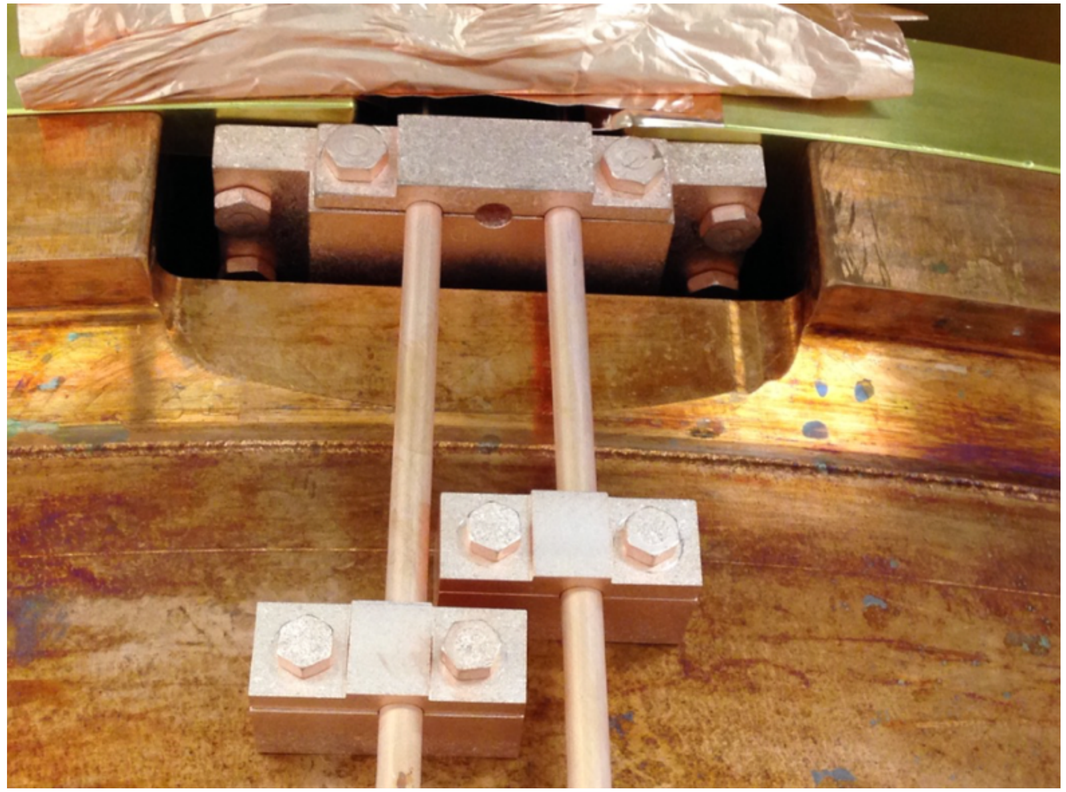




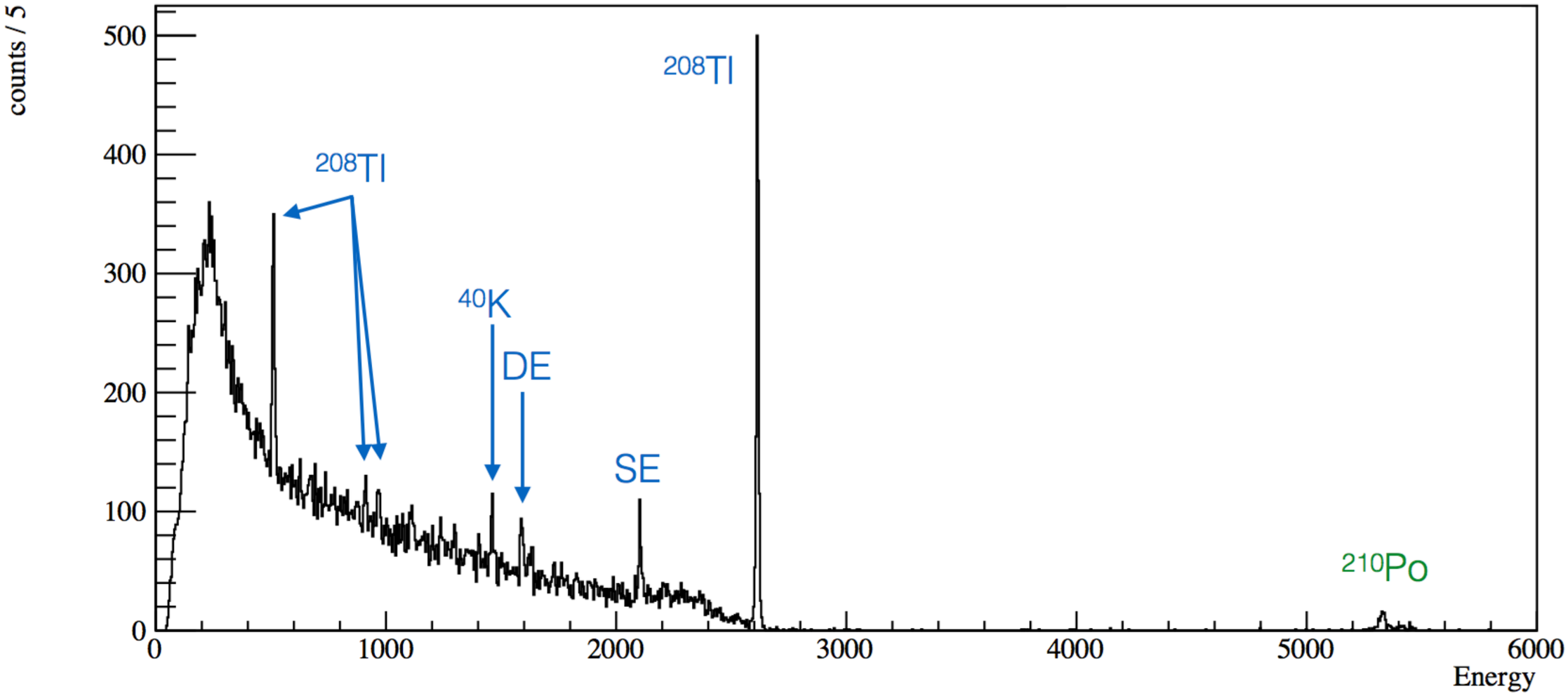
Detector Calibration System



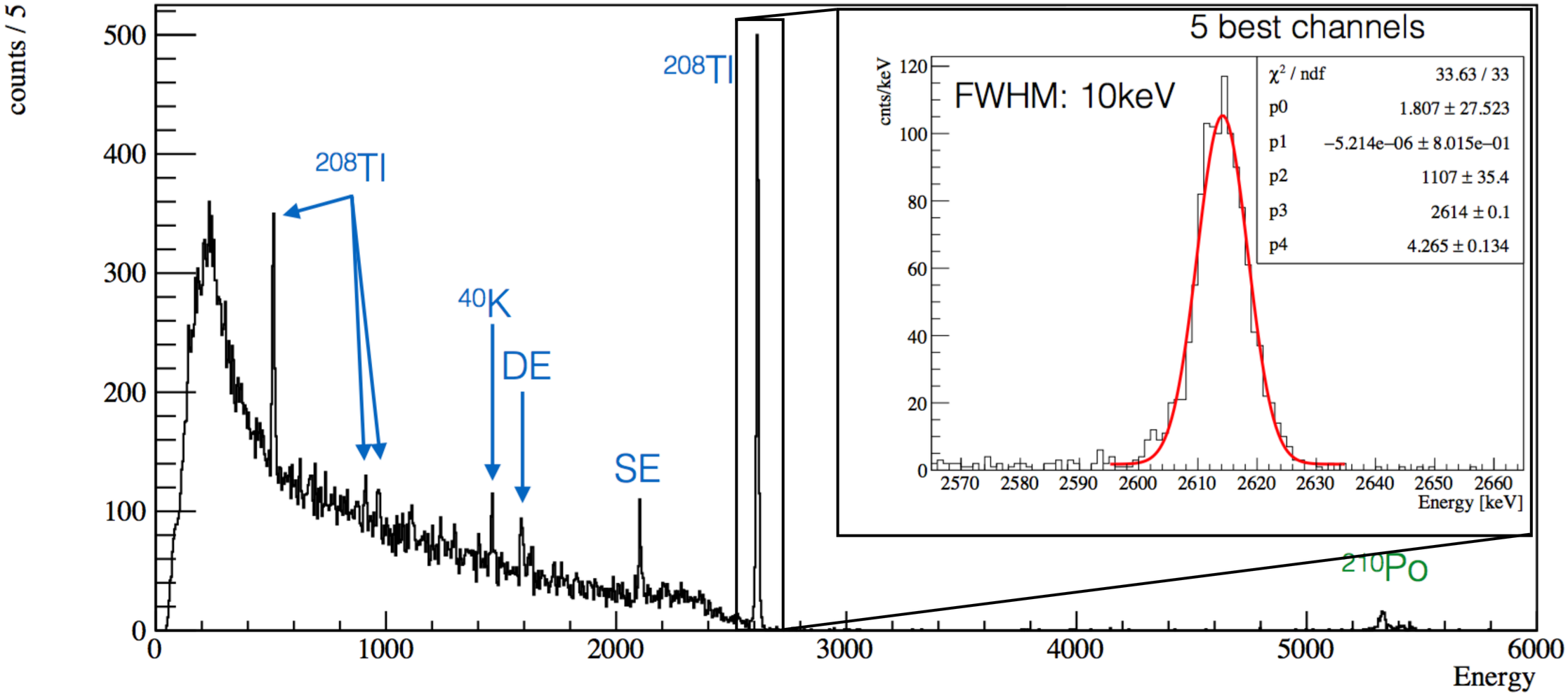
- Successful deployment of calibration sources to 10 mK (6 internal) and 50 mK (6 external)
- Power dissipation compatible with CUORE specs



