

Optimization of integration time and distance cut in the CUPID array

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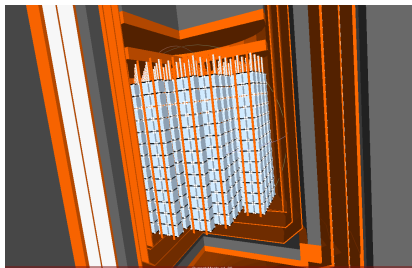
Virginia Tech

DNP October 2021

**Mini-Symposium: Neutrinos and Nuclei XII: Double Beta Decay Analysis
Techniques**

CUPID experiment

- Proposed $0\nu\beta\beta$ search using bolometric array of 1596 Li_2MoO_4 crystals, to be deployed in the CUORE cryostat¹.
- Aims to eliminate dominant background of alpha particles present in CUORE.
- **Are new backgrounds introduced with using a new isotope for the bolometers?**

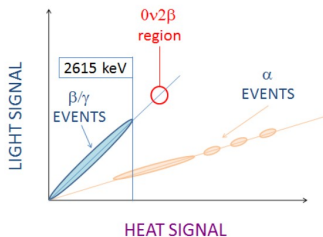
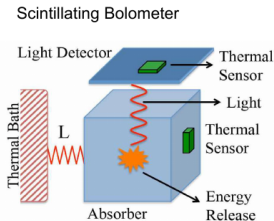


Rendering of proposed CUPID array of Li_2MoO_4 crystals

¹arxiv.org/abs/1904.05745.

Lithium molybdate

- Li_2MoO_4 crystals allow for discrimination of α backgrounds from $\beta\beta$ events ($Q=3034\text{keV}$) via thermal + scintillation signals.
- relatively high isotopic abundance of ^{100}Mo (10%)
- enrichment above 95% already demonstrated in CUPID-Mo².



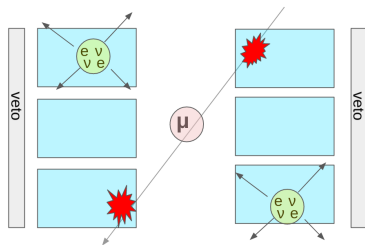
²arxiv.org/abs/1909.02994.

$2\nu\beta\beta$ events and muons

- The rate of $2\nu\beta\beta$ events is not negligible³ in the CUPID array
- Minimizing the distance cut helps avoid mis-labelling random $2\nu\beta\beta$ coincidences as multiplicity 2.
- Assuming a simple muon veto geometry, increasing the distance cut rejects more muon events.

$$T_{1/2}^{2\nu\beta\beta} = 7.1 * 10^{18} \text{ yr}$$

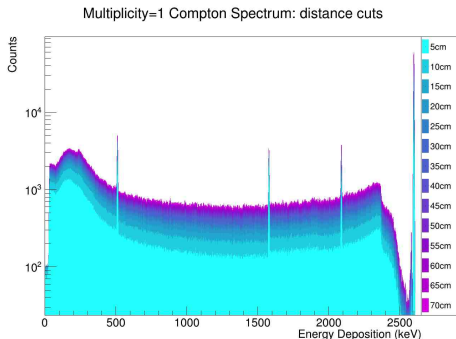
→ single crystal rate $\sim 3 \text{ mHz}$



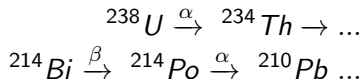
³arxiv.org/abs/1912.07272.

Distance cut in the CUPID array

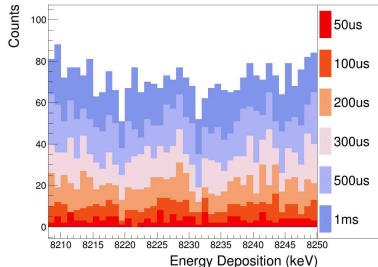
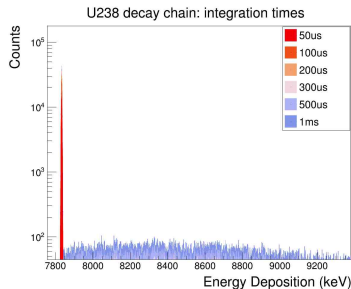
- monte-carlo simulation of 1million 2.6MeV gamma rays in the crystal volume.
- With this energy, we expect multiple scattering events in the crystals.
- higher multiplicity events are discarded from counts



Integration time in the CUPID array

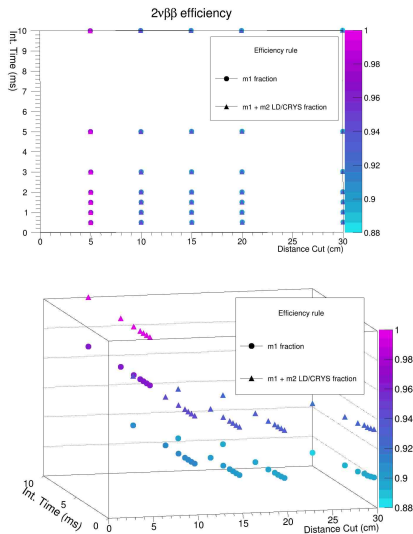


- 100,000 Uranium-238 events (full chain)
- $T_{1/2} {}^{214}\text{Po} \sim 160\mu\text{s}$
- $T_{1/2} {}^{214}\text{Bi} \sim 20 \text{ minutes}$



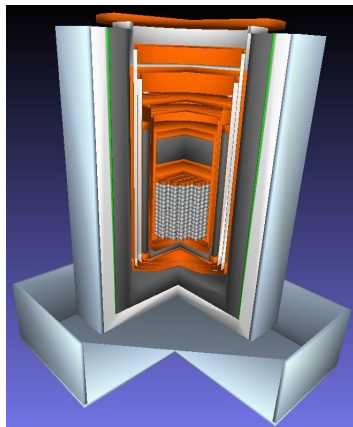
$2\nu\beta\beta$ tagging simulation

- 40 million events generated in crystal volume.
- expect $\sim 90\%$ efficiency for $2\nu\beta\beta$ tagging, when using approximate CUORE parameters
- larger distance cut causes more random coincidences and more variation with integration time
- bremsstrahlung, escape, random coincidences are primary contributors



implementation of muon background

- incorporating scintillating muon veto geometry into monte-carlo simulations
- muon flux at LNGS is $3 \cdot 10^{-8} \text{ muons} / (\text{s} \cdot \text{cm}^2)$
- muon suppression versus distance cut optimization.



preliminary muon veto geometry

summary and future work

- validation of distance cut and integration time
- qualitative understanding of effect on $2\nu\beta\beta$ events
- optimize these parameters with the muon background, potential cosmogenics + in-situ reactions

