Preliminary Examination

Joe Camilleri

Virginia Tech

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Neutrinos in the Standard Model

leptons in the standard model e, μ, τ each have associated neutrinos ν_μ, ν_τ. U(1) gauge symmetry (global phase?) implies conservation of lepton flavor.

$$\begin{pmatrix} \nu_\alpha \\ \ell_\alpha \end{pmatrix} \rightarrow \qquad (1)$$

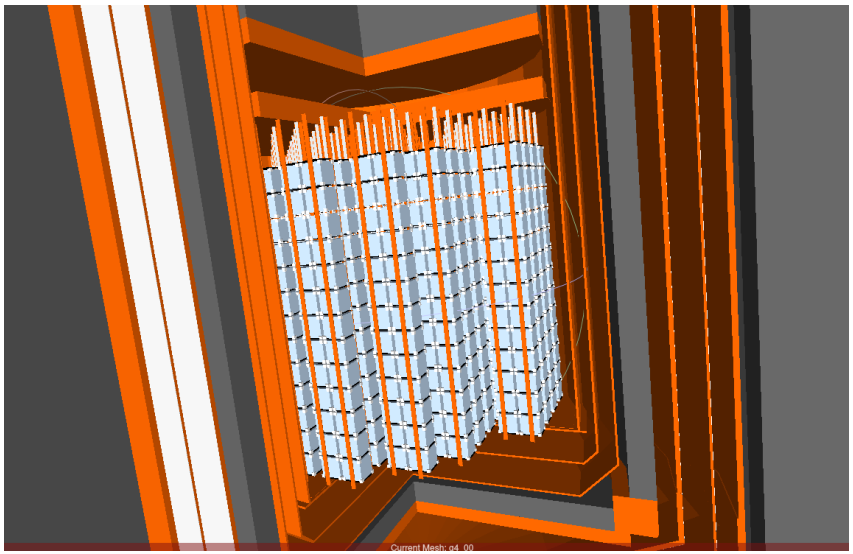
$$\begin{pmatrix} \nu_\alpha \\ \ell_\alpha \end{pmatrix} \rightarrow \qquad (2)$$

- Proposed

[0] **squid**.

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?**

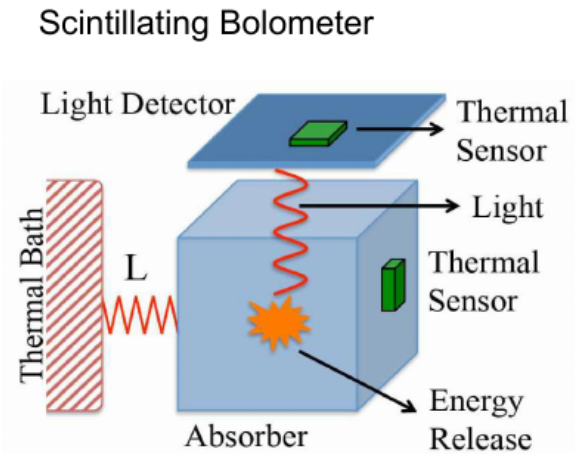


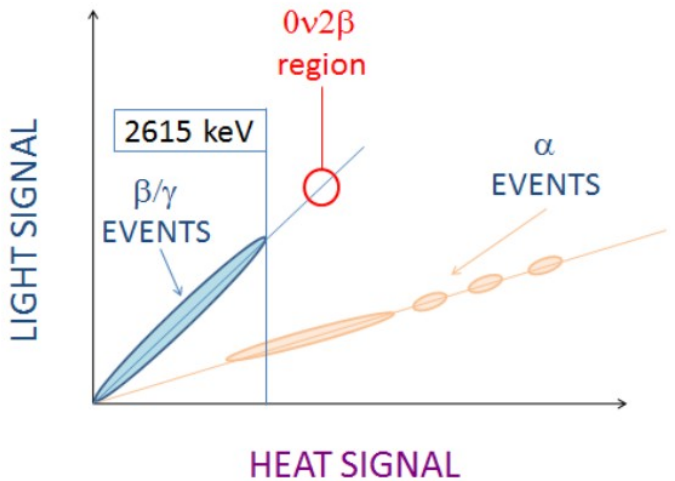
Rendering of proposed CUPID array of Li_2MoO_4 crystals

[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].





