Feasibility study of an accelerator neutrino experiment in China

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Future accelerator neutrino experiments will provide a powerful tool to measure standard oscillation parameters and search for new physics. In this context, we discuss the prospects of building an accelerator neutrino experiment in China. The feasibility of such facilities is investigated by evaluating their prospects to the standard mixing parameters. As an example, we consider an SPPC-based neutrino beamline and CJPL-based neutrino detector with 1736 km baseline length. We find this setup able to significantly improve the precision on δ_{CP}, θ_{23} and Δm_{31}^2.

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1. Introduction

China has rapidly growing infrastructure dedicated to accelerator-based nuclear and particle physics [1]. China Spallation Neutron Source (CSNS), China initiative for Advanced Driven Systems (CiADS) and High Intensity Accelerator Facility (HIAF) in the southern province of Guangdong, for example, are major accelerator facilities with applications ranging from neutron scattering techniques to nuclear transmutation and heavy ion physics. Institute of Modern Physics of Chinese Academy of Sciences (CAS-IMP) in Lanzhou, Gansu, and Proton Linear Accelerator Institute of Nanjing University in Nanjing, Jiangsu, are other notable Chinese laboratories specialized in accelerator-based physics. At the same time, a next-generation collider facility CEPC and its high-energy upgrade SPPC are planned to be constructed in Beijing in the northeast of China. Last but not least, China is home to two major underground physics laboratories designed for investigating fundamental sciences: China JinPing Laboratory (CJPL) in central Sichuan is currently the deepest underground facility in the world and Jiangmen Underground Neutrino (JUNO) Observatory will soon commission the largest liquid scintillator neutrino detector near Kaiping, Guangdong.

In this proceeding, we briefly contemplate the prospects of studying precision neutrino oscillation physics with a future accelerator neutrino experiment in China. We discuss the site selection aspect with respect to the geographical locations of the existing research infrastructure in China. As a concrete example, we consider an experiment configuration where a neutrino beamline is established at the SPPC injector facility and detector at CJPL, giving rise to 1736 km baseline.

This proceeding is organized as follows: We summarize the key points of the laboratory survey in section 2, discuss the physics prospects of the considered setups in the precision measurement of θ_{23}, δ_{CP} and Δm^2_{31} in section 3 and leave concluding remarks in section 4.

2. Survey of research infrastructure in China

China is currently home to a number of accelerator facilities with a range of interests in applied and basic sciences. There are also two major underground research laboratories. If these accelerator and underground laboratories were used in a future accelerator neutrino experiment, the available baseline lengths would range from 84 km to 1742 km. A summary of baseline lengths and required neutrino beam energies to reach the first and second oscillation maximum in these facilities is provided in table 1.

Table 1: Characteristics of the five accelerator laboratories and two underground laboratories in China. Listed items include the baseline lengths and the required neutrino energy to reach first and second oscillation maximum, assuming $\Delta m^2_{31} \simeq 2.517 \times 10^{-3}$ eV^2. This table is taken from Ref. [1].

| Accelerator facility	JUNO			CJPL		
	Baseline	1st maximum	2nd maximum	Baseline	1st maximum	2nd maximum
CAS-IMP	1742 km	3.5 GeV	1.2 GeV	894 km	2.7 GeV	600 MeV
CiADS	146 km	300 MeV	100 MeV	1389 km	1.8 GeV	940 MeV
CSNS	84 km	170 MeV	60 MeV	1329 km	2.8 GeV	900 MeV
Nanjing	1189 km	2.4 GeV	800 MeV	1693 km	3.4 GeV	1.1 GeV
SPPC	1814 km	3.7 GeV	1.2 GeV	1736 km	3.5 GeV	1.2 GeV
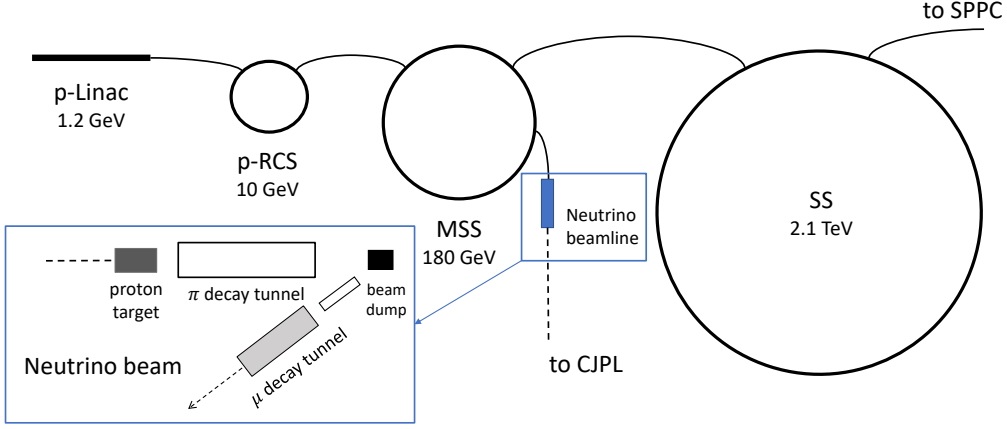
Figure 1: Illustration of a possible realization of neutrino beamline at the SPPC injector facility [1]. Both MSS and SS rings could divert an average of 3.2 MW proton beam to non-collider purposes [2].

