The New 1-ton Neutrino Detector at CJPL

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Workshop of Jinping Neutrino Experiment 2026

2025.07.03

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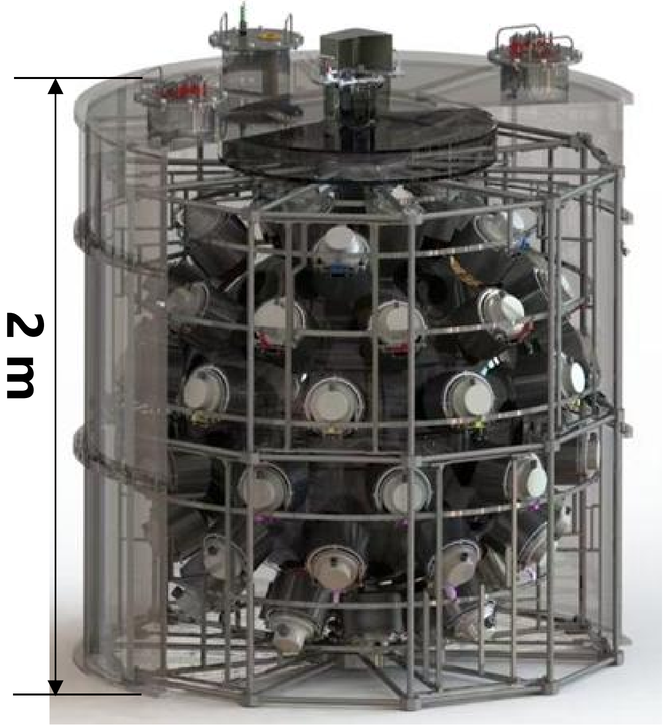
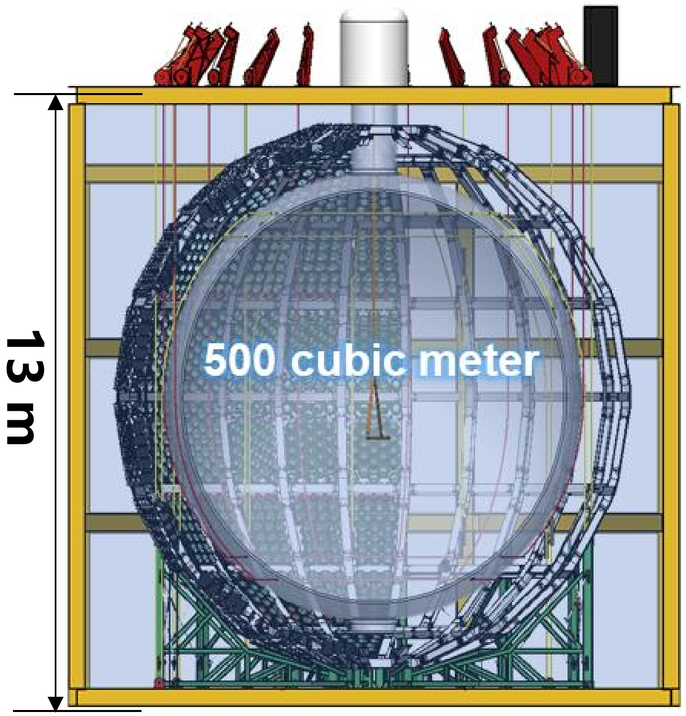
A prototype detector

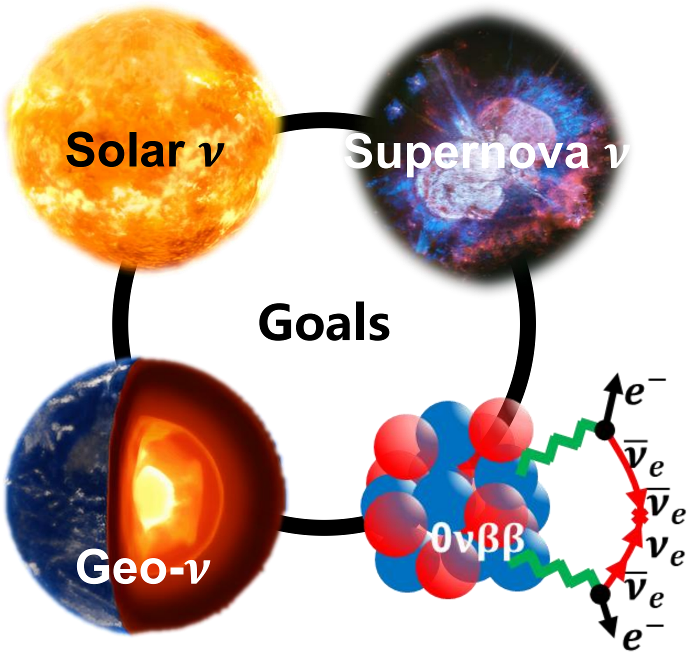
- The 1-ton detector is a small-scale prototype for the Jinping Neutrino Experiment (JNE), located in CJPL-I.
- The JNE located in CJPL-II, is a next-generation neutrino observatory, its physics goals include solar neutrinos, geoneutrinos, supernova neutrinos, and neutrino-less double beta decay.



1-ton detector



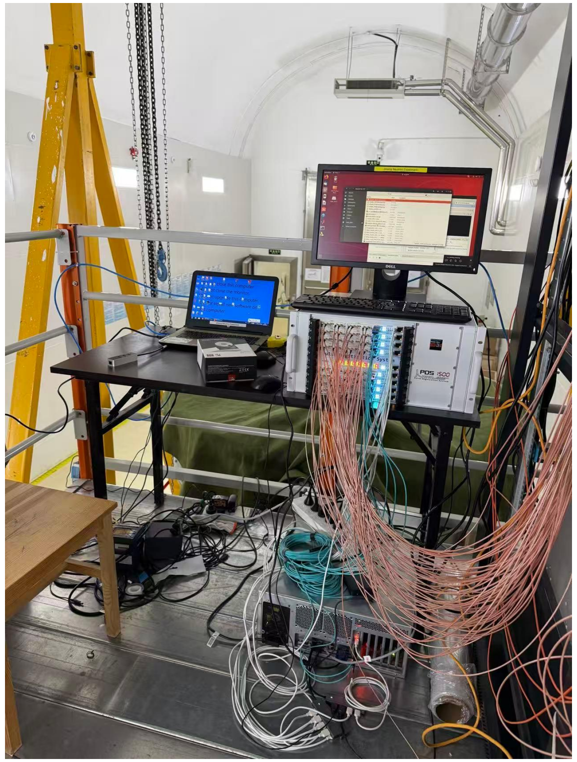
JNE



A testing platform for self-developed technologies

- **Some self-developed equipment and technologies will be applied in the JNE，with the 1-ton detector serving as the verification platform.**

- 8-inch MCP-PMT from NNVT.



