NTL-Enhanced Light Detector in 0νββ Searches

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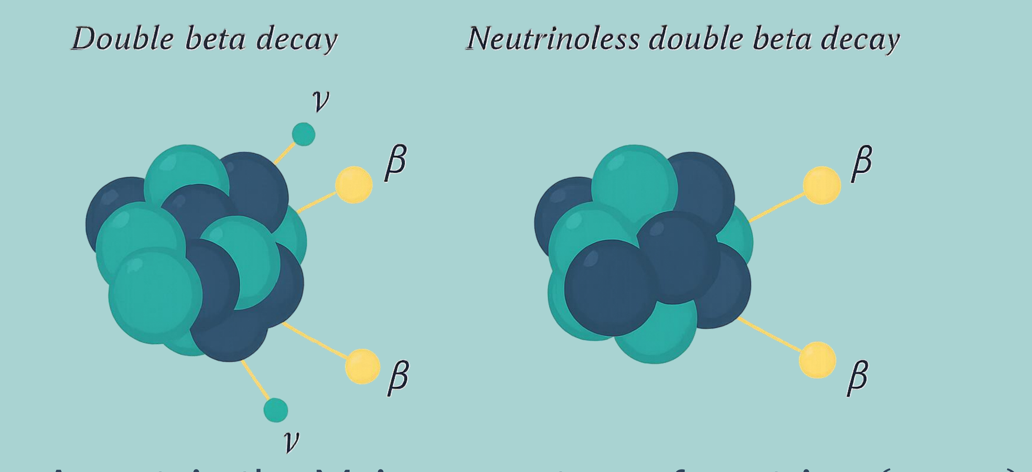
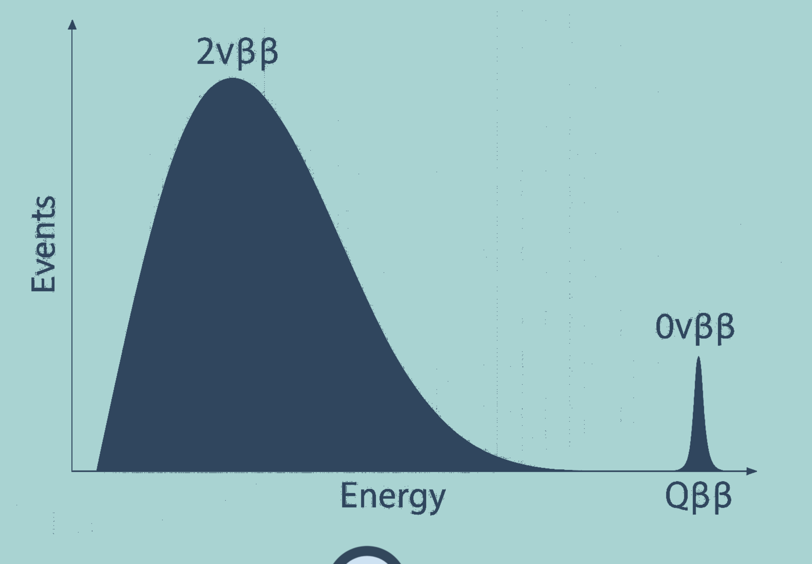
Neutrinoless double beta decay

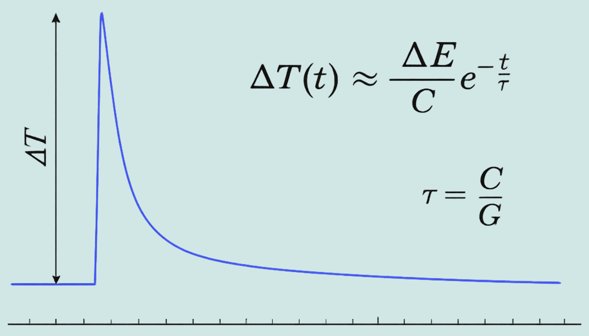


- Ascertain the Majorana nature of neutrino ($\nu = \overline{\nu}$)
- Confirm lepton number violation
- Energetically possible for 35 nuclei (^{76}Ge, ^{100}Mo, ^{130}Te, ^{136}Xe, etc.)

