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Progress of Jinping Neutrino 1-t detector – the prototype of future low background neutrino detectors at CJPL

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CJPL is an ideal place for low background facilities due to its deepest rock overburden. To prepare for future liquid scintillator based experiments such as solar neutrino observation or $0\nu\beta\beta$ searching, Jinping 1-t prototype was built for measuring various backgrounds and verify new technologies. In 2017-2020, it detected numerous MeV radioactive background events, hundreds of high energy muons as well as muon induced neutrons. Radioactive isotope (U, Th, Rn) contamination in liquid scintillator was studied and measured. The radioactivity of LS will be further suppressed after the distillation system is online. Muon flux and neutron yield were investigated, too. Results indicate that CJPL is an ideal place for low background experiments. We are making steady progresses on lowering radioactive isotopes of materials, to prepare for future detectors.

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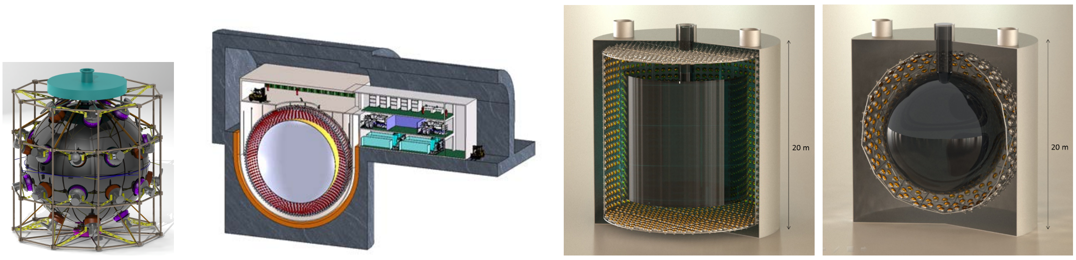
1. CJPL and JNE

Located inside Jinping mountain at Sichuan Province, China, the China Jinping Underground Laboratory (CJPL) is one of the world's deepest underground laboratories [1].

The Jinping Neutrino Experiment (JNE) aims to study MeV-scale neutrinos, including solar-, geo-, and supernova relic neutrinos [2]. A 3-step plan, 1t-500t-3kt is proposed, as shown in Fig. 1.



(a) 1t **(b)** 500t (civil construction) **(c)** 3kt (future plan) [2]

Fig. 1: 3 steps to build kt level detectors at CJPL

2. The Jinping Neutrino 1-t prototype

The 1-ton prototype wa s built to verify the technologies used in detectors, and measure the underground background level in situ [3].

Fig. 2: Photo of 1t

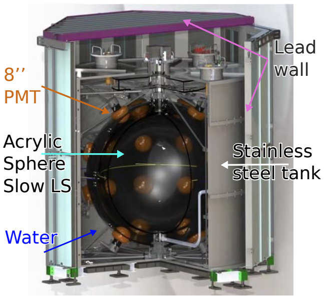


Fig. 3: The 1t model.

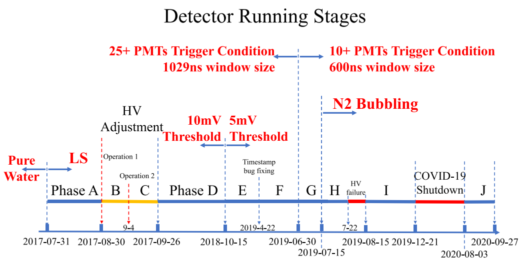


Fig. 4: Running status of 1t

Fig. 3 is the schema of 1-ton core components, while Fig. 2 is the photo of the whole detector.

1-ton DAQ can be divided into several stages, shown in Fig. 4: high ^{222}Rn contamination in the beginning (**A**), followed by high threshold run (**D-F**) and low threshold run (**G-J**).

By utilizing the dark noise and radioisotope decay products, such as αs and γs, we developed several nonauxiliary source calibration methods. PMT gain is measured by dark noise calibration, and PMT transit time is measured using events at detector center. Energy scale is determined by 2.6 MeV γs from ^{208}Tl.

