# DESCRIPTION FOR THE GENERAL PUBLIC

Neutrinos are elementary particles which do not have the electric charge and almost do not have mass–they are the lightest of the particles that constitute matter (quarks and leptons). In the theory that describes the particles and their interactions, called the Standard Model, there are three types (“flavors”) of neutrinos, each related to a corresponding charged lepton–electron, muon and tau. Neutrinos are the second most abundant particle in the Universe (after photon, the carrier of the electromagnetic force). They are produced in huge numbers in the nuclear reactions in start, in supernovae explosions, they were as well created in the Big-Bang. There are also neutrinos produced at Earth: in the atmosphere, Earth's interior, in the nuclear reactors and at the particle accelerators.

Studying of neutrinos is not an easy task as they interact very rarely–they are subject to so called weak interaction only. Therefore the observation of neutrinos requires huge detectors to increase the chance of detection. In one of such detectors, called Super-Kamiokande, a discovery was made in 1998: neutrinos of one type can transform in other type during the flight. It is called neutrino oscillations. The existence of oscillations requires that the neutrinos have mass, while the Standard Model assumed they were massless. The studies on neutrinos allow then not only to better understand the world of elementary particles, but also to search for the signals of so called New Physics, not described by the Standard Model.

Presently, the neutrino oscillations have been observed in several experiments, for neutrinos of various flavors, energies and originated from various sources. We know quite well the parameters describing the oscillations but there are still many questions. One of the most important questions is whether neutrinos and antineutrinos oscillate in a different way (whether so called CP symmetry is violated). If such effect were observed, it may lead to the understanding of the reason why the Universe, where the equal amounts of matter and antimatter were created in the Big-Bang, is now dominated by matter, from which also we are built.

This problem is analyzed by a world class experiment T2K which studies the oscillations of neutrinos produced in J-PARC facility in Japan and observed first in so called Near Detector (a reference measurement before the oscillations happen) and then at the distance of 295 km in the Far Detector, Super-Kamiokande. So far, T2K observed a weak hint that the CP symmetry may be violated, but other similar experiment in US, NOvA, didn't confirm that. Therefore more difficult studies are needed to confirm or reject the CP symmetry violation for neutrinos.

The T2K experiment is now being prepared for the second phase. The Far Detector is renovated and upgraded to obtain higher sensitivity, in particular for antineutrino interactions. The new parts planned for the Near Detector are currently in the test phase. During next few years the intensity of the beam will also be increased. All those upgrades will allow T2K to confirm the violation of CP symmetry (if it exists) at the confidence level of over 99%. Also the oscillation parameters will be measured with an unprecedented precision. There are as well plans of studies devoted to the better understanding of the interactions of neutrinos with matter (measurements of so called cross sections, in simple terms the chances of an interaction) in particular for low energies.

To perform such measurements and make discoveries one has first to put a lot of effort in the understanding of the performance of the improved detectors (simulations, calibration, estimation of systematic errors), the reconstruction of collected interactions and their selection and the understanding of the processes which are the background for the signal we are looking for. There is a need of the development of software tools such as the event reconstruction algorithms and selection methods (including the machine learning) as well as advanced statistical methods allowing for fast and effective comparison of data and models, for huge numbers of events and many model parameters. This project is related exactly to the involvement in the development of such tools and using them in the data analysis. The planned tasks include the understanding of the background, event reconstruction in the Near and Far Detectors with advanced methods (neural networks), selection of interesting events and using them in the oscillation analysis.