Status of Reactor Experiment for Neutrino and Exotics (RENE)

Byeongsu Yang (CNU)

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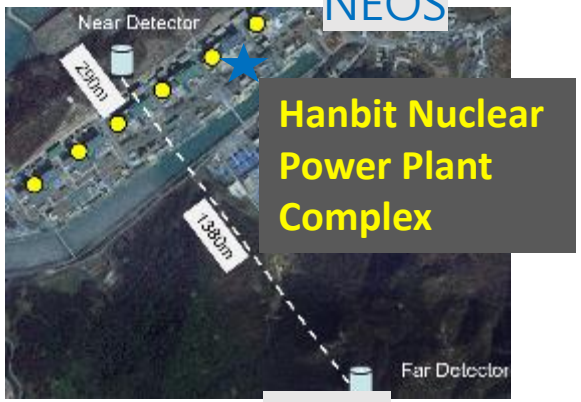
The 4th Workshop on New Physics Opportunities at Neutrino Facilities (NPN 2024)

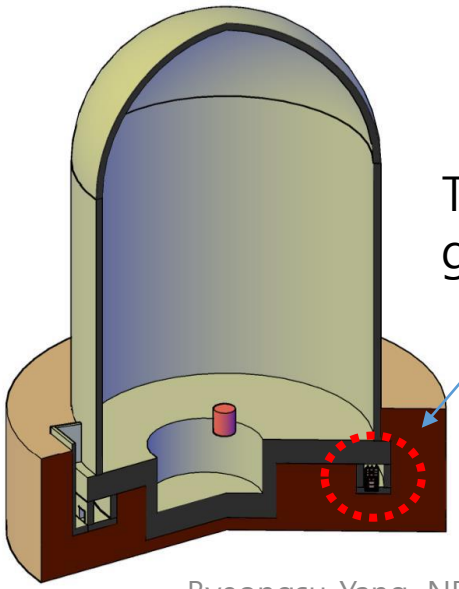
Daejeon, Korea

RENE
(Reactor Experiment for Neutrino and Exotics)

NEOS



RENO



- Will be located in a Tendon gallery of a reactor in Hanbit Nuclear Power Plant Complex.
- Baseline ~23m.
- Aim to search for the sterile neutrino oscillation at $\Delta m^2_{41} \sim 2\ eV^2$, hinted by RENO-NEOS joint analysis (PRD 105 (2022) 111101)

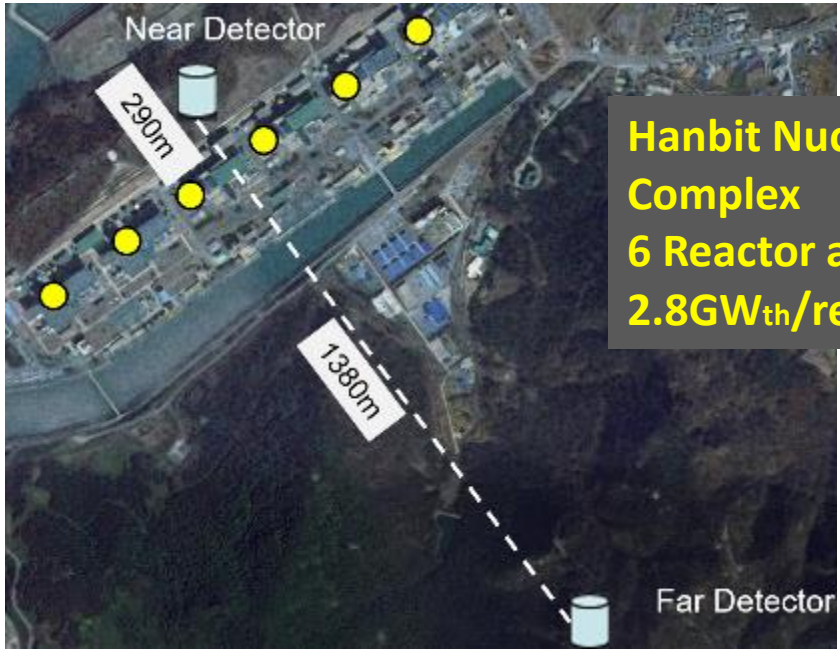
RENE collaboration

12 institutions & about 30 members

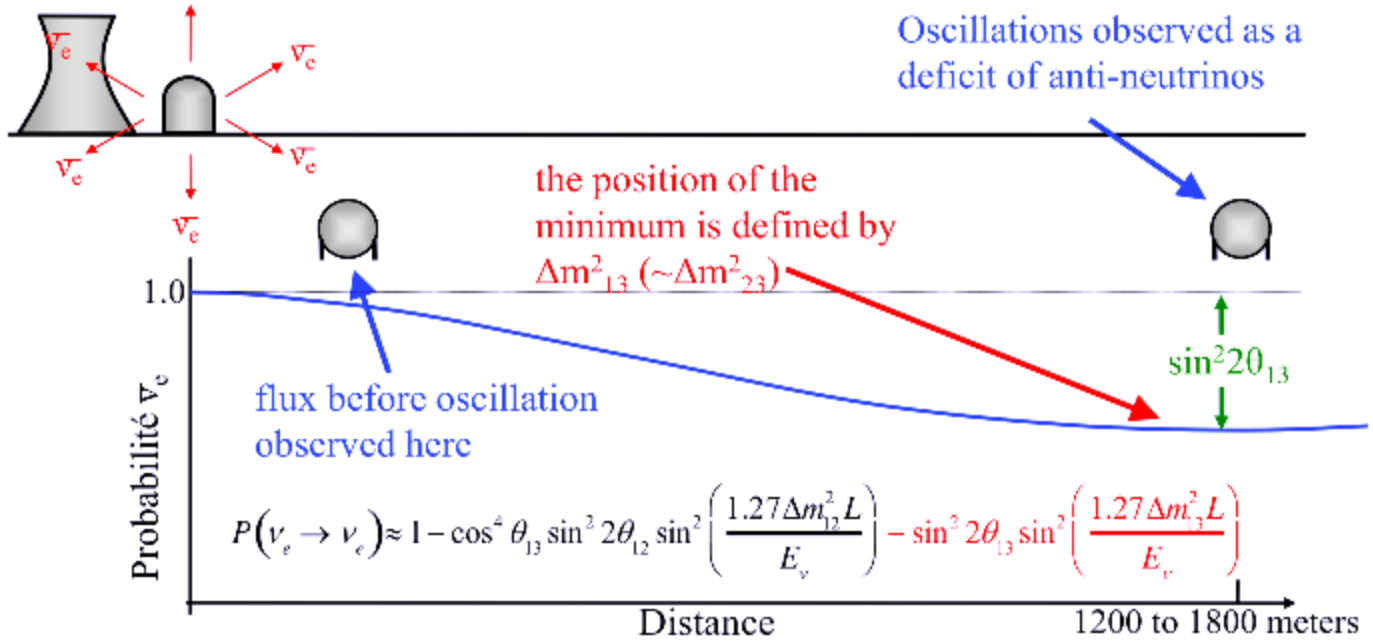
RENO

(Reactor Experiment for Neutrino Oscillation)

- Primary goal: Measurement of θ_{13}
- August 2011~ March 2023



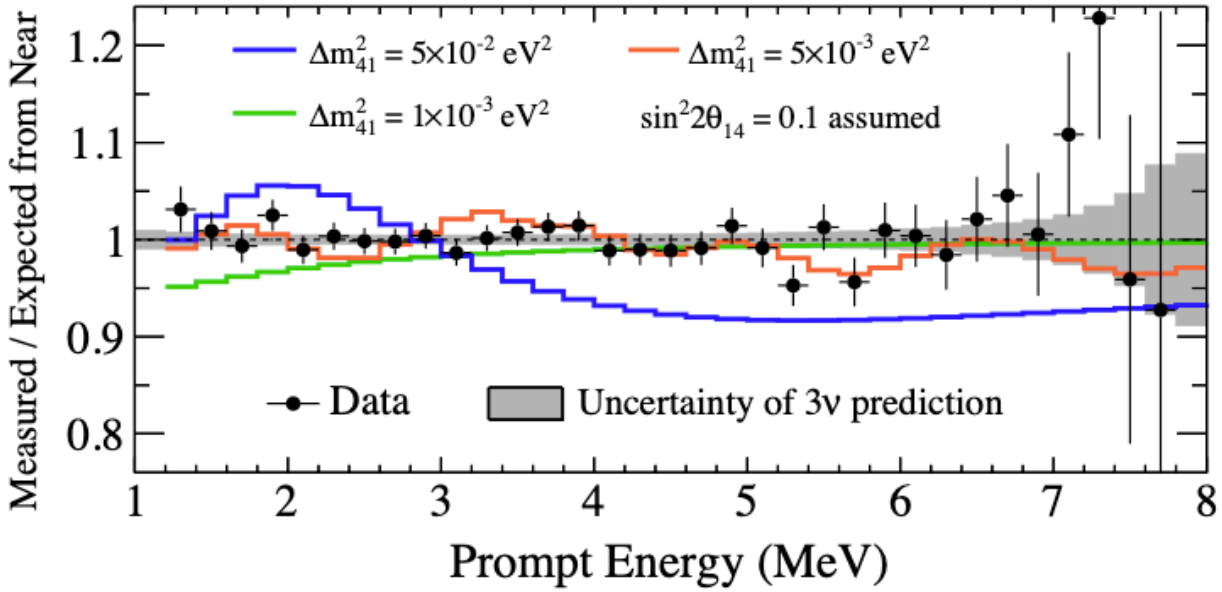
Hanbit Nuclear Power Plant Complex
6 Reactor array
2.8GW$_{th}$/reactor

