Commissioning and calibrating the CUORE neutrinoless double beta decay experiment

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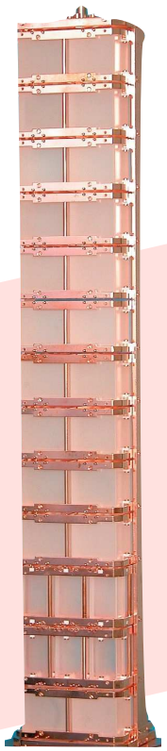
APS April Meeting, 4/13/15

Cuoricino to CUORE

CUORE-0 results just released!
arXiv:1504.02454

Cuoricino (2003-2008)



Astropart. Phys.
34 (2011) 822–831

$T_{1/2}^{0\nu\beta\beta} > 4.0 \times 10^{24}$ y (90% C.L.)

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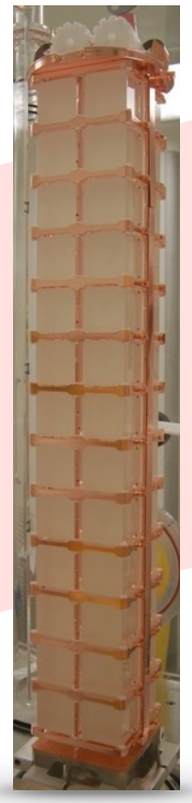
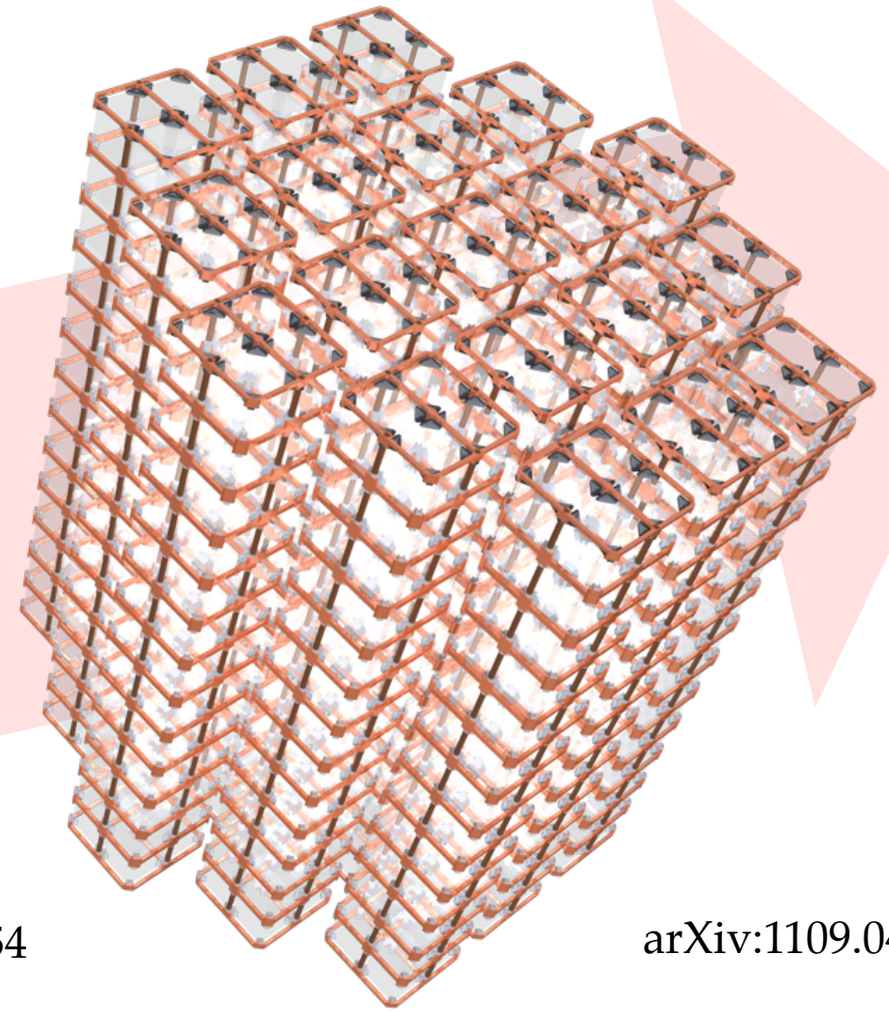
CUORE-0 (2013-2015)



arXiv:1504.02454

CUORE (2015-2020)

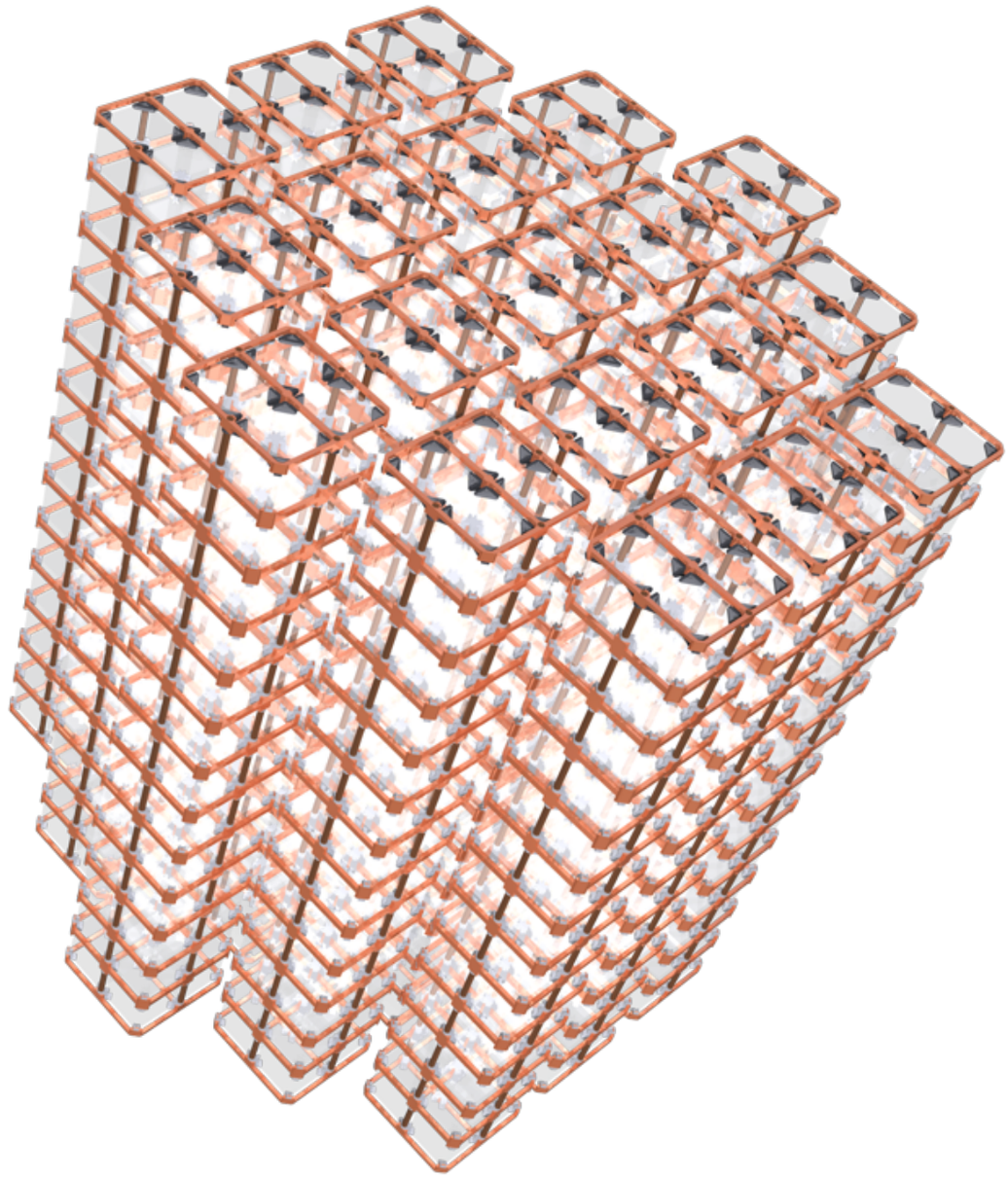


arXiv:1109.0494

Projected:
$T_{1/2}^{0\nu\beta\beta} > 9.5 \times 10^{25}$ yr (90% C.L.)
$m_{\beta\beta} < 50 - 130$ meV

