CUPID: a next-generation neutrinoless double beta decay experiment.

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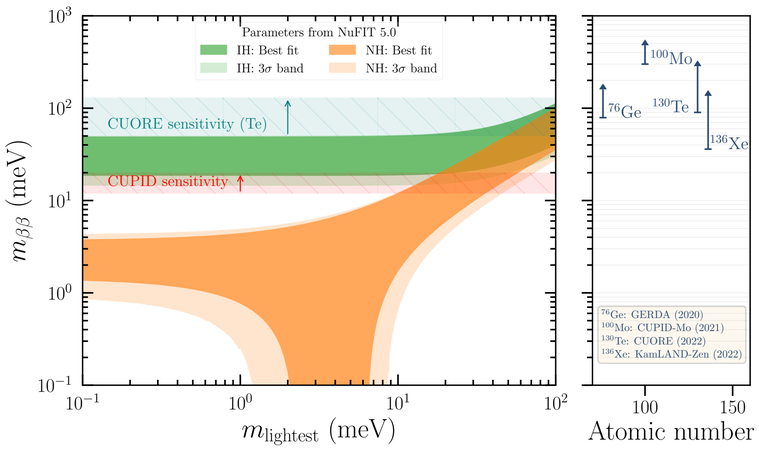
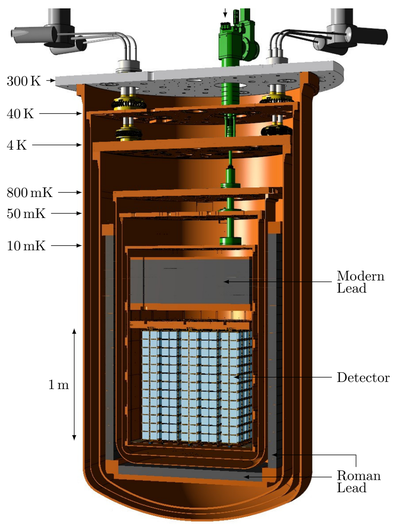
CUPID

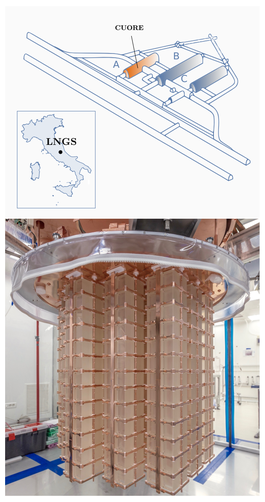
The CUPID experiment

Using the same infrastructure as CUORE (at LNGS), the **C**UORE **U**pgrade with **P**article **ID**entification (**CUPID**) [1], is a next-generation $0\nu\beta\beta$ decay experiment that will use ^{100}Mo as the candidate isotope. With a 3σ discovery sensitivity of 1×10^{27} yr, corresponding to an $m_{\beta\beta}$ range of 12-20 meV, CUPID will be able to probe the full inverted hierarchy region.



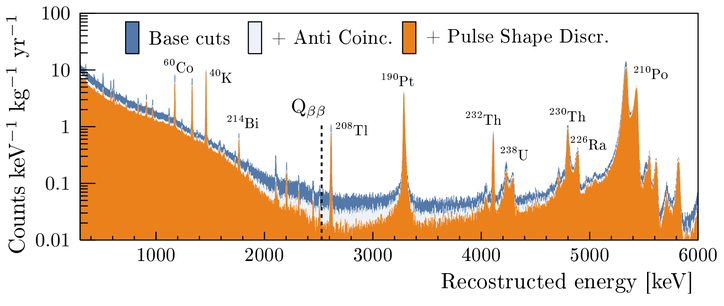
CUORE: Bolometers at the Tonne-Scale





Left: Rendering of the CUORE cryostat. **Right:** Location of CUORE and LNGS.

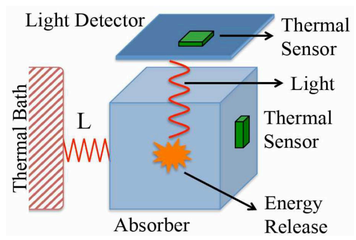
- First bolometric $0\nu\beta\beta$-decay experiment reaching one-tonne scale.
- CUORE has been steadily taking data since 2017.
- CUORE's background well understood:
  - $\sim$ 90%: α particles
  - $\sim$ 10%: natural radioactivity (β/γ)
  - $<$ 1%: muons

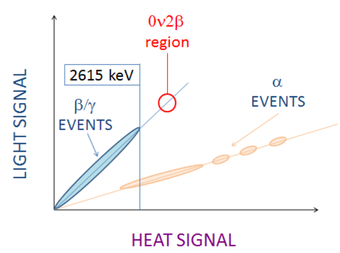


Above: CUORE's unmasked spectrum for 1-tonne exposure [2].

- CUORE will complete its science goal by 2024/2025.