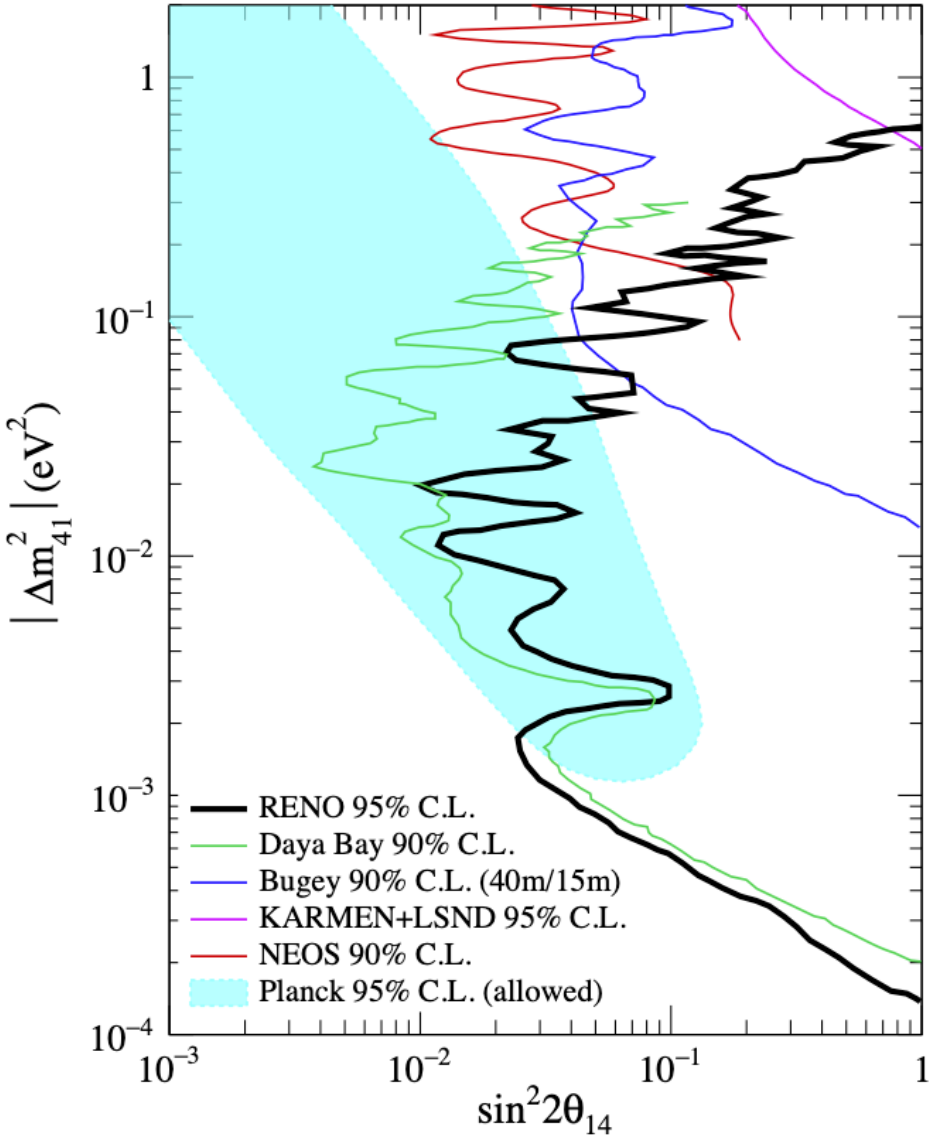


RENO results for sterile neutrino

- Search for Sub-eV sterile neutrino in the 4 ν framework.

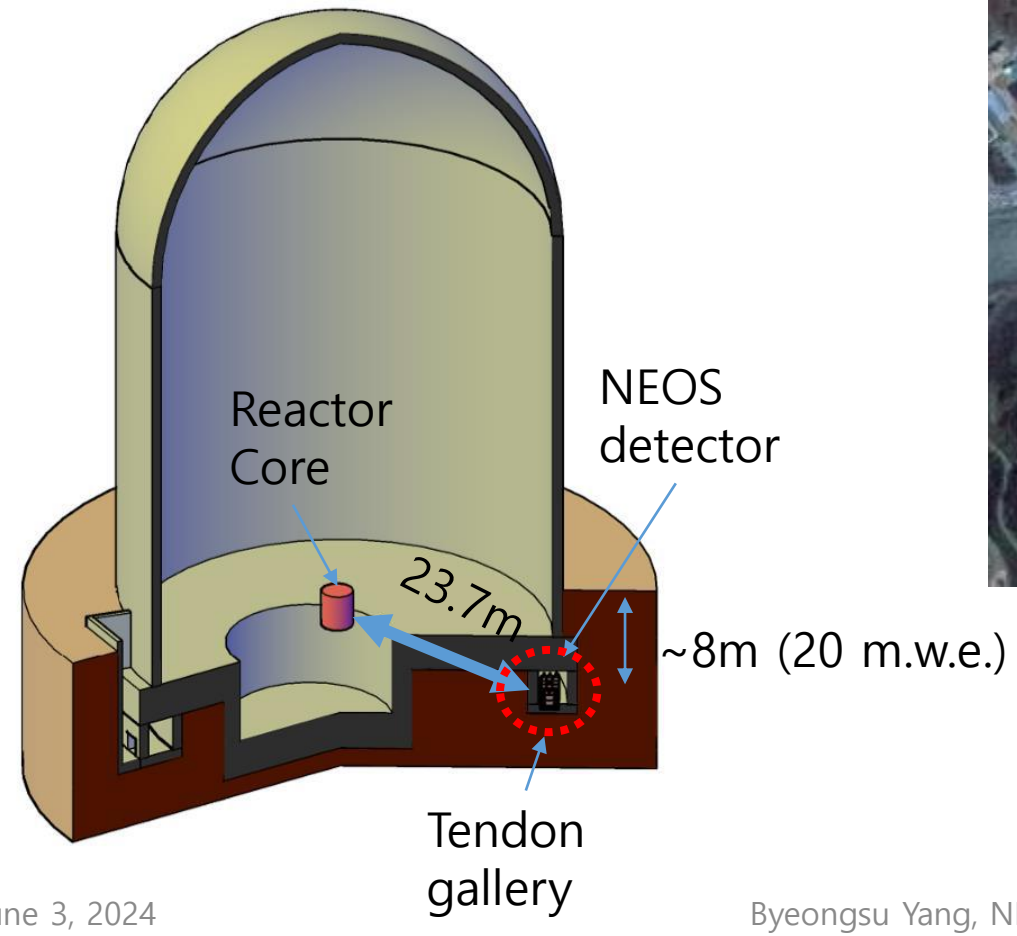
PRL 125 (2020) 191801

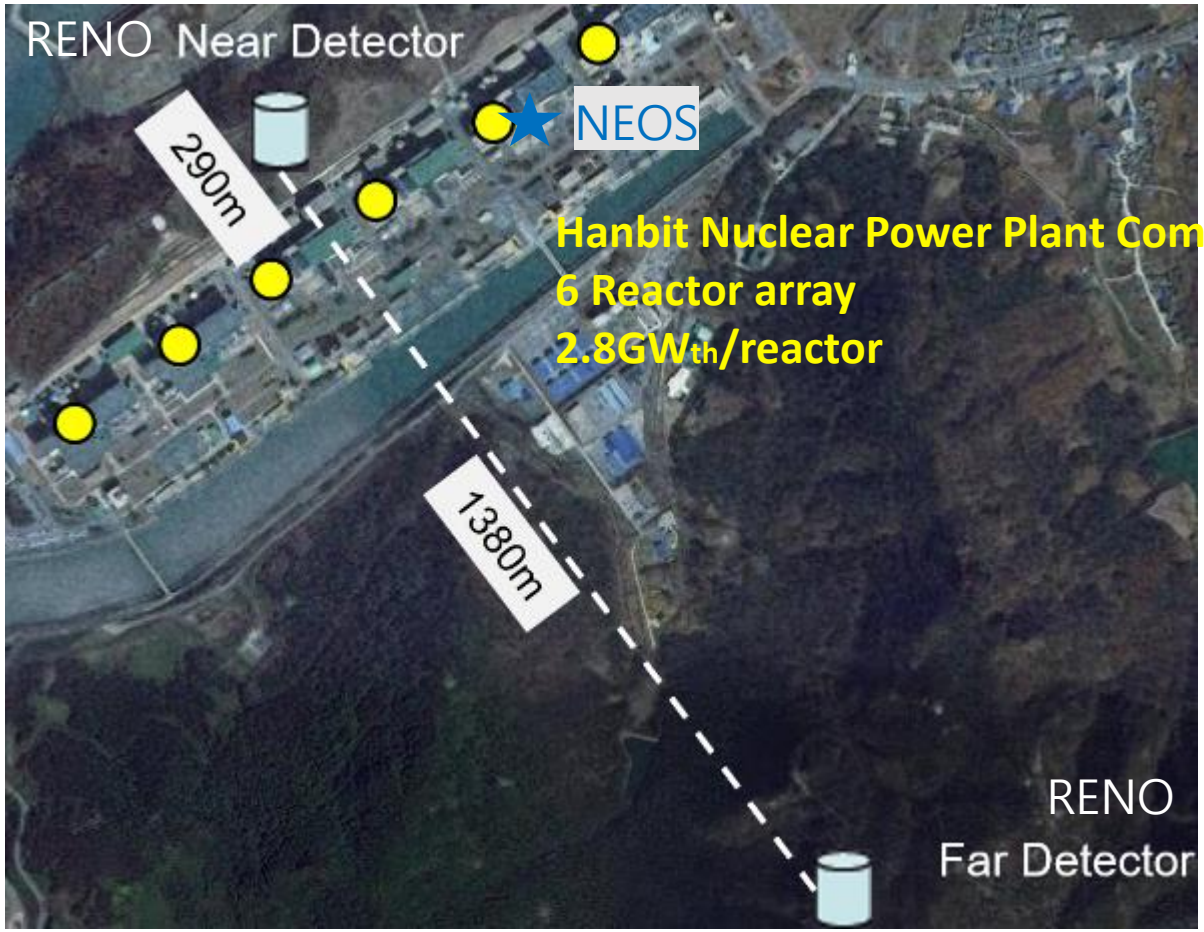




NEOS

(Neutrino Experiment for Oscillation at Short baseline)