An attractive candidate for a future neutrino beam facility site is the SPPC injector chain, as portrayed in figure 1. SPPC is part of the next-generation collider physics program CEPC-SPPC, which is currently under planning in China [2]. The injector chain consists of a proton linac (p-Linac), rapid cycling synchrotron (p-RCS), medium-stage synchrotron (MSS) and final stage synchrotron (SS). Each synchrotron is capable of diverting a proton beam of 3.2 MW to non-collider programs.

3. Precision measurements on δ_{CP}, θ_{23} and Δm^2_{31} with PROMPT

In this proceeding, we present the expected sensitivities for an accelerator neutrino experiment based at the SPPC injector facility in Beijing and CJPL in Sichuan. For future reference, we call this setup *PRecisiOn Measurements and Physics with Tau neutrinos* (PROMPT) due to its affinity to ν_τ physics and perceived physics goals. PROMPT is simulated as a long-baseline neutrino experiment with muon-decay-based beam of 25 GeV parent energy and 50 kton hybrid detector based on magnetized iron and emulsion cloud chamber technologies.

The expected sensitivities for *CP* violation discovery as well as for precision measurement of θ_{23}, δ_{CP} and Δm^2_{31} are shown in figure 2. The simulations are conducted with GLoBES. The sensitivity to CP violation is presented as a function of δ_{CP} values, whereas the precisions on θ_{23}, δ_{CP} and Δm^2_{31} are indicated with respect to the values presently favoured by the world data [3]. The best-fit values are also shown at 1σ CL with grey regions. The sensitivities for PROMPT are shown both with and without sensitivity to ν_τ. The corresponding sensitivities expected for DUNE and T2HK as well as the combination of the three configurations are also included. The sensitivities predicted for PROMPT show excellent precision to δ_{CP}, θ_{23} and Δm^2_{31} both as a standalone experiment and in combination of the simulated data from the superbeam experiments T2HK and DUNE.
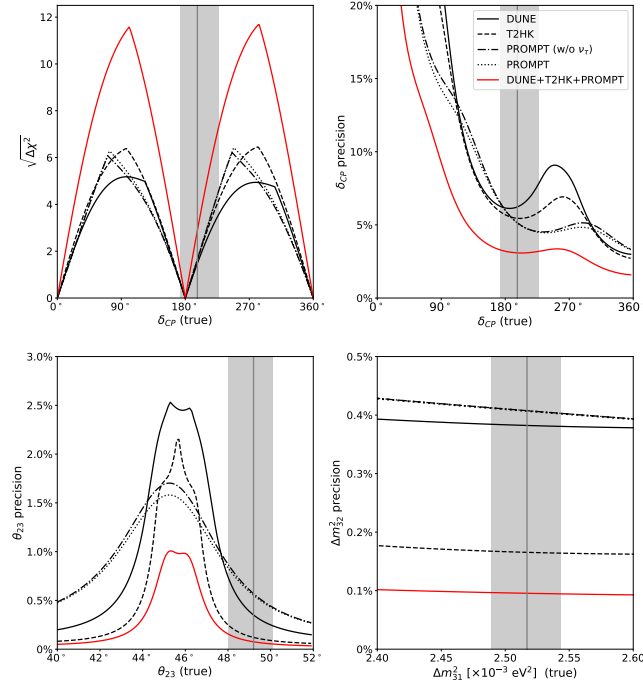
Figure 2: Expected sensitivities to *CP* violation and $1\,\sigma$ CL precision to θ_{23}, δ_{CP} and Δm^2_{31} at PROMPT setup [1]. Precisions are shown with respect to the presently favoured value from a global analysis, which are also indicated within $1\,\sigma$ CL by grey colour. Sensitivities from T2HK and DUNE are also provided.

4. Summary and outlook

China offers a great landscape in research infrastructure dedicated to nuclear and particle physics. In this proceeding, we contemplated the possibility of constructing a future accelerator neutrino experiment in China. As a concrete example, we considered an experiment setup at the SPPC and CJPL sites, which could form a baseline length of 1736 km. We present the expected sensitivities to *CP* violation and the precision of θ_{23}, δ_{CP} and Δm^2_{31} in this setup, which we call PROMPT. We find that PROMPT could significantly improve the experimental precision on the standard mixing parameters.

References

[1] Jian Tang, Sampsa Vihonen and Yu Xu, arXiv:2108.11107.

[2] CEPC-SPPC Study Group, IHEP-CEPC-DR-2015-01, IHEP-AC-2015-01 (2015).

[3] Ivan Esteban, M.C. Gonzalez-Garcia, Michele Maltoni, Thomas Schwetz and Albert Zhou, JHEP **09** (2020) 178, arXiv:2007.14792.