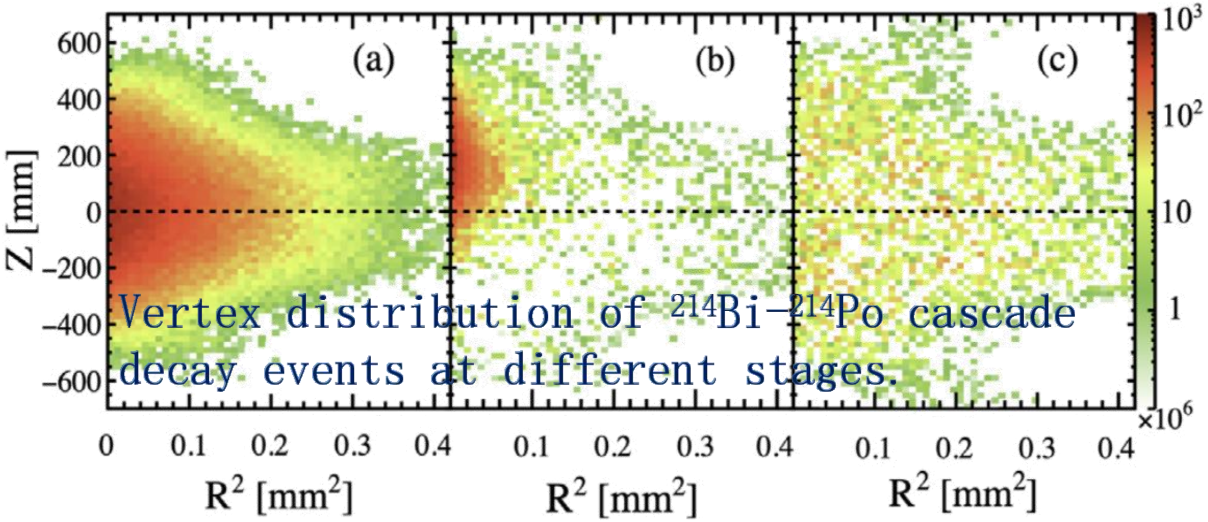
- Self-developed electronics from Tsinghua

- Self-developed liquid scintillator (LS)

A detector for measuring natural radiation and muon flux

- **The 1-ton detector, as a highly sensitive liquid scintillator energy detector, has already produced several physics results.**
- **The new 1-ton detector will further enhance its detection sensitivity.**

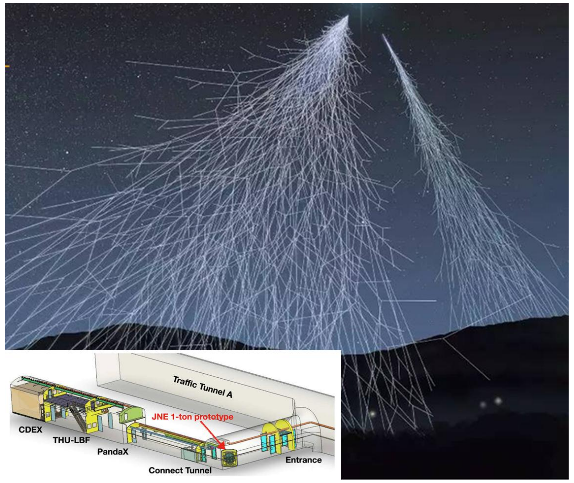
Natural radiation measurement

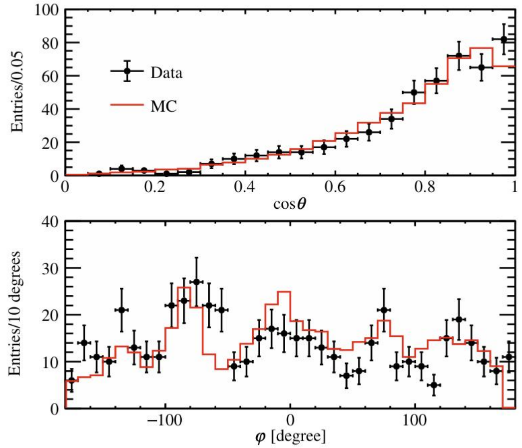


Vertex distribution of ^{214}Bi–^{214}Po cascade decay events at different stages.

PMT	• ^{232}Th→$(1.12\pm0.32)\times10^{-6}$ g/g; ^{40}K→$(4.67\pm1.35)\times10^{-8}$ g/g
LS	• ^{238}U→$(1.28\pm0.16)\times10^{-12}$ g/g; ^{232}Th→$<(2.49\pm0.50)\times10^{-13}$ g/g

Cosmic muon measurement





Muon flux measurement:
- $(3.56\pm0.16\text{stat}\pm0.10\text{syst})\times10^{-10}$ cm^{-2} s^{-1}
- ~0.4/day detected by 1-ton detector.

