J-PARC Project in Japan

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From Japanese fiscal year JFY2001 a new accelerator project to provide high-intensity proton beams proceeded into its construction phase. This project, called the J-PARC (Japan Proton Accelerator Research Complex), is promoted under the cooperation of two institutions, KEK and JAEA. We set a goal to achieve 1 MW proton beams at 3 GeV and 0.75 MW beams at 50 GeV. The project will be completed in JFY2008, with anticipated first beams in the late 2008. In this article I will describe the project itself and examples of Day-1 experiments, in particular, in the area of nuclear and particle physics.

1. WHAT IS J-PARC?

KEK (National High Energy Accelerator Organization) and JAEA (Japan Atomic Energy Agency) are constructing a new proton accelerator at the highest beam power (about 1 MW) in the world. The new accelerator is targeted at a wide range of fields, using K-meson beams, neutrino beams, neutron beams and muon beams, to cover nuclear and particle physics, materials science, biology and nuclear engineering. These beams will be created by bombarding proton beams on nuclei at rest, as illustrated in Figure 1.

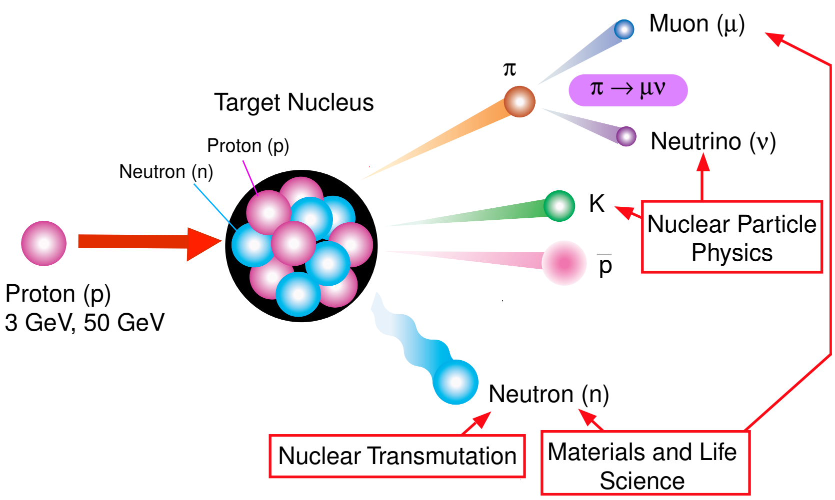

Figure 1. Production of secondary beams and the applications of these beams into a variety of sciences.

When a low-energy proton (typically, at the energy of 1 GeV) hits the nucleus, constituents of the nucleus will be ejected with the proton-induced spallation reaction. Typical particles are neutrons and, thus, neutron sciences can be developed at this facility. Also, a copious production of pions is expected, so that the research with low energy muons, for example, μSR or muonium science, can be conducted. In addition, fast neutrons can be used for the study of nuclear transmutation. At higher beam energies, typically 50 GeV, the proton-nucleus collisions will produce kaons, anti-protons, and high-energy neutrinos. The usage of these beams will open frontier nuclear and particle physics.

The accelerator has the following components: a) A 400 MeV (200 MeV on Day-1) proton Linac (normal conducting) as an injector, b) a 25 MHz 3 GeV proton synchrotron with 1 MW power for neutrons and muons, and c) a 50 GeV proton synchrotron with slow extraction for kaon beams etc. and fast extraction for neutrino beams. The configuration of the entire facility is shown in Figure 2. The accelerator complex is constructed at the Tokai campus of JAEA. Since the entire cost of the project is about 189 billion yen ($\approx$ \$1.6 billion), the Government decided to fund 153 billion yen for Phase 1, as marked in Figure 2. Currently, about 2/3 of the construction was completed. The present scenery of the construction site as viewed from the sky is shown in Figure 3.

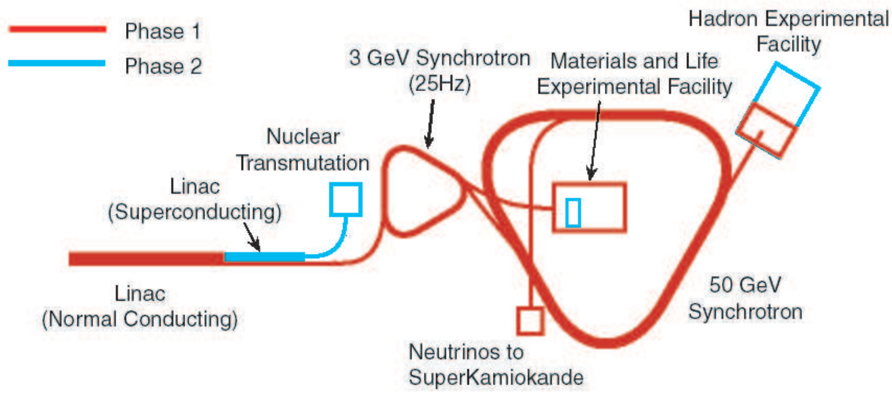

Figure 2. Layout of the JAEA/KEK Joint Project, J-PARC.

Figure 3. Current view of the construction of the J-PARC.

2. EXAMPLE OF DAY-1 EXPERIMENTS AT 50 GEV PS

2.1. Neutrino Experiment, T2K

The first experiment is related to the neutrino oscillation. It is known that, from the most fundamental principle, there are no reasons to assume that the neutrino mass is zero, although it has been believed for many years that the neutrino has zero mass. In a recent experiment at Super Kamiokande [1], where atmospheric neutrinos were detected, it was demonstrated that muon neutrinos (ν_μ) from the sky was converted to tau neutrinos (ν_τ) while traversing through the Earth. This phenomenon gave an evidence on the existence of neutrino oscillation. Since this oscillation can occur only when the neutrino carries a finite mass, this experiment demonstrated the existence of a finite mass of neutrino.

