

Current Status Report of RENE experiment



Dong Ho Moon

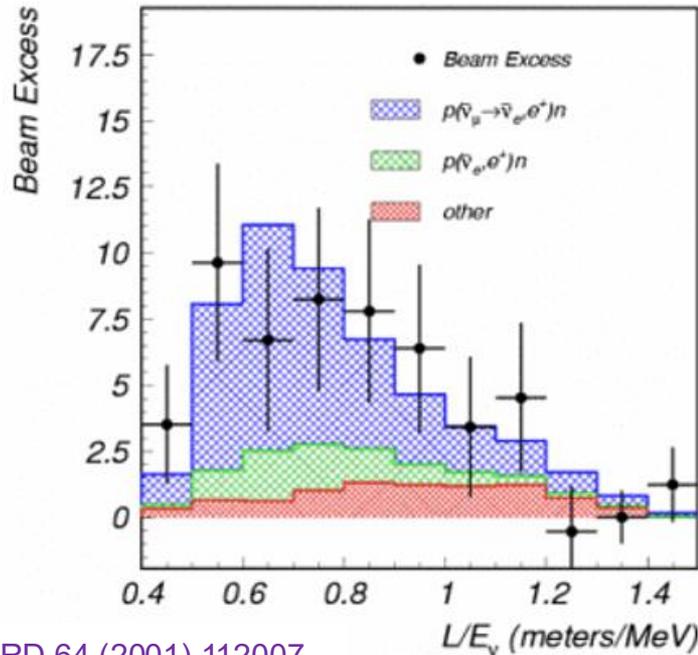
Chonnam National University

on behalf of RENE collaboration

2025/11/11 Baryons 2025 @ Jeju, Korea

Indication of the Existence of Sterile Neutrino

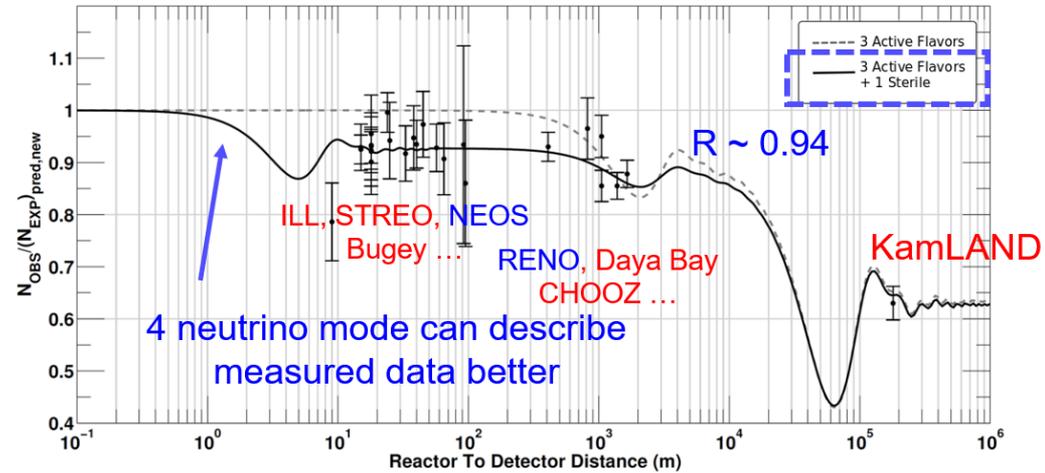
LSND $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ Signal (1987)



- Observed $87.9 \pm 22.4 \pm 6.0$ events
- 3.8 σ significance** of evidence
- MiniBOONE, Gallium experiment claimed similar observations

Reactor Anti-neutrino Anomaly

PLB 829 (2022) 137054, PRD 83 (2011) 073006



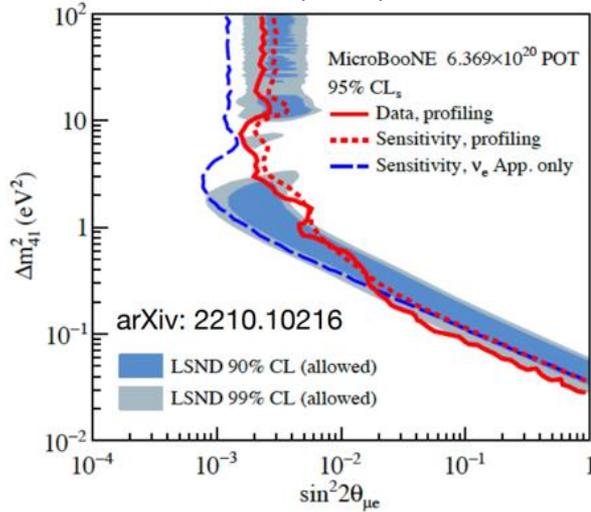
$$P(\nu_e \rightarrow \nu_\mu) = 1 - 2 \sin^2(2\theta) \sin^2 \left(1.27 \frac{\Delta m^2 L}{E} \right)$$

$$\Delta m^2 = m_2^2 - m_1^2$$

- Various reactor experiments were performed
- Average value of ratio based on theoretical calculation can be explained better by **4 neutrino mode**

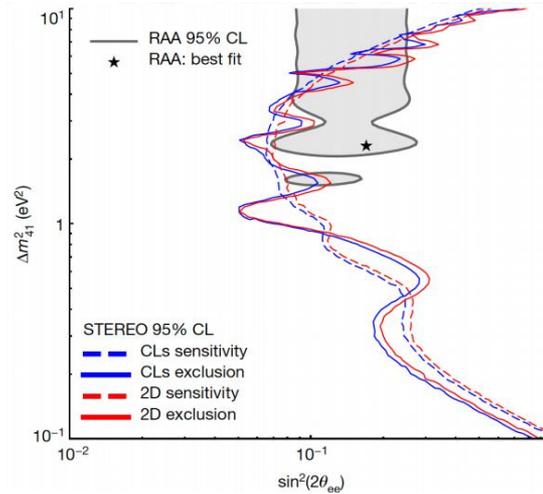
Limitation of neutrino anomaly

PRD 83 (2011) 015015,
PRL 130 (2023) 011801



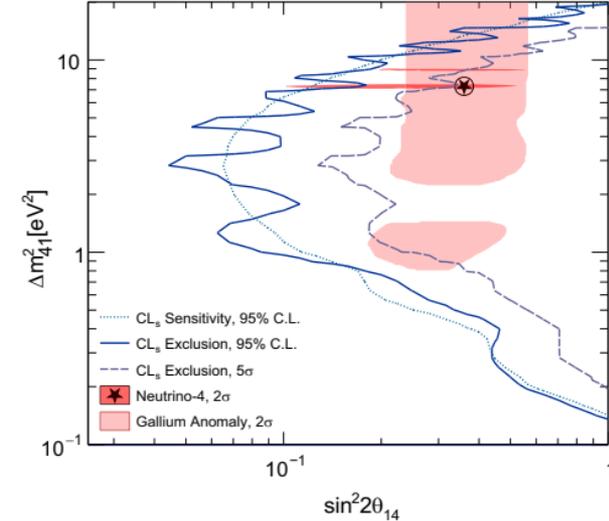
MicroBooNE 2021

Nature 613 (2023) 7943, 257



STEREO 2023

PRL 134 (2025) 151802



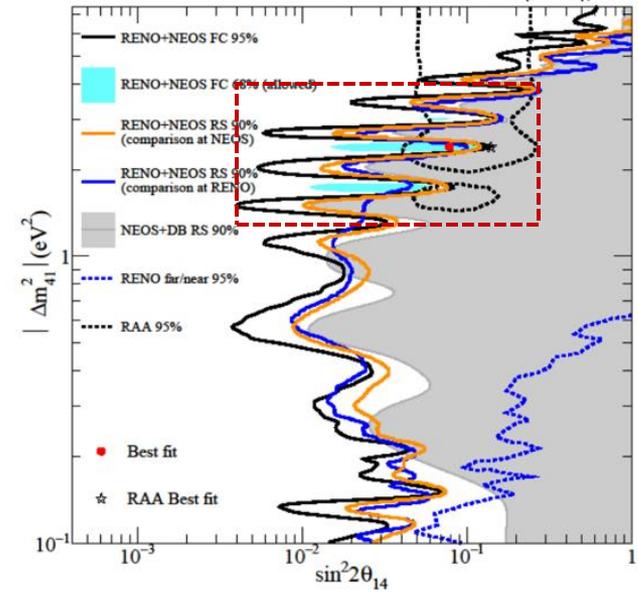
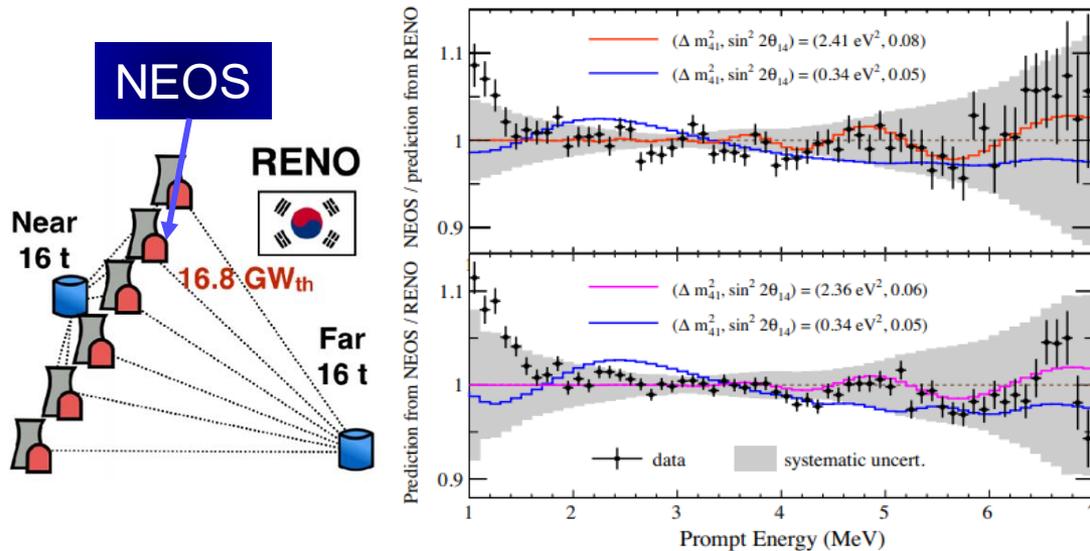
PROSPECT 2025

- KARMEN and MicroBooNE couldn't observe the excess
- Recently, STEREO and PROSPECT ruled out RAA and BEST fit area with 95 % C.L.
- *Experiments employing various detector configuration and baseline setups would offer valuable complementary sensitivity in the search for sterile neutrinos*

