Status of the BeEST Heavy Neutrino Search

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The Beryllium Electron capture in Superconducting Tunnel junctions (BeEST) experiment searches for the signatures of heavy neutrino mass eigenstates by measuring the recoil energy of the Li-7 daughter nucleus from Be-7 electron capture decay. In Phase-II, BeEST has set leading limits on neutrino mixing to a heavy eigenstate in the 100-850 keV mass range using a single superconducting tunnel junction detector. The current Phase-III has expanded the BeEST experiment to a 32-pixel STJ array detector and increased the dose of implanted Be-7. In this poster, we present the status of the BeEST Phase-III and highlight the refined experimental and analytical techniques in Phase-III. We also discuss an improved analysis scheme using pulse shape discrimination enabled by a new continuous data acquisition system.

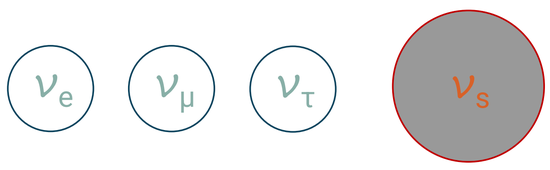
Sterile Neutrino Search

Motivation

Neutrino problems

- ❑ How do neutrinos gain mass?
- ❑ Why are they so light?
- ❑ Where are right-handed neutrinos?

Sterile Neutrinos



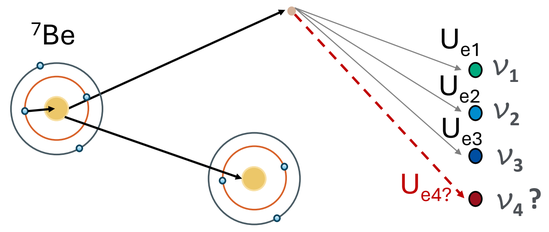
Mass	<1 eV	>1 eV
Forces	Weak, Gravity	Gravity
Parity	Left-handed	Right-handed

❑ Sterile neutrino may be the simplest expansion to explain neutrinos

How do we detect something that do not interact?

- ❑ Indirect search with recoil energy measurement
- ❑ Using high-resolution detector

Electron Capture and ν_s

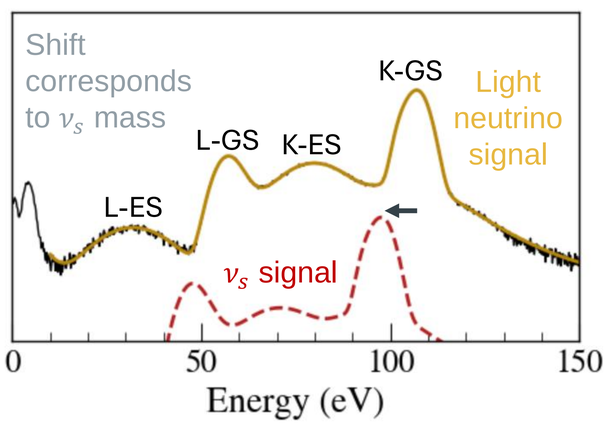


$$^7\text{Li recoil} = \frac{Q^2 - M_\nu^2}{2(Q + M_{\text{Li}})} \approx 57 \text{ eV}$$

- ❑ E_{Recoil} depends on neutrino mass
- ❑ 4 main peaks in ^{7}Be EC
  - ❑ K / L-shell electron capture
  - ❑ to Ground state (GS) / Excited state (ES)

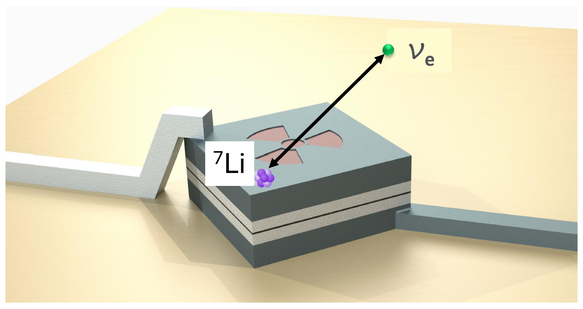
Why ^{7}Be?

- ❑ Large decay energy (862 keV)
- ❑ Highest NR energy (56.8 eV)
- ❑ Simple atomic and nuclear structure



The BeEST Experiment

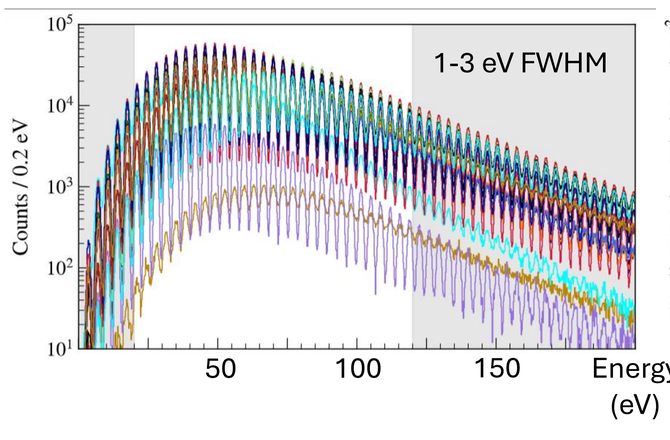
Superconducting Tunnel Junction (STJ)



