Poster #307

NEUTRINO ‘26
International Conference on Neutrino Physics and Astrophysics
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UCI Department of Physics & Astronomy

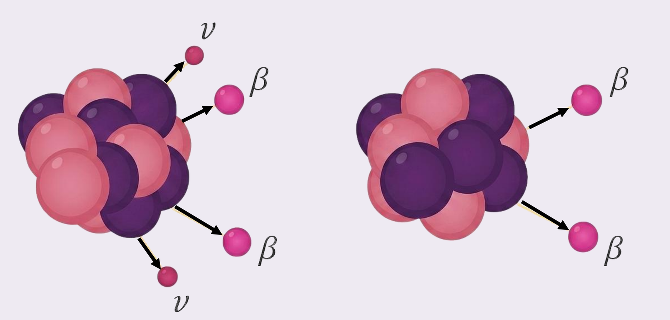
The CUPID 0νββ Experiment

Neutrinoless double-beta decay search with $Li_2{}^{100}MoO_4$ scintillating bolometers

Hawraa Khalife on behalf of the CUPID Collaboration

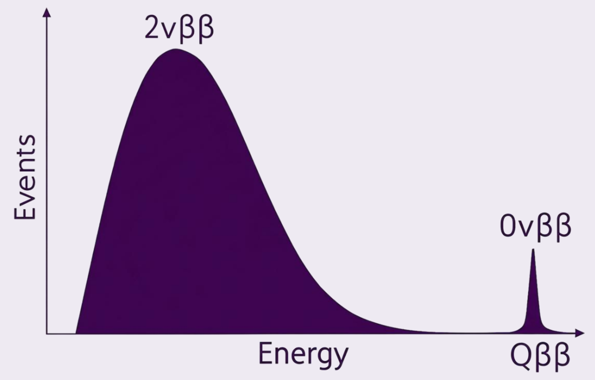
IJCLab Irène Joliot-Curie, Laboratoire de Physique des 2 Infinis

1. MOTIVATION



Its observation will:

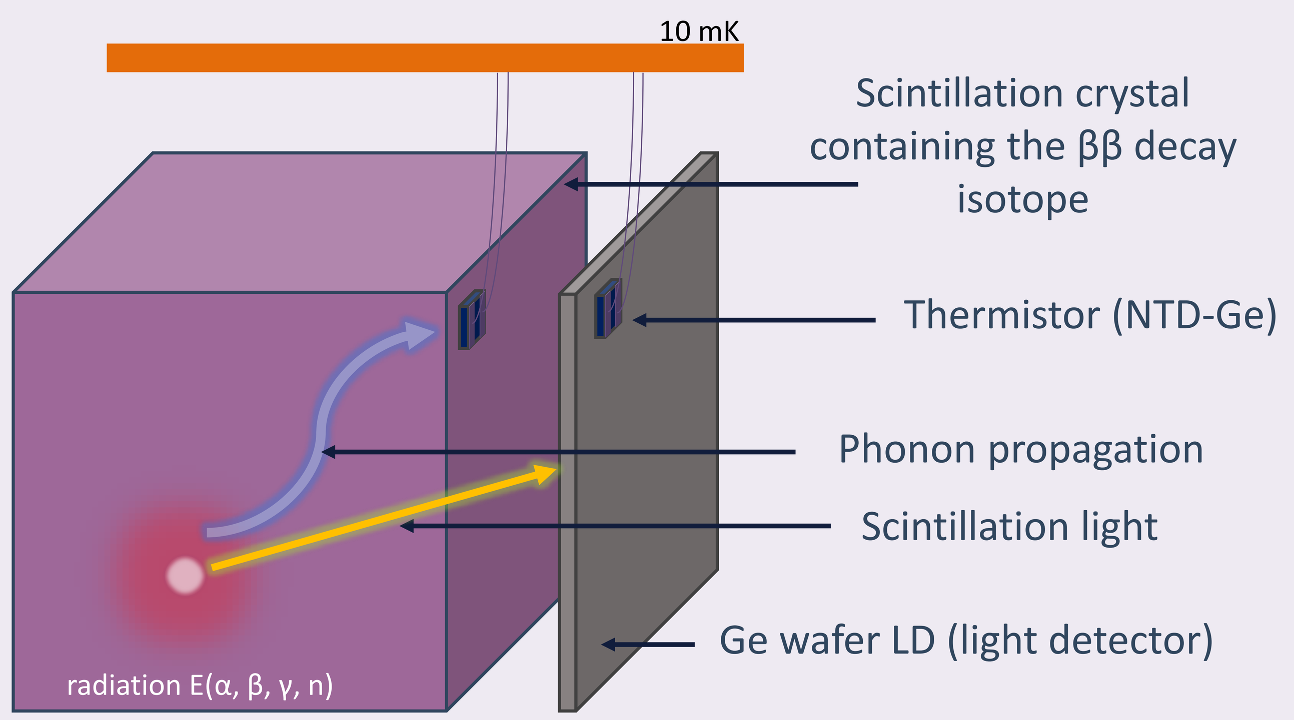
- Establish that neutrinos have a Majorana mass component ($\nu = \overline{\nu}$)
- Confirm lepton number violation
- Energetically possible for 35 nuclei (^{76}Ge, ^{100}Mo, ^{130}Te, ^{136}Xe, etc.)