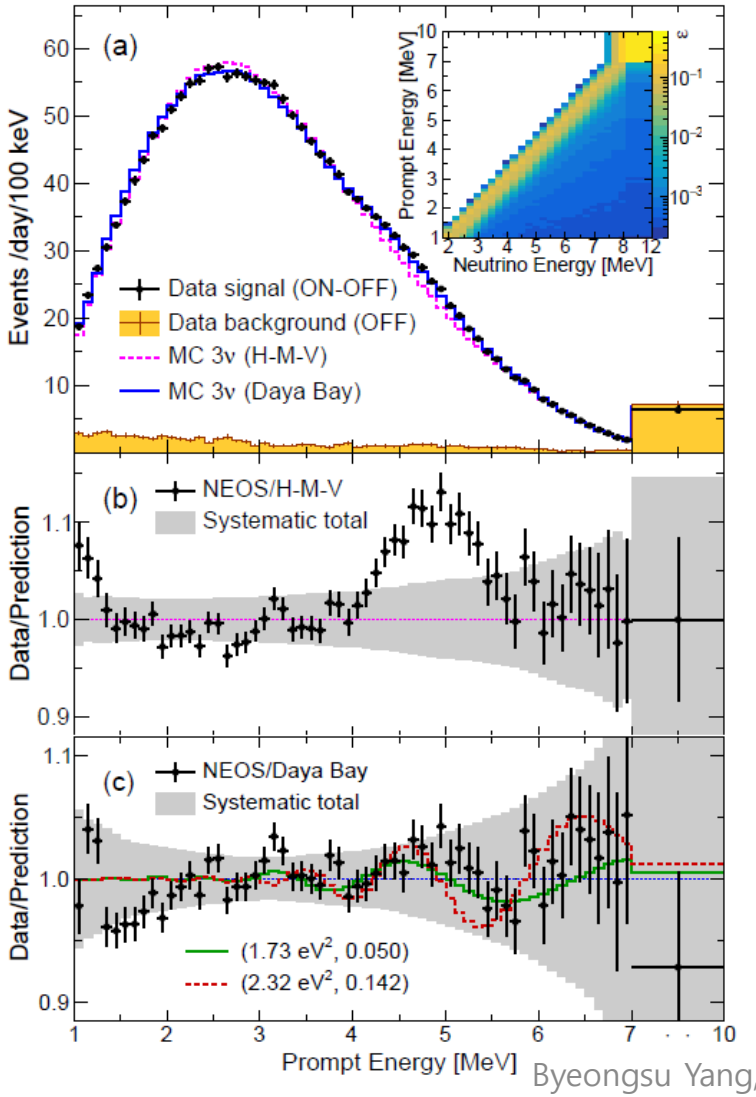


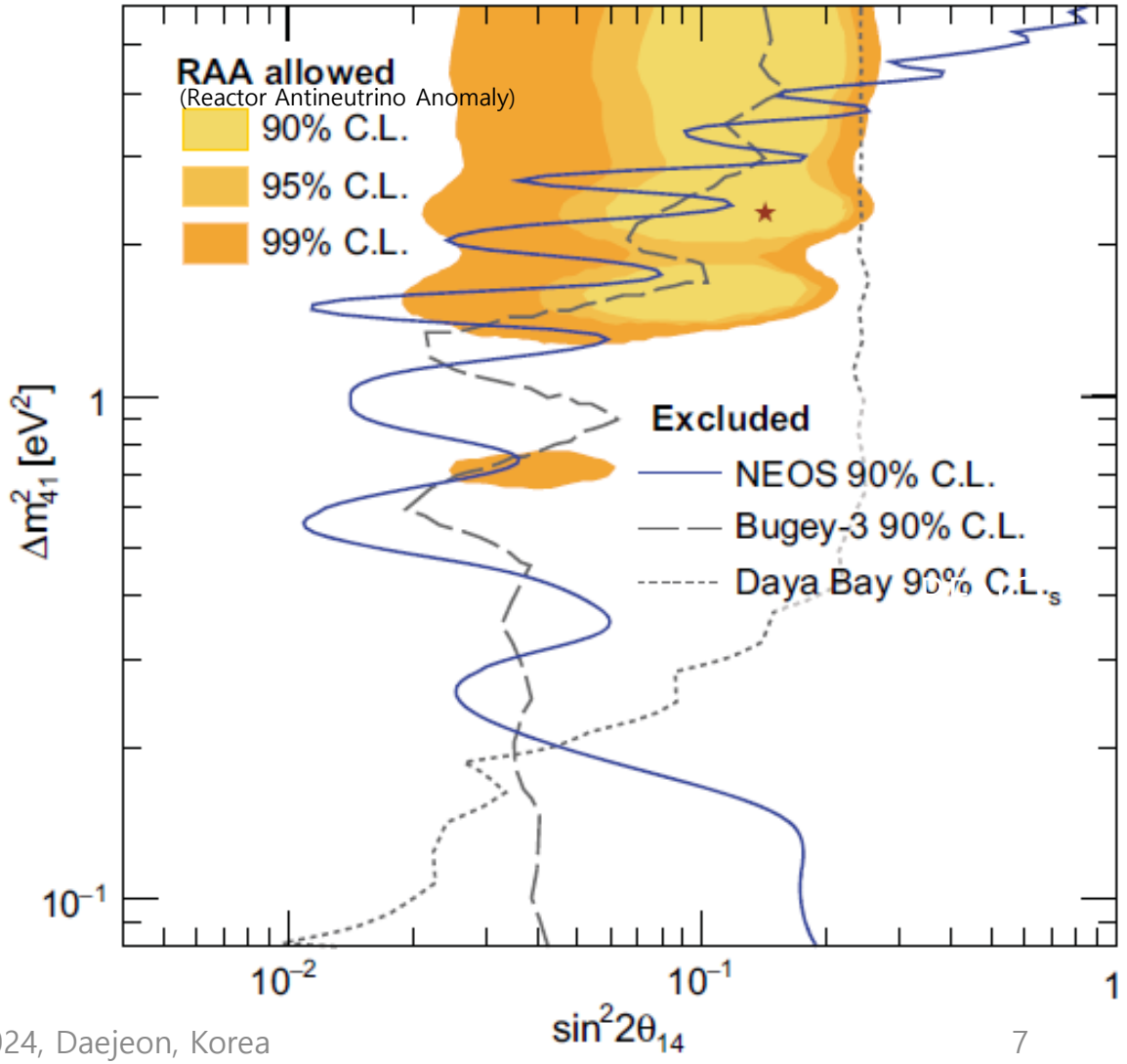


- Primary goal: search for eV scale sterile neutrino in the 4 ν framework.
- NEOS-1: Aug. 2015 - May 2016
- NEOS-2: Sep. 2018 ~ Oct. 2020

NEOS Result for sterile neutrino

PRL 118 (2017) 121802



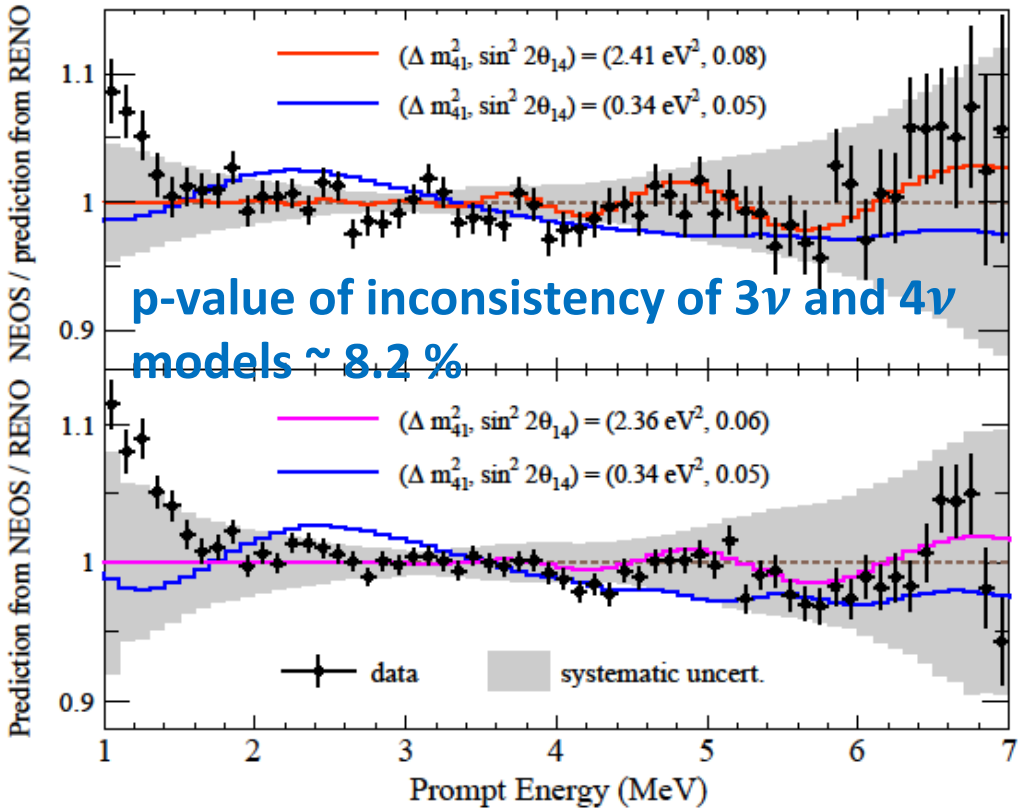


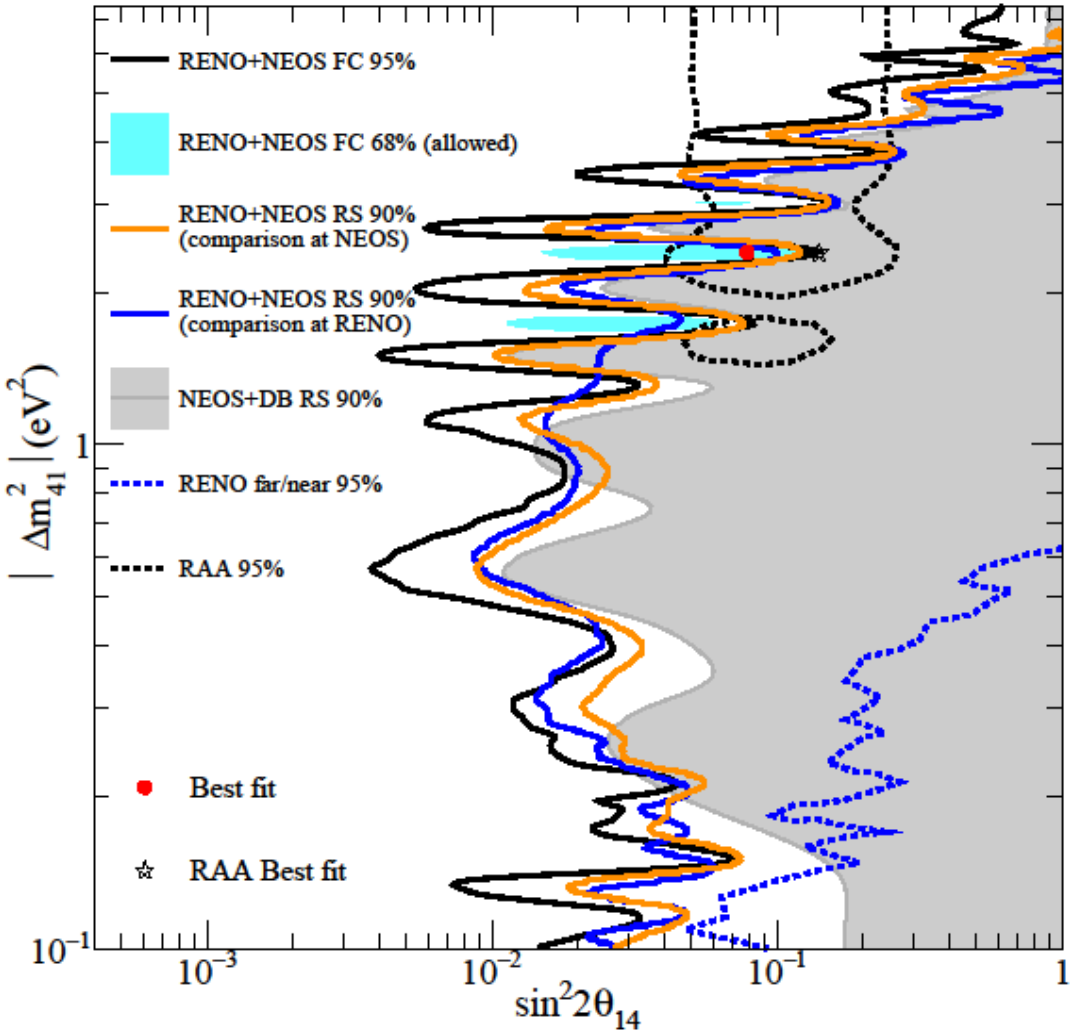
Motivation of RENE

PRD 105 (2022), L111101

RENO and NEOS joint analysis

Hint for the sterile neutrino at $\Delta m^2_{41} \sim 2\ eV^2$.



