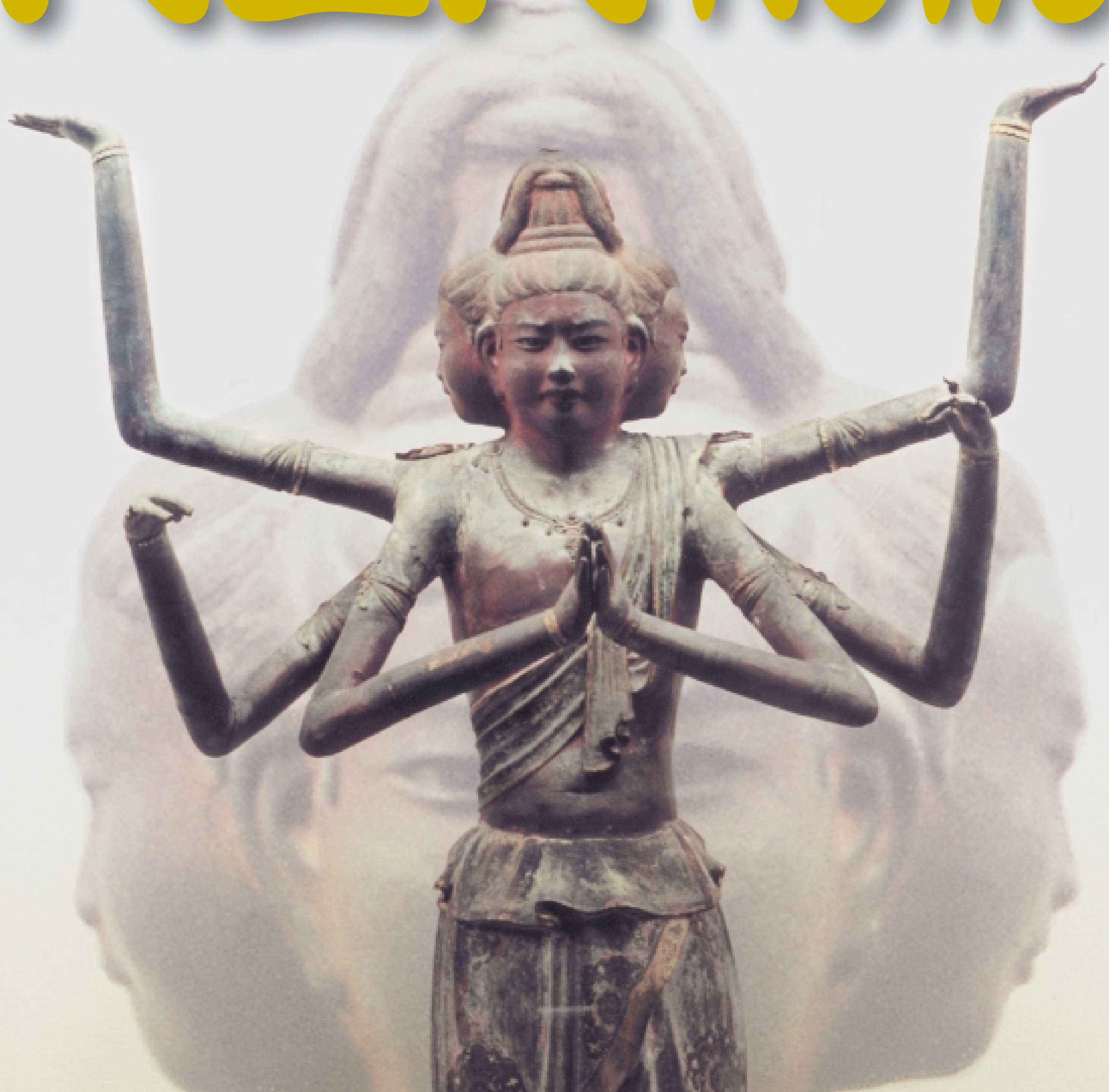
KEK News

Vol.4 No.2



The Joint Project for High-Intensity Proton Accelerators

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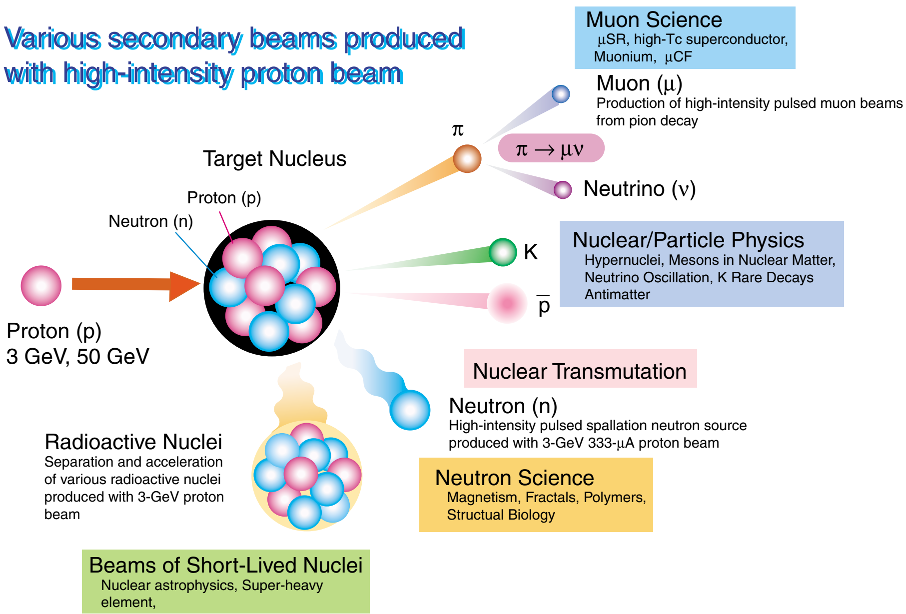
High Energy Accelerator Research Organization