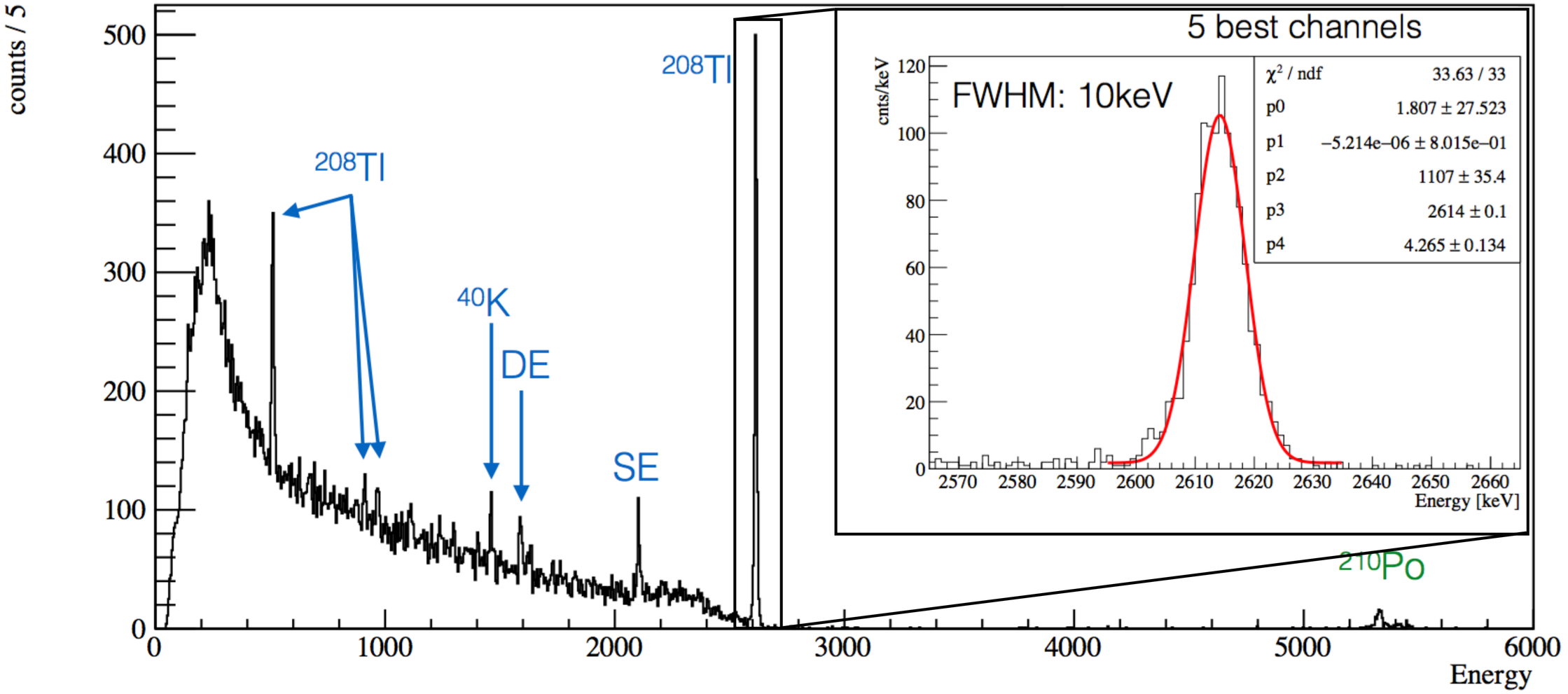
Resolution


counts / 5
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
Energy
208Tl
208Tl
40K
DE
SE
210Po