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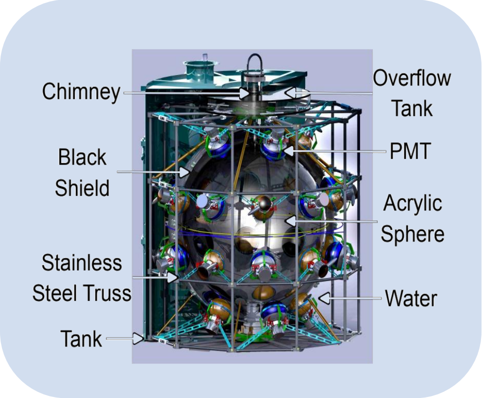
Construction of the new 1-ton detector



Pre-generation 1-ton detector	Remove Lead shielding	Disassembly	Assembly	Dry Run
2017 - 2023.9	2023.9-2024.4	2024.4-5	2024.5-6	2024.6-9

Pre-generation 1-ton detector phase:

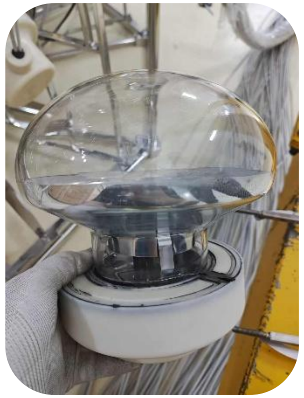
- **Only 30 PMTs from Hamamatsu**

In the process of disassembly and assembly:

- **Upgrade PMT support structure**
- **Employ 60 MCP- PMTs by NNVT.**

The PMT performance is being monitored, and the dark- noise evolution is observed over time.

Water-I and LS-I



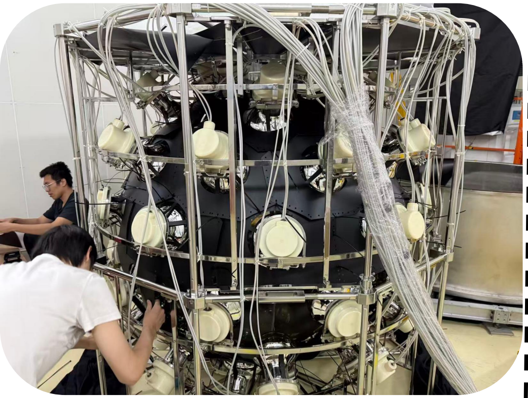
Replace PMT	Pure water filling	Water phase-I	LS filling	LS phase-I
2023.9-10		2024.10-2025.1	2025.1	2025.1-4

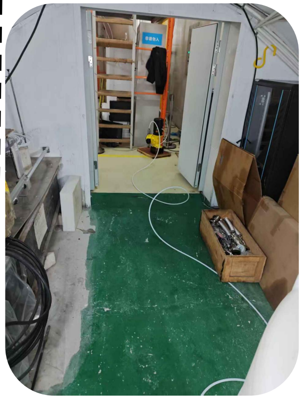
- **Replace the two faulty MCP- PMTs.**
- **Fill with pure water.**

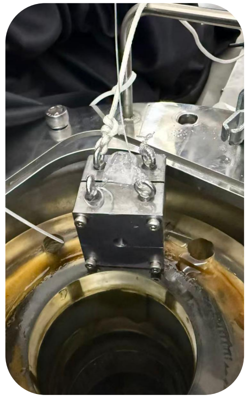
The data were employed for the measurement of the muon flux.

- **The LS was filled using a pure water displacement method.**
- **Following approximately three months of data taking, energy calibration and natural neutron measurements were performed.**

Water-II and LS-II








Light shielding	Water phase-II	LS filling	LS phase-II
2025.6	2025.6-2025.9	2025.9	2025.9-2026.1

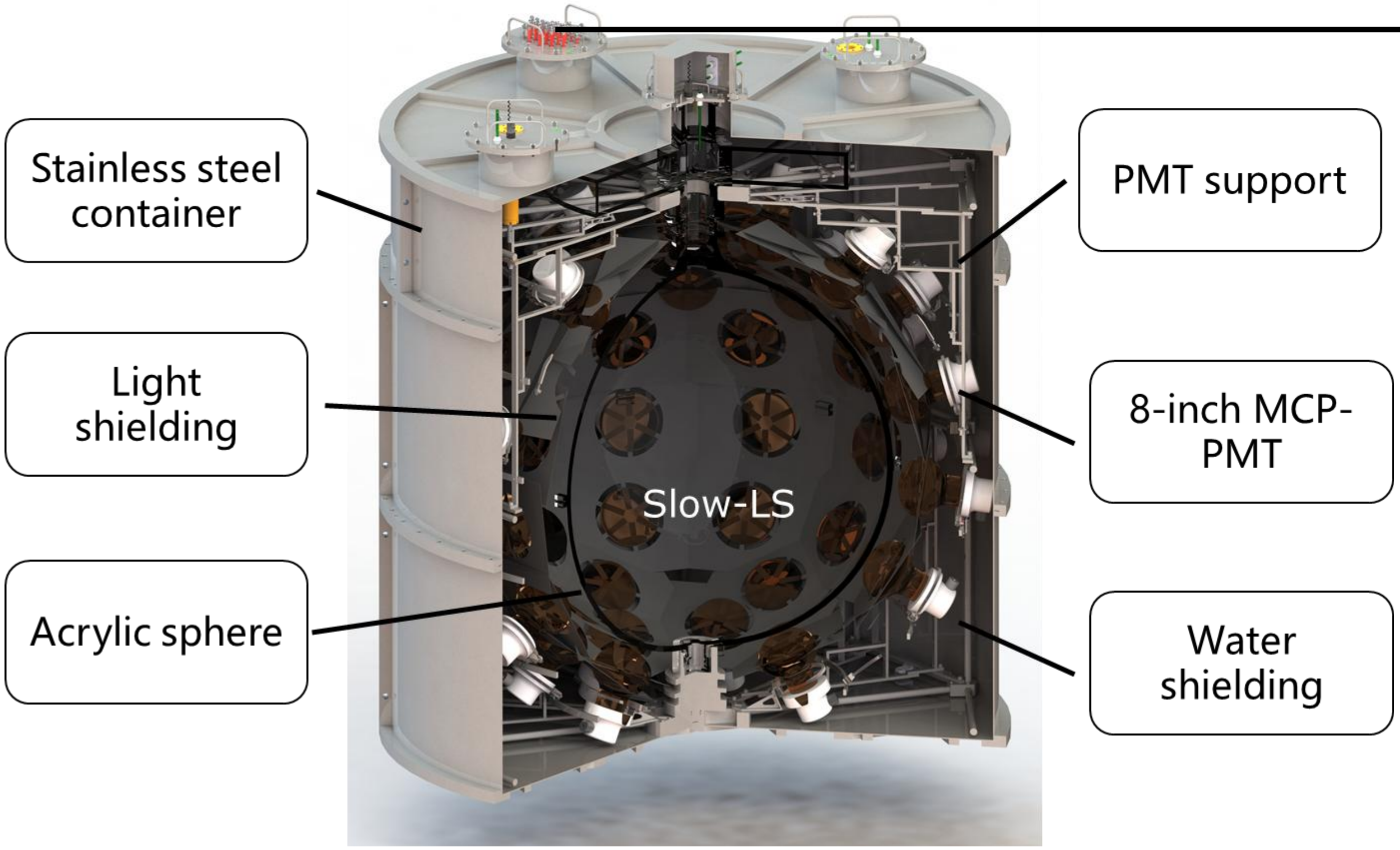
Light shielding layer is made of black PE plastic.