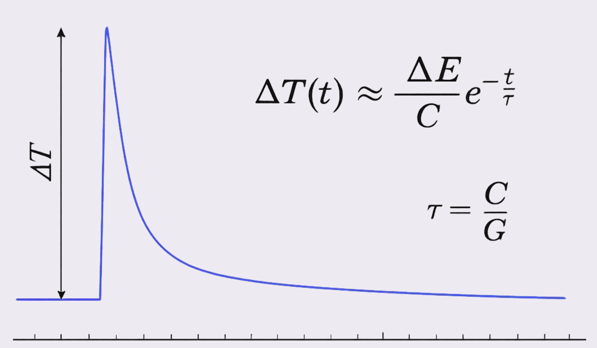


High sensitivity experiment requires:
- Low background in ROI
- Good energy resolution
- High detection efficiency
- Large mass ○ Long data taking

Need to find single events in a **ton of isotope × year(s) of exposure!**

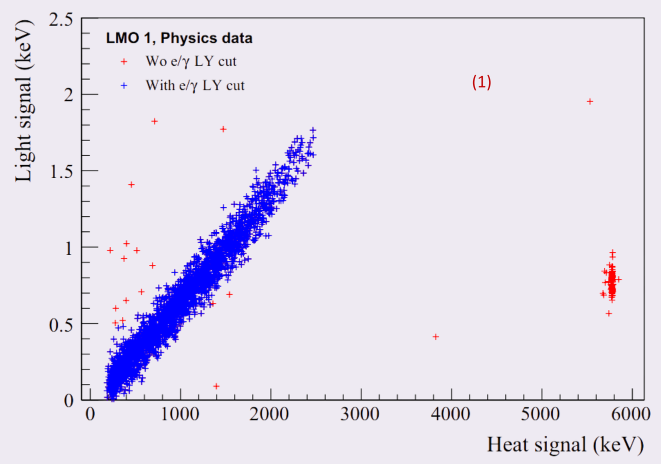
2. SCINTILLATING BOLOMETERS





$$\Delta T(t) \approx \frac{\Delta E}{C} e^{-\frac{t}{\tau}}$$

$$\tau = \frac{C}{G}$$



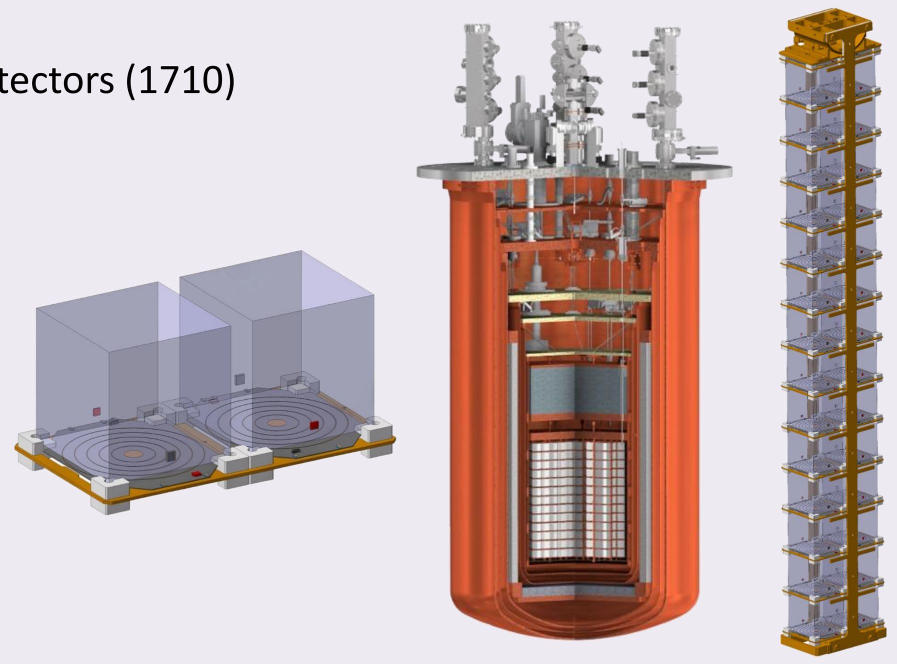
Features
- High energy resolution
- Particle identification capability
- Very low radioactive contamination
- Wide choice of absorber materials (Li_2MoO_4 embedding ^{100}Mo, $Q_{\beta\beta}$ = 3034 keV)