NEOS + RENO joint analysis in Korea

PRL 125 (2020) 191801

PRD 105 (2022), L111101



- Reported the hint for the sterile neutrino at $\Delta m^2 \sim 2 \text{ eV}^2$
- Need to improve systematics for confirmation of $\sin^2 2\theta_{14}$
- p-value of inconsistency of 3 and 4 neutrino modes is 8.2 %
- Probably somewhere in $\Delta m^2 \sim \text{eV}^2$ and $\sin^2 2\theta_{14} \sim 0.1$

➡ *This result strongly motivates a dedicated experiment to confirm or rule out this specific region, leading directly to our new short-baseline project*

- **RENE** : Reactor Experiment for Neutrino and Exotics (started at 2022)
- TDR is published at PTEP in 2025 : PTEP (2025) 093C03
- Main physics goals
 - Sterile neutrino ($\Delta m^2_{41} \sim 2 \text{ eV}^2$)
 - 5 MeV bump structure driven by RENO
- Please refer
 - 10.1093/ptep/ptaf101

Reactor Experiment for Neutrinos and Exotics (RENE) for the Sterile Neutrino Search Using Reactor Neutrinos

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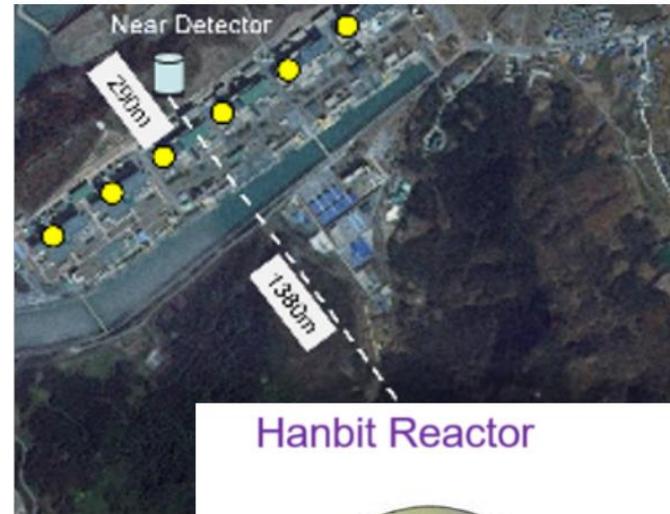
⁹Department of Fire Safety, Seoyeong University, 1 Seogang-ro, Buk-gu, Gwangju 61268, Republic of Korea

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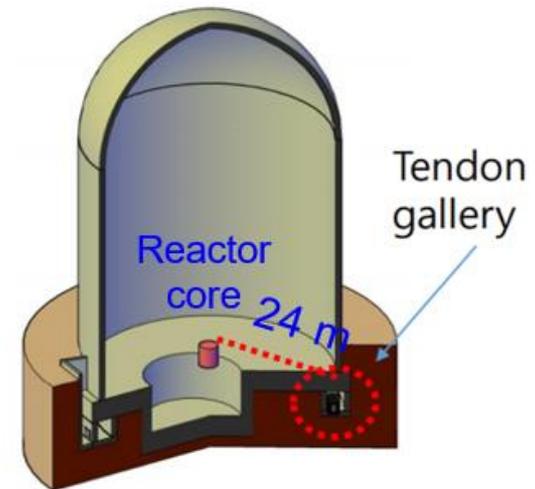
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RENE experiment



Hanbit Reactor



- Plan to install the liquid scintillator based neutrino detector in the tendon gallery of the reactor at Yeonggwang
- Baseline : 24 m

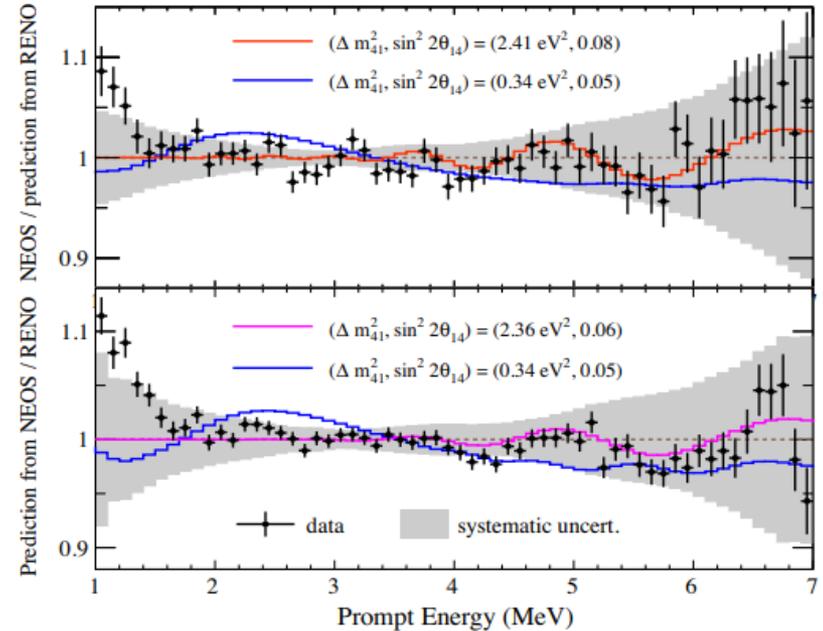
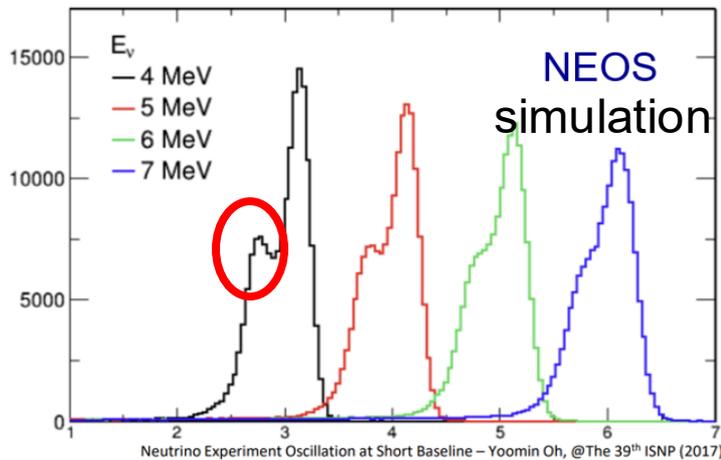
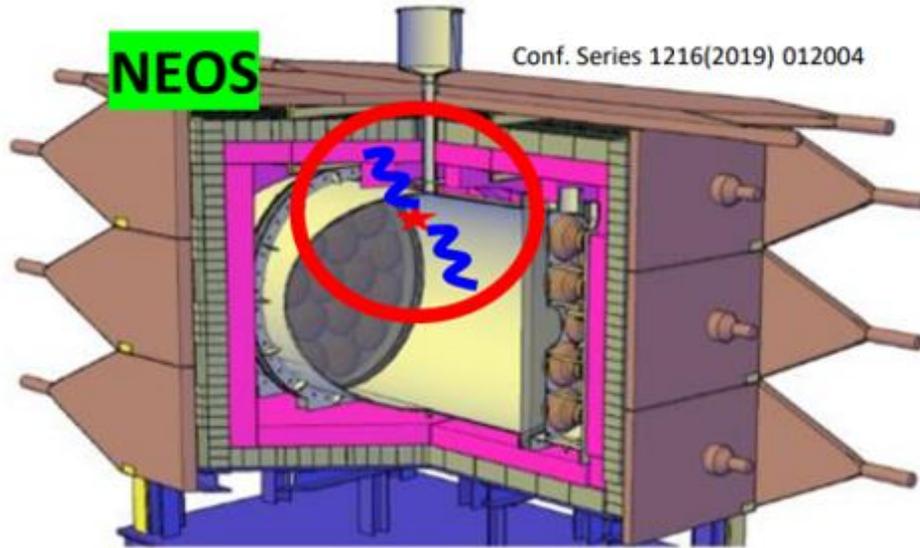
RENE collaboration



12 institutions and ~ 30 members

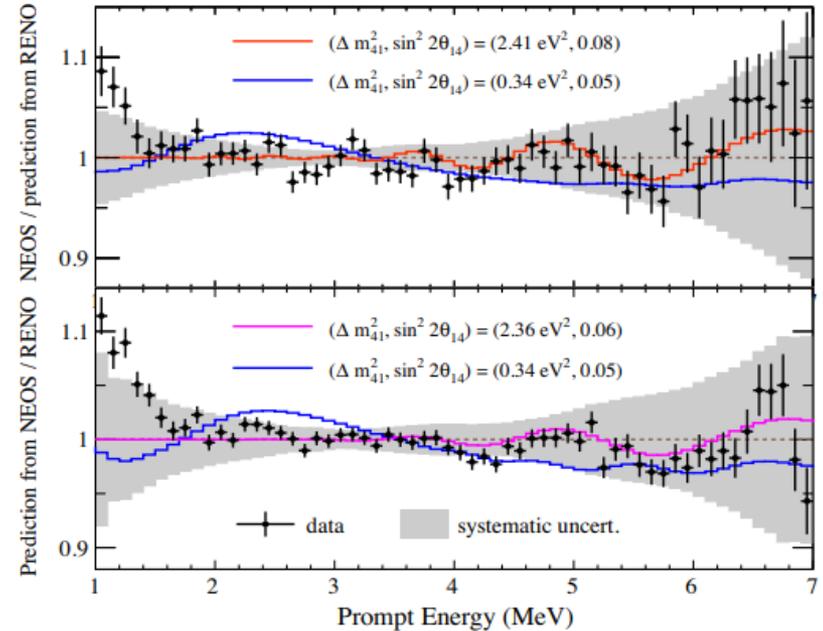
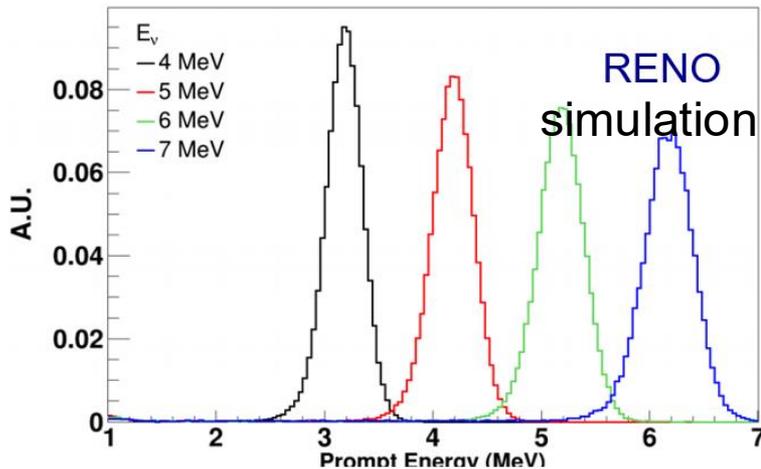
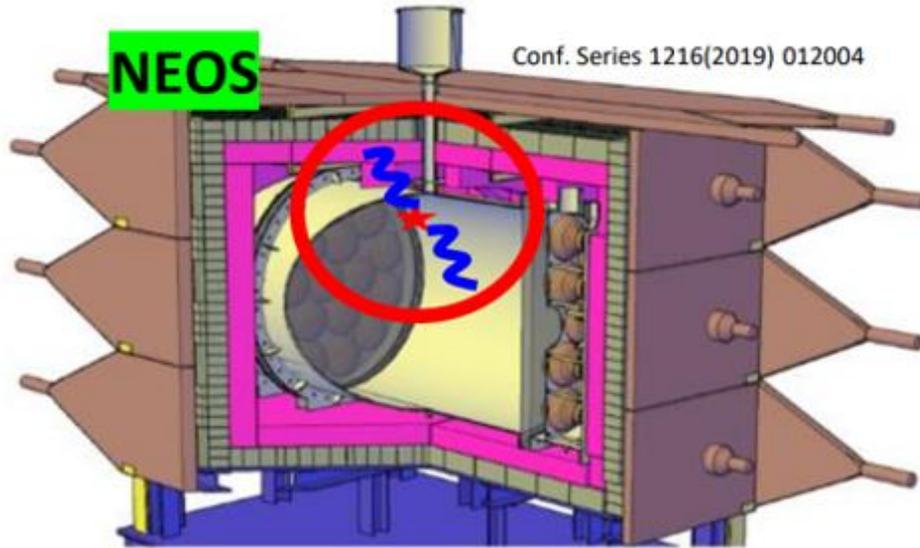
Baryons 2025 @ Jeju, Korea, 2025/11/11, Dong Ho Moon