The Joint Project for High-Intensity Proton Accelerators

KEK and JAERI (the Japan Atomic Energy Research Institute) have been proposing to construct new high-intensity proton accelerators at the JAERI Tokai site (~80 km north-east of KEK) since 1999. The project is to pursue frontier science in particle physics, nuclear physics, material science, life science, and nuclear technology, using a new proton accelerator complex at the world-highest beam power.

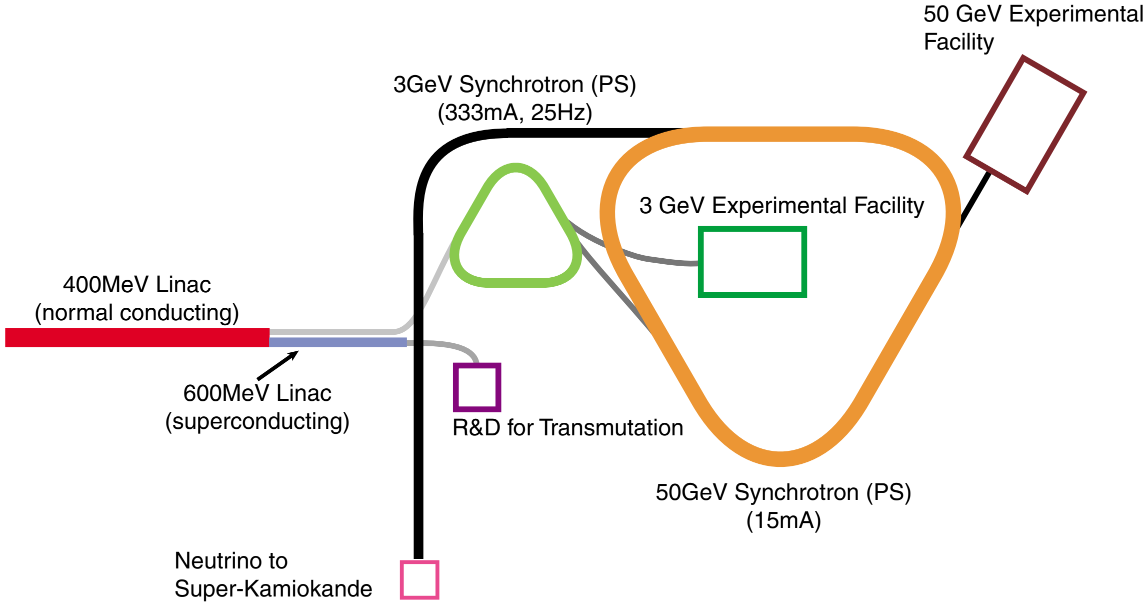
Originally, KEK had a hadron accelerator project called the Japan Hadron Facility, (50-GeV proton synchrotron and a 3-GeV booster ring where the projected power of the latter was 0.6 MW). JAERI had a high-power spallation neutron source project with a proton linear accelerator (Linac), (3-MW pulsed beams for neutron scatterings and 5-MW continuous beams for nuclear transmutation). Since both projects had a common goal to attain high-power proton beams, they were combined into one Joint Project.



The proposed accelerator complex consists of

1) 400-MeV (mega-electron volts) normal-conducting Linac,
2) 600-MeV superconducting Linac to increase the energy from the 400 to 600 MeV,
3) 3-GeV Proton Synchrotron (PS), and
4) 50-GeV PS.

The 400-MeV protons are partly injected into the 3-GeV PS and partly into the 600-MeV Linac. The 600-MeV proton beam will be used for the basic research for nuclear waste transmutation converting long-lived radioactive nuclides into short-lived or non-radioactive nuclides. The main part of the 3-GeV proton beam will be delivered to the neutron/meson facility where extensive research programs on nuclear/particle physics, condensed matter physics, material sciences and structural biology will be carried out by using beams of muon and neutron. A part of the 3-GeV beam will be transferred to the 50-GeV PS. At the 50-GeV PS, nuclear/particle physics experiments using kaon beams, anti-proton beam, neutrino beams, and primary proton beams are planned.



Japan is expected to take a significant leadership role in accelerator science in the 21st century using this facility; the present neutron source facility will be one of three major centers (Asia/Pacific rim, Europe, and North America) in the world, which were strongly recommended for immediate construction by the OECD Mega Science Forum for neutron sources. The OECD Mega Science Forum for nuclear physics also emphasized the scientific importance of the 50-GeV PS as a world center for future hadron physics.