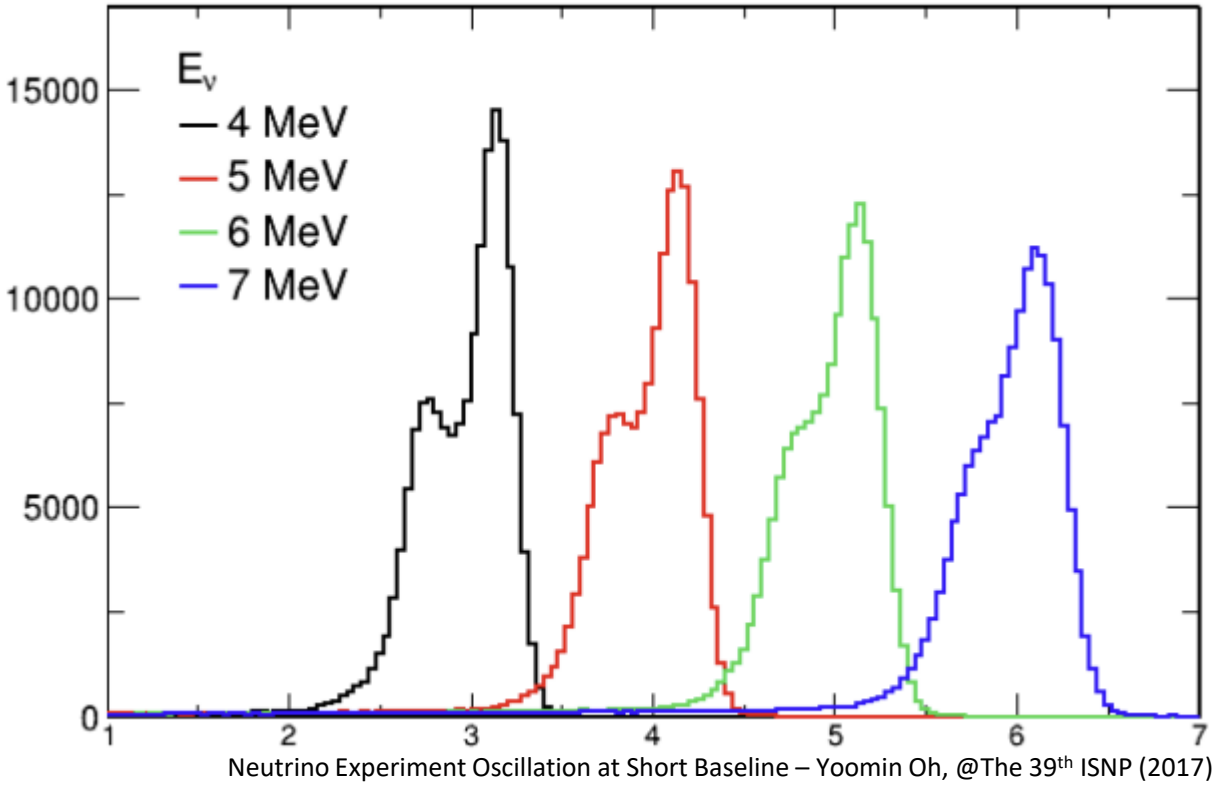


- To confirm θ_{14}, need to **improve systematics.**

Motivation of RENE

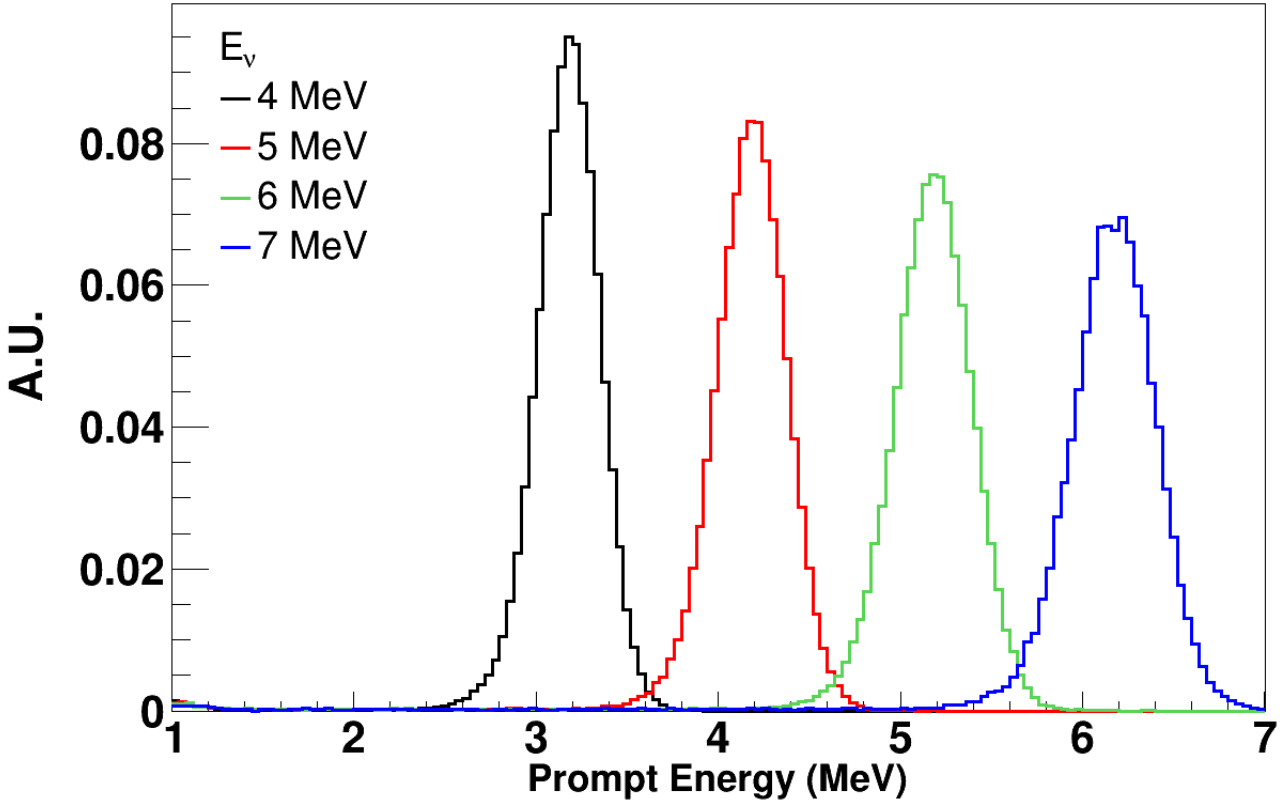
✓ NEOS and RENO **detector responses** to monochromatic ν energies.

- **NEOS**



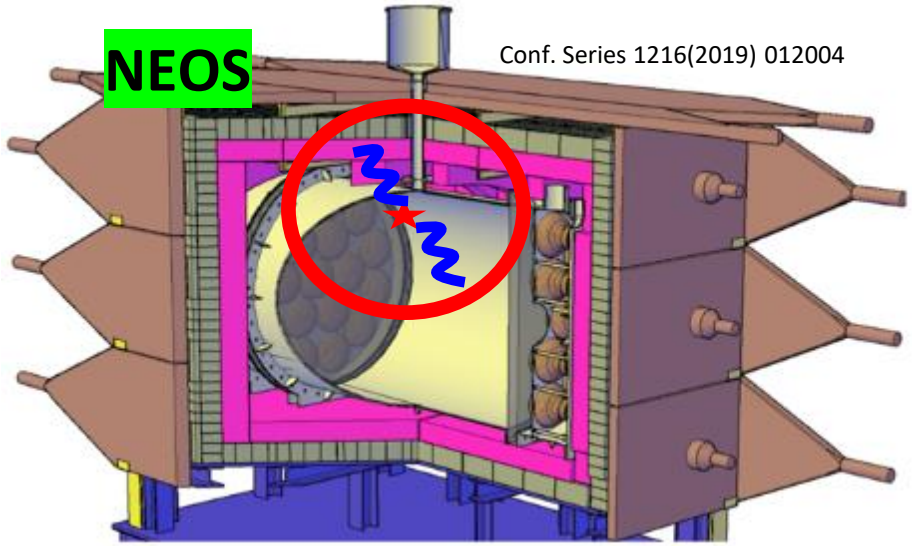
Neutrino Experiment Oscillation at Short Baseline – Yoomin Oh, @The 39th ISNP (2017)

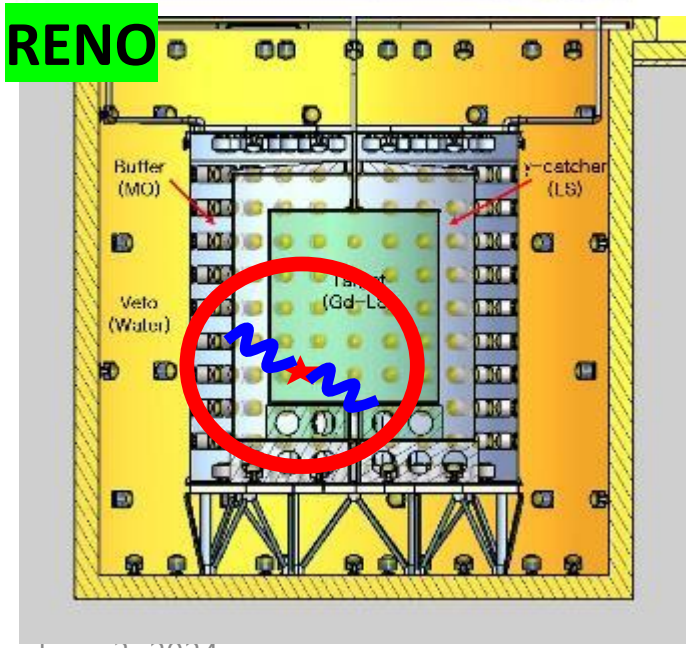
- **RENO**



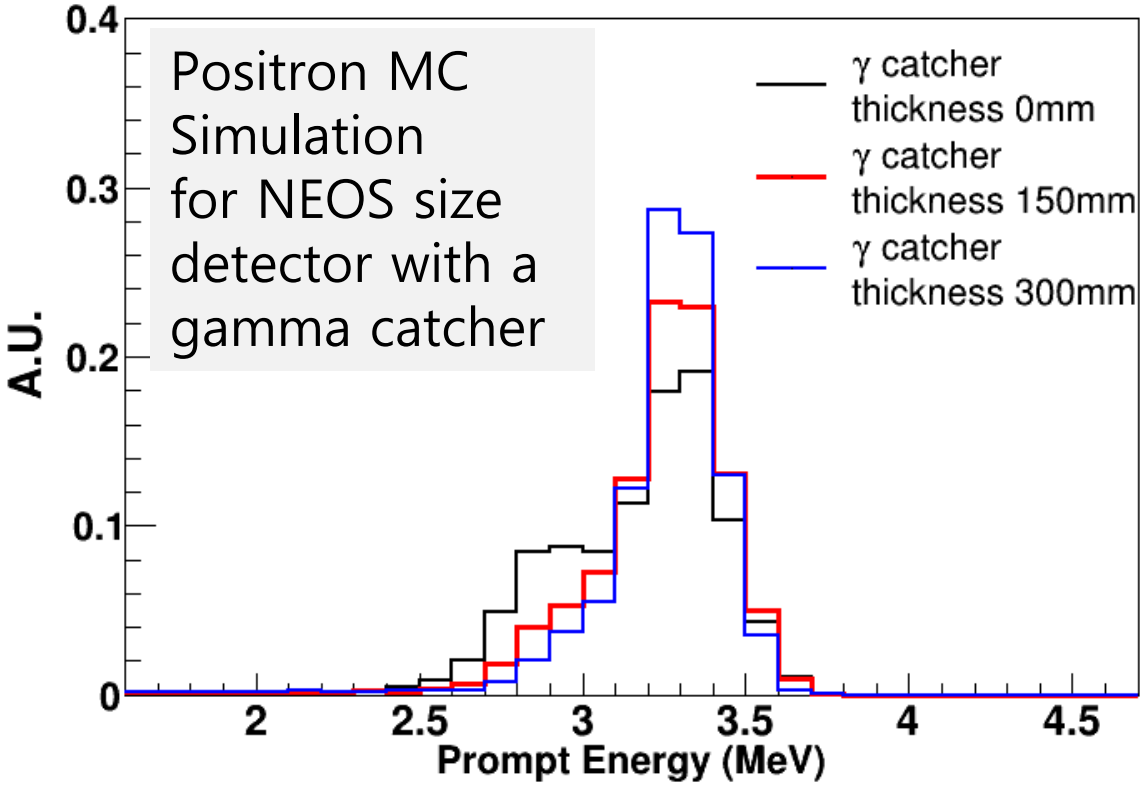
- NEOS detector has **2nd peaks** below the main peaks.