Detector response simulation



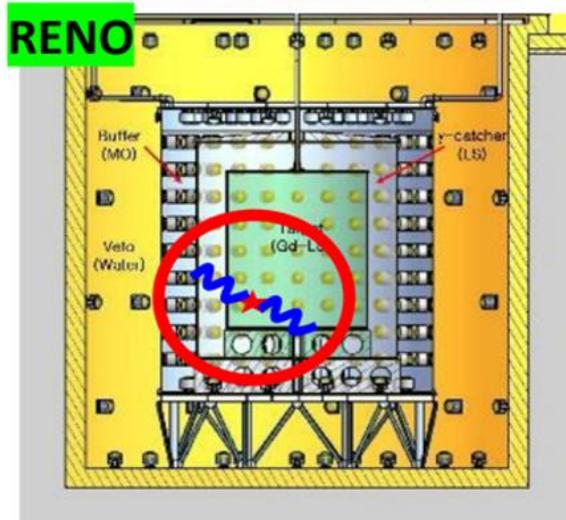
- NEOS : target only experiment for maximizing the volume to adopt IBD events as many as they can
- Need to confirm whether the signal-like shape is real or caused by limited energy resolution induced by escaping γ

Detector response simulation

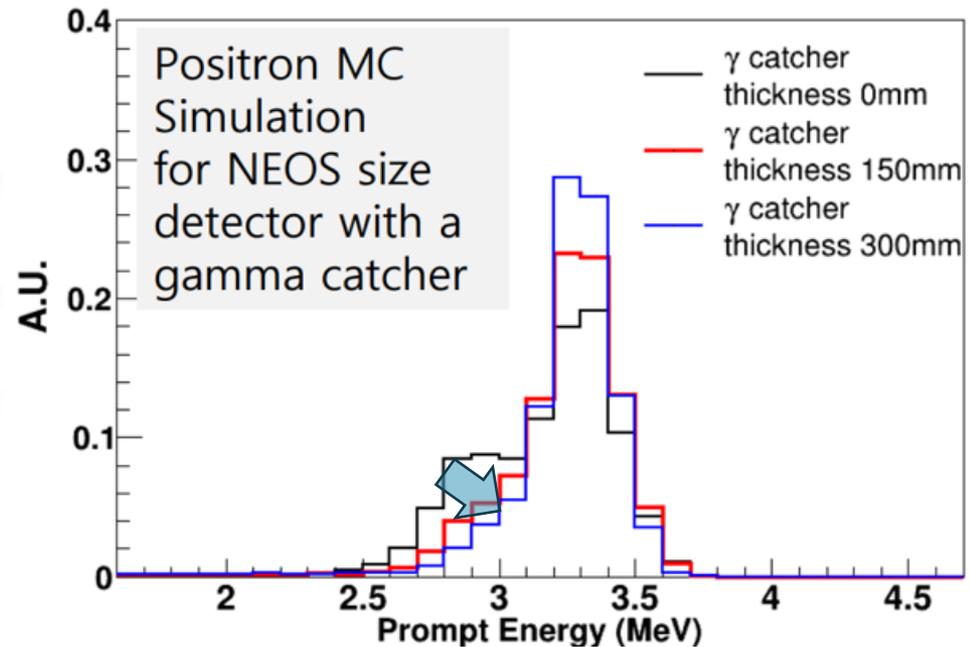


- RENO doesn't have 2nd peak, which means γ -catcher of RENO helped to catch escaping γ
- *New detector configuration is necessary NEOS + RENO type detector >> RENE*

γ -catcher study

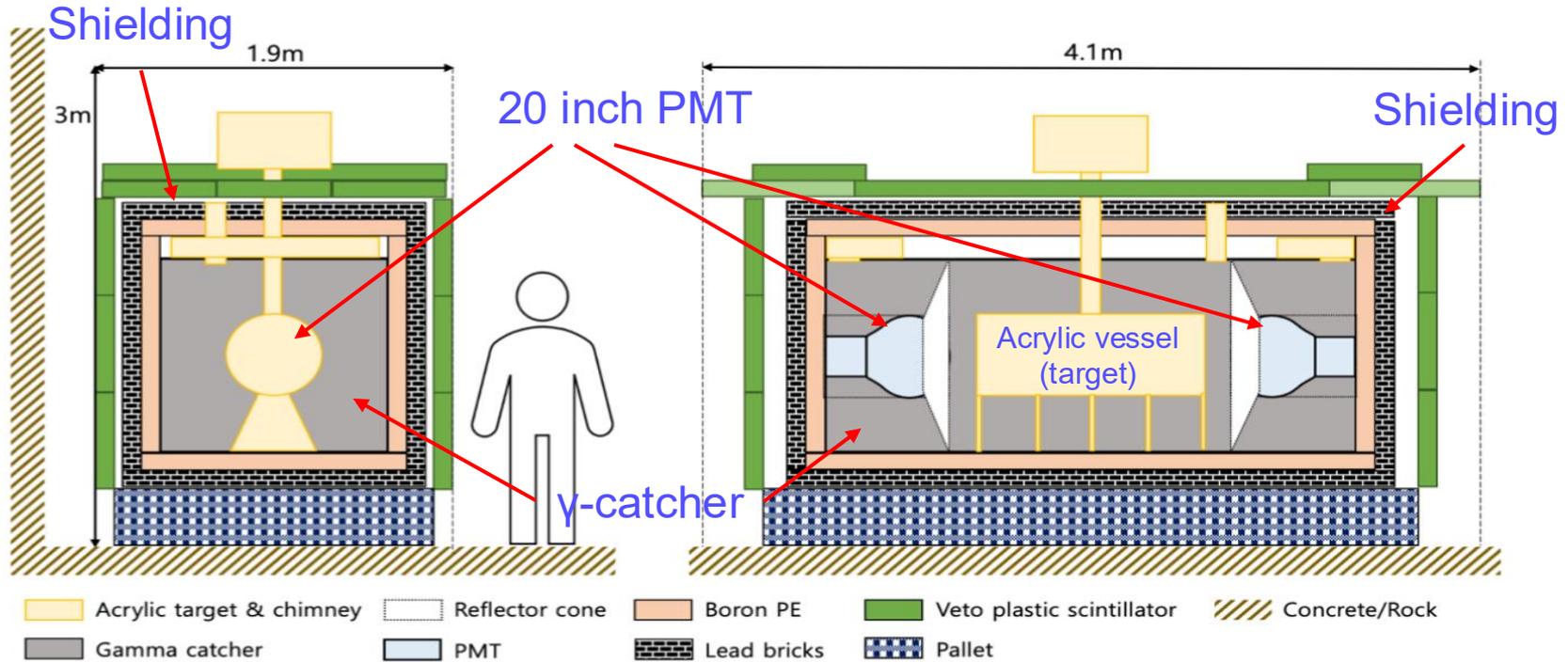


Simulations



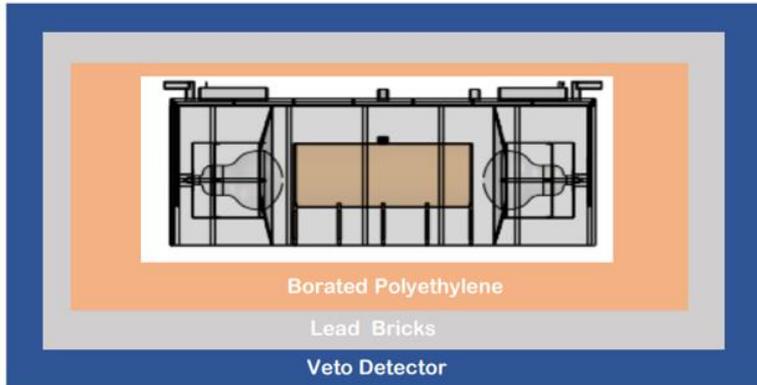
- Apparently escaping γ induce the 2nd peak of energy distributions according to γ -catcher simulation study
- γ -catcher can play an important role to smear the 2nd peak and get better resolution
- 150 mm looks enough to eliminate 2nd peak contributions

Detector design of RENE (inner)

