Optimization of integration time and distance cut in the CUPID array

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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 cryostat[1].

- Aims to eliminate dominant background of alpha particles present in CUORE.

- **Are new backgrounds introduced with using a new isotope for the bolometers?**
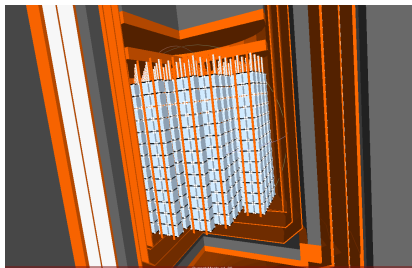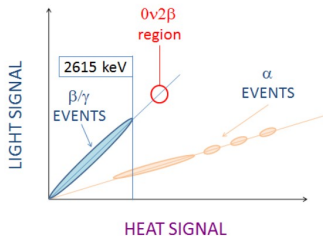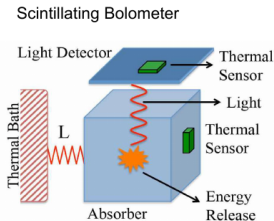

Rendering of proposed CUPID array of Li_2MoO_4 crystals

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[1] **arxiv.org/abs/1904.05745**.

Lithium molybdate

- Li_2MoO_4 crystals allow for discrimination of α backgrounds from $\beta\beta$ events (Q=3034keV) via thermal + scintillation signals.

- relatively high isotopic abundance of ^{100}Mo (10%)

- enrichment above 95% already demonstrated in CUPID-Mo[2].

Scintillating Bolometer

[2]**arxiv.org/abs/1909.02994**.

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

- The rate of $2\nu\beta\beta$ events is not negligible[3] 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.

$$T_{1/2}^{2\nu\beta\beta} = 7.1 * 10^{18} yr$$
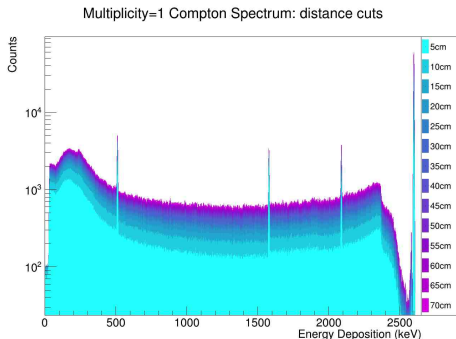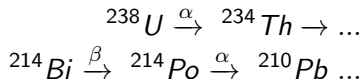$\rightarrow$ single crystal rate $\sim 3mHz$

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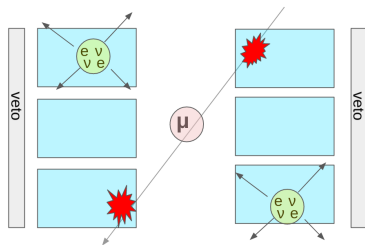
[3]**arxiv.org/abs/1912.07272**.

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

Multiplicity=1 Compton Spectrum: distance cuts

Integration time in the CUPID array

$$^{238}U \xrightarrow{\alpha} {}^{234}Th \rightarrow ...$$
$$^{214}Bi \xrightarrow{\beta} {}^{214}Po \xrightarrow{\alpha} {}^{210}Pb ...$$

- 100,000 Uranium-238 events (full chain)

- $T_{1/2}$ ^{214}Po $\sim 160\mu$s

- $T_{1/2}$ ^{214}Bi ~ 20 minutes



U238 decay chain: integration times
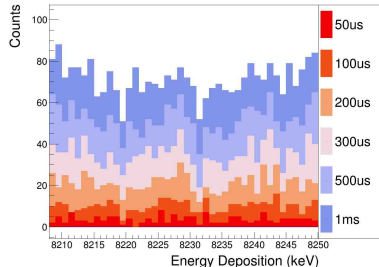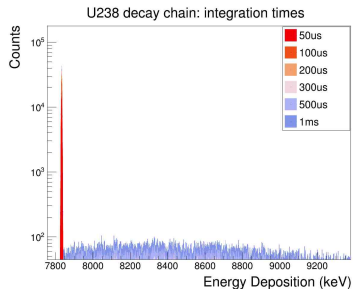
$2\nu\beta\beta$ tagging simulation

- 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
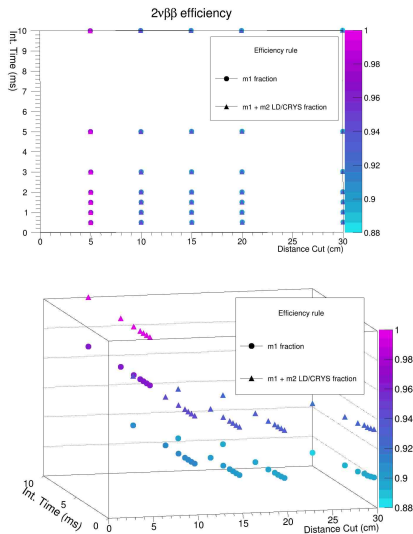
implementation of muon background

- incorporating scintillating muon veto geometry into monte-carlo simulations

- muon flux at LNGS is $3 \cdot 10^{-8}$ muons $/ \left(s \cdot cm^2 \right)$

- muon suppression versus distance cut optimization.
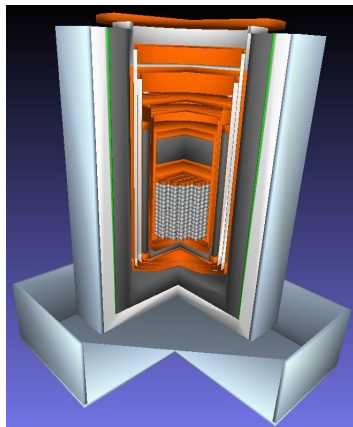
preliminary muon veto geometry

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