The data were employed for the measurement of the muon flux.

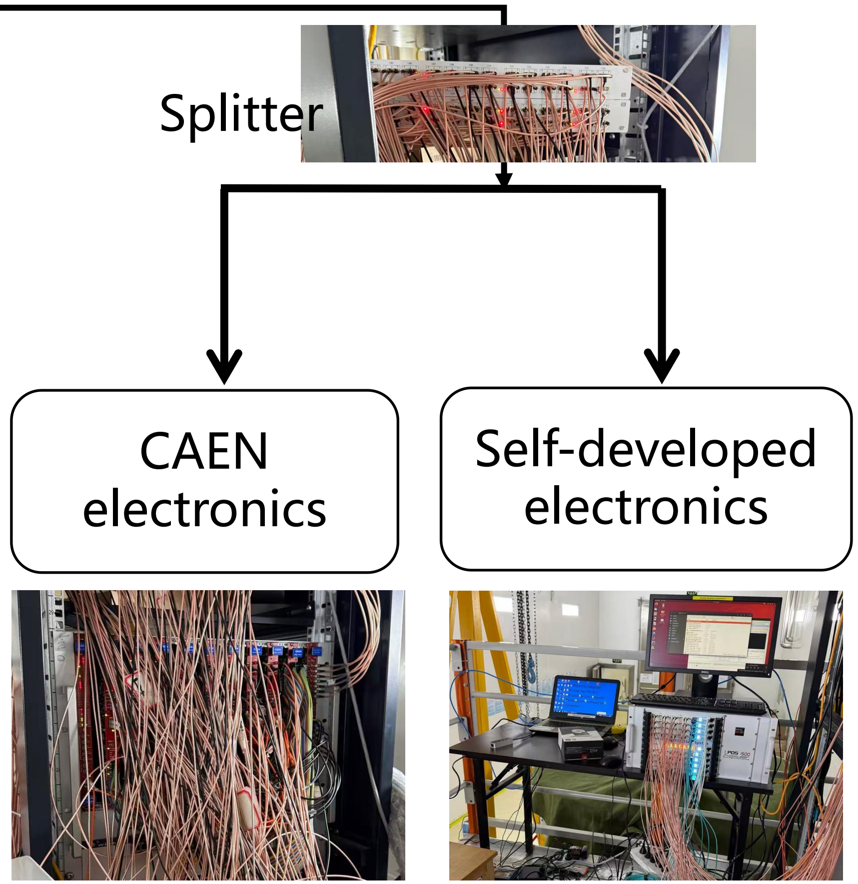
- **This phase comprised filling the LS via the pure water displacement method, performing energy calibration with an AmBe source and time calibration with an LED, and testing the self-developed electronics.**

Last Detector Status

- **Detector status during the final data-taking phase.**



Without the outer lead shielding



V1751+V1495

PDS1500

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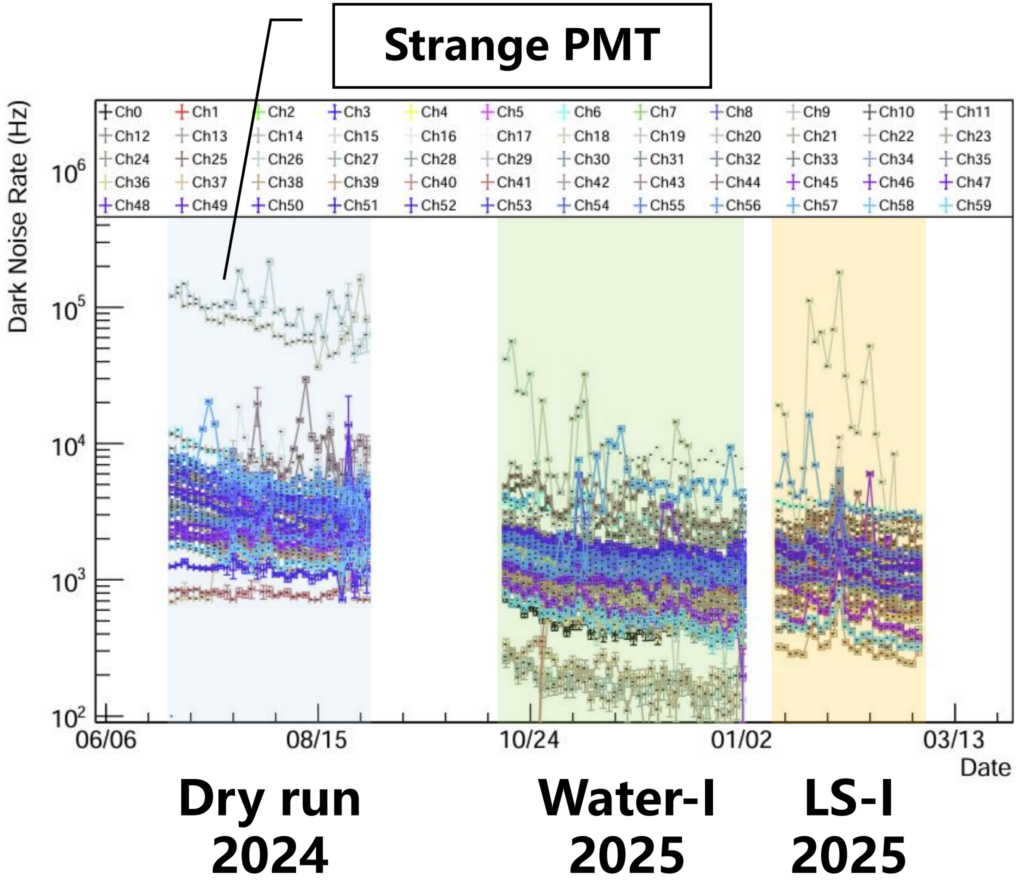
Decrease of 8-inch MCP-PMT dark noise rate