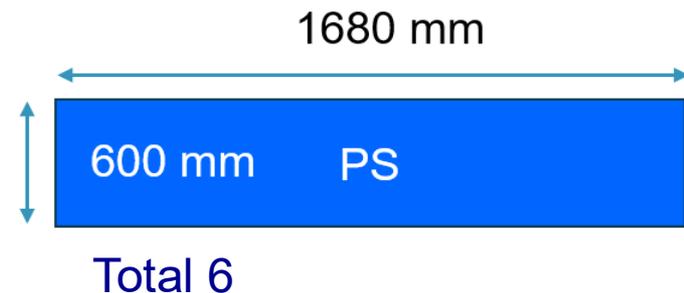
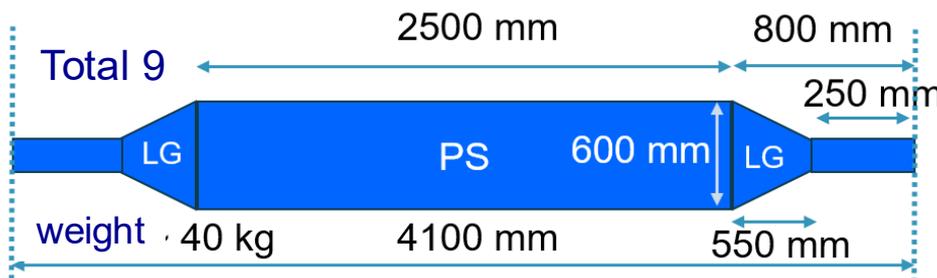
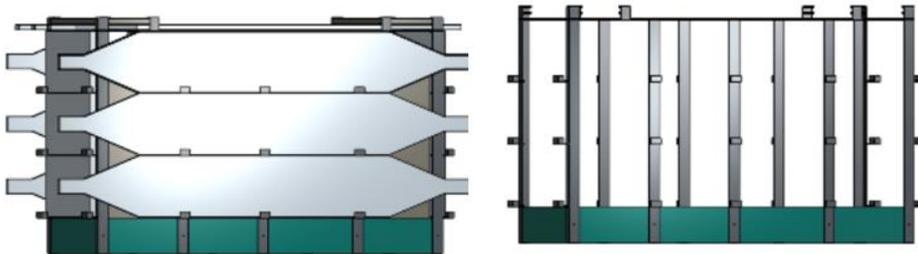


- Cylindrical shape acrylic target filled with 0.5 % Gd-LS (240 L)
- Box type stainless steel γ -catcher filled with LS (3500 L)
- Cone structure for efficient optical photon collection
- Two 20-inch PMTs on left and right
- PMT holder with Mu-metal shielding

Shielding and outer Veto detector (outer)

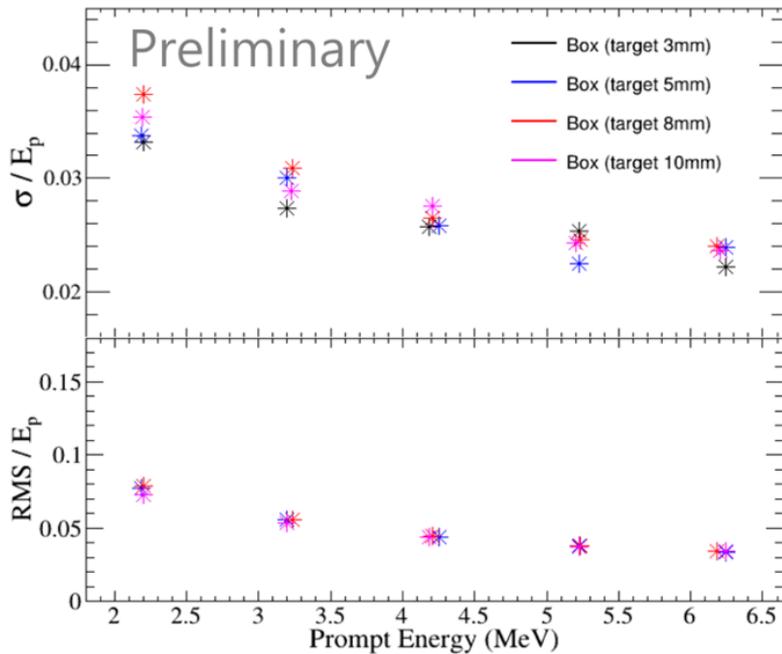


- Shielding
 - Six borated PE plates and lead bricks with 100 mm thickness
- Veto detector
 - 15 plastic scintillator panels
 - 30 2-inch PMTs

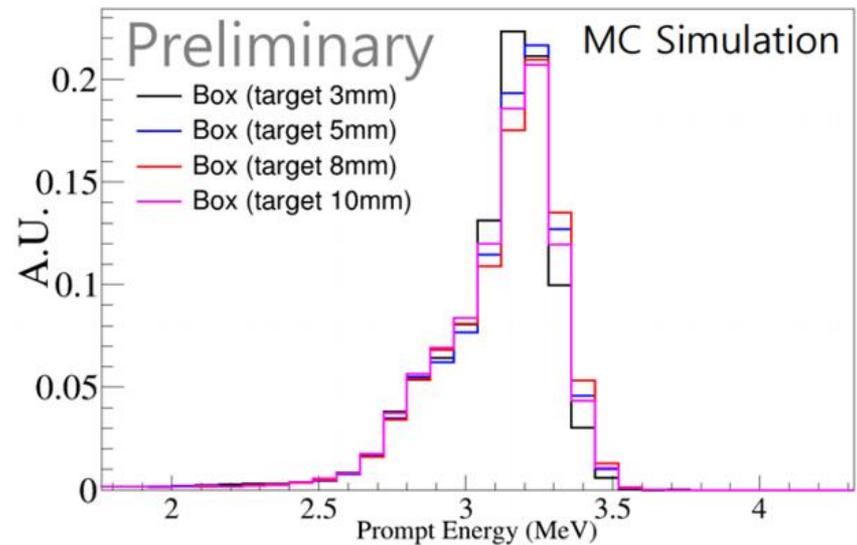


Target detector simulation

✓ Target vessel check. MC Simulation

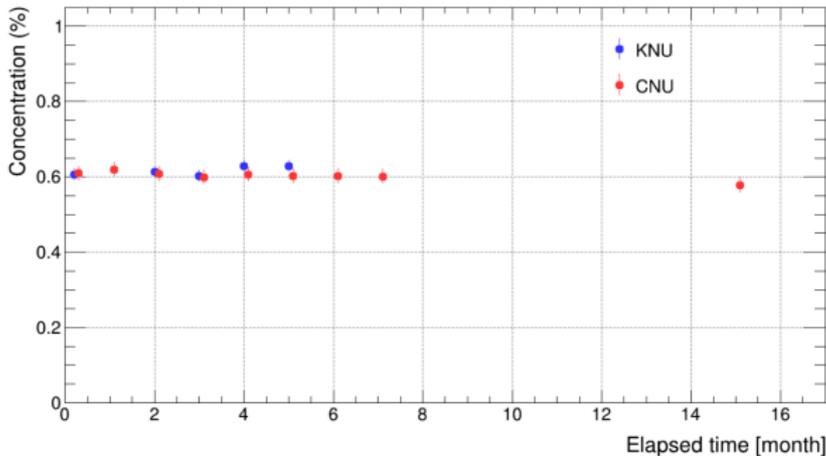
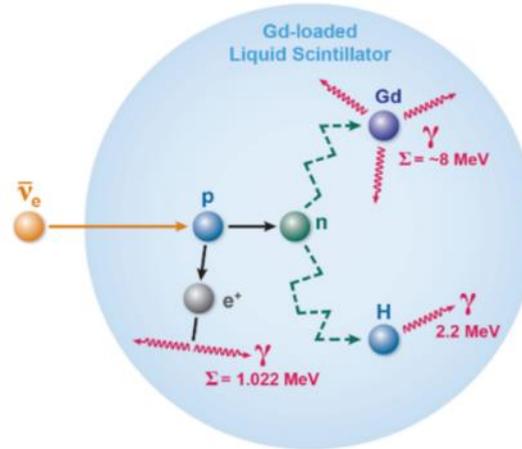
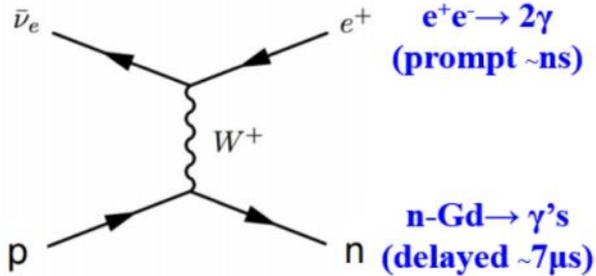


- The thickness of the target acrylic vessel is not significant
- 8 mm-thick target was selected



IBD detection and Gd-LAB

$$\text{IBD} : \bar{\nu}_e + p \rightarrow n + e^+$$

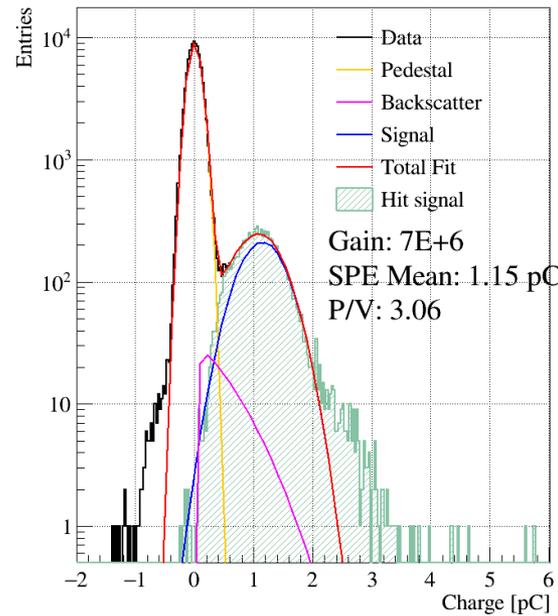


- Total 240 L of 0.6% Gd-LAB solution is ready
- The Gd-LAB has been stable for over one year
- For the precise pulse shape discrimination performance (PSD), DIN will be added later

