Energy Calibration Using Radioactive Sources for the RENE Experiment

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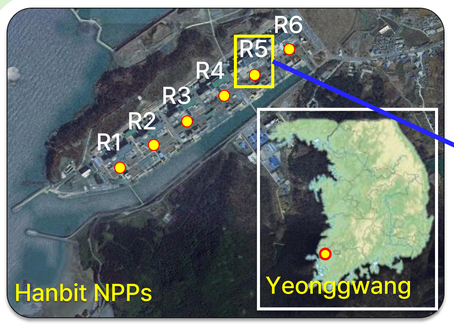
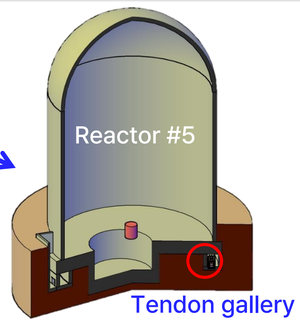
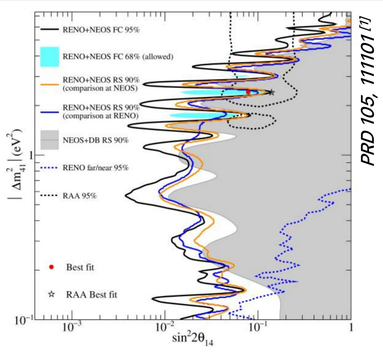
On behalf of RENE Collaboration

Introduction

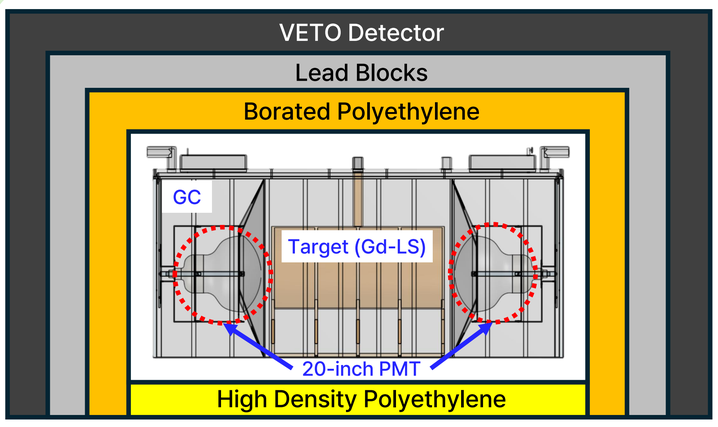




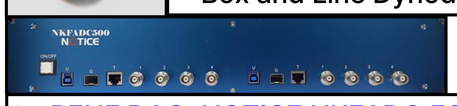


- The RENE (Reactor Experiment for Neutrinos and Exotic) experiment uses the IBD signal from reactor to search for sterile neutrinos at $\Delta m^2_{41} \cong 2eV^2$.
- The detector, which is filled with gadolinium(Gd)-loaded liquid scintillator, will be located in the tendon gallery of Hanbit Nuclear Power Plant at Yeonggwang.
- To improve the detector response, a VETO was employed to reject cosmic-ray backgrounds.
- Energy calibration was performed using various radioactive sources, including ^{137}Cs, ^{60}Co, and ^{252}Cf.

Detector Components



▶ 20-inch PMT (R12860)
- Gain: 1×10^7
- QE: 30 %
- Box and Line Dynode



▶ RENE DAQ: NOTICE NKFADC 500
- 4 + 4 Channels
- Resolution 12 bit
- Sampling rate 500 MS/ch/s
- Dynamic range 2.5 V_{pp}

