LiFE-SNS

LiF Experiment for keV Sterile Neutrino Search

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We conduct a LiF Experiment for keV Sterile Neutrino Search (LiFE-SNS) based on tritium beta decay measurement at mK temperatures. We use LiF crystals with ^{3}H embedded through the Li(n,α)^{3}H process. Magnetic microcalorimeters, one of the high-resolution detector technologies, are adopted to measure the amount of the energy deposited into the crystal absorber from ^{3}H beta decays. Two detector modules have been prepared for the first phase of the project to achieve the highest sensitivity near the 10-keV region with a four-month measurement period. In this poster, we present the short- and long-term goals of the LiFE-SNS project searching for keV-scale sterile neutrinos together with possible systematics.

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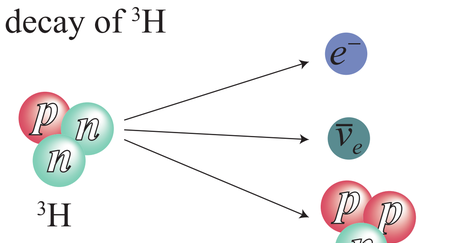
β decay and Sterile neutrino

β decay of ^{3}H

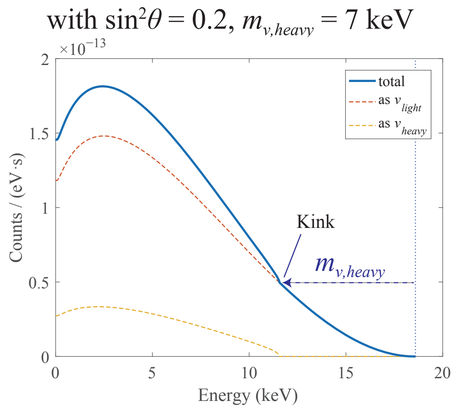


Q =18.59 keV
$T_{1/2}$ = 12.32 y

Possible mixing:

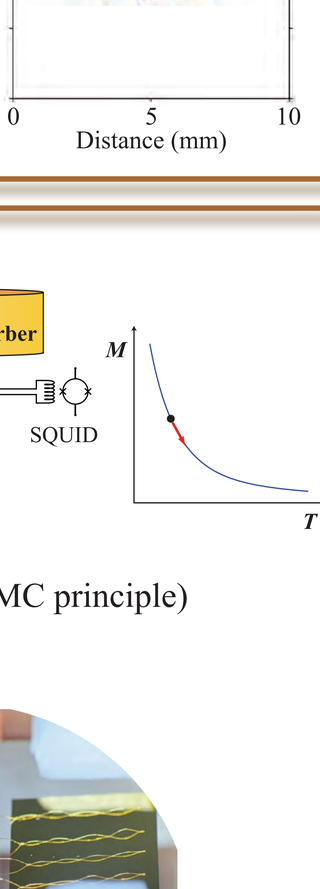
$$\bar{\nu}_e = \cos\theta\,\bar{\nu}_{light} + \sin\theta\,\bar{\nu}_{heavy}$$
$$\bar{\nu}_s = -\sin\theta\,\bar{\nu}_{light} + \cos\theta\,\bar{\nu}_{heavy}$$

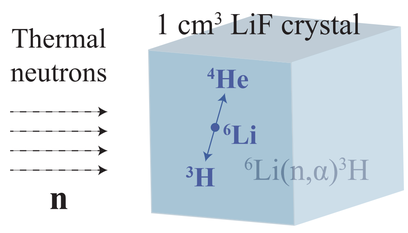
Expected spectrum
with $\sin^2\theta = 0.2$, $m_{\nu,heavy} = 7$ keV



^{3}H in LiF

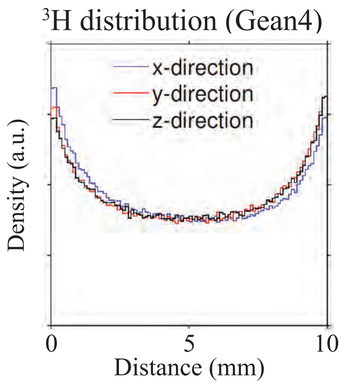
The neutron activation for LiF crystals (1×1×1 cm^3) takes place in a storage facility at KRISS, accommodating one ^{252}Cf and two AmBe sources encased by PE bricks. The expected neutron flux is about 10^7 n/s in the loading zone.