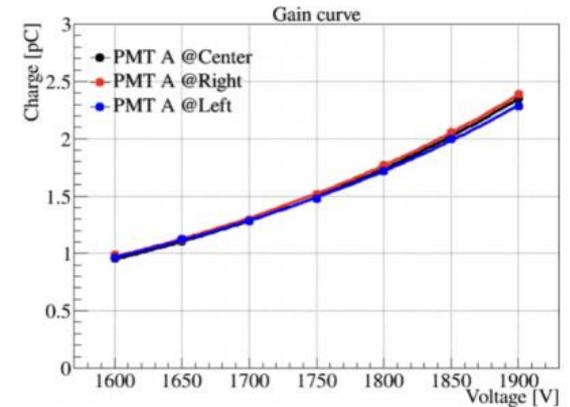
20-inch PMT



Charge distribution at gain = 0.7×10^6

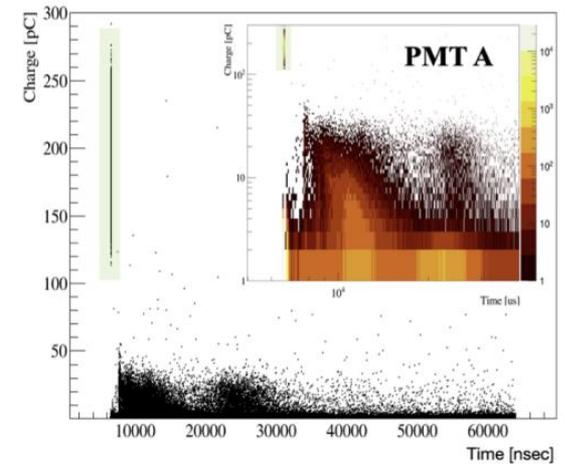


Gain curve



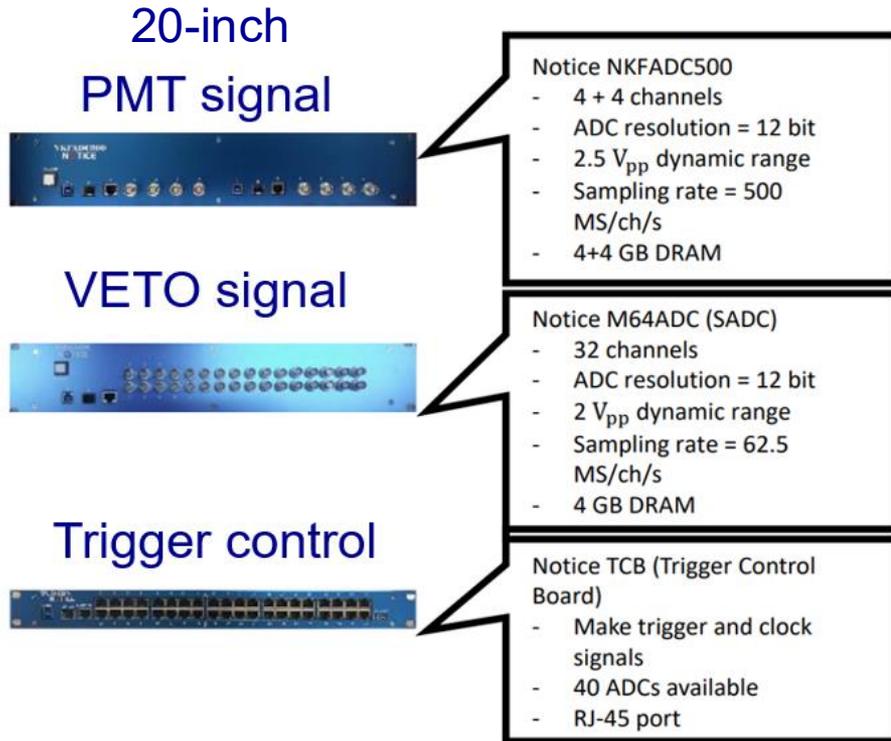
- Hamamatsu R12660
- Fast time response and high stability (TTS ~ 2 ns)
- 30% quantum efficiency
- Tested in dark box by pico-pulse laser.
- Clear SPE peak and good discrimination of afterpulse.
- Position test is done (right, center and left)

Afterpulse

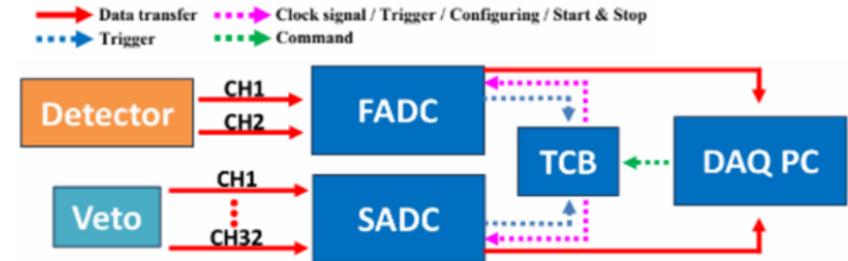


DAQ system

DAQ equipment



DAQ schematic view



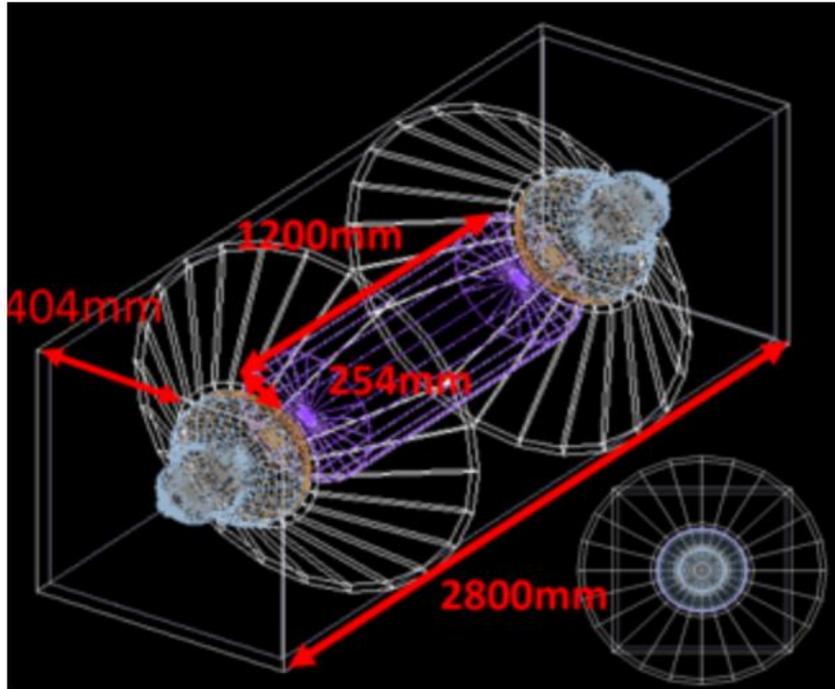
DAQ synchronization



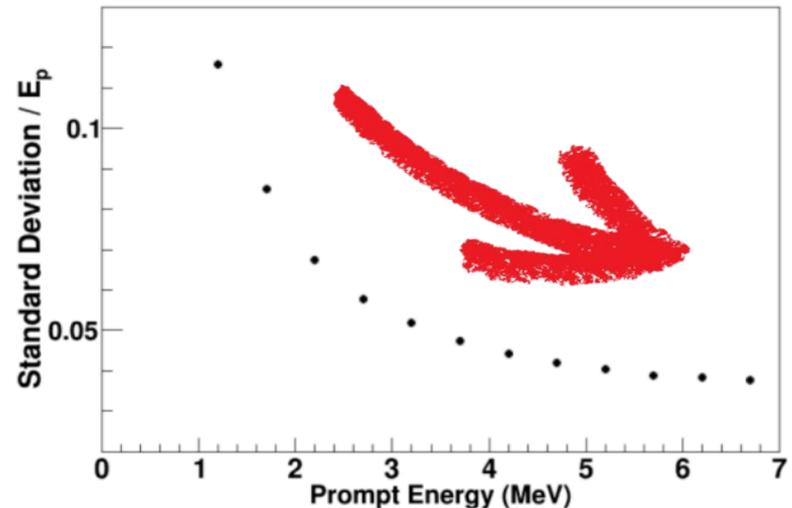
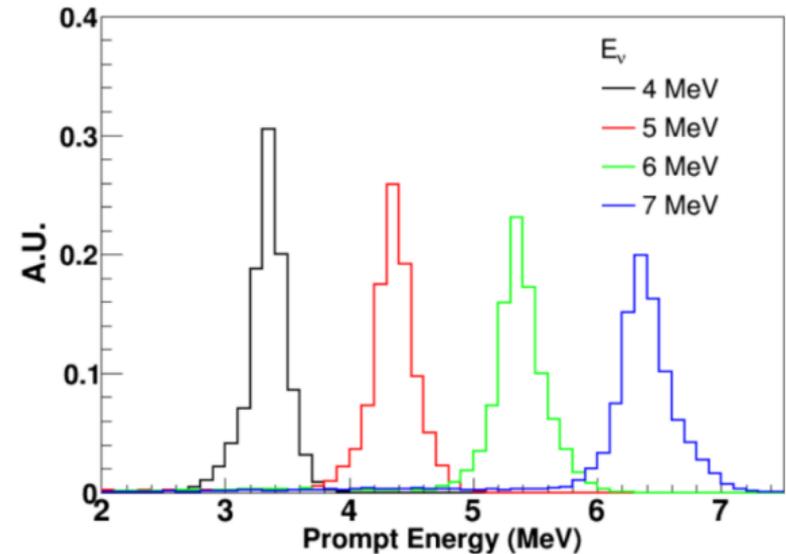
- PSD (pulse shape discrimination) will be performed by using NKFADC500 at offline (12 bit resolution, 2.5 V_{pp}, 500 MS/s, 4+4 channel)
- M64ADC for veto detectors (12 bit resolution, 2 V_{pp}, 62.5 MS/s, 32 channel)
- Trigger Control Board (TCB) for synchronization of trigger and clock

Expected Detector Performance

Schematic view of the RENE detector in MC

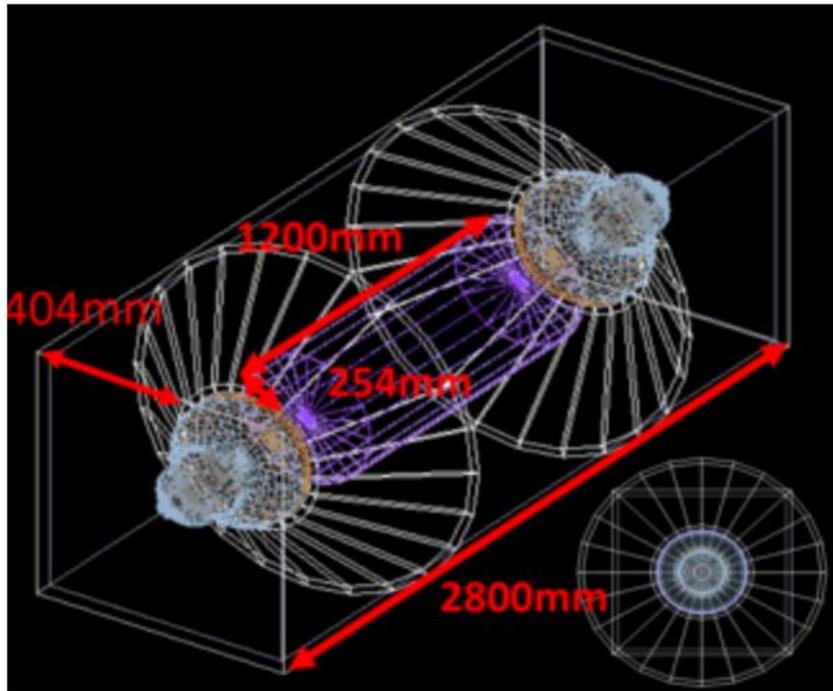


- Simulation toolkit : GLG4SIM
- Energy resolution was evaluated using positrons from IBD events.
- Energy resolution = Standard deviation divided by the corresponding energy

