

J-PARC: Research Accelerated

Last December, experiments got underway at one of three experimental facilities in the Japan Proton Accelerator Research Complex (J-PARC), which has been constructed in Tokaimura in Ibaraki Prefecture. In the future, an extensive array of research topics will be conducted at J-PARC, ranging from fundamental science through to practical applications. **Yukio Oyama**, deputy director of J-PARC, explains the objectives of J-PARC, as well presenting an overview of the facilities and describing some of the experiments that are being conducted.

J-PARC has been jointly built and operated by the Japan Atomic Energy Agency (JAEA) and the High Energy Accelerator Research Organization (KEK). J-PARC consists of a world-class accelerator that generates a powerful proton beam, as well as three experimental facilities that use this beam: the Materials and Life Sciences Facility (MLF), the Nuclear Particle Physics Facility (Hadron Facility) and the Neutrino Facility.

The proton accelerator is, as the name suggests, a device that accelerates protons by subjecting them to an electric field. There are actually three accelerators, all located 15 meters underground below J-PARC. The first is a straight-line accelerator called Linac, which is 330 meters long. The second is a circular accelerator called

3 GeV Synchrotron with a circumference of 350 meters. (A “GeV” is a “giga electron volt,” or a billion electron volts.) The third accelerator is a 50 GeV Synchrotron with a circumference of 1,600 meters.

The high-energy proton beam is accelerated to almost the speed of light and then sent to the three experimental facilities, where it collides with target nuclei (such as mercury, carbon, nickel) that have been set up at each experimental facility. This breaks the nuclei, generating all kinds of secondary particles, such as neutrons, K mesons, muons and neutrinos. These secondary particles are utilized to conduct various experiments at each facility.

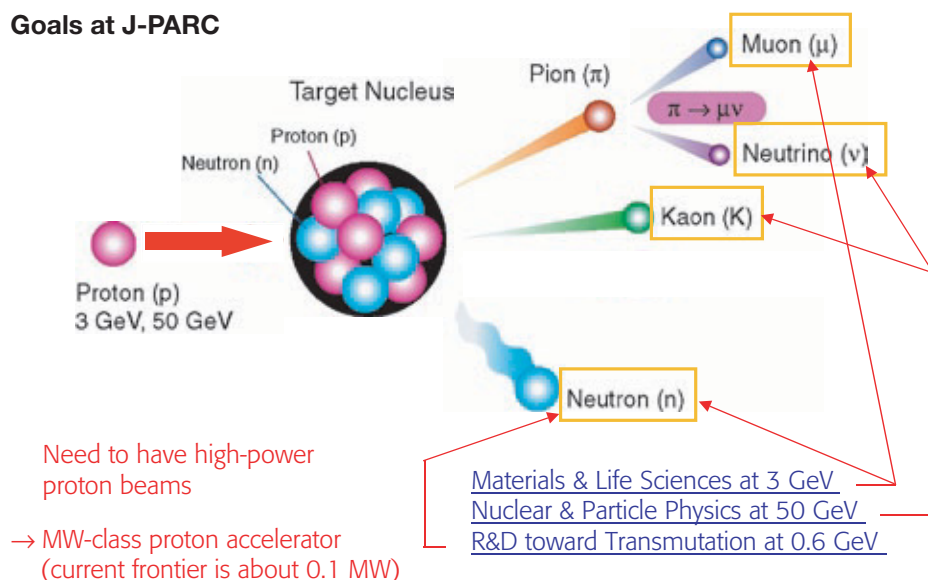
There are several other large-scale accelerators operating around the world, such as the Spallation Neutron Source (SNS) run by the Oak Ridge

National Laboratory (ORNL), the Large Hadron Collider (LHC) in Switzerland run by the European Organization for Nuclear Research (CERN), and the Pulsed Neutron and Muon Source (ISIS) run by the Rutherford Appleton Laboratory in England. However these organizations are all focused on fundamental research in areas such as nuclear particle physics or neutron science. Internationally, J-PARC is unique in being a multipurpose facility where research is conducted in a wide variety of areas, ranging from fundamental research through to industrial applications.