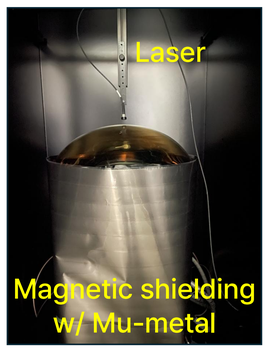
- VETO Detectors: Plastic scintillator (EJ 200) with 32 Ch. 2-inch PMTs
- Background Shielding: 100 mm Borated (about 5%) PE and High-Density PE, 100 mm Lead Blocks
- Gamma Catcher (GC) : 2800 mm × 1200 mm × 1200 mm, Liquid scintillator
- Target: radius 275 mm, length 1200 mm, 0.5% Gd-Loaded with Liquid Scintillator (Acrylic)

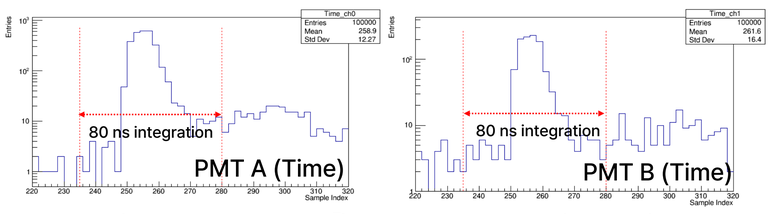
20-inch PMT Performance

- We measured PMT response, gain curve and charge stability in dark box.

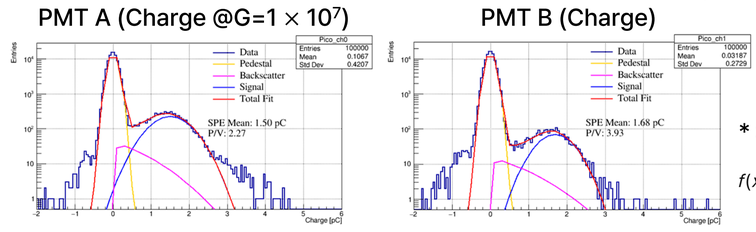
▶ Time and Charge response

Dark box ➔





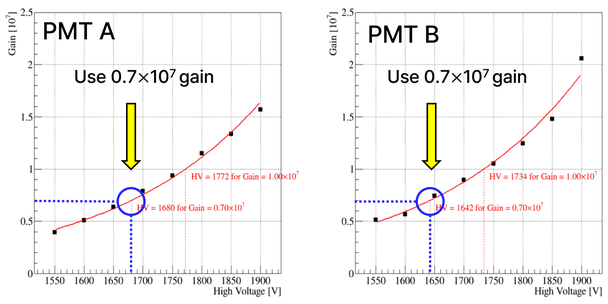
PMT A (Charge @G=1 × 10^7) PMT B (Charge)



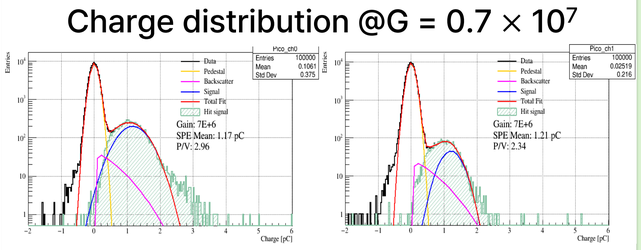
* SPE Fit function:

$$f(x) = \sum_{i=1}^{2} A_i \cdot \exp\left(-\left(\frac{x-\mu_i}{\sqrt{2}\sigma_i}\right)^2\right) + A_3 \cdot \left[\mathrm{erf}\left(\frac{x-\mu_3}{\sigma_3}\right) - \mathrm{erf}\left(\frac{x-\mu_2}{\sigma_2}\right)\right]$$

