Research and Development of Jinping Neutrino Experiment

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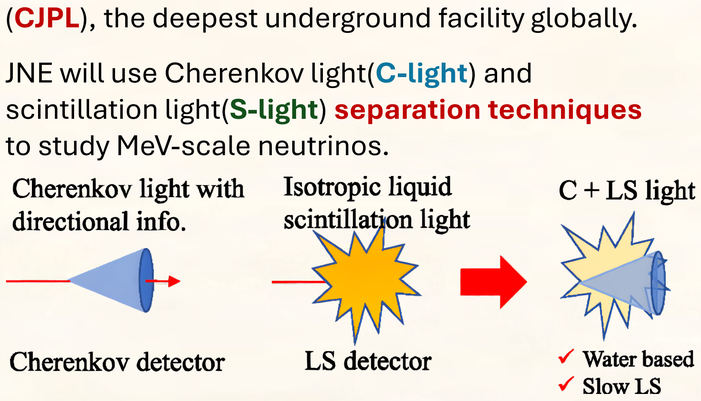
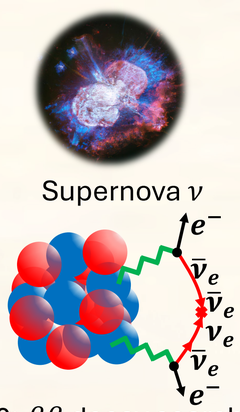
Ⅰ. Introduction

- The Jinping Neutrino Experiment (**JNE**) is conducted at the China Jinping Underground Laboratory (**CJPL**), the deepest underground facility globally.
- JNE will use Cherenkov light(**C-light**) and scintillation light(**S-light**) **separation techniques** to study MeV-scale neutrinos.



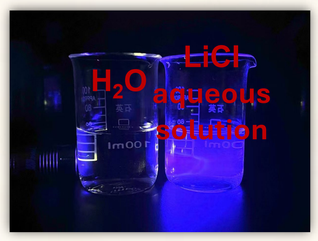


Pre-study of $0\nu\beta\beta$, see poster *No.114 by Haoyang Fu.*

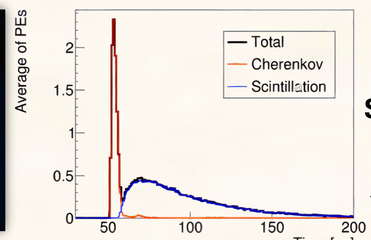
$0\nu\beta\beta$ decay search

Ⅱ. Slow Liquid Scintillator

- Have good angular resolution and energy resolution.
- **Reduce the interference of S-light → Get direction**
  - Control the S-light yield(water-based LS)
  - Control the emission speed(oil-based LS)



(Water-based)



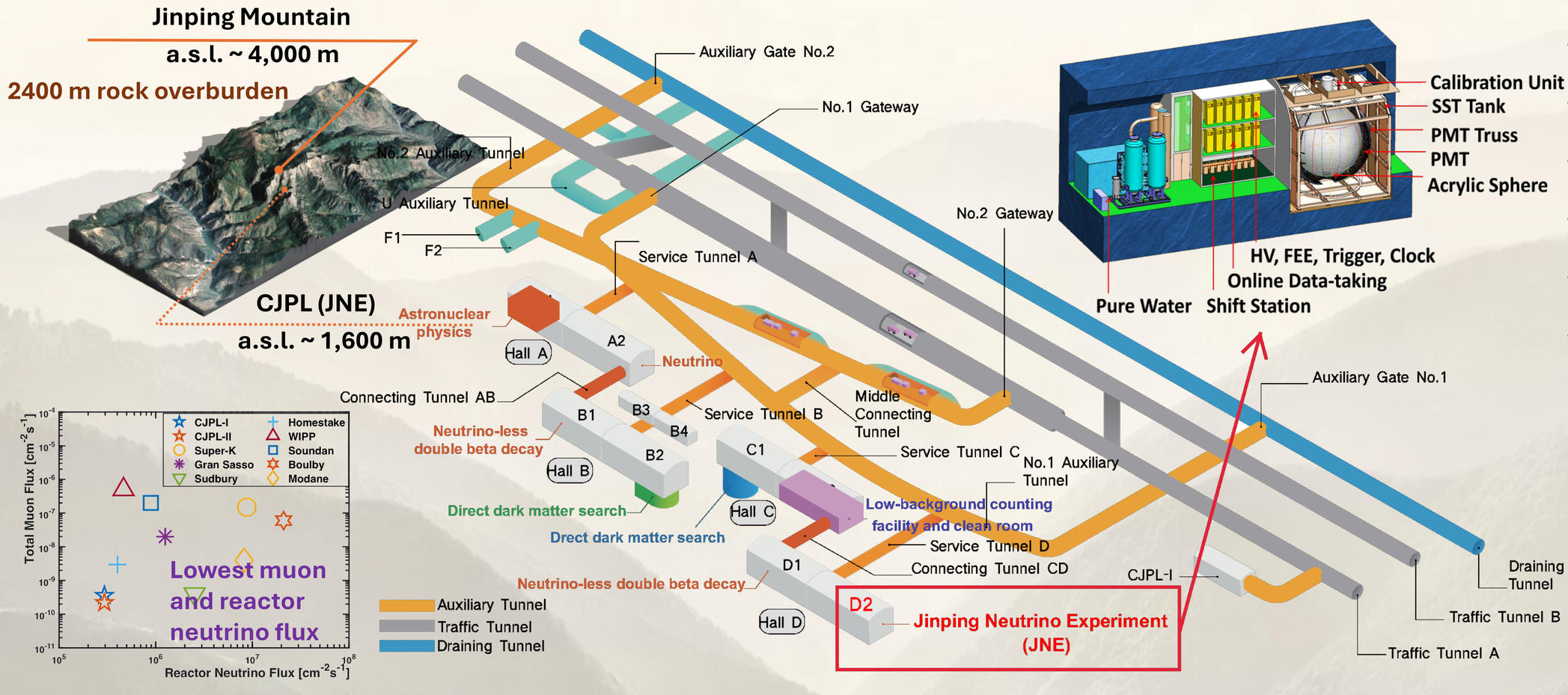
Time spectrum of slow LS samples (Oil-based)

