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Jinping Neutrino Experiment

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Jinping Neutrino Experiment

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Abstract. Jinping Neutrino Experiment (Jinping) is a unique observatory for low-energy neutrino physics, astrophysics and geophysics. Jinping is located in China JinPing underground Laboratory (CJPL), identified by the thickest overburden, lowest reactor neutrino background, etc. For solar neutrinos, Jinping has the capacity to measure the oscillation transition phase from vacuum to matter, to discover the CNO cycle neutrino, and to address the solar metallicity problem. Jinping will be able to precisely measure geo-neutrinos with signal-to-background ratio of 8.2:1.0 in the energy range of 1.8 MeV to 3.3 MeV. The ratio of U/Th can be determined to 10%. We also expect a promising sensitivity for neutrinos from a Milky Way supernova, the diffuse supernova neutrino background, and dark matter annihilation. The first, small phase of the laboratory (CJPL I) is already in operation, hosting dark matter experiments. The second, large phase (CJPL II) is already under construction, with $\approx 100,000 \text{ m}^3$ being excavated.

1. Introduction

1.1. Experimental Site

The experimental site of Jinping Neutrino Experiment [1] is located in Jinping Mountain, Sichuan Province, China, 2 hours' drive from the closest airport. The site has the thickest neutrino observatory overburden in the world: 2,400 m (6,720 meter water equivalent assuming a constant rock density 2.8 g/cm^3), and thus the lowest muon flux. Reactor neutrinos with oscillation effect from reactors listed in IAEA [2] is considered, and the reactor neutrino background in Jinping is derived to be low, because of the far-away location from any nuclear power plants ($\geq 900 \text{ km}$), as shown in Fig. 1.

The first phase of Jinping laboratory (CJPL I) was used for two dark matter experiments: CDEX [3] and PandaX [4] from 2009. The second phase of Jinping laboratory (CJPL II) started in the end of 2014. Totally $\sim 100,000 \text{ m}^3$ is being evacuated [5].

1.2. Detector Concept

A conceptual design of the neutrino detector can be seen in Fig. 2 for a cylinder vessel. Details can be found in the letter of intend for Jinping Neutrino Experiment [1].

The central vessel is made of acrylic, and the height and diameter of the cylinder and the diameter of the sphere are both 14 meters.

The new water-based (or oil based) slow liquid scintillator is a very attracting option for target material [6]. In this material, Cherenkov light and scintillation light will be distinguishable in time spectra, with a fine-structure waveform readout from PMTs. Cherenkov light can be used for the directional reconstruction of charged particles as in the Super Kamiokande Experiment, while scintillation light can be used for the energy reconstruction of particles as in the Borexino



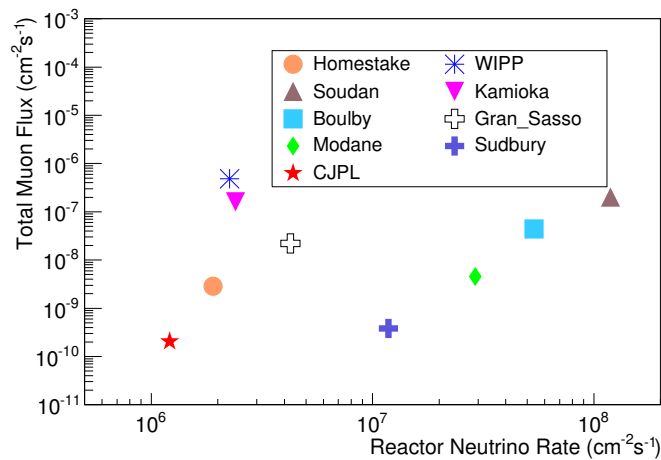


Figure 1. Jinping with the lowest muon flux and reactor neutrino background.

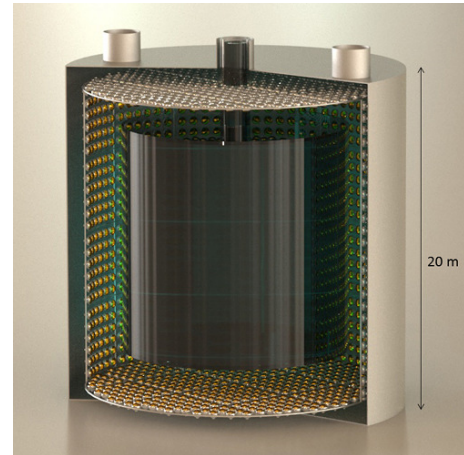


Figure 2. The conceptual design for a cylindrical neutrino detector at Jinping.

Experiment. Furthermore, Cherenkov and scintillation light yield have different dependencies on particle momentum, enabling particle identification.

In the following, the result of a sensitivity study is reported, where the required energy resolution is determined to be 500 P.E./MeV.

2. Solar Neutrinos

Solar neutrinos are unique probes to test the solar model as well as solar neutrino oscillation.