Thermal neutrons in a ^{6}Li target
Mean free path: 2.3 mm in LiF with 7.6% ^{6}Li

^{3}H isotopes likely occupy interstitial lattice sites as H^- ions. [Kazumata, JPSJ 35(5), 1442 (1973)]

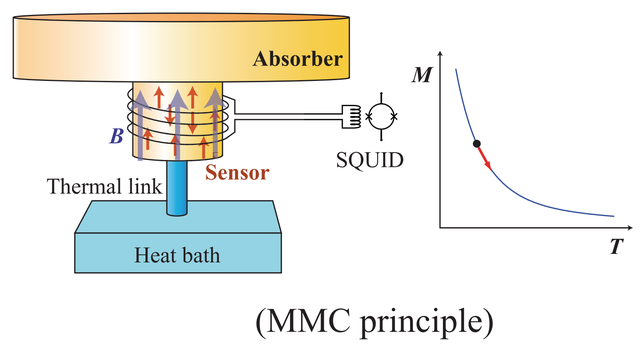


- Geant4 simulation:
  - Nearly isotropic distribution of capture locations
  - One-week exposure results in 20 Bq.
  - We measured 22 Bq of the ^{3}H activity

Detector setup

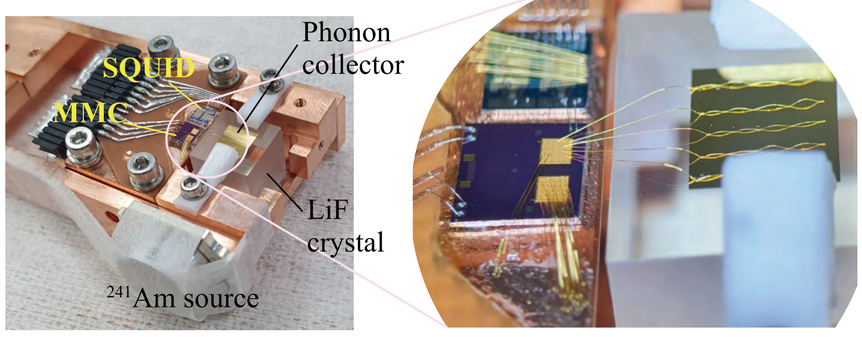
Magnetic microcalorimeter (MMC):
High-resolution sensor technology in low-temperature thermal calorimetric detection

$$E \rightarrow \Delta T \rightarrow \Delta M \rightarrow \Delta \Phi \rightarrow \Delta V$$



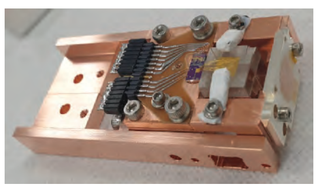
(MMC principle)

LiFE-SNS: MMC + LiF(^{3}H)

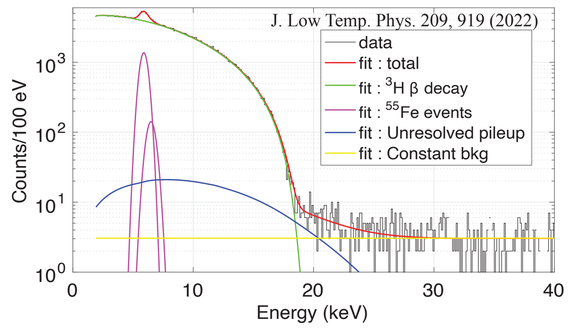


Proof-of-Principle for LiFE-SNS

Preliminary setup for the proof



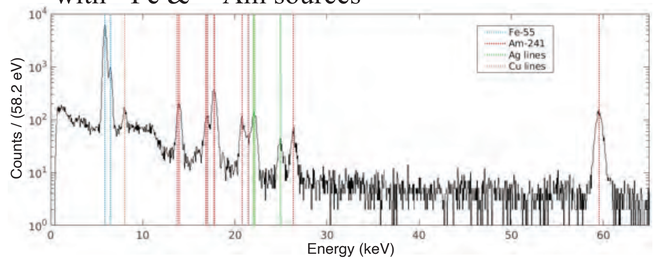
Measured spectrum w. an ^{55}Fe source

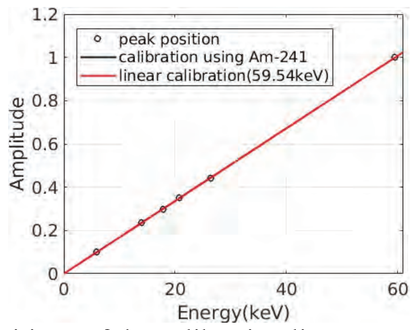


A 10-hour measurement obtained a reasonable spectrum for ^{3}H β decay, which is in good agreement with the calculations. Additionally, the ^{3}H activity was 22 Bq, close to the MC result. These preliminary results indicate that this type of LiF detector can be used to conduct an experimental search for sterile neutrinos on the keV scale.

