
CUORE/CUPID BUQ Workflow (in progress)

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Nov. 13, 2024

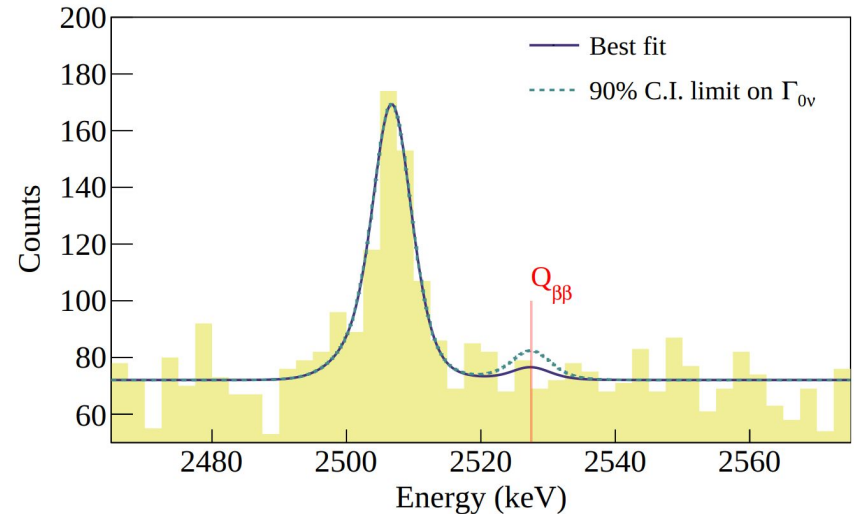
Overview of Main Inference Problem

Looking for neutrinoless double-beta decay ($0\nu\beta\beta$): peak at known location ($Q_{\beta\beta}$) in detector energy spectrum.

Rare event search data is difficult to obtain & detector lineshape function is complicated & typically described per-observation.

Unbinned (extended) likelihood: model region-of-interest (left) as mixture model of signal contribution, along with background contributions (nearby ^{60}Co peak & continuum background), plus nuisance parameters.

Sample with MCMC to make inference on possible rate of $0\nu\beta\beta$



$$\mathcal{L} = \prod_{\text{DS, C}} \frac{e^{-\lambda} \lambda^n}{n!} \prod_i \left[\frac{s}{\lambda} f_{0\nu}(E_i | \vec{\theta}_{0\nu}) + \frac{c}{\lambda} f_{\text{Co}}(E_i | \vec{\theta}_{\text{Co}}) + \frac{b}{\lambda \Delta E} \right]$$

Inference Dimensionality & Comments

Main parameter of interest: rate of neutrinoless double beta decay

- Plus ~handful of signal-only nuisance params.

Data collection divided into “dataset” (DS) periods: currently have 28, expect full experimental exposure to have ~45. Future CUPID experiment may expect ~100.

- Currently have ~6 nuisance parameters per dataset within Bayesian model: total fit dimensionality of ~200, but want to “future-proof” for up to ~1000-2000.
- Additionally have input from ~1000’s/DS of nuisance parameters from e.g. detector calibration: these are fixed in current model but will be the focus of future work

Forward-model: throwing “toy” spectra - just resampling observations, perhaps with additional non-inferred nuisance params.

Workflow

Legacy fitting code using random-walk Metropolis-Hastings unsuitable to problem dimensionality now at-hand... Working on re-implementing inference model into a modern framework:

- Have been pursuing NumPyro, but seems finicky to implement this form of mixture model
- Likely to use blackjax samplers with our own density implementation: less plug-and-play, but more tailorable

Workflow development will be focus post re-implementation: open to suggestions from folks further along in project development :-)

- Sampler performance comparison
- Robustness of Bayesian discovery criteria & discovery sensitivity for CUPID with inclusion of nuisance parameters
- Re-analysis of CUORE data to benchmark new framework
- Use beyond neutrinoless double-beta decay in CUORE & CUPID