Resolution


counts / 5
208Tl
208Tl
40K
DE
SE
210Po
Energy
5 best channels
FWHM: 10keV
cnts/keV
χ² / ndf 33.63 / 33
p0 1.807 ± 27.523
p1 −5.214e−06 ± 8.015e−01
p2 1107 ± 35.4
p3 2614 ± 0.1
p4 4.265 ± 0.134
Energy [keV]

Resolution

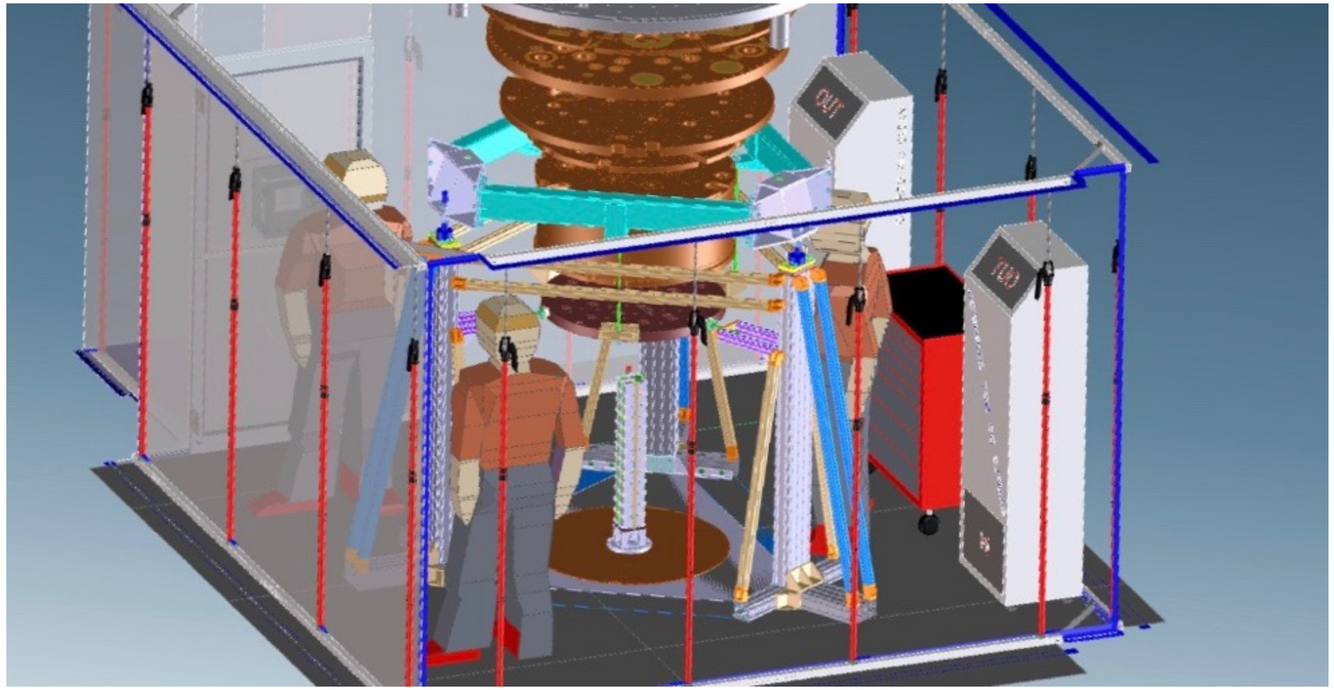


March 2016: Cryogenic commissioning complete.
Detector installation in Summer 2016

Detector installation

- In March 2016 started the refurbishing of the cryostat area for the installation of the radon free clean room (CR6).
- Procedure for the installation already tested.
- Detector installation team already trained in realistic conditions.

