Sterile ν search with a CsI(Rb) crystal

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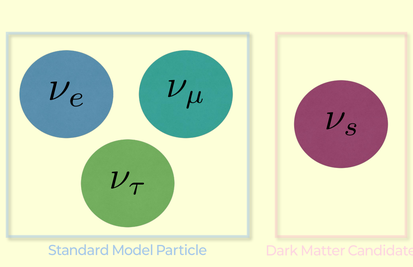
Why ^{87}Rb for Sterile ν Search?

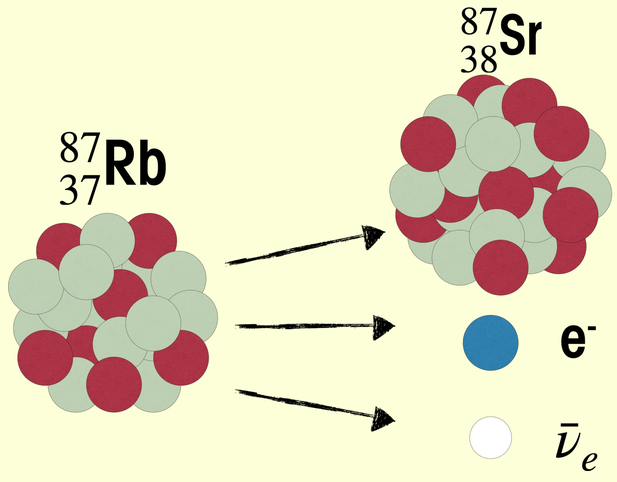


- Eigen state of electron neutrino :

$$|\nu_e\rangle = \sum_{i=1}^{3} U_{ei}|\nu_i\rangle + U_{e4}|\nu_4\rangle$$

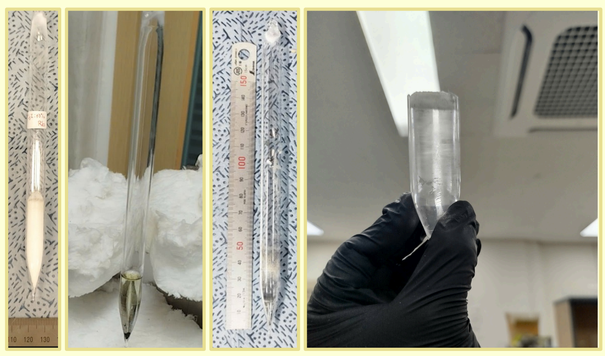
→ $|U_{e4}|^2$: probability of emitting ν_4/ β decay

- Beta spectrum divided into two terms, resulting in a kink on the spectrum

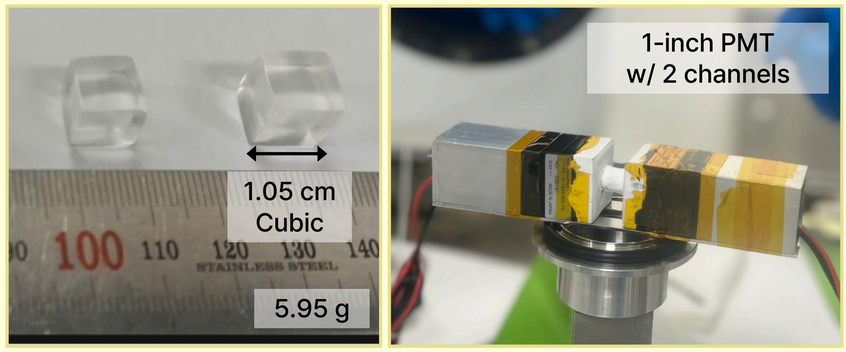


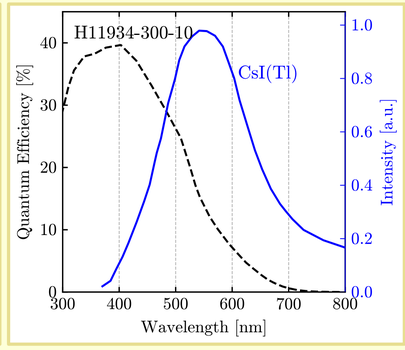
- Long-lived isotope ^{87}Rb ($T_{1/2} \approx 4.97\times10^{10}$ year) undergoes **a third-forbidden non-unique β⁻ decay** to ^{87}Sr that makes distortion at β-spectrum
- **End point E_0 = 283.3 keV**
- So, experimental half-life time and spectral shape show discrepancies compared with the theory
- Accurate modeling of its β-spectrum's shape factor C(W) is helpful for sterile neutrino searches and refining nuclear matrix elements (NME) relevant to 0νββ decay
- This information is very important not only for the particle physics but also for the archaeological applications