CUORE

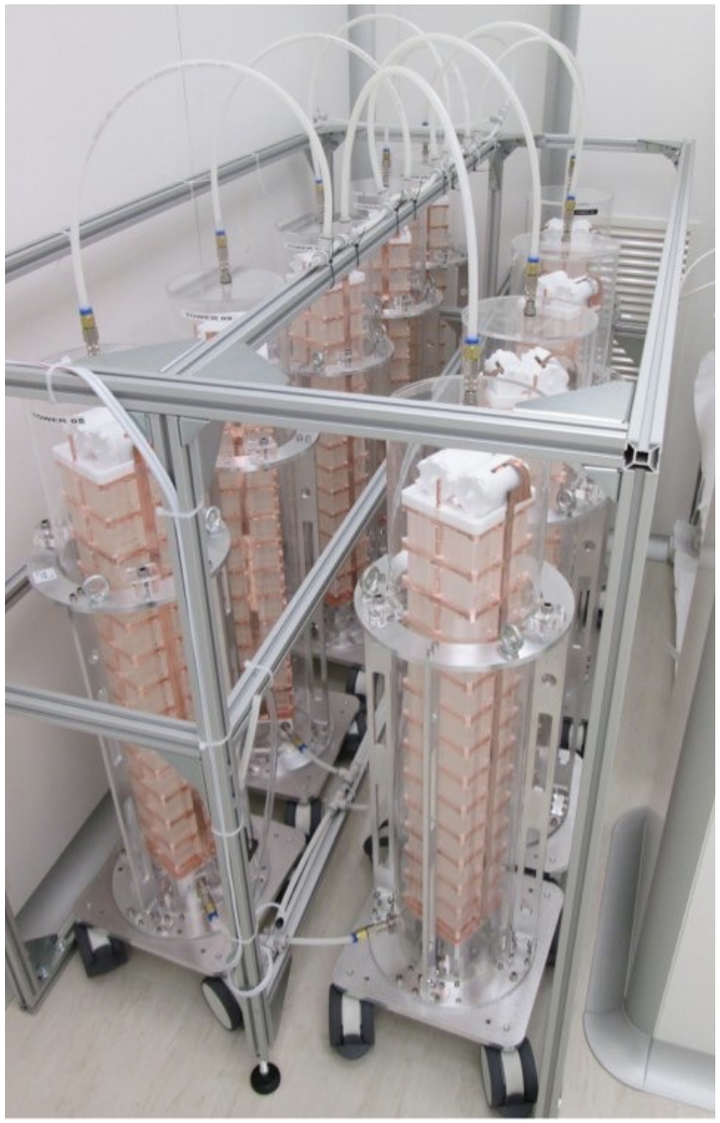
- The Cryogenic Underground Observatory for Rare Events (CUORE) will search for neutrinoless double beta decay ($0\nu\beta\beta$) in ^{130}Te
- Located deep underground at the Laboratori Nazionali del Gran Sasso (LNGS) in Assergi, Italy
- CUORE is composed of 988 TeO_2 crystals (total mass of 741 kg, with 206 kg of ^{130}Te)
- 19 times the mass of CUORE-0
- Will be run in a new custom-built dilution refrigerator with much lower backgrounds