Motivation of RENE

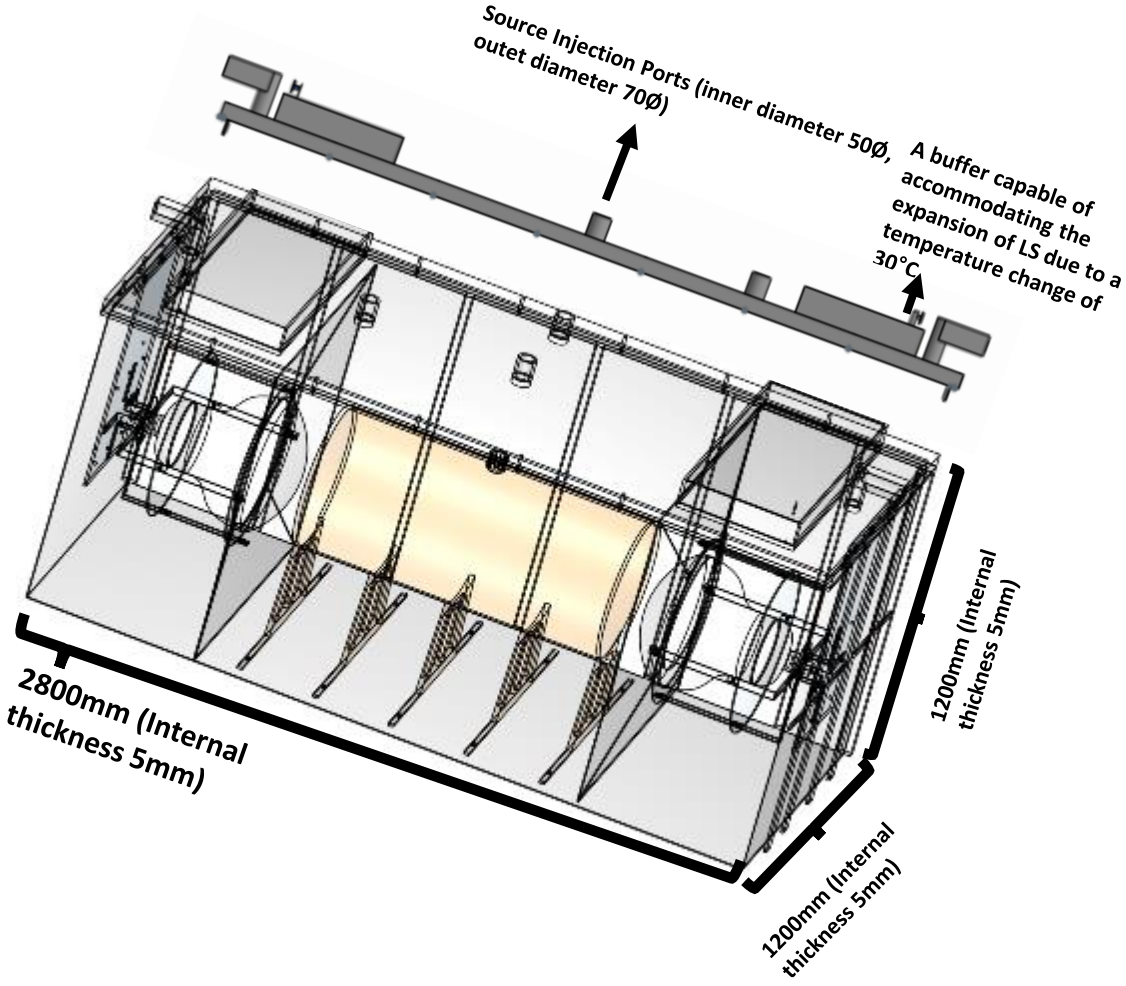




- **Escaping gammas** make the 2nd peak.
- The NEOS detector doesn't have gamma catcher different from the RENO detectors.
- To improve the energy resolution, RENE detector will have a gamma catcher.

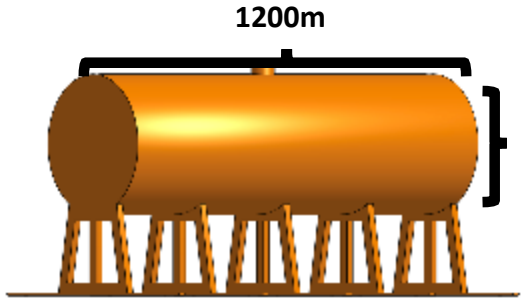


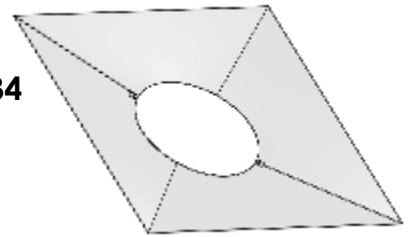
Prototype Detector Design

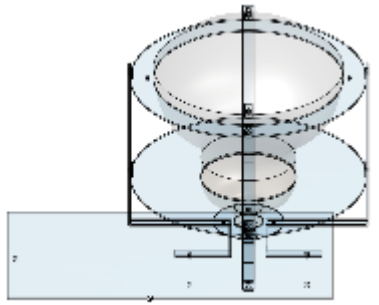


Detector inner structure

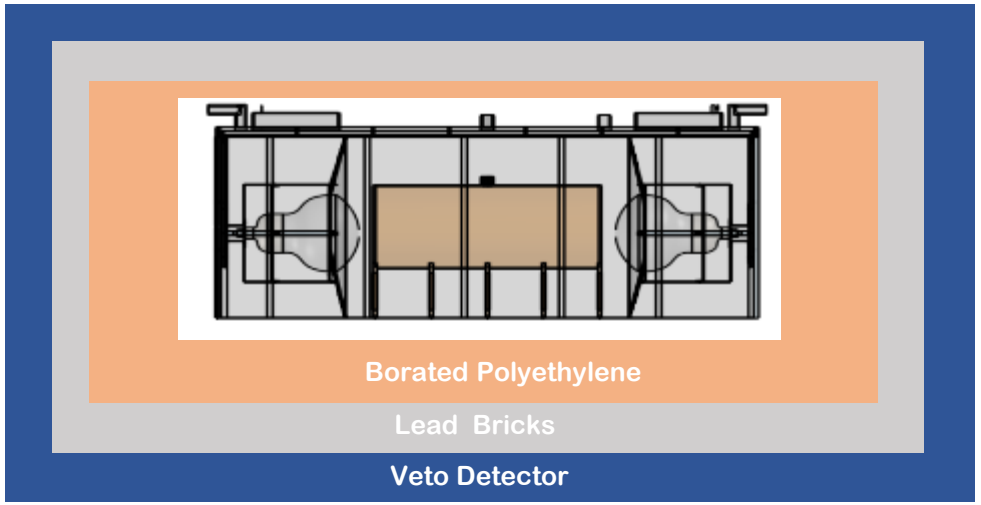
- Cylinder shape acrylic target filled with 0.5% Gd-LS.
- Box shape stainless gamma catcher filled with LS.
- Cone structure for optical photon collection.
- Two 20-inch PMTs on left & right.
- PMT holder with Mu-metal shield.