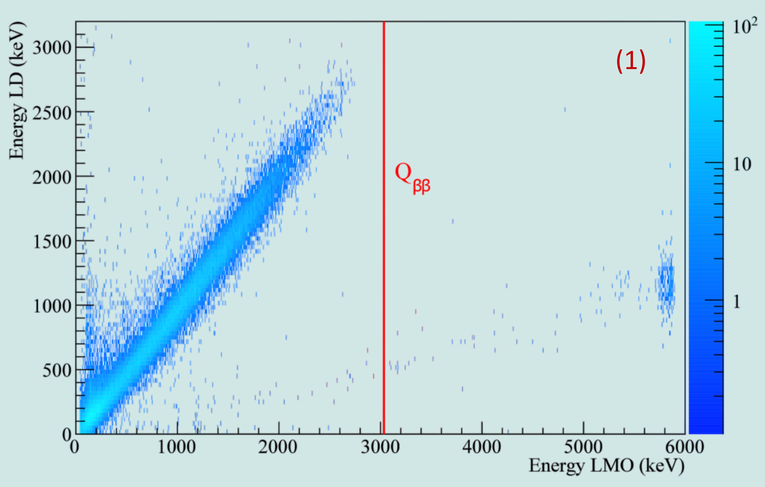


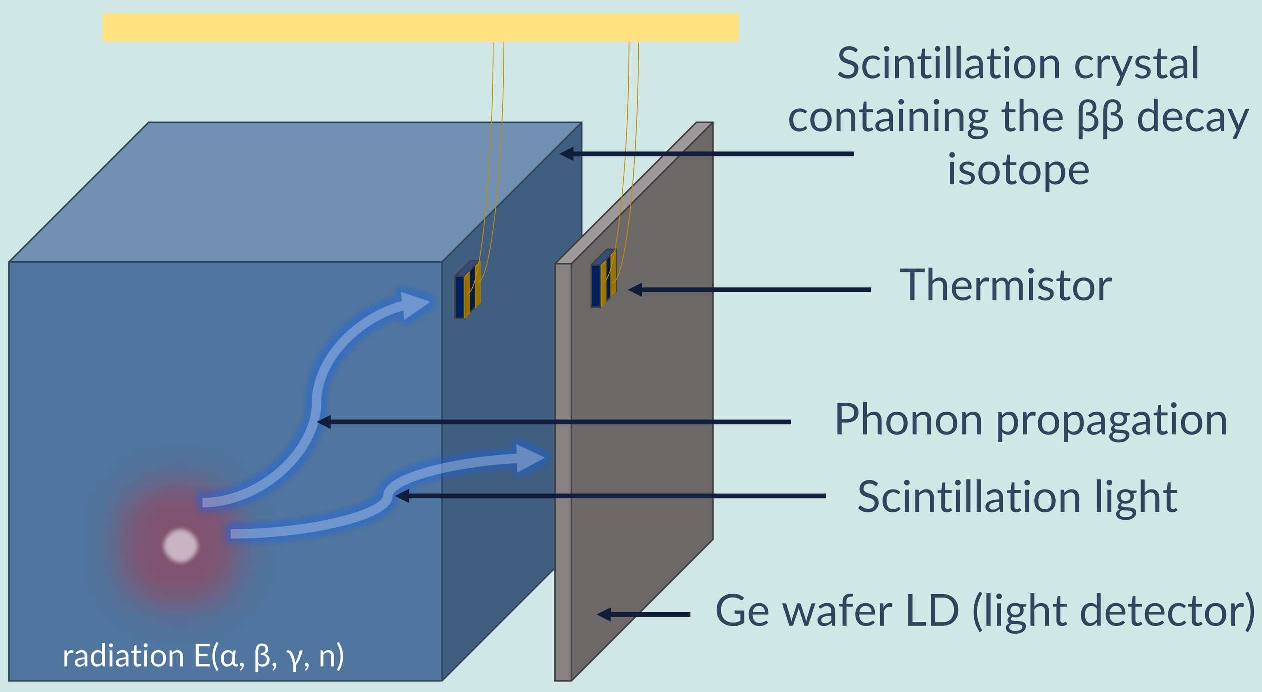
Need to find single events in a **ton of isotope × year(s) of exposure!**

Scintillating bolometer



The dual heat-light readout allows to reject the alpha contamination thanks to the lower light output of α