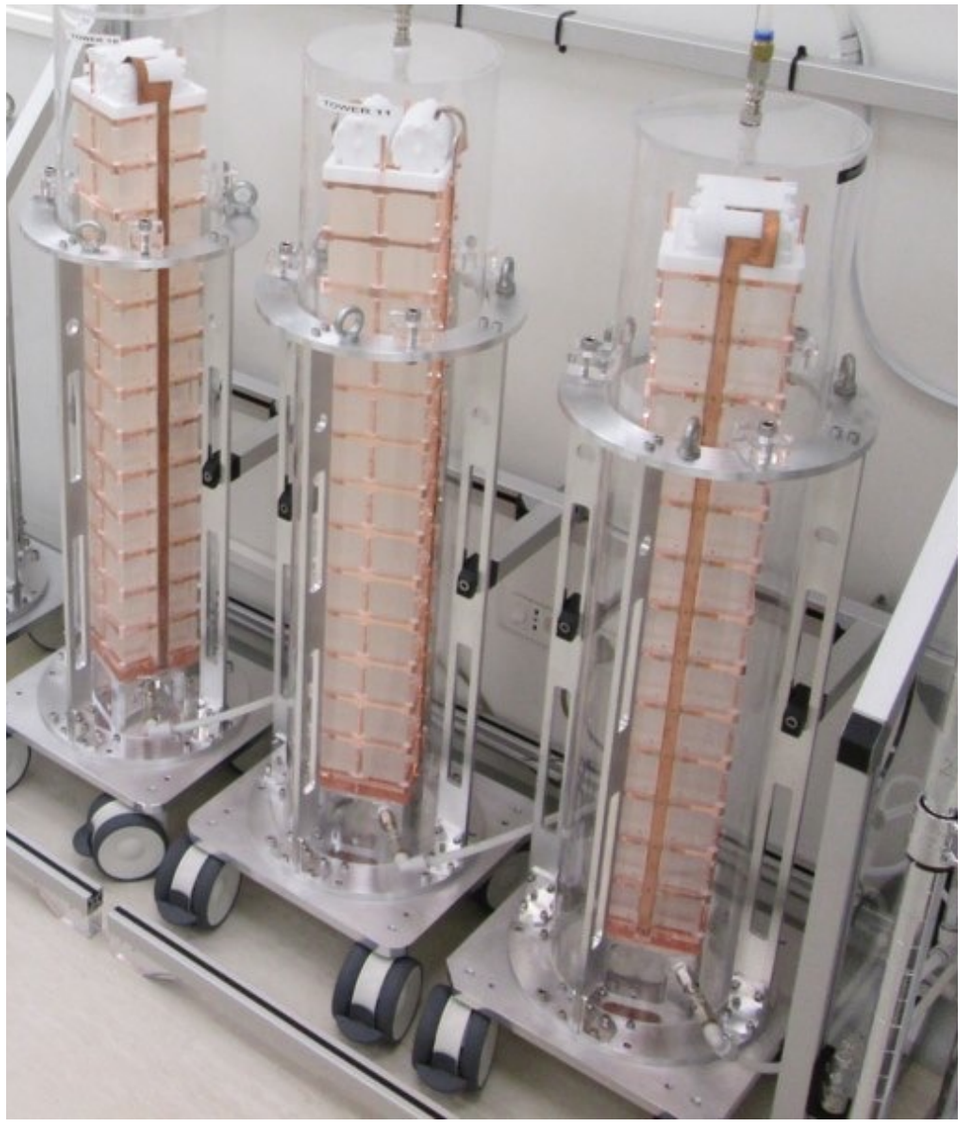


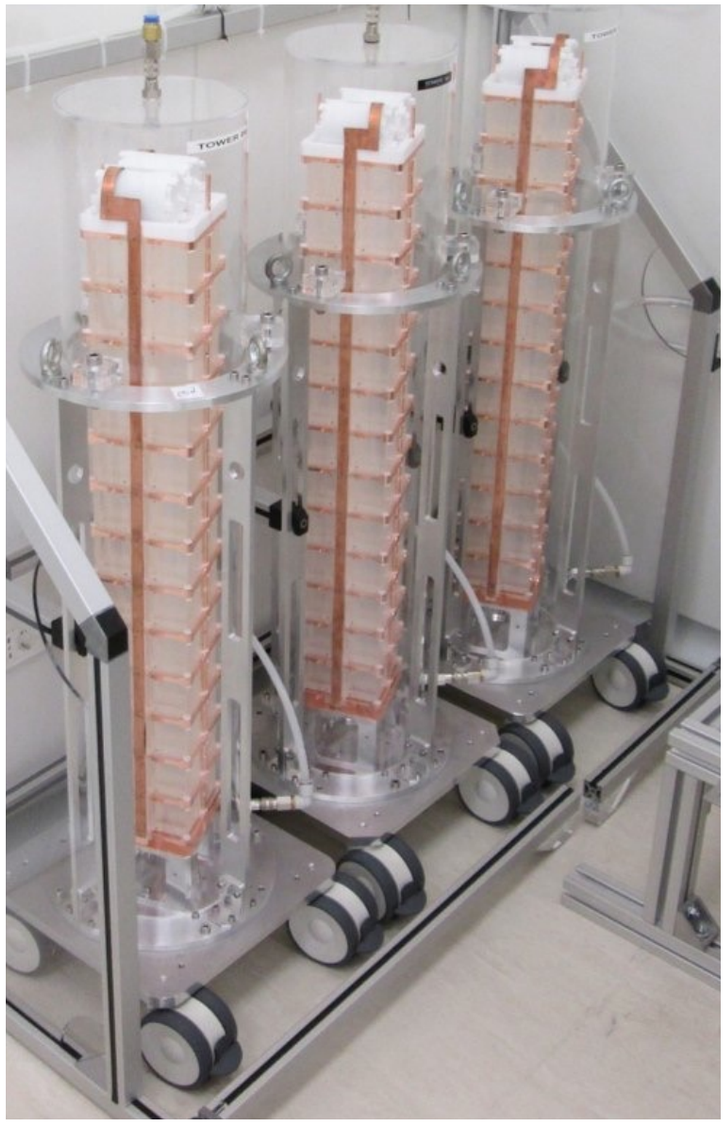
$$T^{0\nu}_{1/2}\ \text{sensitivity} \propto a \cdot \epsilon \sqrt{\frac{M \cdot t}{b \cdot \delta E}}$$

Tower construction

- Construction of all 19 CUORE towers is complete
- Towers are stored under nitrogen to avoid radon contamination



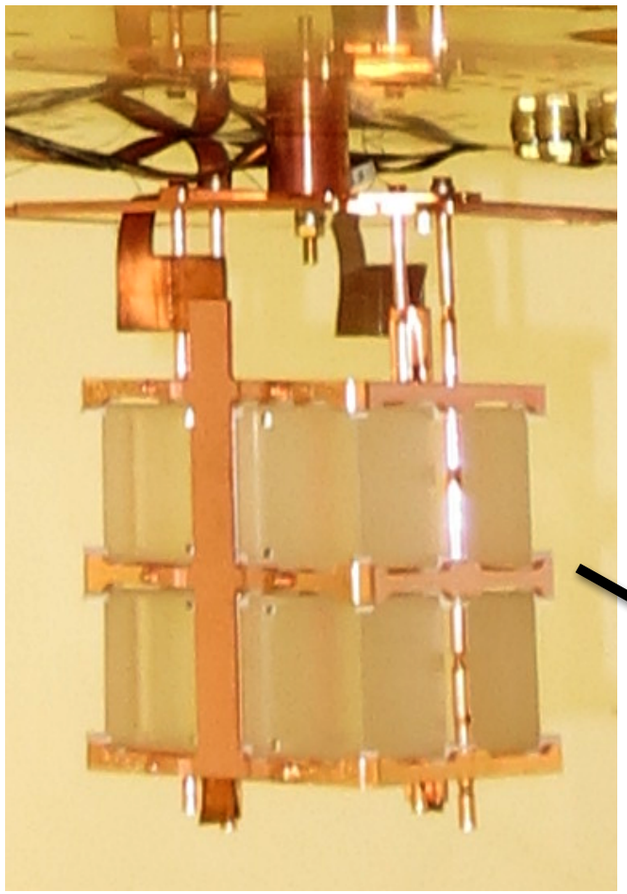




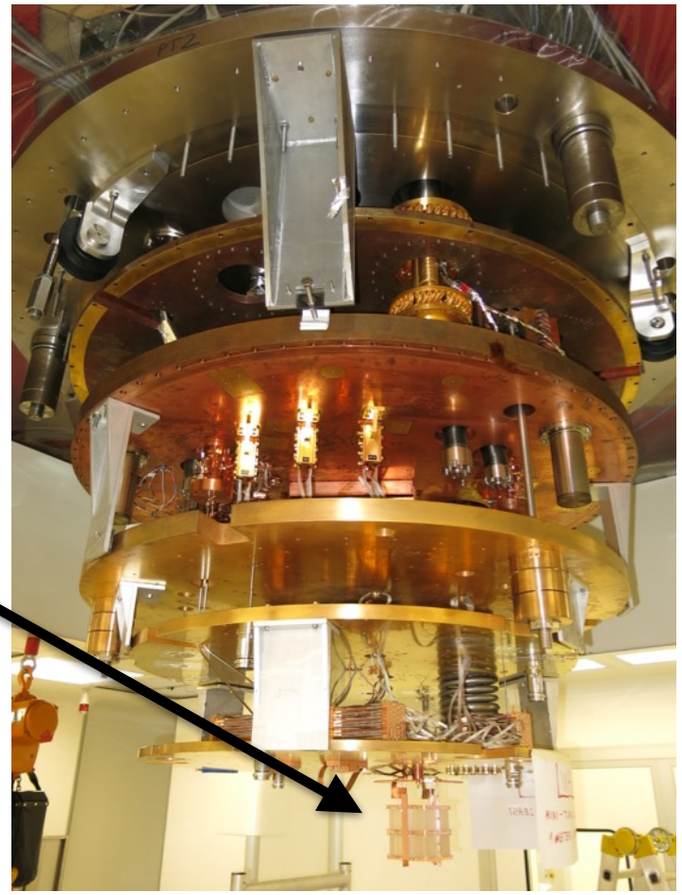
Cryostat commissioning

- CUORE Cryostat has reached stable base temperature of 5.9 mK in test runs
- Mini-tower (8 CUORE crystals) successfully operated in cryostat to test wiring and electronics
- Final preparations are underway for full detector installation this summer