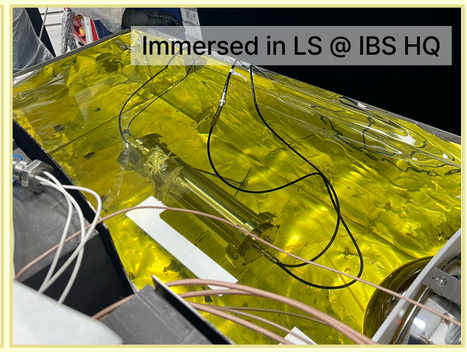
Experimental Setup



- Bridgman method growing of CsI with 10 mol% Rb
- Crystal powder
  - CsI : from KIMS dark matter project
  - RbI : 99.9%, Sigma Aldrich
  - TlI : from CUP, IBS

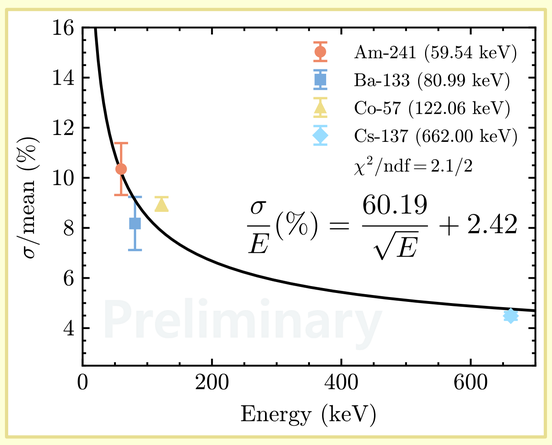




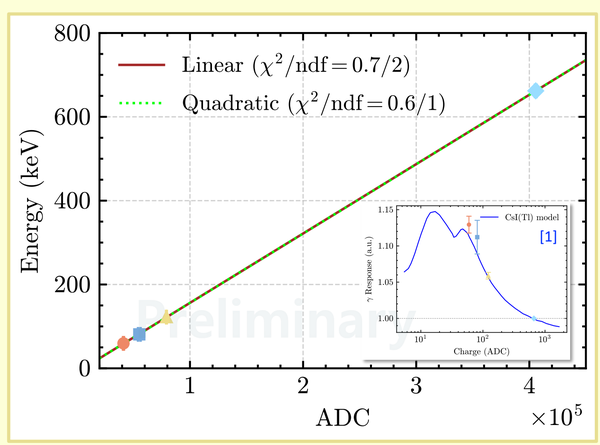


- 1-inch H11934-300-10 PMT has high Quantum Efficiency(~40%) for CsI
- Optical pad is placed between the crystal and PMT window
- For background shielding, detector was immersed in liquid alkyl benzene (LAB) based liquid scintillator
- Calibration source : Am^{241}, Ba^{133}, Co^{57}, Cs^{137}
- Measured light yield : **4.73 ± 0.13 photoelectrons/keV**

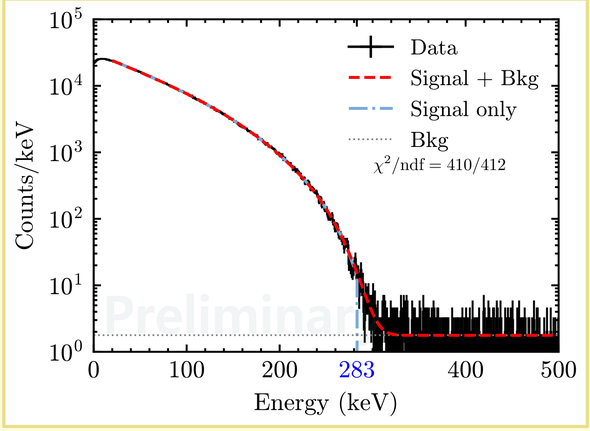
Energy Resolution



Calibration Curve



Shape Factor of β-SPECTRUM



- Analysis with 5 hours of data
- Fit on quadratic calibrated spectrum

$$N(E_{\text{obs}}) = N_0 \int_0^E \underbrace{R(E_{\text{obs}}, E)}_{\text{Resolution}} \underbrace{F(Z,E)}_{\text{Fermi function}} \underbrace{C(p,q;a,b)}_{\text{Shape factor}} p(E+m_e)(E_0-E)^2$$