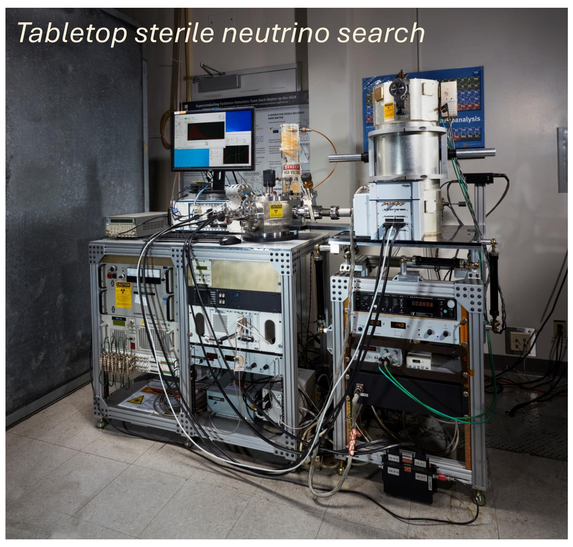
Superconducting (STJ) Detector

- ❑ Two superconducting electrodes separated by a thin insulating barrier
- ❑ Small energy gap $\Delta \approx 1$ meV
- ❑ High energy resolution: 1-3 eV FWHM
- ❑ High rate: 10^4 counts/s^{-1} per pixel

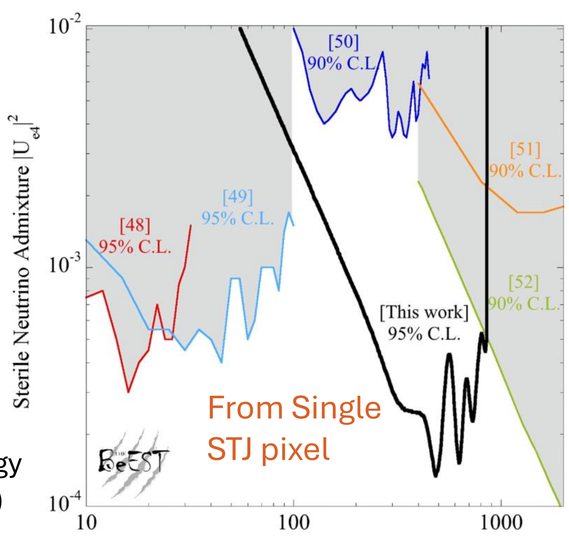
In-situ Laser Calibration



Tabletop sterile neutrino search



World-leading Limits



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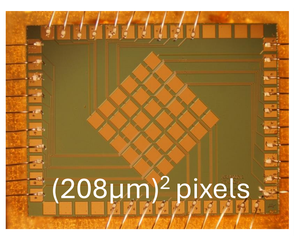
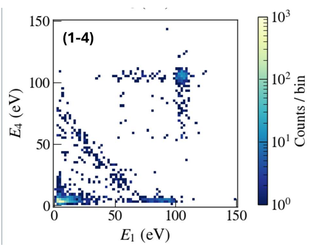
Phase-III: Detector Arrays