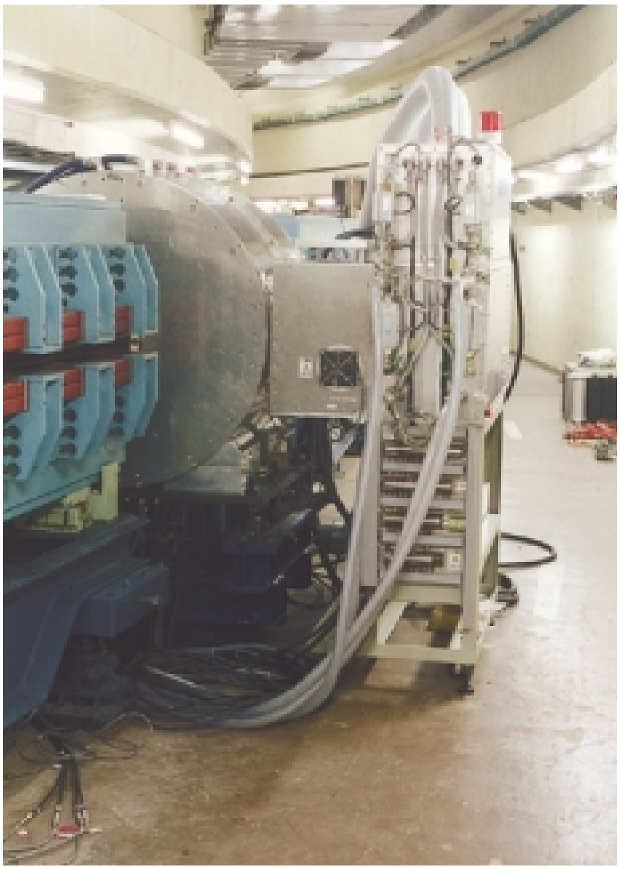
Phase 1 of the Joint Project was approved very recently including construction of 400-MeV Linac, 3-GeV PS, 50-GeV PS, major part of the 3-GeV neutron/meson facility, and a portion of the 50-GeV experimental facility. We plan to complete it within 6 years.

The author of this article, Professor ***Shoji NAGAMIYA***, is the project director of the Joint Project.

The Accelerators for the Joint Project

Toward the frontier of the world-highest beam power, the present accelerator technology does not surely guarantee the proton beam power beyond 1 MW. Among the three spallation neutron source projects in the world, the present design of the Joint Project is going to use the concept (page 1) of the accelerator complex comprising a linac, a rapid-cycling booster synchrotron (RCS), and a main proton synchrotron, while other two facilities will use a concept of full-energy linac (1-GeV class) and storage ring.

Some of the difficulties to realize the several-GeV RCS are summarized in the following. Since the number of protons accelerated at one time in a synchrotron is limited by the Coulomb force, the acceleration cycle of the synchrotron should be increased (up to 25 cycles per second in the present design) in order to obtain the high beam current required. The rapid cycling of the synchrotron implies rapid acceleration of the beam. The beam is accelerated by radio-frequency (RF) electric field. The rapid acceleration requires that the higher voltage per unit length (electric field) should be applied to the beam. For a realistic design of the present RCS, one needs a field of ~50 kV/m, which is not feasible with a conventional ferrite-loaded RF cavity. Since the increase in velocity of the particles is faster, the circulating period of the beam in the ring is shorter. So, the other difficulty is that the frequency of the RF cavity should be adjusted rapidly to follow this rapid change.


The MA-loaded cavity

Recently, KEK has solved both of these problems by developing an RF cavity loaded with a new type of magnetic alloy (MA) such as FINEMET. The MA-loaded cavity should withstand over 100 kV/m, and no tuning is necessary. The cavity has already been power-tested up to 50 kV/m, and has been beam-tested in various ways.

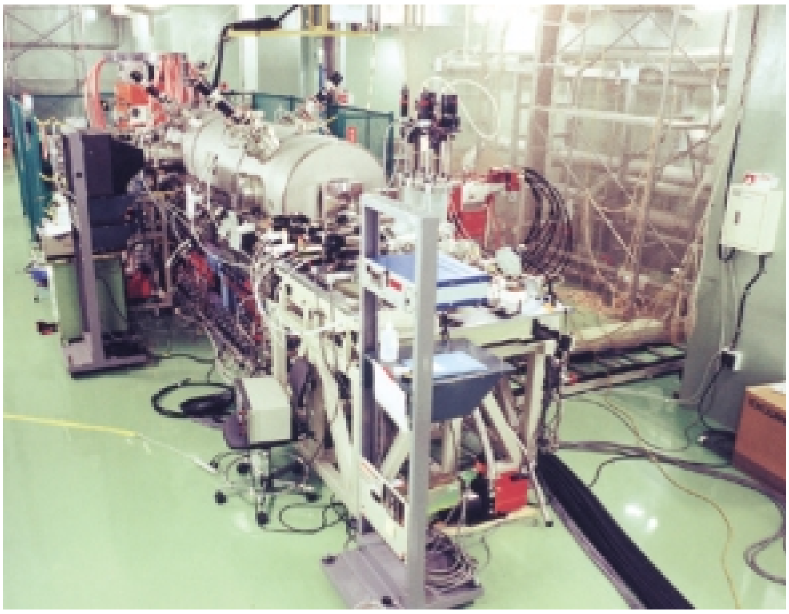
The construction of the low-enegy front (60 MeV) of the proton linac started in 1998. The linac comprises a volume-production type of negative hydrogen ion source, a 3-MeV radio-frequecy quadrupole (RFQ) linac, a 50-MeV drift-tube linac (DTL), and a 60-MeV separated DTL (SDTL). The SDTL will be extended up to

