



CUPIID-1 Ton

Exploring the Normal Ordering with Ton-Scale Bolometric Array

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cupidexperiment.org

Probing Neutrino Nature via $0\nu\beta\beta$

Annual Reviews: 52:115-151

- Lepton number violation ($\Delta L = 2$)
- Hints to matter-antimatter asymmetry
- Majorana nature => explains tiny mass
- Can also constrain the mass of neutrinos

CUORE Demonstrated Ton-scale $0\nu\beta\beta$ Cryogenic Calorimetric Technology

Cryogenic Calorimetry

- Energy measurement through heat
- Excellent energy resolution and low backgrounds
- Flexibility in $0\nu\beta\beta$ candidate choice

10 years of stable operation
Main physics program complete

Four decades of improvements in $0\nu\beta\beta$ half-life with cryogenic calorimetry by scaling mass and lowering background

CUPIID to Extend Sensitivity by Further Advancing the Detector Technology

CUPIID's staged approach

Stage I: 2030 Stage II: 2034

Heat channel for energy and light channel for particle identification

Whether the next generation sees a signal or not, bolometers offer a demonstrated path forward with a **larger, lower-background** detector

Background Reduction x1/20

Active veto and passive shielding

Detector timing resolution and multi-site reconstruction

Event topology, detector optimization, active veto, and material production

Ongoing detector R&D is progressively suppressing backgrounds toward the CUPIID-1T requirement

CUPID IT Goal

CUPID Reach CUPID Baseline

Data-driven CUPID Background Index [counts/keV/kg/yr]

CUPIID-1T Detector Parameters

Parameter	CUPID	CUPID-1T
Crystal	$\text{Li}_2^{100}\text{MoO}_4$	$\text{Li}_2^{100}\text{MoO}_4$
Detector mass	450 kg	1871 kg
^{100}Mo mass	240 kg	1000 kg
Energy resolution (FWHM)	5 keV	5 keV
BI [cts/(keV kg yr)]	10^{-4}	5×10^{-6}
Lifetime	10 yr	10 yr
$T_{1/2}$ exclusion (90% C.L.)	1.6×10^{27} yr	9.1×10^{27} yr
$T_{1/2}$ discovery (3σ C.L.)	1×10^{27} yr	8×10^{27} yr
$m_{\beta\beta}$ exclusion (90% C.L.)	10 – 28 meV	4.0 – 11.8 meV
$m_{\beta\beta}$ discovery (3σ C.L.)	12 – 35 meV	4.3 – 12.5 meV

Multiple Approaches to Mass Scaling x4

Single large cryostat Multiple (CUPIID size) cryostats

- Single location
- Distributed worldwide

- Multi-isotope option: e.g. ^{130}Te , ^{82}Se , ^{116}Cd , ...
- Leverage worldwide interest in $0\nu\beta\beta$ physics and cryogenic calorimetry technology
- Crucial for confirming a discovery

Cooling power comparable to CUORE

Active Detector R&D Toward CUPIID-1 Ton

Quantum Sensors
High-bandwidth TESs and MKIDs to reduce $2\nu\beta\beta$ pileup

Event Topology
CERES: Position dependence of calorimetric response

CROSS: Al-Pd coating on LMO for surface event identification

CROSS and BINGO demonstrated surface contaminants removal

Detector Structure and Active Veto
BINGO: Minimize passive assembly materials and implement active cryogenic veto

High-Q Isotopes
TINY: $0\nu\beta\beta$ search with ^{150}Nd & ^{96}Zr

Light Detector R&D
R&D to improve light detectors using Indium-Tin-Oxide coating on Silicon wafers

TESs demonstrated to be effective for pileup removal

OPOSSUM and DEMETER
Utilize fast timing response and multiplexing for single vs multi-site reconstruction

Also see posters #149, #291 and #339 for multiplexing R&D for CUPIID-1T

Cryogenics are achievable with current technology

$0\nu\beta\beta$ Reach with CUPIID-1T

CUPIID Stage I Starts in 2030

CUPIID Starts in 2034

CUPIID 1 ton

Upper Limits
Katrin JHEP12(2024)216
Cosmology PRD 111,093006 (2025)

CUPIID-1T is the natural extension of worldwide efforts to advance cryogenic calorimetry, reaching into the **normal ordering**