- **Oil-based slow LS**, see arXiv:1511.09339, 1607.01671, 1708.07781
- **LiCl aqueous solution**, see arXiv:2203.01860, 2211.05023

S-light time spectrum:

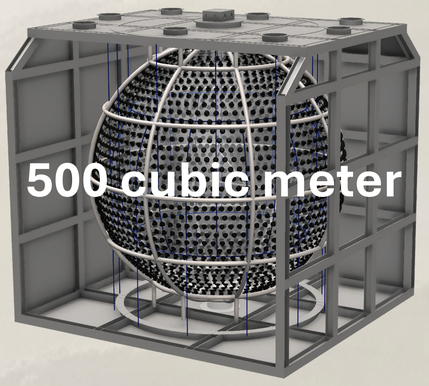
$$n(t) = \frac{\tau_r + \tau_d}{\tau_d^2}\left(1 - e^{t/\tau_r}\right) \cdot e^{t/\tau_d}$$

Ⅲ. JNE Multi-Hundred Ton Detector



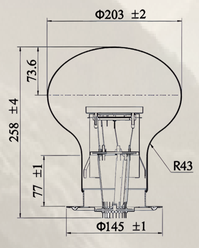
Detector Structure

- **Stainless steel tank:** 14.5 m *12.9 m *13.2 m
- **SST PMT truss:** Diameter(D): 12.16 m
- **Acrylic vessel:** D: 9.96 m Thickness: 5 cm
- **Rope network:** holding-up and holding-down
- **Shieling material:** Water and SST (or lead)
- **MCP-PMT+ light collector:** ~4000, ~50% Coverage



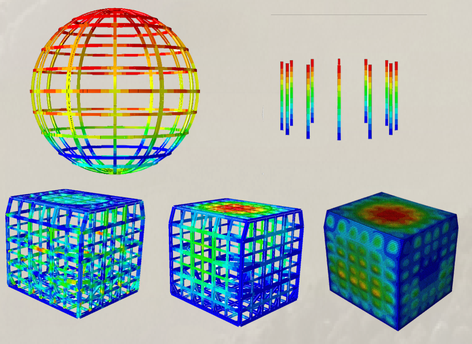
Novel 8-inch MCP-PMTs

- U、Th: <4e-8 g/g，K-40: <4e-9 g/g
- High QE: ~30%
- Good TTS: <1.8 ns



600 MCP-PMTs have been produced.
More details see arXiv:2303.05373, 2402.13266

- Mechanical analysis of the SST framework has been finished.
- Finite element software ABAQUS is adopted.