200 MeV in the Joint Project linac, followed by the annular-ring coupled structure (ACS) up to 400 MeV.

The RFQ linac is well field-stabilized by π-mode stabilizing loops (PISLs) devised in KEK. The prototype of the 3-MeV RFQ linac with PISLs had been beam-tested several years ago, accelerating an H^- beam of 13 mA in peak. The design beam current of the present one is 30 mA. The SDTL devised in KEK has excellent power efficiency over the conventional DTL. The ACS is axially symmetric in contrast to the commonly used side-coupled structure, which is axially asymmetric. Because the axial symmetry is one of important factors in order to reduce the beam loss, the ACS has been studied and realized in KEK first. The several prototypes of the ACS have already been power-tested.

The conventional accelerator technology is not sufficient for realizing the proposed beam power. For this reason, the results of many innovations have already been incorporated for the Joint Project accelerators in order to push forward the beam power front of the accelerator technology. Yet, further development will be necessary to realize the challenging features of the Joint Project.

Young, ambitious scientists and engineers are thus invited to join the project.



RFQ installed in a tunnel in KEK

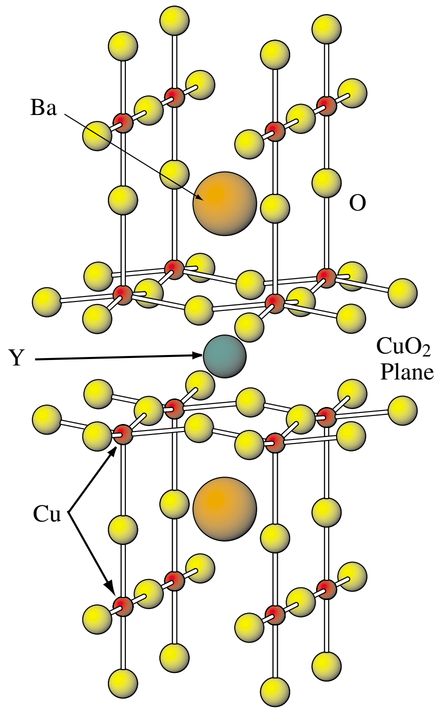
The author of this article, Professor ***Yoshishige YAMAZAKI***, has been the group leader of the accelerator group in the Joint Project.

Neutron and Muon Beam Lines at the 3-GeV PS

Neutron Science

Neutron gives very important information of atomic structure and dynamics of material in microscopic scale, even of magnetic ones, which is indispensable to understand properties and functions of material, and leads to improvement of material's function and invention of new materials. The neutron facility in the Joint Project is a pulsed spallation neutron source and creates very intense neutrons in very wide range of energy from μeV to MeV region. Therefore, there are huge variety of application with neutron from the facility for studying materials, ranging from bio-molecules, organic/inorganic chemical molecules, medicines, food artifacts, ferro-electrics, magnets, semiconductors, superconductors, electric/fuel battery materials, glasses, amorphous, liquids to gases, and even for study on fundamental physics. It will be also used for diagnostic investigation of products of industry, and for archaeology purpose by using radiographic method.

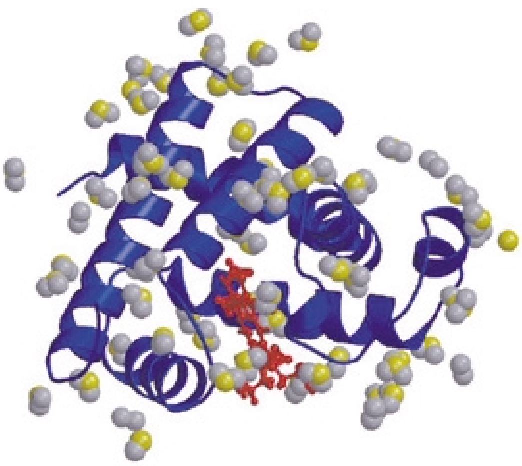
Here, we demonstrate two scientific examples, which will be performed in the neutron facility of the Joint Project.



Crystal structure of a high-Tc superconductor $YBa_2Cu_3O_7$

a. High-Tc superconductor

Superconductivity of oxide-high-Tc superconductor occurs in the two dimensional Cu-O_2 plane. Hence, studies on the spin-spin correlation, charge-lattice interaction in the plane as well as crystal structure are indispensable to elucidate the mechanism.