The Materials and Life Sciences Facility

The Materials and Life Sciences Facility (MLF), where experiments started last December, is mainly engaged in research that uses neutrons to investigate the structure of matter at the atomic level. Similar research has been conducted in Japan already, at the SPring-8 large synchrotron radiation facility in Hyogo Prefecture, which has produced significant results by using X-rays generated by an accelerator to conduct experiments that investigate the structure of matter. However, X-rays can only observe the electrons in matter, and so it is difficult to observe the structure of lighter elements such as hydrogen, which only has one electron. However, neutrons can be used to observe nuclei, making it possible to observe exactly the location of even lighter elements such as hydrogen. It is important to be able to observe the hydrogen atom for life science and material science. In the field of life science, this will initially be utilized in order to analyze the structure of proteins including hydrogen atoms. The surfaces of proteins are usually covered with water molecules, and the interaction between protein and water is thought to play a significant role in drug efficacy. Investigating the location of water molecules in proteins and the function

Goals at J-PARC



of the bonded water molecules in proteins—which it has not been possible to observe until now—should be useful for developing new medicines.

In the field of materials science, the new facilities can be used to develop hydrogen-fuel cells. Fuel cells produce electricity from the reaction of hydrogen and oxygen. Progress is already being made with research into catalyst materials that cause this reaction and hydrogen storage alloys that store and release hydrogen fuel for fuel cells, but neutrons can be used to observe where the hydrogen is located in the catalyst and storage alloys, and how it behaves. This should lead to the development of catalysts that can produce efficiently electricity with low cost and storage alloys that can store and release large volumes of hydrogen.

Other research being conducted at the MLF includes elucidating the mechanism behind high temperature superconductivity, unraveling the structure of macromolecules such as plastics, and investigating materials with new functions.

The MLF allows for up to twenty-three experimental facilities (known as “beam lines”) to be installed, and the MLF is now making an international call for submissions for research topics. At present experiments are being conducted by universities, private companies and other research institutions using seven of the available beam lines.

The Nuclear Particle Physics Facility

Experiments will start at the Nuclear Particle Physics Facility (Hadron Facility) from February this year. One of the research topics that will be pursued here is to use K mesons to try to get closer to solving the puzzle of the mass of matter. There are two types of elementary particles that make up the smallest units of matter, namely “quarks” and “leptons.” The protons found in atomic nuclei are simply a collection of three quarks, but the mass of a proton is not simply three

times the mass of a quark but actually about 100 times the mass of a single quark. Nobody has been able to explain exactly why protons are so heavy even though they are made up of only three quarks. In order to try to work this out, researchers at the Hadron Physics Facility will inject K mesons (which consist of two quarks) into target nuclei and study the changes of the mass of the K mesons inside the nuclei.

The Neutrino Facility

Experiments at the neutrino experimental facility will start from April this year. These experiments will fire a neutrino beam at the Super Kamiokande neutrino detector located 295 kilometers away in Hida City in Gifu Prefecture.


It was once thought that neutrinos had no mass. But experiments using the Super Kamiokande detector have demonstrated the phenomenon of “neutrino oscillation,” which can only occur if neutrinos have mass.

The accelerator used in these neutrino oscillation experiments was the High Energy Accelerator Research Organization (KEK) proton accelerator in Tsukuba City in Ibaraki Prefecture. In these experiments, the KEK

accelerator was used to create a neutrino beam, which was fired at the Super Kamiokande detector, allowing researchers to observe about 100 neutrino oscillation phenomena between 1999 and 2004. However, the J-PARC neutrino beam will be a hundred times stronger than the KEK neutrino beam, which will make it possible for researchers to observe 100 neutrino oscillation phenomena in as little as two weeks.

By observing a large number of neutrinos, researchers will further verify the neutrino oscillation phenomenon, by analyzing the details of transitions from muon neutrinos to tau neutrinos, for example, or by observing a transition from a muon neutrino to an electron neutrino, a transition that has yet to be discovered.

These neutrino experiments will involve more than 450 researchers from twelve countries.

In the meantime, the first phase of the J-PARC plan has concluded with the completion of the accelerator and the three experimental facilities. The next step is to start working on creating the Transmutation Experimental Facility, which we proposed as the plan for the second phase. 

Yukio Oyama is the deputy director of J-PARC.