Detector installation



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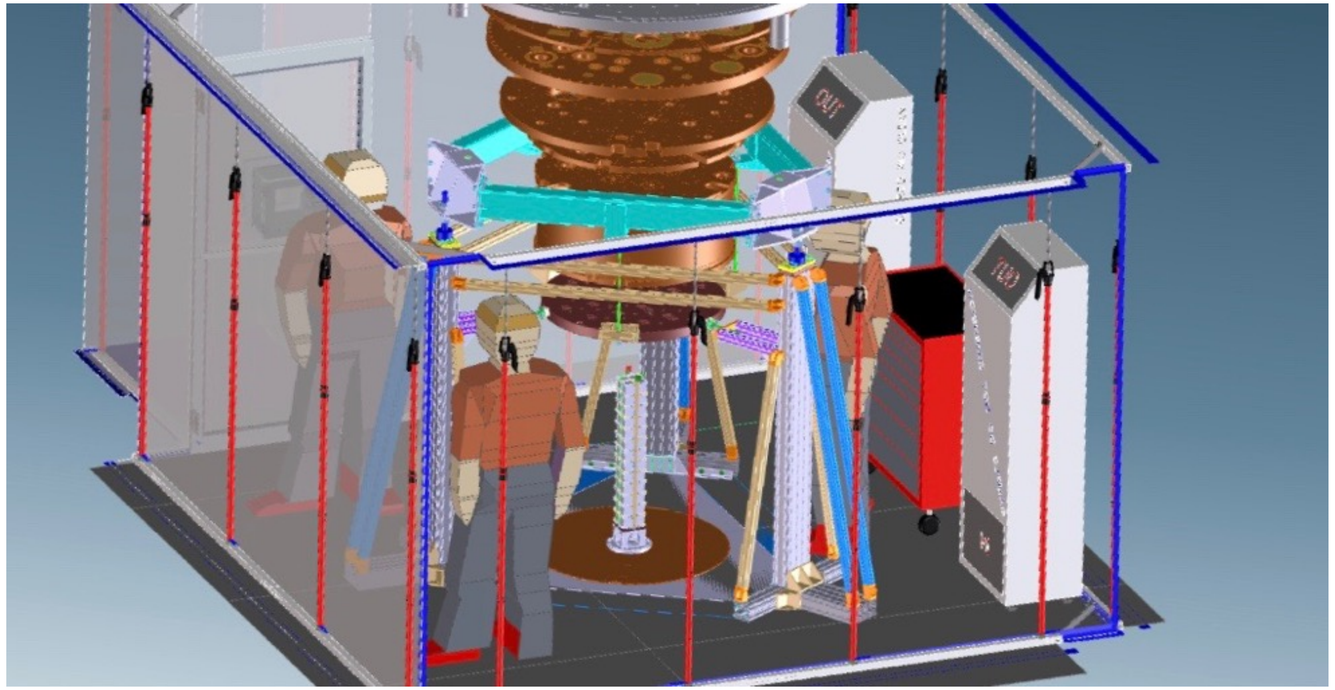