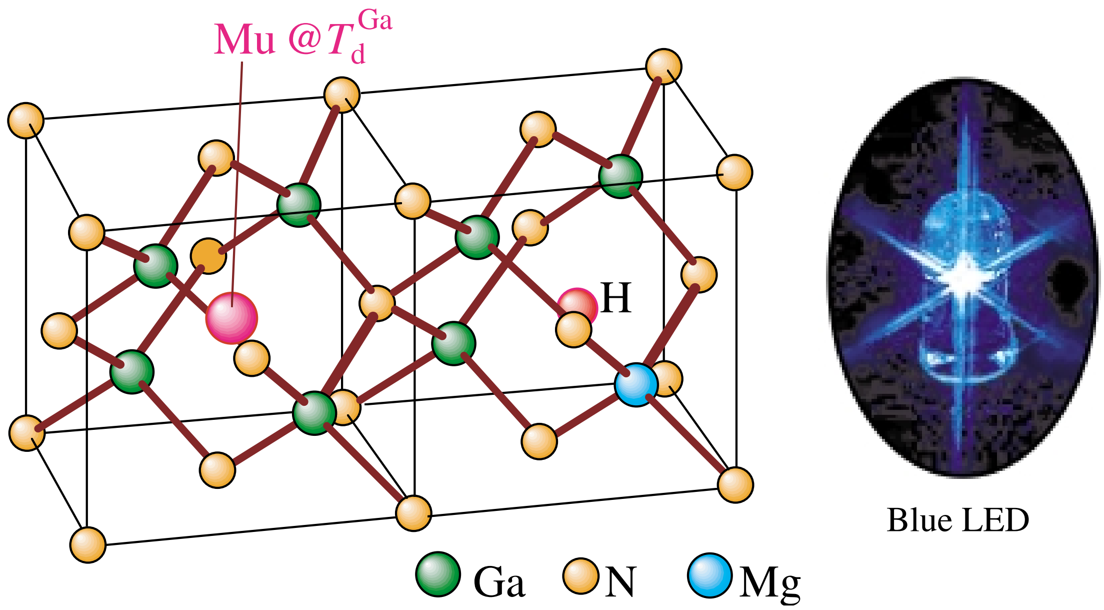
Protein structure and water molecule

b. Structure and dynamics of bio-molecules

It has been understood that the function of protein is activated when its shape is unfolded in a water solution. This problem is called folding-unfolding property of protein. A certain kind of dynamics has also important role for the function. Neutron can study the mechanism of functionality of protein.

Muon Science

"Muon Science" is the research program to develop the application of muon, an elementary particle obtained by the natural decay of a pion, which will be mass-produced with unprecedented intensity in the planned facility. While the use of positively charged muon as a hydrogen isotope with ultrahigh sensitivity is rapidly growing in material research, the negatively charged muon is drawing wide interest as a smart catalyst of d-t nuclear fusion at low temperature. The program covers various research fields including the study on the microscopic origin of distinct material properties such as high-T_c superconductivity and magnetism, the structure and dynamics of hydrogen isotopes and their environment in various semiconductors and organic materials. In particular, the realization of ultra-slow muon beam will facilitate much wider application of muons.



Positive muons simulate the state of the hydrogen (Mu) in semiconductors and provide detailed microscopic information.

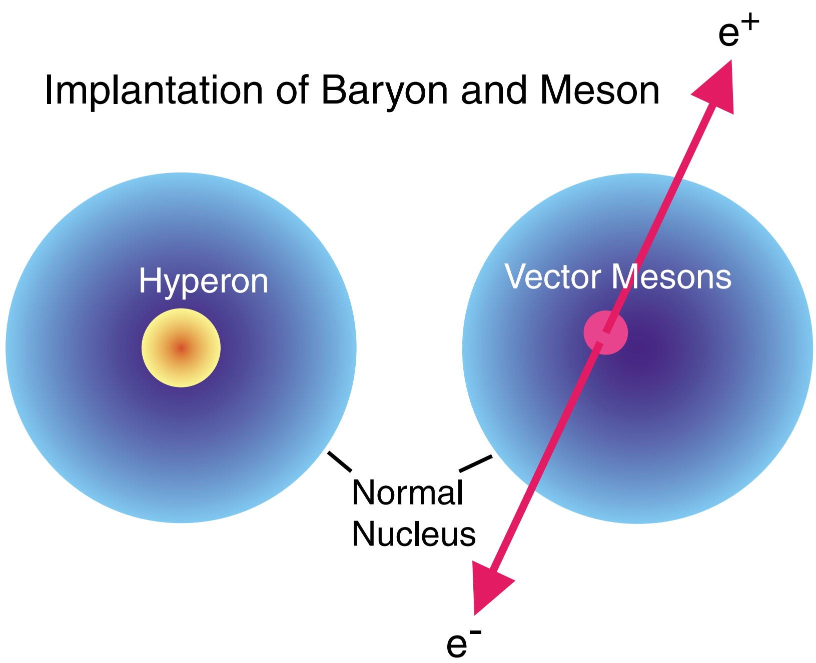
The author of this article, Professors ***Masatoshi ARAI*** (left) and ***Ryosuke KADONO*** (right), are working in Neutron Science and Muon Science, respectively, at KEK.