Mini-tower

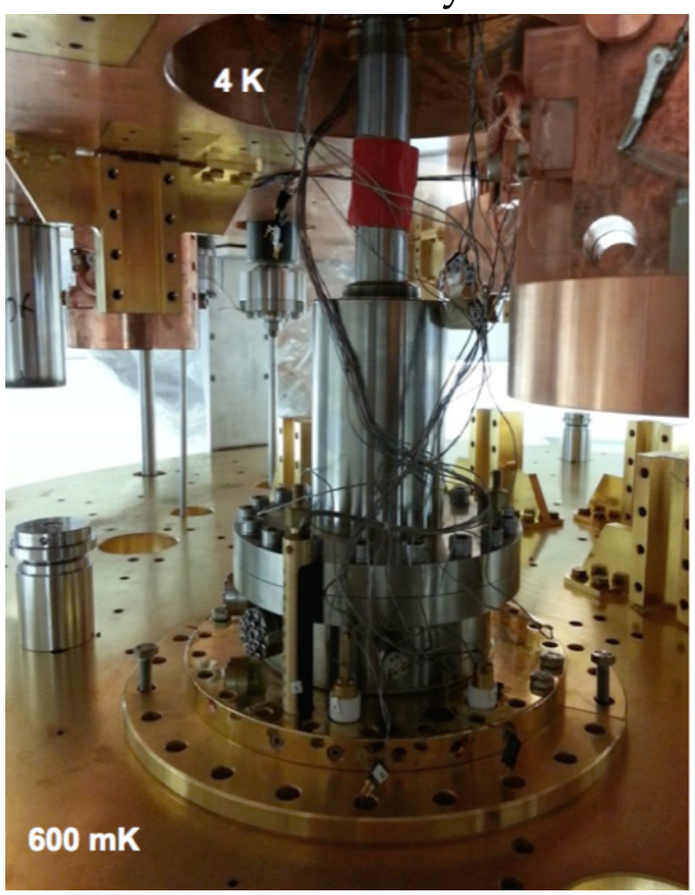


Cryostat vessel flanges



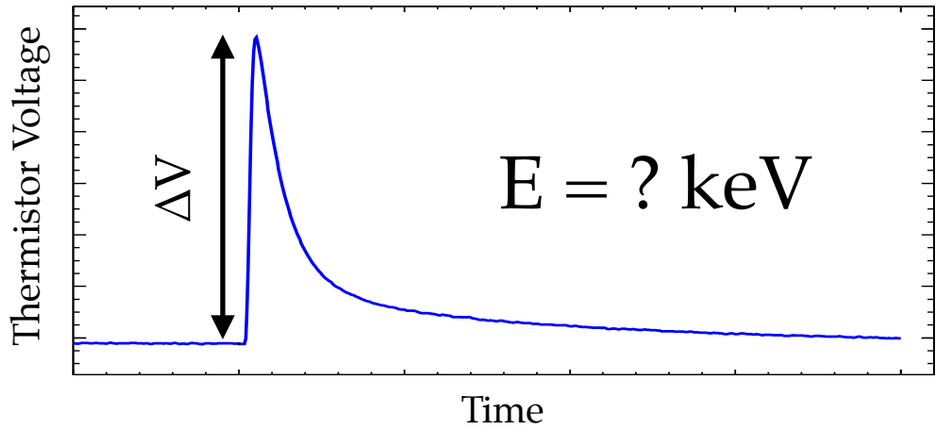
Dilution unit test stand

Dilution unit installed in cryostat

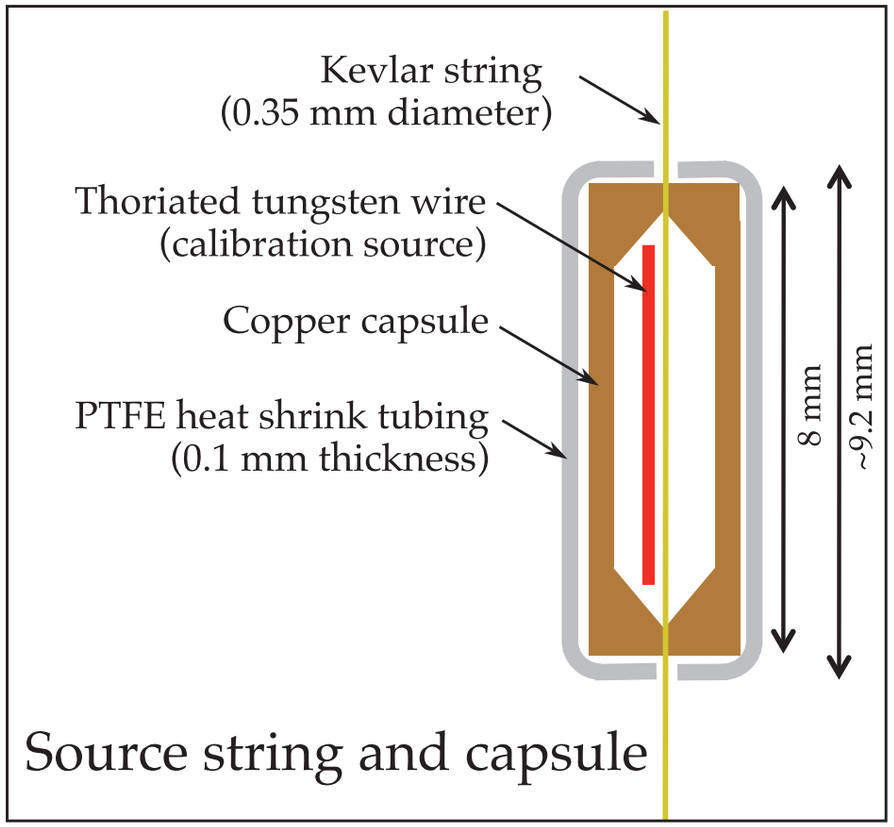


Bolometer calibration

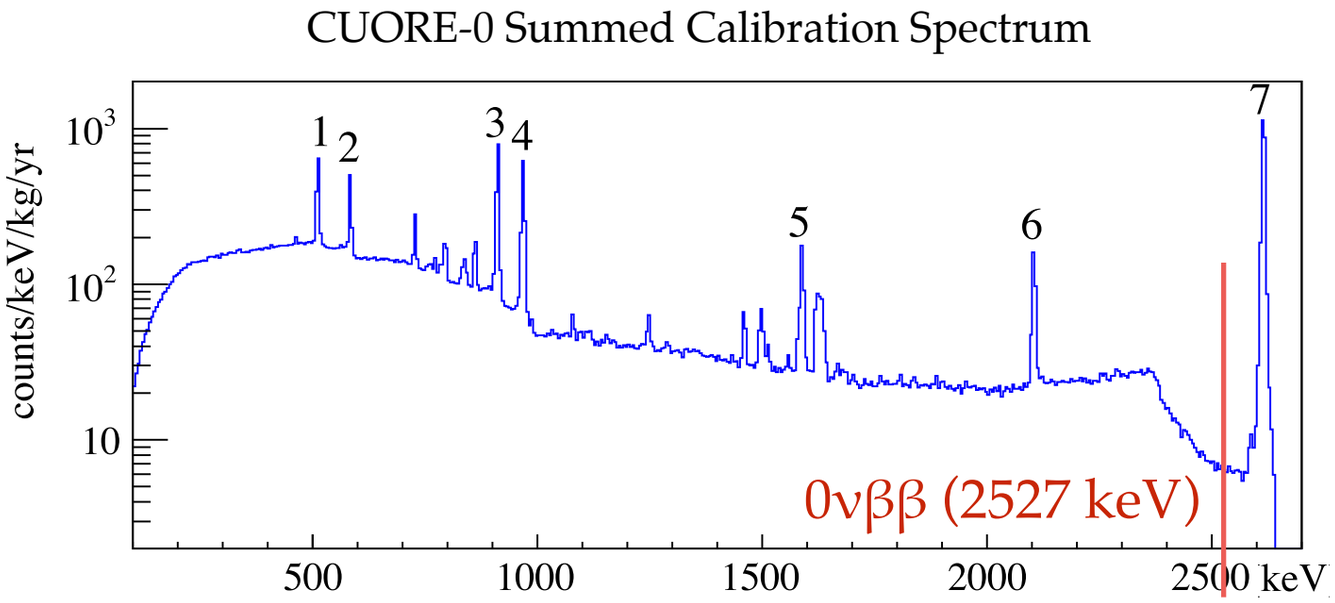
- Voltage signals from the thermistors must be calibrated
- Bolometers require independent *in situ* energy calibration



