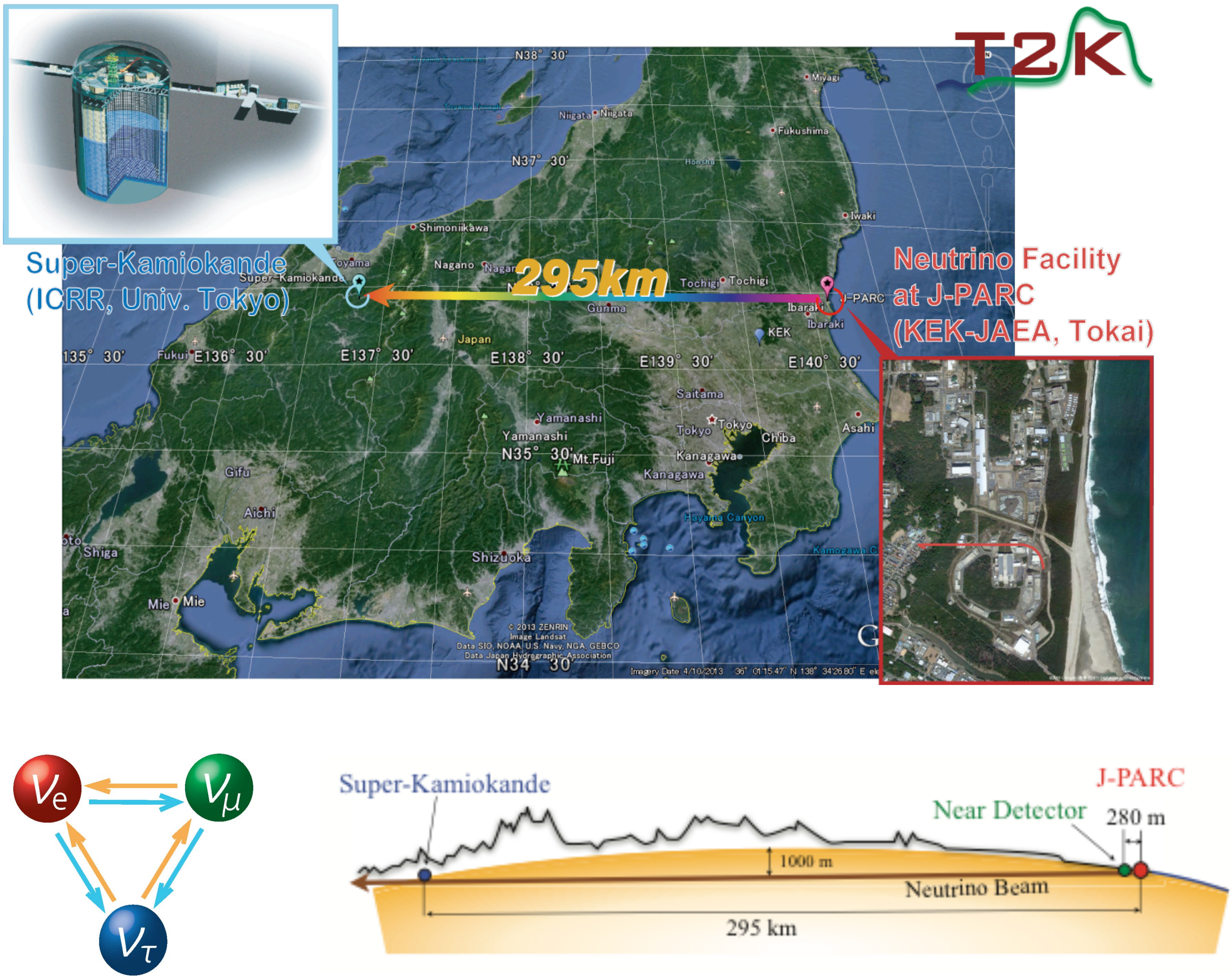

Figure 1 Overview of the T2K experiment

The proton beams extracted from the main ring synchrotron at J-PARC are directed in a westward direction through the T2K primary beam line. The beams strike a target composed of graphite rods (image 1 in figure 2), and produce a large number of positively-charged pions. The directions of motion of these pions are made to converge in the forward direction by some magnetic horns.

