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

Simone Copello on behalf of the CUORE collaboration

INFN - Sezione di Genova, Genova I-16146, Italy - Dipartimento di Fisica, Università di Genova, Genova I-16146, Italy

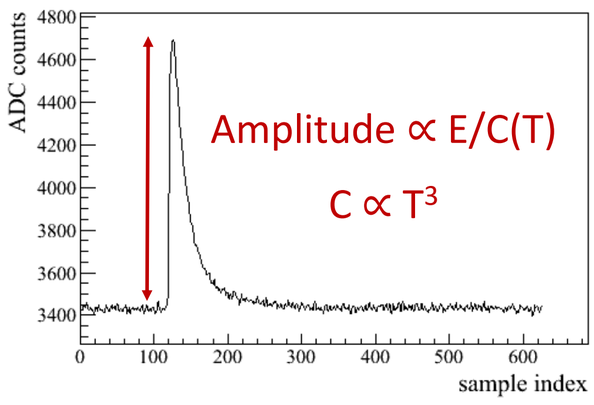
CUORE is a ton-scale experiment approaching the data taking phase in Gran Sasso National Laboratory. Its primary goal is to search for the neutrinoless double-beta decay (0νββ) of ^{130}Te using TeO_2 crystals. The crystals are operated as bolometers at ≈10 mK taking advantage of one of the largest dilution cryostat ever built. The cryostat commissioning consisted in a sequence of cool down runs each one integrating new parts of the apparatus. The last run was performed with the fully configured cryostat and the thermal load at 4 K reached the impressive mass of about 14 tons. In that run the base temperature of 6.3 mK was reached and maintained for more than 60 days. An array of 8 crystals, the mini-tower, was used to check bolometers operation, readout electronics and DAQ.

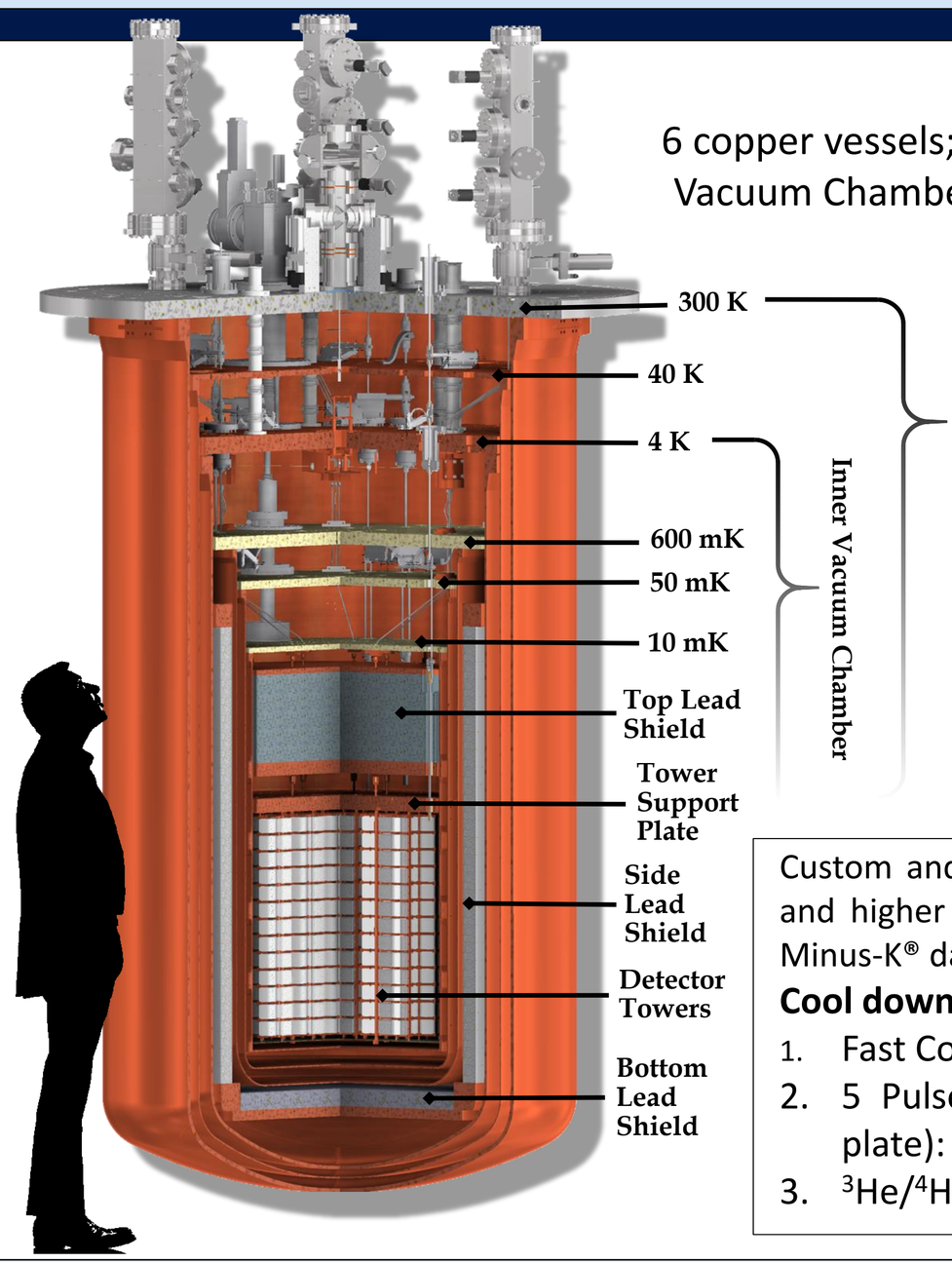
CUORE experiment

CUORE (Cryogenic Underground Observatory for Rare Events) main features:

- **Primary goal:** 0νββ of ^{130}Te
- **Detectors:** 988 TeO_2 crystals, divided in 19 towers, total mass 741 kg (~200 kg of ^{130}Te)
- **Expected background:** 10^{-2} counts/keV/kg/year (at 2527 keV, 0νββ ROI)
- **Target energy resolution:** 5 keV at 2527 keV
- $\mathbf{T}_{1/2}^{0\nu\beta\beta}$ (5 years, 90% C.L.): $>9.5 \cdot 10^{25}$ y

Each bolometer (TeO_2 crystal) works at ~10 mK. The particle energy deposition causes an heating measured by a thermistor glued on the crystal.