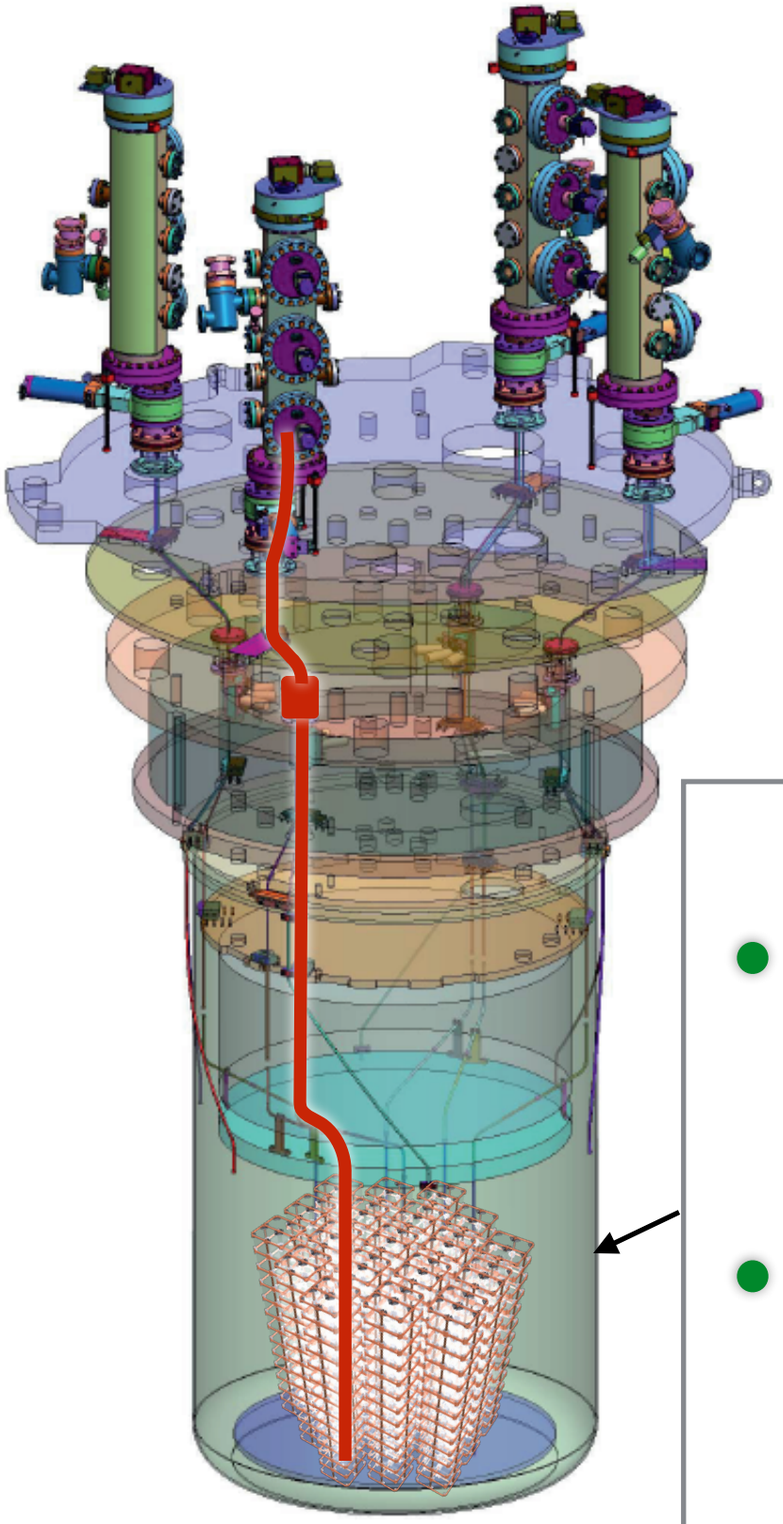
- Monthly, the crystals will be exposed to ^{232}Th γ-ray sources inside copper capsules crimped onto kevlar strings



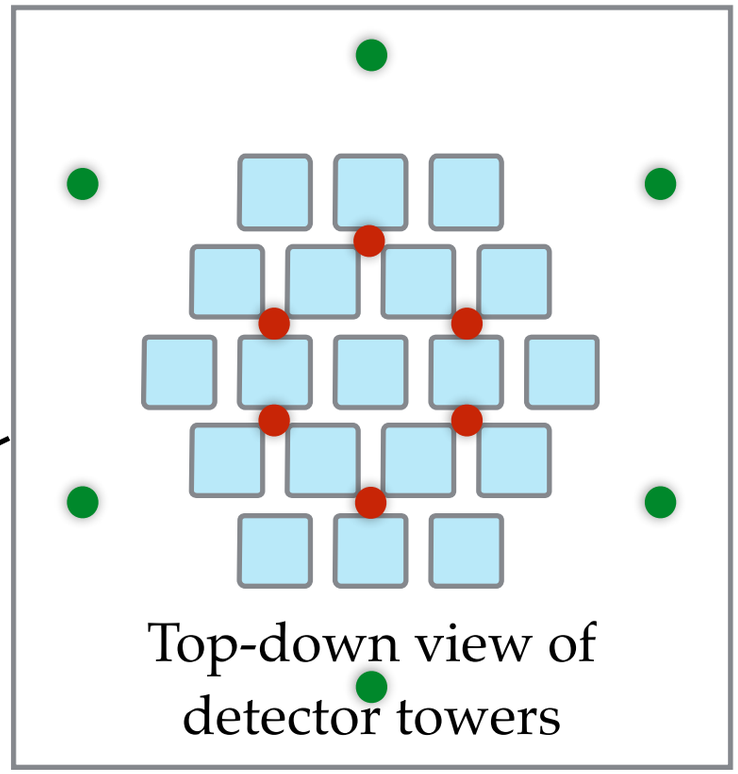
- 4 – 7 lines in the ^{232}Th decay chain are used to calibrate each bolometer



Calibration source deployment



- During physics data-taking, strings are wound on spools attached to motors at room temperature
- Motors turn to lower the sources into the cryostat for calibration, and strings move under their own weight
- A system of copper and stainless steel tubes guide the sources to their final deployment positions
- Strings are cooled from 300 K to 10 mK as they are lowered through guide tubes



Top-down view of detector towers

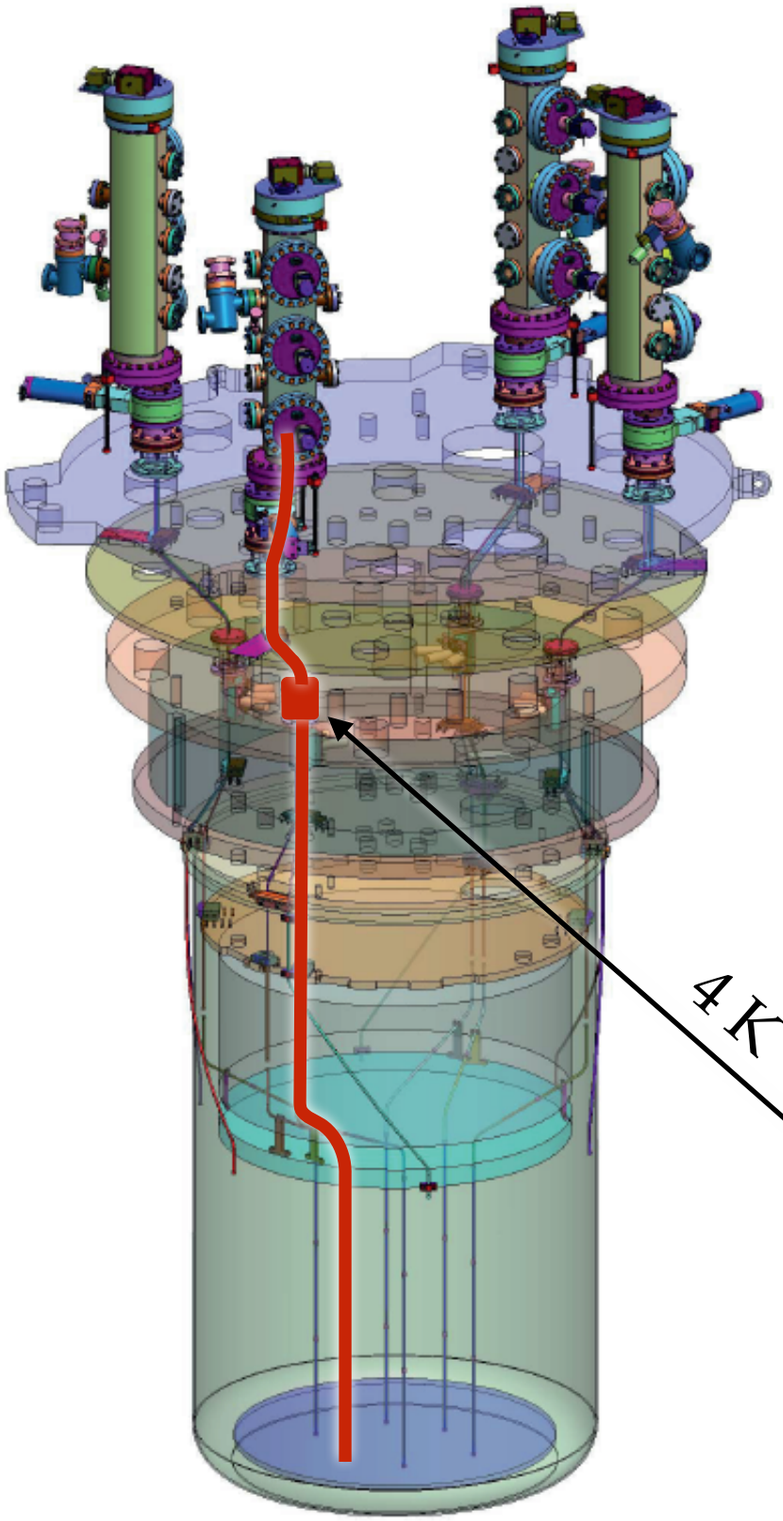
6 inner source strings

- 3.5 Bq each
- Guided between the bolometer towers to illuminate the inner detectors

