

DESCRIPTION FOR THE GENERAL PUBLIC

Neutrinos are elementary particles that are almost impossible to stop: they can traverse our bodies, earth, rocks or water with speed very close to the speed of light. They are electrically neutral, almost massless and they interact very weakly with matter. Studying their properties is therefore a challenging task and large expensive laboratories and research devices are needed.

There exist three types of neutrinos, physicists call them flavors: electron, muon and tau. Scientists are particularly interested in a phenomenon called oscillations, in which neutrinos change flavor during their propagation in space. Observation of these transitions gives us a unique opportunity to explore uncharted areas of particle physics. The existence of this phenomenon has been experimentally confirmed in 1998 by the Super-Kamiokande experiment in Japan, which studied atmospheric neutrinos by observing their interactions in water. Since then an intensive research program is being implemented which already led to a substantial increase in our knowledge of neutrino transformation mechanisms. However, there is still a need for further studies, to confirm existence of charge conjugation-parity (CP; C stands for matter-antimatter symmetry and P for space inversion) symmetry violation in the neutrino oscillations. If this symmetry was broken, neutrinos would oscillate differently than their antiparticles, called antineutrinos. This would help to solve a cosmological puzzle: why the Universe is composed of matter and not antimatter.

Experimental neutrino physics requires accelerators and huge underground particle detectors. In one laboratory a flux of neutrinos is produced. Then they travel a long distance, simply to give them time to oscillate. Finally, after traveling hundreds of kilometers they cross large underground detectors. Probability of neutrino interaction with matter inside the detector is tiny. That is why we build such huge devices, because the larger the apparatus mass, the higher the chances to observe neutrinos. Neutrinos are never seen directly. In the detectors physicists only see flashes of light or other signals coming from particles produced in neutrino interactions with atomic nuclei, and this allows them to gain information about neutrinos features.

In the T2K experiment in Japan, neutrinos are produced in JParc laboratory near Tokai and detected 295 km away in the Super-Kamiokande laboratory in Japanese Alps. Scientists compare energies of neutrinos observed in Super-Kamiokande with energies of neutrinos emitted in the beam trying to gain knowledge about their oscillation. Neutrino energy is not known directly, it has to be calculated looking at particles created in interactions and accepting certain theoretical assumptions.

The aim of this project is to verify these assumptions and improve the energy calculation method by estimation how many interactions are coming from a so-called two particles – two holes (2p-2h) mechanism. This mechanism was studied earlier in electron scattering. Usually neutrinos interact with individual nucleons inside atomic nuclei. The process of interest here is different: the interaction takes place on nucleon pairs and is more difficult to describe theoretically. Its existence spoils neutrino energy reconstruction, and indirectly has a negative impact on neutrino oscillation research. Precise knowledge of this mechanism is relevant for nuclear physics and will lead to an improvement of precision of oscillation experiments. This will in turn mean that we will have more ways to improve our knowledge about the Universe and processes that take place in it.