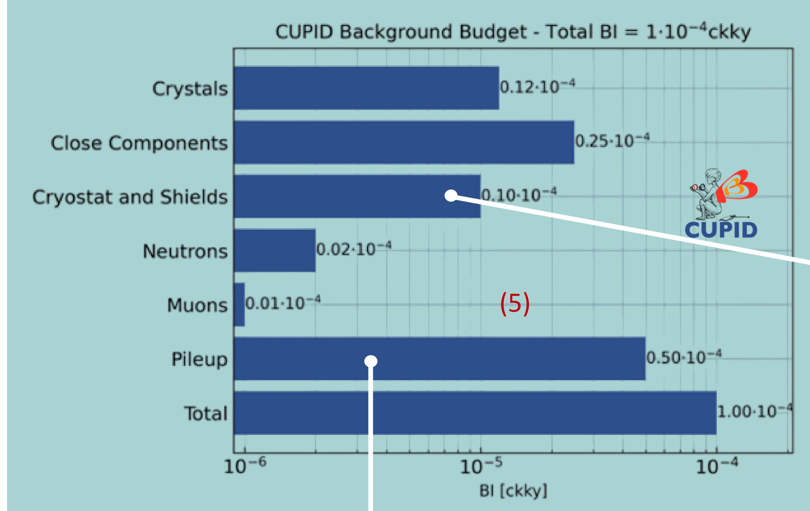
Features

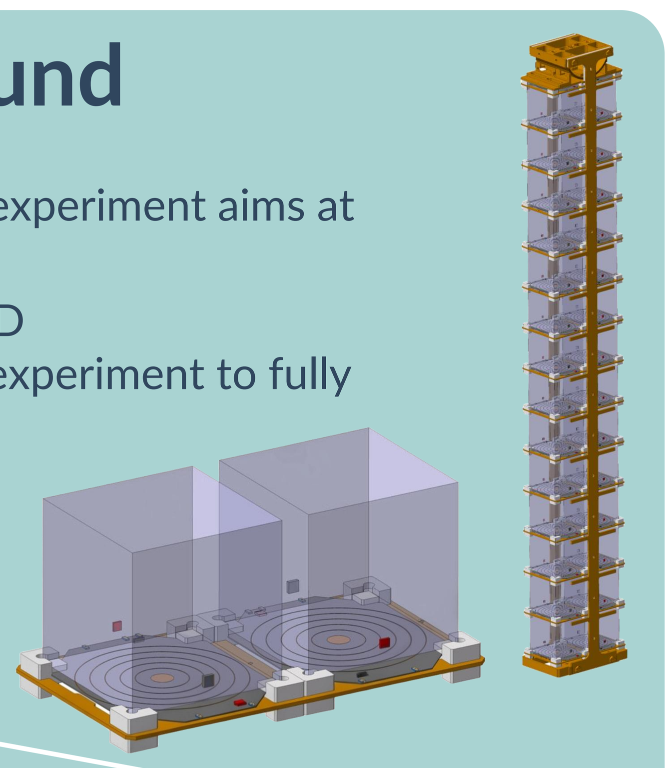
- High energy resolution
- Particle identification capability
- Very low radioactive contamination
- Wide choice of absorber materials (Li_2MoO_4, TeO_2)

Background

CUPID[2], the next generation bolometric experiment aims at testing:

- 1596 Li_2MoO_4 each coupled to a Ge LD
- Increase the sensitivity of bolometric experiment to fully explore the inverted hierarchy region



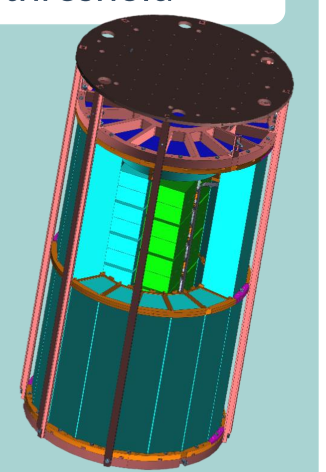


Relatively fast decay rate of ^{100}Mo ($T^{2\nu}_{1/2} = 7.1 \times 10^{18}$ yr)
+
slow pulses in heat channel
↓
Random coincidences of 2νββ in ROI