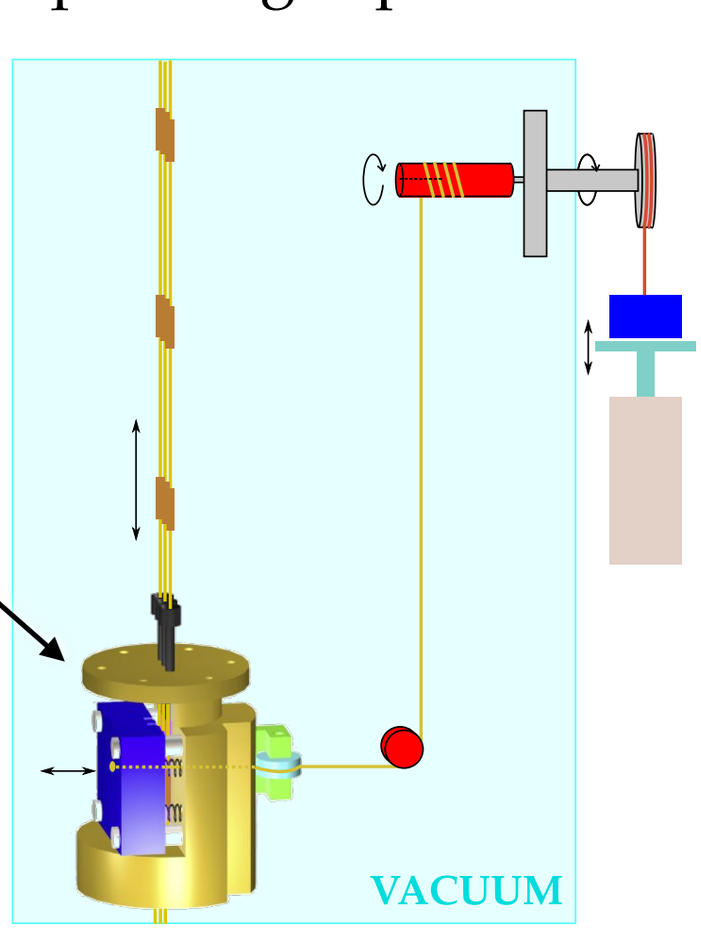
6 outer source strings

- 19.4 Bq each
- Guided to outside of detector region and allowed to hang freely

Source thermalization

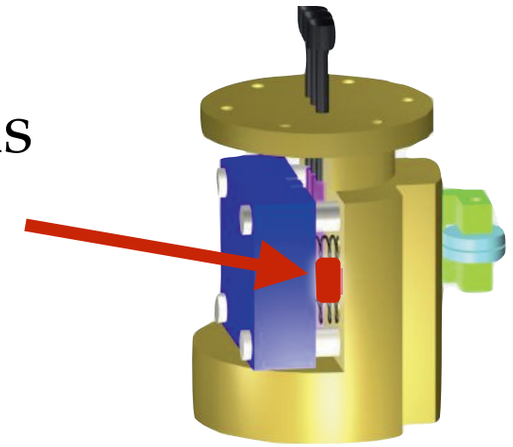


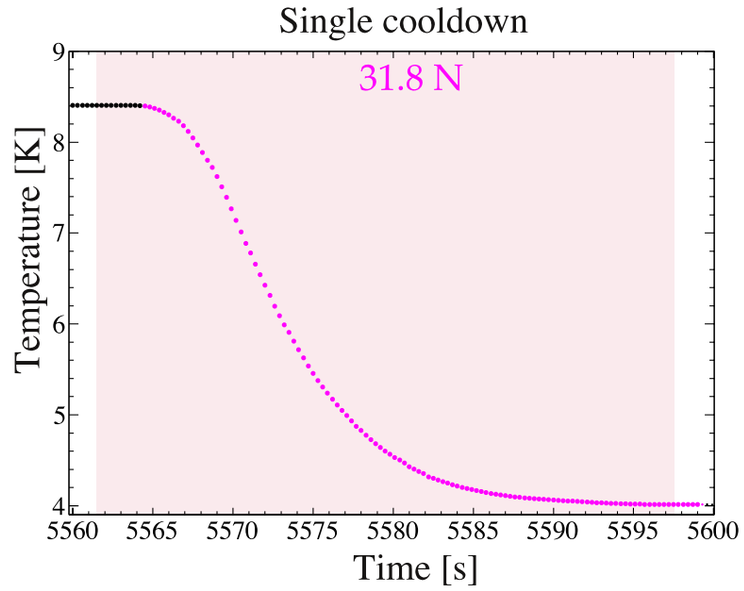
- Source capsules start at 300 K and must be thermalized as they are lowered through the cryostat
- Capsules thermalize with progressively colder guide tubes along bends in tubes
- Thermalization at 4 K is done by mechanically squeezing capsules



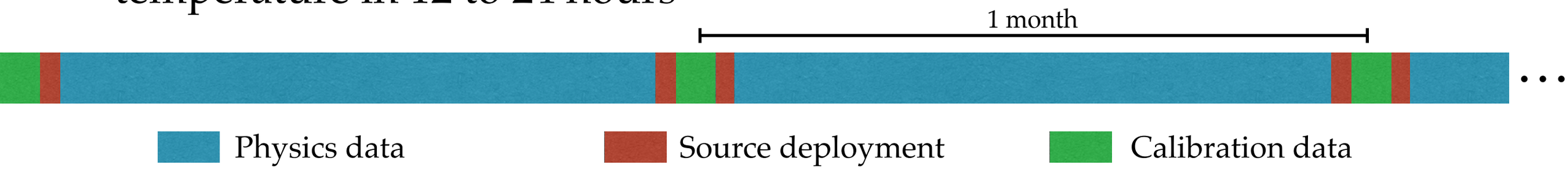
String deployment

- String deployment time cannot be used for taking physics data, so string deployment into the cryostat must be as quick as possible
- Cryostat cooling power high ≥ 4 K, but much lower in colder stages
- A Si diode thermometer made to imitate a copper source capsule was squeezed by the thermalizer at 4 K