In the future, we will upgrade 1t to install more high QE MCP-PMTs for testing, and deploy liquid scintillator purification system to further suppress radioactivity.

3. Backgrounds of 1-ton

3.1 Radioactive backgrounds

As shown in Fig. 5, γs can easily penetrate water, dominating backgrounds. α and β don't, only by coincidence analysis can they be tagged. So, for single events, energy spectrum fitting is performed to extract ^{40}K (E.C. 1.4 MeV) and ^{208}Tl (β^- 2.8 MeV) signal, as Fig. 6 shows. They are mainly from detector components outside acrylic sphere, such as PMTs.

For ^{238}U and ^{232}Th, their decay chains are marked via ^{214}Bi-^{214}Po and ^{212}Bi-^{212}Po coincidence signal. Due to the low Q value of ^{212}Bi and short half-life of ^{212}Po, the detection efficiency of ^{212}Bi-^{212}Po is suppressed, so only upper limit is given.

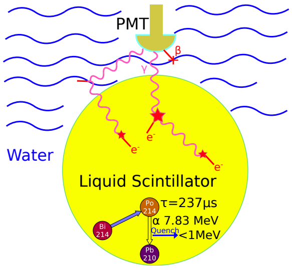


Fig. 5: Radioactive backgrounds overview

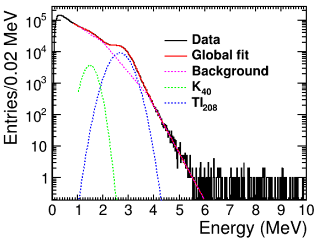


Fig. 6: Energy spectrum fit

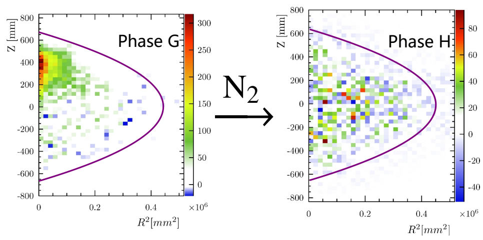


Fig. 7: ^{214}Bi vertex distribution change

In July 2019, N_2 gas system was deployed to improve air tightness and repel Radon. Due to the leakage of Radon from detector top, ^{214}Bi events concentrated in the upper hemisphere, as shown in Fig. 7. After the N_2 gas system online, ^{214}Bi vertex distribution went normal. Also, ^{214}Bi event rate drops significantly due to the N_2 sealing.

The measured contamination of radioactive isotopes is: [1]

Table 1: Radioactive backgrounds

Isotope	Contamination (mass fraction) g/g
^{40}K(PMT)	$(5.73 \pm 0.79_{sys} \pm 1.49_{stat}) \times 10^{-8}$
^{232}Th(PMT)	$(2.64 \pm 0.18_{sys} \pm 0.58_{stat}) \times 10^{-6}$
^{238}U(LS)	$(6.98 \pm 0.73) \times 10^{-13}$
^{232}Th(LS)	$<3.56 \times 10^{-13}$

3.2 Cosmic background

For details about cosmic background analysis, please refer to [4] and [5].

The muon flux is measured at $(3.61 \pm 0.19_{sys} \pm 0.10_{stat})$ cm^{-2}s^{-1}, with average energy of 3.40×10^2 GeV.

The muon induced neutron yield at CJPL is $(3.44 \pm 1.86_{sys} \pm 0.76_{stat})$ μ^{-1}g^{-1}cm^2.

[1] ^{238}U, ^{232}Th result is preliminary.

4. Conclusion

By collecting data with JNE 1-ton prototype and measuring its cosmic and radioactive backgrounds, we have verified that CJPL is an ideal place for low background experiments. We are making steady progresses on lowering radioactive contamination of materials and developing new technologies, to prepare for future detectors with rich physics prospects.

References

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