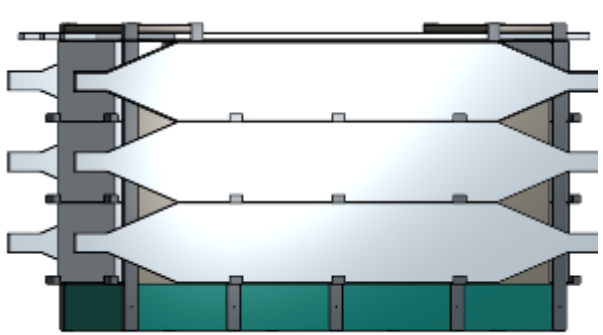


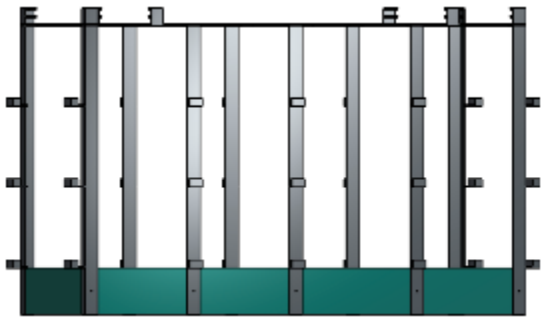


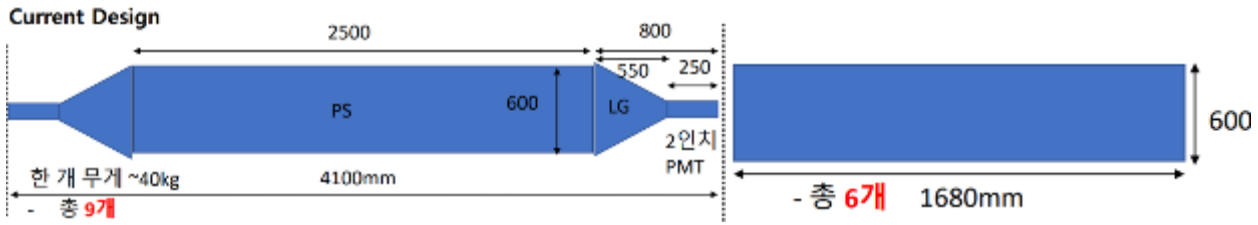


Prototype detector shielding structure









Detector outer structure

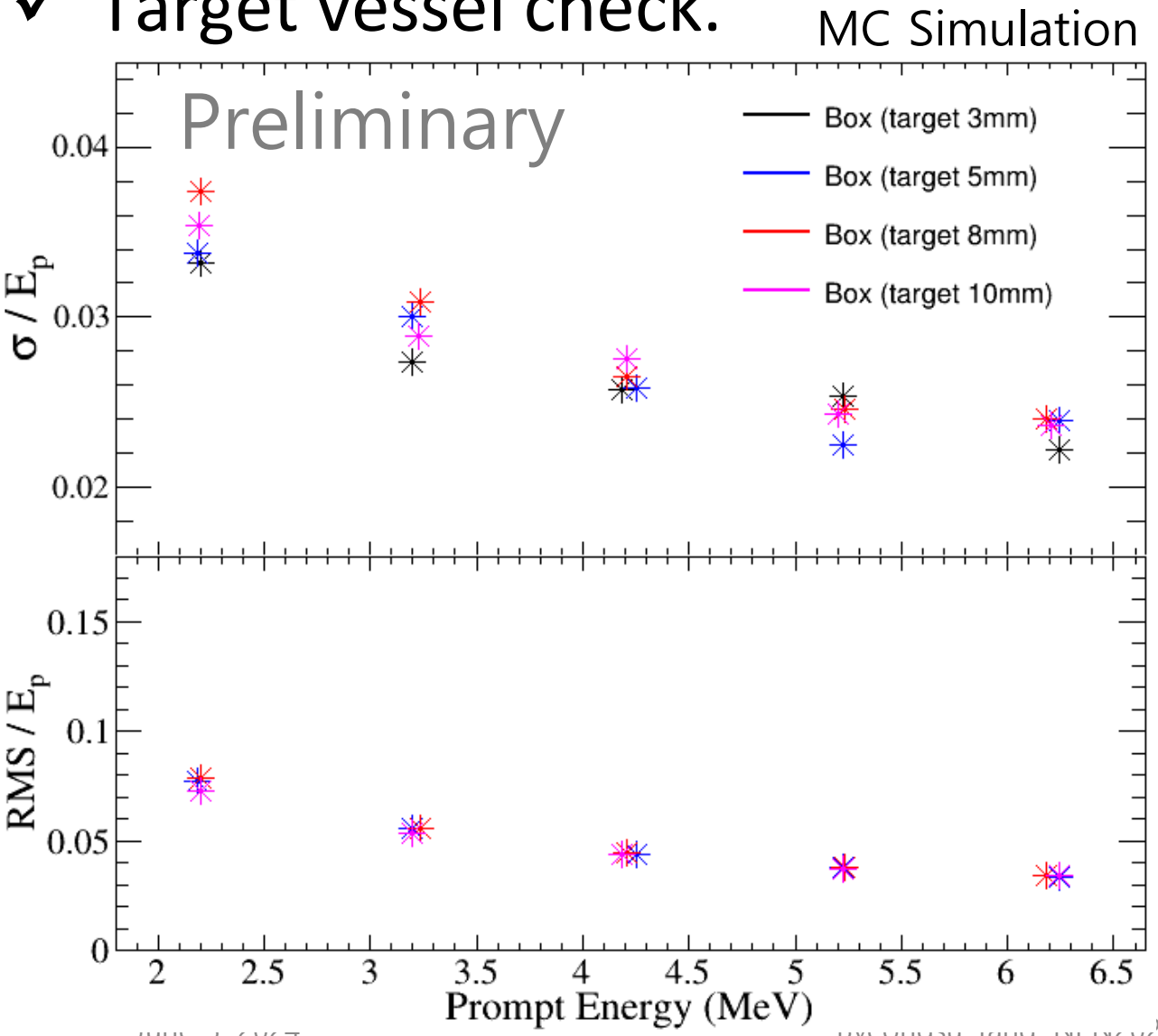
1. Shielding
   - Six borated PE plates with 100 mm thickness
   - ~3,300 lead bricks with 100 mm thickness
2. Veto
   - 15 plates of plastic scintillators from the NEOS collaboration.
   - Thirty two 2-inch PMTs.

Prototype detector Construction

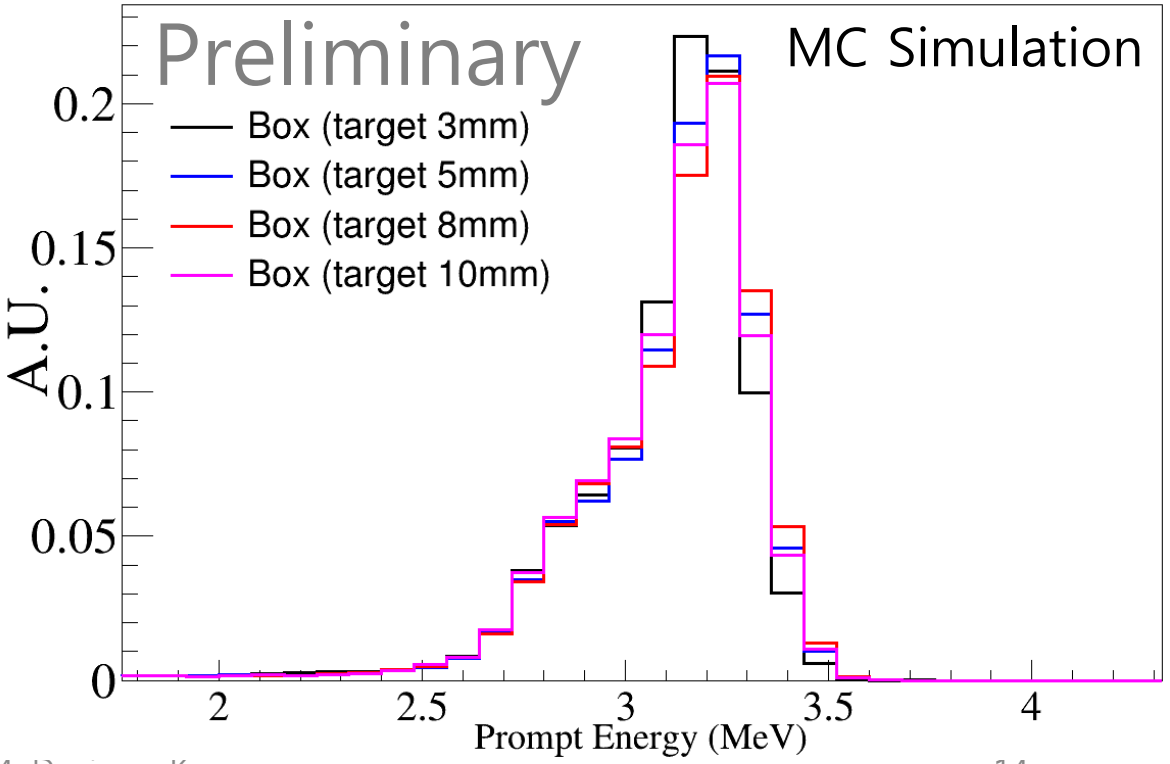
- Manufactured the stainless gamma catcher and PMT holder in 2024. 04. 15
- Currently in the process of manufacturing the acrylic target.

Prototype detector simulation

✓ Target vessel check.



- The thickness of the target acrylic vessel is **not significant**!
- We decide to make **8 mm-thick target vessel** for the safety reason.



Liquid Scintillator

- The target will be filled with 0.5% Gd-LS. DIN will be added for pulse shape discrimination.
- The gamma catcher will be filled with LS.

- Last summer, ~210L 0.6% Gd-LS was made. More LS will be made for gamma catcher and Gd-LS dilution.

- **Checked the stability of high-concentration Gd-LS, light yield, and so on.**

<0.6% Gd-LS>

Liquid Scintillator production

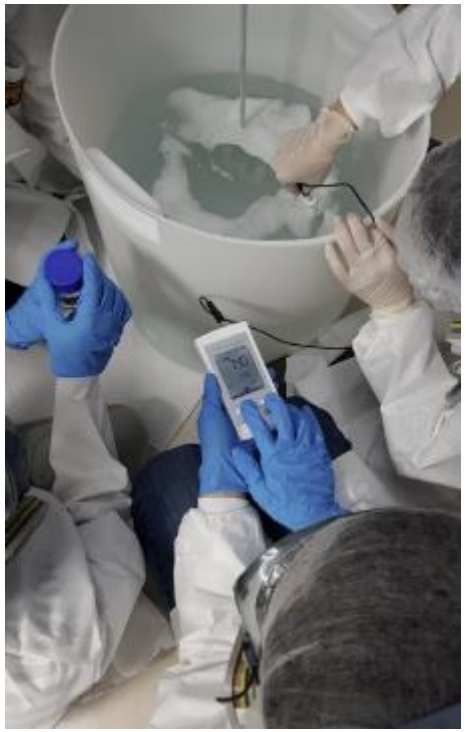
Replaced the broken motors

- At RENO far site

- For safety, newly make a production tent with the ventilation system.
- Refurbish the Gd-LS production line.

Liquid Scintillator production

- At RENO far site

- After the refurbishment, about 10 members made Gd-LAB from July 25 to August 10 in 2023.

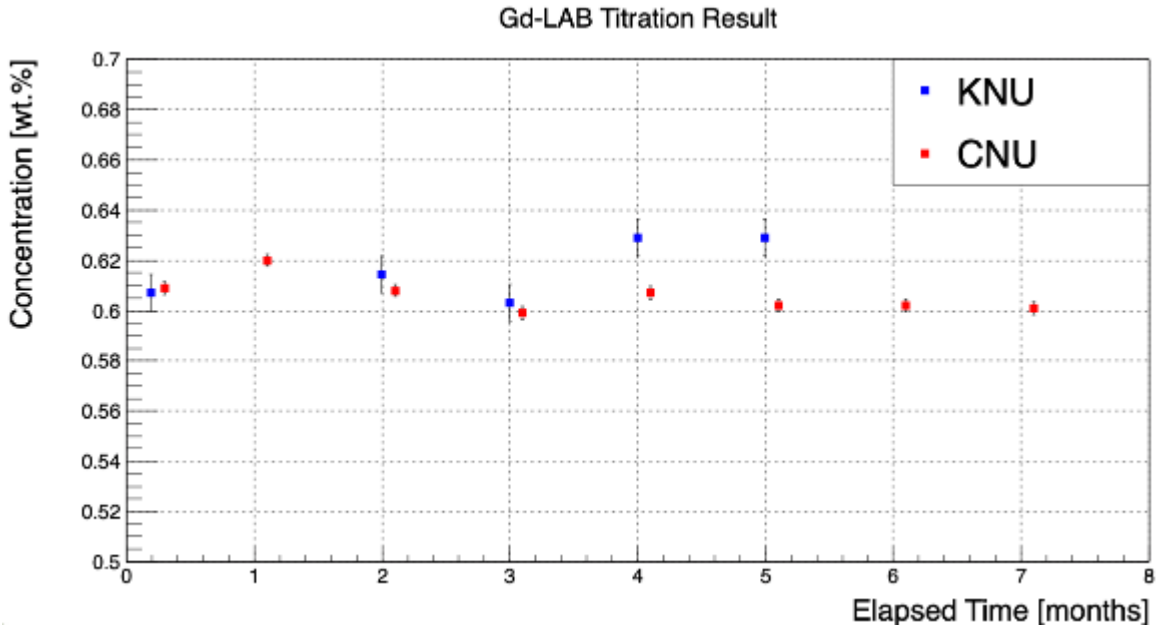
Liquid Scintillator Stability

Stability test result

- The Gd-LAB is stable even at a high concentration of 0.6% over 7 months

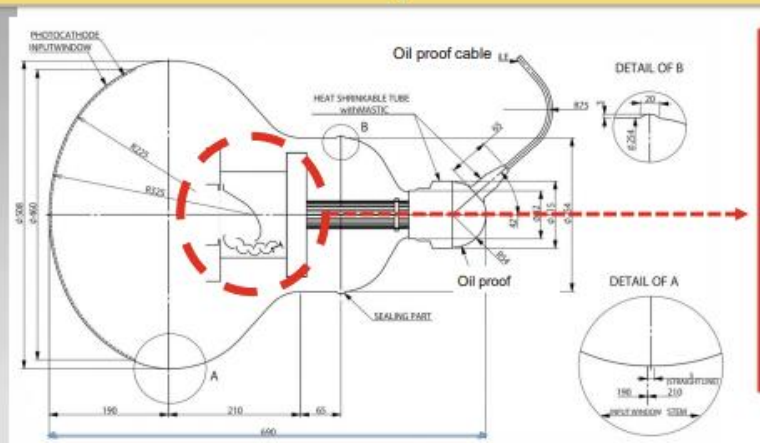
Plan

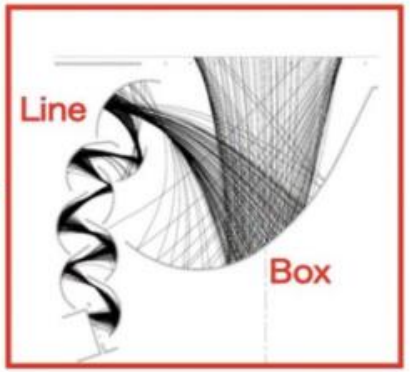
- Manufacturing the samples with different types and amounts of DIN additives, and checking stability.