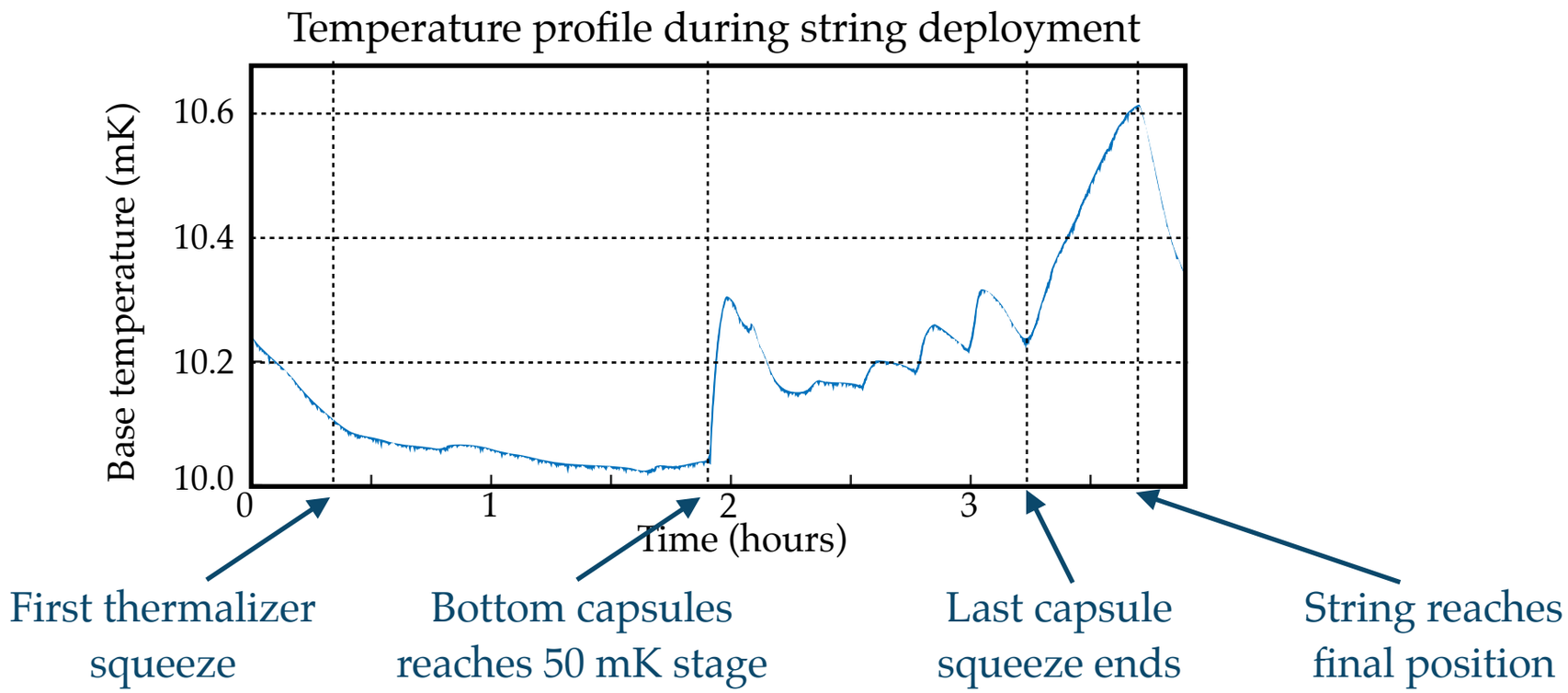


- Capsules can be cooled by the thermalizer to 4 K in ~30 s
- All 12 strings will be cooled and deployed from 300 K to base temperature in 12 to 24 hours