The pions then decay into muons and muon neutrinos in a 100-metre-long tunnel known as the decay volume (image 2 in figure 2). The muons and any remaining pions are stopped by a second layer of graphite, while the muon neutrinos pass through this layer. The composition of the muon-neutrino beam is measured by a near detector located 280 metres downstream of the target (image 3 in figure 2). Neutrino oscillations are studied by comparing the composition of the muon-neutrino beam at the near detector with its composition at Super Kamiokande, which is 295 km from the target.

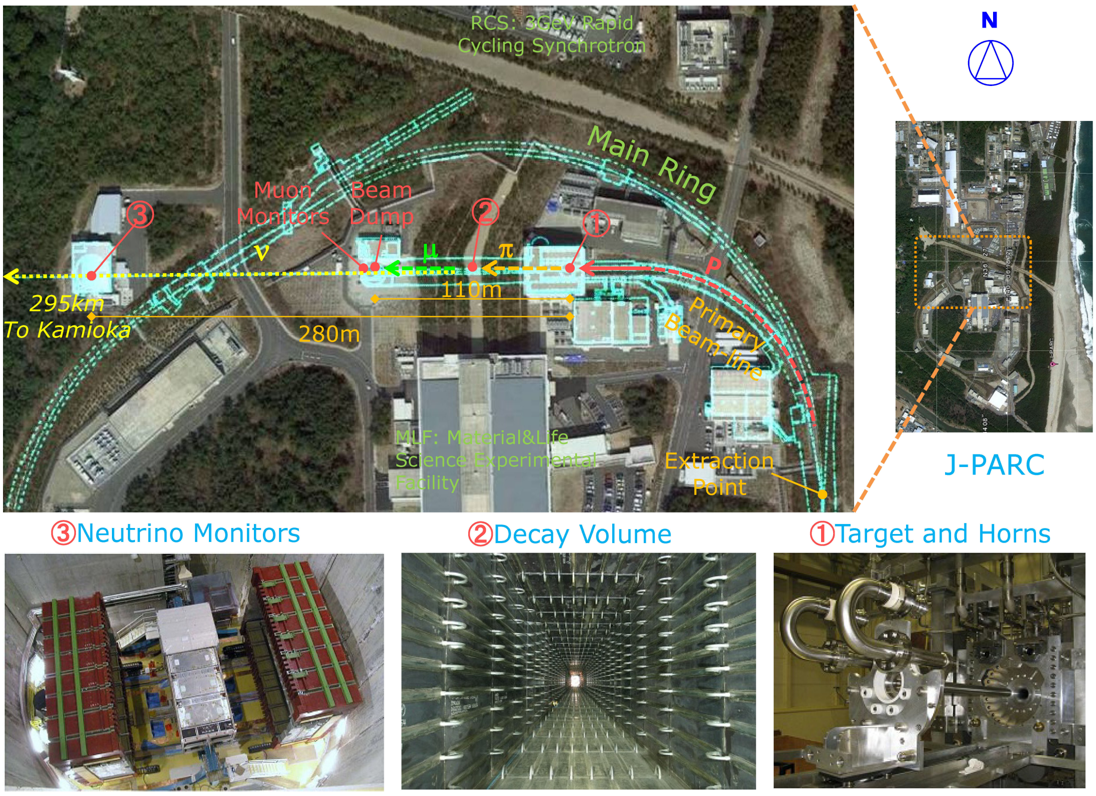

Figure 2 J-PARC neutrino experimental facility

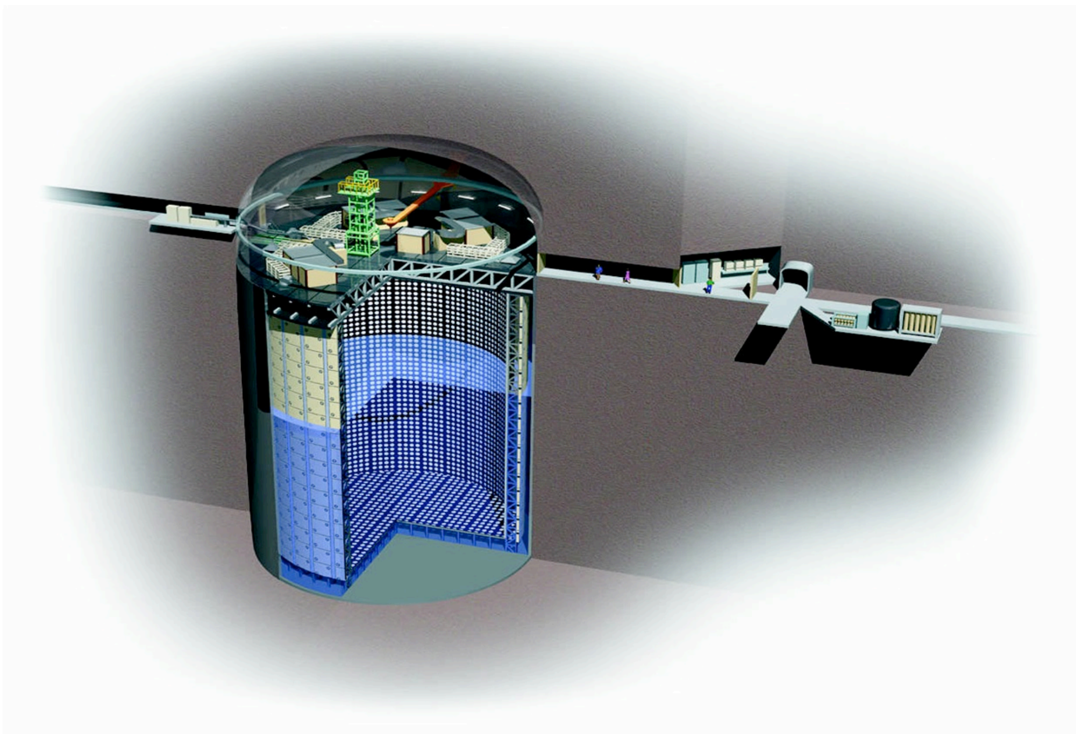

Figure 3 Super-Kamiokande detector

Super Kamiokande is the world's largest underground neutrino detector, and is located 1000 metres underground in Kamioka Mine, Hida, Gifu Precture, Japan. It is affiliated with the Kamioka Observatory of the Institute of Cosmic Ray Research at the University of Tokyo. In addition to detecting T2K neutrinos, Super Kamiokande observes neutrinos produced by collisions between cosmic rays and molecules in the Earth's upper atmosphere. It is also searching for proton decays, which have never been observed to date. Super Kamiokande consists of a large cylinder 39.3 metres in diameter and 41 metres high that contains 50,000 tons of ultra-pure water. The inner walls of the cylinder are lined with about 11,200 photomultiplier tubes to detect Cerenkov light, which is emitted when a charged particle travels faster than the speed of light in water (this is three-quarters of its speed in vacuum).