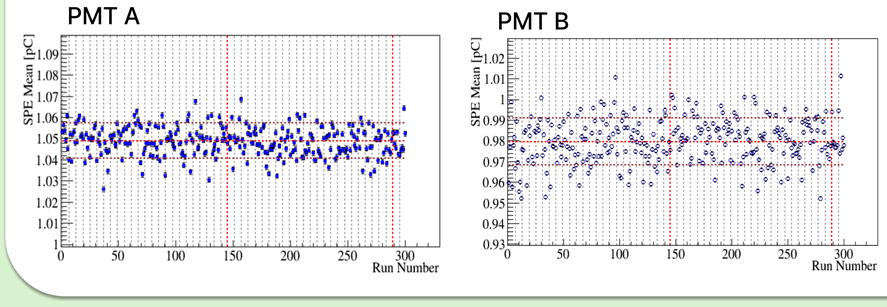
▶ Gain Curve



Charge distribution @G = 0.7 × 10^7



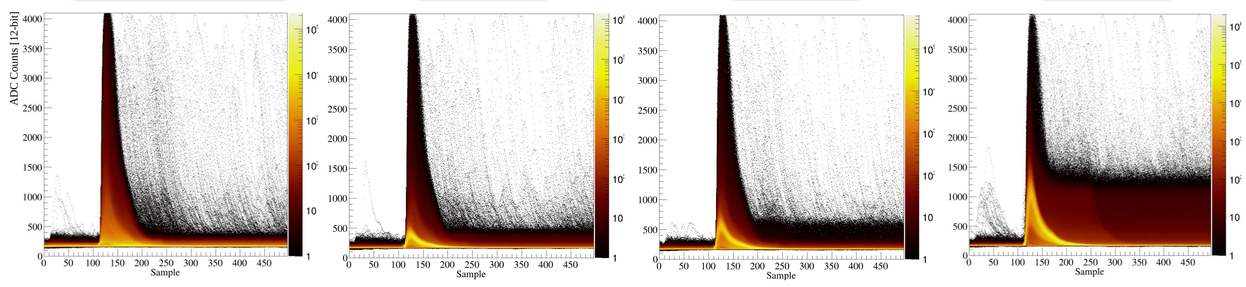
▶ Charge Stability



- Measured charge stability for three days
- Charge was confirmed to be stable.

Radioactive Source

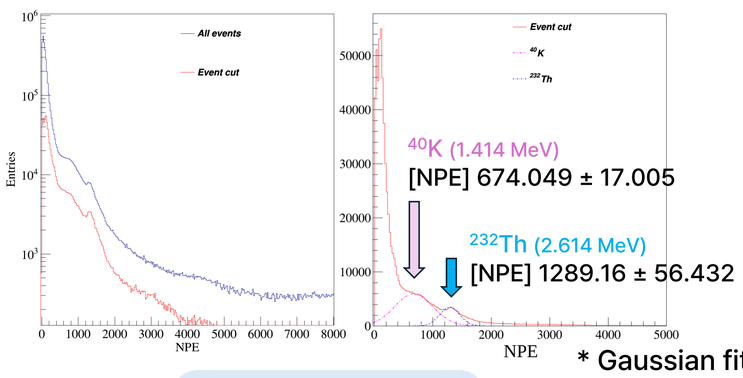
Waveform



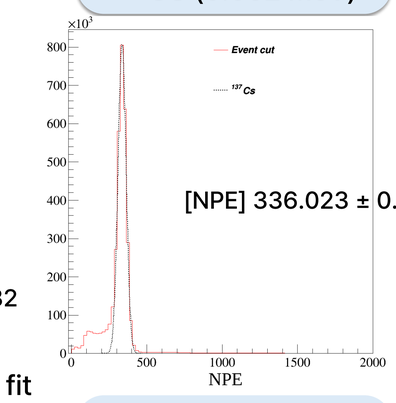
- Density of accumulated waveforms for each source is different in energy deposition and timing.