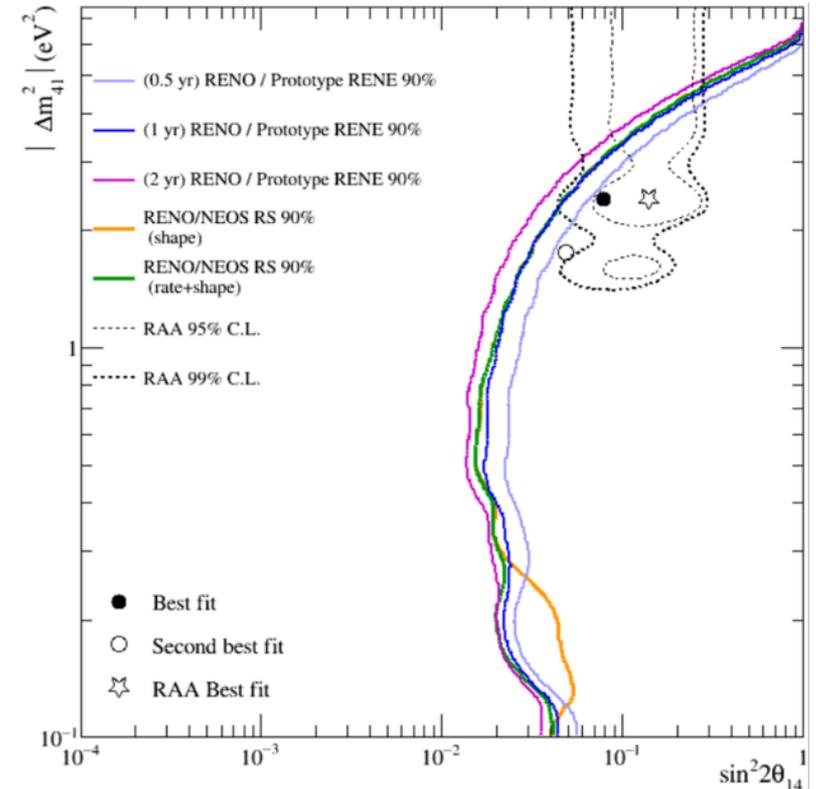


Expected Detector Performance

Schematic view of the RENE detector in MC

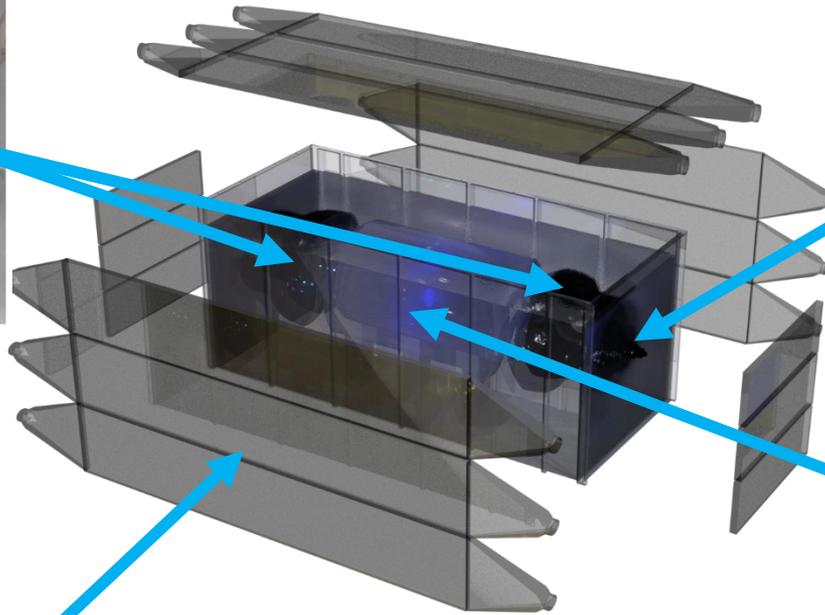
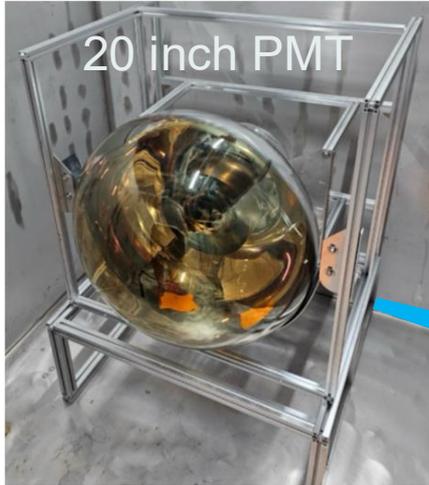


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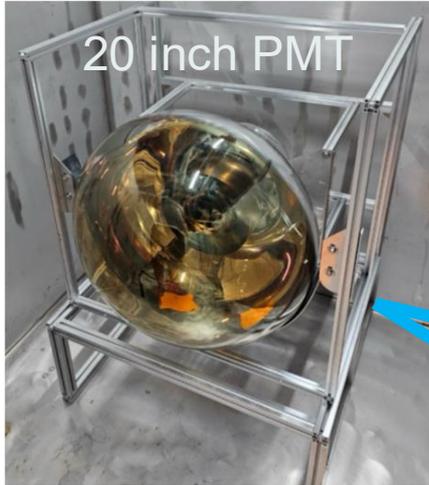


- Expected ~300 IBD events per day
- χ^2 method is used for the estimation for 0.5, 1, 2 years
- Combines with the RENO near detector data

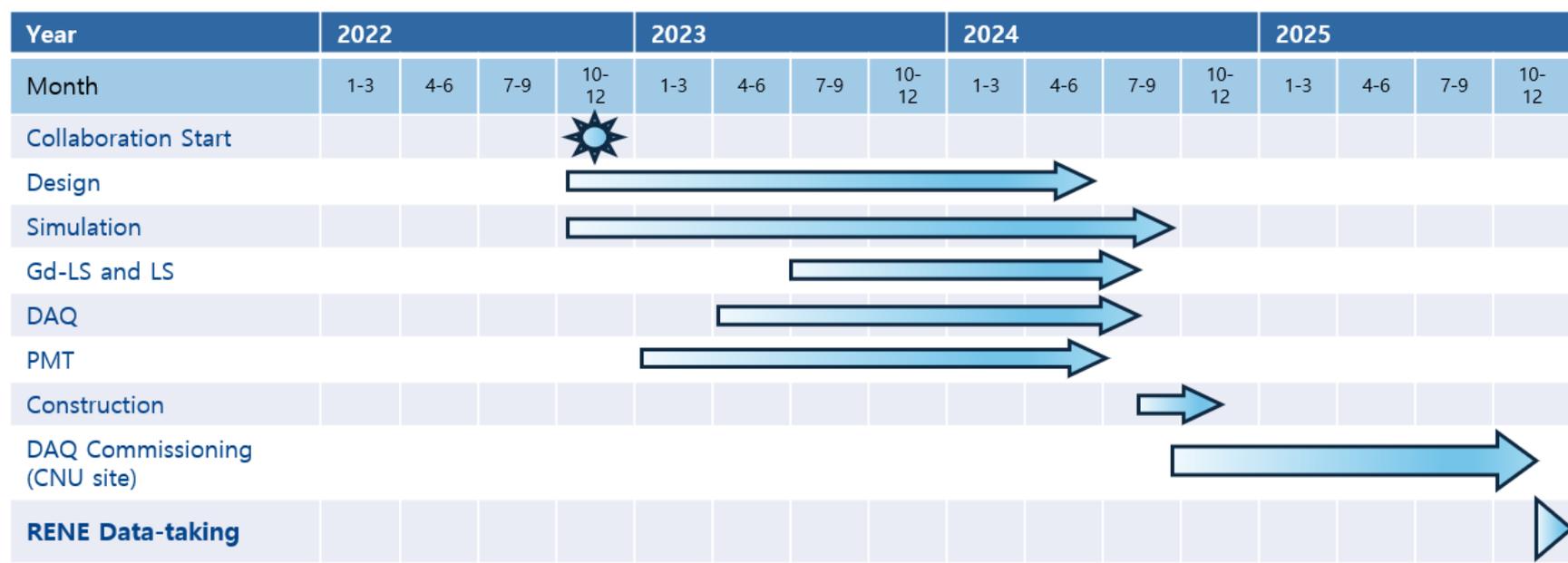
RENE detector assemble



RENE detector assemble



Project Schedule



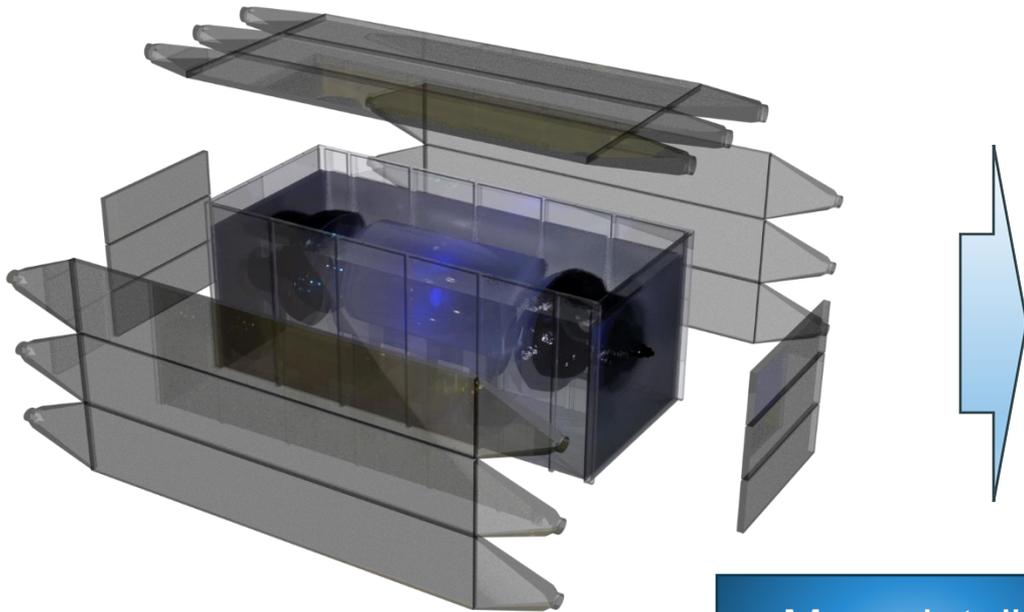
: RENE started

We are in the detector commissioning phase at CNU !!!



Summary and outlook

- Inspired by the hint of RENO-NEOS joint analysis, RENE has begun to search for the sterile neutrino around $\Delta m^2 \sim 2 \text{ eV}^2$
- Detector commissioning is ongoing at CNU
- Waiting for approval of installation in tendon gallery at Hanbit reactor
- Please stay tuned to the RENE experiment !!!