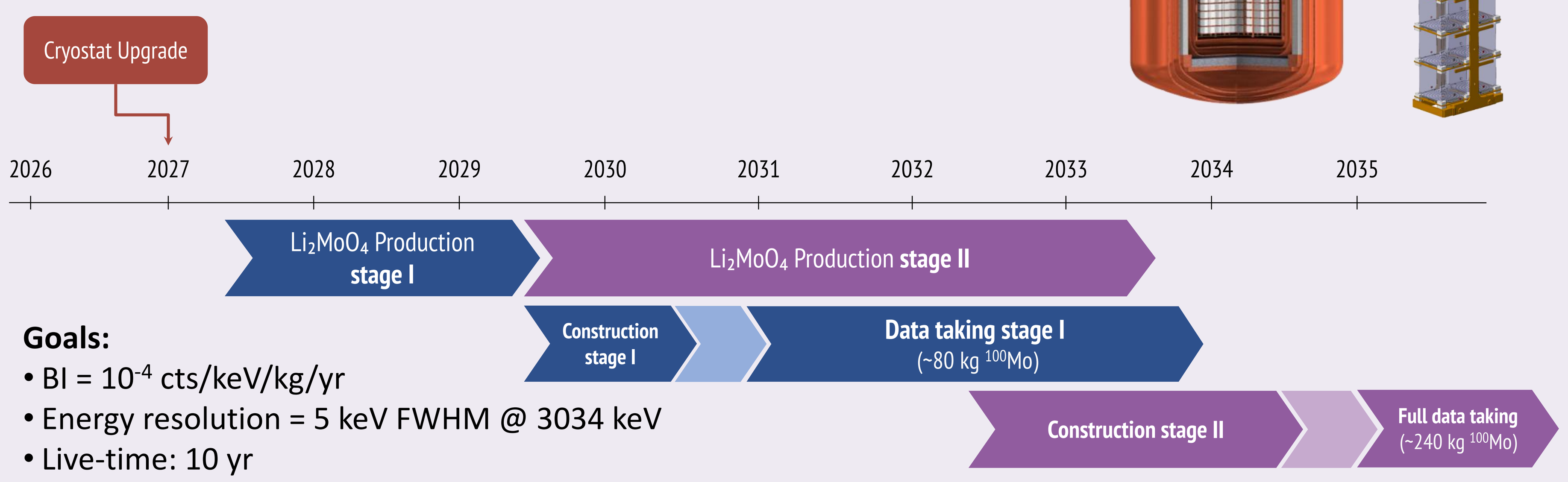
3. THE CUPID EXPERIMENT

CUPID (CUORE Upgrade with particle IDentification), the next generation bolometric experiment, aims at increasing the sensitivity of bolometric experiment to fully explore the inverted hierarchy region.

CUPID will build on the experience of CUORE, utilizing its existing cryogenic infrastructure that will host (2):

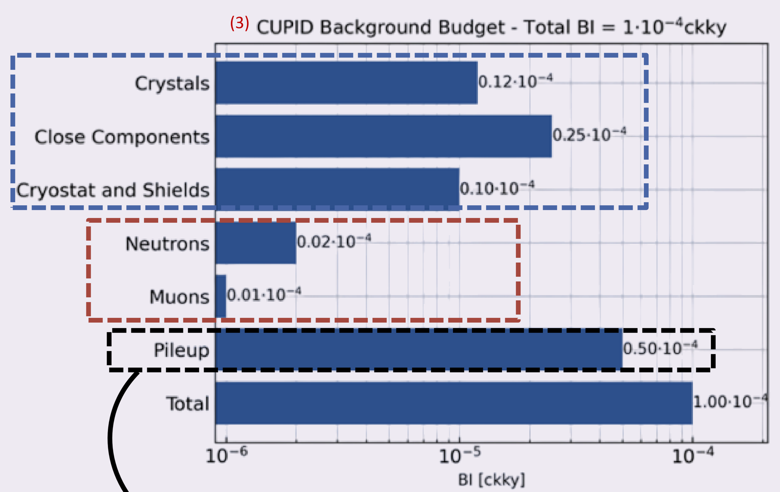
- 1596 $Li_2{}^{100}MoO_4$ coupled to Ge wafer light detectors (1710)
- 240 kg of ^{100}Mo (> 95% enrichment)
- Total mass: 450 kg
- Arranged in 57 towers of 14 floors
- The experiment will be divided into 2 stages:
  - Smooth CUORE → CUPID transition
  - Room for optimization/improvement
  - Early science with competitive sensitivity





