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Searching for a keV sterile neutrino via ^{241}Pu beta spectrum

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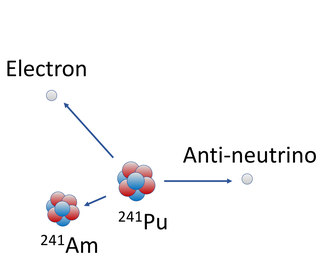
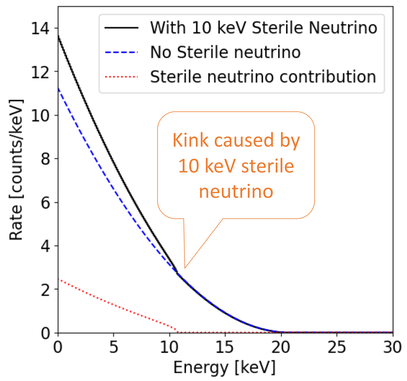
Introduction

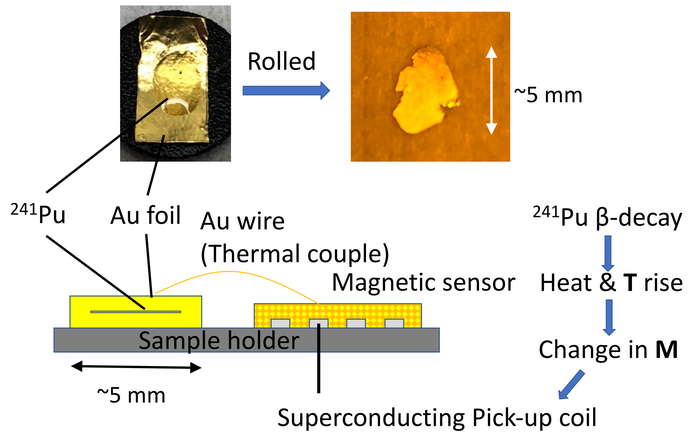
- keV-scale sterile neutrino is neutral and massive as a viable dark matter candidate
- Sterile neutrino mixing $|U_{e4}|^2$ can be searched by beta spectrum measurement.
- Neutrino mass causes spectral drop off near the beta end point energy due to $E_{\max} = Q - m_\nu$
- The beta spectrum can show a 'kink' for non-zero sterile neutrino mixing in electron antineutrino





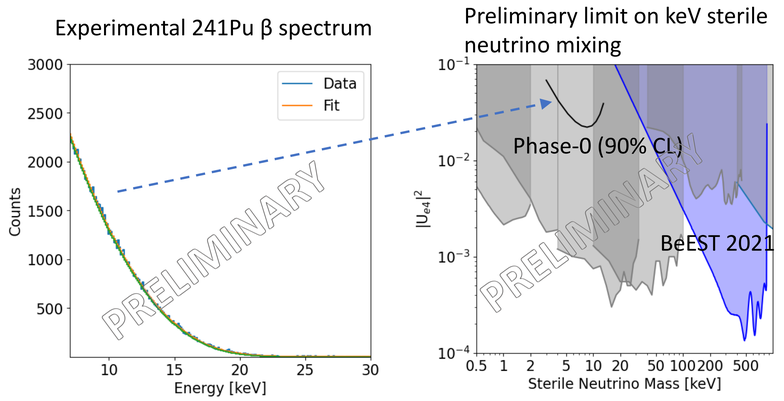
Experiment setup with MMC

- Cryogenic decay energy spectrometry (DES) with magnetic microcalorimeters (MMCs)
- Measure all particles and total energy releases from decays (except neutrinos)
- Performance goal: 100% detection efficiency, 50 eV energy resolution, and 1,000 counts/s per pixel.



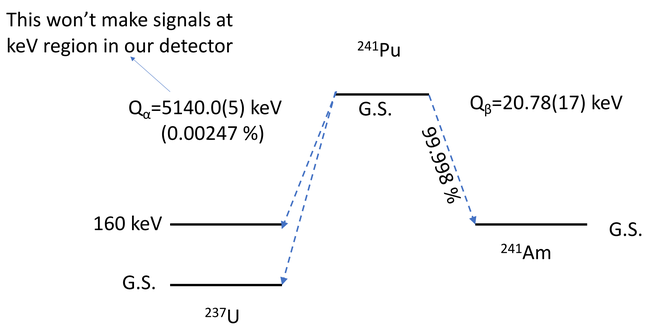
Preliminary result and sensitivity

- Preliminary experiment was performed for 24 hours with a single-pixel 4 Bq ^{241}Pu detector.
- Measured beta spectrum is agreed well with the theoretical shape.
- The first exclusion limit on keV-scale sterile neutrino with ^{241}Pu beta decays was set from this preliminary data.

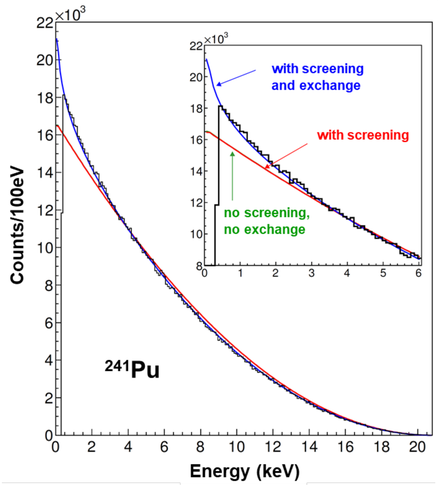


Tracing keV sterile neutrino with ^{241}Pu beta

- We are searching for a sterile neutrino in the 1 keV – 20 keV range
- Choice of ^{241}Pu:
  - Single-branch beta decay
  - Q = 20.78 keV, serves best as a beta spectrum to study keV-scale sterile neutrino dark matter.
  - However, theoretical β-shape calculation needs several corrections from nuclear and atomic effects as this is a high-Z nuclide



Theoretical calculation and systematic uncertainties



Nuclear&Atomic effects
- Exchange effect
- Radiative corrections
- Overlap correction
- Shaking

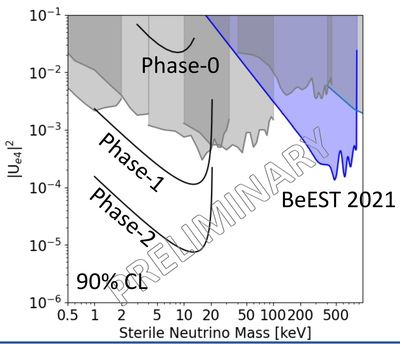
Detector effects
- Energy calibration
- Pile-up
- Photon Background

Theoretical uncertainty
- End-point energy

Exchange effect - Phys. Rev. A 86, 042506
Beta measurement - Applied Radiation and Isotopes 68, 1454-1458 (2010)

Current and Future Experimental Plans

- **Phase-I (current):** Extended 100-day measurement with four 100 Bq ^{241}Pu pixels (x10000 statistics)
- **Phase-II:** 1-year measurement with hundred pixels and 1,000 Bq each, using "ultra-fast MMC" detectors that are under development.
- **Tritium measurement:** We will repeat measurements with ^{3}H source and combine with the ^{241}Pu result, to reduce systematic uncertainties from nuclear and atomic effects.



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