Preliminary results from the latest CUPID Prototype Tower

Poster ID #231
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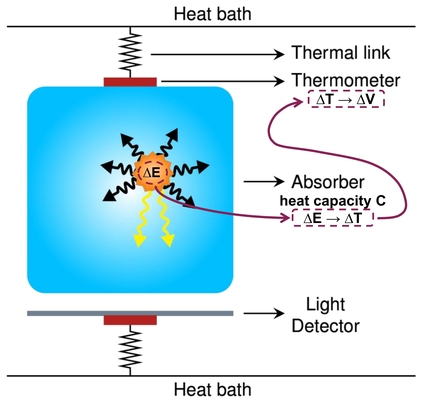
UCI Department of Physics & Astronomy

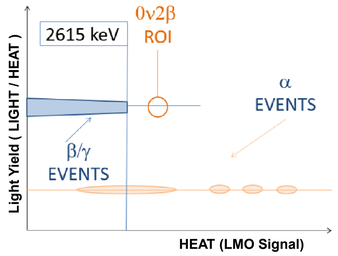
1. The CUPID Experiment

Searching for $0\nu\beta\beta$ decay:
LNV process ➔ Neutrino Majorana nature and mass scaling

CUPID baseline
More details Poster #307

- Isotope ^{100}Mo ($Q_{\beta\beta}$ = 3034 keV)
- Double Readout (heat/light)
  - ➔ 1596 Li_2MoO_4 crystals, 240 kg of ^{100}Mo (95% enrichment)
    Energy resolution of 5keV FWHM
    Light Yield for β/γ ~ 0.3 keV/MeV (Particle ID)
  - ➔ Ge-wafer light detectors (LD) with NTL amplification
    Timing Resolution < 170 us (Pile-up Rejection)
  - ➔ Each LMO has two LDs as side, top and bottom

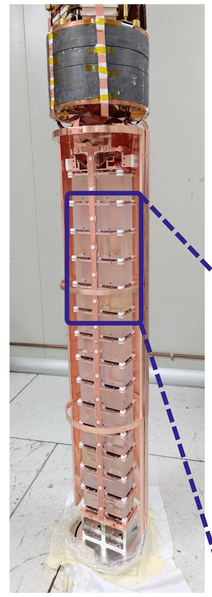


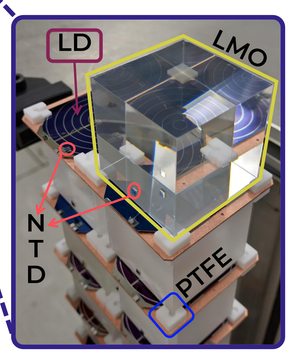


Main Objective
- 10 yr of livetime
- Background index ~10^{-4} ckky
- $T_{1/2}^{0\nu\beta\beta} > 1.0 \times 10^{27}$ yr (90% C.L.)

2. VSTT – Vertical Slice Test Tower

(Deployed @LNGS, July '25 – Ongoing)

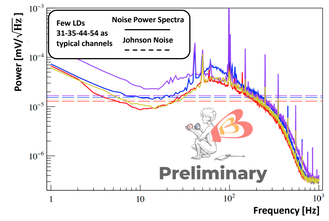




- 28 Li_2MoO_4 crystals (LMO)
  - ➔ 2 columns × 14 floors
- 30 Ge-wafers (Light Detector, LD)
  - ➔ two LDs per LMO
- ➔ read-out through NTD thermistors

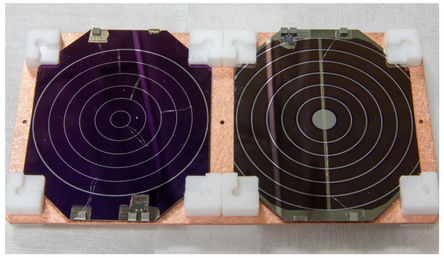
Tower Design
- Supports and wiring
  - ➔ PTFE supports
  - ➔ frames optimised for wire-bonding
- Operation of NTL (Neganov-Trofimov-Luke)-assisted LDs
- Optical Fibres
  - ➔ running along the sides of the tower
- DAQ and Electronics

Mechanical Validation
- No excess low-frequency noise for the LDs.
- Uniformity of the tower's temperature during the cooldown.



