【Grant-in-Aid for Scientific Research (S)】

Towards the discovery of neutrino CP violation using the world's highest intensity beam and most precise neutrino interaction measurements

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Purpose and Background of the Research

●Outline of the Research

Why present universe is filled primarily with matter and little antimatter is found ? When this universe was created, it is believed that there were equal numbers of particles and antiparticles but then somehow only the particles that create matter remained. In order to create this universe, particle-antiparticle symmetry (CP symmetry) must be broken. The size of the CP violation in quarks cannot explain the matter-antimatter asymmetry in the universe. On the other hand, recent studies have pointed out a possibility that CP violation in neutrinos may explain the matter-antimatter asymmetry of the universe. Many particle physicists are now focusing their attention on neutrinos as the most promising candidate to solve this mystery. We aim to discover neutrino CP violation and study whether the size of the neutrino CP violation is large enough to produce the matter-antimatter asymmetry of the universe.

●Research Plan and Method

This research will be performed at Tokai to Kamioka neutrino oscillation experiment, T2K. A high-intensity neutrino beam will be generated at J-PARC, and neutrinos will be measured by a near detector and Super-Kamiokande. Neutrino oscillation will be measured as a quantum wave interference of neutrinos during their flight in 295 km (Fig. 1). The CP symmetry will be measured by comparing the probability of a neutrino oscillation from muon-type (μ) to electron-type (e) between neutrinos and antineutrinos. This is currently the only method that can probe neutrino CP violation.

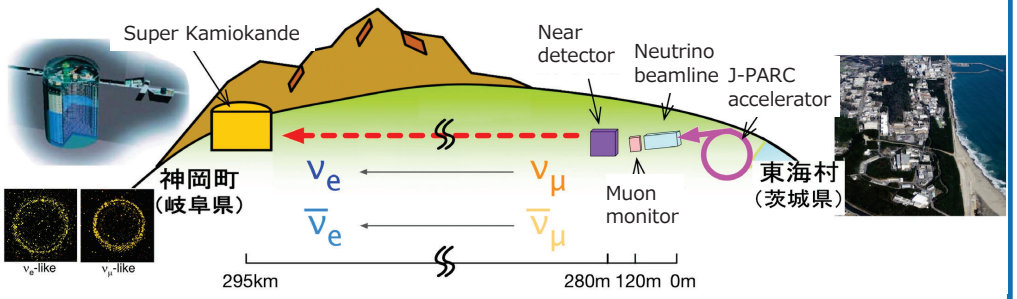

Figure 1. Overview of the T2K experiment.

We started physics data taking at T2K since 2010. Based on the data collected until 2019, we found that the CP symmetry is violated in neutrino oscillations with a 95 % confidence level. This result was published in the journal Nature and also featured in a domestic TV program. We can say that these results have been received attention from the entire scientific community and society.

We aim to discover neutrino CP violation by realizing the world's highest intensity neutrino beam (Fig. 2) and by establishing precise neutrino measurements (Fig. 3) in this project.

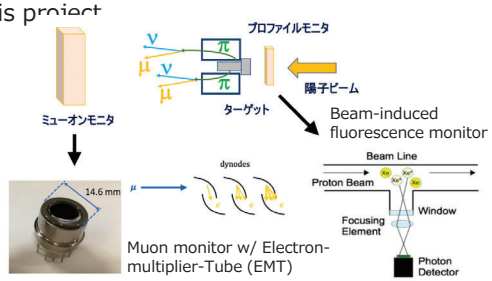

Figure 2. New proton beam monitor and muon monitor will be implemented.

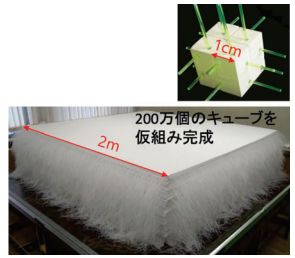

Figure 3. A new type of detector with 2 million scintillator cubes of 1 cm cubic to measure neutrino-nucleus interaction precisely.

Expected Research Achievements

●Research Objectives and Target Goals of the Project

Neutrino oscillations among the three neutrino types is governed by three mixing angles and one complex phase, δ_{CP}. The three mixing angles have been measured over the last 20 years and the remaining δ_{CP} determines the size of CP violation in neutrinos. In the case δ_{CP} is ±90deg, CP symmetry is maximally broken and the muon neutrino to electron neutrino transition probabilities differ by 30% between neutrinos and antineutrinos. The current T2K result indicates that δ_{CP} is close to −90deg (Fig.4) .

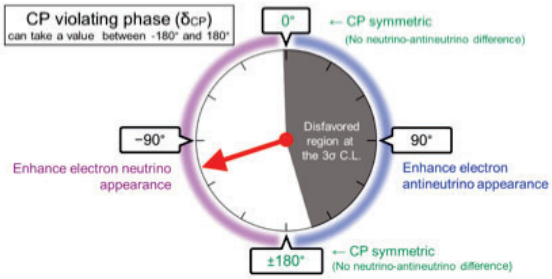

Figure 4. The arrow indicates the value most compatible with the T2K data. The gray region is disfavored at 99.7% C.L. The phase which conserves CP symmetry has not yet been excluded with 99.7% C.L.

The goal of this project is to explore the CP violation with a confidence level of 99.7% (Fig. 5). If the CP phase is away from -90 degree, we can not discover the neutrino CP violation but we can constraint the CP phase and verify some of theoretical models describing neutrino physics. There are still remaining two patterns of the neutrino mass order, namely normal and inverted ordering. One of goals of this project is to determine the mass ordering by combining the T2K data with other experiments.

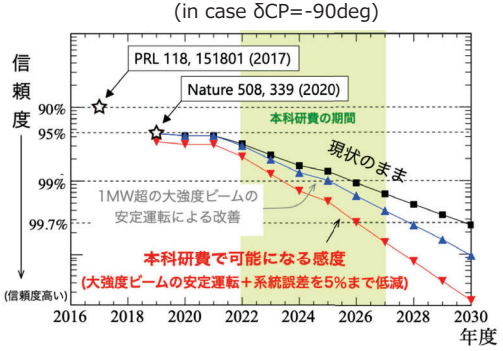

Figure 5. Expected sensitivity of CP violation in this project.

Homepage Address, etc.	http://t2k-experiment.org/