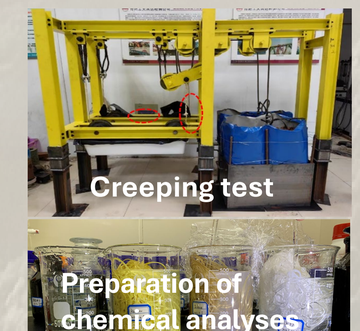
FADC for PMT waveform readout

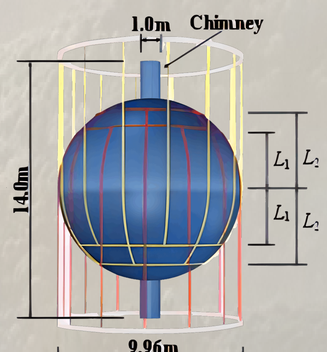
- 350 mW/ch, 12-bit, 1 GSps
- Readout board, Bandwidth 300 MHz, 40Gbps

The whole system will be tested on the one-ton prototype this year.
More details see arXiv:2404.10373

Rope to hold the acrylic vessel

- Hold acrylic sphere (Water, LS, or Doped LS)
- **Density difference to water: ±20%**
- Low background
- High strength, low creeping, water compatibility



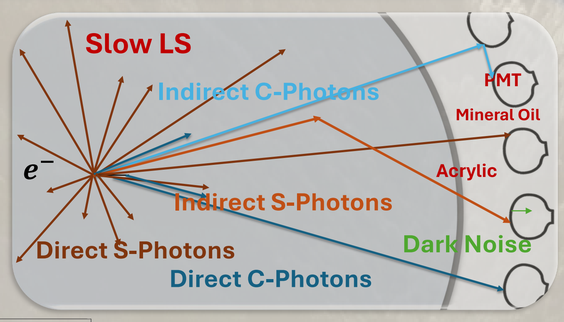


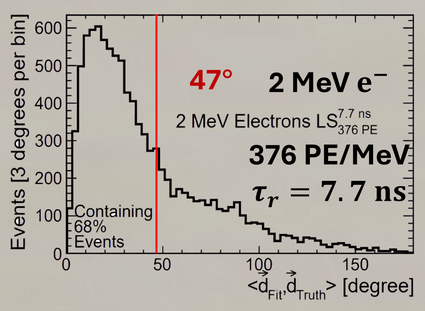
Ⅳ. Reconstruction Algorithm of Slow LS

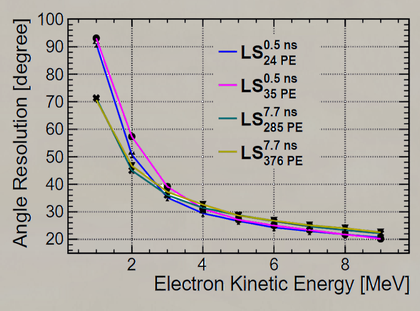
$$\mathcal{L}\left(n_i^{\mathrm{Obs}}, t_{ij} \middle| E, x, y, z, t_{\mathrm{event}}, \vec{d}_{\mathrm{Fit}}\right) = \prod_i^{N_{\mathrm{PMT}}} P_i^{\mathrm{C}} \prod_j^{n_i^{\mathrm{Obs}}} P_{ij}^{\mathrm{T}}$$

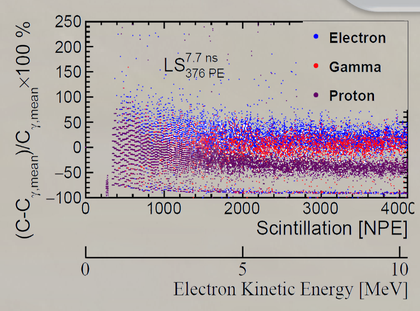
N_{PMT} Total number of PMT
n_i^{Obs} Number of the observed PE

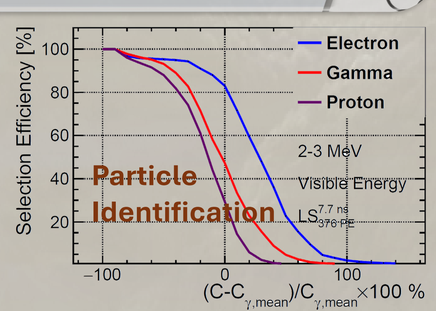
Known quantities **Fit parameters** **Probability of the Charge and Time**











- Outline each complex process within the **full simulation** using simplified functions.
- Perform **directional reconstruction**.
- C-light emission capability ranking: **e > γ > p ≈ α**
- Obtain the number of C-light from the reconstruction results.
- More details, see arXiv:2209.13772

Ⅴ. Conclusion

- Multi-hundred ton solar neutrino observatory at CJPL-II will be constructed by **2026.**
- **Novel MCP-PMT**, low background, fast, high QE.
- ADC chips and waveform readout electronics under design and testing.
- Explored the option with **LiCl aqueous solution.**
- Successfully developed a reconstruction algorithm based on slow LS, capable of **direction reconstruction and particle identification.**
- Rich physics with MeV-scale neutrinos at CJPL-II, see arXiv:1602.01733, 1612.00133, http://jinping.hep.tsinghua.edu.cn