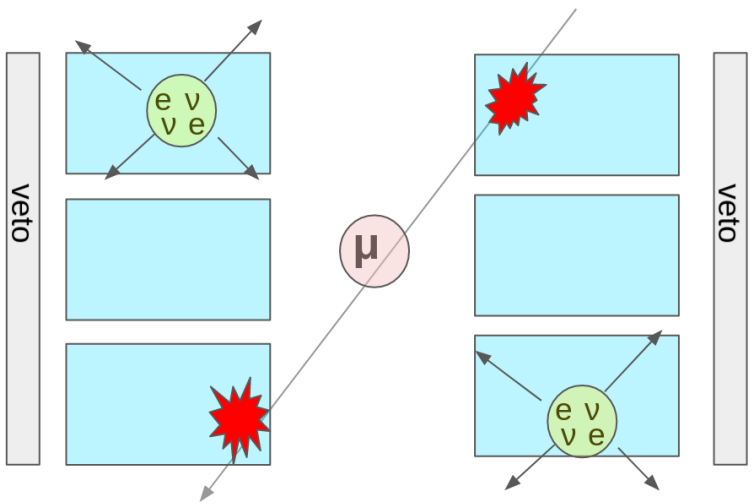
[2] **arxiv.org/abs/1909.02994**.

$2\nu\beta\beta$ 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.

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

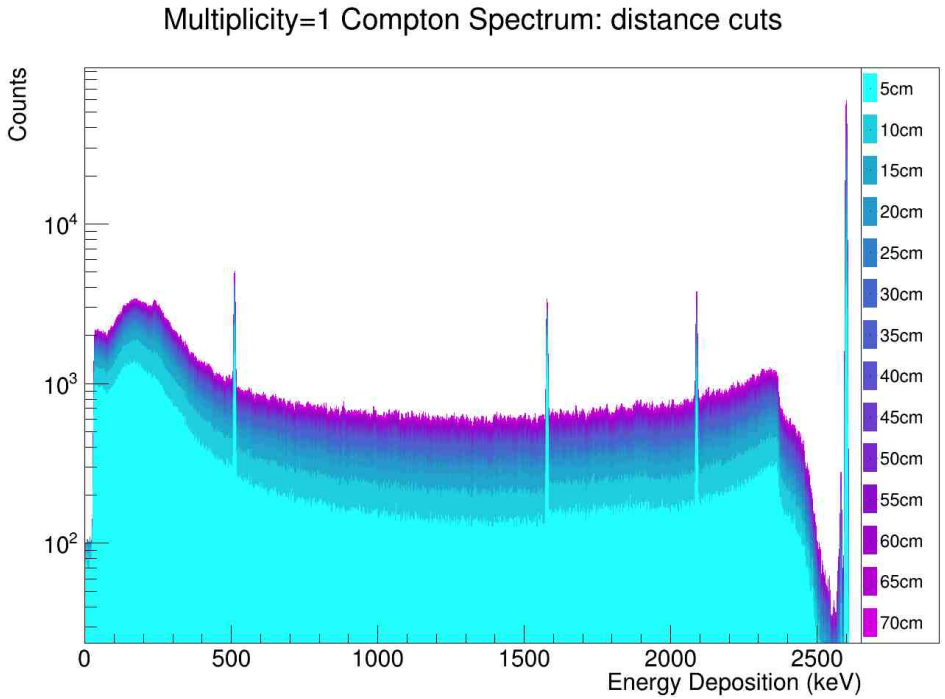
$\rightarrow$ single crystal rate $\sim 3mHz$