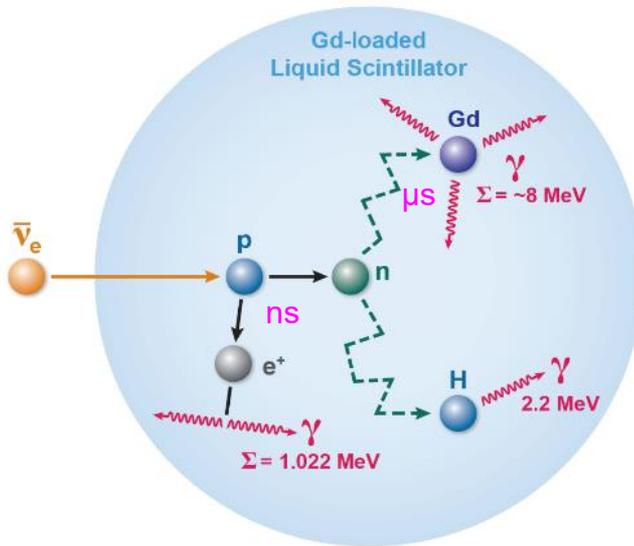
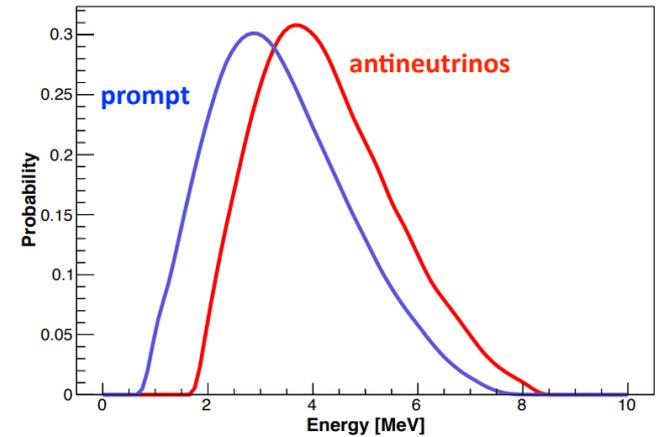
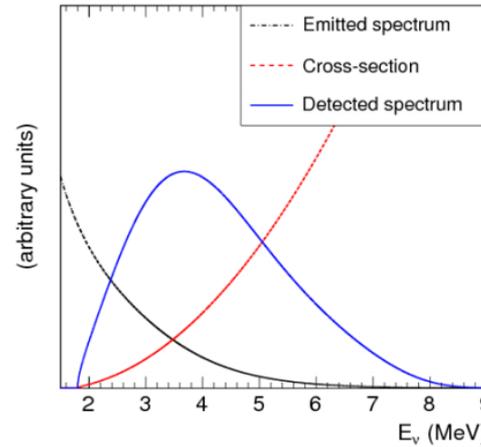
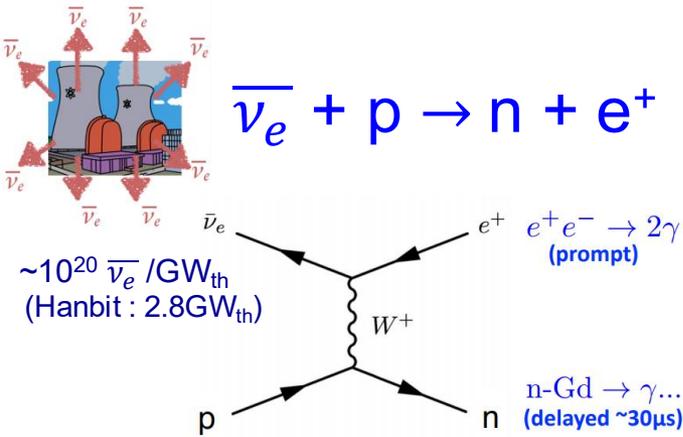


More details
in next talk
(Daeun Jung)

A vibrant watercolor splash in shades of purple, blue, green, and yellow, centered on a white background. The splash has a soft, painterly texture with some darker spots and a light glow around it.

Back Up

Neutrino detection (IBD)



$$E_\nu^{\text{thr}} = \frac{(m_n + m_p)^2 - m_p^2}{2m_p} = 1.806 \text{ MeV}$$

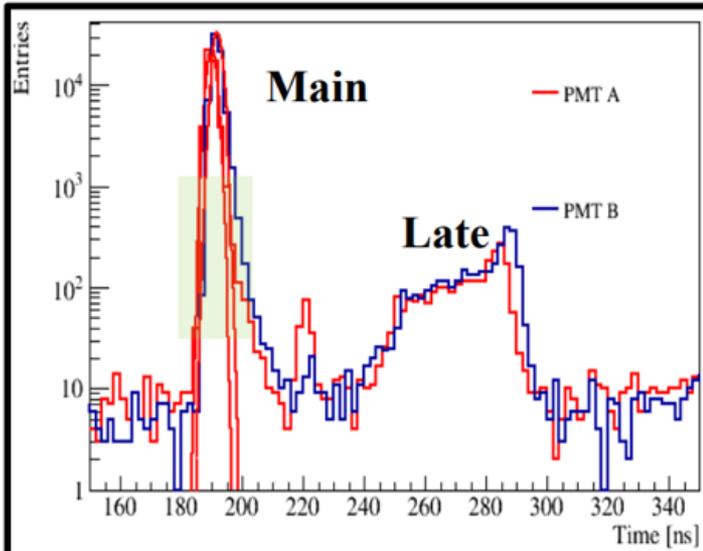
$$E_{\text{prompt}} = K.E.(e^+) + 2 \times (0.511) \text{ MeV}$$

$$\simeq E_\nu - 0.78 \text{ MeV}$$

- Prompt signal : electron positron annihilation in ns
- Delay : n-Gd capture in μs
- Timing constraints help to reject the background events

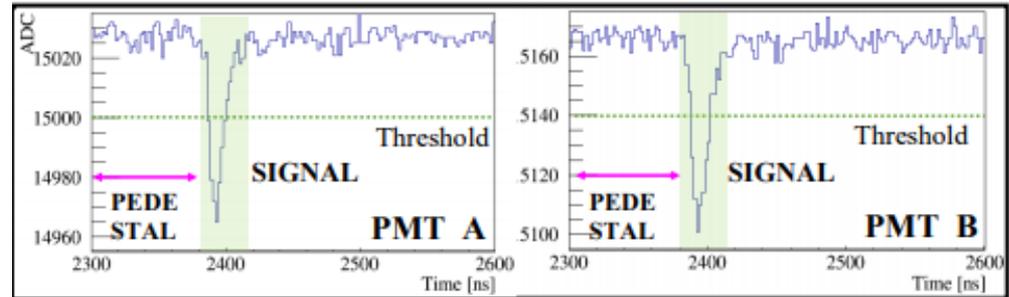
20-inch PMT

Time response

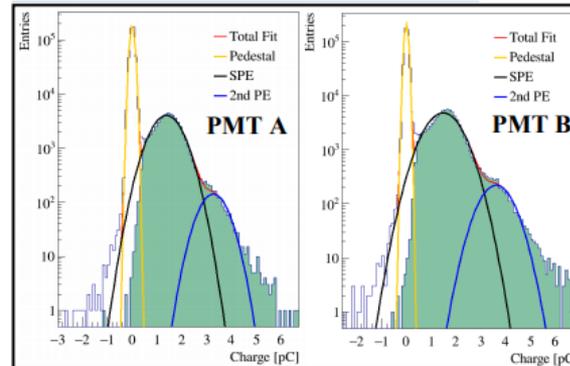


- Main Time response (A): 189 ± 0.0078 ns
- Main Time response (B): 191 ± 0.0072 ns
- Late Time response: Main + 100 ns
- Transit Time Spread (TTS) ≈ 2 ns

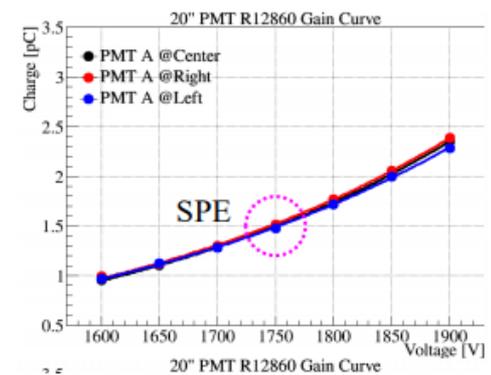
Wave form



Charge distribution



Gain measurement



*Time response: Trigger time – PMT falling time

- Single photo electron : 1.48 (A), 1.51 (B) pC
- Peak to valley : ~ 3
- Acting voltage : 1750 V
- Gain, position dependence and after pulse study are done