Nuclear and Particle Physics at the 50-GeV PS

In nuclear and particle physics, one of current interests is to study the origin of mass. One is related to the mass of matter. It is known that over 99% mass of the matter is carried by atomic nuclei. A nucleus is an assembly of protons and neutrons. Each proton or neutron is made of three quarks. One puzzle which has not been solved quantitatively until now is that the mass of proton (or neutron) is ~1 GeV/c^2, whereas the constituent quark mass is less than 1/100 of the proton mass. It is believed that the creation of a large proton mass is due to the symmetry breaking (called the chiral symmetry breaking), while a quantitative nature of this symmetry breaking has not been studied well. Theoretically, it is expected that the quantitative aspect of the symmetry breaking can be studied by inserting a meson (which is made of quark and anti-quark) or a baryon (which is made of three quarks) in the interior of extreme conditions and by studying the change of its mass.

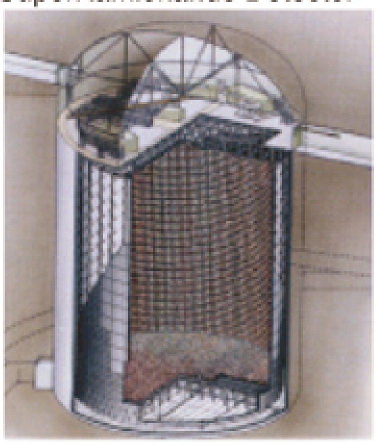
One approach is to implant mesons or baryons in the interior of nuclear matter. Restoration of symmetry breaking is expected theoretically, so that the mass of meson or baryon would be reduced in these extreme conditions.

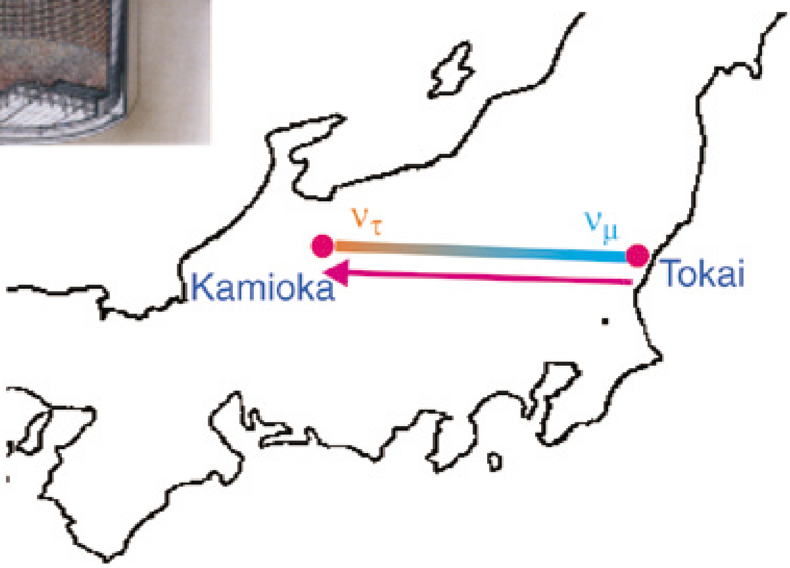
The other is related to the mass of neutrino. From the most fundamental principle, there are no reasons to prohibit a neutrino from having a mass, although it has been believed for many years that the neutrino has zero mass. In a recent experiment at SuperKamiokande, it was demonstrated that muon neutrinos (ν_μ) from the sky (which is called the atmospheric neutrinos) might be converted to another type of neutrinos called tau neutrinos (ν_τ) while traversing through the Earth.



This phenomenon is called the neutrino oscillation and it can occur only when the neutrino carries a mass. In order to pin down this observation at the SuperKamiokande, it is planned at the Joint Project to produce ν_μ beams from the 50-GeV PS and to measure the ν_μ flux both at the immediate exit of the accelerator and at the site of SuperKamiokande which is located at a distance of 300 km from the Tokai site. This type of experiment is already conducted at KEK by having ν_μ beams from the 12-GeV PS. Our Joint Project, however, can produce high-flux neutrino beams with intensity of more than 100 times of the neutrino flux present KEK facility can provide. Thus, a higher accuracy experiment on the origin of the neutrino mass can be done at the Joint Project.