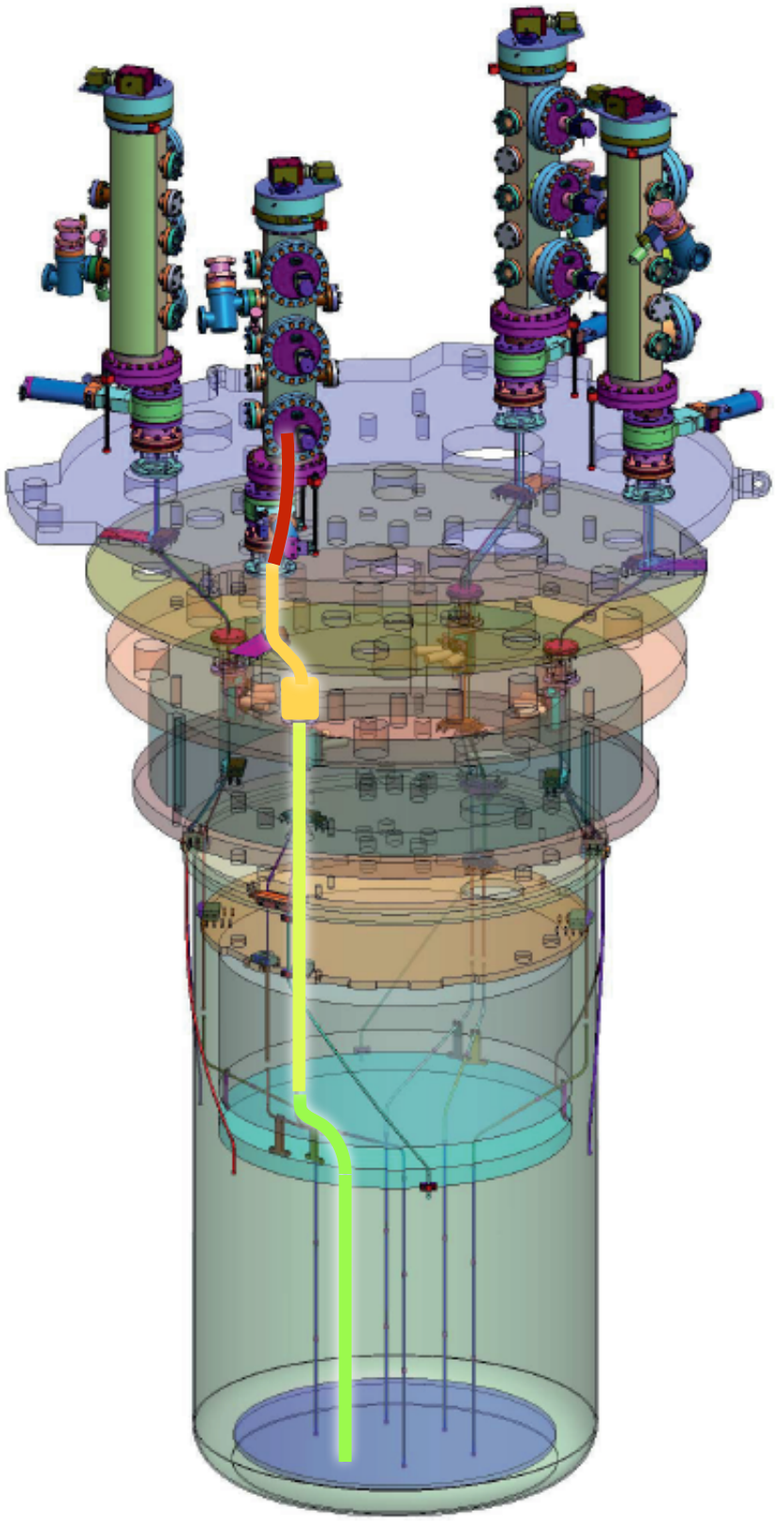


Detector temperature during calibration

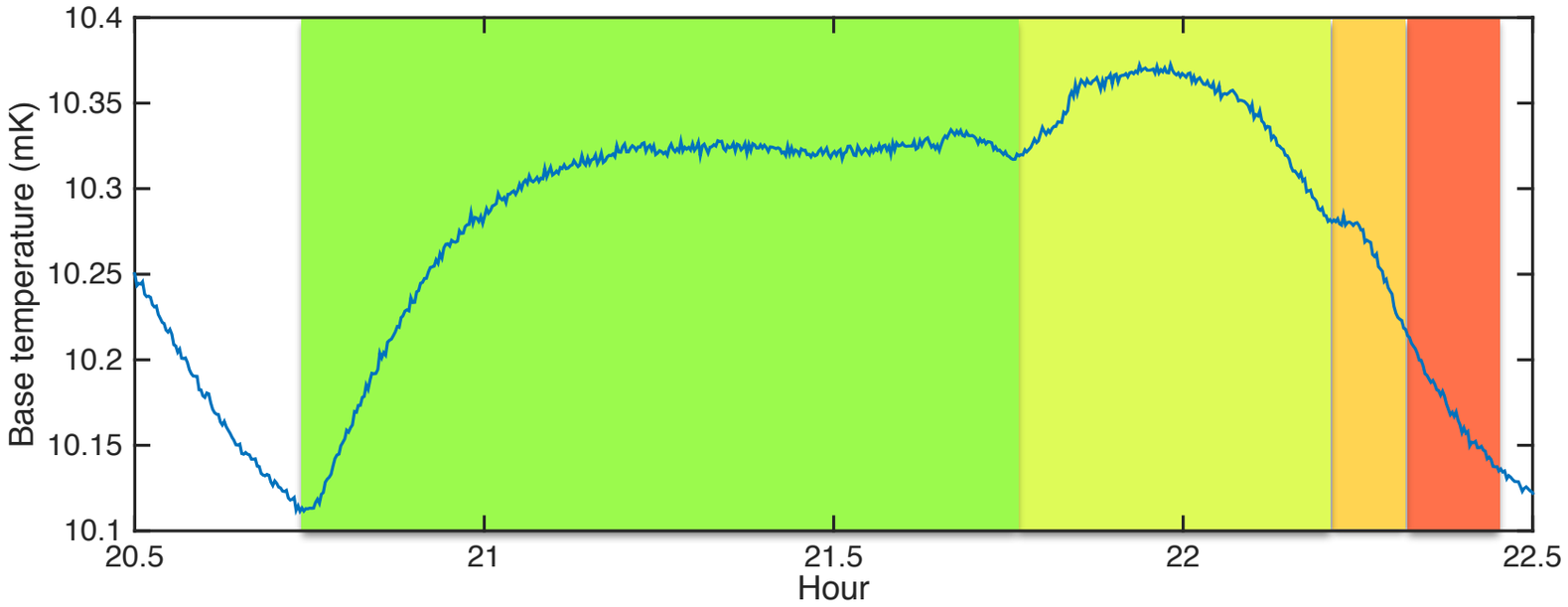
- Requirement for calibration system: operating baseline temperature of bolometers cannot be significantly disturbed
- We do not want to cause temperature effects much greater than a few MeV deposition into bolometer (1 MeV → ~0.1 mK rise)
- We have successfully lowered and cooled a string fully to base temperature with a baseline effect of < 0.6 mK



String extraction



- Cryostat base temperature was also measured during string extraction

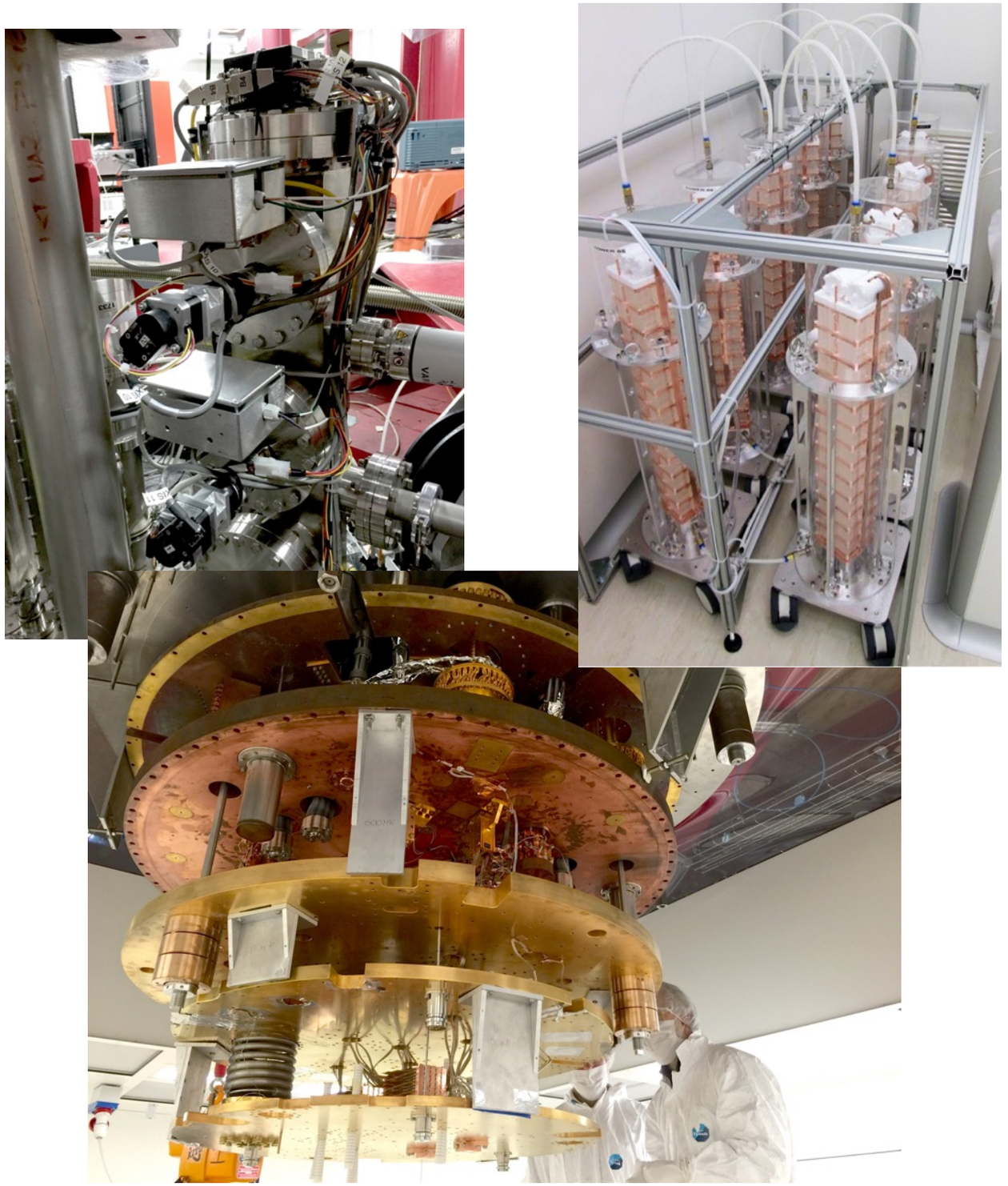


- Very slow raising speed is required when sources are in 10 mK region due to frictional heating

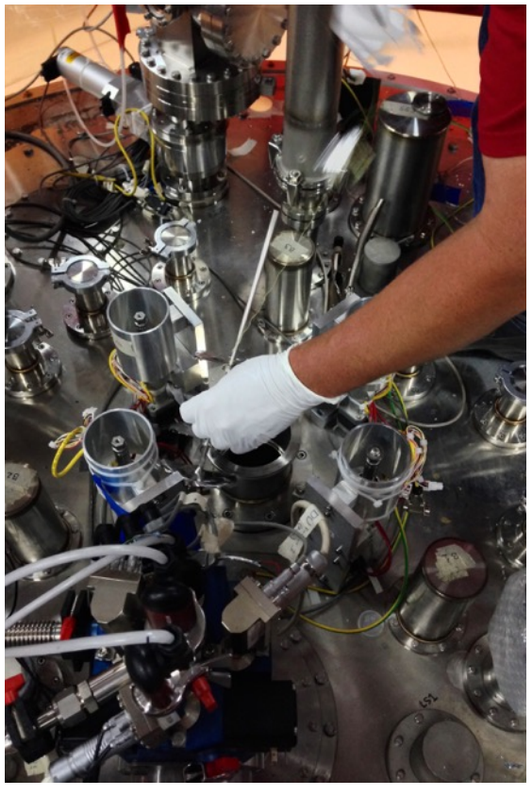
Prospects

Completed

- ☑ All 19 towers constructed, all 988 bolometers instrumented
- ☑ CUORE Cryostat cooled to stable base temperature of 5.9 mK
- ☑ Calibration strings lowered and cooled from 300 K to 10 mK while maintaining cryostat base temperature



Prospects



Next

- Full installation and commissioning of Detector Calibration System and all cryostat components and shielding this spring
- Detector installation in radon-suppressed clean room this summer

Beginning of CUORE operations scheduled for late this year

CUORE