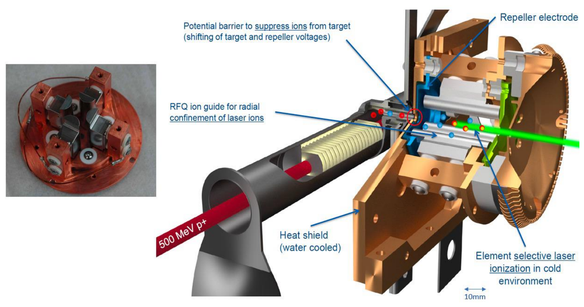
Multi-pixel Array Operation

- ❑ Increased statistics
- ❑ Allows high-multiplicity events analysis



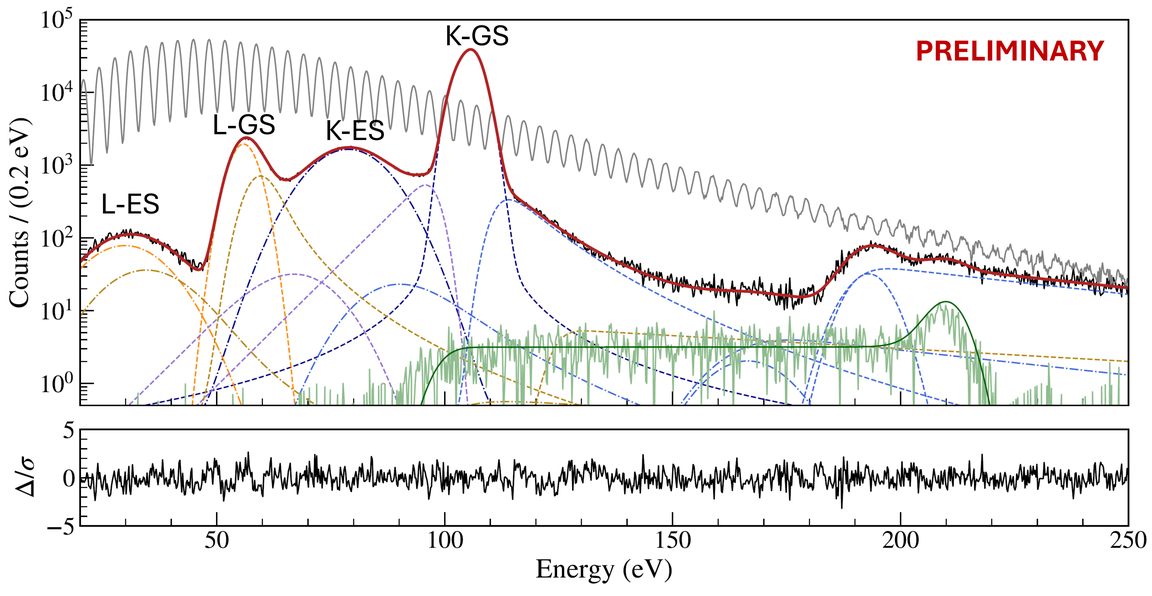


Improved ^{7}Be Implantation



- ❑ The Ion guide laser ion source (IG-LIS): Highly selective ion beam to only select ^{7}Be → ^{7}Li suppression of x4,000 achieved

Background Modeling



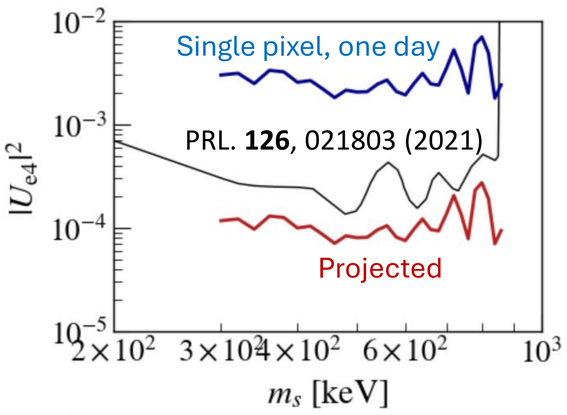
Background Reduction

- ❑ Correct for drift, reject pick-up and pile-up
- ❑ Remove coincident signals (substrate events)

- ❑ Improved background modeling with shake-up / shake-off effects
- ❑ Significantly reduced background that allow more precise fit
- ❑ Consistent fit from all 15 STJ pixels obtained

Limits and Improvements

Phase-III Sensitivity

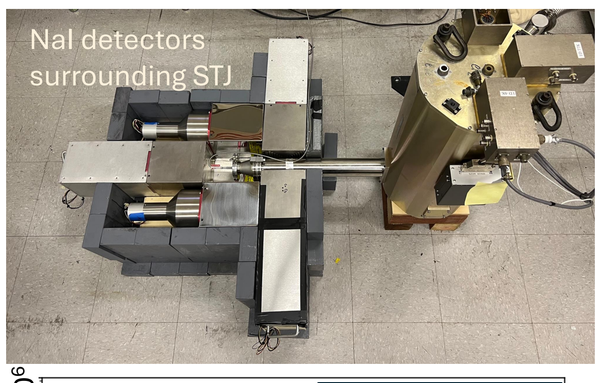


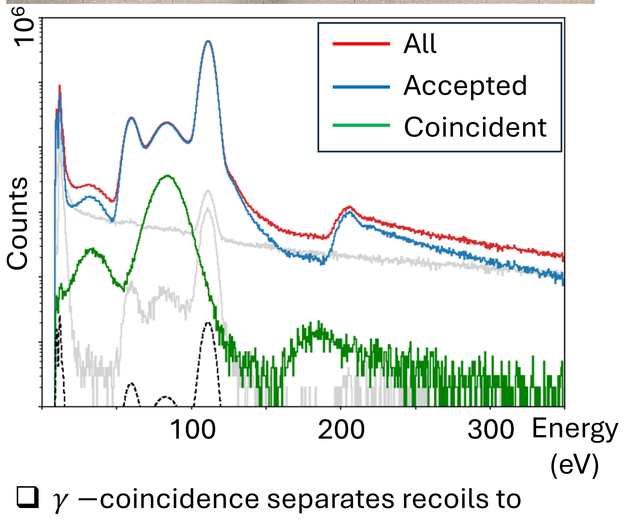
- ❑ Expect 2 – 3 × lower limits
- ❑ Monte-Carlo to verify sensitivity

Summary

- ❑ BeEST searches for the neutrino transition to heavy mass eigenstate by precisely measuring the nuclear recoil of ^{7}Be EC decay
- ❑ Various improvements have been made in Phase-III of the BeEST Experiment
- ❑ The Phase-III sensitivity is >× 3 more stringent than the previous phase
- ❑ Progresses are being made for both the hardware and the modeling

γ –recoil Coincidence





- ❑ γ –coincidence separates recoils to excited states

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