PMT test for RENE prototype

20" PMT R12860 specifications

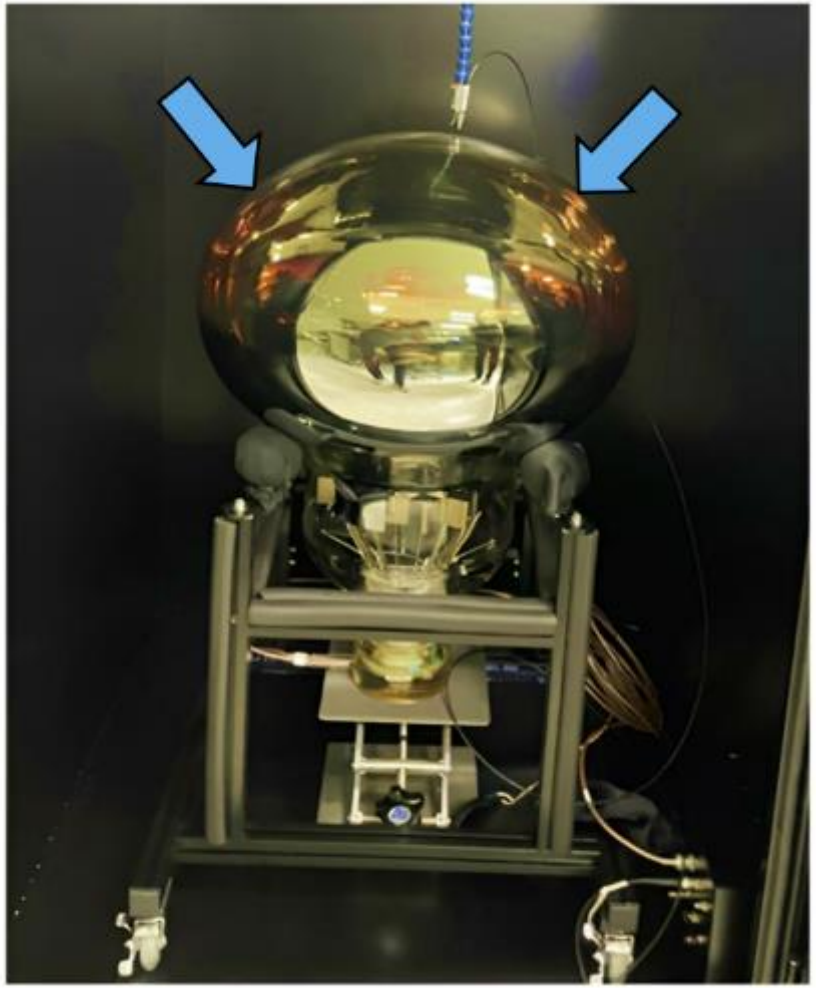




- **Specifications (Typ.)**
- **- Spectral response: 300nm to 650nm / λ_{peak}: 420nm / Peak to Valley: 1.5~2.8**
  - Gain: 1×10^7 1.6pC / Applied voltage: 2000V (Temp.: 25 ℃)
- **Dynode structure**
  - Box (Efficient collection) & Line (uniform drift path) dynode
- **Features**
  - Fast time response & High stability
  - Quantum efficiency: 30%

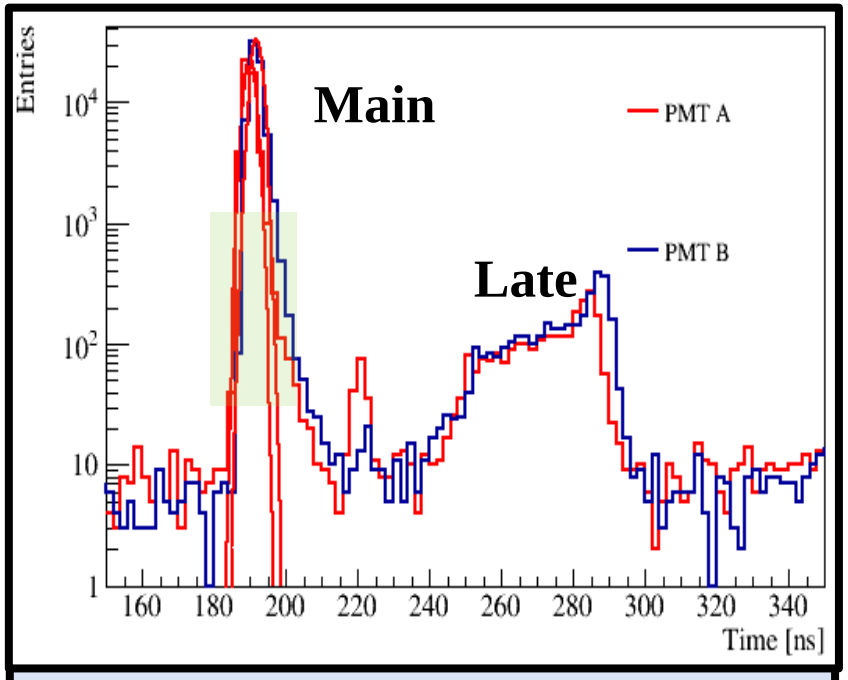
ref. Hamamatsu handbook

PMT Test bench



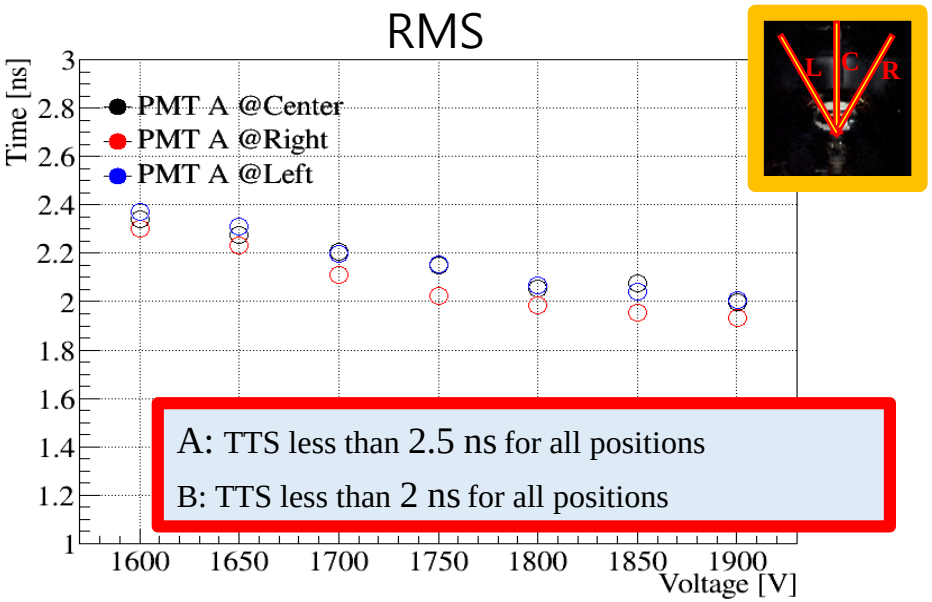
PMT timing response

Time response



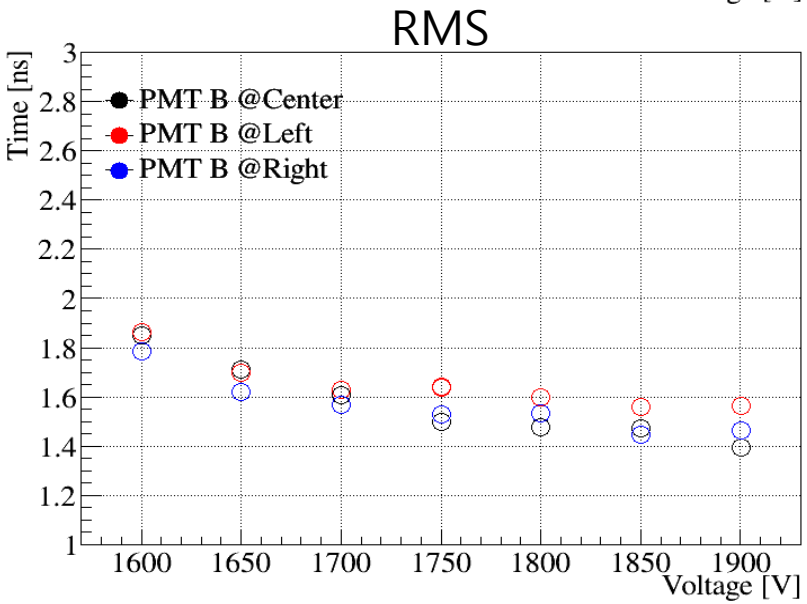
- Main Time response (A): **189 ± 0.0078 ns**
- Main Time response (B): **191 ± 0.0072 ns**
- Late Time response: **Main + 100 ns**
- Transit Time Spread (**TTS**) ≈ **2 ns**

*Time response: Trigger time – PMT falling time



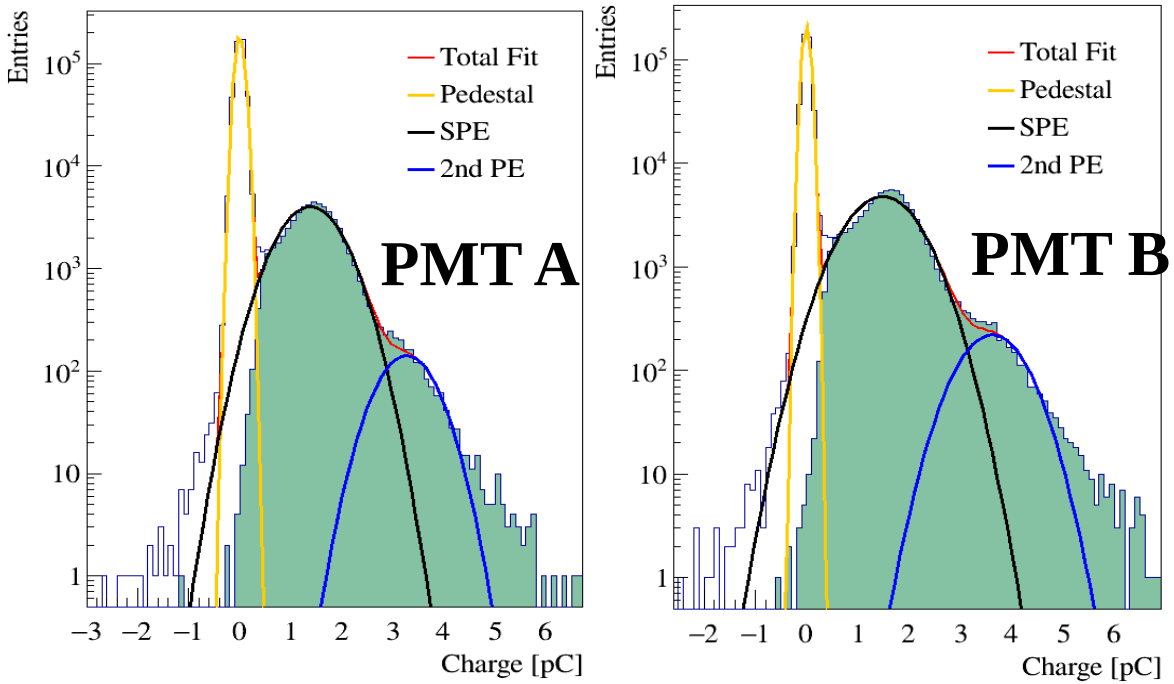
A: TTS less than 2.5 ns for all positions