- **The dark noise rate evolution of the 8-inch MCP-PMTs was analyzed during the data phase of Dry run, Water-I, and LS-I.**

- **A clear decrease in the dark noise rate over time can be observed.**
- **The rate decreases over time, dropping to 1/3 within 8 month.**
- **The dark noise rate is 1.1kHz (2025.3)**
- **We plan to study the reason of the decrease.**



Time calibration

- **The intrinsic time offset exists among the electronics channels.**
- **Two methods of the detector time calibration :**

① The natural background calibration:

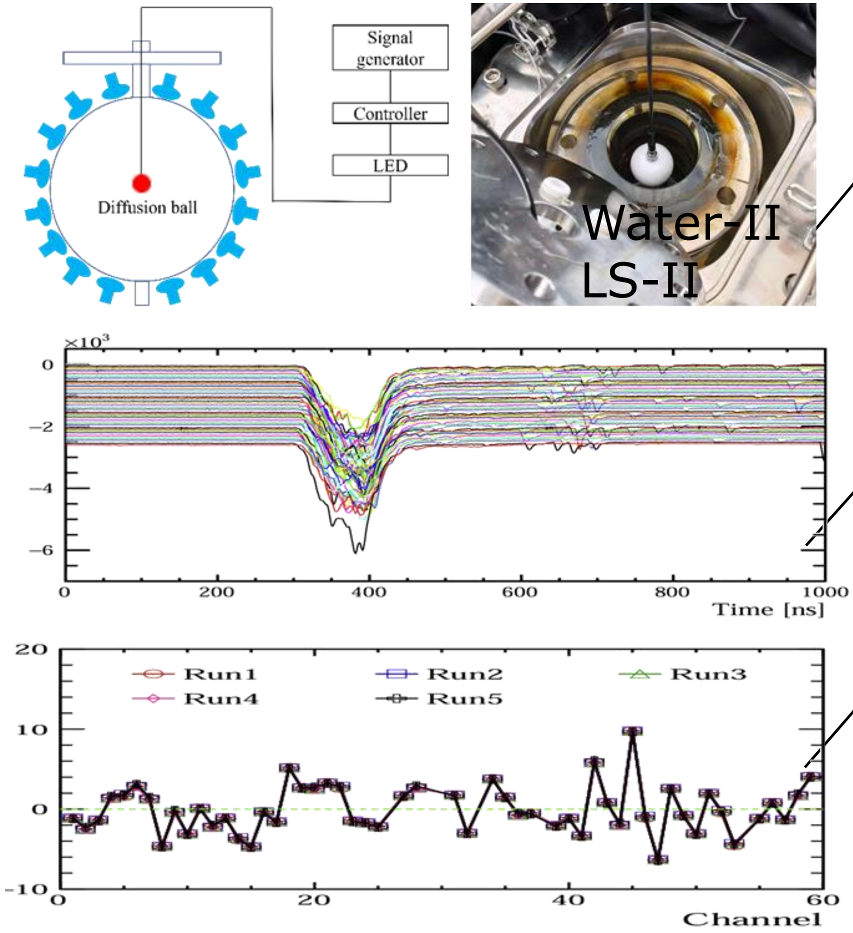
- ☐ **Using the signals from the center of the detector to align PMT signals.**

② The LED calibration:

- ☐ **Using the 415nm LED diffusion ball at the center of the detector to align PMT signals.**

- **The results from the two methods are consistent on the 1-ton detector.**

LED calibration



LED diffusion ball

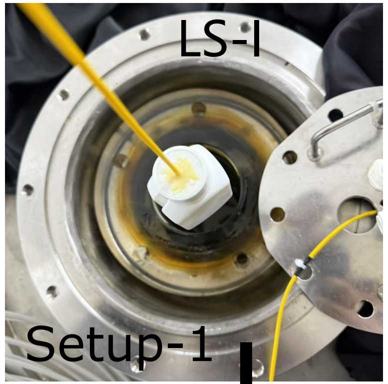
PMT waves

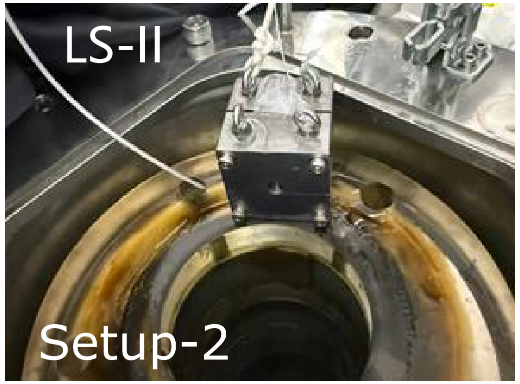
Time offsets among channels

Energy calibration

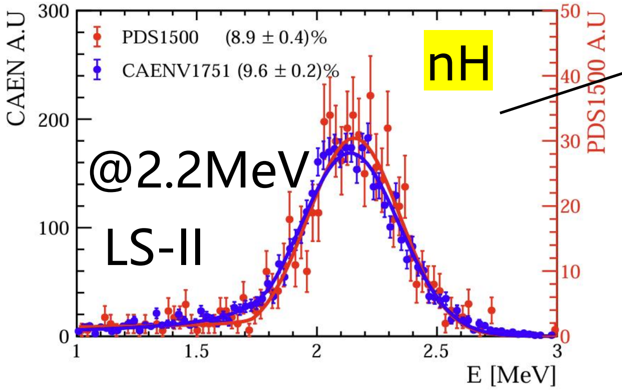
- **Detector energy calibration can provide the energy resolution and nonlinearity.**
- **The detector is calibrated with radioactive sources.**