SuperKamiokande Detector





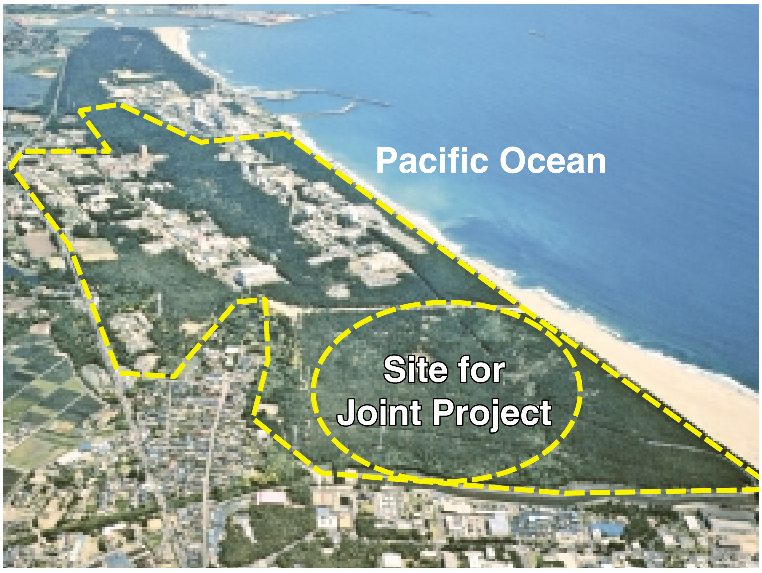
The author of this article, Dr. ***Tomofumi NAGAE***, is working in Nuclear Physics at KEK, and a member of the Project Office.

JAERI and Tokai Site

Japan Atomic Energy Research Institute (JAERI), a core institute of comprehensive nuclear energy research in Japan, was established in June 1956. Since then, JAERI has endeavored to be a pioneer in the nuclear field by engaging in advanced research and development activities, which are conducted at the six research establishments, i.e., Mutsu-, Tokai-, Naka-, Oarai-, Takasaki-, and Kansai Research Establishments, along with Tokyo Headquarters.

Currently, the JAERI's major research activities include: (1) completion of construction of the High Temperature Engineering Test Reactor at the Oarai, (2) research and development of a nuclear fusion reactor at the Naka, (3) promotion of neutron science research at the Tokai, (4) research of advanced photon science such as X-ray lasers at the Kizu site of the Kansai, (5) radiation application research (mainly ion irradiation research) at the Takasaki, (6) promotion of the most advanced basic research in the nuclear field at the Tokai directed by the Headquarters, and (7) synchrotron radiation research using SPring-8 (Super Photon Ring 8 GeV) at the Harima site of the Kansai.

The facility complex of the Joint Project will be constructed in the Tokai Research Establishment located in Tokai-Mura, 80km north-east of KEK and faces to the Pacific Ocean as shown here.



Tokai Research Establishment of JAERI

The author of this article, Dr. ***Yukio OYAMA***, is the co-leader of the Neutron group of the Joint Team, and the deputy director of Center for Neutron Science of JAERI.

Accelerator Driven Transmutation Facility

Nuclear energy system can not be completed without establishing its nuclear waste management system. Although it has been addressed that the principle scenario of the waste stream in Japan is the deep land burial of high level waste (HLW), the HLW still remains as potential hazards. Accordingly, it is encouraged to pursue a way to reduce HLW to mitigate a potential load of the waste management. The accelerator driven system (ADS) has been recognized world wide as an attractive option for the nuclear transmutation of HLW. Japan Atomic Energy Research Institute has proposed an ADS concept for the nuclear transmutation of HLW. With the ADS, a hazard level of HLW is estimated to be reduced to 1/200 comparing to a case without the ADS in 500 years.

To realize ADS, we have to do various areas of fundamental researches and technical developments. They are the spallation target technology, the sub-critical reactor physics, a hybrid system operation and controls, the nuclear transmutation process, etc. Among those, the development of the material for the spallation target and the sub-critical reactor physics driven by the high-energy proton beam are the most important issue to evaluate the technical feasibility for the ADS. In order to make a breakthrough in ADS technology development, we are proposing two experimental facilities to be built under this JAERI-KEK joint project. They are (1) Accelerator Material Irradiation Facility, and (2) ADS Physics Experimental Facility. The former is aiming at evaluating soundness of the materials, which are exposed by extremely severe proton and neutron irradiation under a high temperature lead-bismuth flow. The proton beam of 600 MeV and 0.33mA (200 kW) is used. The latter facility is for researches of the basic sub-critical reactor physics, e.g., sub-criticality, reactivity, power profile, etc. and reactor power control with the beam power, with a low power proton beam of up to 10 W.

We do believe that the basic experiments for ADS under the joint project will enrich our knowledge and will be the first and a great step toward a new horizon of the nuclear energy system in the 21st century.

The author of this article, Dr. ***Yujiro IKEDA***, is the leader of Neutronics Group of JAERI, and also is the leader of ADS Nuclear Transmutation Experimental Group under the Joint Project.

Inden “印伝”

“Inden” is a method to prepare deer skin on which fine patterns are printed using Japanese lacquer made of sap from a lacquer tree “Urushi”. For many centuries, Urushi has been widely used to protect surfaces from abrasion and weather. It was also used to decorate armor for Japanese worriers, “Samurai”.

Various Inden patterns by Mr. Nishitoge

Inden is one of the classic Japanese crafts. The name “Inden” is an abbreviation of “Indo-denrai” where “Indo” means “India”, “denrai” means, “learned from” in Japanese, hence it means “an art learnt from India”.