Energy Spectrum

Environmental Background

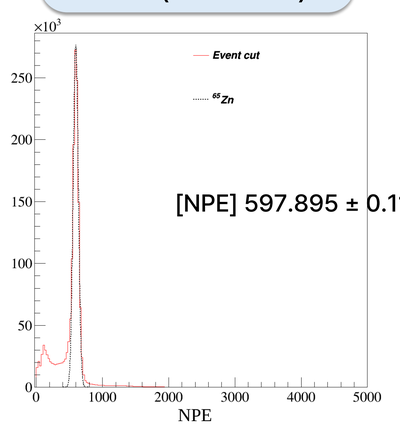


137Cs (0.662 MeV)

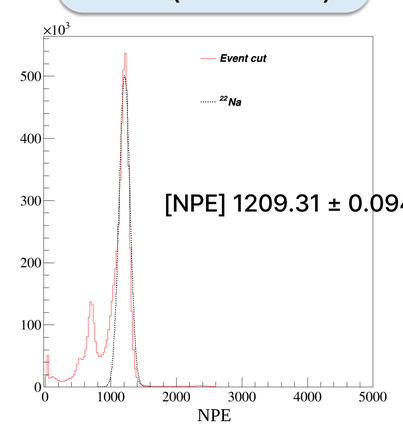


* Gaussian fit

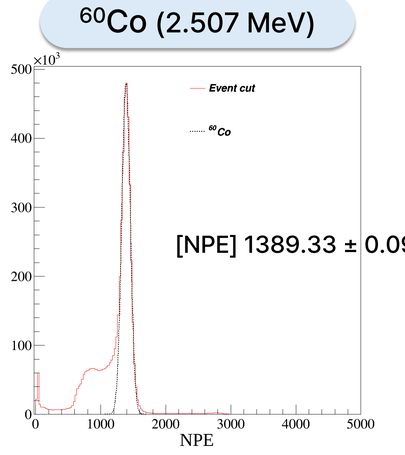
65Zn (1.115 MeV)



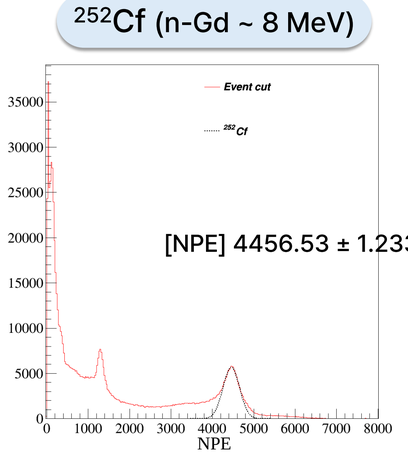
22Na (2.296 MeV)



60Co (2.507 MeV)



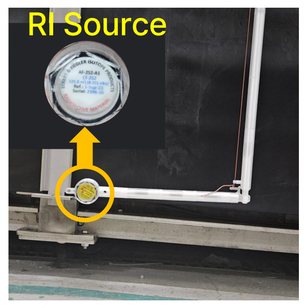
252Cf (n-Gd ~ 8 MeV)



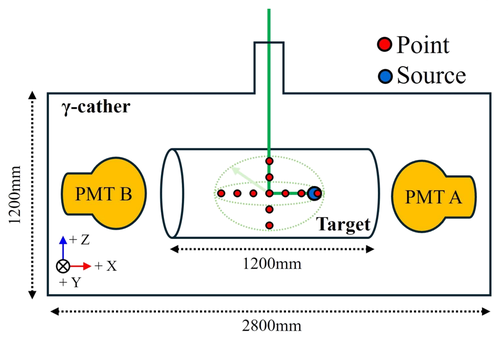
- The effect of environmental radioactivity, including ^{40}K and ^{232}Th, was investigated.
- Energy spectrum of each source were measured and analyzed with energy cuts to separate signals from background.

Plan

- 3D calibration is currently in progress using the newly developed rod.
- Detailed investigations are ongoing to ensure its performance.
- The system is intended to enable calibration over a wide area of the target.



A 3D Calibration rod



Reference

[1] Z. Atif et al., Phys. Rev. D 105, L111101 (2022)
[2] Y. Zhang et al., "Dark Count of 20-inch PMTs Generated by Natural Radioactivity," arXiv:2307.15104 [physics.ins-det] (2023).