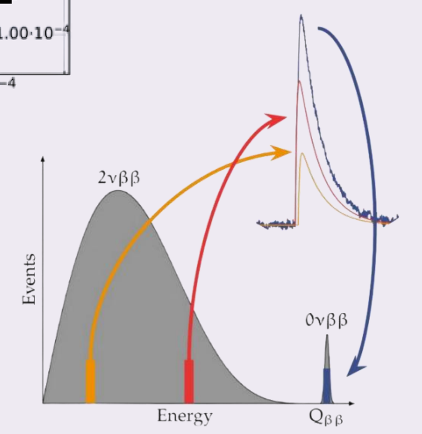
Goals:
- BI = 10^{-4} cts/keV/kg/yr
- Energy resolution = 5 keV FWHM @ 3034 keV
- Live-time: 10 yr

4. BACKGROUND BUDGET & SENSITIVITY

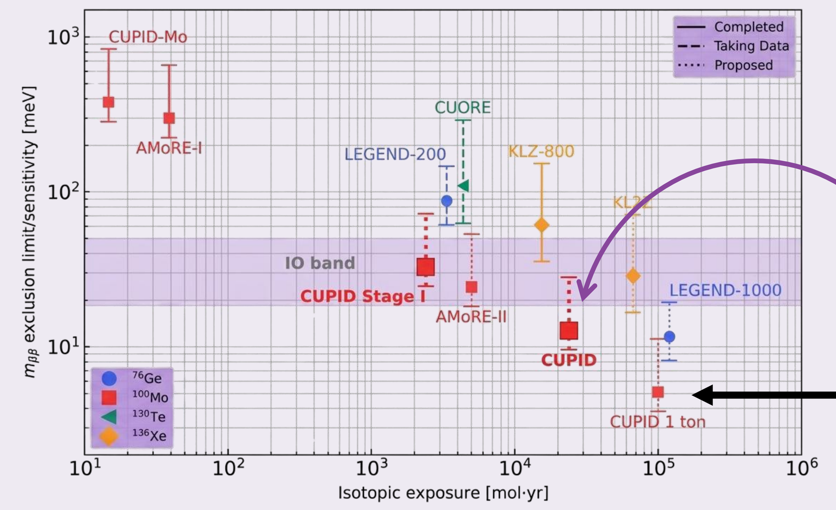


β/γ and α contamination:
- Shielding, ultra-clean component selection, and strict handling
- Delayed coincidence cuts to reject U/Th chains bkg
- > 99.9% of α background rejected by PID (validated with CUPID-Mo (3))
- Shields
- Muon veto system with 99% geometric efficiency

Relatively fast decay rate of ^{100}Mo ($T_{1/2}^{2\nu} = 7.07 \times 10^{18}\ yr$) (4)
+
slow pulses in heat channel (~30 ms rise-time)



Rely on Neganov-Trofimov-Luke light channel (which is faster) to reject pileups through PSD



0νββ 3σ discovery sensitivity goal:
- $T_{1/2} = 10^{27}$ yr
- $m_{\beta\beta}$ = 12 - 21 meV (depending on the adopted NME model)

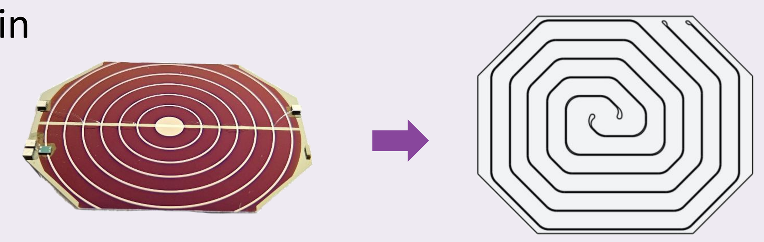
90% C.L. half-life exclusion sensitivity: $1.8 \cdot 10^{27}$ yr

[Poster #149]

5. STATUS

$Li_2{}^{100}MoO_4$ crystals
- Pre-production (in China at “SICCAS”) the cryogenic testing of the crystals are ongoing in terms of:
  - Detector performance, optical properties (light yield), and radiopurity