Calibration setup





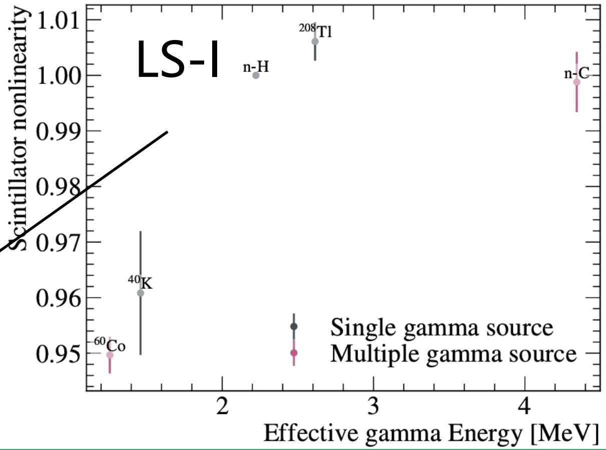
Vertex	Source	E_{eff} MeV	E MeV	E_{rec} MeV	Nonlinearity
^{60}Co	^{60}Co Calib	1.258	2.506	2.930 ± 0.010	1.169 ± 0.004
^{40}K	PMT	1.461	1.461	1.728 ± 0.020	1.183 ± 0.013
n-H	AmBe Calib	2.223	2.223	2.737 ± 0.001	1.2312 ± 0.0004
^{208}Tl	PMT	2.614	2.614	3.281 ± 0.005	1.238 ± 0.004
n-C	AmBe Calib	4.343	4.945	6.081 ± 0.033	1.230 ± 0.007



Resolution

Two electronics:
- $(8.9 \pm 0.4)\%$**-3 h**
- $(9.6 \pm 0.2)\%$**-19 h**

Nonlinearity



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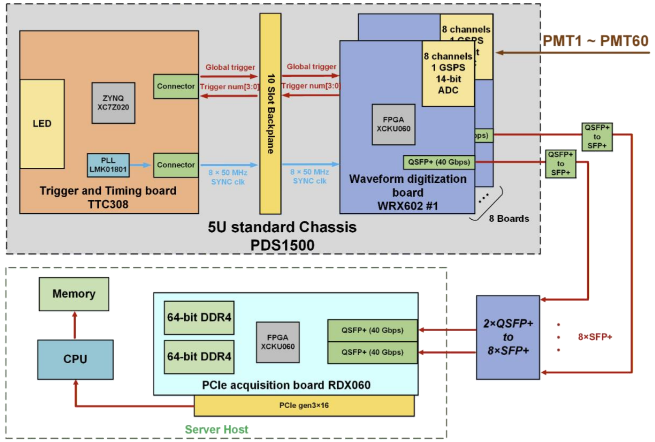
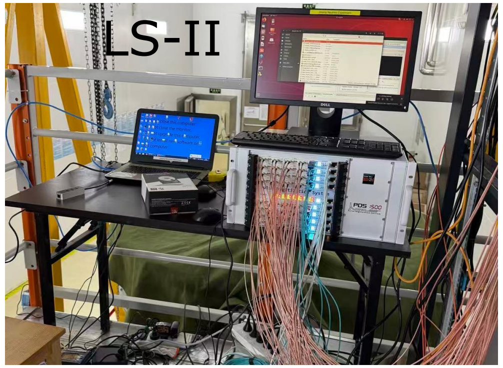
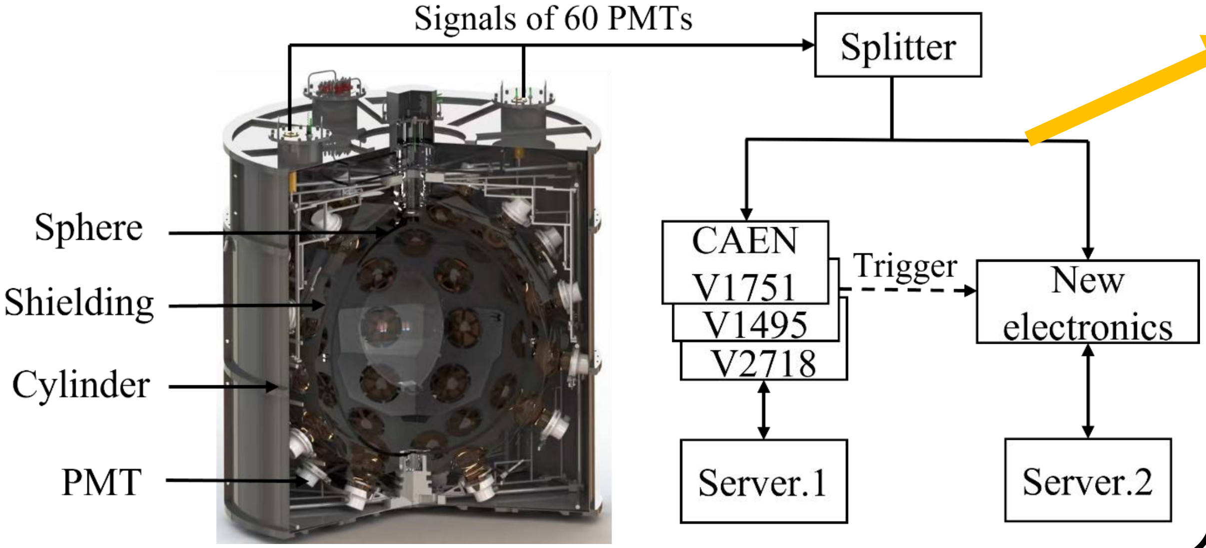
Self-developed electronics performance

- **To meet the future requirements of JNE, self-developed electronics with waveform data acquisition have been developed.**