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

Distance cut in the CUPID array

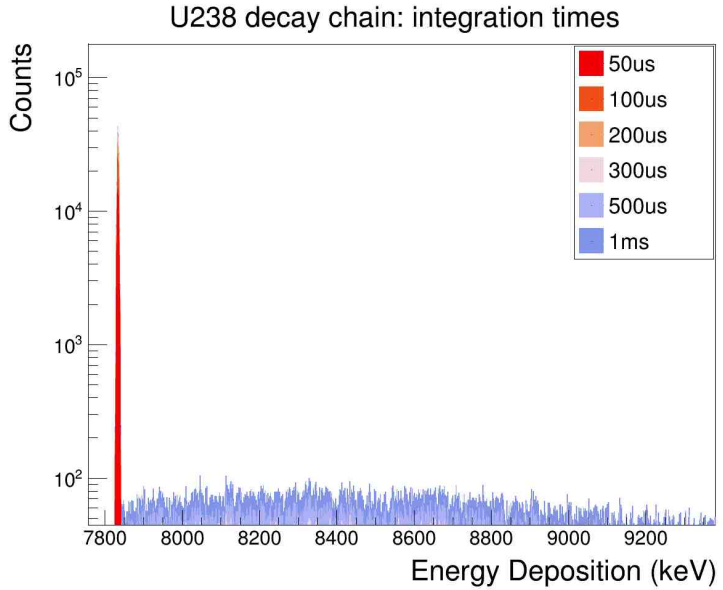
- monte-carlo simulation of 1million 2.6MeV gamma rays in the crystal volume.
- With this energy, we expect multiple scattering events in the crystals.
- higher multiplicity events are discarded from counts

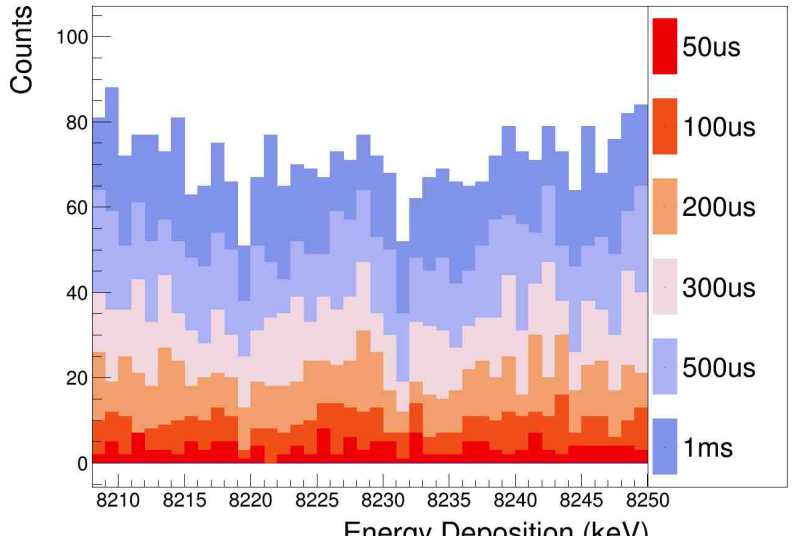


Integration time in the CUPID array

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

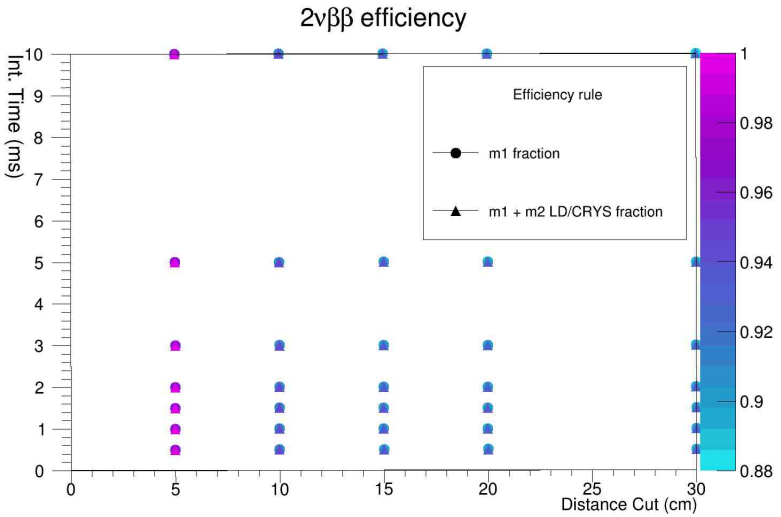
- 100,000 Uranium-238 events (full chain)
- $T_{1/2}$ ^{214}Po $\sim 160\mu$s
- $T_{1/2}$ ^{214}Bi $\sim$ 20 minutes