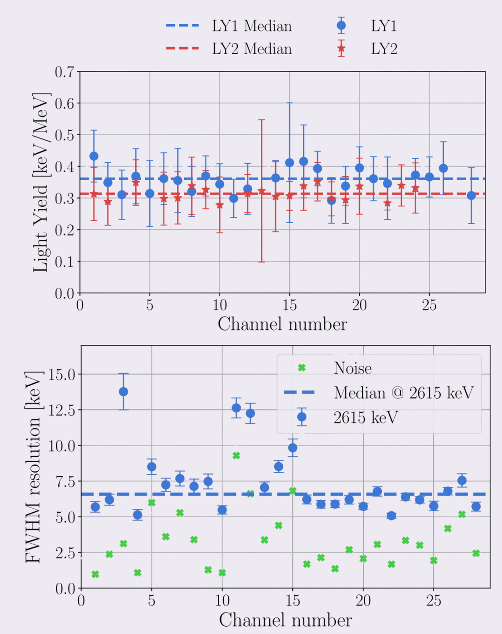
Light detectors
- Ge substrate equipped with electrodes for an enhanced thermal signal using Neganov-Trofimov-Luke effect (NTL) [Poster #312]
- SiO antireflective coating for an enhanced light collection
- The technology concept is validated in CROSS experiment (5)
- Further optimization is needed to increase production success rate and improve electrodes geometry to increase gain

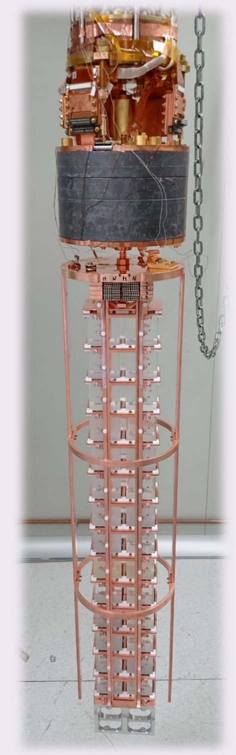


6. TESTS

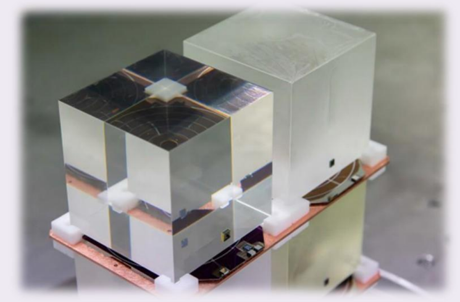
Gravity Design Prototype Tower (6):
- Tested in July-October 2022 at LNGS
- 28 LMO crystals
- 30 Ge LD (no NTL effect)

Main results
- Validation of the assembly procedure
  - Copper/LMO ratio < 20%
- Good temperature stability (±0.5 mK at 10 mK)
- **(6.6 ± 2.2) keV** median FWHM @2615 keV (close to CUPID goal)
- **0.36 keV/MeV** light yield (LY) (fulfills CUPID goal)
- Some excess noise on the LD -> issue solved with the new mechanical assembly in VSTT





In operation test: VSTT (Vertical Slice Test Tower)
- NTL LDs for pileup rejection
- Changes the LD holding system to mitigate the noise
- Optical fibers along the tower
- New electronics and DAQ



CONCLUSIONS

- CUPID will be built on the expertise and infrastructure of CUORE
  - Risk mitigations
  - Robust background estimations
- Data taking of CUPID Stage I expected to start by 2030
- CUPID will be one of the leading experiment covering the inverted hierarchy region of the neutrino mass
- CUPID approach is scalable to normal hierarchy region

References

(1) Armengaud, E., Augier, C., Barabash, A.S. *et al.* The CUPID-Mo experiment for neutrinoless double-beta decay: performance and prospects . *Eur. Phys. J. C* **80**, 44 (2020)
(2) CUPID Collaboration. CUPID, the CUORE upgrade with particle identification. *Eur. Phys. J. C* 85, 737 (2025)
(3) Armengaud, E., Augier, C., Barabash, A.S. *et al.* The CUPID-Mo experiment for neutrinoless double-beta decay: performance and prospects . *Eur. Phys. J. C* **80**, 44 (2020)
(4) C. Augier, et al. Measurement of the 2νββ Decay Rate and Spectral Shape of 100 Mo from the CUPID-Mo Experiment, Phys. Rev. Lett. 131, 162501 (2023)
(5) A. Armatol *et al.* Cryogenic light detectors with thermal signal amplification for 0νββ search experiments. *JINST* **21** P01035 (2026)
(6) CUPID Collaboration. A gravity-based mounting approach for large-scale cryogenic calorimeter arrays. Eur. Phys. J. C 85, 935 (2025)

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