- Rely on light detector (which is faster) to reject pile-up through PSD
- Need to improve S/N in LDs by amplifying the thermal signal

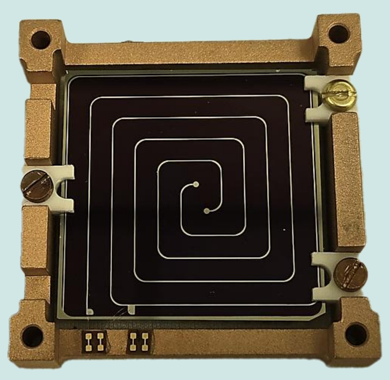
For Next-Next generation experiment

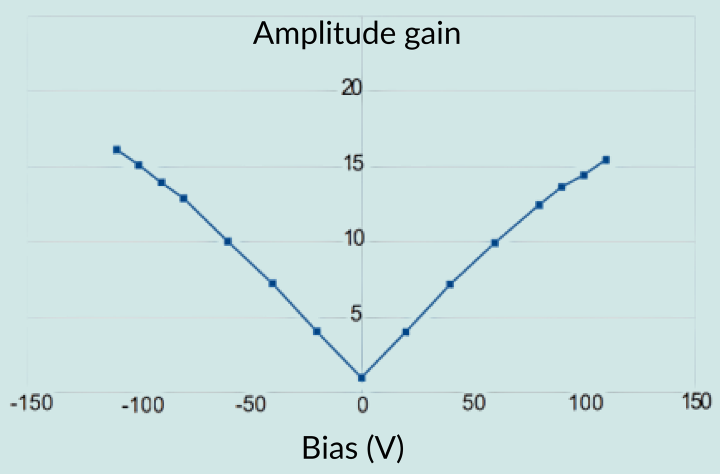
- BINGO[3] proposes the use of an active veto to reject external γ radiation through anti coincidence
- The veto is composed of scintillating crystals facing LDs
- Need to improve the LDs S/N to achieve low energy threshold