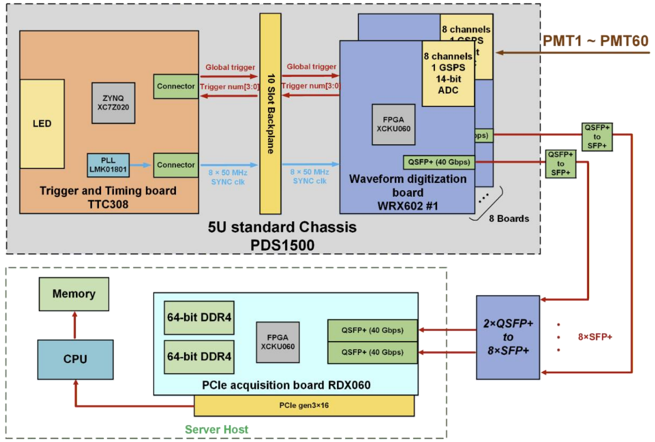


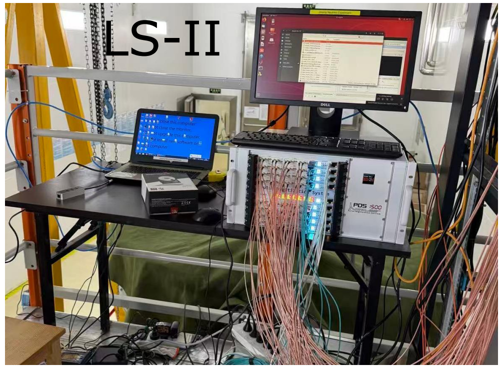


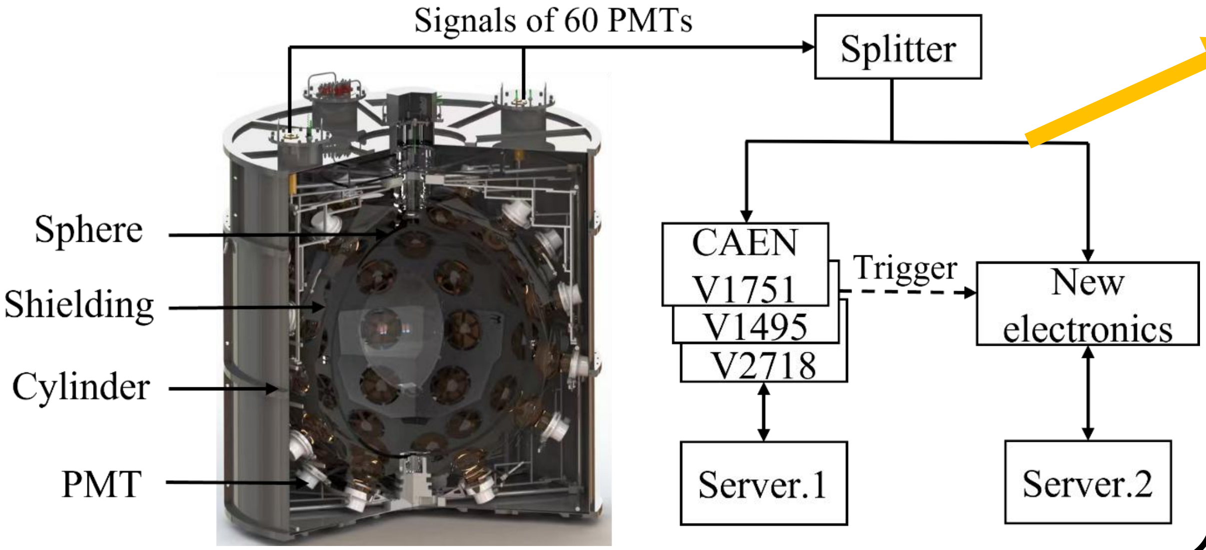
Terms	CAEN V1751	PDS1500
Bit number	10 Bits	14 Bits
Sampling rate	1 Gsa/s	1 Gsa/s
Data set	1023998	1024000
Baseline noise	~0.6 mV	~0.2 mV
Wave quality	Agreement	
Time drift	16 ns	0.3 ns
Threshold	0.5 MeV	<0.1 MeV
Energy resolution	$(\mathbf{9.6 \pm 0.2})\%$ **19 h**	$(\mathbf{8.9 \pm 0.4})\%$ **3 h**

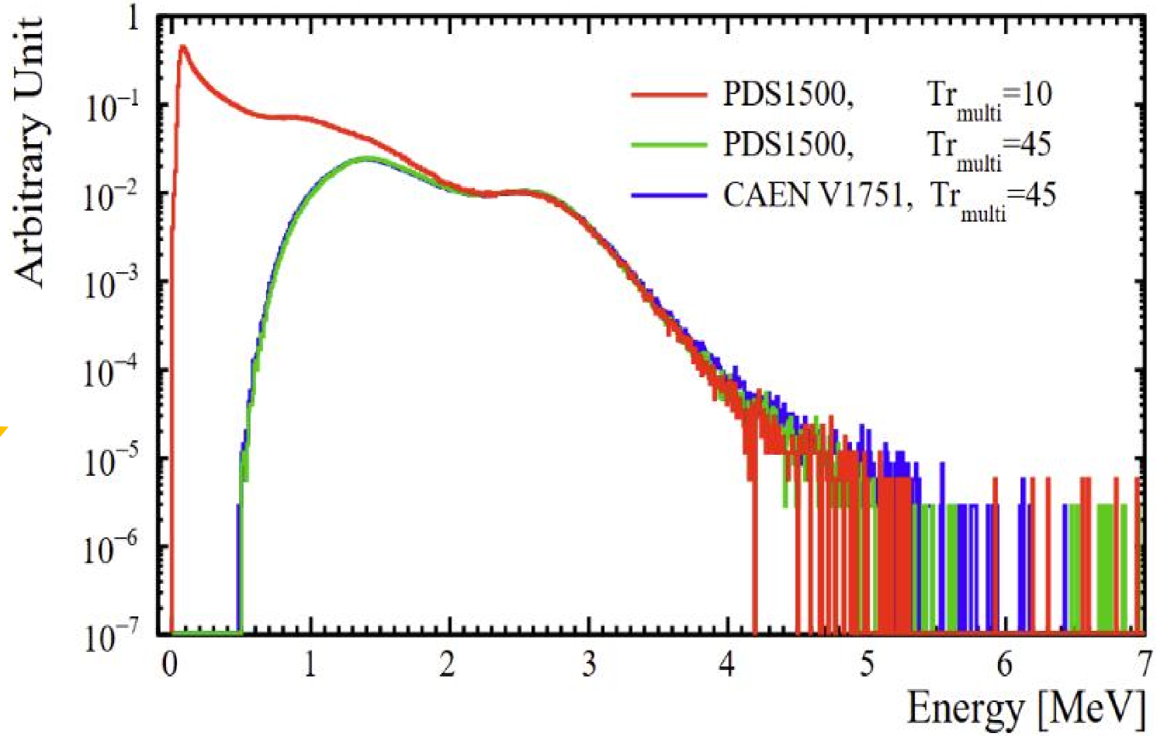
Self-developed electronics performance

- **To meet the future requirements of JNE, self-developed electronics with waveform data acquisition have been developed.**