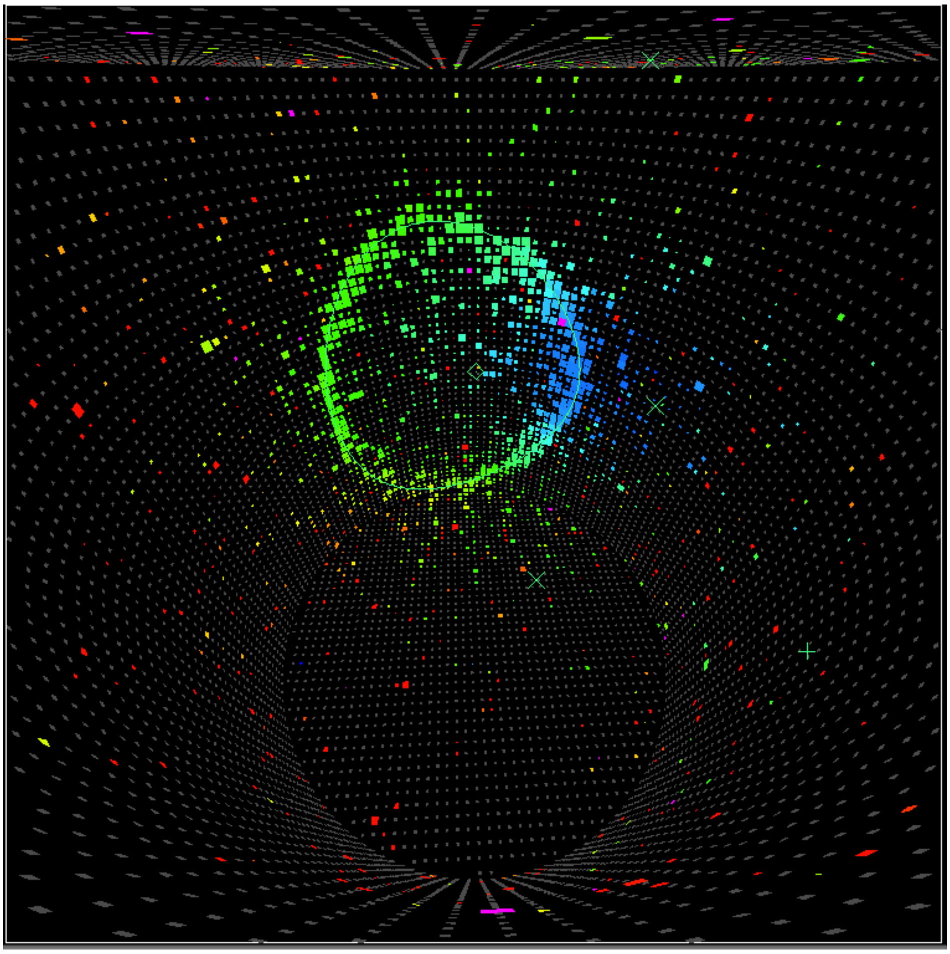

Figure 4 A candidate electron-neutrino event in Super Kamiokande

In this 3D image of the cylindrically-shaped Super Kamiokande, each coloured dot represents a photomultiplier that detected light. An electron neutrino interacts with a neutron in a nucleus of a water molecule to produce an electron and a proton. The electron often travels faster than the speed of light in water, and causes Cerenkov light to be emitted from the water atoms. This light is seen as a ring by the photomultipliers of Super Kamiokande. The image shows the first electron-neutrino candidate observed after the recovery from the earthquake on the east coast of Japan in 2011.