Cryostat

6 copper vessels; 2 vacuum-tight volumes: Inner Vacuum Chamber and Outer Vacuum Chamber

Custom and cryogen-free (less mechanical noise and higher duty cycles). Suspended thanks to 3 Minus-K® damping springs.

Cool down procedure in 3 steps (~1 month):

1. Fast Cooling System: 300 K to 50 K
2. 5 Pulse Tubes (cold fingers on the 4 K plate): 100 K to 4 K
3. $^3He/^4He$ dilution unit (DU): 4 K to 10 mK

Commissioning Runs

The commissioning was carried out in four steps (runs), each one consisting in the addition of new experiment parts and a cool down.

Run I

Setup: all vessels and plates, DU already tested in a dedicated cryostat, no shields.
Results: 5.9 mK reached!

Run II

Setup: Added read-out wiring (2600 wires from 300 K to 10 mK) and Detector Calibration System. **Results:** DU cooling power can sustain the heat injection due to the wiring.

Run III

Setup: Added the top lead shield (2.1 t of modern lead at 50 mK).
Results: sources of mechanical noise highlighted and reduced.

Run IV

The cryostat commissioning phase was concluded in March 2016 with the Run IV.

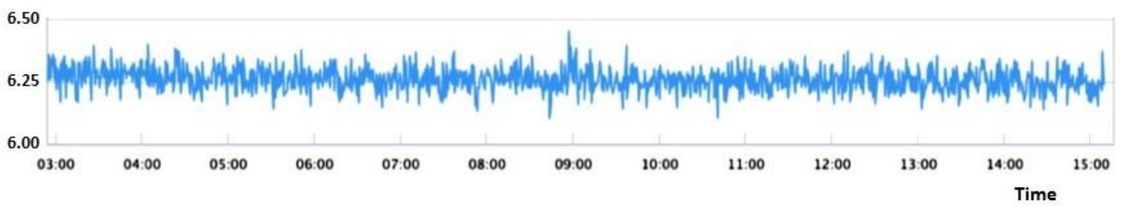
Setup

fully commissioned cryostat apart from the detectors, added bottom and side shields of roman lead (0.004 Bq/kg ^{210}Pb). *Final load:* 14 t at 4K, 1.5 t at 10 mK.

Achievements

- Mechanical noise reduced (by acting on cryostat cardanic joints and the Pulse Tube flex lines)
- Measure the cooling power on the mixing chamber of the dilution unit: 3 μW at 10 mK as expected
- Stable temperature of (6.3 ± 0.2) mK maintained, thanks to the temperature stabilization system, for more than 60 days

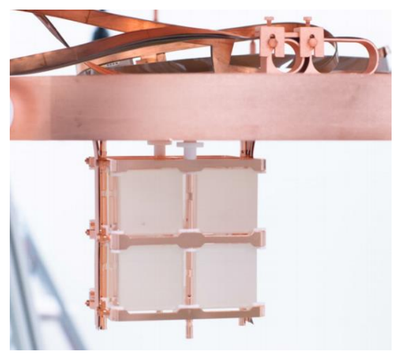
Base Temperature on mixing chamber (mK)

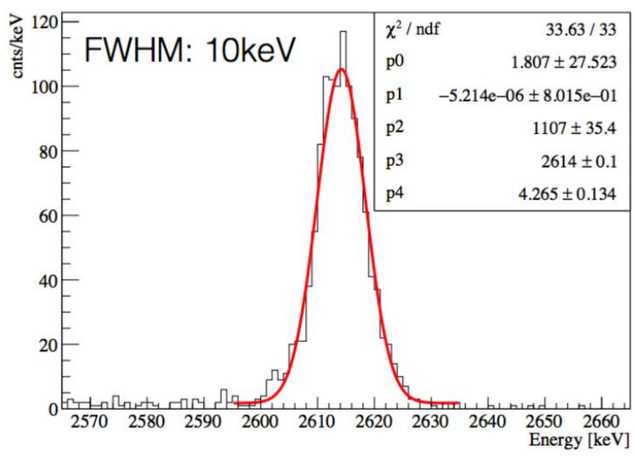


Mini-Tower

A 8 crystals array mounted on Tower Support Plate before Run III. It permitted to check several subsystems such as:

- Detector Calibration System (12 strings, each one containing 25 capsules with thoriated tungsten wire, ^{232}Th)
- Readout electronics (Front End and Bessel Filters)
- Data acquisition system
- Temperature stabilization system (PID)





First estimation of the detectors energy resolution:
10 keV at 2615 keV

External lead shield lifted up: no evidence of unaccounted background sources.

After Run IV: All detector towers were installed in summer 2016. The experiment is currently at base temperature and detectors optimization is going on. Data taking will start very soon!

scopello@ge.infn.it