B: TTS less than 2 ns for all positions

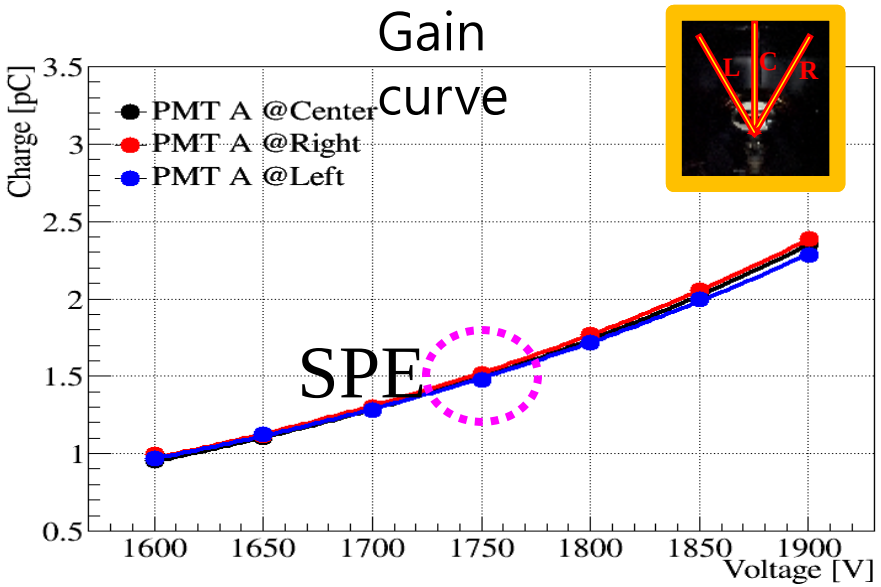


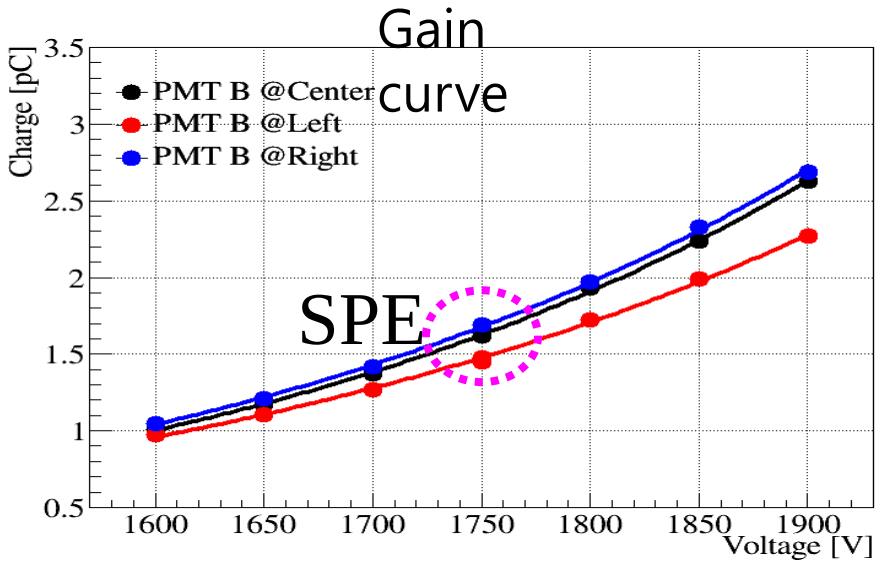
PMT charge response

Charge Distribution



- Single Photoelectron (A) **: 1.48 ± 0.0029 pC**
  Single Photoelectron (B) : **1.51 ± 0.0028 pC**
- Peak to Valley (A, B) ≈ **3**
- SPE amp./ 2PE amp.(A, B) ≈ **4 % (avg.)**
- Poisson **λ**: **1.02**





A: Below 10^7 gain, the variation within 1%
B: Below 10^7 gain, the variation within 5%

DAQ

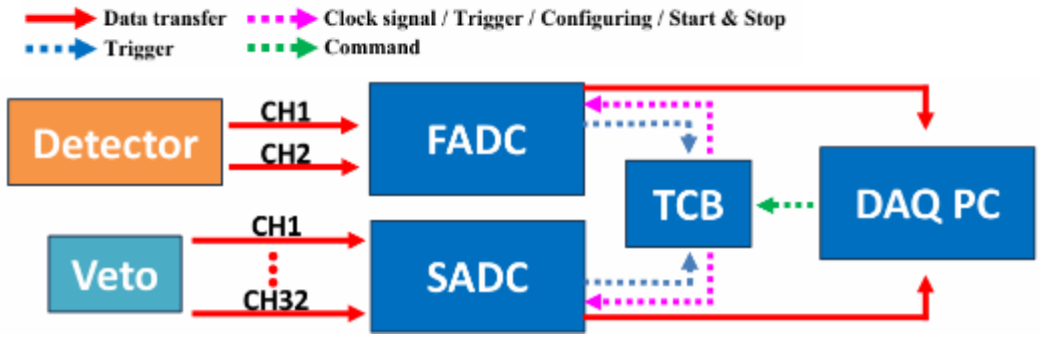
DAQ Equipment

Notice NKFADC500
- 4 + 4 channels
- ADC resolution = 12 bit
- 2.5 V_{pp} dynamic range
- Sampling rate = 500 MS/ch/s
- 4+4 GB DRAM

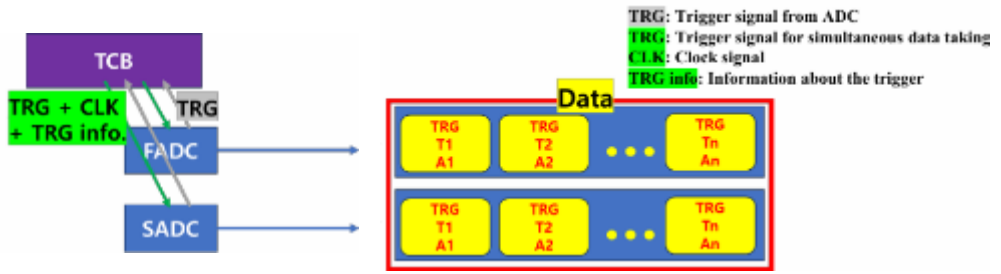
Notice M64ADC (SADC)
- 32 channels
- ADC resolution = 12 bit
- 2 V_{pp} dynamic range
- Sampling rate = 62.5 MS/ch/s
- 4 GB DRAM

Notice TCB (Trigger Control Board)
- Make trigger and clock signals
- 40 ADCs available
- RJ-45 port

DAQ schematic

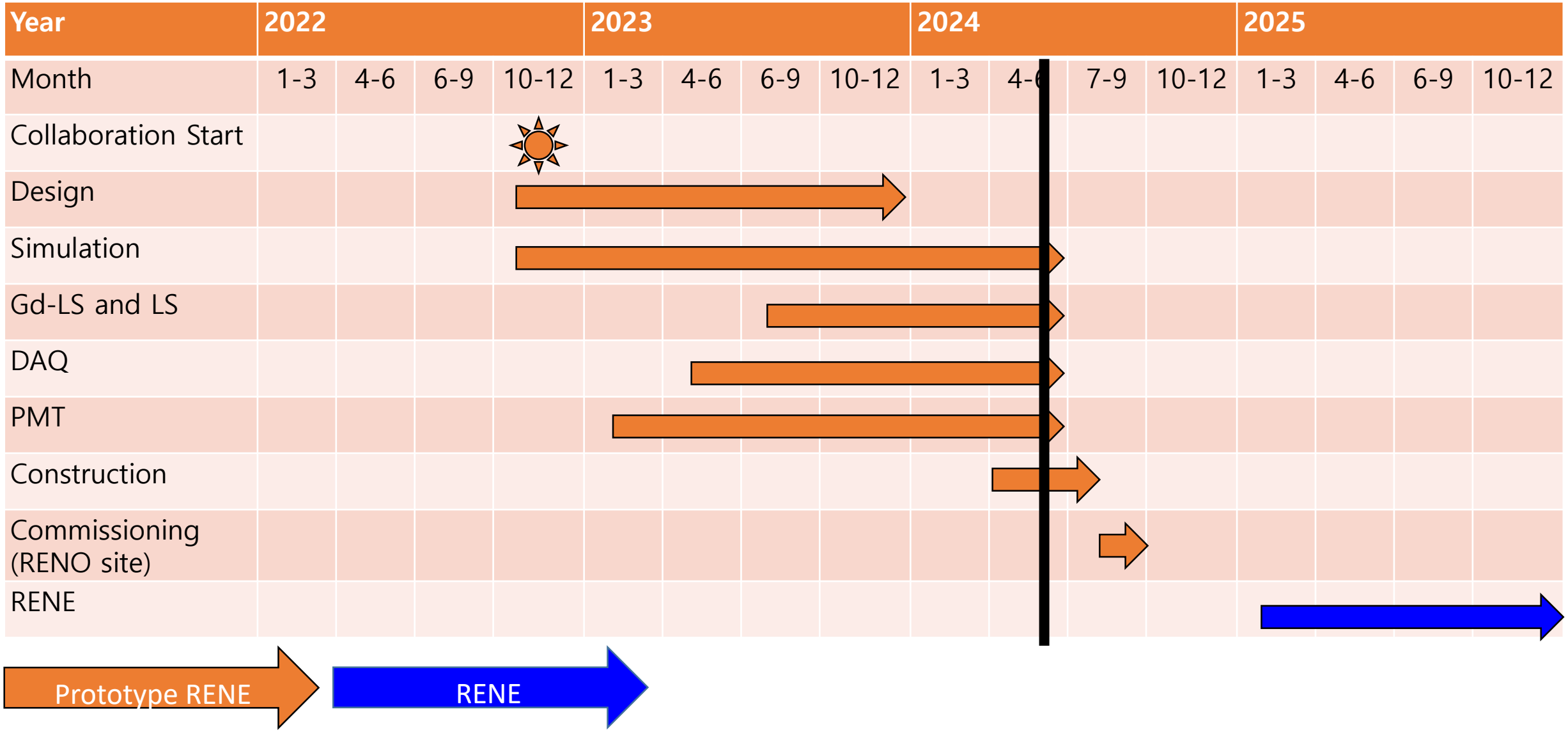


DAQ synchronization



- Utilizing the FADC, **PSD(pulse shape discrimination)** will be used.
- Utilized NOTICE's NKFADC500 and M64ADC with TCB.

Plan


Year
2022
2023
2024
2025
Month
1-3
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6-9
10-12
1-3
4-6
6-9
10-12
1-3
4-6
7-9
10-12
1-3
4-6
6-9
10-12
Collaboration Start
Design
Simulation
Gd-LS and LS
DAQ
PMT
Construction
Commissioning (RENO site)
RENE
Prototype RENE
RENE

Summary

- RENO-NEOS joint analysis shows an interesting hint for the existence of the sterile neutrino at $\Delta m^2_{41} \sim 2$ eV^2.
- RENE (Reactor Experiment for Neutrino and Exotics) collaboration aims to search for the sterile neutrino oscillation around $\Delta m^2_{41} \sim 2$ eV^2.
- To commission the prototype detector this summer, we are doing our best.