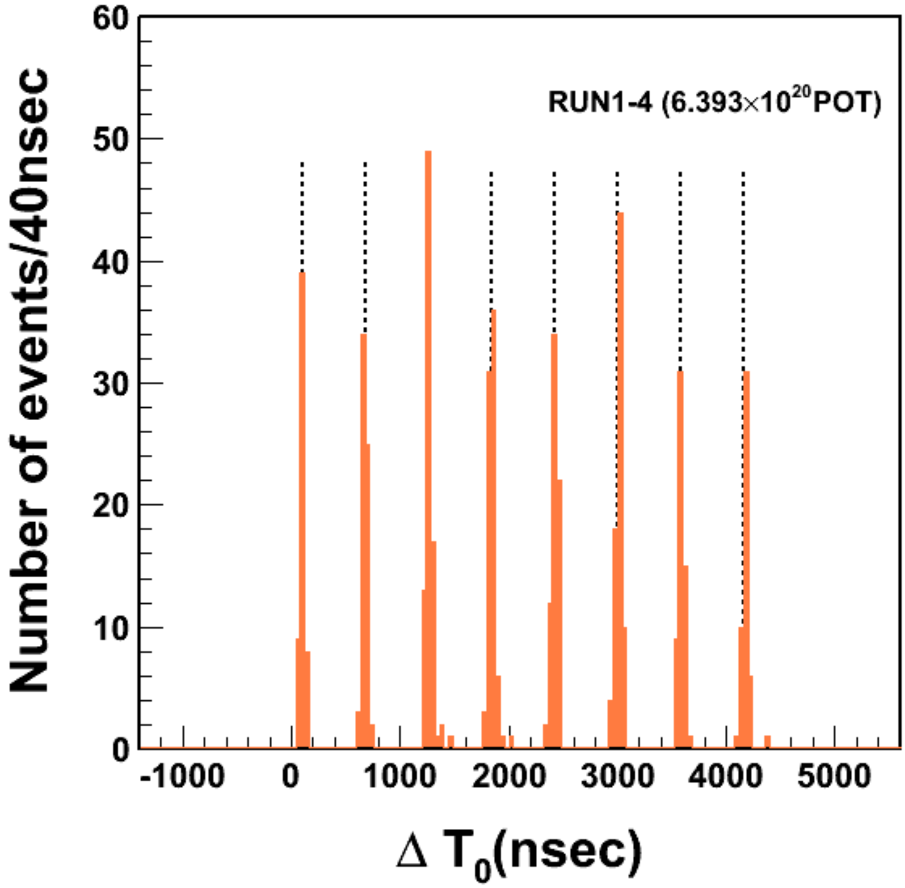

Figure 5 Distribution of the times of T2K neutrino events observed at Super Kamiokande

At J-PARC, the neutrino beam is produced as a pulse every 2.5 seconds. Each pulse has 8 “bunches” of neutrinos due to the method of accelerating the proton beam. Figure 5 shows the distribution of times of neutrino events, and the bunch structure can be clearly seen (zero on the horizontal axis is the time at which the start of the pulse arrives at Super Kamiokande).