Energy calibration

with ^{55}Fe & ^{241}Am sources

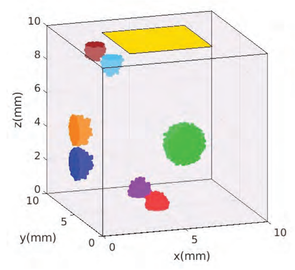


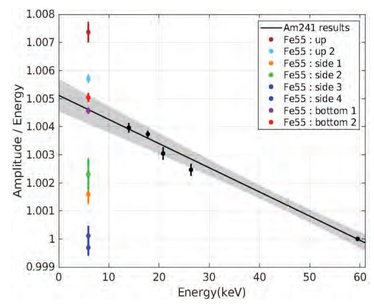


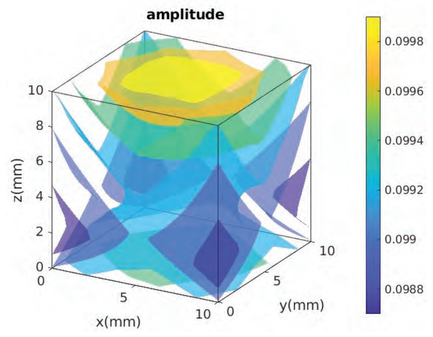
– A quadratic calibration function can be fitted to the positions of the calibration lines

Position dependence study

Positions of 6 keV X-ray events

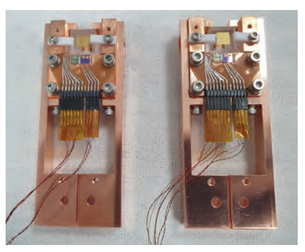






4D interpolation from measured points

Present status and Expected sensitivity

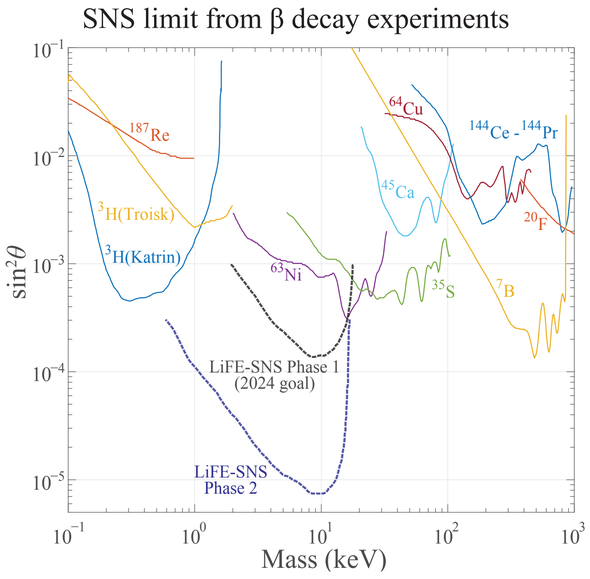


Two detectors are now taking data at 30 mK

300 eV FWHM at 6 keV

Rise-time: 250 μs

SNS limit from β decay experiments



- LiFE-SNS Phase1 (2024 goal)
  - Two LiF detectors show 30-Bq β events.
  - Data taking began in May/2024.
  - 4-months data reach $\sin^2\theta \sim 10^{-4}$ (stat. only).
  - Understanding systematics
- LiFE-SNS Phase2
  - 100 Ch ×100 Bq × 1 year
  - $\sin^2\theta$ sensitivity: better than 10^{-5} at10 keV
- Possible systematics
  - Position dependence: ^{3}H locations and sensitivities
  - Unresolved pileups
  - Atomic corrections associated with H^- states (exchange effect, screened Coulomb potential, FSD)
  - Environmental fine structure
  - Surface escapes