3. NTL Amplification

More details Poster #312



Phonon Amplification

1. Photons absorbed by the wafer are converted, energy gap ε, into electron-hole pairs.
2. The released charges drift according to the electric field, V_b ~ 10 - 100 V.
3. Their drifting produces additional heat, i.e. phonons. Thus, amplifying the response of the NTL sensor (gain ~ 10).

Gain Loss

Charge accumulation over time worsens the effective gain, requiring then the regeneration of the wafers.

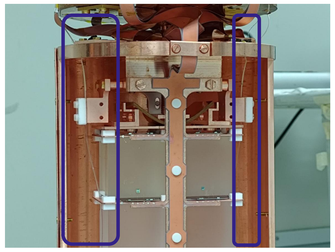
$$E_{tot} = E_0\left(1 + \eta\frac{e \cdot V_b}{\varepsilon}\right)$$

LD Signal — Efficiency — NTL Gain

4. Optical Injection System

A system capable of injecting light pulses of a given wavelength to be absorbed by a group of LDs.
- ➔ Laser Diode (635nm) operated in pulsed mode (LED regime)
- ➔ Diffusive optical fibres

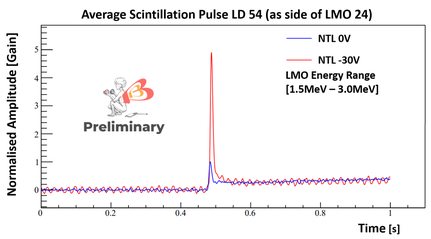
Applications:
- Regeneration process for the NTL
- Evaluation of the LDs' pile-up rejection power
- Optical Calibration of the LDs



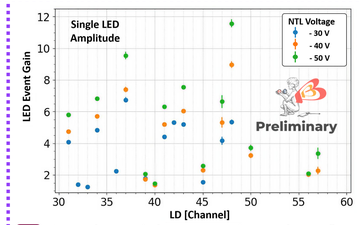
OPTICAL FIBRES

5. VSTT NTL-assisted LDs

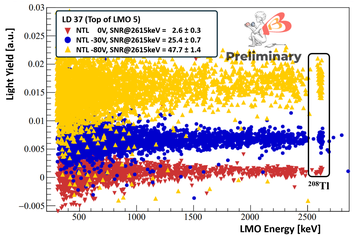
VSTT is the first Cupid tower with NTL-assisted LDs.



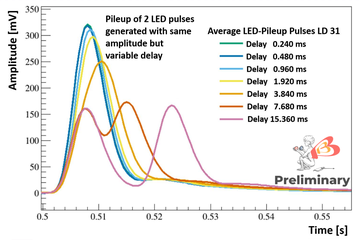
A Tested the amplification of the light signal through NTL effect.



B Study, with LED signals, of the achievable amplification of light at different voltages.



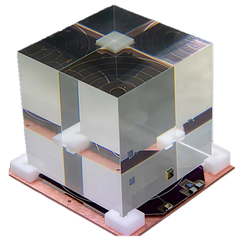
C Verified that amplification allows to achieve an improvement in terms of SNR, reporting here a factor ~20, and of discrimination power, here boosted ~3.5 times.



D Plan to employ LED signals for the NTL regenerations and to induce LED pileup events to characterise the rejection power through PSD

E The improvement of the S/N ratio, even in the case of sub-optimal LD response, because the scintillation signal is amplified with respect to the noise.

6. Outlooks



VSTT served to validate the new tower design of CUPID, and even more, to test NTL-assisted LDs, which is the current baseline.

Several tests are already planned for the next months. Under the idea to further explore the achievable performances of the LDs at higher voltages for the NTL, since the optimal value is *O*(100V).

Improving the duty time for the data-taking:
- by performing a few optimisations of the facility.
- by moving the tower to LNGS-Cryoplatform (Hall-B).

References
[1] CUPID, the CUORE Upgrade with Particle IDentification. Eur. Phys. J. C 85, 737 (2025)
[2] A gravity-based mounting approach for large-scale cryogenic calorimeter arrays. Eur. Phys. J. C 85, 935 (2025)
[3] Novel technique for the study of pileup events in cryogenic bolometers. Phys. Rev. C 104, 015501 (2021)

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