A recent K2K experiment [2] using ν_μ beams from the KEK 12 GeV accelerator and to detect ν_μ at Super Kamiokande also showed an additional evidence that ν_μ would oscillate while traversing from KEK to Super Kamiokande. Furthermore, a later SNO result [3] suggests that neutrinos from the Sun (primarily ν_e) also oscillate due to a finite mass of neutrino.

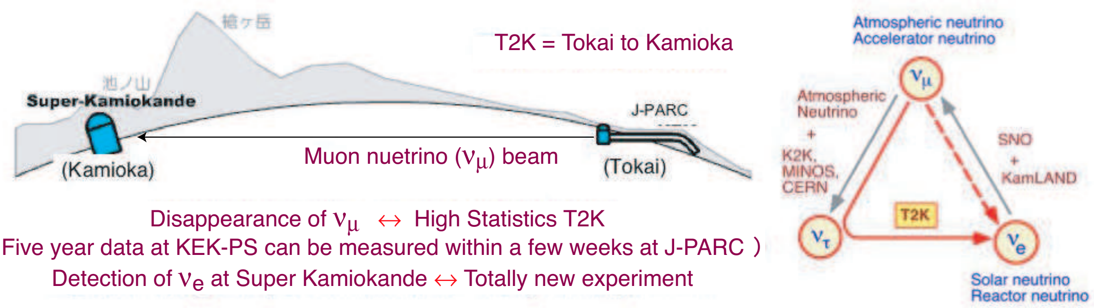

Figure 4. T2K (Tokai to Kamioka) experiment using ν_μ beams from J-PARC.

At the forthcoming J-PARC an anticipated ν_μ neutrino flux is by one hundred times stronger than the flux obtained at the present 12 GeV PS at KEK. Therefore, precise measurements of the neutrino mass can be expected at the 50 GeV facility at J-PARC. See Figure 4. Experimentalists also expect to observe $\nu_\mu \rightarrow \nu_\mathrm{e}$ oscillation by observing ν_e appearance at Super Kamiokande. By observing this new mode, a new mixing between ν_τ and ν_e, called θ_{23}, can be measured. This T2K experiment, thus, shall determine a completely new and unknown mixing parameter.

2.2. Meson and Hyperon Implantation in Nuclei

It is known that over 99% mass of the matter is carried by atomic nuclei and, thus, by protons and neutrons. Each proton or neutron is made of three quarks. One puzzle which has not been solved quantitatively until now is an exact reason that the mass of proton (or neutron) is as heavy as $\cong 1$ GeV/c^2, whereas the constituent quark mass is much lighter, being less than 1/100 of the proton mass. Qualitatively, it is believed that the creation of a large proton mass is due to a spontaneous chiral symmetry breaking. Theoretically, it is also predicted that this symmetry breaking can be studied by implanting a meson (which is made of quark and anti-quark) in the interior of extreme conditions and by studying the change of chiral properties such as an order parameter [4] in these conditions.

The first intriguing result came from GSI, where a pion imbedded deeply inside the nucleus [5] formed a meta-stable state. From the analysis of a width and an isotope shift of the peak, it was concluded that the order parameter for pion is reduced by one third when a pion is imbedded inside normal nuclear matter. The result is striking, since, if this is true, this experiment clearly demonstrates, for the first time, that a chiral symmetry is partially restored if a meson is imbedded in the interior of nuclear matter.

Another very interesting result reported recently is an observed sharp peak associated with a kaon bound inside the nucleus [6]. This experimental search was triggered originally by a theoretical work by Akaishi and Yamazaki [7] which predicts the existence of a deeply-bound kaonic state (I = 0, Z = 1 and 100 MeV in binding energy). Furthermore, this kaon might play a role as a catalyzer to induce the formation of an extremely high-density system [7]. If this is the case, a further study of properties of kaon in nuclear matter for a variety of nuclei is intriguing, in particular, for the purpose of studying a partial restoration of chiral symmetry for a kaon in nuclear matter. Detailed studies on strange baryons and strange mesons in nuclei are actively planned as Day-1 experiments at J-PARC by using high-flux kaon beams.

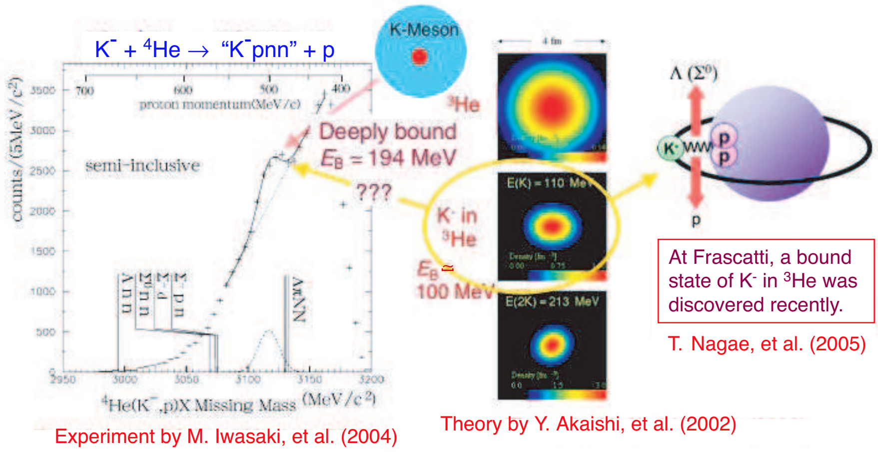

Figure 5. K-meson implanted in nuclear matter.

The J-PARC team has about 300 staff members who are working day and night, even in the weekends and holidays. I would like to thank all the members of the project team.

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