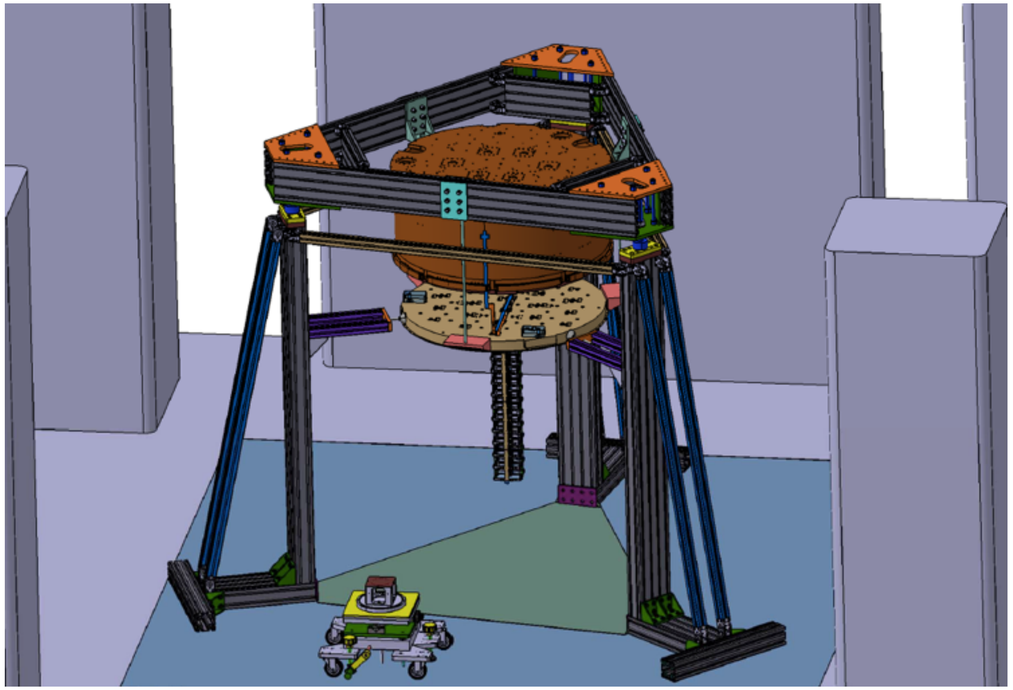

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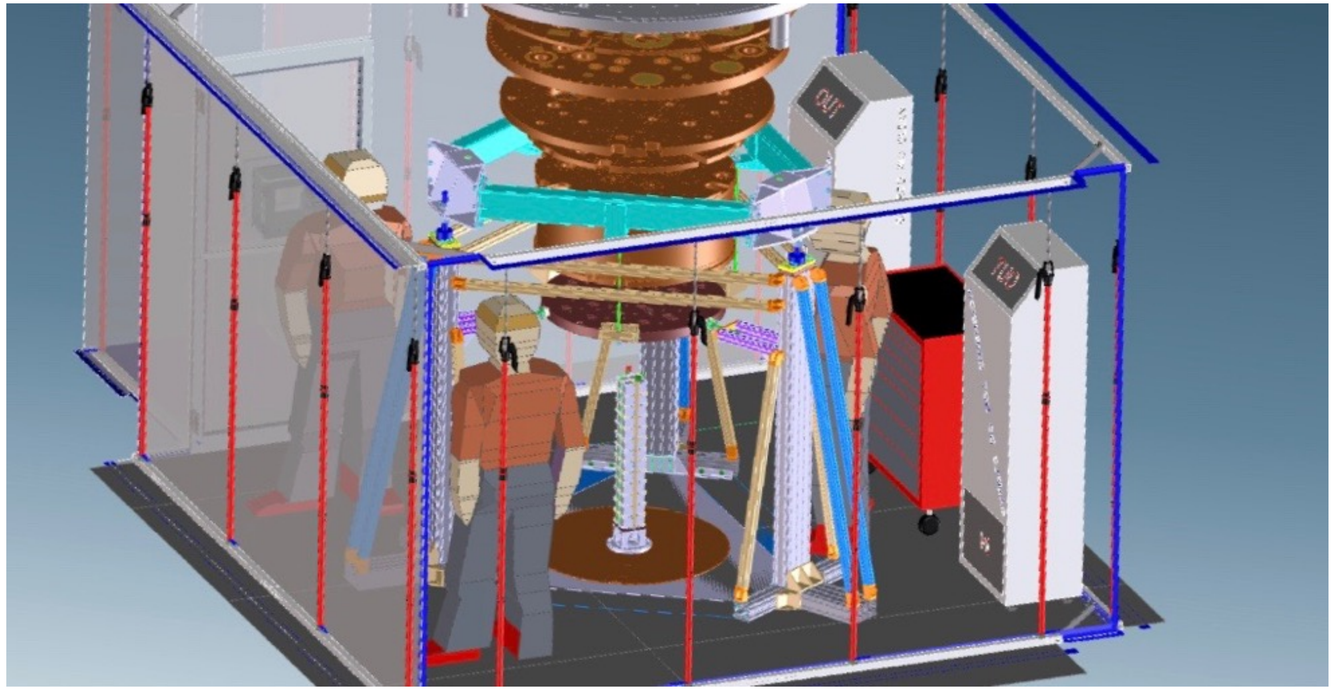
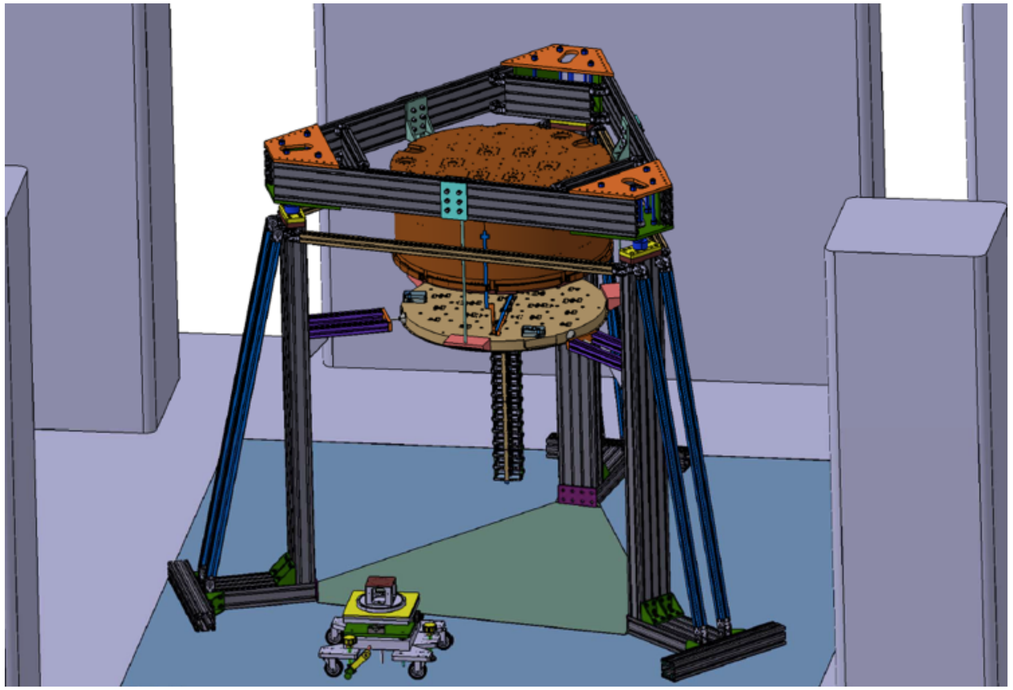
Detector installation