Short baseline (SBL) experiments

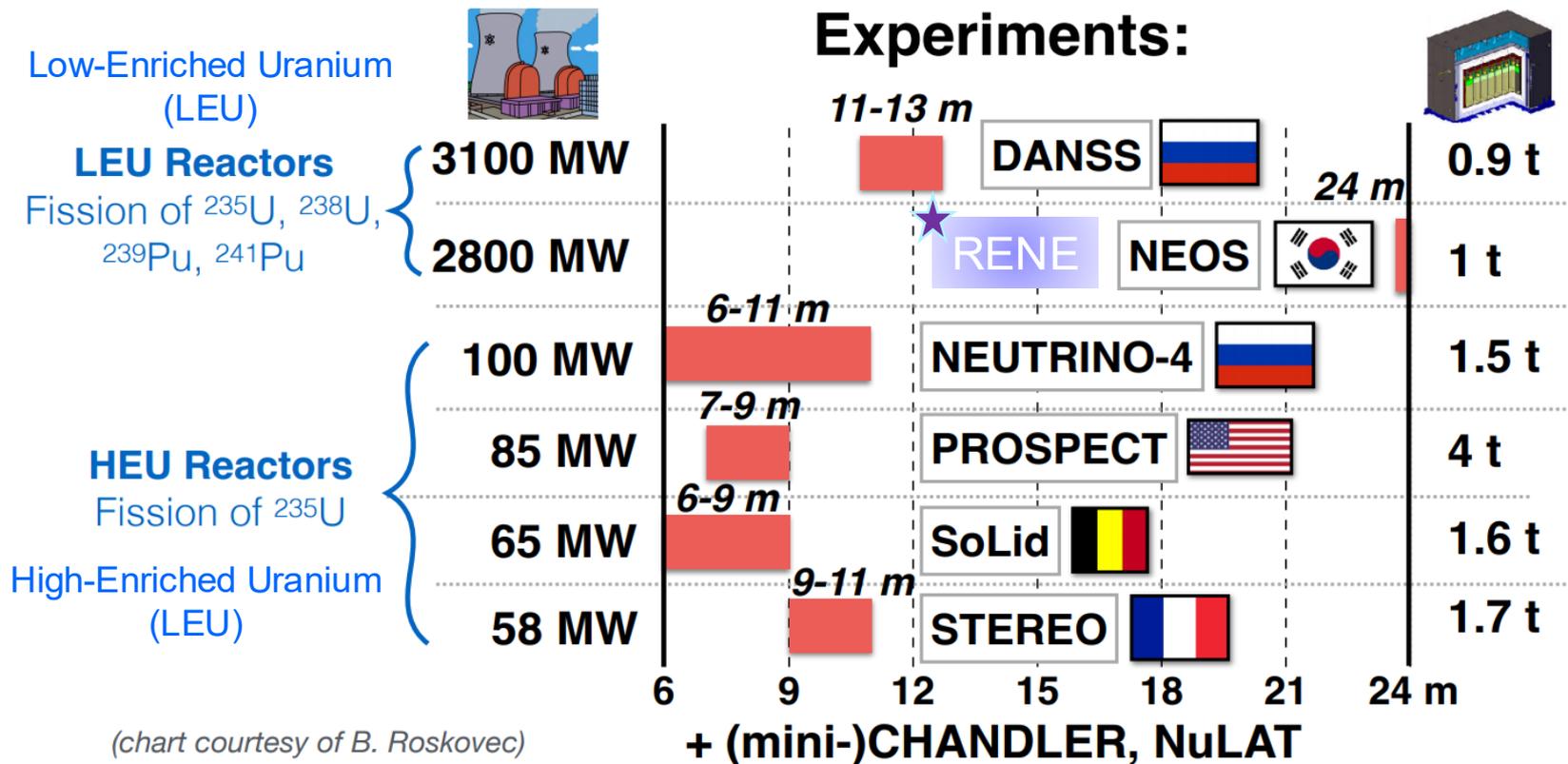
Neutrino 2023 J. Ochoa-Ricoux

2) Short-Baseline (SBL) Experiments

Hope to join in the world race soon !!!

- Primary goal: search for a sterile neutrino with O(10 m) baselines

Motivation: anomalies in neutrino physics that can be explained by sterile neutrino mixing with $\Delta m_{41}^2 \sim 1 \text{ eV}^2$, including the reactor antineutrino anomaly

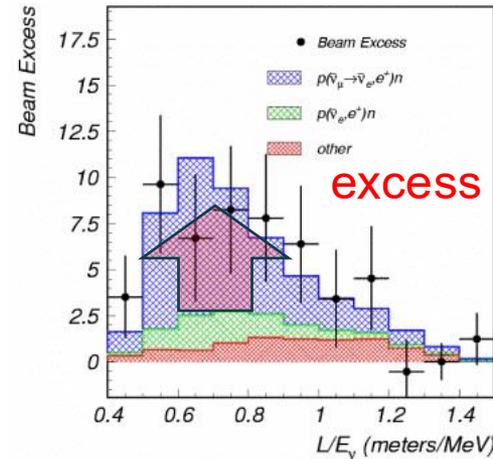
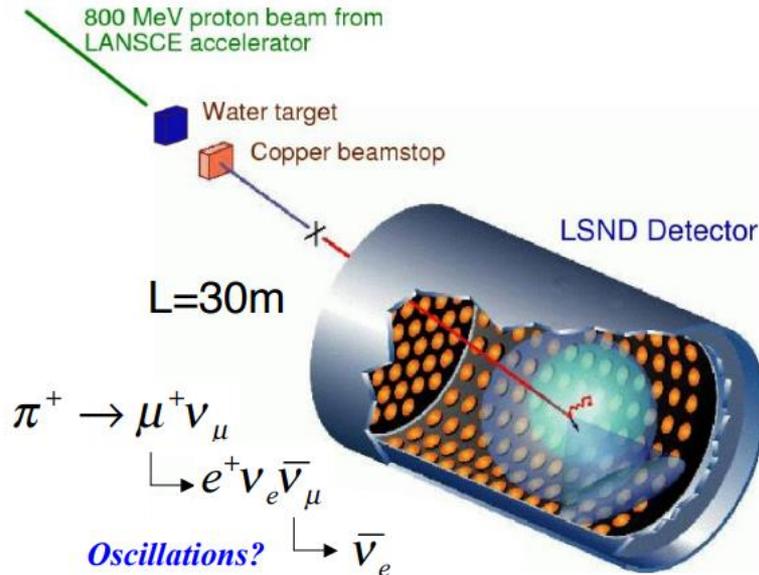


Indication of the Existence of Sterile Neutrino

- LSND (Liquid Scintillator Neutrino Detector) reported observation of excess in 1997.

LSND $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ Signal

Appearance



$L/E_\nu \sim 1$

Possibility
of new type of
neutrino
(4th neutrino ?)

PRD 64 (2001) 112007

Saw an excess of:
 $87.9 \pm 22.4 \pm 6.0$ events.

With an oscillation probability of
 $(0.264 \pm 0.067 \pm 0.045)\%$.

3.8σ evidence for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

Los Alamos Meson Physics Facility,
LANL 1993-1998

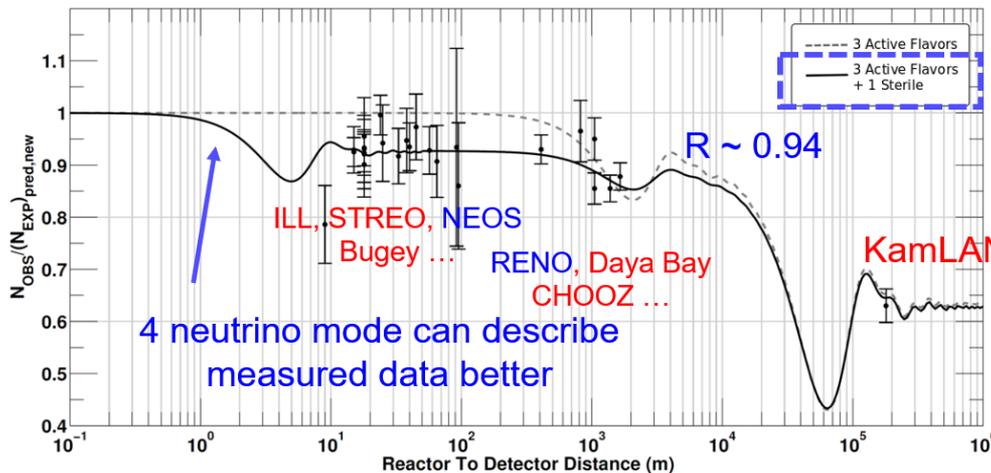
- Observed $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ with baseline of 30 m ($\Delta m^2 \approx 1 \text{eV}^2$).

Indication of the Existence of Sterile Neutrino

Experiments	Neutrino source	signal	type	Significance σ
LSND	μ Decay-At-Rest	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	appearance	3.8
MiniBooNE	π Decay-In-Flight	$\nu_\mu \rightarrow \nu_e$	appearance	4.5
		$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	appearance	2.8
		combined		4.7
Ga(calibration)	e capture	$\nu_e \rightarrow \nu_X$	disappearance	2.7
Reactors	Beta decay	$\bar{\nu}_e \rightarrow \bar{\nu}_X$	disappearance	3.0

- Neutrino anomaly observations were reported at various reactor experiments.

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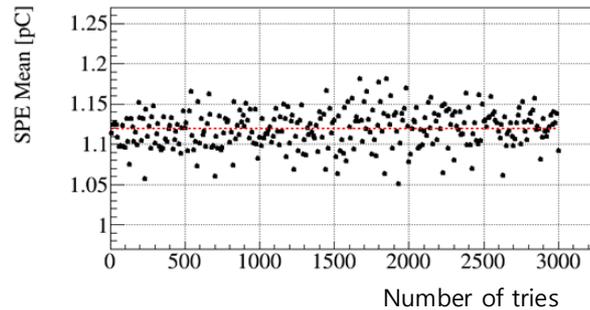
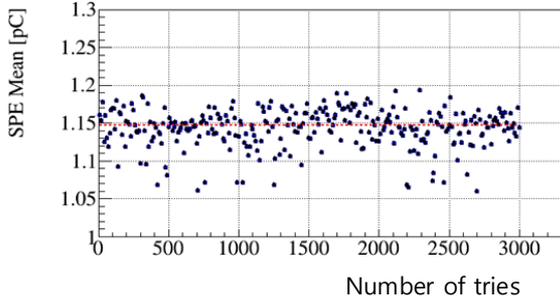
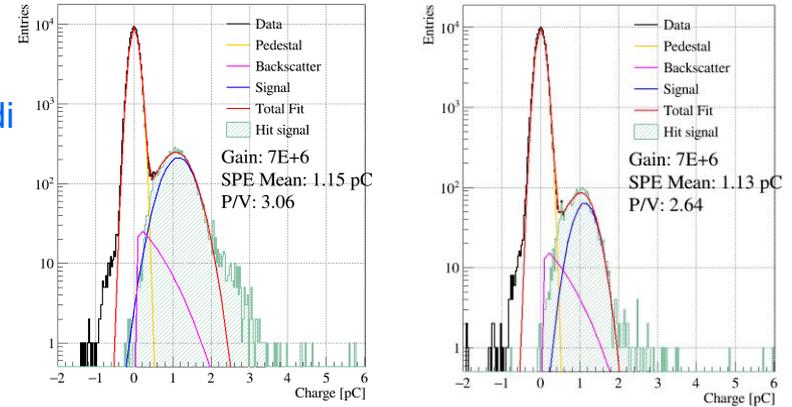
$$P(\nu_e \rightarrow \nu_\mu) = 1 - 2 \sin^2(2\theta) \sin^2 \left(1.27 \frac{\Delta m^2 L}{E} \right)$$

$$\Delta m^2 = m_2^2 - m_1^2$$

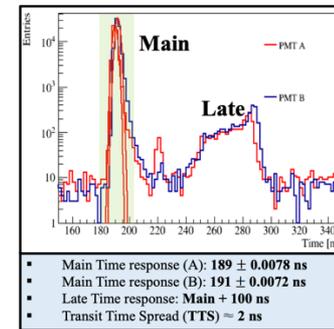
20-inch PMT

- Hamamatsu R12660 (Ref. Hamamatsu handbook)
 - Fast time response and high stability (TTS ~ 2 ns)
 - 30% quantum efficiency
- Characterized in a dark box using a pico-pulse laser
- Clear single photoelectron (SPE) peak and good afterpulse di
- Position dependence test completed (center vs. edge).

Charge distribution at gain = 0.7×10^6



Time response



*Time response: Trigger time - PMT falling time

Dark box



Jiyoung Choi