Muon flux measurement from the water phase

- **The 1-ton detector observed muons with an average energy of 350 GeV using the slow-LS. In addition, the water-phase dataset enables muon detection via Cherenkov radiation.**

Water phase

Source	Unceraint y	Flux Uncertainty	
		PhaseI	PhaseII
Latitude, Longitude	±100 m	1.2%	2.7%
Elevation	±100 m	2.0%	2.0%
Acrylic sphere	±0.5 cm	0.3%	1.4%
PMT position &	[0.3, 2]cm	0.5%	1.3%
PMT angle	±5 degree	1.2%	0.8%
Water Absorption Length	[1/50, 1]	16.4%	1.3%
Hole on Shielding Sphere	[0,10]mm		3.4%
Radius of Shielding Sphere	±2 cm		4.6%
Rock thickness	±50 cm	2.2%	0.6%
Physical model	±5%	0.6%	1.3%
muon generator		2.0%	1.7%
Energy Scale	±10%		0.8%
Total		16.9%	7.1%

Without light shielding

Number of hit PMT selection

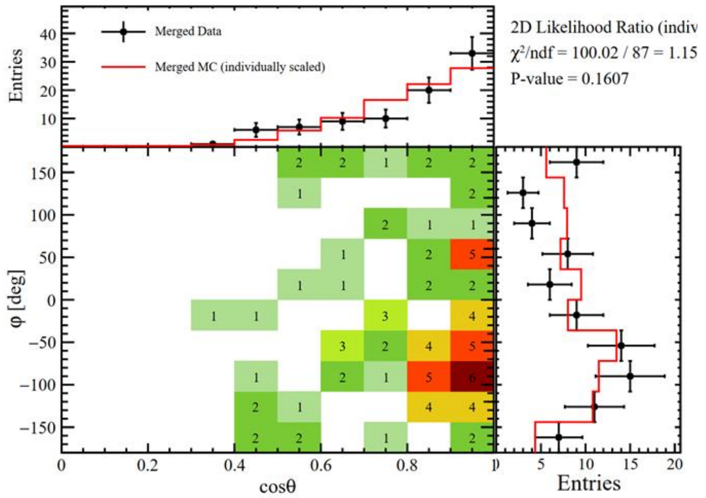
Energy selection

Muon flux measurement

- **Water Phase-I (3.60±0.71)x10^{-10} cm^{-2} s^{-1}**
- **Water Phase-II (3.53±0.53)x10^{-10} cm^{-2} s^{-1}**
- **Previous results from slow-LS: (3.56±0.16stat±0.10syst)x10^{-10} cm^{-2} s^{-1}**

Direction distribution

- **Conforms to the shape of the Jinping mountain.**



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Move the 1-ton detector to CJPL-II

- **The 1-ton detector has now been moved to CJPL-II, which is the site of the JNE detector.**

Disassembly and transport

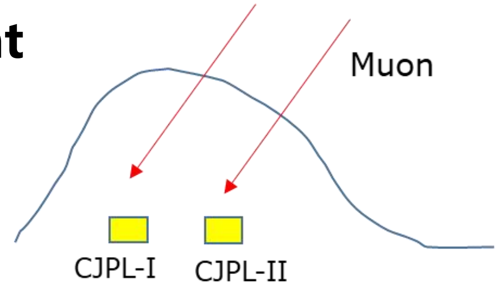
Assembly in CJPL-II

The outer lead shielding will be added.

Future

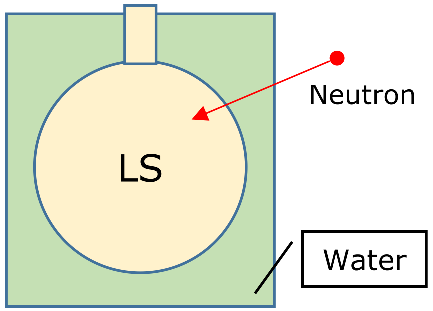
① The muon measurement in CJPL-II:

- Muon flux measurement check.
- Two-point mountain imaging.



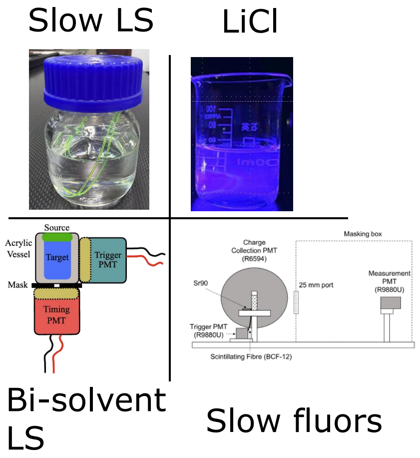
② The environmental neutron background:

- Neutrons are one of the main backgrounds in JNE.
- The neutron flux will be measured using high-light LS or GdLS.



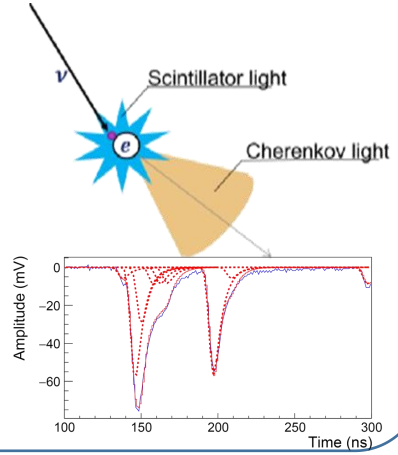
③ Testing the new LS:

- Performance testing of these LS in a larger detector.



④ Investigate the direction reconstruction in LS:

- Waveform analysis to event reconstruction.
- Scintillation and Cherenkov light are processed independently.




Thanks