Ancient Japanese learned from India all sorts of things such as Buddhism as well as other arts and crafts. I have asked an Indian physicist if he knew anything similar in India. He immediately brought me a beautiful silk cloth that shows quite similar pattern (Keri pattern) to a traditional Inden pattern. He also mentioned that his wife had seen similar patterns printed on leather in south India. International relations between Japan and India goes back over 1000 years (through China in most cases). KEK now have various collaborations with Indian physicists.

One of Indian patterns, Keri

The art of producing Inden is slowly disappearing as modern materials are taking over the market. Mr. Masayoshi Nishitoge is one of the forerunner of the art actively producing the Inden products although he is already at the age of 88.

He himself invented various techniques to make the Inden product available to customers at competitive prices. He is the one who established a technique to prepare deer skin to be a practical chamois cloth.

Deer skin, all of which he is get-

Mr. Nishitoge at work

ting from China now, is tanned and smoked.

Only the middle layer between the outer and inner surface of deer skin is used. It takes three months to be ready for the final printing stage. The finished Inden has delicate soft texture that man made materials can not quite compete, yet has durability for daily use.

Mr. Nishitoge has been introduced in several books and newspapers for his excellence. It is gratifying to know that there are many places in Japan where traditional method is more valued over modern method.

Last year, the year of dragon, Mr. Nishitoge made a framed large Inden piece with white dragon motif and donated it to Motoise-Kono Shrine in Kyoto prefecture. It is a difficult challenge to make such a large piece without any fault as the printing is done using a paper pattern on silk screen and the printing must be completed with a single stroke. It is his years of experience that made this beautiful piece possible.

Inden with white dragon motif that was presented to Motoisekono Shrine

November 6-10

KEK Art Festival week was lively with many exhibitions of arts and crafts as well as a concert participated by a professional pianist Mr. Takashi Fujii from Germany.

November 6-15

The 15th International Collaboration on Advanced Neutron Sources was held at Tsukuba International Congress Center. 262 participants actively discussed about the future plan for safe, high intensity neutron source facility.

November 11 and 18

Public lecture "Where is the anti-matter - Broken symmetry" in Tsukuba.

November 14 through 17

The 6th KEK-SLAC ISG Meeting on linear colliders was held in KEK. Participants from USA(SLAC, LBNL, LLNL), Russia and Japan exchanged ideas actively.

December 6

Prof. Akira YAMAMOTO of KEK Cryogenic Center received Nishina Memorial Prize for his work on observation on anti-protons with a superconducting magnet.

December 21 and 22

The 5th IHEP/KEK Collaboration Meeting was held in IHEP, Beijing, China.

December 26

ATLAS Central Solenoid (superconducting) was tested and successfully worked under 8400A which is the highest required current for the solenoid.

January 4, 2001

KEK Director General, Hirotaka SUGAWARA gave a speech on new years resolution all in English, showing his strong intention to make KEK more user-friendly to international community. His strong will to promote liner collider project was the main theme. (Visit KEK web site for the full text of his speech)

January 6, 2001

As a part of Japanese government reorganization, former Ministry of Education (Monbusho) and former Science and Technology Agency were merged into one government organization, Ministry of Education, Culture, Sports, Science and Technology.

February 4, 2001

Mr. Katsuhiro MIMORI of KEK was the third in Masters Marathon Championship (age 60-64 class) held in Saitama pref. He also was the 7th to reach the goal in Boston Marathon (Senior Division) held on April 17th, 2000.

February 9, 2001

KEK International Party 2001 was organized by non-Japanese physicists and their family members. 54 people from 12 countries (11 from Russia, 3 from Sweden, 4 from USA, 4 from Bangladesh, 4 from India, 2 from China, 2 from Korea, 1 from Myanmar, 1 from Canada, 2 from France, 1 from UK, 1 from Vietnam, 1 from Australia, 18 from Japan) attended. The party was further enhanced by all sorts of dishes of their own countries prepared by the party attendants.

Picture on front cover

The front cover shows one of the Buddhism statue, Ashura, of Kofukuji Temple in Nara. (8th century) With the 6 arms and three faces, the Ashura handles all sorts of situations just like the several beam line branches of the High Intensity Proton Accelerator complex. The Ashura is believed to have originated from India. The three faces look at everywhere, while the Accelerator complex looks at KEK, Tokaimura and Kamioka. I thought the coincidence is interesting. We thank people in Kofukuji very much for their understanding and support.

Picture on back cover

The building in Hiroshima was within 600m from the A-bomb explosion on August 6, 1945. It was registered on the UNESCO World Heritage. At the entrance to the 21st century, it stays as a reminder to physicists that physics can create something that may not be good for the creatures on the Earth. A museum is near by which tries to promote peace and to reduce hatred. We appreciate the museum very much for their help.

Readers comment

An ex-staff member of INS sent the editor a comment on Vol.3, No.2, saying that it should have been noted that the 350MeV electron storage ring of INS-ES was the first facility dedicated only for synchrotron light users.
Editor welcomes readers comments as it would make the publication better.

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