- Shape factor is parameterized with a & b

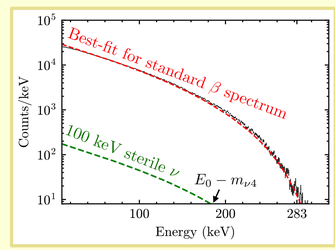
$$C(W) = q^4 + ap^2q^2 + bp^4$$

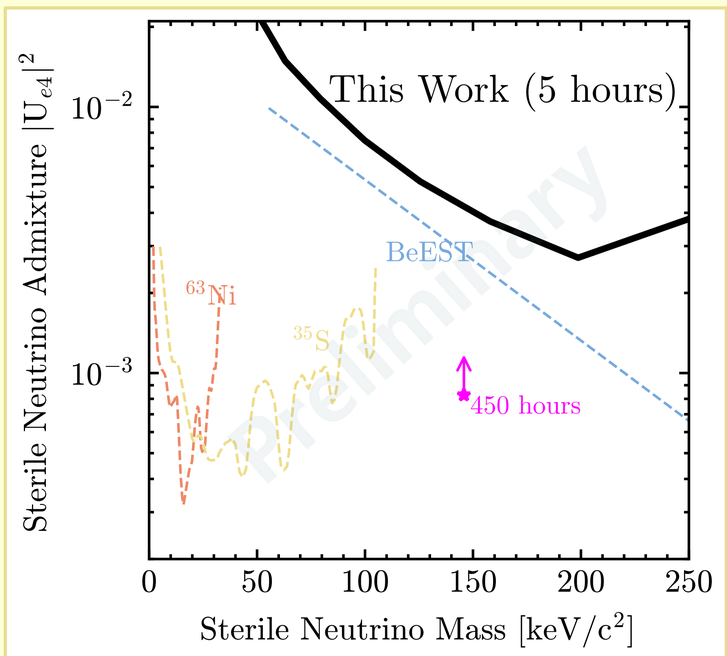
		a	b
Theoretical	C_A/C_V = −1.25	0.303 ± 0.008	0.010 ± 0.003
	C_A/C_V = −1.0	0.281 ± 0.009	0.004 ± 0.002
Experimental	Kossert *et al.* [2]	0.354	0.003
	Kossert *et al.* [3]	0.305 ± 0.009	0.011 ± 0.008
	Belli *et al.* [4]	0.3607 ± 0.001	0.00620 ± 0.00003
	This Work (preliminary)	**0.3481 ± 0.0018**	**0.00616 ± 0.00007**

Limits on the Mixing Parameter (95% C.L.)

- Spectrum fit fixing the shape factor, changing sterile neutrino mass

$$\frac{dN}{dE} = C\left[\underbrace{(1-|U_{e4}|^2)pE(E_0-E)^2}_{\text{standard beta spectrum}} + \underbrace{|U_{e4}|^2 pE(E_0-E)\left[(E_0-E)^2 - m_{\nu_4}^2\right]^{1/2}\theta(E_0-E-m_{\nu_4})}_{\text{sterile neutrino contribution}}\right]$$





- Over 1 month of accumulated data under analysis, this experiment has strong potential to probe new parameter space in the keV-scale sterile neutrino search
- Systematics will be considered such as trigger efficiency, resolution, calibration curve, and etc
- Data collection at Yemilab is planned for low-background operation

Reference

[1] **Gwin *et al.*,** "Scintillation Process in CsI(Tl). II. Emission Spectra and the Possible Role of Self-Trapped Holes ", Phys. Rev. **131, 508** (1963)
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[3] **Kossert *et al.*,** "New advances in the determination of the ^{87}Rb shape factor function", *Nucl. Phys. A* **767,** 248-258 (2006)
[4] **Belli *et al.*,** "Electron spectral shape of the third-forbidden beta-decay of ^{87}Rb measured using a Rb_2ZrCl_6 crystal scintillator", *Eur. Phys. J. A* **62,** 16 (2026)
[5] **Flynn *et al.*,** "Half-Life and Beta Spectrum of ^{87}Rb", *Phys. Rev.* **116, 3,** 744-748 (1959)
[6] **MacGregor *et al.*,** "The Third Forbidden Beta Spectrum of Rubidium-87", *Phys. Rev.* **94, 1,** 138-140 (1953)

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