The overburden of Jinping shields the cosmic-ray muon factor of 200 lower than Borexino or a factor of 2 lower than SNO. Internal and environmental radioactive backgrounds are scaled to a similar level with Borexino. 2.0 kiloton fiducial mass is assumed out of 4.0 kiloton target material, and the livetime is assumed to be 1,500-day exposure.

Under the above assumption, a simulation study was carried to give an estimate of sensitivity for physics topics. A discovery of ^{15}O solar neutrinos from the CNO cycle is found to be possible in Jinping. The high and low metallicity hypotheses [7, 8] with known neutrino oscillation angles can be resolved with more than 5 sigma. Jinping will also be able to measure the transition phase for solar neutrinos oscillation from the vacuum to the matter effect, as shown in Fig. 3.

3. Geo Neutrinos

Geo neutrinos provide a powerful measurement for the radioactive energy from the earth crust and mantle, leading to better understanding of the Earth's energy budget.

Located far away from any reactors, Jinping has a low reactor neutrino background, which is the main background for geo-neutrino detection. The estimated event rates of 31 U and 8 Th geo-neutrino events/year/kton will be significantly above the expected reactor neutrino background of 5 events/year/kiloton in geo-neutrino energy region of 1.8 MeV to 3.3 MeV.

We assume 3.0 kiloton of target mass and 1,500 days of data-taking in this study. No constrain is placed on the Th/U ratio or on the reactor neutrino flux. The likelihood fitting result is shown in Fig. 4.

Jinping will be able to precisely measure geo-neutrinos with an unambiguous separation on U and Th cascade decays from the dominant crustal anti-electron neutrinos. With a unique domination of geo-neutrinos by crustal neutrinos, Jinping geo-neutrino measurement result can be combined with other geo-neutrino measurements to derive the mantle neutrino flux, and thus examine the Earth model.

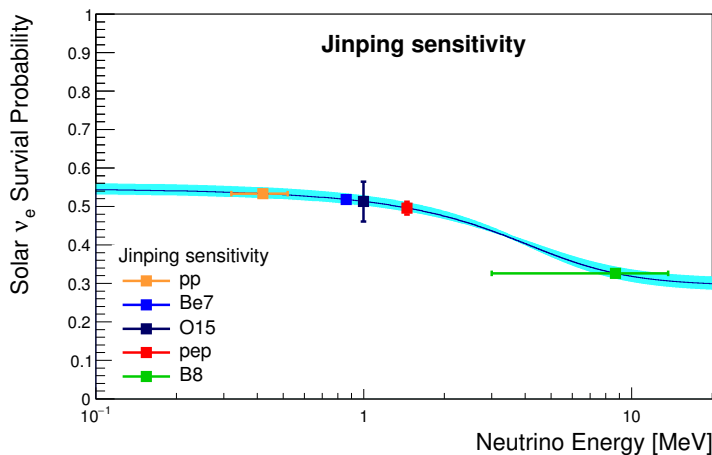


Figure 3. The transition of oscillation probability from the vacuum to matter effect as a function of neutrino energy with Jinping’s sensitivities.

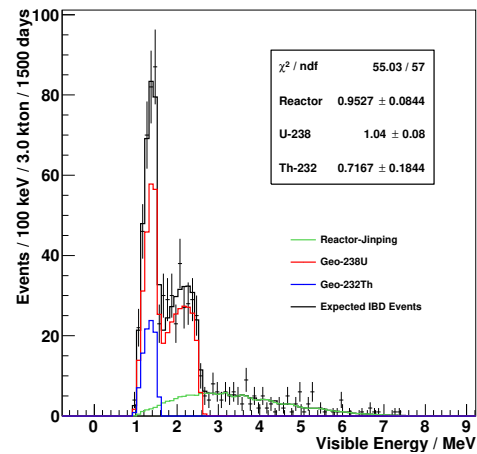


Figure 4. Likelihood fit result for free Th and U geo-neutrino signals and background.

4. Supernova Neutrinos

The detection of supernova neutrinos is important in sense of stellar evolution as well as neutrino oscillation. With supernova burst neutrinos, a global supernova early warning system is achievable.

The planned 2-detector setting at Jinping will provide a robust coincidence detection for supernova burst neutrinos against uncorrelated backgrounds, enhancing the detection probability for supernova burst. With the extremely low spallation background induced by muon in Jinping, and target material of slow liquid scintillator used to distinguish Cherenkov and scintillation light, the background for Supernova relic neutrinos will be greatly suppressed, making it promising towards SRN discovery.

5. Summary

Jinping, with an extremely low cosmic-ray muon flux and reactor neutrino flux and with several other good features, is an ideal observatory for low background neutrino experiments.

With 2.0 kiloton fiducial mass for the solar neutrino physics and equivalently 3.0 kiloton for the geo-neutrino and supernova neutrino physics, Jinping will be able to discover the neutrinos from the CNO fusion cycles of the Sun, to shed light on the solar metallicity problem, to precisely measure the transition phase for the solar neutrinos oscillation, to precisely determine the geo-neutrinos’ flux, the U, Th ratio, and to help to determine the Earth’s energy budget.

Reference

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