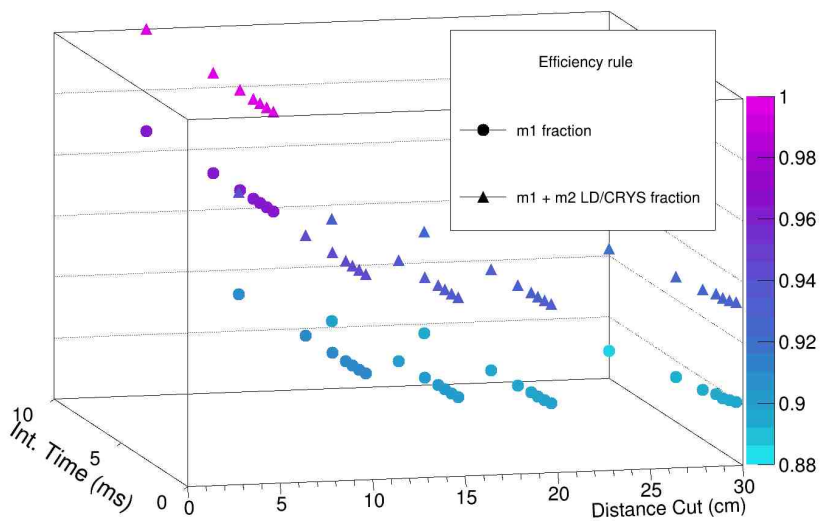




$2\nu\beta\beta$ tagging simulation

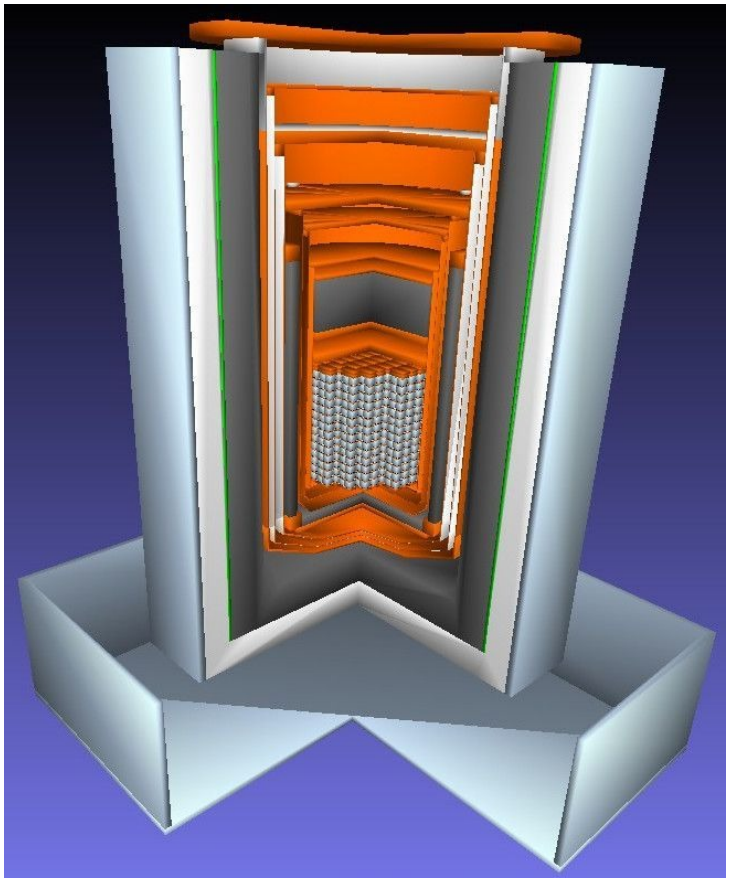
- 40 million events generated in crystal volume.
- expect $\sim$ 90% efficiency for $2\nu\beta\beta$ tagging, when using approximate CUORE parameters
- larger distance cut causes more random coincidences and more variation with integration time
- bremsstrahlung, escape, random coincidences are primary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





implementation of muon background

- incorporating scintillating muon veto geometry into monte-carlo simulations
- muon flux at LNGS is $3 \cdot 10^{-8}$ 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