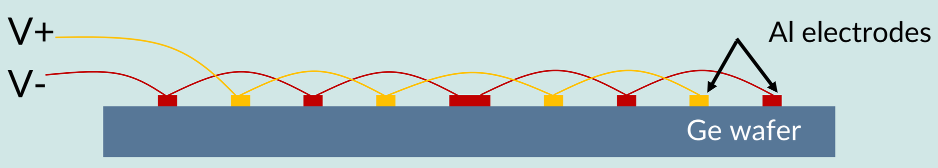


CROSS and BINGO demonstrators study and develop enhanced LDs

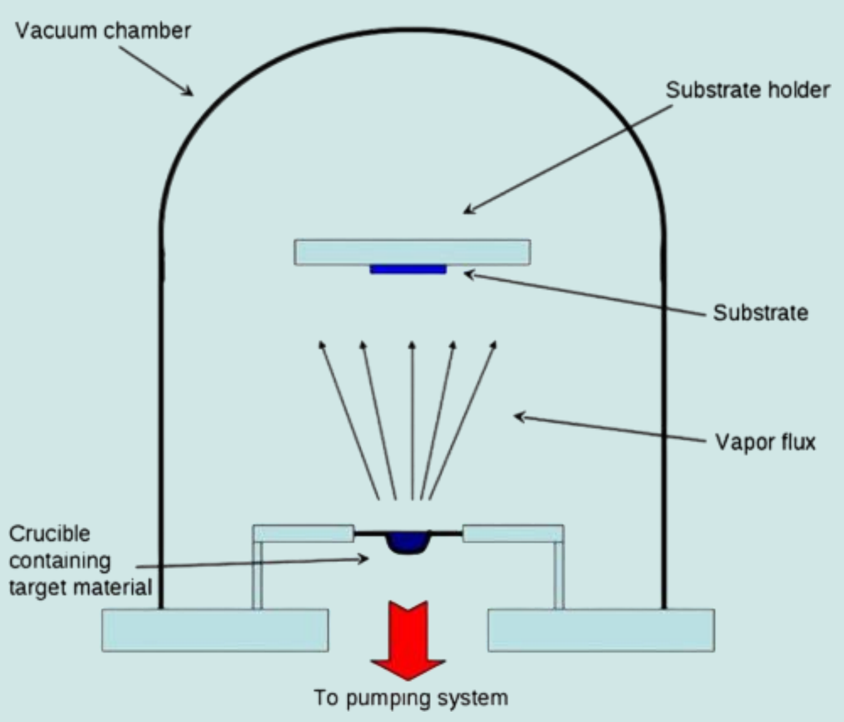
Neganov-Trofimov-Luke effect







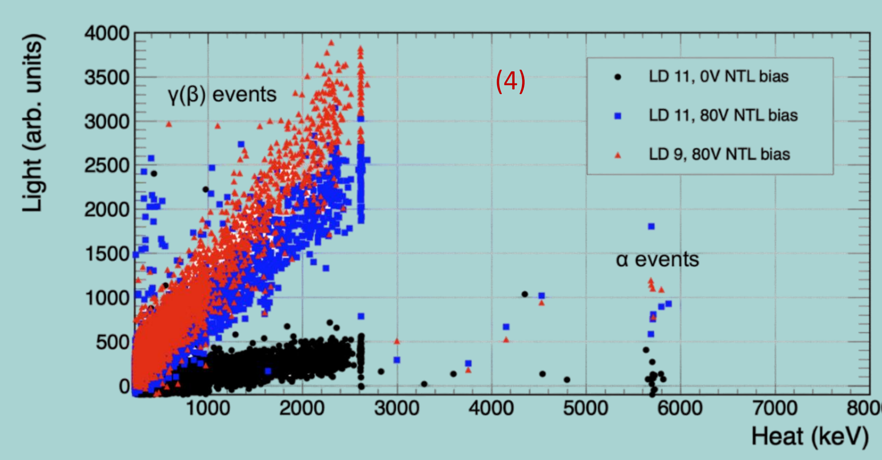
Ge wafer provided with Al electrodes on its surface
↓
Apply voltage across the electrodes which establishes an EF
↓
Photons absorption produces electron-hole pairs that drift
↓
Charge carriers collide with the lattice during the drift, increasing the temperature
↓
Signal amplification

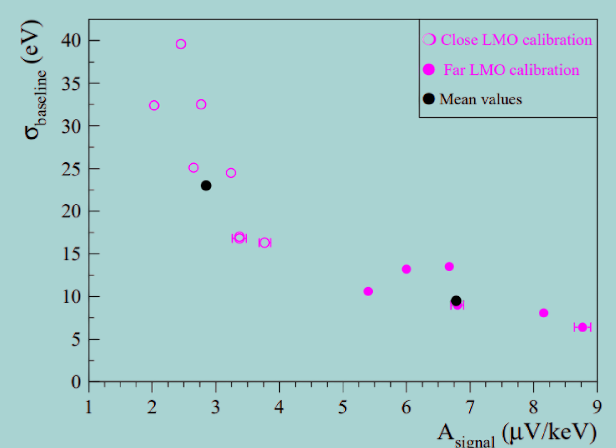


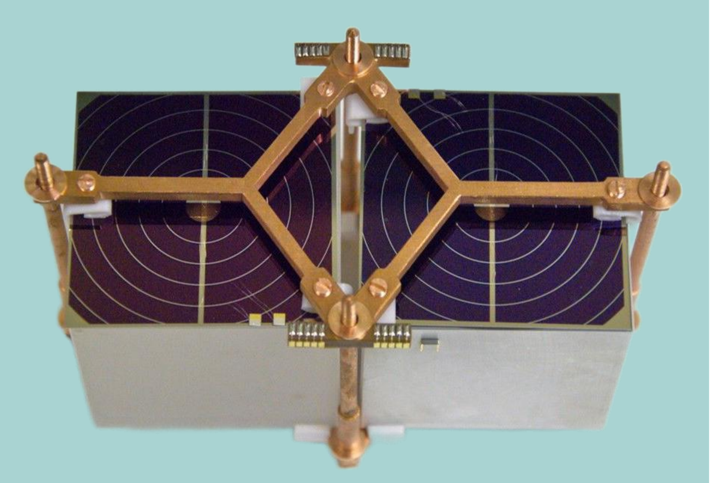
Shadow mask

- The electrodes are deposited using a physical vapor deposition technique such as evaporation
- Ar bombardment to clean the surface (from oxidation)
- AmGe:H underlayer deposition to prevent leakage current
- Al film deposition
- Anti-reflective (AR) coating

