# The CROSS Demonstrator: Structure, Low-Background Techniques, and Physics Reach

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## Abstract

Cryogenic calorimeters are among the most sensitive detectors for the search for neutrinoless double beta decay ($0\nu\beta\beta$), a hypothetical process whose observation would demonstrate lepton number violation and establish the Majorana nature of neutrinos. The discovery potential of these experiments strongly depends on the suppression of radioactive background especially in the region of interest around the decay $Q$-value.

The CROSS demonstrator, installed at the Canfranc Underground Laboratory in Spain and taking data since October 2025, combines high-resolution cryogenic calorimeters with active particle-identification techniques designed to mitigate the dominant background sources affecting bolometric experiments.
The detector array is based on lithium molybdate ($Li_2MoO_4$) and tellurium dioxide ($TeO_2$) crystals operated as bolometers at millikelvin temperatures. Most of the $Li_2MoO_4$ crystals (32 out of 36) are enriched in $^{100}$Mo, while all $TeO_2$ crystals are enriched in $^{130}$Te. A major experimental challenge is the rejection of degraded surface $\alpha$ events, which can mimic a potential $0\nu\beta\beta$ signal.

To address this issue, CROSS employs scintillating bolometers coupled to cryogenic light detectors. The simultaneous measurement of heat and scintillation light enables efficient particle identification, since $\alpha$ particles produce significantly less scintillation light than $\beta/\gamma$ interactions at the same energy. The experiment integrates both Germanium and Silicon light detectors, with Silicon-based devices representing a promising and cost-effective solution for future large-scale experiments such as CUPID.

CROSS also incorporates Neganov-Trofimov-Luke (NTL) amplified light detectors. By applying an electric field across the absorber, the thermal signal generated by absorbed scintillation photons is amplified through charge-carrier drift, significantly improving the signal-to-noise ratio. This enhancement is particularly important for pile-up rejection and particle identification at low energy levels.

The demonstrator features a compact geometry, a reduced amount of passive material near the crystals, and stringent radiopurity requirements for detector components, all essential for achieving the ultra-low-background conditions required in rare-event searches.

The CROSS demonstrator represents an important technological step toward the future CUPID experiment, providing a large-scale validation of the detector concepts and background-rejection techniques required for tonne-scale cryogenic experiments.
By combining excellent energy resolution with active particle identification and amplified cryogenic light detection, CROSS aims to significantly improve the background suppression capabilities of bolometric detectors. This is pivotal for next-generation neutrinoless double beta decay experiments such as CUPID, which aim to achieve an ultra-low background index of the order of $10^{-4}$ counts/(keV kg yr), enabling a nearly background-free exploration of the inverted neutrino mass hierarchy region.

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