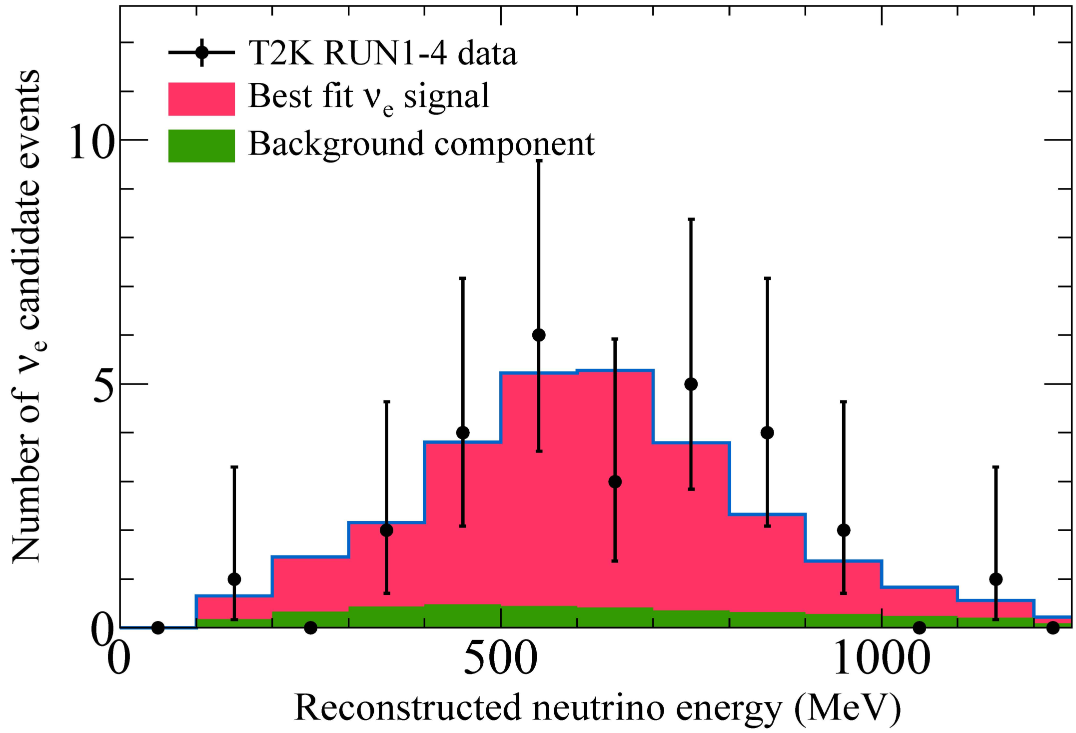

Figure 6 Distribution of reconstructed energy of electron-neutrino candidates in Super Kamiokande

The distribution of reconstructed energies of the electron-neutrino candidates in Super Kamiokande is shown in figure 6, with black points representing the data, the pink histogram representing the expected energy distribution of electron-neutrino candidates that have oscillated from muon neutrinos, and the green histogram representing the expected energy distribution of non-oscillated electron neutrinos. These non-oscillated electron neutrinos are expected to be seen in Super Kamiokande, and are due in part to a small fraction (1%) of electron neutrinos in the muon-neutrino beam produced at J-PARC.

Glossary

1. The T2K experiment

T2K means “Tokai to Kamioka”, and it is a long-baseline neutrino experiment. It produces a muon-neutrino beam at the J-PARC proton accelerator in Tokai, and sends it to the far detector Super Kamiokande, which is located at a distance of 295 km in Kamioka mine, Gifu Prefecture. One of the main aims of T2K is to find oscillations from muon neutrinos to electron neutrinos, and this announcement is to confirm that these oscillations have been observed. T2K is an international collaboration with about 500 reserachers from 11 countries: Japan, U.S., U.K., Italy, Canada, Switzerland, Spain, Germany, France, Poland and Russia. In Japan, 85 researchers and students participate as core members of T2K; they are from the Osaka City University, Okoyama University, Kyoto University, KEK, Kobe University, Tokyo Metropolitan University, University of Tokyo, Institute for Cosmic Ray Research of the University of Tokyo, Kavli IMPU of the University of Tokyo, and Miyagi University of Education.

2. Neutrinos

Neutrinos are elementary particles that come in three types: electron neutrinos, muon neutrinos and tau neutrinos. They are electrically neutral, and their masses are not known but are believed to be of the order of one millionth of the masses of quarks and electrons.

3. Neutrino oscillations

Neutrinos change from one type to another as they travel. This change of type is called “neutrino oscillation”, and it can only happen if neutrinos have different masses. It was first predicted by Pontecorvo, Maki, Nakagawa and Sakata in 1962. Oscillations can take place between any of the three types of neutrino and any other type.

4. Electron-neutrino appearance

This announcement is to confirm that T2K has observed oscillations from muon neutrinos to electron neutrinos, which is one of its main aims. These oscillations are called “electron-neutrino appearance” since the electron neutrinos appear in a beam of muon neutrinos.

5. CP violation

CP means “Charge-Parity”, where a “Charge” transformation changes a particle to its antiparticle, and a “Parity” transformation changes the handedness of the particle. A “Charge-Parity” or CP transformation changes a left-handed neutrino to a right-handed antineutrino or vice versa. A right-handed particle has its spin vector pointing in the same direction as its motion, whereas a left-handed particle has its spin vector pointing in the opposite direction to its motion. “CP violation” means that the laws of physics change when a CP transformation is made. An example of CP violation would be the probability of oscillation from muon neutrinos to electron neutrinos being different from the probability of oscillation from muon antineutrinos to electron antineutrinos. A search for CP violation is very important as it could explain why the Universe is composed entirely of matter when equal quantities of matter and antimatter were created in the Big Bang.

6. Leptons

Leptons are a group of six elementary particles consisting of the electron, muon and tau and the three neutrinos. Each lepton is thought to have a one-to-one correspondence with one quark, for example the electron has a correspondence with the up quark. However the details of this correspondence have yet to be determined. Each lepton has an antiparticle as does each of the six quarks.