Results







R&D on 9 NTL LDs @ Laboratorio Subterraneo de Canfranc (LSC), Spain

- 8/9 can hold up to 100 V
- Avg. gain on S/N: 8.5 @ 80 V
- Fast signals: mean rise-time (10%-90%) 0.54 ms, important for pile-up rejection
- Pileup BI = 6.1e-5 ckky with 90% pulse acceptance (projected to CUPID geometry), close to CUPID goal

Si NTL LDs test (preliminary)

- Si wafer is cheaper than Ge
- Hold high voltages > 100 V
- High production success rate (no leakage current)
- Excellent gain (30) at 100 V for scintillation light

Perspectives

CUPID requirement

- Full electrodes coverage
- Higher V operations through pre-selection for higher gain

Develop a 4 K testing system to preselect NTL LDs

- Holder design for practical and efficient testing

Large film coating chamber

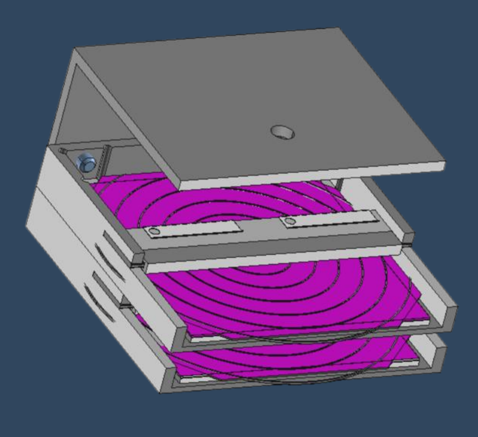
- Multiple samples simultaneously → ~ 50-80 LDs/week
- Fast pumping and venting times
- Multi-crucible electron beam gun

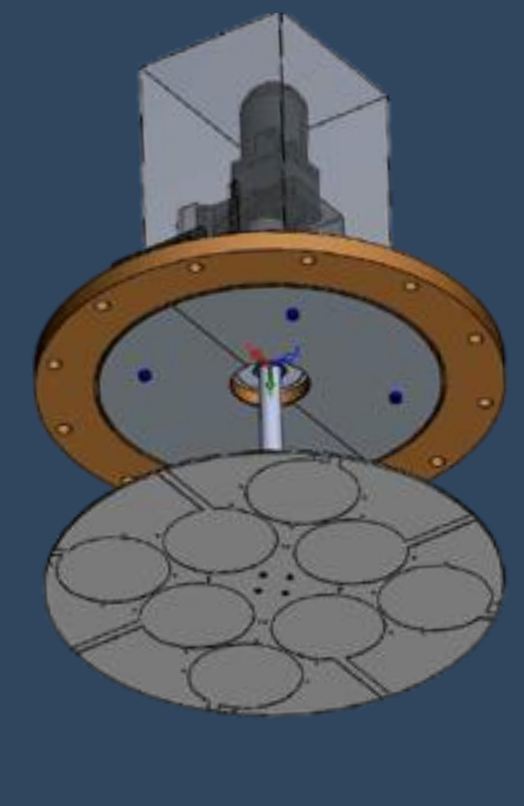
Mitigation of leakage current

- Fabricate NTL LDs on undiced wafers
- Better protection of surface during dicing
- Chemical etching

Si NTL

- Validate bolometric performance
- Study AR coating to increase light collection





References:
[1] B. Schmidt et al., New limit from the search for 0nbb-decay of 100Mo with the CUPID-Mo experiment, Neutrino2020 conf
[2] Alfonso, et al. CUPID, the CUORE upgrade with particle identification. Eur. Phys. J. C 85, 737 (2025)
[3] A. Armatol, et al. BINGO innovative assembly for background reduction in 0νββ bolometric experiments, NIMA 1069, 169936 (2024)
[4] A. Armatol, et al. Cryogenic light detectors with thermal signal amplification for 0νββ search experiments, arXiv:2507.15732 (2025)
[5] C. Augier, et al. Measurement of the 0νββ Decay Rate and Spectral Shape of 100 Mo from the CUPID-Mo Experiment, Phys. Rev. Lett. 131, 162501 (2023)