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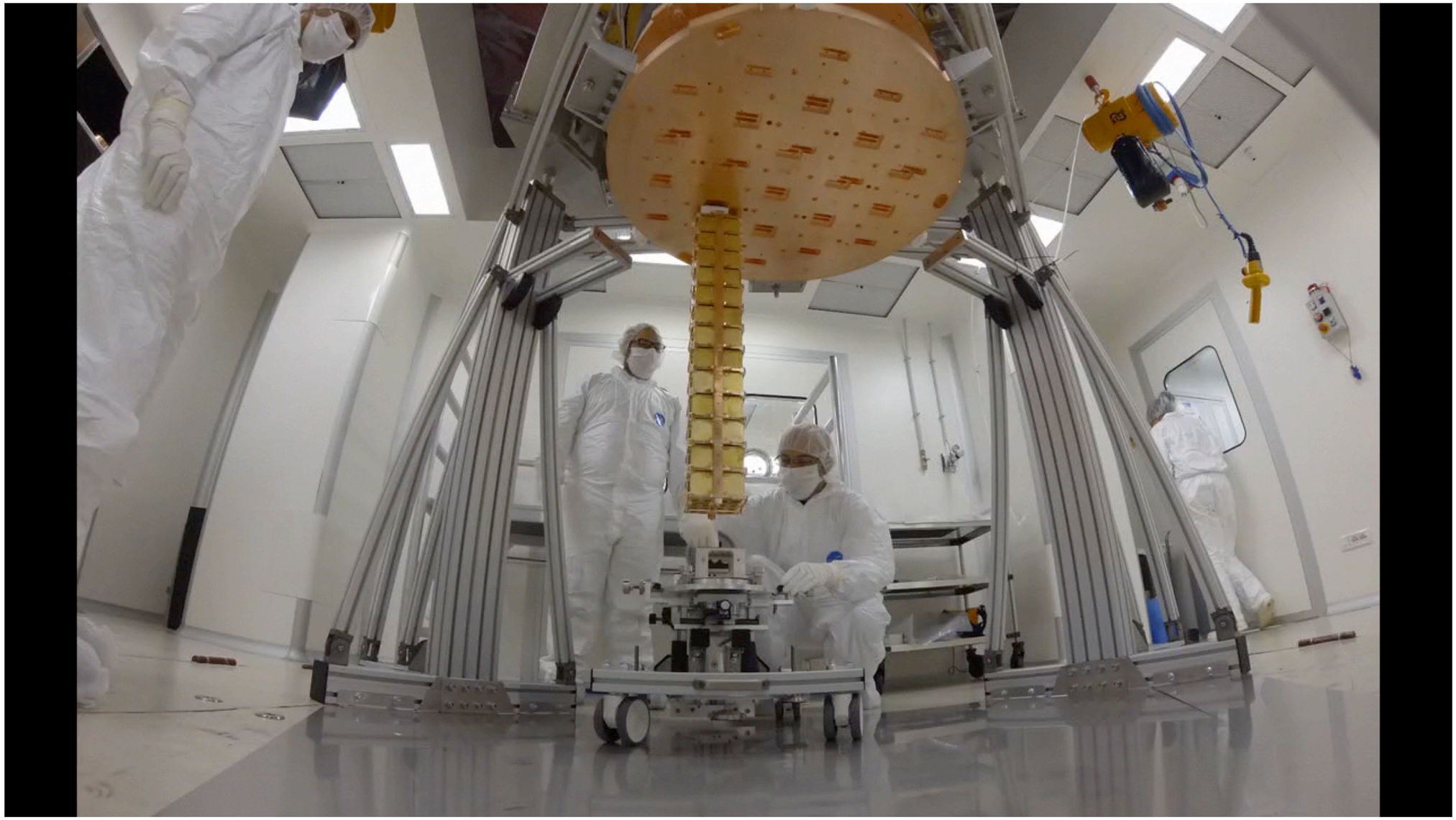
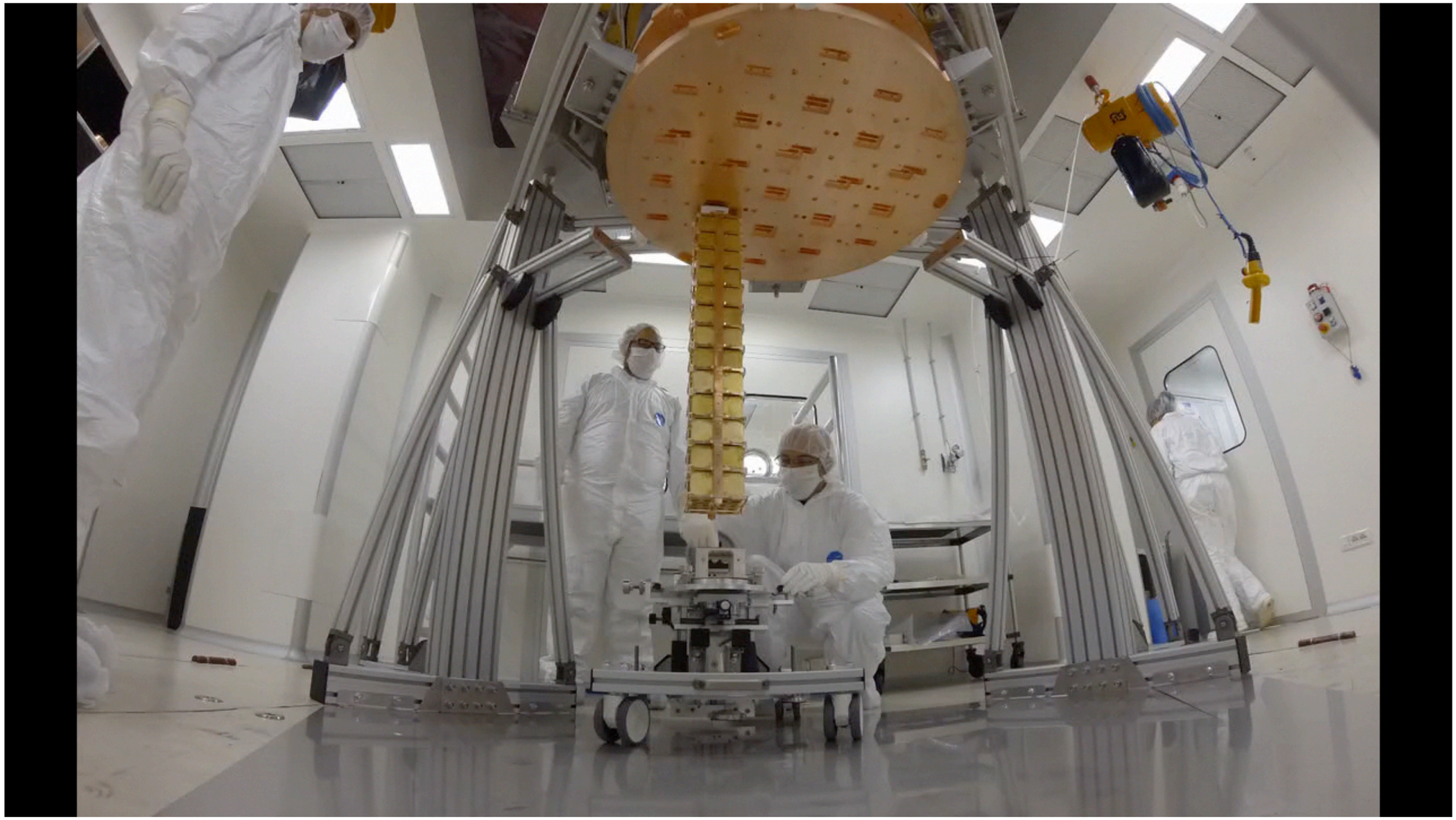
Tower installation procedure



Tower installation procedure



Conclusions

CUORE-0

- Achieved its energy resolution and background level objectives
- Improved 0vDBD limit for ^{130}Te (no 0vDBD evidence)
- Indicated CUORE sensitivity goal is within reach.

CUORE

- Assembly of the 19 CUORE towers is complete.
- CUORE cryostat assigning is completed
  - stable base temperature of ~ 6 mK
  - positive indications on noise and performances
  - DCS successfully tested
- The cryostat is now ready to host the detector
- Detector installation foreseen in summer 2016
- CUORE cool down expected in late 2016

The CUORE collaboration