CUPID's bolometers and α-rejection





Left: Schematic of a CUPID scintillating bolometer.
Right: Concept of α-rejection

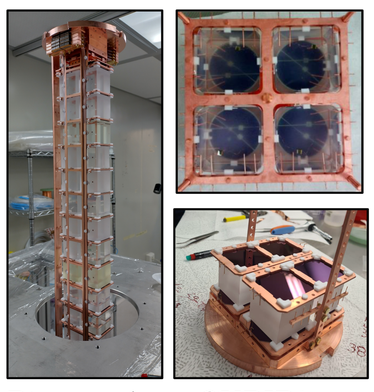
- Dual-readout for heat and light signals.
- Germanium light detectors.
- Successful prototypes/demonstrations at the $\sim$ 10 kg scale:
  - CUPID-Mo [3]
  - CUPID-0 [4]
- $\alpha-$rejection efficiency demonstrated to be $> 99.9\%$ [5].
- Energy resolution: FWHM$<$ 10 keV at $Q_{\beta\beta}$.

CUPID's concept and optimization

- 1596 $Li_2^{100}MoO_4$ crystals ($45 \times 45 \times 45$ mm^3) distributed in 57 towers.
- 240 kg of ^{100}Mo.
- Enrichment $> 95\%$, crystal quality.
- $Q_{\beta\beta} = 3034$ keV (above β/γ backgrounds).
- Background Index (B.I.) goal: $< 10^{-4}$ cts/(keV kg yr).
- Muon-veto system.

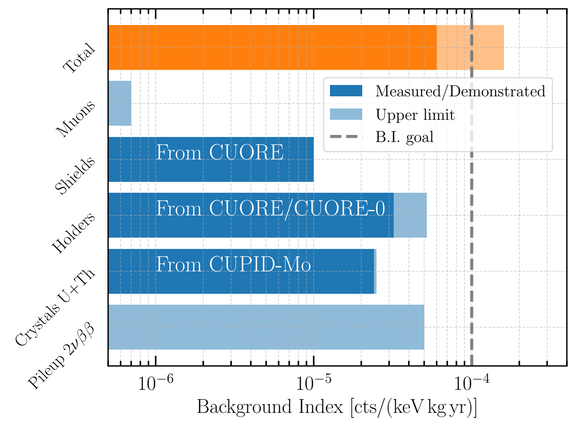
Detector optimization

- Define crystal shape and tower structure.
- Optimize light detector position and test reflecting foil.
- Verify quality of crystals from different origins.
- Test assembly procedures.
- Characterization of mechanical, thermal, and vibrational properties of full CUPID baseline tower.
- Studies of pile-up rejection.



Above: Pictures from CUPID's test assembly

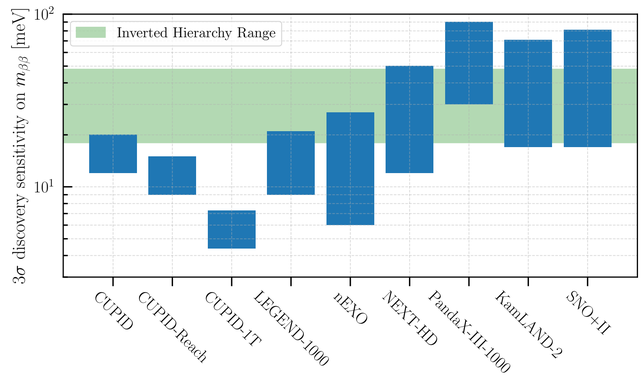
CUPID's background projection and sensitivity



CUPID's background projection [1].

- Cosmogenic muons tagged with muon-veto.
- β/γ backgrounds reduced with material selection, cleaning, shielding and delayed coincidence cuts (U/Th chains).
- $2\nu\beta\beta$ decay pileup addressed with high light-detector timing resolution ($\sim 160\,\mu$s), low noise electronics and machine learning techniques.

The envisioned background index goal will allow CUPID to explore the full inverted ordering region, putting it among the world-leading next-gen $0\nu\beta\beta$ decay experiments.



References:

[1] W. R. Armstrong et al. (CUPID), "CUPID pre-CDR", arXiv:1907.09376 (2019).

[2] D. Q. Adams et al. (CUORE), "Search for Majorana neutrinos exploiting millikelvin cryogenics with CUORE", Nature **604**, 53–58 (2022).

[3] C. Augier et al., "Final results on the $0\nu\beta\beta$ decay half-life limit of ^{100}Mo from the CUPID-Mo experiment", arXiv:2202.08716 (2022).

[4] O. Azzolini et al. (CUPID-0), "Final result of CUPID-0 phase-I in the search for the ^{82}Se Neutrinoless Double-β Decay", Phys. Rev. Lett. **123**, 032501 (2019).

[5] A. Armatol et al. (CUPID), "Optimization of the first CUPID detector module", arXiv:2202.06279 (2022).

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